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A Seamless Process-based Model Evaluation Framework for Subseasonal-to-Decadal Timescales

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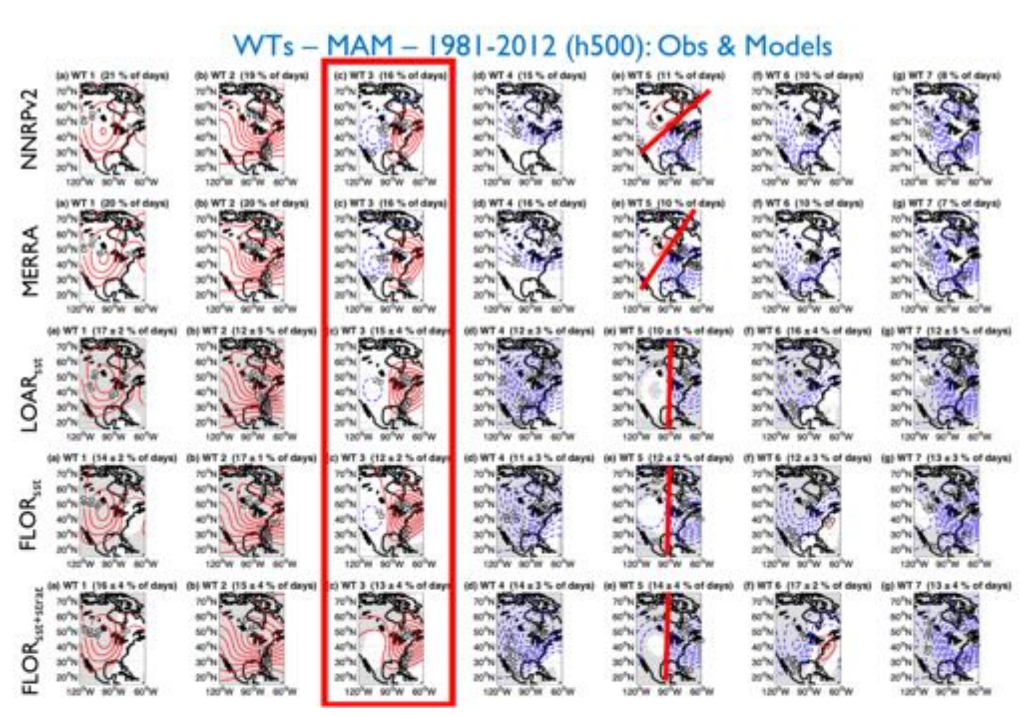
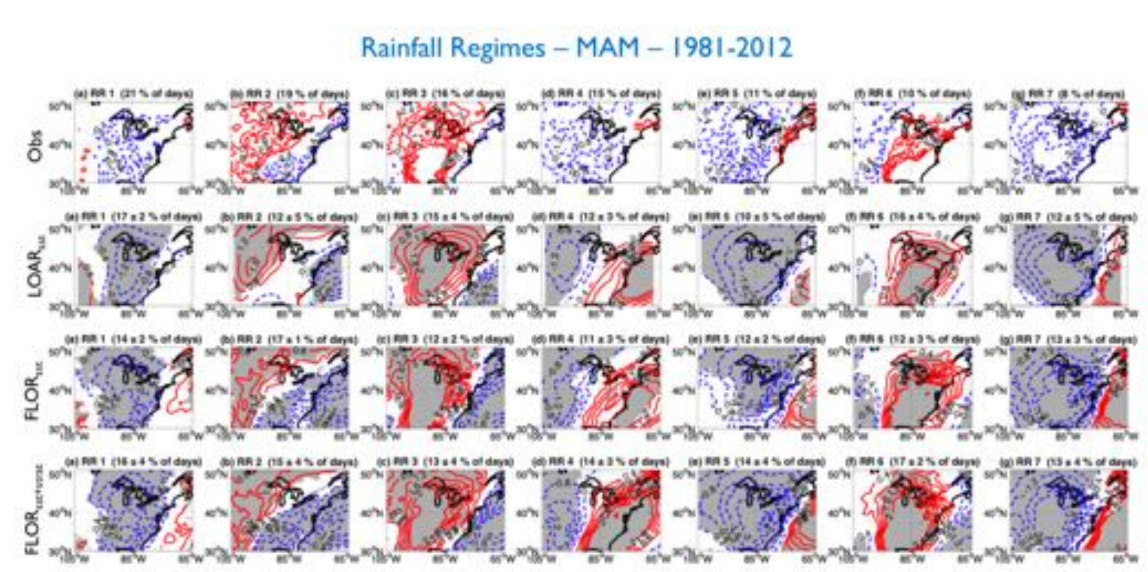
Abstract

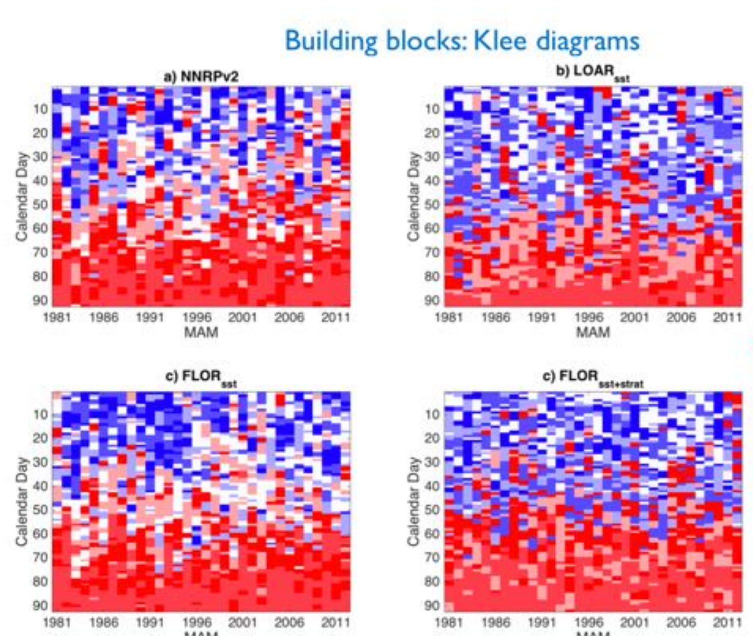
Common approaches to diagnose systematic errors involve the computation of metrics aimed at providing an overall summary of the performance of the model in reproducing the particular variables of interest in the study, normally tied to specific spatial and temporal scales. However, the evaluation of model performance is not always tied to the understanding of the physical processes that are correctly represented, distorted or even absent in the model world. As the physical mechanisms are more often than not related to interactions taking place at multiple time and spatial scales, cross-scale model diagnostic tools are not only desirable but required. Here, a recently proposed circulation based diagnostic framework (Muñoz et al 2017) is extended to consider systematic errors in both spatial and temporal patterns at multiple timescales. The framework, which uses a weather-typing dynamical approach, quantifies biases in shape, location and tilt of modeled circulation patterns, as well as biases associated with their temporal characteristics, such as frequency of occurrence, duration, persistence and transitions.

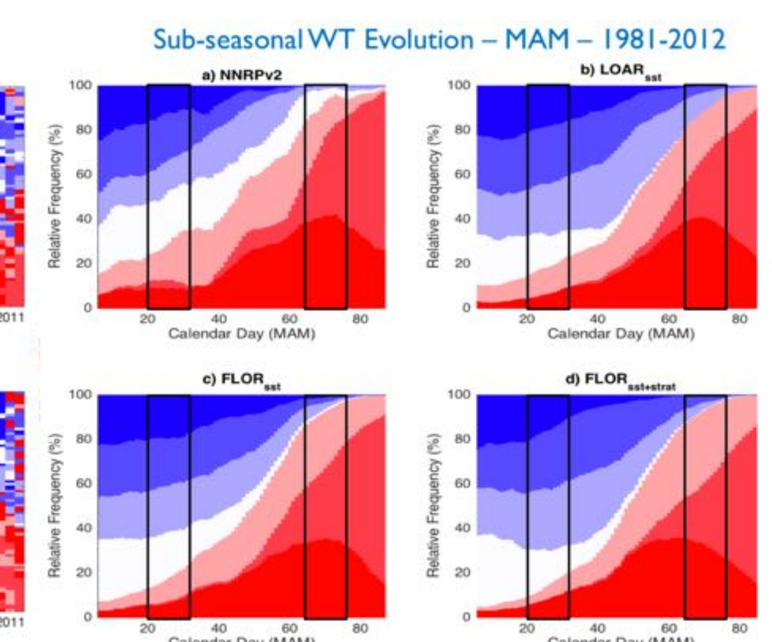
Spatial Patterns

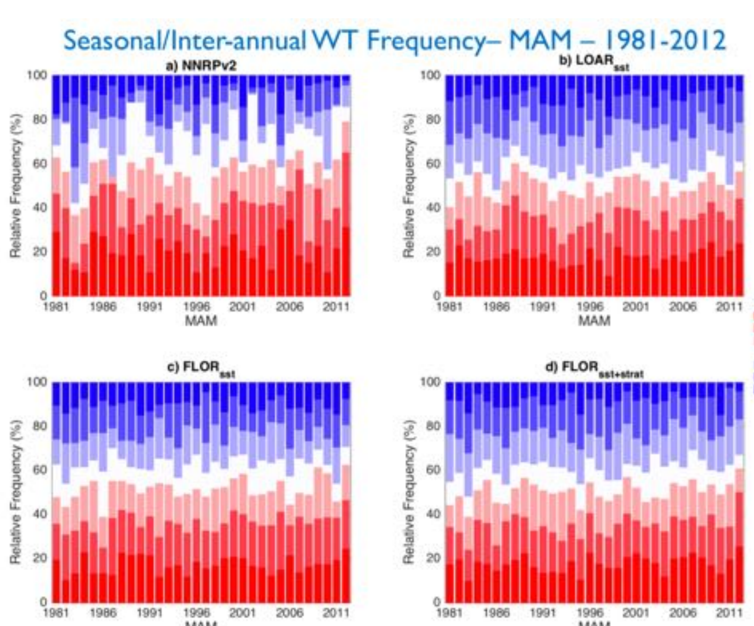




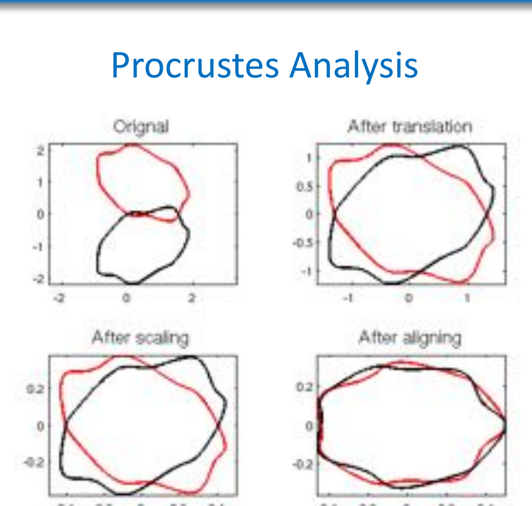
Temporal Evolution

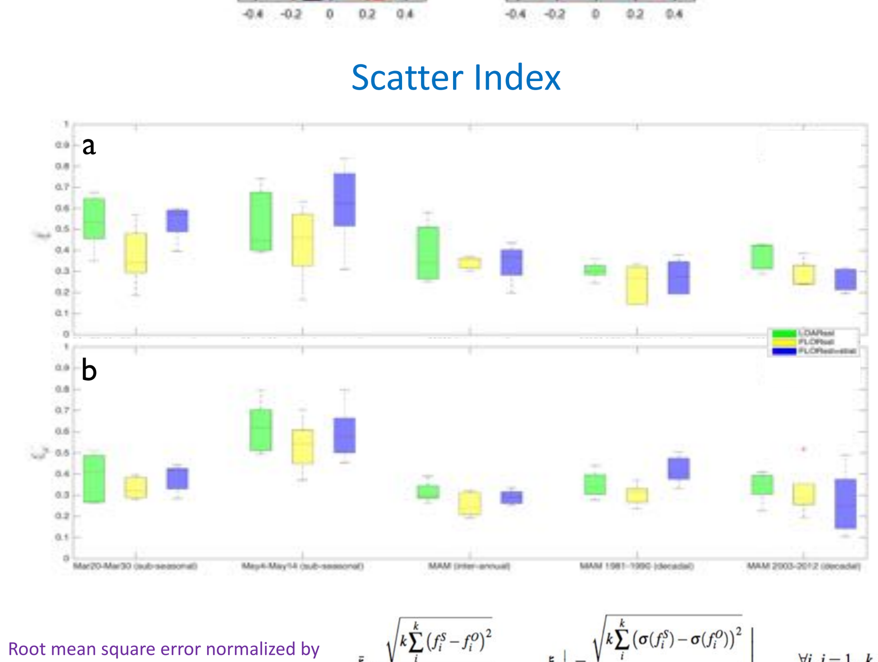


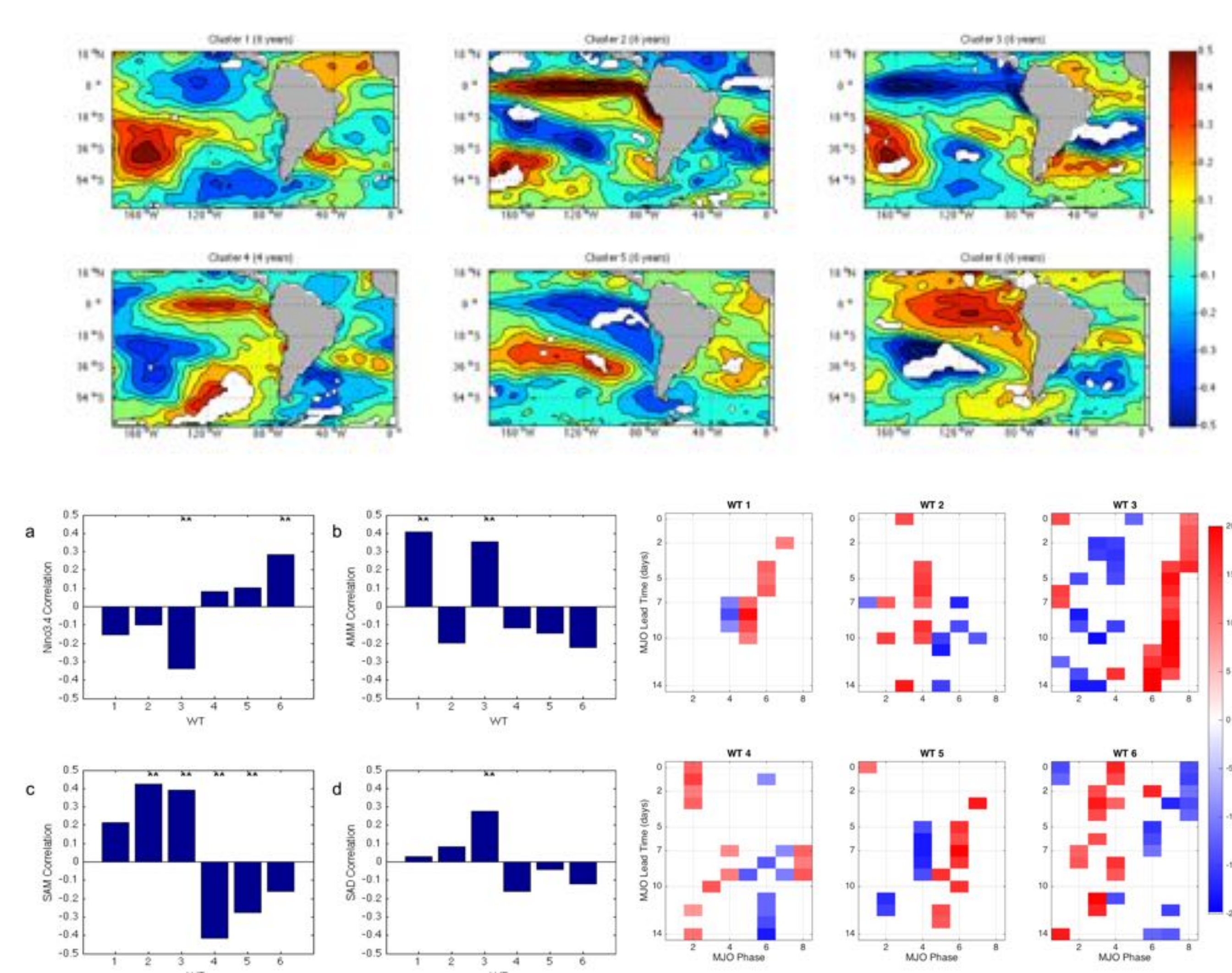




Misrepresented Physical Processes: example







Examples of types of teleconnections that a model should be able to reproduce: SST and MJO.

Summary

Metric	Characteristics	Description	Reference
Cross-timescale scatter index for mean (or standard deviation)	Temporal features	Root mean squared error of observed and simulated mean (or standard deviation) frequencies, normalized by the weather type mean (or standard deviation) frequency, all sampled for the time-scale of interest.	Muñoz et al 2017a
Daily transition matrix	Temporal features	Bias in the simulated daily transition probability between weather types.	Muñoz et al 2017a
Anomaly correlation coefficient	Spatial features	Pattern correlation between observed and simulated weather types.	Muñoz et al 2017a
Procrustes	Spatial features	Geometrical transformations (translation T, reflection Re, rotation Ro and scaling S) required to maximize the spatial similarity between observed and simulated weather types.	Based on Kendall 1989
Spatial correlation	Tele-connections	Spatial correlation between the frequency of occurrence of weather types and --for example-- SST patterns.	Robertson et al 2015
Temporal correlation	Tele-connections	Temporal anomaly correlation between the frequency of occurrence of weather types and climate indices (e.g., ENSO or MJO).	Robertson et al 2015

Diagnostic	Metric(s)	Potential Recommendation(s)
Rainfall extremes are zonally shifted (WT is zonally shifted)	Procustes	Decrease the mountain gravity-wave propagating drag parameter. Assess boundary layer formulation, cloud parameterizations and ocean mixing parameterizations to correct SST biases in the tropics.
Rainfall extremes are meridionally shifted (WT is meridionally shifted)	Procustes	Assess impact of cloud and boundary layer parameterizations to correct SST biases in the extra-tropics.
Frequency of extreme rainfall events is too low/high (frequency of WT is too low/high)	Scatter index Daily transition matrix bias Temporal and/or spatial correlations	Potential problems with meridionally propagating Rossby waves from tropical sources. Probably, baroclinic waves are not well represented in the model. Check moist convection parameters.

- Process-based multi-timescale diagnostic of CMIP5 and CMIP6-era Earth System Models.
- The proposed work focuses on how accurately extreme rainfall events, both wet and dry, are represented over the US in CMIP5/6 models.
- Develop process-informed cross-timescale tools to diagnose CMIP5/6 historical and climate-change projections over North America based on large-scale recurrent, persistent weather types (WTs), also known as large-scale meteorological patterns (LSMPs).
- These regimes provide a dynamically informative intermediary between the large-scale drivers of climate variability and change from sub-seasonal to decadal timescales, and mid-latitude high-impact weather events, through the mechanism of synoptic control.
- Process-level understanding on rainfall extremes in CMIP5/6 simulations, developing standard metrics that model developers and users can apply to these models easily.

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