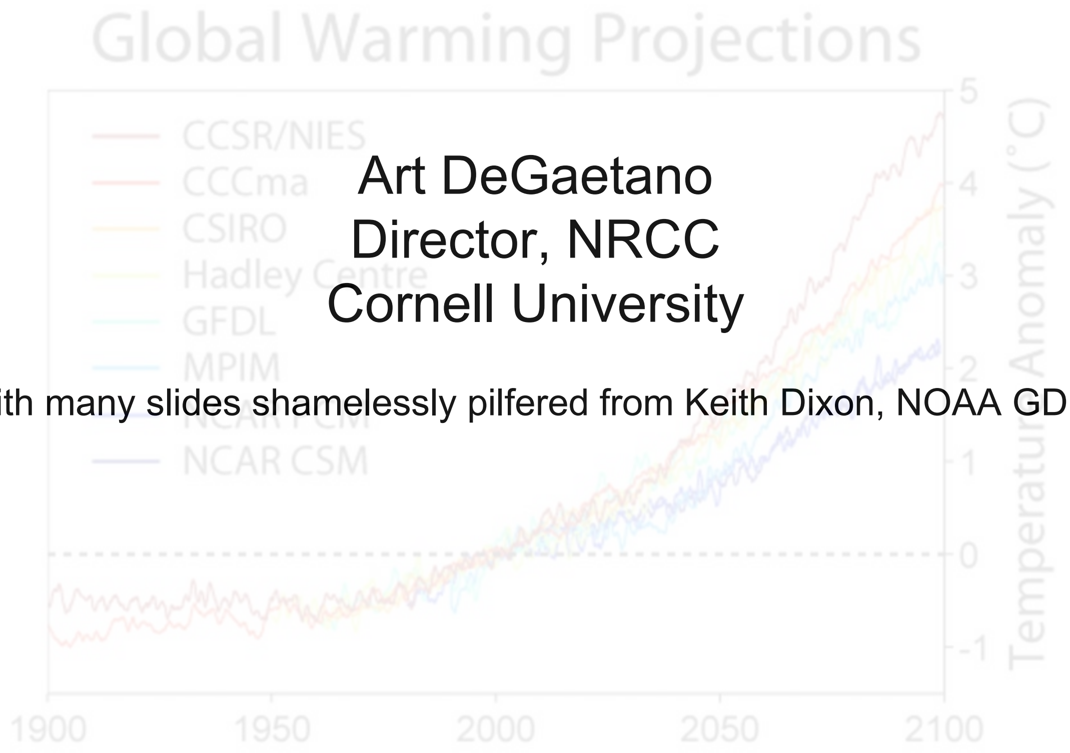
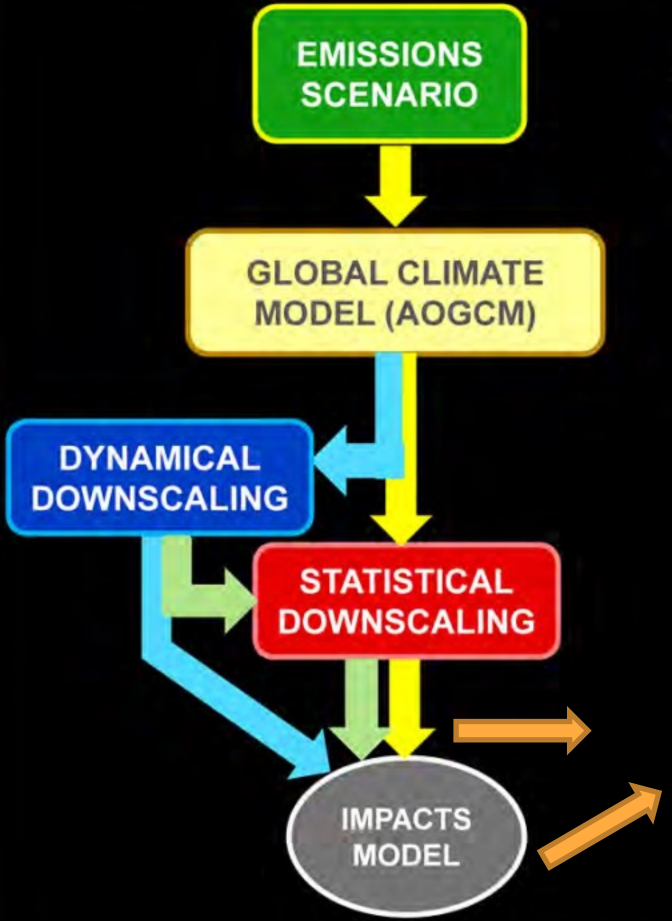
A Quick Overview of Climate Projections



Art DeGaetano
Director, NRCC
Cornell University

With many slides shamelessly pilfered from Keith Dixon, NOAA GDFL

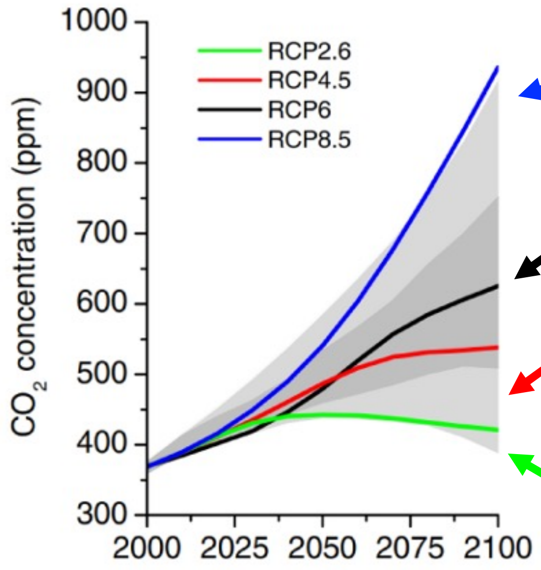


A simplified view of the process…

…mindful that "uncertainties" are introduced in each step of the process

Projections!!!!!

Understanding Societies Priorities and Pathways

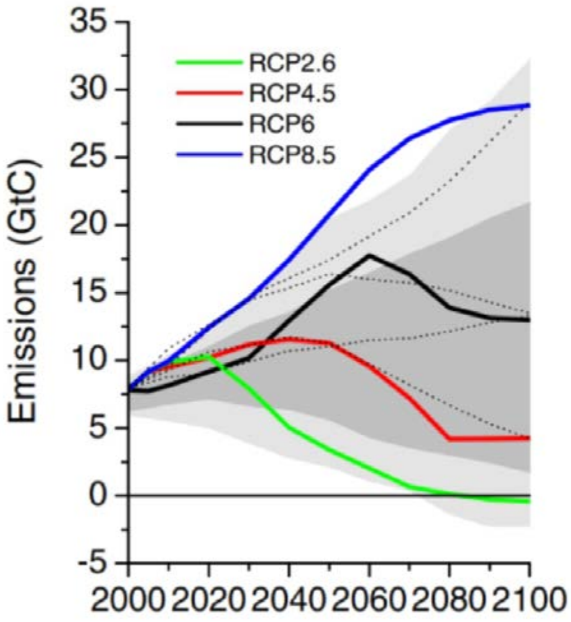


RCP8.5 (4C) - Little curbing of emissions
We are on this path!

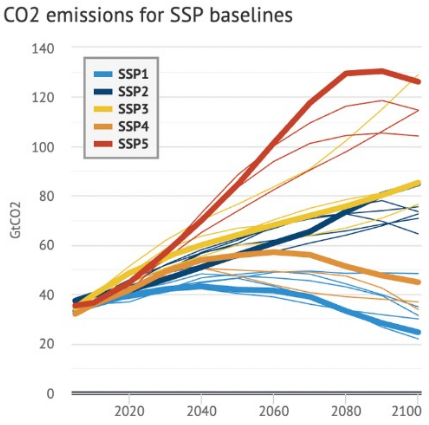
RCP6.0 - Some mitigation leads to lower emissions

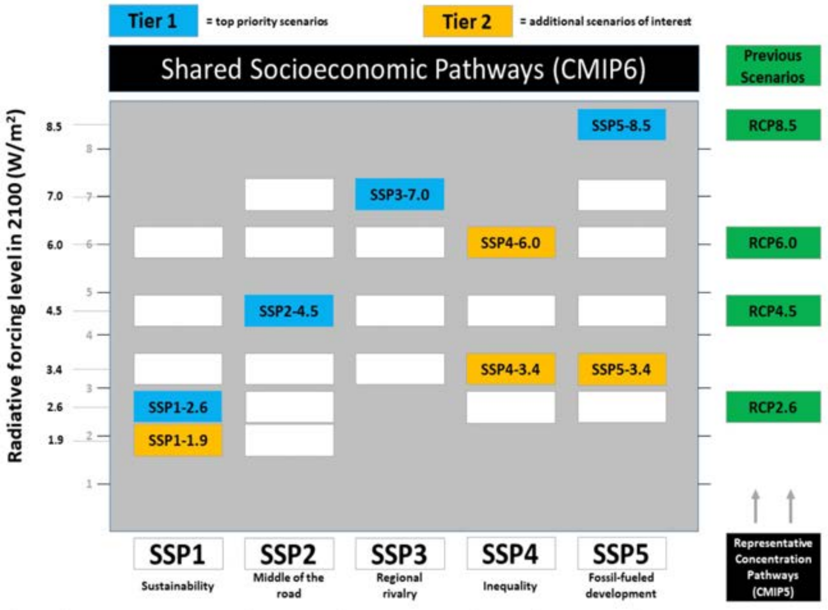
RCP4.5 (2C) – More intense mitigation implemented with some stabilization late in the century

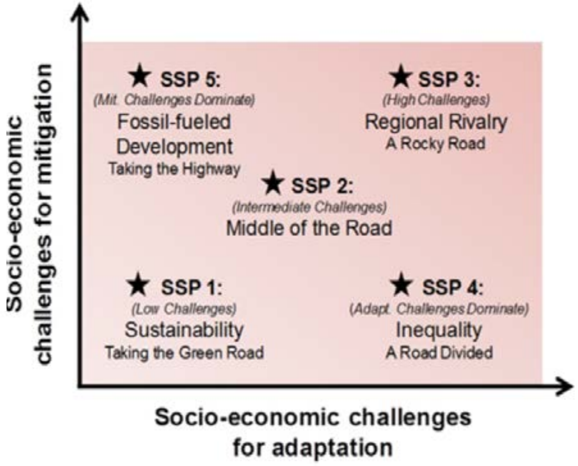
RCP2.6 – Very ambitious mitigation. All countries most participate and technologies to remove carbon from the atmosphere applied



Understanding Societies Priorities and Pathways







Anatomy of a Climate Model

Equations (all models)

Conservation of momentum:

$$\frac{\partial \vec{V}}{\partial t} = -(\vec{V} \cdot \nabla)\vec{V} - \frac{1}{\rho}\nabla p - \vec{g} - 2\vec{\Omega} \times \vec{V} + \nabla \cdot (k_m \nabla \vec{V}) - \vec{F}_d$$

Conservation of energy:

$$\rho c_v \frac{\partial T}{\partial t} = -\rho c_p(\vec{V} \cdot \nabla)T - \nabla \cdot \vec{R} + \nabla \cdot (k_T \nabla T) + C + S$$

Conservation of mass:

$$\frac{\partial \rho}{\partial t} = -(\vec{V} \cdot \nabla)\rho - \rho(\nabla \cdot \vec{V})$$

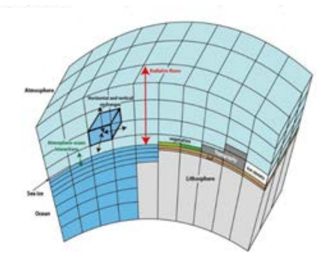
Conservation of H_2O (vapor, liquid, solid):

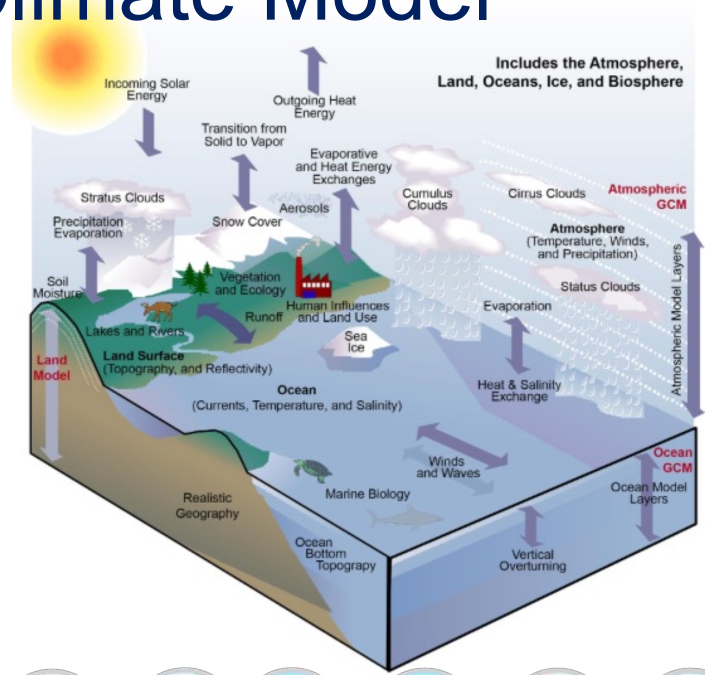
$$\frac{\partial q}{\partial t} = -(\vec{V} \cdot \nabla)q + \nabla \cdot (k_q \nabla q) + S_q + E$$

Equation of state:

$$p = \rho R_d T$$

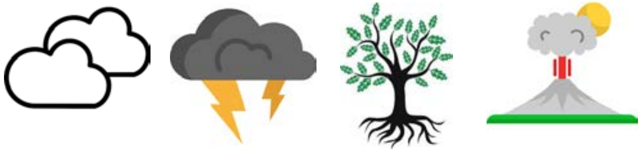
Grid

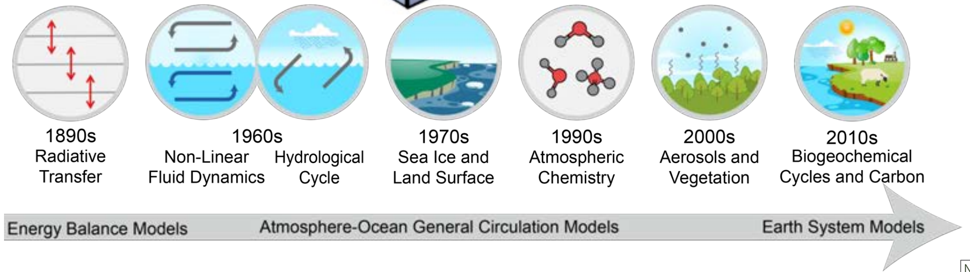




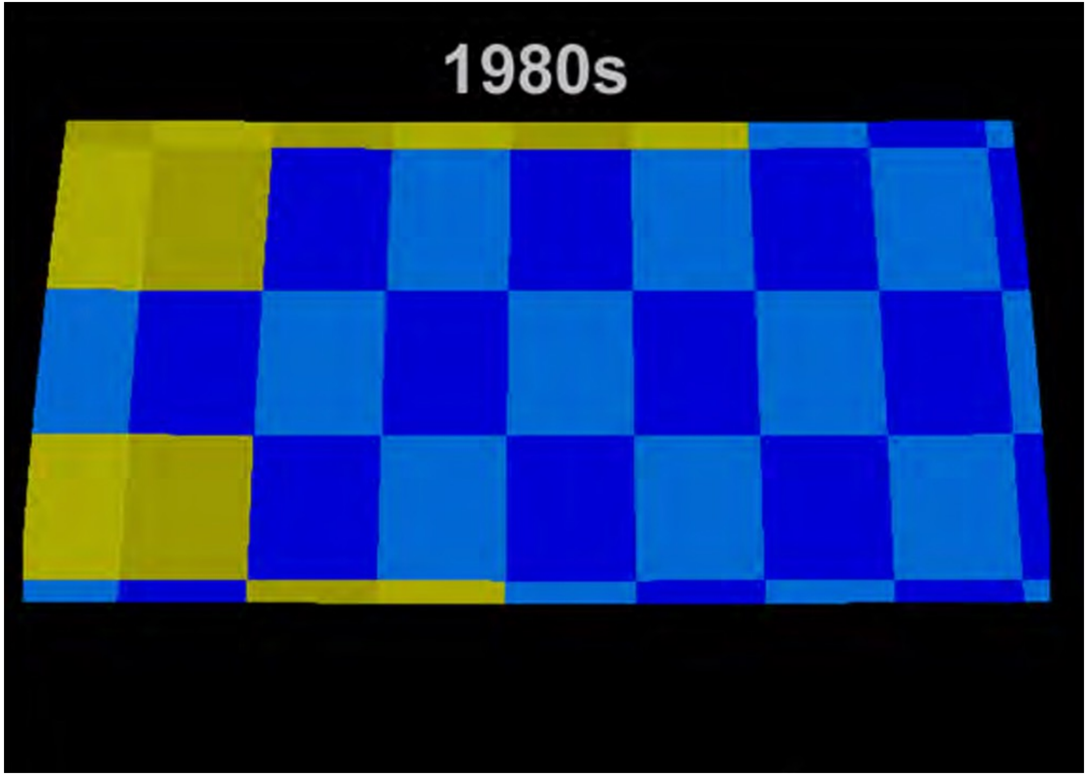
Components Interconnected to allow for Feedbacks

Parameterizations (differ by model)

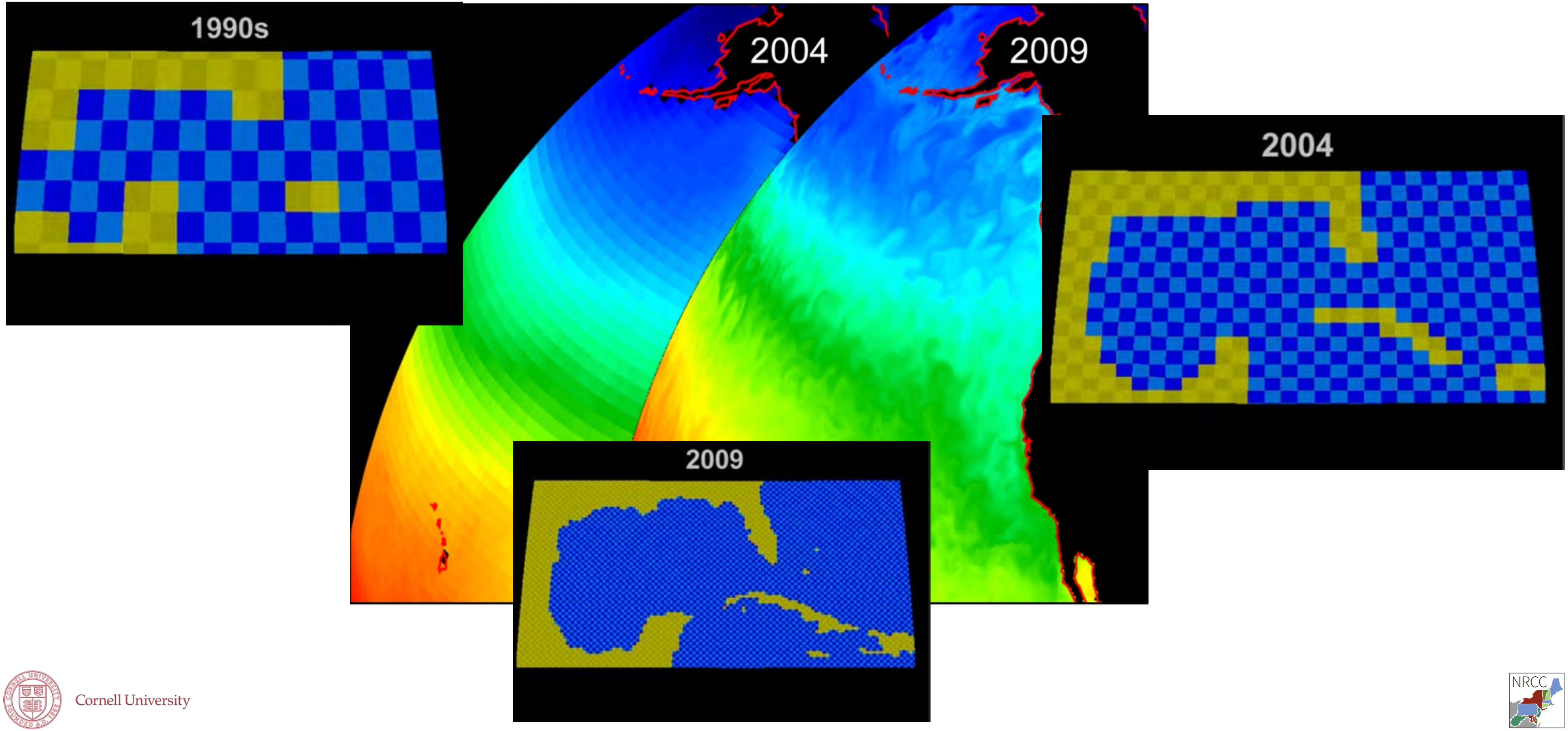




Anatomy of a Climate Model

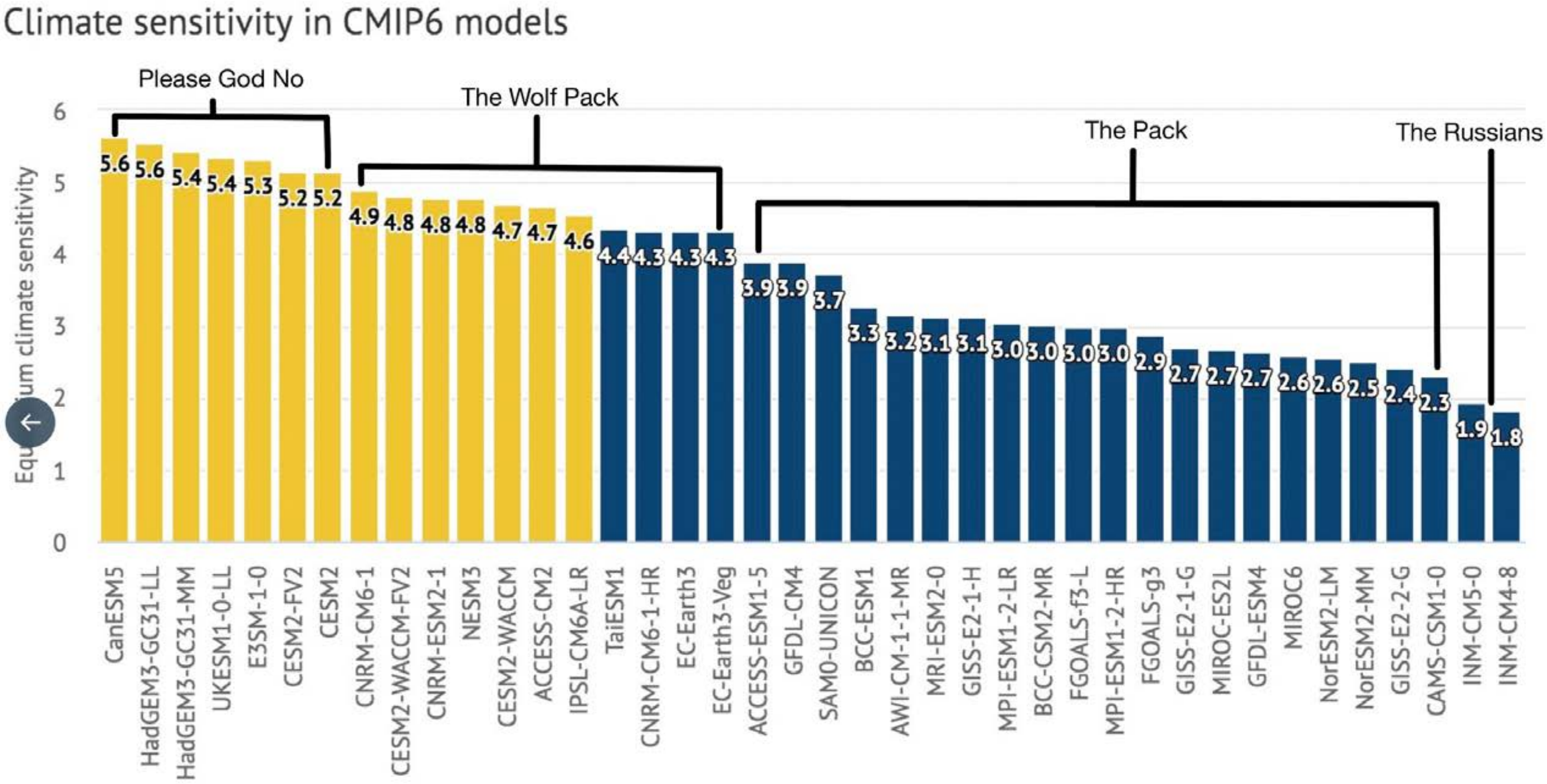


Anatomy of a Climate Model



Anatomy of a Climate Model

amount of global warming over hundreds of years after a doubling of the atmospheric CO_2 concentration.



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Source: Zeke Hausfather https://twitter.com/hausfath

NRCC

Impacts Occur at Finer Scales than GCM Resolution

General Circulation Model
GCM

Statistical Downscaling

- Change Factors
- Regression Methods
- Analog Approaches
- Stochastic Weather Simulators

Dynamical Downscaling
Finer Resolution
Regional Climate Models (RCM)

Downscaled Climate Outputs

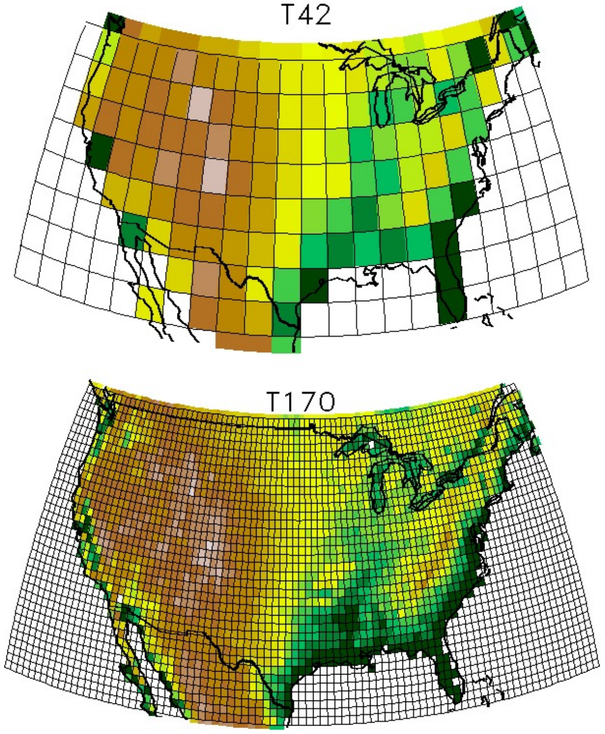
	Atmosphere resolution	Ocean resolution	
SPEAR_LO	100 km	1°	*Global*
SPEAR_MED	50 km	1°	*Region*
SPEAR_HI	25 km	1°	

What is Downscaling?

GOALS WHEN PRODUCING STATISTICAL DOWNSCALED CLIMATE MODEL PROJECTIONS:

A refinement of dynamical model results, informed by observations

1) Account for GCM biases relative to observations
2) Add spatial detail or localized info not present in coarse resolution GCMS
3) Do Not markedly distort the GCM's climate change signal



FAQ

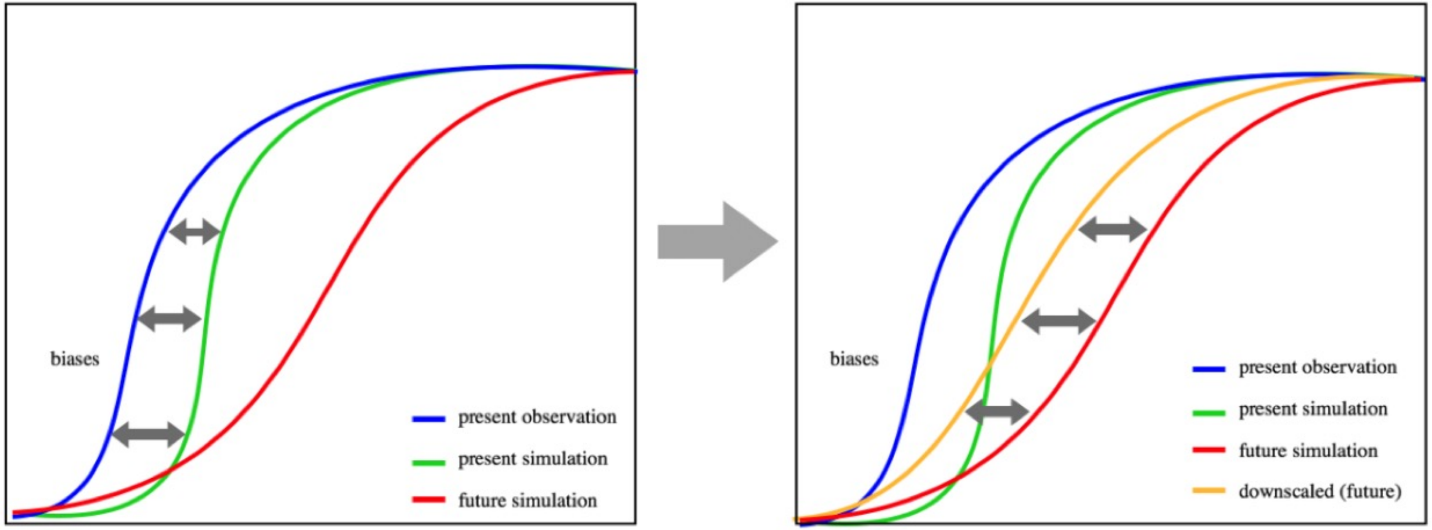
Which is the best downscaling method?

A: It depends on several factors, including what is the intended end use (application).

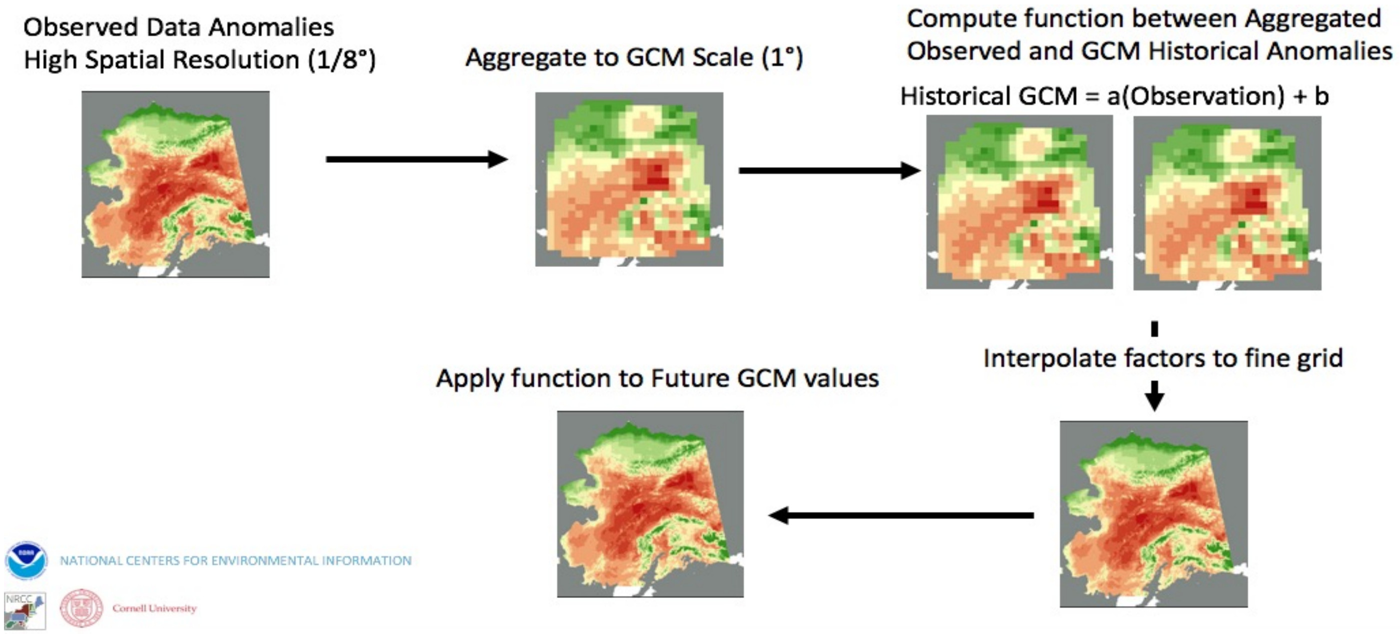
- Time & spatial scales of interest.
- Climate variables of interest.
- Sensitivity to central tendencies vs. extremes or spells.
- Whether ensembles are to be considered.

etc.

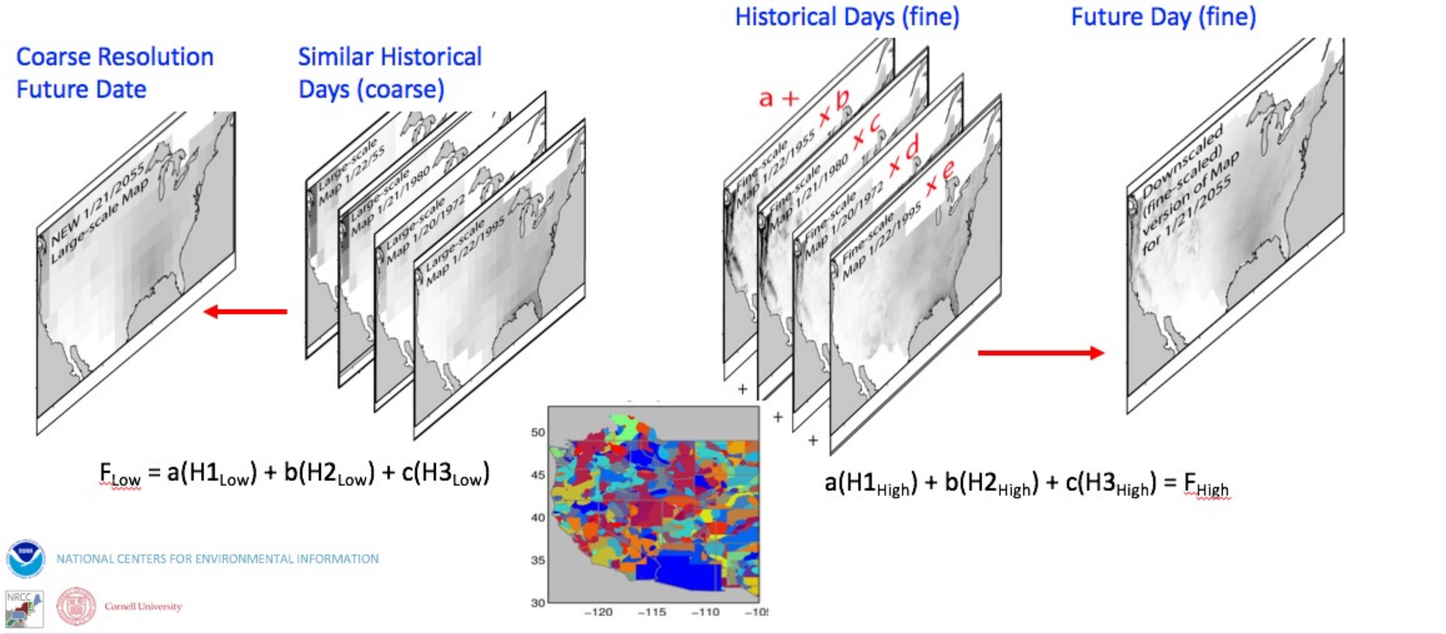
Delta Method Downscaling
Bias Correction



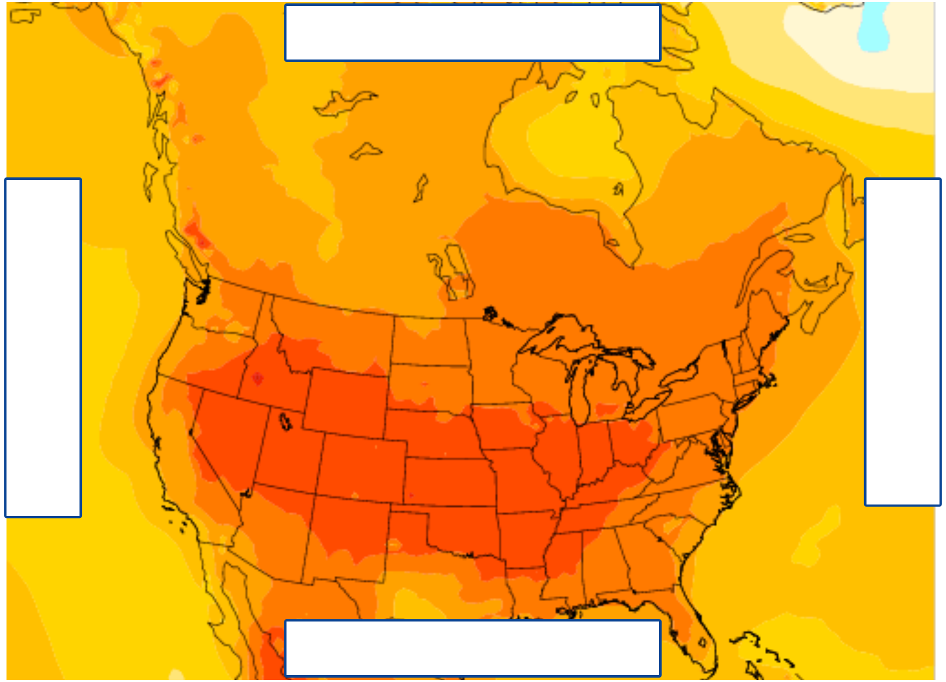
Bias Correction and Spatial Downscaling



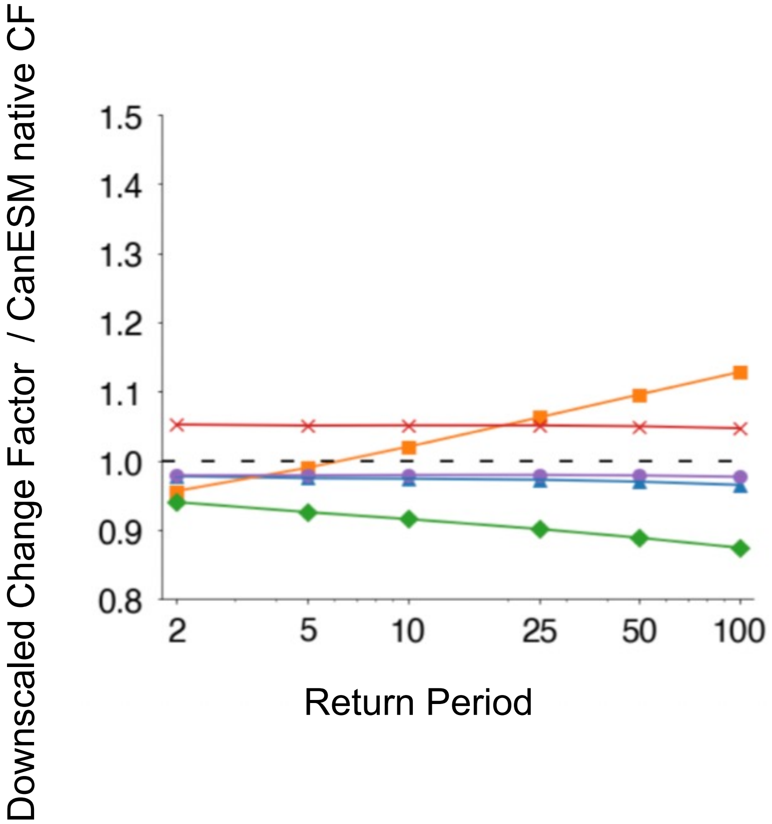
Localized Constructed Analogs



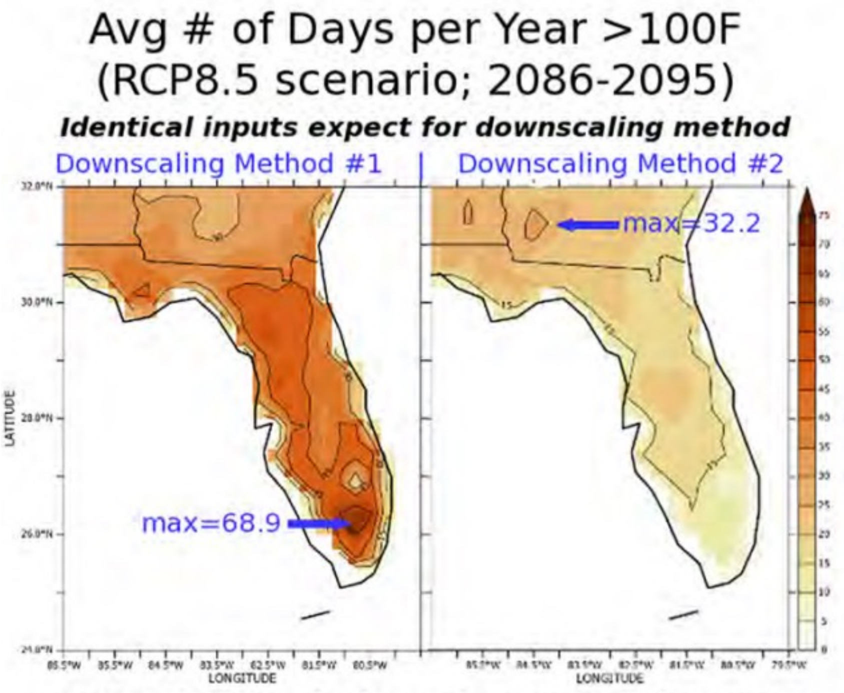
Dynamic Downscaling



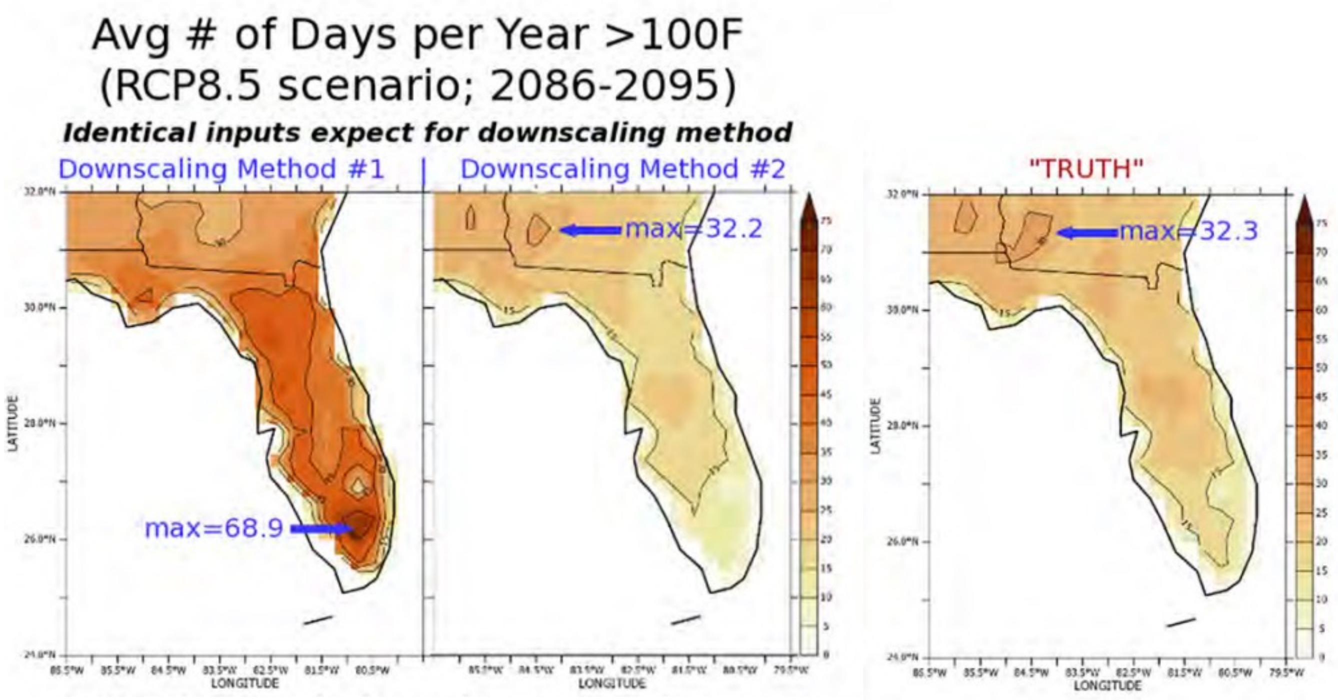
Distort GCM signal



What Method is best?



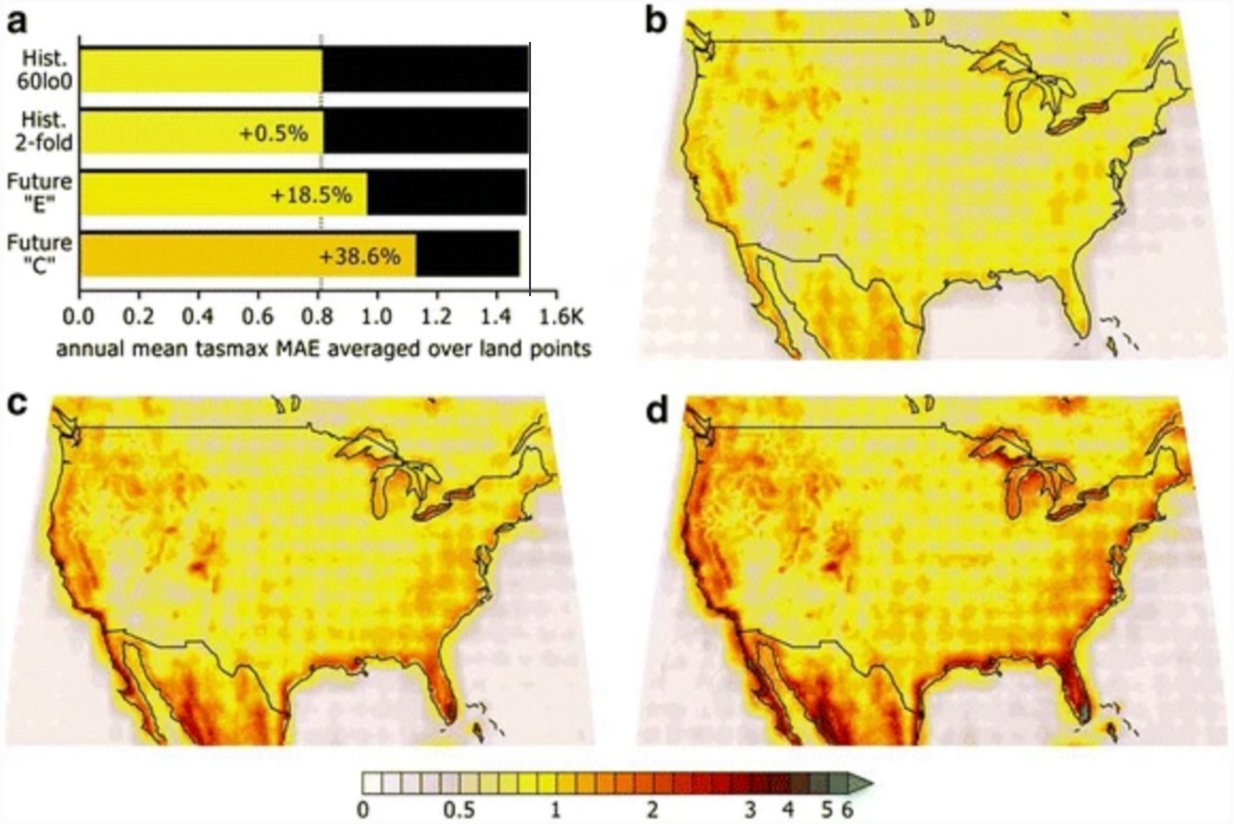
What Method is best?



What Method is best?

Black bars
Coarsened – high res (no downscaling)

Yellow Bars
Downscaled coarsened – high res



Dixon, K.W., Lanzante, J.R., Nath, M.J., Hayhoe, K., Stoner, A., Radhakrishnan, A., Balaji, V. and Gaitán, C.F., 2016. Evaluating the stationarity assumption in statistically downscaled climate projections: is past performance an indicator of future results?. *Climatic Change*, *135*, pp.395-408.

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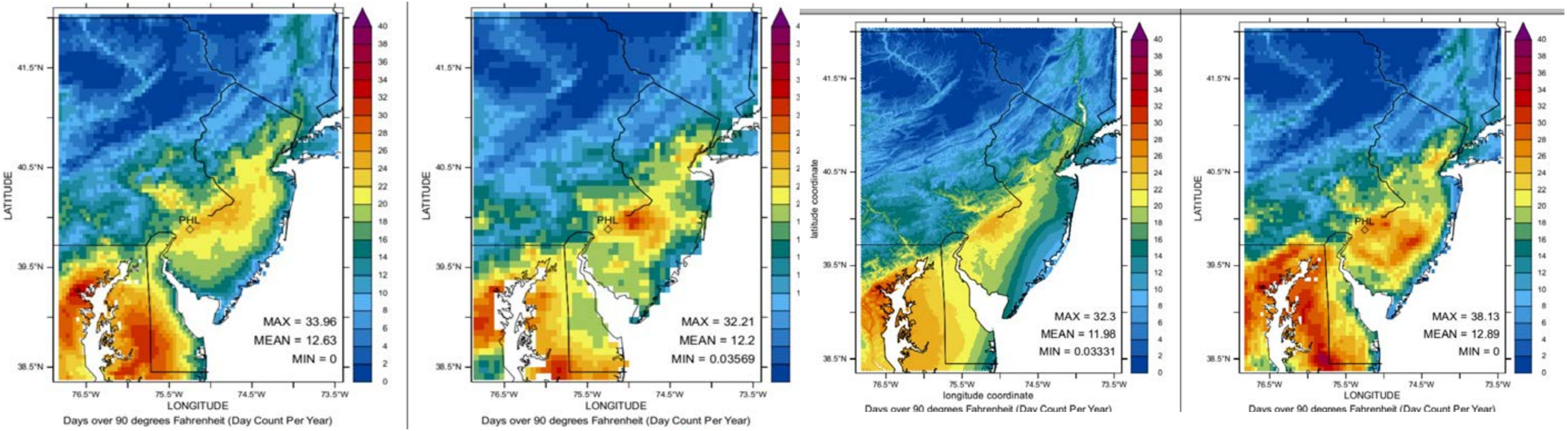
Even Observed Data Set Matters!

Annual Number of Days > 90



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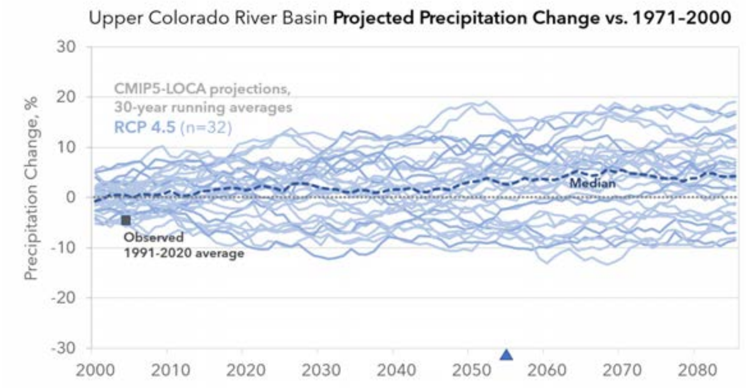
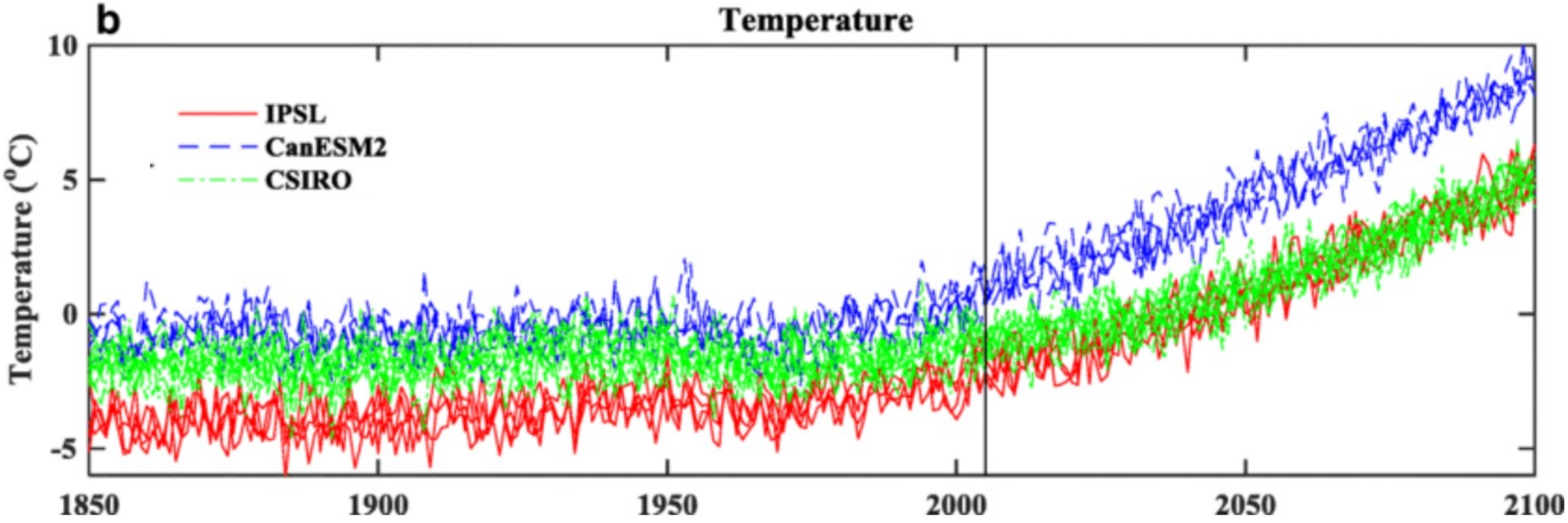
Source: Keith Dixon

Multi Model Ensembles

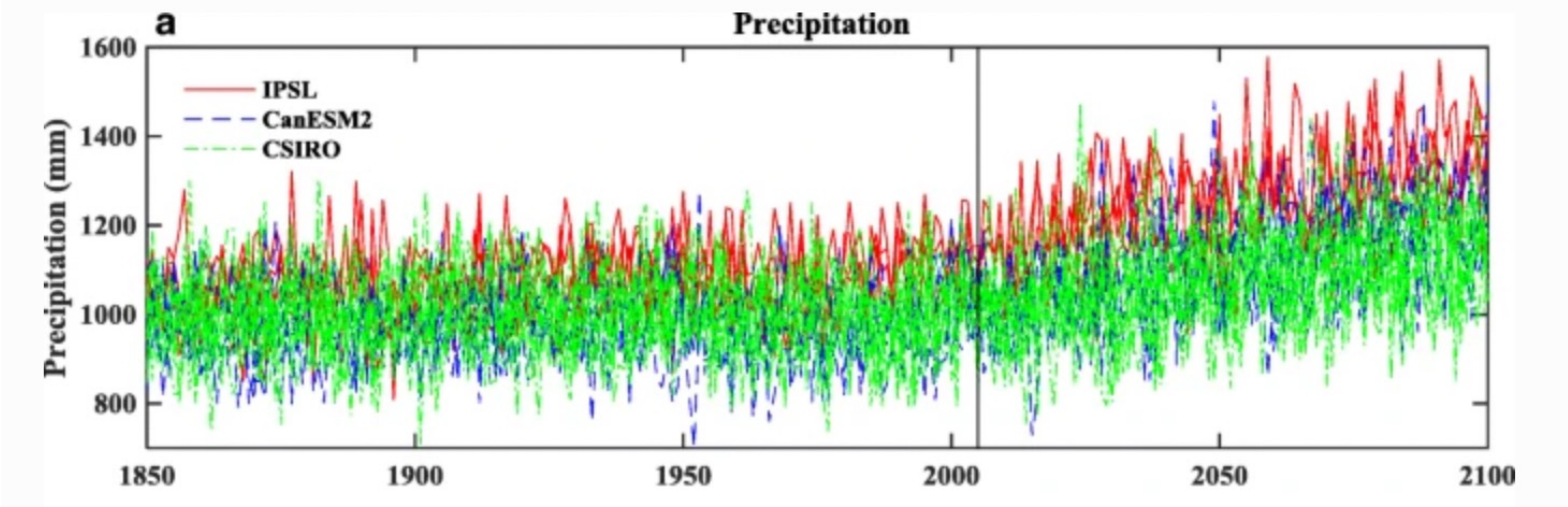


Single Model Ensembles



Chen, J., Brissette, F.P. and Caya, D., 2020. Remaining error sources in bias-corrected climate model outputs. *Climatic Change*, *162*(2), pp.563-582.

Single Model Ensembles



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CMIP5 vs CMIP6

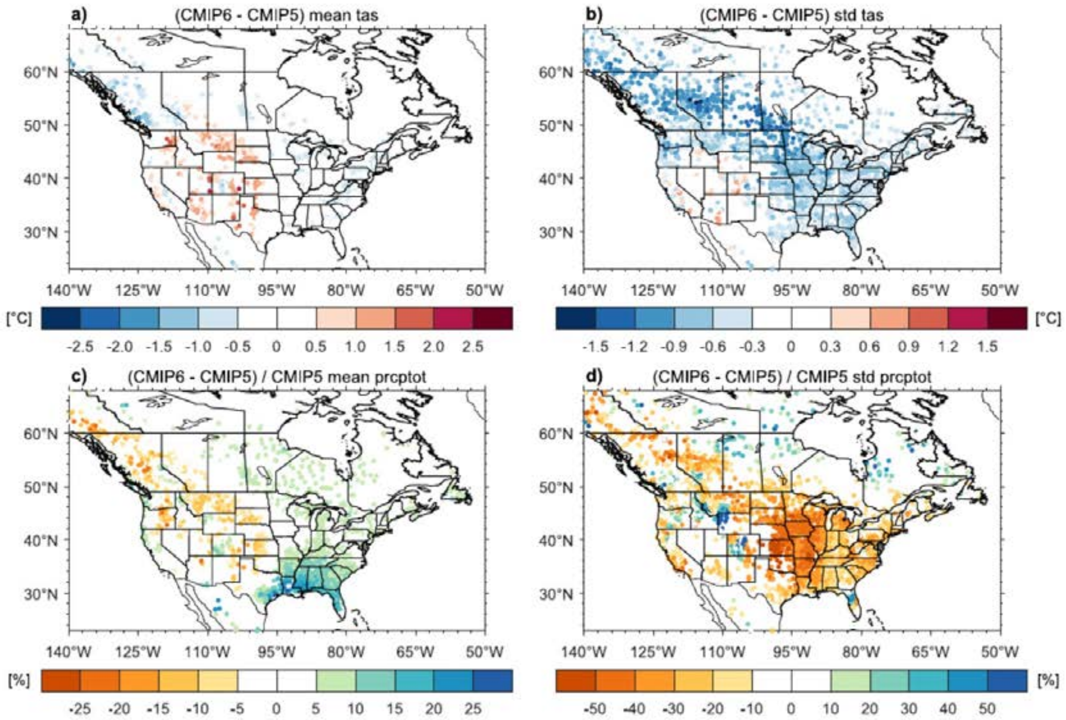

Figure 1. Differences between both raw Coupled Model Intercomparison Project Phase 6 (CMIP6) and Coupled Model Intercomparison Project version 5 (CMIP5) multimodel means (a and c) and inter-model standard deviation (b and d) over the 2070–2099 period for mean annual temperature (tas; a and b) and total precipitation (prcptot; c and d).

Martel, J.L., Brissette, F., Troin, M., Arsenault, R., Chen, J., Su, T. and Lucas-Picher, P., 2022. CMIP5 and CMIP6 model projection comparison for hydrological impacts over North America. *Geophysical Research Letters*, *49*(15), p.e2022GL098364.

Questions?

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