Improvement of snow analysis using an offline land-surface model

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1 Introduction

Land-surface conditions and their initialization significantly affect the accuracy of lower-atmosphere variables in numerical weather prediction models. In particular, the presence or absence of ground snow cover is a critical factor because the significantly lower heat capacity of snow can have a great impact on near-surface temperatures, especially under clear-sky conditions when radiative cooling is dominant.

In the JMA's operational regional Meso Scale Model (MSM) with 5-km horizontal grid spacing, information on the status of ground snow cover is provided via a snow analysis system. As the results of snow cover analysis remain unchanged during the forecast period, the current model cannot incorporate consideration of increasing or decreasing snow extents.

Our verification revealed that inaccurate, overspread snow cover often causes significant errors in near-surface temperature forecasting during winter night-time (known as "runaway cooling") in the MSM. To address this problem, the snow analysis system was updated in November 2014. The new system employs an offline land surface model called eSiB to generate the first guess (background field) of snow depth distribution, which is used to estimate the snow cover extent. This report gives a brief overview of the new system and its impacts on MSM accuracy.

2 New snow analysis method

Figure 1 shows schematic diagrams of the old and new snow analysis systems. In the old system, snow depth distribution data offered by the JMA's Global snow depth analysis (with 1 x 1-degree grid spacing) were modified using observations from ground station reports. Our investigation revealed that snow cover results from Global snow analysis tended to be overestimated, especially in regions where observation stations are sparsely distributed. Excessive snow cover results were a major source of near-surface temperature forecast errors associated with runaway cooling.

To reduce these errors, the new snow analysis method employs a higher-resolution two-dimensional optimum interpolation system (2D-OI) in which snow depth first guesses (FGs) are estimated by an offline version of the land-surface model (Offline-LSM) with the same domain and grid spacing as the MSM.

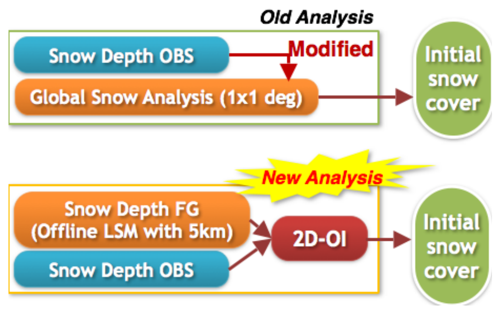

Figure 1: Snow analysis flow-charts comparing old and new

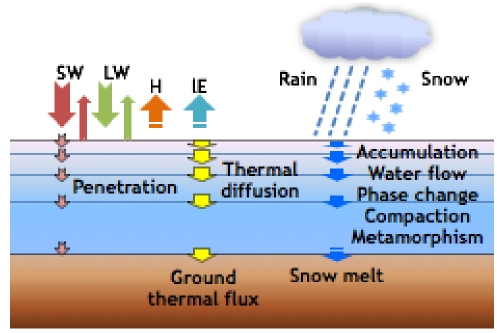

Figure 2: A schematic diagram of a multi layer snow model in eSiB (Kusabiraki, 2013).

The offline LSM (eSiB; Kusabiraki, 2013), which includes a multi-layer snowpack model, simulates typical snow processes such as accumulation and ablation (Figure 2). Temperature and wind velocity at the lowest atmospheric level and radiative flux toward the surface as predicted by the MSM are provided to eSiB for atmospheric forcing as necessary in order to drive the LSM. Radar/Raingauge-Analyzed Precipitation data [1] are also provided for forcing.

The snow depth predicted using eSiB and observations made through SYNOP and AWS facilities in Japan (AMeDAS; Automated Meteorological Data Acquisition System) are handed over to the 2D-OI system. The standard deviations of observation and background errors are set at 4 and 3 cm, respectively. The methodology of OI (e.g., formulation of horizontal correlation) is based on Brasnett (1999), where the horizontal and vertical length parameters ($1/c$ and h; see Eqs.(5) and (6) in Brasnett, 1999) are set to 25 km and 500 m, respectively.

[1] http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text13-2.pdf

Grid squares with an analysis-based snow depth greater than 5 cm are classified as snow-covered ground. In the next running of eSiB, initial values of snow water equivalent are estimated from analyzed snow depth and snow density in the previous run so that snow amounts in eSiB are consistent with analysis-based snow depth fields.

3 Results

The results of experimentation conducted to evaluate the impacts of the new snow analysis method show improvement of predicted screen-level temperature in the MSM. Figure 3 shows snow cover extents determined from the old (OLD; left) and new (NEW; right) analysis for 14 January 2014 over Japan's Hokuriku region. The new analysis provides much finer definition of snow cover extents because forecasts from eSiB are used as the FG instead of coarser snow analysis. Figure 4 shows the impact of more accurate snow cover analysis on screen level temperature prediction. The old analysis represents the snow cover area near the Fukui ground station point (indicated by blue arrows in Figure 3). MSM with snow cover initialized via the old snow analysis system (the green line in Figure 4) produces significantly lower screen-level temperature than the Fukui observation station data (the black line in Figure 4) at nighttime. Meanwhile, with snow cover information provided by the new snow analysis system, the predicted screen-level temperature is much closer to the corresponding observation. It can be concluded that the new snow analysis approach supports the generation of more realistic fields of snow cover and results in more accurate screen level temperature prediction.

A look at statistical errors calculated from a large number of samples also illustrates the accuracy improvement achieved. Figure 5 shows mean errors of the MSM with snow cover initialized using the old and new snow analysis methods (denoted as CNTL and TEST, respectively). While forecasts based on the new configuration still have cold biases at nighttime, these are reduced in TEST (indicated by red lines) against CNTL (green lines), and the root mean square errors (RMSE) in TEST are also reduced in comparison to CNTL (not shown). These figures illustrate that the new snow analysis method produces better determination of snow cover extents and screen-level temperature forecasts.

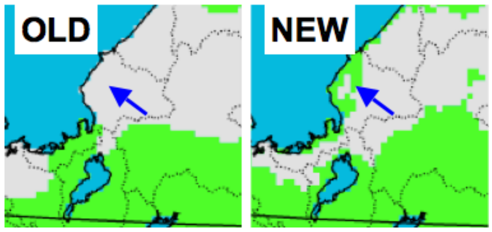

Figure 3: Example of analysis-based snow cover extents from the old and new snow analysis systems for Japan's Hokuriku region on 14 January 2014. White shading indicates snow-covered areas. Fukui ground observation station is denoted by blue arrows.

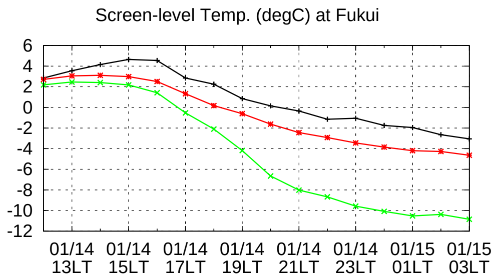

Figure 4: Time-series representation of screen-level temperature at Fukui. The red line shows forecasts of the MSM with the new snow analysis method (corresponding to the right side of Figure 3), and the green line shows that of the MSM with the old method (corresponding to the left side of Figure 3). The black line shows observations at Fukui. The x-axis shows the localtime (LT; UTC+9hrs).

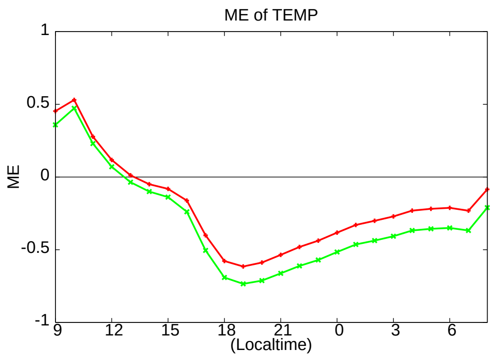

Figure 5: Time-series representation of mean errors in screen-level temperature forecasts. The green line shows CNTL results (MSM forecast with OLD), and the red line shows TEST results (MSM forecast with NEW). Statistics are computed based on AWS observations (about 300 points) for the period from 8 January to 28 February 2014. The x-axis shows the localtime (UTC+9hrs).

References

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