The more extreme nature of North American monsoon precipitation in the Southwestern United States

Christopher L. Castro[1], Hsin-I Chang[1], David K. Adams[2], Thang M. Luong[1,3], Timothy Lahmers[1], and Carlos Ochoa-Moya[2]

[1]Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, Arizona USA

[2]Centro de Ciencias de la Atmósfera, National Autonomous University of Mexico, Mexico DF Mexico

[3]Physical Science Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

Invited Presentation

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Outline

- Monsoon weather hazards
- Convective-permitting modeling and monsoon meteorology
- High resolution modeling approach, performance
- Changes in atmospheric environment, extreme weather
- Information translation
- Concluding points

Acknowledgement: Funding from Strategic Environmental Research and Development Program, Resource Conservation and Resiliency (Project RC-2205).

Monsoon Severe Weather Hazards

Effects of Anthropogenic Climate Change?

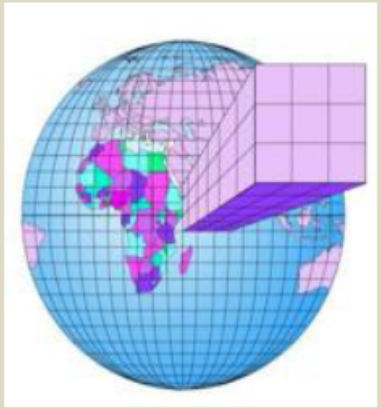
Forecast concerns

- Precipitation amount
- Precipitation intensity
- Wind gusts (outflow boundaries)
- Spatial location
- Timing

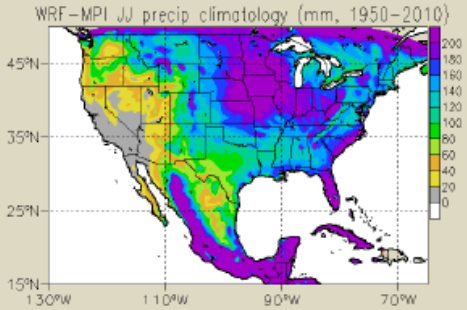
Conditions in Atmosphere for Strong Monsoon Thunderstorms

- Thermodynamic
  - Instability
  - Moisture
- Dynamic
  - Lifting
  - Wind shear

Methodological approach using regional convective-permitting modeling

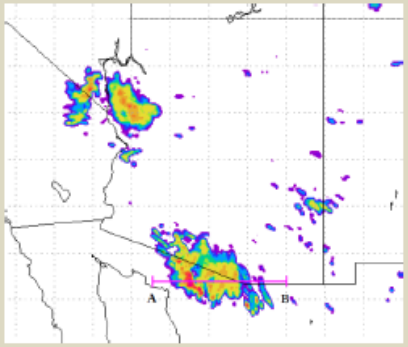


Long-term dynamical downscaling as RCM



Simulate identified severe weather events in RCM simulation

Radar reflectivity of simulated organized convection in Arizona



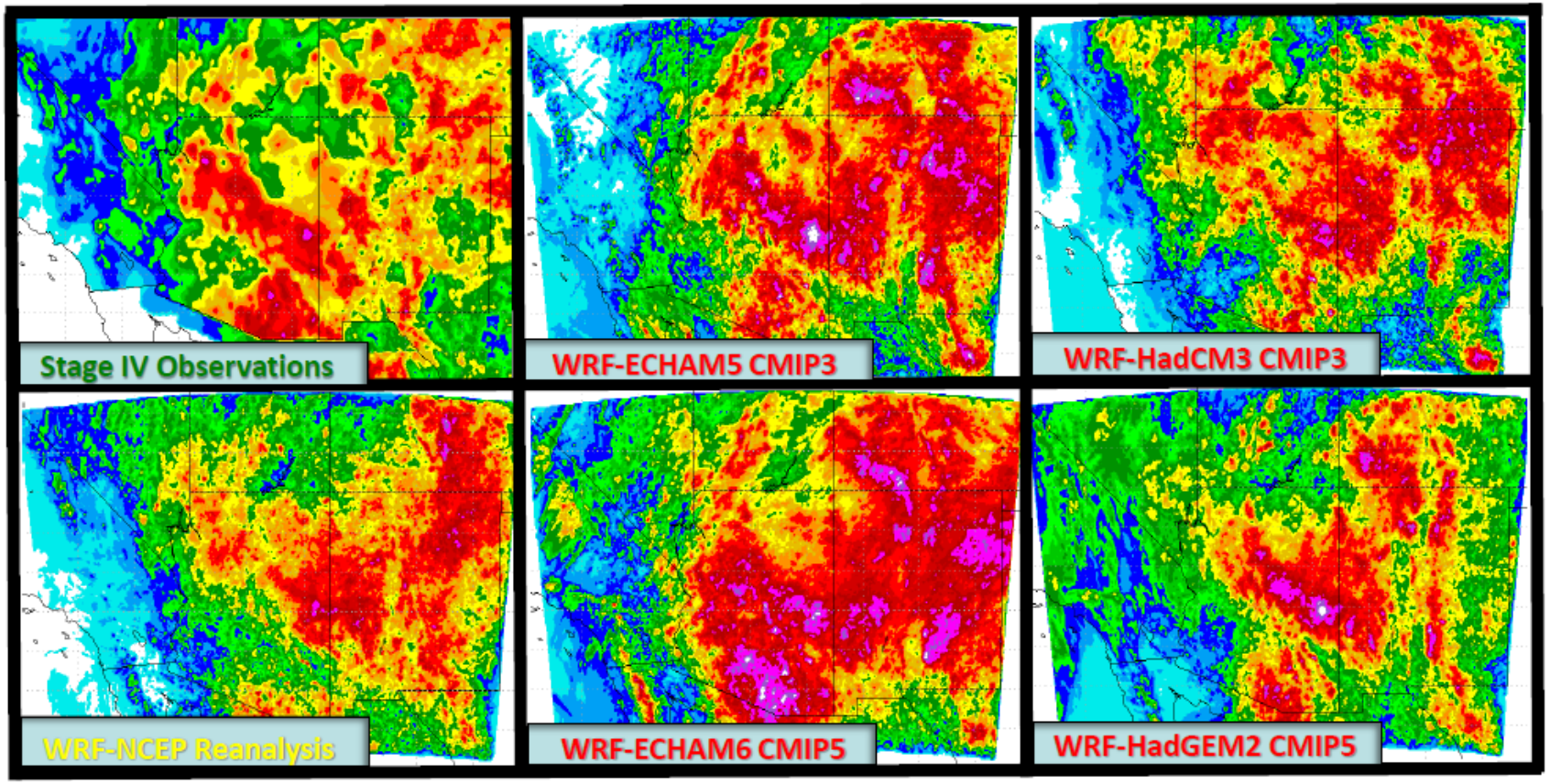
Select CMIP3 and 5 models & global reanalysis
1-2.5° resolution

Baseline WRF long term regional climate model simulations for historical and future periods
35-50 km resolution

High resolution numerical weather prediction type simulations
2.5 km resolution

Daily Average Precipitation

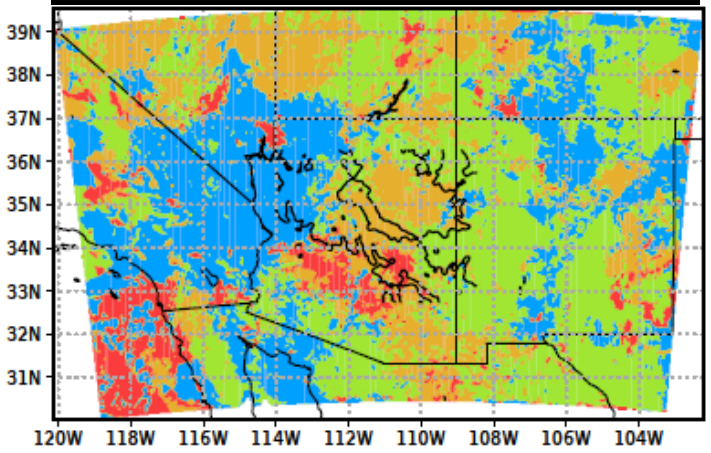
Modeled vs. Observations



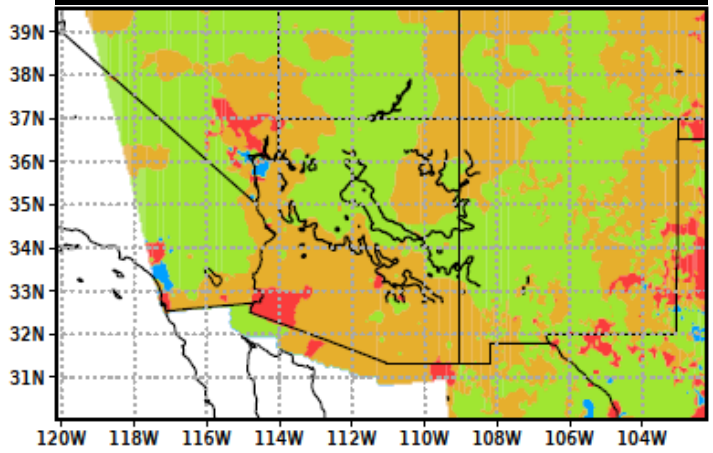
Luong et al. (2017, J. Appl. Meteor. Climatol.)

Timing of Peak Convective Rainfall
Model versus Observations

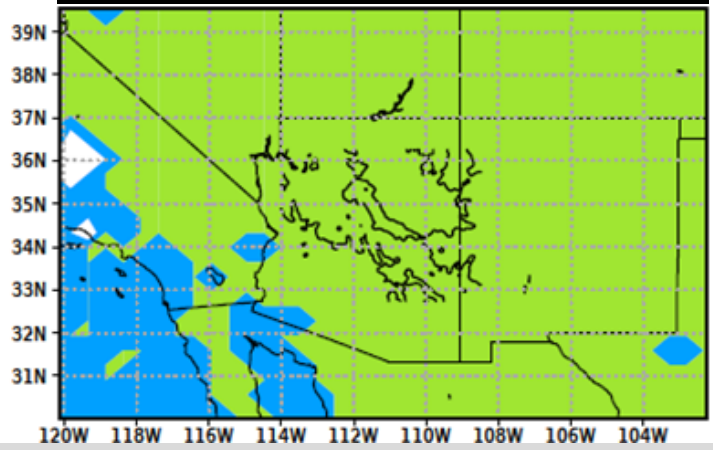
High resolution model (2.5 km)



Observations



Coarse resolution model (35 km)



Peak Rainfall (LT)

5 am – 11 am

11 am – 5 pm

5 pm – 11 pm

11 pm – 5 am

Luong et al. (2017, J. Appl. Meteor. Climatol.)

Atmospheric Thermodynamic Conditions

Changes During the Last 30 Years

- Long-term modeled and observed increases in instability, precipitable water
- Changes can be attributed to (anthropogenic) climate change

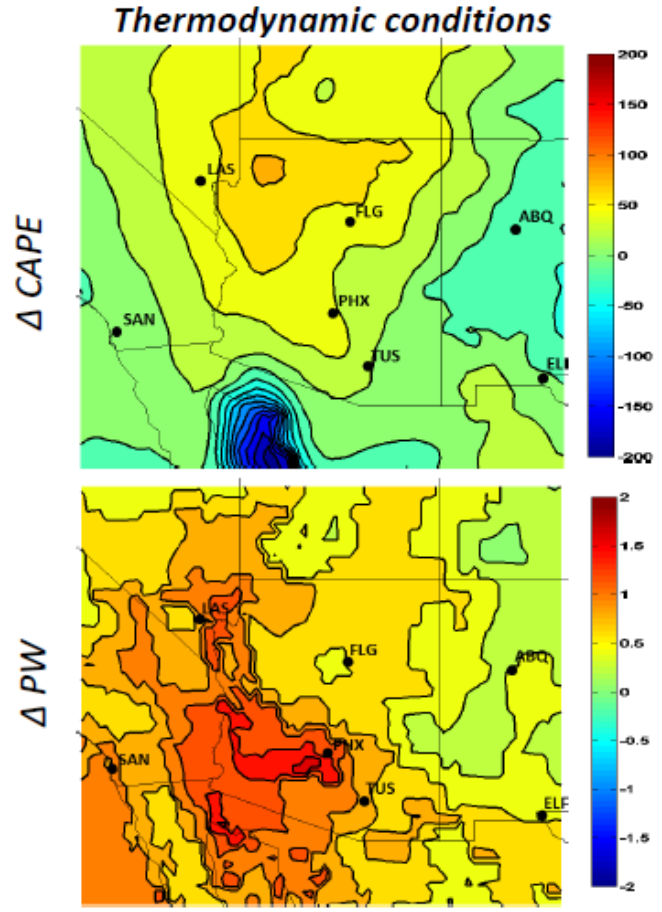
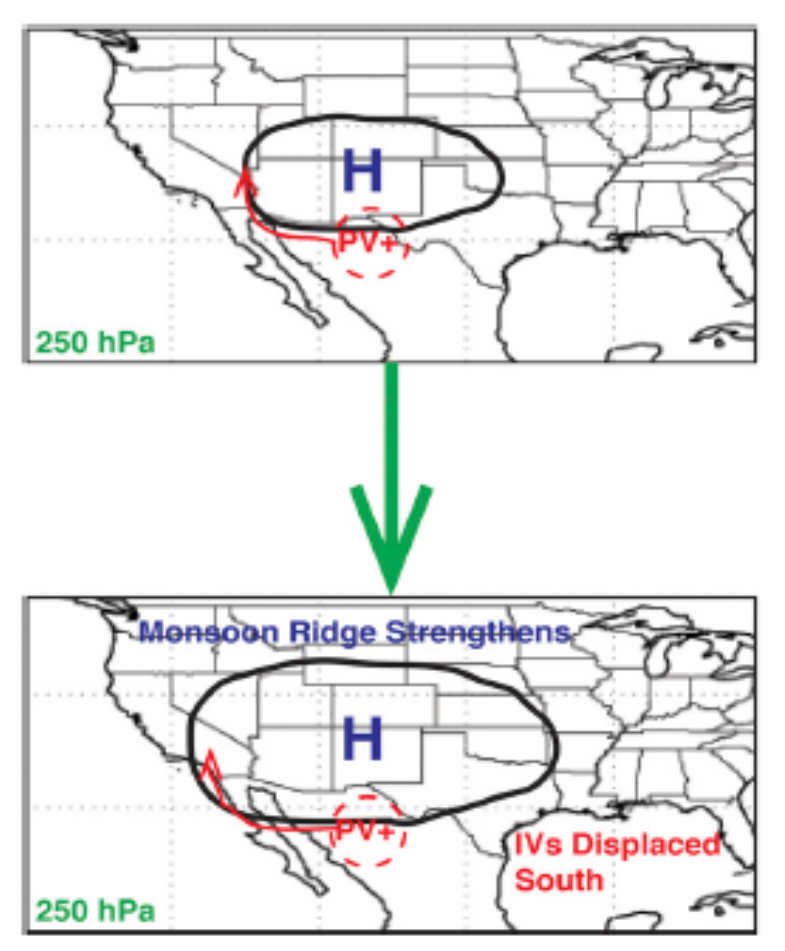


Figure 2: JA differences in downscaled reanalysis (1980-2010 minus 1950-1979) for convective available potential energy (CAPE, J kg^{-1}) and precipitable water (PW, mm). Operational radiosonde sites indicated. (Jares et al. in preparation)

Atmospheric Dynamic Conditions

Changes over late 20th century

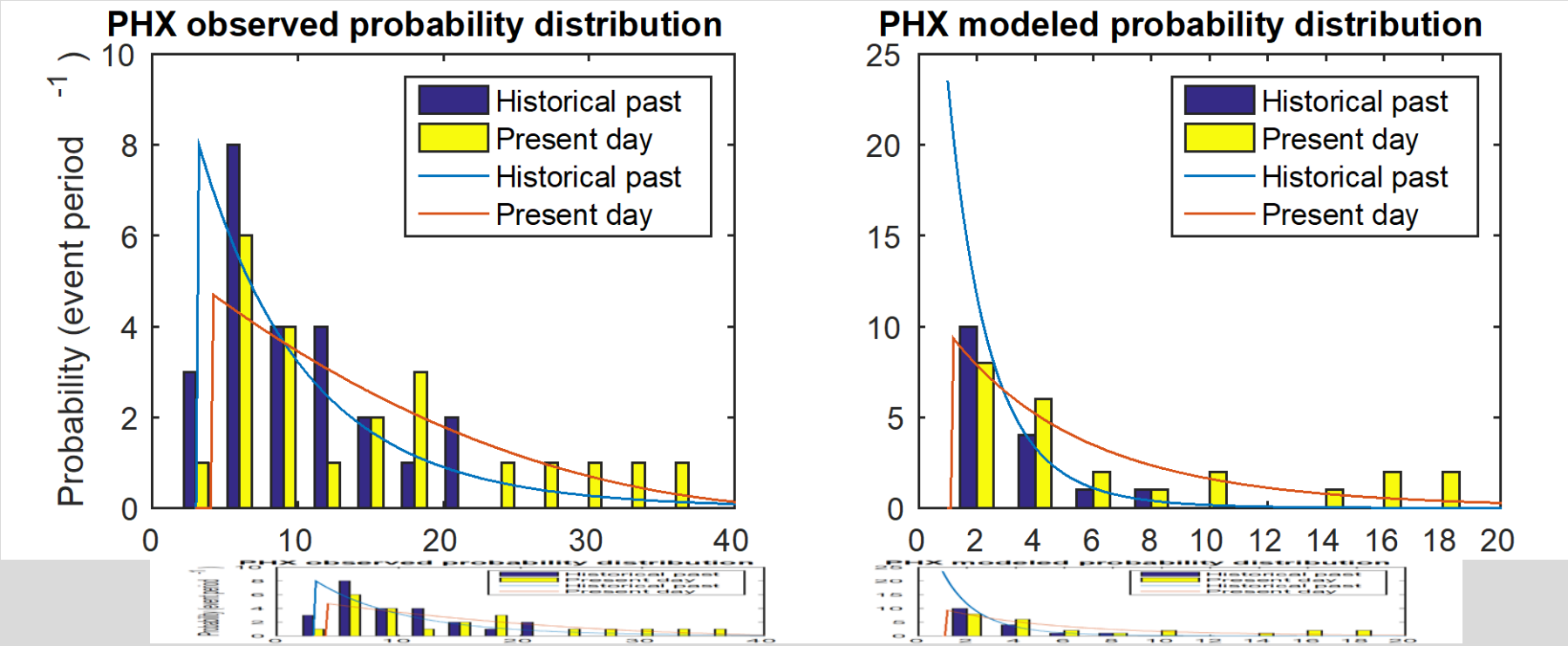


- The monsoon ridge has expanded
- Upper level disturbance displaced further south of the Southwest U.S.
- Less frequency of organized convective events in Arizona, but these events will be more intense

Lahmers et al. (2016, J. Climate)

Distribution of Extreme Daily Precipitation

Lower Frequency, More Intense Events

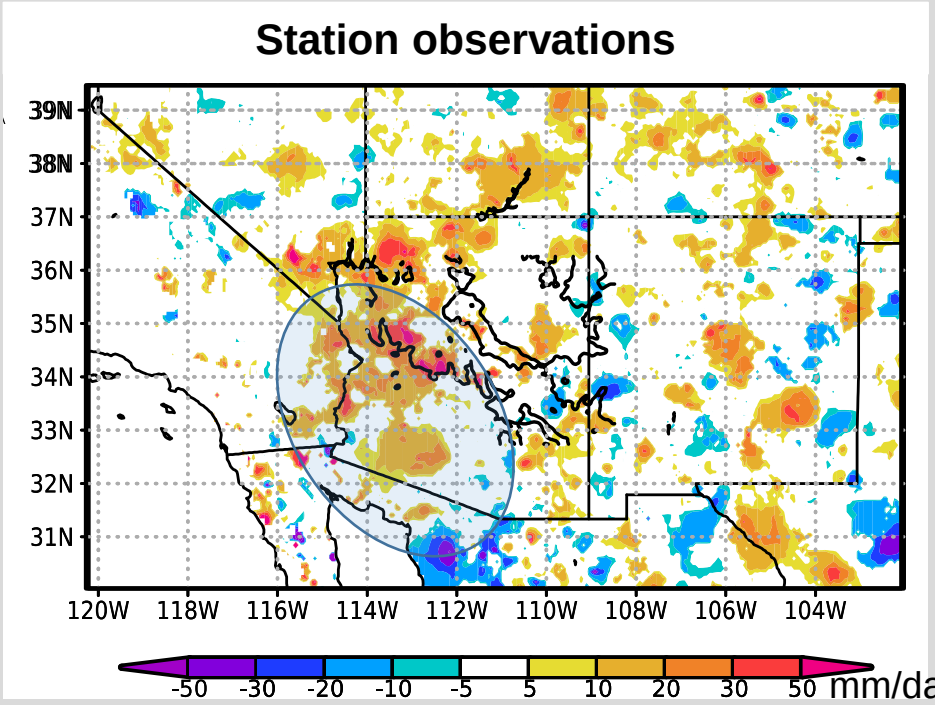


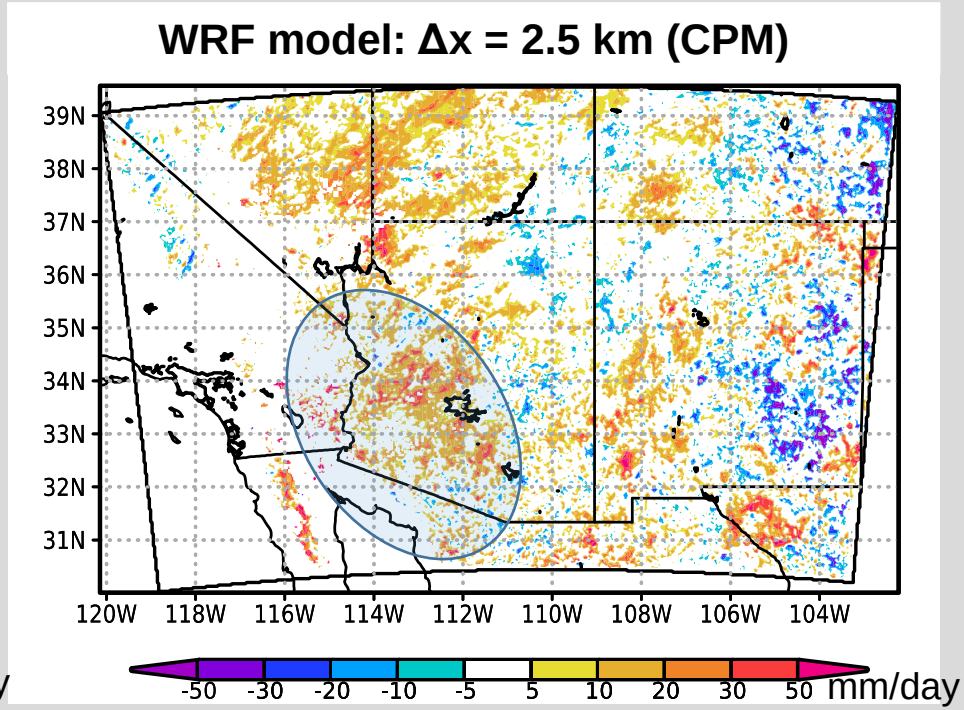
Notes: Historical past = 1950-1970; present day = 1990-2010
Results shown are for Phoenix, Arizona (PHX)

Luong et al. (2017, J. Appl. Meteor. and Climatol.)

Significant Changes: Extreme Precipitation

Largest Increase in Southwest Arizona



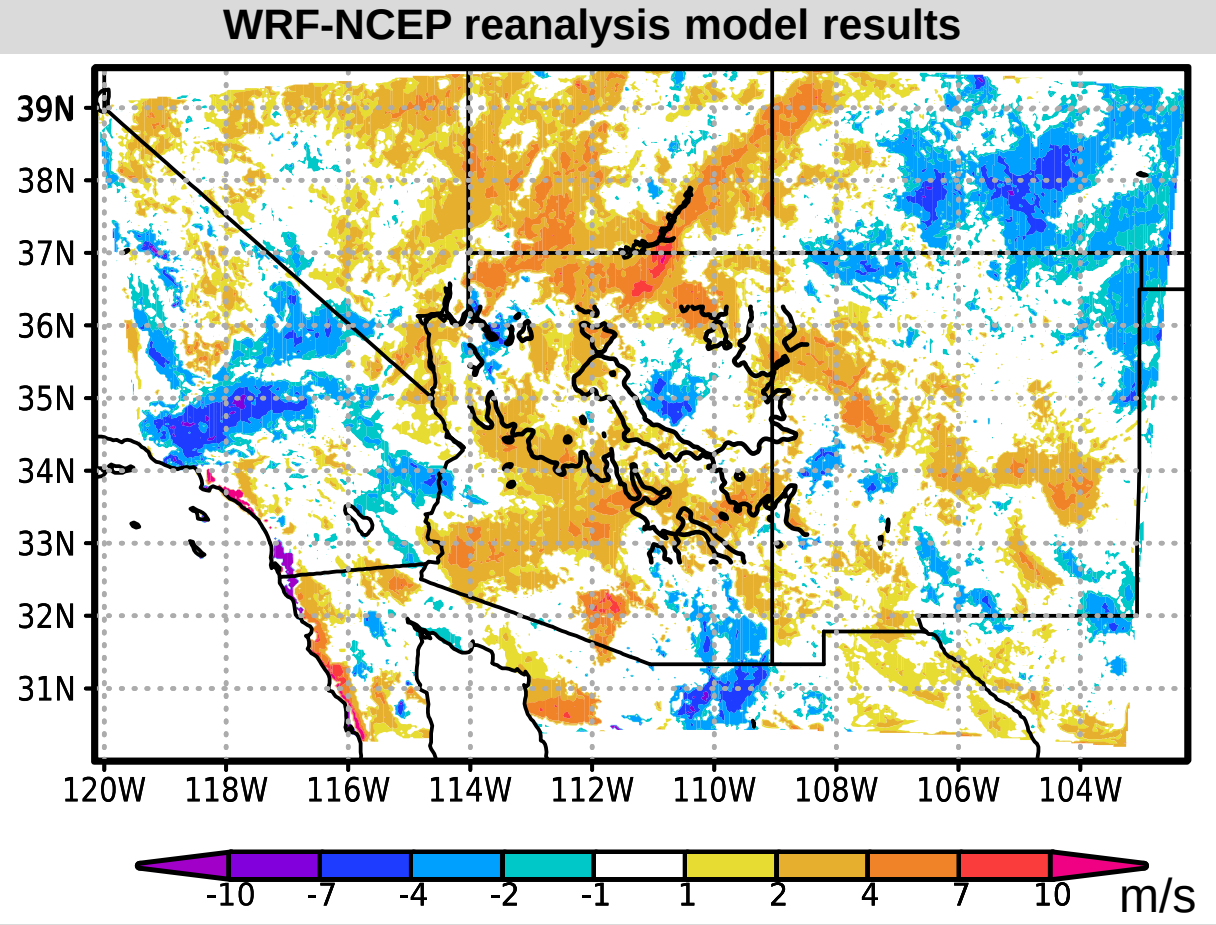


Note: 1950-1970 vs. 1990-2010

Luong et al. (2017, J. Appl. Meteor. and Climatol.)

Extreme Downdraft Wind Speed

Significant Change



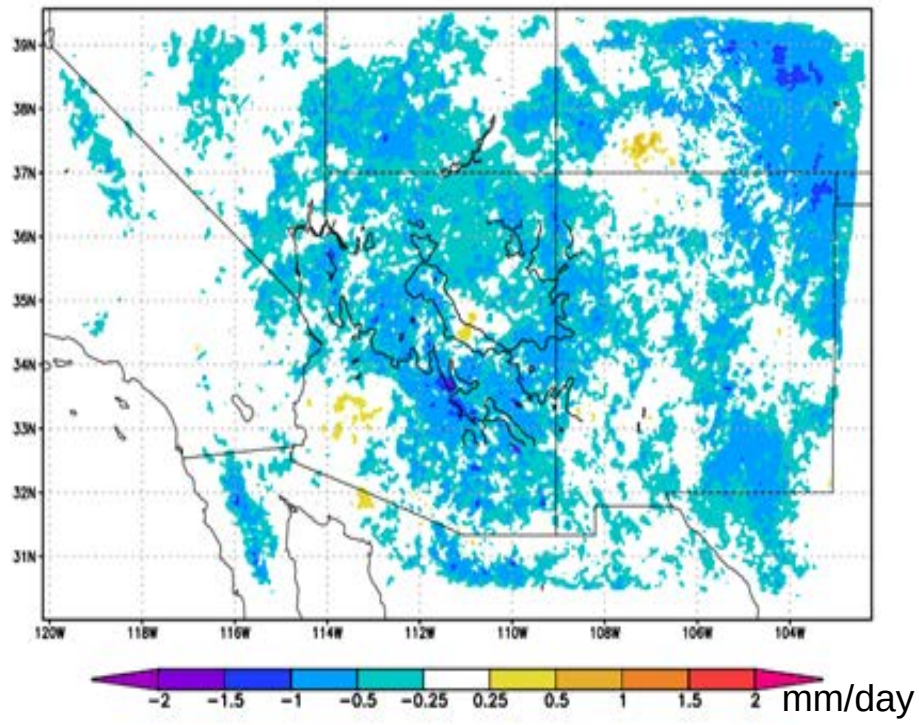
Note: Timeframes 1950-1970 vs. 1990-2010

Luong et al. (2017, J. Appl. Meteor. and Climatol.)

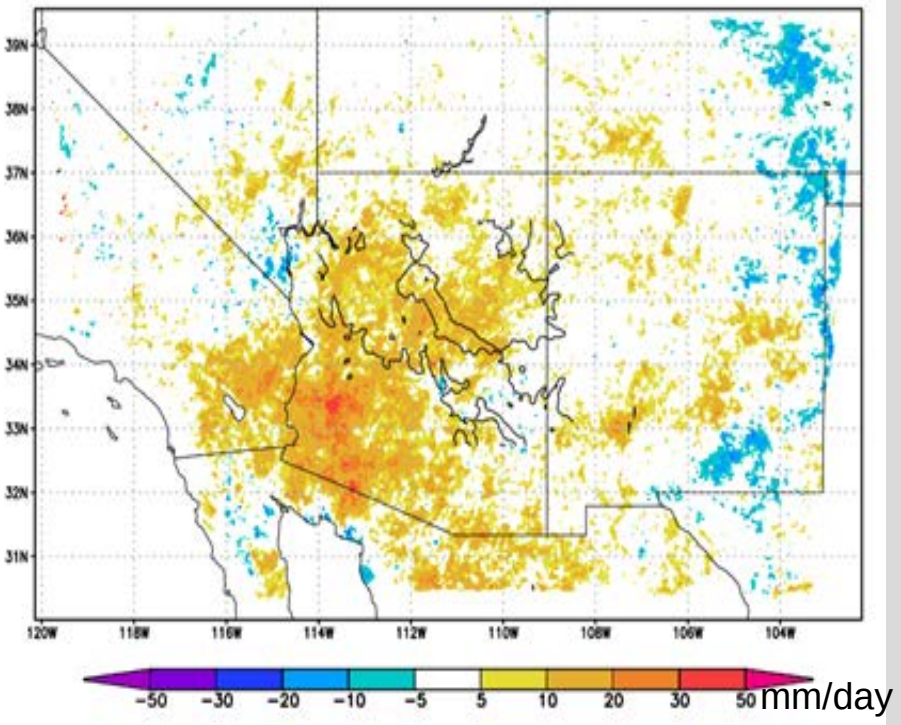
Precipitation

Significant Change, Ensemble of Four CMIP3 and CMIP5 Global Climate Models

Mean trend from model ensemble



Extreme trend from model ensemble



Note: Time period is 2021-2040 minus 1991-2010

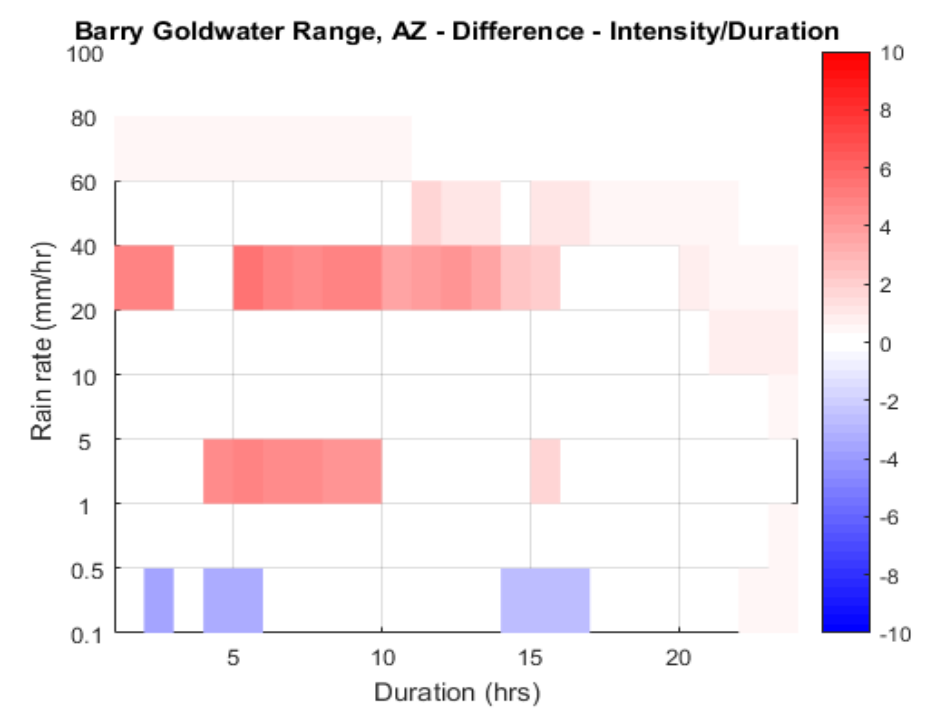
Castro et al. (in prep)

Precipitation Intensity and Duration

Significant Percentage Changes

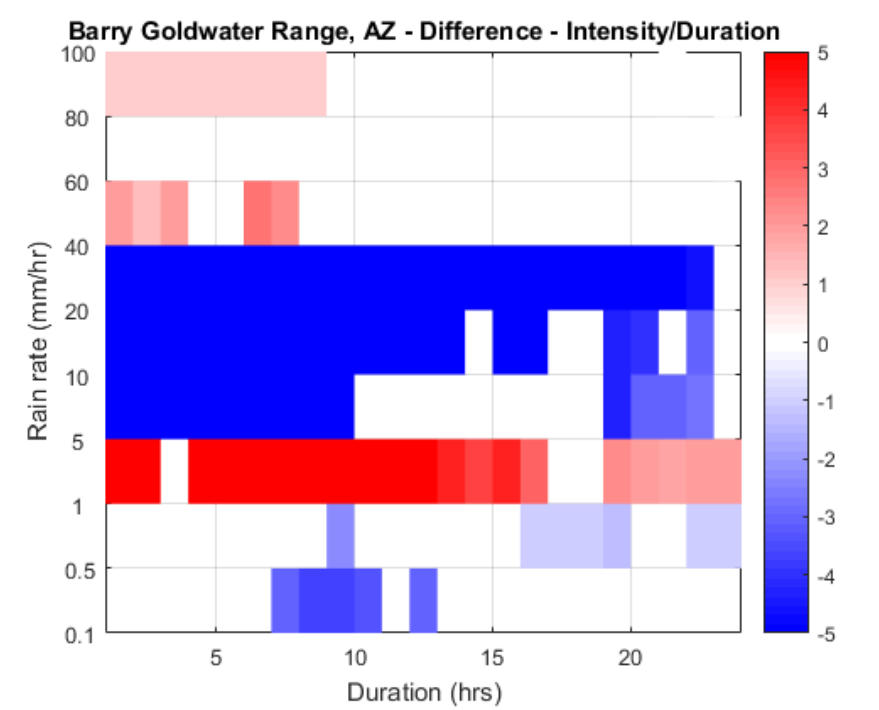
WRF NCEP

1990-2010 minus 1950-1970



WRF CMIP Ensemble Average

2021-2040 minus 1990-2010



Concluding Points

- There has been a long term increase in atmospheric moisture and instability in recent decades, due to anthropogenic climate change
- The more favorable thermodynamic environment is causing monsoon thunderstorms to be more extreme, though they are becoming less frequent
- High resolution atmospheric modeling is able to pinpoint southwestern Arizona as a local ‘hot spot’ where monsoon storms are now more intense, and this trend is projected to continue
- The model information generated by this work is at a spatial scale that is informative for decision making and conforms to weather watch and warning criteria

News Headlines, Awards

CLIMATE CENTRAL

Researching and reporting the science and impacts of climate change

Global Warming Is Fueling Arizona's Monstrous Monsoons

By Bobby Magill

Published: August 4th, 2017

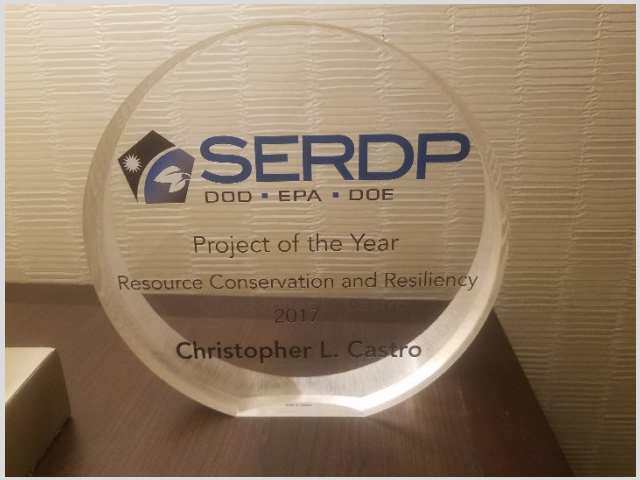
Summer in Arizona and throughout the Southwest is monsoon season, which means a daily pattern of afternoon thunderstorms, flash floods, dramatic dust clouds and spectacular displays of lightning over the desert.

As the climate changes, Arizona's monsoon rainfall is becoming more intense even as daily average rainfall in parts of the state has decreased, according to a new study. Increasingly, extreme storms threaten the region with more severe floods and giant dust storms called haboobs.

A haboob dust storm rolls over suburban Phoenix in 2012. Credit: Jasper Nance /flickr

Every summer, rivers of moisture in the lower troposphere — the monsoonal flow — stream into the Southwest from the Gulf of Mexico and Gulf of California. Nearly every day in midsummer, the sun heats the mountains and the deserts, creating convection. The rising warm air allows thunderclouds to build during the day before exploding into dramatic electrical storms in the afternoon and evening.

But today's monsoons aren't like the ones travelers on Route 66 would have driven through 60 years ago.



ARIZONA REPUBLIC
TUESDAY, JULY 25, 2017 azcentral.com PART OF THE USA TODAY NETWORK

STUDY: MONSOON PACKING BIGGER PUNCH

MICHAEL CHOW/THE REPUBLIC

The driver of this vehicle attempted to cross a flooded street in Apache Junction on Monday. She later had to be rescued.

Much of state is seeing fewer, but stronger, summer storms

WELDON B. JOHNSON
THE REPUBLIC | AZCENTRAL.COM

If you think Phoenix-area monsoon storms are worse now than they were years ago, you might be right.

A team of University of Arizona climate scientists released a study that concludes that central and southwestern Arizona are getting fewer but more intense monsoon storms than 50 years ago.

Christopher Castro, a co-author of the study, said that while rain totals over the course of the monsoon haven't increased significantly, much of that rain has fallen in a few large storms.

He said to picture the storms over the course of a season as a line, with the minor storms represented on the left and the storms gaining intensity as they progress along that line.

See MONSOON, Page 7A

SAM CARAVANA/THE REPUBLIC

A sign marks a closed portion of Citrus Road between Lower Buckeye and Broadway roads in the West Valley. The area saw flooding following recent monsoon storms.

More online: Go to **azcentral.com** to watch a video of a water rescue and to see more photos from Monday's monsoon storms.