Evaluation of a New Land Surface Model for JMA-GSM

- using CEOP EOP-3 reference site dataset

Masayuki Hirai
Takuya Sakashita
Takayuki Matsumura
(Numerical Prediction Division,
Japan Meteorological Agency)

Background (1)
- Development of a new land surface model

JMA-GSM : Operational global NWP model at JMA produces 9 days forecasts to support an official 1-week forecasts.

Operational SiB model (Op-SiB)

• JMA-GSM currently adopts a Simple Biosphere (SiB) model, which is developed by Sellers in 1986.

• In 1989, the SiB model implemented in JMA-GSM.

•The SiB model has not been modified substantially since then.
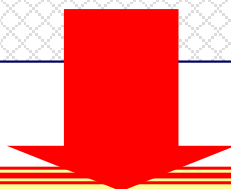
A New Land Surface Model (New-SiB)
… Snow and soil processes are improved substantially.

Background (2)
- Execution of CEOP project

- **CEOP** (Coordinated Enhanced Observing Period) project was launched in 2001 in order to enhance prediction of the global water cycle variation based on improved understanding of hydrological processes.

- CEOP is striving to integrate a huge datasets from in-situ observations, satellites and model outputs with a common format and easy of access for users.

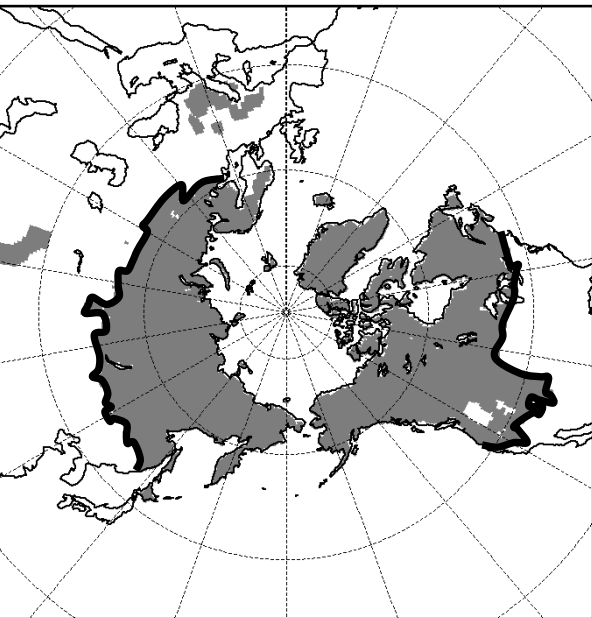CEOP affords an unique opportunity for an evaluation of a NWP model.

Model outputs

Global NWP model

Land surface model

coupling

Evaluation

Observation data

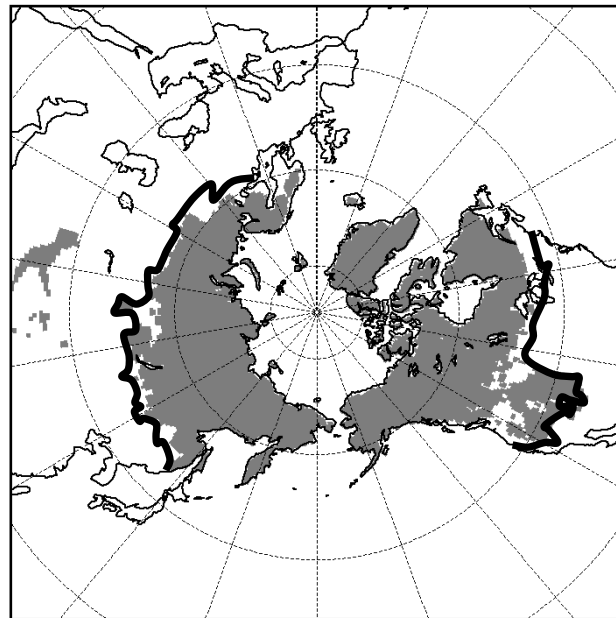In-situ observations

satellites

Refinement the model
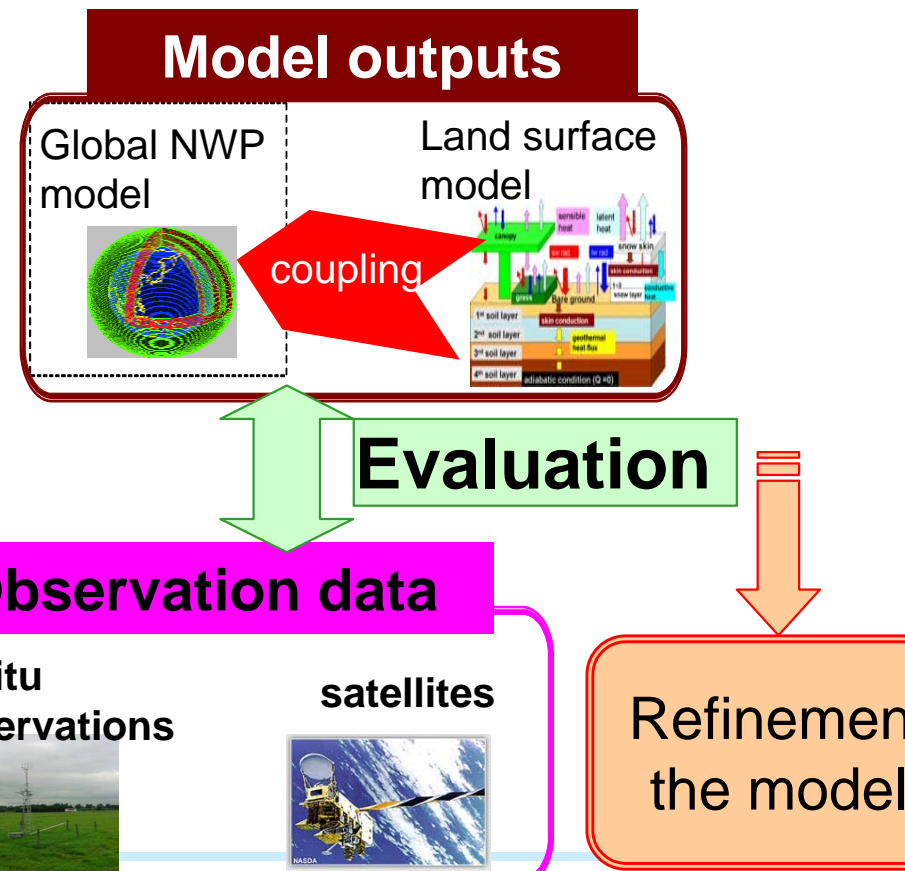
■ Overestimate of thaw

▼Area in which monthly mean SWE forecast is
larger than 4 kg/m^2 in April 2004.

Initial states

120-h forecasts

The southern edge of th
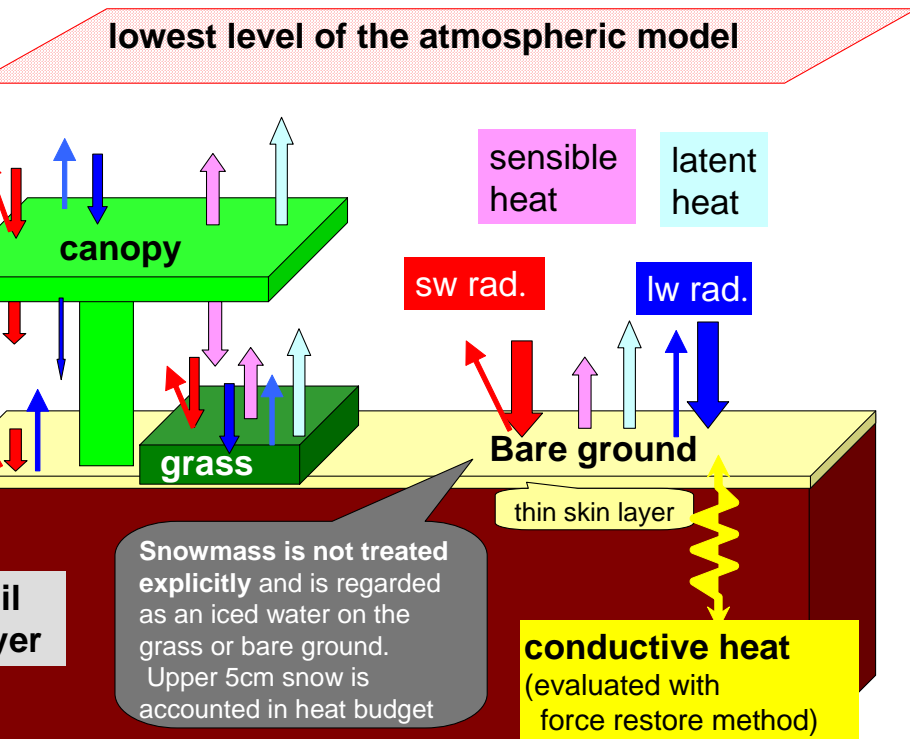snow cover tends to
retreat faster comparing
with the initial states.

■ Insufficiency of diurnal change over frozen soil areas in summer

▼Time series of surface skin temperature for Yakutsk site. Forecasts with the initial time of 12 UTC 1 July 2001 are compared with the CEOP EOP-1 in-situ dataset.
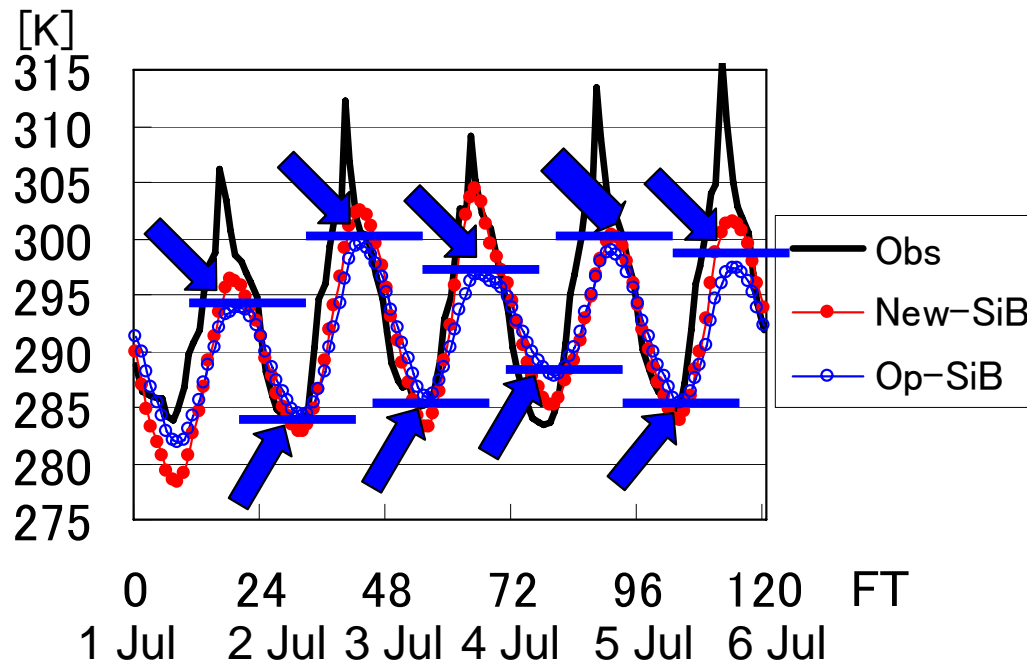
Op-SiB tends to underestimate a diurnal range of surface skin temperature for Yakutsk si

Heat budget considered in **Op-SiB**

lowest level of the atmospheric model

sensible heat

latent heat

canopy

sw rad.

lw rad.

grass

Bare ground

thin skin layer

Snowmass is not treated **explicitly** and is regarded as an iced water on the grass or bare ground. Upper 5cm snow is accounted in heat budget

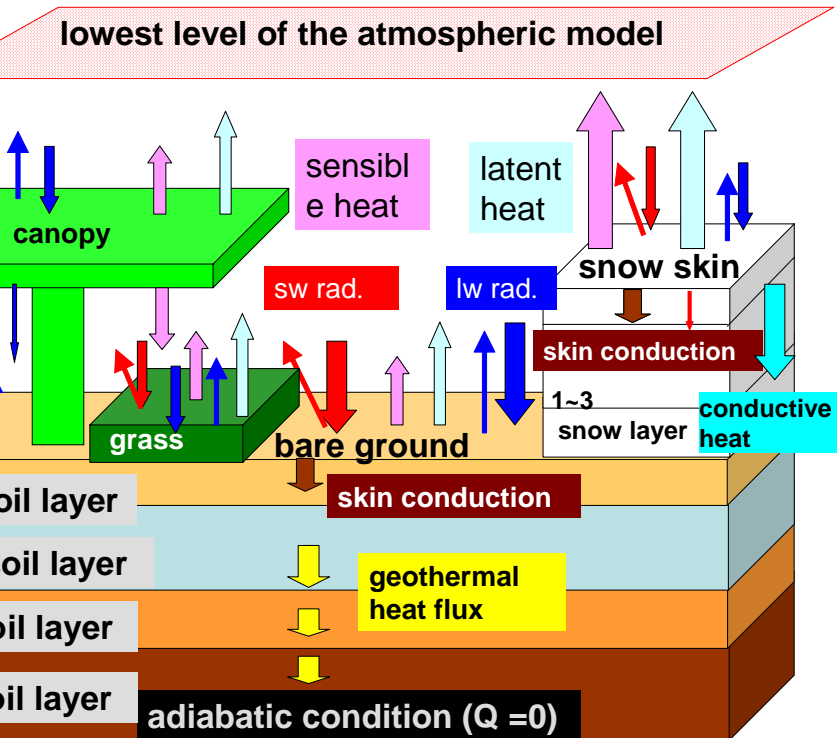**conductive heat**
(evaluated with force restore method)

Prediction of Soil temperature
- Only 1 soil layer.
- Force restore method for predicting soil temperature.
- No regard to phase change of s water/ice.

Representation of Snow Layer
- Snowmass is not treated explici and is regarded as an iced water a bare ground.
- The upper 5cm snow (iced wate is accounted in heat budget.
  >> Heat energy is not strictly conserved.
- Heat conductivity of snow and t of soil is same.

Heat budget considered in the **New-SiB**

lowest level of the atmospheric model

sensible heat

latent heat

canopy

sw rad.

lw rad.

snow skin

skin conduction

1~3 snow layer

conductive heat

grass

bare ground

skin conduction

soil layer

soil layer

geothermal heat flux

soil layer

soil layer

adiabatic condition (Q =0)

Snow model

SW rad.

Precipitation

Latent Heat

LW rad.

Snow Skin

1st snow layer

2nd snow layer

Water content due to snowmelt or rain

Sensible Heat

Heat Conduction

Viscous flow

3rd snow layer

1st soil layer

Surface

Prediction of Soil temperature
- 4 soil layers.
- heat conductivity is explicitly calculated.
- Phase change of soil water/ic is considered.

Representation of Snow Layer
- Multiple snow layers.
- Partial snow cover in a grid fo little snow
- Albedo decreasing due to agi effect.
- Other sophisticated snow processes are introduced suc as temporal changes in snow density and heat conductivity, keeping of liquid water in snow layers and so on.
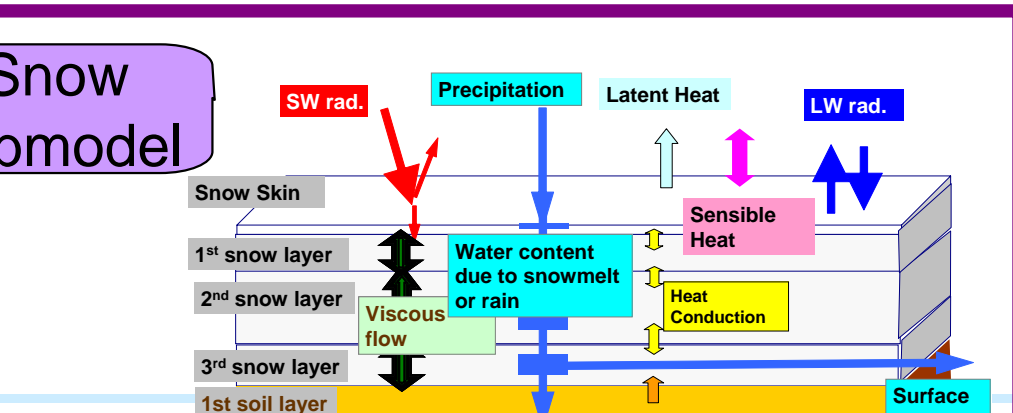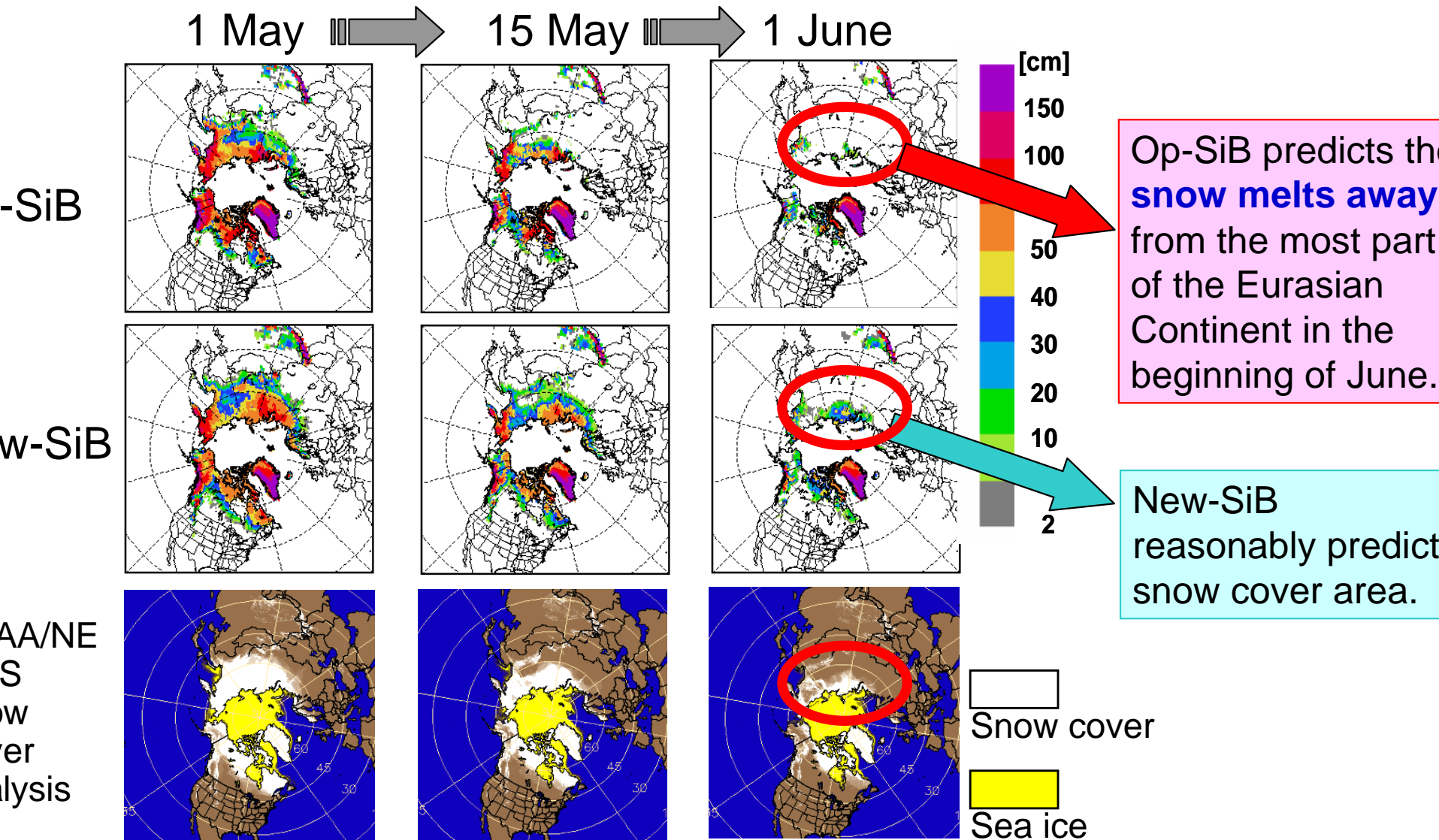
Long-range forecast experiment
>> Snow cover area reproducibility

■ Experiment methods

- Two 4-years forecasts (JMA-GSM, T106L40)

  a) Op-SiB

  b) New-SiB

- Initial time : 12UTC, 1 August 2002

- Daily snow cover forecasts averaged over 4 years are compared with the 5-years averages (1999~2003) of the daily snow cover analysis by NOAA/NESDIS.

Improvement of snow melting forecasts using by New-SiB

1 May ➡ 15 May ➡ 1 June

-SiB

w-SiB

AA/NE
S
ow
er
alysis

[cm]
150
100
50
40
30
20
10
2

Op-SiB predicts the **snow melts away** from the most part of the Eurasian Continent in the beginning of June.

New-SiB reasonably predict snow cover area.

Snow cover

Sea ice

Evaluation of a diurnal change in the model
using the CEOP EOP-3 reference site dataset

5-days forecast (JMA-GSM, T213L40) with an hourly output

Initial : 12UTC   1 October 2002

12UTC   1 December 2002

12UTC   1 January 2003   (valid 1~6 January 2003)

Verified with CEOP EOP-3 datasets released from the CEOP data archive center – UCAR.

Some sites consist of more than two observing stations. Such a site has an advantage in taking representativeness or heterogeneity into consideration. The observation data at such sites are used after averaging the data of constituents.

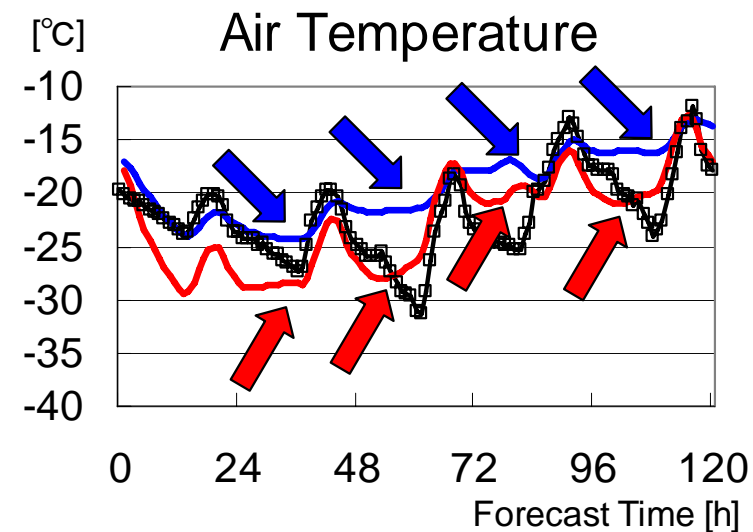# Results of using the new scheme
- Example (1) CAMP/Mongolia
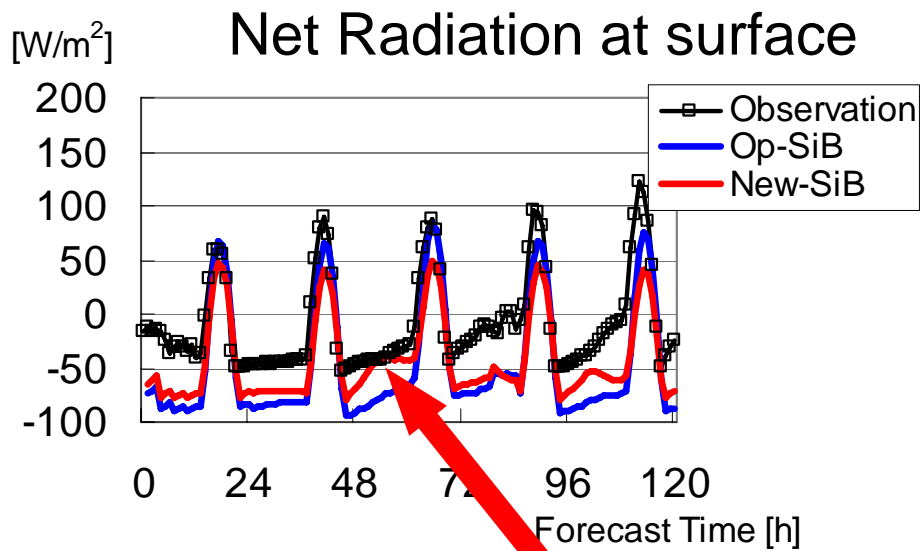### (Initial time of 1 January 2003)
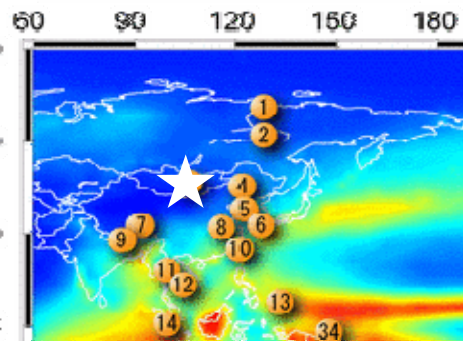
CAMP/ Mongolia

Elevation (actual/model) 1368/1357 m
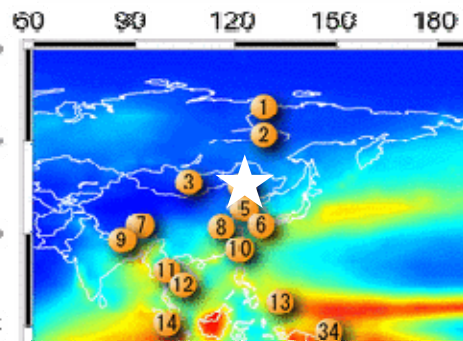Model Vegetation Type : Grassland

Air Temperature

Net Radiation at surface

New-SiB better simulates a diurnal range of temperature.

New-SiB better simulates a radiation balance
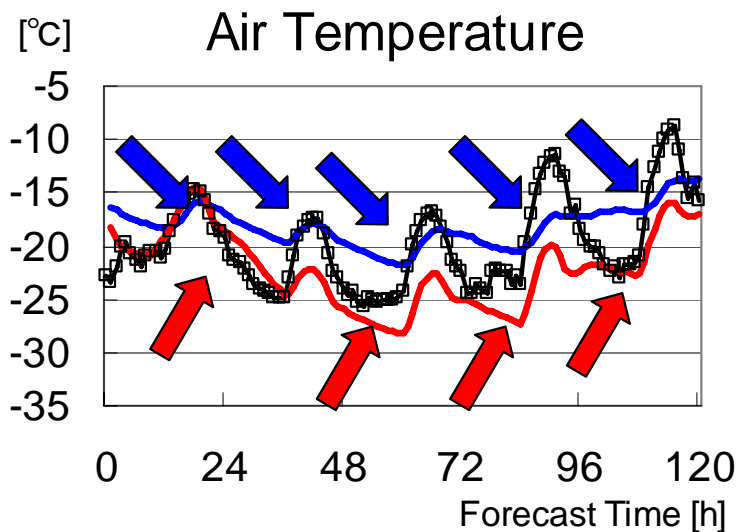
Results of using the new scheme
- Example (2) CAMP/Inner Mongolia
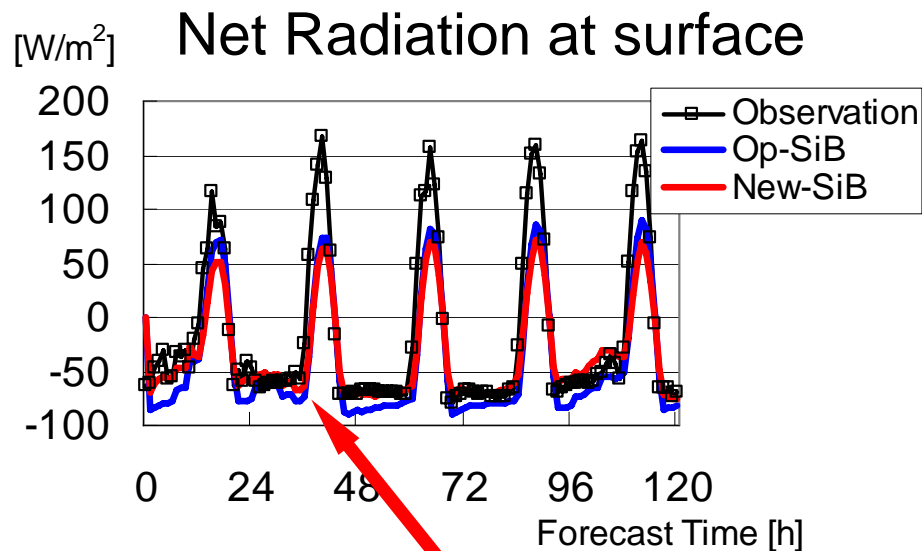### (Initial time of 1 January 2003)

CAMP/ Inner Mongolia

Elevation (actual/model) ----/173 m

Model Vegetation Type : Grassland

Air Temperature

[°C]

New-SiB better simulates a diurnal range of temperature.

Net Radiation at surface
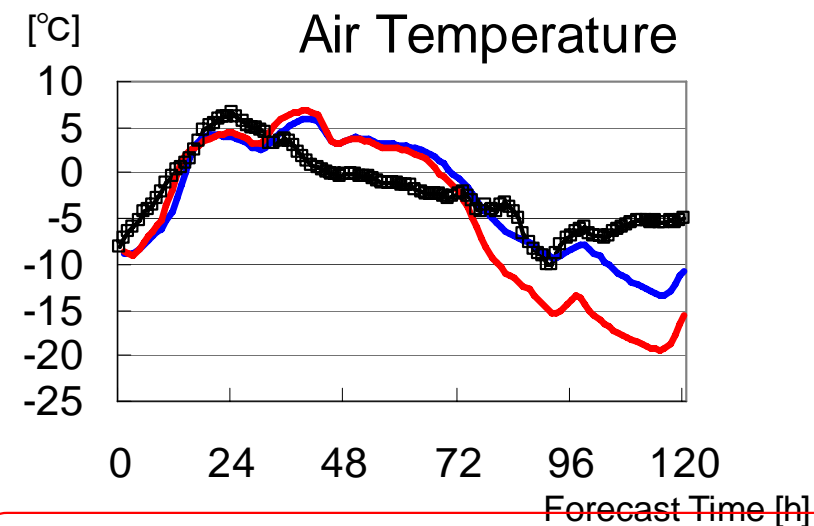
[W/m^2]

- Observation
- Op-SiB
- New-SiB

**New-SiB better simulates a radiation balance**

Revelation of the new shortcomings (1)

New-SiB predicts a near surface temperature much colder than the actual in some cases.

- In the beginning of a formation of snow cover **(BALTEX/ Linedenberg)**

[°C] Air Temperature

[mm] Previous 1 Hour Precipitation

Legend: Observ... Op-SiB... New-S...

Forecast Time [h]

After snowpack forms, predicted temperature tends to be much cooler than the actual in the New-SiB.
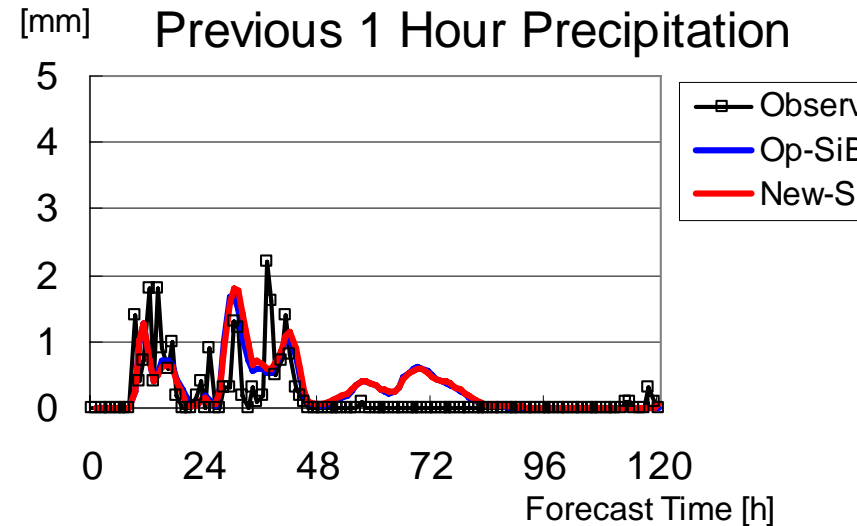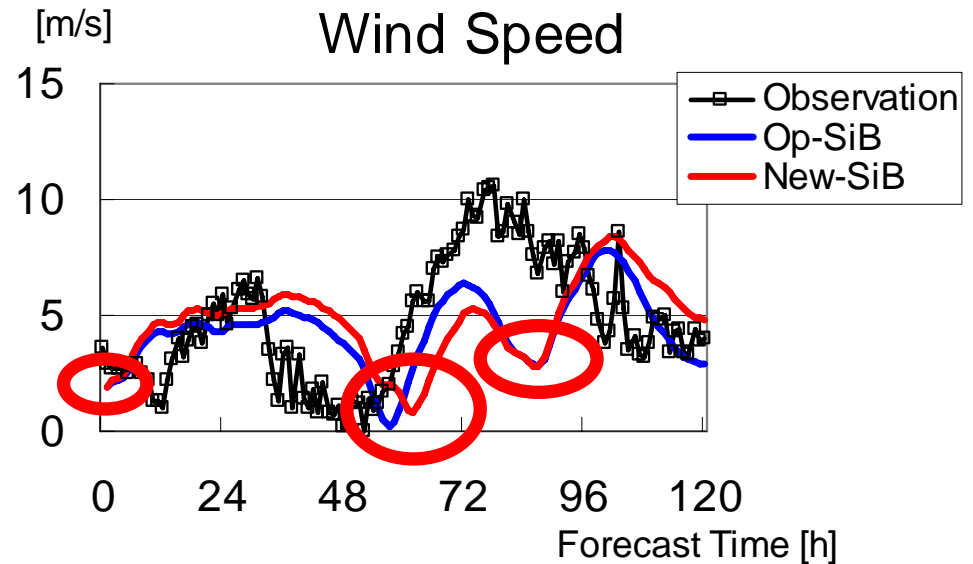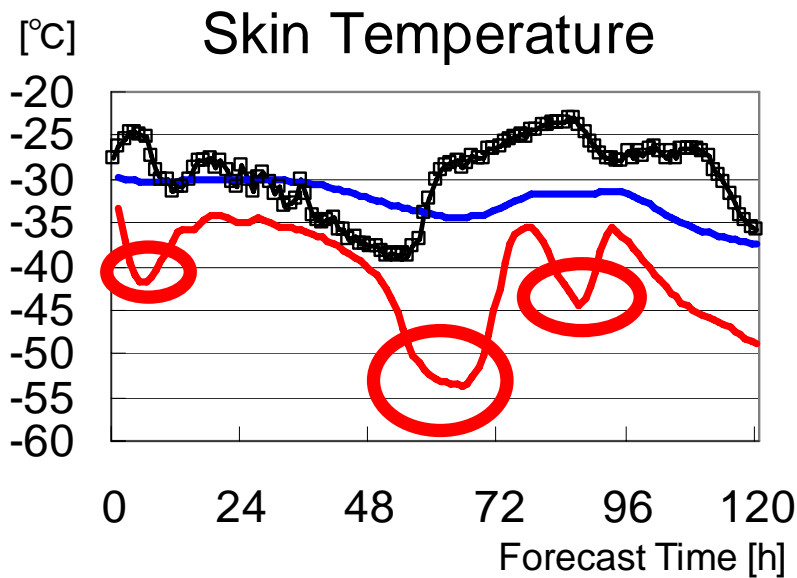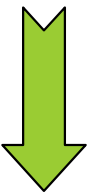
Model
Observation

Snowpa...
formatio...

Revelation of the new shortcomings (2)

■ Under a clear weather in polar night
(**ARM North Slope of Alaska - Barrow**)

When a wind speed becomes light, a cooling bias of near surface temperature is remarkable in the New-SiB.

Conclusion (1)

- ■ Development of a new land surface model
  - • New-SiB   - treats snow and soil processes elaborately.

- ■ Long-range forecast experiment shows that;
  - • Op-SiB overestimates a snow melt in a melting season

  - • New SiB predicts a snow cover area reasonably

Conclusion (2)

- An evaluation of the model using the CEOP EOP-3 reference site datasets make it clear that;

  - New-SiB better simulates a radiation balance at surface and a near surface temperature in Eurasian grassland area than Op-SiB.

  - It is revealed that the near surface temperature is predicted much colder than the actual in some cases.

Future Plans

New-SiB should be refined on heat conduction process, such as

- a setting for **<u>snow coverage for a little snow</u>**,
- **<u>heat conduction</u>** between surface skin layer and the upper soil layer,
- a setting of the **<u>uppermost soil layer thickness</u>**,
- estimation of **<u>vertical heat transportation</u>** between land surface and the lowest layer of the atmospheric model <u>under strong stability</u>.

verification the model against the CEOP in-situ observation data for second-half of EOP-3 and EOP-4 and a satellite dat

Validation of the other schemes in the model, such as a radiation, boundary layer and so on, with the CEOP observation datasets.

Acknowledgement

- We gratefully acknowledge the contributions and efforts of the University Corporation for Atmospheric Research (UCAR) in elaborating the CEOP integrated database for in situ observation.

- We also express sincere appreciations to managers of the following CEOP reference sites.
    - ARM North Slope of Alaska
    - BALTEX/ Lindenberg
    - CAMP/ Inner Mongolia
    - CAMP/ Mongolia

  The reference site data is highly valuable for evaluation of the JMA's global model.

- The operational snow cover analysis by NOAA/NESDIS (National Environmental Satellite Data, and Information Service) is referred in a verification of snow cover forecasts.