Improved Tropical Cyclone Predictions by Assimilation of GSMaP Precipitation with Gaussian Transformation

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Abstract

Assimilation of precipitation has been generally unsuccessful because: a) errors associated with precipitation are not Gaussian, and this violates the basic assumption of current data assimilation methods, and b) forcing the model to rain where observed by moistening or drying the atmosphere, as done in assimilation of precipitation in the past, does not change the main dynamical variable (potential vorticity) and thus is forgotten as soon as the forcing of the "assimilation of moisture" ceases. *Lien et al.* (2013, 2016a, 2016b) and later *Kotsuki et al.* (2017) developed a methodology that successfully addressed these problems: They performed a transformation of observed and modeled precipitation into Gaussian variables (anamorphosis) which made the errors also much more Gaussian. They also used ensemble-based data assimilation approaches that are more naturally able to assimilate precipitation and directly influence the model potential vorticity, since the ensemble members that precipitate closely as observed, receive higher weights in the ensemble analysis, and therefore "donate" their more correct dynamics to the analysis mean, thus creating an analysis mean that is closer to having the right dynamics. As a result, both *Lien et al.* (2016) and *Kotsuki et al.* (2017) showed that assimilation of remotely sensed precipitation (NASA TMPA, and JAXA GSMaP) improves the forecast skill for over 5 days.

The goal of this study is to investigate whether we can improve the Tropical Cyclone (TC) predictions by precipitation assimilation with the Gaussian Transformation. We implement the precipitation assimilation module into the Local Ensemble Transform Kalman Filter (LETKF) assimilation system for the mesoscale model SCALE-RM developed at the RIKEN Advanced Institute for Computational Science in Japan.

We conducted assimilation experiments for 4 typhoon cases in 2015 by assimilating additional Level-3 JAXA GSMaP retrievals. Our results show that with additional assimilation of JAXA GSMaP retrievals,

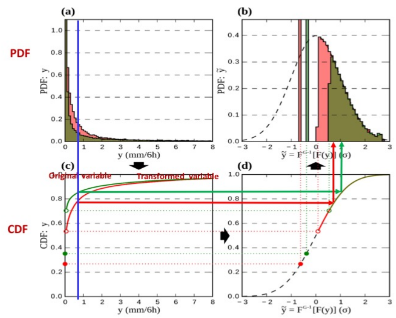
(1) The minimum SLP analysis is closer to the value of the JMA best track datasets;
(2) The hydrometeor distribution analysis is closer the GMI Level-2 retrievals;
(3) Both the 3-day track and intensity forecasts are improved.

Gaussian Transformation

$$F^G(\tilde{y}) = F(y) \quad \Rightarrow \quad \tilde{y} = F^{G^{-1}}[F(y)]$$

y : original variable (mm/6hr) $\quad$ $\tilde{y}$: Transformed variable (sigma)

$F(\,)$: CDF of original variable $\quad$ $F^G(\,)$: CDF of Gaussian distribution



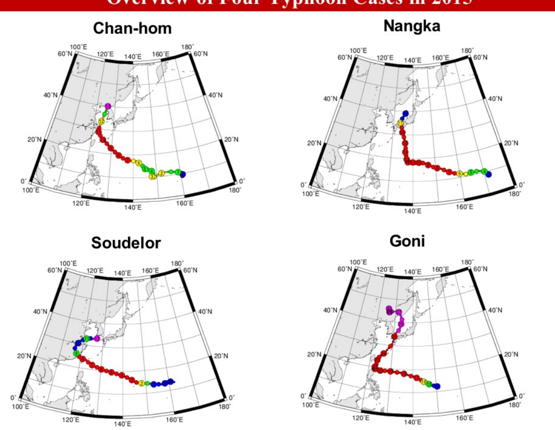
Step 0: Obtain PDF & CDF

Step 1: Compute $F(y)$

Step 2: Compute $\tilde{y} = F^{G^{-1}}[F(y)]$

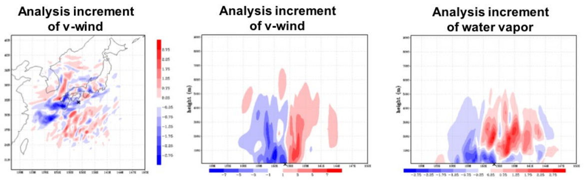
(*Lien et al.* 2013, 2016b)

Overview of Four Typhoon Cases in 2015



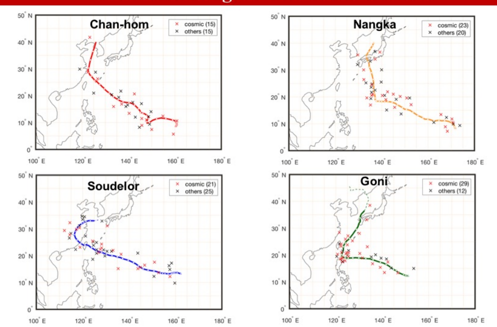
Best track of Typhoon Chan-hom, Nangka, Soudelor, and Goni in 2015. Figures from http://agora.ex.nii.ac.jp

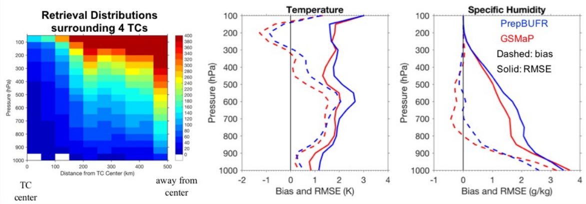
Single-observation Experiment



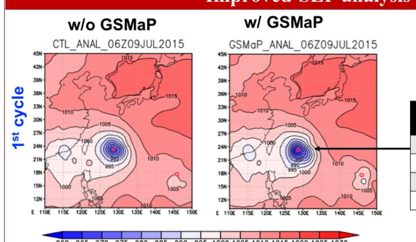
The analysis increment ($\mathbf{x}^a$-$\mathbf{x}^b$) map of the v-wind at the surface (left), and the cross section of the v-wind (middle) and the water vapor (right) along the latitude where the observation resides. The location of the single GSMaP observation is marked by a black cross.

Verification Against GPS RO Profiles



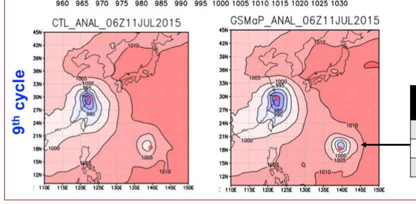


Improved SLP analysis



Chan-hom

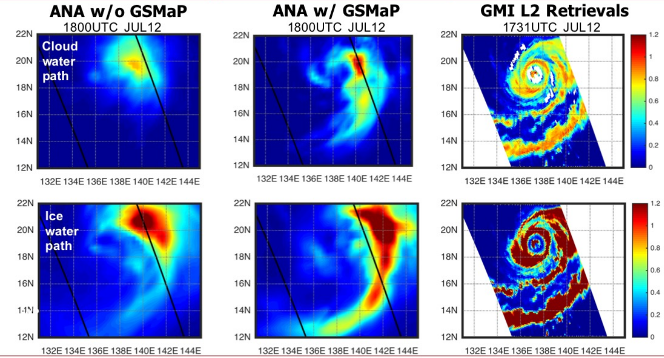
Source	Min. SLP (mb)
Background	973.8
w/o GSMaP	967.4
w/ GSMaP	**960.2**
JMA Best Track	**960**



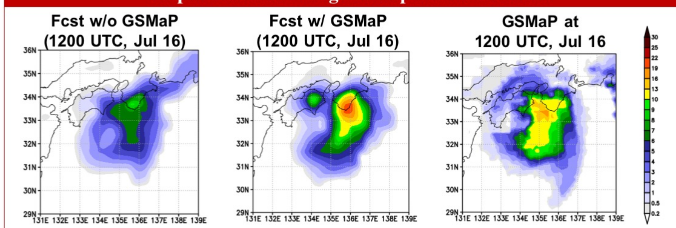
Nangka

Source	Min. SLP (mb)
w/o GSMaP	997.8
w/ GSMaP	985.7
JMA Best Track	945

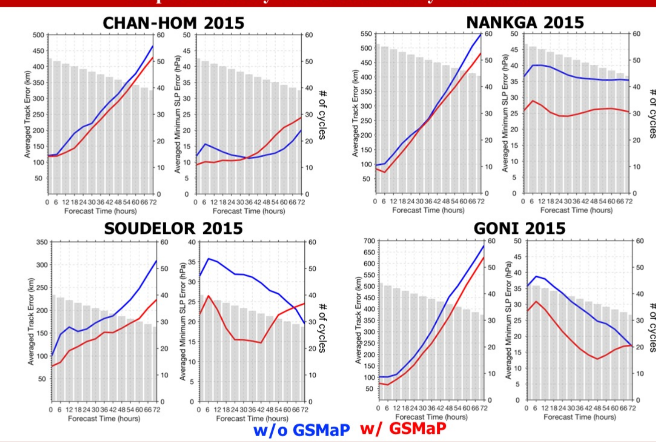
Improved Hydrometeor Analysis



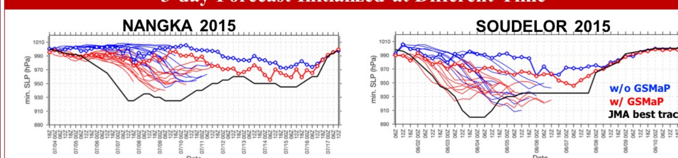
Improved short-range Precipitation Forecast



Improved 3-day Track & Intensity Forecasts



3-day Forecast Initialized at Different Time



Reference

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