A Cross-Timescale Diagnostic Framework for Coupled Circulation Models

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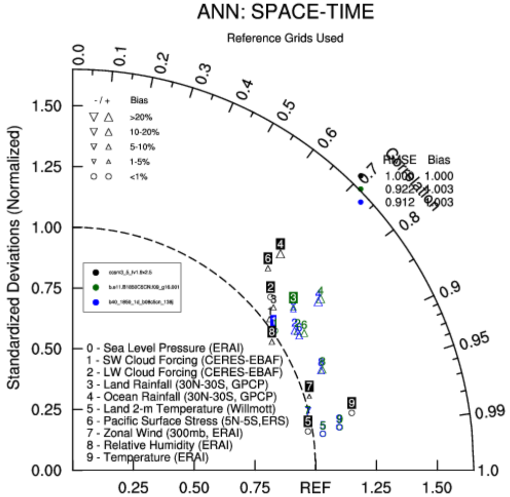
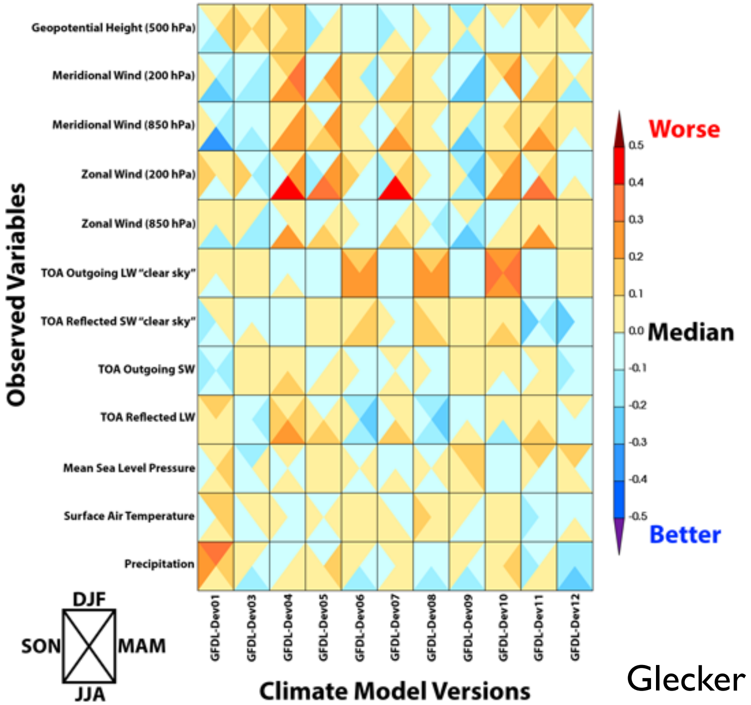
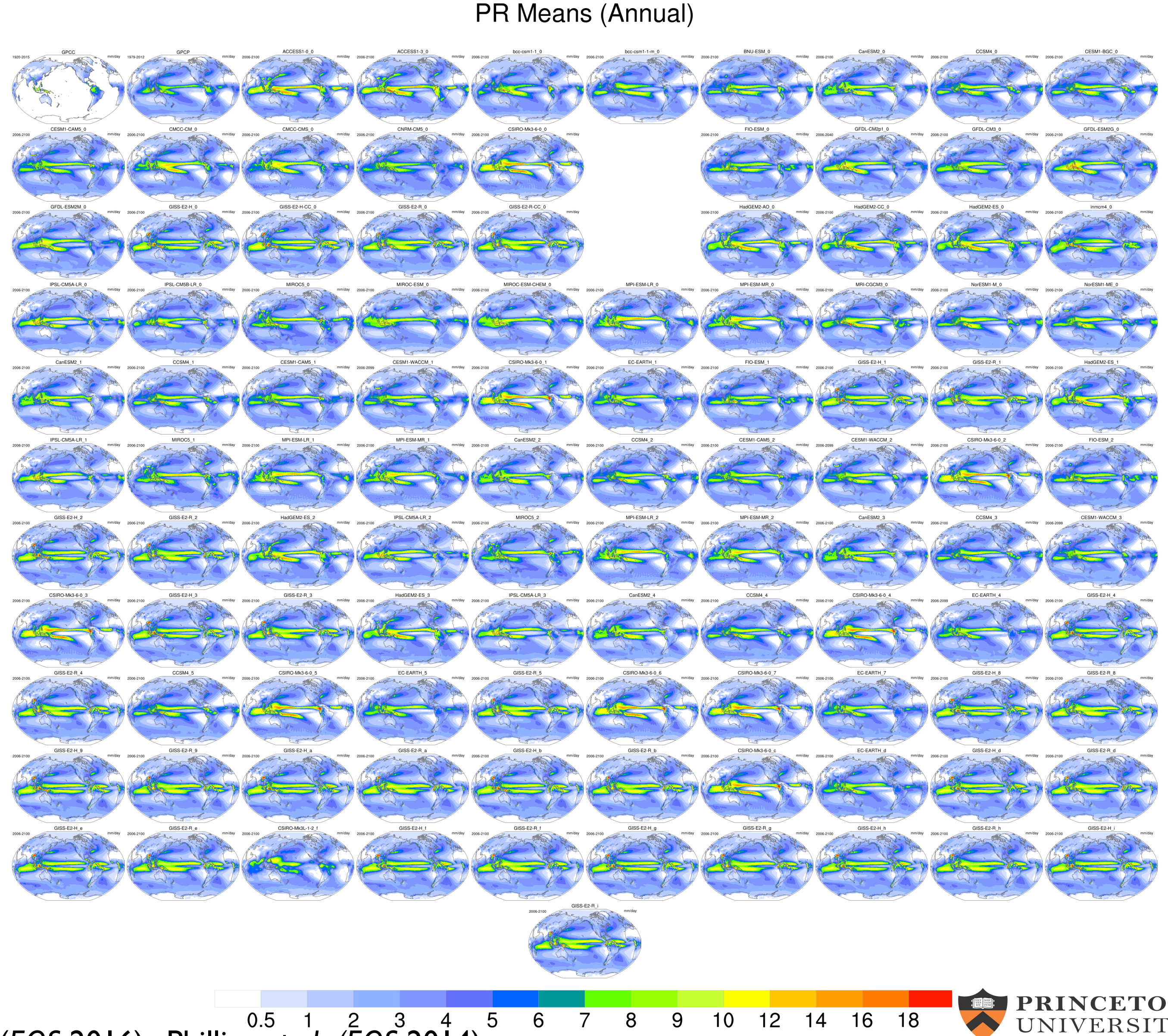
Outline

1. Brief Introduction
2. Circulation patterns (weather types)
3. Model Experiments
4. Diagnostics
5. Conclusions

How are models diagnosed?







Glecker *et al.*, (*EOS* 2016); Phillips *et al.*, (*EOS* 2014)

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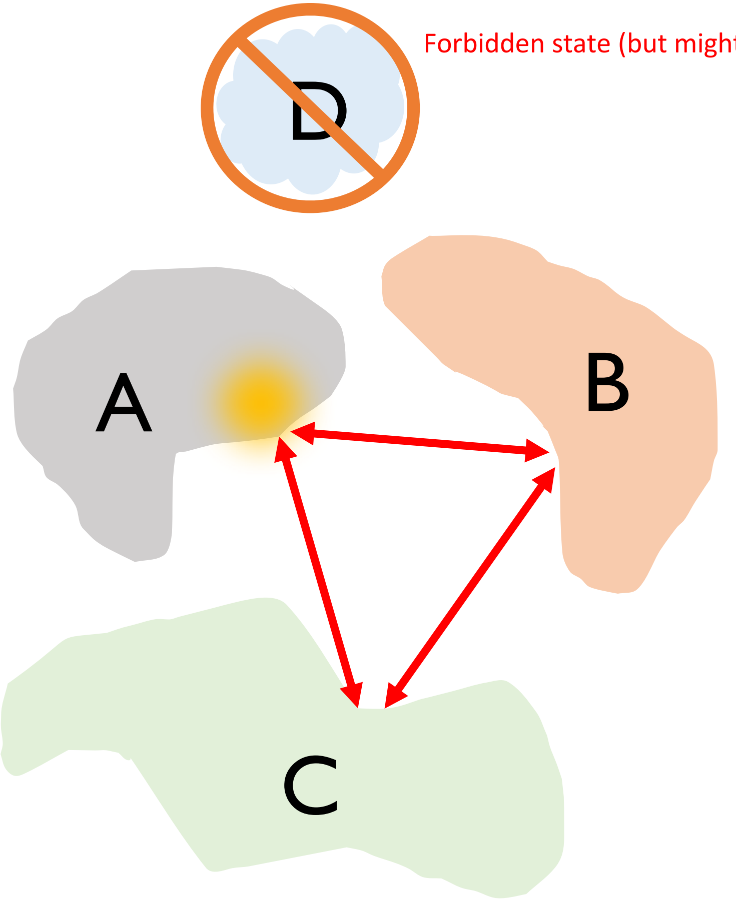
Dynamical System Approach: Available States



Available physical states and transitions

AB
ABC
ABA
BBC
CAC
…

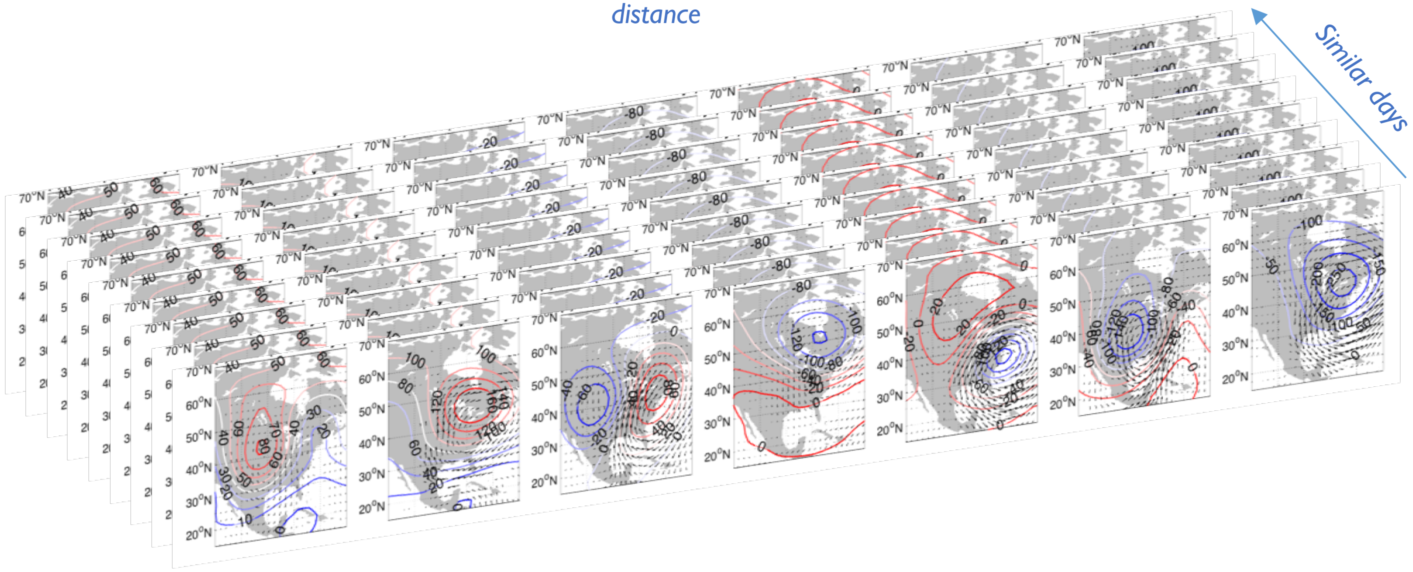
Events are described in terms of sequences of available states

Weather types as a proxy for states

Minimize the function:

$$W(P) = \sum_{j=1}^{N} \sum_{x \in C_j} d^2(X, Y_j),$$

Euclidean distance



Key features to evaluate

- Shape, location and magnitude of spatial patterns
- Daily transitions, duration, sub-seasonal and seasonal (and decadal, and…) statistics
- Link to climate drivers

Some "basic" questions

- Can we build an integrated diagnostic framework based on weather type's spatial patterns and frequencies of occurrence to facilitate the identification of model systematic errors across multiple timescales?
- Can we identify regime-dependent sources of systematic errors?
- What is the role of horizontal resolution?
- What is the impact of different nudging approaches?

Michelangeli *et al.* (*JAS*, 1995); Robertson and Ghil (*J.Clim.*, 1999); Robertson *et al.* (2015); Muñoz *et al.* (*J.Clim.*, 2015, 2016, accepted)

Model Experiments

"Same model", different resolutions (C48 vs C180, both 32 vertical levels)

- LOAR (van der Wiel *et al.*, 2016)
- FLOR (Vecchi *et al.*, 2014)

Nudging (e.g., Jia *et al.*, 2017)

- SST-only
- SST+stratosphere

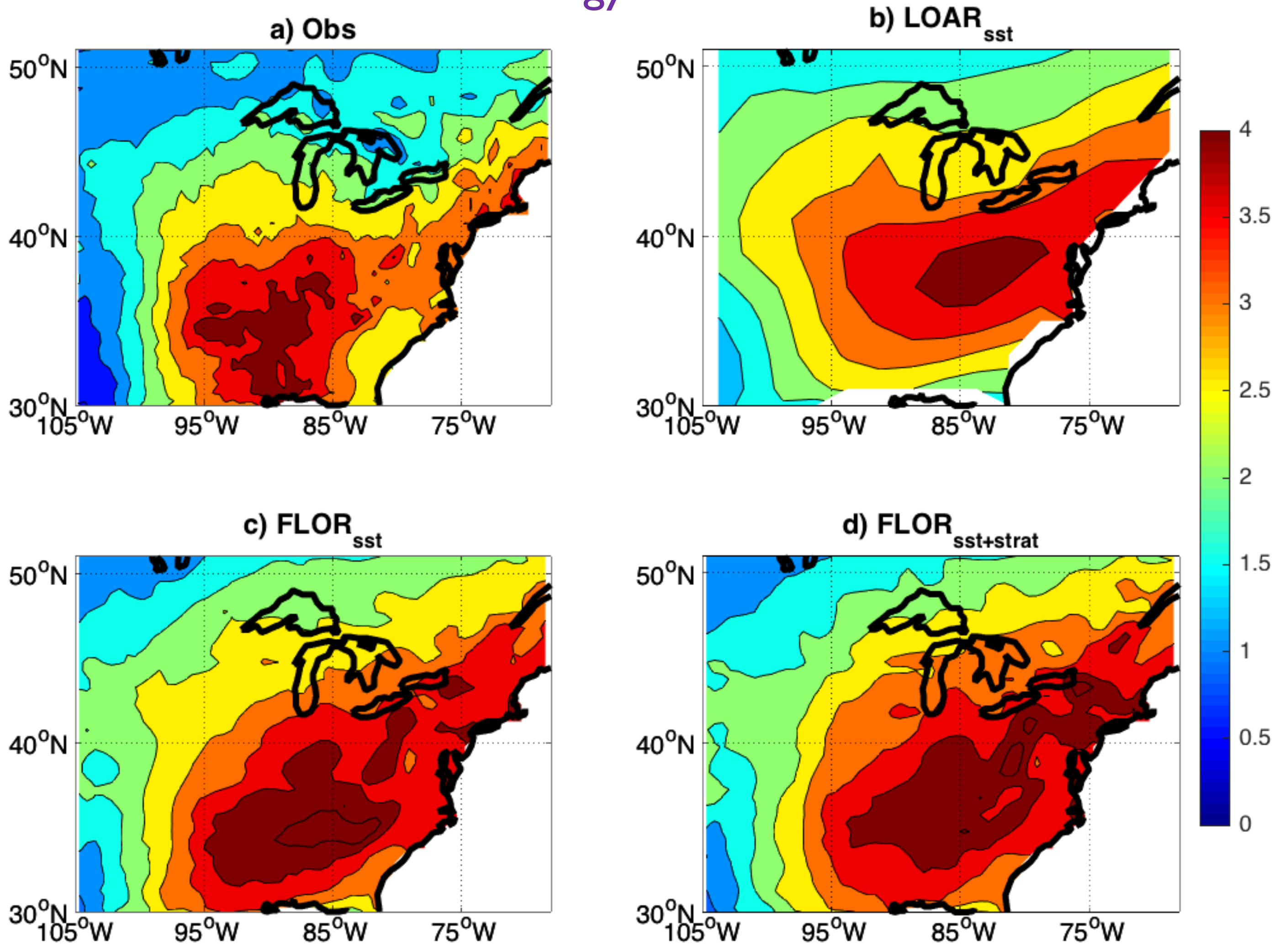
3 sets of experiments (MAM 1981-2012):

- LOAR_{sst}
- FLOR_{sst}
- $\text{FLOR}_{\text{sst+strat}}$

"Observations":

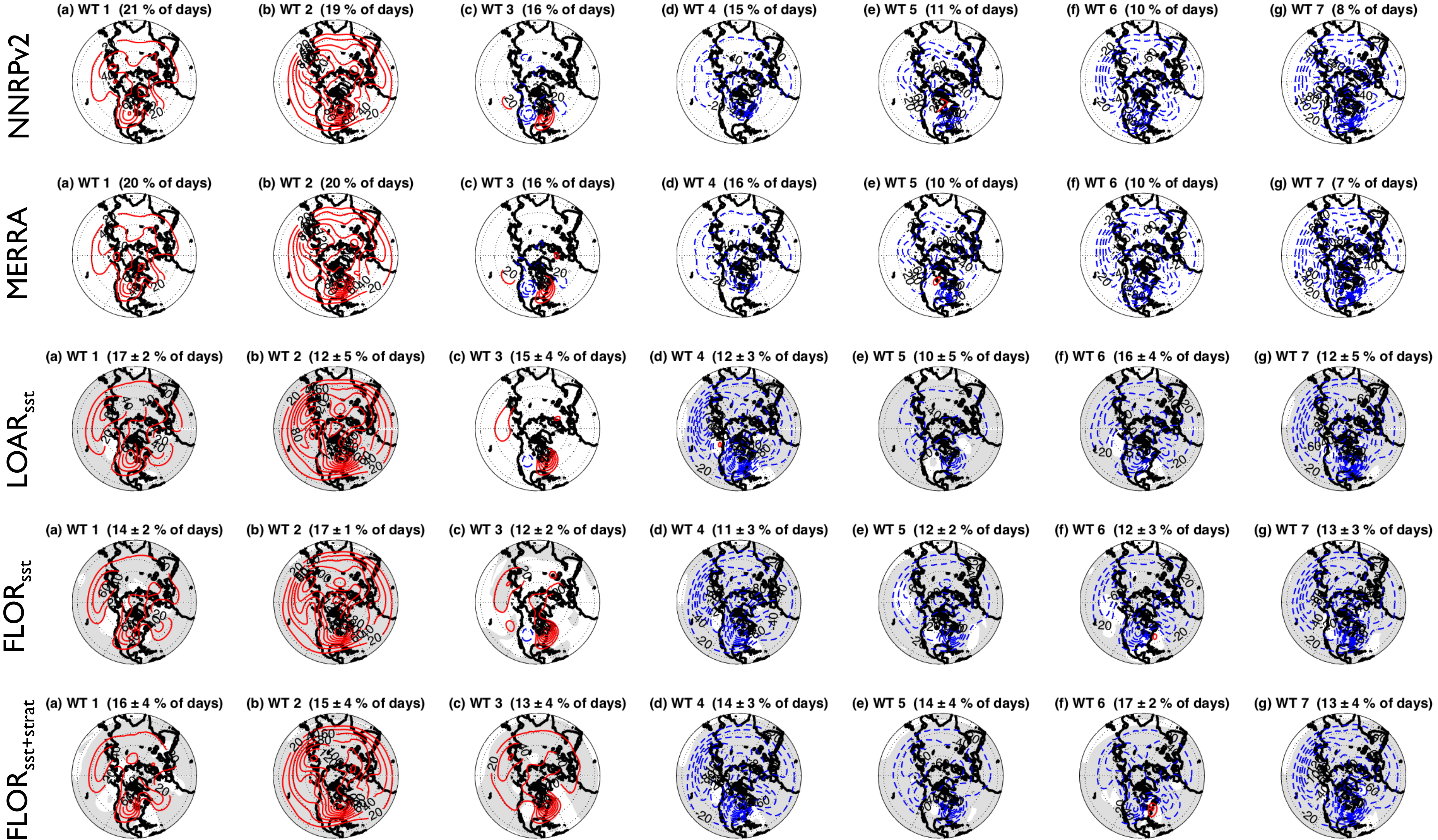
- NNRPv2
- MERRA
- NOAA-NCEP-CPC Unified Precip.

Rainfall Climatology - MAM – 1981-2012

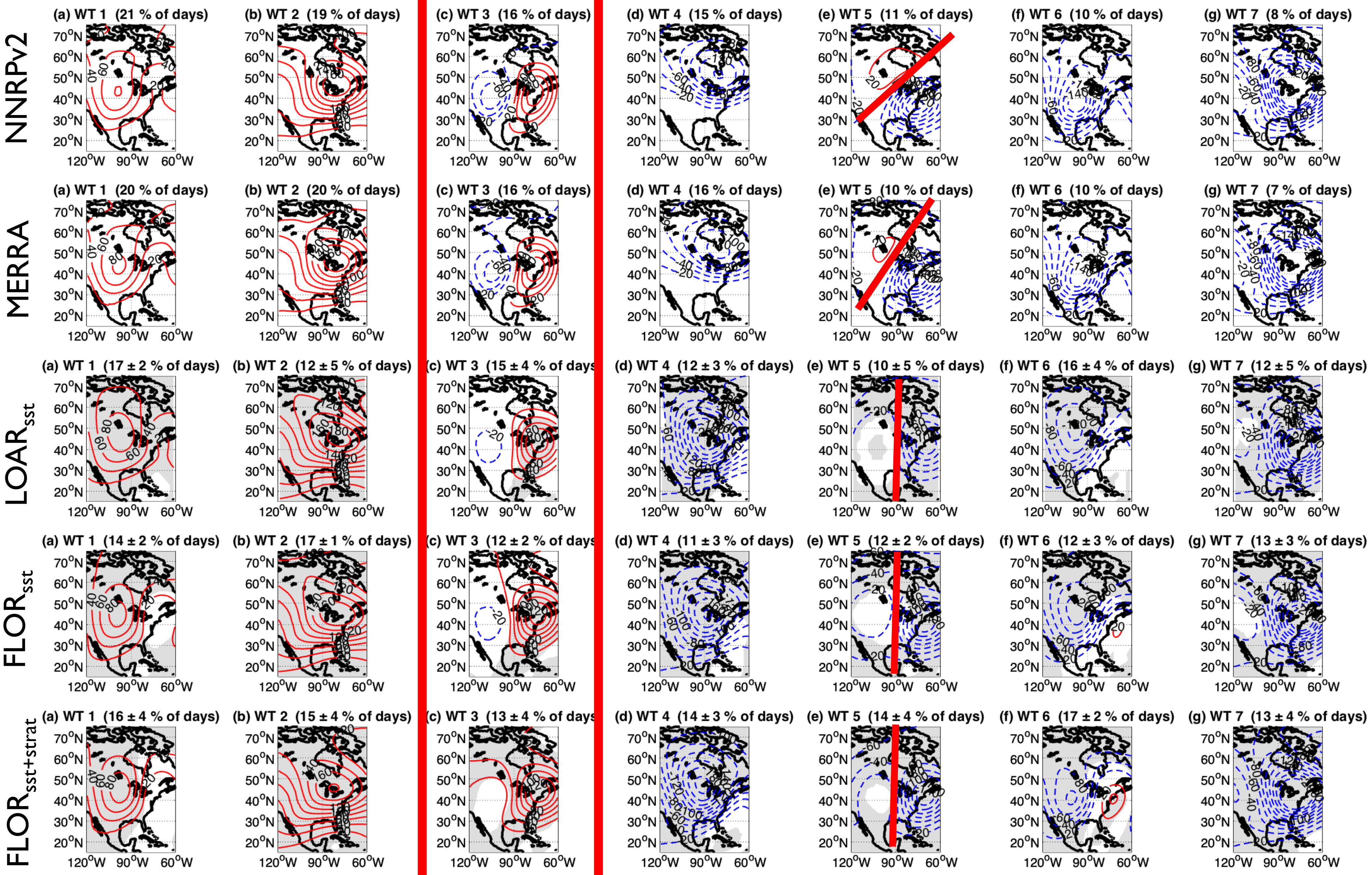


Muñoz *et al.* (*J.Clim.*, accepted)

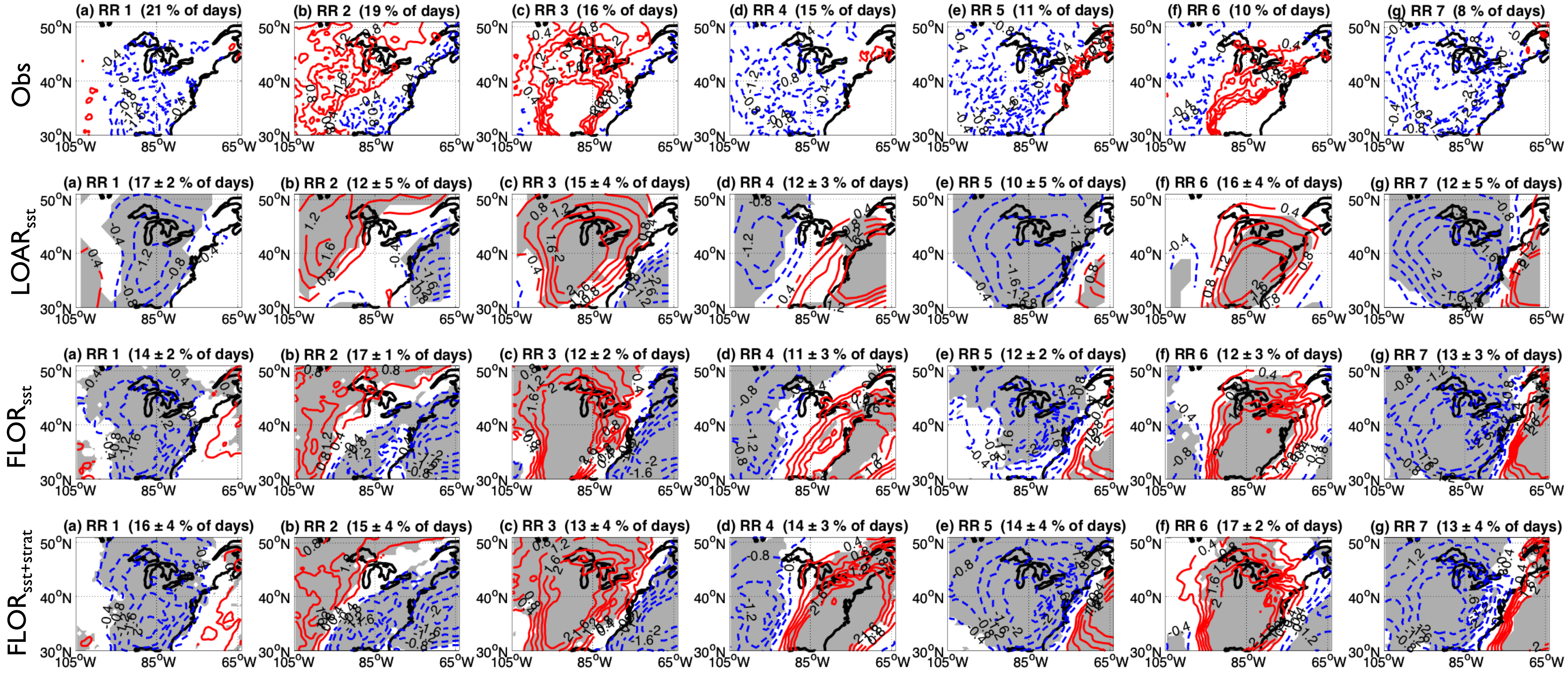
WTs – MAM – 1981-2012 (h500): Obs & Models



WTs – MAM – 1981-2012 (h500): Obs & Models



Rainfall Regimes – MAM – 1981-2012



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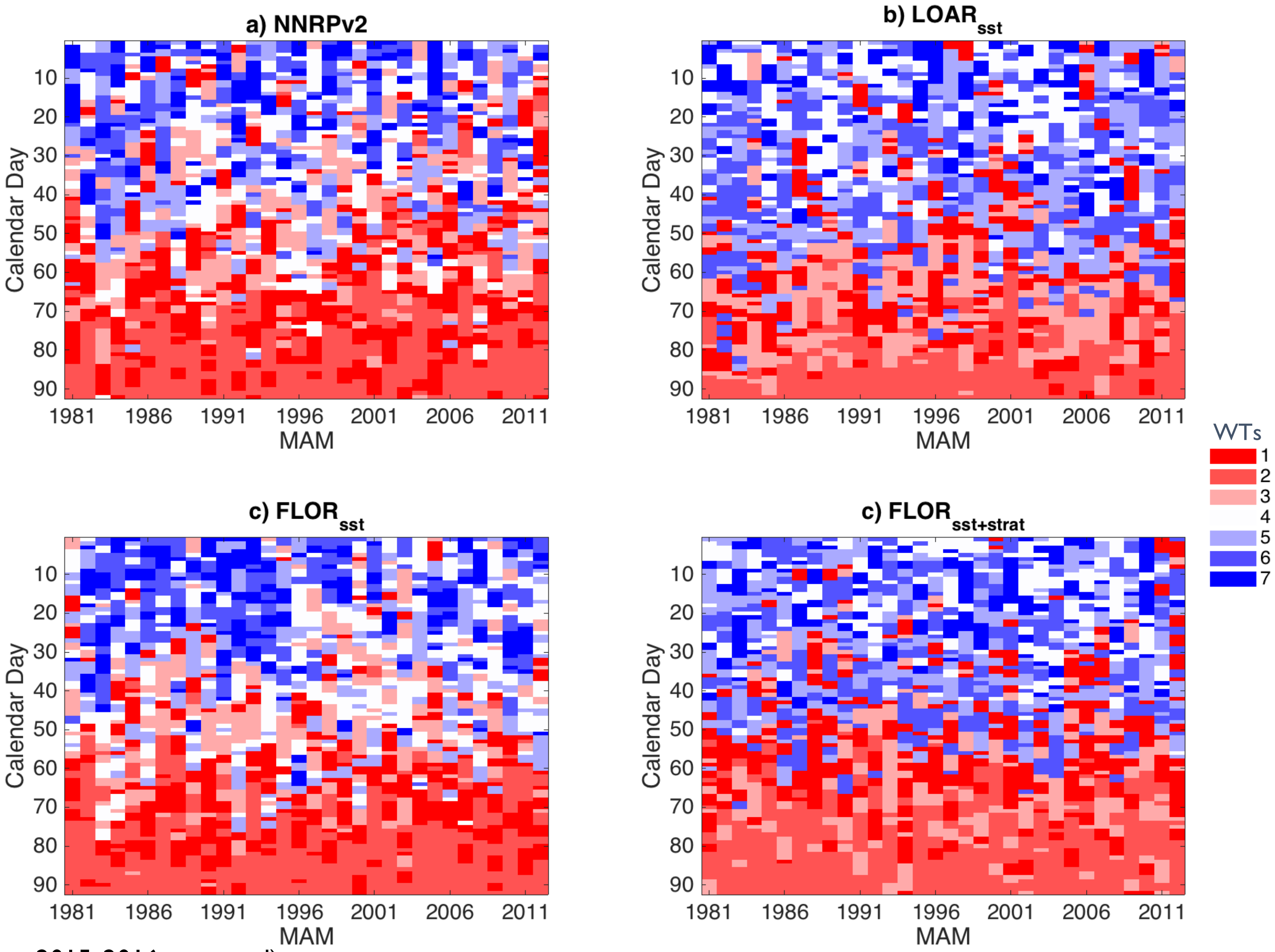
Building blocks: Klee diagrams



Paul Klee (1879-1940)

Muñoz *et al.* (*J.Clim.*, 2015, 2016, accepted)

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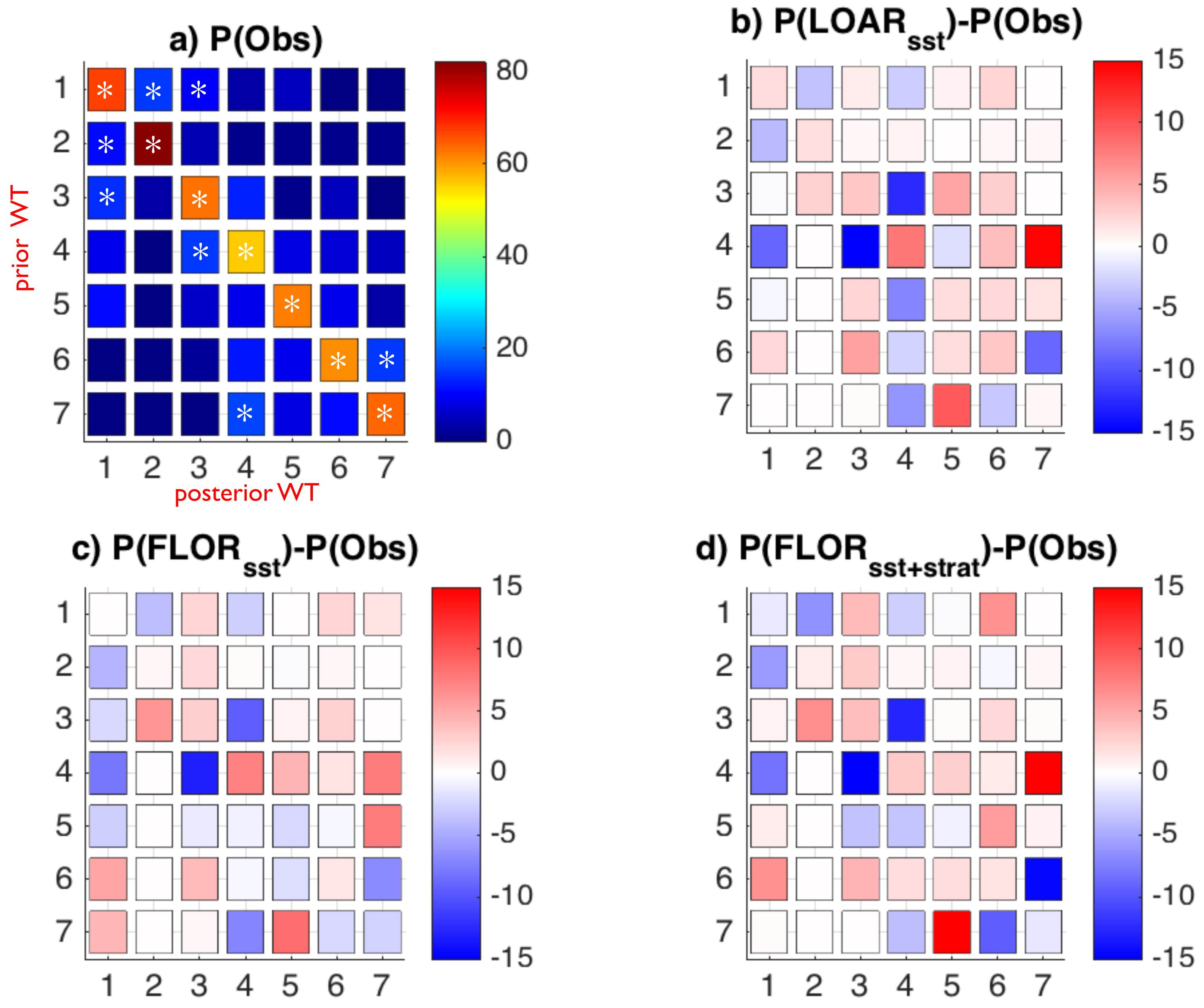
Daily Transitions



Vautard (1990); Muñoz *et al.* (accepted)

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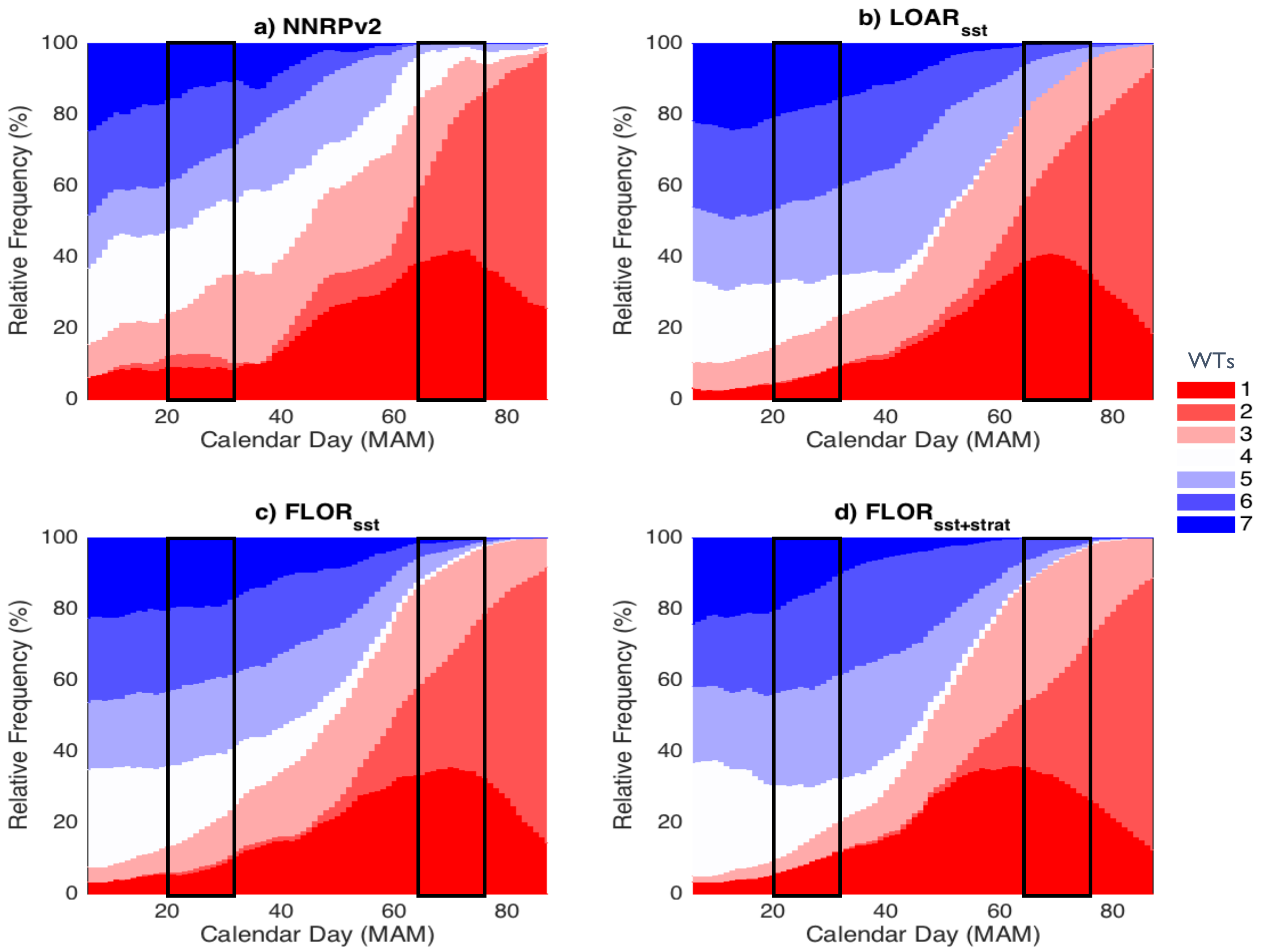
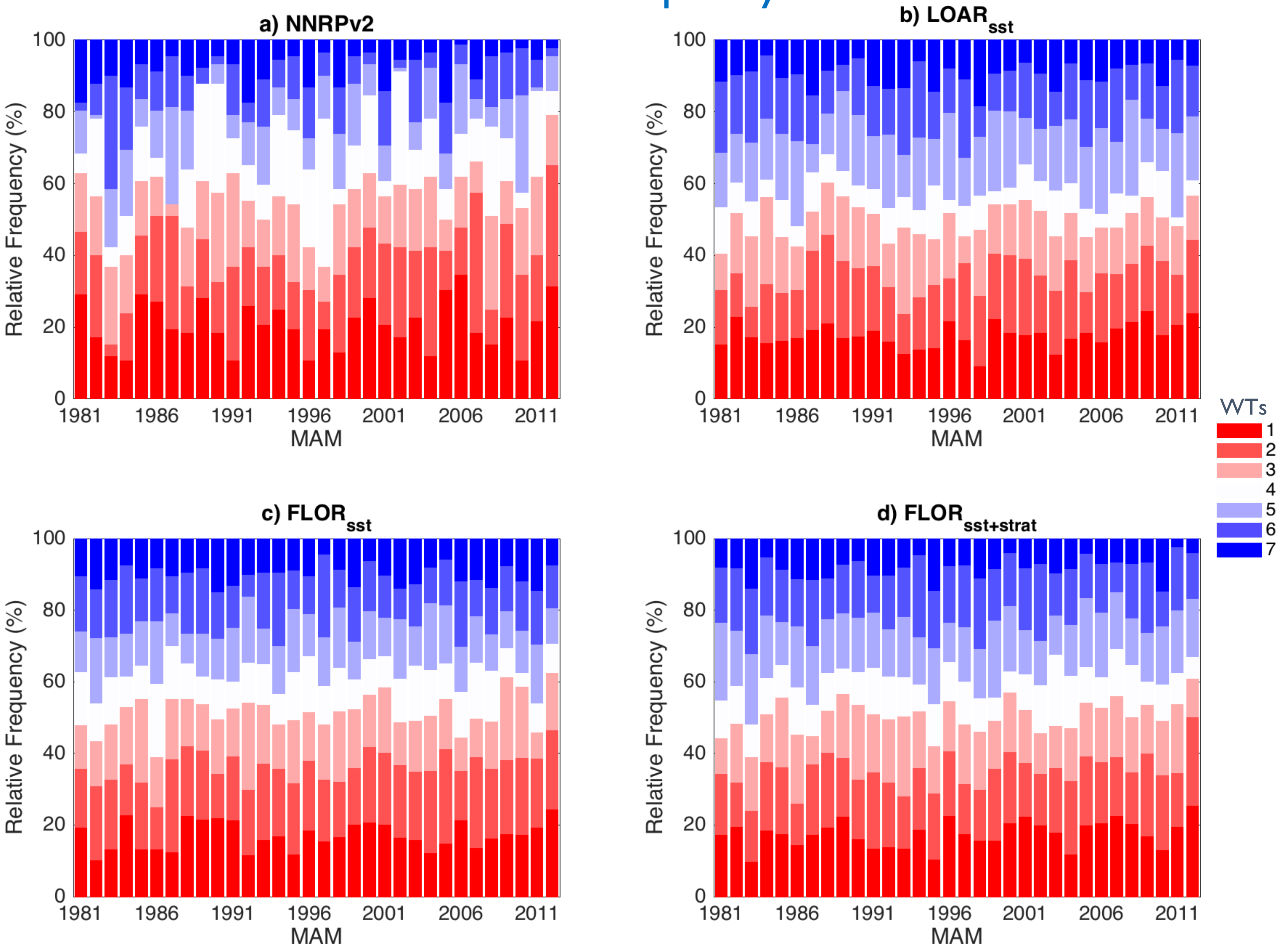
Sub-seasonal WT Evolution – MAM – 1981-2012



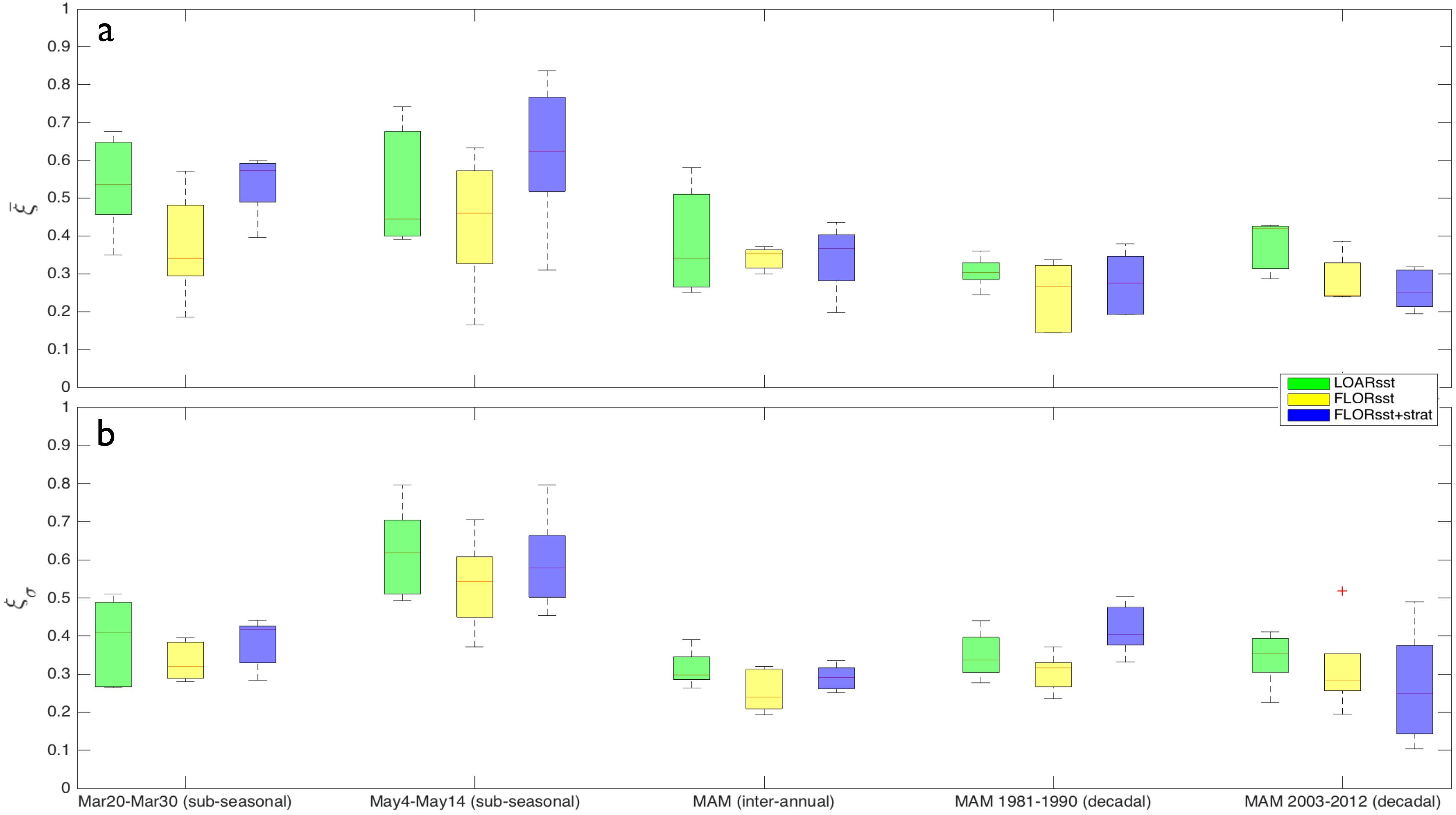
Seasonal/Inter-annual WT Frequency– MAM – 1981-2012



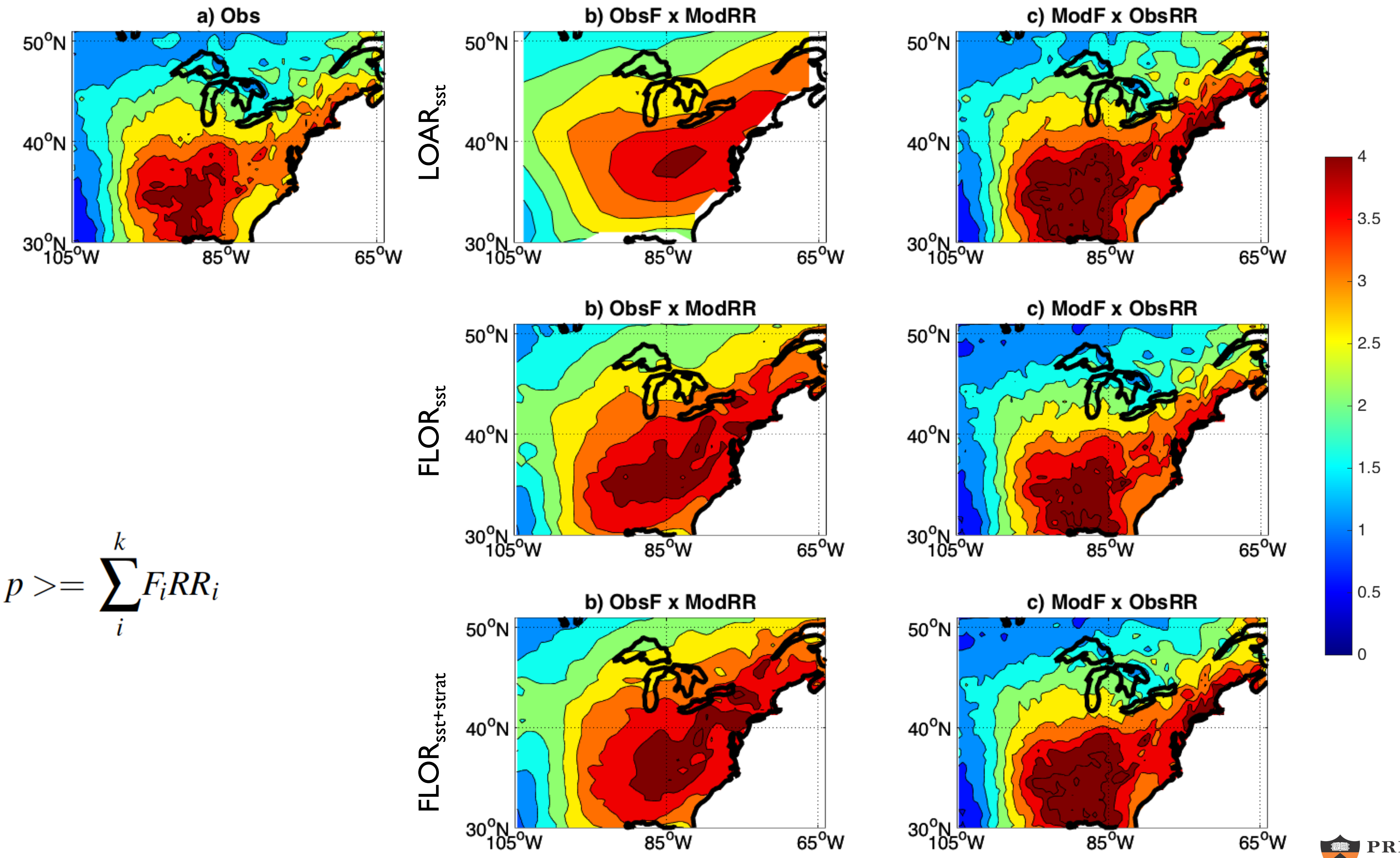
Root mean square error normalized by mean frequency of weather types (e.g., ECMWF)

Summarizing: Scatter Index

$$\bar{\xi} \equiv \frac{\sqrt{k\sum_i^k \left(f_i^S - f_i^O\right)^2}}{\sum_i^k f_i^O} \qquad \xi_\sigma\Big|_t \equiv \frac{\sqrt{k\sum_i^k \left(\sigma(f_i^S) - \sigma(f_i^O)\right)^2}}{\sum_i^k \sigma(f_i^O)}\Bigg|_t \qquad \forall i, j = 1 \ldots k$$



Reconstructing the climatology



$$< p >= \sum_{i}^{k} F_i RR_i$$

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Conclusions

1. A weather-type based cross-timescale diagnostic framework complements other approaches, providing guidance on the regime-dependent sources of biases in models from a physical point of view.

2. Process-based metrics can be defined considering spatial patterns and residence time of modeled WTs.

3. Experiments with a suite of GFDL models tend to represent well the *location, shape and magnitude* of daily circulation regimes and associated rainfall patterns, although certain biases are present (e.g., rotated axis of the dipole in WT5).

4. *Frequency characteristics* of WT tend to be well represented. Nonetheless, biases in 'preferred' daily transitions (and persistence) of WTs propagate to larger timescales: *sub-seasonal to inter-annual (to decadal and climate change scales?)* [weather-climate continuum].

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Conclusions

4. *Overall*, no statistically significant differences in WT characteristics when using different resolutions (both in obs and models), and nudging approaches. Of course, differences can be important when considering particular regions/timescales (e.g., WT3 and extreme rainfall events).

5. It is possible to take advantage of the "fair" representation of temporal characteristics of WTs in low-res models like LOAR and CM2.1 to re-construct observed fields, with potential for computationally economic but skillful predictions of certain variables (depending on the timescale).

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