Application of an improved Noah snow albedo scheme in the simulation of snow processes over the Tibetan Plateau

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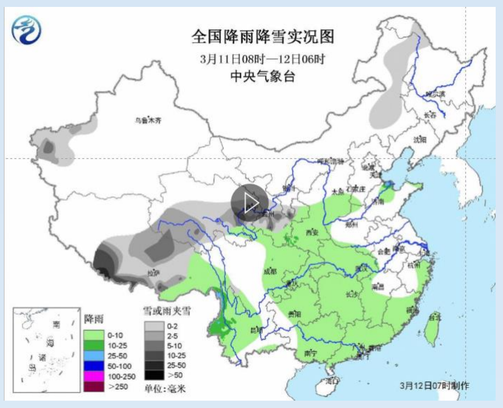
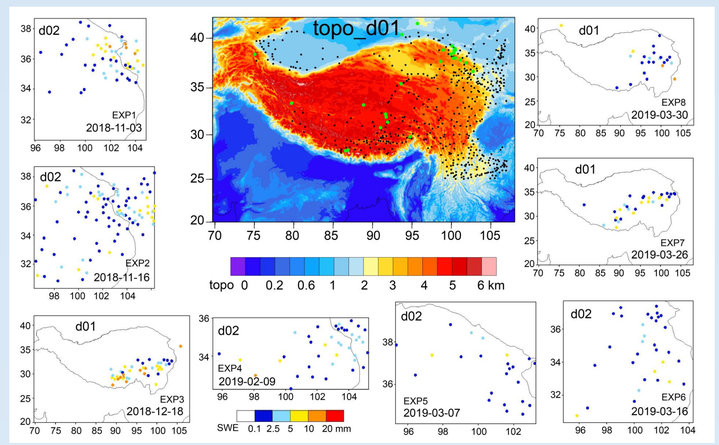
Abstract

Snow albedo is a significant factor in the land surface energy balance and the water cycle. It is usually parameterized as functions of snow-related variables in land surface models (LSMs). However, the default snow albedo scheme in the widely used Noah LSM shows evident drawbacks in land-atmosphere interactions simulations during snow processes on the complex topographic Tibetan Plateau (TP). We firstly demonstrate that the improved Noah snow albedo scheme performs well in relation to near-surface meteorological elements estimates after including MODIS albedo products and explicit considering snow depth (SD) as an additional factor. Then, we comprehensively evaluate the performance of the improved snow albedo scheme implemented in the coupled WRF/Noah in simulating additional eight snow events on the TP. The modeling results are compared with WRF run with the default Noah scheme and in-situ observations. The improved albedo scheme shows strong potential in land-atmosphere interaction estimates during heavy snow events.

A severe snow event in March 2017 over the TP



WRF domains and daily snowfall of 8 snow events in 2018-2019



Albedo parameterization schemes

- **Noah albedo scheme**

$$\alpha_{s1} = \alpha_s + L_v(0.85 - \alpha_s)$$

$$\alpha_{s2} = \alpha_{s1}(A^{(\frac{t_s}{86400.0})^B})$$

$$\alpha = \alpha_{bg} + S_c(\alpha_{s2} - \alpha_{bg})$$

- **Improved albedo scheme**

(Oerlemans & Knap, 1998)

$$\alpha_{snow}^{(i)} = \alpha_{firn} + (\alpha_{freshsnow} - \alpha_{firn})e^{(\frac{s-i}{t^*})}$$

$$\alpha^{(i)} = \alpha_{snow}^{(i)} + (\alpha_{ice} - \alpha_{snow}^{(i)})e^{(\frac{-d}{d^*})}$$

$d(i) - d(i-1) \geq 0.02$ m snowfall on day i

Experimental designs for the snow event in 2017 (25 km Res.)

Exp.	LSM	Albedo scheme	estimate parameters in albedo scheme
CTL	Noah	Noah default	None
WRFO	Noah	The improved scheme (d*0.023, t*0.42, 0.51, 0.79, 0.19)	Observed SD, MODIS reflectance
WRFM	Noah	The improved scheme (d*0.11, t*1.38, 0.13, 0.79, 0.19)	Model SD, MOD09CMG
WRFC	CLM	CLM default	None

Experimental designs for the snow events in 2018-2019 (5km, 1km)

Exp.	LSM	Albedo scheme
def_scheme	Noah	Noah default
new_scheme	Noah	The improved scheme in WRFM

Results

Near-surface air temperature & Albedo for the 2017 event

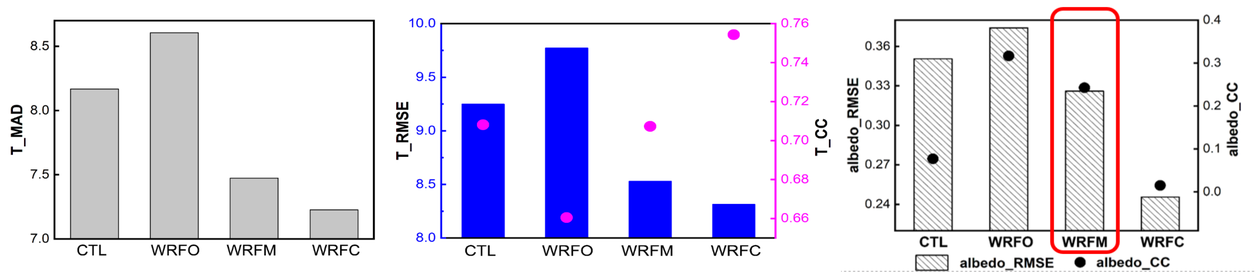


Fig. 1 RMSE, correlation coefficient (CC) and mean absolute deviation (MAD) of near-surface air temperature (T) and albedo estimates during the snow event in March 2017

Near-surface air temperature for 8 snow events in 2018-2019

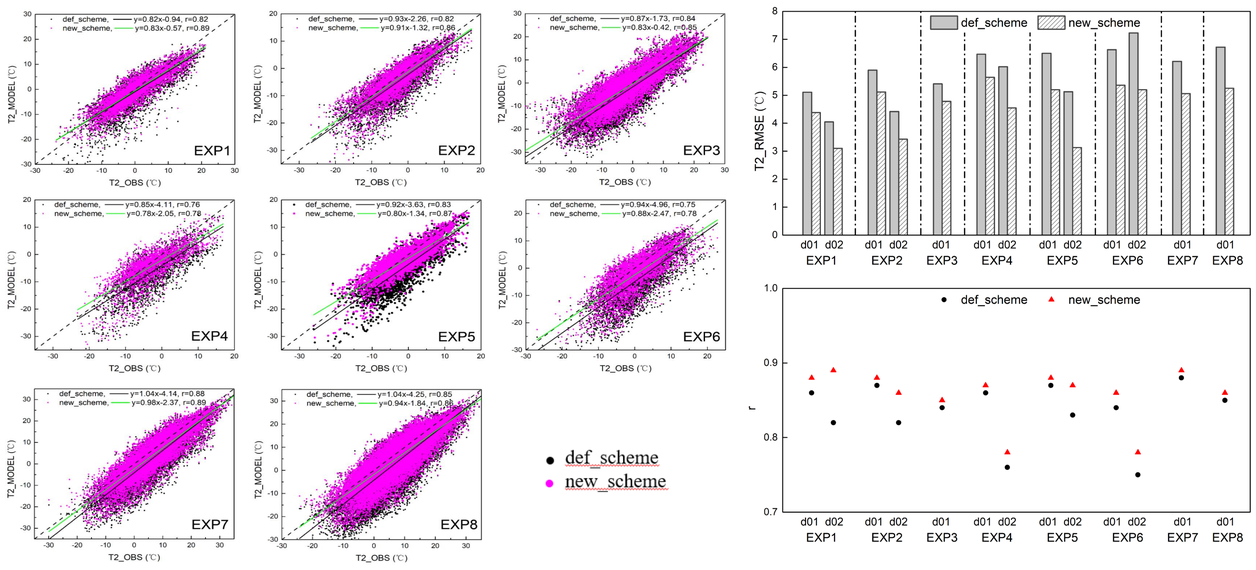


Fig. 2 The model estimates and in-situ observations of near-surface air temperature (T2), and the RMSE and correlation coefficient (r) during 8 snow events in 2018-2019

Albedo for 8 snow events in 2018-2019

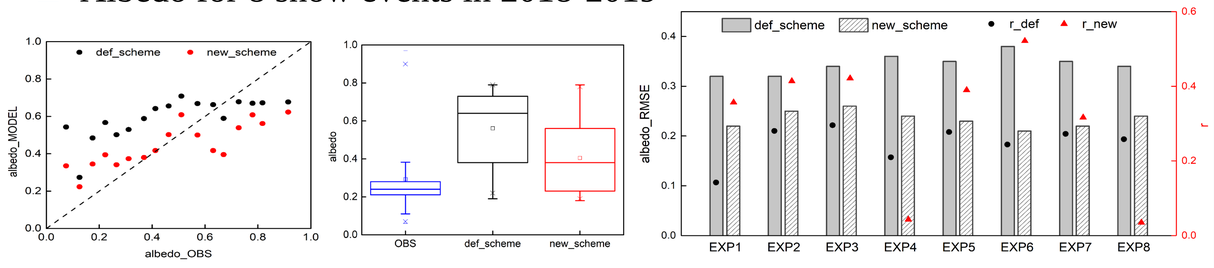


Fig. 3 The model estimates and in-situ observations of albedo, and the RMSE and correlation coefficient (r) during 8 snow events in 2018-2019

Turbulent heat and water vapor exchanges

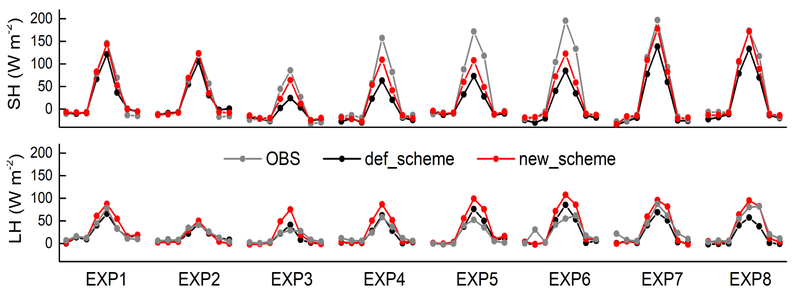


Fig. 4 The diurnal patterns of the model estimates and in-situ observations of surface sensible (SH) and latent (LH) heat fluxes during 8 snow events in 2018-2019

The link between land surface parameters and boundary meteorological variables

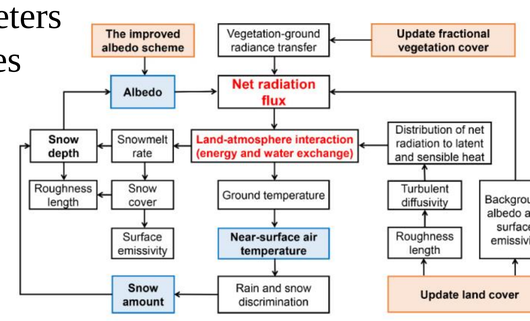


Fig. 5 The effects of the albedo scheme and the updated vegetation type and cover on model estimates of near-surface air temperature, albedo and solid precipitation during snow events

Conclusions

- The improved snow albedo scheme based on MODIS spectral albedo products and snow depth, and shows strong applicable potential in simulating snow events on the Tibetan Plateau; Compared with Noah's default snow albedo scheme, WRF applying the improved scheme significantly improves the performance of the model for air temperature, albedo and sensible heat flux;
- The improved albedo scheme significantly alleviates the overestimation of albedo, especially during snowmelt. The albedo RMSE decreased by 32%, which is the potential reason of the performance of air temperature estimates increase by 27%;
- Albedo is the key factor of surface energy balance, which determines the redistribution of turbulent water vapor and heat flux. The improved albedo scheme reduces the underestimate of sensible heat flux with an improvement of 13%. However, it is not working on improving the model's performance for latent heat flux estimates.

Reference

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2. Liu, L., Ma, Y., Menenti, M., Su, R., Yao, N., Ma, W. 2021. Improved parameterization of snow albedo in Noah coupled with Weather Research and Forecasting: applicability to snow estimates for the Tibetan Plateau, Hydrol. Earth Syst. Sci., 25, 4967-4981.
3. Liu, L., Menenti, M., Ma, Y., Ma, W. 2022. Improved parameterization of snow albedo in WRF + Noah: Methodology based on a severe snow event on the Tibetan Plateau. Adv. Atmos. Sci., 39(7), 1079-1102.