

# Regional Climate-Change Projections Through Next-Generation Empirical and Dynamical Models

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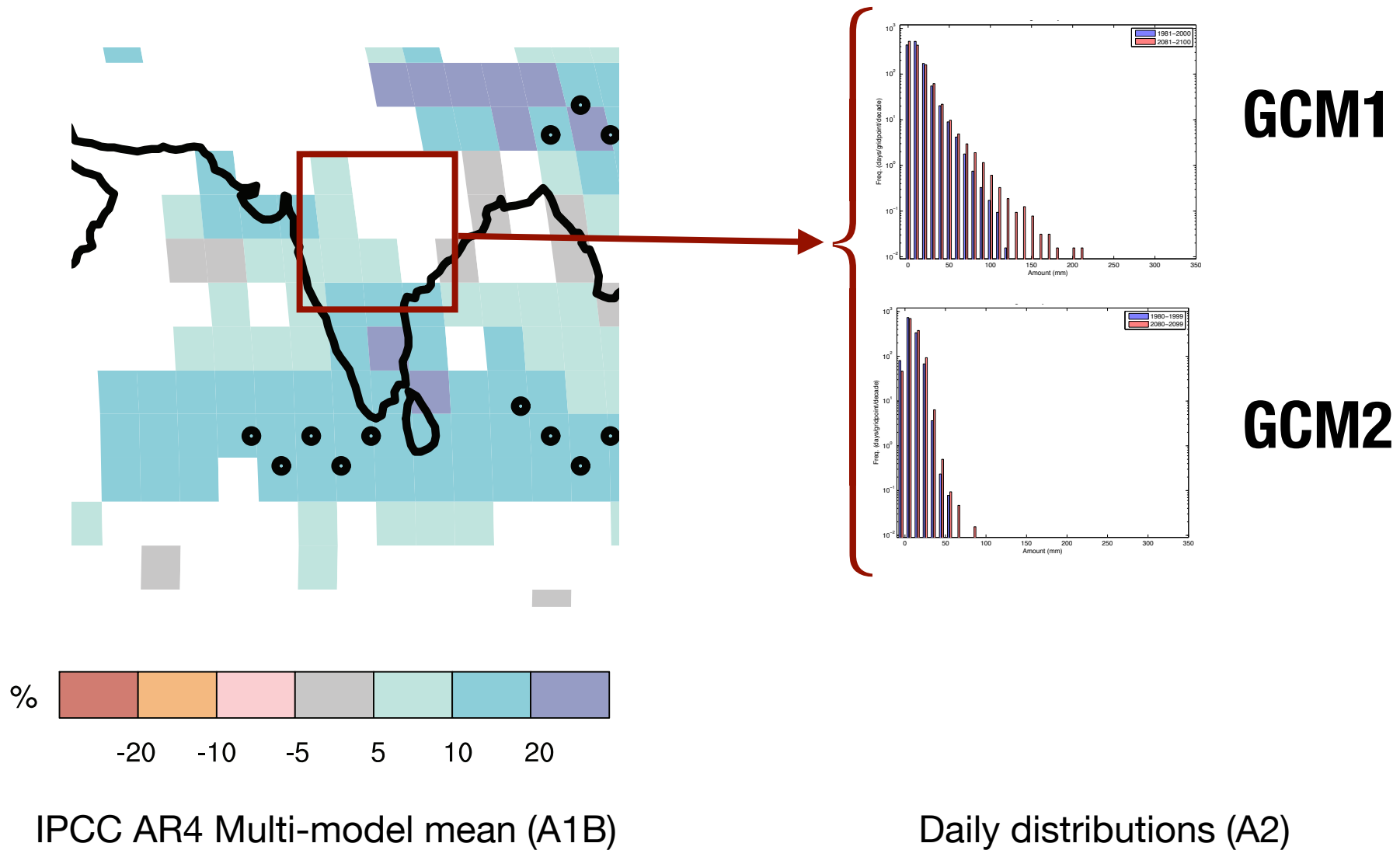
**Andrew W. Robertson, Arthur Greene, IRI, Columbia University, New York**

**Michael Ghil, Mickael Chekroun, Dmitri Kondrashov, University of California, Los Angeles**

**Sergey Kravtsov, Marcia Glaze Wyatt, University of Wisconsin, Milwaukee**

**Padhraic Smith, Scott Triglia, University of California, Irvine**

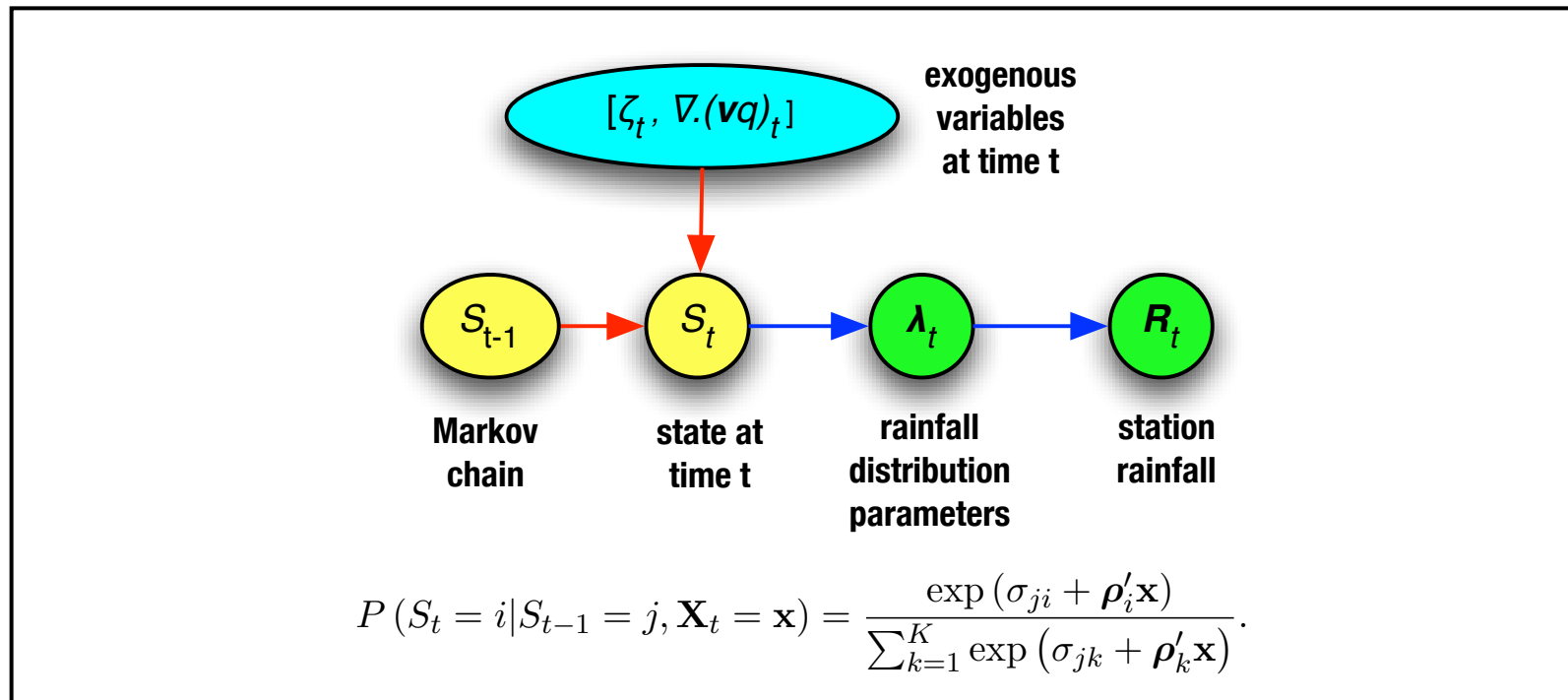
# End-of-century GCM projected precip changes over India





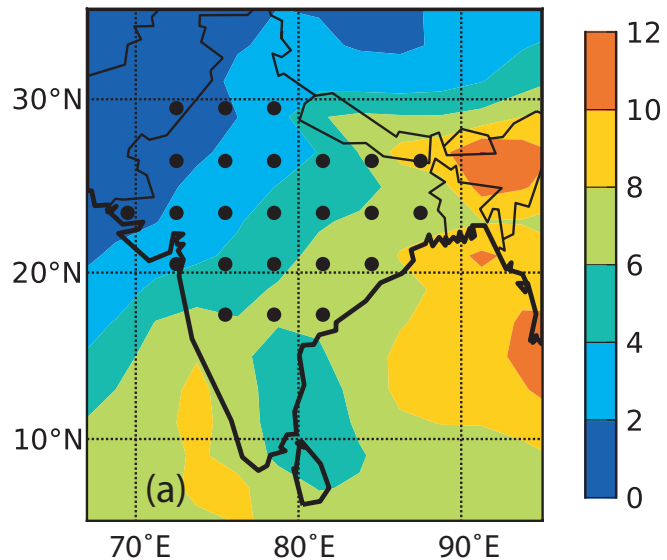
# State-space models of daily rainfall patterns: Hidden Markov Models

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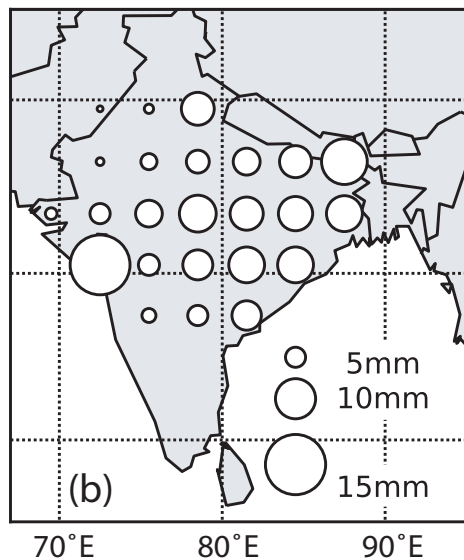


Non-homogeneous HMM: “NHMM”

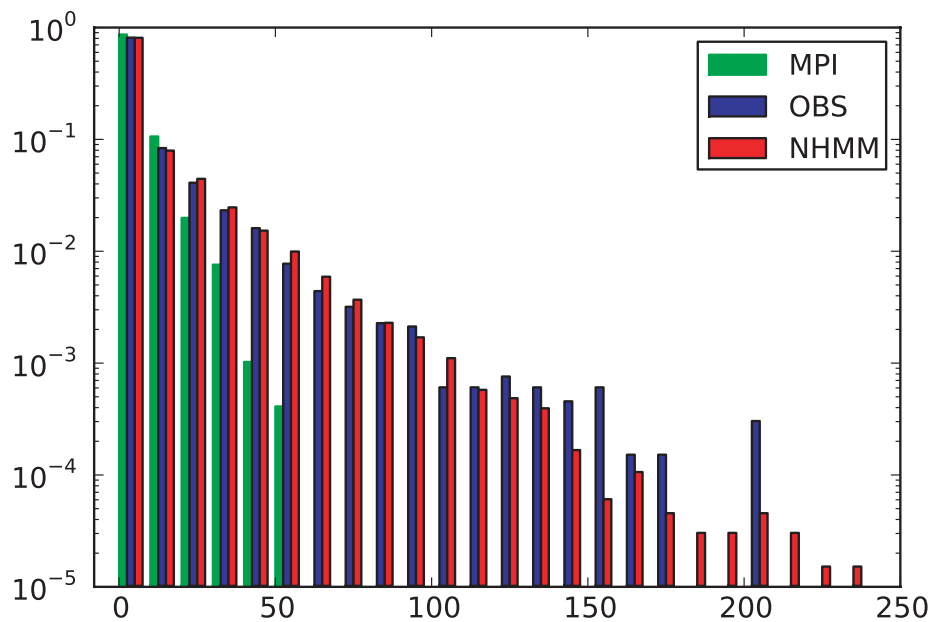
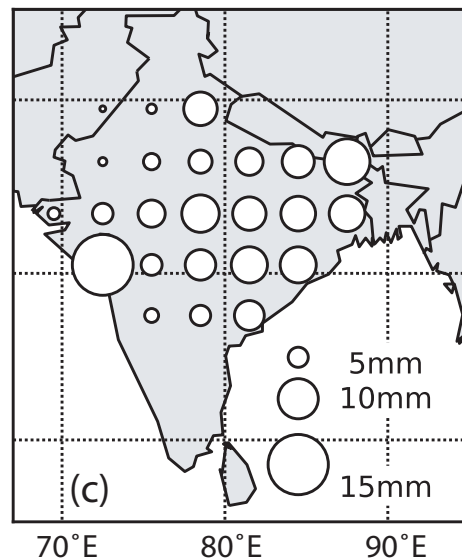
Multimodel mean



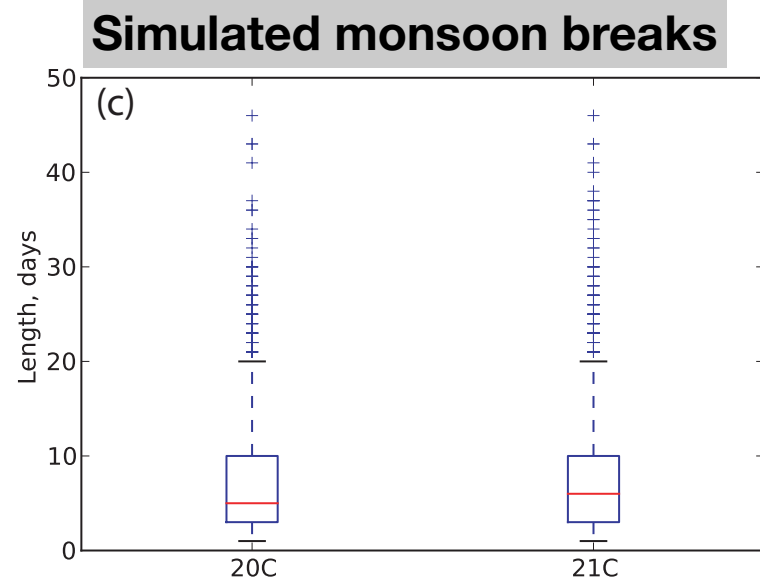
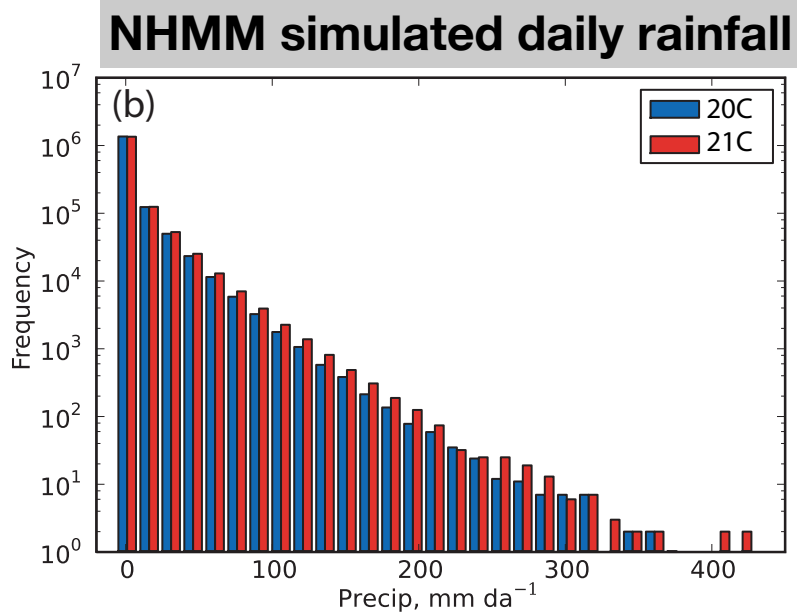
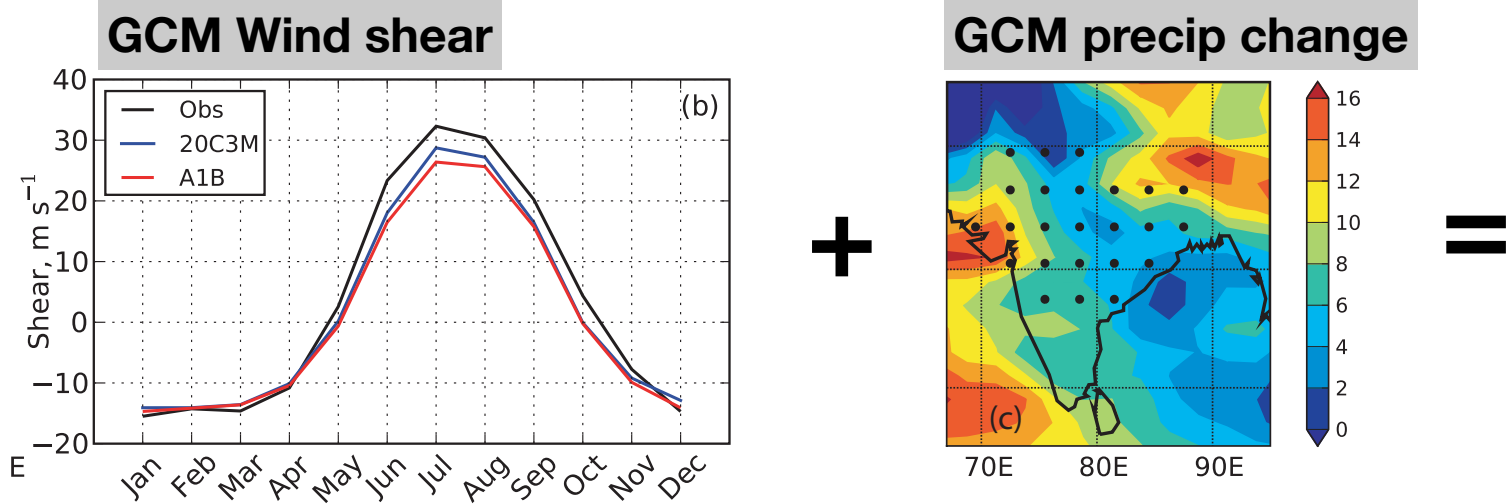
Observations



20C simulation



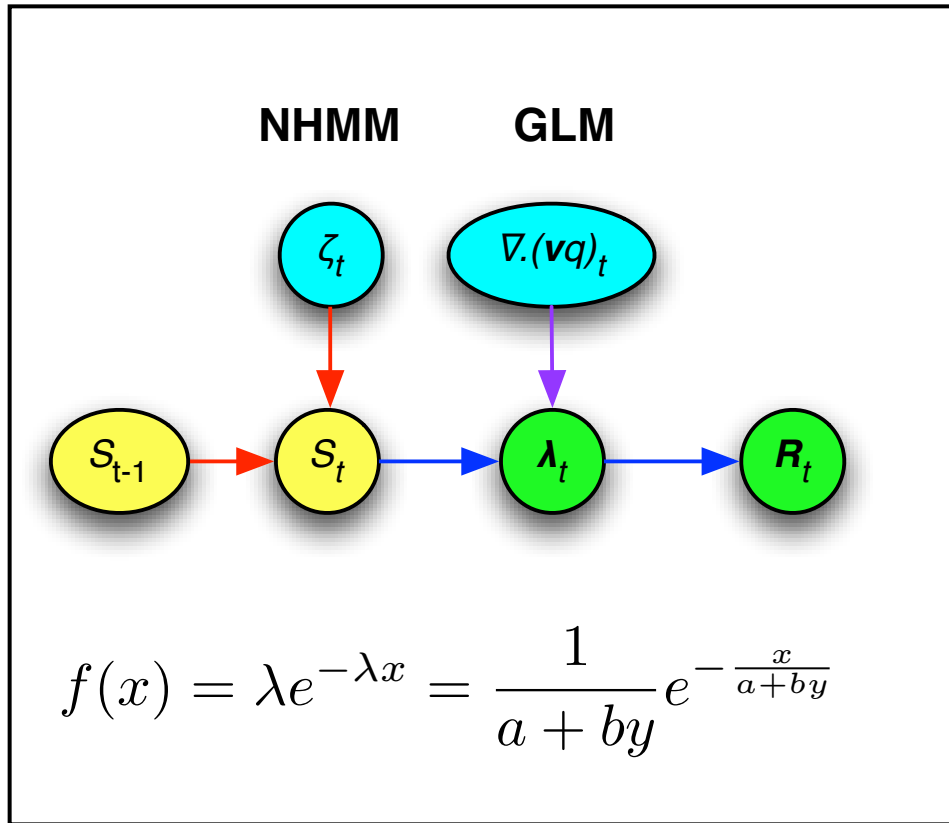
# Climate change downscaling: (1) *Disaggregation with shear-driven NHMM*



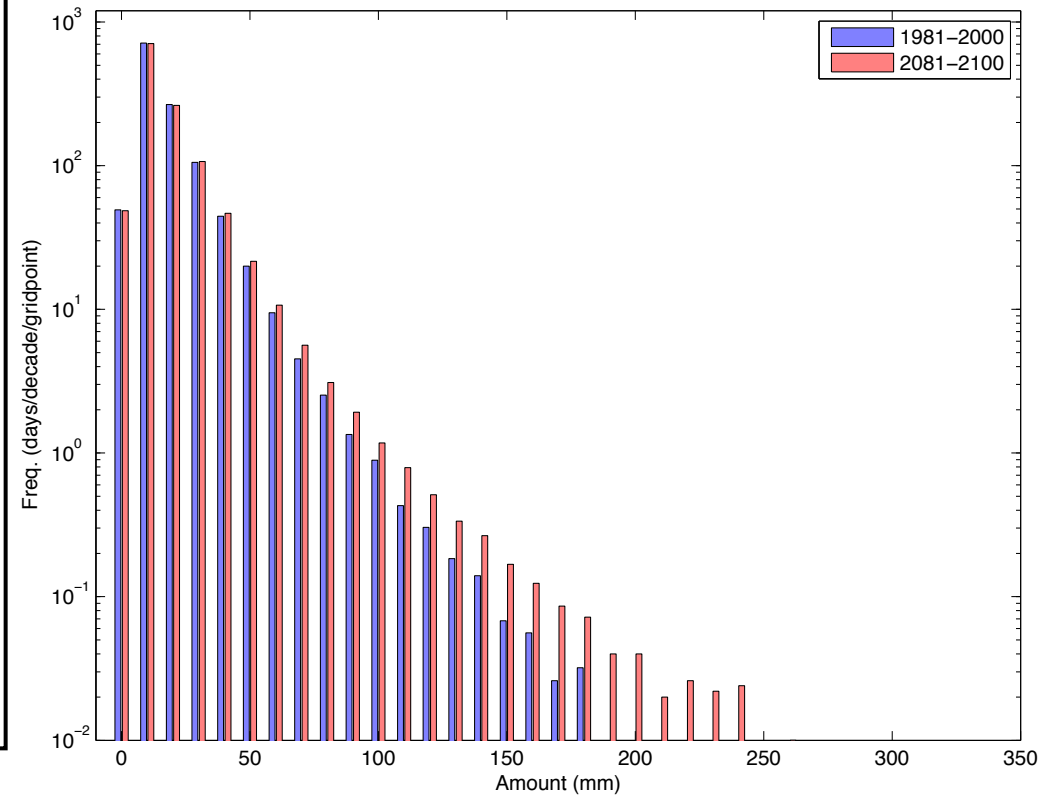
poster:  
Greene et al.

# Climate change downscaling:

## (2) *Generalized linear model for rainfall intensity*



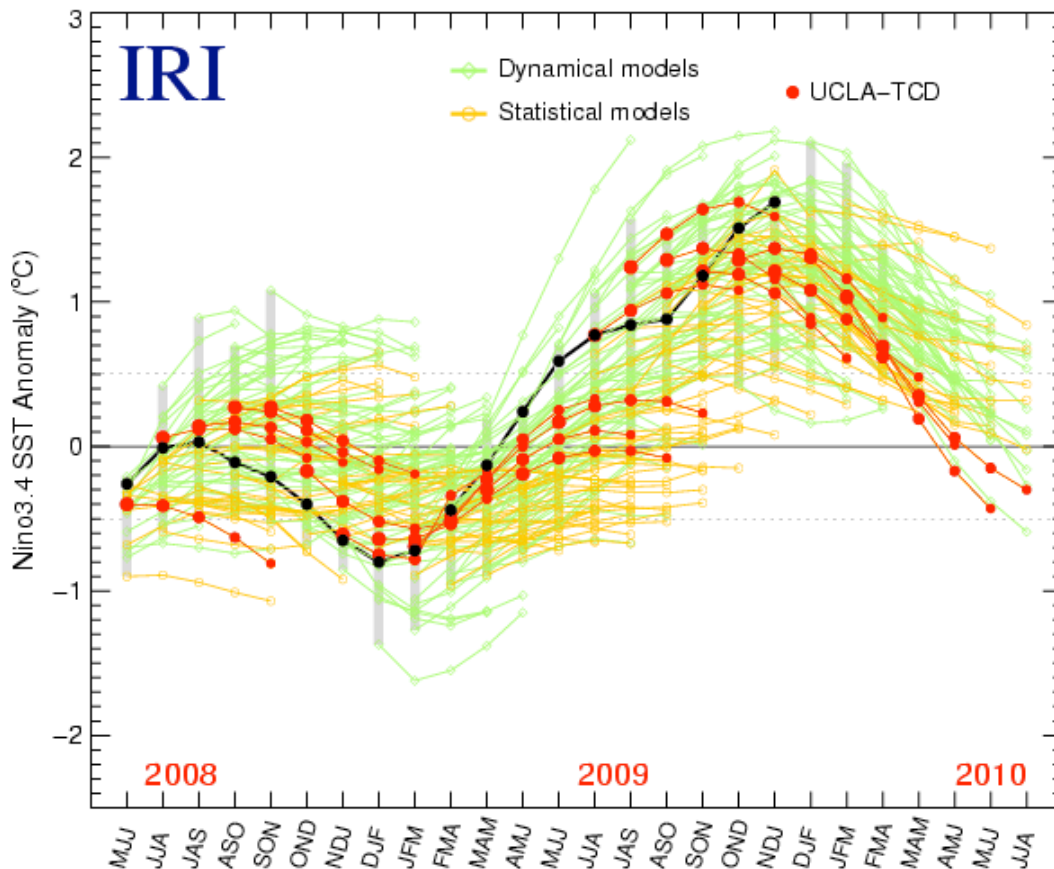
**NHMM-GLM simulated daily rainfall**



# Empirical prediction models:

## (1) *Empirical mode reduction (EMR)*

ENSO Forecast from May 2008 to Feb 2010

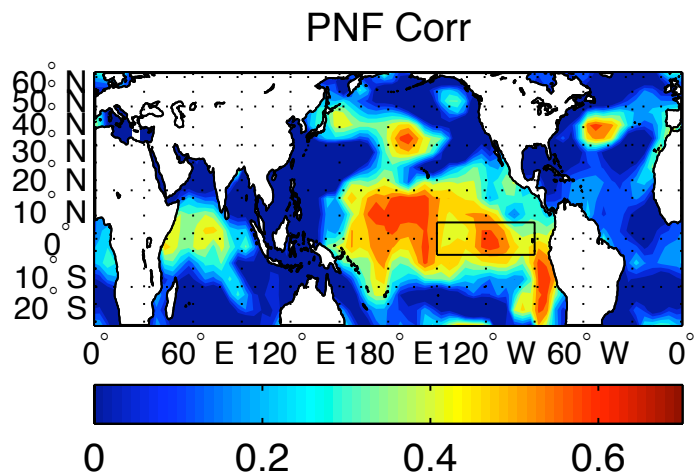
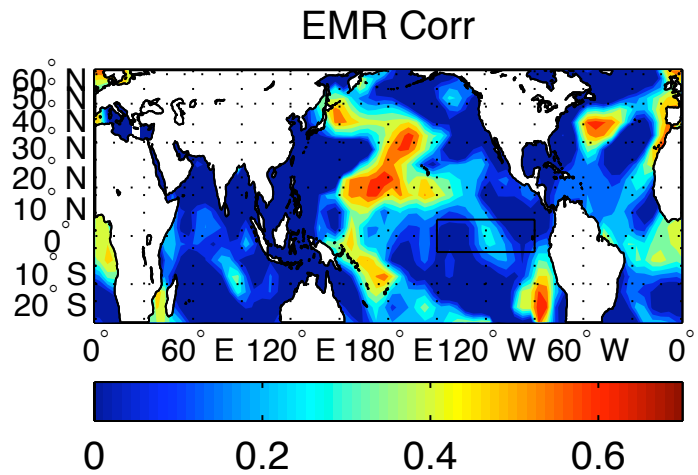


- EMR methodology attempts to construct low-order nonlinear system of prognostic equations driven by stochastic forcing, and to estimate both the dynamical operator and properties of the driving noise directly from observations or high-level model simulation:

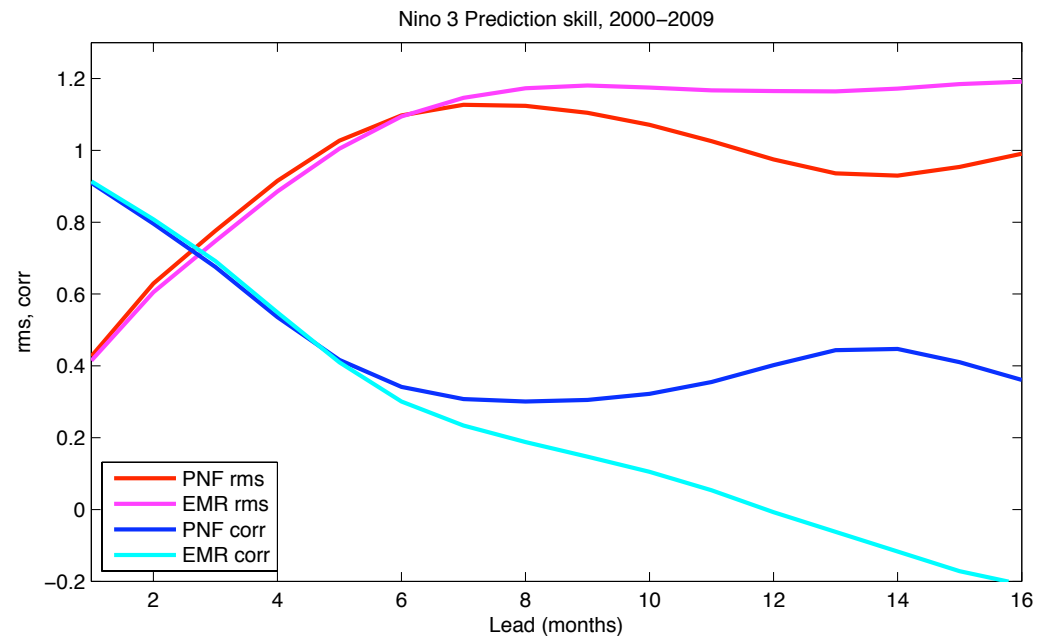
$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}(\mathbf{x}, \mathbf{x}) + \mathbf{L}(\mathbf{x}, \mathbf{r}_t^k, \xi_t, t),$$

$$\dot{\mathbf{r}}_t^k = \mathbf{b}_k(\mathbf{x}, \mathbf{r}_t^0, \dots, \mathbf{r}_t^k) + \mathbf{r}_t^{k+1}, k \in \{0, \dots, K\}$$

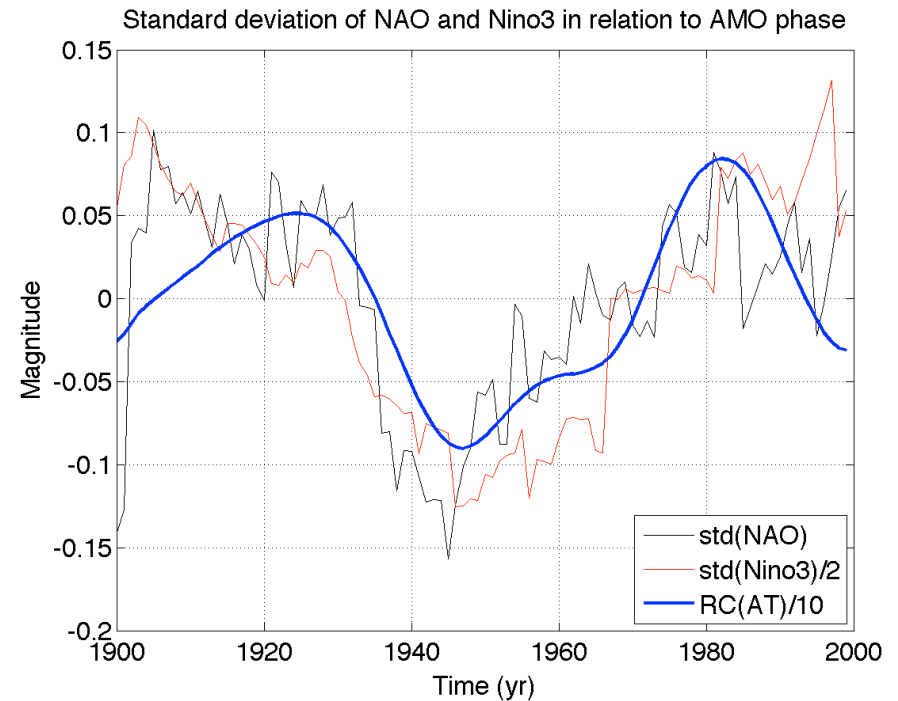
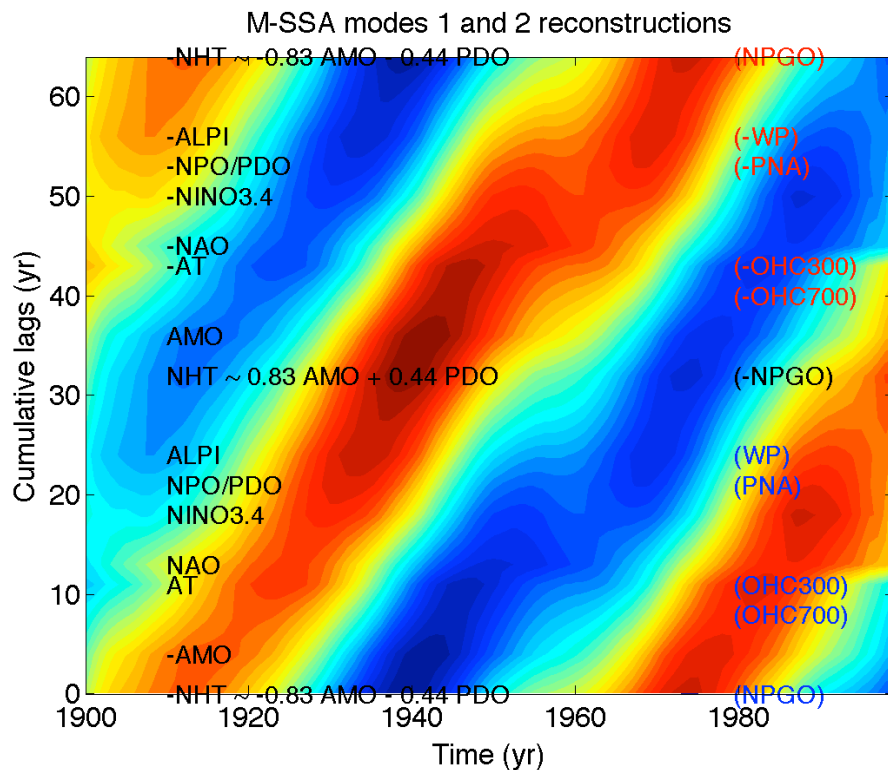
# Sampling past noise to drive ENSO forecasts: (2) *EMR + Past-Noise Forcing*



- Since EMR estimates the history of the noise  $\xi_t$  that ENSO “lives” on, it offers an opportunity to refine ensemble mean of standard EMR prediction, by exploiting pathwise relation of LFV episodes to the driving noise.



# Identification of low-frequency modes



“Stadium Wave” propagation in the “space” of 15 climate indices, as identified by singular spectrum analysis of observed data

Dependence of NAO and ENSO variability on stadium-wave multi-decadal signal in the AT index

# Summary

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- Hidden Markov Models for probabilistic downscaling of GCM climate predictions and projections
  - ▶ identification of “dynamical” vs “thermodynamical” components of regional climate change
- Empirical low-order non-linear models with stochastic forcing for interannual prediction
- Identification of interdecadal modes in historical data and CMIP3 simulations



# Posters

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- **Multidecadal Oscillation and Northern Hemisphere's climate**  
*M. Wyatt, S. Kravtsov, and A. A. Tsonis*
- **Sampling past noise to drive ENSO forecasts**  
*D. Kondrashov, M. Chekroun, and M. Ghil* (joint with Robust Climate Projections and Stochastic Stability of Dynamical Systems PI'd by M Ghil)
- **Dynamical and extra-dynamical influences on Indian monsoon rainfall: Projections using a nonhomogeneous hidden Markov model**  
*A. M. Greene, A. W. Robertson, P. J. Smyth & S. Triglia*