Development of a Real-Time Automated Tropical Cyclone Surface Wind Analysis:

A Year 1 Joint Hurricane Testbed Project Update

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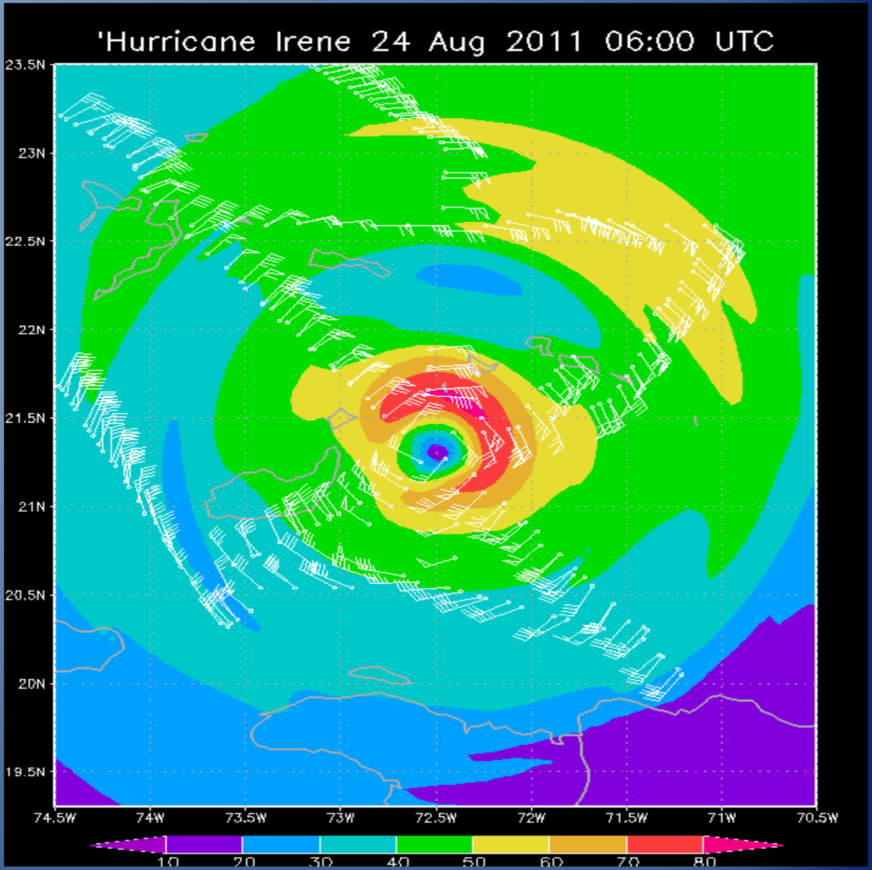
Purpose

- This project seeks to create **a real-time and fully automated surface wind analysis system** at the National Hurricane Center (NHC) by combining the existing satellite-based six-hourly multi-platform tropical cyclone surface wind analysis (MTCSWA) and aircraft reconnaissance data.
- Replicate the subjective procedures used in NHC operations



Overview: Methods and Considerations

- **When/How to run the analysis**
- **How the reconnaissance and MTCSWA inputs are used**
- **Analysis details**
  - Analysis methodology
  - Determination of sufficient data
  - Flight-level-to-common-flight-level changes
  - Data weighting
  - Automated Quality control/RMW determination
- **Reduce analysis to a 10-m estimated wind**
  - Flight-level-to-surface-wind reduction.
  - Land vs. Marine exposure

Current Process

1. Active storms?
2. Gather track information

1. Gather HDOBS
2. Gather MTCSWA
3. Motion relative framework
4. Sufficient Data?

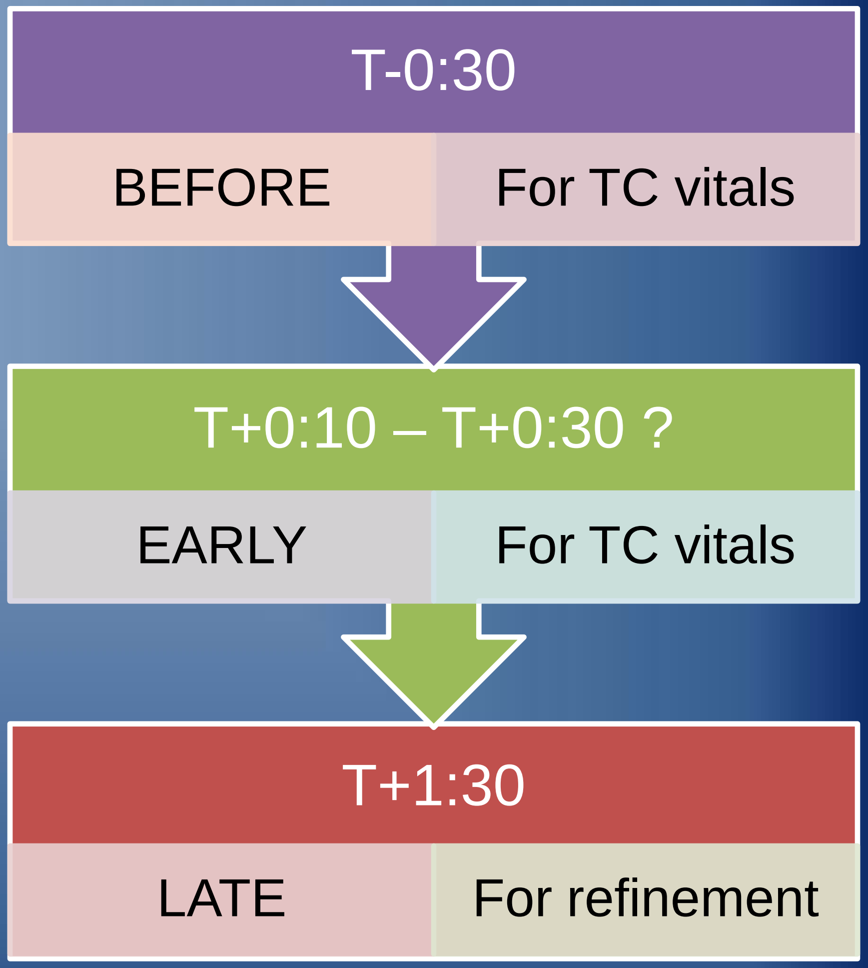
1. Correct data to common level (rmw=50km)
2. Analyze
3. QC (40%)
4. Repeat 2&3 (30%)

1. Analyze
2. Find observed rmw
3. Re-correct data to common level
4. Final analysis

1. Flight-level-to-surface reduction
2. Diagnostics
3. Fix generation
4. Gridding and display

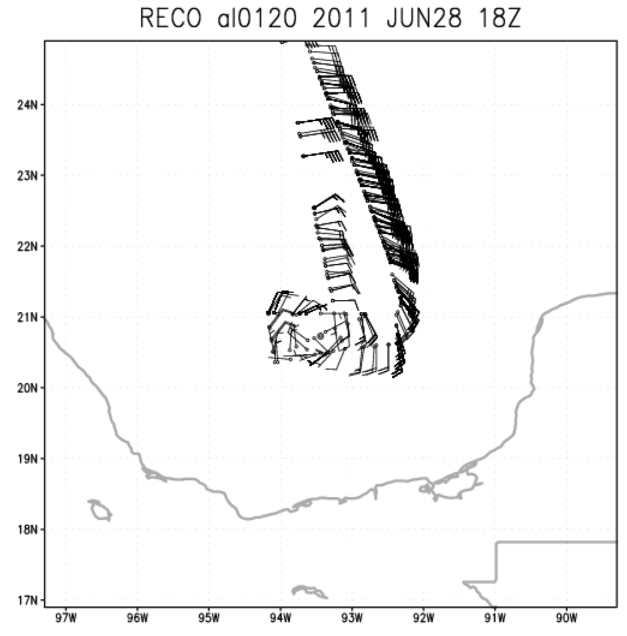
When/How to Run

- **(BEFORE)** Just before the synoptic time (T) for assistance with the TC vitals (Bogus)
- **(EARLY)** Just after T for assistance with generating the TC vitals prior to requesting model guidance be run.
- **(LATE)** After the TC vitals has been prepared and after the model guidance has been submitted.



Data Usage

1. Storm tracking
   - (**BEFORE**) operational best track (OBT) + aircraft center fixes (AF) + T-6 forecast (F-6)
   - (**EARLY**) OBT + AF + F-6
   - (**LATE**) OBT + AF + interpolated forecast (OFCI)
   - A **tensioned cubic spline** is used to interpolate position as a function of time.
2. HDOBS are decoded
3. Motion relative data composites valid at T
   - 6 hours prior and
   - up to 3 hours following the T
   - Below 600 hPa
4. Current MTCSWA , at the analysis center



Analysis Details (1)

Analysis methodology

- Variational method
- Polar grid (4km x 10º)
- Allows inputs as vector components, and scalar speeds
- Allows for variable data weights (w_k, w_m)
- Allows for variable smoothing constraints (α, β) (i.e. spatial filters in the r and Θ directions)

Cost Function Equation

$$C = \frac{1}{2}\sum_{k=1}^{K} w_k \left[(u_k - U_k)^2 + (v_k - V_k)^2 \right]$$

$$+ \sum_{m=1}^{M} w_m (s_m - S_m)^2$$

$$+ \sum_{i=1}^{I}\sum_{j=1}^{J} \left\{ \begin{array}{l} \alpha \left[(\delta_{xx} U_{ij})^2 + (\delta_{xx} V_{ij})^2 \right] \\ + \beta \left[(\delta_{yy} U_{ij})^2 + (\delta_{yy} V_{ij})^2 \right] \end{array} \right\}$$

Analysis Details (2)

Sufficient Data?

- Is there aircraft data?
- Within 150 km is there less than 22 km in the radial direction where the azimuthal data gap is less than or equal to 180 degrees?

NHC's recommendations

Flight-level-to-common-flight-level

- All analyses at 700 hPa
- Flight-level and surface wind speeds are corrected to 700 hPa (via Franklin et al. 2003)
- Radius of maximum wind (rmw) is used to estimate the eyewall (<2rmw) and outer vortex (> 4rmw) regions, interpolated elsewhere
- Convective wind correction factors are assumed everywhere.

Analysis Details (3)

Data weighting

- If collocated and flight-level wind (FLW) speeds are > 64 kt
  - SFMR wind speeds are weighted more heavily (wm=0.5)
  - FL W vectors weighted less (wk=0.35)
- Else if FLW speeds < 50 kt
  - SFMR weighed less (wm = 0.175)
  - FLW vectors weighted more (wm=1.0)
- Linear interpolation of weights for FLW speed between 50 and 64 kt.
- If not collocated, wm=0.175, wk=1.0
- MTCSWA is gradually weighted beyond 150 km, and within 50 km of land, weights are 0.6 beyond 300km
- Questionable data flags result in weight reduction of 50%

Automated Quality control

- Initial analysis; uses
  - rmw = 50 km
  - Conservative filter weights
- Observations that have differences from the analysis > 40 % are given zero weighting
- Repeat this process with 30% threshold.

Prepare for final analysis

- Find the azimuthal average rmw.
- Re-adjust data to a common flight-level using the observed rmw
- Run final analysis with more robust smoothness constraints

Flight-level to Surface Reduction

Assumptions

- Two regions
  - Eyewall (r ≤ 2rmw)
  - Outer vortex (r ≥ 4rmw)
- 4 % azimuthal variation of reduction factors with maximum on the left and minimum on the right
- Six-hour motion used for the asymmetry
- 20 degree inflow angle
- Over land, additional 20 degree inflow and 20% reduction

Reduction Factors

Level (hPa)	Eyewall	Outer Vortex
600-800	0.88	0.83
800-900	0.78	0.78
900-990	0.73	0.73
990-Sfc	0.77	0.77

Process Repeated

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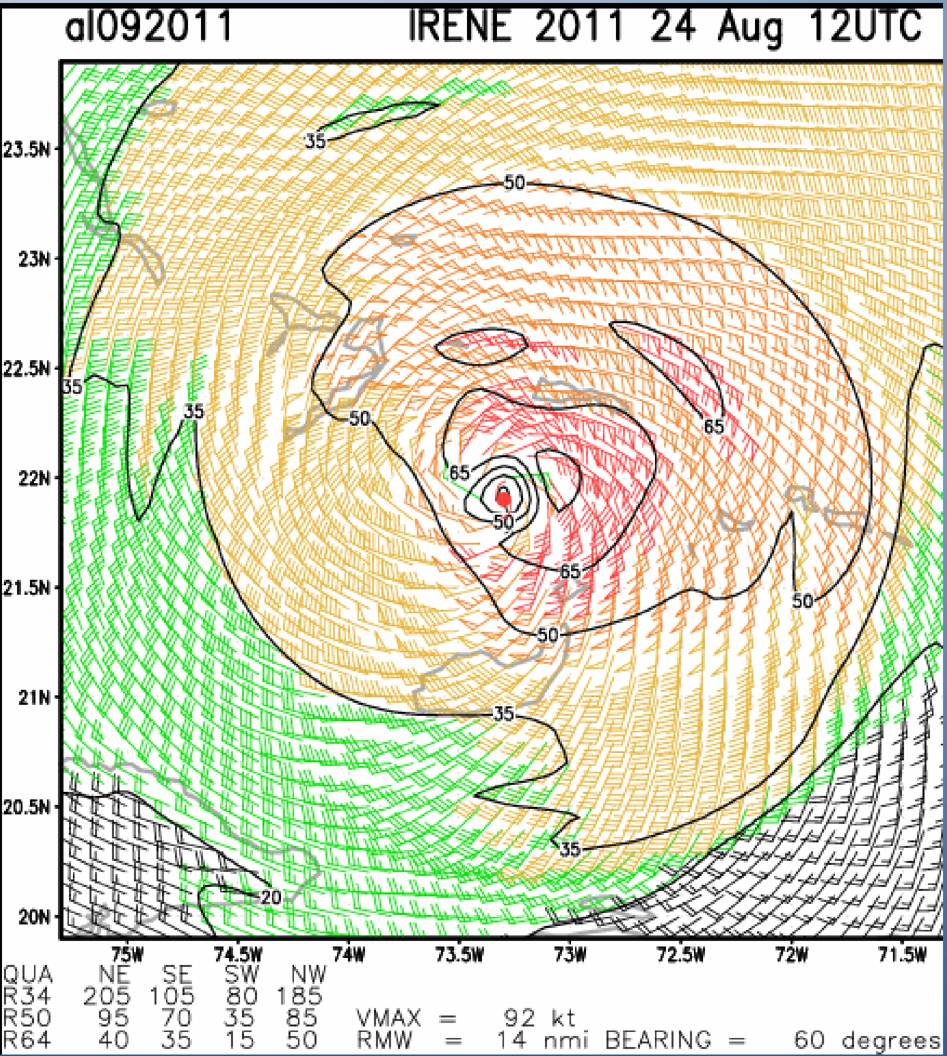
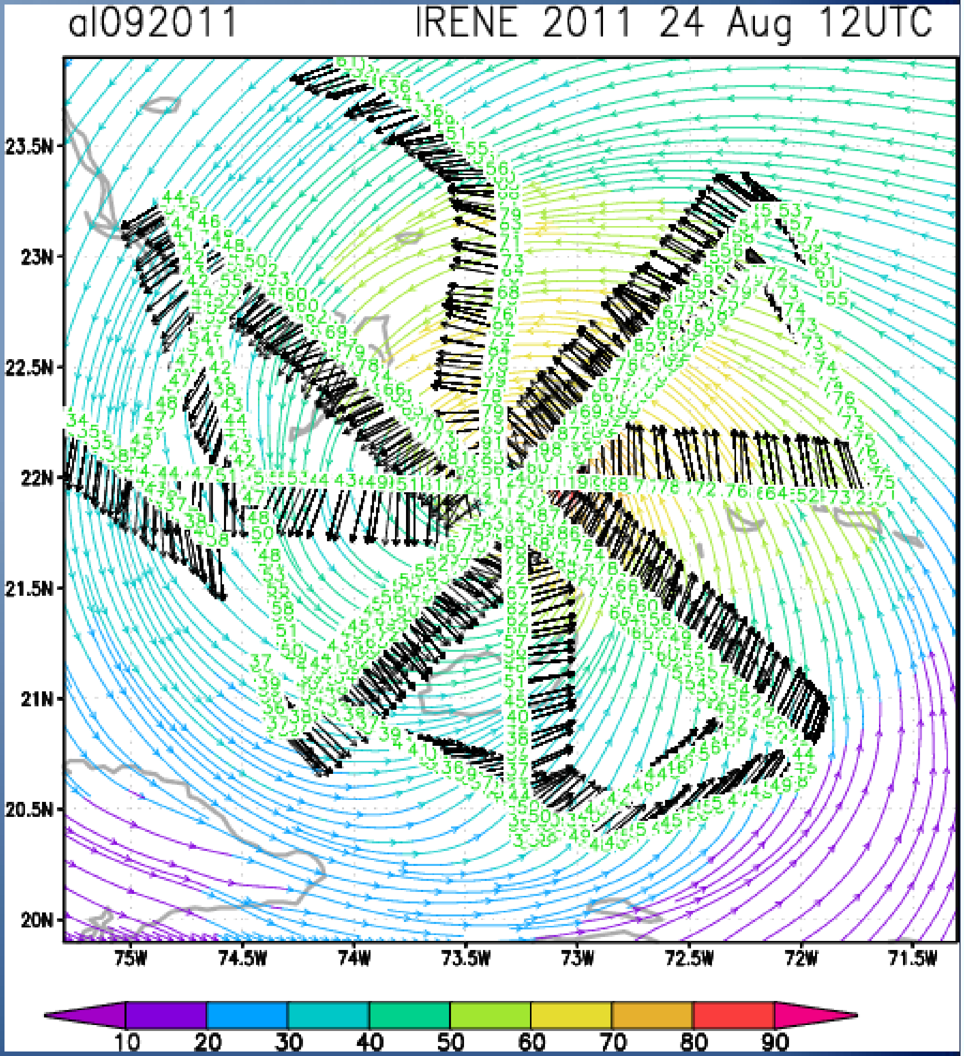
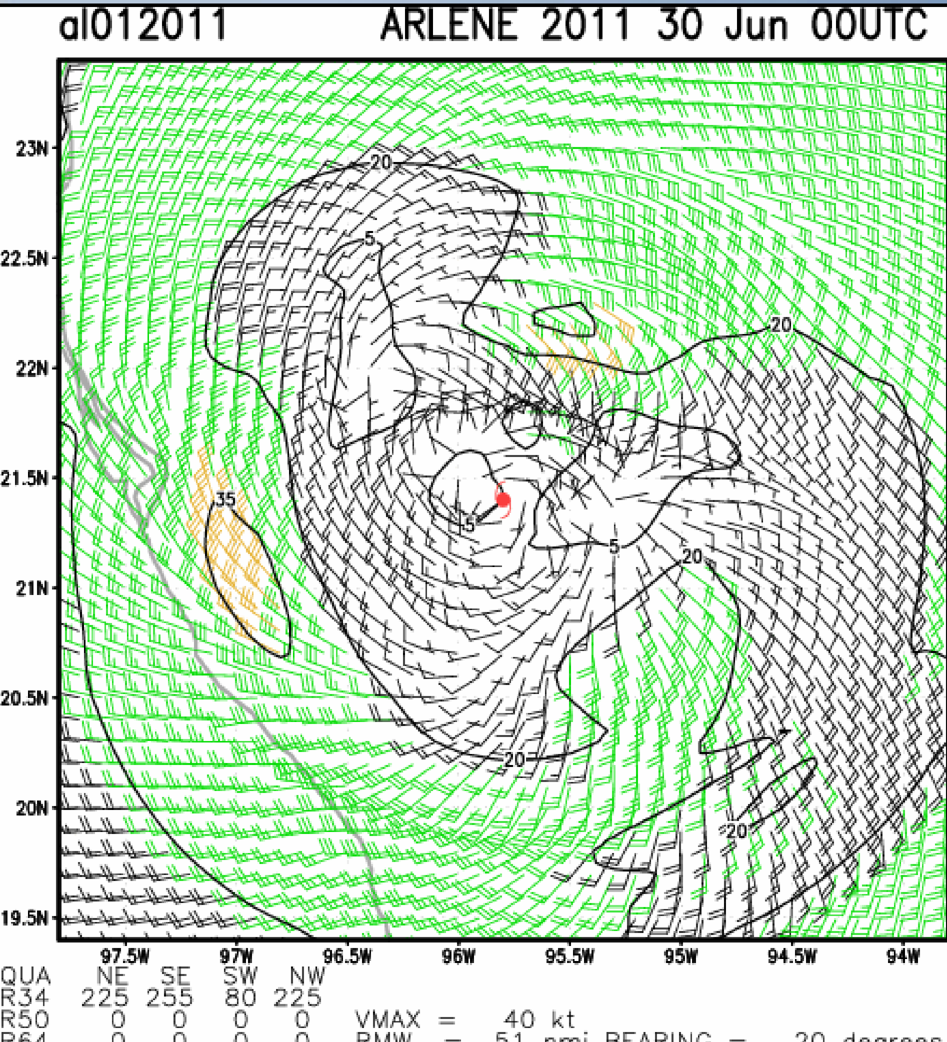
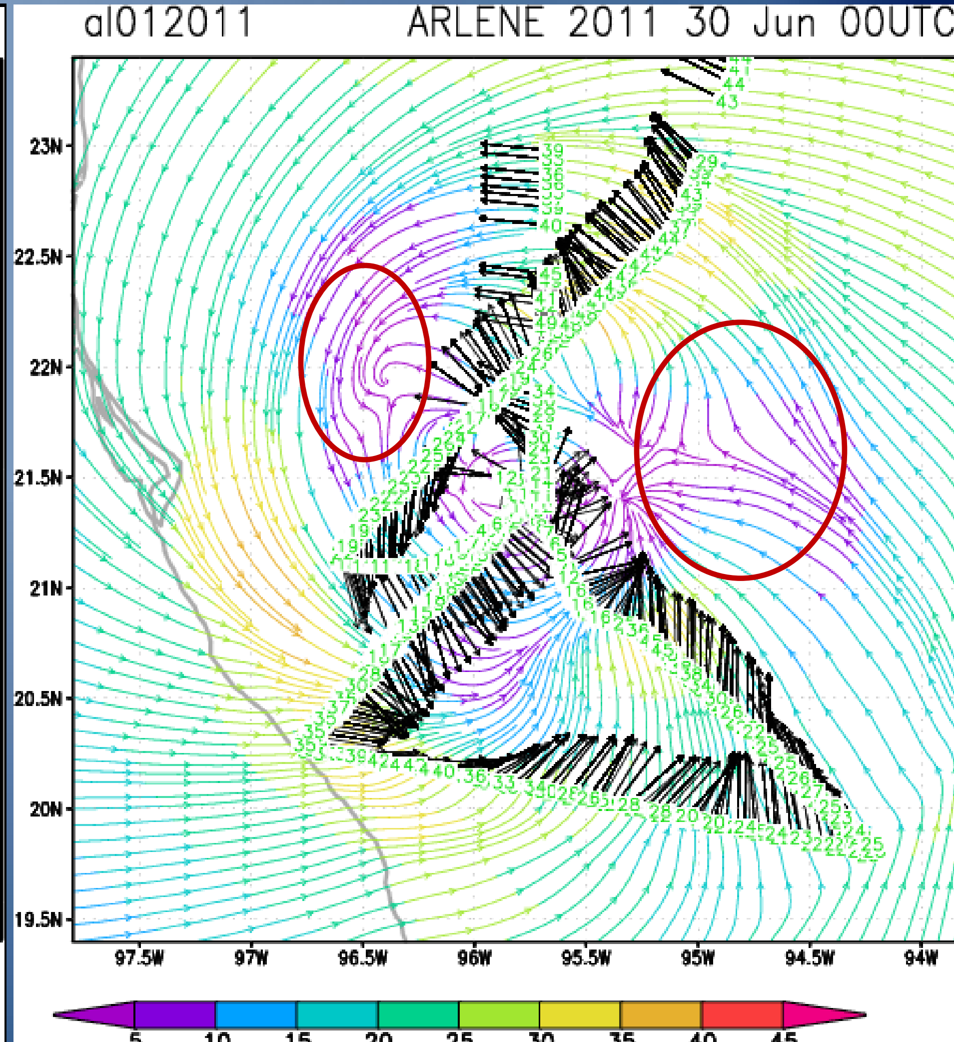
Example: Irene (Relatively Easy)



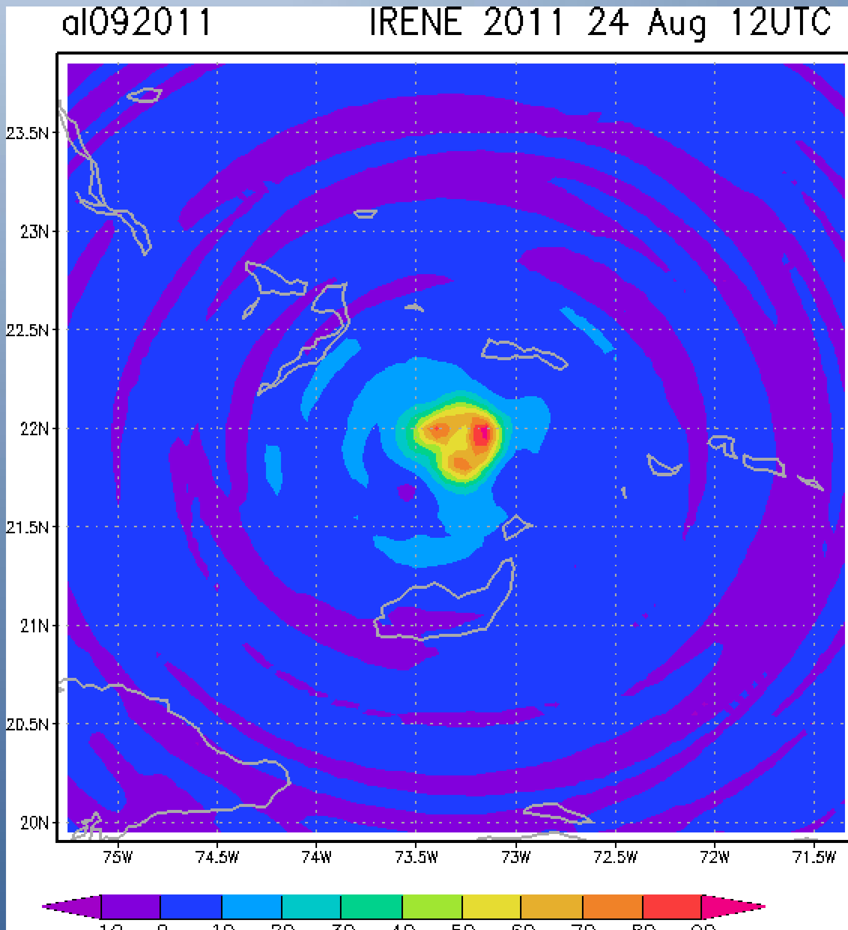


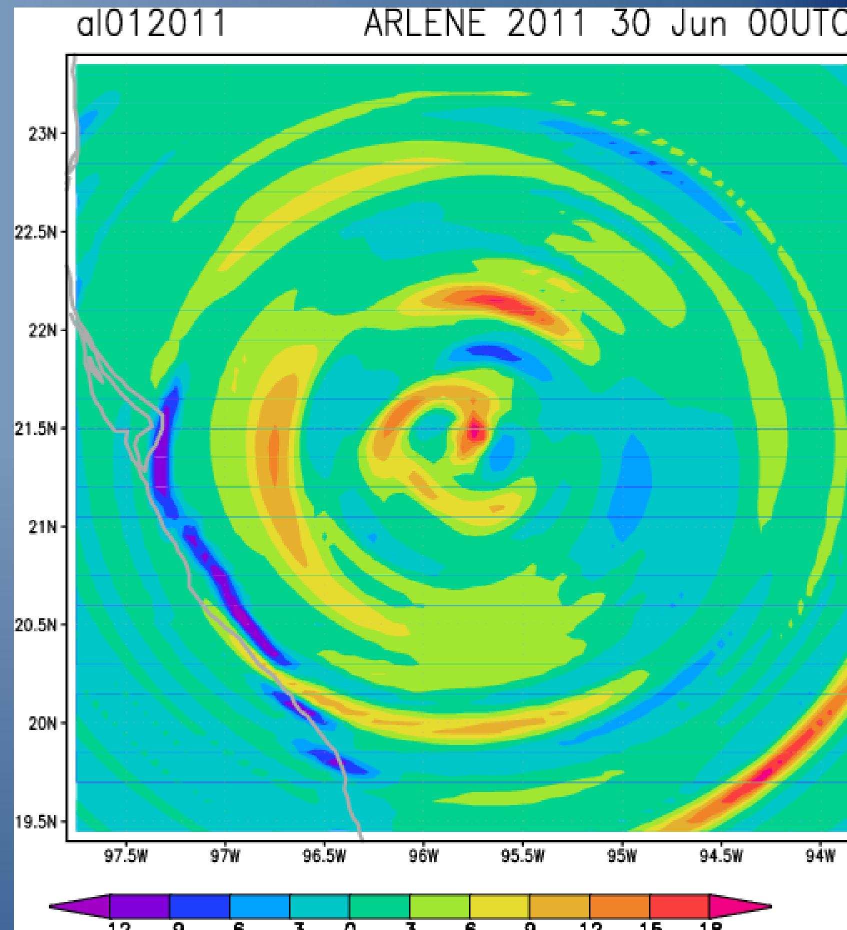
Example: Arlene (Not So Easy)





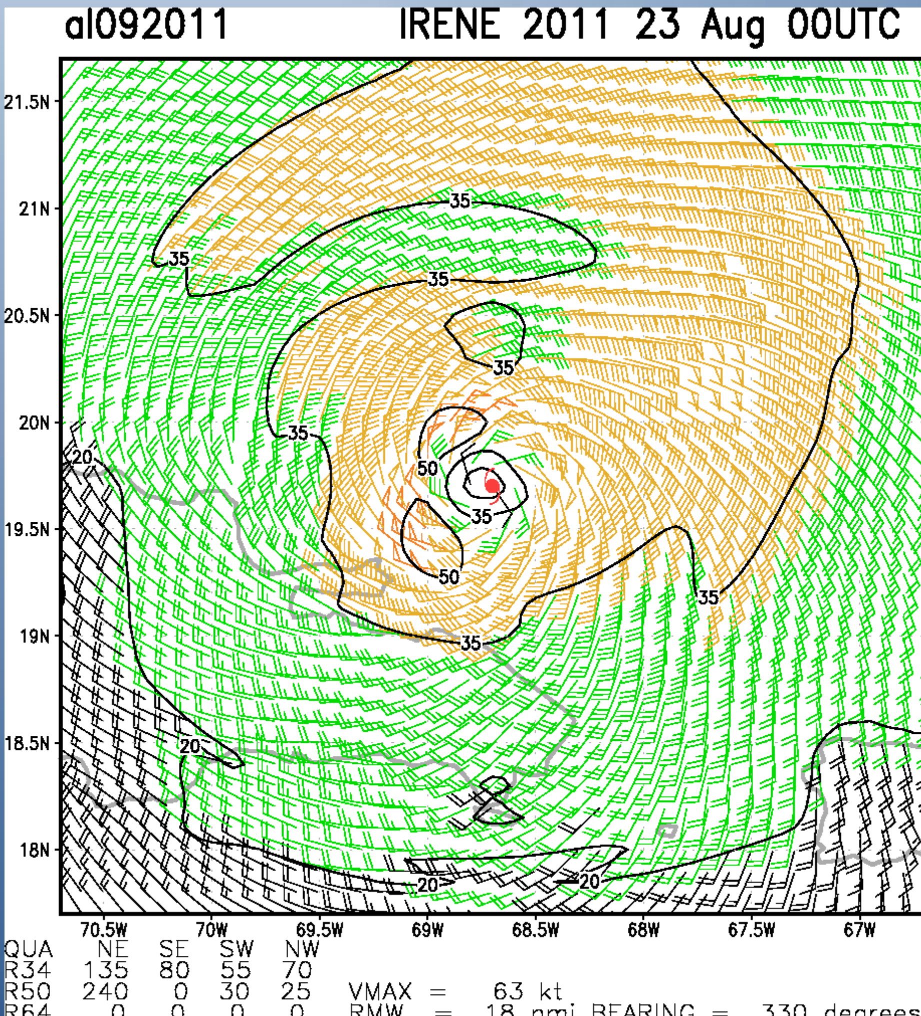
Vorticity Fields (*10^4)

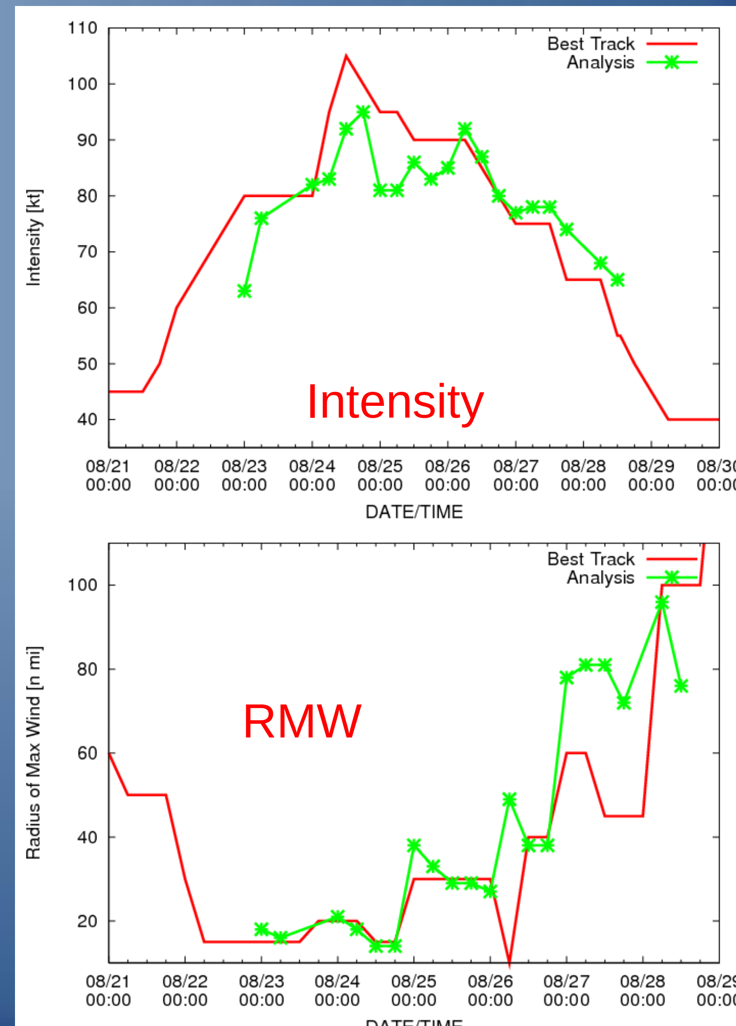




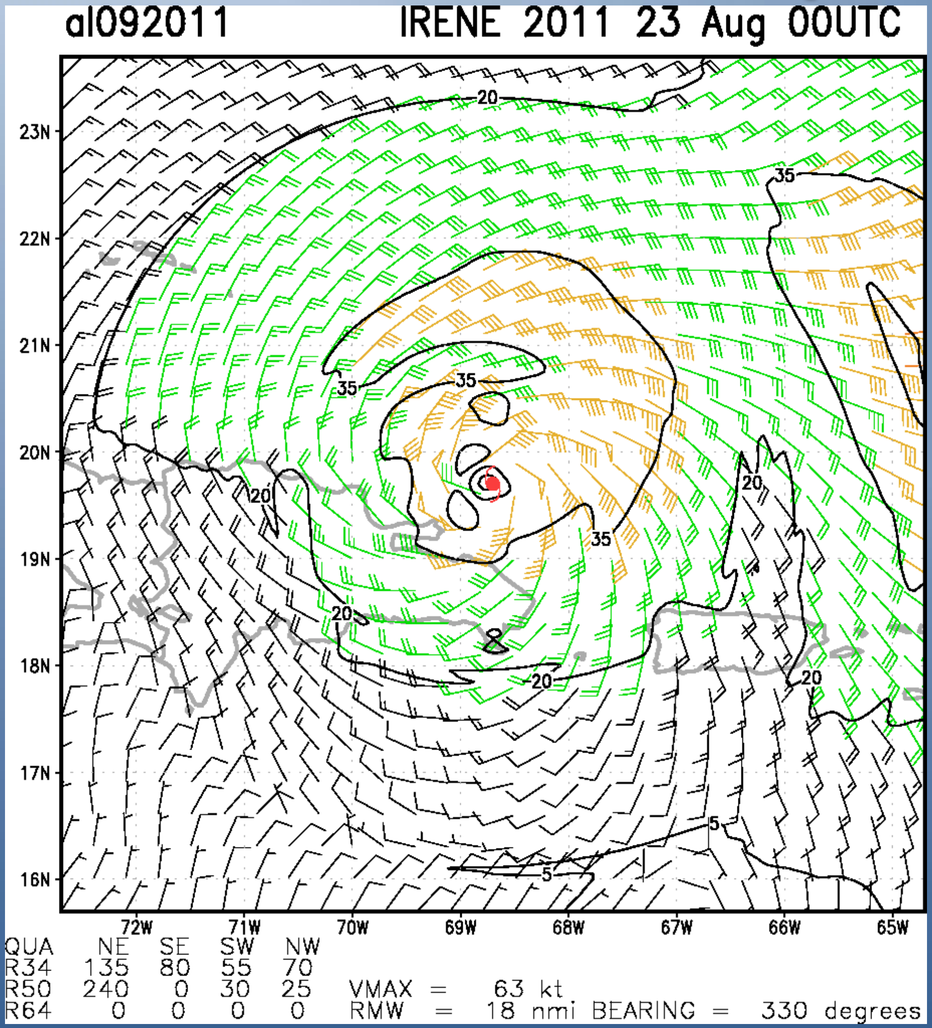
No visible data artifacts, looks reasonable given our knowledge

Irene Time Series





Examples: Irene



Combining the MTCSWA with aircraft recon allows for a large-scale analysis of the environment, given the limitation of the MTCSWA.

Next Steps

Setting things up

- Port code to NHC
  - Need an account (May?)
  - Clean up scripts add python control scripts
  - Work with NHC on display
  - Fixes or data to ATCF
  - Run in real-time (Sept)
- Questions
  - Maximum winds in ATCF fixes?
  - Flight-level-to-surface, other methods

Concerns

- Data availability
  - All examples are run (LATE)
  - Will the plane be there long enough?
- NAWIPS and AWIPS II
  - How to make sure we can display the output…

Questions?

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USWRP
Joint Hurricane Testbed