

Preliminary results of introducing soil moisture data assimilation to the JMA Global Analysis

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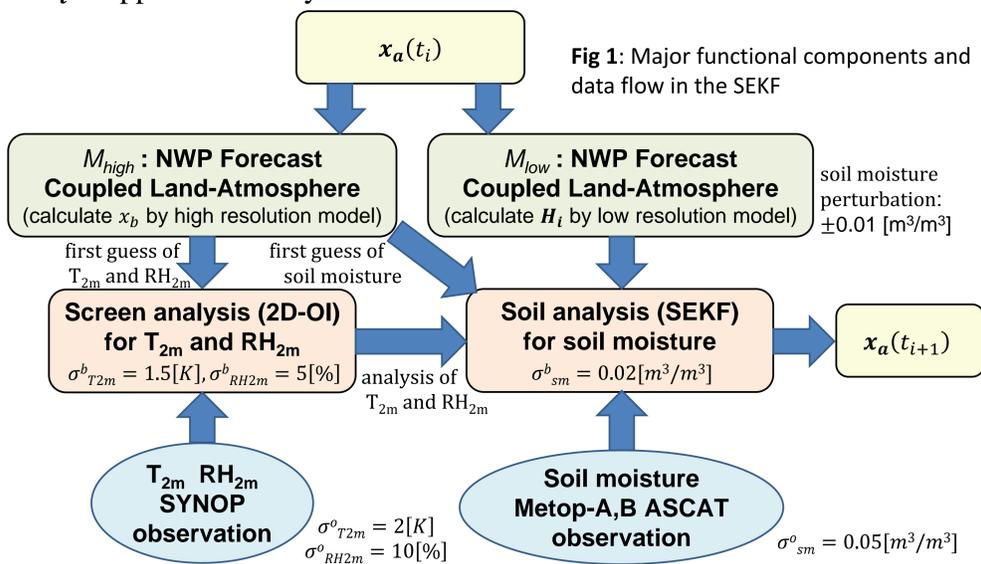


Introduction

- Japan Meteorological Agency (JMA) operationally uses climatological monthly mean soil moisture as initial conditions for the land model of its Global Spectral Model (GSM) and Global Ensemble Prediction System (GEPS). This configuration could potentially degrade forecast results, especially for lower atmosphere, because climatological data doesn't represent the "day-to-day" variation about the initial soil moisture.
- In order to improve the quality of the initial soil moisture and lower atmosphere conditions, simplified Extended Kalman Filter (SEKF; Drusch et al., 2009, de Rosnay et al., 2013) has been tested in the JMA Global Analysis (GA).
- NWP-type experiment and its evaluation against in-situ observations have also been executed to assess the impact of soil moisture analysis cycle.

Assimilation Method

- In the SEKF, analyzed state vector x_a is computed at time t_i for each grid point as below:
 - x_b : first guess y^o : observation
 - M : nonlinear forecast model H_i : nonlinear observation operator
 - $x_b(t_i) = M[x_a(t_{i-1})]$ K_i : kalman gain matrix
 - $x_a(t_i) = x_b(t_i) + K_i[y^o(t_i) - H_i(x_b)]$ B : background - error covariance matrix
 - $K_i = [B^{-1} + H_i^T R^{-1} H_i]^{-1} H_i^T R^{-1}$ R : observation - error covariance matrix
 - H_i : linearized observation operator
- B and R are static as same as de Rosnay et al. (2013).
- H_i is approximated by finite differences of soil moisture state vector.



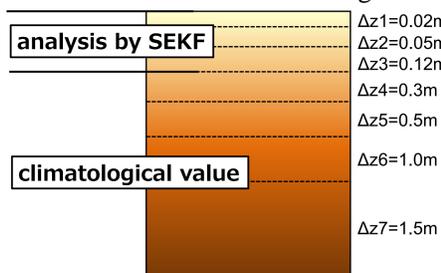
- ASCAT surface soil moisture product (Bartalis et al., 2007) is matched to the JMA land model soil moisture climatology using CDF matching (de Rosnay et al., 2011).

Experimental Settings

Table 1: Specifications of the GA and GSM.

	CNTL (operational version)	TEST
Forecast model	<ul style="list-style-type: none"> GSM 1705 (JMA, 2019) TL959L100 (approx. 20km, 100 vertical levels up to 0.01hPa) 	
Initial conditions of atmosphere	4D-Var global objective analysis	only difference between CNTL and TEST
Initial conditions of land model	<ul style="list-style-type: none"> Soil moisture content: climatological values using offline model forced by GSWP3(Kim, 2017) Snow water equivalent: Snow analysis (2D-OI) Other variables: forecast guess 	<ul style="list-style-type: none"> Soil moisture content: Soil analysis (SEKF) Observations: SYNOP (T_{2m}, RH_{2m}), Metop-A,B (ASCAT soil moisture)

- All the experiments are based on the latest operational GA and GSM including parameters, except for the SEKF in TEST.
- To prevent unrealistic soil moisture drifting after long-term integration, initial soil moisture between 4th and 7th layer is set to climatological value (Fig. 2).
- Such configuration can be applied in the deeper layers, considering small sensitivity of the Jacobians of T_{2m} , RH_{2m} .
- Period:** Jun. 10, 2017 to Oct. 11, 2017

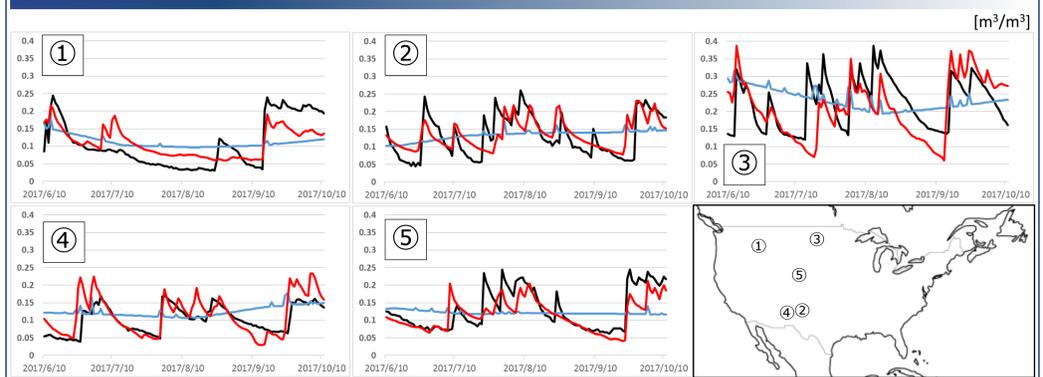


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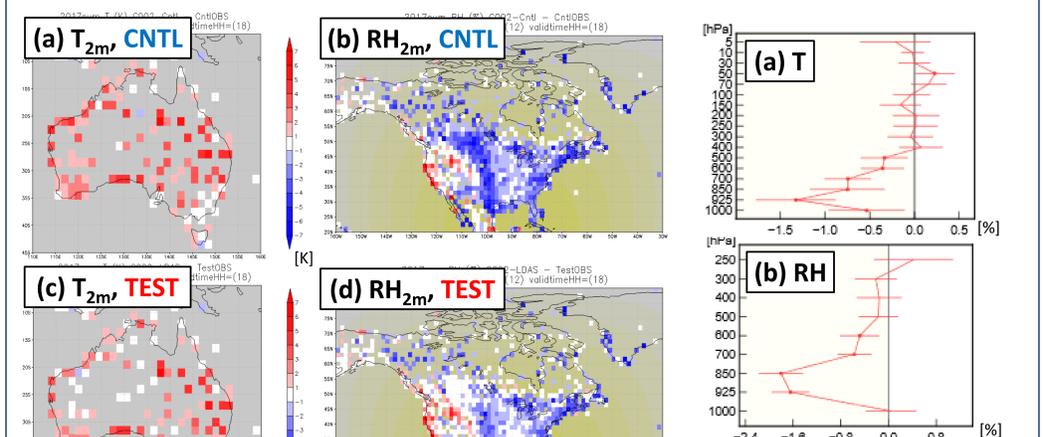
Summary

- The quality of lower-atmosphere initial conditions are improved by introducing the SEKF to the JMA Global Analysis.
- Improved initial soil moisture and lower atmosphere conditions made better forecast skills in near surface atmosphere.

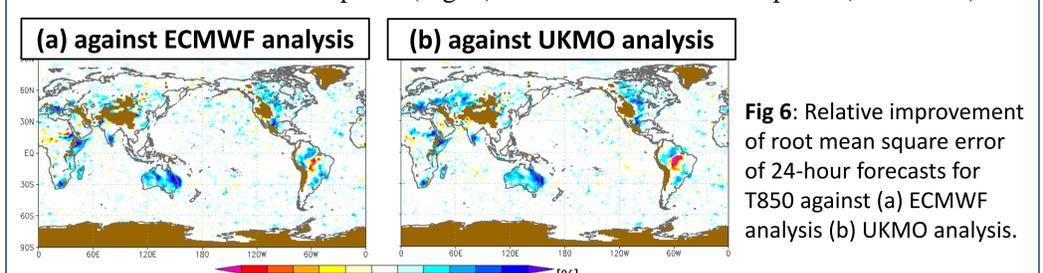
Results



- Initial conditions of soil moisture obtained from the SEKF cycle can represent day-to-day variation (Fig. 3).



- Warm biases on Australia in nighttime and moist biases on the Great Plains in daytime are improved at T+6-hour for July to September (JAS) 2017 (Fig. 4).
- First-guess departure statistics for radiosondes are improved in the lower atmosphere over the Northern Hemisphere (Fig. 5) and the Southern Hemisphere (not shown).



- Improvements (plotted in blue) in RMSE of T850 are seen over land areas against ECMWF and UKMO analysis (e.g. Central Asia, Australia, North America, and South America; Fig. 6).
- Forecast skills of lower temperature and humidity in the short range are improved over the Northern Hemisphere (Fig. 7).
- The improvement is not clearly seen on sub-seasonal to seasonal timescale. It is one of the future challenges to obtain improvement in the extended-range forecasts.

Future Works

- Further investigation are planned as below:
 - To validate soil moisture with other in-situ observations.
 - To modify parameters of the SEKF to match with next version of GA (4DVar-LETKF hybrid data assimilation system) and GSM.
 - To use flow dependent background errors (B) and linearized observation operator (H) obtained from the next version of GA.