Improvement of rainfall forecast by assimilations of ground-based GPS data and radio occultation data

Hiromu SEKO*, Yoshinori SHOJI*, Masaru KUNII**, and Toshitaka TSUDA***

*Meteorological Research Institute, Japan Meteorological Agency
**University of Maryland
** Research Institute for Sustainable Humanosphere, Kyoto University
Contents

1. Assimilation method of GPS radio occultation data.

2. Synergistic improvement of the heavy rainfall forecast using GPS RO data and ground-based GPS data.

Motivations

• Heavy rainfall often occurs when humid airflow is supplied from the sea.
• Dry air at middle level enhances convections.
• ‘Water vapor distribution over the sea’ and ‘Vertical profile of water vapor’ are important for accurate forecasts.
Motivations

• GPS radio occultation data is useful data, because it provides this information.

• Impacts of GPS radio occultation data on forecasts of heavy rainfall are investigated.
Torrential rainfall on 16 July 2004

• At Ohyu, rainfall amount of 133 mm/day was observed due to this rainfall band.
GPS radio occultation data

CHAMP/ISDC (GFZ): Challenging Mini-Satellite Payload for Geoscientific Research and Application Information System and Data Center

Level3(1): Profiles of refractive index,...

Refractive index (RI):

\[ RI = 1 + 77.6 \times 10^{-6} \frac{P}{T} + 0.373 \frac{e}{T^2} \]

⇒ RI is a function of temperature and water vapor.

RI is expected to improve rainfall forecasts.
• Tangent point data was provided.
• Tangent point was the point closest to the earth on the path.
• In the estimation of tangent point data, spherical uniform distribution was assumed.
Tangent point → Path data

Path data was reproduced from tangent point data by path-length weighting average.

\[
RI_{p1} = \frac{L_{3a}RI_{tp3} + L_{2a}RI_{tp2} + L_{1}RI_{tp1} + L_{2b}RI_{tp2} + L_{3b}RI_{tp3}}{L_{3a} + L_{2a} + L_{1} + L_{2b} + L_{3b}}
\]
• RO occurred near the rainfall band at 12 JST 16 July, just before the occurrence of heavy rainfall.
Observed and first guess profiles of the path data

• Observed RI was larger than that of first guess below 5 km.

• The forecasted rainfall is expected to be intensified by the assimilation of RO data.
Ground-based GPS data

- **Zenith Total Delay (ZTD)** is obtained by GPS software (GIPSY).

- **Mapping function, residuals and gradient** are obtained in the estimation of the ZTD.

- We can retrieve the **Slant Total Delay (SWV)** from the ZTD, mapping function and residuals.

- PWV and SWV were estimated from the ZTD, STD and surface meteorological data.
Positions of RO and ground-based GPS data

- Grids of which spatial interpolation weights are positive in the assimilations of ground-based GPS data (PWV, SWV) and RO data.
D-values of ground-based GPS data

- D-value of PWV (Obs. - First guess) from 12 JST to 15 JST.
Reproduced 3-hour rainfall of forecast time from 0 to 3 hours reproduced from the analyzed fields. Valid time is 15 to 18 JST 16 July 2004.

Heavy rainfall was not reproduced by assimilation of conventional data.
Synergistic improvement using RO and ground-based GPS data

- **RO**: Rainfall band was intensified.
- **Ground-based GPS**: Rainfall in the western Japan was reproduced.
Synergistic improvement using RO and ground-based GPS data

- **RO**: Water vapor near rainfall band was increased.
- **Ground-based GPS**: Water vapor in western Japan was increased and that on north of band was decreased.
Synergistic improvement using RO and ground-based GPS data

- **RO**: Low-level water vapor in rainfall band was increased.
- **Ground-based GPS**: Water vapor on the northern side of the band was decreased.
Summary of synergistic improvement

- GPS Radio occultation data and ground-based GPS data and improved the rainfall forecast.

- When RO data and ground-based GPS data are assimilated simultaneously, rainfall forecast and water vapor fields are much improved.
Forecast Result

Ps and 3-hour rainfall (FT=00 - 96)

When the global analysis is used for the initial field, the typhoon is not formed in the forecast model.

By contrast, when the global analysis is replaced by the meso 4D-Var analysis in the experiment, the generation of the typhoon is successfully simulated.
Typhoon central pressure

With GPS refractivity assimilated, the simulated typhoon intensity is closer to the best-track data.

Figure. Time series of the central pressure of the typhoon Usagi predicted by the NHM.
Differences of Analysis fields in winter experiment
December 20, 2008 00UTC～(Ozawa et al, 2011)

Data distribution
Red : COSMIC  Blue : MetOp
Green : GRACE

T(TEST)- T(CNTL) at 300hPa
T(CNTL) at 300hPa Analysis 200812200000
Improvement rates of zonal mean at FT=72

\[
\text{improvement rate} = \frac{\text{RMS}(\text{cntl}) - \text{RMS}(\text{test})}{\text{RMS}(\text{cntl})} \times 100 \%
\]

Pressure [hPa]

Summer experiment
Red: Improvement
Blue: deterioration

Winter experiment

COSMIC data have been using in operation since November 1, 2010.
Thank you for your time