CSSEF Atmospheric Model Development

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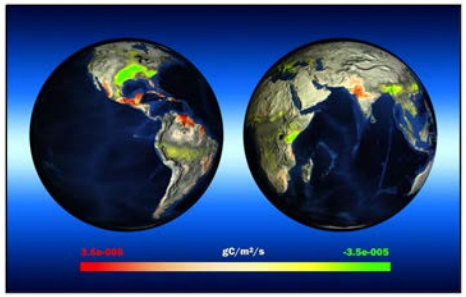
*Atmosphere Team Leadership

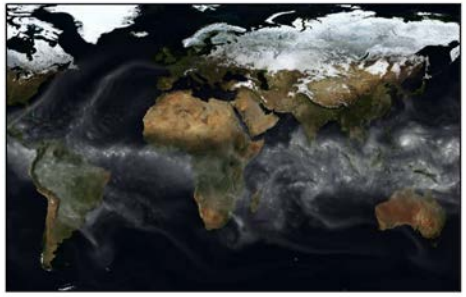
FASTER Project Meeting, March 19, 2012

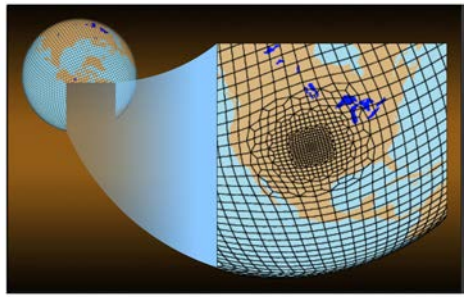
Climate Science for a Sustainable Energy Future (CSSEF)

Project Characteristics

- Large DOE multi-laboratory project focused on the development of the Community Earth System Model Next Generation + 1
- Major thrusts for the Atmosphere, Land, and Ocean Models
- Development of **TESTBEDS** where models can rapidly be prototyped
- Model analysis and calibration with Uncertainty Quantificiation (UQ) techniques
- Model automation and process workflow being developed for models that will be too large to work with in the ways that we do today

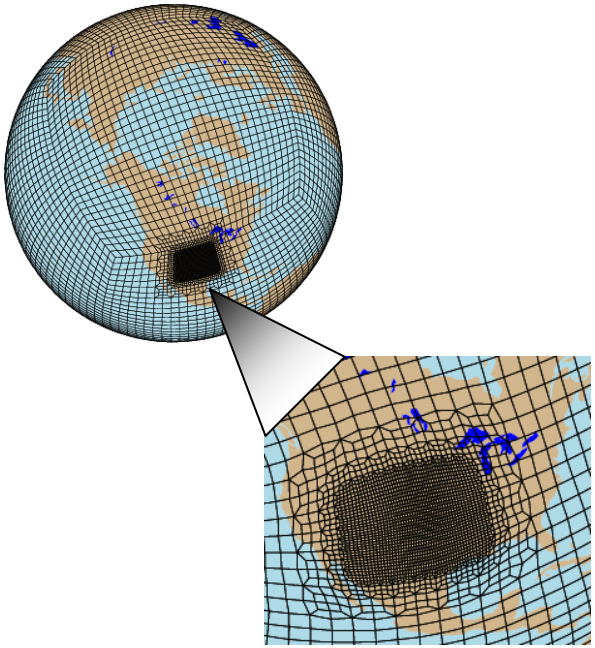






Atmospheric Model Development

Calibration Platform



Science Goals

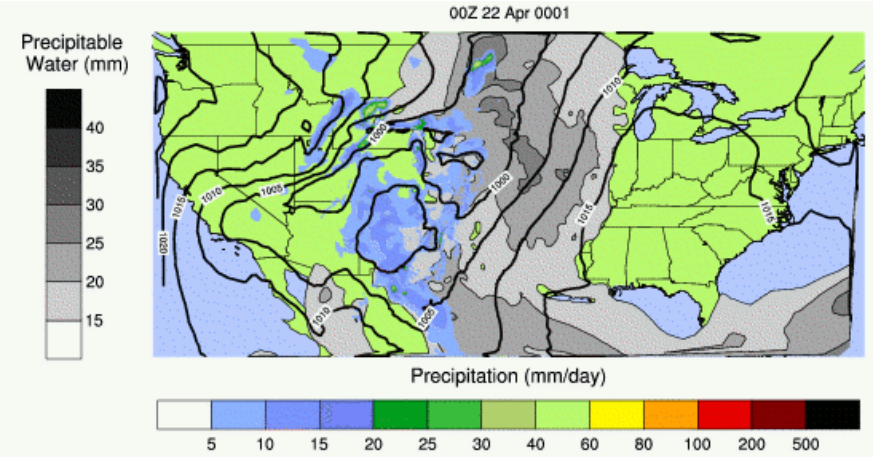
- Improved prediction of precipitation & hydrologic cycle
- Improved prediction of regional climate

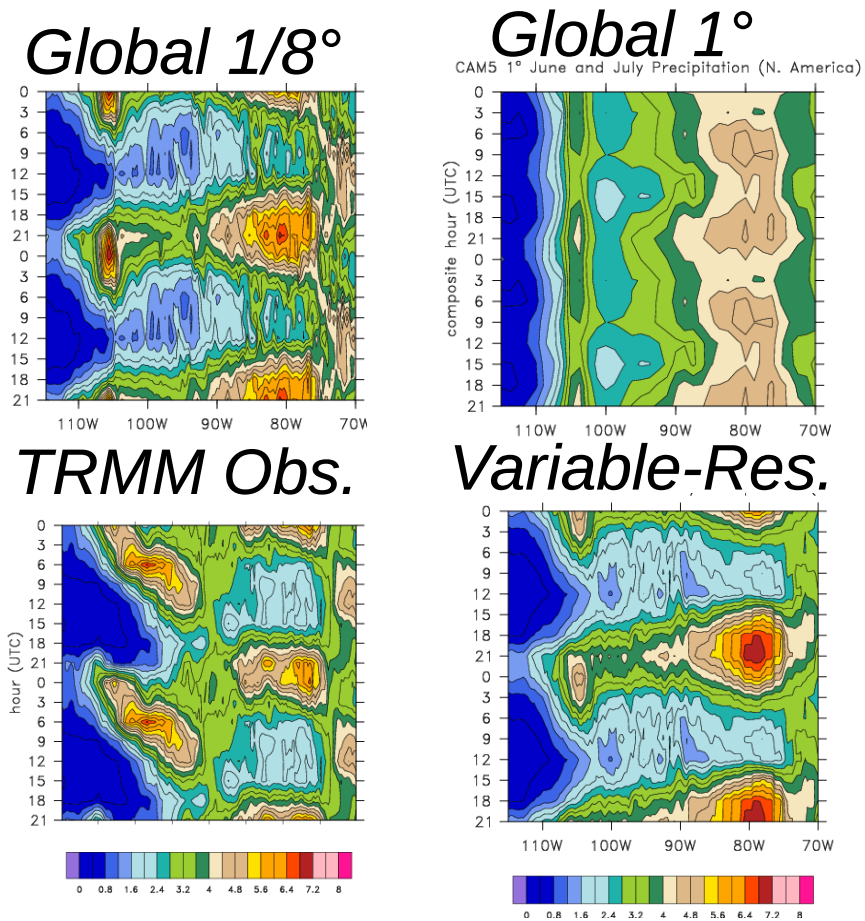
Components

- Development of the tools for high-resolution (~13 km initially) and regionally-refined modeling
- Creation of an atmospheric test-bed that uses the latest ARM & satellite observations of the hydrologic cycle
- Utilization of UQ techniques for rapid model calibration with observations and the identification of structural weaknesses in model parameterizations

CAM-SE Variable Resolution Simulations

Mark Taylor, Rich Neale

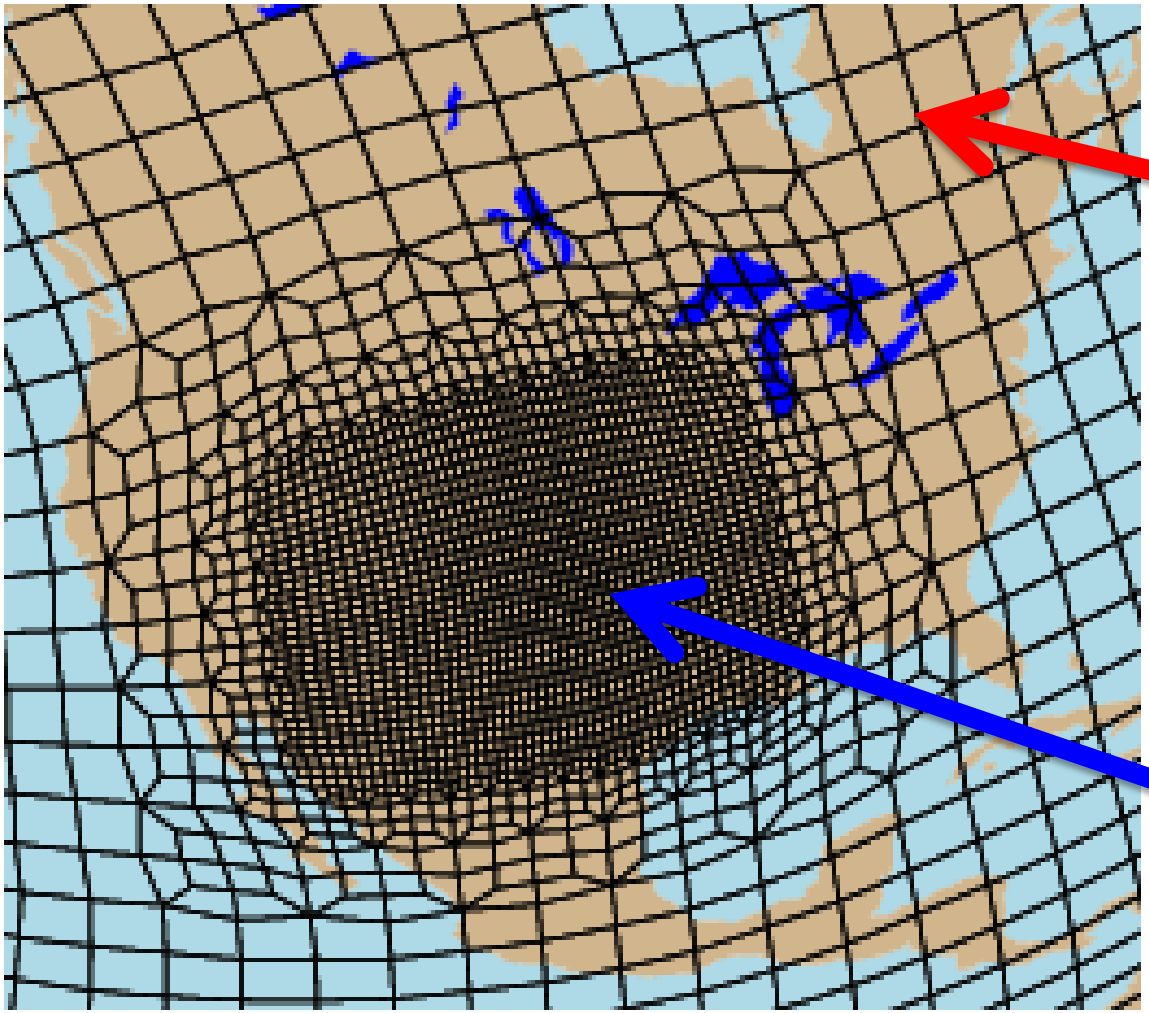




- Global 1/8° simulation completed (requires 6M core-hours per year on Intrepid)
- Variable resolution simulation with 1/8° resolution over central US running at 0.12M core-hours per year. Many features in high resolution region match global 1/8° simulation.
- Var-res animation (top left) shows formation of convective system in high-resolution region, then loosing definition as it moves into low-resolution region.
- Hovmoller diagrams of precip diurnal cycle over central US: Some improvements going from 1° to 1/8°, captured in both global high-res and variable resolution simulations

Weather-Mode Testbed

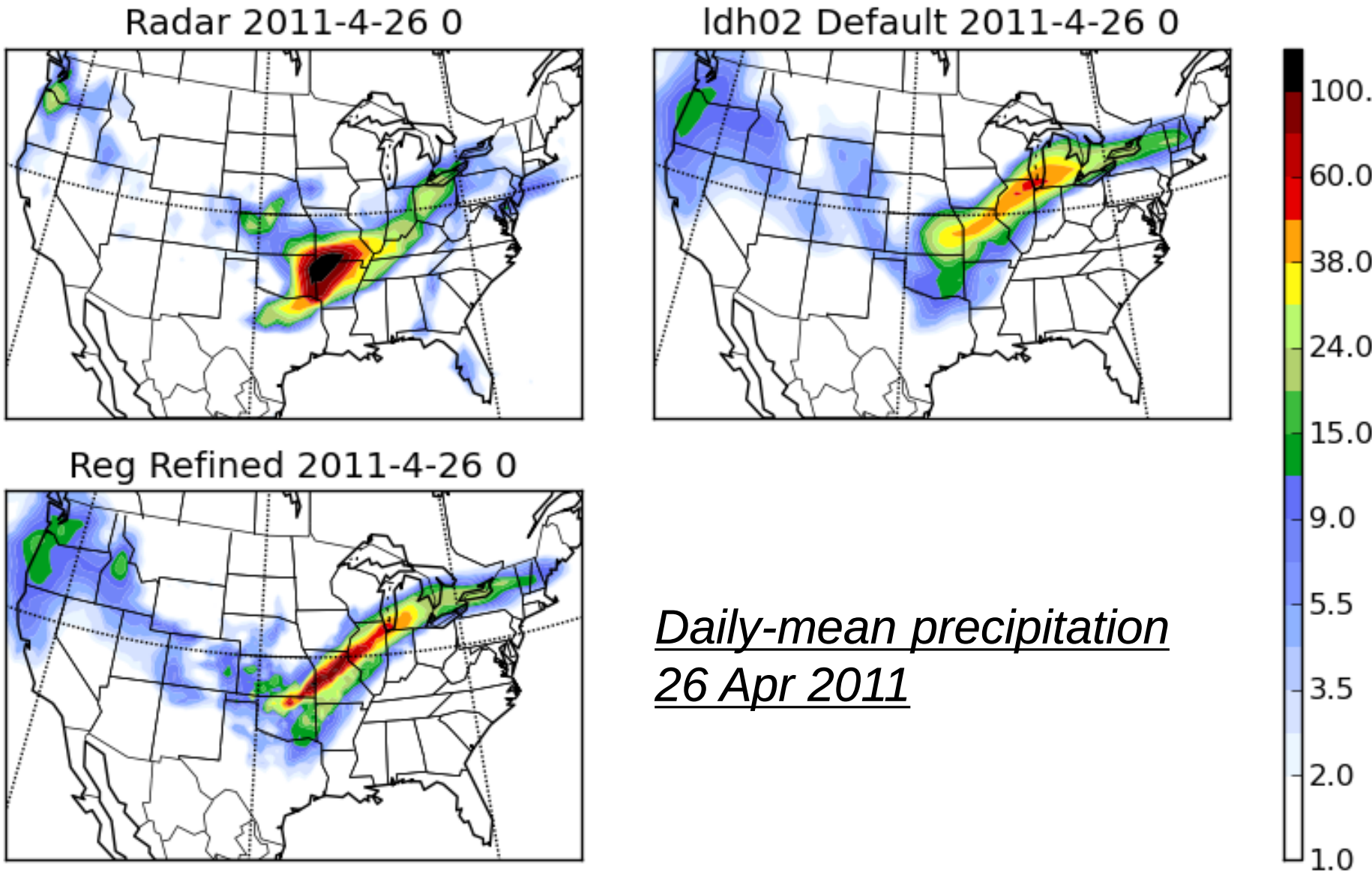
Jim Boyle, John Tannahill



Nudge to Analysis Data (e.g. MERRA, ECMWF) on coarse 1° grid

No nudging on fine 13 km grid

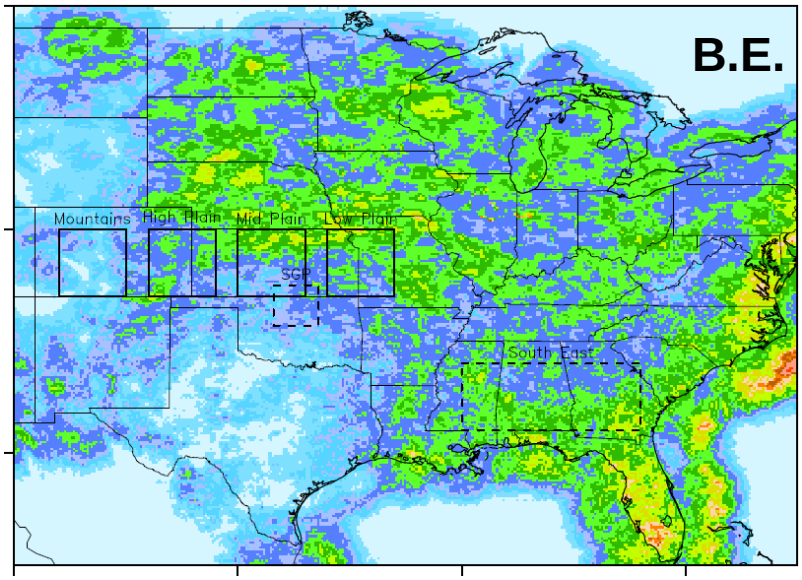
Pseudo-"Regional Model" Approach



Daily-mean precipitation
26 Apr 2011

Radar Precipitation Data Development

- Scott Giangrande (in partnership with others) produced a 0.1° and 1° resolution hourly CONUS NEXRAD precipitation product for 2009-2011 with uncertainties
- Scott Giangrande (in partnership with others) has been working to produce precipitation products from ARM new precipitation radars

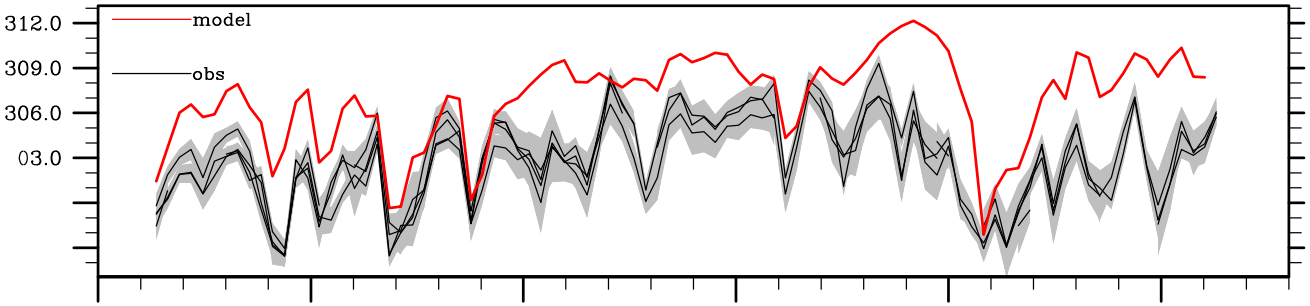


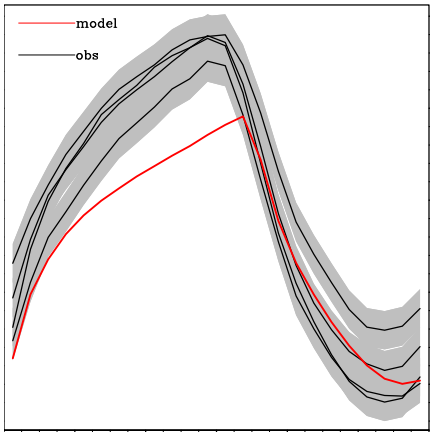
NEXRAD Precipitation
Best estimate, JJA 2011

CSSEF ARMBE Dataset

- Improved utility of ARMBE surface meteorological observations for testbed and UQ by adding instrument uncertainties and automatic reading of data quality reports
- Extended ARMBE to all ARM SGP facilities with data in 2011
- Published dataset on observations with instrument uncertainties
- NCL scripts created for diagnostic plots of diurnal cycle and daily average time series.

Comparison of 1° nudged CAM-SE to ARMBE observations

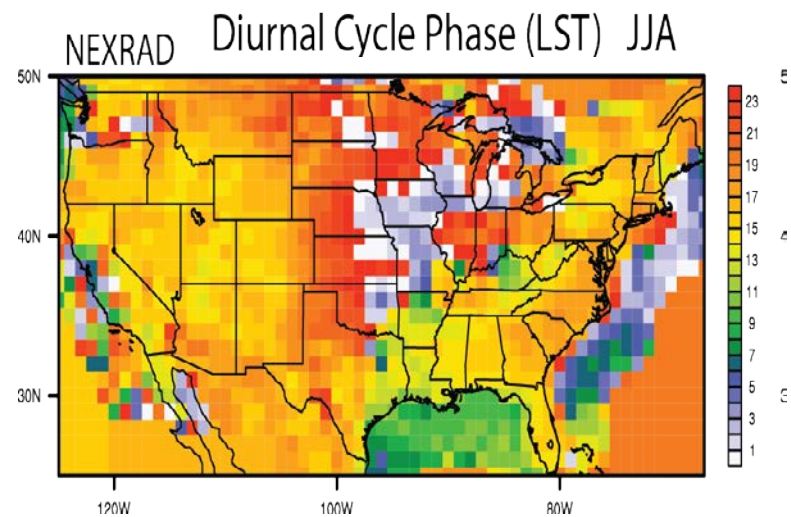




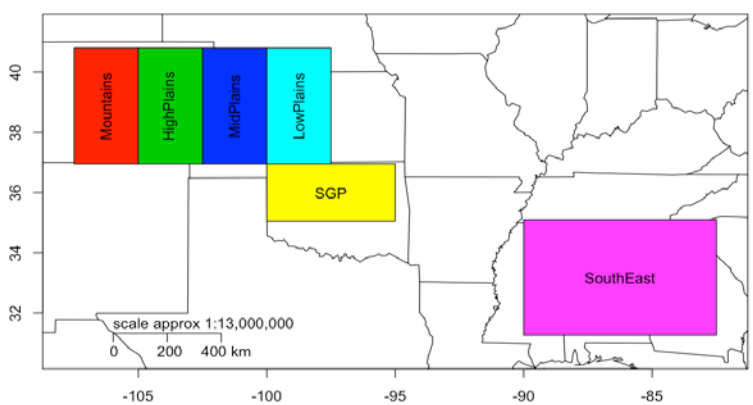
Hydrologic Metric Development

- Metrics defined:
  - Diurnal cycle of precipitation in 6 regions in the continental U. S. (amplitude & phase of 1st few harmonics)
  - Precipitation intensity (50th, 90th, 95th percentiles)
- Standardized metric scripts applied to all runs and datasets

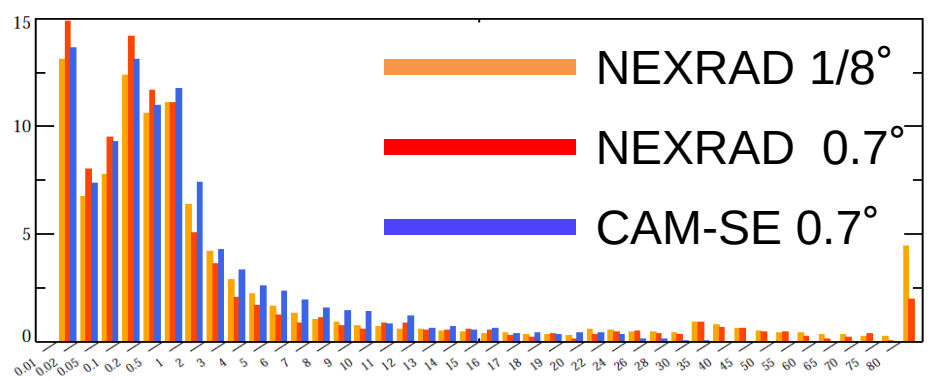
Diurnal hour with greatest precipitation in NEXRAD observations



Focus Regions

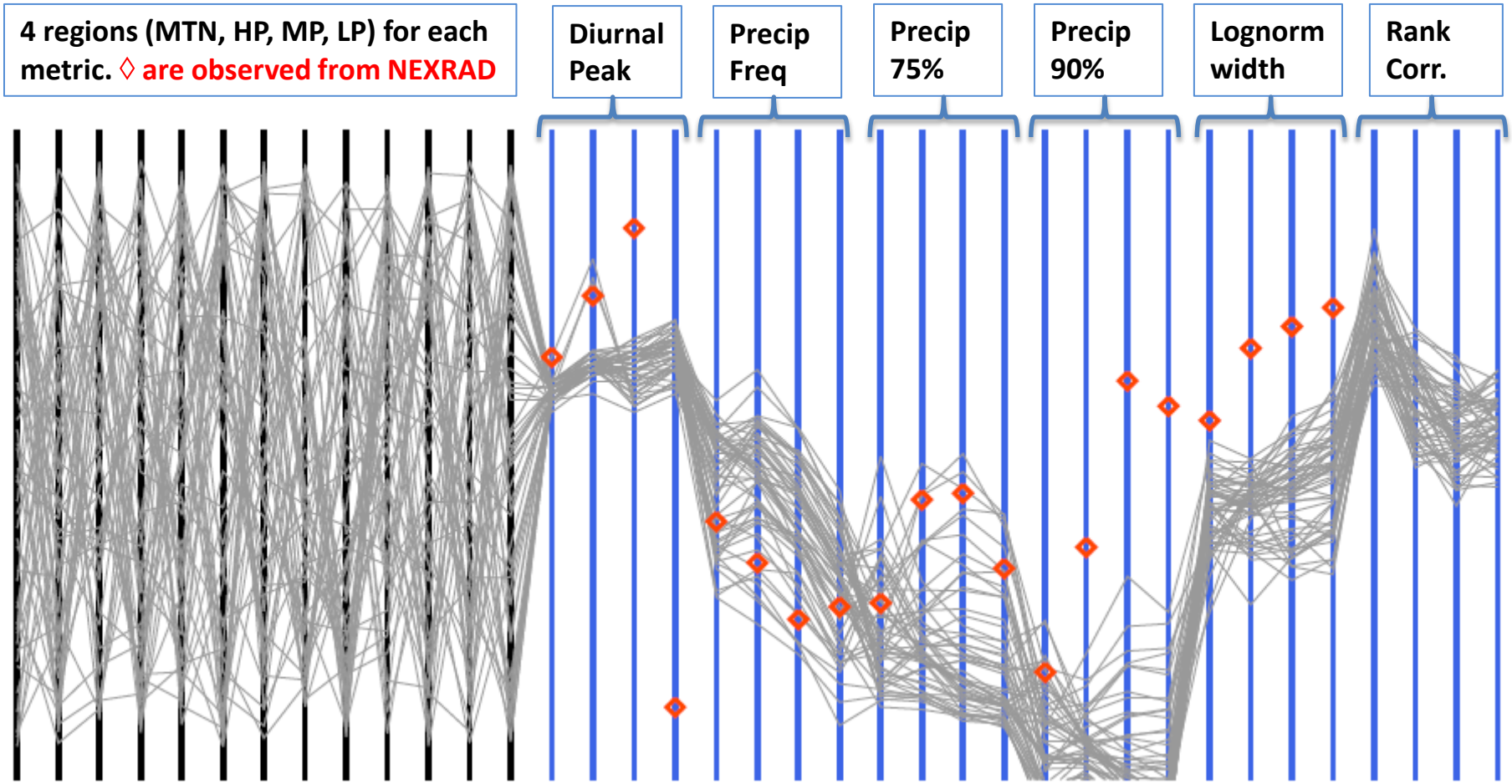


JJA 2011 Precipitation PDF from NEXRAD and CAM-SE 1° nudging



Wuyin Lin

Parallel-coordinate view of the metrics for 54 of 130 nond01 runs



Physics Parameters (*normalized*) **Hydrologic Metrics** (JJA, 2011)

No simulation reproduces the observed nocturnal maximum in precipitation in the lower Plains!

CSSEF Priorities for the Coming Year

- Develop auto-mated diagnostics to compare regionally-refined simulations to ARM (and broader area) diagnostics of the hydrologic cycle
  - Convective / Stratiform precipitation partitioning Scott Giangrande, Wuyin Lin Laura Riihimaki
  - Low-Level Jet Laura Riihimaki
  - Entraining CAPE / CIN Laura Riihimaki
  - Low and mid-level humidity
  - Water vapor transports and budgets for Central U. S. Larry Berg

further off, but coming…

- Develop a regionally-refined model for a tropical

The End

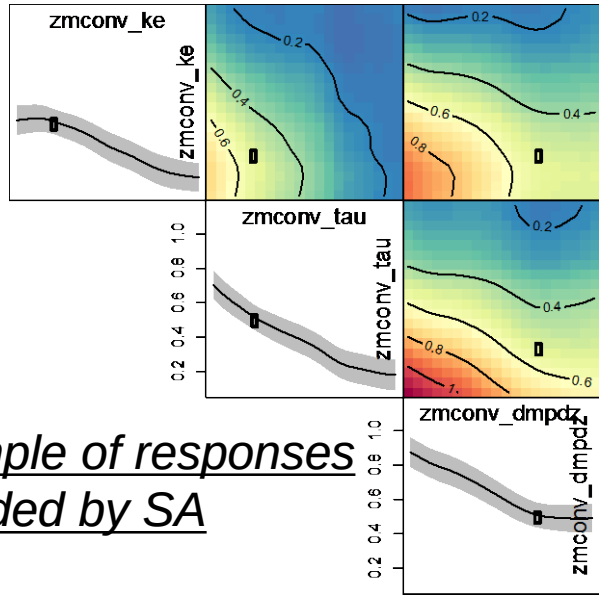
Uncertainty Quantification: Sensitivity Analysis (SA)

Gardar Johannsen, Don Lucas, Yun Qian, Laura Swiler, Tim Wildey

CAM5 2° /free Sensitivity Analysis

- Perturbed-Parameter Simulations
  - 1100 runs, 22 parameters, Latin Hypercube sampling
- Carried out sensitivity analysis of PNNL/LLNL/PNNL+LLNL ensembles with respect to precip metrics

→ General agreement across the multiple methods tried by LLNL, SNL & PNNL



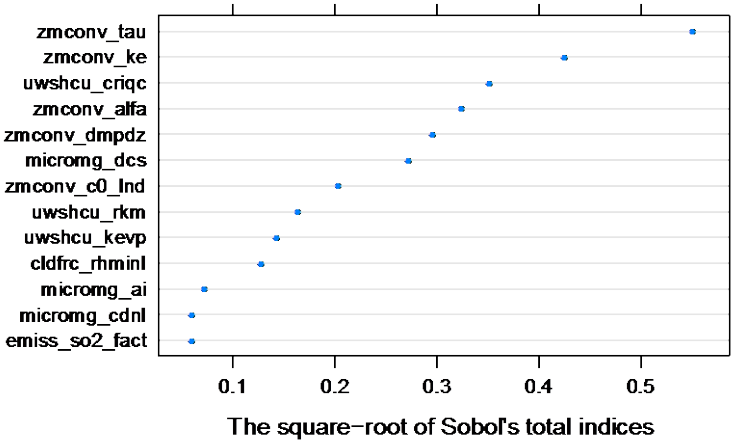
Example of responses provided by SA

CAM5 1° /nudged Sensitivity Analysis

- Perturbed-Parameter Simulations
  - 27 One-at-a-time & 130 Latin Hypercube runs
  - 13 parameters targeted using 2° /free SA results
- The 10 most sensitive parameters are identical between ensembles

→ Short nudged simulations provide insight for longer AMIP-style simulations

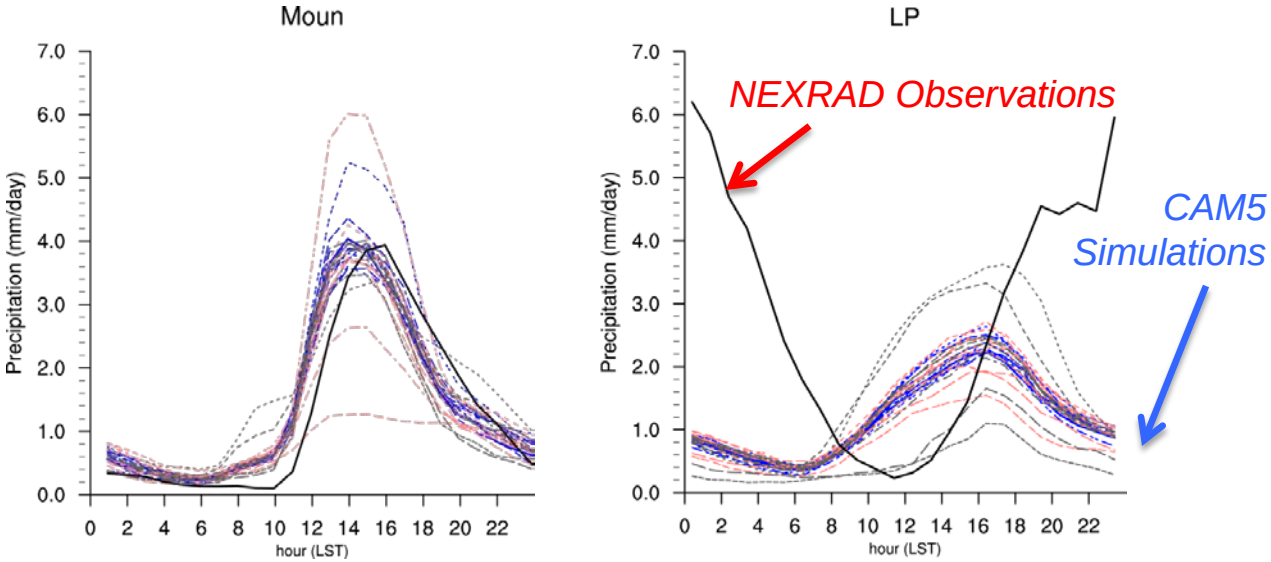
Aggregate sensitivity index



Uncertainty Quantification: Calibration

- When and for what does calibration to the observations make sense?
- What are the difficulties of calibration given various sources of error?
  1. Emulation model
  2. Natural variability of the simulation
  3. Model structural error
  4. Observational error and uncertainty
- Start with a simpler problem eliminating error sources #3 & #4

Diurnal cycle of JJA 2011 Precipitation in the Mountain and Low Plains Regions from NEXRAD Observations and perturbed parameter ensemble of 1° CAM5 nudged simulations

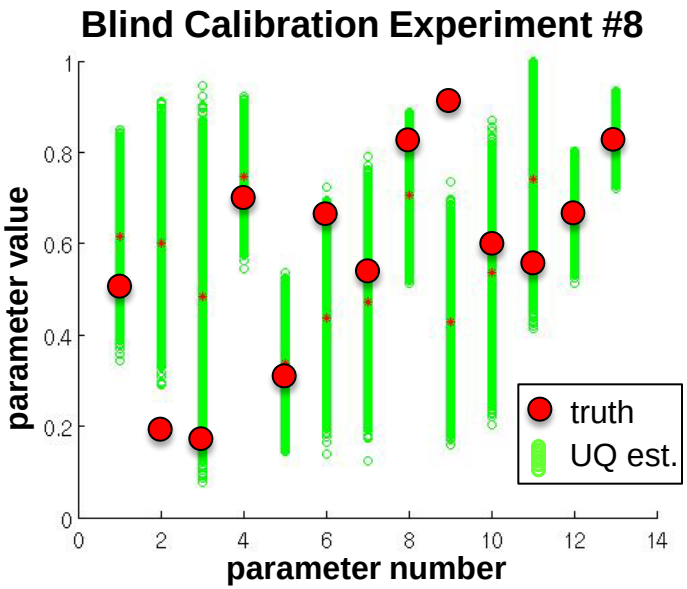


Robust Parameter Estimation Through "Blinded" CAM5 Experiments

Goal: given precipitation metrics data, develop UQ methods to estimate parameter values in CAM5

Requirements:

- different UQ methods should give about the same answer
- need to account for uncertainties in the model, method, observations, and internal variability



Initial Blind Experiments:

$\{p_1, p_2, \ldots, p_n\}_1$

$\{p_1, p_2, \ldots, p_n\}_2$

$\{p_1, p_2, \ldots, p_n\}_x$

CAM5

$\{metrics\}_1$

$\{metrics\}_2$

$\{metrics\}_x$

UQ

unknown ← **known**