Impact of Representing Model Error in a Hybrid Ensemble-Variational Data Assimilation System for Track Forecast of Tropical Cyclone Hudhud (2014)

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INTRODUCTION

Uncertainties in Numerical Weather Prediction (NWP) models are generally not well represented in ensemble based data assimilation (DA) systems. The performance of an ensemble based DA system becomes suboptimal, if the sources of error are undersampled in the forecast system (Berner et al., 2015).

We investigated the effect of two types of model error treatment schemes and their combinations in hybrid ensemble transform Kalman filter (ETKF) – Three dimensional variational (3DVAR) DA system.

(i) Multiphysics approach which uses different combination of cumulus, microphysics and planetary boundary layer schemes (Meng and Zhang, 2007).

(ii) Stochastic Kinetic Energy Backscatter (SKEB) scheme which perturbs horizontal wind and potential temperature tendencies, stochastically (Shutts, 2005).

(iii) A combination of both Multiphysics and SKEB scheme.

More specifically, the impact of flow-dependent ensemble error covariances in a DA system with and without explicit model error representation for the track forecast of tropical cyclone (TC), Hudhud, is explored.

SYNOPTIC OVERVIEW

The TC considered in this study is Hudhud, which started forming as a low pressure system on October 6, 2014, over the Bay of Bengal region of North Indian Ocean. On October 9, 2014, Hudhud was declared as a severe cyclonic storm just before it underwent rapid deepening and intensification. Hudhud made a landfall on October 12, 2014, a few hours prior to the storm just before it underwent rapid deepening and intensification.

DATA ASSIMILATION SYSTEMS

(i) Three dimensional - Variational Data Assimilation System (3DVAR) (Bareker et al., 2004).

(ii) Hybrid ensemble transform Kalman filter (ETKF) – 3DVAR DA system. (Wang et al., 2008)

Model: Advanced Weather Research and Forecast (ARW WRF) - Version:3.6.1

Hybrid DA system

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The hybrid model is configured to have two domains with 27 km and 9km horizontal resolution and 36 vertical levels.

The spatial extent of the outer domain is mostly comparable to India Meteorological Department (IMD) operational domain in WRF model simulations.

SKEBS

The SKEB scheme introduces temporally and spatially correlated random perturbations to potential temperature and a rotational component of horizontal winds.

\[ \psi(x, y, t) = \sum_{l=1}^{L/2} \sum_{m=-l}^{l/2} \frac{\psi_l(t) e^{i(2\pi l y \Delta y / y_0)}}{\Delta y} \]

MULTIPHYSICS

The multiphysics ensembles, 40 in number, were created by the combinations shown below:

<table>
<thead>
<tr>
<th>Experiment (without)</th>
<th>Microphysics</th>
<th>Planetary boundary layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain-Fritsch</td>
<td>YSU</td>
<td>MYMRFMYNN</td>
</tr>
<tr>
<td>Betta-Miller-Jaeger</td>
<td>YSU</td>
<td>MY M5</td>
</tr>
<tr>
<td>Grell-Davis-Krueger</td>
<td>YSU</td>
<td>MY</td>
</tr>
</tbody>
</table>

EXPERIMENTAL DESIGN

The first analysis time for all the experiments was at 00 UTC on October 6, 2014, and assimilation experiments every 12 h intervals until October 9, 2014. The model was then integrated into free forecast mode, till the cyclone made the landfall.

Six experiments were conducted:

3DVAR - utilizes the static covariances for assimilating observations

HYBRID50 - 50% weight was placed on ensemble covariances and other 50% assigned on static covariances

HYBRID100 - 100% weight placed on ensemble covariances

HYBRID-Multi - ensembles uses multiphysics configuration

HYBRID-SKEB - ensembles uses SKEB scheme

HYBRID-MultiSKEB ensembles uses multiphysics and SKEB schemes

The experiments which explicitly accounts for system error in HYBRID DA system shows considerable improvement in track forecast during the initial hours of the forecast.

The HYBRID DA system is significantly benefited by using MultiSKEB model error scheme in simulating TC track position during the initial hours of the forecast.

RESULTS

From the vertical profile of ensemble spread and RMSE, the ensemble system is found underdispersive which suggests that flow-dependent error covariances estimated from this ensemble system are possibly underestimated. SKEB scheme effectively increases ensemble spread for horizontal wind than using Multiphysics scheme.

However, for temperature and humidity Multiphysics scheme is found to be more effective than SKEB for treating undependence spread. The higher values of spread are mostly concentrated over the TC region. In comparison to SKEB scheme, higher ensemble spread values are seen over a larger spatial extent when multiphysics ensemble scheme is employed.

CONCLUSION

Explicit model error representation is found to be beneficial in treating the underdispersive ensembles which results in substantial improvements in the track forecast of tropical cyclone initialized from a hybrid DA system.

Among all the model error treatment schemes used in this study, a combination of multiphysics and SKEB schemes has outperformed other two schemes with improved track forecast of a tropical cyclone.

REFERENCES


ACKNOWLEDGEMENTS

The authors thank the supercomputing facility of Indian Institute of Tropical Meteorology, Pune for providing computational resources. This work supported by funding from Indian Institute of Space Science and Technology, Thiruvananthapuram, India.