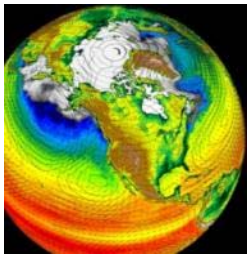

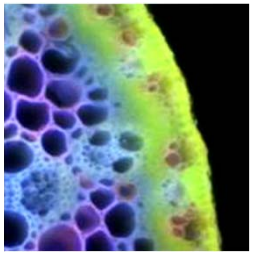

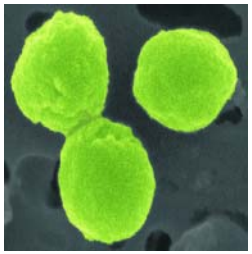

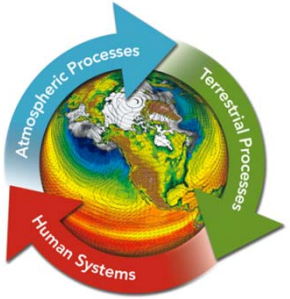

Community Modeling and Long-term Predictions of the Integrated Water Cycle

Topical Breakout Templates

Washington DC

September 24-26, 2012

Topic 5: Prediction, analysis, and uncertainty quantification of water cycle mean and extremes

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- Bill Collin
- Noah Diffenbaugh
- Dave Easterling
- Randy Dole
- Leo Donner
- **Chris Forest**
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- Jim Kinter
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- Rob Wood
- Minghua Zhang
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Topic 5: Prediction and UQ

Priority Research Directions (1-2)

1.1 Observational global to local water-cycle distributions: Observational effort to produce a validated water-cycle/ precipitation distribution and quantify uncertainty in that product as function of space and time scale- avoid blind downscaling (VII). Observational constraints…

1.2 Process-prioritized hi-res model development: Develop a coherent strategy to advance high-resolution modeling that will resolve processes and scales for precipitation phenomena (VI). Scale dependence of physical parameterizations is an essential part of process.

Topic 5: Prediction and UQ

Priority Research Directions (3-4)

1.3 High-frequency/high-resolution water-cycle reanalysis: Model-assimilation system for the water cycle will be critical for producing high-frequency/high-resolution water-cycle reanalysis required by user communities. Push assimilation of moist physics. (V). Very useful for impacts research. Use of forecast cycle for model verification.

1.4 Development of decision-relevant extremes and distributions: Need: better descriptive framework for extremes / distributions (VI). Could this be an opportunity for interaction with the user community – frame this in terms of functional impacts. Get descriptive of decision-relevant extremes. Co-variation of extremes.

Need for comprehensive metrics. Emergent phenomena that are multi-variate (V). Assessing fidelity of process representations. More realistic drought indices. Appropriate impact metrics.

Topic 5: Prediction, etc.

Priority Research Direction 1.1: Observational global to local water-cycle distributions with precip focus.

Scientific Needs/Opportunities

A. Observational constraints are not as tight as needed to validate models.
B. Precipitation: what is global #? Models higher still, big spread.
C. Fundamental higher-order statistics of light/heavy precipitation - lack of validated data.
D. Probes into soil column: large range of time-scales. Need observational grounding.

Research Approaches (Multi-agency)

A. Determine what is the observing system required to detect changes in water cycle: OSSEs.
B. Bottom up / top-down attack.
C. Optimize use of existing surface observations.
D. Validated paleo proxies to understand long-term variations in water cycle.

Scientific Impacts

A. Physical robustness must require "out-of-sample" tests.
B. Would trigger integration with process-level data: right answer for right reasons.
C. Knowing the water availability better.

User Impacts

A. Following consultation with the user community, they would/might have improved confidence in predictions.
B. Users could incorporate forecasts at entire range of times scales (>= minutes) if users knew **skill scores** as function of scale.
C. Users need prediction and explanation.

Topic 5: Prediction and UQ

Priority Research Direction 1.2: Process-prioritized hi-res model development

Scientific Needs/Opportunities

A. Necessary and sufficient computational resources for systematic, robust prediction and UQ and D'n'A.
B. We need to know the asymptotically accurate model = function(question).
C. Need for convection-permitting + PBL-resolving models. What is this resolution?
D. What are the key process interactions that determine asymptotes?
E. Variable resolution global models.
F. Research in numerical methods.

Research Approaches

A. Understand interactions between higher resolution and process representation.
B. Determine relationship between emergent phenomena of interest, resolution, and process fidelity.
C. How to exploit lower-res. Models to prep for cloud-system-resolving scales.
D. Methodology for **systematic** exploration of resolution impacts, process enhancements

Scientific Impacts

A. Learning physics of climate system at cloud-system-permitting scales.
B. Understanding multi-scale interactions.
C. Systematic characterization of model uncertainty and controls = function(resolution, parameters, structural errors)
D. Better predictions.

User Impacts

A. Figure out from users what scale breaks in the system would determine the asymptotic models.
B. If we had more confidence in parameterizations through systematic testing, then models would be useful even at scales > cloud systems.
C. ….

Topic 5: Prediction and UQ

Priority Research Direction 1.3: High-frequency/high-resolution water-cycle reanalysis:

Scientific Needs/Opportunities

A. Background models have systematic biases that cross-couple different components of the water cycle.
B. Need for consistent long-duration reanalyses that address temporal evolution of observing systems. Esp. water vapor
C. Improved observations of soil moisture, ocean state (salinity and SST). Exchange of water from ocean <-> land.

Research Approaches

A. Understand link between prognostic fields, processes, and (direct) observables.
B. Links directly to OSEs / OSSEs. OSEs allow you to design what observations are most effective.
C. Methods for assimilating precip.
D. ….

Scientific Impacts

A. Assimilate obs directly to model.
B. Better information about vertical transport in convection.
C. Could resonate with advances in models and parallel advances in assimilation: synergy in these activities.

User Impacts

A. Best way to get space-time distributions at user-relevant scales currently inaccessible to observing systems.
B. Advanced provenance of analysis – why are the specific answers obtained?
C. Uncertainties in the analysis. Develop uncertainties that would be useful to the user community.
D. Opportunity for feedback from user community.
E. Multi-variate data for impacts models.

Topic 5: Prediction and UQ

Priority Research Direction 1.4: Development of decision-relevant extremes and distributions:

Scientific Needs/Opportunities

A. Need observational data on the extremes (river flow, etc)
B. Need to combine with policy context due to manmade controls that affect the physical system.
C. Nexus between use-inspired and predictability research. Stake-holder community will declare what are the triggers for IAV and policy.
D. Improved seasonal to decadal forecasting of statistics.

Research Approaches

A. Evaluate models reproduction of observations of extremes.
B. Determine whether policy triggers are (inherently) predictable
C. ….

Scientific Impacts

A. Unique insights from discussion of triggers for IAV.
B. New methods for bias correction and downscaling that are useful for correcting for mean errors and shape of distributions.
C. ….

User Impacts

A. Better understanding of stream temperature, droughts, floods
B. Supporting better predictions of land-energy interactions (wind and other renewables)
C. Improving predictions of rainfall in very mountainous regions
D. Hedging for both tails of the rainfall distribution, including the low (drought) end.

Original discussion of topics follows next.

Topic 5: Predictability and UQ

Priority Research Directions (3 to 5)

1.1 Develop better understanding of how to integrate observation and model UQ (II)

1.2 Observational effort to produce a validated water-cycle/ precipitation distribution and quantify uncertainty in that product as function of space and time scale- avoid blind downscaling (VII). Observational constraints…

1.3 Develop a coherent strategy to advance high-resolution modeling that will resolve processes and scales for precipitation phenomena (VI). Scale dependence of physical parameterizations

1.4 Model-assimilation system for the water cycle will be critical for producing high-frequency/high-resolution water-cycle reanalysis required by user communities. Push assimilation of moist physics. (V). Very useful for impacts research. Use of forecast cycle for model verification.

Topic 5: Prediction and UQ

Priority Research Directions (3 to 5)

2.1 Goal: understand the linkage between mean bias and extreme events in the water cycle (I)

2.2 Quantify predictability vs. skill in the current models (I)

2.3 Focus on causes of US great plains dry bias in current GCMs (I). Causes: missing MCS's.

2.4 Wide variation of precipitation predictions across scenarios among the models is a serious problem (I). Lack of convergence of models. Challenge: difficulty in testing using the current record given weak trend.

Finding ways to objectively and systematically quantify what is genuine model difference vs. natural fluctuations.

Topic 5: Prediction and UQ

Priority Research Directions (3 to 5)

3.1 Need: better descriptive framework for extremes / distributions (VI). Could this be an opportunity for interaction with the user community – frame this in terms of functional impacts. Get descriptive of decision-relevant extremes. Co-variation of extremes.

(MERGE WITH 3.4???)

3.2 Model based uncertainty quantification – mega model ensemble. Stochastic physics (I) for UQ. 2+2=4+/-epsilon

3.3 Are there any innovative ways to use ensembles for sampling distributions (for tails) vs. higher-resolution for smaller scales and higher process fidelity (II). Value added from adding representations of new components of the water cycle.

3.4 Need for comprehensive metrics. Emergent phenomena that are multi-variate (V). Assessing fidelity of process representations. More realistic drought indices. Appropriate impact metrics.

3.5 What kind of synoptic and mesoscale details are required for users? (I)

Topic 5: Prediction and UQ

Priority Research Directions (3 to 5)

4.1 Are future predictions realistic in domains dominated by tropical cyclones and convection (I)

4.2 Atmospheric rivers – need for phenomenological approach.

4.3 Developing community models of the human system (I)

4.4 Look at error interaction across coupled modeling systems (I).

4.5 Integrati

Terminology for Templates

Topical Breakouts

- Priority Research Direction (PRD) - A high-priority research direction with high potential for producing revolutionary scientific breakthroughs that could dramatically advance the use of models for decision support.
  - Scientific Needs/Opportunities
  - Research Approaches
  - Scientific Impacts
  - User Impacts