Establishing Community Requirements of Hierarchical System Development for Earth System Models

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CESM Workshop: June 14, 2023

Developmental Testbed Center

What is Hierarchical System Development (HSD)?

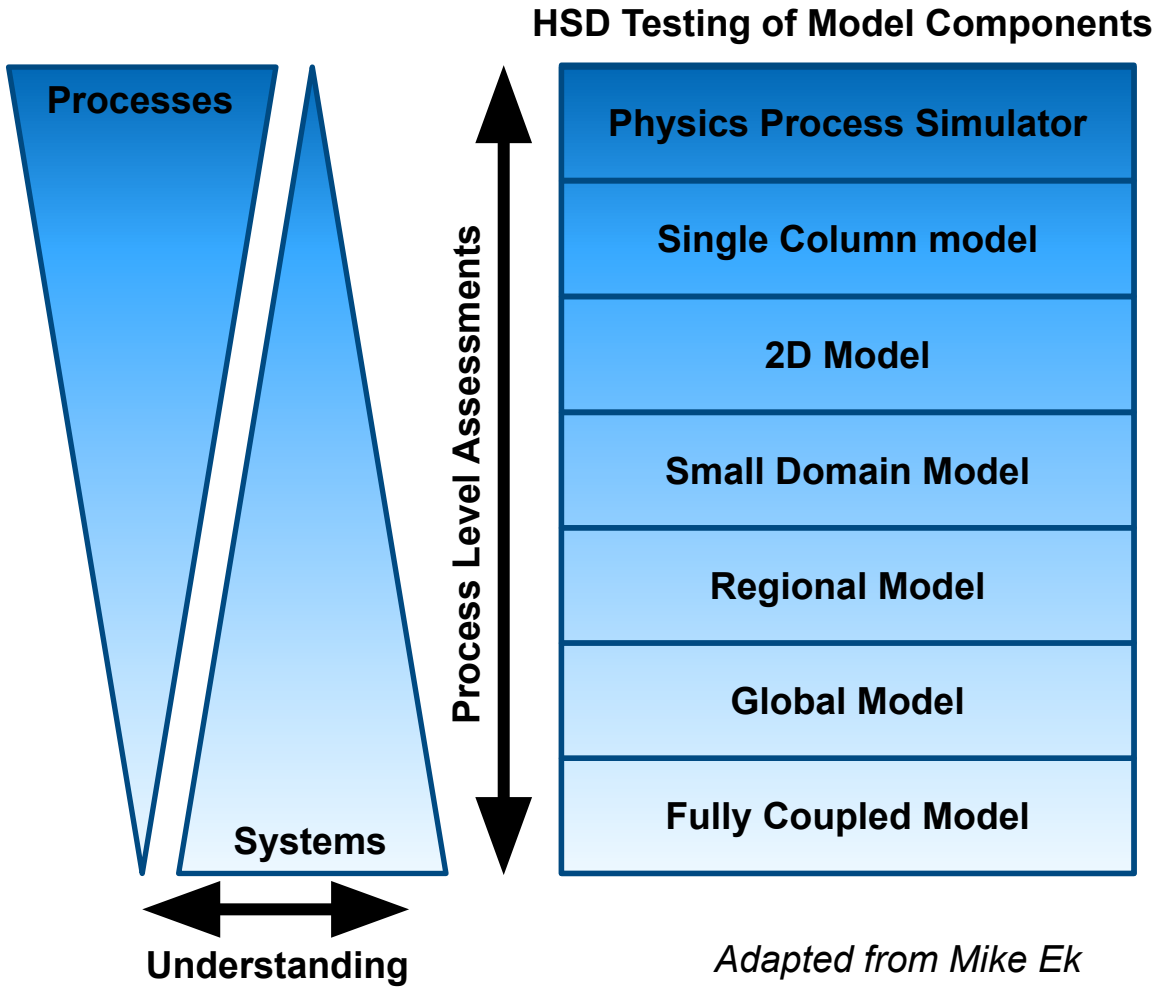
Hierarchical System Development (HSD) is an efficient pathway for model development, enabling the community with multiple entry points for research efforts spanning simple to complex models**.**

Many **unique perspectives** of HSD, defined by

- Model complexity, Model configurations (Jeevanjee et al. 2017), or Principles of large-scale circulation (Maher et al. 2019).

Serves as an **end-to-end system**

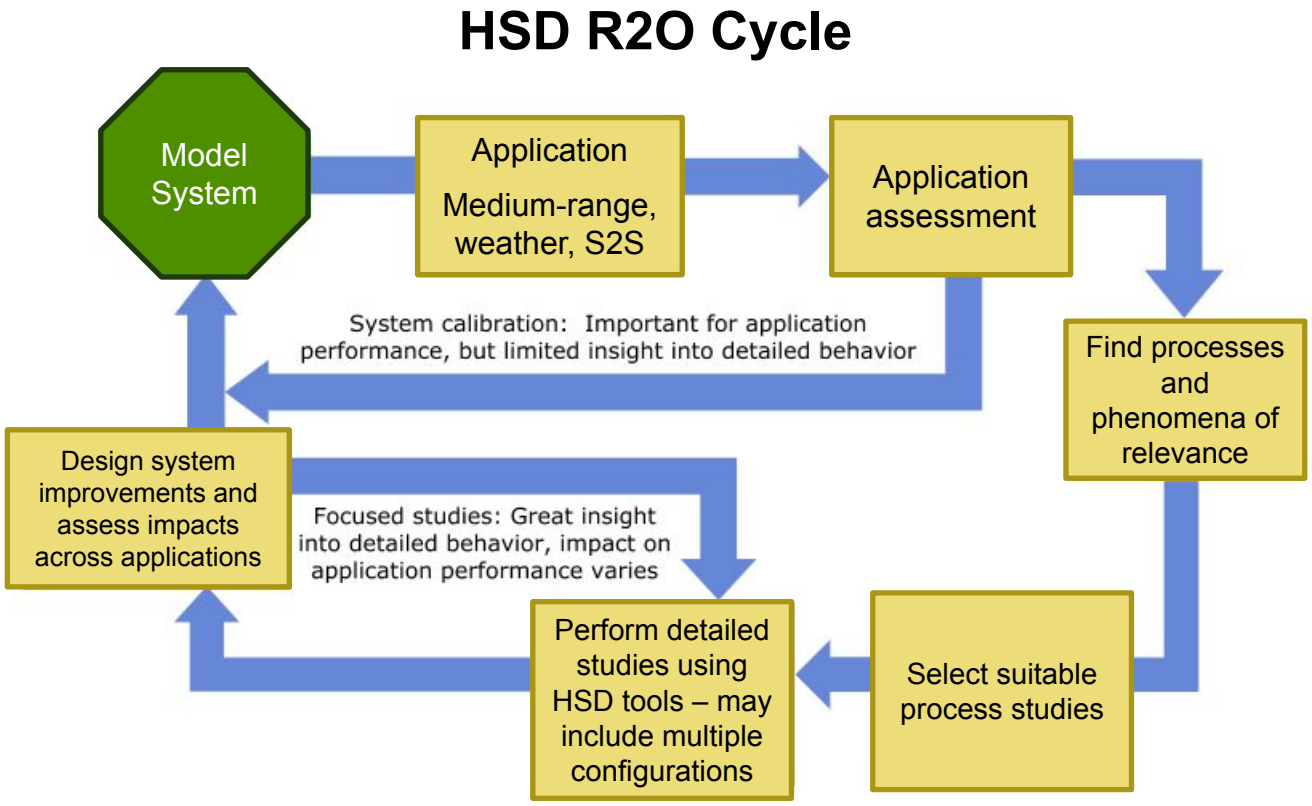
- Provides a configurable workflow ideally to handle pre-processing, running the model, post-processing, and infrastructure for software testing.



Adapted from Mike Ek

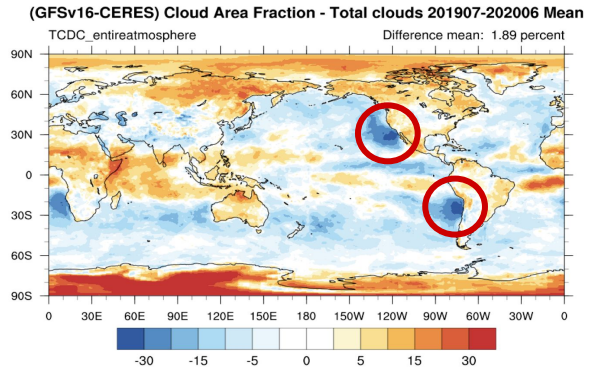
Why do we need HSD?

- The **systematic representation of model hierarchies** connects our understanding from idealized models to the comprehensive models.
- Provides the research community with simpler versions of a more complex system, that are easier to understand and work with.
- Enables R2O by providing testing pathways for innovations and updates from the research community.
- Efficient use of compute resources.



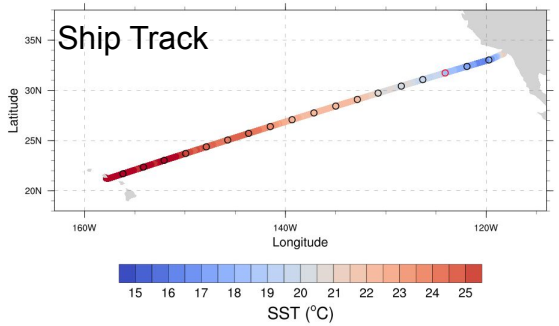
Adapted from Christian Jakob: BAMS 2010

Example: Physics Testing and Evaluation for UFS models



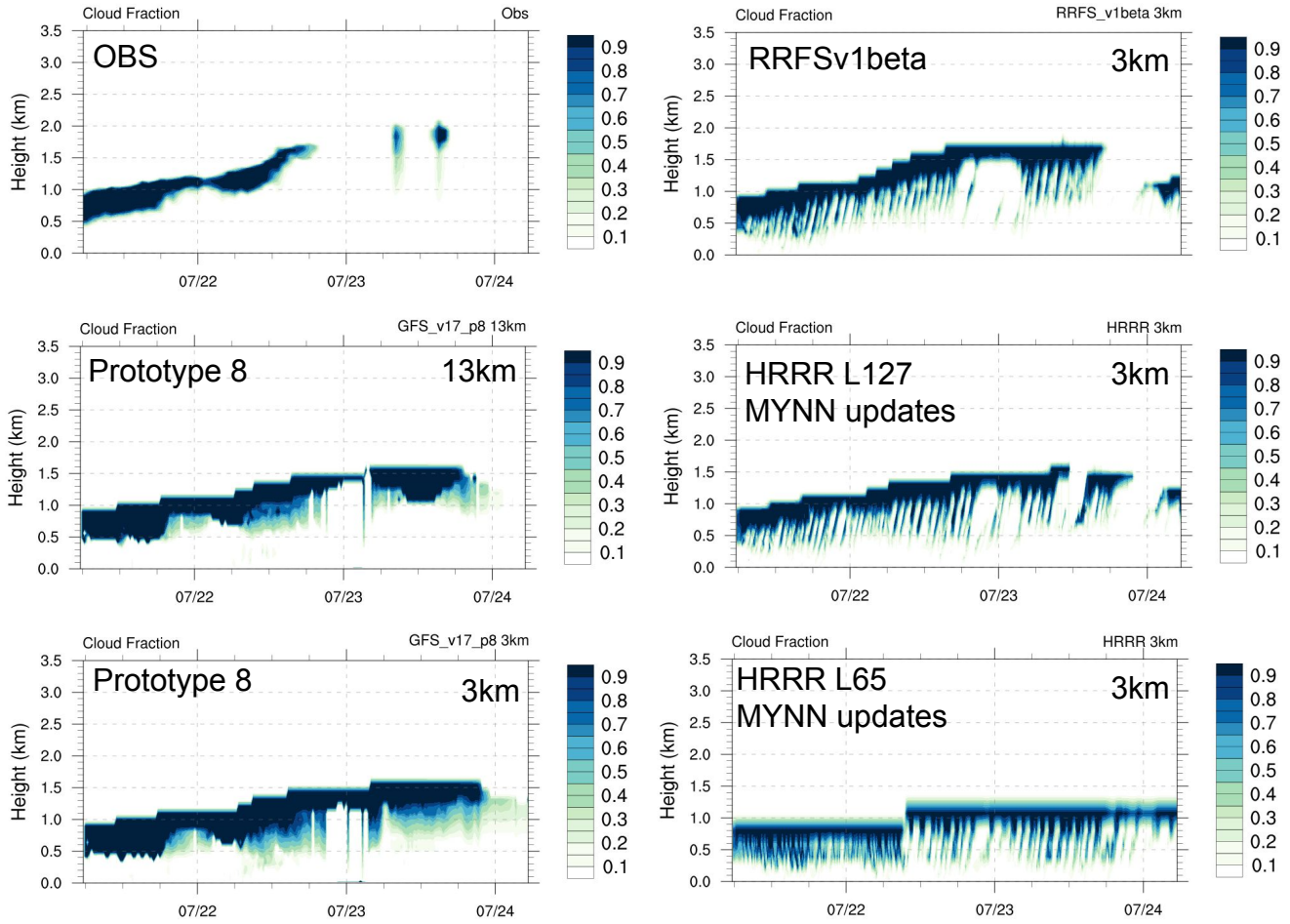
Global model GFSv16 retrospective assessment reveals negative bias in marine stratocumulus off the west coast of continents.

Case Study: MAGIC
(Marine ARM GPCI Investigation of Clouds)



Ship traversing LA to HI to observe and characterize the properties of clouds and precip.

CCPP SCM v6+ Simulations of Total Cloud Fraction



Using the ARM MAGIC case to evaluate model performance of physics suites, innovations, and updates, and horizontal and vertical grid spacing with respect to representation of the Sc regime and transition to shallow Cu.

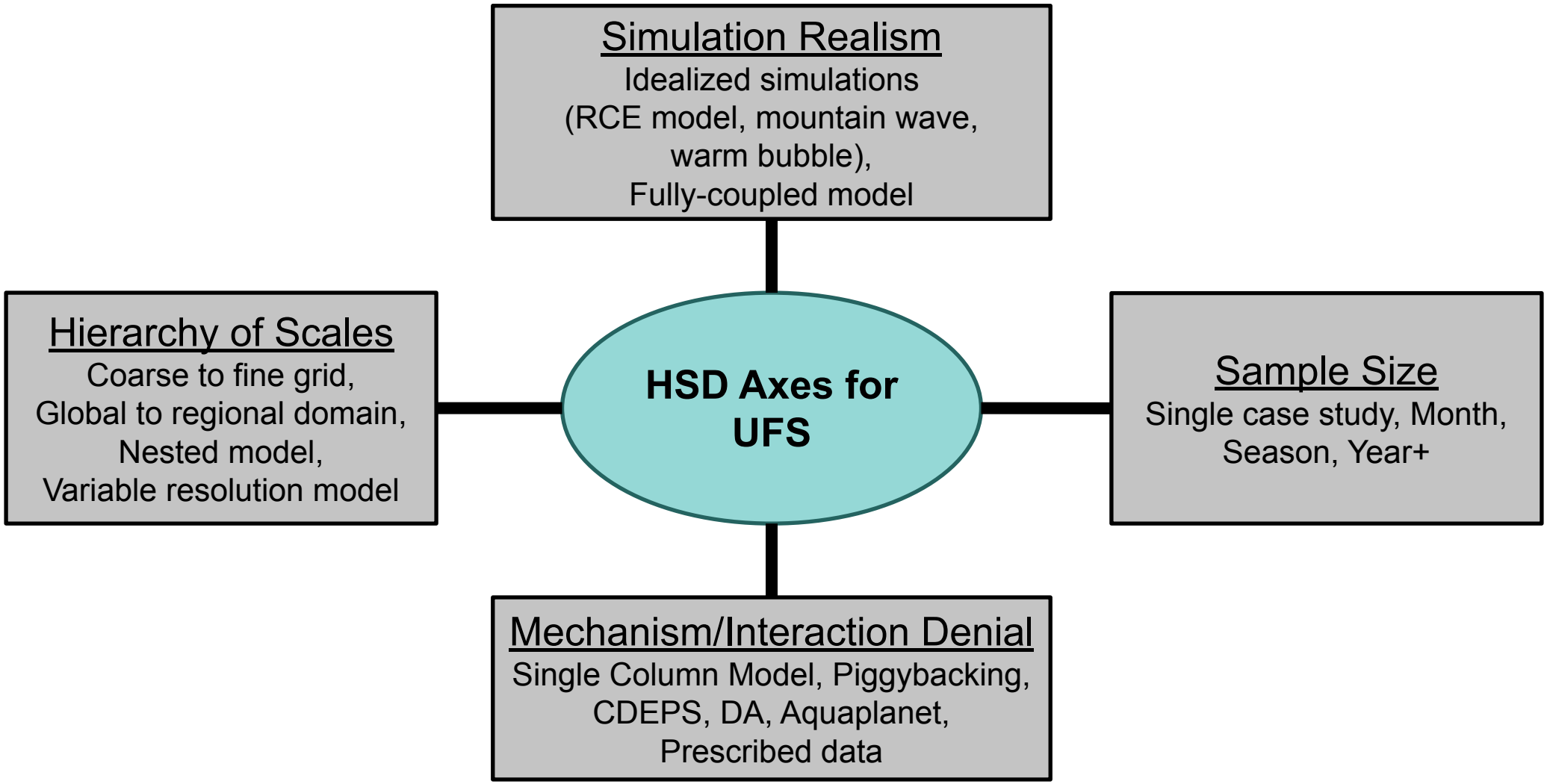
Supporting EPIC in Development of HSD Capabilities

- The DTC is charged with creating a white paper, documenting the ***long-term vision for UFS HSD and the plan for its progressive implementation.***
  - Collaborating closely with EPIC to establish community requirements for HSD.
  - Soliciting input from the community via a broadly distributed survey.
- Providing the building blocks and vision for the HSD framework for EPIC to stand up and support the UFS community.
- Integrate HSD capabilities together in a holistic way to support and accelerate R2O processes.
  - Identify additional developmental capabilities for HSD.
- Supplying UFS case studies that represent known biases in the Global Forecast System (GFS).
  - Includes data and code for researchers to configure and run the UFS.

DTC: Developmental Testbed Center
EPIC: Earth Prediction Innovation Center

Proposed HSD Axes for UFS

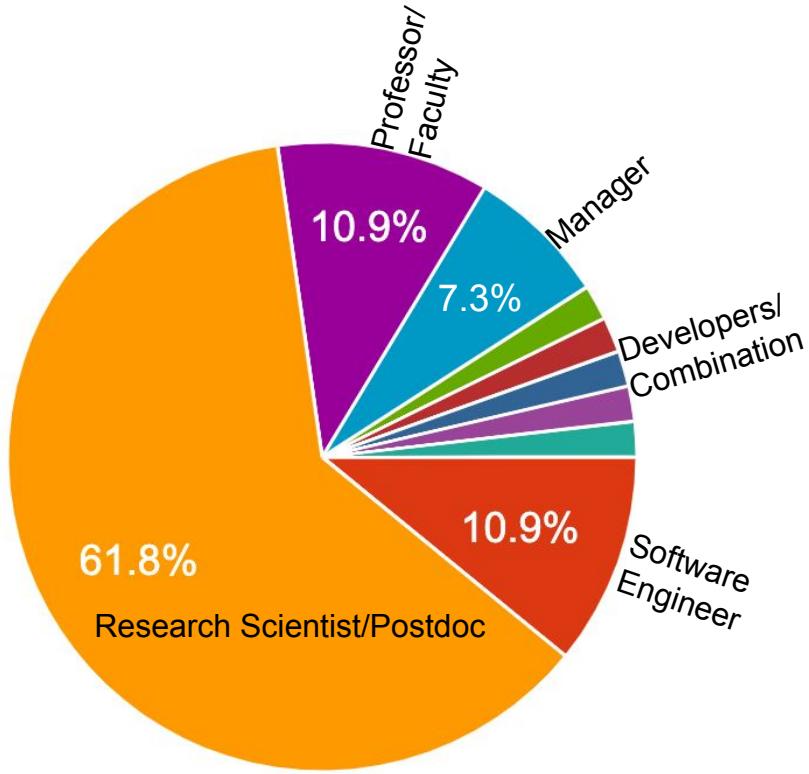
"The term hierarchy is a misnomer, and it becomes clear that if a strict, hierarchical ordering is sought, it must exist along multiple axes simultaneously." – Jeevanjee et al. 2017



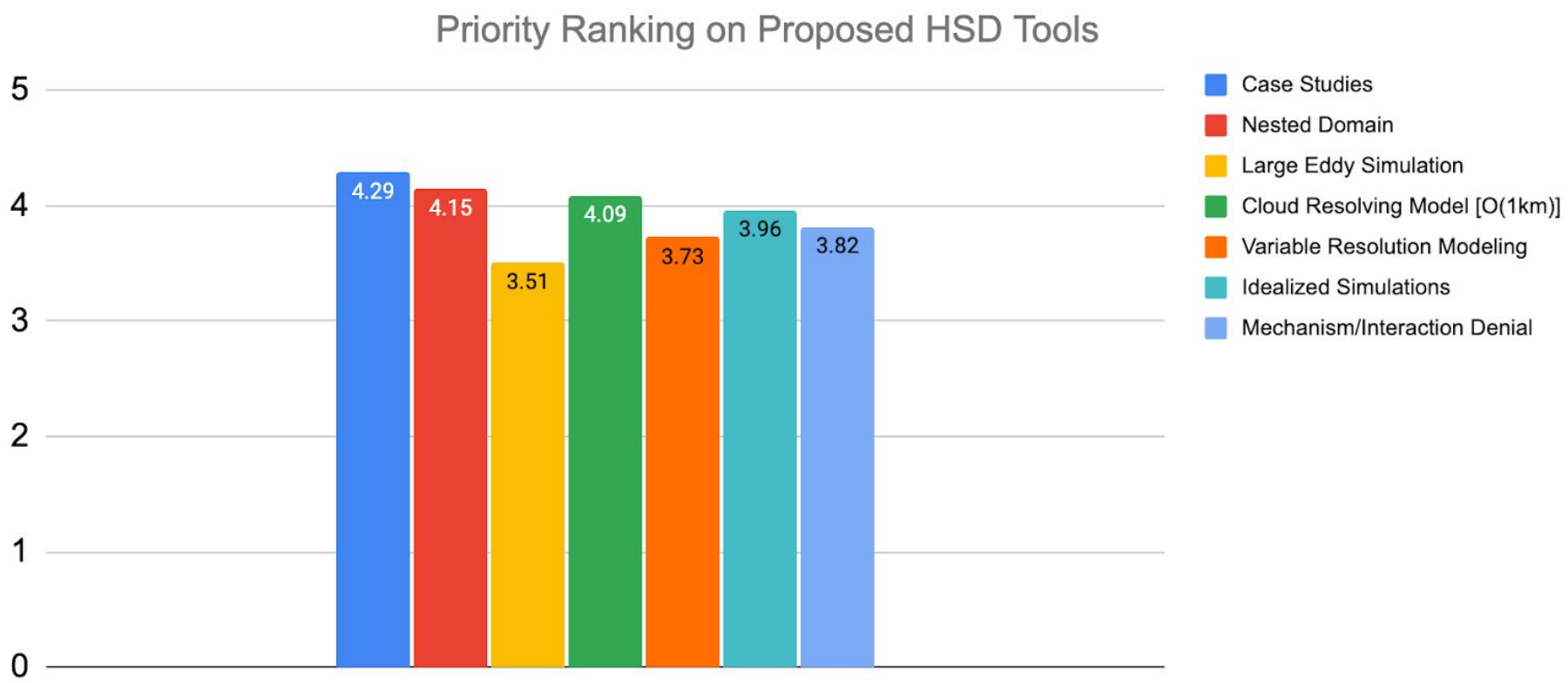
Community Engagement Survey

Purpose: To ***gather insights and feedback*** from the broader community to help ***shape the future direction of HSD***. The results will be incorporated into a white paper, which will define the current state, future needs, and recommendations for HSD.

- 55 participants from a broad spectrum of disciplines and organizations.
- 41.8% use HSD in some aspect of their work, 3.6% were unsure, and 54.5% do not use HSD capabilities.
- Questions pertained to the necessity to develop HSD capabilities such as nesting/idealized/LES/CRM/etc.
- Queried the community on perceived gaps in HSD.



HSD Capability/Tools Rankings



- Weighted average from a ranking of 1 (not important) to 5 (extremely important)

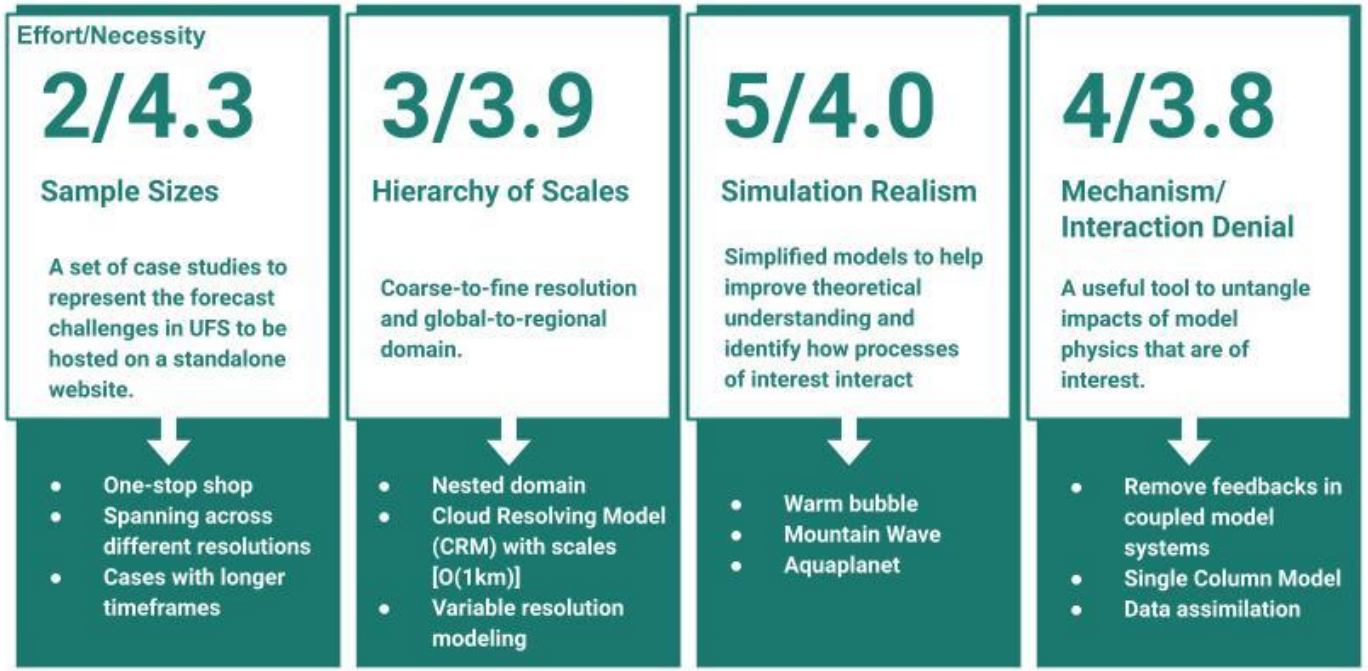
Survey Themes

Emerging themes

- Importance of HSD to span across all model components.
- Capability to initialize a model with a large variety of datasets.
- Improved data management with easy access to reliable and consistent data.
- Need for highly configurable and well-documented testing workflows, such as for idealized cases.
- ”One-stop-shop” to test relevant case studies using different UFS capabilities, tools, and software, which are readily available and easy to install.
- Establishing methodologies and criteria across levels of testing.

HSD Recommendations

- **Sample size**: A suite of case studies that represent model shortcomings, hosted on a community website.
- **Hierarchy of Scales**: Capability of traditional nesting or variable resolution modeling available to the community.



- **Simulation Realism**: Develop a highly configurable and well-documented framework for running idealized simulations.
- **Mechanism/Interaction Denial**: Continued enhancement of existing capabilities and inclusion of new configurations and capabilities.

HSD Recommendations (Continued)

Other Aspects

- A common testing infrastructure, including software testing on top of scientific advancement, for all model components and applications.
- Expand initial conditions/boundary condition datasets supported by the modeling system.
- Improved data management and accessibility to allow for consistent and reliable data for scientific testing and model comparison.
- Develop a hierarchical workflow that adequately supports HSD allowing multiple configurations.

Summary

- **Hierarchical System Development** is an efficient pathway for model development, providing the community with multiple entry points catered to their specific research needs and interests.
- It **connects our understanding** from simple-to-complex models, by providing researchers with tools enabling better understanding of the model processes.
- **Enables R2O** by providing testing frameworks for innovations and updates from the research community.
- A community-wide survey provided valuable feedback regarding current state and future needs in HSD for UFS.
- Recommendations are being assembled based off current expertise, survey responses, and feasibility.