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Multiscale evaluation of the improvements in surface snow simulation

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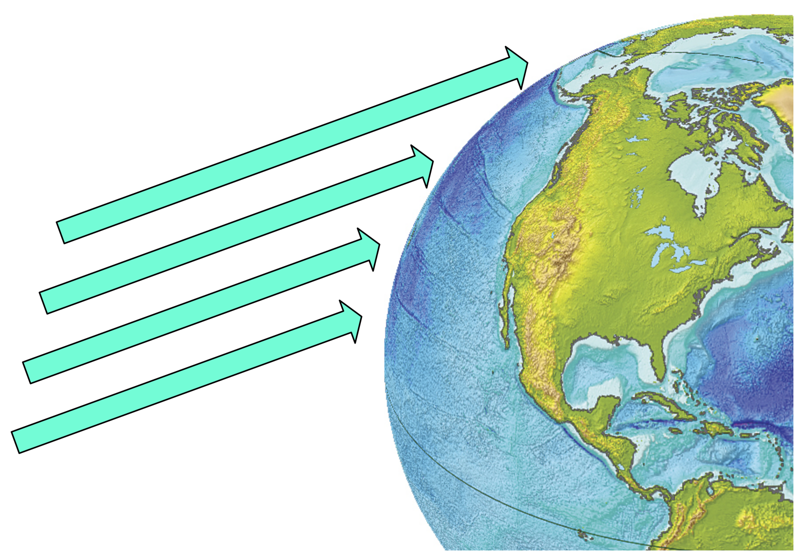
INTRODUCTION

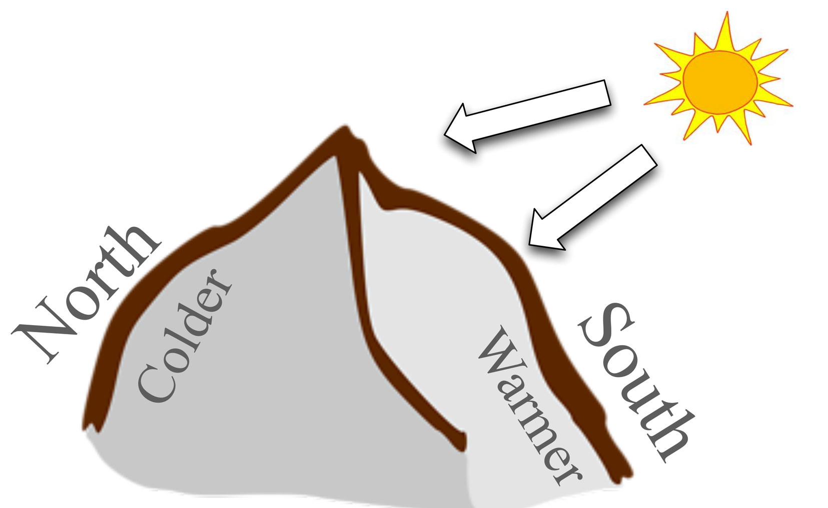
The downwelling shortwave radiation on the Earth's land surface is affected by the terrain characteristics of slope and aspect. These adjustments in turn impact the evolution of snow over such terrain. In this study, we evaluate the impact of terrain-based adjustments to incident shortwave radiation on snow simulations over two mid-latitude regions.



The influence of terrain aspect for radiation adjustment is most important in the mid-latitudes. At the equitorial regions, all slopes receive the same amount of radiation, as the sun is nearly overhead throughout the seasons. Over the high latitudes, the sun is too low on the horizon during the winter to provide enough radiation, whereas during the summer and spring all slopes receive radiation of similar intensity when summed through the long solar days.

In the northern hemisphere, the North facing slopes receive less radiation from the sun during winter relative to the South-facing slopes. These effects are reversed in the Southern hemisphere with the South-facing slopes receiving less radiation than the North-facing slopes.

The east-facing slopes receive radiation from the sun in the morning when the air temperatures are colder while the west-facing slopes receive sun in the afternoon when the air temperatures are warmer. These terrain effects subsequently influence the evolution of snow over these slopes.



APPROACH

The downward incident shortwave radiation is first separated into direct and diffuse components. The slope-aspect correction is then applied to correct the direct component. The diffuse component has no directional dependence and no adjustments are made to it.

The corrected direct shortwave flux is computed as:

$$SW'_{direct} = SW_{direct}[cos(\beta) + \frac{sin(\theta)sin(\beta)cos(\alpha_r)}{cos(\theta)}]$$

where β is the slope of the surface, θ is the solar zenith angle, α_r is the relative aspect defined as the difference $(\alpha - \alpha_o)$ between the aspect of the surface α relative to the north and solar aspect α_o relative to the north. The solar aspect α_o is calculated as:

$$\alpha_o = cos^{-1}\frac{(sin(\Lambda)cos(\theta) - sin(\delta))}{cos(\Lambda)sin(\theta)}$$

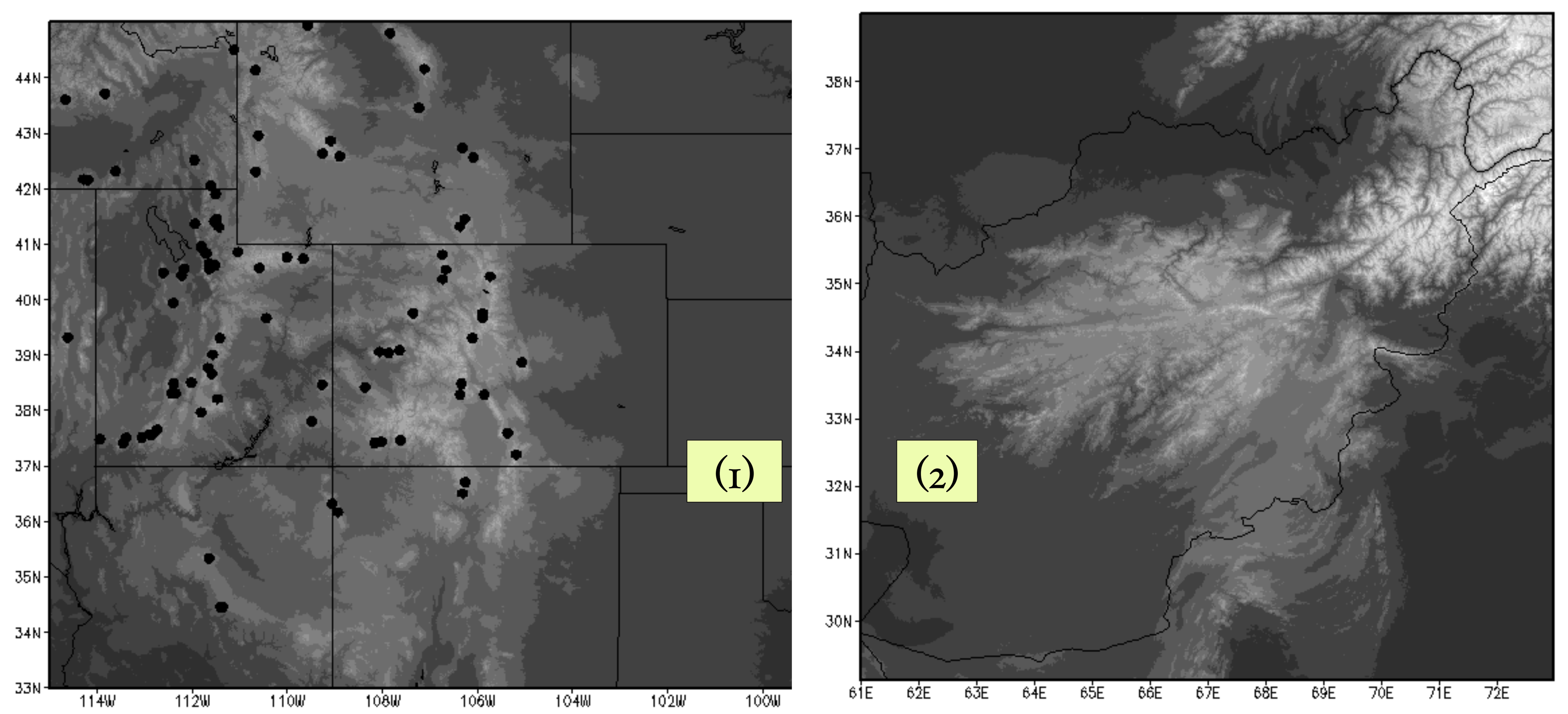
where Λ is the latitude and δ is the declination of the sun.

The corrected downward shortwave flux for a sloping surface is then computed as:

$$SW' \downarrow = SW'_{direct} + SW_{diffuse}$$

EXPERIMENTAL SETUP

In this study, we consider two mid-latitude regional domains in the Northern hemisphere at 1km spatial resolution (1) a 1600 km x 1200 km domain for the Colorado Headwater Region (CHR) and (2) a 1200 km x 1000 km domain over Afghanistan.



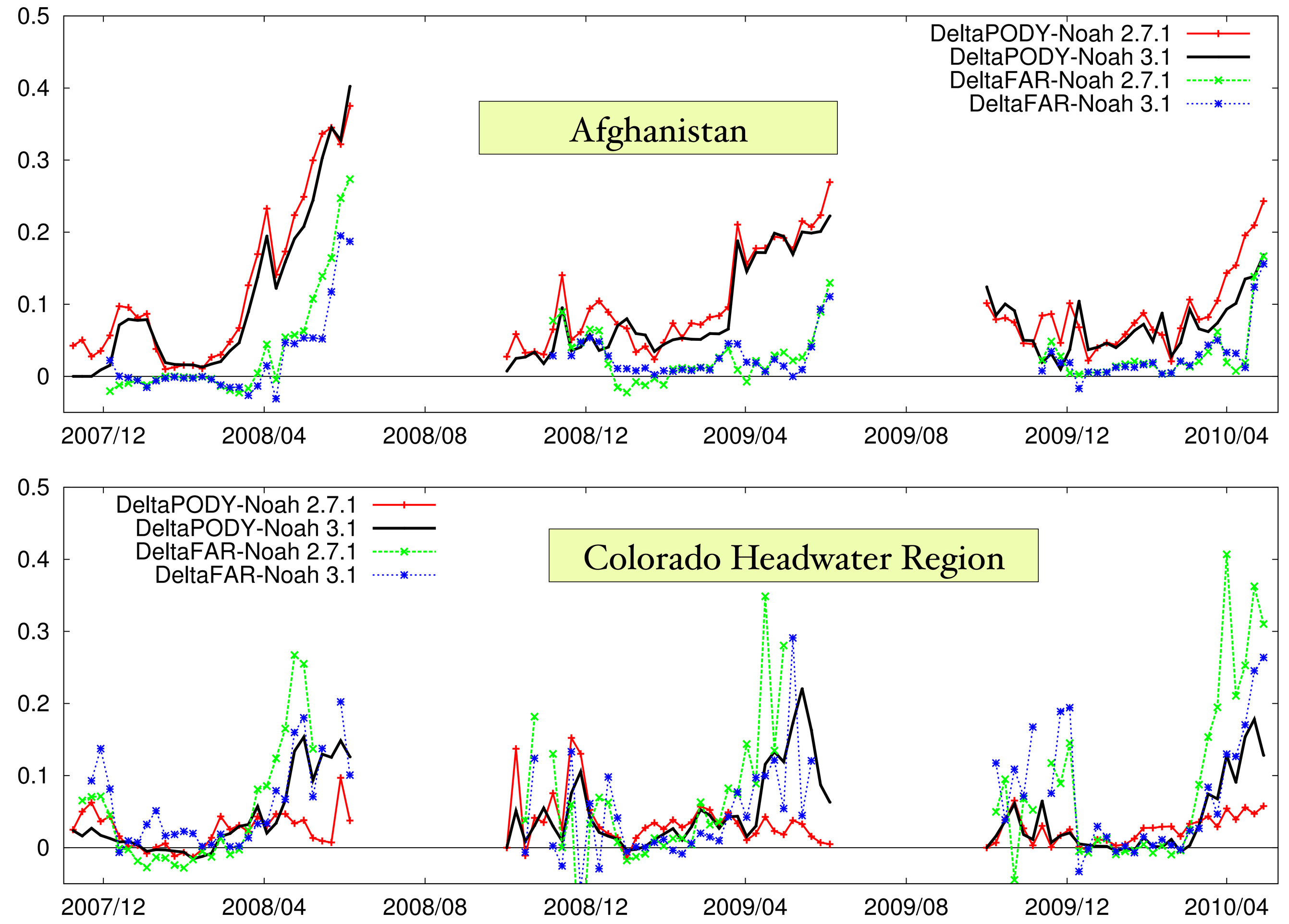
The model simulations are conducted using two versions of the Noah land surface model (versions (2.7.1 and 3.1), forced with meteorological data from NCEP Global Data Assimilation System (GDAS) and precipitation inputs from NOAA CPC's Merged Analysis of Precipitation (CMAP product. The global, high-resolution (30 m) elevation data from the Shuttle Radar Topography Mission (SRTM) is used to derive the topography datasets of elevation, slope and aspect at 1km spatial resolution.

The fractional snow cover extent global 500m product from the MODIS instrument is used as the reference data for evaluating snow cover simulations.

EVALUATION OF SNOW COVER SIMULATIONS

The snow cover simulations are evaluated using categorical measures, such as the probability of detection of "yes" events (PODy), which measures the fraction of snow cover presence that was correctly simulated and false alarm ratio (FAR), which measures the fraction of no-snow events that was incorrectly simulated.

Time series of **DeltaPODy (PODy(corrected) – PODy(uncorrected))** and **DeltaFAR (FAR(uncorrected) – FAR(corrected))** of snow cover from the LSM simulations compared against MODIS data.

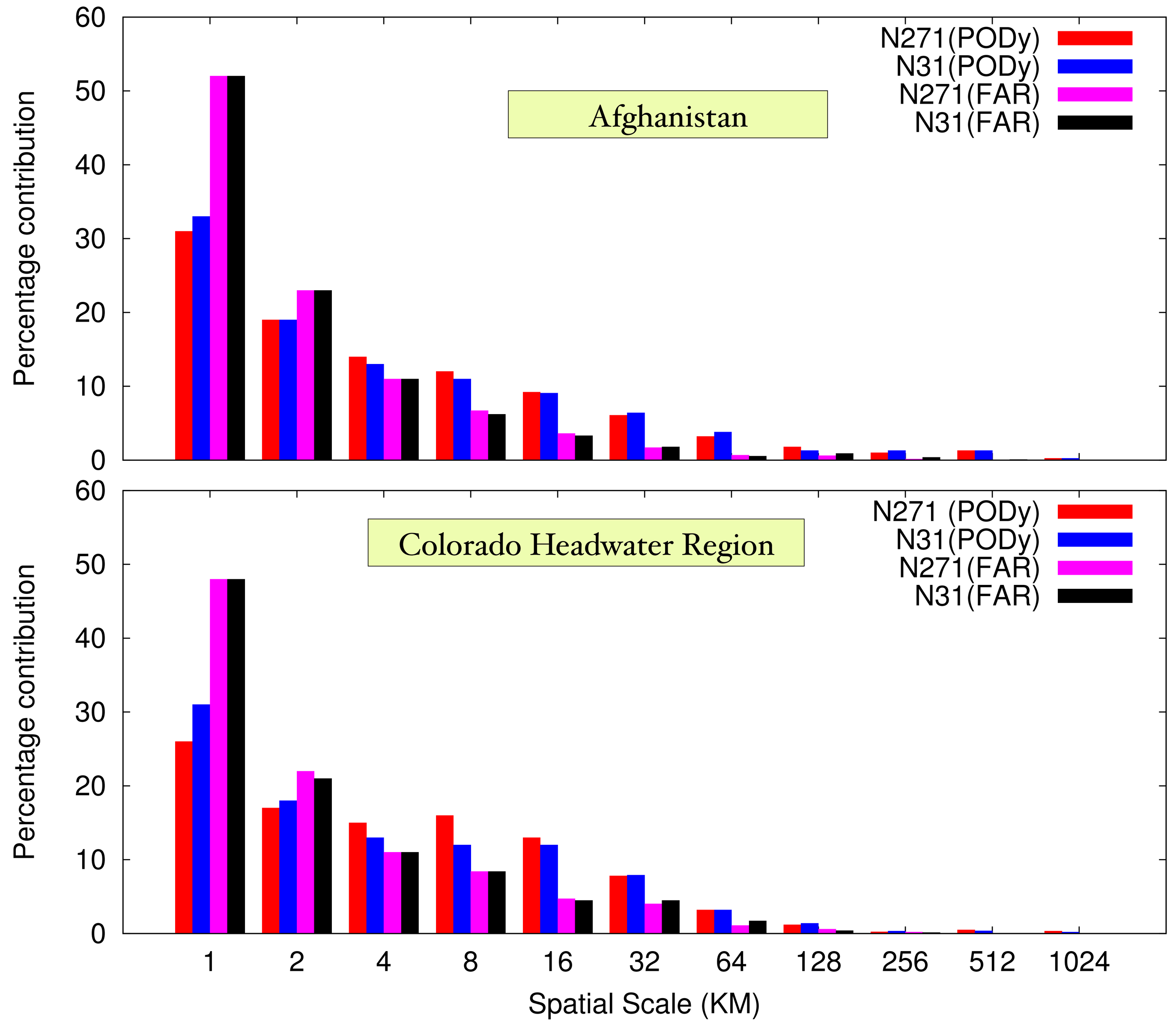


The Delta metric is generally positive through the three-year simulation period, suggesting that the topographic correction to shortwave radiation translates to systematic improvements in snow cover simulations. The observed improvement trends are similar in both versions of Noah, which suggest that the improvements obtained through topographic adjustments are retailed as added enhancements on top of the newer physics in Noah 3.1.

SCALE DECOMPOSITION ANALYSIS

The intensity-scale approach of Casati et al (2004) is used to perform the scale decomposition of the snow cover improvement fields for PODy and FAR. A two-dimensional Haar wavelet decomposition is applied to the error fields, which decomposes the 1km fields of DeltaPODy and DeltaFAR to sum of components at different spatial scales (at 2, 4, 8, 16, up to 1024 km). The mean squared error (MSE) of error fields is the sum of the MSE of different spatial scale components.

The percentage contribution of each spatial scale to the total improvement is computed as MSE(l)*100/MSE for l=1,2,..., L with L being 9 (2^9 = 1024) and is shown below



Most of the improvements in PODy and FAR are provided by the fine scales and it decreases rapidly at coarser scales. Approximately 30% of the improvements in PODy and 50% of the improvements in FAR are a function of the 1km scale alone. At resolutions coarser than 16 km, the percentage contribution drops to below 10% for PODy. For FAR, the contribution of the spatial scale is largely limited to 4km and finer.

SUMMARY

The results of this study indicate that systematic improvements in the snow fields are observed as a result of the topographic adjustments to radiation. The results indicates that the terrain-based correction of radiation leads to systematic improvments in the snow cover estimates (with roughly 12% improvement in PODy and 5% improvement in FAR), with larger improvements observed during the snow accumulation and melt periods. The scale decomposition analysis indicates that PODy improvements in snow cover simulation drop to below 10% at scales coarser than 16 km whereas the FAR improvements are below 10% at scales coarser than 4km.

ACKNOWLEDGEMENTS

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