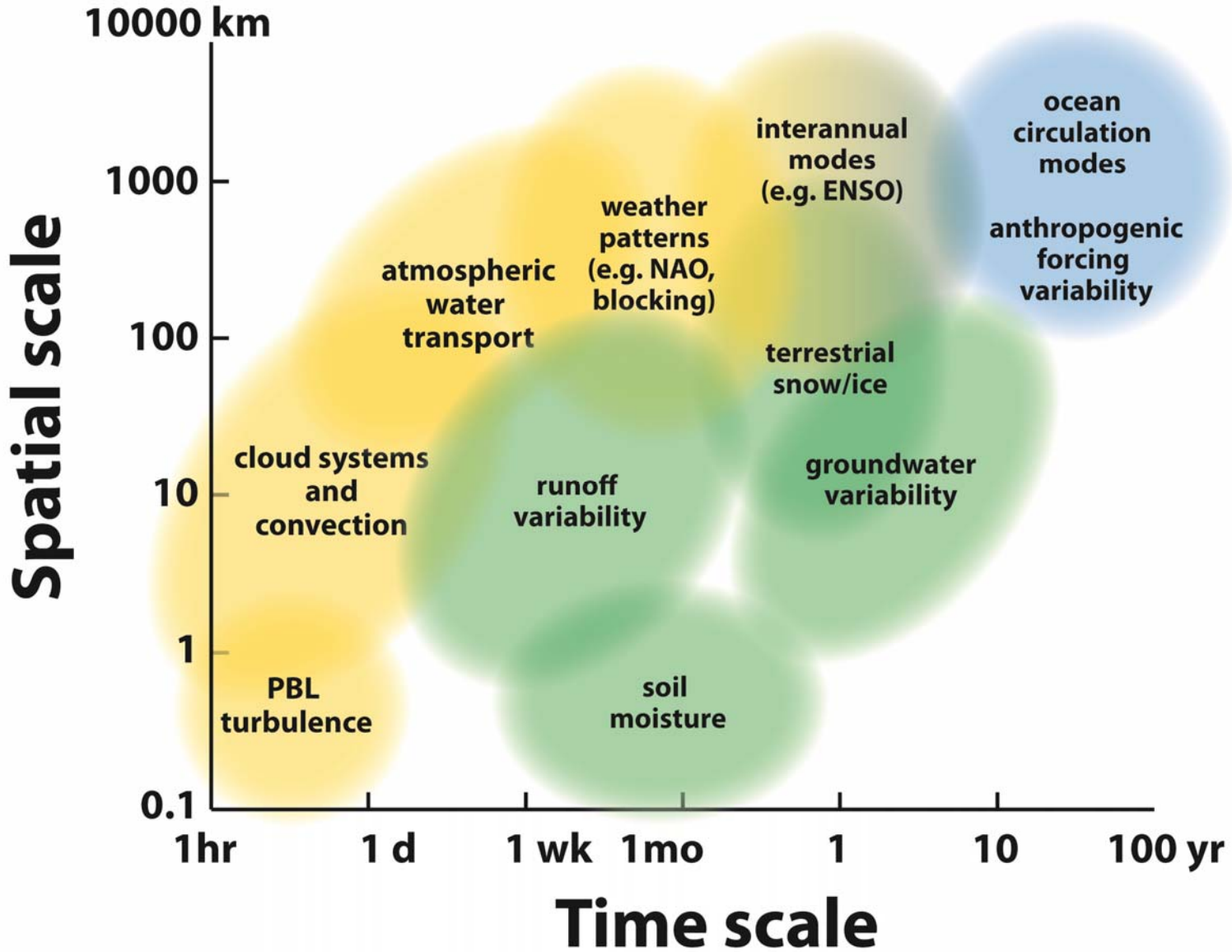
Topic 1: Multi-scale behaviors of the water cycle

- Ana Barros
- Julio Bacmeister
- Bill Collins
- Randy Dole
- Leo Donner
- Chris Duffy
- Inez Fung
- Bill Gutowski
- Reed Maxwell
- Guido Salvucci
- Siegfried Schubert
- Soroosh Sorooshian
- Graeme Stephens
- Mike Wehner
- Cathy Wilson
- Eric Wood
- **Rob Wood**
- **Xubin Zeng**
- Shaocheng Xie

Approach

- Invited talks covering diversity of topics relevant to multi-scale water cycle phenomena
- Others invited to talk for two minutes about pressing issues
- Review of issues and synthesis into Priority Research Directions
- Flesh out Scientific Needs/Opportunities, Research Approaches, Scientific Impacts, User Impacts

The Water Cycle: Key space and time scales of important phenomena



Lunchtime invited presentations

- **Sorooshian**
  - Hydrometeorological challenges in multi-scale water cycle research
  - Approach to represent impacts of irrigation on surface temperature
- **Leo Donner**
  - Five challenges in convection. Importance of organization of small scales for generating realistic precipitation at larger scales
- **Julio Bacmeister**
  - Exploration of resolution dependence (100 to 25 km) of precipitation patterns. Resolution is not a panacea for precipitation biases
- **Inez Fung**
  - Importance of small-scale exploration of root-rock-soil interactions for understanding vegetation resilience and runoff timing/magnitude
- **Ana Barros**
  - Tight coupling between small-scale organization of clouds, precipitation and orography. Scaling relationships.

Topic 1: Multi-scale characteristics

Develop strategy to systematically explore behavior of models with increasing resolution.

Scientific Needs/Opportunities

- Better understand two-way interactions between small and large scale phenomena/processes and to develop scaling theories for atmospheric and land processes
- Current understanding of resolution-dependence of climate models is poor
- Need to develop new metrics for evaluating high resolution models that leverage existing observing capabilities and spur the development of new ones
- Key processes important in water cycle are not currently resolved. Need for US to catch up with international efforts.

Develop strategy to systematically explore behavior of models with increasing resolution.

Research Approaches

- Run a suite of nested/telescoping models on a continental scale testbed with variable resolution (from 1 -100 km)
- Evaluate scales at which key phenomena (e.g. MCS) and couplings with land surface models emerge and become well-represented
- Use simulations to develop scale-aware parameterization for lower resolution 'workhorse' models
- Develop collaborative teams to design experiments, specify necessary model outputs and design evaluation strategies

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Develop strategy to systematically explore behavior of models with increasing resolution.

Scientific Impacts

- Understand the degree to which land surface heterogeneity influences projections of the water cycle
- Develop understanding of how small scale processes (e.g. convective organization) upscale to regional and global scales

Develop strategy to systematically explore behavior of models with increasing resolution.

User Impacts

- Decisionmaking community will benefit from better knowledge about the fundamental behavior and predictability of the system

Topic 1: Multi-scale characteristics

Develop strategy to systematically explore behavior of models with increasing resolution.

Requirements/Leverages

- Hardware-software codesign to produce computers specifically focused upon solving fluid dynamics equations
- Leverages existing DOE investments in computing and observational infrastructure
- Team approaches fostering cross-disciplinary engagement and to bring together model software/hardware developers, process modelers and observational scientists.

Issues of upscaling. How small scale processes move upscale. New models have broader range of scales. How does energy etc. transfer between scales? Many processes relevant to water cycle.

Scale mismatch, but effects are profound. Do we need a focused regional strategy? What areas are suitable targets? Responses might be very different in different regions. Need to exploit existing streamflow data on streams with minimal human impact, grouping types of root-rock regimes.

Is there a single region/phenomenon that might address both atmos and surface concerns? For example, MCSs, atmospheric rivers

Testbeds. Where, when, how? Existing DoE facilities. Interaction with other agencies (NOAA HMT).

Better representation of vegetation in models at high resolution. Biologists have better models of water use. Current eco models do not capture the diversity. Land models do not link plants to landscape in the correct manner. Possible need for hyper-resolution (100m- few km). Analogous to LES for PBL processes. Difficult to know how to specify uncertain boundary conditions for these models. Importance to understand how these inform larger scale models.

Examine sensitivity of different hydroecological systems to climate changes. Which regions are more susceptible and how might the impacts feed back on the broader climate system?

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Priority Research Directions (3 to 5)

Multiscale model that can be telescoped and tested using single-site observations, the knowledge from which can be used to upscale. Need more systematic way to take process models and degrade/coarse-grain to lower resolution.

Need to consider temporal multiscaling in addition to spatial scaling. New data that can separate out the short timescale variability in ET/soil/subsurface response to precipitation events. Use to constrain models

Is it possible to find a scaling theory/methodology for hydrology/land behavior. Soil scale (mm-few m). Plant to copse scale (1-100m). Geomorphic scale (100m-10km). Geologic scale that can sustain horizontal moisture. How can suitable atmospheric forcings for hyperresolution land models to be constructed?

DoE investing in variable-resolution models to understand scales at which precipitation forms (mesoscale convective systems). Exploit these.

Spatial scales: developing scale-aware parameterizations.

What resolution is needed to couple various components of different models. Very high resolution LES over all Germany.

How do errors in precipitation feed into errors in land/hydrologic models?

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Priority Research Directions (3 to 5)

- No convergence in moving to high resolution atmospheric models (100 to 25 km). Community needs to move to continental cloud “permitting” (<1 km) scale models to systematically evaluate if convergence can be reached. Do statistics of precipitation converge, and can existing observations confirm this? Use high res models to guide low resolution models.
- Why are other nations running higher resolution models with fewer resources than are available in the US?
- Need to design computers specifically focused upon solving fluid dynamics equations, not a general purpose computer. Requires hardware-software codesign.
- Develop team approaches which foster cross-disciplinary engagement and activities focused upon specific problems. Establishing teams of model developers, process modelers and observational scientists is critical. Dedicated science teams focused on specific cross-disciplinary research themes for relatively short periods (e.g. 3-5 years) should be encouraged.

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Priority Research Directions (3 to 5)

HIGH RESOLUTION MODELING: Develop strategy to systematically explore behavior of models with increasing resolution.

- Variable scale model telescoping in on particular focus region(s) to aid understanding of key phenomena and processes, their coupling and scaling properties.
- Currently, convergence in moving to high resolution atmospheric models (100 to 25 km) is poor. Develop telescopic modeling testbed for continental cloud “permitting” (<1 km) scale models.
- Systematically evaluate if convergence can be reached using carefully-designed model experiments. What are the criteria for convergence? Do water cycle statistics converge, and can existing observations confirm this? Use high res models to guide low resolution models.
- Develop steps/strategy for evaluation of model performance as resolution increases (e.g. ARM measurements, satellite, ground based radar).

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Priority Research Directions (3 to 5)