Ensemble – based Sensitivity Analysis Applied to a heavy rainfall event over Uttarakhand State

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Introduction

- Understanding the dynamics of forecast uncertainties and error growth is essential for accurate prediction of severe weather events.
- The short term predictability of extreme rainfall events are limited due to rapid error growth and nonlinearity.
- Sensitivity Analysis provides a basis for understanding dynamics of forecast errors and it identifies the region where additional observation needs to gathered to reduce the forecast errors.
- Ensemble sensitivity analysis (ESA) can be defined as how a forecast metric responds to changes in initial conditions and hence reveals the features associated with the flow.
- Such a statistical estimation of the relationship between the response functions and number of initial condition variables can then be used to improve the predictability of the forecasts.
- In this study ESA is applied to an extreme weather event happened over Uttarakhand during June 2013 using the ARW-WRF model DART based Ensemble Kalman Filter.

Objectives

- Several studies addressed the structure and dynamics of the heavy rainfall over Uttarakhand. However, the predictability aspect of the event has not been studied.
- This study attempts to understand the short range predictability of the Heavy rainfall event over Uttarakhand using Ensemble Sensitivity Analysis.

Ensemble Sensitivity Analysis

- How changes in initial conditions affects a forecast metric?

$$\frac{\partial J}{\partial x_i} = \frac{cov(J, x_i)}{var(x_i)}$$

x_i – ith state variable $(1 \times M)$

J – forecast metric $(1 \times M)$

- Confidence testing is applied using ensemble statistics
- No adjoint or tangent linear model required

Case Overview

7 - 13 June 2013

Heavy Precipitation due to Deep Convection. Cold cloud-top.

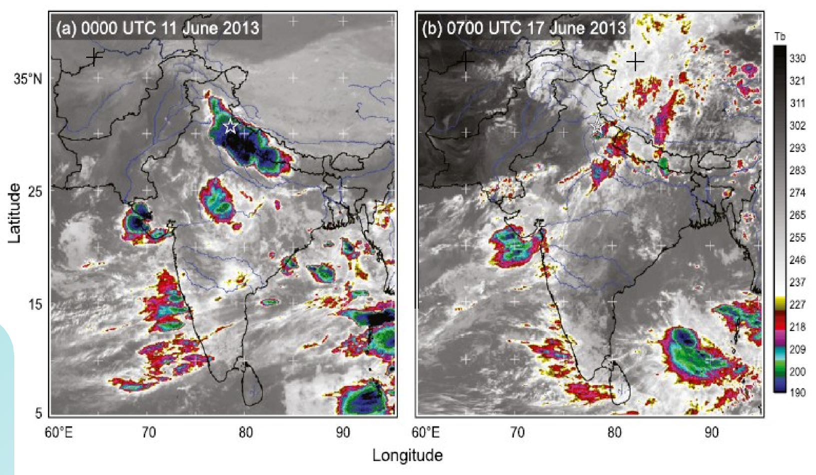

Fig.1 Meteosat-7 infrared satellite imagery for (a) 0000 UTC 11 Jun and (b) 0700 UTC 17 Jun 2013. *Courtesy: R. A. Houze Jr., and Coauthors, 2017: Multiscale aspects of the storm producing the June 2013 flooding in Uttarakhand, India. Mon. Wea. Rev., Vol.145, 4448- 4466.*

14 - 17 June 2013

Warm cloud-top pattern. More precipitation Non-convective storm Merging of a trough in the westerlies with a low pressure.

Experimental Design

- Weather Reasearch and Forecasting (WRF) model version 3.8.1
- Data Assimilation Research Testbud (DART) ensemble adjustment Kalman Filter (EAKF) is used to assimilate observations with 80 ensembles
- Domain resolution : 27km
- Vertical levels : 36
- **Forecast Metric (J)**: 48 hr Accumulated Precipitation
- **State Vectors (x)**: 500hPa Geopotential height, Sea level pressure and Wind vectors

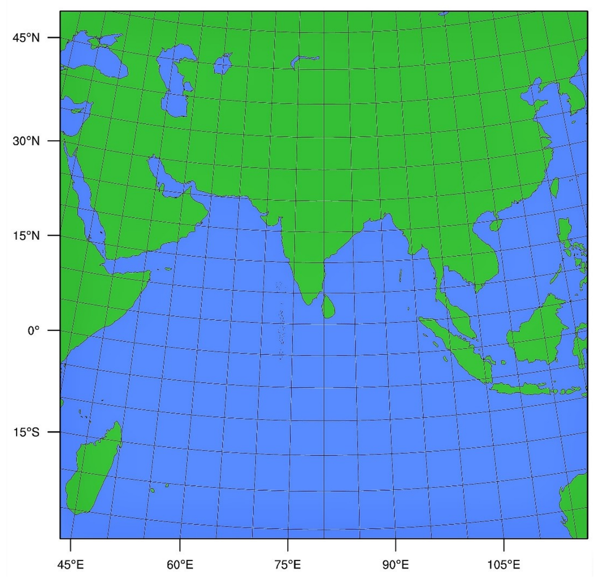

Fig. 2 Model Domain

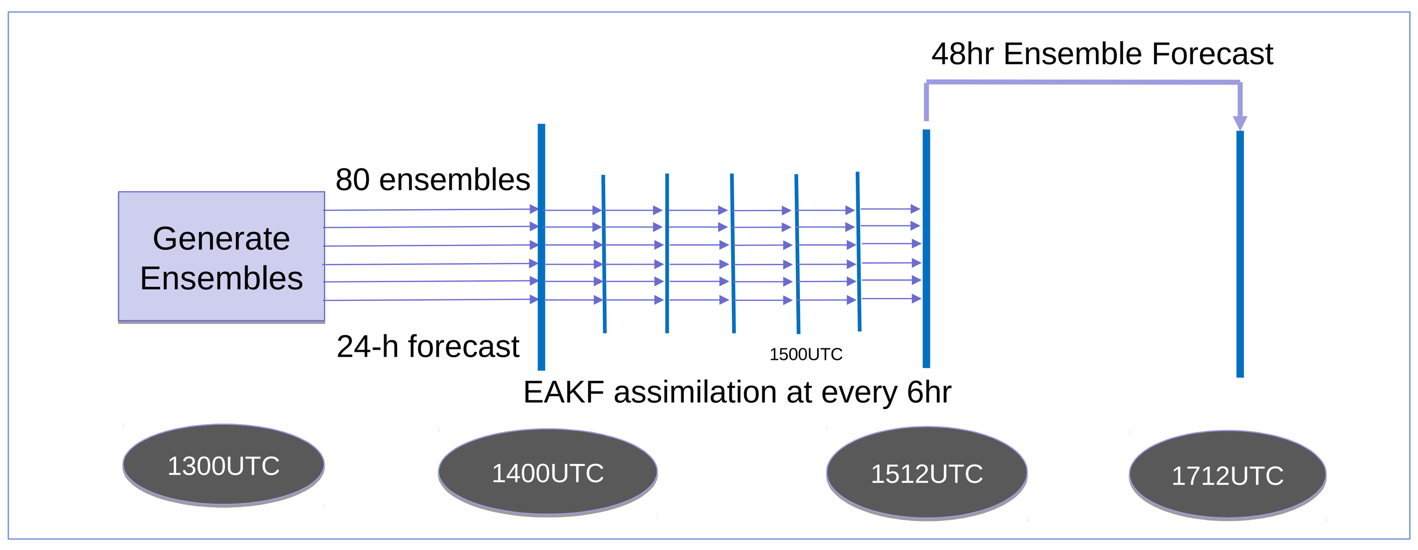

Fig. 3 Experimental Design

Results

Sensitivity of 48-h Accumulated Precipitation to 500hPa Geopotential Height

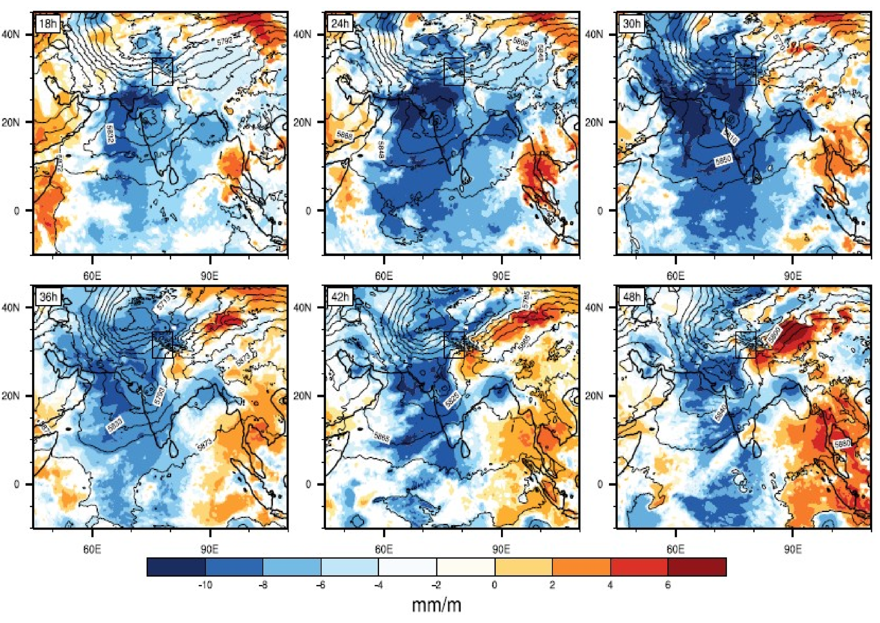

Fig. 4. Sensitivity (shading) of 48-h accumulated precipitation at 1200 UTC 17 June 2013 to 500hPa geopotential height and ensemble mean geopotential height (contoured every 40m) at 0600 UTC 16 June 2013, 1200 UTC 16 June 2013, 1800 UTC 16 June 2013, 0000 UTC 17 June 2013, 0600 UTC 17 June 2013 and 1200 UTC 17 June 2013. The black box represents the area of the response function over Uttarakhand.

Sensitivity of 48-h Accumulated Precipitation to Sea Level Pressure

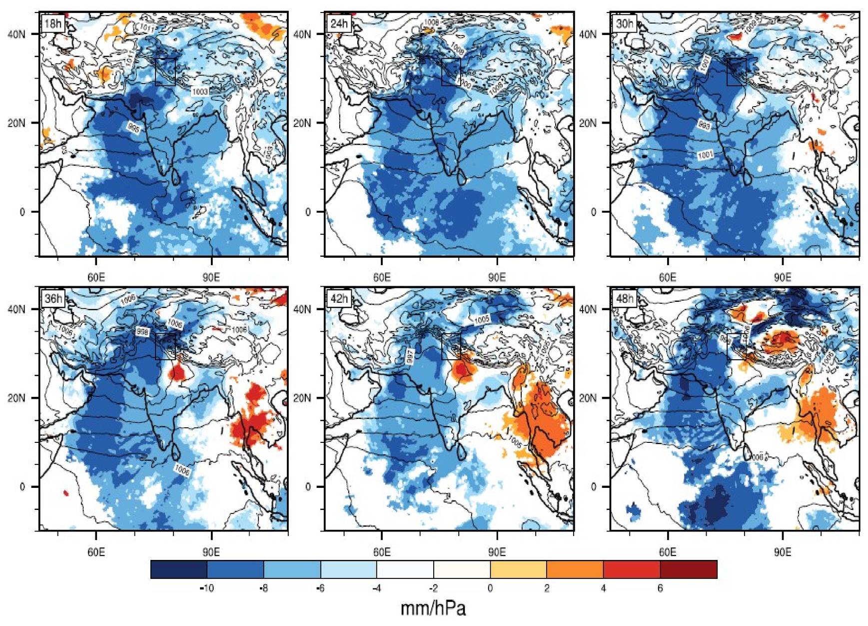

Fig. 5. Sensitivity (shading) of 48-h accumulated precipitation at 1200 UTC 17 June 2013 to sea level pressure and ensemble mean SLP (contoured every 4hPa) at 0600 UTC 16 June 2013, 1200 UTC 16 June 2013, 1800 UTC 16 June 2013, 0000 UTC 17 June 2013, 0600 UTC 17 June 2013 and 1200 UTC 17 June 2013. The black box represents the area of the response function over Uttarakhand.

Sensitivity of 48-h Accumulated Precipitation to 700hPa U-wind

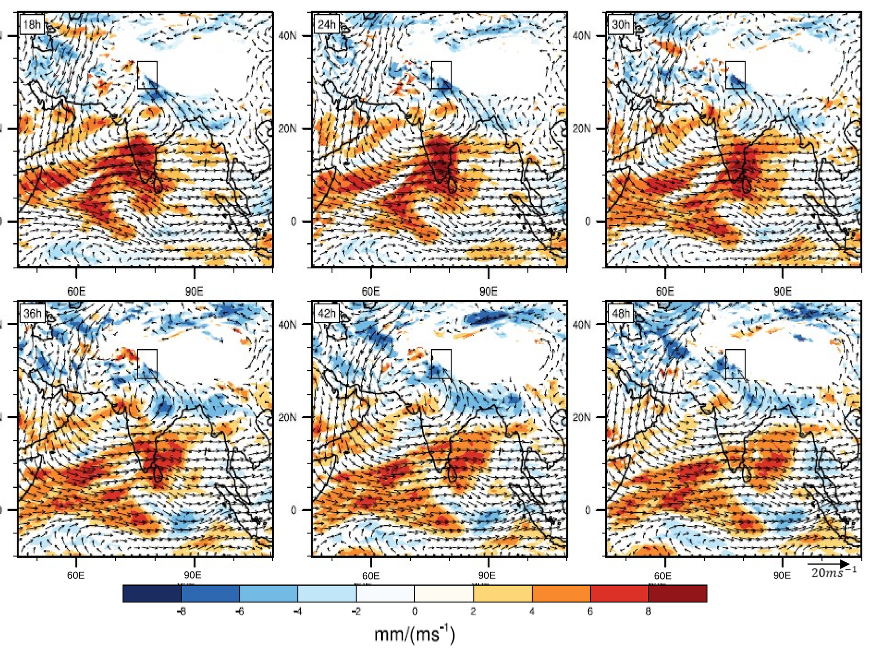

Fig. 6. Sensitivity (shading) of 48-h accumulated precipitation at 1200 UTC 17 June 2013 to 700hPa U-wind and ensemble mean wind vectors at 0600 UTC 16 June 2013, 1200 UTC 16 June 2013, 1800 UTC 16 June 2013, 0000 UTC 17 June 2013, 0600 UTC 17 June 2013 and 1200 UTC 17 June 2013. The black box represents the area of the response function over Uttarakhand.

Sensitivity of 48-h Accumulated Precipitation to 700hPa V-wind

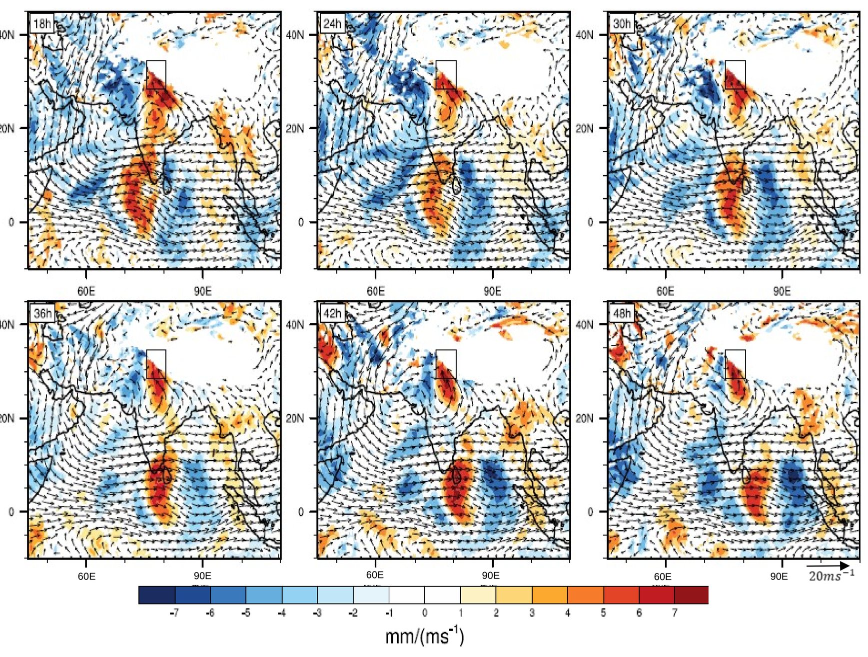

Fig. 7. Sensitivity (shading) of 48-h accumulated precipitation at 1200 UTC 17 June 2013 to 700hPa V-wind and ensemble mean wind vectors at 0600 UTC 16 June 2013, 1200 UTC 16 June 2013, 1800 UTC 16 June 2013, 0000 UTC 17 June 2013, 0600 UTC 17 June 2013 and 1200 UTC 17 June 2013. The black box represents the area of the response function over Uttarakhand.

Conclusions

- Sensitivity of 48-h accumulated precipitation is investigated with respect to different state variables that might be important for the dynamics of the extreme rainfall over Uttarakhand in June 2013.
- The observed sensitivity patterns reveal the features of the flow associated with the heavy rainfall activity over Uttarakhand and they are consistent with the observed dynamics.
- The strong gradient in sensitivity observed in the results can provide information on how the gradient in geopotential height, SLP and wind vectors relates to the precipitation forecast.
- These sensitive regions can be targeted as locations for additional observations to improve the forecast skill.

References

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