

Improving Earth System Models via Hierarchical System Development

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Hierarchical System Development (HSD) is an efficient way to effectively integrate the model development process, with the ability to test small elements (e.g., physics schemes) in an Earth System Model (ESM) first in isolation, then progressively connecting elements with increased coupling between ESM components, so essentially a systems engineering approach. *System* in HSD is end-to-end: it includes data ingest/quality control, data assimilation, modeling, post-processing, and verification. HSD includes individual physics simulators, Single Column Models (SCMs; including “on/off switches” for individual physics elements), small-domain and regional models, all the way to complex fully-coupled global ESMs with atmosphere/chemistry/aerosol, ocean/wave/sea-ice, land-hydrology/snow/land-ice, and biogeochemical cycle/ecosystem components. Datasets used for the different HSD steps are obtained from observational networks and field programs, ESM output, or idealized conditions (e.g., used to “stress-test” ESM elements and components). Advancing from one HSD step to the next requires appropriate verification metrics of ESM performance, many at the process level. This process is concurrent and iterative such that more complex HSD steps can provide information to be used at simpler HSD steps and vice versa. The HSD approach can also help understand spatial and temporal dependencies in model solutions, where consistency across HSD steps is required for different models and resolutions. The Common Community Physics Package (CCPP) is designed to lower the bar for community involvement in physics testing and development through increased interoperability, improved documentation, and continuous support to developers and users. CCPP and its companion CCPP SCM, developed and supported by the Developmental Testbed Center (DTC), provide an enabling software infrastructure to connect HSD steps. The HSD approach and use of CCPP will be illustrated and discussed through Testing and Evaluation (T&E) examples, and is applicable to MPAS T&E.