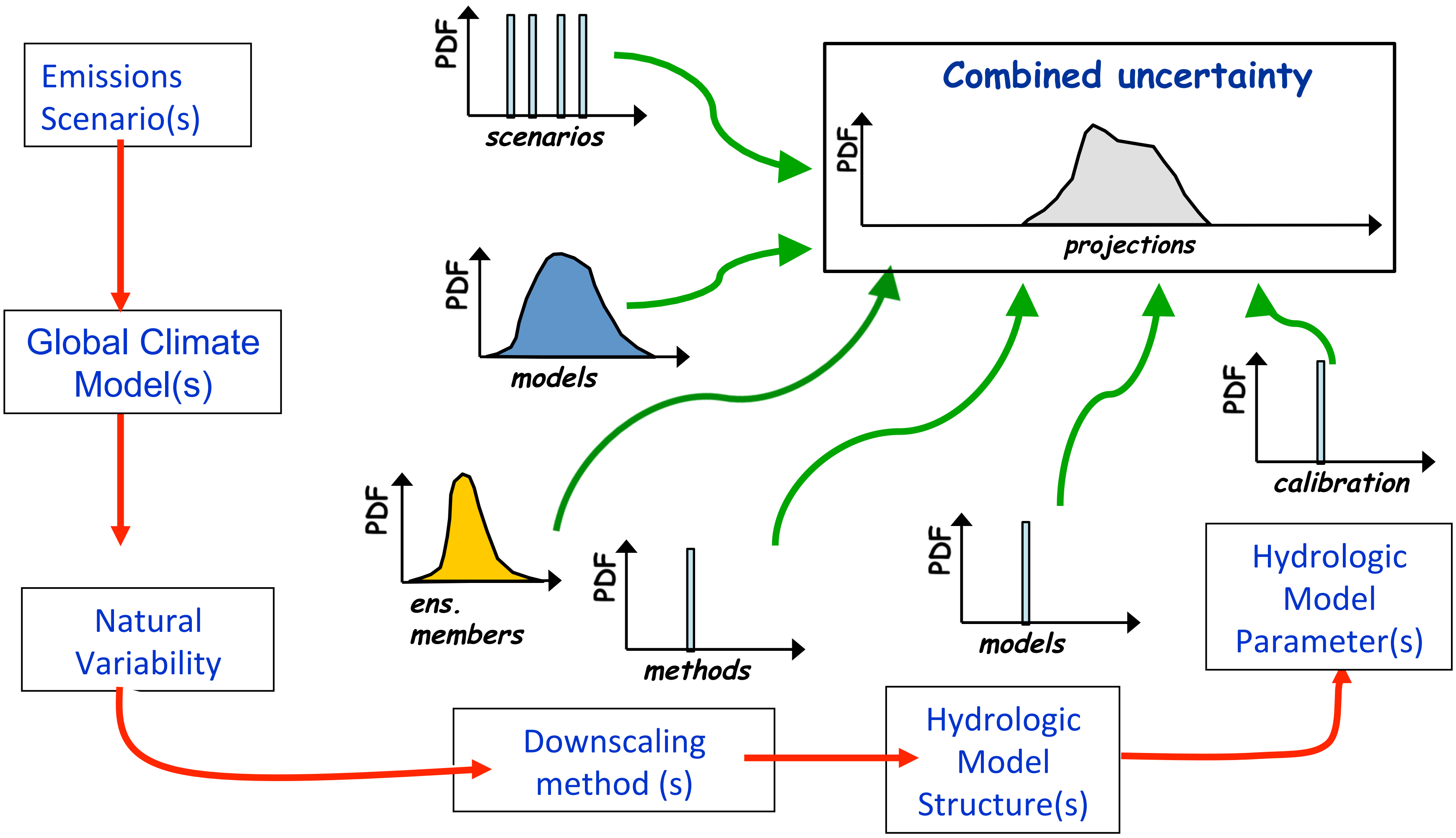
Sources of Uncertainty in Climate Projections

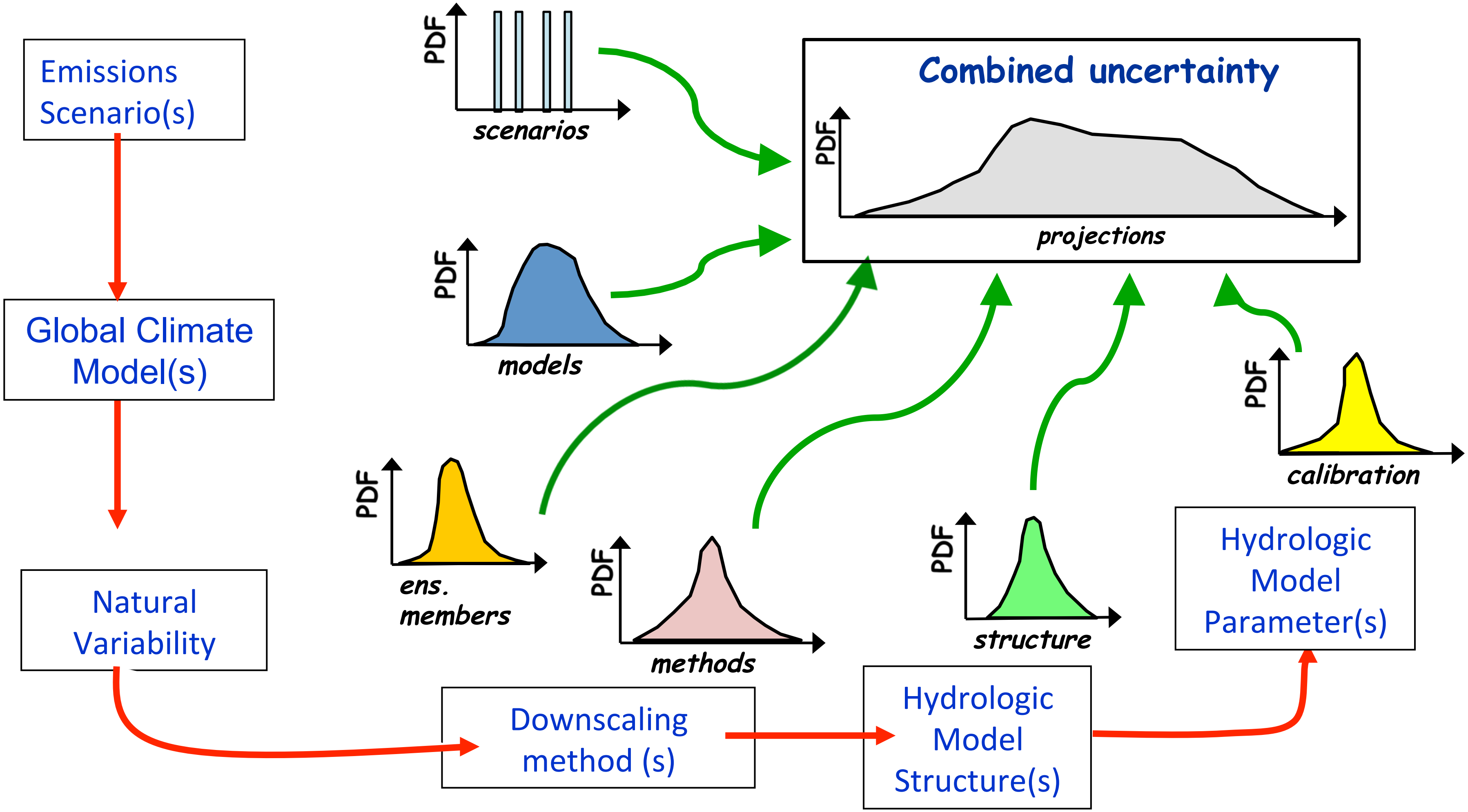
Ethan Gutmann, Martyn Clark,
Jeffrey Arnold, Clara Desser, Kyoko
Ikeda, Roy Rasmussen, et al.

"Uncertainty is an uncomfortable position.
But certainty is an absurd one."
-Voltaire

Revealing the uncertainties



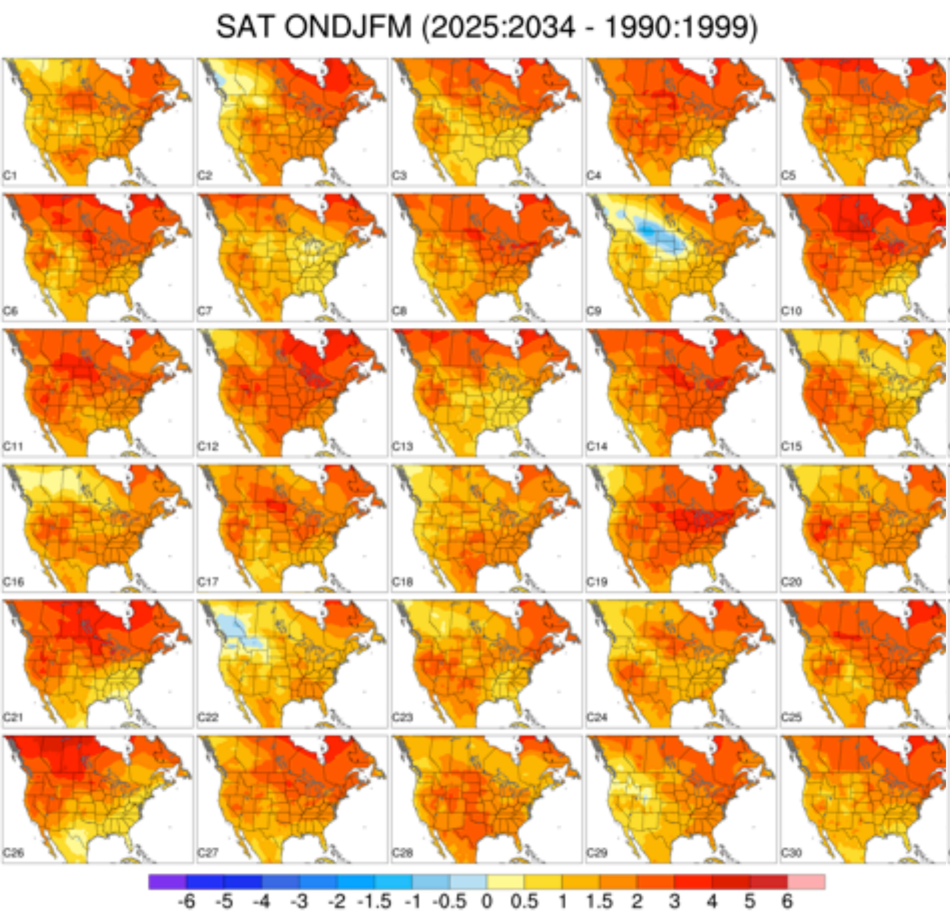
Revealing the uncertainties

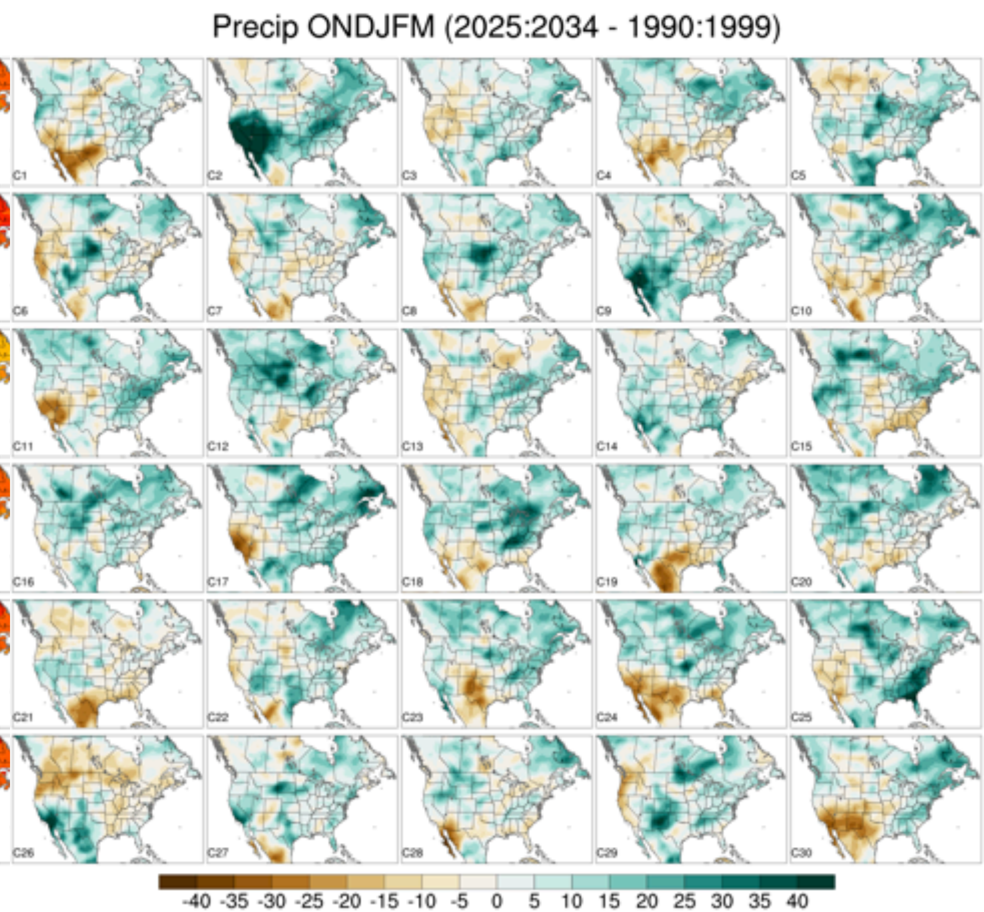


What will the future look like?

Warmer
Air Temperature
(mostly)

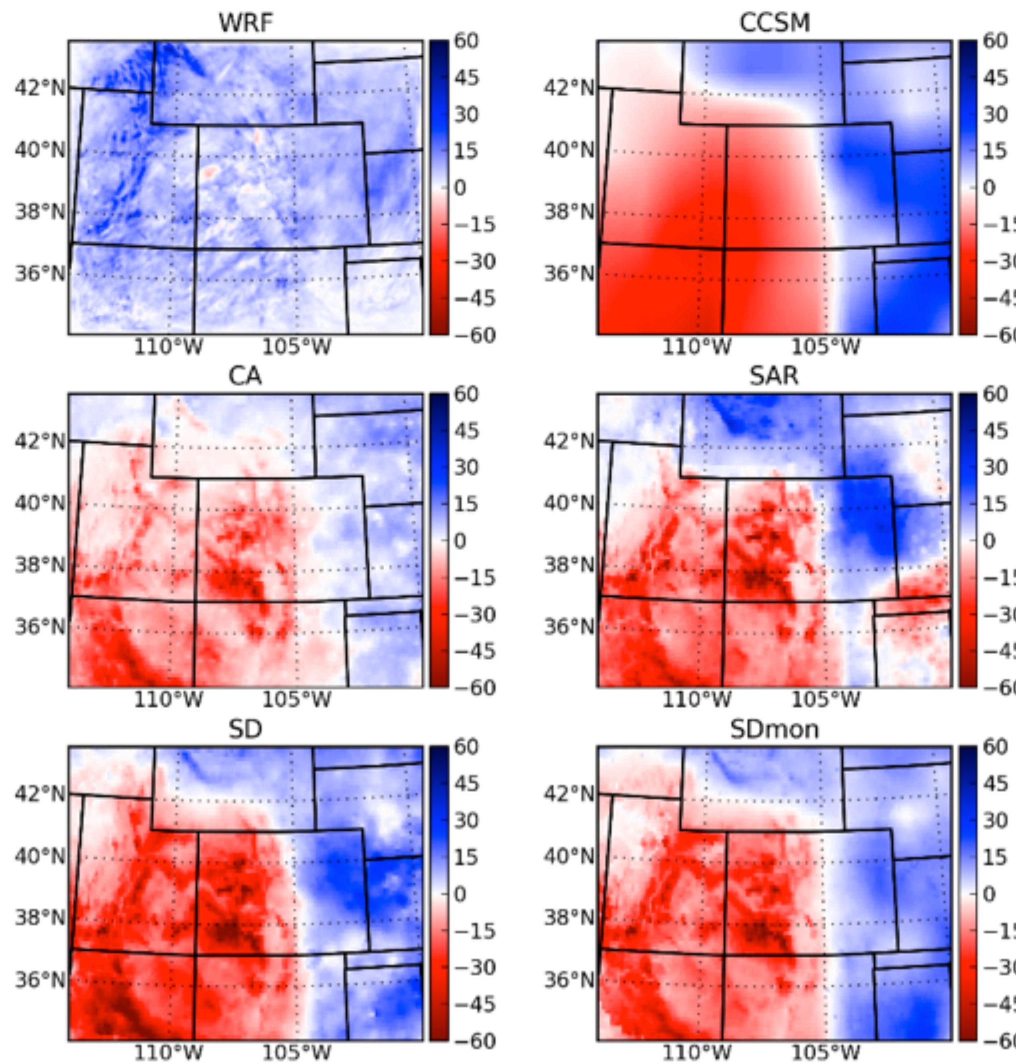
Wetter
And Drier…
(Sometimes?)





Representation of Climate Change

- Problems with historical fidelity aside…
- How do different methods represent climate change.
- Statistical methods are almost identical.
- Dynamical simulation is very different.



A dichotomy of downscaling options

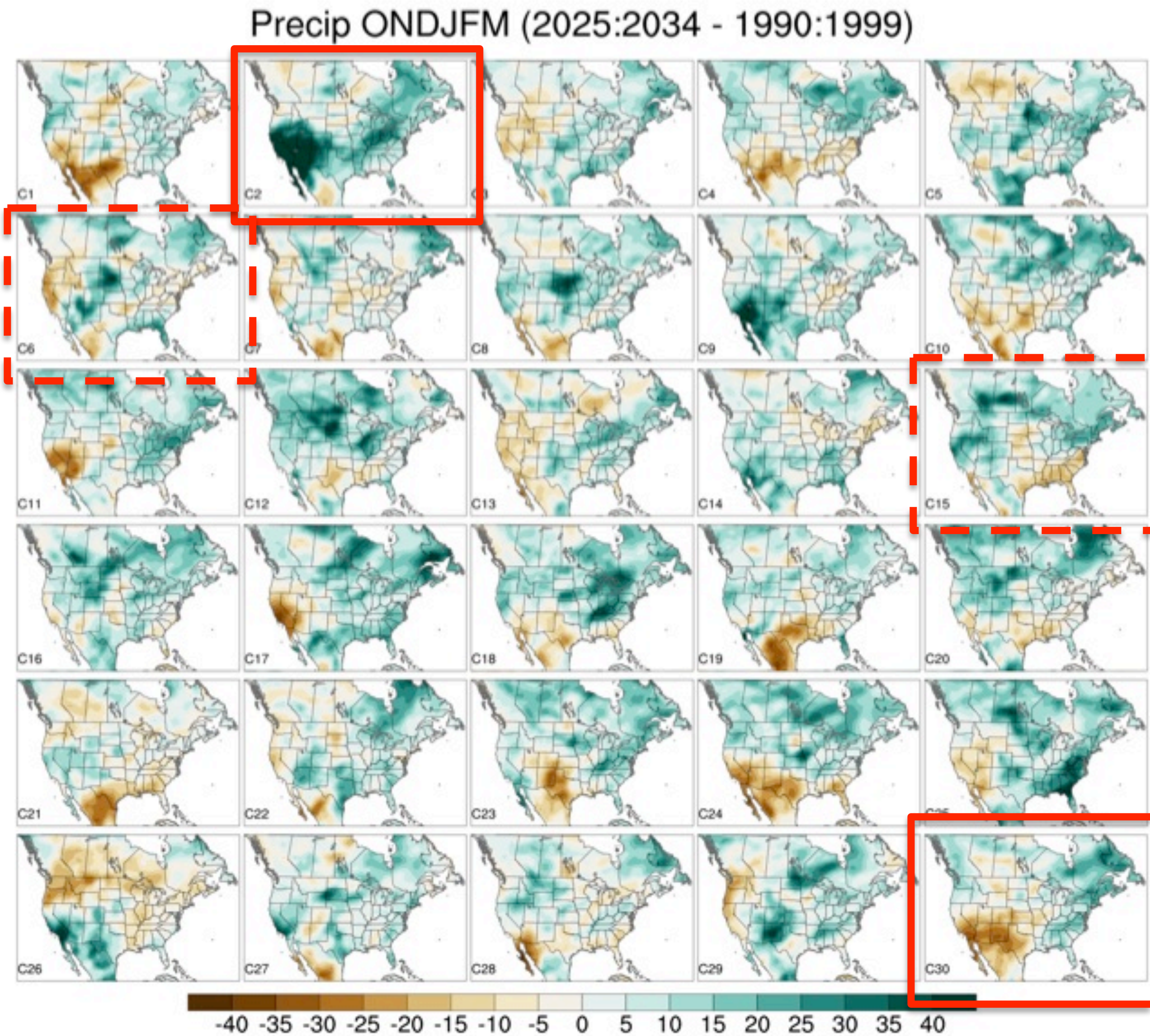
False

increasing physical representation

- Statistical downscaling based on rescaling GCM outputs
  - BCSD, BCCA, AR
- Statistical downscaling based on GCM dynamics (water vapor, wind, convective potential, etc.)
  - Regression-based methods
  - Analog methods
- Sophisticated circulation methods to relate the space-time variability of downscaled fields to synoptic scale atmospheric predictors (self-organized maps, etc.), possibly enhanced stochastically
- Dynamical downscaling using simple weather models
- Dynamical downscaling using state-of-the-art RCMs

The CESM Large Ensemble
Variability in the Climate Signal

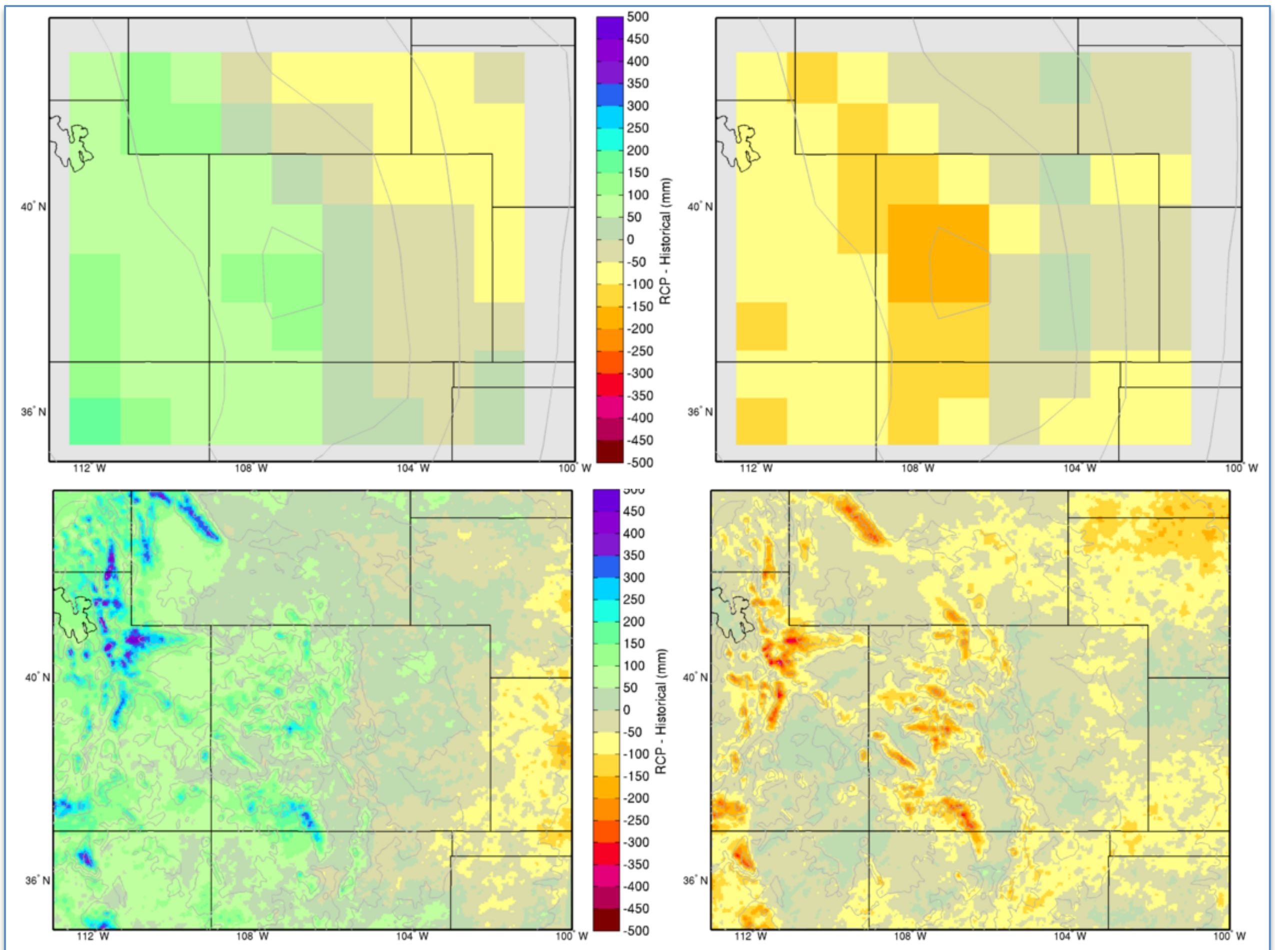
- **CESM-LE simulates tremendous variability in precipitation changes**
- **Will this variability increase or decrease with a more sophisticated treatment of the physics?**
- **Initially selected two end members for WRF downscaling**
  - Increasing Precipitation (Ens 2)
  - Decreasing Precipitation (Ens 30)
- **Now adding 4 more**
  - dashed lines + 2 not shown 6, 15, 34, and 35
  - 34 & 35 are new and stored hourly precip from CESM



Change in Annual Precipitation

Increasing Precipitation (Ens. 2)

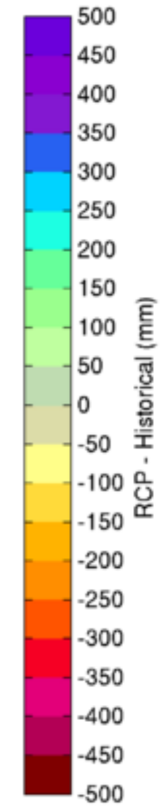
Decreasing Precipitation (Ens. 30)



CESM 111km

↓

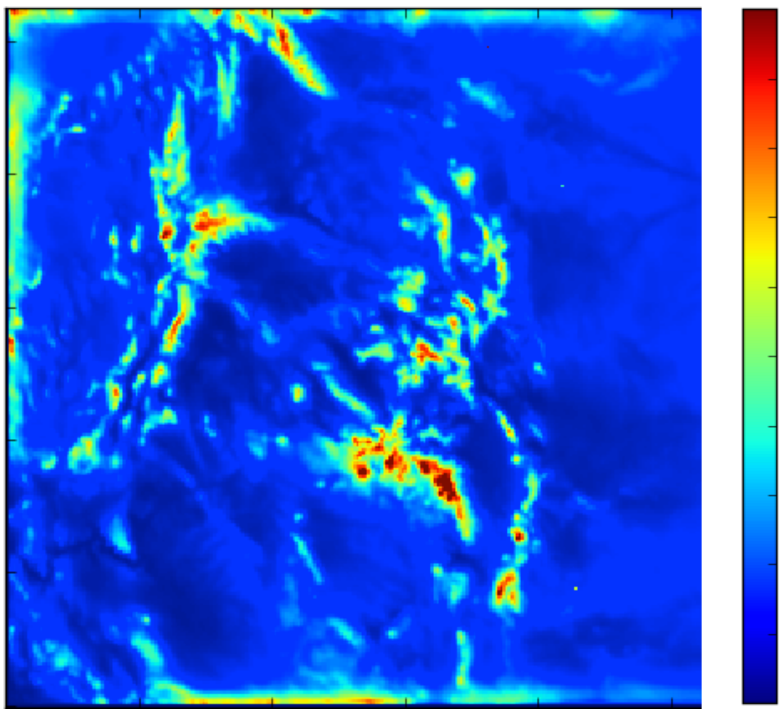
WRF 4km



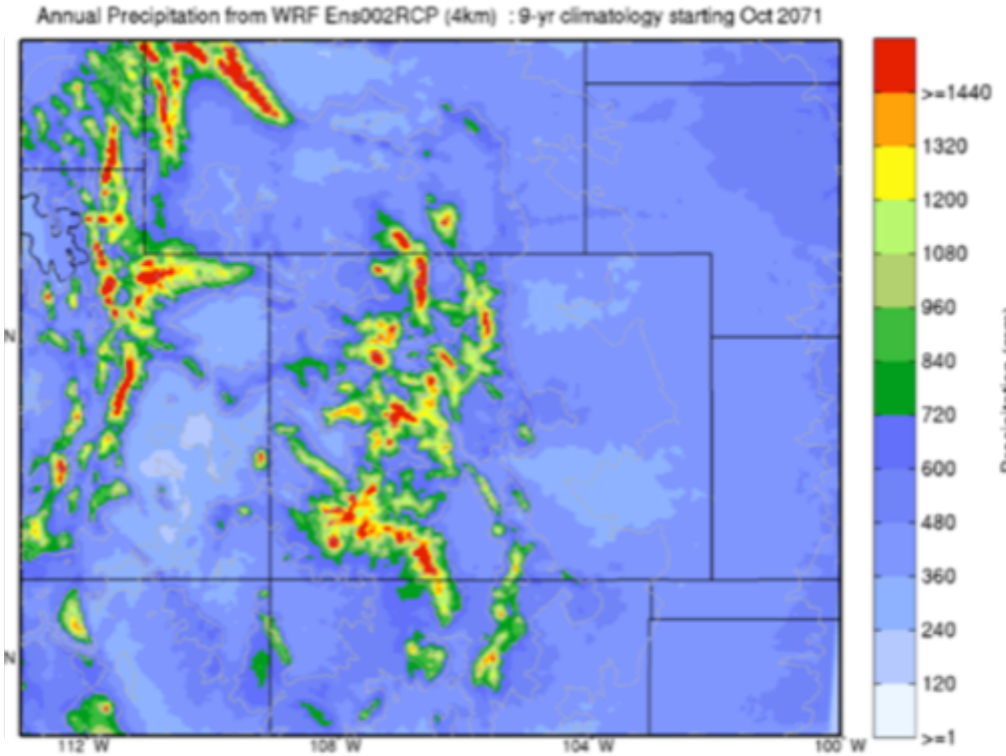
mm

ICAR Precipitation (Run with CESM)

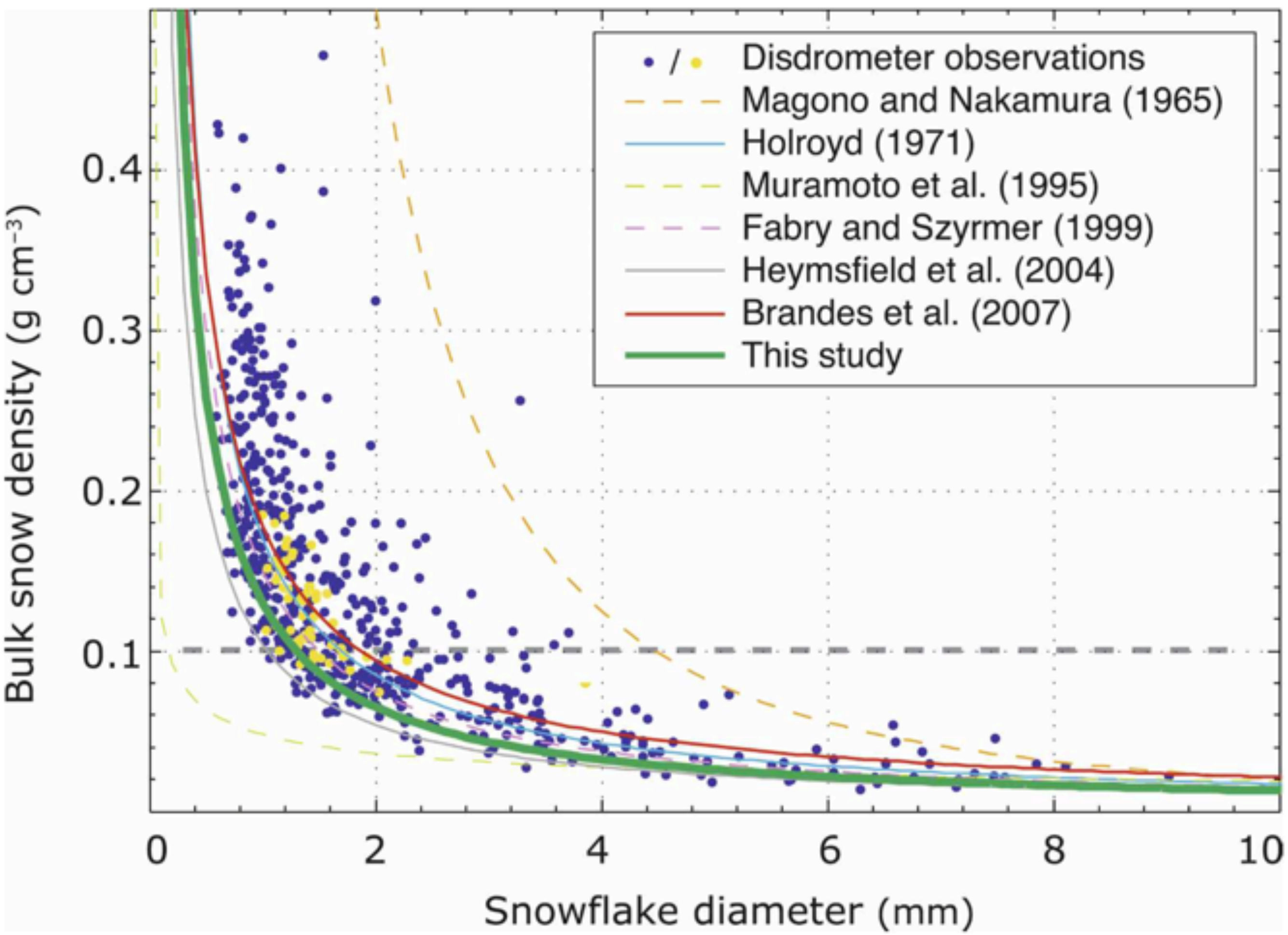
ICAR (30 member average)



WRF (10 year average)



Uncertainty within Physics parameterizations

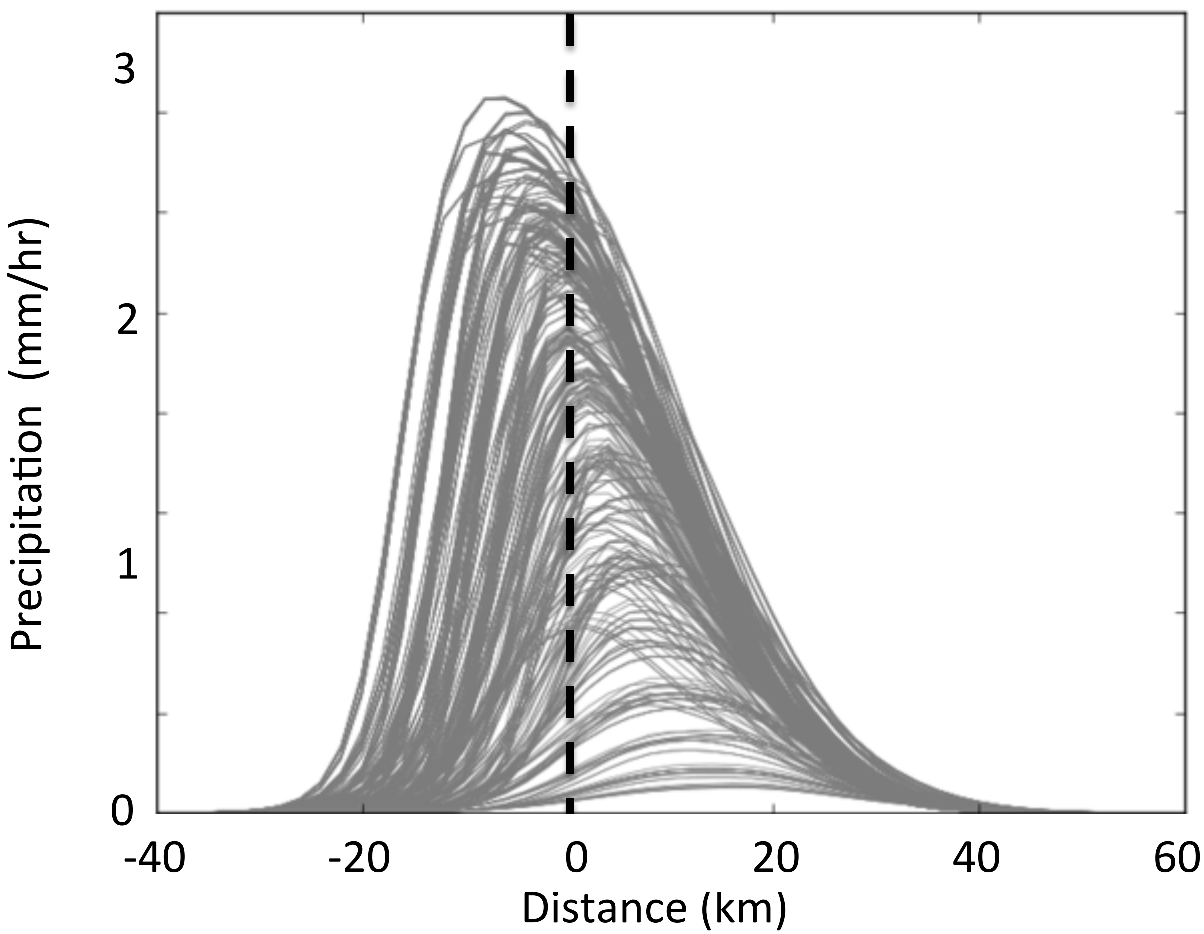


Uncertainty in Microphysics

Parameter Name	Description	Range	Description
Ntc:	Droplet number concentration	50 cm^{-3} – 1000 cm^{-3} Clean air - Polluted	Related to Aerosol concentration
TN0:	Cloud ice number concentration parameterization	0.5 to 50	Vary deposition ice nucleation with a factor of 100.
av_s, bv_s, fv_s:	Snow fall speed parameters	Original Mitchell and Heymsfield (2005). **Test**: Locatelli and Hobbs (1974) used in other microphysical schemes.	
av_i:	Cloud ice fall speed	Original: 1847 (Ferrier, 1994) **Test**: 700 (Ikawa and Saito, 1991).	
c_{cube}:	Capacitance (ice, graupel and snow)	Original: 0.5 **Test**: 0.25 (Lin 2008)	Deposition and sublimation dependent on capacitance. Reduced c_{cube} based on Lin (2008)
Bigg:	Droplet freezing	0 : Some aerosol types(?) -5 : Default (most aerosol types) -10 : Relatively clean air (some aerosol types)	Change the temperature for where droplet freezing occur
Ef_sw_l	Snow collecting cloud water.	Original: efficiency < 1 **Test**: efficiency = 1 (used in many microphysical schemes)	Variable collection efficiency based on median volume diameter of snow and cloud water.

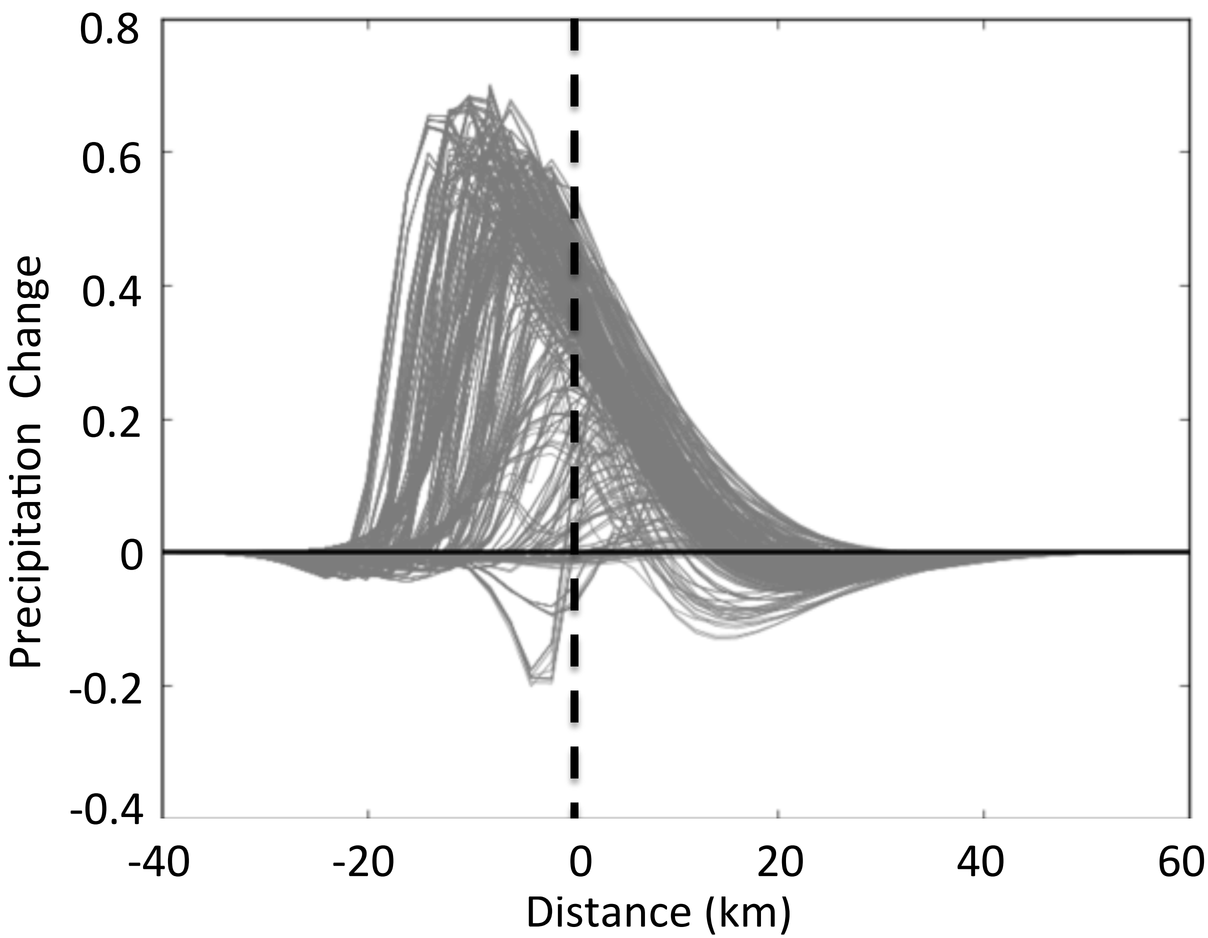
Ideal Hill Case

- Varying all microphysical parameters results in large changes in precipitation
- (Some of these may be unrealistic…)



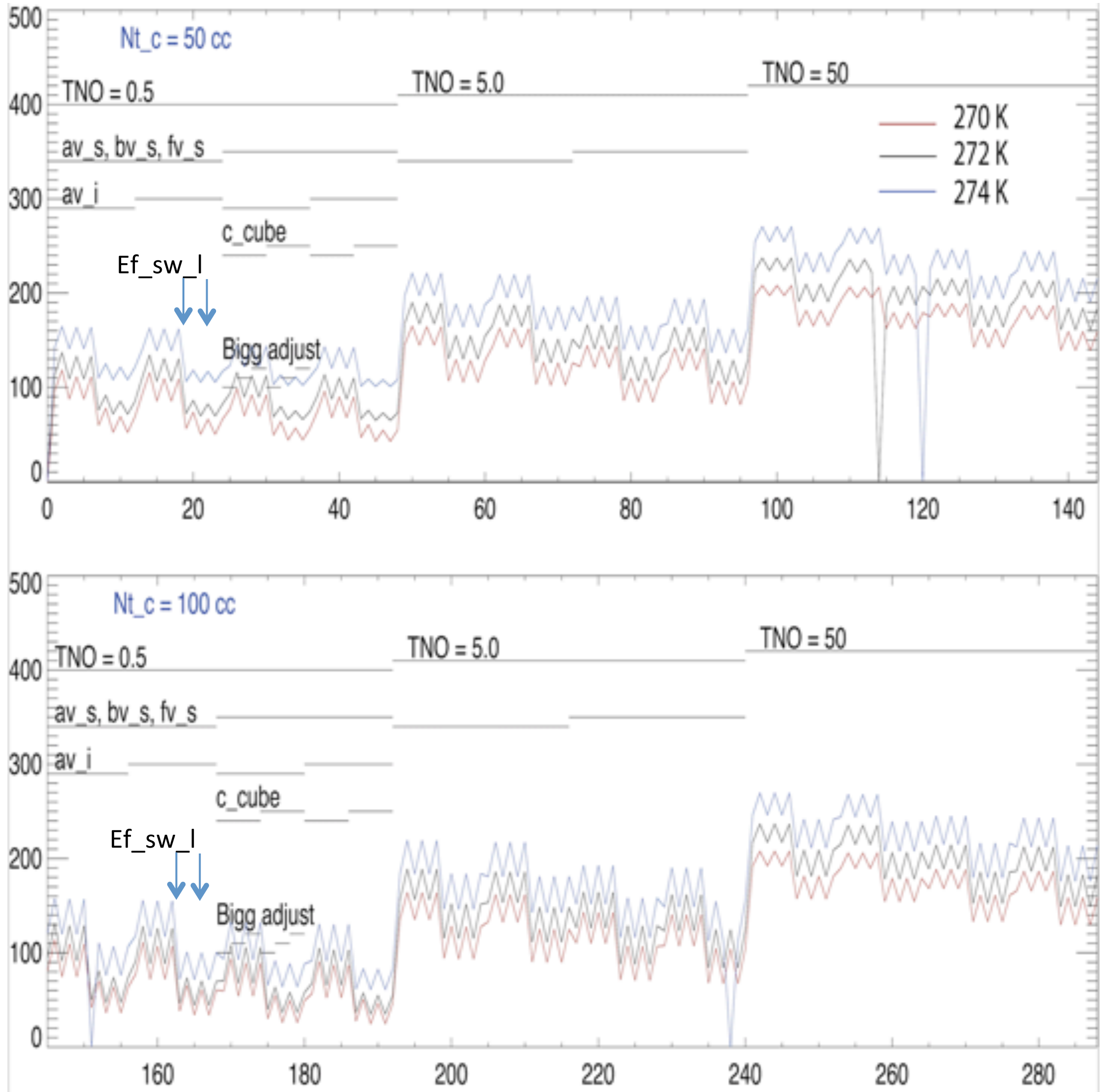
Ideal Change Signal

- These changes affect a climate change signal strongly as well (2°C warming)



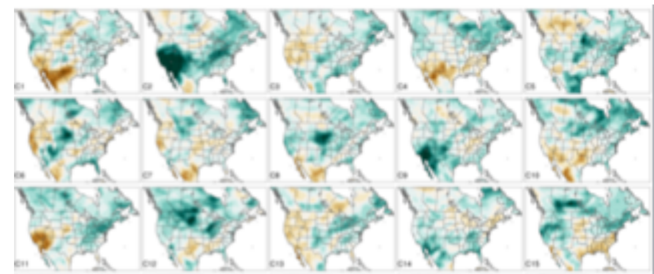
Parameter space

- Mapping these changes back to parameter space can suggest sensitive parameters for further evaluation
- Most important parameters are related to conversion efficiency
  - conversion of cloud ice to snow flakes

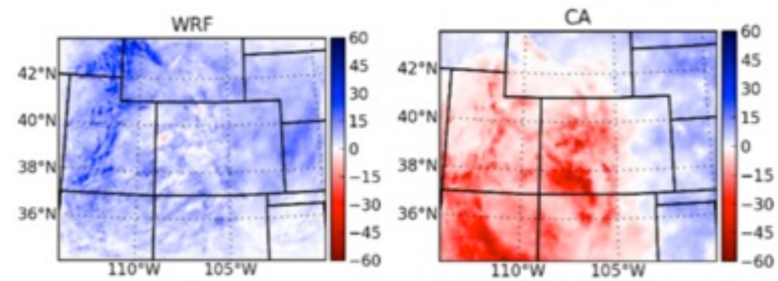


Summary

- Uncertainty in GCM and Internal variability



- Uncertainties in downscaling scheme are significant



- Uncertainty in physics parameters may be large