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RESEARCH REPORT

RESEARCH ON DIMENSIONLESS UNIT HYDROGRAPH AND TIME OF CONCENTRATION FOR MARYLAND WATERSHEDS

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16. Abstract

Observed data from 100 rainfall-runoff events on 54 watersheds in Maryland and Delaware were used to investigate two watershed characteristics: the dimensionless unit hydrograph (DUH) and time of concentration (Tc). Streamflow hydrograph data were obtained from US Geological Survey gaging stations. Event hyetographs were generated from US Weather Service NEXRAD Radar Stage III data (DPR) using a method developed in this study. The gamma-function form of the Natural Resources Conservation Service unit hydrograph was assumed. For each event, an optimization method was used to determine the time to peak and gamma parameter (related to the Peak Rate Factor, PRF) that give the best-fit direct runoff hydrograph when convolved with the rainfall excess hyetograph. Tc was estimated by differentiation of the unit hydrograph. Efforts to predict PRF and Tc using watershed properties, and to update an existing regression equation, were inconclusive. Future investigations will focus on improving the event baseflow separation and determination of rainfall excess.

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Unit hydrographs, time of concentration, peak rate factor, peak discharge, watersheds, weather radar, rainfall, streamflow	This document is available from the Research Division upon request.

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Introduction

The goal of this study was to investigate two properties of unit hydrographs (UH) for Maryland watersheds: time of concentration, T_c, and Peak Rate Factor, PRF. The Natural Resources Conservation Service (NRCS) UH, as implemented in their WinTR-20 software, is widely used in Maryland. The PRF and T_c together define the shape and scale of the NRCS UH.

A hydrograph is a representative of watershed response, in terms of volumetric flow rate, to a certain precipitation event as a time function. They are normally used by engineers to assist in designing hydraulic structures (e.g., culverts, bridges, dams…). For design purposes, one of the most practical ways to estimate final design hydrograph is to convolve unit hydrographs of watersheds with associated precipitation events. (i.e., 20-year storm) (Horst & Gurriell, 2019). Unit hydrographs (UH) are crucial tools to estimate runoff hydrograph resulting from storm rainfall. The application of unit hydrograph is primarily on the runoff estimation on ungauged watersheds, in which they are known as synthetic unit hydrographs. Unit hydrograph models were developed by Clark (1945), Snyder (1938), and Mockus (1957) and they are applied in a variety of hydrological modelling (Sheridan et al., 2002).

A UH can be established through analysis of the precipitation-runoff events which can be found through historical data or through the analysis of various watershed characteristics applied in combination with a synthetic unit hydrograph model. Dooge (1959) discussed that the UH model to estimate stream flow is one of the most powerful tools in applied hydrology. Natural Resources Conversation Service unit hydrograph (a.k.a NRCS's synthetic unit hydrograph) method developed by Victor Mockus (1957) is among the most popular unit hydrograph models and is the basis of most engineering practice in the state of Maryland. This UH model makes use of a Peak Rate Factor to quantify the peak of the UH. Based on the NRCS formula, peak flow can be estimated as follows:

$$q_p = PRF\frac{AQ}{t_p} \qquad \text{(Eq. 1)}$$

where q_p = peak flow[cfs]; PRF = peak rate factor; A = watershed area [mi^2]; t_p = time to peak [hr]. The PRF is both a unit conversion and a scaling factor between a dimensionless UH and the dimensional UH.

PRF is a representative of unit hydrograph shape (i.e., volume distribution). That is, it shows a degree of peakedness of the unit hydrograph. Typical PRF reproduced by Mockus (1957) is 484, which resemble the distribution of 3/8 of the volume of the streamflow runoff on the rising limb of the hydrograph and 5/8 of the streamflow volume on the recession side of the unit hydrograph. Alternatively, a PRF of 284 which is derived from Delmarva unit hydrograph (Welle et al. [1980]; Welle and Woodward [1989]) estimates a volume distribution of 22% under the unit hydrograph rising limb and 78% under the unit hydrograph receding side. PRF of 284 applies to the watersheds in coastal areas. Based on the handbook published in 1972, NRCS stated that "the value of the PRF vary from around 300 for roughly swampy and flat catchments to 600 for steep watersheds", however, (NRCS 2007) based on the more recent research, PRF ranges from below 100 to above 600.

The accurate estimation of PRF is crucial for engineering design of hydraulic structures and current approaches do not seem to accurately estimate PRFs due to inconsistencies and erroneous process in the unit hydrograph modelling. This study aims to use fine-resolution sub-hourly precipitation data and associated sub-hourly runoff data for multiple events to model NRCS unit hydrograph and to estimate PRF and time of concentration for a series of watersheds. This study also investigates if there is any local/regional trend for estimated PRFs can be observed and if each watershed can be represented with a single PRF.

An additional objective of this study was to investigate watershed time of concentration (T_c) and its dependence on watershed characteristics. This aspect of the research was intended to extend an in-depth study by W. Thomas and colleagues (2000) for the state of Maryland, which in turn built on work by Dillow (1998). We refer to that study as Thomas (2000).

Study Locations and Data

Study locations were selected from USGS gaging stations. Since the decision was made to use WSR-88 Radar (NEXRAD) DPR product for the precipitation (discussed below), we were limited to the time period for which those data are available. Our original intent was to select events between 1994 and 2017, however, the NEXRAD DPR product is only available starting in 2012. The annual maximum discharge time series for the gages were examined to identify events with peak flows greater than a 2-year return period (less than 50% annual exceedance probability). We selected event runoff hydrographs with a smooth, single-peak shape for consistency with the assumptions of the method. Additionally, watersheds were restricted in size to 100 mi^2 (259 km^2) as larger catchments tend to be inconsistent with the assumptions of the unit hydrograph methodology.

The results discussed here are for a total of 54 gaging stations in the two provinces, 30 in Province 1 (Piedmont, Blue Ridge and Appalachian Plateau geographic regions) and 24 in Province 2 (Eastern and Western Coastal Plains). The stations are listed in Table 1; this table also identifies which stations were included in the Thomas (2000) T_c study (21 of 30 in Province 1, and 13 of 24 in Province 2). The study watershed locations are mapped in Figure 1. Further details on the study watersheds are provided later in this report.

The following section presents the steps followed to analyze the events. The steps are illustrated for a selected watershed and event. A complete catalog of results is provided as an Appendix to this report.

Table 1. Watersheds Analyzed in this Study

Province 1 (Piedmont, Blue Ridge, Appalachian Plateau)			Province 2 (Eastern and Western Coastal Plain)		
Station (USGS)	Number of Events	Included in Thomas (2000)	Station (USGS)	Number of Events	Included in Thomas (2000)
1580000	1	Y	1483200	1	Y
1581500	1	--	1484100	2	Y
1581700	3	Y	1485500	1	Y
1582000	1	Y	1486000	2	Y
1583100	2	Y	1486500	1	--
1583500	4	Y	1490000	1	--
1583570	1	--	1491500	2	--
1583580	1	--	1492500	3	--
1583600	1	Y	1493112	3	--
1584500	2	--	1493500	2	Y
1585200	1	Y	1581757	3	--
1586000	1	Y	1585090	1	--
1586210	3	Y	1585100	3	Y
1586610	2	Y	1585104	2	--
1589300	3	Y	1585230	1	--
1589440	7	Y	1589500	1	Y
1591000	6	Y	1594526	1	Y
1591400	3	Y	1649500	2	Y
1591700	3	Y	1651000	2	Y
1593500	1	Y	1653600	1	Y
1594000	2	Y	1658000	2	--
1596500	2	Y	1660920	2	Y
1599000	1	--	1661050	1	Y
1617800	3	Y	148471320	2	--
1637500	2	Y			
1639140	1	--			
1643500	4	Y			
1644371	2	--			
1644372	1	--			
1644375	1	--			

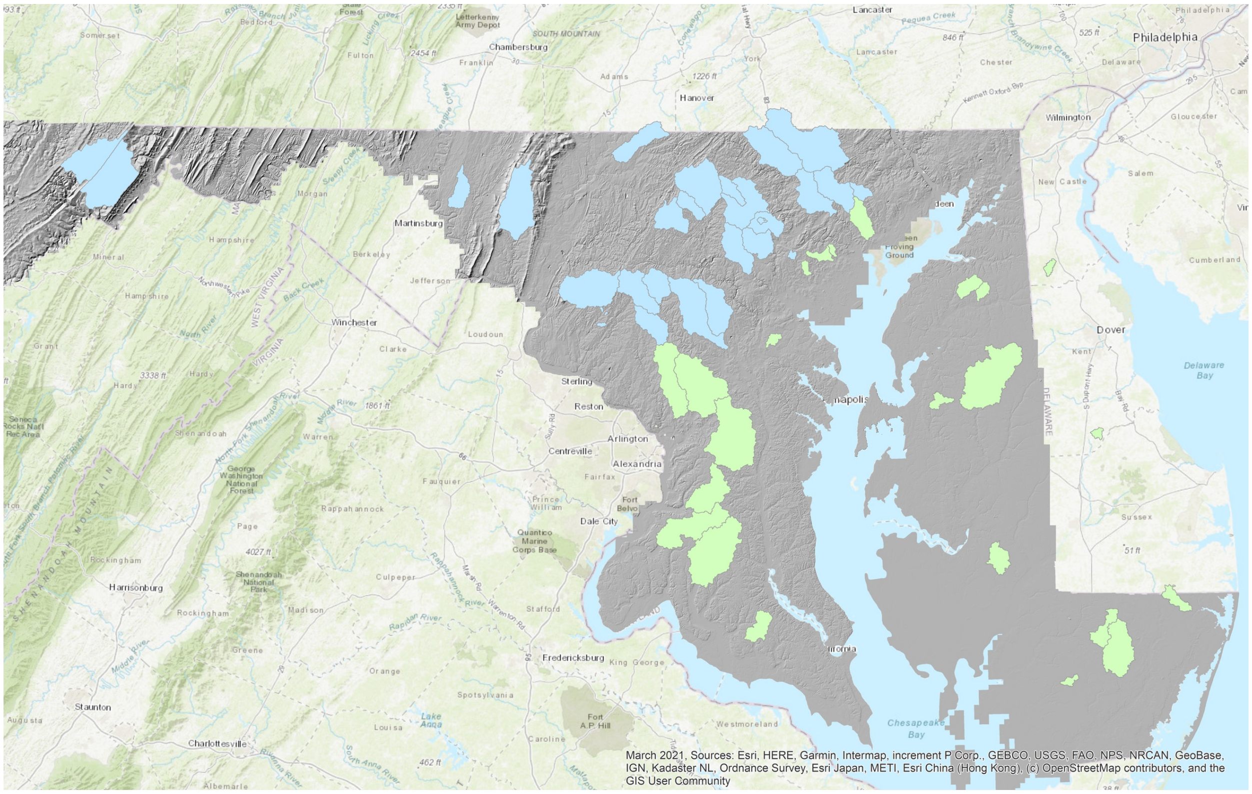


Figure 1. Watersheds selected for the study. Blue: Province 1 (Piedmont, Blue Ridge, and Appalachian Plateau); Green: Province 2 (Eastern and Western Coastal Plains). Map created in ESRI ArcMap. Some small or nested watersheds are hidden at this zoom level.

Methods

Event Hydrograph Data

For the selected discharge events, 15-minute stream gauge data were downloaded from U.S. Geologic Survey's (USGS) National Water Information System (https://waterdata.usgs.gov/md/nwis/uv/?referred_module=sw).

Event Hyetograph Data

Corresponding precipitation events were required at sub-hourly rates. Very few sub-hourly precipitation gages are available in Maryland. This project introduces the application of the National Oceanic and Atmospheric Administration's (NOAA) Next Generation Weather Radar System (NEXRAD) products in developing unit hydrographs. Event hydrograph development followed these steps.

1. Archived Digital Precipitation Rate (DPR) data were downloaded from the National Centers for Environmental Information (NCEI) online data server. The DPR data are Level III, meaning that the information has been processed from the raw reflectivity signal to a gridded precipitation intensity. We selected the DPR data set because it provides precipitation intensity at sub-hourly time intervals, as frequently as 3 minutes in heavy events. The DPR data are available from 2012 to the present. Another Level III data set provided by NCEI, the Digital Precipitation Array (DPA) is available starting in May 1992; however, the DPA reports hourly accumulation at the same irregular times as the DPR, and at coarser resolution; time did not allow us to complete the computational steps to disaggregate the trailing-sum hourly accumulations to sub hourly intensities and depths as applied in our methods. The University Corporation for Atmospheric Research (UCAR) provides a Stage IV precipitation product at 4-km spatial resolution on regular 1-hour time intervals starting in 2002; however, this data set is not provided by the NCEI and we became aware of it very late in the course of this study. The applicability of that data set to this study and future work is discussed later in this report.

Several NEXRAD radars cover parts of Maryland. This study uses data from the WSR-88D radar at Sterling, Virginia (KLWX) because its range captures the entire state. Data are provided in a binary (non-text) format; NCEI recommends the use of their Weather and Climate Toolkit (WCT) application to view and process the data. The DPR data product is arranged on a radial grid centered on the KLWX radar; the grid elements are 1 degree by 250 m (radial distance). The DPR radial grid is illustrated in Figure 2. We use the WCT to export a day's DPR values to comma-separated values (CSV) format text files, one for each reporting time during that day. NEXRAD records the DPR product as frequently as 3-minutes during intense rainfall; therefore, a 24-hour day could have up to 480 CSV files, each identified by date and time. We operate on

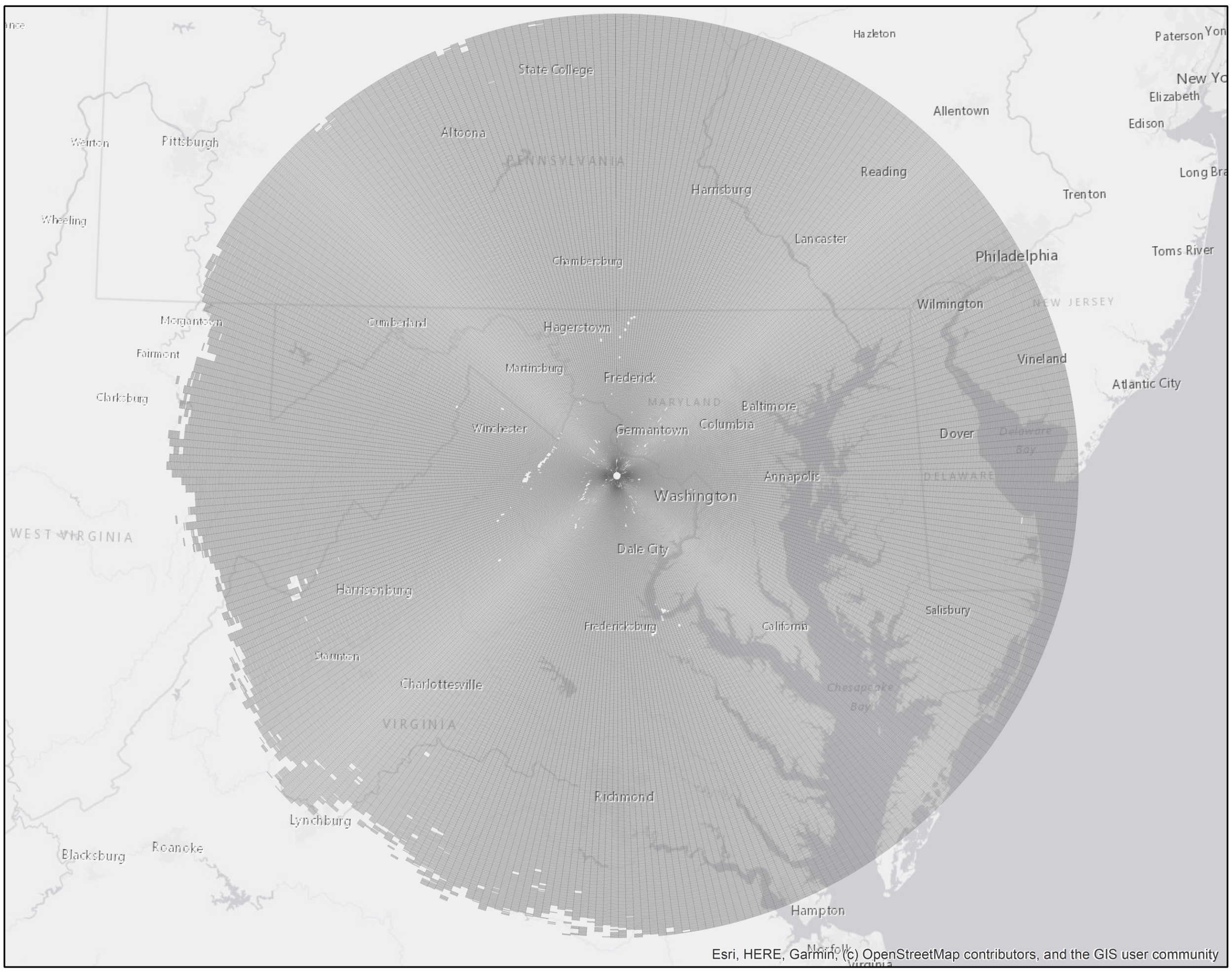


Figure 2. Example NEXRAD DPR image showing the radial grid centered on the Sterling, VA WSR-88D radar (KLWX). This image from Hurricane Sandy (October 2012) illustrates well the KLWX grid because precipitation is reported over nearly the entire sweep (the color scale normally seen in a radar image has been suppressed to emphasize the grid). DPR provides precipitation intensity for non-uniform cells 250 m in the radial direction and 1 degree in the angular direction. The grid consists of 360 angular increments and 920 radial increments, for a total of 331,200 irregularly sized grid cells. Individual cells are visible at the southwest border of the sweep image; the smooth edges elsewhere indicate complete coverage of detected precipitation to the maximum range (230 km).

these CSV files, using Unix text editing tools, to simplify them to a data set containing three columns: precipitation intensity value, angle, and radial distance.

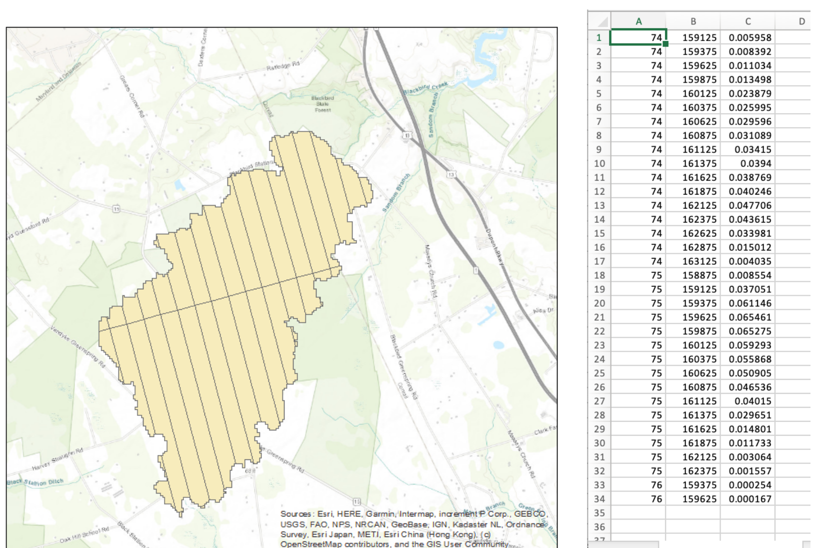
2. For a given reporting time, *t*, average rainfall depth over a watershed is given by the integral of spatially-varying precipitation depth, p(**x**,*t*):

$$\bar{p}(t) = \frac{1}{A}\int p(\mathbf{x},t)dA \qquad \text{(Eq. 2)}$$

where *A* is total area of the watershed. To perform this integral, each study watershed is subdivided into cells corresponding to the DPR's radial grid, using the polygon intersection tool in ArcGIS. We mapped the DPR polygons by using the WCT to export a single time sweep with nearly full coverage (Figure 2) in GIS shapefile format. An example of the watershed/DPR Grid intersection is shown in Figure 3(a). The area fraction of the watershed corresponding to each intersecting DPR grid cell is tabulated; an example is given in Figure 3(b). With each row of the DPR CSV file corresponding to a cell in the grid, the average rainfall depth can be calculated as a weighted average,

$$\bar{p}(t) = \sum_{i=1}^{n}\frac{A_i}{A}p_i(t) \qquad \text{(Eq. 3)}$$

where *n* is the number of DPR radial grid cells that intersect with the watershed, A_i/A is the area fraction of the intersection, and $p_i(t)$ is the DPR precipitation rate in that grid cell at that time. The DPR precipitation values and the area fractions are referenced to the DPR grid by (radial distance, angle) indices, 1 to 920



	A	B	C	D
1	74	159125	0.005958	
2	74	159375	0.008392	
3	74	159625	0.011034	
4	74	159875	0.013498	
5	74	160125	0.023879	
6	74	160375	0.025995	
7	74	160625	0.029596	
8	74	160875	0.031089	
9	74	161125	0.03415	
10	74	161375	0.0394	
11	74	161625	0.038769	
12	74	161875	0.040246	
13	74	162125	0.047706	
14	74	162375	0.043615	
15	74	162625	0.033981	
16	74	162875	0.015012	
17	74	163125	0.004035	
18	75	158875	0.008554	
19	75	159125	0.037051	
20	75	159375	0.061146	
21	75	159625	0.065461	
22	75	159875	0.065275	
23	75	160125	0.059293	
24	75	160375	0.055868	
25	75	160625	0.050905	
26	75	160875	0.046536	
27	75	161125	0.04015	
28	75	161375	0.029651	
29	75	161625	0.014801	
30	75	161875	0.011733	
31	75	162125	0.003064	
32	75	162375	0.001557	
33	76	159375	0.000254	
34	76	159625	0.000167	
35				
36				

(a) (b)

Figure 3. Example of polygon intersection of watershed with NEXRAD DPR angle-radius grid: USGS 1483200 Blackbird Creek at Blackbird, DE: (a) polygons in ESRI ArcMap; (b) CSV formatted file with angle and radial distance uniquely identifying each polygon.

for the radial distance and 1 to 360 for the angle. Watershed average precipitation rate can be efficiently calculated by elementwise multiplication (Hadamard product) of two matrices,

$$\bar{p}(t) = \boldsymbol{\alpha} \odot \mathbf{P}(t) \quad \text{(Eq. 4)}$$

where $\mathbf{P}(t)$ is the (radial distance, angle) matrix of precipitation at time t, and $\boldsymbol{\alpha}$ is the (radial distance, angle) matrix of watershed area fractions. A Matlab script is used to calculate a time series of watershed average precipitation for each selected event.

3. The NEXRAD DPR data are finely resolved in space and time; however, they are subject to unquantified bias. We use an independent precipitation data set to adjust the watershed average time series. We selected the daily gridMET data, obtained from the online Climate Engine server (http://climateengine.org/). According to the gridMET webpage, “gridMET blends spatial attributes of gridded climate data from PRISM with desirable temporal attributes (and additional variables) from regional reanalysis (NLDAS-2) using climatically aided interpolation. The resulting product is a spatially and temporally complete, high-resolution (1/24th degree ~4-km) gridded dataset of surface meteorological variables.” Climate Engine allows us to download daily watershed average gridMET precipitation by uploading a shapefile outline of the watershed. Using a Matlab script, the fine-scale time series (at irregular time intervals) are cumulated and adjusted on a daily basis to match the daily watershed totals from gridMET. The corrected cumulated watershed average precipitation is disaggregated to a regular time interval of 0.1 hour (6 minutes). An example is shown in Figure 4.

The result of these three steps is an event hyetograph of watershed average precipitation at 6-minute (0.1-hour) intervals for the study watershed.

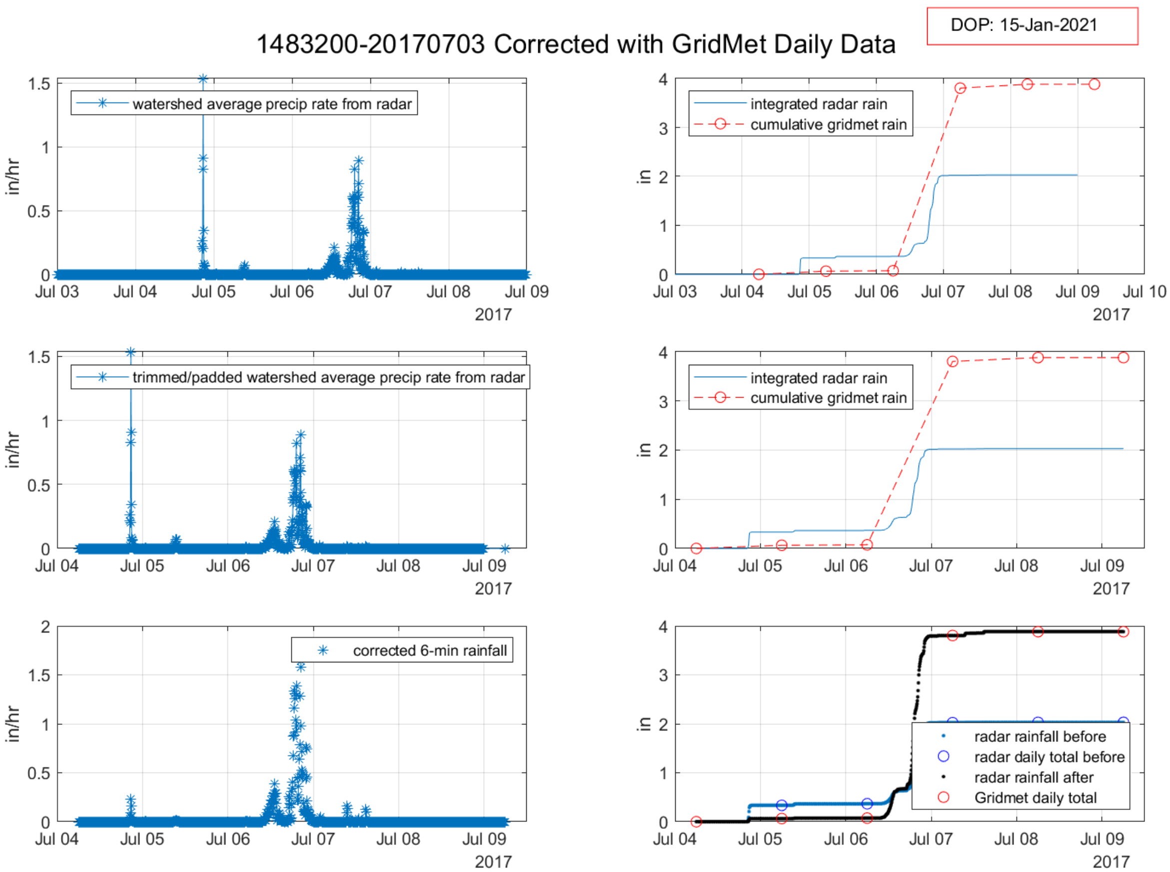


Figure 4. An example of adjustsing watershed-average radar rainfall using gridmet watershed-average daily values. The original data, with radar data on a variable time step and gridmet data on a daily timestep (top row), are trimmed or extended as necessary to cover matching time periods (second row). The radar data are adjusted on a daily basis to match the gridmet, then disaggregated to a 6-minute time series (bottom row).

Event Hydrograph and Hyetograph Processing

The Unit Hydrograph (UH) transforms precipitation excess into direct runoff. To derive a UH from a precipitation/runoff event, it is necessary to separate the event hyetograph into precipitation excess and losses (or abstracted precipitation) and to separate the runoff hydrograph into direct runoff (water that reached the stream gage by quick overland routes) and baseflow (water that reached the stream gage by infiltrating and moving more slowly to the gage, or water previously stored in the subsurface that flows to the gage during the event).

Baseflow Separation and Direct Runoff Estimation

Several methods exist in the literature to separate baseflow from a hydrograph (e.g., constant-discharge, constant-slope, recursive filtering, concave, …). Most graphical hydrograph separation methods require the analyst to identify an "inflection point" on the receding limb, which is assumed to indicate the end of direct runoff and the beginning of pure baseflow. This "inflection point" does not necessarily match the mathematical definition, and its identification is often subjective. We hoped to eliminate some of this subjectivity by applying an algorithm to automate the identification of baseflow recession. Pure baseflow is assumed to follow an exponential decay curve. The algorithm traces the recession curve and identifies the time after which the hydrograph best fits an exponential decay equation. That time is tagged as end of direct runoff / beginning of pure baseflow. In a modification of the concave method, baseflow is assumed to rise linearly from the beginning of the event until the end of the precipitation. At that time, the linear rise intersects the extended exponential recession curve and baseflow is defined for the entire event. In some cases, it is necessary to continue pre-event baseflow recession in a downward-sloping line for a short time before drawing the rising linear segment to connect to the recession curve, to avoid the assumed baseflow-rise line falling above the total hydrograph curve. Like other graphical separation methods, this one approximates the complex, spatially and temporally variable processes occurring in a watershed.

Once the baseflow is successfully separated, the time series of direct runoff (DRO) is calculated by subtracting baseflow from the total event hydrograph. The event depth of DRO is computed by numerical integration of the resulting DRO hydrograph. Our MATLAB script takes as input the event hydrograph, watershed area, and the date/time of the end of the precipitation event as inputs, separates the baseflow and finally estimates the direct runoff (DRO) volume (normalized by watershed area) as an output.

Figure 5 represents the result of baseflow separation for event 2017/07/03, watershed 1483200.

Determination of Rainfall Excess

Under the assumptions of the method, the depth of excess precipitation (PEX) equals the depth of the direct runoff. We separated rainfall excess from the event hyetographs using the phi-index method (e.g., McCuen 2016) implemented in a Matlab script. Conceptually, the phi-index method imposes a constant potential loss rate throughout the event, where loss could consist of storage or infiltration, or both. Actual loss during an increment of time equals precipitation or phi, whichever is less. An iterative solution identifies the value of phi at which integrated event excess precipitation equals direct runoff. An example is shown in Figure 6. [We also investigated the NRCS excess precipitation method, but the requirement of watershed curve number (CN) in that procedure created complications].

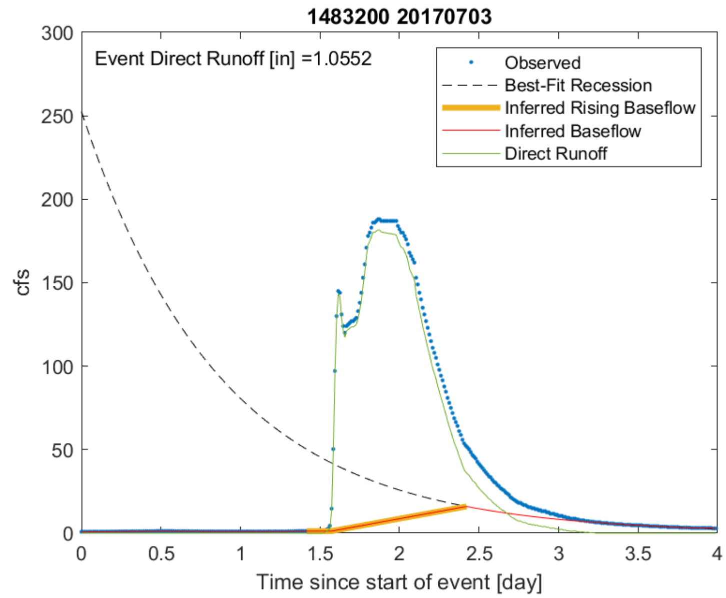


Figure 5. Baseflow separation example.

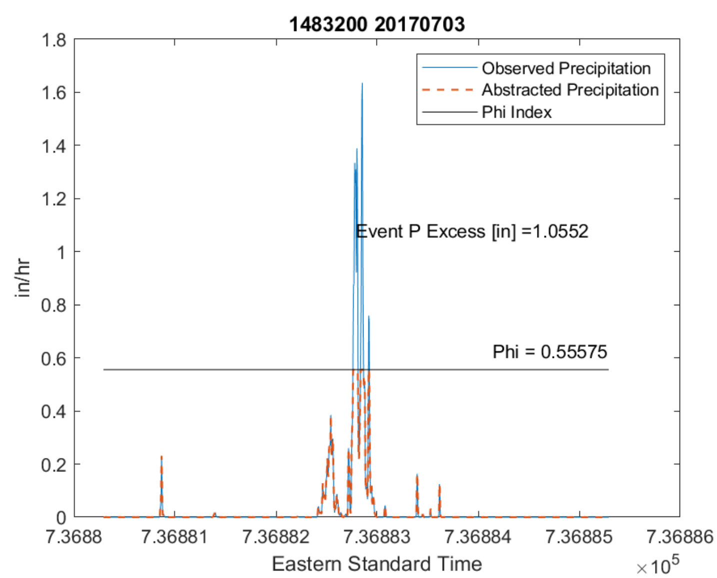


Figure 6. Example of Phi-Index precipitation separation.

Unit Hydrograph Identification

The study imposes the gamma unit hydrograph (UH) to represent the transformation of precipitation excess to direct runoff in all the study watersheds. The UH approach assumes that the watershed's temporal runoff response to each increment of precipitation is identical in shape and proportional to precipitation in that increment of time. The event hydrograph is thus a convolution integral of the precipitation excess time series and the UH. Various methods are described in the literature to identify a UH from PEX and DRO time series. For this study, we implemented an optimization approach. The dimensionless unit hydrograph (DUH) is constrained to follow the gamma function described in NRCS (2007),

$$\frac{q}{q_p} = e^m \left(\frac{t}{t_p}\right)^m e^{-m\frac{t}{t_p}} \qquad \text{(Eq. 5)}$$

where q is discharge [cfs], q_p is peak discharge [cfs], t is time, t_p is time to peak, measured from beginning of hydrograph rise (assumed equal to beginning of precipitation excess), and m is the gamma function shape parameter. Eqn (5) can be rewritten to emphasize its dimensionless form,

$$q^* = e^m (t^*)^m e^{-mt^*} \qquad \text{(Eq. 6)}$$

Where q^* is dimensionless discharge (q/q_p) and t* is dimensionless time (t/t_p). The function takes a maximum, $q^* = 1$, at $t^* = 1$. It equals zero at $t^* = 0$ and is asymptotic to 0 as t^* becomes very large. Eqn. (6), the DUH, does not integrate to 1; the dimensional watershed unit hydrograph (UH) must express dimensional discharge as a function of dimensional time and must integrate to 1; these steps are discussed below.

For a given event, with *DRO*(*t*) and PEX(t) provided, the task is to find the gamma UH that best transfers PEX(t) to DRO(t). There are two free parameters: unit hydrograph t_p and gamma shape parameter m.

The best-fit UH is determined by a quantitative objective function. We applied two different objective functions: (1) The sum of squared differences (SSE) between the observed hydrograph and the convolved hydrograph, and (2) the match between predicted and observed peak discharge – magnitude and timing. Instead of using an optimization algorithm that systematically searches the mathematical (m, t_p) space to optimize the objective functions, our script explores the entire parameter space and calculates the objective functions for all possible parameter pairs. This way, we can observe how the fit between predicted (convolved) and observed DRO changes with the parameter pairs. We chose to use the gamma parameter m rather than the peak rate factor (PRF) at this step because m is dimensionless and more mathematically fundamental. The m parameter can easily be converted to its equivalent PRF (which is tied to the US Customary Unit System).

Estimation of the Unit Hydrograph

For each event, a range of candidate m and a range of t_p are provided to the script, together with numerical increments to define the test values. For each possible ($t_{p,}$ $m,$) pair, the DUH is calculated (Eqn. 6) using the candidate m and integrated numerically. The candidate dimensional unit hydrograph (UH) is obtained as follows: Each ordinate of the DUH is divided by the integral to ensure that the area under the dimensional unit hydrograph equals 1 (1 inch of direct runoff resulting from 1 inch of precipitation excess). The abscissae are divided by the candidate t_p, and the ordinates scaled to maintain area 1. The PEX hyetograph is convolved with the candidate UH and the three objective functions are calculated: sum of squared errors (SSE), difference in peak discharge and difference in time to peak. After this process has been repeated for all candidate ($t_{p,}$ $m,$) pairs, two best-fit ($t_{p,}$ $m,$) pairs are identified: The one resulting in the minimum SSE, and the one at which the Qpeak error = 0 and Tpeak error = 0 contours intersect. An example is shown in Figure 7. The solid-line contours show equal

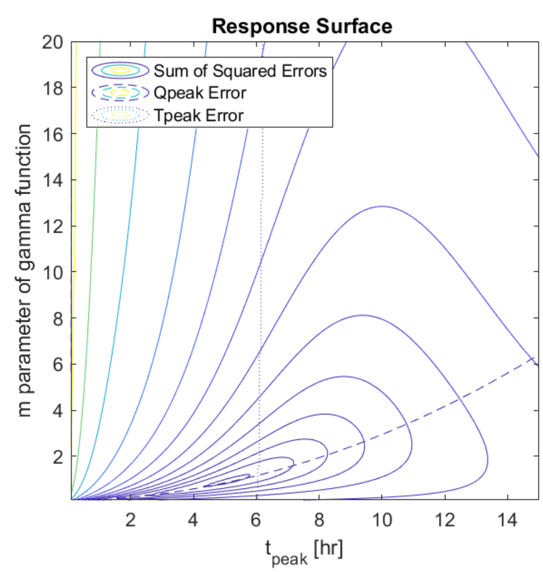


Figure 7. Response surface showing contours of three objective functions (measures of goodness of fit between predicted and observed hydrograph): overall sum of squared errors (solid contours), difference in magnitude of Qpeak (single dashed contour at QpeakError = 0), and difference in time to peak (single light dotted contour at Tpeak error = 0).

values of SSE. The dashed line indicates the (t_p, m,) pairs where the peak discharge difference is zero (Qpeak, predicted = Qpeak, observed). The light dotted line indicates the (t_p, m,) pairs where the time to peak difference is zero (tpeak, predicted = t peak, observed). In this case, the minimum SSE occurs at (t_p, m,) ≅ (5 hr, 1). The predicted hydrograph peak matches the observed peak – both in magnitude and in timing – at (t_p, m,) ≅(6 hr, 1.2). The corresponding convolved hydrographs are shown in Figure 8.

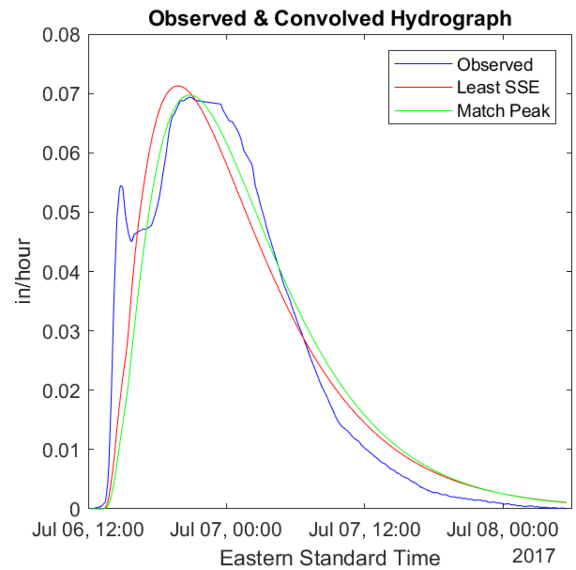


Figure 8. Hydrographs resulting from convolution of selected candidate unit hydrographs by two different goodness-of-fit measures (objective functions): overall Sum of Squared Errors ("Least SSE") and best match to timing and magnitude of peak discharge ("Match Peak").

The dimensionless and dimensional hydrographs corresponding to Figures 7 and 8 are shown in Figure 9.

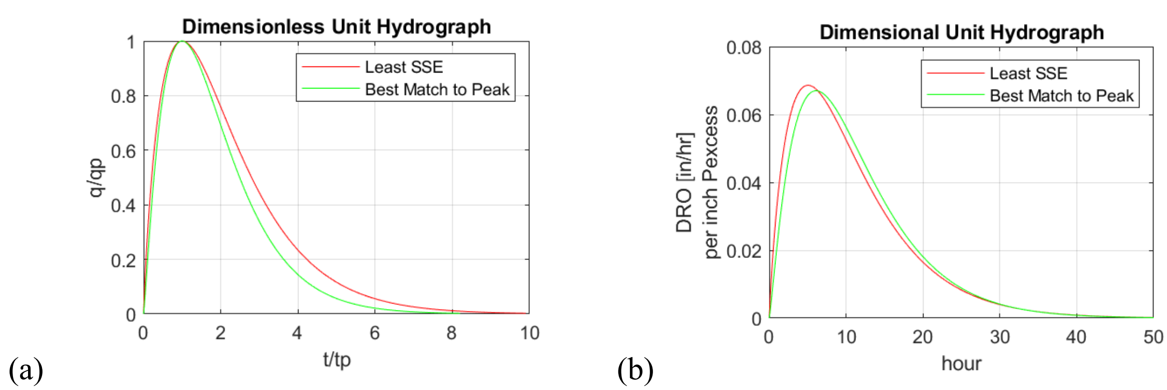


Figure 9. Dimensionless Unit Hydrograph (DUH) (a) and Dimensional Unit Hydrograph (UH) (b) corresponding to the optimal (m,tp) selected by two different objective functions, as shown in Fig. 7. The DUH shapes (a) reflect only the difference in the gamma parameter *m*, and do not integrate to 1. The UH shapes (b) reflect different t_p as well. Both UH curves integrate to 1 inch of direct runoff.

The PRF is widely used in practice and is one of the target variables in this study. Therefore, we calculate and report PRF for each watershed event analyzed. value of the gamma *m* parameter generates a unique dimensionless unit hydrograph and accordingly a unique PRF based on the following equation:

$$PRF = \frac{645.33}{\int q^* \, dt^*} \qquad \text{(Eq. 7)}$$

in which *PRF* is the peak rate factor. The integral in the denominator is dimensionless. Both the *PRF* and the constant 645.33 have units cfs/mi^2 / (in/hr) (NRCS, 2010). Our Matlab script integrates the DUH numerically and reports the PRF.

Determining Time of Concentration from Event Data

In this study, time of concentration [hr] was first estimated from the hydrograph and hyetograph of each event as the elapsed time between end of PEX and end of DRO. This measure is automatically extracted from the analyzed data after the hydrograph and hyetograph separation steps. Several decades of hydrologic practice have introduced numerous definetions of T_c. Conceptually, it is assumed to represent the time required for the entire watershed to contribute to runoff at the outlet. The end of direct runoff (sometimes called an "inflection point") may or may not be appropriate to indicate this response time; if precipitation is assumed uniform over the watershed, it may be reasonable to assume that the final contribution to direct runoff is water arriving from the hydraulically most remote point in the watershed. By applying this automated calculation, we hoped to eliminate some subjectivity in determining T_c. It should be noted that – although automated and arguably objective – this measure is subject to numerous other assumptions and subjective decisions in the process of separating hydrograph and hyetograph. The calculation of T_c by this method for the example watershed event is illustrated in Figure 10.

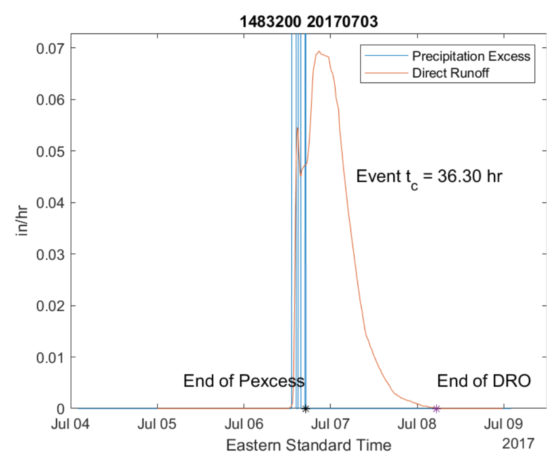


Figure 10. Example of automated determination of event Time of Concentration from Precipitation Excess hyetograph and Direct Runoff hydrograph.

A more conceptually rigorous approach is to determine the time from end of PEX to the inflection point on the receding limb of the event hydrograph. The inflection point is defined as the point at which the hydrograph changes from concave downward to concave upward; it represents a minimum value of the first derivative dQ/dt, that is, a zero of the second derivative, d^2Q/dt^2. Observations and physical reasoning indicate that this change in concavity represents the time at which water is draining from storage in the watershed, and therefore the time when the entire watershed has responded to the rainfall input (one definition of T_c). We again tried to automate this identification procedure using a Matlab script. The script numerically differentiates the total discharge and the DRO hydrographs and identifies the minimum value of the first derivative on the recession limb. The point of minimum dQ/dt on the recession is identified; the minimum dQ/dt corresponds to a change in sign of the second derivative, and a change from concave downward to concave upward. This point is tagged as the inflection point; if several subsequent points in time share the minimum derivative value, the times and discharges are averaged. The time at which precipitation excess (PEX) ends is recorded from prior analysis steps. Tc is calculated as the difference between the two times, T(recession inflection) – T(PEX end). The identification is performed for both the total discharge hydrograph and the direct runoff hydrograph. An example of this procedure is shown in Figure 11.

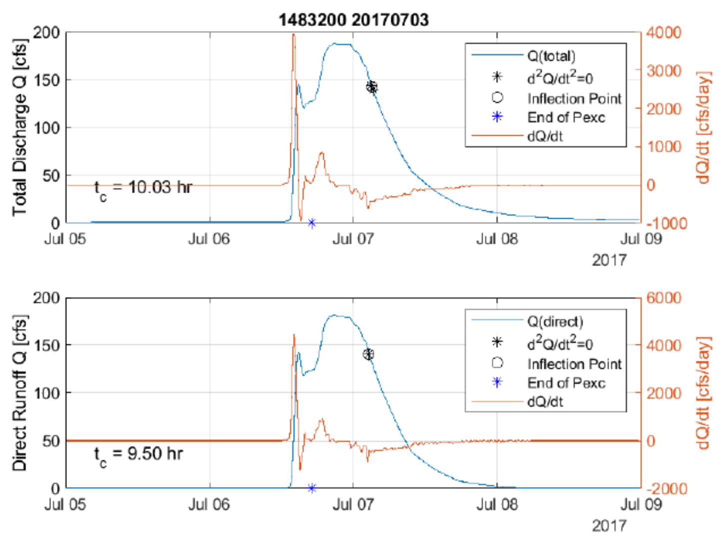


Figure 11. Identification of Time of Concentration using the event hydrograph recession inflection point. The hydrograph (blue) is numerically differentiated (red curve is first derivative dQ/dt).

Through discussions with an expert colleague (W. Thomas, personal communication), we concluded that this method gives a T_c estimate that is more consistent with hydrologic practice than the end of PEX to end of DRO method described above. For a number of events, however, the end of PEX occurred after the inflection point on the hydrograph recession, leading to negative T_c. It is not clear whether this irrational result stems from inaccurate precipitation time series or incorrect precipitation excess separation, or calls into question the inflection point approach to determining T_c. These negative T_c's occurred in multiple watersheds for some of the heavy, long-lasting precipitation events in the data set. Ultimately, we employed a different estimation method to establish T_c for the study watersheds and events. The next section describes that method and demonstrates that it can substitute well for the event hydrograph inflection point method.

Determining Time of Concentration from Unit Hydrograph

The mathematics of the NRCS curvilinear hydrograph assume that t_c is the time from the end of the unit precipitation excess to the mathematical inflection point on the receding limb of the hydrograph (NRCS 2010). Using the gamma unit hydrograph, the inflection point can be mathematically determined by taking the second derivative with respect to time, and setting it equal to 0,

$$t_{infl} = \left(\sqrt{\frac{1}{m}} + 1\right) t_p - 0.1 \qquad \text{(Eq. 8)}$$

where t_{infl} [hr] denotes the time of the inflection point on the dimensional unit hydrograph, measured from the end of precipitation excess (0.1 hr in this analysis). This time is calculated from each unit hydrograph and reported in a summary figure (example in Fig. 12). We denote this time as t_{infl}, time to inflection point, rather than t_c, to emphasize the different methods used in determining the variables.

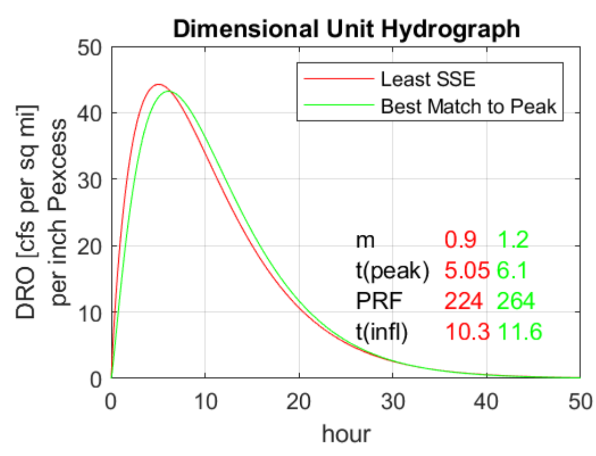


Figure 12. Example final results of unit hydrograph identification, giving values for two candidate UH's: gamma m, time to peak, Peak Rate Factor, and time from end of unit precipitation excess to recession inflection point.

Results

The procedures described above were applied to all watersheds and events, for a total of 100 events, listed by watershed/station in Table 2. The graphical results for each event are included in the Appendix. As mentioned in the descriptions of the different steps, manual adjustments to the automated procedures were sometimes necessary to obtain rational results.

Table 2. Stations and Number of Events Analyzed

Station	Number of Events	Station	Number of Events	Station	Number of Events	Station	Number of Events
1483200	1	1582000	1	1586610	2	1639140	1
1484100	2	1583100	2	1589300	3	1643500	4
1485500	1	1583500	4	1589440	7	1644371	2
1486000	2	1583570	1	1589500	1	1644372	1
1486500	1	1583580	1	1591000	6	1644375	1
1490000	1	1583600	1	1591400	3	1649500	2
1491500	2	1584500	1	1591700	3	1651000	1
1492500	3	1585090	1	1593500	1	1653600	1
1493112	3	1585100	2	1594000	2	1658000	2
1493500	2	1585104	2	1594526	1	1660920	2
1580000	1	1585200	1	1596500	1	1661050	1
1581500	1	1585230	1	1599000	1	148471320	2
1581700	2	1586000	1	1617800	2		
1581757	1	1586210	3	1637500	2		
Total Number of Events							100
Total Number of Stations							54
Average Number of Events per Station							1.85
Number of Stations with 1 Event							27

Analysis

The previous section described the identification of two different best-fit unit hydrographs for each event. In the remaining analysis, we use only the Least SSE solution. We judged that minimizing the sum of squared errors provides the best overall goodness-of-fit measure. (We have included the “Best Match to Peak” analysis in our catalog of results in the Appendix.)

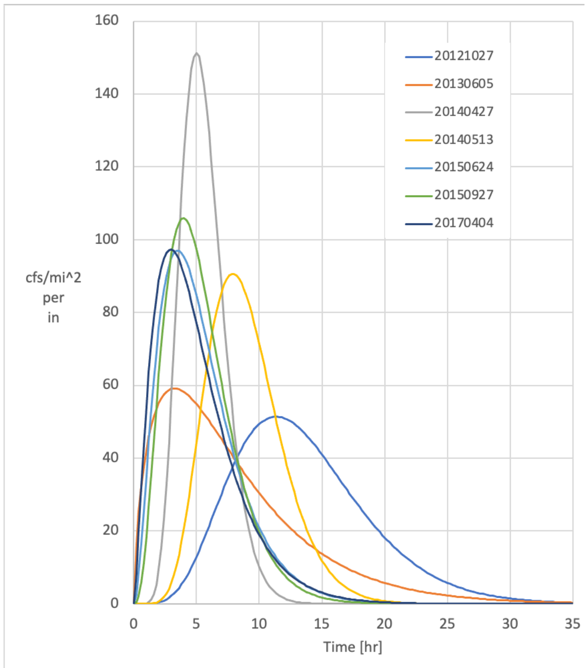


Figure 13. Unit hydrographs (0.1-hr PEXC) for Station 1589440 (Jones Falls at Sorrento, MD).

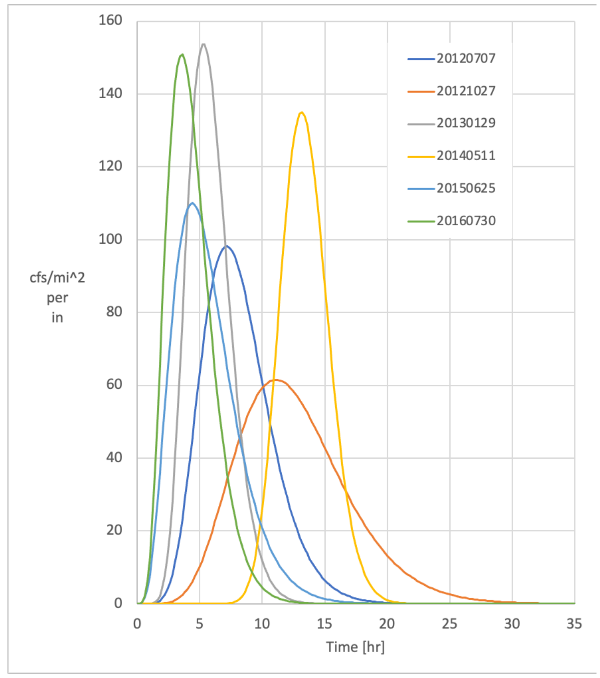


Figure 14. Unit hydrographs (0.1-hr PEXC) for Station 1591000 (Patuxent River near Unity, MD)

Watersheds where multiple events were available for analysis do not show consistency in the gamma *m*, the t_p, or the PRF. For example, the UHs identified from 7 events at Station 1589440 (Jones Falls at Sorrento, MD) are shown in Figure 13. Three events have similar UH; however, the remaining four differ noticeably in their shape (gamma *m*) and time to peak. The UHs identified from 6 events at Station 1591000 (Patuxent River near Unity, MD) are shown in Figure 14. Similarities can be observed between pairs of UH; however, the results show a range of variation in the gamma *m* parameter and time to peak similar to Station 1589440.

Additionally, Figures 13 and 14 illustrate an apparent irrational result in the UH identification. For both stations, the UH for an event in May 2014 (20140513 and 20140511) begins to rise several hours after the precipitation excess begins. We consider this irrational because, by definition, the UH represents streamflow generated by precipitation excess after the delay due to initial abstraction and ongoing losses are removed from the precipitation time series. Under the assumption of spatially uniform unit PEXC over the watershed, the UH should begin to rise immediately when the PEXC begins.

All the analyzed events and the parameters of the Least SSE unit hydrographs are listed in Table 3. Events in which the UH is noticeably delayed are identified with a "†" symbol in Table 3. Many – but not all – of the events so identified have gamma *m* parameters greater than 12. Additionally, events for which the PEX convolved with the identified UH did not fit the observed hydrograph well (visual inspection) are marked with "*" in Table 3. All graphical results are included in the Appendix.

Table 3. Results of Unit Hydrograph and Time of Concentration Identification

Station	Prov	Area [mi^2]	Event Date YYYY MM DD	Qpeak [cfs]	Return Period of Qpeak, T [yr]	Direct Runoff [in]	UH m [ ]	UH t_peak [hr]	UH t_infl [hr]	T_c from event data PEX to end DRO	Tc by Event Inflection Point Total Q	DRO	Note
1483200	1	4.06	20170703	188	2<T<5	1.06	0.9	5.05	10.3	36.3	10.03	9.5	
1484100	2	3.31	20121026	136	25<T<50	1.2	7.7	15.35	20.8	37.7	15.88	17.8	
1484100	2	3.31	20150122	54.9	2<T<5	0.33	3.3	9.8	15.1	27.4	15.5	15.8	
1485500	2	45.47	20121027	1300	5<T<10	0.72	5.3	40.25	57.6	117.1	58.65	58.9	
1486000	2	3.98	20121027	288	5<T<10	1.13	4.2	12	17.8	51.2	9.95	15.7	
1486000	2	3.98	20161007	256	5<T<10	0.68	3.1	9.6	15	28.6	6.28	6.2	
1486500	2	11.18	20170810	1250	na()	3.68	1.5	17.95	32.5	69.5	36.5	47.3	
1490000	2	16.96	20161007	237	2<T<5	0.45	4.6	18.7	27.3	83.1	21.48	22.6	
1491500	2	87.67	20121026	4940	10<T<25	2.64	5.2	26.8	38.5	113.0	25.75	21.8	
1491500	2	87.67	20140427	1990	1.25<T<1.5	1.13	4.65	25.2	36.9	123.5	18.55	19.3	
1492500	2	8	20150116	267	2<T<5	0.57	3.1	9.1	14.2	28.6	10.31	28.5	
1492500	2	8	20160528	283	2<T<5	0.5	5.1	9.45	13.5	22.2	8.2	8.2	
1492500	2	8	20170805	843	10<T<25	1.78	0.7	3.9	8.5	41.4	4.45	4	
1493112	2	6.14	20140811	399	2<T<5	1.09	1.6	5.5	9.7	33.1	13.48	13.9	
1493112	2	6.14	20150626	1310	10<T<25	2.36	1.9	4	6.8	20.0	4.75	4.5	
1493112	2	6.14	20170727	361	2<T<5	0.79	3.85	7.4	11.1	20.7	5.55	5.6	
1493500	2	12.73	20170727	328	1.5<T<2	0.65	3.6	12.85	19.5	43.6	19.98	20.4	
1493500	2	12.73	20180209	667	2<T<5	1.7	15.1	23.7	29.7	67.7	5	5	*†
1580000	1	94.31	20130129	5020	2<T<5	0.67	2.3	4.25	7	26.7	2.8	2.8	
1581500	1	8.79	20170817	3680	10<T<25	1.81	2	1.45	2.4	7.7	1.75	2	
1581700	1	34.64	20150818	5680	5<T<10	0.5	3.8	1.4	2	17.2	1.3	1.6	
1581700	1	34.64	20170817	2800	2<T<5	0.28	1.8	1.35	2.3	13.5	1.68	1.6	
1581757	2	55.85	20140427	6150	na()	2.47	0.5	2.15	5.1	22.1	4.35	4.9	
1582000	1	53.7	20130129	4220	5<T<10	0.84	3.3	2.9	4.4	23.8	3.15	3.4	
1583100	1	12.45	20120825	1230	2<T<5	0.48	0.4	0.6	1.4	26.3	2.15	2.4	
1583100	1	12.45	20150928	1840	10<T<25	0.61	3.1	2	3	35.2	2.2	2.2	
1583500	1	60.31	20120824	6710	10<T<25	0.91	4.5	4.05	5.9	21.4	6.7	6.7	
1583500	1	60.31	20130129	6080	5<T<10	0.96	12.9	5.75	7.3	10.5	6	6.05	
1583500	1	60.31	20140427	3780	2<T<5	1.48	17.7	19	23.4	25.6	-12.6	-13.3	*
1583500	1	60.31	20150928	5060	5<T<10	0.63	5	4.7	6.7	29.2	6.75	6.8	
1583570	1	0.131	20170404	9.32	5	0.31	1	1.1	2.1	9.6	0.4	0.4	
1583580	1	1.49	20150928	283	5<T<10	0.22	1.7	1	1.7	7.0	0.47	0.5	*
1583600	1	20.88	20170402	1350	2<T<5	0.62	1.2	2.4	4.5	16.1	3.38	3.4	
1584500	1	36.04	20140427	5830	5<T<10	1.55	5	4.1	5.8	16.2	1.38	1.5	
1585090	2	2.58	20120813	1680	5<T<10	0.85	4.2	0.6	0.8	7.6	0.37	0.2	
1585100	2	7.56	20150624	4300	10<T<25	2.25	6.8	2.05	2.7	14.2	1.5	1.5	
1585100	2	7.56	20150712	1840	2<T<5	0.72	21.4	3.9	4.6	10.4	4.42	3.72	†
1585104	2	2.44	20120813	877	5<T<10	0.81	6.9	1.4	1.8	4.8	0.97	1	
1585104	2	2.44	20150624	1560	25<T<50	2.45	3.3	1.2	1.8	7.4	0.9	1.2	

Station	Prov	Area [mi^2]	Event Date YYYY MM DD	Qpeak [cfs]	Return Period of Qpeak, T [yr]	Direct Runoff [in]	UH m [ ]	UH t_peak [hr]	UH t_infl [hr]	T_c from event data PEX to end DRO	Tc by Event Inflection Point		Note
											Total Q	DRO	
1585200	1	2.31	20170817	1000	2<T<5	0.3	10.3	0.45	0.5	3.1	0.25	0.3	
1585230	2	3.5	20120628	2180	2<T<5	0.54	10.3	0.35	0.4	3.2	-1.93	-2	
1586000	1	55.48	20130129	5460	5<T<10	1.27	2.5	3.6	5.8	12.6	-7.05	-7	*
1586210	1	14.11	20130129	1520	5<T<10	1.43	1.9	2.45	4.1	4.4	-14	-14	*
1586210	1	14.11	20150928	1120	2<T<5	0.46	1.8	1.9	3.2	11.5	3.25	2.1	
1586210	1	14.11	20160729	1030	2<T<5	0.32	7.2	3.1	4.2	14.4	3.65	3.7	
1586610	1	28.01	20130129	3830	10<T<25	1.44	1.4	2.5	4.5	17.7	1.95	-2.8	*
1586610	1	28.01	20140514	1970	2<T<5	0.5	0.4	5	12.8	23.1	16.65	16.9	†
1589300	1	32.59	20121028	4060	5<T<10	2.61	5.9	11.95	16.8	9.2	-4	-3.7	
1589300	1	32.59	20150929	2920	2<T<5	0.83	5	6.05	8.7	21.0	8.6	8.9	
1589300	1	32.59	20160727	4700	5<T<10	1.43	1.9	3.4	5.8	18.2	7.8	8.1	
1589440	1	25.21	20121027	3510	5<T<10	2.86	5.3	11.35	16.2	44.4	-2.5	-2.2	
1589440	1	25.21	20130605	352	<1.25	0.23	0.7	3.25	7	29.0	-10	-10	
1589440	1	25.21	20140427	6400	10<T<25	3.32	8.8	5	6.6	28.1	-20.1	-19.8	
1589440	1	25.21	20140513	1210	2<T<5	0.48	7.9	7.9	10.6	26.7	11.25	11.5	
1589440	1	25.21	20150624	1730	2<T<5	0.63	1.9	3.5	5.9	30.0	7.35	7.6	
1589440	1	25.21	20150927	1010	1.5<T<2	0.33	2.8	3.95	6.2	18.0	7.6	7.6	
1589440	1	25.21	20170404	1170	2	0.49	1.4	2.95	5.3	24.6	5.65	5.7	
1589500	2	5.04	20121027	240	25<T<50	1.32	5.1	13.25	19	31.9	4.7	5	
1591000	1	34.95	20120707	1710	2<T<5	0.44	7.6	7.15	9.6	22.1	7.35	7.4	
1591000	1	34.95	20121027	3310	5	2.09	7.2	11.1	15.1	54.7	-3.38	-3.2	
1591000	1	34.95	20130129	4620	5<T<10	1.71	10.2	5.3	6.9	3.2	-6.95	-6.9	
1591000	1	34.95	20140511	2500	2<T<5	0.74	47.7	13.15	15	35.8	12.6	12.6	†
1591000	1	34.95	20150625	2640	2<T<5	0.62	3.7	4.4	6.6	17.9	7.5	7.5	
1591000	1	34.95	20160730	3740	5<T<10	0.72	4.5	3.55	5.1	28.0	5.85	6.1	
1591400	1	22.86	20130129	2330	5<T<10	1.42	4.2	3.5	5.1	10.4	-8.3	-8	
1591400	1	22.86	20150624	2080	5<T<10	0.83	2.5	3.5	5.6	18.1	7.15	7.4	
1591400	1	22.86	20160729	2390	5<T<10	0.69	3.1	2.85	4.4	22.3	4.6	4.6	
1591700	1	27.31	20121028	2180	2<T<5	1.75	6.6	9.85	13.6	13.2	-7.8	-12	*
1591700	1	27.31	20150626	2120	2<T<5	0.85	2.8	5.2	8.2	24.4	9.9	9.9	
1591700	1	27.31	20160729	2250	2<T<5	0.59	11.8	6.6	8.4	21.5	9.05	9.1	
1593500	1	38.1	20160729	7230	25<T<50	1.83	6.7	7.15	9.8	20.2	7.5	7.8	
1594000	1	98.25	20121027	10600	10<T<25	2.76	9.8	11.85	15.5	50.1	-1.35	-1.3	
1594000	1	98.25	20150624	5920	2<T<5	0.85	3	6.25	9.8	39.4	11.5	11.5	
1594526	2	89.38	20121027	4100	2<T<5	1.91	3.4	18.95	29.1	84.0	11.1	9.6	
1596500	1	48.53	20140511	2260	2<T<5	0.77	5.4	12.6	17.9	47.8	6.3	6.3	
1599000	1	72.74	20121027	2680	2<T<5	0.86	0.1	1	4.1	112.7	1.05	1.1	
1617800	1	18.34	20121027	121	2<T<5	0.15	2.4	11.75	19.2	43.6	11.9	12.2	
1617800	1	18.34	20180816	136	2<T<5	0.11	1.3	6.75	12.6	71.7	5.92	6.1	
1637500	1	67.33	20121027	8330	10<T<25	2.95	8.3	10.8	14.4	34.9	-3.48	-2.8	
1637500	1	67.33	20140511	6750	10<T<25	1.2	33.3	15.25	17.8	25.7	12.55	7.1	†

Station	Prov	Area $[mi^2]$	Event Date YYYY MM DD	Qpeak [cfs]	Return Period of Qpeak, T [yr]	Direct Runoff [in]	UH m [ ]	UH t_peak [hr]	UH t_infl [hr]	T_c from event data PEX to end DRO	Tc by Event Inflection Point		Note
											Total Q	DRO	
1639140	1	31.37	20121027	6150	25<T<50	3.39	4.2	12.95	19.2	7.2	1.75	-4.2	
1643500	1	62.94	20130129	5750	5<T<10	1.49	4	4.95	7.3	13.5	-7.4	-7.4	*
1643500	1	62.94	20140511	5950	5<T<10	1.04	35	11.9	13.8	26.8	11.8	11.8	†
1643500	1	62.94	20150928	2800	2<T<5	0.27	0.7	1.55	3.3	18.9	0.75	0.8	
1643500	1	62.94	20160727	3930	2<T<5	0.51	4.8	4.7	6.7	16.7	6.5	6.8	
1644371	1	0.42	20130608	252	5<T<10	0.8	3.7	0.45	0.6	2.1	-0.03	0	
1644371	1	0.42	20160729	396	10<T<25	1.32	1.8	0.325	0.5	3.7	0.35	0.3	
1644372	1	0.34	20160729	453	na()	1.33	3.6	0.575	0.8	2.1	0.12	0.1	
1644375	1	1.29	20130608	468	5<T<10	0.76	1.1	0.55	1	5.7	0.88	0.9	
1649500	2	73.2	20121027	4750	2<T<5	1.86	2	6.4	10.8	39.1	-12.1	-12.1	
1649500	2	73.2	20140609	7290	5<T<10	0.31	1	0.65	1.2	4.1	0.23	0.3	
1651000	2	49.33	20121027	5770	2<T<5	2.88	11	9.65	12.5	18.4	-11	-10.7	*
1653600	2	39.43	20121027	1630	2<T<5	1.35	9.8	17.4	22.9	35.4	4.7	2	†
1658000	2	55.57	20140427	1540	2<T<5	0.95	0.7	9.9	21.6	74.4	6.15	6.45	
1658000	2	55.57	20181009	5680	10<T<25	2.03	4.9	16.7	24.1	38.5	15.18	15.2	
1660920	2	81.61	20121027	2620	5<T<10	0.8	10.1	34.45	45.2	67.9	19.82	24.7	†
1660920	2	81.61	20140427	3370	10<T<25	1.85	5.9	26.4	37.2	95.9	24.25	26	
1661050	2	18.18	20170704	1410	2<T<5	0.98	5.1	9.95	14.3	41.7	9.8	7.8	*
148471320	2	6.38	20121026	1040	na()	4.75	0.5	2.55	6.1	35.0	-7.7	-19.4	
148471320	2	6.38	20170810	1290	na()	2.11	8.4	10.15	13.6	29.5	12.35	11.6	†

* Convolved hydrograph is not a good fit with observed.

† Unit hydrograph does not rise at the beginning of Pexcess.

Event T_c determined as described above and tabulated in Table 3, is compared to observed average watershed T_c reported in Thomas (2000). It is important to note a major difference between the semi-automated method used here and the expert interpretation method applied in the previous study. This study measured the time elapsed from end of PEX to end of DRO where the end of DRO was determined using an exponential baseflow recession model. The Thomas (2000) study examined the hydrographs and identified the time from end of precipitation excess to the *first inflection point on the recession limb*. It is clear from Figure 15 that these two times are not the same. This study's event T_c is almost three times the previous expert-identified T_c.

If, instead, the Thomas (2000) expert-identified T_c is compared with the UH t_{infl} calculated in this study, the values are in much better agreement (Figure 16).

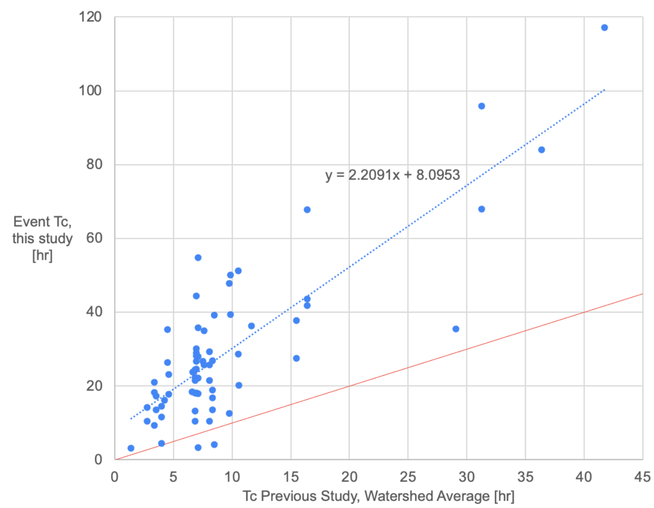


Figure 15. Event time of concentration identified in this study (time from end of precipitation excess to end of direct runoff) compared to watershed average Tc identified by expert inspection of hydrographs in the Thomas (2000) study (end of P excess to first inflection point on the recession). The dashed blue line is the calculated linear regression; the red line is the line of equality.

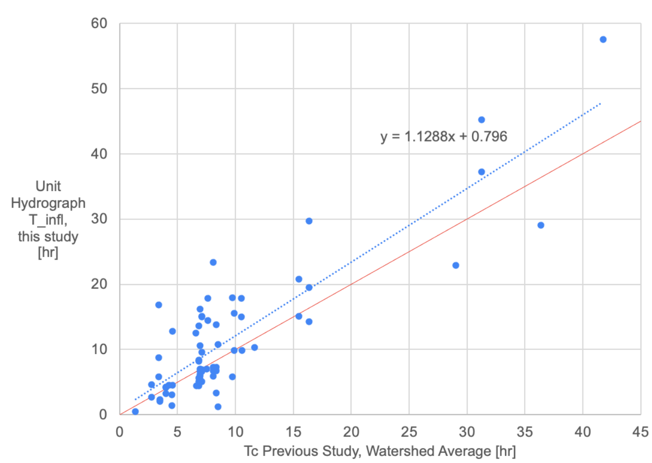


Figure 16. Time from end of Precipitation Excess to the mathematical inflection point on the gamma unit hydrograph (t_{infl}), as calculated in this study, compared to watershed average time of concentration (T_c) determined by expert inspection in the Thomas (2000) study. The dashed blue line is the calculated linear regression, and the red line is the line of equality.

The event Tc determined in this study by automatically determining the recession inflection point are compared to those determined in the Thomas (2000) study (Figure 17). This study's inflection-point values tend to underestimate, especially in the range of longer T_c.

Finally, the T_c estimated from the event hydrographs in this study is compared to t_{infl} calculated from the gamma equation of the UH (Figure 18), The values determined mathematically from the UH tend to be greater than those estimated graphically from the event hydrographs.

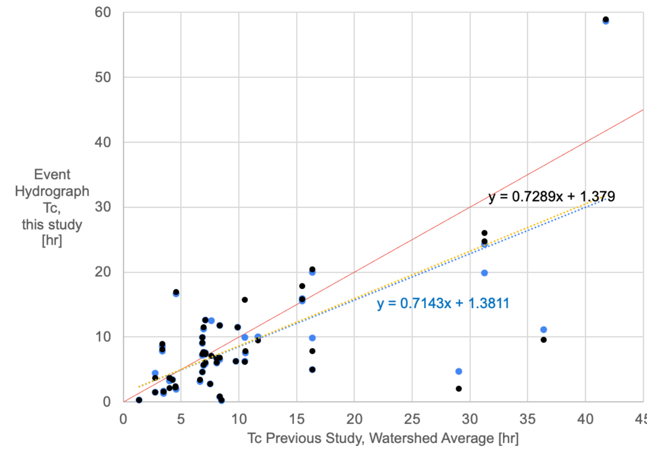


Figure 17. *Tc* estimated using the event hydrograph recession inflection point in this study compared to watershed average *Tc* estimated in Thomas (2000). Blue: estimated from total discharge hydrograph; Black: estimated from direct runoff hydrograph. Irrational negative *Tc* results are excluded. The red line is the line of equality.

Given the large number of irrational results (negative *Tc*) found using the graphical event analysis method and given the good agreement between t_{infl} and the Thomas (2000) *Tc* estimates, we decided to use the UH t_{infl} as the estimate of watershed/event Time of Concentration for the remaining analysis.

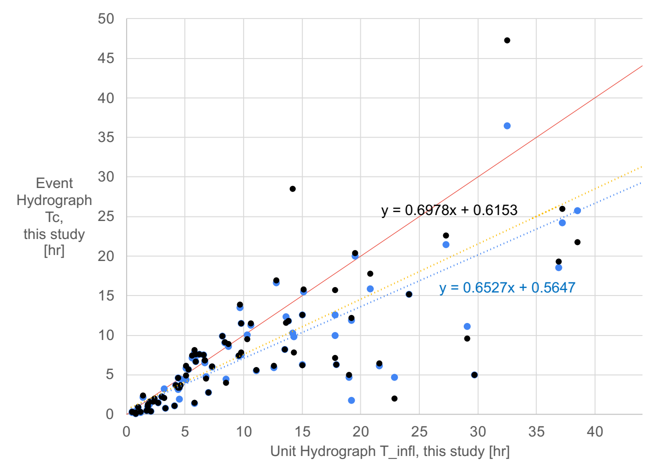


Figure 18. T_c estimated using the event hydrograph recession inflection point in this study compared to T_{infl} calculated from the equation of the gamma unit hydrograph. Blue: estimated from total discharge hydrograph; Black: estimated from direct runoff hydrograph. Irrational negative T_c results are excluded. The red line is the line of equality.

Censoring Result Data

The events identified with * or † in Table 3 were excluded from further analysis. The censored data set consists of 82 events at 47 stations. The remaining analysis consists of an effort to determine whether the parameters of the identified unit hydrographs (*m* and *Tc*) can be related to or predicted by watershed properties.

Watershed Properties as Predictor Variables

It is necessary to have a consistent set of watershed properties to test as predictors. Thomas (2000) found the following variables significant in predicting T_c:

- Channel length [mi]
- Channel slope [ft/mi]
- Forest cover [percentage of watershed]
- Impervious area [percentage of watershed]
- Storage in lakes and ponds [percentage of watershed]
- Geographical Province [binary variables, CP = 1 if in Coastal Plain, 0 otherwise; AP = 1 if in Appalachian Plateau, 0 otherwise]

The values used as input to stepwise regression in Thomas (2000) are provided in Table A6-4 of the Hydrology Panel Report (2020).

Of our censored data, 21 watersheds were included in the Thomas (2000) Study, and 26 were not. For a consistent data set that includes all our study watersheds, we consulted Appendix 1 of the Hydrology Panel Report (HPR-App1), which provides several dozen watershed properties. There are some inconsistencies between Table A6-4 and HPR-App1. The reason for the inconsistencies is that the values in Table A6-4 were determined by Dillow (1998) and the values in Appendix 1 were determined using GIS techniques after 2006. The Dillow (1998) watershed characteristics were retained in Table A6-4 to document the watershed characteristics used in the Thomas and others (2000) study (W. Thomas, personal communication).

Channel Length, which was identified as a significant predictor in the previous study, is not provided in HPR-App1; HPR-App1 reports a "Total Stream Length" variable, which is not the same. We chose to use Watershed Length, which is reported by HPR-App1 and calculated in GISHydroNXT's Basin Statistics step, as the predictor variable instead. This variable is defined as "distance measured along the main channel from the watershed outlet to the basin divide (mi)"

(HPR). The values are strongly correlated with, but slightly greater than, the Channel Length variable used in Thomas (2000) (Figure 19). However, HPR-App1 does not provide values of the length variable for all the study watersheds. The watersheds with missing Watershed Length were analyzed using watershed analysis in GISHydroNXT. The basin statistics output files are included in the Appendix to this report.

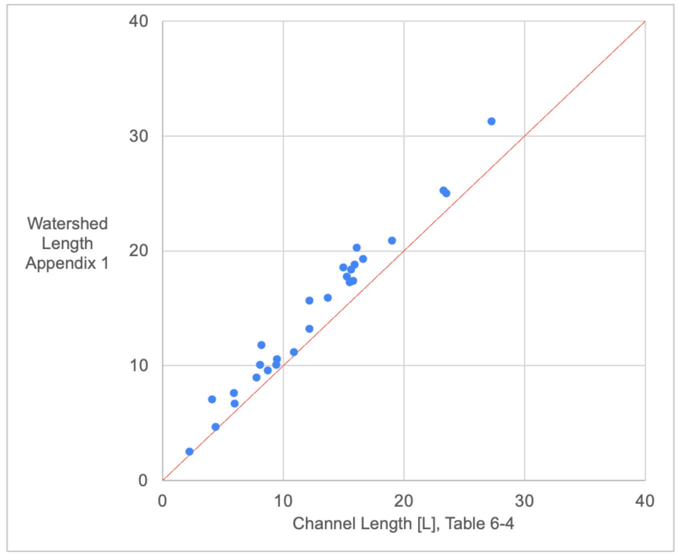


Figure 19. Channel Length from Maryland Hydrology Panel (2020) Table A6-4 and Watershed Length as reported in Maryland Hydrology Panel (2020) Appendix 1 for watersheds included in the Thomas (2000) study.

Four of our study watersheds are not included in HPR-App1: 1486500 (Beaverdam Creek Near Salisbury, Md), 1581757 (Otter Point Creek Near Edgewood, Md), 1639140 (Piney Creek Near Taneytown, Md.), and 1644372 (Little Seneca Creek Tributary at Brink, Md). The required input properties for these four were determined using watershed analysis in GISHydroNXT. The basin statistics output files are included in the Appendix.

Stepwise regression was performed using the Matlab tool/command "stepwiselm." A first test was to run this tool on the Thomas (2000) data provided in HPR Table A6-4. Thomas (2000) used different software tools; the purpose of this test was to confirm that the Matlab tool performs similarly. All rows in HPR Table A6-4 with missing data were removed, leaving 77 observations. The result of this linear regression is:

$$Tc = 0.1654\ SL^{-0.202}\ CL^{0.4678}\ (ST+1)^{0.1463}\ (101\text{-}FOR)^{-0.1541}\ (101\text{-}IA)^{0.838}\ 10^{0.191\ AP}\ 10^{0.36\ CP}$$

The Matlab stepwise regression identifies the same set of significant predictors as Thomas (2000). Table 4 compares the coefficients determined in this exercise to those reported by

Thomas (2000); the exponents deviate from the Thomas (2000) values by several percent; these differences can be attributed to internal computational procedures in the software packages.

Table 4. Results of Stepwise Regression on Thomas (2000) Data to Confirm Consistency of Analysis: Coefficients

	Constant	SL	CL	ST+1	101-FOR	101-IA	AP	CP
Thomas (2000)	0.1654	-0.202	0.4678	0.1463	-0.1541	0.838	0.191	0.36
Test regression	0.133	-0.187	0.475	0.154	-0.144	0.861	0.194	0.366
Fractional difference relative to Thomas (2000)	-0.196	-0.074	0.015	0.053	-0.066	0.027	0.016	0.017

Stepwise regression was performed on the data matrix presented in Table 5. The 12 columns DA through DRO are the predictor variables, and the last 3 columns M, TPEAK, and TINFL are the criterion or response variables. Multiple events on the same watershed were not averaged, because we hypothesized that unit hydrograph properties might reflect differences in event magnitude (DRO). Except for the Province indices CP, PM, BR, and AP, all variables were log transformed for the regression analysis. Forest and Impervious Area percent were transformed as log10(101 – FOR) and log10(101 – IA) and Storage was transformed as log10(ST + 1) as in Thomas (2000), to avoid the possibility of attempting to log transform a value of 0.

The correlation structure of the predictor and response variables is presented in Table 6, which follows Table 5 below.

In Table 5, the variables are defined as follows:

Date YYYYMMDD

Predictor Variables

DA	Drainage Area, [mi^2]
L	Watershed length [mi]
CS	Channel Slope [ft/mi]
LS	Land Slope [ft/ft]
FOR	Percent (by area) forested
IA	Percent (by area) impervious
ST	Percent of area representing storage (lakes, ponds, wetlands)
CP	Index variable for Coastal Plain province
PM	Index variable for Piedmont province
BR	Index variable for Blue Ridge province
AP	Index variable for Appalachian Plateau province
DRO	Direct Runoff [in]

Response Variables

m	Gamma UH m parameter
tpeak UH	Time to peak of the UH
tinfl UH	Time from end of unit Precipitation to recession inflection point of the UH, used as estimate of Time of Concentration

Table 5. Predictor and Response Variables Used in Stepwise Regression

Station	Date	DA	L	CS	LS	FOR	IA	ST	CP	PM	BR	AP	DRO	m	tpeak UH	tinfl UH
1483200	20170703	4.06	4.01	13.5	0.01898	30	4.3	21.4	1	0	0	0	1.06	0.9	5.05	10.3
1484100	20121026	3.31	3.62	5.2	0.0073	19.8	2	25	1	0	0	0	1.2	7.7	15.35	20.8
1484100	20150122	3.31	3.62	5.2	0.0073	19.8	2	25	1	0	0	0	0.33	3.3	9.8	15.1
1485500	20121027	45.47	15.7	3.1	0.00841	72.8	2.3	0.3	1	0	0	0	0.72	5.3	40.25	57.6
1486000	20121027	3.98	7.1	6.4	0.00544	46.9	2.2	0	1	0	0	0	1.13	4.2	12	17.8
1486000	20161007	3.98	7.1	6.4	0.00544	46.9	2.2	0	1	0	0	0	0.68	3.1	9.6	15
1486500	20170810	11.18	6.23	6.354	0.01286	35.4	16.2	1.4	1	0	0	0	3.68	1.5	17.95	32.5
1490000	20161007	16.96	8.4	5.6	0.00757	43.2	0.9	0.5	1	0	0	0	0.45	4.6	18.7	27.3
1491500	20121026	87.67	18.7	3.3	0.01189	31	1.3	0.1	1	0	0	0	2.64	5.2	26.8	38.5
1491500	20140427	87.67	18.7	3.3	0.01189	31	1.3	0.1	1	0	0	0	1.13	4.65	25.2	36.9
1492500	20150116	8	7.4	9.9	0.01948	29.3	1.3	0	1	0	0	0	0.57	3.1	9.1	14.2

Station	Date	DA	L	CS	LS	FOR	IA	ST	CP	PM	BR	AP	DRO	m	tpeak UH	tinfl UH
1492500	20160528	8	7.4	9.9	0.01948	29.3	1.3	0	1	0	0	0	0.5	5.1	9.45	13.5
1492500	20170805	8	7.4	9.9	0.01948	29.3	1.3	0	1	0	0	0	1.78	0.7	3.9	8.5
1493112	20140811	6.14	5.11	14.6	0.01857	7.9	0.4	0.5	1	0	0	0	1.09	1.6	5.5	9.7
1493112	20150626	6.14	5.11	14.6	0.01857	7.9	0.4	0.5	1	0	0	0	2.36	1.9	4	6.8
1493112	20170727	6.14	5.11	14.6	0.01857	7.9	0.4	0.5	1	0	0	0	0.79	3.85	7.4	11.1
1493500	20170727	12.73	7.6	9.9	0.02445	7.2	1	0.5	1	0	0	0	0.65	3.6	12.85	19.5
1580000	20130129	94.31	31.3	17.9	0.103	25.8	3.9	0.1	0	1	0	0	0.67	2.3	4.25	7
1581500	20170817	8.79	7.1	45.1	0.048	14.8	33.4	0	0	1	0	0	1.81	2	1.45	2.4
1581700	20150818	34.64	17.4	30.4	0.07	25.9	13	0	0	1	0	0	0.5	3.8	1.4	2
1581700	20170817	34.64	17.4	30.4	0.07	25.9	13	0	0	1	0	0	0.28	1.8	1.35	2.3
1581757	20140427	55.85	25.87	27.27	0.08477	27	17.8	0.2	0	1	0	0	2.47	0.5	2.15	5.1
1582000	20130129	53.7	18.6	33.1	0.103	38.3	5.3	0.1	0	1	0	0	0.84	3.3	2.9	4.4
1583100	20120825	12.45	9	49.8	0.083	30.8	4.7	0	0	1	0	0	0.48	0.4	0.6	1.4
1583100	20150928	12.45	9	49.8	0.083	30.8	4.7	0	0	1	0	0	0.61	3.1	2	3
1583500	20120824	60.31	18.8	26	0.082	33.7	4.4	0.1	0	1	0	0	0.91	4.5	4.05	5.9
1583500	20130129	60.31	18.8	26	0.082	33.7	4.4	0.1	0	1	0	0	0.96	12.9	5.75	7.3
1583500	20150928	60.31	18.8	26	0.082	33.7	4.4	0.1	0	1	0	0	0.63	5	4.7	6.7
1583570	20170404	0.131	0.73	215.1	0.101	100	0	0	0	1	0	0	0.31	1	1.1	2.1
1583600	20170402	20.88	11.8	45.6	0.076	23.7	27.5	0.1	0	1	0	0	0.62	1.2	2.4	4.5
1584500	20140427	36.04	15.5	21.8	0.071	28.5	6.8	0.1	0	1	0	0	1.55	5	4.1	5.8
1585090	20120813	2.58	3.31	81.9	0.06888	9.3	47.2	0	0	1	0	0	0.85	4.2	0.6	0.8
1585100	20150624	7.56	6.7	54.4	0.061	14.3	42.6	0	0	1	0	0	2.25	6.8	2.05	2.7
1585104	20120813	2.44	3.39	72.1	0.054	28.6	22.5	0	0	1	0	0	0.81	6.9	1.4	1.8
1585104	20150624	2.44	3.39	72.1	0.054	28.6	22.5	0	0	1	0	0	2.45	3.3	1.2	1.8
1585200	20170817	2.31	2.5	63.1	0.059	2	43.2	0	0	1	0	0	0.3	10.3	0.45	0.5
1585230	20120628	3.5	3.8	82.1	0.045	1.8	45.4	0	0	1	0	0	0.54	10.3	0.35	0.4

Station	Date	DA	L	CS	LS	FOR	IA	ST	CP	PM	BR	AP	DRO	m	tpeak UH	tinfl UH
1586210	20150928	14.11	10.1	45	0.079	24.6	14.5	0.2	0	1	0	0	0.46	1.8	1.9	3.2
1586210	20160729	14.11	10.1	45	0.079	24.6	14.5	0.2	0	1	0	0	0.32	7.2	3.1	4.2
1589300	20121028	32.59	15.9	21.2	0.056	21.2	35.7	0.2	0	1	0	0	2.61	5.9	11.95	16.8
1589300	20150929	32.59	15.9	21.2	0.056	21.2	35.7	0.2	0	1	0	0	0.83	5	6.05	8.7
1589300	20160727	32.59	15.9	21.2	0.056	21.2	35.7	0.2	0	1	0	0	1.43	1.9	3.4	5.8
1589440	20121027	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	2.86	5.3	11.35	16.2
1589440	20130605	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	0.23	0.7	3.25	7
1589440	20140427	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	3.32	8.8	5	6.6
1589440	20140513	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	0.48	7.9	7.9	10.6
1589440	20150624	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	0.63	1.9	3.5	5.9
1589440	20150927	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	0.33	2.8	3.95	6.2
1589440	20170404	25.21	10.6	32.3	0.078	23.7	18.9	0	0	1	0	0	0.49	1.4	2.95	5.3
1589500	20121027	5.04	4.7	31.3	0.036	28.8	33.5	0	1	0	0	0	1.32	5.1	13.25	19
1591000	20120707	34.95	13.2	29.8	0.092	42.1	3.9	0.2	0	1	0	0	0.44	7.6	7.15	9.6
1591000	20121027	34.95	13.2	29.8	0.092	42.1	3.9	0.2	0	1	0	0	2.09	7.2	11.1	15.1
1591000	20130129	34.95	13.2	29.8	0.092	42.1	3.9	0.2	0	1	0	0	1.71	10.2	5.3	6.9
1591000	20150625	34.95	13.2	29.8	0.092	42.1	3.9	0.2	0	1	0	0	0.62	3.7	4.4	6.6
1591000	20160730	34.95	13.2	29.8	0.092	42.1	3.9	0.2	0	1	0	0	0.72	4.5	3.55	5.1
1591400	20130129	22.86	9.6	32.3	0.08	22.8	8.3	0.2	0	1	0	0	1.42	4.2	3.5	5.1
1591400	20150624	22.86	9.6	32.3	0.08	22.8	8.3	0.2	0	1	0	0	0.83	2.5	3.5	5.6
1591400	20160729	22.86	9.6	32.3	0.08	22.8	8.3	0.2	0	1	0	0	0.69	3.1	2.85	4.4
1591700	20150626	27.31	11.2	26.5	0.056	32.8	11.5	0.4	0	1	0	0	0.85	2.8	5.2	8.2
1591700	20160729	27.31	11.2	26.5	0.056	32.8	11.5	0.4	0	1	0	0	0.59	11.8	6.6	8.4
1593500	20160729	38.1	17.3	18.8	0.053	19.5	31.2	0.6	0	1	0	0	1.83	6.7	7.15	9.8
1594000	20121027	98.25	25	14	0.059	24	21.5	0.3	1	0	0	0	2.76	9.8	11.85	15.5
1594000	20150624	98.25	25	14	0.059	24	21.5	0.3	1	0	0	0	0.85	3	6.25	9.8

Station	Date	DA	L	CS	LS	FOR	IA	ST	CP	PM	BR	AP	DRO	m	tpeak UH	tinfl UH
1594526	20121027	89.38	20.3	7.7	0.055	33	24.6	0.3	1	0	0	0	1.91	3.4	18.95	29.1
1596500	20140511	48.53	20.9	62.5	0.22802	78.8	1.3	0.4	0	0	0	1	0.77	5.4	12.6	17.9
1599000	20121027	72.74	19.6	58.5	0.17098	71.4	4.2	0	0	0	0	1	0.86	0.1	1	4.1
1617800	20121027	18.34	10.1	25.5	0.035	14.7	9.2	0.1	0	0	1	0	0.15	2.4	11.75	19.2
1617800	20180816	18.34	10.1	25.5	0.035	14.7	9.2	0.1	0	0	1	0	0.11	1.3	6.75	12.6
1637500	20121027	67.33	25.3	45.6	0.124	45.2	6.1	0	0	0	1	0	2.95	8.3	10.8	14.4
1639140	20121027	31.37	16.76	17.8	0.0484	15.1	2.5	1.9	0	0	1	0	3.39	4.2	12.95	19.2
1643500	20150928	62.94	18.4	29.6	0.103	41.7	6.4	0.1	0	0	1	0	0.27	0.7	1.55	3.3
1643500	20160727	62.94	18.4	29.6	0.103	41.7	6.4	0.1	0	0	1	0	0.51	4.8	4.7	6.7
1644371	20130608	0.42	1.32	126.8	0.068	23.5	28	0	0	1	0	0	0.8	3.7	0.45	0.6
1644371	20160729	0.42	1.32	126.8	0.068	23.5	28	0	0	1	0	0	1.32	1.8	0.325	0.5
1644372	20160729	0.34	1.26	112.77	0.06069	28.8	1.6	0	0	1	0	0	1.33	3.6	0.575	0.8
1644375	20130608	1.29	2.45	63.1	0.043	8.6	53.5	0.1	0	1	0	0	0.76	1.1	0.55	1
1649500	20121027	73.2	17.8	27.5	0.055	28.8	28.3	0.2	1	0	0	0	1.86	2	6.4	10.8
1649500	20140609	73.2	17.8	27.5	0.055	28.8	28.3	0.2	1	0	0	0	0.31	1	0.65	1.2
1658000	20140427	55.57	20.7	9.9	0.034	51.4	15.3	0.1	1	0	0	0	0.95	0.7	9.9	21.6
1658000	20181009	55.57	20.7	9.9	0.034	51.4	15.3	0.1	1	0	0	0	2.03	4.9	16.7	24.1
1660920	20140427	81.61	19.3	9.2	0.044	58	9.2	0.2	1	0	0	0	1.85	5.9	26.4	37.2
148471320	20121026	6.38	5.01	2.5	0.00619	30.2	0.9	0	1	0	0	0	4.75	0.5	2.55	6.1

Table 6. Correlation Structure of Predictor and Response Variables

		Predictors												Response		
		DA	L	CS	LS	FOR	IA	ST	CP	PM	BR	AP	DRO	m	tpeak UH	tinfl UH
Predictors	DA	1.000														
	L	0.919	1.000													
	CS	-0.337	-0.401	1.000												
	LS	0.302	0.388	0.400	1.000											
	FOR	0.303	0.289	0.191	0.372	1.000										
	IA	-0.118	-0.138	0.268	0.005	-0.437	1.000									
	ST	-0.193	-0.228	-0.174	-0.273	-0.091	-0.173	1.000								
	CP	0.114	-0.031	-0.498	-0.681	0.069	-0.261	0.288	1.000							
	PM	-0.230	-0.130	0.456	0.405	-0.192	0.369	-0.243	-0.812	1.000						
	BR	0.128	0.188	-0.044	0.107	-0.020	-0.152	-0.041	-0.197	-0.326	1.000					
	AP	0.171	0.193	0.129	0.596	0.439	-0.132	-0.030	-0.111	-0.183	-0.044	1.000				
	DRO	0.113	0.112	-0.185	-0.162	-0.046	0.044	-0.051	0.195	-0.171	0.010	-0.065	1.000			
Response	m	0.097	0.080	-0.043	0.072	-0.048	0.092	0.001	-0.133	0.176	-0.049	-0.076	0.103	1.000		
	tpeak UH	0.340	0.259	-0.475	-0.378	0.317	-0.281	0.109	0.570	-0.561	0.041	-0.006	0.230	0.209	1.000	
	tinfl UH	0.330	0.253	-0.496	-0.407	0.320	-0.290	0.114	0.607	-0.605	0.051	0.004	0.238	0.120	0.991	1.000

Note: Colors denote |correlation| > 0.3, yellow = positive, orange = negative

Stepwise Regression Results

Gamma Unit Hydrograph m Parameter / Peak Rate Factor

Stepwise regression analysis of the log gamma *m* parameter, including all rows of Table 5, identified only one significant predictor, the Appalachian Plateau index:

$$\log m = 0.49932 - 0.633123\ AP \qquad \text{(Eq. 9)}$$

Equivalently, the best estimate of gamma *m* based on these data is a constant value for non-Appalachian Plateau watersheds (AP = 0):

$$m = 10^{0.49932} = 3.157 \qquad \text{(Eq. 10)}$$

and for Appalachian Plateau watersheds

$$m = 10^{(0.49932-0.633123)} = 0.735 \qquad \text{(Eq. 11)}$$

These values of m correspond to PRF of 445 and 198, respectively. The standard error is 105%.

When only the Coastal Plain entries were analyzed, stepwise regression returned a constant model,

$$\log m = 0.448246 \quad \text{(Eq. 12)}$$

$$m = 10^{0.448246} = 2.807 \quad \text{(Eq. 13)}$$

This value corresponds to a PRF of 418, which is considerably higher than the 284 PRF associated with the Delmarva DUH. The standard error is 92.3%.

Finally, the regression was run excluding the Coastal Plain entries. Both the Appalachian Plateau index variable and log of DRO were identified as significant,

$$\log m = 0.557053 - 0.661876\, AP + 0.323558\, (log\ DRO) \quad \text{(Eq. 14)}$$

or

$$\log m = 3.606\, AP^{-0.661876} DRO^{0.323558} \quad \text{(Eq. 15)}$$

The standard error is 107.4%. This result is the only instance where we observed DRO entering a regression model.

Overall, the large standard errors of these models indicate that the gamma *m* parameter – and consequently the PRF – are not successfully predicted with the selected watershed properties.

Gamma Unit Hydrograph Time of Concentration

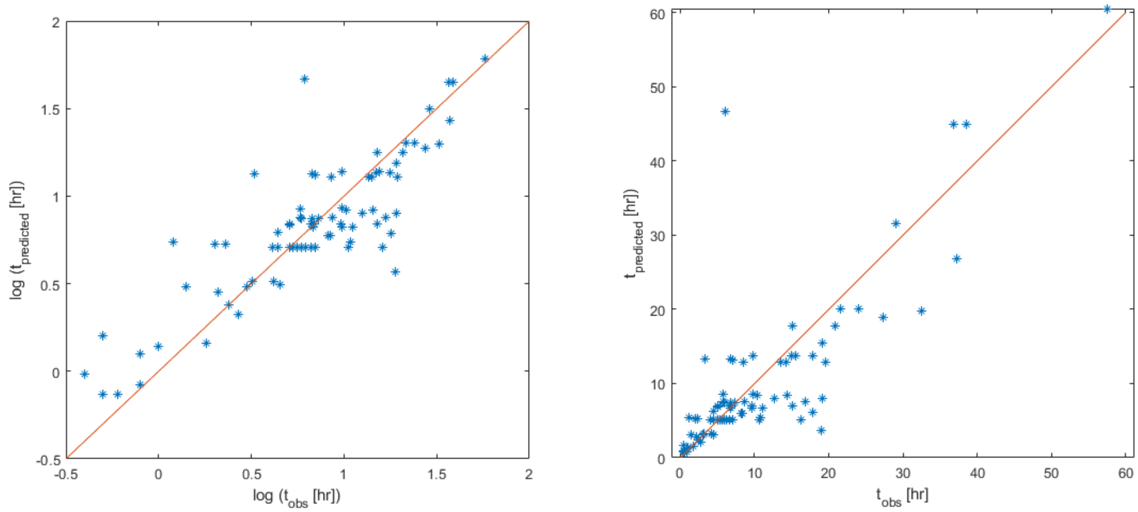
Stepwise regression analysis of the log10(tinfl), the variable which we chose as best representative of *Tc*, identified four significant predictors, Channel Slope, Land Slope, Forest, and Blue Ridge Province index:

$$\mathrm{log10(tinfl)} = 4.13634 - 1.3597\,\mathrm{log10(CS)} + 0.512382\,\mathrm{log10(LS)} - 0.429388\,\mathrm{log10(101 - FOR)} + 0.256902\,\mathrm{BR} \quad \text{(Eq. 15)}$$

or

$$\mathrm{t_{infl}} = 13{,}688\,\mathrm{CS}^{-1.36}\,\mathrm{LS}^{0.512}(101 - FOR)^{-0.429}10^{0.257\,BR} \quad \text{(Eq. 16)}$$

The standard error is 63.8%, which is twice the value of the SE associated with the Thomas (2000) regression for T_c. The results are shown in Figure 20. One outlier is noted (observed =



(a) (b)

Figure 20. Stepwise Regression results for Time of concentration using the UH time to inflection (t_{infl}). (a) Log, (b) dimensional [hr].

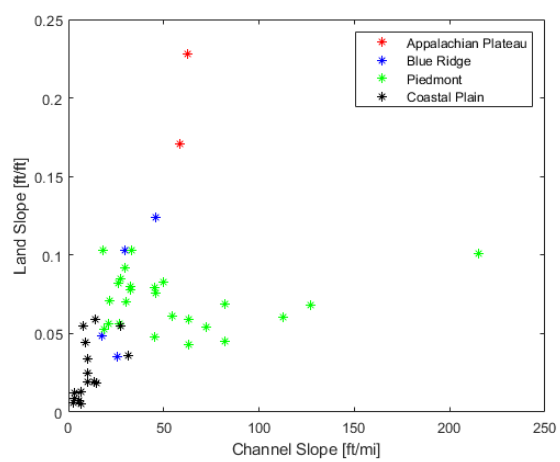


Figure 21. The relationship between Channel Slope and Land Slope shows a dual pattern of positive correlation.

6.1 hr, predicted = 46.7 hr). This point is the last entry in Table 5, Station 148471320 on 20121026. This was a very heavy precipitation event (Hurricane Sandy) on a small watershed in the Coastal Plain. The other event on this watershed was excluded in the data censoring step. The combination of a negative exponent on Channel Slope (CS) and a positive exponent on Land Slope (LS) is puzzling, given that the two variables are positively correlated with each other and both negatively correlated with ti_{nfl} (Table 6). Figure 21 shows that the positive correlation between Channel Slope and Land Slope reflects a bifurcated pattern in the relationship between these two variables; in the Piedmont province, steep channels appear to be associated with less steep hillslopes. It is also surprising that the Blue Ridge Province index (BR) was significant in this model, given that it is nonzero for only 6 of the 82 input events.

The Time of Concentration regression described here was performed only on the new data collected and identified in the current study. The original expectation was that the former events and the current ones could be merged into a single, larger data set including more stream gages and covering a longer time period and a greater range of streamflow events. However, differences between the predictor variables used in the Thomas (2000) study (as inherited from Dillow [1998]) and those obtained for this study from HPR Appendix 1 and GISHydroNXT would need to be resolved.

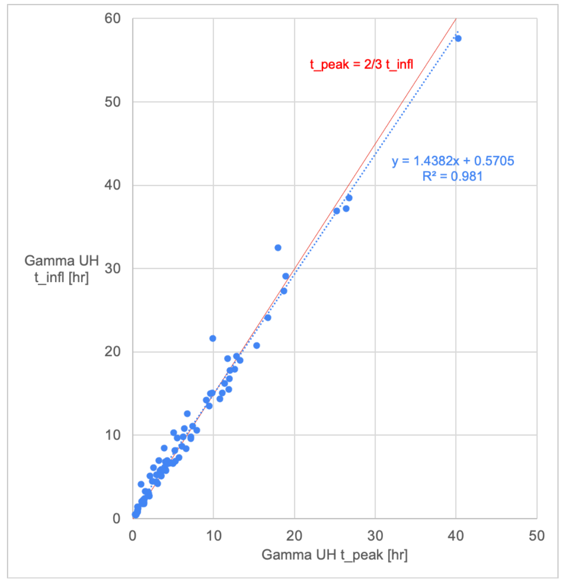


Figure 22. Gamma UH time to peak (t_peak) and time between end of precipitation excess and mathematical inflection point on the receding limb (t_infl). The blue dashed line is the linear regression; the red solid line indicates t_peak = 2/3 t_infl, analogous to the NRCS unit hydrograph assumption that t_p = 2/3 t_c.

Relationship Between UH Time Variables

For the standard NRCS unit hydrograph, the ratio of t_{peak} to t_c is assumed to equal 2/3, where t_c is defined as the inflection point on the UH recession (NRCS, 2010). The two time variables for all 82 events in the censored data set are shown as a scatter plot in Figure 22. The points cluster around the line $t_{peak} = 2/3\ t_{infl}$. Figure 23 shows systematic variation in the ratio of t_{peak} to t_{infl} as a function of gamma shape parameter, *m*. The ratio is not purely a function of *m*, because it is a property of the dimensional UH and incorporates the magnitude of precipitation excess duration relative to t_{peak}. The red circle indicates the 2/3 ratio assumed in the NRCS curvilinear unit hydrograph with PRF 484.

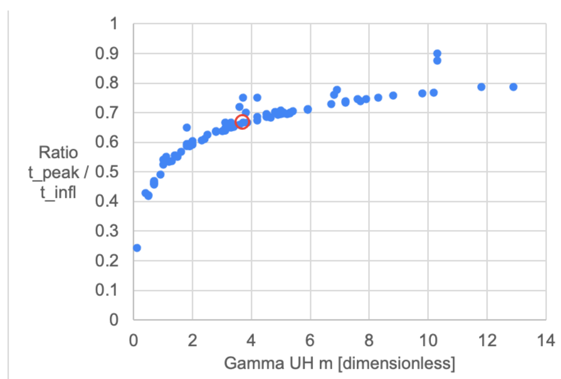


Figure 23. Ratio of time from end of precipitation excess to inflection point (t_infl) to time to peak (t_peak) with *m* parameter for Gamma UH identified for 82 events. The red circle indicates the assumed ratio of t_c to t_p (2/3) for the NRCS unit hydrograph with PRF = 484 (*m* = 3.7).

Conclusions and Recommendations

A gamma unit hydrograph was identified for each of 100 events at 54 stations in Maryland. The *m* parameter of the gamma distribution and the time to peak of the unit hydrograph were selected as fundamental properties, rather than the PRF (which can be directly related to the *m* parameter mathematically). Of these events, 18 were excluded due to irrational results or low-quality fitting.

The gamma UH is defined by the dimensionless gamma *m* shape parameter and by time to peak, t_{peak} [hr]. The censored results, used in the analysis, had a range of gamma *m* from 0.1 to 12.9, which can be interpreted as a range of PRF from 48.8 to 919. This indicates that the shape of the unit hydrograph varies among watersheds, and possibly among events. However, very few systematic relationships were identified between selected watershed properties and the *m* parameter. An attempt to determine such dependence using stepwise log-linear regression indicates that the best estimate of an unknown gamma *m* is a constant between 3.04 and 4.11, corresponding to PRF 411 to 512. Independently estimated, this range encloses the currently accepted PRF 484. A preliminary screening also indicated no systematic relationship between event magnitude (as measured by direct runoff depth) and *m*. Insufficient event data were available to investigate variation with event magnitude for a given watershed.

The response time variable chosen to represent time of concentration is the time from end of precipitation excess to the mathematical inflection point on the (dimensional) gamma unit hydrograph (t_{infl}). This time variable can be identified objectively using the equation of the gamma UH; it was shown to match well with expert-identified event T_c from a previous study. This response time varied among watersheds and among events for watersheds, over a range 0.5 to 57.6 hr in the censored data. A stepwise regression analysis identified three watershed variables as predictors of t_{infl}: channel slope, watershed slope, and forested area.

In this study, t_{infl} was analyzed as a surrogate for time of concentration, T_c. This decision was made for several reasons: First, the determination of T_c from an event hydrograph is highly subjective. Although the hydrologic literature refers to an "inflection point" on the event hydrograph recession limb, that point is often interpreted as a change in slope, rather than the mathematical definition of "change in sign of the second derivative." Because the hydrologic literature generally defines T_c as the time to end of direct runoff, we attempted to make this procedure more objective by calculating T_c as the time from end of Precipitation Excess to end of Direct Runoff, where the two endpoints were determined in a semi-automated process. We abandoned that measure of T_c and attempted to develop an equally objective method to determine T_c as the time from end of Precipitation Excess to the inflection point on the event hydrograph recession. That effort was only partially successful, as the inflection point occurred before the end of Precipitation Excess for many events, resulting in a negative $T_{c.}$ Identifying and mathematically analyzing the unit hydrograph proved to be more robust. Second, we found that our t_{infl} was more consistent with previous estimates of T_c for study watersheds than was our event T_c.

The estimates of event T_c, t_{infl}, t_{peak}, and m are all subject to numerous sources of uncertainty that propagate through the procedures: bias in the NEXRAD precipitation; errors introduced by the simplistic baseflow and precipitation separation; and the timing of precipitation excess. Of the data sources used, it is reasonable to place the most confidence in the USGS streamflow measurement. The assumption of uniform rainfall over the watershed is also questionable for the larger basins during the long rainfall events associated with low probability discharge.

Although the NRCS segment velocity method is widely used to calculate T_c, we did not employ that method in this study. This decision was based on our interpretation of the velocity method as a tool to estimate watershed T_c, not as a definition or measurement of watershed T_c. Much of the hydrologic literature treats the velocity method as definition or measurement; however, that assumption is increasingly being questioned [e.g., Beven (2020), Grimaldi et al. (2012)].

This study developed analytical tools to generate a watershed-average hyetograph at fine temporal resolution using radar data and GIS. These tools released us from having to infer the hyetograph from sparse, remote precipitation gauges. We used an independent daily precipitation data set to correct for unquantified bias in the radar fields; in some cases, this correction was a major shift, either positive or negative. In general, however, the pattern of daily precipitation was consistent. A deeper analysis of bias correction in the radar data would be a major undertaking.

The analysis tools also quantify the spatial variance of precipitation over the watershed. We did not make use of the spatial variance in this study. The UH approach assumes that precipitation is uniform over the watershed; this is well known to be a major simplifying assumption. Our radar data would allow us to evaluate how well or poorly the studied events satisfied that assumption. It is reasonable to expect that the assumption is better satisfied in small watersheds.

Convolved event hydrographs are sensitive to the shape of the UH, and consequently to the choice of gamma m (or PRF). Should the UH shape parameter (or PRF) be treated as a free tuning parameter in hydrologic modeling? If so, then analysts should keep in mind that both t_{peak} and m are required to generate a dimensional UH. If our t_{infl} can be accepted as a substitute for T_c, our results indicate that the ratio t_{peak} to T_c is not constant, but depends on m. Therefore, if analysts employ a different estimate of T_c for a watershed, while adjusting m or PRF, they should use an appropriate scaling ratio to obtain t_{peak} for their UH.

In this study, we invested substantial effort in developing methods to generate watershed event hyetographs from radar rainfall data. In contrast to the physical realism available in the hyetographs, the methods we applied for baseflow separation and precipitation excess are overly simplistic. Some events had to be discarded because the direct runoff inferred by baseflow separation was greater than the total precipitation supply; several of these occurrences were discovered when our algorithm reported a negative phi index. Future work should focus on applying hydrograph and hyetograph separation approaches that are conceptually appropriate, as physically accurate as possible within the assumptions of the UH approach, mutually consistent, and objective.

Recommendations for Practice

1. The study indicates that PRF varies among watersheds. If practitioners apply alternatives to the standard PRF values, they should note that the proportionality between t_{peak} and t_c varies with PRF. They should not automatically apply the 2/3 ratio.

2. The current regression equation for T_c in Maryland (Thomas [2000]) should continue to be used.

Recommendations for Future Research

1. Continue to develop tools for using radar rainfall to generate event hyetographs. Additional data sets should be investigated, including the hourly 4-km Stage IV product distributed by UCAR and the 4-km 1-hour accumulation DPA product distributed by NCEI, both of which could help to extend the study period back to 2000 or earlier.

2. Develop mutually compatible and physically accurate methods to separate streamflow and rainfall, while maintaining DRO equal to PEX for unit hydrograph identification.

3. Ensure compatibility among the predictor variables used at various times, e.g., Channel Length vs. Watershed Length.

4. Analyze the effect and implications of assuming UH t_p = 2/3 T_c when PRF is not equal to 484.

5. Slope variables are important in predicting T_c. Improvements on these estimates should be sought, particularly in the Coastal Plains province.

6. The different relationships between Channel Slope and Land Slope variables among the physiographic provinces is intriguing; examination of more watersheds' tabulated properties and the topography of Piedmont watersheds would reveal whether this is an artifact of sample size or a real physical phenomenon.

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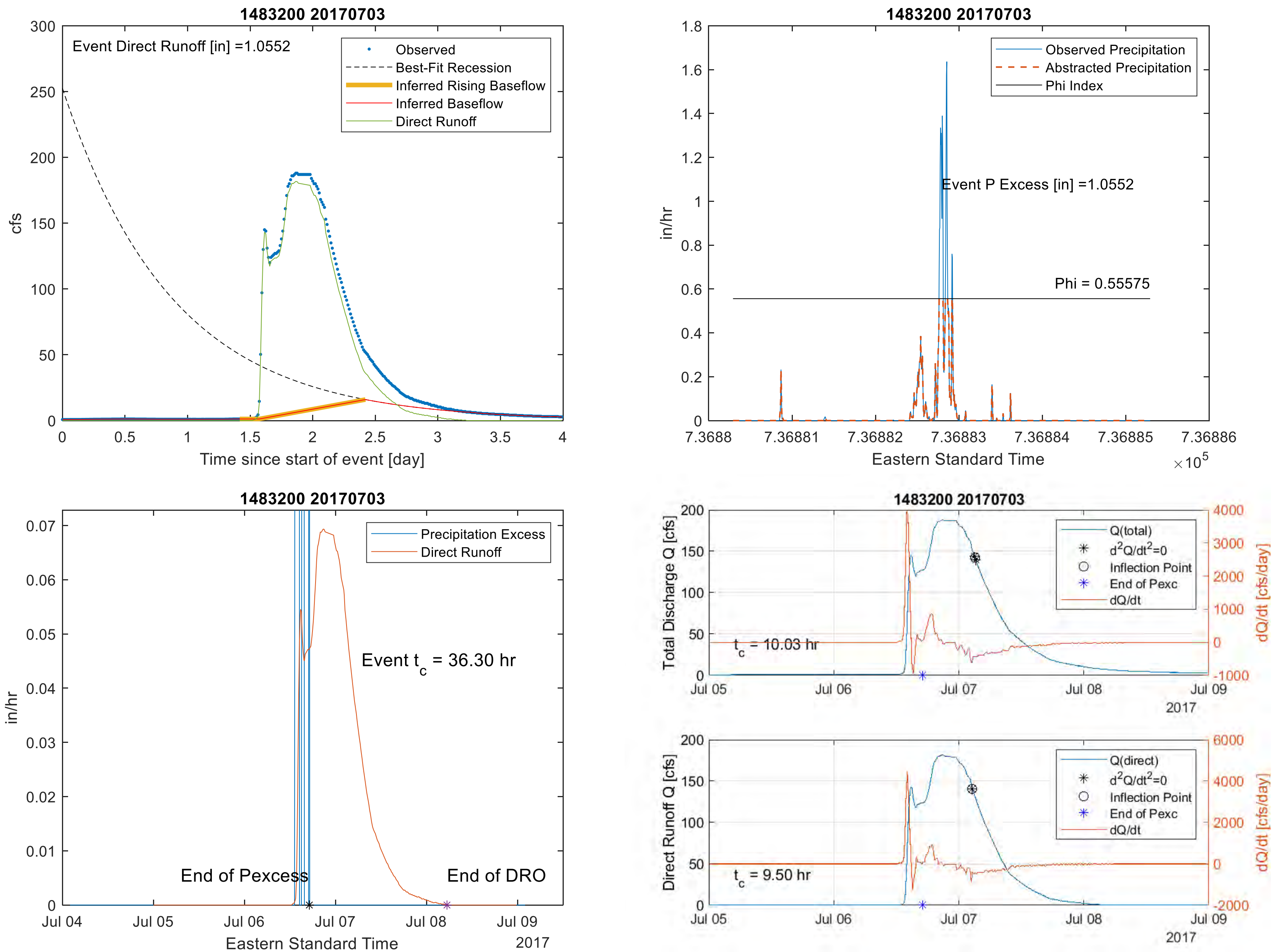
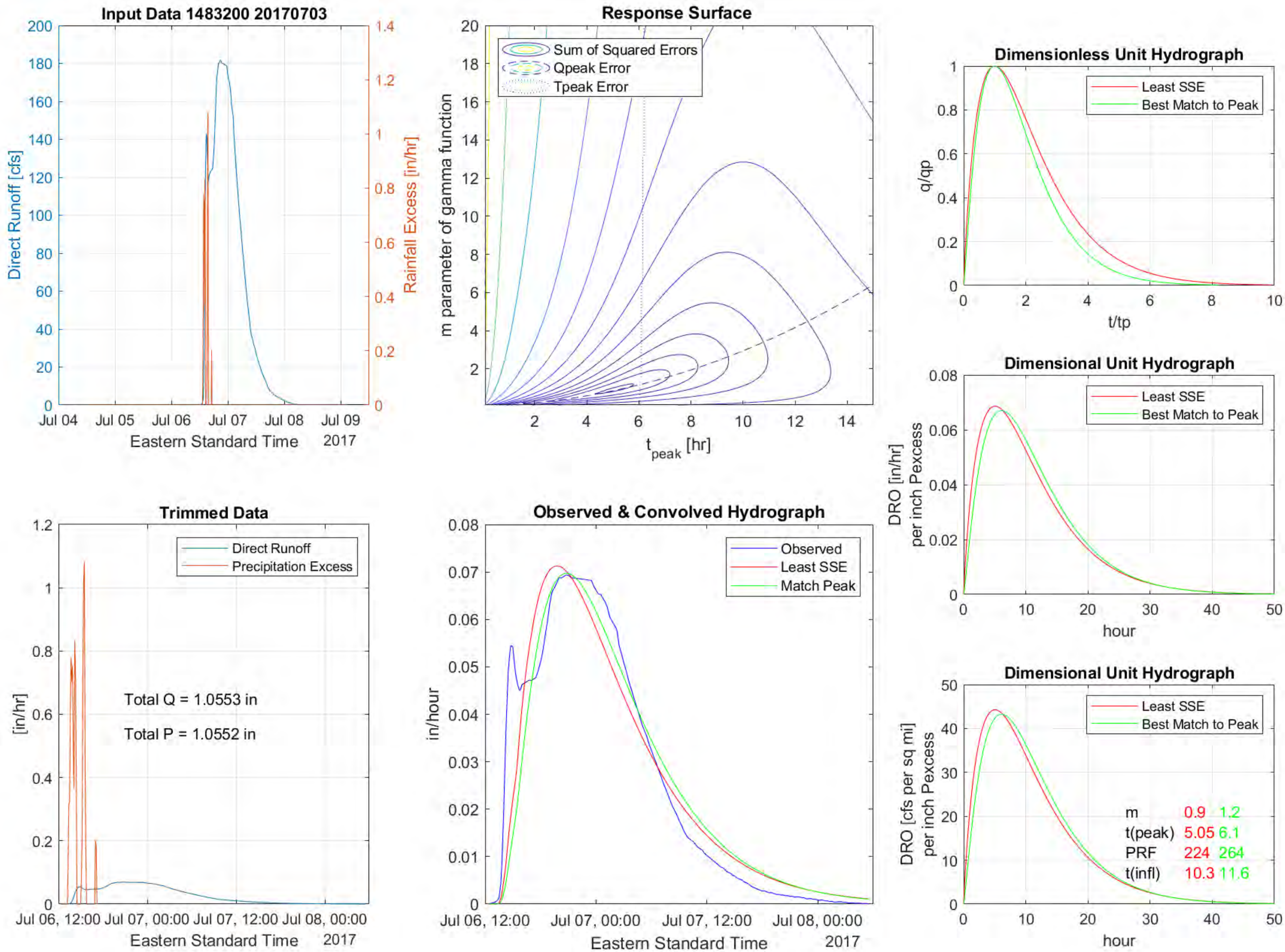
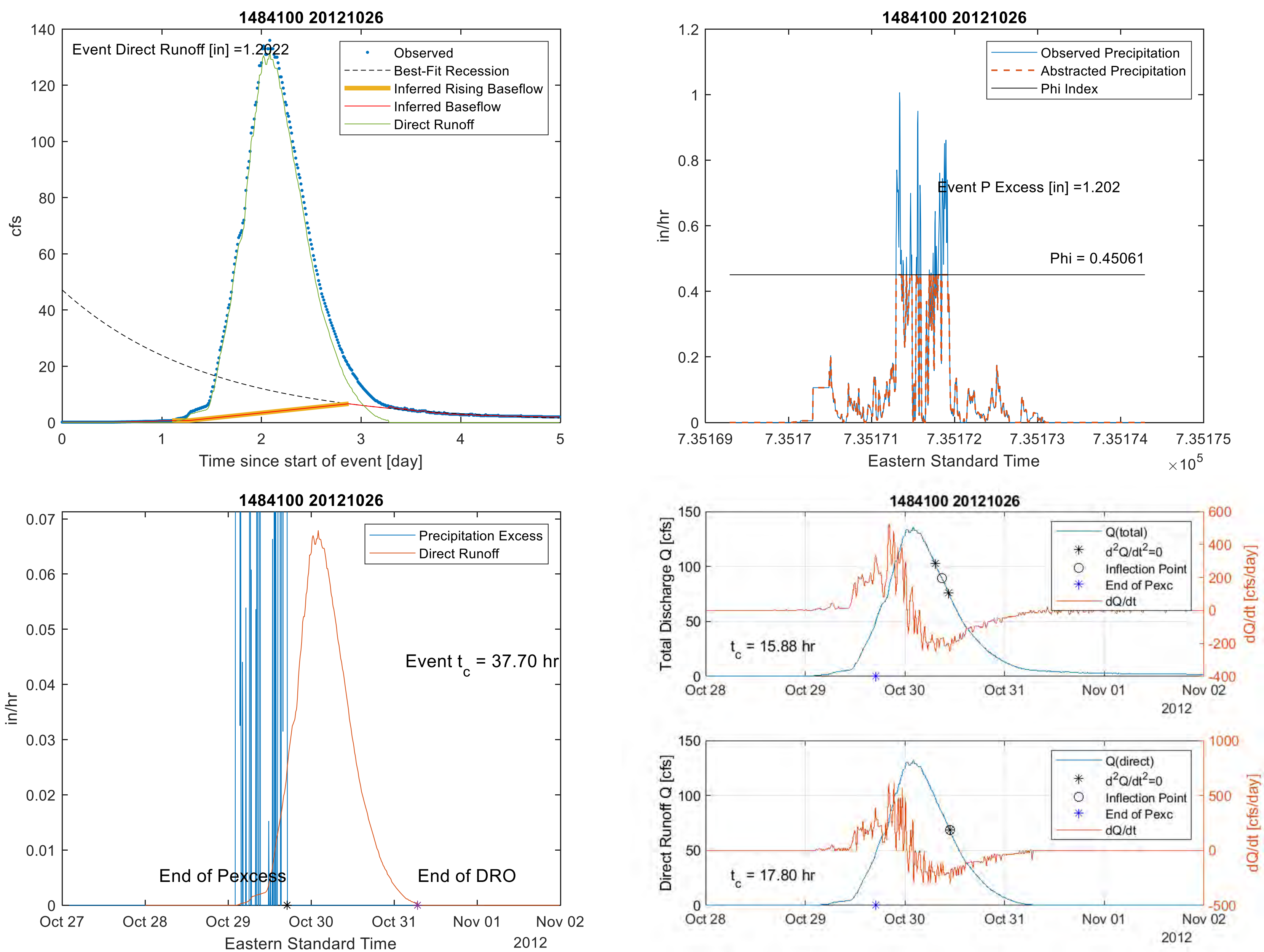
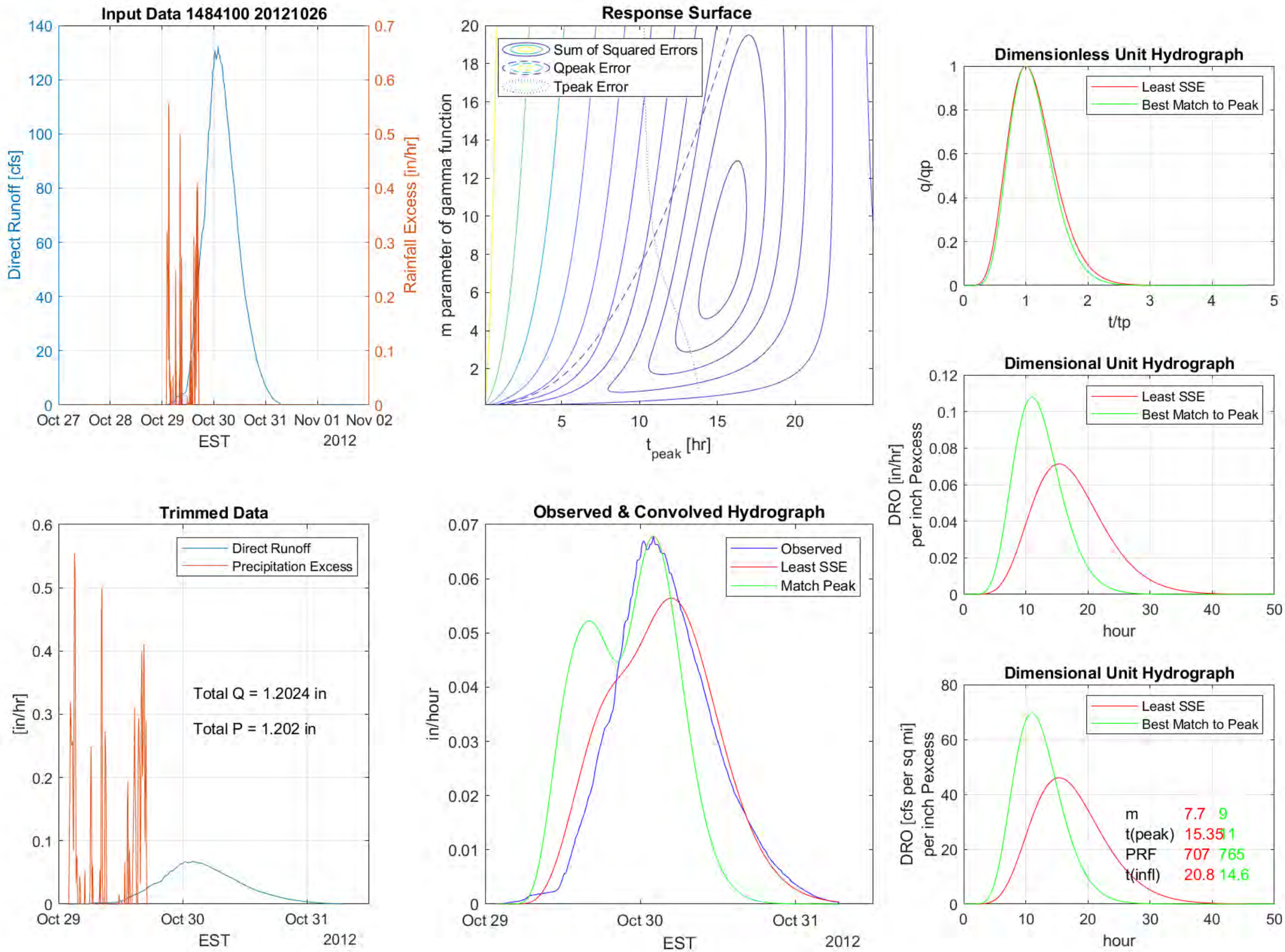
APPENDIX 1
CATALOG OF UNIT HYDROGRAPH PROCESSING STEPS

100 Events
54 Gages

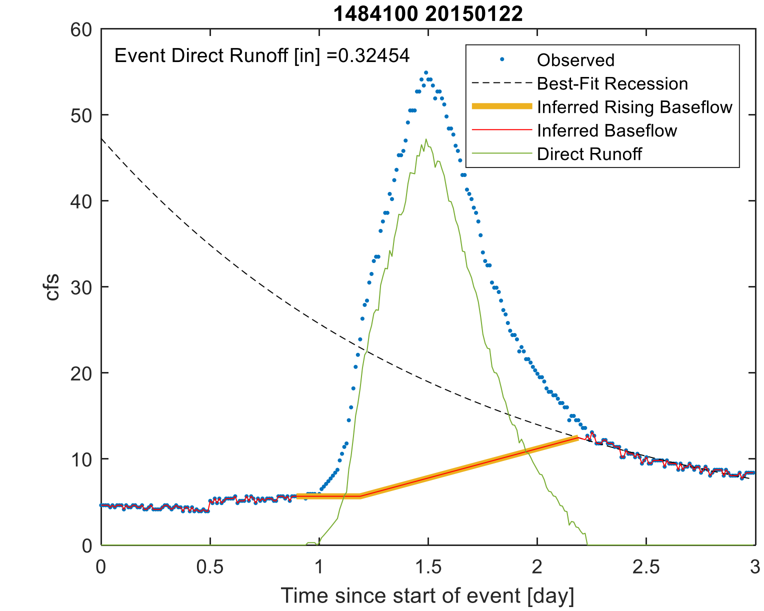

1483200 20170703
Event Direct Runoff [in] =1.0552
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1483200 20170703
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.0552
Phi = 0.55575
in/hr
Eastern Standard Time
×10^5
1483200 20170703
Precipitation Excess
Direct Runoff
Event t c = 36.30 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2017
1483200 20170703
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 10.03 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2017
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 9.50 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2017

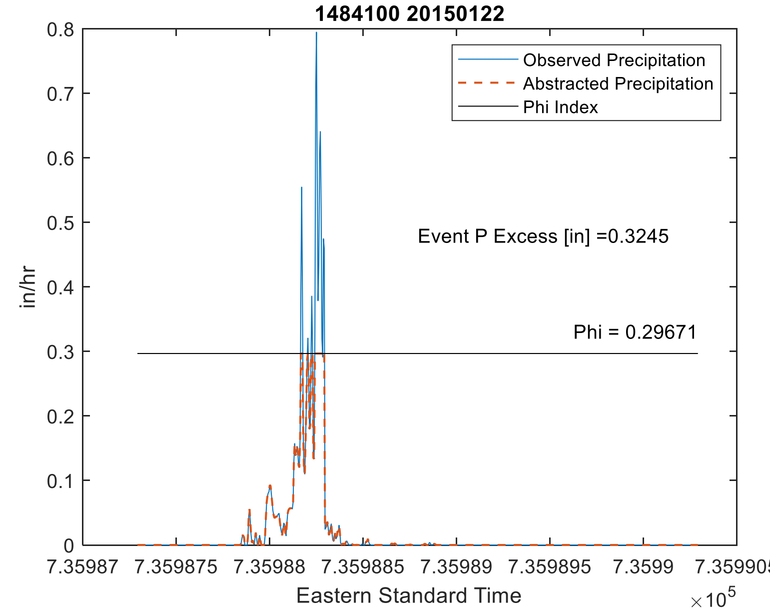

Input Data 1483200 20170703
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 04 Jul 05 Jul 06 Jul 07 Jul 08 Jul 09
Eastern Standard Time 2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.0553 in
Total P = 1.0552 in
[in/hr]
Jul 06, 12:00 Jul 07, 00:00 Jul 07, 12:00 Jul 08, 00:00
Eastern Standard Time 2017
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jul 06, 12:00 Jul 07, 00:00 Jul 07, 12:00 Jul 08, 00:00
Eastern Standard Time 2017
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 0.9 1.2
t(peak) 5.05 6.1
PRF 224 264
t(infl) 10.3 11.6
hour

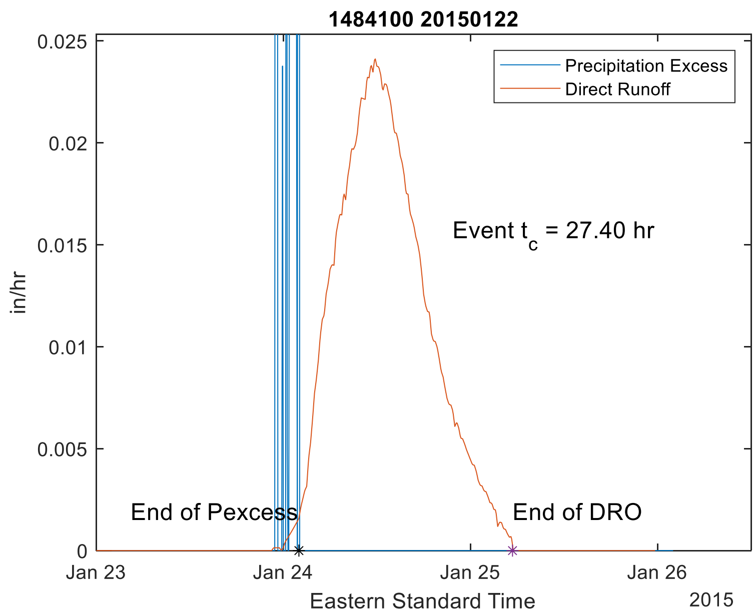

1484100 20121026
Event Direct Runoff [in] =1.2022
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1484100 20121026
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.202
Phi = 0.45061
in/hr
Eastern Standard Time
×10^5
1484100 20121026
Precipitation Excess
Direct Runoff
Event t_c = 37.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012
1484100 20121026
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 15.88 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2012
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 17.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2012

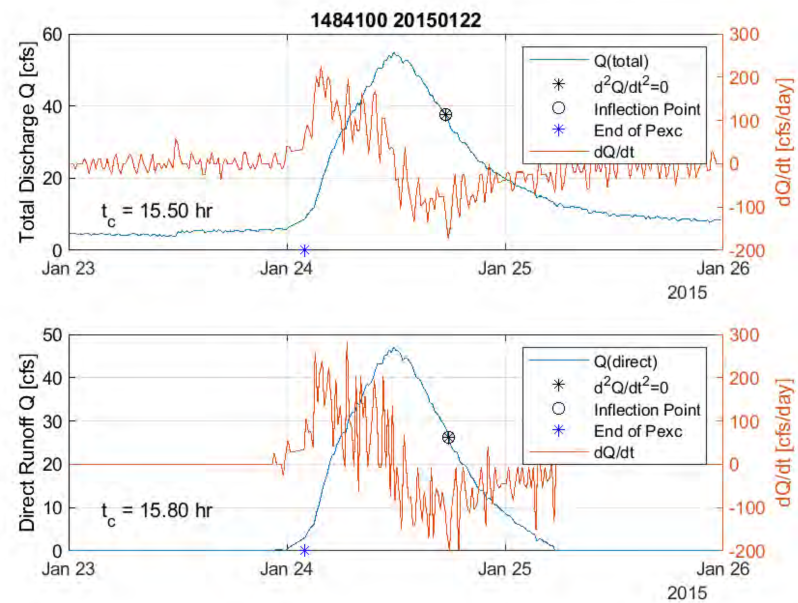


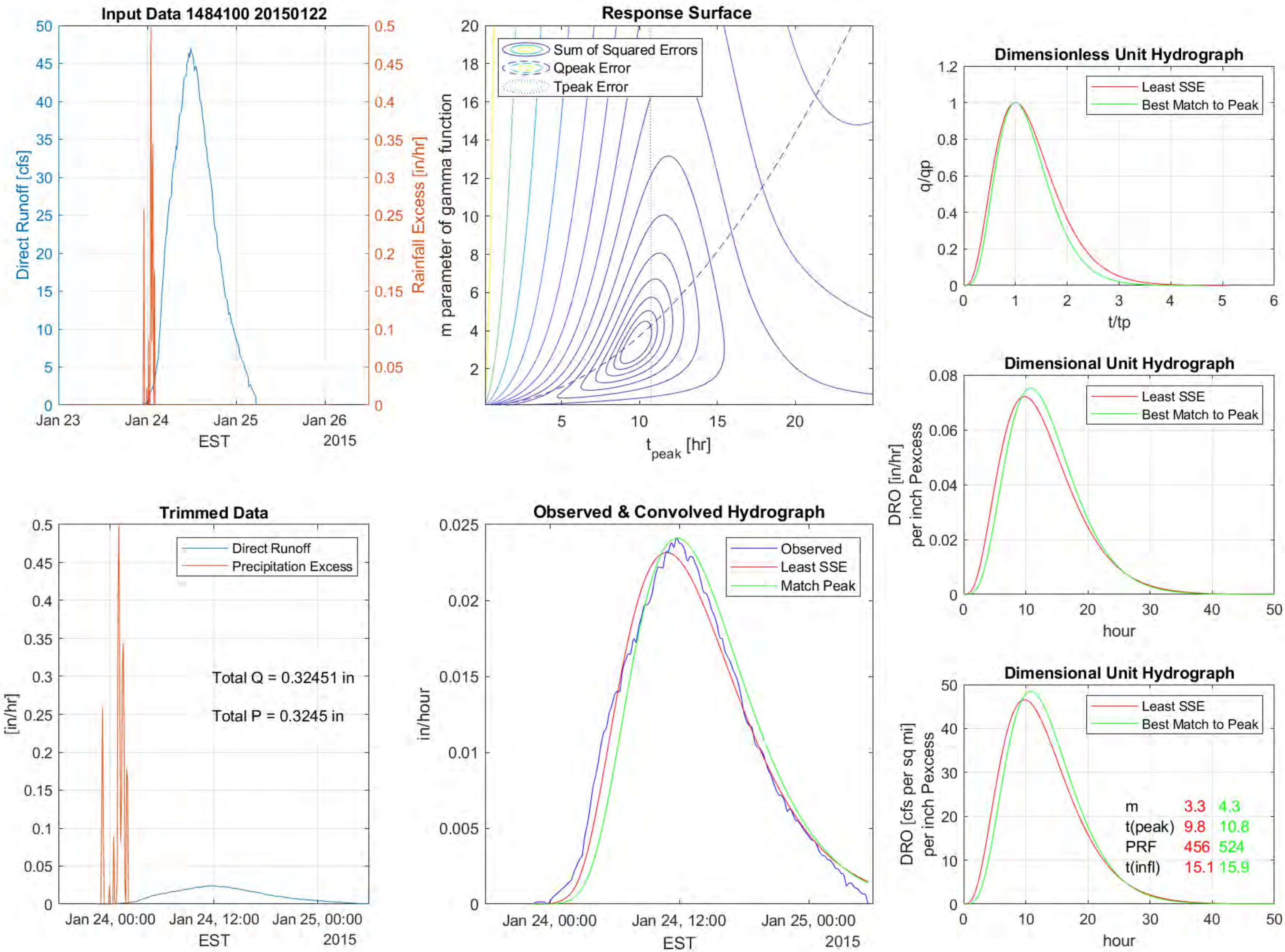
Input Data 1484100 20121026
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 27
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.2024 in
Total P = 1.202 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 7.7 9
t(peak) 15.35 11
PRF 707 765
t(infl) 20.8 14.6

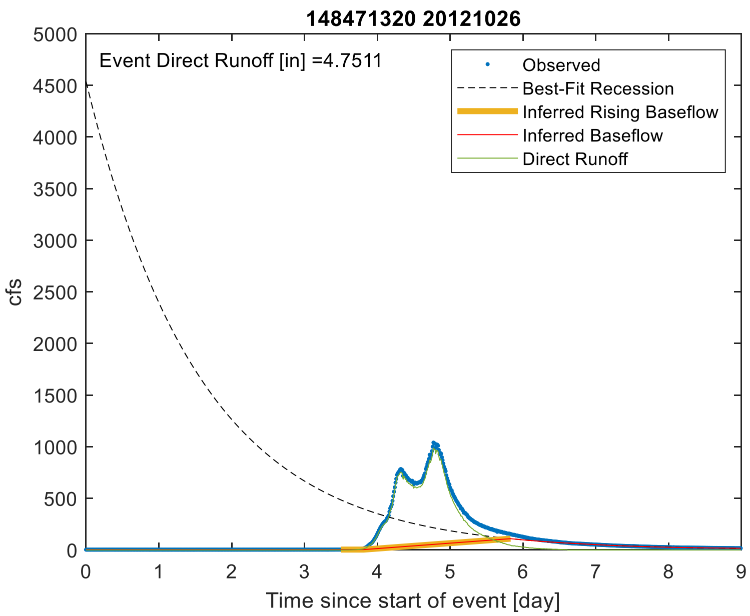

1484100 20150122
Event Direct Runoff [in] =0.32454
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

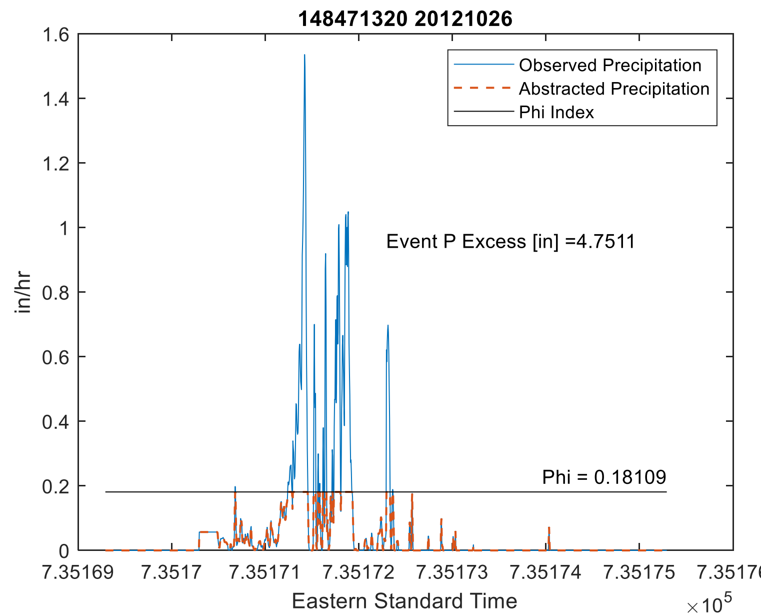

1484100 20150122
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.3245
Phi = 0.29671
in/hr
Eastern Standard Time
×10^5

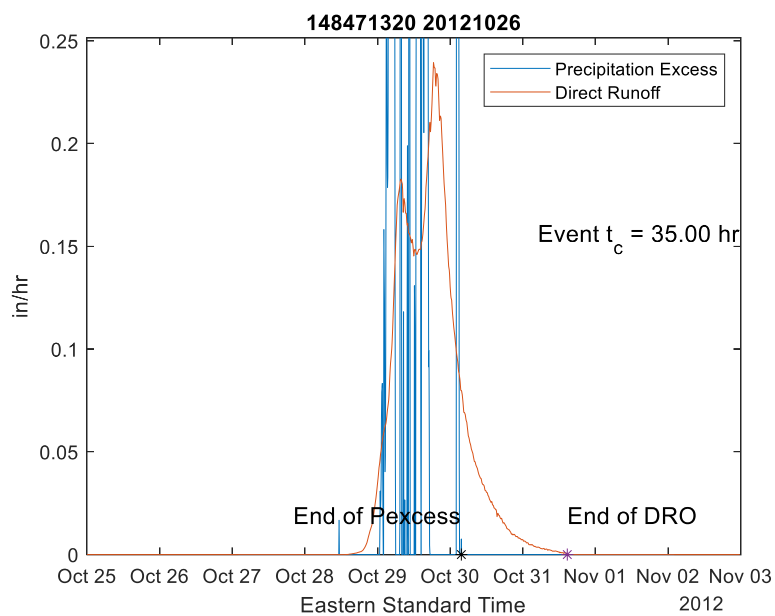

1484100 20150122
Precipitation Excess
Direct Runoff
Event t_c = 27.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2015

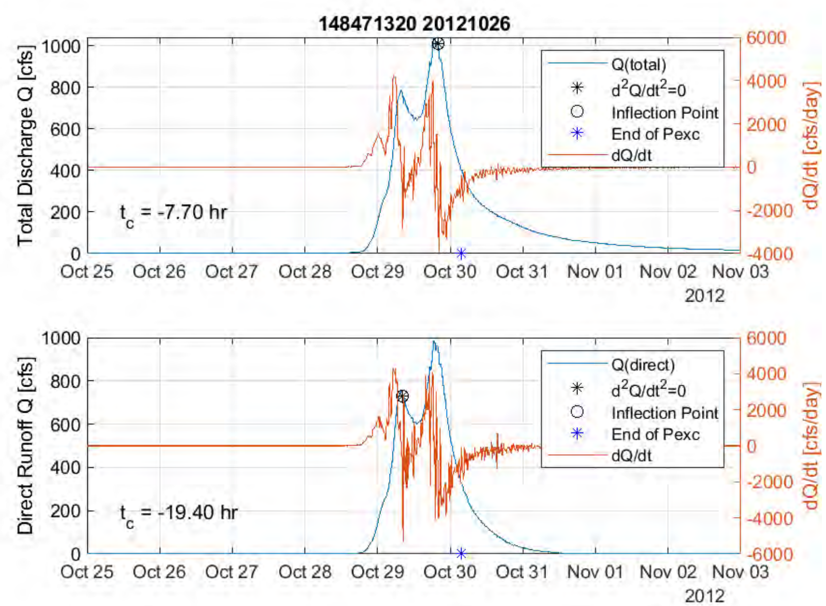

1484100 20150122
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 15.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2015
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 15.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2015

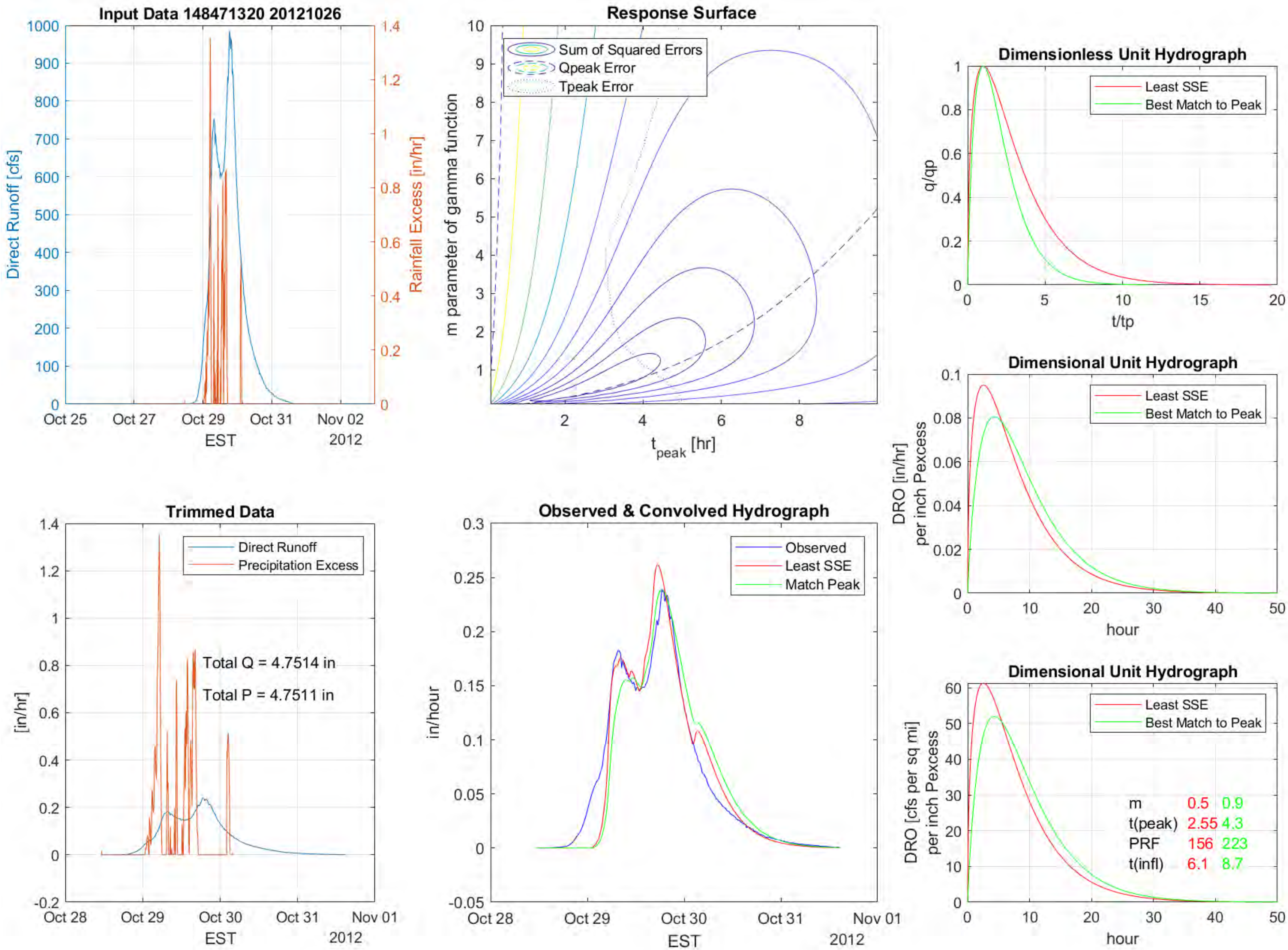

Input Data 1484100 20150122
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 23
Jan 24
Jan 25
Jan 26
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.32451 in
Total P = 0.3245 in
[in/hr]
Jan 24, 00:00
Jan 24, 12:00
Jan 25, 00:00
EST
2015
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.3 4.3
t(peak) 9.8 10.8
PRF 456 524
t(infl) 15.1 15.9
hour

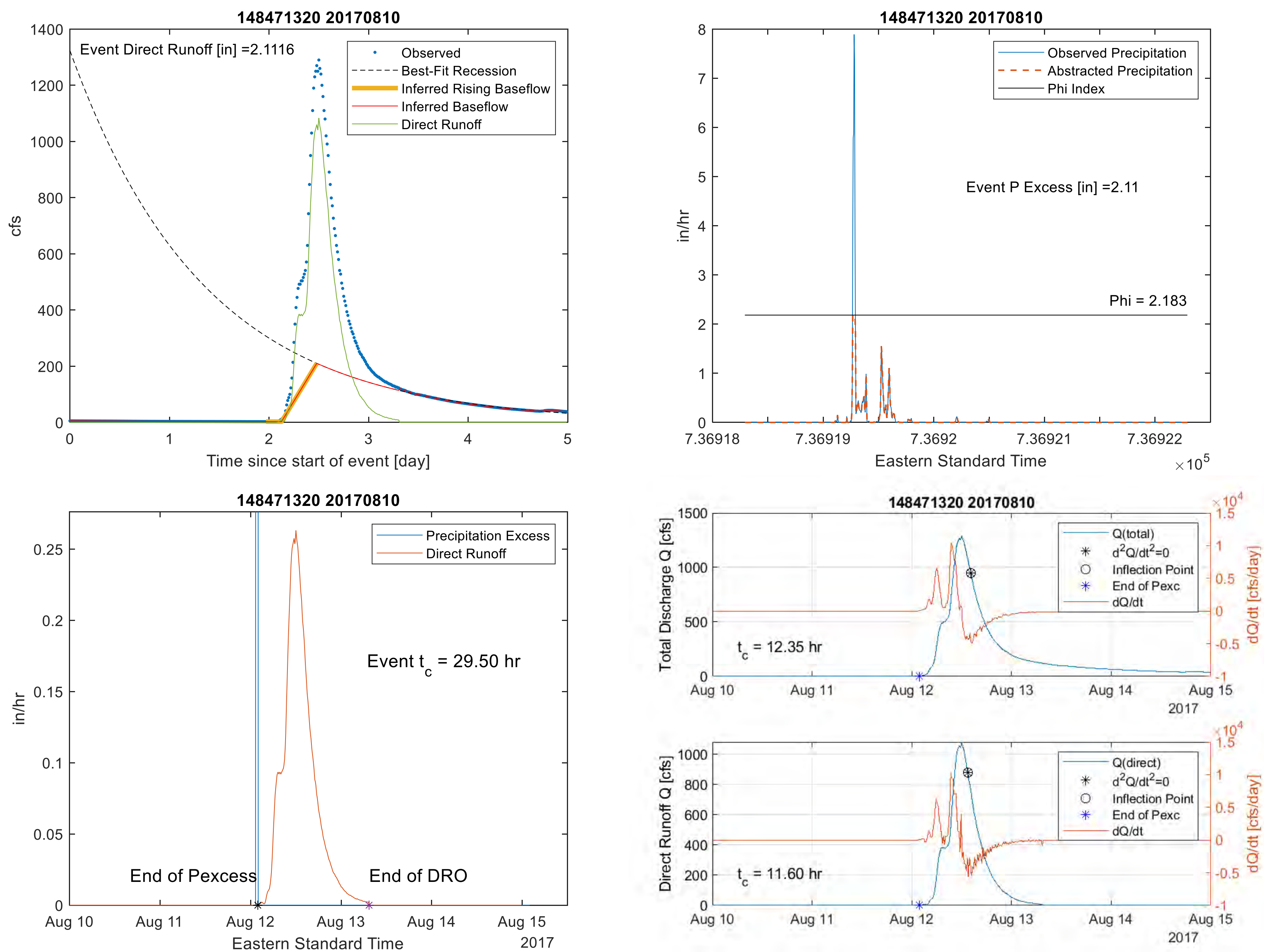

148471320 20121026
Event Direct Runoff [in] =4.7511
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

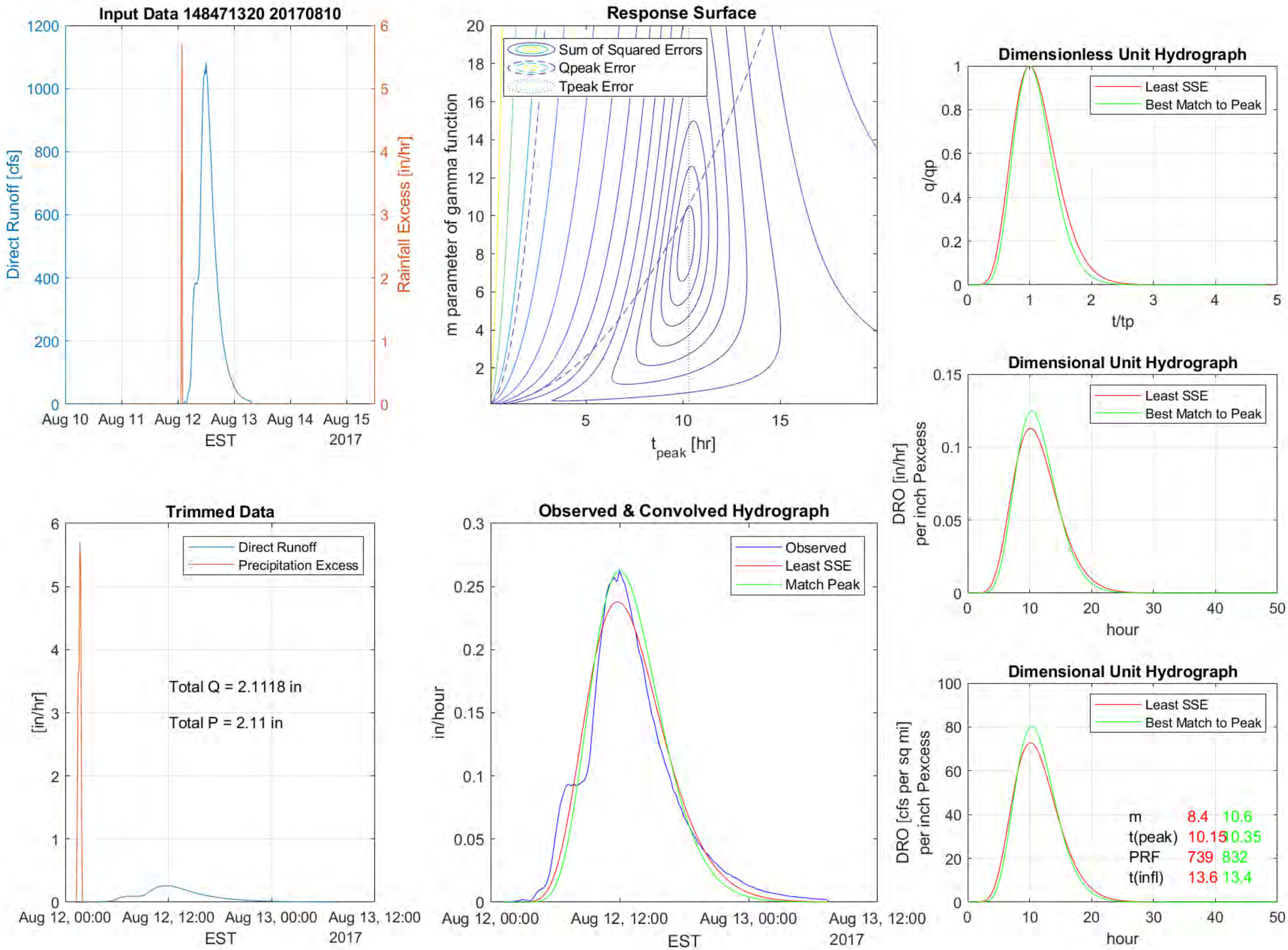

148471320 20121026
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =4.7511
Phi = 0.18109
in/hr
Eastern Standard Time

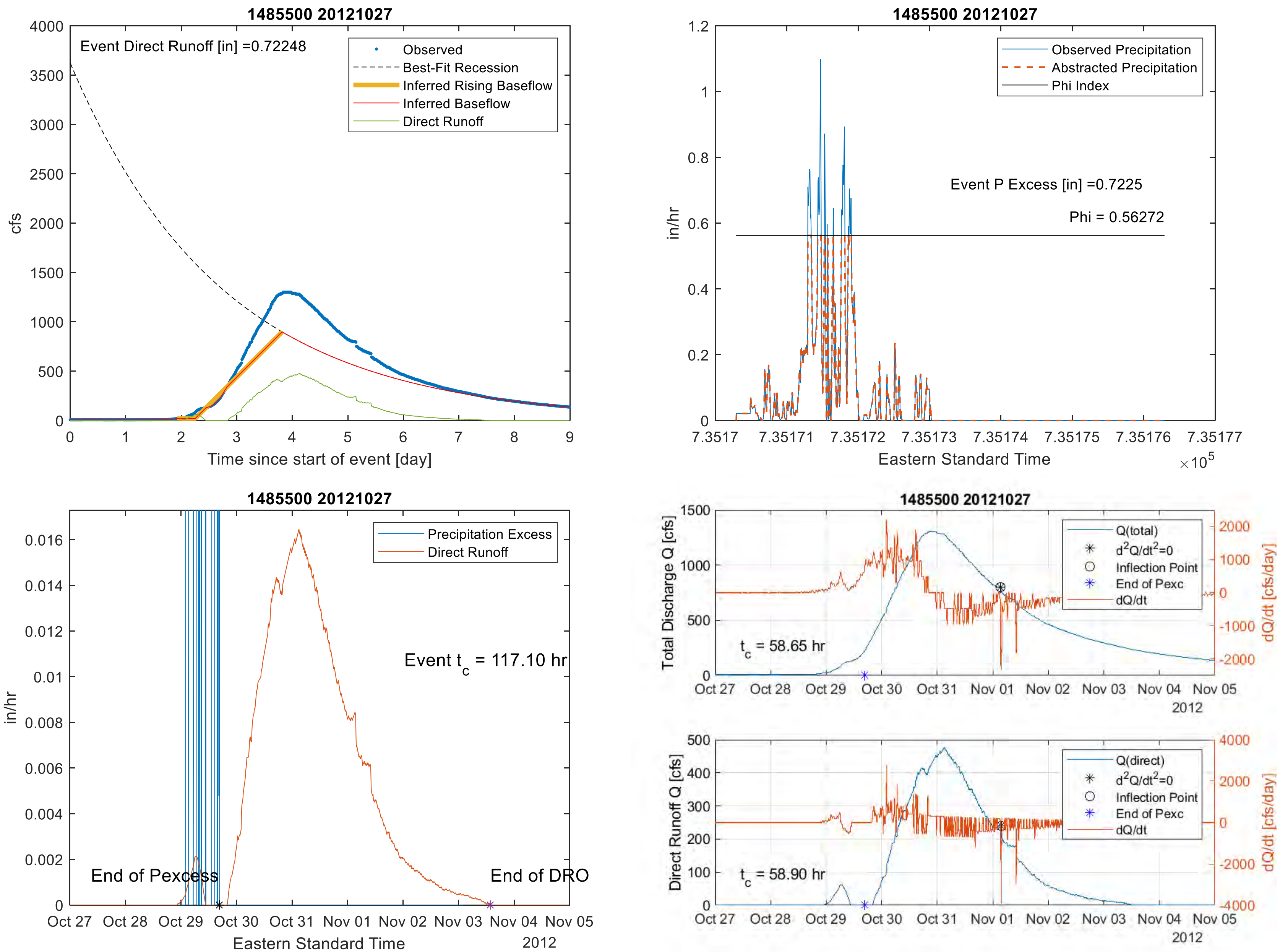

148471320 20121026
Precipitation Excess
Direct Runoff
Event t_c = 35.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

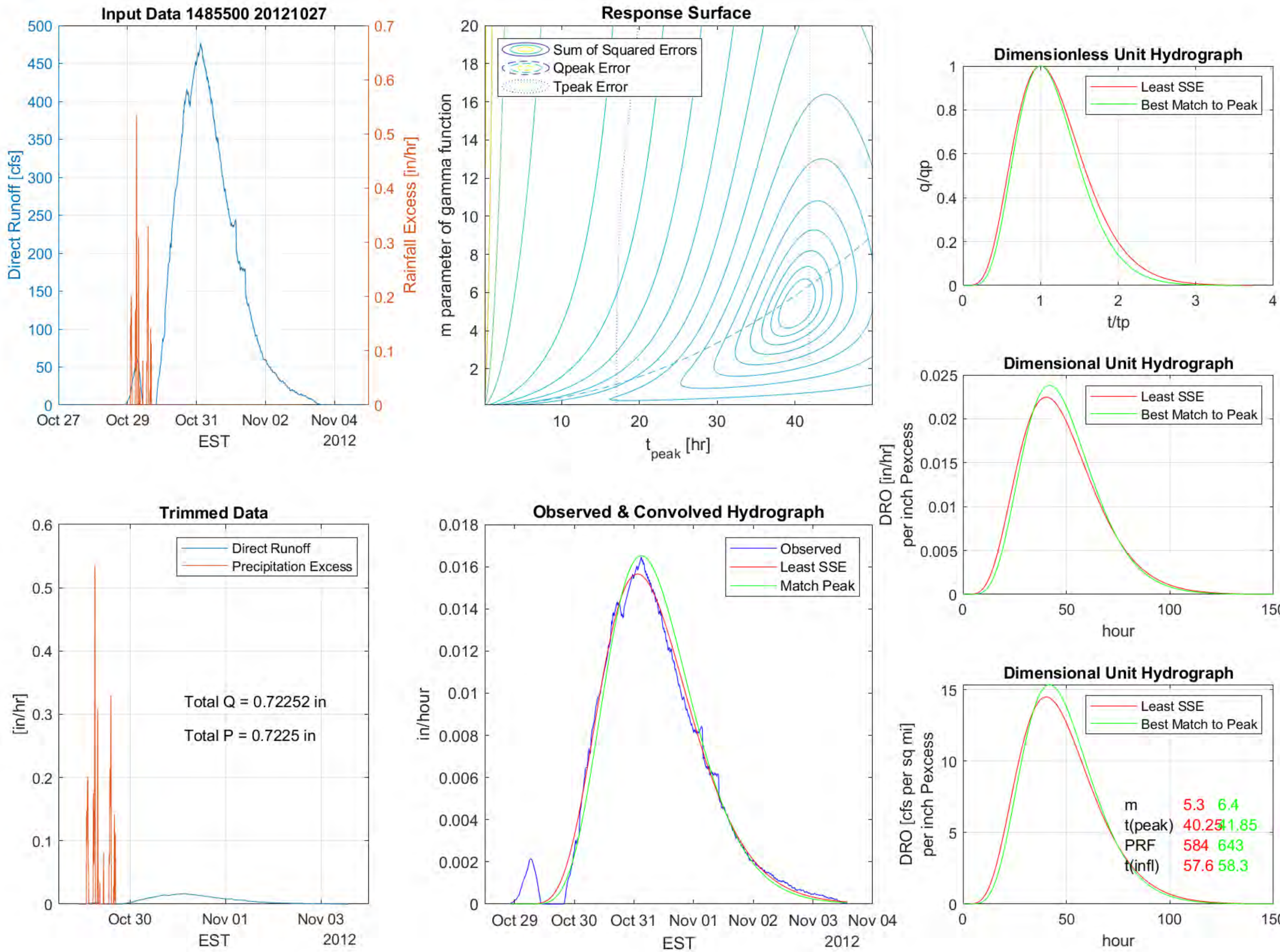

148471320 20121026
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -7.70 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = -19.40 hr
Direct Runoff Q [cfs]

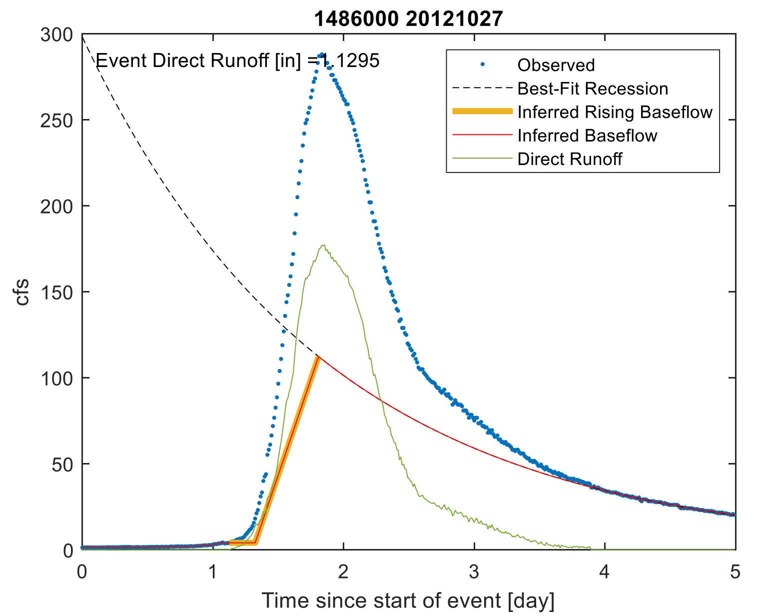

Input Data 148471320 20121026
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 25
Oct 27
Oct 29
Oct 31
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 4.7514 in
Total P = 4.7511 in
[in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 0.5 0.9
t(peak) 2.55 4.3
PRF 156 223
t(infl) 6.1 8.7
hour

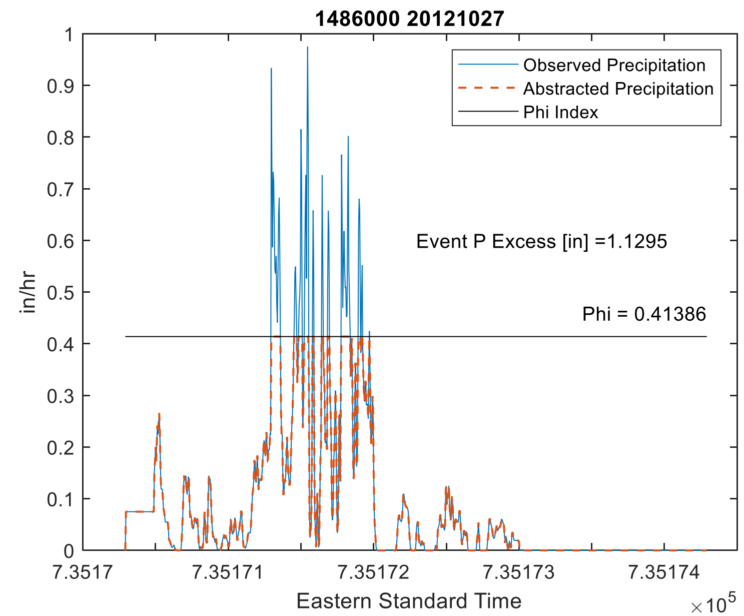

148471320 20170810
Event Direct Runoff [in] =2.1116
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
148471320 20170810
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.11
Phi = 2.183
in/hr
Eastern Standard Time
148471320 20170810
Precipitation Excess
Direct Runoff
Event t_c = 29.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
148471320 20170810
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 12.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 11.60 hr
Direct Runoff Q [cfs]

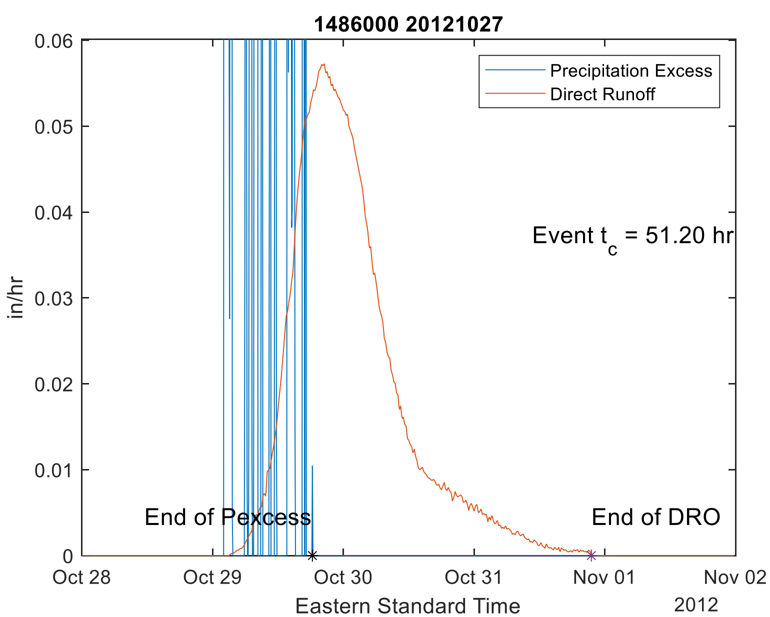

Input Data 148471320 20170810
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
Aug 15
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.1118 in
Total P = 2.11 in
[in/hr]
Aug 12, 00:00
Aug 12, 12:00
Aug 13, 00:00
Aug 13, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 8.4 10.6
t(peak) 10.15 10.35
PRF 739 832
t(infl) 13.6 13.4

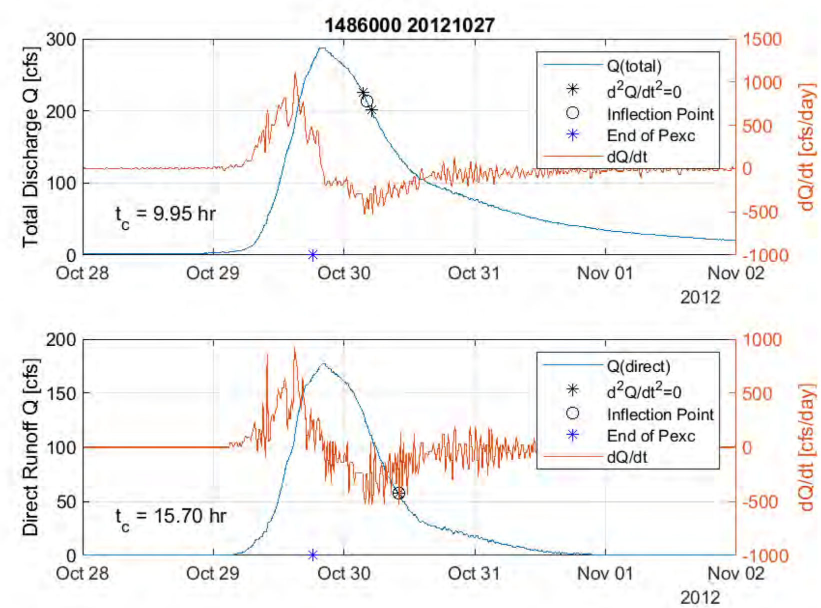

1485500 20121027
Event Direct Runoff [in] =0.72248
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1485500 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.7225
Phi = 0.56272
in/hr
Eastern Standard Time
1485500 20121027
Precipitation Excess
Direct Runoff
Event t_c = 117.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012
1485500 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 58.65 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 58.90 hr
Direct Runoff Q [cfs]

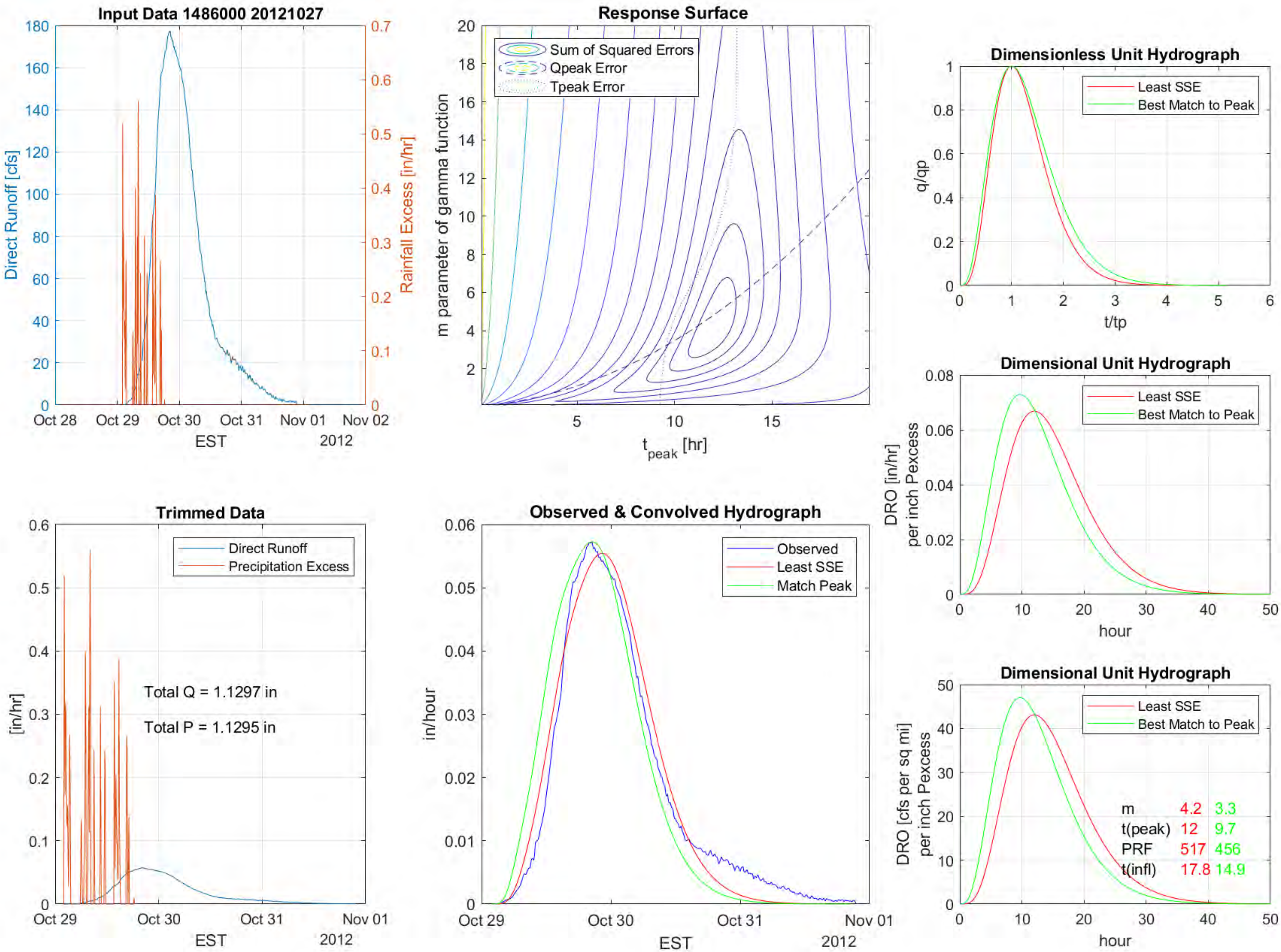

Input Data 1485500 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.72252 in
Total P = 0.7225 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.3 6.4
t(peak) 40.25 41.85
PRF 584 643
t(infl) 57.6 58.3


1486000 20121027
Event Direct Runoff [in] = 1.1295
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

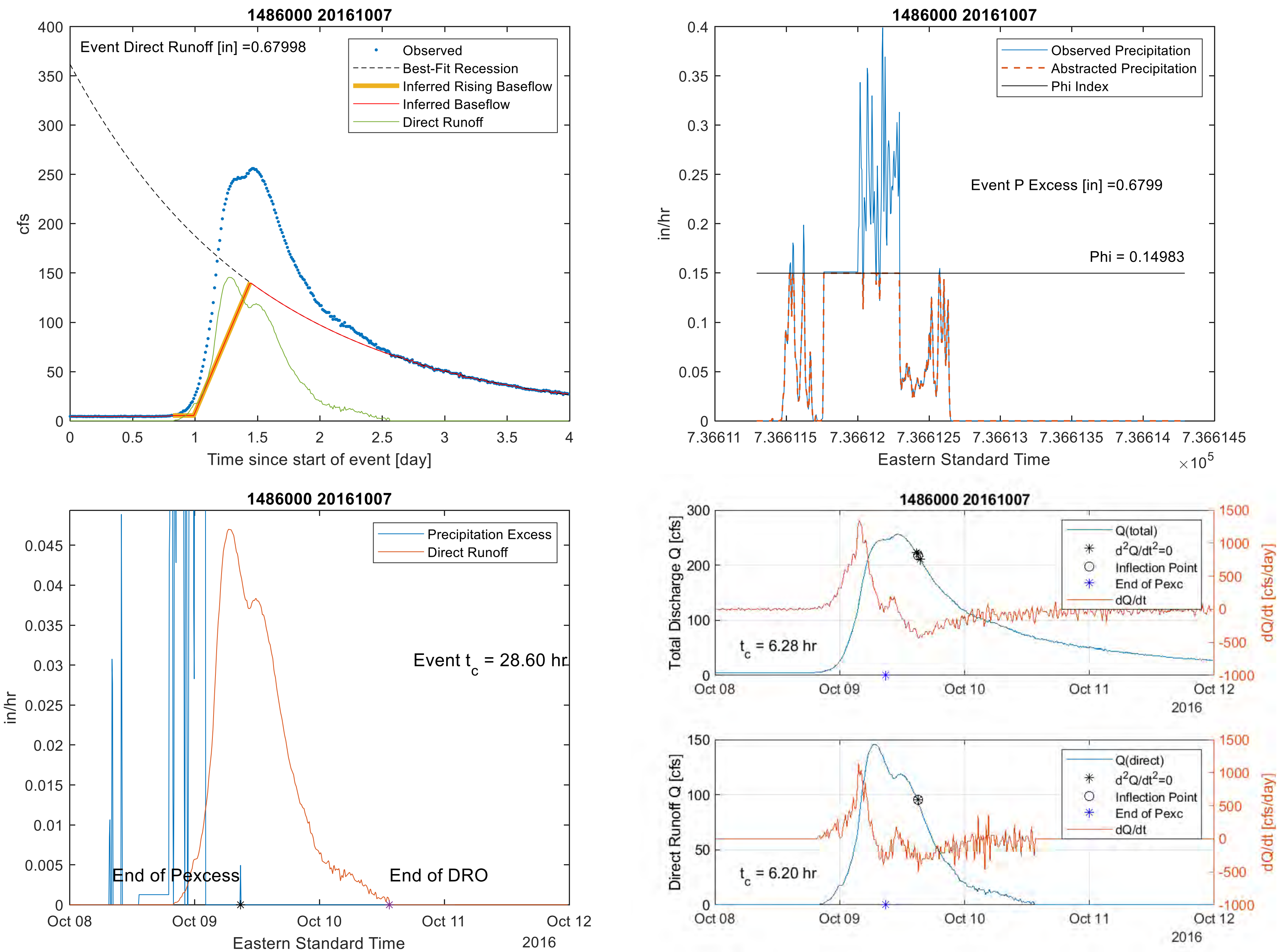

1486000 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.1295
Phi = 0.41386
in/hr
Eastern Standard Time
×10^5

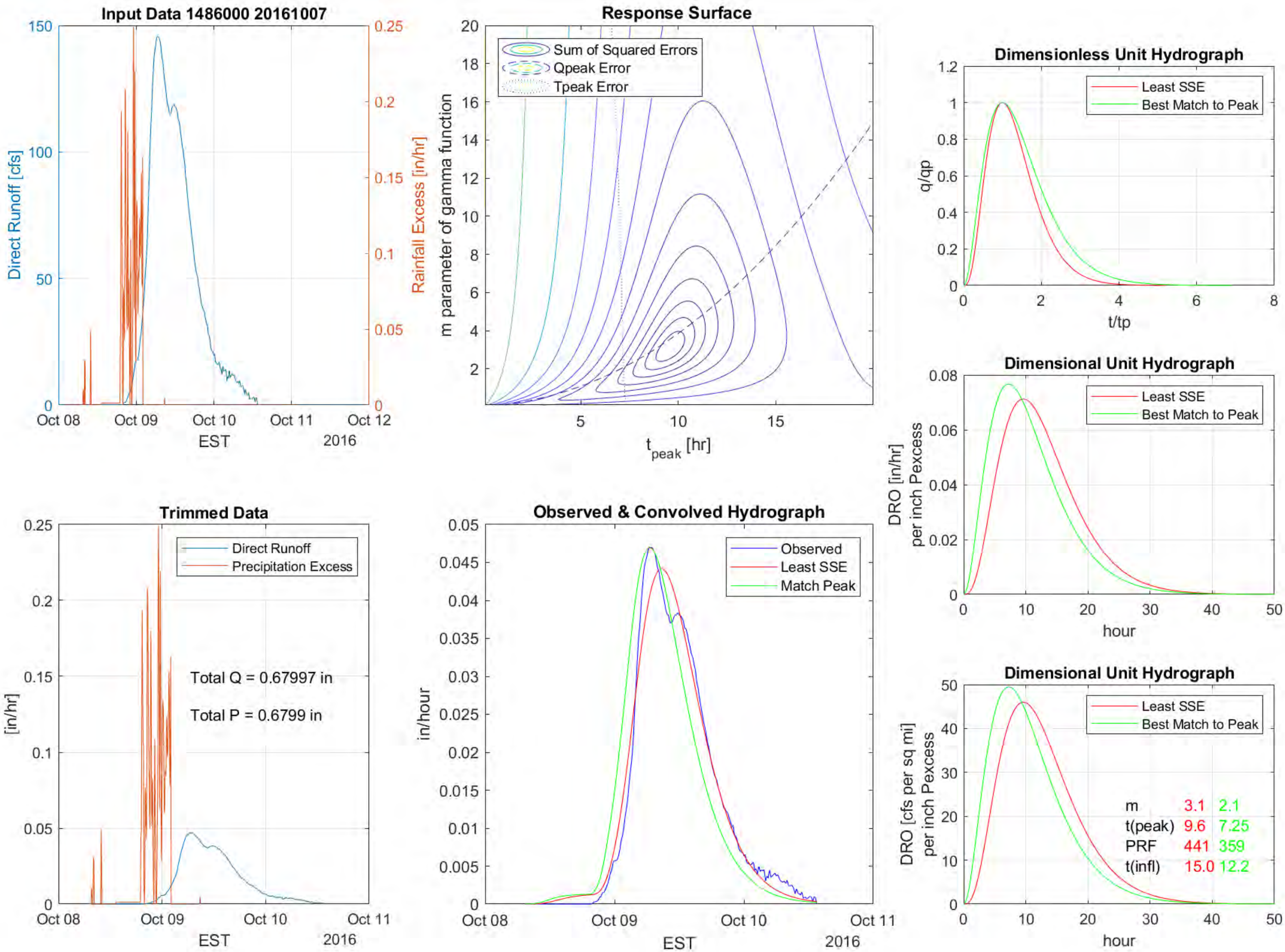

1486000 20121027
Precipitation Excess
Direct Runoff
Event t_c = 51.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012

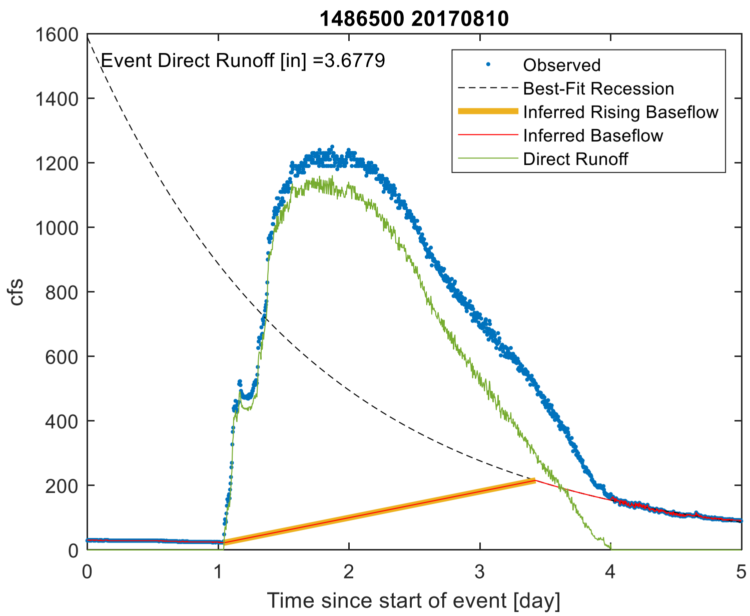

1486000 20121027
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 9.95 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 15.70 hr
Direct Runoff Q [cfs]
2012



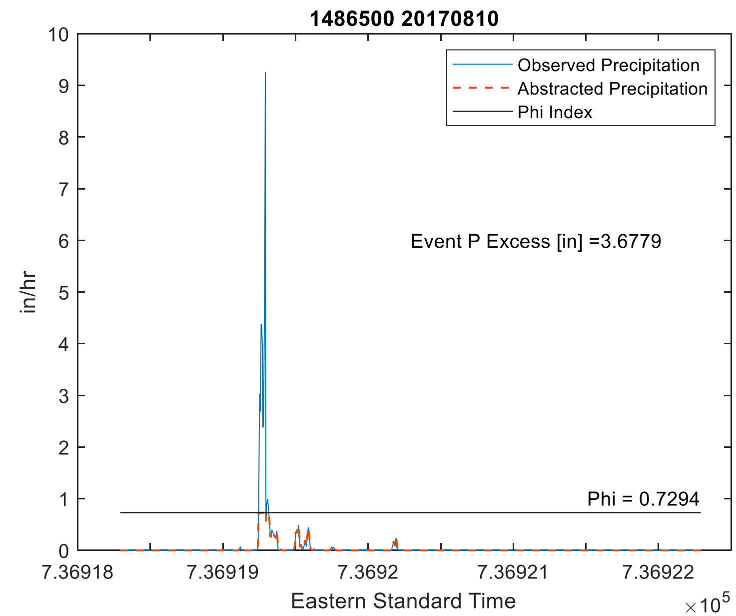
Input Data 1486000 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.1297 in
Total P = 1.1295 in
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
m 4.2 3.3
t(peak) 12 9.7
PRF 517 456
t(infl) 17.8 14.9
hour


1486000 20161007
Event Direct Runoff [in] =0.67998
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1486000 20161007
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6799
Phi = 0.14983
in/hr
Eastern Standard Time
×10^5
1486000 20161007
Precipitation Excess
Direct Runoff
Event t_c = 28.60 hr
in/hr
End of Pexcess
End of DRO
Eastern Standard Time
2016
1486000 20161007
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t_c = 6.28 hr
Q(direct)
Direct Runoff Q [cfs]
t_c = 6.20 hr
Oct 08
Oct 09
Oct 10
Oct 11
Oct 12
2016

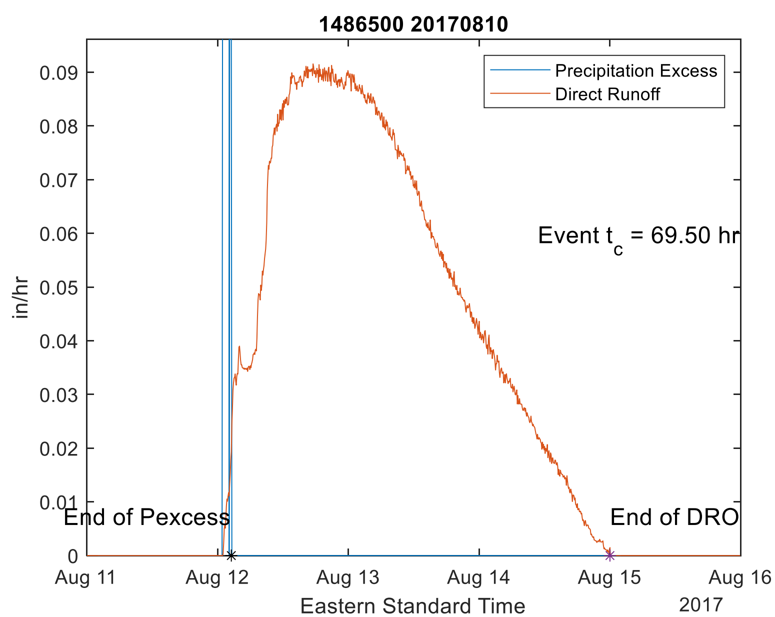

Input Data 1486000 20161007
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 08
Oct 09
Oct 10
Oct 11
Oct 12
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.67997 in
Total P = 0.6799 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.1 2.1
t(peak) 9.6 7.25
PRF 441 359
t(infl) 15.0 12.2



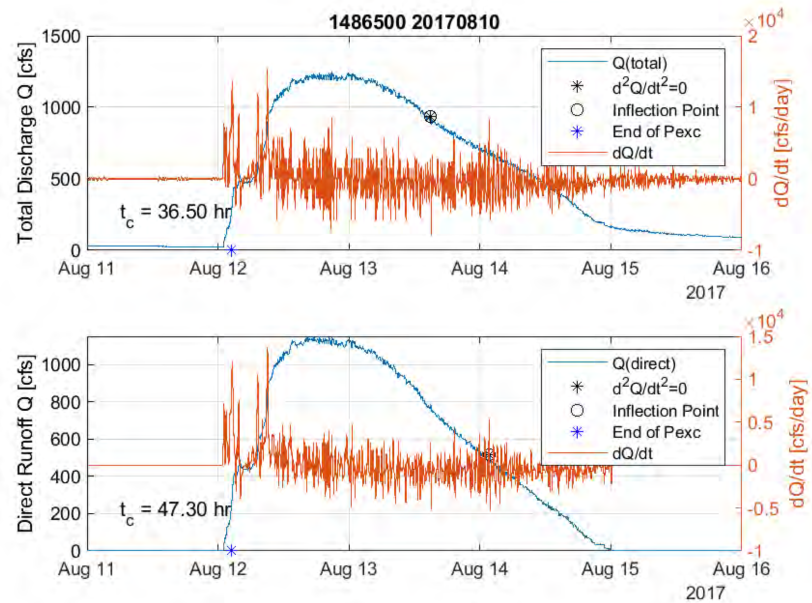
1486500 20170810
Event Direct Runoff [in] =3.6779
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



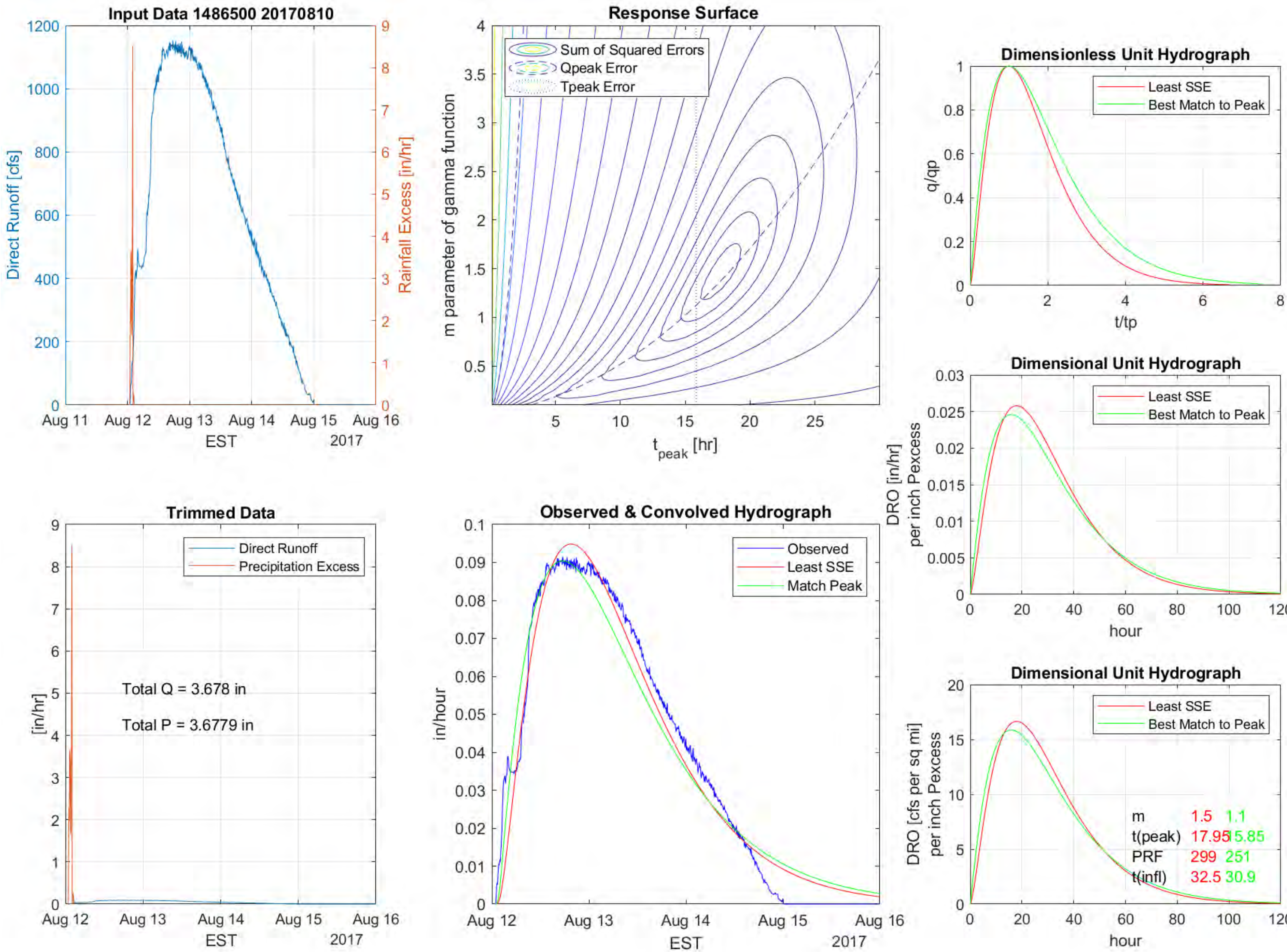
1486500 20170810
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =3.6779
Phi = 0.7294
in/hr
Eastern Standard Time

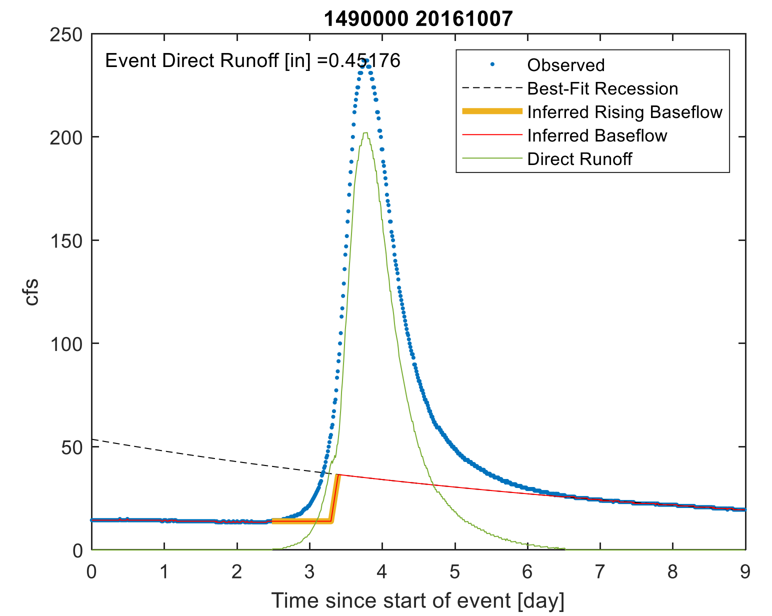


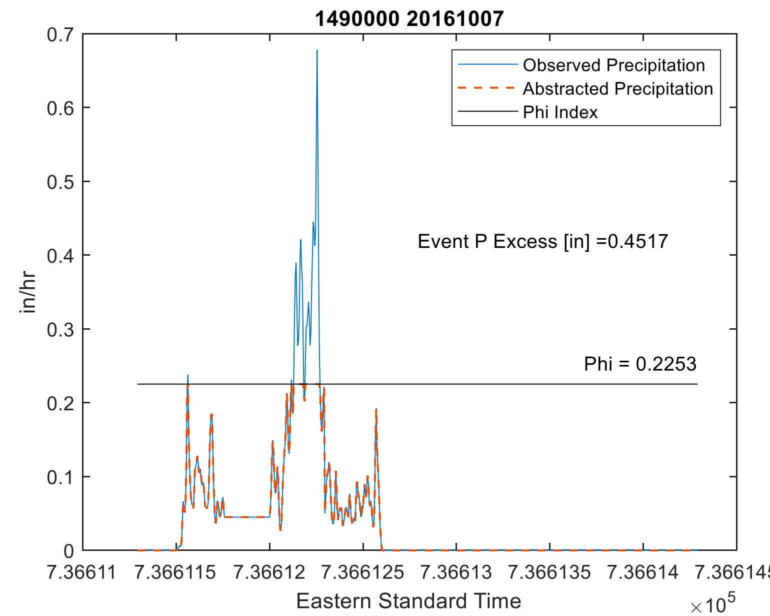
1486500 20170810
Precipitation Excess
Direct Runoff
Event t_c = 69.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

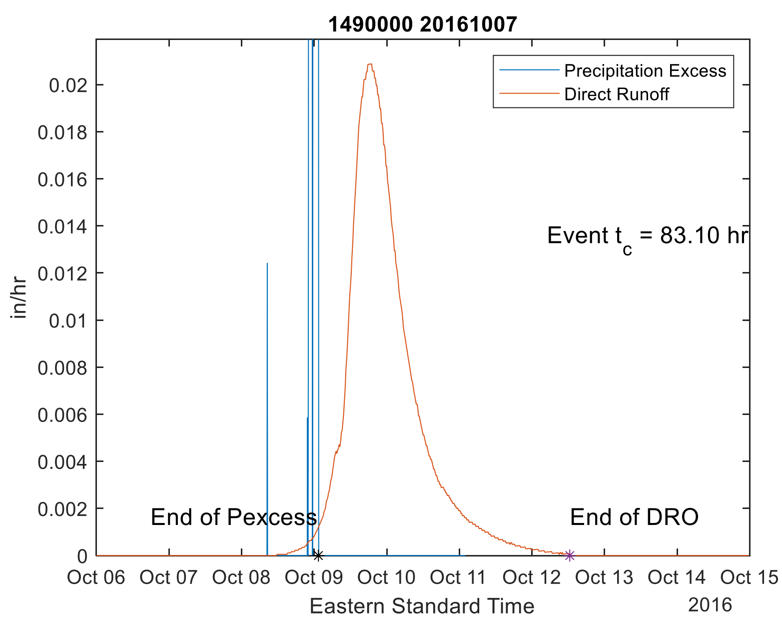


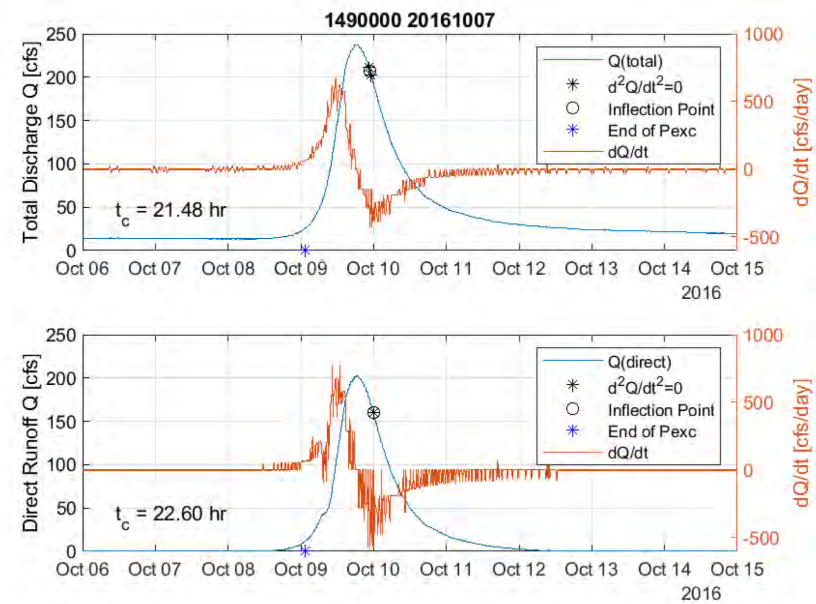
1486500 20170810
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 36.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 47.30 hr
Direct Runoff Q [cfs]

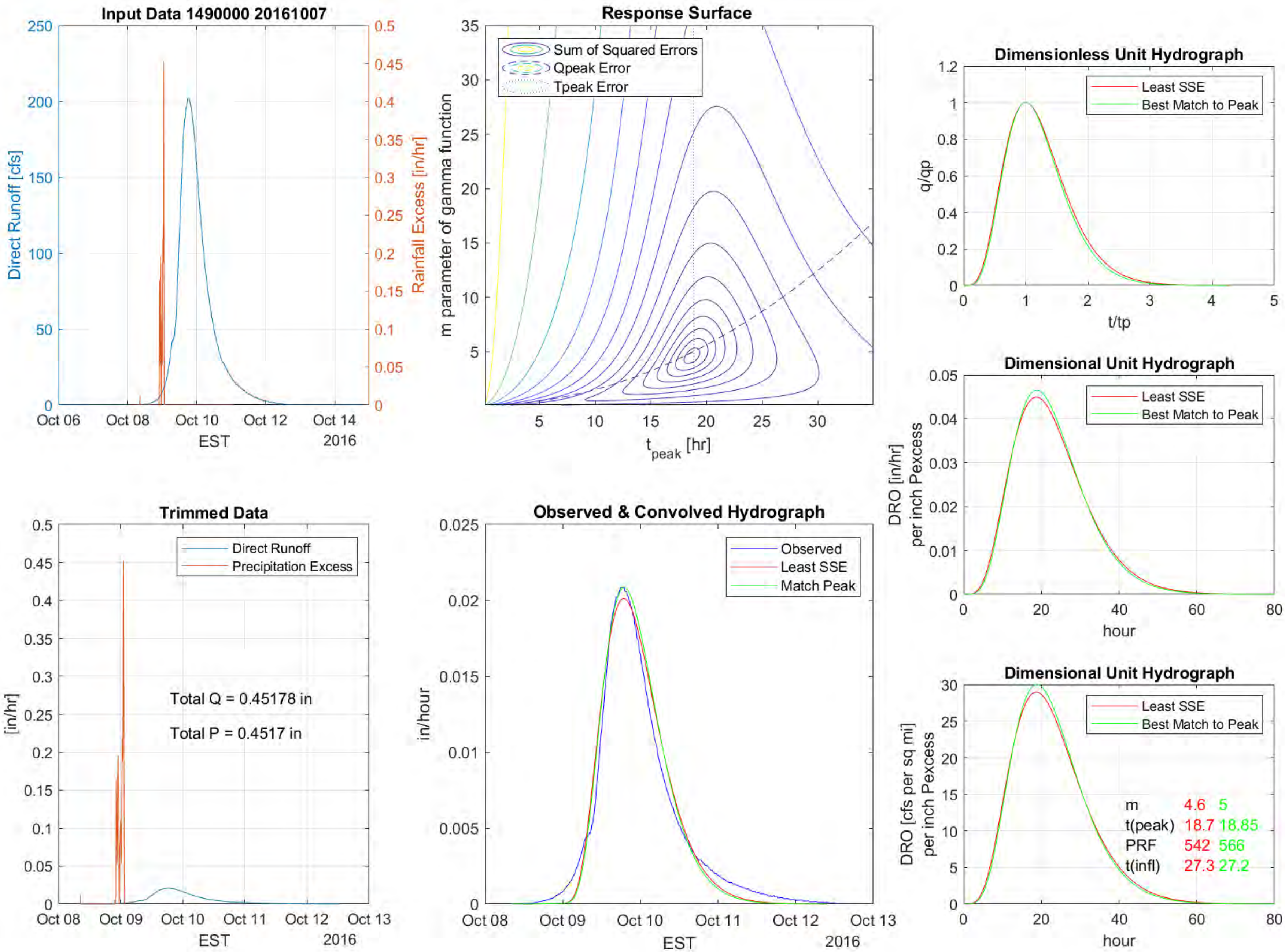

Input Data 1486500 20170810
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 11
Aug 12
Aug 13
Aug 14
Aug 15
Aug 16
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 3.678 in
Total P = 3.6779 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.5 1.1
t(peak) 17.95 15.85
PRF 299 251
t(infl) 32.5 30.9


1490000 20161007
Event Direct Runoff [in] =0.45176
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

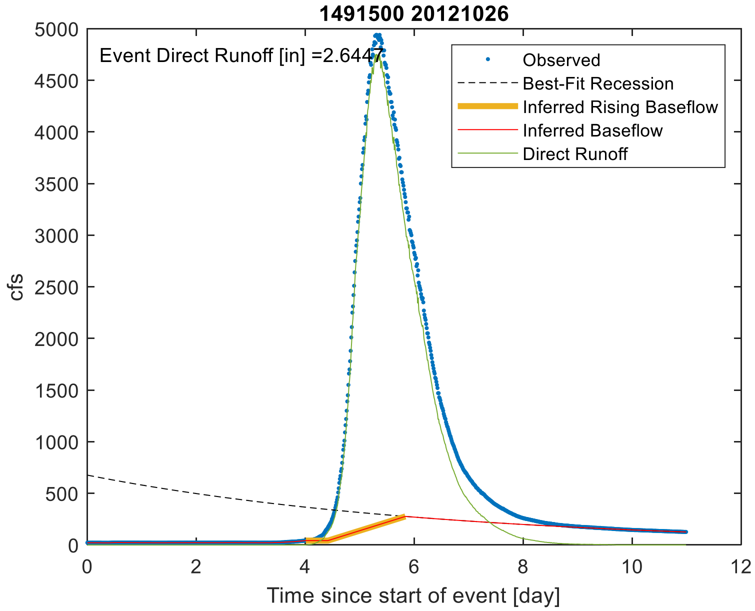

1490000 20161007
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.4517
Phi = 0.2253
in/hr
Eastern Standard Time
×10^5


1490000 20161007
Precipitation Excess
Direct Runoff
Event t_c = 83.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2016

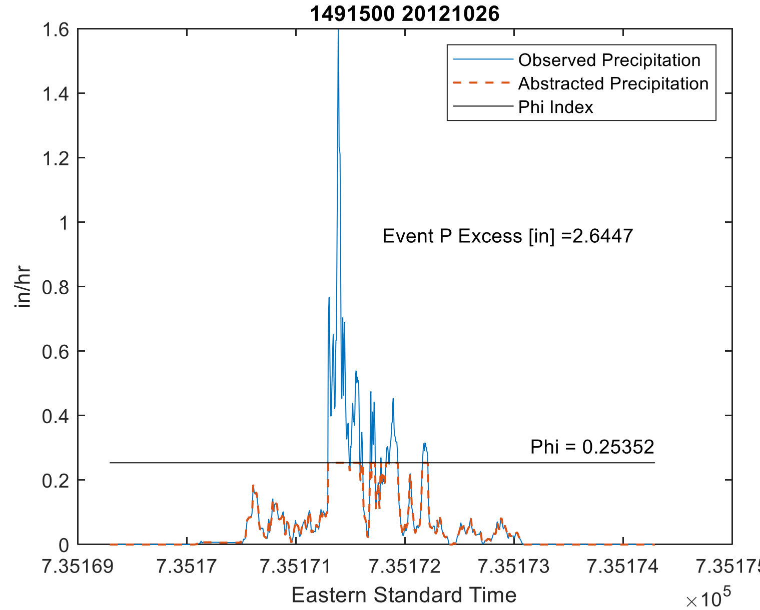

1490000 20161007
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 21.48 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 22.60 hr
Direct Runoff Q [cfs]
2016



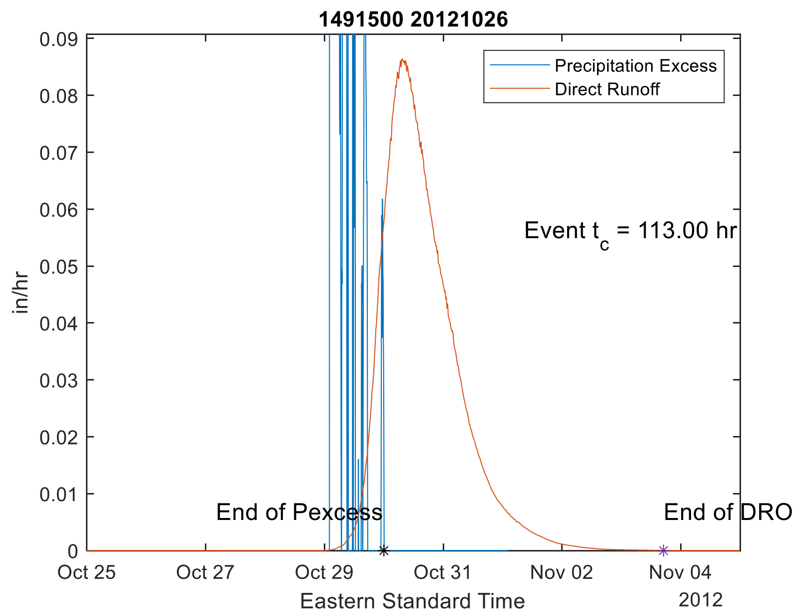
Input Data 1490000 20161007
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 06
Oct 08
Oct 10
Oct 12
Oct 14
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.45178 in
Total P = 0.4517 in
Oct 08
Oct 09
Oct 10
Oct 11
Oct 12
Oct 13
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 4.6 5
t(peak) 18.7 18.85
PRF 542 566
t(infl) 27.3 27.2



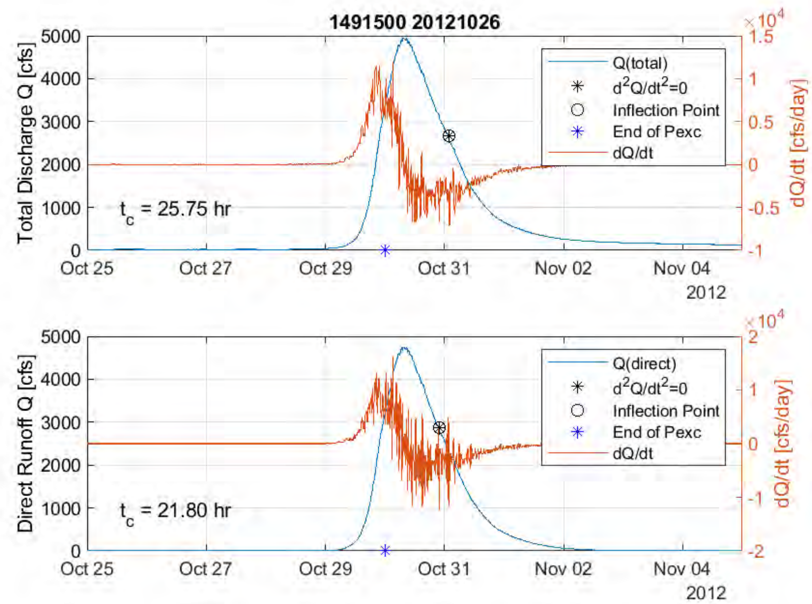
1491500 20121026
Event Direct Runoff [in] =2.6447
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



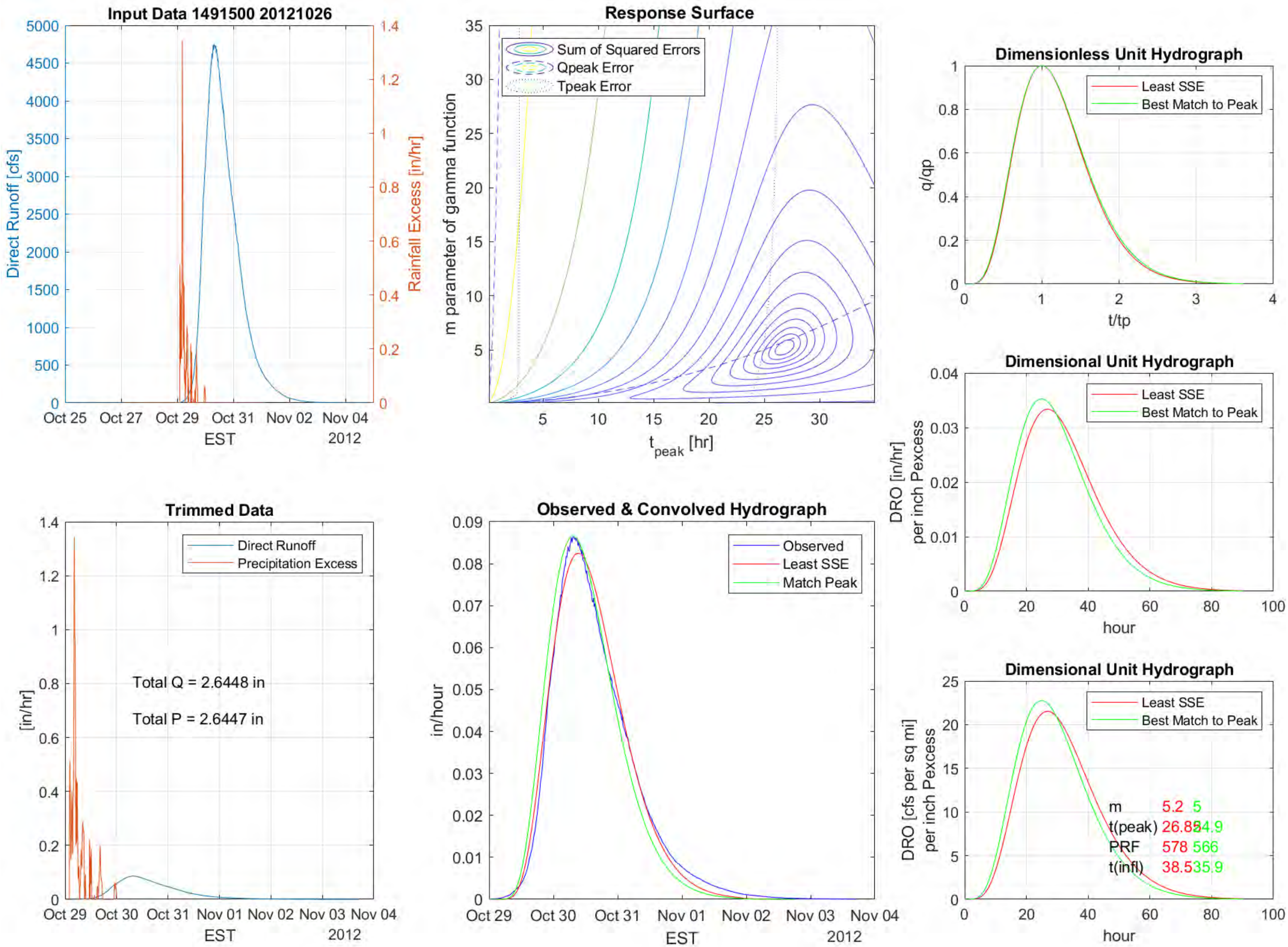
1491500 20121026
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.6447
Phi = 0.25352
in/hr
Eastern Standard Time

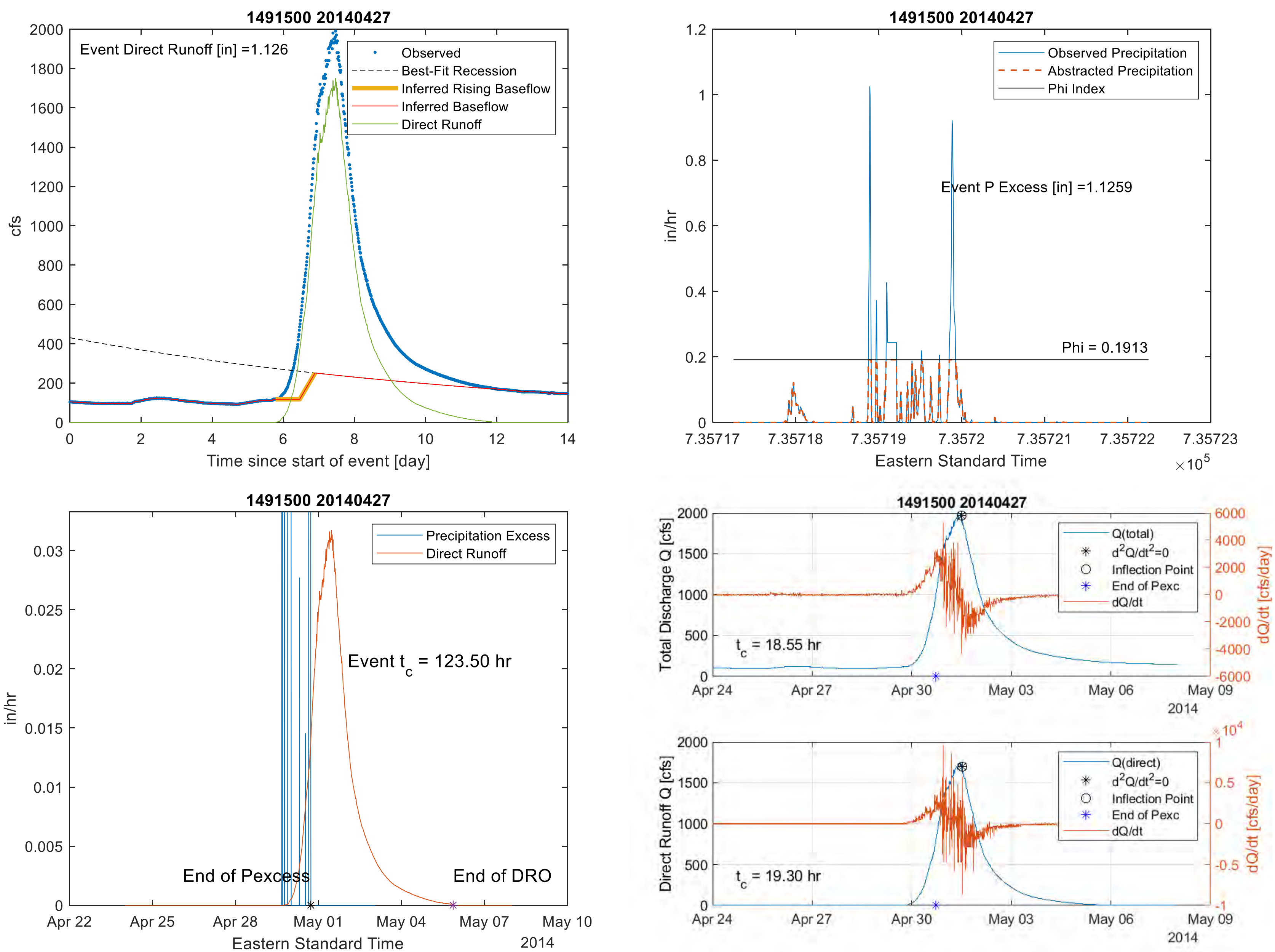


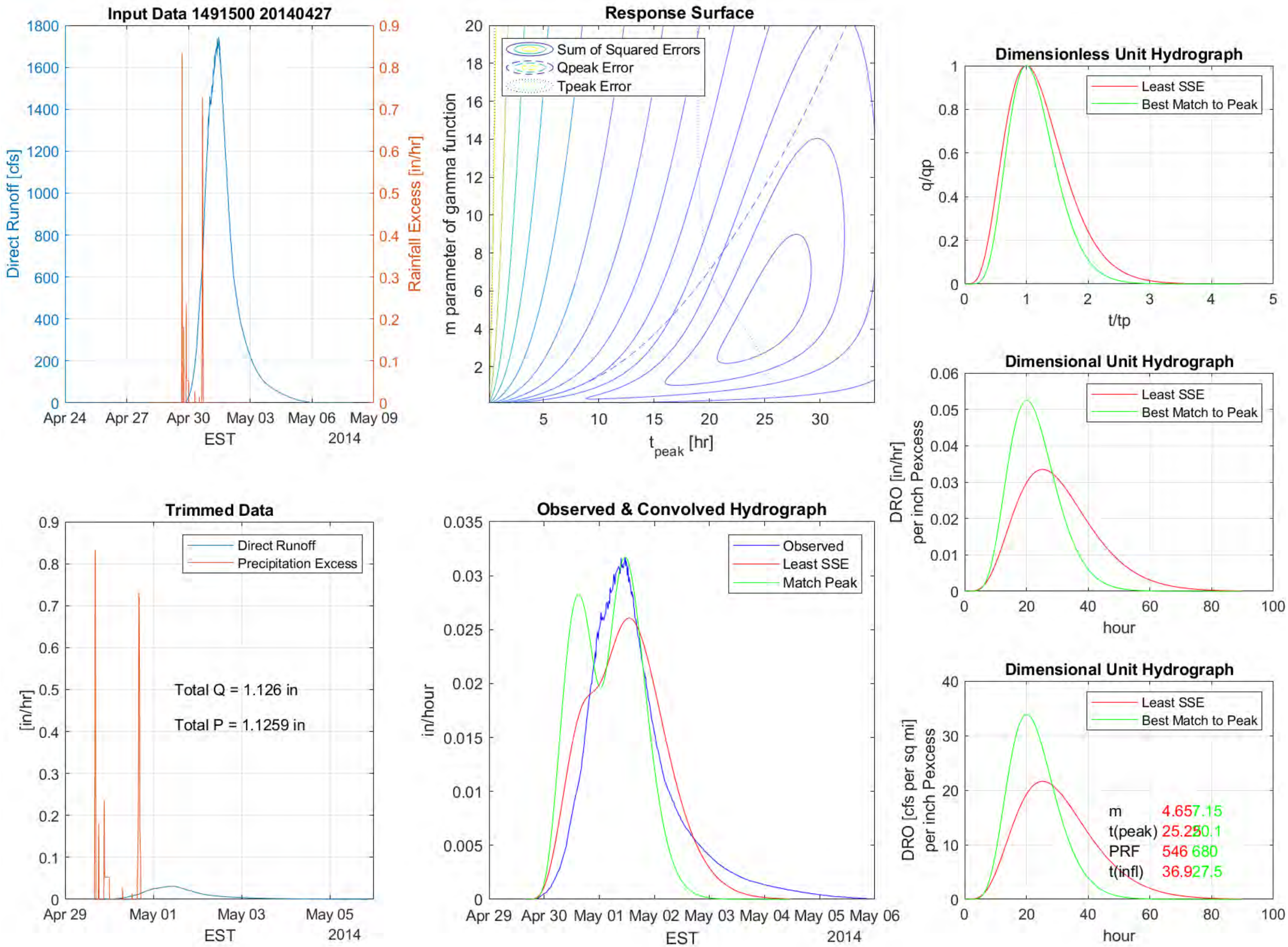
1491500 20121026
Precipitation Excess
Direct Runoff
Event t c = 113.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

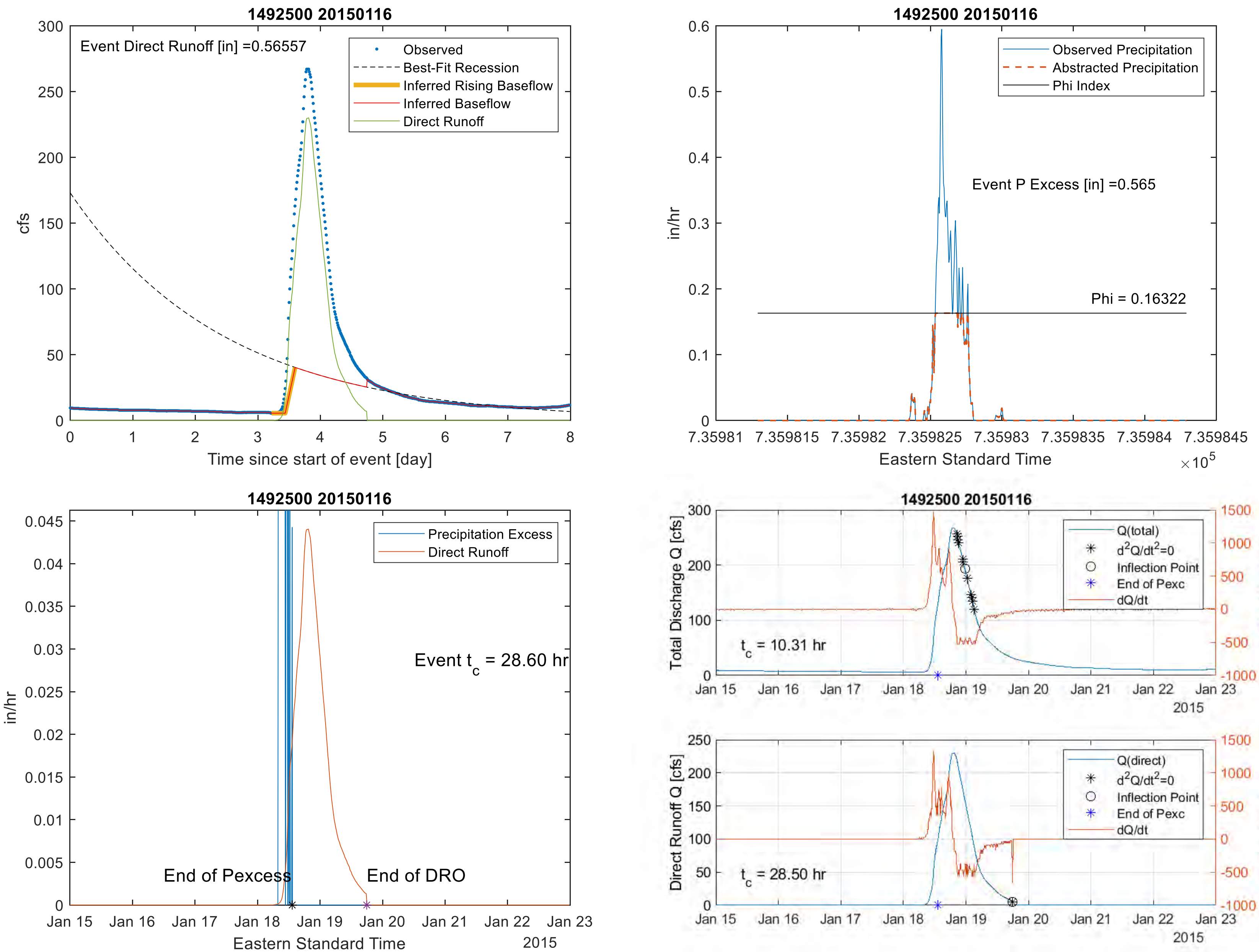


1491500 20121026
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 25.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 21.80 hr
Direct Runoff Q [cfs]

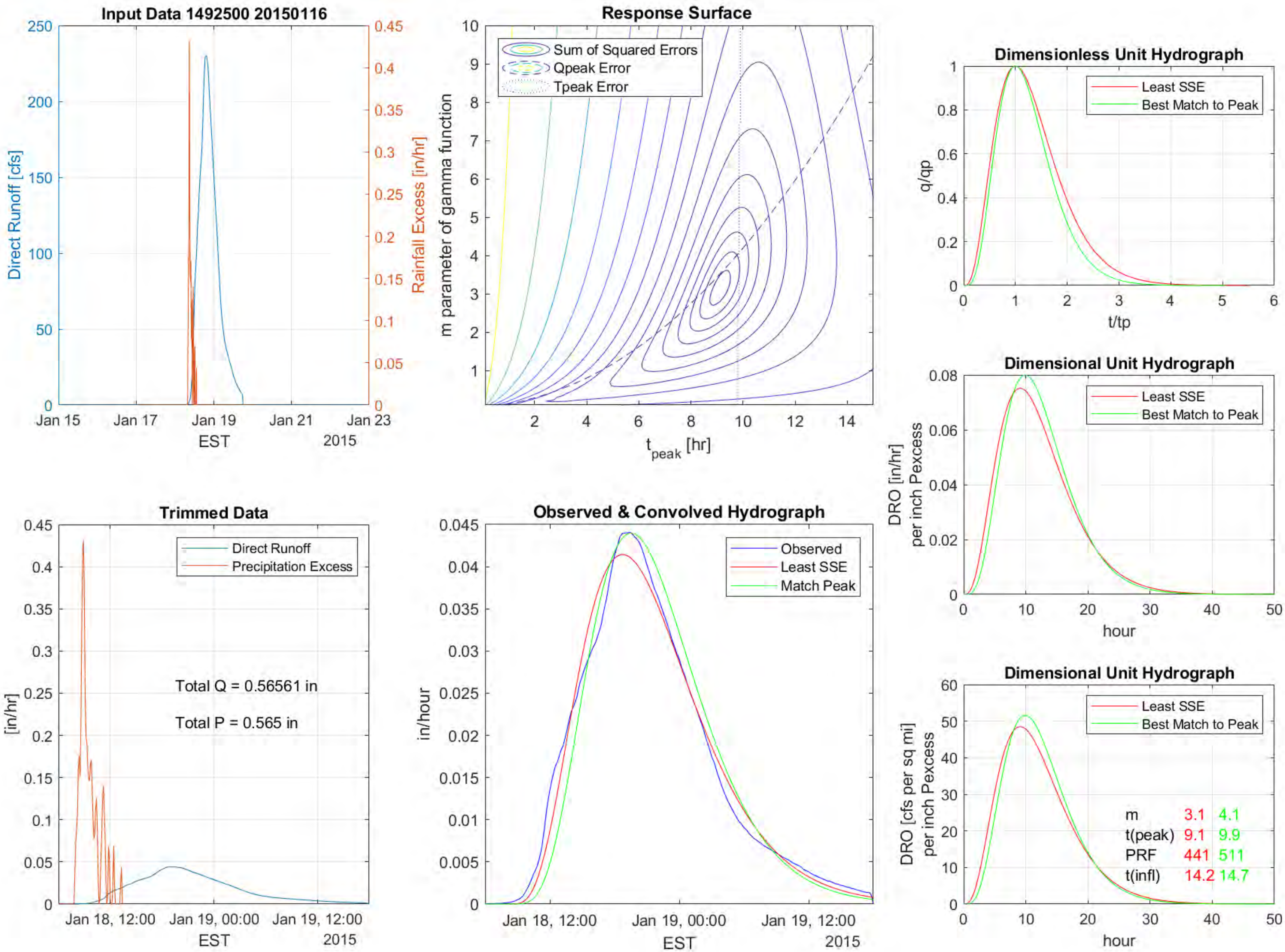

Input Data 1491500 20121026
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 25 Oct 27 Oct 29 Oct 31 Nov 02 Nov 04
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.6448 in
Total P = 2.6447 in
[in/hr]
Oct 29 Oct 30 Oct 31 Nov 01 Nov 02 Nov 03 Nov 04
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.2 5
t(peak) 26.85 24.9
PRF 578 566
t(infl) 38.5 35.9


1491500 20140427
Event Direct Runoff [in] =1.126
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1491500 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.1259
Phi = 0.1913
in/hr
Eastern Standard Time
1491500 20140427
Precipitation Excess
Direct Runoff
Event t c = 123.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1491500 20140427
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
tc = 18.55 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
tc = 19.30 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

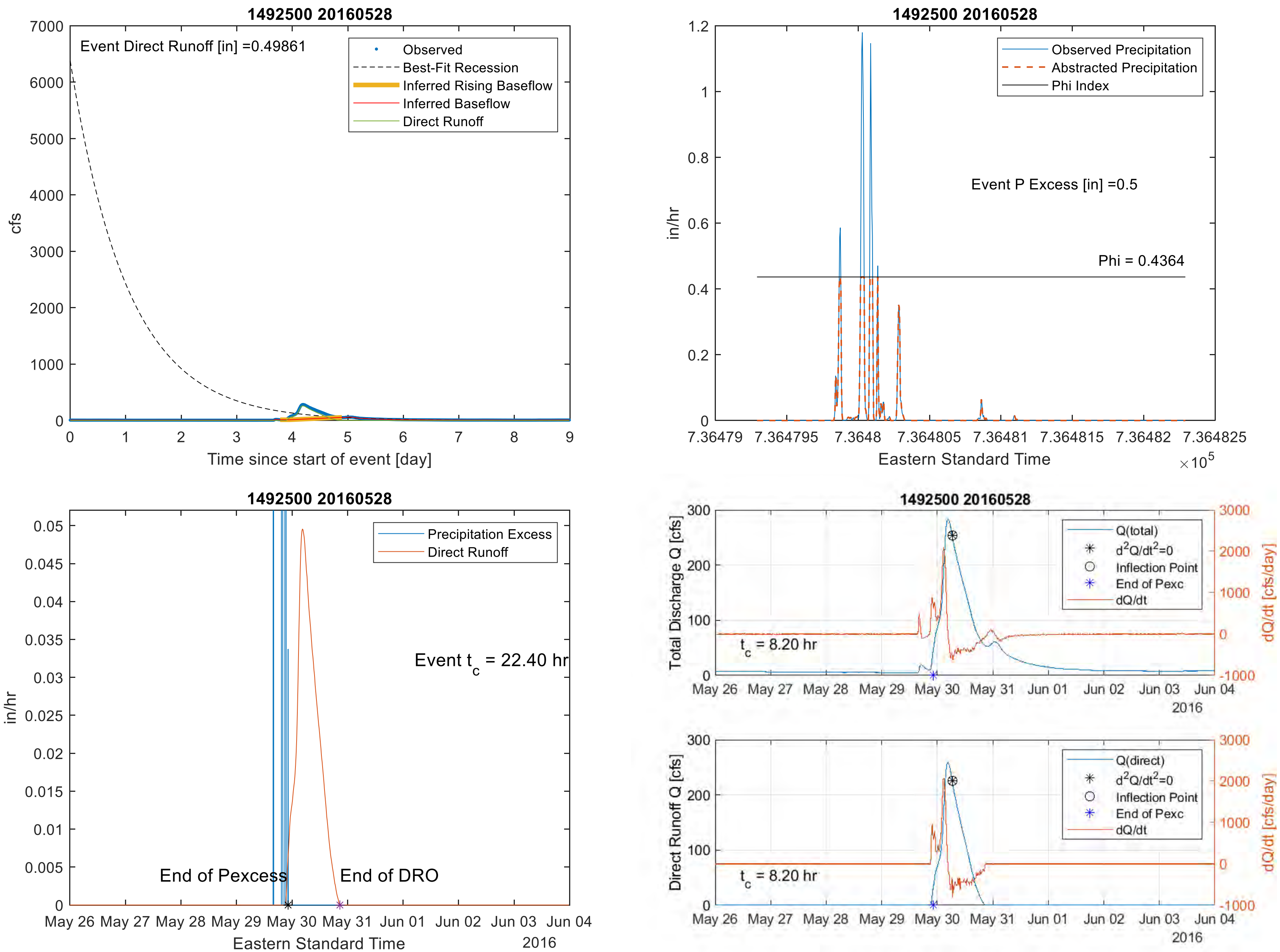

Input Data 1491500 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.126 in
Total P = 1.1259 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4.65 7.15
t(peak) 25.25 20.1
PRF 546 680
t(infl) 36.9 27.5



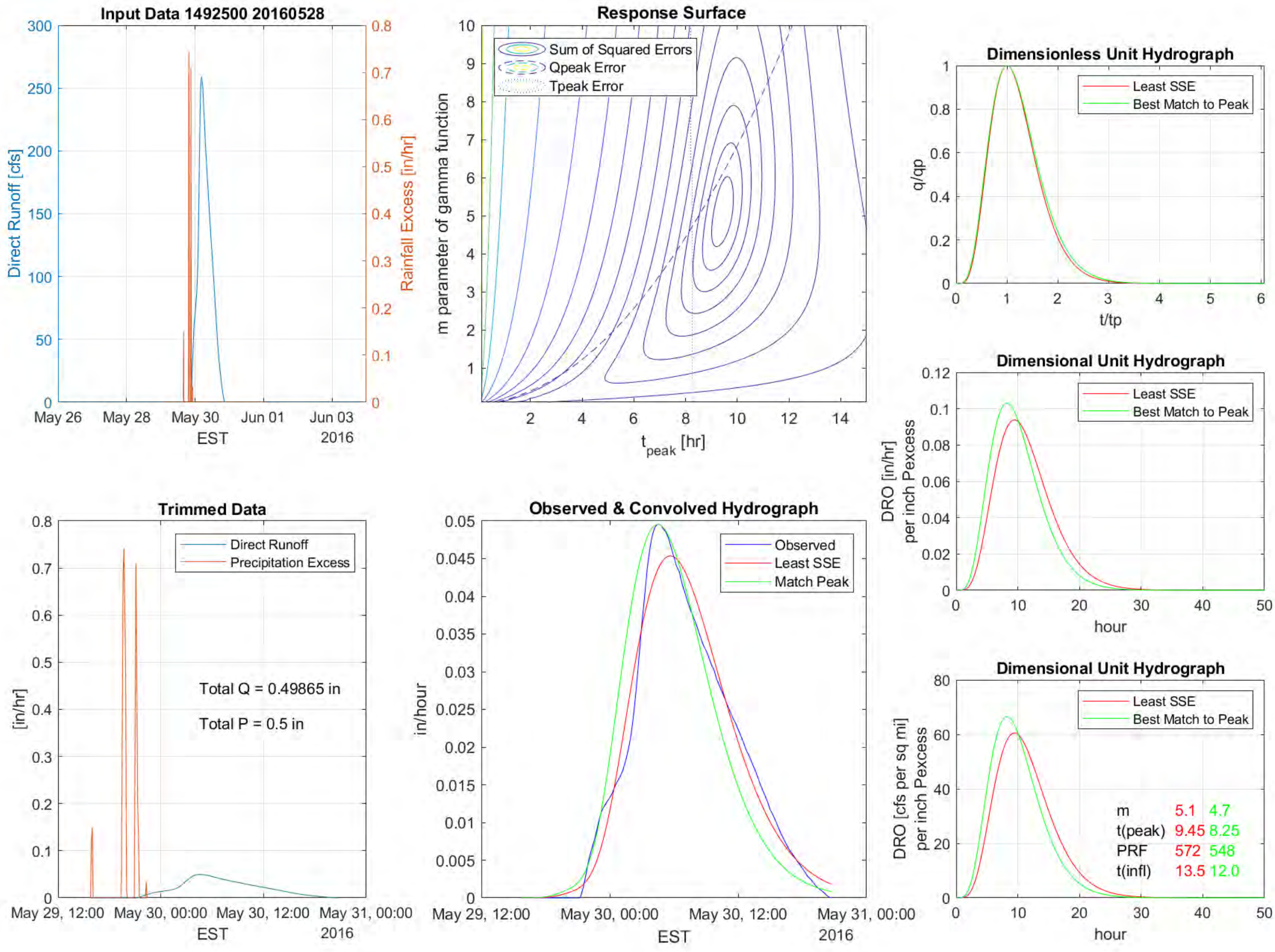
1492500 20150116
Event Direct Runoff [in] =0.56557
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1492500 20150116
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.565
Phi = 0.16322
in/hr
Eastern Standard Time
1492500 20150116
Precipitation Excess
Direct Runoff
Event t c = 28.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2015
1492500 20150116
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t c = 10.31 hr
Q(direct)
Direct Runoff Q [cfs]
t c = 28.50 hr
2015

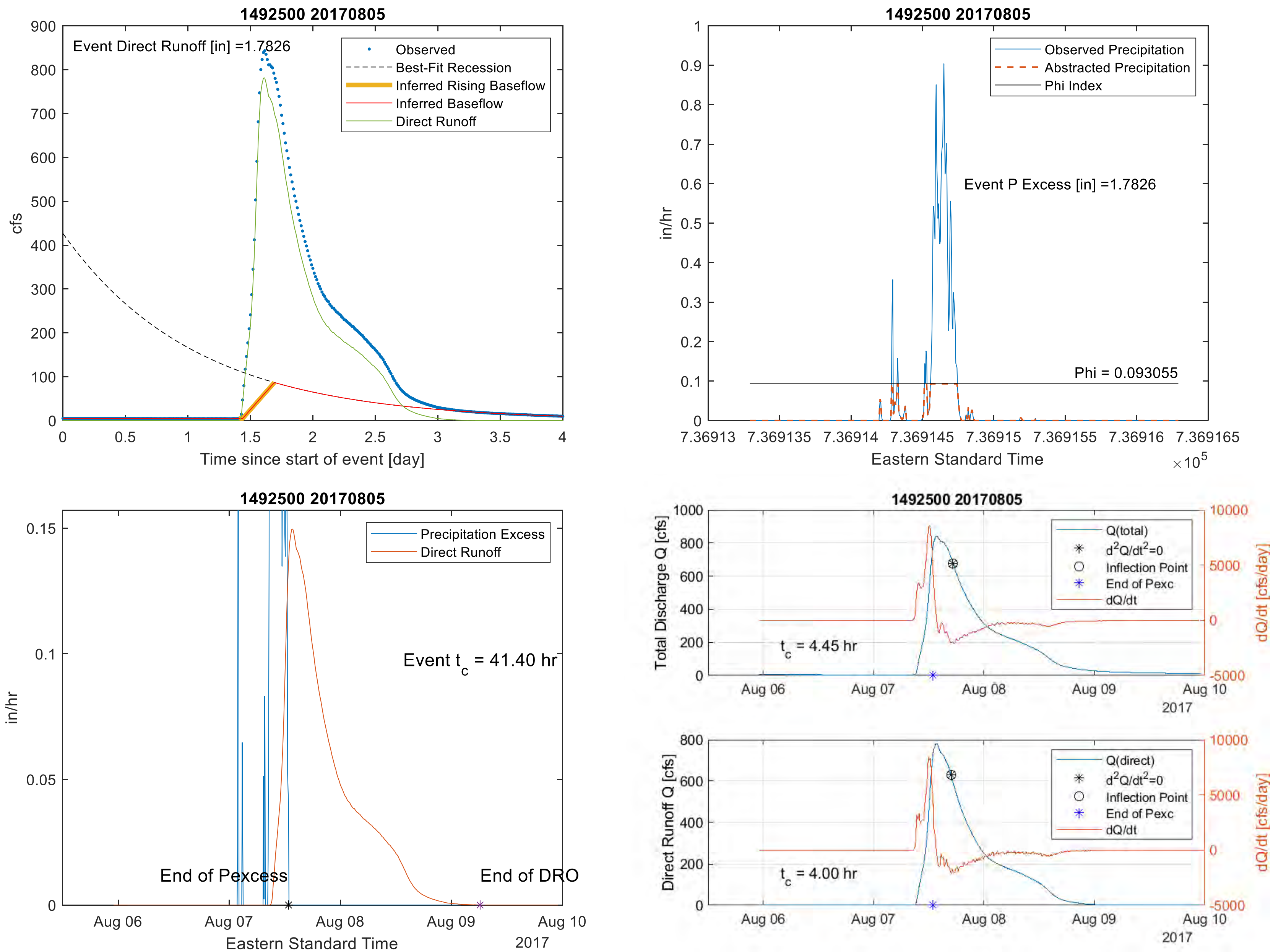


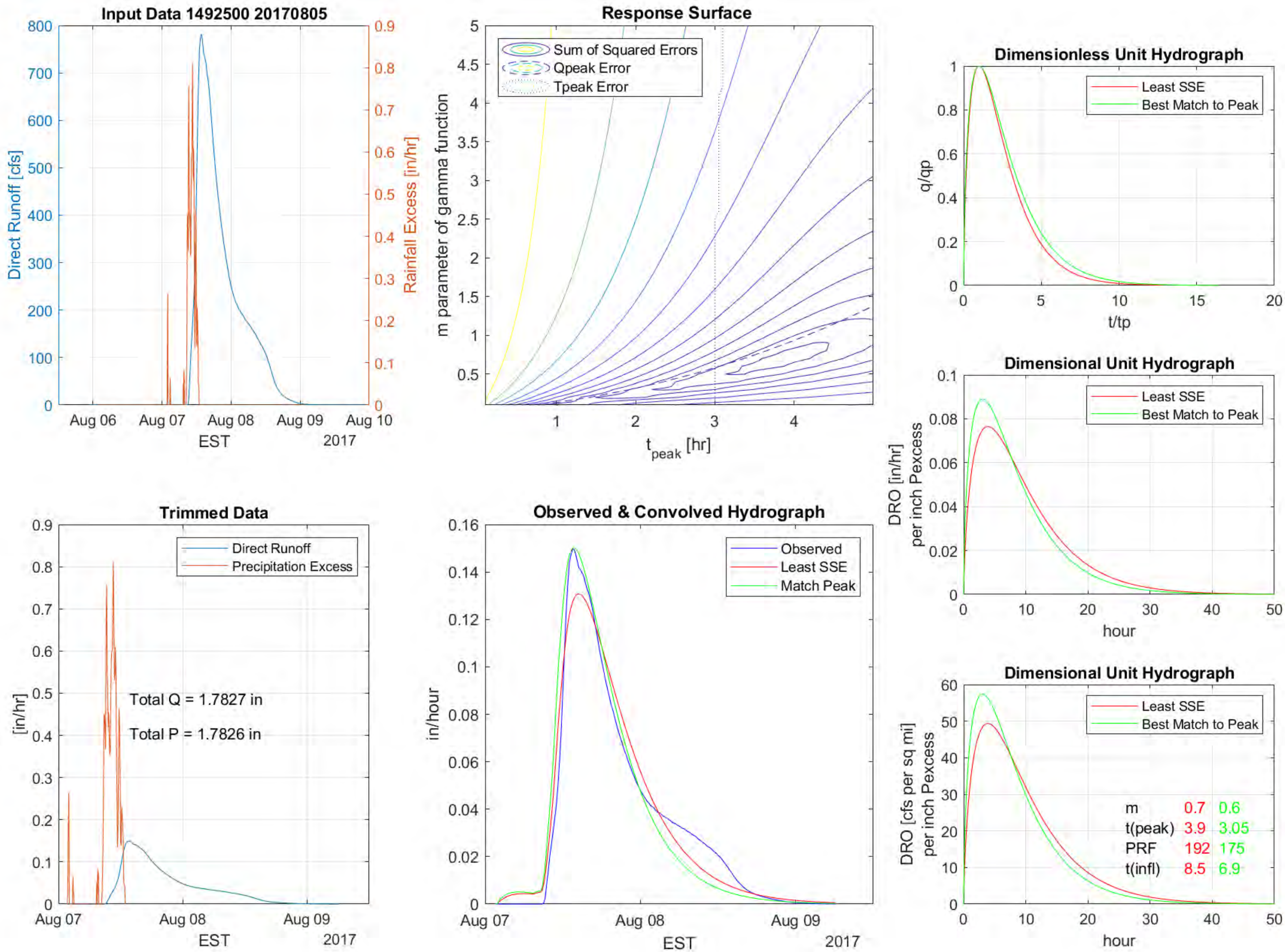
Input Data 1492500 20150116
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 15
Jan 17
Jan 19
Jan 21
Jan 23
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.56561 in
Total P = 0.565 in
Jan 18, 12:00
Jan 19, 00:00
Jan 19, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
DRO [cfs per sq mi] per inch Pexcess
m 3.1 4.1
t(peak) 9.1 9.9
PRF 441 511
t(infl) 14.2 14.7

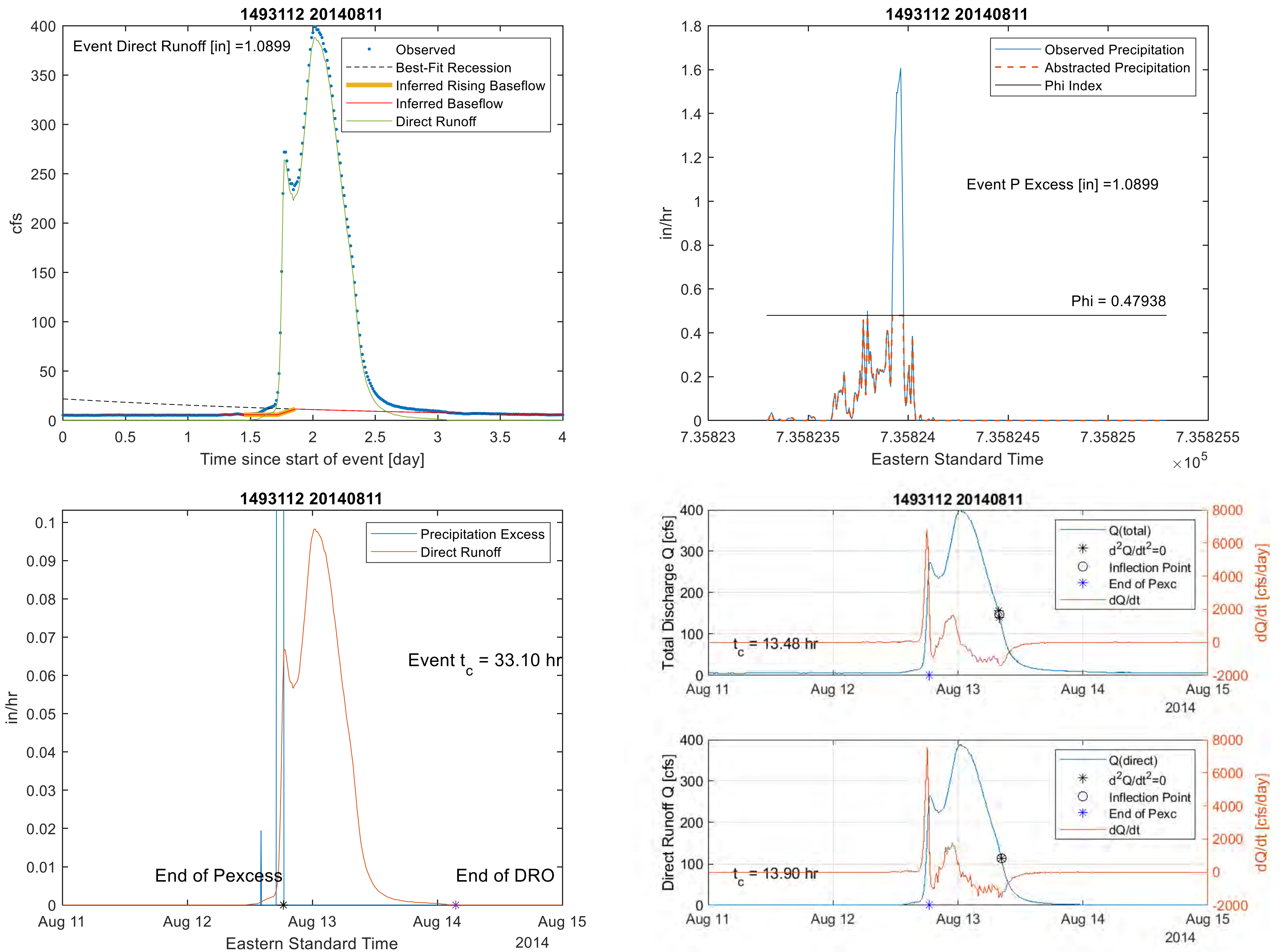


1492500 20160528
Event Direct Runoff [in] =0.49861
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1492500 20160528
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.5
Phi = 0.4364
in/hr
Eastern Standard Time
×10^5
1492500 20160528
Precipitation Excess
Direct Runoff
Event t_c = 22.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2016
1492500 20160528
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 8.20 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2016
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 8.20 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2016

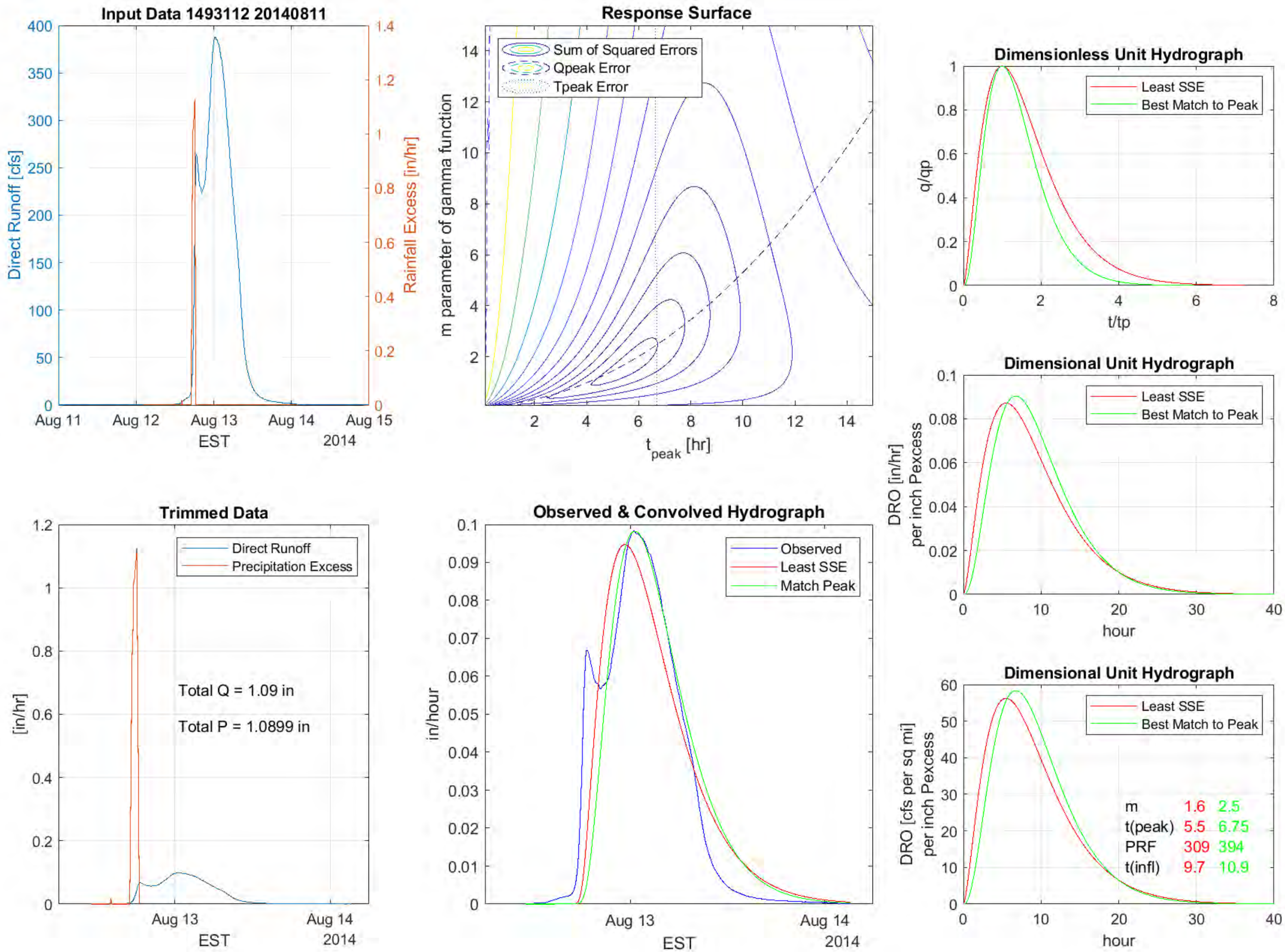

Input Data 1492500 20160528
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 26 May 28 May 30 Jun 01 Jun 03
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.49865 in
Total P = 0.5 in
[in/hr]
May 29, 12:00 May 30, 00:00 May 30, 12:00 May 31, 00:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.1 4.7
t(peak) 9.45 8.25
PRF 572 548
t(infl) 13.5 12.0
hour

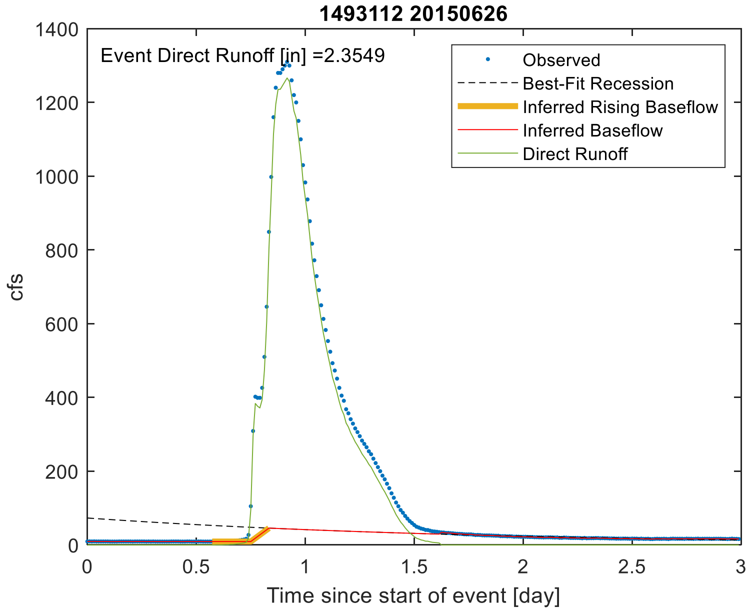

1492500 20170805
Event Direct Runoff [in] =1.7826
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1492500 20170805
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.7826
Phi = 0.093055
in/hr
Eastern Standard Time
×10^5
1492500 20170805
Precipitation Excess
Direct Runoff
Event t c = 41.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2017
1492500 20170805
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 4.45 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2017
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 4.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2017

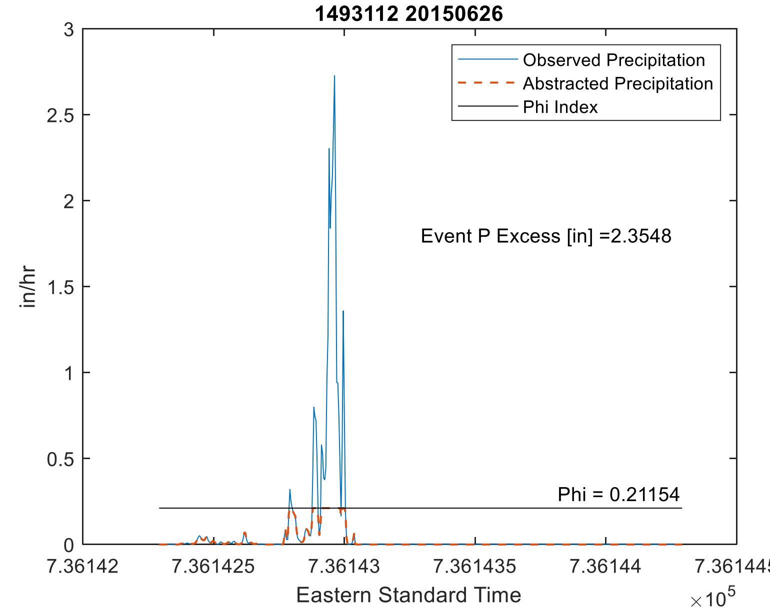

Input Data 1492500 20170805
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 06
Aug 07
Aug 08
Aug 09
Aug 10
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.7827 in
Total P = 1.7826 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 0.7 0.6
t(peak) 3.9 3.05
PRF 192 175
t(infl) 8.5 6.9

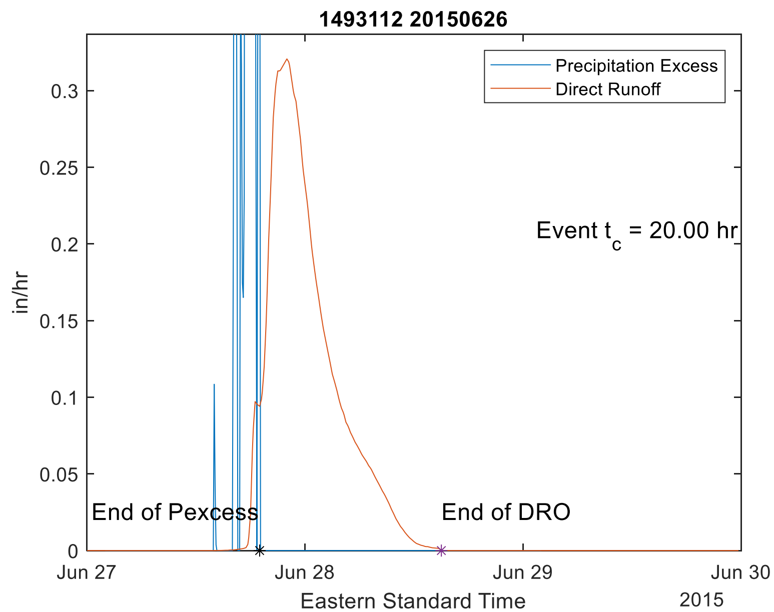


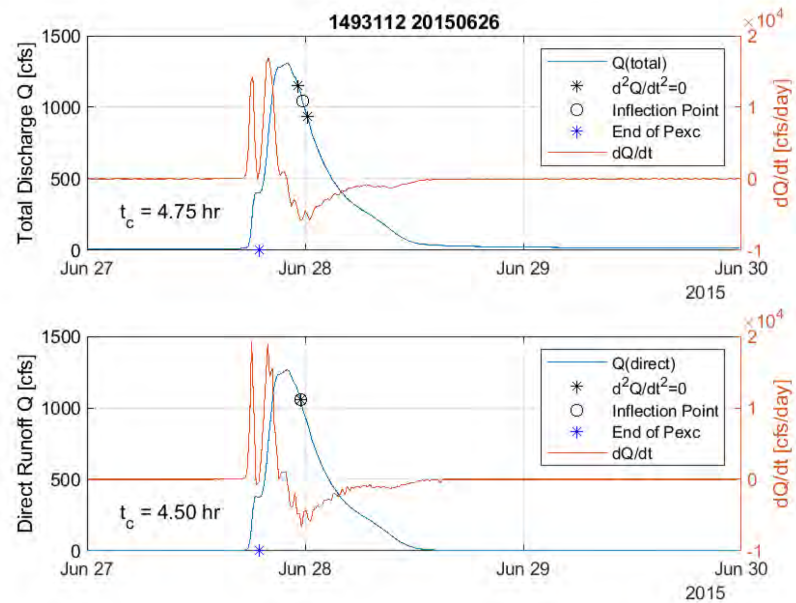
1493112 20140811
Event Direct Runoff [in] =1.0899
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1493112 20140811
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.0899
Phi = 0.47938
in/hr
Eastern Standard Time
1493112 20140811
Precipitation Excess
Direct Runoff
Event t c = 33.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1493112 20140811
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 13.48 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 13.90 hr
Direct Runoff Q [cfs]

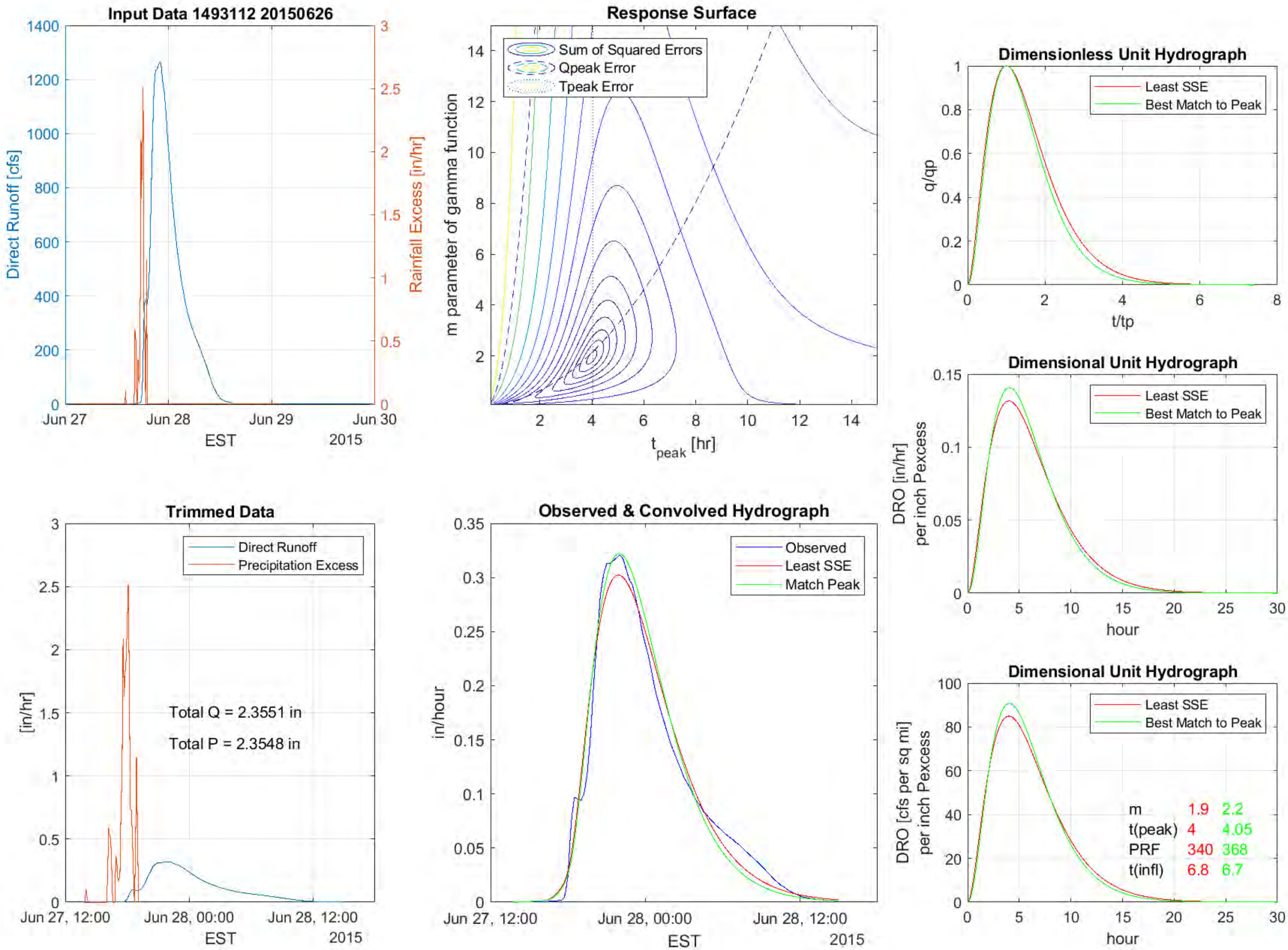

Input Data 1493112 20140811
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 11
Aug 12
Aug 13
Aug 14
Aug 15
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.09 in
Total P = 1.0899 in
[in/hr]
Aug 13
Aug 14
EST
2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Aug 13
Aug 14
EST
2014
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
m 1.6 2.5
t(peak) 5.5 6.75
PRF 309 394
t(infl) 9.7 10.9
hour


1493112 20150626
Event Direct Runoff [in] =2.3549
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
0
200
400
600
800
1000
1200
1400
0.5
1
1.5
2
2.5
3

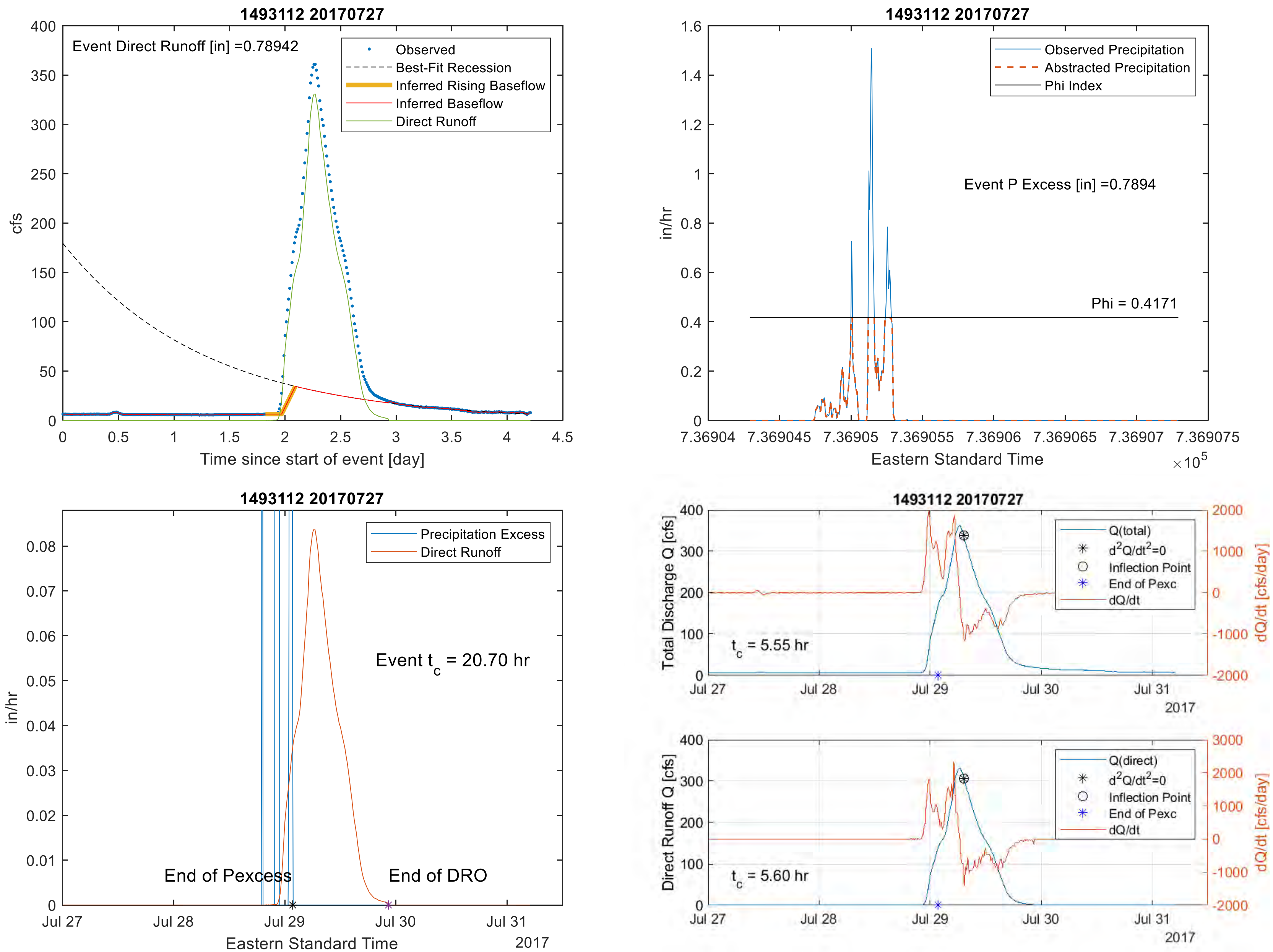

1493112 20150626
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.3548
Phi = 0.21154
in/hr
Eastern Standard Time
×10^5
7.36142
7.361425
7.36143
7.361435
7.36144
7.361445
0
0.5
1
1.5
2
2.5
3

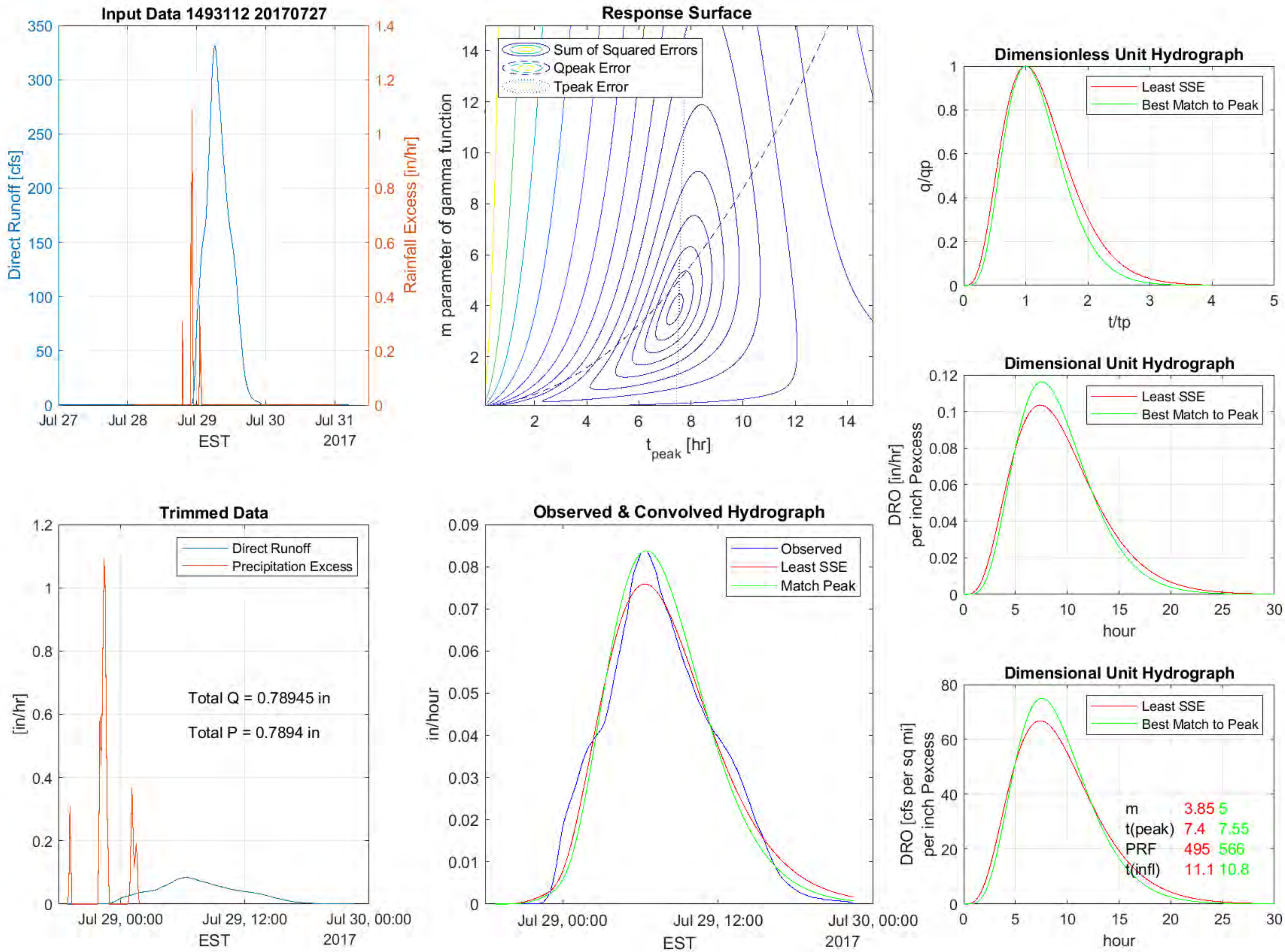

1493112 20150626
Precipitation Excess
Direct Runoff
Event t_c = 20.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
Jun 27
Jun 28
Jun 29
Jun 30
2015
0
0.05
0.1
0.15
0.2
0.25
0.3


1493112 20150626
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 4.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
×10^4
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 4.50 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
×10^4
0
500
1000
1500
-1
1
2
Jun 27
Jun 28
Jun 29
Jun 30
2015

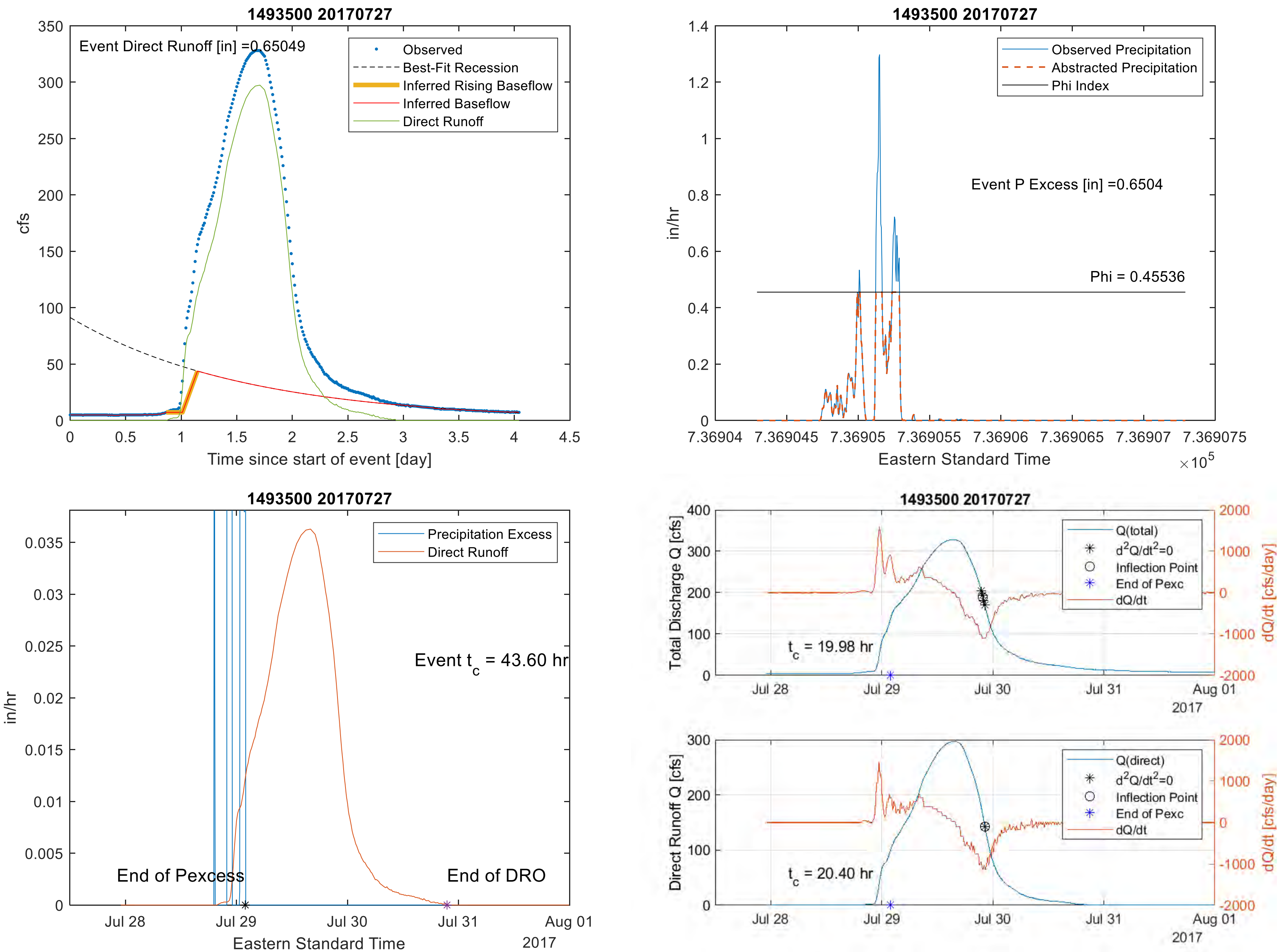


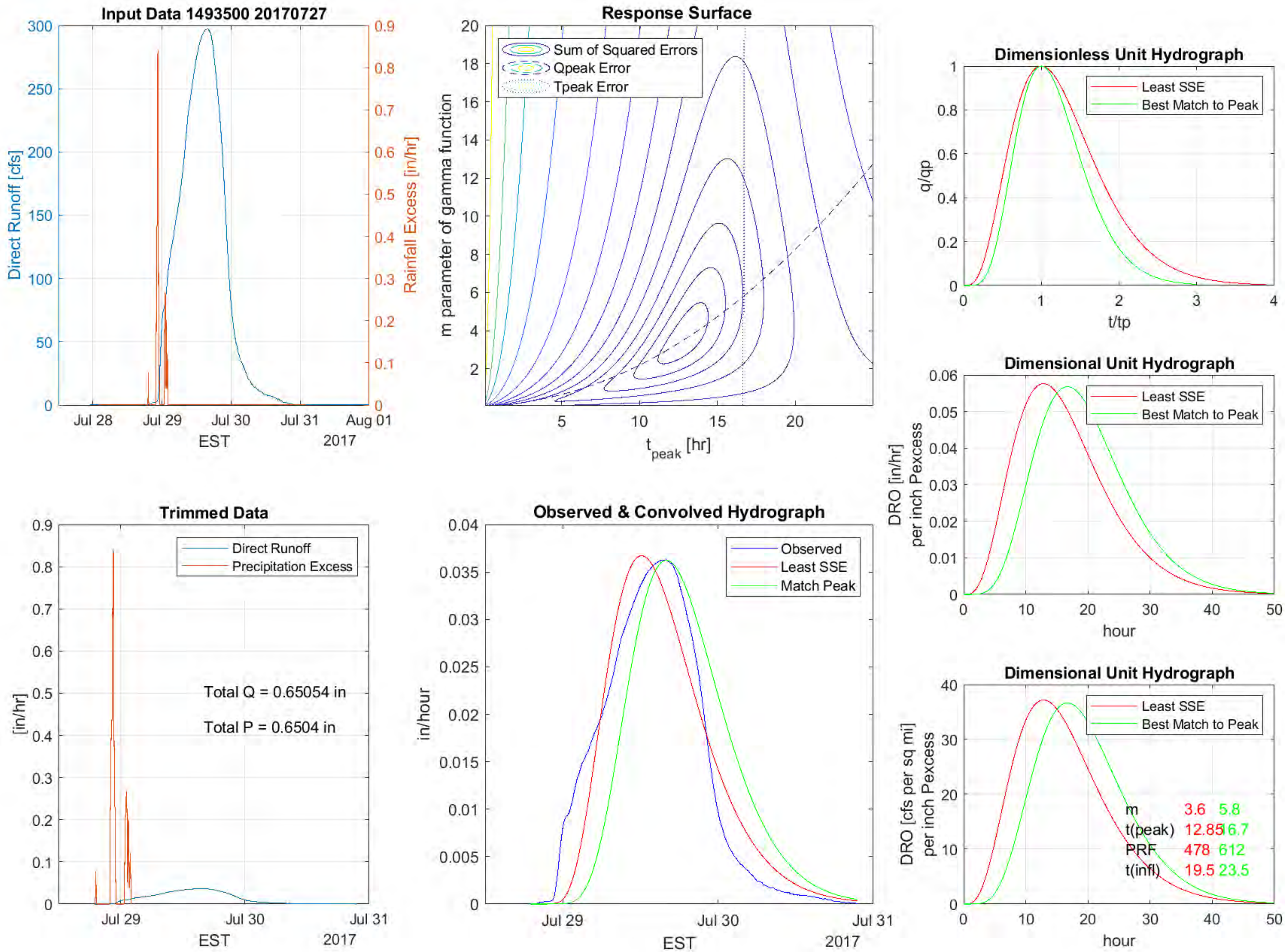
Input Data 1493112 20150626
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 27
Jun 28
Jun 29
Jun 30
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 2.3551 in
Total P = 2.3548 in
Jun 27, 12:00
Jun 28, 00:00
Jun 28, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
DRO [cfs per sq mi] per inch Pexcess
m 1.9 2.2
t(peak) 4 4.05
PRF 340 368
t(infl) 6.8 6.7

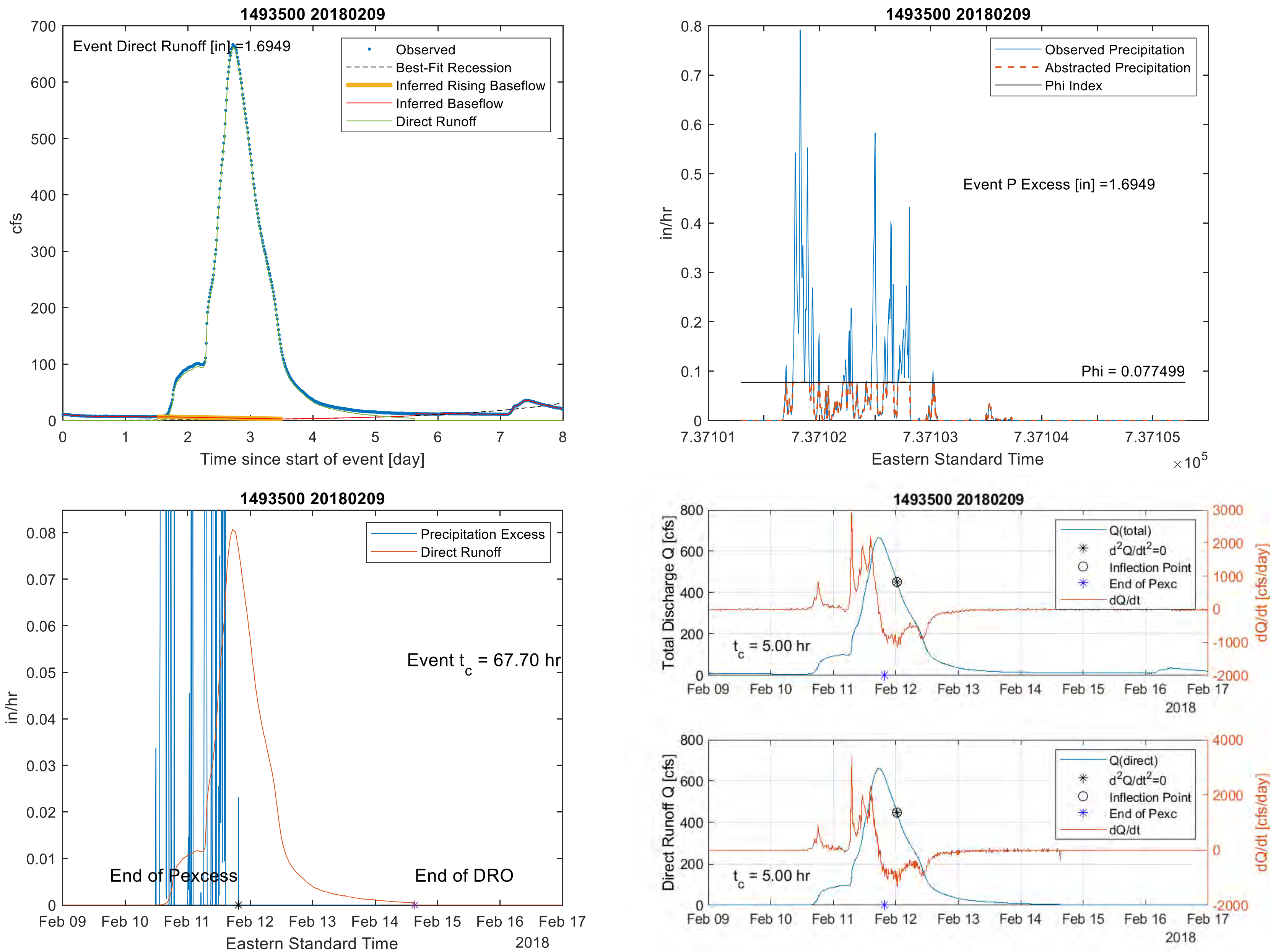

1493112 20170727
Event Direct Runoff [in] =0.78942
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1493112 20170727
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.7894
Phi = 0.4171
in/hr
Eastern Standard Time
1493112 20170727
Precipitation Excess
Direct Runoff
Event t c = 20.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1493112 20170727
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 5.55 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 5.60 hr
Direct Runoff Q [cfs]
2017



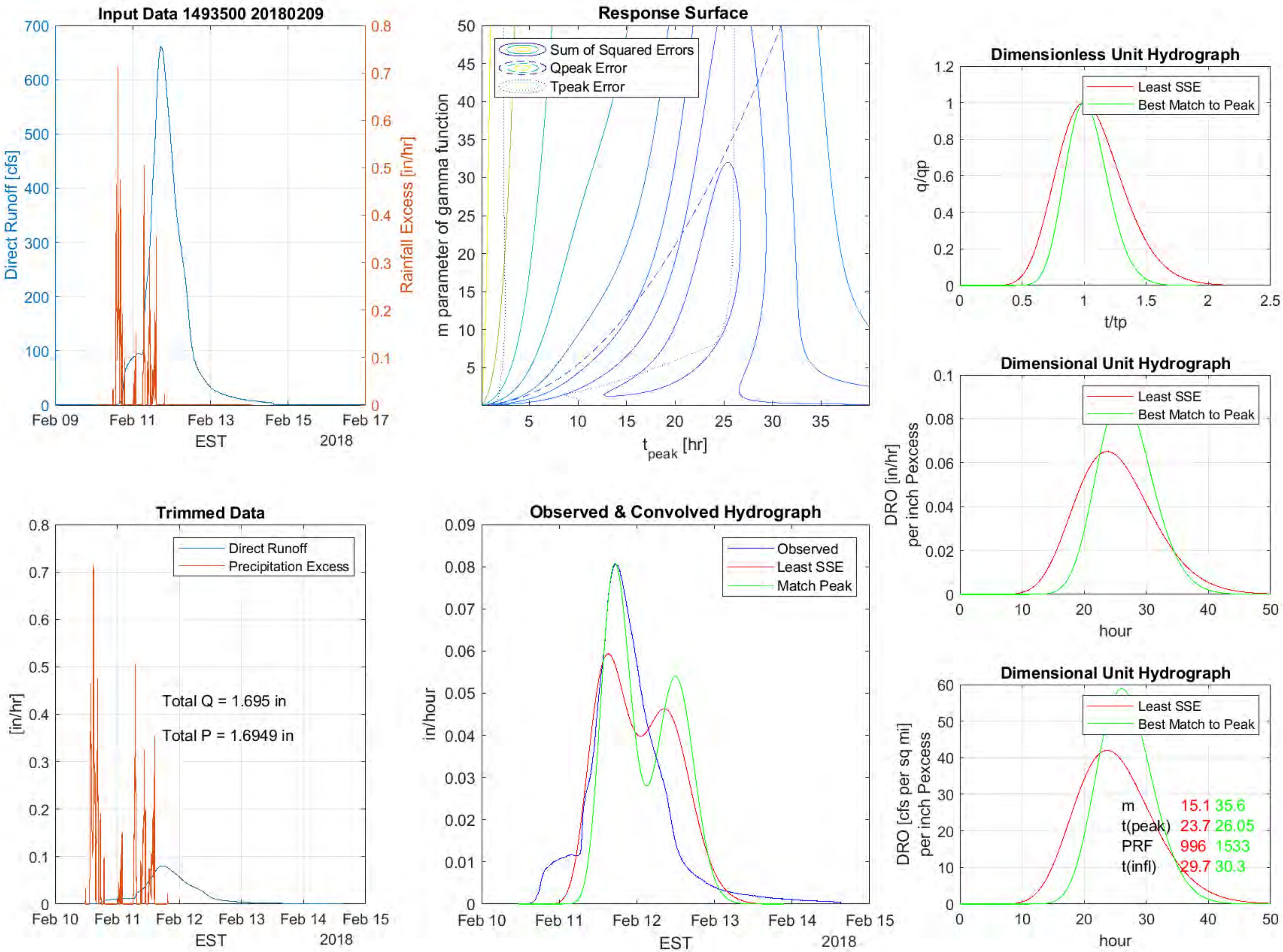
Input Data 1493112 20170727
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 27
Jul 28
Jul 29
Jul 30
Jul 31
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.78945 in
Total P = 0.7894 in
[in/hr]
Jul 29, 00:00
Jul 29, 12:00
Jul 30, 00:00
EST
2017
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jul 29, 00:00
Jul 29, 12:00
Jul 30, 00:00
EST
2017
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 3.85 5
t(peak) 7.4 7.55
PRF 495 566
t(infl) 11.1 10.8
hour

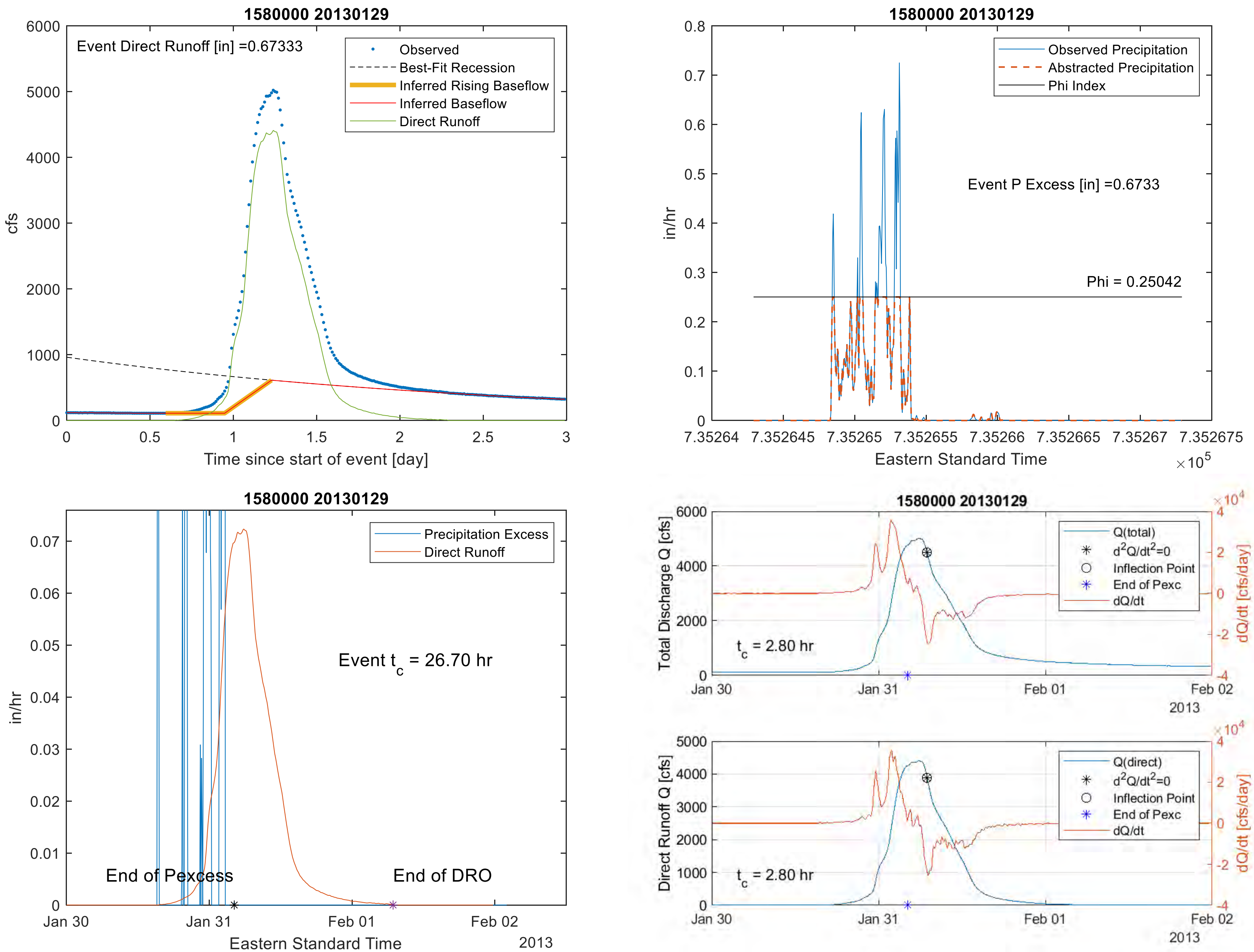

1493500 20170727
Event Direct Runoff [in] =0.65049
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1493500 20170727
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6504
Phi = 0.45536
in/hr
Eastern Standard Time
1493500 20170727
Precipitation Excess
Direct Runoff
Event t c = 43.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1493500 20170727
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 19.98 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 20.40 hr
Direct Runoff Q [cfs]

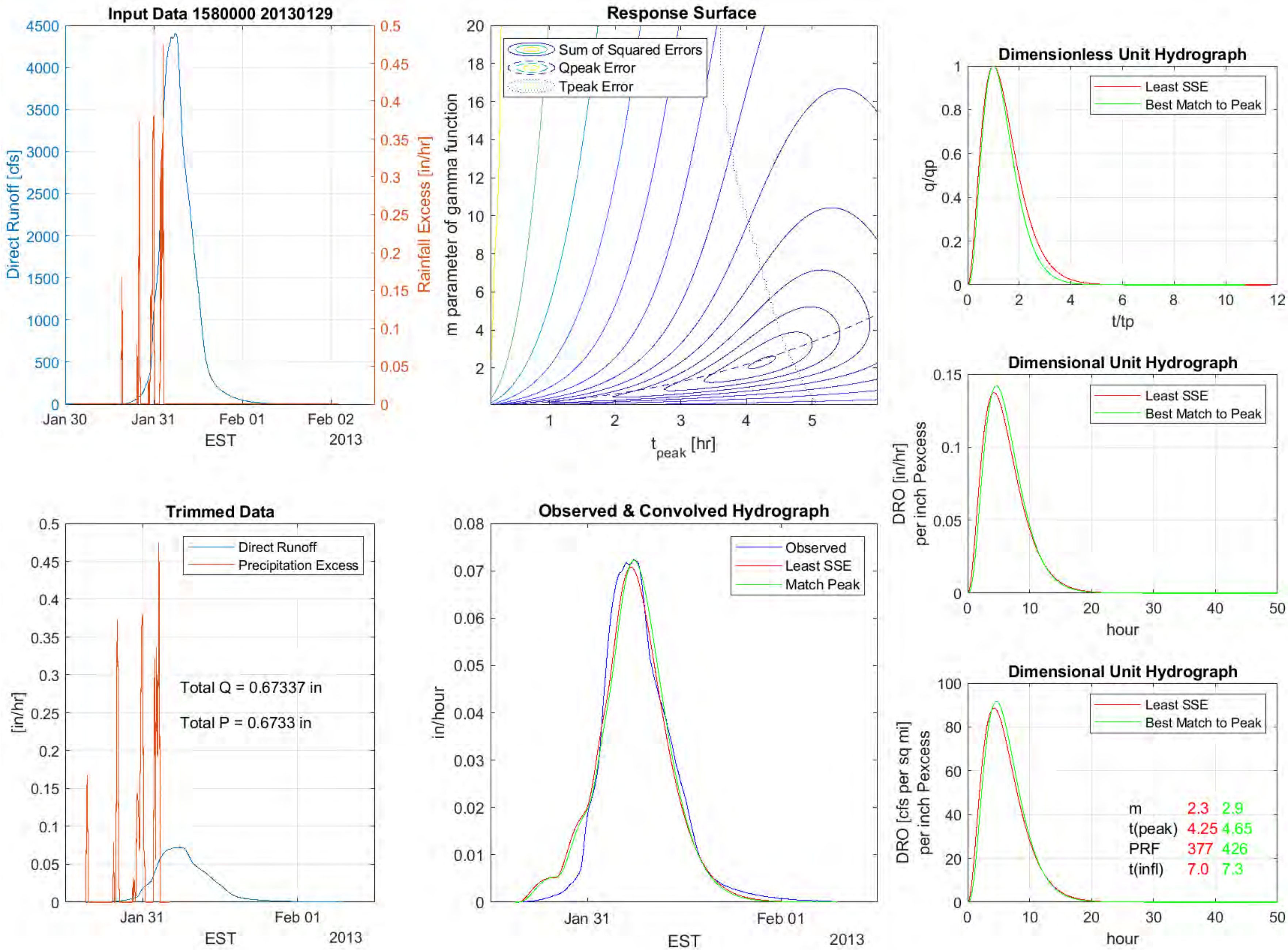

Input Data 1493500 20170727
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 28
Jul 29
Jul 30
Jul 31
Aug 01
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.65054 in
Total P = 0.6504 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.6 5.8
t(peak) 12.85 16.7
PRF 478 612
t(infl) 19.5 23.5

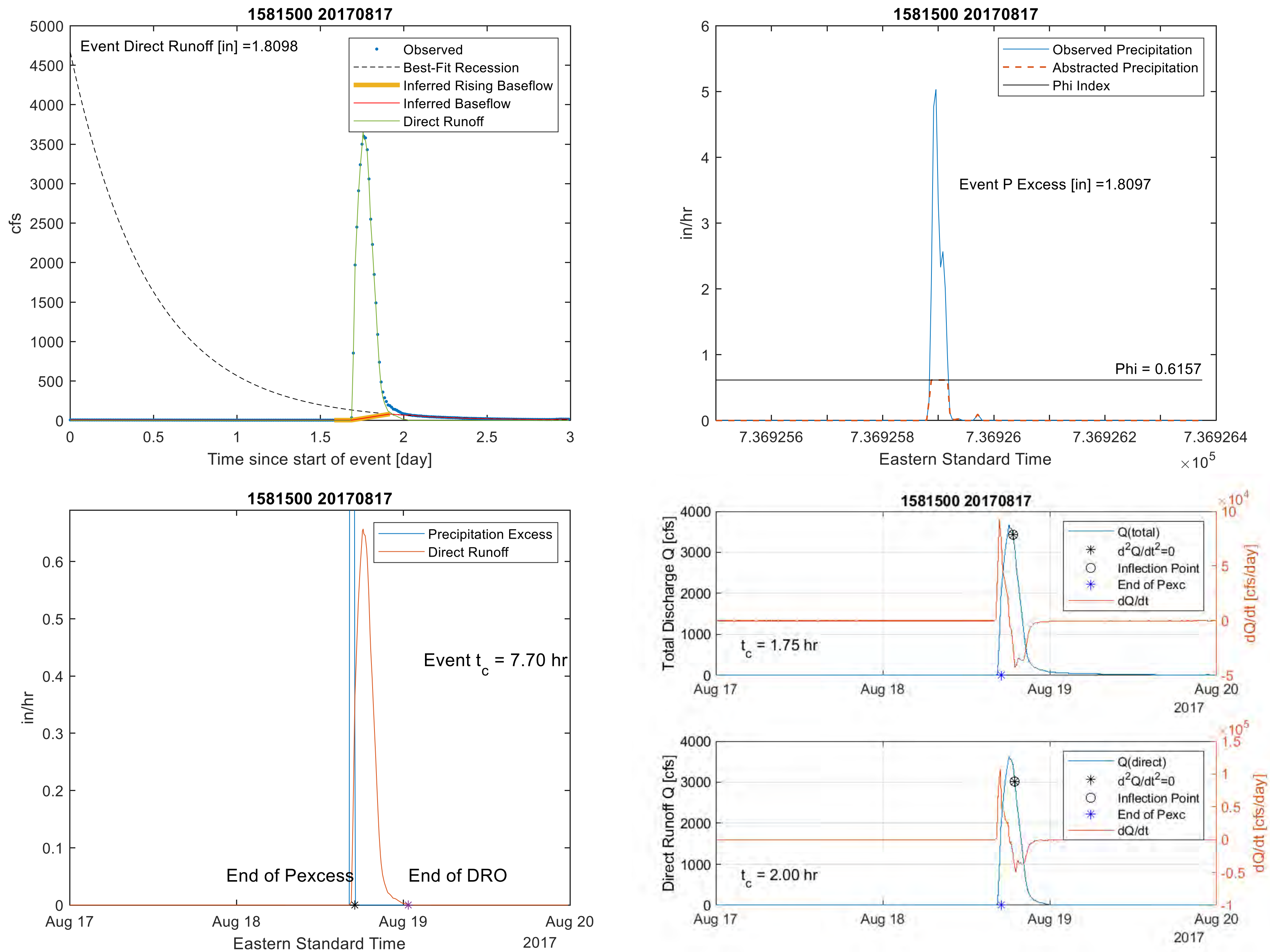


1493500 20180209
Event Direct Runoff [in] =1.6949
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1493500 20180209
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.6949
Phi = 0.077499
in/hr
Eastern Standard Time
×10^5
1493500 20180209
Precipitation Excess
Direct Runoff
Event t_c = 67.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2018
1493500 20180209
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t_c = 5.00 hr
2018
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
t_c = 5.00 hr
2018

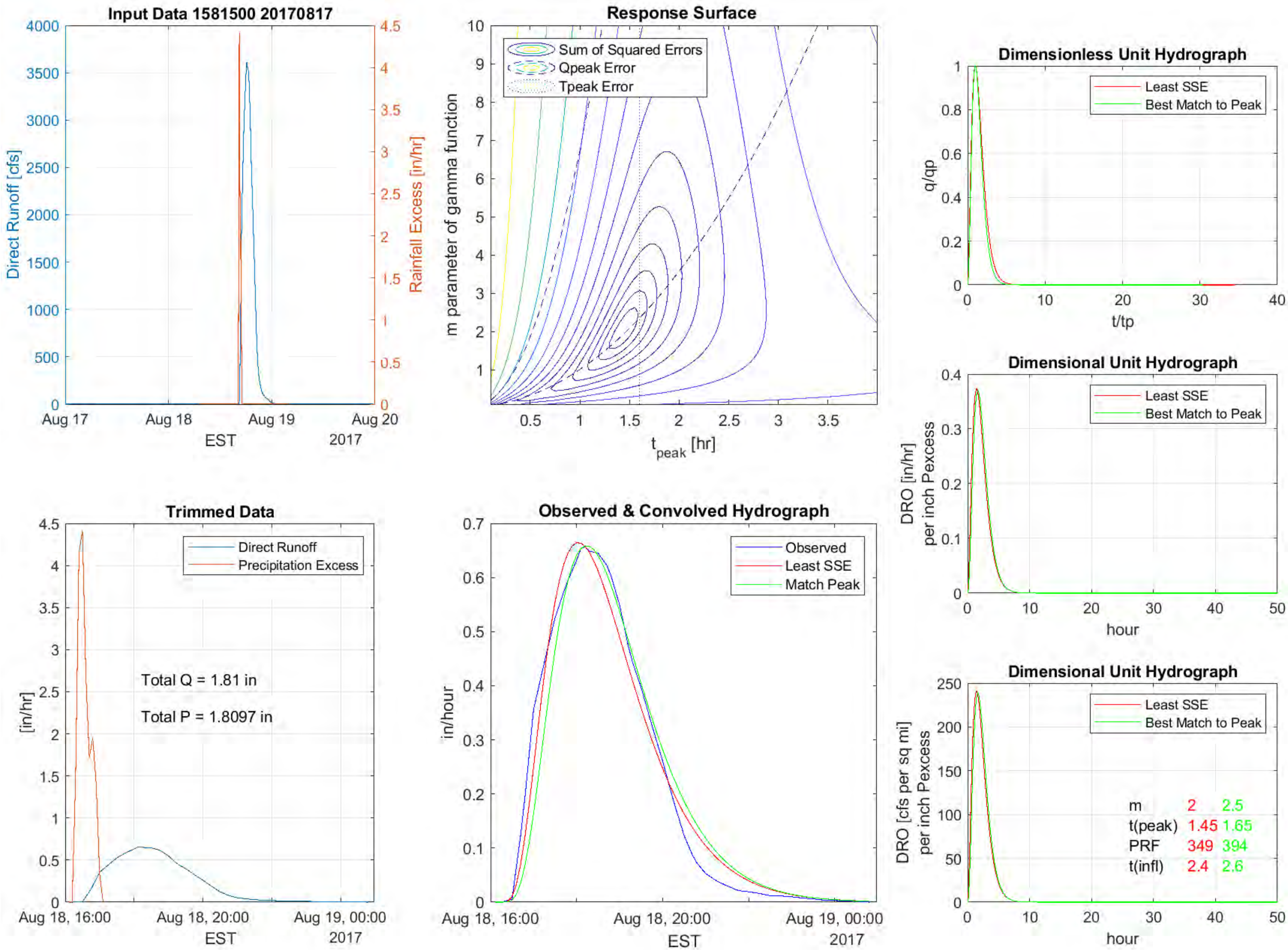

Input Data 1493500 20180209
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Feb 09
Feb 11
Feb 13
Feb 15
Feb 17
EST
2018
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.695 in
Total P = 1.6949 in
Feb 10
Feb 11
Feb 12
Feb 13
Feb 14
Feb 15
EST
2018
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
2018
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 15.1 35.6
t(peak) 23.7 26.05
PRF 996 1533
t(infl) 29.7 30.3
hour

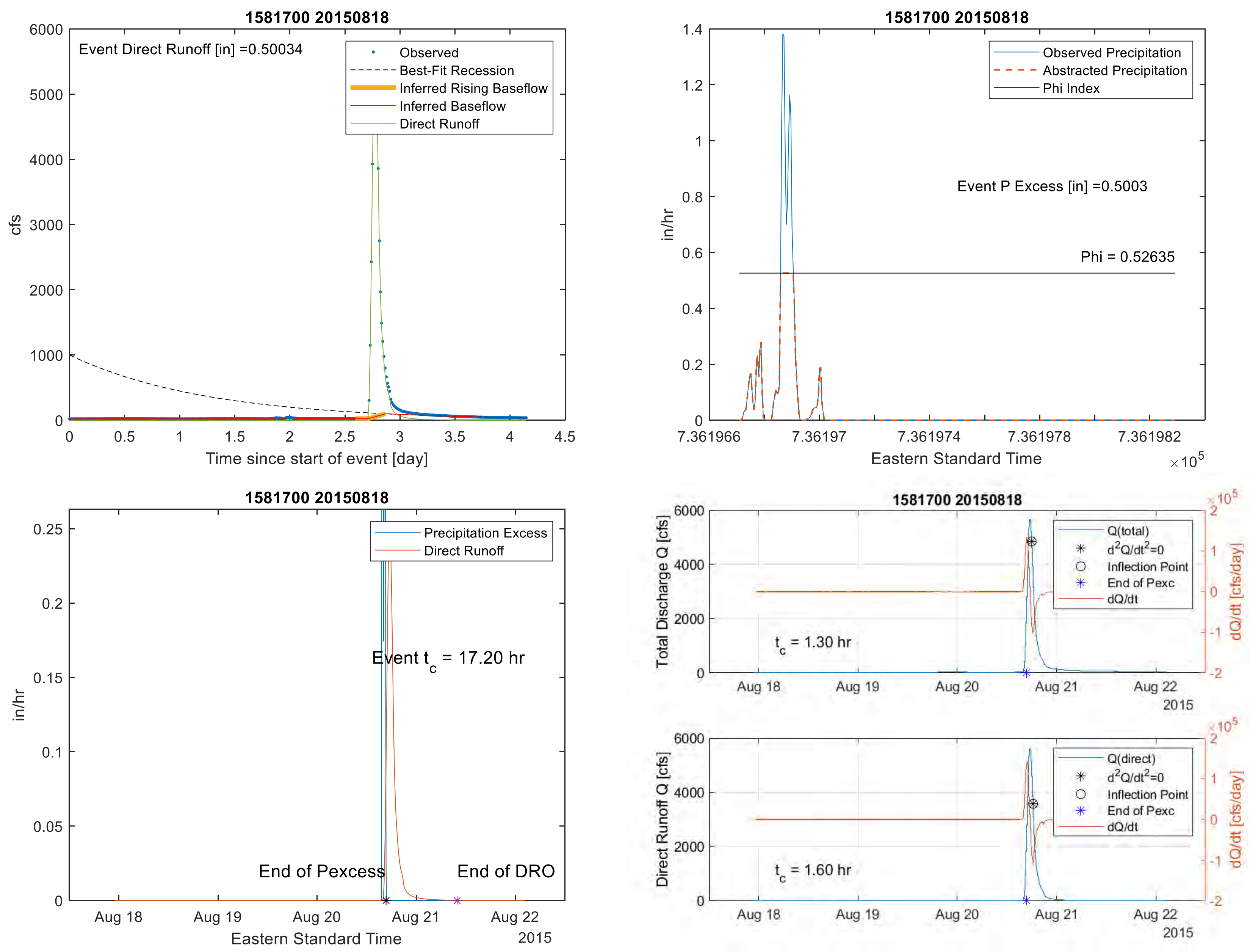

1580000 20130129
Event Direct Runoff [in] =0.67333
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1580000 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6733
Phi = 0.25042
in/hr
Eastern Standard Time
×10^5
1580000 20130129
Precipitation Excess
Direct Runoff
Event t c = 26.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2013
1580000 20130129
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 2.80 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]
Jan 30
Jan 31
Feb 01
Feb 02
2013

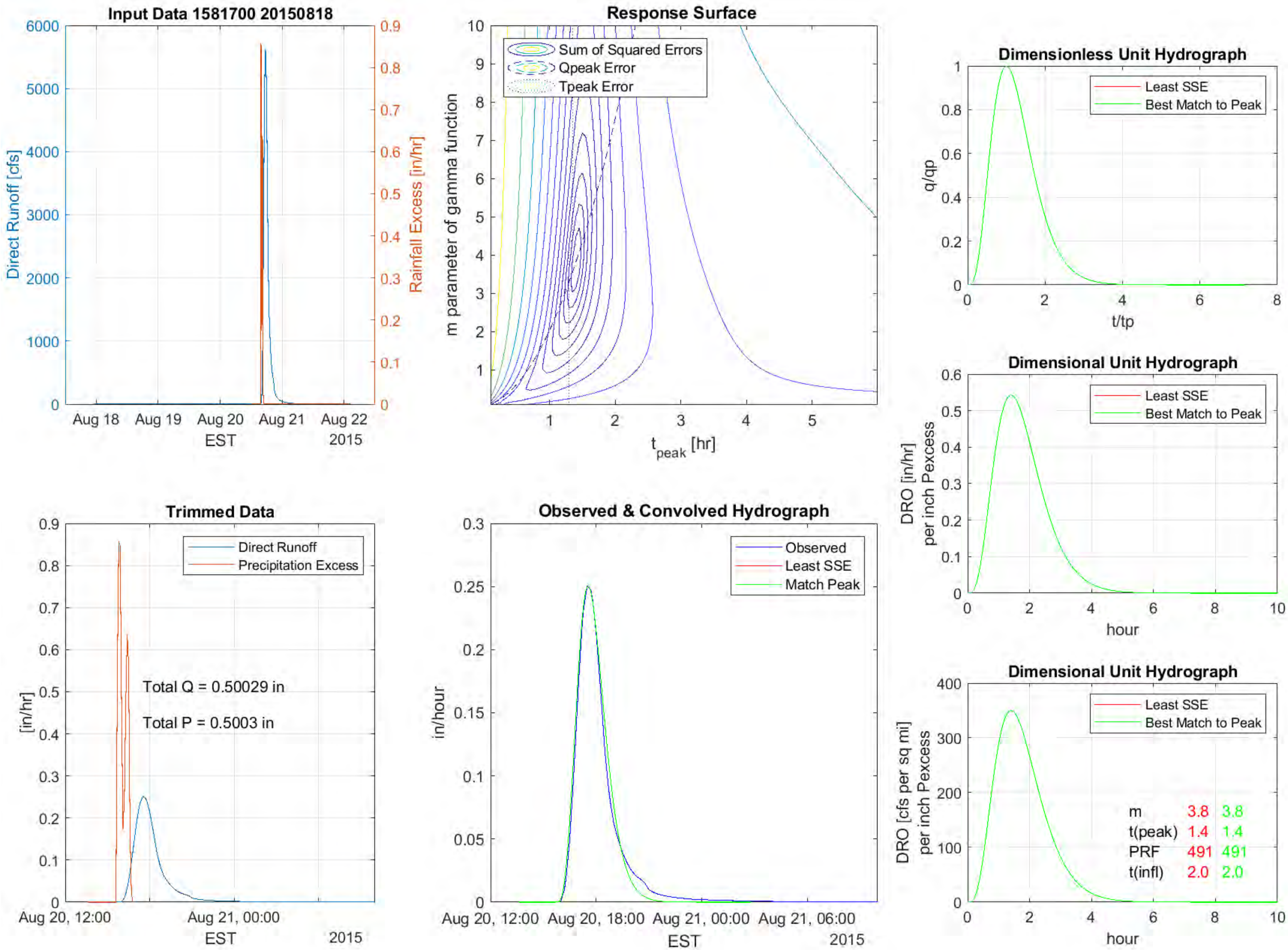

Input Data 1580000 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.67337 in
Total P = 0.6733 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 2.3 2.9
t(peak) 4.25 4.65
PRF 377 426
t(infl) 7.0 7.3

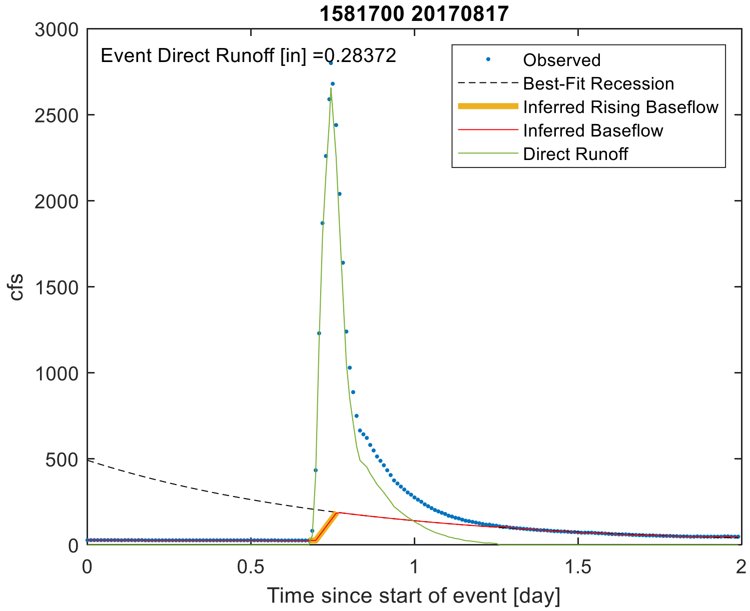


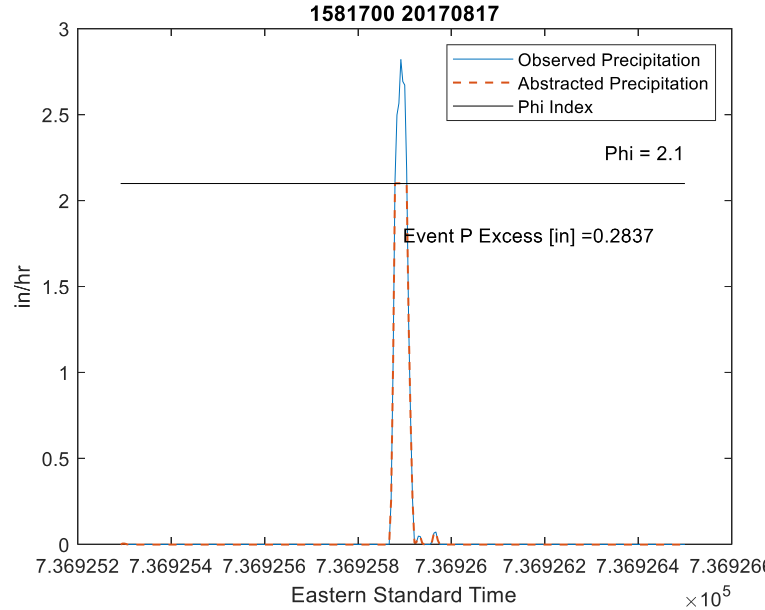
1581500 20170817
Event Direct Runoff [in] =1.8098
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1581500 20170817
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.8097
Phi = 0.6157
in/hr
Eastern Standard Time
1581500 20170817
Precipitation Excess
Direct Runoff
Event t c = 7.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1581500 20170817
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 1.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 2.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

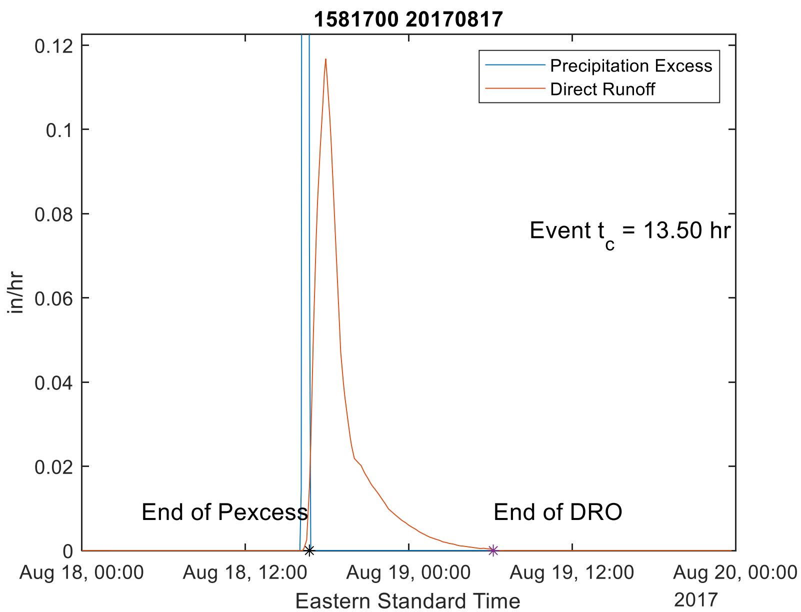

Input Data 1581500 20170817
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 17
Aug 18
Aug 19
Aug 20
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.81 in
Total P = 1.8097 in
[in/hr]
Aug 18, 16:00
Aug 18, 20:00
Aug 19, 00:00
EST
2017
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 2 2.5
t(peak) 1.45 1.65
PRF 349 394
t(infl) 2.4 2.6
hour

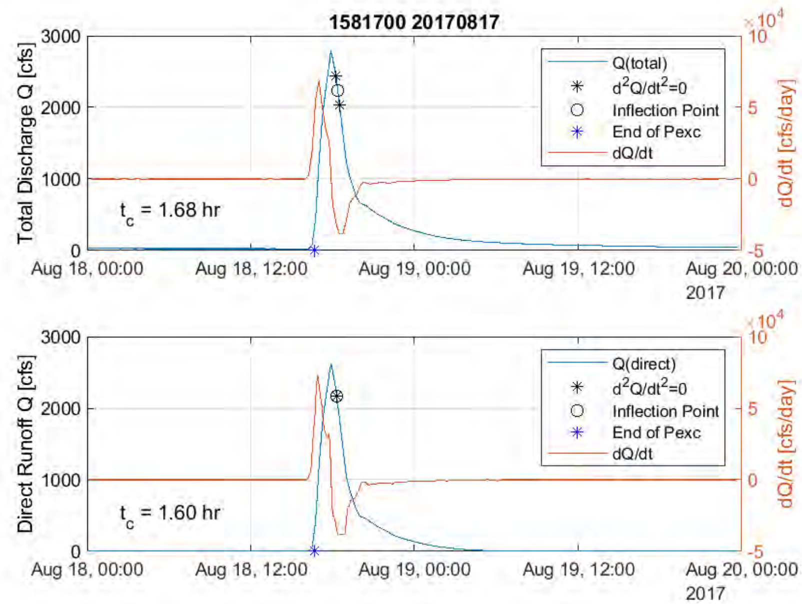

1581700 20150818
Event Direct Runoff [in] =0.50034
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1581700 20150818
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.5003
Phi = 0.52635
in/hr
Eastern Standard Time
1581700 20150818
Precipitation Excess
Direct Runoff
Event t
c
= 17.20 hr
End of Pexcess
End of DRO
in/hr
Aug 18
Aug 19
Aug 20
Aug 21
Aug 22
2015
Eastern Standard Time
1581700 20150818
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t
c
= 1.30 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t
c
= 1.60 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

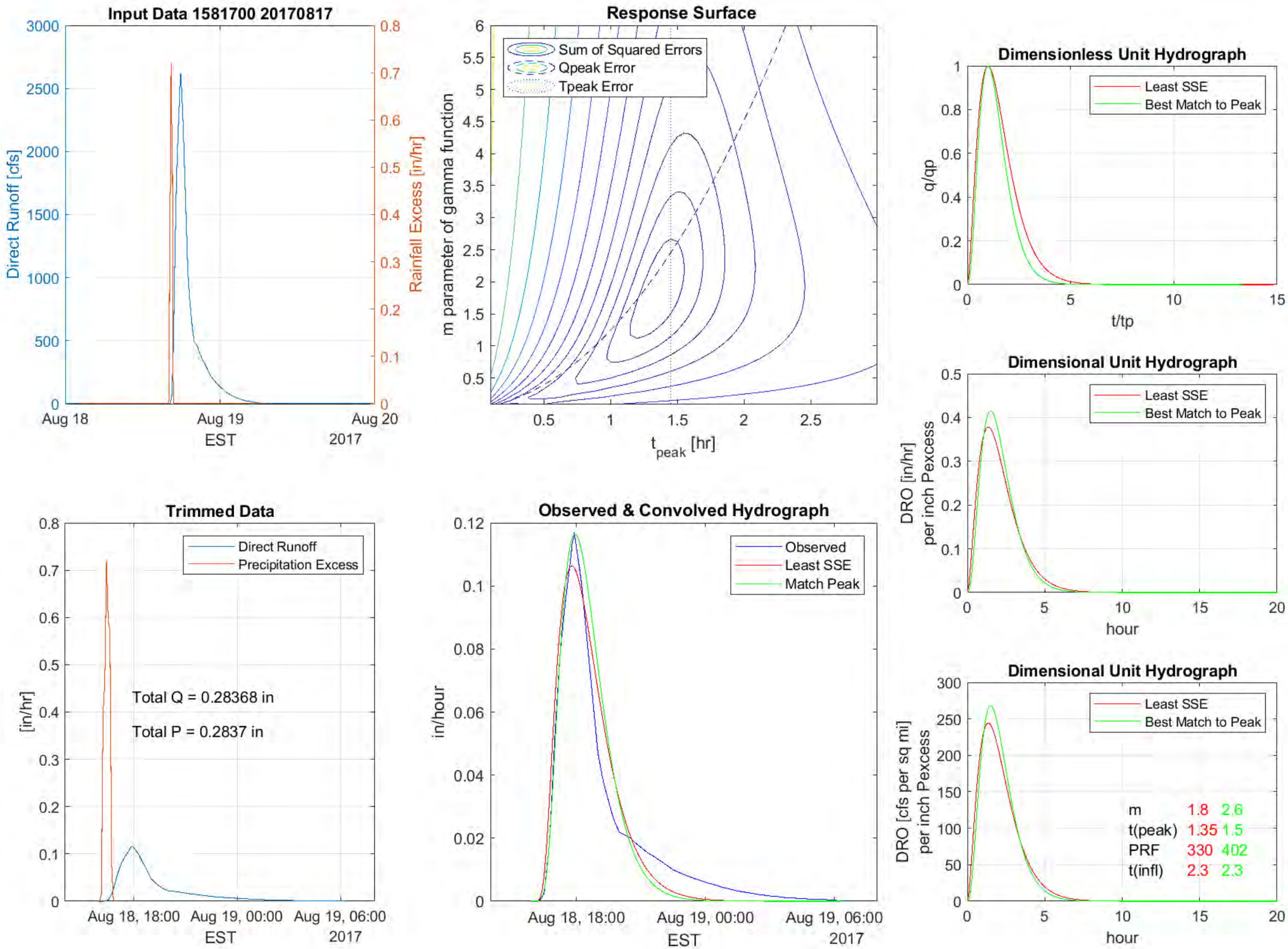

Input Data 1581700 20150818
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 18
Aug 19
Aug 20
Aug 21
Aug 22
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.50029 in
Total P = 0.5003 in
Aug 20, 12:00
Aug 21, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Aug 20, 18:00
Aug 21, 06:00
DRO [cfs per sq mi] per inch Pexcess
m 3.8 3.8
t(peak) 1.4 1.4
PRF 491 491
t(infl) 2.0 2.0

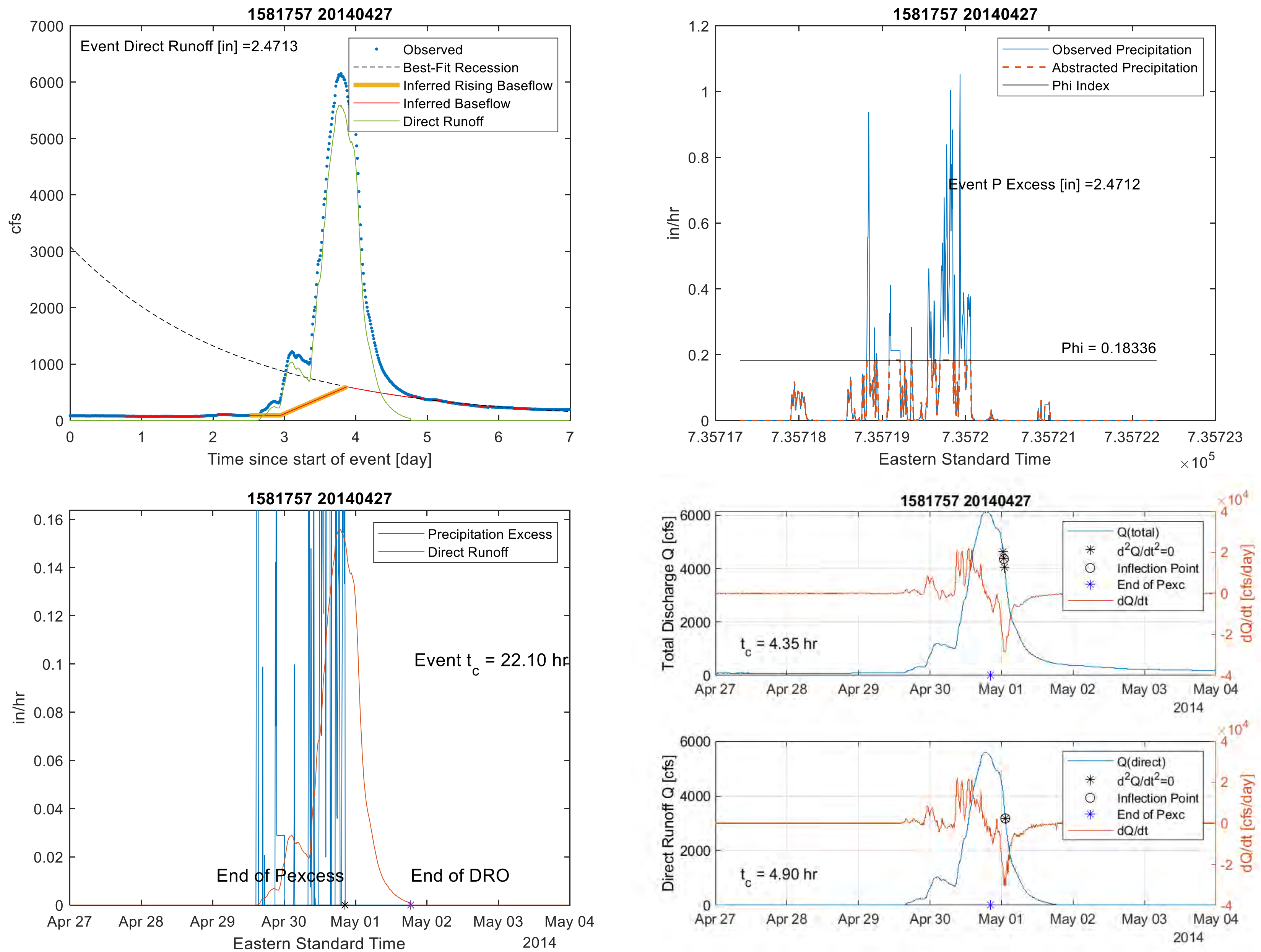

1581700 20170817
Event Direct Runoff [in] =0.28372
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1581700 20170817
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 2.1
Event P Excess [in] =0.2837
in/hr
Eastern Standard Time
×10^5

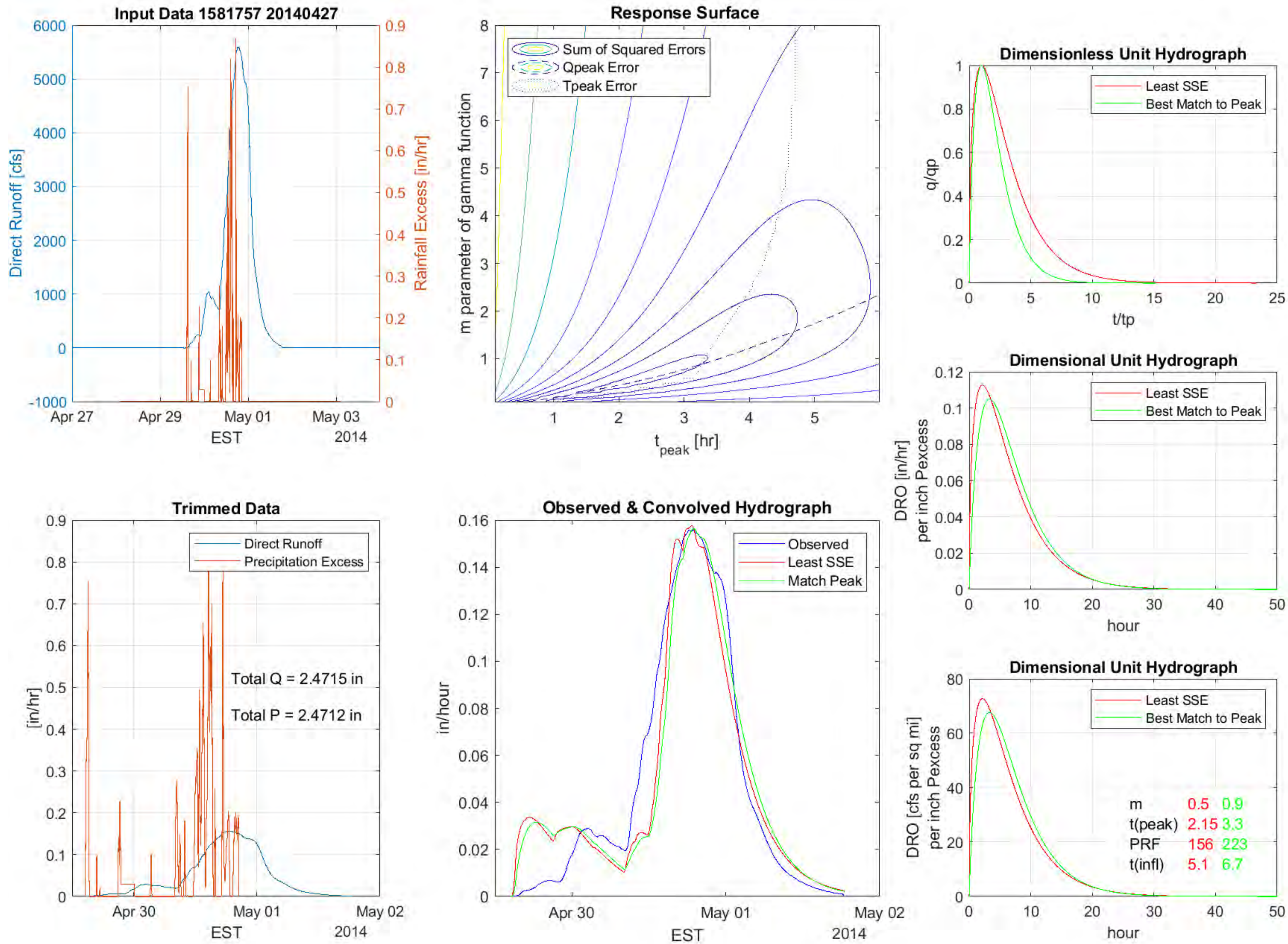

1581700 20170817
Precipitation Excess
Direct Runoff
Event t_c = 13.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

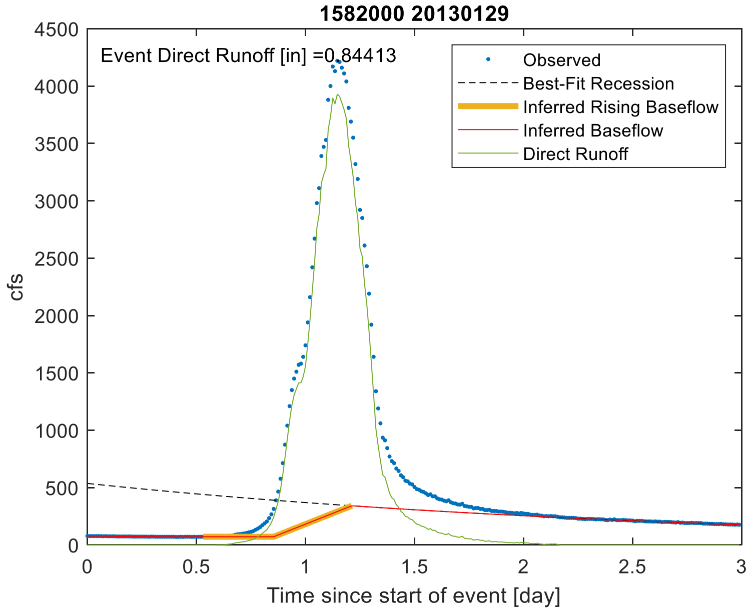

1581700 20170817
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 1.68 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 1.60 hr
Direct Runoff Q [cfs]


Input Data 1581700 20170817
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 18
Aug 19
Aug 20
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.28368 in
Total P = 0.2837 in
[in/hr]
Aug 18, 18:00
Aug 19, 00:00
Aug 19, 06:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.8 2.6
t(peak) 1.35 1.5
PRF 330 402
t(infl) 2.3 2.3

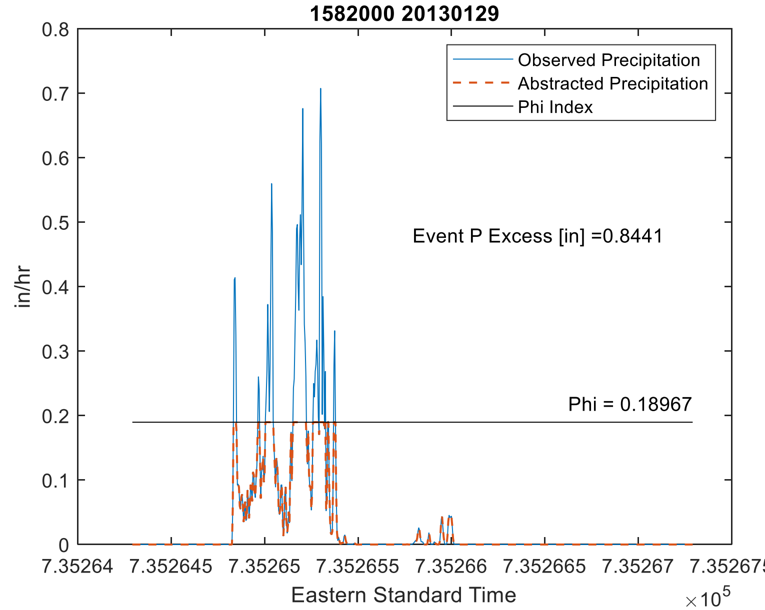


1581757 20140427
Event Direct Runoff [in] =2.4713
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1581757 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.4712
Phi = 0.18336
in/hr
Eastern Standard Time
×10^5
1581757 20140427
Precipitation Excess
Direct Runoff
Event t c = 22.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2014
1581757 20140427
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 4.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 4.90 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2014

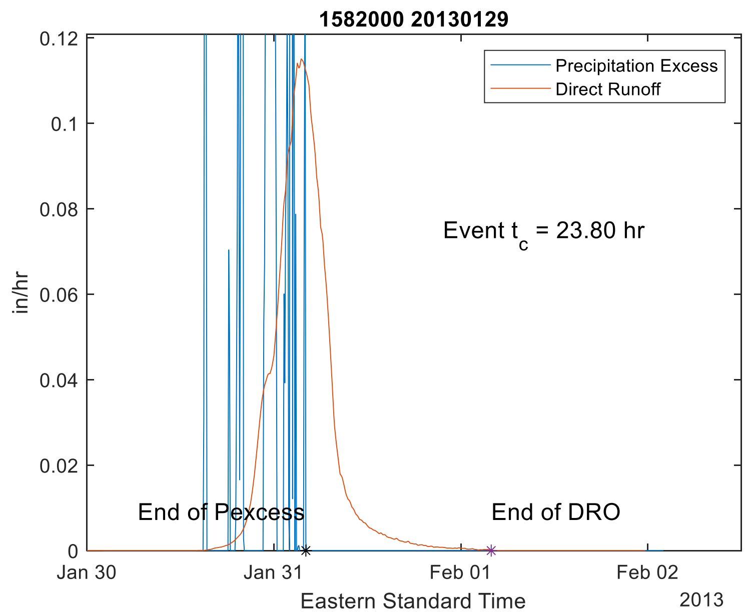

Input Data 1581757 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.4715 in
Total P = 2.4712 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
DRO [cfs per sq mi] per inch Pexcess
m 0.5 0.9
t(peak) 2.15 3.3
PRF 156 223
t(infl) 5.1 6.7



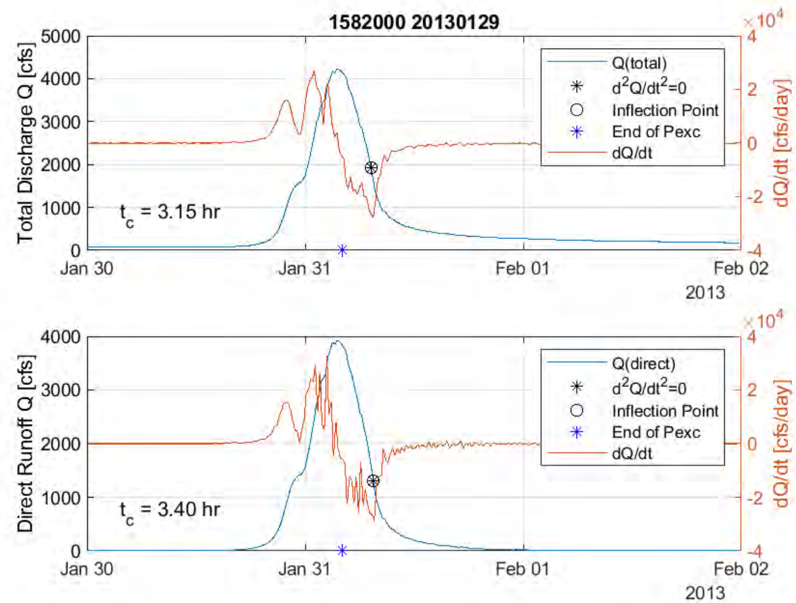
1582000 20130129
Event Direct Runoff [in] =0.84413
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



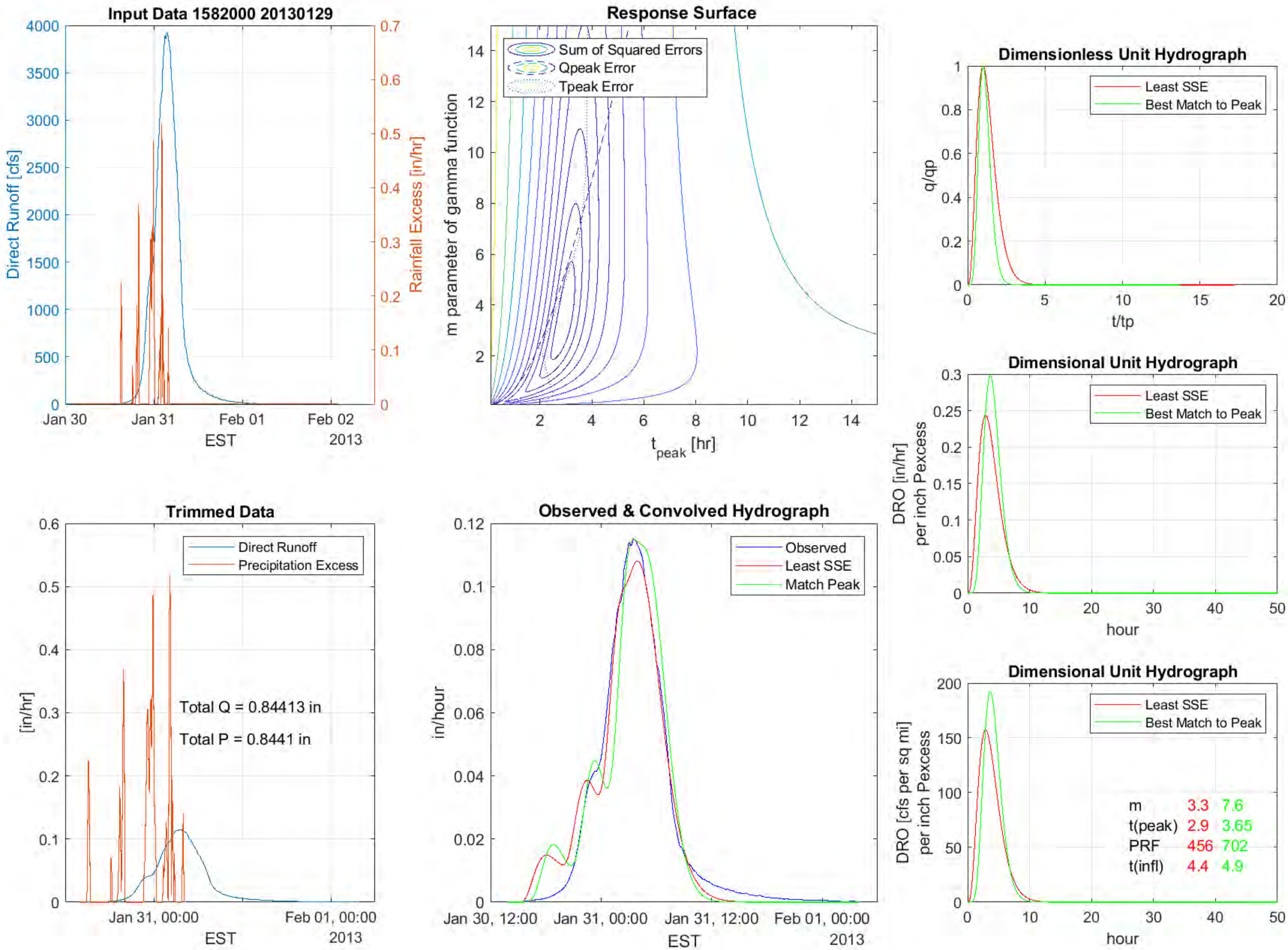
1582000 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.8441
Phi = 0.18967
in/hr
Eastern Standard Time



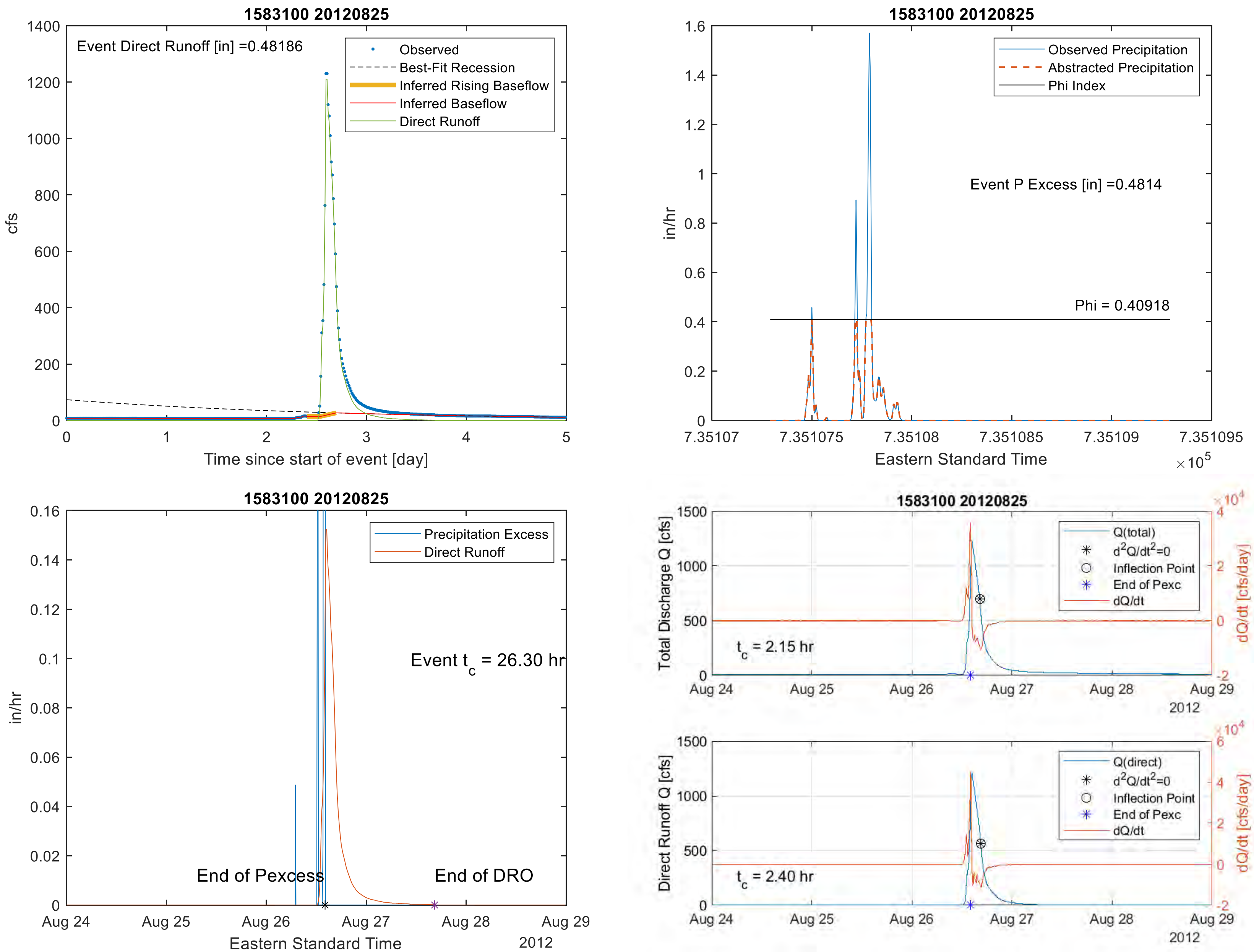
1582000 20130129
Precipitation Excess
Direct Runoff
Event t c = 23.80 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2013

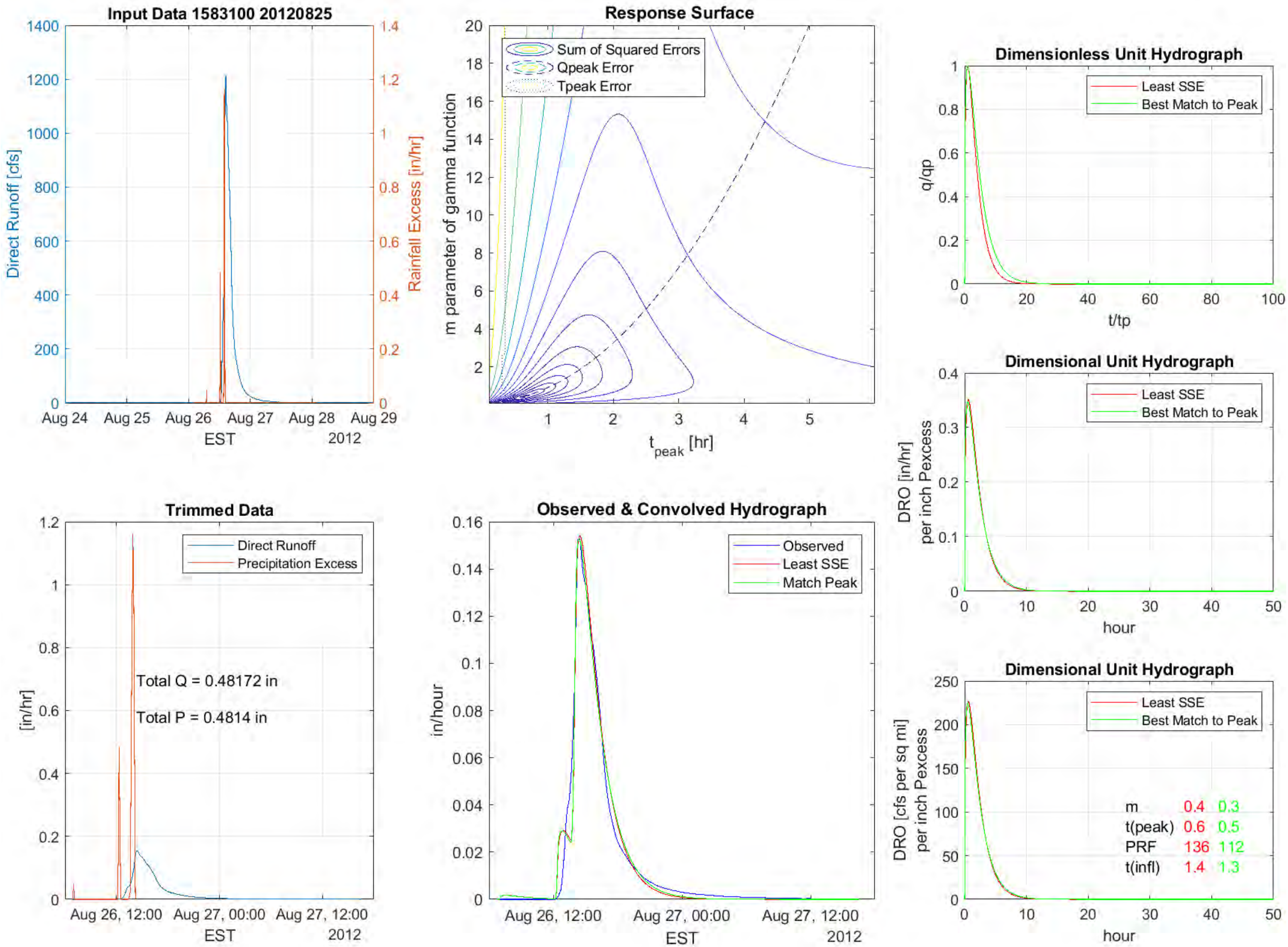


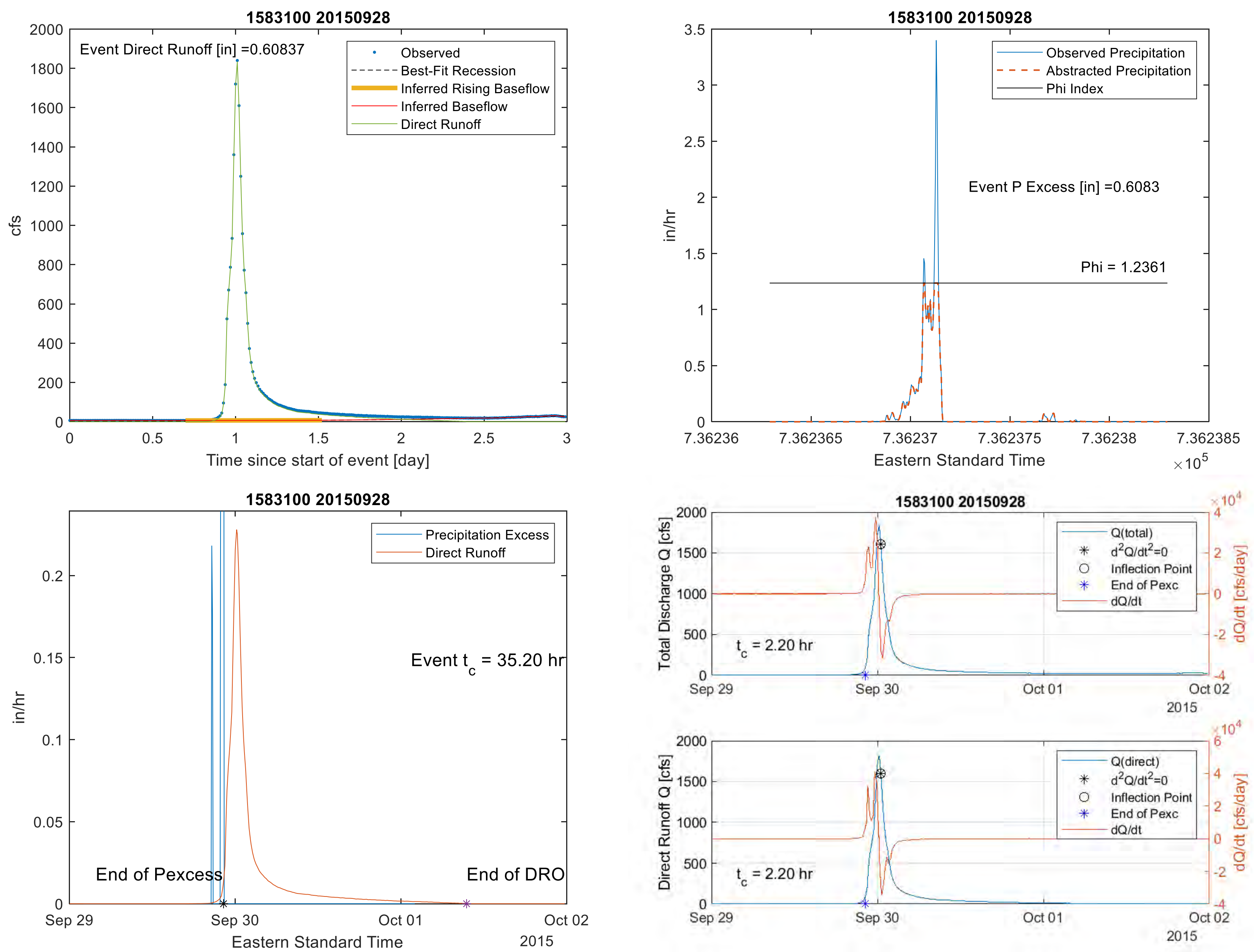
1582000 20130129
Q(total)
Inflection Point
End of Pexc
dQ/dt
t c = 3.15 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 3.40 hr
Direct Runoff Q [cfs]
2013



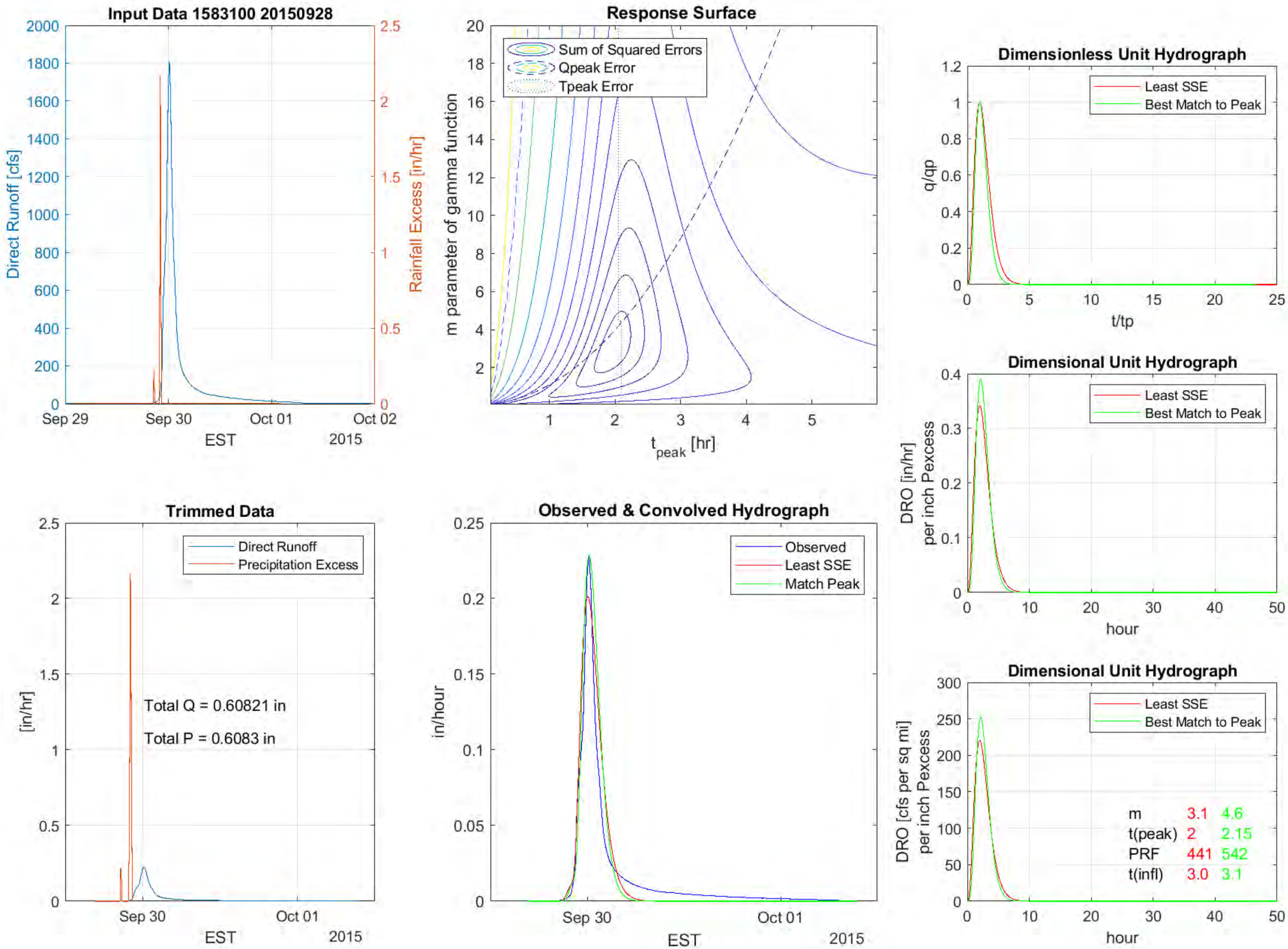
Input Data 1582000 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.84413 in
Total P = 0.8441 in
Jan 31, 00:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
DRO [cfs per sq mi] per inch Pexcess
m 3.3 7.6
t(peak) 2.9 3.65
PRF 456 702
t(infl) 4.4 4.9


1583100 20120825
Event Direct Runoff [in] =0.48186
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1583100 20120825
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.4814
Phi = 0.40918
in/hr
Eastern Standard Time
1583100 20120825
Precipitation Excess
Direct Runoff
Event t c = 26.30 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1583100 20120825
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 2.15 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 2.40 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

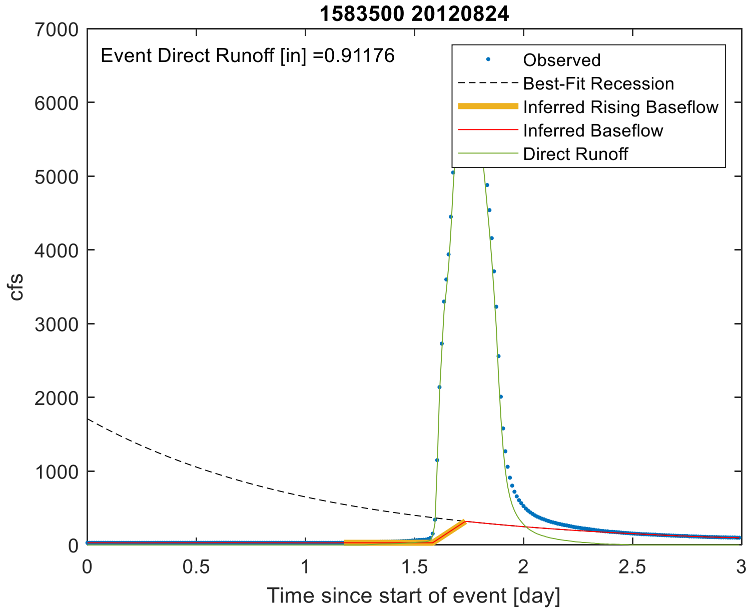

Input Data 1583100 20120825
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 24 Aug 25 Aug 26 Aug 27 Aug 28 Aug 29
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.48172 in
Total P = 0.4814 in
[in/hr]
Aug 26, 12:00 Aug 27, 00:00 Aug 27, 12:00
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 0.4 0.3
t(peak) 0.6 0.5
PRF 136 112
t(infl) 1.4 1.3
hour

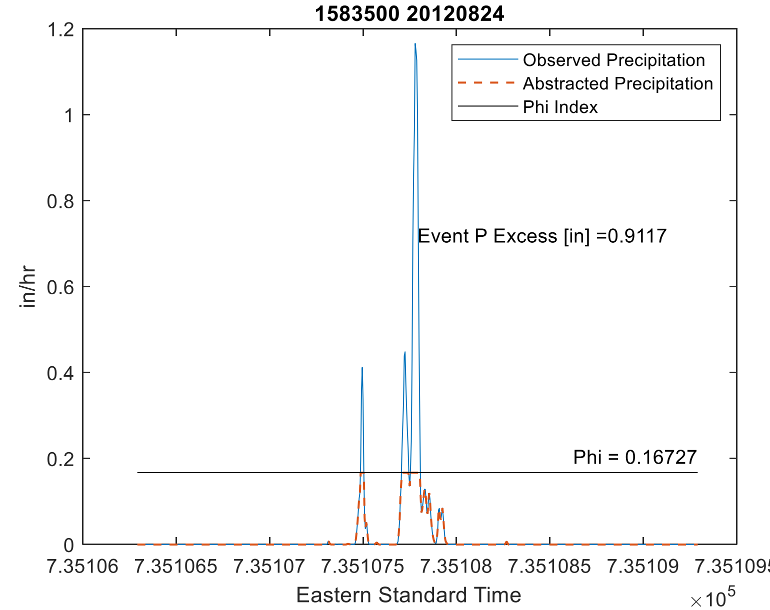


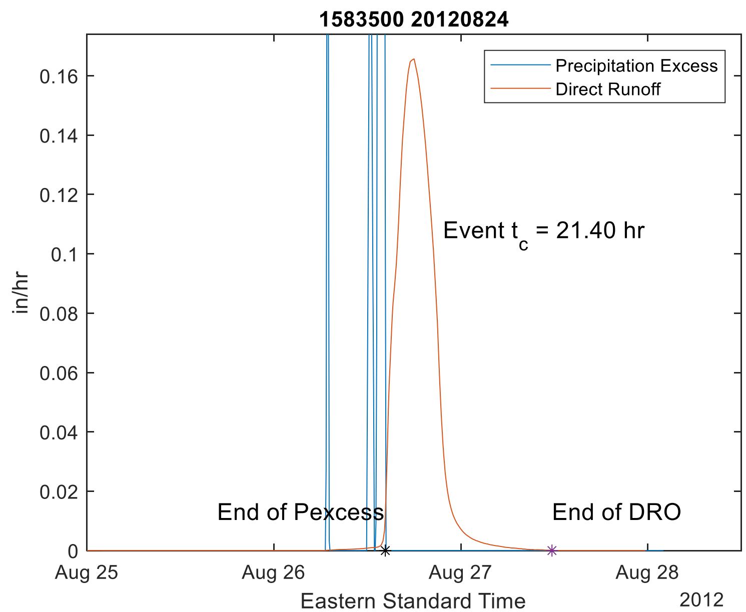
1583100 20150928
Event Direct Runoff [in] =0.60837
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1583100 20150928
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6083
Phi = 1.2361
in/hr
Eastern Standard Time
1583100 20150928
Precipitation Excess
Direct Runoff
Event t c = 35.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1583100 20150928
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 2.20 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]

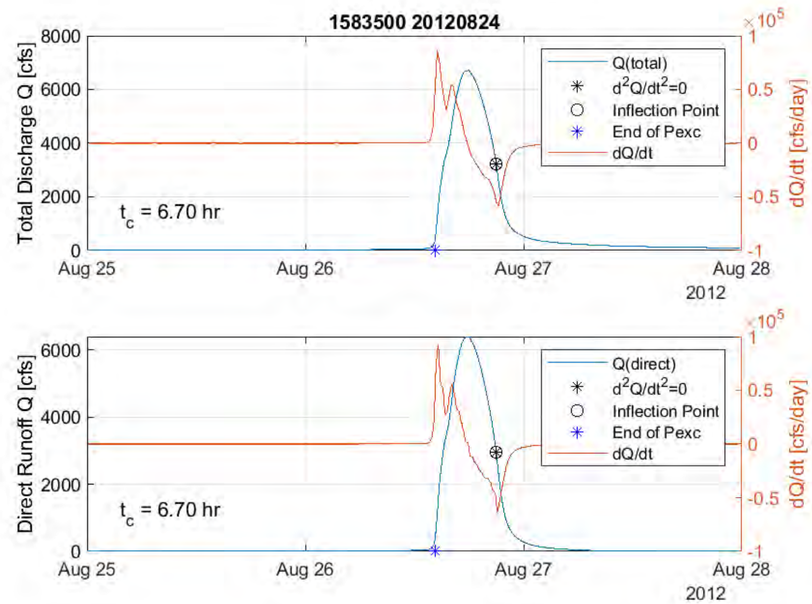


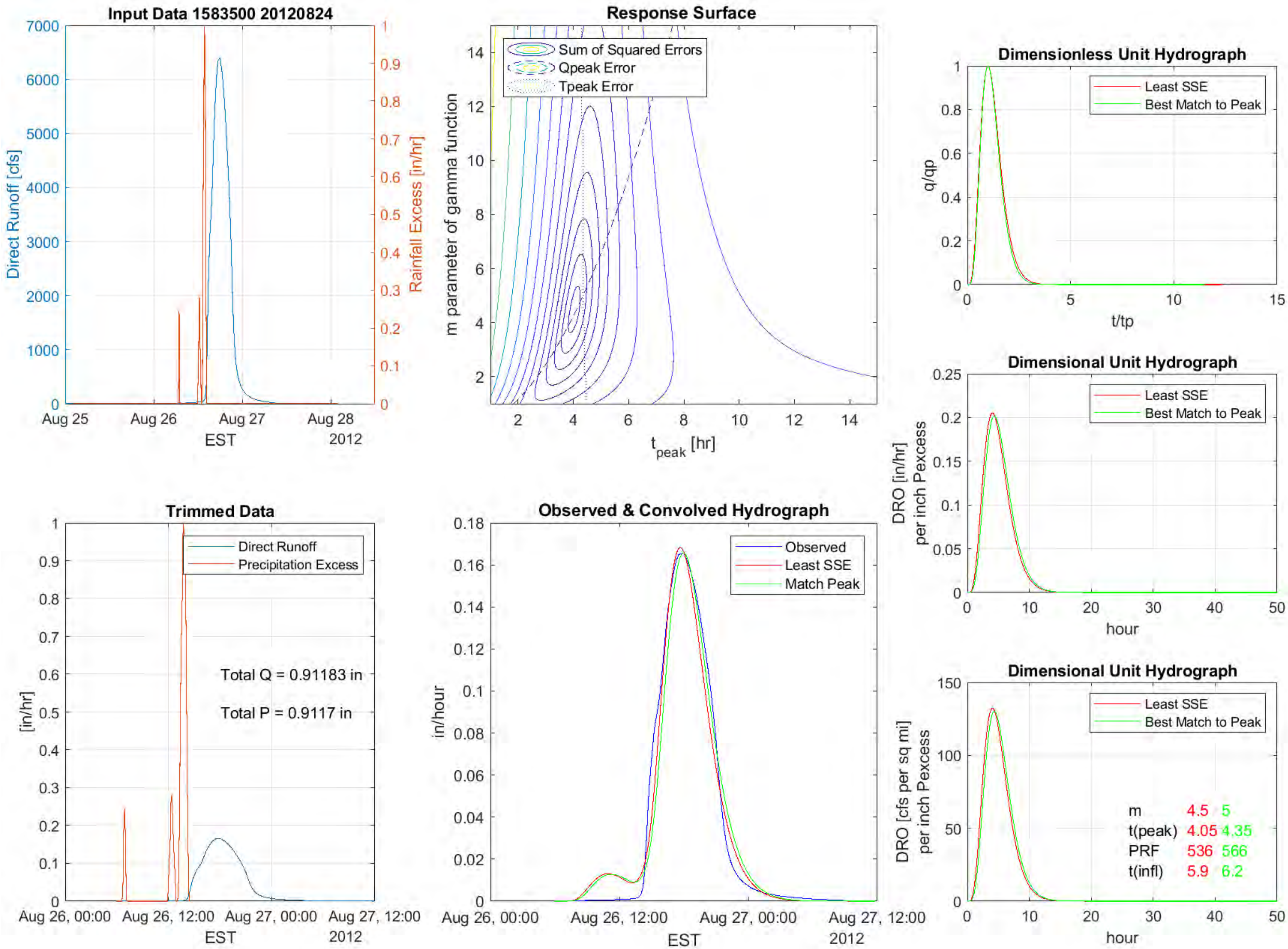
Input Data 1583100 20150928
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 29
Sep 30
Oct 01
Oct 02
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.60821 in
Total P = 0.6083 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.1 4.6
t(peak) 2 2.15
PRF 441 542
t(infl) 3.0 3.1

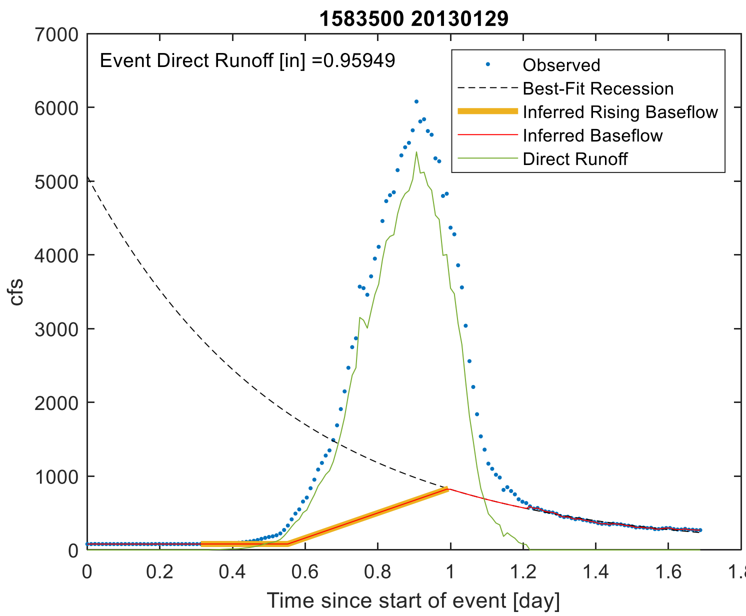

1583500 20120824
Event Direct Runoff [in] =0.91176
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

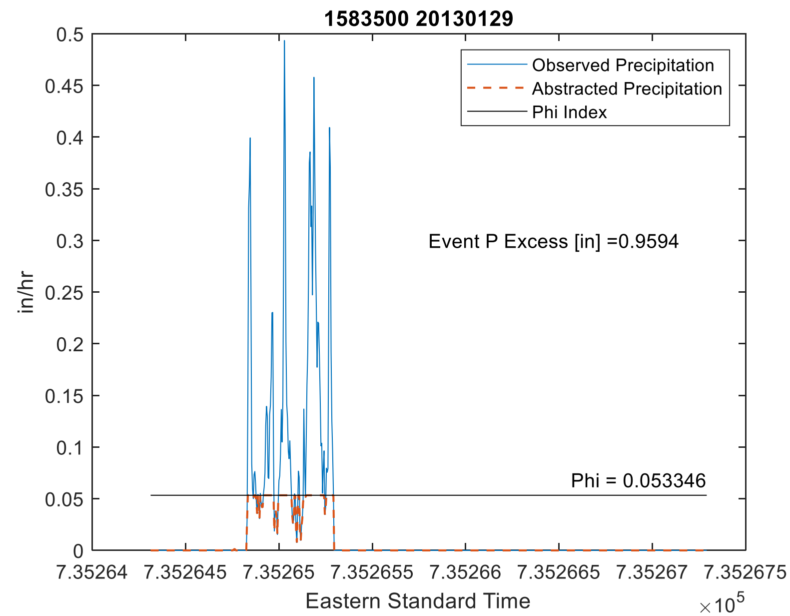

1583500 20120824
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.9117
Phi = 0.16727
in/hr
Eastern Standard Time
×10^5

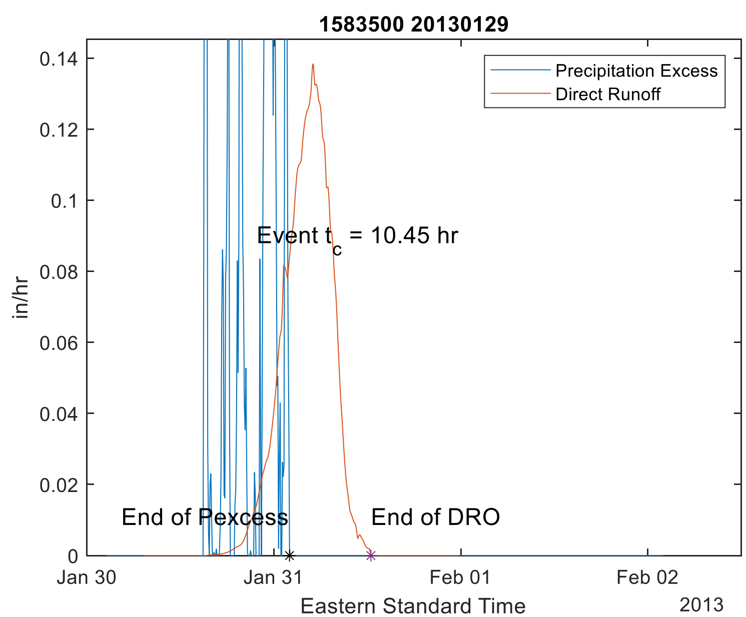

1583500 20120824
Precipitation Excess
Direct Runoff
Event t_c = 21.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012

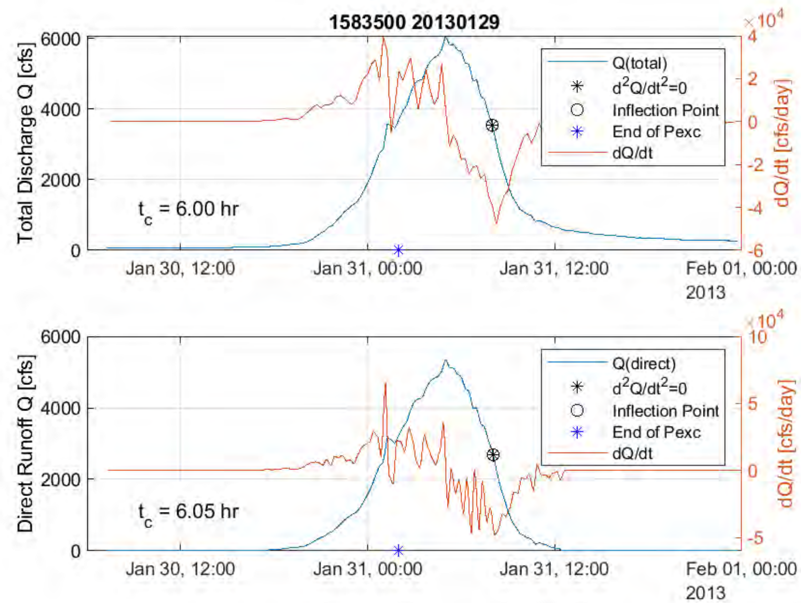

1583500 20120824
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 6.70 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]
2012

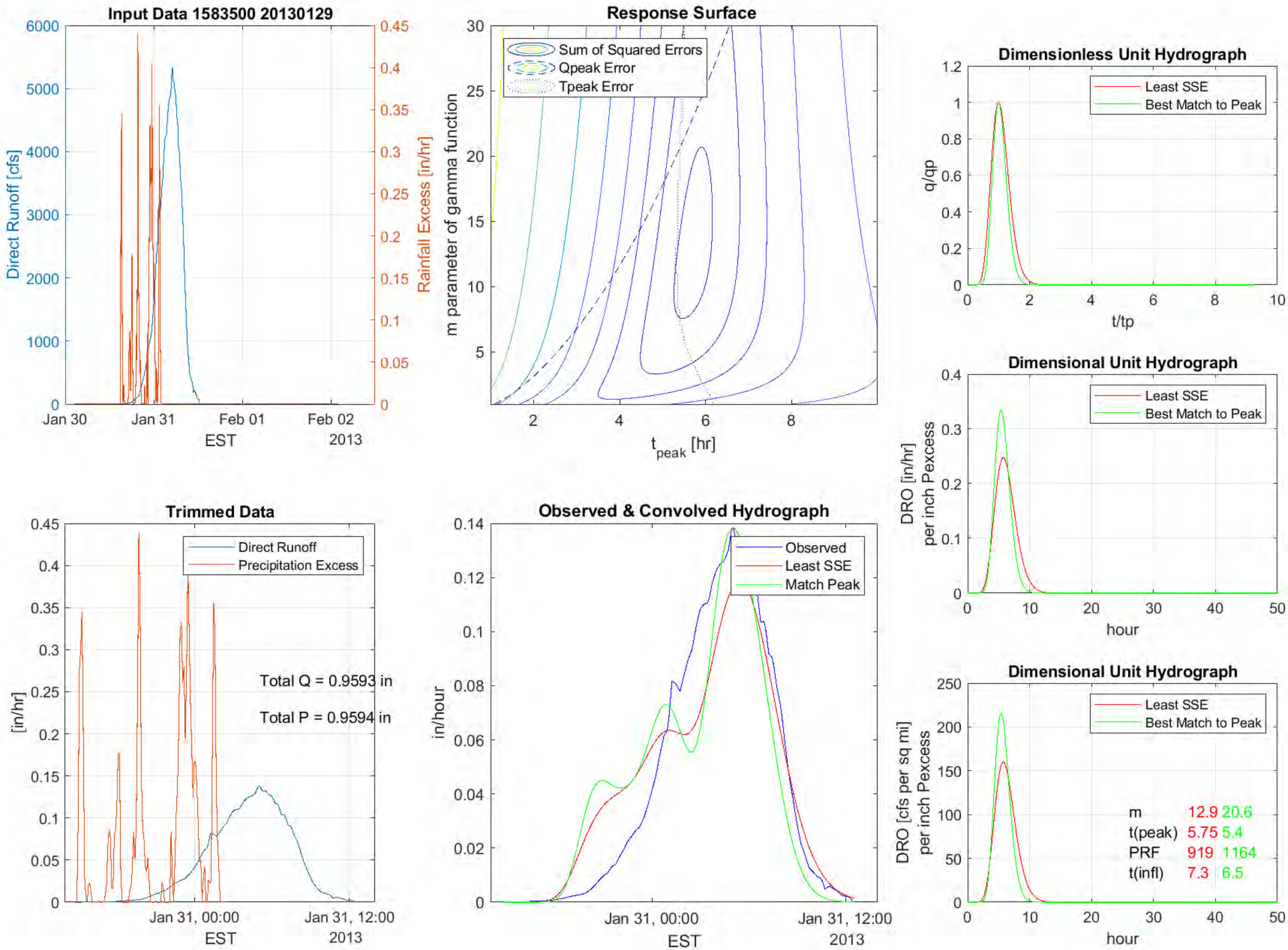

Input Data 1583500 20120824
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 25
Aug 26
Aug 27
Aug 28
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.91183 in
Total P = 0.9117 in
[in/hr]
Aug 26, 00:00
Aug 26, 12:00
Aug 27, 00:00
Aug 27, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4.5 5
t(peak) 4.05 4.35
PRF 536 566
t(infl) 5.9 6.2

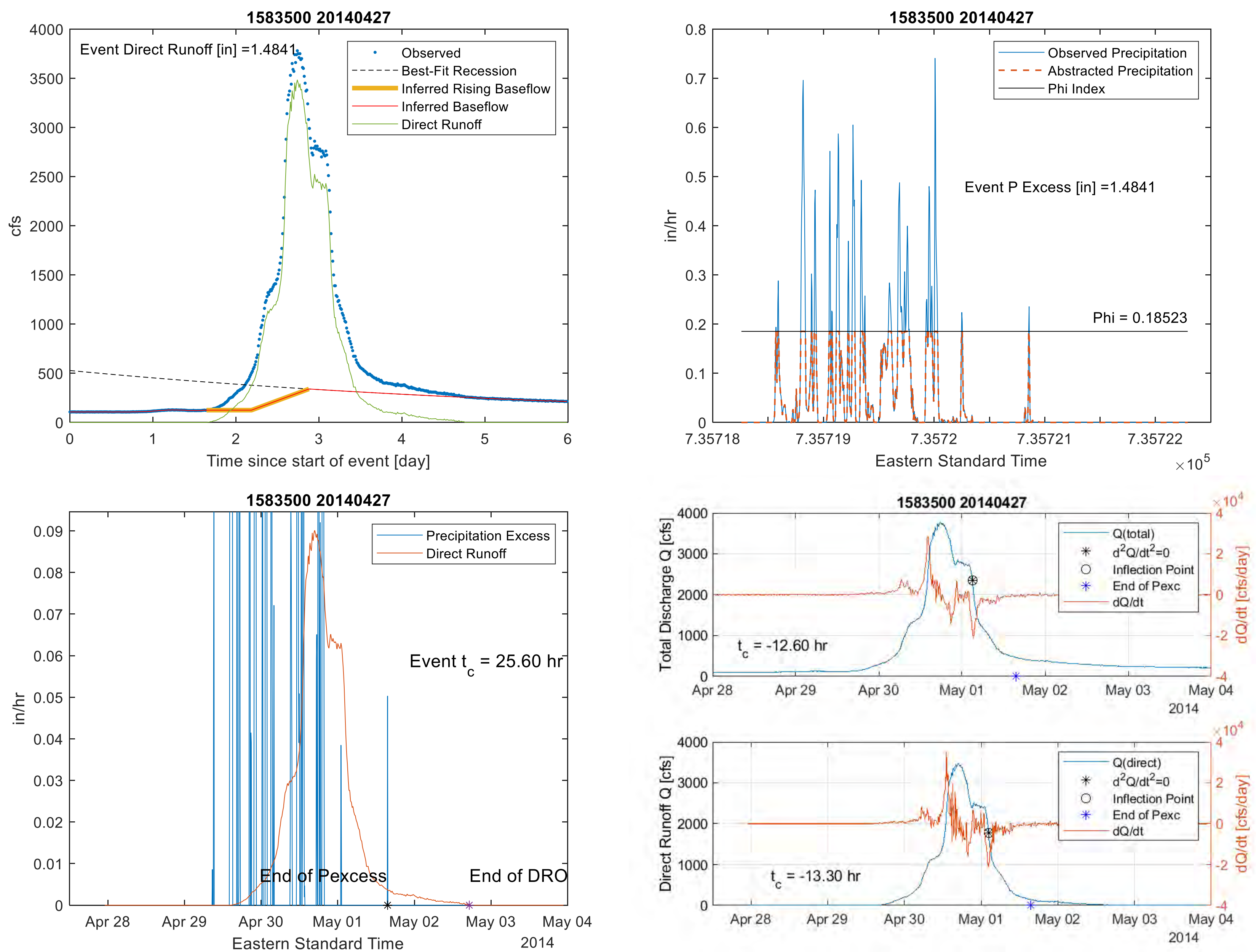

1583500 20130129
Event Direct Runoff [in] =0.95949
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1583500 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.9594
Phi = 0.053346
in/hr
Eastern Standard Time
×10^5

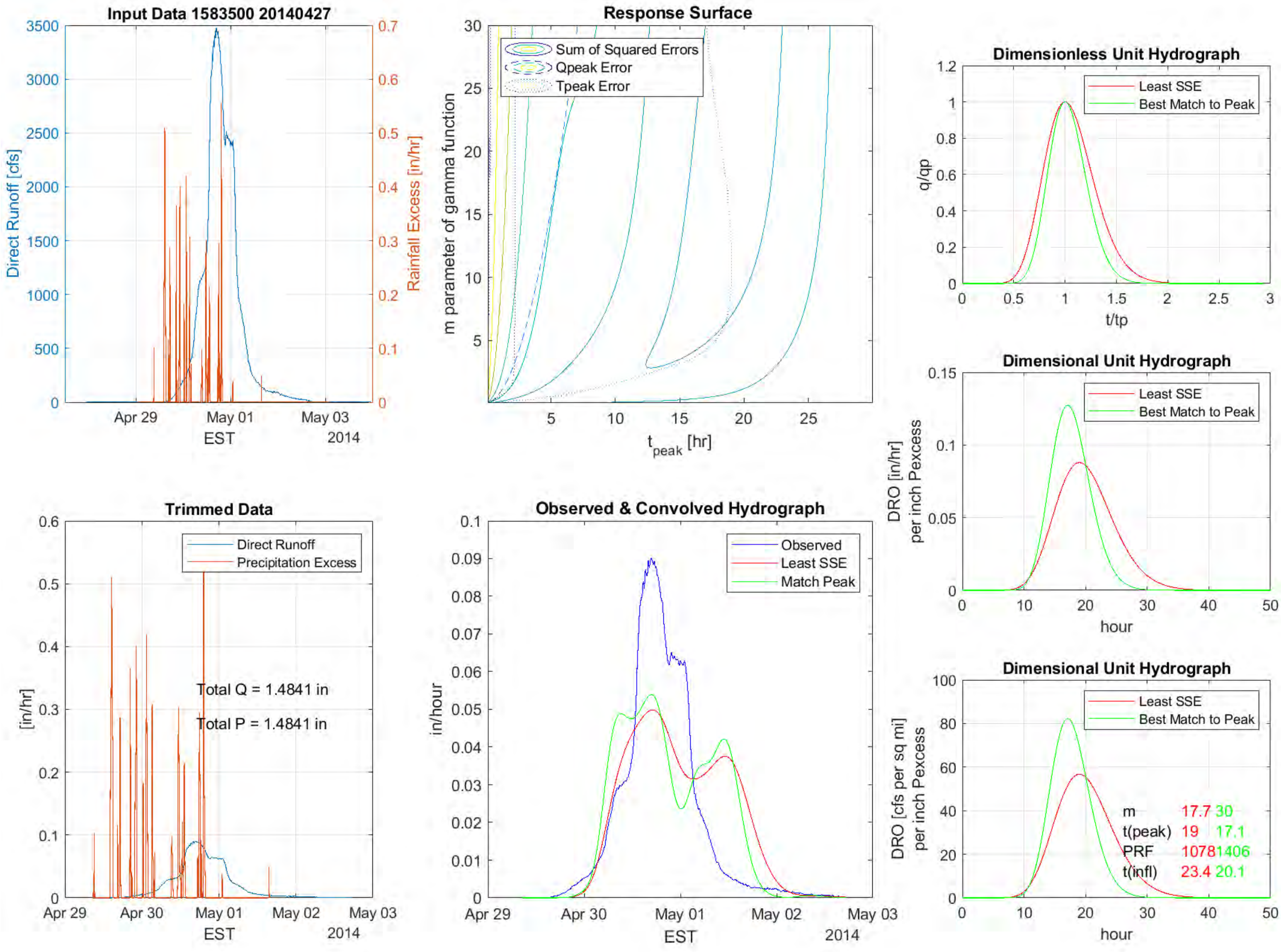

1583500 20130129
Precipitation Excess
Direct Runoff
Event t_c = 10.45 hr
End of Pexcess
End of DRO
in/hr
Jan 30
Jan 31
Feb 01
Feb 02
Eastern Standard Time
2013

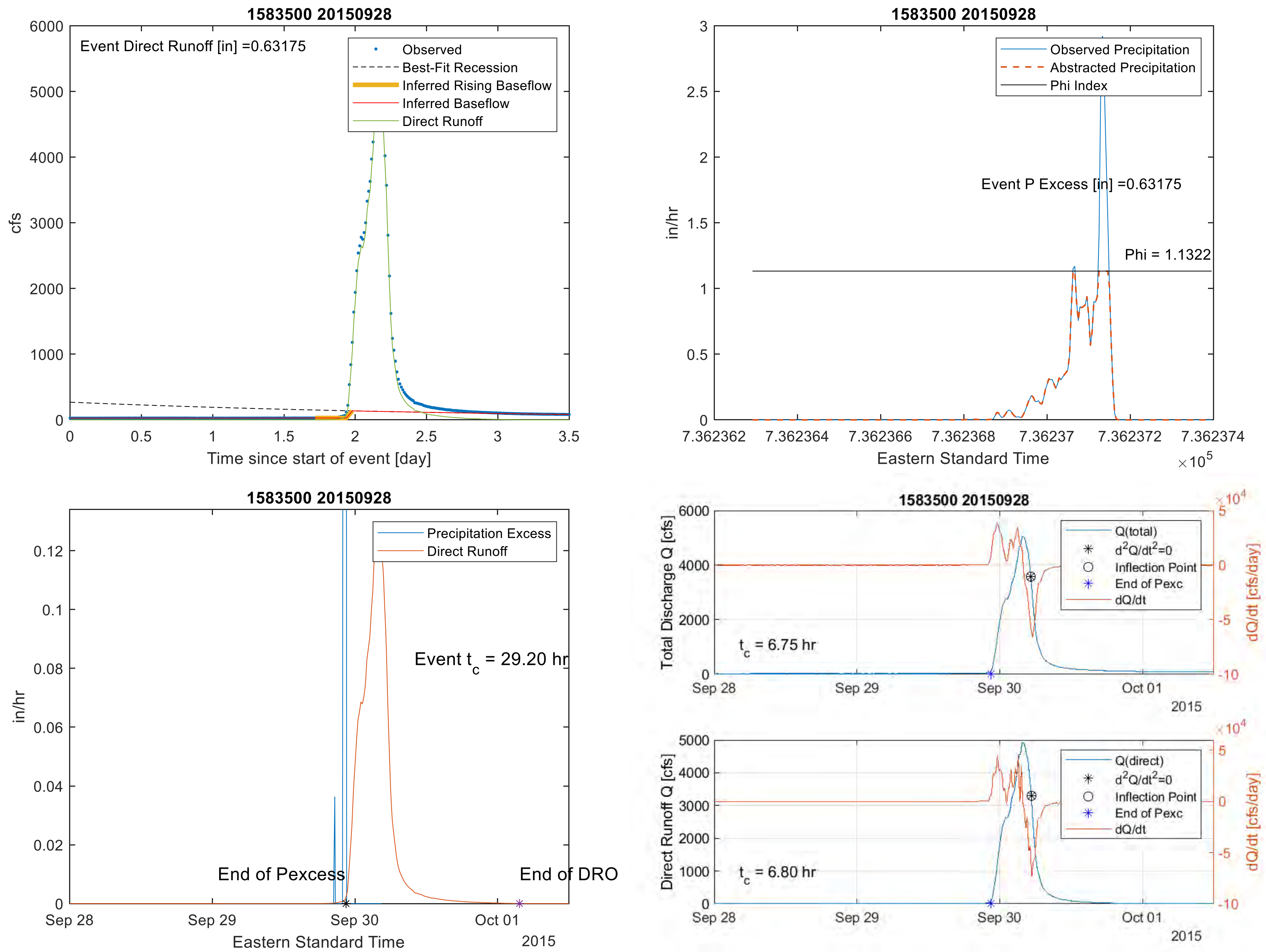

1583500 20130129
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 6.00 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 6.05 hr
Direct Runoff Q [cfs]
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2013

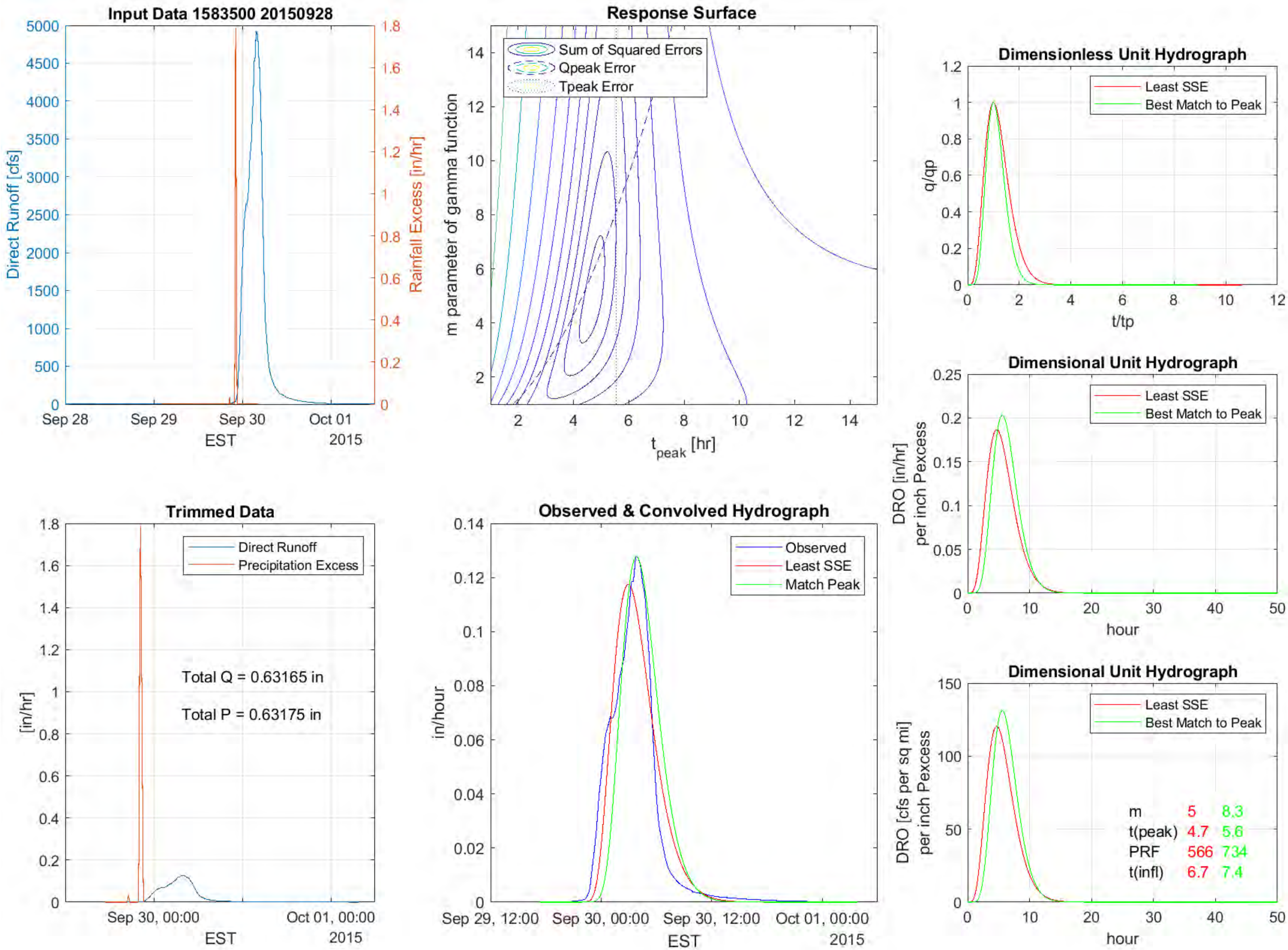

Input Data 1583500 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.9593 in
Total P = 0.9594 in
Jan 31, 00:00
Jan 31, 12:00
EST
2013
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jan 31, 00:00
Jan 31, 12:00
EST
2013
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
hour
m 12.9 20.6
t(peak) 5.75 5.4
PRF 919 1164
t(infl) 7.3 6.5

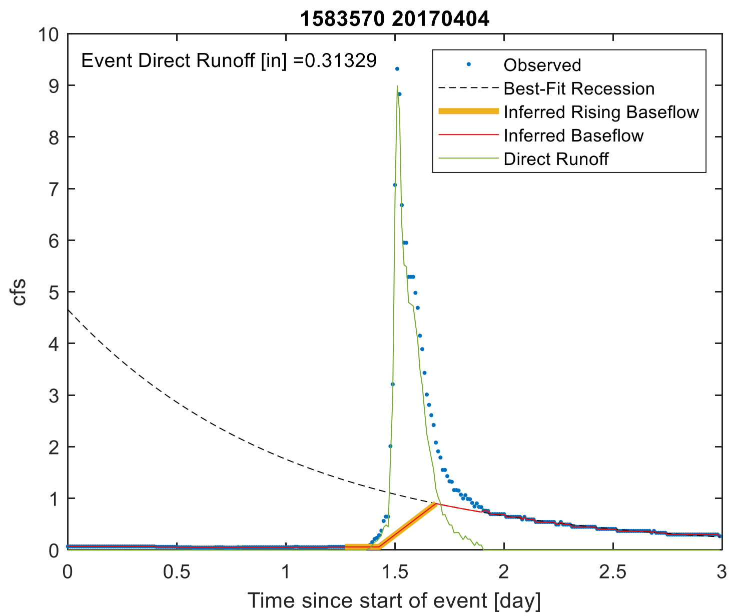


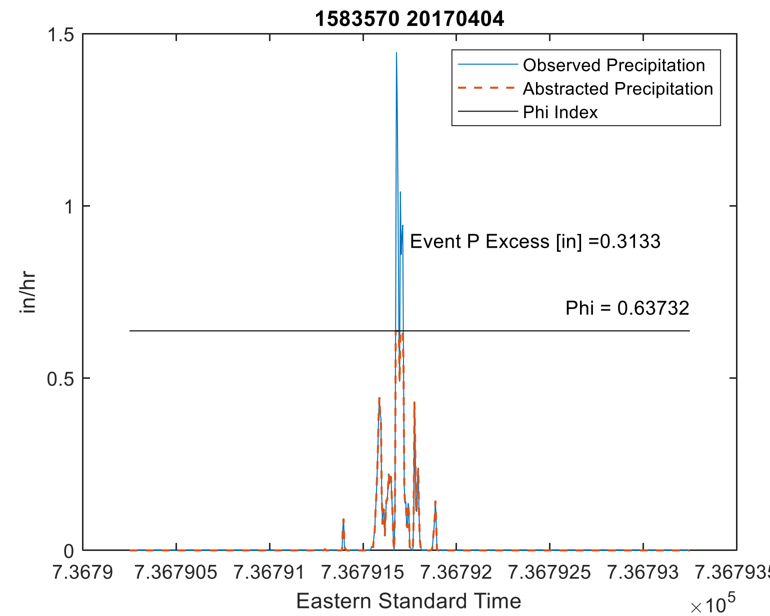
1583500 20140427
Event Direct Runoff [in] =1.4841
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.4841
Phi = 0.18523
in/hr
Eastern Standard Time
Precipitation Excess
Direct Runoff
Event t c = 25.60 hr
End of Pexcess
End of DRO
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t c = -12.60 hr
Q(direct)
Direct Runoff Q [cfs]
t c = -13.30 hr
2014

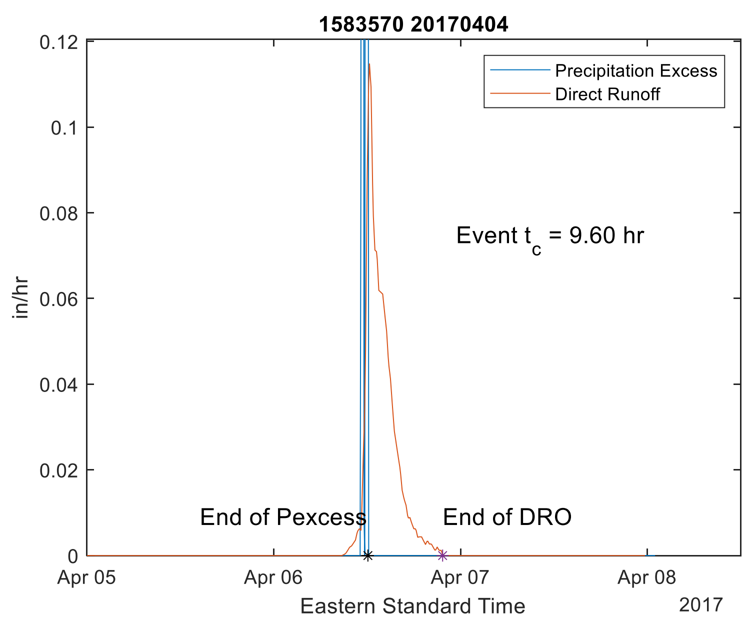

Input Data 1583500 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 29
May 01
May 03
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr]
per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.4841 in
Total P = 1.4841 in
[in/hr]
Apr 29
Apr 30
May 01
May 02
May 03
EST
2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi]
per inch Pexcess
m 17.7 30
t(peak) 19 17.1
PRF 1078 1406
t(infl) 23.4 20.1
hour

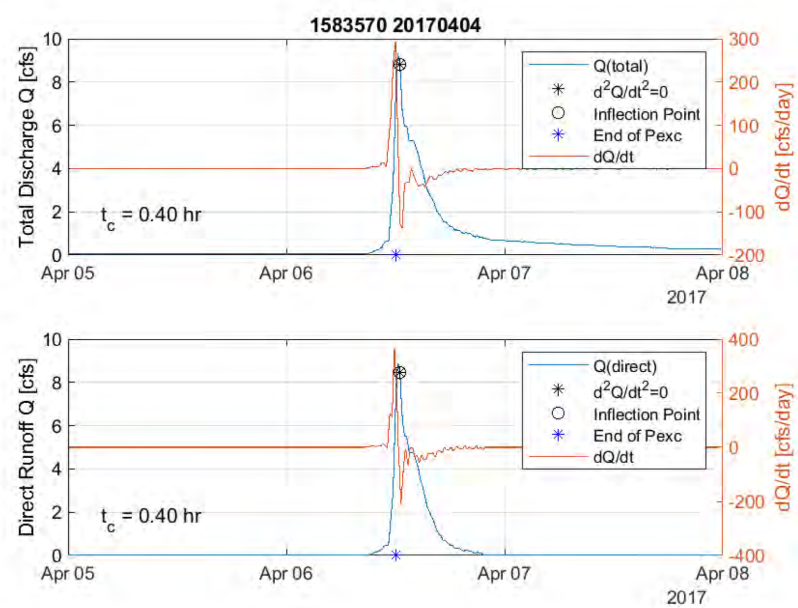

1583500 20150928
Event Direct Runoff [in] =0.63175
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1583500 20150928
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.63175
Phi = 1.1322
in/hr
Eastern Standard Time
1583500 20150928
Precipitation Excess
Direct Runoff
Event t c = 29.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1583500 20150928
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 6.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 6.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

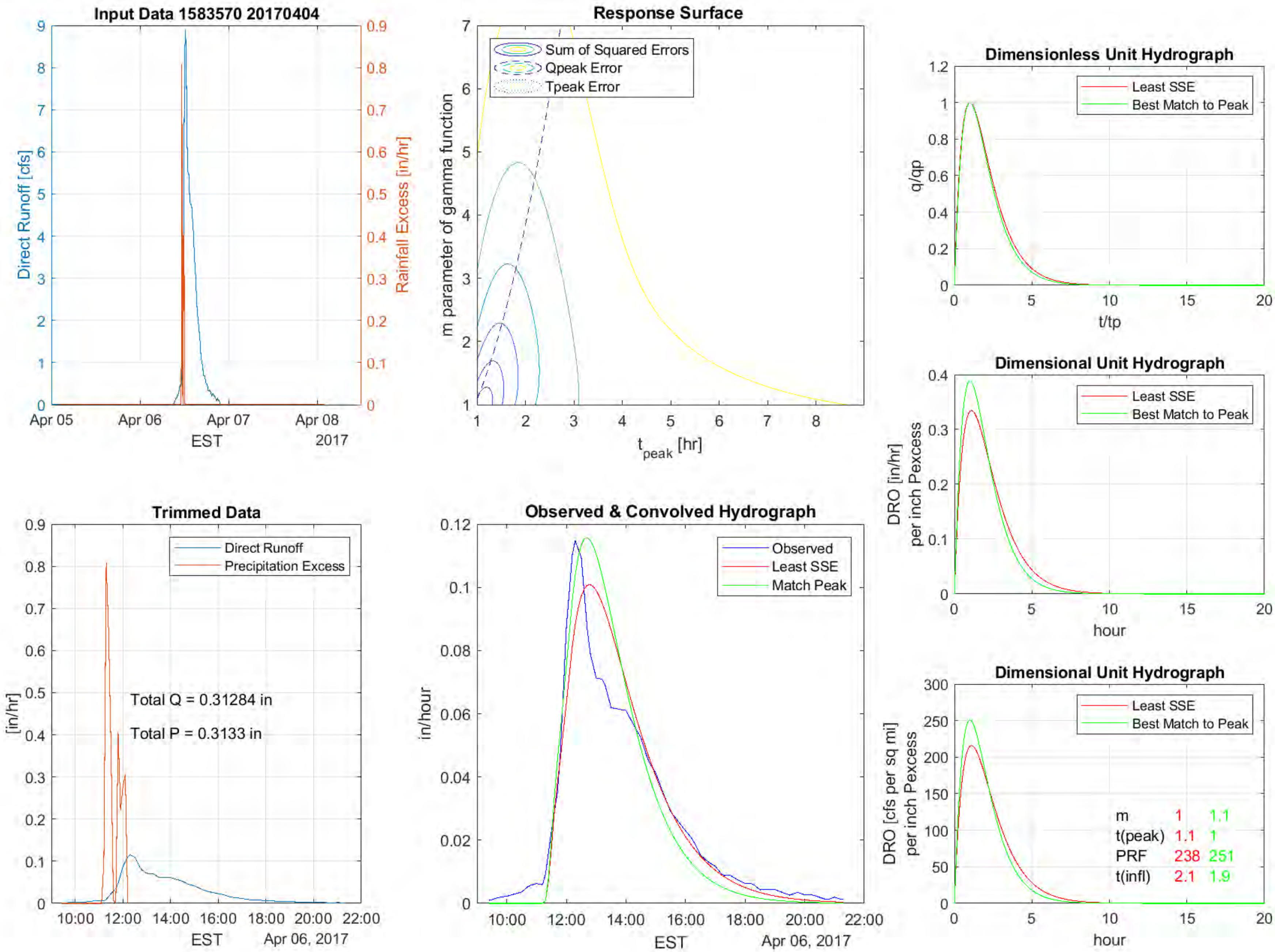

Input Data 1583500 20150928
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 28
Sep 29
Sep 30
Oct 01
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.63165 in
Total P = 0.63175 in
[in/hr]
Sep 30, 00:00
Oct 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Sep 29, 12:00
Sep 30, 00:00
Sep 30, 12:00
Oct 01, 00:00
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5 8.3
t(peak) 4.7 5.6
PRF 566 734
t(infl) 6.7 7.4

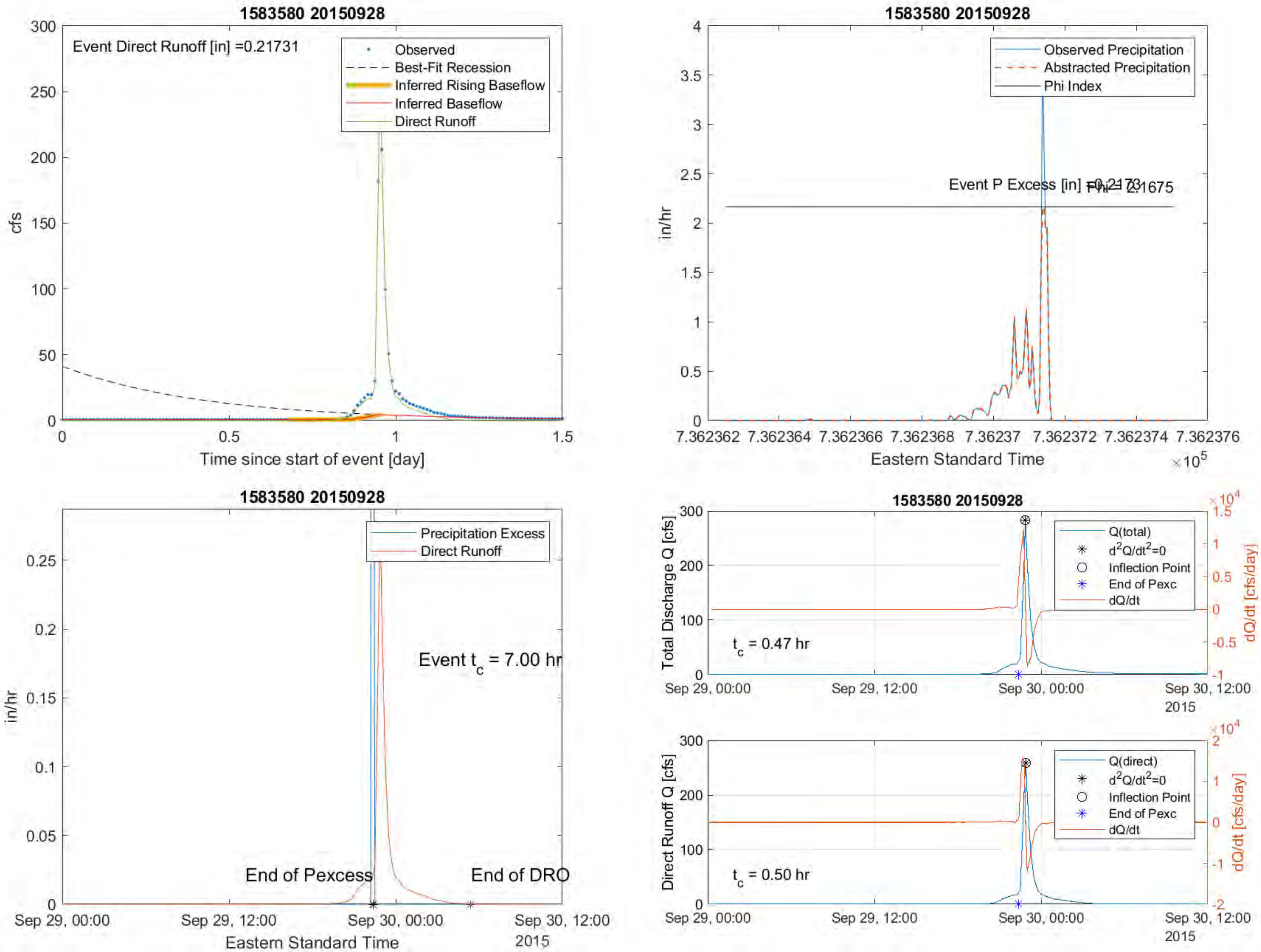

1583570 20170404
Event Direct Runoff [in] =0.31329
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1583570 20170404
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.3133
Phi = 0.63732
in/hr
Eastern Standard Time

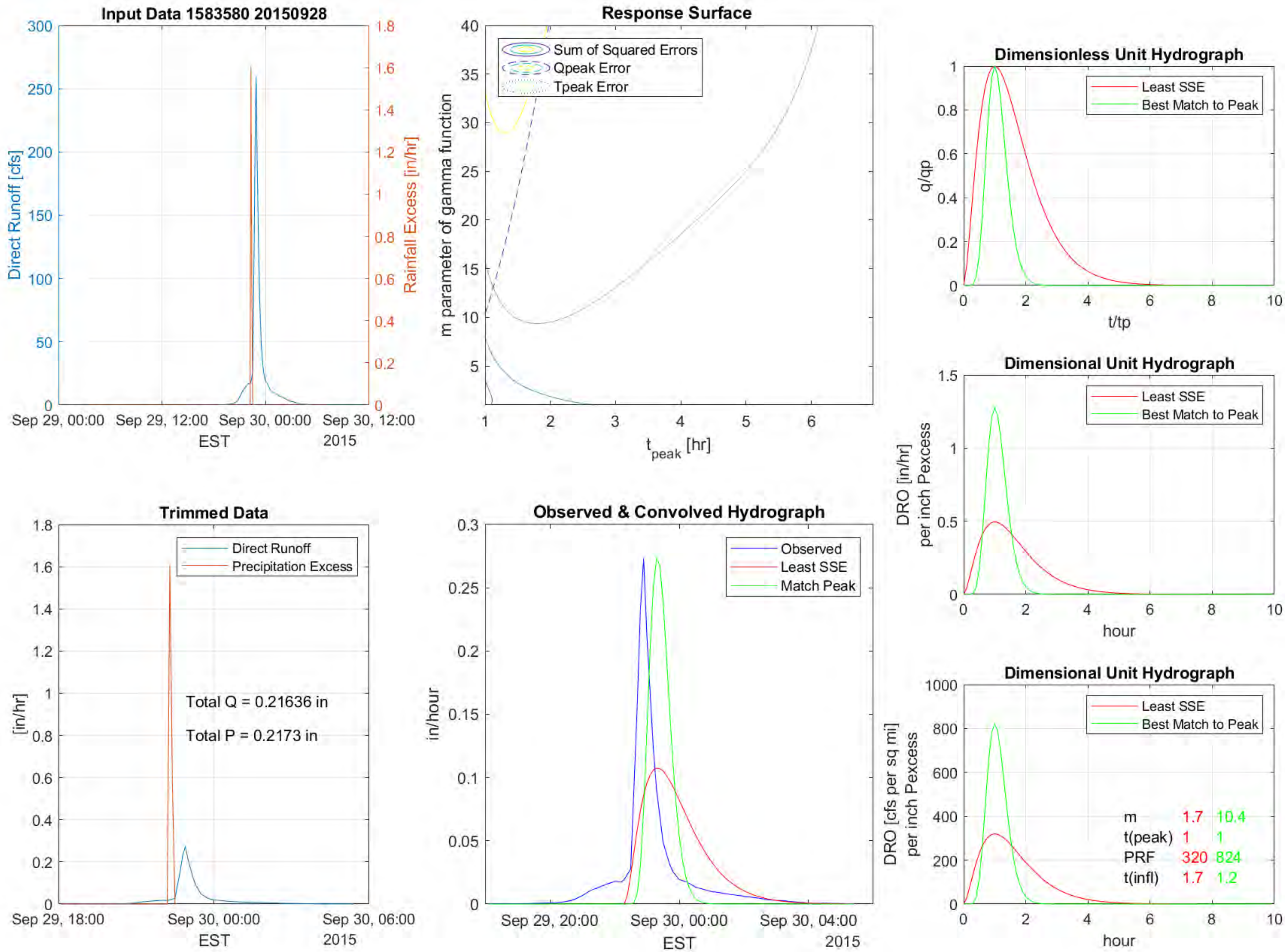

1583570 20170404
Precipitation Excess
Direct Runoff
Event t c = 9.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2017


1583570 20170404
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 0.40 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]
2017

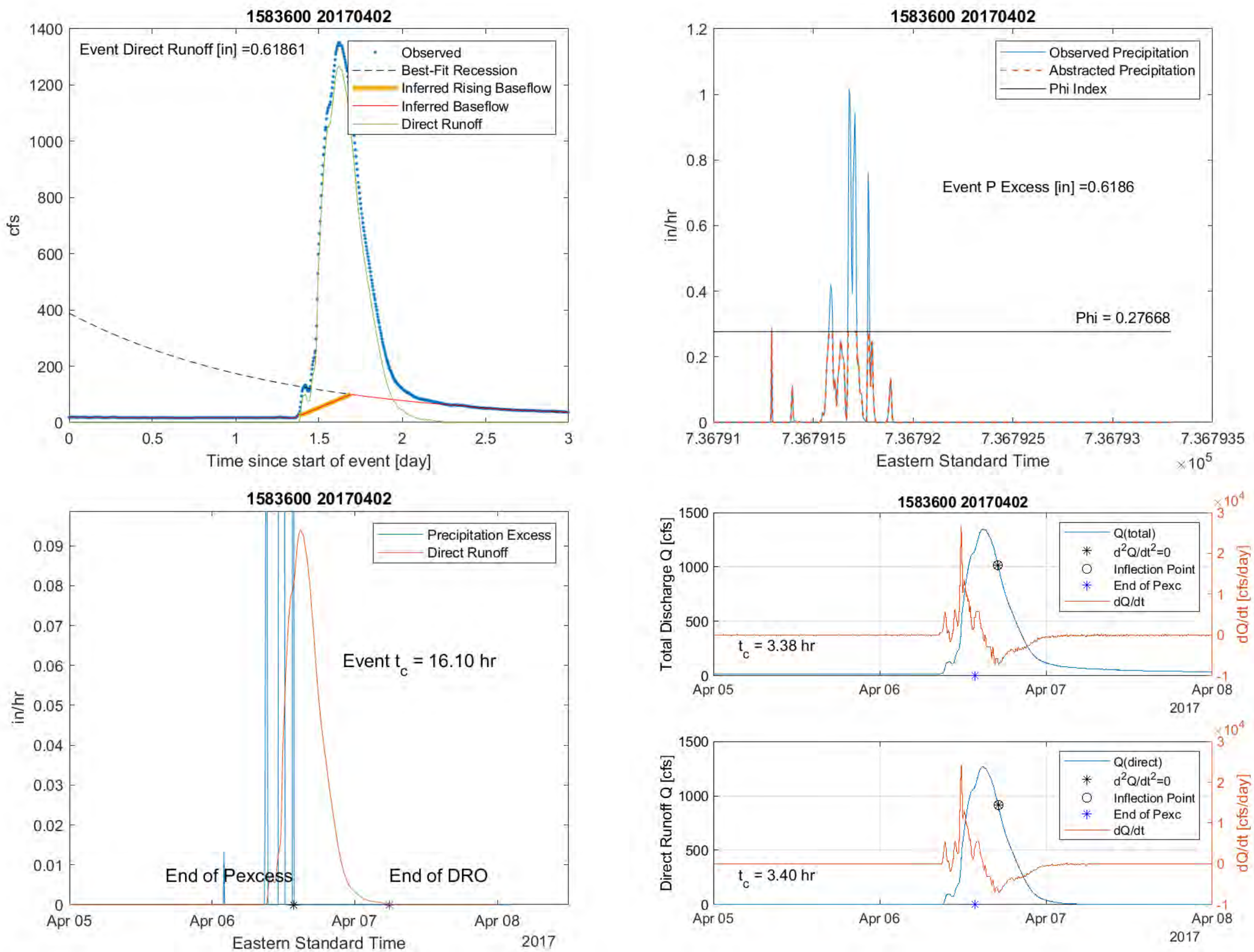

Input Data 1583570 20170404
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 05
Apr 06
Apr 07
Apr 08
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.31284 in
Total P = 0.3133 in
[in/hr]
EST
Apr 06, 2017
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
Apr 06, 2017
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1 1.1
t(peak) 1.1 1
PRF 238 251
t(infl) 2.1 1.9
hour



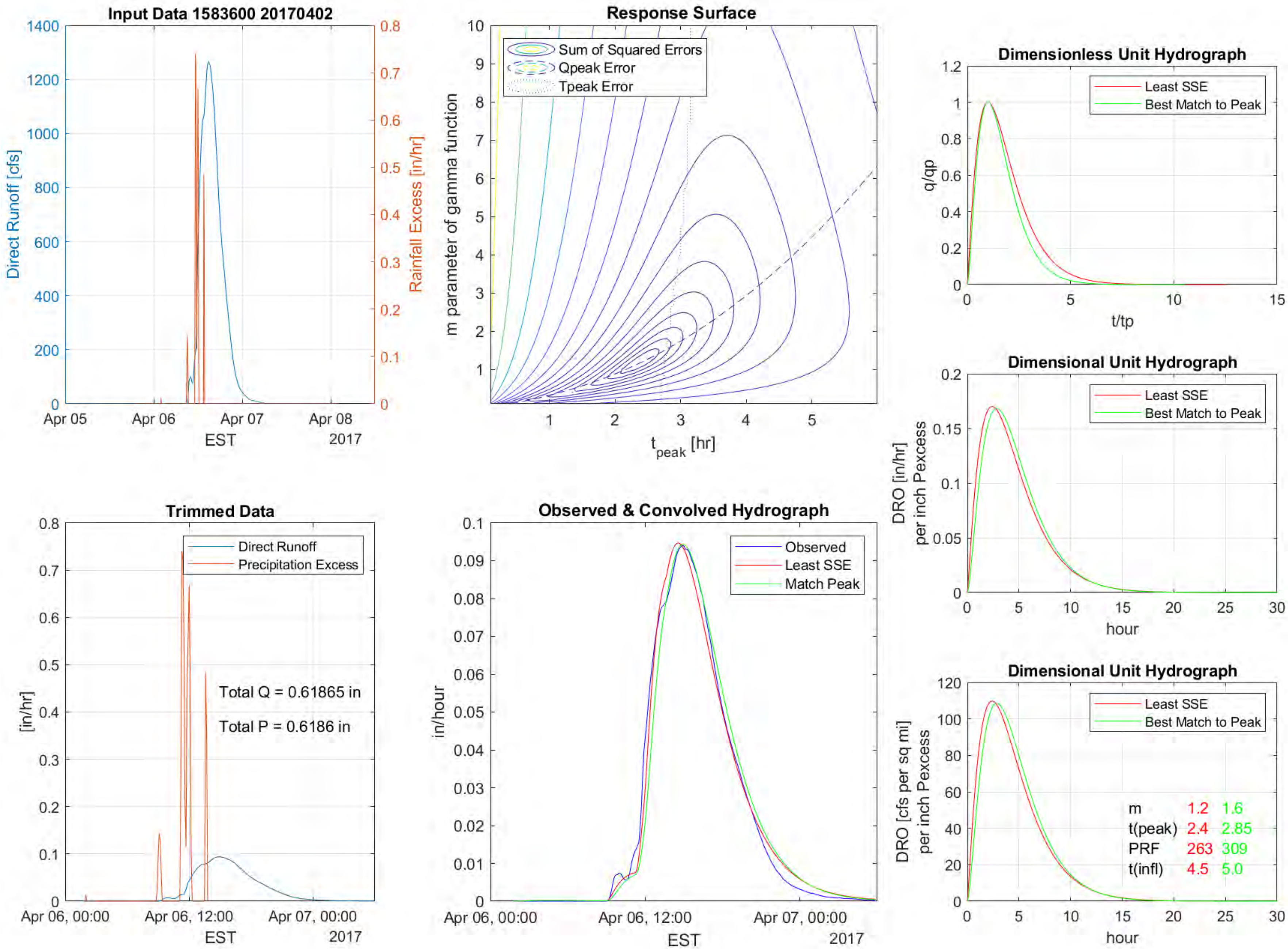
1583580 20150928
Event Direct Runoff [in] =0.21731
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1583580 20150928
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.2173
Phi = 2.1675
in/hr
Eastern Standard Time
1583580 20150928
Precipitation Excess
Direct Runoff
Event t_c = 7.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1583580 20150928
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.47 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.50 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

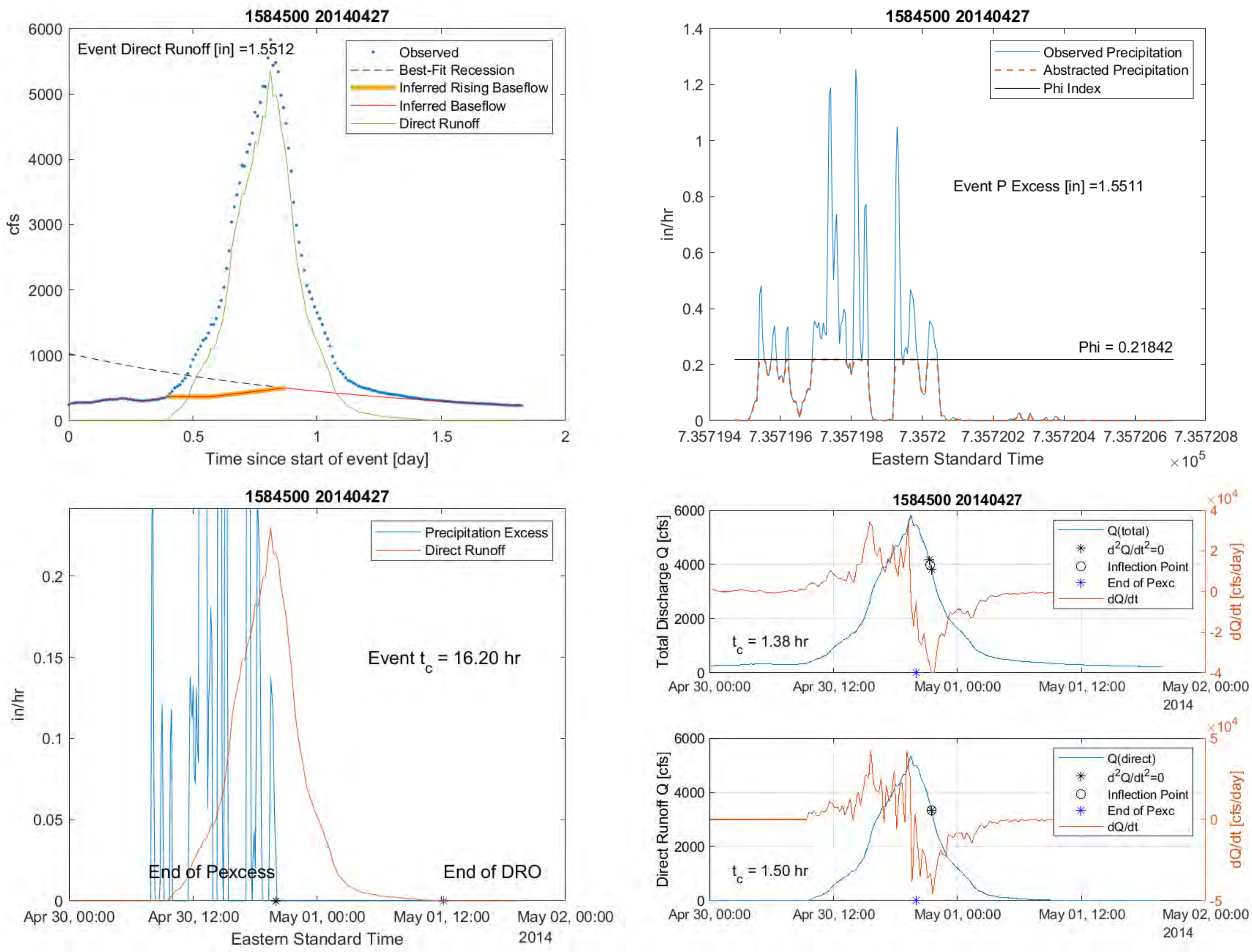


Input Data 1583580 20150928
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 29, 00:00
Sep 29, 12:00
Sep 30, 00:00
Sep 30, 12:00
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.21636 in
Total P = 0.2173 in
[in/hr]
Sep 29, 18:00
Sep 30, 00:00
Sep 30, 06:00
EST
2015
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Sep 29, 20:00
Sep 30, 00:00
Sep 30, 04:00
EST
2015
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 1.7 10.4
t(peak) 1 1
PRF 320 824
t(infl) 1.7 1.2
hour

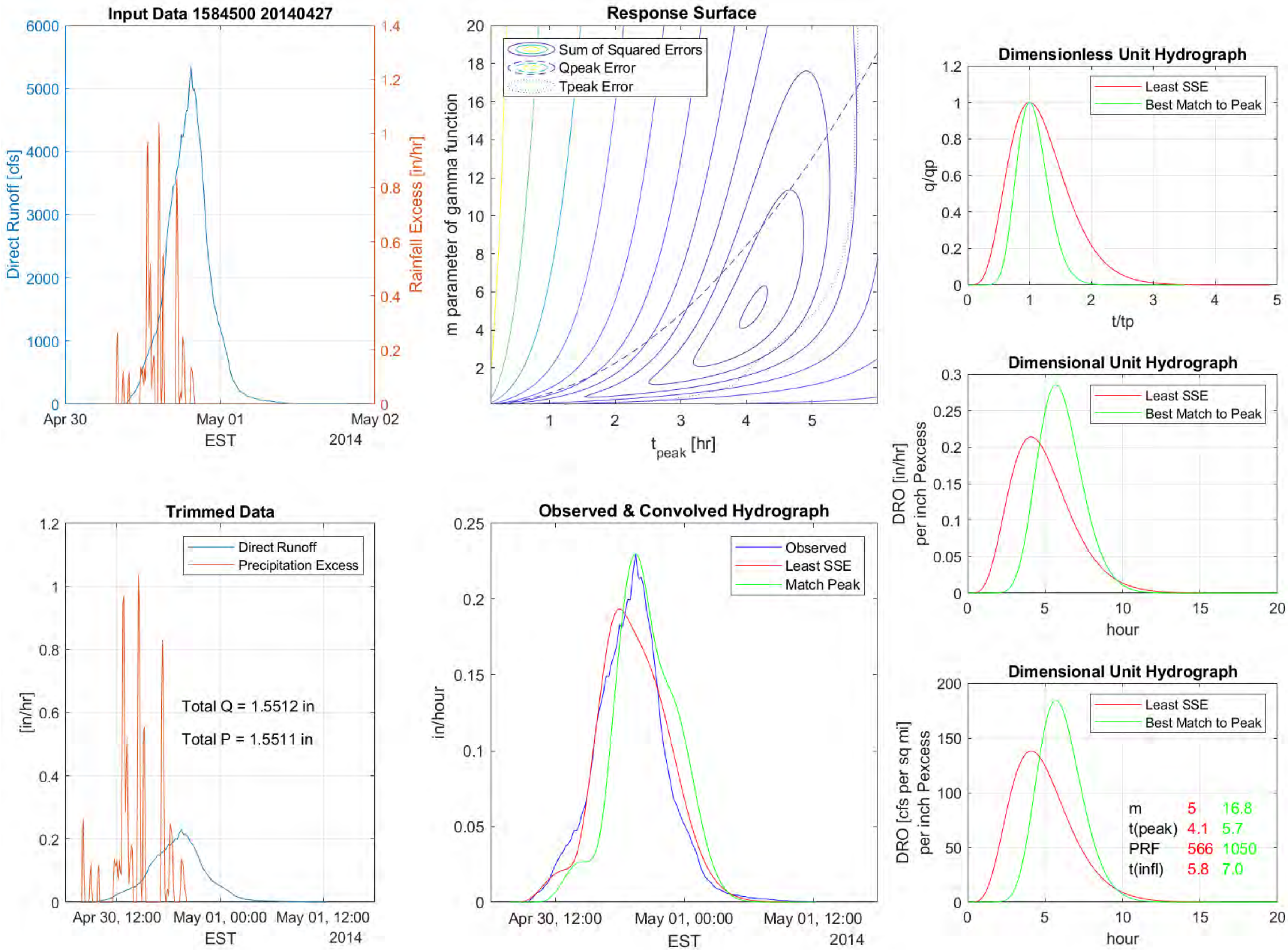


1583600 20170402
Event Direct Runoff [in] =0.61861
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1583600 20170402
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6186
Phi = 0.27668
in/hr
Eastern Standard Time
1583600 20170402
Precipitation Excess
Direct Runoff
Event t_c = 16.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1583600 20170402
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 3.38 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 3.40 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

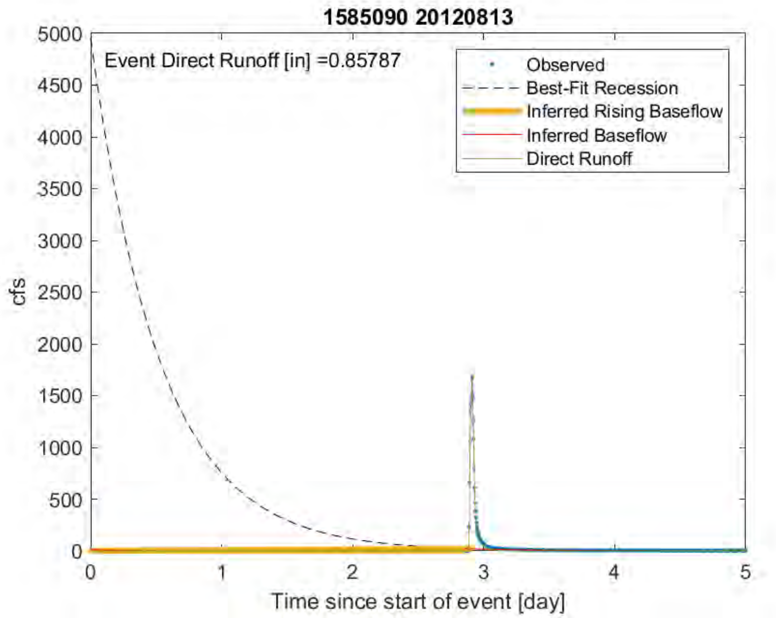

Input Data 1583600 20170402
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.61865 in
Total P = 0.6186 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.2 1.6
t(peak) 2.4 2.85
PRF 263 309
t(infl) 4.5 5.0



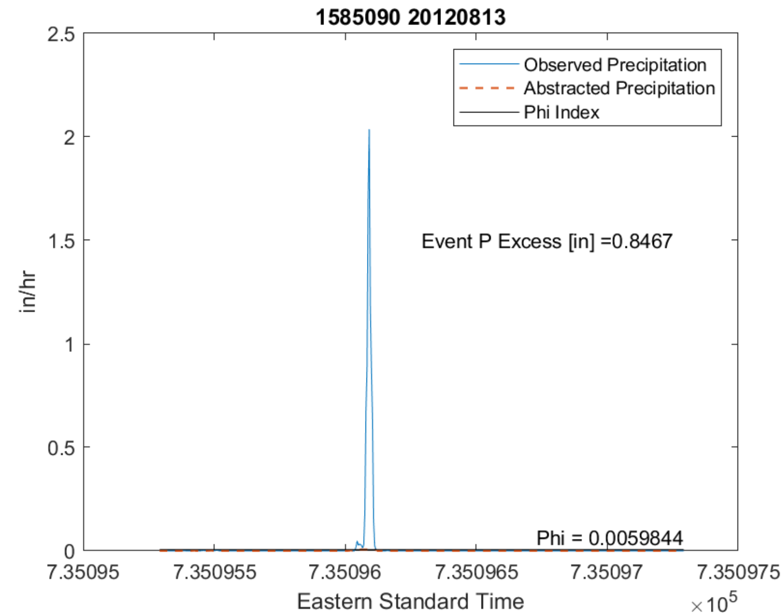
1584500 20140427
Event Direct Runoff [in] =1.5512
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1584500 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.5511
Phi = 0.21842
in/hr
Eastern Standard Time
1584500 20140427
Precipitation Excess
Direct Runoff
Event t_c = 16.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1584500 20140427
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 1.38 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 1.50 hr
Direct Runoff Q [cfs]



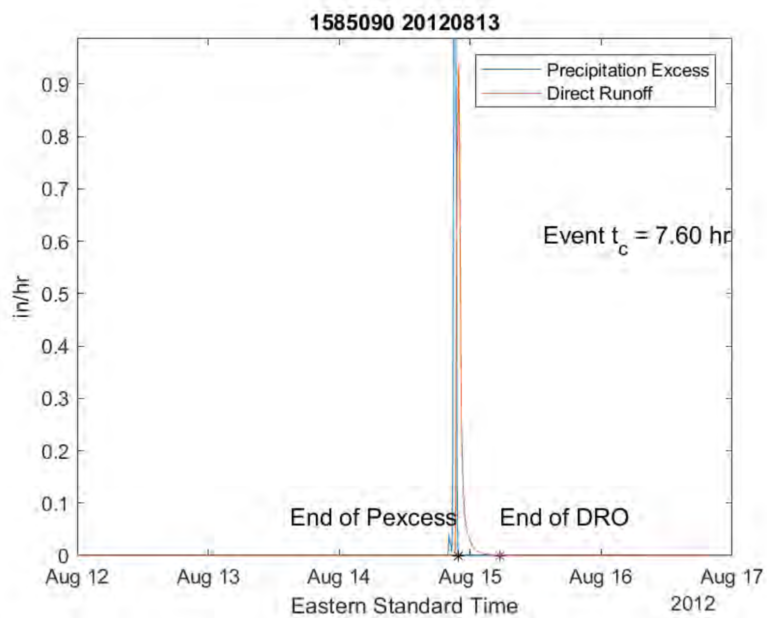
Input Data 1584500 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 30
May 01
May 02
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.5512 in
Total P = 1.5511 in
Apr 30, 12:00
May 01, 00:00
May 01, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5 16.8
t(peak) 4.1 5.7
PRF 566 1050
t(infl) 5.8 7.0



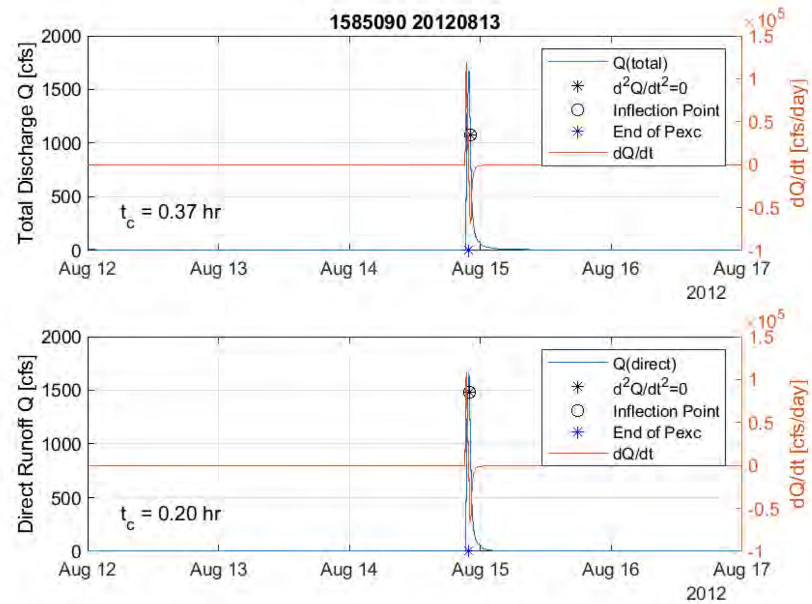
1585090 20120813
Event Direct Runoff [in] =0.85787
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



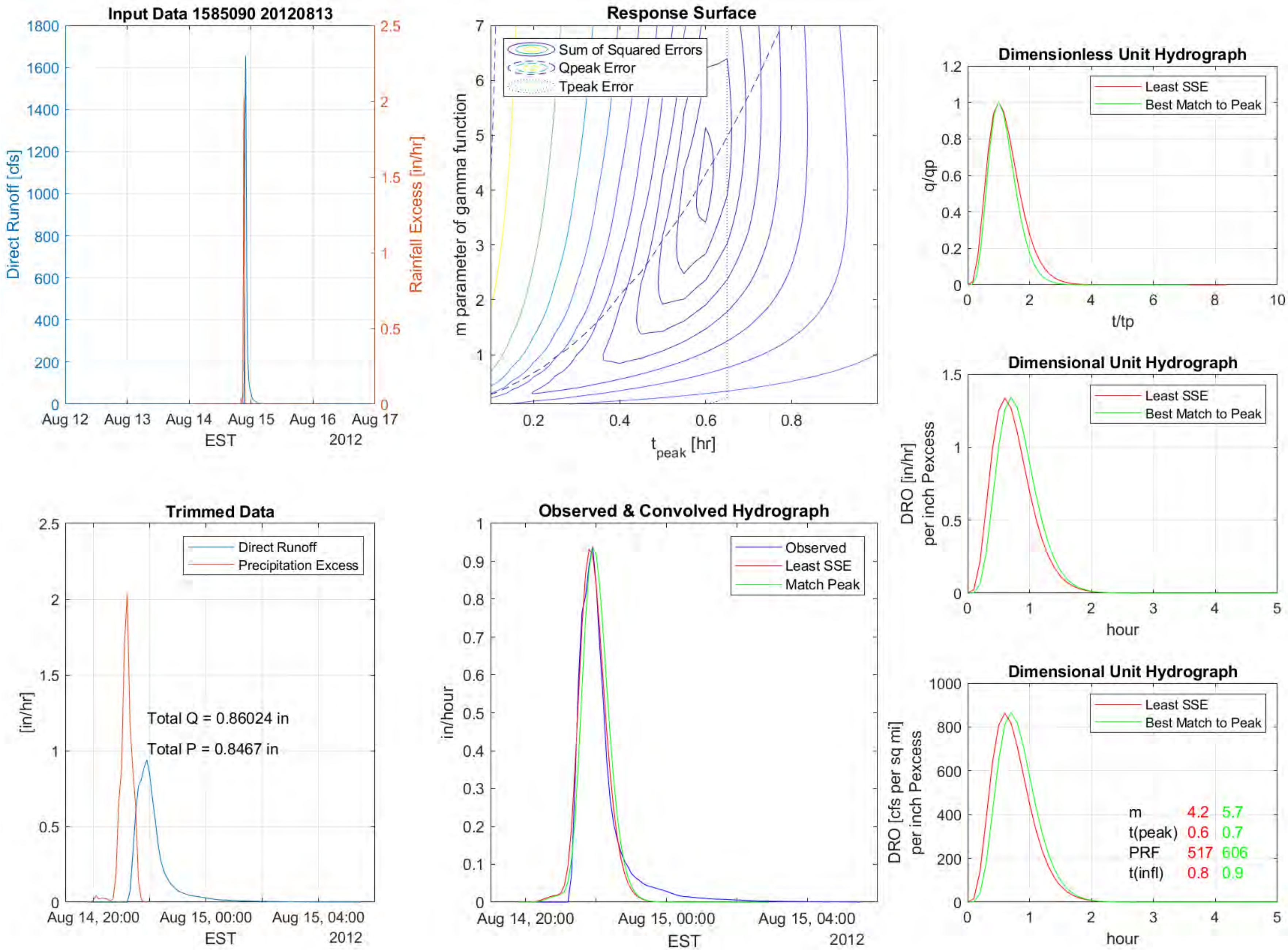
1585090 20120813
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.8467
Phi = 0.0059844
in/hr
Eastern Standard Time



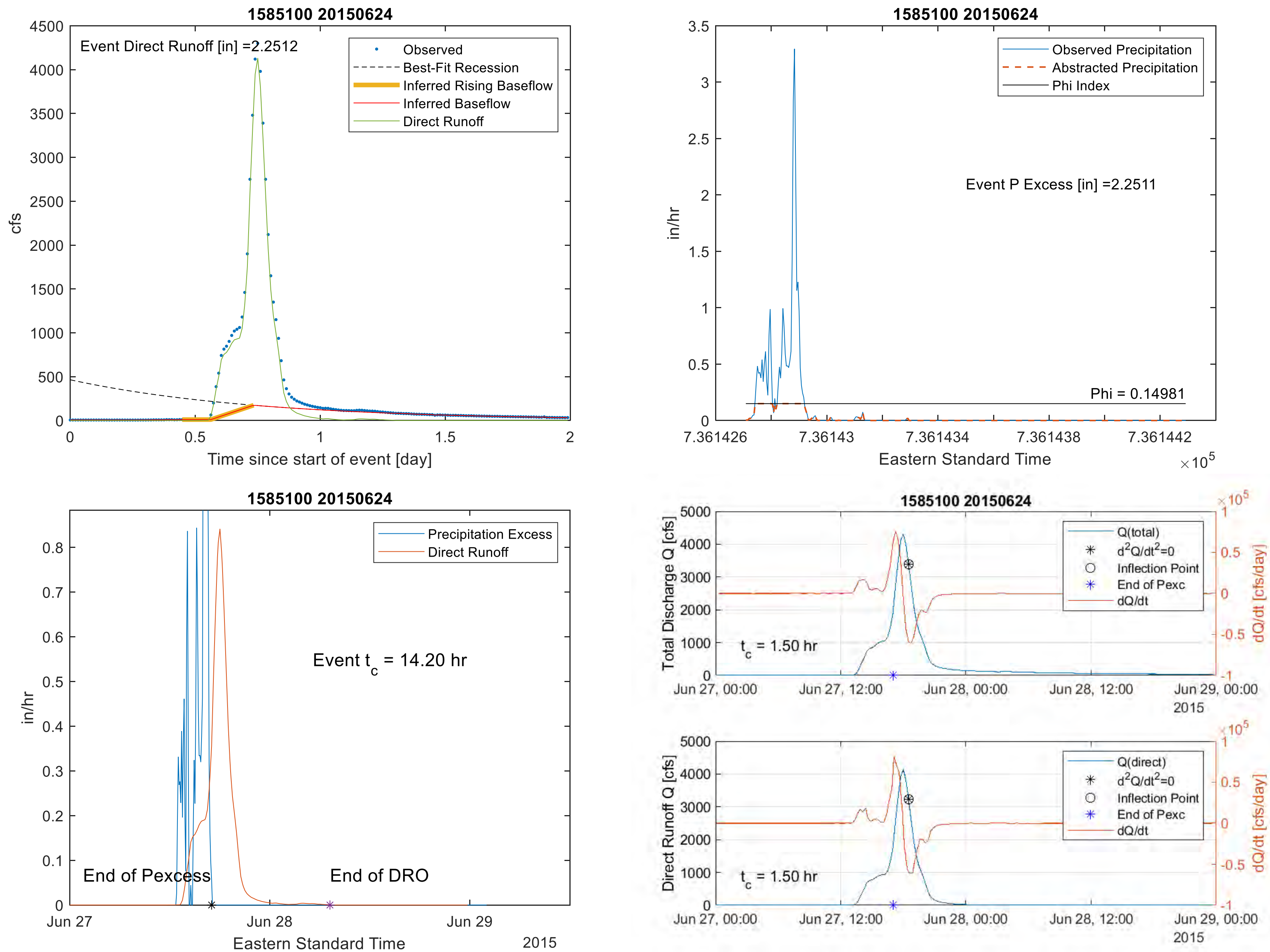
1585090 20120813
Precipitation Excess
Direct Runoff
Event t_c = 7.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

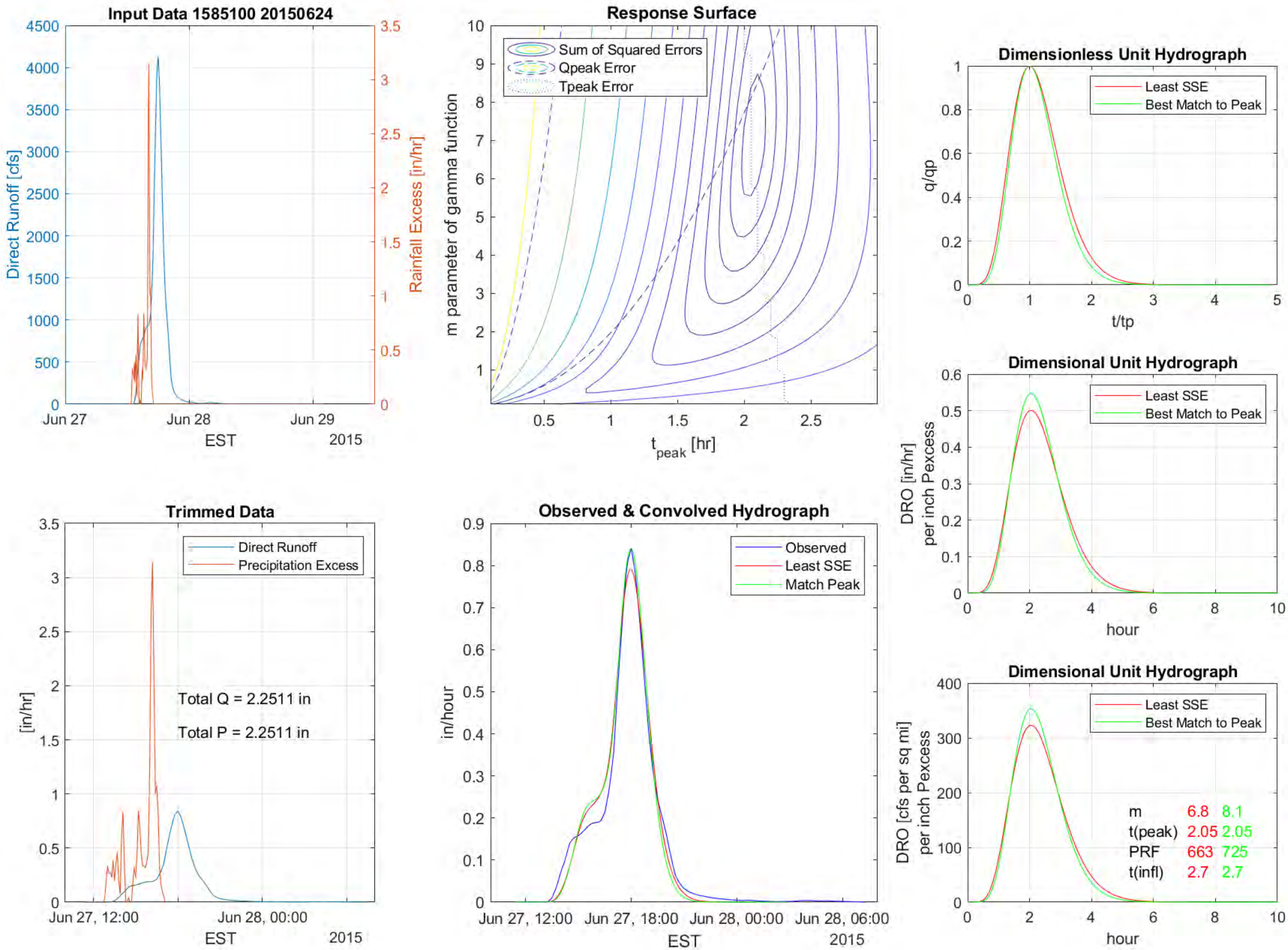


1585090 20120813
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 0.37 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 0.20 hr
Direct Runoff Q [cfs]

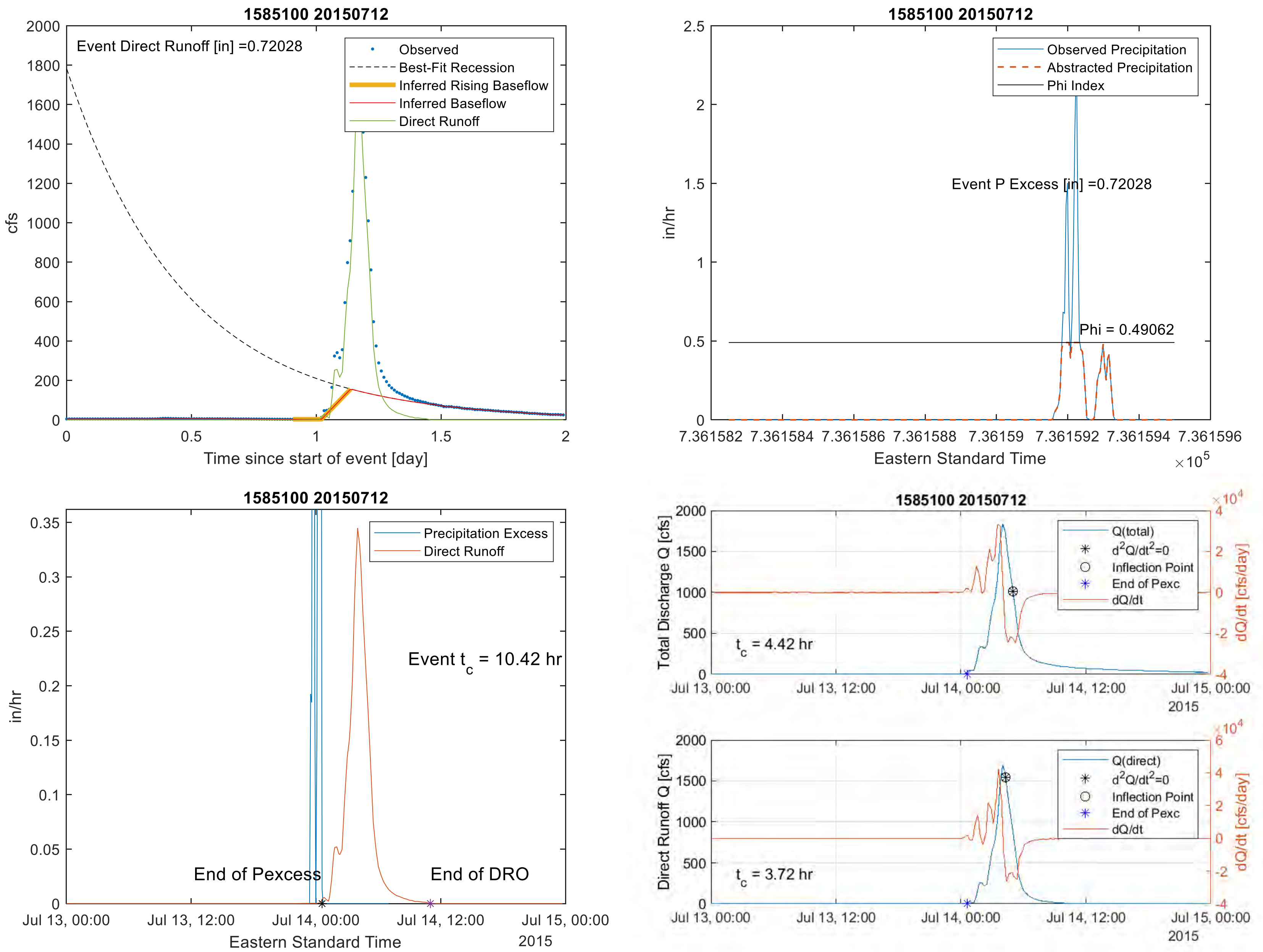


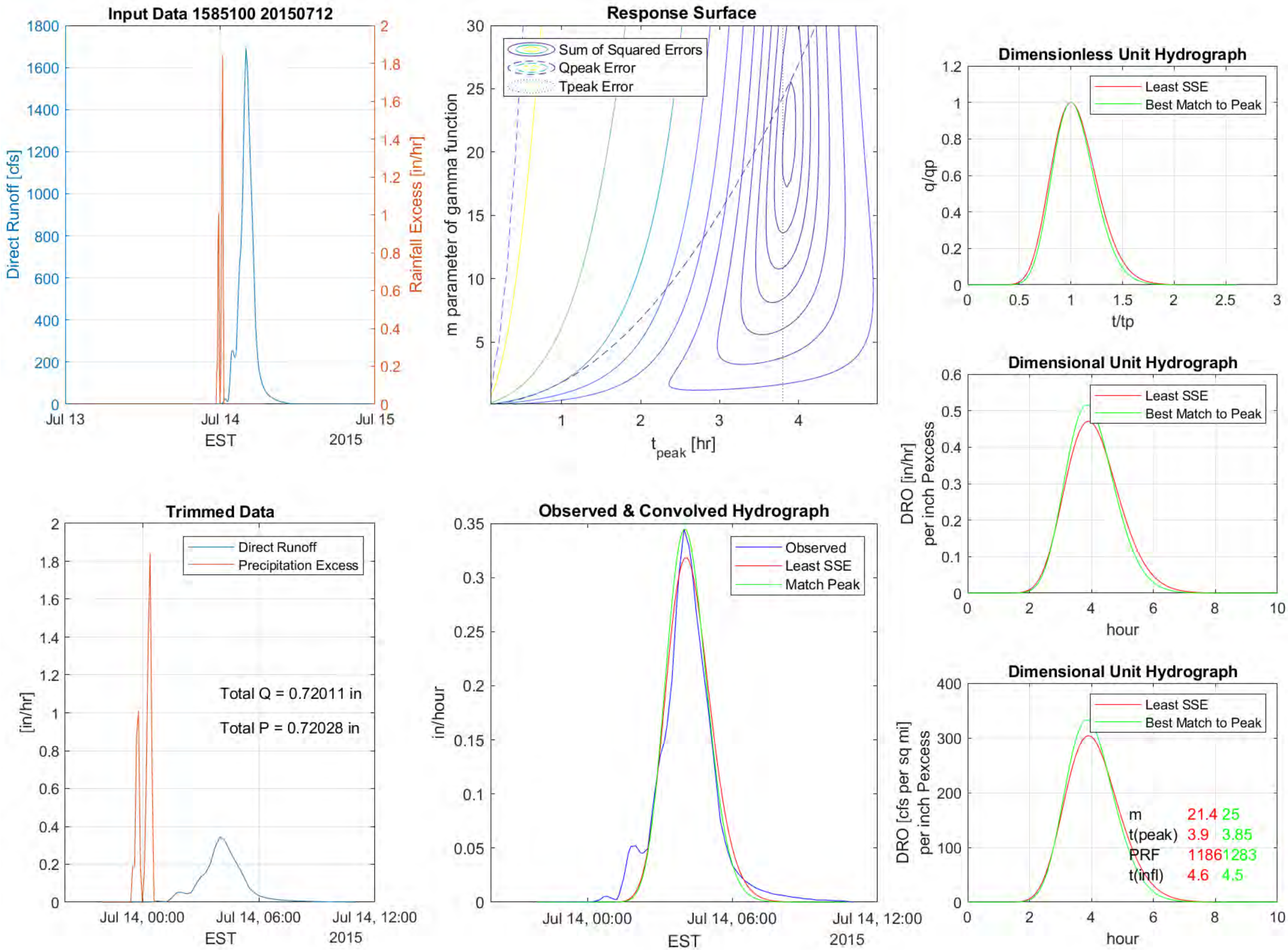
Input Data 1585090 20120813
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.86024 in
Total P = 0.8467 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4.2 5.7
t(peak) 0.6 0.7
PRF 517 606
t(infl) 0.8 0.9


1585100 20150624
Event Direct Runoff [in] =2.2512
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585100 20150624
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.2511
Phi = 0.14981
in/hr
Eastern Standard Time
$\times 10^5$
1585100 20150624
Precipitation Excess
Direct Runoff
Event t_c = 14.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2015
1585100 20150624
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 1.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]

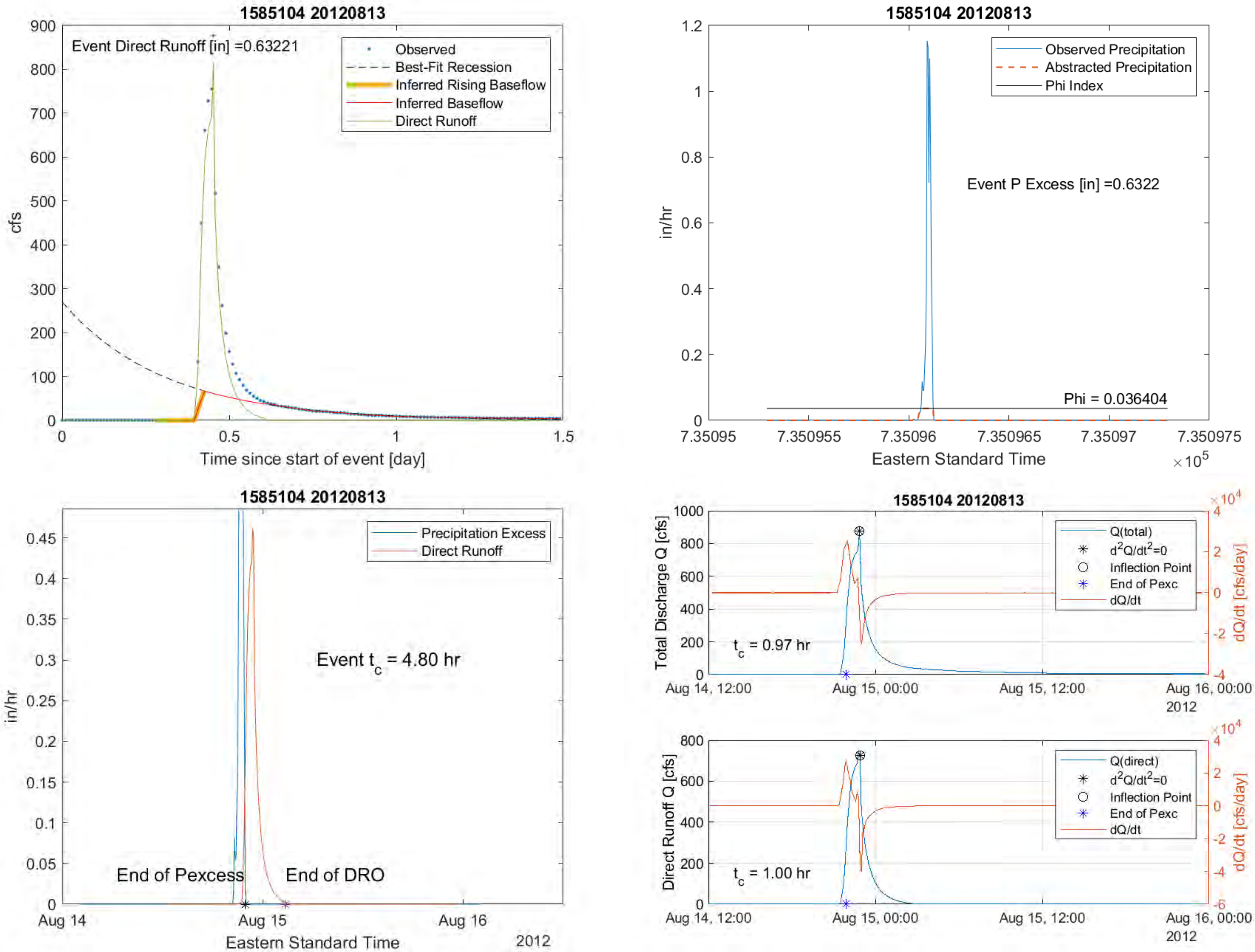


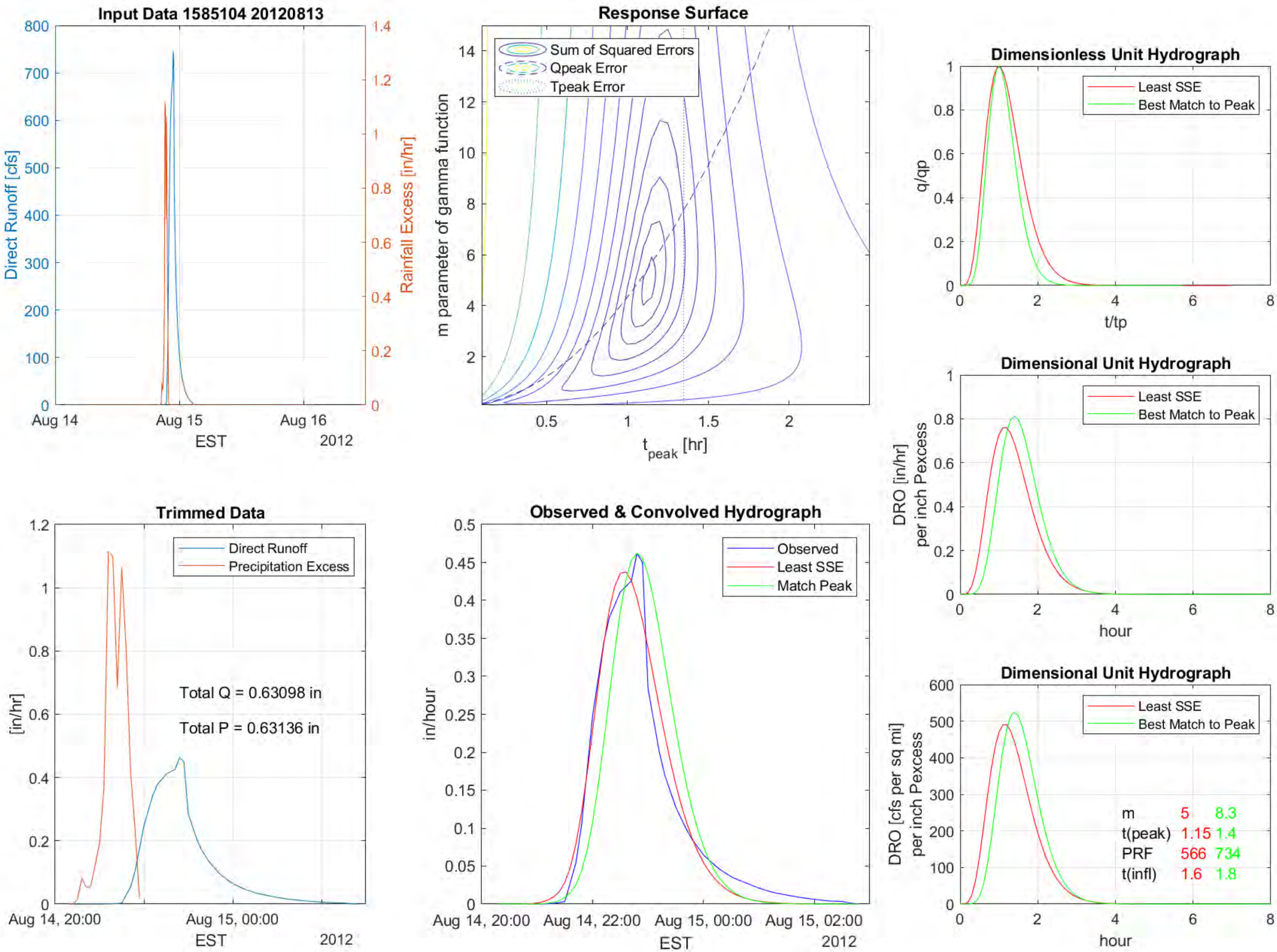
Input Data 1585100 20150624
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 27
Jun 28
Jun 29
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.2511 in
Total P = 2.2511 in
[in/hr]
Jun 27, 12:00
Jun 28, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jun 27, 12:00
Jun 27, 18:00
Jun 28, 00:00
Jun 28, 06:00
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 6.8 8.1
t(peak) 2.05 2.05
PRF 663 725
t(infl) 2.7 2.7

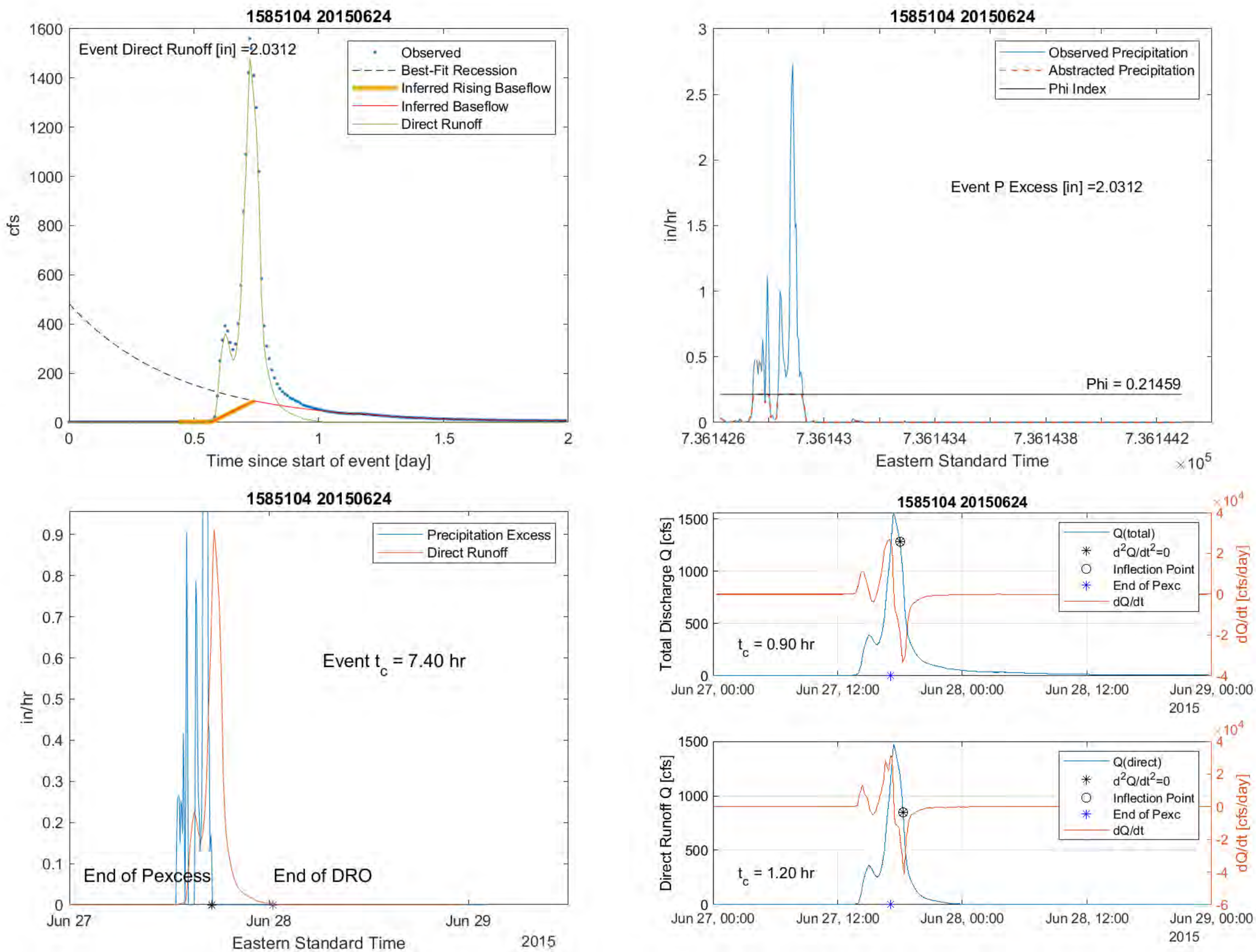

1585100 20150712
Event Direct Runoff [in] =0.72028
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585100 20150712
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.72028
Phi = 0.49062
in/hr
Eastern Standard Time
1585100 20150712
Precipitation Excess
Direct Runoff
Event t_c = 10.42 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1585100 20150712
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 4.42 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 3.72 hr
Direct Runoff Q [cfs]



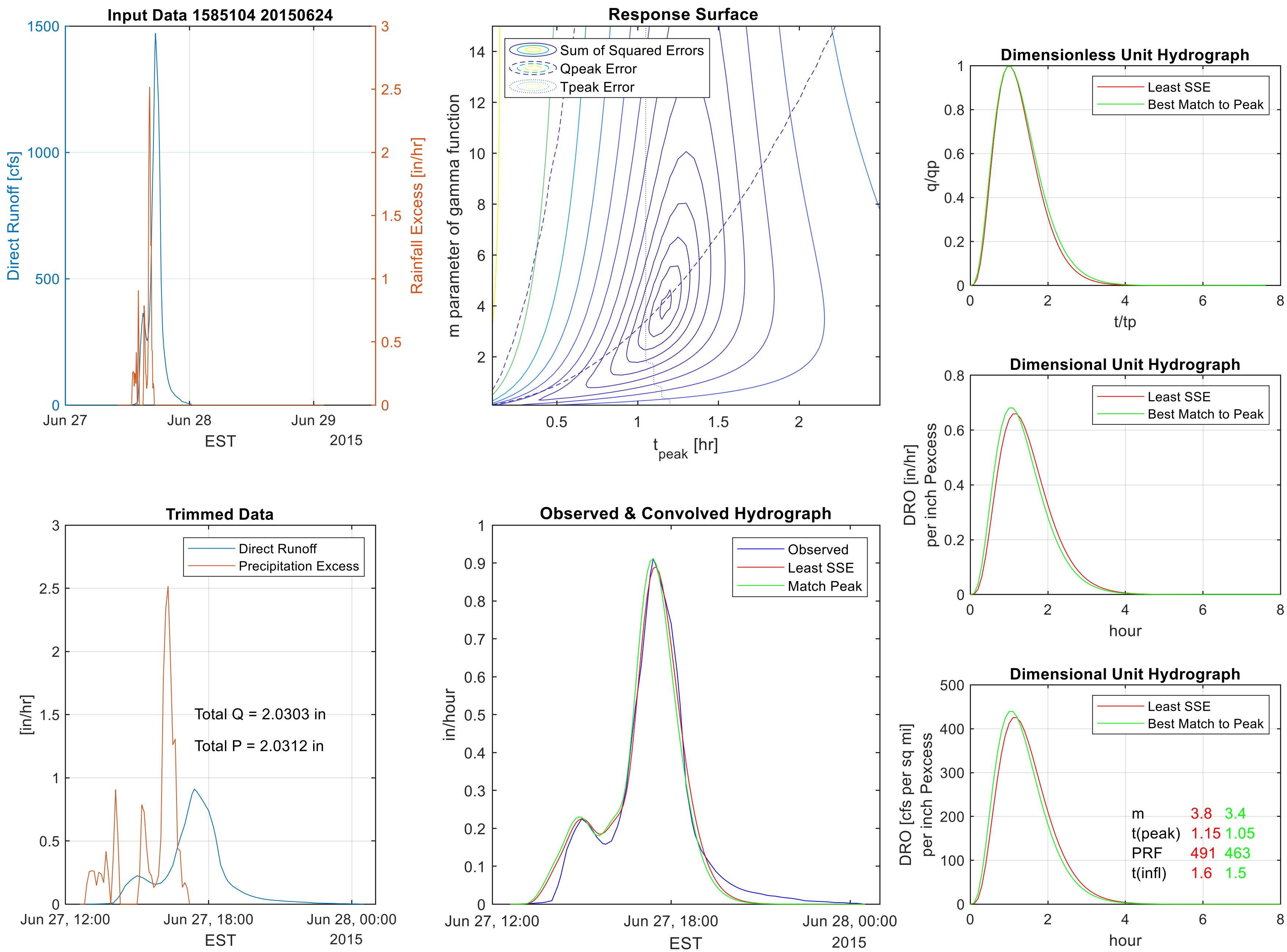
Input Data 1585100 20150712
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 13
Jul 14
Jul 15
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.72011 in
Total P = 0.72028 in
Jul 14, 00:00
Jul 14, 06:00
Jul 14, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 21.4 25
t(peak) 3.9 3.85
PRF 1186 1283
t(infl) 4.6 4.5

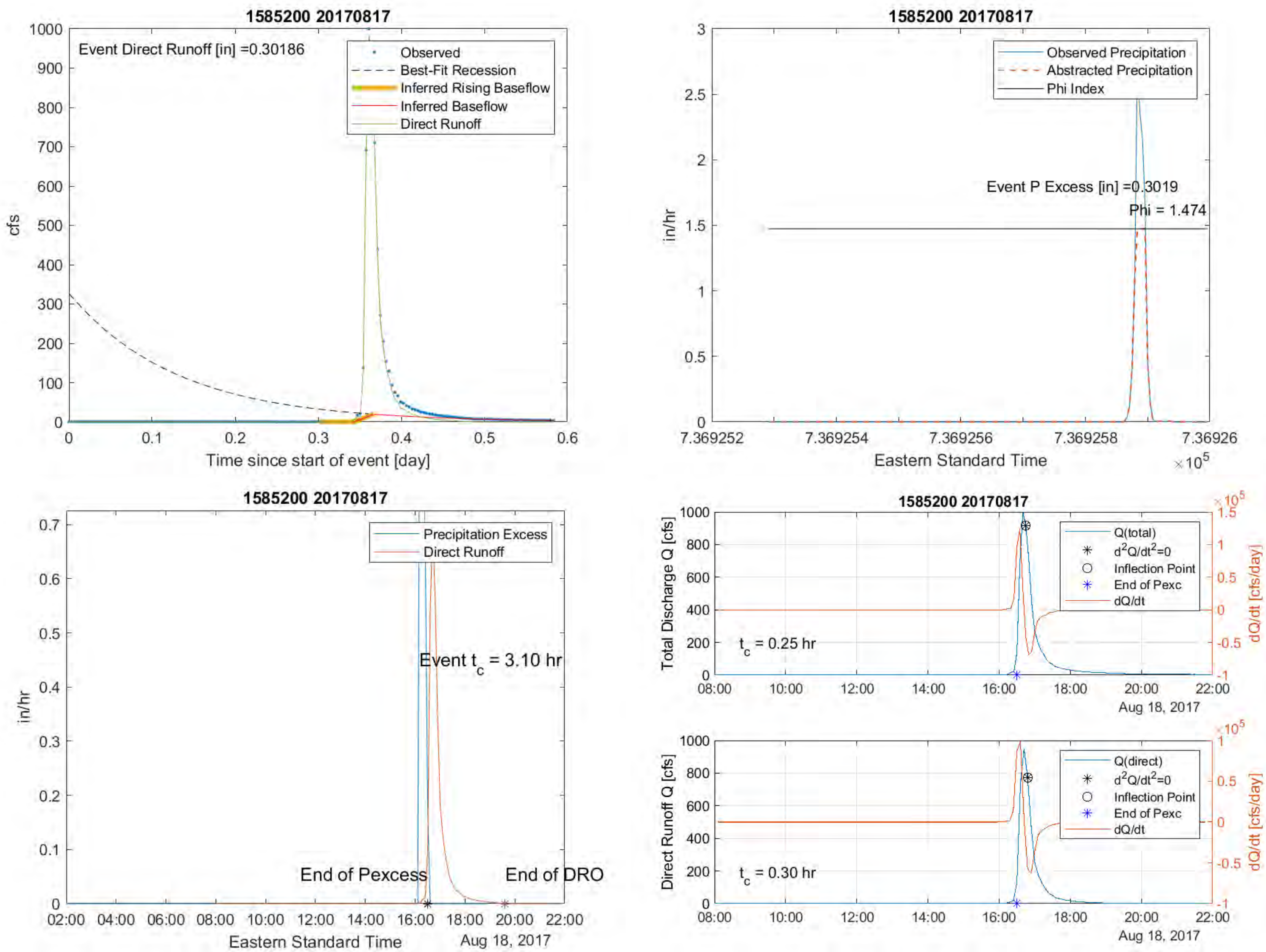

1585104 20120813
Event Direct Runoff [in] =0.63221
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585104 20120813
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6322
Phi = 0.036404
in/hr
Eastern Standard Time
1585104 20120813
Precipitation Excess
Direct Runoff
Event t_c = 4.80 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1585104 20120813
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 0.97 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 1.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

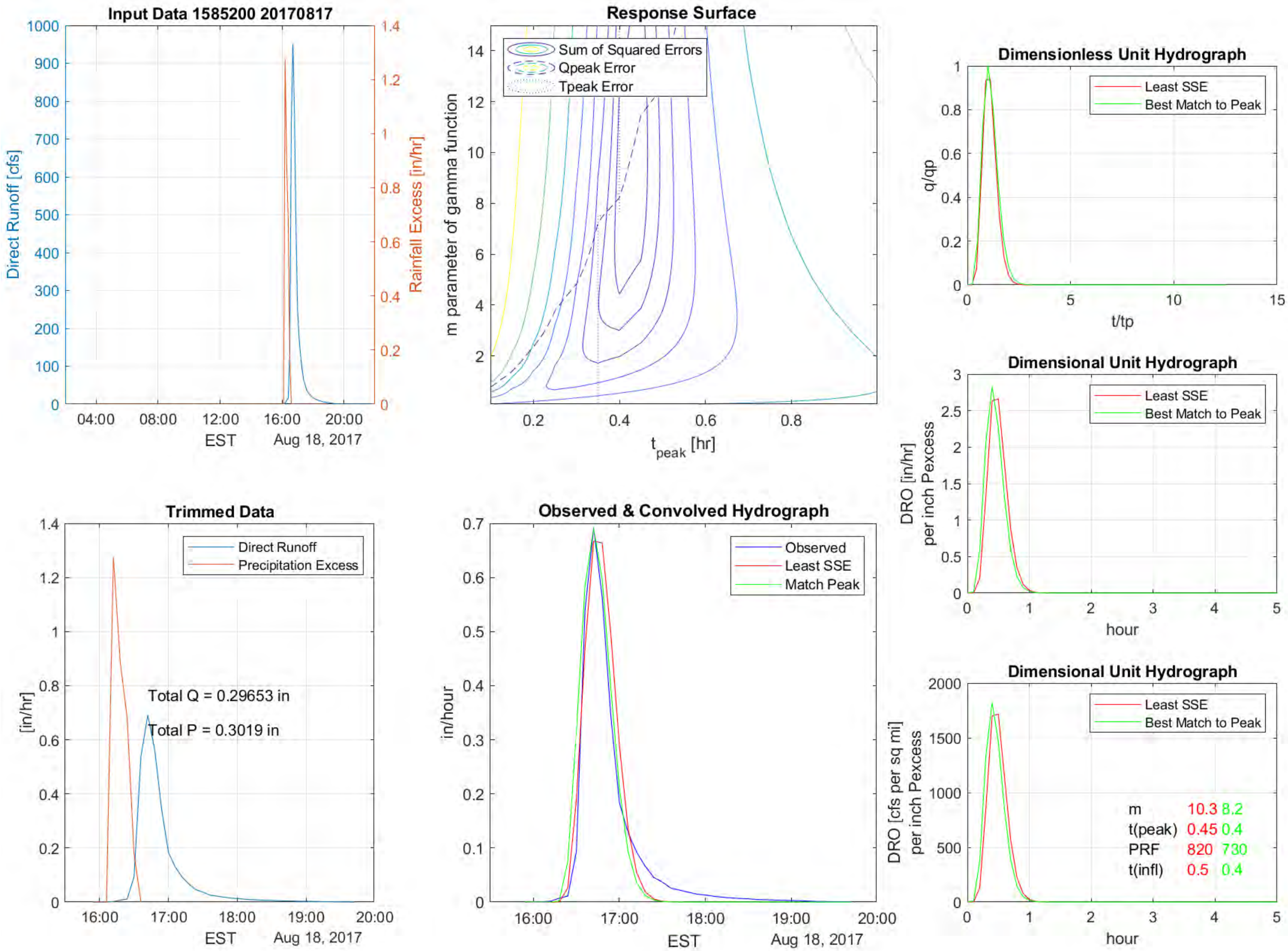

Input Data 1585104 20120813
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 14
Aug 15
Aug 16
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.63098 in
Total P = 0.63136 in
[in/hr]
Aug 14, 20:00
Aug 15, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Aug 14, 22:00
Aug 15, 02:00
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5 8.3
t(peak) 1.15 1.4
PRF 566 734
t(infl) 1.6 1.8

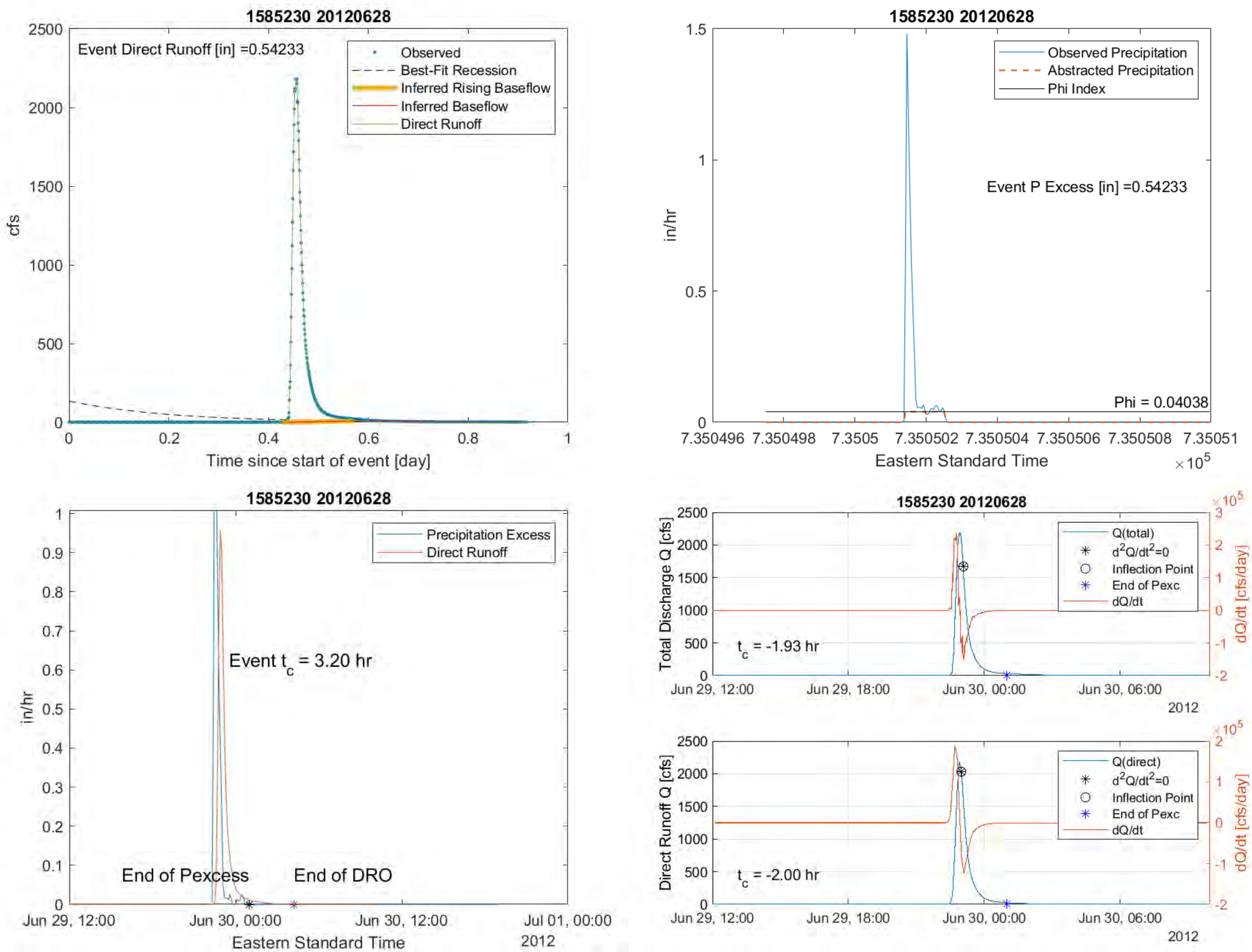


1585104 20150624
Event Direct Runoff [in] =2.0312
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585104 20150624
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.0312
Phi = 0.21459
in/hr
Eastern Standard Time
1585104 20150624
Precipitation Excess
Direct Runoff
Event t_c = 7.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1585104 20150624
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.90 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 1.20 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

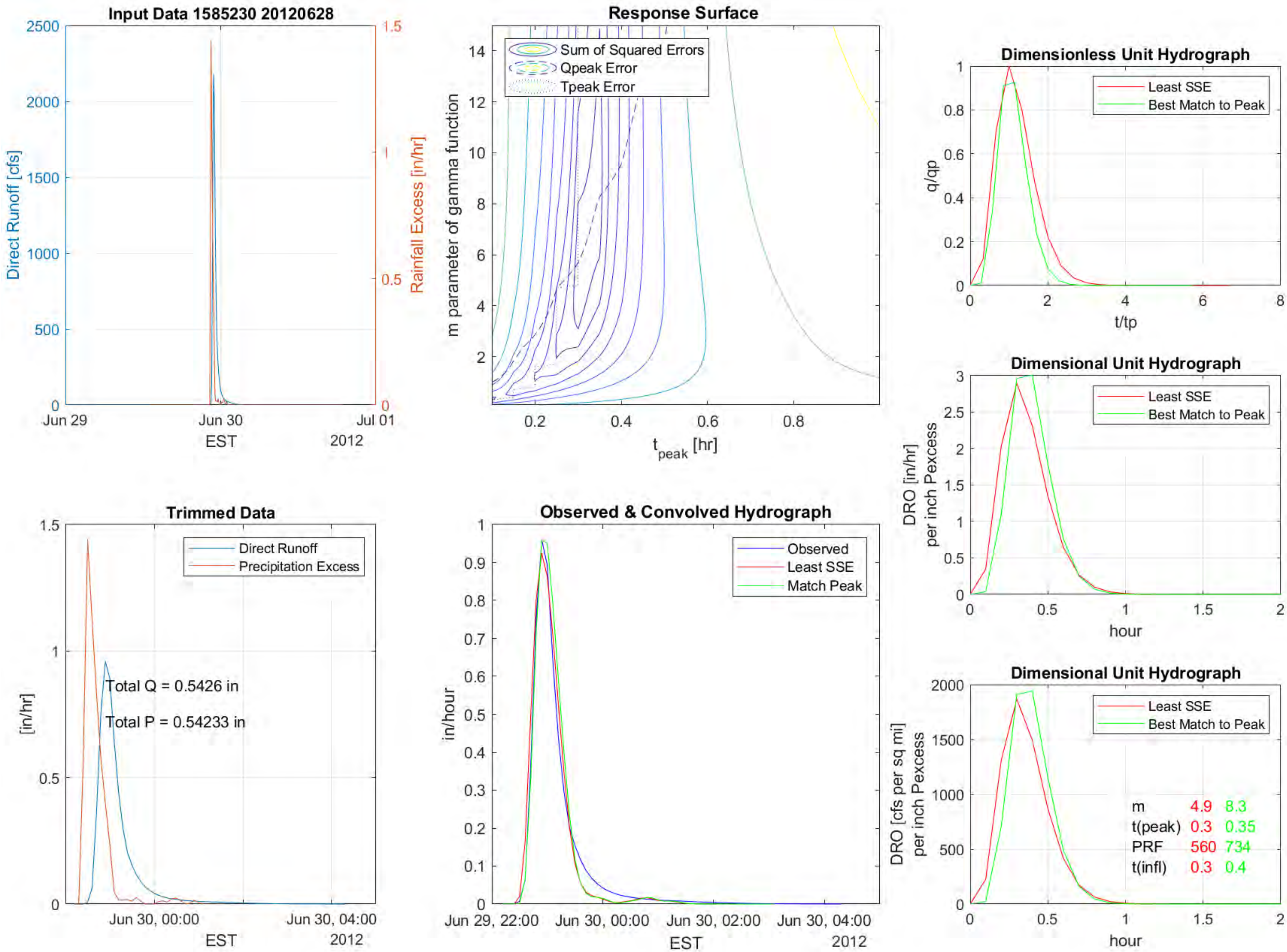

Input Data 1585104 20150624
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 27
Jun 28
Jun 29
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 2.0303 in
Total P = 2.0312 in
Jun 27, 12:00
Jun 27, 18:00
Jun 28, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.8 3.4
t(peak) 1.15 1.05
PRF 491 463
t(infl) 1.6 1.5

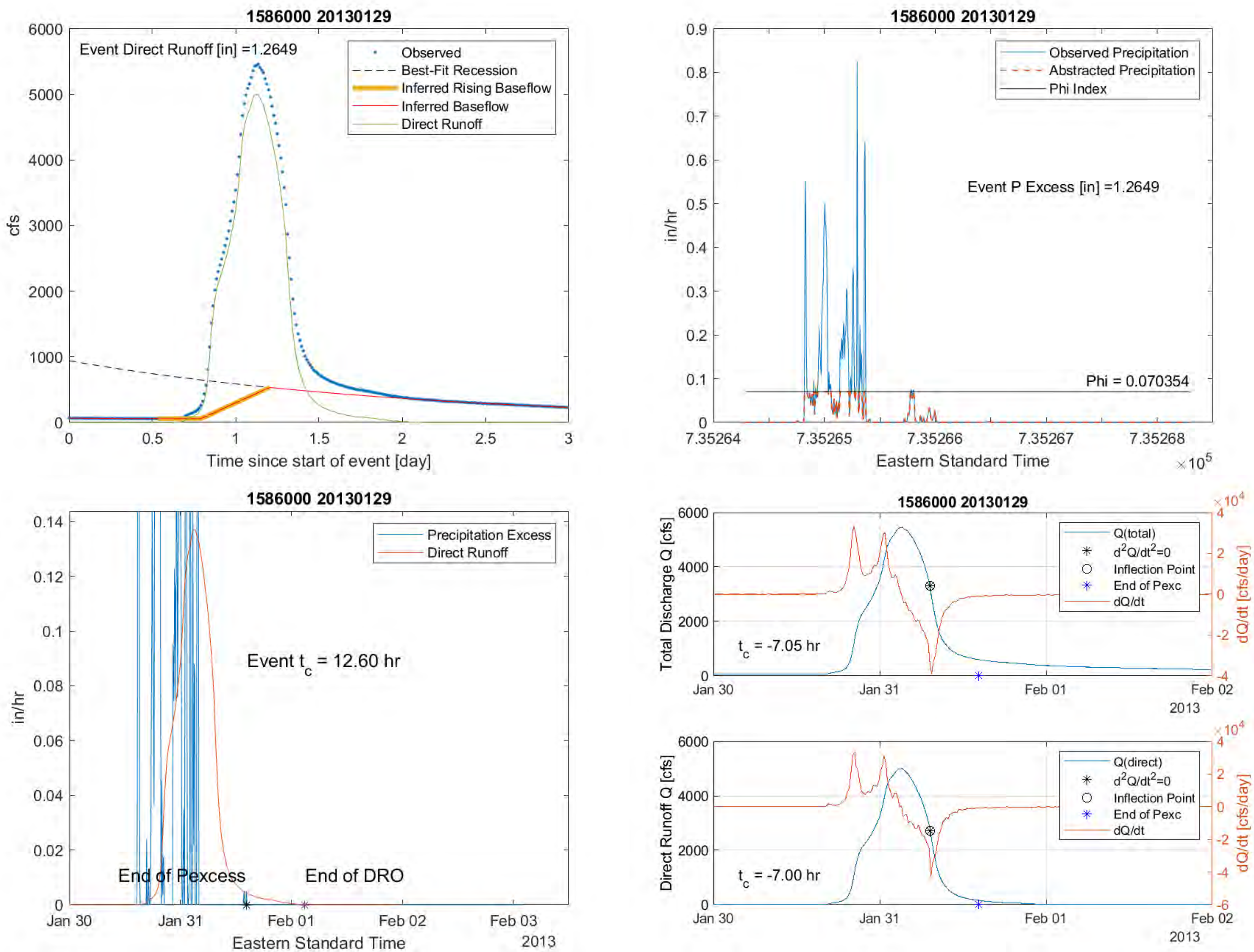

1585200 20170817
Event Direct Runoff [in] =0.30186
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585200 20170817
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.3019
Phi = 1.474
in/hr
Eastern Standard Time
×10^5
1585200 20170817
Precipitation Excess
Direct Runoff
Event t_c = 3.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
Aug 18, 2017
1585200 20170817
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.25 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Aug 18, 2017
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.30 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
Aug 18, 2017

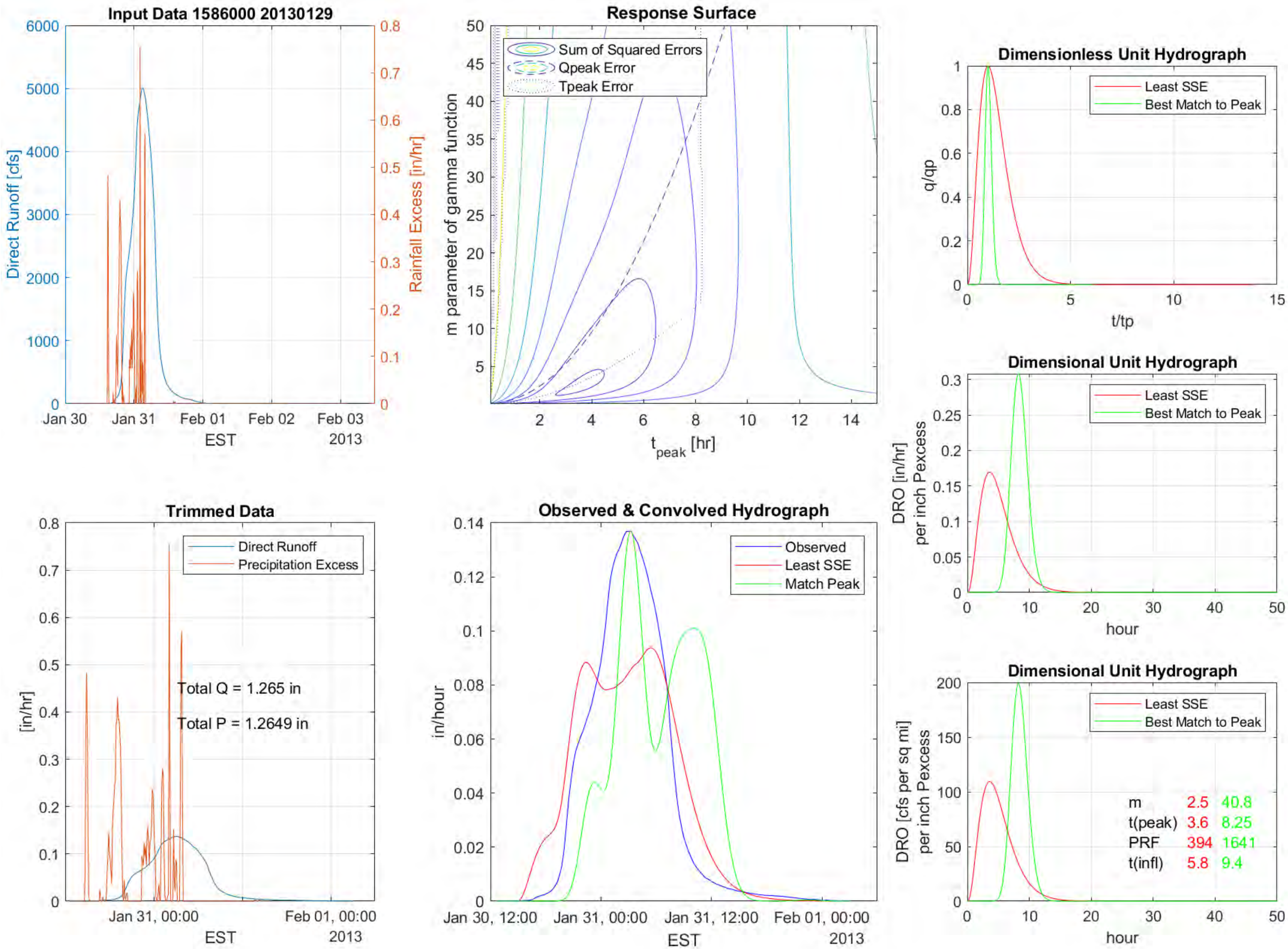

Input Data 1585200 20170817
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
Aug 18, 2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.29653 in
Total P = 0.3019 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 10.3 8.2
t(peak) 0.45 0.4
PRF 820 730
t(infl) 0.5 0.4

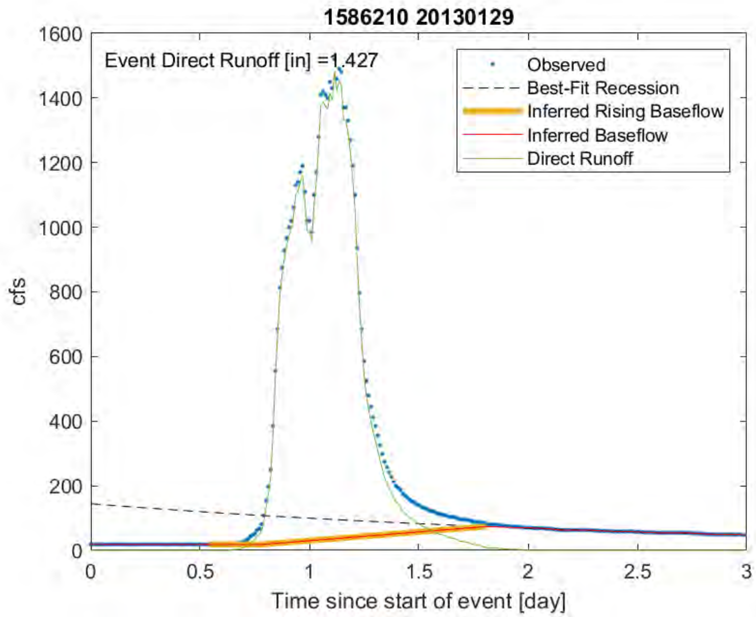


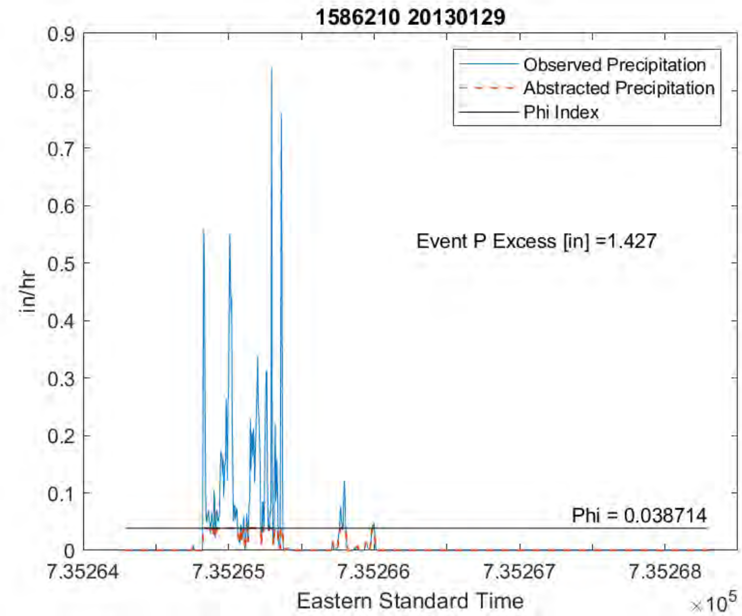
1585230 20120628
Event Direct Runoff [in] =0.54233
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1585230 20120628
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.54233
Phi = 0.04038
in/hr
Eastern Standard Time
1585230 20120628
Precipitation Excess
Direct Runoff
Event t_c = 3.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1585230 20120628
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -1.93 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -2.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

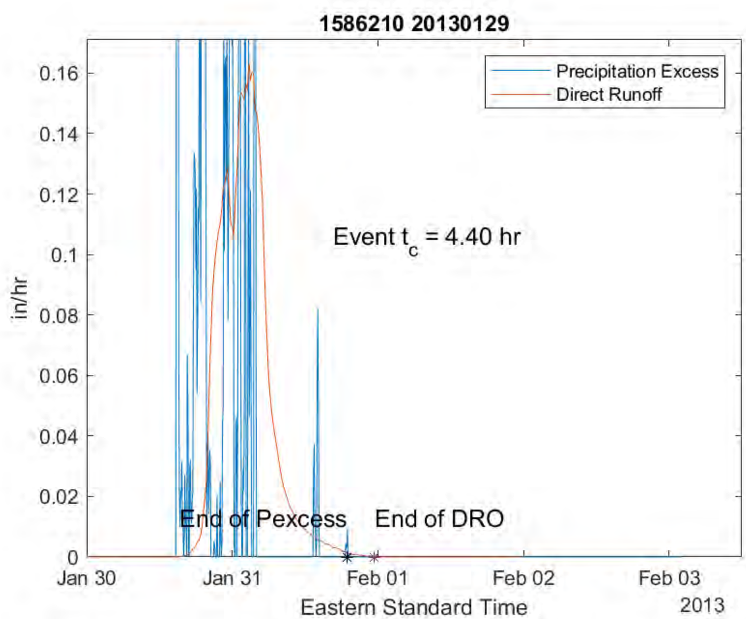

Input Data 1585230 20120628
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 29
Jun 30
Jul 01
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.5426 in
Total P = 0.54233 in
[in/hr]
Jun 30, 00:00
Jun 30, 04:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jun 29, 22:00
Jun 30, 02:00
DRO [cfs per sq mi] per inch Pexcess
m 4.9 8.3
t(peak) 0.3 0.35
PRF 560 734
t(infl) 0.3 0.4

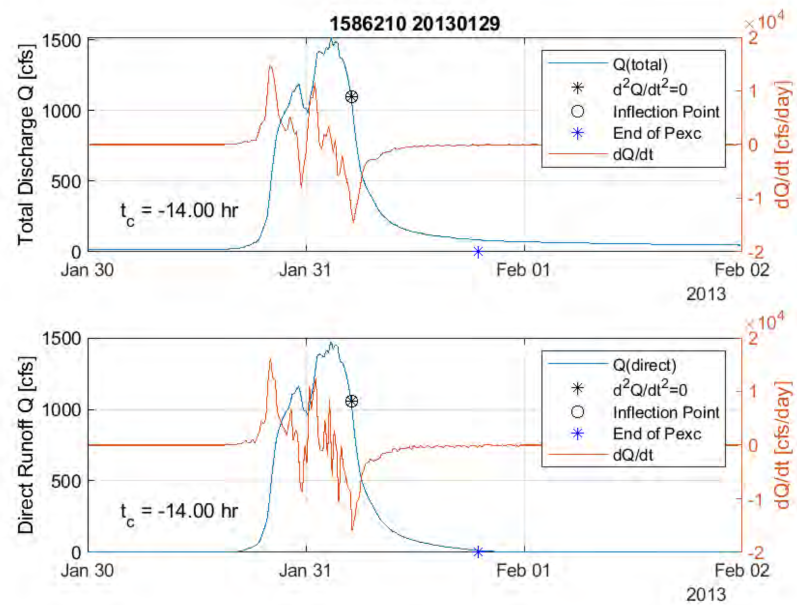

1586000 20130129
Event Direct Runoff [in] =1.2649
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1586000 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.2649
Phi = 0.070354
in/hr
Eastern Standard Time
1586000 20130129
Precipitation Excess
Direct Runoff
Event t_c = 12.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1586000 20130129
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -7.05 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -7.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

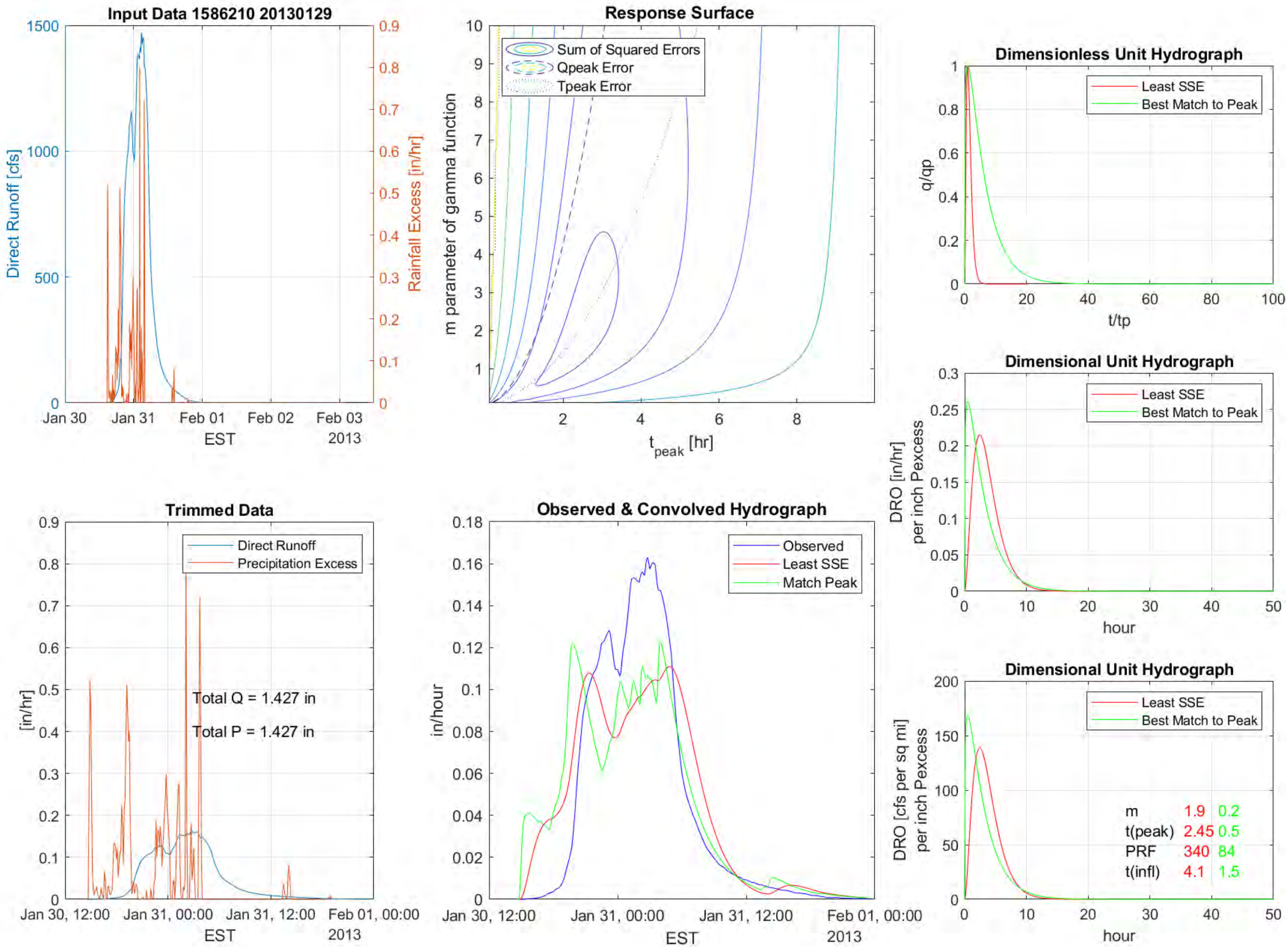

Input Data 1586000 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
Feb 03
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.265 in
Total P = 1.2649 in
[in/hr]
Jan 31, 00:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
DRO [cfs per sq mi] per inch Pexcess
m 2.5 40.8
t(peak) 3.6 8.25
PRF 394 1641
t(infl) 5.8 9.4


1586210 20130129
Event Direct Runoff [in] =1.427
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

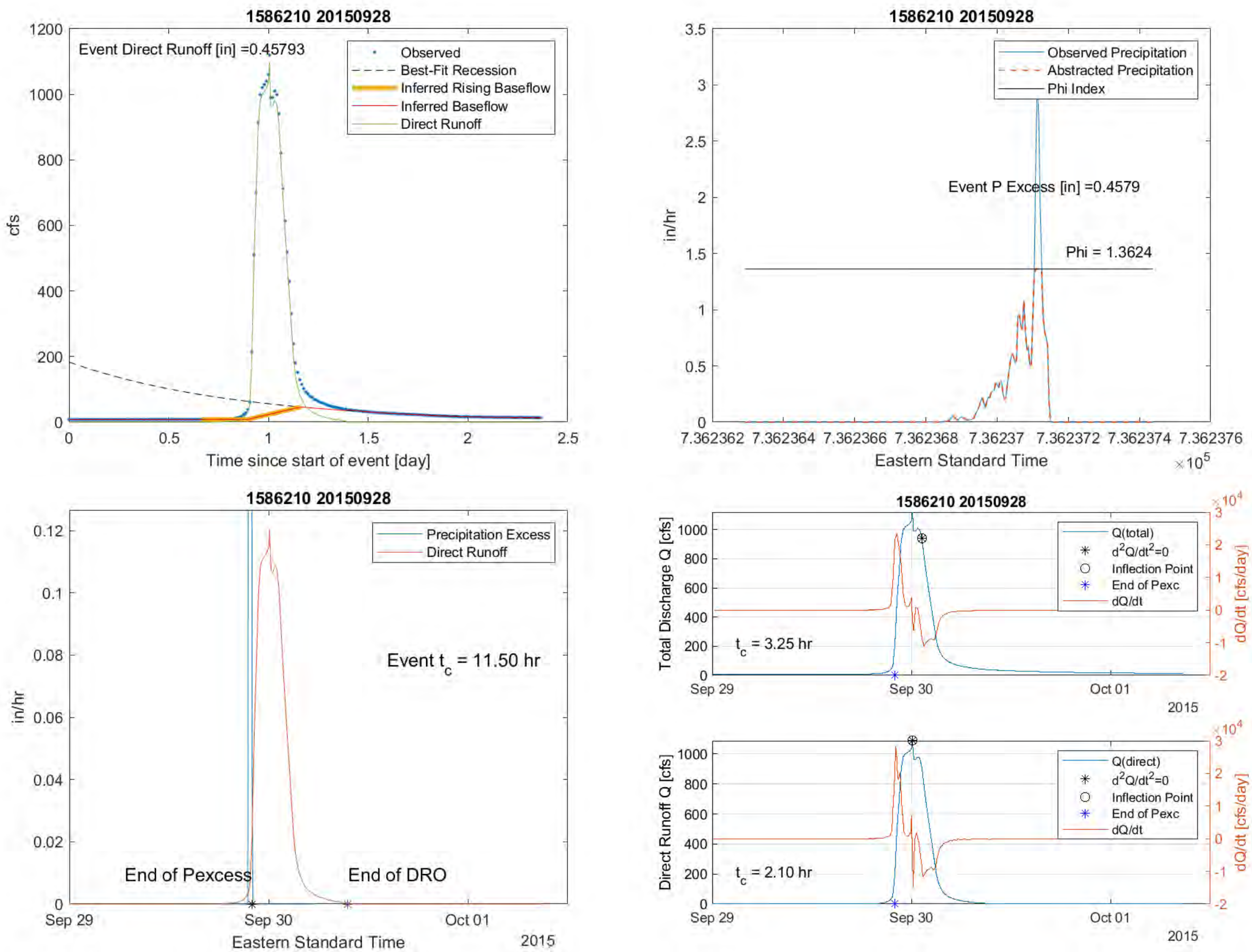

1586210 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.427
Phi = 0.038714
in/hr
Eastern Standard Time
×10^5

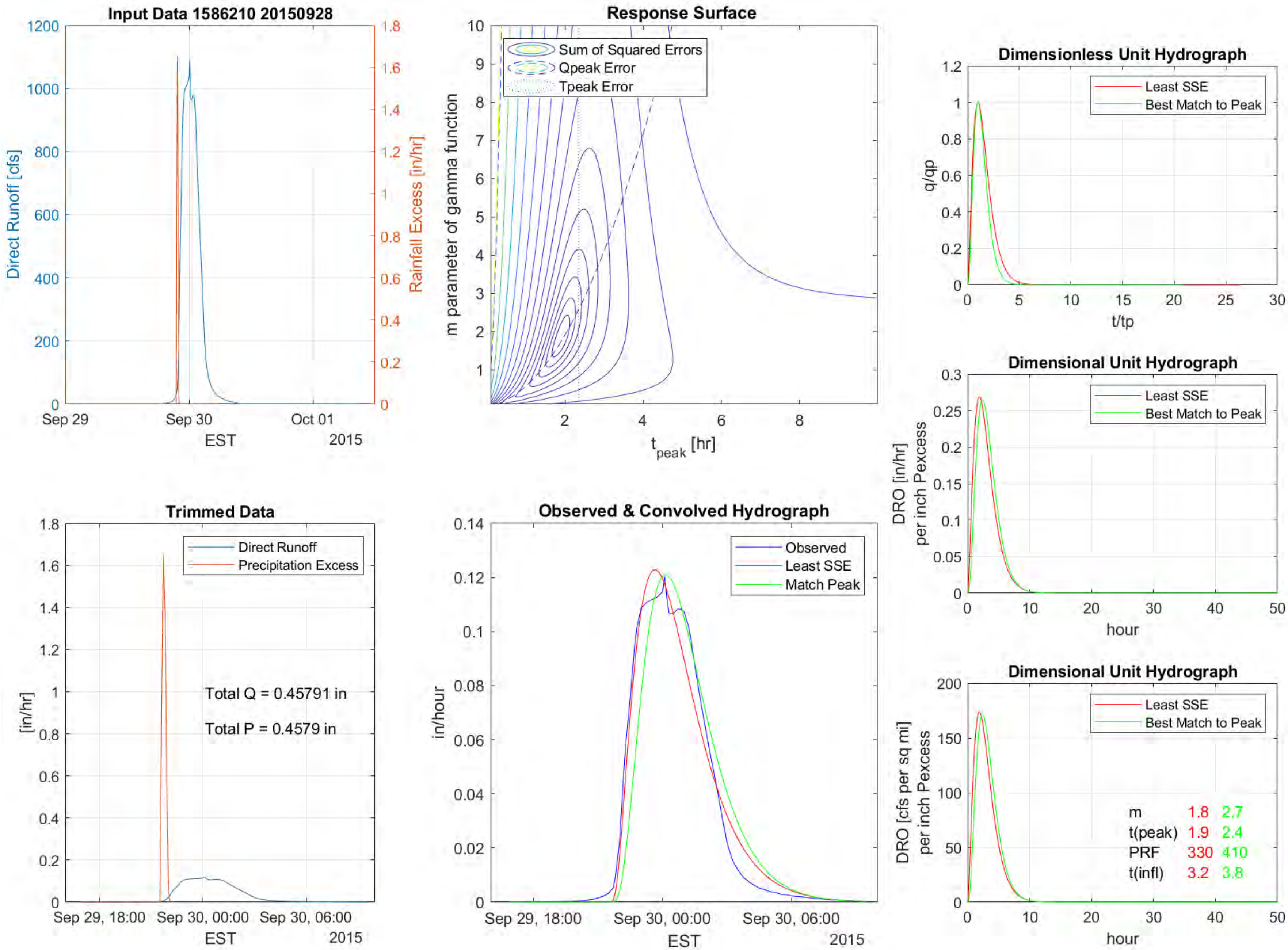

1586210 20130129
Precipitation Excess
Direct Runoff
Event t_c = 4.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2013


1586210 20130129
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -14.00 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
×10^4
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -14.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
×10^4
2013

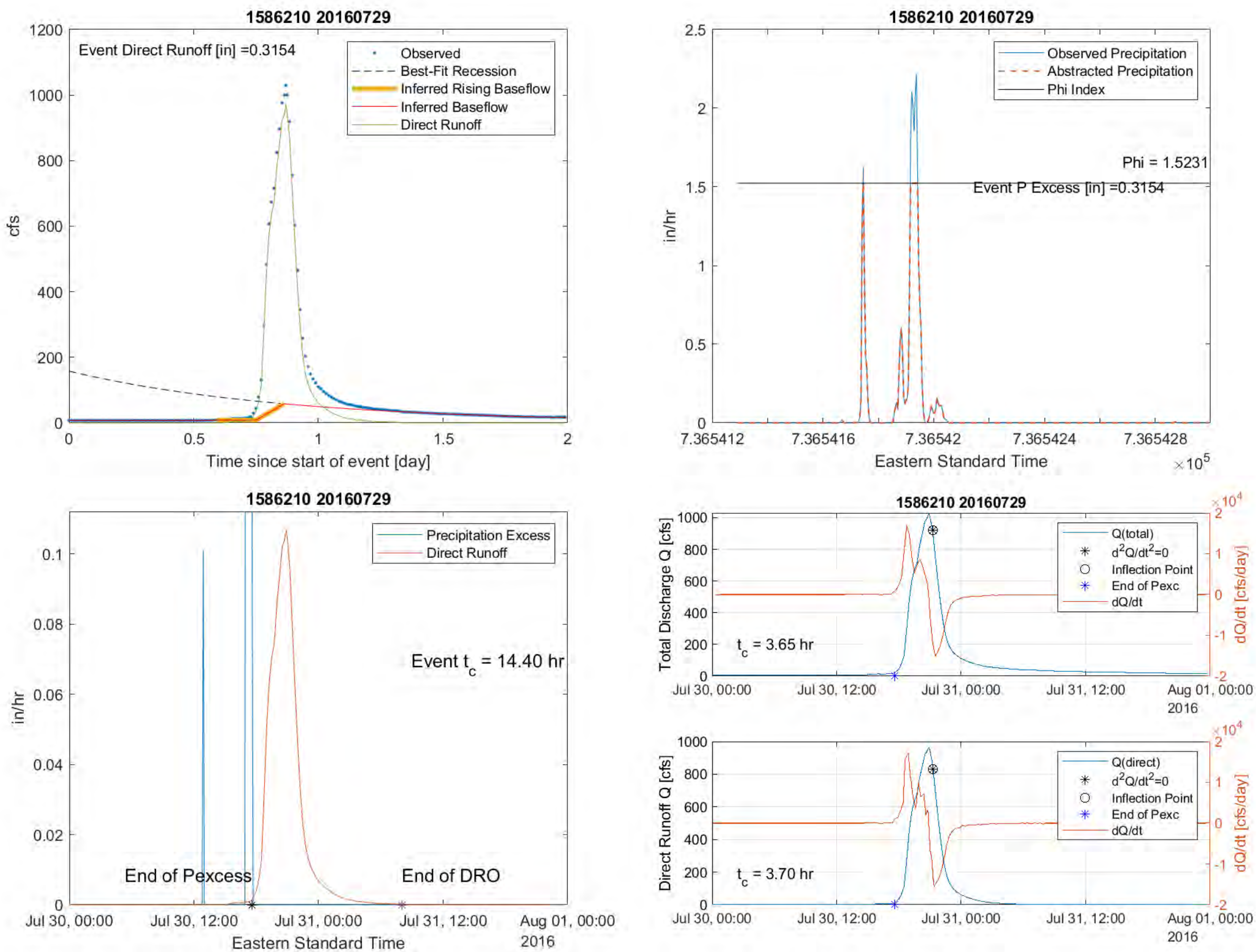


Input Data 1586210 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
Feb 03
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.427 in
Total P = 1.427 in
[in/hr]
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.9 0.2
t(peak) 2.45 0.5
PRF 340 84
t(infl) 4.1 1.5

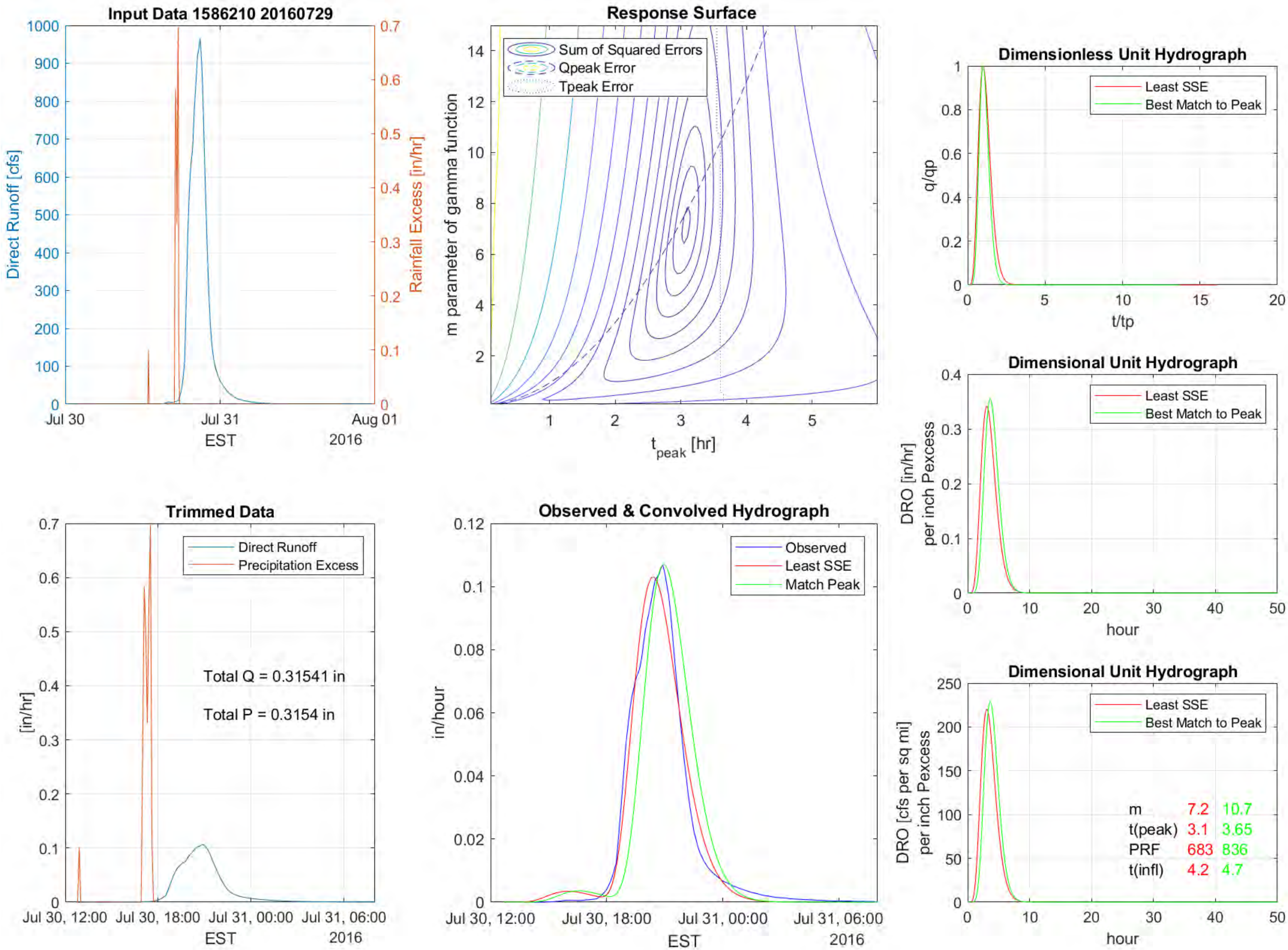

1586210 20150928
Event Direct Runoff [in] =0.45793
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
Event P Excess [in] =0.4579
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 1.3624
in/hr
Eastern Standard Time
Precipitation Excess
Direct Runoff
Event t_c = 11.50 hr
End of Pexcess
End of DRO
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 3.25 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 2.10 hr
Direct Runoff Q [cfs]
Sep 29
Sep 30
Oct 01
2015

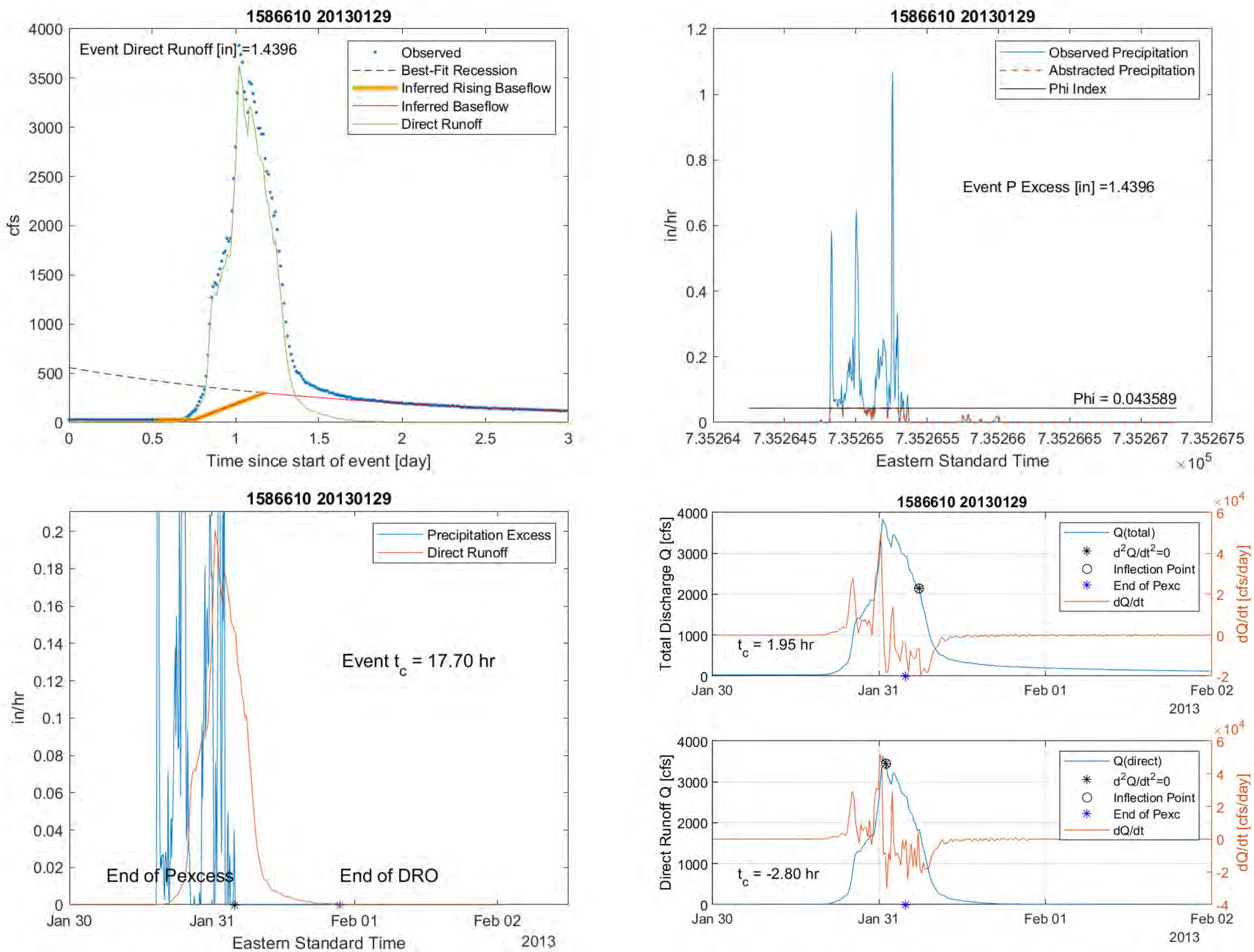


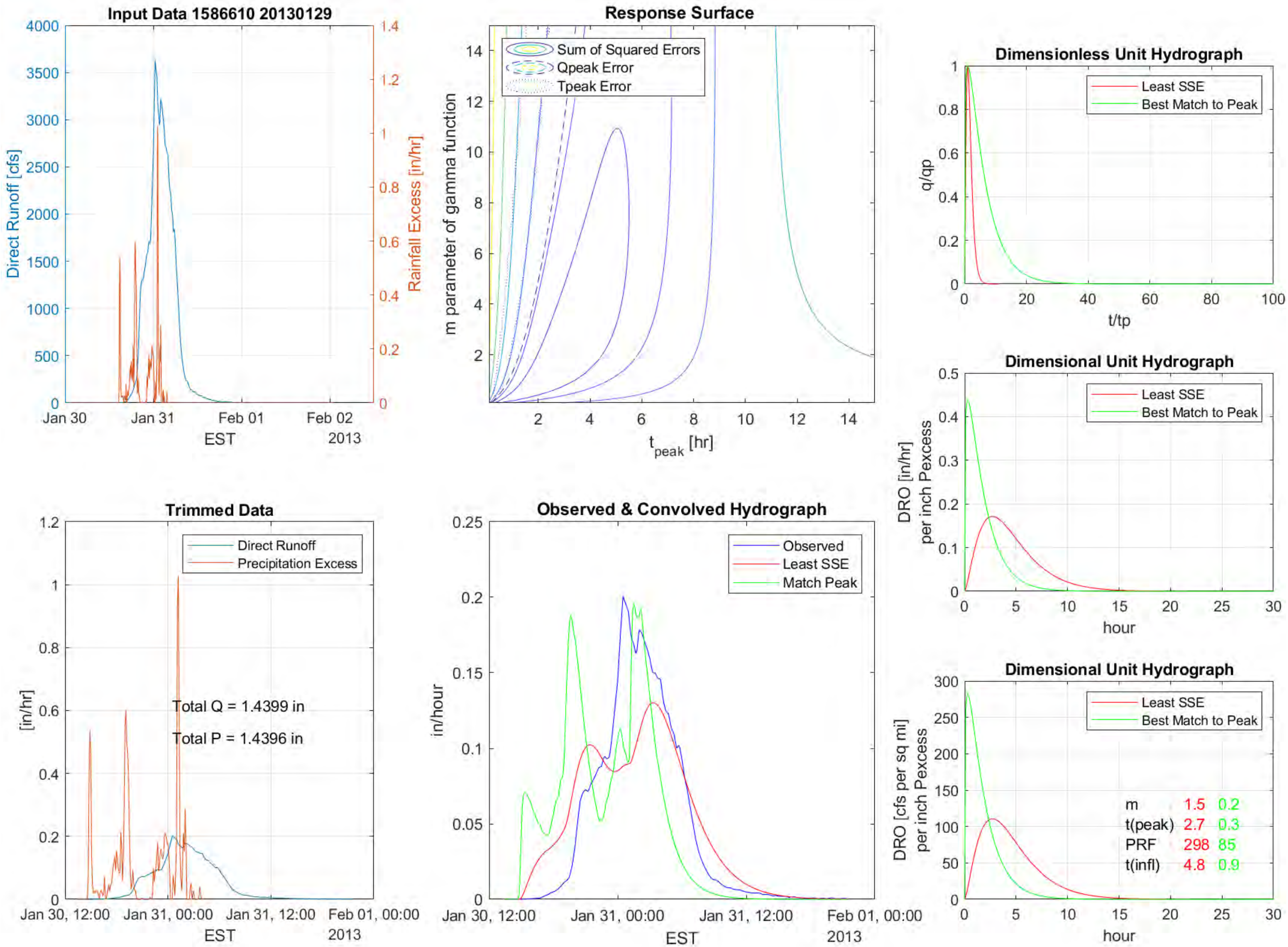
Input Data 1586210 20150928
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 29
Sep 30
Oct 01
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.45791 in
Total P = 0.4579 in
[in/hr]
Sep 29, 18:00
Sep 30, 00:00
Sep 30, 06:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.8 2.7
t(peak) 1.9 2.4
PRF 330 410
t(infl) 3.2 3.8



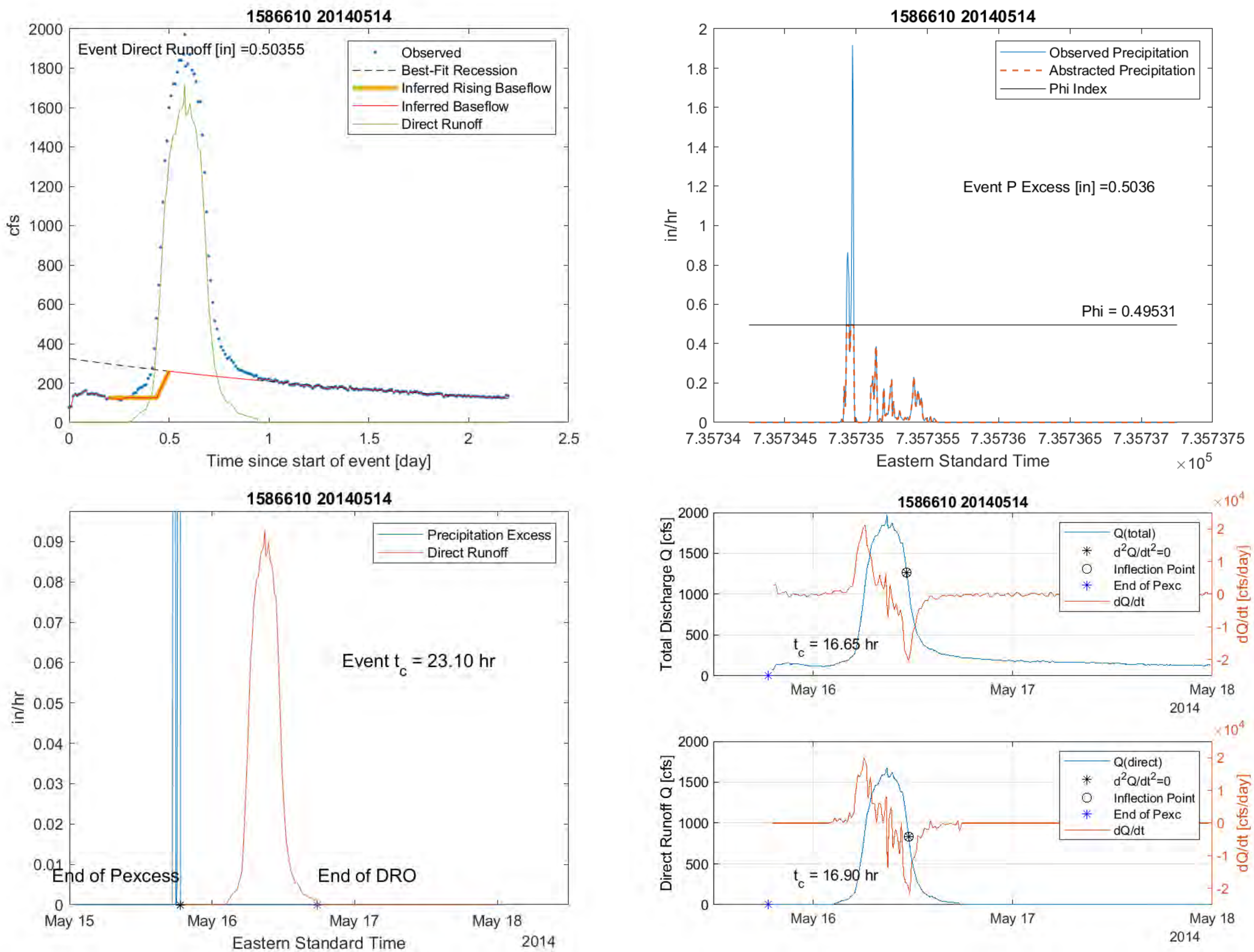
1586210 20160729
Event Direct Runoff [in] =0.3154
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1586210 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 1.5231
Event P Excess [in] =0.3154
in/hr
Eastern Standard Time
1586210 20160729
Precipitation Excess
Direct Runoff
Event t_c = 14.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1586210 20160729
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 3.65 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 3.70 hr
Direct Runoff Q [cfs]

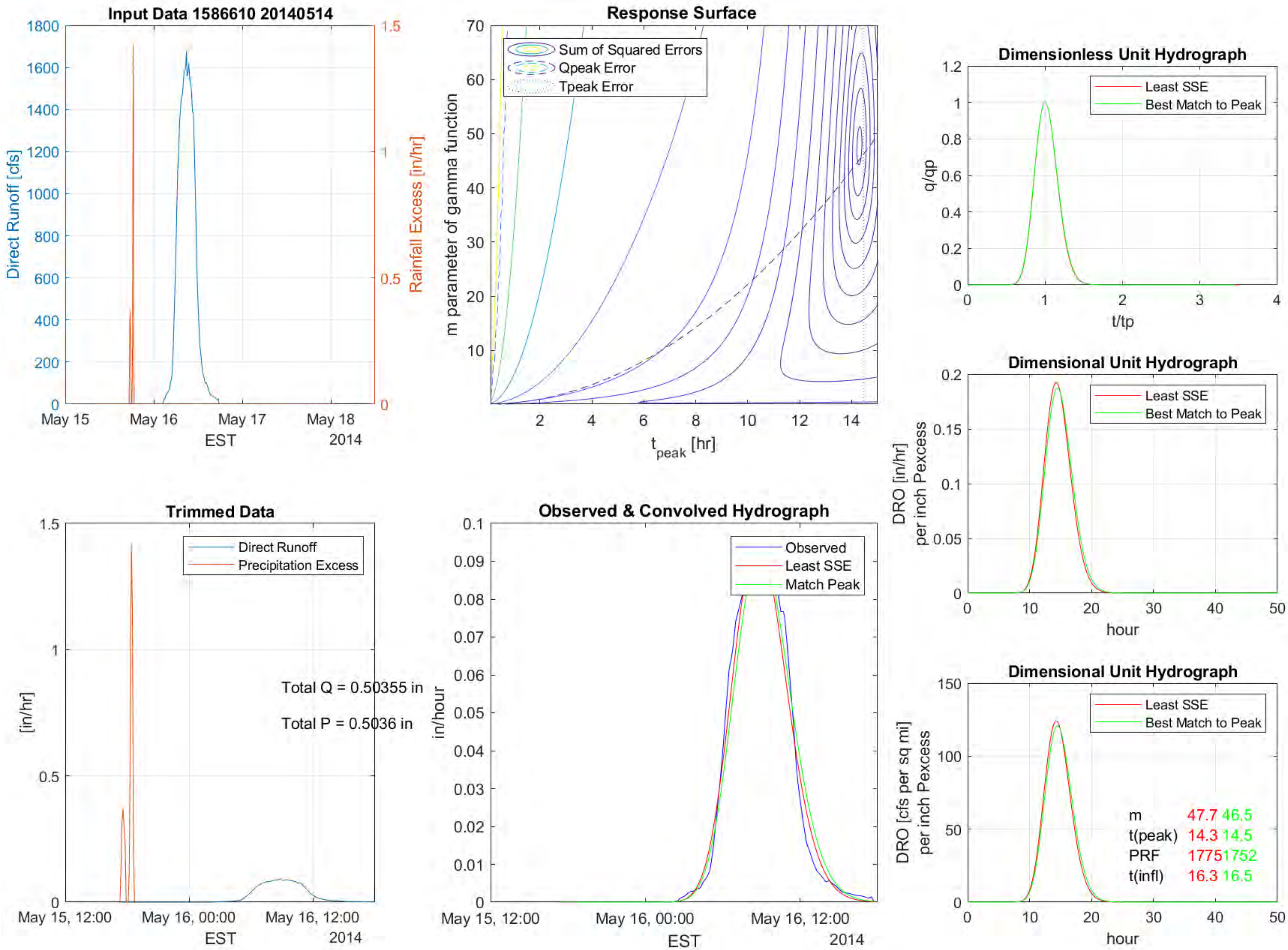

Input Data 1586210 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.31541 in
Total P = 0.3154 in
[in/hr]
Jul 30, 12:00
Jul 30, 18:00
Jul 31, 00:00
Jul 31, 06:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 7.2 10.7
t(peak) 3.1 3.65
PRF 683 836
t(infl) 4.2 4.7
hour

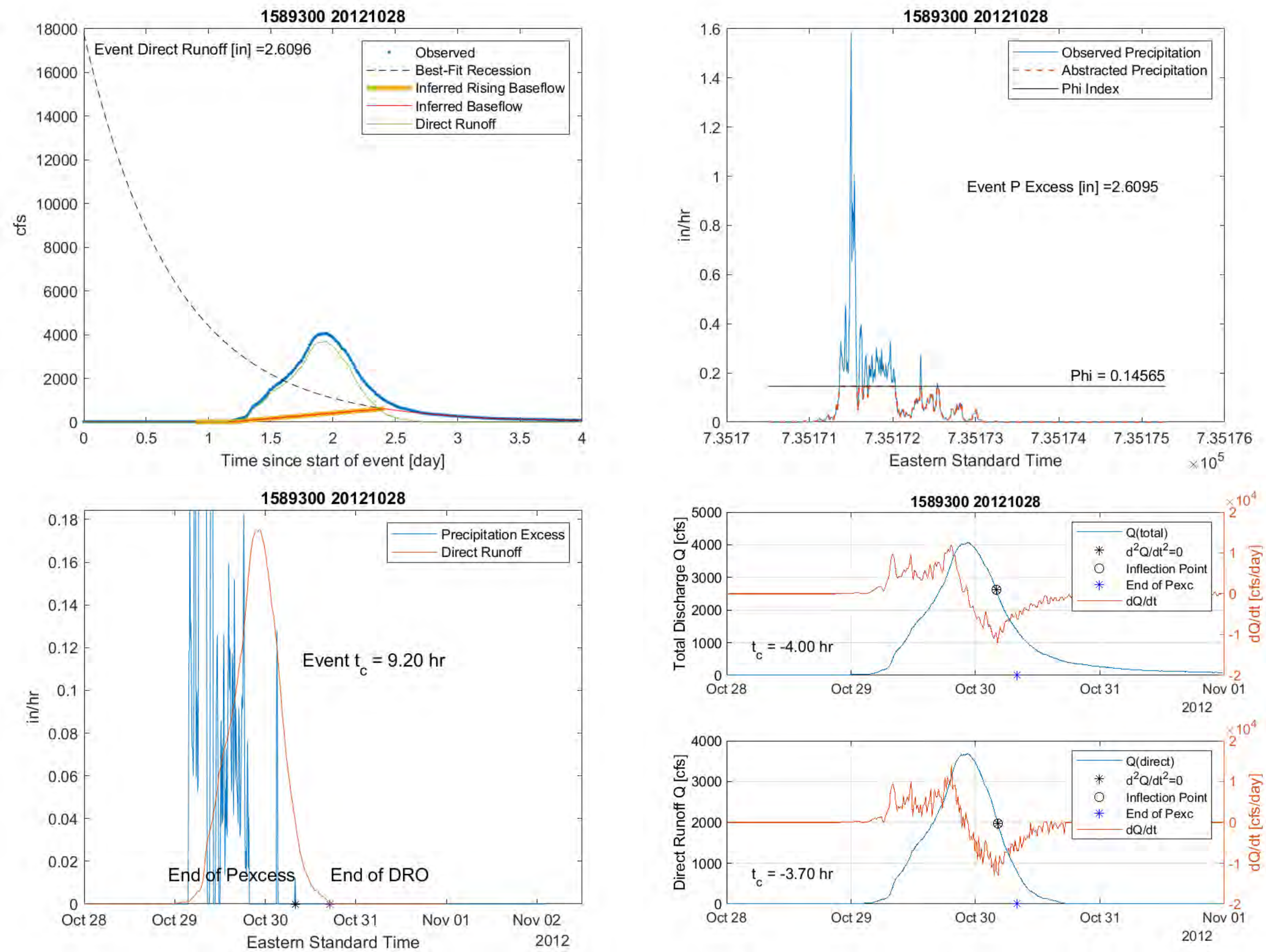

1586610 20130129
Event Direct Runoff [in] =1.4396
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1586610 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.4396
Phi = 0.043589
in/hr
Eastern Standard Time
1586610 20130129
Precipitation Excess
Direct Runoff
Event t_c = 17.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2013
1586610 20130129
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 1.95 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2013
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -2.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2013

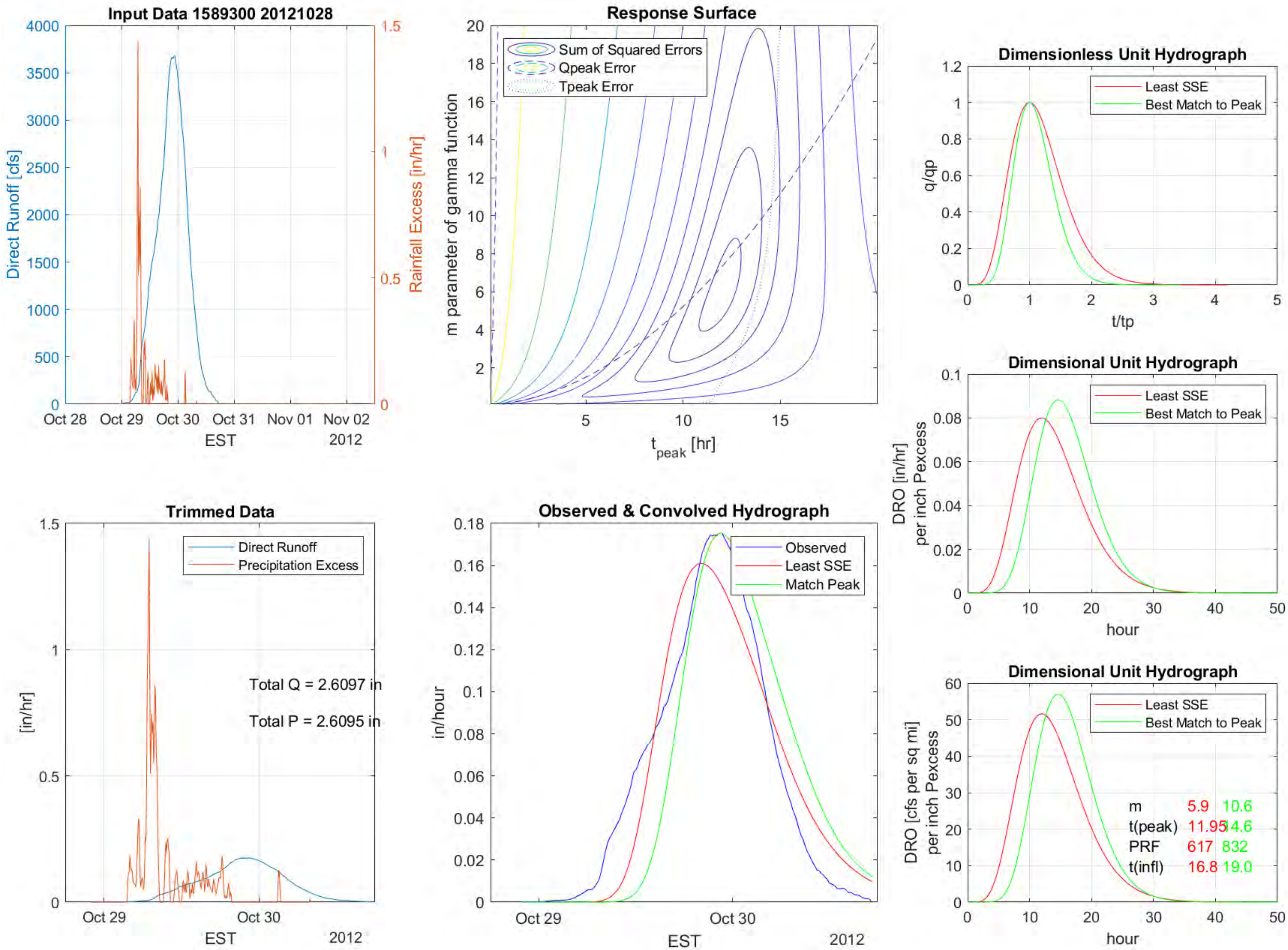


Input Data 1586610 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.4399 in
Total P = 1.4396 in
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.5 0.2
t(peak) 2.7 0.3
PRF 298 85
t(infl) 4.8 0.9

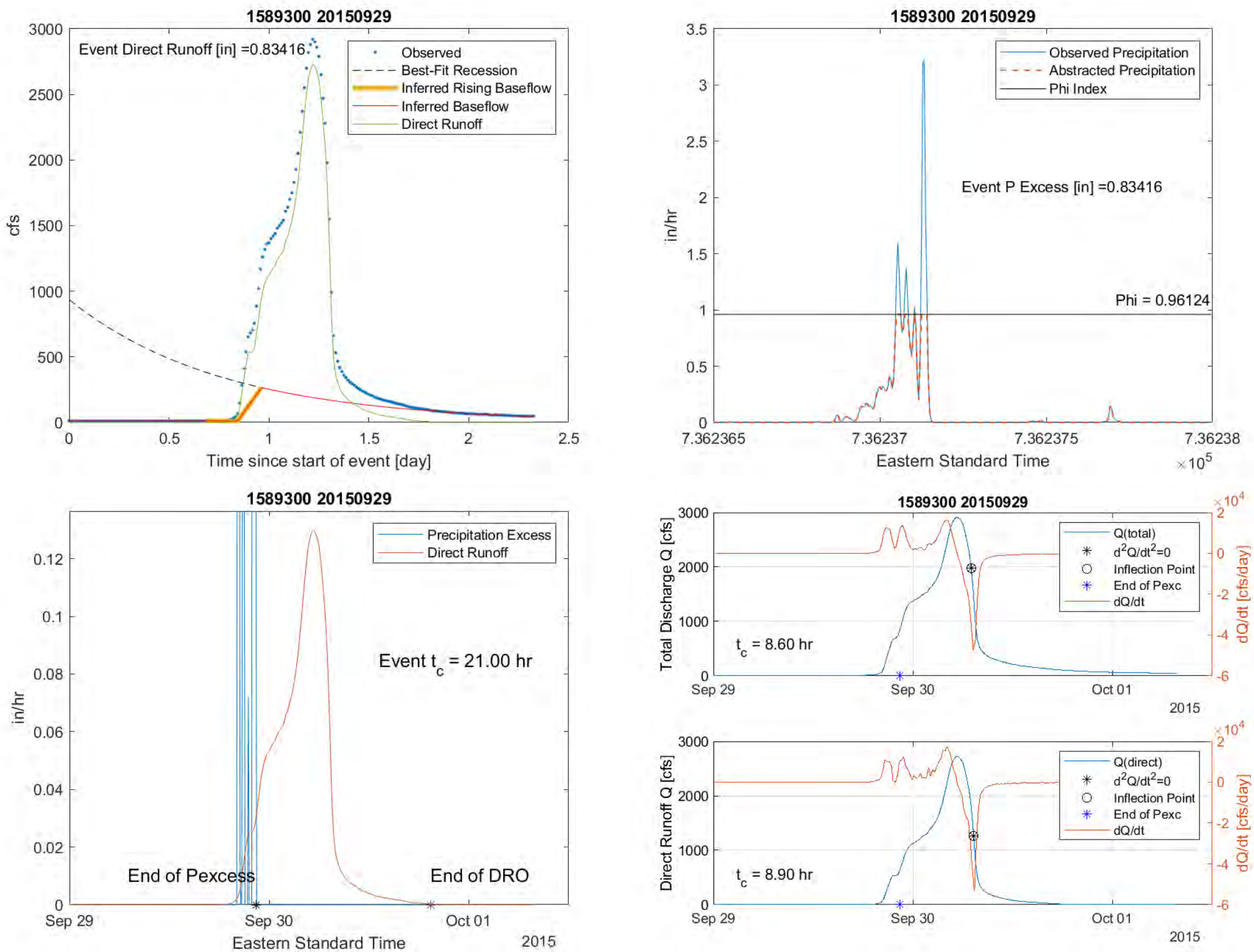

1586610 20140514
Event Direct Runoff [in] =0.50355
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1586610 20140514
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.5036
Phi = 0.49531
in/hr
Eastern Standard Time
1586610 20140514
Precipitation Excess
Direct Runoff
Event t_c = 23.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2014
1586610 20140514
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 16.65 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 16.90 hr
Direct Runoff Q [cfs]
May 16
May 17
May 18
2014

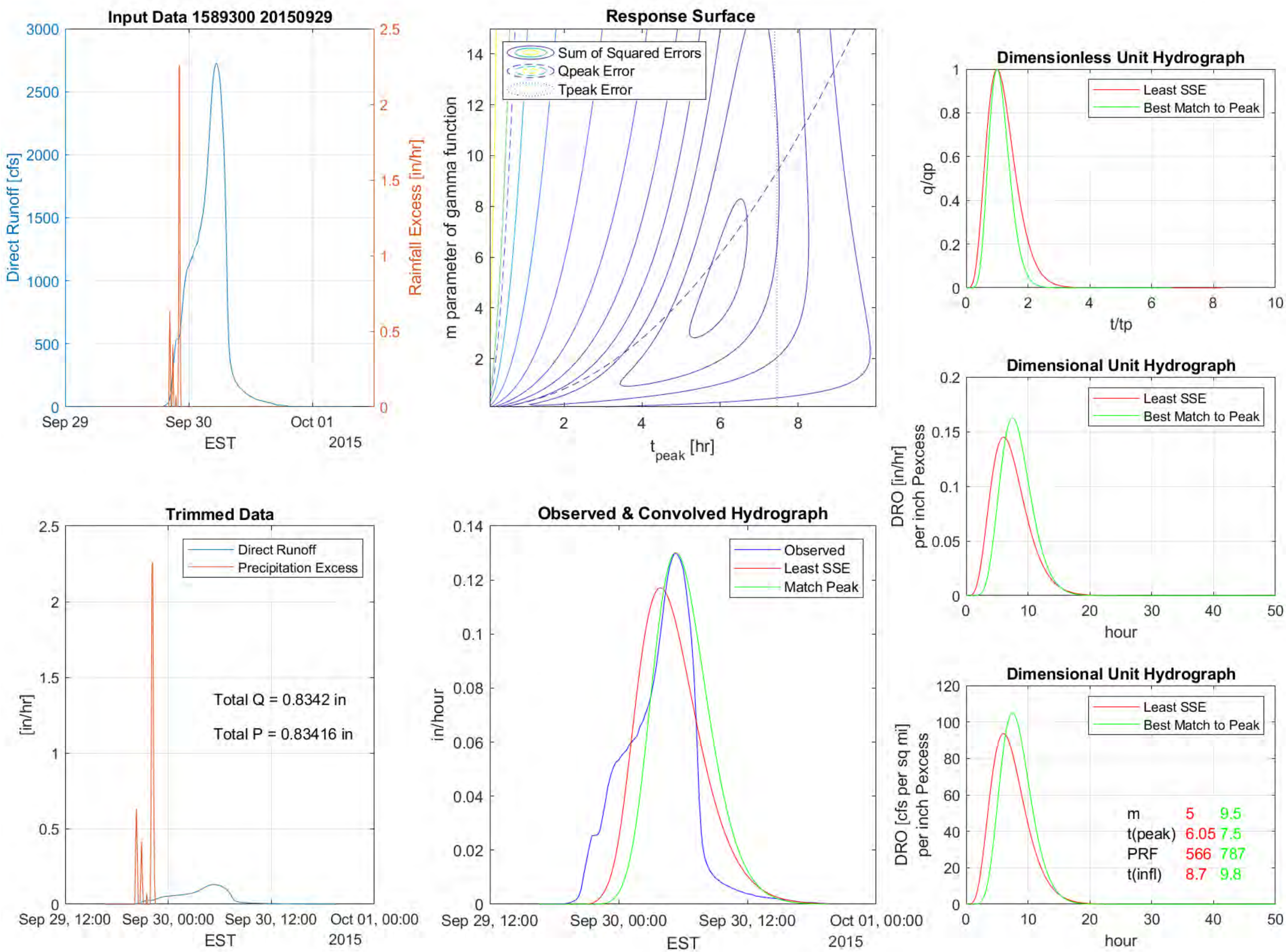

Input Data 1586610 20140514
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 15
May 16
May 17
May 18
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.50355 in
Total P = 0.5036 in
[in/hr]
May 15, 12:00
May 16, 00:00
May 16, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 47.7 46.5
t(peak) 14.3 14.5
PRF 1775 1752
t(infl) 16.3 16.5


1589300 20121028
Event Direct Runoff [in] =2.6096
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589300 20121028
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.6095
Phi = 0.14565
in/hr
Eastern Standard Time
1589300 20121028
Precipitation Excess
Direct Runoff
Event t_c = 9.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589300 20121028
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -4.00 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -3.70 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

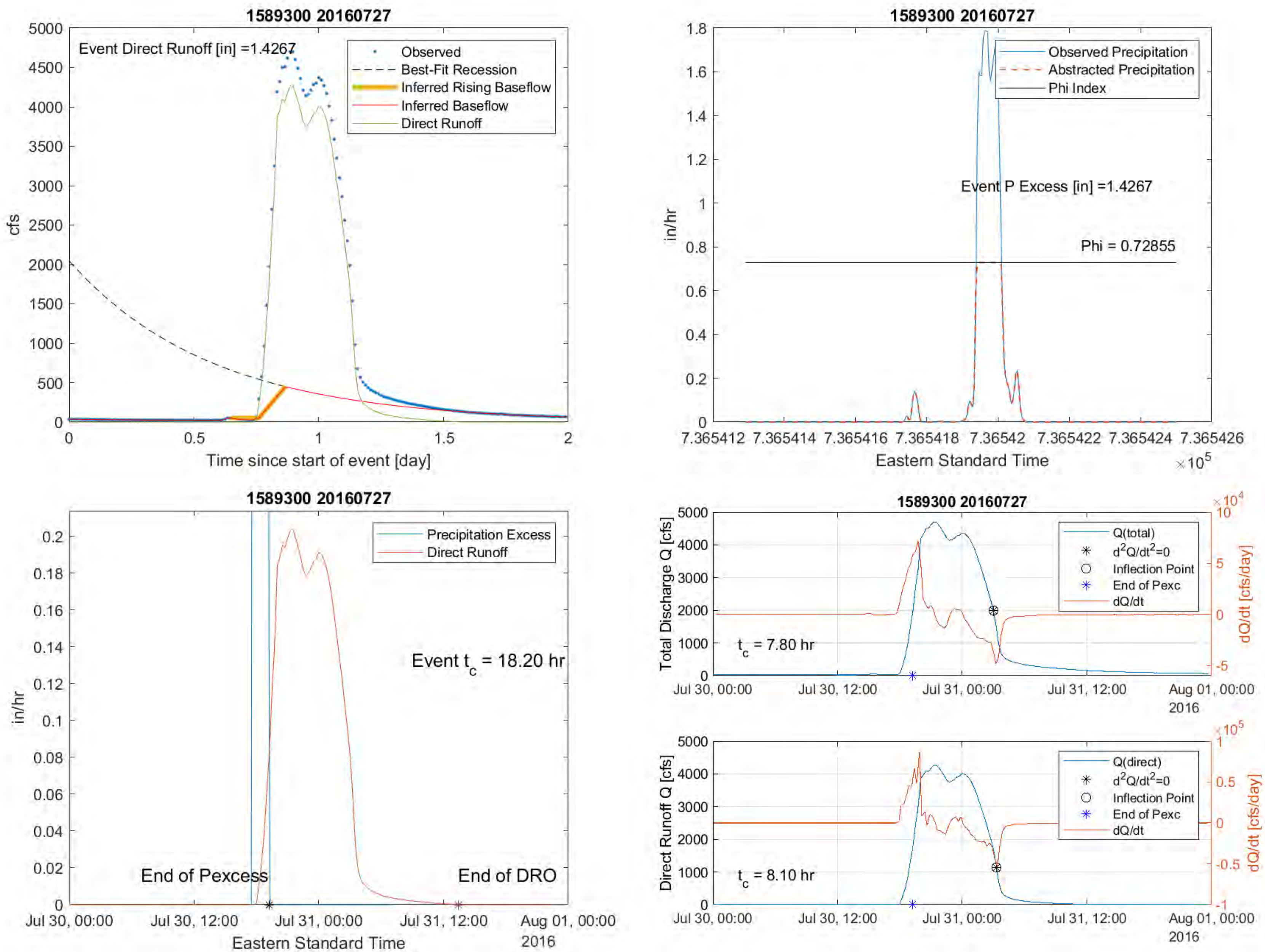


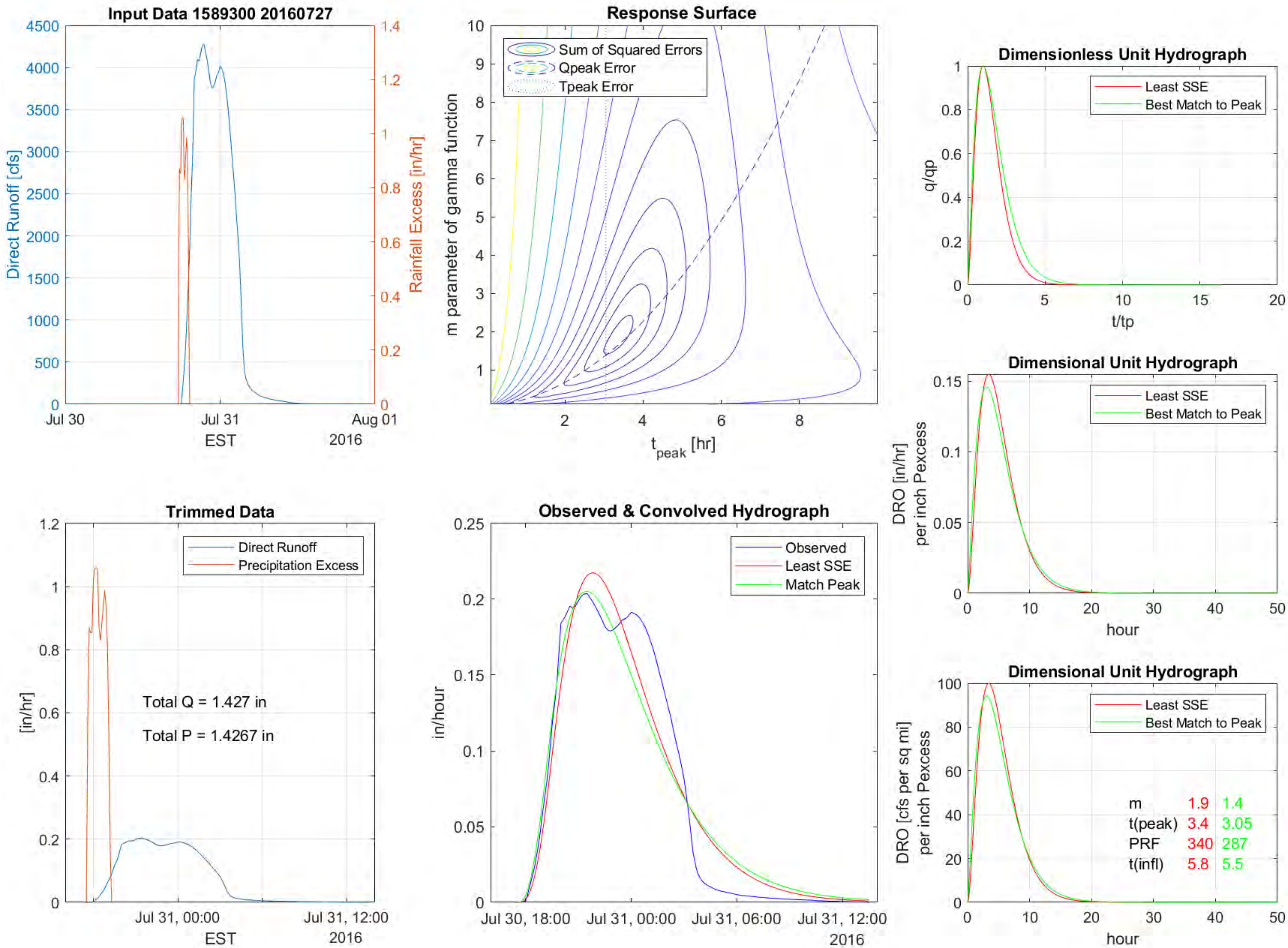
Input Data 1589300 20121028
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.6097 in
Total P = 2.6095 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.9 10.6
t(peak) 11.95 14.6
PRF 617 832
t(infl) 16.8 19.0

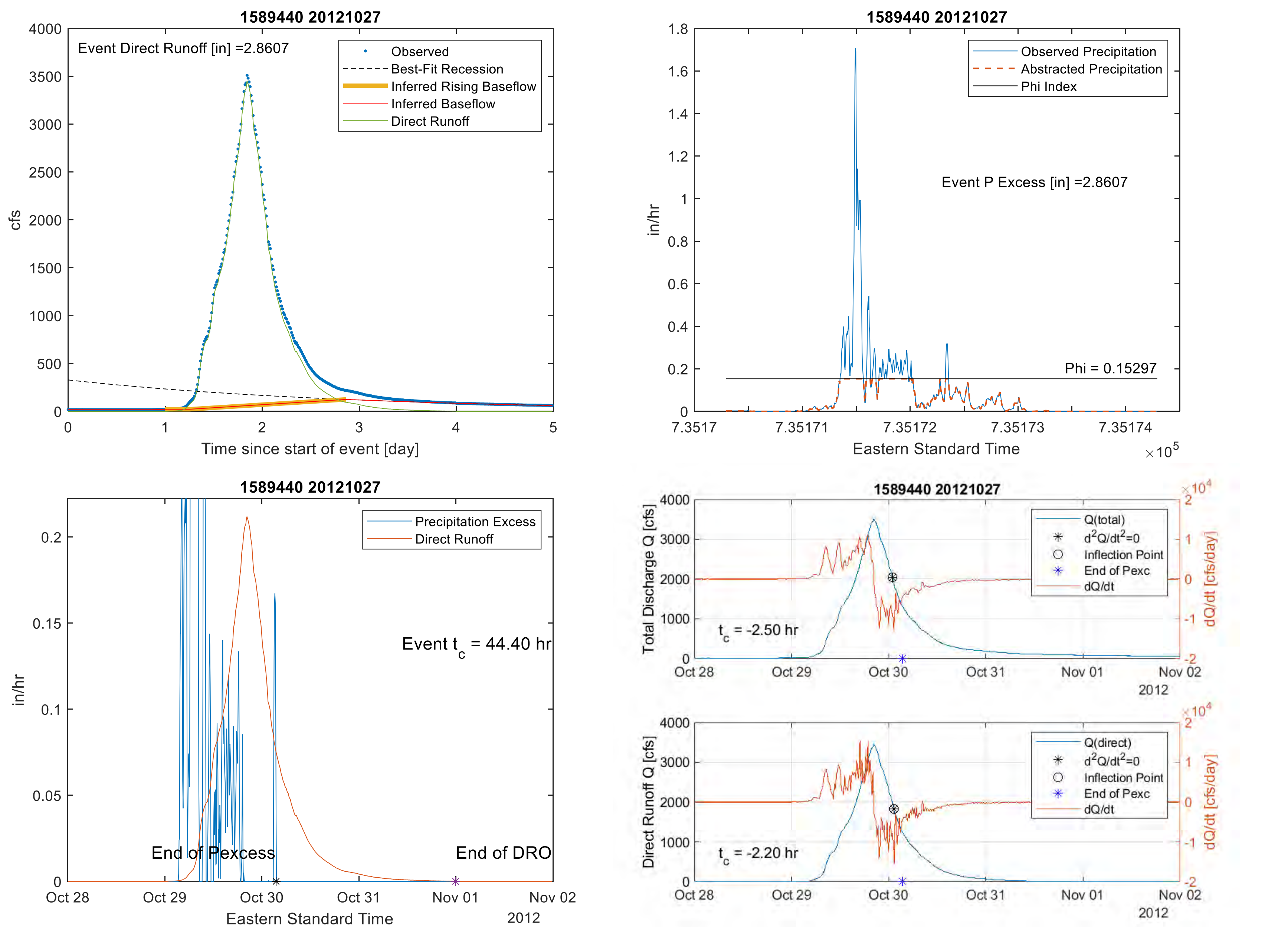

1589300 20150929
Event Direct Runoff [in] =0.83416
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589300 20150929
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.83416
Phi = 0.96124
in/hr
Eastern Standard Time
1589300 20150929
Precipitation Excess
Direct Runoff
Event t_c = 21.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589300 20150929
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 8.60 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 8.90 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
Sep 29
Sep 30
Oct 01
2015

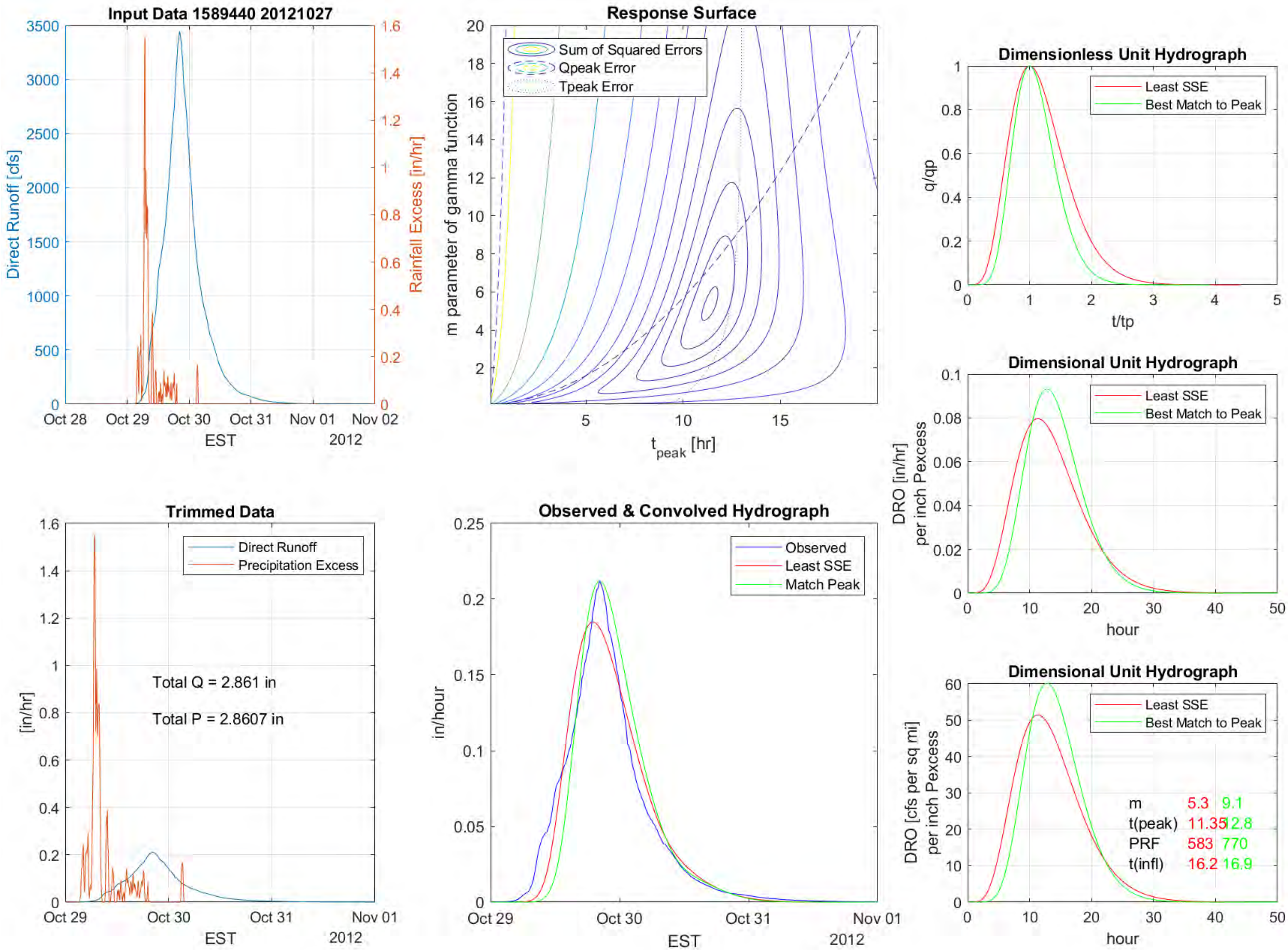


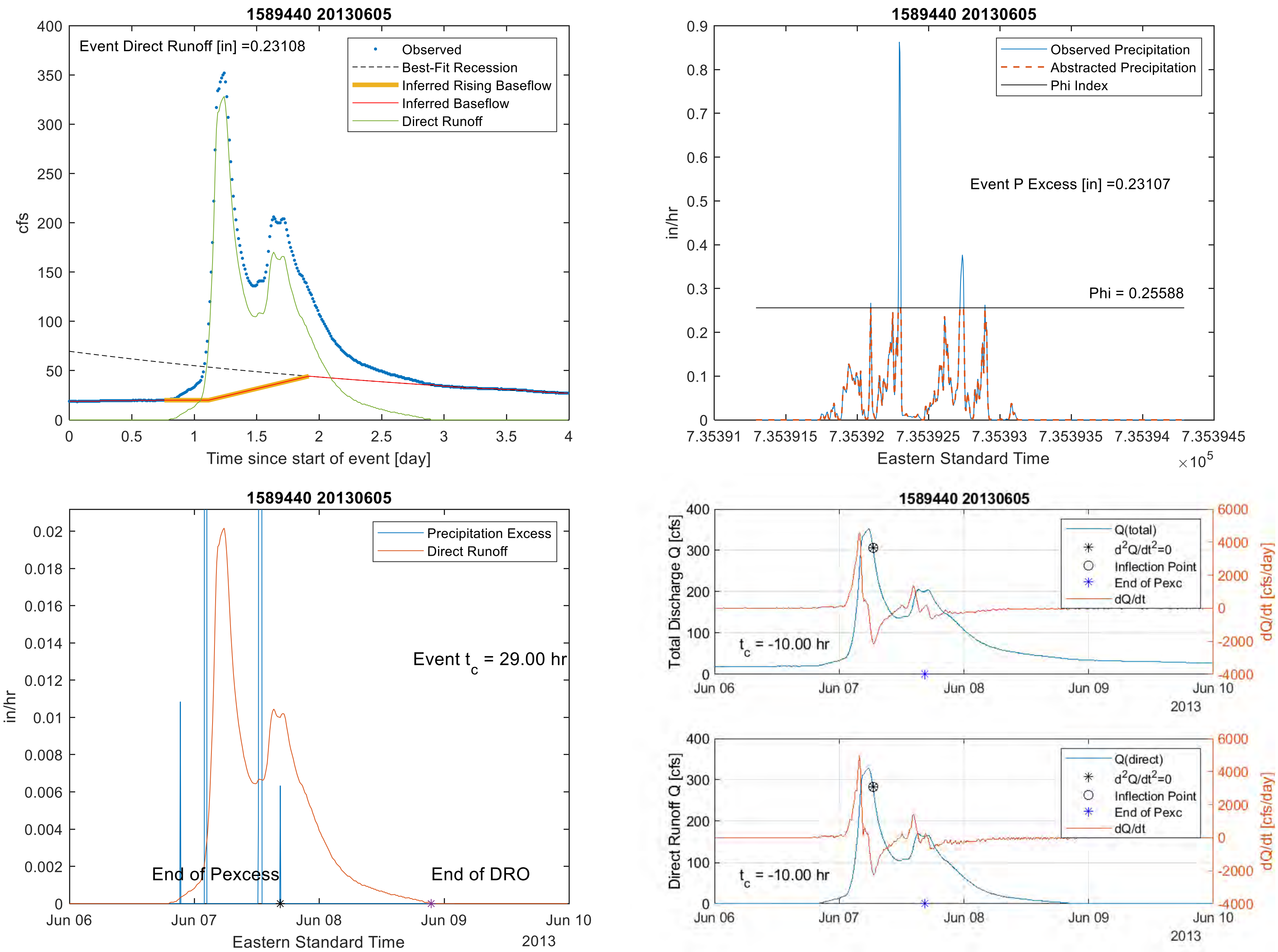
Input Data 1589300 20150929
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 29
Sep 30
Oct 01
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.8342 in
Total P = 0.83416 in
Sep 29, 12:00
Sep 30, 00:00
Sep 30, 12:00
Oct 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5 9.5
t(peak) 6.05 7.5
PRF 566 787
t(infl) 8.7 9.8

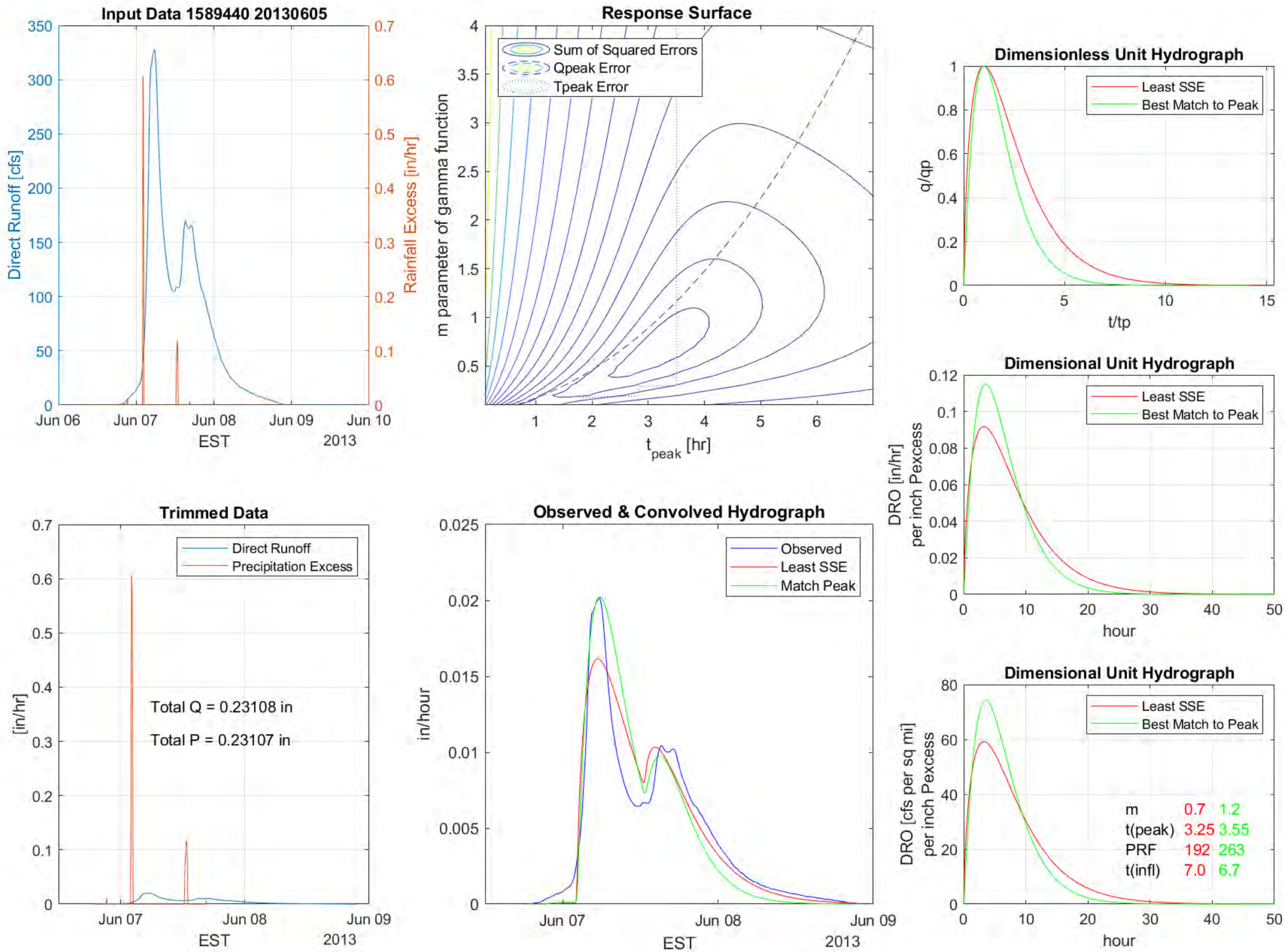

1589300 20160727
Event Direct Runoff [in] =1.4267
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589300 20160727
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.4267
Phi = 0.72855
in/hr
Eastern Standard Time
1589300 20160727
Precipitation Excess
Direct Runoff
Event t_c = 18.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589300 20160727
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 7.80 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 8.10 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]


Input Data 1589300 20160727
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.427 in
Total P = 1.4267 in
[in/hr]
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jul 30, 18:00
Jul 31, 00:00
Jul 31, 06:00
Jul 31, 12:00
2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 1.9 1.4
t(peak) 3.4 3.05
PRF 340 287
t(infl) 5.8 5.5
hour

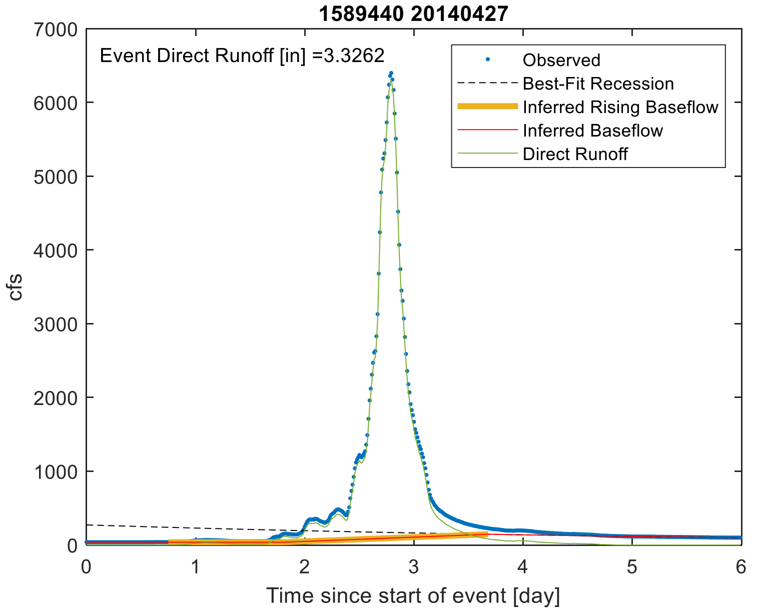

1589440 20121027
Event Direct Runoff [in] =2.8607
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.8607
Phi = 0.15297
in/hr
Eastern Standard Time
1589440 20121027
Precipitation Excess
Direct Runoff
Event t_c = 44.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589440 20121027
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -2.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -2.20 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

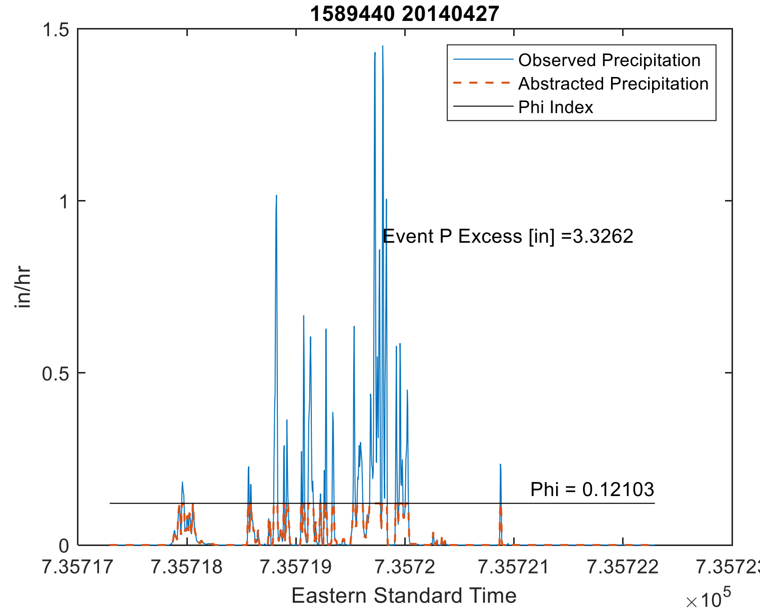

Input Data 1589440 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.861 in
Total P = 2.8607 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.3 9.1
t(peak) 11.35 12.8
PRF 583 770
t(infl) 16.2 16.9

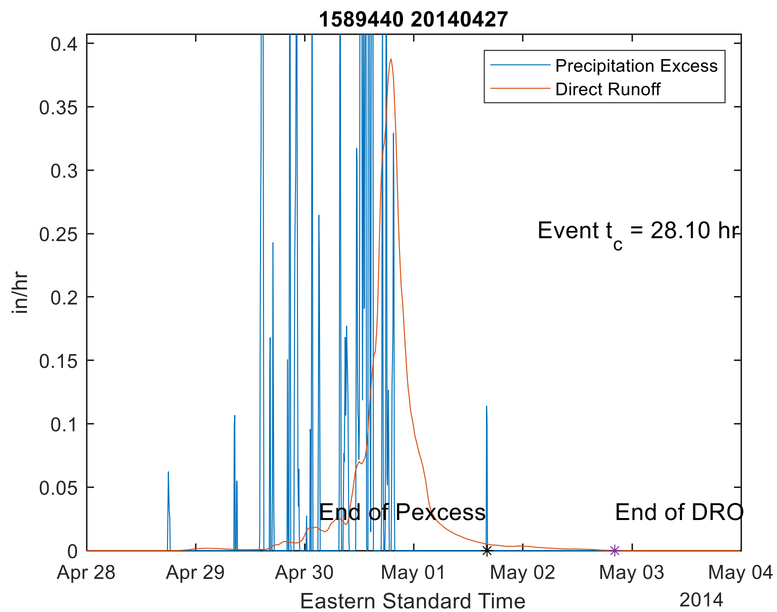

1589440 20130605
Event Direct Runoff [in] =0.23108
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20130605
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.23107
Phi = 0.25588
in/hr
Eastern Standard Time
×10^5
1589440 20130605
Precipitation Excess
Direct Runoff
Event t c = 29.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2013
1589440 20130605
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = -10.00 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2013
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = -10.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2013

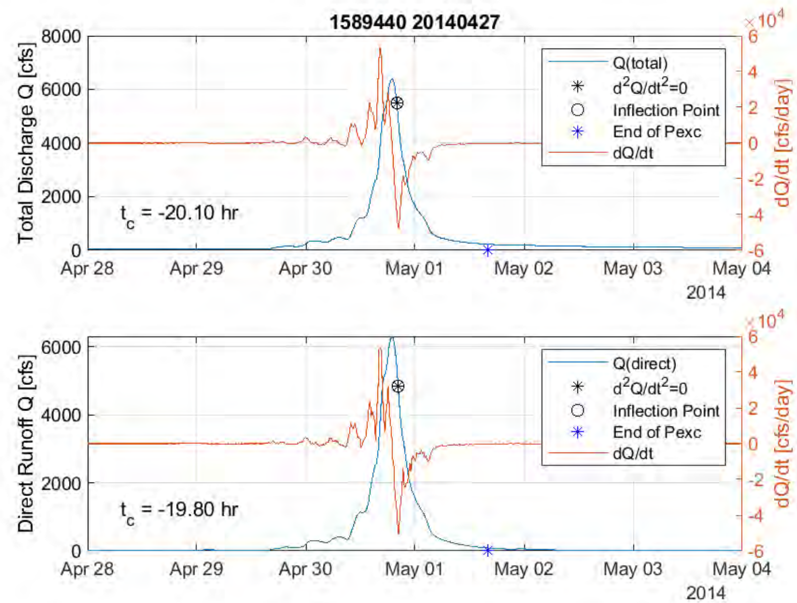


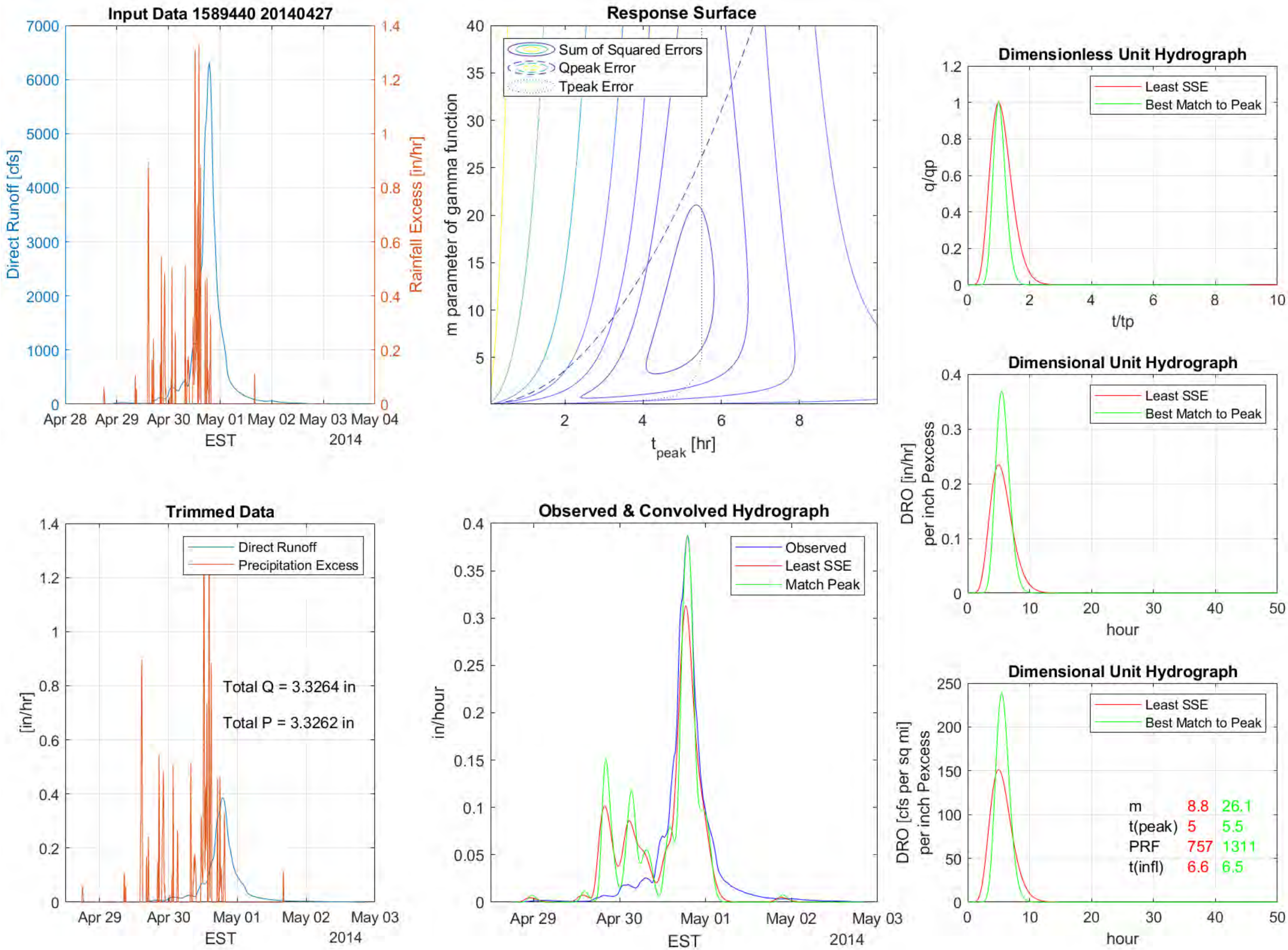
Input Data 1589440 20130605
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 06
Jun 07
Jun 08
Jun 09
Jun 10
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.23108 in
Total P = 0.23107 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 0.7 1.2
t(peak) 3.25 3.55
PRF 192 263
t(infl) 7.0 6.7


1589440 20140427
Event Direct Runoff [in] =3.3262
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

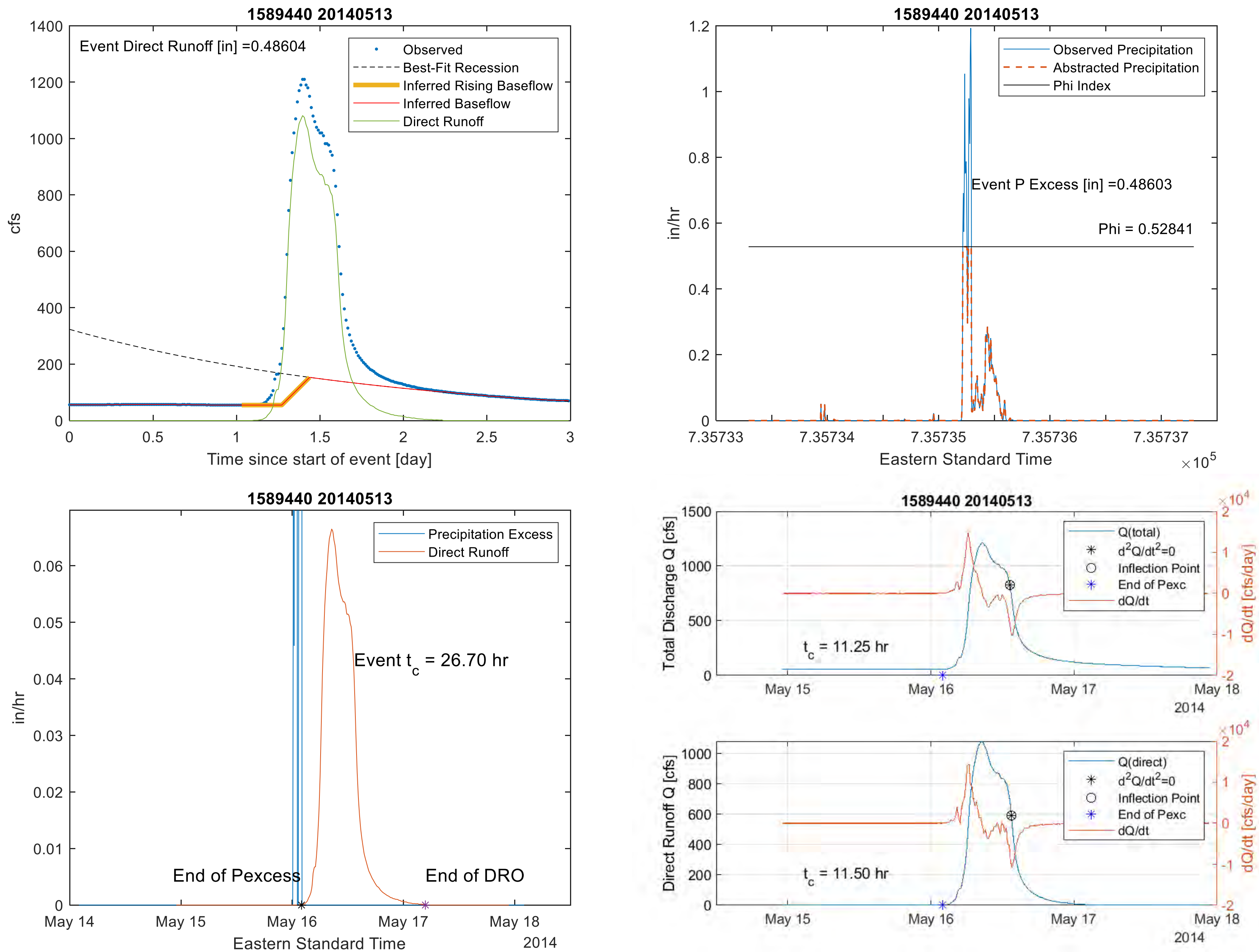

1589440 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =3.3262
Phi = 0.12103
in/hr
Eastern Standard Time
×10^5

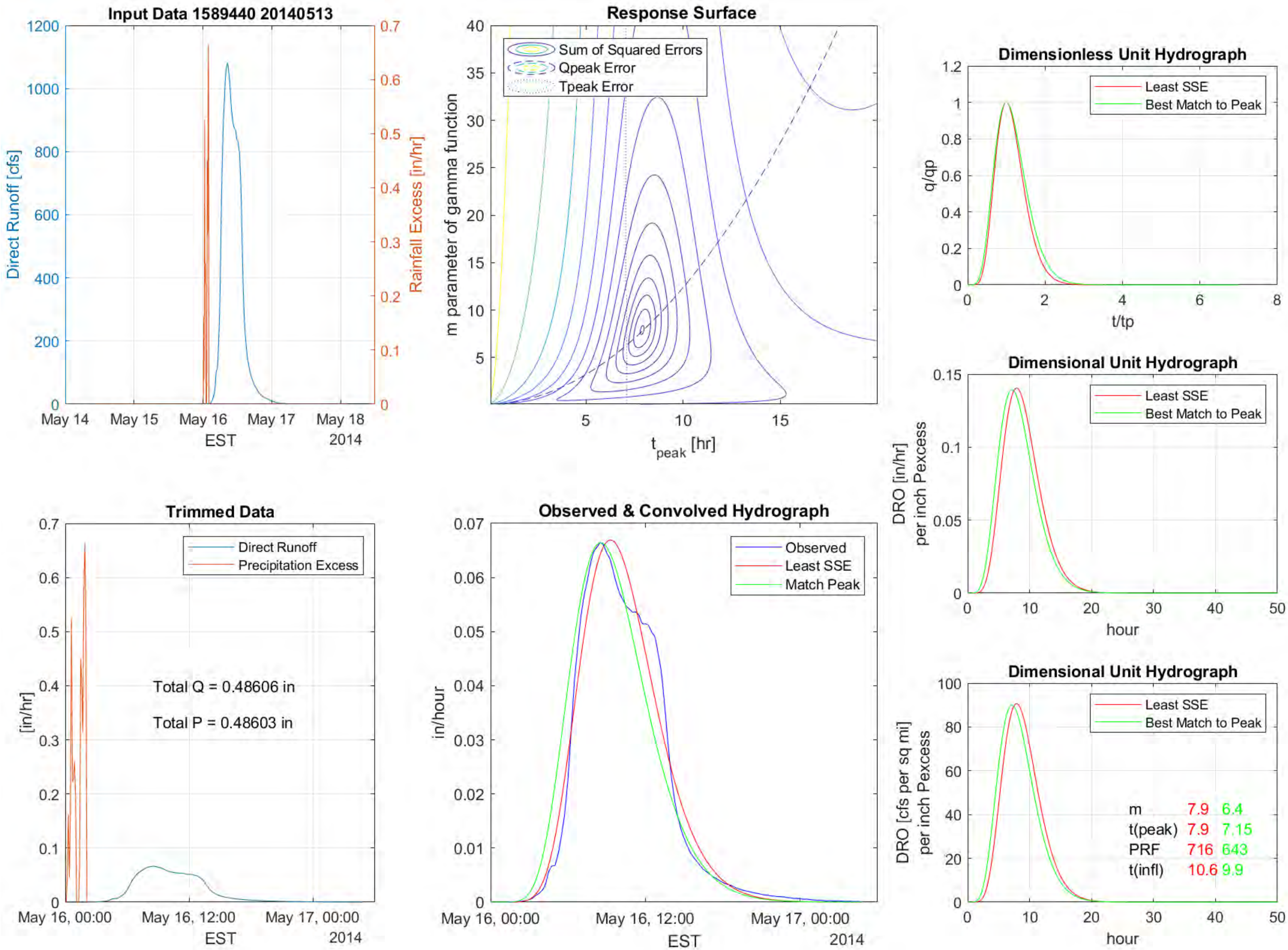

1589440 20140427
Precipitation Excess
Direct Runoff
Event t_c = 28.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2014

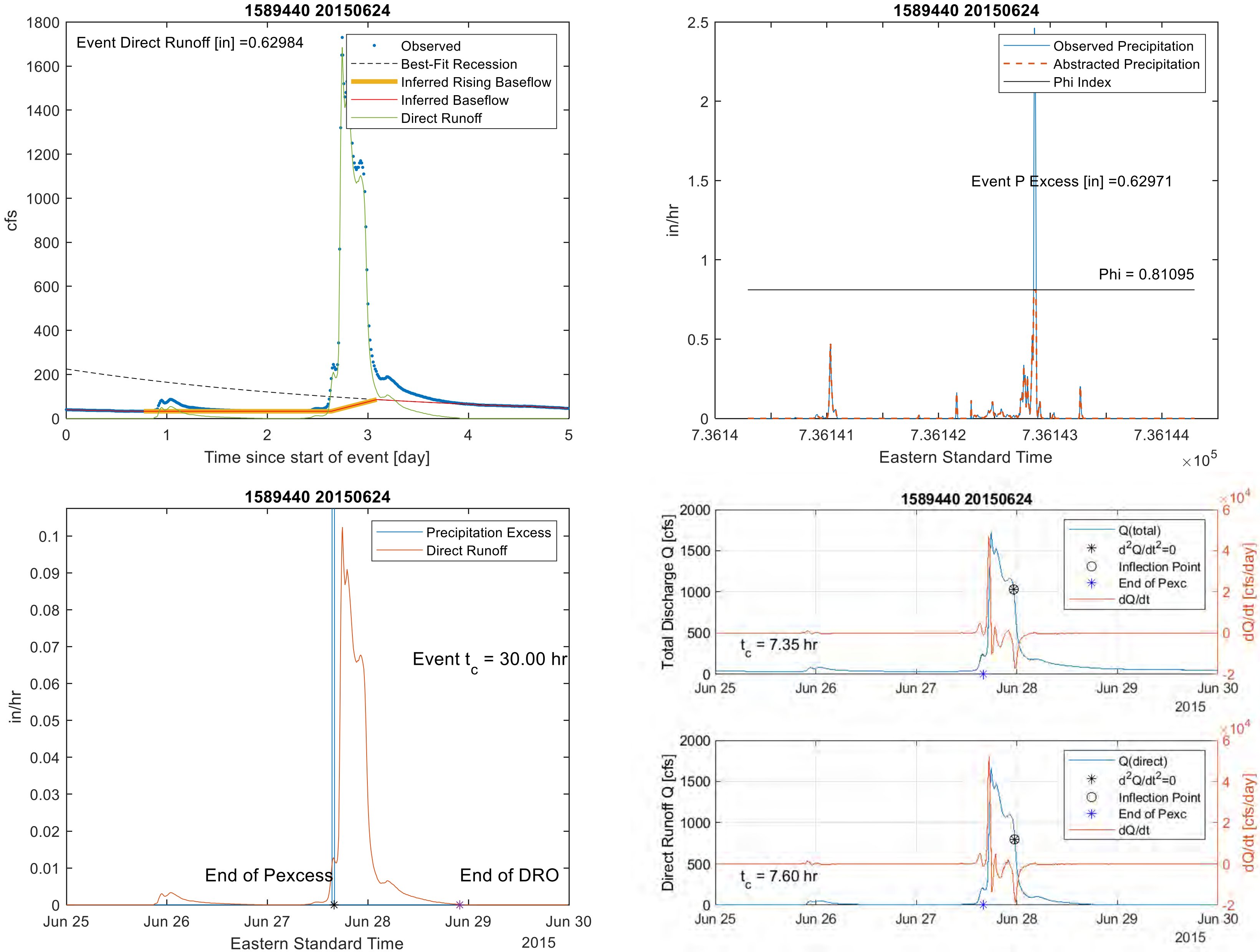

1589440 20140427
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -20.10 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = -19.80 hr
Direct Runoff Q [cfs]
2014



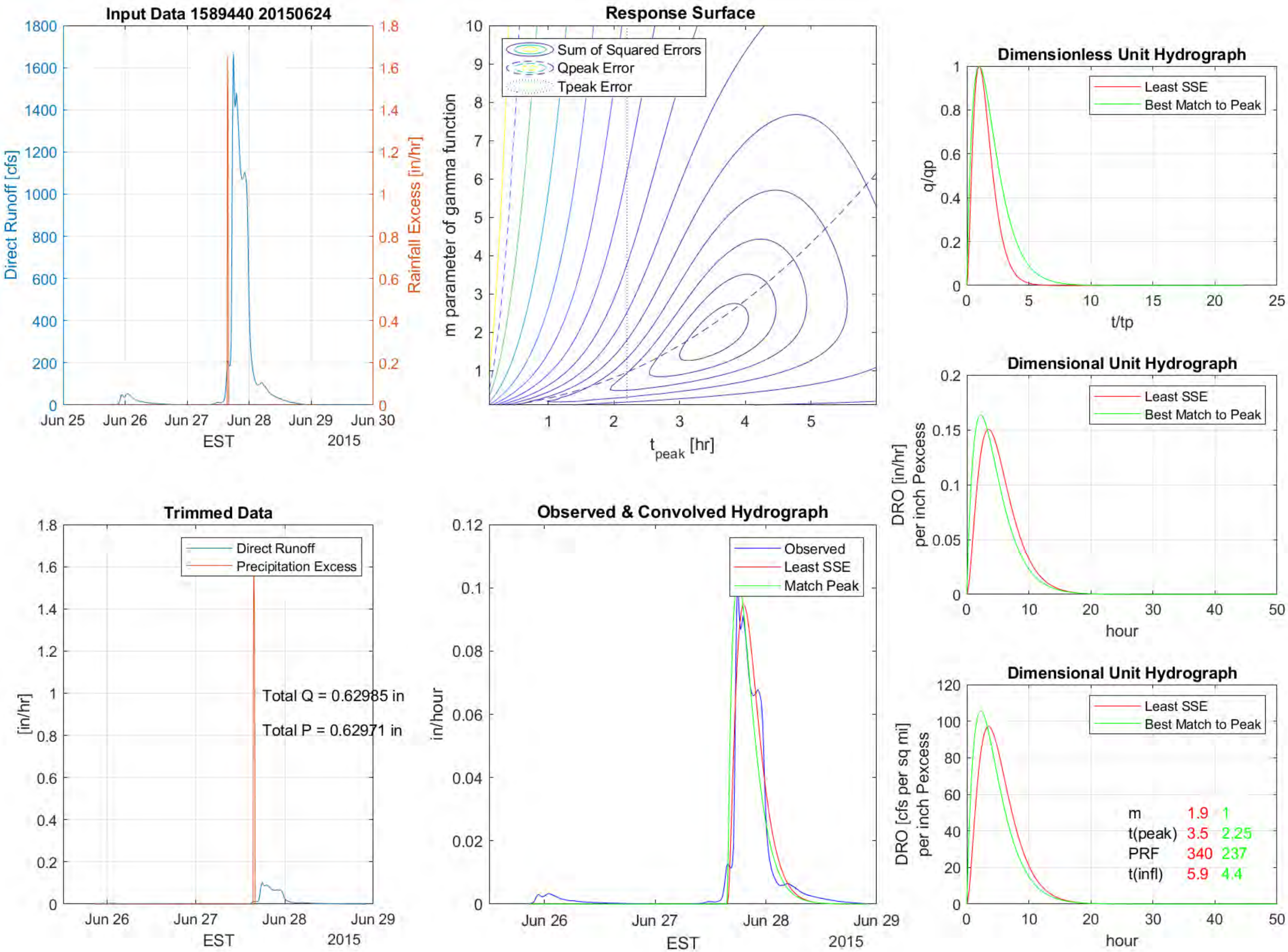
Input Data 1589440 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 28 Apr 29 Apr 30 May 01 May 02 May 03 May 04
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 3.3264 in
Total P = 3.3262 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 8.8 26.1
t(peak) 5 5.5
PRF 757 1311
t(infl) 6.6 6.5


1589440 20140513
Event Direct Runoff [in] =0.48604
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20140513
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.48603
Phi = 0.52841
in/hr
Eastern Standard Time
×10^5
1589440 20140513
Precipitation Excess
Direct Runoff
Event t_c = 26.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
May 14
May 15
May 16
May 17
May 18
2014
1589440 20140513
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 11.25 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 11.50 hr
Direct Runoff Q [cfs]

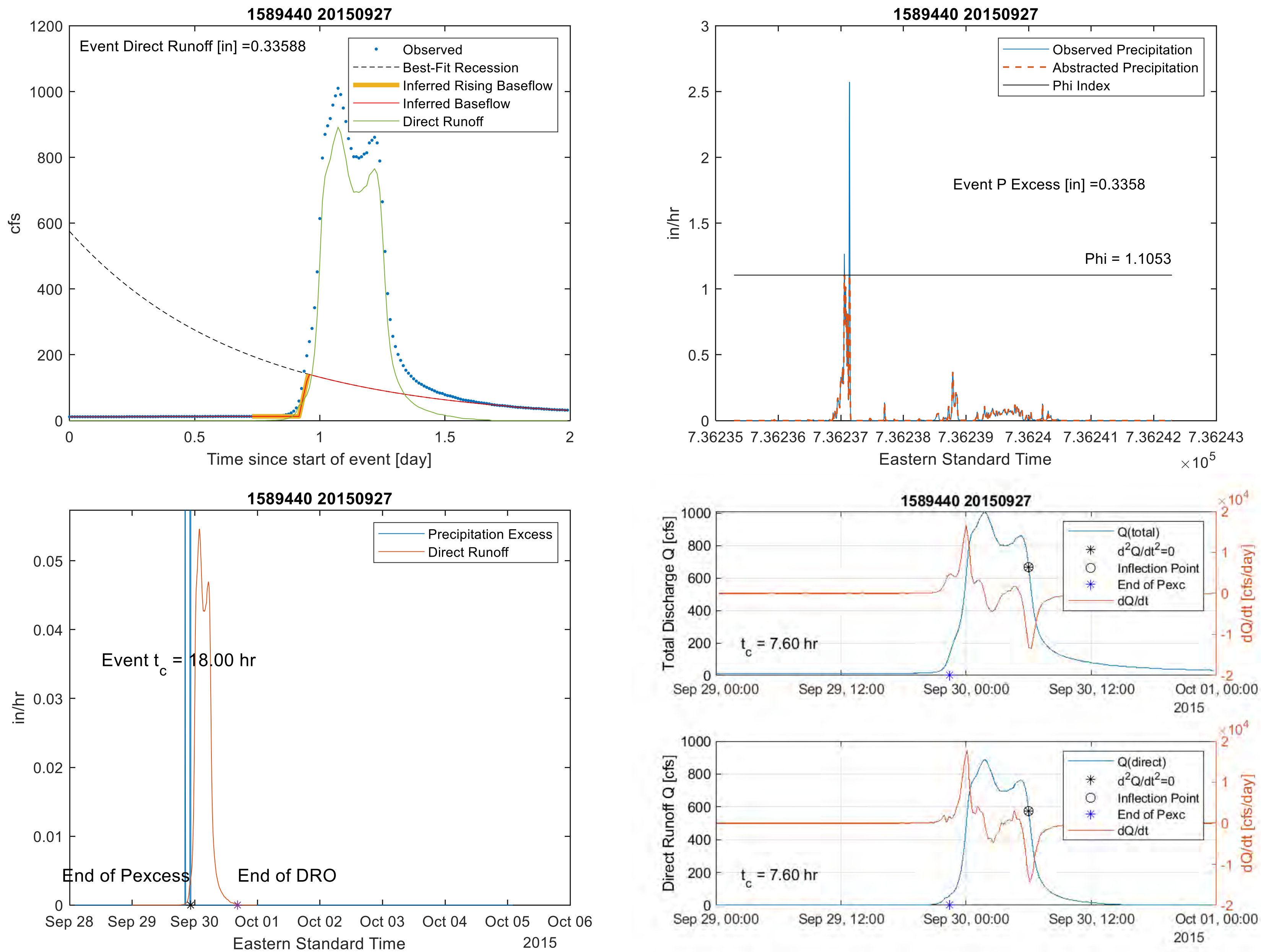

Input Data 1589440 20140513
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 14
May 15
May 16
May 17
May 18
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.48606 in
Total P = 0.48603 in
[in/hr]
May 16, 00:00
May 16, 12:00
May 17, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 7.9 6.4
t(peak) 7.9 7.15
PRF 716 643
t(infl) 10.6 9.9

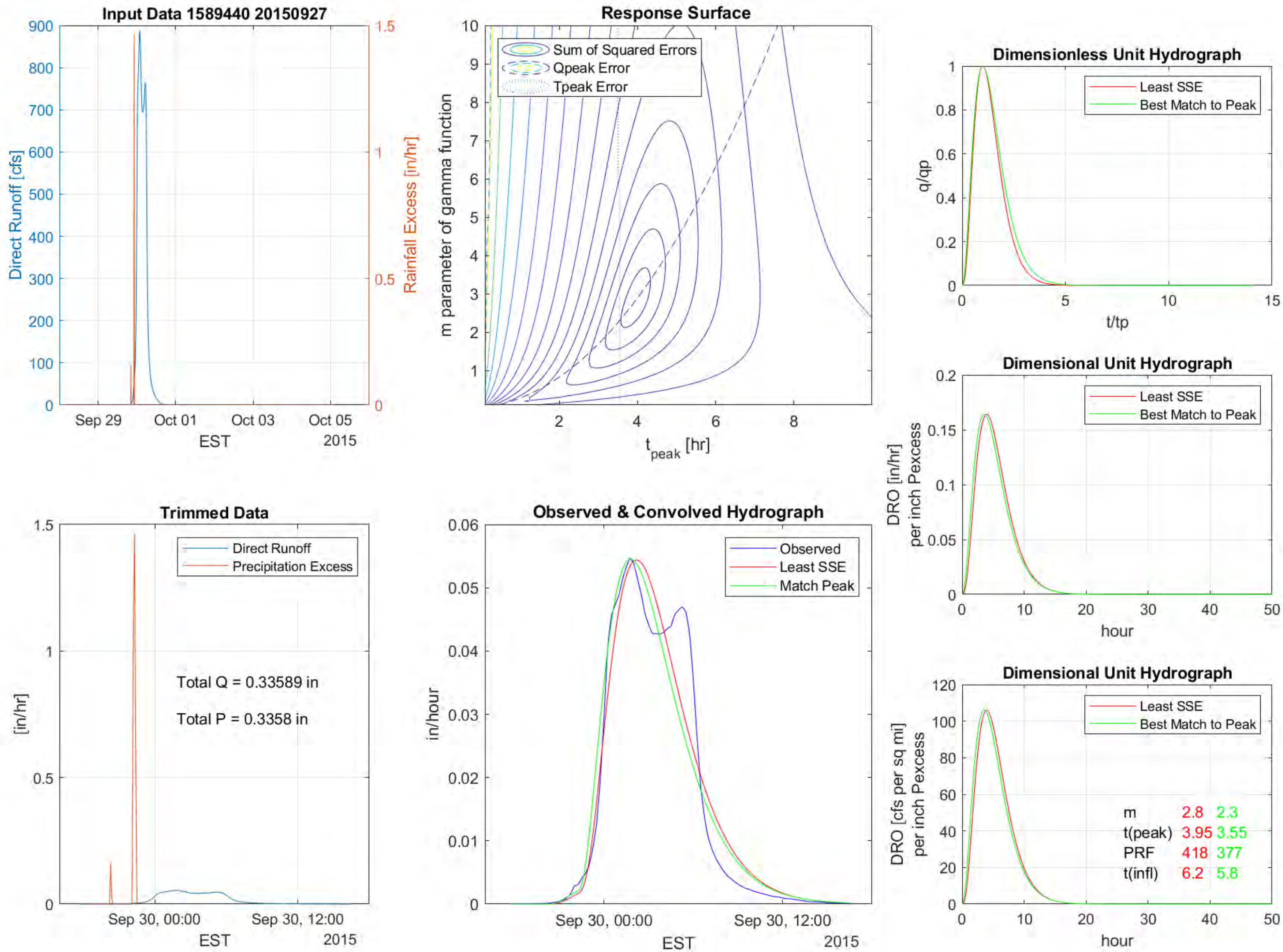


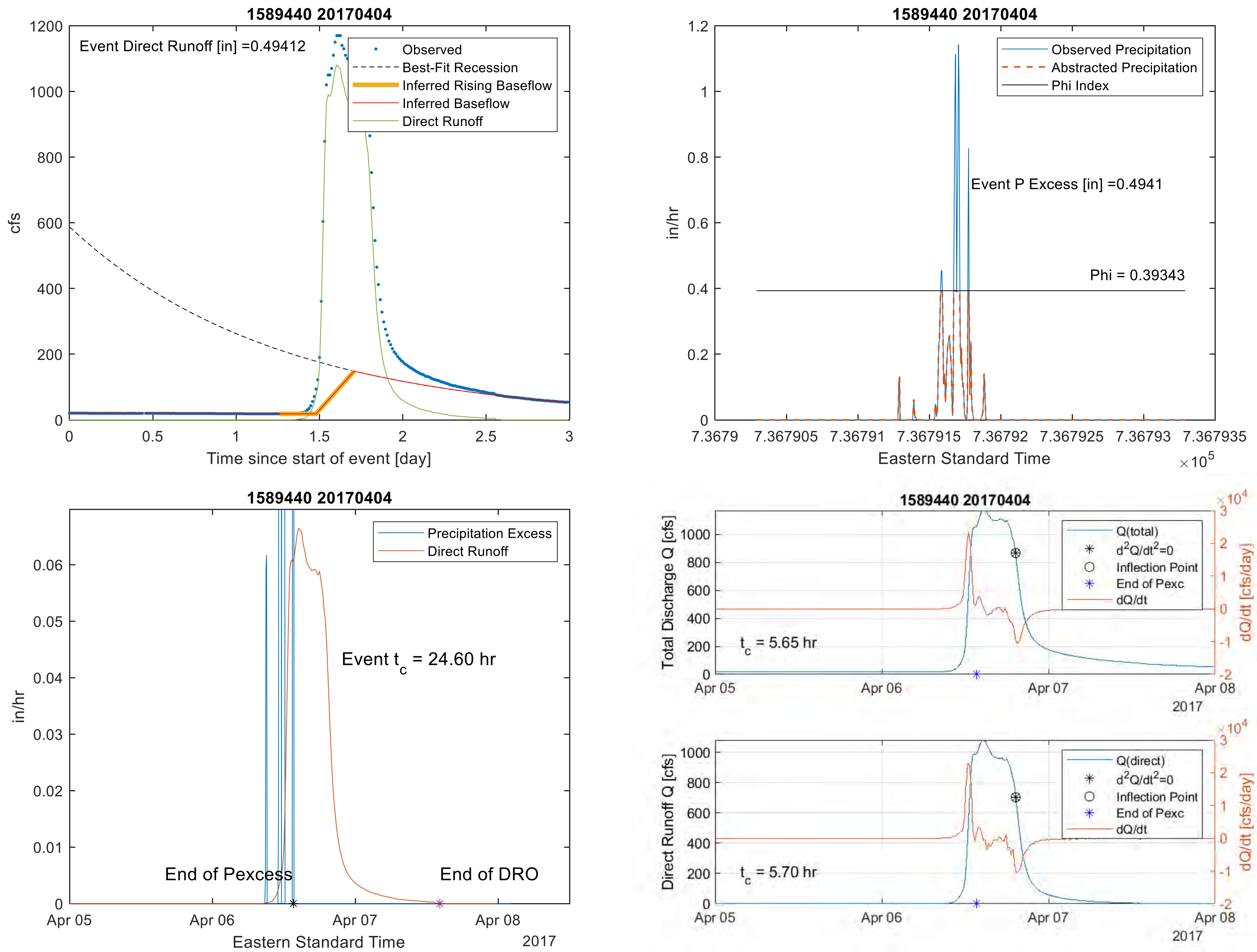
1589440 20150624
Event Direct Runoff [in] =0.62984
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20150624
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.62971
Phi = 0.81095
in/hr
Eastern Standard Time
1589440 20150624
Precipitation Excess
Direct Runoff
Event t c = 30.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589440 20150624
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 7.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 7.60 hr
Direct Runoff Q [cfs]



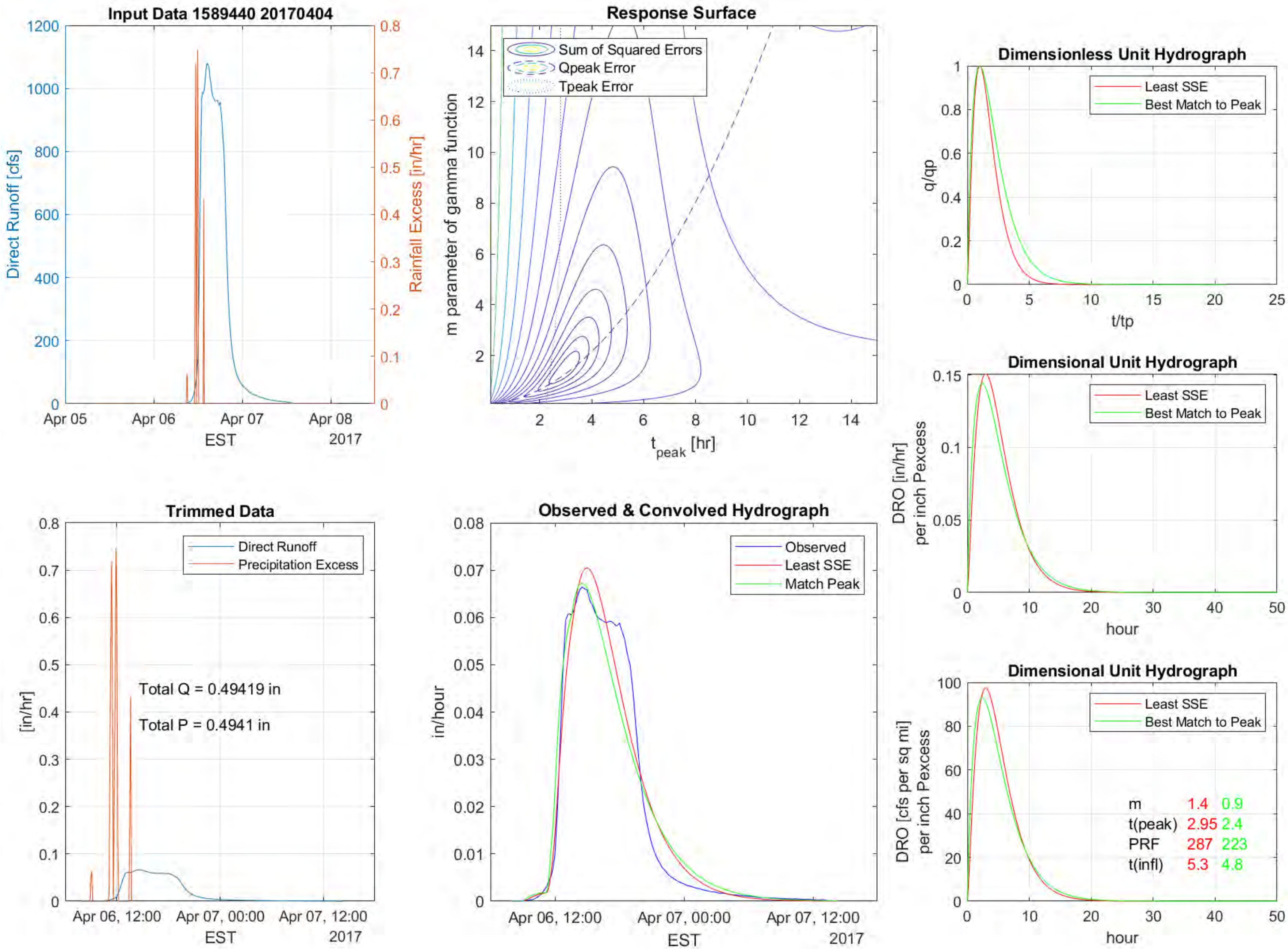
Input Data 1589440 20150624
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 25
Jun 26
Jun 27
Jun 28
Jun 29
Jun 30
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.62985 in
Total P = 0.62971 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.9 1
t(peak) 3.5 2.25
PRF 340 237
t(infl) 5.9 4.4

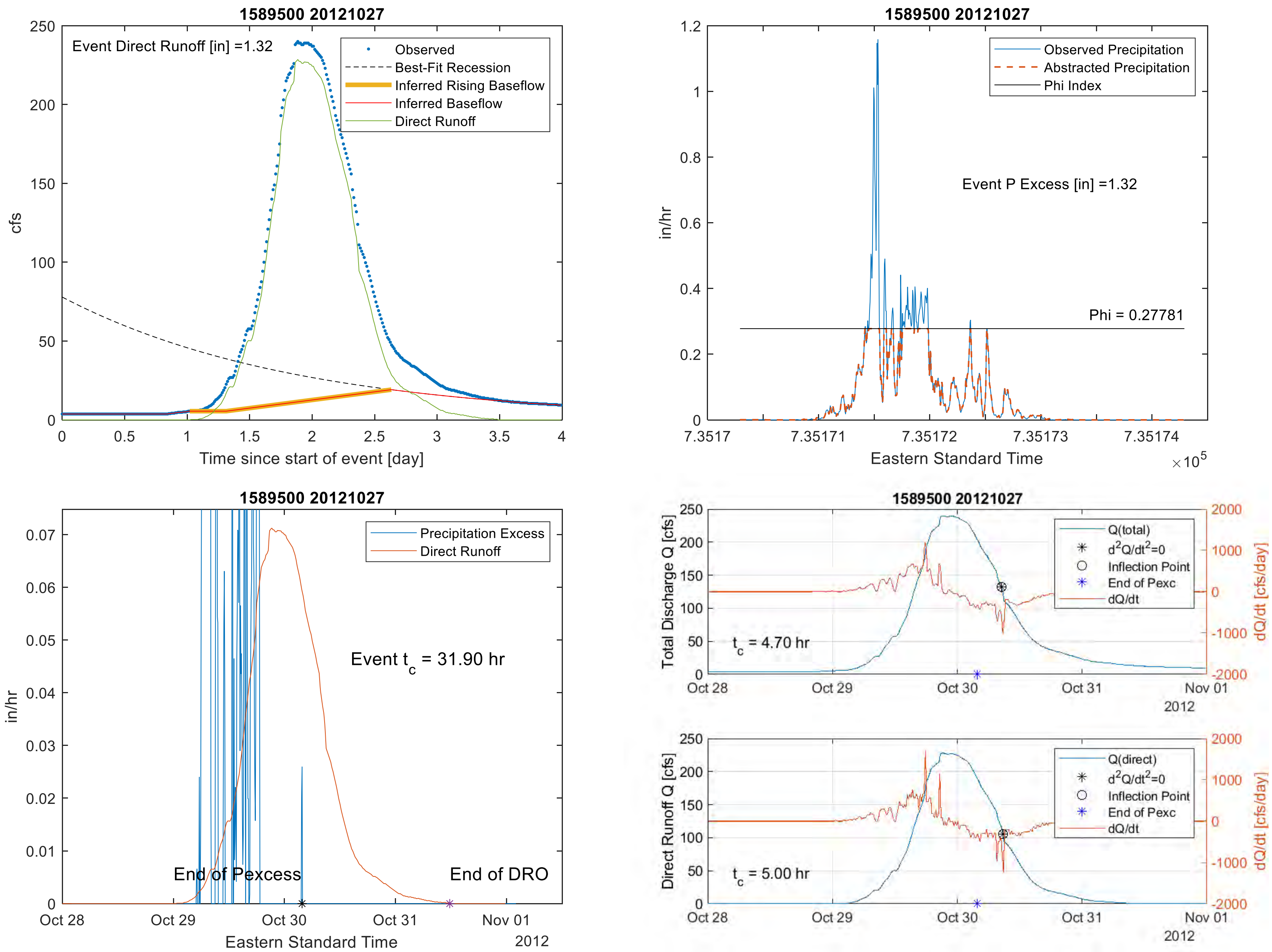

1589440 20150927
Event Direct Runoff [in] =0.33588
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20150927
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.3358
Phi = 1.1053
in/hr
Eastern Standard Time
1589440 20150927
Precipitation Excess
Direct Runoff
Event t_c = 18.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2015
1589440 20150927
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 7.60 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]
2015

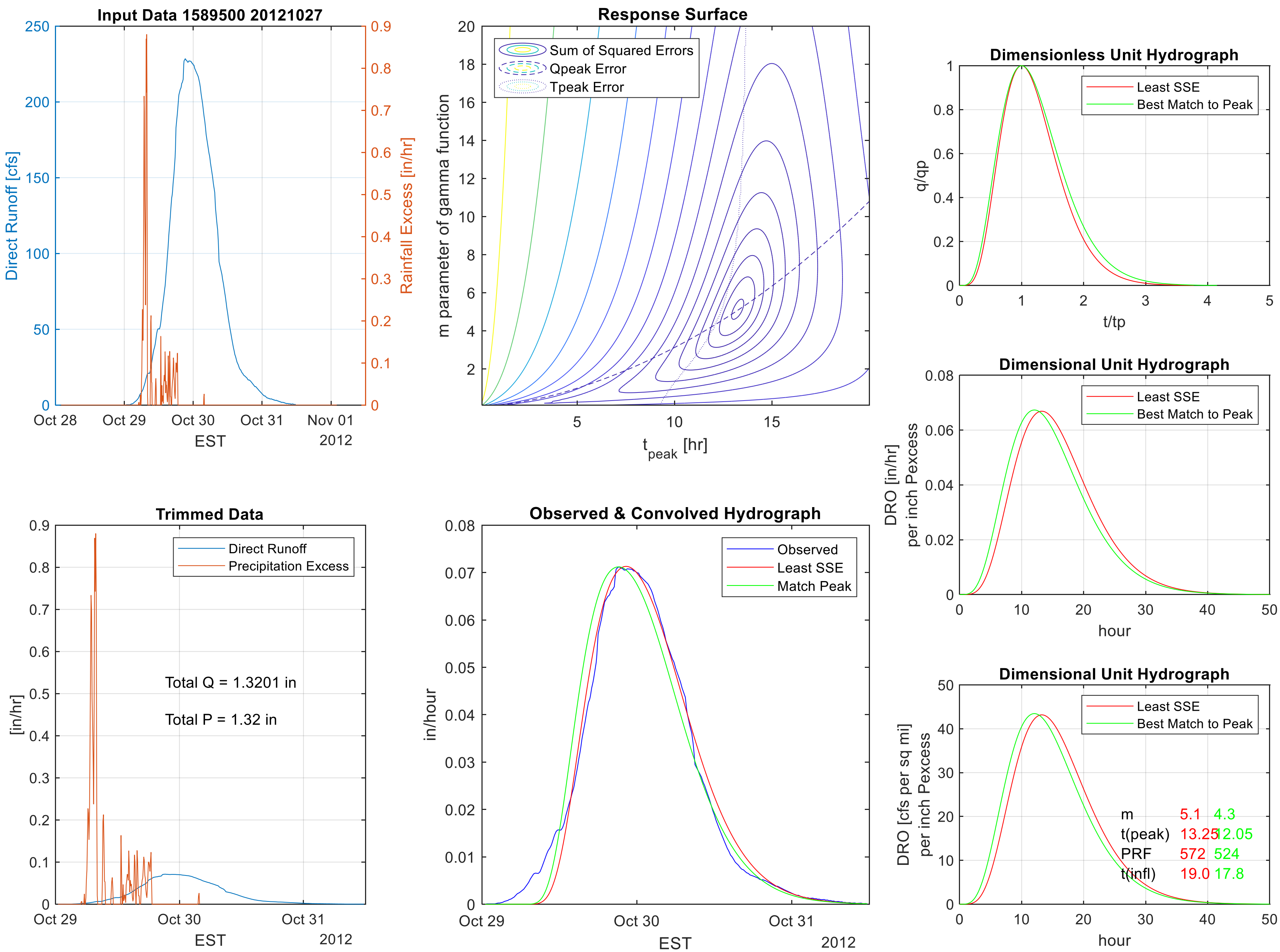

Input Data 1589440 20150927
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 29
Oct 01
Oct 03
Oct 05
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.33589 in
Total P = 0.3358 in
[in/hr]
Sep 30, 00:00
Sep 30, 12:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 2.8 2.3
t(peak) 3.95 3.55
PRF 418 377
t(infl) 6.2 5.8



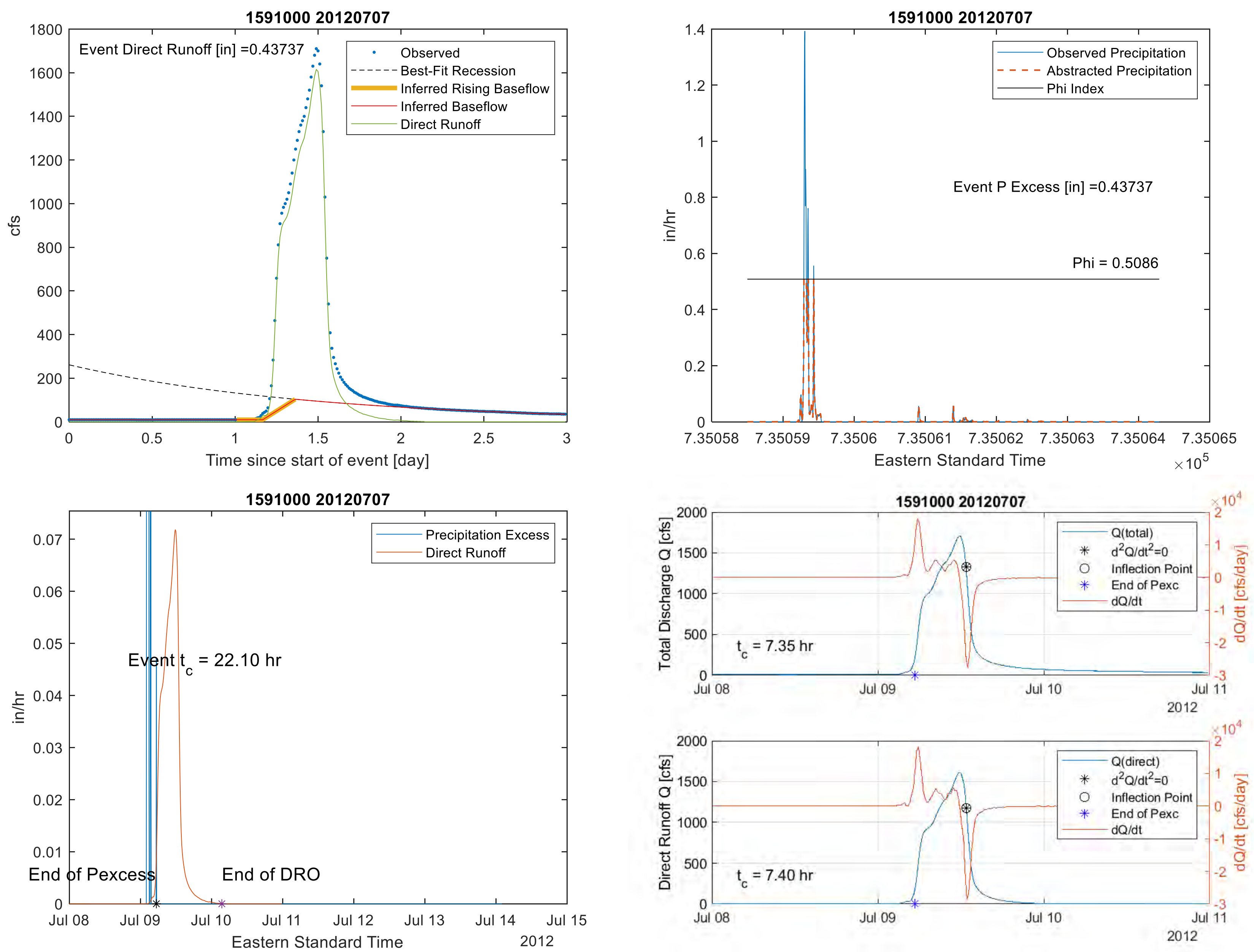
1589440 20170404
Event Direct Runoff [in] =0.49412
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589440 20170404
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.4941
Phi = 0.39343
in/hr
Eastern Standard Time
1589440 20170404
Precipitation Excess
Direct Runoff
Event t_c = 24.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589440 20170404
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 5.65 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 5.70 hr
Direct Runoff Q [cfs]

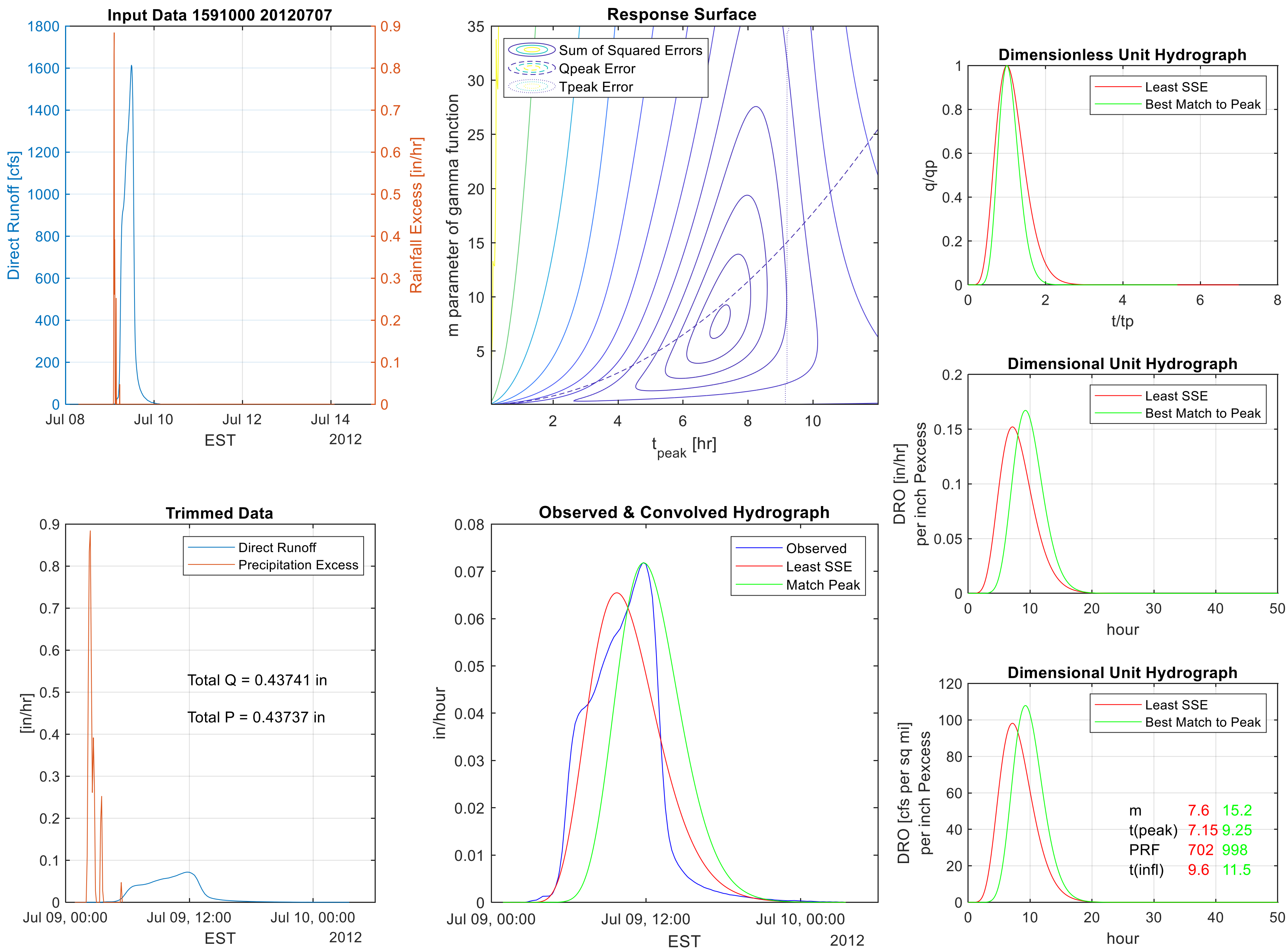

Input Data 1589440 20170404
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 05
Apr 06
Apr 07
Apr 08
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.49419 in
Total P = 0.4941 in
[in/hr]
Apr 06, 12:00
Apr 07, 00:00
Apr 07, 12:00
EST
2017
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.4 0.9
t(peak) 2.95 2.4
PRF 287 223
t(infl) 5.3 4.8
hour

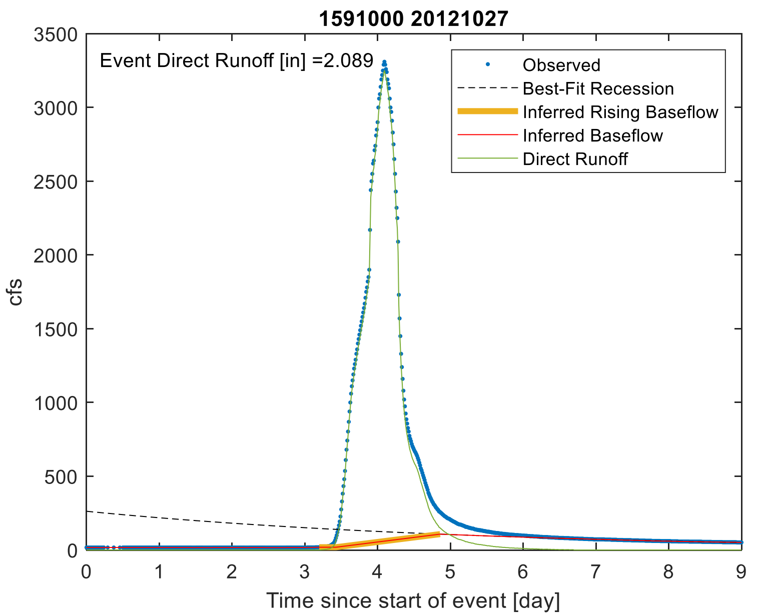

1589500 20121027
Event Direct Runoff [in] =1.32
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1589500 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.32
Phi = 0.27781
in/hr
Eastern Standard Time
1589500 20121027
Precipitation Excess
Direct Runoff
Event t_c = 31.90 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1589500 20121027
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 4.70 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 5.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

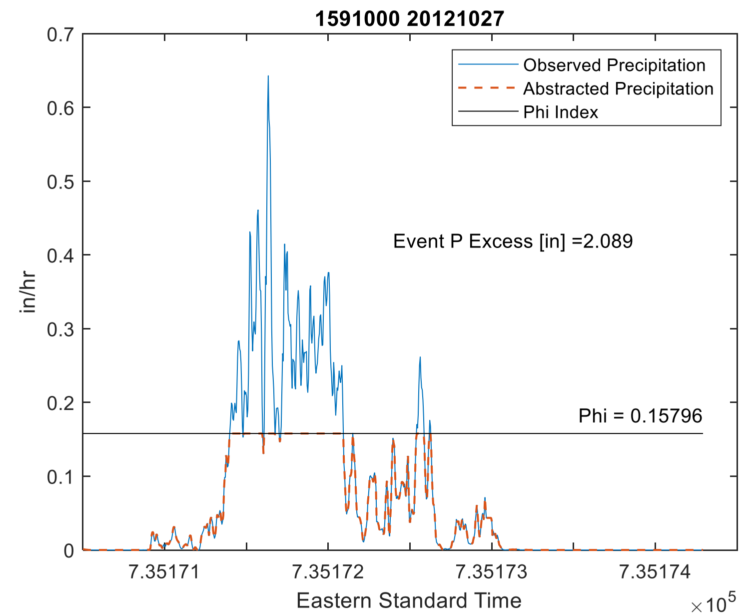


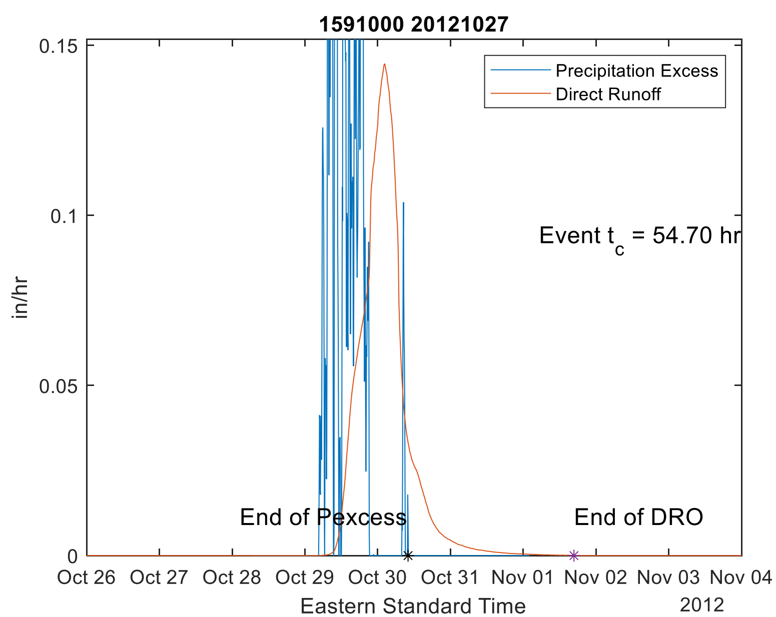
Input Data 1589500 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.3201 in
Total P = 1.32 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.1 4.3
t(peak) 13.25 12.05
PRF 572 524
t(infl) 19.0 17.8

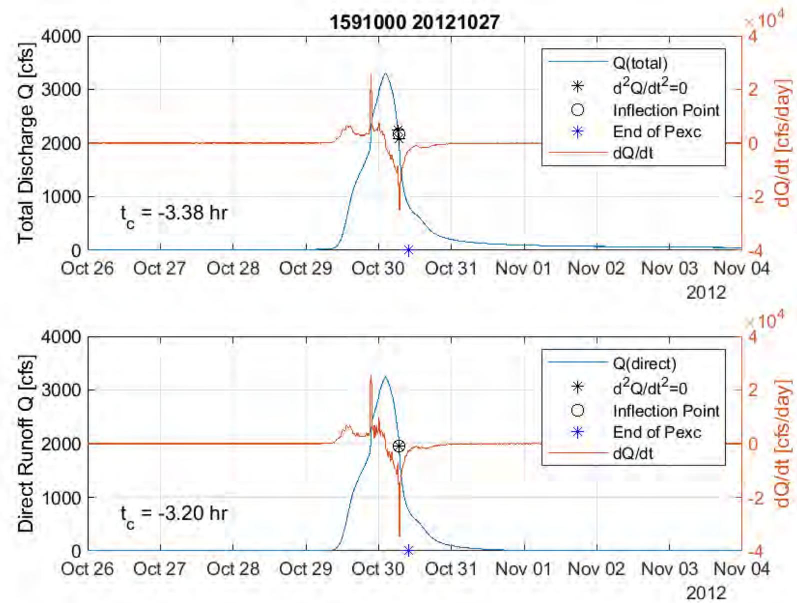

1591000 20120707
Event Direct Runoff [in] =0.43737
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591000 20120707
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.43737
Phi = 0.5086
in/hr
Eastern Standard Time
×10^5
1591000 20120707
Precipitation Excess
Direct Runoff
Event t_c = 22.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012
1591000 20120707
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 7.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 7.40 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2012

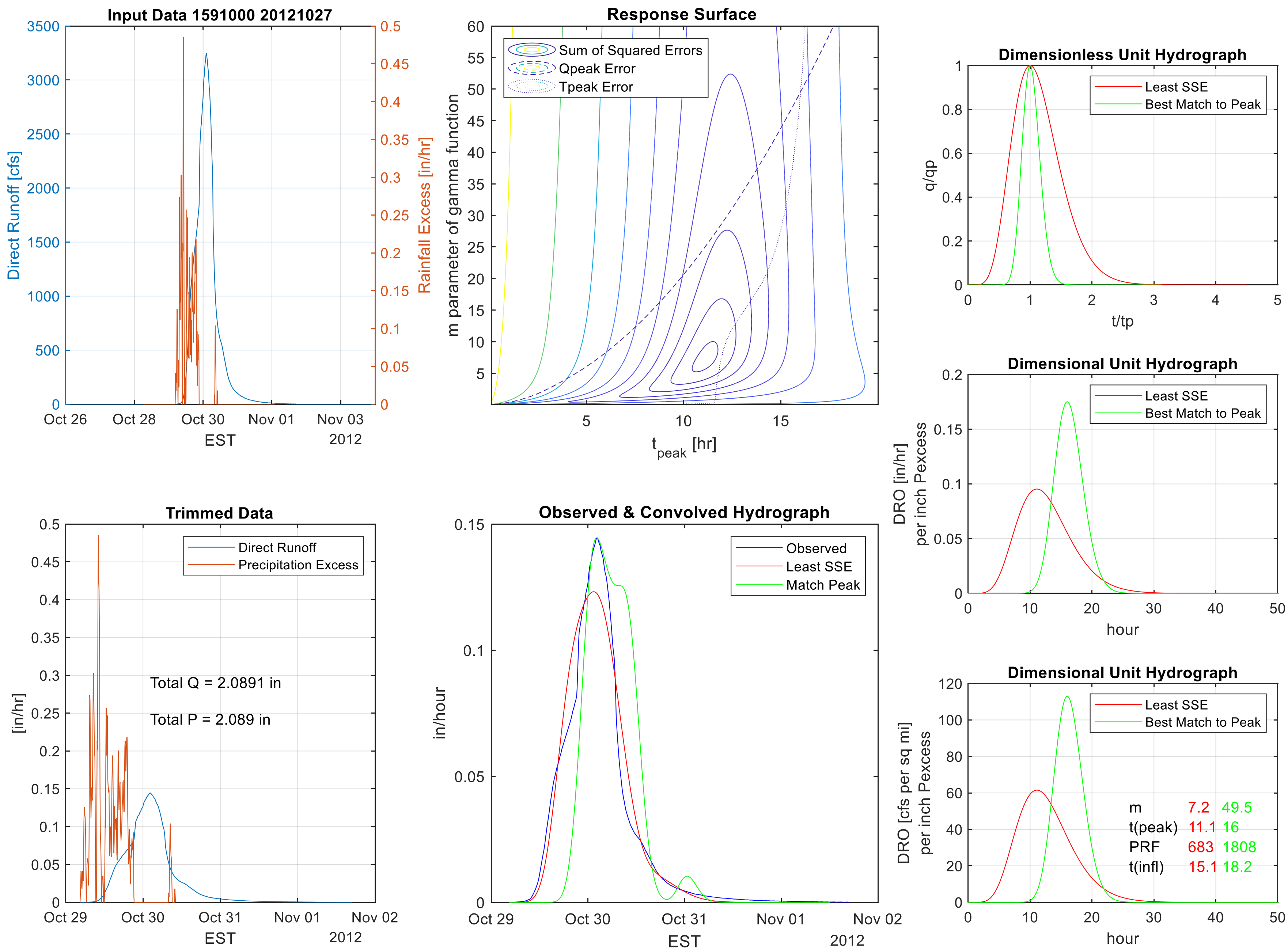

Input Data 1591000 20120707
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.43741 in
Total P = 0.43737 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 7.6 15.2
t(peak) 7.15 9.25
PRF 702 998
t(infl) 9.6 11.5

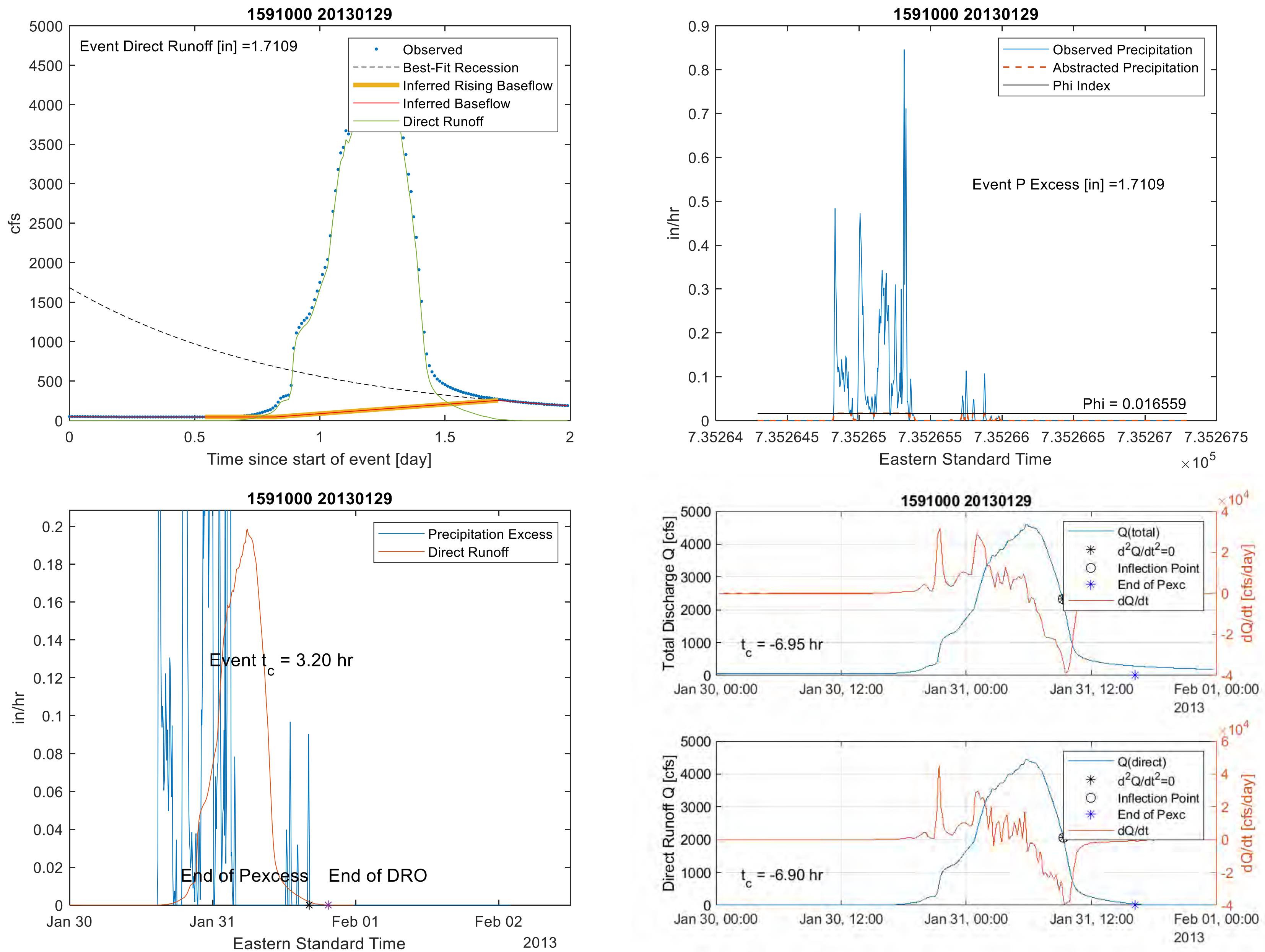

1591000 20121027
Event Direct Runoff [in] =2.089
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1591000 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.089
Phi = 0.15796
in/hr
Eastern Standard Time
×10^5

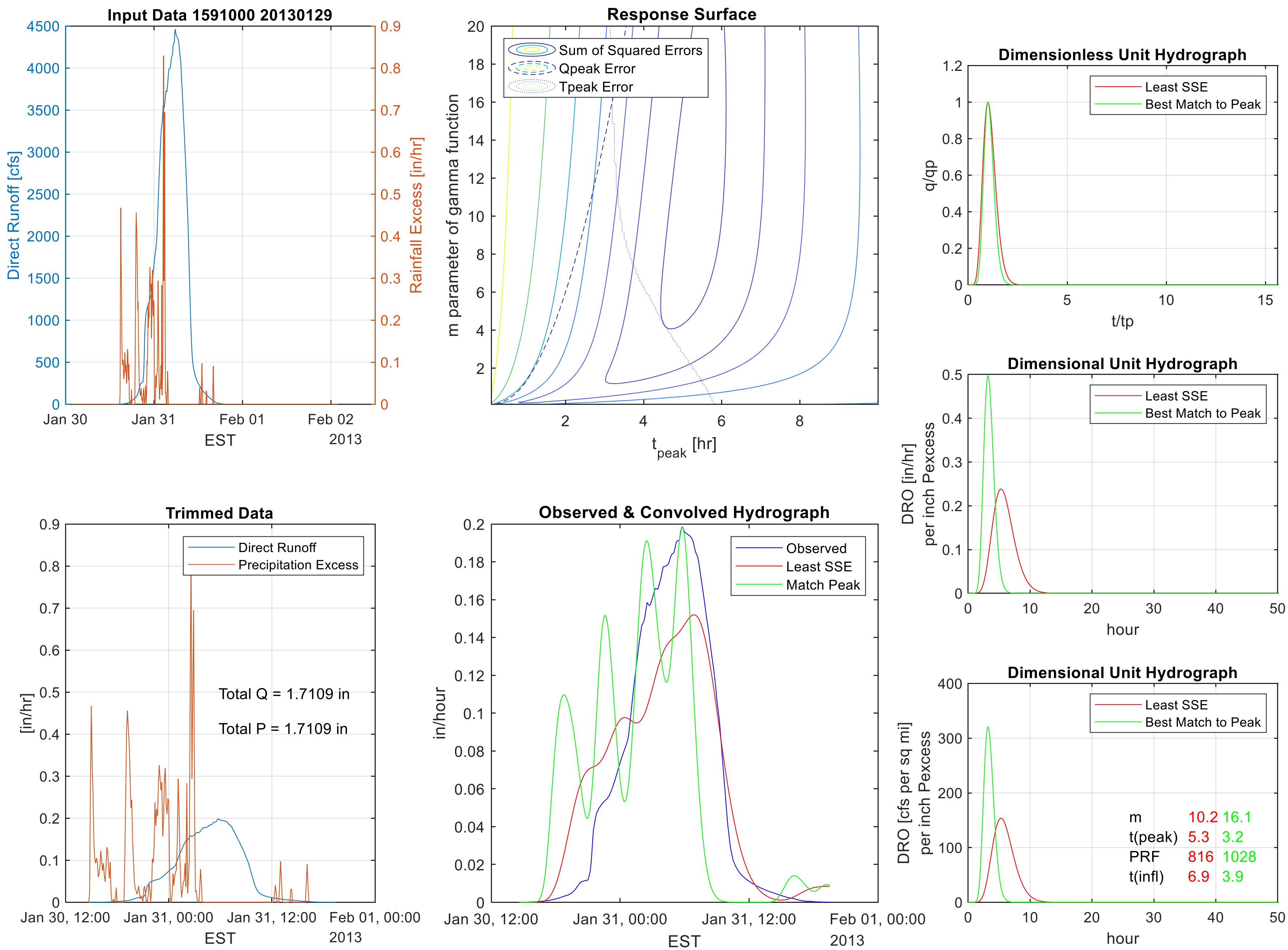

1591000 20121027
Precipitation Excess
Direct Runoff
Event t_c = 54.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012

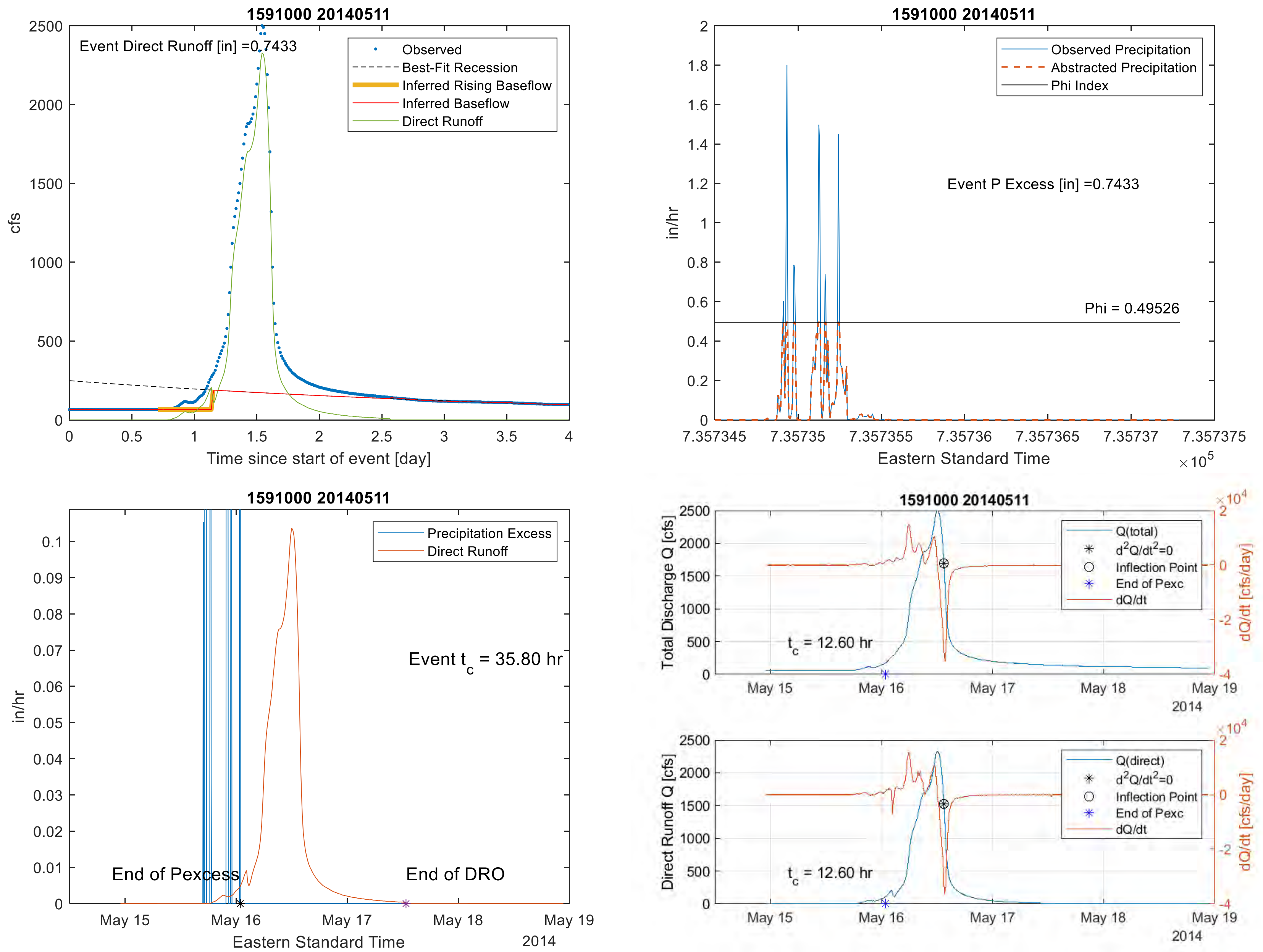

1591000 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -3.38 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = -3.20 hr
Direct Runoff Q [cfs]
2012

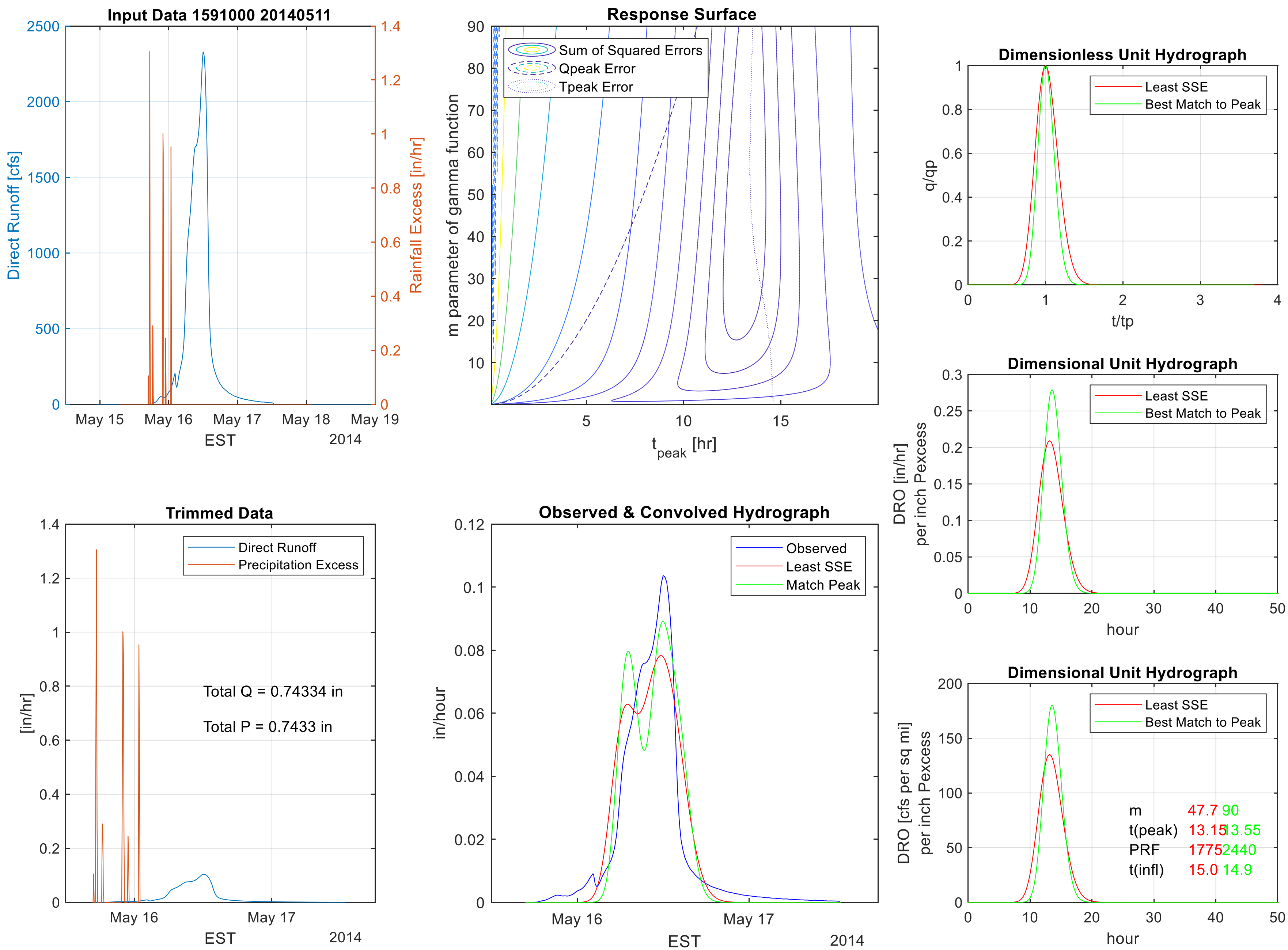

Input Data 1591000 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 26
Oct 28
Oct 30
Nov 01
Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.0891 in
Total P = 2.089 in
[in/hr]
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
m 7.2 49.5
t(peak) 11.1 16
PRF 683 1808
t(infl) 15.1 18.2
hour



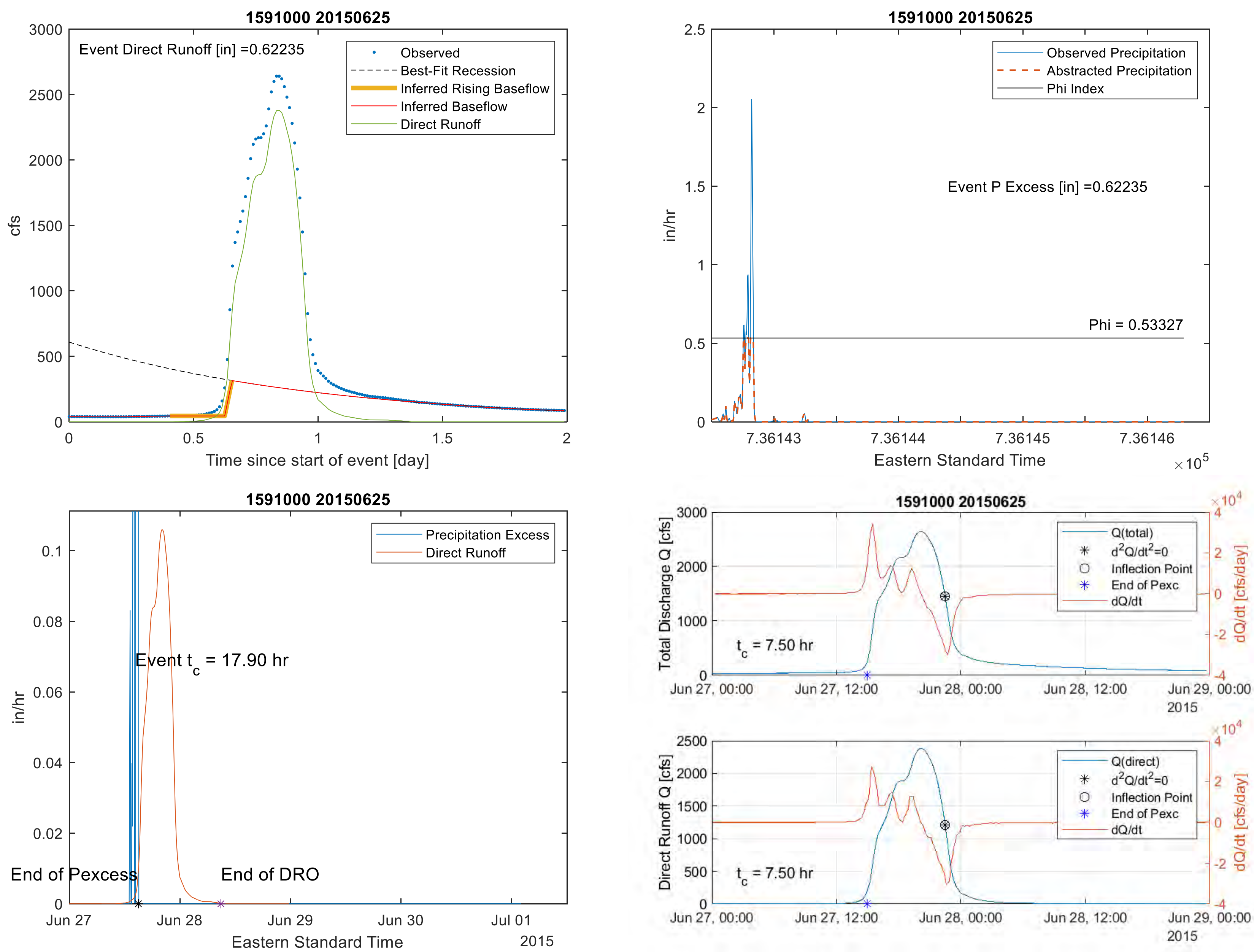
1591000 20130129
Event Direct Runoff [in] =1.7109
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591000 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.7109
Phi = 0.016559
in/hr
Eastern Standard Time
1591000 20130129
Precipitation Excess
Direct Runoff
Event t c = 3.20 hr
End of Pexcess
End of DRO
in/hr
Jan 30
Jan 31
Feb 01
Feb 02
2013
Eastern Standard Time
1591000 20130129
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t c = -6.95 hr
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
t c = -6.90 hr
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2013


Input Data 1591000 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.7109 in
Total P = 1.7109 in
[in/hr]
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 10.2 16.1
t(peak) 5.3 3.2
PRF 816 1028
t(infl) 6.9 3.9

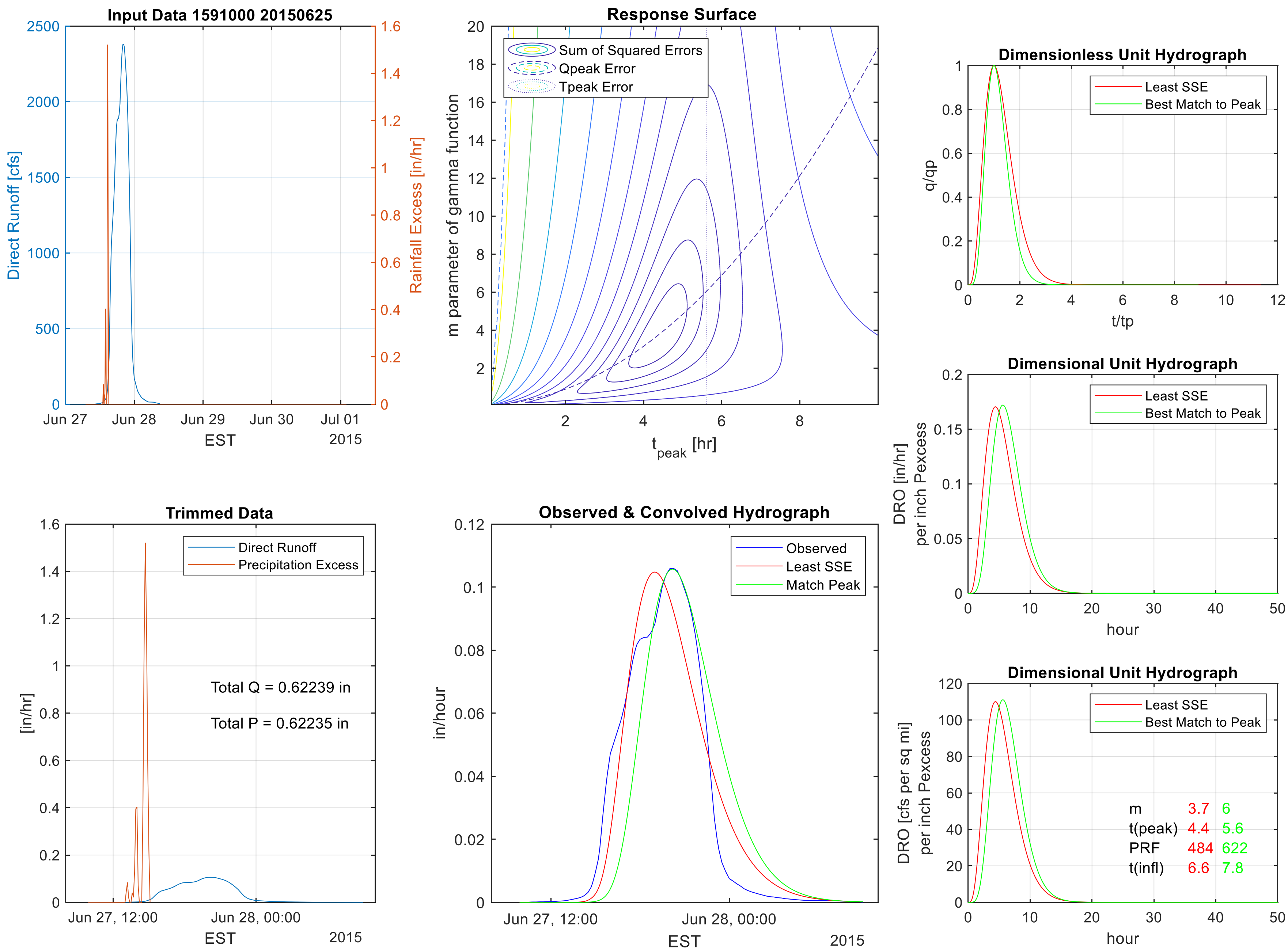

1591000 20140511
Event Direct Runoff [in] =0.7433
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591000 20140511
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.7433
Phi = 0.49526
in/hr
Eastern Standard Time
1591000 20140511
Precipitation Excess
Direct Runoff
Event t c = 35.80 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1591000 20140511
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 12.60 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 12.60 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

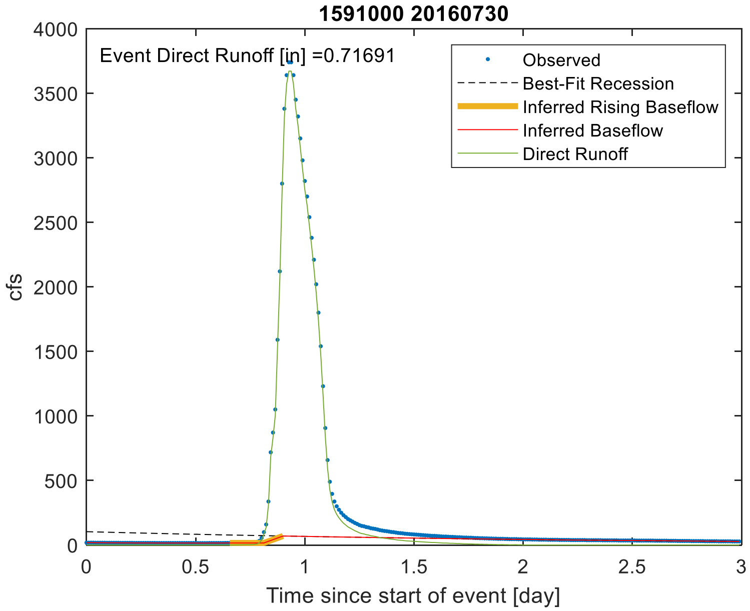


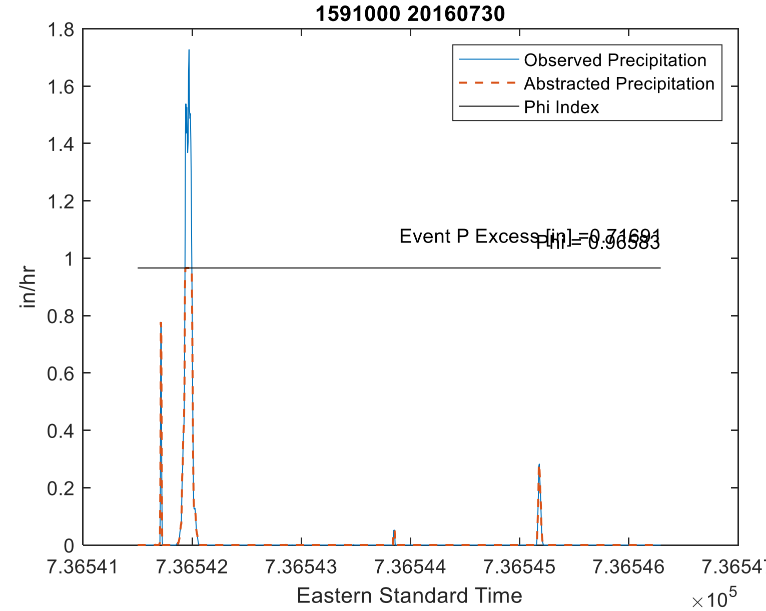
Input Data 1591000 20140511
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 15
May 16
May 17
May 18
May 19
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.74334 in
Total P = 0.7433 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 47.7 90
t(peak) 13.15 13.55
PRF 1775 2440
t(infl) 15.0 14.9

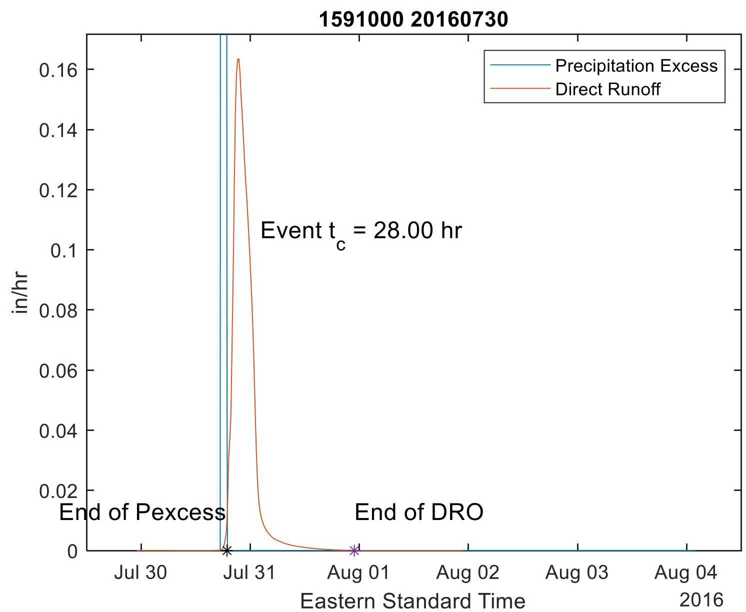


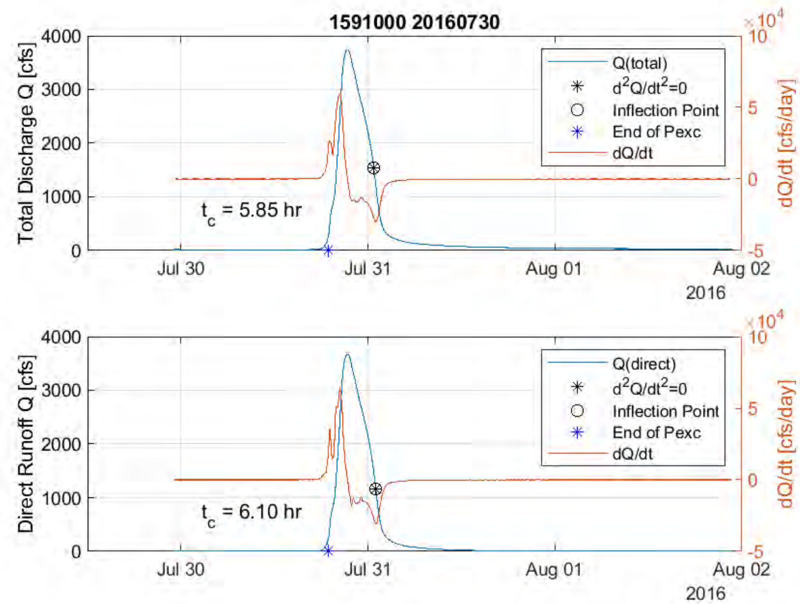
1591000 20150625
Event Direct Runoff [in] =0.62235
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591000 20150625
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.62235
Phi = 0.53327
in/hr
Eastern Standard Time
1591000 20150625
Precipitation Excess
Direct Runoff
Event t
c
= 17.90 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1591000 20150625
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t
c
= 7.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]

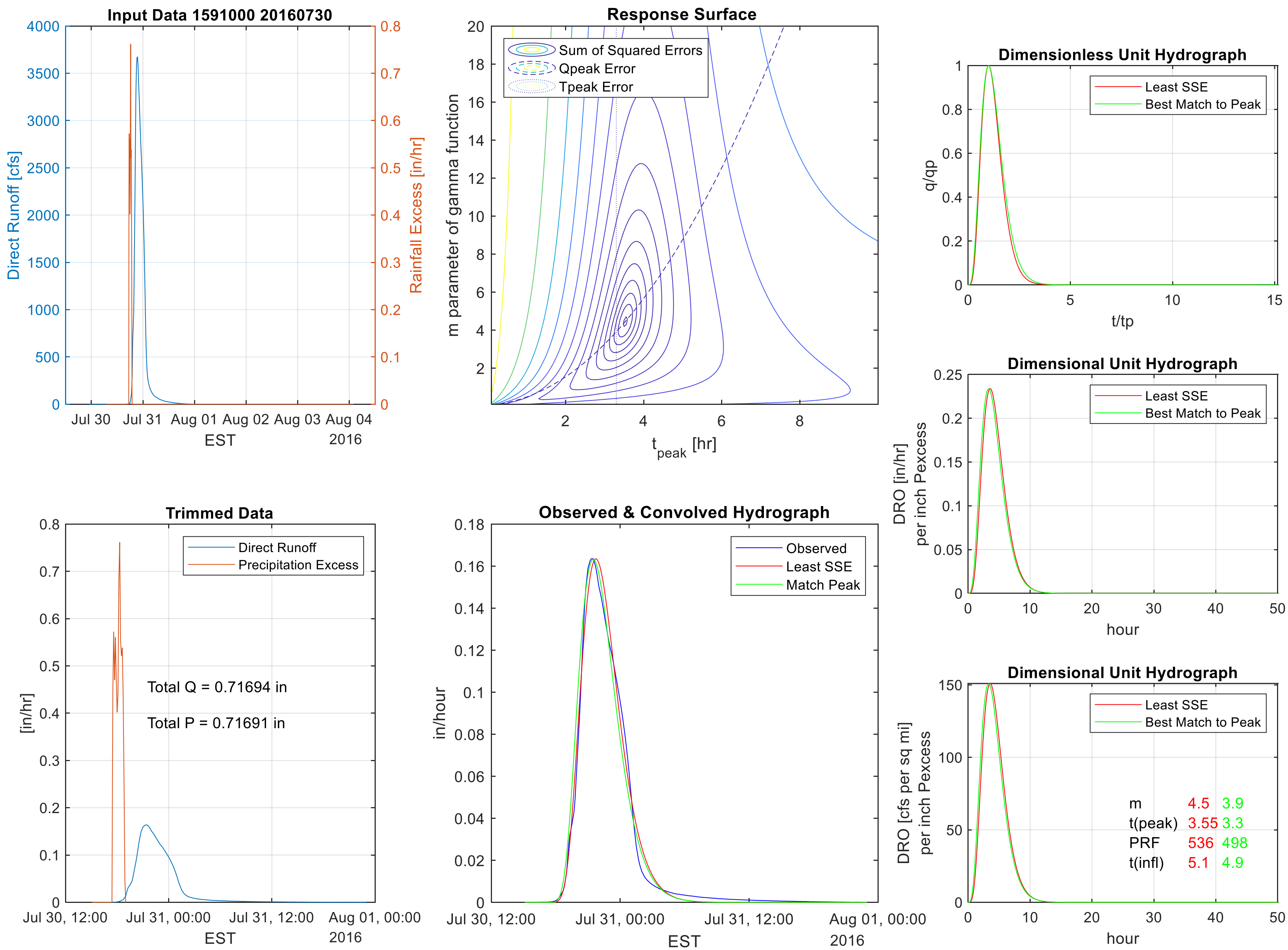

Input Data 1591000 20150625
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 27
Jun 28
Jun 29
Jun 30
Jul 01
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.62239 in
Total P = 0.62235 in
[in/hr]
Jun 27, 12:00
Jun 28, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.7 6
t(peak) 4.4 5.6
PRF 484 622
t(infl) 6.6 7.8

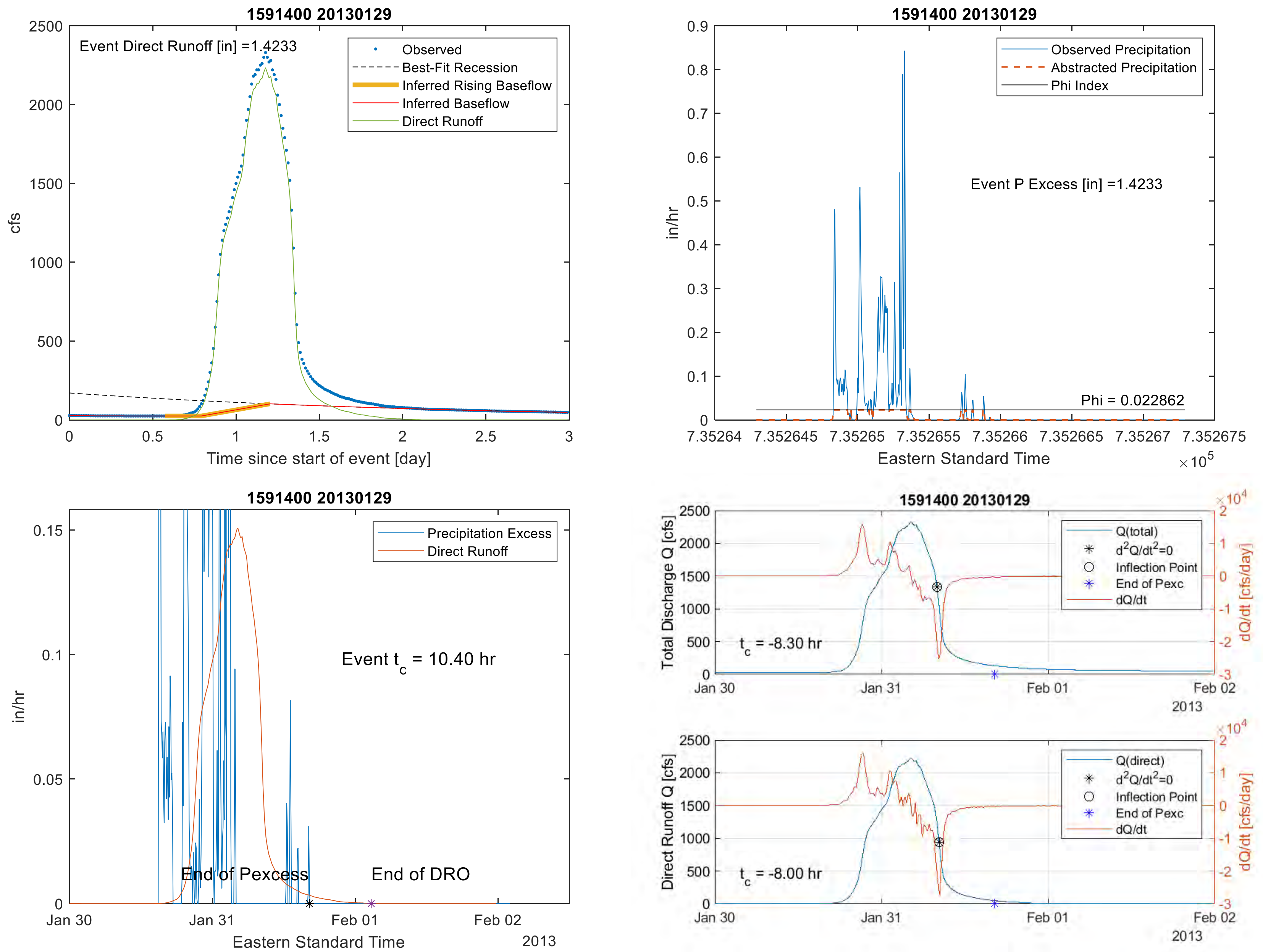

1591000 20160730
Event Direct Runoff [in] =0.71691
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

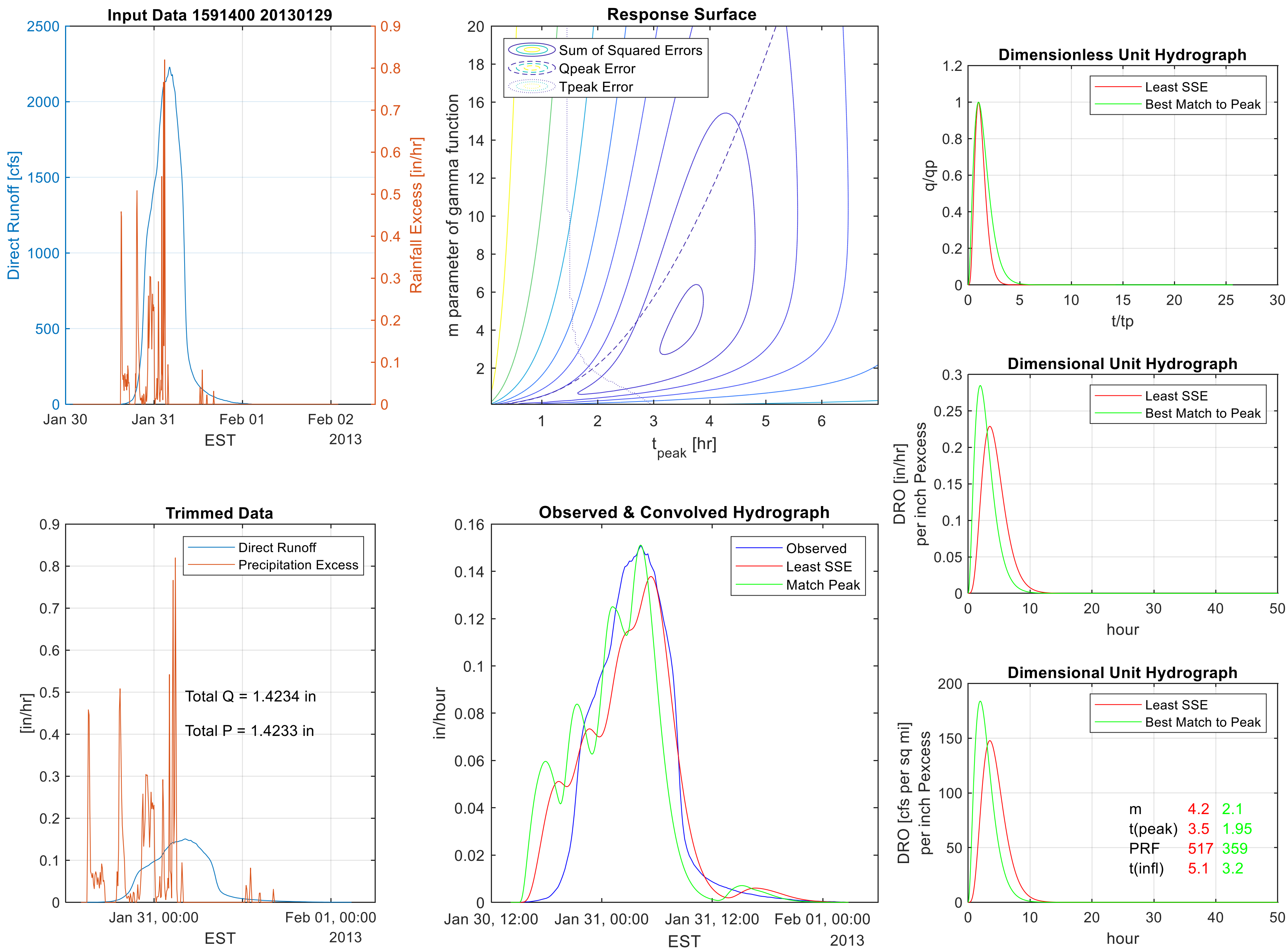

1591000 20160730
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.71691
Phi = 0.96583
in/hr
Eastern Standard Time
×10^5

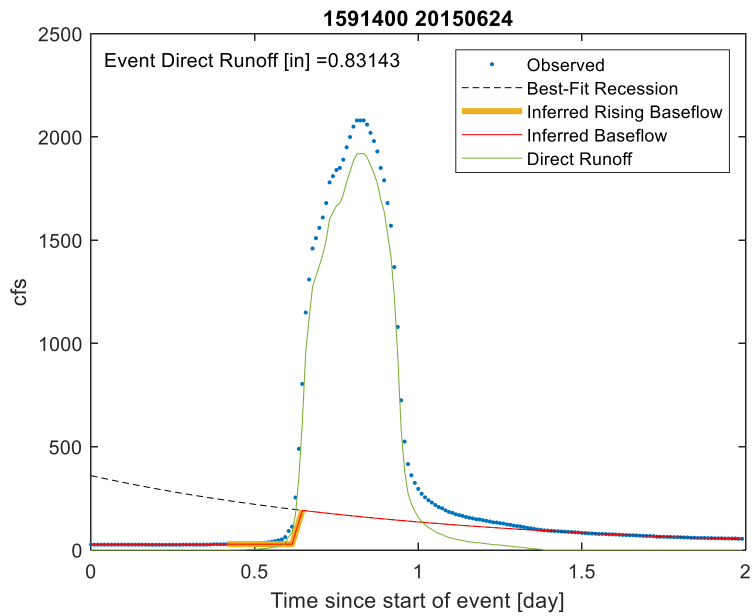

1591000 20160730
Precipitation Excess
Direct Runoff
Event t_c = 28.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2016

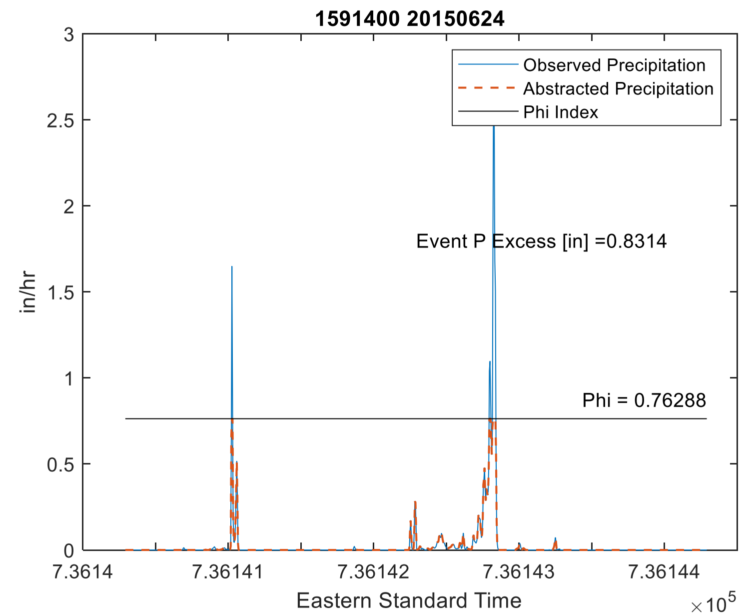

1591000 20160730
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 5.85 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 6.10 hr
Direct Runoff Q [cfs]
2016

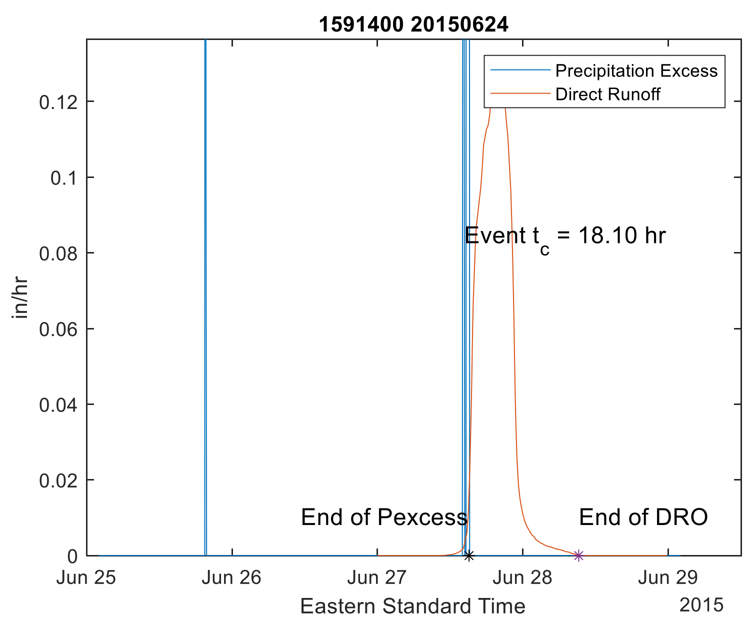

Input Data 1591000 20160730
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30 Jul 31 Aug 01 Aug 02 Aug 03 Aug 04
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.71694 in
Total P = 0.71691 in
[in/hr]
Jul 30, 12:00 Jul 31, 00:00 Jul 31, 12:00 Aug 01, 00:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4.5 3.9
t(peak) 3.55 3.3
PRF 536 498
t(infl) 5.1 4.9

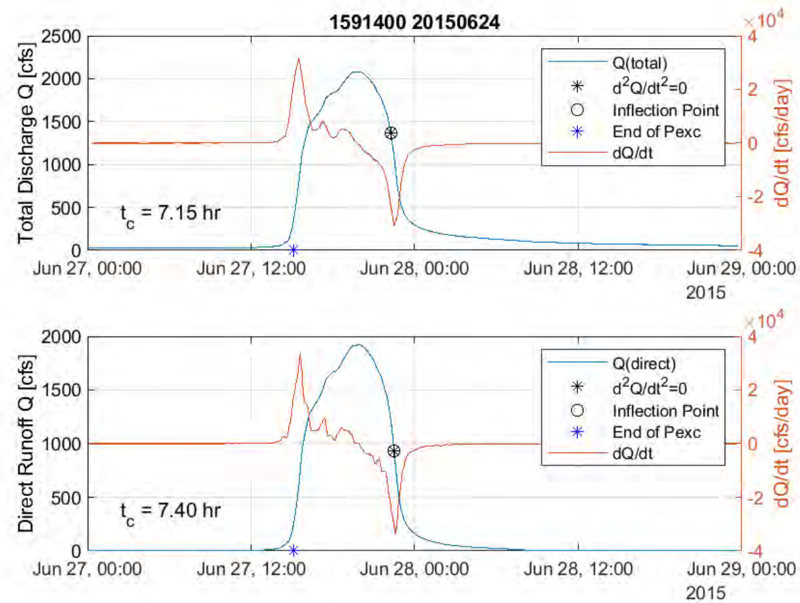

1591400 20130129
Event Direct Runoff [in] =1.4233
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591400 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.4233
Phi = 0.022862
in/hr
Eastern Standard Time
1591400 20130129
Precipitation Excess
Direct Runoff
Event t_c = 10.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1591400 20130129
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -8.30 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -8.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
Jan 30
Jan 31
Feb 01
Feb 02
2013

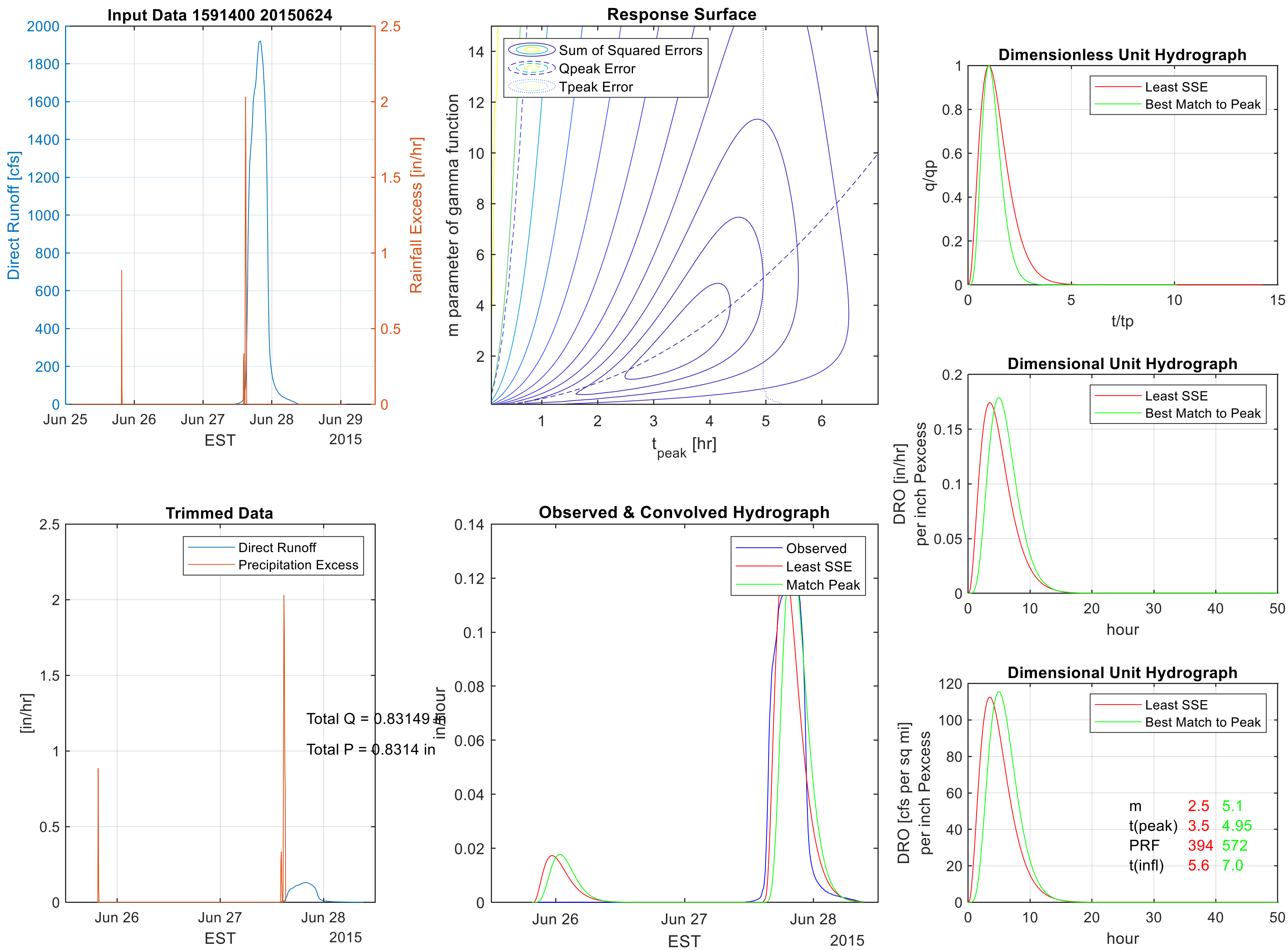

Input Data 1591400 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
2500
2000
1500
1000
500
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan 30
Jan 31
Feb 01
Feb 02
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
20
18
16
14
12
10
8
6
4
2
1
2
3
4
5
6
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total Q = 1.4234 in
Total P = 1.4233 in
Jan 31, 00:00
Feb 01, 00:00
EST
2013
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
EST
2013
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
200
150
100
50
0
m 4.2 2.1
t(peak) 3.5 1.95
PRF 517 359
t(infl) 5.1 3.2
0
10
20
30
40
50
hour

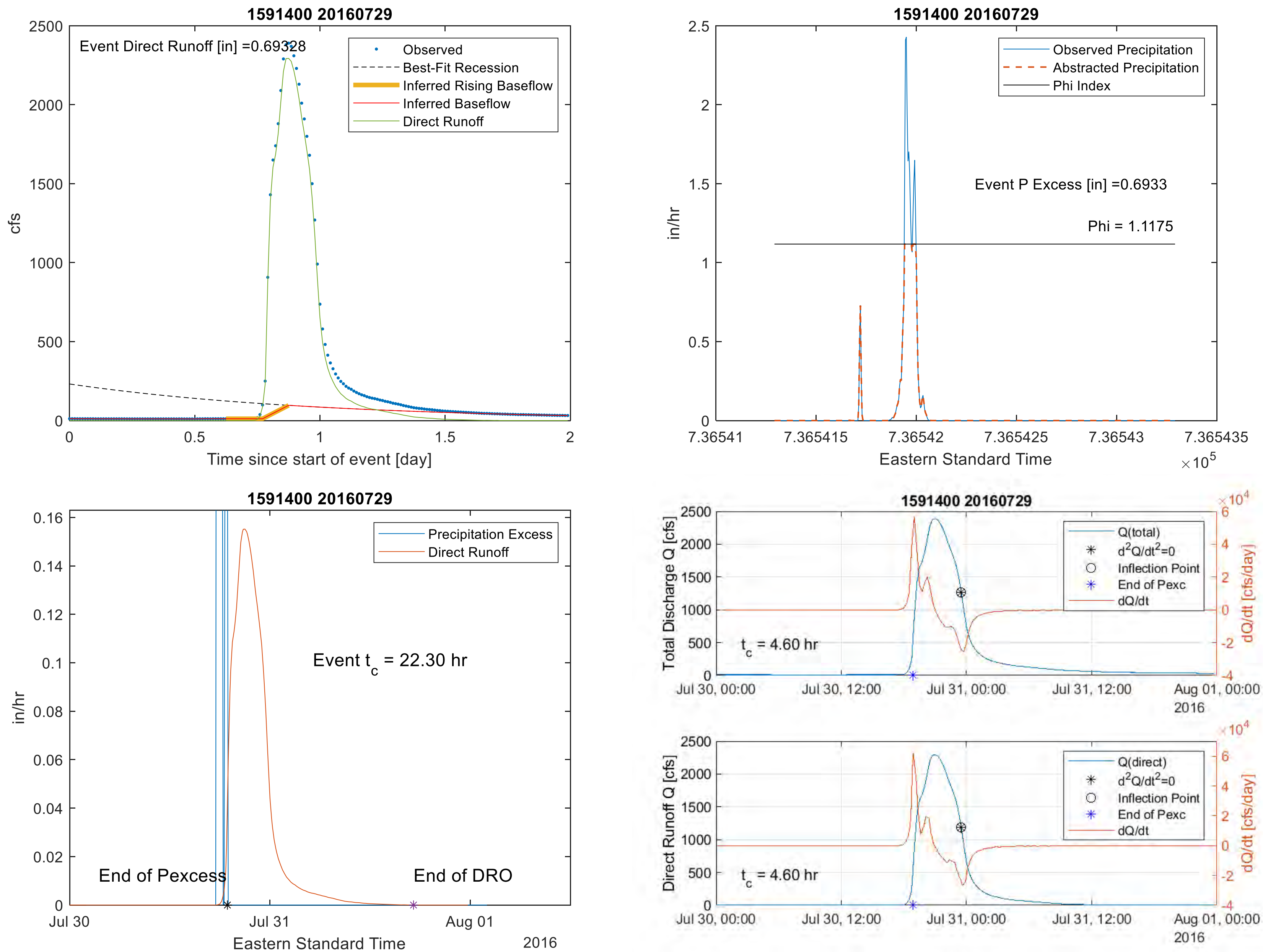

1591400 20150624
Event Direct Runoff [in] =0.83143
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1591400 20150624
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.8314
Phi = 0.76288
in/hr
Eastern Standard Time

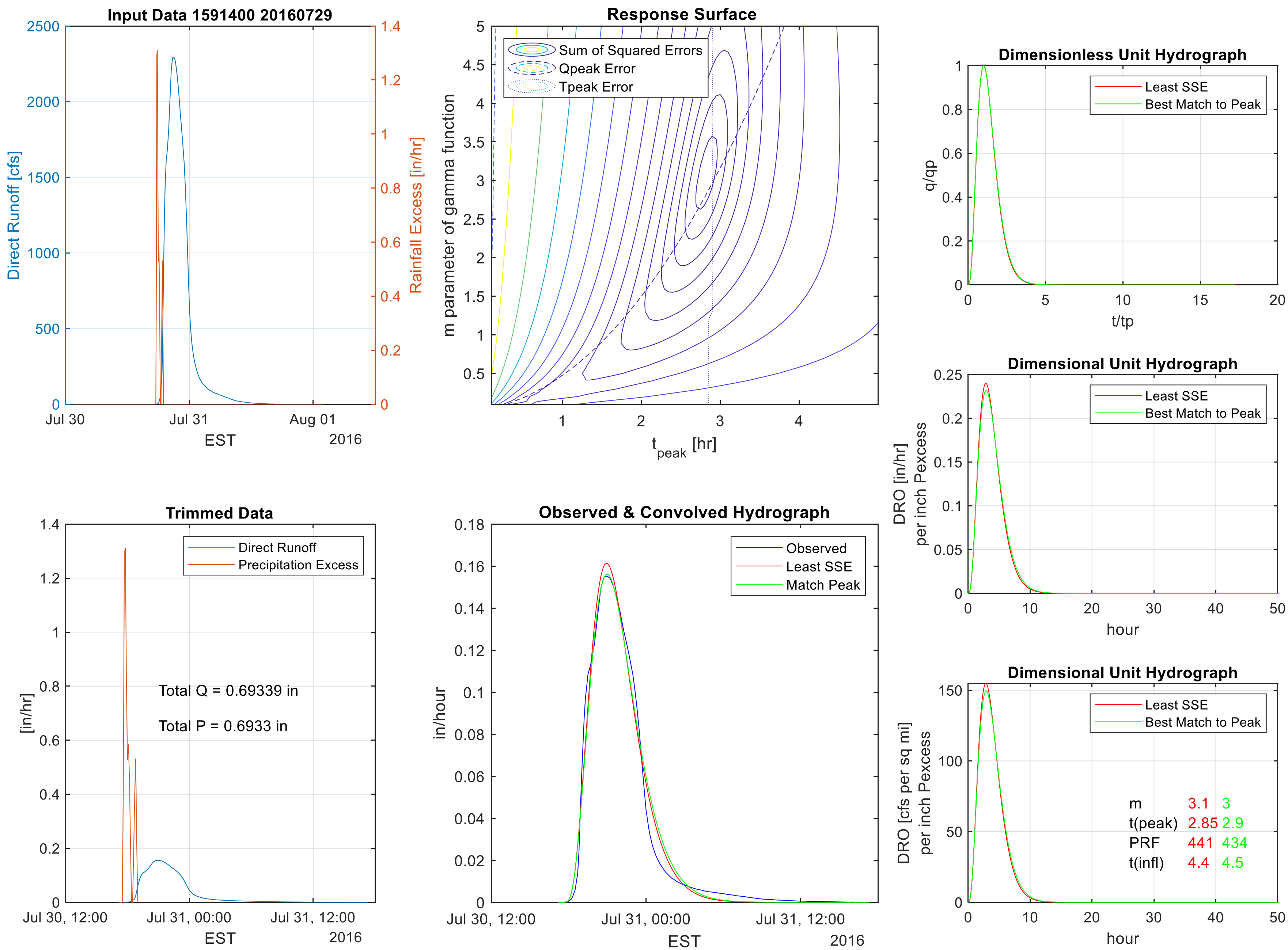

1591400 20150624
Precipitation Excess
Direct Runoff
Event t_c = 18.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

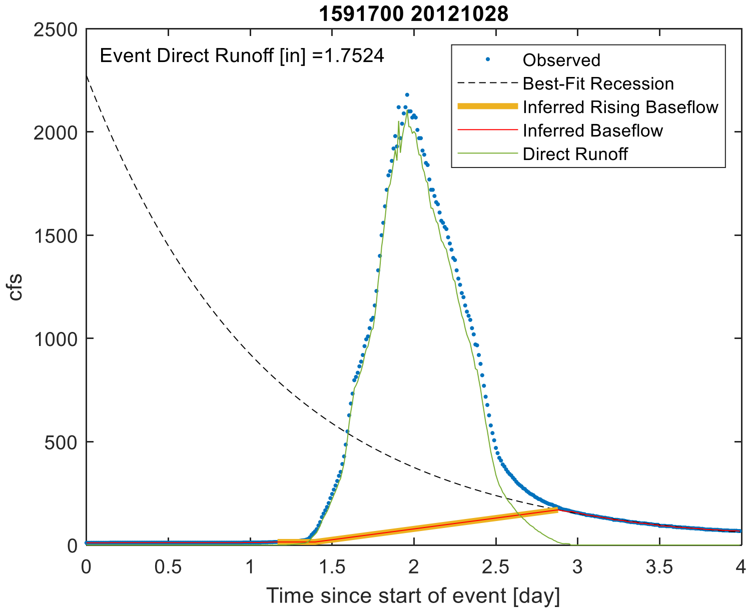

1591400 20150624
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 7.15 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 7.40 hr
Direct Runoff Q [cfs]


Input Data 1591400 20150624
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 25
Jun 26
Jun 27
Jun 28
Jun 29
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.83149 in
Total P = 0.8314 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 2.5 5.1
t(peak) 3.5 4.95
PRF 394 572
t(infl) 5.6 7.0

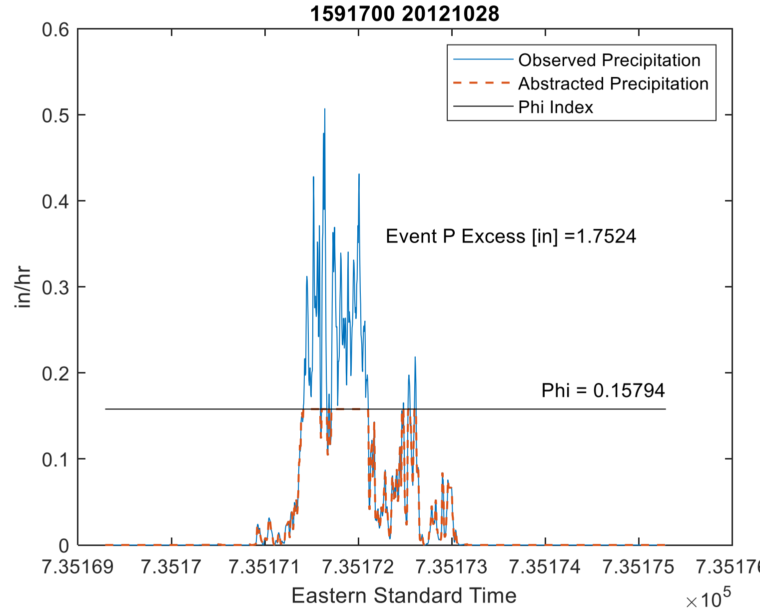


1591400 20160729
Event Direct Runoff [in] =0.69328
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591400 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.6933
Phi = 1.1175
in/hr
Eastern Standard Time
1591400 20160729
Precipitation Excess
Direct Runoff
Event t_c = 22.30 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2016
1591400 20160729
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t_c = 4.60 hr
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
t_c = 4.60 hr
2016

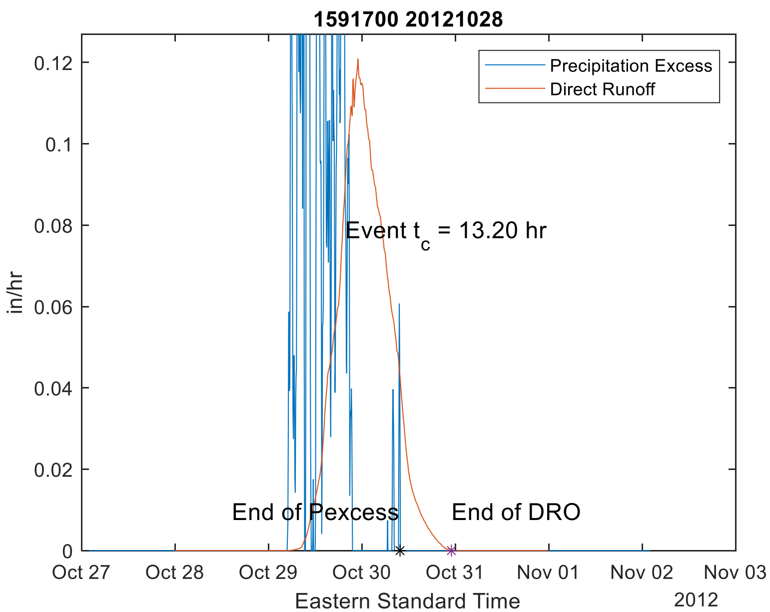

Input Data 1591400 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.69339 in
Total P = 0.6933 in
Jul 30, 12:00
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3.1 3
t(peak) 2.85 2.9
PRF 441 434
t(infl) 4.4 4.5
hour



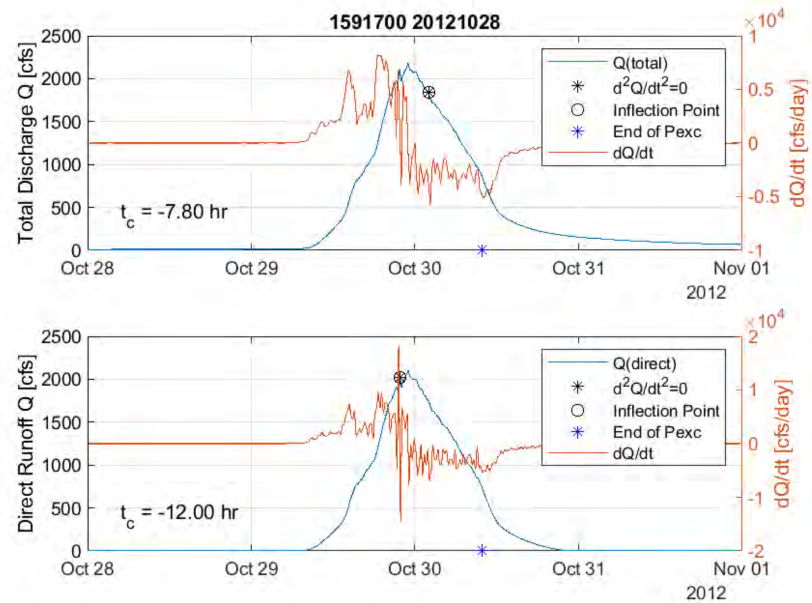
1591700 20121028
Event Direct Runoff [in] =1.7524
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



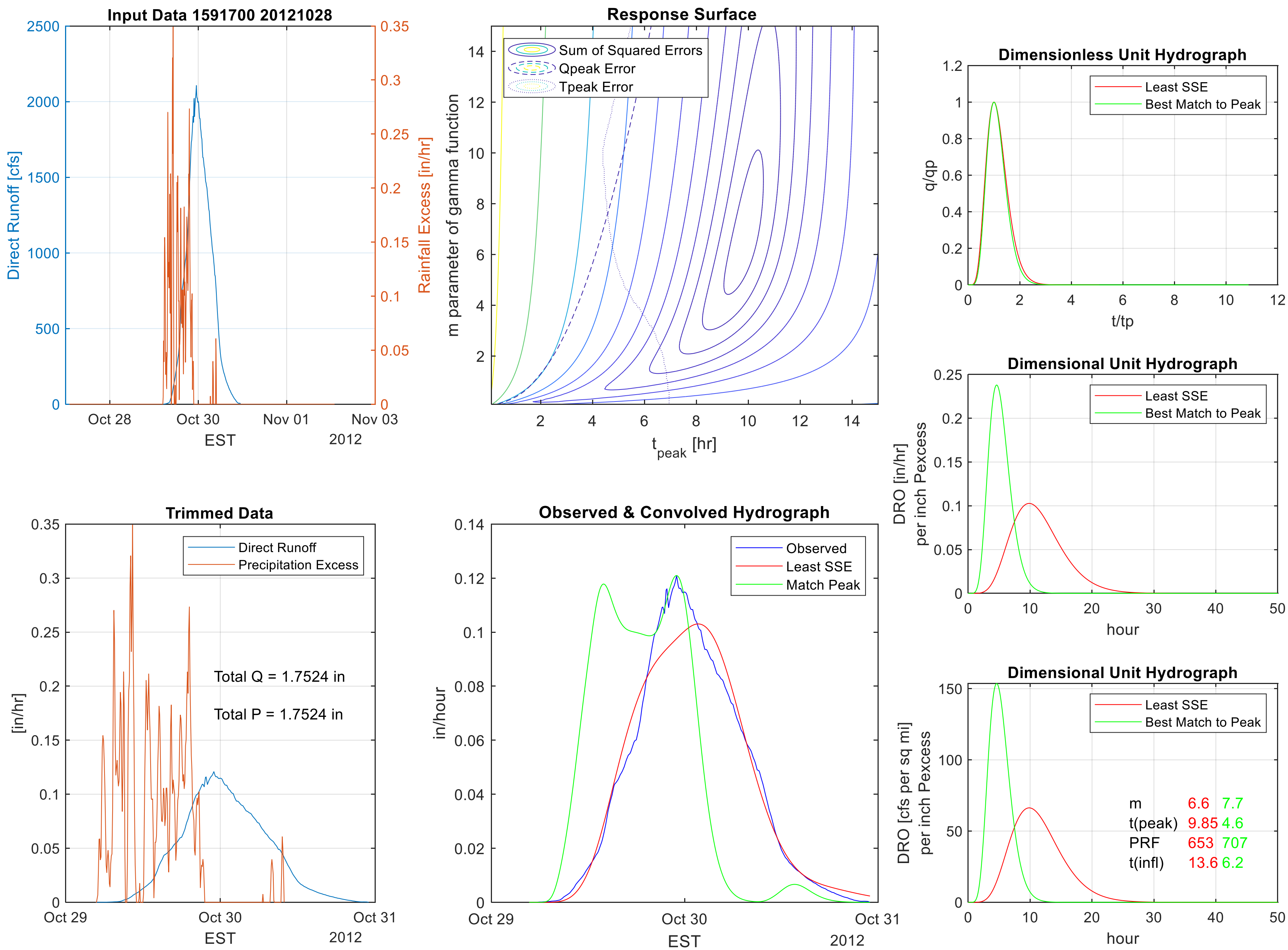
1591700 20121028
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.7524
Phi = 0.15794
in/hr
Eastern Standard Time

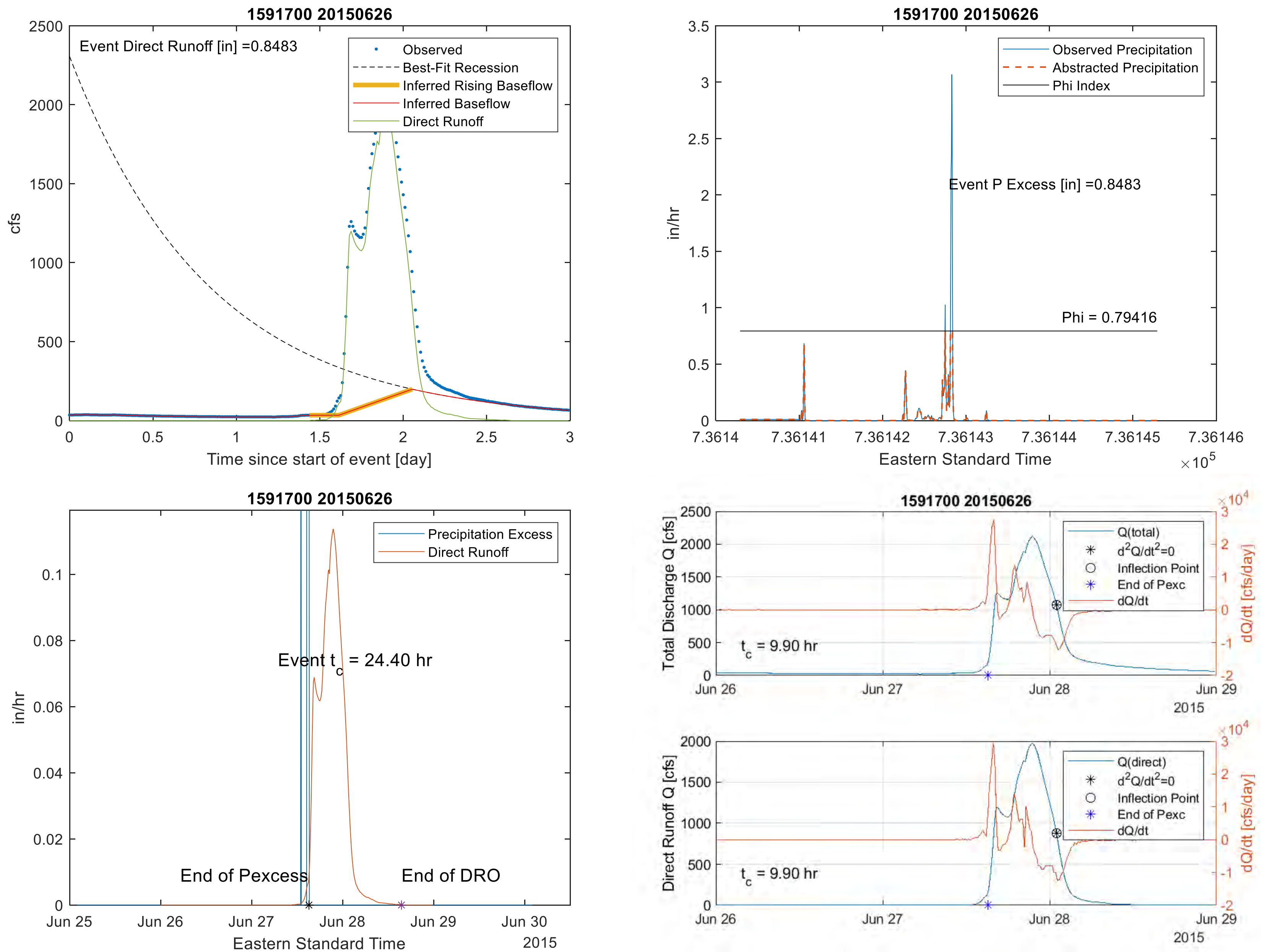


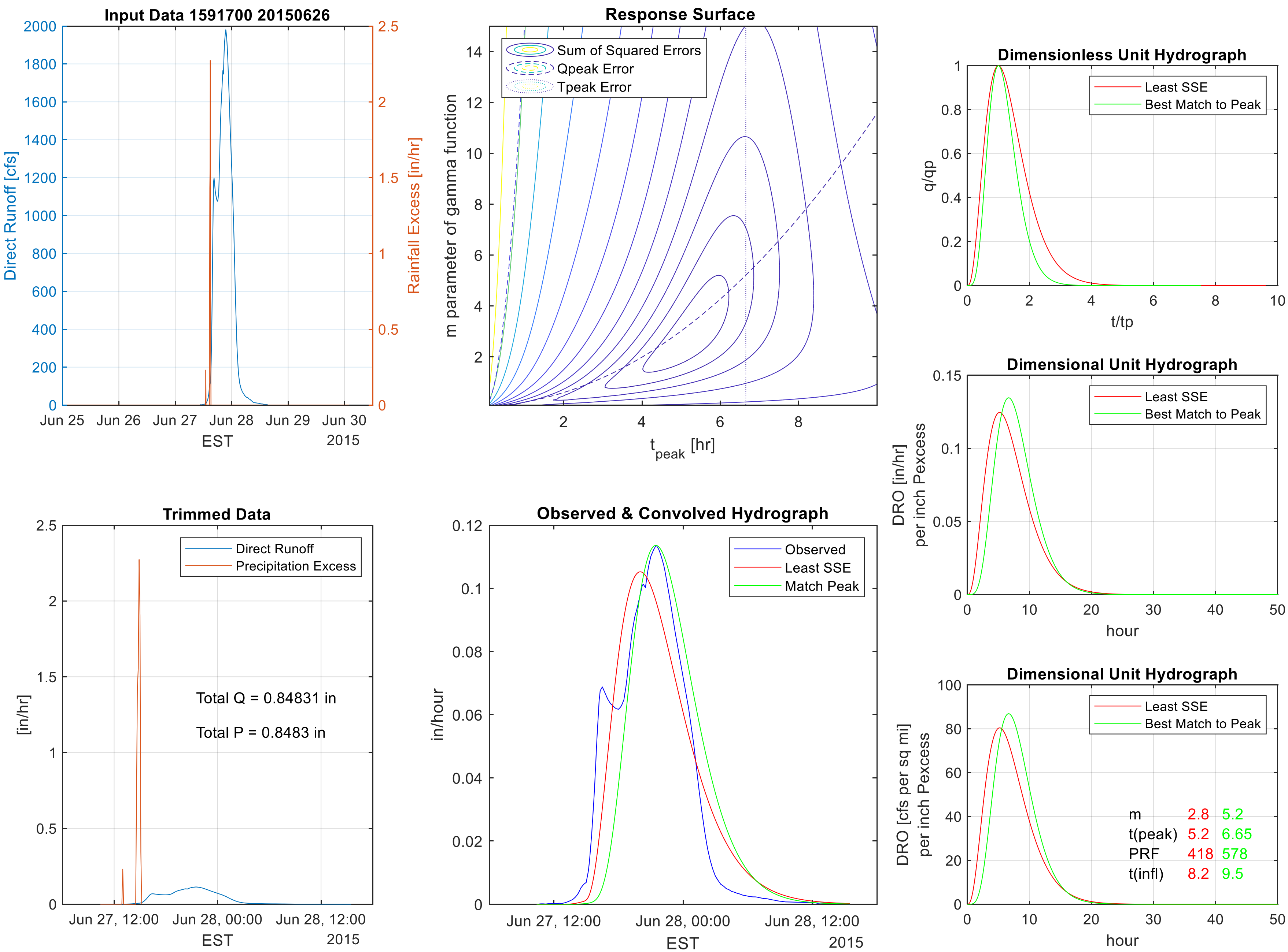
1591700 20121028
Precipitation Excess
Direct Runoff
Event t c = 13.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012

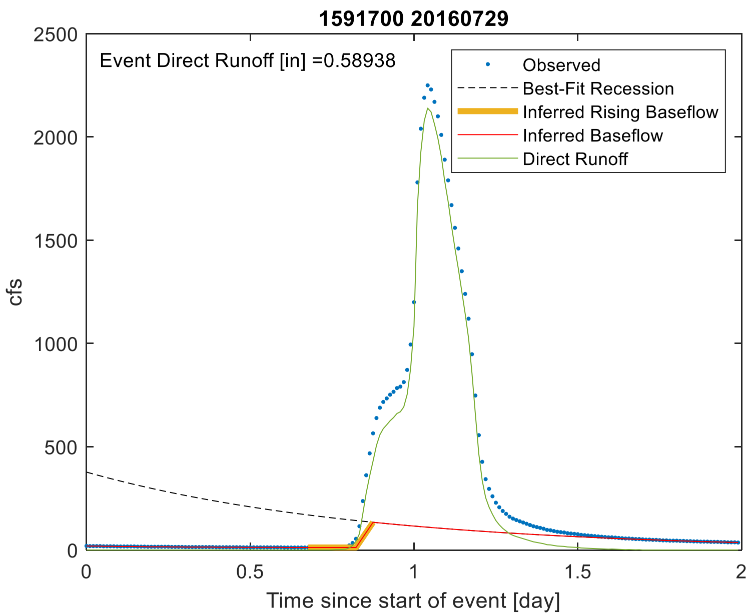


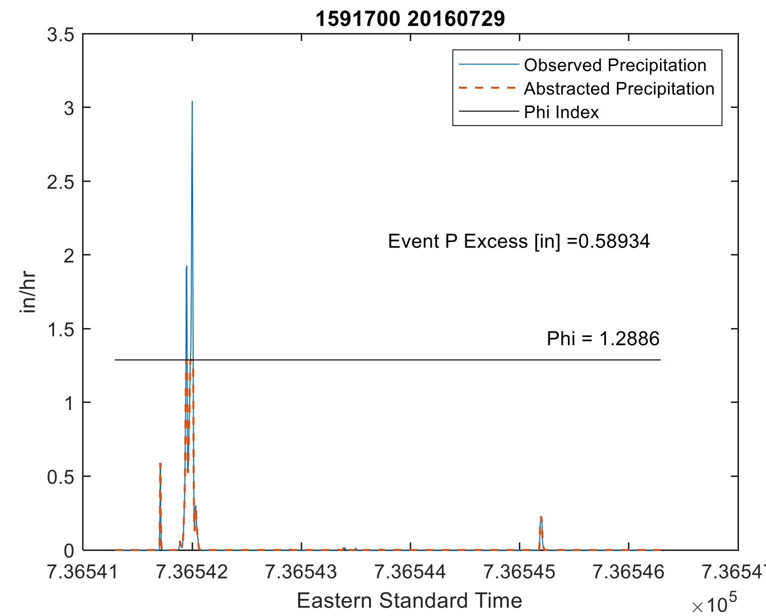
1591700 20121028
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = -7.80 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = -12.00 hr
Direct Runoff Q [cfs]
2012

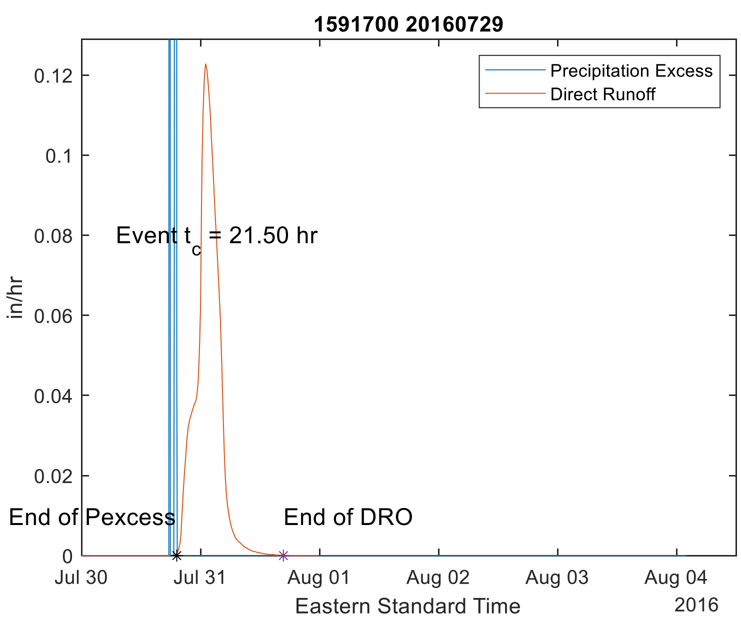

Input Data 1591700 20121028
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 30
Nov 01
Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.7524 in
Total P = 1.7524 in
[in/hr]
Oct 29
Oct 30
Oct 31
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Oct 29
Oct 30
Oct 31
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
m 6.6 7.7
t(peak) 9.85 4.6
PRF 653 707
t(infl) 13.6 6.2
hour

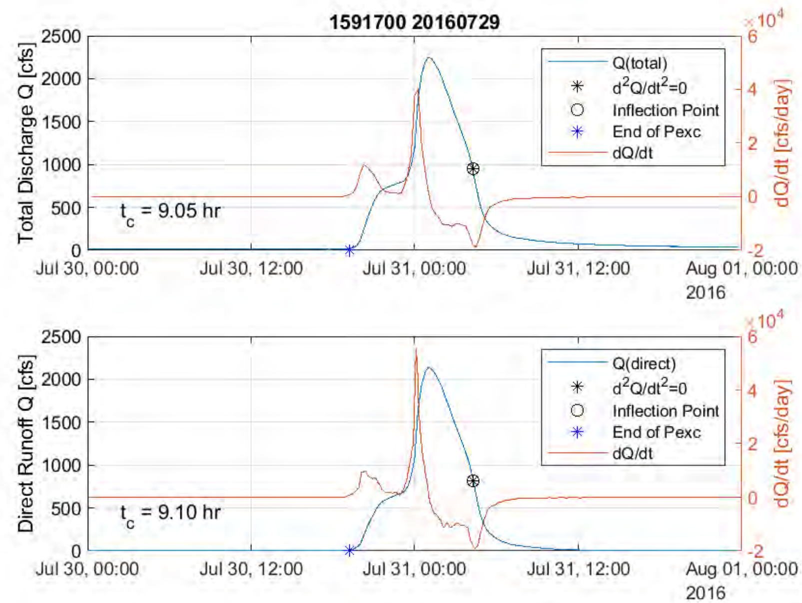

1591700 20150626
Event Direct Runoff [in] =0.8483
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1591700 20150626
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.8483
Phi = 0.79416
in/hr
Eastern Standard Time
1591700 20150626
Precipitation Excess
Direct Runoff
Event t c = 24.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1591700 20150626
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 9.90 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]

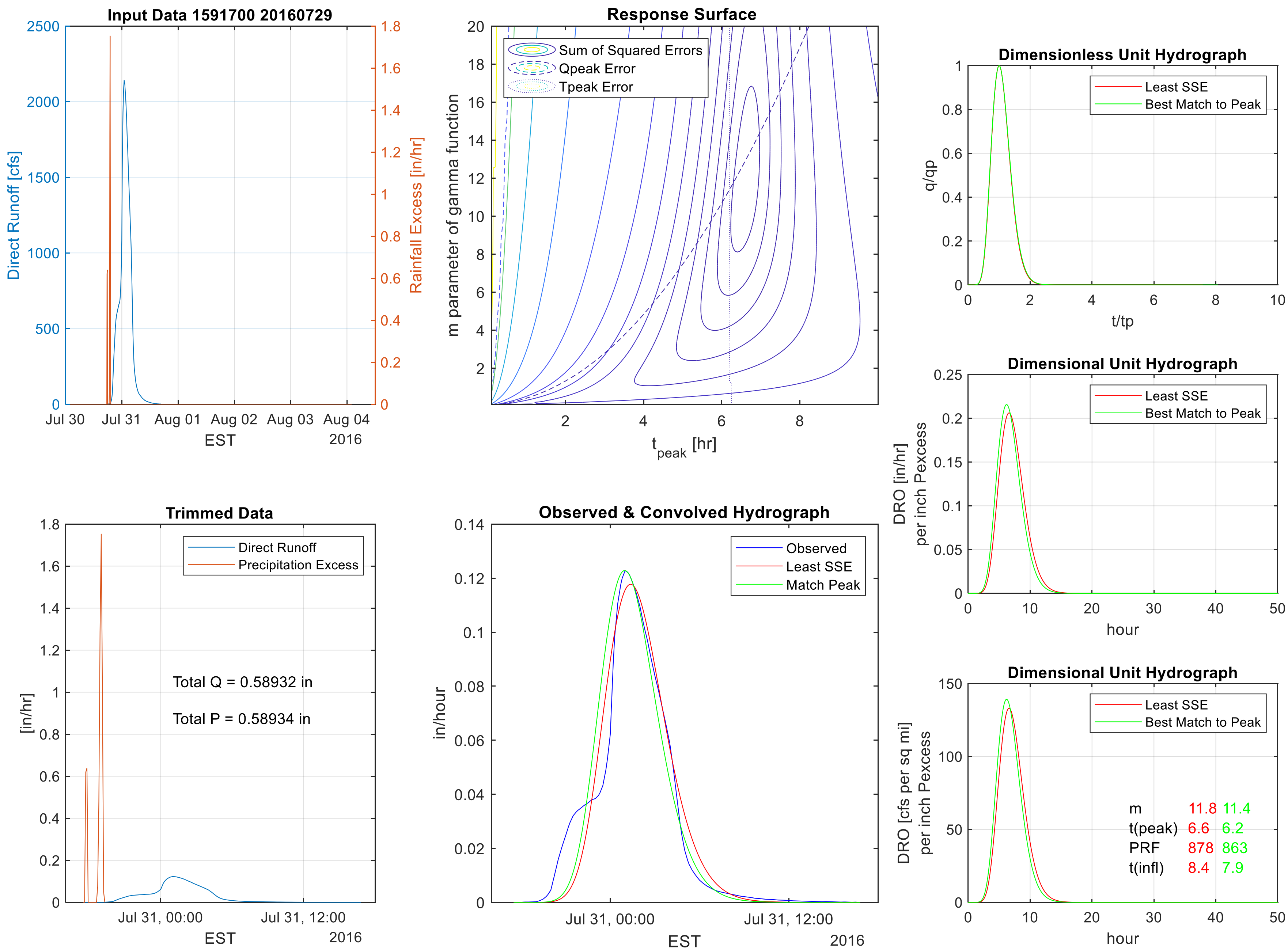

Input Data 1591700 20150626
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 25
Jun 26
Jun 27
Jun 28
Jun 29
Jun 30
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.84831 in
Total P = 0.8483 in
[in/hr]
Jun 27, 12:00
Jun 28, 00:00
Jun 28, 12:00
EST
2015
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 2.8 5.2
t(peak) 5.2 6.65
PRF 418 578
t(infl) 8.2 9.5
hour


1591700 20160729
Event Direct Runoff [in] =0.58938
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

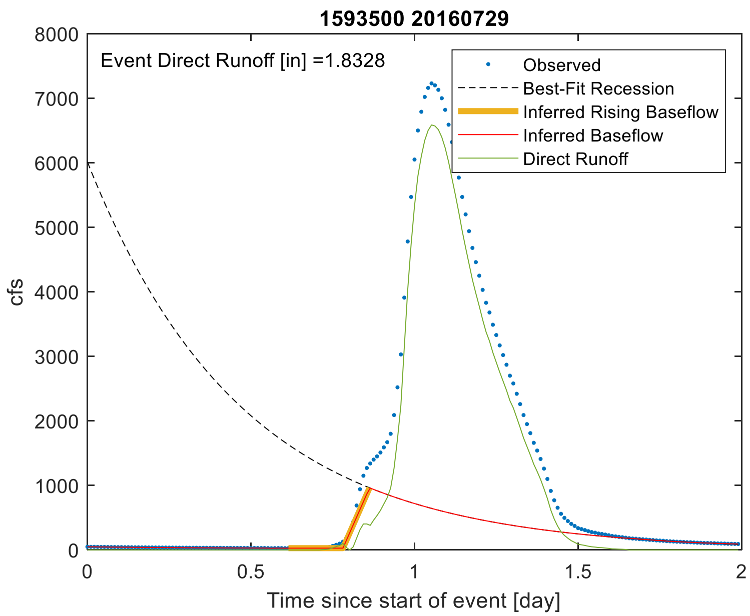

1591700 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.58934
Phi = 1.2886
in/hr
Eastern Standard Time

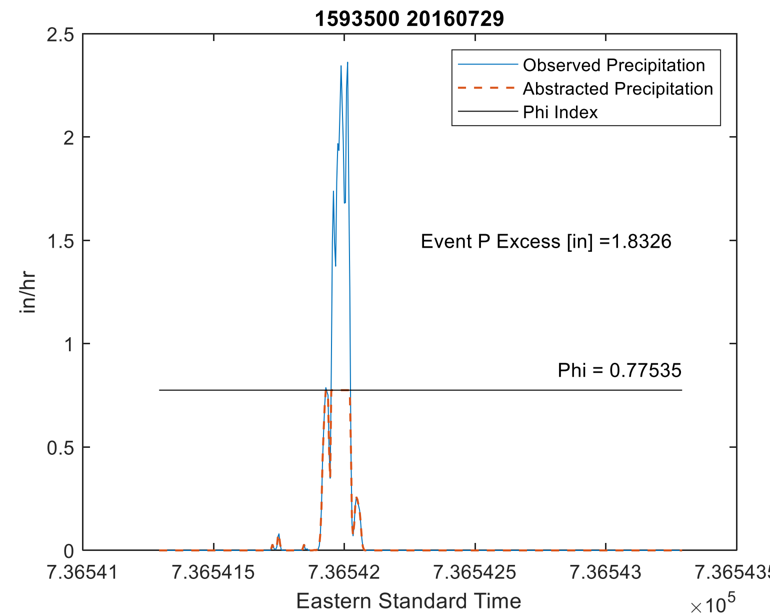

1591700 20160729
Precipitation Excess
Direct Runoff
Event t$_c$ = 21.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

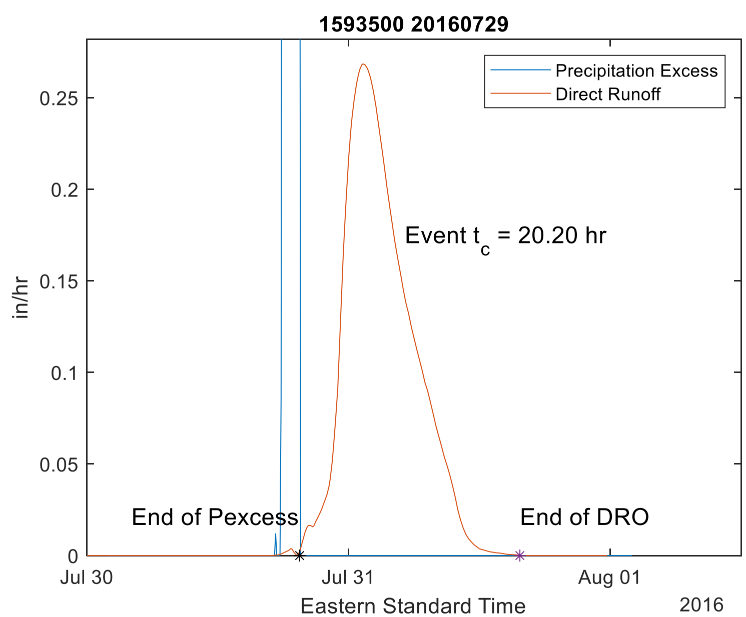

1591700 20160729
Q(total)
d^{2}Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t$_c$ = 9.05 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t$_c$ = 9.10 hr
Direct Runoff Q [cfs]

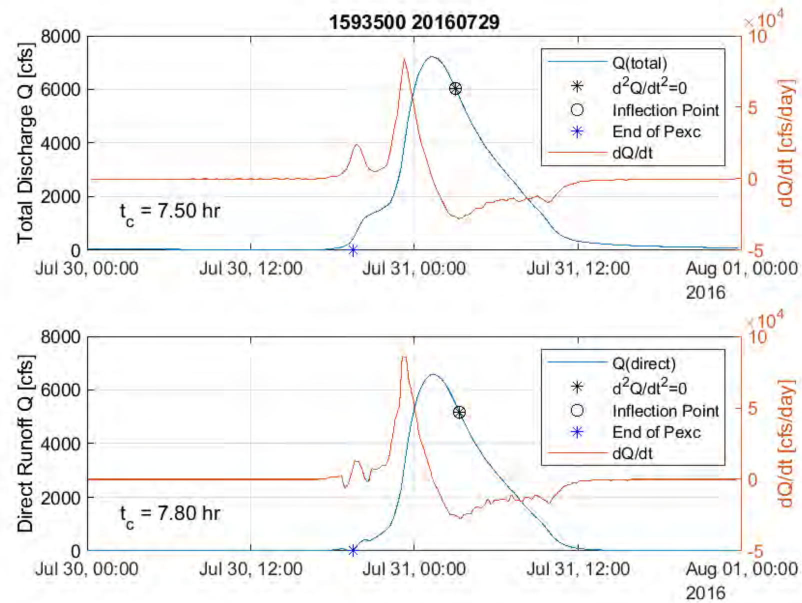


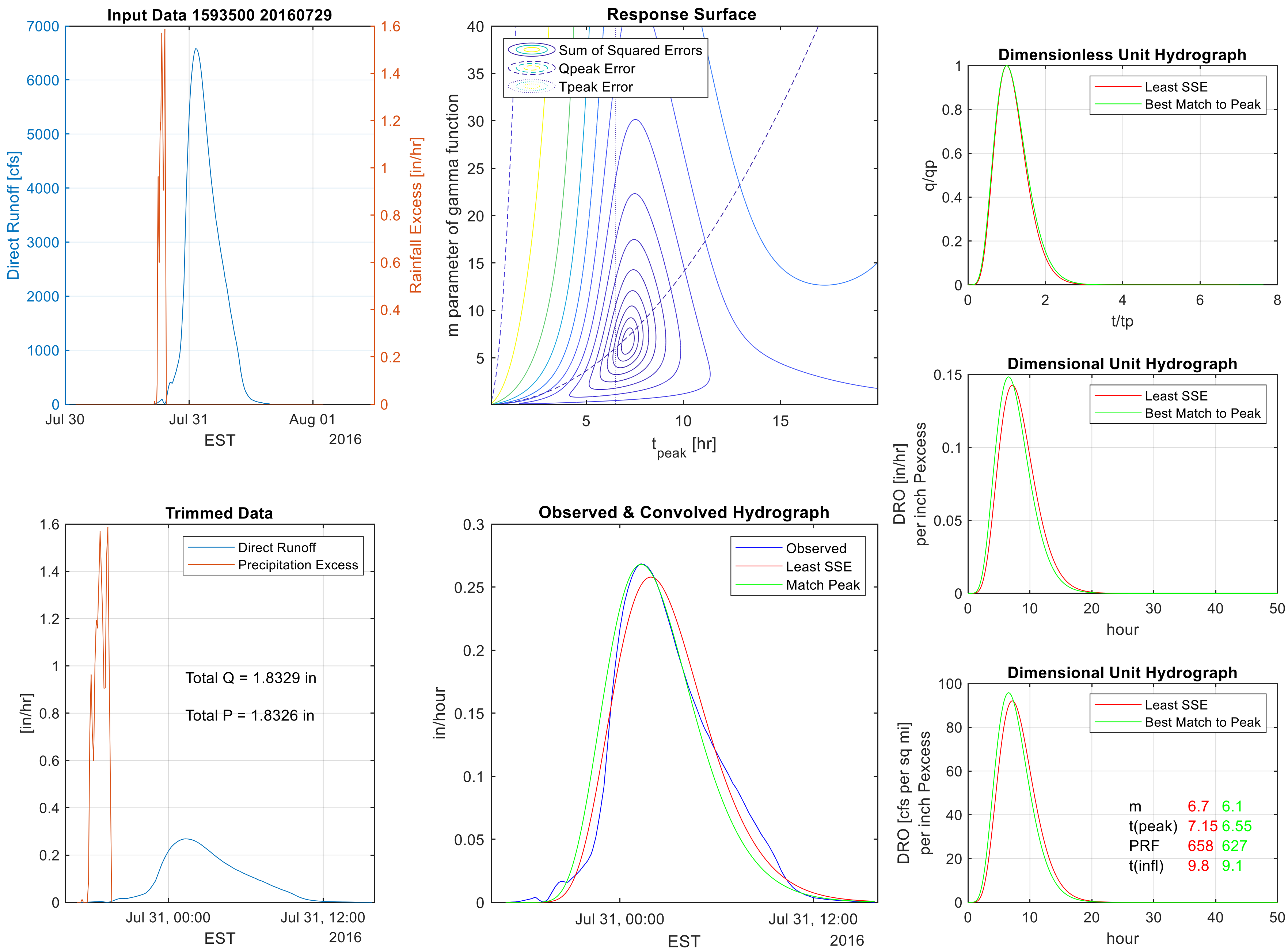
Input Data 1591700 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
Aug 02
Aug 03
Aug 04
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.58932 in
Total P = 0.58934 in
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 11.8 11.4
t(peak) 6.6 6.2
PRF 878 863
t(infl) 8.4 7.9
hour

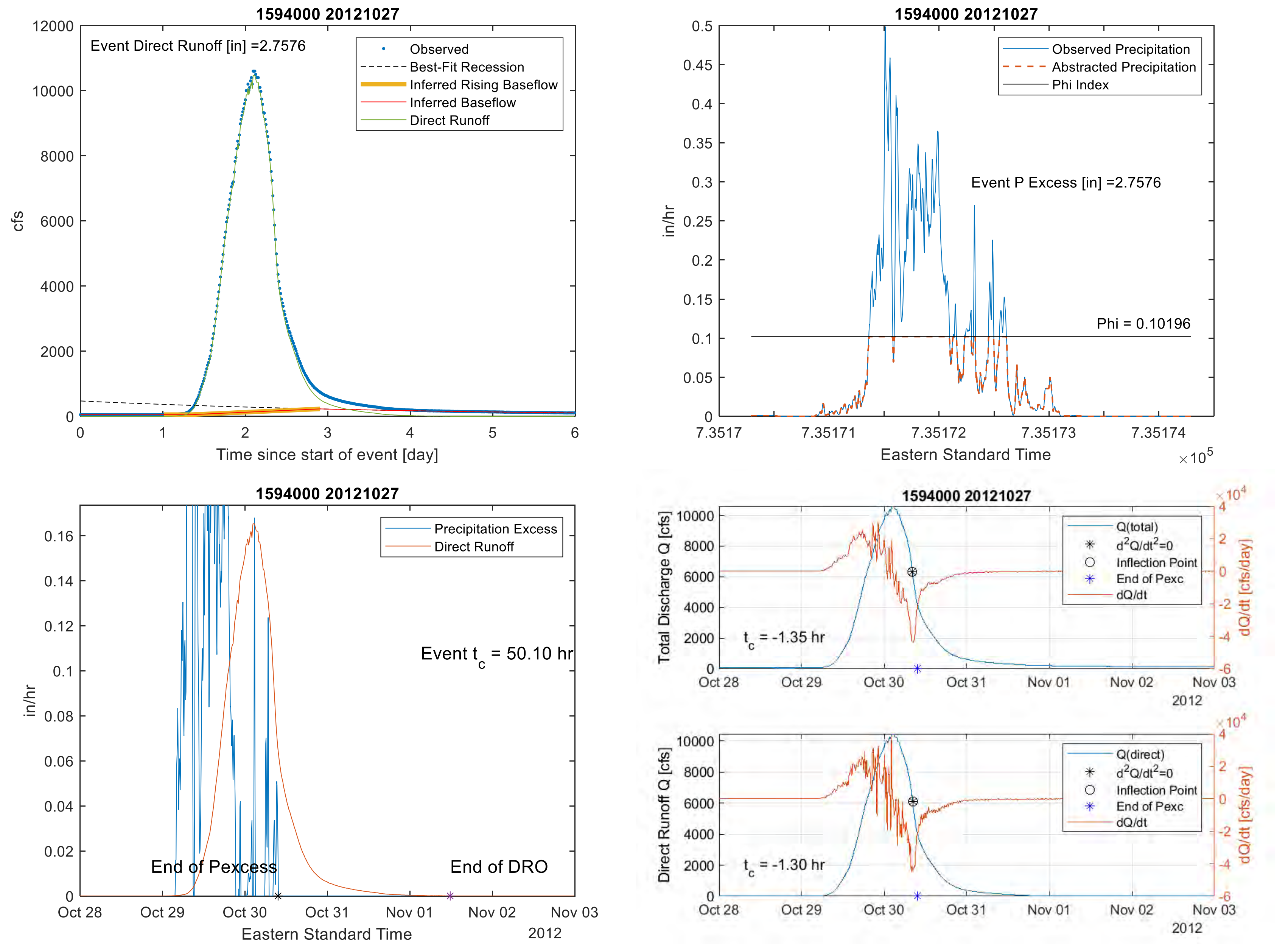

1593500 20160729
Event Direct Runoff [in] =1.8328
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1593500 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.8326
Phi = 0.77535
in/hr
Eastern Standard Time
×10^5

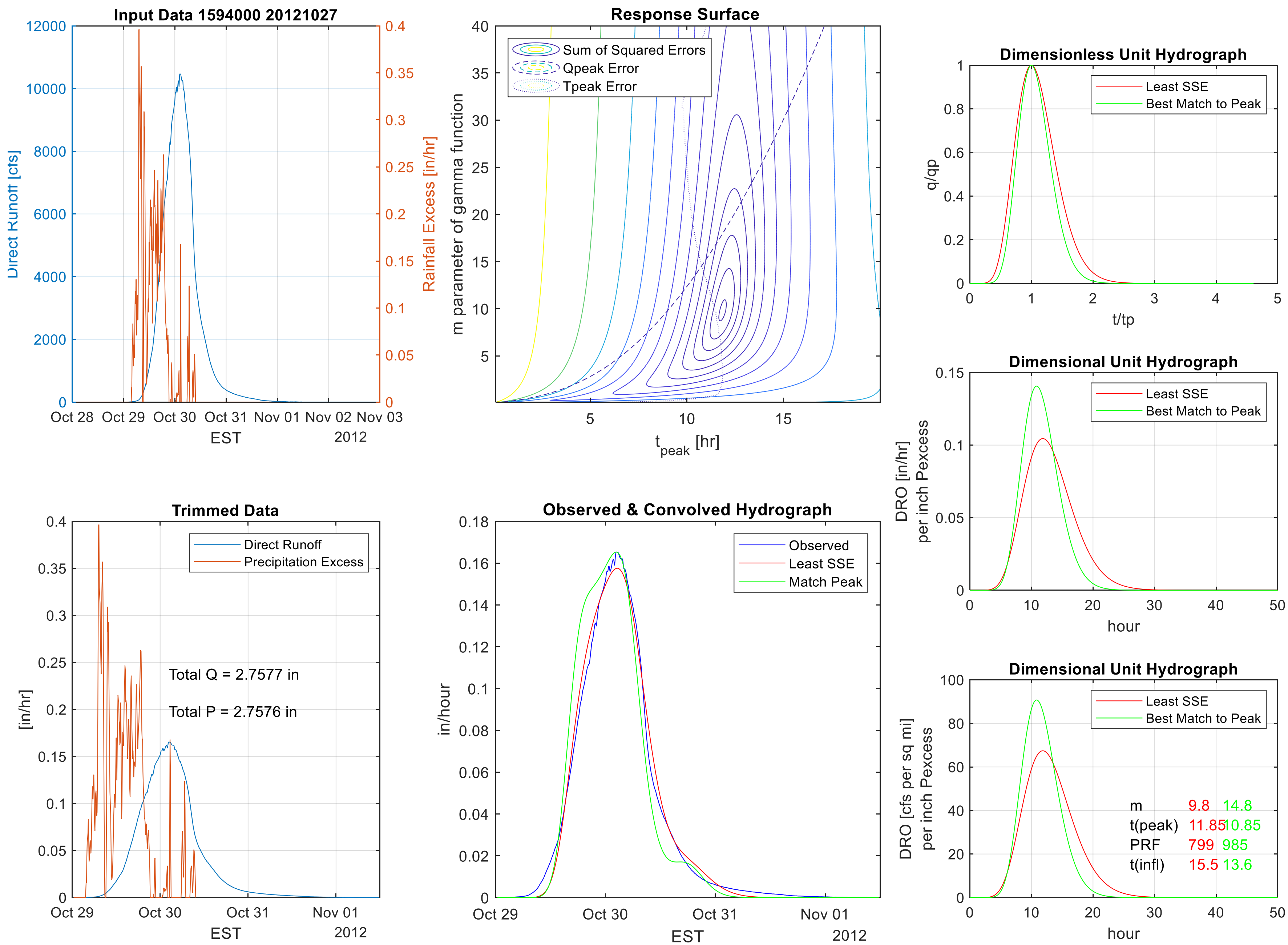

1593500 20160729
Precipitation Excess
Direct Runoff
Event t_c = 20.20 hr
End of Pexcess
End of DRO
in/hr
Jul 30
Jul 31
Aug 01
Eastern Standard Time
2016


1593500 20160729
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 7.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 7.80 hr
Direct Runoff Q [cfs]
Jul 30, 00:00
Jul 30, 12:00
Jul 31, 00:00
Jul 31, 12:00
Aug 01, 00:00
2016

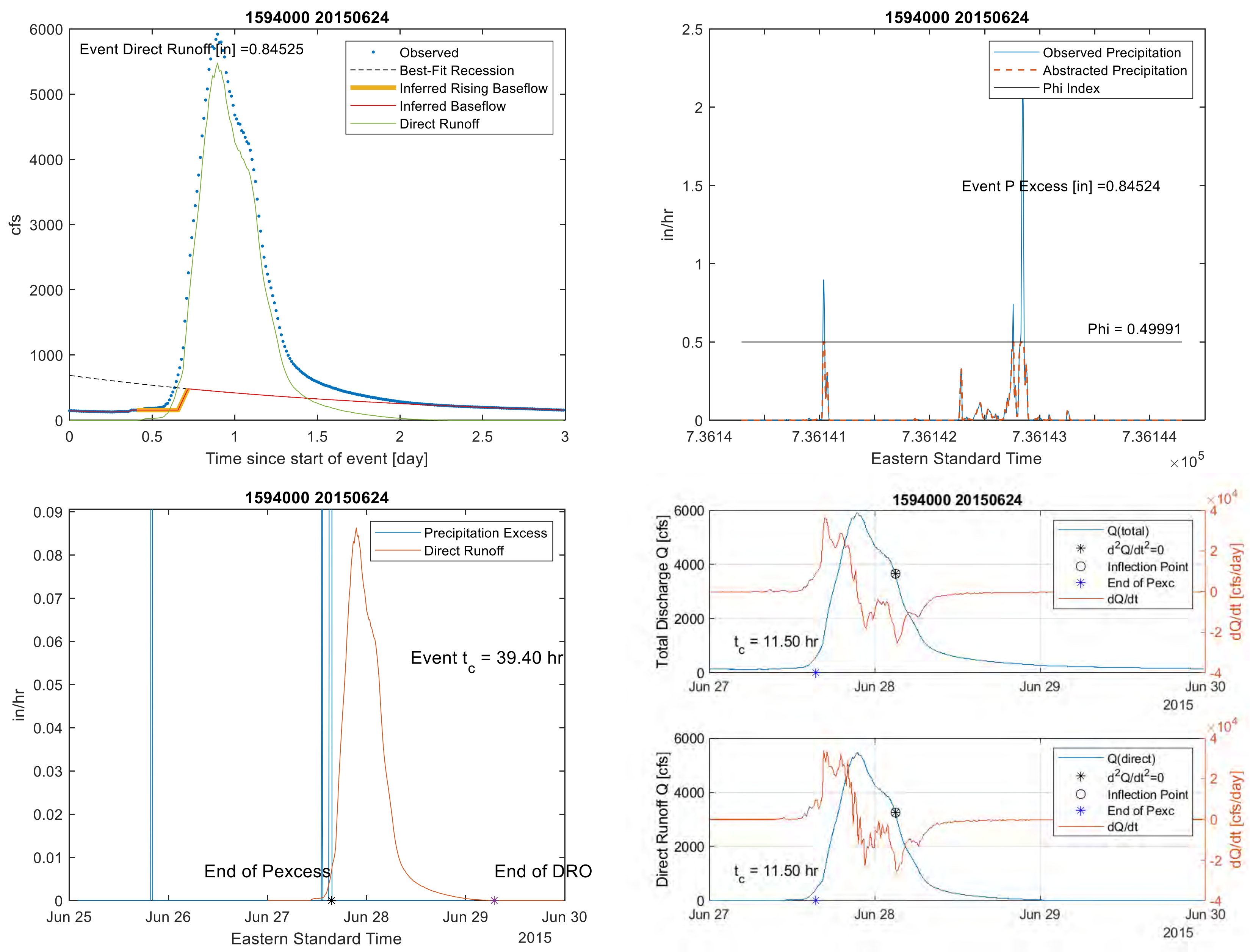

Input Data 1593500 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.8329 in
Total P = 1.8326 in
[in/hr]
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jul 31, 00:00
Jul 31, 12:00
EST
2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 6.7 6.1
t(peak) 7.15 6.55
PRF 658 627
t(infl) 9.8 9.1

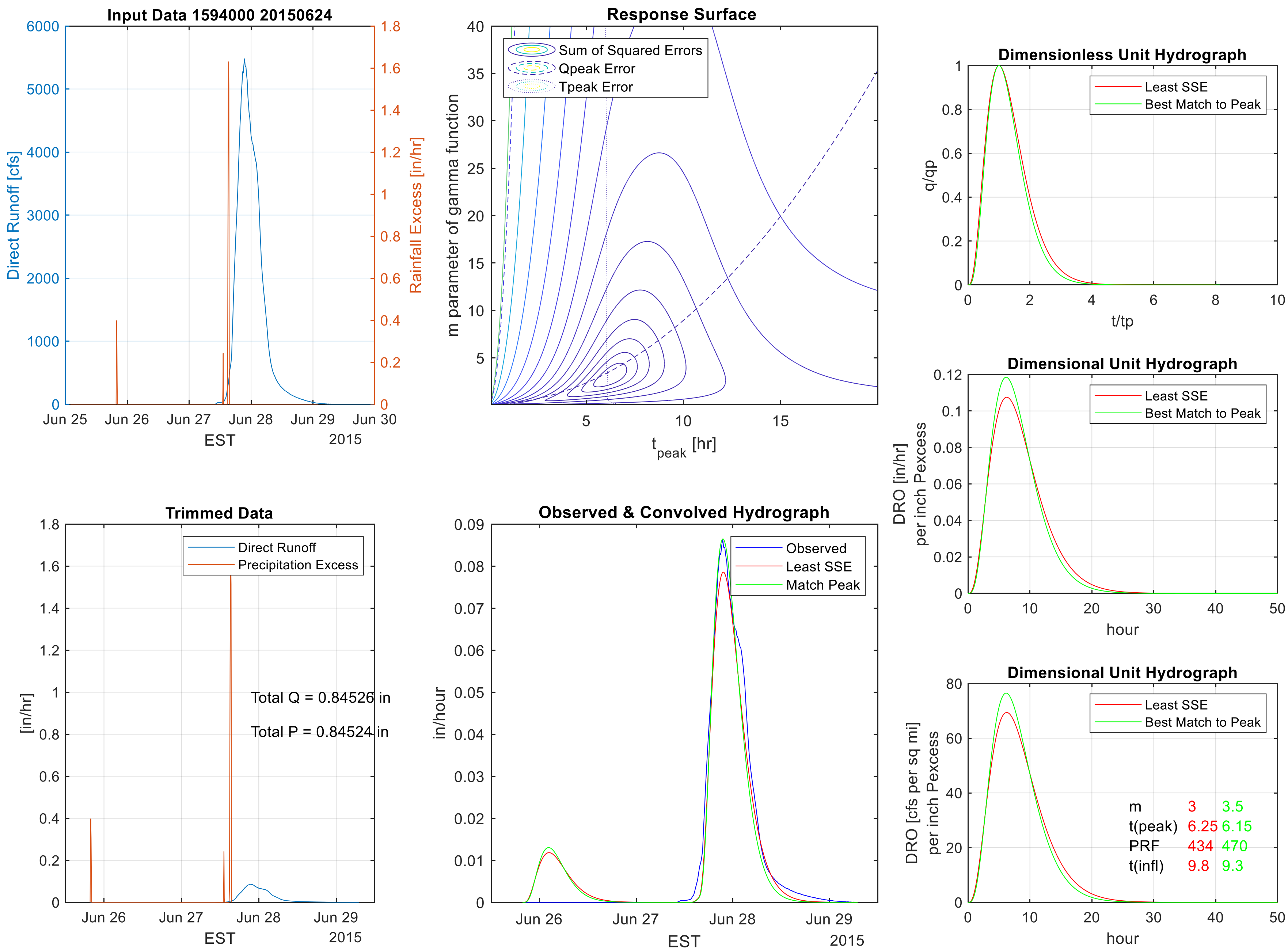


1594000 20121027
Event Direct Runoff [in] =2.7576
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1594000 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.7576
Phi = 0.10196
in/hr
Eastern Standard Time
1594000 20121027
Precipitation Excess
Direct Runoff
Event t c = 50.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1594000 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = -1.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = -1.30 hr
Direct Runoff Q [cfs]

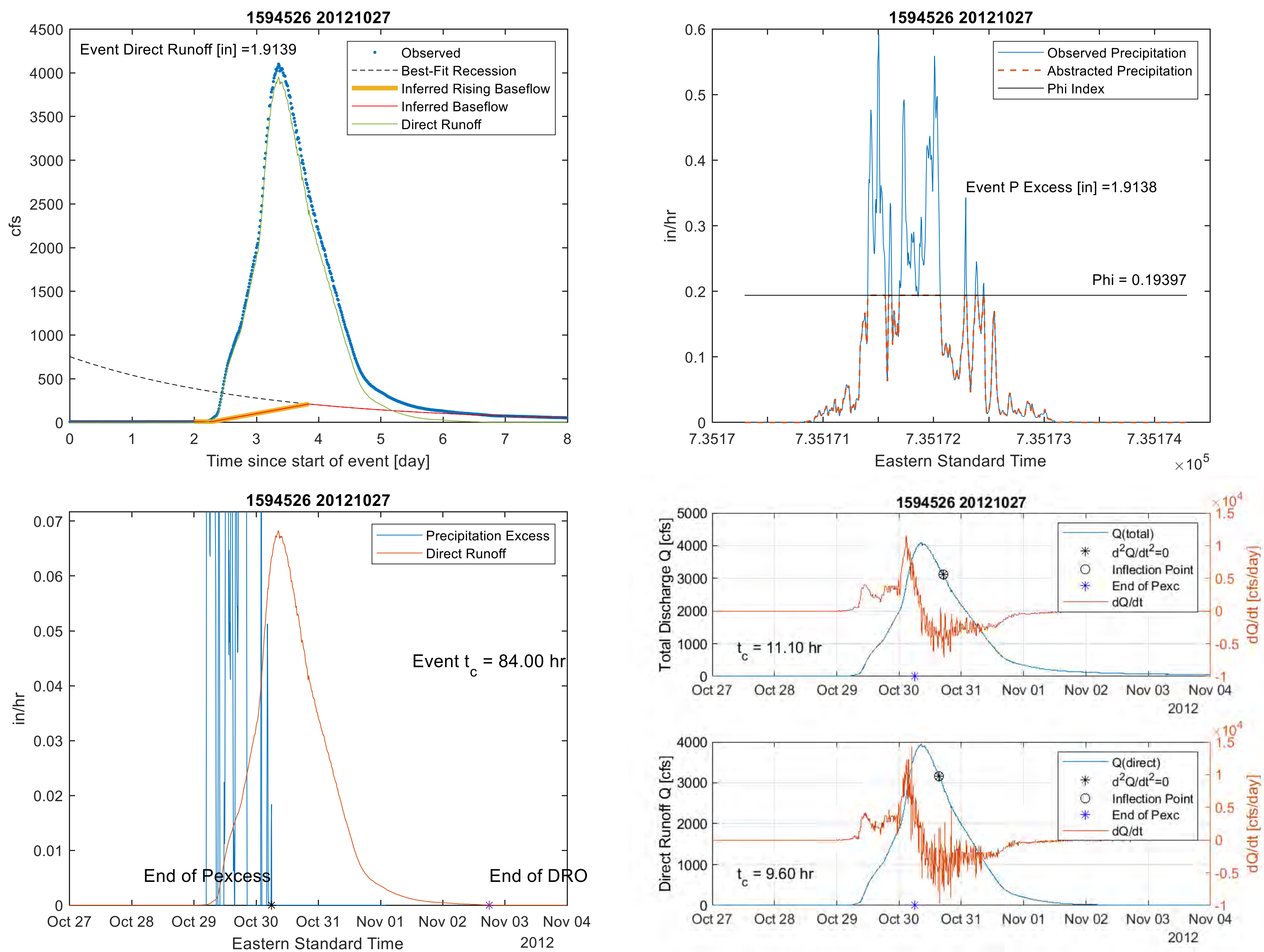


Input Data 1594000 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
12000
10000
8000
6000
4000
2000
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Oct 28 Oct 29 Oct 30 Oct 31 Nov 01 Nov 02 Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
40
35
30
25
20
15
10
5
5
10
15
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
0.15
0.1
0.05
0
0
10
20
30
40
50
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Total Q = 2.7577 in
Total P = 2.7576 in
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Oct 29
Oct 30
Oct 31
Nov 01
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
100
80
60
40
20
0
m 9.8 14.8
t(peak) 11.85 10.85
PRF 799 985
t(infl) 15.5 13.6
0
10
20
30
40
50
hour

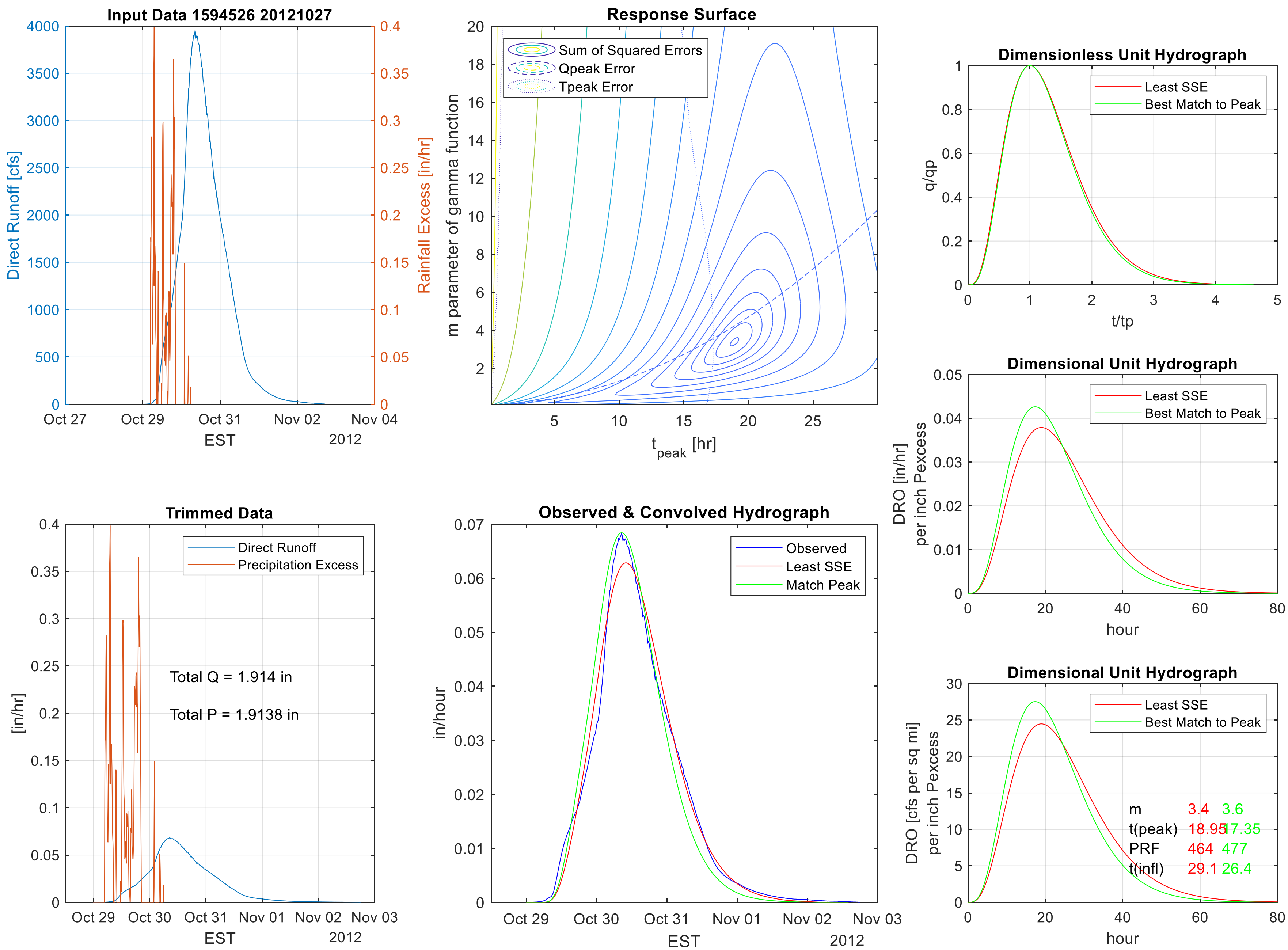

1594000 20150624
Event Direct Runoff [in] =0.84525
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1594000 20150624
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.84524
Phi = 0.49991
in/hr
Eastern Standard Time
1594000 20150624
Precipitation Excess
Direct Runoff
Event t_c = 39.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1594000 20150624
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 11.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]
2015



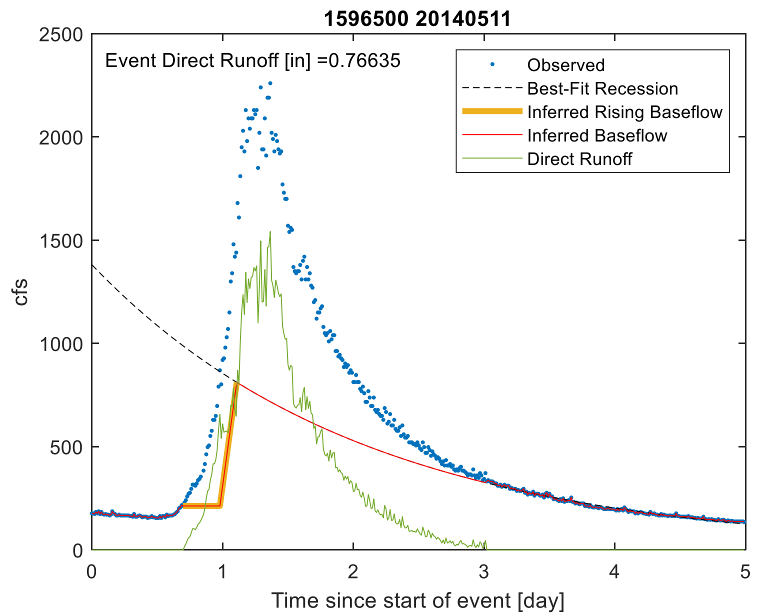
Input Data 1594000 20150624
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 25
Jun 26
Jun 27
Jun 28
Jun 29
Jun 30
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.84526 in
Total P = 0.84524 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 3 3.5
t(peak) 6.25 6.15
PRF 434 470
t(infl) 9.8 9.3

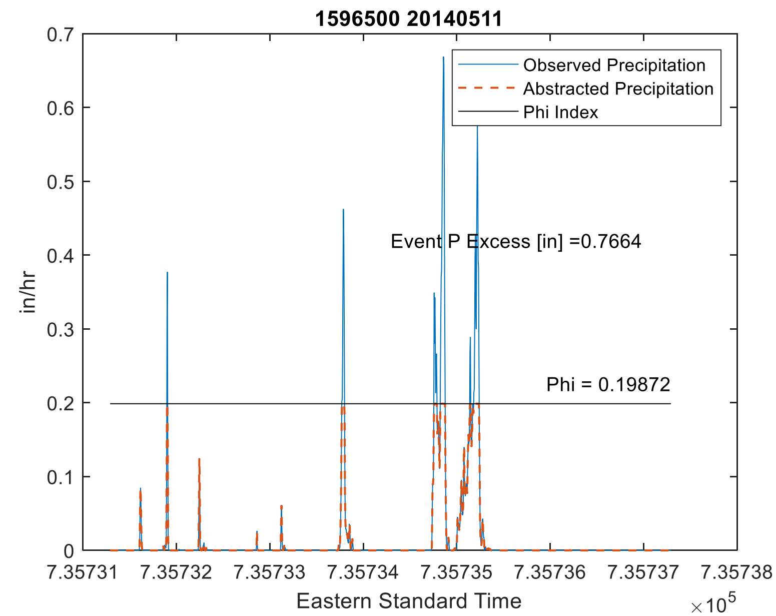


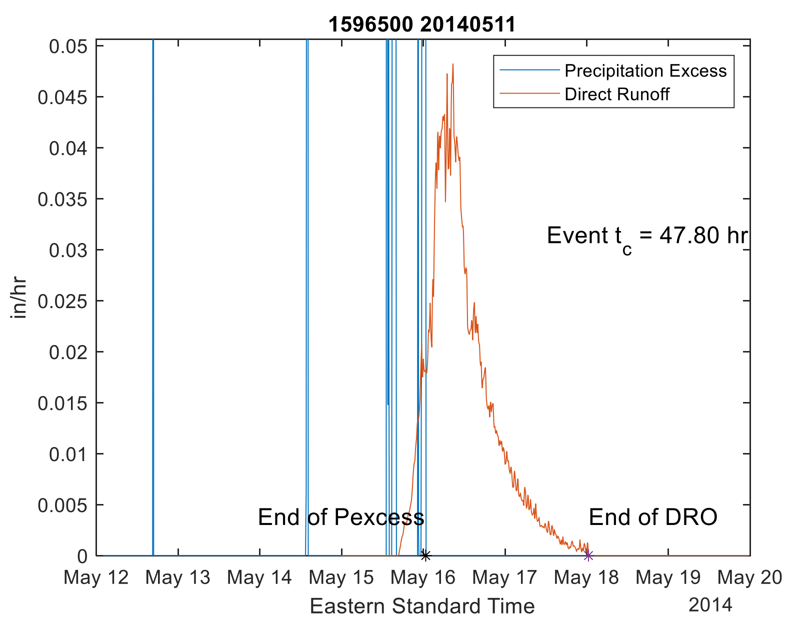
1594526 20121027
Event Direct Runoff [in] =1.9139
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1594526 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.9138
Phi = 0.19397
in/hr
Eastern Standard Time
1594526 20121027
Precipitation Excess
Direct Runoff
Event t c = 84.00 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1594526 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 11.10 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 9.60 hr
Direct Runoff Q [cfs]

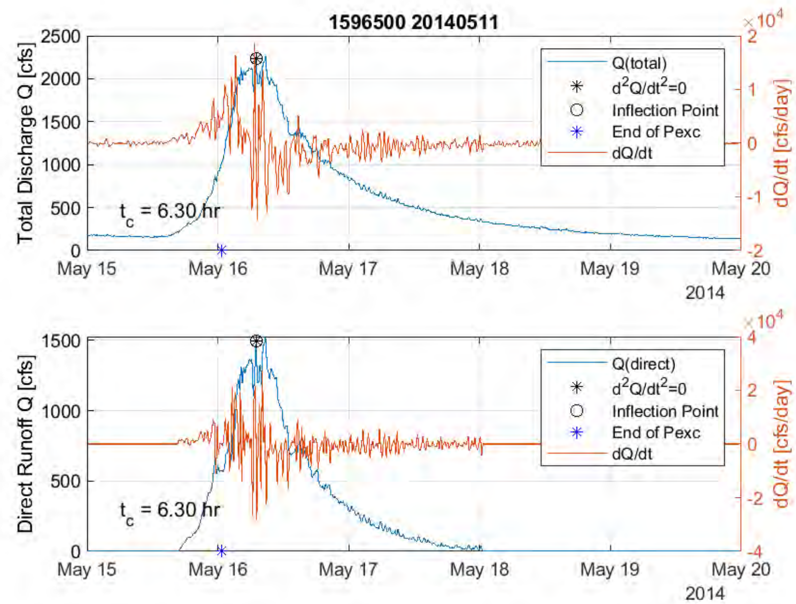


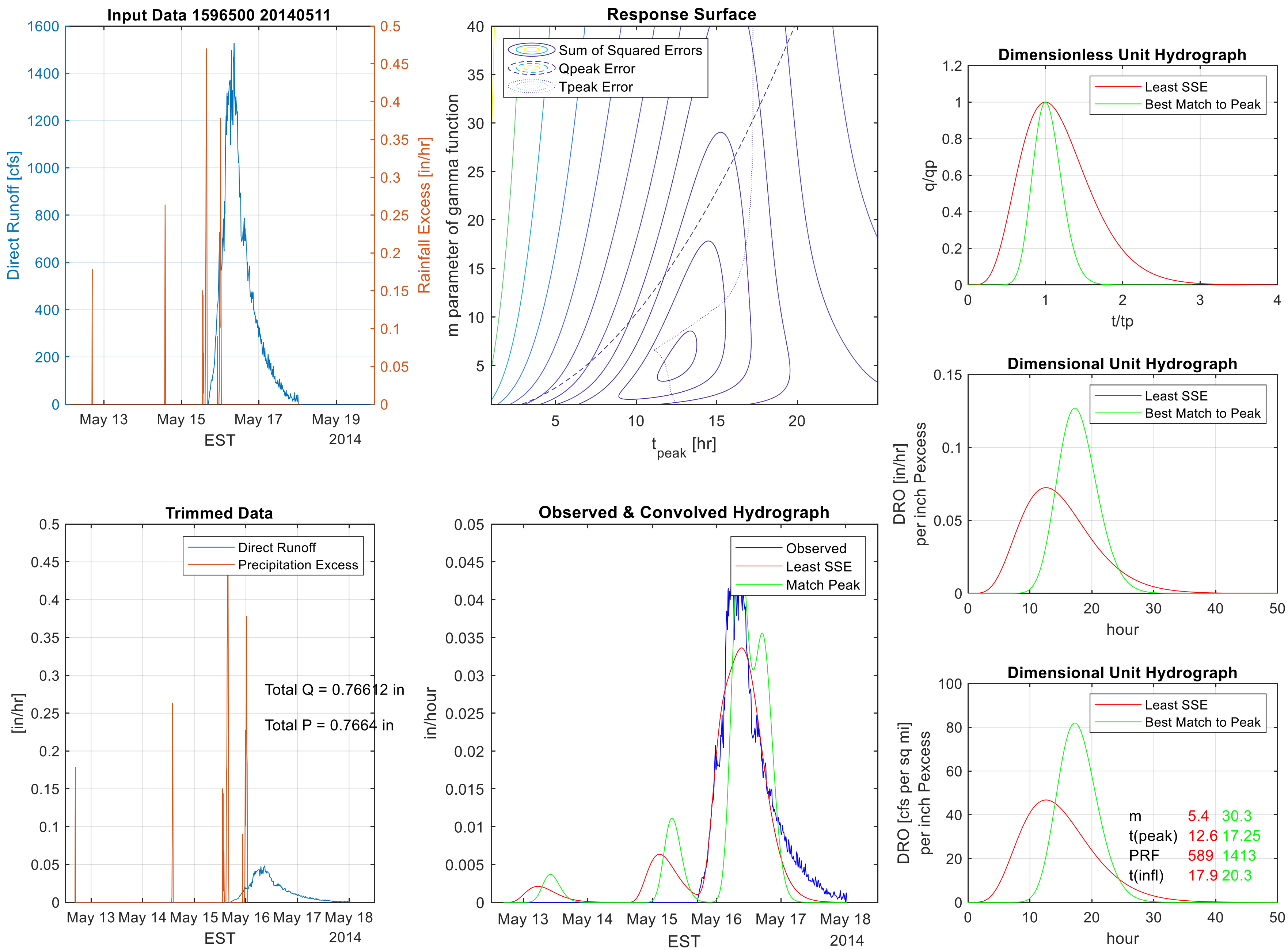
Input Data 1594526 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
4000
3500
3000
2500
2000
1500
1000
500
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Oct 27
Oct 29
Oct 31
Nov 02
Nov 04
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
20
18
16
14
12
10
8
6
4
2
5
10
15
20
25
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.914 in
Total P = 1.9138 in
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
Nov 03
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
Nov 03
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
30
25
20
15
10
5
0
0
20
40
60
80
m 3.4 3.6
t(peak) 18.95 17.35
PRF 464 477
t(infl) 29.1 26.4


1596500 20140511
Event Direct Runoff [in] =0.76635
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
2500
2000
1500
1000
500
0
0
1
2
3
4
5
Time since start of event [day]

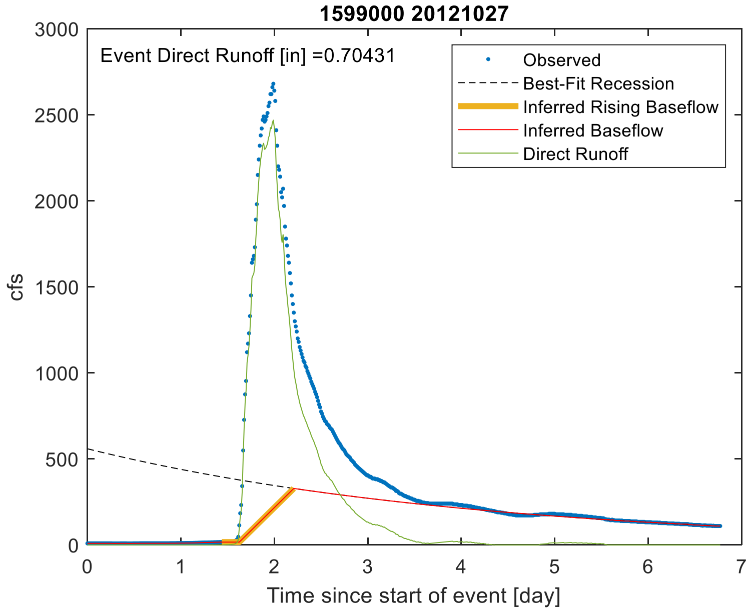

1596500 20140511
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.7664
Phi = 0.19872
in/hr
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7.35731
7.35732
7.35733
7.35734
7.35735
7.35736
7.35737
7.35738
Eastern Standard Time
×10^5

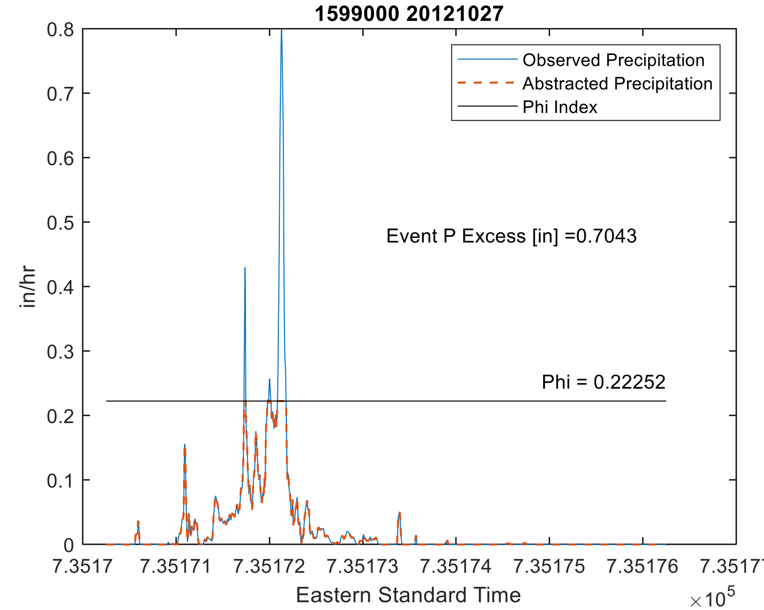

1596500 20140511
Precipitation Excess
Direct Runoff
Event t_c = 47.80 hr
End of Pexcess
End of DRO
in/hr
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
May 12
May 13
May 14
May 15
May 16
May 17
May 18
May 19
May 20
2014
Eastern Standard Time

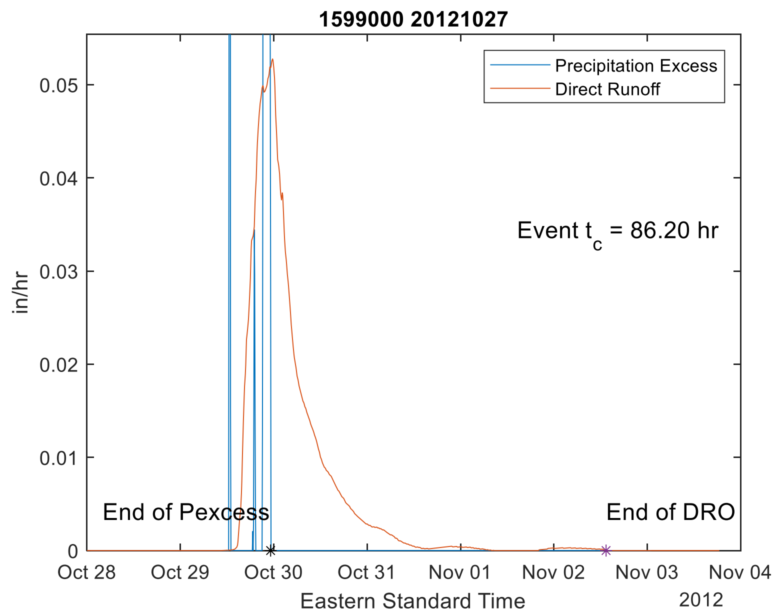

1596500 20140511
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 6.30 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
×10^4
May 15
May 16
May 17
May 18
May 19
May 20
2014
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 6.30 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
×10^4
May 15
May 16
May 17
May 18
May 19
May 20
2014

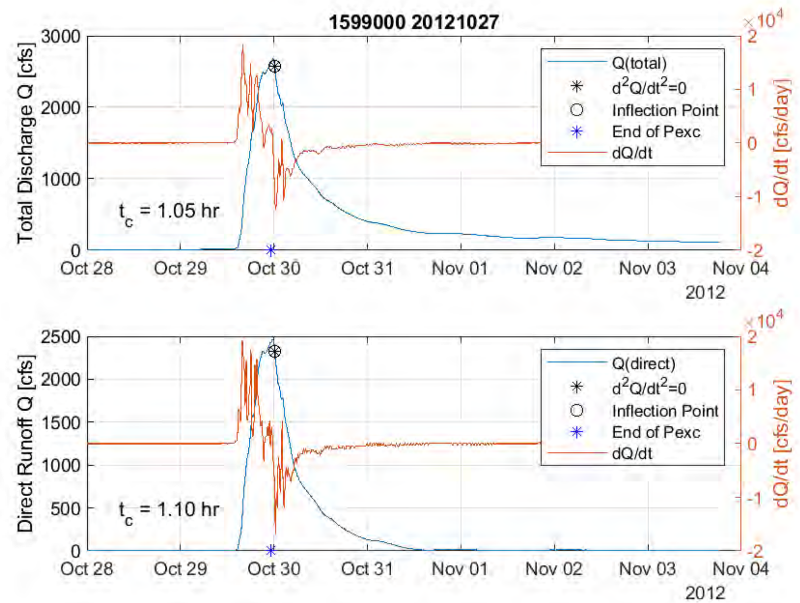


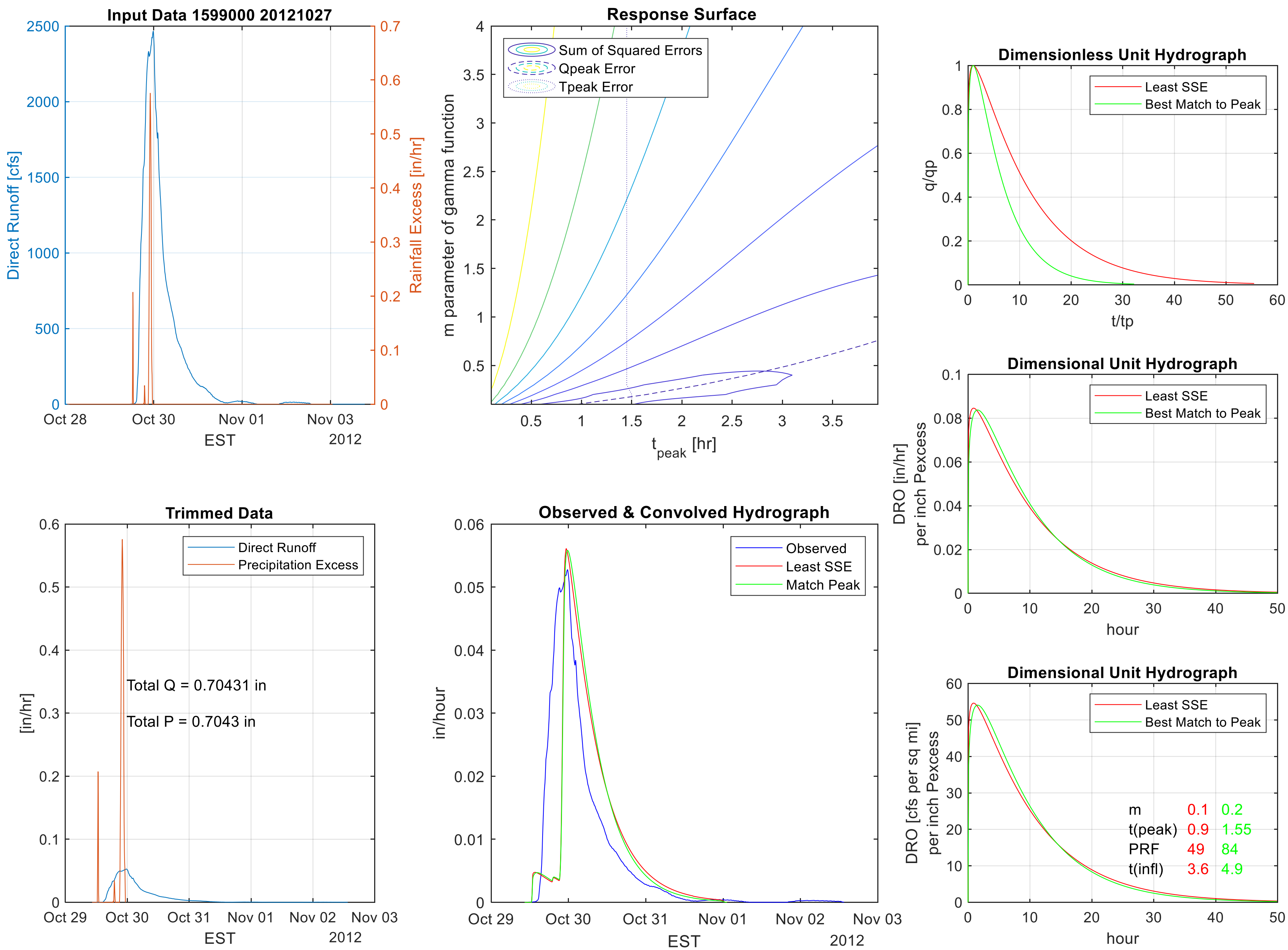
Input Data 1596500 20140511
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 13
May 15
May 17
May 19
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.76612 in
Total P = 0.7664 in
May 13 May 14 May 15 May 16 May 17 May 18
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
May 13 May 14 May 15 May 16 May 17 May 18
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.4 30.3
t(peak) 12.6 17.25
PRF 589 1413
t(infl) 17.9 20.3

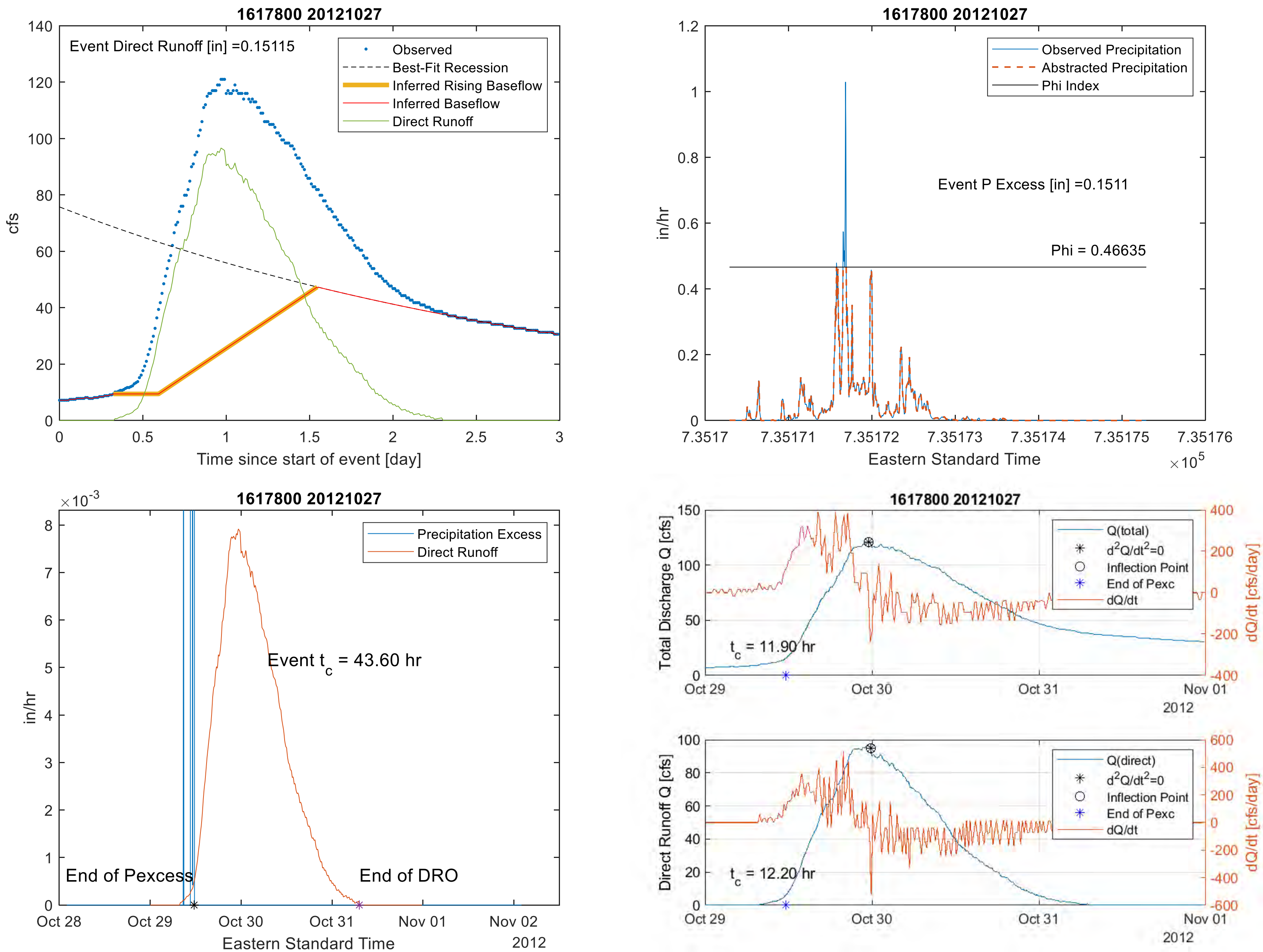

1599000 20121027
Event Direct Runoff [in] =0.70431
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]

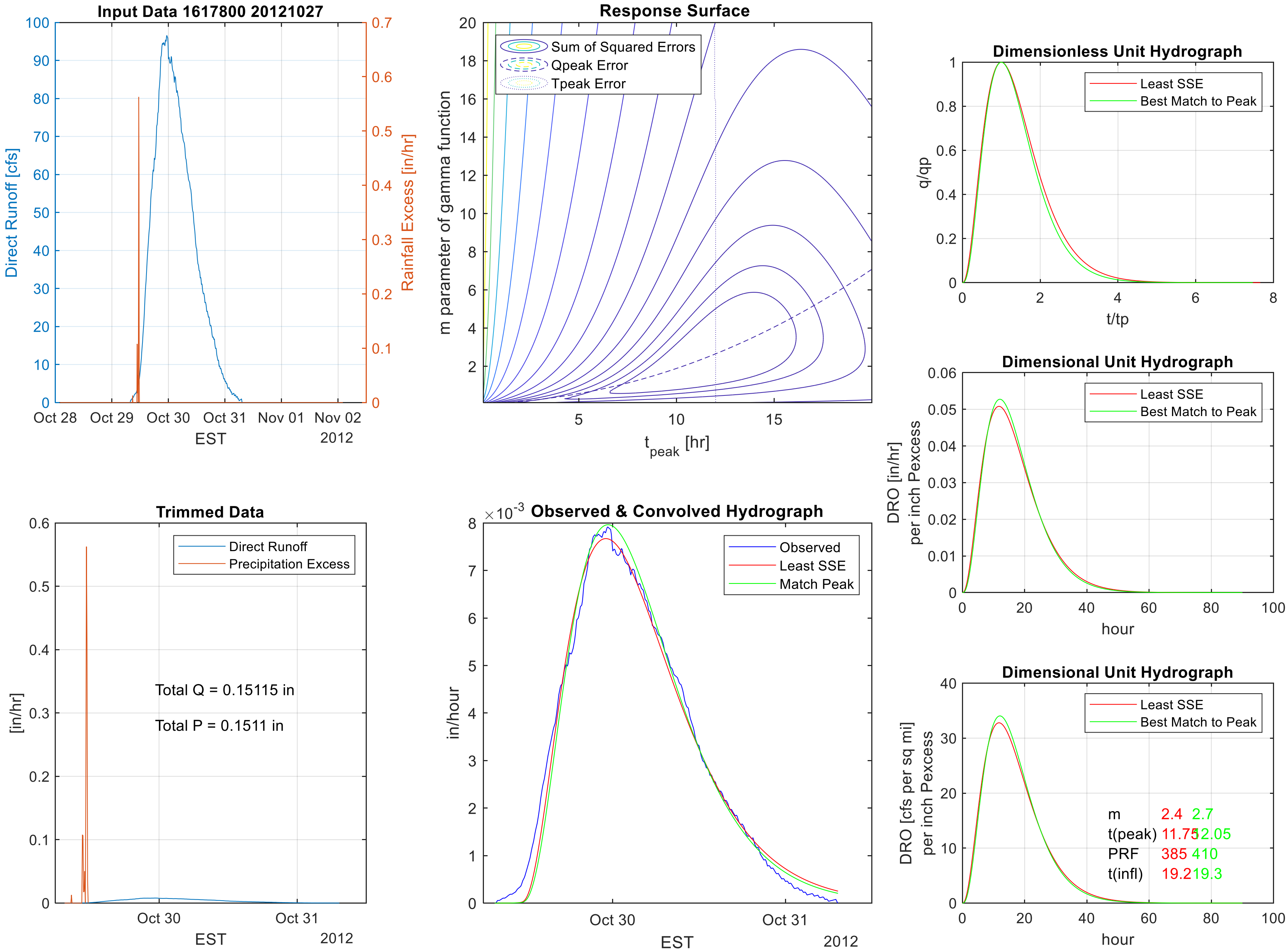

1599000 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.7043
Phi = 0.22252
in/hr
Eastern Standard Time
×10^5

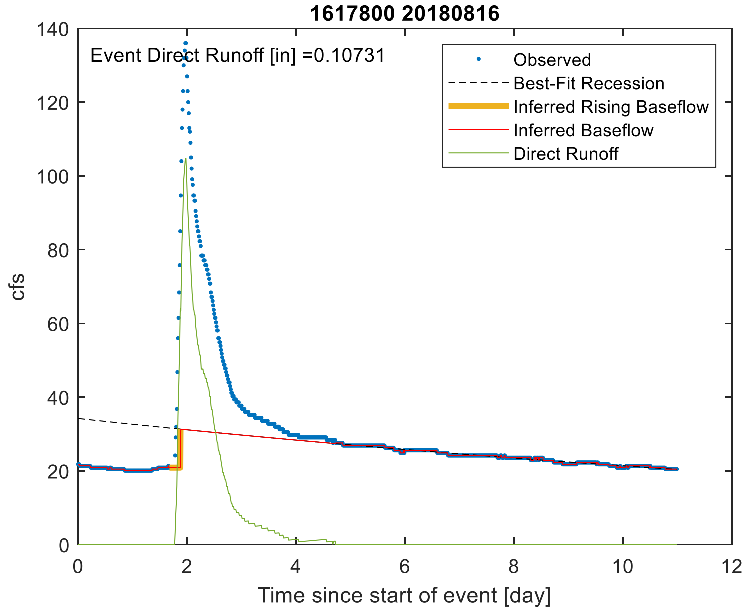

1599000 20121027
Precipitation Excess
Direct Runoff
Event t_c = 86.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012

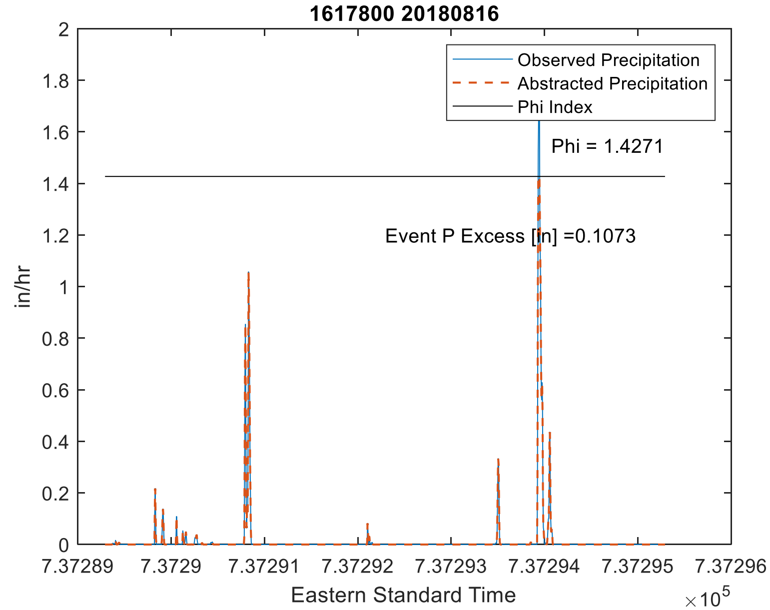

1599000 20121027
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 1.05 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2012
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 1.10 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2012

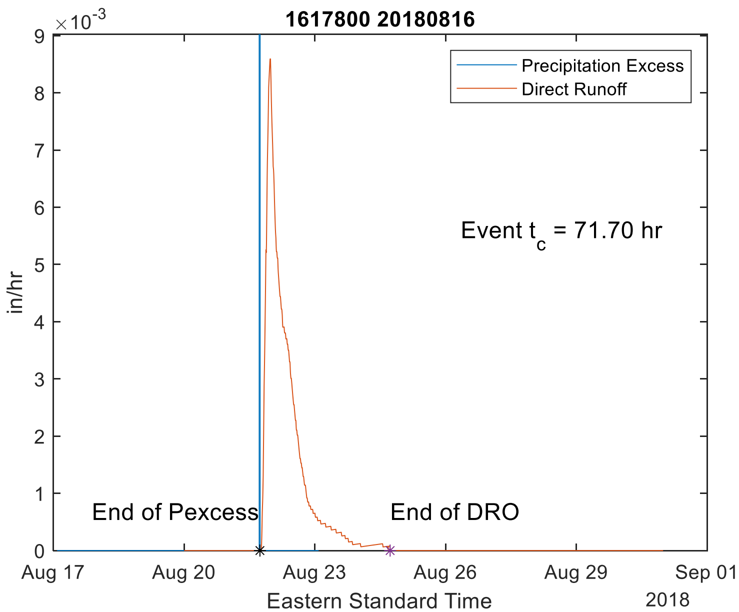

Input Data 1599000 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 30
Nov 01
Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.70431 in
Total P = 0.7043 in
[in/hr]
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
Nov 03
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 0.1 0.2
t(peak) 0.9 1.55
PRF 49 84
t(infl) 3.6 4.9
hour

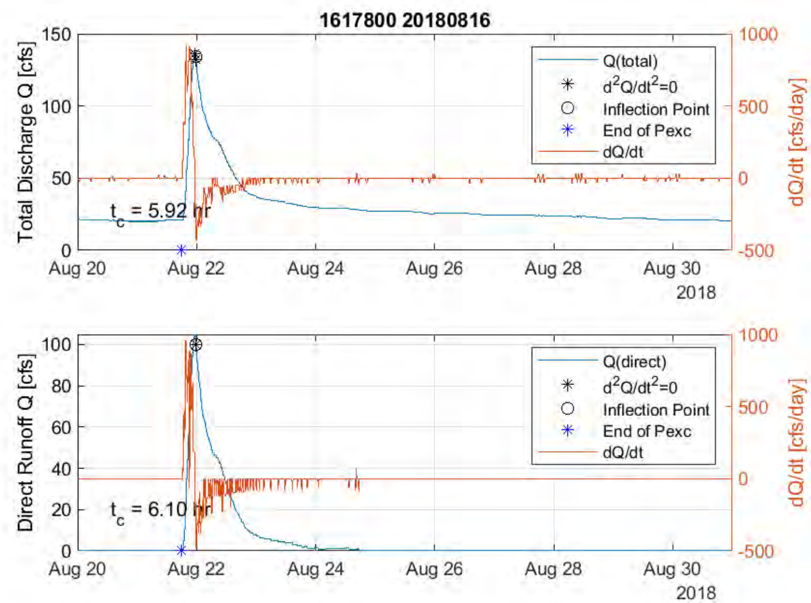

1617800 20121027
Event Direct Runoff [in] =0.15115
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1617800 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.1511
Phi = 0.46635
in/hr
Eastern Standard Time
1617800 20121027
Precipitation Excess
Direct Runoff
Event t_c = 43.60 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1617800 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 11.90 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 12.20 hr
Direct Runoff Q [cfs]

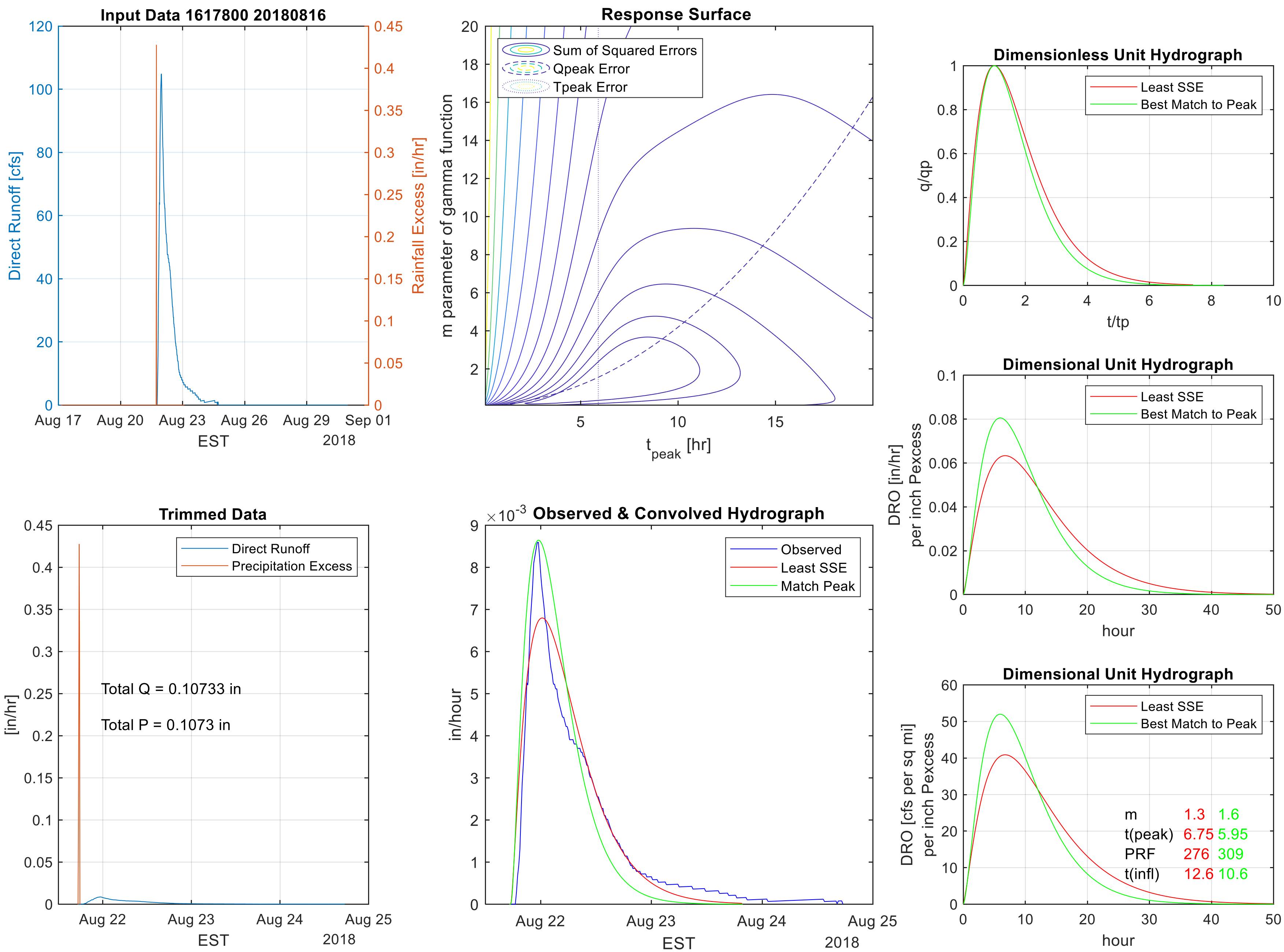

Input Data 1617800 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.15115 in
Total P = 0.1511 in
[in/hr]
Oct 30
Oct 31
EST
2012
Observed & Convolved Hydrograph
$\times 10^{-3}$
Observed
Least SSE
Match Peak
in/hour
Oct 30
Oct 31
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 2.4 2.7
t(peak) 11.75 12.05
PRF 385 410
t(infl) 19.2 19.3

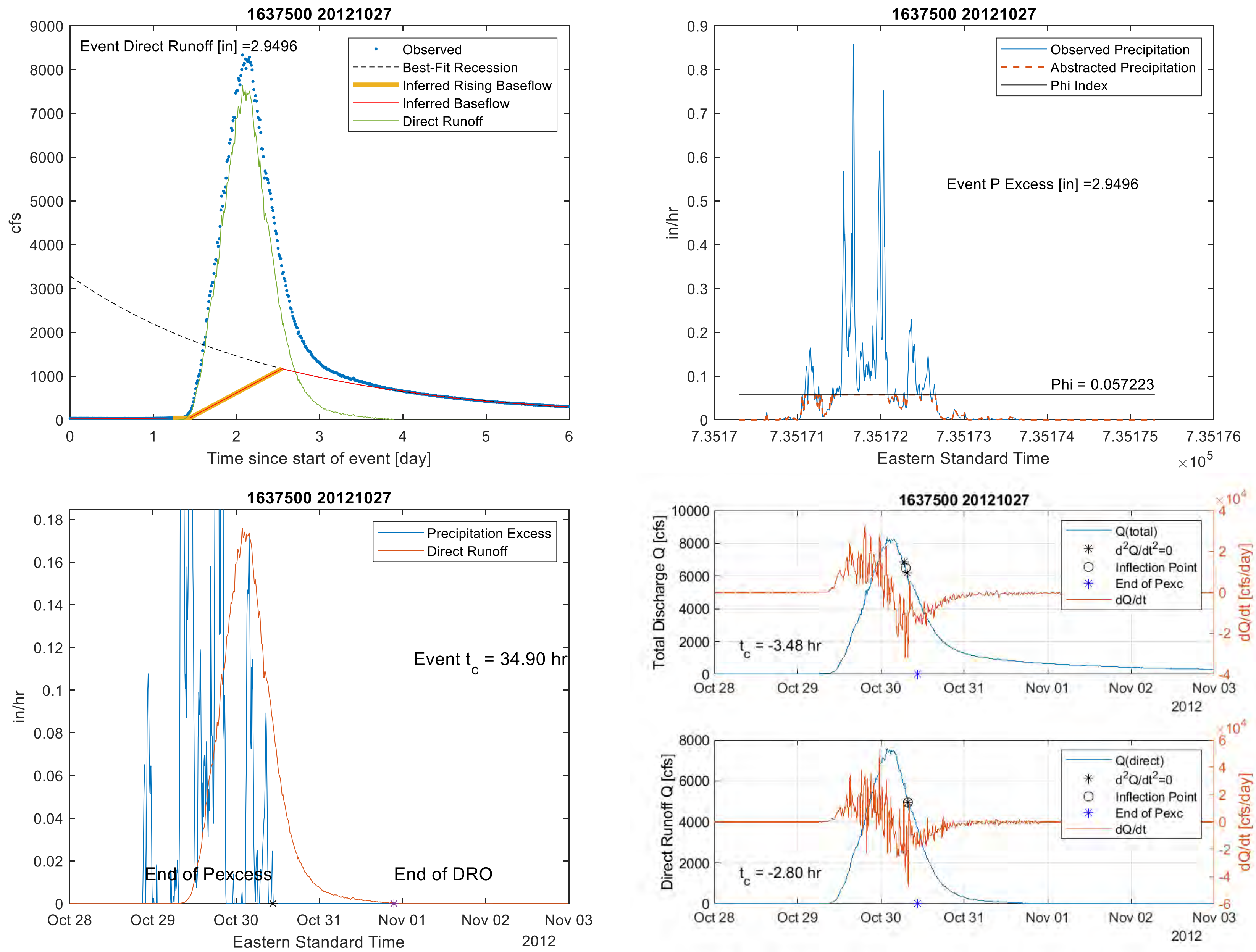

1617800 20180816
Event Direct Runoff [in] =0.10731
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1617800 20180816
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 1.4271
Event P Excess [in] =0.1073
in/hr
Eastern Standard Time

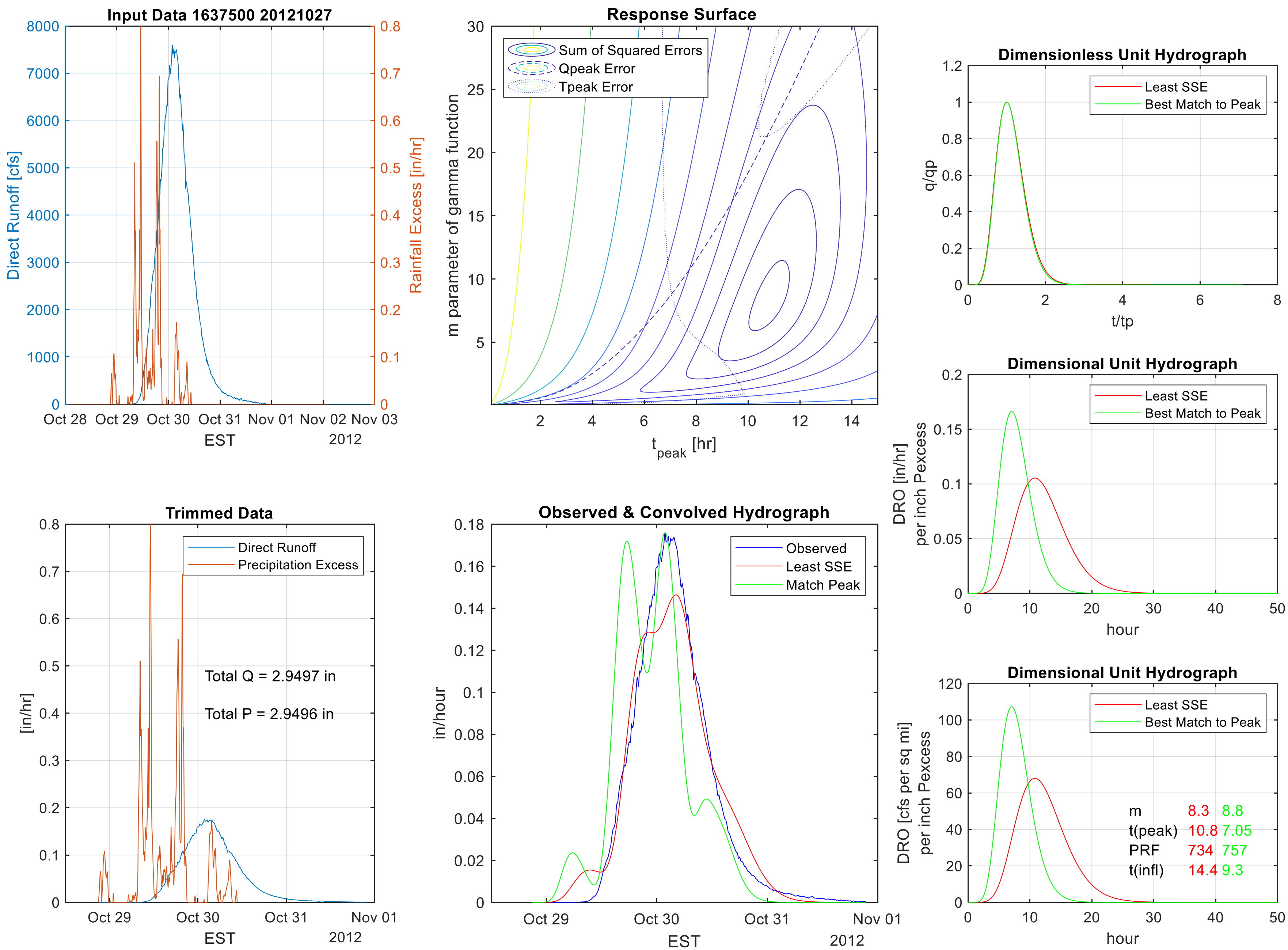

1617800 20180816
Precipitation Excess
Direct Runoff
Event t c = 71.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time


1617800 20180816
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 5.92 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 6.10 hr
Direct Runoff Q [cfs]

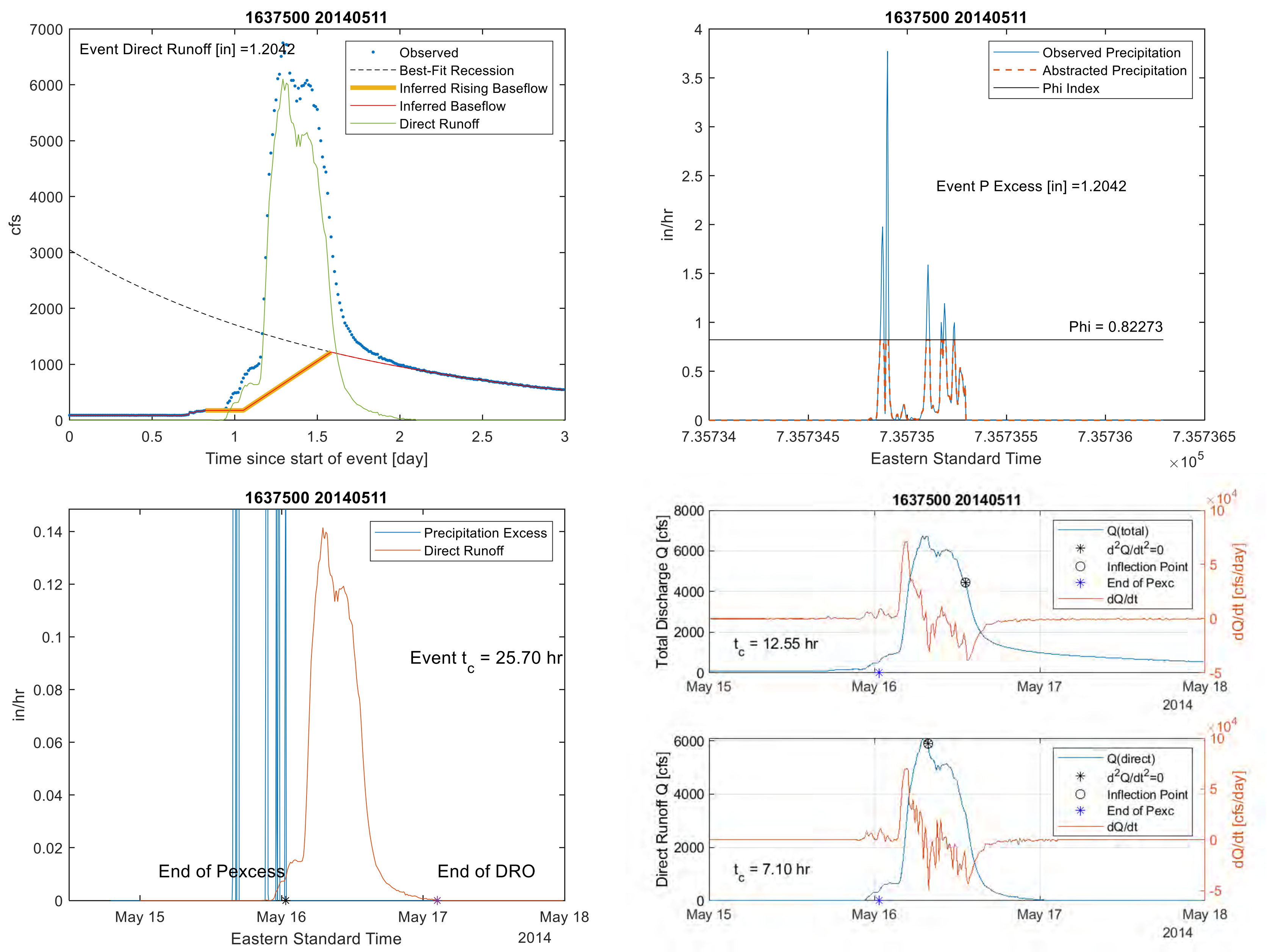

Input Data 1617800 20180816
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Aug 17
Aug 20
Aug 23
Aug 26
Aug 29
Sep 01
EST
2018
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.10733 in
Total P = 0.1073 in
[in/hr]
Aug 22
Aug 23
Aug 24
Aug 25
EST
2018
Observed & Convolved Hydrograph
×10^-3
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 1.3 1.6
t(peak) 6.75 5.95
PRF 276 309
t(infl) 12.6 10.6
hour



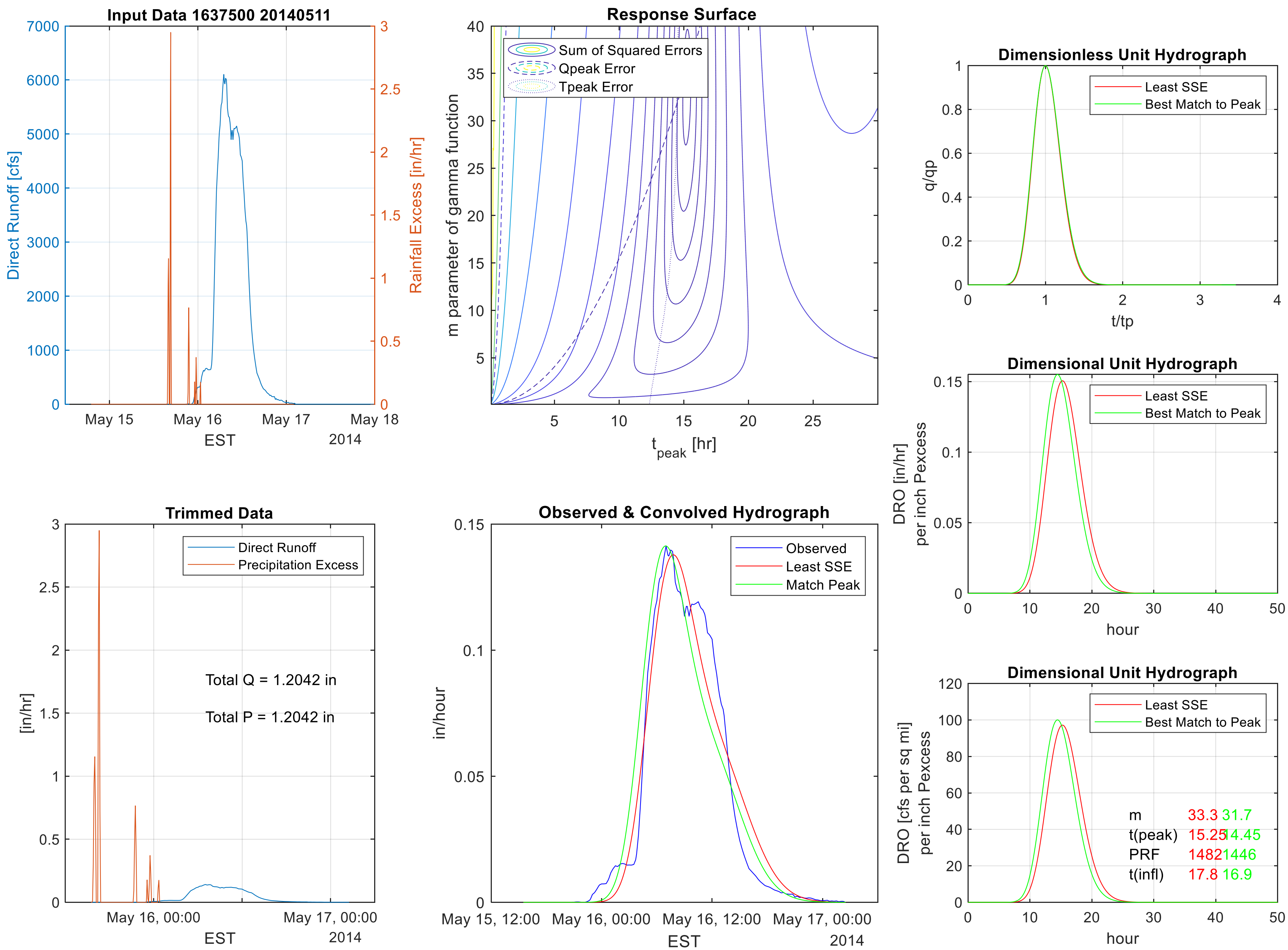
1637500 20121027
Event Direct Runoff [in] =2.9496
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1637500 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.9496
Phi = 0.057223
in/hr
Eastern Standard Time
1637500 20121027
Precipitation Excess
Direct Runoff
Event t_c = 34.90 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1637500 20121027
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -3.48 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = -2.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]



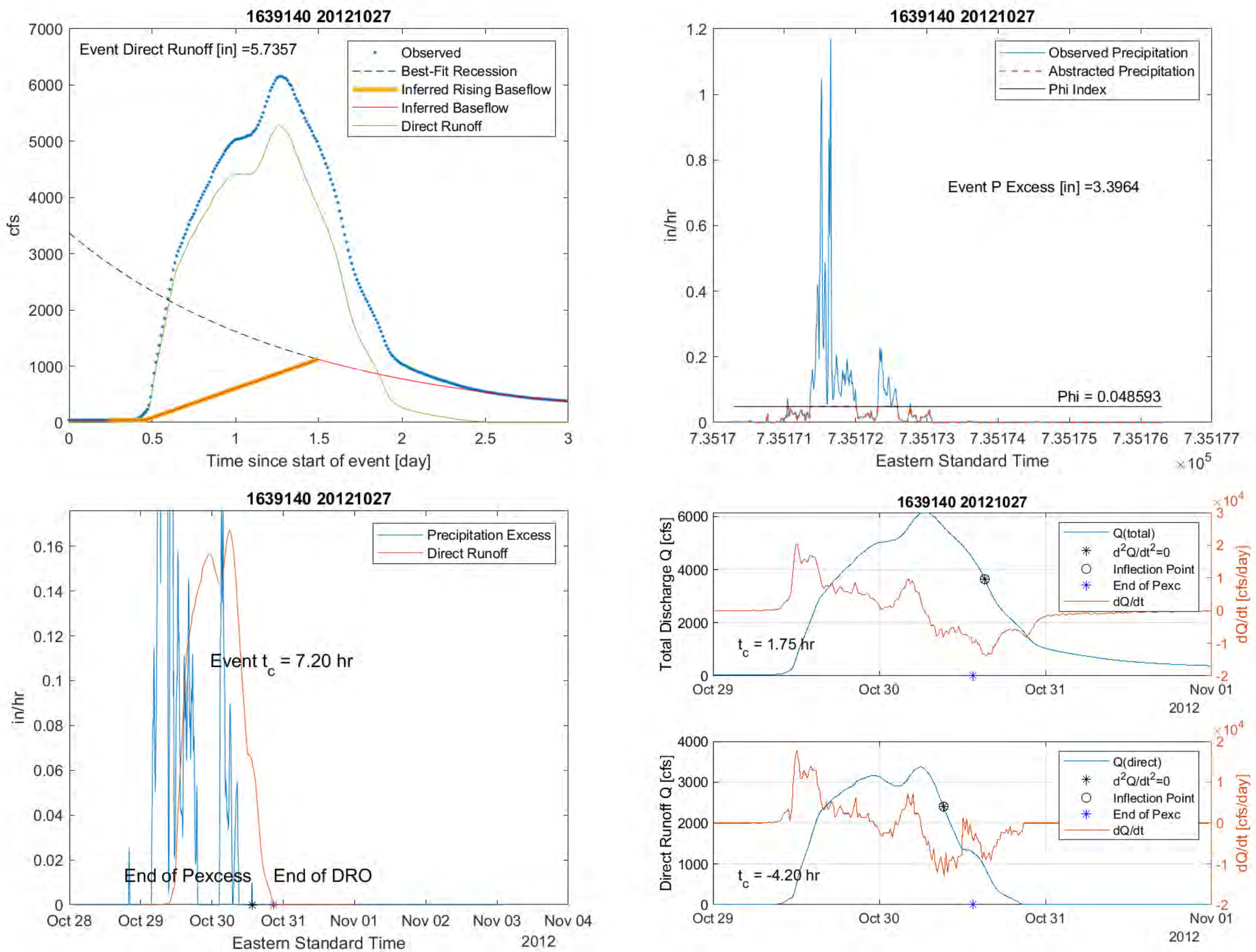
Input Data 1637500 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28 Oct 29 Oct 30 Oct 31 Nov 01 Nov 02 Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.9497 in
Total P = 2.9496 in
[in/hr]
Oct 29 Oct 30 Oct 31 Nov 01
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Oct 29 Oct 30 Oct 31 Nov 01
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 8.3 8.8
t(peak) 10.8 7.05
PRF 734 757
t(infl) 14.4 9.3



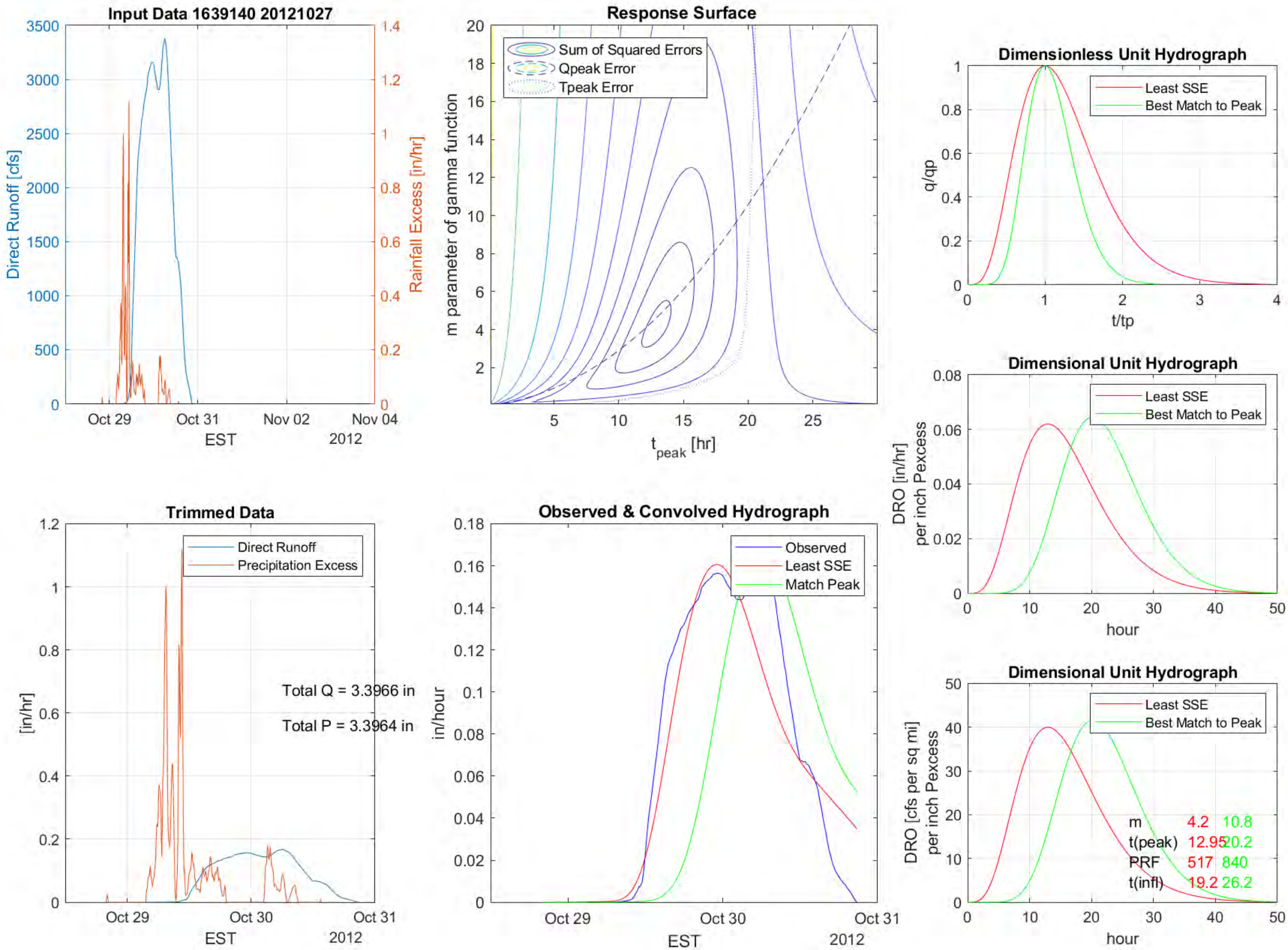
1637500 20140511
Event Direct Runoff [in] =1.2042
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1637500 20140511
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.2042
Phi = 0.82273
in/hr
Eastern Standard Time
1637500 20140511
Precipitation Excess
Direct Runoff
Event t c = 25.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1637500 20140511
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 12.55 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 7.10 hr
Direct Runoff Q [cfs]

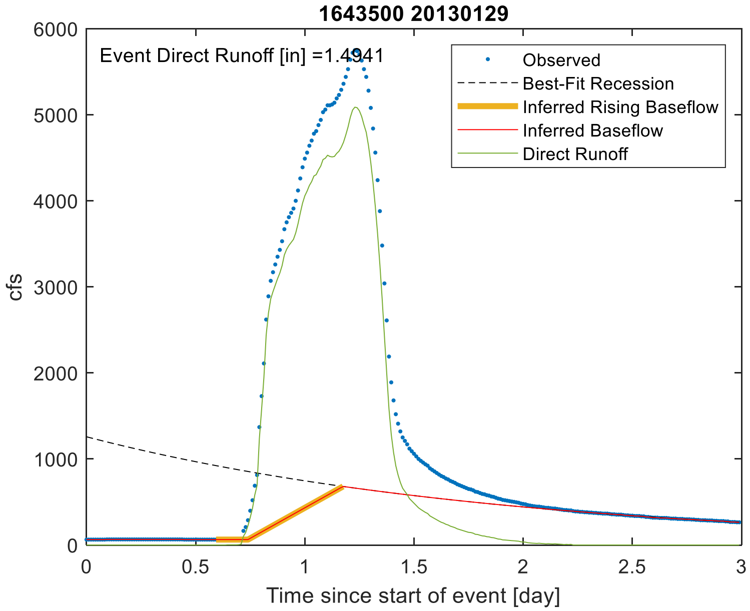


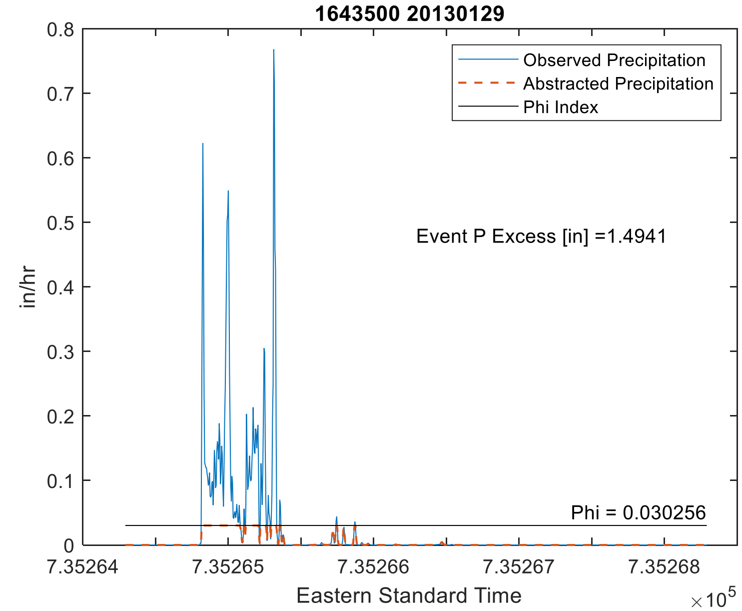
Input Data 1637500 20140511
Direct Runoff [cfs]
Rainfall Excess [in/hr]
7000
6000
5000
4000
3000
2000
1000
0
3
2.5
2
1.5
1
0.5
0
May 15
May 16
May 17
May 18
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
40
35
30
25
20
15
10
5
10
15
20
25
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
0.15
0.1
0.05
0
0
10
20
30
40
50
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.2042 in
Total P = 1.2042 in
3
2.5
2
1.5
1
0.5
0
May 16, 00:00
May 17, 00:00
EST
2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
0.15
0.1
0.05
0
May 15, 12:00
May 16, 00:00
May 16, 12:00
May 17, 00:00
EST
2014
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
120
100
80
60
40
20
0
m 33.3 31.7
t(peak) 15.25 14.45
PRF 1482 1446
t(infl) 17.8 16.9
0
10
20
30
40
50
hour

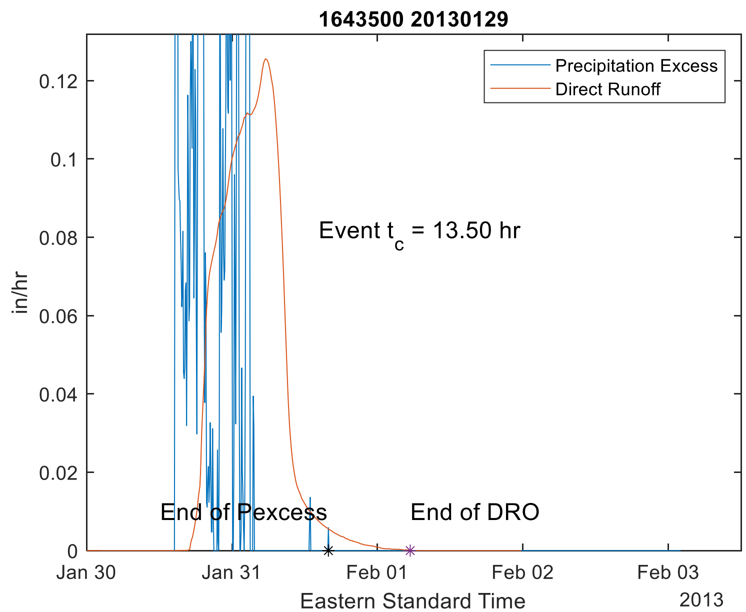


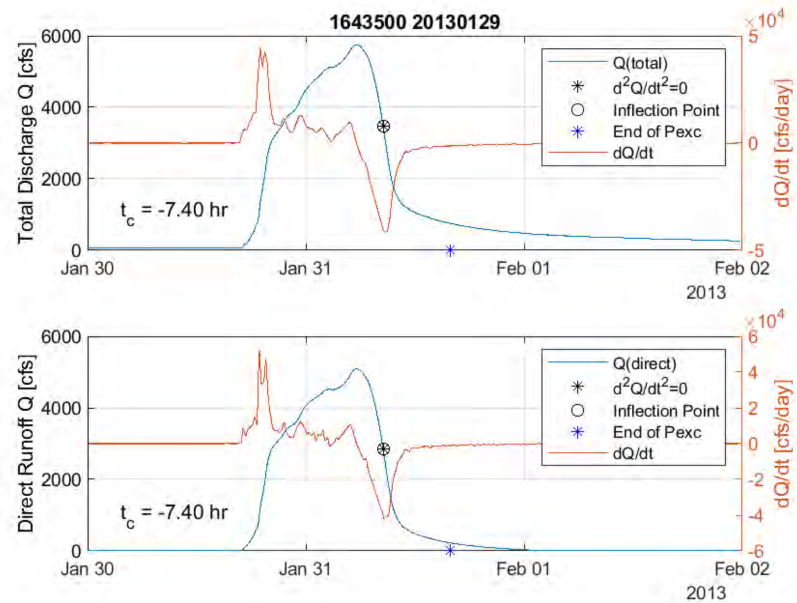
1639140 20121027
Event Direct Runoff [in] =5.7357
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1639140 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =3.3964
Phi = 0.048593
in/hr
Eastern Standard Time
1639140 20121027
Precipitation Excess
Direct Runoff
Event t c = 7.20 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012
1639140 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 1.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2012
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = -4.20 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2012

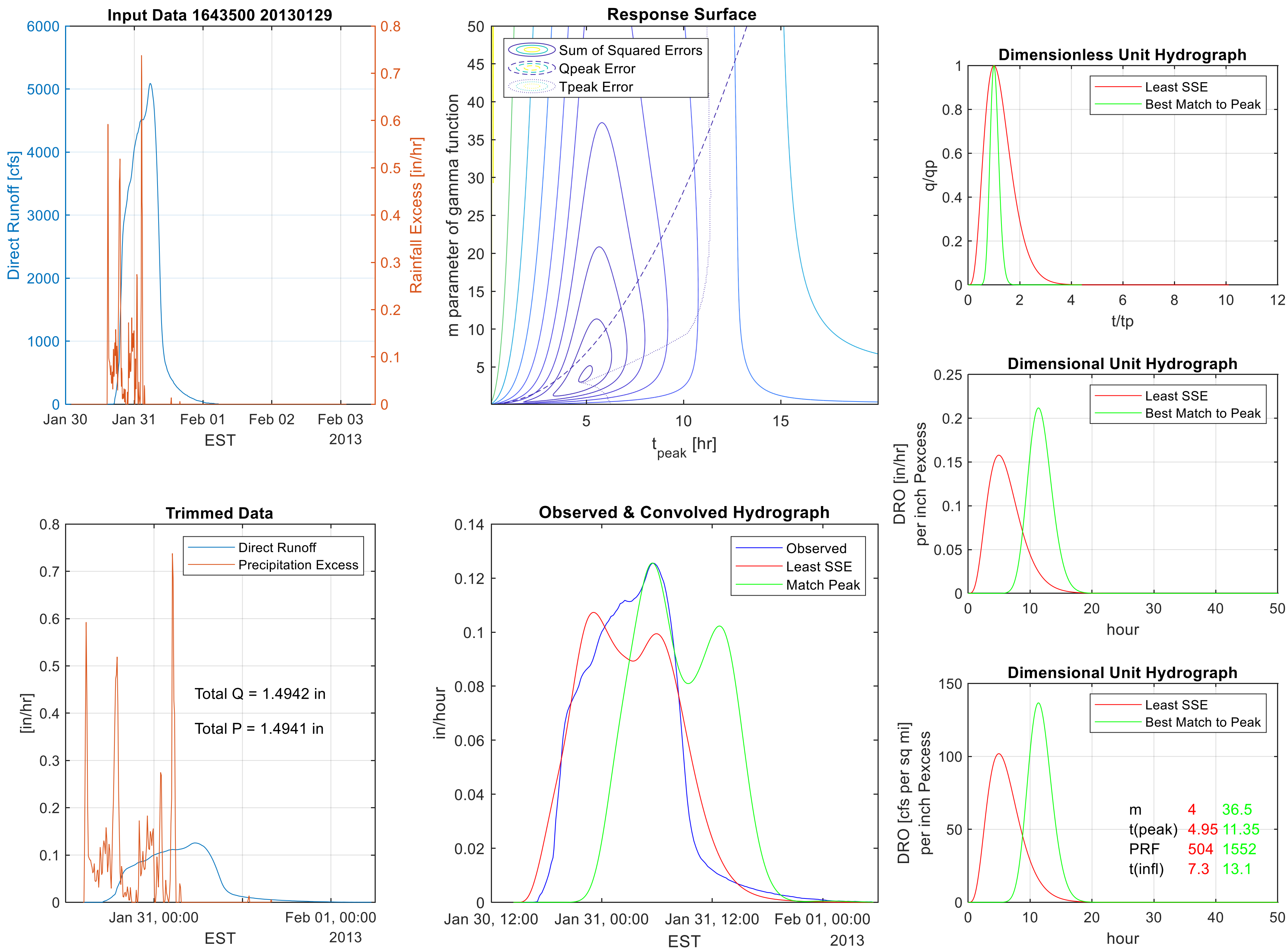

Input Data 1639140 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 29
Oct 31
Nov 02
Nov 04
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 3.3966 in
Total P = 3.3964 in
[in/hr]
Oct 30
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
DRO [cfs per sq mi] per inch Pexcess
m 4.2 10.8
t(peak) 12.95 20.2
PRF 517 840
t(infl) 19.2 26.2

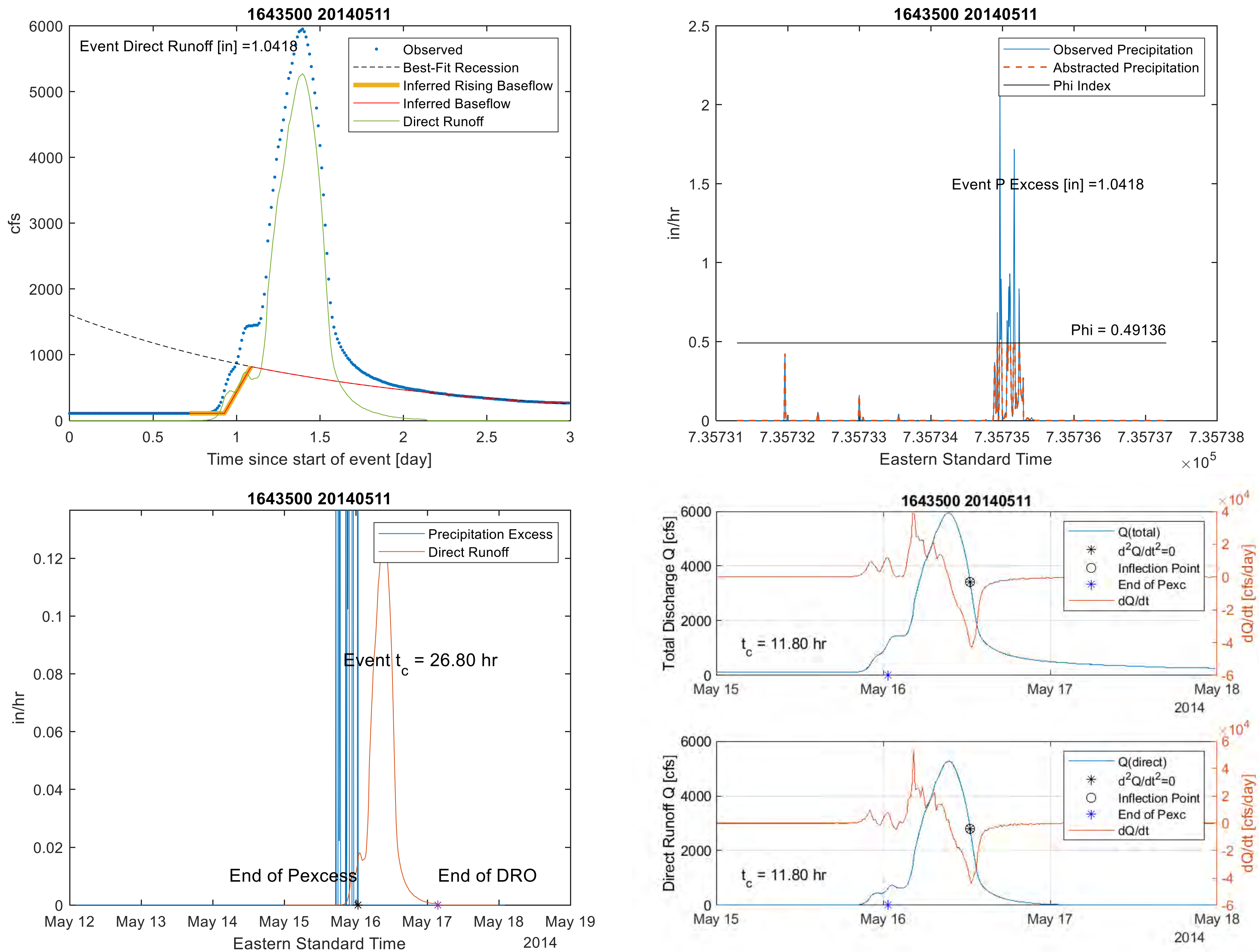

1643500 20130129
Event Direct Runoff [in] =1.4941
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
6000
5000
4000
3000
2000
1000
0
0
0.5
1
1.5
2
2.5
3
Time since start of event [day]

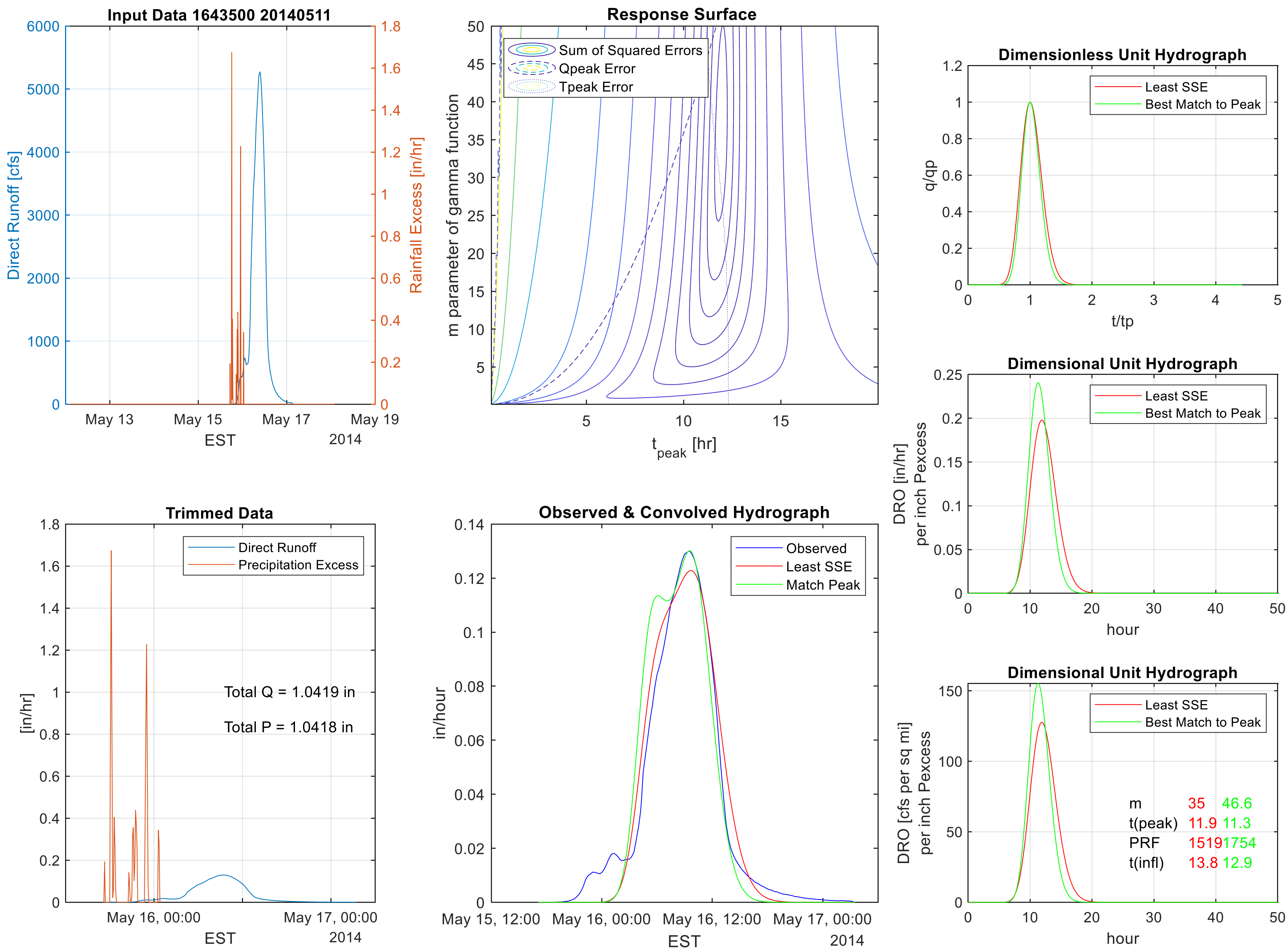

1643500 20130129
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.4941
Phi = 0.030256
in/hr
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7.35264
7.35265
7.35266
7.35267
7.35268
Eastern Standard Time
×10^5

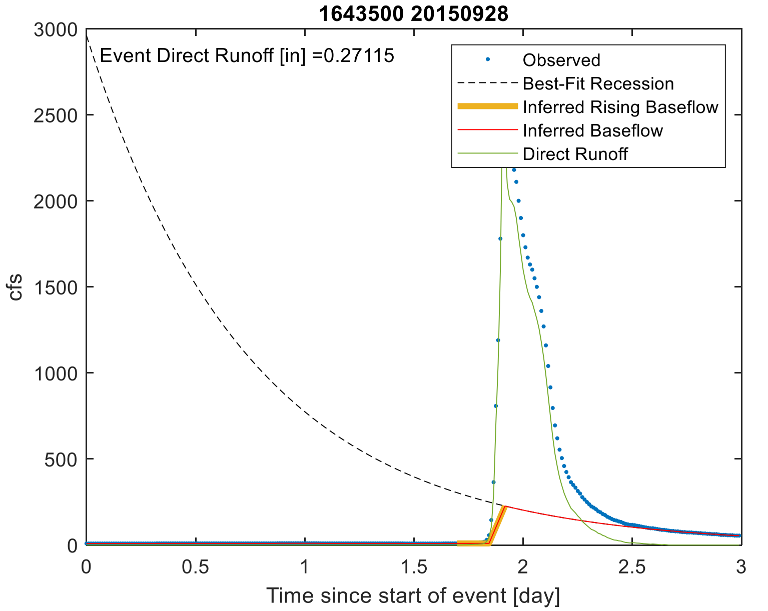

1643500 20130129
Precipitation Excess
Direct Runoff
Event t_c = 13.50 hr
End of Pexcess
End of DRO
in/hr
0.12
0.1
0.08
0.06
0.04
0.02
0
Jan 30
Jan 31
Feb 01
Feb 02
Feb 03
2013
Eastern Standard Time


1643500 20130129
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -7.40 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
×10^4
6000
4000
2000
0
5
0
-5
Jan 30
Jan 31
Feb 01
Feb 02
2013
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = -7.40 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
×10^4
6000
4000
2000
0
6
4
2
0
-2
-4
-6
Jan 30
Jan 31
Feb 01
Feb 02
2013

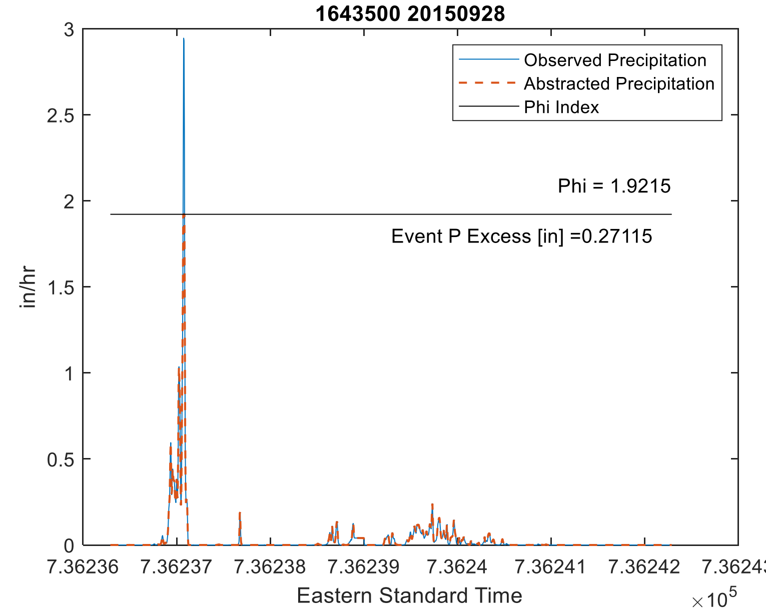

Input Data 1643500 20130129
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jan 30
Jan 31
Feb 01
Feb 02
Feb 03
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.4942 in
Total P = 1.4941 in
[in/hr]
Jan 31, 00:00
Feb 01, 00:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4 36.5
t(peak) 4.95 11.35
PRF 504 1552
t(infl) 7.3 13.1


1643500 20140511
Event Direct Runoff [in] =1.0418
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1643500 20140511
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.0418
Phi = 0.49136
in/hr
Eastern Standard Time
1643500 20140511
Precipitation Excess
Direct Runoff
Event t c = 26.80 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1643500 20140511
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 11.80 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
Direct Runoff Q [cfs]

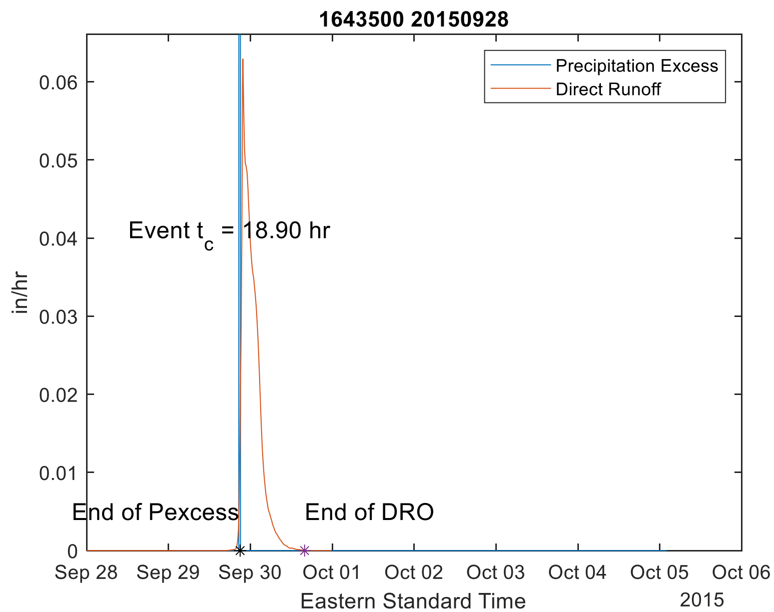

Input Data 1643500 20140511
Direct Runoff [cfs]
Rainfall Excess [in/hr]
May 13
May 15
May 17
May 19
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.0419 in
Total P = 1.0418 in
[in/hr]
May 16, 00:00
May 17, 00:00
EST
2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
May 15, 12:00
May 16, 00:00
May 16, 12:00
May 17, 00:00
EST
2014
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 35 46.6
t(peak) 11.9 11.3
PRF 1519 1754
t(infl) 13.8 12.9
hour



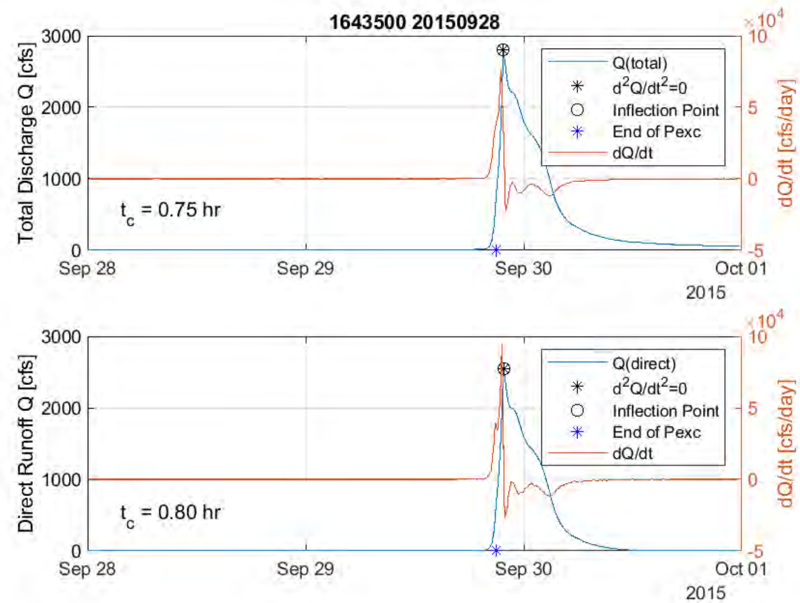
1643500 20150928
Event Direct Runoff [in] =0.27115
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
3000
2500
2000
1500
1000
500
0
0
0.5
1
1.5
2
2.5
3
Time since start of event [day]



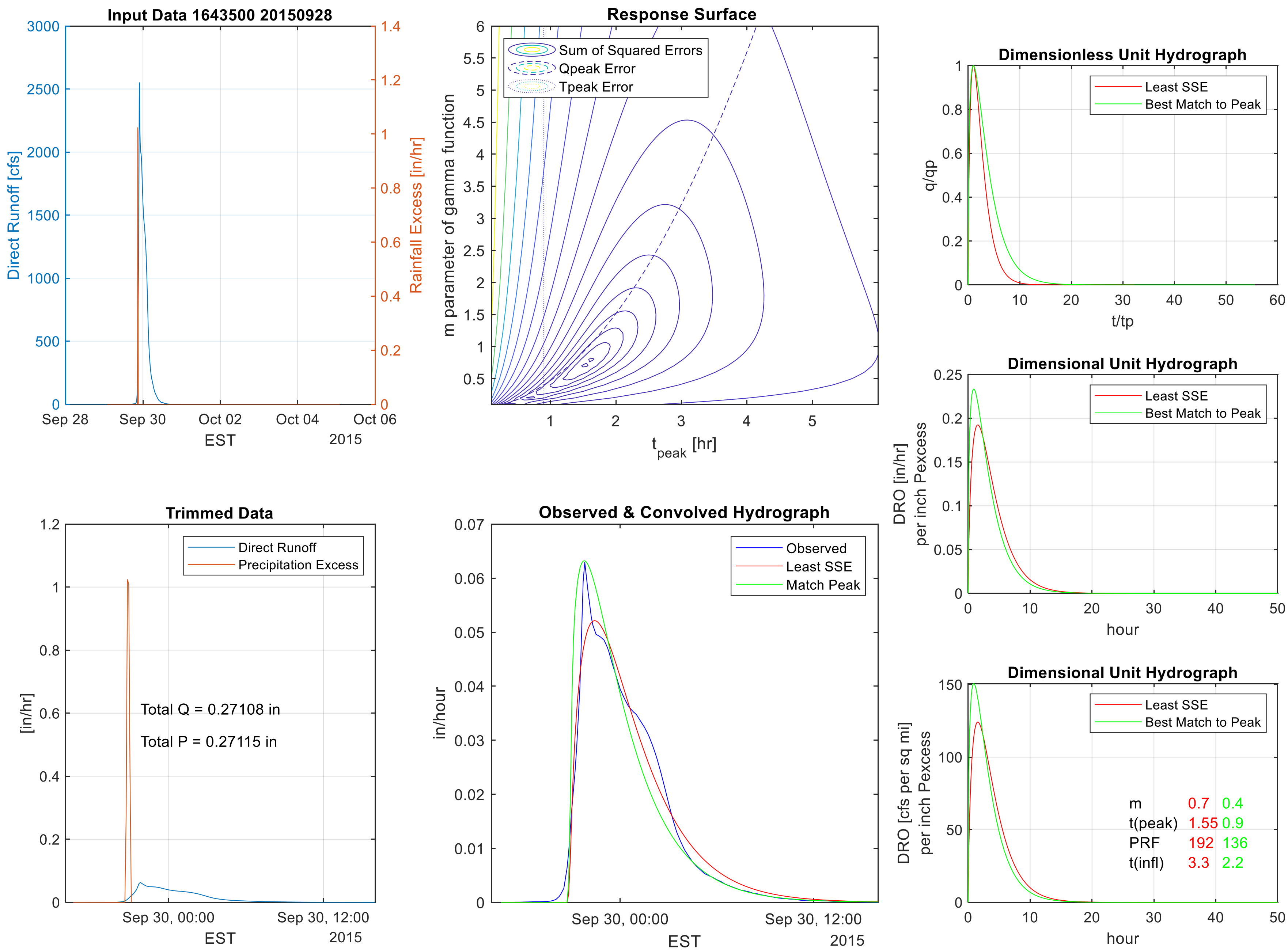
1643500 20150928
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 1.9215
Event P Excess [in] =0.27115
in/hr
3
2.5
2
1.5
1
0.5
0
7.36236
7.36237
7.36238
7.36239
7.3624
7.36241
7.36242
7.36243
Eastern Standard Time
×10^5

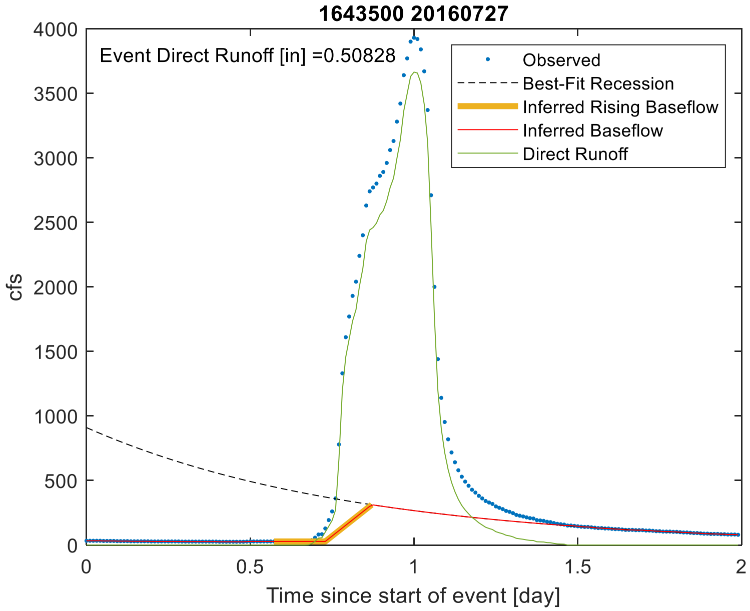


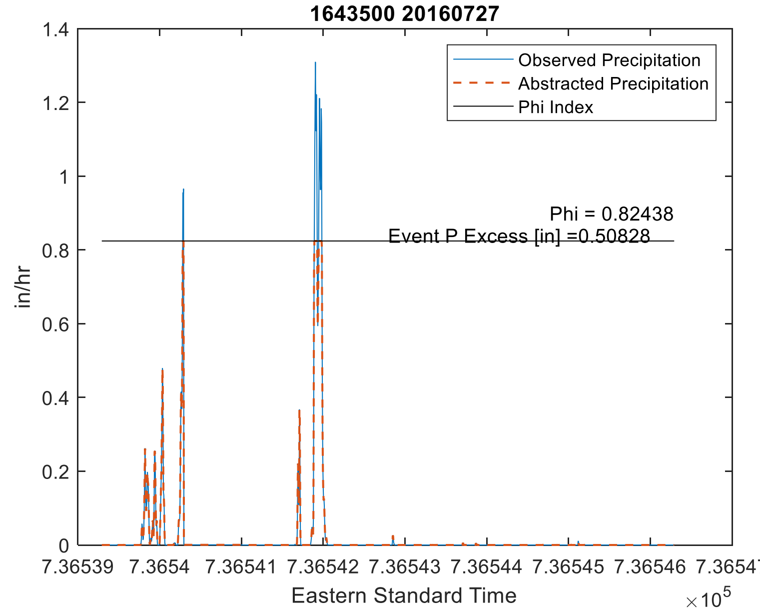
1643500 20150928
Precipitation Excess
Direct Runoff
Event t_c = 18.90 hr
End of Pexcess
End of DRO
in/hr
0.06
0.05
0.04
0.03
0.02
0.01
0
Sep 28
Sep 29
Sep 30
Oct 01
Oct 02
Oct 03
Oct 04
Oct 05
Oct 06
Eastern Standard Time
2015

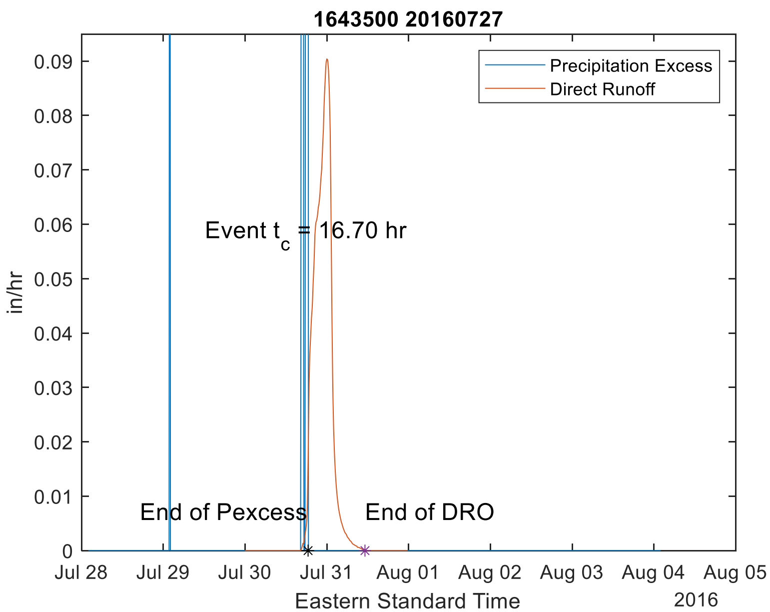


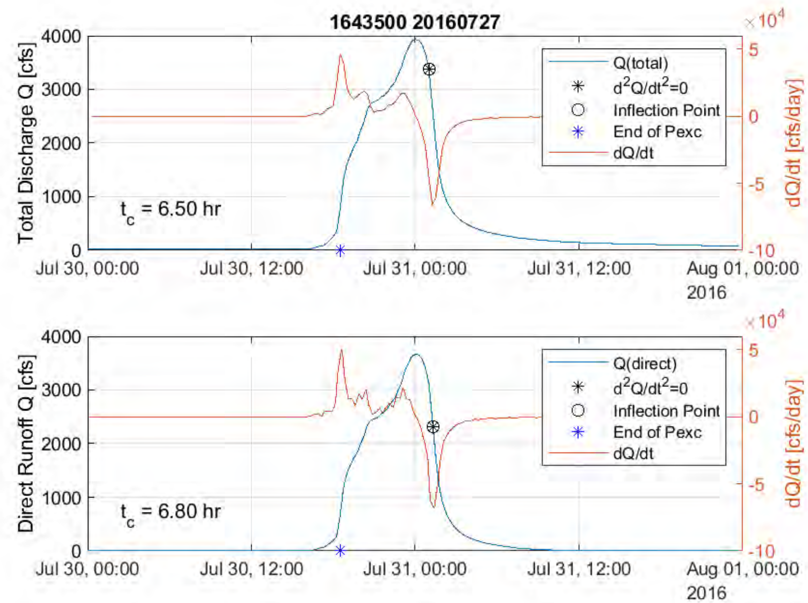
1643500 20150928
Q(total)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.75 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
×10^4
3000
2000
1000
0
10
5
0
-5
Sep 28
Sep 29
Sep 30
Oct 01
2015
Q(direct)
d²Q/dt²=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.80 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
×10^4
3000
2000
1000
0
10
5
0
-5
Sep 28
Sep 29
Sep 30
Oct 01
2015

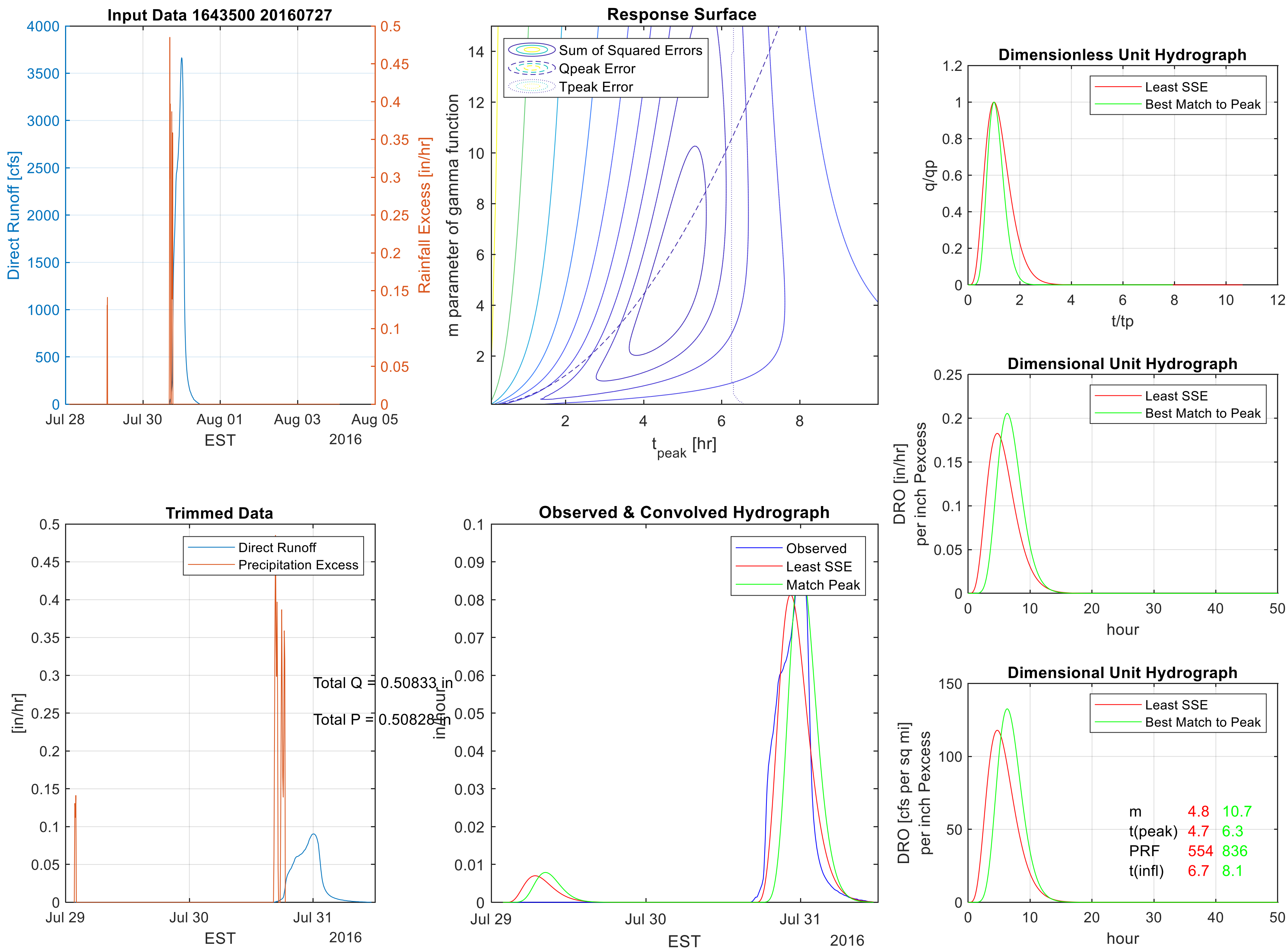

Input Data 1643500 20150928
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Sep 28
Sep 30
Oct 02
Oct 04
Oct 06
EST
2015
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.27108 in
Total P = 0.27115 in
Sep 30, 00:00
Sep 30, 12:00
EST
2015
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Sep 30, 00:00
Sep 30, 12:00
EST
2015
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 0.7 0.4
t(peak) 1.55 0.9
PRF 192 136
t(infl) 3.3 2.2

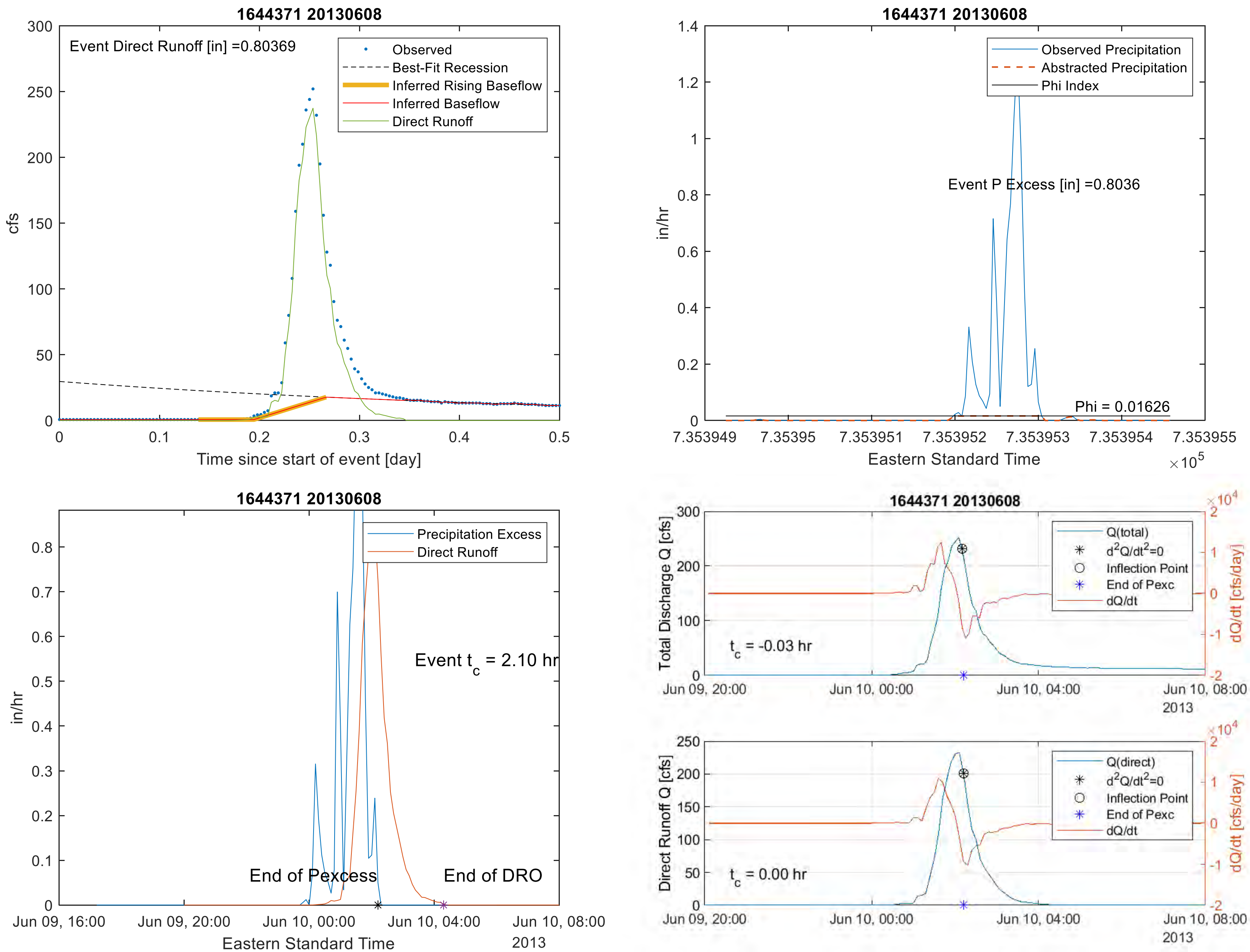

1643500 20160727
Event Direct Runoff [in] =0.50828
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1643500 20160727
Observed Precipitation
Abstracted Precipitation
Phi Index
Phi = 0.82438
Event P Excess [in] =0.50828
in/hr
Eastern Standard Time

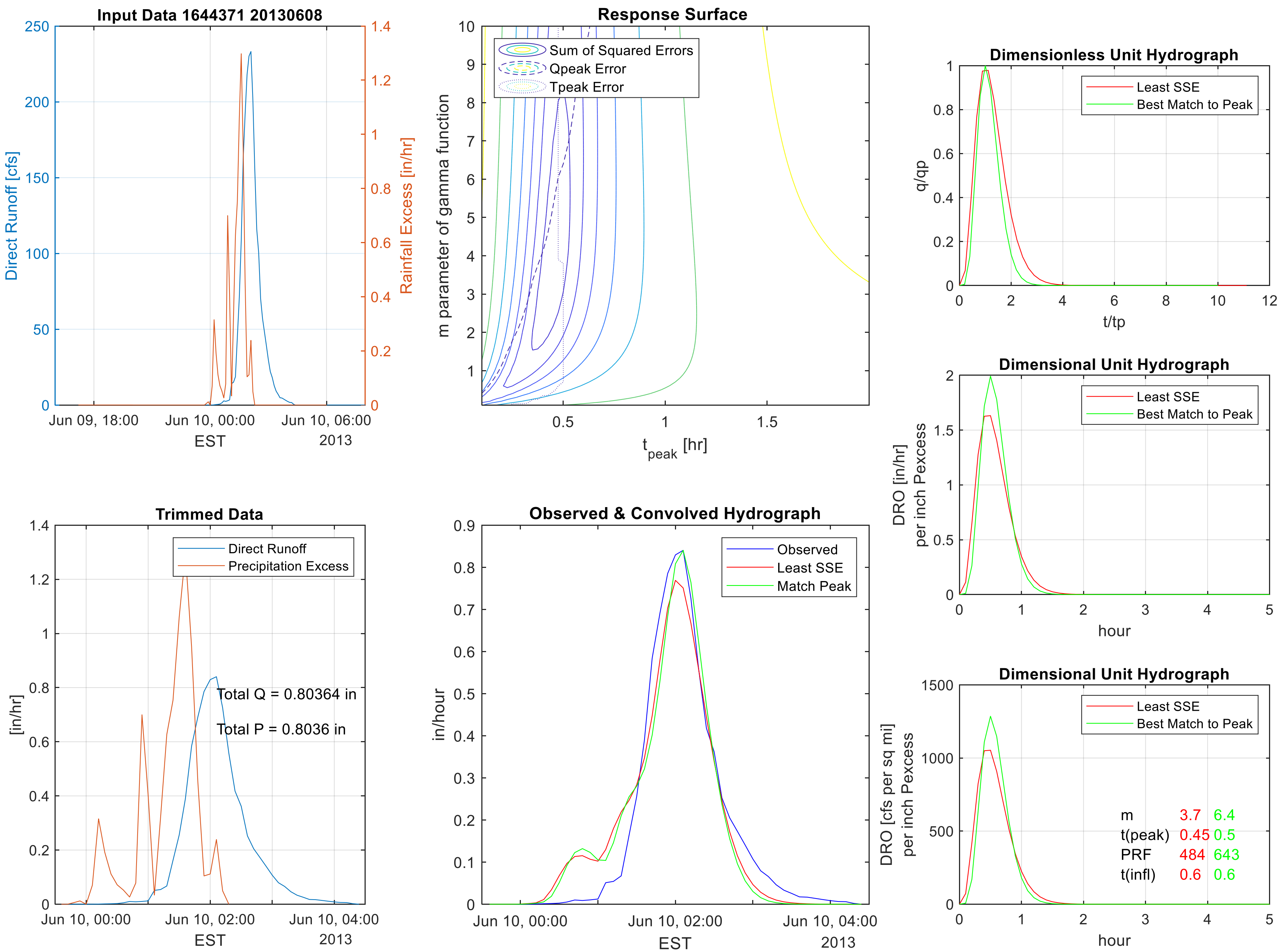

1643500 20160727
Precipitation Excess
Direct Runoff
Event t_c = 16.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

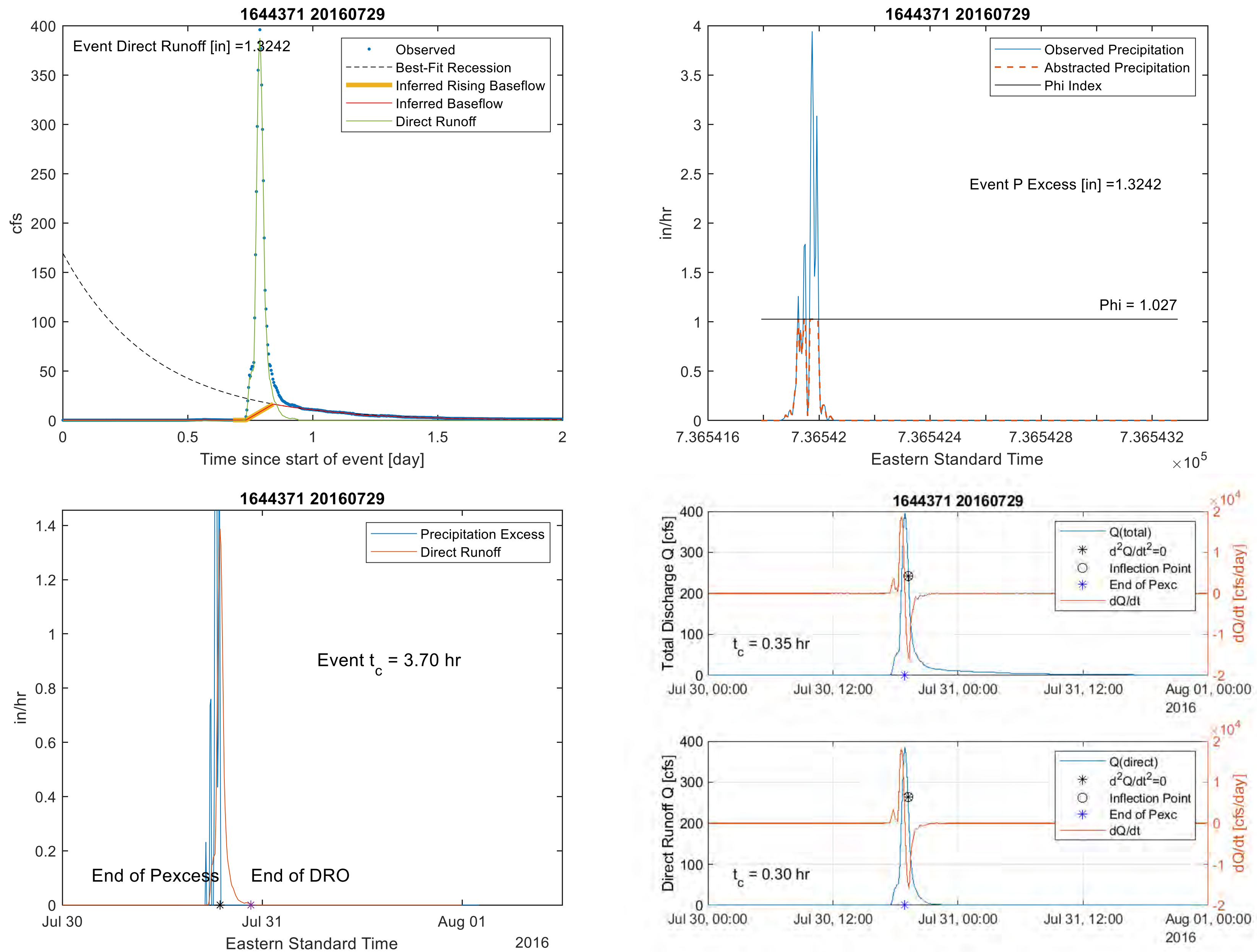

1643500 20160727
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 6.50 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 6.80 hr
Direct Runoff Q [cfs]

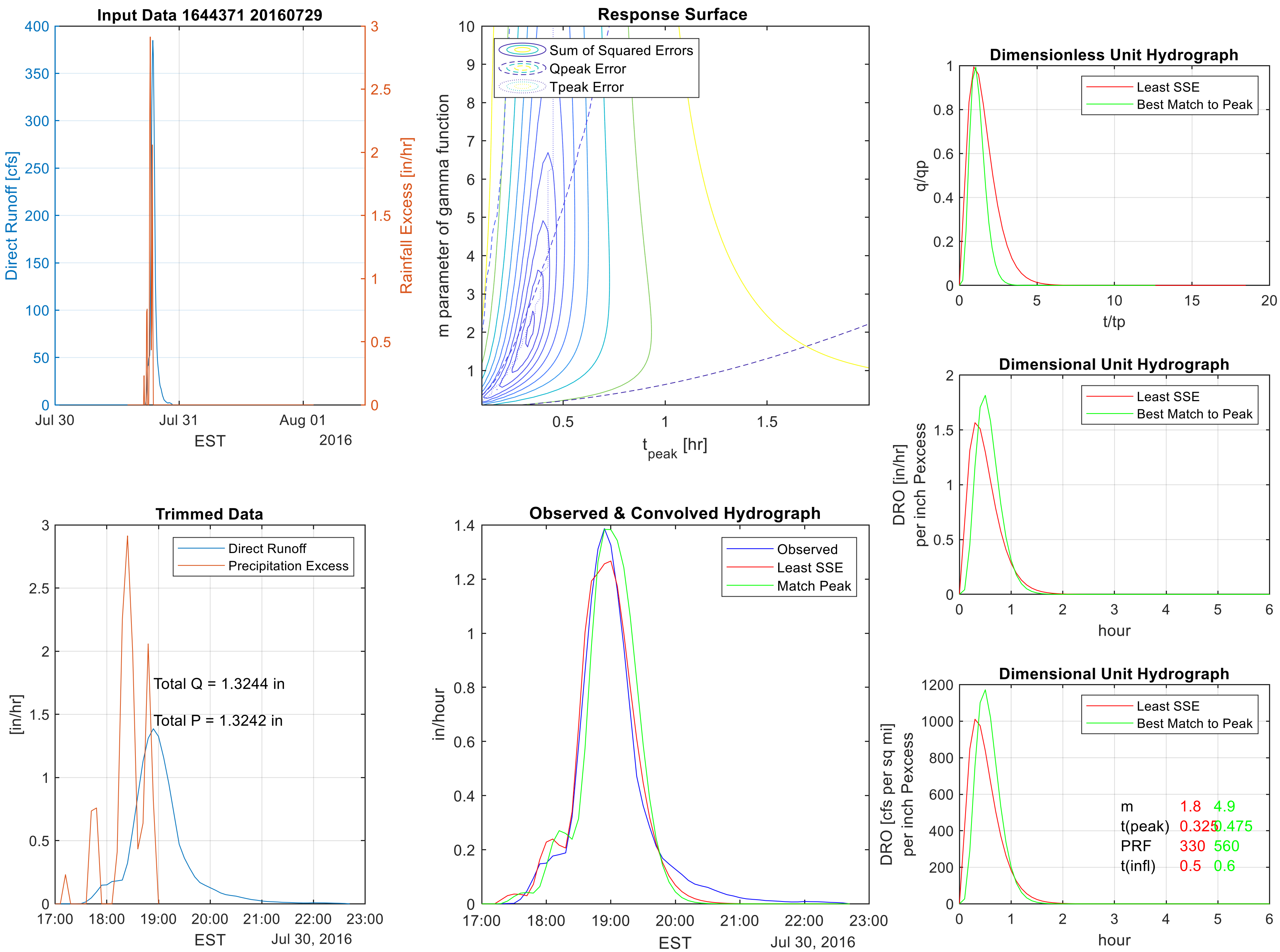

Input Data 1643500 20160727
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.50833 in
Total P = 0.50828 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 4.8 10.7
t(peak) 4.7 6.3
PRF 554 836
t(infl) 6.7 8.1

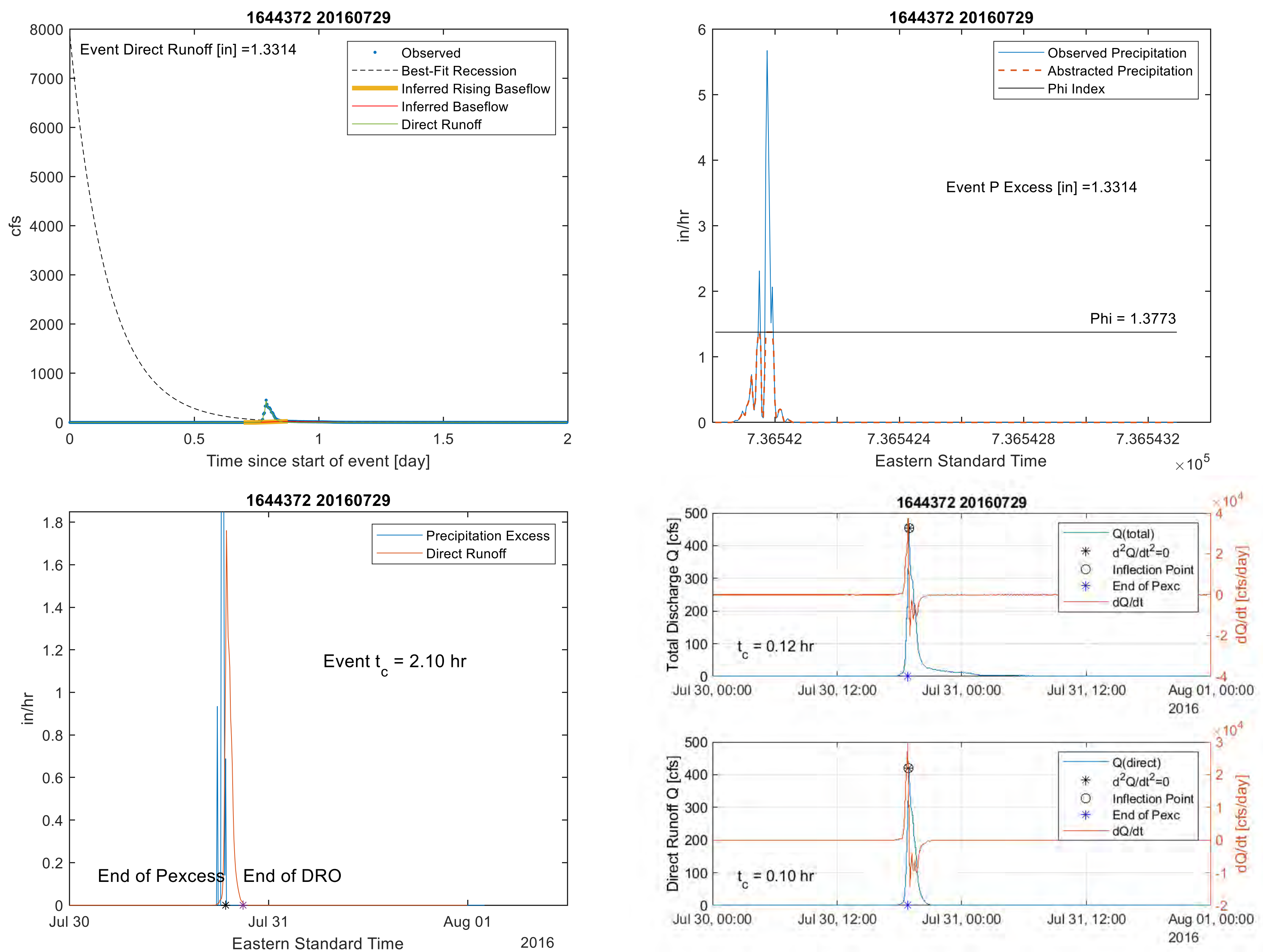


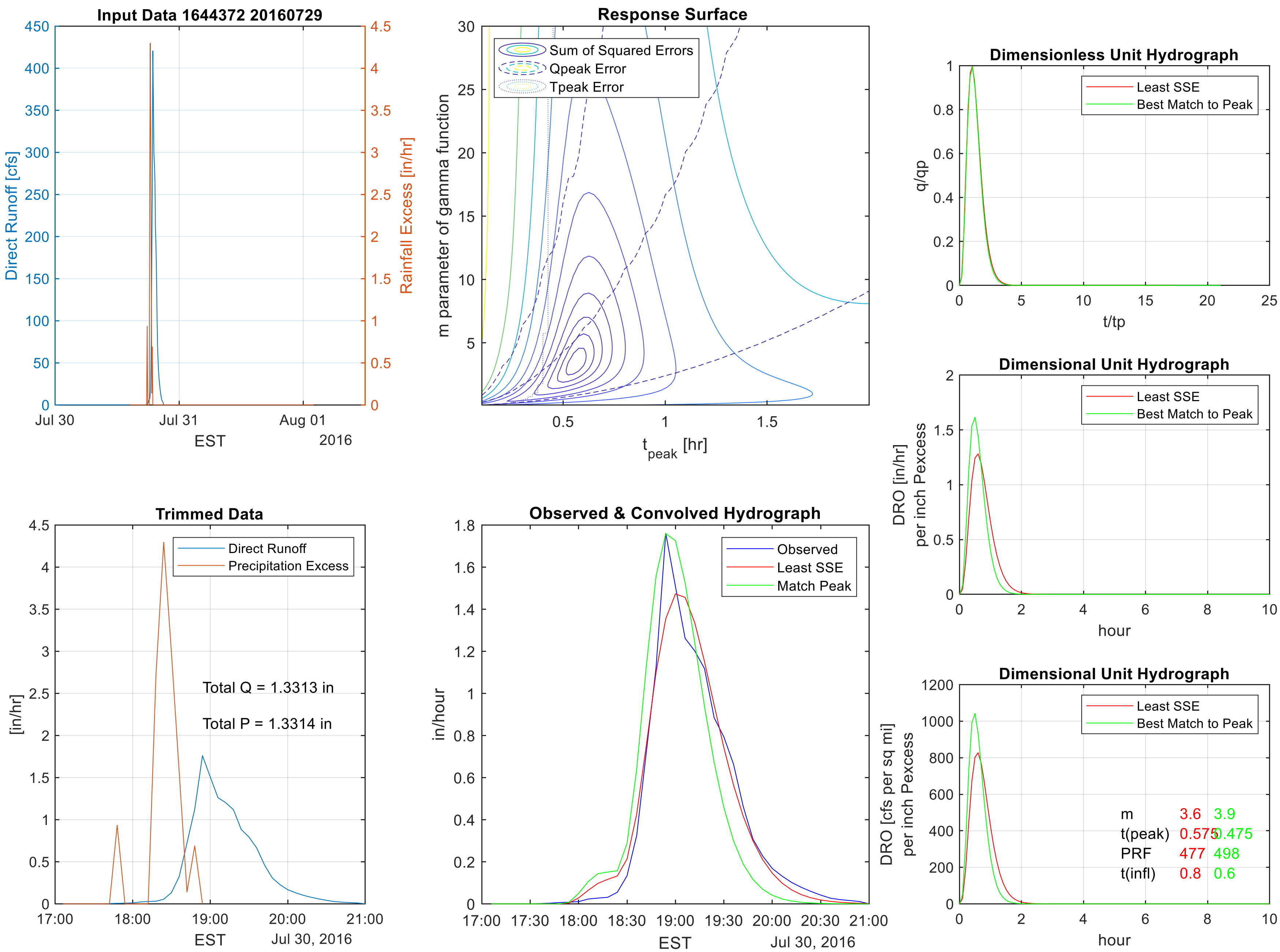
1644371 20130608
Event Direct Runoff [in] =0.80369
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1644371 20130608
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.8036
Phi = 0.01626
in/hr
Eastern Standard Time
1644371 20130608
Precipitation Excess
Direct Runoff
Event t c = 2.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1644371 20130608
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t c = -0.03 hr
Q(direct)
Direct Runoff Q [cfs]
t c = 0.00 hr

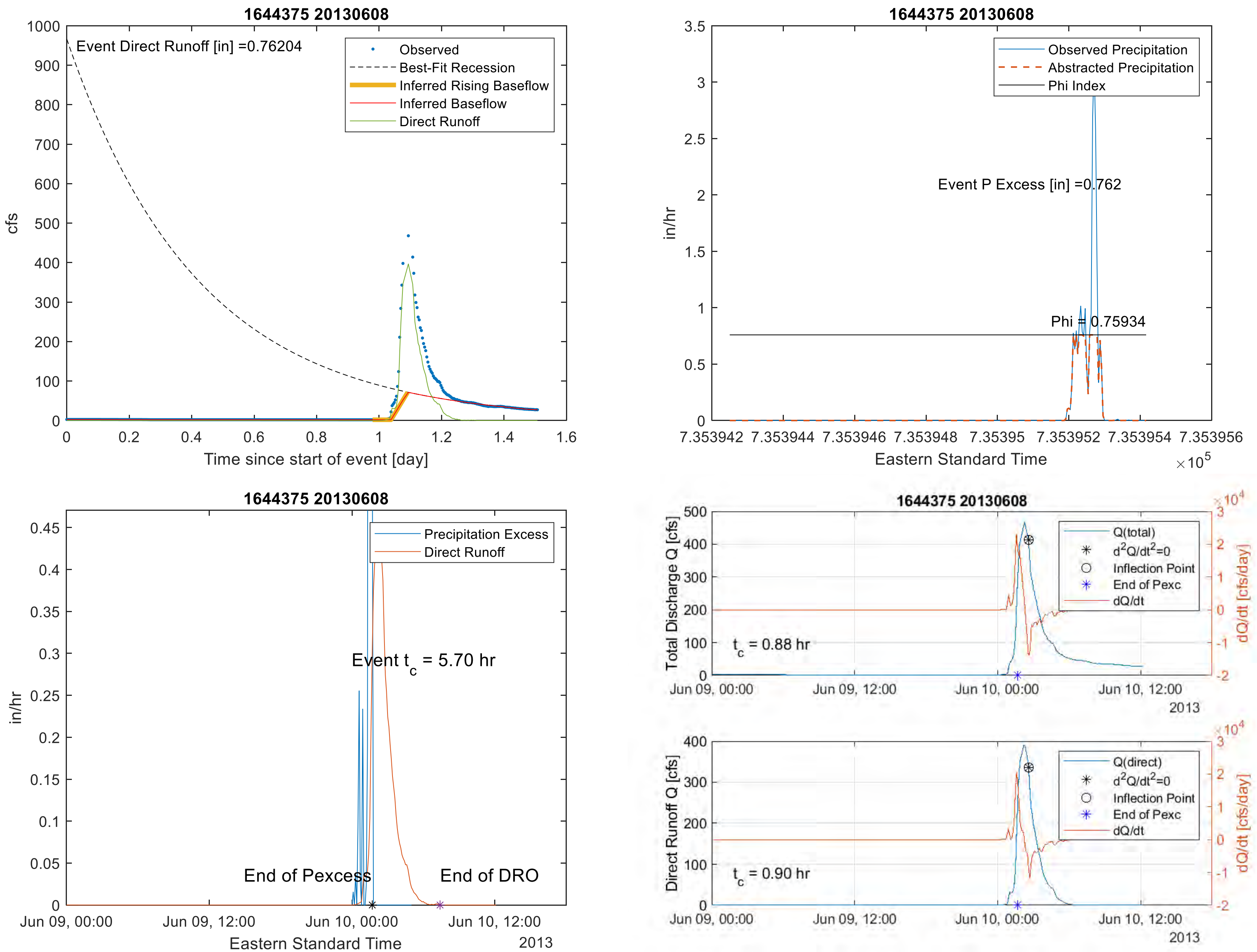

Input Data 1644371 20130608
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 09, 18:00
Jun 10, 00:00
Jun 10, 06:00
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.80364 in
Total P = 0.8036 in
Jun 10, 00:00
Jun 10, 02:00
Jun 10, 04:00
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
DRO [cfs per sq mi] per inch Pexcess
m 3.7 6.4
t(peak) 0.45 0.5
PRF 484 643
t(infl) 0.6 0.6


1644371 20160729
Event Direct Runoff [in] =1.3242
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1644371 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.3242
Phi = 1.027
in/hr
Eastern Standard Time
×10^5
1644371 20160729
Precipitation Excess
Direct Runoff
Event t_c = 3.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2016
1644371 20160729
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.35 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.30 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
Jul 30, 00:00
Jul 30, 12:00
Jul 31, 00:00
Jul 31, 12:00
Aug 01, 00:00
2016

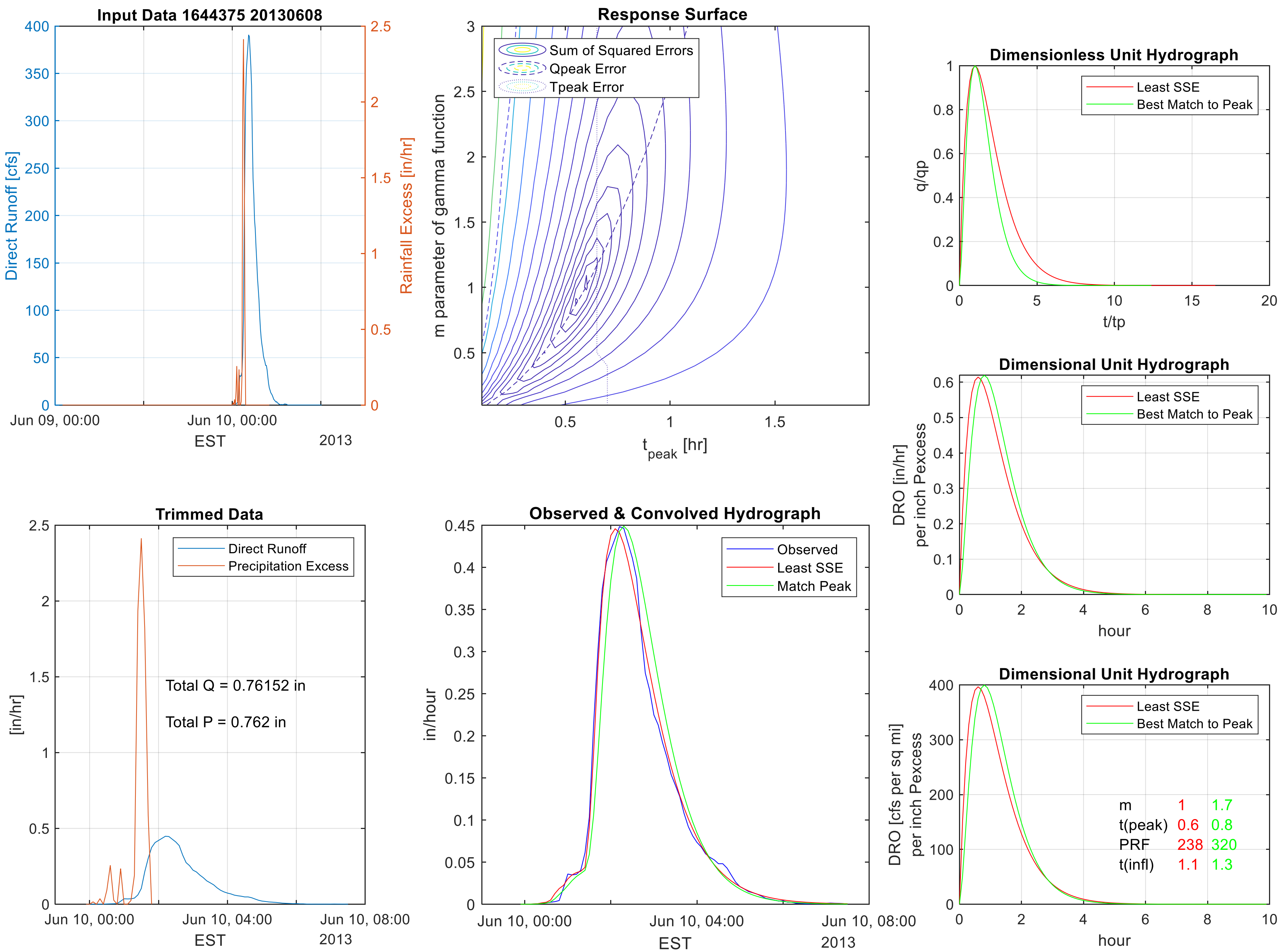

Input Data 1644371 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.3244 in
Total P = 1.3242 in
[in/hr]
EST
Jul 30, 2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
Jul 30, 2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 1.8 4.9
t(peak) 0.325 0.475
PRF 330 560
t(infl) 0.5 0.6
hour

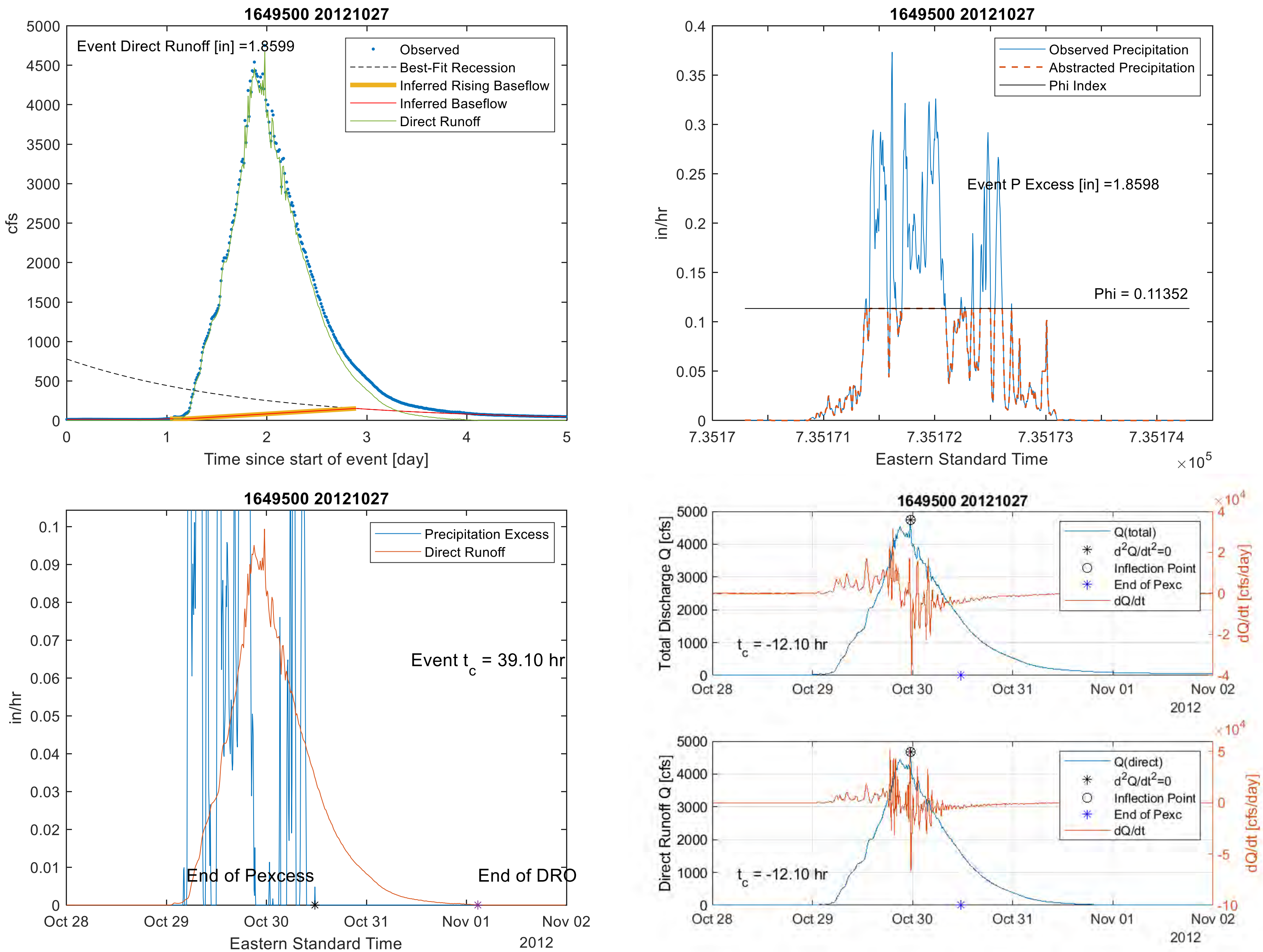

1644372 20160729
Event Direct Runoff [in] =1.3314
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1644372 20160729
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.3314
Phi = 1.3773
in/hr
Eastern Standard Time
1644372 20160729
Precipitation Excess
Direct Runoff
Event t_c = 2.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1644372 20160729
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.12 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 0.10 hr
Direct Runoff Q [cfs]


Input Data 1644372 20160729
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 30
Jul 31
Aug 01
EST
2016
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.3313 in
Total P = 1.3314 in
[in/hr]
EST
Jul 30, 2016
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
Jul 30, 2016
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 3.6 3.9
t(peak) 0.575 0.475
PRF 477 498
t(infl) 0.8 0.6

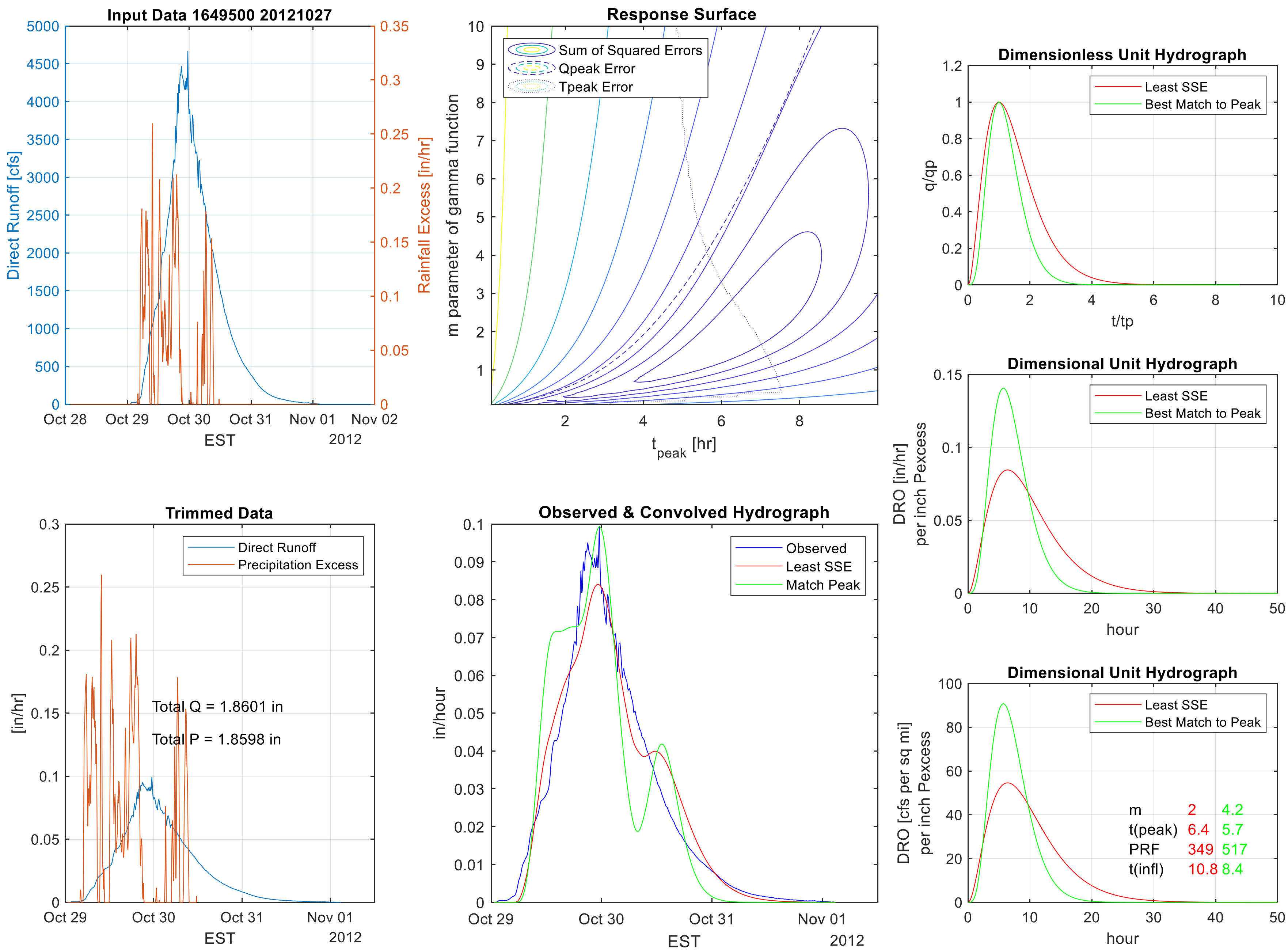


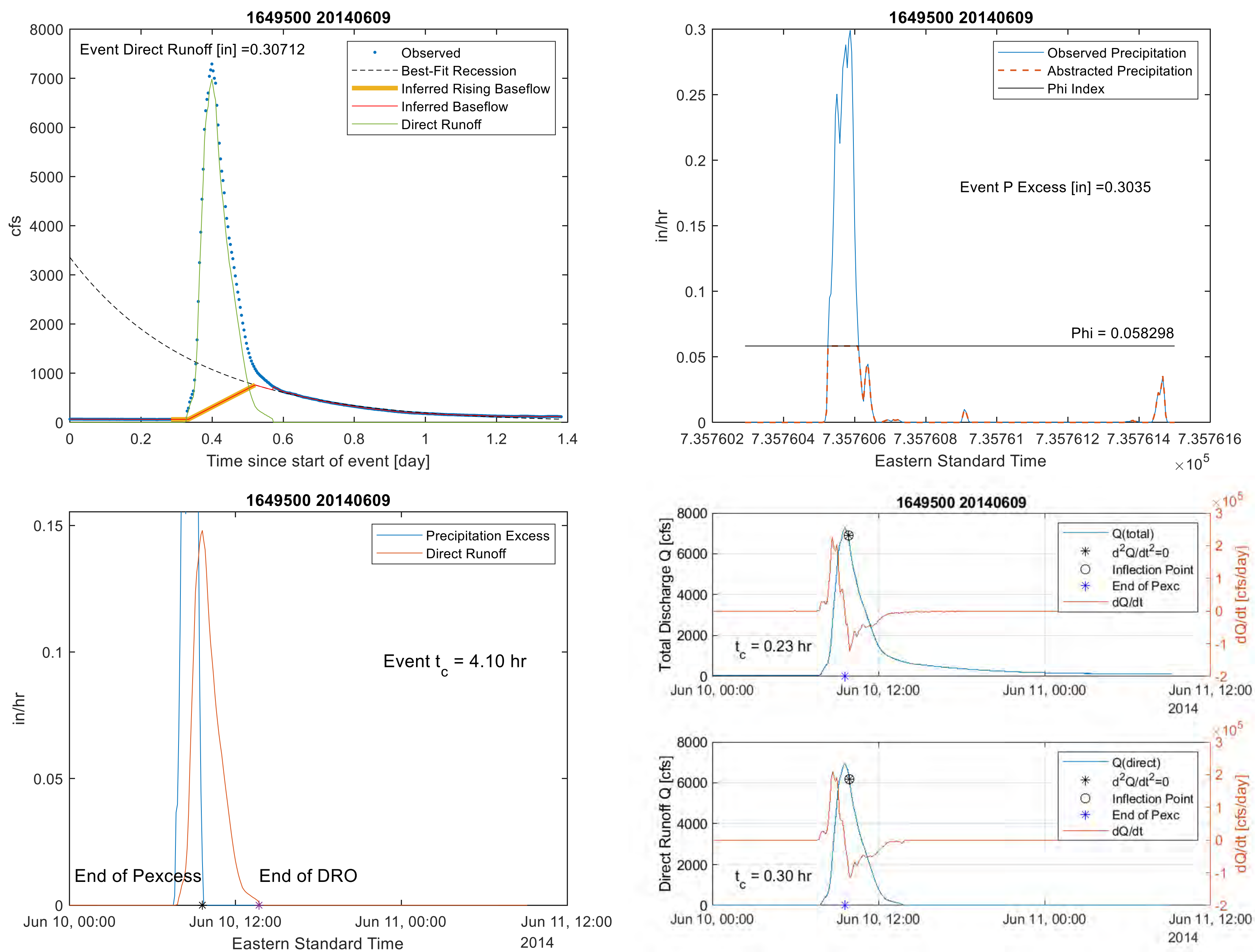
1644375 20130608
Event Direct Runoff [in] =0.76204
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1644375 20130608
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.762
Phi = 0.75934
in/hr
Eastern Standard Time
1644375 20130608
Precipitation Excess
Direct Runoff
Event t c = 5.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1644375 20130608
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 0.88 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 0.90 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

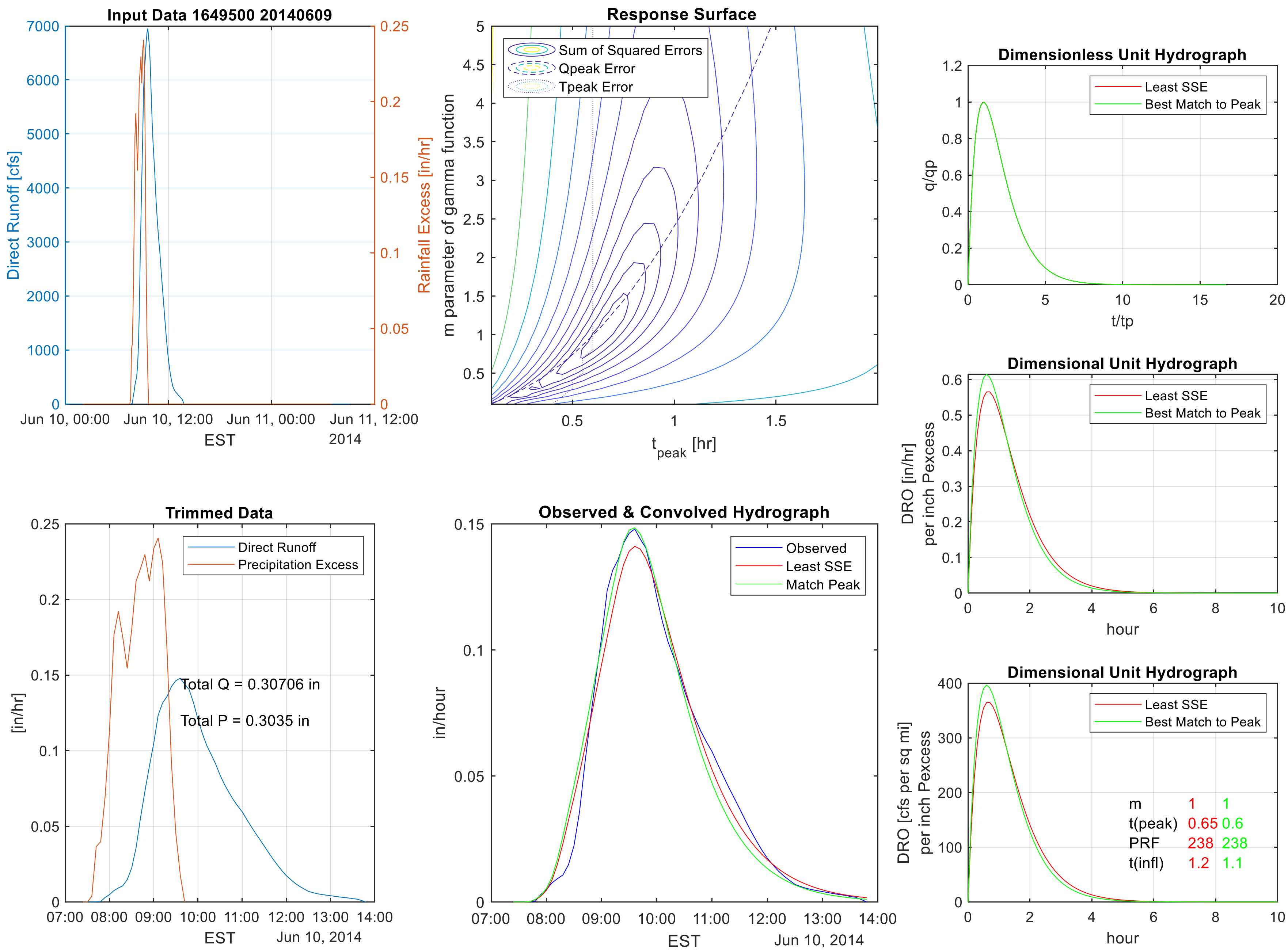

Input Data 1644375 20130608
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 09, 00:00
Jun 10, 00:00
EST
2013
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.76152 in
Total P = 0.762 in
[in/hr]
Jun 10, 00:00
Jun 10, 04:00
Jun 10, 08:00
EST
2013
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Jun 10, 00:00
Jun 10, 04:00
Jun 10, 08:00
EST
2013
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
hour
m 1 1.7
t(peak) 0.6 0.8
PRF 238 320
t(infl) 1.1 1.3



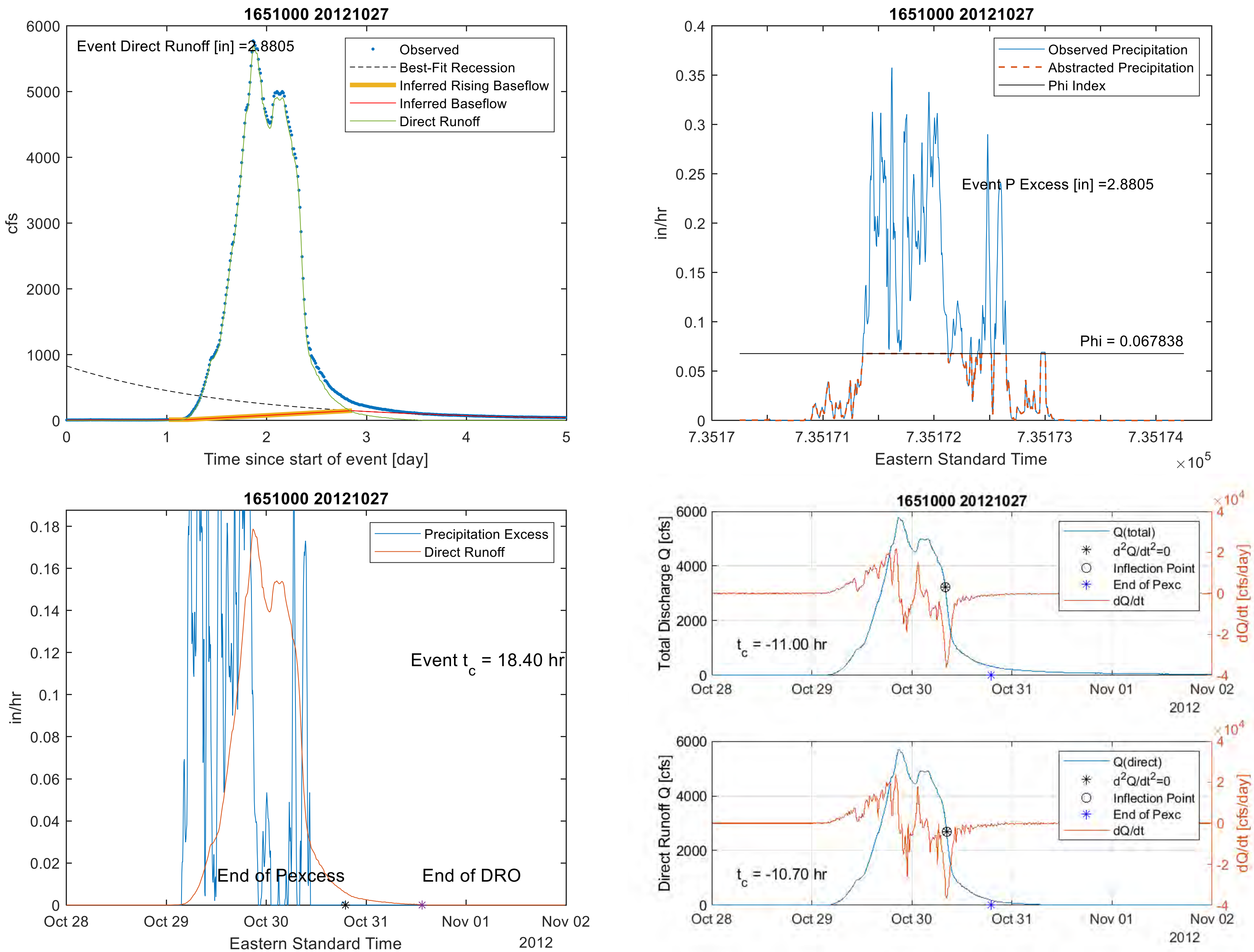
1649500 20121027
Event Direct Runoff [in] =1.8599
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1649500 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.8598
Phi = 0.11352
in/hr
Eastern Standard Time
×10^5
1649500 20121027
Precipitation Excess
Direct Runoff
Event t_c = 39.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2012
1649500 20121027
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -12.10 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2012
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = -12.10 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2012

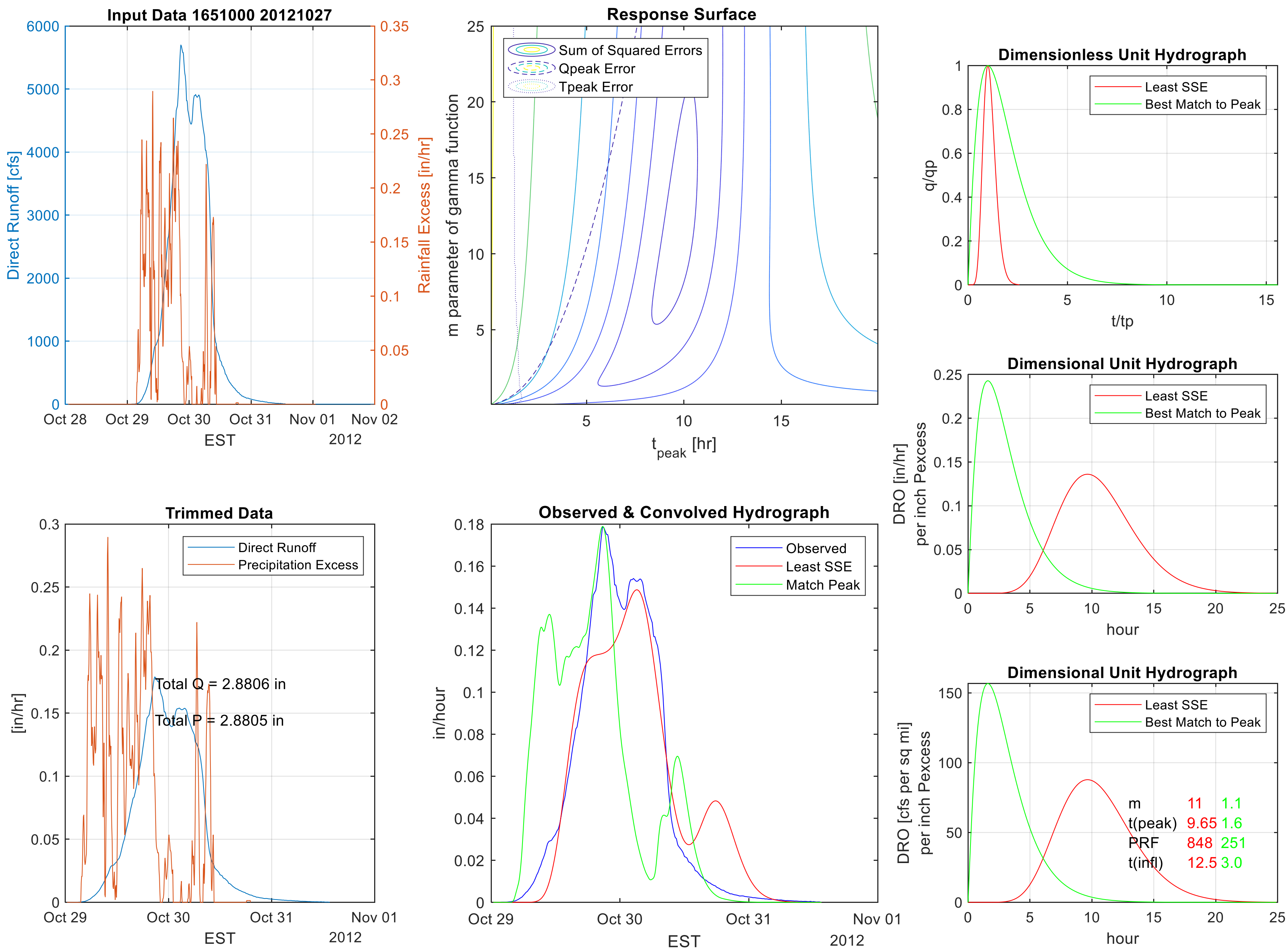

Input Data 1649500 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.8601 in
Total P = 1.8598 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 2 4.2
t(peak) 6.4 5.7
PRF 349 517
t(infl) 10.8 8.4

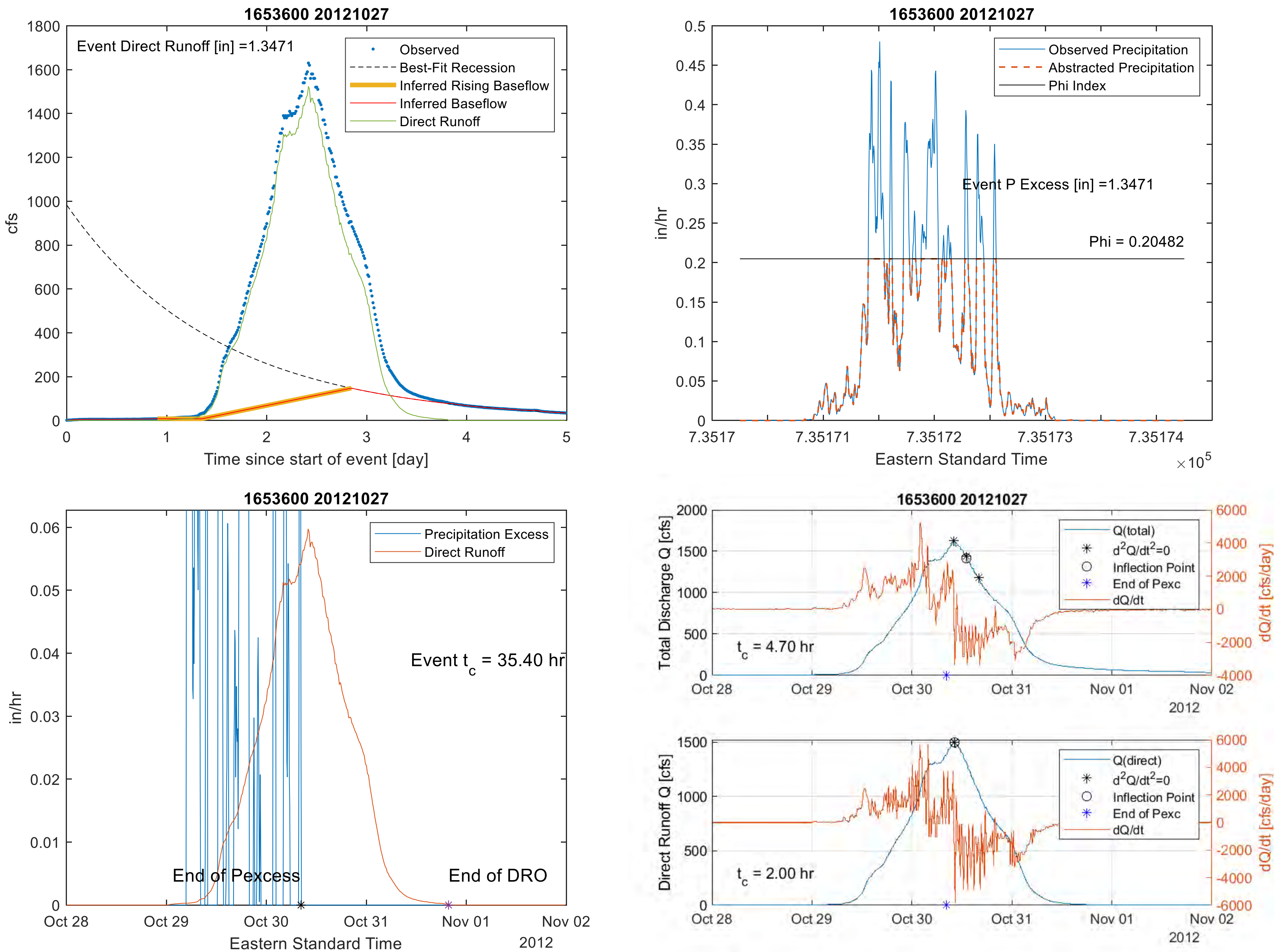

1649500 20140609
Event Direct Runoff [in] =0.30712
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1649500 20140609
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.3035
Phi = 0.058298
in/hr
Eastern Standard Time
1649500 20140609
Precipitation Excess
Direct Runoff
Event t_c = 4.10 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1649500 20140609
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 0.23 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 0.30 hr
Direct Runoff Q [cfs]
Jun 10, 00:00
Jun 10, 12:00
Jun 11, 00:00
Jun 11, 12:00
2014



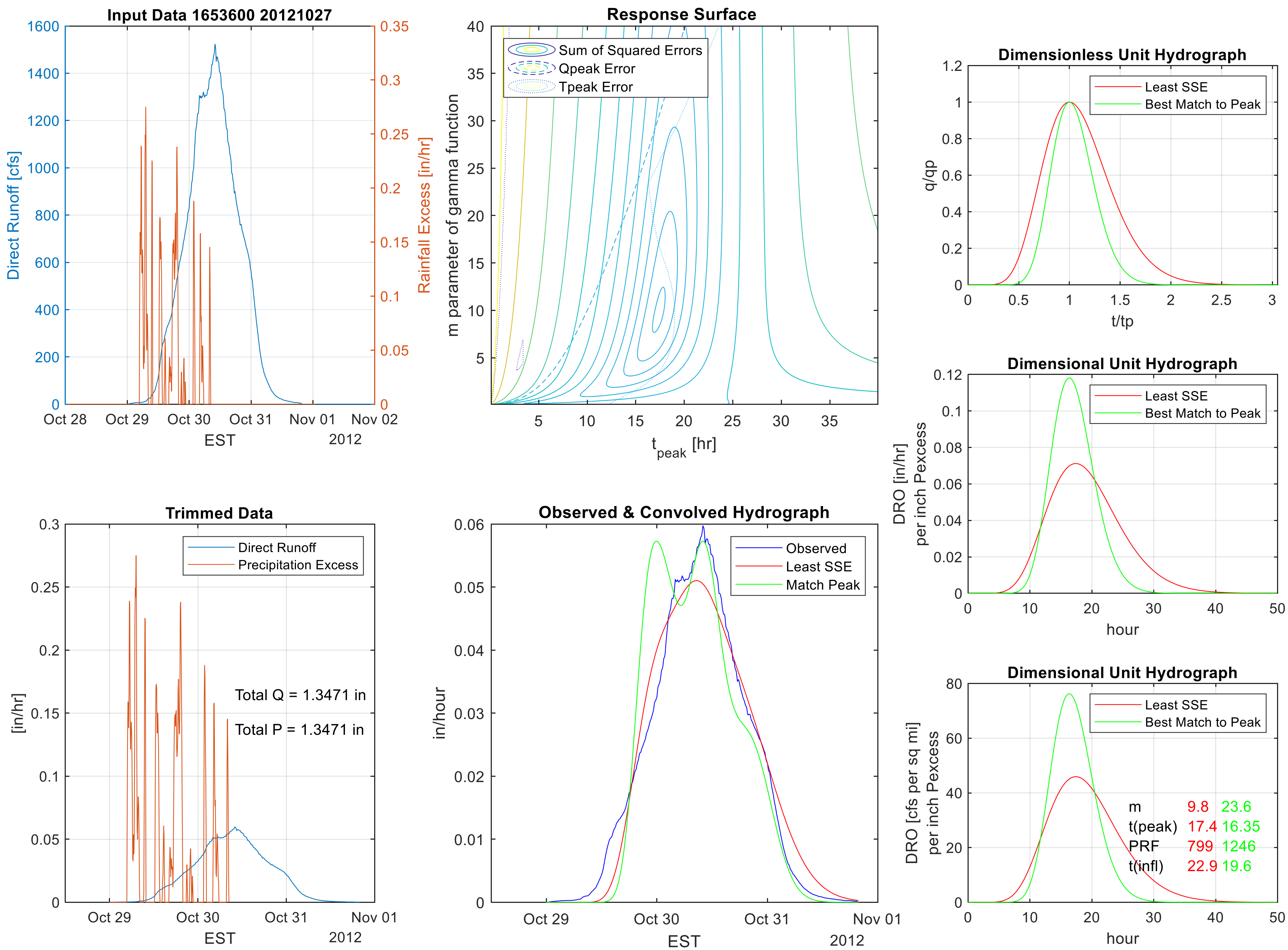
Input Data 1649500 20140609
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jun 10, 00:00
Jun 10, 12:00
Jun 11, 00:00
Jun 11, 12:00
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr]
per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.30706 in
Total P = 0.3035 in
[in/hr]
EST
Jun 10, 2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
Jun 10, 2014
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi]
per inch Pexcess
m 1 1
t(peak) 0.65 0.6
PRF 238 238
t(infl) 1.2 1.1
hour


1651000 20121027
Event Direct Runoff [in] =2.8805
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =2.8805
Phi = 0.067838
in/hr
Eastern Standard Time
Precipitation Excess
Event t c = 18.40 hr
End of Pexcess
End of DRO
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
Total Discharge Q [cfs]
dQ/dt [cfs/day]
t c = -11.00 hr
Q(direct)
Direct Runoff Q [cfs]
t c = -10.70 hr
2012

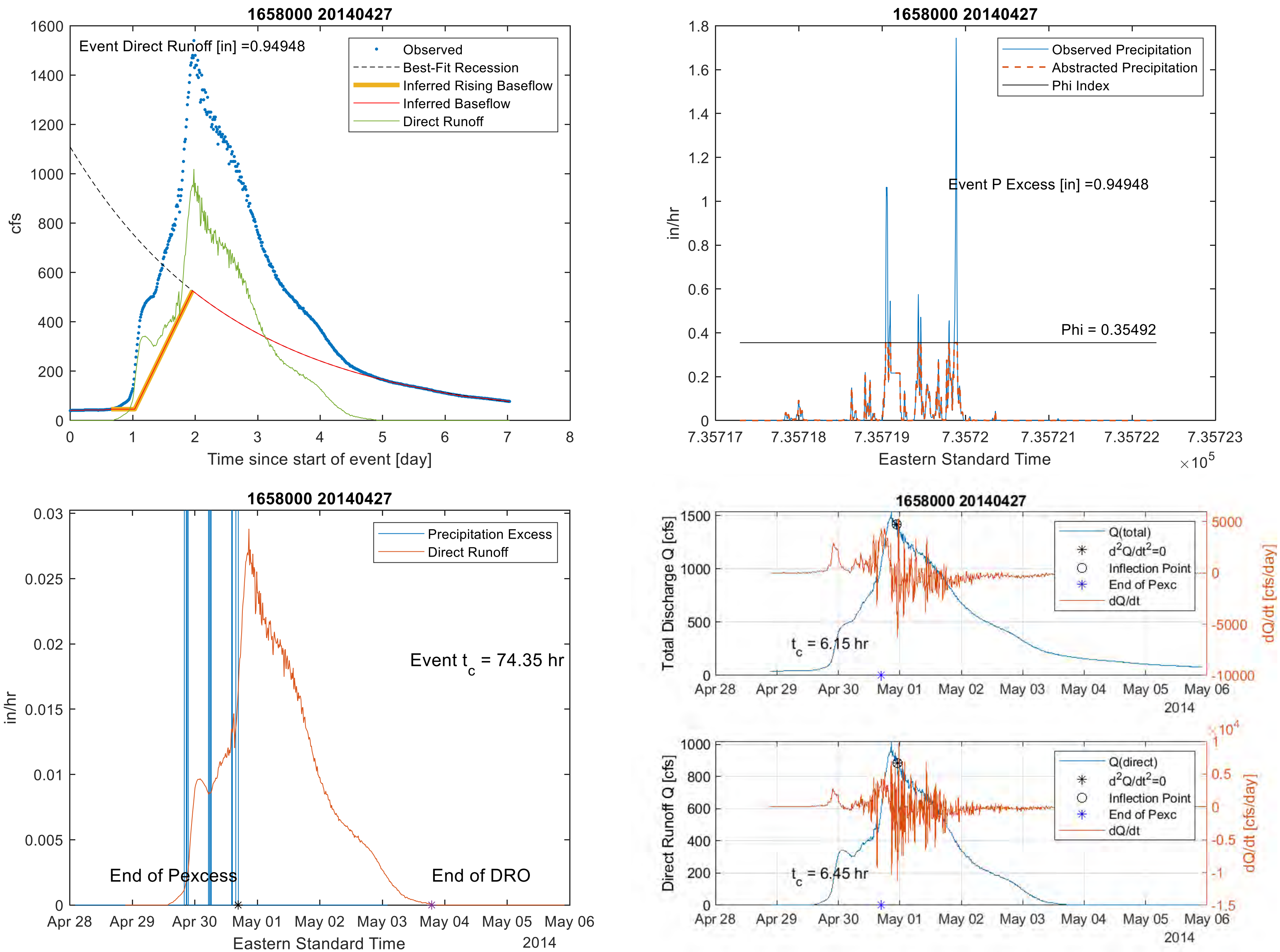

Input Data 1651000 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28
Oct 29
Oct 30
Oct 31
Nov 01
Nov 02
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 2.8806 in
Total P = 2.8805 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 11 1.1
t(peak) 9.65 1.6
PRF 848 251
t(infl) 12.5 3.0

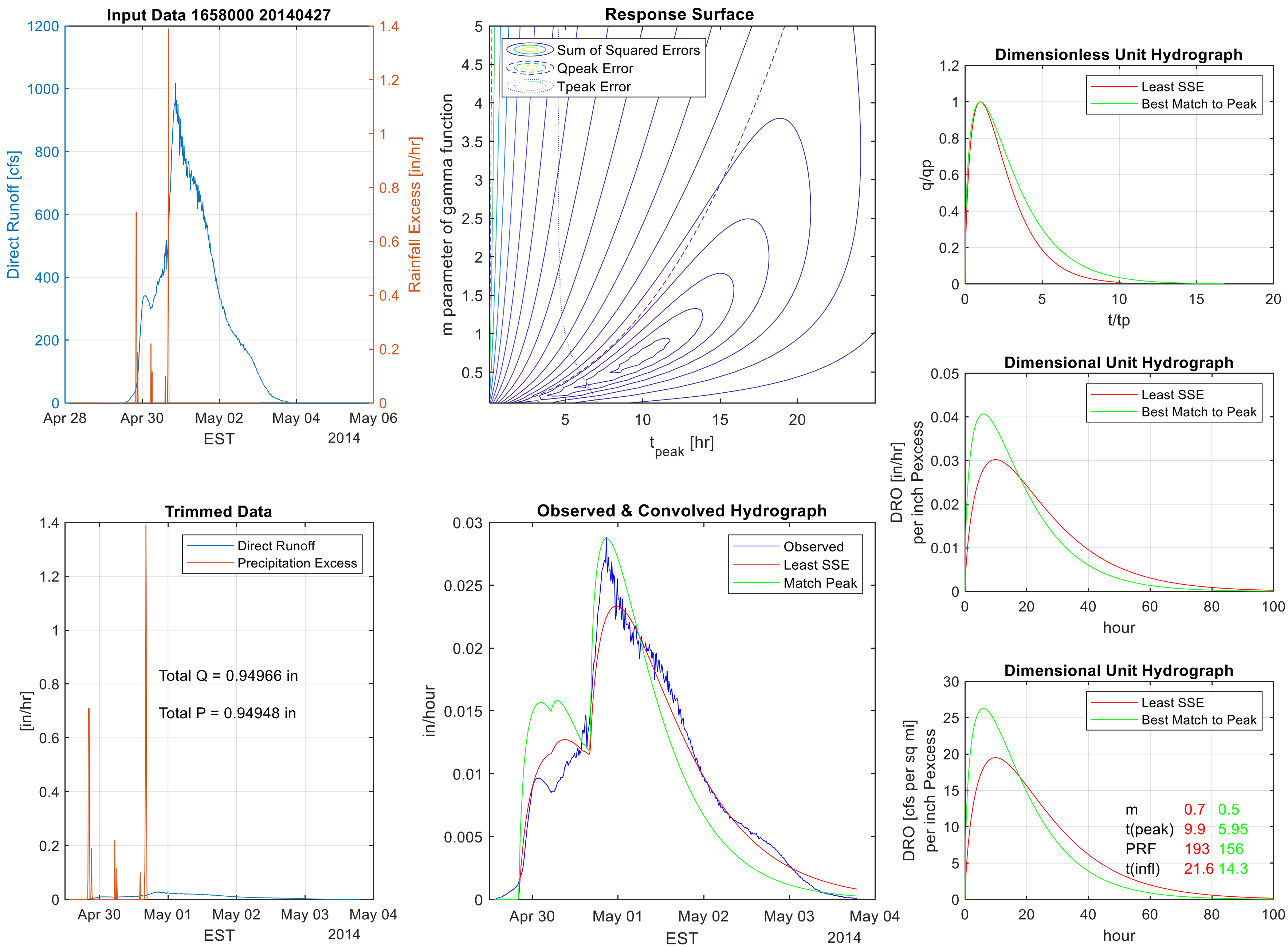


1653600 20121027
Event Direct Runoff [in] =1.3471
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1653600 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.3471
Phi = 0.20482
in/hr
Eastern Standard Time
1653600 20121027
Precipitation Excess
Direct Runoff
Event t_c = 35.40 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
1653600 20121027
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 4.70 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 2.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]

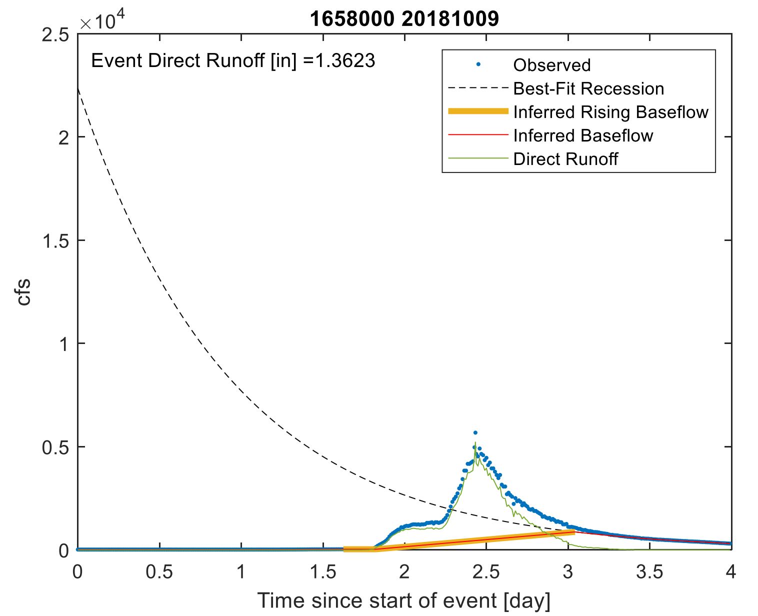


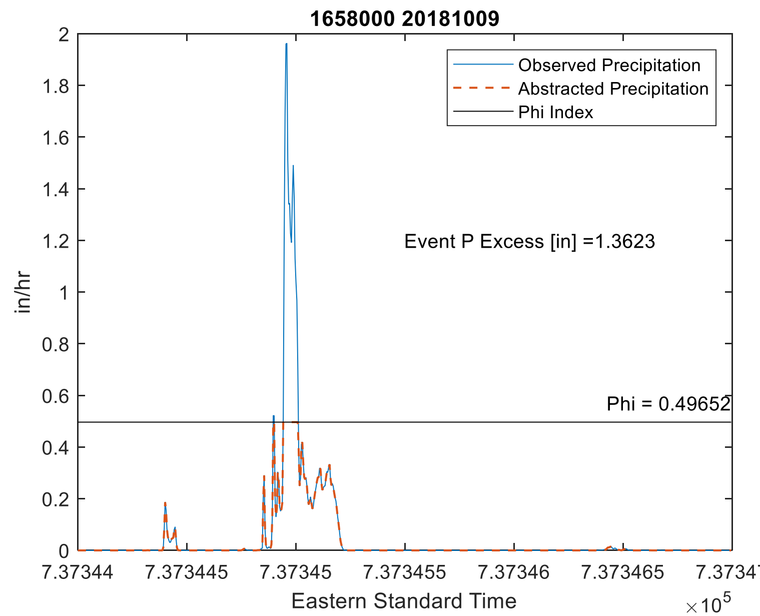
Input Data 1653600 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.3471 in
Total P = 1.3471 in
[in/hr]
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 9.8 23.6
t(peak) 17.4 16.35
PRF 799 1246
t(infl) 22.9 19.6
hour

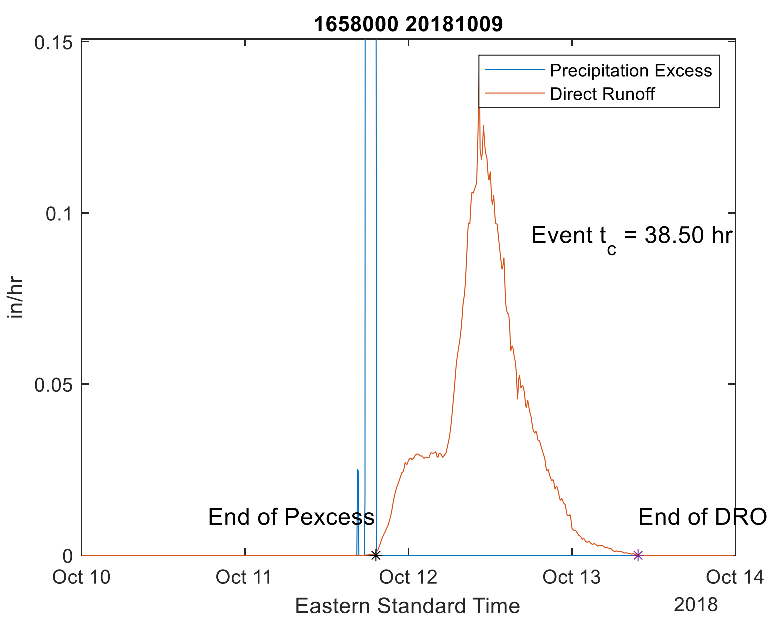

1658000 20140427
Event Direct Runoff [in] =0.94948
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1658000 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.94948
Phi = 0.35492
in/hr
Eastern Standard Time
1658000 20140427
Precipitation Excess
Direct Runoff
Event t c = 74.35 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2014
1658000 20140427
Q(total)
d2Q/dt2=0
Inflection Point
End of Pexc
dQ/dt
t c = 6.15 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t c = 6.45 hr
Direct Runoff Q [cfs]
Apr 28
Apr 29
Apr 30
May 01
May 02
May 03
May 04
May 05
May 06
2014

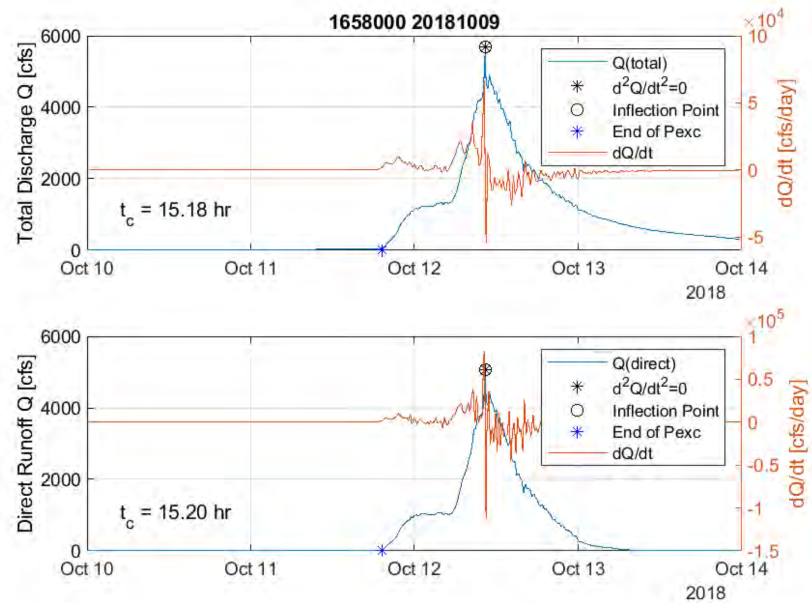


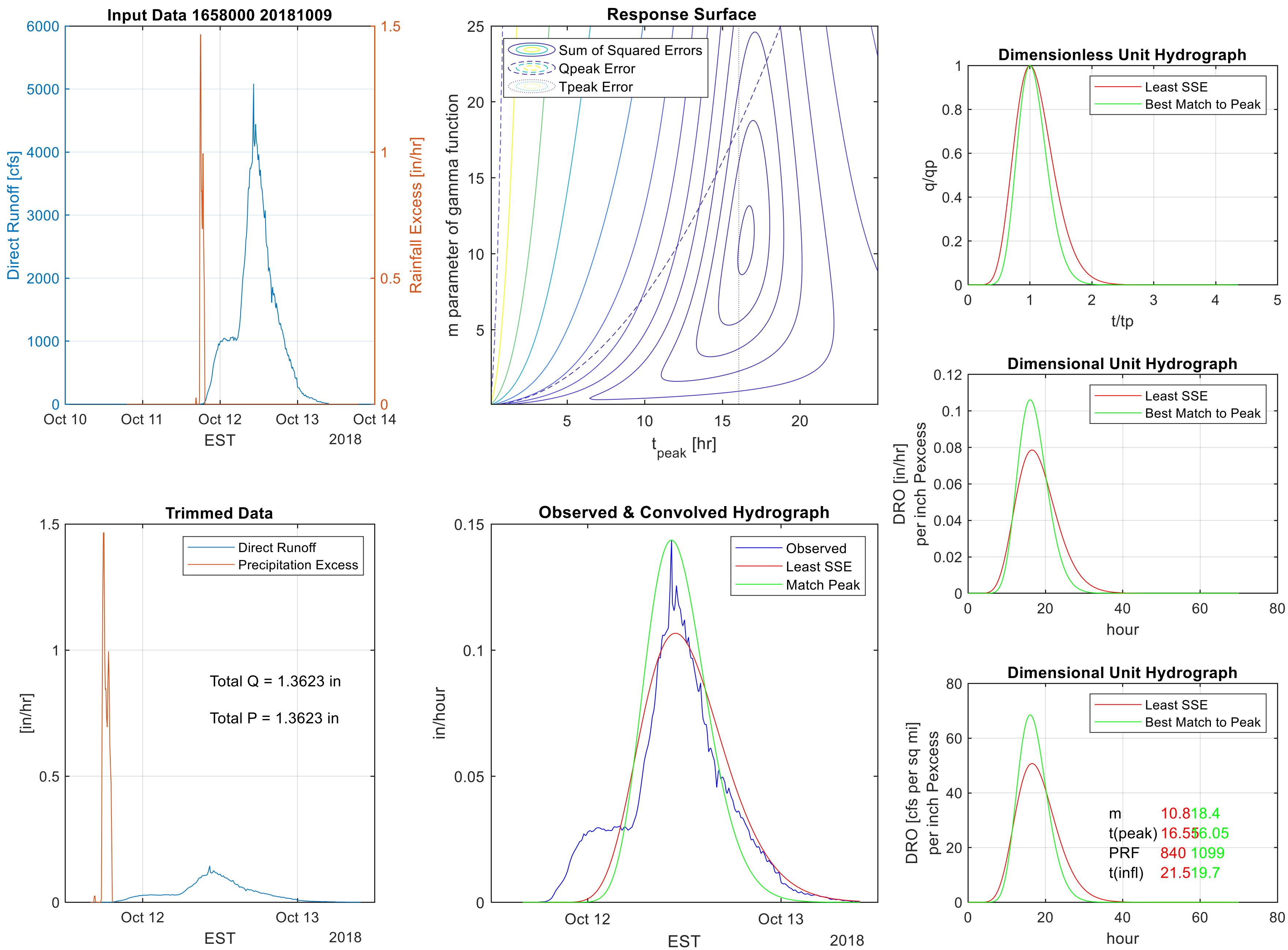
Input Data 1658000 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.94966 in
Total P = 0.94948 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
DRO [cfs per sq mi] per inch Pexcess
m 0.7 0.5
t(peak) 9.9 5.95
PRF 193 156
t(infl) 21.6 14.3

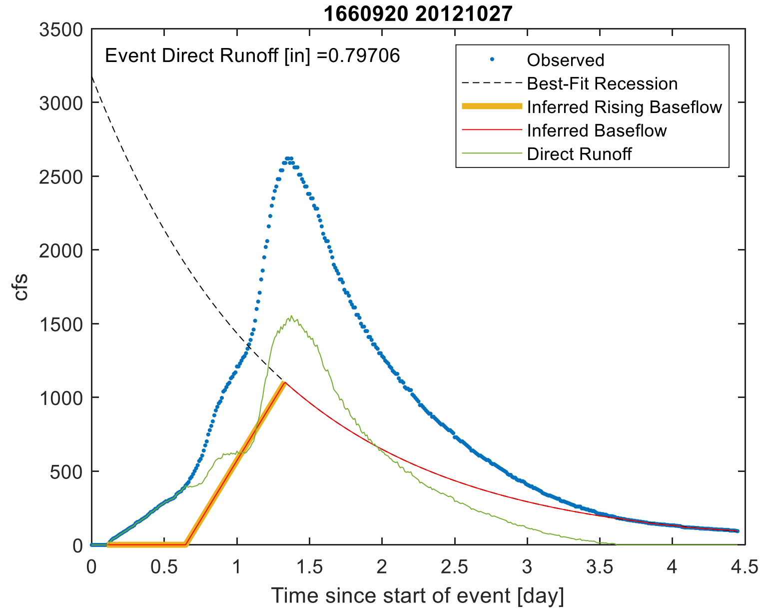

1658000 20181009
Event Direct Runoff [in] =1.3623
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1658000 20181009
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.3623
Phi = 0.49652
in/hr
Eastern Standard Time

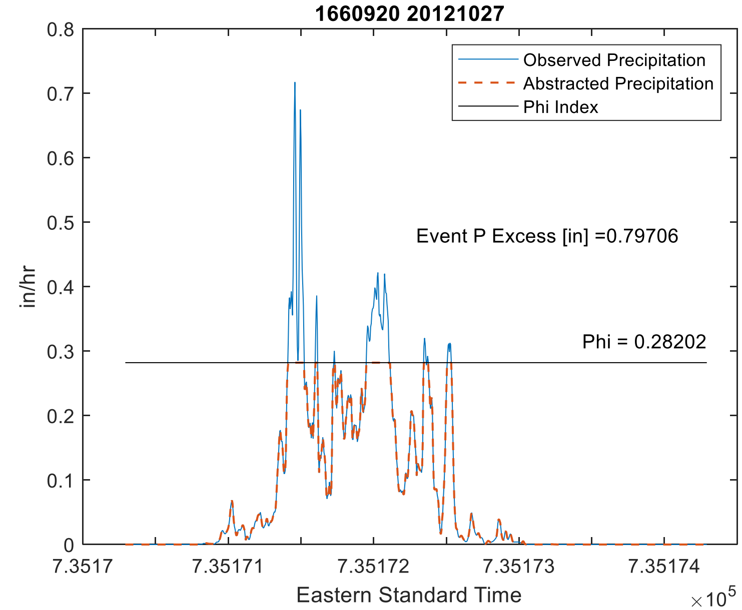

1658000 20181009
Precipitation Excess
Direct Runoff
Event t$_c$ = 38.50 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2018


1658000 20181009
Q(total)
d^{2}Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t$_c$ = 15.18 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
2018
Q(direct)
d^{2}Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t$_c$ = 15.20 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2018

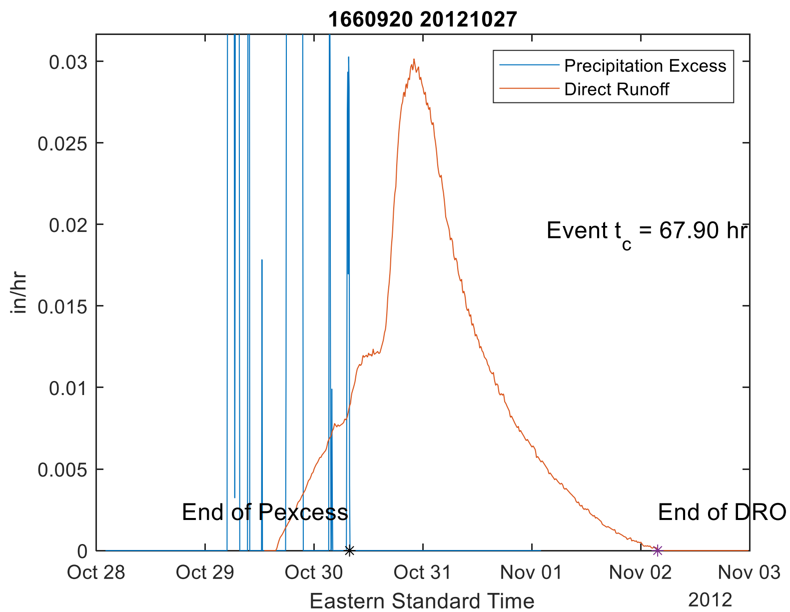

Input Data 1658000 20181009
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 10
Oct 11
Oct 12
Oct 13
Oct 14
EST
2018
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 1.3623 in
Total P = 1.3623 in
[in/hr]
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 10.818.4
t(peak) 16.556.05
PRF 840 1099
t(infl) 21.519.7



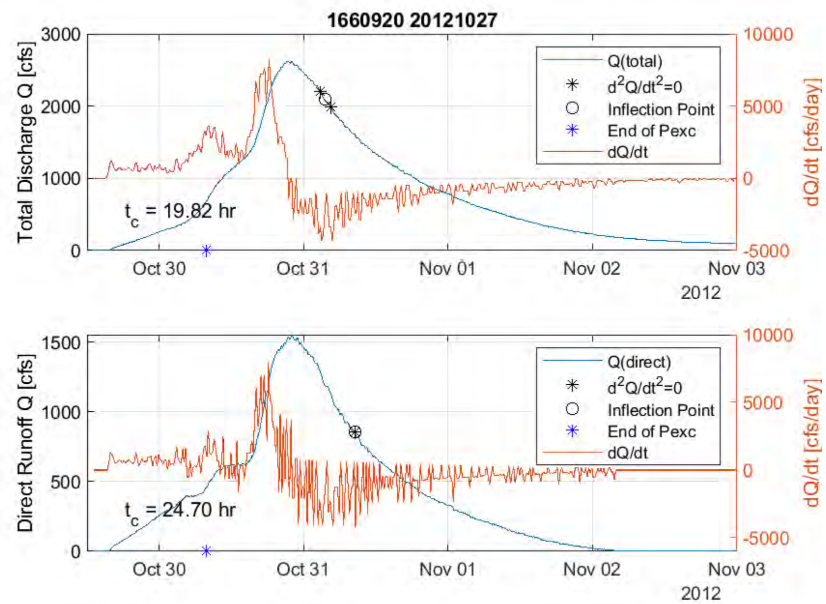
1660920 20121027
Event Direct Runoff [in] =0.79706
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]



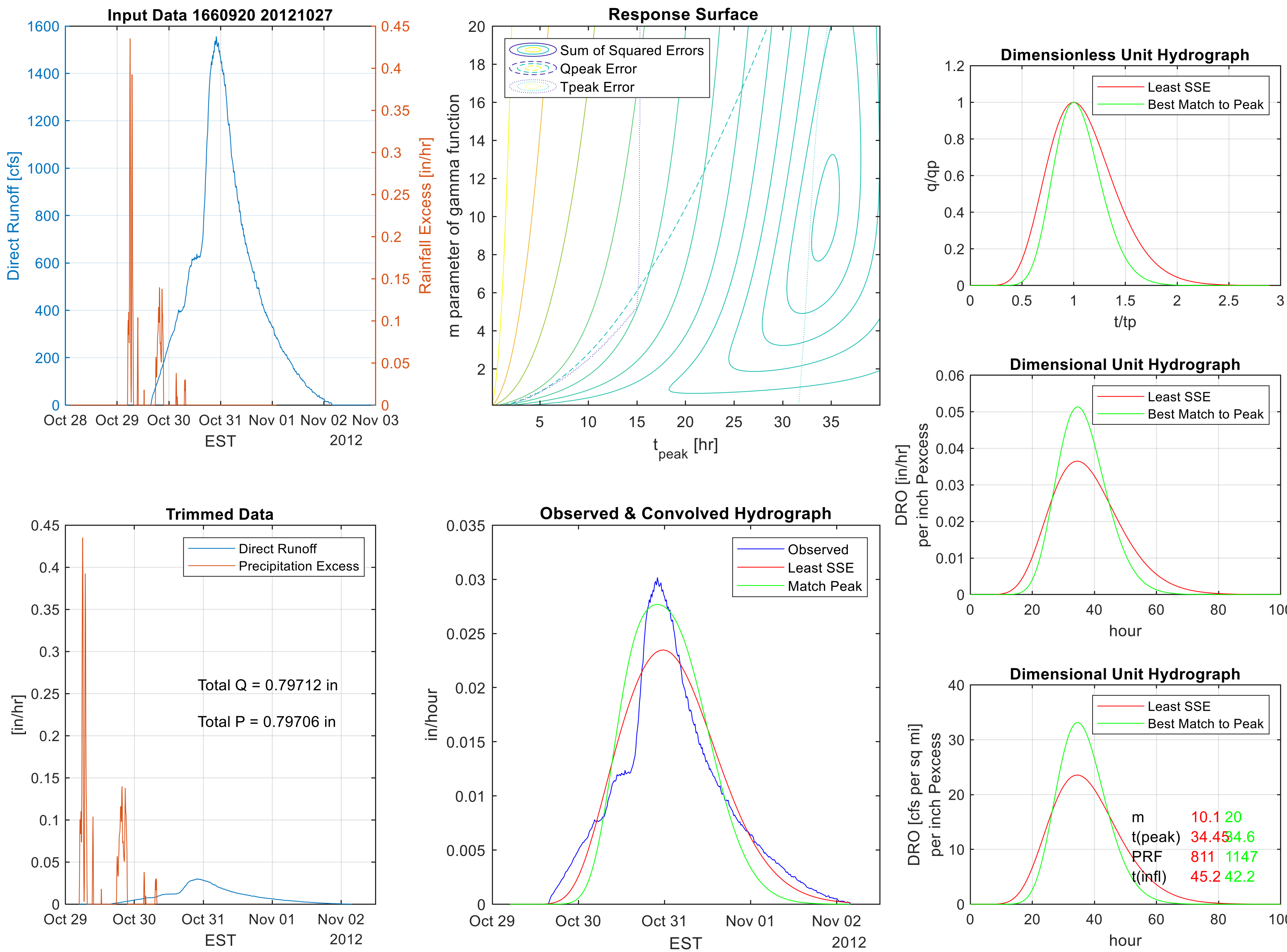
1660920 20121027
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.79706
Phi = 0.28202
in/hr
Eastern Standard Time

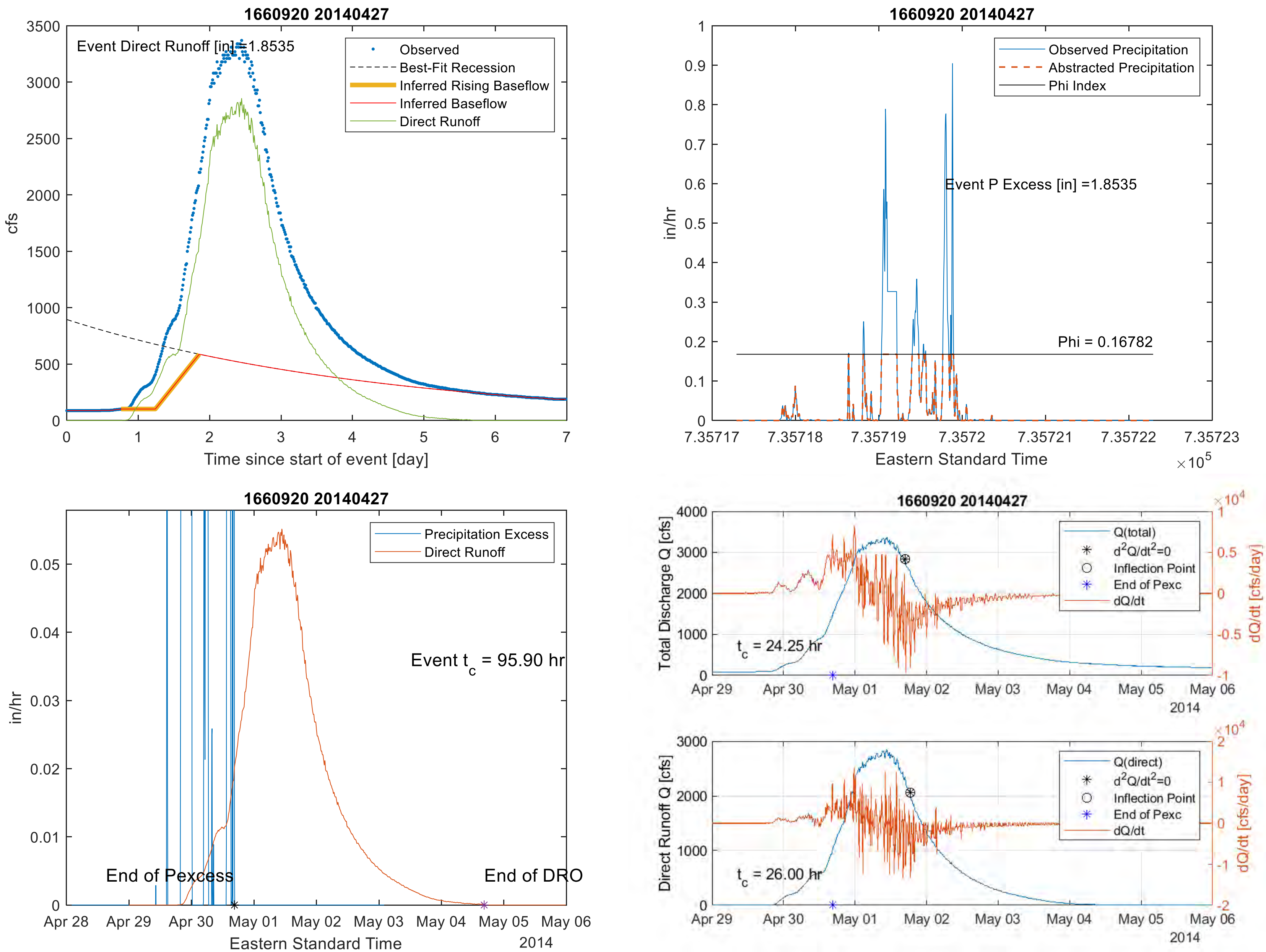


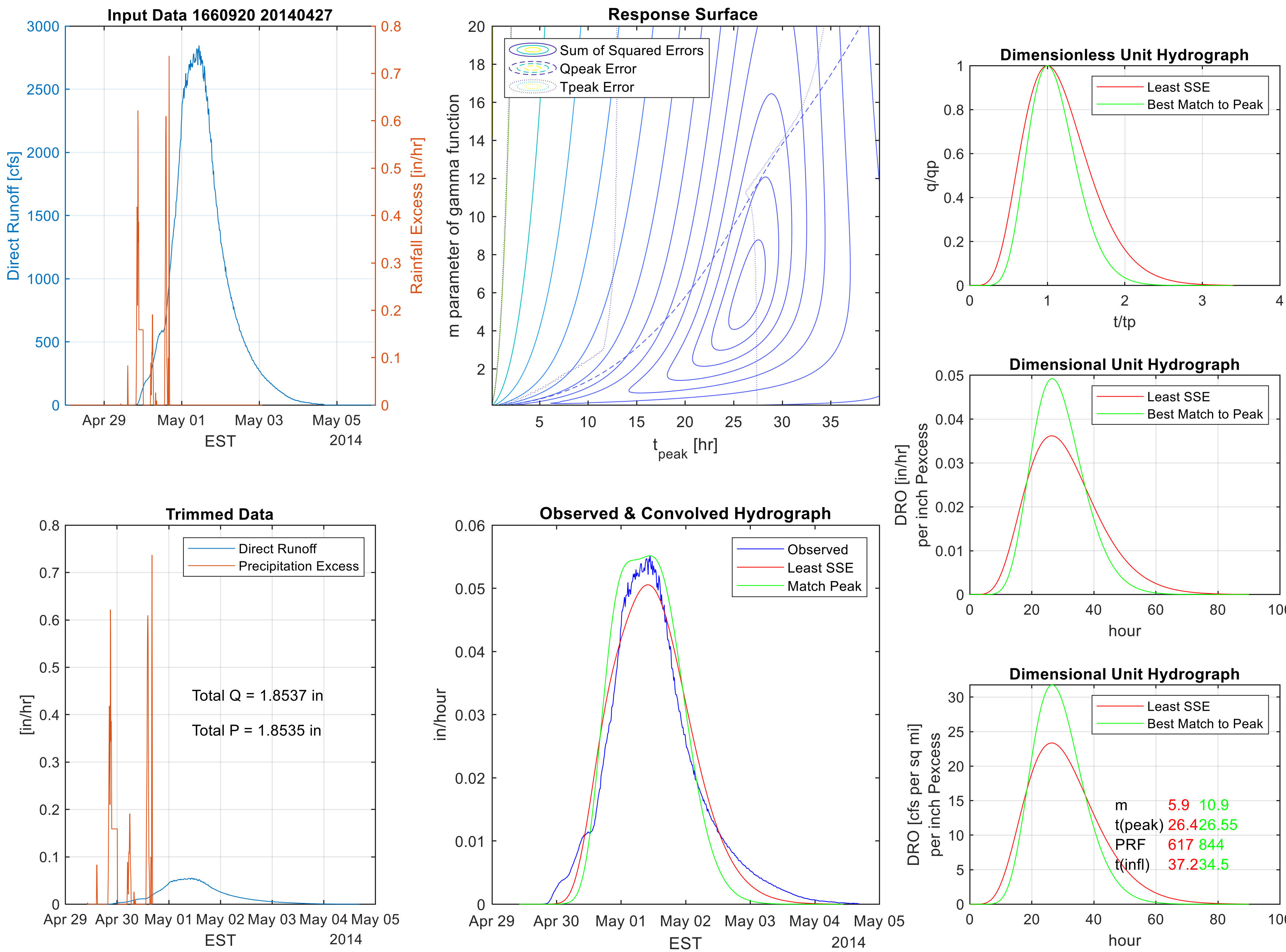
1660920 20121027
Precipitation Excess
Direct Runoff
Event t_c = 67.90 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time

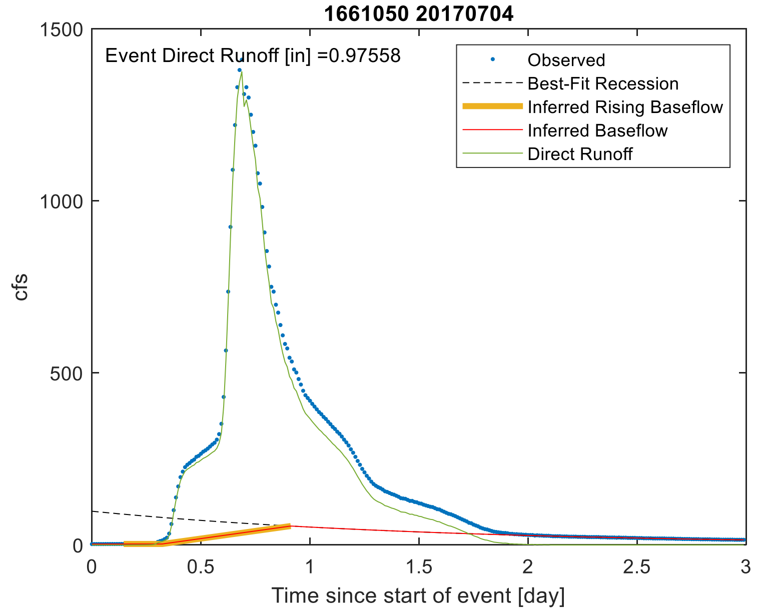


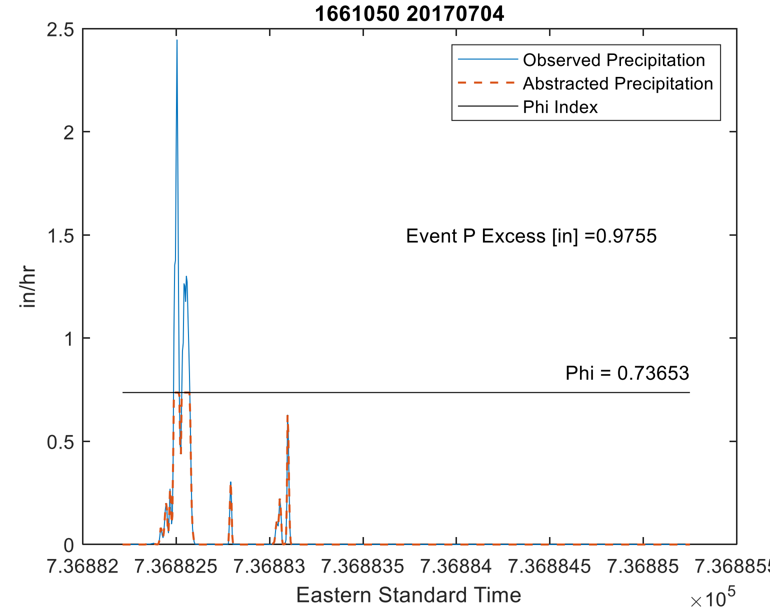
1660920 20121027
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 19.82 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 24.70 hr
Direct Runoff Q [cfs]

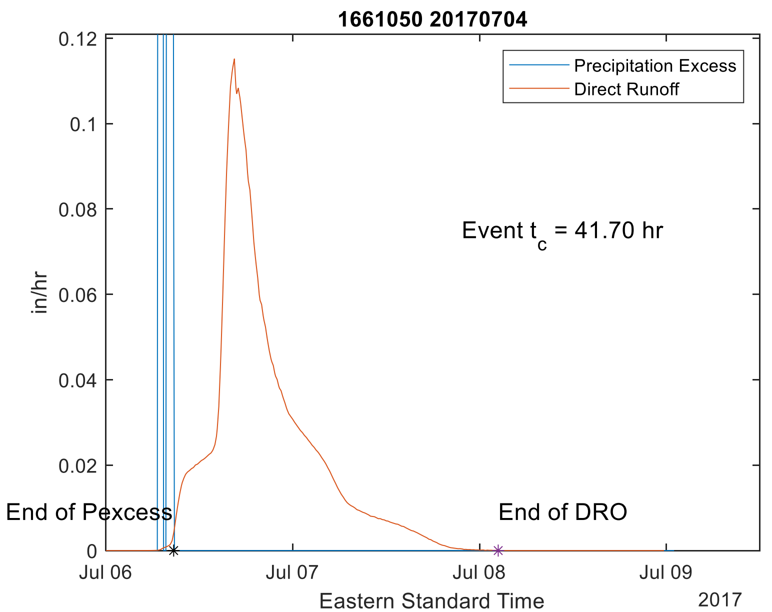

Input Data 1660920 20121027
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Oct 28 Oct 29 Oct 30 Oct 31 Nov 01 Nov 02 Nov 03
EST
2012
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
Total Q = 0.79712 in
Total P = 0.79706 in
[in/hr]
Oct 29 Oct 30 Oct 31 Nov 01 Nov 02
EST
2012
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Oct 29 Oct 30 Oct 31 Nov 01 Nov 02
EST
2012
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
hour
m 10.1 20
t(peak) 34.45 34.6
PRF 811 1147
t(infl) 45.2 42.2

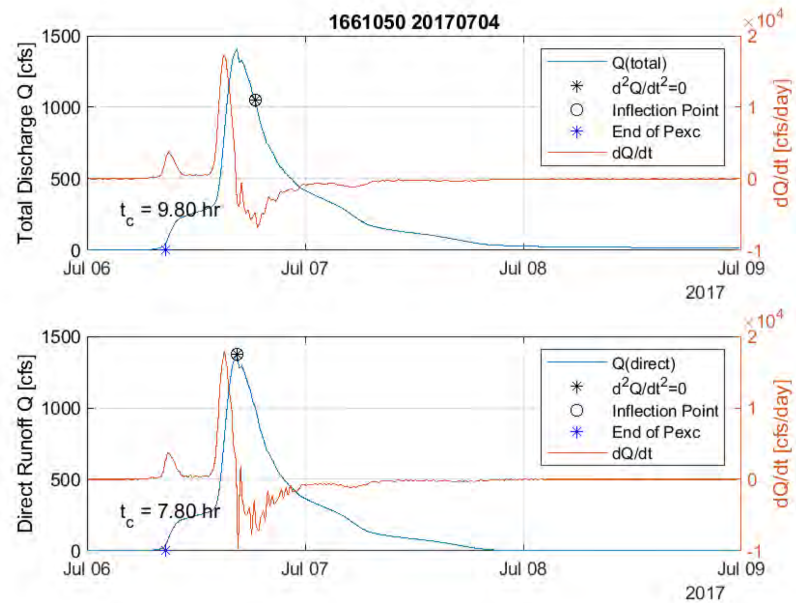

1660920 20140427
Event Direct Runoff [in] =1.8535
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]
1660920 20140427
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =1.8535
Phi = 0.16782
in/hr
Eastern Standard Time
×10^5
1660920 20140427
Precipitation Excess
Direct Runoff
Event t_c = 95.90 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time
2014
1660920 20140427
Q(total)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 24.25 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
d^2Q/dt^2=0
Inflection Point
End of Pexc
dQ/dt
t_c = 26.00 hr
Direct Runoff Q [cfs]
dQ/dt [cfs/day]
2014

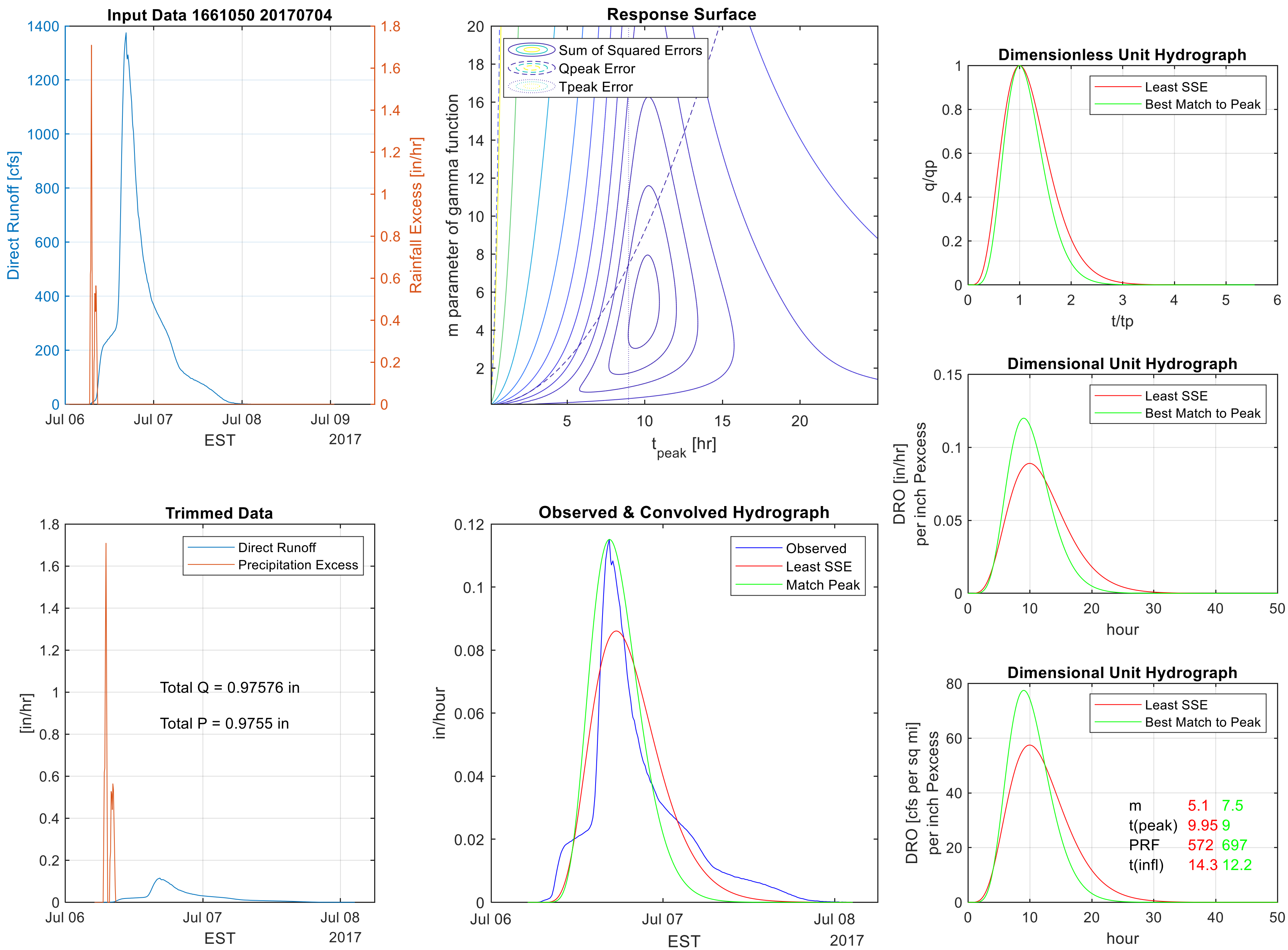

Input Data 1660920 20140427
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Apr 29
May 01
May 03
May 05
EST
2014
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t peak [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 1.8537 in
Total P = 1.8535 in
Apr 29
Apr 30
May 01
May 02
May 03
May 04
May 05
EST
2014
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
EST
2014
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [in/hr] per inch Pexcess
hour
Dimensional Unit Hydrograph
Least SSE
Best Match to Peak
DRO [cfs per sq mi] per inch Pexcess
m 5.9 10.9
t(peak) 26.4 26.55
PRF 617 844
t(infl) 37.2 34.5
hour


1661050 20170704
Event Direct Runoff [in] =0.97558
Observed
Best-Fit Recession
Inferred Rising Baseflow
Inferred Baseflow
Direct Runoff
cfs
Time since start of event [day]


1661050 20170704
Observed Precipitation
Abstracted Precipitation
Phi Index
Event P Excess [in] =0.9755
Phi = 0.73653
in/hr
Eastern Standard Time


1661050 20170704
Precipitation Excess
Direct Runoff
Event t_c = 41.70 hr
End of Pexcess
End of DRO
in/hr
Eastern Standard Time


1661050 20170704
Q(total)
$d^2Q/dt^2=0$
Inflection Point
End of Pexc
dQ/dt
t_c = 9.80 hr
Total Discharge Q [cfs]
dQ/dt [cfs/day]
Q(direct)
t_c = 7.80 hr
Direct Runoff Q [cfs]



Input Data 1661050 20170704
Direct Runoff [cfs]
Rainfall Excess [in/hr]
Jul 06
Jul 07
Jul 08
Jul 09
EST
2017
Response Surface
Sum of Squared Errors
Qpeak Error
Tpeak Error
m parameter of gamma function
t_{peak} [hr]
Dimensionless Unit Hydrograph
Least SSE
Best Match to Peak
q/qp
t/tp
Dimensional Unit Hydrograph
DRO [in/hr] per inch Pexcess
hour
Trimmed Data
Direct Runoff
Precipitation Excess
[in/hr]
Total Q = 0.97576 in
Total P = 0.9755 in
Observed & Convolved Hydrograph
Observed
Least SSE
Match Peak
in/hour
Dimensional Unit Hydrograph
DRO [cfs per sq mi] per inch Pexcess
m 5.1 7.5
t(peak) 9.95 9
PRF 572 697
t(infl) 14.3 12.2

APPENDIX 2
BASIN STATISTICS FROM GISHYDRONXT

(Watersheds with missing "Length" or "Storage" Variables in Hydrology Panel Report 2020, Appendix 1)

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1483200
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           NLCD 2011
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              514663 m (MD Stateplane, NAD 1983)
     Outlet Northing:             189507 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                4.06 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               13.49100410 feet/mile (0.00255511 feet/feet)
     Land Slope:                  0.01898160 feet/feet
     Urban Area (percent):        0.5
     Impervious Area (percent):   0.8

     Time of Concentration:       16.82 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       5.53 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           4.01 miles
     Basin Relief:                38.35 feet
     Average CN:                  72.3
     Forest Cover (percent):      26.5
     Storage (percent):           21.4
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  33.8
        B Soils:                  33.0
        C Soils:                  12.4
        D Soils:                  20.5
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  33.8
        B Soils:                  33.0
        C Soils:                  12.4
        D Soils:                  20.5
     2-Year,24-hour Prec.:        3.20 inches
     Mean Annual Prec.:           43.78 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           NLCD 2011
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              528940 m (MD Stateplane, NAD 1983)
     Outlet Northing:             138561 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                3.31 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               5.23820418 feet/mile (0.00099208 feet/feet)
     Land Slope:                  0.00729976 feet/feet
     Urban Area (percent):        0.2
     Impervious Area (percent):   0.4

     Time of Concentration:       19.18 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       6.61 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           3.62 miles
     Basin Relief:                15.50 feet
     Average CN:                  79.8
     Forest Cover (percent):      12.6
     Storage (percent):           25.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  30.3
        B Soils:                  5.1
        C Soils:                  0.0
        D Soils:                  64.7
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  30.3
        B Soils:                  5.1
        C Soils:                  0.0
        D Soils:                  64.7
     2-Year,24-hour Prec.:        3.36 inches
     Mean Annual Prec.:           45.04 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              491624 m (MD Stateplane, NAD 1983)
     Outlet Northing:             144877 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                87.64 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               3.25669128 feet/mile (0.00061680 feet/feet)
     Land Slope:                  0.01188516 feet/feet
     Urban Area (percent):        2.6
     Impervious Area (percent):   1.3

     Time of Concentration:       28.97 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       21.84 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           18.70 miles
     Basin Relief:                46.08 feet
     Average CN:                  75.6
     Forest Cover (percent):      31.0
     Storage (percent):           0.1
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  20.7
        B Soils:                  22.2
        C Soils:                  30.1
        D Soils:                  26.8
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  20.7
        B Soils:                  22.2
        C Soils:                  30.1
        D Soils:                  26.8
     2-Year,24-hour Prec.:        3.25 inches
     Mean Annual Prec.:           44.17 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1493112
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              491415 m (MD Stateplane, NAD 1983)
     Outlet Northing:             177041 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                6.14 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               14.54702336 feet/mile (0.00275512 feet/feet)
     Land Slope:                  0.01858567 feet/feet
     Urban Area (percent):        0.6
     Impervious Area (percent):   0.4

     Time of Concentration:       11.88 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       5.68 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           5.11 miles
     Basin Relief:                50.01 feet
     Average CN:                  78.5
     Forest Cover (percent):      7.9
     Storage (percent):           0.5
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.2
        B Soils:                  28.6
        C Soils:                  65.7
        D Soils:                  5.4
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.2
        B Soils:                  28.6
        C Soils:                  65.7
        D Soils:                  5.4
     2-Year,24-hour Prec.:        3.24 inches
     Mean Annual Prec.:           44.64 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              426882 m (MD Stateplane, NAD 1983)
     Outlet Northing:             201372 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Piedmont
     Outlet State:                Maryland
     Drainage Area                0.14 square miles
       -Piedmont 100.00 percent of area

     Channel Slope:               190.26297335 feet/mile (0.03603465 feet/feet)
     Land Slope:                  0.10482415 feet/feet
     Urban Area (percent):        0.0
     Impervious Area (percent):   0.0

     Time of Concentration:       2.28 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       0.84 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           0.73 miles
     Basin Relief:                99.27 feet
     Average CN:                  59.4
     Forest Cover (percent):      100.0
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.0
        B Soils:                  75.6
        C Soils:                  13.1
        D Soils:                  11.3
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.0
        B Soils:                  75.6
        C Soils:                  13.1
        D Soils:                  11.3
     2-Year,24-hour Prec.:        3.29 inches
     Mean Annual Prec.:           46.65 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1585090
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              443440 m (MD Stateplane, NAD 1983)
     Outlet Northing:             190278 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Western Coastal Plain
     Outlet State:                Maryland
     Drainage Area                2.64 square miles
       -Piedmont 78.38 percent of area
       -Western Coastal Plain 21.62 percent of area

     Channel Slope:               80.56496106 feet/mile (0.01525852 feet/feet)
     Land Slope:                  0.07127592 feet/feet
     Urban Area (percent):        78.4
     Impervious Area (percent):   46.7

                ******************************************************
                    Watershed is within 5km of physiographic
                    province boundary.  You should consider
                    sensitivity of discharges to region location.
                ******************************************************

     Time of Concentration:       2.16 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       1.63 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           3.31 miles
     Basin Relief:                170.22 feet
     Average CN:                  85.5
     Forest Cover (percent):      9.9
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.0
        B Soils:                  5.2
        C Soils:                  45.0
        D Soils:                  49.8
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.0
        B Soils:                  5.2
        C Soils:                  45.0
        D Soils:                  49.8
     2-Year,24-hour Prec.:        3.37 inches
     Mean Annual Prec.:           49.62 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              448874 m (MD Stateplane, NAD 1983)
     Outlet Northing:             190665 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Western Coastal Plain
     Outlet State:                Maryland
     Drainage Area                2.45 square miles
       -Piedmont 30.56 percent of area
       -Western Coastal Plain 69.44 percent of area

     Channel Slope:               71.98719869 feet/mile (0.01363394 feet/feet)
     Land Slope:                  0.05599917 feet/feet
     Urban Area (percent):        40.4
     Impervious Area (percent):   22.1

                ******************************************************
                    Watershed is within 5km of physiographic
                    province boundary.  You should consider
                    sensitivity of discharges to region location.
                ******************************************************

     Time of Concentration:       4.76 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       2.26 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           3.39 miles
     Basin Relief:                142.61 feet
     Average CN:                  79.8
     Forest Cover (percent):      29.1
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  2.1
        B Soils:                  13.0
        C Soils:                  50.0
        D Soils:                  35.0
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  2.1
        B Soils:                  13.0
        C Soils:                  50.0
        D Soils:                  35.0
     2-Year,24-hour Prec.:        3.34 inches
     Mean Annual Prec.:           48.37 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1585230
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              440082 m (MD Stateplane, NAD 1983)
     Outlet Northing:             184792 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Western Coastal Plain
     Outlet State:                Maryland
     Drainage Area                3.48 square miles
       -Piedmont 21.86 percent of area
       -Western Coastal Plain 78.14 percent of area

     Channel Slope:               79.29394052 feet/mile (0.01501779 feet/feet)
     Land Slope:                  0.05014206 feet/feet
     Urban Area (percent):        90.6
     Impervious Area (percent):   45.4

                ******************************************************
                    Watershed is within 5km of physiographic
                    province boundary.  You should consider
                    sensitivity of discharges to region location.
                ******************************************************

     Time of Concentration:       3.69 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       2.15 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           3.80 miles
     Basin Relief:                183.76 feet
     Average CN:                  85.8
     Forest Cover (percent):      1.8
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  1.5
        B Soils:                  11.1
        C Soils:                  24.8
        D Soils:                  62.6
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  1.5
        B Soils:                  11.1
        C Soils:                  24.8
        D Soils:                  62.6
     2-Year,24-hour Prec.:        3.34 inches
     Mean Annual Prec.:           47.68 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1644371
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              377919 m (MD Stateplane, NAD 1983)
     Outlet Northing:             173718 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Piedmont
     Outlet State:                Maryland
     Drainage Area                0.47 square miles
       -Piedmont 100.00 percent of area

     Channel Slope:               116.82425413 feet/mile (0.02212581 feet/feet)
     Land Slope:                  0.07780400 feet/feet
     Urban Area (percent):        55.5
     Impervious Area (percent):   27.5

     Time of Concentration:       1.35 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       0.97 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           1.32 miles
     Basin Relief:                99.45 feet
     Average CN:                  77.3
     Forest Cover (percent):      24.0
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.0
        B Soils:                  54.8
        C Soils:                  32.5
        D Soils:                  12.7
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.0
        B Soils:                  54.8
        C Soils:                  32.5
        D Soils:                  12.7
     2-Year,24-hour Prec.:        3.08 inches
     Mean Annual Prec.:           42.56 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              376153 m (MD Stateplane, NAD 1983)
     Outlet Northing:             170143 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Piedmont
     Outlet State:                Maryland
     Drainage Area                1.23 square miles
       -Piedmont 100.00 percent of area

     Channel Slope:               63.88346191 feet/mile (0.01209914 feet/feet)
     Land Slope:                  0.04769627 feet/feet
     Urban Area (percent):        67.7
     Impervious Area (percent):   53.4

     Time of Concentration:       1.39 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       1.73 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           2.45 miles
     Basin Relief:                73.06 feet
     Average CN:                  82.6
     Forest Cover (percent):      9.9
     Storage (percent):           0.1
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.0
        B Soils:                  83.2
        C Soils:                  6.7
        D Soils:                  10.0
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.0
        B Soils:                  83.2
        C Soils:                  6.7
        D Soils:                  10.0
     2-Year,24-hour Prec.:        3.08 inches
     Mean Annual Prec.:           42.44 inches
```

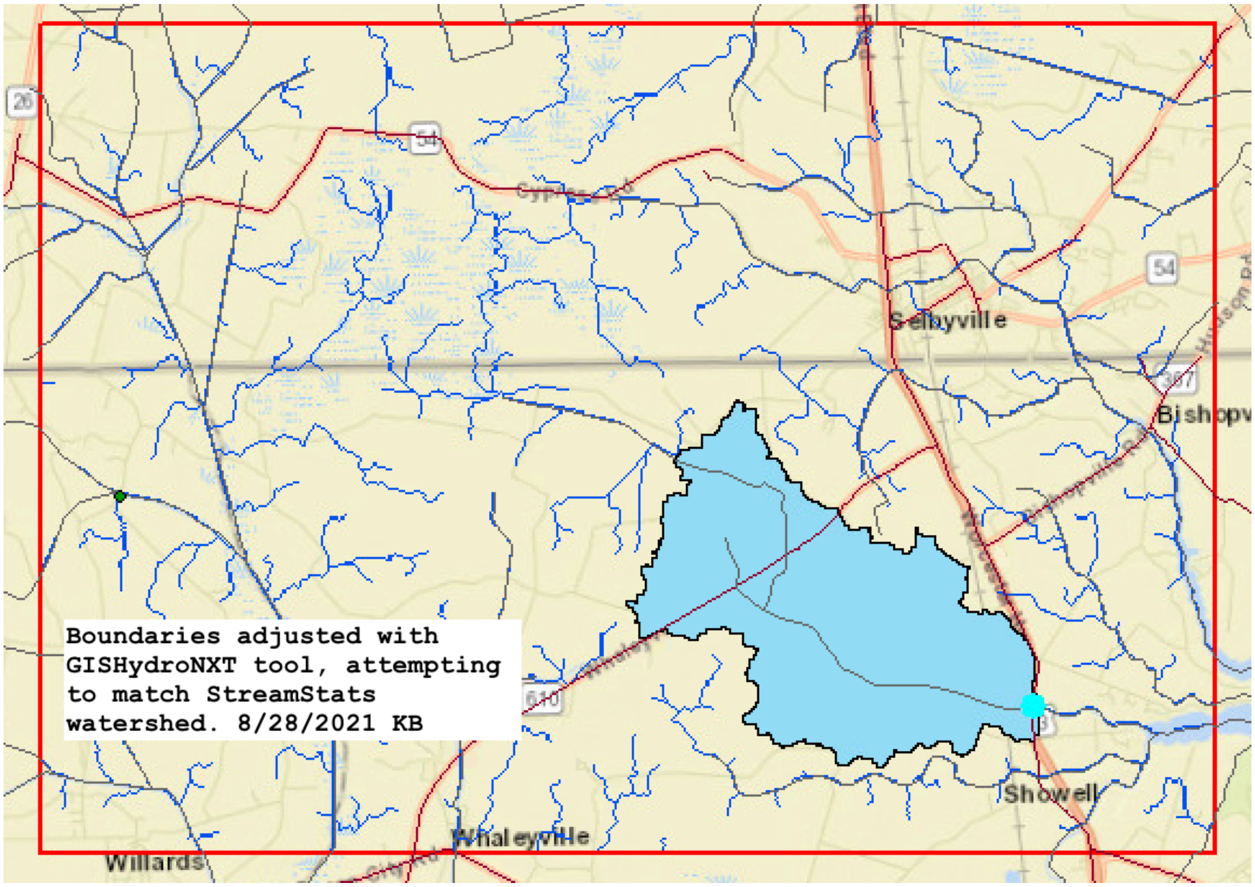
```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              556120 m (MD Stateplane, NAD 1983)
     Outlet Northing:             84016 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                5.25 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               7.91528944 feet/mile (0.00149911 feet/feet)
     Land Slope:                  0.00847407 feet/feet
     Urban Area (percent):        4.3
     Impervious Area (percent):   3.2

     Time of Concentration:       12.95 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       9.25 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           5.01 miles
     Basin Relief:                27.57 feet
     Average CN:                  74.7
     Forest Cover (percent):      41.4
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  28.3
        B Soils:                  10.7
        C Soils:                  21.0
        D Soils:                  40.0
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  28.3
        B Soils:                  10.7
        C Soils:                  21.0
        D Soils:                  40.0
     2-Year,24-hour Prec.:        3.43 inches
     Mean Annual Prec.:           45.63 inches
```

Watershed 148471320 Birch Branch at Showell, MD

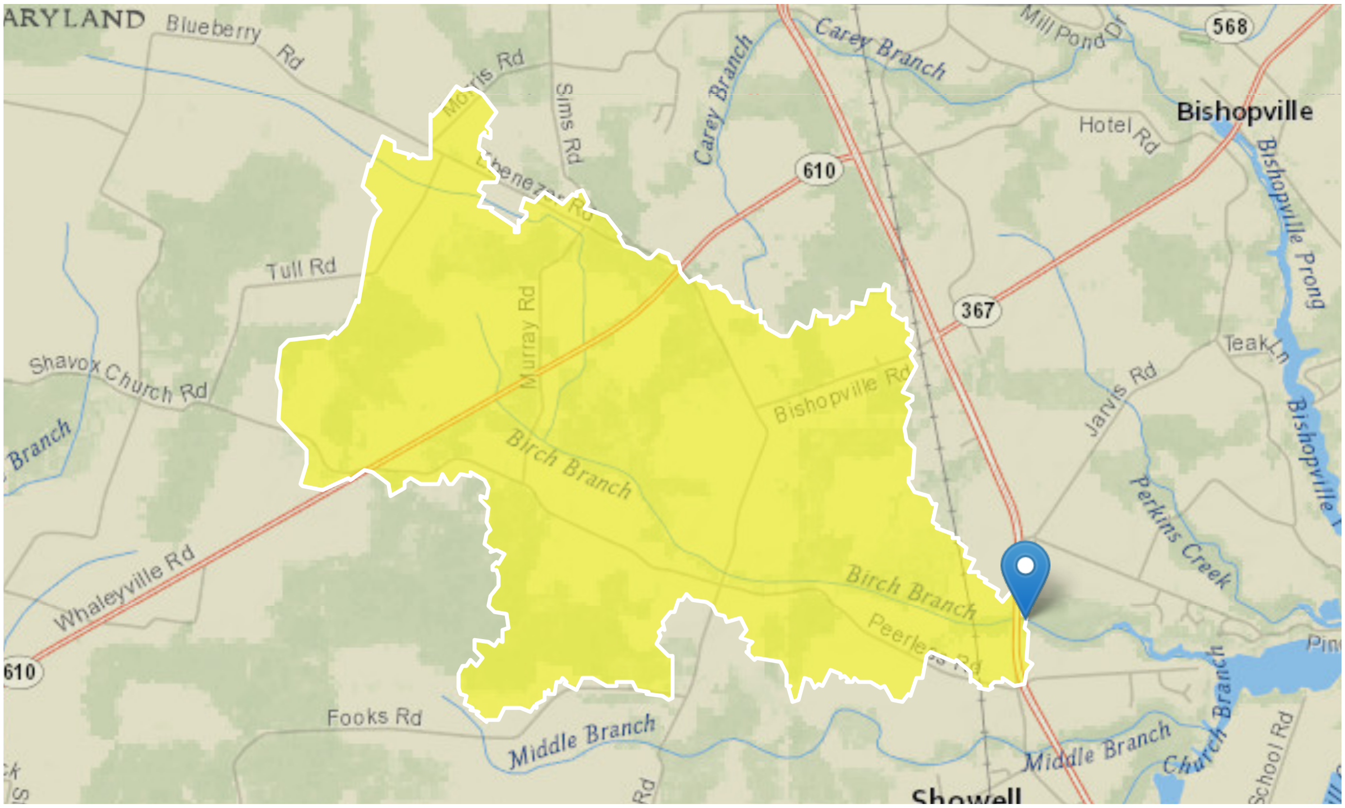
This watershed lies in the Eastern Coastal Plain on the Delmarva Peninsula. GISHydroNXT's watershed delineation in this location is unreliable due to the coarse (30-m pixel) representation of very flat terrain. GISHydroNXT's "Adjust Boundaries" tool was used to force the delineated watershed into agreement with that reported by USGS StreamStats (next page). The Basin Statistics reported on the previous page correspond to the watershed delineation shown here.



StreamStats enforces the boundaries in the Watershed Boundary Dataset included in the National Hydrography Dataset Plus (NHDPlus, https://pubs.er.usgs.gov/publication/ofr20191096).

StreamStats Report

Region ID: MD
Workspace ID: MD20210828174423117000
Clicked Point (Latitude, Longitude): 38.40938, -75.21206
Time: 2021-08-28 13:44:47 -0400



USGS 148471320 Birch Branch at Sowell MD, for reference in delineating watershed in GISHydroNXT.

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
ADJCOEFF	Coefficient to adjust estimates for percentage of carbonate rock in Western Maryland	0	dimensionless
BSLDEM10ff	Mean basin slope computed from 10 m DEM in feet per foot	0.00607	foot per foot
DRNAREA	Area that drains to a point on a stream	5.19	square miles
FOREST	Percentage of area covered by forest	40.4	percent

Parameter Code	Parameter Description	Value	Unit
FOREST_MD	Percent forest from Maryland 2010 land-use data	42.2	percent
IMPERV	Percentage of impervious area	3.33	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	6.14	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.79	percent
LIME	Percentage of area of limestone geology	0	percent
PRECIP	Mean Annual Precipitation	44.8	inches
SOILCorD	Percentage of area of Hydrologic Soil Type C or D from SSURGO	64.5	percent
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	12.2	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	8.7	percent
STATSGOD	Percentage of area of Hydrologic Soil Type D from STATSGO	7.43	percent

Application Version: 4.6.2

StreamStats Services Version: 1.2.22

NSS Services Version: 2.1.2

APPENDIX 3
BASIN STATISTICS FROM GISHYDRONXT

(Watersheds that are not included in Hydrology Panel Report 2020, Appendix 1)

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1486500
Analysis Date:                    August 01, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              525011 m (MD Stateplane, NAD 1983)
     Outlet Northing:             76995 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Eastern Coastal Plain
     Outlet State:                Maryland
     Drainage Area                11.18 square miles
       -Eastern Coastal Plain 100.00 percent of area

     Channel Slope:               6.35401010 feet/mile (0.00120341 feet/feet)
     Land Slope:                  0.01286013 feet/feet
     Urban Area (percent):        25.7
     Impervious Area (percent):   16.2

                ******************************************************
                    IMPERVIOUS AREA IN WATERSHED EXCEEDS 10%.
                    Calculated discharges from Fixed Region
                    Regression Equations may not be appropriate.
                ******************************************************

     Time of Concentration:       14.96 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       10.65 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           6.23 miles
     Basin Relief:                25.31 feet
     Average CN:                  68.4
     Forest Cover (percent):      35.4
     Storage (percent):           1.4
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  50.0
        B Soils:                  0.5
        C Soils:                  4.9
        D Soils:                  43.2
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  50.0
        B Soils:                  0.5
        C Soils:                  4.9
        D Soils:                  43.2
     2-Year,24-hour Prec.:        3.46 inches
     Mean Annual Prec.:           46.08 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1581757
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              459683 m (MD Stateplane, NAD 1983)
     Outlet Northing:             197033 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Western Coastal Plain
     Outlet State:                Maryland
     Drainage Area                55.85 square miles
       -Piedmont 95.08 percent of area
       -Western Coastal Plain 4.92 percent of area

     Channel Slope:               27.27076896 feet/mile (0.00516492 feet/feet)
     Land Slope:                  0.08477213 feet/feet
     Urban Area (percent):        40.2
     Impervious Area (percent):   17.8

                ******************************************************
                    Watershed is within 5km of physiographic
                    province boundary.  You should consider
                    sensitivity of discharges to region location.
                ******************************************************

     Time of Concentration:       8.97 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       11.87 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           25.87 miles
     Basin Relief:                382.91 feet
     Average CN:                  71.6
     Forest Cover (percent):      27.0
     Storage (percent):           0.2
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  1.7
        B Soils:                  67.9
        C Soils:                  18.5
        D Soils:                  11.7
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  1.7
        B Soils:                  67.9
        C Soils:                  18.5
        D Soils:                  11.7
     2-Year,24-hour Prec.:        3.30 inches
     Mean Annual Prec.:           47.99 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     My Project
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           NLCD 2011
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              381046 m (MD Stateplane, NAD 1983)
     Outlet Northing:             221379 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Blue Ridge and Great Valley
     Outlet State:                Maryland
     Drainage Area                31.37 square miles
       -Piedmont 21.52 percent of area
       -Blue Ridge and Great Valley 78.48 percent of area

     Channel Slope:               17.80400682 feet/mile (0.00337197 feet/feet)
     Land Slope:                  0.04839904 feet/feet
     Urban Area (percent):        5.5
     Impervious Area (percent):   2.5

                ******************************************************
                    Watershed is within 5km of physiographic
                    province boundary.  You should consider
                    sensitivity of discharges to region location.
                ******************************************************

                ******************************************************
                    Watershed is within 1km of underlying limestone
                    geology.  You should consider sensitivity
                    of discharges to percent limestone calculated.
                ******************************************************

     Time of Concentration:       9.56 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       9.98 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           16.76 miles
     Basin Relief:                180.71 feet
     Average CN:                  75.4
     Forest Cover (percent):      15.1
     Storage (percent):           1.9
     Limestone (percent):         2.5
     Selected Soils Data Statistics Percent:
        A Soils:                  0.5
        B Soils:                  48.3
        C Soils:                  23.0
        D Soils:                  27.9
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.5
        B Soils:                  48.3
        C Soils:                  23.0
        D Soils:                  27.9
     2-Year,24-hour Prec.:        3.01 inches
     Mean Annual Prec.:           42.73 inches
```

```
GISHydro Release Version Date:    February, 2021
Project Name:                     KB1644372
Analysis Date:                    August 28, 2021
Data Selected:
     DEM Coverage:                NED DEM 201805
     Land Use Coverage:           2010 MOP
     Soil Coverage:               SSURGO 201805
     Hydrologic Condition:        Good
     Impose NHD stream Locations: Yes
     Outlet Easting:              378438 m (MD Stateplane, NAD 1983)
     Outlet Northing:             172752 m (MD Stateplane, NAD 1983)
Findings:
     Outlet Location:             Piedmont
     Outlet State:                Maryland
     Drainage Area                0.34 square miles
       -Piedmont 100.00 percent of area

     Channel Slope:               112.77474476 feet/mile (0.02135885 feet/feet)
     Land Slope:                  0.06069387 feet/feet
     Urban Area (percent):        6.1
     Impervious Area (percent):   1.6

     Time of Concentration:       1.74 hours [W.O. Thomas, Jr. Equation]
     Time of Concentration:       0.99 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:           1.26 miles
     Basin Relief:                81.09 feet
     Average CN:                  79.6
     Forest Cover (percent):      28.8
     Storage (percent):           0.0
     Limestone (percent):         0.0
     Selected Soils Data Statistics Percent:
        A Soils:                  0.0
        B Soils:                  17.1
        C Soils:                  74.4
        D Soils:                  8.5
     SSURGO Soils Data Statistics Percent (used in Regression Equations):
        A Soils:                  0.0
        B Soils:                  17.1
        C Soils:                  74.4
        D Soils:                  8.5
     2-Year,24-hour Prec.:        3.09 inches
     Mean Annual Prec.:           42.66 inches
```