Noah-MP Land Surface Model Developments in WRFv3.7 and Beyond

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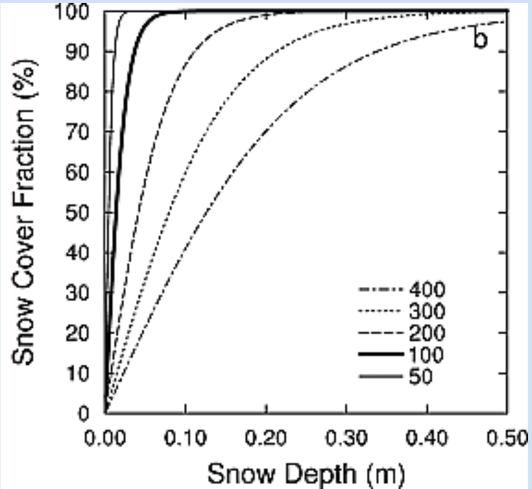
WRF v3.7 release cycle: Noah-MP modifications

1. precipitation partitioning: an option is included to use WRF microphysics output of liquid and frozen precipitation, including snow, graupel and hail; also convective/large-scale fraction is used for canopy interception
2. precipitation heat advection: include the heat advected by precipitation in the surface energy budgets
3. new-snow albedo fix: remove the timestep dependence on whether new snow resets the snow albedo to the “brightest” value
4. update MP table for consistency among land cover types
5. z_0 consistency with WRF: make sure Noah-MP and WRF are using the same roughness length for vegetation
6. snow cover/melt parameter variation: removed as a global constant and included in parameter table
7. patchy snow option for T_s calculation: allow for consistency between fractional snow in albedo and surface temperature calculations
8. parameter assignment: moved to single subroutine call in land surface driver; toward facilitating parameter estimation studies
9. dynamic vegetation fix: fixed bug that prevented vegetation from growing back in a second season; also reduce turnover and better initialization through LAI dataset

Noah-MP Parameter Improvements

- Many Noah-MP parameters are hard-coded prohibiting efficient testing
- In the WRFv3.7, progress was made to move parameters to a common location
- Some parameters are global and questionably so, e.g., the snow cover shape parameter
- Snow cover is defined by S_c= tanh(h / (2.5 * z_{0g} * (ρ_{snow} /ρ_{new})^m))
  - Increasing snow height (h) increases snow cover
  - Increasing snow density (ρ_{snow}) decrease snow cover
  - m parameter controls shape
  - *"m, a melting factor determining the curves in melting season, is adjustable depending on scale (generally, a larger value for a larger scale)"* (Niu 2007)



Noah-MP Parameter Improvements

- In WRF v3.6, *m* = 1 performed well in western US, but produced cold bias in central US due to overly persistent snow
- Setting *m* = 3, reduced central US cold bias, but in the western US, Noah-MP snow water equivalent prediction was sub-optimal
- Added the capability to have land cover dependent *m* parameter via MPTABLE.TBL
- One year 20-km-resolution simulations to test *m*
- Verification based on PRISM daily T_{max} and T_{min}

Noah-MP Parameter Improvements

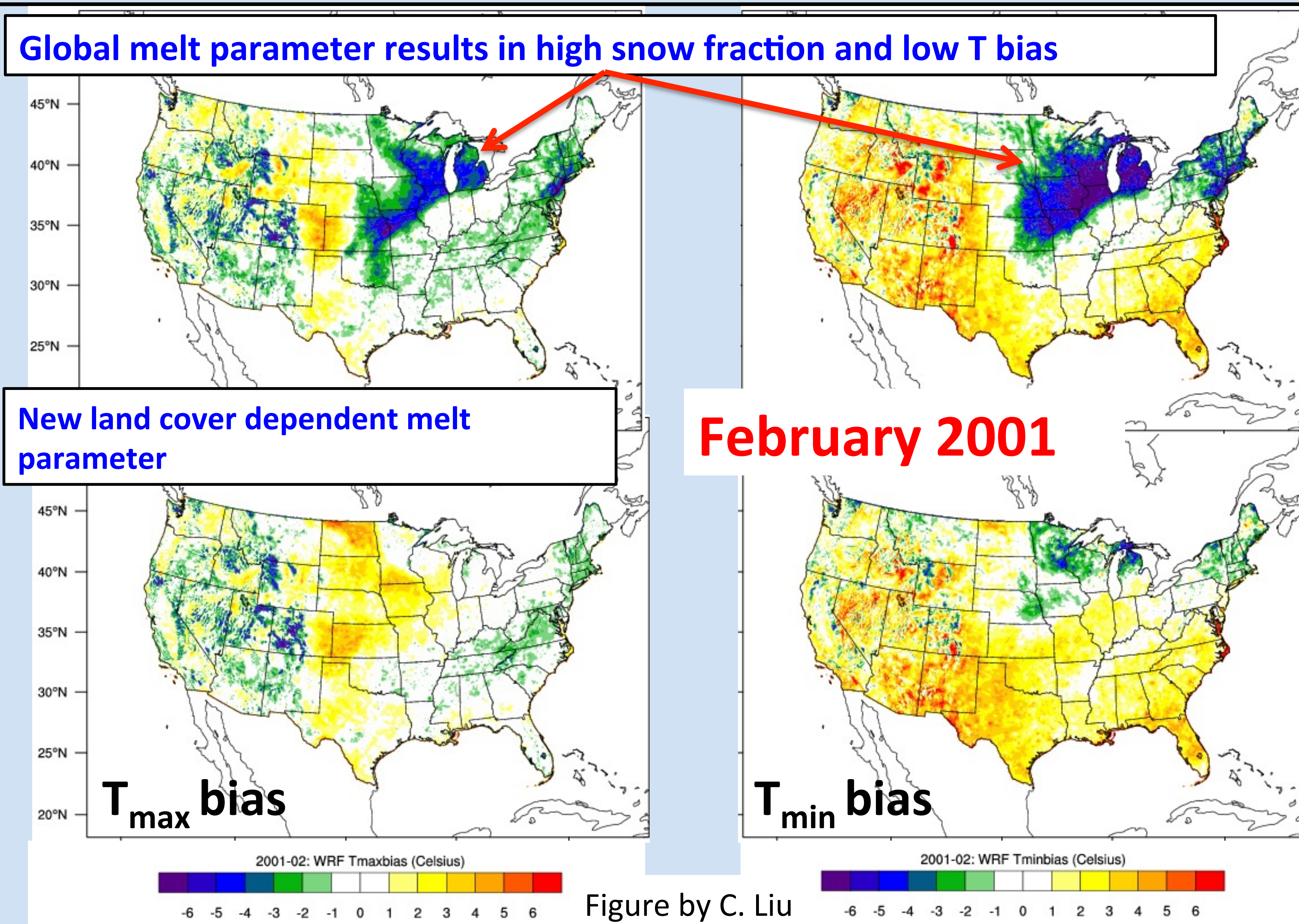
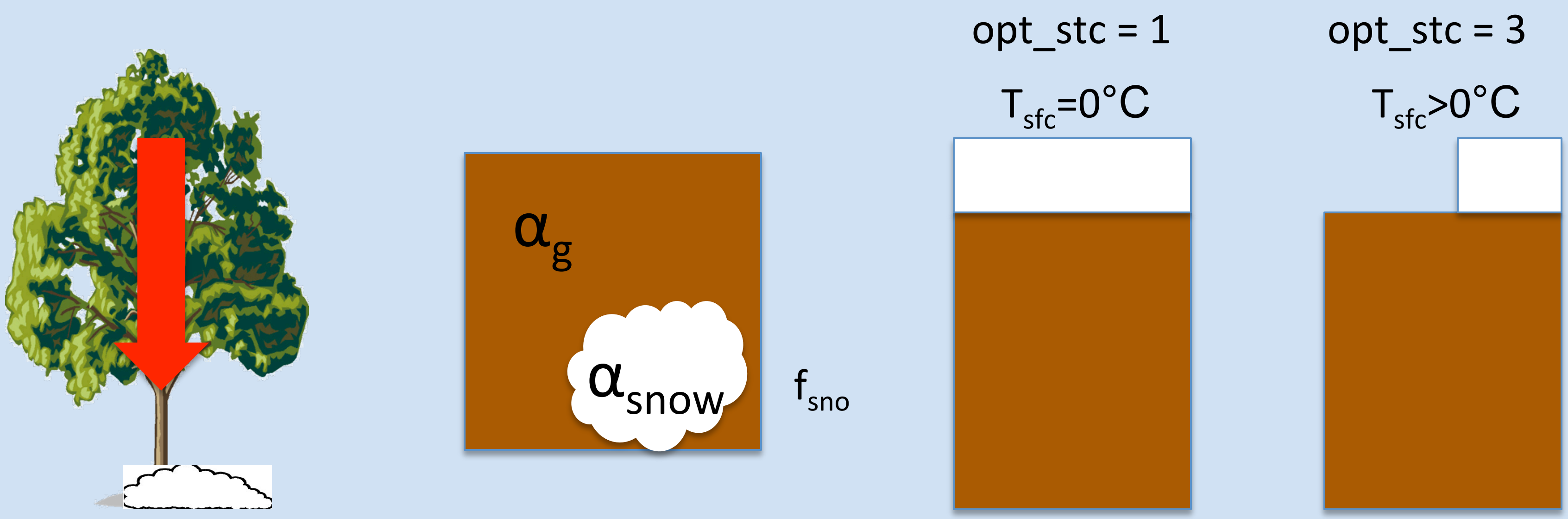


Figure by C. Liu

Noah-MP Structure Improvements

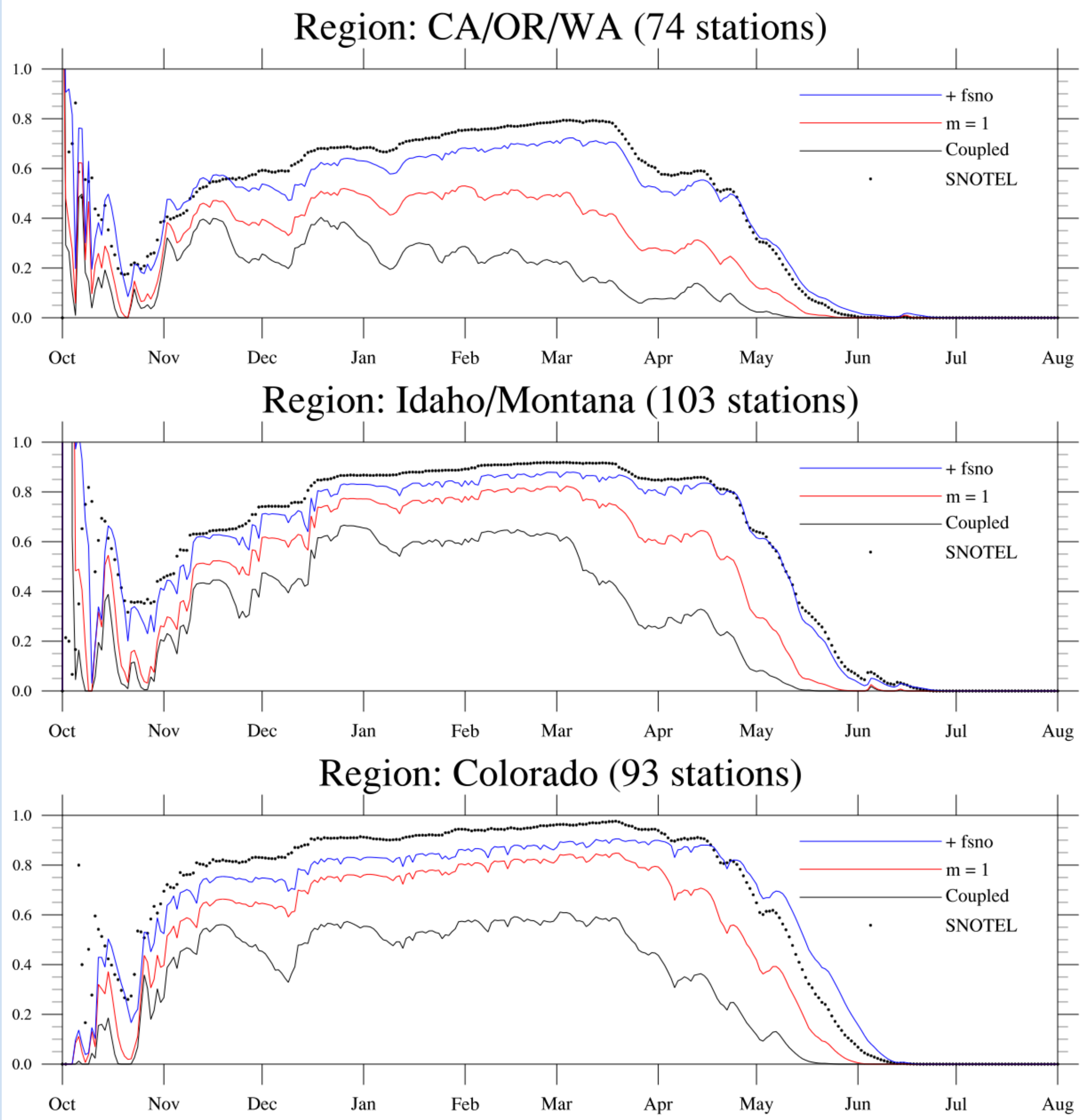
- Additionally, snow cover fraction is used to define the albedo of the surface, but in v3.6 is not used in the surface temperature calculation
  - When snow is melting, T_{sfc} is prohibited from going below 0°C
  - T_{sfc} > 0°C now allowed in “patchy” snow situations
  - If not, too much energy input to the snow pack



Noah-MP Structure Improvements

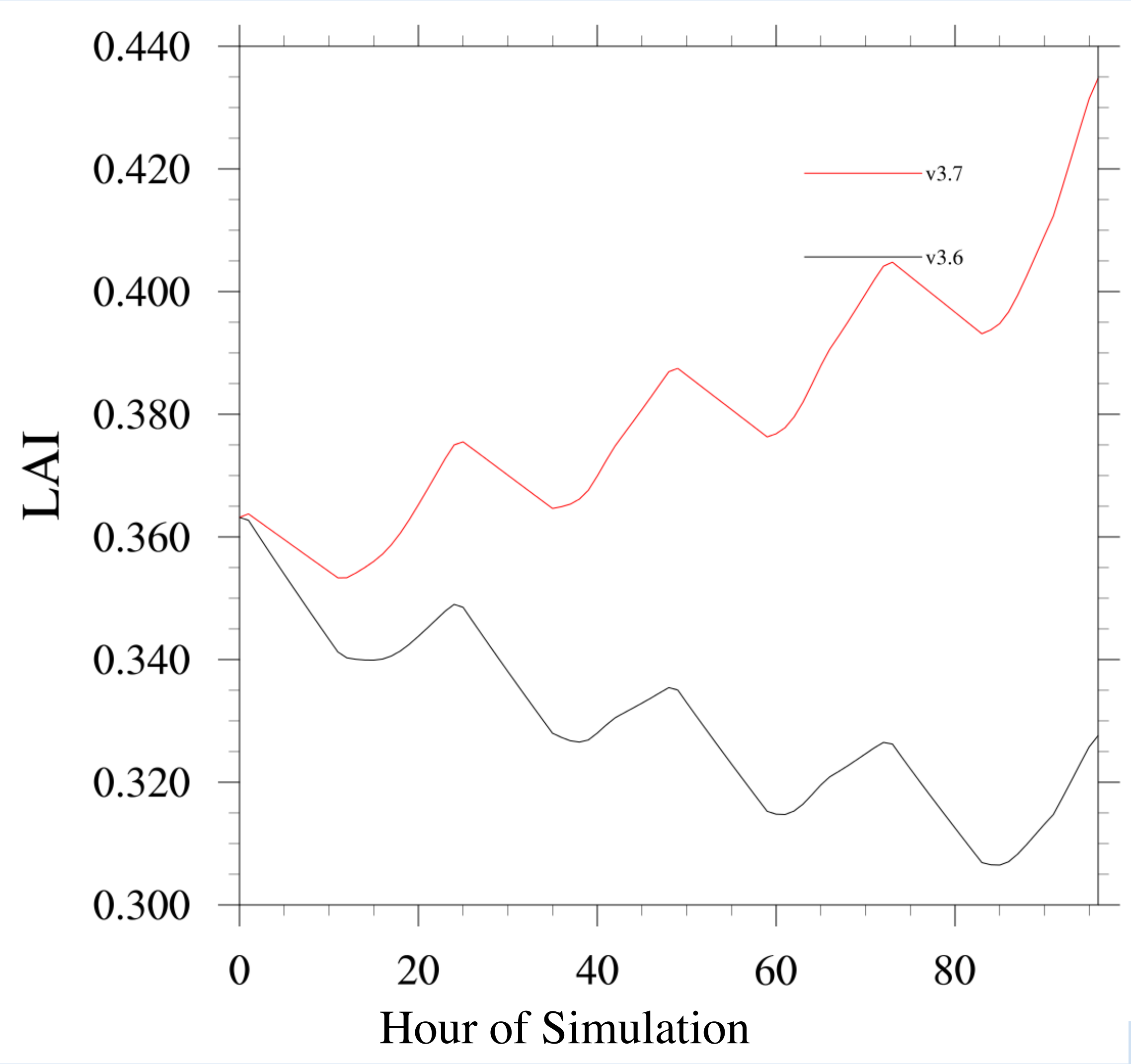
- One-year simulation in the western US
- Comparison with SNOTEL snow water equivalent
- Showing the ratio of observation/model SWE to input snow from observations/model:

$$\frac{\text{SWE}}{\text{accum. snowfall}}$$



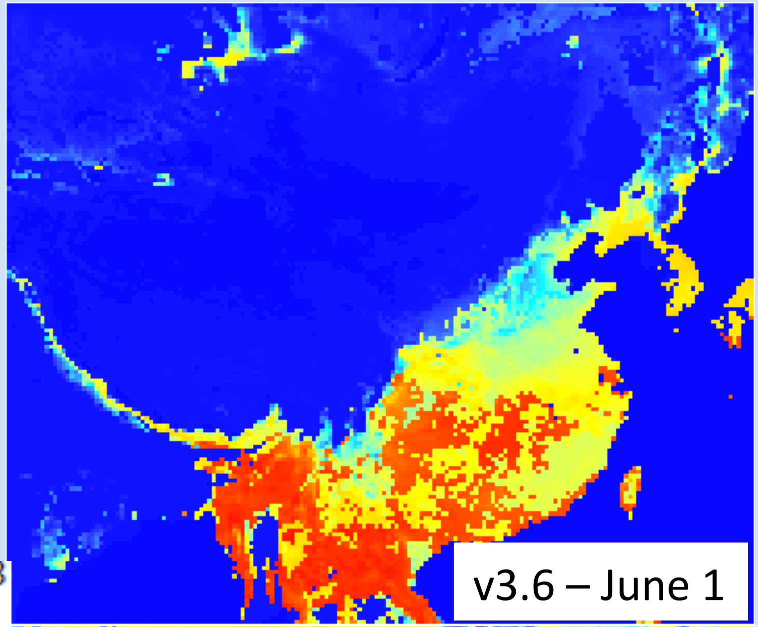
Noah-MP Improvements – dynamic vegetation

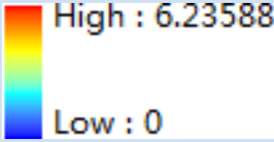
- Noah-MP dynamic vegetation module produced too much turnover loss for leaf/ stem carbon pools
- Resulted in nighttime loss that was not compensated by daytime gain
- LAI prediction too low especially for vegetation >30°
- 4-day simulation for grassland grid in central US beginning May 1 with modified turnover rates

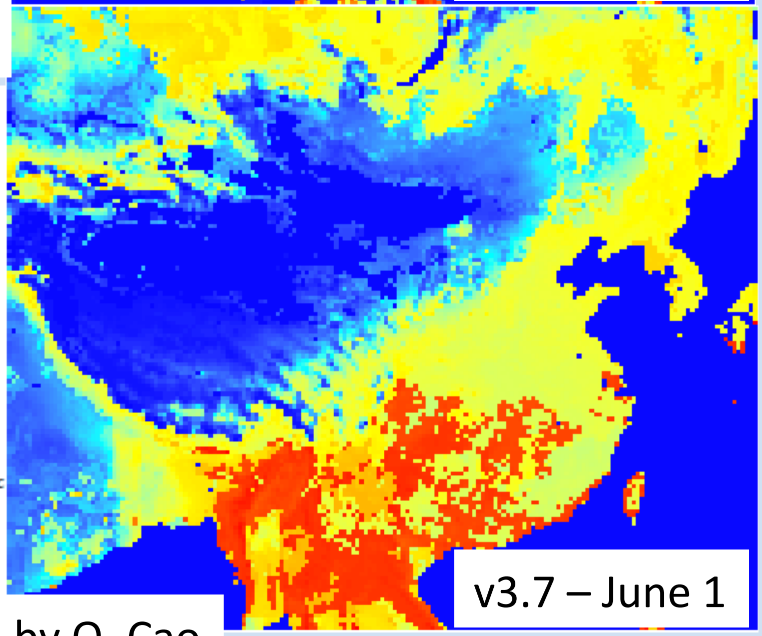


Noah-MP Improvements – dynamic vegetation

- Six-month simulations initialized Jan 1
- Run with dveg=5 option; initialized with LAI climatology (released in v3.6)
- Bottom: run with reduced turnover rate







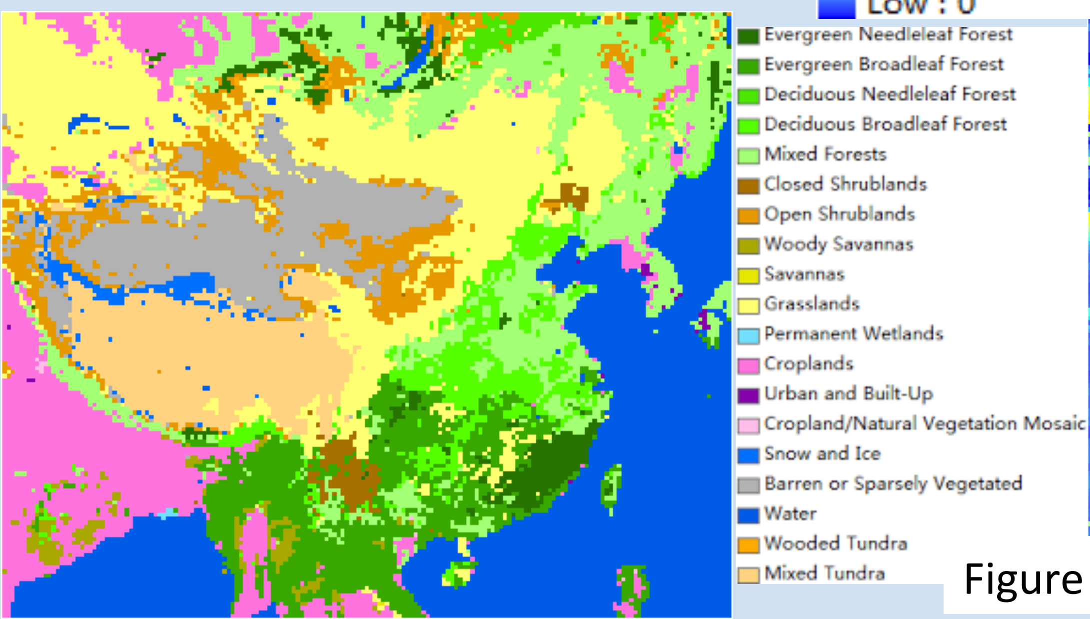


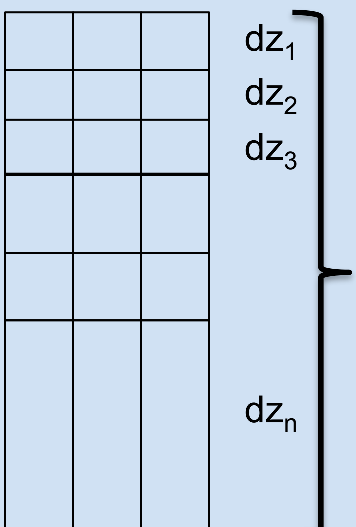
Figure by Q. Cao

Expanding Noah-MP capabilities

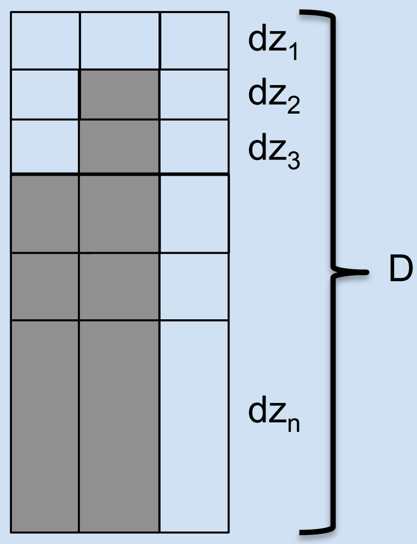
Default – 4 layers, constant depth/thickness

- Added capability to specify soil properties horizontally and with depth
- Increasing the use of non-standard soil properties databases
- Ability to use non-standard profiles

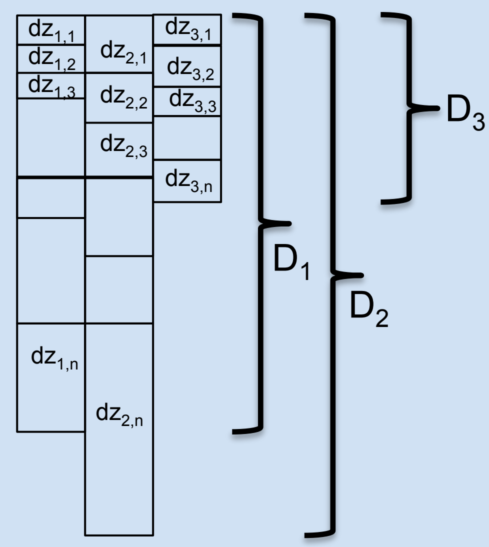
Case 1 – n layers, constant depth/thickness



Case 2 – n layers, constant depth/thick, impermeable layer



Case 3 – n layers, variable depths and thicknesses

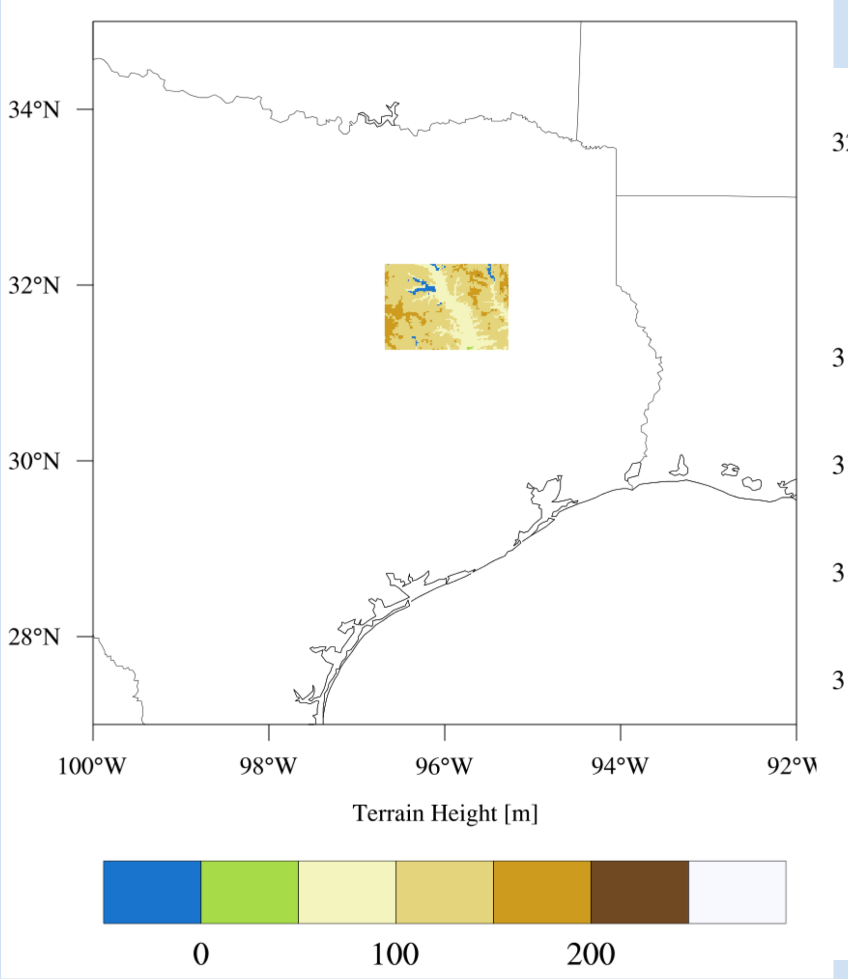


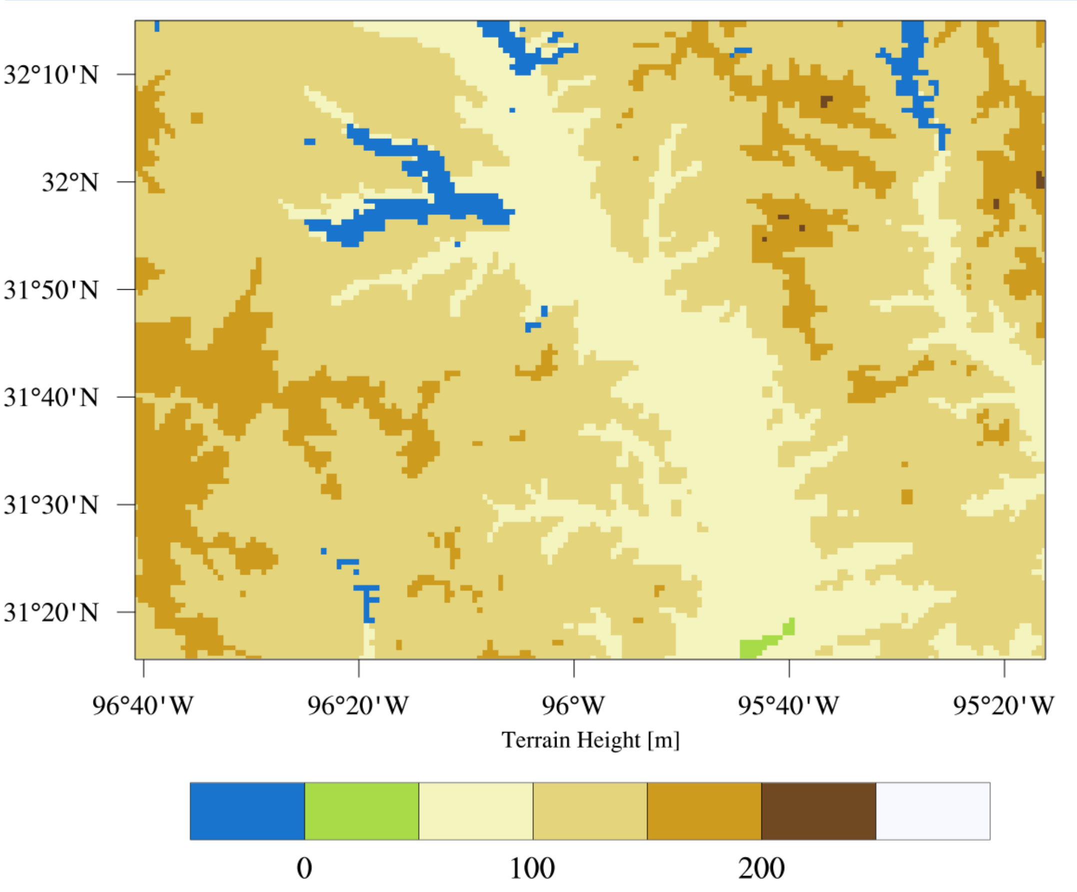
Data Structure in Noah-MP

- Introducing a “land surface properties file” concept
- Soil properties are a first step to more general method to import surface characteristics
- Implications for parameter estimation

```
float bexp(Time, soil_layers_stag, south_north, west_east) ;
        bexp:description = "Clapp-Hornberger B exponent" ;

float smcdry(Time, soil_layers_stag, south_north, west_east) ;
        smcdry:description = "Soil Moisture Limit: Dry" ;

float smcmax(Time, soil_layers_stag, south_north, west_east) ;
        smcmax:description = "Soil Moisture Limit: Max" ;

float smcref(Time, soil_layers_stag, south_north, west_east) ;
        smcref:description = "Soil Moisture Limit: Reference" ;

float smcwlt(Time, soil_layers_stag, south_north, west_east) ;
        smcwlt:description = "Soil Moisture Limit: Wilt" ;

float dksat(Time, soil_layers_stag, south_north, west_east) ;
        dksat:description = "Saturated Soil Conductivity" ;

float dwsat(Time, soil_layers_stag, south_north, west_east) ;
        dwsat:description = "Saturated Soil Diffusivity" ;

float psisat(Time, soil_layers_stag, south_north, west_east) ;
        psisat:description = "Saturated Matric Potential" ;

float quartz(Time, soil_layers_stag, south_north, west_east) ;
        quartz:description = "Soil Quartz Content" ;

float refdk(Time, south_north, west_east) ;
        refdk:description = "Reference Soil Conductivity" ;

float refkdt(Time, south_north, west_east) ;
        refkdt:description = "Soil Infiltration Parameter" ;
```

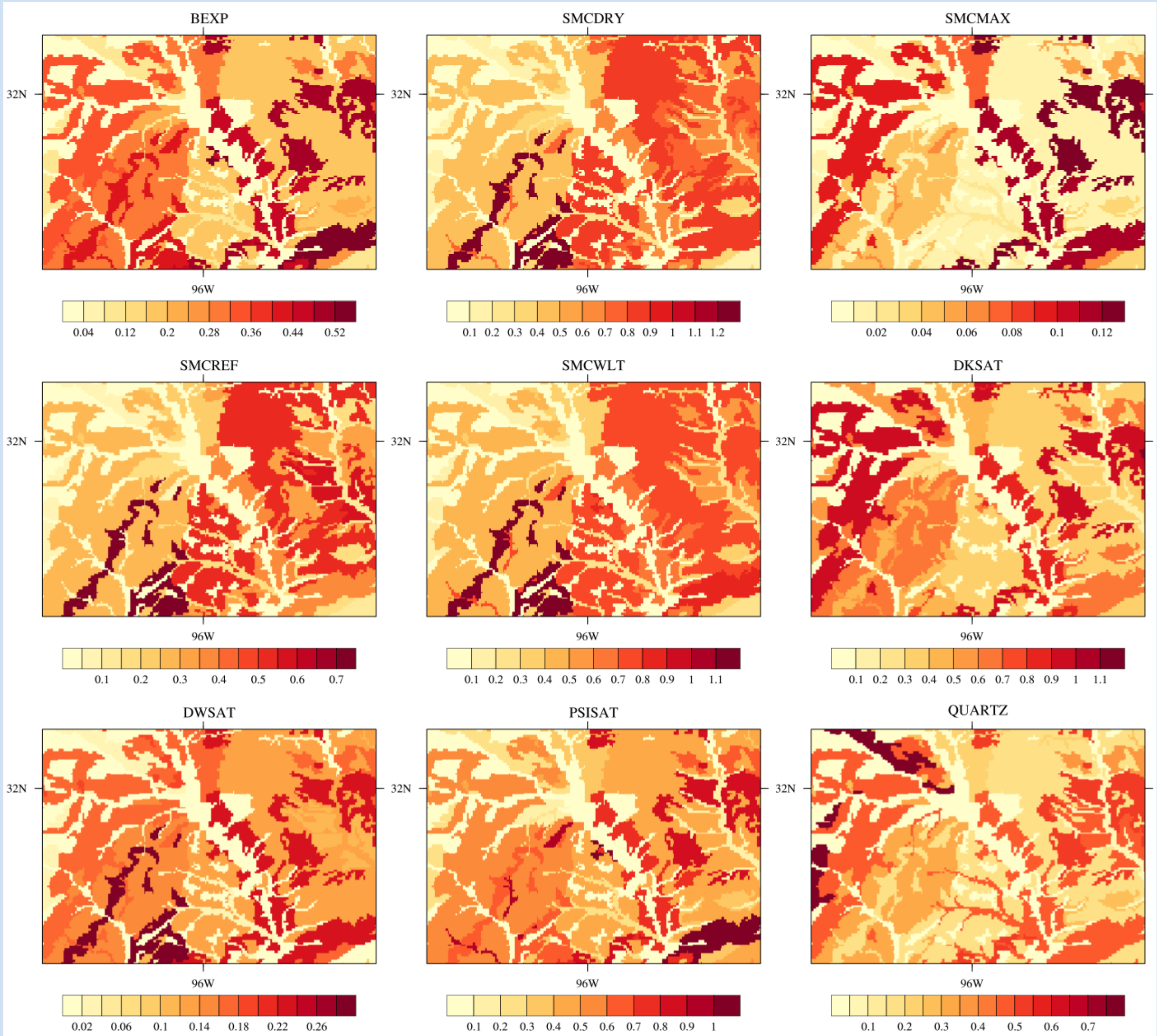
Soil Parameter Test Domain





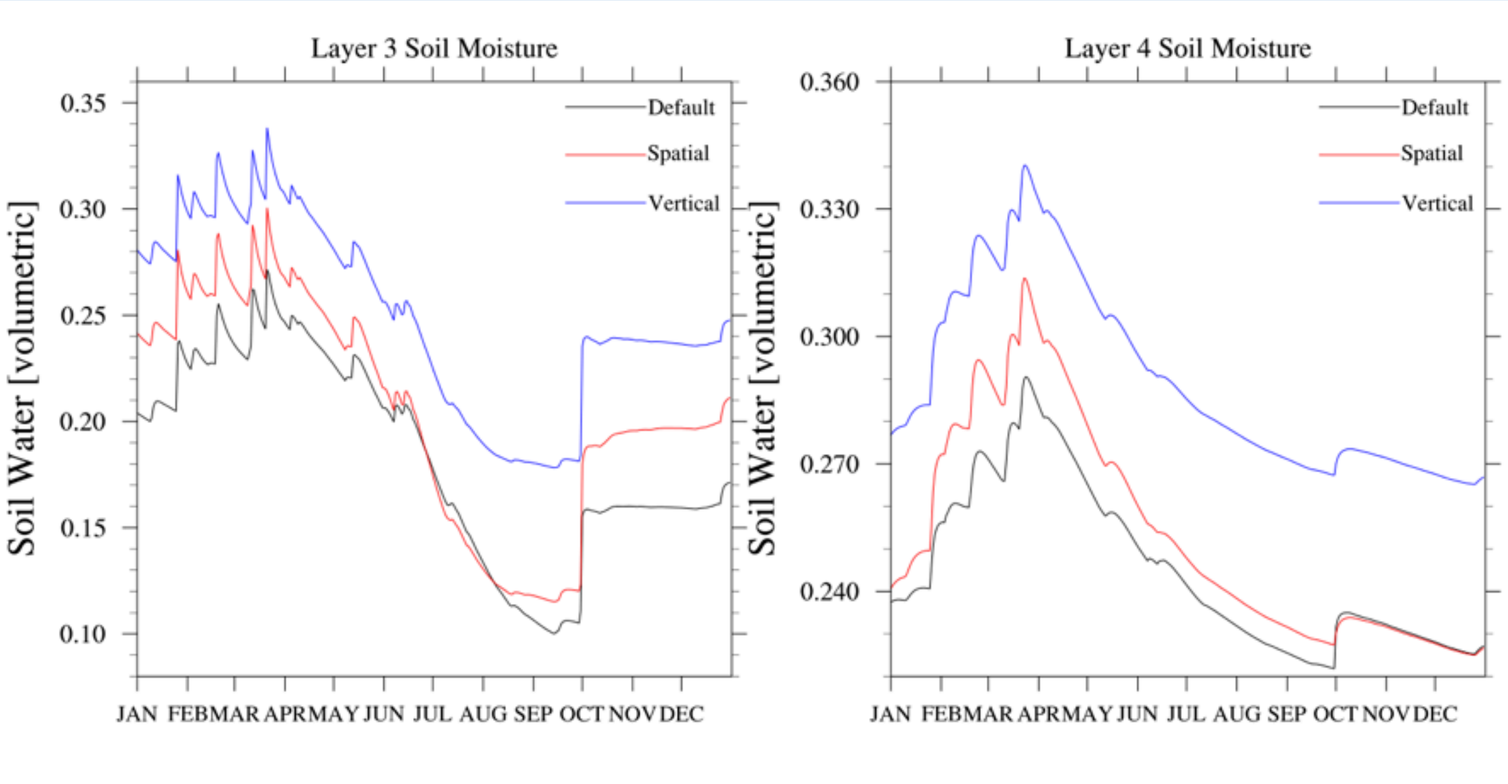
- East Texas test domain

Soil Property Data based on dSSURGO



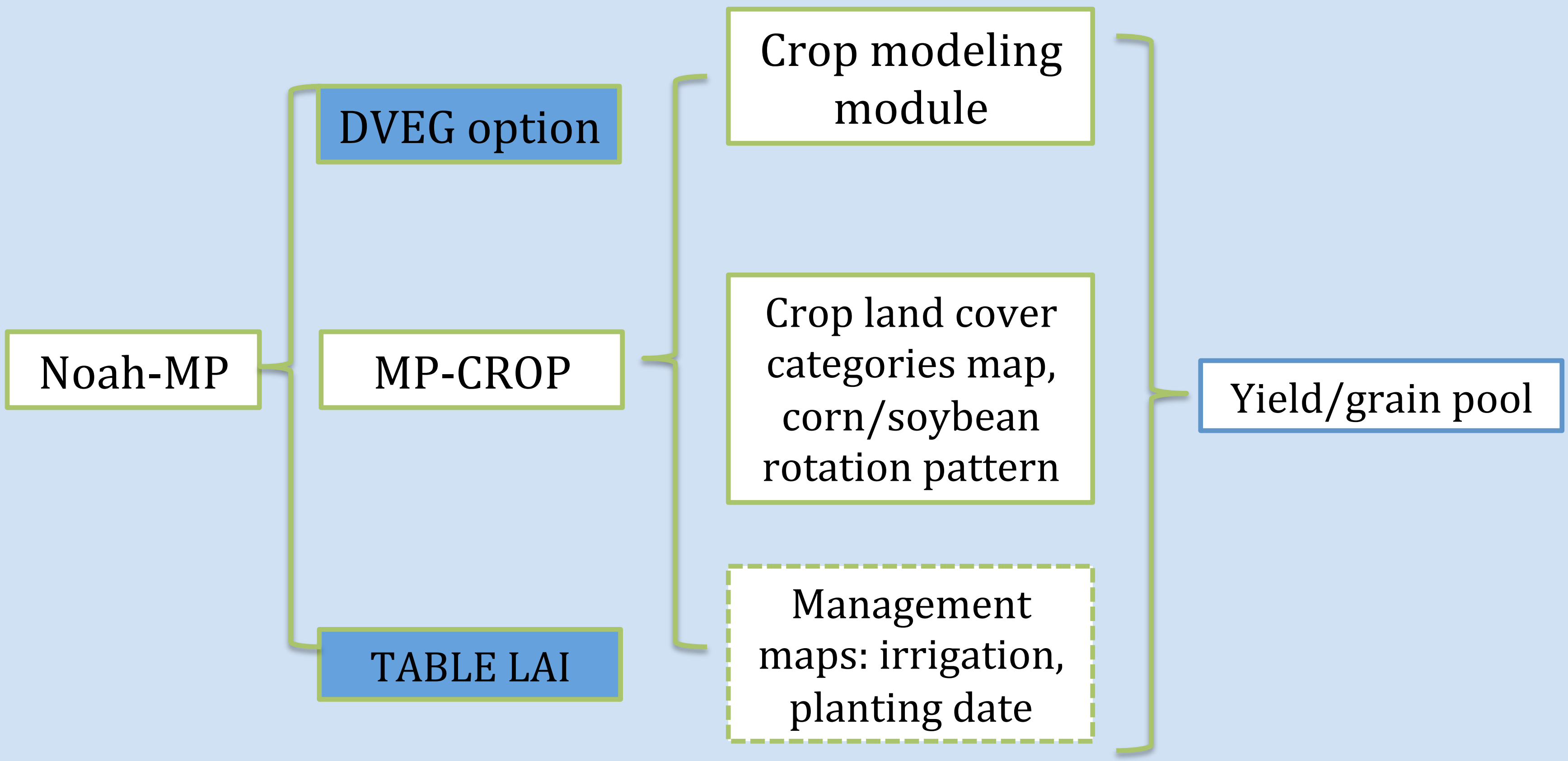
- Standard deviation of soil properties in the vertical

Sensitivity Results



- Annual time series of soil moisture

Noah-MP-Crop – future capability



Noah-MP-Crop Results

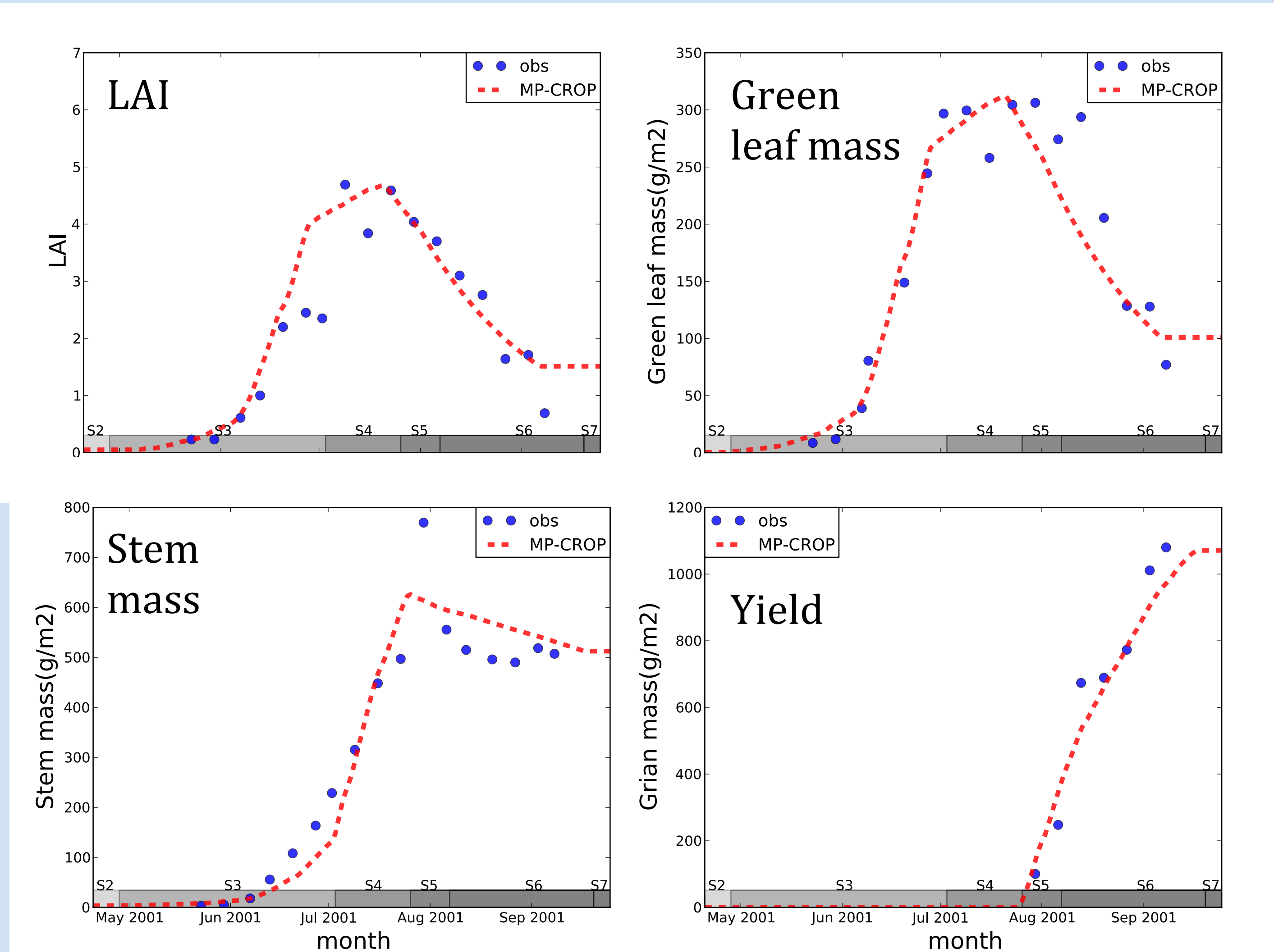


Figure by X. Liu

Corn
Bondville, IL 2001

Summary

Several modifications and fixes were added to Noah-MP v3.7 in coordination with users and their needs and concerns, resulting in a better and more robust model.

The future Noah-MP is focused on expanding capabilities (crop modeling, non-standard datasets) and facilitating parameter estimation.

Users are encouraged to integrate the Noah-MP LSM into their studies, test/develop/propose new options, and interact with us on results/concerns.