Meteorological Cause & Characteristics of Widespread Heavy Daily Precipitation events in the Texas-Gulf Water Resource Area 2003-18

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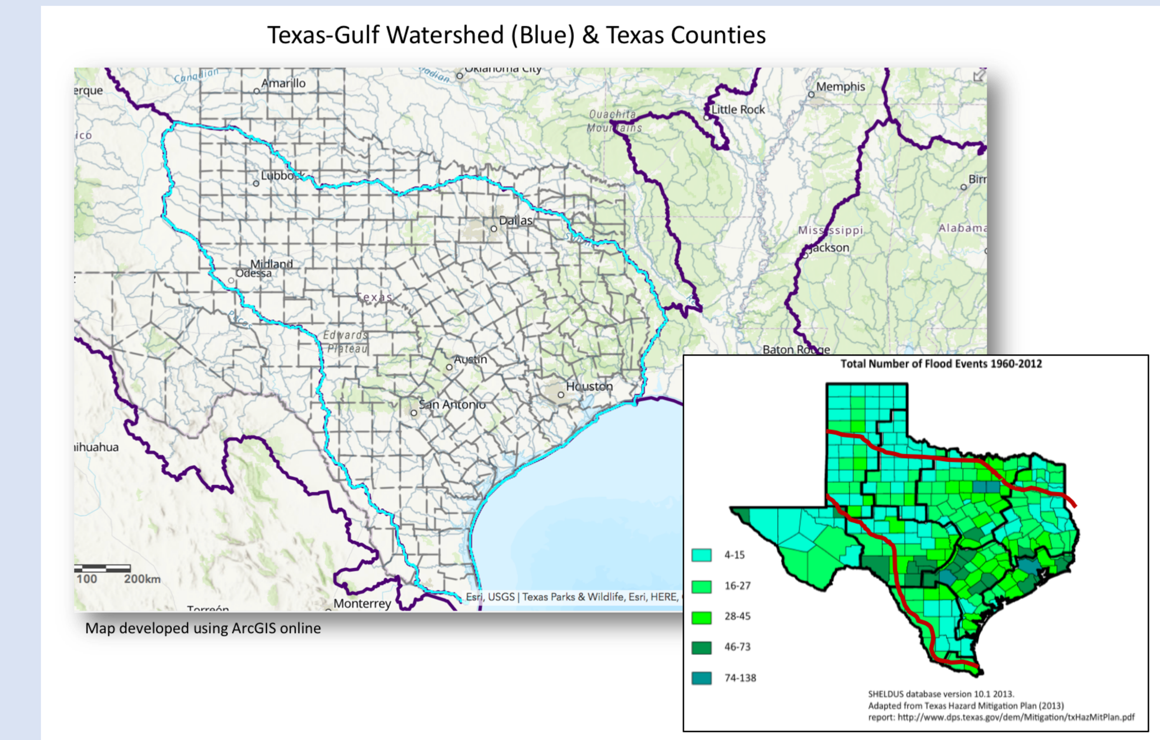
Key Message

The Texas Gulf Water Resource Area (WRA, Figure right) contains 11 key watersheds that supply a large proportion of water to the state. The region is also climatically diverse, and is experiencing continued population growth in its urban corridors. *Over the past few years, large flood events have highlighted the region's vulnerability to extreme precipitation*, with floods being a relatively frequent occurrence in and around highly populated areas (inset figure, right). *Here, we examine the character and cause of heavy precipitation in the recent past, focusing on spatially-widespread and heavy precipitation (WHP) days.* These are defined as the top 10% of all days based both on spatial areal coverage, and total accumulated precipitation >95th percentile, with the definition being seasonally-relative. *We find that these days contribute 20-80% of the seasonal accumulation across the WRA, and are most frequent in the summer, followed by the fall.* WHP events are statistically distinct from more localized heavy precipitation days - having longer duration and higher mean and maximum rain-rates. To examine these events further, we follow work by Kunkel et al. (2012) and Dowdy and Catto (2017) and identify their meteorological cause based on robust subjective techniques, focusing on combined causes, and examining how these causes vary seasonally and inter-annually. *The vast majority of WHP days show convective activity, and in all but the summer, fronts and/or extratropical cyclones along with convection were dominant causes.* Fall and summer showed the most diversity of cause, and winter the least. Throughout, there has been notable variability in the weather events that produced widespread heavy precipitation, with the pluvial period 2015-18 showing almost twice as many incidences of the front/convection combination compared to the earlier period (2003-10)

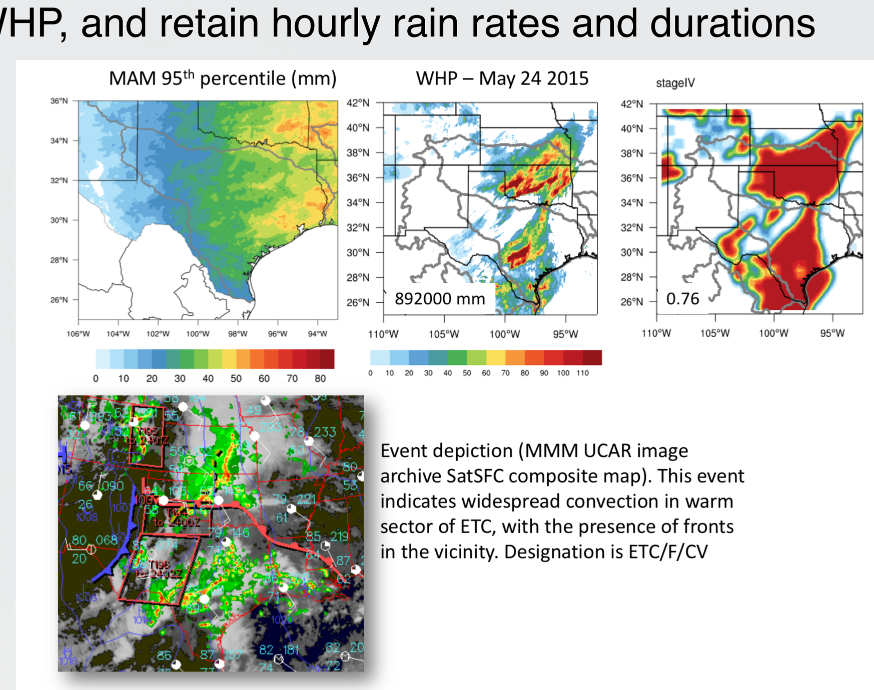


1. Defining WHP Days & their cause

We evaluate the spatial extent of precipitation at or above the 95th percentile, with the baseline climatology calculated for each season (DJF, MAM, JJA, SON) using years 2003-18 from *Stage IV 4-km gridded data (Lin 2011).* For this analysis we focus primarily on 24-hr accumulations (end 12 UTC) to derive WHP, and retain hourly rain rates and durations for additional analysis.

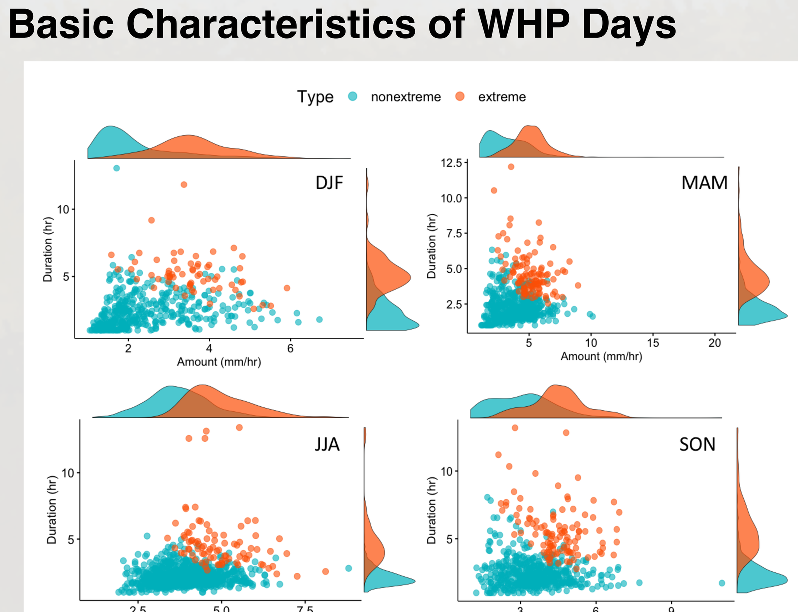
WHP = top 10% of days in record in terms of areal coverage and total WRA accumulations.

Figure 1 (right): Depicts the spring 95th percentile daily accumulation (mm), an example of a WHP event in terms of accumulations (center) and areal extent (right). The bottom panel shows the surface satellite depiction of the event in question from the *NCAR/UCAR image archive.*



Meteorological cause was designated based on visual analysis of the weather type during the period of peak precipitation using weather maps. This analysis was performed three times over a period of several months by the author, without consulting the previous iteration. Discrepancies were resolved with an additional check of the relevant dates. Subjective methods do suffer from increased potential for human error, in addition to being very time-consuming. Future work intends to employ automated techniques for identification of major weather types such as fronts and cyclones.

Basic Characteristics of WHP Days



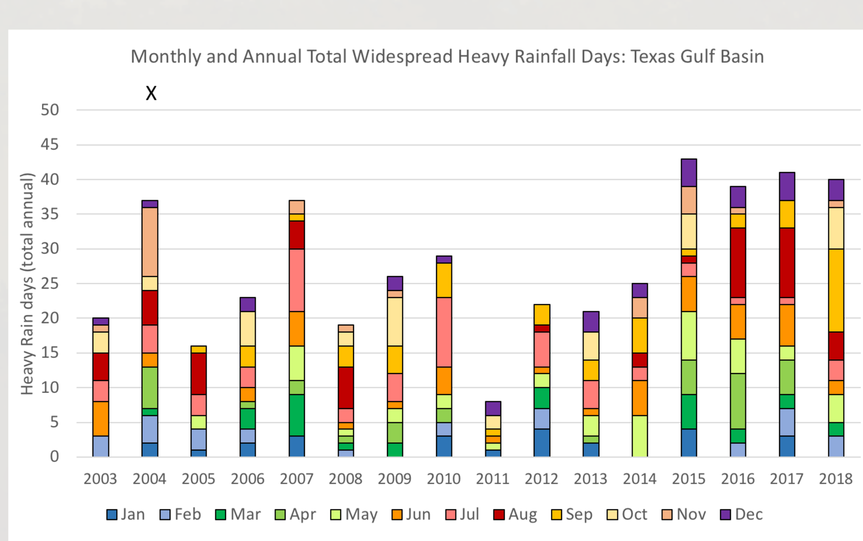


Figure 2 Left shows scatterplots and distributions of the WRA average rain-rates and durations at any given point in the region between WHP days (red), and days falling below this threshold (blue). *WHP days show statistical-significance in both increased duration and rain rate, more so for the former* (Students 2-tailed T-test and bootstrapped CI, 500 replications). **Figure 3 (right)** shows the interannual monthly breakdown of WHP frequencies. The past four years show consistently higher frequencies of WHP days compared with the prior 11 years. *Wet years show higher frequencies of WHP, particularly in spring-early fall, while low years show the opposite. The top WHP months include July, August, September and May, and the low months November, January and December.*

2. A seasonal & temporal cause-climatology of WHP Days

Figure 4: Seasonal cause climatologies for frequency (sub-panel top) and contribution to seasonal total accumulations (sub-panel bottom) for winter (top left), summer (top right), spring (bottom left) and fall (bottom right). The pie-charts in each case depict the average breakdown by cause. Fall showed the greatest diversity in the meteorological causes, and winter the least. *In winter, 88% of all WHP days were associated with either a mid-latitude storm (ETC) accompanied by fronts and convection, or weather fronts and convection. In the summer, this dropped to 42%, with a much larger contribution of MCS and/or widespread airmass convection in the absence of fronts.* The transition seasons showed the front/convection combination being most frequent. *Winter WHP days showed the largest fractional contribution to total seasonal precipitation, and summer events the least.* This reflects the fact that summer (winter) events were typically the least (most) aerially extensive. *Tropical cyclones tended to produce a greater fractional precipitation contribution relative to their frequency, highlighting their propensity for abundant precipitation.* The past four years have showed a larger contribution of fronts/convection versus the prior years, roughly twice as many during 2011-18 (mostly 2015-18) compared with 2003-10, mostly during spring and fall. By contrast, the next wettest year of 2007 was heavily contributed to by summer widespread convection and persistent upper-level lows (designated as ETC/low/convection).

These results highlight the intrinsic variability of weather, as well as the potential modulating role of climate variability. A caveat of using daily WHP is noted is that multiple consecutive WHP days can occur with the same parent weather system - between 20-40% of days fit into this category. Therefore, ongoing work is switching to examine WHP by individual events rather than days, an example of which is shown next.

3. Event-relative assessment: Example for Winter

Figure 5 (right) shows statistics of duration and accumulation for the two dominant WHP causes – now defined by the passage of weather systems across the WRA, as oppose to calendar days. Drawn out by using this definition is the *propensity for front/convection to be of longer duration (often the result of stagnant fronts). ETC/front/convection typically has similar-to-higher rain-rates and total accumulation when all events are considered*, though the significance of this result has not yet been tested.

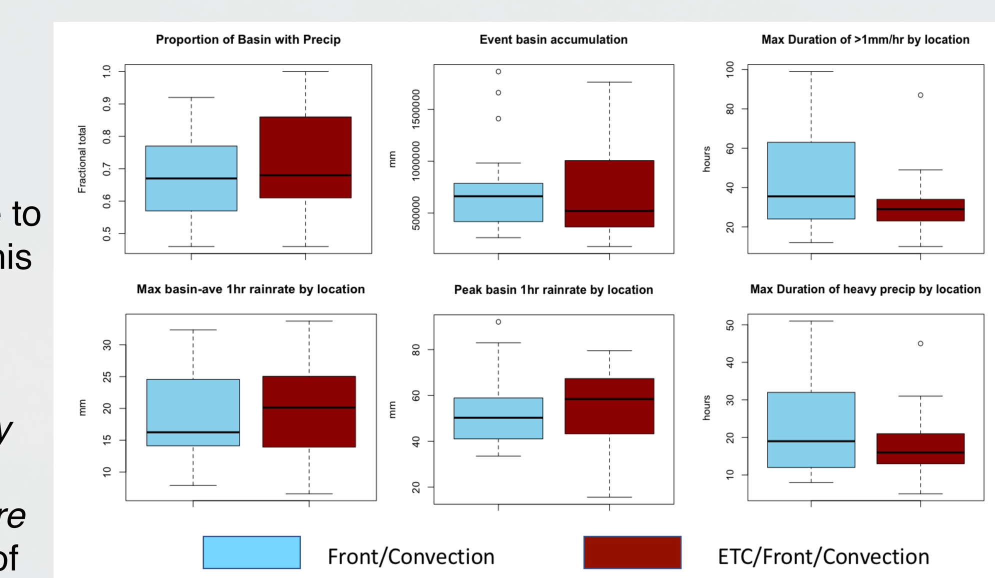
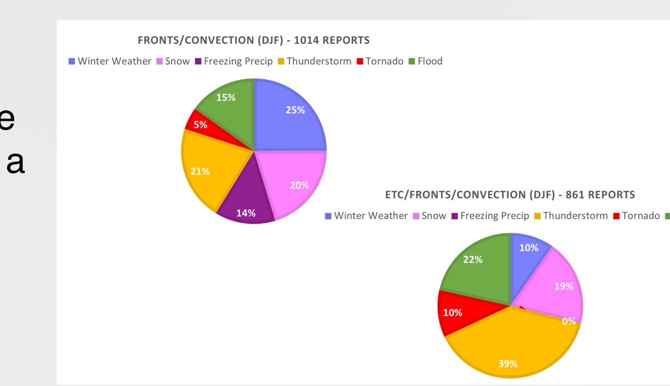


Figure 6 (right) uses the Storm Data database to examine associated hazardous weather reports with the above causes. Fronts/convection were associated with a wider variety of associated winter weather hazards. ETC/front/convection showed lower incidence of winter weather, and a greater frequency of thunderstorm and tornado reports. *Flood reports were respectively the fourth and second most frequent hazard reported.*



4. Future work

This work is the preliminary foray into more temporally and spatially extensive (yet still regional) weather-systems analysis of heavy precipitation. There is a general dearth of literature in this area, perhaps associated with the complexities of assignments of meteorological cause at climate-length scales, with much left to explore. Two focus areas to investigate include:

- *Climate-change impacts on the thermodynamics and evolution of heavy precipitation, delineated by meteorological cause.* We intend to use a high resolution pseudo-global warming experiment to examine precipitation intensity and spatial coverage changes associated with different causes and in different seasons.
- *Focus more specifically on weather fronts, and their regional variability & precipitation potential across different modes of climate variability*.

5. References

Data & Imagery:

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