EnKF OSSE Experiments assessing the impact of HIRAD wind speed and HIWRAP radial velocity data on analysis of Hurricane Karl (2010)

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INTRODUCTION AND METHODS

MOTIVATION

Previous studies (e.g., Zhang et al. 2009, Wong et al. 2011) have shown that radial velocity data from airborne and ground-based radars can be assimilated into ensemble Kalman filter (EnKF) systems to produce accurate analyses of tropical cyclone motion, which can reduce forecast intensity errors. Recently, wind speed data from SIFMR technology has also been assimilated into the same types of systems and has been shown to improve the forecast intensity of mature tropical cyclones. Two instruments that measure these properties were present during the NASA Genesis and Rapid Intensification Processes (GRIP) field experiment in 2010 which sampled Hurricane Karl, and will most likely become co-located on the same aircraft for the upcoming NASA GReIPEX (Global Rapid Intensification Experiment) campaign. The High Altitude Wide Swath Profiling Radar (HIWRAP) is a scanning Doppler radar mounted upon NASA’s Global Hawk unmanned aerial vehicle, and the contribution of its radial velocity data to assimilation has not been previously examined. Since the radar scans from above a fairly large fixed elevation angle, it observes a large component of the vertical winds which could degrade EnKF analyses compared to analyses taken from lower elevation angles. The NASA Hurricane Sounding Radiometer (HIRAD) is a passive microwave radiometer similar to SIFMR, and measures emissivity and retrieves hurricane surface wind speeds and rain rates in a much wider region. Thus, this study examines the impact of assimilating simulated HIWRAP radial velocity data into an EnKF system, assimilated HIRAD wind speed, and HIWRAP/HIRAD with the Weather Research and Forecasting (WRF) model and compares the results to no data assimilation and also to the Truth from WRF-EnKF analyses of both instruments.

• The same WRF-EnKF system as in Zhang et al. (2009) is used

Assimilating model setup:

- 275-km AMR WRF V11.1
- Assimilation is from 0000 UTC 13 Sep 2010 to 0000 UTC 14 Sep 2010
- Vertical levels: 35 layers
- Model top at 50 km
- 400-km grid for all other levels
- WSM-6 microphysics
- YSU scheme for planetary boundary layer
- Processes:
  - Random, balanced, large-scale perturbations are added to the GFS analysis at 0000 UTC 13 September (48 h) and the Truth is selected as the member that best captures Karl’s rapid intensification but is also reasonable with track error. The ‘truth’ member is then rerun with Goddard microphysics to represent model error.

TRUTH and PURE ENSEMBLE (No DA)

RESULTS: IMPROVEMENT OF ENKF ANALYSES

SIMULATED OBSERVATIONS

HIWRAP

- Instantaneous simulated radar scans are performed every ~24 km along the flight path within the truth simulation with Goddard microphysics. The scans are then divided into 1-h segments whose lengths are consistent with the Global Hawk air speed of 150-200 kts. For example, observations representing the time from 1150 to 1230 UTC are extracted from the 1200 UTC model output file and assimilated at 1200 UTC. This combination is 12 radial wind locations per hour.

- Observations collected every ~3 km radially and azimuthally, and observation error is assumed to be Gaussian with a standard deviation of 1 m/s for EnKF analysis.

- No data collected when estimated IRH < 0.1
- Attenation relationship (dB/2):

HIRAD

The simulated HIRAD data is taken by imaging the left and right positions of real HIRAD observations of Karl from GRIB into the domain of the truth and simulating the total speeds that it would observe at locations following the storm every hour. The nature of the HIRAD data is spatially and temporally very dense, so the observation locations were thinned such that the EnKF system would accept a large and yet still comprehensive amount of data from the observation locations to the covariance based on the number of ensemble members for assimilation. Random error is estimated and included for all wind speeds assimilated.

ANALYSIS CYCLES

- Thirteen assimilation cycles are completed for HIWRAP. Also, thirteen assimilation cycles are completed for HIWRAD. For the HIWRAP + HIWRAD experiment, one cycle of HIWRAD data is assimilated into the 13th HIWRAP-only analysis (effectively, 12 cycles of HIWRAP only + 1 cycle of HIWRAP + HIWRAD). The impact of the HIRAD observations is assessed.

COMPARING HIWRAP-ALONE AND HIRAD-ALONE OSSES ANALYSES TO CONTROL & TRUTH

Analysis of Figures 6. and 7. shows that although the HIWRAP-only observations drop the minimum control pressure faster, it also tends to overestimate the intensity by the end of the assimilation period. On the contrary, HIRAD-based HIRAD-only analyses more accurately predict the maximum wind speed compared to the HIWRAP-only analyses. Combining these two sets of assimilated observations will produce the most optimal forecast of the intensity, as shown in the preliminary results in Figure 5.

SUMMARY

Preliminary results show that radial velocity data from the HIWRAP radar can be useful for assimilating into a WRF-EnKF system. This is also true for wind speed data from HIRAD. In the vicinity of the hurricane, the error of the EnKF posterior analyses is significantly less than that in an ensemble with no data assimilation. This reduction in error is due to corrections in both the storm position and intensity. Though the simulated HIWRAP and HIRAD data have been shown to improve the truth simulation to nearly perfect in terms of several factors: First, the wind speeds near the eyewall are improved. Second, the over-estimation of HIWRAP-only is suppressed so that the minimum sea level pressure is identical to the Truth and the wavenumber of the hurricane center is corrected. The error is diminished compared to no data assimilation (Fig. 5) for both experiments. The quality of the analysis with simulated HIWRAP-HIRAD data shows improvement over HIRAD-only or HIWRAP-only. Several experiments were performed with simulated HIWRAD + HIRAD-only data but it is just the first preliminary result of assimilating HIRAD data, and certainly adding HIRAD to HIWRAP. The results are encouraging, nonetheless, and evidence the promising contribution that both of these observing systems will have on intensity modeling, especially when combined. This is yet another reason why colocating these two instruments during IH3 will prove especially beneficial for the hurricane modeling community.

REFERENCES


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