Increasing Vegetation Data Assimilation Through the Evolution of Land Model Structure

NCAR

RESEARCH APPLICATIONS LABORATORY

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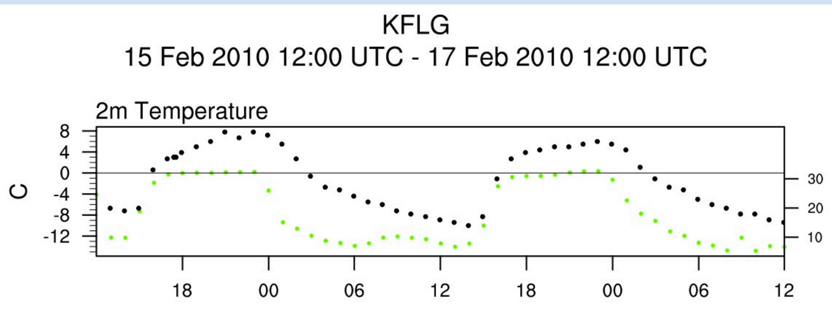
Study Motivation

- Temperature biases in the Noah land surface model can reduce the number of satellite-based land and atmospheric observations that are assimilated
- Deficiencies exist in the current forecast system, so of which can be attributed to model structural deficiencies
- Advances in model structure aim to improve near-surface forecasts, and increase both atmospheric and land data assimilation

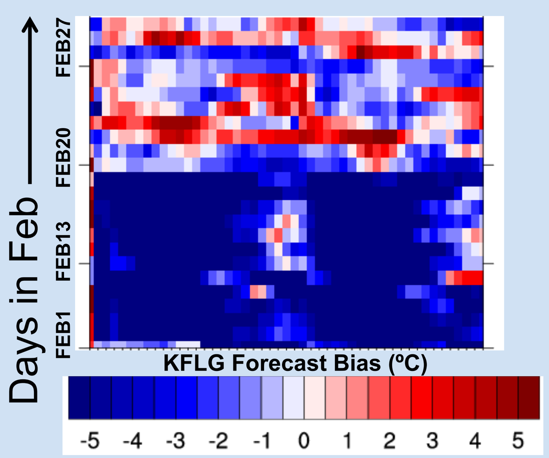
Challenges with Noah LSM Structure

- Noah LSM uses a bulk treatment of the surface, which can introduce problems with heterogeneous surfaces

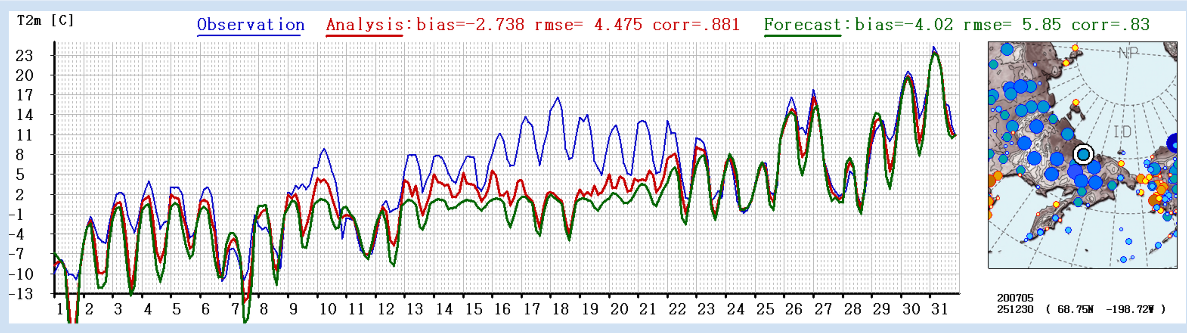


Flagstaff WRF/Noah v3.2 T_{2m} simulation (green) compared to METAR observations(black)

Forecast Hour (Initialized at 12Z daily)



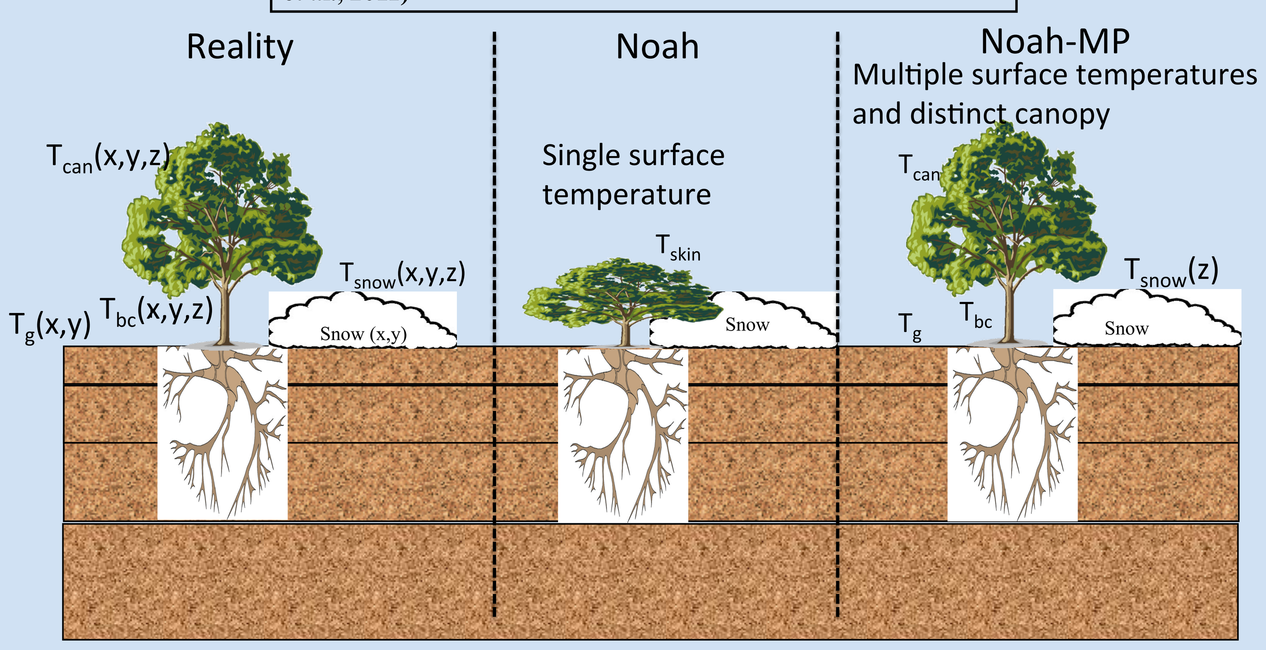
- Cold bias during the day results from capping surface temperature at freezing
- Bias recovers during the night
- When snow is gone, bias decreases



- May 2007 temperature time series for a single location in Arctic System Reanalysis (3D-Var, land assimilation of vegetation, snow and albedo)
- Observations in blue, analysis in red and model forecast in green
- Pre-snowmelt period cold bias exists, assimilation helps
- Significant cold bias exists during melt period (up to 15°C)
- Post-melt period performance is quite good

Model Structural Differences

Noah LSM in NCEP Eta, MM5 and WRF Models (Pan and Mahrt 1987, Chen et al. 1996, Chen and Dudhia 2001, Ek et al., 2003)
Noah-MP LSM in WRF and NCEP CFS (Yang et al., 2011; Niu et al., 2011)



Relationship to Land Data Assimilation

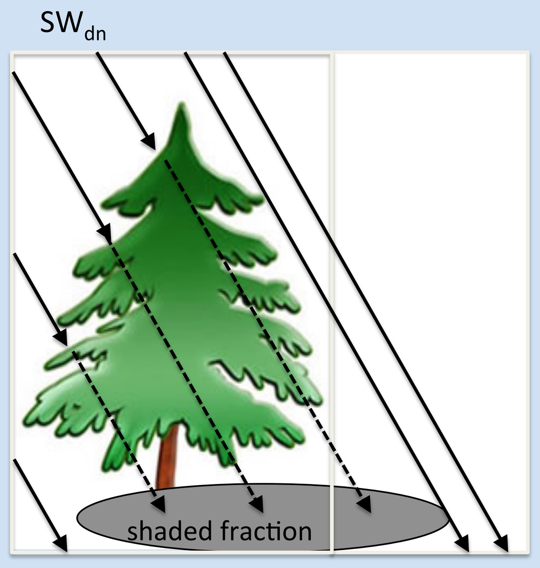
- **Noah model land data assimilation**
  - Favorable to directly assimilate (use) "bulk" land surface properties
    - Albedo
    - Green vegetation fraction (via NDVI or EVI)
    - Leaf Area Index (LAI)
  - Bulk surface treatment causes problems when heterogeneity is necessary (e.g., snow and vegetation)
- **Noah-MP model land data assimilation**
  - Increased prognostic states for assimilation
    - LAI through dynamic vegetation model
    - Albedo needs to be treated differently (parameter estimation)
    - Vegetation fraction: what does it mean in the model?
  - More available states that can inform surface emissivity models
    - Prognostic LAI, partition of canopy water into ice/liquid
- **Both models use similar soil moisture treatment for soil moisture assimilation**

Advantages with Noah-MP Structure

Noah-MP uses a two-stream radiative transfer treatment through the canopy based on Dickinson (1983) and Sellers (1985)

Canopy parameters:
- Canopy top and bottom
- Crown radius, vertical and horizontal
- Vegetation element density, i.e., trees/grass leaves per unit area
- Leaf and stem area per unit area
- Leaf orientation
- Leaf reflectance and transmittance for direct/diffuse and visible/NIR radiation

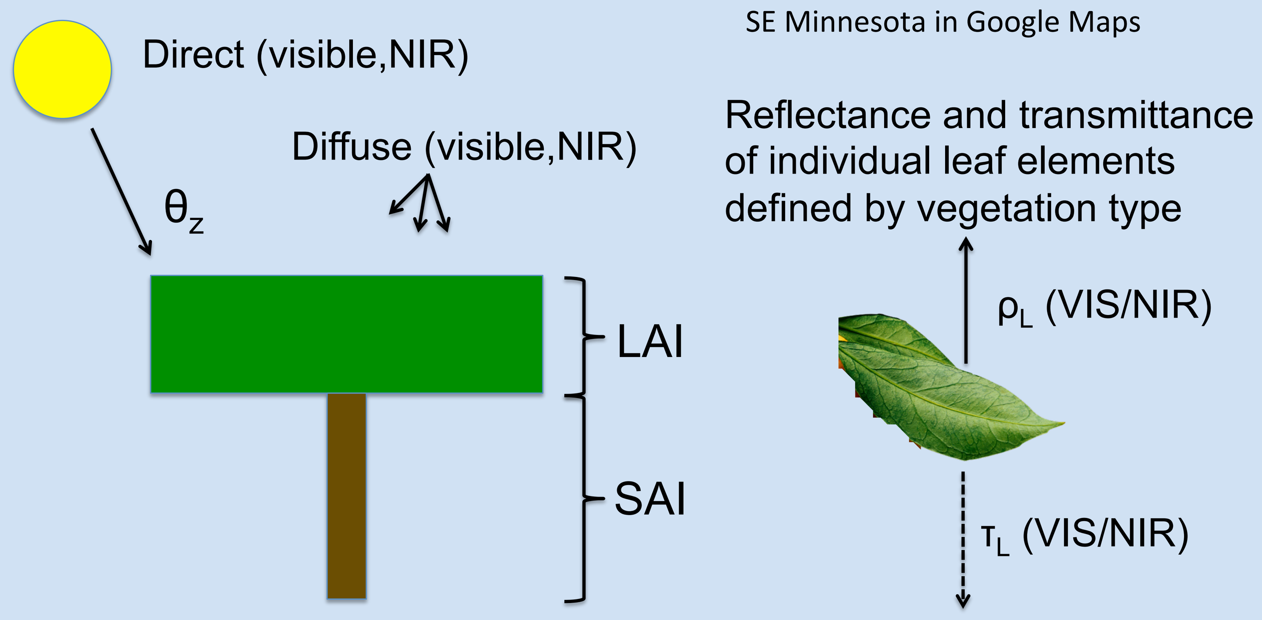
Multiple options for spatial distribution
- Full grid coverage
- Vegetation cover equals prescribed fractional vegetation
- Random distribution with slant shading



Noah-MP Canopy Structure

- Over a Noah-MP grid, individual tree elements can be randomly distributed and have overlapping shadows
- Noah-MP albedo is calculated based on canopy parameters
- Noah prescribes snow-free and snow-covered albedo from satellite climatology

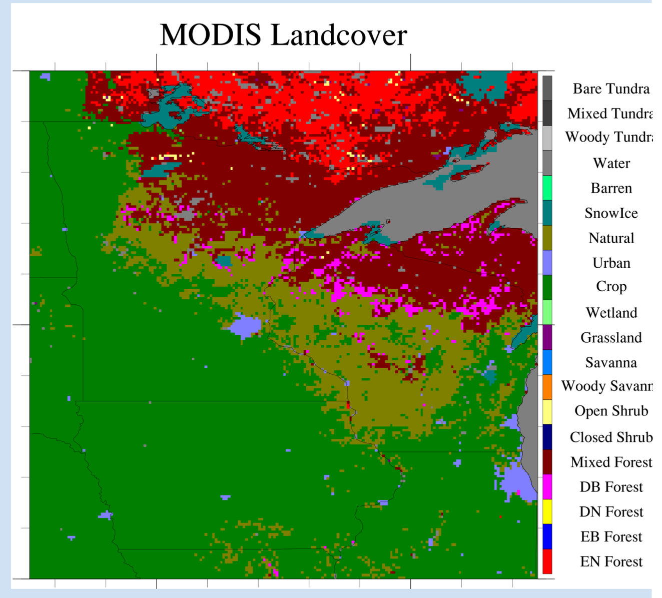
SE Minnesota in Google Maps



Canopy radiative transfer is controlled by parameters, both physical and unphysical.

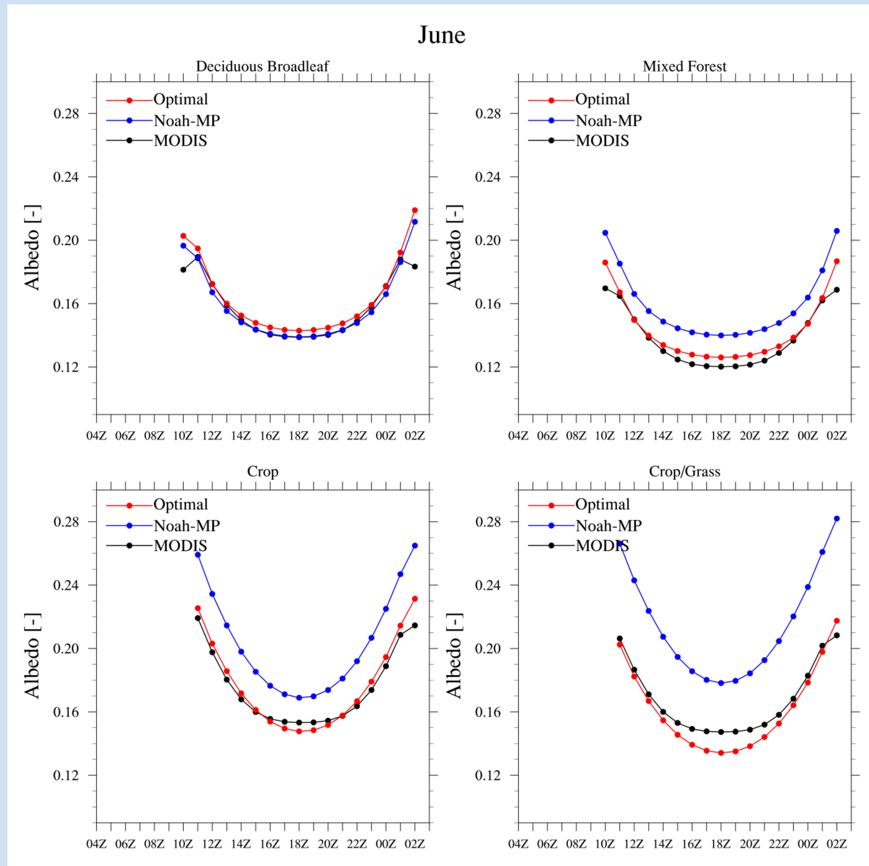
Using MODIS albedo in Noah-MP

- Create forward model of Noah-MP canopy radiation routine
  - Inputs: LAI; $\rho_{L,S}$, $\tau_{L,S}$ (VIS/NIR); zenith angle (others to be added)
  - Outputs: Total surface reflectance, VIS/NIR
- Test domain (10°x10°)
  - Central US (0.05° spatial)
  - Dominated by crop and forest
  - Known summer warm bias
- For this initial test, use default table LAI
- Conduct three-month hourly simulations (June – August)
- Do optimization of $\rho_{L,S}$, $\tau_{L,S}$ (VIS/NIR) minimizing error in total reflected energy over 3-month period (implicit zenith angle weighting)



Use MODIS 8-day BRDF parameters to determine diffuse and direct radiation as a function of zenith angle.

Monthly-averaged Diurnal Cycles of Albedo



00Z Temperature Bias at 2m – METAR observations

	All	ENF	MIX	CROP	CROP/ GRASS
N	262	2405/2	7451/28	21214/179	5176/2
Control JUN	2.1	1.7	1.2	2.2	1.7
Optimal JUN	1.4	1.0	0.4	1.5	1.0

Summary

- If models such as Noah-MP are adopted by operational centers, significant modifications to existing assimilation infrastructure must established to account for the structural differences in models.
- The direct use of many operational satellite land products will no longer be applicable.

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