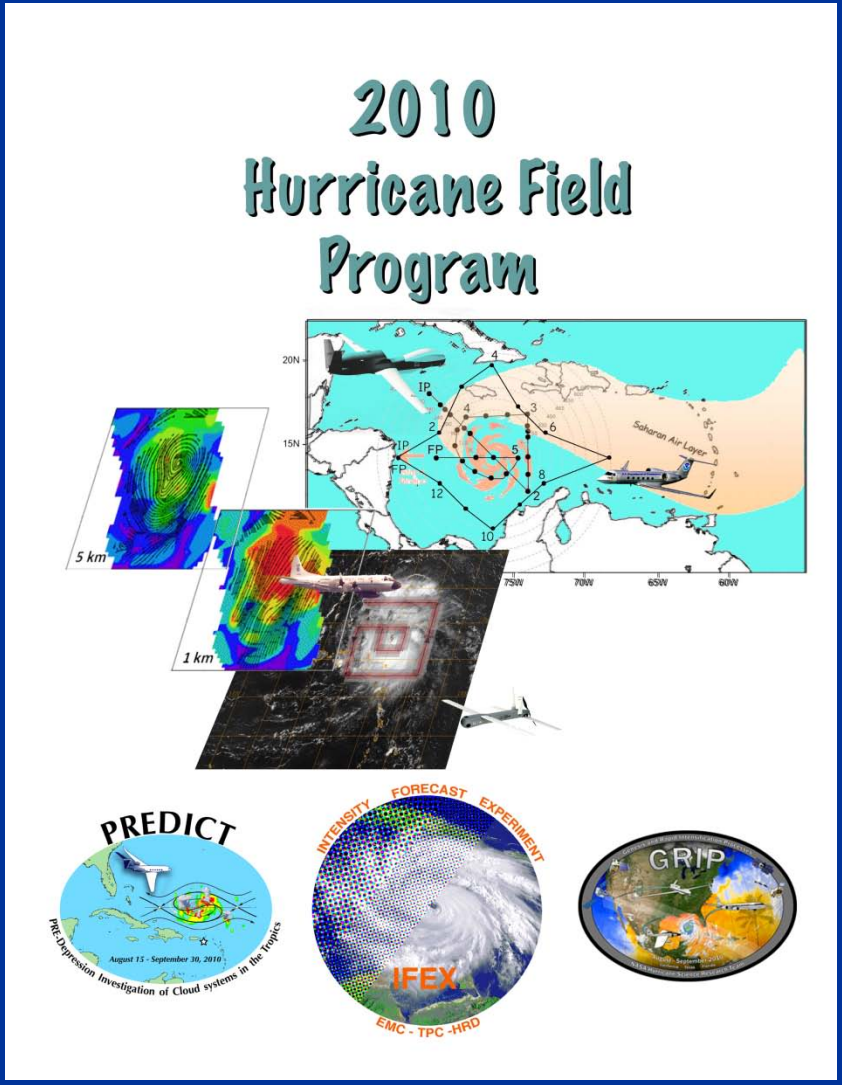
Summary of NOAA's 2010 Hurricane Field Program (IFEX)

Robert Rogers – 2010 HFP Field Program Director



Intensity Forecasting Experiment (IFEX; Rogers et al., BAMS, 2006)

THE INTENSITY FORECASTING EXPERIMENT

A NOAA Multiyear Field Program for Improving Tropical Cyclone Intensity Forecasts

BY ROBERT ROGERS, SIM ABERSON, MICHAEL BLACK, PETER BLACK, JOE CIONE, PETER DODGE, JASON DUNION, JOHN GAMACHE, JOHN KAPLAN, MARK POWELL, NICK SHAY, NAOMI SURGI, AND ERIC UHLHORN

In probing the whole life cycle of these storms—not just mature hurricanes—IFEX is taking a new approach to developing physical understanding and forecast abilities as well as testing and enhancing real-time observational capabilities.

MOTIVATION FOR IFEX. One of the key activities in the National Oceanic and Atmospheric Administration's (NOAA's) strategic plan is to improve the understanding and prediction of tropical cyclones (TCs). The NOAA National Hurricane Center (NHC), a part of the National Centers for Environmental Prediction (NCEP), is responsible for forecasting TCs in the Atlantic and east Pacific basins, while NCEP's Environmental Modeling Center (EMC) develops the numerical model guidance for the forecasters. With support from NOAA's Hurricane Research Division (HRD) and others in the research community, continual progress has been made in improving forecasts of the TC track over the past 30 years (Franklin et al. 2003a; Aberson 2001). Advancements in state-of-the-art global and regional modeling systems at EMC and other operational numerical weather prediction centers have led to improvements in track skill over the past three decades, including a significant acceleration in improvements over the past decade. These advancements include improved assimilation of satellite and

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The abstract for this article can be found in this issue, following the table of contents.
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IFEX intended to improve prediction of TC intensity change by:

1) collecting observations that span TC life cycle in a variety of environments for model initialization and evaluation
2) developing and refining measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment
3) improving understanding of physical processes important in intensity change for a TC at all stages of its life cycle

These goals provide the linkage between observations, modeling, and theory that form the foundation of the Hurricane Forecast Improvement Project (HFIP)

Focus areas for 2010

IFEX goal 1: Collecting observations for model initialization/evaluation

- Tail Doppler radar
- Synoptic surveillance with Global Hawk
- HWRFx/HFIP real-time runs and HEDAS data assimilation

IFEX goal 2: Developing and refining measurement technologies

- GALE low-level UAS
- Doppler Wind Lidar
- Ocean winds/AWRAP
- Global Hawk high-level UAS (partnership with NASA)

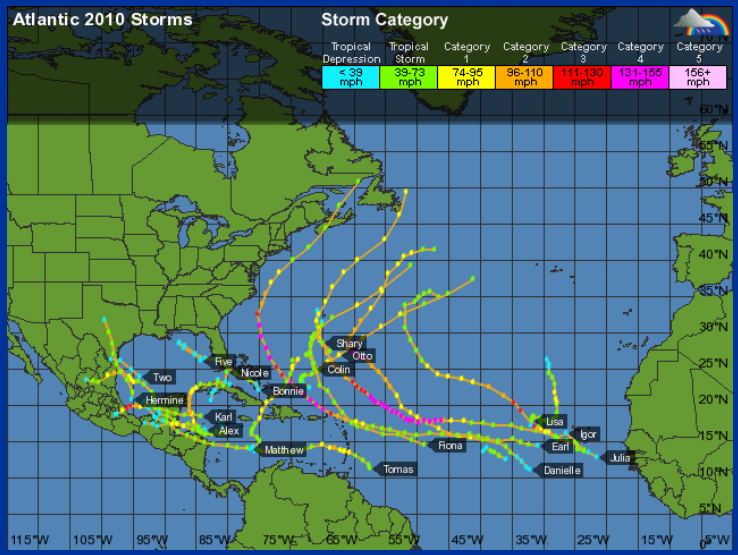
IFEX goal 3: Improving understanding

- Genesis
- Rapid Intensity Change
- TC-Ocean interaction
- Saharan Air Layer
- Landfall and Inland Decay
- TC/AEW Arc Cloud
- Hurricane PBL Entrainment Flux
- Aerosol/Cloud Droplet measurement

Intensity Forecast experiment (IFEX 2010)

- Summary:
  - ✓ NOAA aircraft flew ~420 h (28 P-3 and 19 G-IV missions) in 9 tropical systems, and 3 Gulf ocean survey missions
  - ✓ Deployed ~1000 GPS dropsondes; ~200 ocean probes (AXBT/CP/CTD)
  - ✓ Performed 79 Doppler analyses & SO data sets
  - ✓ Performed 125 H*Wind analyses
  - ✓ Performed 380 HWRFx simulations in 11 storms and 9 invests
  - ✓ 17 HEDAS analyses & HWRFx runs for Hurricanes Earl, Karl, and Tomas
  - ✓ 2 coordinated P-3/Global Hawk missions – 1 each in Earl & Karl
  - o ONR DWL installation delayed
  - o G-IV TDR acceptance tests delayed

- TD 2 & 5, TS Alex, Bonnie, Matthew, Richard, Hurricanes Earl, Karl and Tomas plus 3 Gulf pre-storm ocean survey missions (+10 ocean survey missions in support of DWH spill - unprecedented upper ocean data set over Gulf of Mexico for coupled modeling)



Courtesy wunderground.com

For details see:
http://noaahrd.wordpress.com/category/ifex-discussion

Interactions with other experiments

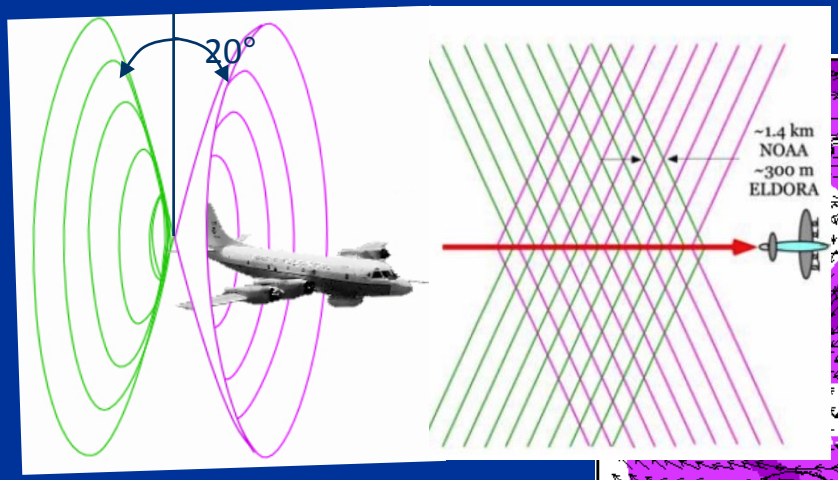
- **NASA GRIP** (Genesis and Rapid Intensification Processes, 8/15-9/30)
  - DC-8 -- based in Ft. Lauderdale, GH -- based in Dryden, CA
  - Scott Braun, Ed Zipser, Gerry Heymsfield aircraft leads
  - GH flew missions over Hurricanes Earl and Karl, good coverage of RI stage of Karl

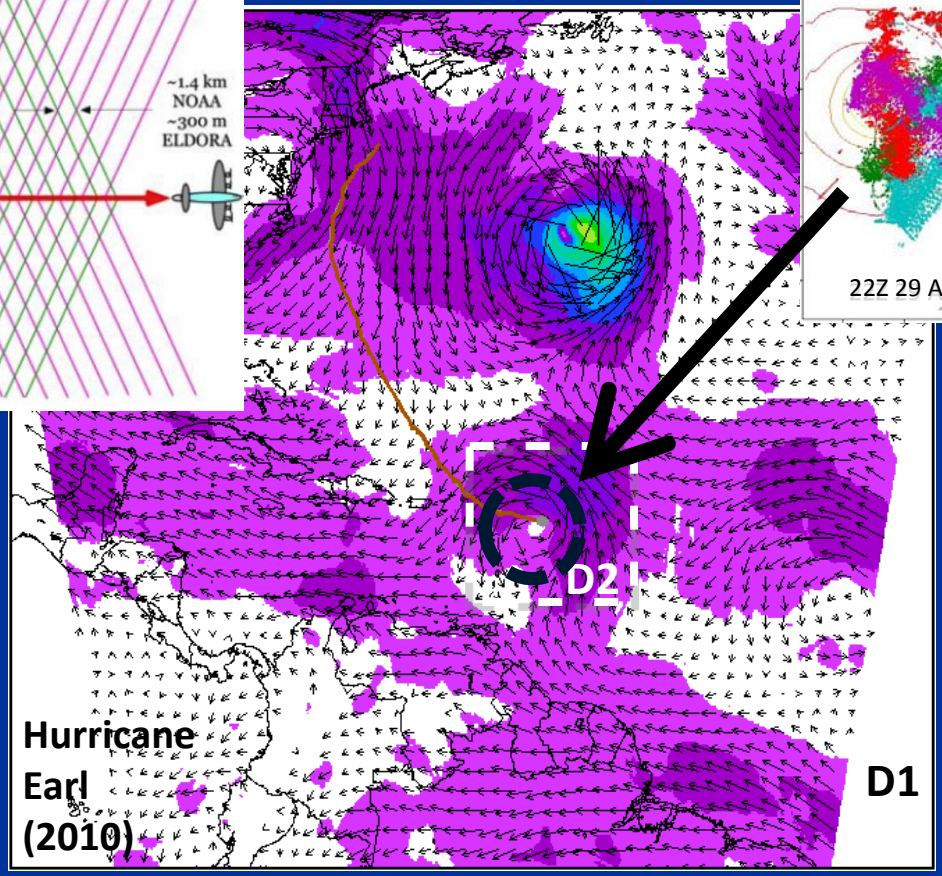
- **NSF PREDICT** (PRE-Depression Investigation of Cloud systems in the Tropics, 8/15-9/30)
  - G-V – based in St. Croix
  - Mike Montgomery, Chris Davis, Andy Heymsfield, Lance Bosart leads
  - Excellent dropsonde coverage in pre-genesis stage of Karl

IFEX Goal 1: Data Assimilation

HEDAS: HWRF Ensemble Data Assimilation System

EnKF data assimilation of inner core observations





Real-time SOs transmitted during P-3 mission and assimilated into HWRFx using HEDAS

IFEX Goal 1: Data Assimilation

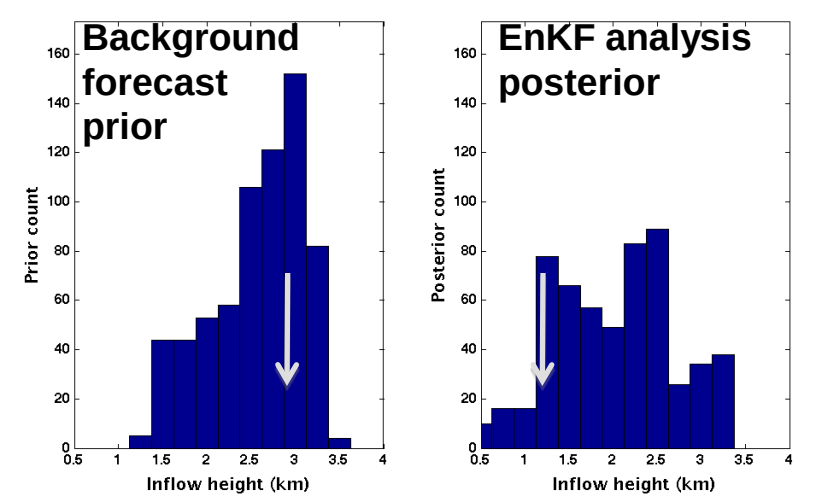
EnKF airborne data assimilation using HEDAS to diagnose systematic model deficiencies and identify how to reduce them

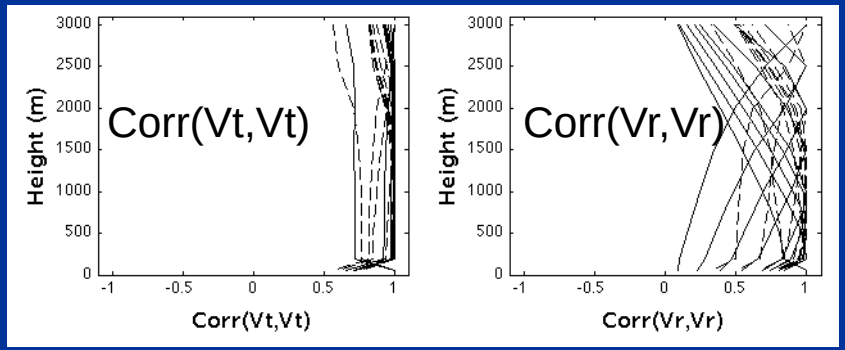
In the assimilation the forecast showed inflow layer that is systematically too deep relative to Doppler wind observations

Distribution of inflow layer depth (Earl cases)

Ensemble-based vertical error correlations within PBL point to excessive vertical mixing

Wind error correlations in inner core





Solid - within a zone of maximum winds
Dashed - outside this zone

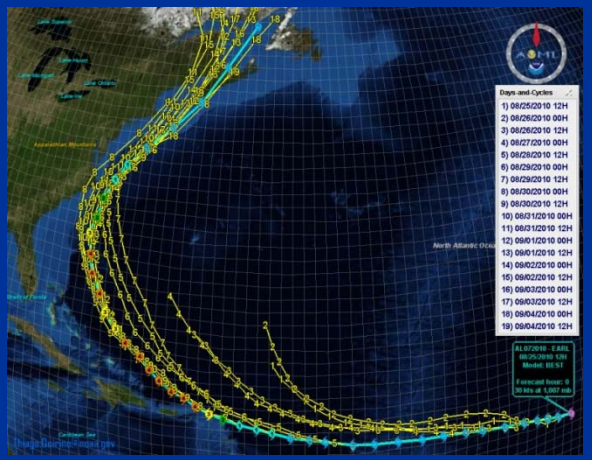
We would study improvements to the PBL and surface layer parameterizations in the HWRF model by stochastic estimation of the critical parameters using data assimilation

IFEX Goal 1: Numerical modeling

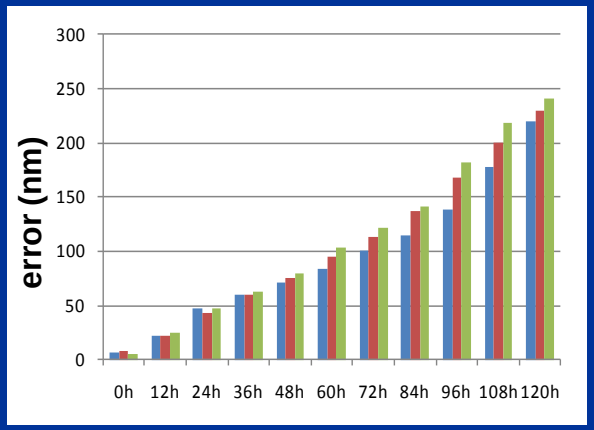
Experimental 3-km version of HWRF model (called “H3HW” here)

Hurricane Earl

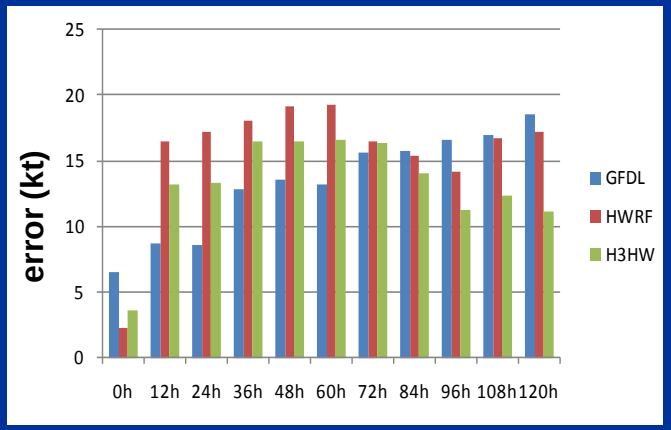
H3HW Forecast tracks



Track forecast error

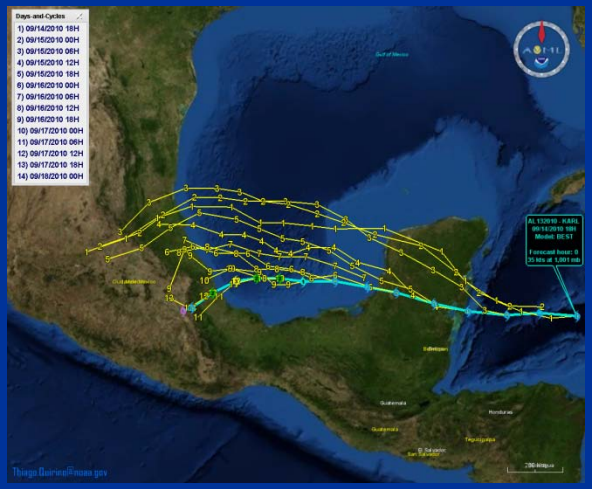


Intensity forecast error

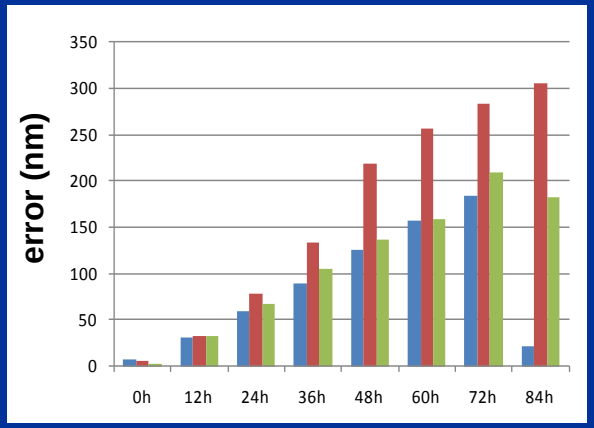


Hurricane Karl

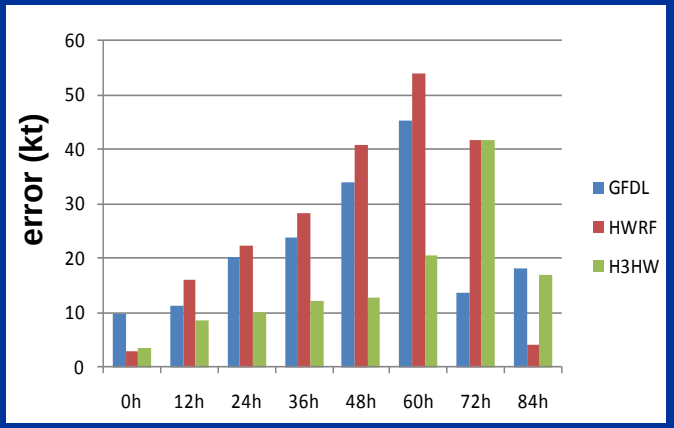
H3HW Forecast tracks



Track forecast error

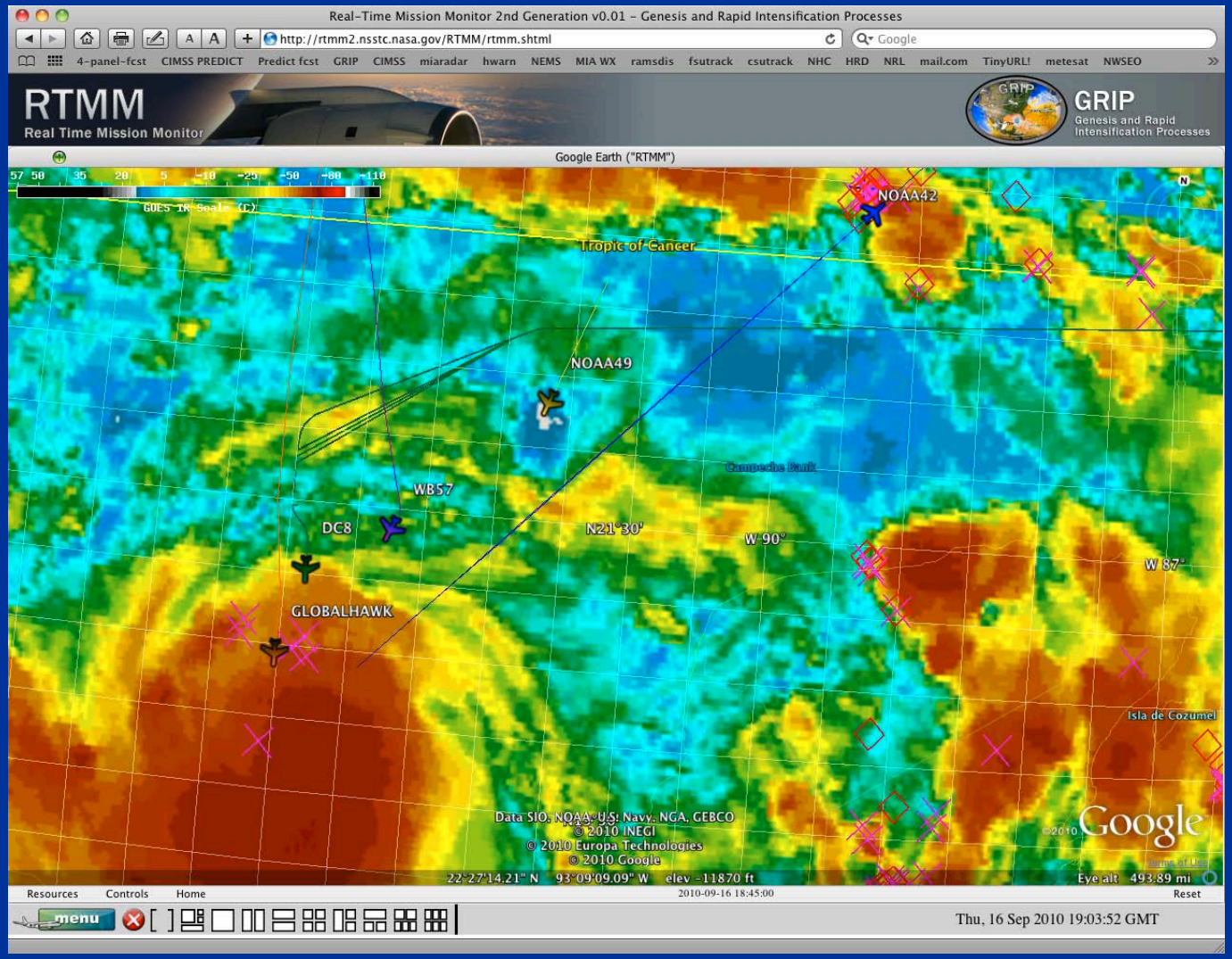


Intensity forecast error



IFEX Goal 2: Global Hawk UAS (partner with NASA)

Multiple aircraft sampling Hurricane Karl

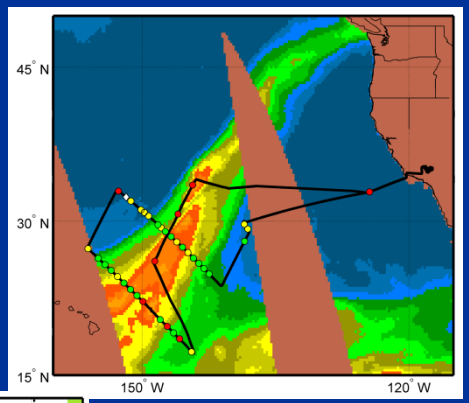


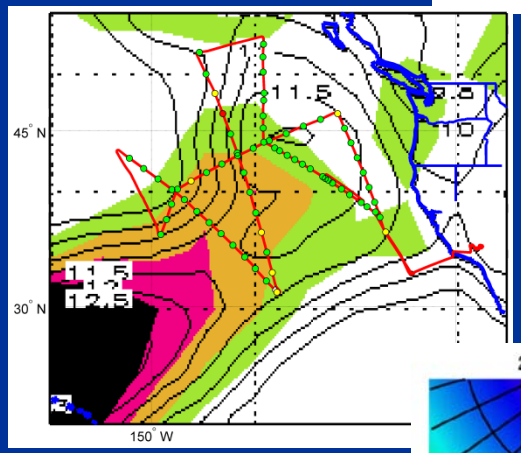
- ability of Global Hawk to overfly inner-core of hurricane
- dropsondes from Global Hawk not available during GRIP

Winter Storm and Pacific Atmospheric Rivers (WISPAR) Experiment

- Demonstration of the scientific application of the Global Hawk dropsonde system for NOAA operational and research objectives
- 3 science flights targeted:
  - Atmospheric Rivers
  - Winter Storms Reconnaissance
  - Arctic Weather
- February-March 2011
- Just under 70 hours flown
- 177 total dropsondes deployed
- Additional measurements from HAMSR

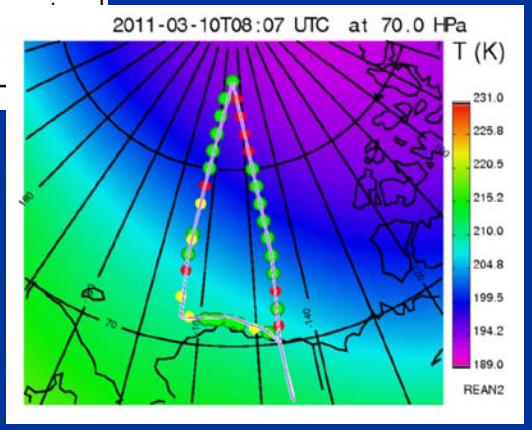
Atm. Rivers
11-12 Feb
37 sondes





Winter Storms
3-4 March
70 sondes

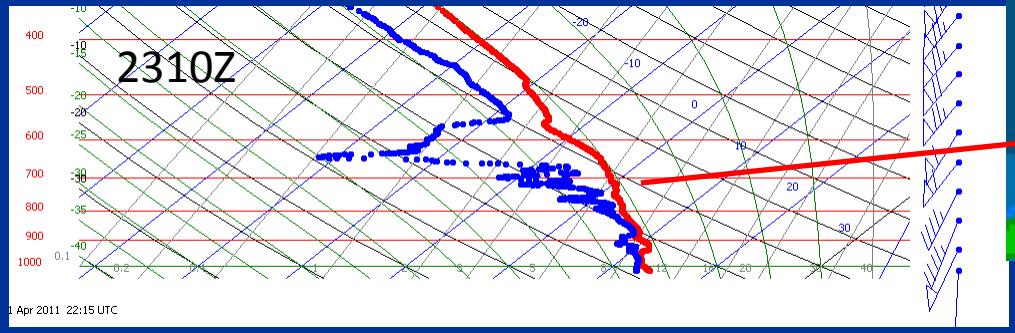
Arctic Weather
9-10 March
70 sondes
35 N of AK

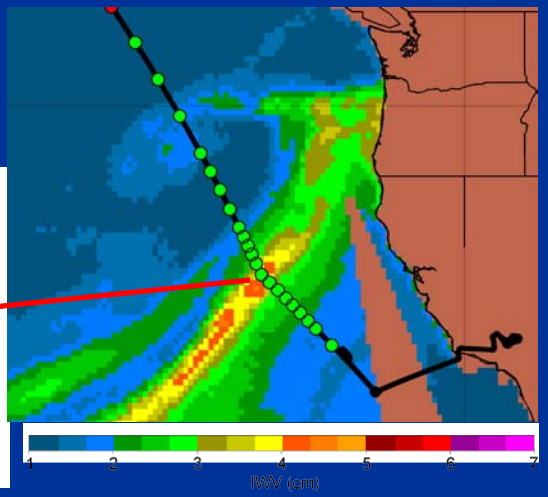


WISPAR Results and Lessons Learned

- Overall an excellent engineering test and operational demonstration
- Dropsondes and dropsonde system performed well
  - See spot Wednesday pm; G. Wick here today and tomorrow
- Significant mission flexibility observed
  - Able to specify lines and regions for drops and alter during flight
  - Working with New York Oceanic may be more challenging
- Dropsonde operations are labor intensive
- Good science expected
  - Comparisons with HAMSR a priority

Arctic Flight AR Crossing
10 Mar 2011, ~0200 UTC

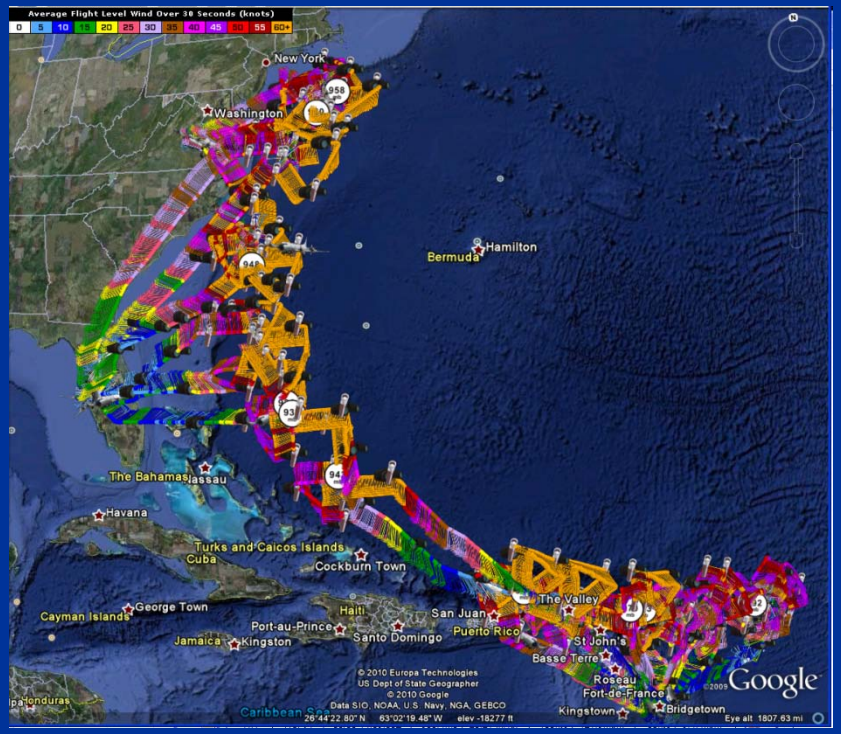




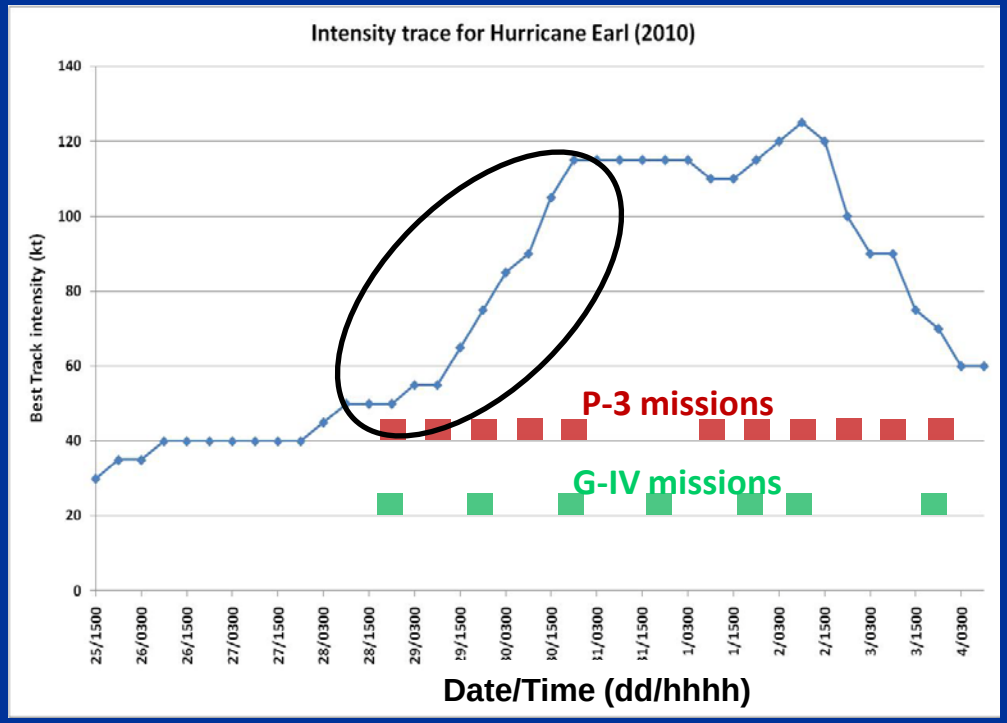
IFEX Goal 3: Rapid intensification

Hurricane Earl – intensively-sampled lifecycle

Geographic coverage of Earl P-3 flights



Lifecycle coverage of Earl P-3 and G-IV flights

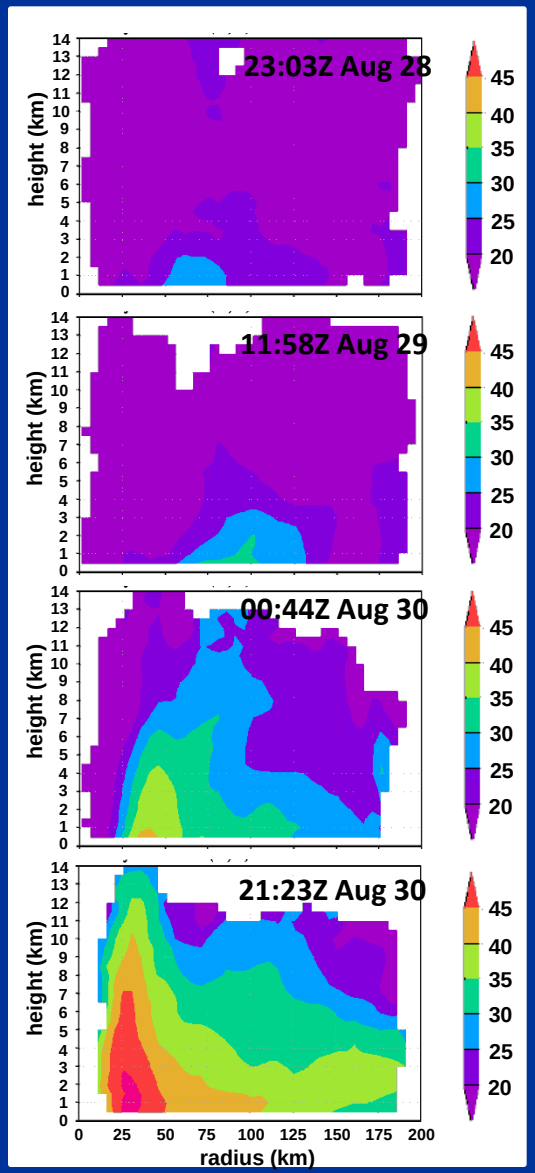


- 60 kt intensification in 36 h sampled by P-3's and G-IV
- 12-h P-3, 24-h G-IV missions for 8 days nearly continuously
- Pre-RI, RI, steady-state major, weakening phases sampled

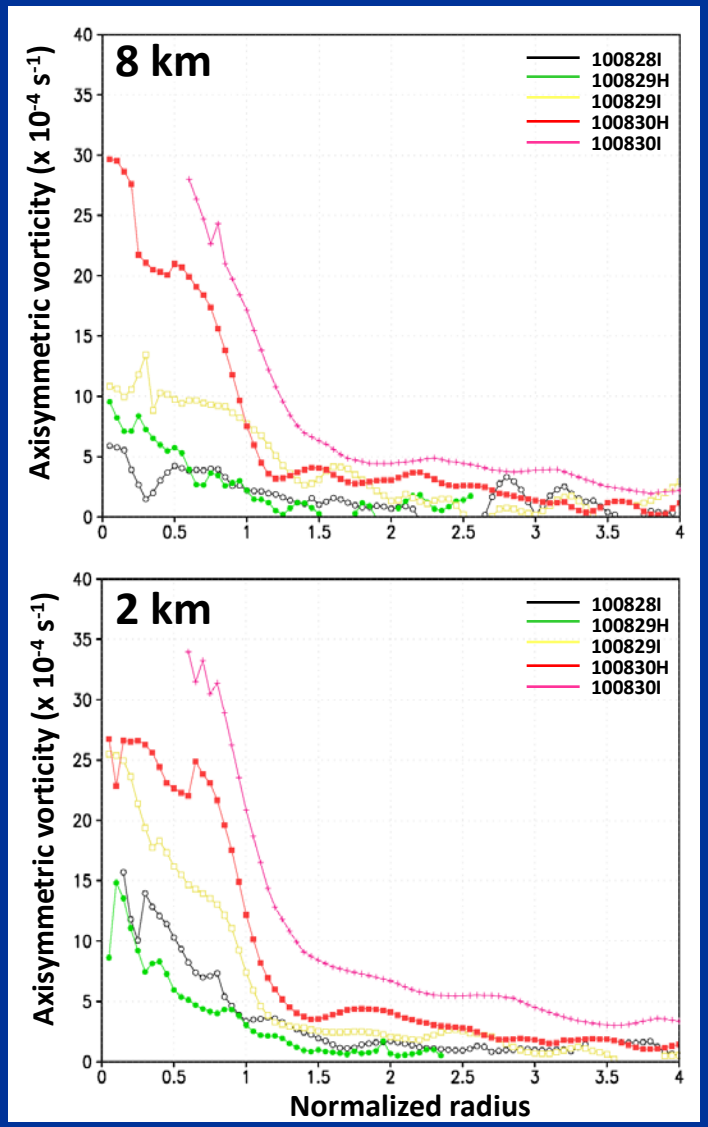
IFEX Goal 3: Rapid intensification

- How does vortex evolve during RI (symmetric/asymmetric, kinematic/thermodynamic)?
- What is relative role of convective-, vortex-, and environmental-scale processes in RI?

Axisymmetric tangential wind (shaded, m/s)

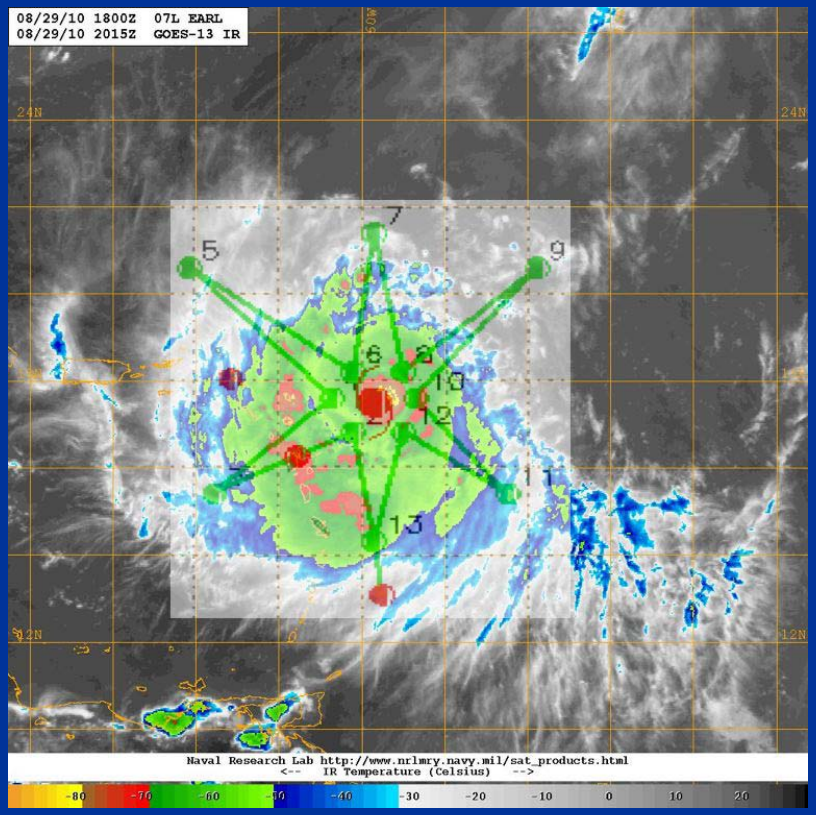


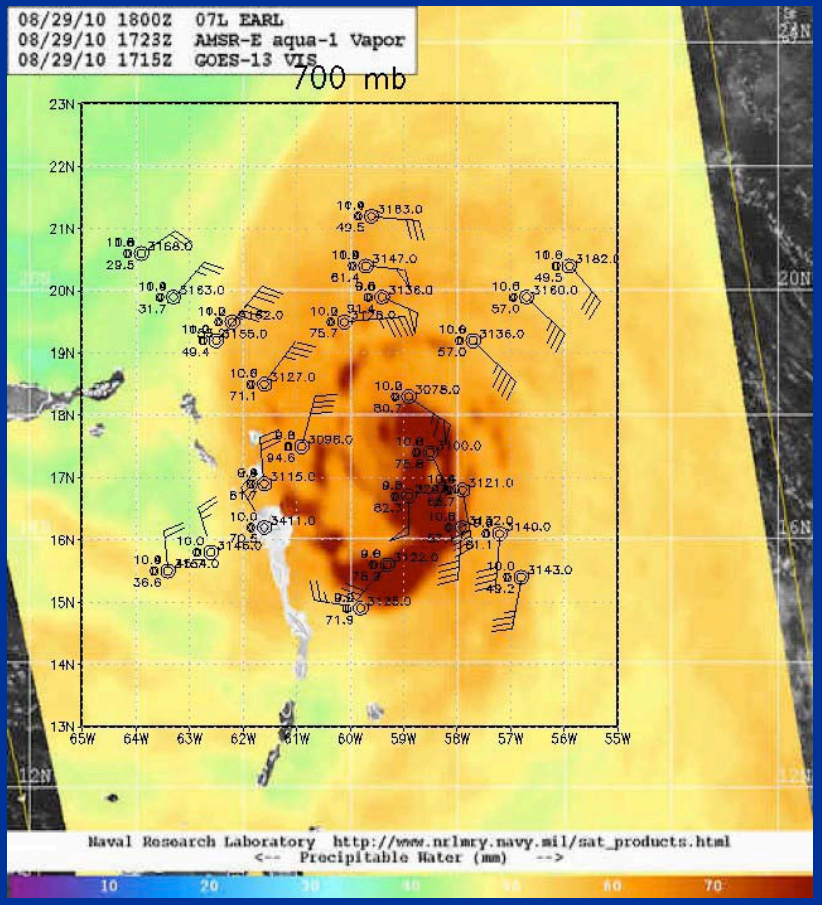
Axisymmetric vertical vorticity (x 10^{-4} s^{-1})



IFEX Goal 3: Rapid intensification

G-IV flight track and drops – August 29

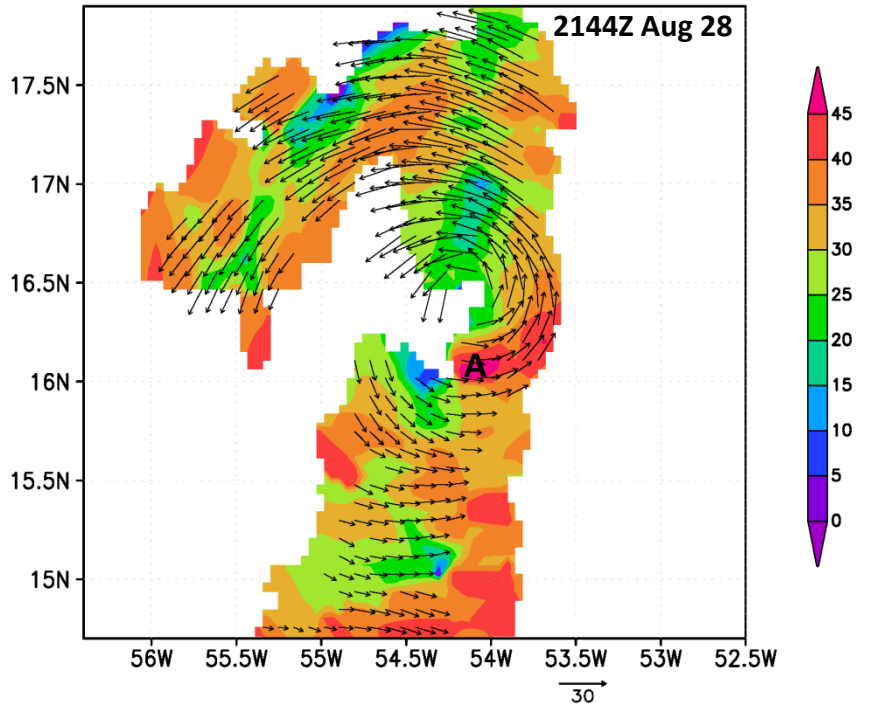




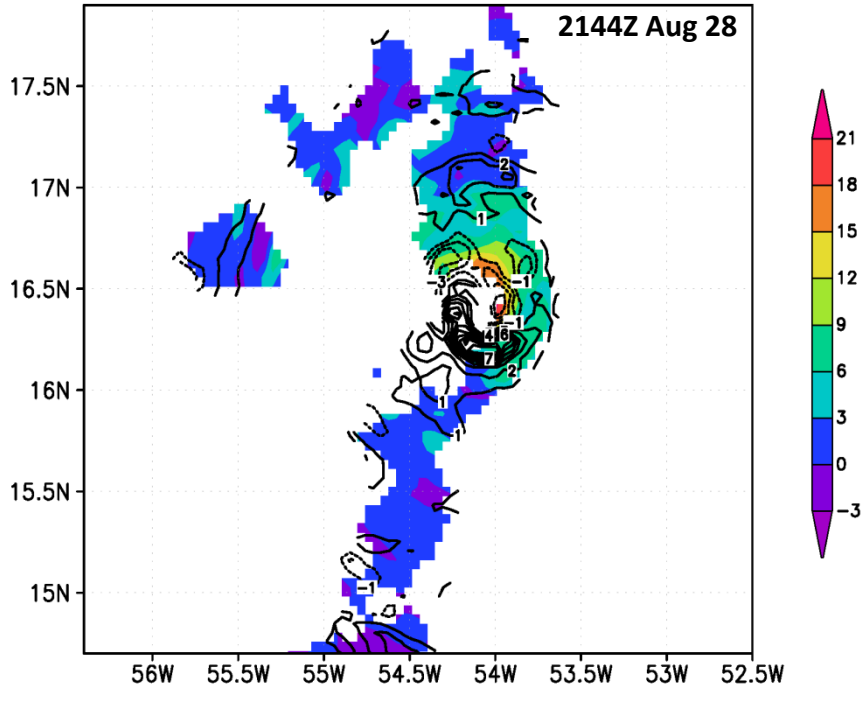
IFEX Goal 3: Rapid intensification

Convective burst evolution

Reflectivity (shaded, dBZ)
horizontal winds (vector, m s-1) at 3 km



Vertical vorticity (shaded, x 10^{-4} s^{-1}) at 3 km
2-6 km averaged vertical velocity (contour, m s-1)



IFEX Goal 3: Rapid intensification

Convective burst evolution

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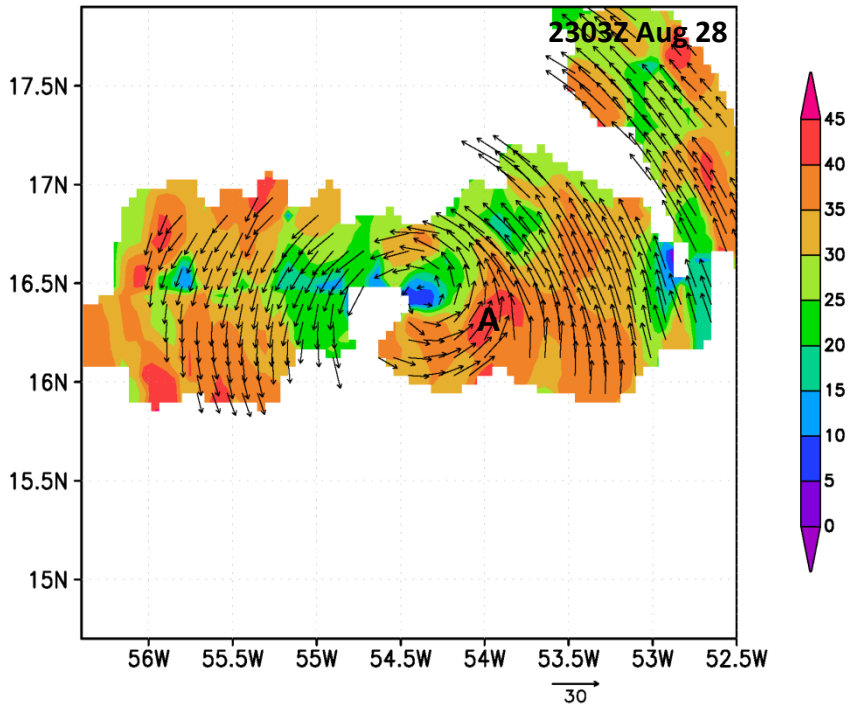

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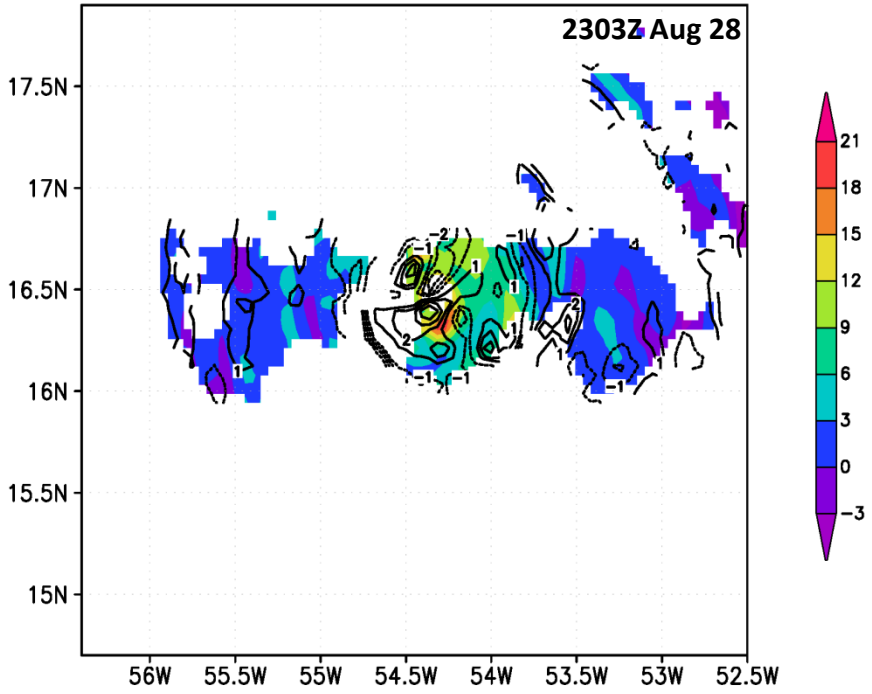
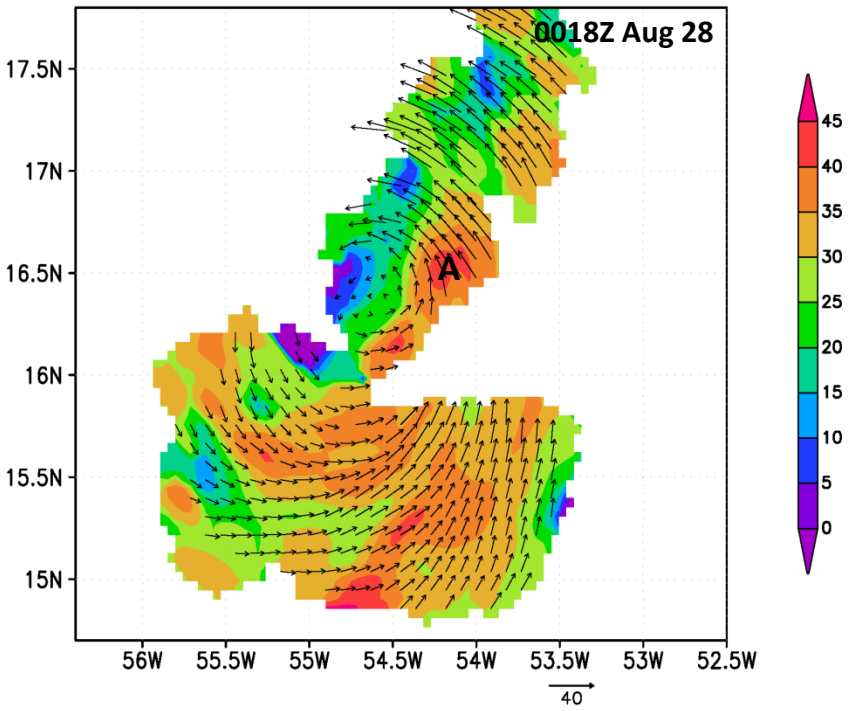


~ 1 h 15 min after first pass

IFEX Goal 3: Rapid intensification

Convective burst evolution

Reflectivity (shaded, dBZ)
horizontal winds (vector, m s-1) at 3 km



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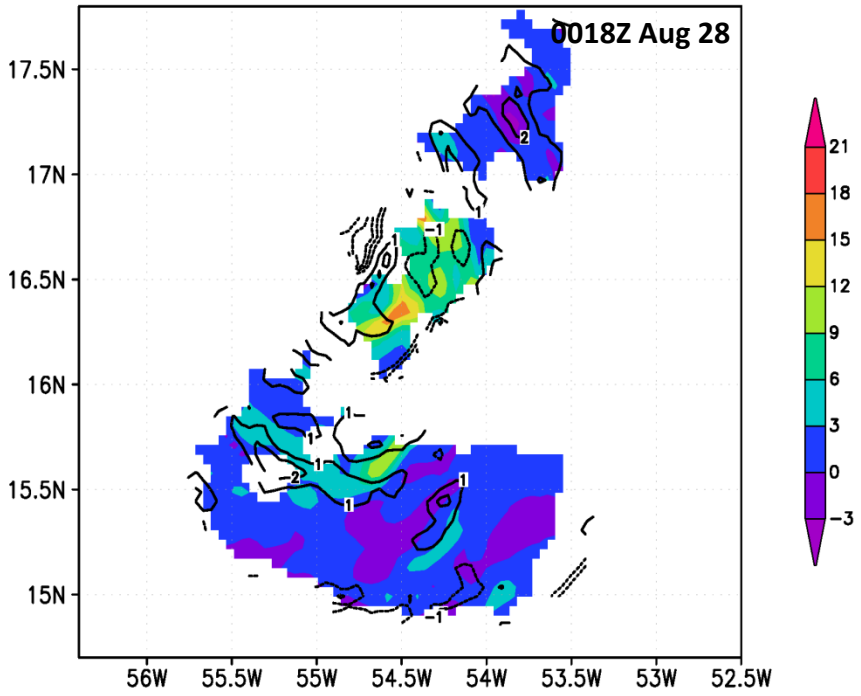
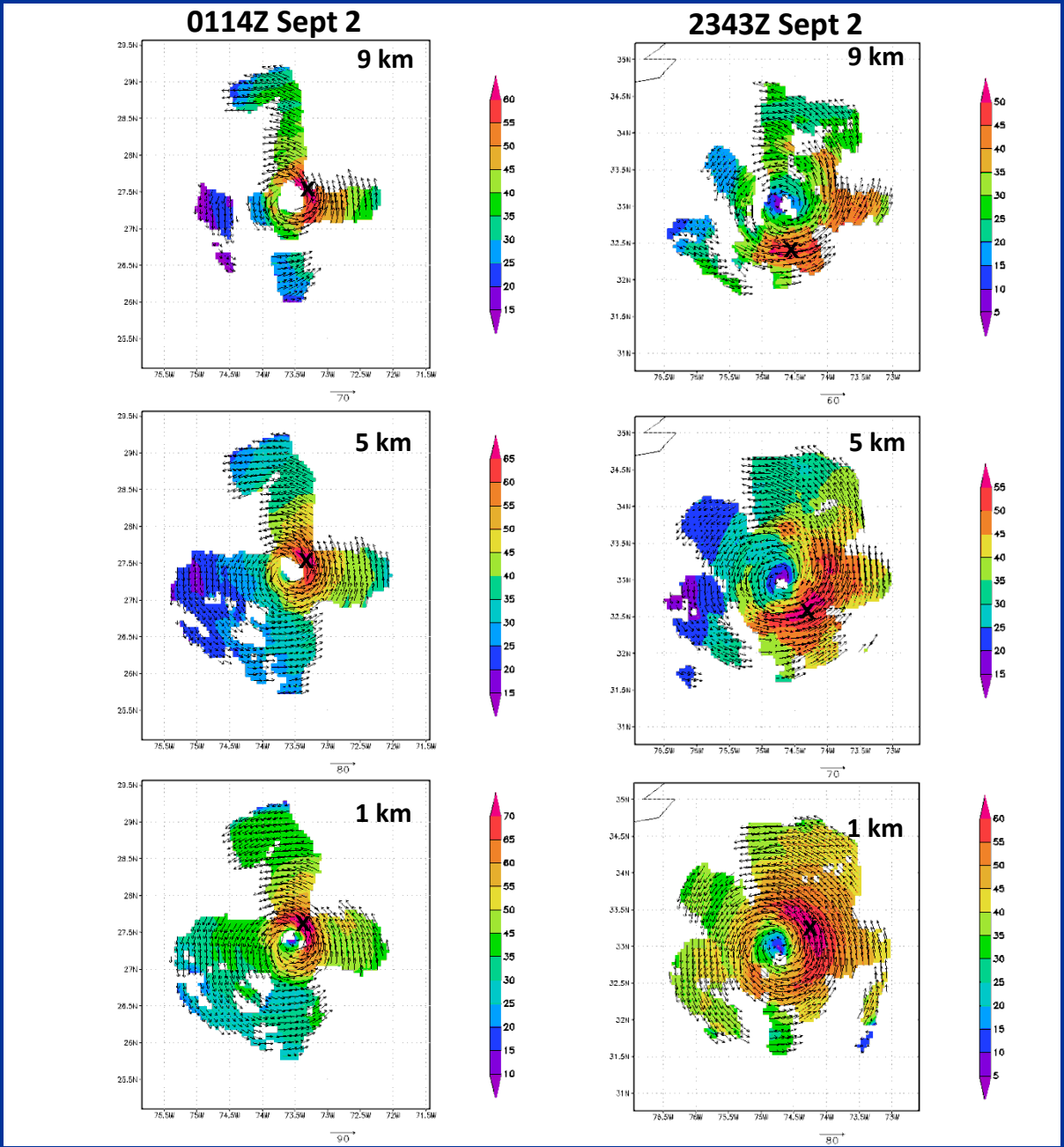


~ 2 h 30 min after first pass

Evolution of wind speed (shaded, m/s) from 1-9 km altitude during steady-state phase of Earl

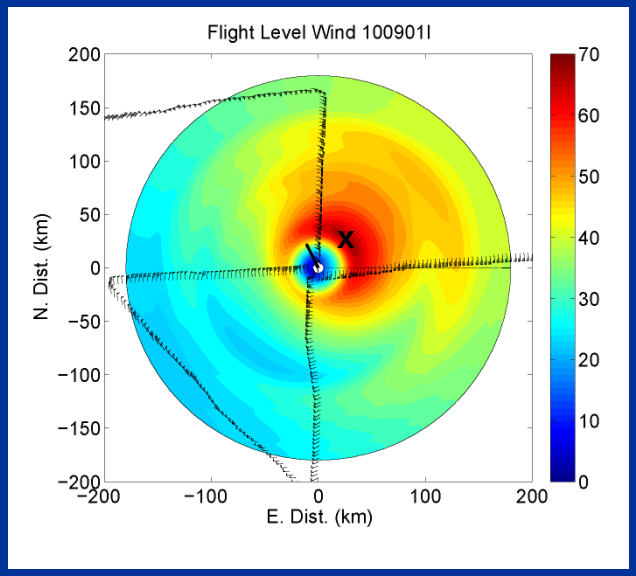


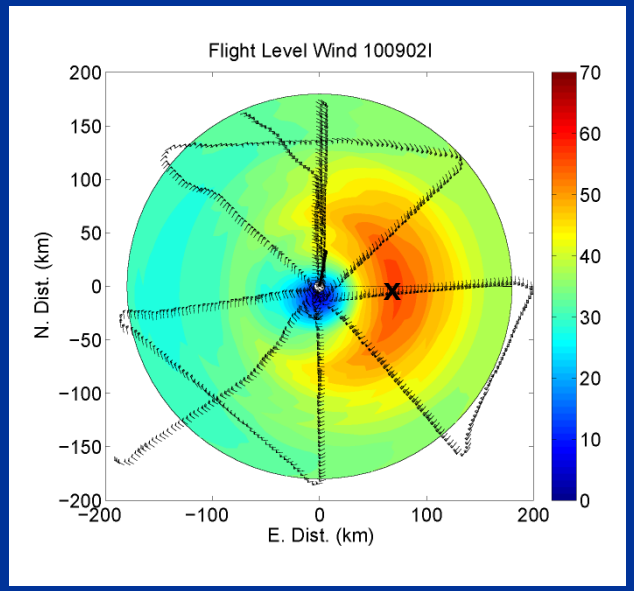
Surface and flight-level wind speed (shaded, m/s) during steady-state phase of Earl

Sept 1

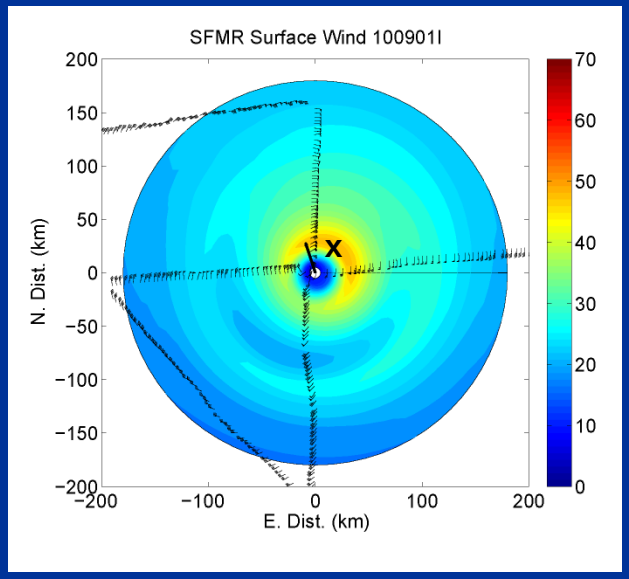
Sept 2

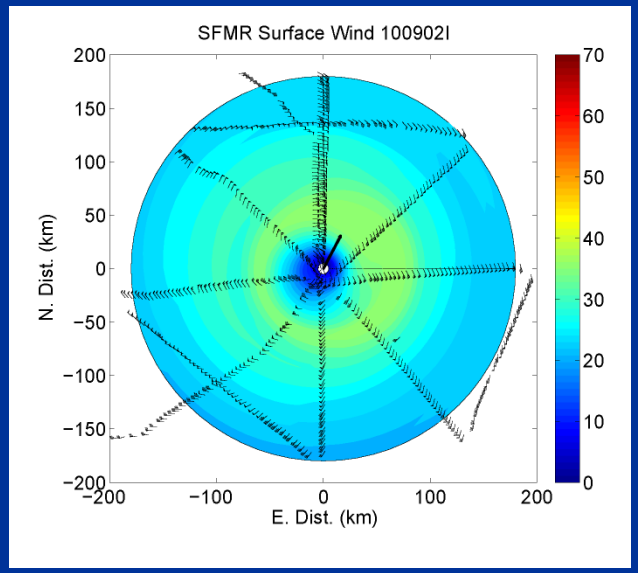
flight-level (~ 3.5 km)



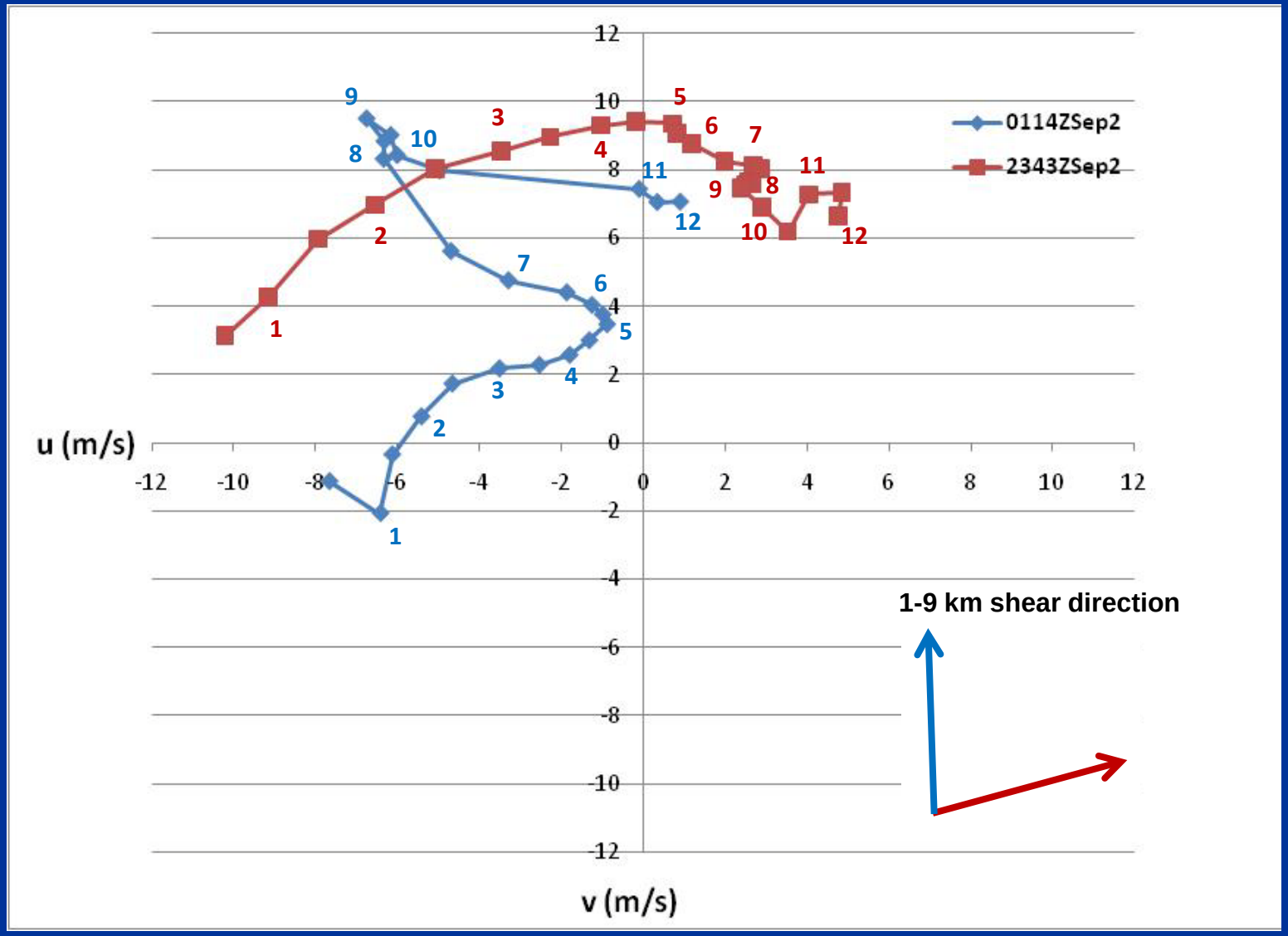


surface





Hodographs of inner-core winds (m/s) from 0.5-12 km altitude for Earl



Summary for Earl flights

- historic dataset collected in Hurricane Earl
- nearly complete lifecycle, sampled at 12-h intervals for inner core by P-3's, 24-h intervals for environment by G-IV
- significant RI episode sampled by Doppler radar prior to, during, and after
- steady-state period as a major hurricane sampled, including vortex interaction with increasing upper-level SW shear
- weakening stages sampled, including period leading up to ET

First thoughts on questions to address

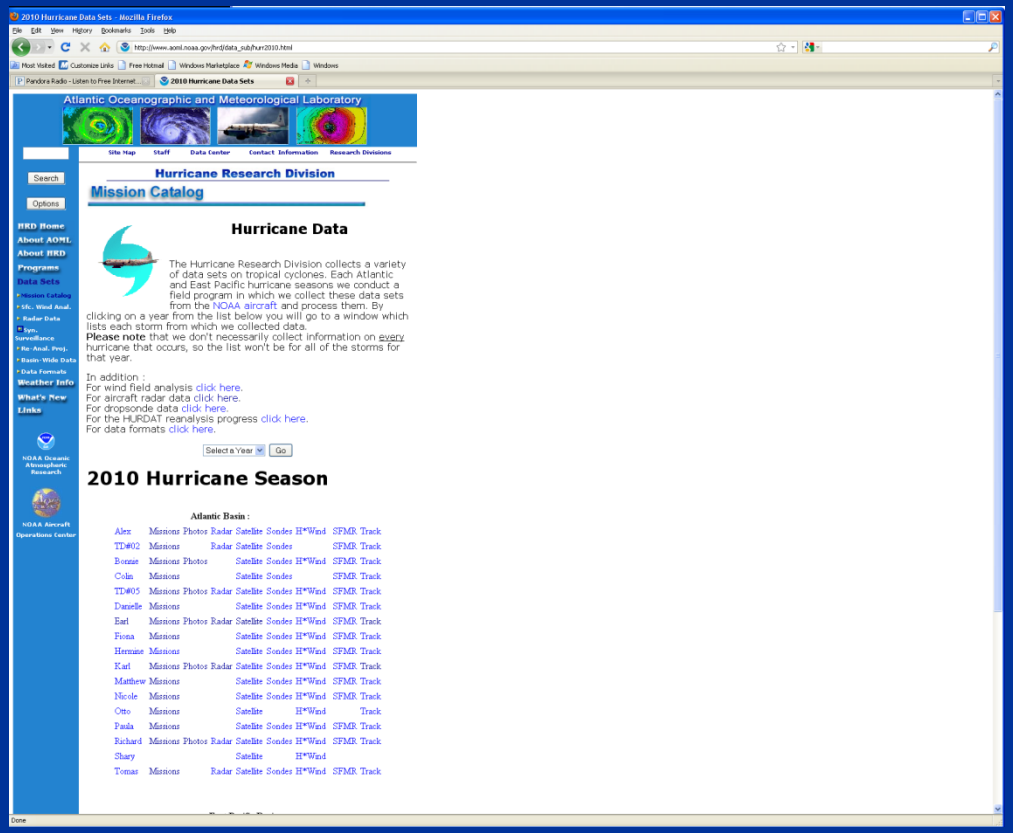
- how does vortex evolve during RI? Symmetric and asymmetric evolution? Kinematic and thermodynamic evolution?
- what's relative role of convective-, vortex-, and environmental-scale processes in RI?
- how does mature hurricane respond to increasing vertical shear (tilt, wind field asymmetries)?
- what is structural change during weakening and prior to ET?
- and many more…..

Summary

- Several objectives of IFEX for 2010 were accomplished
- Data assimilation system, numerical model advancing as inner-core data collection continues and model evaluation of inner-core structures begins
- Viability of new observing technologies demonstrated by working with NASA partners
- Excellent multi-scale dataset for RI collected in Hurricane Earl
  - near-continuous sampling of major portion of lifecycle, including significant RI event

Accessing the HRD data

http://www.aoml.noaa.gov/hrd/data_sub/hurr2010.html



- Review HRD data policy, at http://www.aoml.noaa.gov/hrd/datapolicy.html
- Flight-level and SFMR data (netCDF)
- Lower-fuselage, tail Doppler radar images (see John.Gamache@noaa.gov for data)
- Dropsonde data (multiple formats)
- Mission summaries
- H*Wind surface wind analyses
- See me (Robert.Rogers@noaa.gov) for additional questions and POC's