# Changes in spatio-temporal characteristics of precipitation intensities in Arizona: what we have observed during the last sixty years?

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**13th RISE Symposium**

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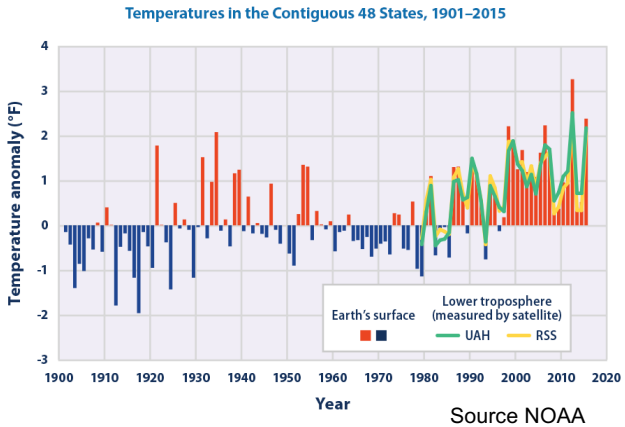
Source: https://commons.wikimedia.org/wiki/File:Prairie_San_Pedro_Valley_Near_Tombstone_Arizona_2015-04-27.JPG

# The increase in extreme rainfall has significant impacts on society and biophysical systems

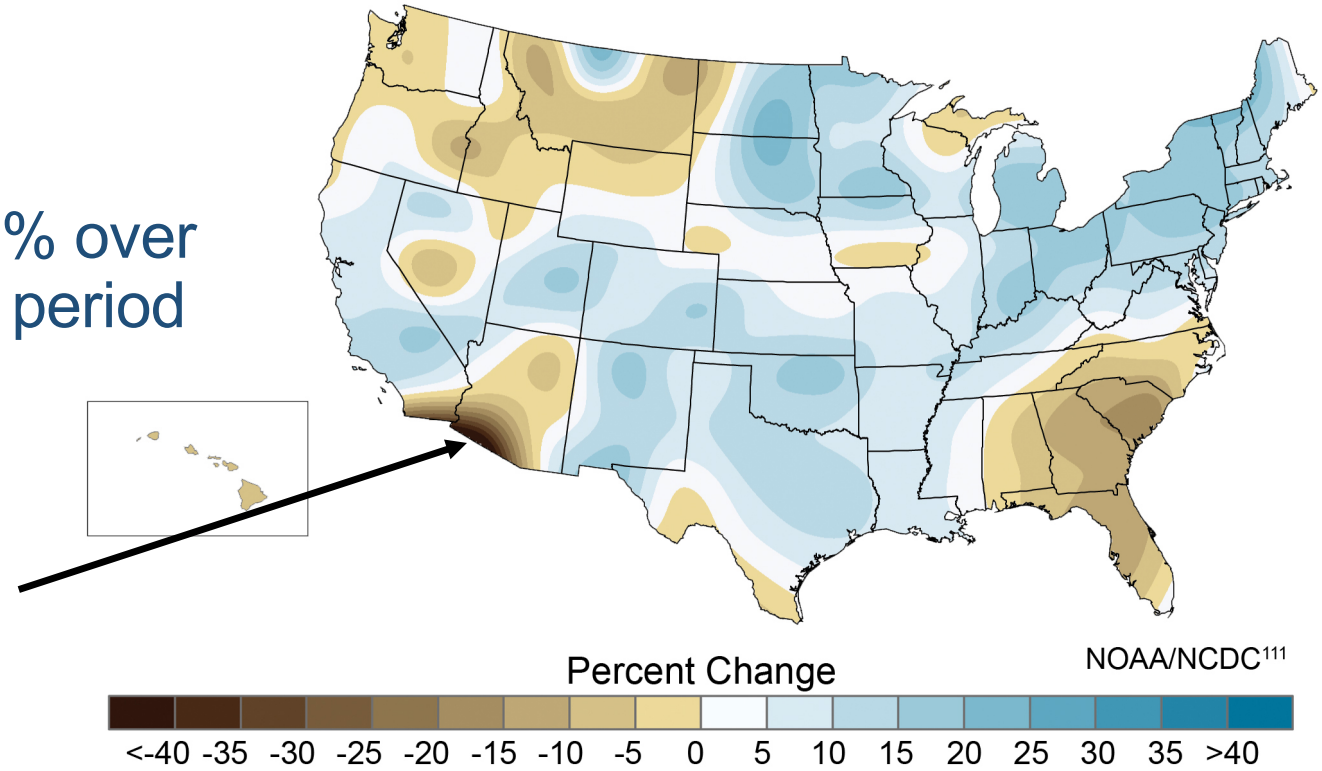
Do we need to update the storms used for structural design?




Source NOAA

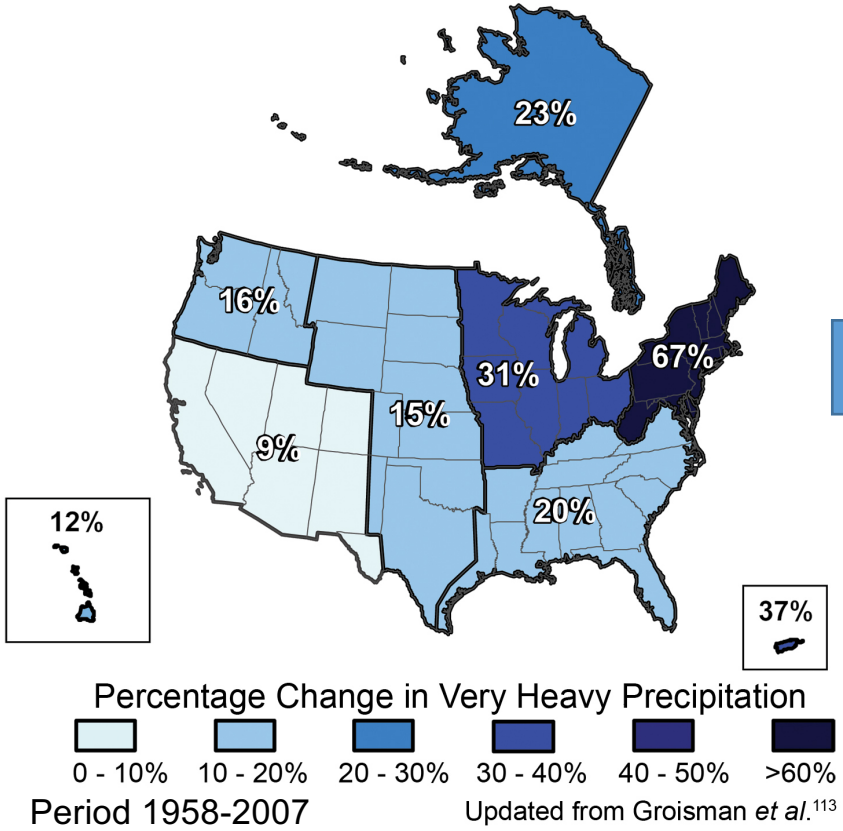
# Important regional differences in annual average precipitation

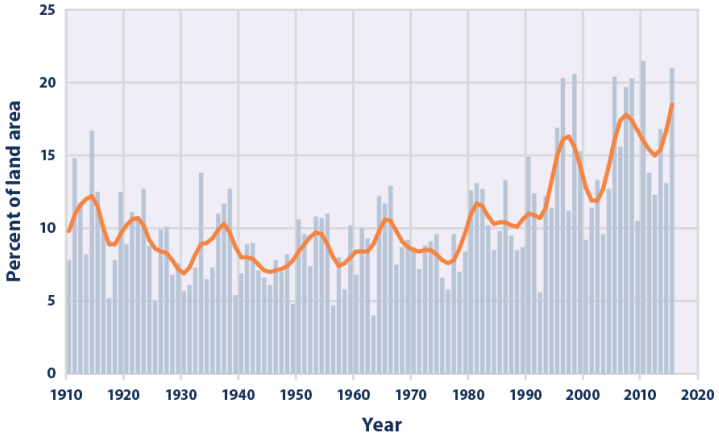
Increased by 5% over the 1958-2008 period




Source: Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

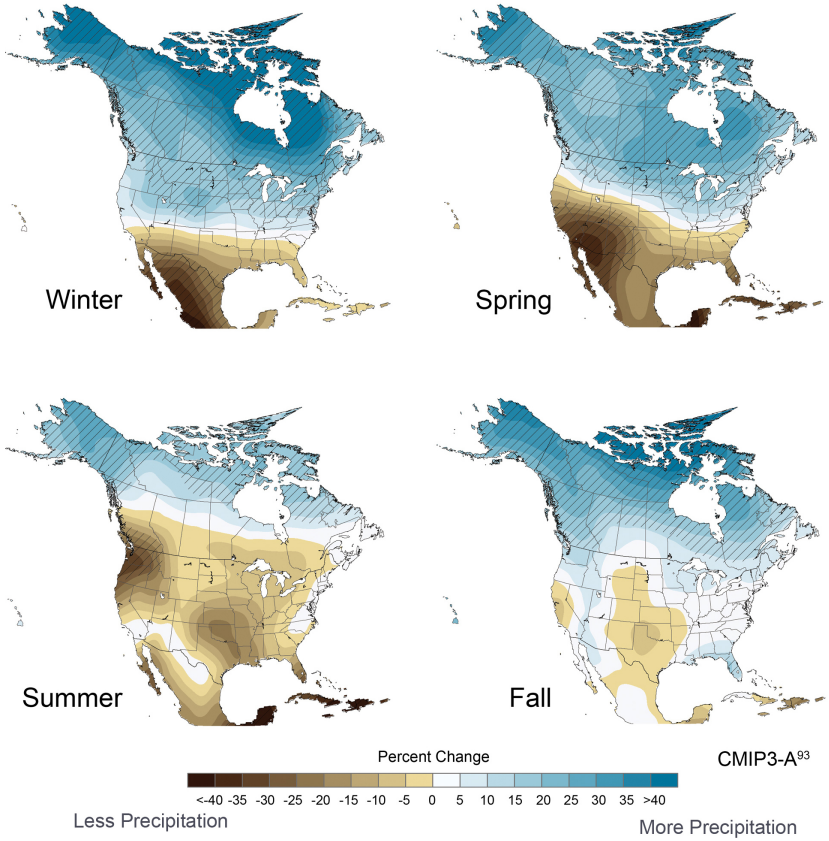
# Very heavy daily precipitation (top 1%) also increased

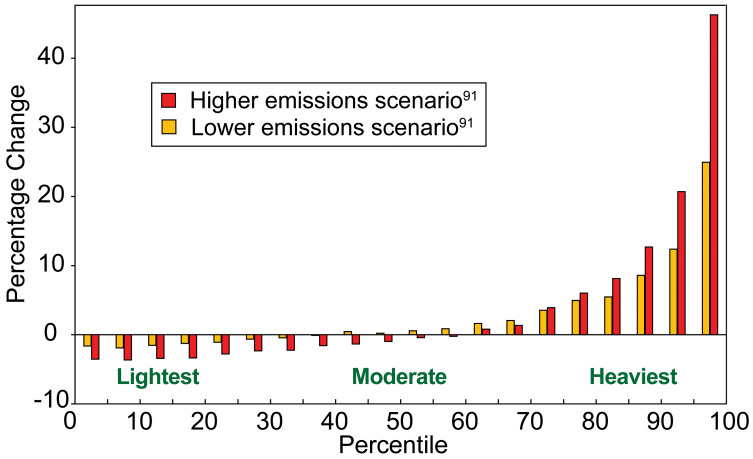



Extreme One-Day Precipitation Events in the USA 1910-2015 (NOAA)

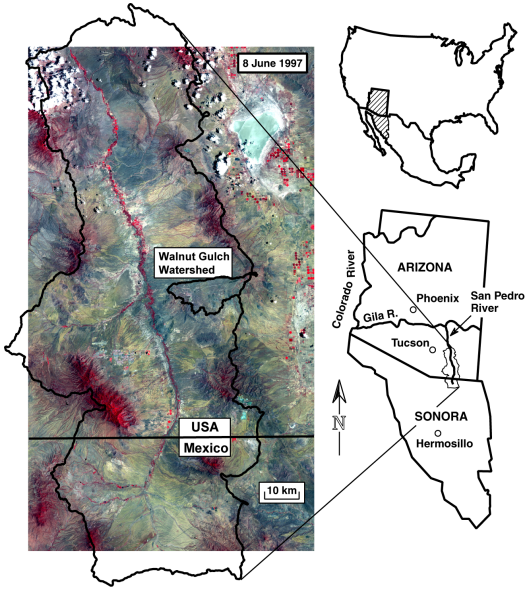
# The West likely to become drier by the end of the 21st C



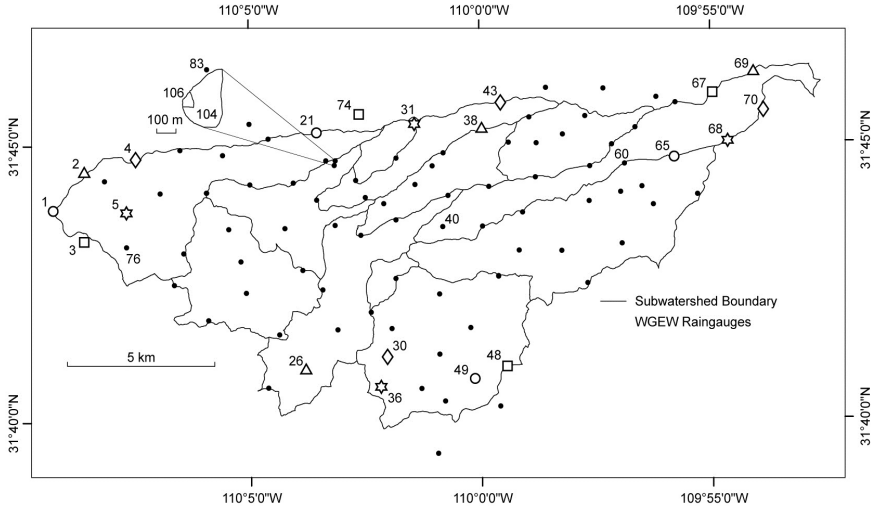




*However, climate model projections shown increases in heavy precipitation*

# Have we observed spatial-temporal changes in summer convective storms?




Courtesy David Goodrich




- Located in southeastern Arizona
- Area 150 km$^2$
- ~ 1 rain gauge/0.5 km$^2$

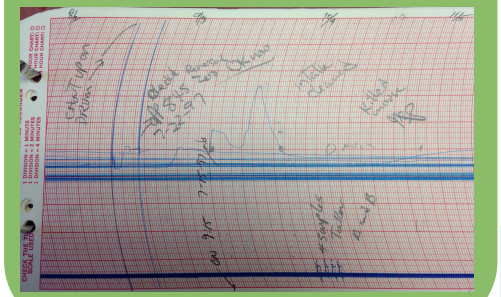
# Sub-daily precipitation has been **professionally** measured in WGEW since the late '50s

Belfort weighing rain gauge

< year 2000

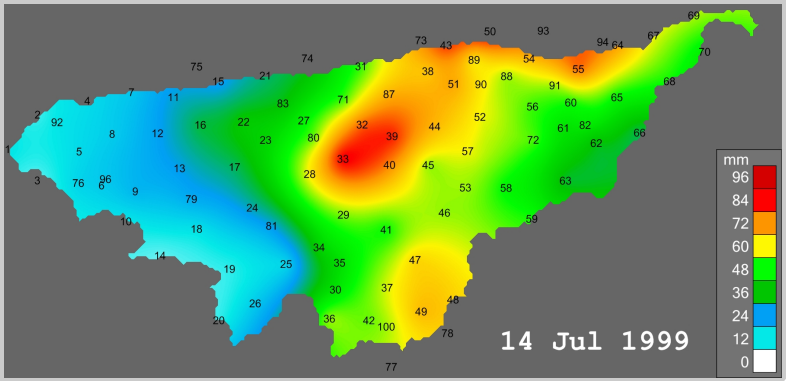
2000 - on

Analog Paper Charts

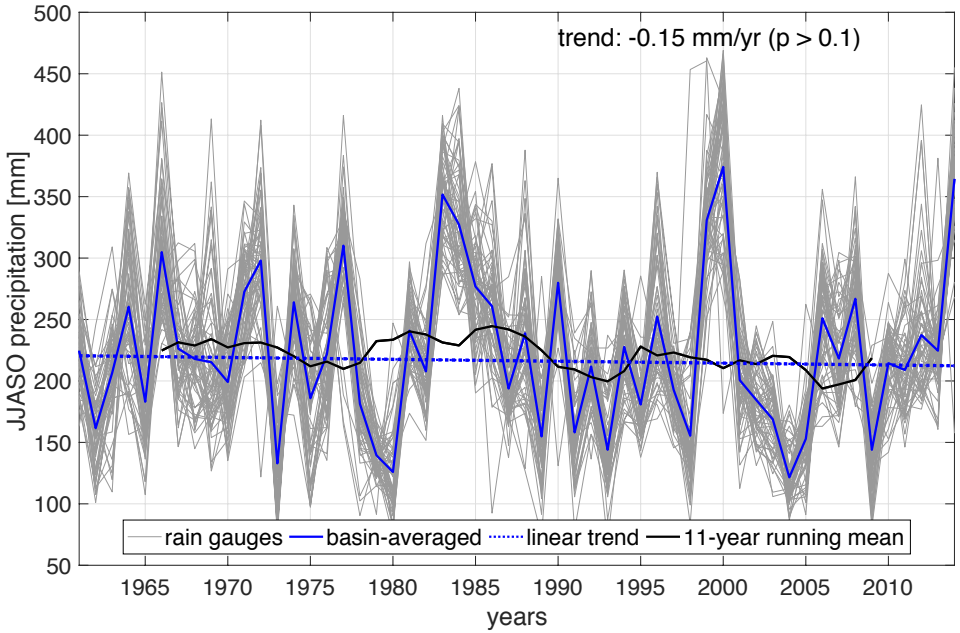


Digital electronic system

Spatial and temporal representation of storms



# Natural variability masking temporal trends in warm season precipitation in WG during the last 60 years



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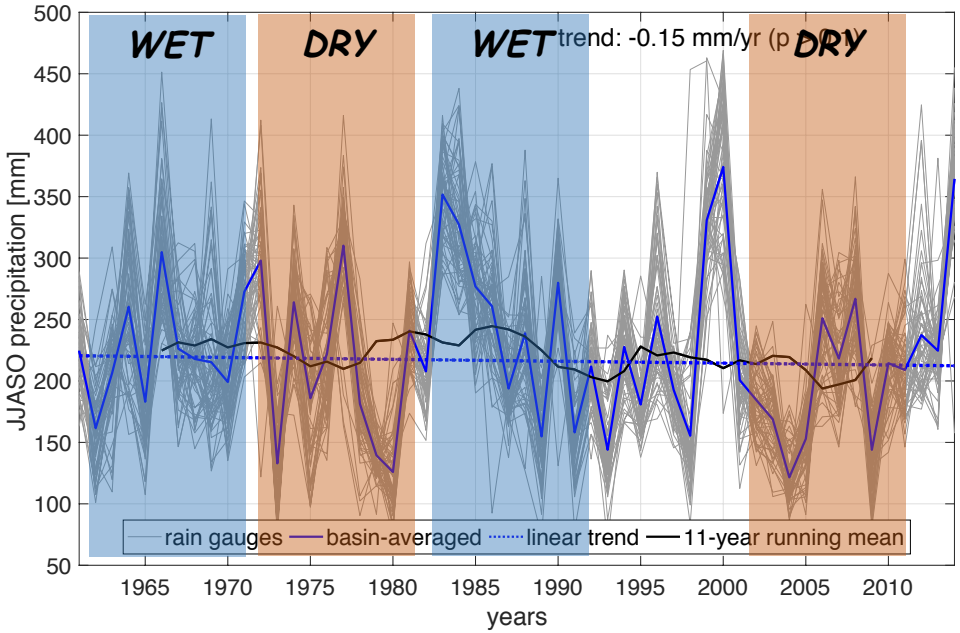

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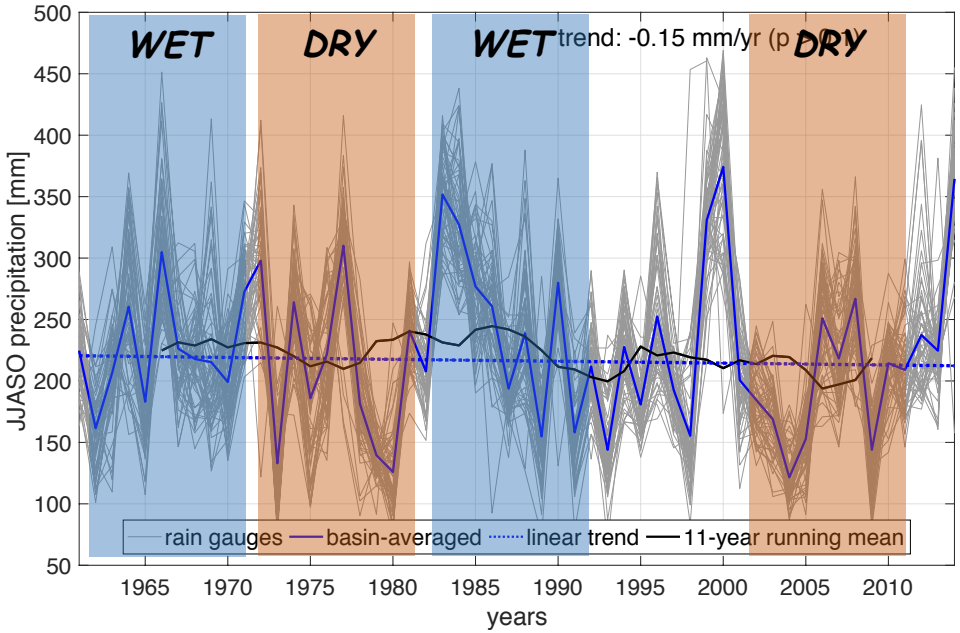
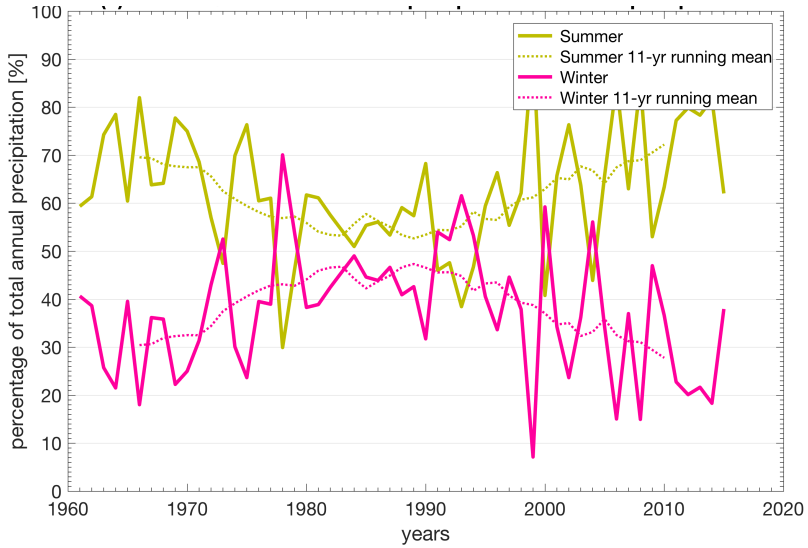
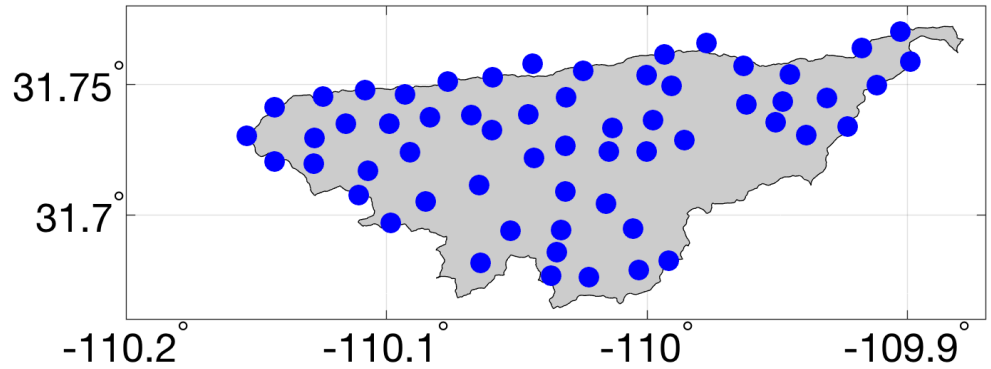



- Wet winter conditions in 1980-90s
- El Nino events

- Warm season (JJASO) convective rainfall
- Maximum rainfall intensities for 5 to 1440-min durations
- Linear trends analysis (Mann-Kendall)
- Fit probability distributions



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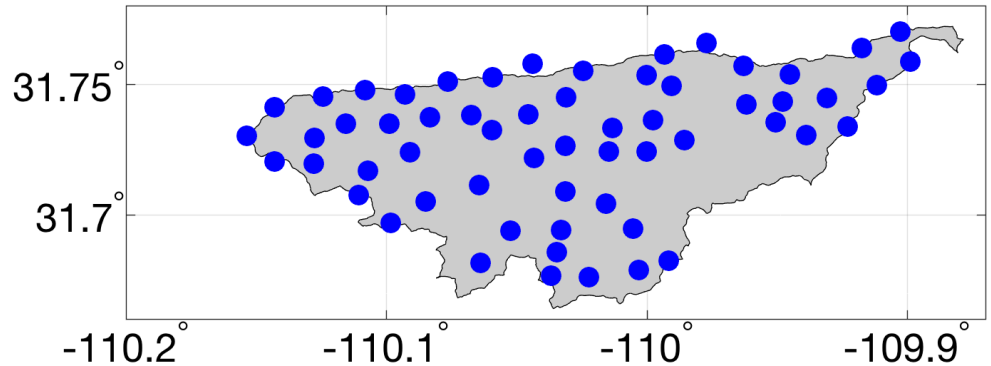
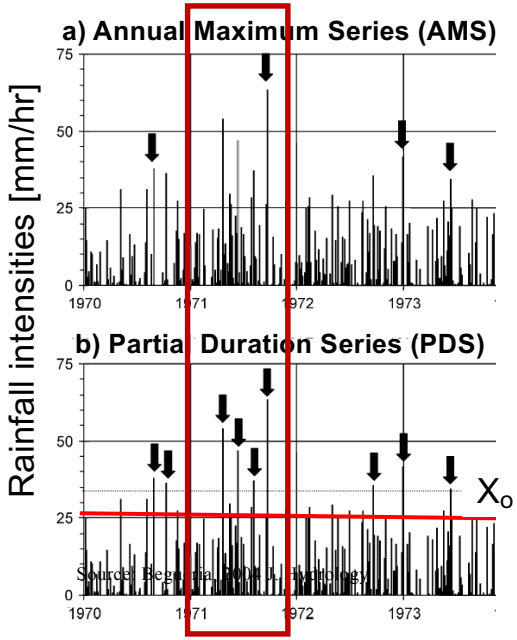
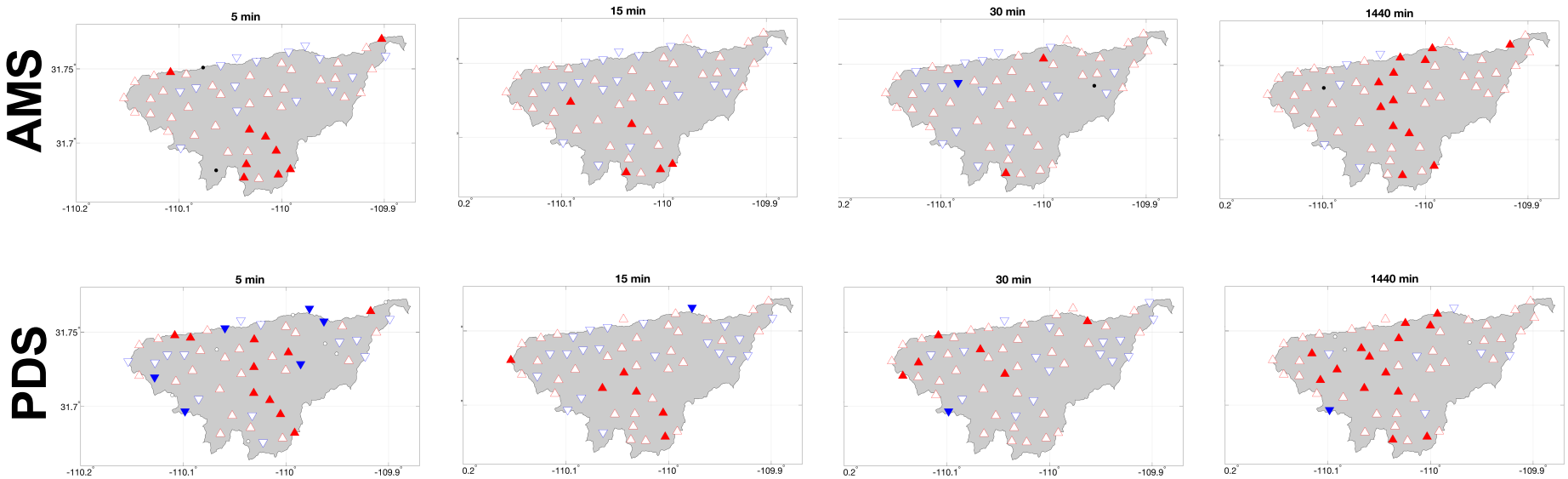



a) Annual Maximum Series: one intensity value per year for each duration → GEV Distribution

b) Partial Duration Series: all intensity values exceeding Xo → Generalized Pareto Distribution

# Linear trends have not been consistent across the watershed




▲ increasing trend ▼ decreasing trend

… however, statistically significant trends are positive

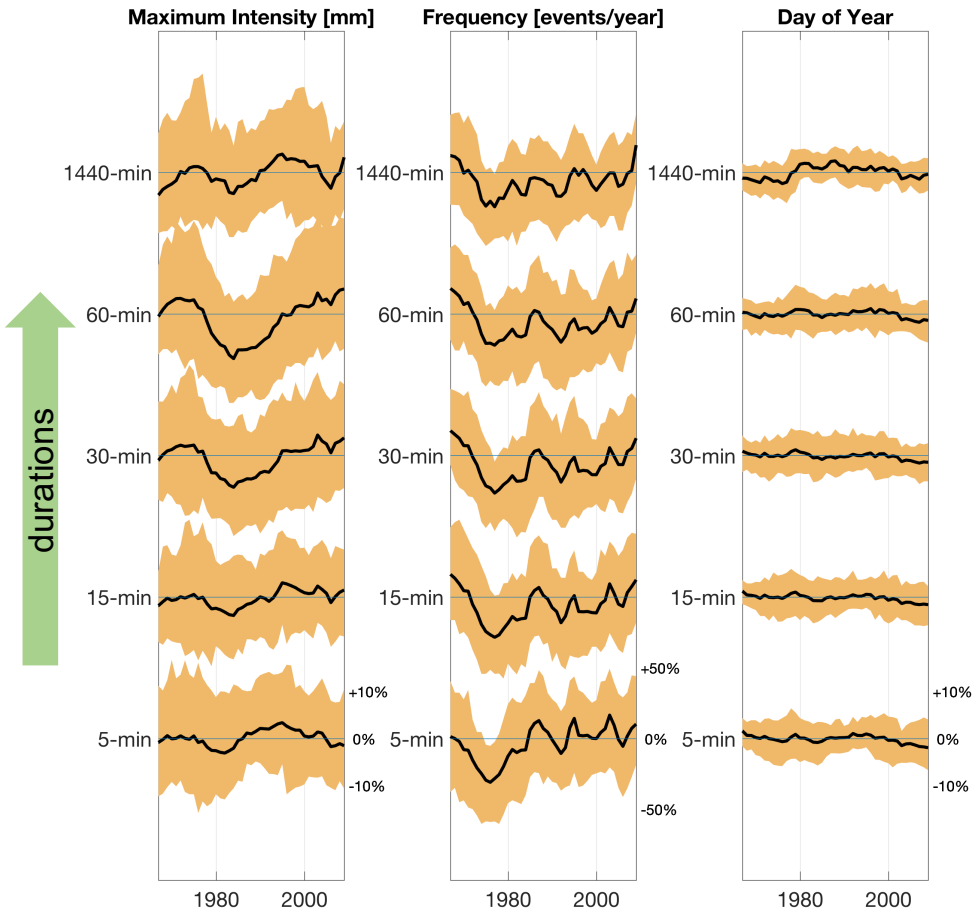
*JJASO Period 1961-2014*

| | | | Increase | | Significant Increase | | Decrease | | Significant Decrease | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Duration (min) | | AMS | PDS | AMS | PDS | AMS | PDS | AMS | PDS |
| semi-arid | | 5 | 41 | 32 | 9 | 10 | 15 | 19 | 0 | 6 |
| | short | 15 | 38 | 37 | 5 | 6 | 20 | 21 | 0 | 1 |
| | | 30 | 40 | 41 | 2 | 6 | 17 | 17 | 1 | 1 |
| | intermediate | 60 | 41 | 38 | 5 | 7 | 17 | 20 | 1 | 1 |
| | long | 1440 | 50 | 48 | 12 | 14 | 6 | 7 | 0 | 1 |
| | Total [%] | | 72 | 68 | 11 | 15 | 26 | 29 | 1 | 3 |

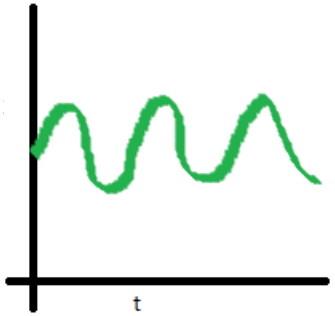
# Is it natural variability masking trends?

- Below average changes* magnitude early in the period (before 1990) and above average late in the period
- More oscillation in the frequency of events with a positive trend in more recent decades
- No changes in average DOY

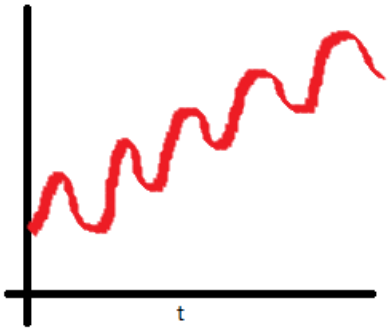
* Changes wrt to each rain gauge long term average



# If precipitation intensities are non-stationary, how structural design will be affected?



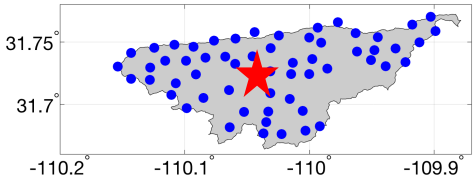

Stationary series

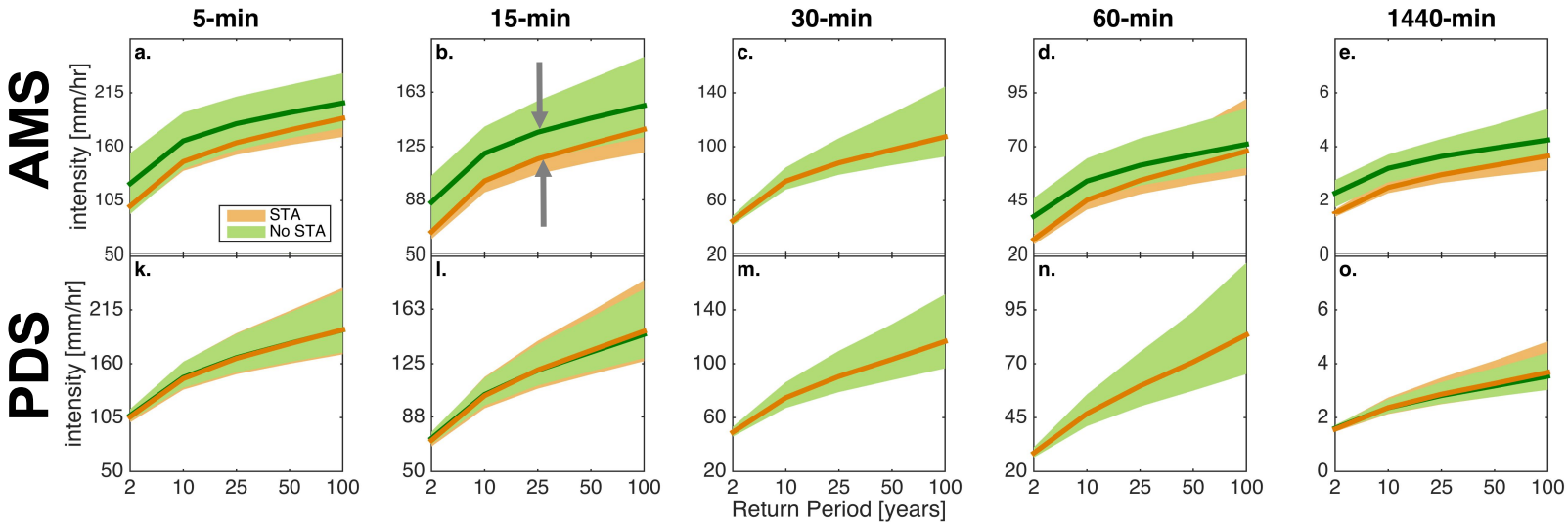



Non-Stationary series

?

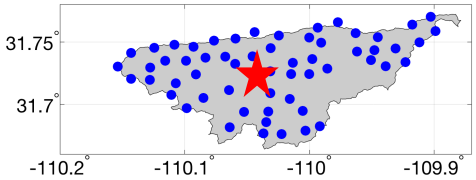
# Ignoring non-stationary in precipitation intensities underestimates design storms

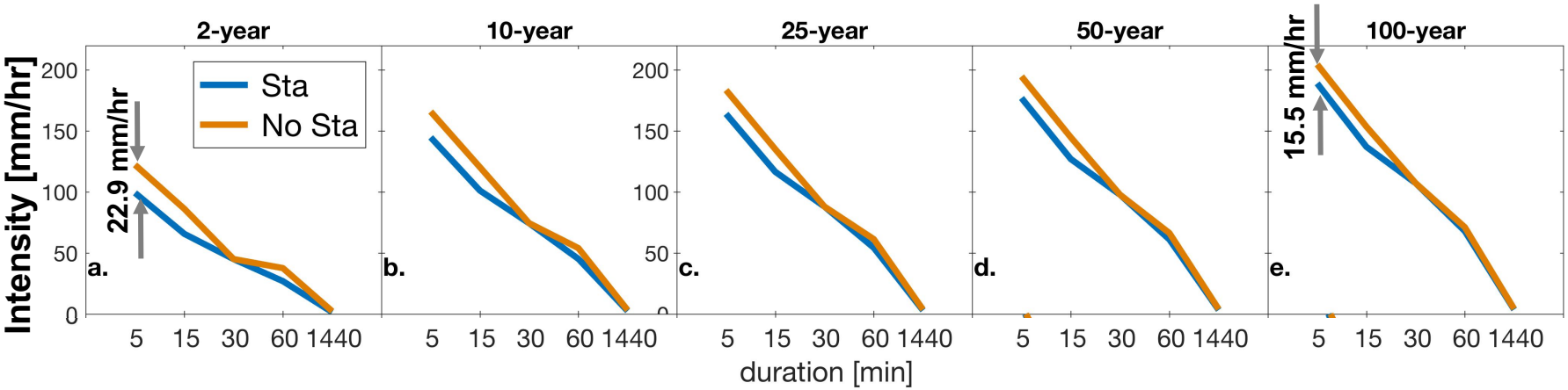


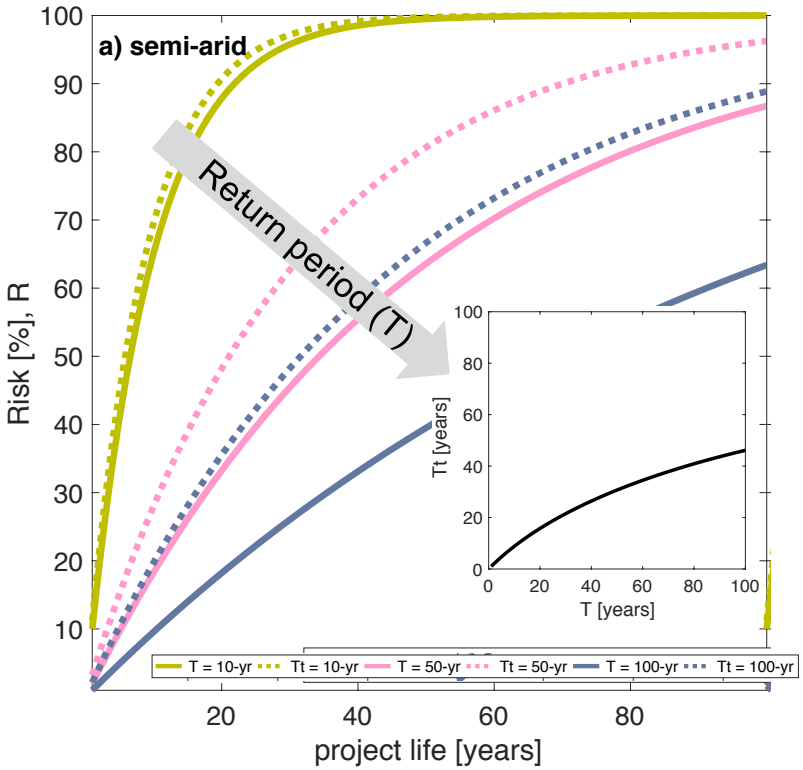

**Demaria, Goodrich, and Keefer, under review WRR**

# Largest absolute differences between stationary and non-stationary conditions for short durations



# What is the risk of not including trends in hydrologic design?



$$R = 1 - \left(1 - \frac{1}{T}\right)^n \quad or \quad R = 1 - \prod_{t=1}^{n}\left(1 - \frac{1}{T_t}\right)$$

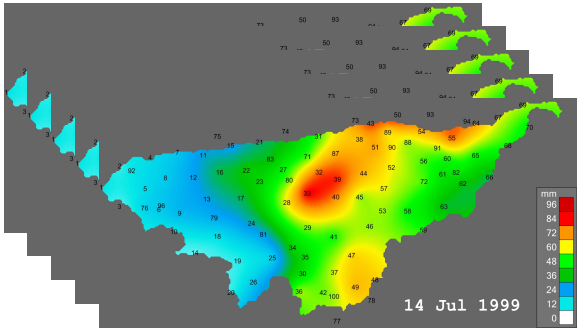
*for T = 100 years and a project life of 100 years risk of failure is 25% higher under non-stationary conditions*

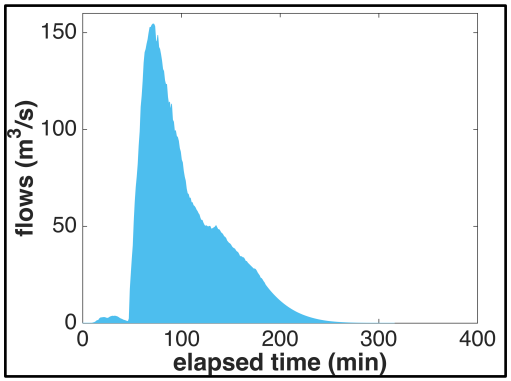
# next

- Are we seeing any temporal changes in the shape of the storms?

- What is the relationship between climate teleconnections and changes in precipitation patterns?

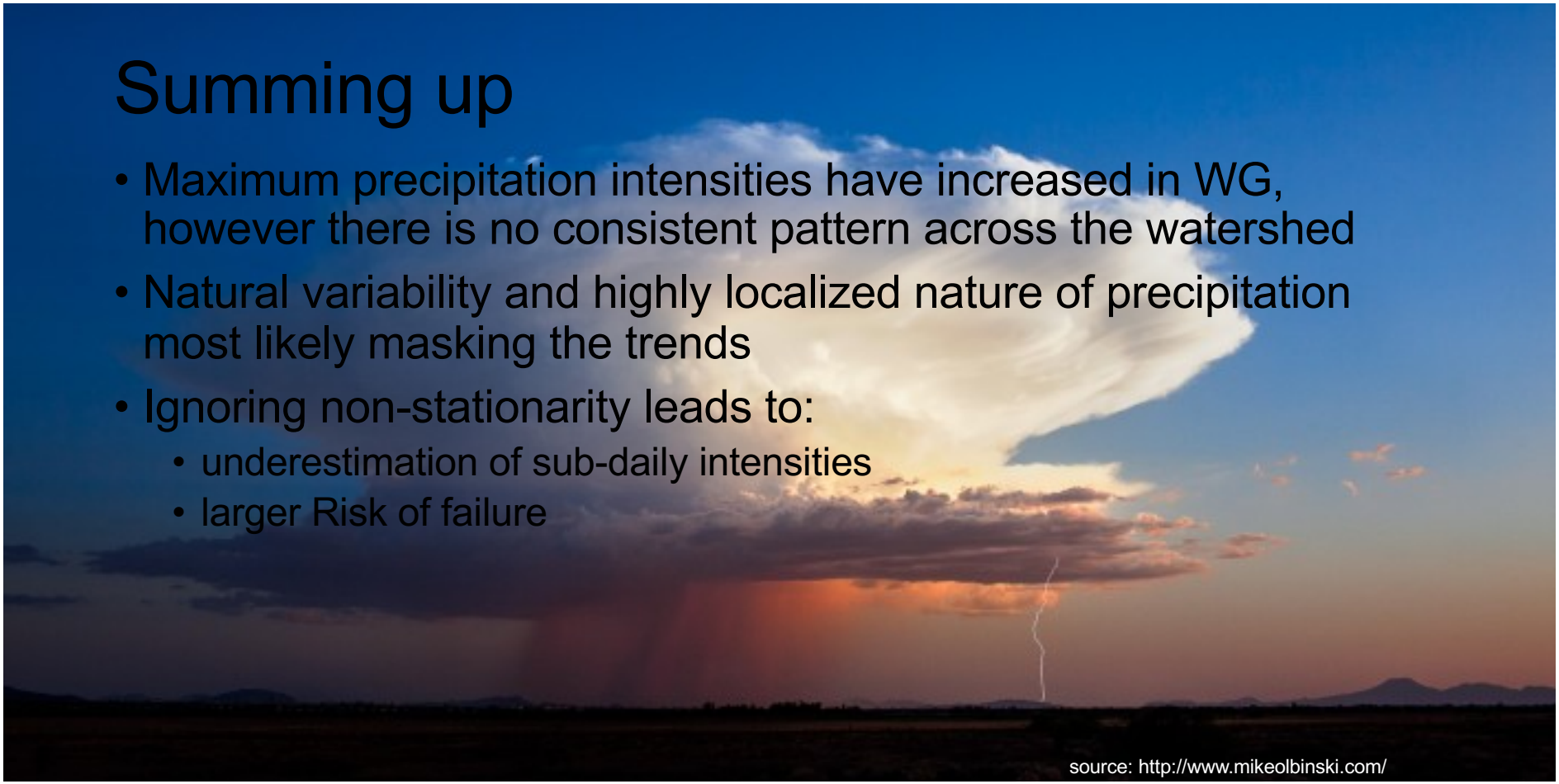
- How changes in upland vegetation have impacted runoff generation in WG?



# Summing up

- Maximum precipitation intensities have increased in WG, however there is no consistent pattern across the watershed
- Natural variability and highly localized nature of precipitation most likely masking the trends
- Ignoring non-stationarity leads to:
  - underestimation of sub-daily intensities
  - larger Risk of failure



source: http://www.mikeolbinski.com/