Tropical Cyclone Structure and Satellite Data Assimilation

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Motivation

Results from the recently-concluded High-resolution Hurricane test (HRH) demonstrate that increasing horizontal model resolution produces no significant increase in forecast skill, and, with regard to some metrics (wind radii), can actually lead to a *decrease* in skill. These results serve to illuminate the problem of vortex initialization and its impact on the subsequent evolution of the model tropical cyclone (TC).

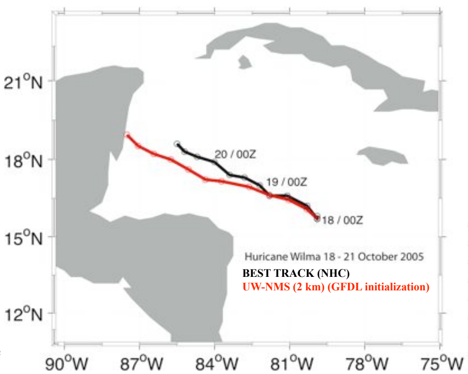
It also casts light on the broader problem of predicting tropical cyclone structure and its relationship to the more traditional metrics of position and intensity. Of particular interest are the structure changes than herald or accompany rapid intensification (RI), secondary eye wall formation (SEF) and eye wall replacement (ERC). Difficulty in predicting these structures accounts for a large degree of the current lack of success in TC intensity forecasting.

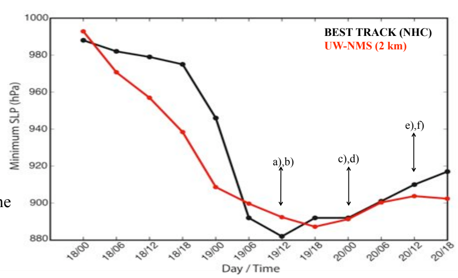
Deterministic Forecast

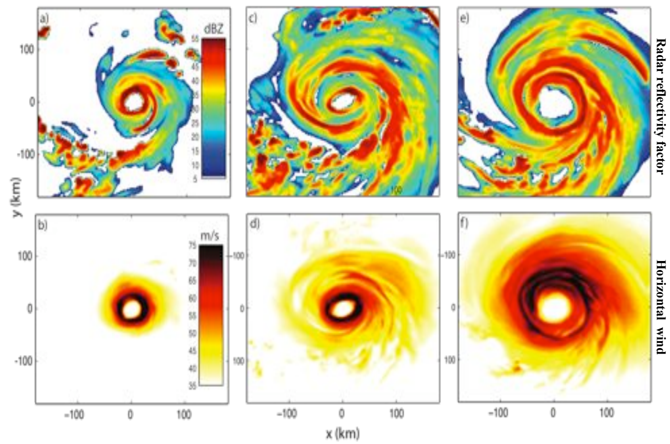
Hurricane Wilma is an outstanding example of a tropical cyclone undergoing the structural changes detailed above. The figures at the right depict the true (best track) and forecast track and intensity for Wilma over the period 18-21 Oct.

This particular forecast does an excellent job of capturing the rapid intensification and subsequent weakening of the hurricane. However, forecasts initialized only 6 hours before and after didn't perform as well (not shown). In addition, the forecast initialized at 00Z was found to be extremely sensitive to the surface flux scheme employed (not shown).

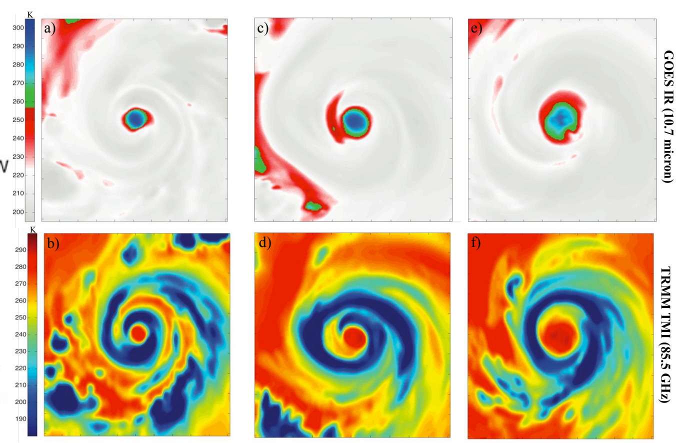
This motivates a probabilistic investigation into the sensitivity of the solutions to various structures present in the initial conditions as well as to physical parameterizations.







12Z 19 OCT | 00Z 20 OCT | 12Z 20 OCT



Structure Changes in Wilma

The figures to the left illustrate the structural changes which occurred in the simulated TC as it rapidly intensified, formed a secondary eye wall, and then completed an eye wall replacement cycle.

Figures a) and b) show simulated reflectivity factor and horizontal wind speed, respectively, at 4.5 km on 19 Oct at 12Z. At this stage Wilma has a rather limited precipitation shield and a tight core. Twelve hours later, as shown in c) and d), there has been a dramatic increase in the coverage of both convective and stratiform precipitation, and a secondary eye wall is forming at a radius of 80-100 km. Finally, figures e) and f) show that at 12Z on Oct. 20 the secondary eye wall has become dominant and is in the process of replacing the primary one. The expansion of the wind field over this 24-hour period is dramatic and illustrates that ERCs do not necessarily indicate significant weakening. In fact, they may actually increase the destructive potential of the TC.

Research Plan

Using an ensemble Kalman filter (EnKF), we intend to assimilate all available conventional and airborne observations, as well as observations from geostationary satellites (IR and WV channels) and polar orbiters (active and passive microwave) for a number of TC cases at high model resolution (~ 2 km), beginning with Wilma. Simulated GOES-12 IR (upper row) and TMI 85.5 GHz (bottom row) brightness temperatures are shown at left, and show that the salient features of Wilma's structure are captured in these observations. Given the superior temporal sampling of the geostationary platform, we anticipate the most significant impact from these data.

Within this context, we intend to employ ensemble-based diagnostic tools, such as ensemble sensitivity analysis (ESA), to explore the various hypotheses for RI and SEF / ERC. Given the demonstrated sensitivity to surface physics, we also plan a set of experiments using parameter estimation to examine the impact on the solutions as well as to gain some insight into the underlying surface processes.