Mid-Pliocene North American Monsoon in Weather Resolving Coupled Simulations

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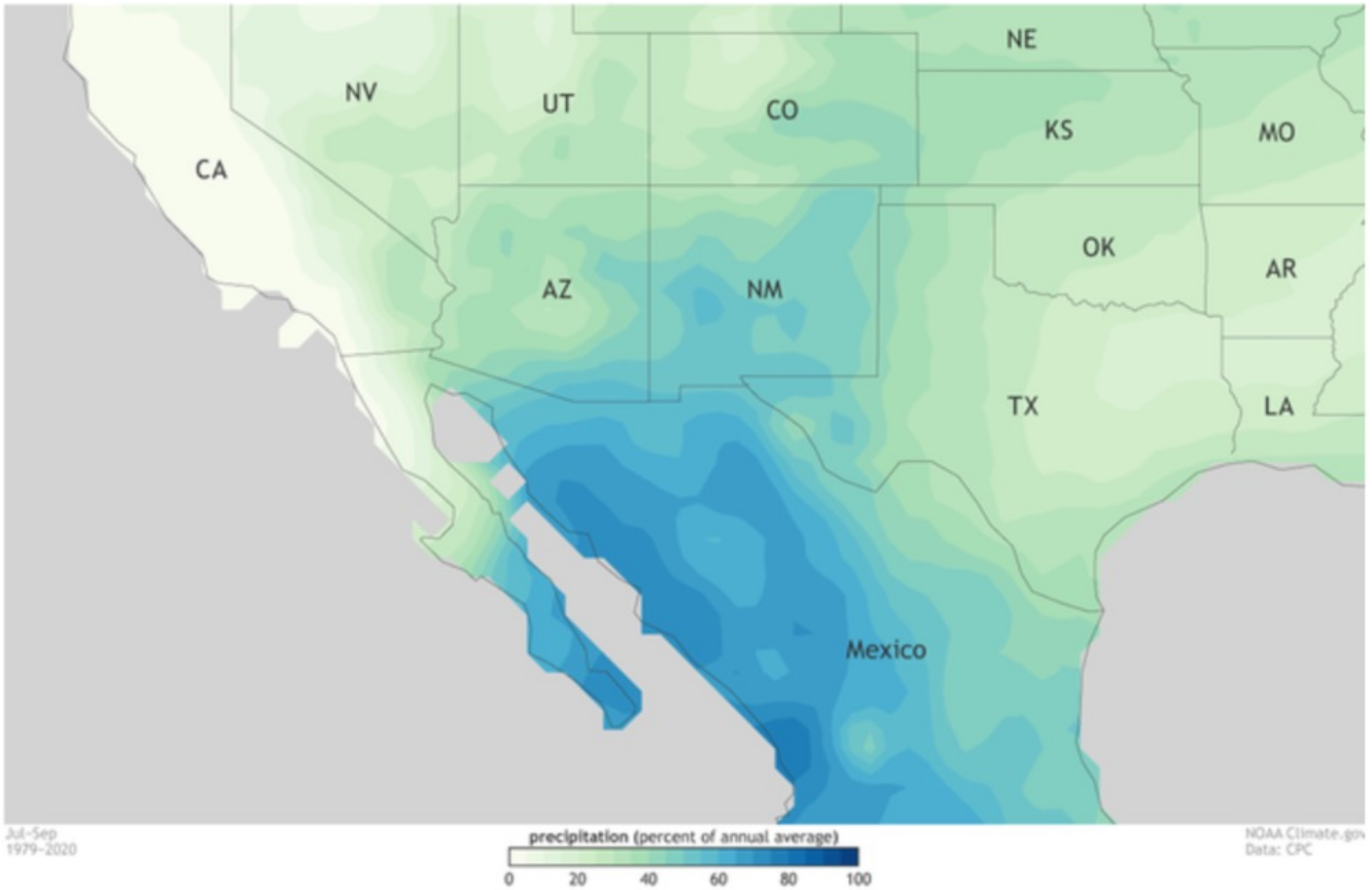
The North American Monsoon (NAM)

- Atmospheric circulation feature of hydroclimate in the North American Southwest (SW NA)
- Mechanically forced by high orography of Sierra Madre Occidental (SMO) mountains
  - Boos & Pascale, 2021

Percent of annual rainfall that occurs during the NAM

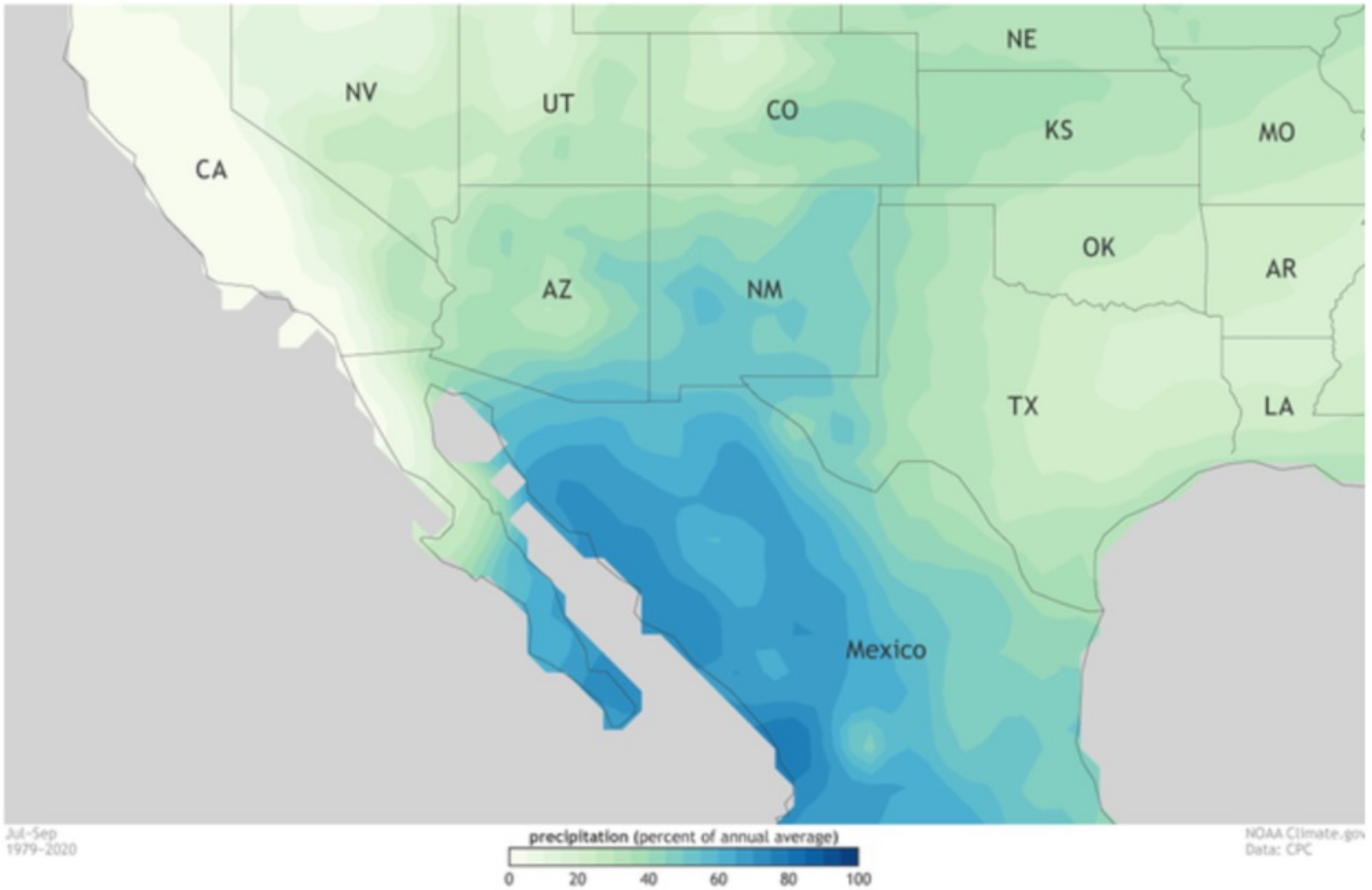


https://www.climate.gov/news-features/blogs/enso/north-american-monsoon

The North American Monsoon (NAM)

- Rainfall is important for those living in SW NA
- Mid-Pliocene (3.3-3.0 Ma) as an analog for future change

Percent of annual rainfall that occurs during the NAM



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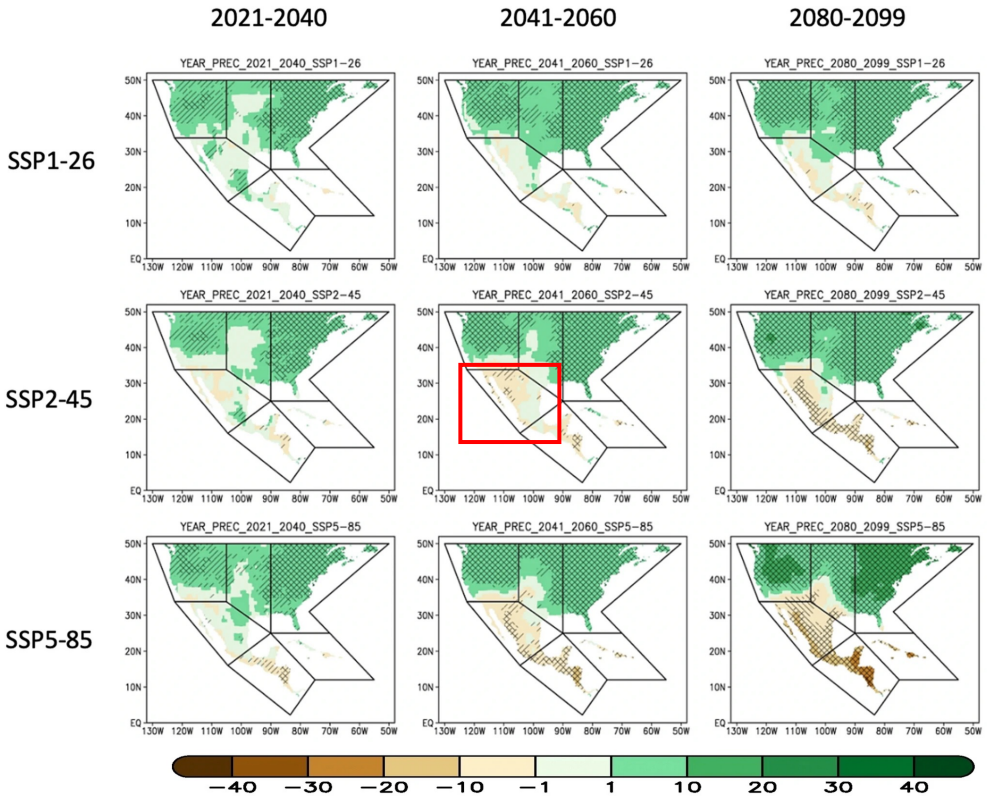
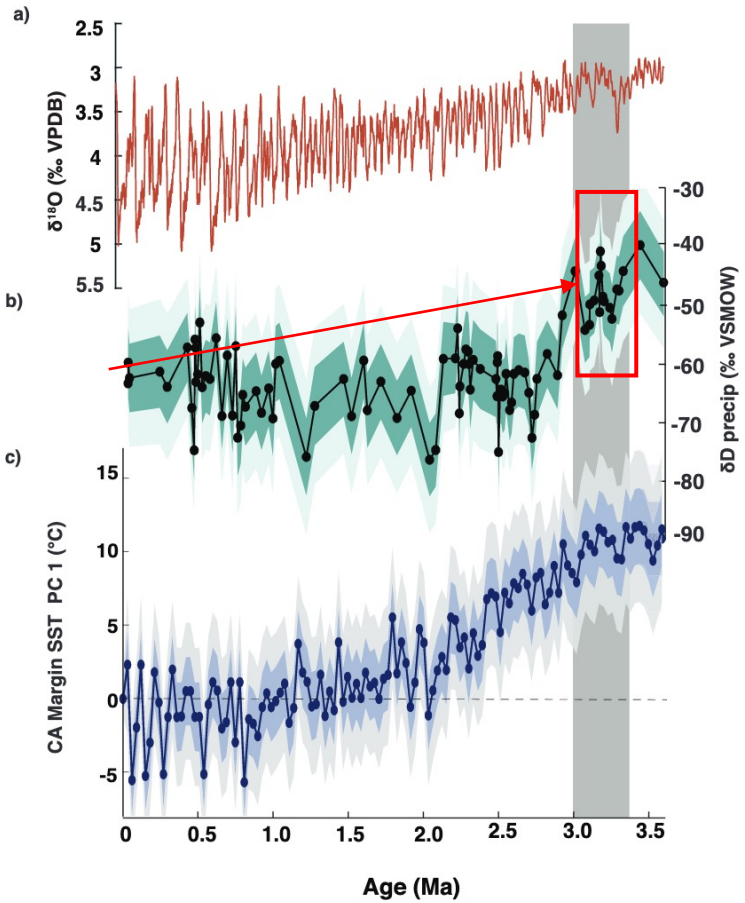
Inconsistency between future predictions of NAM and proxy evidence

CMIP6 Ensemble projections of future precipitation changes (%)



Almazroui et al., 2021

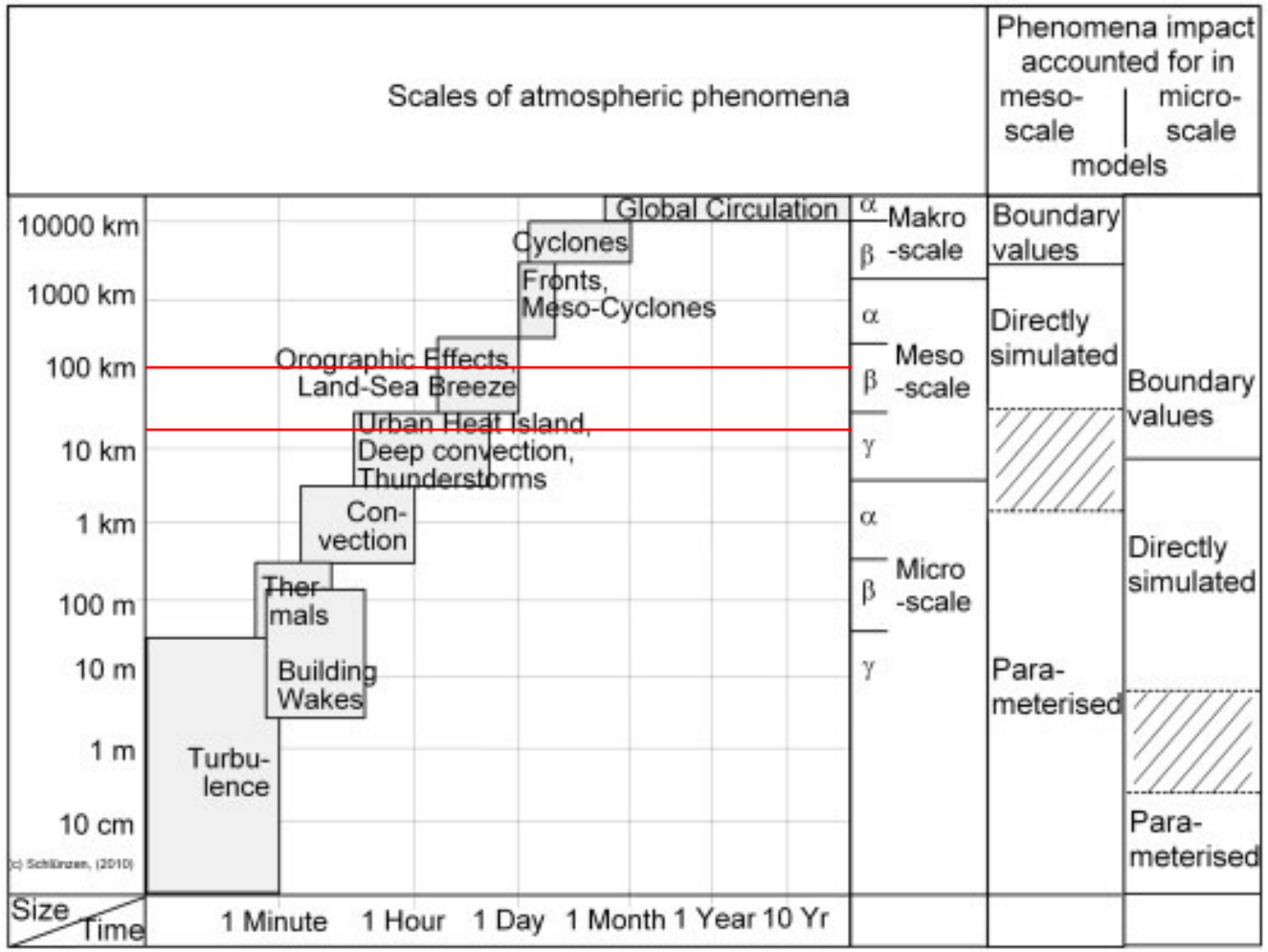
Proxy evidence of wetter conditions



Bhattacharya et al., in review

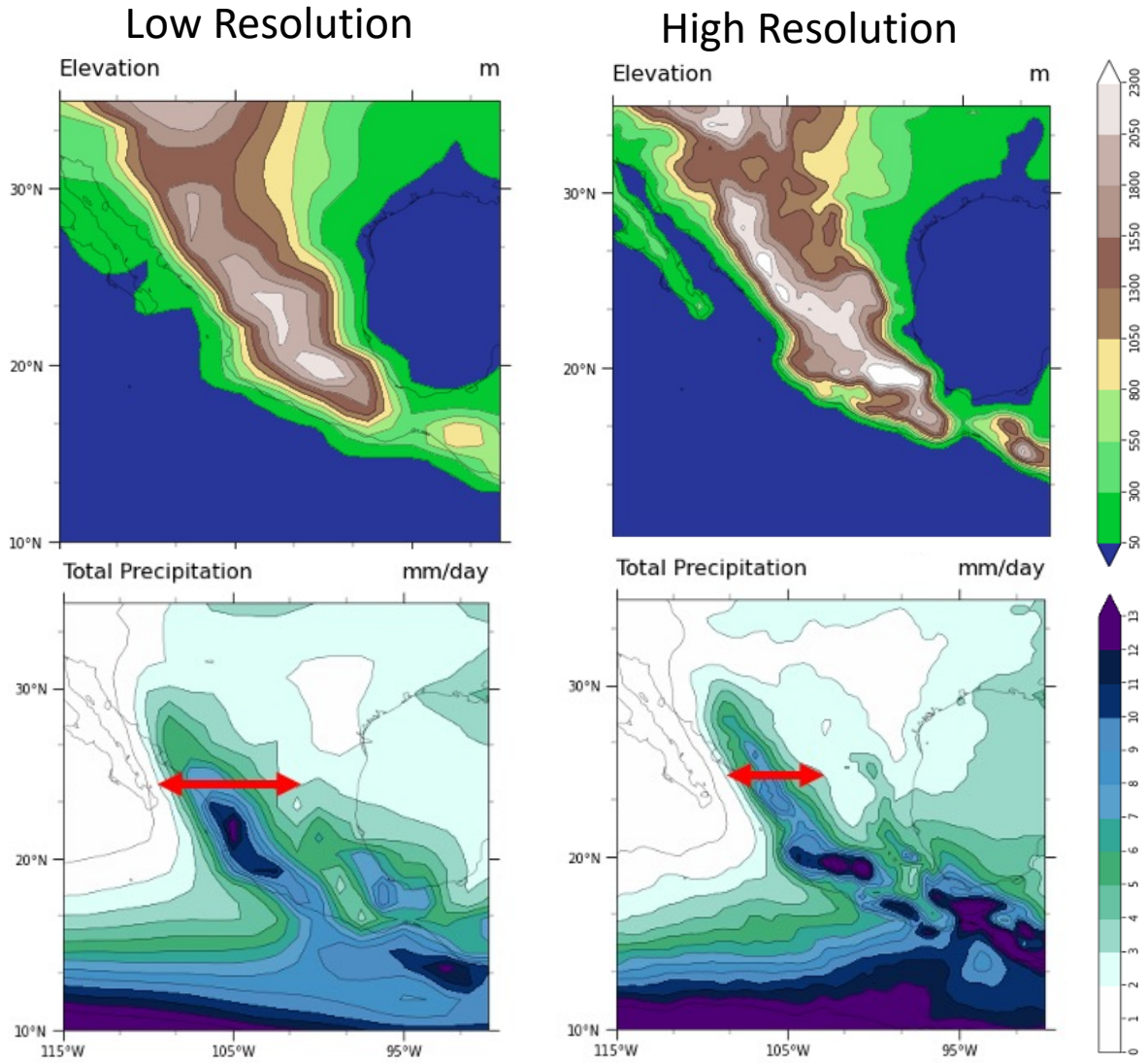
Models for the high and low res simulations

- Community Earth System Model 1.3
  - Atmosphere and land
    - About 25 km resolution
  - Ocean and sea ice
    - Typical 100 km resolution
- Community Earth System Model 1.2
  - Atmosphere and land
    - 100 km resolution
  - Ocean and sea ice
    - 100 km resolution



Schlunzen et al., 2011

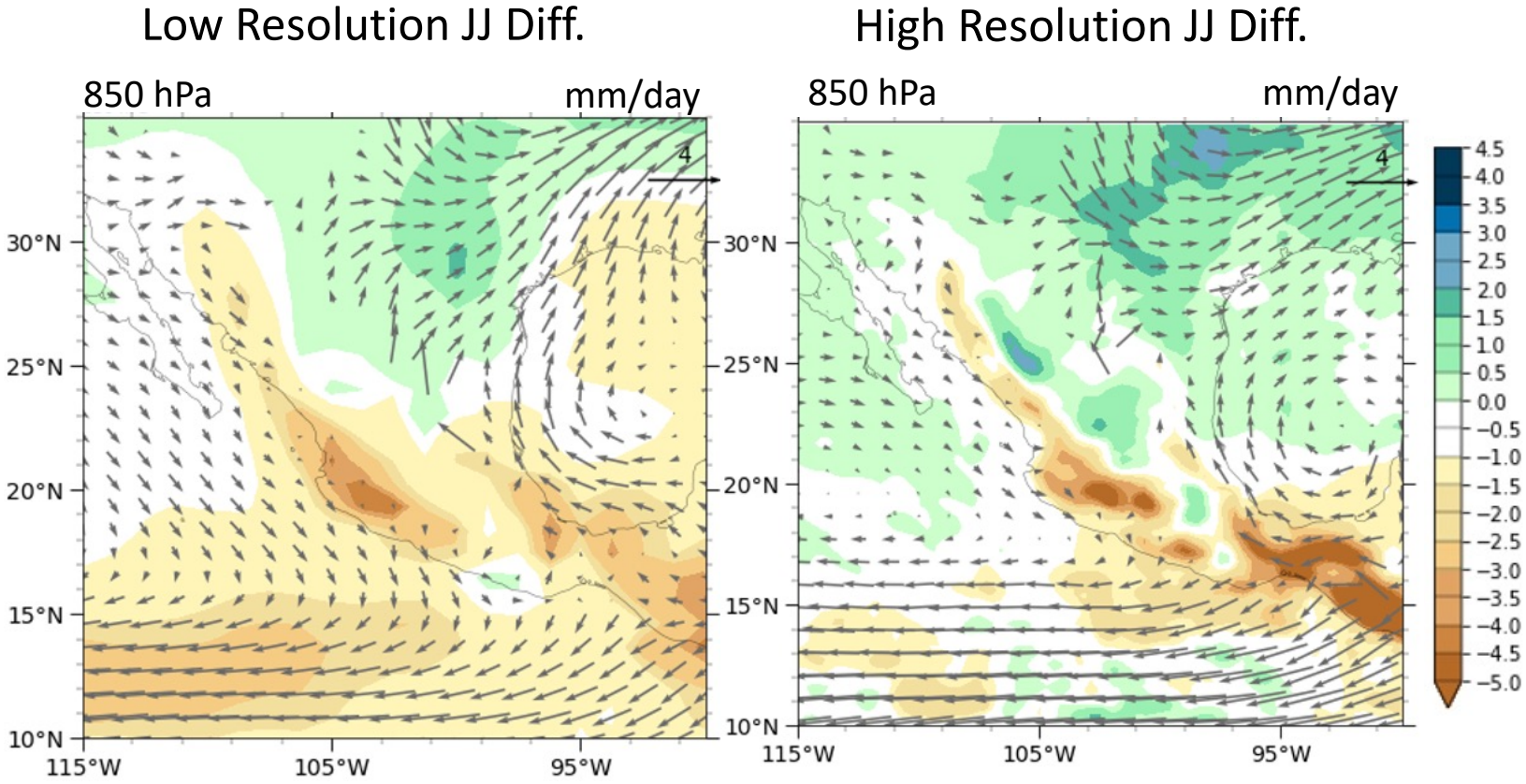
Importance of horizontal resolution in NAM simulations



- Better resolve elevation and geometry of Sierra Madre Occidental (SMO) in high resolution
  - Causes a greater upslope deflection of air
  - More narrowly defined band of high JJAS precip in high resolution

Early summer precipitation changes (Pliocene minus Preindustrial)

- Lowered elevation of SMO during Pliocene
  - Dowsett et al., 2016
- Enhancement of the eastern monsoon rain belt during the early summer in the high res run

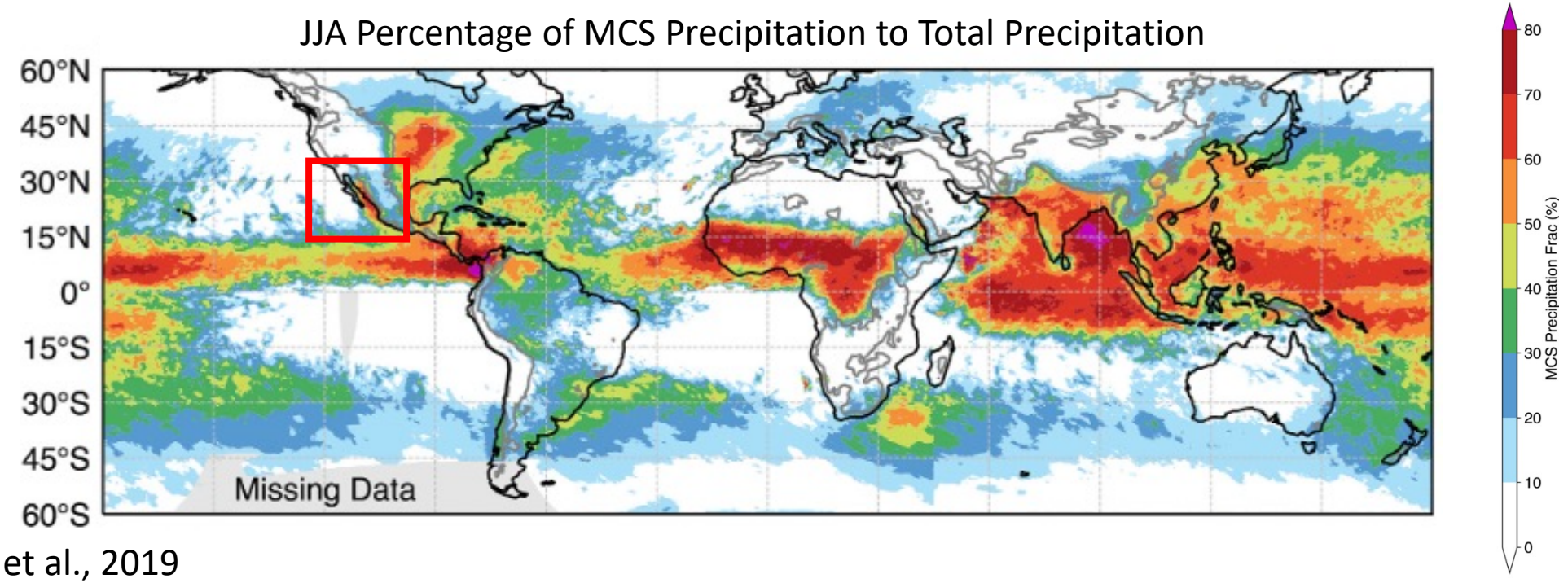


Are differences due to Mesoscale Convective Systems?

Mesoscale Convective Systems (MCS)

- Organized complex of thunderstorms
  - Can travel far and persist for multiple hours
- MCSs form along the west coast of Mexico
  - Can contribute to about 40-60% of summer precipitation in NAM region
- More intense MCS-type convection expected for future of NAM

JJA Percentage of MCS Precipitation to Total Precipitation

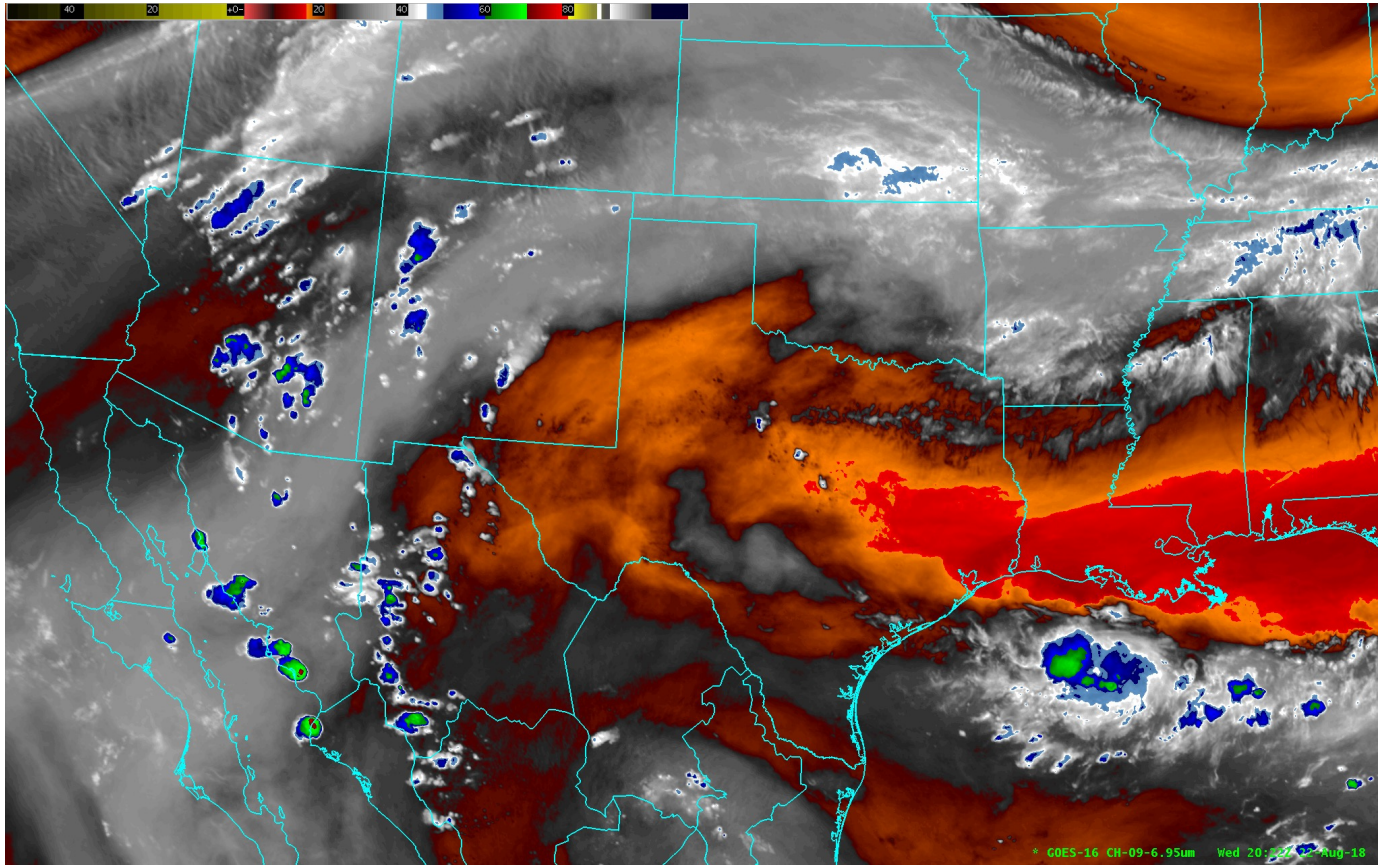


Feng et al., 2019

Tracking MCSs in simulations

- TempestExtremes (Ullrich et al., 2021)
  - First detects intense precipitation in simulations
  - Then determines if the event is a propagating feature

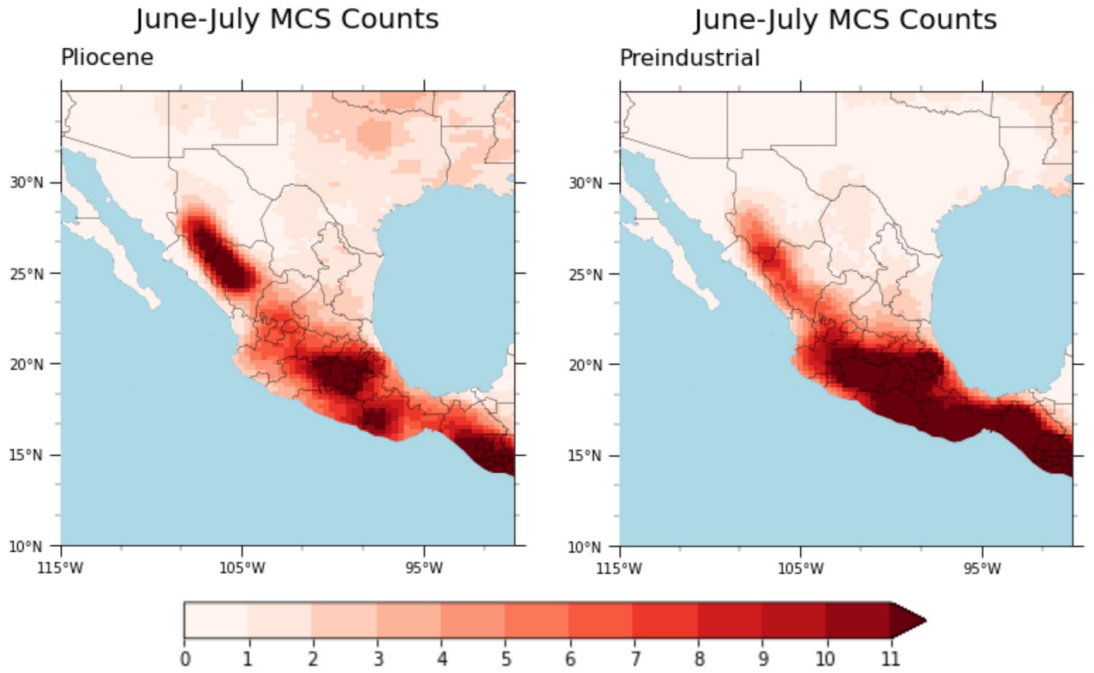
NAM pattern: 22 Aug 2018

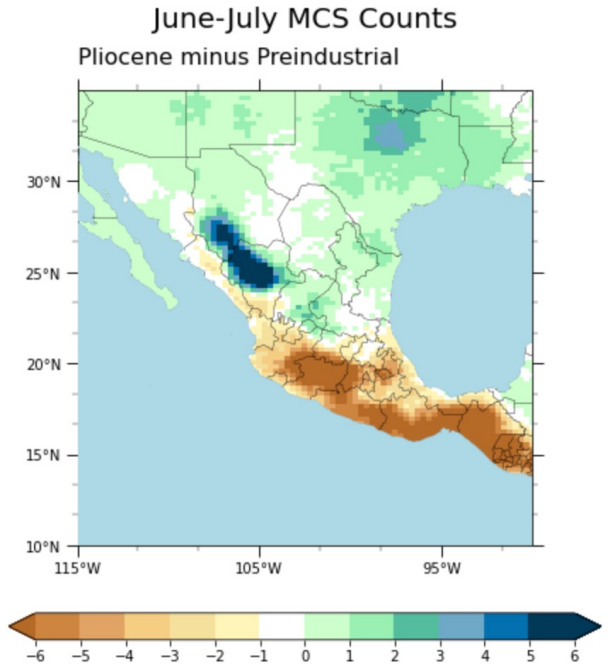


https://www.weather.gov/abq/northamericanmonsoon-intro

Results of MCS Tracking

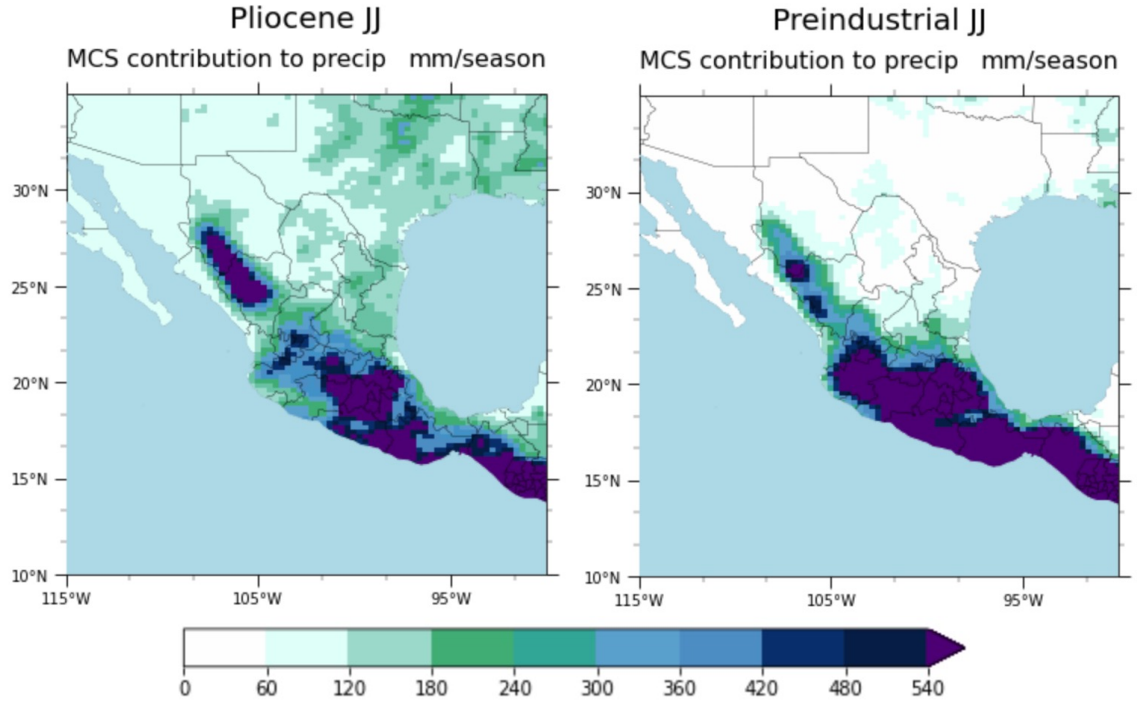
- Overall increase of MCS frequency in the NAM region during the Pliocene

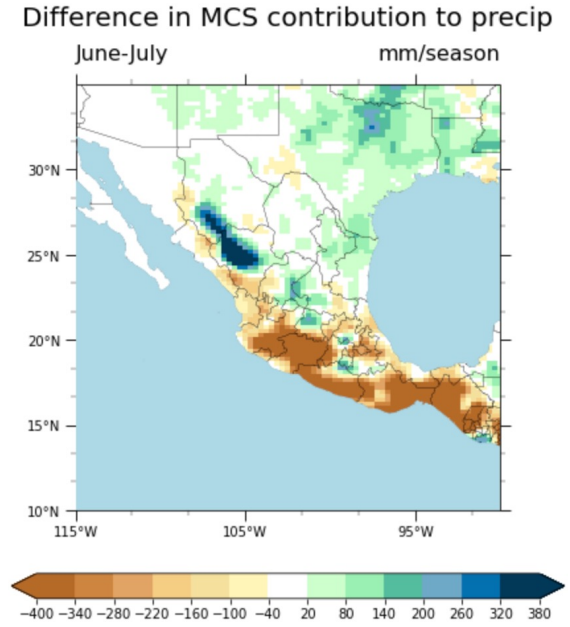




MCS contribution to precipitation

- Increased frequency of NAM MCSs corresponds to greater amount of precipitation brought by MCSs to this region





Conclusion

- High resolution simulation is more consistent with Pliocene proxy records for the hydroclimate changes in the NAM region
- Preliminary results suggest the increase in summer precip is associated with an increase in MCS frequency

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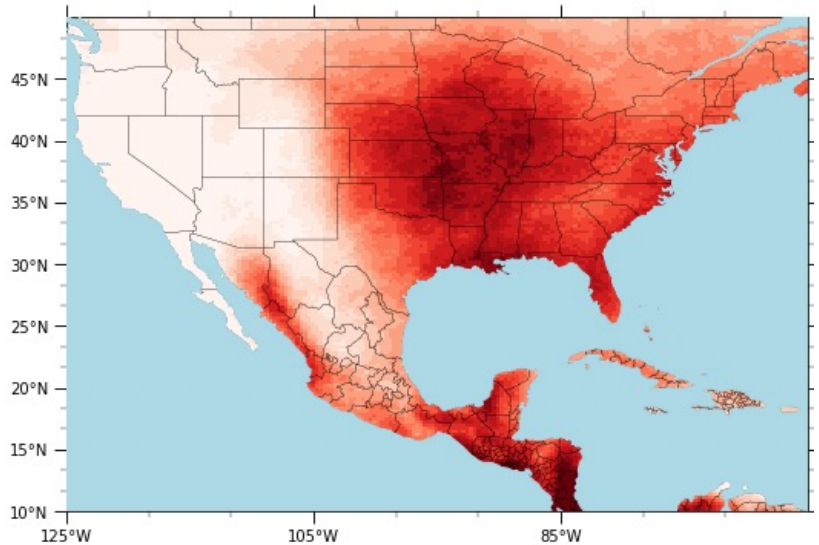
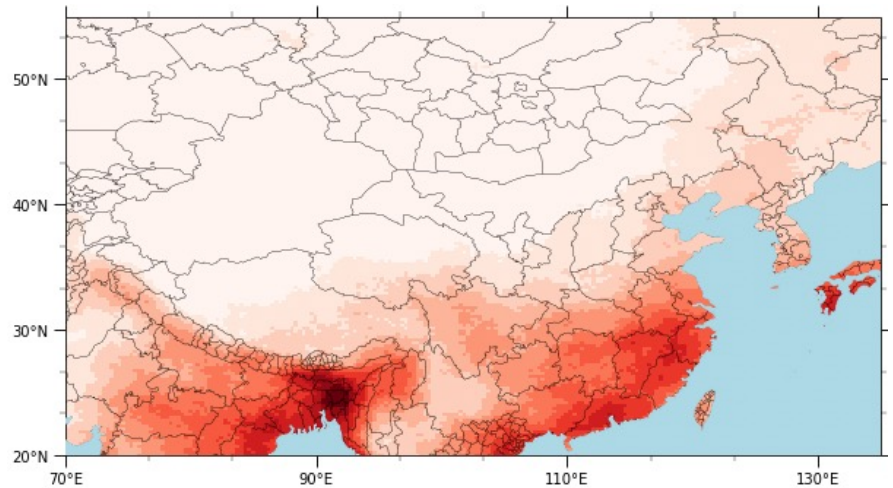
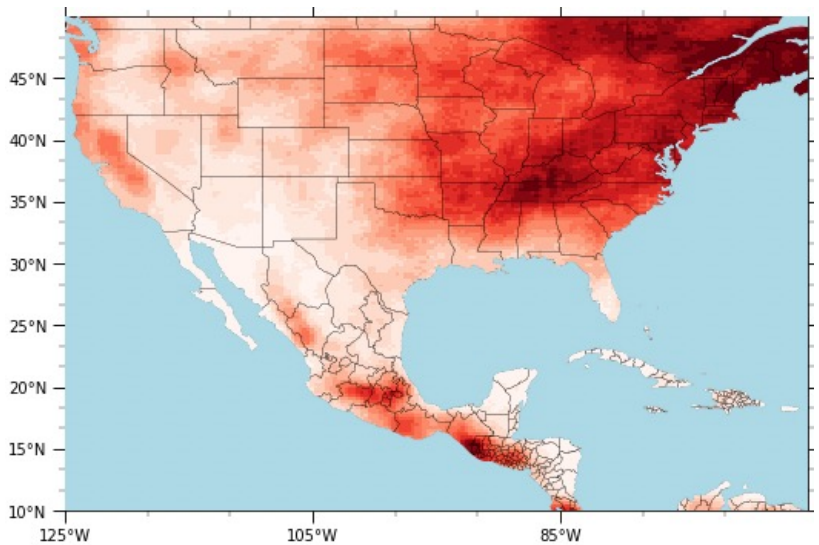
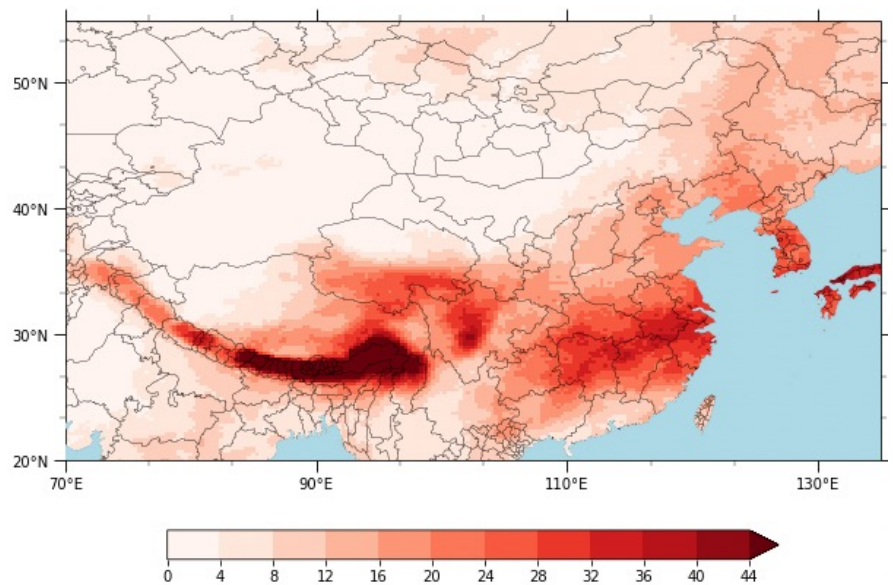
Observed March-August MCS Counts



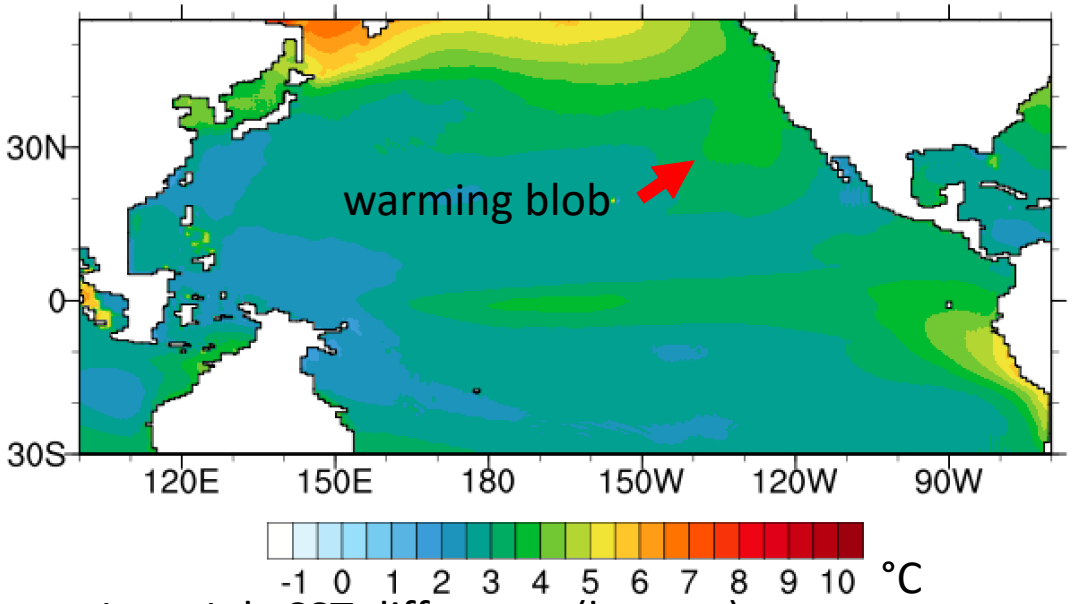


Simulated March-August MCS Counts





June-July SST difference (high res)



June-July SST difference (low res)