Specification of Tropical Cyclone Parameters From Aircraft Reconnaissance

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Motivation

This paper is part of on-going work to improve the OWI Tropical PBL model for delivery as part of the MORPHOS project. Determining the dataset for model evaluation is the first step.

The primary motivation is to develop a new dataset of tropical inputs for the Tropical PBL model to assess model upgrades that make best use of available aircraft flight level and surface data.

Methodology

Following an expanded version of a cost function introduced by Willoughby and Rahn (2004), determine the double exponential pressure profile that best fits the flight level tangential winds, flight level heights and surface pressures.

$$S^2 = \sum_{k=1}^{K} \{[v_o(r_k) - v_g(r_k, B)]^2 + g[z_o(r_k) - z(r_k, B)]^2 L_z^{-1}\}$$

Develop a new database of tropical parameters for model evaluation.

Drive the present Tropical PBL model with the new parameter sets and assess against SFMR surface wind estimates.

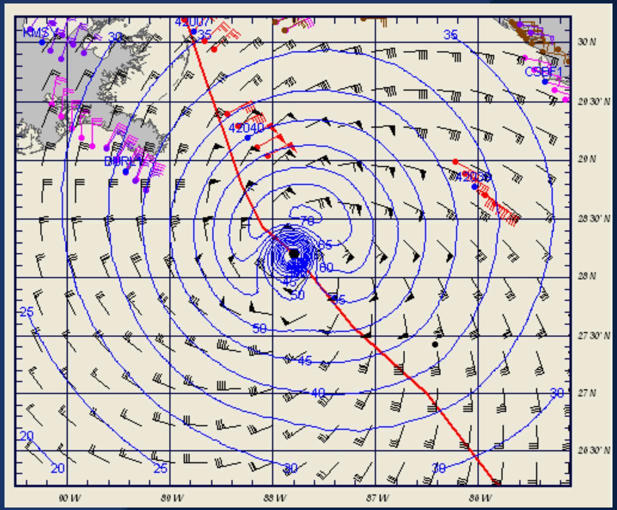
Conclusions

Good reason to come to Hawaii!

Tropical Planetary Boundary Layer Model (TropPBL)

So called "TC-96" model after Thompson and Cardone 1996

Storm track and storm parameters are used to drive a numerical primitive equation model of the cyclone boundary layer to generate a complete picture of the time-varying wind field associated with the cyclone circulation



Applied in the hindcasting historical storms, forecast applications (NOPP), and in Joint Probability Method (JPM) applied most recently in Louisiana and Texas coast surge modeling.

TropPBL Inputs

$$P(r) = Po + \sum_{i=2}^{n} dp_i e^{-\left(\frac{R_{pi}}{r}\right)^{Bi}}$$

Storm Position – Latitude/Longitude

Storm Motion – Speed/Direction

Po - Central Pressure of Storm

Available from standard sources such as HURDAT

Rp_i – Scale Pressure Radius

Related to the Radius of Maximum Wind (RMW) expressed as a inner and outer radii

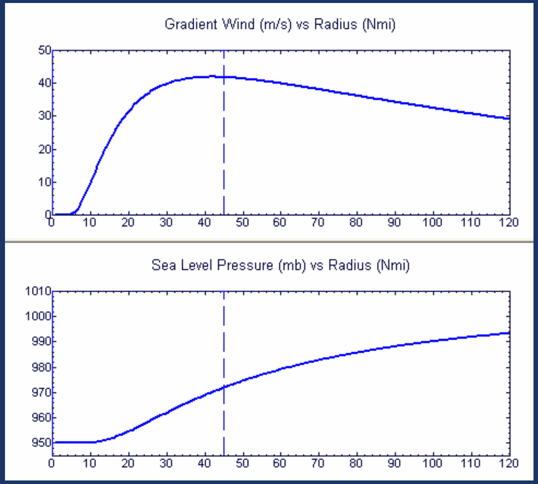
Dp_i – Total Pressure Drop (*Pfar-Po*)

Pfar may be derived from synoptic maps or atmospheric model output, however the % associated with each Rp_i *must be determined*

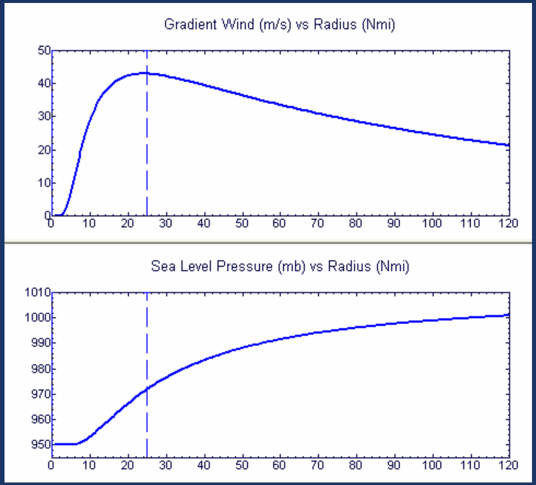
B_i – Holland's B associated with each Rp_i

Controls the peakedness of the pressure and resultant wind profile

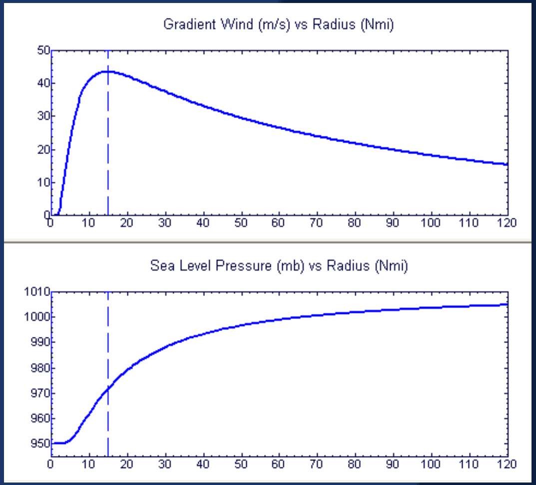
TropPBL Inputs: Examples of Rp and B



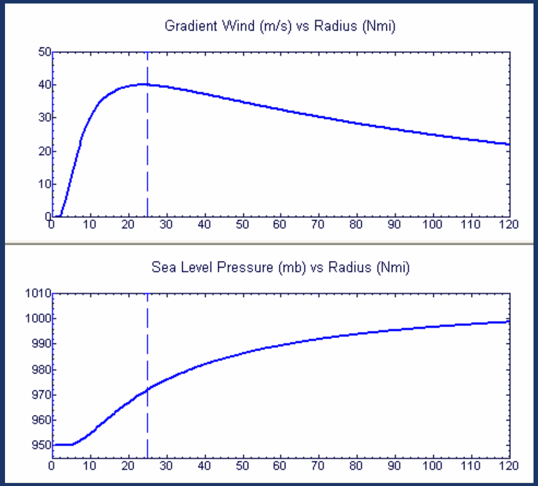
Rp=45 Nmi



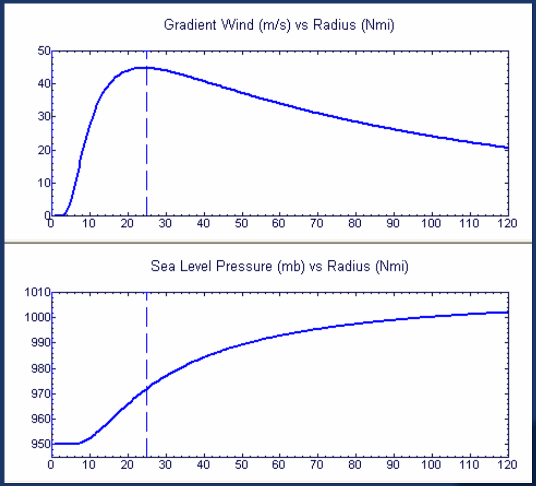
Rp=25 Nmi



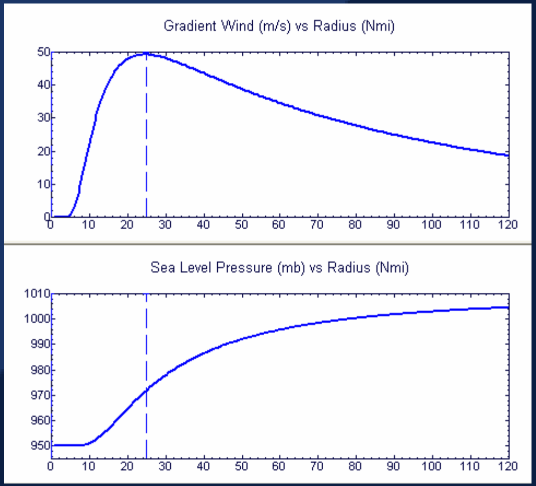
Rp=15 Nmi



B=1.00



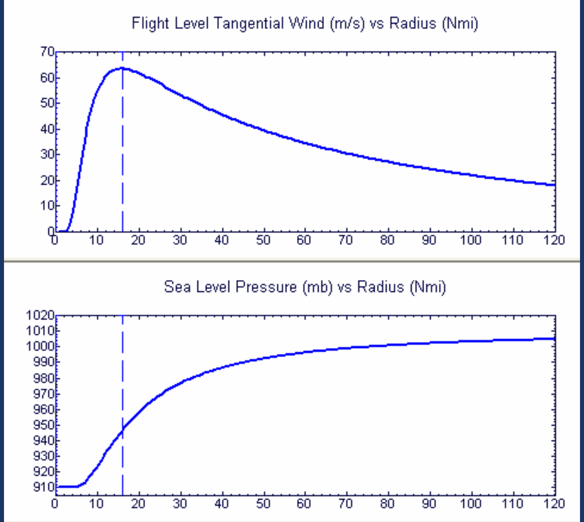
B=1.25



B=1.5

TropPBL Inputs: Single vs. Double Profile

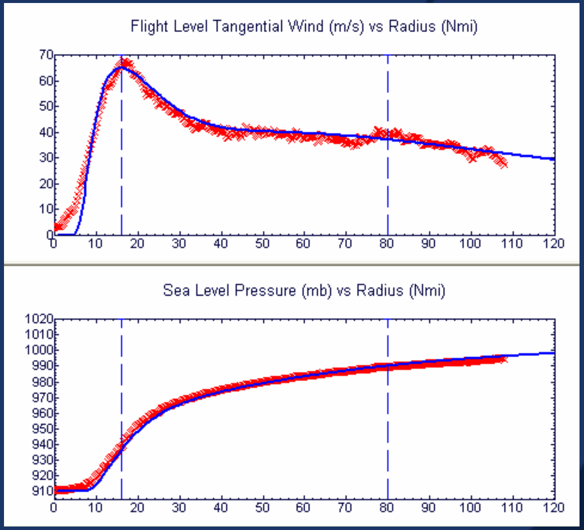
The Storm? Katrina 2005



Cp=910, Pfar=1010, Dp=100 mb

Rp1=16 Nmi

B1=1.45



Cp=910, Pfar=1010, Dp=100 mb

Rp1=16 Nmi Rp2=80 Nmi

B1=2.1 B2 = 1.7

TropPBL History

1978 Version restricted B=1, single exponential profile

1996 Version allowed variable B, double exponential profile

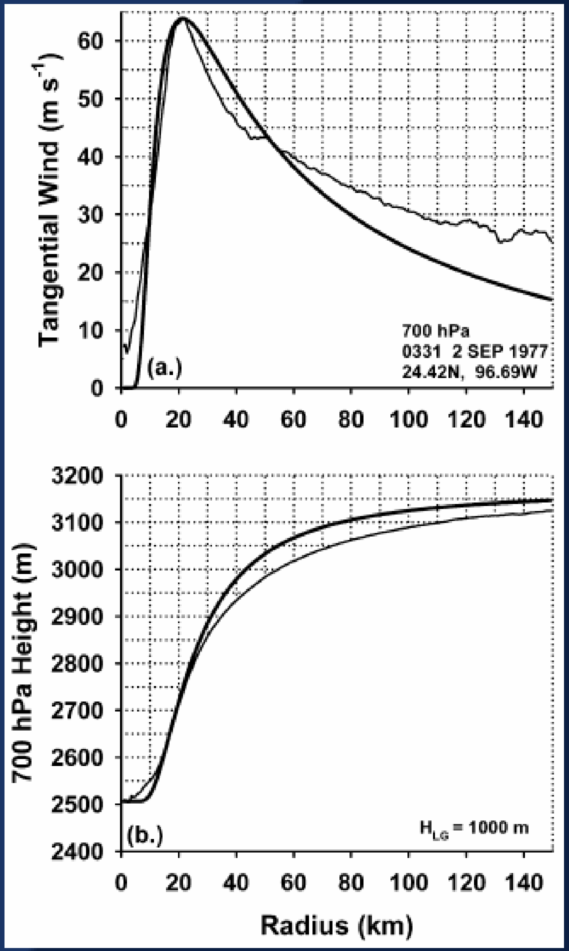
2007 Version allows Dp, B to vary by quadrant

Existing database of tropical inputs for historical storms varies with the version of model applied. Early storms primarily used a B=1, later systems applied a variable B but rarely applied the double exponential due to the difficultly in getting coherent fits. Tropical inputs were modified on a per-storm basis to best describe the storm given the model version. Storms with complex and double exponential profile typically applied TC96 in the core and handled outer profile via kinematic analysis

Needed: A new set of "clean" tropical inputs that fully exploit the azimuthally varying double exponential profile of the TropPBL model

Willoughby and Rahn (2004) Methodology

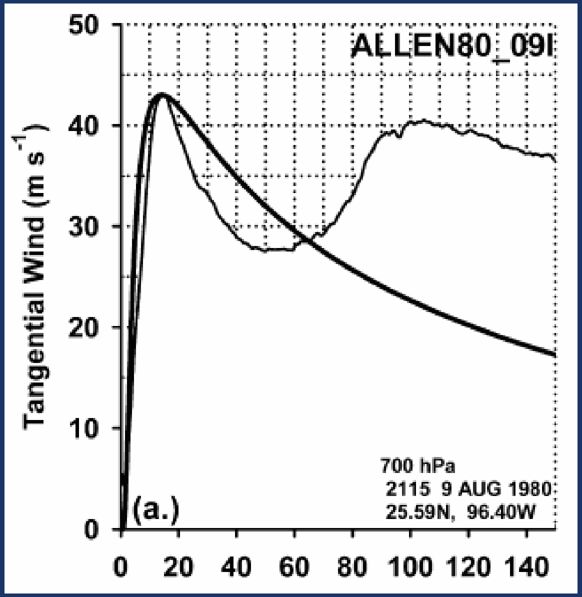
$$S^2 = \sum_{k=1}^{K} \{[v_o(r_k) - v_g(r_k, B)]^2 + g[z_o(r_k) - z(r_k, B)]^2 L_z^{-1}\}$$

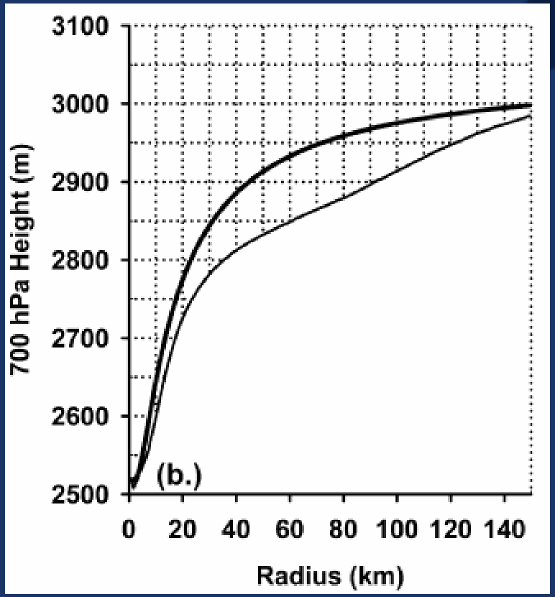


Attempts to minimize the difference between the observed flight level tangential wind and flight level heights to obtain a RMW and B combination

Applied for a single exponential wind profile

Willoughby and Rahn (2004) Methodology

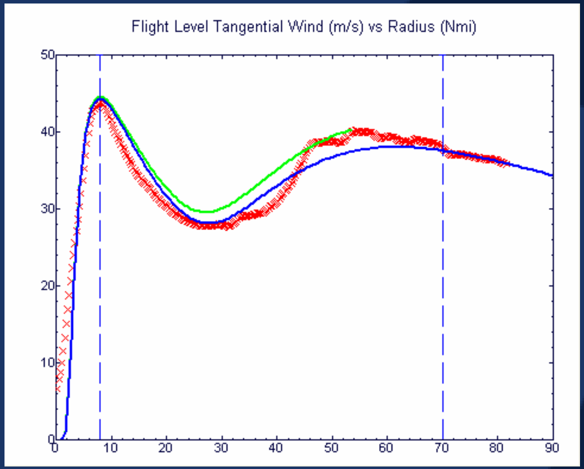


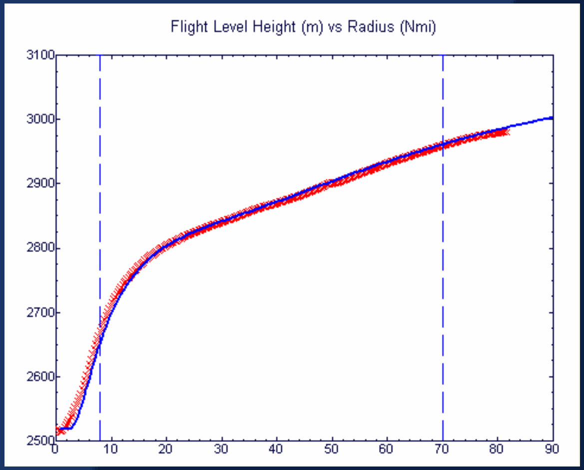


Large discrepancies observed when attempting to fit a single exponential wind profile to a storm displaying a double wind maxima

Methodology

- *Apply double exponential pressure profile as implemented in TropPBL*
- *Expand cost function to allow sea level pressure measurements as well as flight level tangential wind and height*
- *Display available fit information in work station to allow storm analysis which tracks the parameter set throughout the storm life cycle*

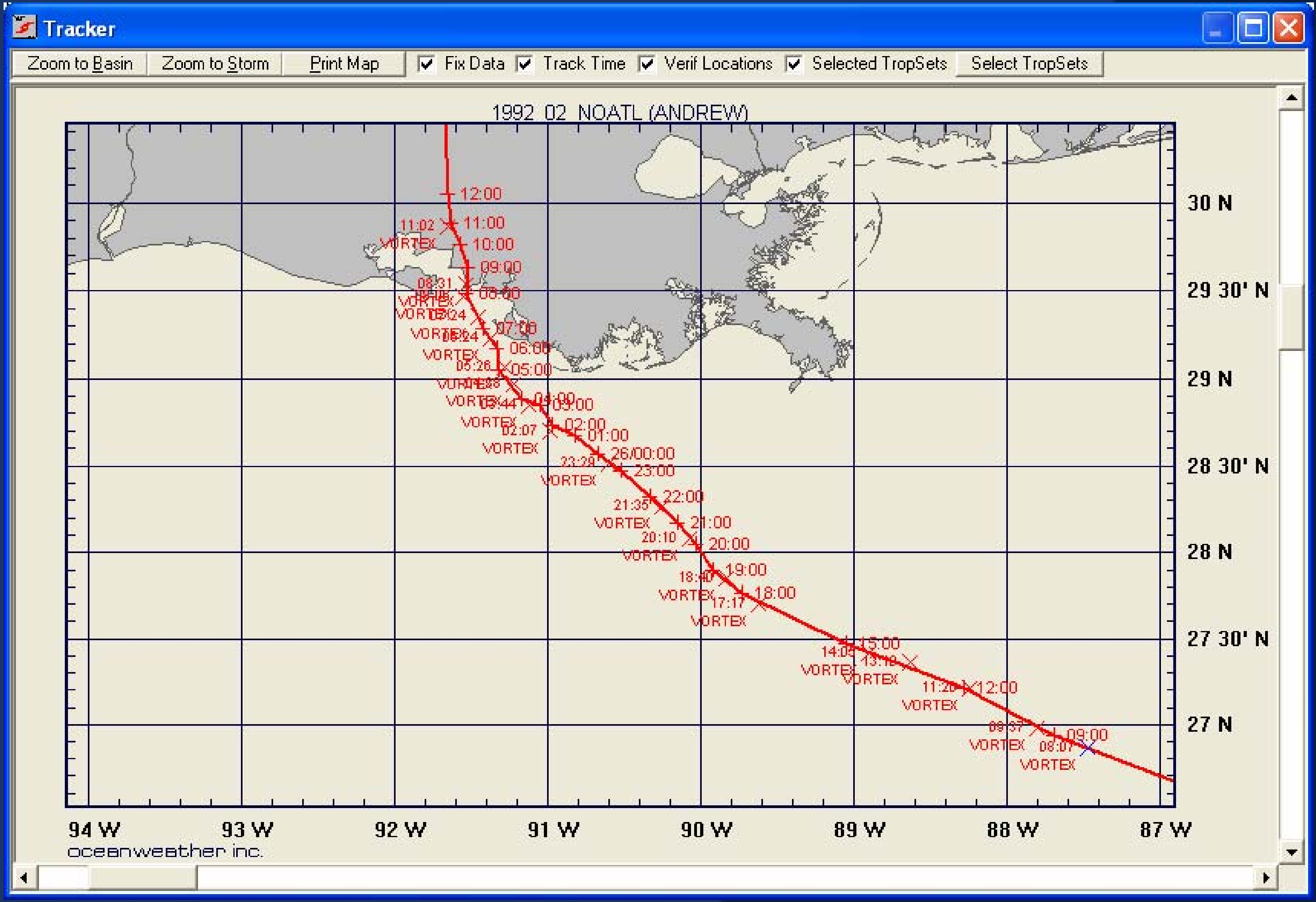




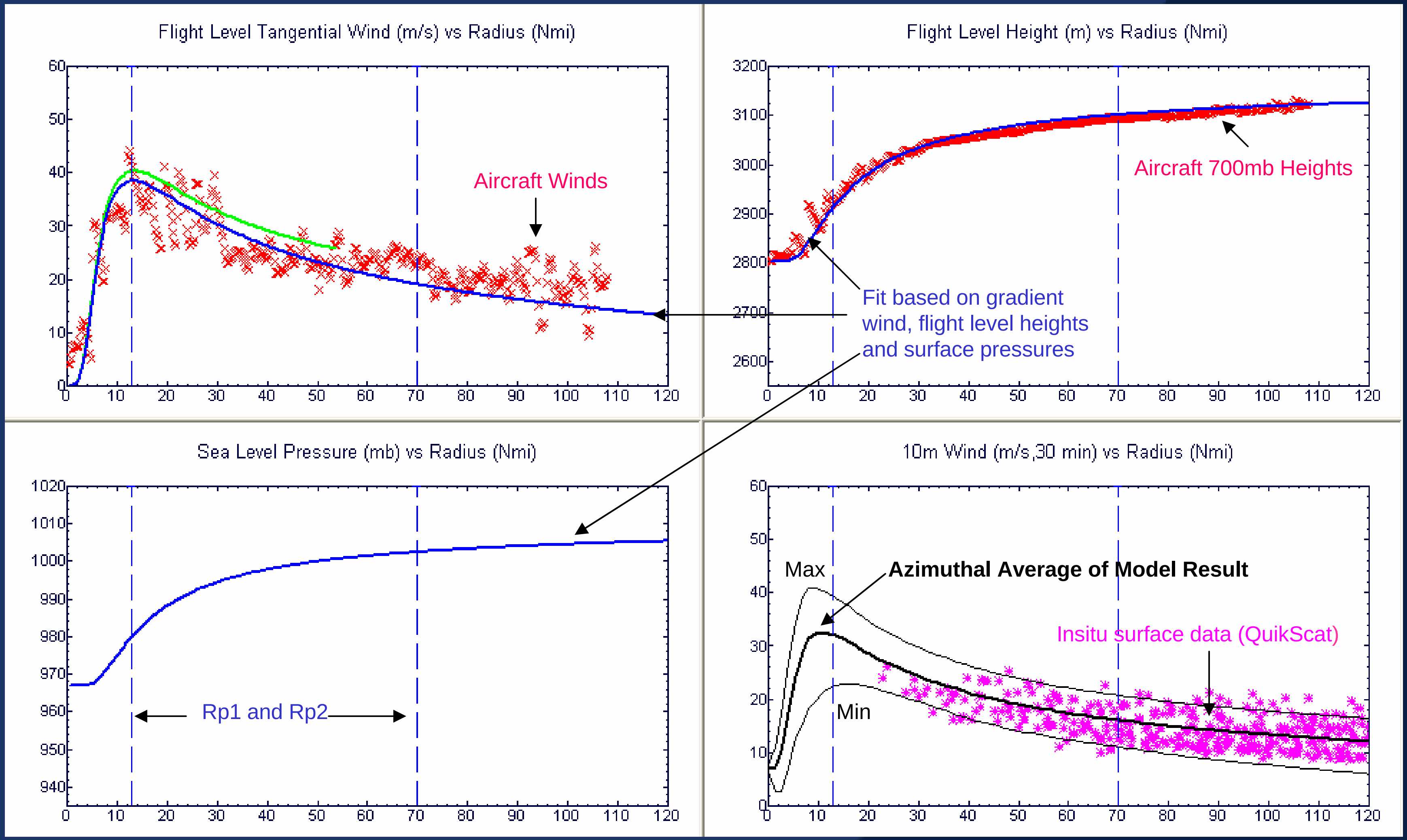
Storm Analysis

- *Revise HURDAT track based on available center fixes from aircraft, satellite and radar*
- *Compute storm speed/direction from reanalyzed track*
- *Revise HURDAT central pressures based on available aircraft data and landfall estimates*
- *Estimate Pfar from synoptic pressure data in each quadrant*
- *Azimuthally average available aircraft reconnaissance and display the flight level tangential wind and flight level heights*
- *Reposition available insitu data and apply available pressure observations*
- *Determine combination of Rp and B's (single or double radii) for each snapshot then evaluate for time continuity over entire storm*

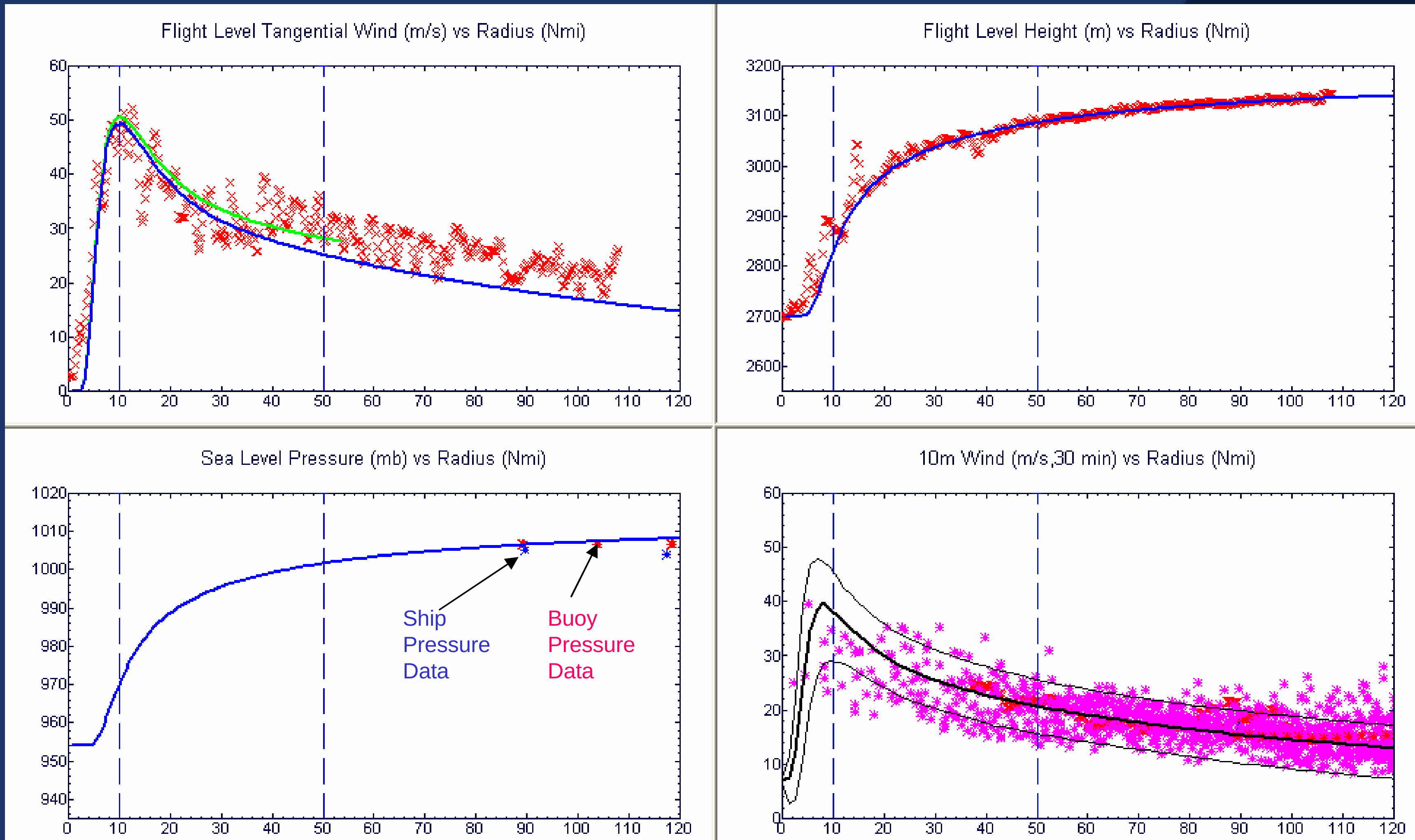
Example of Track Revisions in Andrew (1992)



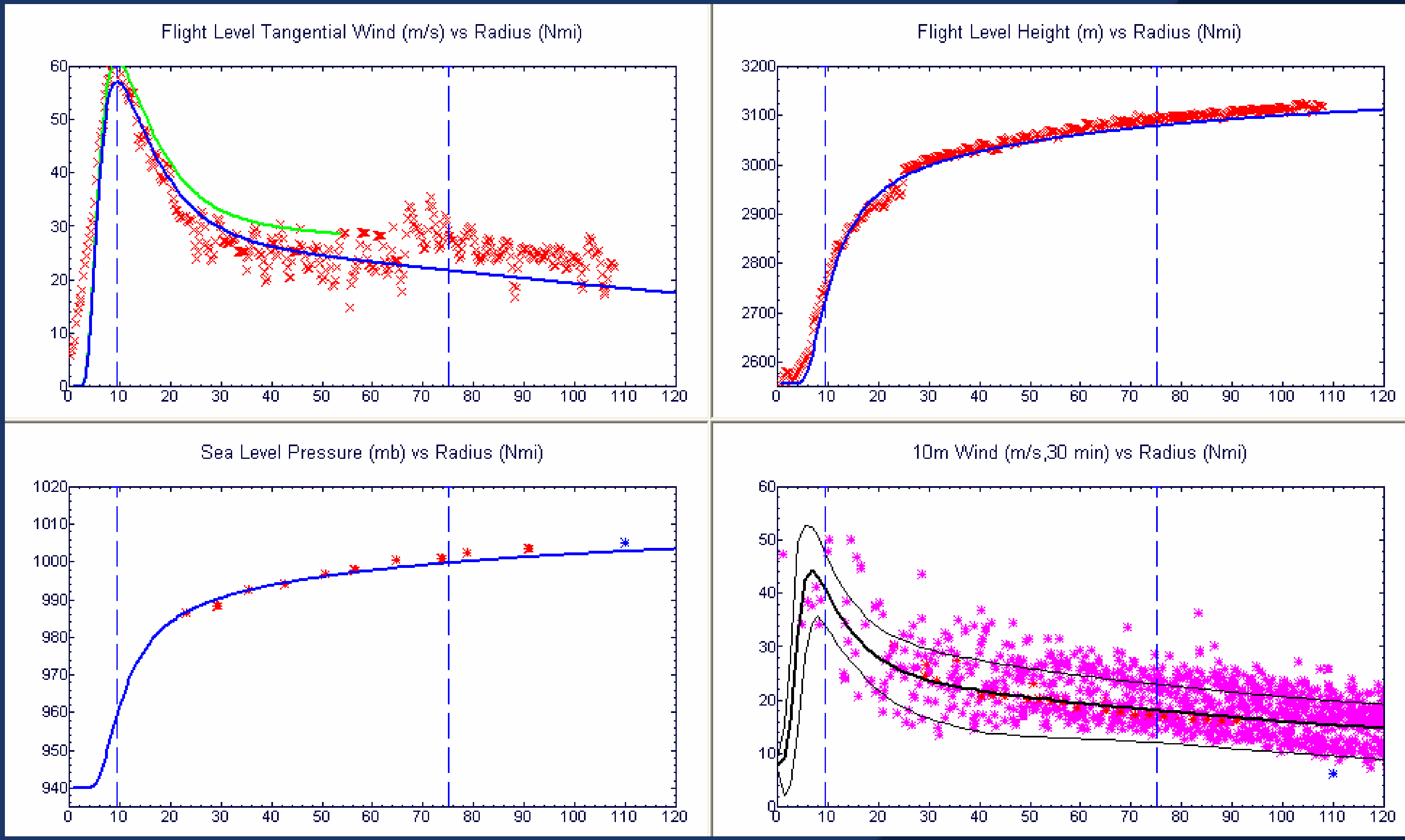
Fits During Lili (2002): October 2, 2002 00 UTC



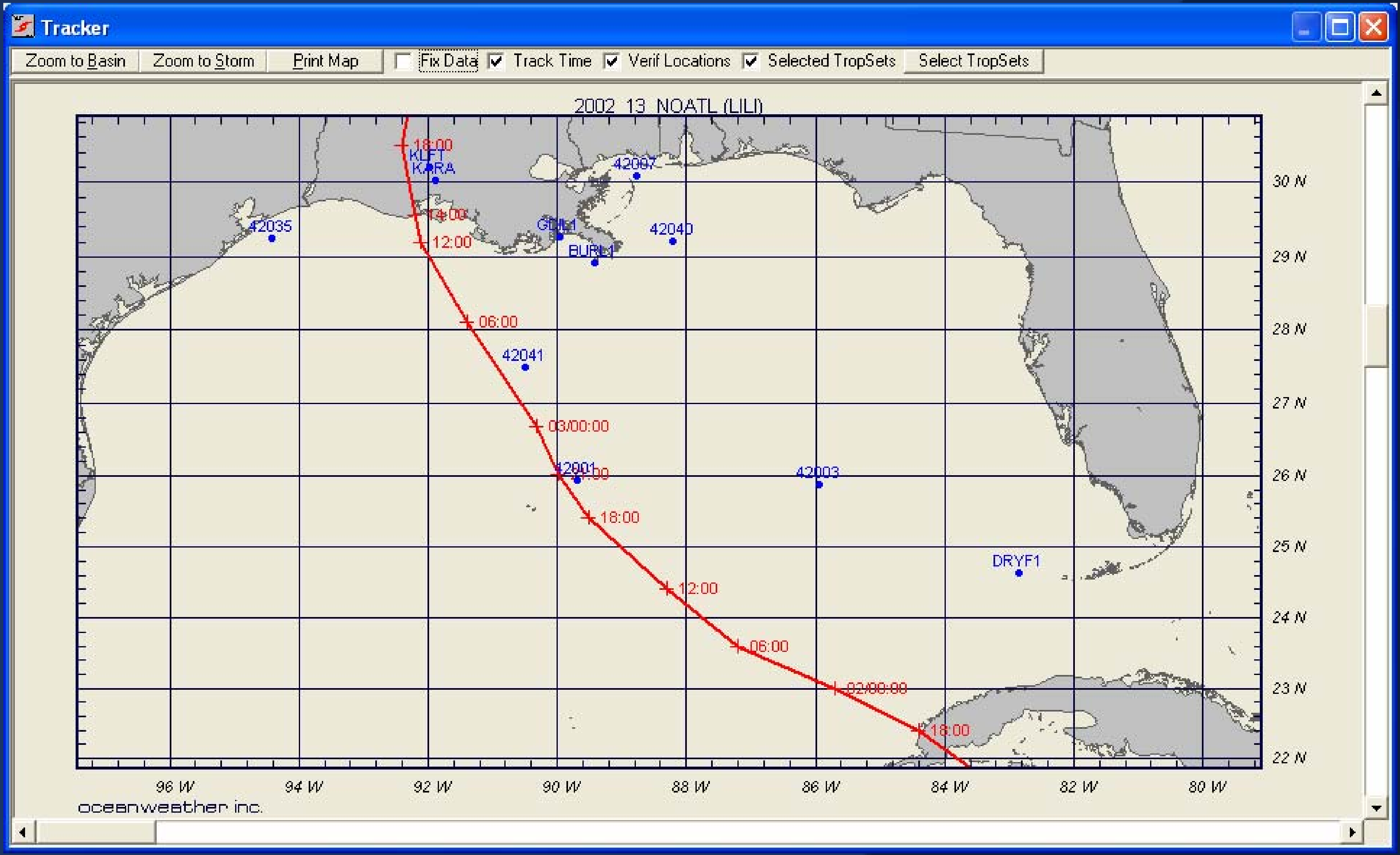
Fits During Lili (2002): October 2, 2002 12 UTC



Fits During Lili (2002): October 3, 2002 00 UTC



NDBC Buoy/CMAN Data During Lili (2002)



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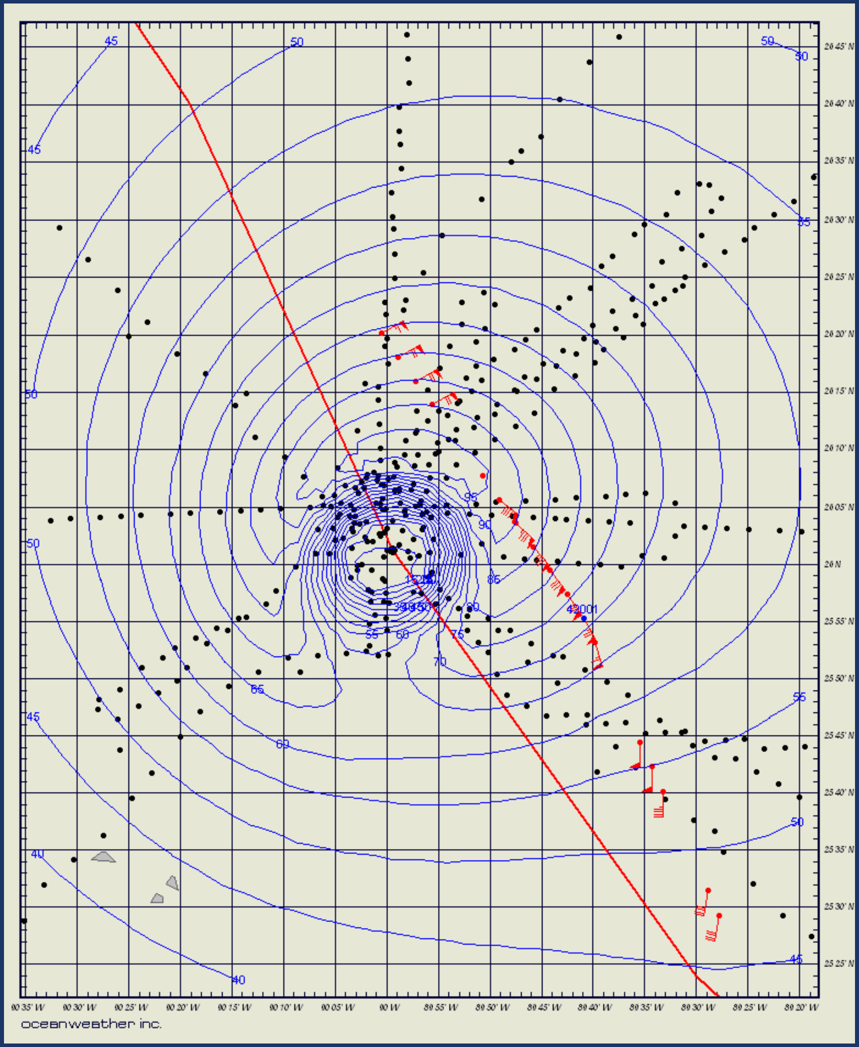
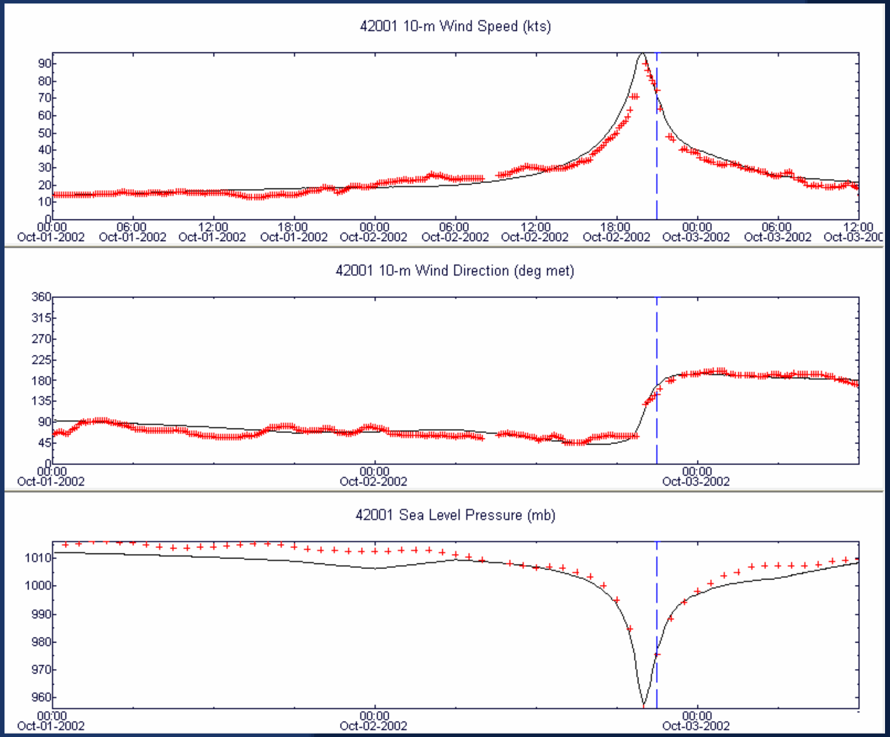
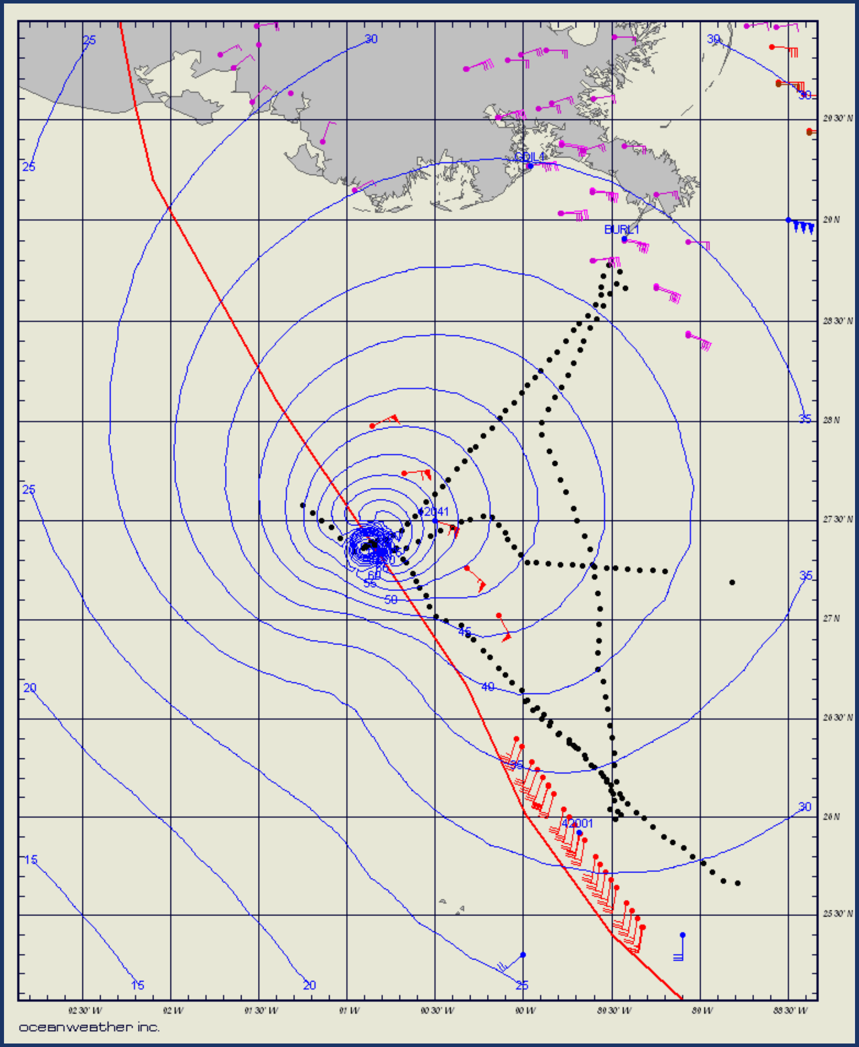
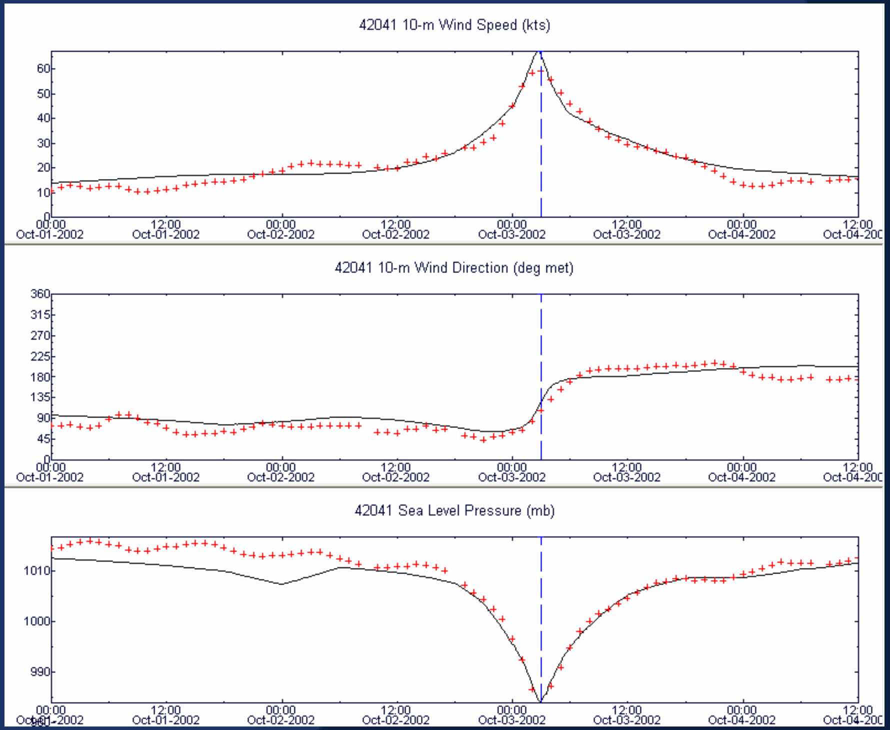
NDBC Buoy 42001 During Lili (2002)





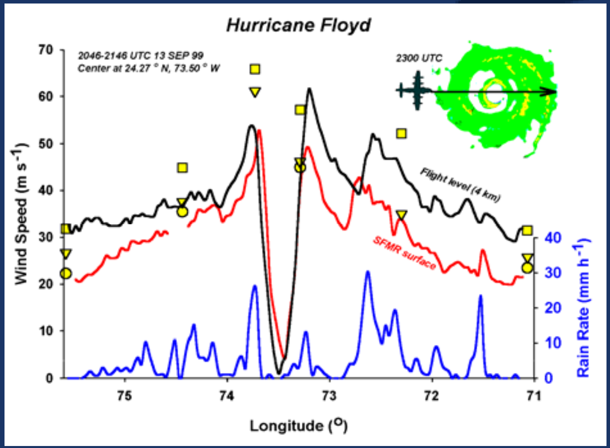
NDBC Buoy 42041 During Lili (2002)

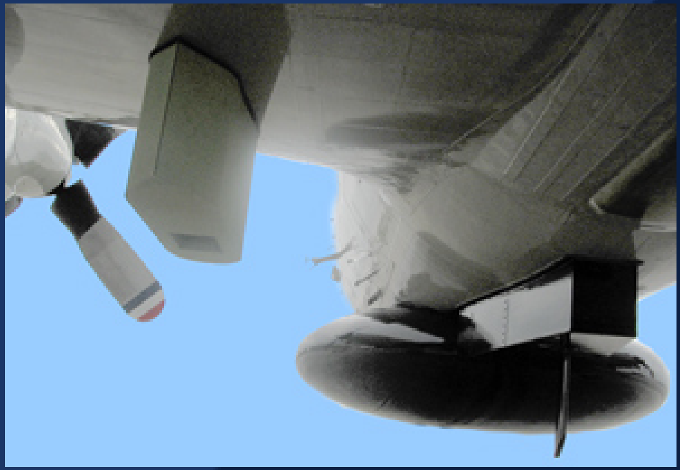




SFMR: Stepped Frequency Microwave Radiometer

- *Surface wind speed estimates taken from aircraft*
- *Instrument on NOAA aircraft since 1998*
- *Entire archive reprocessed in 2007 using new wind speed retrieval algorithm*
- *Data represent a 1-minute peak wind at 10 meter reference level*





Images courtesy of the Hurricane Research Division

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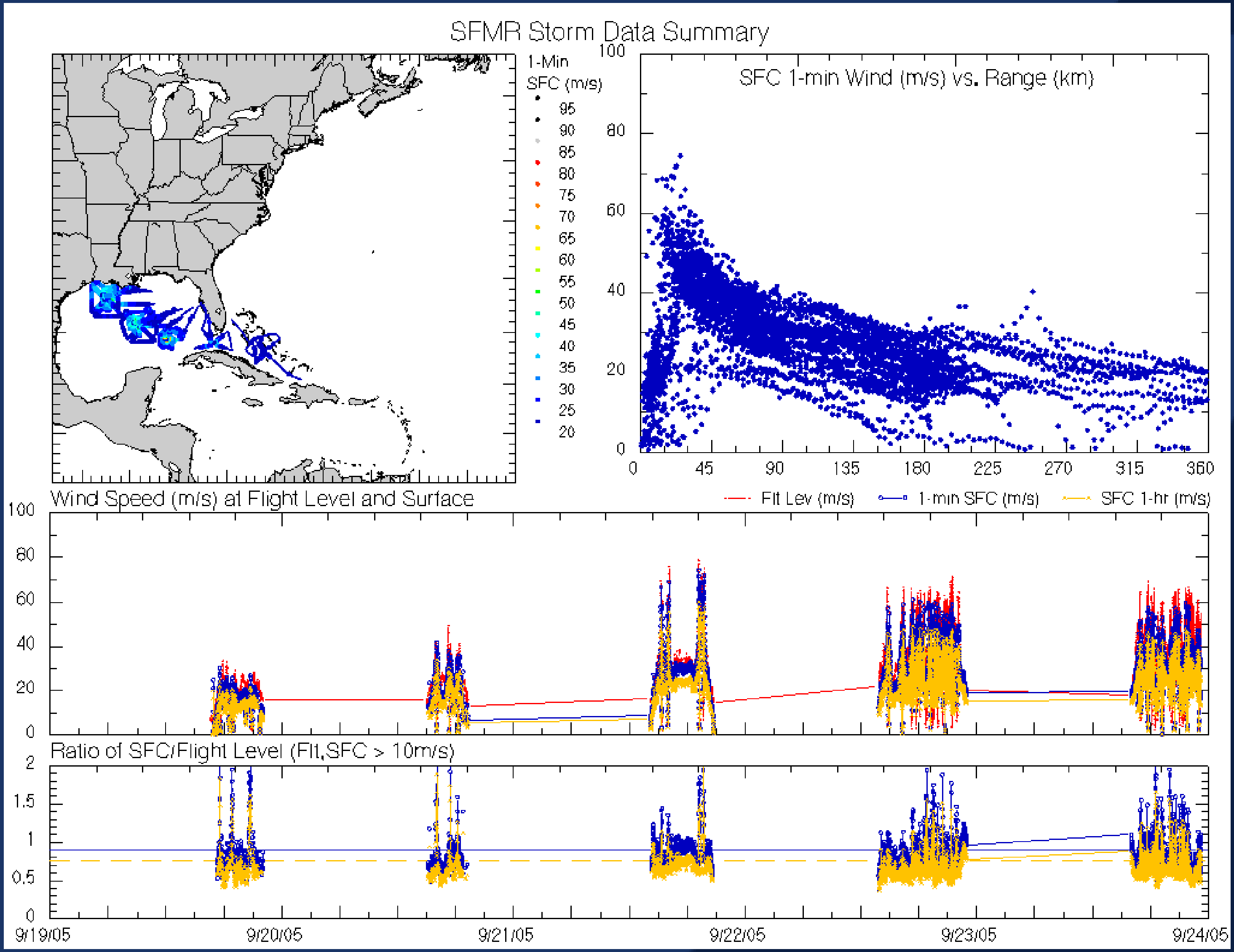
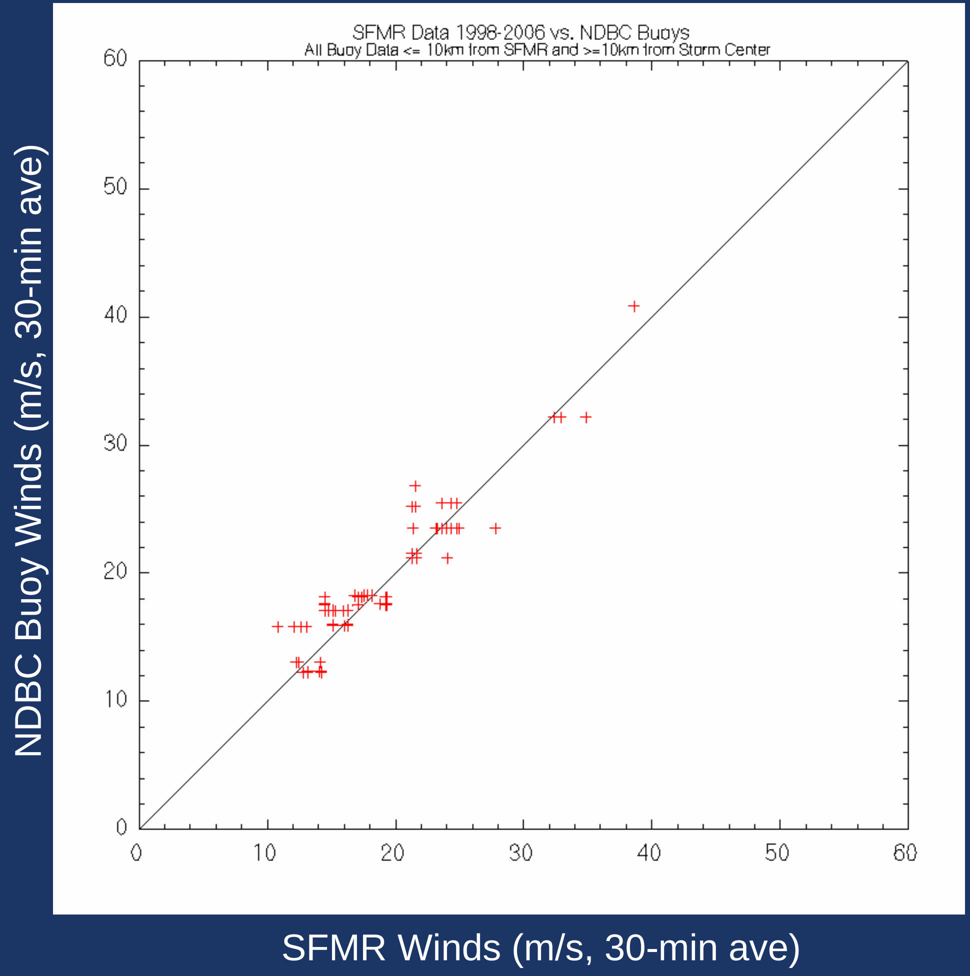
SFMR Data Available During Rita 2005



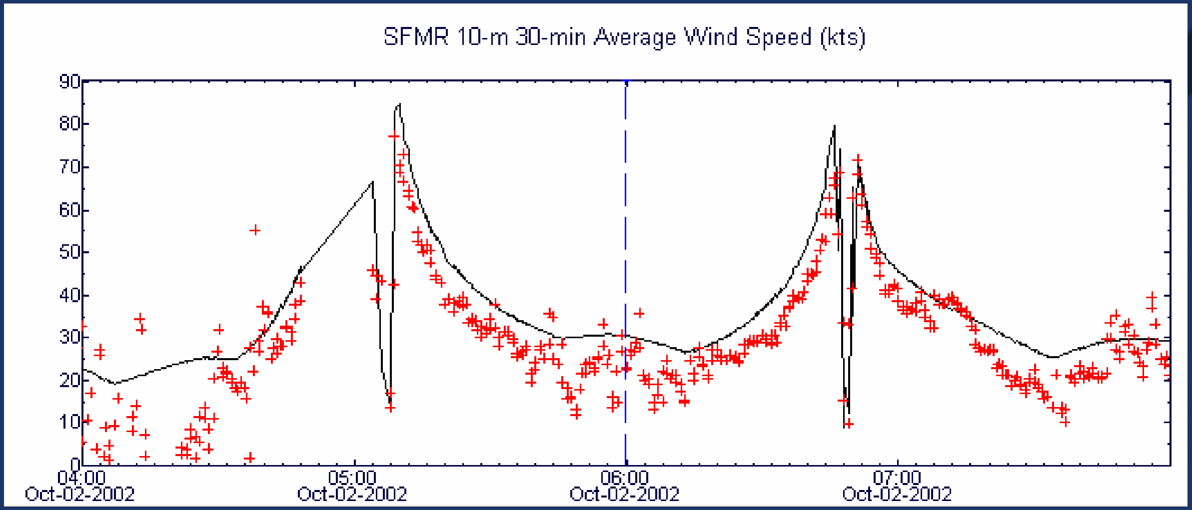
Comparison of SFMR Data at 30-Minute Average



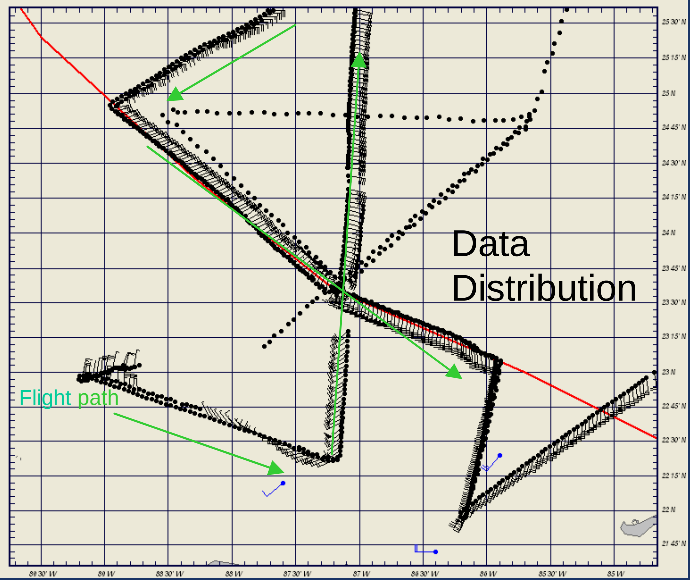
Comparison of 30-minute SFMR wind derived estimates (EDSU Gust Factor Adjustment) with 30-minute average NDBC buoy observations during hurricane conditions

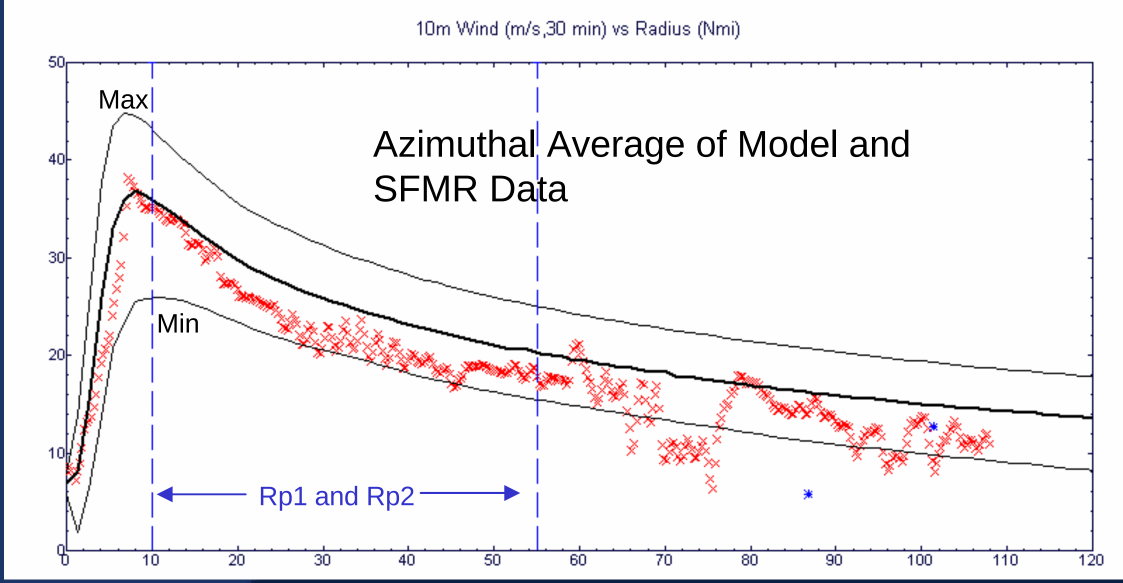
SFMR measurements within 10 km from buoy and within 15 minutes of buoy observation

SFMR Data in Lili 2002 (October 2, 2007 6 UTC)



Comparison of SFMR transect through storm





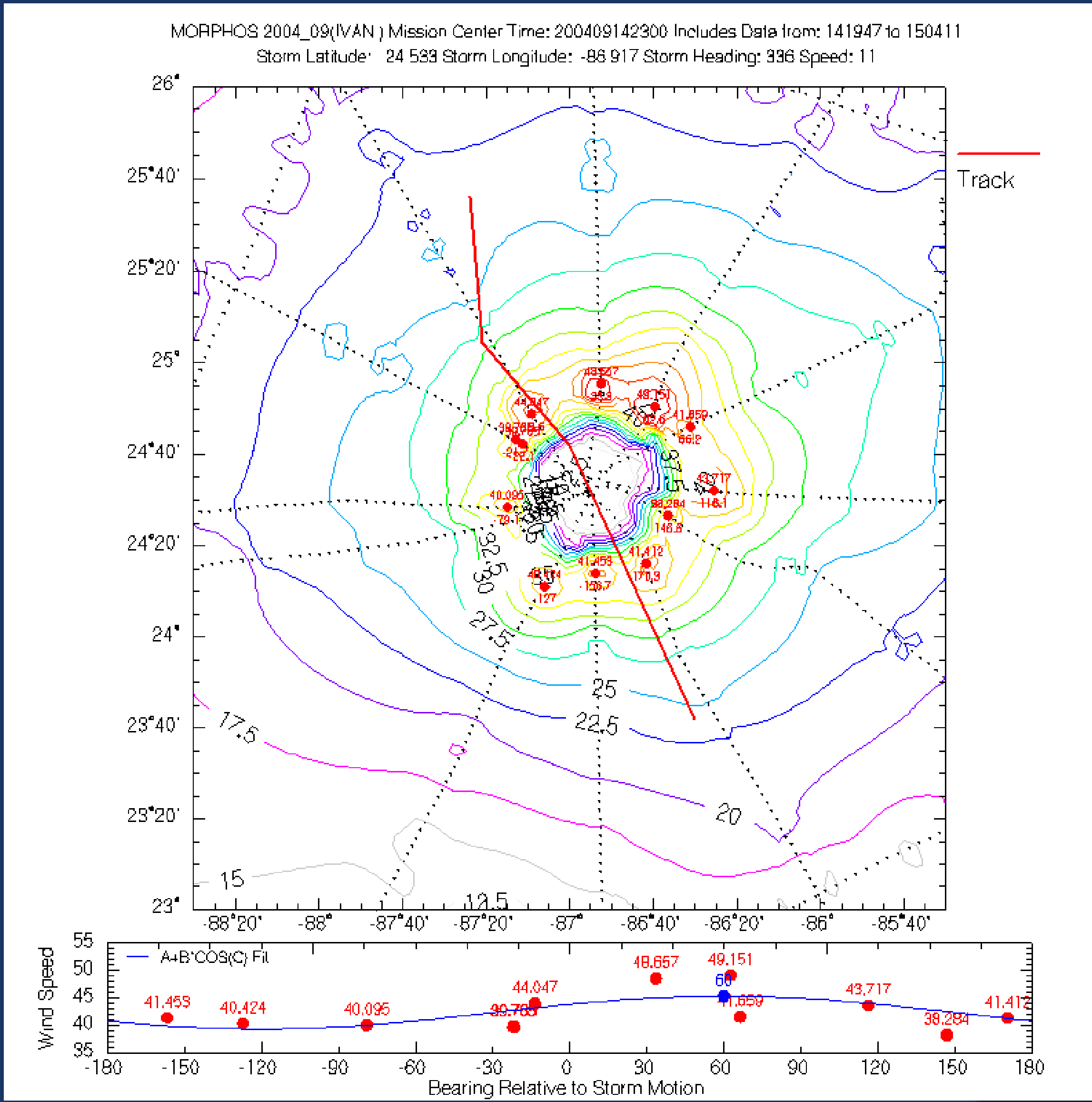
On Going Work

Development of database of tropical parameters during the SFMR period

SFMR data contains 33 missions during 15 storms which:

a) Sufficient SFMR data were available in a composite field to represent all storm quadrants

b) Storm system was sufficiently away from the coast



Initial work in comparing location of surface wind maxima in SFMR vs. TropPBL model

Conclusions

The double exponential pressure profile does a better job at describing the flight level wind and height profiles measured from aircraft than a single exponential profile

Tropical parameters derived from the new methodology result in wind and pressure fields that closely match insitu buoy measurements as well as SFMR wind estimates

Work is on going in the evaluation of the TropPBL model with measurements from the SFMR instrument