Application of Proper Orthogonal Decomposition Mapping Method in Land Surface Models

A Multiscale Reduced-Order Method for Integrated Earth System Modeling

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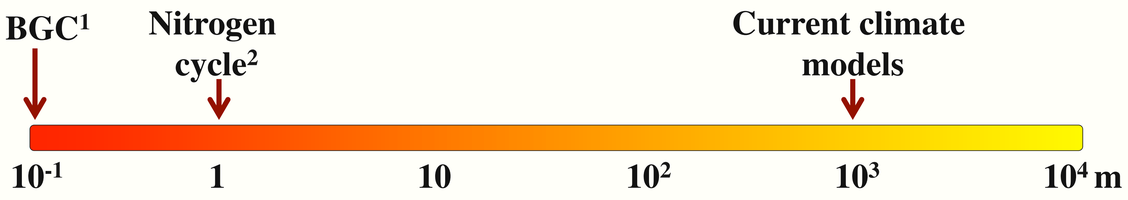
SCIENCE DRIVER

- Accurate description of BGC processes, e.g. methanogenesis, requires preservation of subgrid heterogeneity.
- Global fully coupled process-based models at BGC scales are computationally expensive: **accurate sensitivity & uncertainty analyses will be nearly impossible with these models.**



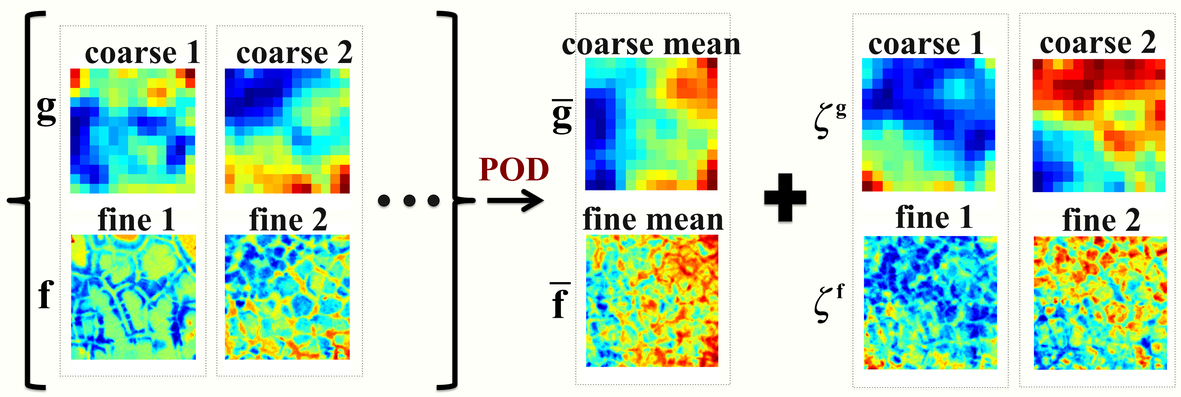
We develop methods that preserve heterogeneous structure of the solutions accurately (negligible error) and efficiently (significantly faster).

[1]Frei et al., J Geophys Res-Biogeo, 117, 2012. [2]McClain et al., Ecosystems, 6, 301-312, 2003.

METHODS

POD-MM: Proper orthogonal decomposition mapping method[3]

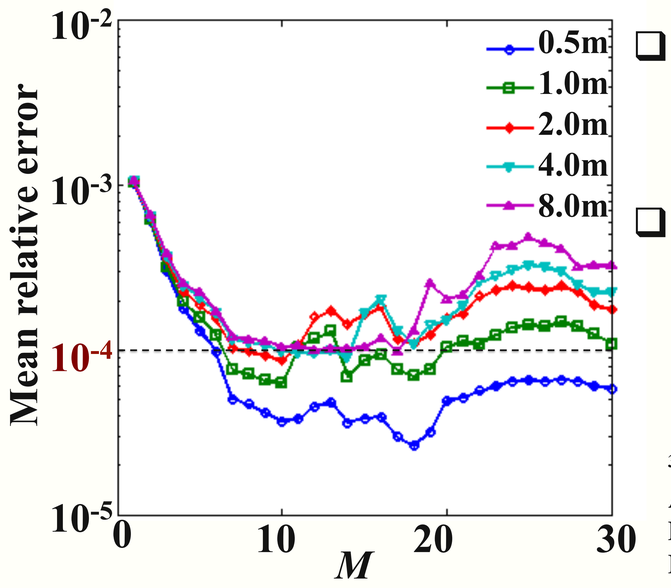
OFFLINE STEP: Statistical/historic/adaptive sampling



Coarse & fine snapshots — Decomposition: POD procedure

ONLINE STEP: Fast, cheap and accurate approximation

- Perform a coarse-scale simulation
- Map onto fine-scale grid by solving a least-square problem to determine best combination of POD bases.



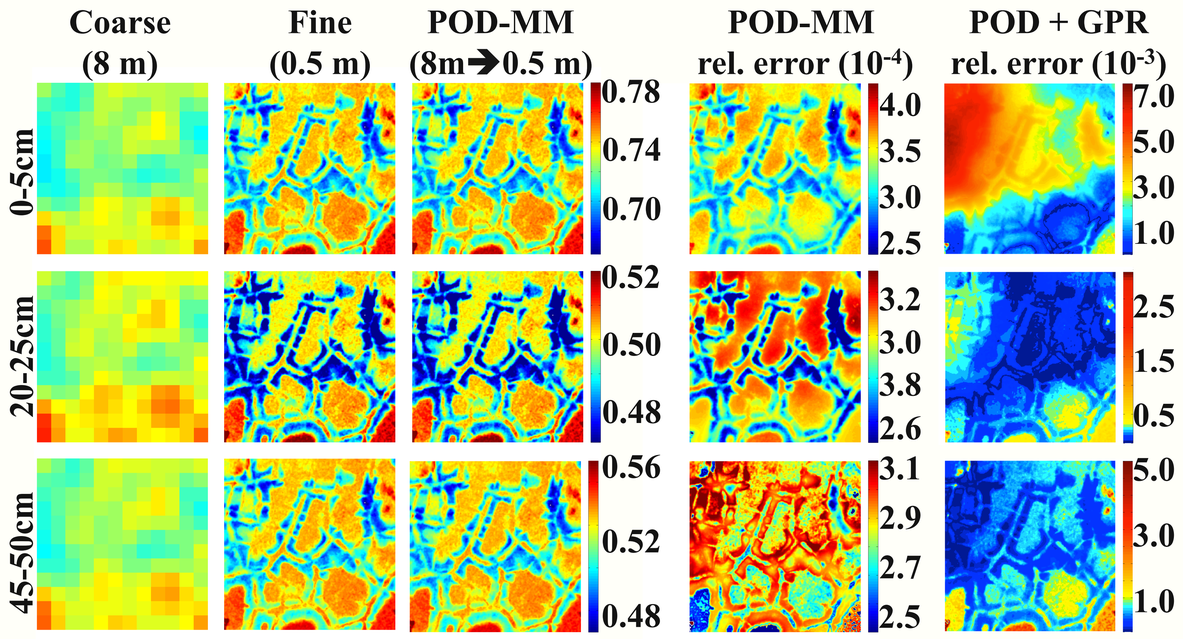
- POD-MM approximation

$$\mathbf{f}^{\text{POD-MM}} = \bar{\mathbf{f}} + \sum_{i=1}^{M} \alpha_i^{\text{POD-MM}} \zeta_i^{\mathbf{f}}$$

- ROM's accuracy increases with *M* and information content (coarse-grid resolution).

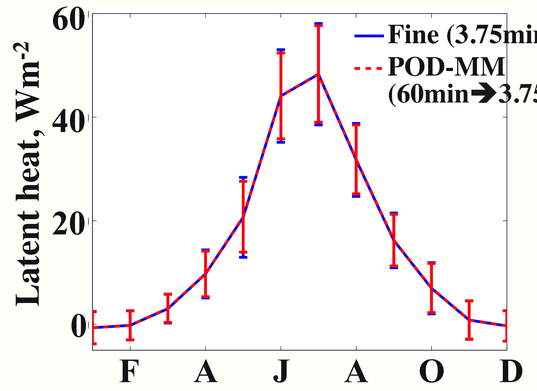
[3]Robinson et al., 47th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Reston, Virginia, 2012.

SUBGRID SCALE SOIL MOISTURE: NGEE-ARCTIC

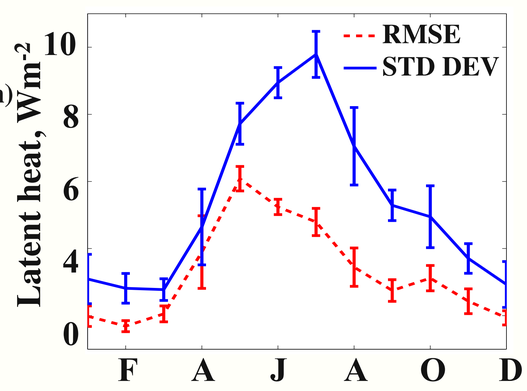


- Preserves fine-grid heterogeneity with relative error of $O(10^{-4})$ and speedup of $O(10^{3})$.
- Order of magnitude better than a more typical emulator (based on POD + Gaussian process regression (GPR)); requires no tweaking of hyperparameters.

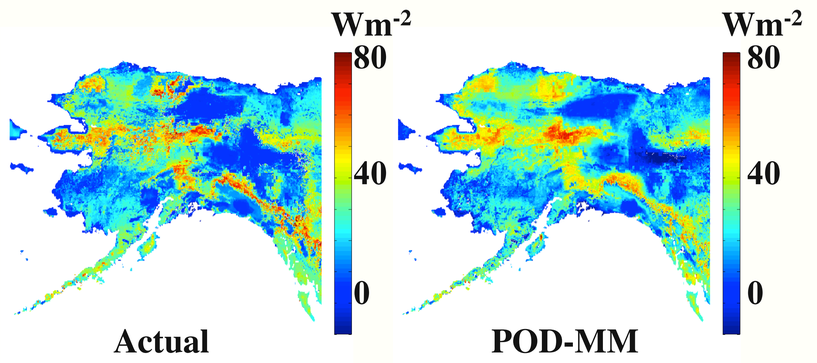
REGIONAL SCALE LATENT HEAT: ALASKA



Negligible difference in monthly climatological mean (mean: 0.05 Wm^{-2}) and mean of std dev (mean: 0.3Wm^{-2}).



RMSE of pointwise difference is smaller than the pointwise std dev: spatial pattern is approximately preserved.



Heterogeneous structure is preserved even on day with the largest RMSE.

SCIENCE IMPACT

POD-MM provides fast and accurate approximation that preserves heterogeneous structure in the solution, allowing climate modeling at the desired subgrid scale.

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