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# Representing subgrid snow cover and snow depth variability in a global land model: offline validation

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## 1. Introduction

Because of its large impact on surface temperature and surface energy and moisture budgets, seasonal snow cover is a key variable in the global climate system. It also plays an important role in hydrological cycle. In the present study, we incorporated the SSNOWD subgrid snow cover parameterization into the MATSIRO land surface model in order to improve the representation of snow cover fraction.

## 2. Model

### a. Land surface model MATSIRO

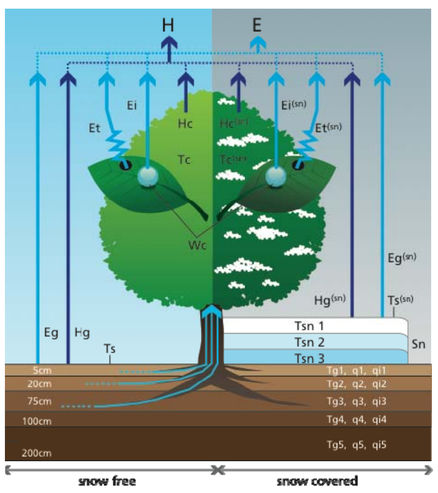


**Fig.1** Schematic diagram of MATSIRO

The MATSIRO land surface model was originally developed for climate studies at global and regional scales, and has been used also as a macro scale hydrological model in stand-alone. The latest version of MATSIRO consists from 6 soil layers (14m in total), 3 snow layers, and a single canopy layer. It prognoses the temperature and water amount of canopy, soil and snow. The surface fluxes are calculated in snow-covered and snow-free portions of the each tile and averaged weighted by the snow cover fraction. This is the same way that Liston (2004) suggested.

Snow cover fraction $A_{sn}$ is defined as

$$A_{sn} = \min\left(\frac{S_n}{S_{nmax}}, 1\right)$$

$S_n$: SWE, $S_{nmax}$: critical value at which the whole of grid is covered with snow

### b. SSNOWD (Subgrid SNOW Distribution model; Liston, 2004)

- **Accumulation season**

SSNOWD assumes that the whole grid is covered with snow and the subgrid snow water equivalent (SWE) distribution follows a lognormal distribution function $f(D)$.

$$f(D) = \frac{1}{D\zeta\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\frac{\ln(D) - \lambda}{\zeta}\right]^2\right\}$$

$$\lambda = \ln(\mu) - \frac{1}{2}\zeta^2$$

$$\zeta^2 = \ln(1 + \mathrm{CV}^2),$$

$D$: SWE, $\mu$: accumulated snow fall,
CV: coefficient of variation

The coefficient of variation (CV) is determined for global 9 categories, accounting for the physical processes that produce subgrid SWE variability.

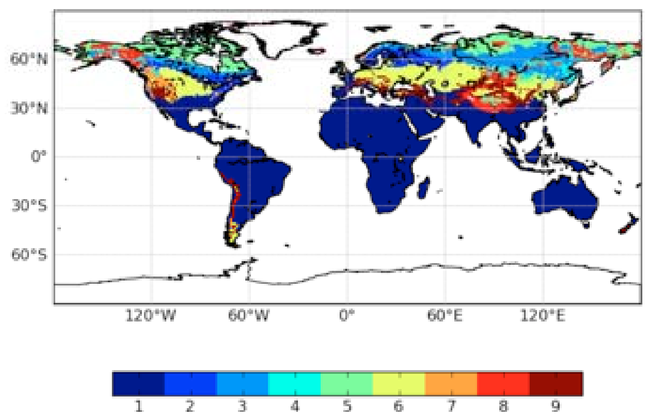


**Fig.2** Global map of the coefficient of variation (CV) categories for the subgrid SWE depth distribution function

- **Ablation season**

Snow cover fraction is represented as

$$A_{sn} = 1 - \left(1 - \frac{D_m}{D_{mmax}}\right)^{n_m}$$

$D_m$ is accumulated melt and calculated from the grid average snow water equivalent

$$S_n = \max\left(0, S_{nmax}\left(1 - \frac{D_m}{D_{mmax}}\right)^{n_m}\right)$$

## 3. Data and Experimental Design

**Experimental design**

- Period: 29 years from 1979 to 2007
- Horizontal Resolution: 1 × 1degree
- Meteorological Forcings: JRA25 corrected by GPCC (Kim et al., 2009)
- Boundary Condition: GSWP2
- Two sets of 29-year offline simulations were performed
  1. Control run using the standard version of MATSIRO (**MAT5**)
  2. MATSIRO with SSNOWD (**SSNOWD**)

**Validation Data**

- **MODIS** snow cover product (Hall et al., 2006)
- **IMS** snow analysis (National Ice Center, 2008)

## 3. Results

### a. Northern Hemisphere snow cover fraction

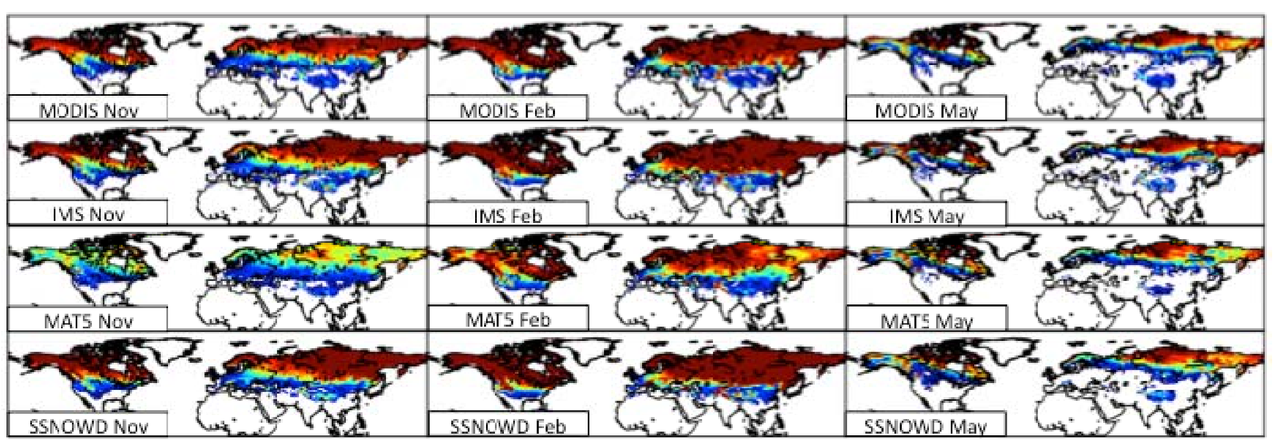


**Fig.3** Northern Hemisphere monthly snow cover fraction from MODIS, IMS, MAT5, and SSNOWD for Nov. (left), Feb. (center), and May (right), 2001-2007.

### b. Northern Hemisphere daily snow cover area

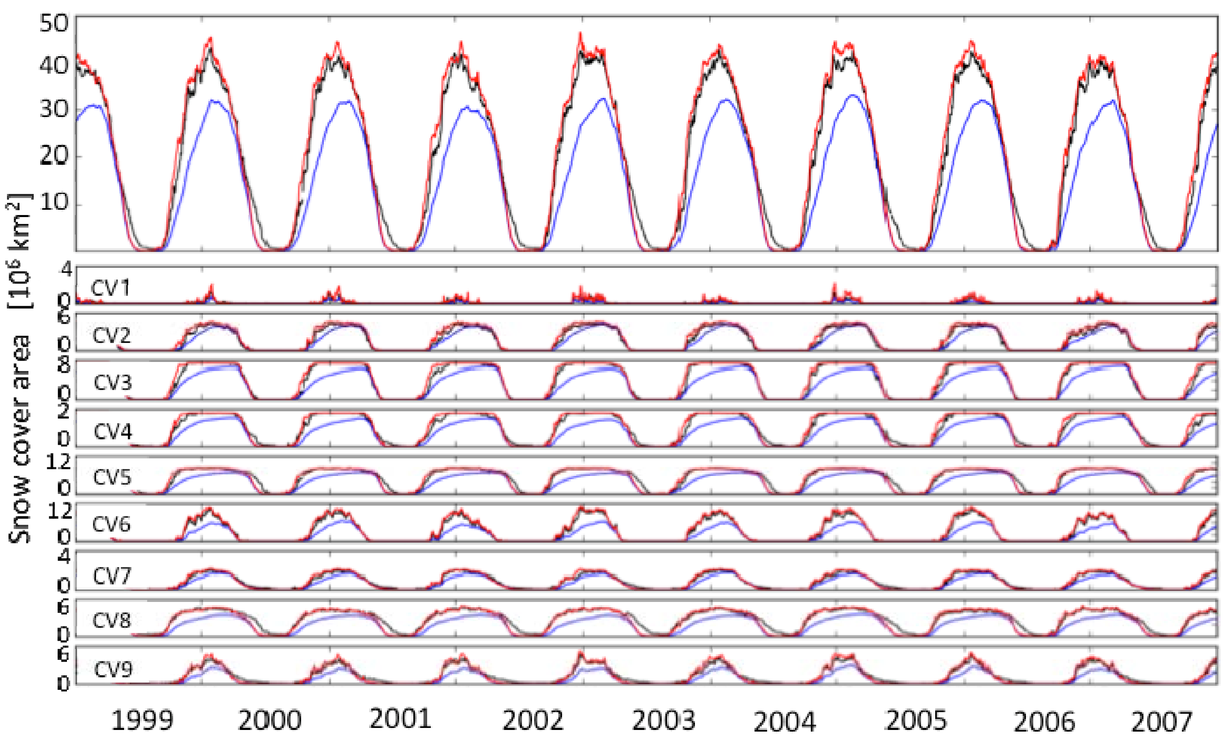


**Fig.4** Northern Hemisphere daily snow cover area from IMS (black line), MAT5 (blue line), SSNOWD (red line) for Northern Hemisphere (top) and regions with each CV categories (bottom)

| | RMSE | Bias (Sim-Obs) | Cor. |
|---|---|---|---|
| MAT5 | 7.20 | -5.59 | 0.97 |
| SSNOWD | 2.48 | 0.69 | 0.99 |

### c. Relationship between the snow depth and snow cover fraction

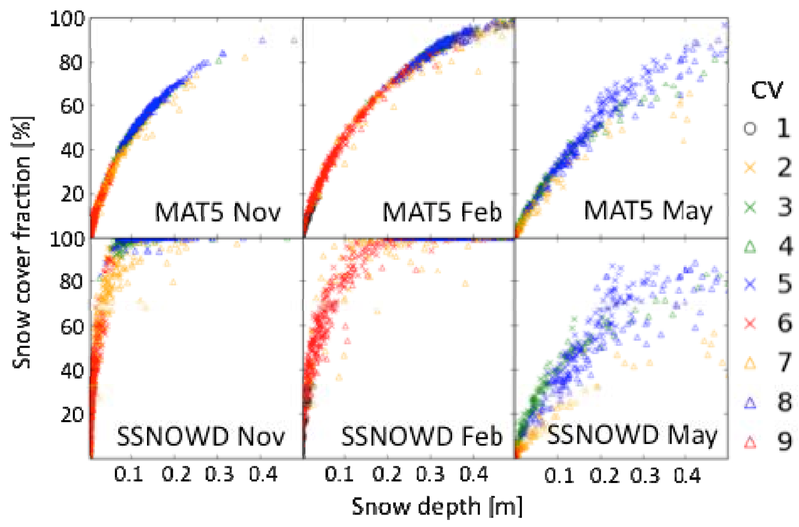


**Fig.5** Relationship between the snow depth and snow cover fraction. Niu and Yang (2007) analyzed observed snow depth and snow cover fraction for the major basins over the North America from 1979-1996. We compare the simulation results against their analysis.

## 4. Summary

We incorporated the SSNOWD subgrid snow cover parameterization into the MATSIRO land surface model. Two, 29-year offline simulations were performed: one with and one without SSNOWD. The results show that the original MATSIRO underestimates the snow cover fraction, especially for the accumulation season and/or the regions with relatively small amounts of snowfall. In contrast, the inclusion of SSNOWD improved the spatial pattern of snow cover fraction. The SSNOWD simulation largely agrees with the IMS snow analysis and led to an improved seasonal cycle of snow-covered area in the Northern Hemisphere.

**Reference**

Liston, G. E., 2004: Representing subgrid snow cover heterogeneities in regional and global models. Journal of Climate, 17 (6), 1381–1397.

Niu, G.-Y. and Z.-L. Yang, 2007: An observation-based formulation of snow cover fraction and its evaluation over large North American river basins. J. Geophys. Res., 112 (D21), D21 101.

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