Recent development and evaluation of moist processes in the operational Global Spectral Model (GSM) of the Japan Meteorological Agency (JMA)

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KAKUSHIN

Ⅰ Improvement to the stratocumulus scheme of GSM

1. Introduction and Motivation

➢ In the operational 4D-VAR analysis of JMA, negative analysis increment of SLP (Sea Level Pressure) can be frequently seen in North America in the analysis of 00UTC. (Fig1-1)
➢ This increment is given by radiosonde temperature observation.
➢ By monitoring cloud cover over this area, we found that the stratocumulus scheme of GSM (Kawai and Inoue, 2006) creates pseudo-clouds in afternoon (Fig1-2) which makes the temperature lower than the observation in the lower troposphere.
➢ The stratocumulus scheme in GSM is designed to represent subtropical marine stratocumulus off the west coast mainly as a function of inversion strength. (Fig1-3)

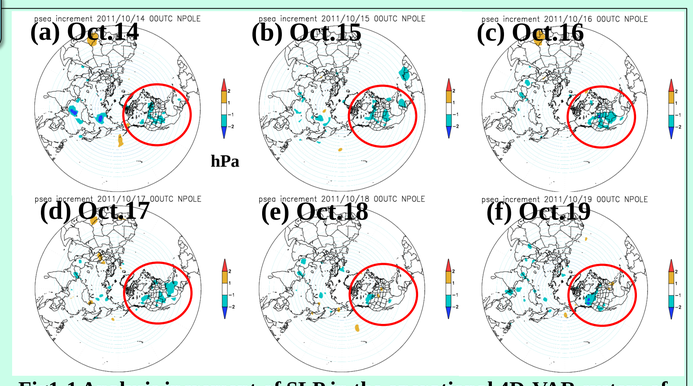


Fig1-1 Analysis increment of SLP in the operational 4D-VAR system of JMA at 00UTC from Oct. 14 (a) to Oct. 19 (f), 2011.

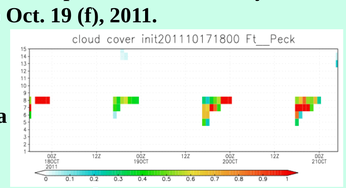


Fig1-2 Time Series of cloud cover forecasting from 18UTC Oct. 17, 2011 at one point of North America (Ft. Peck 48.26N, 105.00W) .

(a) w/ stratocumulus (b) w/o stratocumulus

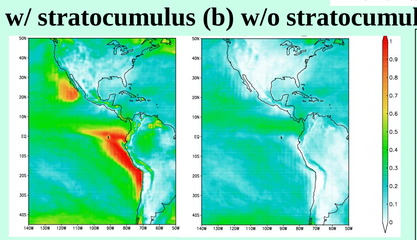


Fig1-3 Monthly average of low cloud cover of Oct. 2010. (Tl319 Analysis) (a) with stratocumulus, (b) without stratocumulus scheme.

Conditions to diagnose stratocumulus in GSM.
(1) $-\frac{\partial\theta}{\partial p} > 0.07$ K/hPa (just above the layer)
(2) $-\frac{\partial\theta}{\partial p} < 0.01$ K/hPa (near the surface)
(3) The height of the layer is below 940 hPa.

And, a new condition
(4) Relative humidity of the layer is above 80%.

➢ To reduce this pseudo-cloud over the continent, a new threshold of relative humidity is added to this stratocumulus scheme.

CNTL: Operational GSM TEST: GSM with modified stratocumulus scheme

2. Evaluation in North America

Result of Tl319 analysis cycle experiment (preliminary low resolution experiment before high resolution Tl959 experiment) in Oct. 2010.
➢ This modification reduced pseudo-cloud over North America. (Fig2-1).
➢ The difference of temperature at 850hPa between the sonde observation and first guess of GSM decreases. (Fig2-2)
➢ The average monthly analysis increment of SLP at 00UTC decreases at North America. (Fig 2-3)

(a) GOES-W(visible) (b) CNTL (c) TEST

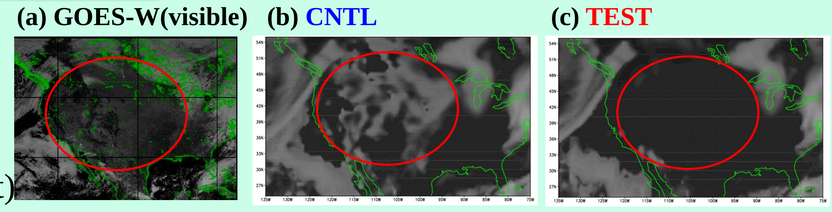


Fig2-1 (a)Visible Image of GOES-WEST, and simulated visible cloud image of GSM (b) CNTL (c) TEST on 18UTC 14 Oct. 2010

(a) CNTL (b) TEST

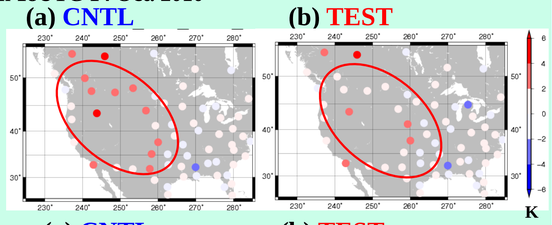


Fig2-2 The difference of temperature between the sonde observation and first guess of GSM at 00UTC Oct. 15 2010. (a) CNTL (b) TEST

(a) CNTL (b) TEST

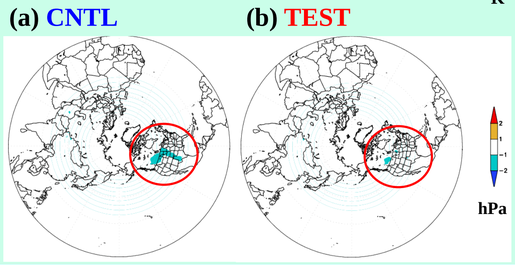
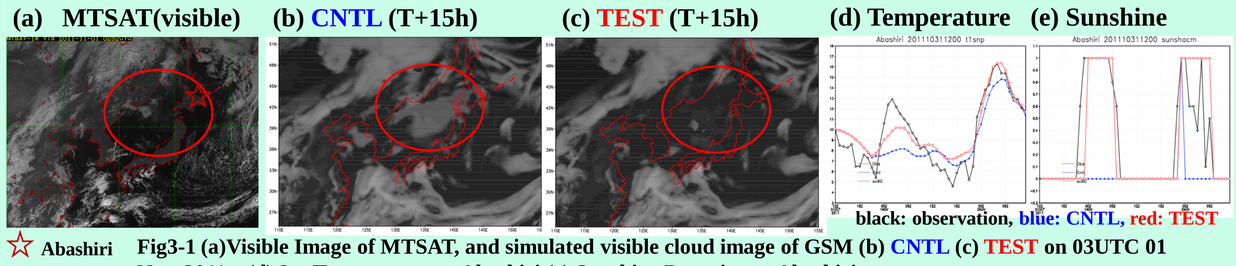


Fig2-3 Average monthly analysis increment of SLP at 00UTC of Oct. 2010 (a)CNTL (b)TEST

3. Evaluation around Japan

Result of high-resolution Tl959 GSM forecast from 12UTC Oct. 31, 2011.

(a) MTSAT(visible) (b) CNTL (T+15h) (c) TEST (T+15h) (d) Temperature (e) Sunshine



black: observation, blue: CNTL, red: TEST

☆ Abashiri

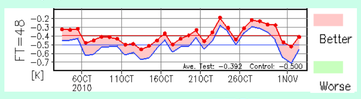
Fig3-1 (a)Visible Image of MTSAT, and simulated visible cloud image of GSM (b) CNTL (c) TEST on 03UTC 01 Nov. 2011. (d) 2m Temperature at Abashiri (e) Sunshine Duration at Abashiri

➢ The pseudo-cloud around the Sea of Japan decreases. And at the surface, the temperature and sunshine duration approach the observation.

4. Global Evaluation

Result of Tl319 analysis/forecast cycle experiment (preliminary low resolution experiment) on Oct. 2010.
➢ Mean error and RMSE of Temperature at 850hPa compared to sonde improves. (Fig3-1)
➢ Positive growth can be seen in the rate of improvement in **TEST** (Fig3-2) $\frac{RMSE_{cntl} - RMSE_{test}}{RMSE_{cntl}}$

(a) ME



(b) RMSE — TEST — CNTL

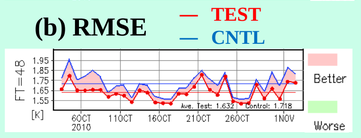


Fig3-1 Verification to sonde of T850 at 2 days forecast. (a) Mean Error, (b) RMSE

(a) SLP (b)T850 (c)Z500 (d)wspd850

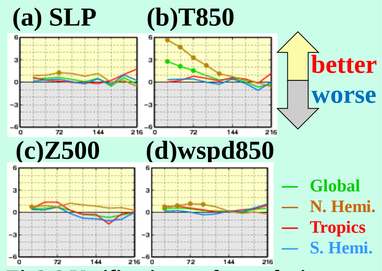


Fig3-2 Verification to the analysis (Rate of Improvement)

5. Summary

➢ By adding a new threshold of relative humidity to the stratocumulus scheme of GSM, the pseudo-cloud decreases and reduce the analysis increment of SLP.
➢ It is effective to monitor the daily analysis increment in order to improve moist processes.

Ⅱ Evaluation of GSM using the data of special observation T-PARC 2008

1. Introduction and Motivation

➢ T-PARC was a multi-national and multi-institution field campaign conducted from August to October 2008 in order to understand the lifecycle of tropical cyclones, especially in genesis, recurvature and extra-tropical transition.
➢ During this project, many dorpsondes were deployed around tropical cyclones to improve TC forecasts. (Fig1-1)
➢ Here, we evaluate moist processes of GSM using these data.

(a)T0813 SINLAKU (b)T0815 JANGMI

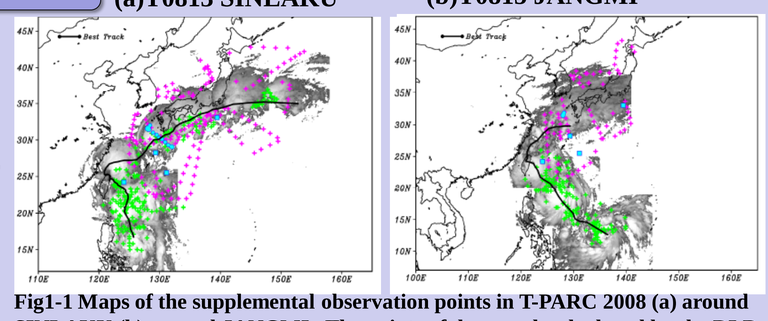


Fig1-1 Maps of the supplemental observation points in T-PARC 2008 (a) around SINLAKU (b) around JANGMI. The points of dropsondes deployed by the DLR Falcon aircraft (pink), and by other planes such as P3 (green).

2. Evaluation in the subtropical region

➢ Red points in Fig2-1 show the locations where dropsondes were deployed around SINLAKU at around 06UTC. Vertical cross section along the green line in Fig2-1 is provided.
➢ GSM predicts moister lower troposphere (around 900 hPa) compared to dropsonde observations and ECMWF forecast. (Fig2-2)
➢ In order to evaluate each processes of NWP models, the moistening rates of physical and dynamic processes are compared (Fig2-3).
➢ Compared to ECMWF convection scheme, GSM convection scheme conveys less moisture from the boundary layer to the free atmosphere. This may cause the moister boundary layer.

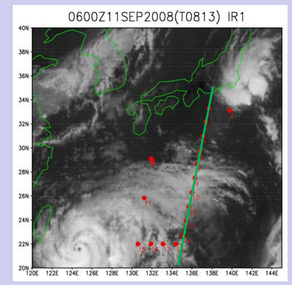


Fig2-1 The points of dropsondes deployed around SLINLAKU at around 06UTC Sep. 11, 2008. The green line shows the cut line.

pressure (a)Dropsonde (b)GSM CNTL(T+18h) (c)ECMWF (T+18h)

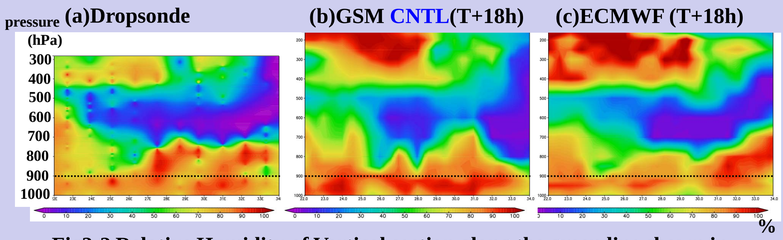
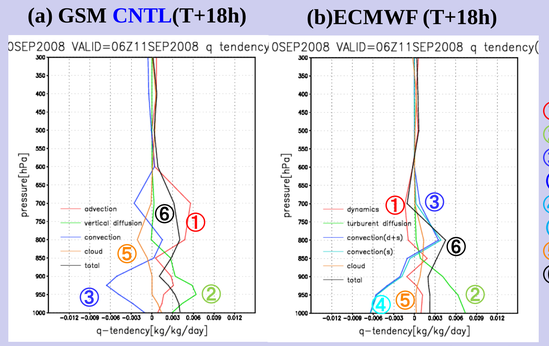


Fig2-2 Relative Humidity of Vertical section along the green line shown in Fig2-1. (a) dropsondes (interpolated) (b) GSM (c) ECMWF

(a) GSM CNTL(T+18h) (b)ECMWF (T+18h)



①advection
②vertical diffusion
③convection (shallow+deep)
④shallow convection (only ECMWF)
⑤cloud
⑥total

Fig2-3 Each physical and dynamic tendencies of specific humidity along the green line shown in Fig2-1. (a) GSM (b) ECMWF

3. Evaluation of tropical cyclone genesis

➢ Also, vertical cross section is provided around JANGMI which is in the process of genesis. (Fig3-1)
➢ Compared to dropsonde observations and ECMWF forecast, GSM moisture is larger in the boundary layer (Fig3-2 a,b,c), and smaller in the free atmosphere.
➢ By applying the modification of convection and cloud scheme (Komori and Yoshimoto, 2011) intended to reduce "spin-down" problem of GSM, the relative humidity forecast approaches dropsonde observations and ECMWF forecast. (Fig3-2 d)
➢ This modification makes upward mass flux in the convection scheme to vary depending on relative humidity, which may be the main cause of this change.

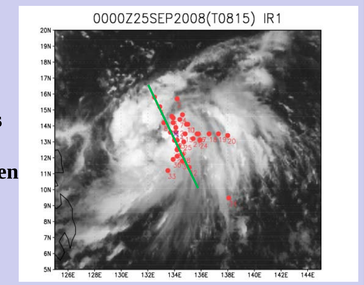
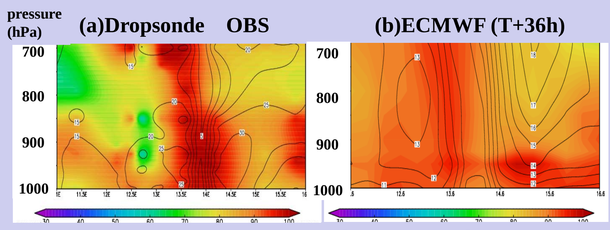


Fig3-1 The map of dropsondes around JANGMI at around 00UTC Sep. 25, 2008. The green line shows the cut line.

pressure (hPa) (a)Dropsonde OBS (b)ECMWF (T+36h)



(c) GSM(T+36h) CNTL (d)GSM (T+36h) TEST

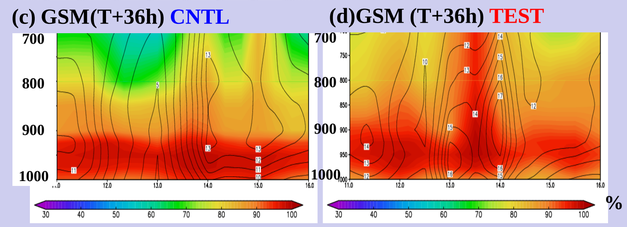


Fig3-2 Relative humidity (shade) and horizontal wind speed (contour) of the vertical section along the green line shown in Fig3-1. (a) dropsondes (interpolated) (b) ECMWF (c) GSM(CNTL) (d)GSM(TEST)

4. Summary

➢ The data of T-PARC 2008 showed that relative humidity in the boundary layer of GSM forecast tends to be higher than that of dropsonde observations and ECMWF forecast; this may be caused by the scheme of convection and vertical diffusion.
➢ These data of special observation is also useful for development of moist processes.

References

•Kawai, H., and T. Inoue, 2006: A simple parameterization scheme for subtropical marine stratocumulus. *SOLA*, 2, 17-20.
•Komori, T. and Yoshimoto, K., 2011: Laborious Linkage between Moist Physics Parameterization and Observations: Spin-down Problem in an NWP System. *ECMWF workshop on "Representing Model Uncertainty and Error in Weather and Climate Prediction", ECMWF*

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➢The image of GOES-WEST is provided by the dataset of geostationary satellites of the Center for Environmental Remote Sensing, Chiba University, and this dataset is supported by "Virtual Laboratory for the earth's climate diagnostics" project funded by MEXT.
➢ECMWF forecast data is supplied through the YOTC data server.