The Response of the North American Monsoon to Increased GHG Forcing
The North American Monsoon

source: Adams & Comrie, 1997
Delayed monsoon onset/withdrawal w/ +GHG

*a Global

source: % Prec Change, Seth et al, 2011
Gross stability of the tropical troposphere is the difference between the moist static energy and is defined as

\[ \text{MSE} = \text{DSE} + Lq \]

where

- \( \text{DSE} \) is the dry static energy,
- \( Lq \) is the latent heat of evaporation,
- \( T \) is the layer temperature,
- \( g \) is gravity,
- \( p \) is the pressure,
- \( c_p \) is the specific heat at constant pressure,
- \( L \) is the layer thickness,
- \( Z \) is the geopotential height, and
- \( gZ \) is the specific volume.

Because there is little water vapor in the flow aloft, the local mechanism is related to increased stability that results from a warmer tropical specific humidity. The precipitation reduction is stronger and extends deeper into the rainy season over land (Fig. 2, b), while the late rainy seasons (Feb–Mar, 2001) show clear strengthening of summer hemisphere rainfall. Can this global-scale shift in the timing of tropical precipitation be understood in terms of the mechanisms outlined above? Recall the remote mechanisms outlined above? Recall the remote...
The North American Monsoon

source: Seth et al, 2011
How well do CMIP5 models simulate the NAM?

How does the NAM respond to +GHG forcing in the CMIP5 experiments (historical vs RCP 8.5)?

Are these shifts consistent with stability changes due to atmospheric warming and changes in surface moisture?
Moist Static Energy

\[ MSE_{700}^* = C_p T_{700} + L_v q_{700}^* + g z_{700} \]

\[ MSE_{surf} = C_p T_{2m} + L_v q_{2m} \]

JAS Precipitation, % of Annual

Monthly Climatology

a. b.
Higher Resolution

b.

- GPCC
- CCSM4
- CNRM–CM5
- HadGEM2–CC
- HadGEM2–ES
- MIROC5

Tuesday, February 12, 13
ΔPrecip, RCP 8.5, mm d⁻¹ (2080–2099 vs 1980–1999)

- CCSM4
- CNRM–CM5
- CSIRO–MK3.6.0
- CanESM2
- GFDL–CM3
- GFDL–ESM2G
- GFDL–ESM2M
- HadGEM2–CC
- HadGEM2–ES
- MIROC5
- MPI–ESM–LR
- GFDL–CM3
- GFDL–ESM2G
- GFDL–ESM2M
- HadGEM2–CC
- HadGEM2–ES
- MIROC5
- MPI–ESM–LR

b.

Tuesday, February 12, 13
Total Change, Monsoon Season (Jun-Oct): -2%

Total Change, Annual Total: -26%
Δ Precip, RCP 8.5, mm d (2080−2099 vs 1980−1999)
Moist Static Energy

\[ \Delta \text{MSE}^* - \Delta \text{MSE}_{\text{surf}} \]
CMIP5 models show changes in the NAM consistent with other monsoon areas

Physics consistent with expected change to atmospheric stability

Model wet biases?