Improving the Process for Earth System Model Development via Hierarchical System Development (HSD)

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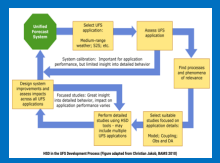
Changing paradigm for Earth system model development

"Toss it over the fence" ?!

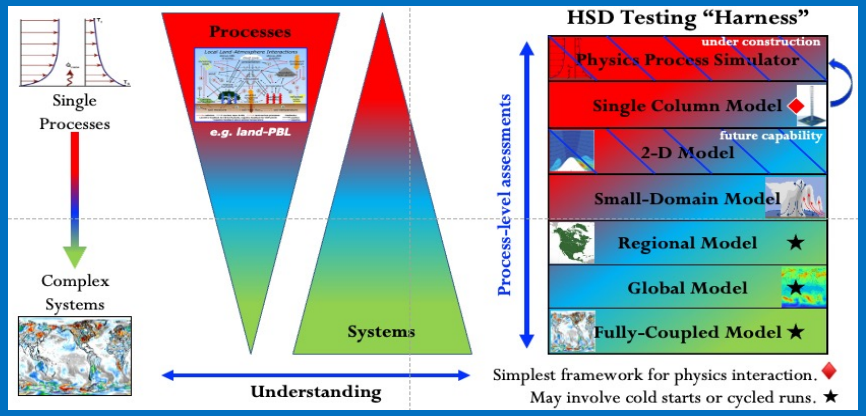
HSD: Background

- WCRP workshop in 2016: Climate community uses hierarchical approach to test Earth system components first for better process understanding and proper use of compute resources, before fully-coupled ESM runs with long simulations.
- Tim Palmer (Univ. Oxford, UK MetOffice, ECMWF): "*Hierarchical thinking should be second nature for weather and climate scientists (of course).*"
- Julia Slingo's (UK MetOffice) 2017 WCRP review: focus on process-level model improvements, connect weather&climate.
- Christian Jakob (Monash Univ., Australia; AMS BAMS 2010): *"To address long-standing systematic errors, community needs to improve the diagnosis of key processes contributing to these errors, and more model developers are needed."*


Adapted Jakob (2010)

2016 Workshop

Hierarchical System Development (HSD): What is it?

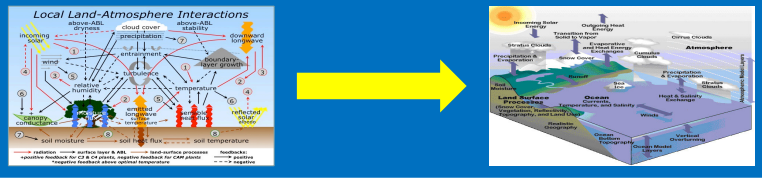


- Systematic approach: test small elements (i.e. physics schemes) in an Earth System Model (ESM) first in isolation, then progressively connect ESM elements with increased coupling between all ESM components (atmos., land, ocean, etc).
- HSD yields better understanding of *Processes* and *Systems*.
- *System* in HSD means end-to-end: includes data ingest and quality control, data assimilation, modeling, post-processing, and verification.
- An efficient infrastructure: necessary to connect HSD steps for an effective model improvement process (see CCPP to the right).
- Leverage GEWEX, GASS, GABLS/DICE and GLASS projects and activities for HSD.

www.ufscommunity.org/articles/hierarchical-system-development-for-the-ufs

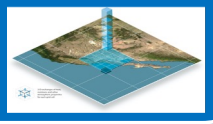
HSD: Why do we need it?

- To better understand model biases, need the ability to simplify the atmosphere and other ESM components down to key processes and interactions.
- Efficient use of compute resources: identify/fix biases early in testing process.
- Many Earth System processes to consider, from Local to Regional & Global.



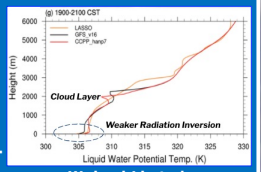
Common Community Physics Package (CCPP): HSD enabler

- CCPP software development led by the Developmental Testbed Center (DTC).
- CCPP Physics: Collection of community-contributed physical parameterizations (PBL, cumulus, etc) to support various high-res, med.-range & seasonal models.
- CCPP Infrastructure connects physics to models, runtime selection of schemes & suites, frequency of physics calls, etc.
- CCPP Single Column Model: physics processes and their interplay can be studied in a simplified setting.



HSD Example

- DTC project: *Physics Testing and Evaluation for the Unified Forecast System Weather & Medium-Range-to-S2S Applications* (NCEP GFS/global).
- Evaluated GFSv17/GEFSv13, identified biased partitioning between liquid and ice → biased radiation at surface (biased cloud liquid & ice water path).
- Used HSD approach: CCPP SCM simulation vs LASSO LES model output, compared with GFS.
- Pinpointed key processes for weak radiation inversion: (1) stronger entrainment/capping inversion → excessive clouds; (2) windy lower levels, stronger entrainment, not warm enough surface → weak nocturnal radiation inversion.



Weiwei Li et al,
DTC UFS-R2O project