Ensemble Kalman Filter Assimilation of HIWRAP Observations of Hurricane Karl (2010) from the Unmanned Global Hawk Aircraft

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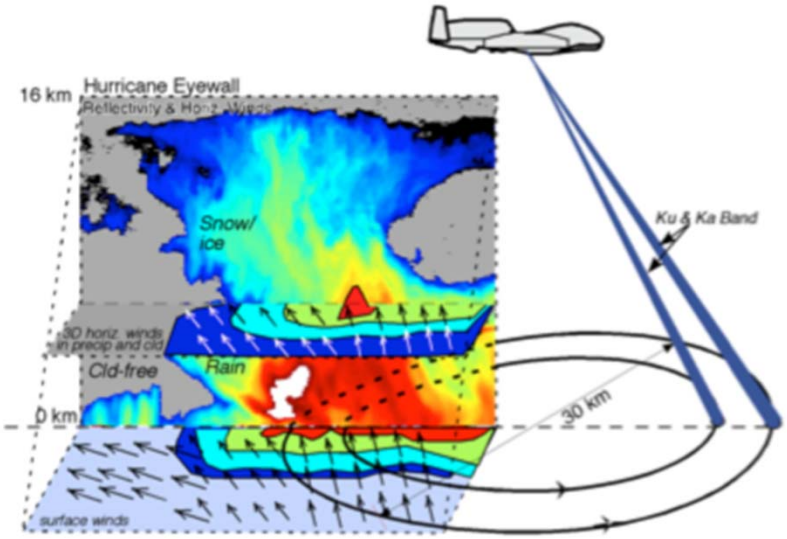
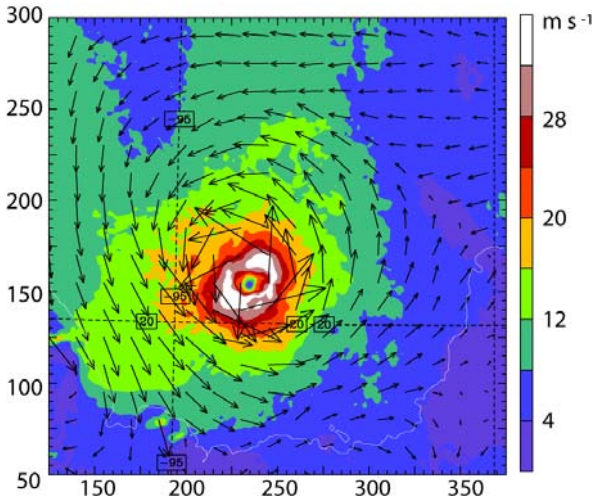
HIWRAP basics

- HIWRAP is a conically scanning Doppler radar mounted upon NASAs Global Hawk UAV
- It was first used to observe hurricanes in GRIP (2010) and is currently being used in HS3
- Simulated-data results (Sippel et al. 2013) suggest HIWRAP Vr can be assimilated to improve hurricane analyses

HIWRAP Schematic

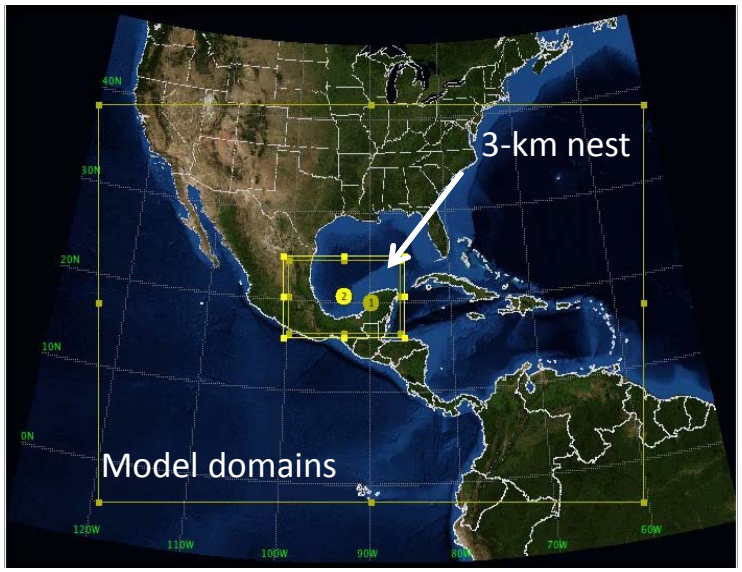


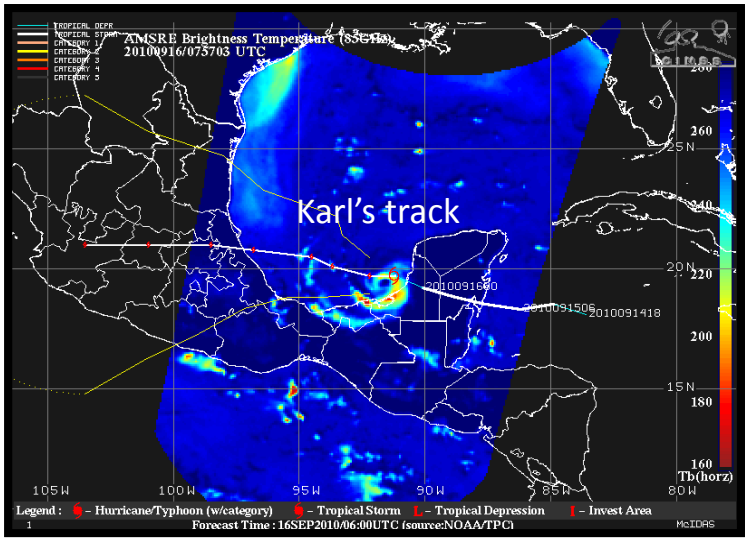
EnKF analysis from simulated data



Experiment setup

- Looking at Karl & Matthew (2010) – only storms that HIWRAP data is available for
- WRF-EnKF from Zhang et al. (2009) with 30 members
- Similar Karl setup as Sippel et al. (2013) OSSEs

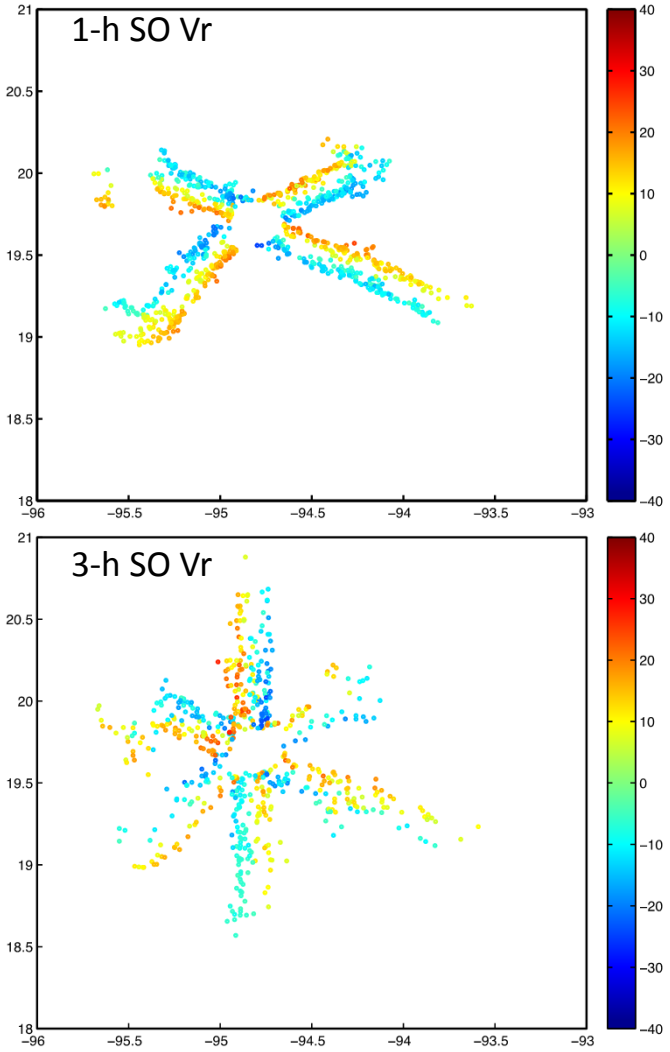




Difficulties with Vr

- Significant issues
  - Outer beam unavailable for Karl
  - Unfolding not possible for some legs
  - QC removes large regions of Vr elsewhere
  - Fallspeed correction non-trivial
  - Large, asymmetric analysis increments
- Solutions
  - Assimilate position & intensity (P/I) in addition to HIWRAP data
  - For each hour, combine obs from t +/- 1h
  - Constrain increments by rejecting observation with larger innovations
  - Try assimilating HIWRAP VWPs instead

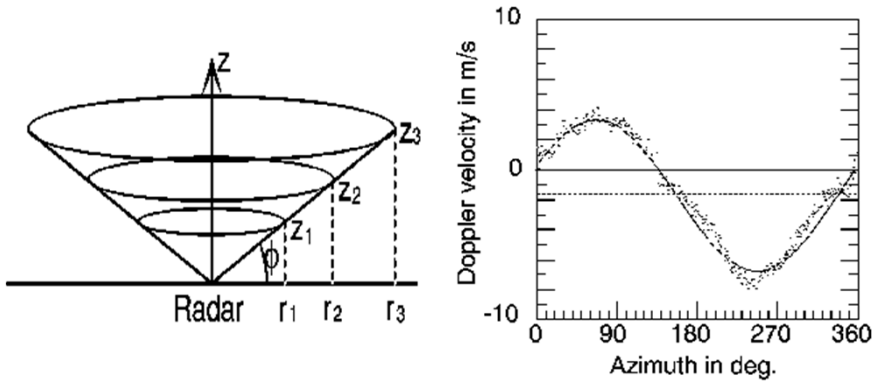
Comparing Vr coverage from 1-h and 3-h windows



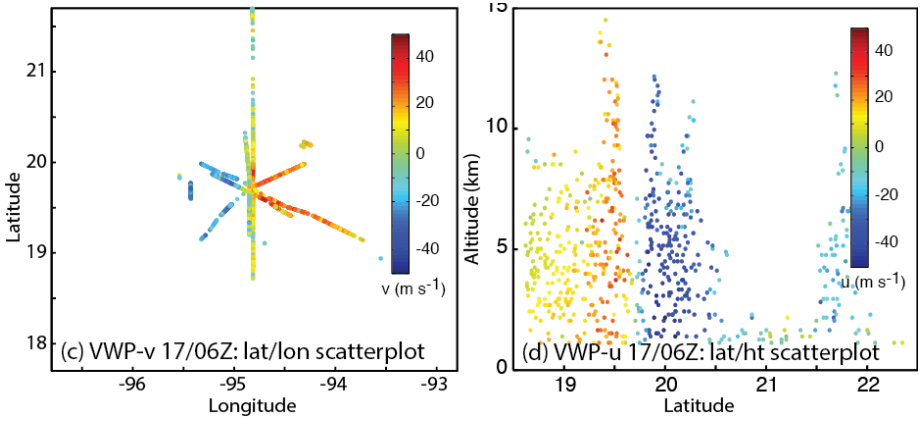
HIWRAP Vr vs. VWP

- As with WSR-88Ds, VWP estimations of horizontal winds can be computed
- U and V components avoid *w*-covariance and fallspeed uncertainty
- Since VWP is a *fit* to Vr data, less QC is required (better coverage)

VWP Methodology

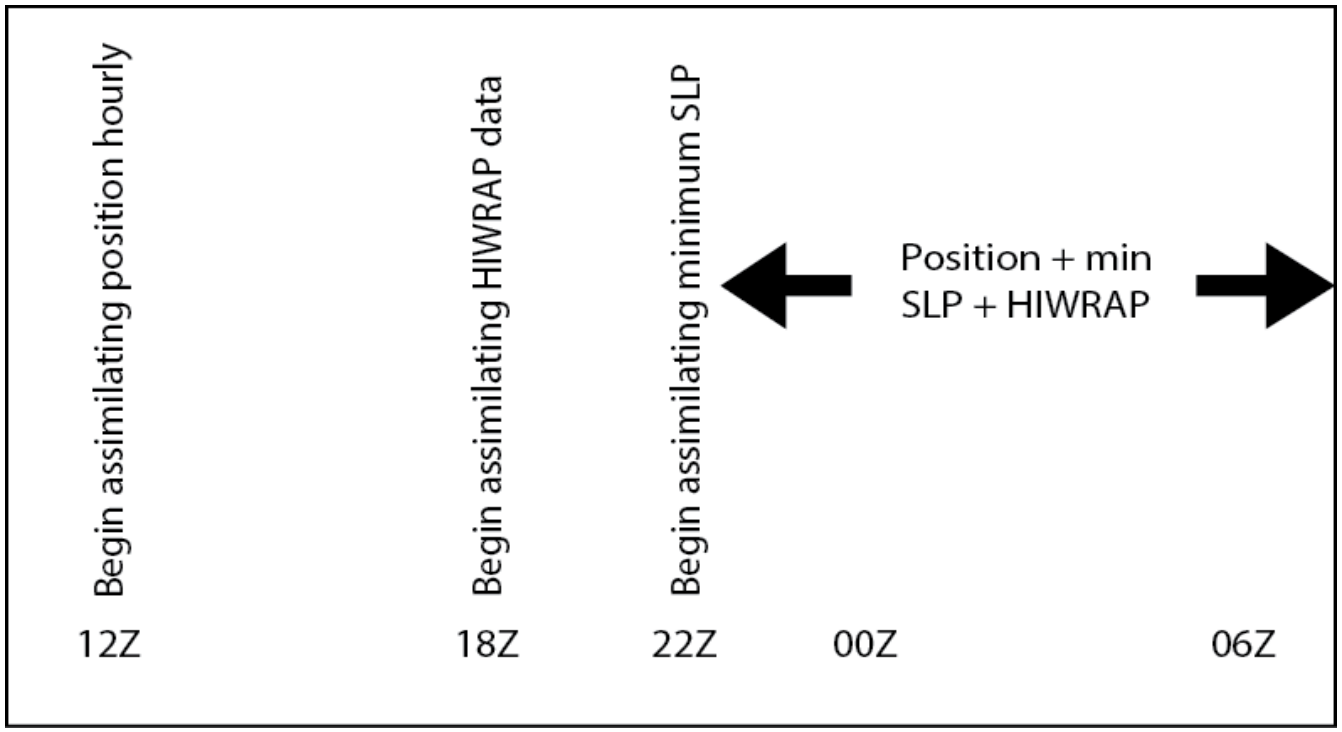


Examples of HIWRAP VWP U and V components



Assimilation details

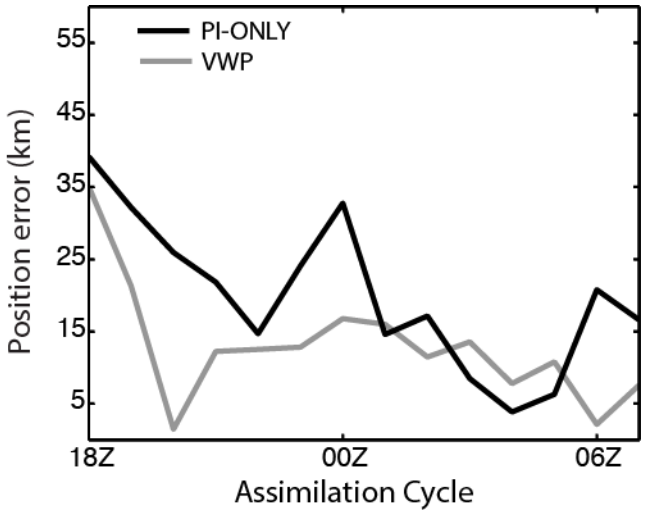
- Assimilate position first, then position + VWP, then P/I + VWP
- Assimilating position beforehand helps with bad first guesses



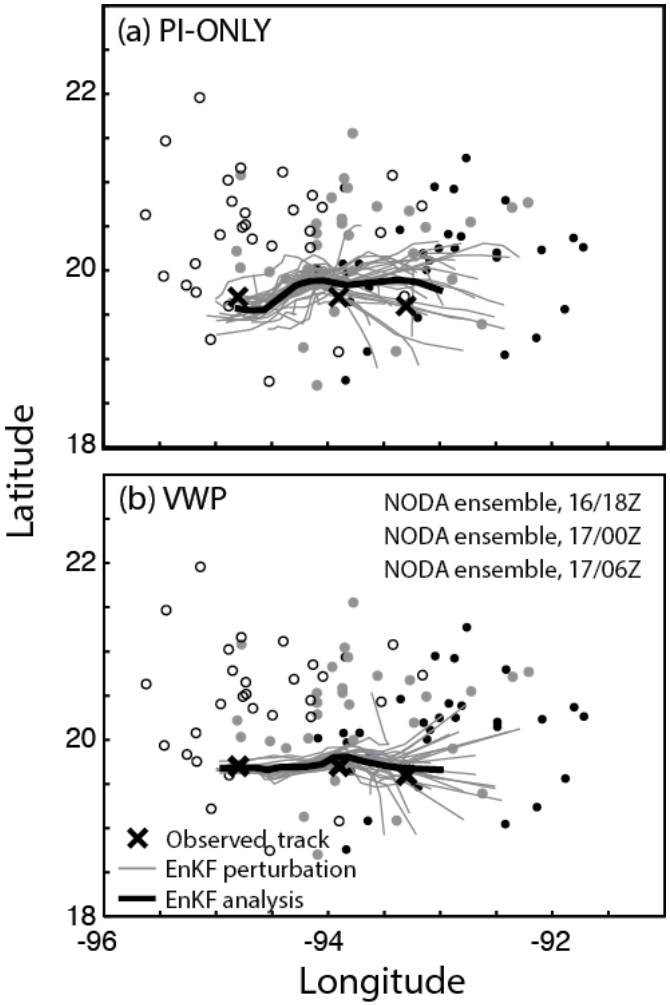
Karl assimilation schematic

Karl results: EnKF storm position

- Both analyses better than NODA
- Lower error and spread with VWP than PIONLY



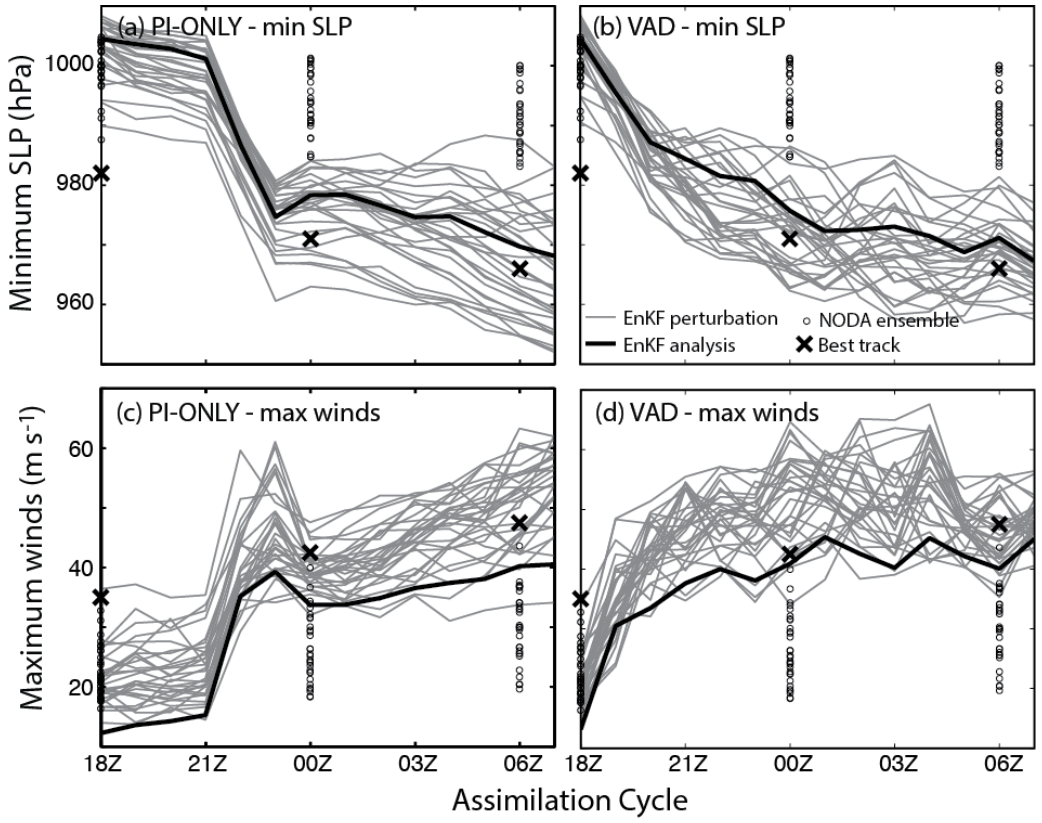
Track evolution from EnKF analyses



Karl results: EnKF max intensity

- Both experiments improve upon NODA
- PI-ONLY distribution looks good, but analysis is weak
- VWP shows improvement and spins up faster with less spread

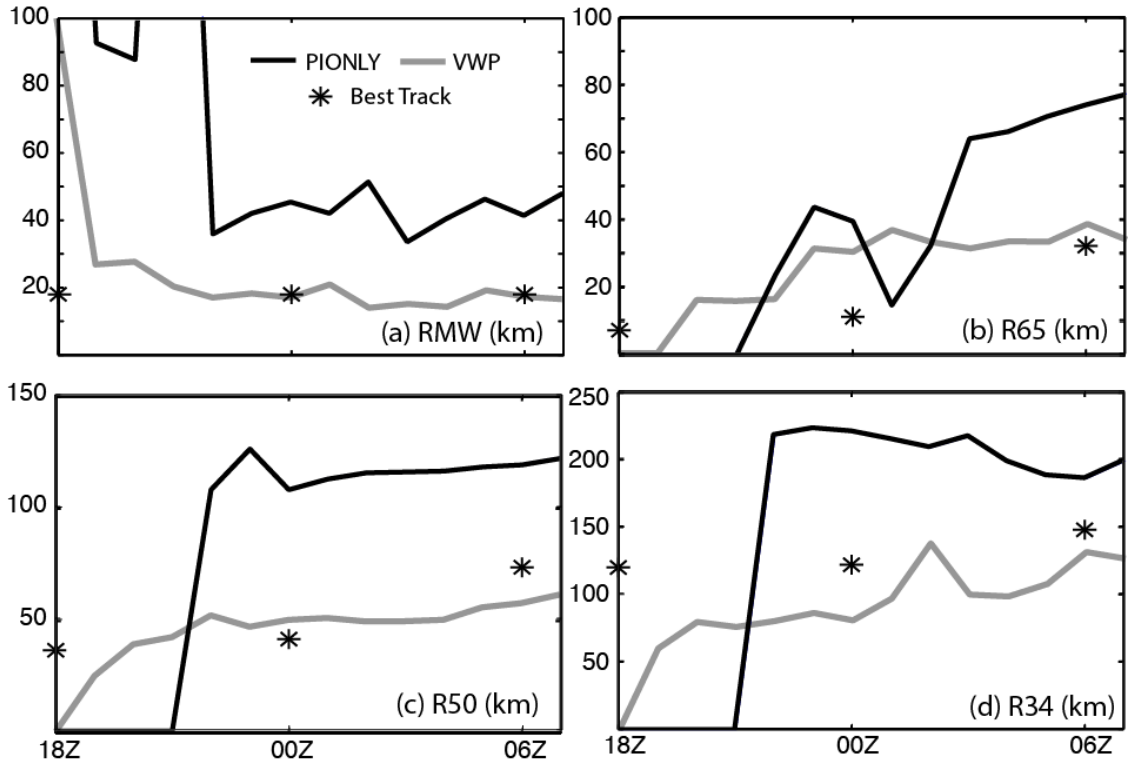
Maximum intensity evolution from EnKF analyses



Karl results: EnKF wind radii

- PIONLY produces a storm that is much too large, especially for smaller radii
- Analysis with VWP data is in much better agreement with best-track and spins up faster

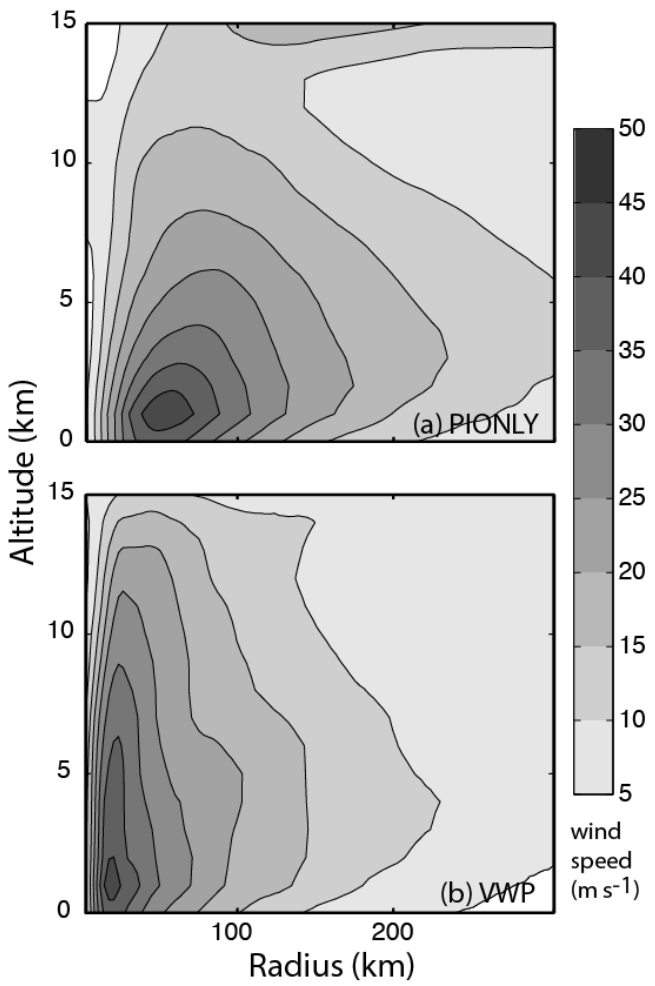
Wind radii evolution from various EnKF analyses



Karl results: Vertical structure

- PIONLY analysis produces a shallower, broad vortex that looks unrealistic for a major hurricane
- VWP analysis is much more realistic with a tall, compact inner core
- VWP experiment structure agrees better with obs

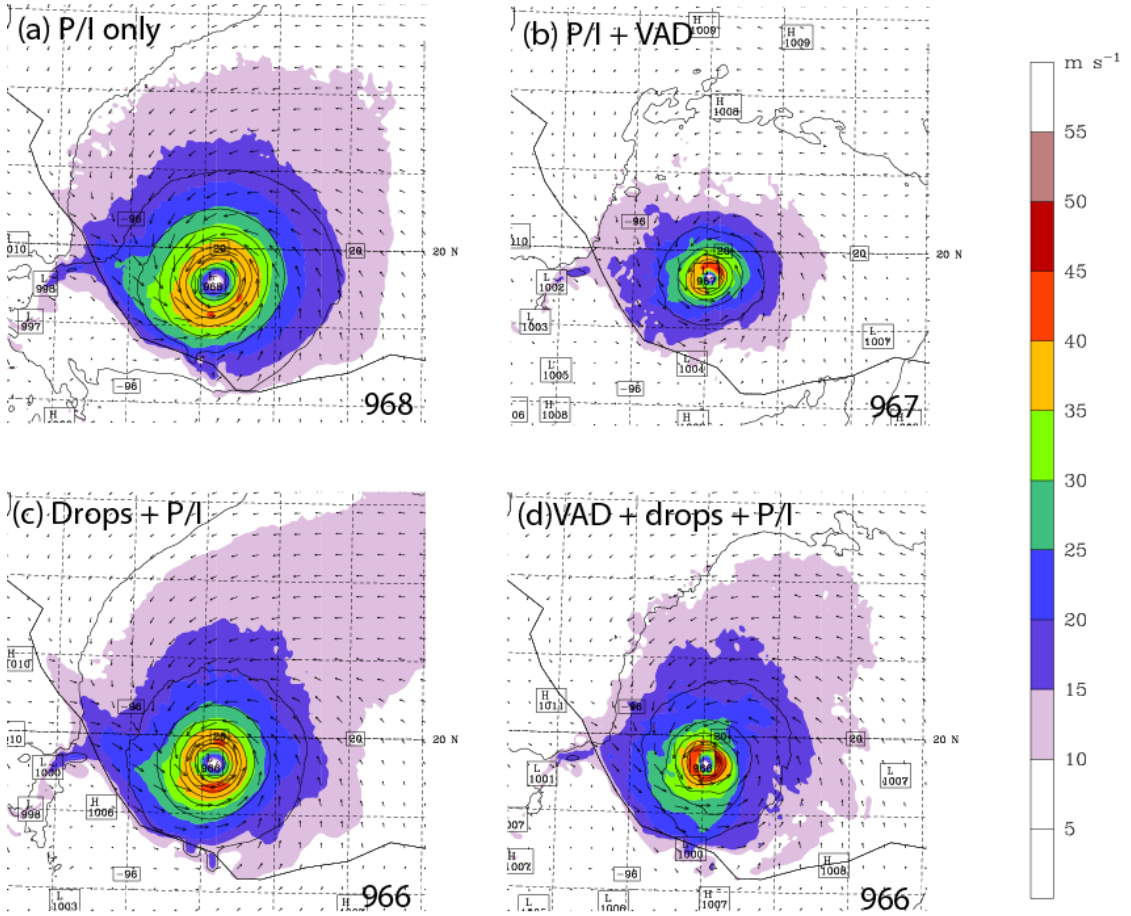
Azimuthal mean wind speeds at last cycle



Karl results: Adding dropsondes

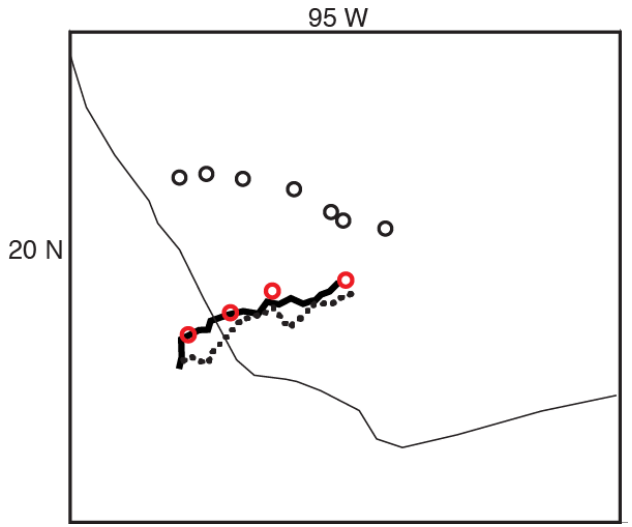
- VWP needed to capture compact inner core
- Addition of dropsondes strengthens outer wind field, closer to best track

Surface winds and isobars from various EnKF analyses



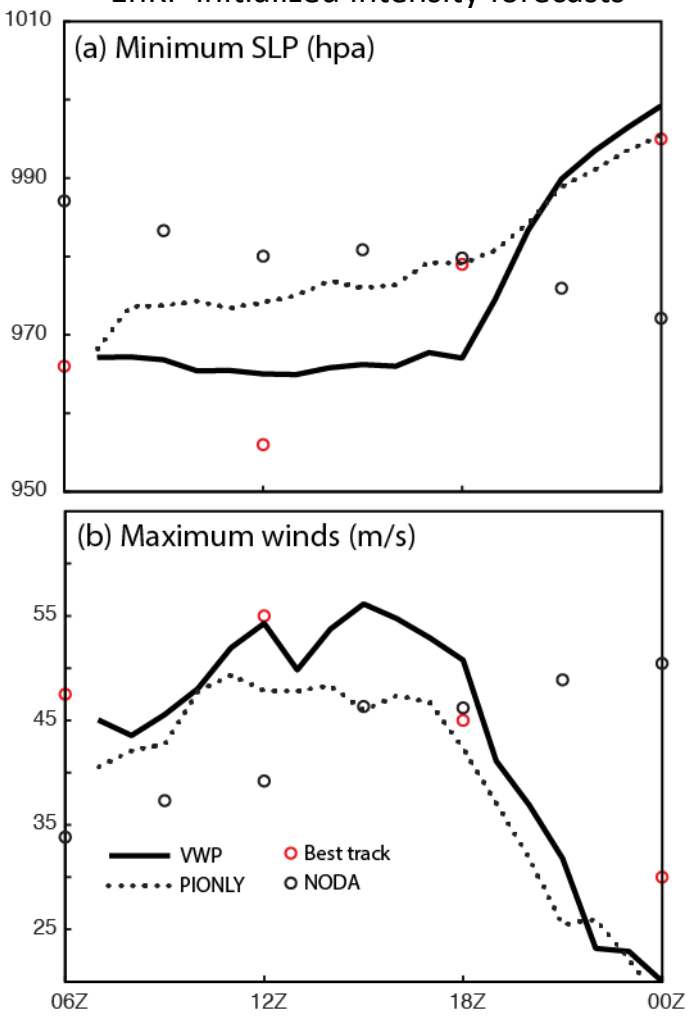
Karl results: Deterministic forecasts

- Both PIONLY and VWP-based forecasts better than NODA, but VWP-based forecast best due to a better initial structure



Comparison of best track with NODA and EnKF-initialized track forecasts

Comparison of best track with NODA and EnKF-initialized intensity forecasts

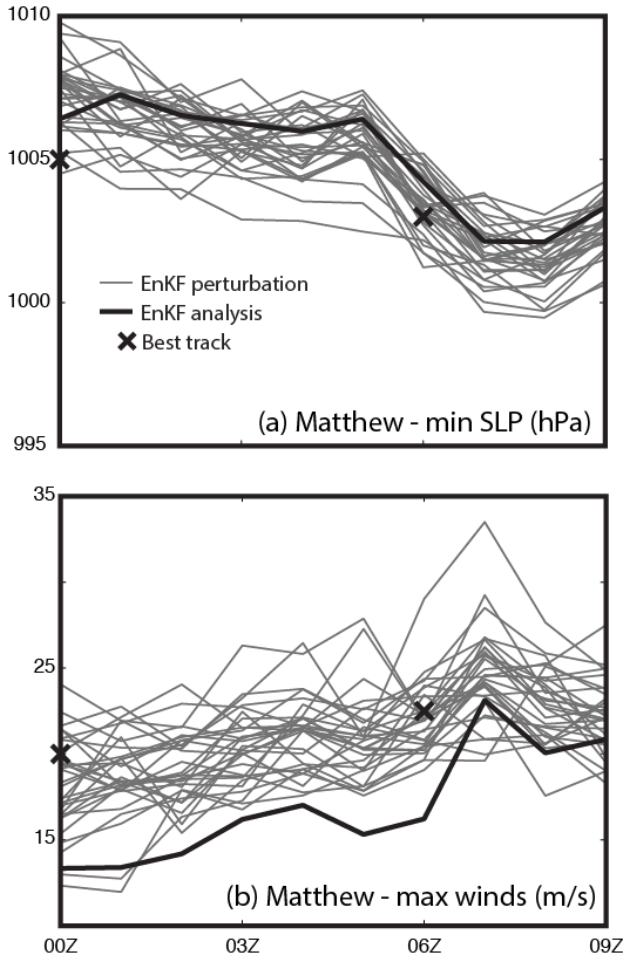


Matthew results

- EnKF assimilation of HIWRAP VWP data appears to capture Matthew's intensity well, but more work to be done here

- EnKF-based forecast track improves upon NODA (not shown)

Maximum intensity evolution from EnKF analysis



Summary + Future Work

HIWRAP data appears to be useful for EnKF analyses of TCs

- Despite difficulties with early HIWRAP data, EnKF analyses with HIWRAP VWP data produce accurate estimates of maximum intensity, location, and wind radii

- As a result of the analysis improvement, there is also an improvement in forecast intensity and structure.

- Future work will examine the impacts of additional Global-Hawk-based data, including dropsondes, surface wind speeds from HIRAD and water vapor and temperature retrievals from S-HIS