

# Climate Change Recommendations for Regional Flood Planning

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April 16, 2021

OSC Report 2021-01

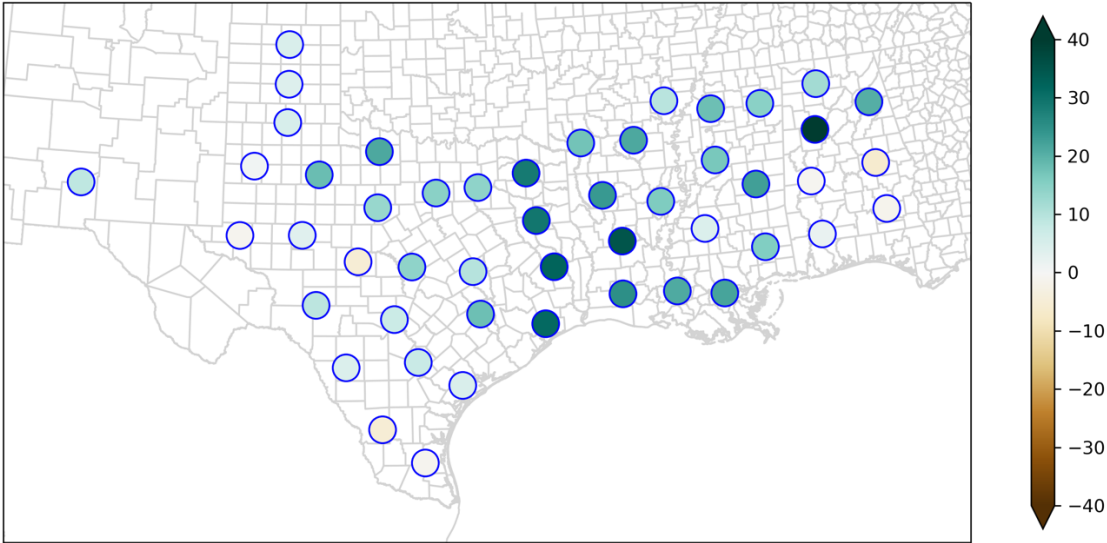
Regional Flood Planning Groups may wish to take into account potential effects of climate change on extreme rainfall and flood frequency and magnitude. Climate change may lead to substantial increases in flood vulnerability over and above increases due to greater population (Swain et al. 2020). To facilitate consistency across planning regions, specific climate change scenarios are suggested here.

Increases in extreme precipitation in middle and higher latitudes consistently emerge as a likely consequence of climate change. Evidence in support of such an increase is found in observed trends, in climate model simulations and projections, and in the basic thermodynamic principles of precipitation rate dependence on temperature, and all three lines of evidence can be used to estimate future precipitation extremes (Wasko et al. 2021).

Local trends of extreme precipitation can be noisy, due to the quasi-random nature of extreme events and the relatively short period of record. To maximize the ability to identify climate-driven trends in extreme rainfall in Texas, Nielsen-Gammon (2020) used two approaches: creating extended station data from NOAA Atlas 14 annual precipitation maxima using bias-minimizing hot deck resampling, and creating composite individual county precipitation maxima time series and pooling the results across multi-county regions. Nonstationary generalized extreme value distributions were then fit to the time series, using carbon dioxide concentration as a covariate. See Nielsen-Gammon (2020) for further technical details.

That analysis is extended here to include the remainder of Texas. The county composite analysis, modified to use simulated global mean surface temperature as a covariate, finds a positive trend in estimated 1-day 100-year rainfall amounts from 1960 to 2020 of about 15% in central and eastern parts of Texas and 6% in western Texas (Fig. NGJ1). The extended analysis of NOAA Atlas 14 data that station-specific trends are mostly positive, especially in central and eastern Texas (Fig. NGJ2). These trends are consistent with trends found in other studies (such as Wright et al. 2019 and Van Oldenborgh et al. 2017 & 2018). Note that these trends imply that the stationary NOAA Atlas 14 values underestimate present-day return values and will further underestimate future return values, although recent events such as Hurricane Harvey may have led to a temporary overestimate of return values in southeast Texas (Nielsen-Gammon 2020).

The trends are similar to or greater than what would be expected from thermodynamic considerations alone, with a warmer atmosphere containing more water vapor when at 100% relative humidity. Intense rainfall can also be affected by climate change through changes in storm frequency or storm intensity, but the direct effect of temperature seems to dominate across the United States (Pfahl et al. 2017). Models confirm the direct thermodynamic effect on extreme precipitation (Allan et al. 2014).

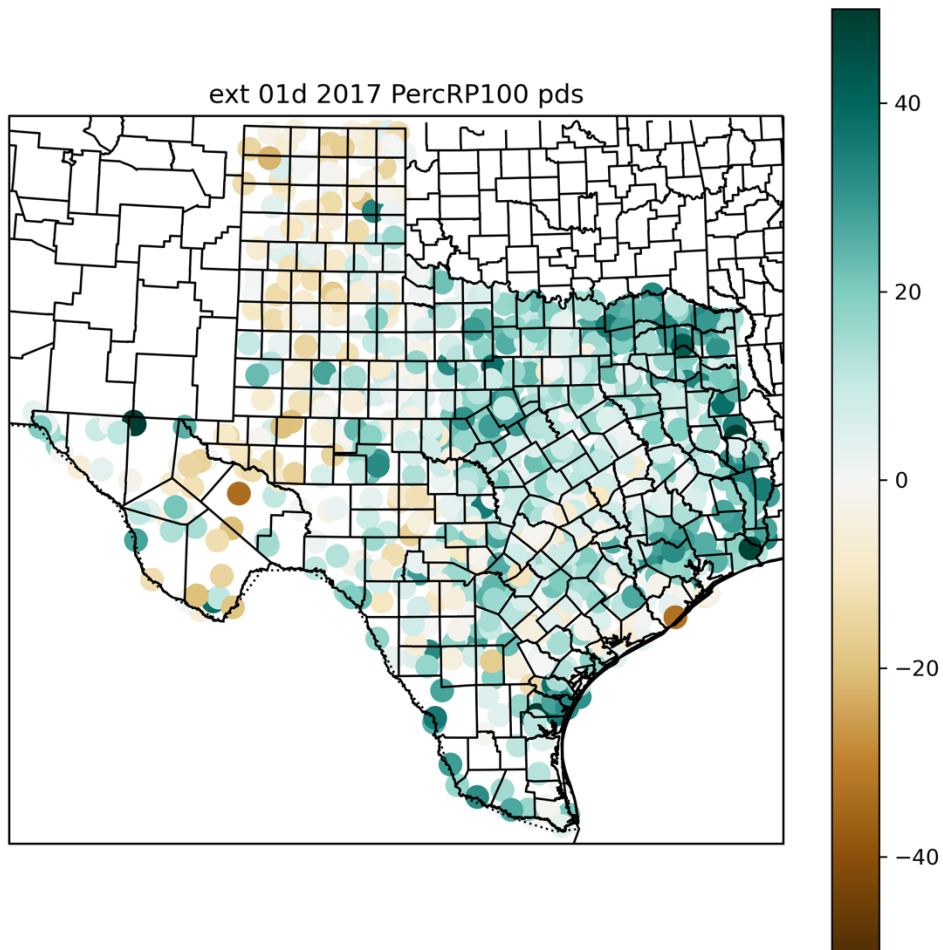


*Figure NGS1: Magnitude of climate-correlated trends in 100-year return values of 1-day precipitation amounts, based on nonstationary analysis of sets of composite station records. Trends are expressed as percentage difference between return values in 1960 and 2020, with positive changes indicating an increase in return values. Most trends are positive. The variations in trend from location to location are interpreted as random rather than representing reliable differences in the impacts of climate change. Note: The New Mexico region includes the three southernmost counties along the Rio Grande and El Paso County in Texas. No composite station analysis is performed for the rest of the Trans Pecos because of large spatial variations in return values among nearby stations.*

Climate models consistently simulate increases in extreme rainfall over the United States due to climate change, and consistently show larger fractional increases at longer return periods (Swain et al. 2020). When downscaled to local daily precipitation extremes, the model ensembles indicate large uncertainty in the magnitude of the change, though, implying sensitivity to the statistical assumptions used in downscaling (Lopez-Cantu et al. 2020).

Nielsen-Gammon (2020) argued that variations in trends across different regions of the southern United States are not robust, and that trends from many regions needed to be combined to obtain a reliable estimate of historic changes in extreme rainfall distributions. Downscaled spatial patterns of extreme rainfall trends are patchy, with spatial details not robust across different models or different downscaling techniques. This further supports the

idea of relying on large-scale average trend magnitudes for both historical trends and future projections.



*Figure NGS2: Magnitude of climate-correlated trends in 100-year return values of 1-day precipitation amounts, based on nonstationary analysis of extended data records used in NOAA Atlas 14. Trends are expressed as percentage difference between return values in 1960 and 2020, with positive changes indicating an increase in return values. Most trends are positive. The variations in trend from location to location are interpreted as random rather than representing reliable differences in the impacts of climate change*

Based on the above considerations, a relationship of a 7% increase in extreme rainfall amounts per Kelvin global temperature increase is suggested as a basic projection. Since present-day global temperatures are 0.5-1 K warmer than they were over most of the historical NOAA Atlas 14 analysis period, extreme rainfall return values should already be 5% above NOAA Atlas 14 values in most of the state. An additional 1 K of warming is generally anticipated by 2050-2060 according to moderate climate mitigation scenarios, which would correspond to a total increase

over NOAA Atlas 14 of 12%. Thus, in a basic climate change scenario, a present-day enhancement of 5% and a mid-21st century enhancement of 12% would be appropriate.

However, observed trends are greater than 7%/K across most of the Gulf Coast region and in most of Texas. A trend of 12%/K is regionally representative. This would correspond to a present-day enhancement of 8% and a mid-21st century enhancement of 20% in an extrapolation climate change scenario.

To be useful for flood planning, the rainfall changes must be translated into flood risk changes. In urban areas with high impervious cover and small catchments, the increased intense rain should translate directly into increased runoff. There, proportional increases in discharge can be assumed, and in the absence of special hydrologic simulations, increased flood levels can be inferred from extrapolation/interpolation of existing flooding simulations using relationships between flood elevation and flow volumes.

In larger, more rural catchments, the situation is more complicated. Despite the unanimity among models for an increase of intense precipitation, models project flooding outcomes for Texas ranging from increased river floods to decreased peak streamflows (Swain et al. 2020; Asadieh and Krakauer 2017; Do et al. 2020). The dichotomy between extreme rainfall and river basin flooding is due in part to decreases in soil moisture (Nielsen-Gammon et al. 2020), which lead to greater amounts of rainfall required for runoff over initially dry soils. Swain et al. (2020) based their flooding analysis on rainfall changes alone while the other studies were based on coupled model simulations of runoff. If decreased soil moisture does indeed lead to a larger rainfall threshold for flooding, minor floods may become less likely while major floods may become more likely.

On balance, future river flooding projections are the least constrained aspect of future rain and flood hazards. In the face of such uncertainty, it may be inappropriate to assume that river floods will not change at all. Suggested scenarios include both increases and decreases and involve a larger range of possibilities than extreme rainfall to reflect the larger uncertainty.

In summary, the reference scenarios in the following table are suggested for planning groups considering the implication of climate change on future flooding risk. The percentages in the table represent increases over the published NOAA Atlas 14 25-year to 500-year precipitation values.

Scenario	2021		2050-2060	
	Urban	River	Urban	River
Low	5%	-2%	12%	-5%
High	12%	5%	20%	10%

The listed scenarios assume that NOAA Atlas 14 accurately estimates the risk of extreme rainfall under the assumption of stationarity. Additional adjustments may be applied if NOAA Atlas 14 return values are found to be unreliable.

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