# Improving the Noah Land Model for Better Noah/CRTM Coupling and Accelerated Use of Satellite Data

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## Introduction

The goal of the JCSDA is to accelerate the use of satellite observations in operational numerical predictions. To reach this goal, a major revision of the land component of these models (i.e., the Noah land model) is needed.

The overall goals of our project are to do a major revision of the Noah model to better couple the Noah model with CRTM and to accelerate the operation use of satellite data over land.

One of our major upgrades of Noah is improving the snow treatment over forest areas: Noah has a widely recognized problem in early snowmelt. While revisions from previous efforts improve the Noah snow simulations, their impacts on snow-related processes (e.g., net radiation, sensible and latent heat fluxes) were sometimes not reported.

The question we address is

*Is it possible to robustly improve the Noah simulation of snow processes and other variables (e.g., latent and sensible heat fluxes, LH and SH) without changing the model structure (for easy operational implementation at NCEP)?*

## Deficiencies & Our Revisions

➢ For deep snow with full ground snow cover under trees, Noah does not consider vegetation shading effect and computes a single temperature for vegetation, bare soil, and snow Layer. Therefore, it would overestimate the potential evapotranspiration and hence snow sublimation and snowmelt.

➢Noah only considers the aerodynamic resistance (ra). When the air temperature is greater than surface skin temperature with strong wind (i.e., under weakly stable condition), ra is found to be too small, which leads to the overestimation of downward *SH* and hence the snowmelt.

➢ There is also a Noah deficiency in the ground heat flux *G* computation in Noah because G ~ 0 under deep snow condition.

➢ The roughness length for momentum is not adjusted under snow condition in Noah.

➢ There is an abrupt change of snow density in Noah when surface temperature is near 0°C.

➢ The turbulent exchange coefficient is iteratively obtained with no more than 5 iterations in Noah. However, the model fails to converge in the turbulence computation under very stable conditions.

We have developed revised formulations for each of these deficiencies

## Results

➢ With the vegetation shading effects on snowmelt and sublimation, Exp 2 improves the SWE. The snow depth is still underestimated.
➢The under-canopy resistance (Exp 3) further improves the SWE and snow depth simulation, but Hsn is still underestimated.
➢The revision of snow density around 0°C (Exp 6) does not affect the SWE but significantly improves snow depth.
➢Other revisions do not change much the results in Fig. 1, but they are still important for other cases or particular periods.

**Figure 1: Comparison of daily mean SWE and snow depth from the seven simulations in Table 1 over the Niwot Ridge forest site (40.03°N, 105.55°W).**

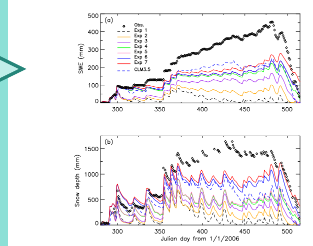


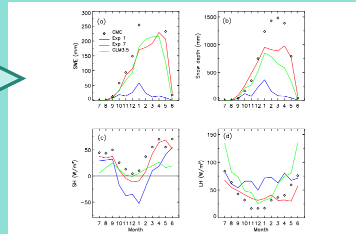
Table 1 The description of the seven Noah simulations with our revisions over the boreal forest site.

| | |
|---|---|
| 1 | Control run |
| 2 | Exp 1 + vegetation shading effect |
| 3 | Exp 2 + under canopy resistance |
| 4 | Exp 3 + adjusted ground heat flux |
| 5 | Exp 4 + revised z0m under snow condition |
| 6 | Expe 5 + adjusted snow density near 0° C |
| 7 | Exp 6 + maximum iteration of 30 |

➢ Noah (Exp 1) substantially underestimates SWE and snow depth over the Niwot Ridge site. Our revisions (Exp 7) significantly improve the Noah simulation, CLM3.5 also provides a reasonable snow simulation (Figs. 2a,b).

➢ Noah control run overestimates LH and downward SH. Our revisions agree with observational data very well. CLM3.5 simulated SH well, but is still deficient in LH simulation in summer.

**Figure 2: Comparison between the Noah control run (Exp 1), Noah new run with all revisions (Exp 7), and NCAR CLM3.5 in monthly averaged (a) SWE; (b) snow depth; (c) sensible heat flux; and (d) latent heat flux from July 2006 to June 2007 over the Niwot Ridge site.**



➢ Noah control run (Exp 1) substantially under-estimates SWE and snow depth.
➢ The new run with all revisions (Exp 7) improve SWE and snow depth significantly.
➢ In particular, snow essentially disappears at least one month too early in Exp 1 compared to observations, while the timing of snow disappearance is much more reasonable in Exp 7.

**Figure 3: Comparisons between Exp 1, Exp 7, and CLM3.5 of daily SWE in (a) and snow depth in (b) with observations over the Fraser forest site (39.53°N, 105.53°W).**

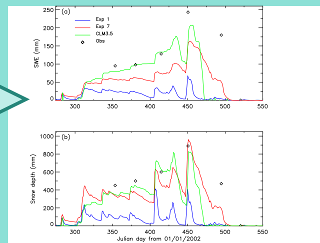
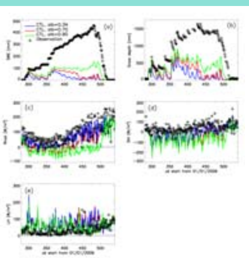


**Figure 4: Sensitivity of the Noah model (Exp 1) to the maximum snow albedo = 0.34 (control) and 0.70 and 0.9 over the Niwot Ridge forest site.**



➢ Increasing αmax, sn from 0.34 to 0.9 in Exp 1 only slightly increases SWE and snow depth. However, the early snowmelt problem still remains.
➢ Figure 4c,d,e shows that Rnet is underestimated, both *LH* and downward *SH* are overestimated using the larger maximum snow albedo = 0.9.

**Figure 5: Comparison of daily averaged SWE from Noah control run and new run with CMC data for river basins from 1993 to 1995.**

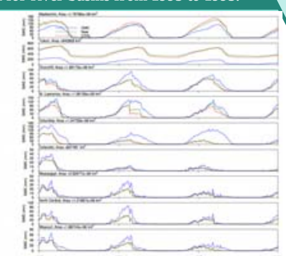
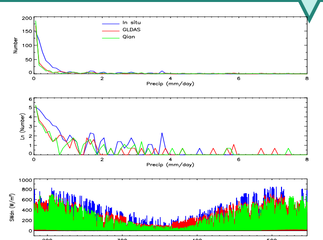


**Figure 6: Comparison of GLDAS, Qian's forcing data, and in-situ data over the boreal forest site in (a) PDF of precipitation rate; (b) Ln (PDF) of precipitation rate; and (c) Incoming SW.**



➢Figures. 6a,b shows that the Probability Distribution Function (PDF) in precipitation from Qian's NCAR reanalysis and GLDAS are less than that from in-situ data over the boreal forest site.
➢ Figure 6c indicates that downward SW radiation from GLDAS and Qian's NCAR reanalysis are less than observations.

➢ The results from single point tests and global tests indicate that our new revisions have significantly positive impact on the snow simulation using in situ forcing data, but minimal effect using GLDAS forcing data. Question: Is this related to the robustness of our revisions or issues with the forcing data?

## Conclusions

➢ Our revisions significantly improve the Noah snow simulations such as SWE, snow depth, *SH*, and *LH* over the Niwot Ridge site and the boreal forest site.
➢ Without any tunings, our revisions significantly improve the Noah snow simulation over another high-altitude midlatitude forest site (the Fraser forest site).
➢ Without any tunings, our revisions over the Valdai grassland site improve the SWE in some years and do not degrade the Noah simulation in any years.
➢ Our revisions maintain the Noah model structure and do not introduce new prognostic variables for easy implementation in NCEP operational models and WRF.
➢ Noah with our revisions is as good as or slightly better than the much more complicated CLM3.5 in snow simulation over the three forest sites.
➢ Global tests of our new revisions do not show significant impacts, and it is most probably related to the forcing data quality.
➢ For instance, precipitation and incoming SW from GLDAS and NCAR reanalysis are found to be less than those from the in situ data.