Implementation of GPS-RO data processing system for data assimilation

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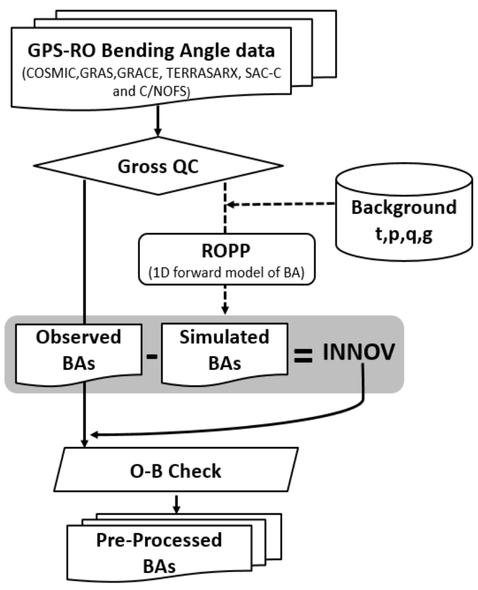
ABSTRACT

The data preprocessing and quality control modules for bending angle measurements of global positioning system radio occultation (GPS-RO) have been implemented and examined. GPS-RO data processing system is composed of several steps for checking observation locations, missing values, physical values for Earth radius of curvature, and geoid undulation. An observation-minus-background check is implemented by use of a one-dimensional observational bending angle operator and tangent point drift is also considered in the quality control process.

We have tested GPS-RO observations utilized by the Korean Meteorological Administration (KMA), based on both the KMA global model and the National Center for Atmospheric Research (NCAR) Community Atmosphere Model-Spectral Element (CAM-SE) as a model background. Background fields from the CAM-SE model are incorporated for the preparation of assimilation experiments with LETKF data assimilation system, which has been successfully implemented to a cubed-sphere model with fully unstructured quadrilateral meshes. As a result of data processing, the bending angle departure statistics between observation and background shows significant improvement. Also, the first experiment in assimilating GPS-RO bending angle within LETKF data assimilation system shows encouraging results.

DATA PROCESSING SYSTEM



[Flow chart of data preprocessing system]

- **1D forward model of bending angle**

$$\propto(a) = -2a\int_a^\infty \frac{1}{\sqrt{x^2-a^2}}\frac{dln(n)}{dx}dx$$

Where, α: bending angle
a: impact parameter
n: refractivity

- Applying 1d forward model for bending angle from ROPP package
- Calculate a vertical profile of bending angle from profiles of temperature, humidity and pressure.

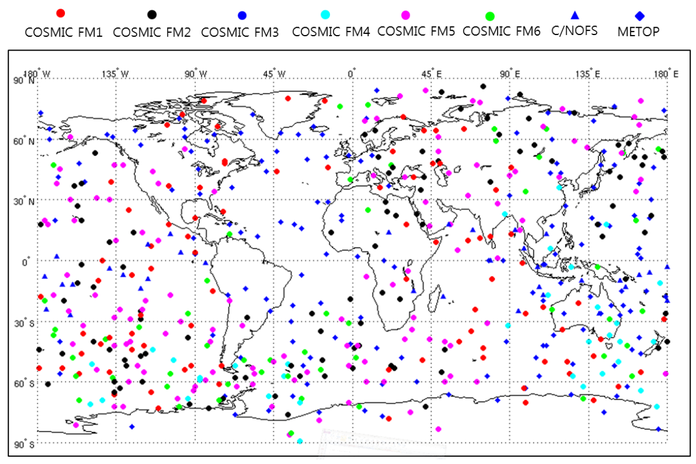
- **Background Check**

ABS (yobs – ycalc) > 5*Osigma

Assign of observation error
(adopted from ECMWF)

- Between surface and 10km : fractional error falls with height (20 % ~ 1 %)
- Above 10km : 1 %

GPS-RO DATA

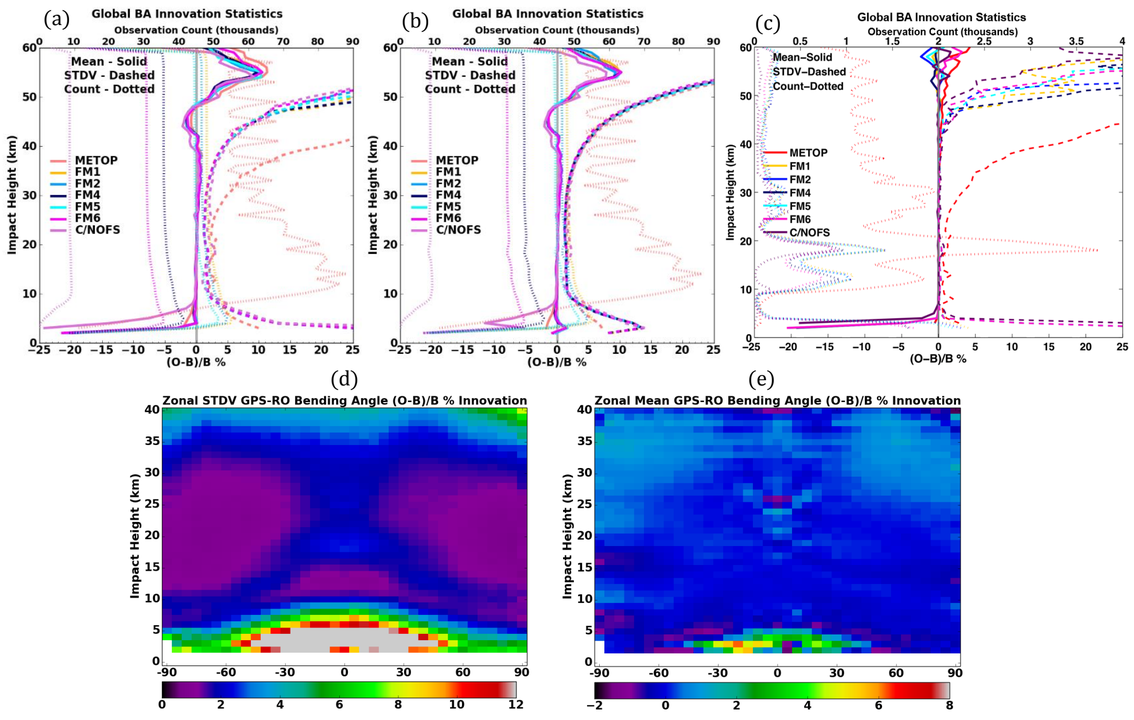


[Six-hour coverage of the GPS radio occultation events on November 7, 2012. The total number of profiles is 591]

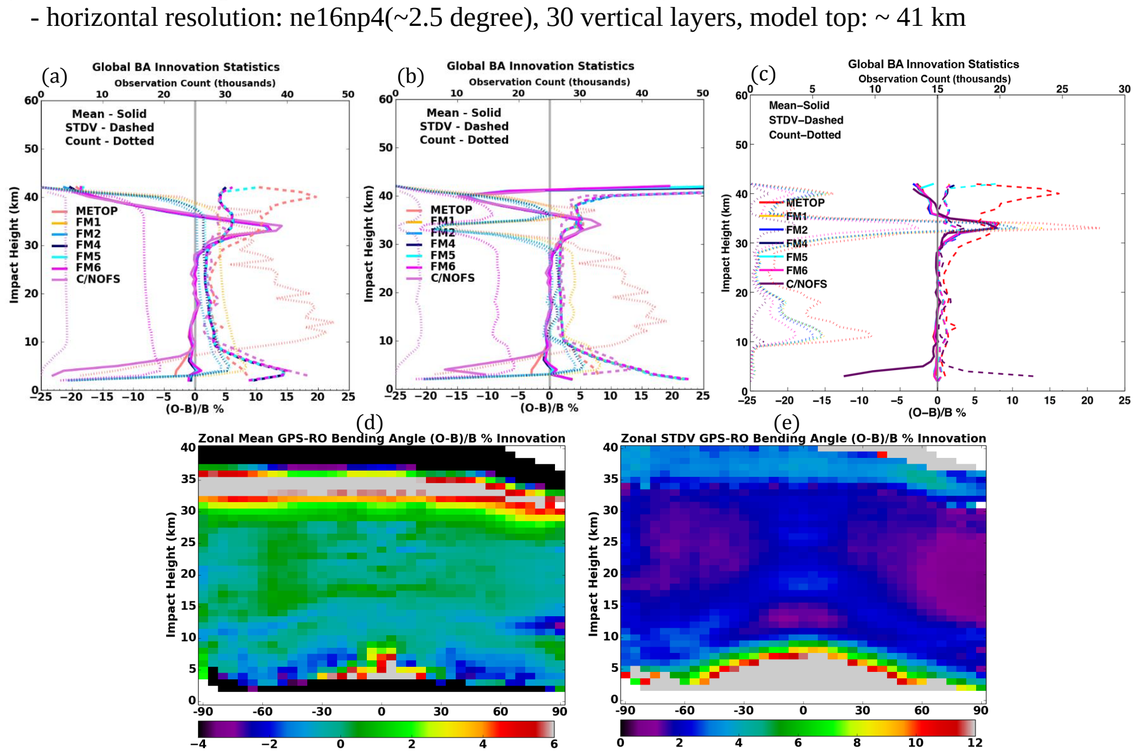
DATA PROCESSING

- **Departure statistics between the observation and background calculations of bending angles for the month of November 2012**

1) Used model background: KMA(UM) forecast
- horizontal resolution:25km, 70 vertical layers, model top: ~ 80km



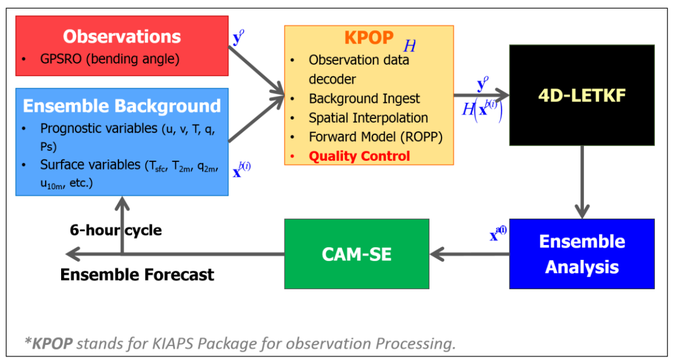
2) Used model background: CAM-SE forecast (30 ensemble)
- horizontal resolution: ne16np4(~2.5 degree), 30 vertical layers, model top: ~ 41 km



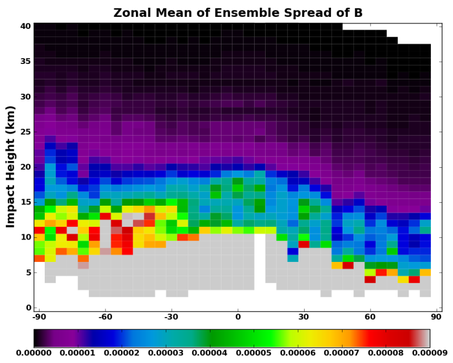
- (a) and (b): Global mean bending angle innovation and number of observations as a function of impact parameter before and after quality control, respectively.
- (c): Difference of departure statistics between (a) and (b) (a minus b).
- (d) and (e): Zonal mean and standard deviation of bending angle innovation for all satellites after quality control.
- Statistics are calculated based on each satellite data and displayed with different colors.

DATA ASSIMILATION

- **4D-LETKF Data assimilation system**

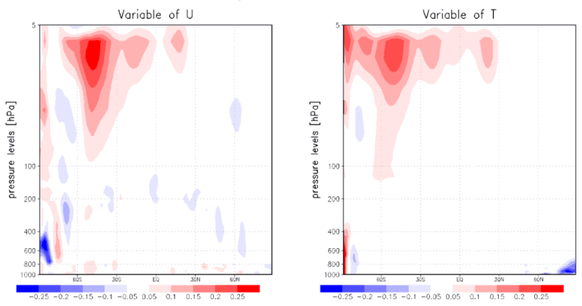


- 6-hr assimilation window,
- 9-hr forecast and every hour I/O
- Adaptive multiplicative inflation (Miyoshi, 2011)



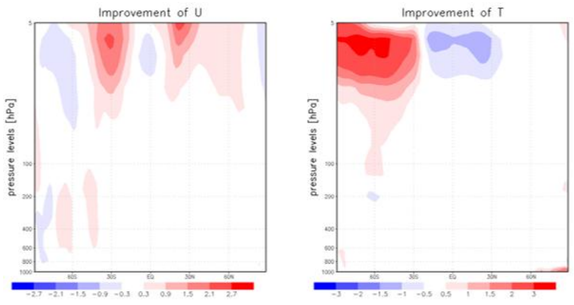
[Zonal mean of ensemble spread in the bending angle observation space (unit: radians), at the initial time of assimilation]

- **Analysis increments**

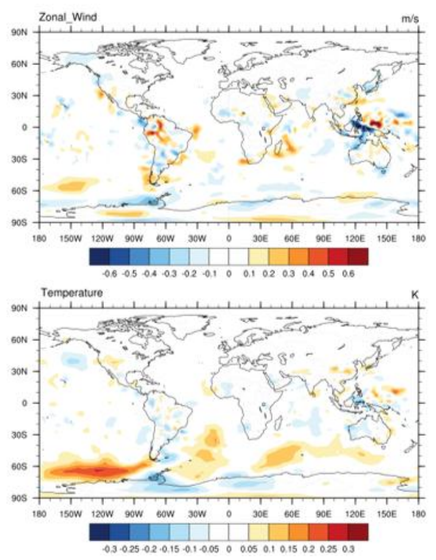


[Difference of zonally averaged analysis increments of U (left, unit: m/s) and T (right, unit: K) between CTRL_SONDE and EXP_RO for a 2-week analysis from November 15, 2011]

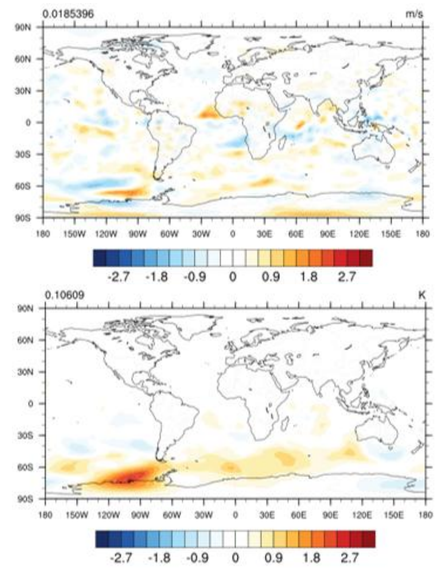
- **Improvement of analysis**



[Vertical cross section of zonally averaged improvement of EXP_RO analysis from CTRL_SONDE, toward ERA interim, computed by the equation $|\bar{x}^a_{sonde} - \boldsymbol{ERA}| - |\bar{x}^a_{ro} - \boldsymbol{ERA}|$ for U (left, unit: m/s) and T (right, unit: K)]



[Difference of horizontal analysis increment of U (left, unit: m/s) and (right, unit: K) between CTRL_SONDE and EXP_RO at the level of 100 hPa for a 2-week analysis from November 15, 2011]



[Improvement of EXP_RO analysis from CTRL_SONDE, toward ERA interim, computed by the equation $|\bar{x}^a_{sonde} - \boldsymbol{ERA}| - |\bar{x}^a_{ro} - \boldsymbol{ERA}|$ for U (left, unit: m/s) and T (right, unit: K) at the level of 100 hPa]

* Positive values indicate analysis of EXP_RO closer to ERA interim data than CTRL_SONDE and vice versa