Impacts of climate change on water resources:

A unified approach to simulate hydrologic processes

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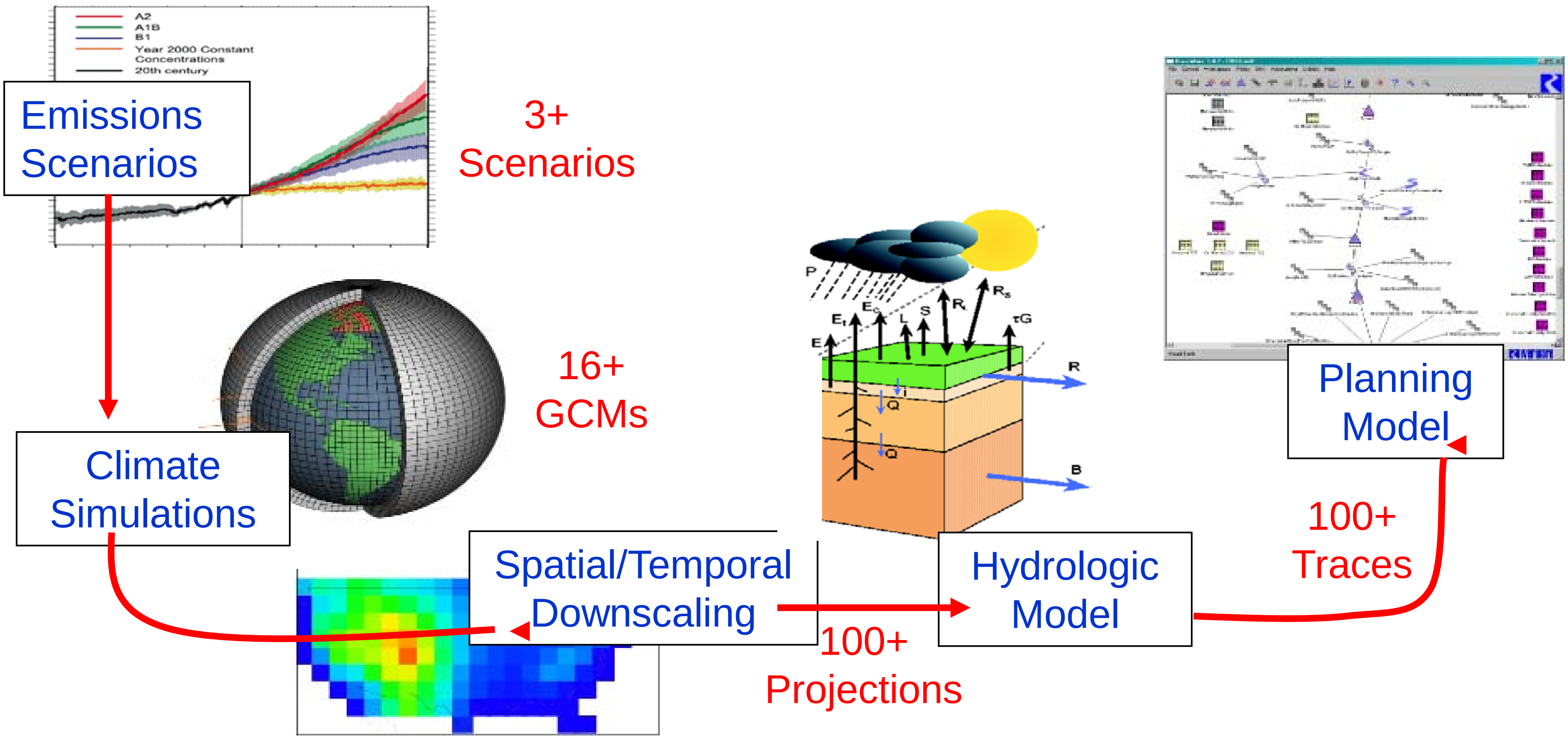
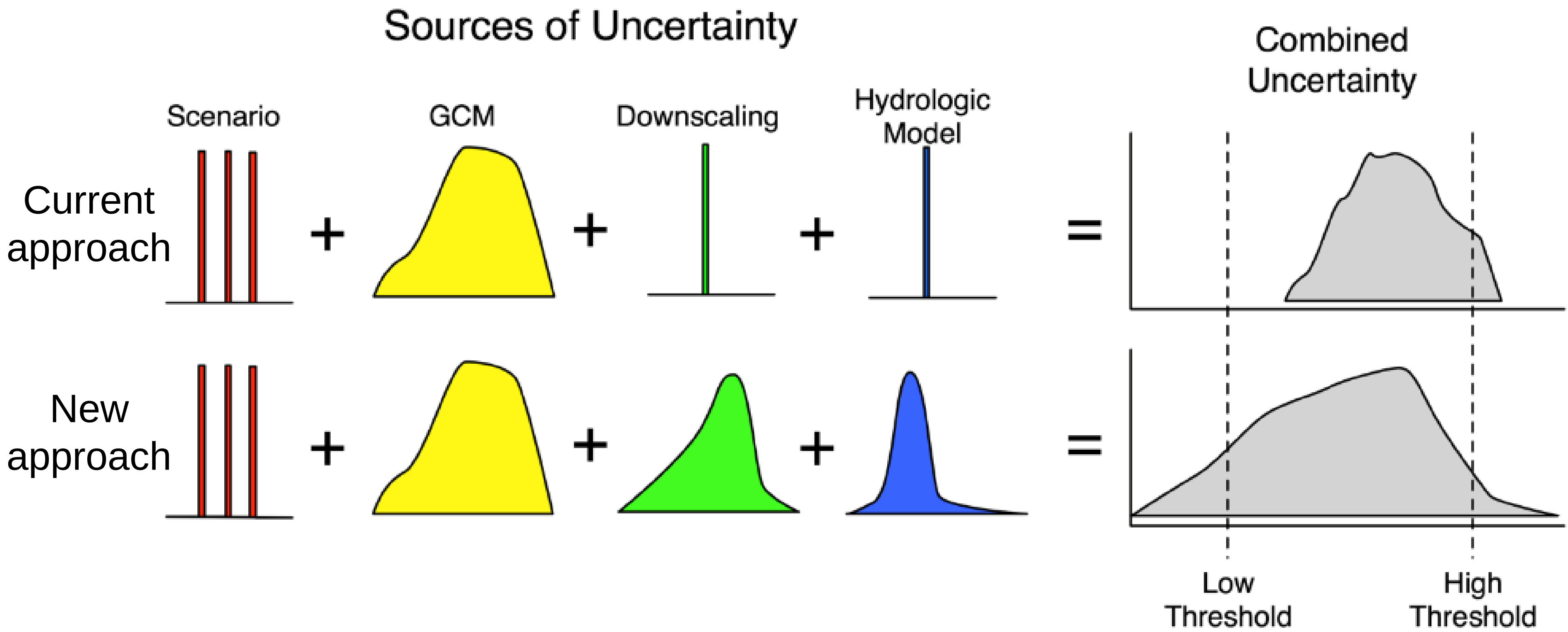
Outline

- Motivation
  - Incomplete characterization of uncertainty in climate impact assessments
- Improve hydrologic modeling
  - Integrate different approaches to simulate hydrologic processes
  - Preferential selection of modeling alternatives (don’t reject entire models, just model components)
  - Directly characterize main sources of uncertainty (understand the interplay between model parameters and process parameterizatrions)
- Summary & Discussion

Methodology to Incorporate Climate Change Information into Water Supply Projections

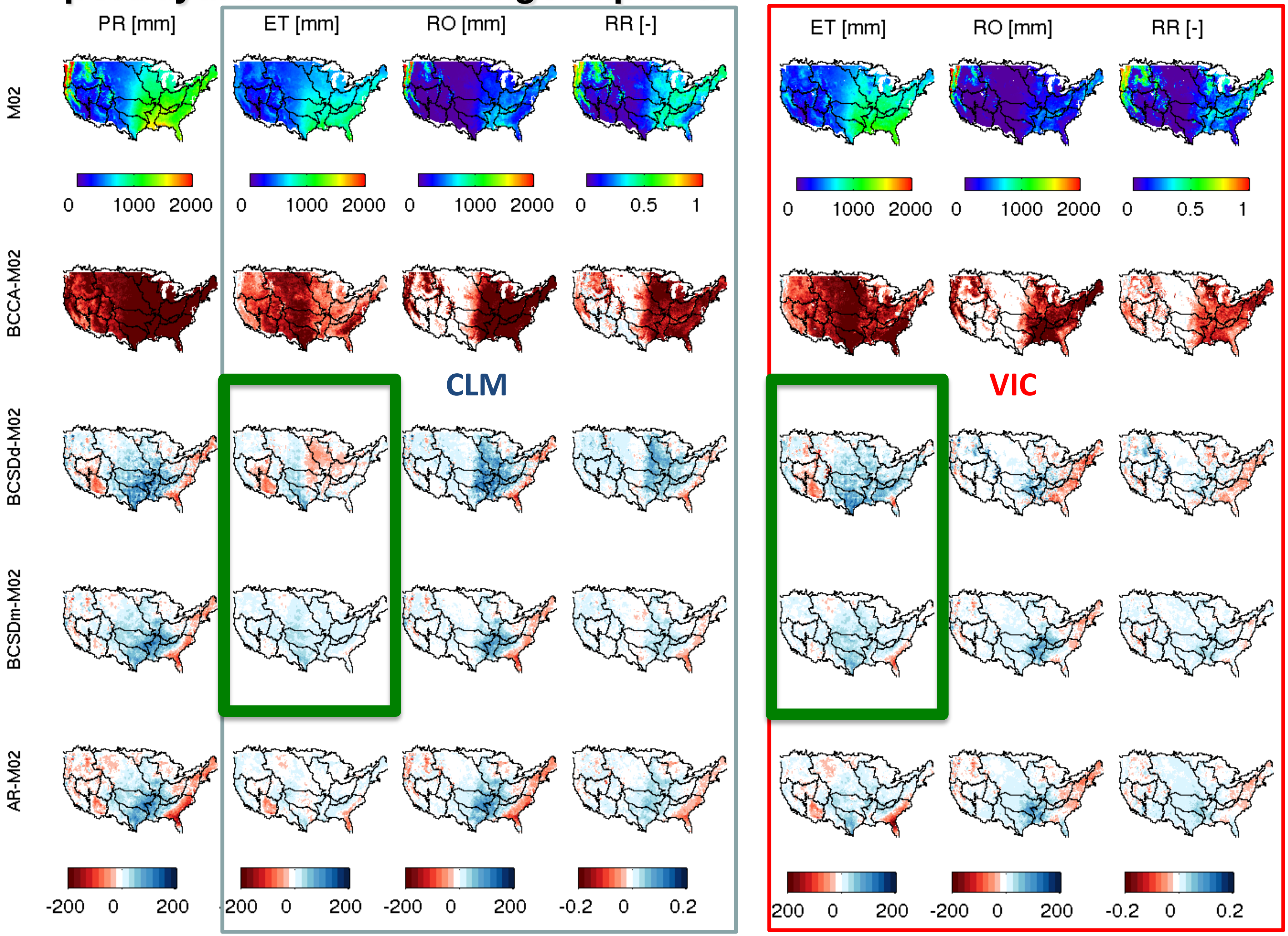


Expectations for the future



Accounting for hitherto neglected sources of uncertainty will invariably mean impact assessments will portray increased uncertainty
→ same as the IPCC experience

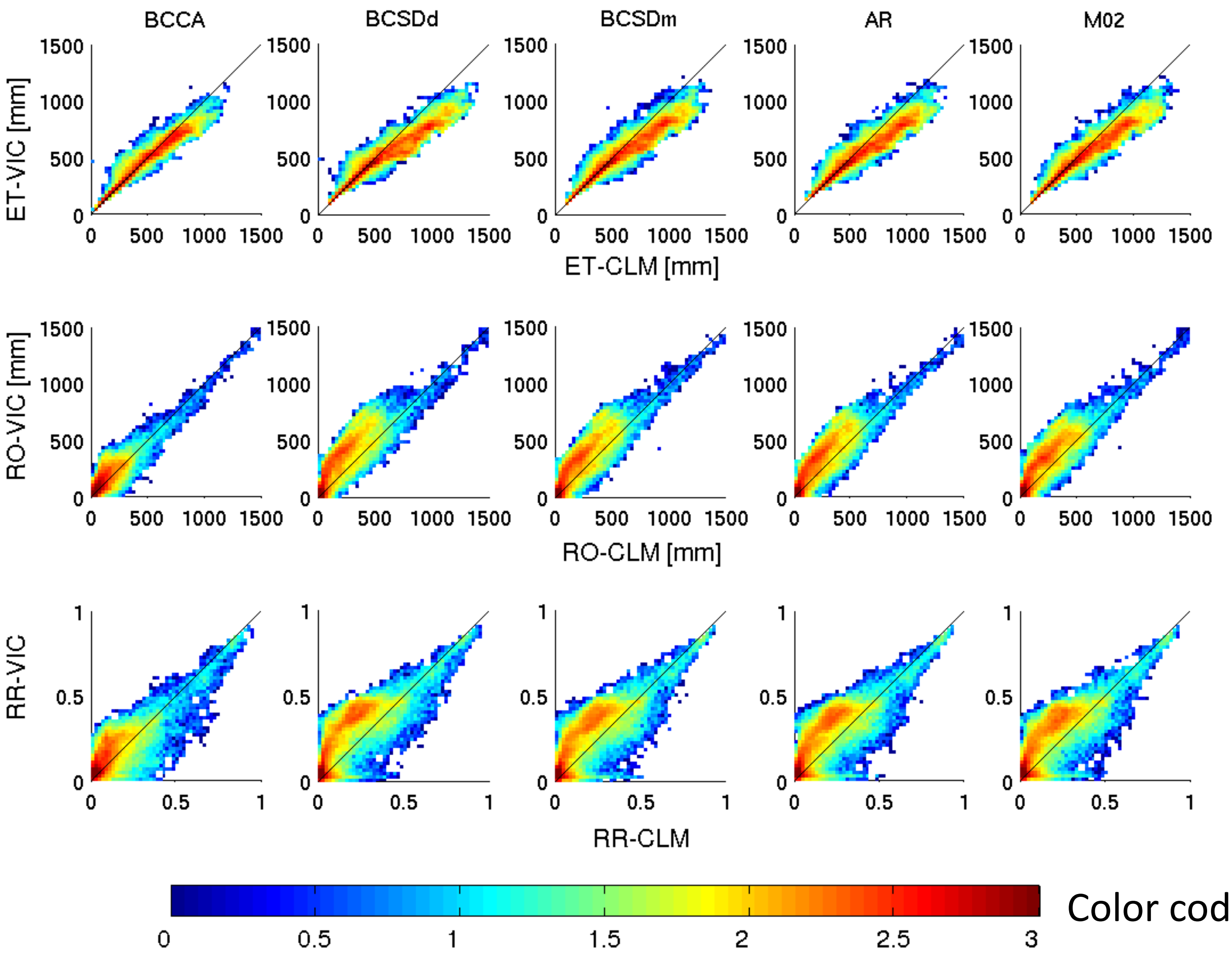
Impact of downscaling methodology and hydrologic model on the portrayal of climate change impacts



Inter-model differences in ET and runoff

CLM compared to VIC

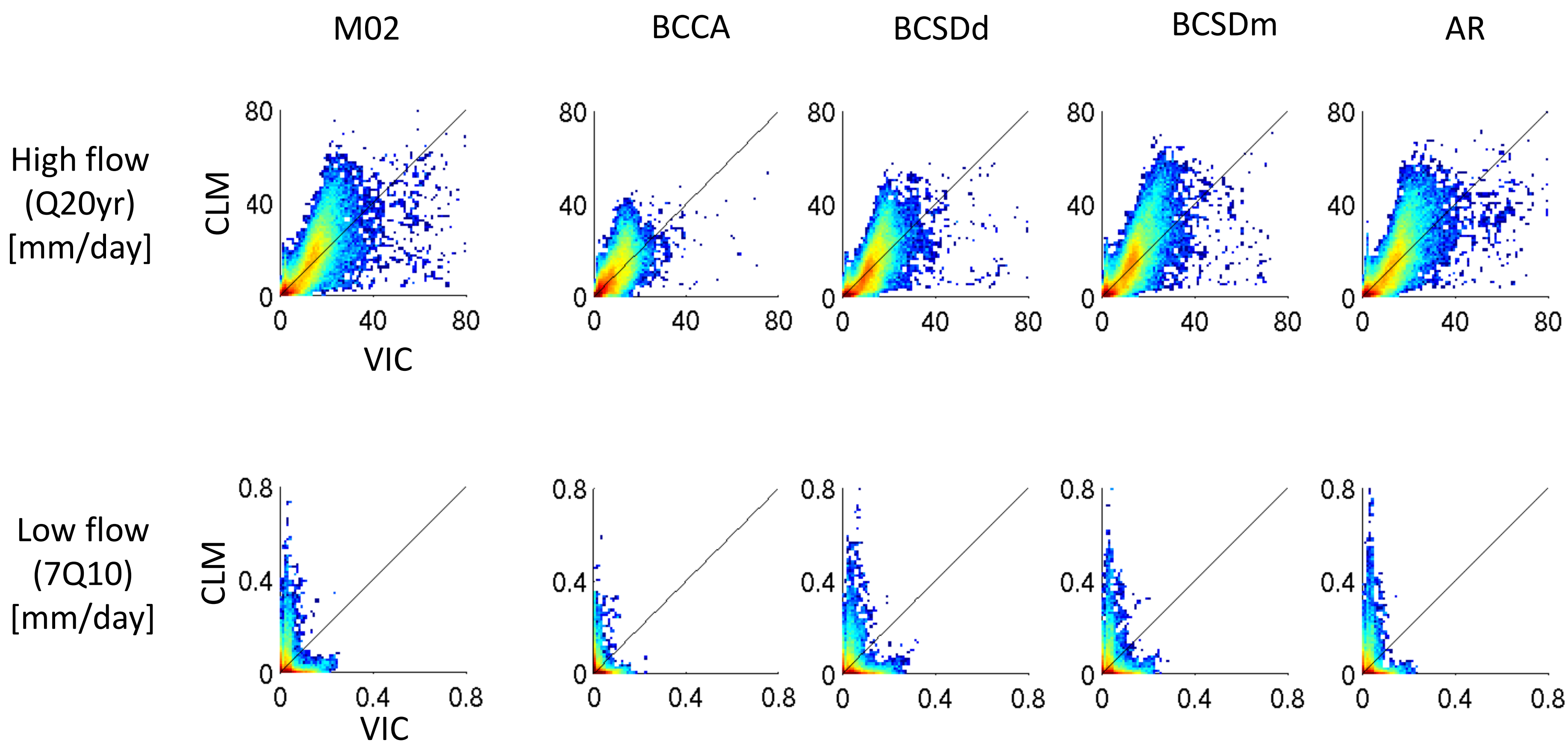
Comparison of annual water fluxes [mm] – 12km CONUS wide



Color code: log10(N)

- VIC produces less ET where > 500mm
- VIC produces more runoff where <500mm
- VIC and CLM agree better when they are forced by BCCA than by the other products

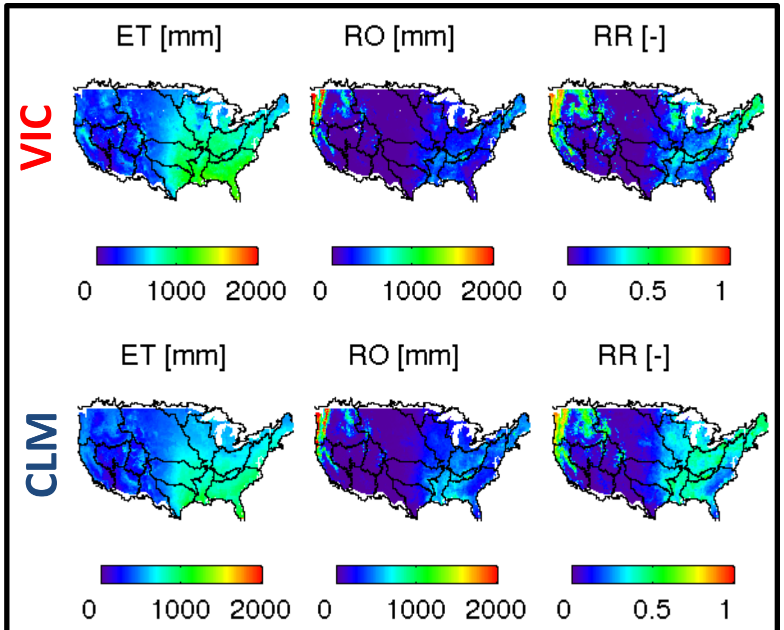
Comparison of extreme runoff
- Inter-model difference



Low flow estimate is more dependent on models

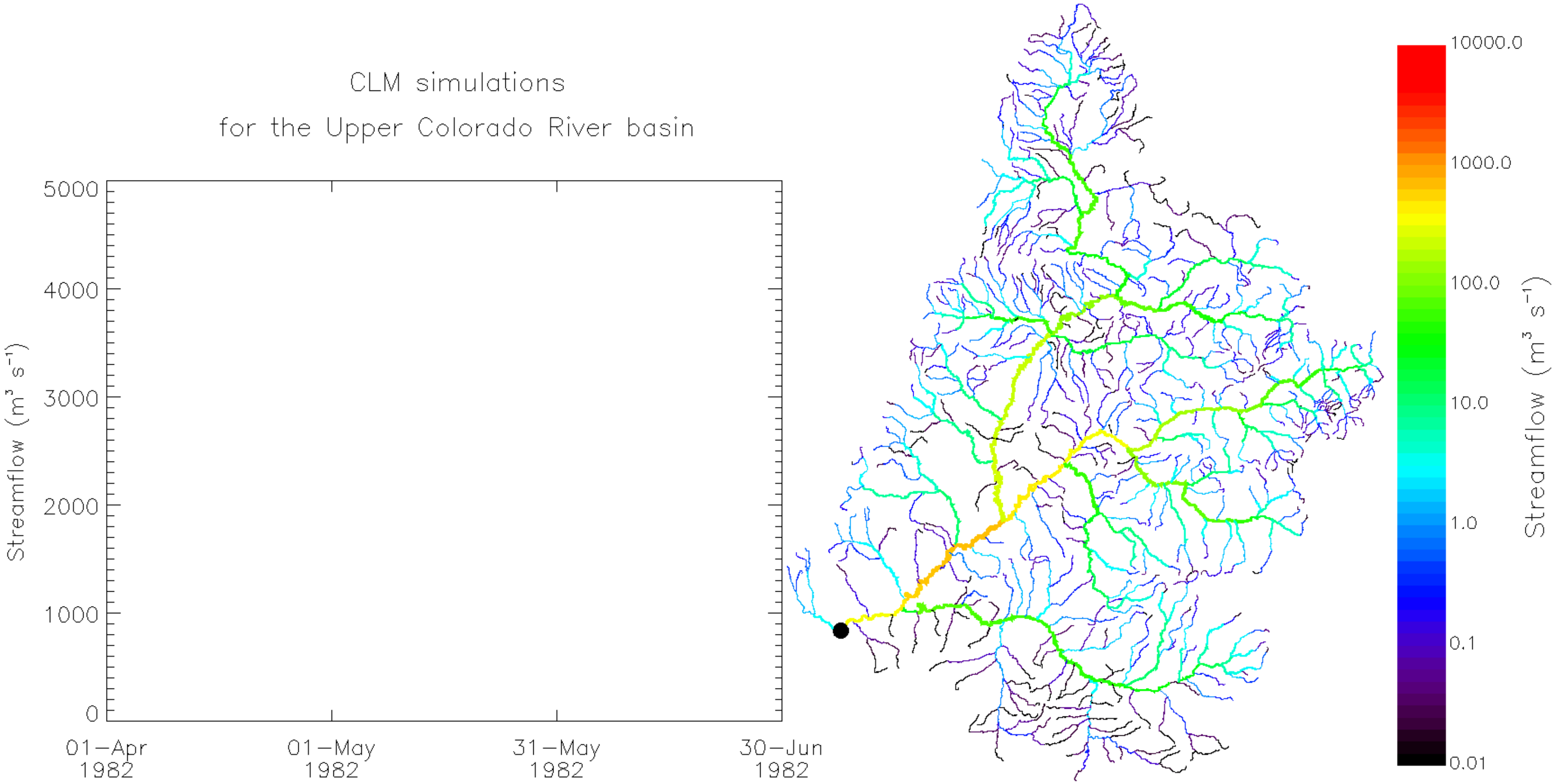
Ongoing research:
Move from single-model to multi-model approaches

- Continental-scale application of existing 1-d hydrologic and land-surface models
  - Models applied on either Hydrologic Response Units (HRUs) or grids
- Routing using the USGS river network topology from the Geo-spatial Fabric
  - Simulate streamflow at all USGS stream segments
    - Simple time-delay routing models (like used in VIC)
    - Lagrangian kinematic wave routing model
    - (more)
- Use of default model parameters



\+
PRMS
Noah-MP

CLM simulations coupled with network-based routing model configured for the USGS geospatial fabric



Problems

- Sub-optimal model fidelity
  - Some models have poor representation of specific processes
- Ad-hoc characterization of uncertainty
  - Selection of models not constrained to characterize uncertainty in process representation

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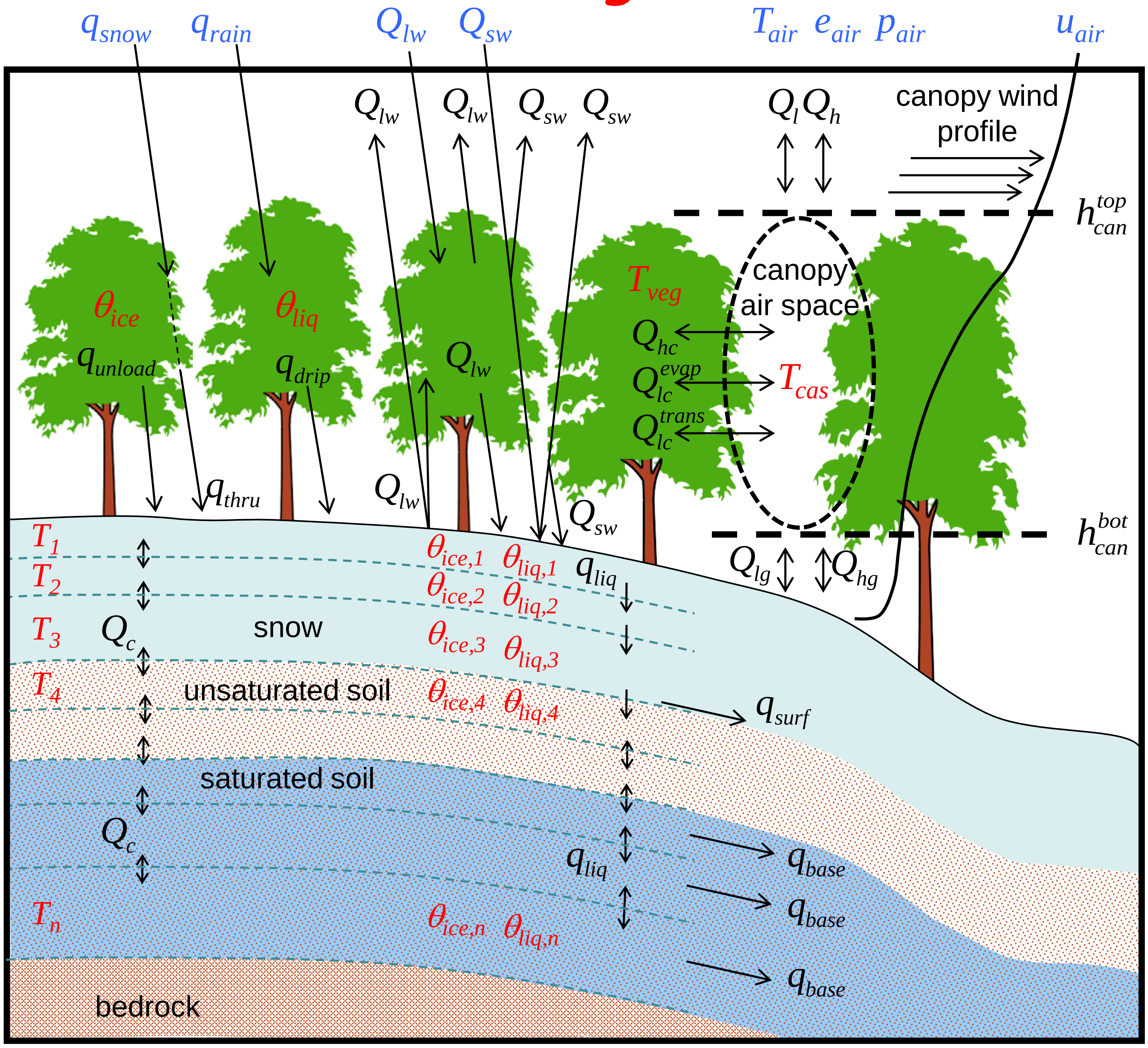
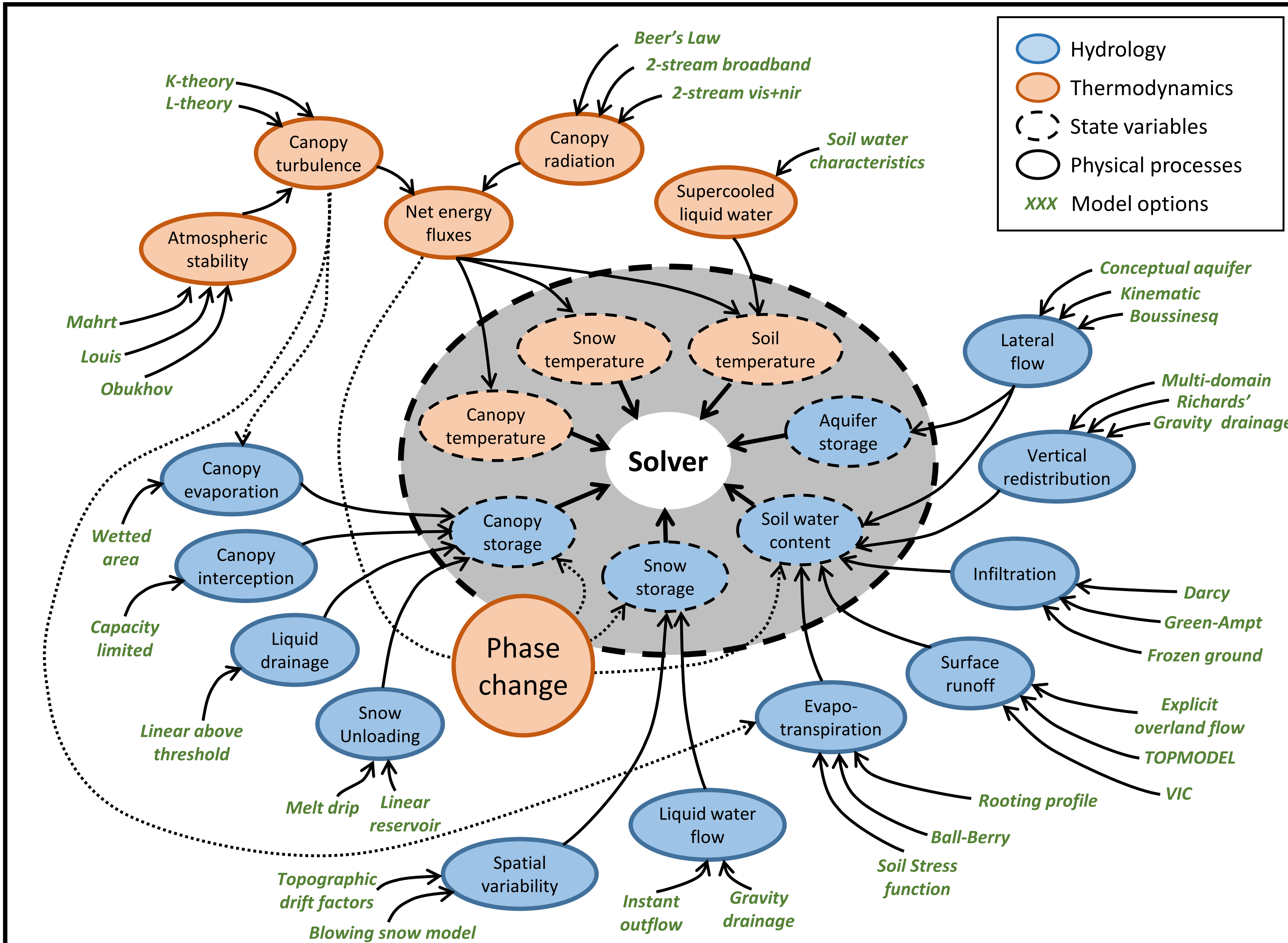
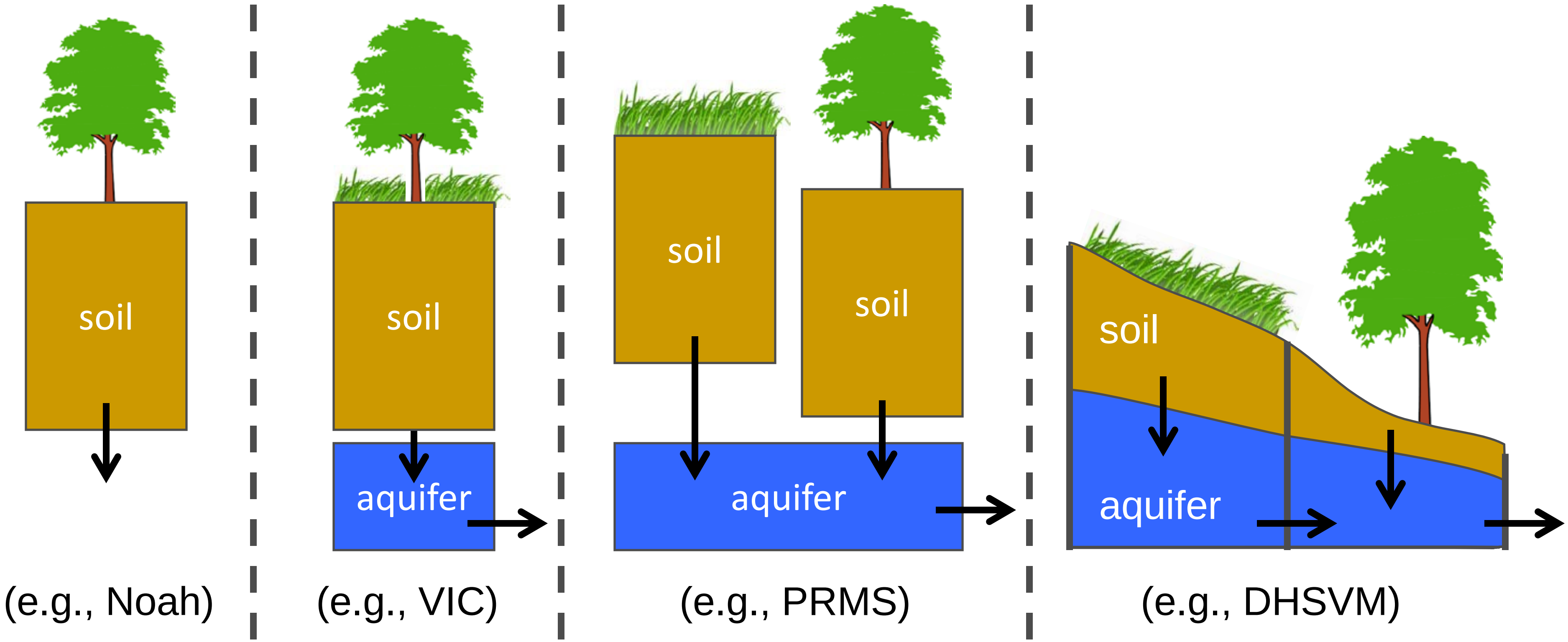
Understanding areas of model agreement…

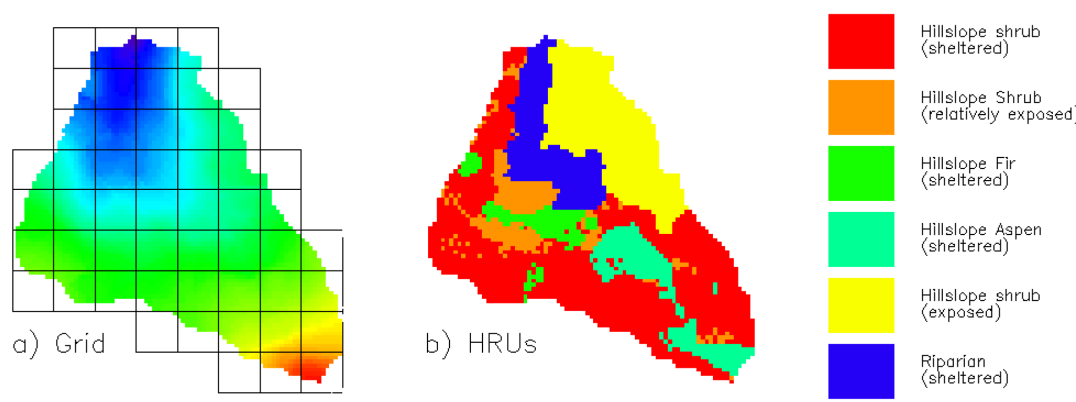


…a unified approach to hydrologic modeling



Model architecture (spatial variability and hydrologic connectivity)





Linkages to CLM development

- CLM concepts/code used
  - Hierarchal data structures
    - Spatial variability and hydrologic connectivity
  - Canopy radiation
    - Two-stream shortwave canopy radiation parameterization
    - Canopy longwave parameterization
  - Stomatal resistance
    - Ball-Berry
  - Snow
    - Subdivision and merging of snow layers
- Possible enhancements to CLM
  - Canopy snow interception
  - Hydrologic similarity concepts
  - Lateral flow and hydrologic connectivity
  - (more)

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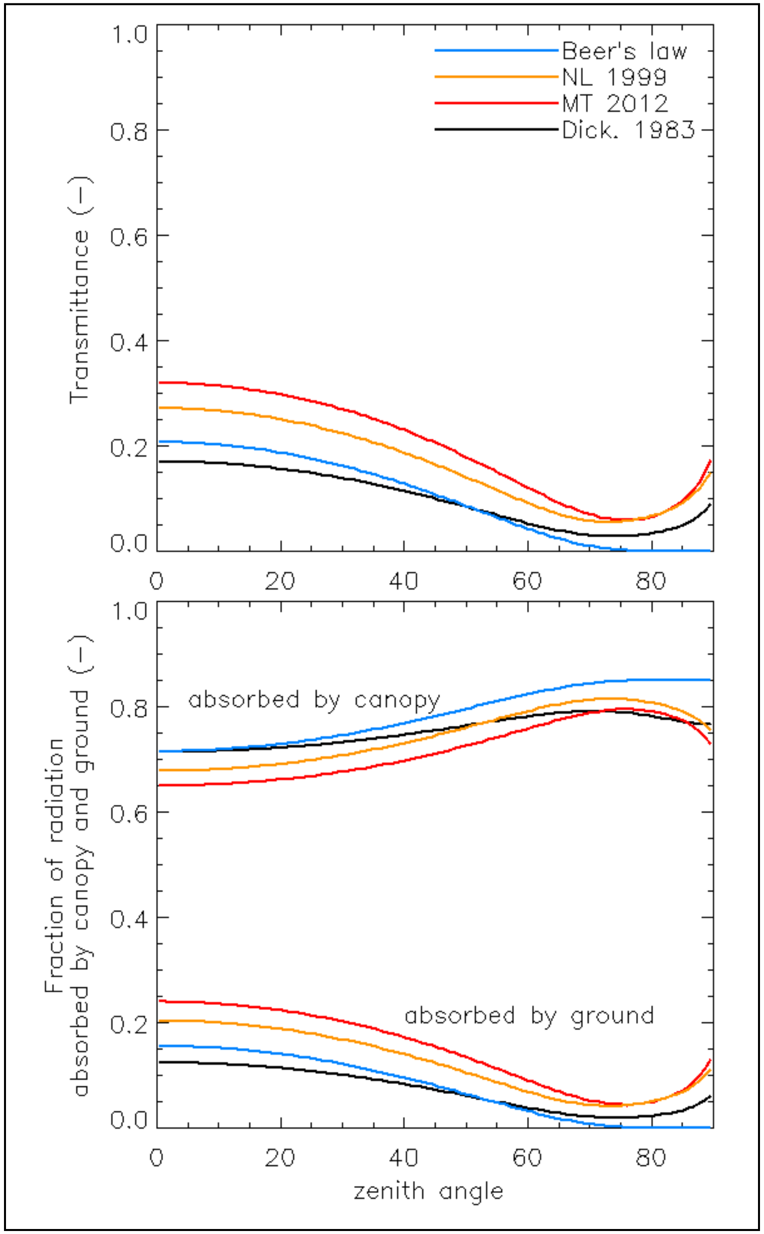
Preferential selection of modeling alternatives

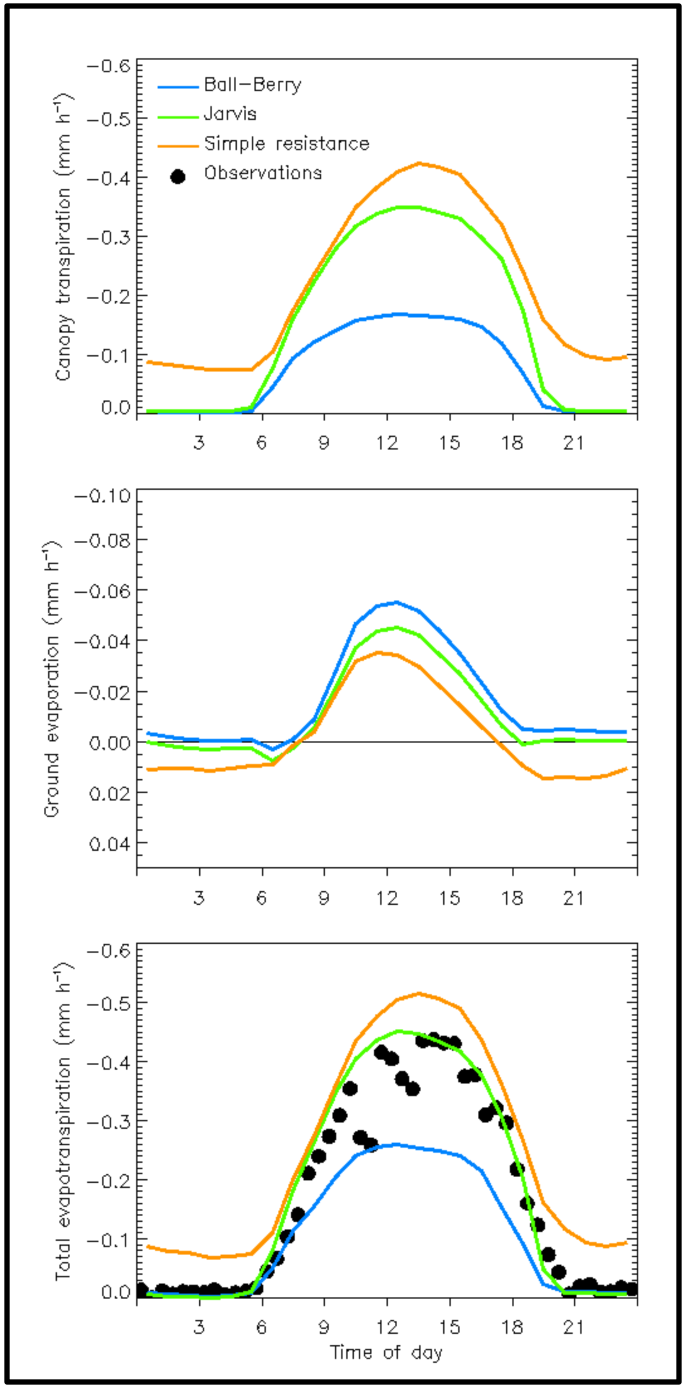
Canopy SW radiation parameterizations

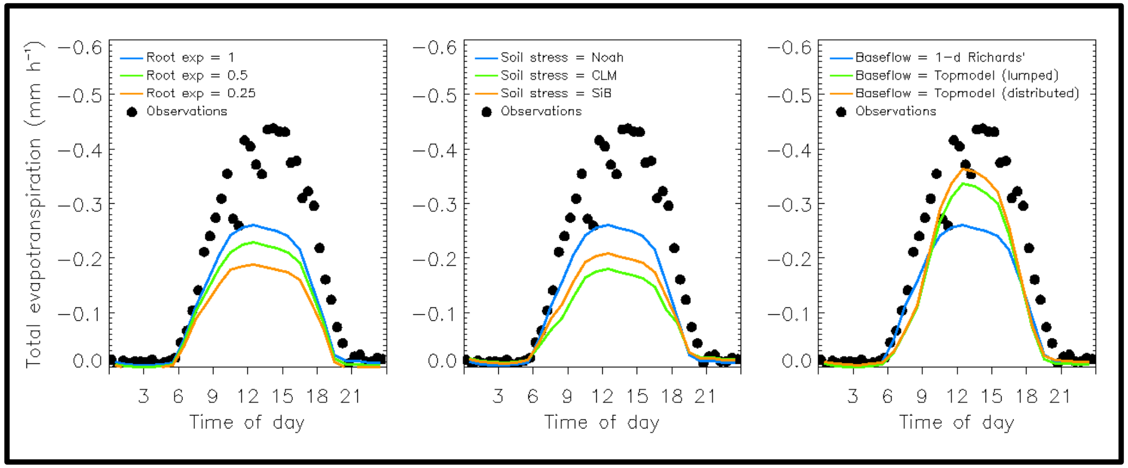


Simple application of Beer's Law does not explicitly account for the higher transmission of diffuse radiation at higher zenith angles

Preferential selection of modeling alternatives

Transpiration



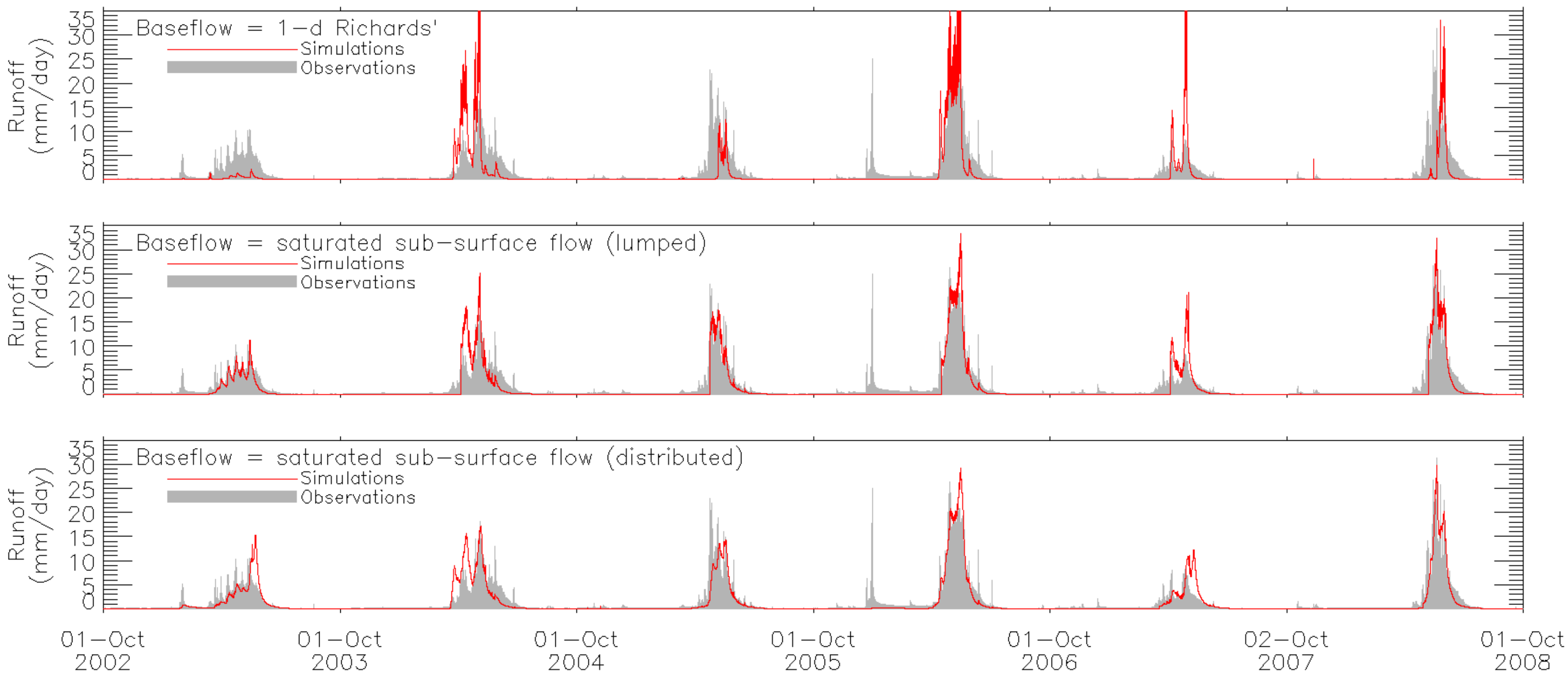


Interplay between model parameters and model parameterizations

Biophysical representations of transpiration necessary to represent diurnal variability

Preferential selection of modeling alternatives

spatial variability and hydrologic connectivity



- ❑ 1-D Richards' equation somewhat erratic
- ❑ Lumped baseflow parameterization produces ephemeral behavior
- ❑ Distributed (connected) baseflow provides a better representation of runoff

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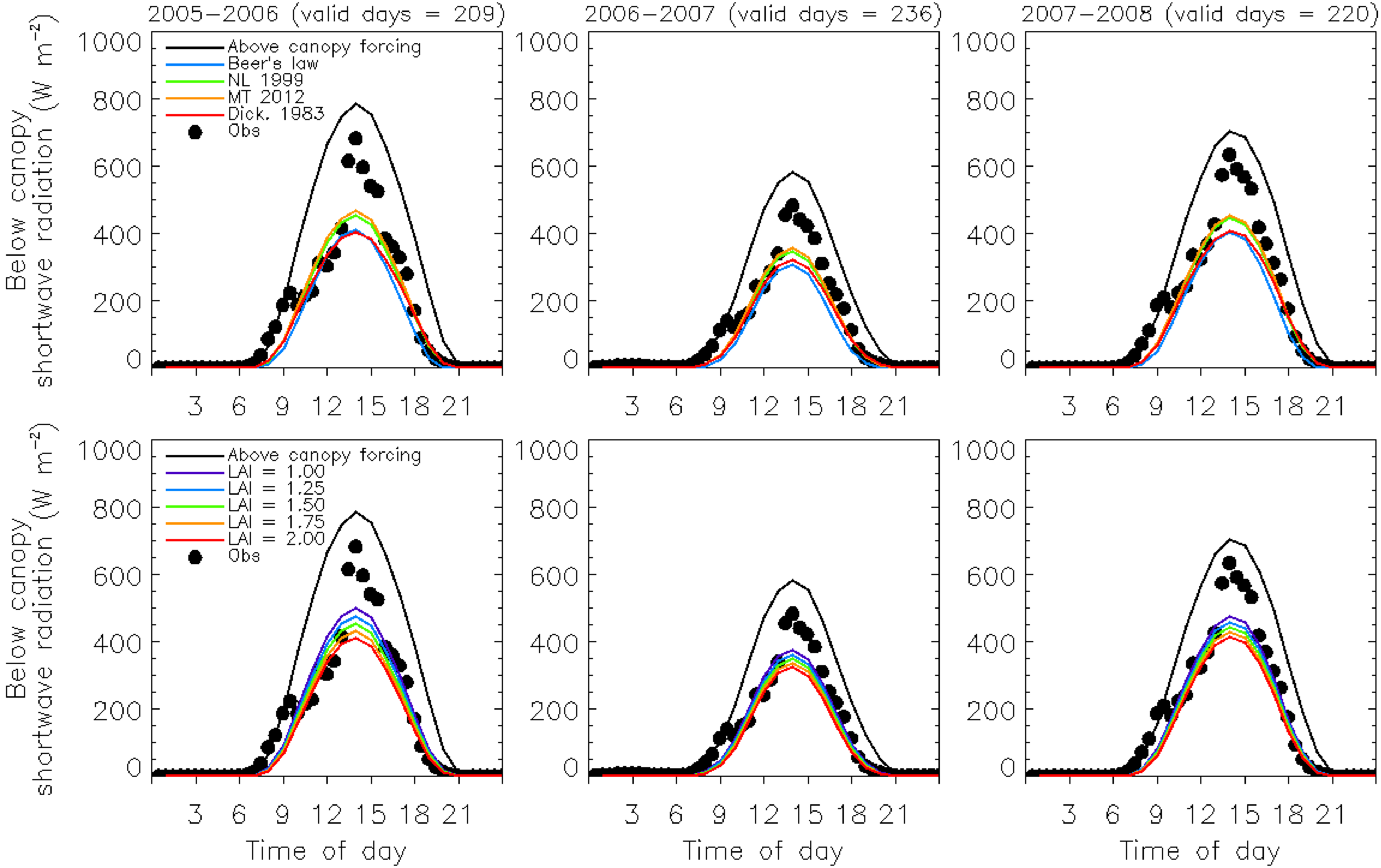
Characterization of uncertainty

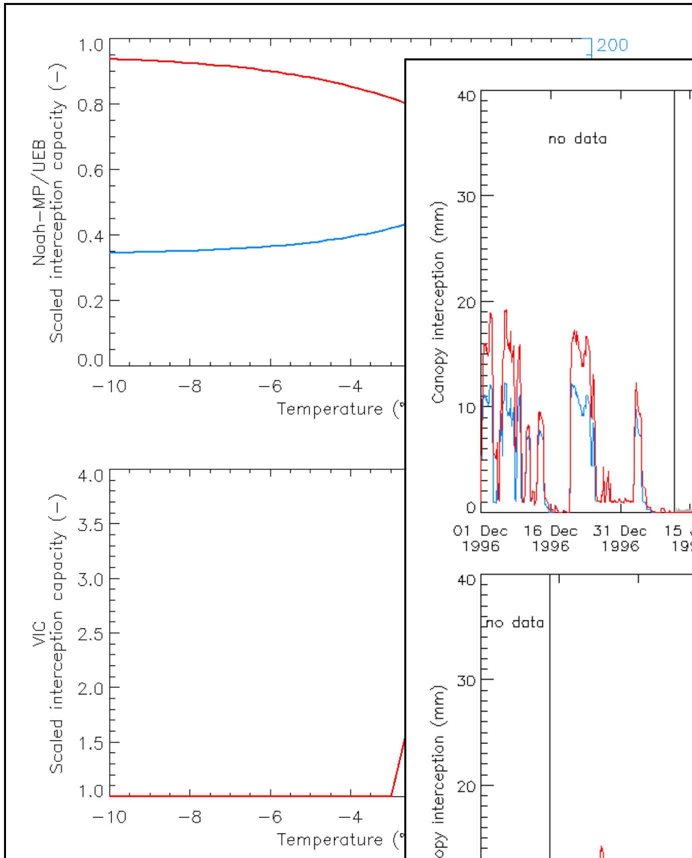
Interplay between model parameters and model structure



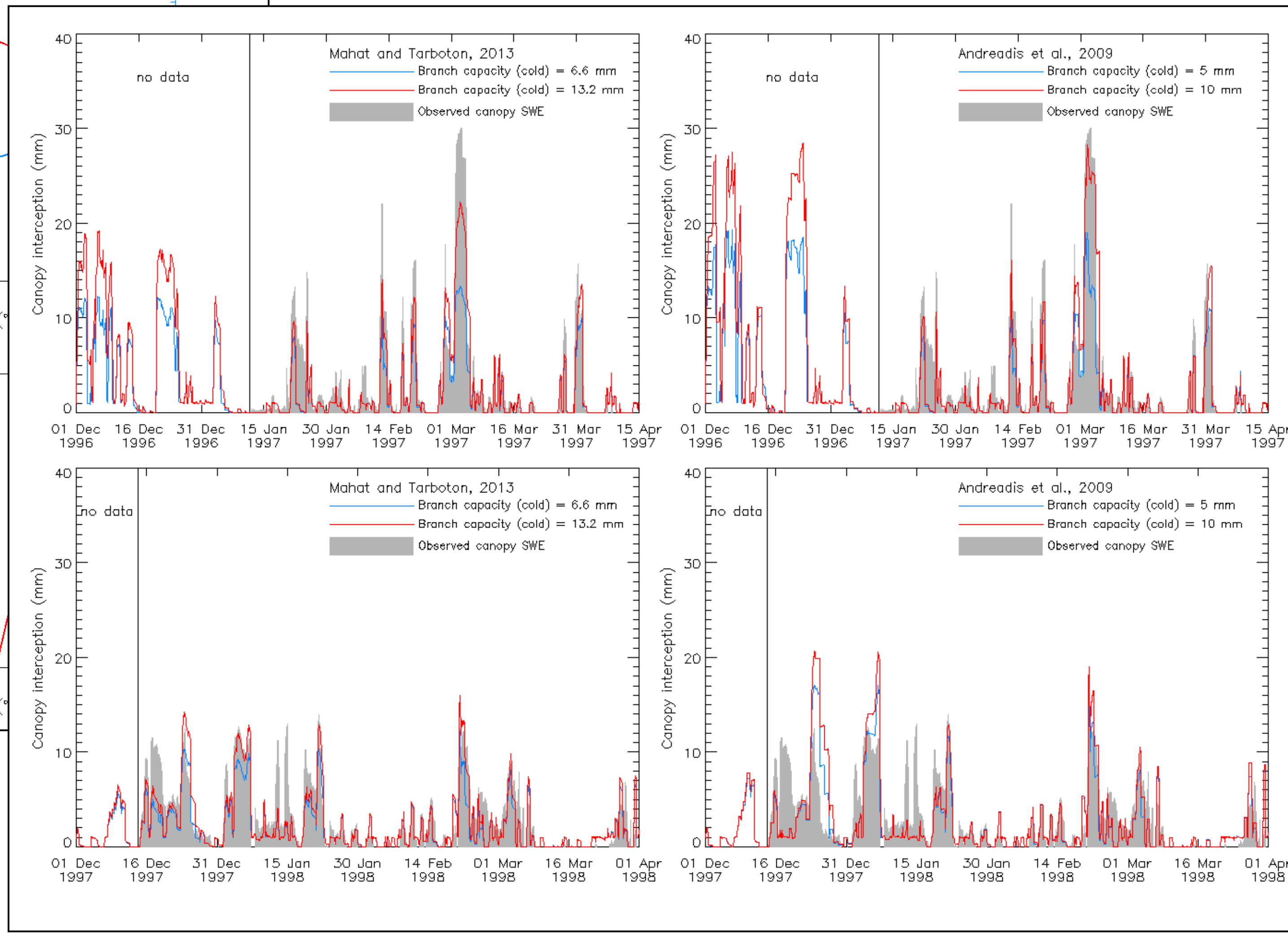
Characterization of uncertainty

Absolutely no idea what is "correct"

Different interception formulations



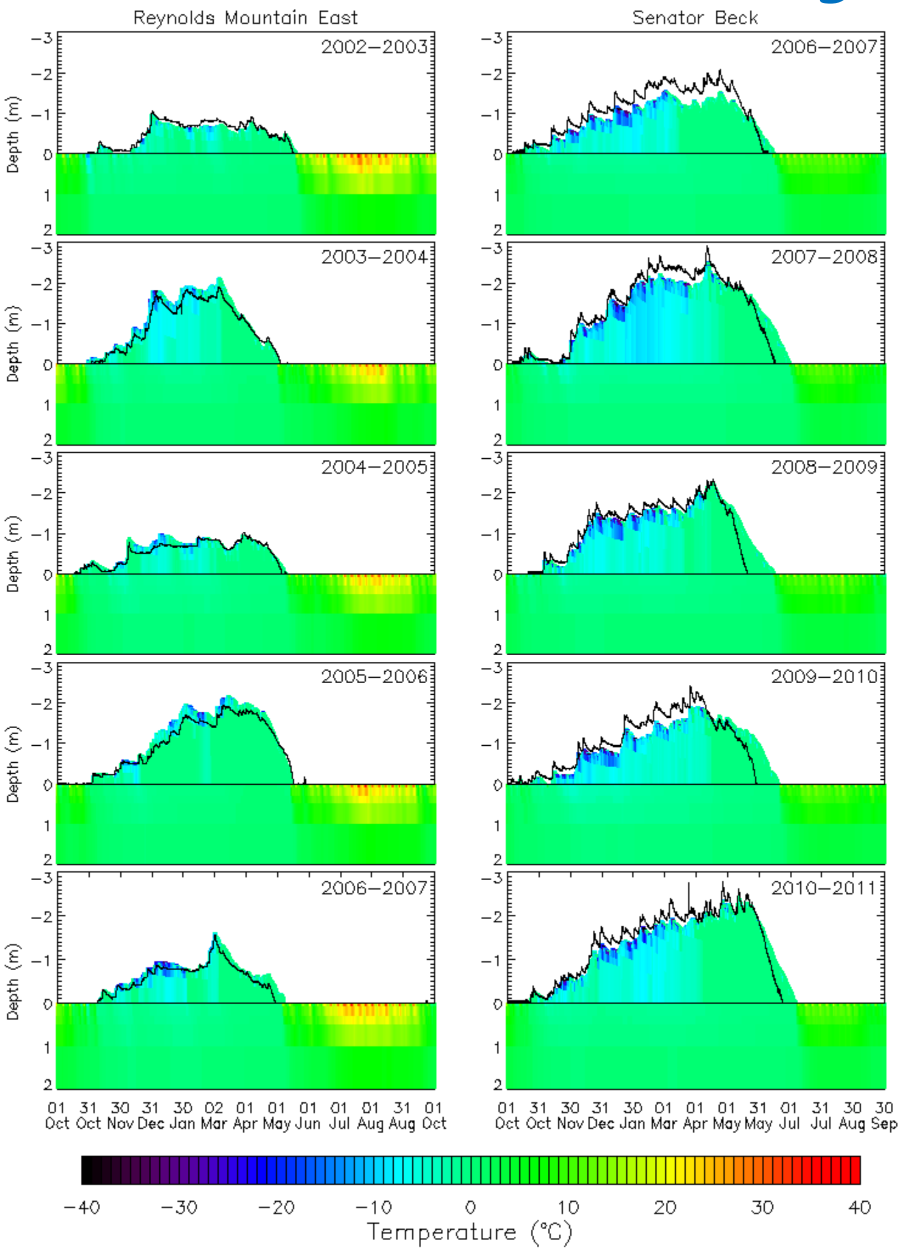
Simulations of canopy interception (Umpqua)

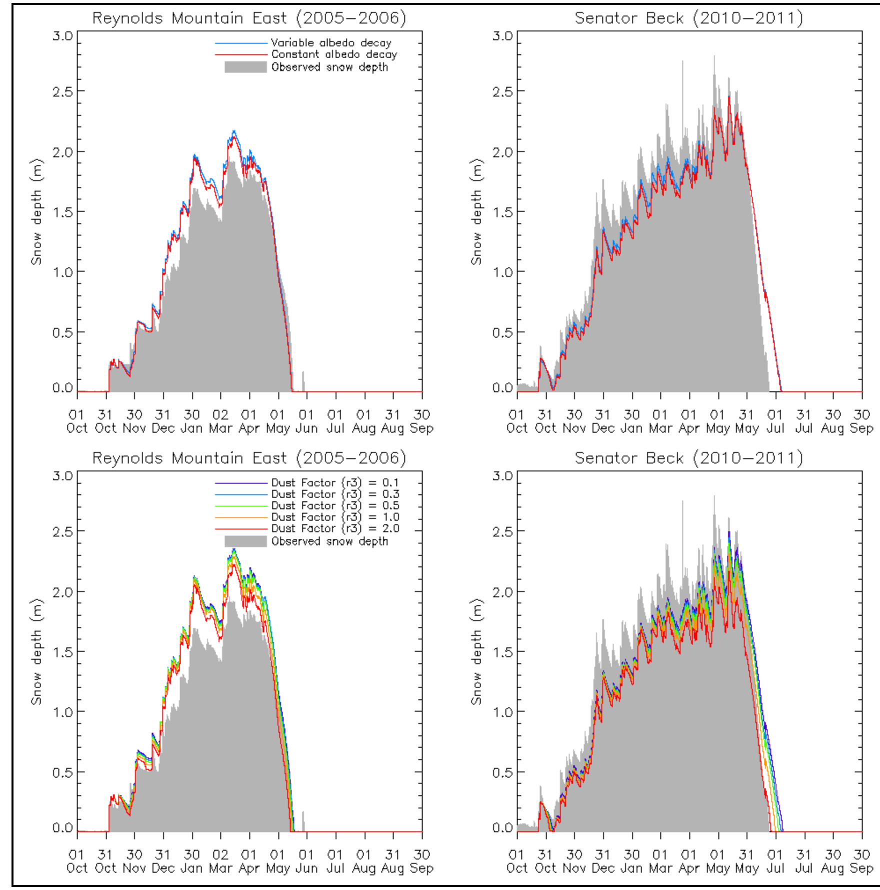


- *Again, model fidelity and characterization of uncertainty can be improved through parameter perturbations*

Characterization of uncertainty

The wrong results for the same reasons





- *Different model parameterizations (top plots) do not account for local site characteristics, that is dust-on-snow in Senator Beck*
- *Model fidelity and characterization of uncertainty can be improved through parameter perturbations (bottom plots)*

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Summary

- Objectives
  - ❑ Better representation of observed processes
  - ❑ More precise representation of model uncertainty
- Approach
  - ❑ Detailed evaluation of different modeling approaches
    - o Recognizes that different models are based on the same set of governing equations
    - o Defines a "master modeling template", to reconstruct existing modeling approaches and derive new modeling methodologies
    - o Provides a controlled approach to model development and evaluation
- Outcomes
  - ❑ Provided guidance for future model development
  - ❑ Improved understanding of the impact of different model development decisions – typology of model structural adequacy
  - ❑ Improved operational applicability of process-based hydrologic models

Component-level model integration can improve hydrologic model simulations

- Improve model fidelity: Identify preferable modeling approaches (defines the “dream model”)
  - *Numerical methods*
    - Prognostic canopy air space
    - Coupled hydrology and thermodynamics
    - Numerical error control and adaptive sub-stepping
    - Separation of governing equations from their numerical solution
    - Flexible hierarchal data structures
  - *Physical representations*
    - Variably saturated flow
    - Below-canopy wind profiles
    - Two-stream radiative transfer models
    - Biophysical representation of transpiration
    - Hydrologic similarity concepts to represent sub-grid variability
    - Explicit representation of lateral flow
- Better characterize model uncertainty
  - *Characterize uncertainty in model parameters*
  - *Represent ambiguity in process parameterizations, where necessary (interception example)*
  - *Include residual uncertainty, to account for situations where all models are wrong for the same reasons (snow albedo example)*