NCAR

Use of Synthetic Profiles to Diagnose Simulated Tropical Cyclones in Regional Hurricane Models

Jonathan Vigh, Chanh Kieu, Vijay Tallapragada,
Ligia Bernardet, and Eric Uhlhorn

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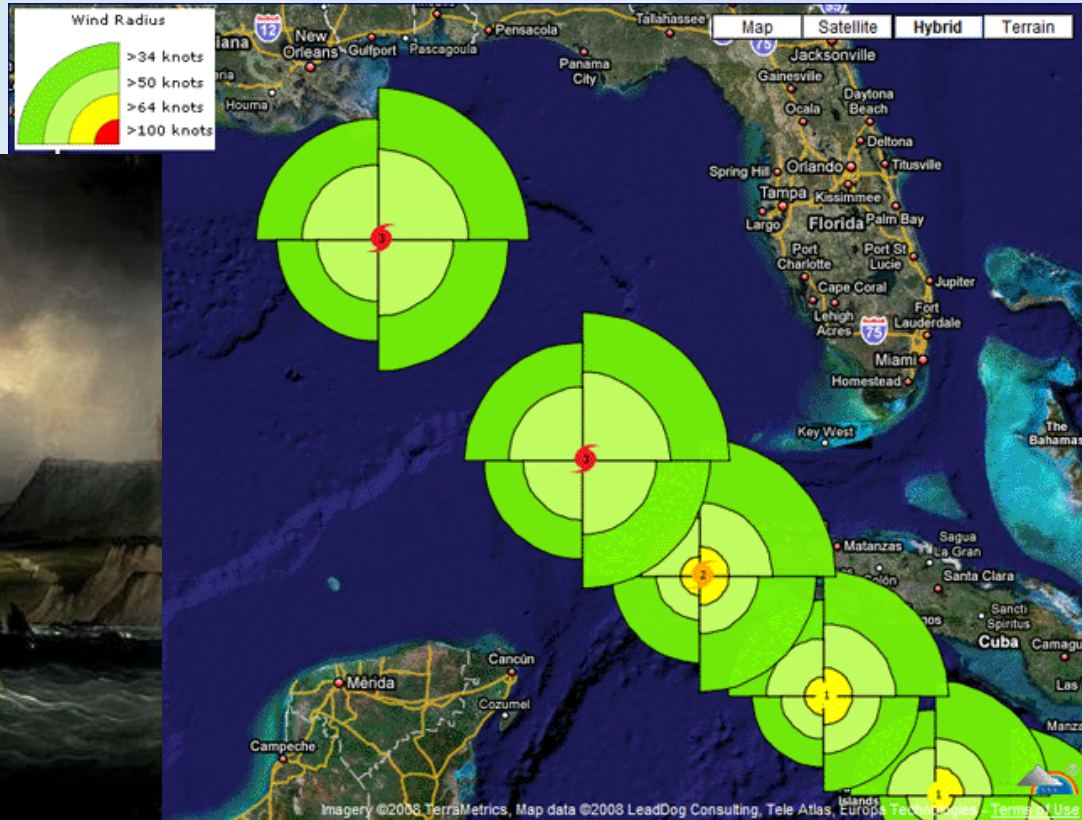
Traditional TC Metrics

- **Intensity and wind radii, as defined by NHC make great sense if you are a clipper ship**
- **But these metrics are quite inadequate if you are an insurance company or a model diagnostician**

The Clipper Ship "Flying Cloud" off the Needles, Isle of Wight, 1859-1860 – by Buttersworth. Image from Wikipedia.

Image from wunderground.com



Parametric Wind Profiles: varying R_{max}, Holland-B

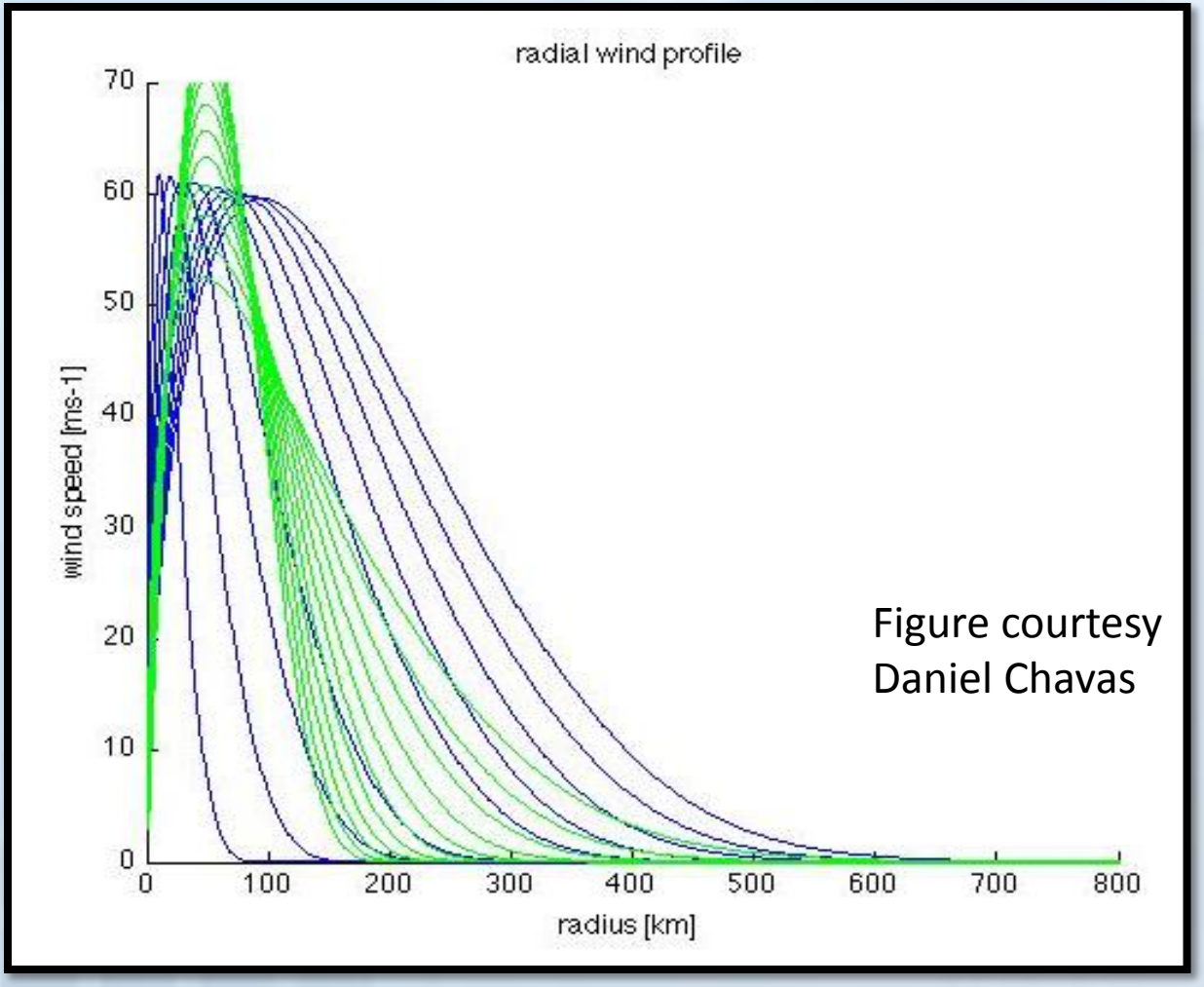
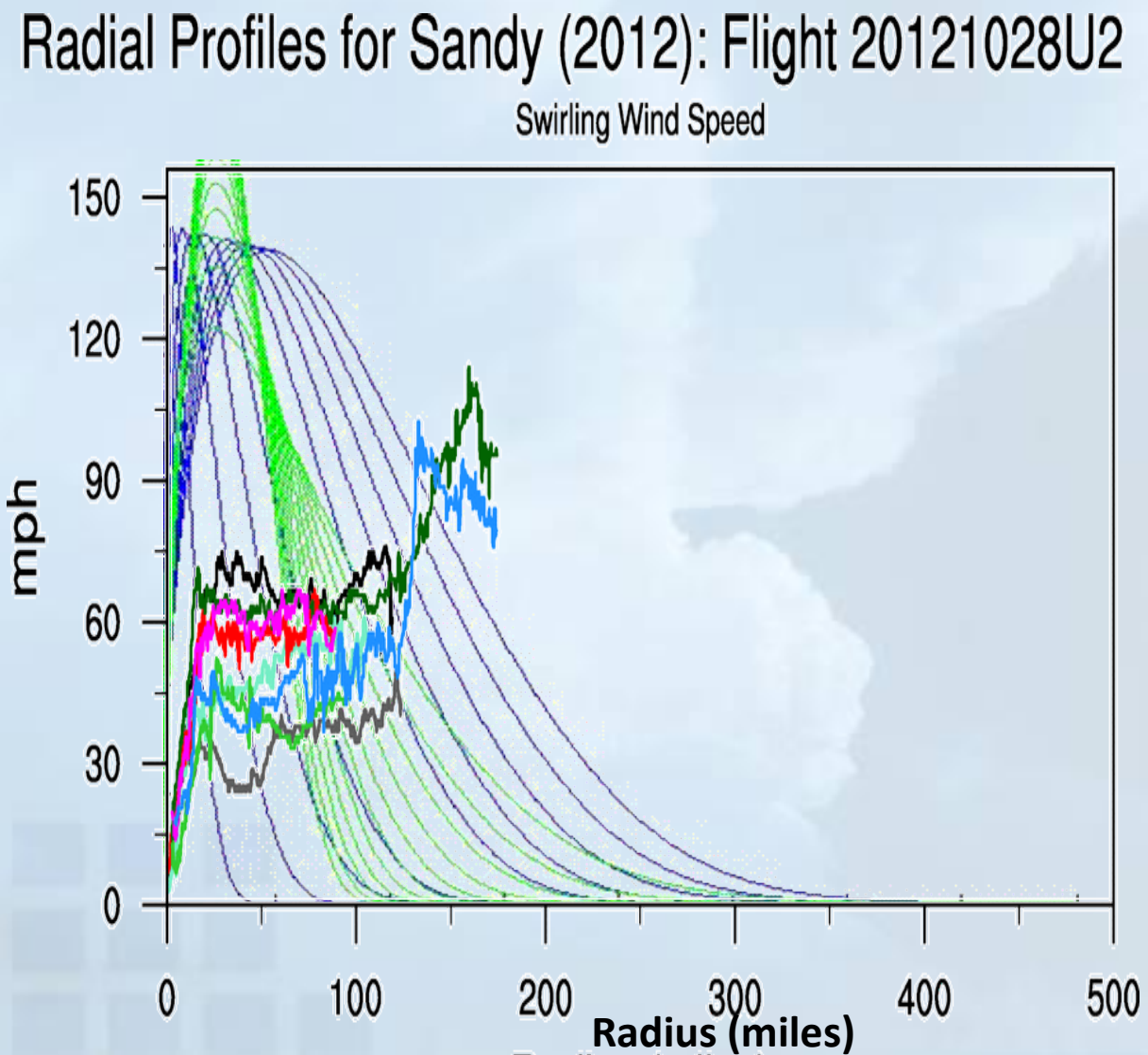
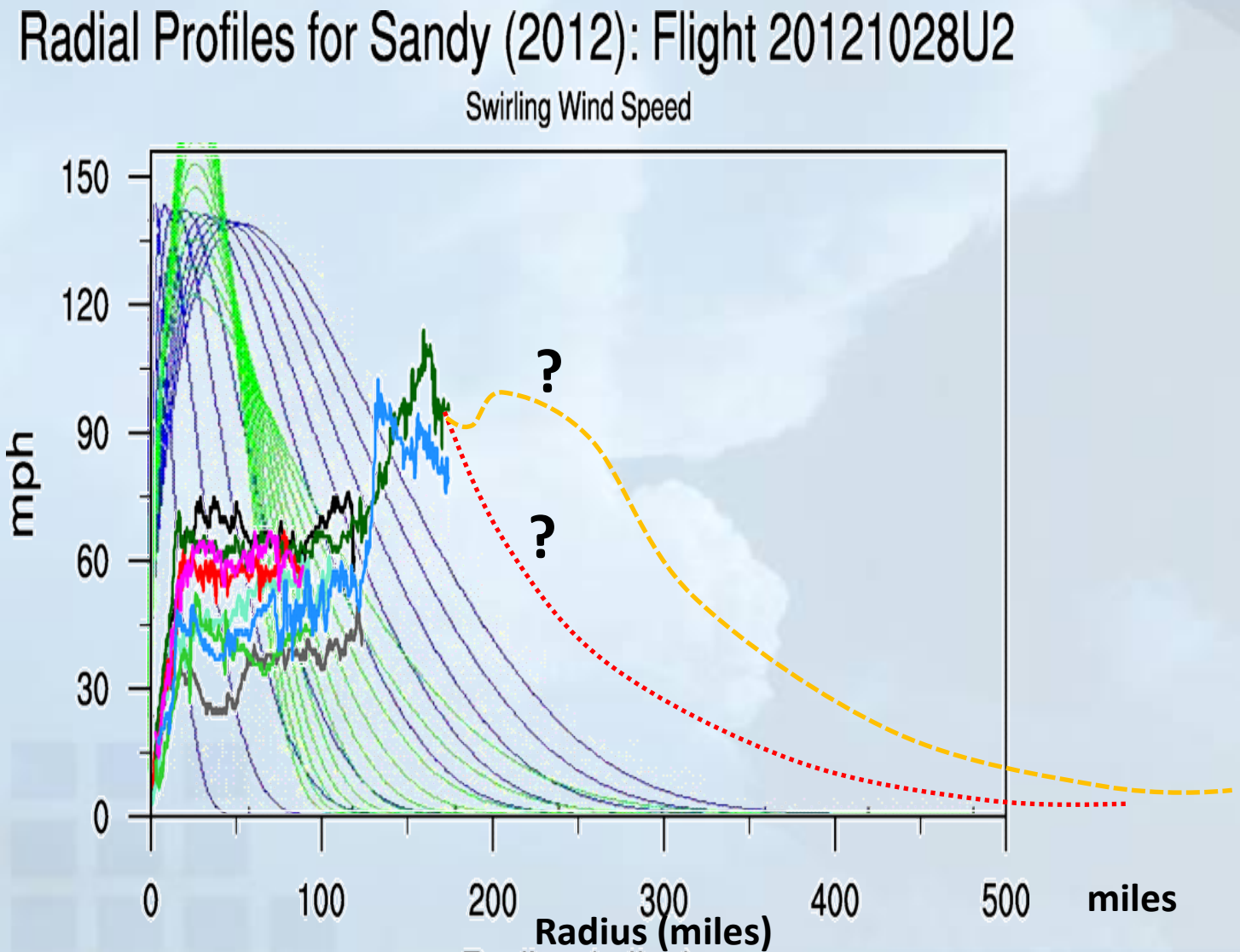


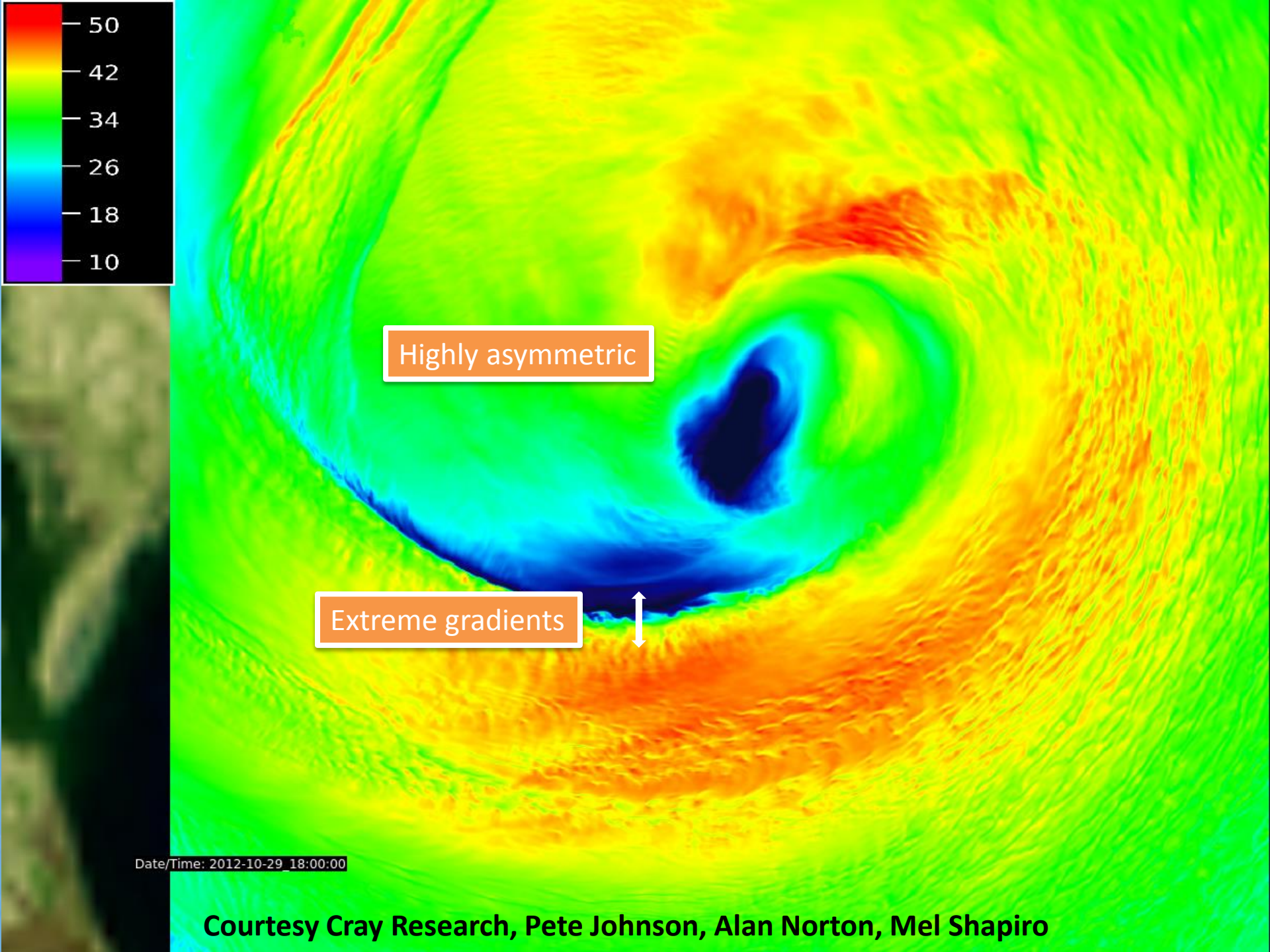
Figure courtesy
Daniel Chavas

Parametric Wind Profiles: varying R_{max}, Holland-B



Parametric Wind Profiles: varying R_{max}, Holland-B

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Extreme gradients
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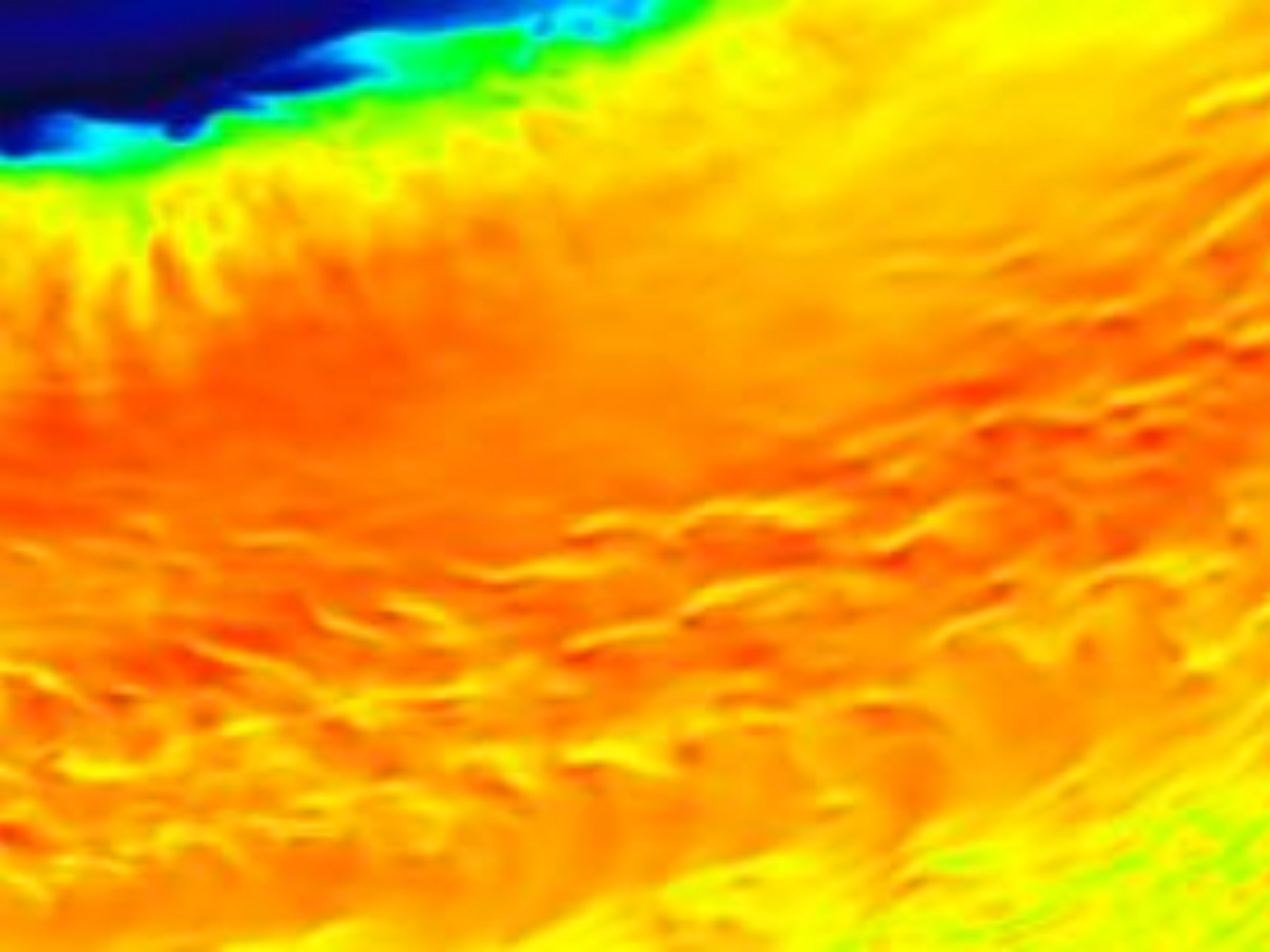
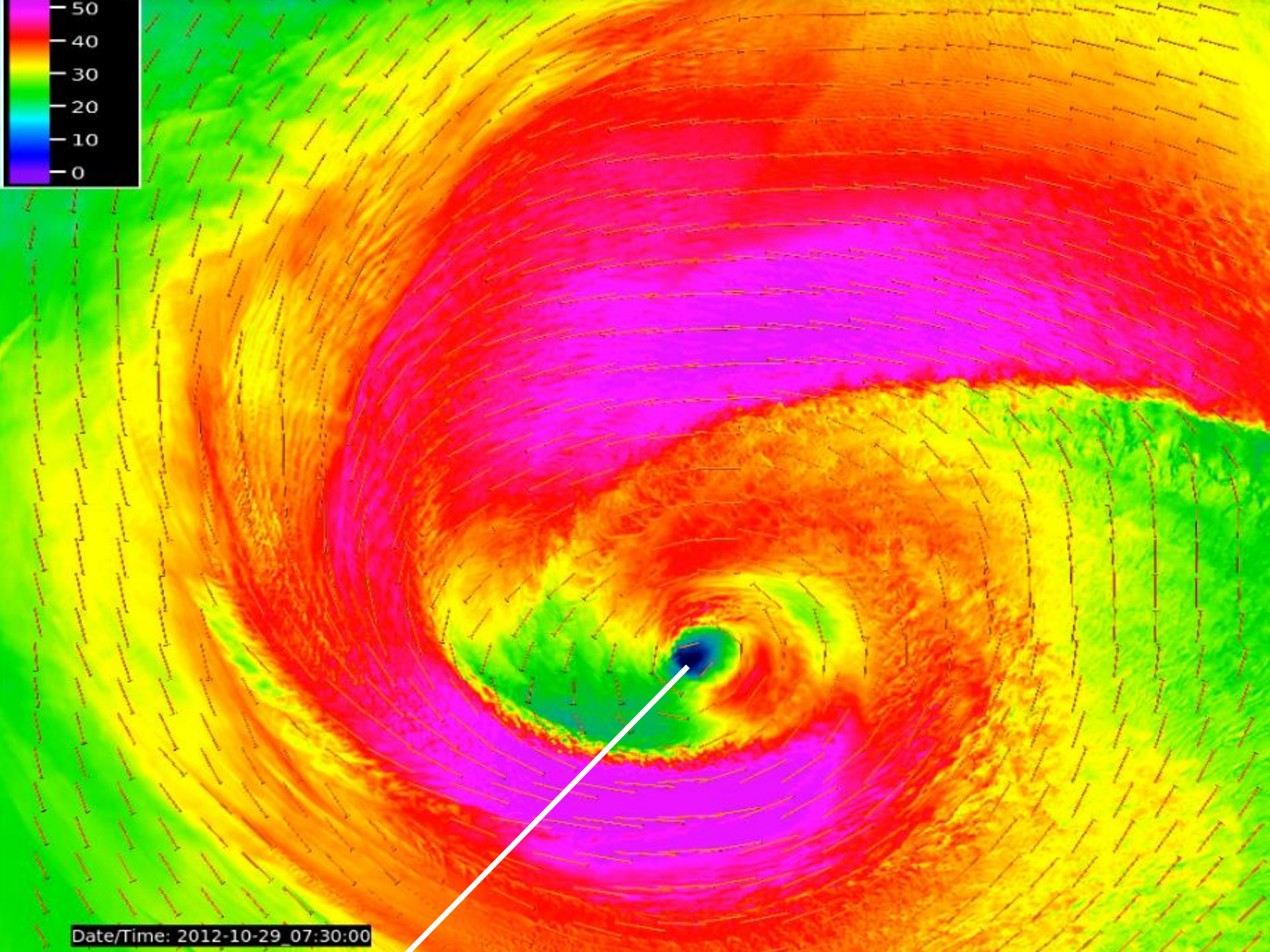
Courtesy Cray Research, Pete Johnson, Alan Norton, Mel Shapiro

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Use of Synthetic Profiles to Evaluate Simulated Tropical Cyclones

Goal:

Conduct an apples-to-apples comparison between the simulated vortex structure and direct in situ and remote sensing observations from aircraft

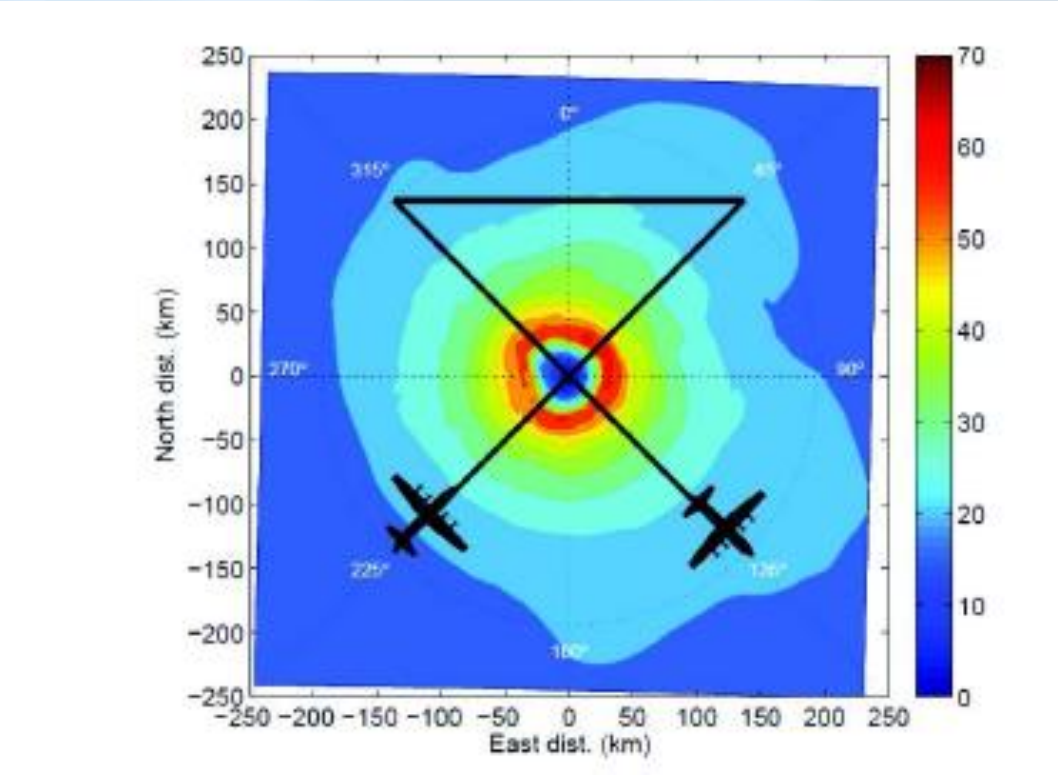
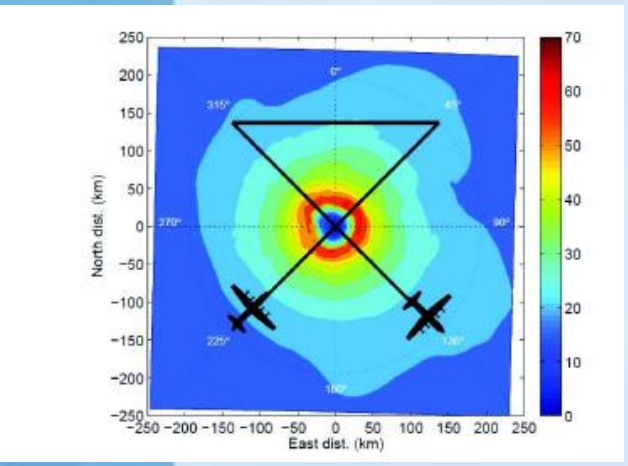


Figure 6 from Uhlhorn and Nolan (2012)

- **The resulting traces of surface and flight level wind speed in time, obtained by sampling the model storm along the flight paths shown to the left.**



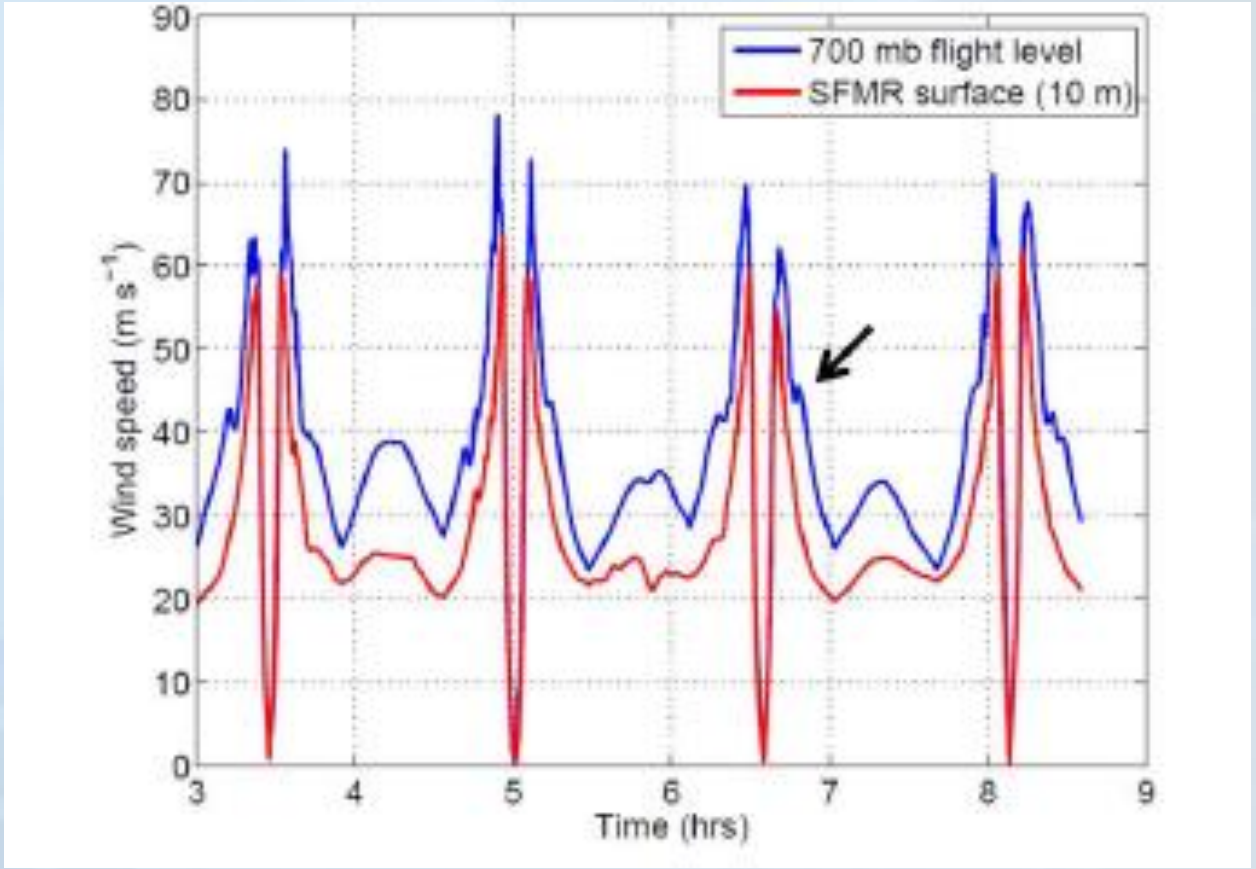


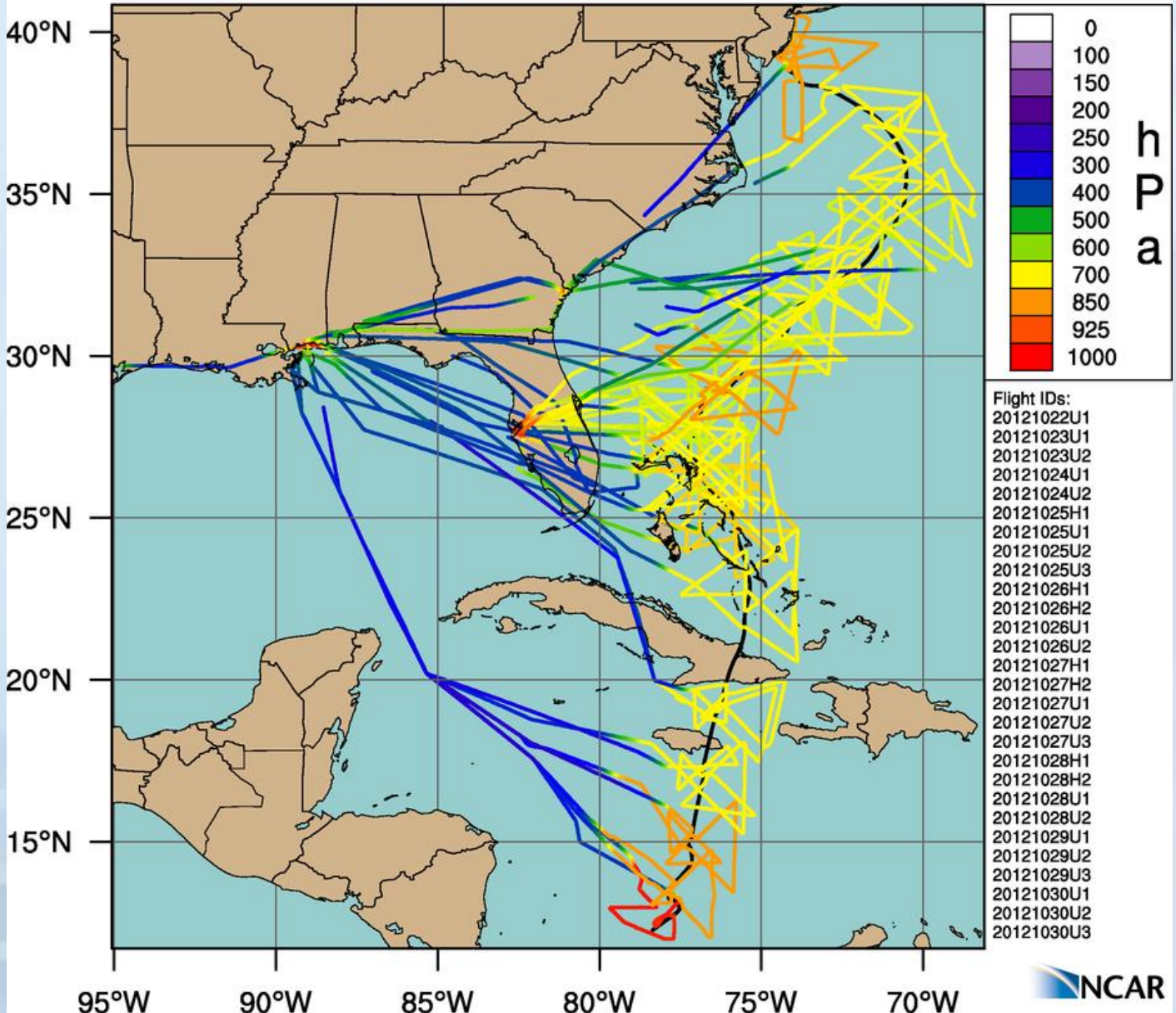
Figure 8 from Uhlhorn and Nolan (2012)

IDEA: Apply to simulations of actual storms with real data

- **Develop technique to construct synthetic profiles through simulated storms along the observed flight paths**
  - determine storm track in simulation
  - navigate resulting flight path in storm-relative coordinates onto the moving center of the simulated storm
  - sample through simulated storm along translated flight trajectory
  - smooth observed wind profile to match the effective resolution of the synthetic wind profile from the simulation for direct comparison

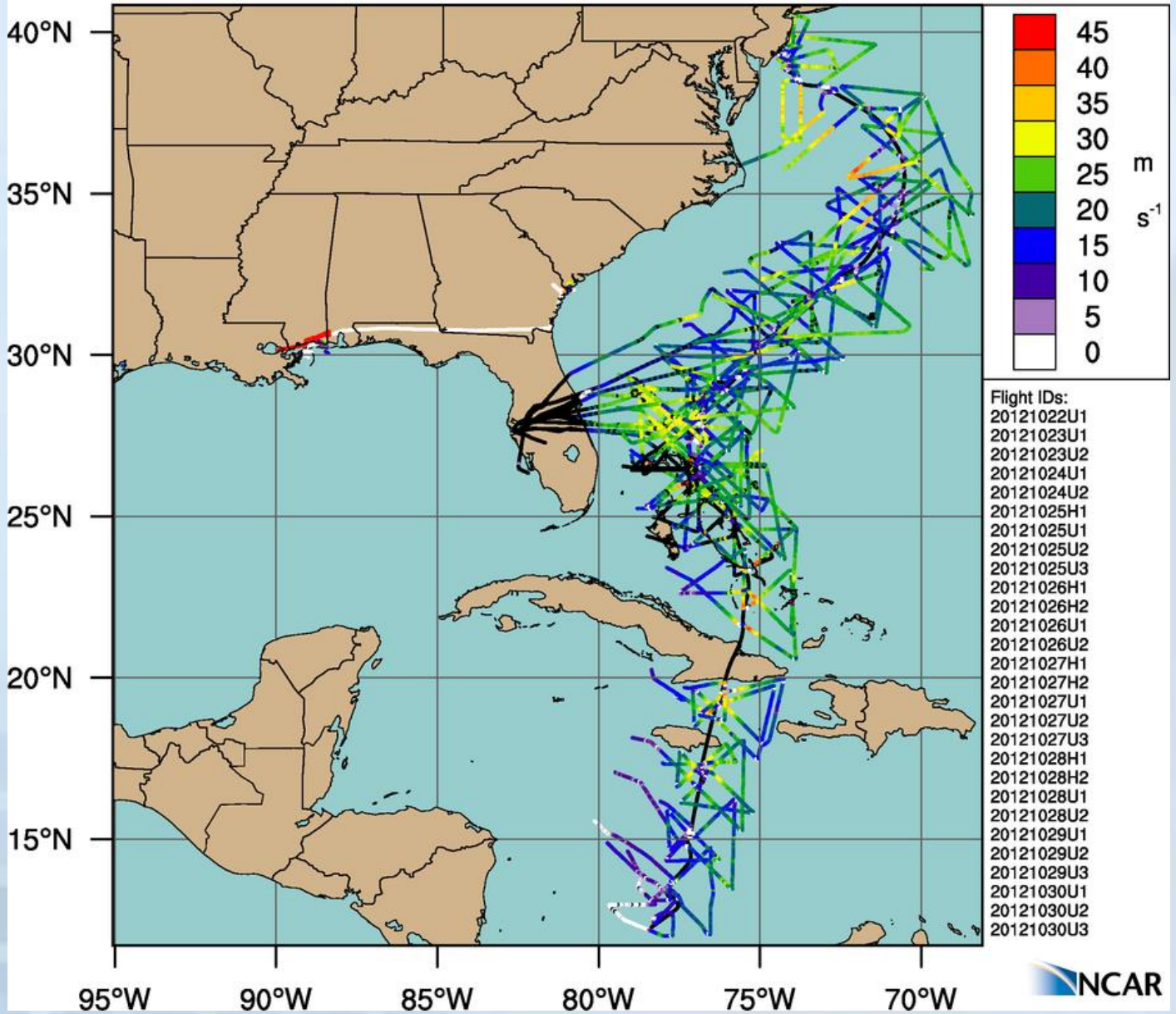
Hurricane Sandy

Flight Level Pressure



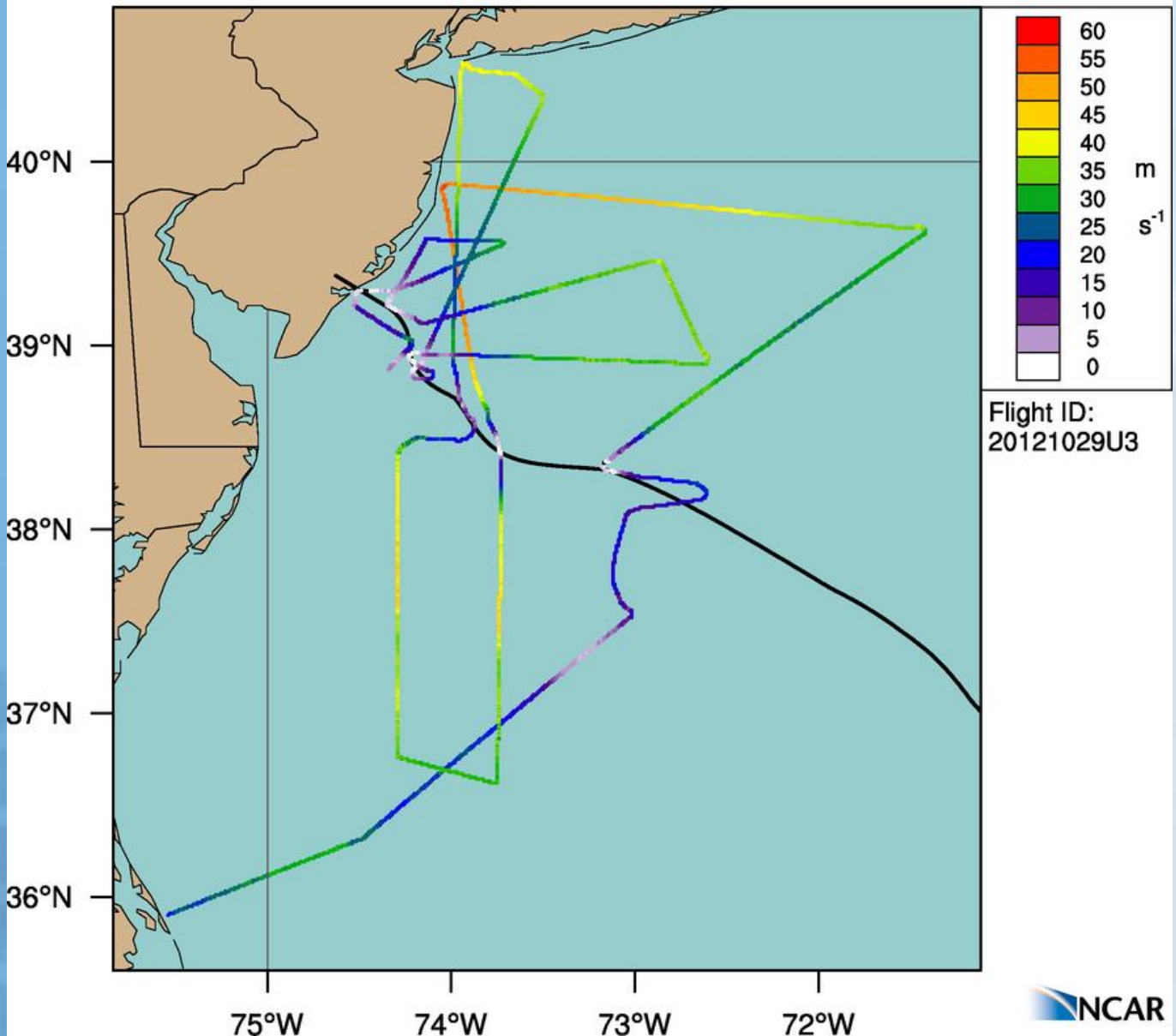
Hurricane Sandy

SFMR Surface Wind Speed



Hurricane Sandy

Flight Level Wind Speed



Processing of flight level data

- **Raw flight level data used to calculate dynamic center of storm – a track is produced and fit to these center using Ooyama's beta splines**
  - Willoughby, H.E., and M. B. Chelmow, 1982, "Objective determination of hurricane tracks from aircraft observations", *Mon. Wea. Rev.*, **110**, p.1298-1305.
  - Neal Dorst (HRD) generates these tracks.
- **Winds are translated to the moving storm center, decomposed into radial and tangential components**

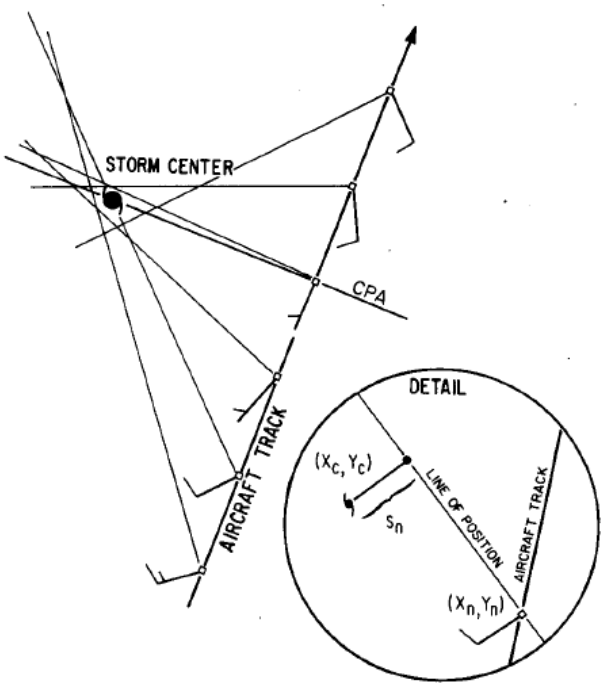
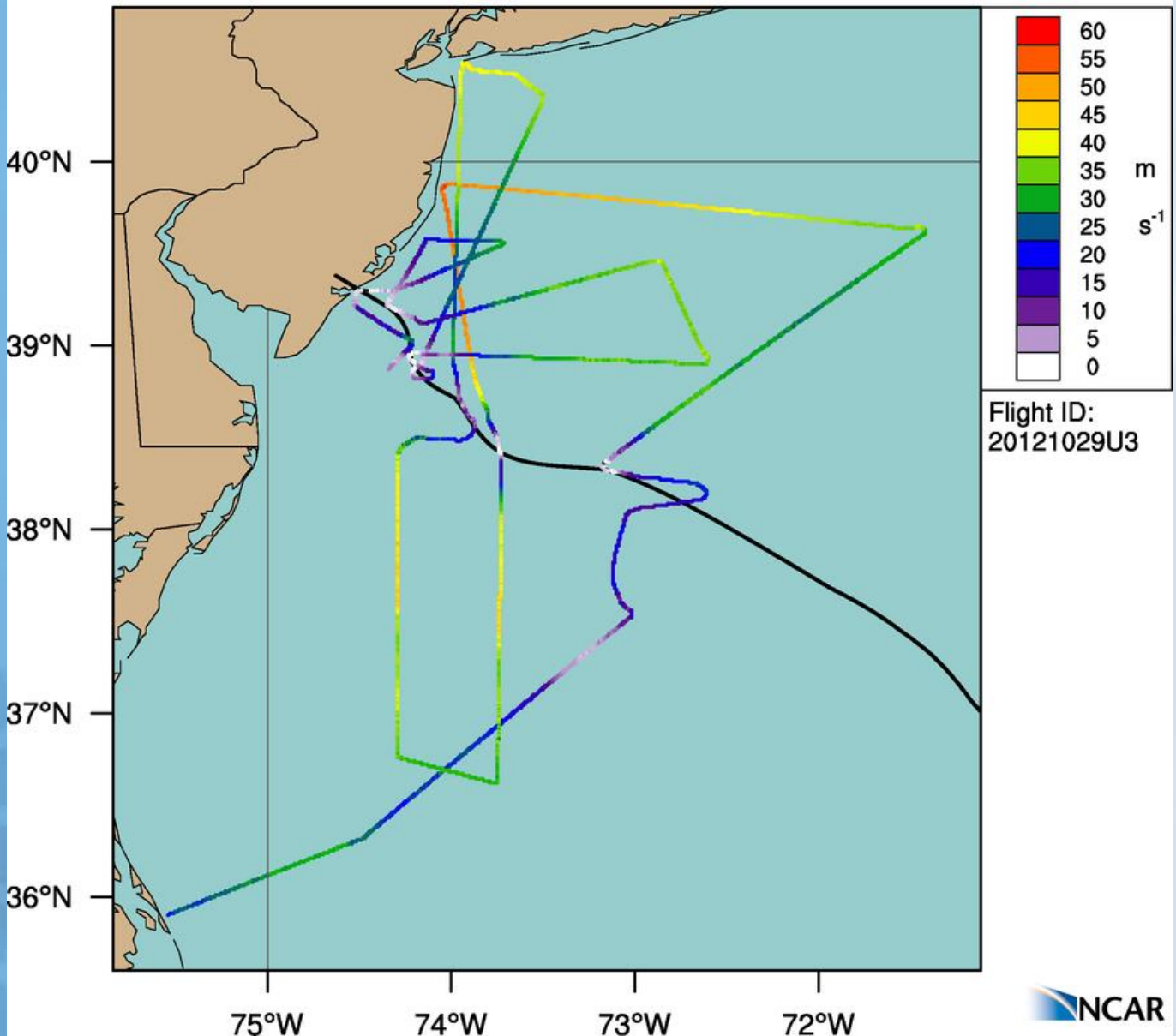
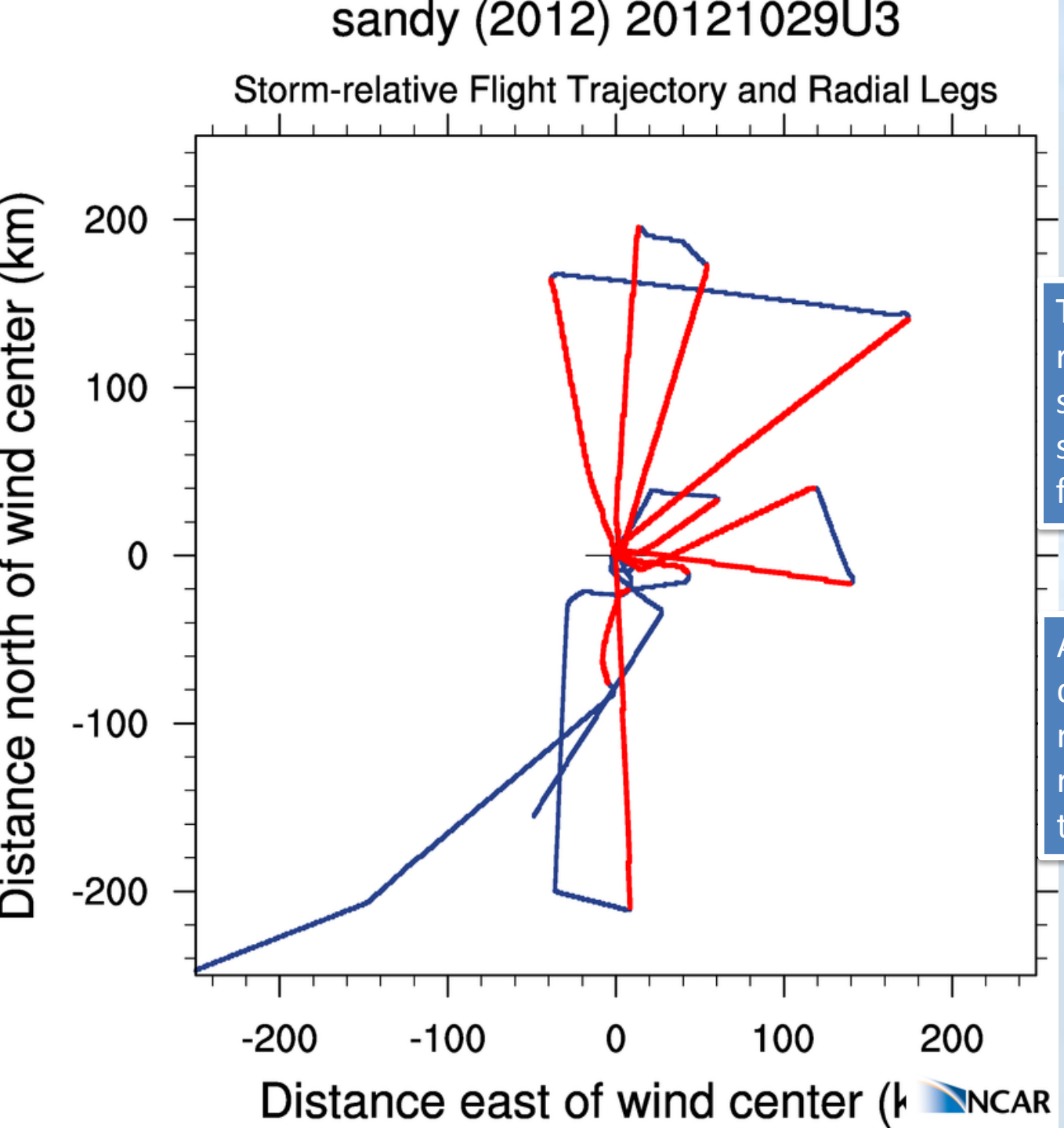


FIG. 2. The geometric relations among the aircraft track, lines of position (LOP's) and the dynamic center.

Hurricane Sandy

Flight Level Wind Speed





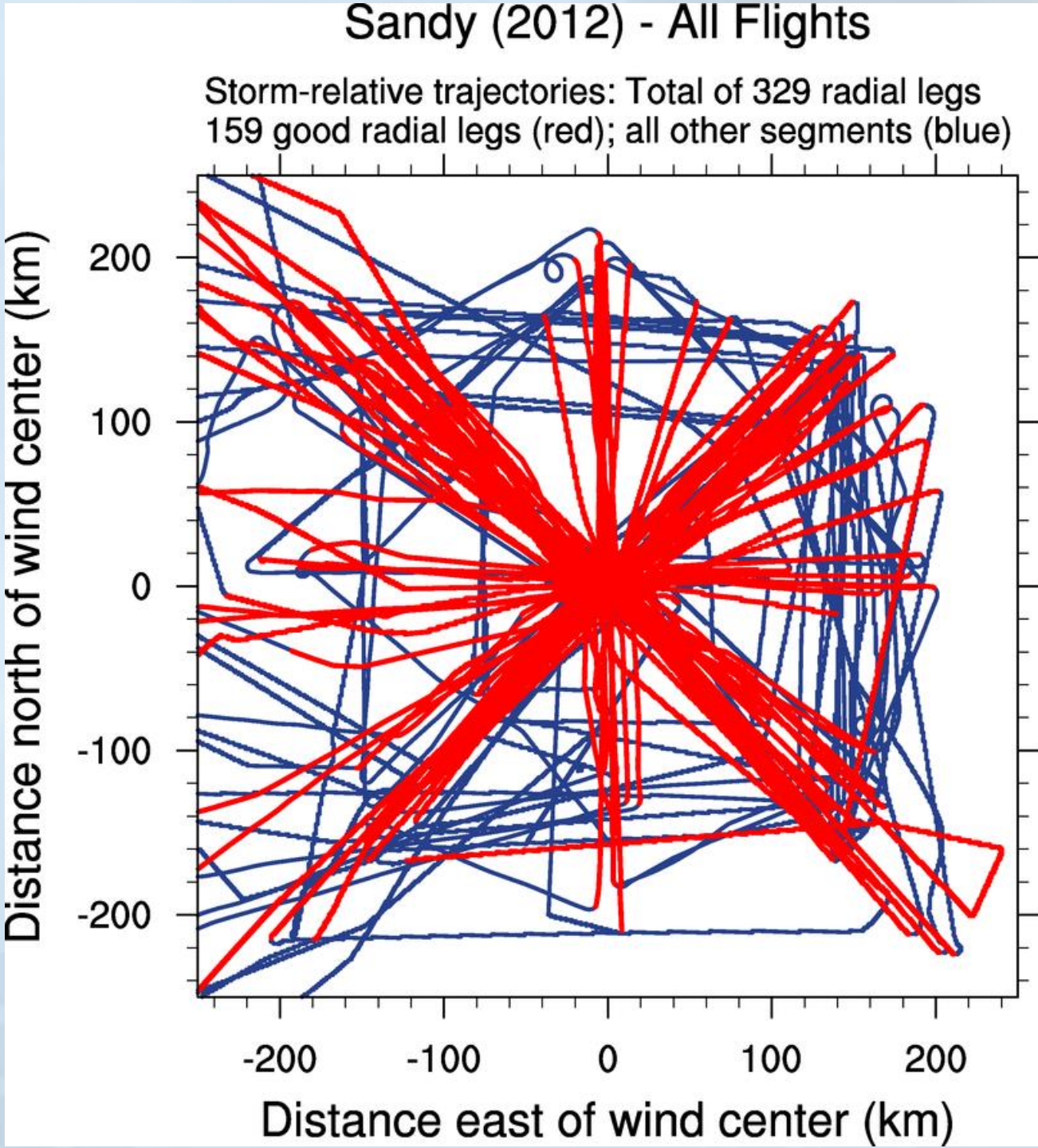
Transform to storm-relative coordinates by subtracting the moving storm center (at flight level) from each observation

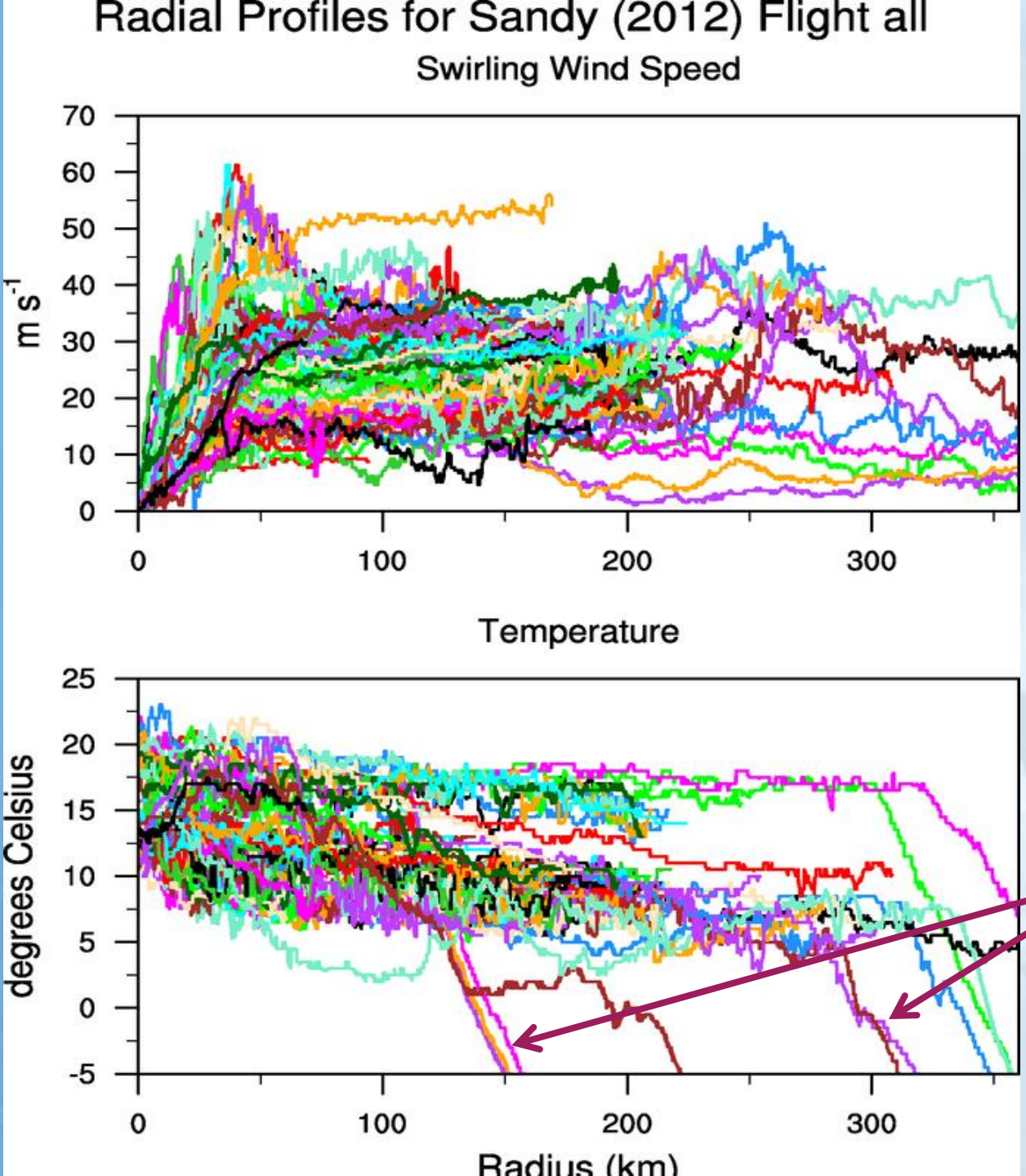
An algorithm has been devised to parse the “good” radial legs that pass in relatively straight lines near the storm center

159 good legs identified out of **329** candidate legs

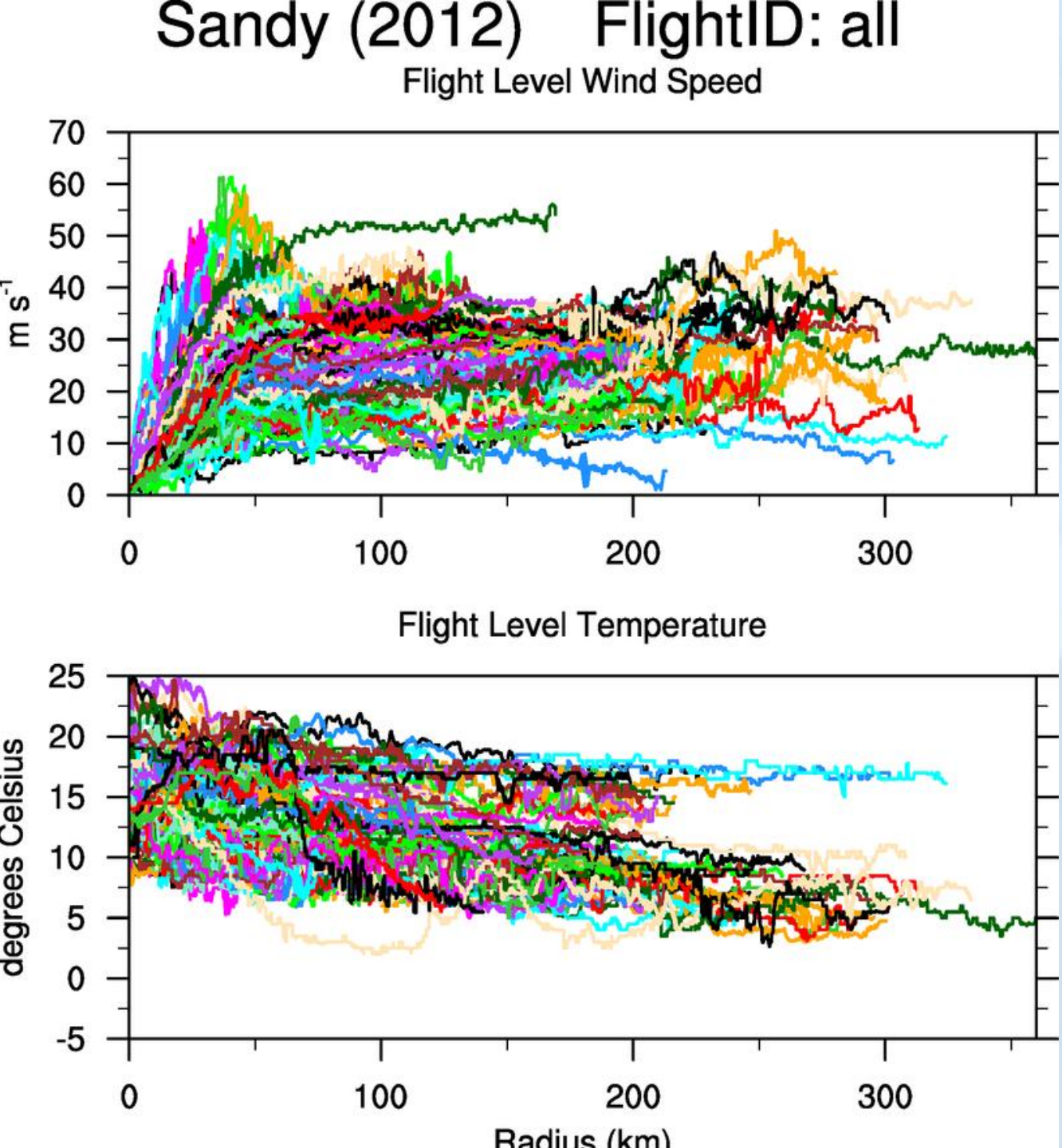
Algorithm appears to be about **98% accurate**

Allows for years worth of data to be processed without labor-intensive hassle of picking where radial legs begin and end



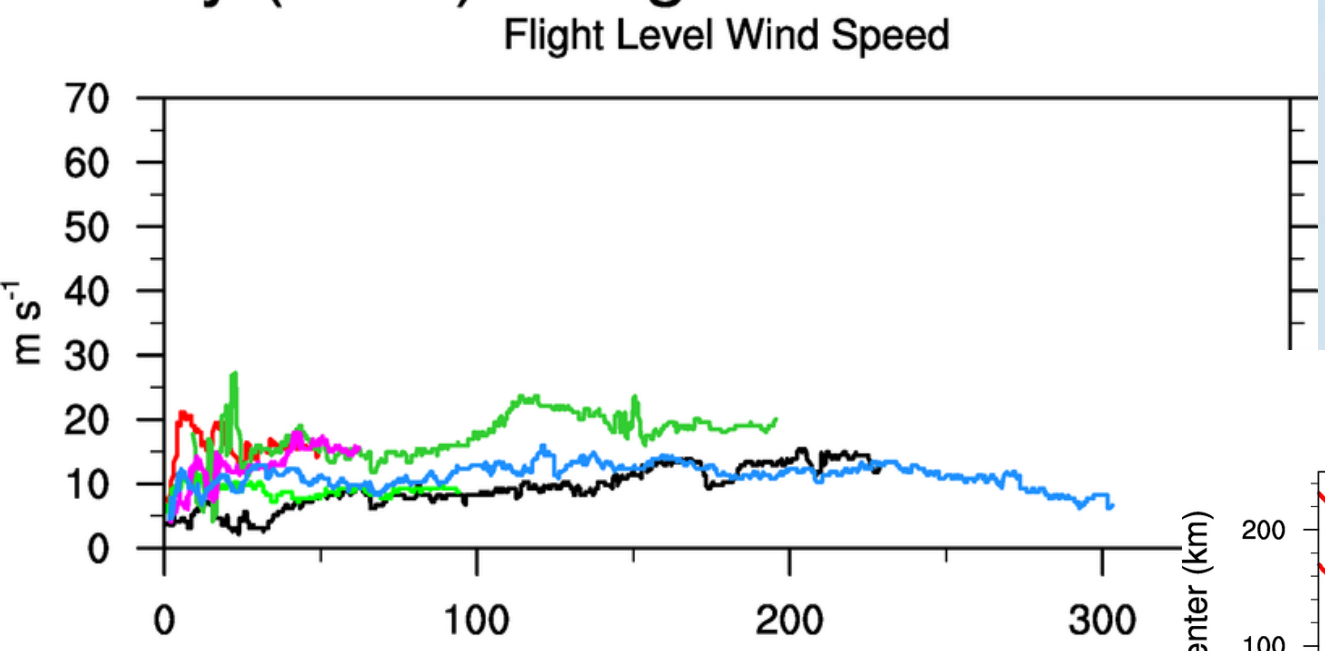


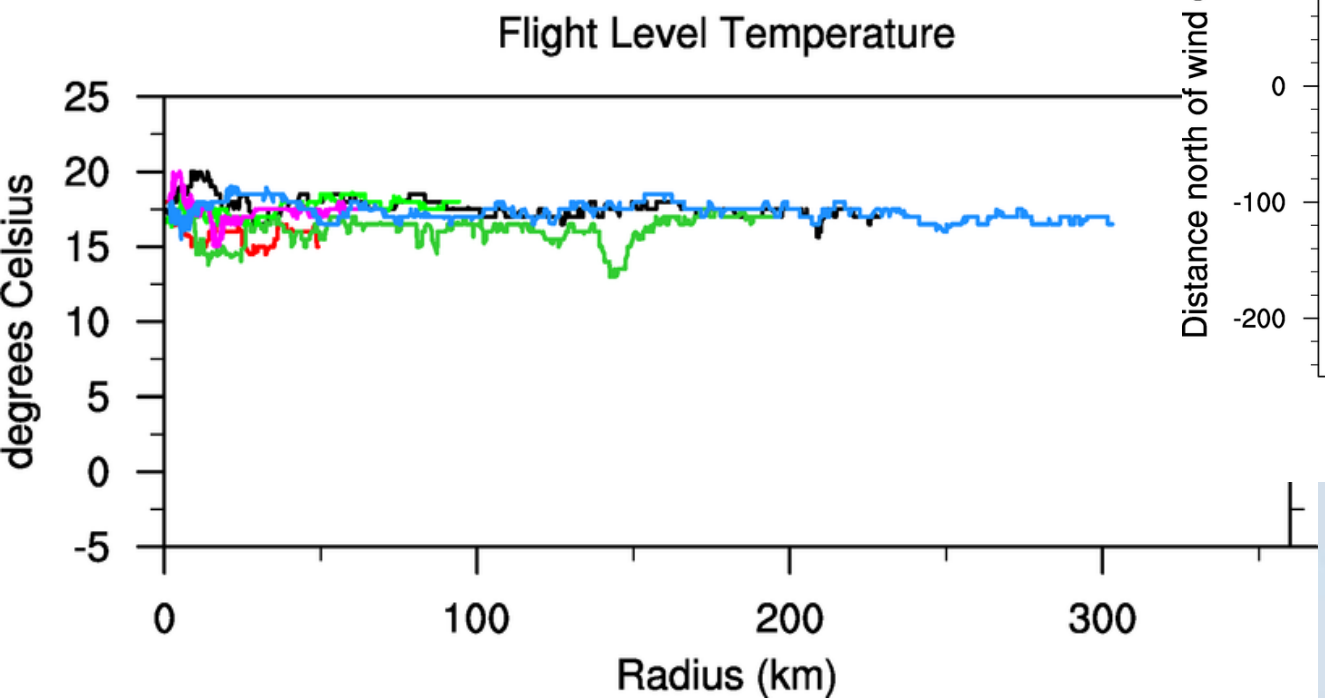
Plane ascending during end of leg

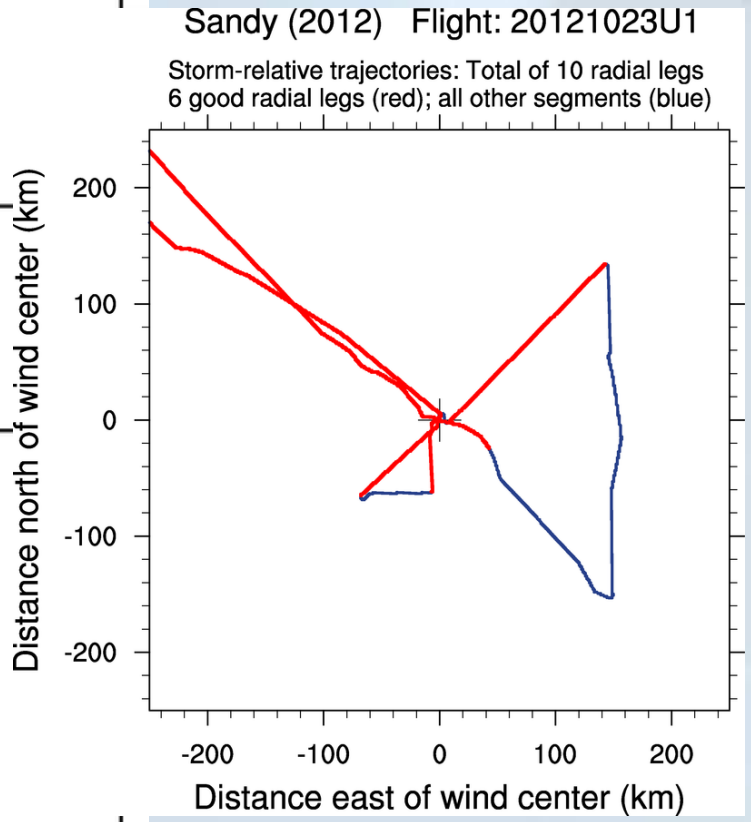


Radial leg terminated if pressure changes more than 10 mb from the average pressure within the first 25 km of the storm center

Sandy (2012) FlightID: 20121023U1







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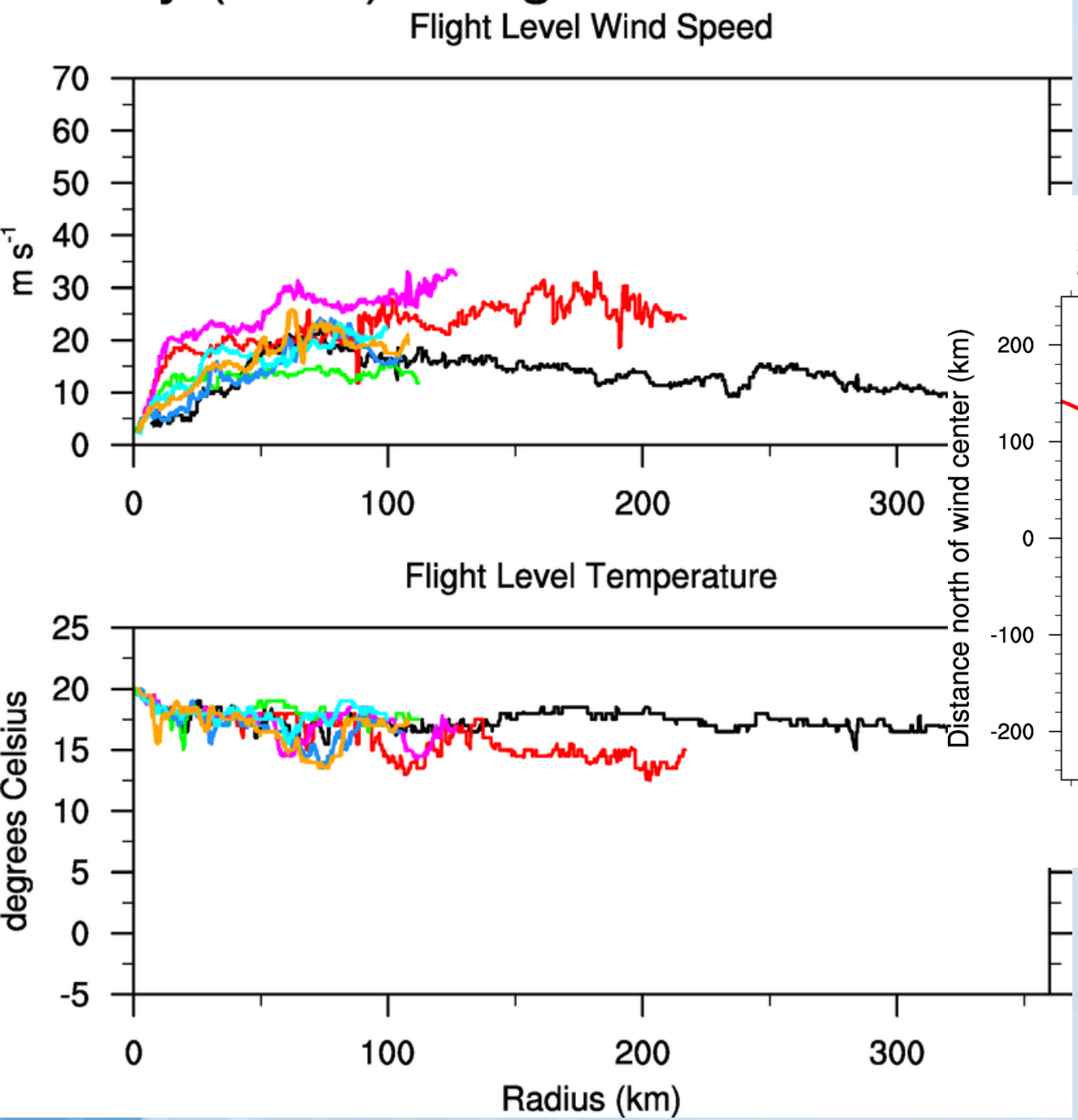

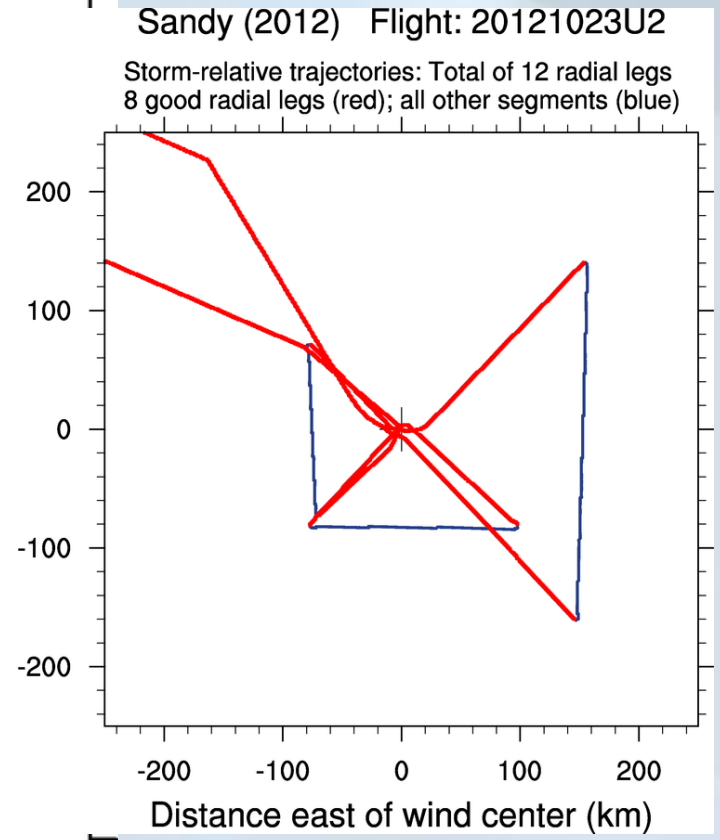

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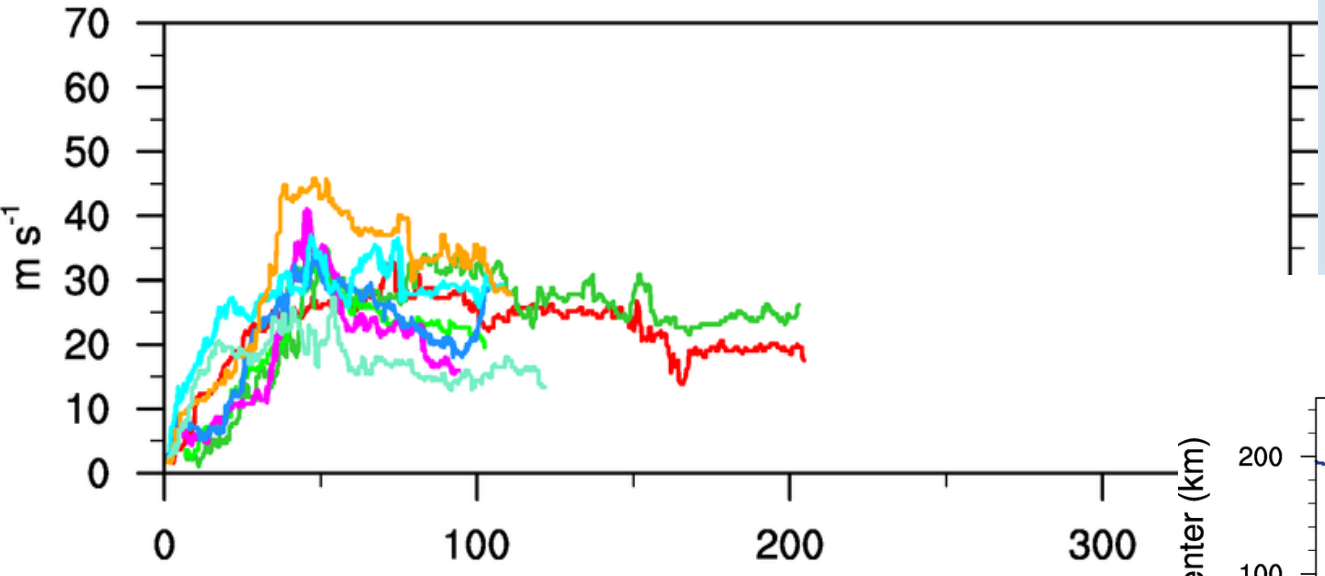
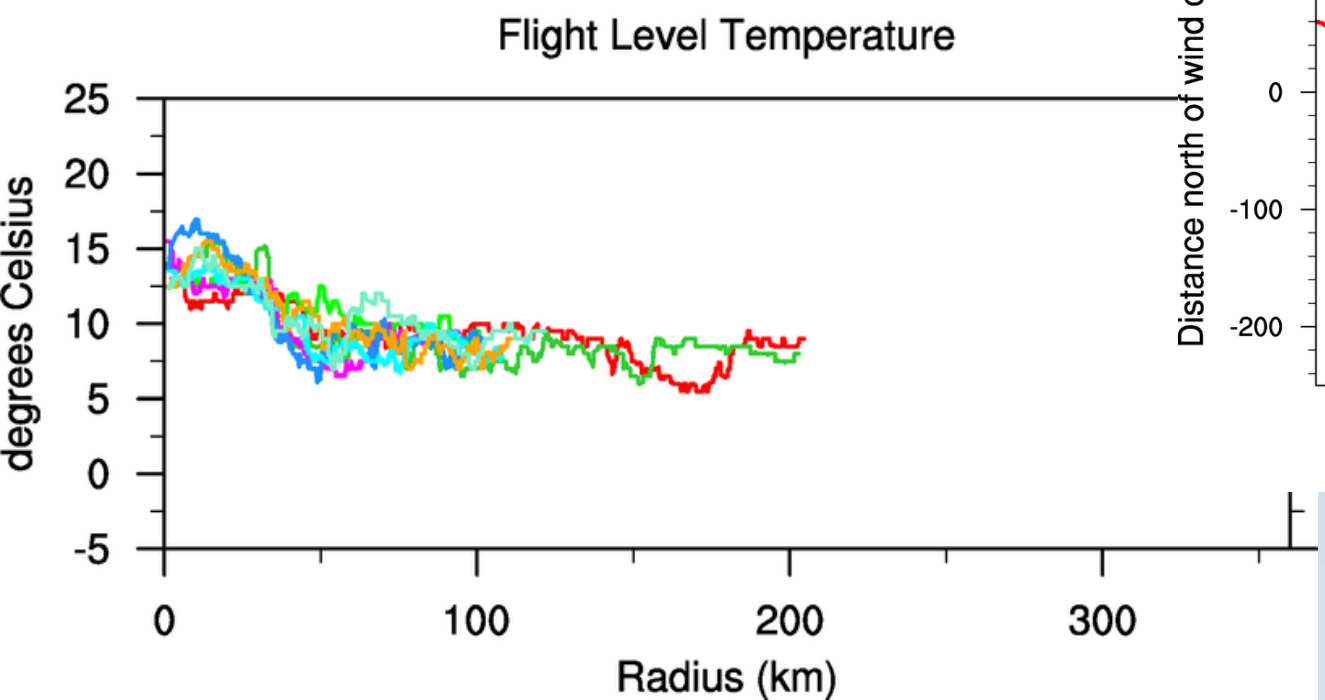
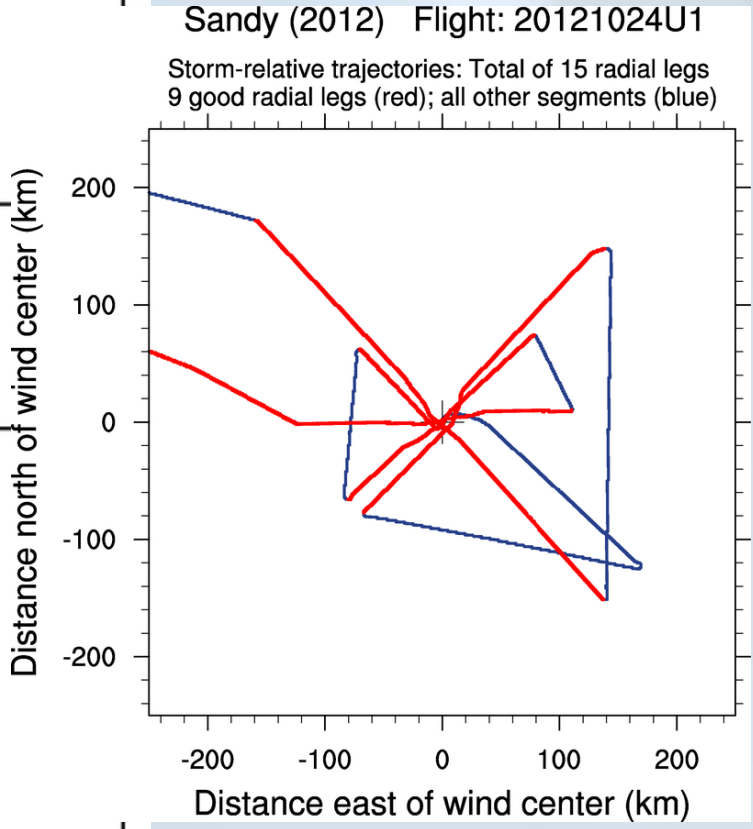
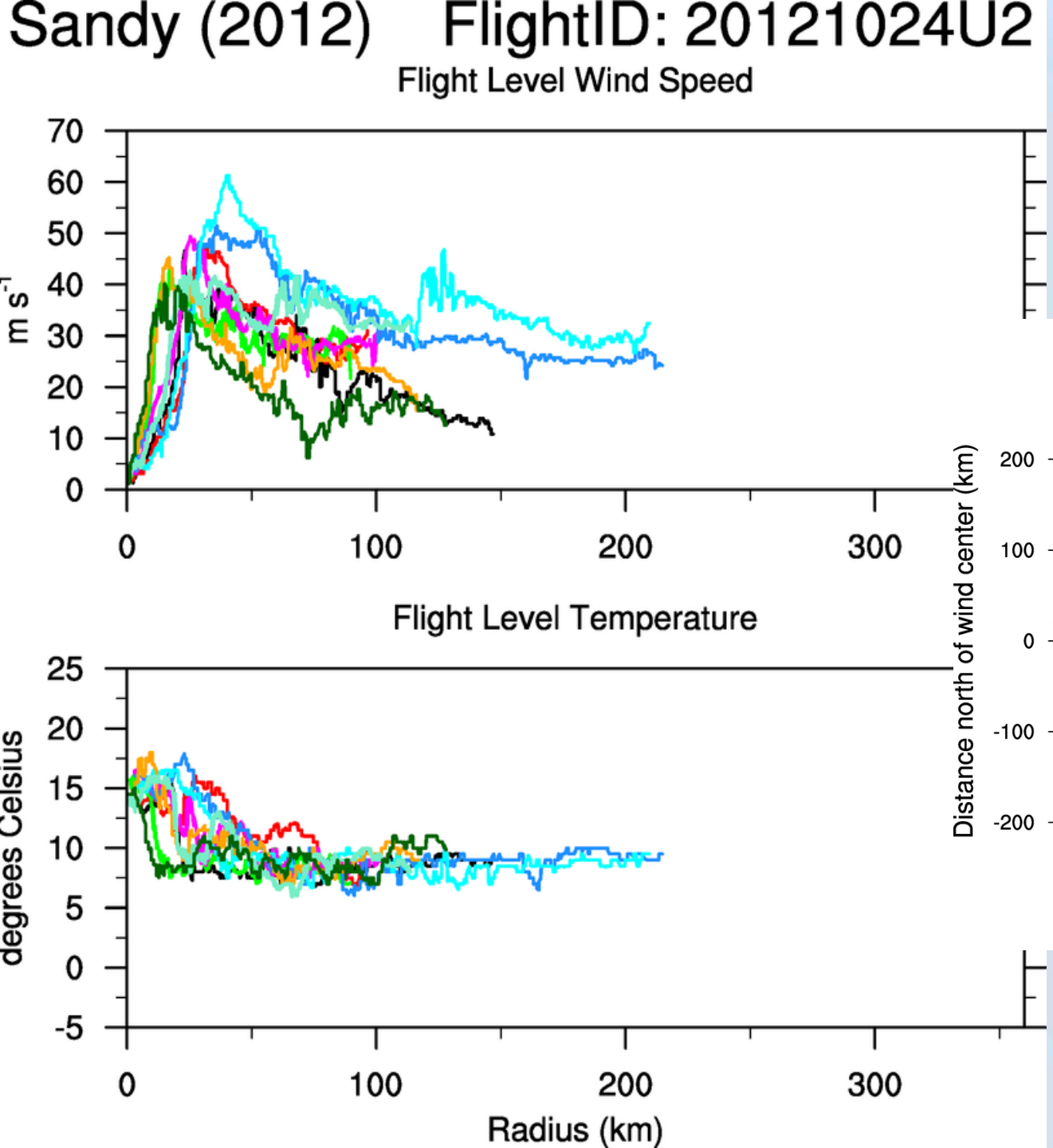
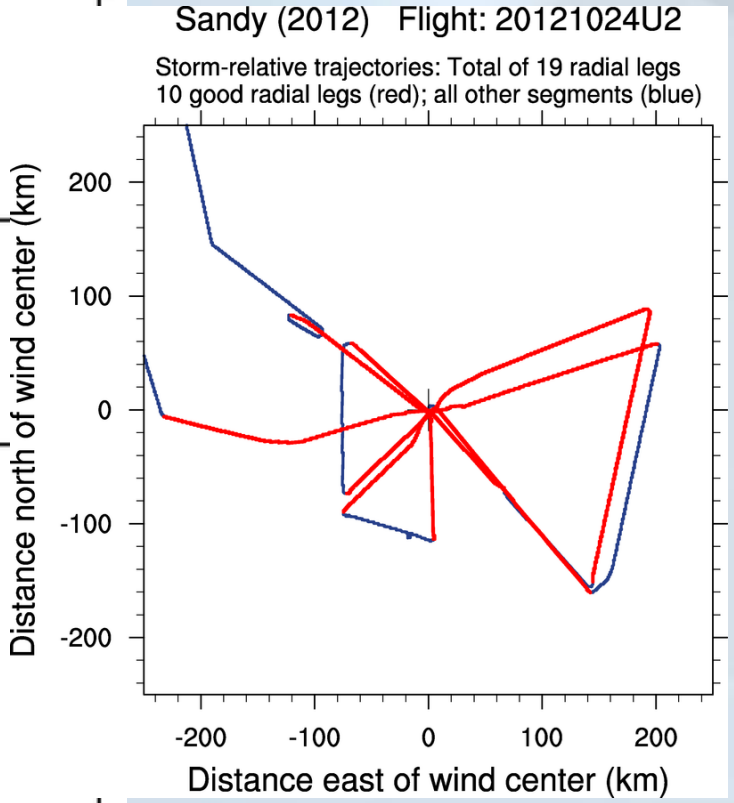


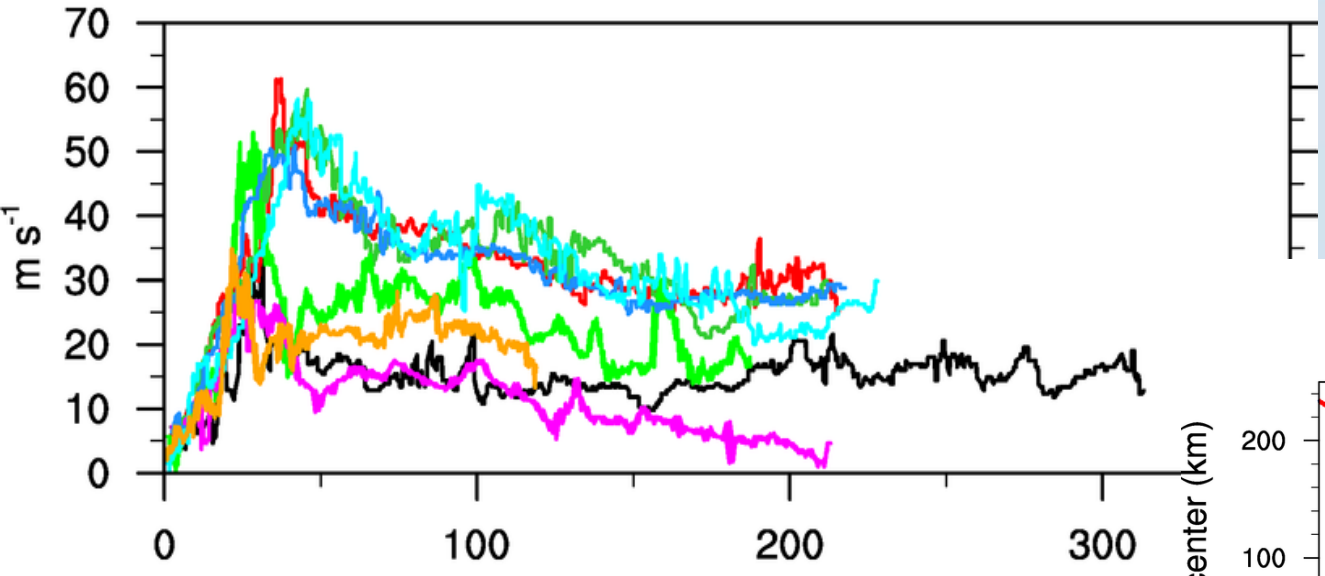


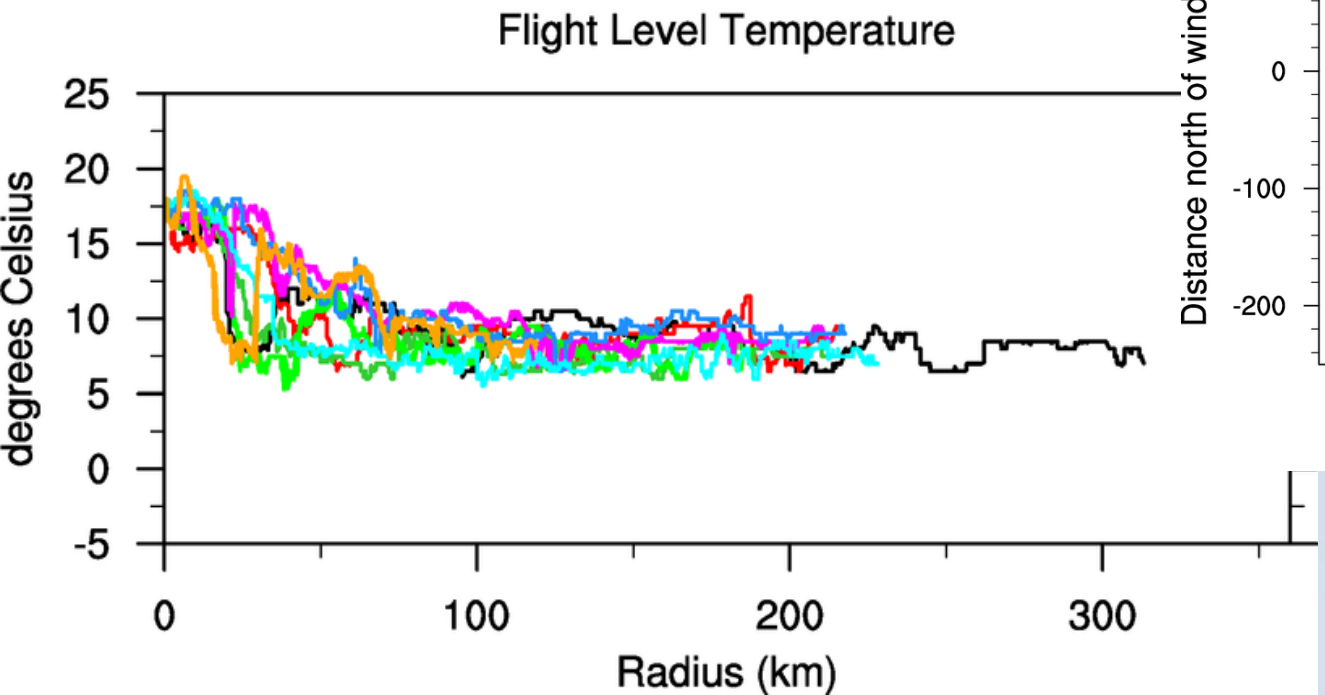


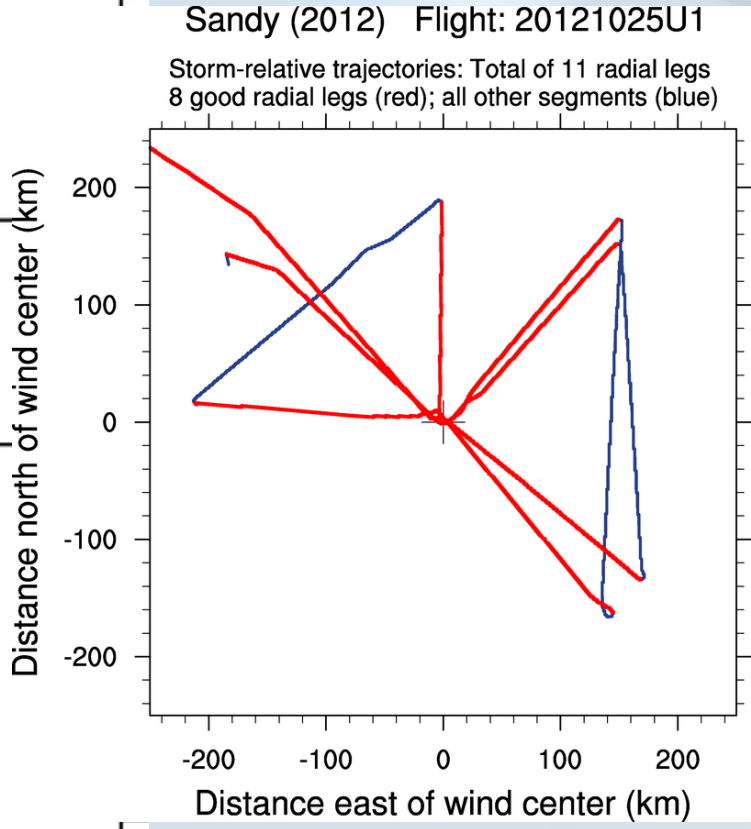

Sandy (2012) FlightID: 20121024U2
Flight Level Wind Speed
m s-1
70
60
50
40
30
20
10
0
0
100
200
300
Flight Level Temperature
degrees Celsius
25
20
15
10
5
0
-5
0
100
200
300
Radius (km)


Sandy (2012) Flight: 20121024U2
Storm-relative trajectories: Total of 19 radial legs
10 good radial legs (red); all other segments (blue)
Distance north of wind center (km)
200
100
0
-100
-200
-200
-100
0
100
200
Distance east of wind center (km)

Sandy (2012) FlightID: 20121025U1







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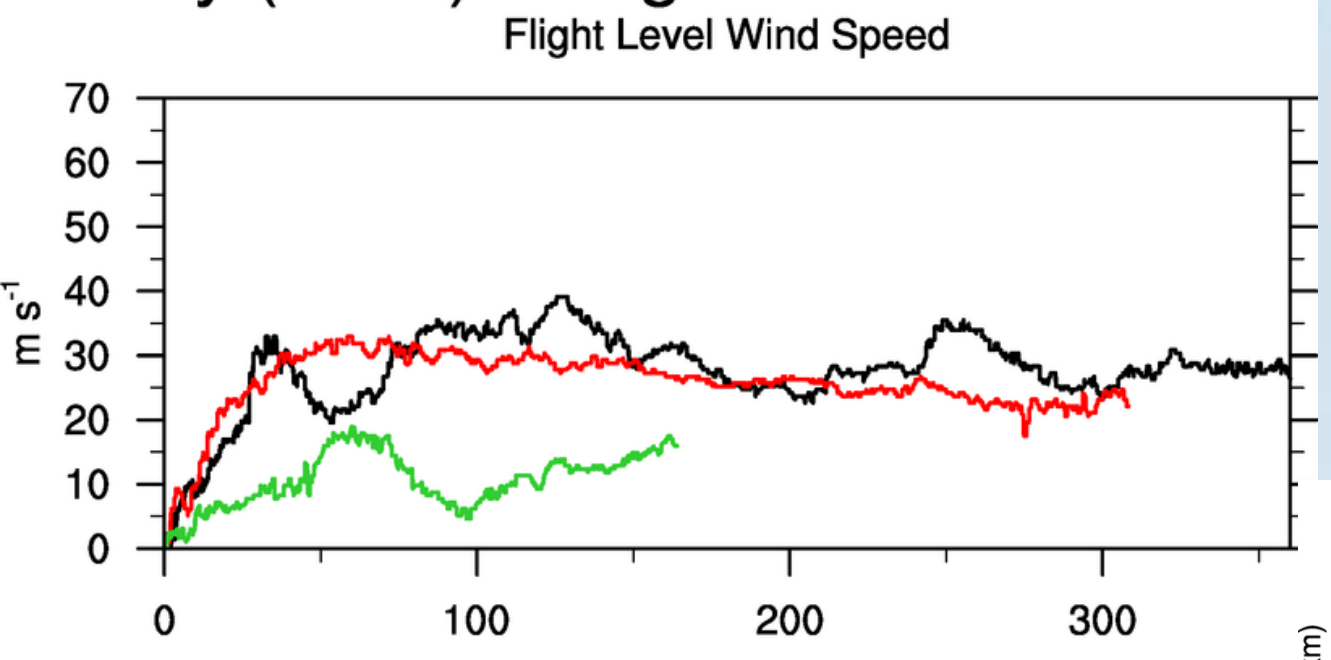

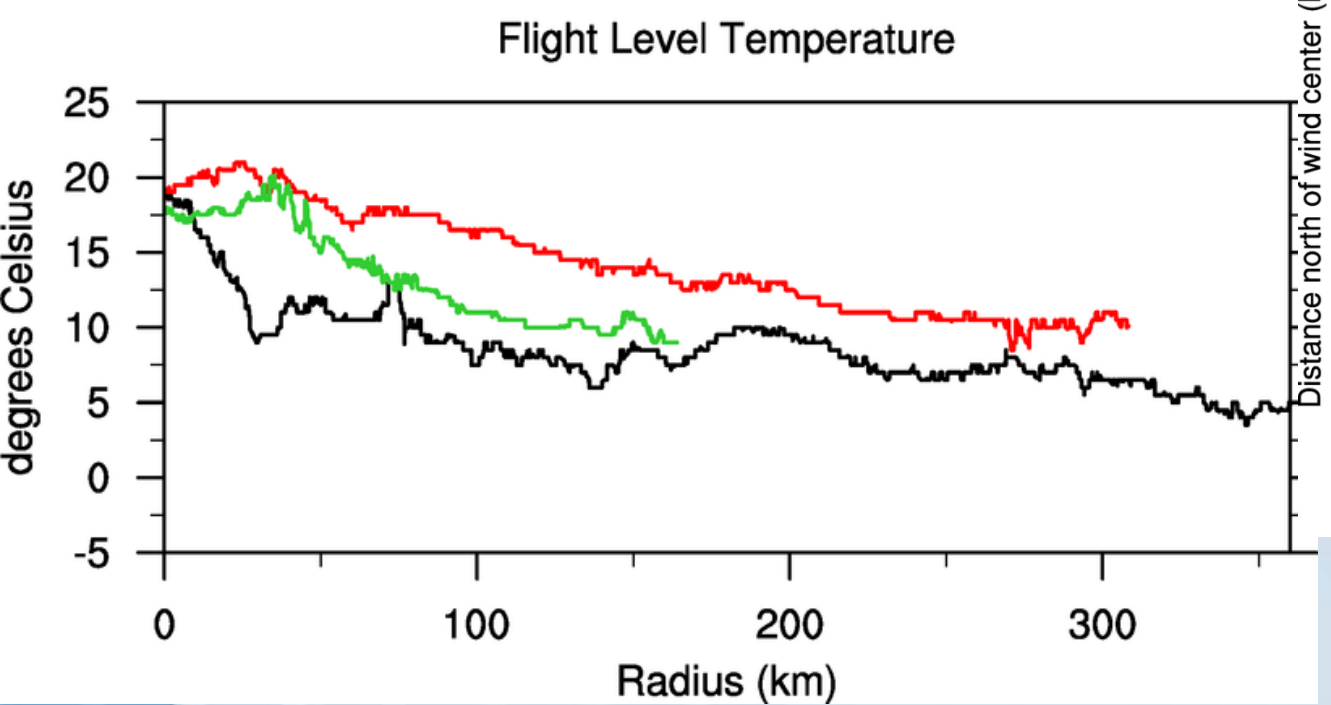

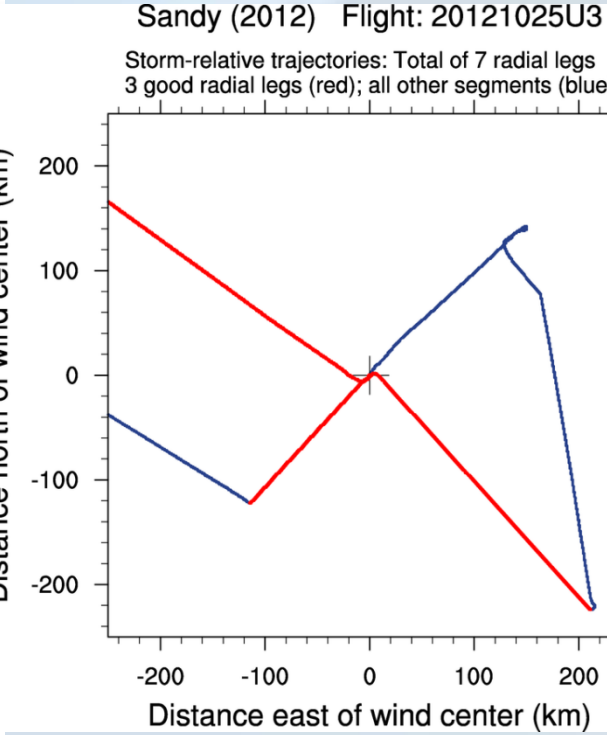

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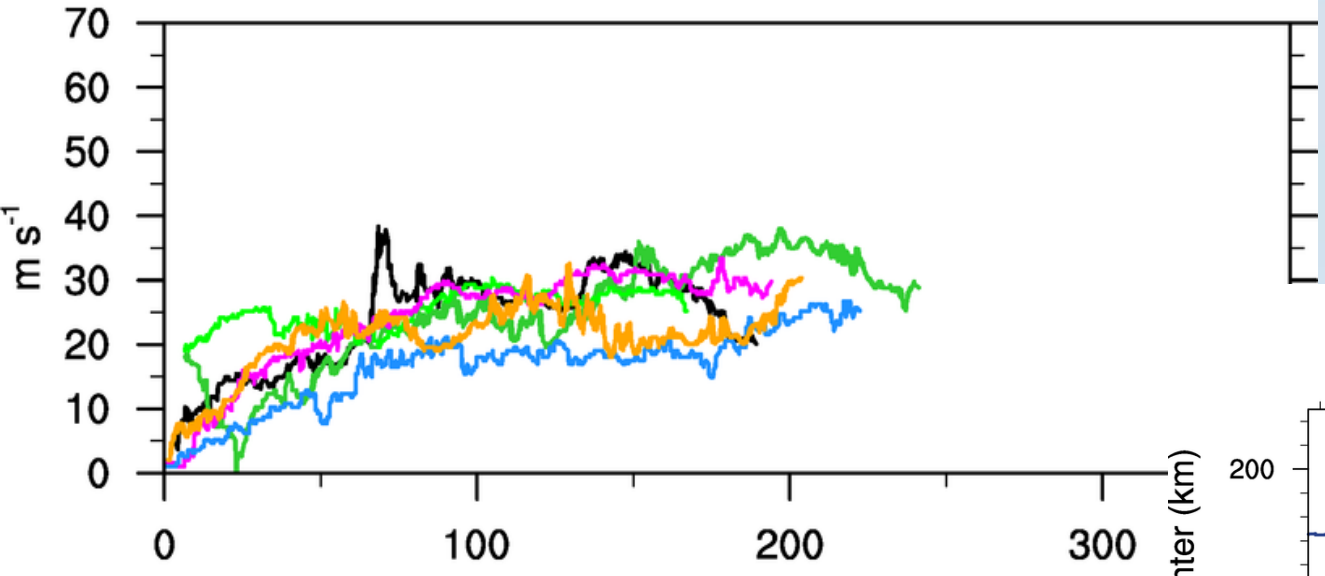

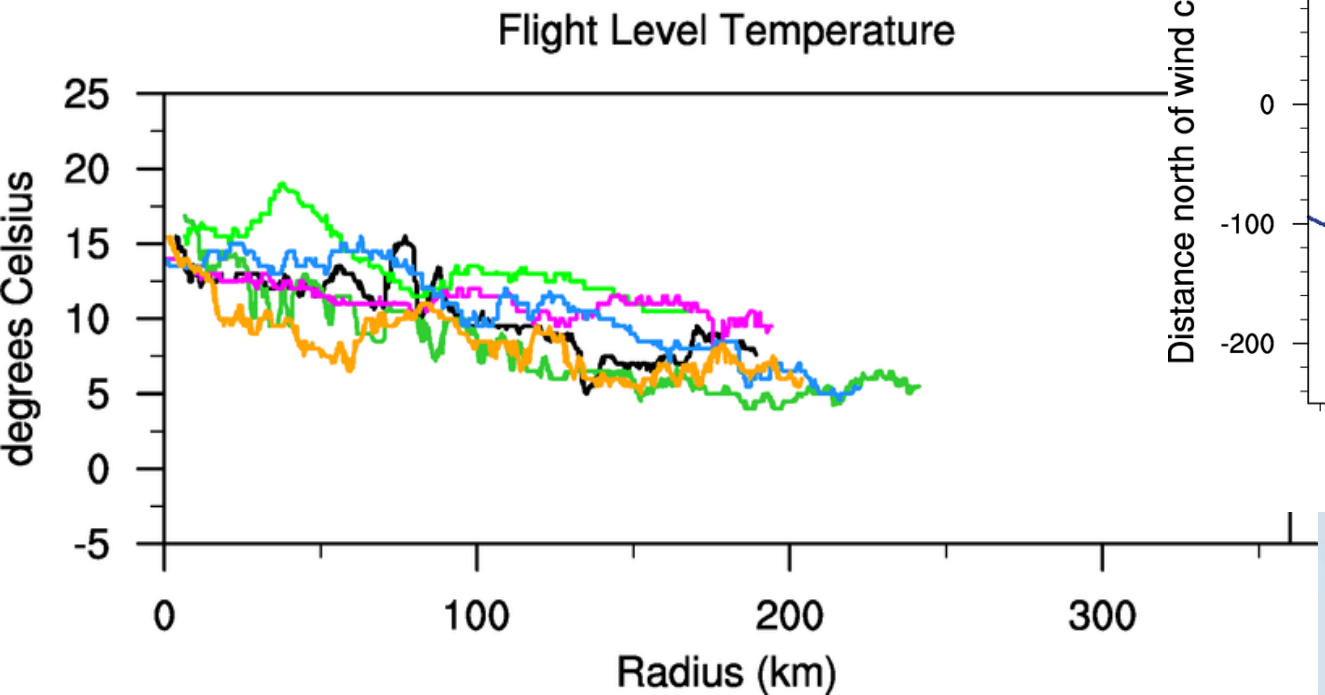

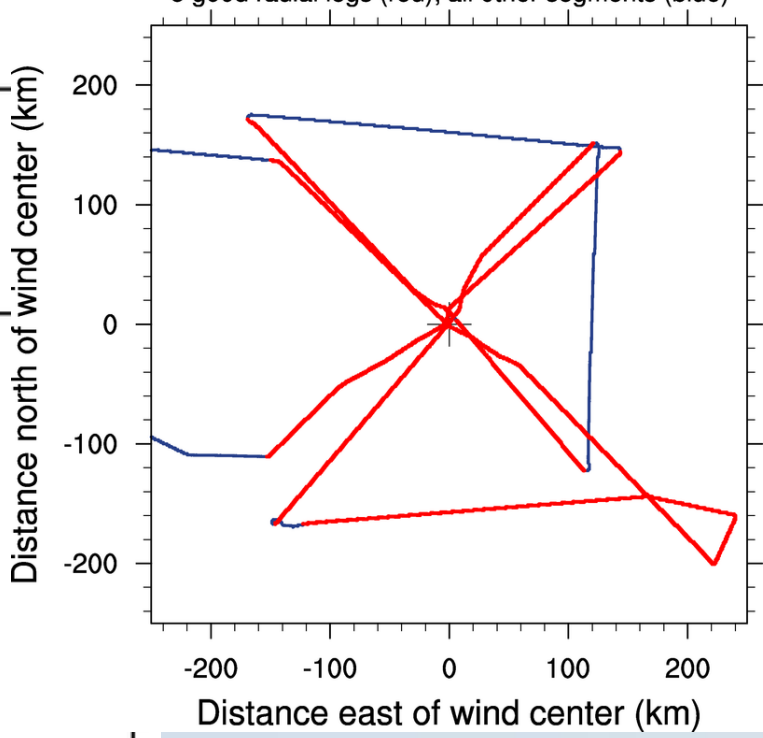

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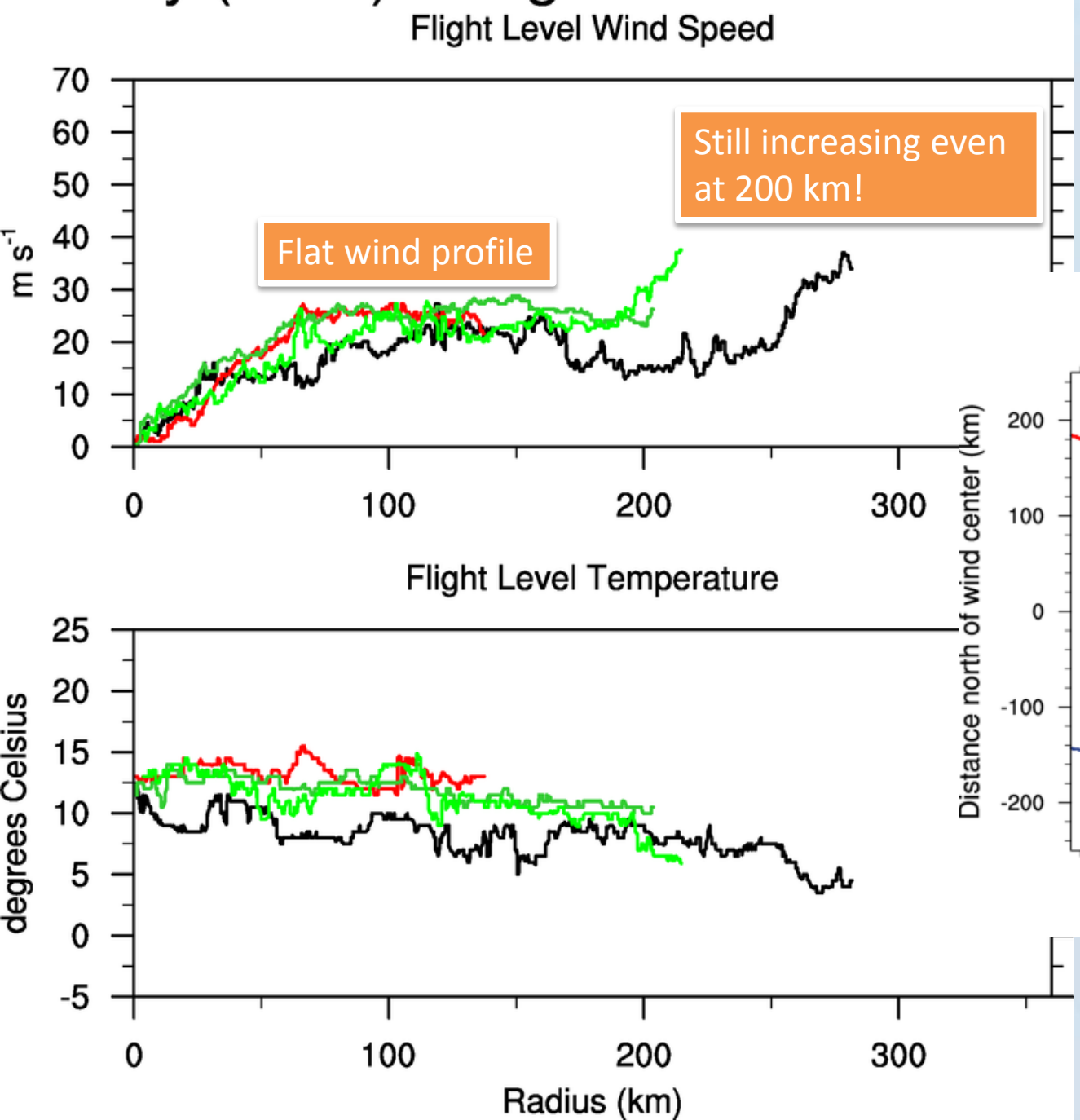

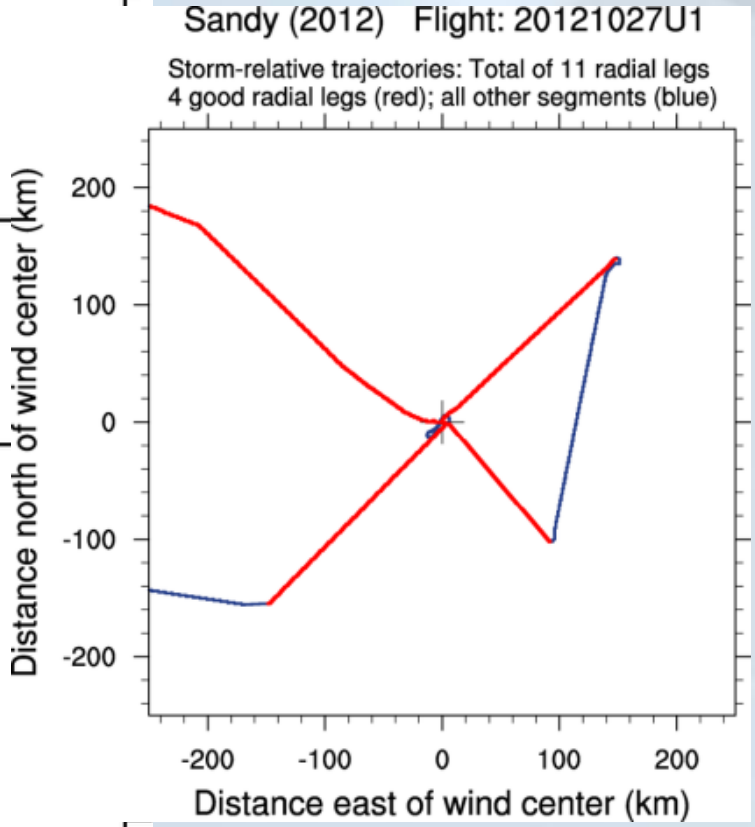

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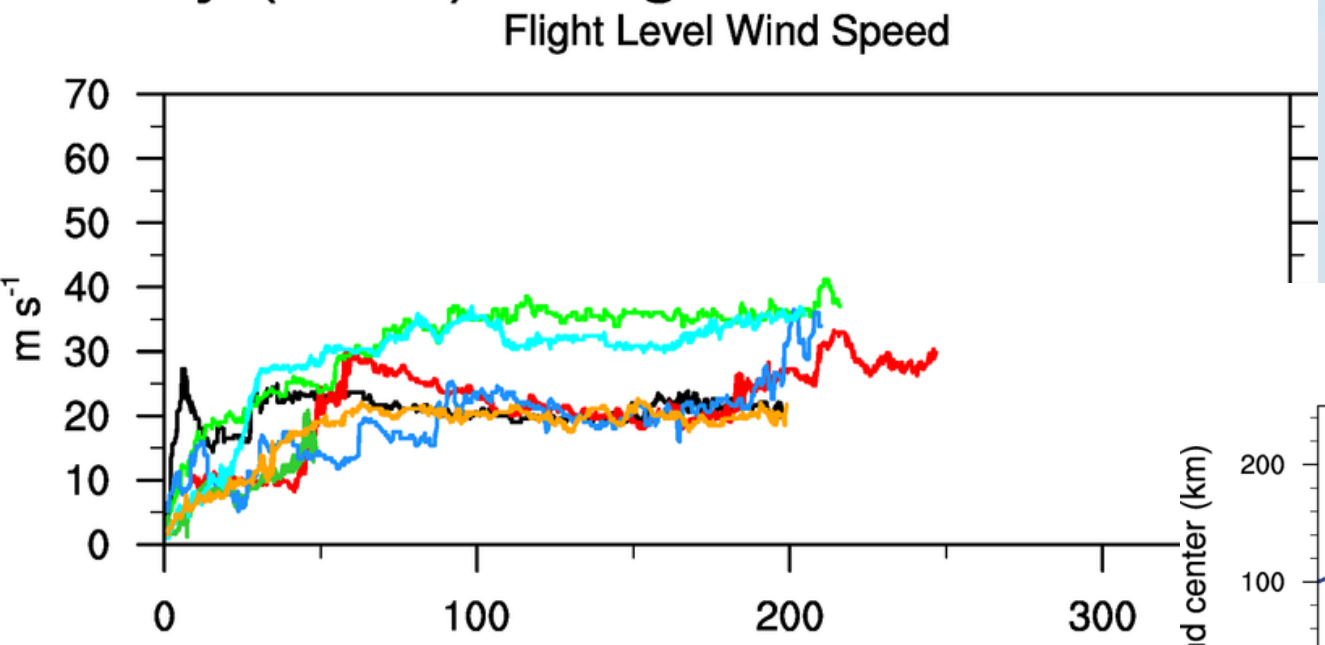

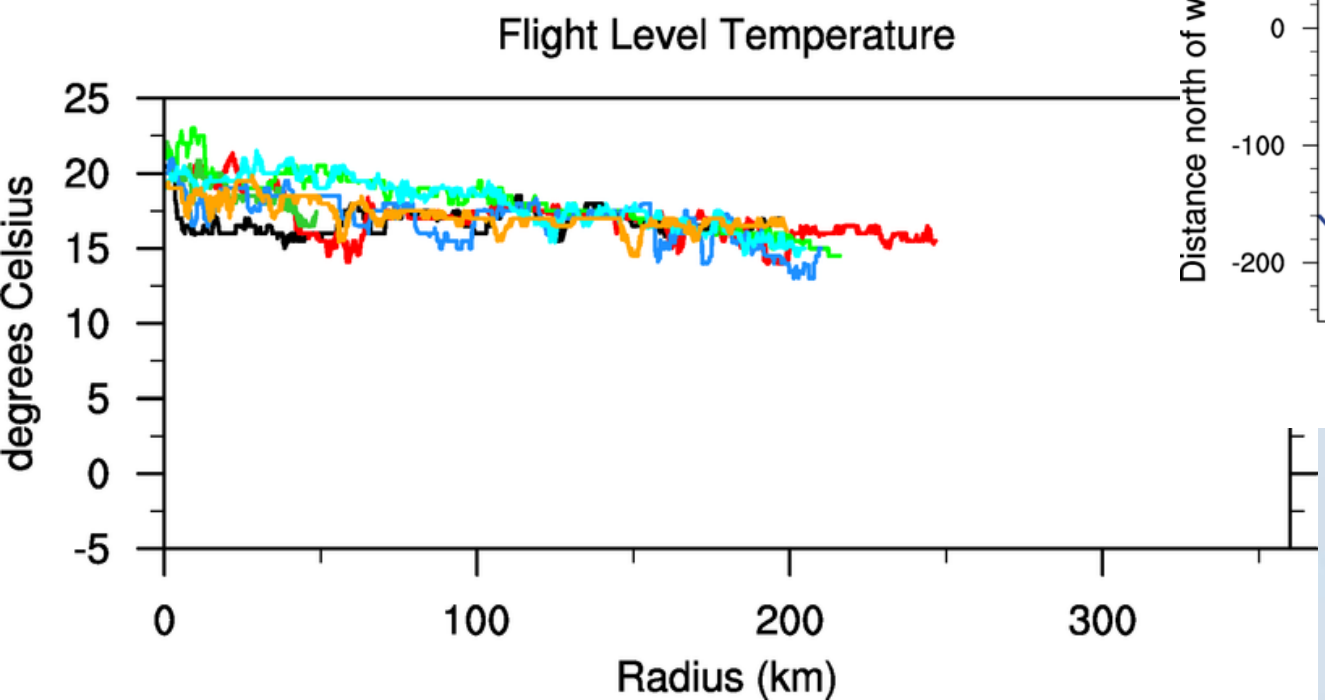

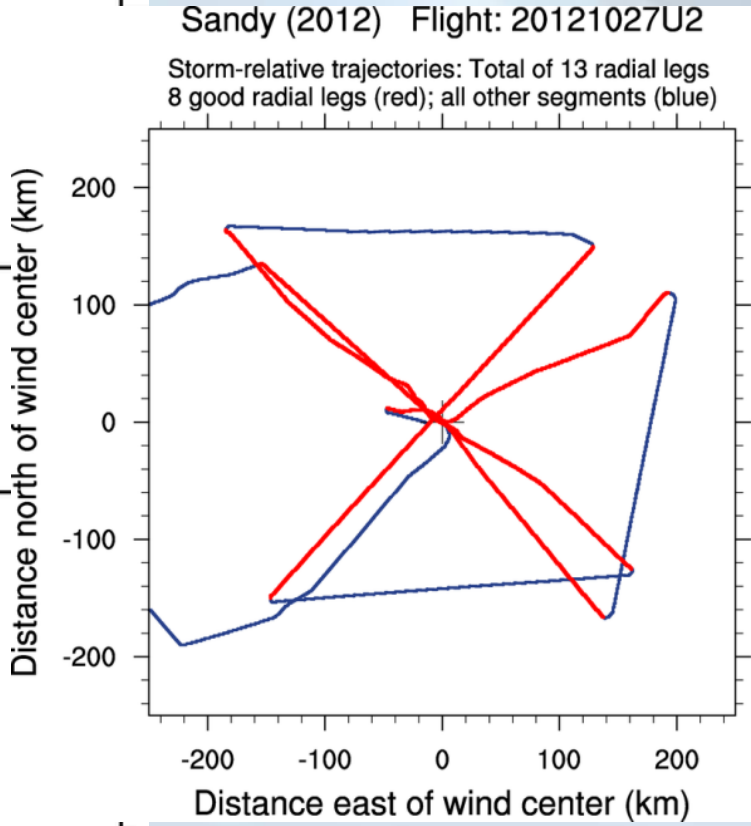

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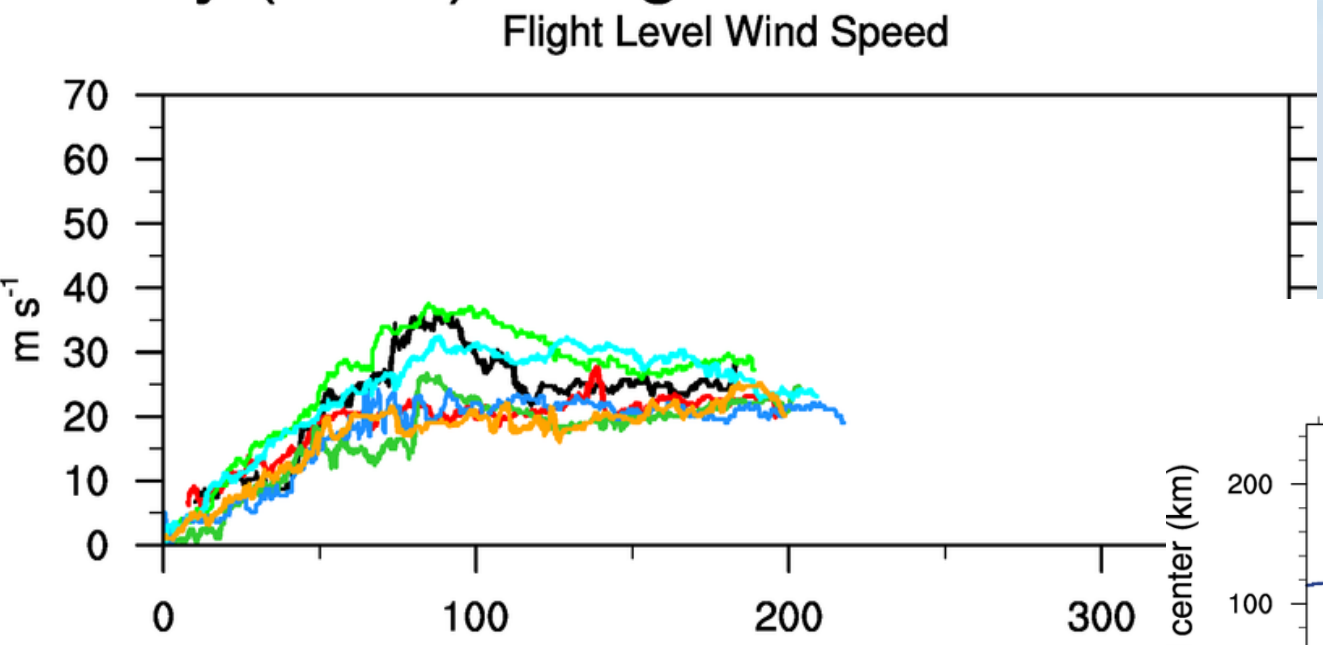

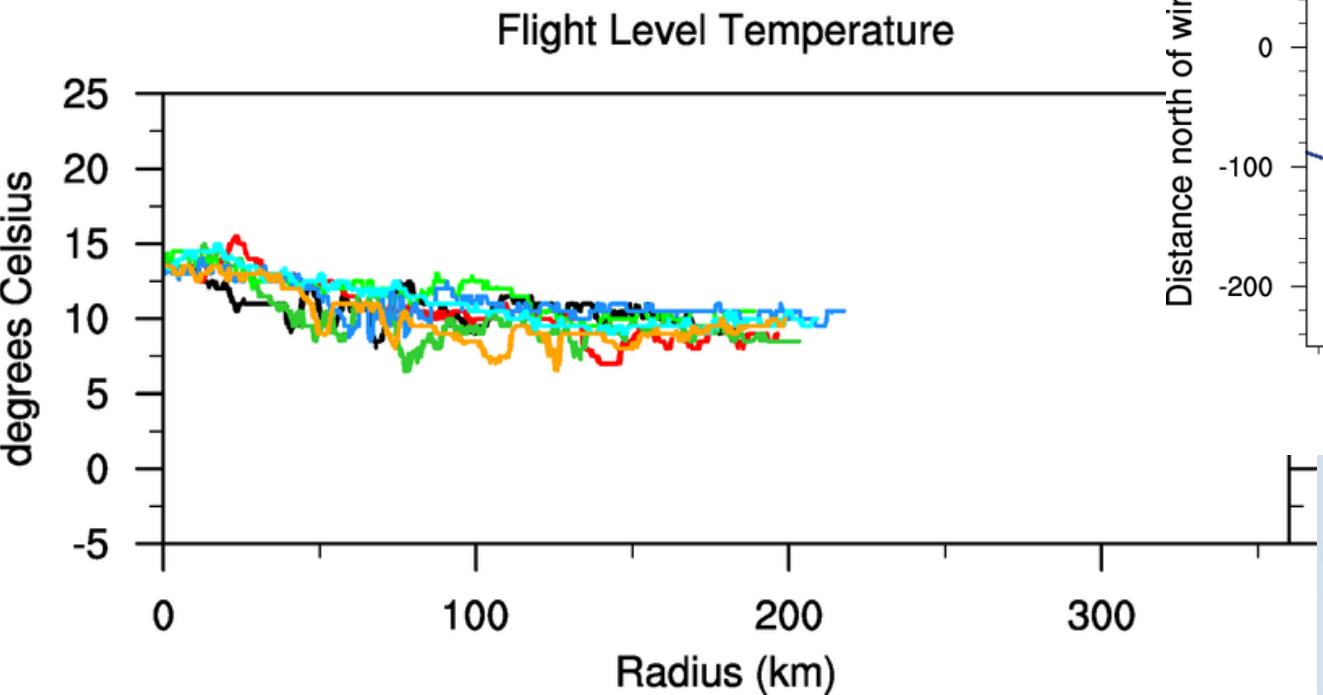

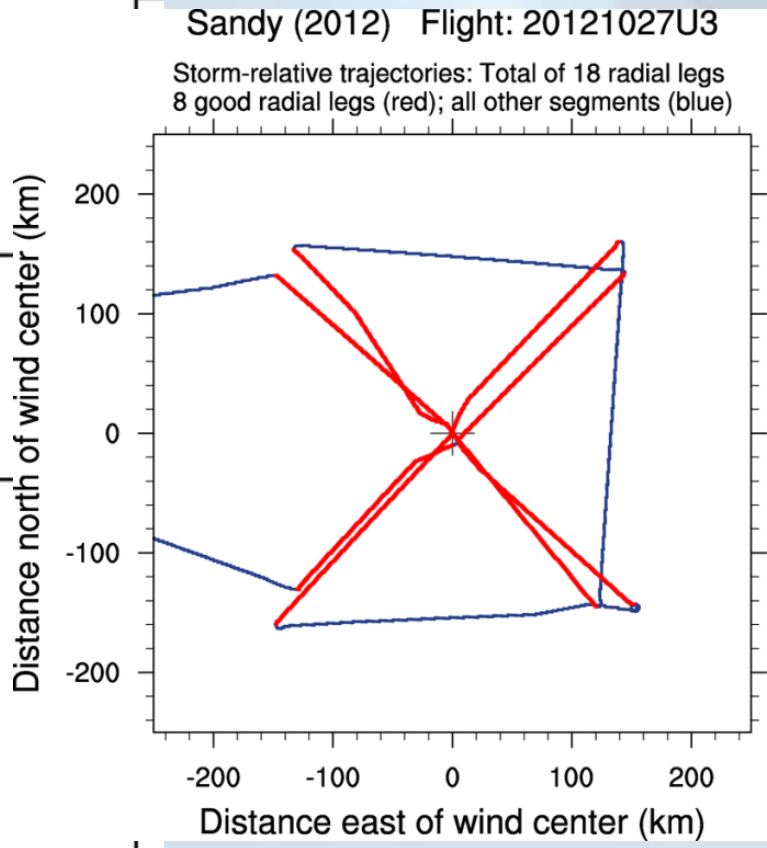

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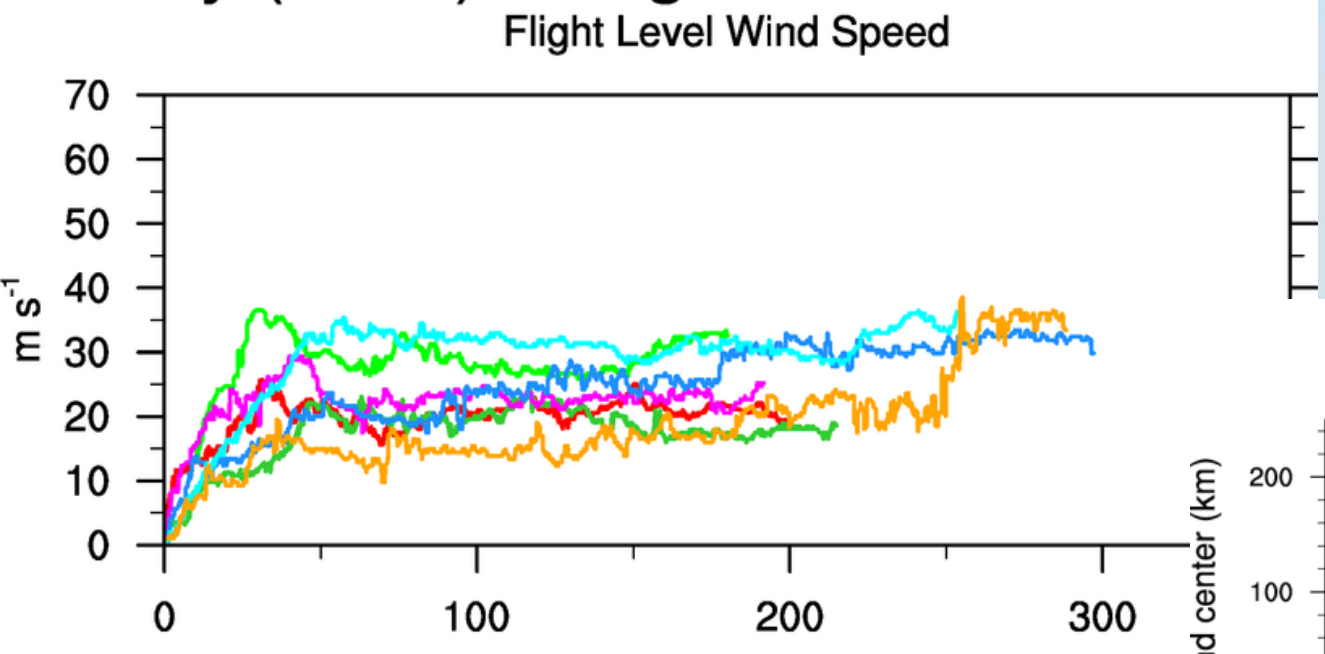

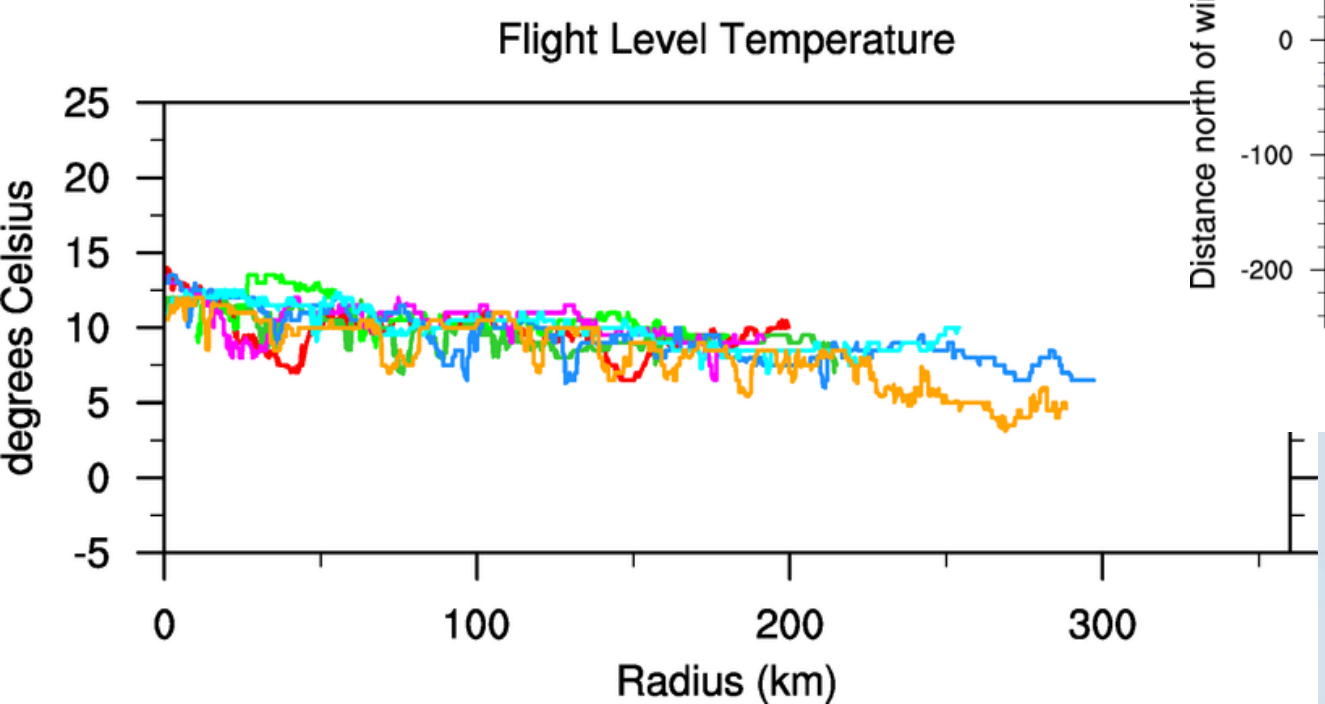

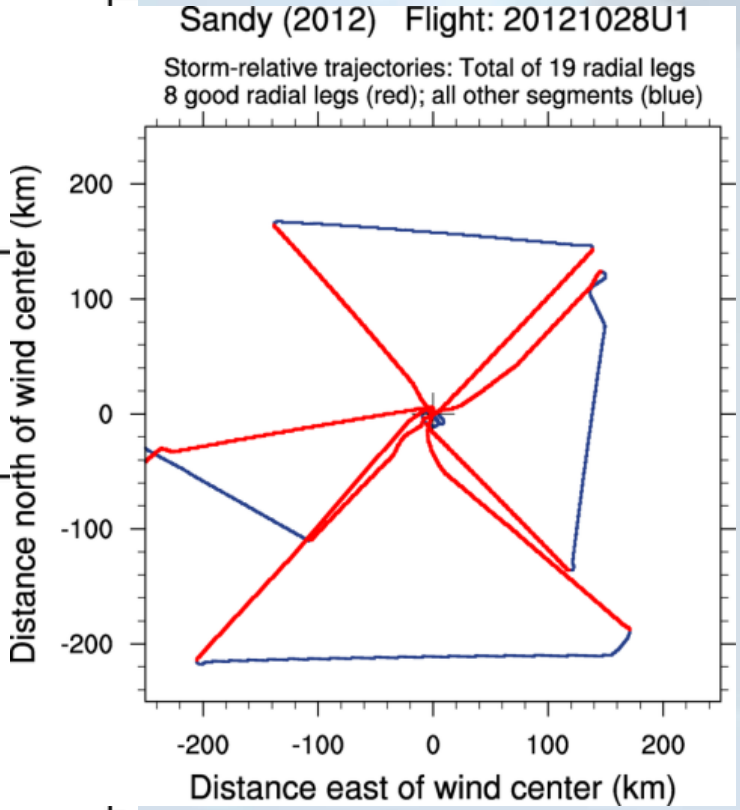

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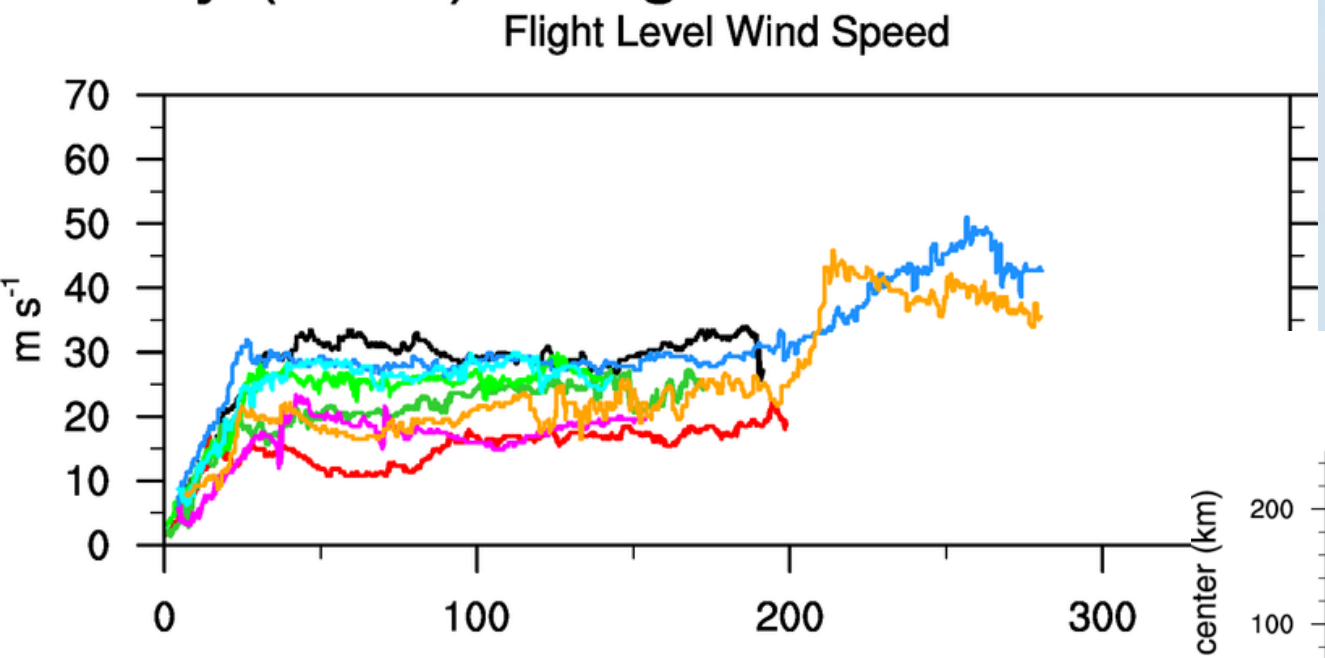

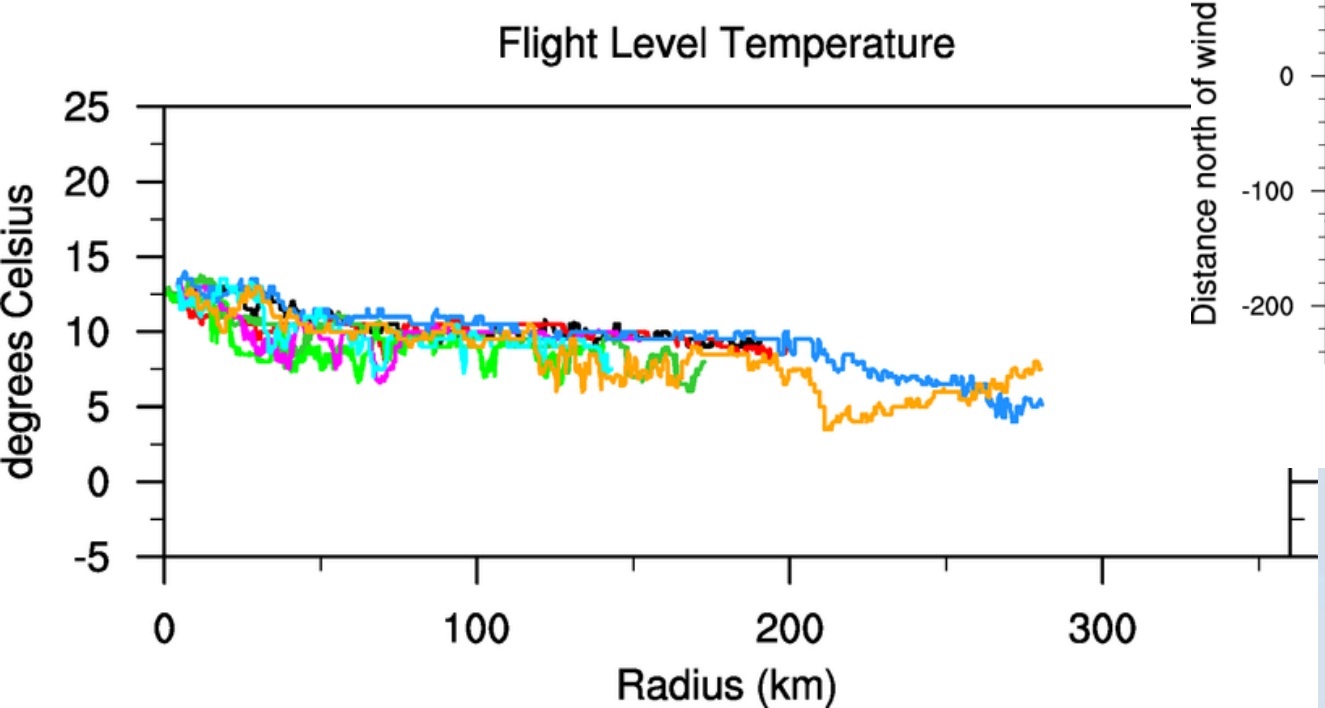

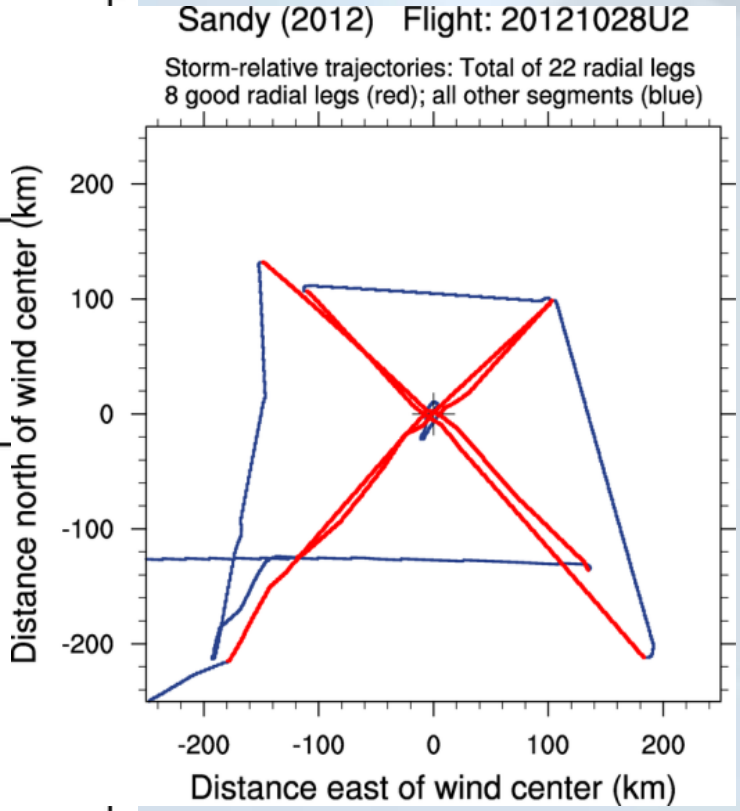

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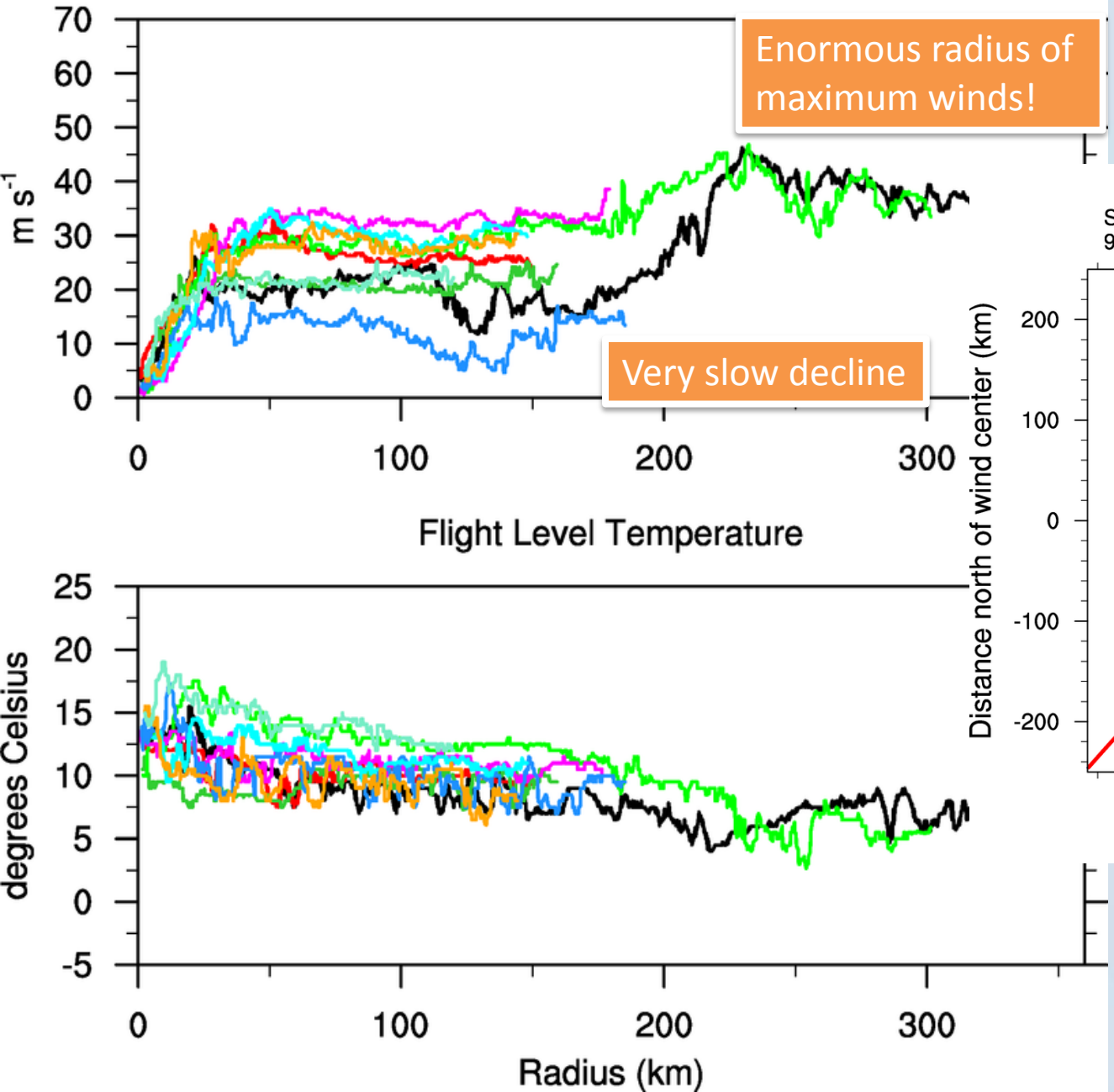
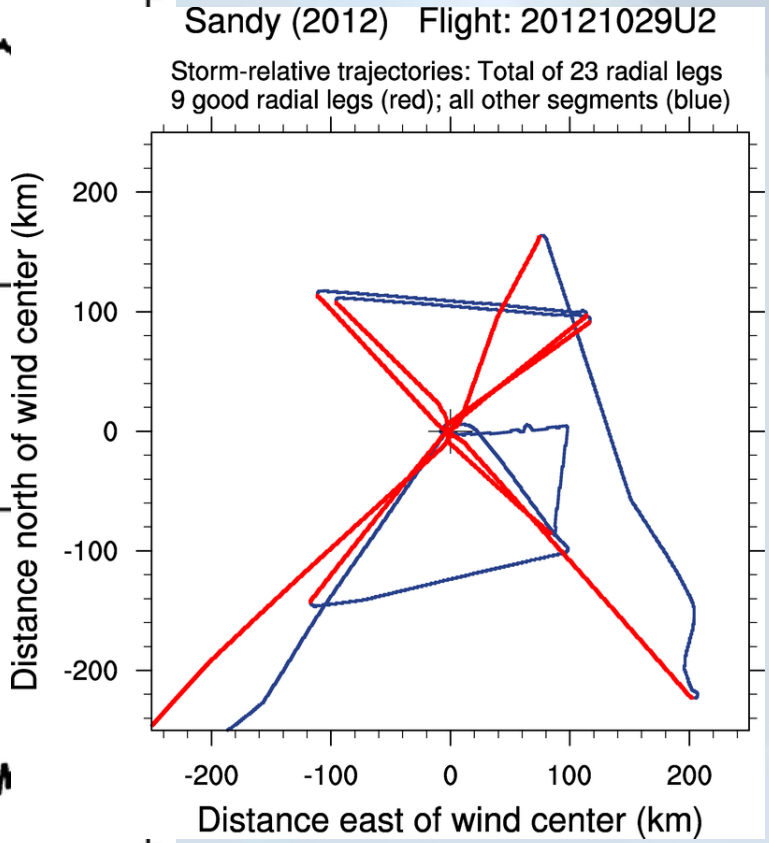
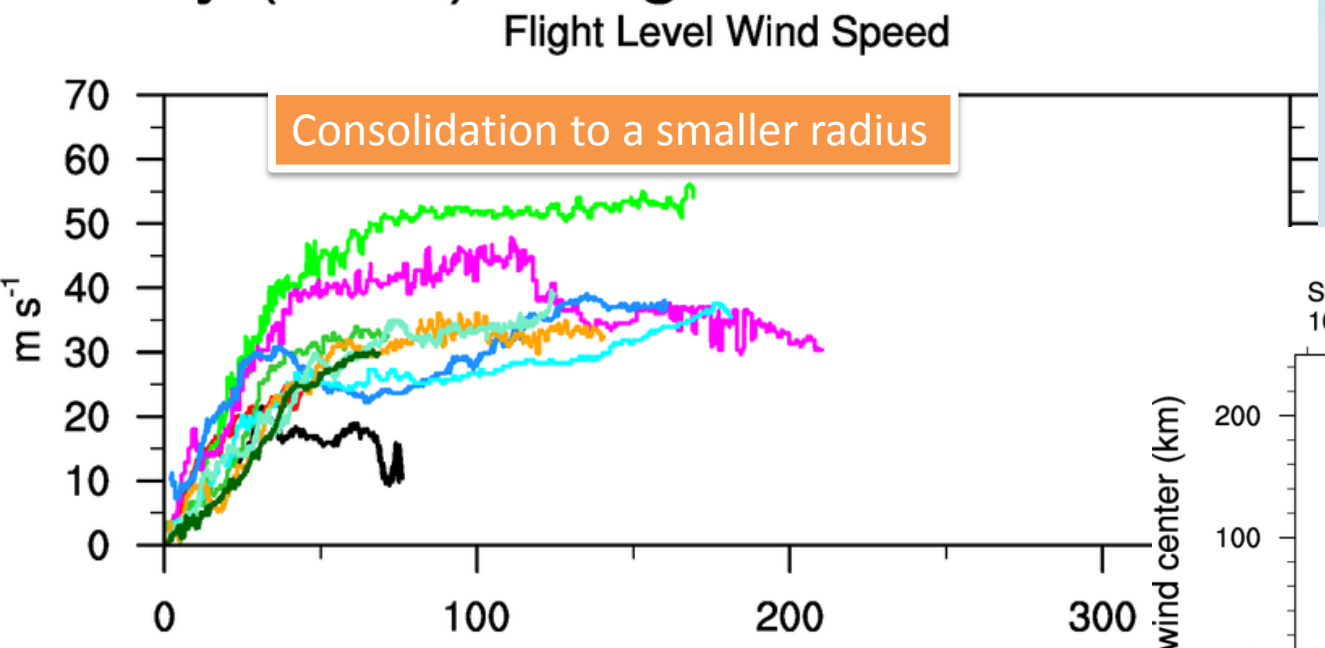
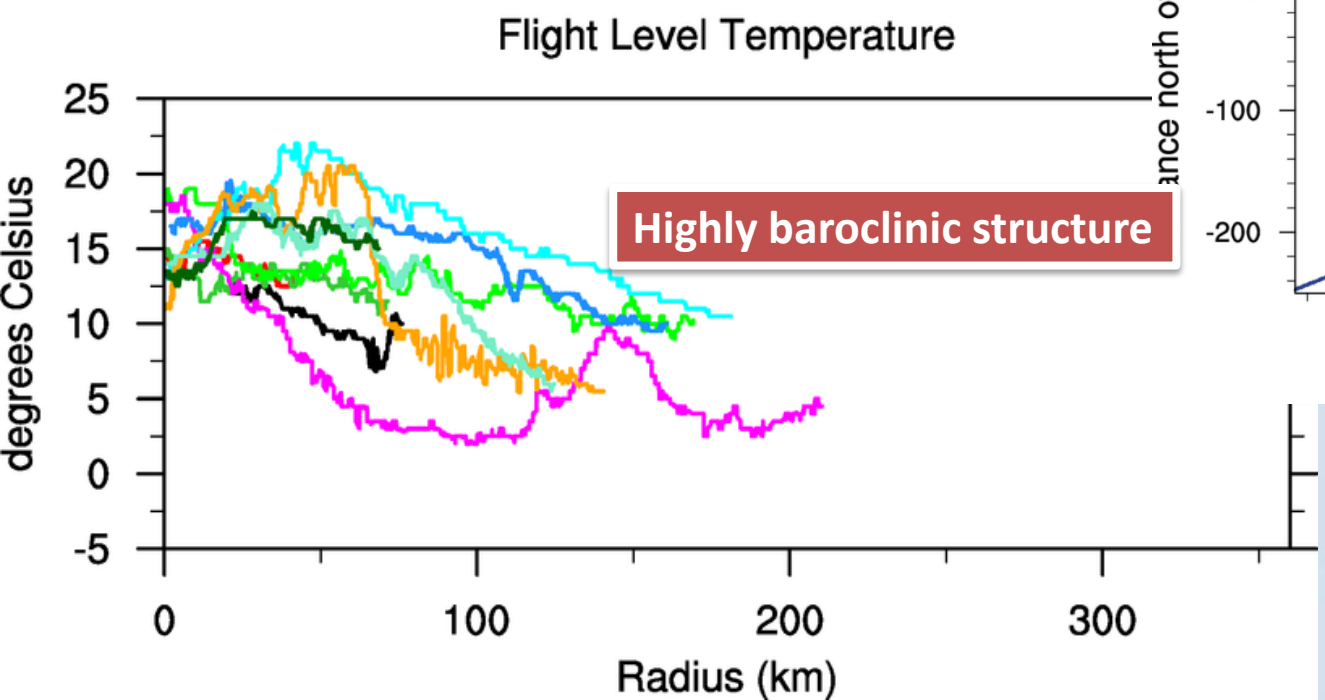
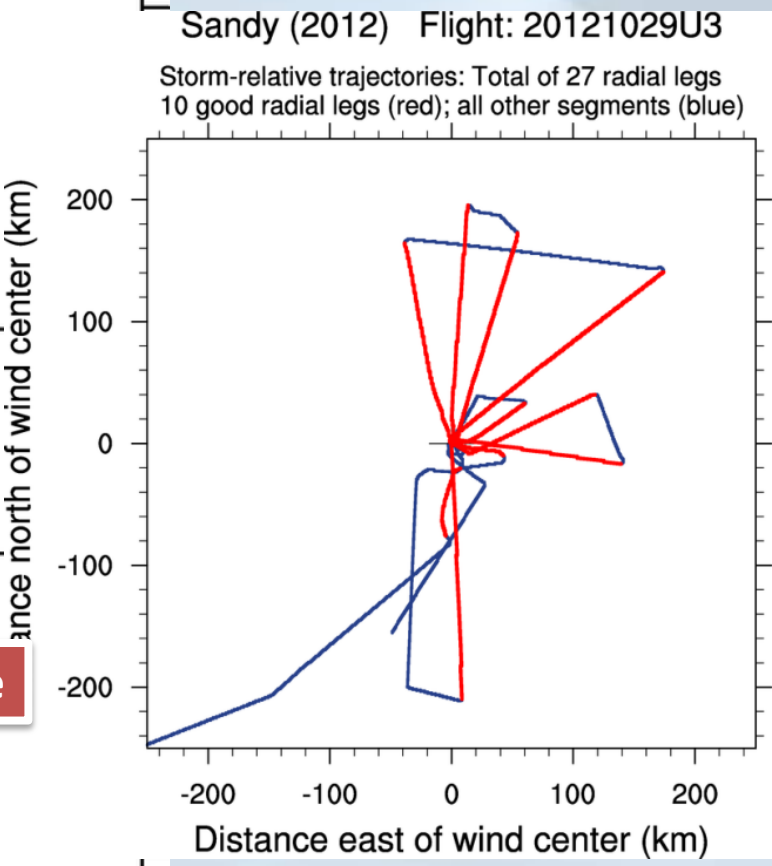




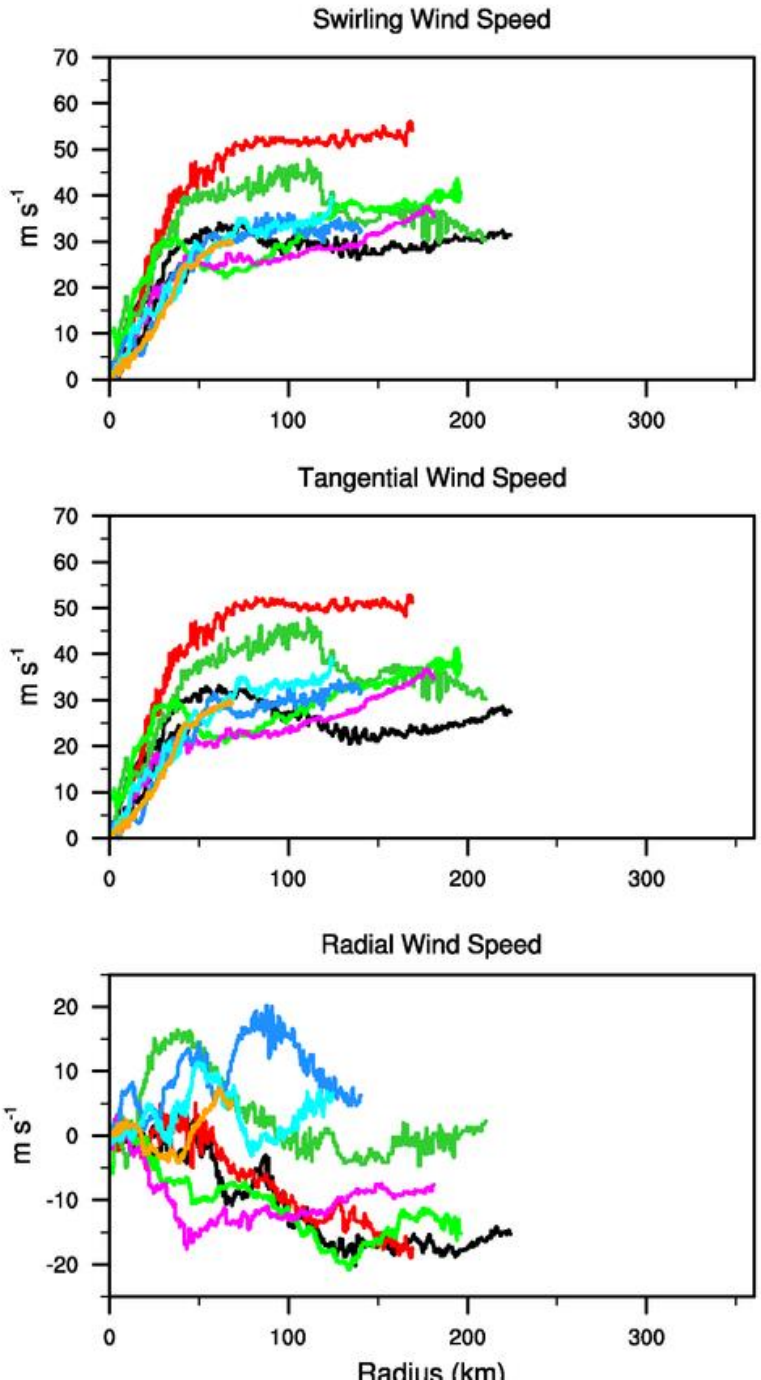
Sandy (2012) FlightID: 20121029U3







Radial Profiles for Sandy (2012) Flight 20121029U3

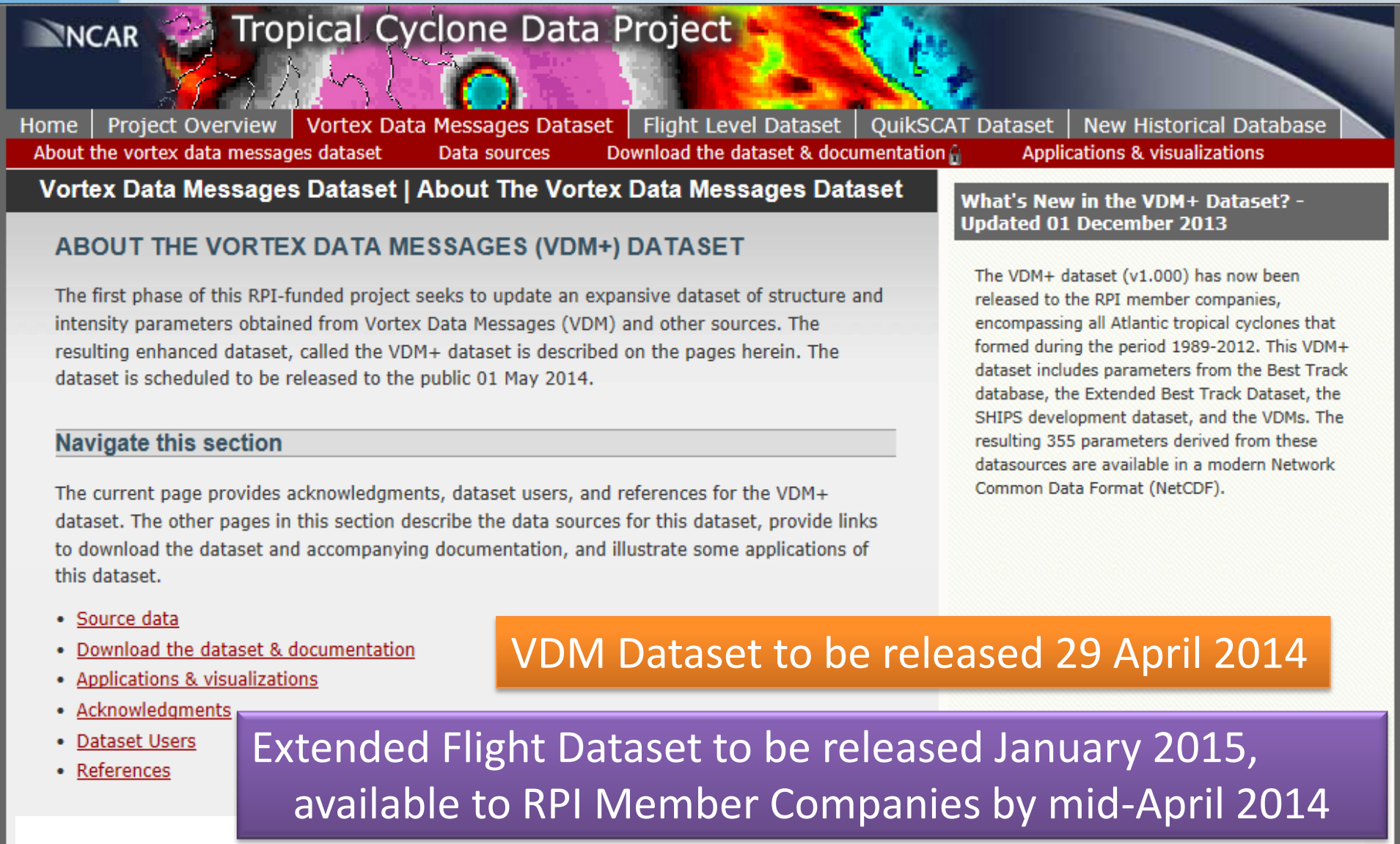


Characteristics of Willoughby-Rahn Flight Level Data Set (1977-2001)

- The flight level data were parsed **by hand** into the "good" radial legs - other portions of flight discarded
- Data are put into 300 overlapping radial bins using a linear distance weighting (Bartlett window). Weighting decreases linearly from 1.0 at the nominal bin radius to 0.0 at plus or minus the half bin width (DR).
- **Typical half bin width of 1.0 km** with bins 0.5 km apart, so each data point is represented in 4 bins. Typical profiles go out to **150 km**.
- Legacy format is "ASCII ProFile" with accompanying metadata listed in a variety of other little ASCII files which serve as indices for navigating the data by flight and leg.

Extended Flight Level Dataset

- Readers coded up for ~20 distinct data formats
- **Standardized** variable names
- Primary navigational information included
- Provides full high resolution data in both earth-relative and storm-relative coordinates **at the native sampling rate (e.g.** 1-sec, 10-sec, 30-sec)
- **Automatic parsing** of radial legs
- Radial profiles interpolated to **100-m radial grid out to 700 km** (7001 grid points)
- Automatic visualization capabilities for QC
- Codeset uses NCAR Command Language (NCL) and produces **NetCDF output**
  - Readable by Matlab, IDL, NCL, etc.
  - All data and metadata included in same file
  - Flexible data structure – no rigid file formats
- Initial dataset spans **1997-2013 for Atlantic, Eastern Pacific, and Western Pacific**



VDM Dataset to be released 29 April 2014

Extended Flight Dataset to be released January 2015, available to RPI Member Companies by mid-April 2014

http://verif.rap.ucar.edu/tcdata/

Community Wiki for Data Provenance

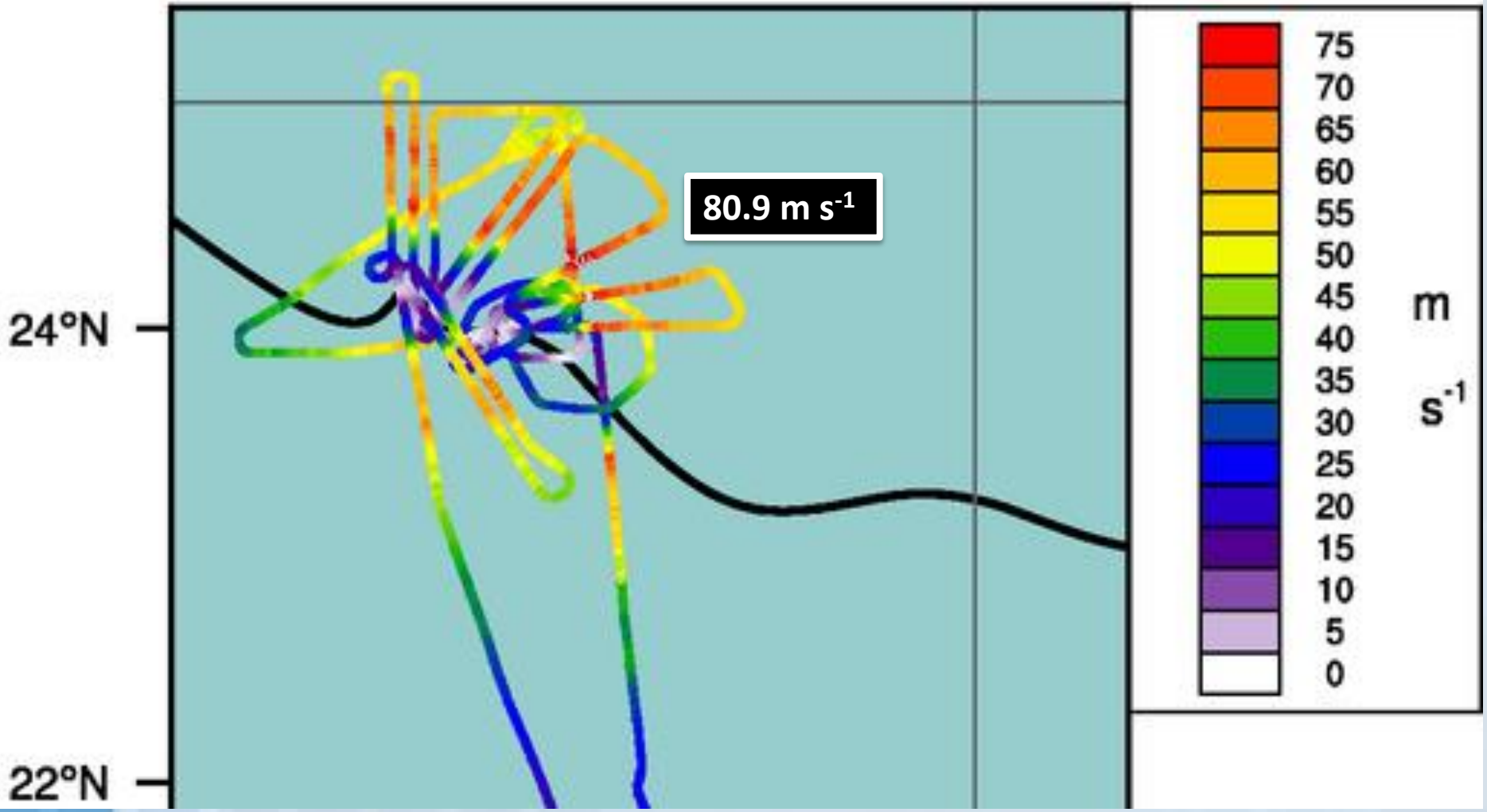
Michael - 2012	AL132012	VDMs indicate AFRES flights; no data files on HRD server									
Patty	AL162012		USFAR only	.1sec.txt	1	**L1 - r858 by JV on caldera using NCL 6.2.0-12Feb2014_0234**	**ERP**	**PARSED**		8	3
Rafael	AL172012	**20121016H1_AC.nc - max FL wind speed 227 m s-1** data files currently include 4 ferry flights	USAFR and NOAA	AXC.nc AC.nc .1sec.txt	14	**L1 - r858 by JV on caldera using NCL 6.2.0-12Feb2014_0234**	**ERP**	**PARSED**		163	57
Sandy	AL182012	**Bad lat/lon values were noted in the NOAA NetCDF file for 20121025H1OAA: The bad lat value was 1.671 deg, while the bad longitude value was -3.591 deg.** I implemented a lat/long check to screen out all points beyond 2.0 degN and -4.0 degE. data files currently include 2 aborted flights data files currently include 4 ferry flights	USAFR and NOAA	AXC.nc AC.nc .1sec.txt	28	**L1 - r858 by JV on caldera using NCL 6.2.0-12Feb2014_0234**	**ERP**	**PARSED**		329	159
2012 Eastern Pacific Storms						**L1 PROCESSING DONE**	**DONE**	**L2 DONE**			
Bud	EP022012		USAFR only	.1sec.txt	2	**L1 - r858 by JV on caldera using NCL 6.2.0-12Feb2014_0234**	**ERP**	**PARSED**		17	10

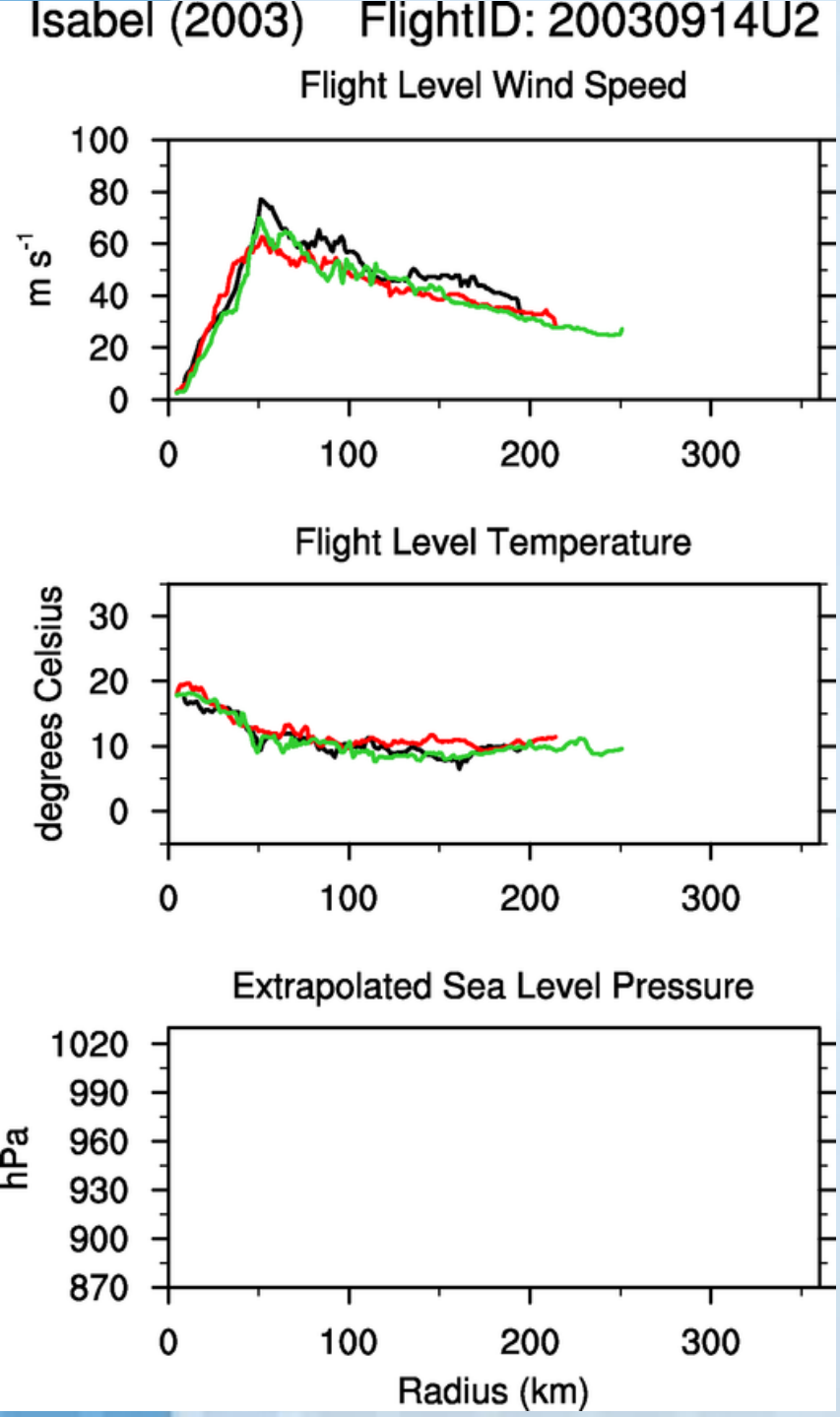
Future Work

- **Observations side:**
  - Determine appropriate way to subtract the storm motion vector from the storm-relative winds (vary by radius?)
  - Experiment with additional binning techniques
- **Model side:**
  - Finish the profile sampling
  - Examine sensitivity to various sampling methods
  - Complete visualizations of synthetic profiles vs. radial profiles in the real storm
  - Find optimal smoothing for the observed profiles
  - Implement as a near-real-time diagnostics for other regional and global models

Isabel (2003)

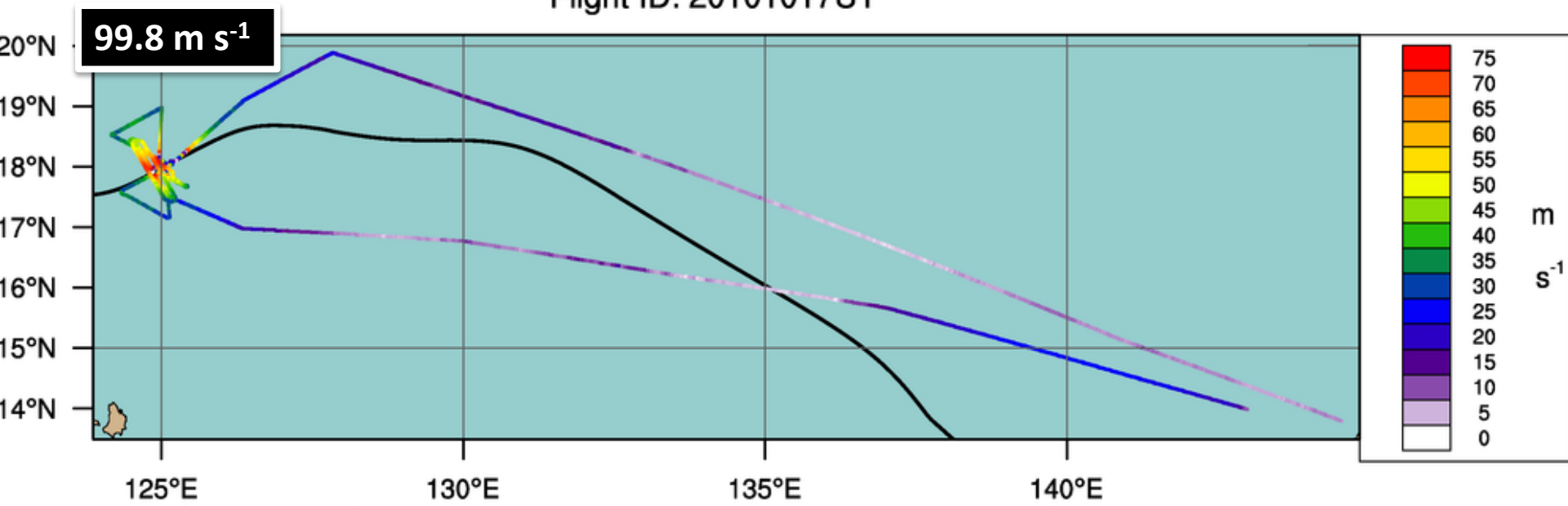
Flight Level Wind Speed
Flight ID: 20030914H1




Isabel (2003) FlightID: 20030914U2
Flight Level Wind Speed
m s-1
100
80
60
40
20
0
0
100
200
300
Flight Level Temperature
degrees Celsius
30
20
10
0
0
100
200
300
Extrapolated Sea Level Pressure
hPa
1020
990
960
930
900
870
0
100
200
300
Radius (km)

Megi (2010)

Flight Level Wind Speed
Flight ID: 20101017U1



Additional information about this flight:

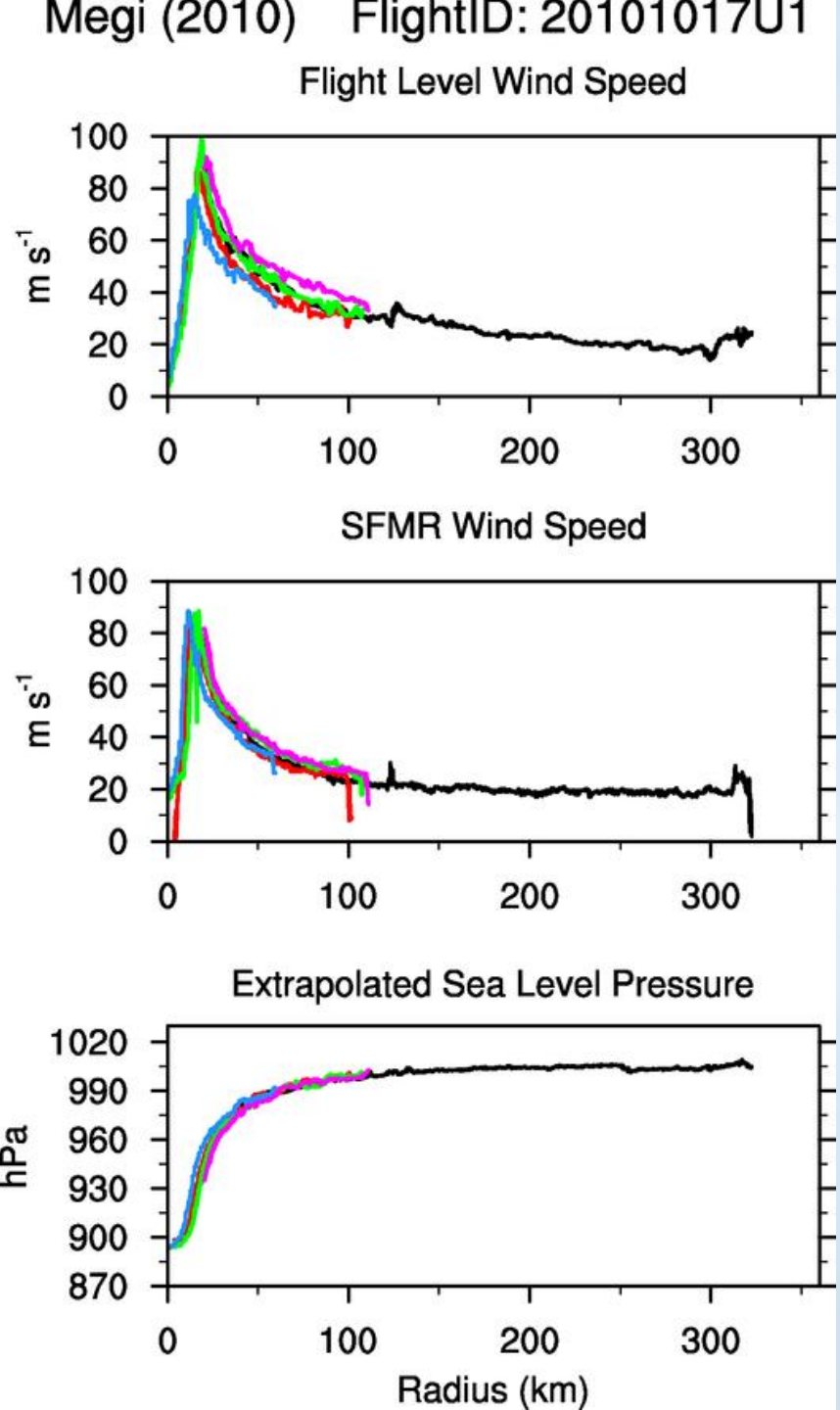
iflight = 6
read filename: 20101017U1.1sec.txt
type of platform: USAFR C-130
software version: usafr_ascii_15.400.25.0
sampling period of data: 1 seconds

Min FL wind speed for flight: 1.0 m s^{-1}
Max FL wind speed for flight: 99.8 m s^{-1}

Flight start time:
Oct 17 06:58 UTC

Flight end time:
Oct 17 18:39 UTC

Flight duration:
11.70 hrs


Megi (2010) FlightID: 20101017U1
Flight Level Wind Speed
m s-1
100
80
60
40
20
0
0
100
200
300
SFMR Wind Speed
m s-1
100
80
60
40
20
0
0
100
200
300
Extrapolated Sea Level Pressure
hPa
1020
990
960
930
900
870
0
100
200
300
Radius (km)

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  - NASA/TCSP Grant NNG06GA54G
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    - Neal Dorst
    - Frank Marks
  - NOAA Aircraft Operations Center
    - Barry Damiano
    - Richard Henning
  - Florida International University: Hugh Willoughby
  - NCAR: Christopher Williams