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

Cerese Albers (FSU), Jason A Sippel (Morgan State & GSFC), Scott A Braun (NASA GSFC), Timothy Miller (NASA MSFC)

INTRODUCTION AND METHODS

MOTIVATION

Previous studies (e.g., Zhang et al. 2009, Wang 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 vortex, which can reduce forecast intensity error. Recently, wind speed data from SPMR 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 Griffin and Rapid Intensification Processes (GRIP) field experiment in 2010 which sampled Hurricane Karl, and will not be co-located on the same antenna for the subsequent NASA GSFC 2011 Hurricane season. The High Altitude Wind Profiling Radar (HIWRAP) is a conically scanning Doppler radar mounted upon NASA’s Global Hawk unmanned aerial vehicle, and the remaining of its radial velocity data assimilation has not been previously examined. Since the radar scans from above with a fairly large, fixed elevation angle, it observes a large component of the vertical wind, which could improve EnKF analyses compared to analyses with data taken from lower elevation angles. The NASA Hurricane Imaging Radiometer (HIRAD) is a passive microwave radiometer similar to SPMR, and measures intensity and retrieves hurricane surface wind speeds and rain rates over a much wider region. Thus, this study examines the impact of assimilating simulated HIWRAP radial velocity data into an EnKF system, simulated 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 setups with both instruments.

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

ASSIMILATION model setup:

- 2700 km WRF V1.1.1
- 35 vertical layers
- Model top at 30 km
- WSM-6 microphysics, and YSU the scheme for planetary boundary layer processes
- Successive covariance localization: (ROI) for 189 obs. D0-3
- 36 km ROI for another 29 on D0-3
- 18 km ROI for another 6 on D3
- Lateral diffusion: 0.35 km for another 6 on D3
- Mixing with eddy

ENKF setup:

- wFA = 1 - d(x) + d(x)

SIMULATED OBSERVATIONS

HIRWRAP

- Instantaneous simulated radar scans are performed every ~24 km along the flight path within the truth simulation with Global Ocean Physics. The scans are then divided into 1-km segments whose lengths are consistent with the Global Hawk air speed of 350 km/h. Thus, observations representing the time from 1100 to 1230 UTC are extracted from the 1200 UTC model output file and assimilated at 1200 UTC. This combination of 24 km radial wind locations per box.

• Observations collected every 3 km radially and azimuthally, and observation error is assumed to be Gaussian with a standard deviation of 10 m/s for HIRAD.

HIRAD

• No data collected when estimated wind speed < 10
• No-data error: wind speed increased from 0 to 0.8. using

RESULTS: IMPROVEMENT OF ENKF ANALYSES

Fig. 3. Schematics showing the method for gathering data and de-dimension data. (a) a vertical slice. (b) flight track of 124 24 km radar scans superposed upon 1 km reflectivity. (c) schematic illustrating the three-dimensional distribution of a single simulated observation. (d) The track of the cyclone from 12-24 km superposed upon the location of all data points. (e) the average vertical distribution of observations.

Fig. 4. Simulated HIRAD observations would be a point-bound feature, as depicted here, typical wind speed with Global Ocean Physics. The result would be a wind speed of 48 km with a resolution of 1.5 km, and would provide total wind speed in the range of 10-30 km/h. (b) the actual track of the HIRAD instrument aboard the WB-57F during the GRIP flight campaign. Legs 2 and 4 have been used in the simulation of HIRAD as well.

ASIMILATION CYCLES

- EnKF assimilation cycles are completed for HIRWRAP. Also, assimilation cycles are completed for HIRAD. For the HIRWRAP + HIRAD experiment, one cycle of HIRAD data is assimilated into the 12/4 HIRWRAP-only analysis (effectively, 12 cycles of HIRWRAP-only + 1 cycle of HIRAD+HIRWRAP). and the impact of the HIRAD observation is assessed.

COMPARING HIWRAP-ALONE AND HIWRAD-ALONE OSSE ANALYSES TO CONTROL & TRUTH

Fig. 6. (a) Comparison of minimum SLP (blue) evolution in EnKF analyses and no DA ensemble from 12 to 24 h for HIWRAD-only. b) HIWRAP-only. c) truth only.

An 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 tends to drop the minimum sLP more slowly and not as dramatically, but it still underestimate the intensity. With regard to winds however, the spread in the ensemble members for the HIWRAP-only analysis and the HIRAD-only analysis are almost identical, which is likely attributed to the maximum wind speed compared to the HIWRAD-only analysis. Combining these two sets of assimilated results will predict 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 (Figs. 5-8). This reduction in error is due to corrections in both the storm position and intensity. Though the simulated HIRAD wind speed intensity is lower than the simulated HIWRAD wind speed intensity, both have too strong a cycle, the addition of simulated HIRAD observations for even just one assimilation cycle to the end of the HIWRAD-only 13-cycle assimilation improves the intensity estimation to nearly perfect in terms of several factors: First, the wind speeds near the eyewall are improved. Second, the over-estimation of HIRAD-only is improved so that the minimum sea level pressure is identical to the Truth and the wave number of the hurricane center is corrected. The error is diminished compared to no data assimilation (Fig. 5) for every experiment.

The quality of the analysis with simulated HIRWRAP-HIRAD data shows improvement over HIWRAD-only or HIRAD-only. Several experiments were performed and assimilated, but this is just the first preliminary result of assimilating HIRAD data, and certainly adding HIRAD to HIRWRAP. 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 HES will prove especially beneficial for the hurricane modeling community.

REFERENCES


Fig. 5. Truth, HIWRAP-Only EnKF analysis, and HIWRAP+HIRAD EnKF analysis, respectively, of (a, c, e) reflectivity and surface pressure, and (b, d, f) surface wind speed and vectors at 0000 UTC 17 September, after 13 analysis cycles. Axis increments are in model grid points on D3.

Fig. 7. (a) As a comparison of maximum wind speed (blue) evolution in EnKF analyses and no DA ensemble from 12 to 24 h for HIWRAD-only. b) HIWRAD-only. c) truth only.