Improving the Parameterization of Cloud and Rain Microphysics in E3SM using a Novel Observationally-Constrained Bayesian Approach

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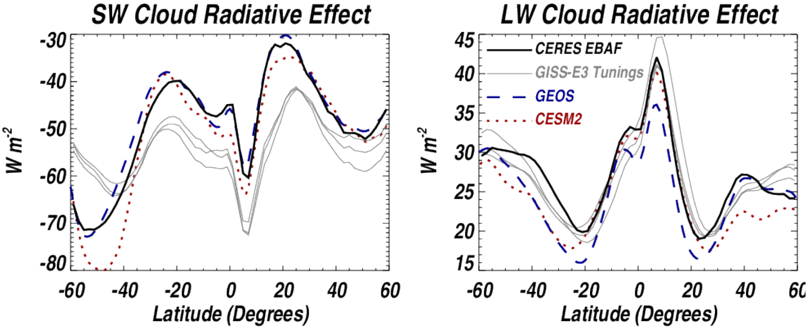
Motivation

There is considerable disagreement among climate models



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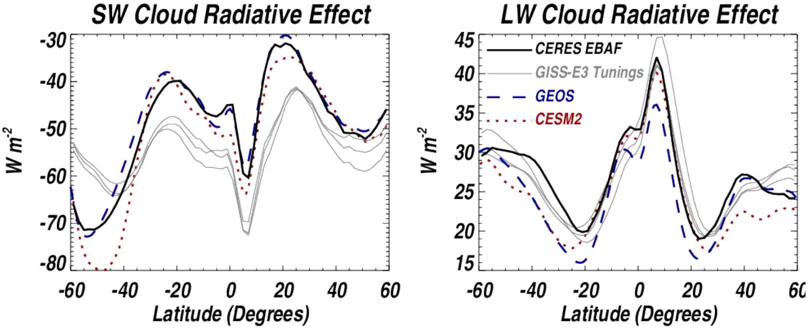

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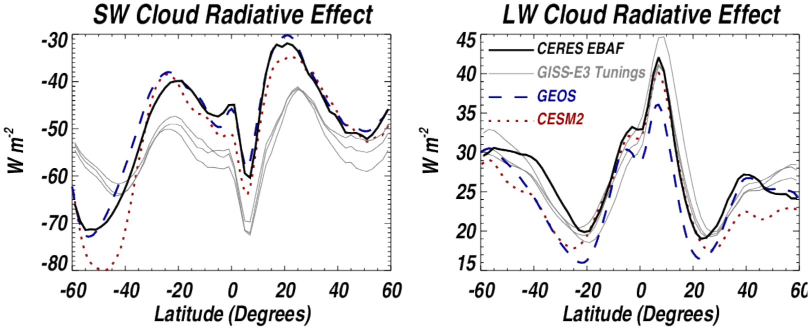

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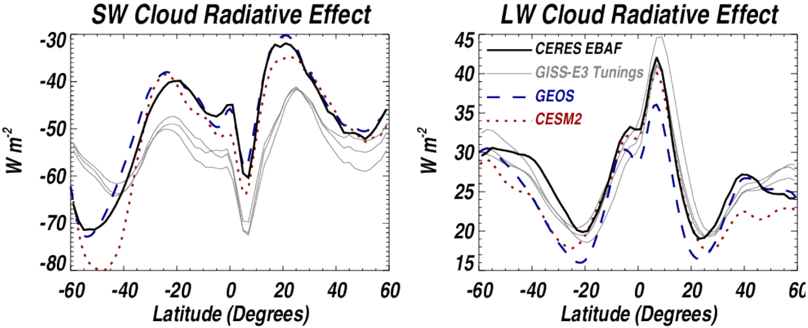

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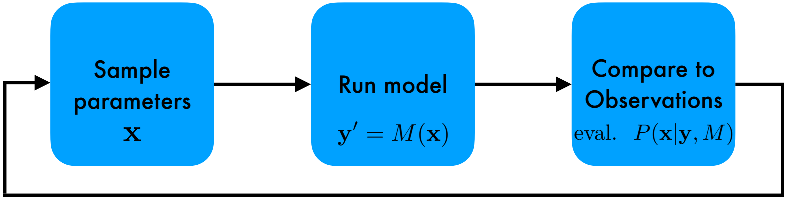

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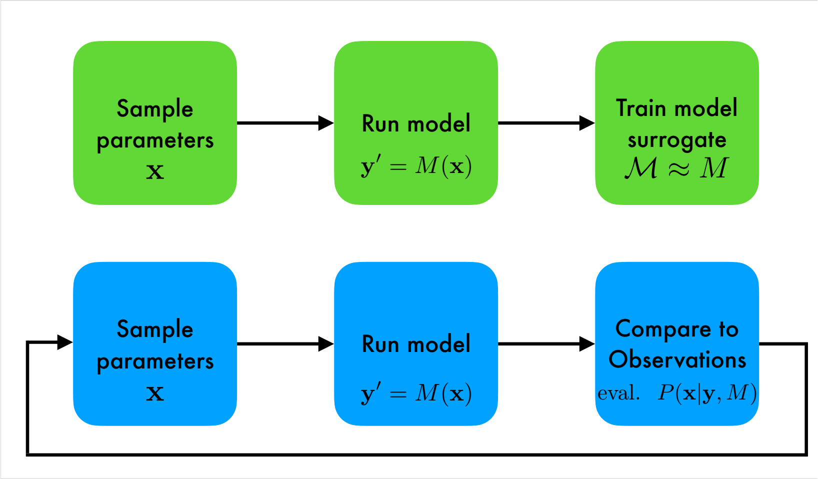

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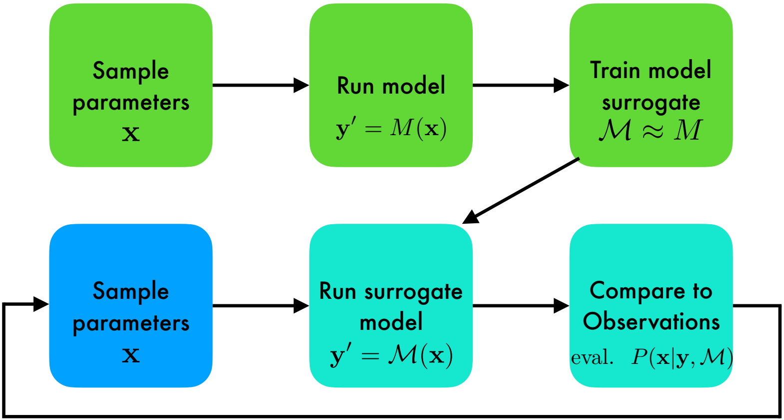

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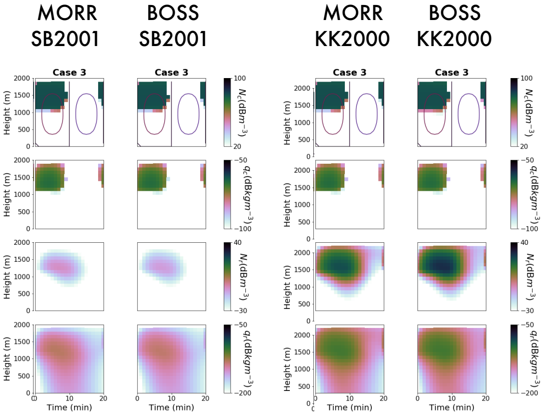
This process typically only considers *parameter* estimation — what about *both* structural uncertainties?

Big picture 3/3: Address structural errors using BOSS

The Bayesian Observationally-constrained Statistical-physical Scheme (BOSS) was developed to provide a structurally flexible warm microphysics parameterization scheme (Morrison et al. JAS 2020, van Lier-Walqui et al. JAS 2020)



Big Picture: E3SM BOSS PPE

Surrogate-accelerated PPE inference

Run a large PPE used to train a *fast* surrogate model, perform inference on the fast model using global satellite observations.

Unify bottom-up and top-down constraints

Probabilistically unify detailed bottom-up process-level insights with emergent global constraints from satellite observations.

Address structural uncertainties in microphysics

Use BOSS to relax structural inflexibilities in (MG2/P3) microphysics, move beyond the limitations of the state-of-the-art schemes (Morrison et al. JAMES 2020)

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Resolving structural uncertainty

Sources of model uncertainty:

- Structural uncertainty: *don't know the equations*
- Initial/boundary condition uncertainty: *don't know the initial state and/or forcing*
- Numerical uncertainty: *don't know how to solve the equations*
- Parametric uncertainty: *don't know the parameter values in the equations*

Using BOSS to address uncertainty

BOSS can systematically explore and quantify *structural uncertainty* via model expansion and parsimony

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Parsimony

the idea that a model should only be as complex as needed to adequately represent the phenomenon being simulated, in the absence of theoretical knowledge (i.e., avoid over-fitting)

Overly complicated schematic