Optimized Physics Ensemble Modeling to Advance Seamless Weather-Climate Prediction and Uncertainty Estimation

Xin-Zhong Liang
Department of Atmosphere & Ocean Science
Earth System Science Interdisciplinary Center
University of Maryland, College Park

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Weather/Climate Prediction Uncertainty

Tebaldi and Knutti (2007) group into four major sources:

① initial condition

- Fuqing Zhang, Jun Du

② boundary forcing

- surface/external conditions are prescribed over time

③ parameterization parameter

- schemes contain parameters that are uncertain from observations or physical principles – PPE

④ model structure

- spread caused by choices in model formulation design – MME, OPE

MM Superensemble Improves Climate Forecast

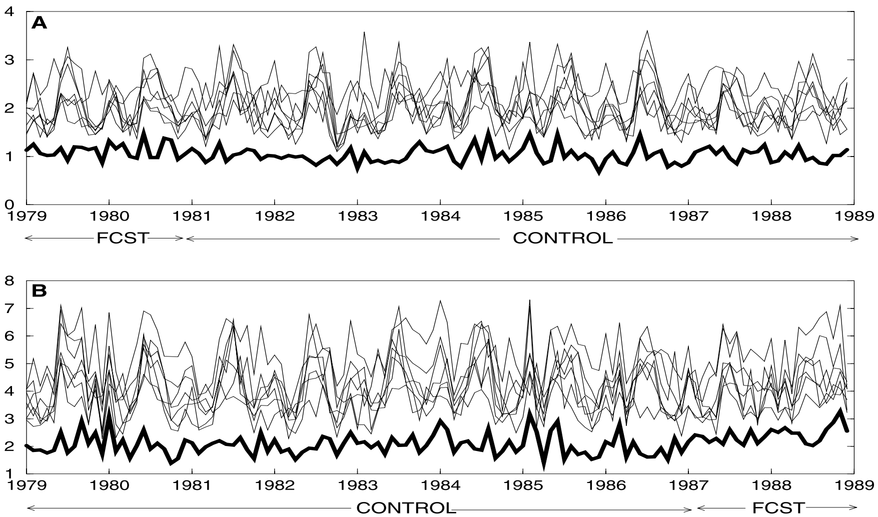


Fig. 1. Asian monsoon domain average rms error for the superensemble (heavy line) and the selected AMIP models (thin lines) for 850-hPa meridional wind (**A**) and precipitation (**B**). Units in (A) are ms^{-1} and units in (B) are mm day^{-1}.

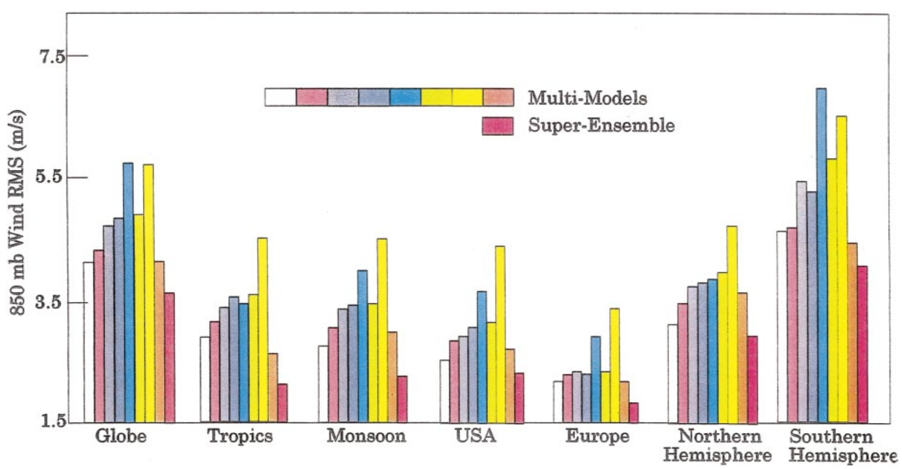


FIG. 6. The rms error of the 850-hPa winds on day 3 of the forecasts during Aug 1998. The results for the multimodels follow from left to right, and the results for the ensemble mean and the superensemble are shown in the far right, respectively, (m s^{-1}).

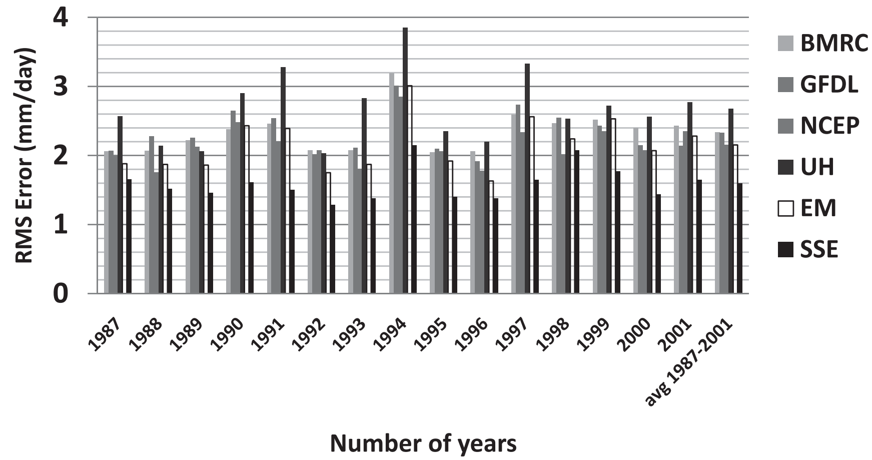


FIG. 8. The vertical bars shows RMS error (along ordinate) for single-model ensemble mean as compared to the overall ensemble mean (clear bar) and superensemble (dark bar) shown in at far right for each year . Also shown in the far right side is the overall average for 15 yr. These results pertain to the larger monsoon domain. The least RMS error are seen for the superensemble in the far right of each sets of bar.

Optimized weights varying in space and depending on individual member models' performance

Adopted from Krishnamurti (1999, 2000, 2011)

MME Improves Weather & Climate Forecast

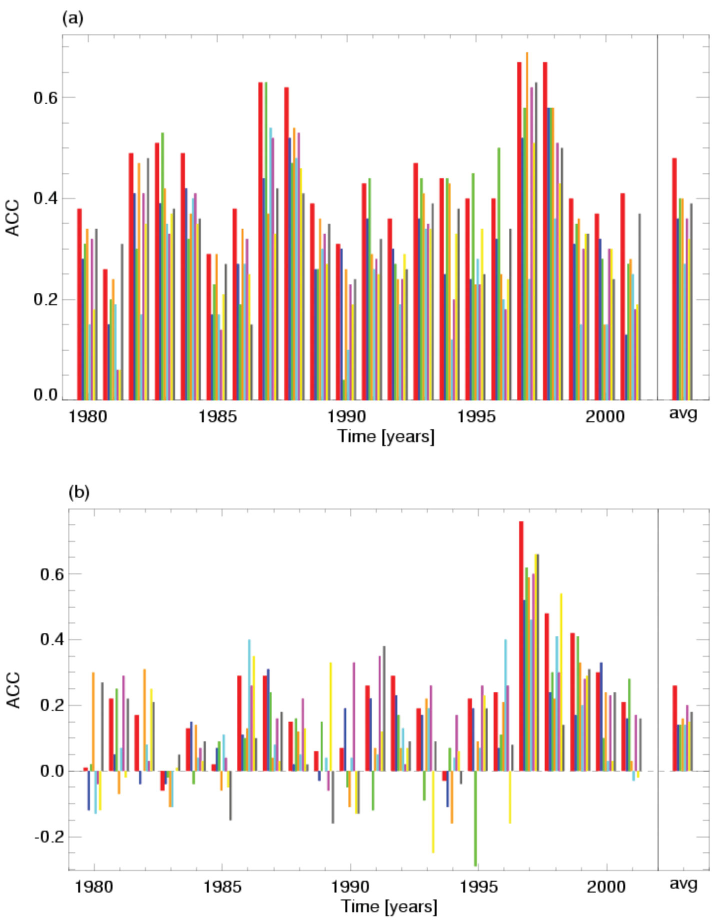


Fig. 2. Time series of the ensemble-mean precipitation anomaly correlation coefficients for the multimodel (thick red bars) and all individual models (thin bars; ECMWF: blue, Met Office: green, Météo-France: orange, MPI: cyan, LODYC: pink, INGV: yellow, CERFACS: gray). (a) One-month lead summer (JJA) precipitation in the Tropics (latitudinal band of 30°S–30°N); (b) 1-month lead winter (DJF) precipitation in the northern extratropics (latitudinal band of 30°–87.5°N). Additionally, the average over the whole period 1980–2001 is shown at the end of each plot.

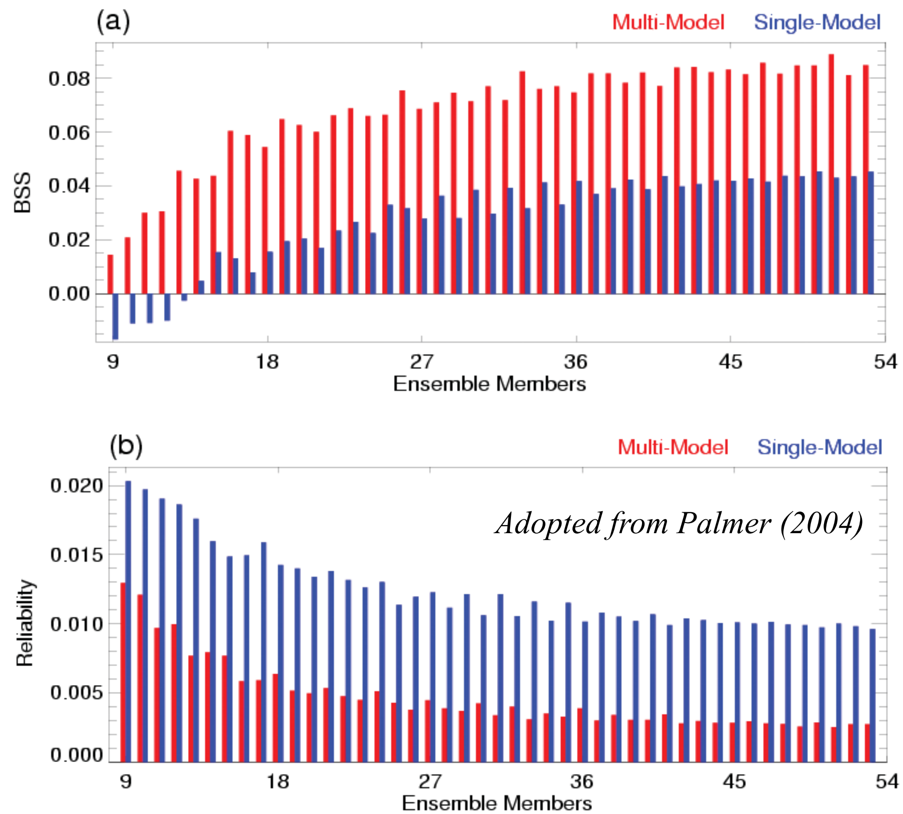
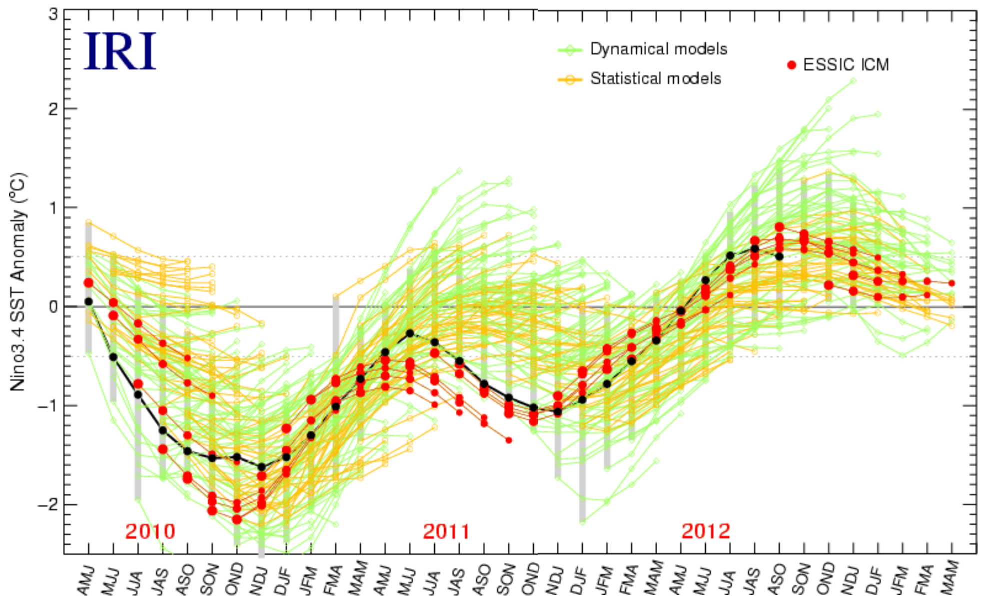
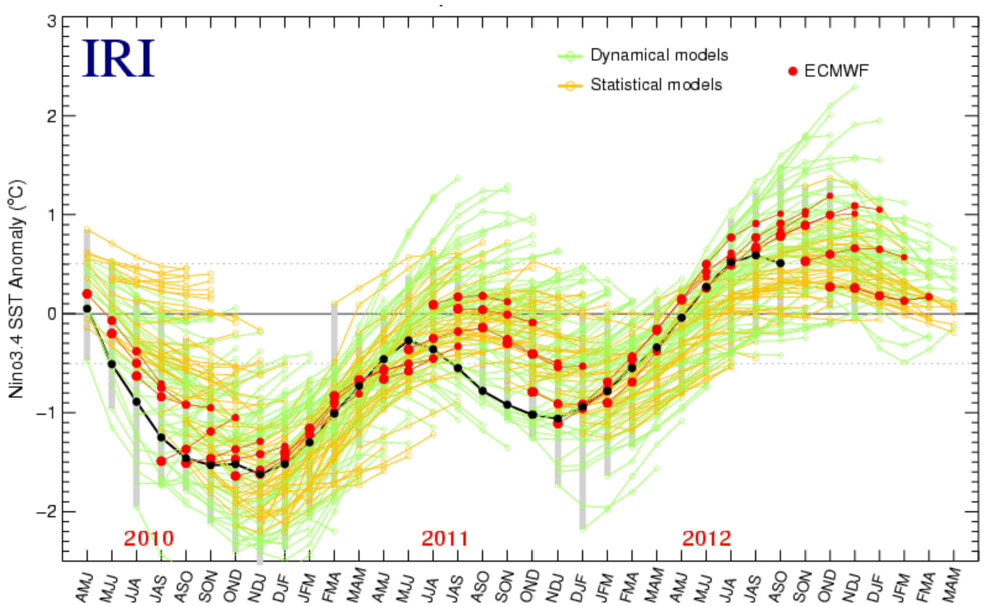


Fig. 5. (a) Brier skill score and (b) reliability component of Brier score for the 1-month lead tropical summer (JJA) precipitation 1987–99 for the single ECMWF control model (blue) and the DEMETER multimodel (red). The event is "precipitation anomalies above zero." Results are shown for different ensemble sizes from 9 to 54 members. Note that lower values of the reliability term mean better reliability.

ensemble of opportunity





Questions

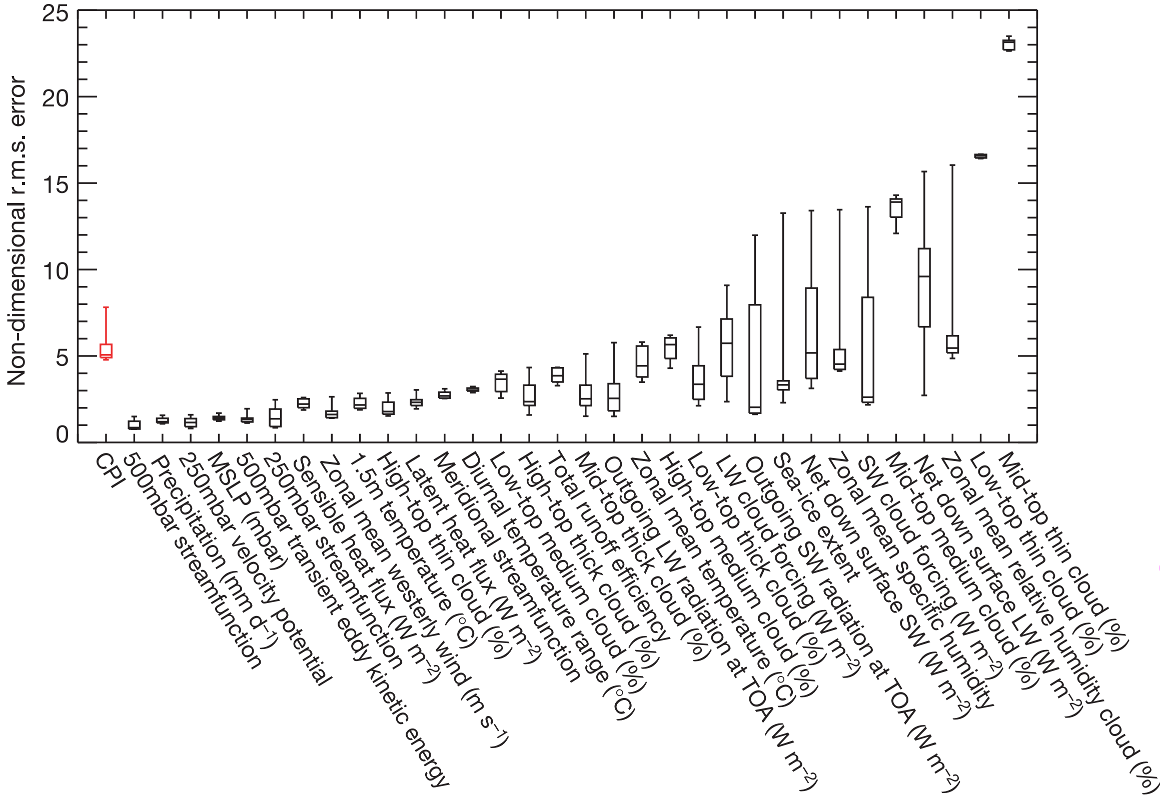
If MME outperforms always?

If optimal weighting is better?

If fidelity constraint is better?

If ensemble of op is adequate?

Parametric Uncertainty – PPE

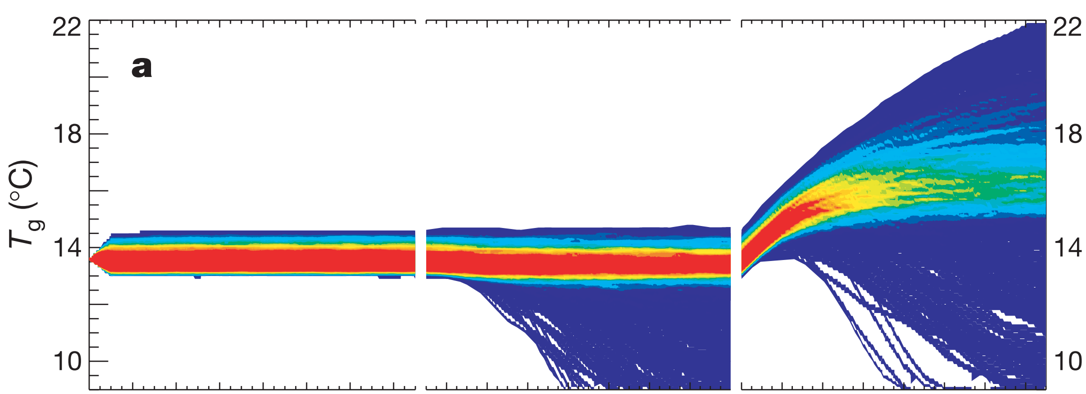


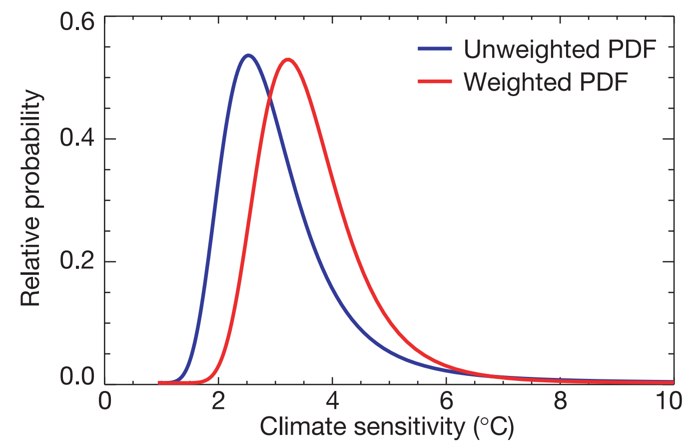
Perturbations (min, med, max) to the sensitive parameters of key physics parameterizations in a single GCM.

Murphy et al. (2004)

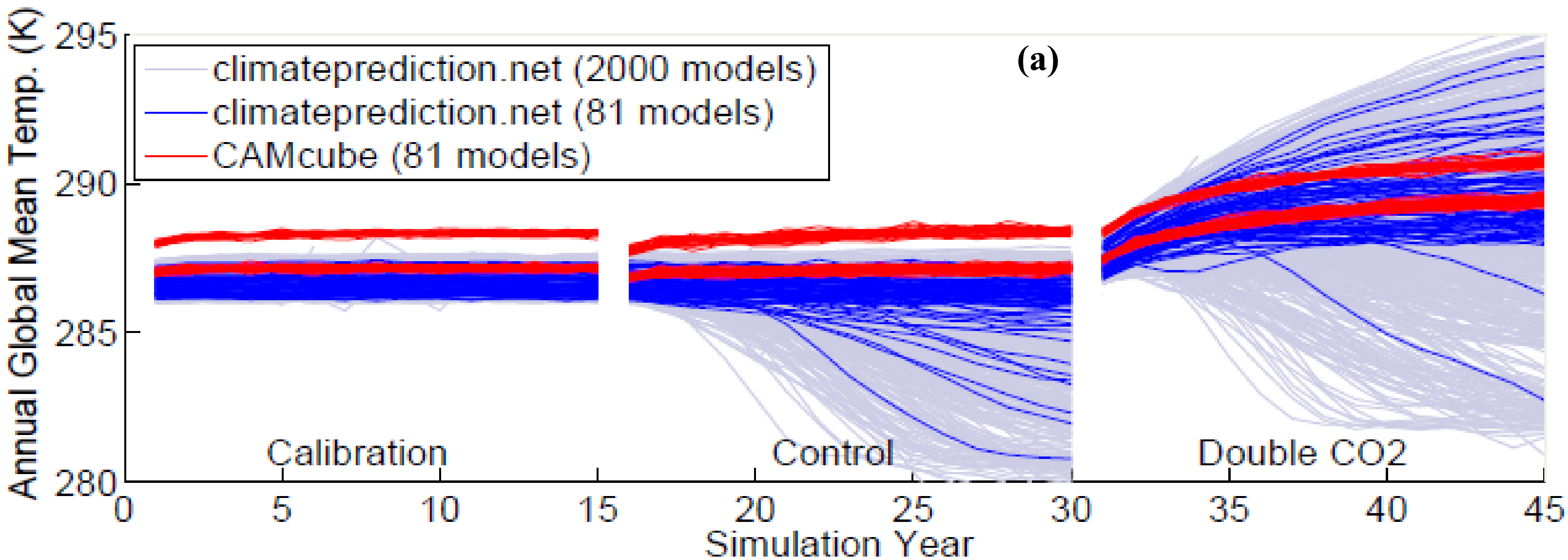
Stainforth et al. (2005)

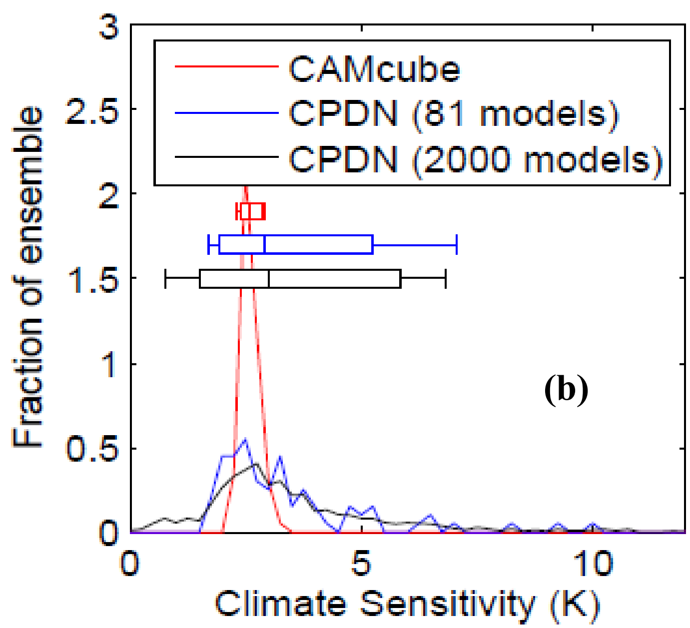
design for sensitivity range





Structural Uncertainty – MME





models differ in sensitivity

Figure 1. (a) Global annual mean temperature of each member in both the CAM and HAD (climateprediction.net) ensembles during three 15-year simulations: the calibration, control and double CO_2 stages. **(b)** Distributions of climate sensitivity created from the CAM and HAD ensembles using 1K bins and normalized by the respective total number of members. Both a 2000-member and an 81-member subset of the HAD ensemble are shown.

Adopted from Sanderson (2011).

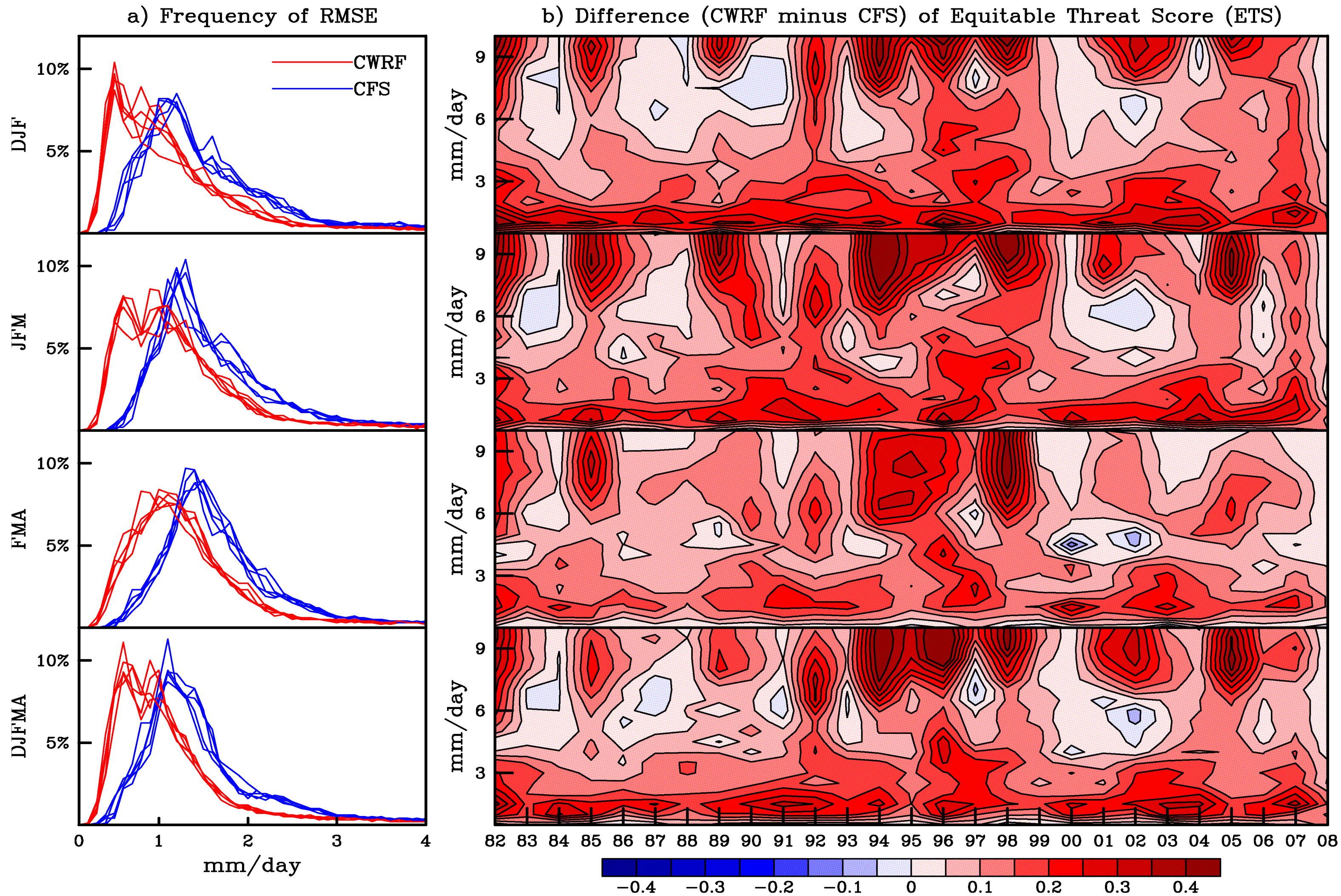
Can Multiple Physics Ensemble of a Single Model Work & How?

Optimized Physics Ensemble

Increasing predictive skill

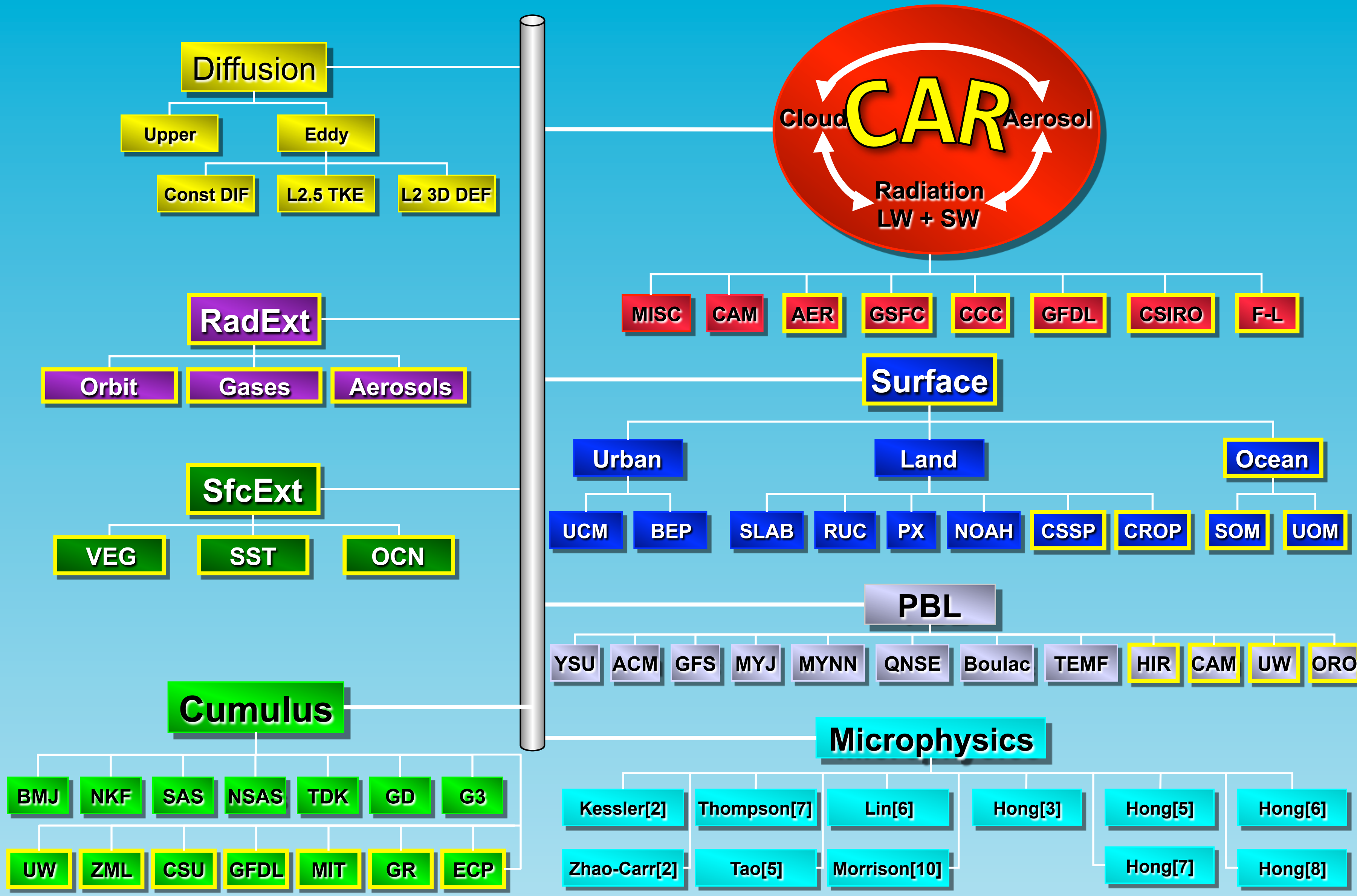
Quantifying uncertainty

CWRF Improves Seasonal Climate Prediction

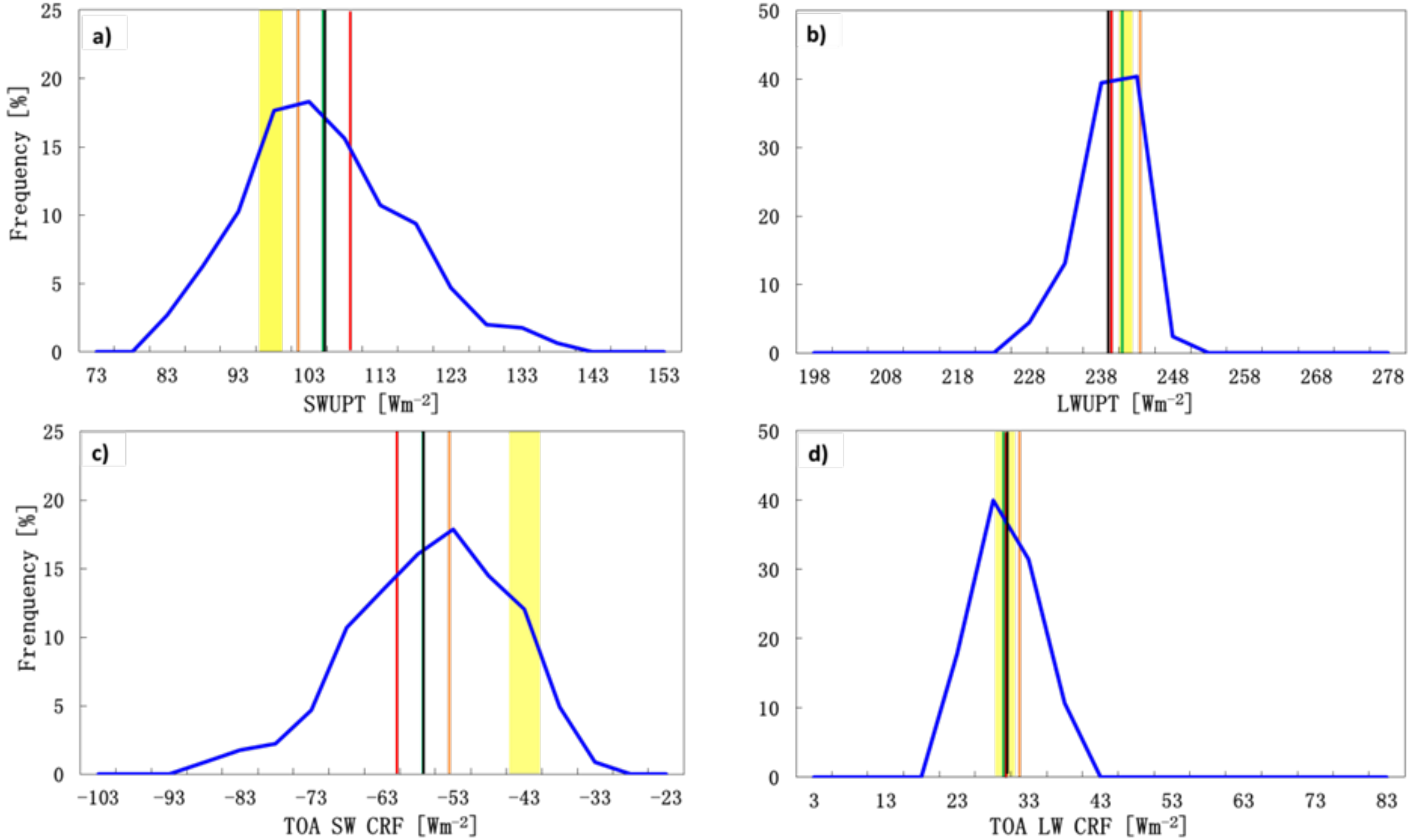


a) Spatial frequency distributions of root mean square errors (*RMSE*, mm/day) predicted by the CFS and downscaled by the CWRF and **b)** CWRF minus CFS differences in the equitable threat score (*ETS*) for seasonal mean precipitation interannual variations. The statistics are based on all land grids over the entire inner domain for DJF, JFM, FMA, and DJFMA from the 5 realizations during 1982-2008. *From* Yuan and Liang 2011 (GRL).

CWRF Physics Options

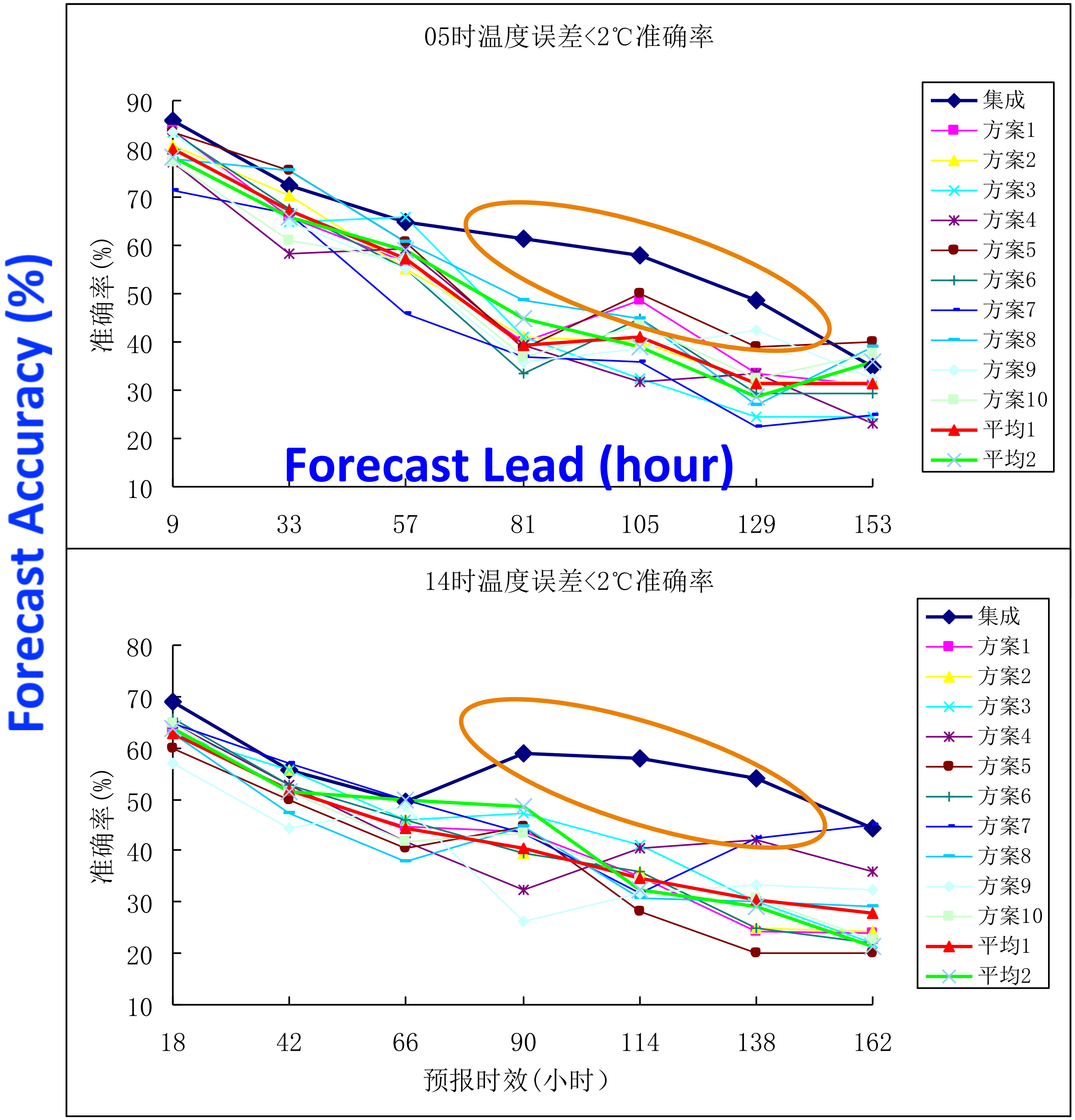


http://cwrf.umd.edu



Frequency distribution of TOA radiative flux and CRF averaged over [60ºS, 60ºN] in January 2004 from the CAR ensemble of 960 members

Adopted from Liang and Zhang (2012)

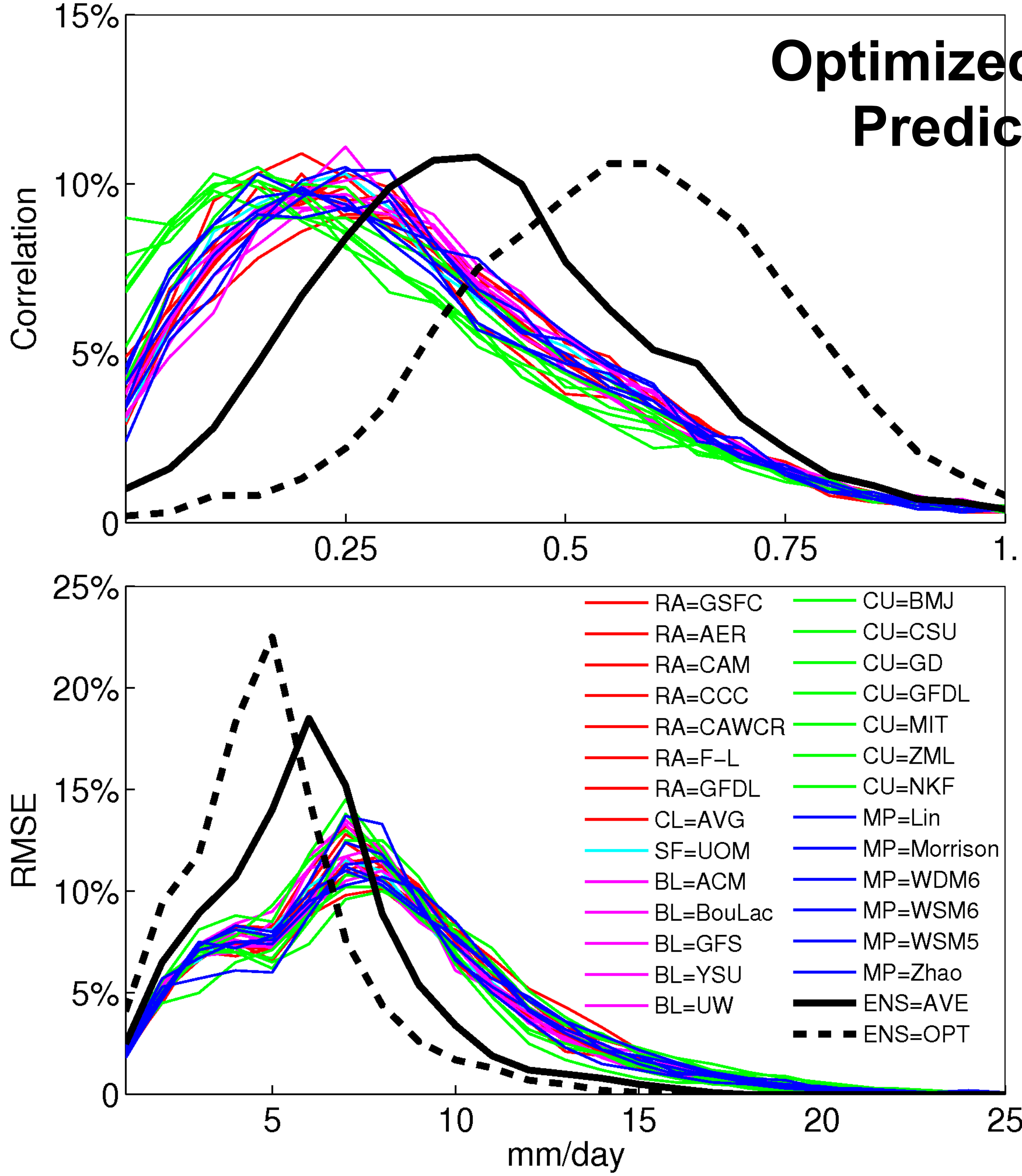


T2m Nanjing

CWRF 10 套不同的物理参数化方案集成预报南京地区日最低、最高温度，结果表明，此种方法具有良好预报效果。

Adopt from Zeng et al. (2008)

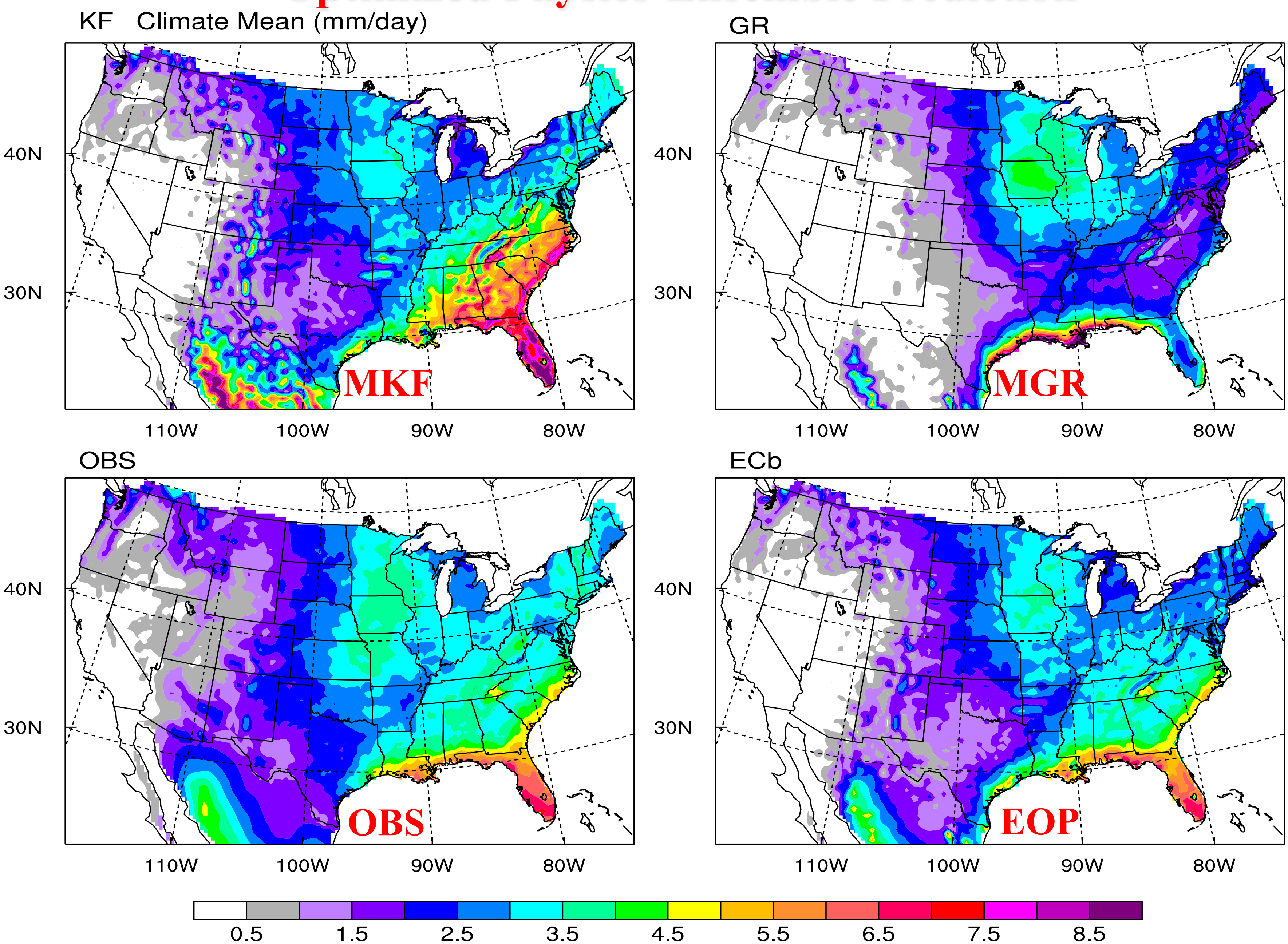
Optimized Physics Ensemble Prediction of Precipitation In summer 1993



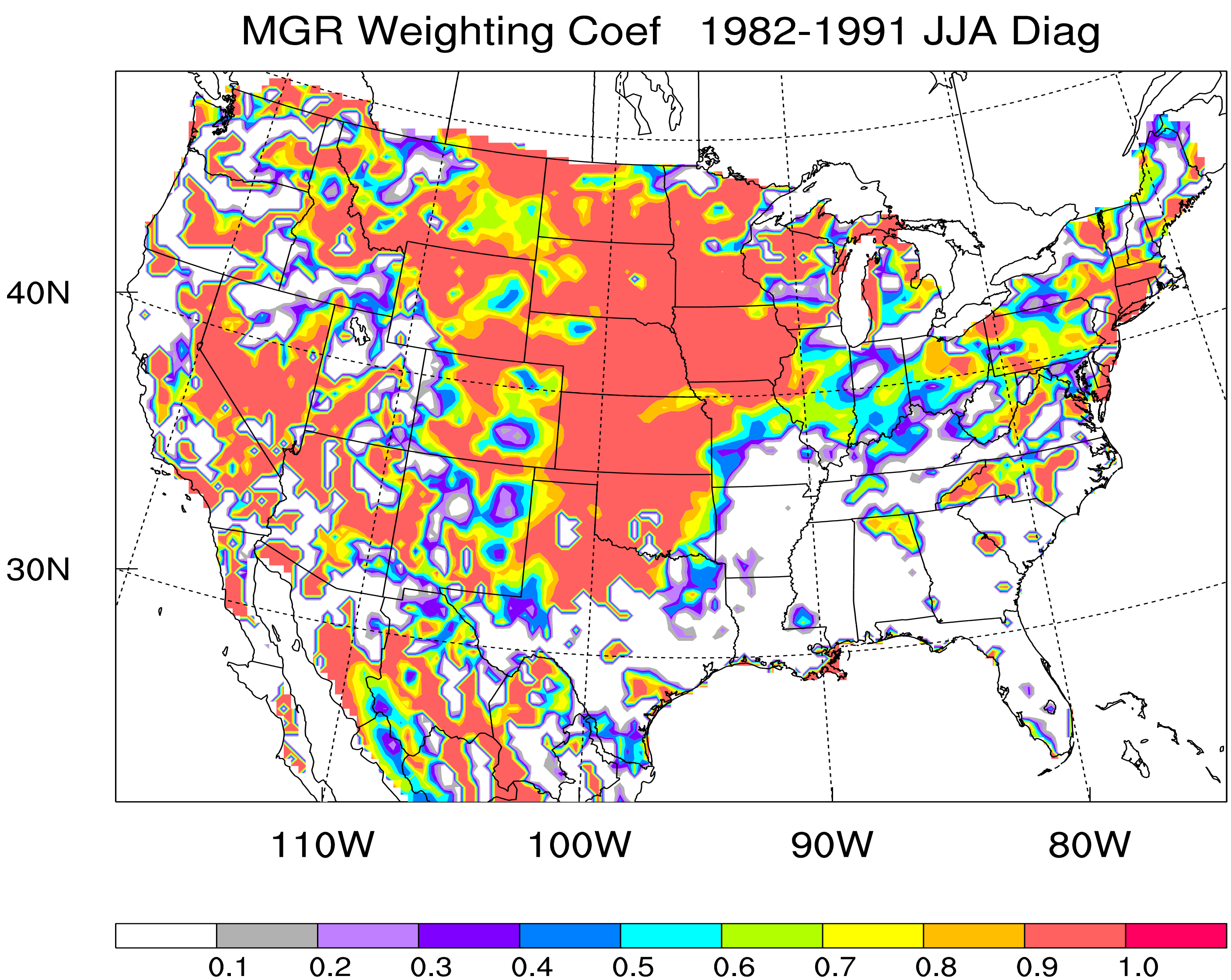
The physics ensemble mean substantially increases the skill score over individual configurations, and there exists a large room to further enhance that skill through intelligent optimization.

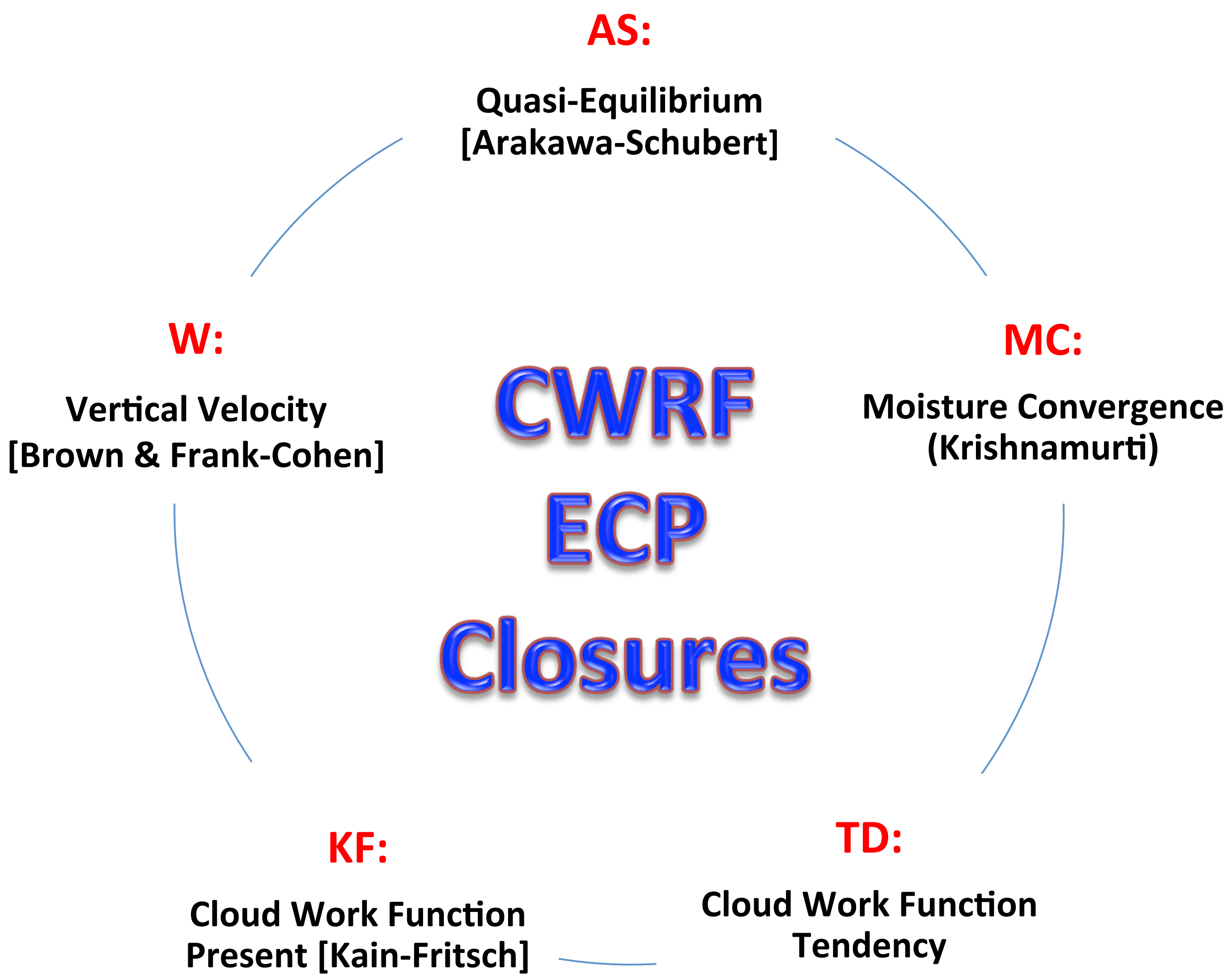
Spatial frequency distributions of correlations (*top*) and rms errors (*bottom*) between CWRF and observed daily mean rainfall variations in summer 1993. Each line depicts a specific configuration in group of the five key physical processes (*color*). The ensemble result (ENS) is the average of all runs with equal (Ave) or optimal (OPT) weights, shown as *black solid* or *dashed* line.

Optimized Physics-Ensemble Prediction

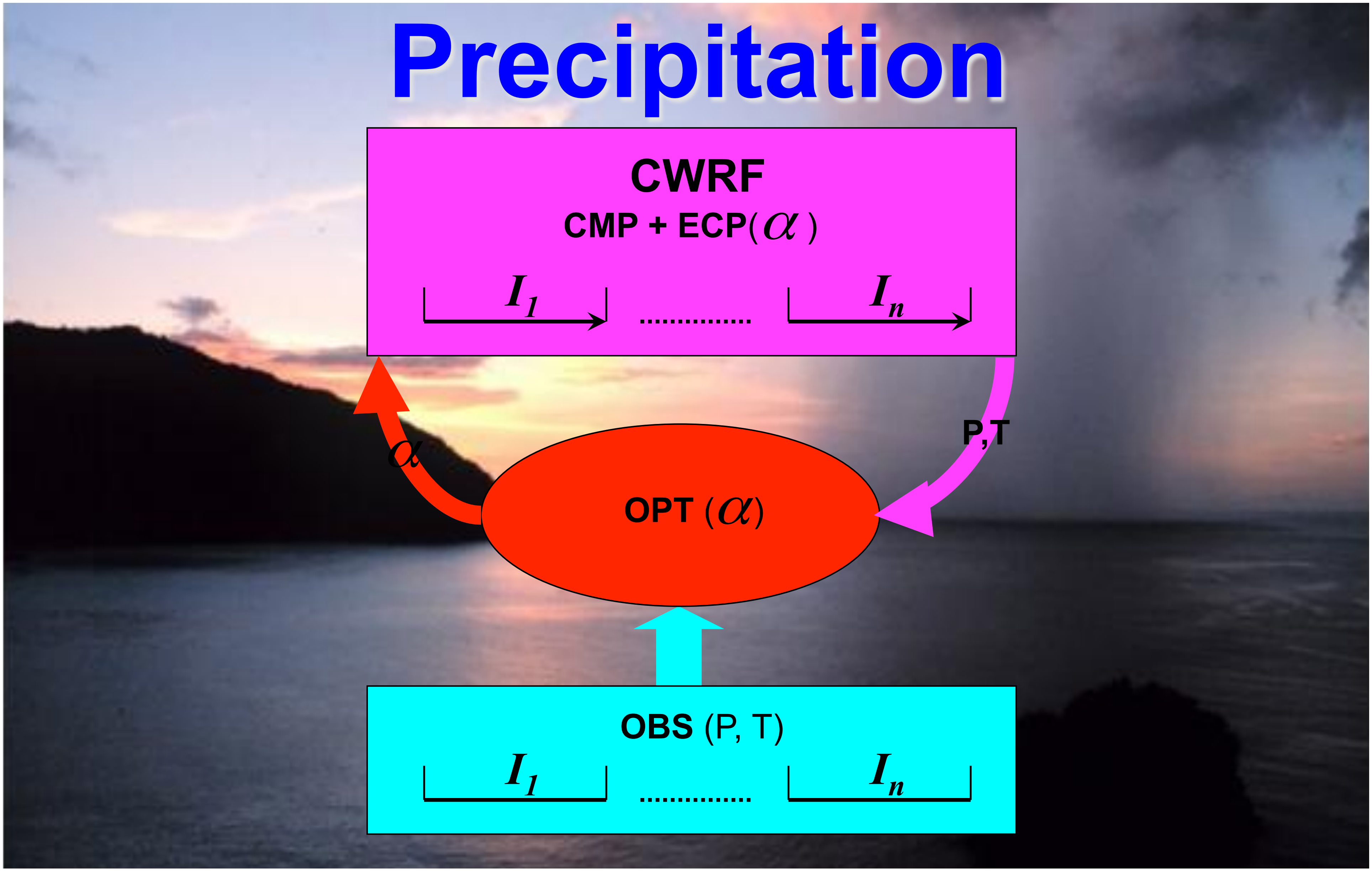


Optimal Weight Distribution Exhibits Large-Scale Features




AS:
Quasi-Equilibrium
[Arakawa-Schubert]
W:
Vertical Velocity
[Brown & Frank-Cohen]
CWRF
ECP
Closures
MC:
Moisture Convergence
(Krishnamurti)
KF:
Cloud Work Function
Present [Kain-Fritsch]
TD:
Cloud Work Function
Tendency

Dynamic-Statistical Optimization of Mesoscale Model Representation of Precipitation



Regional OPE Prediction