Ensemble-based sensitivity analysis on an WRF-Ensemble Kalman Filter Output of Typhoon Morakot (2009)

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Outline

• Impact of Typhoon Morakot
• Ensemble-based sensitivity analysis
• Methodology
• Results
• Summary
Record-breaking rainfall
468 death, 162 missing
$3.3 USD damages
Rainfall forecast of Ensemble members

(Zhang et al. 2010)
Sensitivity analysis

• Forecast sensitivity provides an objective evaluation of how changes to an initial condition affect a forecast
• In a predictability context, sensitivity analysis provides a basis for understanding the forecast errors
• For adaptive observation, sensitivity analysis tells us how to assimilate the additional observation to reduce errors.
Ensemble-based sensitivity analysis

• Ensemble-based sensitivity analysis uses the sample statistics to estimate relationship between forecast metrics and initial conditions.

• Forecast metrics can be any variables that are interested by forecasting.
Methodology

• Method is first outlined in Hakim and Torn (2008).

• For an ensemble of size $M$, the forecast metric $J$ to a analysis state variable is determined by

$$\frac{\partial J}{\partial x} = \frac{\text{cov}(J, X)}{\text{var}(X)}$$

Where $X$ and $J$ are $1 \times M$ ensemble estimates of the state variable and forecast metric respectively.
Data and definitions

• Ensemble output is provided by the WRF forecast of Typhoon Morakot (2009) coupled with the Ensemble Kalman Filter data simulation technique (Zhang et al. 2010).
• Forecast metrics are box averaged rainfall and averaged sea level pressure (SLP) at landfall time of 1800 UTC August 7.
• Analysis of wind, height and water vapor mixing ratio at 700 mb are examined.
Sensitivity of averaged rainfall to 700mb wind
Sensitivity of averaged rainfall to 700mb height

Wind

00h

12h

24h

36h

48h

60h

Wind

Wind

Wind

Wind

Wind

Wind

-4.2 -3.6 -3 -2.4 -1.8 -1.2 -0.6 0.6 1.2 1.8 2.4 3 3.6 4.2
Sensitivity of averaged rainfall to water vapor
Sensitivity of averaged SLP to 700mb wind
Sensitivity of averaged SLP to 700mb height
Sensitivity of averaged SLP to water vapor

Wind

00h

12h

24h

36h

48h

60h

Contour from 0.35 to 3.40 by 0.2

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Contour from 0.35 to 3.40 by 0.2

-2 -1.8 -1.6 -1.4 -1.2 -0.8 -0.4 0.4 0.8 1.2 1.4 1.6 1.8 2
summary

• The domain averaged rainfall and SLP are highly sensitive to height, water vapor flux and wind speed, especially the wind in the maximum wind radius and the wind in southwest monsoon region.
• Meanwhile, the large wind has positive impact on wind, which means the intensity and organization of typhoon is important to precipitation formation.
• For 700 mb height, the field in the outer environment of typhoon is more important than the inner core field, especially the sub-tropical high and monsoon trough.
• The sensitivity responds from wind field and height is mainly large scale errors.
• Small scale errors of water vapor contribute much to forecast metrics.