Regional Climate-Weather Research and Forecasting (CWRF) Model Development & Application

SI Climate Prediction

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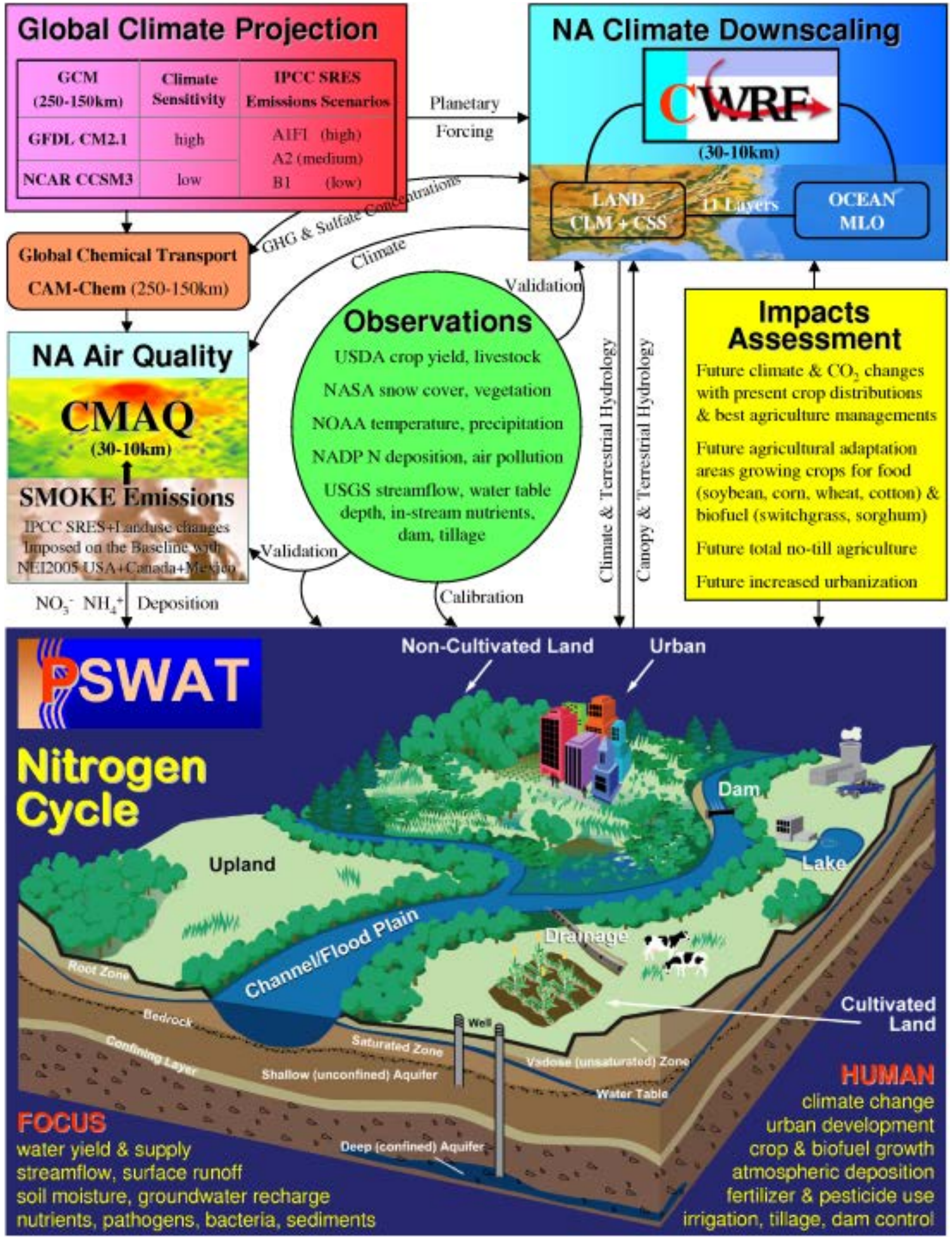
EPA STAR
2003-2011

FOCUS

Consolidate
O_3

Elaborate
PM

Explore
Hg



EPA STAR
2009-2012

FOCUS

Nutrients

Pathogens

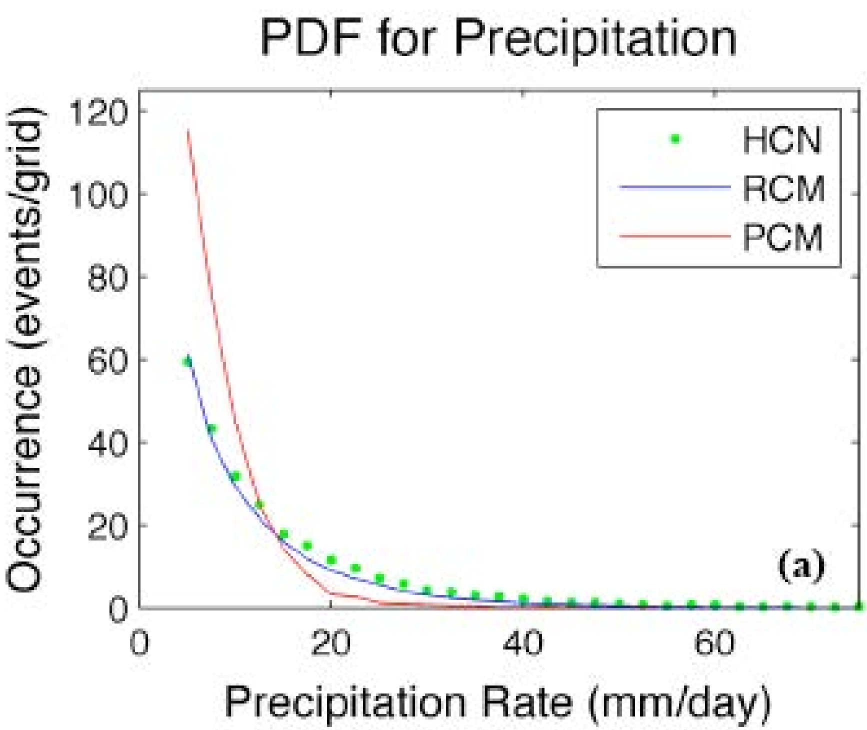
Bacteria

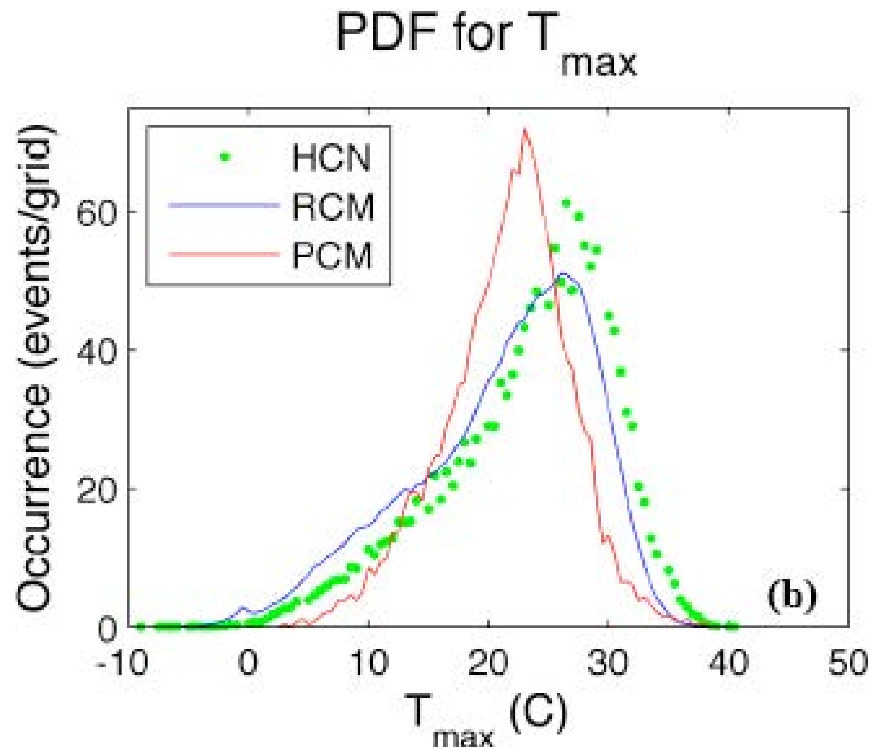
Sediments

Agriculture

Urban

RCM Better Resolves Extremes

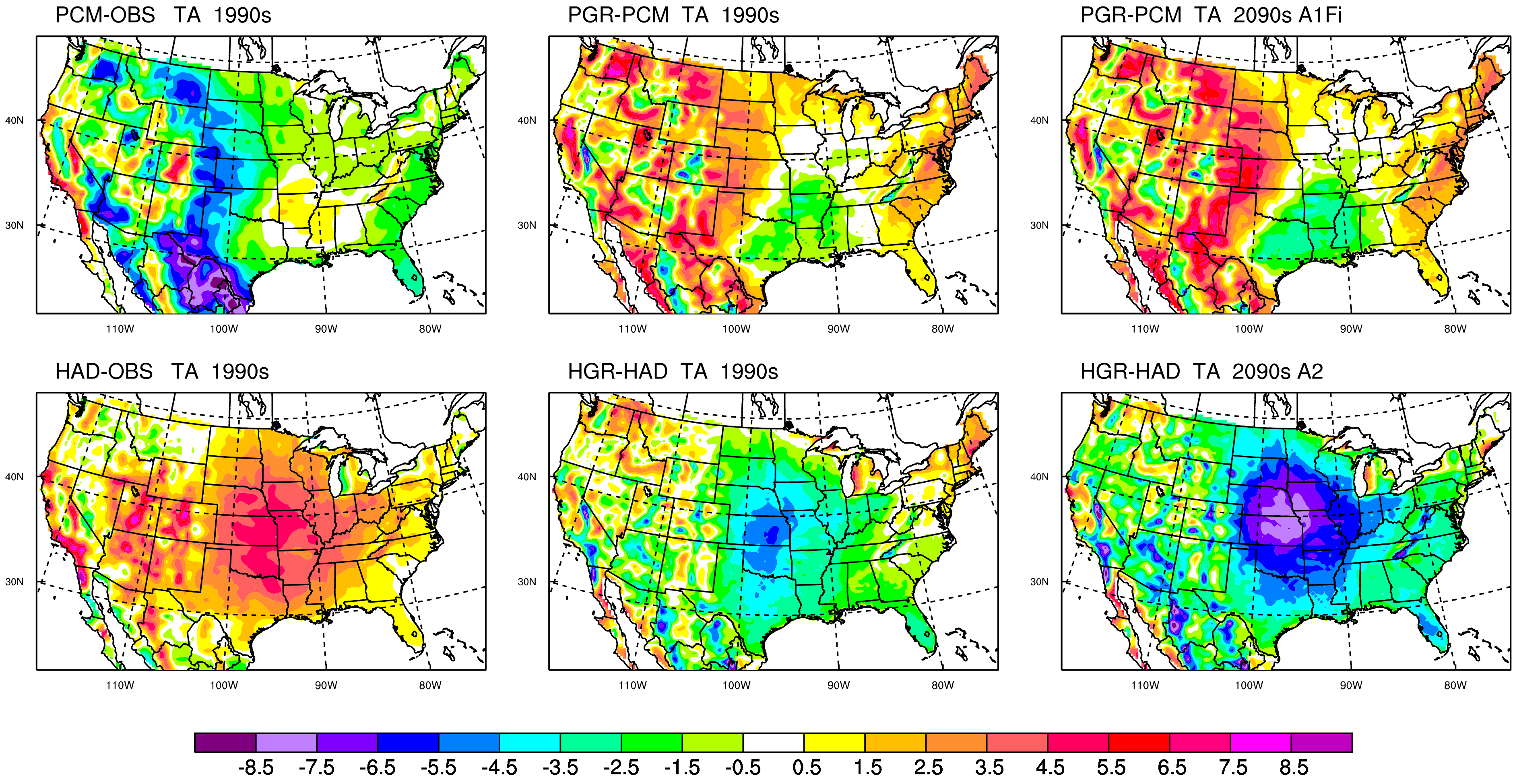




Northeast U.S. Assessment

Anderson, B.T., K. Hayhoe, and X.-Z. Liang, 2009: Anthropogenic-induced changes in the 21st Century summertime hydroclimatology of the Northeastern US., *Climate Change*, doi.10.1007/s10584-009-9673-3.

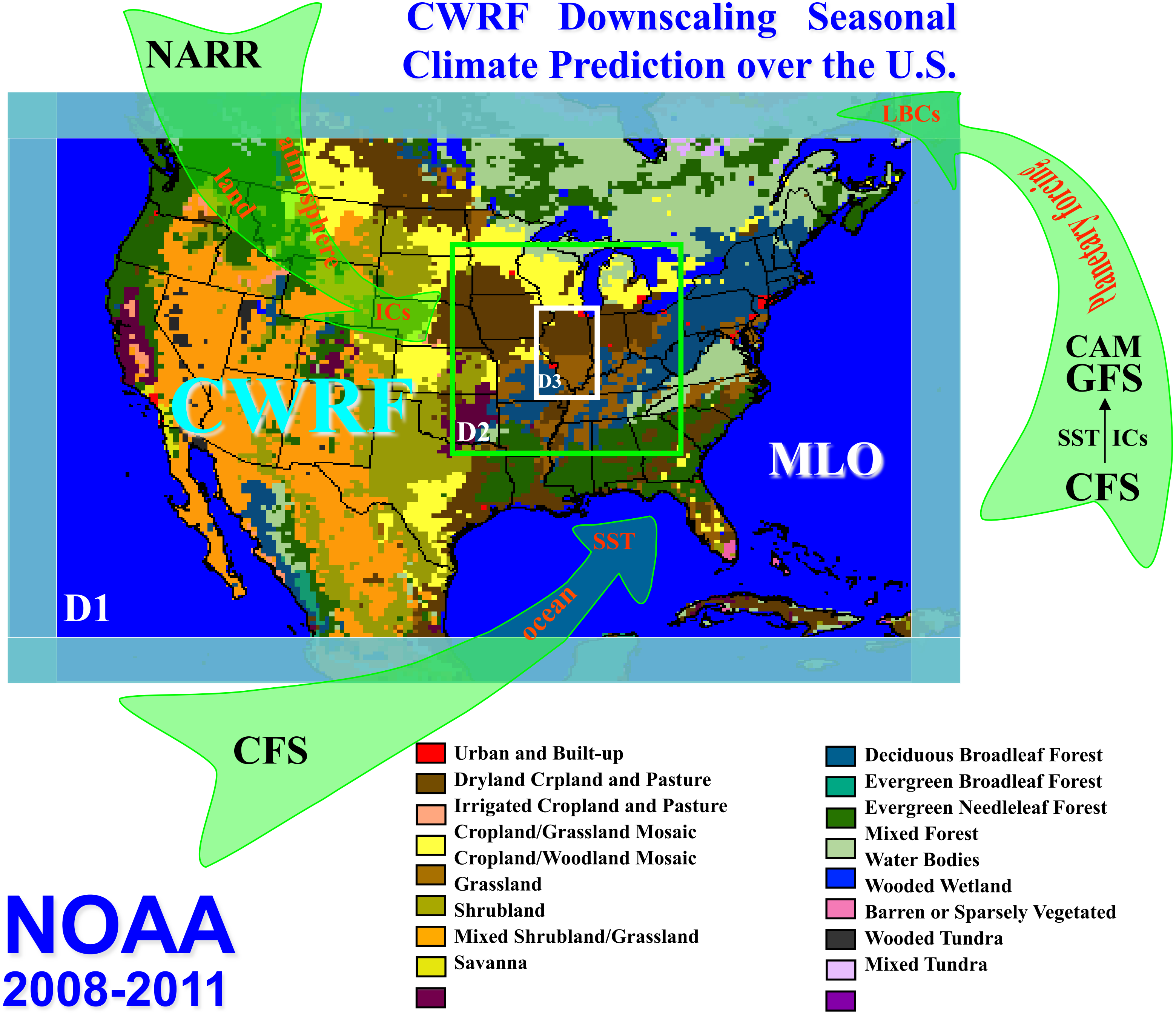
Propagation of GCM Present Climate Biases into Future Change Projections: Temperature



Outline

- What is RCM – the EaSM core?
- What are values added by RCM downscaling?
- What are CWRF advances over other RCMs?
- What are needed to make a credible RCM run?
- What challenges face RCM development?
  - Scale dependence
  - Physics configuration selection
  - Optimized physics ensemble
  - System uncertainty

CWRF Downscaling Seasonal Climate Prediction over the U.S.



NOAA

2008-2011

RCM Downscaling is Science + Art

- Do NOT take an RCM off the shelf (localization)
- Domain Design (integrating planetary forcing)
- Physics Configuration (regime & scale dependence)
- Verification or Evaluation (obs. data & added values)
- Ensemble Approach (prediction skill & uncertainty)

Doing details is the key to success!

Ensemble Global Forecast System

⇒ICs, SSTs, LBCs

NCEP
ECMWF
……

OP DASs
⇒ICs

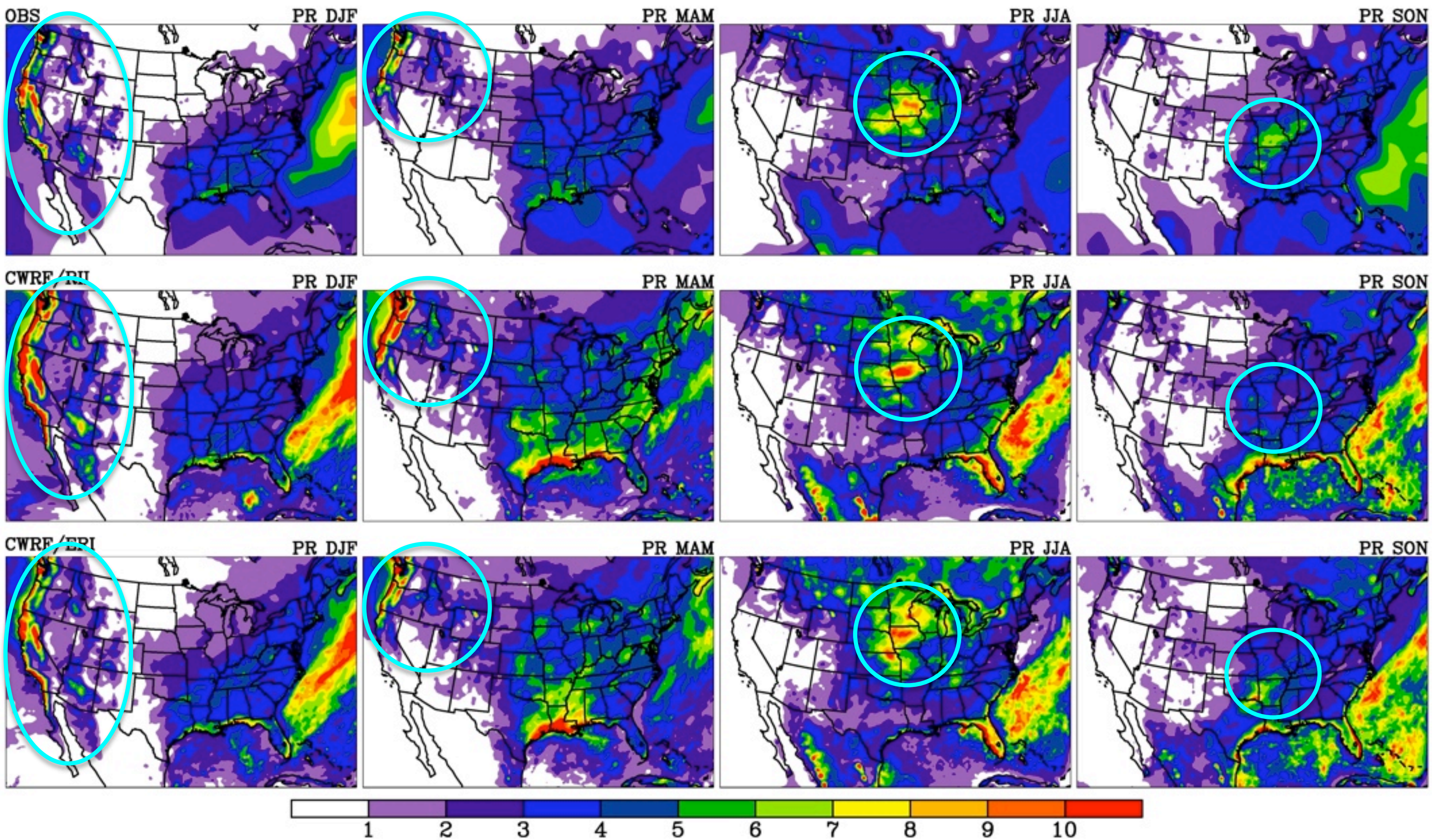
NOAA CFS
NASA GEOS
……
Bias corrections

OP CGCMs
⇒SSTs

NOAA GFS
NCAR CAM
IRI ECHAM
……

AGCMs
⇒LBCs

NCEP/AMIP II vs ECMWF-Interim Reanalysis

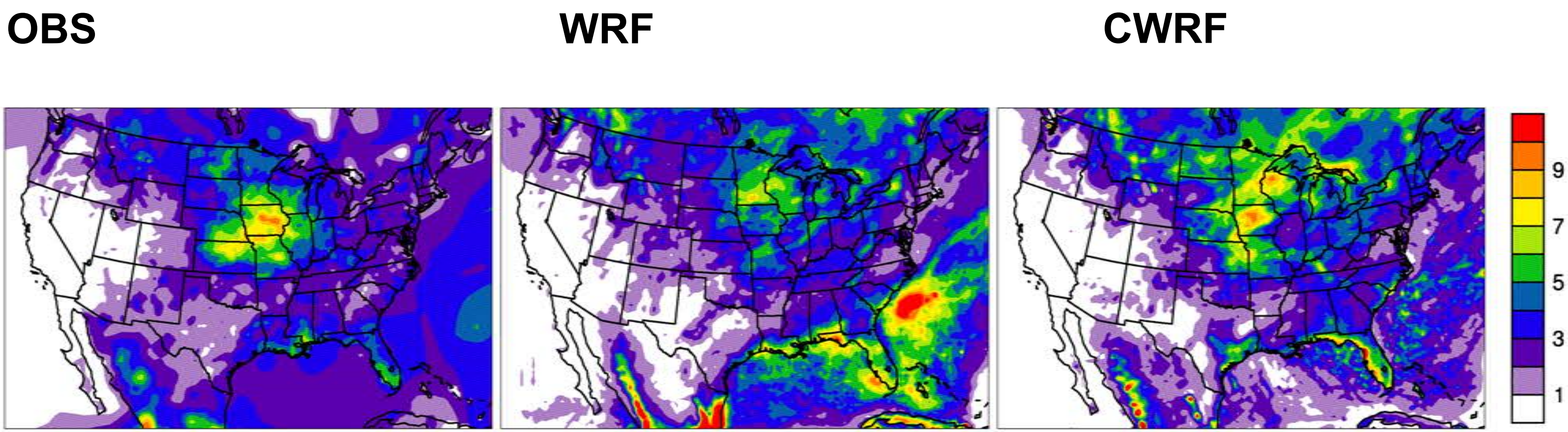


Recent Advances
Comparing with Other RCMs

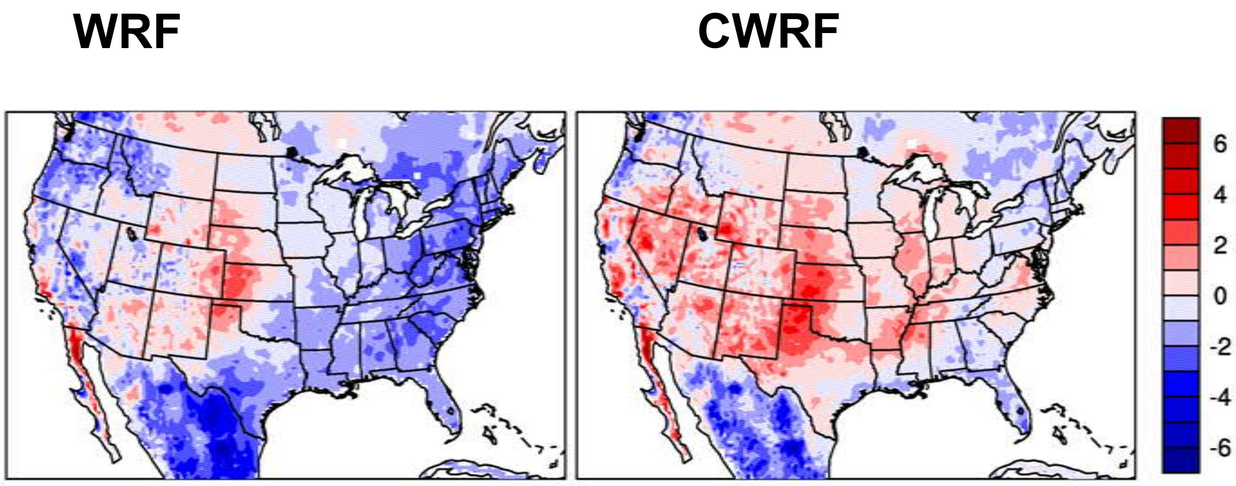
Ability to reproduce observations

- All driven by the same reanalysis
- Result comparison on
  - Seasonal variations
  - Interannual anomalies
  - Extreme events

Summer 1993 U.S. Midwest Record Flood



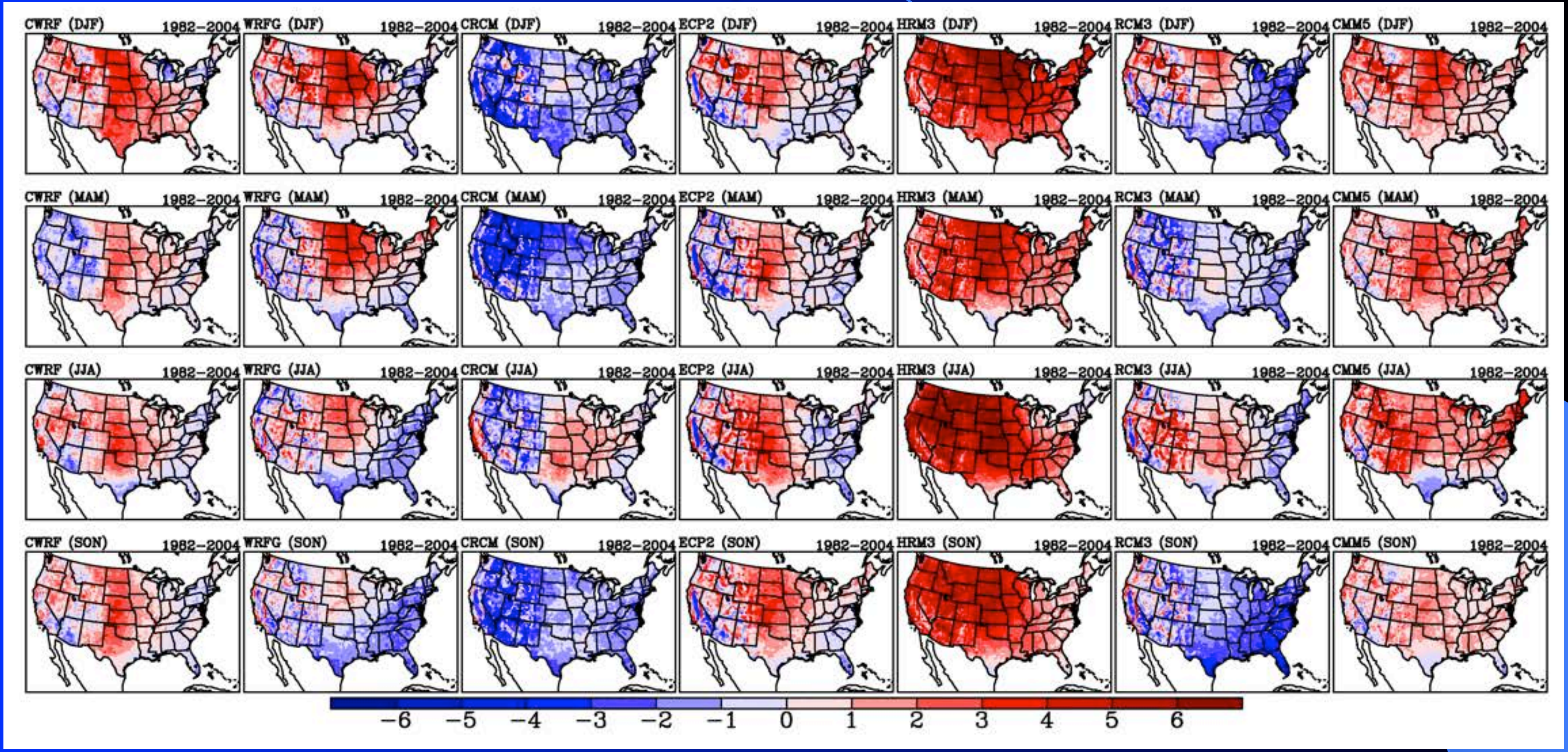
Rainfall (mm d^{-1})



CWRF has made significant improvements.

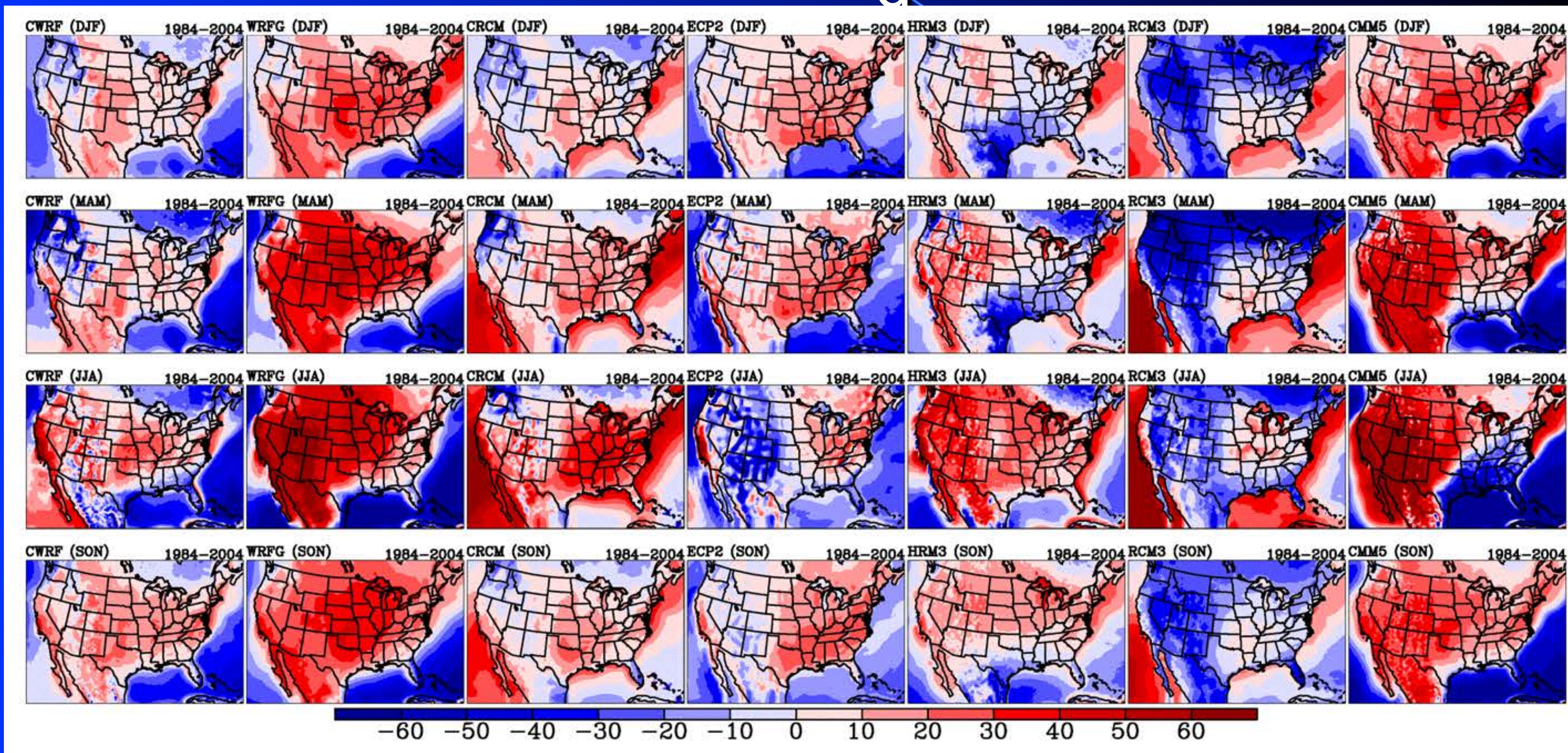
T2m Bias (°C)

Surface Temperature Biases



All driven by NCEP/DOE AMIP II Reanalysis

Surface SW_d Biases

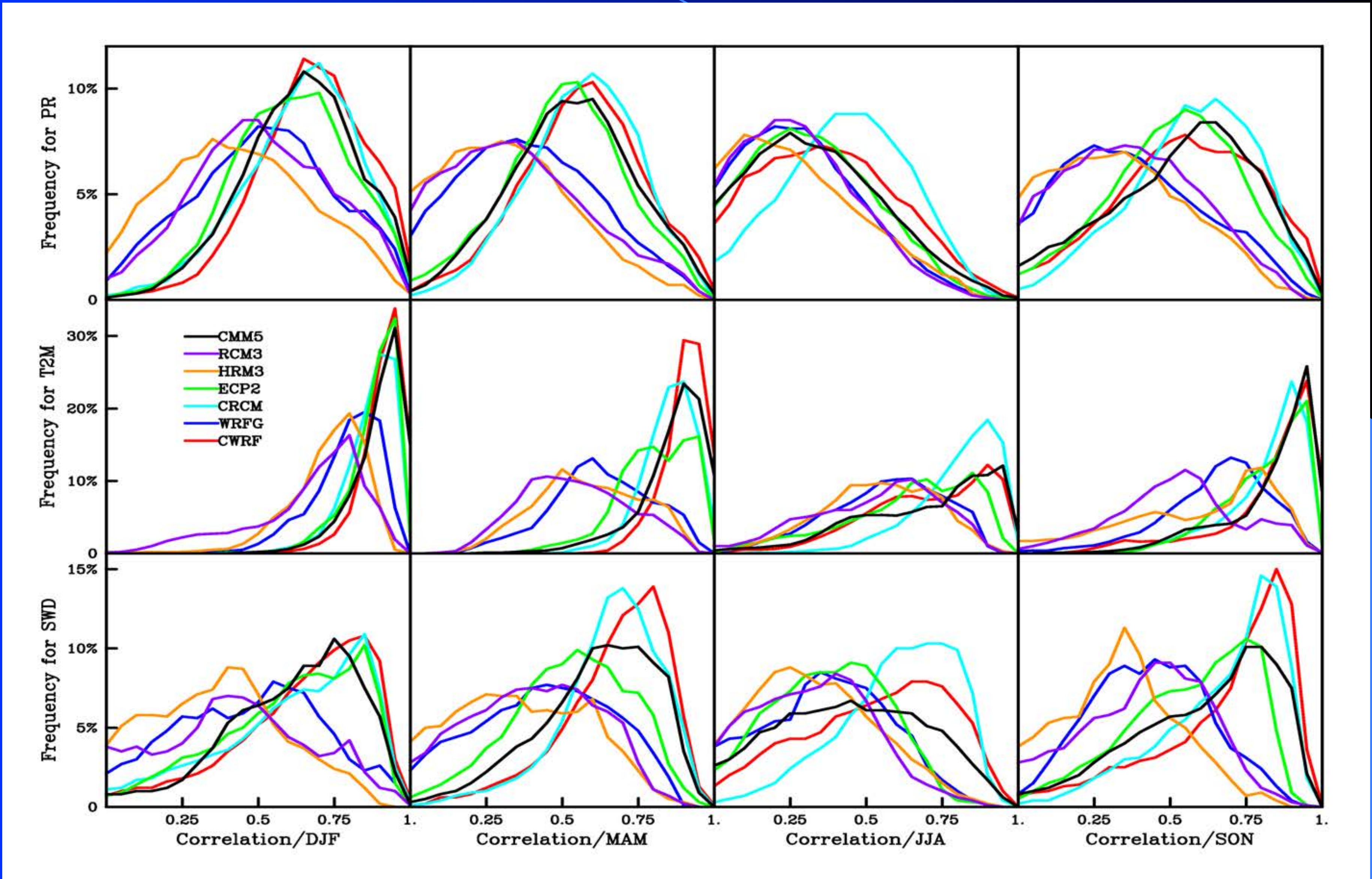


All driven by NCEP/DOE AMIP II Reanalysis

Understanding Biases

- WRFG & CMM5: SWd are too large,
  while T2m biases are relatively small
- HRM3: SWd is quite realistic,
  while T2m is substantially overestimated
- CRCM: SWd is fairly realistic,
  but T2m has notable cold biases
- RCM3: SWd is substantially underestimated,
  yet T2m is reasonable
- CWRF: SWd and T2m both are quite realistic
- Conclusion: SWd seems not the dominant factor that cause T2m biases; the latter may largely result from deficiencies in the water cycle.

Interannual CORR over USA



Why Do RCM Results Differ?

- Domain: U.S. + Adjacent for CWRF & CMM5, Extended North America for NARCCAP
- Resolution: 30 km for CWRF & CMM5, 50 km for all other NARCCAP RCMs
- Forcing: linear-exp relaxation in buffer zones of 14 (CWRF, CMM5), 10 (WRFG) grids
  linear relaxation in 4 grids (MM5I, HRM3)
  domain spectral nudging (ECP2, CRCM)
  NARCCAP IA correlations differ largely due to the strength of forcing integrated
- Physics: CWRF is much better than CMM5, being identical in all other settings
  Different dynamics may also contribute

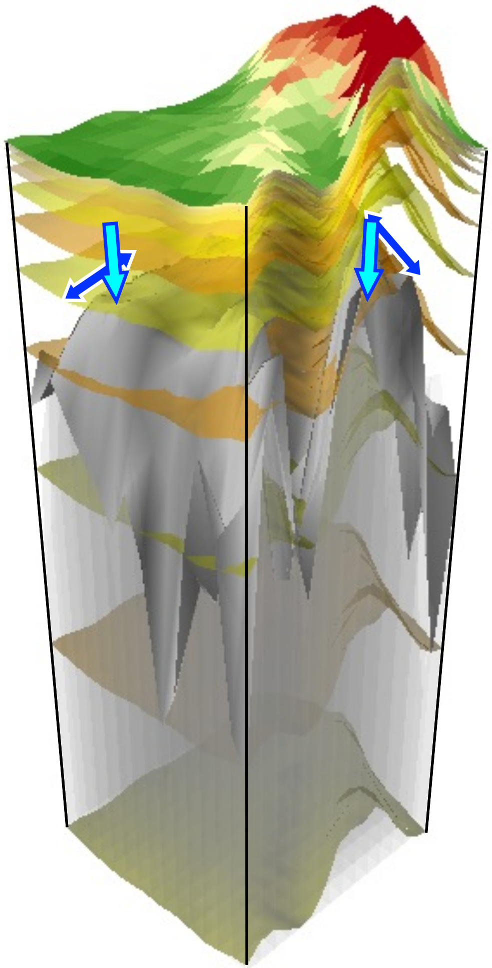
Physics Representation

Evaluating Skill under Correct Forcing Conditions

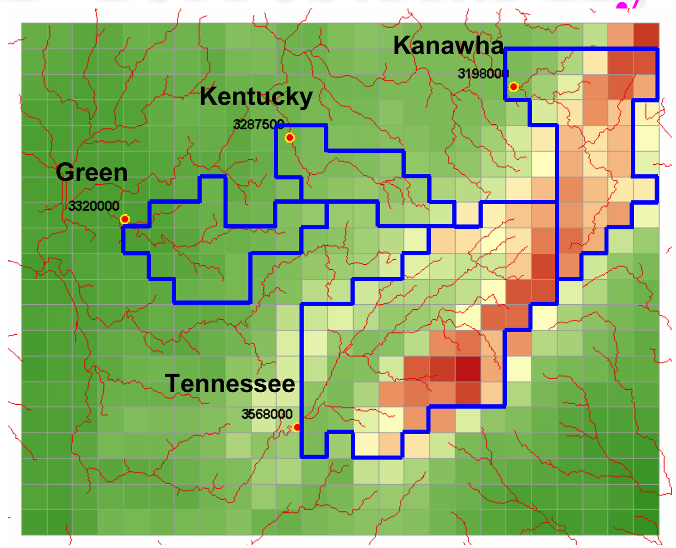
Scale Dependence

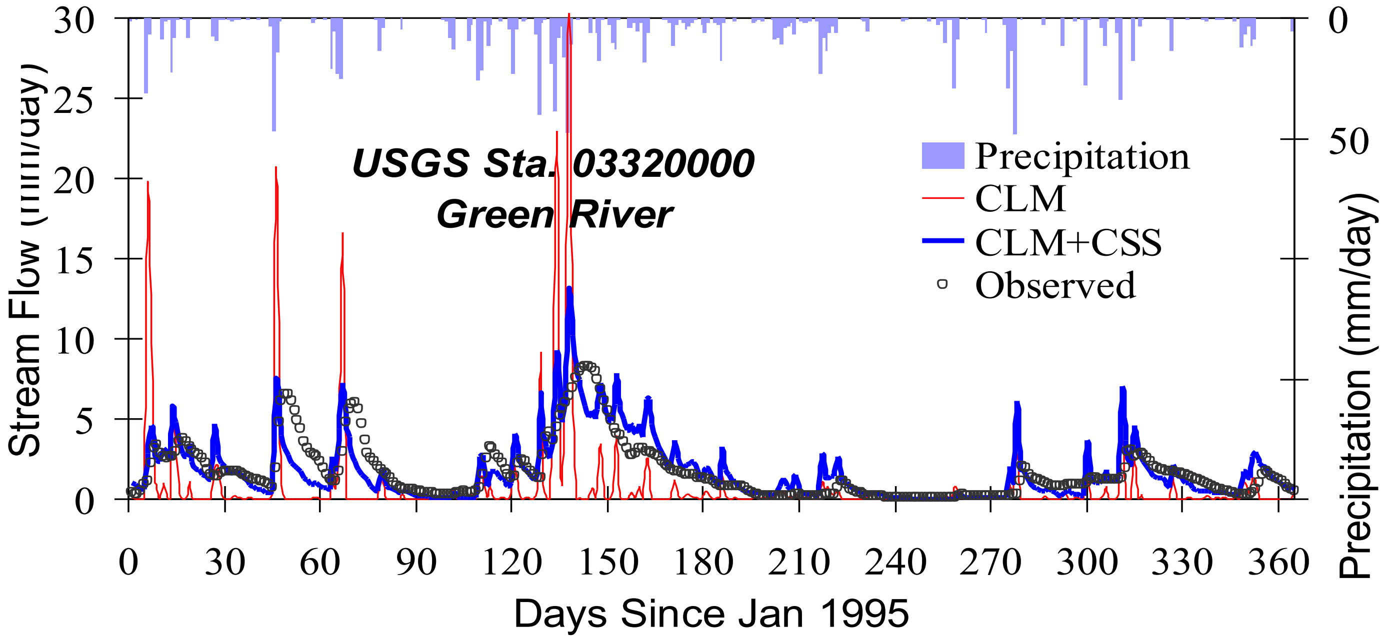
Model physics representation and predictive skill depend on spatial scale

Challenging



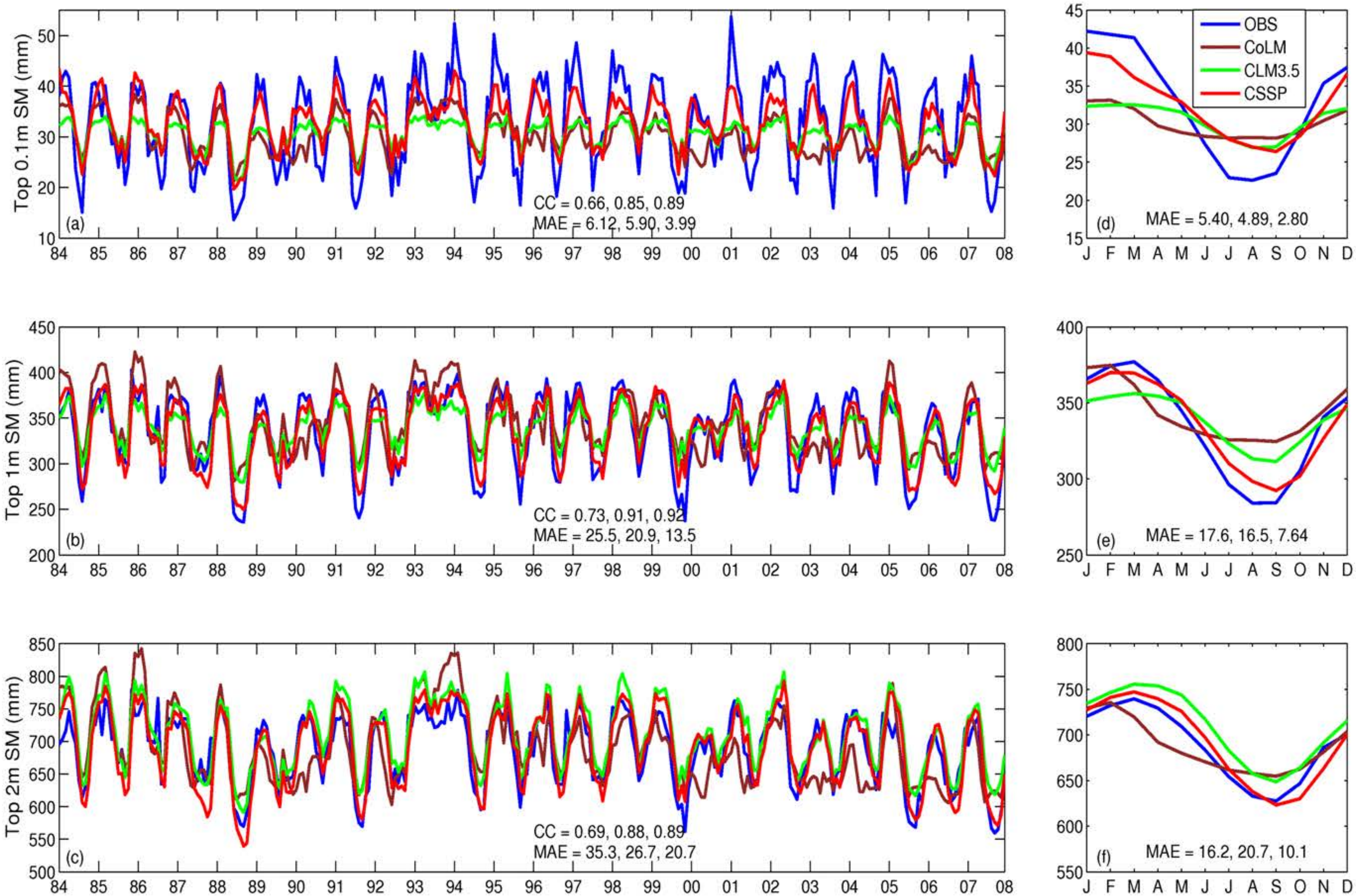
CWRF Terrestrial Hydrology





Choi 2006; Choi et al. 2007, 2011; Choi and Liang 2010; Yuan and Liang 2010; Liang et al. 2010d

Illinois Soil Moisture Simulations Driven by NARR

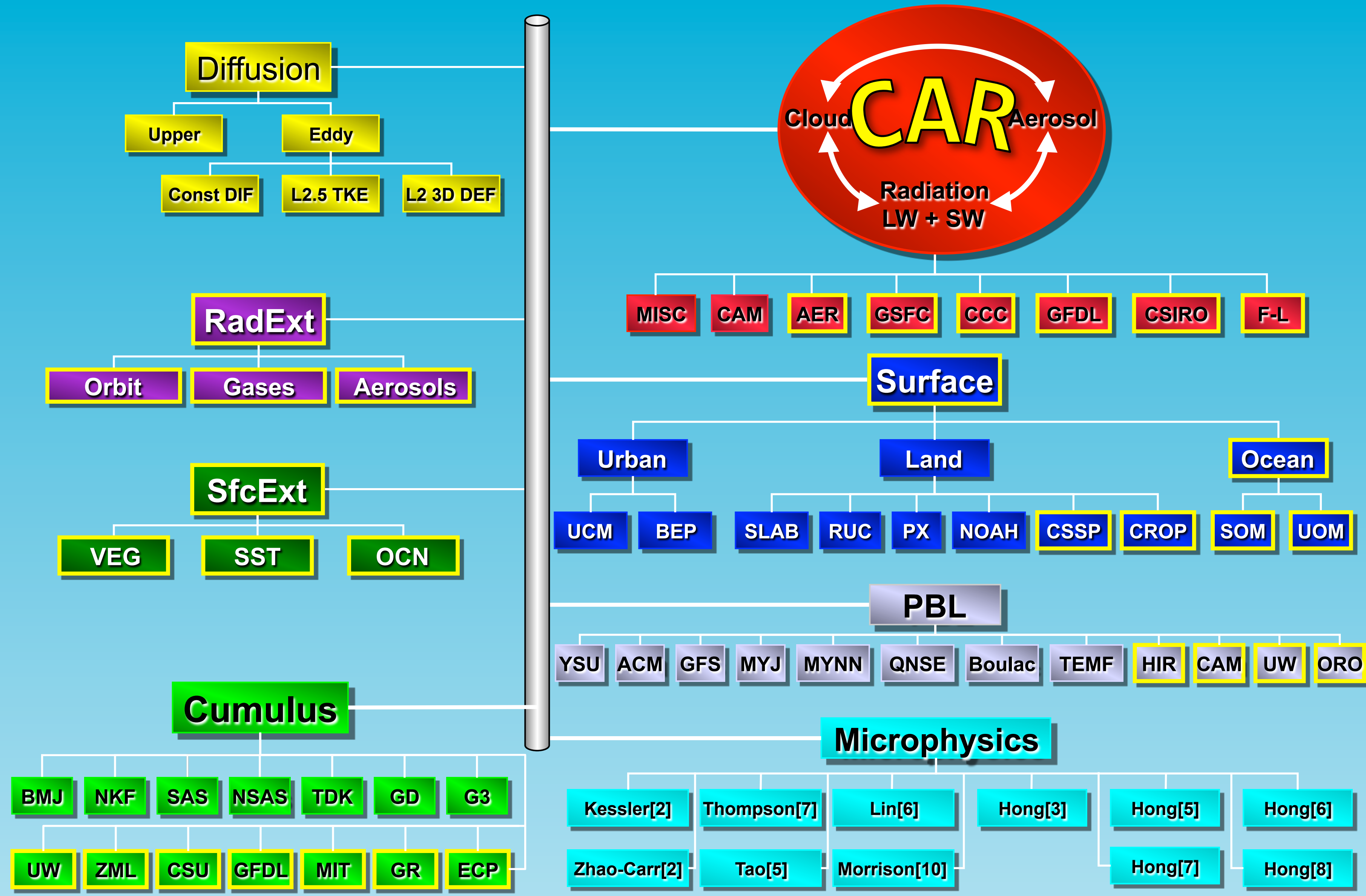


Yuan and Liang 2011 (J. Hydrometeorology)

PHYSICS CONFIGURATION

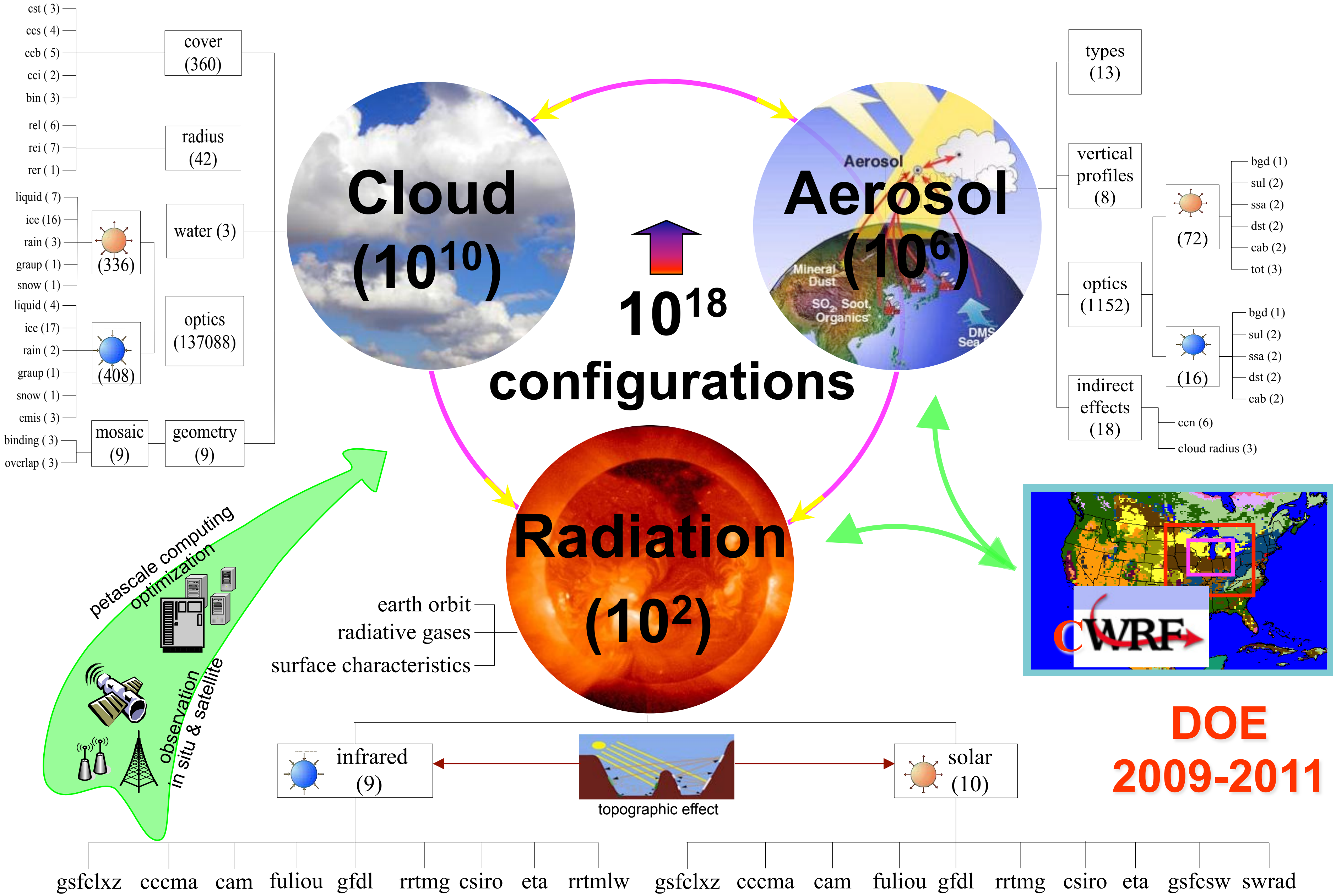
SELECTING OPTIMAL PARAMETERIZATION SCHEMES

CWRF Physics Options

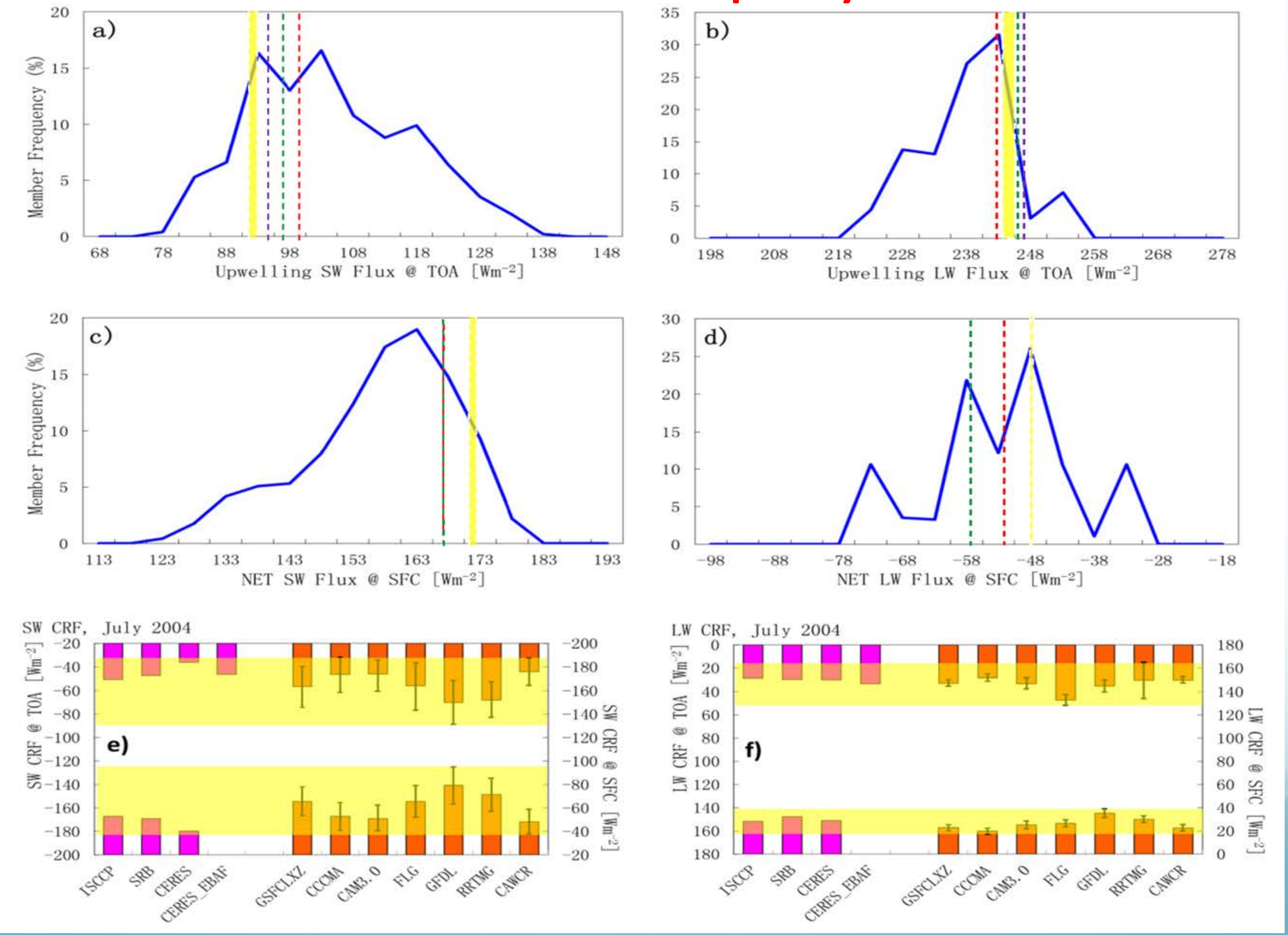


http://cwrf.umd.edu

Cloud-Aerosol-Radiation Ensemble Model



CAR Ensemble Flux Frequency Distribution

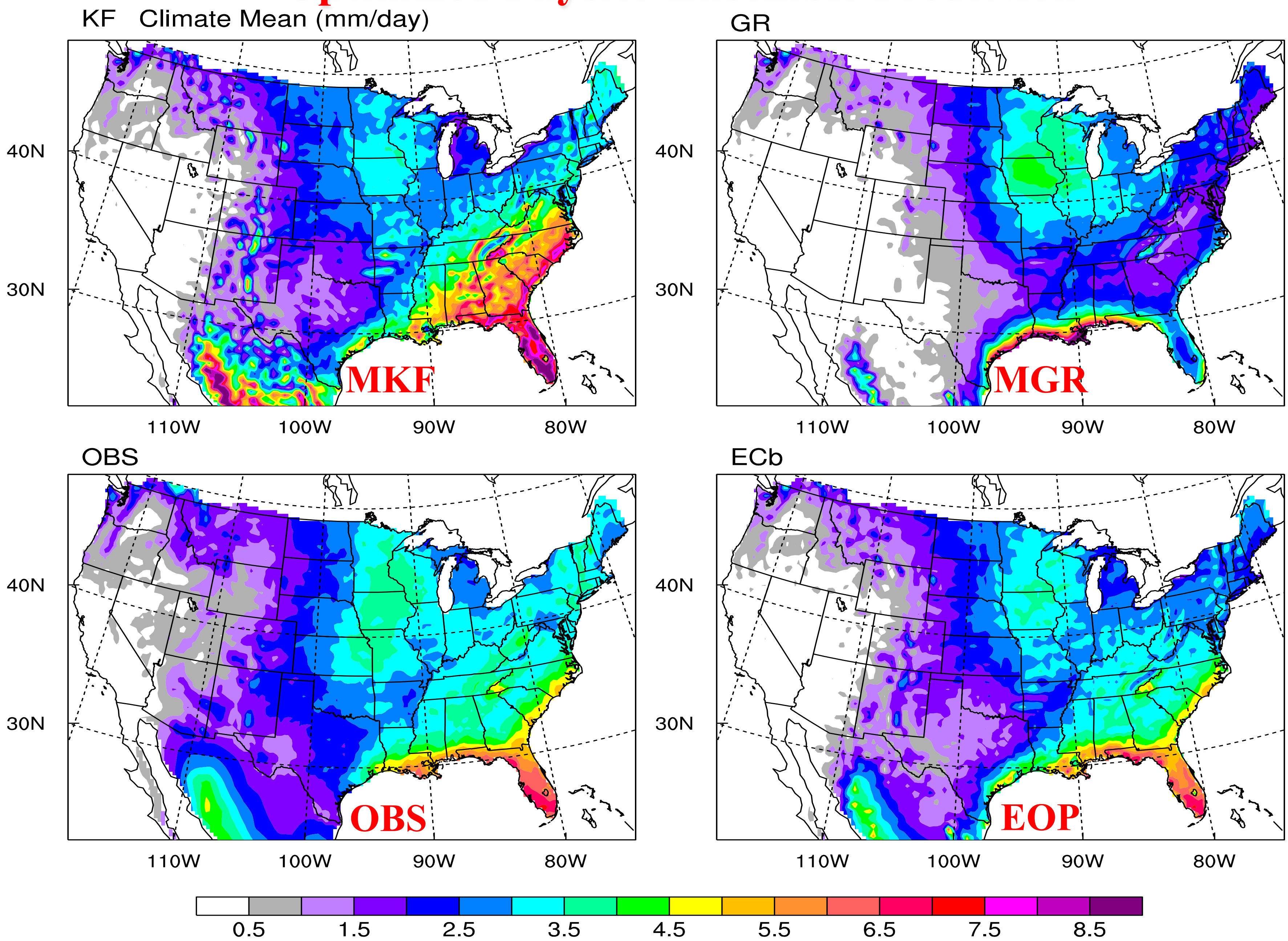


Optimized Physics Ensemble

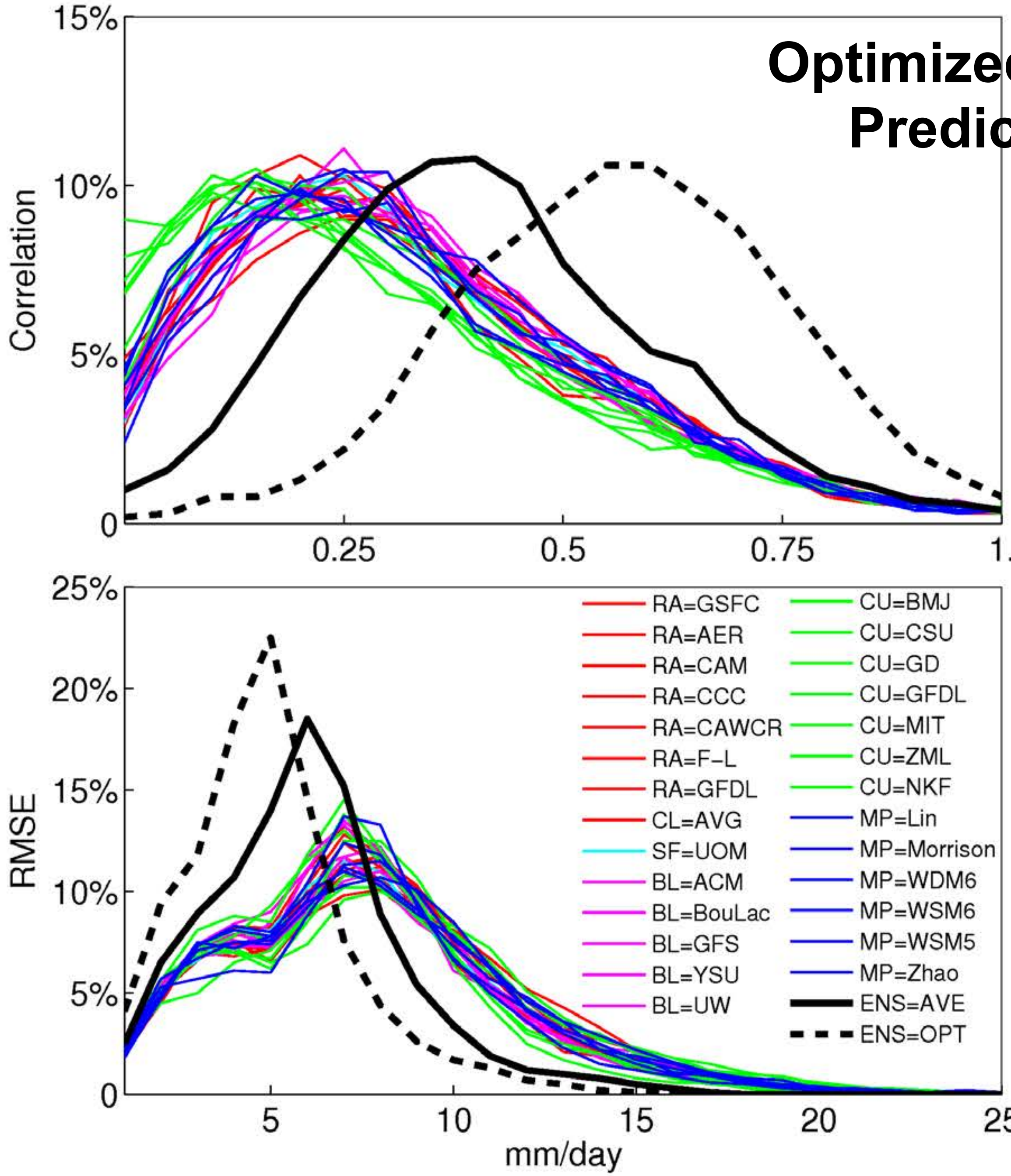
Increasing predictive skill

Quantifying uncertainty

Optimized Physics-Ensemble Prediction



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.

CWRF

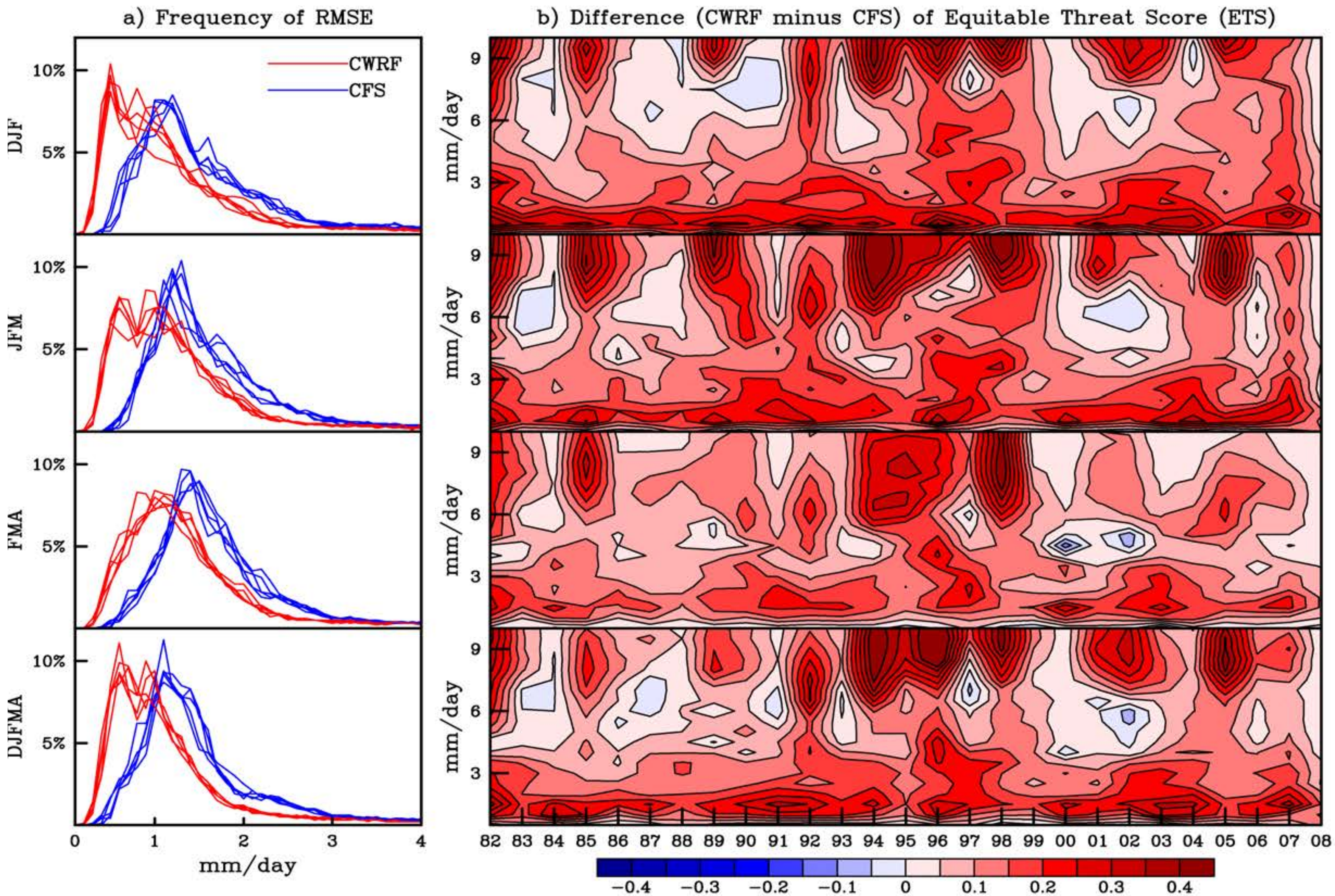
Seasonal-Interannual Climate Prediction

Nested with NOAA Operational

CFS

Yuan, X., and X.-Z. Liang, 2011: Improving cold season precipitation prediction by the nested CWRF-CFS system. *Geophys. Res. Lett.,* **38**, L02706, doi:10.1029/2010GL046104 .

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 improves predictions at regional-local scales

- CWRF includes advanced physics schemes crucial to climate
- CWRF couples essential components directly linking to impacts
- CWRF builds upon a super ensemble of alternative physics schemes for skill optimization and uncertainty quantification
- CWRF has greater capability & better skill than CMM5, WRF…
- CWRF downscaling improves CFS precipitation predictions

Faculty & Student

- **Research**
  - ✧ Develop, test, evaluate physics parameterization
  - ✧ Improve weather forecast, climate prediction
  - ✧ Project climate change and impacts
  - ✧ Understand process, mechanism
- **Thesis**
  - ✧ Develop new schemes
  - ✧ Compare schemes
  - ✧ Diagnose processes
- **Fun**

CWRF