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Noah-OWP-Modular for Nextgen: Enhancement, Modularization, and Implementation of the Basic Model Interface

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Background

Widely used by the hydrologic and land surface modeling communities, Noah-MP simulates the water and energy balances in the operational National Water Model (NWM).

As a result of its demonstrated skill and previous NWM usage, we have identified Noah-MP as a model to test in Nextgen NWM development.

To make the model Nextgen-compatible and have it comport to more modern coding standards, we have refactored Noah-MP into Noah-OWP-Modular, which includes the enhancements described herein.

Objectives & Approach

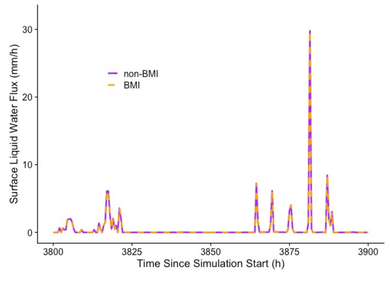
1. Enhance modularity through refactoring of the codebase from a single file into multiple thematic modules with derived data types
2. Simplify model operation through separation of concerns
3. Enable interoperability through application of the Basic Model Interface (BMI)

Unit Testing

After refactoring the code, we performed extensive unit testing on Noah-OWP-Modular. We first ensured proper behavior of the BMI functions.

```
$ ./noahowp_test.exe ../run/namelist.input
 Initializing...
 Component name = Noah-OWP-Modular
 Total input vars =            8
 Total output vars =           3
```

We also compared output from the non-BMI and BMI versions of Noah-OWP-Modular. We found a 1:1 match in model output.



Basic Model Interface (BMI) and associated model functions
- Initializes, runs, and finalizes model
- *get_value* and *set_value* used to pass data

Model Driver
- Controls operation in standalone mode

`NoahModularDriver.f90`

- Initialize
  - Define Data Types
    - `LevelsType DomainType`
    - `OptionsType ParametersType`
    - `ForcingType`
    - `EnergyType WaterType`
  - Initialize Variables
  - Open Forcing and Output Files
- Update
  - Solve Model
    - `UtillitiesModule.f90`
    - `ForcingModule.f90`
    - `InterceptionModule.f90`
    - `EnergyModule.f90`
      - `AtmProcessing.f90`
      - `ThermalPropertiesModule.f90`
      - `PrecipHeatModule.f90`
      - `ShortwaveRadiationModule.f90`
      - `EtFluxModule.f90`
      - `SnowSoilTempModule.f90`
    - `WaterModule.f90`
      - `CanopyWaterModule.f90`
      - `SnowWaterModule.f90`
      - `SoilWaterModule.f90`
  - Advance In Time
- Finalize
  - Close Output File

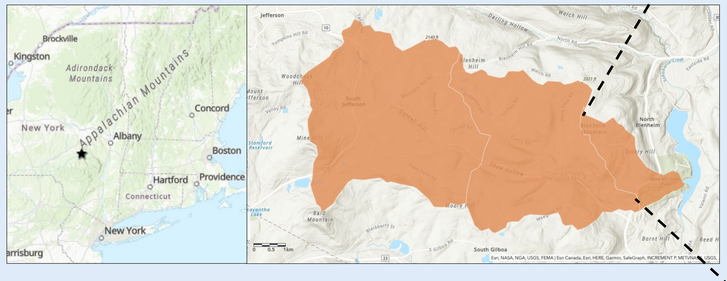
Derived Data Types
- Include all non-local variables
- Correspond to model components
- Similar to C structs

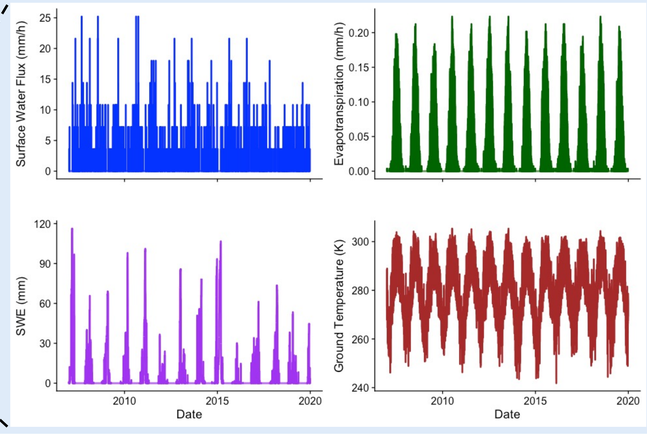
Modules
- Formerly subroutines in Noah-MP
- Forcing, Energy, and Water modules call more granular modules (green boxes) with related subroutines

Noah-OWP-Modular Provides a Modern, Flexible Representation of Hydrologic Processes in Nextgen

Using 13 years of AORC forcing data, we ran Noah-OWP-Modular in Nextgen. We specified output to be written using BMI output vars.

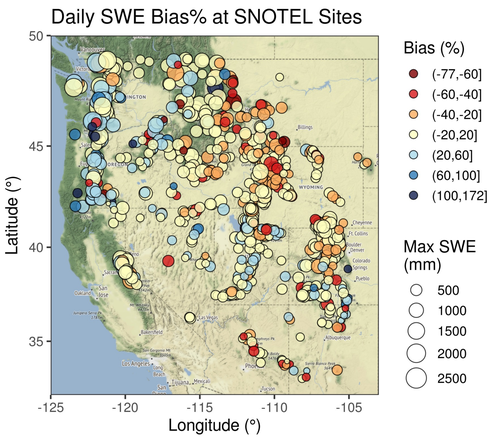
```
$ ./ngen catchment_data.geojson cat-1 nexus_data.geojson
nex-2 Realization_01350140_noah_owp_modular.json
```



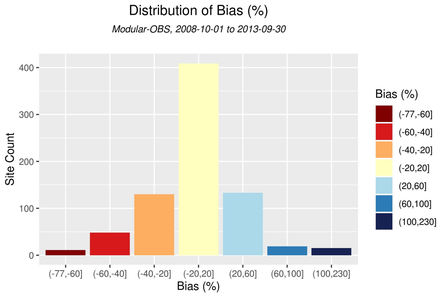


Standalone Snow Test

We ran Noah-OWP-Modular at western US SNOTEL stations from 2008-10-01 to 2013-09-30.



Biases were large in some cases, but were typically within the range of ±20%.



Contributions Welcome!

Scan the QR code to visit the Noah-OWP-Modular repo on GitHub. We welcome community engagement. Have any suggestions? Found any bugs? Let us know!

ACKNOWLEDGMENTS:

We are grateful for the initial refactoring effort begun by members of the Hydrometeorological Applications Program at the NCAR, particularly Cenlin He. We also thank Dr. He for sharing several SNOTEL-related modeling datasets that were used in model evaluation.

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BMI: https://csdms.colorado.edu/wiki/BMI

Noah-MP: https://github.com/NCAR/noahmp/

Niu, Guo-Yue, et al. "The community Noah land surface model with multiparameterization options (Noah-MP): 1. Model description and evaluation with local-scale measurements." *Journal of Geophysical Research: Atmospheres* 116.D12 (2011).

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