Case study for the typhoon in the KIAPS 3DVAR system

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Abstract

The Korea Institute of Atmospheric Prediction Systems (KIAPS) is a government funded non-profit research and development institute located in Seoul, South Korea. KIAPS is developing the KIAPS-Global Model, a backbone for the next-generation operational global numerical weather prediction (NWP) system. In second stage, Test Model Development (2014-2016), we have a beta version of the KIAPS Integration Model (KIM) that can produce reasonable global forecasting. This model has a cubed-sphere grid and is based on the spectral element method for horizontal spatial discretization.

We also started semi-real time forecast with the 3-dimensional variational (3DVAR) data assimilation system since July, 2015. With continuous developing, it is capable of processing the satellite radiance data (AMSU-A, IASI, CRIS, ATMS, AMV, CSR), GPS Radio Occultation (GPS-RO), AIRCRAFT and synoptic observation (SONDE and SURFACE) in now. To evaluate the performance of the 3DVAR system, we conducted a case study for the typhoon.

Experimental Settings

KIAPS 3DVAR System

- Background (6 hour forecast)
  - KIM: **K**IAPS **I**ntegrated **M**odel
  - Cubed-sphere grid based on the spectral element method for horizontal spatial discretization
  - Horizontal resolution: ne120np4 (~ 25 km), Vertical resolution: 50 levels (top = 0.3 hPa)
- Data assimilation
  - 3DVAR (Horizontal resolution: ne60np4 (~50 km))
  - **Background Error covariance: Nonlinear balance equation approach** (ECMWF, KIAPS)

$$\nabla^2 M_{bal} = \nabla(-f\hat{k} \times \mathbf{V}_\psi - \mathbf{V}_\psi \nabla \mathbf{V}_\psi)$$
$$M_{bal} = \Phi_{bal} + RT_r \ln p_{bal}$$

- Relatively free from sampling error, consideration of advection terms

Experimental Settings

- Experimental Date: 00UTC, 13th July, 2015.
  - Center: 19.6 N, 137.2 E (950 hPa)
- Typhoon "NANGKA": 2015.07.04 ~ 2015.07.18 UTC
- Typhoon Verification: Geophysical Fluid Dynamics Laboratory (GFDL) vortex tracker (JTWC Best track)

To evaluate the performance of the 3DVAR in typhoon, we divided the assimilation in 3 steps.

- **Background**: No assimilation
- **CONV**: assimilate the conventional observation (sonde, surface, aircraft)
- **CONV+WIND**: assimilate the conventional observation + AMV + SCATWIND
- **CONV+WIND+MASS**: assimilate the conventional observation + AMV + SCATWIND + GPS-RO + AMSU-A + ATMS + IASI + CRIS+ CSR + MHS

Results: Case study "Typhoon: NANGKA"

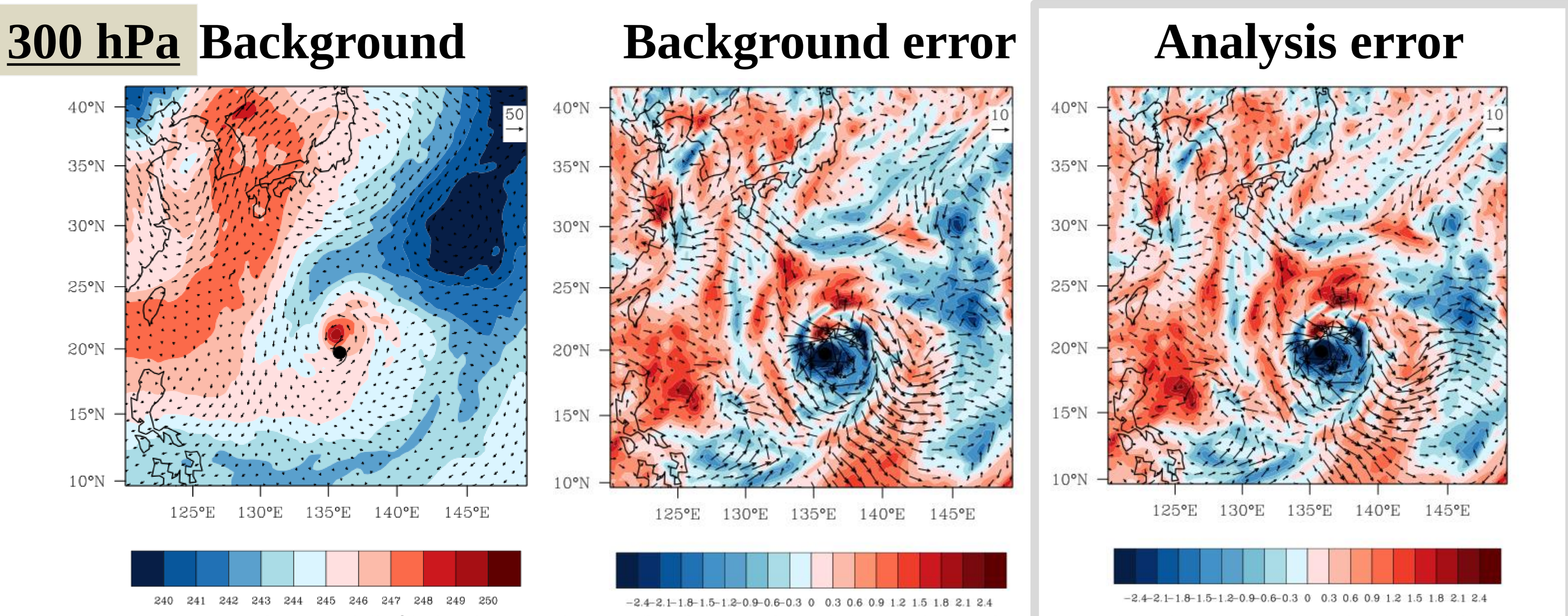

Figure1. Background (left), background error (background-IFS) (center), Analysis error (Analysis – IFS) (right) at 300 hPa. Temperature (K) (shading), wind (vector) (m/s). Typhoon symbol represents the location of typhoon center (best track).

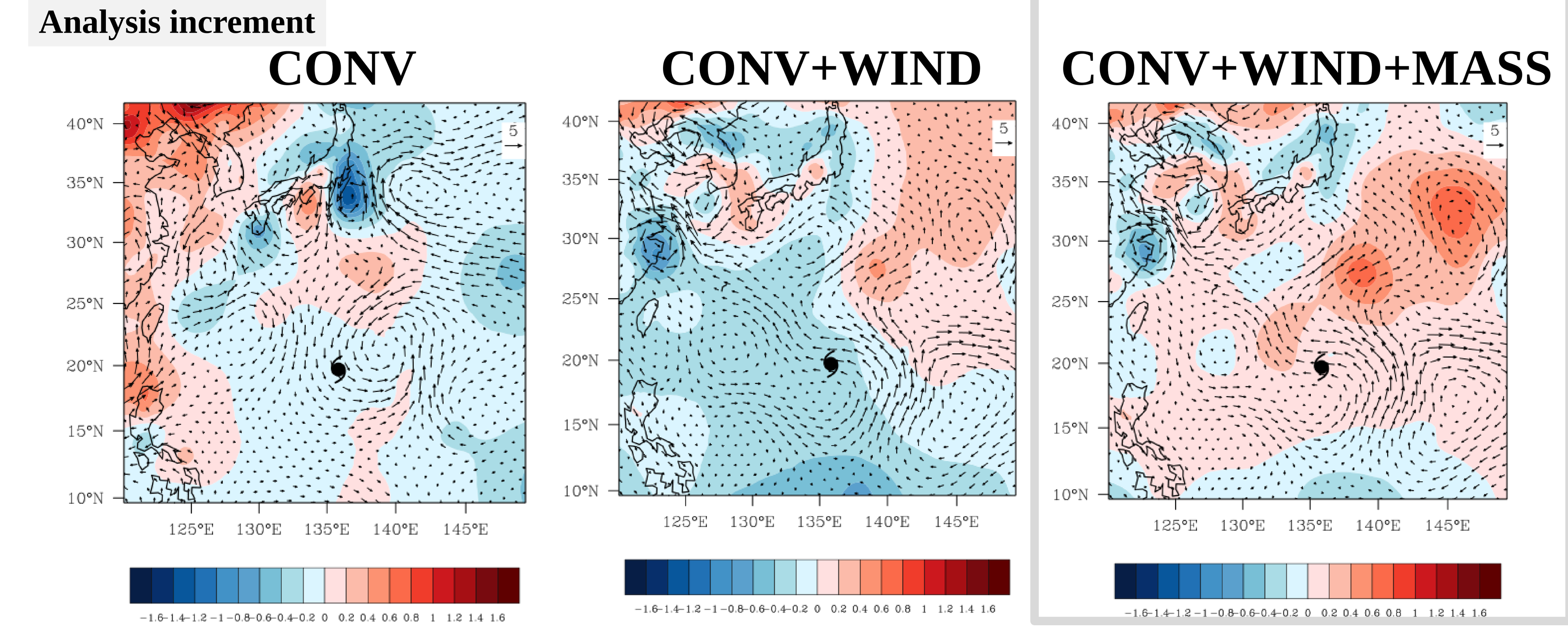

Figure2. Analysis increment of CONV (left), CONV+WIND (center), CONV+WIND+MASS (right) at 300 hPa. Temperature (K) (shading), wind (vector) (m/s). Typhoon symbol represents the location of typhoon center (best track).

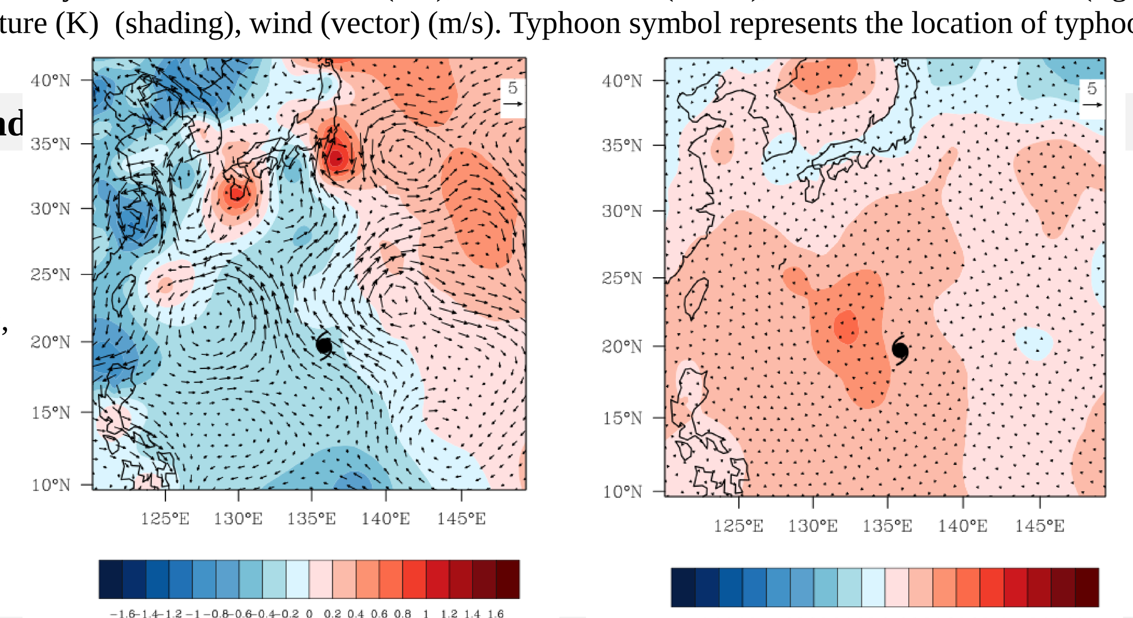

Figure3. Analysis increment by adding wind observation (left), by adding mass observation (right). Typhoon symbol represents the location of typhoon center (best track).

- Wind observations are rising the cyclonic circulation in typhoon center and anti-cyclonic circulation in near the typhoon.
- Wind corrections leads the temperature change with respect to circulation direction (Ex- cyclonic circulation: cold core).
- Mass information corrects the wrong temperature increment.

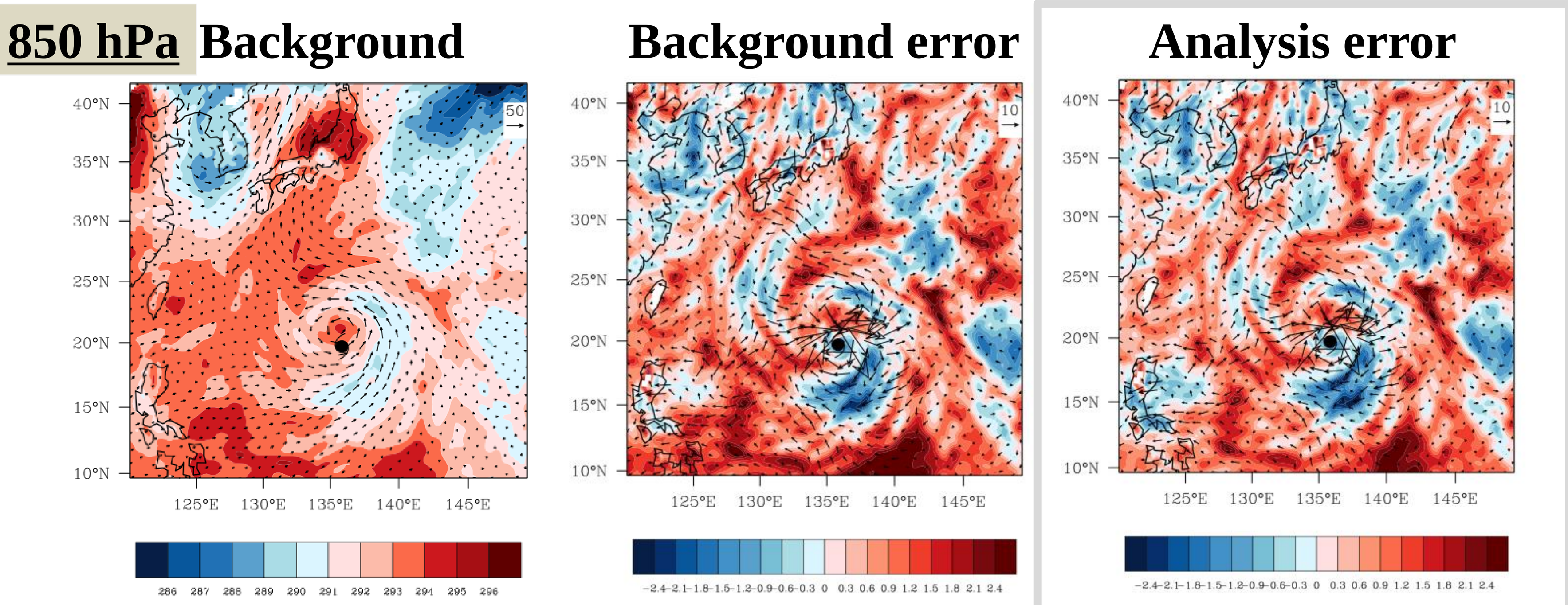

Figure4. Background (left), background error (background-IFS) (center), Analysis error (Analysis – IFS) (right) at 850 hPa. Temperature (K) (shading), wind (vector) (m/s). Typhoon symbol represents the location of typhoon center (best track).

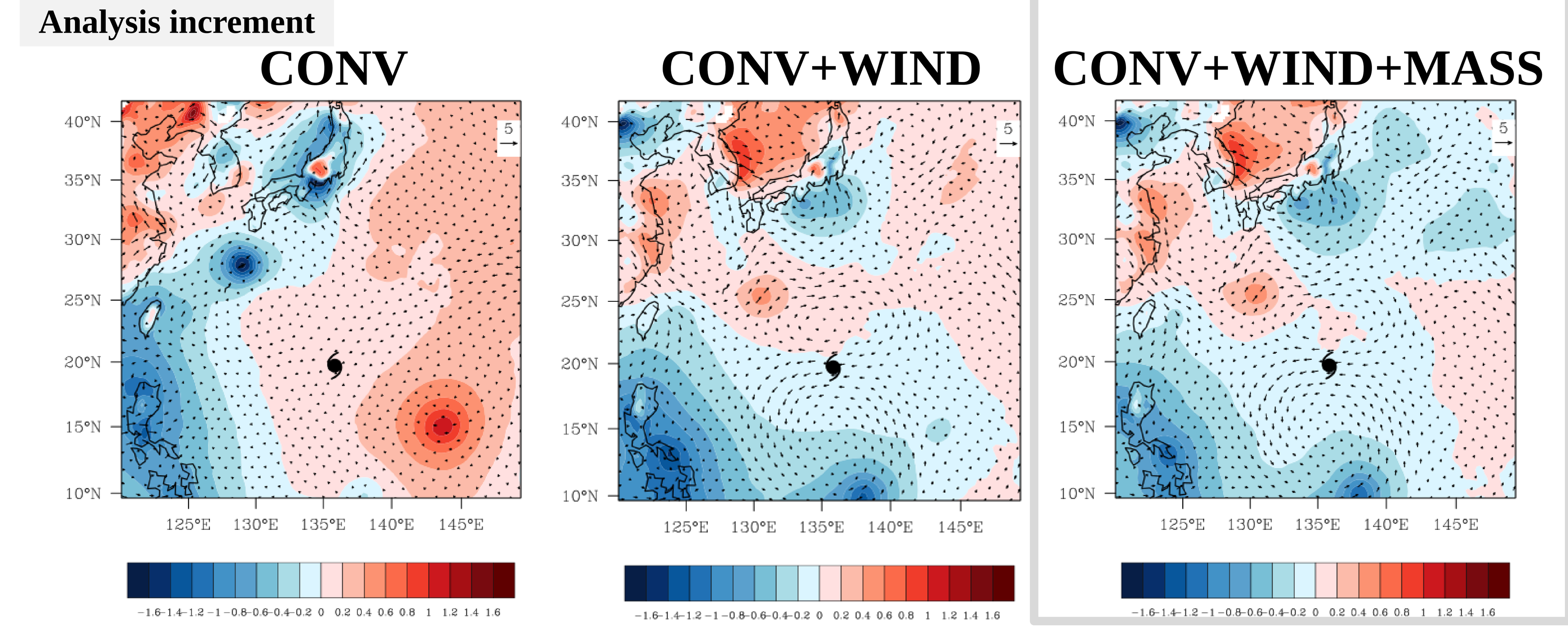

Figure5. Analysis increment of CONV (left), CONV+WIND (center), CONV+WIND+MASS (right) at 850 hPa. Temperature (K) (shading), wind (vector) (m/s). Typhoon symbol represents the location of typhoon center (best track).

- Conventional observation produces the increasing the background error in temperature (ocean).
- Wind observation corrects the wrong temperature increment with respect to wind mass relationship.

- The KIAPS 3DVAR system is well worked on the typhoon case with producing the reasonable analysis increment.
- Data assimilation makes the typhoon track is closer to the best track.

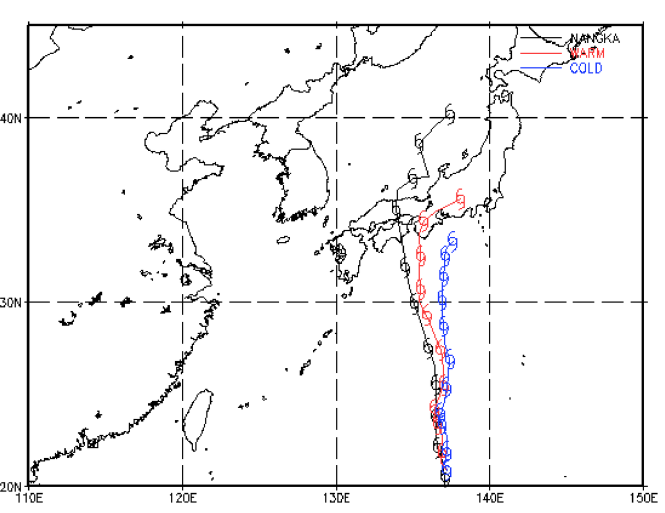

Figure6. Track of typhoon during 120 h forecast. Initial time: 2015071300 UTC. NANGKA (Black) is JTWC Best track, WARM is (CONV+WIND+MASS), COLD is background

Summary

The KIAPS 3DVAR system reduces the background error during assimilation process. These experiments show the background error covariance describes the relationship between the wind and mass in typhoon case. Based on the conventional assimilation, adding the wind observation experiment produces the wind and temperature corrections in near the typhoon area. When the mass observation gets together, the wrong temperature correction induced by wind is corrected. Finally, the change of the wind and temperature fields makes typhoon track is more realistic.