Land surface analysis at JMA

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  - Land surface model
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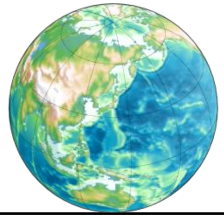
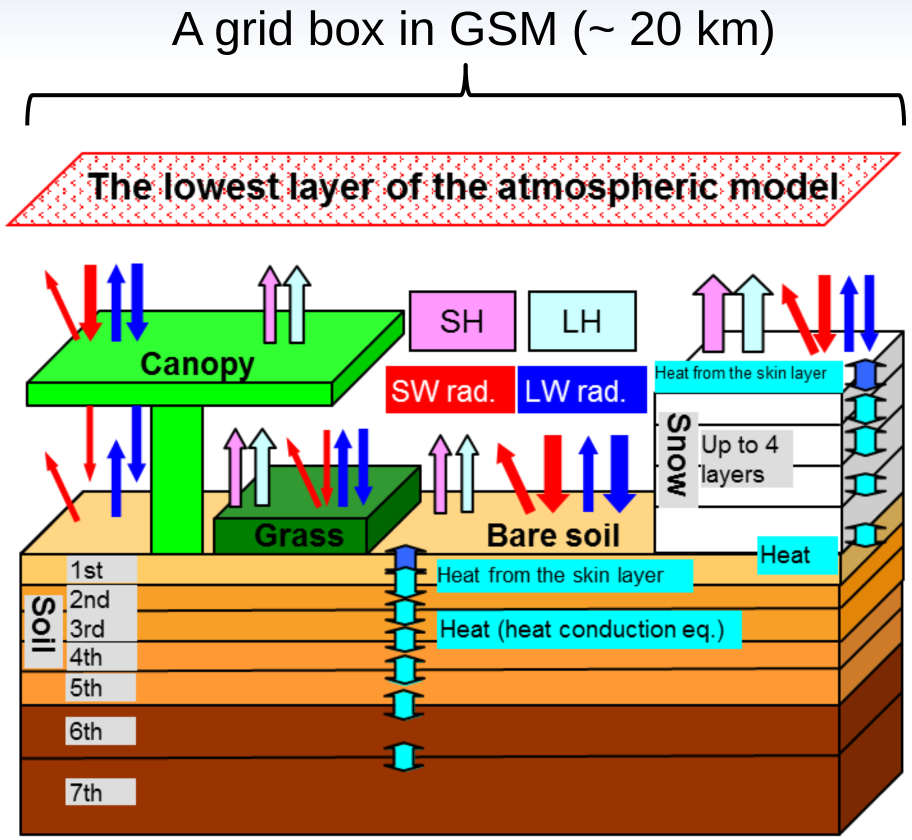
Current operational NWP models in JMA

	In Operation					
	Global Spectral Model **GSM**	Meso-Scale Model **MSM**	Local Forecast Model **LFM**	Global Ensemble **GEPS**	Meso-scale Ensemble **MEPS**	Seasonal Ensemble **CPS2**
objectives	Short- and Medium-range forecast	Disaster reduction Aviation forecast	Aviation forecast Disaster reduction	One-week forecast Typhoon forecast Early warning on extreme weather One-month forecast	Disaster reduction Aviation forecast	Seasonal forecast (three month forecast, cold/warm season outlook) El Nino outlook
Forecast domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 	Global 	Japan and its surroundings (4080km x 3300km) 	Coupled Global Atmosphere and Ocean 
Horizontal resolution	TL959 (0.1875 deg)	5km	2km	TL479 / TL319 (0.375 / 0.5625 deg)	5km	Atmos.: 1.125 deg Ocean:0.3-0.5x1 deg
Vertical levels / Top	100 0.01 hPa	76 21.8km	58 20.2km	100 0.01 hPa	76 21.8km	Atmos.: 60 (~0.1 hPa) Ocean: 52 with BBL* *Bottom Boundary Layer
Forecast Hours (Initial time)	132 hours (00, 06, 18 UTC) 264 hours (12 UTC)	51 hours (00, 12 UTC) 39 hours (03, 06, 09, 15, 18, 21 UTC)	10 hours (00-23 UTC hourly)	264 h (00, 12 UTC) 132 h (06, 18 UTC)* 27 members Extend to 432 h (4times/week) 816 h (4times/week) 13 members	39hours (00,06,12,18 UTC) 21 members	210 days (00UTC) 51 members / month
Initial Condition	Global Analysis (Hybrid 4D-Var)	Meso-scale Analysis (4D-Var)	Local Analysis (3D-Var)	Global Analysis with ensemble perturbations (SV, LETKF)	Meso-scale Analysis with ensemble perturbations (SV)	JRA-55 with ensemble perturbations (BGM)

* when a TC of TS intensity or higher is present or expected in the RSMC Tokyo - Typhoon Center's area of responsibility (0º–60ºN, 100ºE–180º).

Current operational status: Land surface model in GSM



Configuration

- Two-layer energy balance scheme based on SiB (Simple Biosphere; Sellers et al. 1986; Sato et al. 1989)
- Five components:
  - Canopy
  - Canopy air space
  - Ground (grass and bare soil)
  - Snow
  - Soil
- Two tiles (snow-covered/snow-free)
- Each grid box is isolated

Current operational status and issues: Land data assimilation

<u>Snow depth</u>

- Optimal interpolation using only ground-based SYNOP observation
  - Lead to widespread increment in data-sparse regions
- Old and low-quality climatological values are used in first-guess.

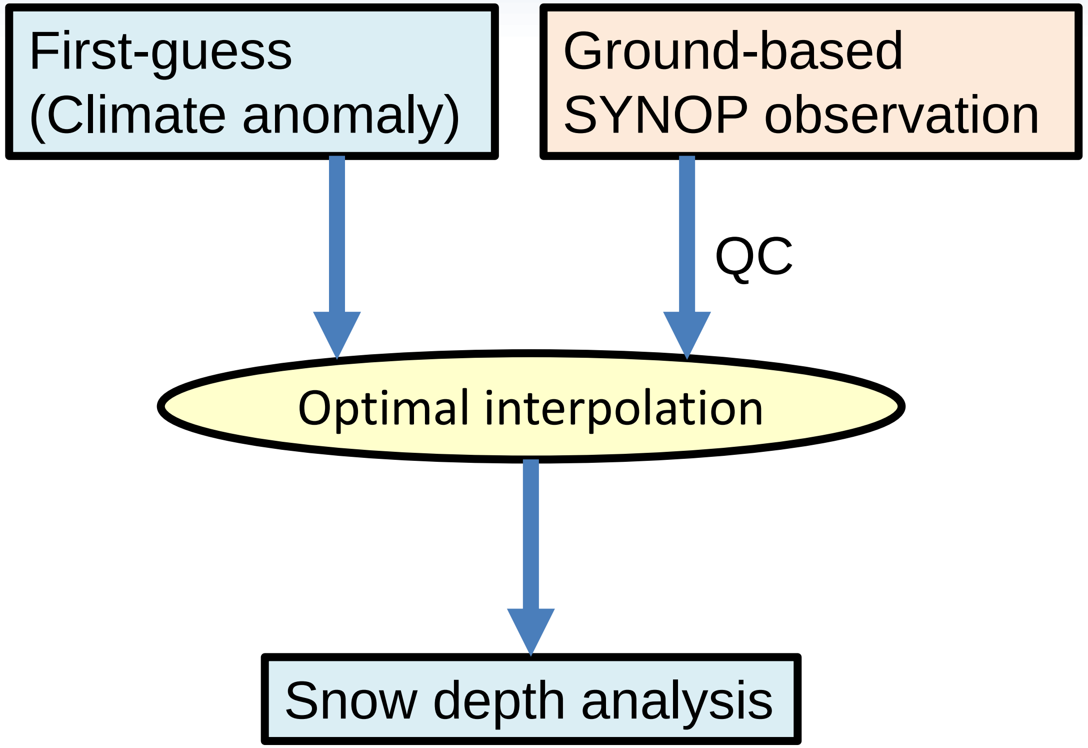
<u>Soil moisture</u>: no data assimilation

- Climatological monthly mean values are used as initial conditions.
  - Derived from a 10 years (2001-2010) offline run of the land surface model
  - Atmospheric forcing data: GSWP3 (Kim, 2017)
- Day-to-day variations cannot be represented.

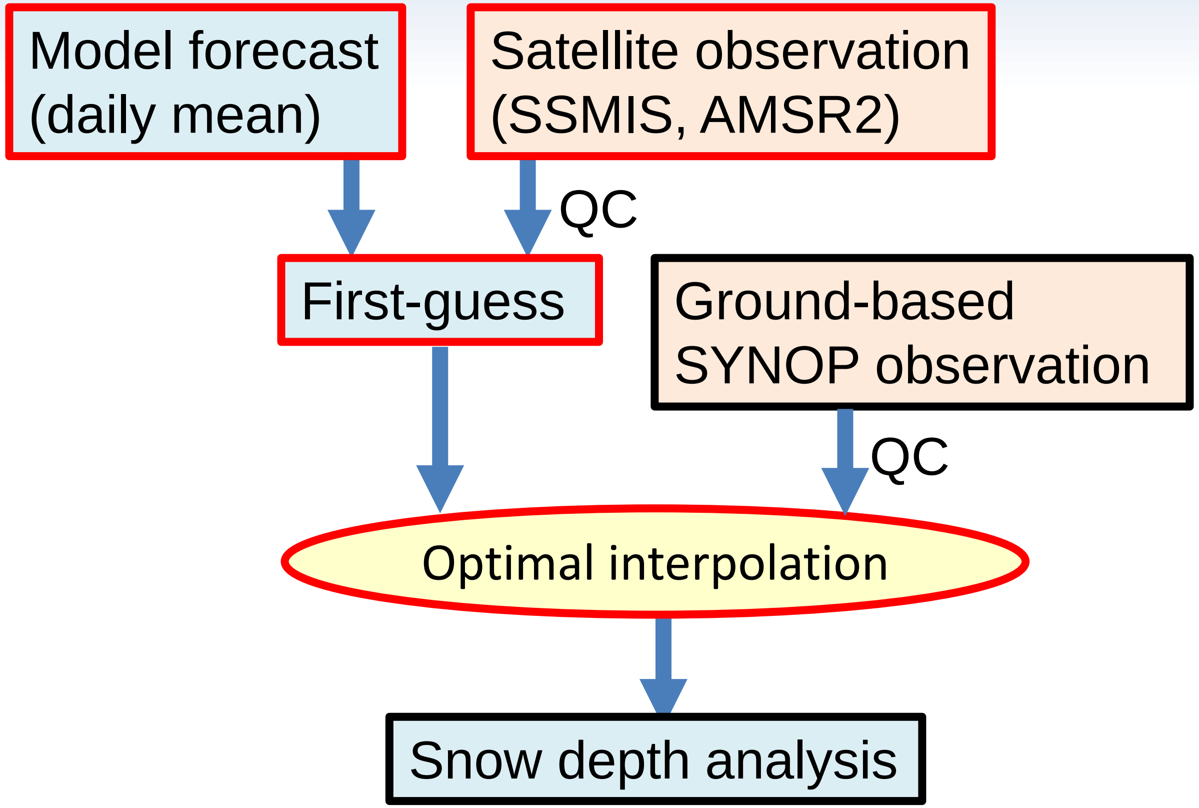
- Upgrade of snow depth analysis and introduction of new soil moisture analysis system are planned to be operational next spring.

Snow depth analysis system

Operational system



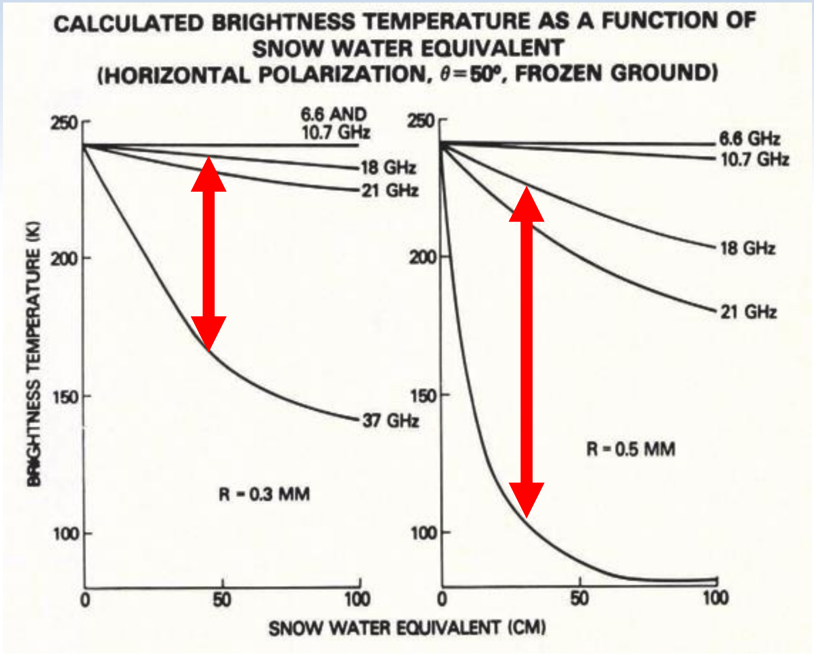
New system



- Major update
  - First guess: combination of model forecast and satellite observation
  - Background error structure function used in OI

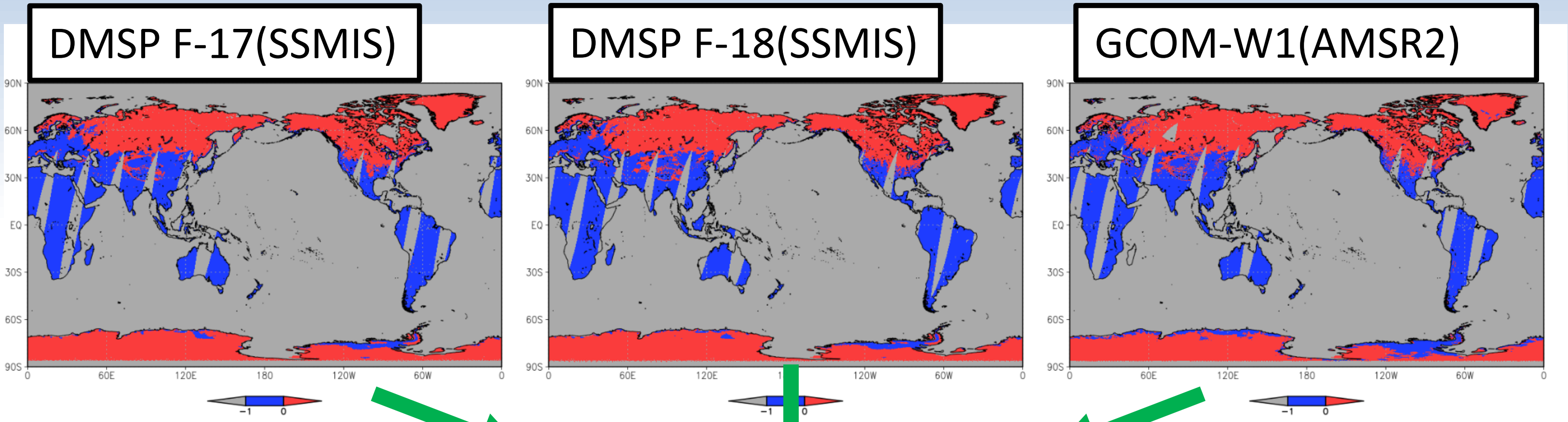
Satellite observation used in snow depth analysis

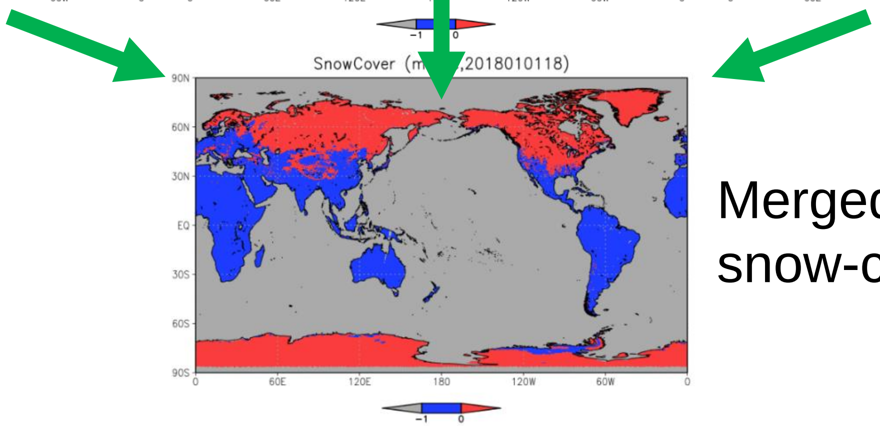
Brightness Temperature



Snow Water Equivalent (cm)

Chang et al.(1987)





Merged satellite snow-cover product

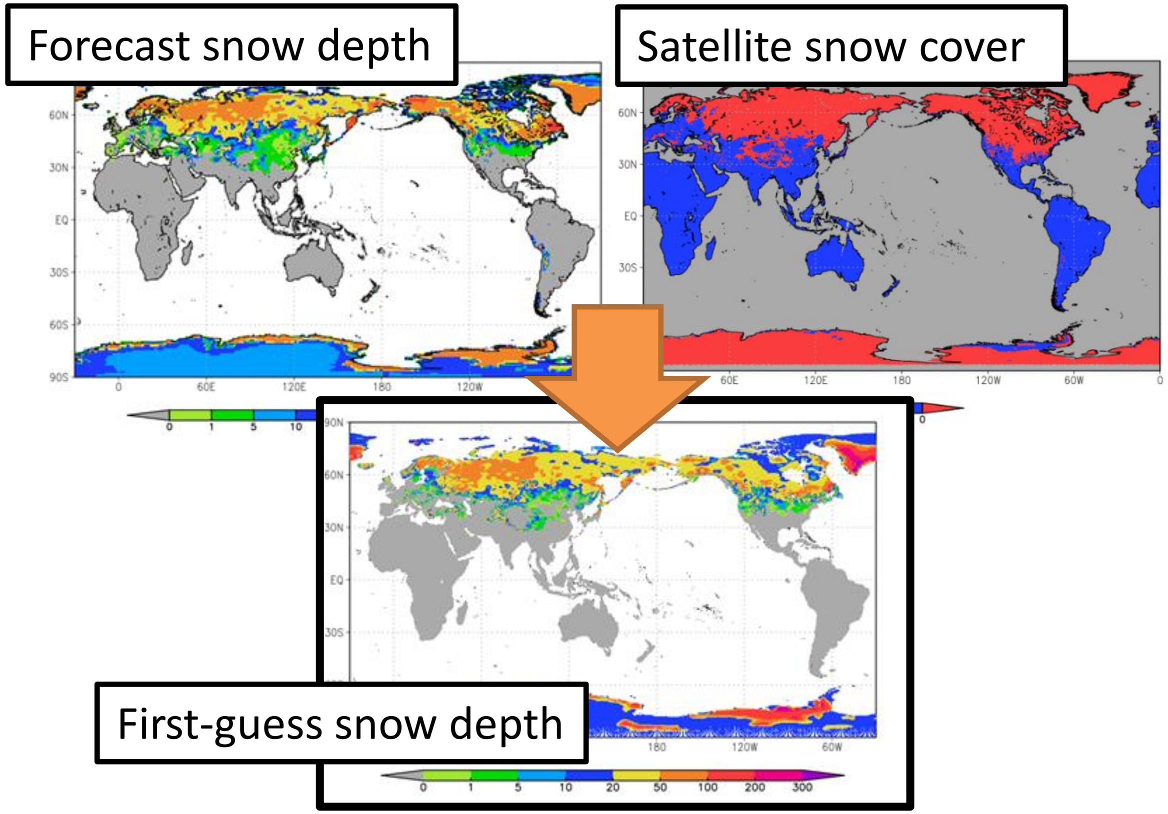
- Satellite data: SSMIS(DMSP F-17,F-18) and AMSR2(GCOM-W1)
- Snow-covered areas are estimated from microwave brightness temperature differences caused by scattering effects of snow.

$$Tb_{19GHz} - Tb_{37GHz} > Tb_{threshold}$$

First guess for optimal interpolation

- First-guess fields for snow depth depend on the satellite snow-cover product and forecast snow depth as bellow.

Satellite / Model	Snow	Snow free
Snow	Forecast snow depth	0 cm ※
Snow free	0 cm	0 cm



※ If climatological probability of snow exceeds 80%, forecast snow depth is used as first-guess.

Optimal interpolation for snow depth analysis

- Analysis increments are calculated as the sum of weighted innovations (O-B) for each grid point.

$$\Delta S = \sum_{i=1}^{N} (w_i \times \Delta S_i)$$

$$\sum_{i=1}^{N} \left(\mu_{ij}^{G} + \frac{\sigma_o^2}{\sigma_b^2} \mu_{ij}^{O} \right) w_i = \mu_j^{G}$$

σ_b: background error standard deviation
σ_o: observation error standard deviation

- Background error structure function will be updated to avoid widespread increment (following Brasnett et al, 1999).

Operational system

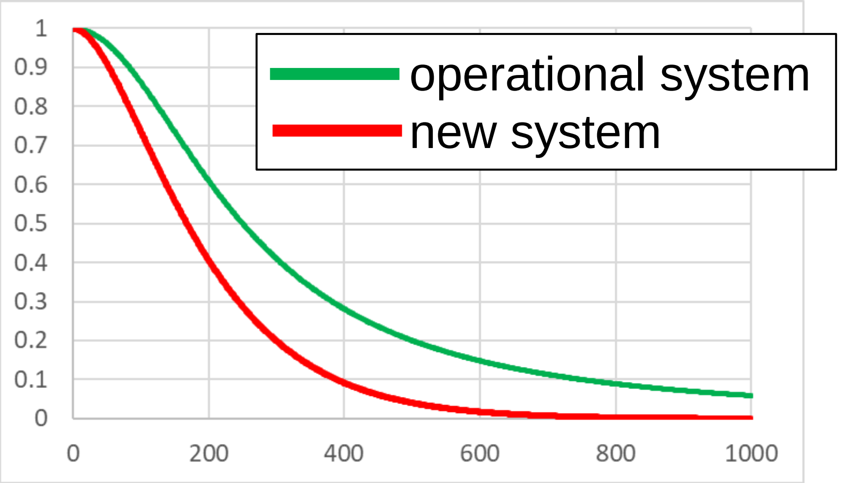
$$\mu_{ij}^{G} = \frac{1}{1 + Lr^2} \frac{1}{1 + Hz^2}$$

New system

$$\mu_{ij}^{G} = \left(1 + \frac{r}{L}\right) exp\left(-\frac{r}{L}\right) exp\left[-\left(\frac{z}{H}\right)^2\right]$$

L: 100 km, H: 800 m

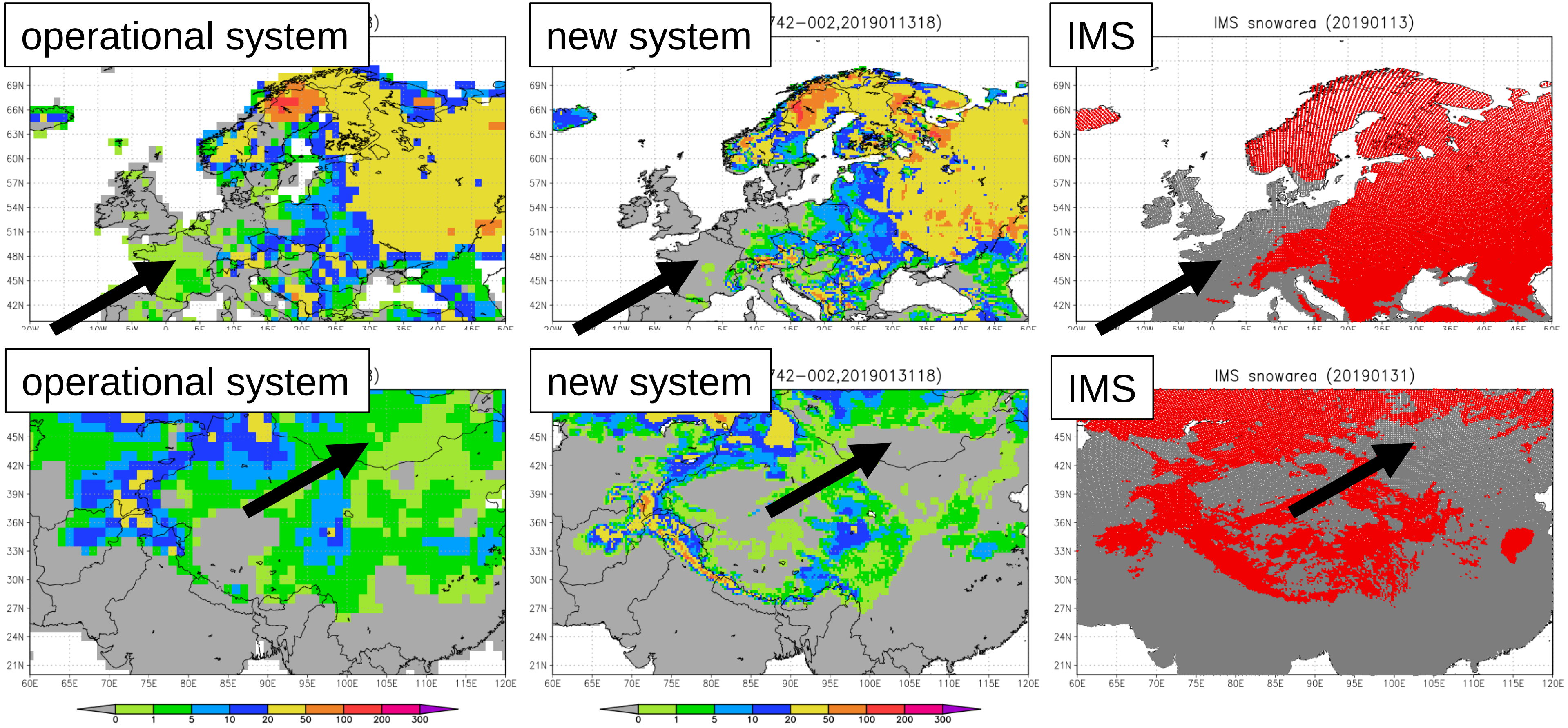
Horizontal structure function



Horizontal distance (km)

Impact of updating snow depth analysis

- Analysis of snow-covered area is improved by introducing satellite snow-cover product and updating optimal interpolation scheme.
  - In addition to the improvement, surface temperature cold biases are reduced in several regions.



13th January 2019

31st January 2019

Recent developments: Soil moisture analysis in GSM

- Simplified Extended Kalman Filter(SEKF) is planned to be operational.
  - SEKF: Drusch et al.(2009), de Rosnay et al.(2013)

$$\boldsymbol{x_b}(t_i) = M[\,\boldsymbol{x_a}(t_{i-1})]$$

$$\boldsymbol{x_a}(t_i) = \boldsymbol{x_b}(t_i) + \boldsymbol{K_i}[\boldsymbol{y^o}(t_i) - H_i(\boldsymbol{x_b})]$$

$$\boldsymbol{K_i} = \left[\boldsymbol{B}^{-1} + \boldsymbol{H_i^T}\boldsymbol{R}^{-1}\boldsymbol{H_i}\right]^{-1}\boldsymbol{H_i^T}\boldsymbol{R}^{-1}$$

$\boldsymbol{x_b}$: first – guess $\boldsymbol{y^o}$: observation

M: nonlinear forecast model

H_i: nonlinear observation operator

$\boldsymbol{K_i}$: kalman gain matrix

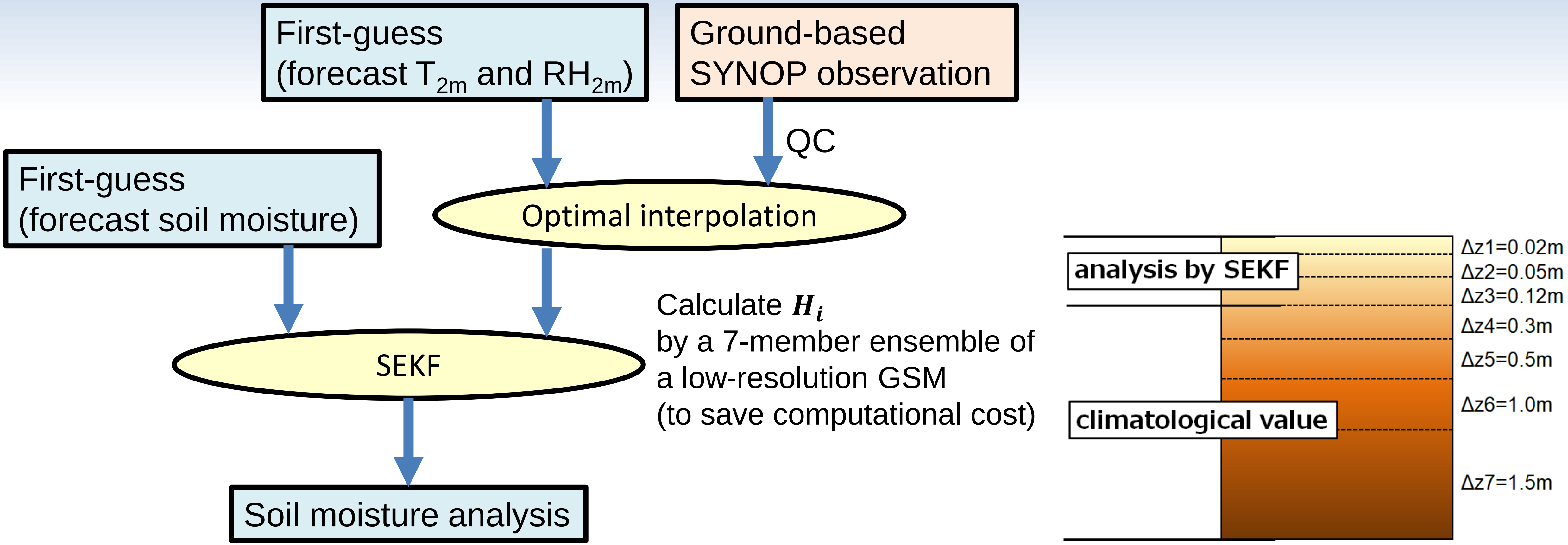
$\boldsymbol{B}$: background – error covariance matrix

$\boldsymbol{R}$: observation – error covariance matrix

$\boldsymbol{H_i}$: linearized observation operator

- ***B*** and ***R*** are static as same as de Rosnay et al. (2013).
- $\boldsymbol{H_i}$ is approximated by finite differences of soil moisture state vector.

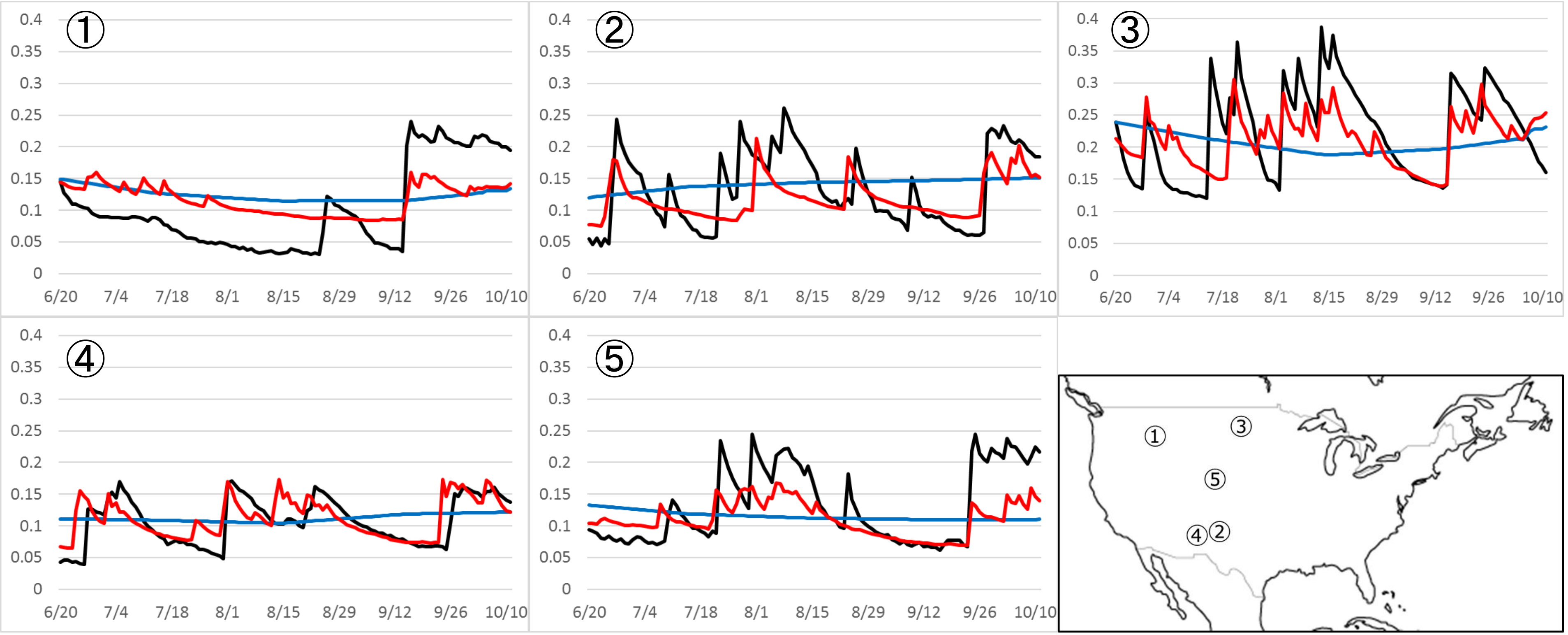
Soil moisture analysis system



- Analyses of screen-level temperature and relative humidity are assimilated.
- To prevent unrealistic soil moisture drifting after long-term integration, initial soil moisture below the 4th layer is set to the climatological value.

Impact of introducing new soil moisture analysis

- Analyzed new soil moisture obtained from the SEKF cycle can represent day-to-day variation successfully by using 6-hour forecast as first-guess field.



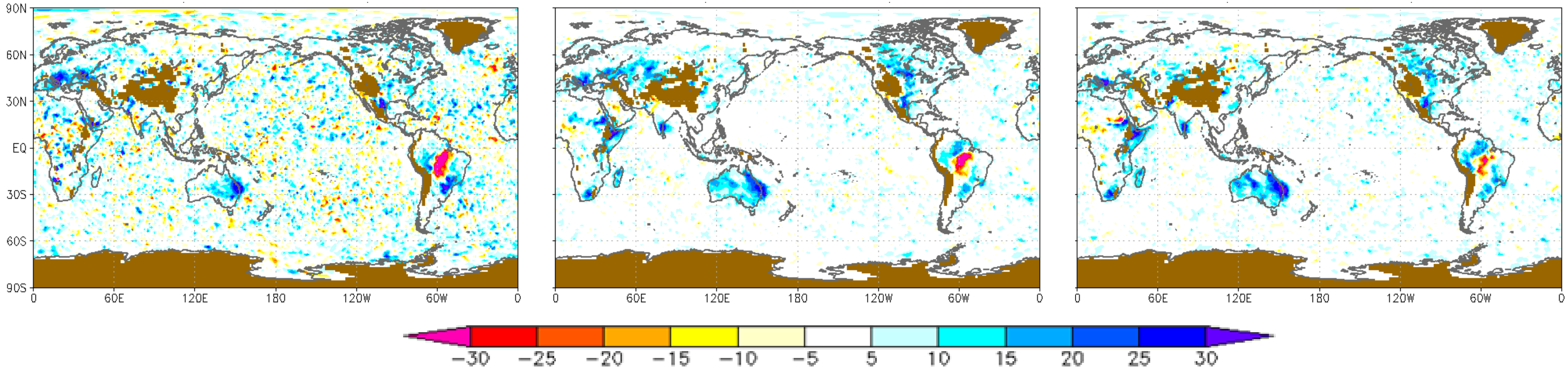
Comparison of the soil moisture analysis (2nd layer) with USDA SCAN observations (at 5cm-depth) for five selected sites.
Black: USDA SCAN, **Blue: operational system**, **Red: new system**.

Period: 20th June 2017 to 11th October 2017

Impact of introducing new soil moisture analysis

- SEKF introduction reduced the RMSEs of temperature at 850 hPa for land areas (e.g., Central Asia, Australia, North America and South America).

(a) against JMA analysis (b) against ECMWF analysis (c) against UKMO analysis

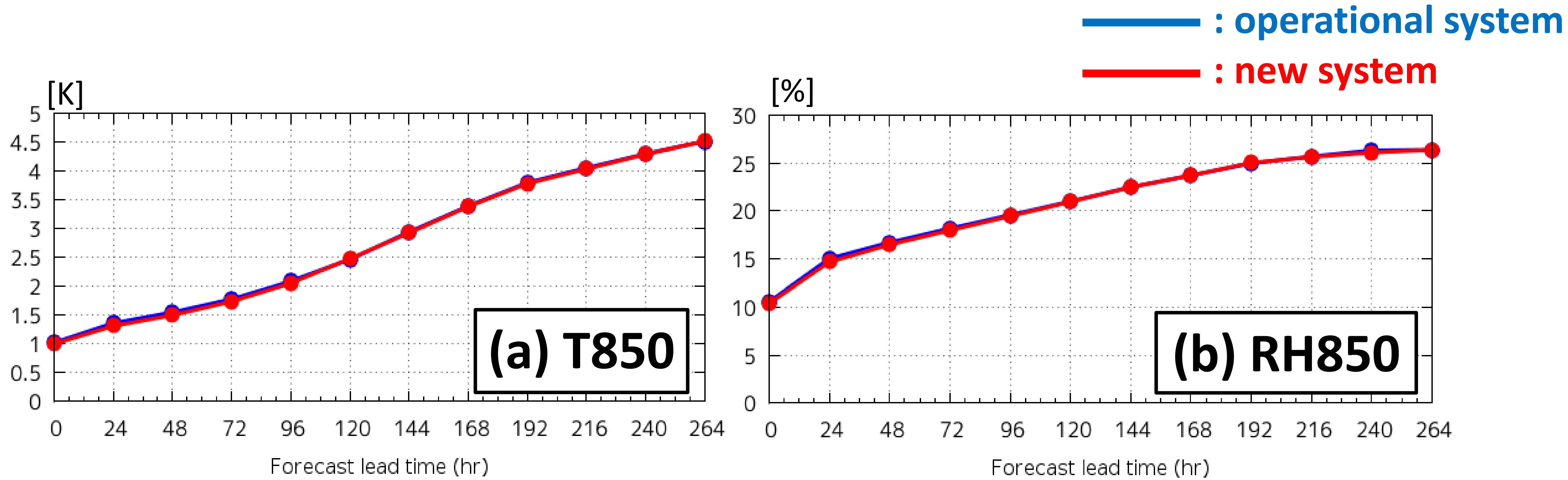


Percentage of relative improvement in root mean square error for 24-hour forecasts of temperature at 850 hPa verified against (a) JMA, (b) ECMWF and (c) UKMO operational analysis.

Period: July 2017 to September 2017

Impact of introducing new soil moisture analysis

- Forecast skills of lower temperature and humidity in the short range were improved against radiosondes in the Northern Hemisphere.



Root mean square error of (a) T850 (b) RH850 against radiosondes in the NH (20◦N–90◦N).

Period: July 2017 to September 2017

Summary

- JMA plans an upgrade of snow depth analysis and introduction of a soil moisture analysis system in the next spring.
- The improved initial snow depth, soil moisture and lower-atmosphere conditions provide better forecasts in the near-surface atmosphere.

Future plans

- Snow depth analysis
  - Increase frequency of the snow analysis to 4 times a day (00, 06, 12 and 18UTC)
  - Improve satellite snow cover (use new satellite product and update estimate algorithm)
- Soil moisture analysis
  - Use satellite product (ASCAT, etc.)
  - Calculate ***B*** and ***H*** using ensemble-based data assimilation (Hybrid 4DVAR-LETKF in JMA)