Noah LSM Limitations Related to Snow Processes and Future Solutions

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1. Introduction

- The Noah land surface model (Ek, et al. 2003) is a widely-used water and energy balance model.
- Noah is used in many NCEP global and regional models and in the WRF mesoscale weather forecasting model
- Noah does not separate vegetation canopy from snow
- This results in too low surface temperatures when snow is present under a canopy and too early snow disappearance
- We look at three model simulations:
  - Default Noah v3.2
  - Default Noah with an aggressive set of tuned parameters with the sole purpose of maintaining snow pack
  - Noah-MP, the next-generation of the Noah LSM (Niu, et al. 2011), which contains a separate vegetation canopy including radiative transfer through canopy, a multi-layer snow model with liquid water retention (see Table 1)
- These simulations are run within the High Resolution Land Data Assimilation System (HRLDAS; Chen, et al. 2007), a Noah driver that uses near-surface observations of temperature, humidity, wind, radiation and precipitation to drive an offline version of Noah

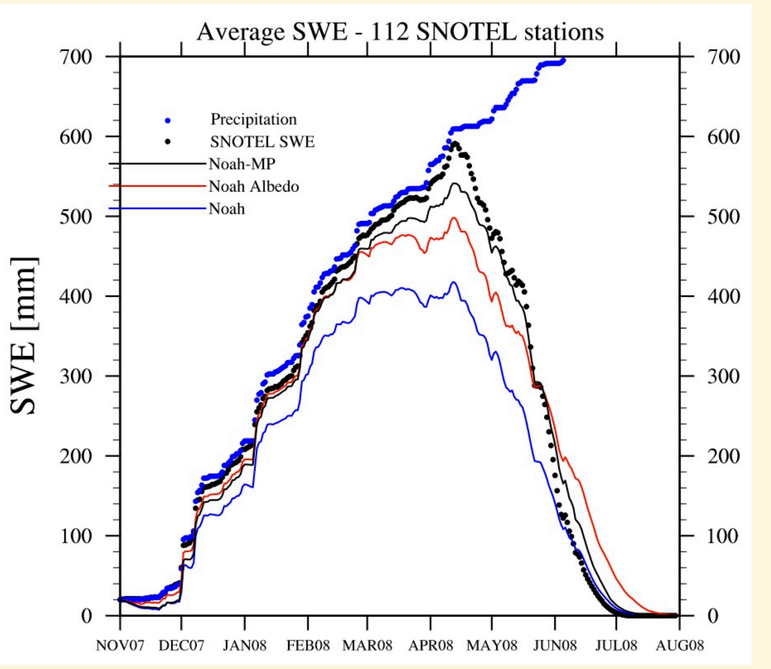
2. Comparison of Model Physics

	Separated Canopy	Canopy Radiation Transfer	Vegetation Interception	Under-canopy heat flux
Noah	N	N	Liquid	N
Noah-MP	Y	Two-stream	Liquid and ice	M-O similarity
	Time-varying snow density	**Time-varying snow albedo**	**Snow layers**	**Water transfer between layers, refreeze**
Noah	Y	Y	1 (blend w/soil)	N
Noah-MP	Y	Y	Up to 3	Y

Table 1. Snow-related characteristics of the default Noah and Noah-MP models used in this study.

3. Simulation Results vs. SNOTEL Obs

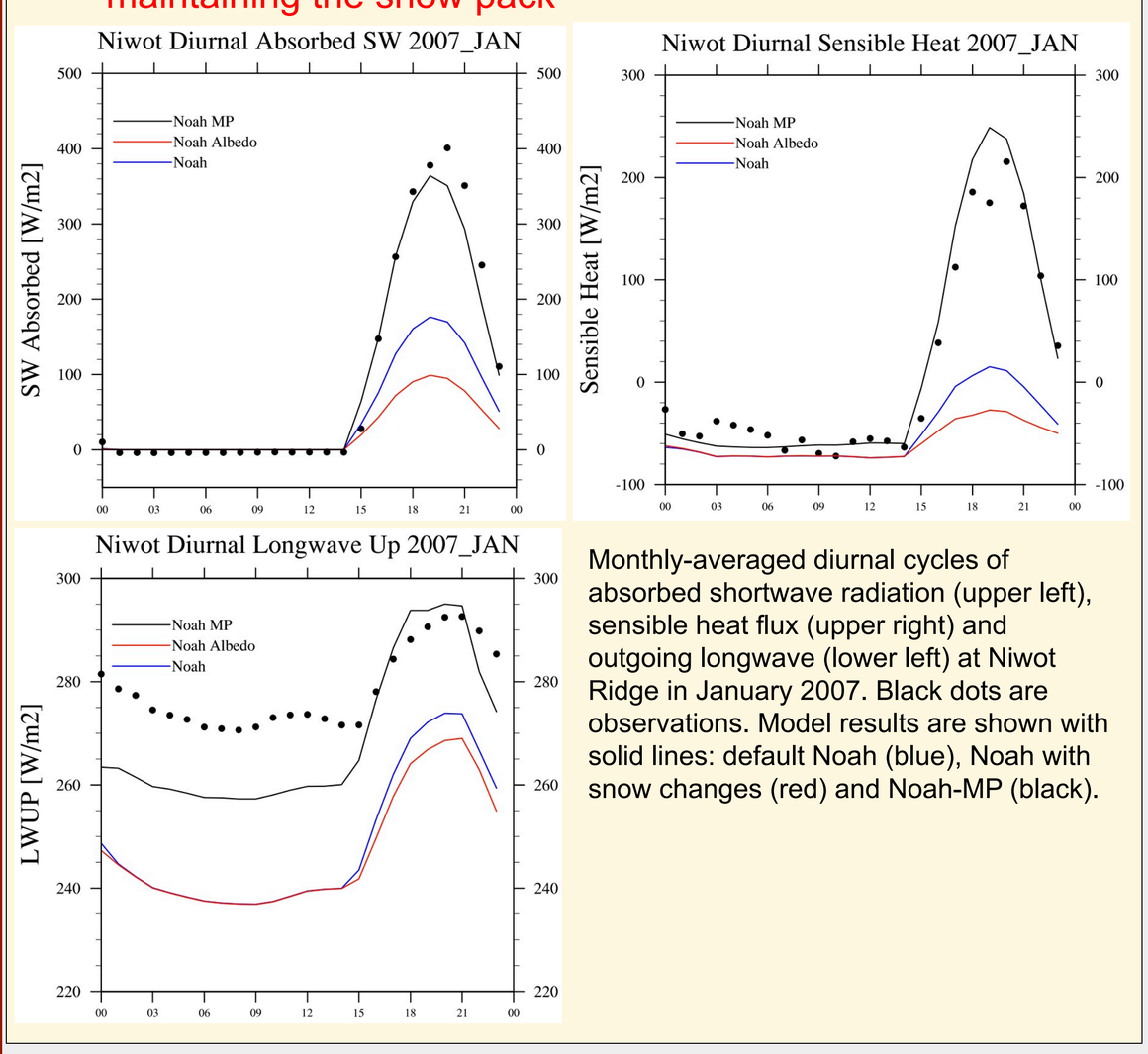
- Simulations are done at 112 SNOTEL sites located in Colorado using validated WRF model output
- The SNOTEL locations are high-elevation sites equipped with snow water equivalent (SWE) measurement devices along with other meteorological data
- Below is a time series of SNOTEL site averaged SWE for November 2007 – July 2008 along with the output from the three models. Key points:
  - Noah underpredicts peak SWE by about 200mm
  - SWE simulation is improved by aggressively adjusting parameters, but snow remains too long in spring
  - Noah-MP does a very good job throughout the season



Annual time series of SWE averaged at 112 SNOTEL locations. Observed SWE (black) and forcing precipitation (blue) are shown with dots. The default Noah (blue), Noah with aggressive albedo tuning (red) and Noah-MP (black) are shown with solid lines.

4. Simulation Results vs. Ameriflux Obs

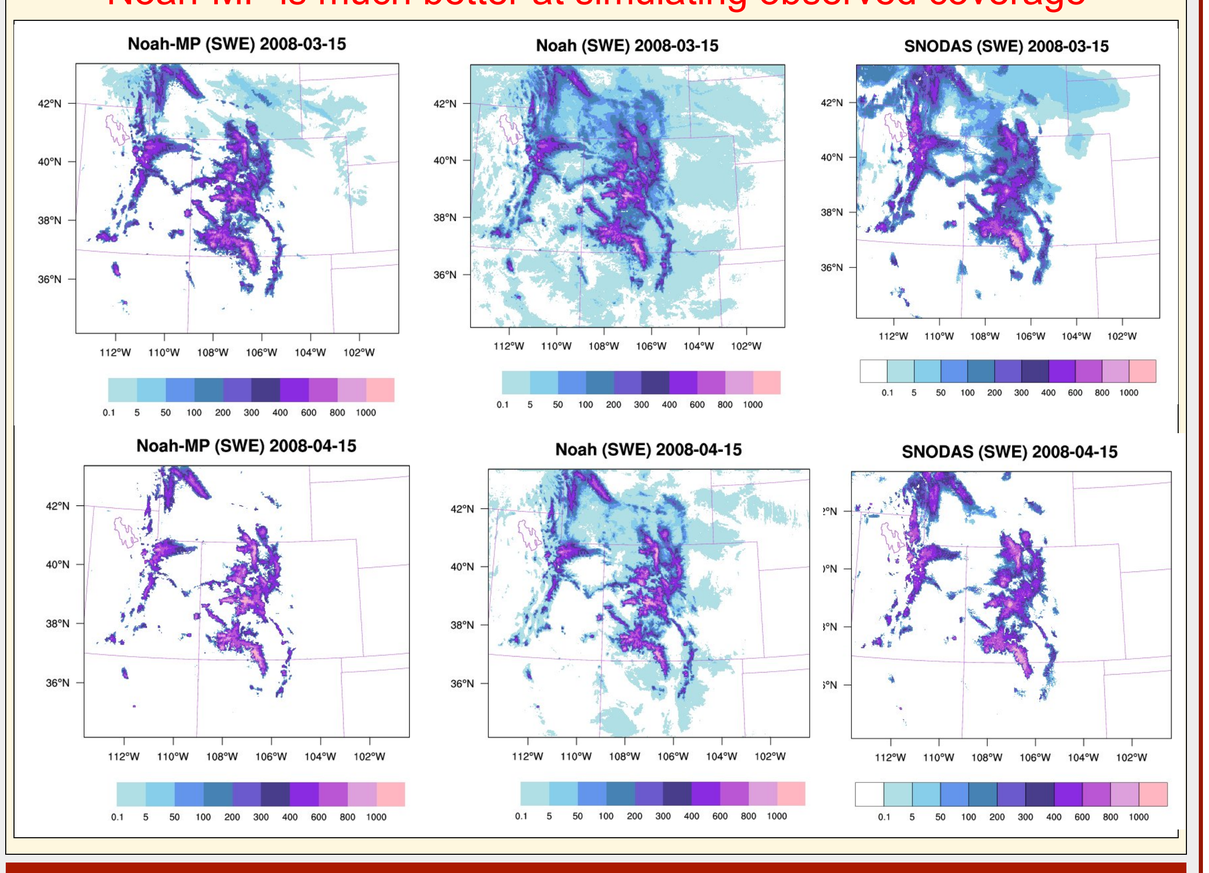
- Simulations are done at an Ameriflux observation site located at Niwot Ridge, Colorado using validated forcings from NLDAS from January 2004 – December 2008
- The Ameriflux site at the forest-dominated Niwot Ridge has eddy-covariance measurements of sensible and latent heat flux, four-component radiation and several levels of meteorological variables
- The focus here is on comparing monthly-averaged observed diurnal cycles of surface energy components with the output from the three models. Key points:
  - Aggressively adjusting parameters to maintain snow produces much too low of an albedo and therefore little absorbed shortwave radiation
  - This results in large low biases in sensible heat flux and surface skin temperature
  - The default Noah does better in surface energy components but still has a large low bias
  - The Noah-MP with its separate canopy is capable of a much better simulation of surface energy while still maintaining the snow pack



Monthly-averaged diurnal cycles of absorbed shortwave radiation (upper left), sensible heat flux (upper right) and outgoing longwave (lower left) at Niwot Ridge in January 2007. Black dots are observations. Model results are shown with solid lines: default Noah (blue), Noah with snow changes (red) and Noah-MP (black).

5. Simulation Results vs. SNODAS

- Simulations are done over the western U.S. centered on Colorado using validated WRF model output
- SNODAS, a data assimilation system that blends observations and models, is used to validate snow coverage in spring
- Compared below are modeled SWE from a simulation run November 2007 – July 2008 from two models (default Noah omitted) and SNODAS output at 15Mar and 15Apr. Key points:
  - Aggressively adjusting parameters results in improved SWE simulation in mid-winter, but maintains the snow for too long
  - Noah-MP is much better at simulating observed coverage



6. Summary

- The default Noah land surface model is not able to reproduce observed snow, especially in forested regions, due to its lack of separate canopy. The model structure results in too low surface temperature and too low energy fluxes compared to observations.
- Parameters within the Noah model can be tuned to produce more snow. This improves the mid-winter snow prediction but make the low biases in temperature and energy flux worse. Snow also remains for too long in the spring.
- A new version of the Noah model, called Noah-MP, has a separate canopy along with several other more physical representations of the surface. Noah-MP is able to maintain the snow pack both during peak time and during melt season while simultaneously improving surface energy and temperature prediction.

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References

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