Expanding Community UFS Land Model Development Through Advancing Land Component and Land Data Assimilation Capabilities

UIFCW Workshop, July 21, 2022

NOAA National Weather Service

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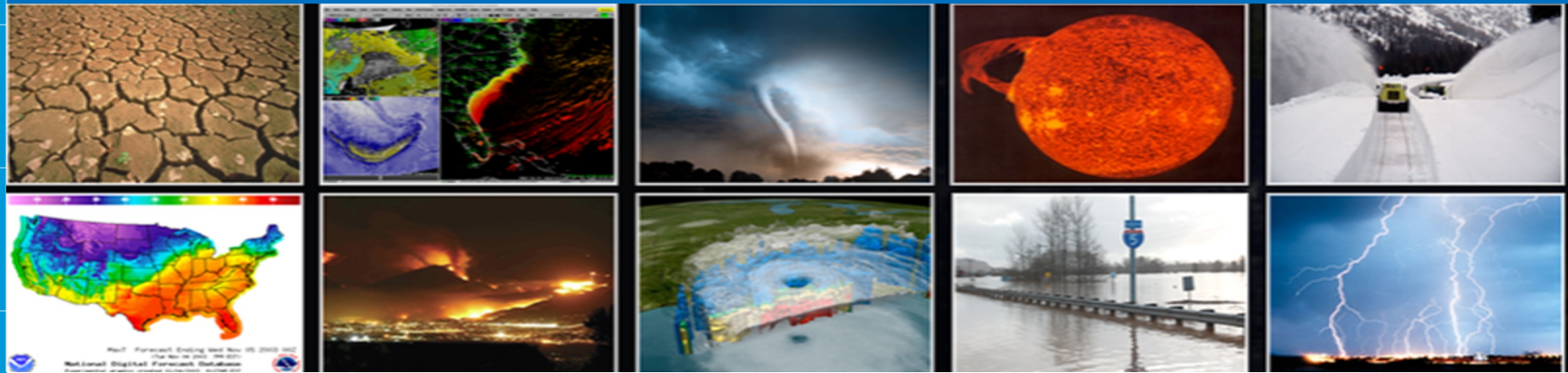
UFS Land Working Group Co-lead

Acknowledgements: EMC Land Team; UFS Land WG



Unified Forecast System

- The Unified Forecast System (UFS) is a community-based, coupled, comprehensive Earth modeling system. It is designed to support the NOAA Weather Enterprise and to be the source system for NOAA's operational numerical weather prediction applications.
- The UFS is organized around applications. Each application has a forecast target. The UFS numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal.
- Application Teams (subset)

  Short-Range Weather (SRW): Atmospheric **(and land)** behavior from less than an hour to several days

  Medium-Range Weather (MRW): Atmospheric **(and land)** behavior out to about two weeks

  Subseasonal-to-Seasonal (S2S): Atmospheric and ocean **(and land)** behavior from about two weeks to about one year
- Working Groups: Chemistry, DA, Dynamics, Ensembles, Marine, Physics, Post-Proc, **LAND**

Inaugural UFS Land Advisory Panel

- Brent Lofgren (NOAA/GLERL)
- Trey Flowers (NOAA/NWC)
- Clara Draper (NOAA/PSL/CIRES)
- Andy Fox (JCSDA)
- Sujay Kumar (NASA/HSL)
- Paul Dirmeyer (GMU)
- Joe Santanello (NASA/HSL)
- Elena Shevliakova (NOAA/GFDL)
- David Lawrence (NCAR/CGD)
- Tanya Smirnova (NOAA/GSL/CIRES)
- Guo-Yue Niu (U. Arizona)
- Fei Chen (NCAR/RAL)
- Zong-Liang Yang (UT-Austin)
- Xiwu Zhan (NOAA/NESDIS)
- Maoyi Huang (NWS/OSTI)
- Michael Ek (NCAR/DTC) – Co-Lead
- Michael Barlage (NOAA/EMC) – Co-Lead

} Hydrology

} Land Data Assimilation

} Land-Atmo Interactions

} Climate Development

} NWP Development

} Land Satellite Data

Working Group open to all interested:
michael.barlage@noaa.gov

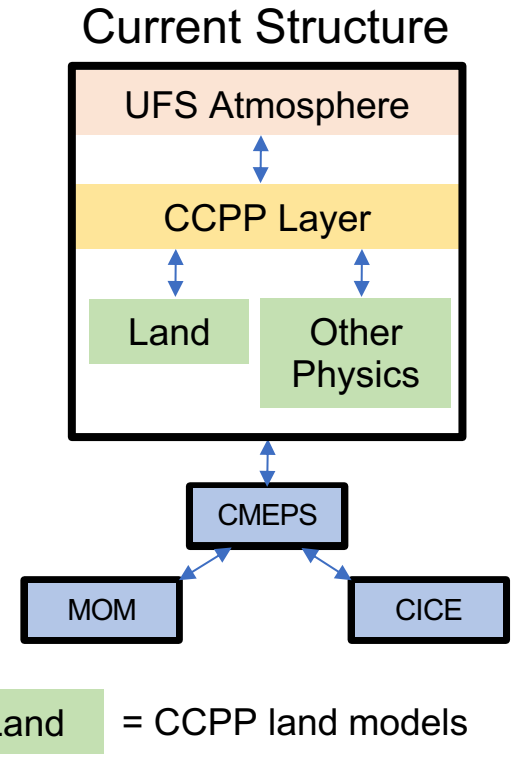
UFS Land Working Group and Workshop

- Currently WG meetings organized around centers of interest - quarterly
  - community open meetings where we discuss status of UFS Land Component(s) and issues relevant to the land model in general (EPIC, Infrastructure, Interactions (apps/physics), Coastal); invited speakers to enhance community usage of UFS (e.g., App Teams)
  - community-focused meeting designed to communicate modeling needs/performance and new advances from the community (lightning-style talks)
  - land "steering committee" meetings (long-term planning)

- UFS Land Workshop (May 25-26, 2021)
  - developing design requirements for UFS land models
  - identifying priorities of land model development and metrics
  - better representations of key processes for capturing UFS land-atmosphere-ocean interactions
  - next 2 to 5 years timeframe

Workshop Report

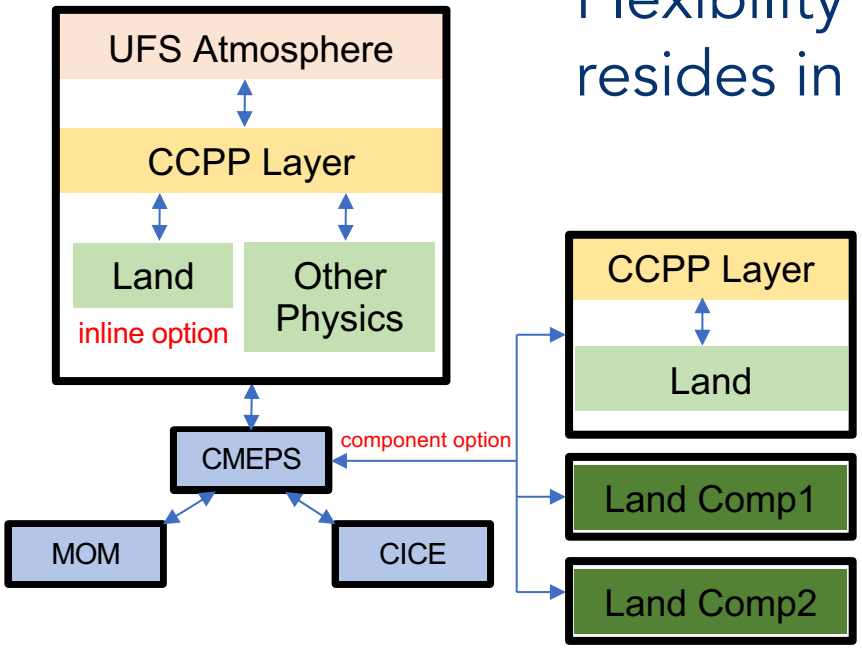
UFS Land – Current Infrastructure



- Current land models (Noah, Noah-MP, RUC) reside inside the atmospheric model (tightly coupled)
- These models are essentially modules/subroutines within the CCPP (Common Community Physics Package) repository
- Currently, CCPP modules are assumed to be 1D column models – no horizontal communication
- History and restarts are controlled by the atmosphere

UFS Land – Future Infrastructure

Possible Future Structure



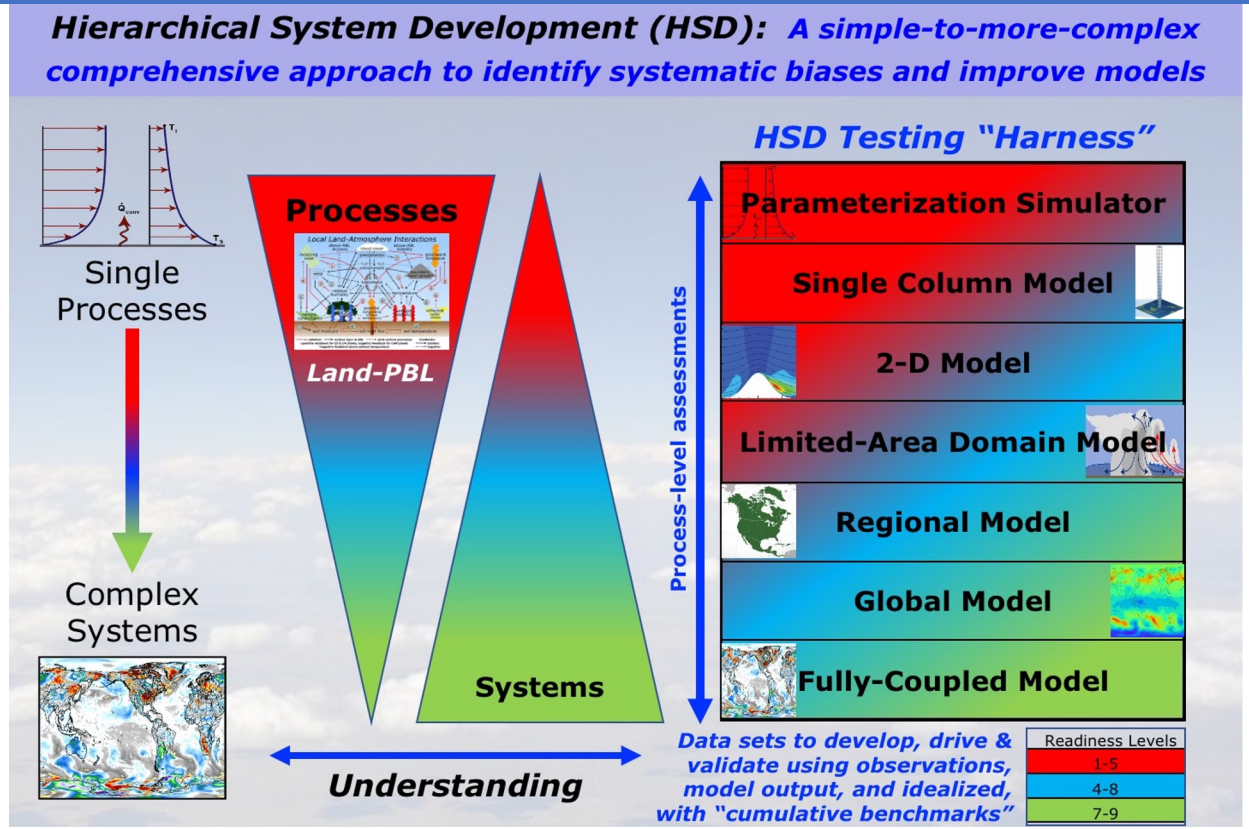
Flexibility on where the land model resides in the system

- inline with the atmosphere
  - advantage: faster physics/coupling
- as a separate component
  - advantage: land model testing within a well-designed framework (i.e., with a data atmosphere)
  - advantage: evaluating fluxes across interface

Land = CCPP land models

Land = component land models, including lakes, routing, etc.

Hierarchical Testing/Evaluation Framework

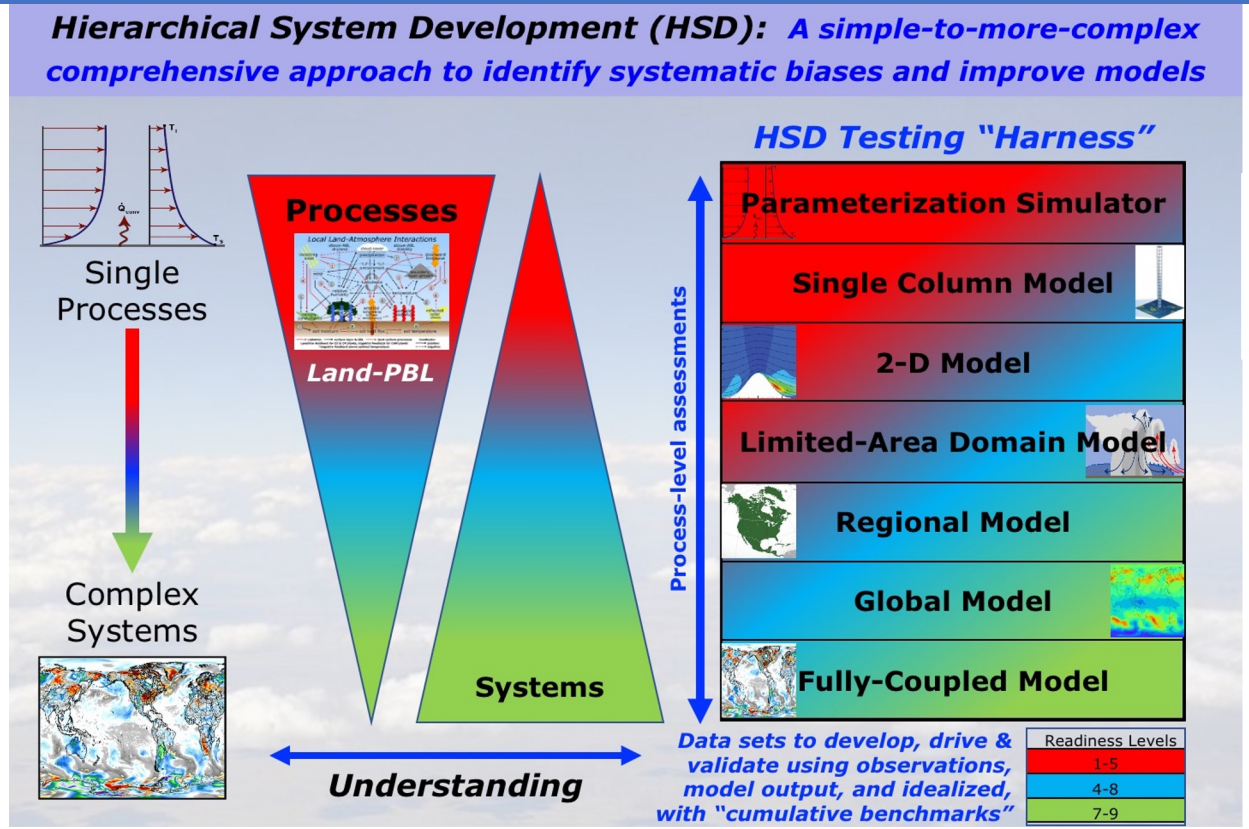


Goals:

- remove the barriers to participation in the development and advancement of UFS [Land]
- plug into the process with simpler (but relevant) models that have fewer dependencies and can run with minimal resources

Source: Michael Ek, NCAR

Hierarchical Testing/Evaluation Framework



Student/ Researcher

Exploring model output:

https://registry.opendata.aws/noaa-ufs-s2s/

A repository of UFS Global Coupled Model Development Output

Source: Michael Ek

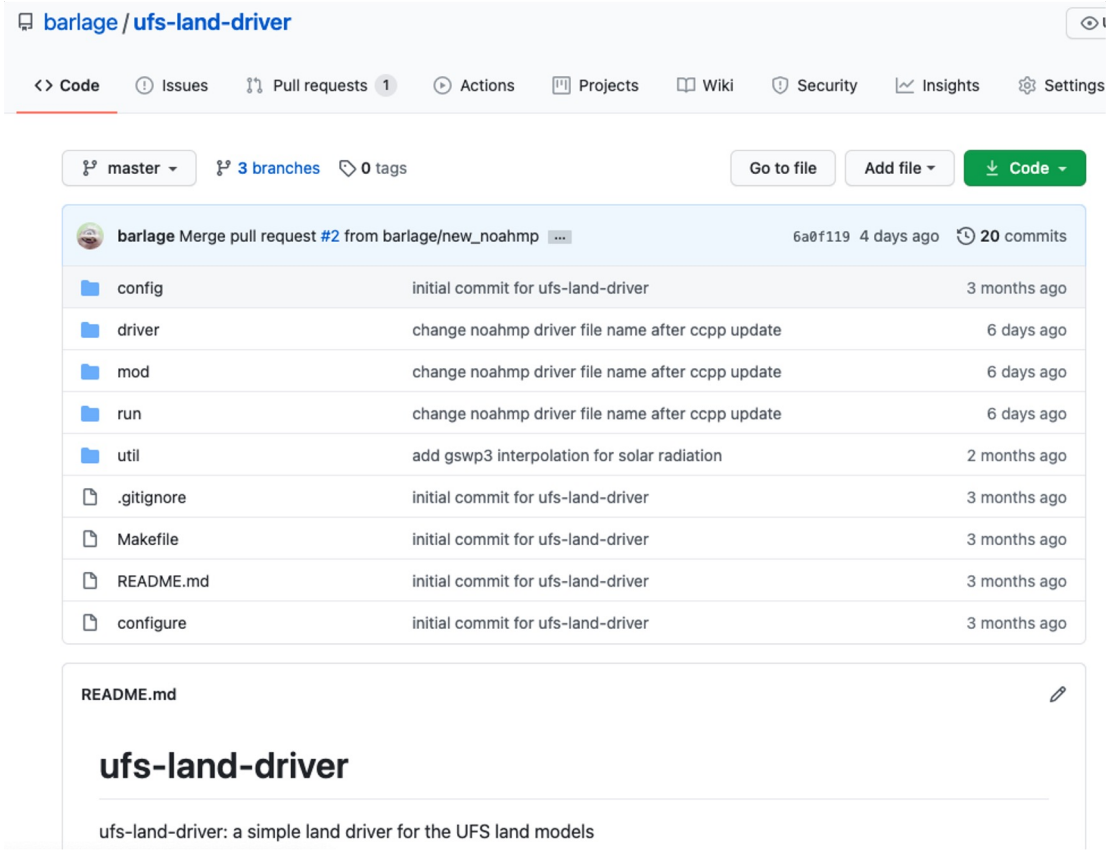
Hierarchical Testing/Evaluation Framework

- Land model process testing and evaluation
  - Essentially non-existent in UFS land models (and most other land models)
- Land model testing and evaluation
  - Essentially land model drivers: GLDAS, NLDAS, HRLDAS, LIS
  - These are more useful if connected directly to code used in UFS/ops repositories
- Single column model (CCPP-SCM)
  - Very useful for efficient testing of land-atmosphere coupling
  - Rapid L-A sensitivity tests of land model parameters and physics
- Global/regional land-atmosphere – SRW or MRW App cases
- Global coupled cases

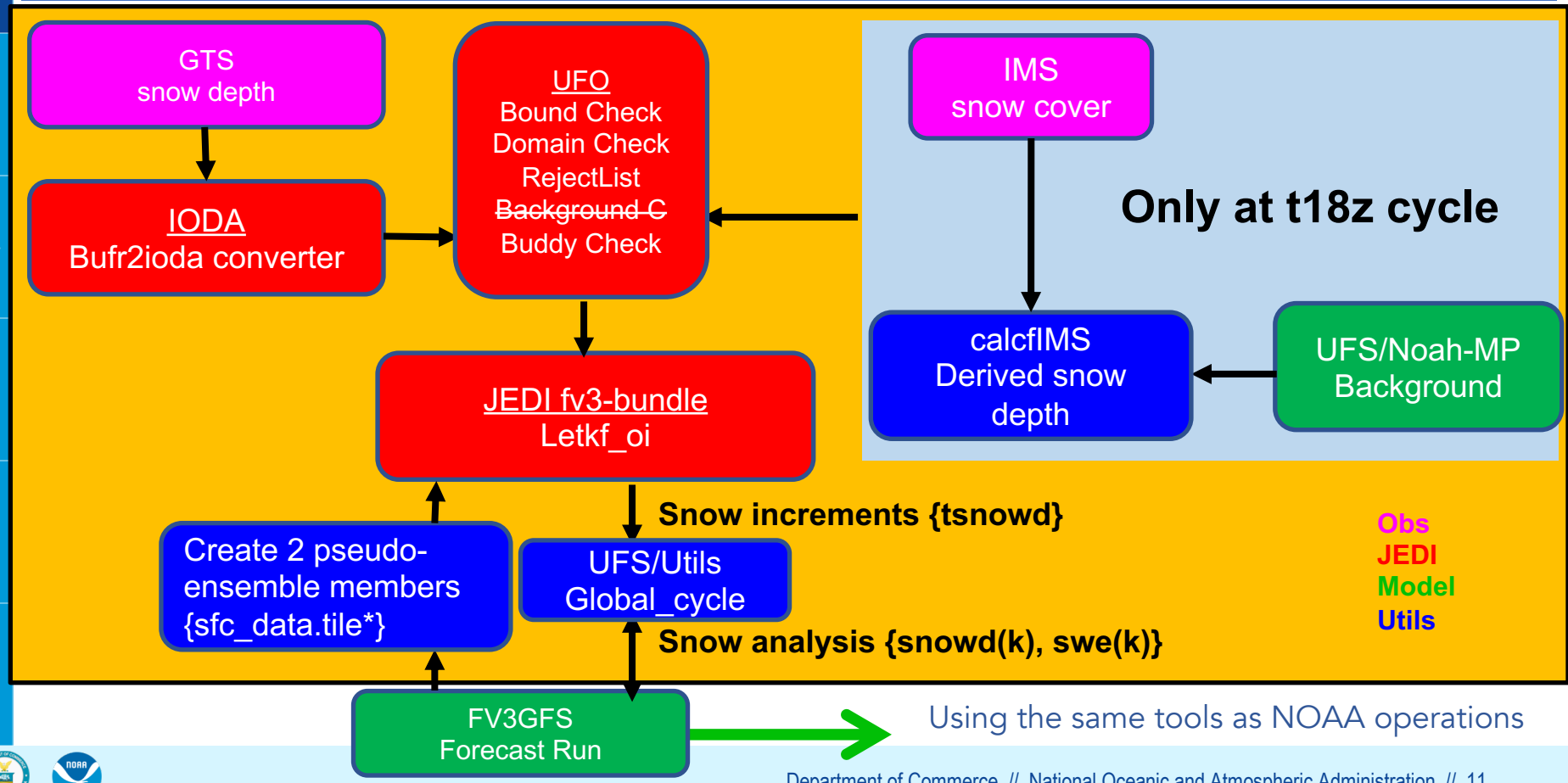
Hierarchical Testing/Evaluation Framework

- UFS land driver that plugs directly into CCPP Physics repository
- Designed for ease-of-use
- Graduate/ Undergraduate student laptop capability
- Two dependencies: Fortran compiler and NetCDF library

github.com/barlage/ufs-land-driver



Land Data Assimilation Framework



Using the same tools as NOAA operations

UFS Land Workshop Summary

- Resources are needed to support UFS land physics and UFS-JEDI land data assimilation tools that contribute to a standardized and automated hierarchical development approach and provide a distribution mechanism to the UFS land community.

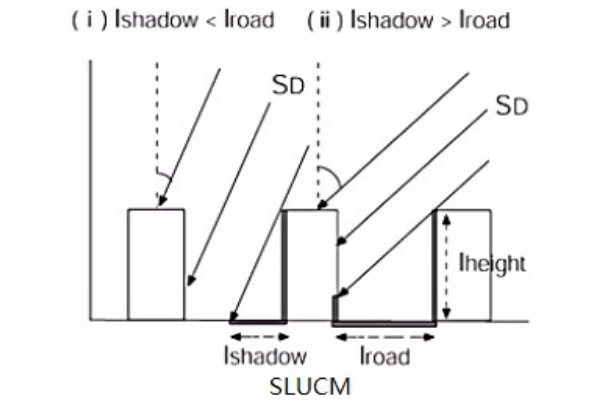
Outstanding Land Infrastructure Issues

- A challenge with multiple physics options: need well defined requirements between physics schemes
- Consistency between land model coupling (or fractional grid components) to the PBL scheme
  - Flexibility with PBL scheme (K/TKE-EDMF, MYNN, etc.)
  - Need for more coordination with PBL group
- Current land models within CCPP are not modeling "systems"; they have no self-contained history and restart capabilities

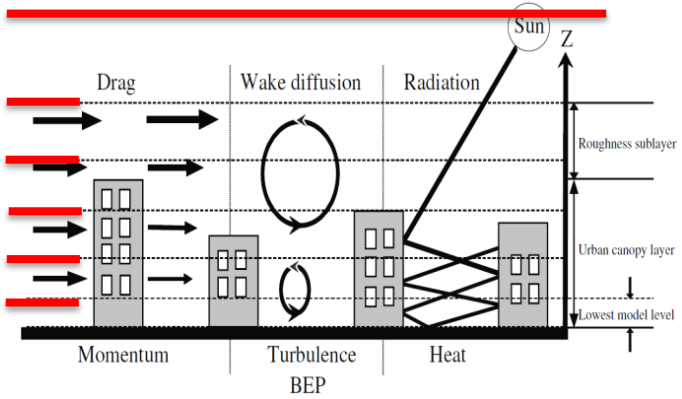
UFS Land – Gaps: Urban Modules

- All current UFS land models have very crude representation of urban areas
- As horizontal and vertical resolutions increase, more sophisticated representation of urban processes become necessary

Model Forcing Level



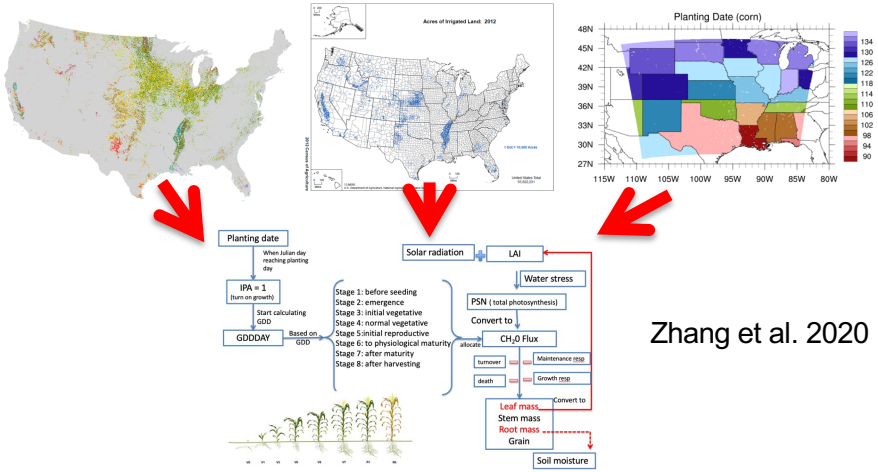
Model Forcing Levels



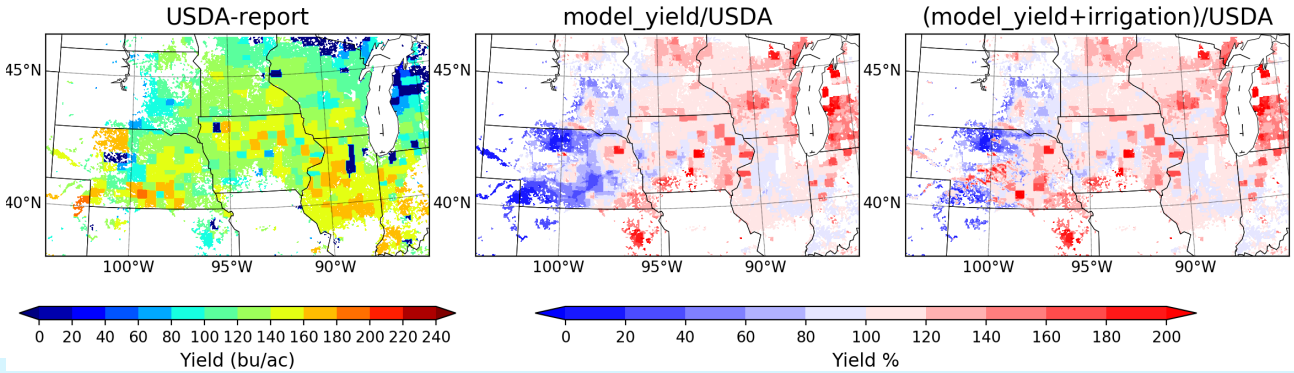
Chen et al. 2011

UFS Land – Gaps: Agriculture Modules

- High resolution information of crop types, irrigation and management
- Potential for providing county-level information to agriculture stakeholders

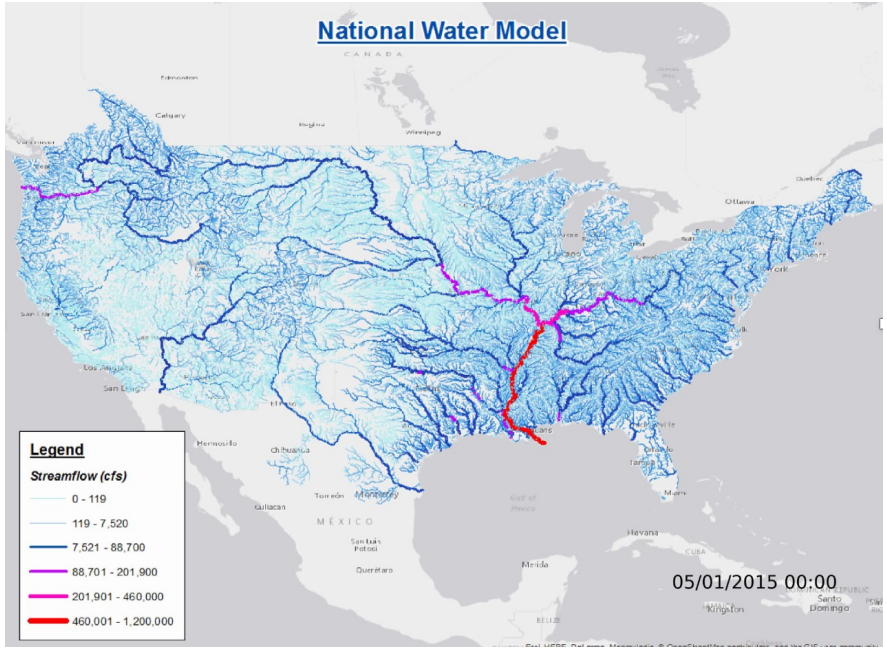


Zhang et al. 2020



UFS Land – Gaps: Hydrology and Lakes

- No lake model running in regional or global models
- Options being developed
  - FLake – in CCPP
  - CLM lake model – being added
  - FVCOM for Great Lakes
- No reservoirs or management
- No routing module means link between column land surface model and ocean model does not exist
  - Current JTTI project to connect UFS SRW configuration (RRFS) to National Water Model
- Crude treatment of groundwater



UFS Hierarchical Testing/Evaluation Gaps

- Need common evaluation capabilities throughout hierarchical development, METplus is the obvious choice
  - discussions ongoing to add land-specific evaluation to METplus
  - streamline community contributions (e.g., observations)
- UFS Metrics Workshop was an important step toward elevating land-specific metrics, moving beyond those driven by atmospheric priorities
  - soil moisture/temperature, turbulent fluxes, coupling metrics, snow/streamflow

UFS Land Workshop Summary

- Resources are needed to support UFS land physics and UFS-JEDI land data assimilation tools that contribute to a standardized and automated hierarchical development approach and provide a distribution mechanism to the UFS land community.
- More comprehensive land-related verification needs to be added to UFS evaluation and verification packages, including land process and land-atmosphere coupling metrics.

Community Engagement and Collaboration

- Provide clear, defined hierarchical path from research to operations
  - Involve both operational-priority "super" metrics ***and*** land process metrics
  - Are land process metrics stable throughout the hierarchical path?
- Increasing collaboration with the community
  - Grows organically with a well-designed Hierarchical Testing and Evaluation Framework
  - Need to give the community a core set of tools and cases to facilitate onboarding
    - ufs_land_driver is one of those tools (as is CCPP-SCM)
- Get onboard…not only running the UFS, but developing as well

UFS Land Workshop Summary

- Resources are needed to support UFS land physics and UFS-JEDI land data assimilation tools that contribute to a standardized and automated hierarchical development approach and provide a distribution mechanism to the UFS land community.
- More comprehensive land-related verification needs to be added to UFS evaluation and verification packages, including land process and land-atmosphere coupling metrics.
- Clear communication needs to be established with the research community to provide requirements and restrictions imposed on land physics and land data assimilation for transition to the operational NWP setting. A central location with priorities of known model deficiencies with example cases should be established.
- Land research to operations transition projects should be required to use the UFS hierarchical framework, including both testing and evaluation, beginning with land-only and progressing to coupled-model simulations using standard test cases and pre-existing testing and evaluation tools.