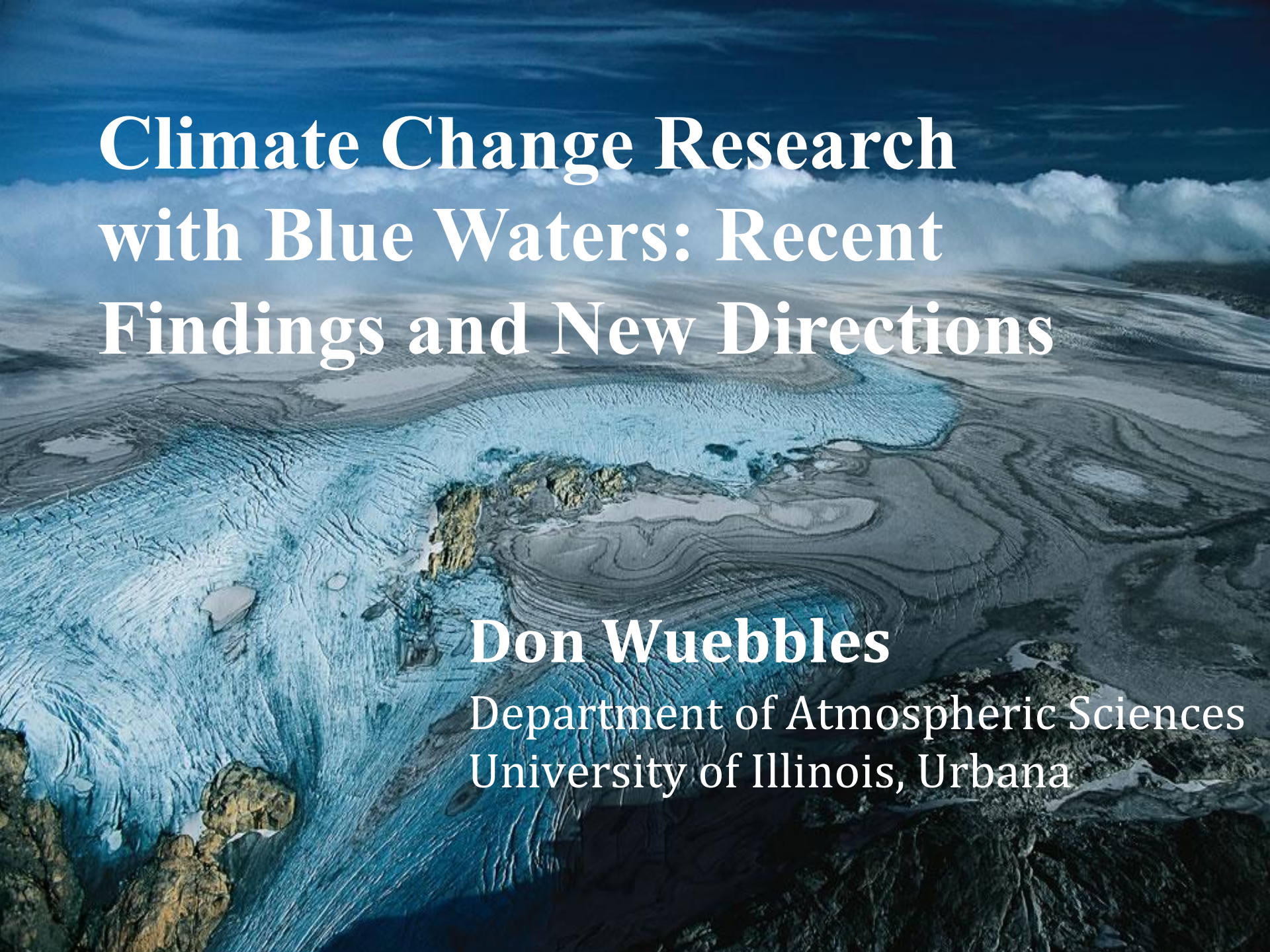
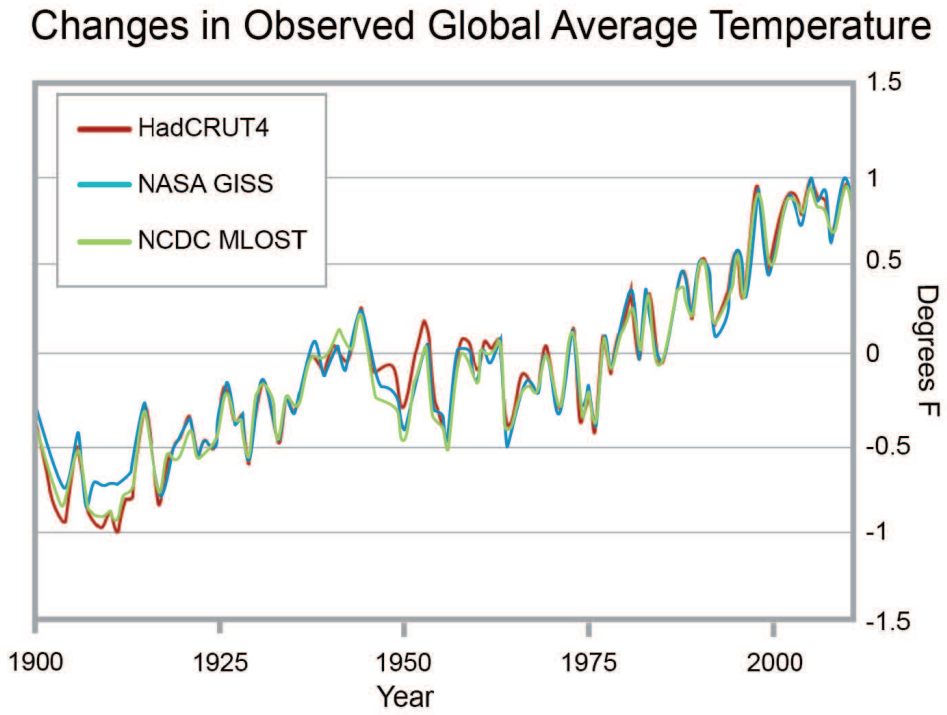


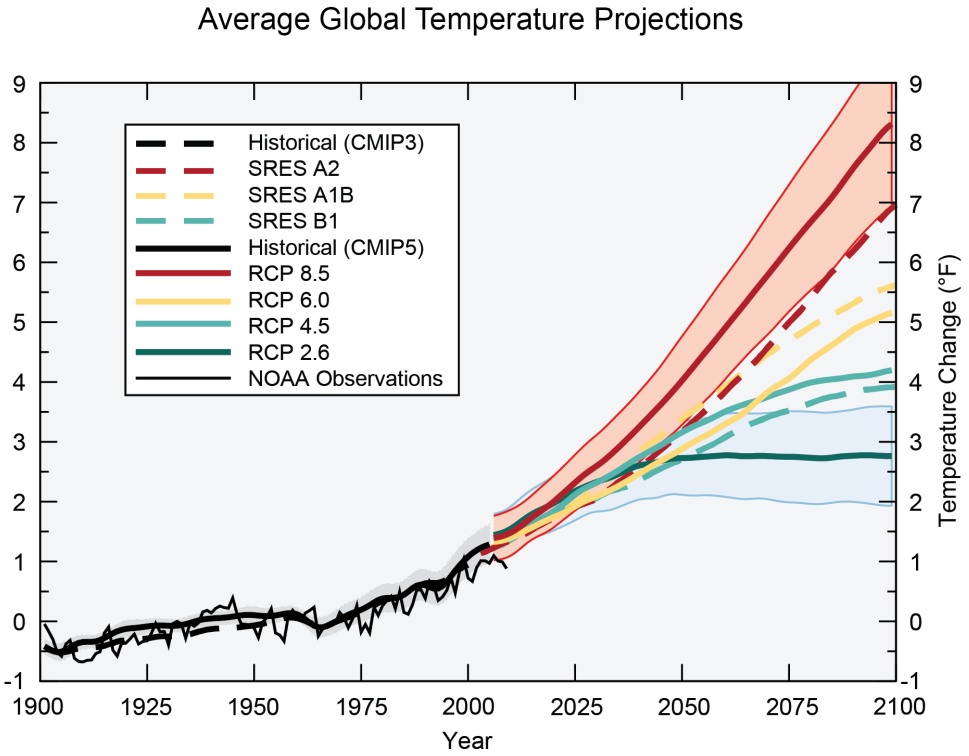
Climate Change Research with Blue Waters: Recent Findings and New Directions

Don Wuebbles
Department of Atmospheric Sciences
University of Illinois, Urbana

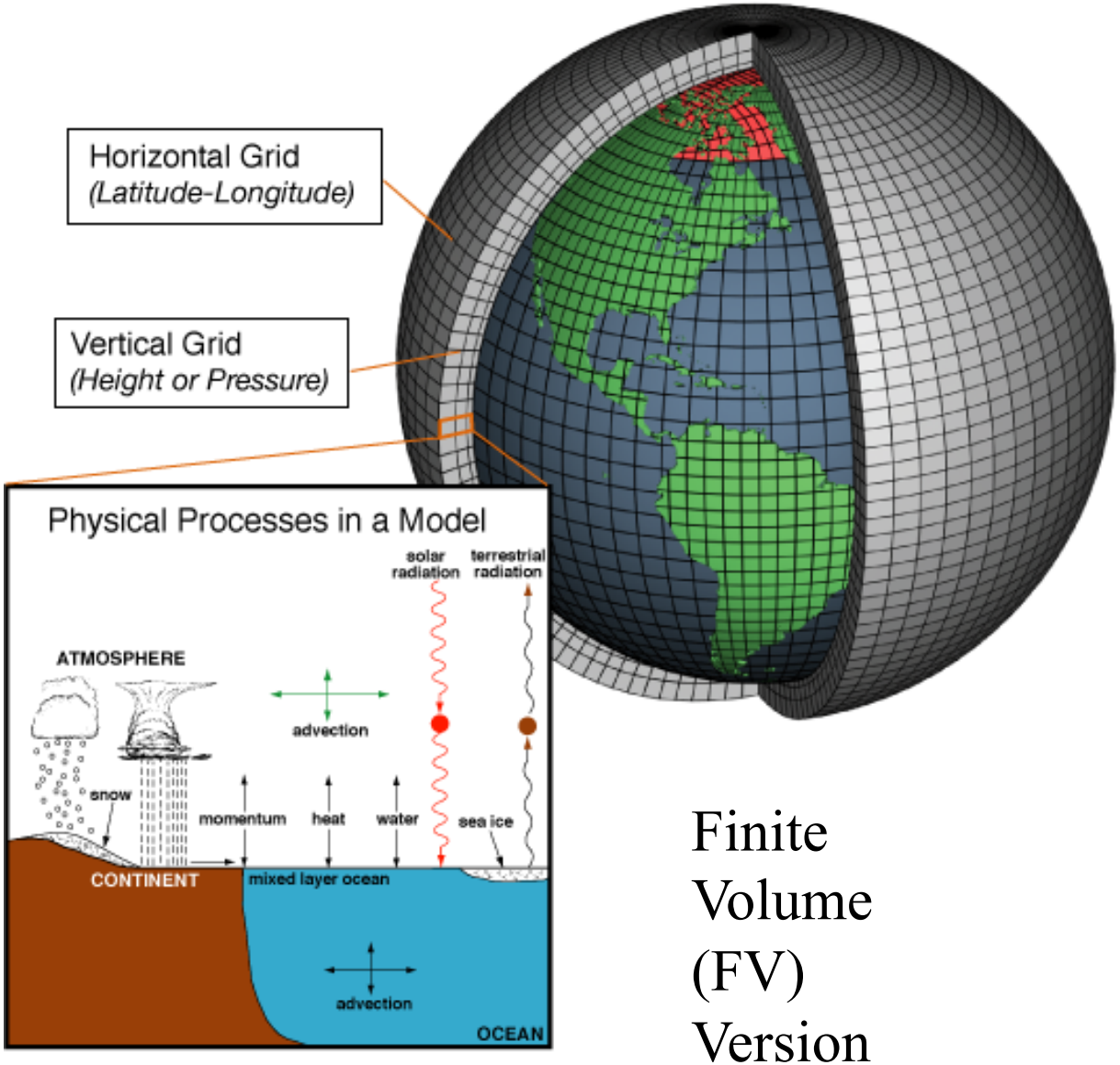


Observations: Earth's Climate is Changing Rapidly, and Evidence Points to Human Activities

Climate Change Likely to Result in Large Impacts during this Century



Community Earth System Model



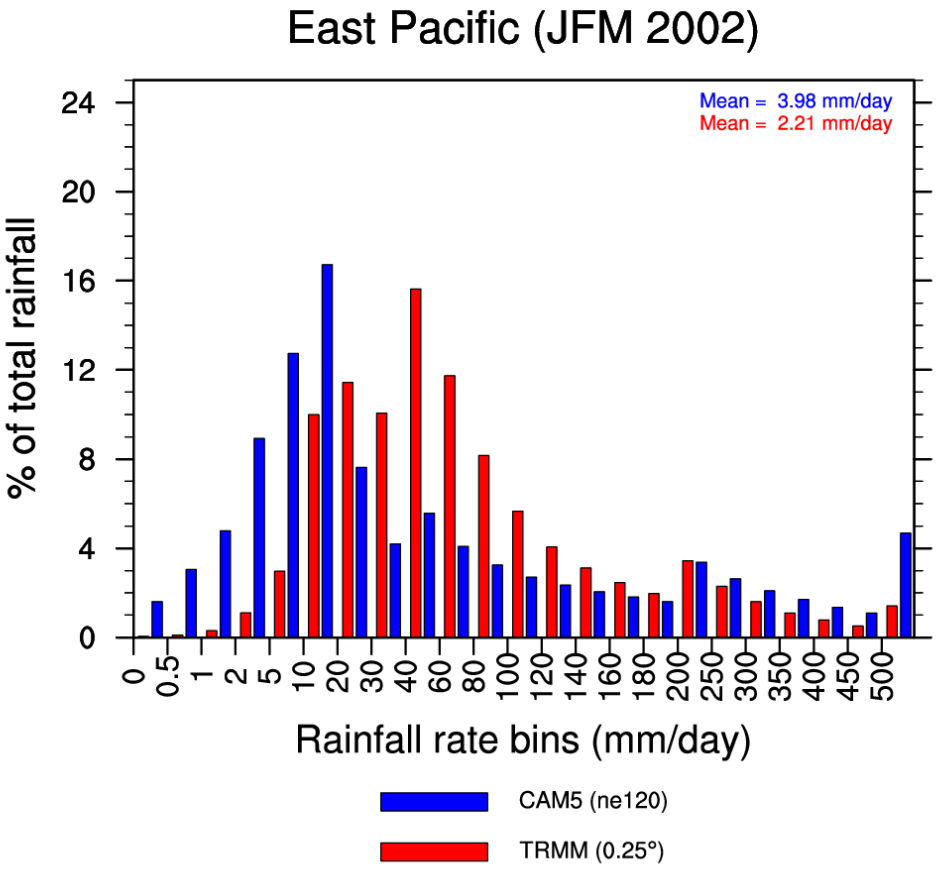
Finite Volume (FV) Version

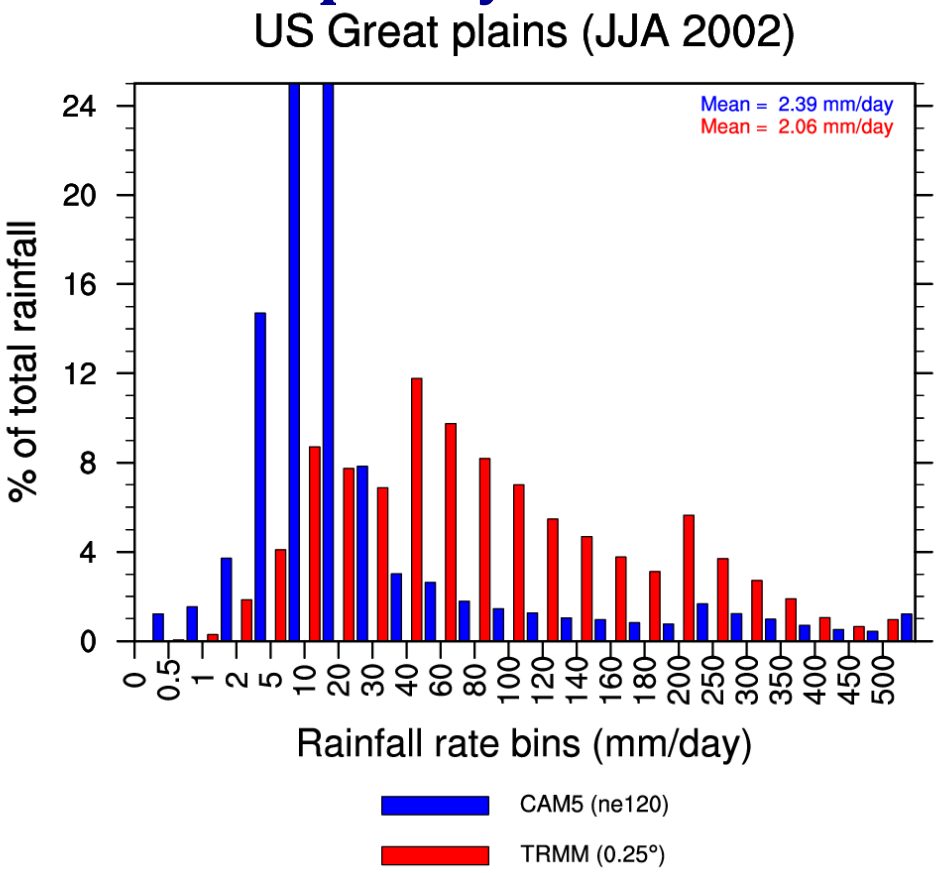
- Systems of differential equations that describe fluid motion, radiative transfer, etc.
- Planet divided into 3-dimensional grid to solve the equations
- Atmosphere and land traditionally on same horizontal grid
- Similarly for ocean/ice
- Sub-gridscale processes are parameterized

Current Climate Models Inadequate for Regional Analyses

Common bias for many regions and most/all models: Too much light rainfall, not enough heavy

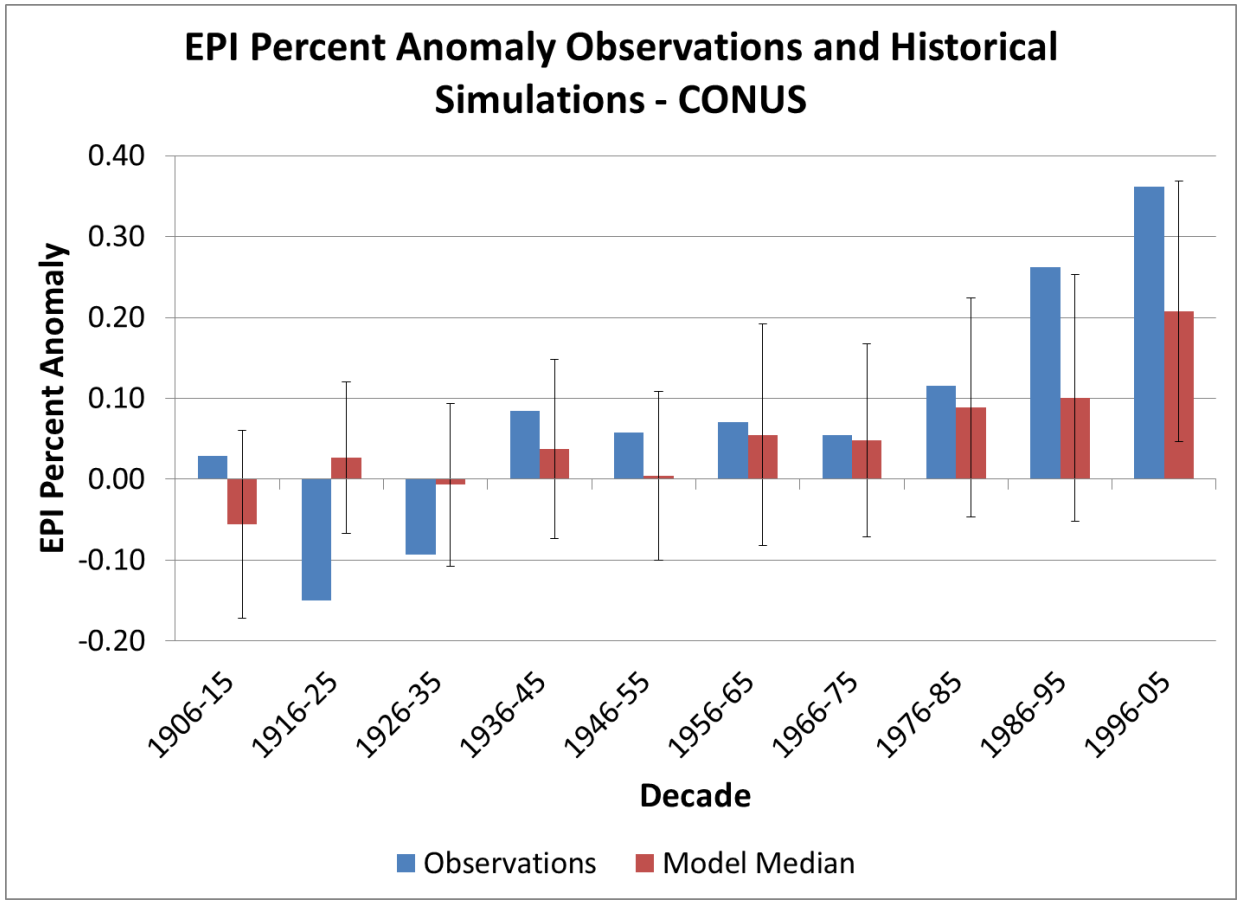
CESM1 Bias in Rainfall Frequency





Courtesy of Rich Neale

Current Models Underestimate Trends in Severe Precipitation



- 2day duration 5year return
  - EPI calculated annually for 1901-2005,
  - Decadal averages calculated for 1906-2005

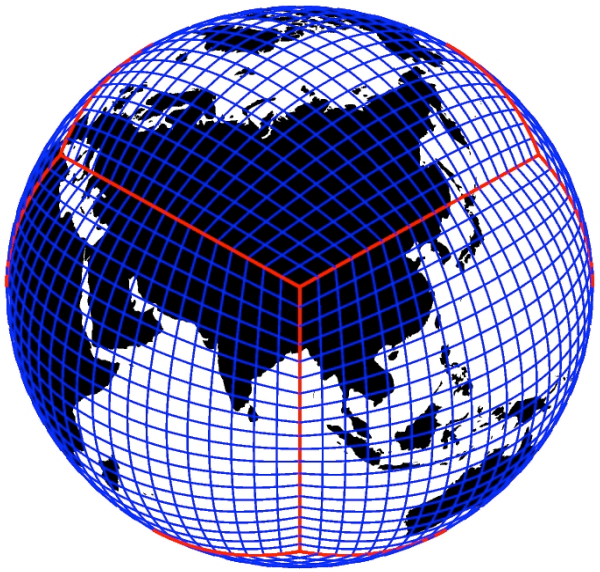
Multi-model median of CMIP5 simulations shows an increasing trend in EPI anomalies over last 4 decades

- But it is smaller than observed
- Standard deviation between models large

Uniqueness of CESM on Blue Waters

- **High-resolution Spectral Element (SE) dynamical core development , tuning, and testing**
- **Time-slice runs for 1979-2010 AMIP study at 0.25° (~25 km) resolution, and then for 2070-2100 using high RCP8.5 scenario.**
- **UIUC/NCAR project with NSF to run CESM1 at 0.25° (~25 km) resolution with 1° ocean**
  - **150+ years in past and 100 years future**
  - **Multiple realizations (scenarios)**
- **Uncertainty analyses to enhance understanding of radiative-cloud-aerosol interactions**

Replace Finite-Volume (FV) with new Spectral Element (SE) dynamical core



- **New default for calculations using horizontal resolutions of 100 km (1 degree) or finer.**
- **SE dycore uses accurate, high-order numerical methods on rectangular elements in a cubed-sphere geometry.**
- CAM-SE possesses nearly linear scaling to processor counts of up to one cpu per element. In addition, CAM-SE has regional mesh-refinement capability.

- CAVEAT: Small but significant biases in low cloud forcing when CAM-SE is used. These biases are believed to be related to differences in vertical advection schemes used in CAM-FV and in the current implementation of CAM-SE.

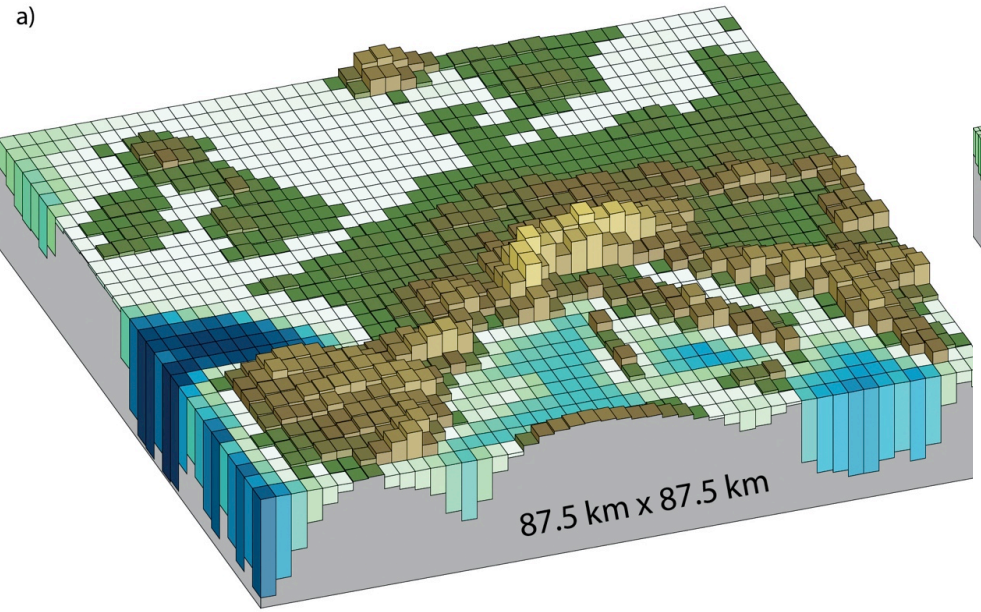
Resolution of Climate Models

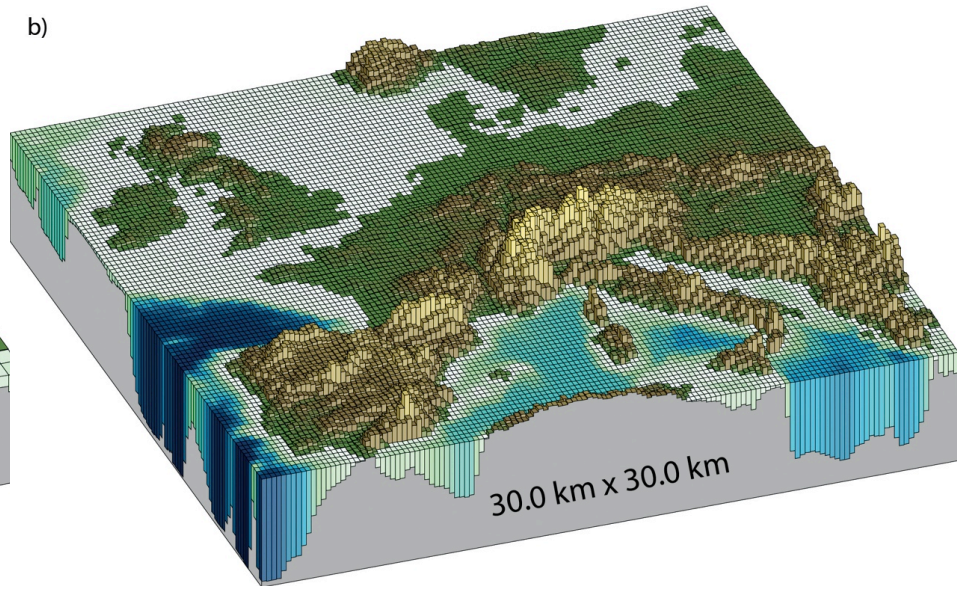
IPCC AR5

1-2° horiz (100-200 km)

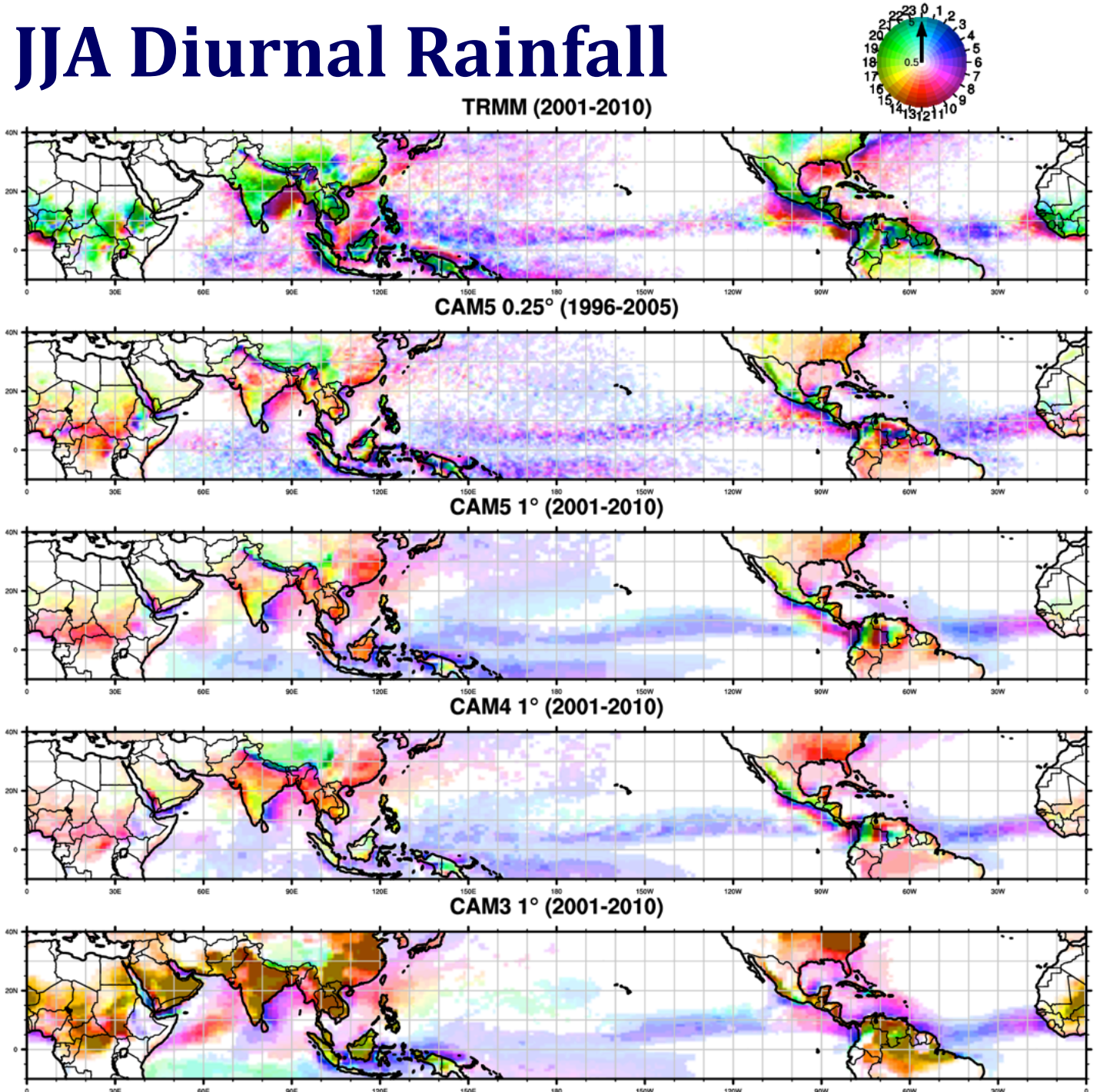
Blue Waters

0.25 (25 km)

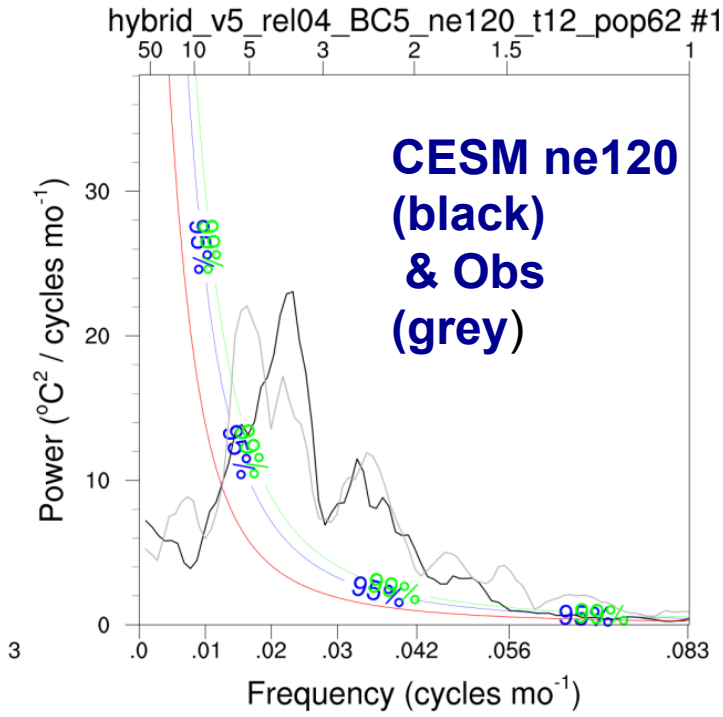


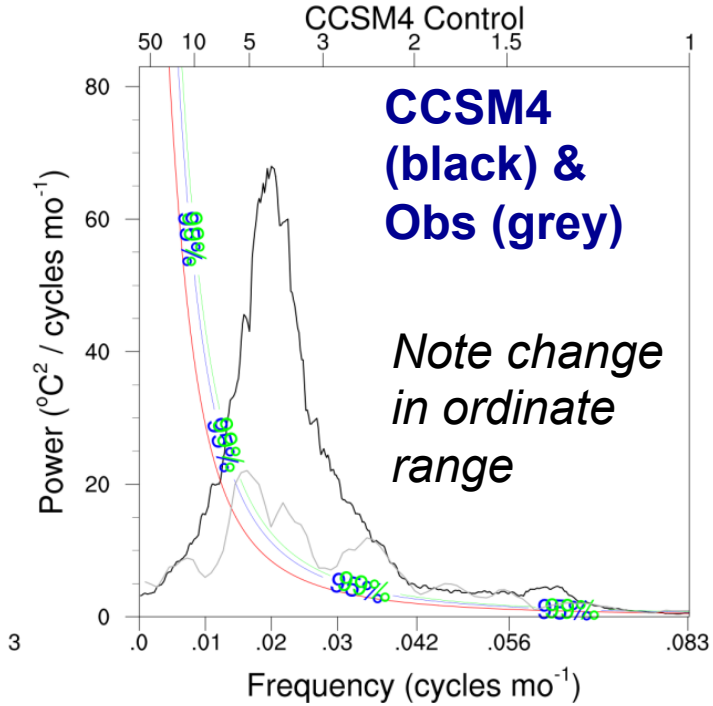


Improved JJA Diurnal Rainfall



Courtesy of Rich Neale





Improved ENSO Niño3.4 index

Power spectrum of Nino3.4 index

Observations (thin line)

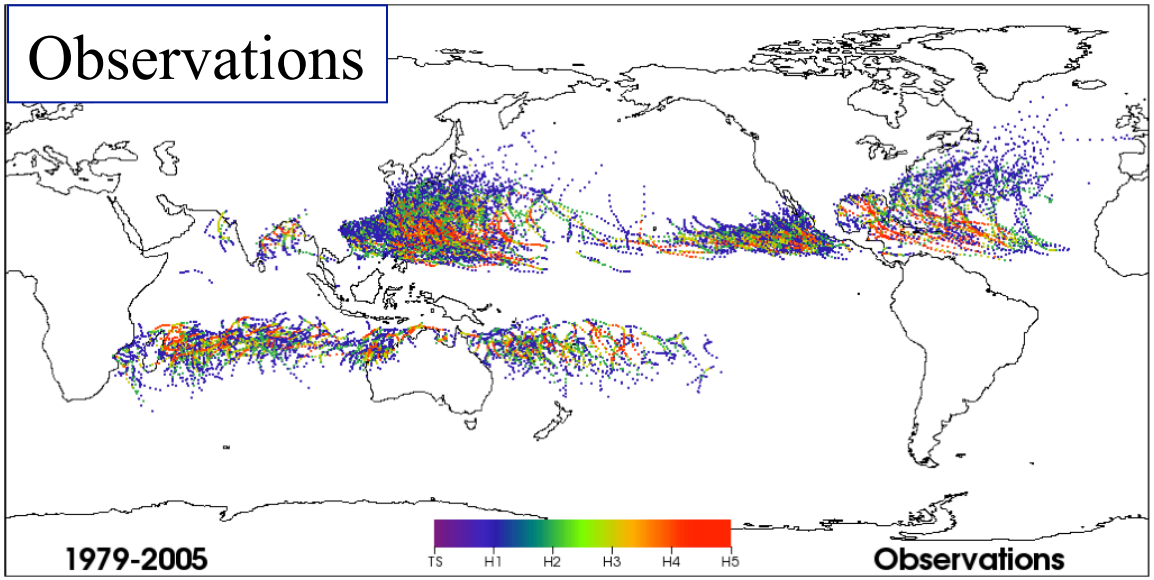
Top: High-resolution coupled model (thick solid line)

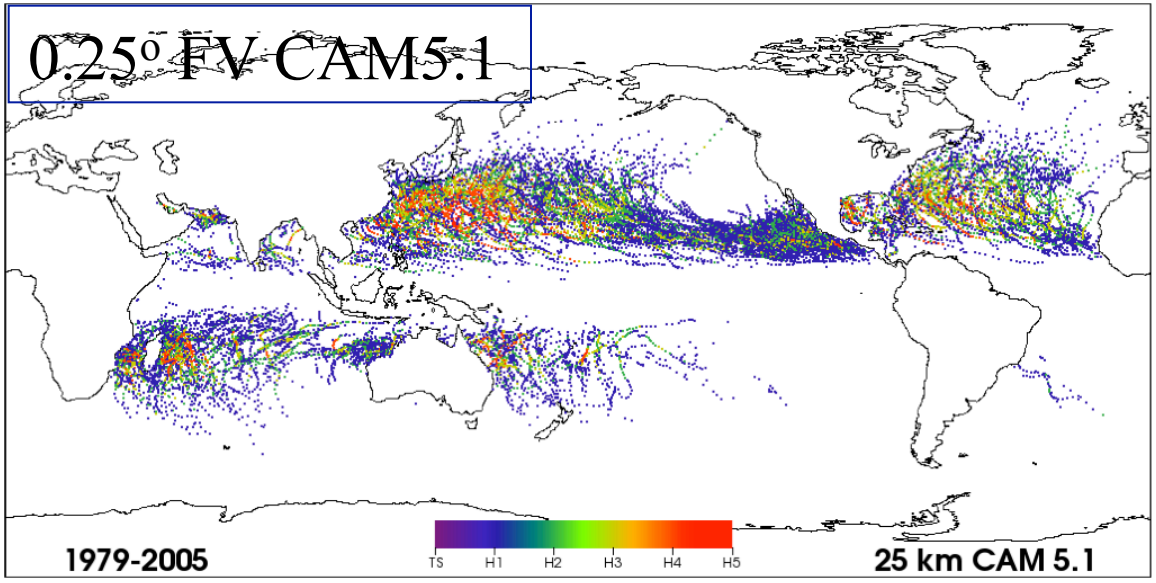
Bottom: Standard resolution CCSM4 long baseline run.

95% significance levels are overlaid.

Coutesy of Justin Small

Tropical Cyclones

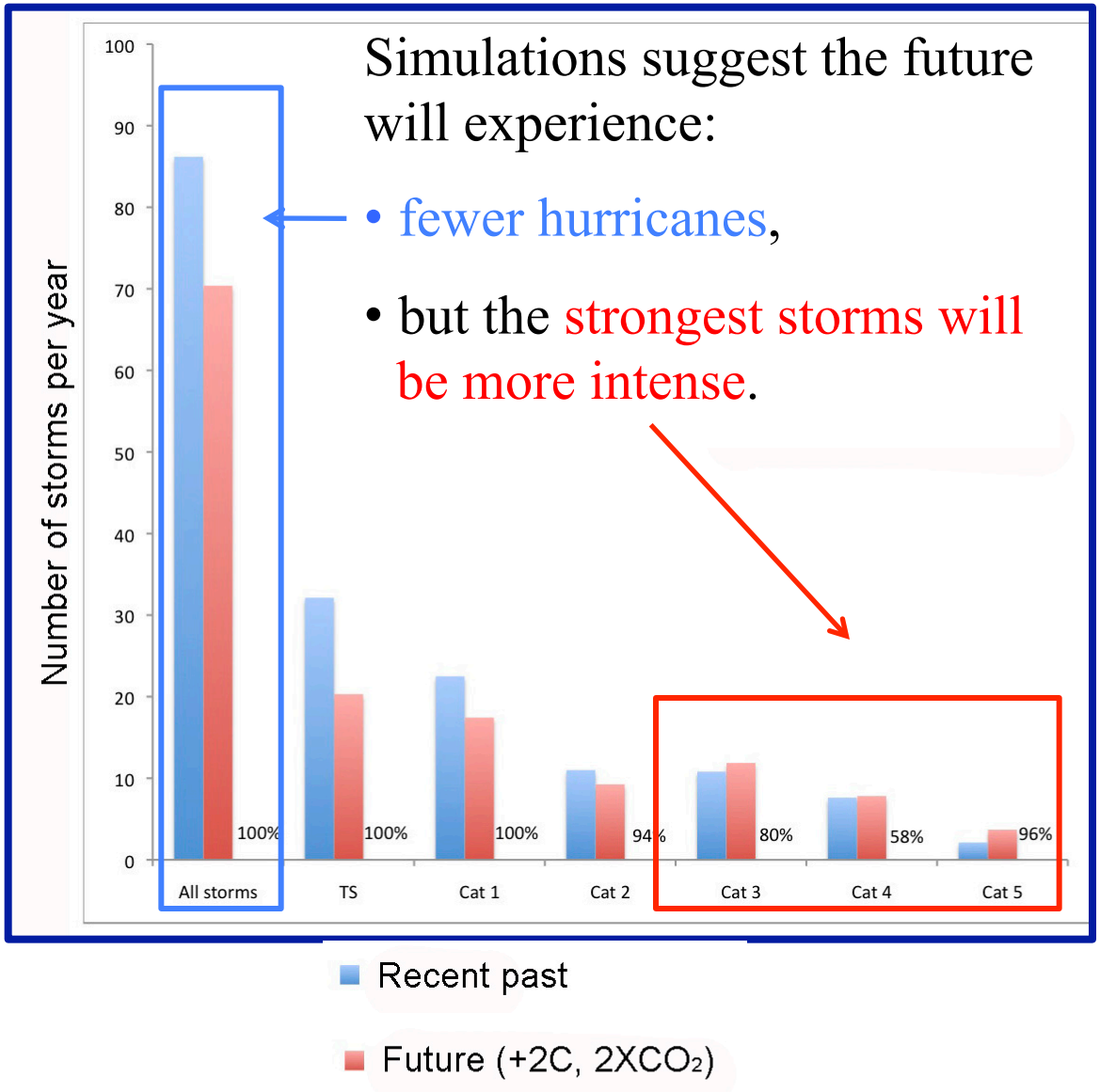




High resolution (0.25°) atmosphere CAM simulations produce an excellent global hurricane climatology

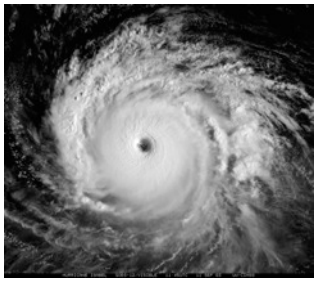
Courtesy of Michael Wehner, LBNL

Projected Increasing Hurricane Intensity

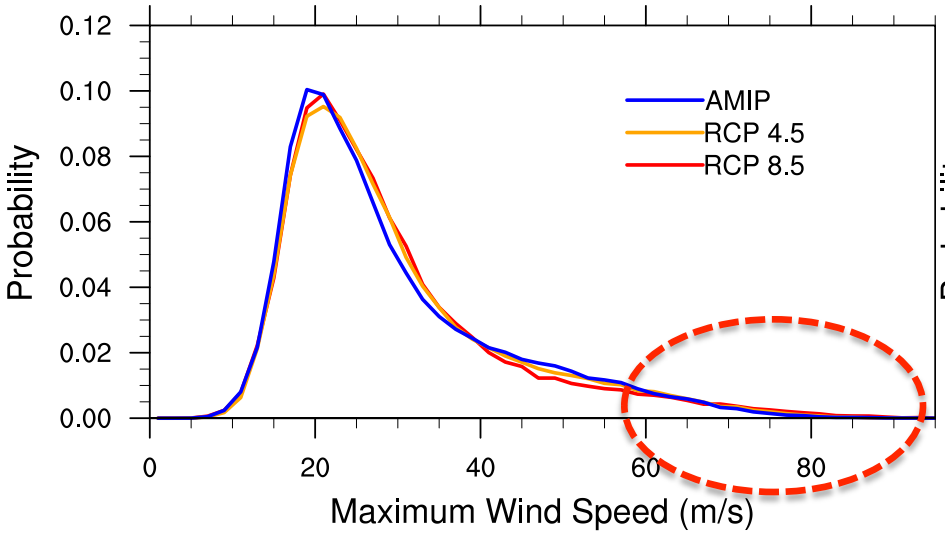


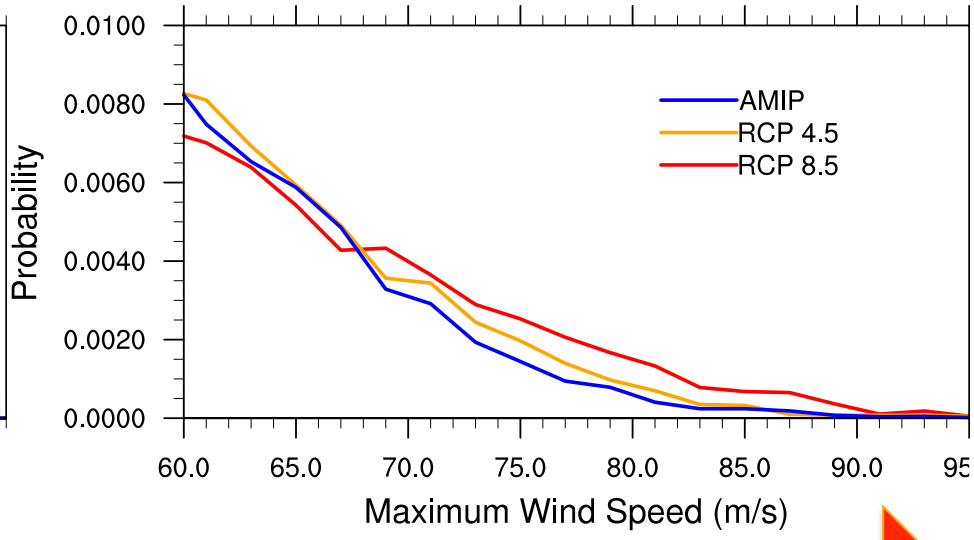
High resolution (0.25°) atmosphere simulations produce an excellent global hurricane climatology

Courtesy of Michael Wehner, LBNL



Future Climate Scenarios (time-slices): Storm Tracks *(Kevin Reed, ASP)*

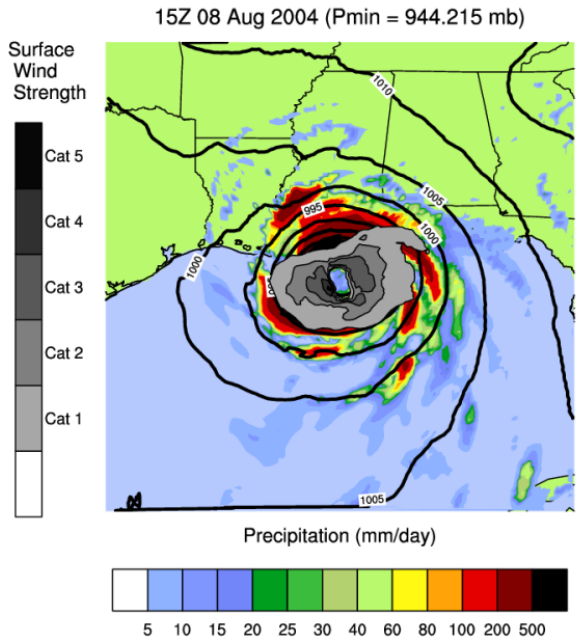


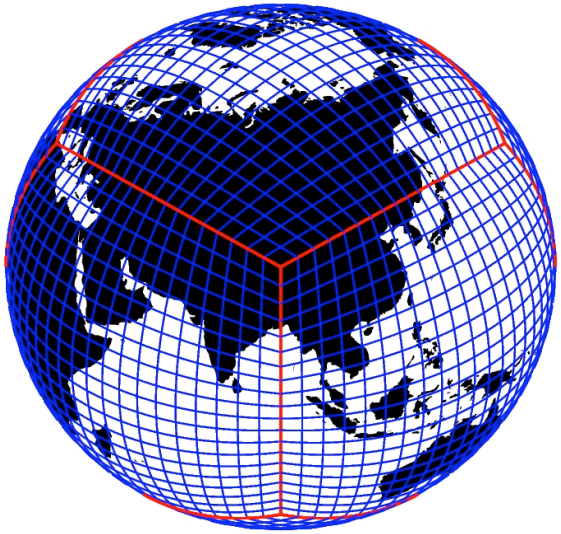


Cat. 5

Multi-Century Analyses of CESM Will be Unprecedented

12-km CAM-SE Run

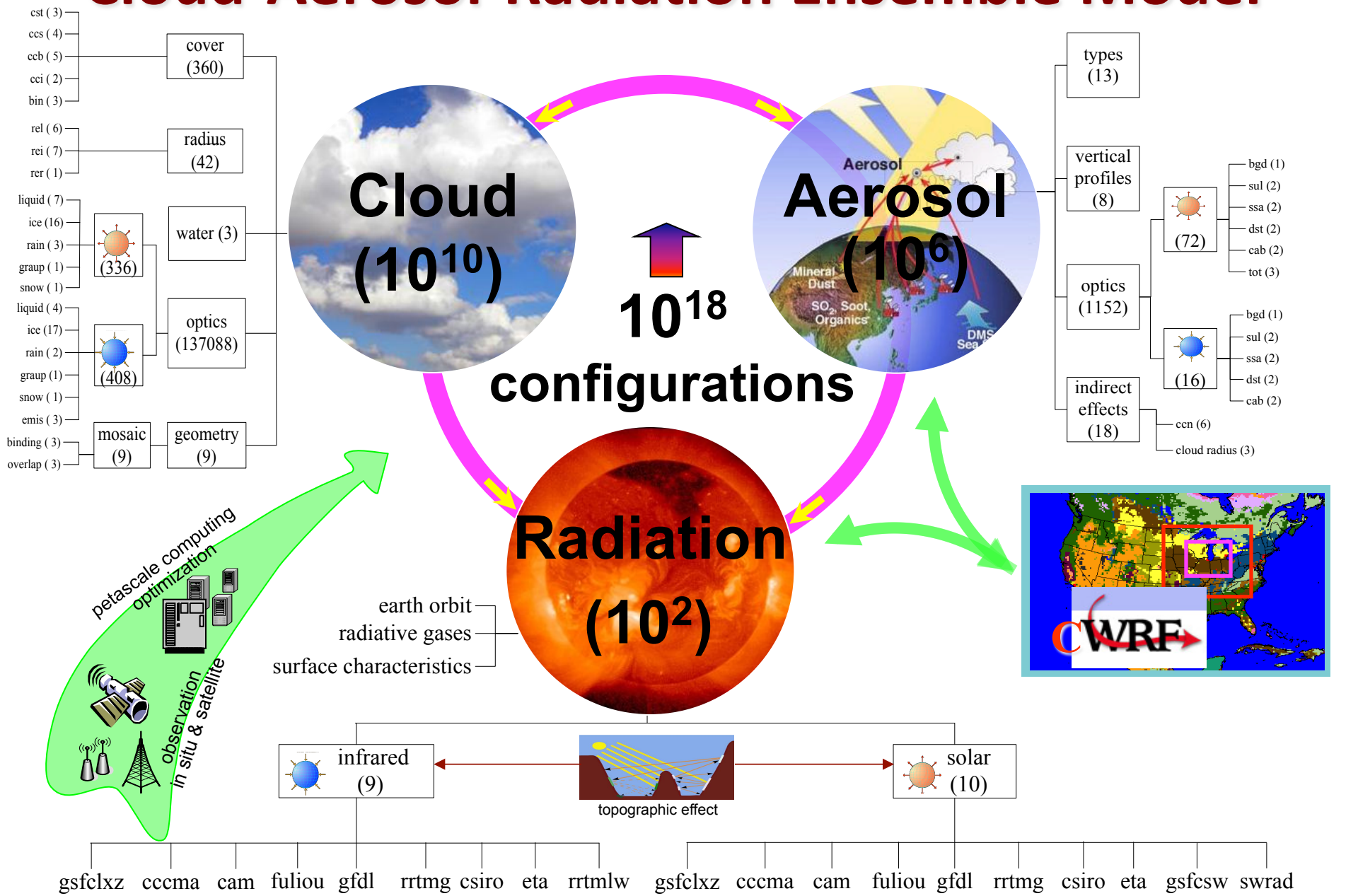




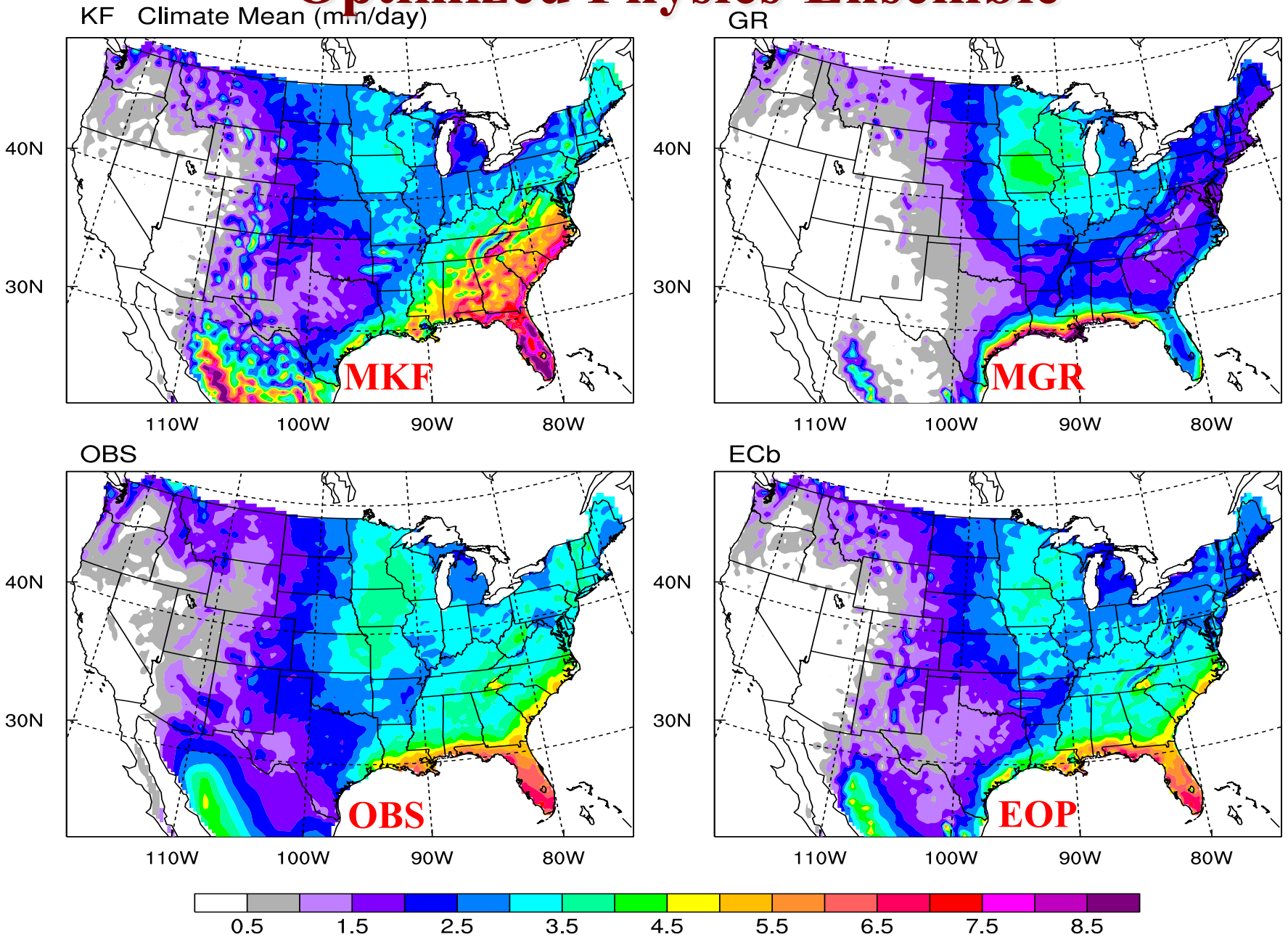
- Fully couple configuration
  - 25km CAM5-SE
  - 1-degree ocean
- Multi-century integration
- 1850-2100
- Currently Running on Blue Waters

Enhanced understanding of climate change, e.g., severe weather and regional effects

Cloud-Aerosol-Radiation Ensemble Model



Optimized Physics-Ensemble



Plan for CWRF/CAR Experiments

- Define a subset from ~100 CAR configurations based on CWRF runs over North America (driven by ERI reanalysis) that can capture the observed climate characteristics.
- Run CWRF/CAR for 1979-2012 over both North America and Asia as driven by ERI as well as CCSM4 simulations in CMIP5 for 1950-2005 and future 2006-2060 under RCP4.5 and RCP8.5.
- Use CWRF (Liang et al. 2012) with the built-in CAR (Liang and Zhang 2013) to estimate the range of future climate change projections at regional scales.
- This range is anticipated to be significant and serve as a proxy for the regional response to the potential CESM climate sensitivity.

Thank You