Assimilation experiments with COSMIC GPS radio occultation measurements and ground-based GPS PWV: Typhoon "Nari" in 2007

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1. Introduction

In spite of the improvement of Numerical Weather Prediction (NWP) model and observational technique, it is hard to forecast the weather phenomenon such as typhoon and the heavy rainfall due to the inadequate observation of the distribution of moisture in time and space. Tropical cyclones are developed by the moisture field over tropical oceans, but there are less observations than land area. This limitation makes a drop the predictability of tropical cyclones (Smith, 2007).

The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) of the United States and the Formosa Satellite Mission 3 (FORMOSAT-3) of Taiwan can provide the information to improve tropical cyclone forecasting (Anthes, 2008). In this research, we have conducted the assimilation experiments with the refractivity from Radio Occultation (RO) and Precipitable Water Vapor (PWV) retrieved from Global Positioning System (GPS). And we have analyzed the effect of each data in the WRF-3DVAR for Typhoon "Nari" in 2007. Sensitivity experiments with the refractivity and PWV are performed and effects of both data are discussed in this study.

2. Data assimilation and Numerical experiment

In order to assimilate with the refractivity from GPS RO and GPS PWV, we used the neutral atmospheric profiles from COSMIC Data Analysis and Archival Center (CDAAC) and PWV from the Korea Astronomy and Space Science Institute (KASI) GPS network. Sensitivity experiments were executed to evaluate each effect of refractivity and PWV to the data assimilation. Figure 1 is the schematic diagram of sensitivity experiments in domain 1. The assimilation starts at 12 UTC on September 14 and 15 in domain 1 and 2. For domain 3, it starts 00UTC 16 September 2007. Horizontal grid resolution of each domain is 18, 6, 2km and the vertical level is 28 layers (Table 1). The initial and lateral boundary conditions was used the 1˚ x 1˚ National Center for Environmental Prediction (NCEP) Final Analysis (FNL) data.

Figure 2(a) shows the distribution of RO events with COSIMC in domain 1 at the initial time and figure 2(b) shows the location of KASI GPS site in domain 3. The refractivity from RO and GPS PWV was assimilated into WRF model.

3. The results of sensitivity experiments

In this research, we focused on the heavy rainfall events recorded more than 500mm per day (12UTC 15 September to 12UTC 16 September 2007) over Jeju Island, South Korea, caused by typhoon "Nari". The results of assimilation with the refractivity and PWV have shown that the track of Typhoon and the amount of the precipitation improved like as the results of Huang et al. (2005).

Table 2 shows the quantitative analysis of the predictability of Typhoon "Nari" in the NWP model. It gives a statistical threat scores with thresholds of 5mm, 10mm, 20mm and 30mm for the 6-hour accumulated rainfall with and without GPS assimilation experiments during the peak time (00-12UTC 16 September 2007) of rainfall. Both results (the refractivity and PWV) of assimilation experiments show the improvement comparing with CTL. The threat scores of data assimilation with GPS RO are better than that of GPS PWV.

As shown in Figure 3, the time series of 1-hour accumulated rainfall with GPS RO data assimilation is compared with CTL. The CTL does not have the large change of 1 hour rainfall during the precipitation peak period, but the GPS RO has the peak as the observation. The improvement in the typhoon predictability is due to the positive impact for the initial conditions with GPS data.

4. Summary and Discussion

The objective of this research is to analyze the effects of GPS data assimilation on Typhoon "Nari" case over Jeju Island and the southern part of Korea on 16 September 2007.

Sensitivity experiments to evaluate effects the refractivity from GPS RO and GPS PWV show that the refractivity is more sensitive for precipitation than GPS PWV. The reason is GPS RO has the advantage to provide the vertical profile data and the information for typhoon over the ocean.

The data assimilation still has limitations as the quality for GPS data and the balance in the NWP model. The result of this research shows the predictability of Typhoon "Nari" case was improved by all experiments of assimilating the refractivity from GPS RO and GPS PWV. Therefore, it can be expected that the improvement of data quality from GPS and the data assimilation technique can support the better results of heavy rainfall accompanying with Typhoon.

Acknowledgement

This work was funded by the Korea Meteorological Administration Research and Development Program under Grant CATER 2006-3104.

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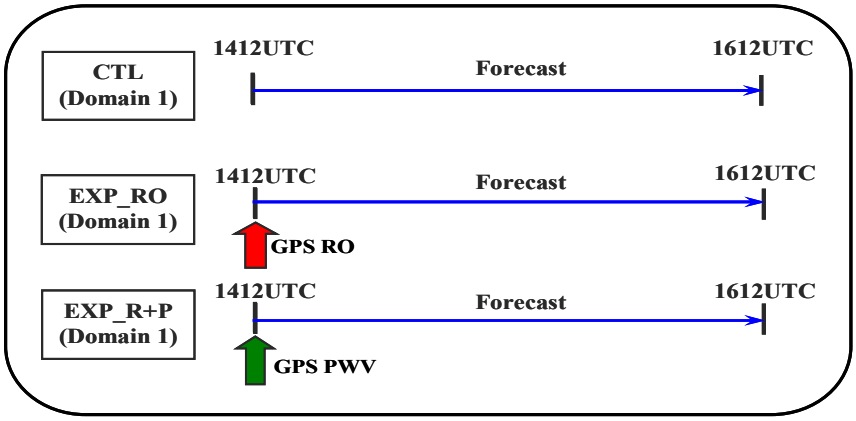

Fig. 1. Schematic diagram of experimental design for GPS RO and PWV data assimilation.

Table 1. Model configuration.

	Domain 1	Domain 2	Domain 3
Horizontal Dimensions	211 x 211	181 x 181	181 x 181
Vertical layers/Model Top	28 sigma levels / 50hPa		
Horizontal grid distance	18km	6km	2km
Time integration	48h(Δt = 120s)	24h(Δt = 40s)	12h(Δt = 15s)
Center of the model	34°N x 126°E		
Microphysics	WSM 6-class graupel		
Cumulus Parameterization	Kain-Fritsch	None	
Planetary Boundary Layer	YSU		
Radiation	rrtm/Dudhia		
Nesting	1 - way		

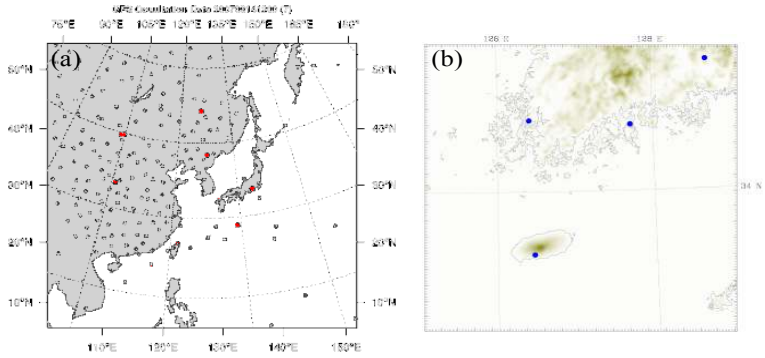

Fig. 2. (a) The positions (red dot) of COSMIC RO events in Domain 1. (b) the positions of KASI GPS site in Domain 3 (blue dot).

Table 2. Threat scores of the accumulated rainfalls between 0-6 hour (00-06UTC 16 Sep.) and 6-12 hour (06-12UTC 16 Sep.) of different thresholds for Typhoon "Nari" simulation with and without GPS data assimilation.

Thresholds	CTL(0-6h)	GPS RO(0-6h)	PWV(0-6h)	CTL(6-12h)	GPS RO(6-12h)	PWV(6-12h)
5mm	0.356	0.480	0.426	0.404	0.623	0.525
10mm	0.294	0.366	0.303	0.217	0.415	0.255
20mm	0.238	0.281	0.269	0	0.272	0.08
30mm	0.214	0.192	0.2	0	0.154	0.067

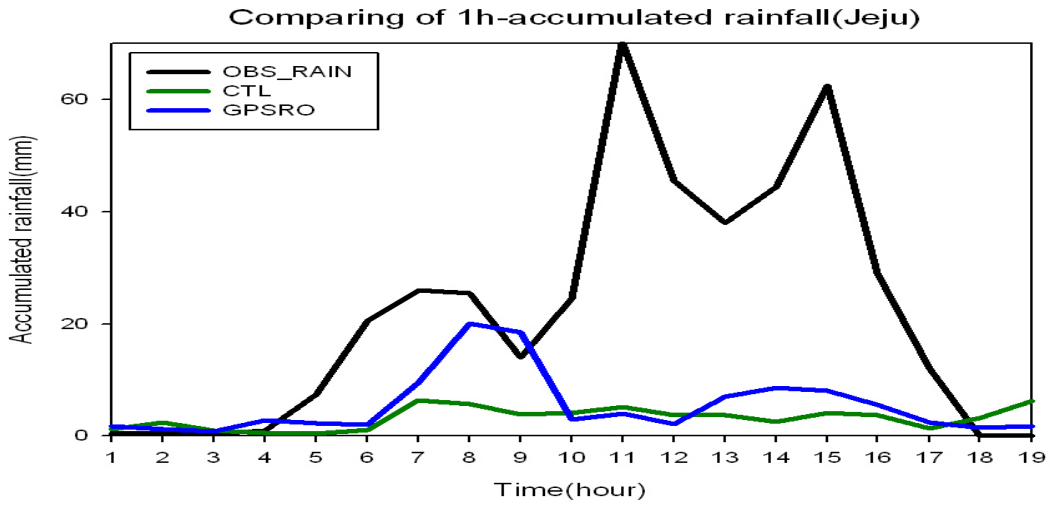

Fig. 3. Time series of hourly precipitation for observation, CTL and GPS RO data assimilation over Jeju from 18UTC 15 to 12UTC 16 Sep. 2007.