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

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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

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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

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

Long-term dynamical downscaling as RCM

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

Simulate identified severe weather events in RCM simulation

High resolution numerical weather prediction type simulations 2.5 km resolution

Radar reflectivity of simulated organized convection in Arizona
Daily Average Precipitation
*Modeled vs. Observations*

Timing of Peak Convective Rainfall

Model versus Observations

High resolution model (2.5 km)

Coarse resolution model (35 km)

Observations

Peak Rainfall (LT)

5 am – 11 am

11 am – 5 pm

5 pm – 11 pm

11 pm – 5 am

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

WRF-NCEP reanalysis model results

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

Barry Goldwater Range, AZ - Difference - Intensity/Duration

Rain rate (mm/hr)

Duration (hrs)
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
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.

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.