HFP-IFEX 2011 Field Experiments/ Modules Planning Meeting

Shirley Murillo

February 24, 2011

- **Purpose of Meeting**
- **IFEX overview**
- **Science experiments/modules**

Purpose of meeting

- Discuss flight experiment and modules
- Science review by audience
- Outcomes for this meeting and action items
- Upcoming HFP-IFEX related events
  - 28 Feb – 3 March IHC
  - 3 March (next Thursday) "PGI 2010 Season in Review"
    - starting at 1pm (AOML,1st Fl conf rm)
  - 22-24 March Aviation Water Safety Training
  - 11-12 May HFIP obs workshop (@ AOML)
  - (May) HFP-IFEX Logistics meeting
  - (May) Radar/Dropsonde/LPS training
  - (May) Aviation online safety courses and DVD viewing

IFEX Overview

IFEX Goals: Collect observations throughout the tropical cyclone (TC) life cycle

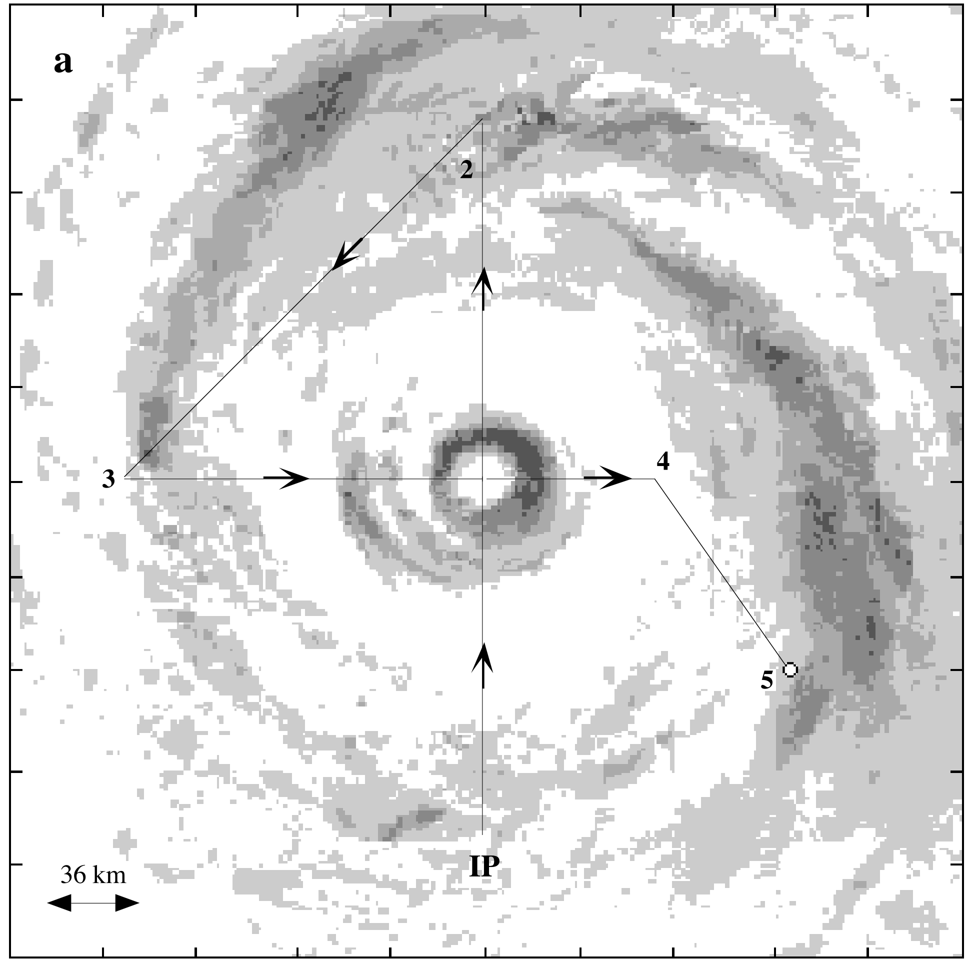
Develop and refine measurement technologies for real-time monitoring of TC structure and intensity

Improve understanding of the physical processes important in TC intensity change.

Bob Black - Microphysics Experiment

Microphysical Survey

- The IP is ~80 km from the center.
- Altitudes: Any, from 1.5 - 6.0 km
- IMPORTANT: DO NOT AVOID THE CONVECTION!!!



R. Black

What we think we know
(and what we don't)

- Rain water content as a function of reflectivity (mixing ratio and number concentration)
- Ice mixing ratio and number concentration near melting level.

- Cloud droplet concentration (any altitude)
- Supercooled cloud LWC
- Particle content (mixing ratio and number concentration) above 25K ft MSL

R. Black

Wish list

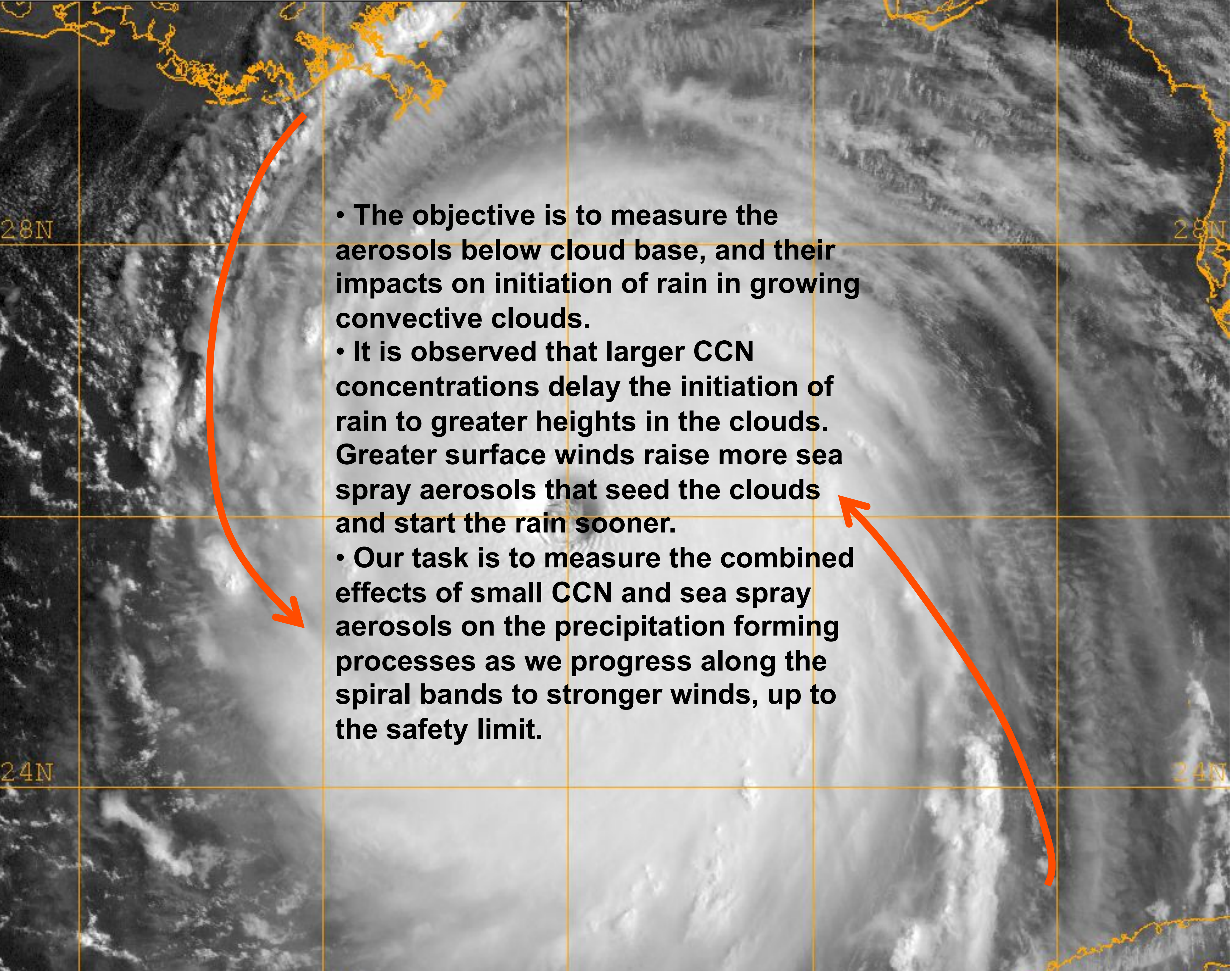
- Fly right down the convection in the heaviest rain
- Doesn’t have to be in the eyewall
- Up in the ice is important
- Duration in precipitation is needed

R. Black

Flight Patterns for Measuring Cloud-Aerosol Interactions

- Flights must be conducted visually, therefore only during daylight time.
- Preference should be given to events with high pollution or dust aerosols, because the majority of the situations are with relatively clean maritime air.
- Flights will be conducted from the very outer fringes of the spiral bands inward, up to the point where surface winds will be deemed by the pilots to be too strong for this flight pattern.
- CCN and cloud measurements well within the eye are highly desirable, and will be measured down to the lowest safe flight level there.

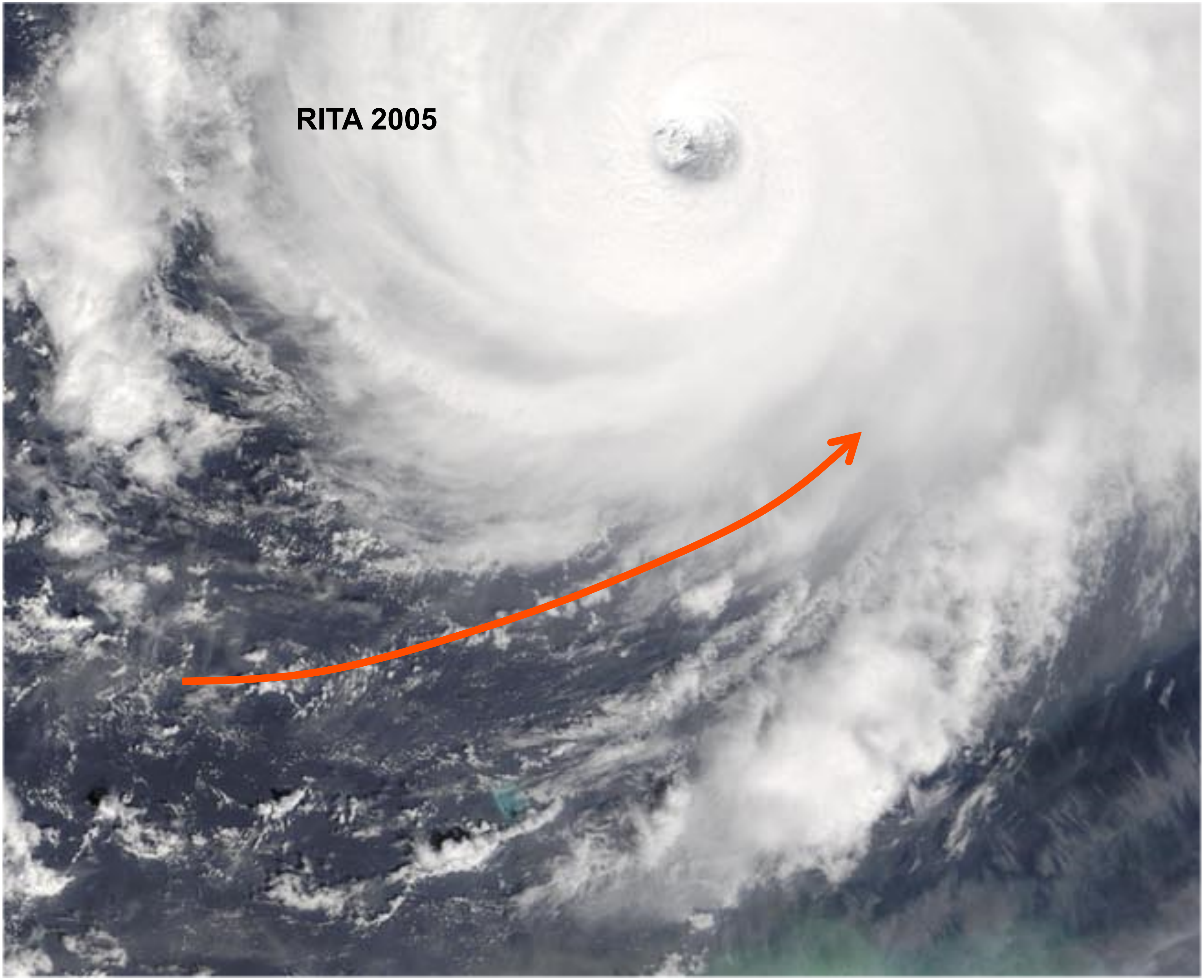
R. Black



• The objective is to measure the aerosols below cloud base, and their impacts on initiation of rain in growing convective clouds.

• It is observed that larger CCN concentrations delay the initiation of rain to greater heights in the clouds. Greater surface winds raise more sea spray aerosols that seed the clouds and start the rain sooner.

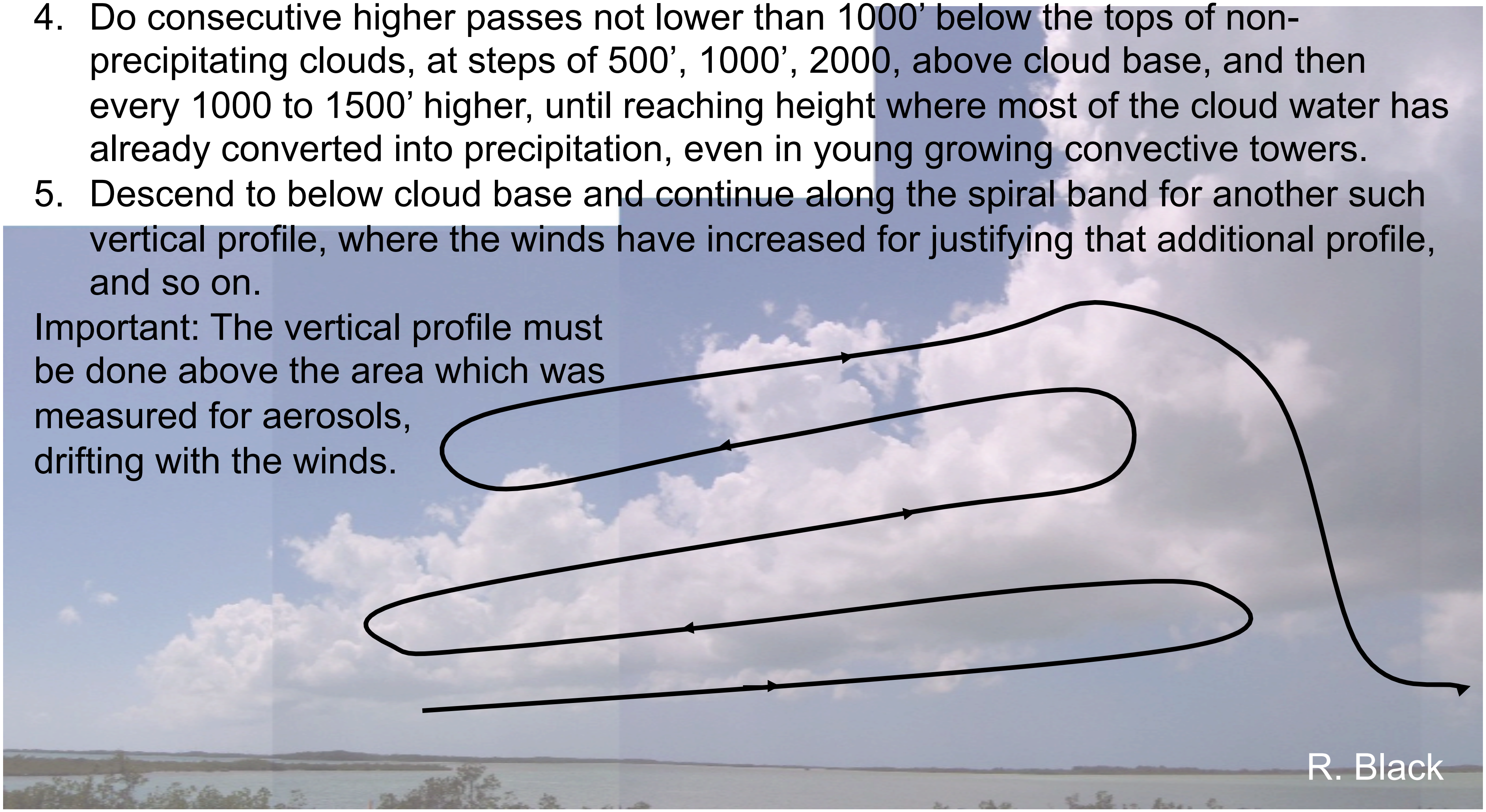
• Our task is to measure the combined effects of small CCN and sea spray aerosols on the precipitation forming processes as we progress along the spiral bands to stronger winds, up to the safety limit.

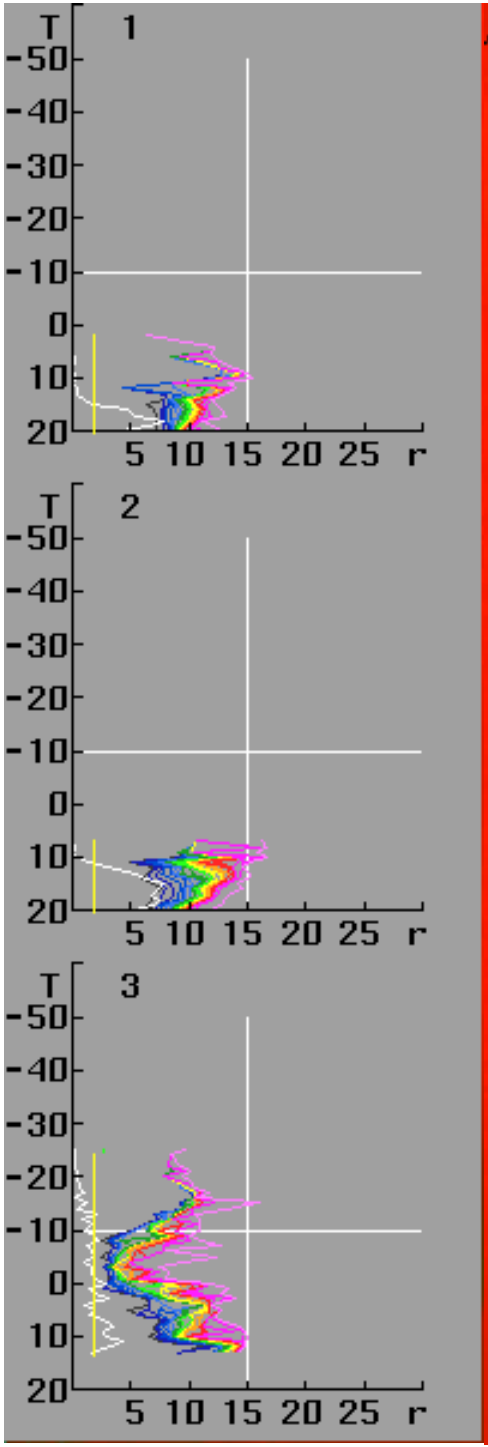

RITA 2005

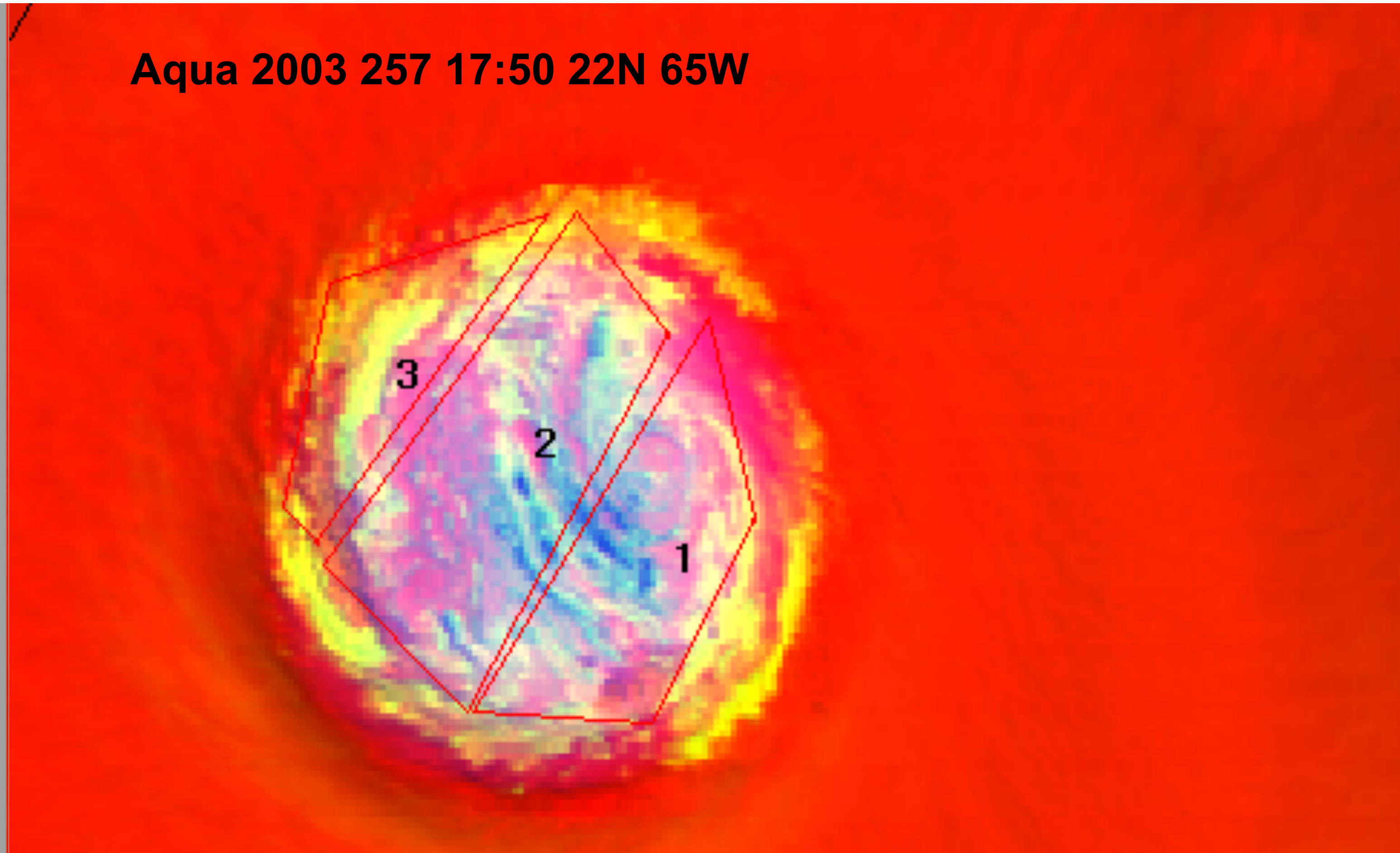
The measurements of the aerosols and clouds in the very outer spiral bands:

1. Select a segment with new growth of convective clouds with tops at varying heights, that are not under higher precipitating clouds.
2. Measure the aerosols and CCN spectrum below the cloud bases, but not in rain.
3. Measure non precipitating well defined lowest cloud base, such that the surface is barely visible, for at least 20 seconds cumulative time in cloud.
4. Do consecutive higher passes not lower than 1000’ below the tops of non-precipitating clouds, at steps of 500’, 1000’, 2000, above cloud base, and then every 1000 to 1500’ higher, until reaching height where most of the cloud water has already converted into precipitation, even in young growing convective towers.
5. Descend to below cloud base and continue along the spiral band for another such vertical profile, where the winds have increased for justifying that additional profile, and so on.

Important: The vertical profile must be done above the area which was measured for aerosols, drifting with the winds.







- Cloud drop effective radius in the eye is ~ 10 microns, which is much smaller than calculated by cloud models until now.
- Sample the clouds and aerosols inside the eye.
- The cloud top temperatures within the center of the eye reach the 10-15C isotherm level.
- Measuring the clouds and aerosols as low as safely possible is of great scientific importance.

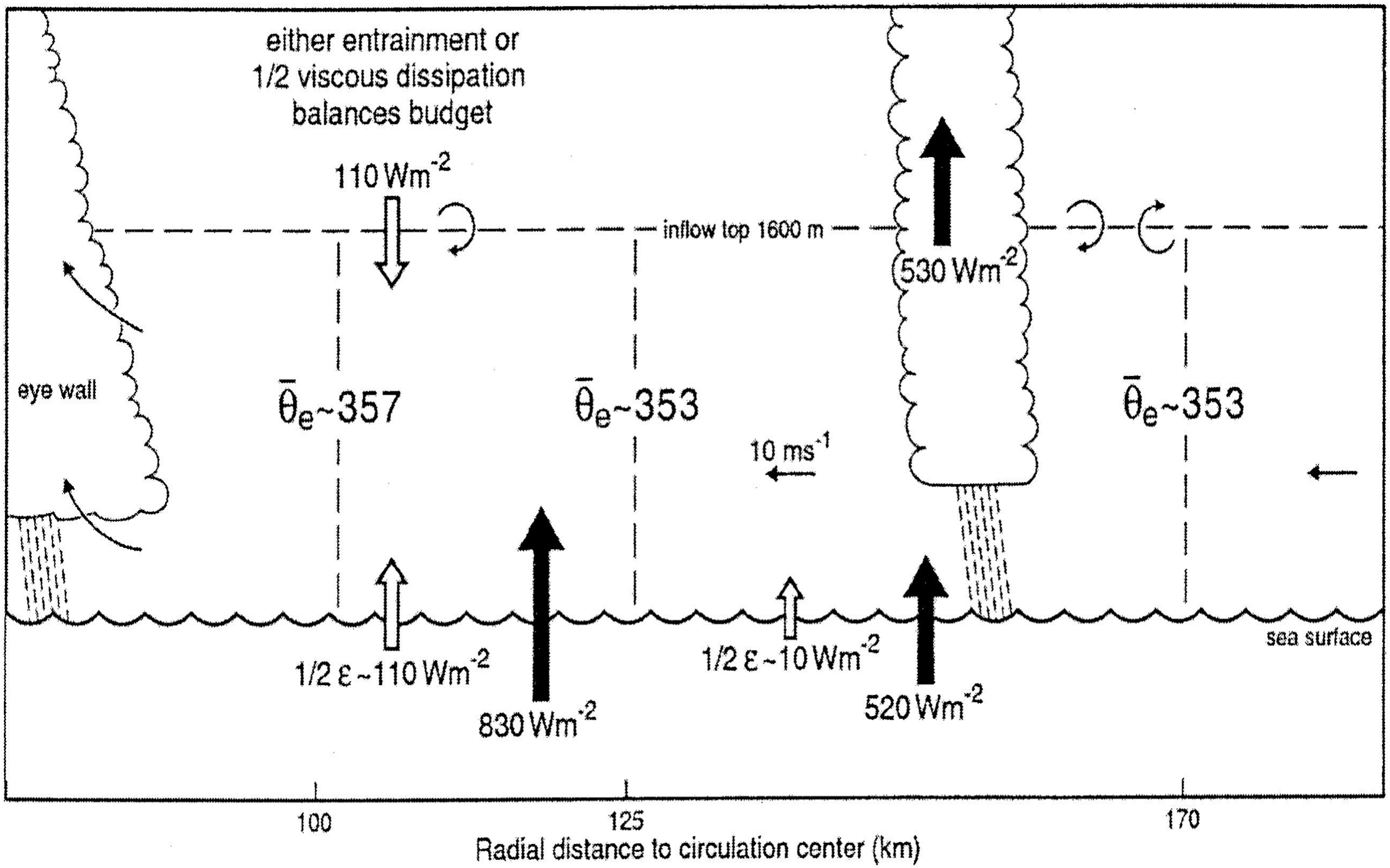
R. Bla


Interpretation of colors in the previous slide
Eye Wall
Mid level layer clouds
Low clouds in the eye
R. Black

Jun Zhang and Gary Barnes – Hurricane PBL Entrainment Flux Module

Hurricane PBL Entrainment Flux

Jun Zhang and Gary Barnes

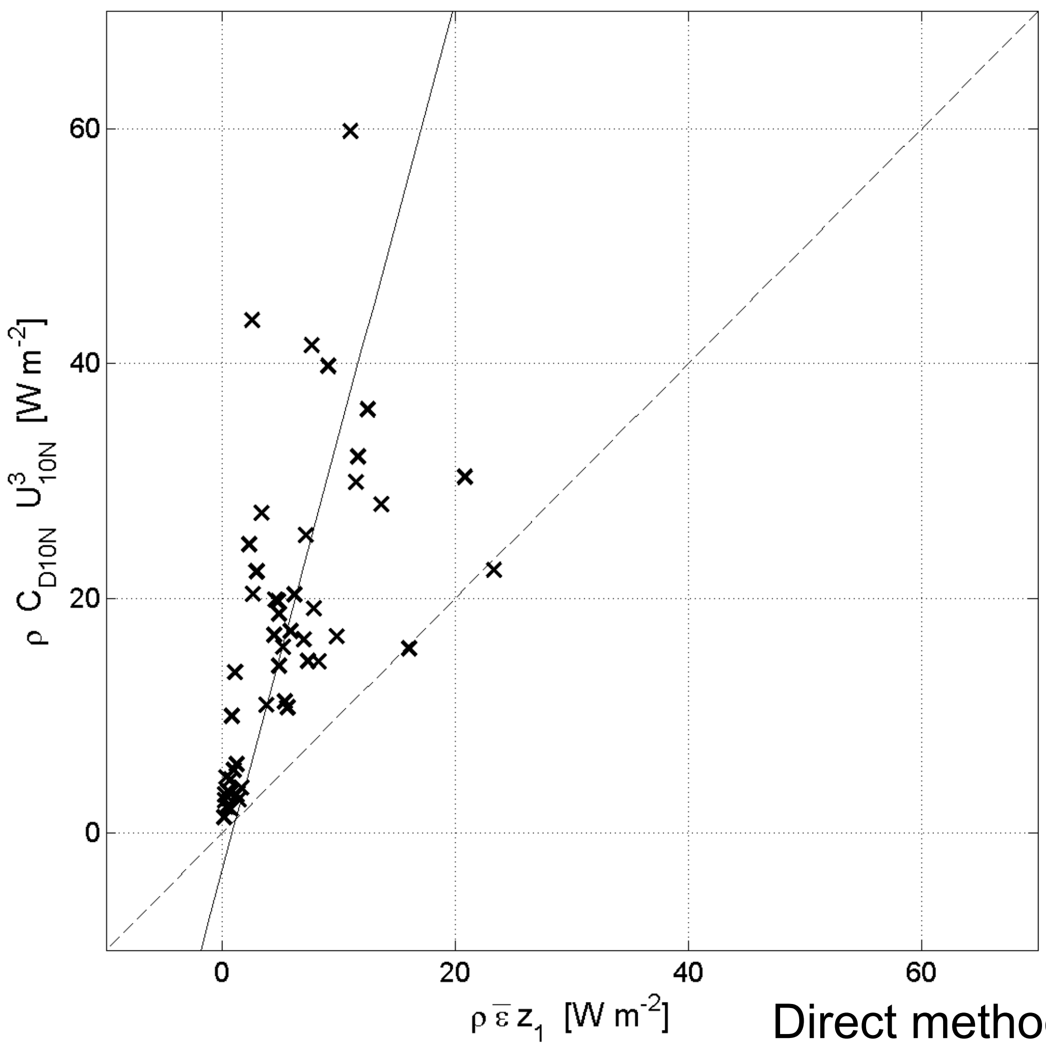


Wroe and Barnes 2003

J. Zhang

Dissipative heating

Zhang 2010



Direct method

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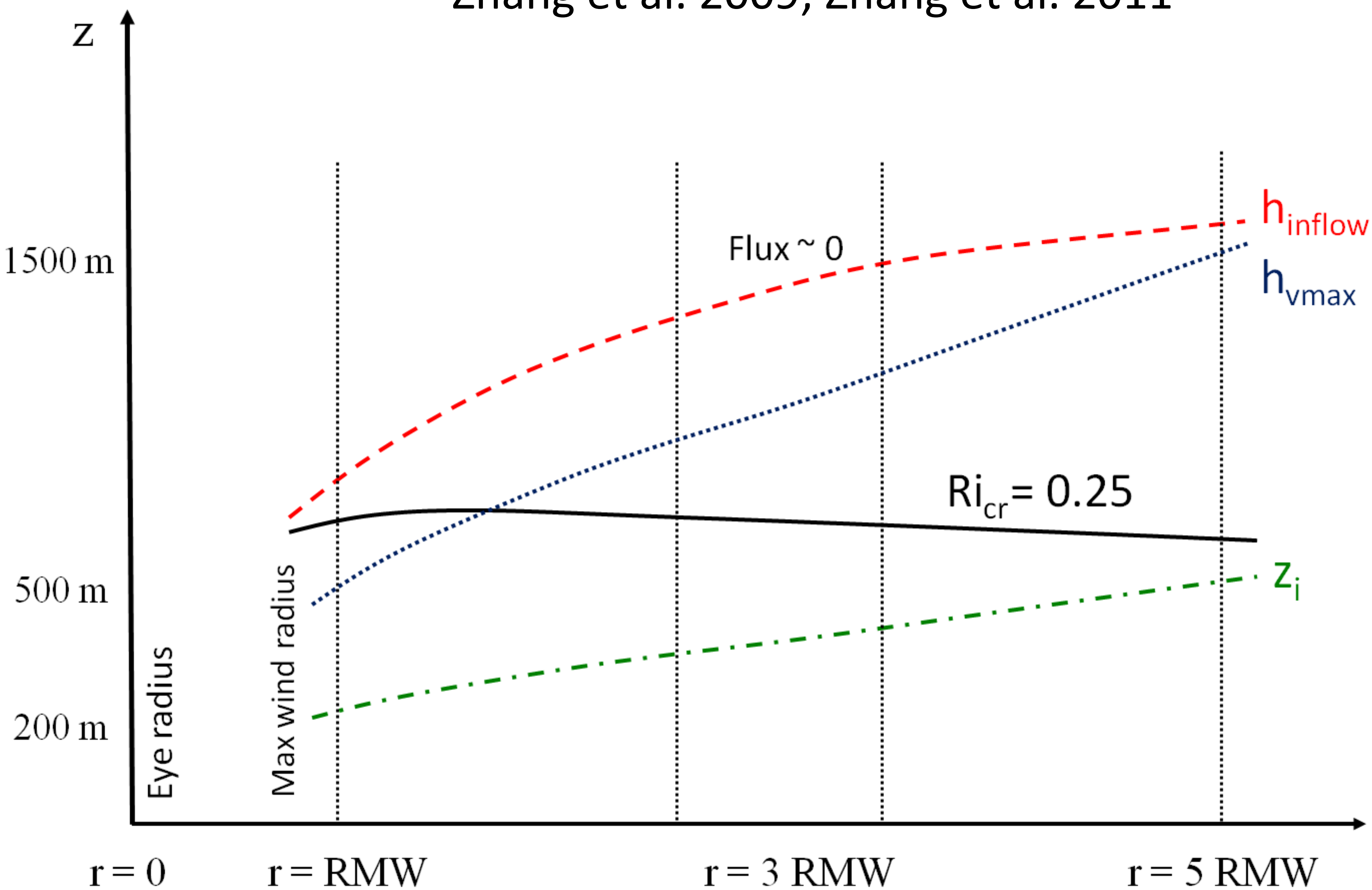
Where is the top of the hurricane boundary layer?

Zhang et al. 2009; Zhang et al. 2011



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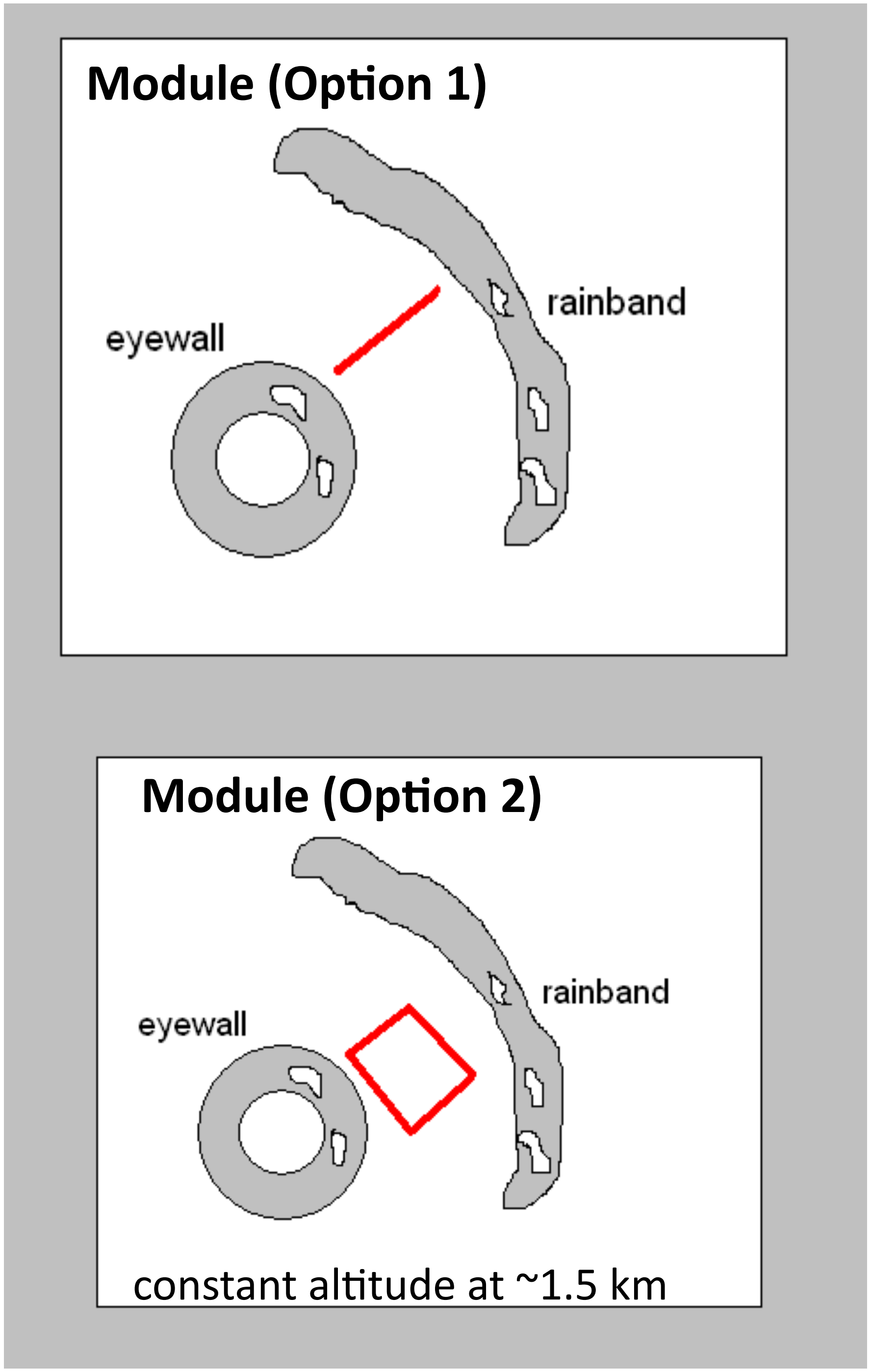
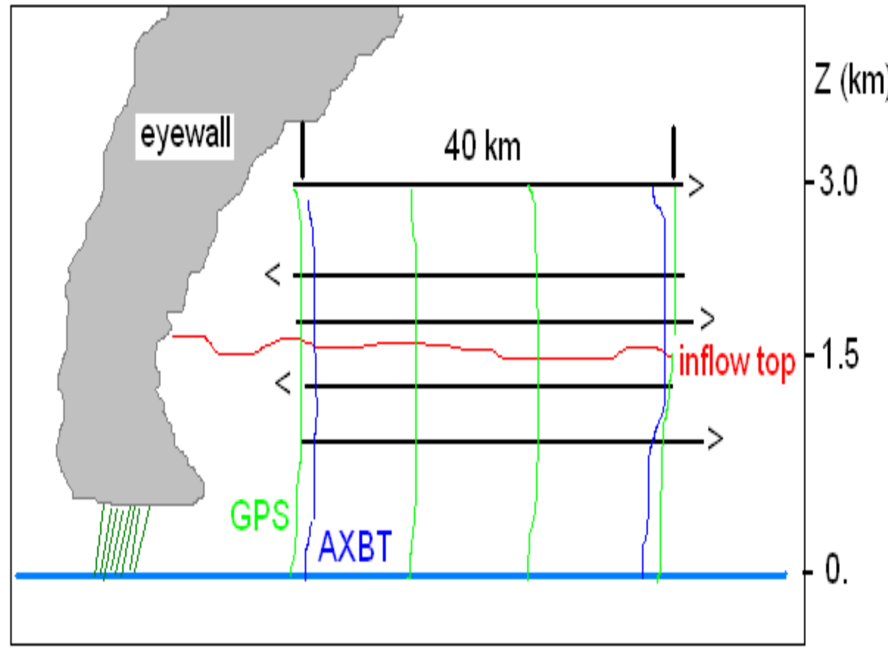


Module (Option 1) cross section



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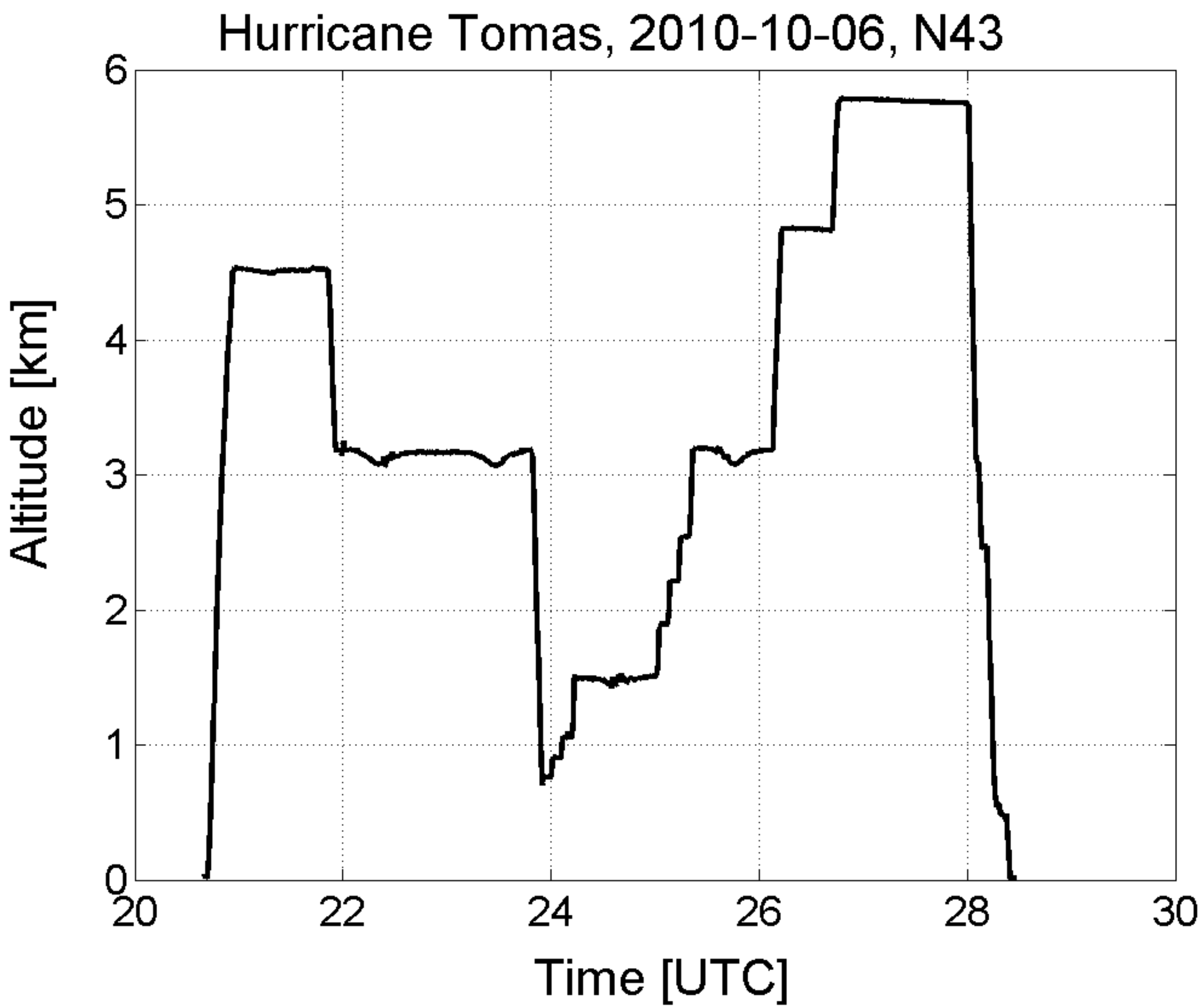
Sample flight from last year



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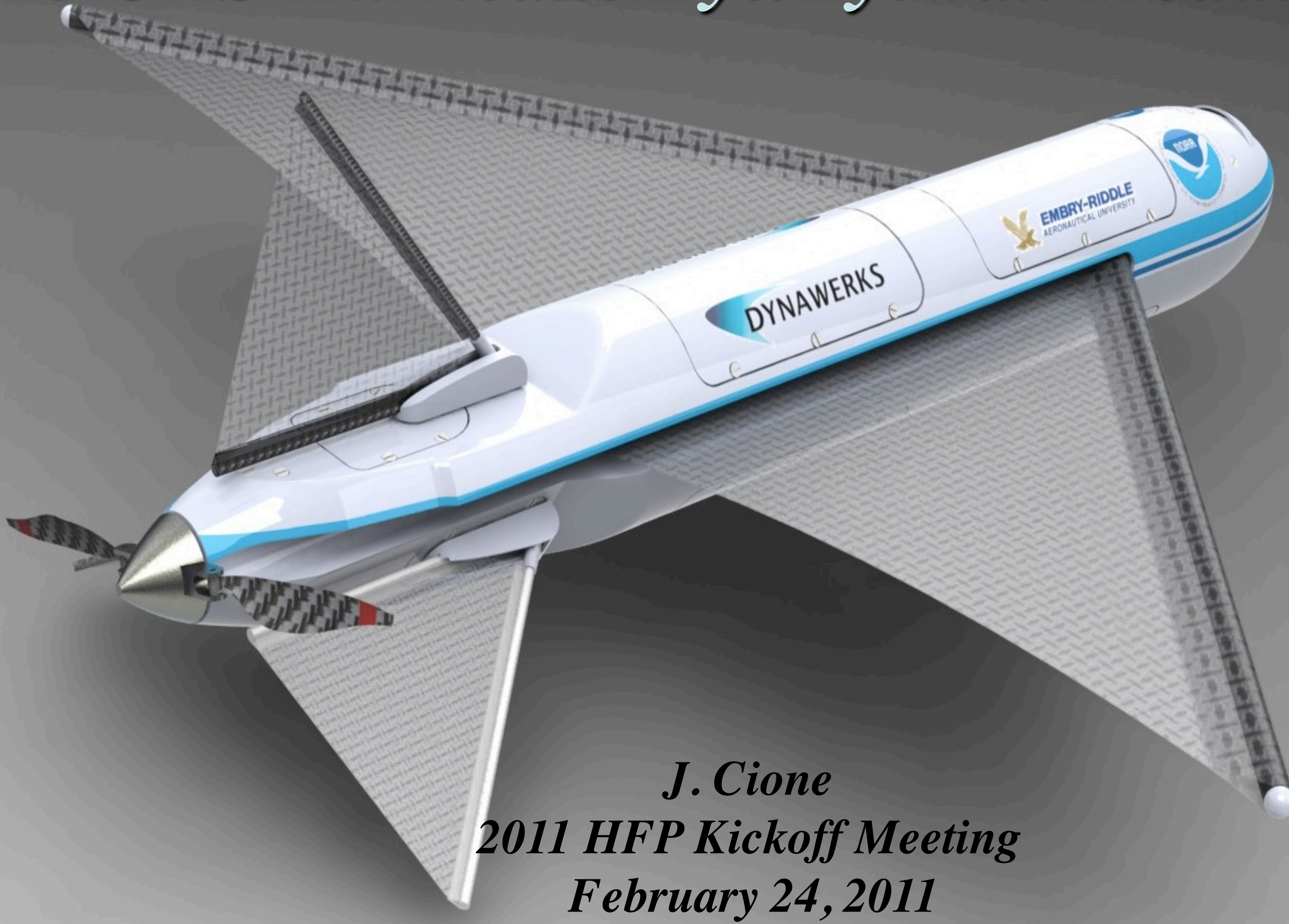
Joe Cione – UAS

P-3 UAS Hurricane Eye/Eyewall Module



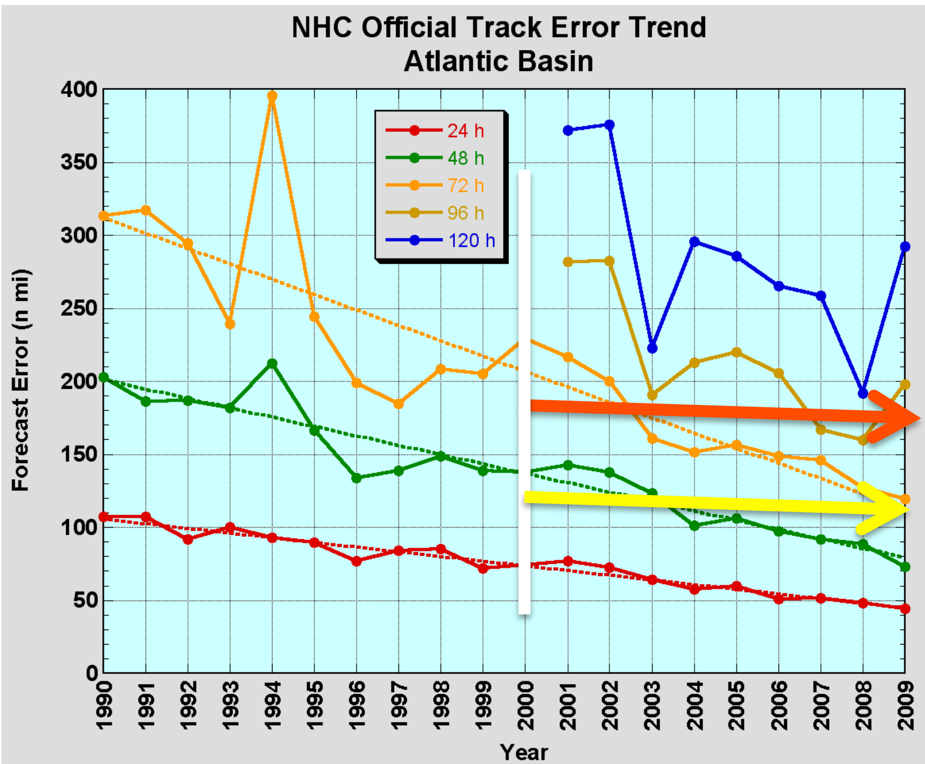
J. Cione

2011 HFP Kickoff Meeting

February 24, 2011

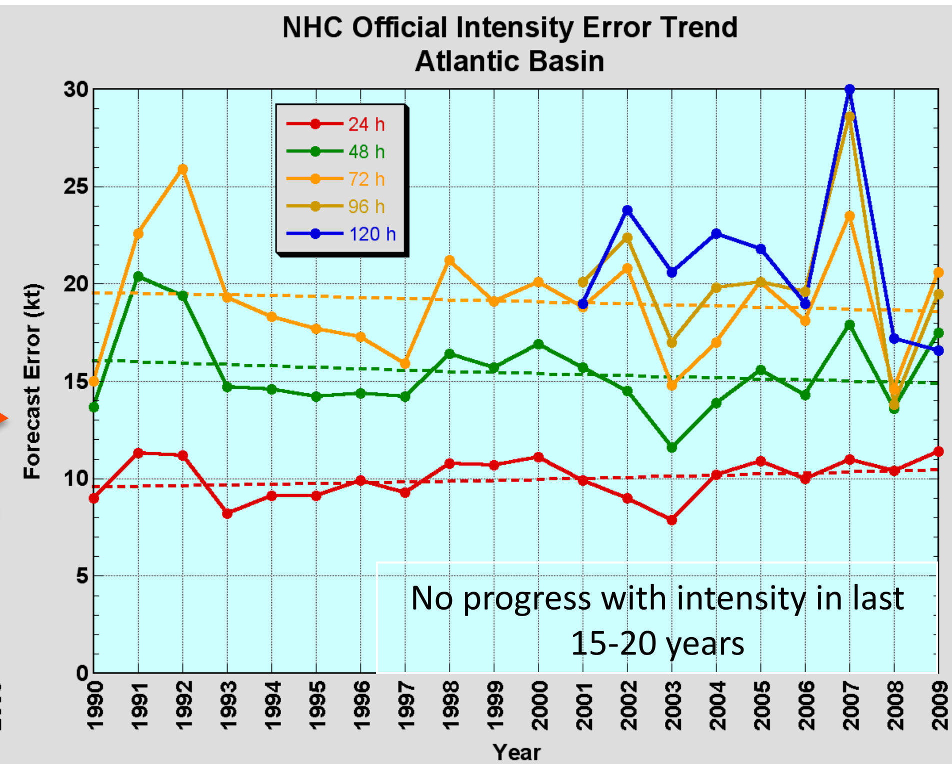
Long-term forecast trends….

The Good – track forecast improvements



- Errors cut in half over past 15 years
- 10-year improvement - As accurate at 48 hours as we were at 24 hours in 1999

The Bad - Intensity no real gains



- 24-48h intensity forecast off by **1** category
- Off by **2** categories perhaps 5-10% of time

J. Cione

Accurately predicting hurricane intensity change?
We have our work cut out for us…

* As previously mentioned, forecasts for hurricane track have slowly improved over the past 25 years. Not so much for intensity change….

Still, hurricane research is progressing and one particular area ripe for new observation and improved understanding is the rarely observed, yet critically important, high-wind hurricane boundary layer environment.

- ***Why rarely observed ?*** This severe weather environment (salt spray, 50ft+ waves, 50 m/s+ winds, deep cloud layers (satellite)) make it difficult for both in-situ platforms and remote sensing instrumentation to adequately provide reliable data on a consistent basis. Manned reconnaissance at low altitude is impossible due to the severe safety risks involved. As such, it remains a poorly understood and sparsely-observed region of the storm….

- ***Why critically important ?*** All storms ultimately get their energy from the sea. However, the process by which that thermal energy is extracted from the ocean to the atmosphere and ultimately converted to kinetic energy (i.e. high winds) has never been fully-documented and as such, is not fully understood. In order to improve our understanding of this important process, measurements of upper ocean temperature as well as high-resolution (in time and space) observations of atmospheric temperature, pressure, moisture and winds are required.

Today, analyses of boundary layer thermodynamic conditions in operational hurricane forecast models do not closely match the few observationally-based air-sea analysis currently available.

However, it stands to reason that improving numerical models to more accurately represent reality should ultimately lead to improved future forecasts of hurricane intensity change…

Tools to study the hurricane boundary layer environment:

UAS: Unmanned Aircraft Systems

Low Altitude Air-Deployed (LAAD)

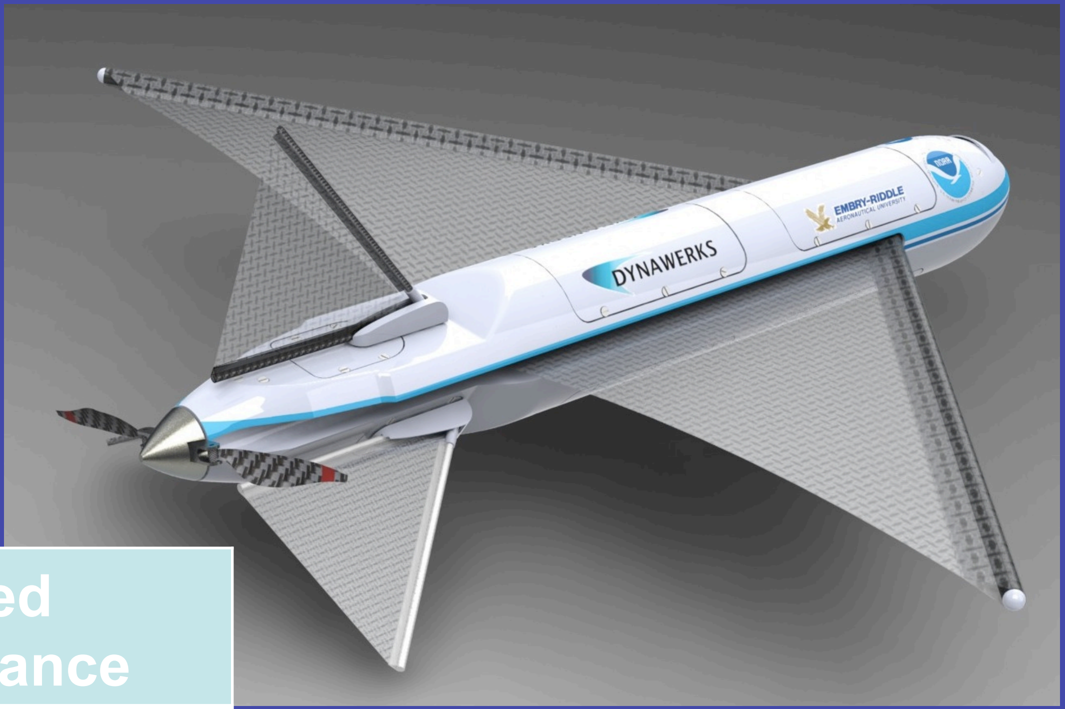
Gale (Embry Riddle; Dynawerks)
(2009-ongoing)

Primary Low Altitude UAS Mission Objectives:

- **Fill critical data gaps. Provide observations from an important region of the tropical storm that is very difficult (and dangerous) to observe.**
  - **Provide high resolution near-surface observations (V, P, T & RH)-**
  - **Ensure real-time data availability** (NHC/EMC & other collaborators/partners)
- **Fully demonstrate the UAS' platform's overall capabilities and survivability in a variety of meteorological conditions.**
  - ***Attempt to fly at very low altitudes ($\leq$200m) in high wind conditions***
  - ***Fully test the UAS platform's endurance***
  - ***Test the limits of onboard sensor capabilities (in a very harsh environment)***
  - ***Push operational feasibility limits as well…***
    - ***Mission readiness once we pull the pin (48h? 72h?)***
    - ***In-flight mission flexibility (how often and how fast can we adapt and adjust)?***
    - ***Multiple UAS configurations possible? (e.g. one in one out; 2 at once an option?)***
- **Utilize NOAA P-3 manned aircraft to further enhance the utility of UAS-tropical cyclone missions.**

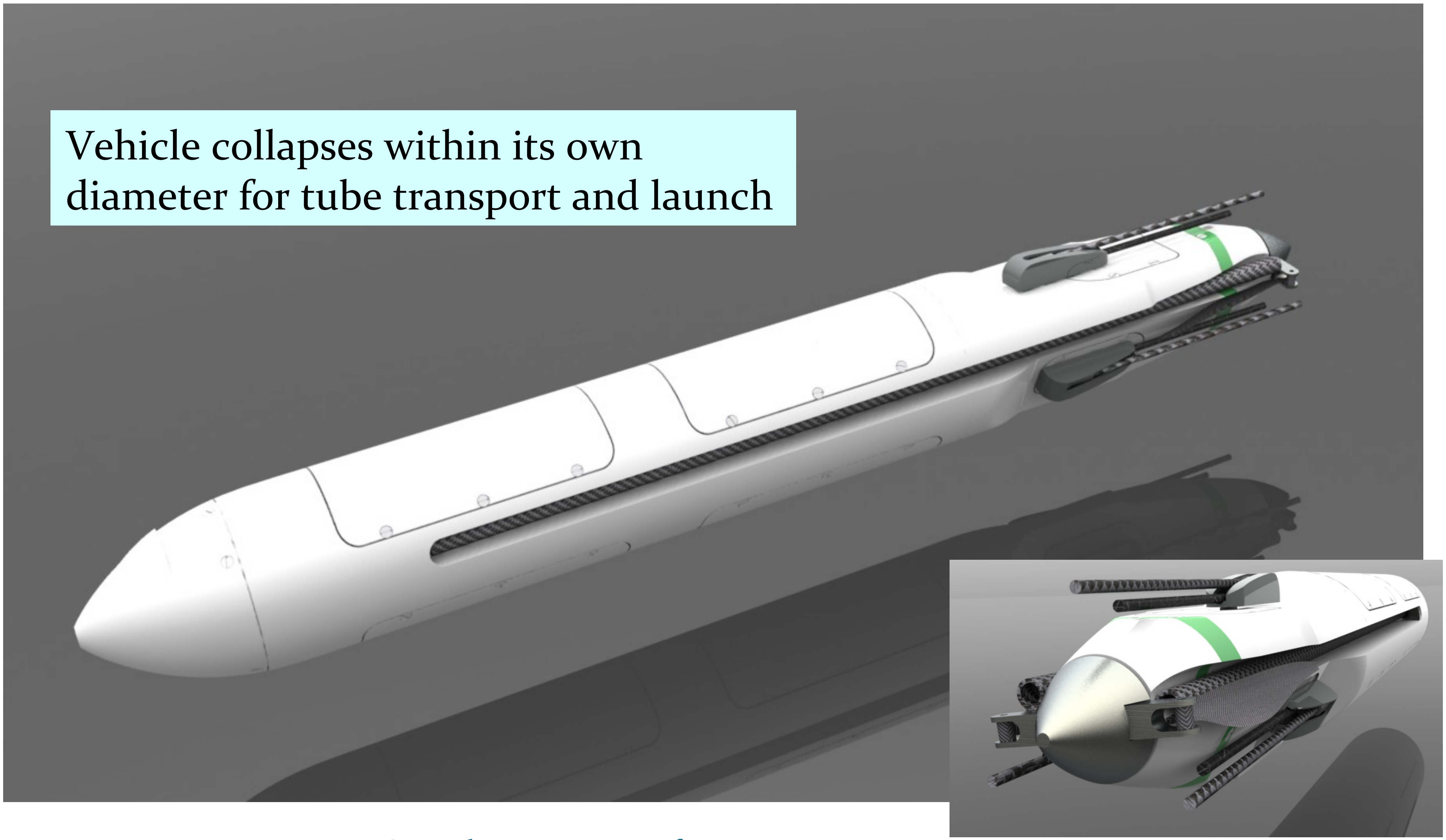
J. Cione

Gale UAS

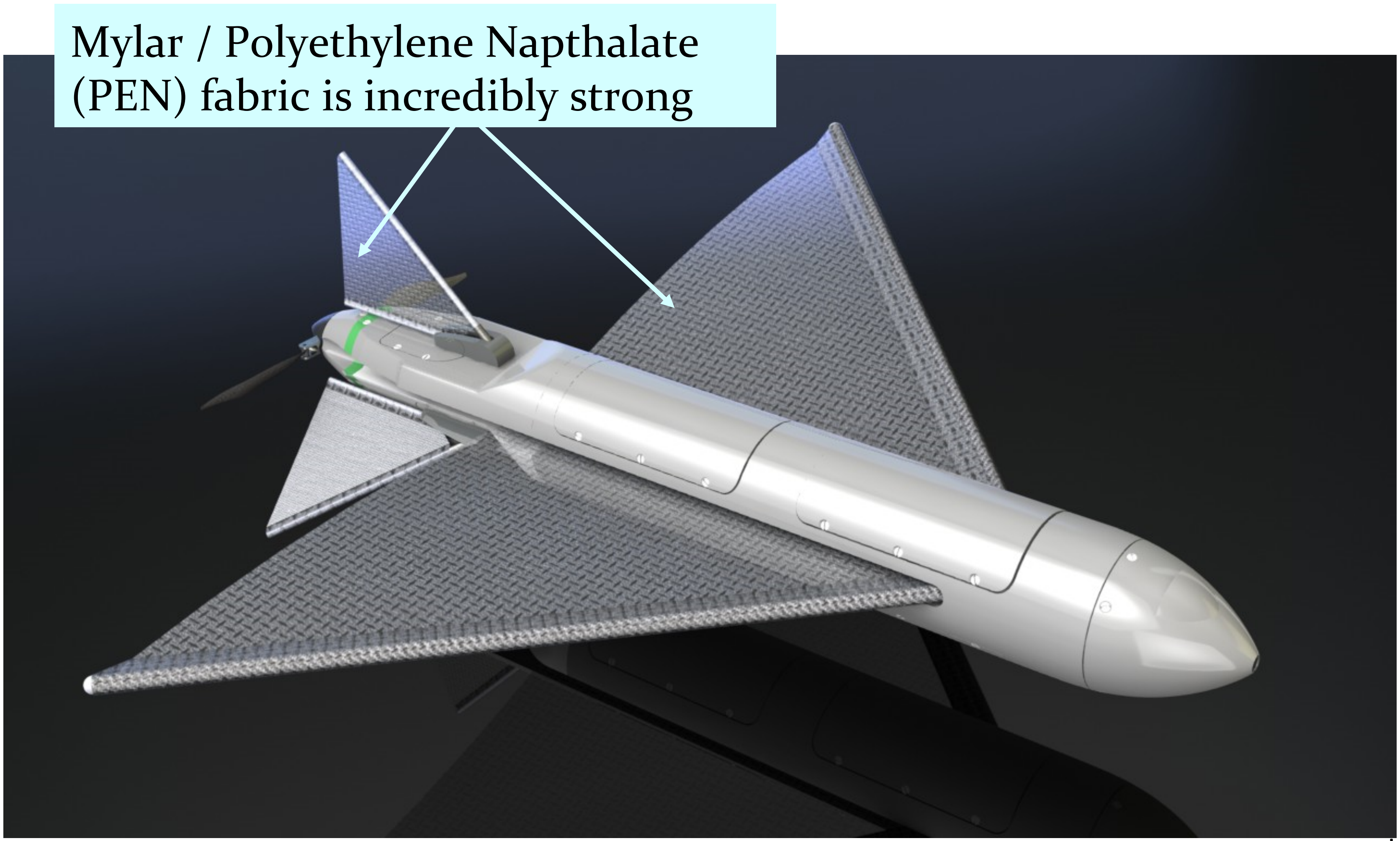


Performance Attribute	Estimated Performance
Mission Weight	8.0 lbm
Cruise Speed	42 kts
Dash Speed	110 kts
Stall Speed	22 kts
Mission Endurance	60 minutes

UAS Design Features



UAS Design Features (2)



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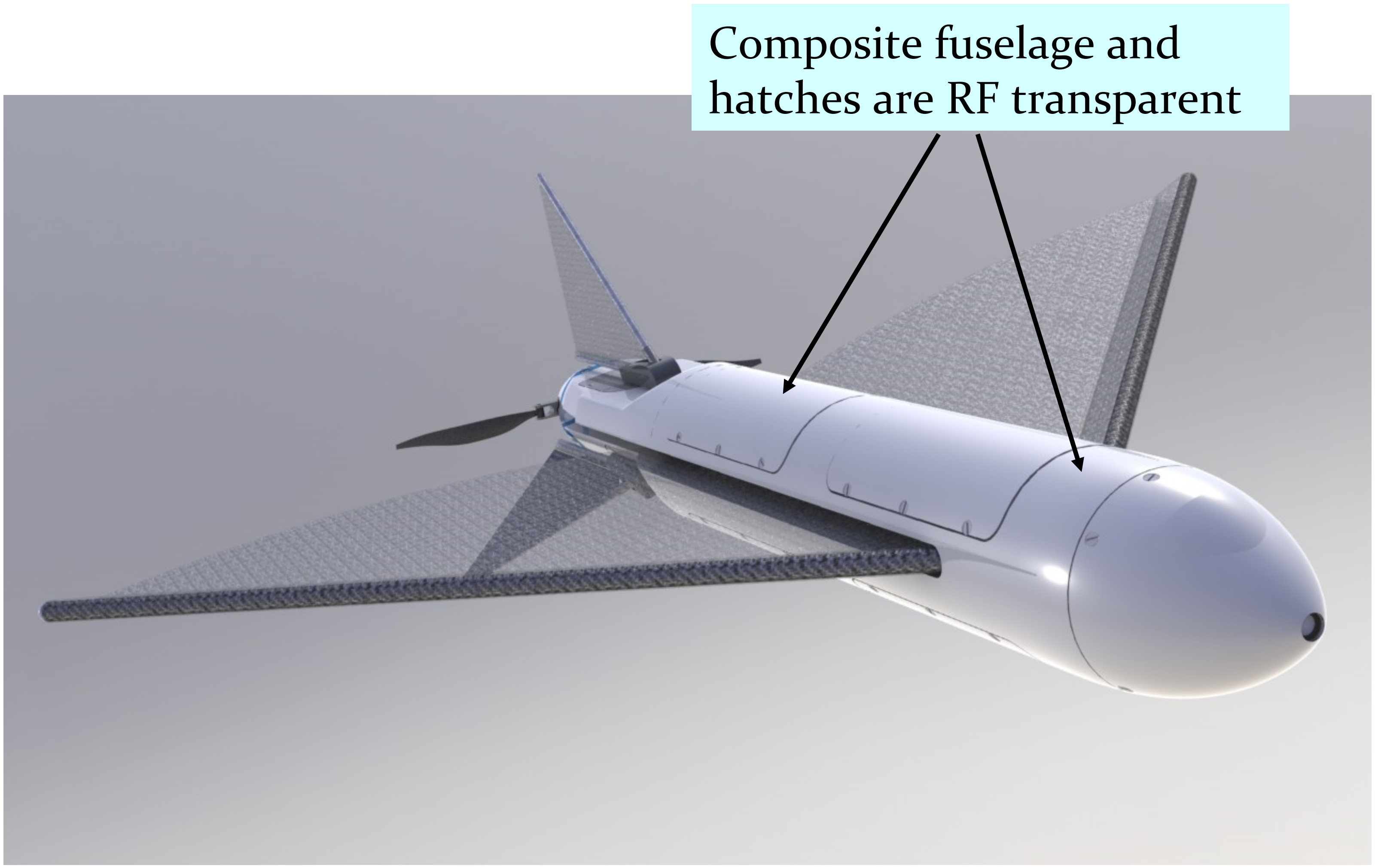
UAS Design Features (3)



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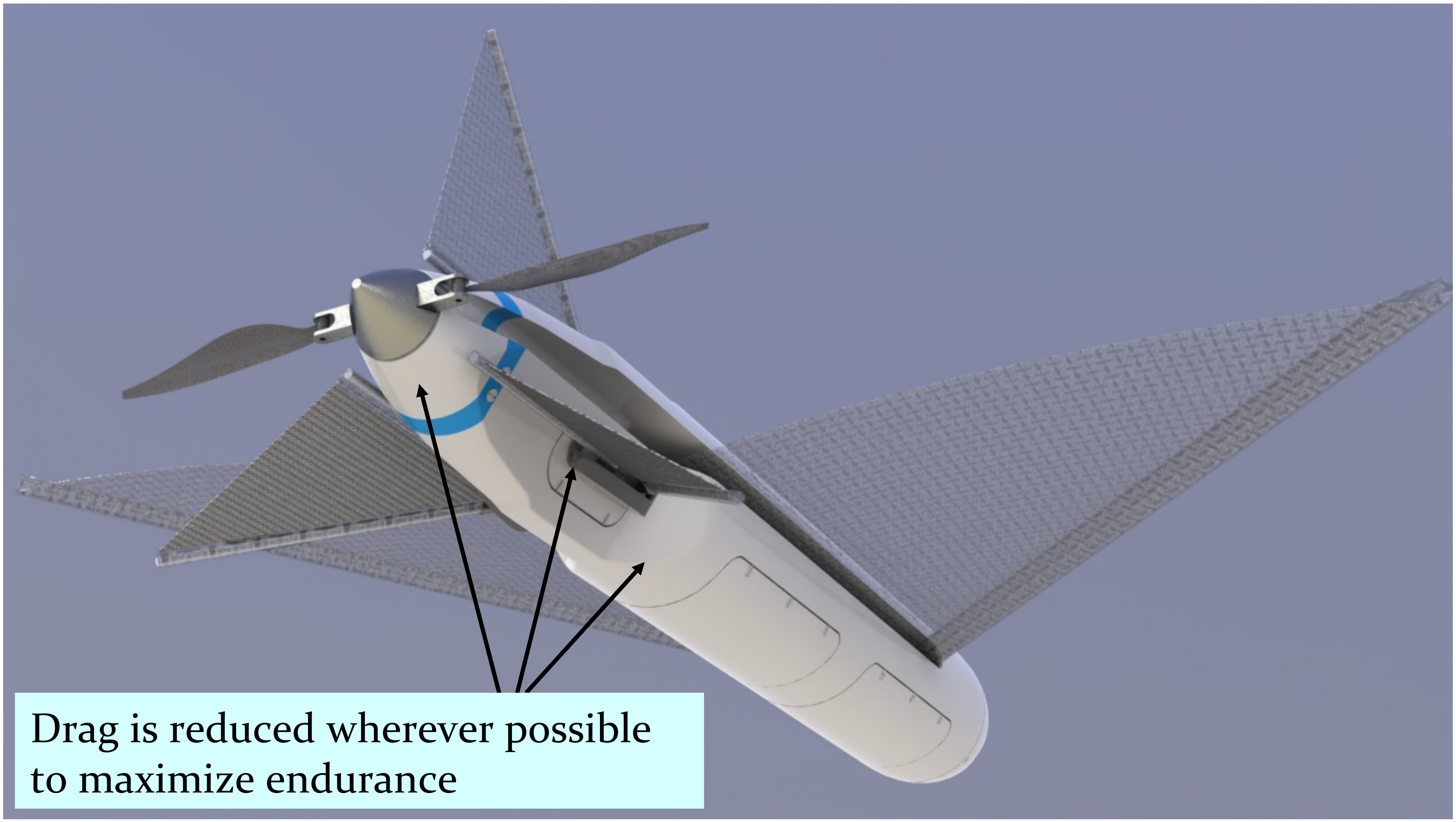
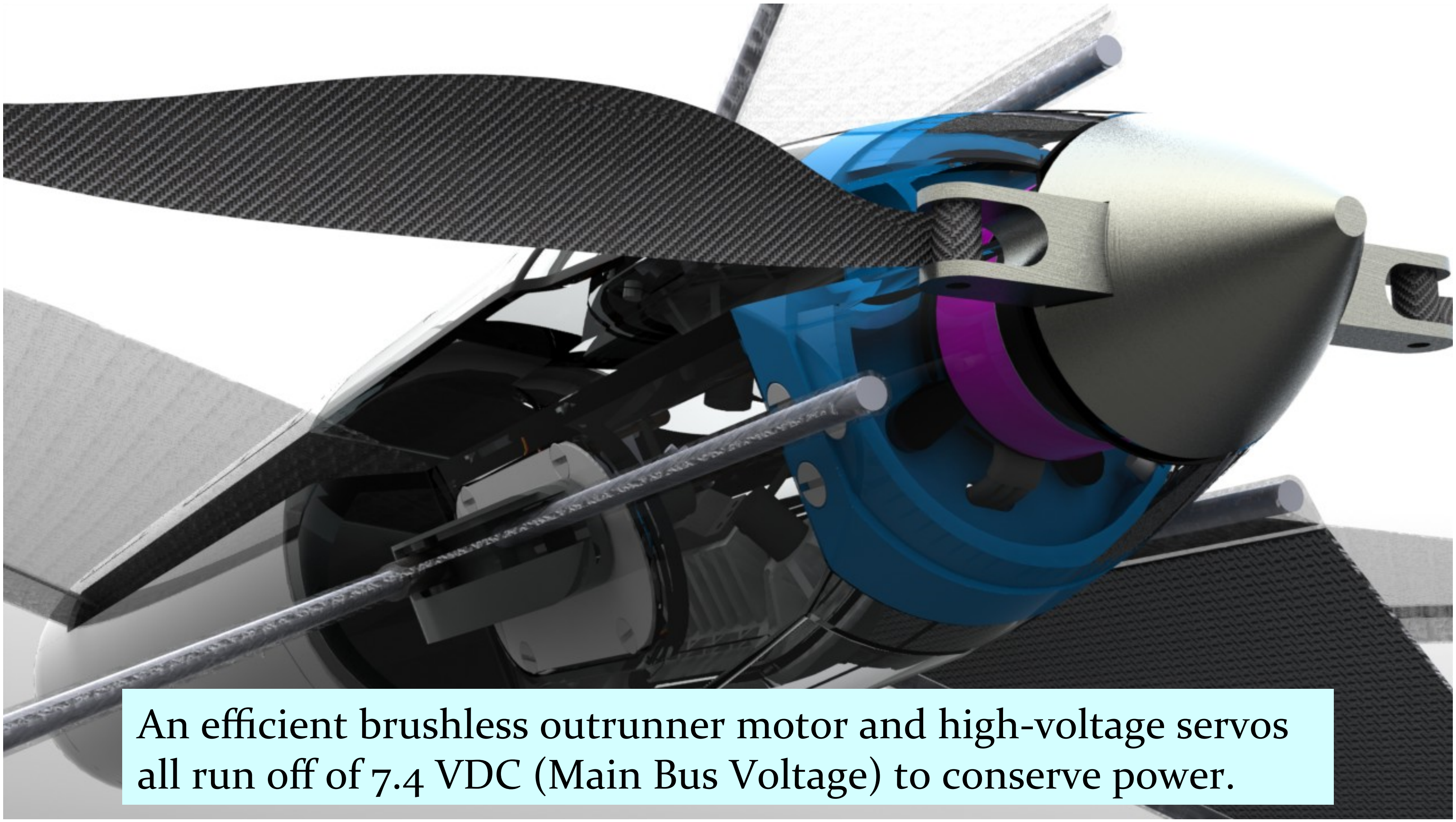
UAS Design Features (4)

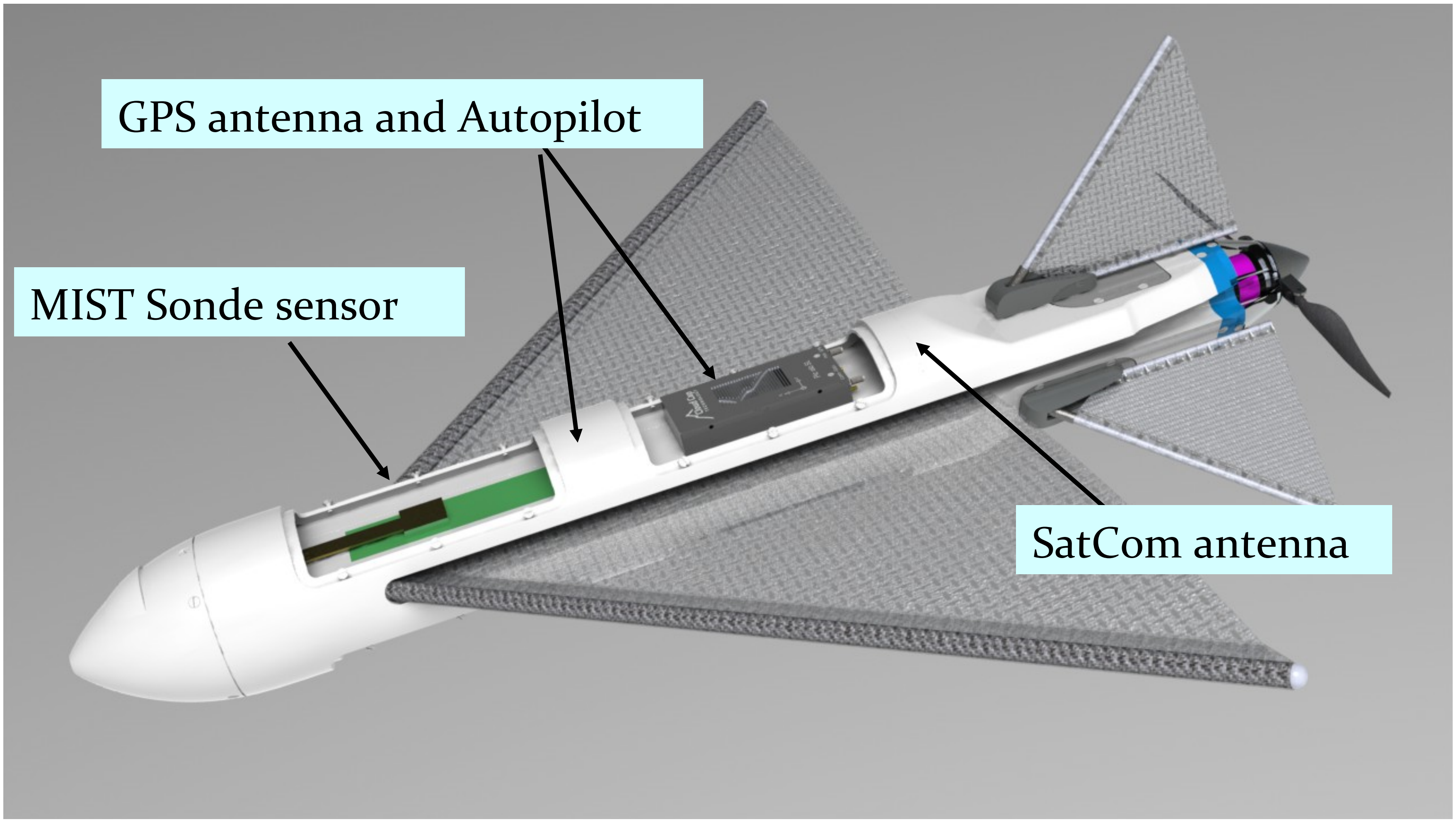


UAS Design Features (5)



An efficient brushless outrunner motor and high-voltage servos all run off of 7.4 VDC (Main Bus Voltage) to conserve power.

UAS Design Features (7)



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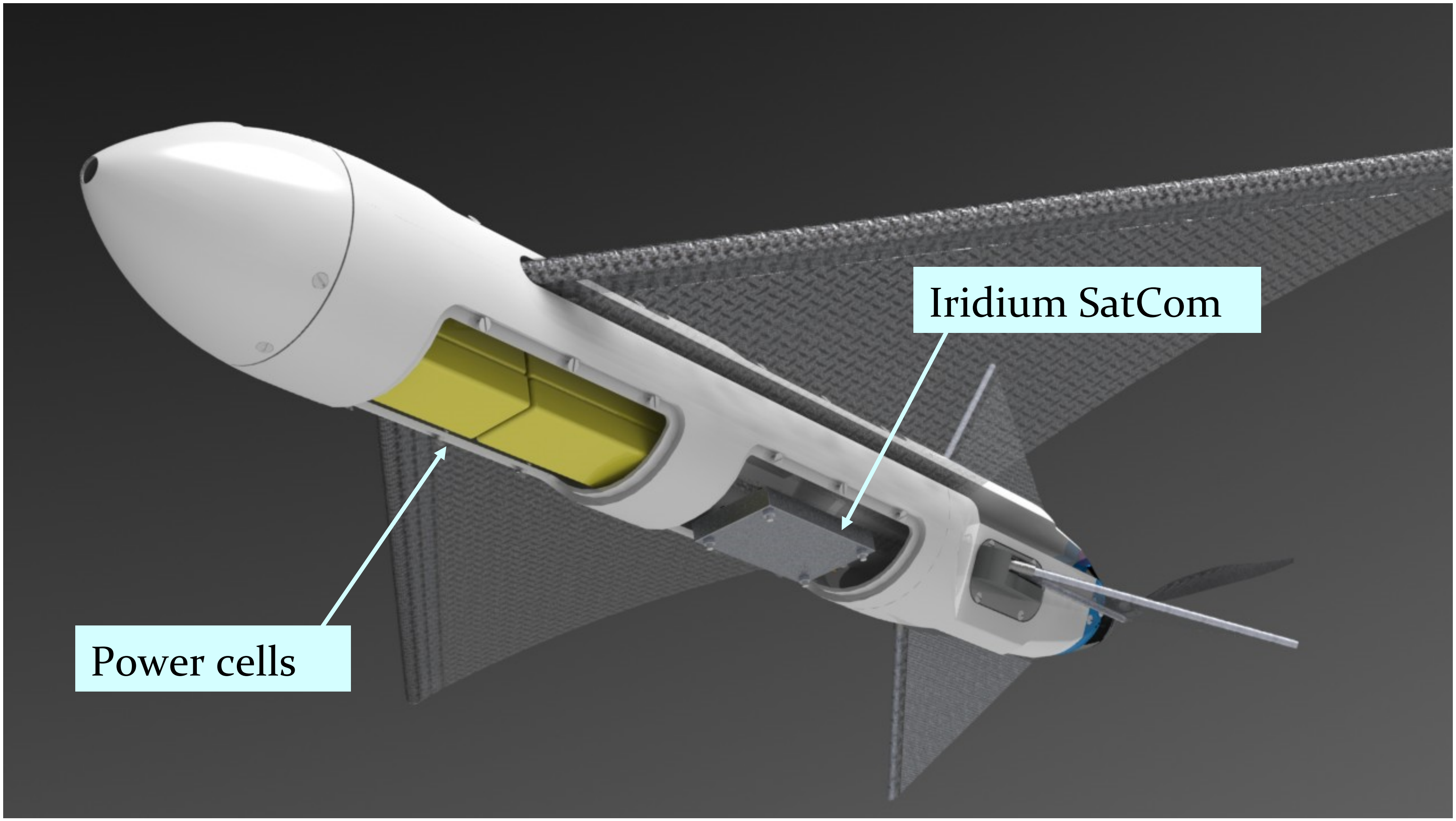
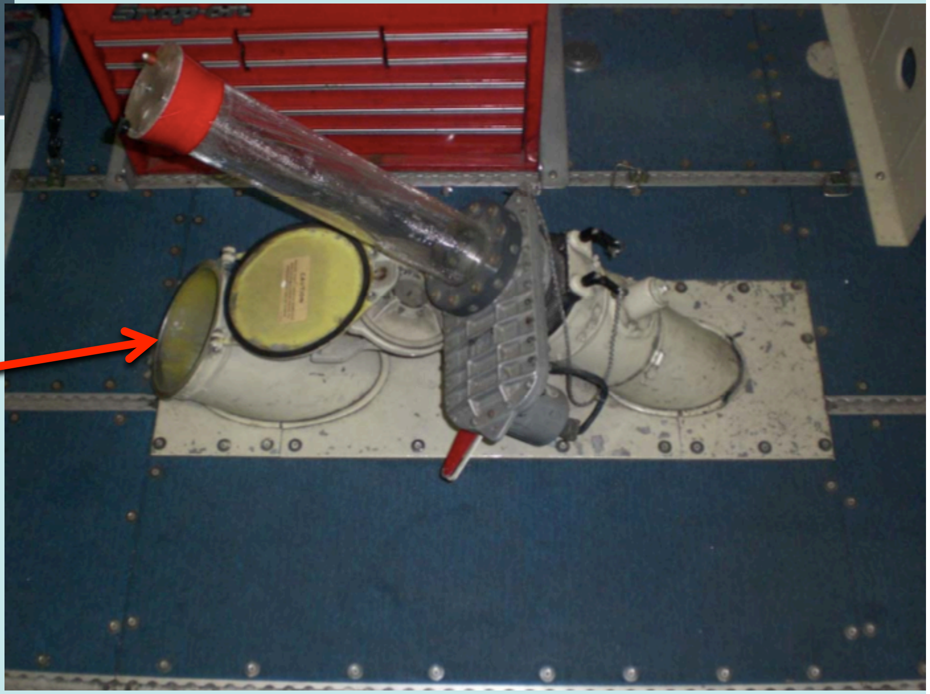
UAS Design Features (8)



NOAA WP-3D Aircraft



Free-fall AXBT chute

J. Cione

Air-deployed UAS Tropical Cyclone Mission Possibilities…

EYE SOUNDING/LOITERING/EYEWALL EXPERIMENTS-

Research objectives:

- **Improve understanding of TC eye/eyewall heat, moisture and momentum exchange processes;**
- **Continuously monitor TC intensity with the possibility of capturing a rapid intensity change event.** ***(This particular module for 2011 would be proof-of-concept only since capturing TC intensity change would require multiple back-to-back GALE UAS launches.)***

Mode of UAS transport: As the "launch, command and control" P-3 conducts orbits within the eye at altitude (10,000ft), the UAS would initially be deployed in the eye and then circumnavigate ($r \leq 50$km) the hurricane eyewall. For the TC monitoring/intensity change module, the UAS would provide PTHU profile and near surface data within the hurricane eye.

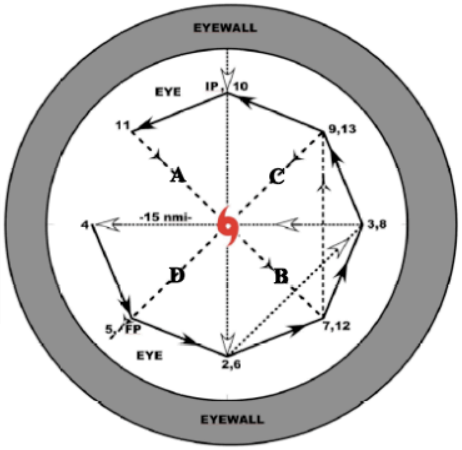
Potential operational benefits?

1. **Unique -continuous- measurements of near-surface winds in the eyewall. Should potentially help NHC better estimate 'maximum surface wind speed'.**
2. **Possible early detection of a rapid intensity change process as 'loitering' in the eye takes place.**

J. Cione

Operational Flight Plan: Eye Module

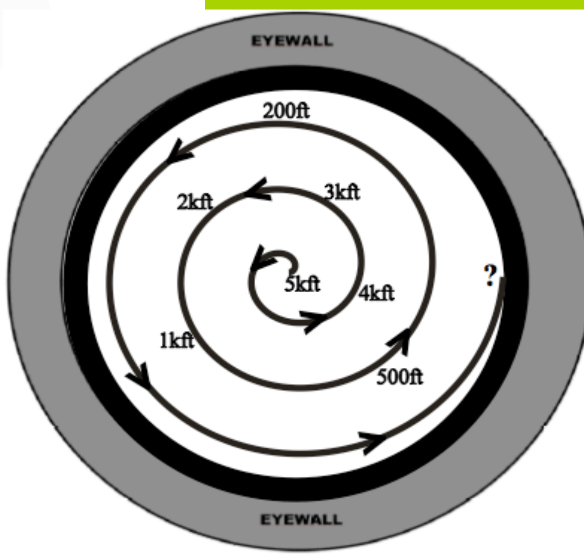
UAS - P3 Mature Hurricane Eye Module



P-3 FLIGHT PATTERN

P-3 Altitude 10,000 feet

- 14 Dropsondes launched
- 9 AXBTs launched



UAS FLIGHT PATTERN

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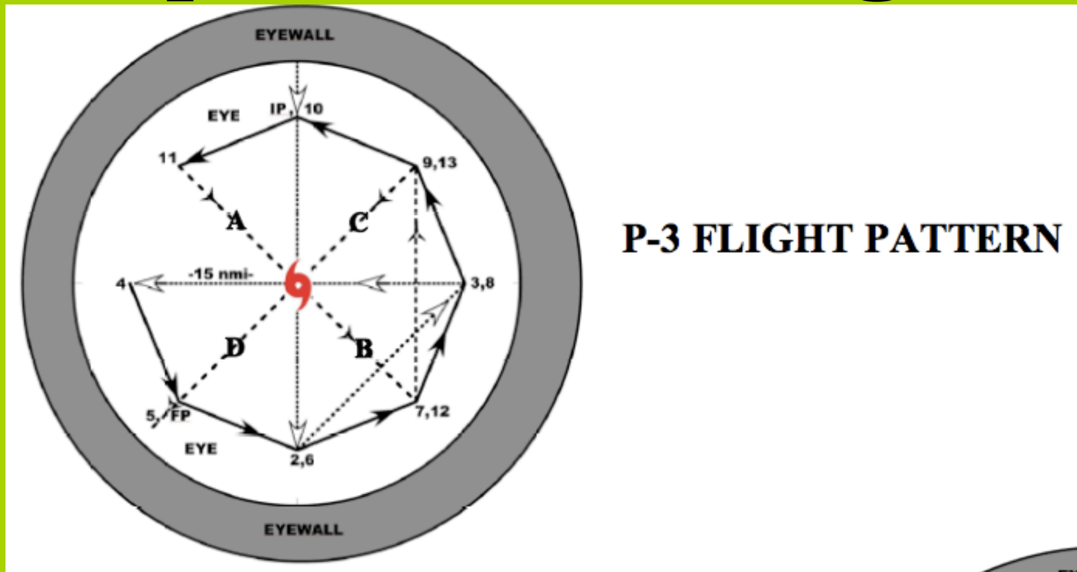
Operational Flight Plan: Eyewall



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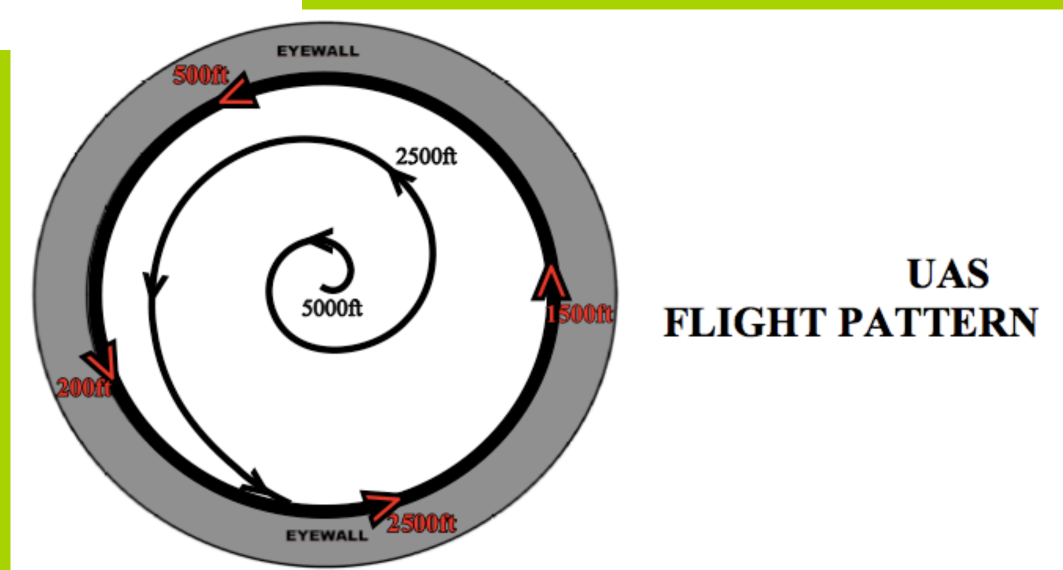

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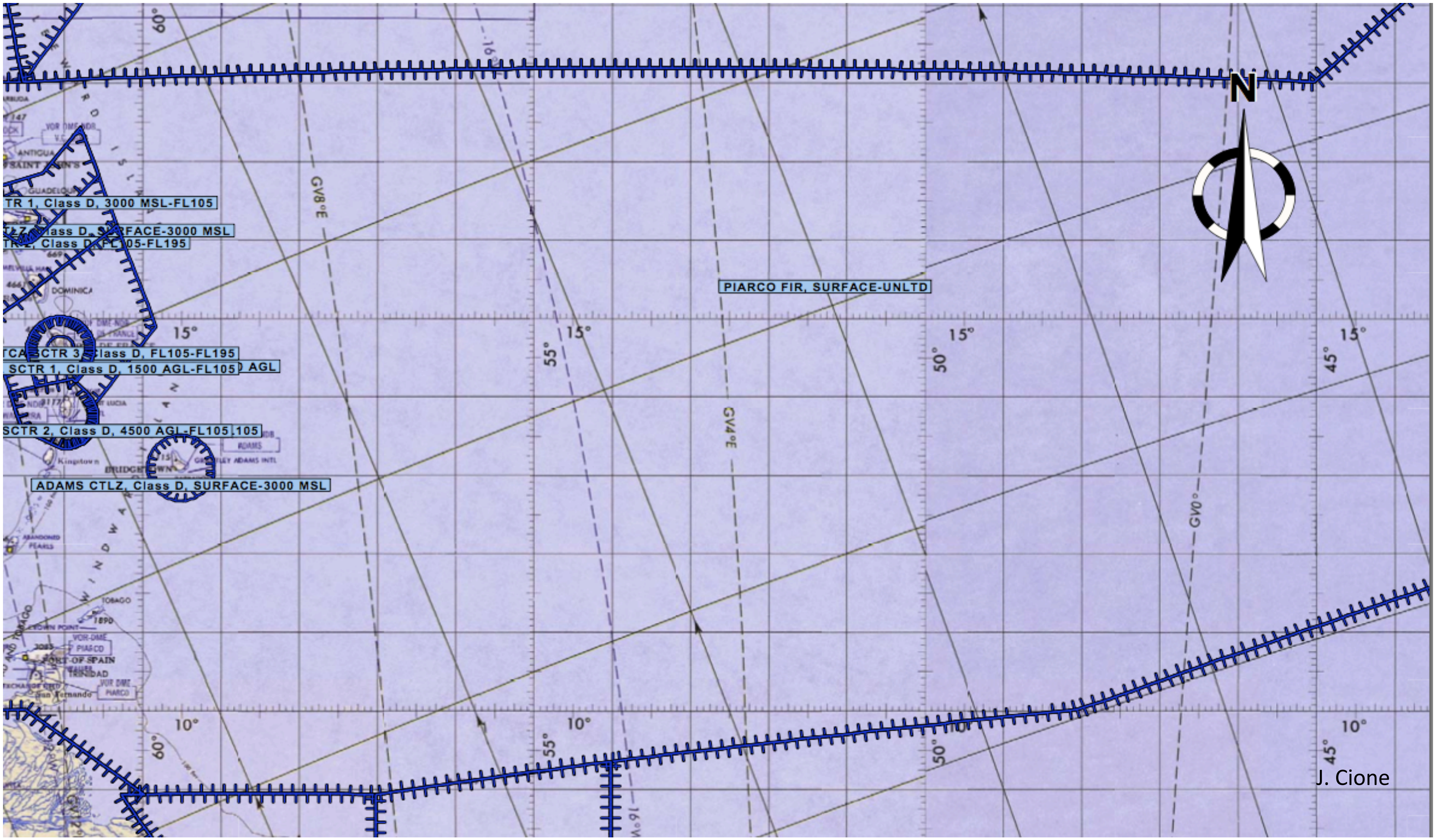
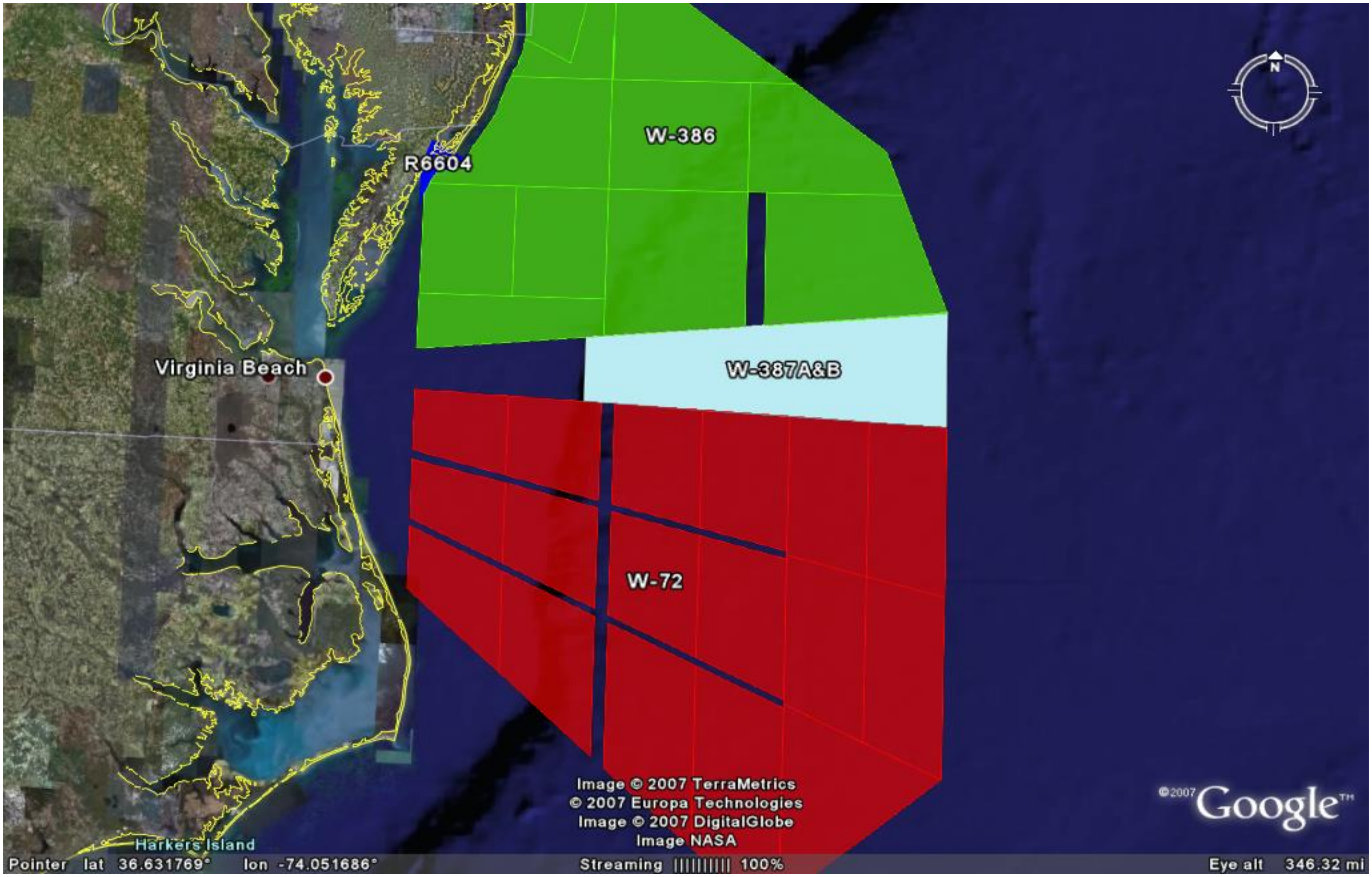
In-storm air space options: Barbados and PIARCO



In-storm air space options: NASA Wallops



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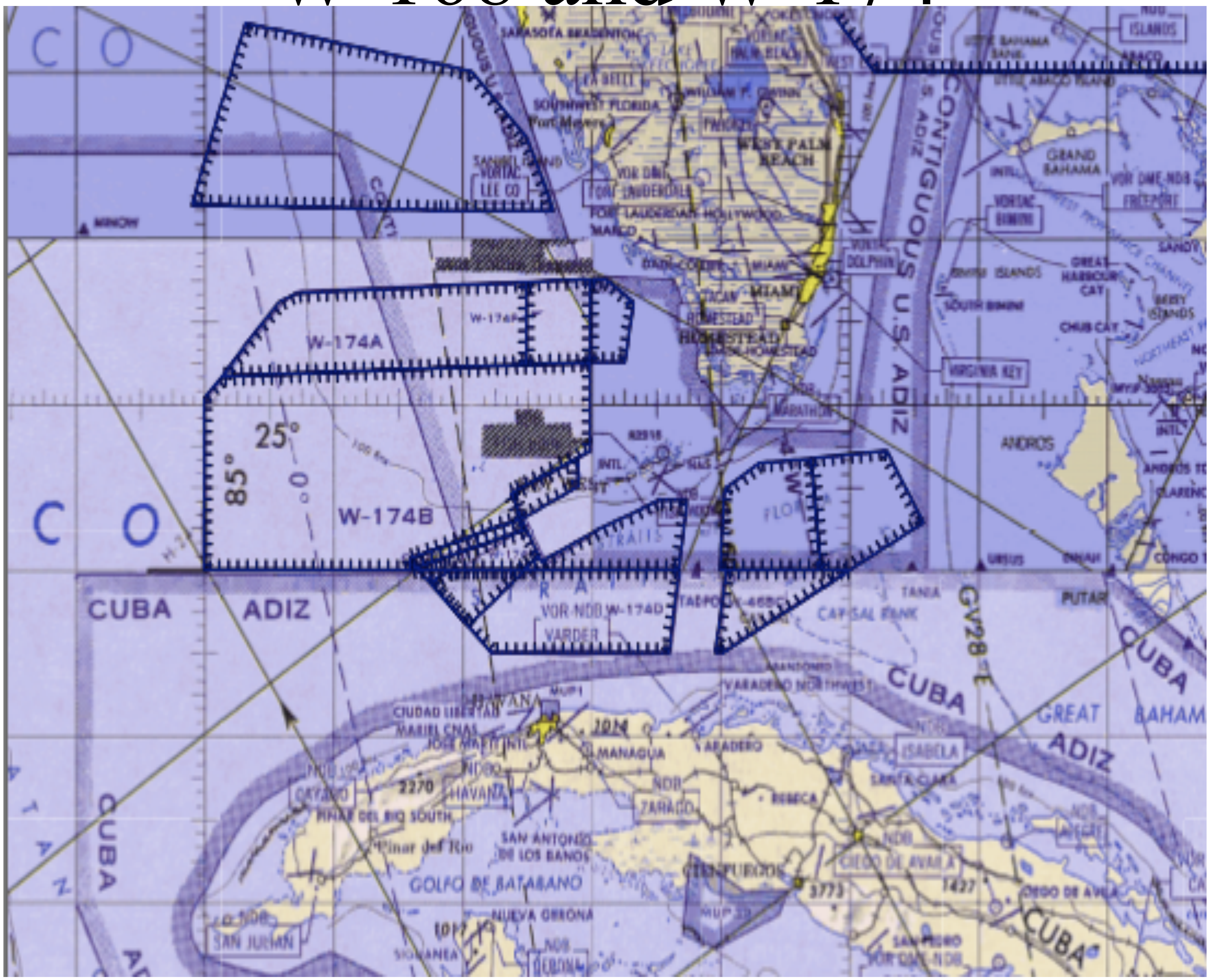
In-storm air space options: W-168 and W-174



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Gale UAS in-storm open questions….

- Can small UAS survive (and adequately perform) in a hurricane environment?

This includes (but is not limited to) assessing the UAS' effectiveness with respect to to in-storm survivability; 2-way communications and data transmission; flight duration (≥1.5h); and quality of measurements (PTHU).

- 2011 and beyond… Additional options, flexibility and improved capabilities?

i. In-storm release of multiple UAS?
ii. Multiple command and control aircraft and/or deployment vehicle options?
iii. Significant (4h+?) increase in UAS flight duration? (Battery, airframe enhancement?)
iv. Significant increase with respect to UAS-to-command aircraft separation/range?
v. More payload possibilities? (Sophisticated and/or higher quality sensors, additional payload space and/or carry capacity?)

J. Cione

Launch and Recovery

- Launch:
  - Drop via sonobouy tube on P-3
  - Parachute pulls sleeve away from Gale
  - Gale exits sleeve and tail surfaces deployed
  - Once aircraft descent under control, wings deploy
  - Enter flight regime at approximately 5,000 ft
- Recovery:
  - Clear air operations: belly landing
  - Hurricane operations: no recovery

Concept of Operations #1

- Mature Hurricane Eye Mission
  - Launch at 10,000 ft
  - UAS enters flight regime at 5,000 ft
  - From, 5,000 ft to 1,000 ft,
    - Hold for 3 minutes
    - Descent 1000 ft
  - From 1,000 ft to 200 ft
    - Hold for 3 minutes
    - Descent 100 ft.
  - Eyewall penetration if aircraft reaches 200 ft

Concept of Operations #2

- Mature Hurricane Eyewall Mission
  - Launch at 10,000 ft
  - UAS enters flight regime at 5,000 ft
  - From, 5,000 ft to 2,500 ft,
    - Gradual descent within the eye
    - Breach eyewall at 2,500 ft
  - From 2,500 ft to 200 ft
    - Hold for 3 minutes
    - Descent 100 ft.
  - Maintain 200 ft until failure of aircraft battery

J. Cione

John Kaplan and Rob Rogers – Rapid Intensification Experiment (RAPX)

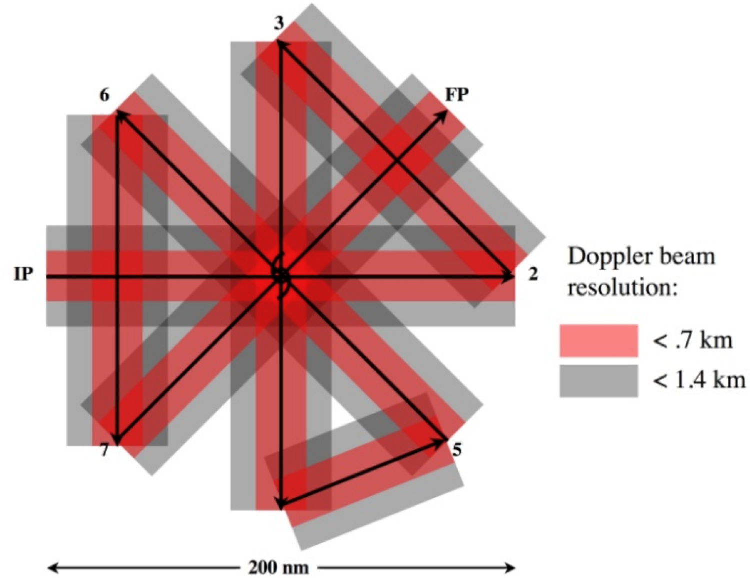
Scientific goal

- Employ NOAA P3 and G-IV aircraft to collect oceanic, kinematic, and thermodynamic observations within the inner-core (i.e., radius < 120 nm) and surrounding large-scale environment (i.e., 120 nm < radius < 240 nm) for systems with potential to undergo RI within 24-72 h

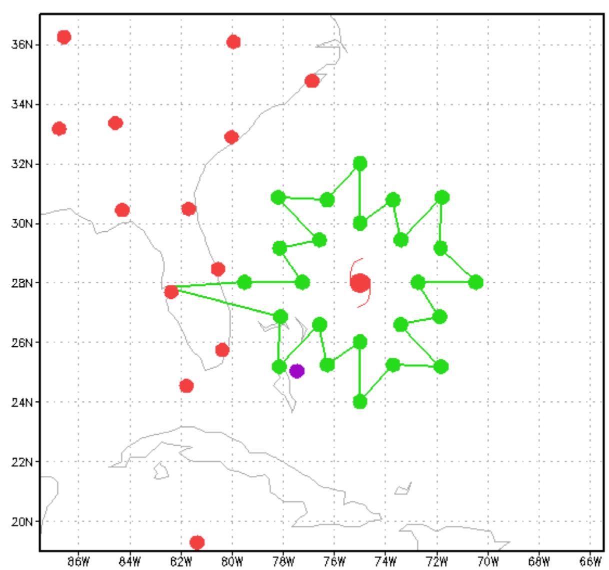
J. Kaplan & R. Rogers

Experiment Flight Patterns

P-3



G-IV



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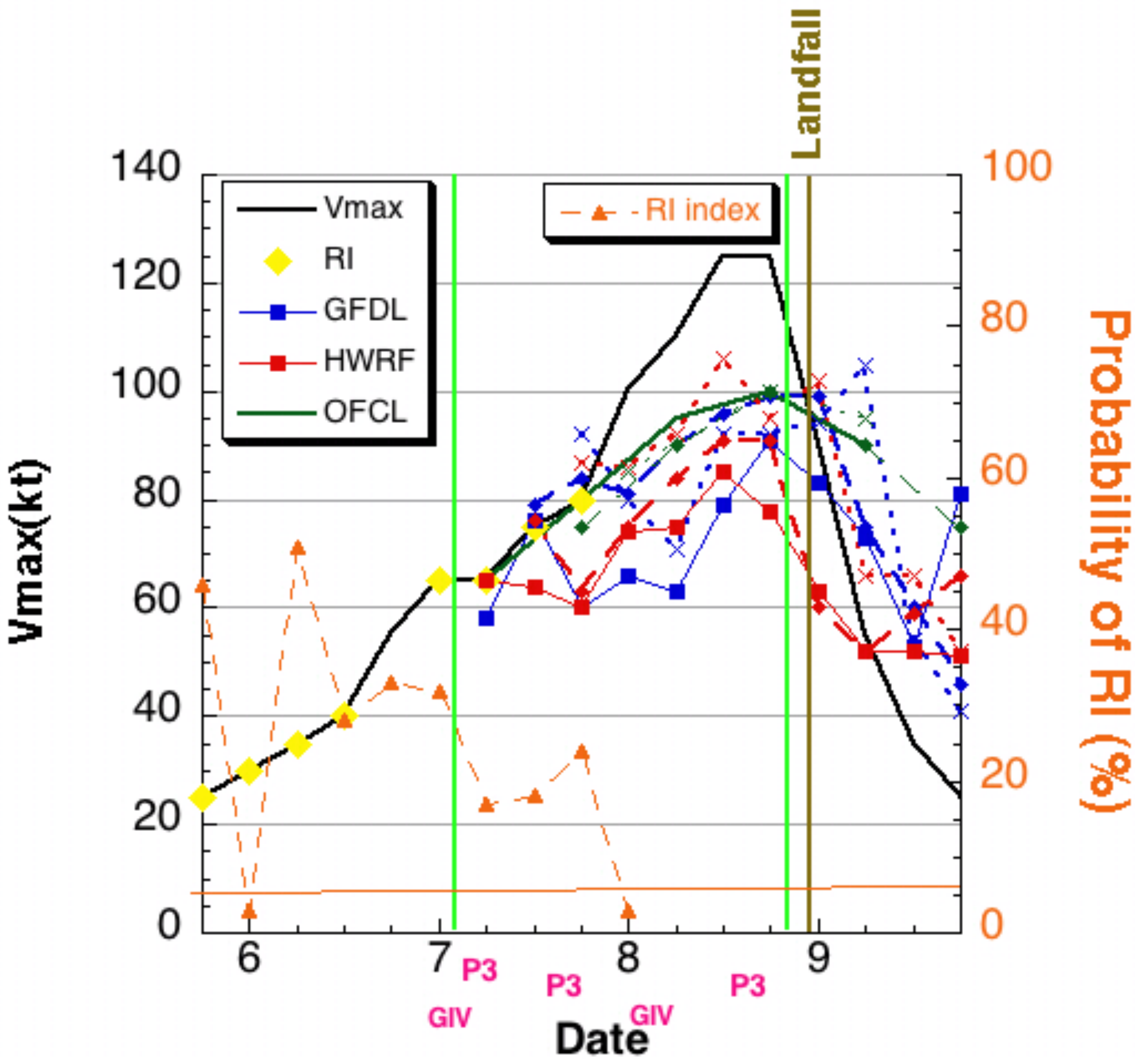
Paloma Operational Model Forecasts



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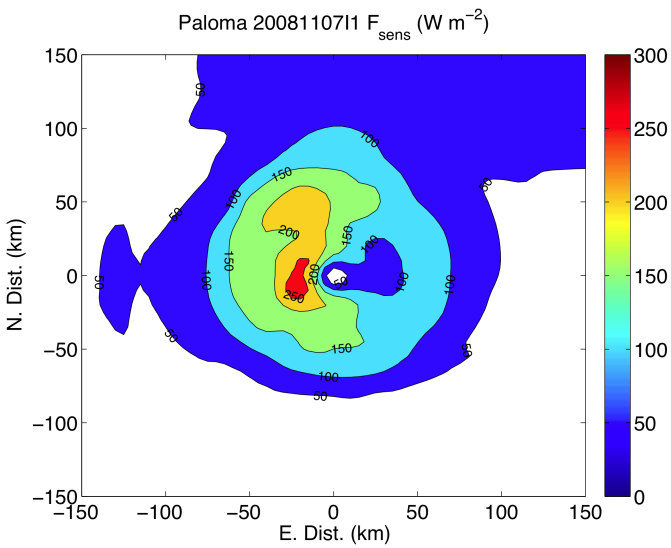
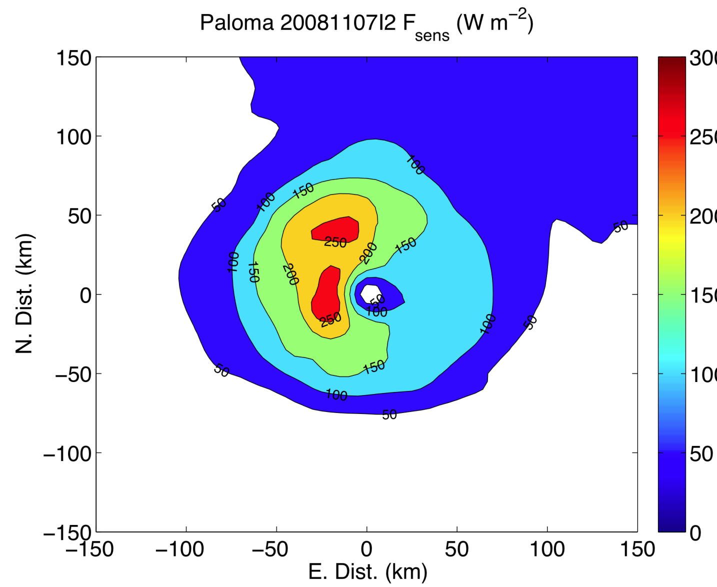
Sensible Heat flux

0600 UTC

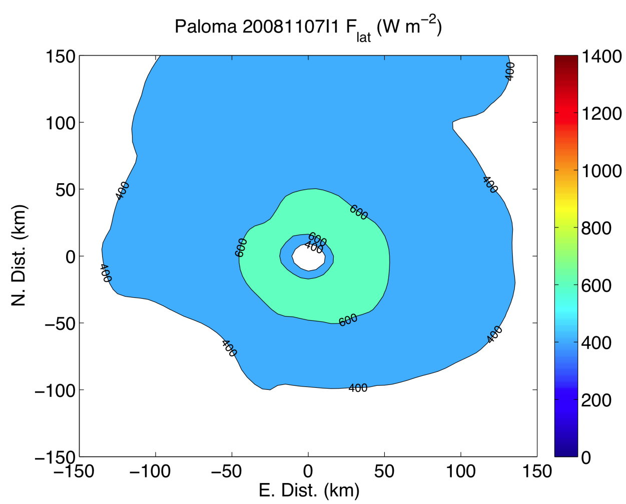


1800 UTC

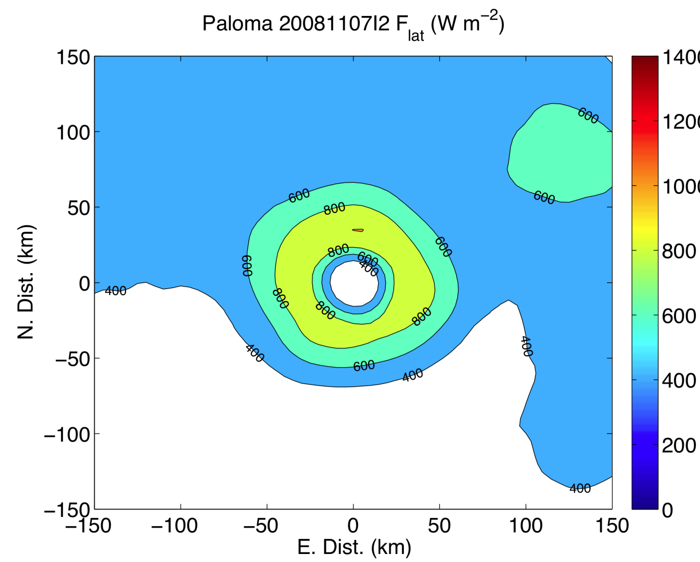


Latent Heat flux

0600 UTC



1800 UTC



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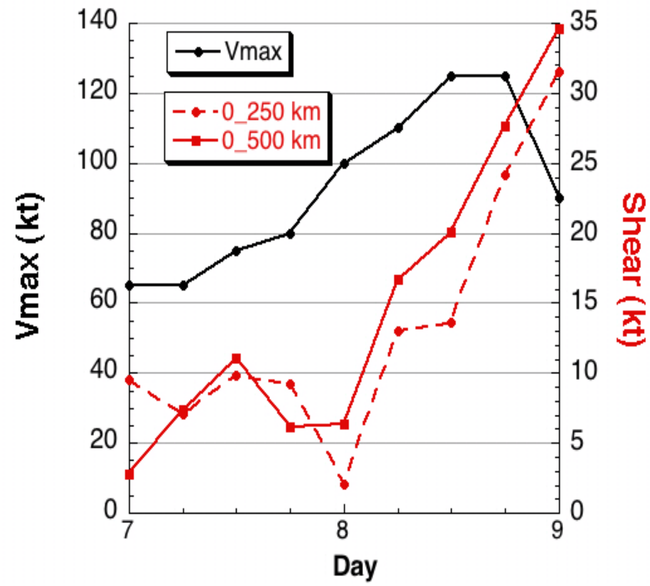
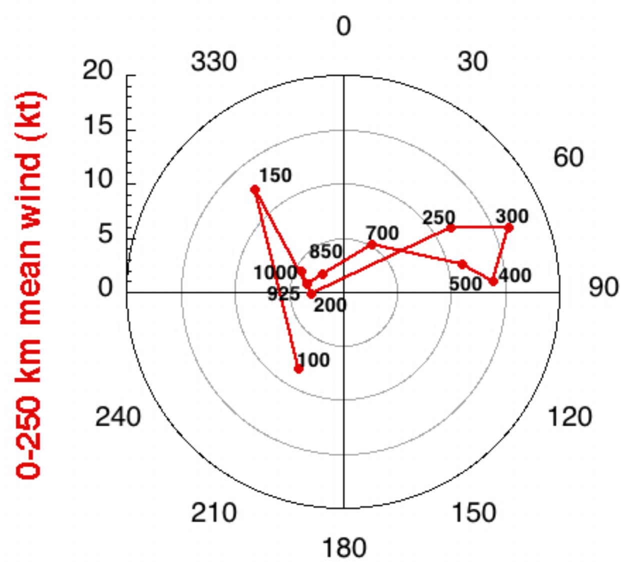
Vertical Shear evolution



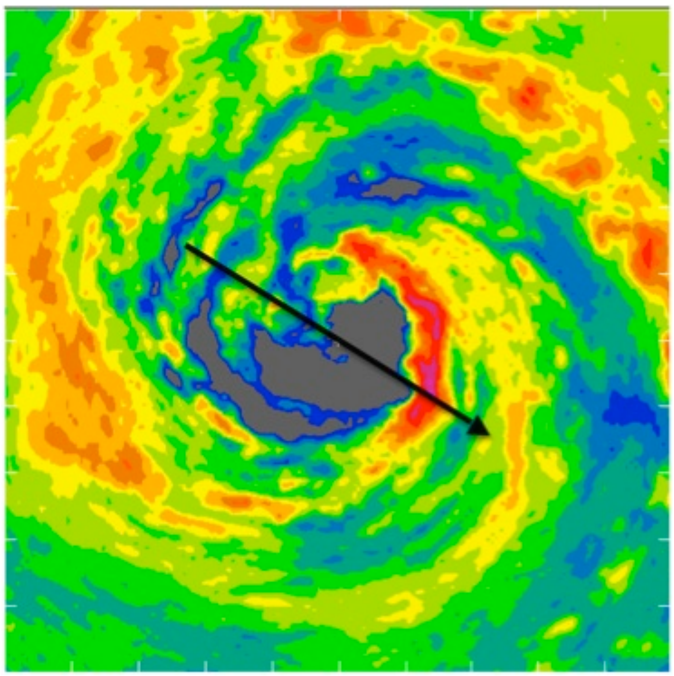


1800 UTC

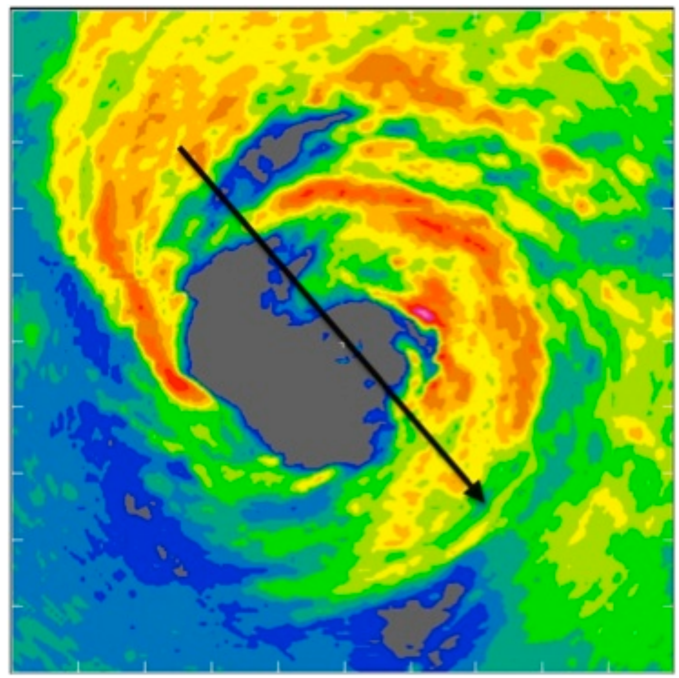
J. Kaplan & R. Rogers

Paloma Radar evolution

11/7 0743 UTC



11/7 1754 UTC



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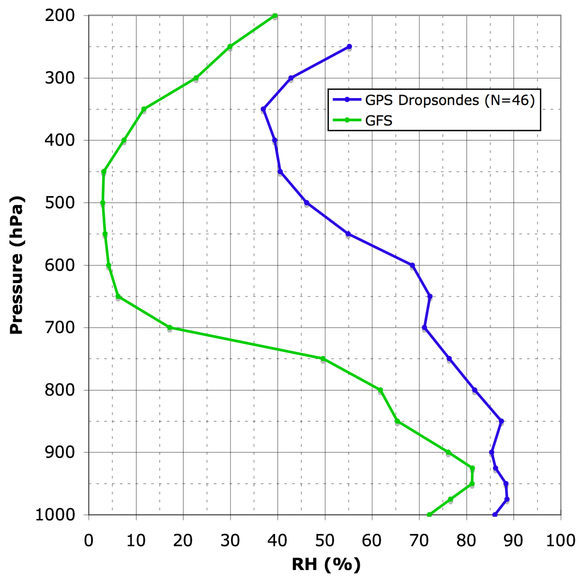
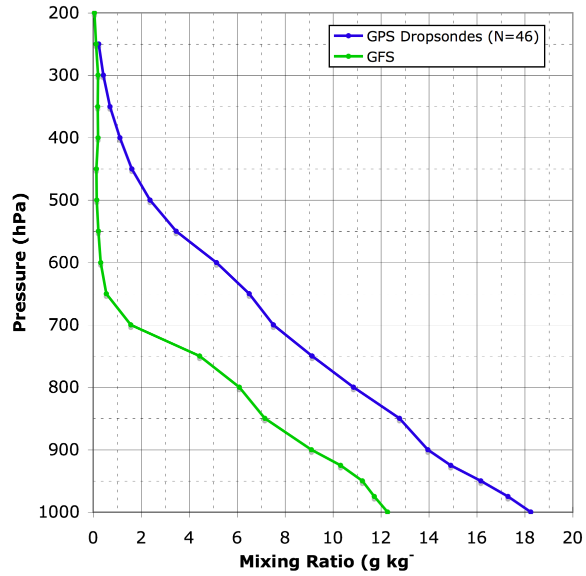
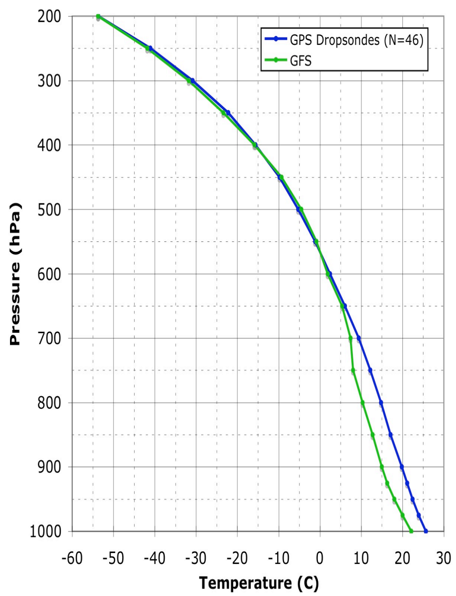
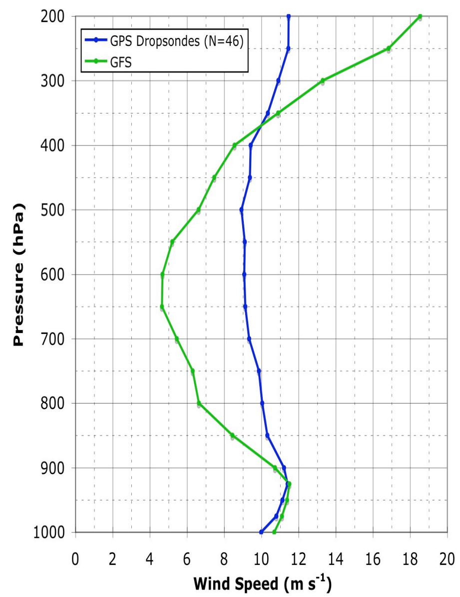
Comparison of GFS analysis vs dropsondes



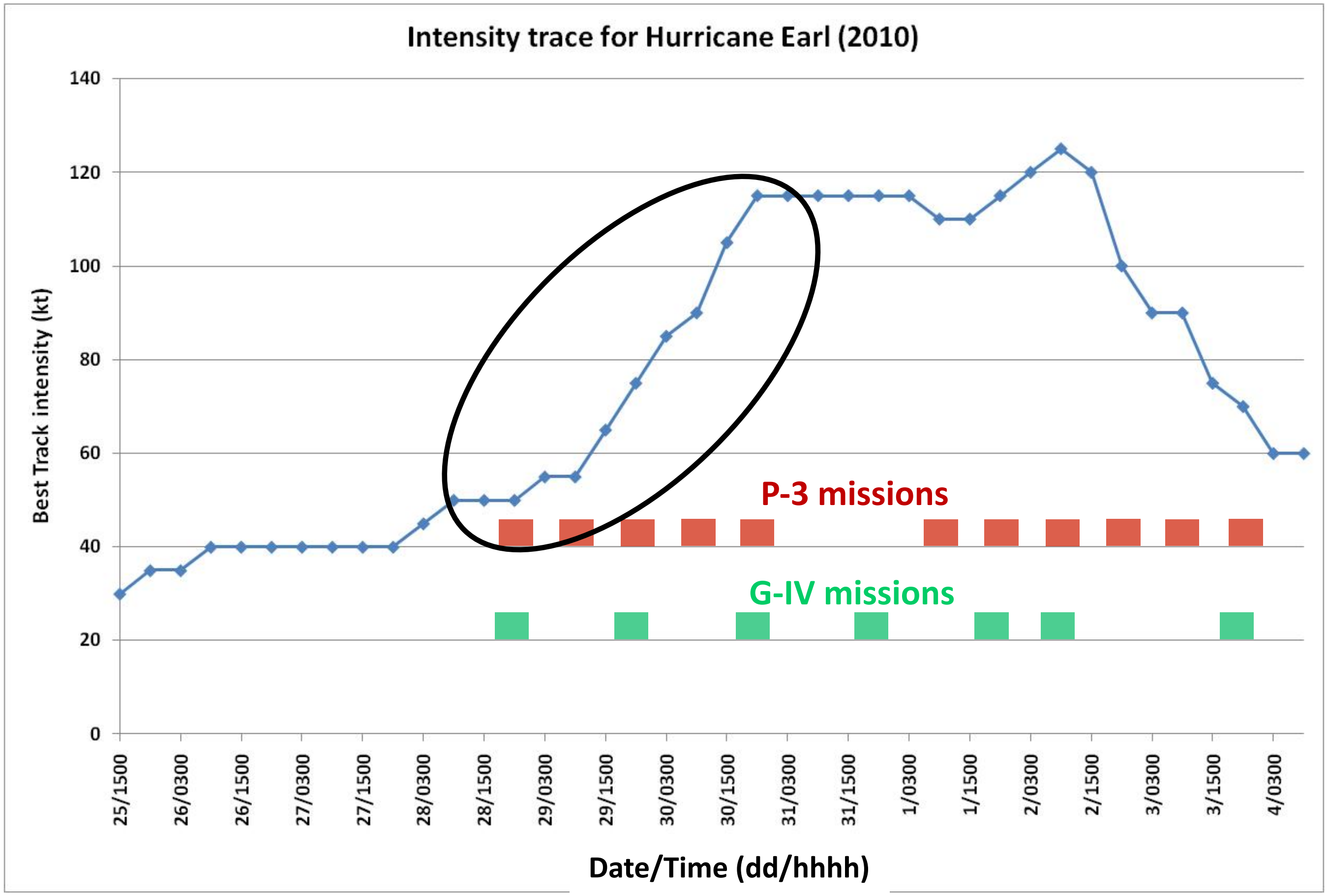






J. Kaplan & R. Rogers

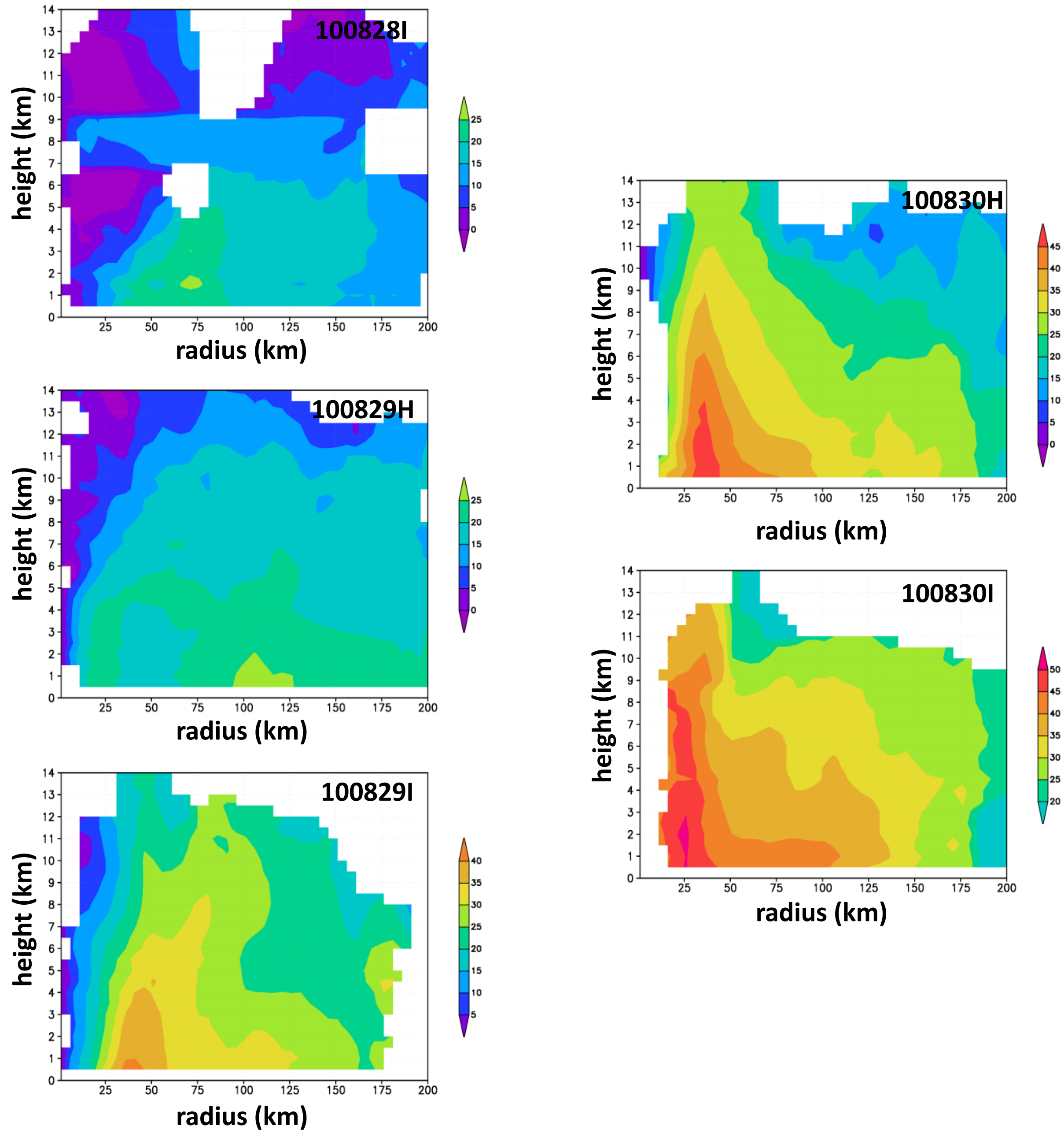
P-3 and G-IV coverage during intensity evolution of Earl



J. Kaplan & R. Rogers

Vortex-scale evolution

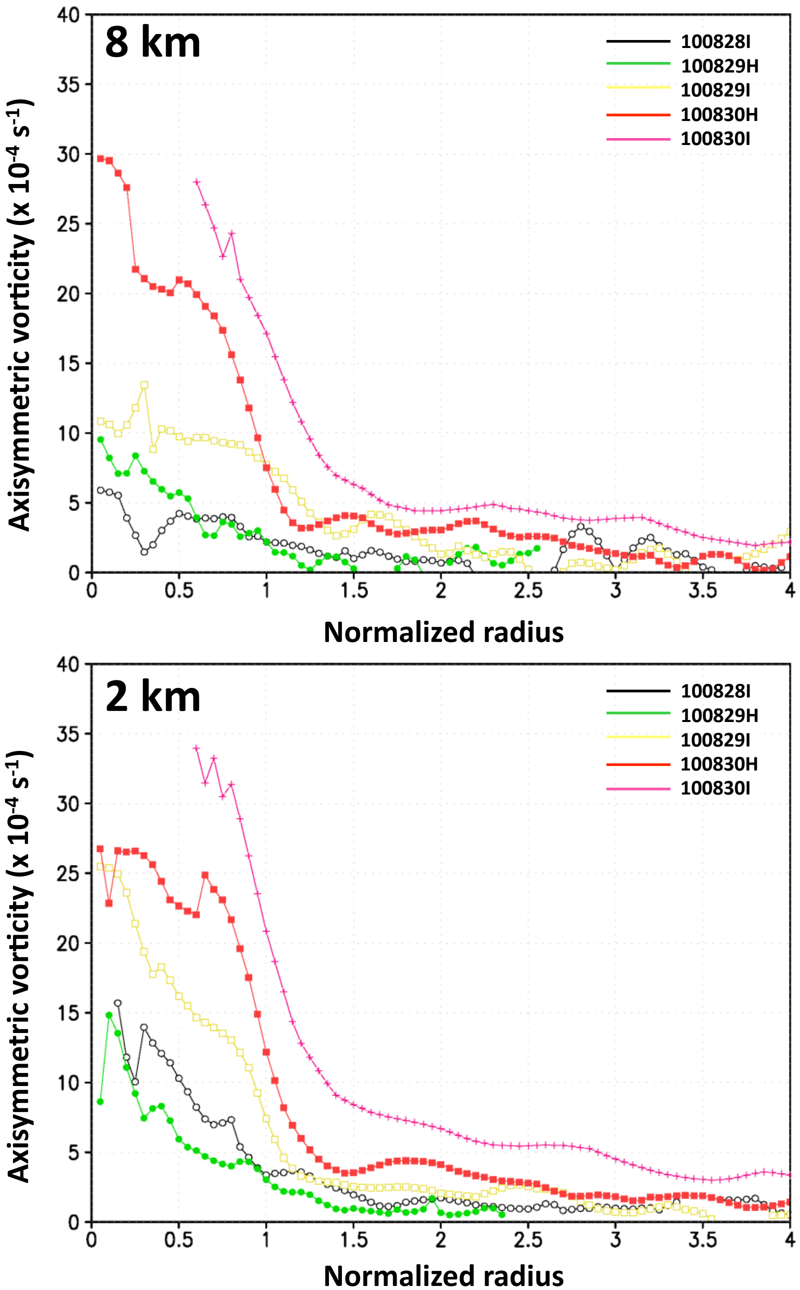
Axisymmetric tangential wind (shaded, m/s)



J. Kaplan & R. Rogers

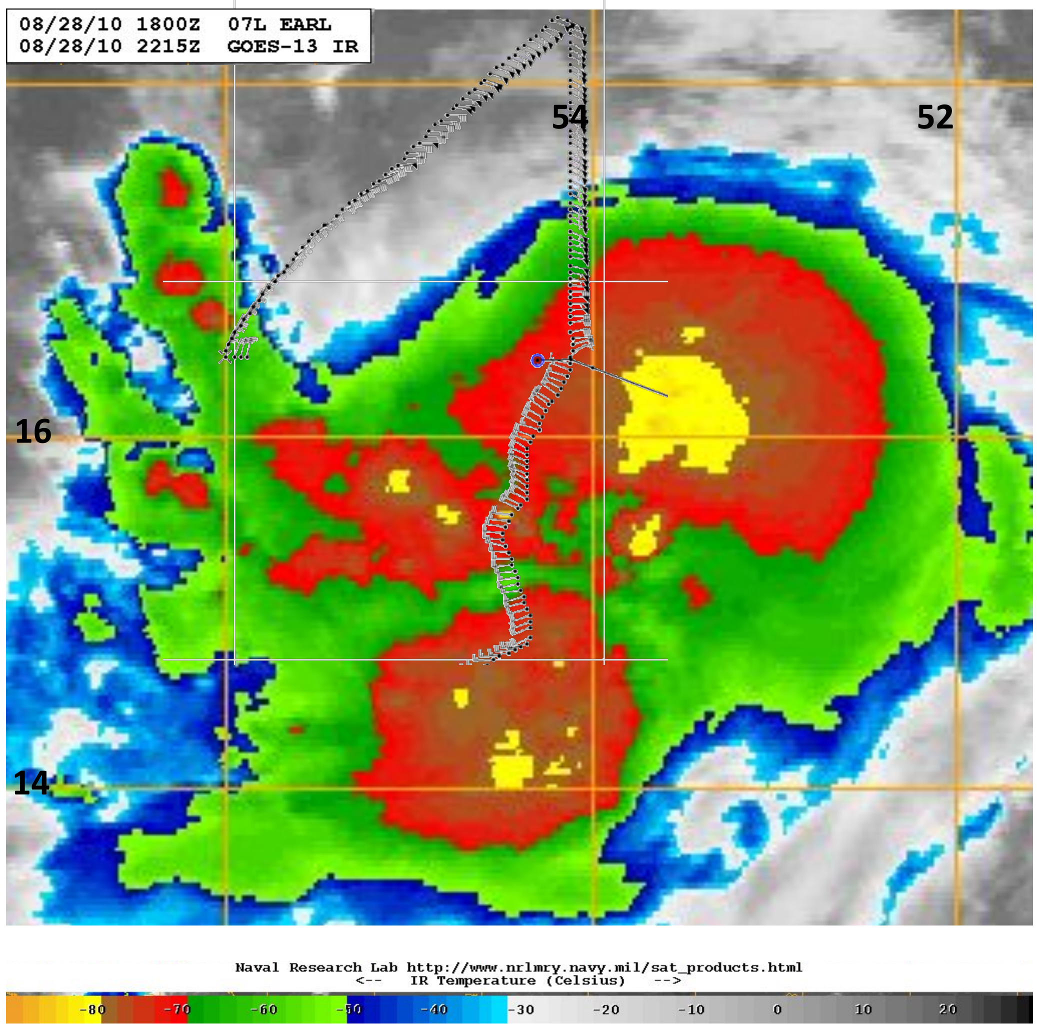
Vortex-scale evolution

Axisymmetric horizontal vorticity (shaded, x 10^{-4} s^{-1})



J. Kaplan & R. Rogers

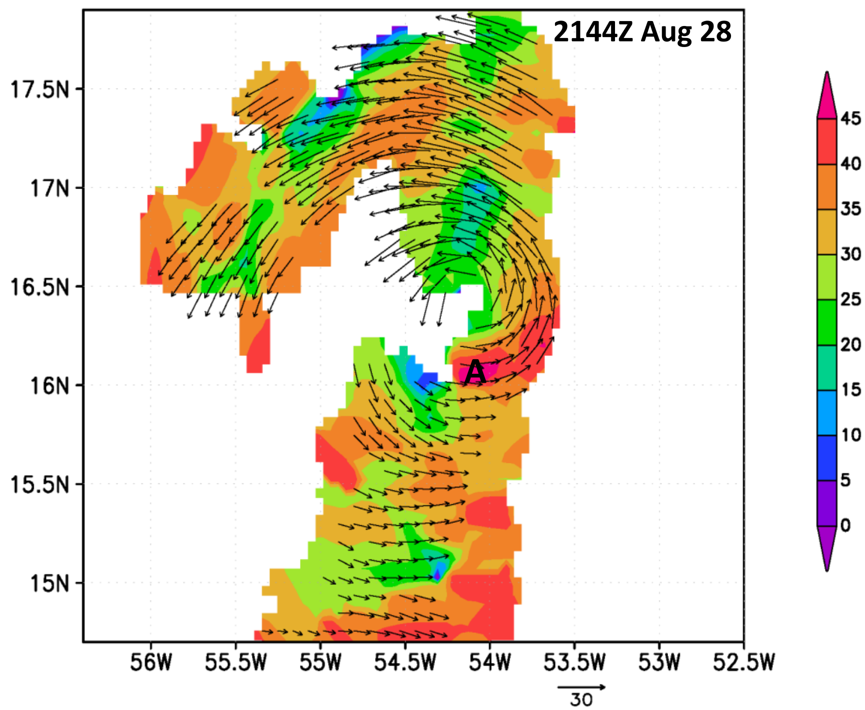
GOES enhanced IR valid 2215Z Aug 28 and radar leg overlain



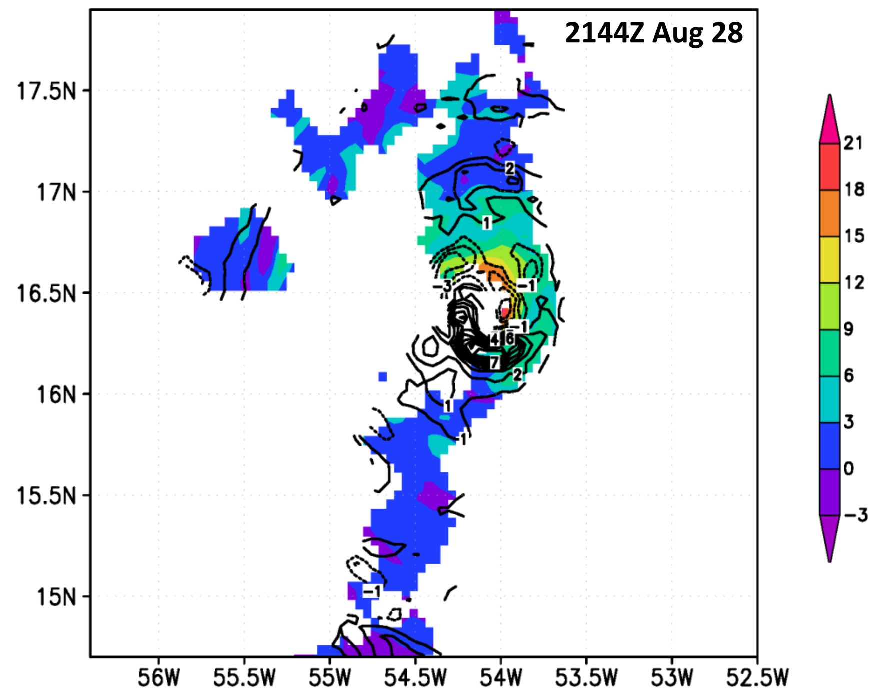
J. Kaplan & R. Rogers

Convective burst evolution

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



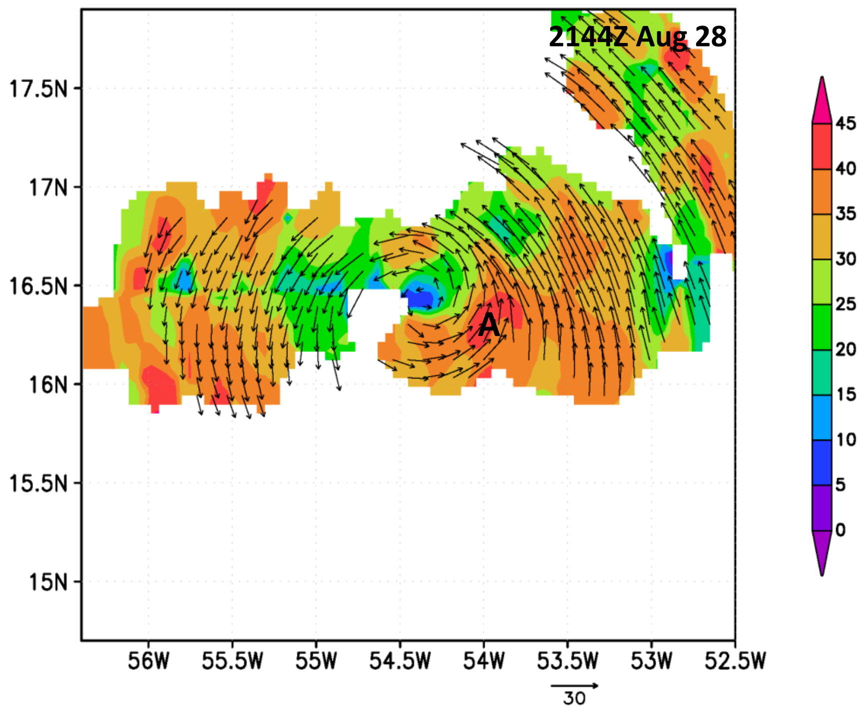
Horizontal vorticity (shaded, x 10^{-4} s^{-1}) and 2-6 km averaged vertical velocity (contour, m s-1)



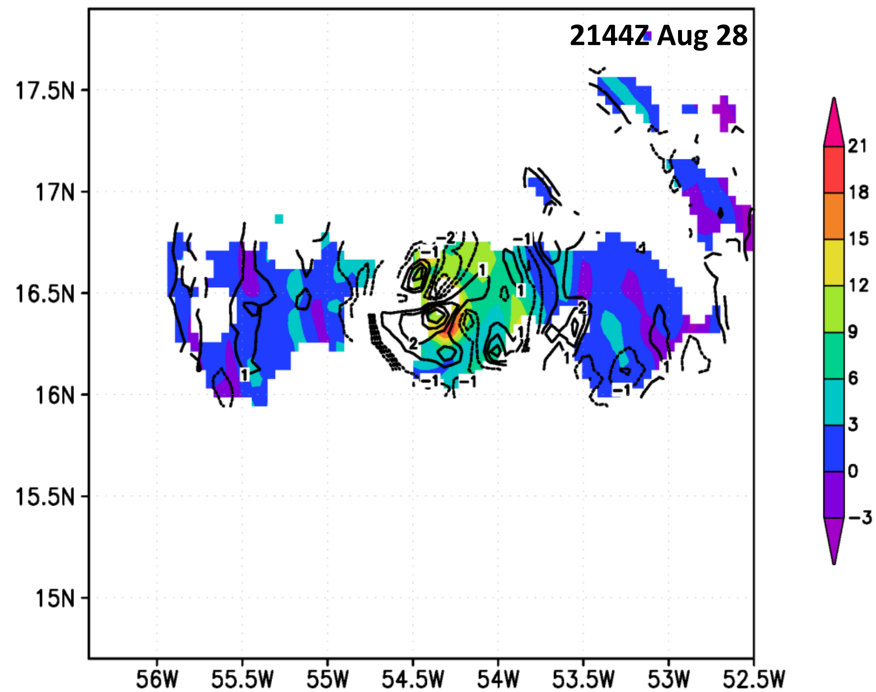
J. Kaplan & R. Rogers

Convective burst evolution

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



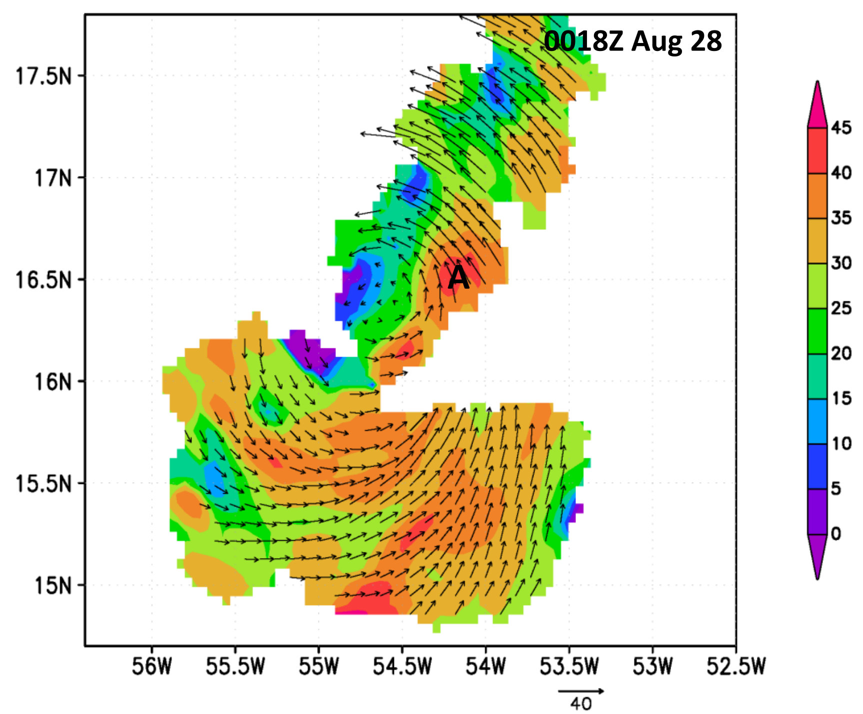
Horizontal vorticity (shaded, x 10^{-4} s^{-1}) and
2-6 km averaged vertical velocity (contour, m s-1)



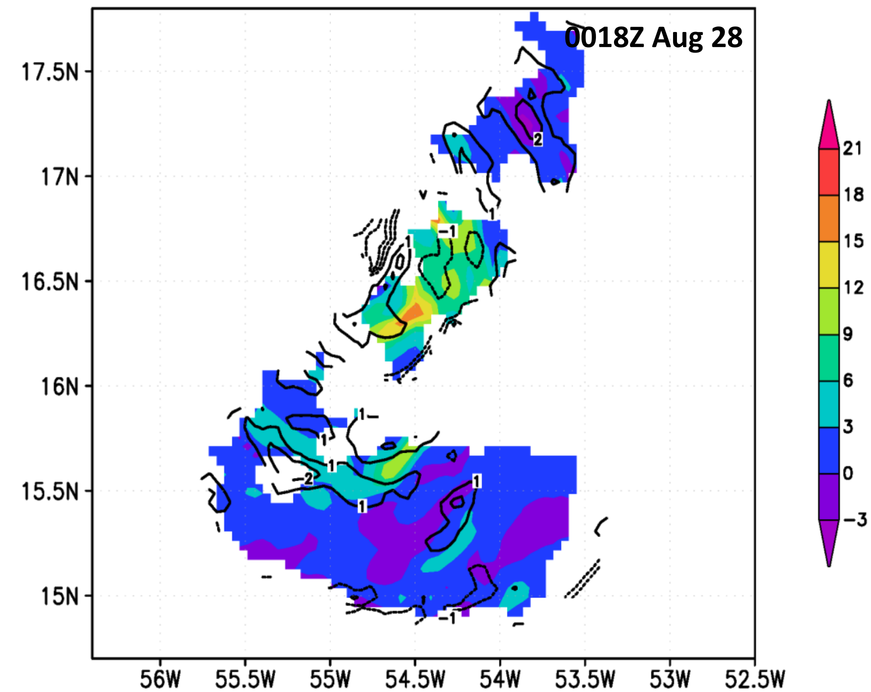
J. Kaplan & R. Rogers

Convective burst evolution

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



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



J. Kaplan & R. Rogers

Rob Rogers and Paul Reasor – Tropical Cyclogenesis Experiment (GenEX)

Tropical cyclogenesis experiment (GenEx)

Rob Rogers and Paul Reasor

Scientific goals

- **Convective/mesoscale interactions during genesis (e.g., "bottom-up" vs. "top-down", role of convective vs. stratiform processes)**
- **Synoptic-scale influences on genesis (e.g., SAL, "marsupial" paradigm)**
- **Coordinated G-IV/P-3 missions provide multiscale, broad temporal coverage**

Recent history of genesis datasets

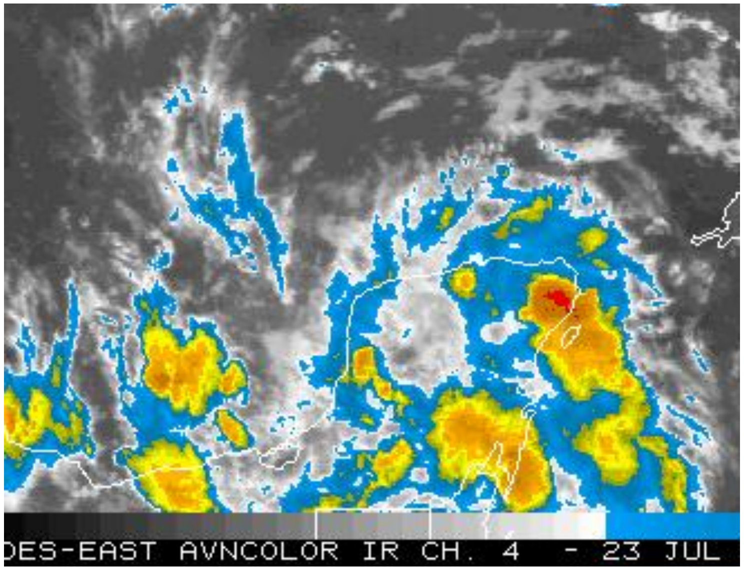
- Four primary genesis datasets in last 10 years
  - T.S. Gert (2005)
  - T.S. Fay (2008)
  - T.D. #2 (2010)
  - Hurricane Karl (2010)
- Have demonstrated capability of sampling with maximum possible temporal resolution (i.e., P-3 flights separated by 12 h)
- All four datasets have had problems either with proximity to land, or limited distribution of scatterers, or both
- Still looking for dataset that satisfies criteria of "fantastic" genesis dataset
  - high temporal resolution
  - maximum possible Doppler coverage, ability to resolve higher wavenumbers
  - broad distribution of dropsondes
  - away from land masses

T.S. Gert - 2005

- Consecutive flights over 36-h period (4 P-3)
- Interaction with Yucatan, in western coast of Bay of Campeche
- Some dropsonde coverage, decent Doppler coverage at times, but in close proximity to Yucatan early in lifecycle
- Best Doppler coverage was only on last flight, just before landfall in Mexico

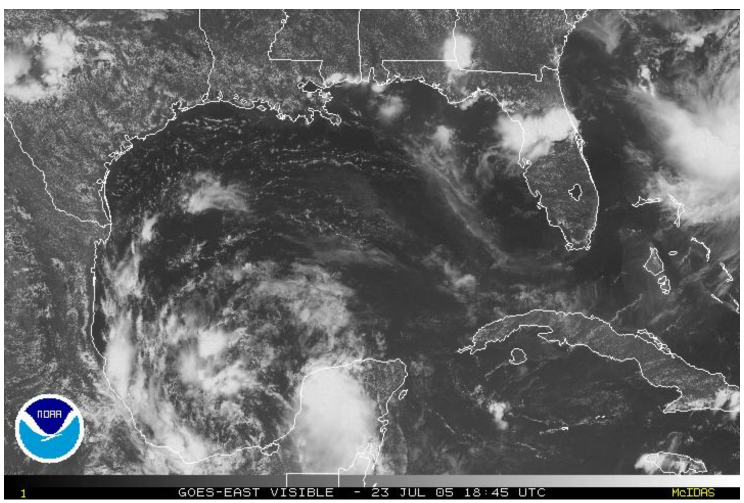
Gert proximity to land…..

GOES enhanced IR early July 23

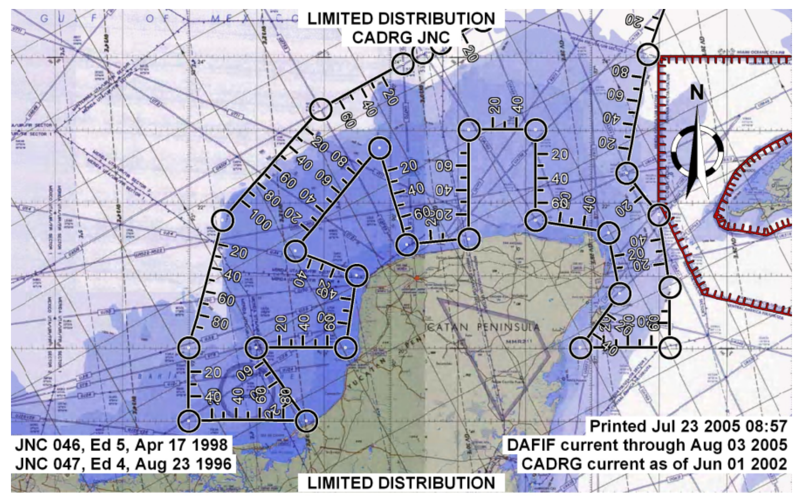


Proposed flight track for 050722I

GOES visible 1845 UTC July 23



Proposed flight track for 050723H



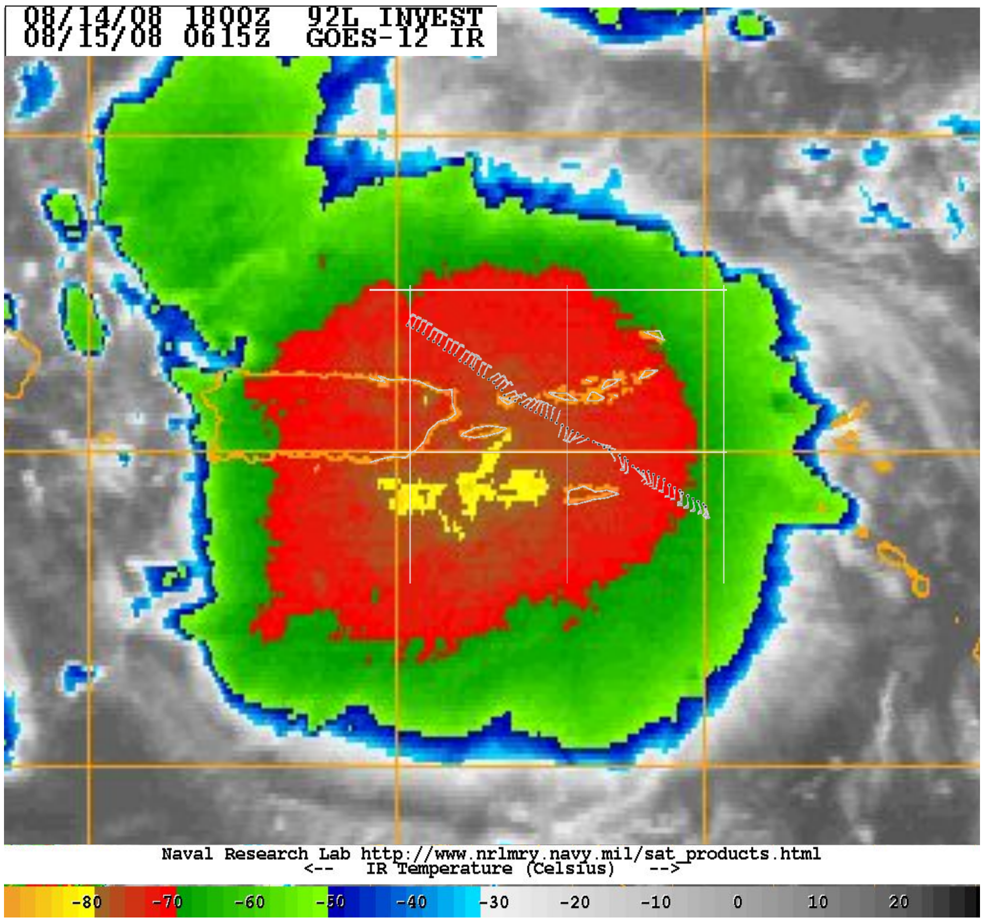
R. Rogers and P. Reasor

T.S. Fay - 2008

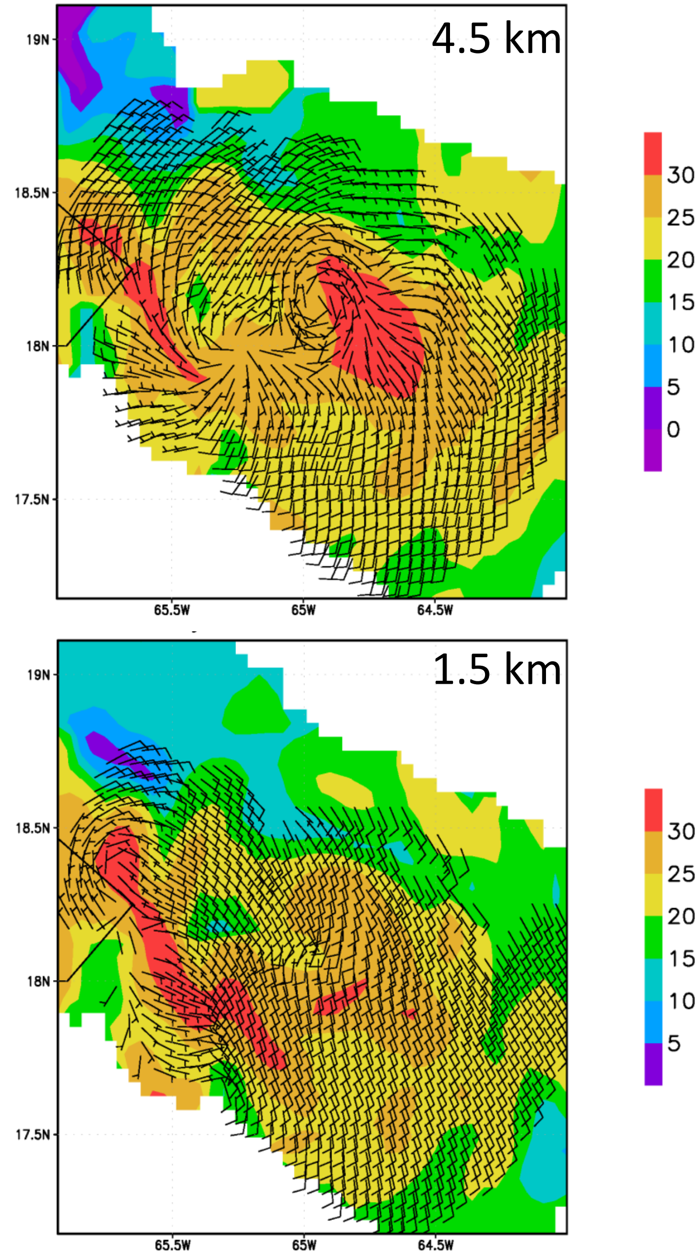
• Consecutive flights over 36-h period (4 P-3)
• Interaction with Puerto Rico
• Some dropsonde coverage, decent Doppler coverage at times, but in close proximity to Hispaniola

R. Rogers and P. Reasor

Fay – Satellite, reflectivity and winds at 0554Z Aug. 15



0554Z 15 Aug



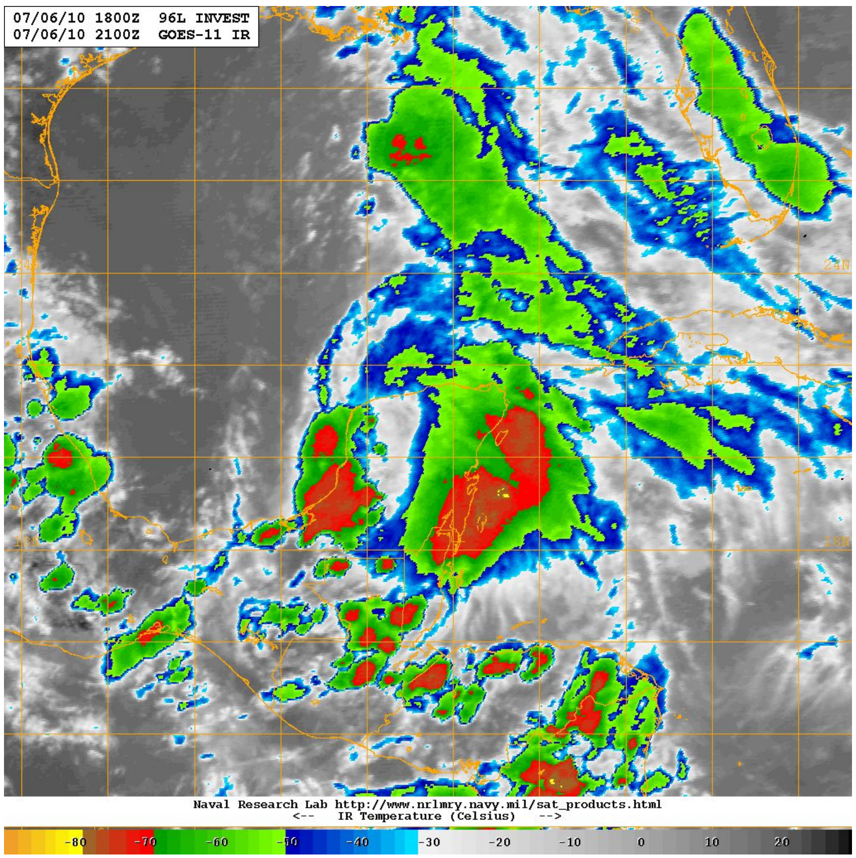
R. Rogers and P. Reasor

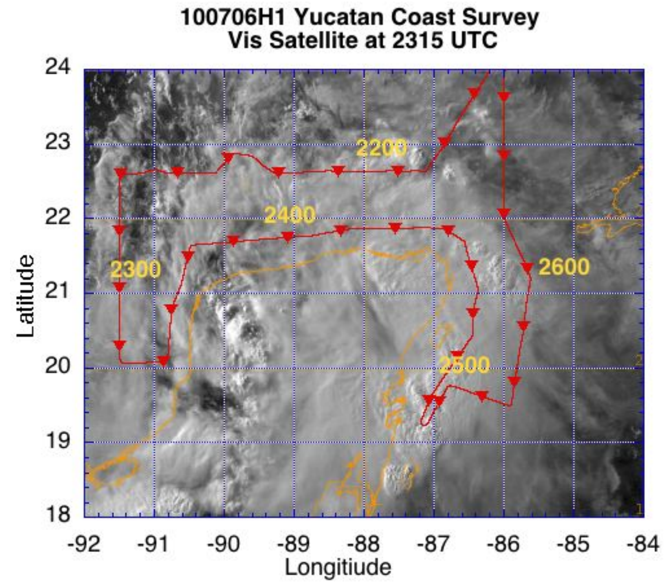
Tropical Depression #2 - 2010

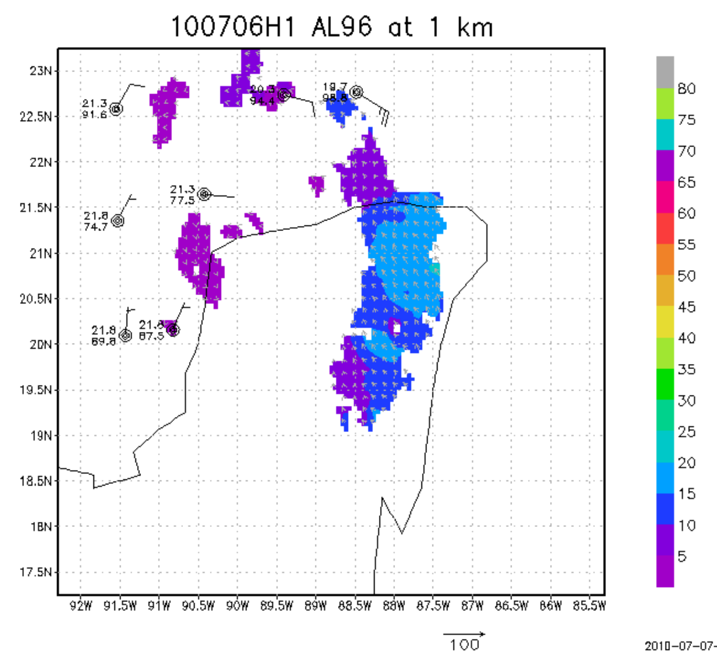
- Consecutive flights over 24-h period (3 P-3, 2 G-IV)
- Interaction with Yucatan peninsula
- Some dropsonde coverage, limited Doppler coverage throughout

R. Rogers and P. Reasor

TD#2 – Satellite, flight track and Doppler winds/dropsonde composite for 100706H1







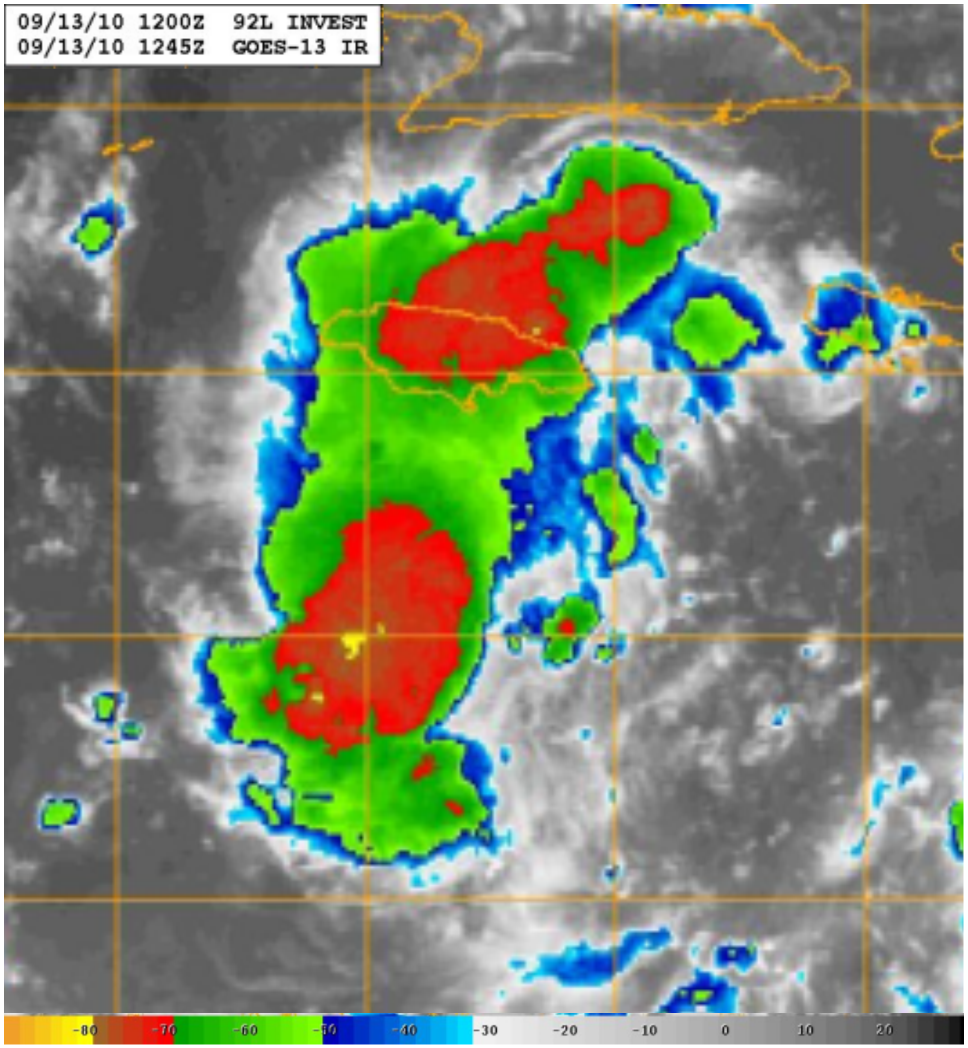
R. Rogers and P. Reasor

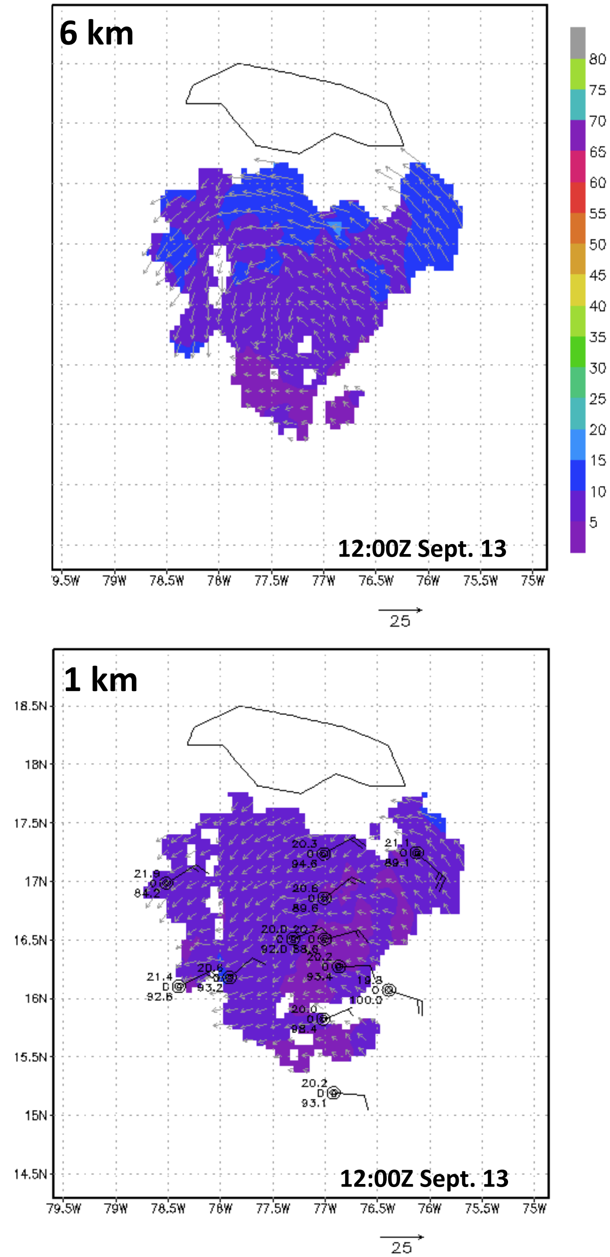
Hurricane Karl - 2010

• Consecutive flights over 24-h period (3 P-3, 2 G-IV)
• Near southern coasts of Hispaniola and Jamaica
• Good dropsonde coverage, especially from multi-agency, but very limited Doppler coverage

R. Rogers and P. Reasor

Karl –Satellite, Doppler winds/dropsonde composite valid 1200Z Sep. 13

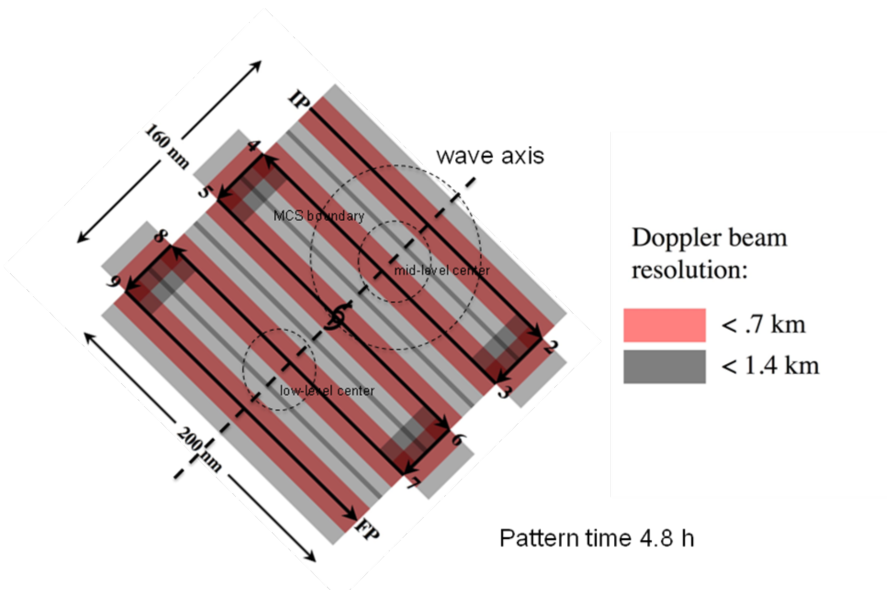




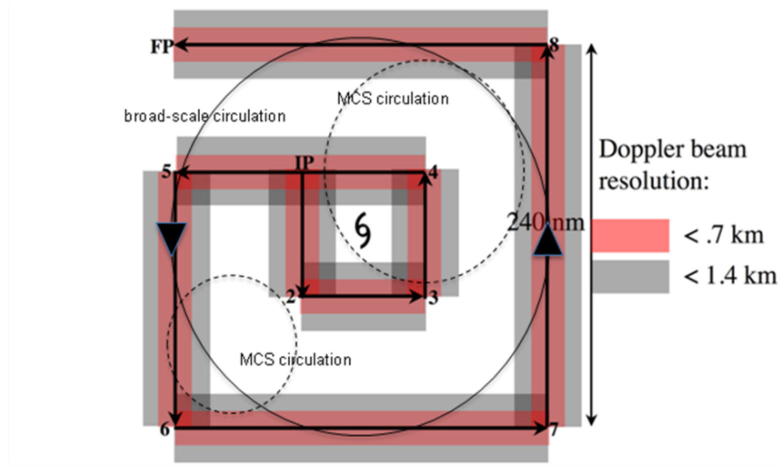
R. Rogers and P. Reasor

Genesis Experiment: P-3 pre-genesis survey patterns

Aircraft at 10-12,000 ft altitude



Pattern time 4.8 h

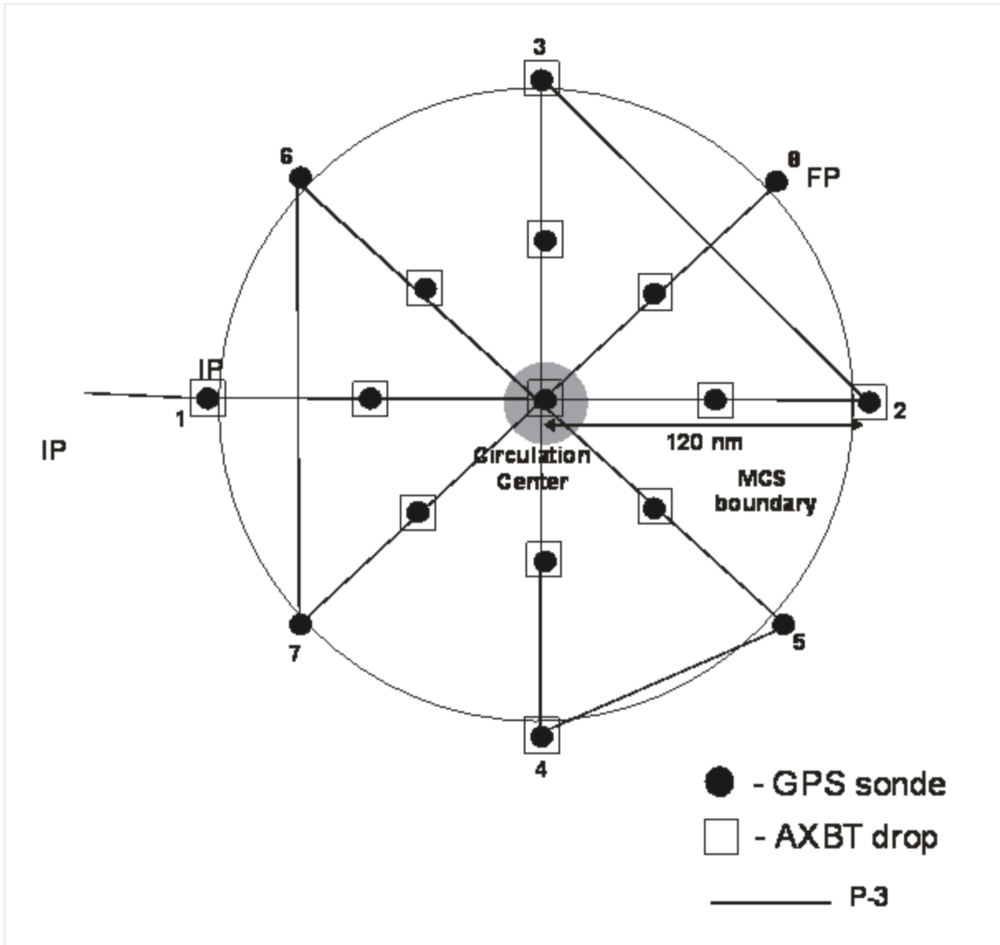


Pattern time 5.33 h

R. Rogers and P. Reasor

Genesis Experiment: P-3 post-genesis patterns

Aircraft at 10-12,000 ft altitude

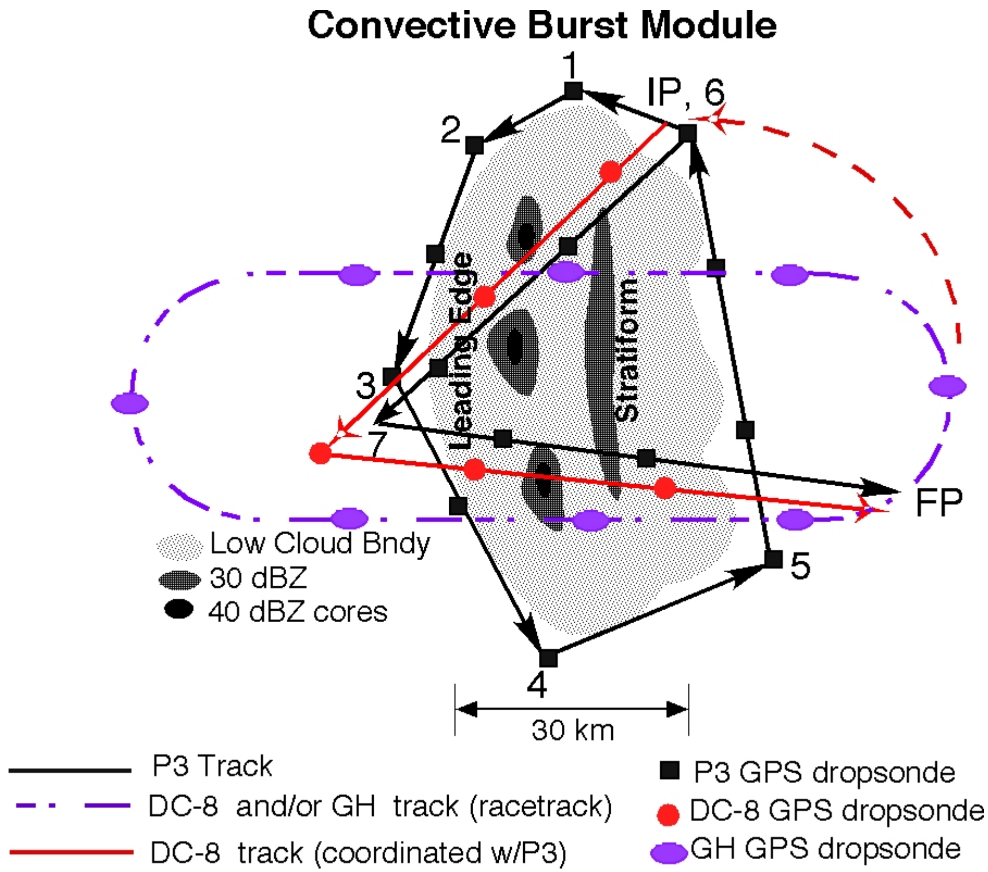


R. Rogers and P. Reasor

Genesis Experiment: P-3 convective burst module

Aircraft at 10-12,000 ft altitude for first circumnavigations, penetration
Aircraft at 2000 ft for second circumnavigation (for flight-level winds at low altitude)

- module intended for intensive repeated sampling of an individual burst to sample evolution at high (< 1 hourly) time evolution
- drop sondes only on first circumnavigation, penetration
- only do penetration if P-3 has microphysical probes for in situ measurements



R. Rogers and P. Reasor

Tropical cyclogenesis experiment

- Challenges for genesis experiment
  - often scatterers are limited
  - difficulty planning missions for undeveloped system, especially for deployments

- Suggested changes for this year
  - target any potential system, not just easterly-wave systems
  - any system likely to be within 200 km of land within 48 h from time of first flight will not be targeted
  - only consider targets that can provide a minimum of 3 consecutive P-3 flights (12-h separation), 4 or more flights optimal
  - Gulf of Mexico genesis cases would be considered as candidates
    - while synoptic environments may be different, convective/mesoscale processes still operative and likely minimally different (other than impact of different environments on convective processes)

R. Rogers and P. Reasor

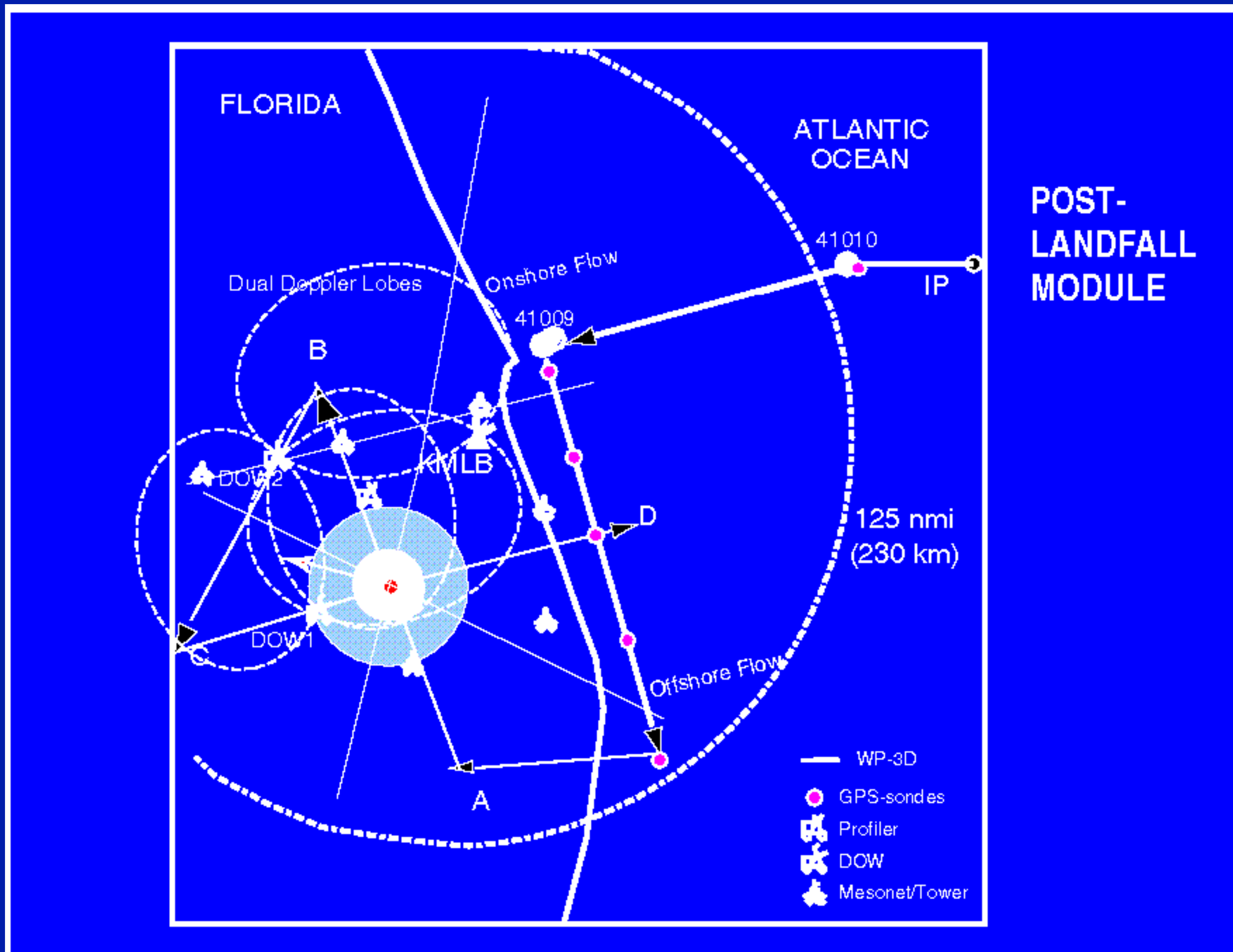
Peter Dodge and John Kaplan – TC Landfall and Inland Decay Module

Tropical Cyclone Landfall and Inland Decay

- 1. Real Time Module
  Radar wind fields at or near landfall
- 2. Coastal Survey Module
  Onshore vs Offshore flow, PBL features
- 3. Inland Decay Module
  Validate Inland Decay Model
- 4. Offshore Intense Convective Feature Module
  Possible tornadic cells in rainbands

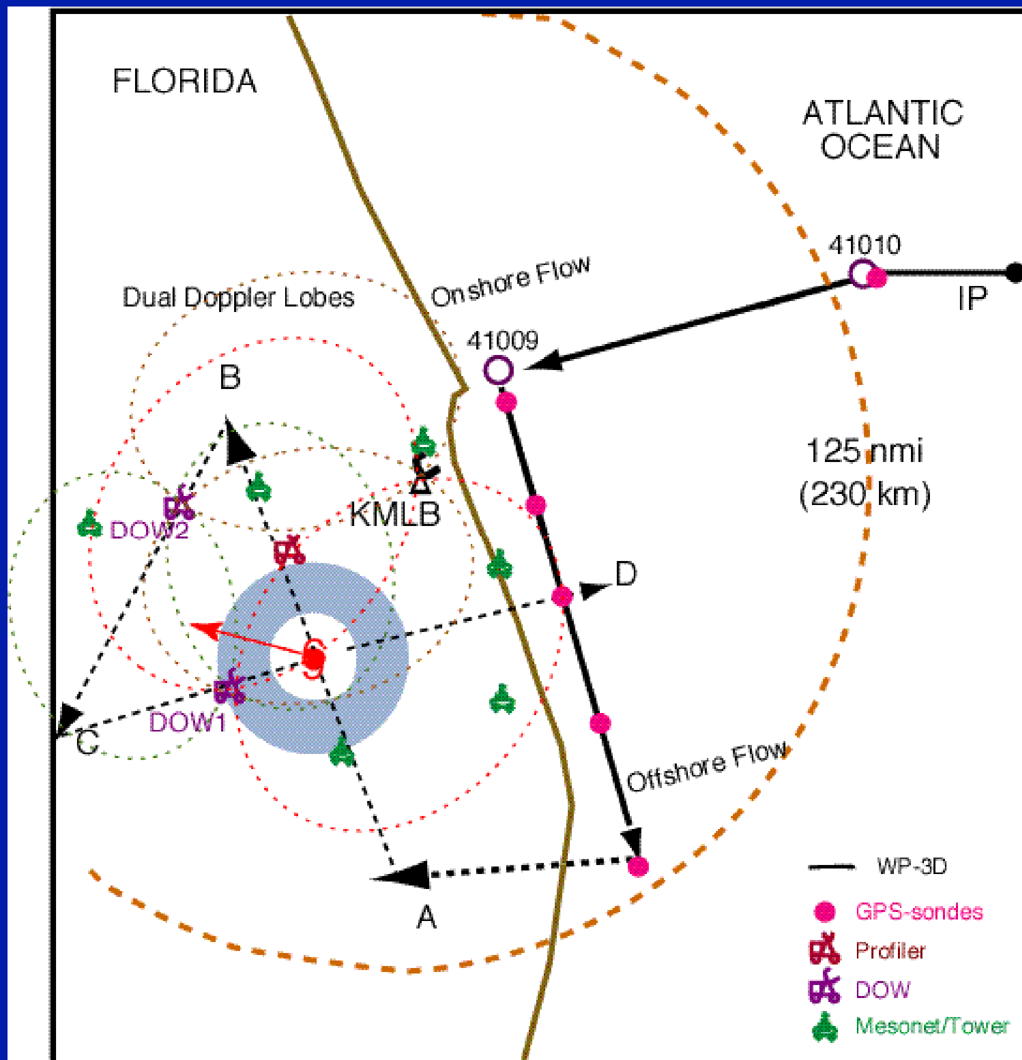
P. Dodge

Inland Decay Module



P. Dodge

Intense Convection Module



P. Dodge

Overland Hurricane Wind Decay Verification

Goal

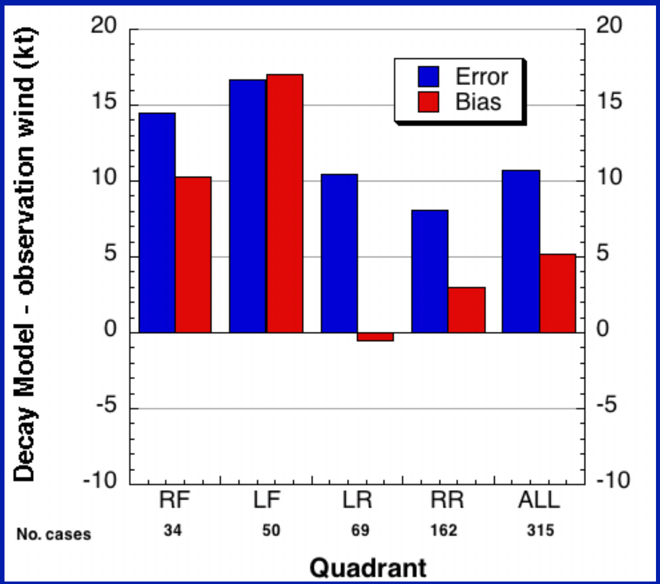
Use in-situ surface wind data collected during HRD HFP to validate numerical and empirical overland wind forecasts for landfalling storms.

Methodology

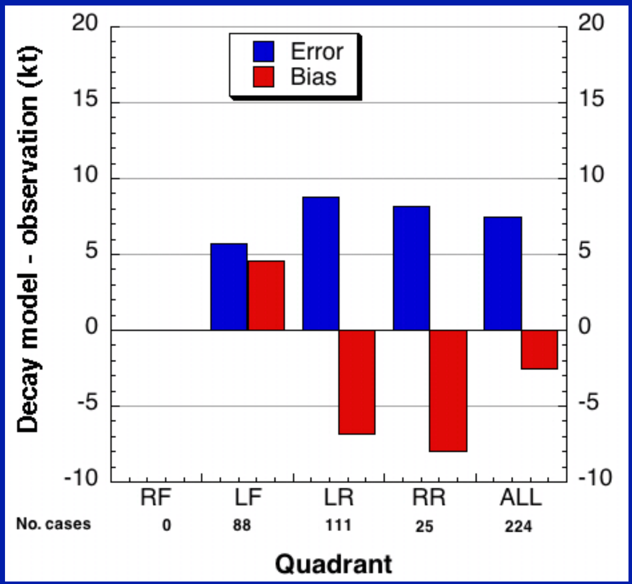
Compare numerical (HWRF-X) and empirical decay (Kaplan and DeMaria 1995) model 10-m 1-minute sustained wind forecasts as a function of the radial and azimuthal distance and time after landfall of each observation in storm relative coordinates.

Hurricane Wilma (10/24) 00 UTC

0-300 km dt=0-6 h



300-600 km dt=0-6 h



P. Dodge

John Gamache – TDR mission

HWRF Doppler Support Missions

"Three-dimensional Doppler Winds Experiment"

Purpose:

1. To provide a comprehensive wind data set for initialization of hurricane numerical simulations such as HWRF and HWRF-X—*in 2011, EMC will run parallel HWRF runs using airborne Doppler observations*
2. To validate models using statistics derived from Doppler observations from many flight legs into TCs
3. Provide data sets to increase understanding of RI and intensity change, using regular, periodic, collection.
4. To improve and evaluate technologies for observing tropical cyclones
5. To refine and test rapid real-time communications of the observations back to NCEP, as well as research community

J. Gamache

HWRF Doppler Support Missions

"Three-dimensional Doppler Winds Experiment"
Data Collection

1. 2 P-3 Flights per day--on-station time centered on 0, 6, 12, and 18 UTC analysis periods--optimum 3 days of flights in a row starting at tropical depression or maybe pre-depression stage
2. Data may be collected for 3 hours on either side of the synoptic time, and QC data must be delivered to NCO within 4 hours of the synoptic time, for example, for a 12 GMT analysis, data must be collected from 0900-1500 GMT, and they should arrive at NCO by 1600 GMT. Thus, P-3 takeoffs will be planned (within personnel and safety constraints) to maximize time within this window

J. Gamache

Real-time Doppler Data

1. ASCII files containing wind fields at 0.5 and 1.0 km, and vertical cross-sections, available to NHC, could be extended upward to other levels
2. Real-time 3D wind fields on AOML ftp site for possible assimilation/initialization of models
3. Higher-resolution radial-vertical cross sections of all 3 wind components
4. Trimmed, quality-controlled Doppler radials to NCO for assimilation into parallel HWRF
5. Doppler radial-velocity superobs transmitted to AOML ftp site for researchers to assimilate

J. Gamache

Resulting data analyses

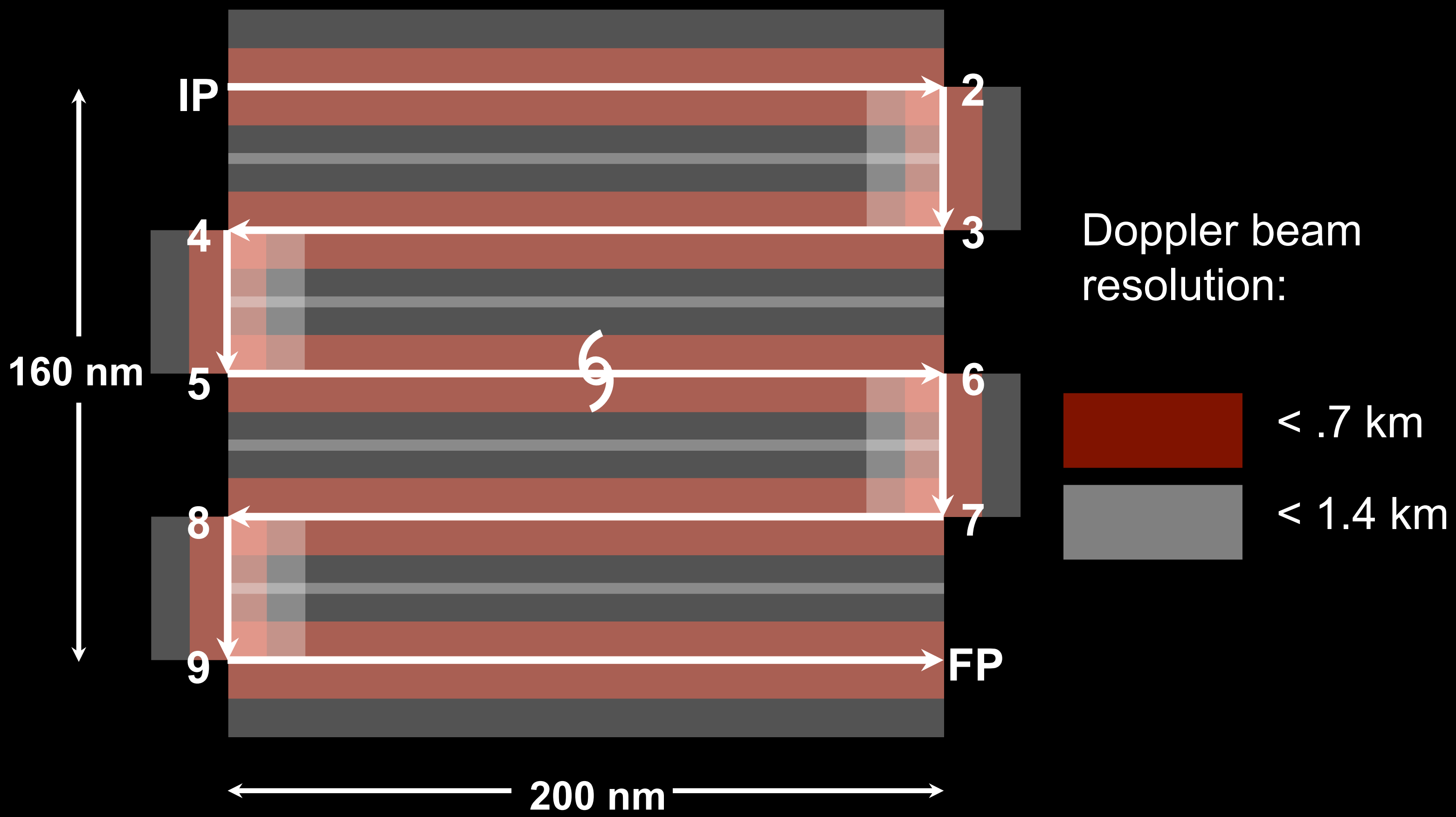
- Assimilation development at HRD
- Composite storm-structure studies
- Observing System Experiments (OSEs)
- Evaluation of error characteristics of airborne Doppler data and analyses

Notes:

1. Preferred flight level will be 12,000 ft to get maximum benefit from GPS dropwindsondes
2. For radar analyses, any level above 5000 ft is equally good
3. We will continue this summer to use RVP-5, the old radar processing system
4. Single PRF will be used, and set to 2100 (TD or TS), 2400 (Hurricane), or 2800 (Category 3 or more)
5. Unless approved by PI, antenna scanning should always be set to FAST continuous, whether NOAA or French antenna
6. Any orientation of nominal flight plans may be used
7. Nominal flight pattern will depend upon whether maximum radial coverage, or maximum azimuthal coverage is required

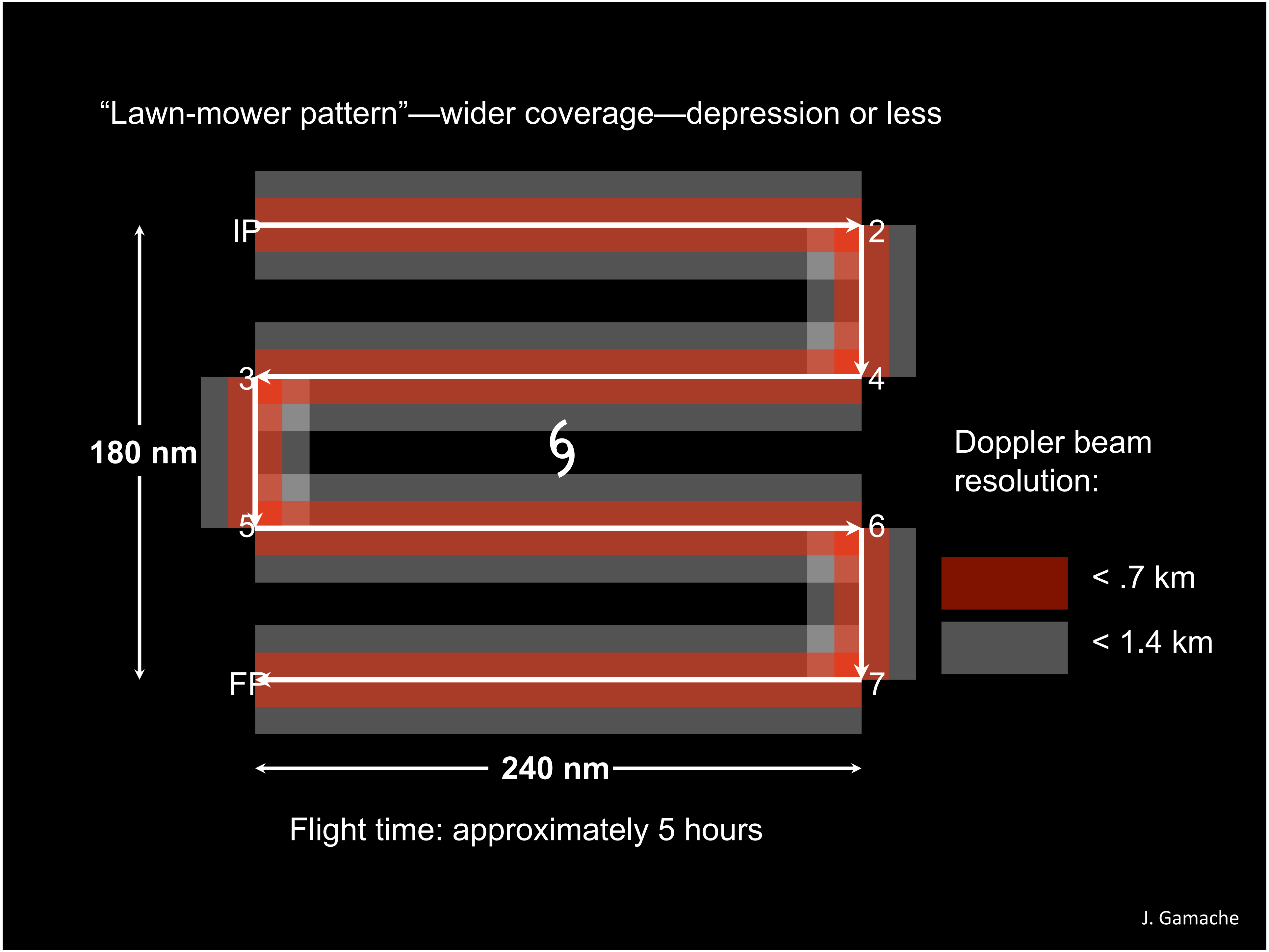
J. Gamache

“Lawn mower pattern”—full coverage—depression or less

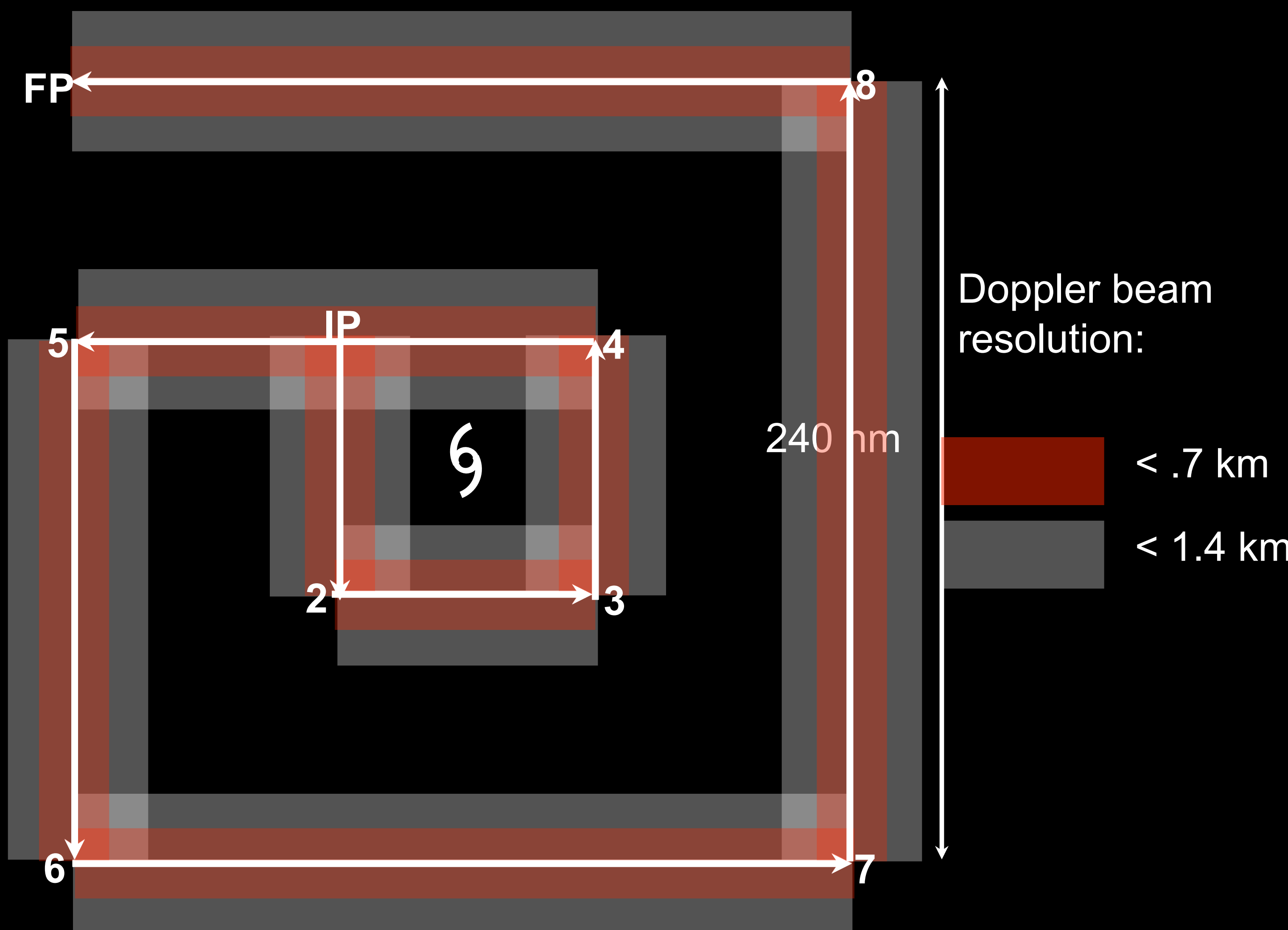


Flight time: approximately 5 hours

J. Gamache

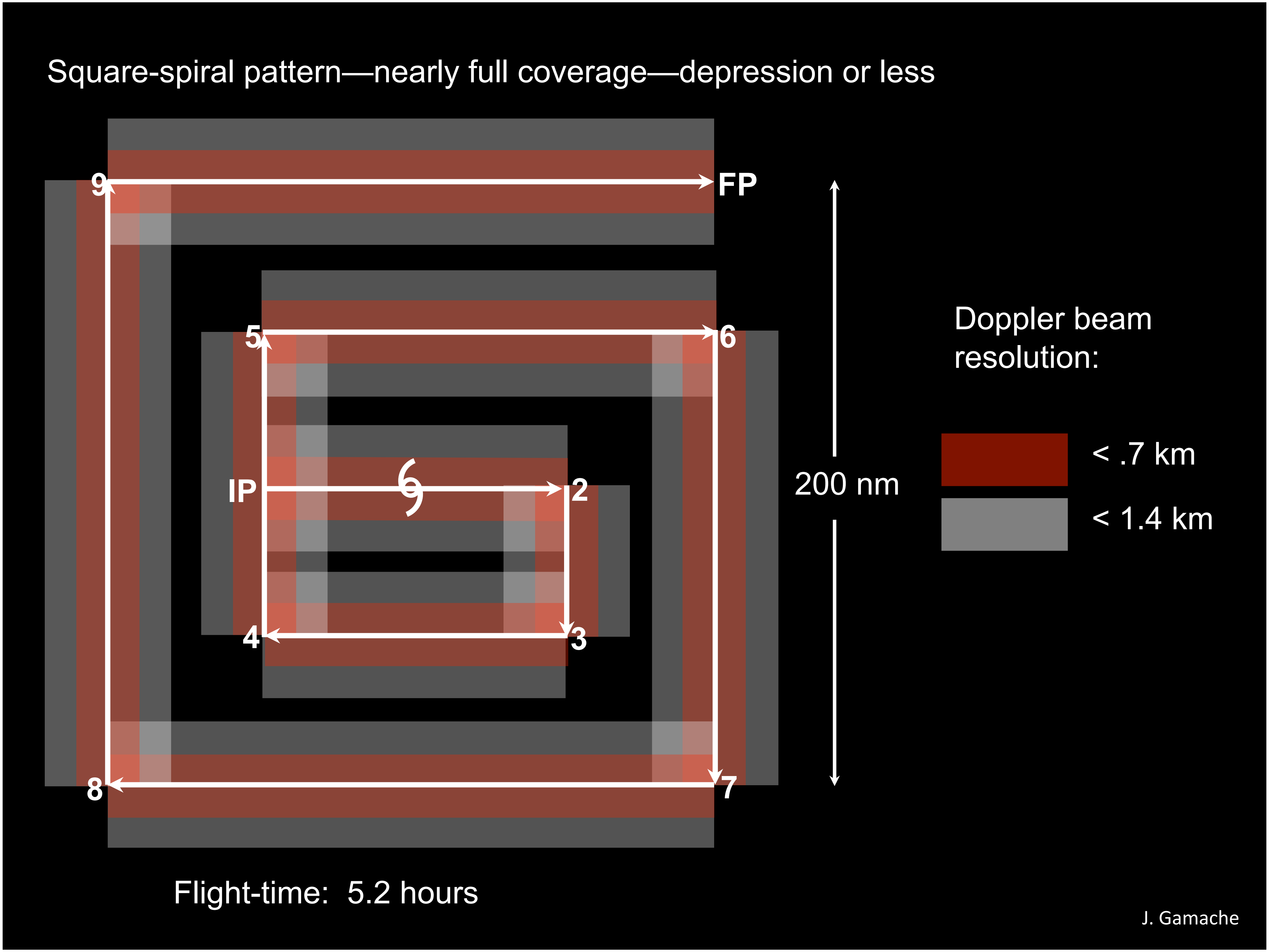

"Lawn-mower pattern"—wider coverage—depression or less
IP
2
3
4
5
6
7
FP
180 nm
240 nm
Doppler beam resolution:
< .7 km
< 1.4 km
Flight time: approximately 5 hours
J. Gamache

Square-spiral pattern—wider coverage—depression or less

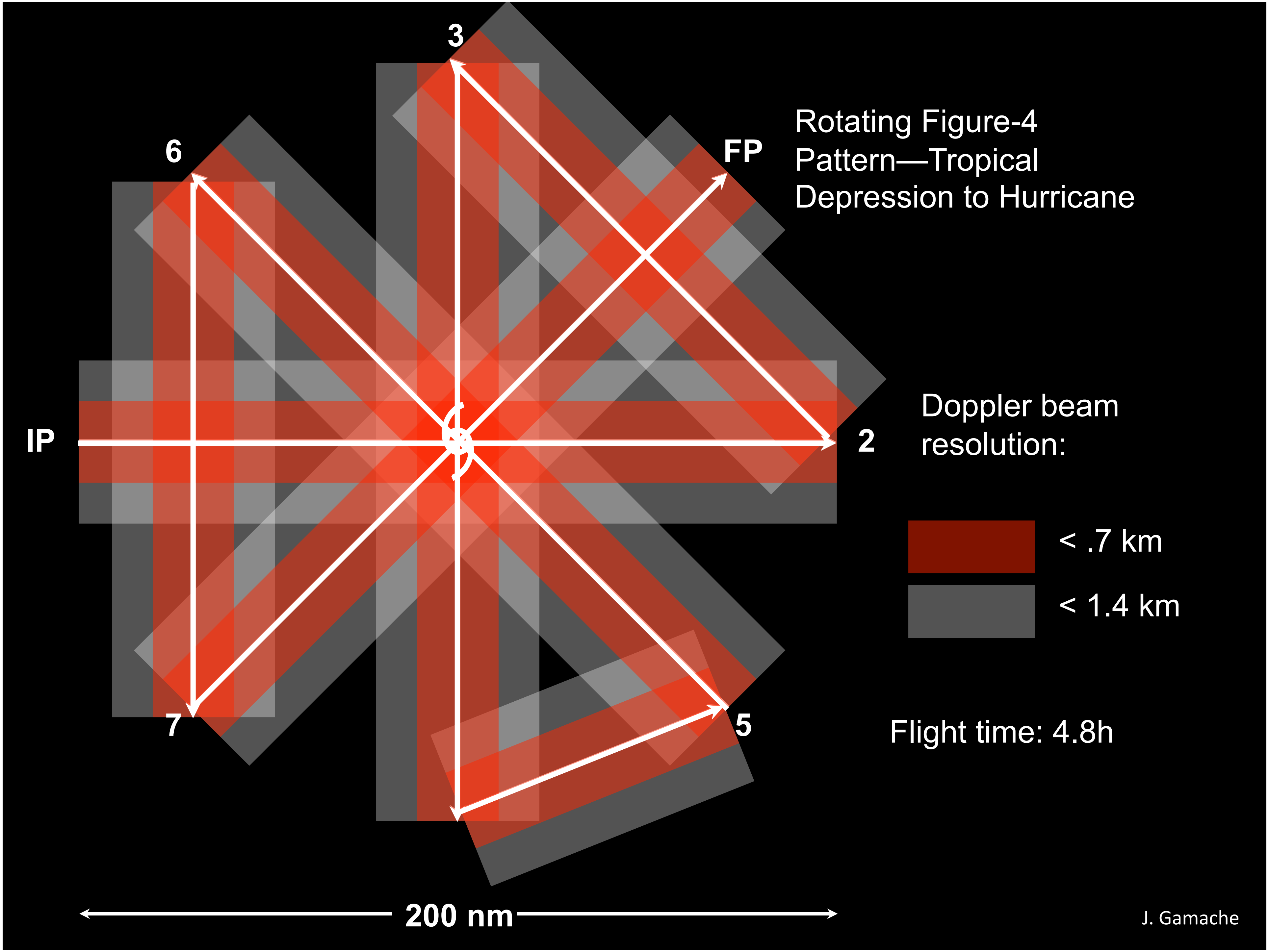


Flight time: 5.5 hours

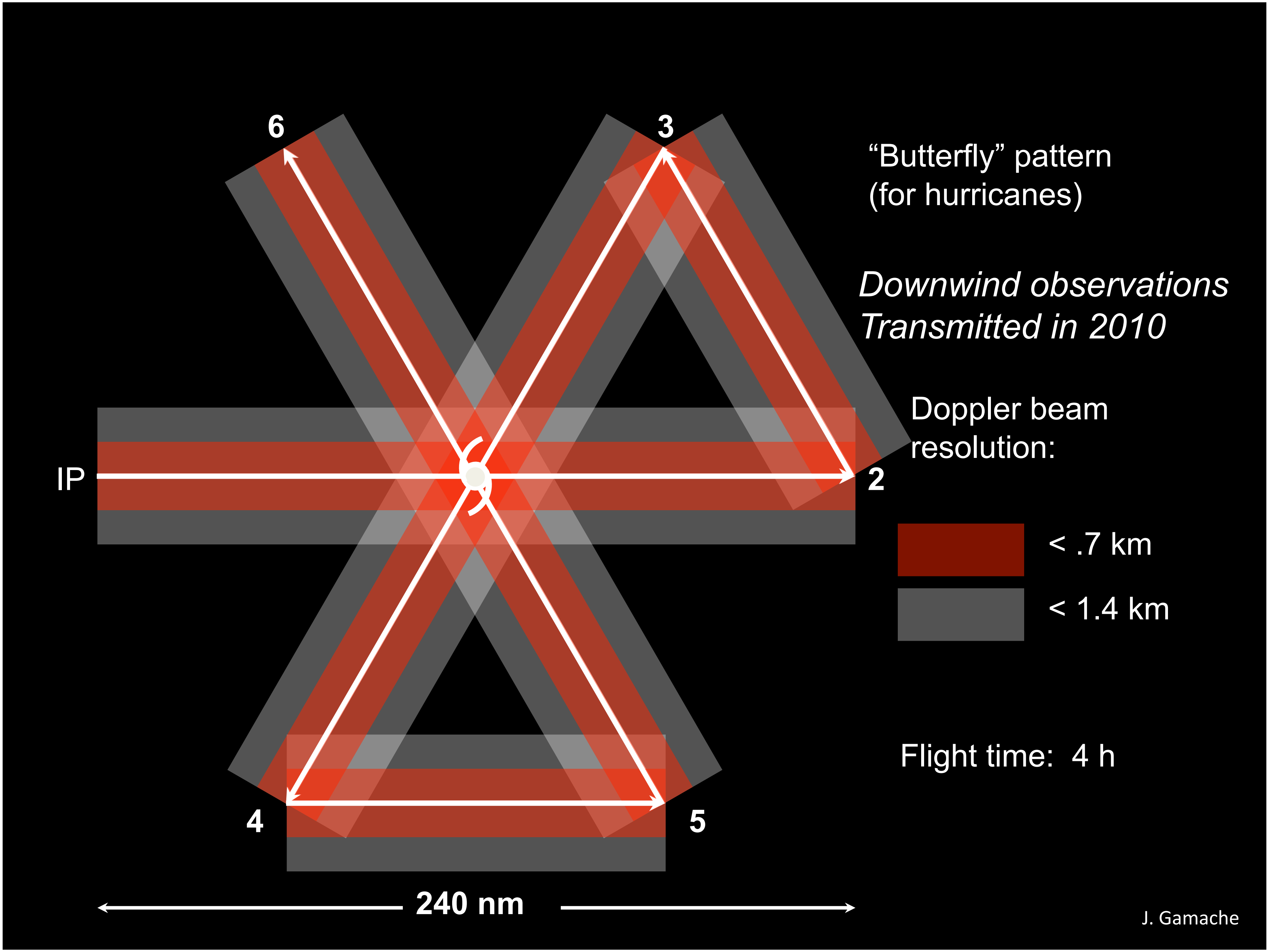
J. Gamache

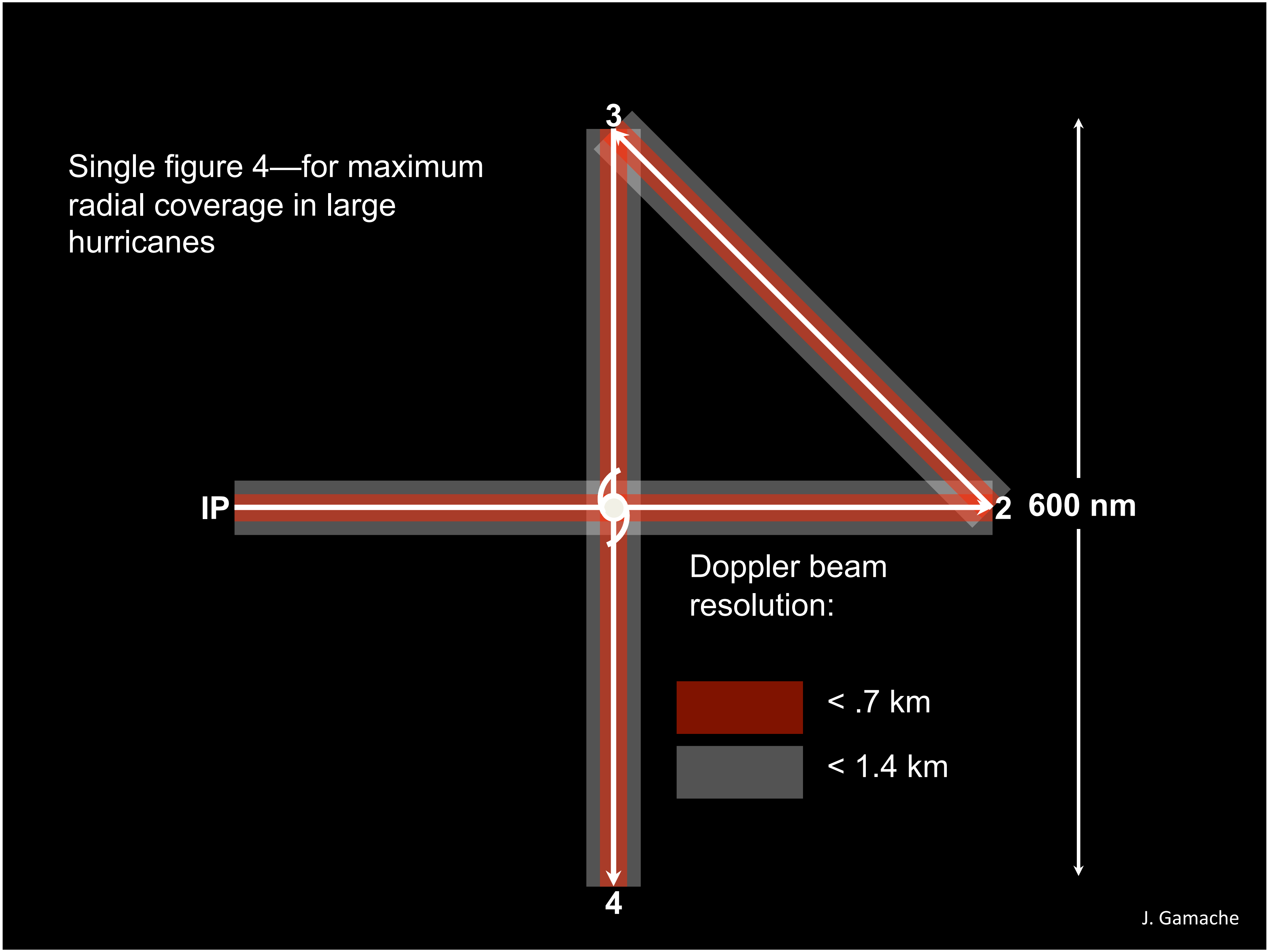


Square-spiral pattern—nearly full coverage—depression or less
9
FP
5
6
IP
2
4
3
8
7
200 nm
Doppler beam resolution:
< .7 km
< 1.4 km
Flight-time: 5.2 hours
J. Gamache



Rotating Figure-4
Pattern—Tropical
Depression to Hurricane
3
6
FP
IP
2
7
5
Doppler beam
resolution:
< .7 km
< 1.4 km
Flight time: 4.8h
200 nm
J. Gamache


6
3
"Butterfly" pattern
(for hurricanes)
Downwind observations
Transmitted in 2010
Doppler beam
resolution:
IP
2
< .7 km
< 1.4 km
Flight time: 4 h
4
5
240 nm
J. Gamache


Single figure 4—for maximum radial coverage in large hurricanes
3
IP
2
600 nm
4
Doppler beam resolution:
< .7 km
< 1.4 km
J. Gamache

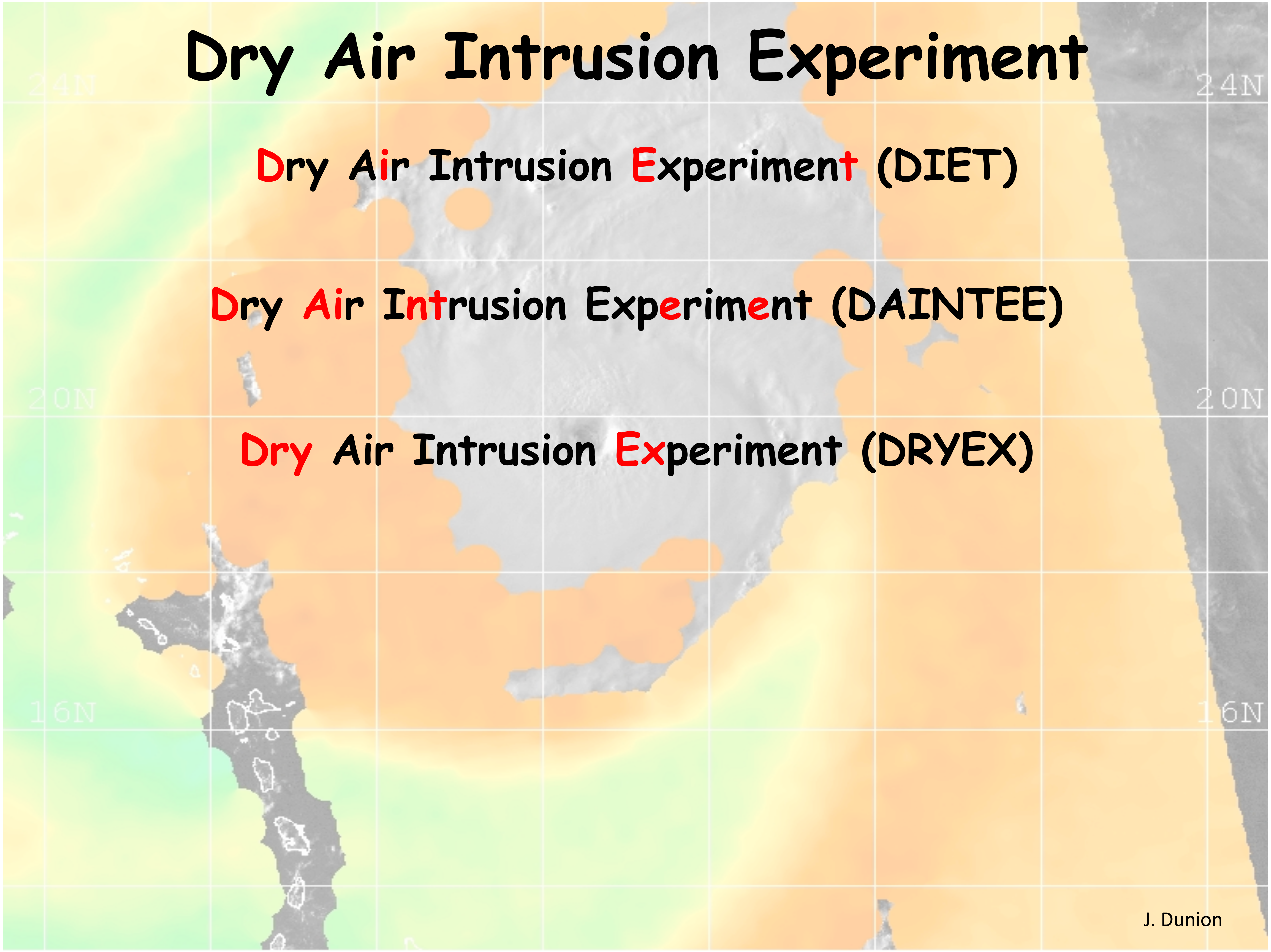
Jason Dunion – Dry Air Intrusion Experiment

Dry Air Intrusion Experiment

Dry Air Intrusion Experiment (DIET)

Dry Air Intrusion Experiment (DAINTEE)

Dry Air Intrusion Experiment (DRYEX)



J. Dunion

Dry Air Intrusion Experiment

Hypotheses:

1) Low to mid-level dry air follows fairly predictable pathways around a TC;
2) Certain storm quadrants are more/less vulnerable to dry air intrusions;
3) Arc clouds can be used to diagnose the interaction between low to mid-level (~600-850 mb) dry air and an AEW/TC…and may limit short-term intensification (enhanced low-level outflow, BL stabilization, etc);
4) When the shear vector with large enough magnitude (~10-15+ kt) aligns with a quadrant containing substantial low to mid-level dry air (e.g. SAL or mid-latitude dry air intrusion), dry air entrainment (i.e. arc cloud formation) is likely;
5) When arc clouds form in a forward quadrant, the modified BL may more significantly impact the storm (relative to arc clouds that form in a rear quadrant)…i.e. you don't want to run over the mess you've made;

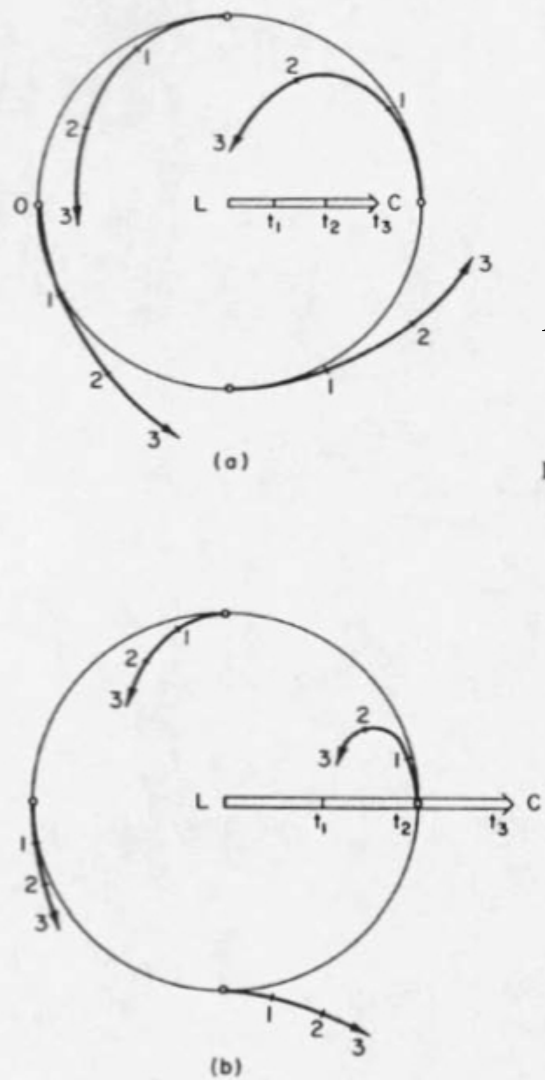
Objectives (G-IV to start; links w/ GENEx, RI patterns):

1) Test hypotheses 1-2 using theoretical trajectory calculations, model trajectories, and satellite data from GOES, MSG, and MW polar orbiters;
2) Test hypotheses 3-4 using GPS dropsonde observations from the NOAA G-IV and analyses/forecasts from SHIPS;
3) Test hypothesis 5 using GPS dropsonde observations & idealized modeling;

J. Dunion

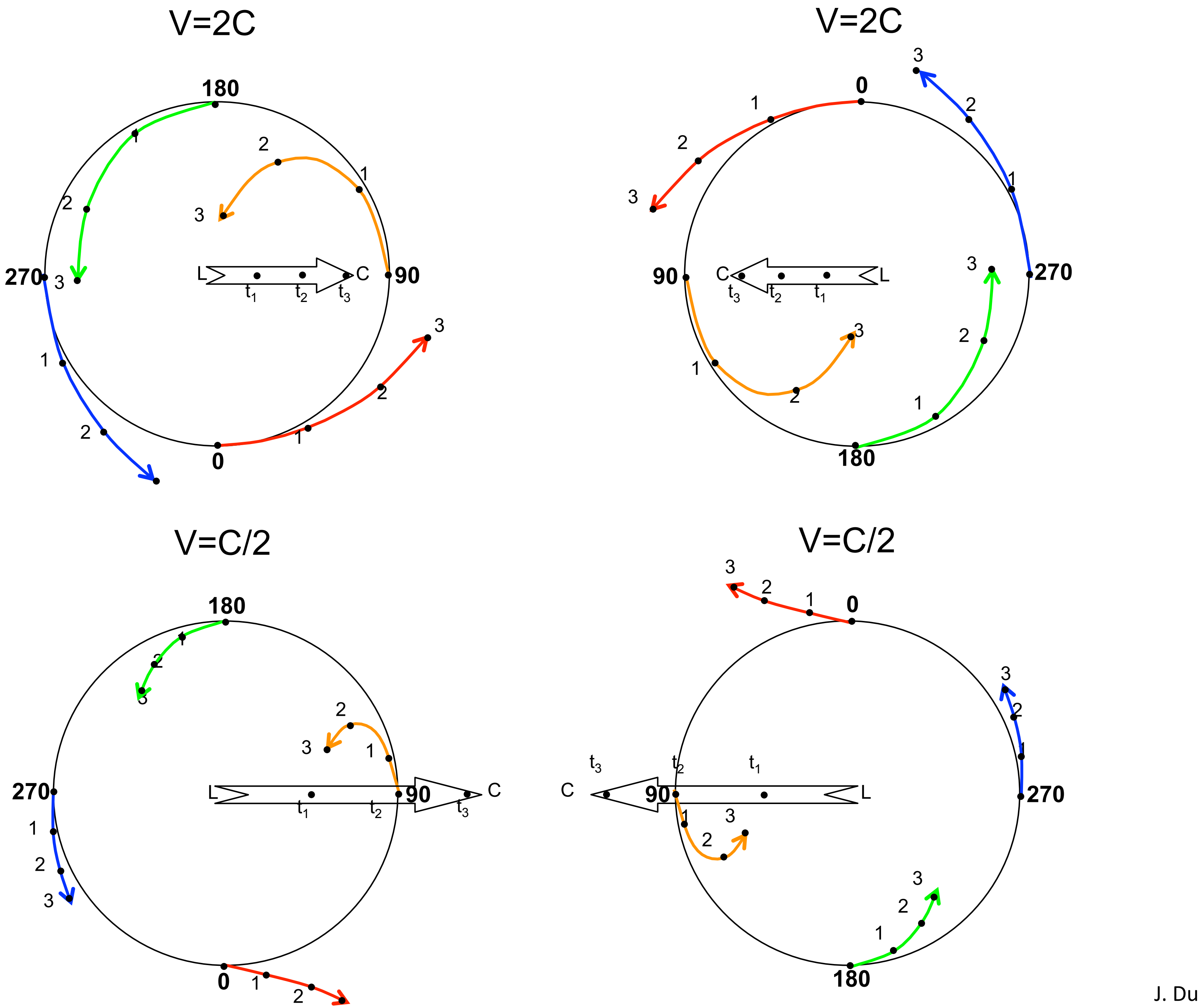
V= Tangential Wind at Radius (R)

C= Forward Motion

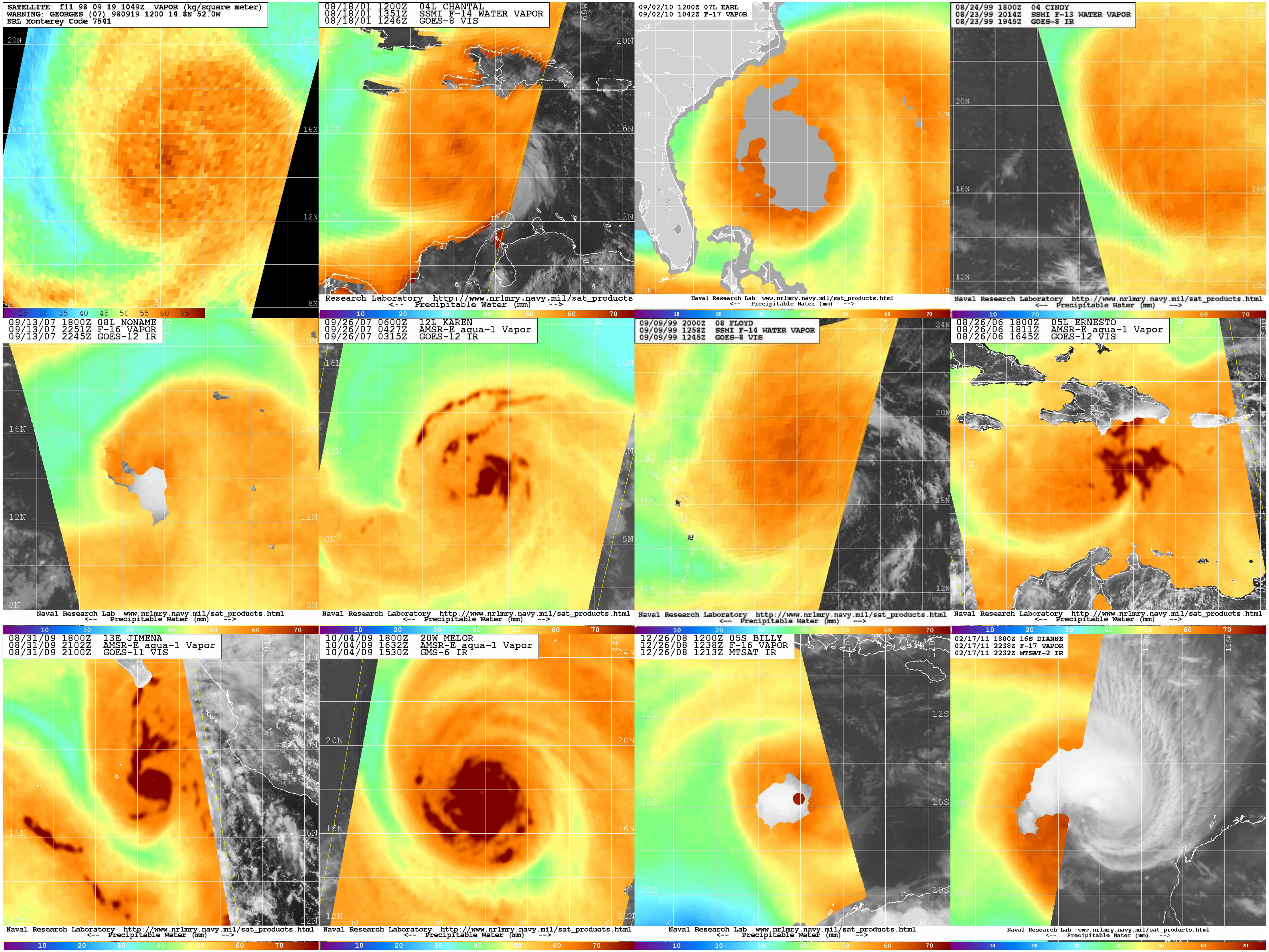


$$R_t = R_s \left(1 - \frac{C \cos \gamma}{V}\right)^{-1}$$

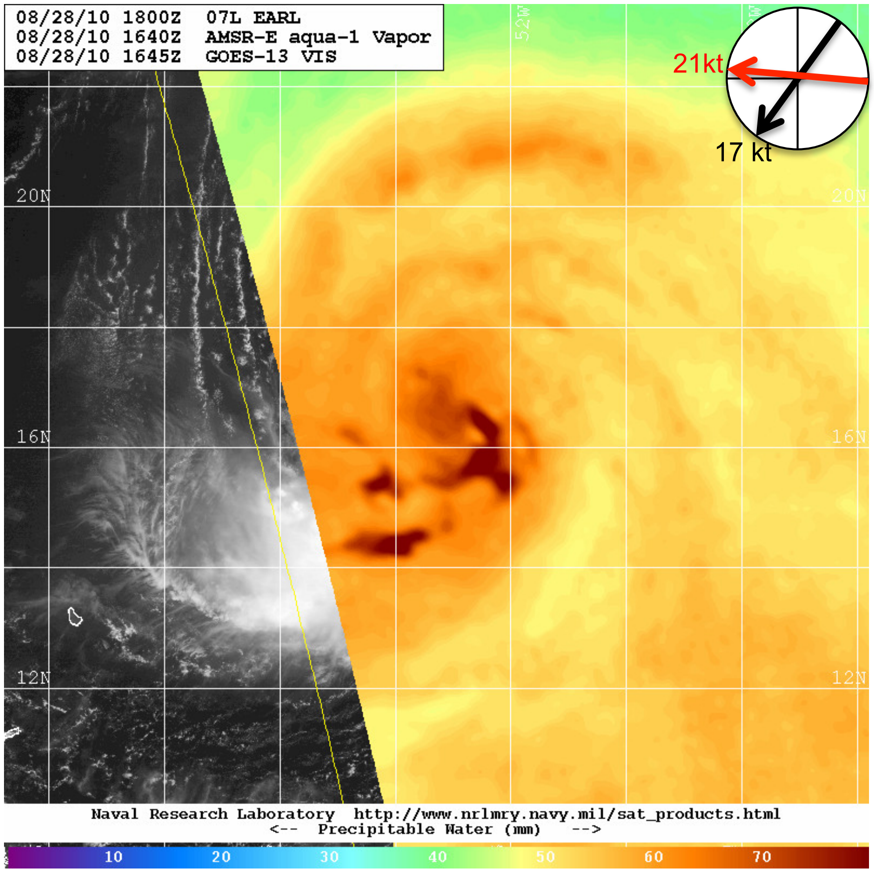
Fig. 3.7 Trajectories for moving circular cyclonic circulation systems in the Northern Hemisphere with (a) $V = 2C$ and (b) $2V = C$. Numbers indicate positions at successive times. The L designates a pressure minimum.

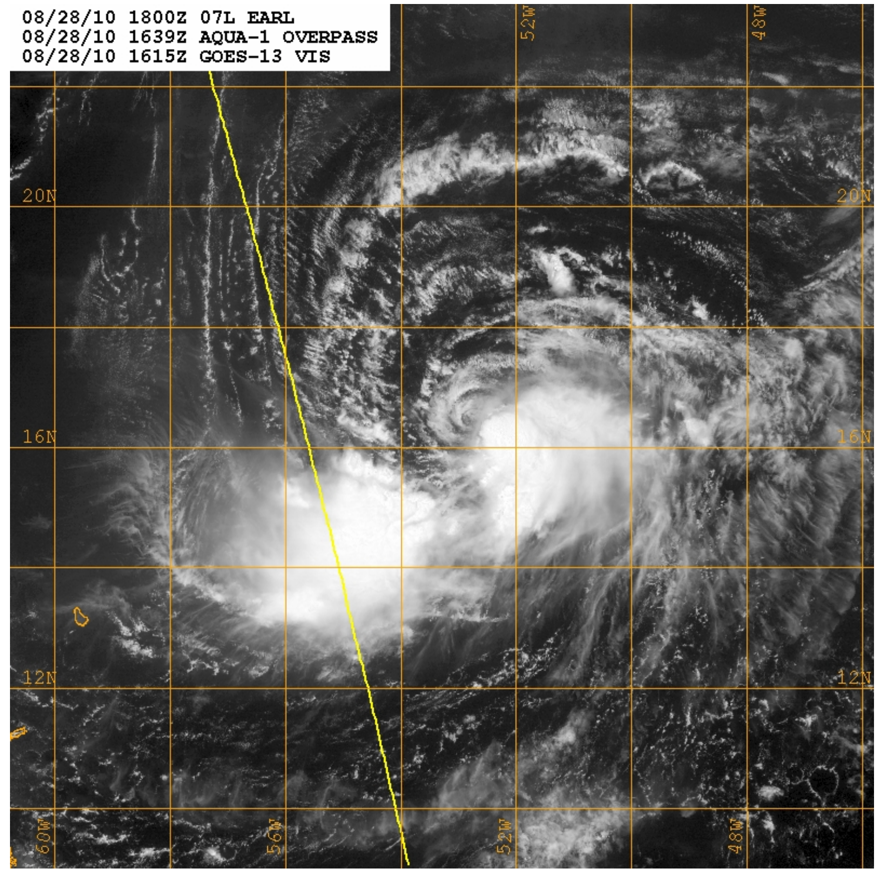


J. Dunion


SATELLITE: f11 98 09 19 1049Z VAPOR (kg/square meter)
WARNING: GEORGES (07) 980919 1200 14.8N 52.0W
NRL Monterey Code 7541
08/18/01 1200Z 04L CHANTAL
08/18/01 1351Z SSMI F-14 WATER VAPOR
08/18/01 1246Z GOES-8 VIS
Research Laboratory http://www.nrlmry.navy.mil/sat_products
<-- Precipitable Water (mm) -->
09/02/10 1200Z 07L EARL
09/02/10 1042Z F-17 VAPOR
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
08/24/99 1800Z 04 CINDY
08/23/99 2014Z SSMI F-13 WATER VAPOR
08/23/99 1945Z GOES-8 IR
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
09/13/07 1800Z 08L NONAME
09/13/07 2251Z F-16 VAPOR
09/13/07 2245Z GOES-12 IR
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
09/26/07 0600Z 12L KAREN
09/26/07 0427Z AMSR-E aqua-1 Vapor
09/26/07 0315Z GOES-12 IR
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
09/09/99 2000Z 08 FLOYD
09/09/99 1258Z SSMI F-14 WATER VAPOR
09/09/99 1245Z GOES-8 VIS
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
08/26/06 1800Z 05L ERNESTO
08/26/06 1811Z AMSR-E aqua-1 Vapor
08/26/06 1645Z GOES-12 VIS
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
08/31/09 1800Z 13E JIMENA
08/31/09 2102Z AMSR-E aqua-1 Vapor
08/31/09 2100Z GOES-11 VIS
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
10/04/09 1800Z 20W MELOR
10/04/09 1632Z AMSR-E aqua-1 Vapor
10/04/09 1530Z GMS-6 IR
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
12/26/08 1200Z 05S BILLY
12/26/08 1238Z F-16 VAPOR
12/26/08 1213Z MTSAT IR
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->
02/17/11 1800Z 16S DIANNE
02/17/11 2238Z F-17 VAPOR
02/17/11 2232Z MTSAT-2 IR
Naval Research Lab www.nrlmry.navy.mil/sat_products.html
<-- Precipitable Water (mm) -->

Earl: 28 Aug 2010 1640 UTC





SHIPS Deep Layer Shear:

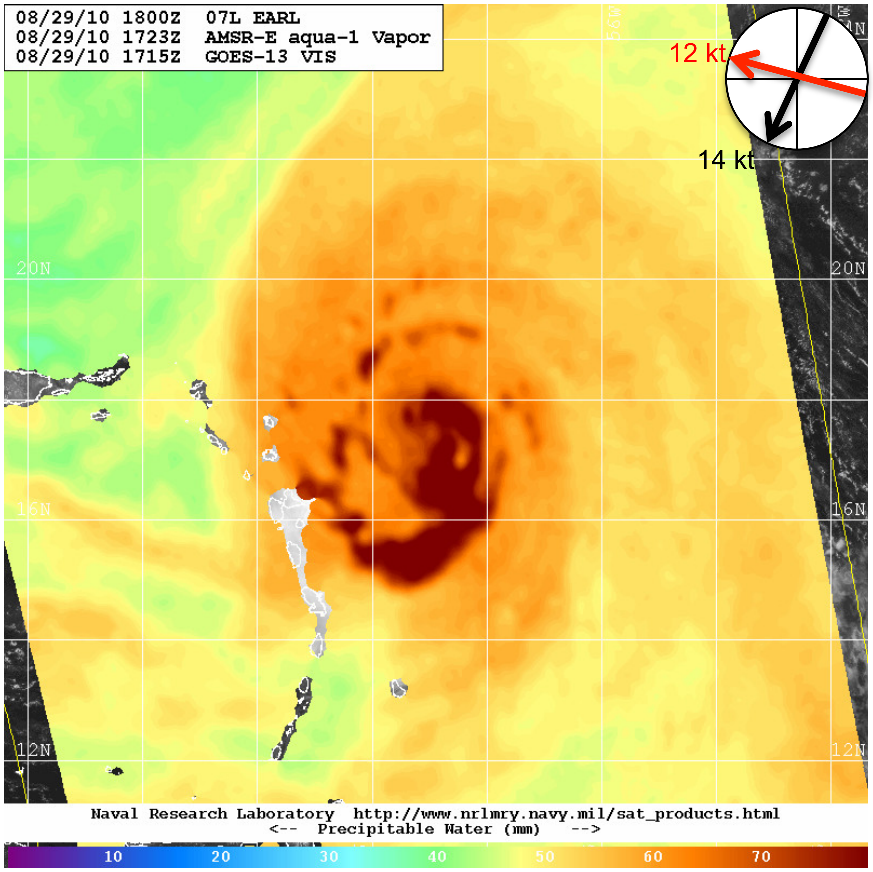
t +24 hr: 10 kt @52 deg

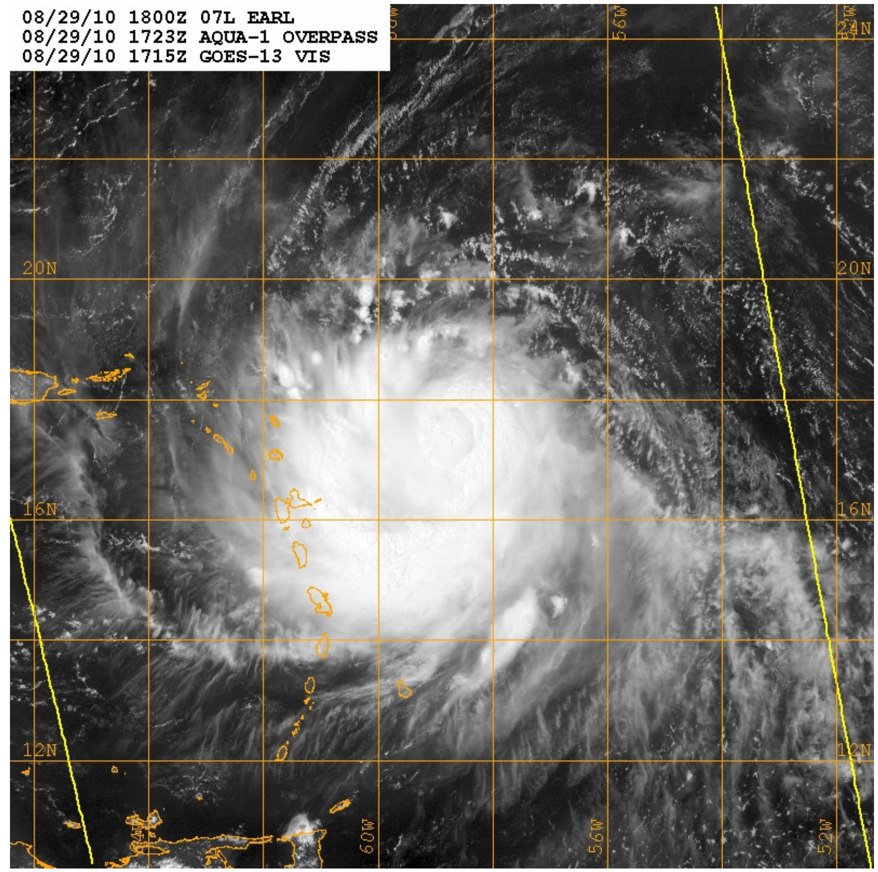
t +48 hr: 4 kt @33 deg

t +72 hr: 15 kt @237 deg

J. Dunion

Earl: 29 Aug 2010 1723 UTC





SHIPS Deep Layer Shear:

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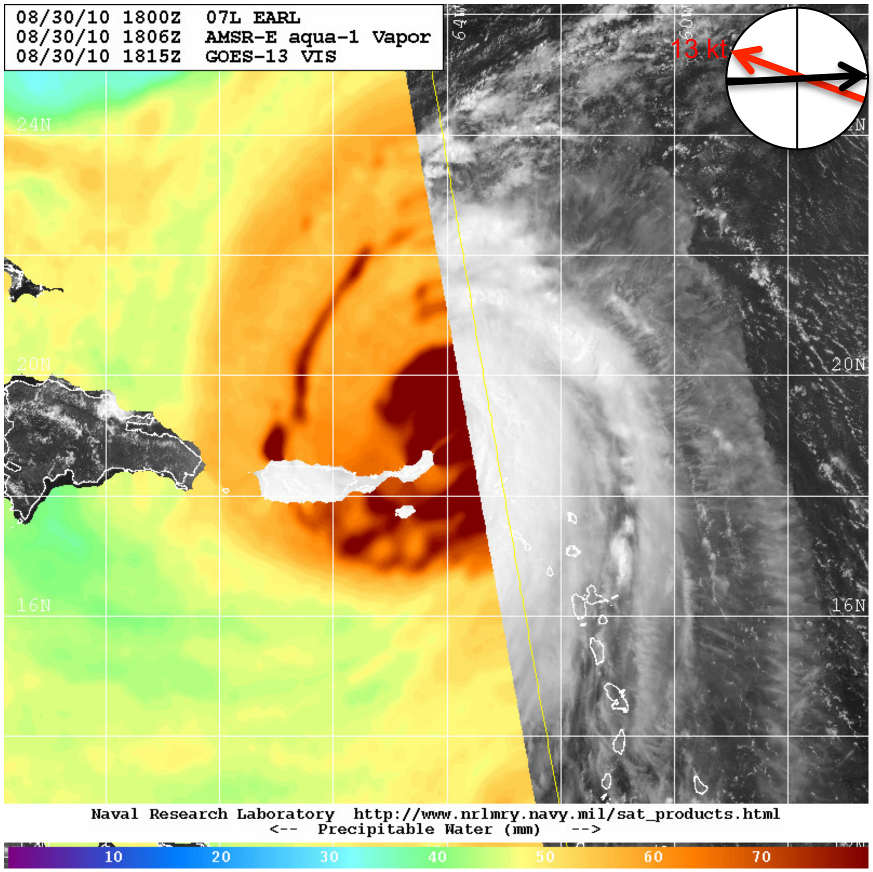
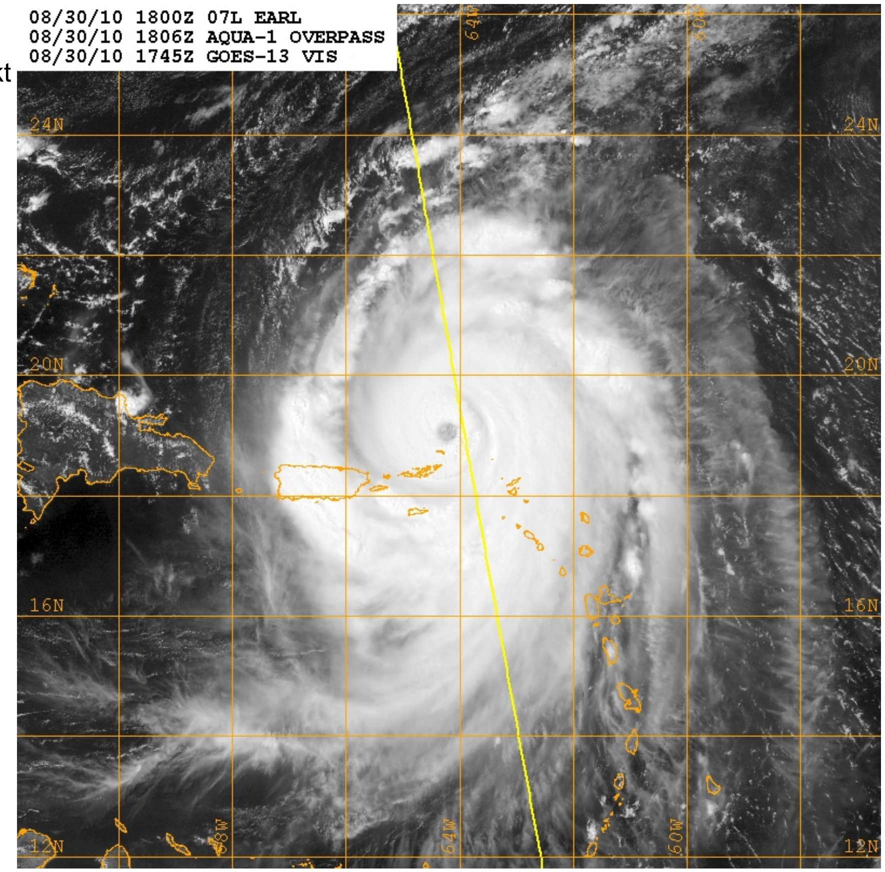
t +48 hr: 11 kt @191 deg

t +72 hr: 13 kt @172 deg

J. Dunion

Earl: 30 Aug 2010 1806 UTC





<u>SHIPS Deep Layer Shear:</u>

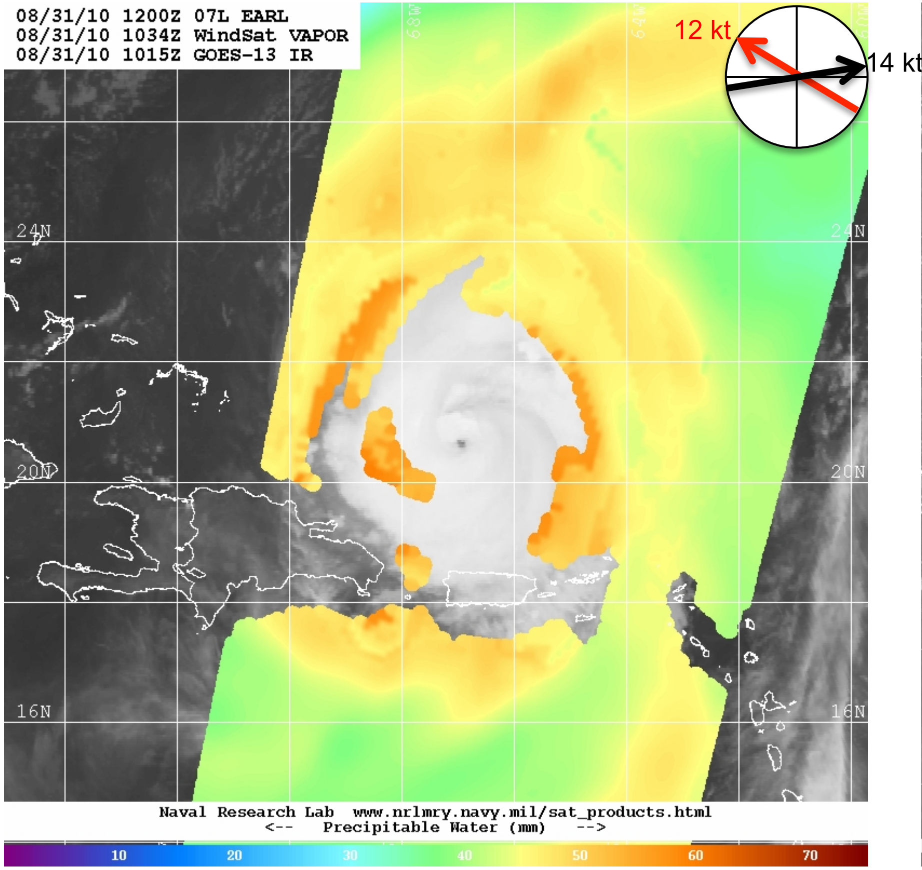
t +24 hr: 15 kt @191 deg

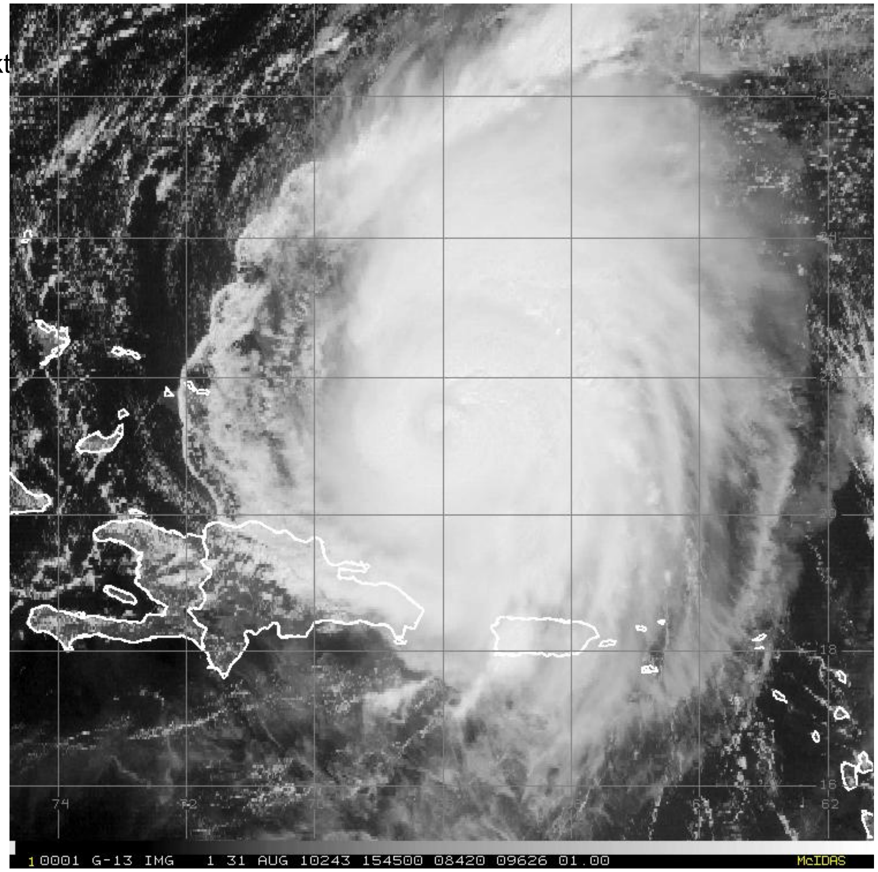
t +48 hr: 22 kt @177 deg

t +72 hr: 14 kt @174 deg

J. Dunion

Earl: 31 Aug 2010 1034 UTC





<u>**SHIPS Deep Layer Shear:**</u>

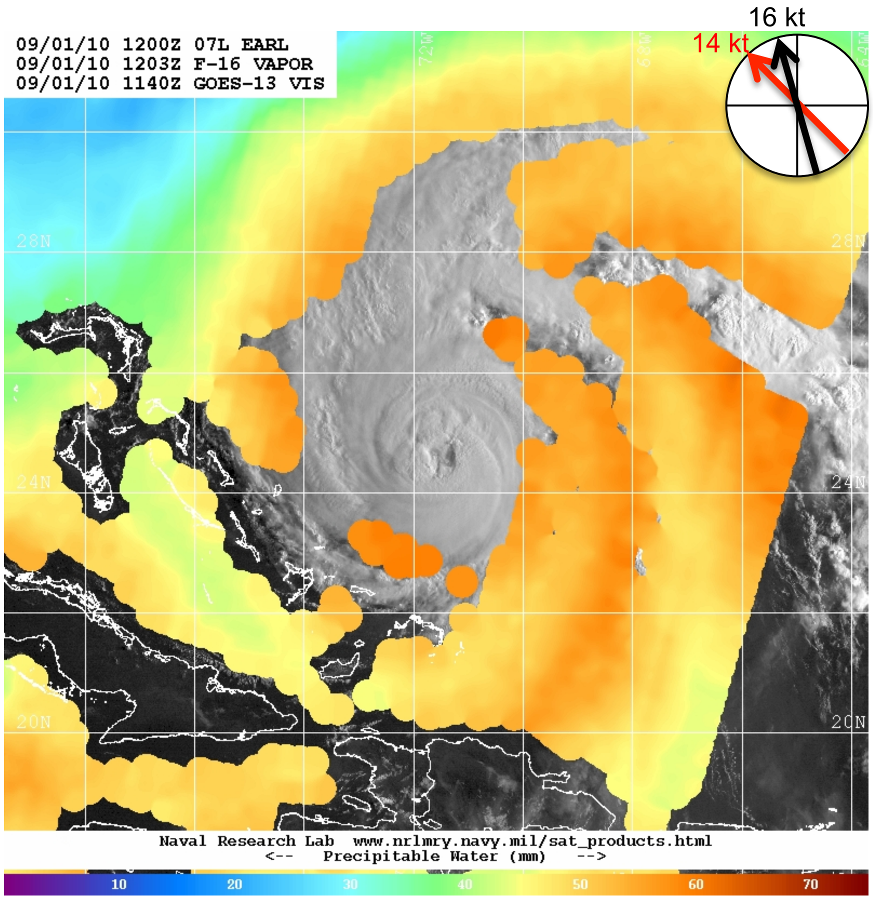
t +24 hr: 18 kt @187 deg

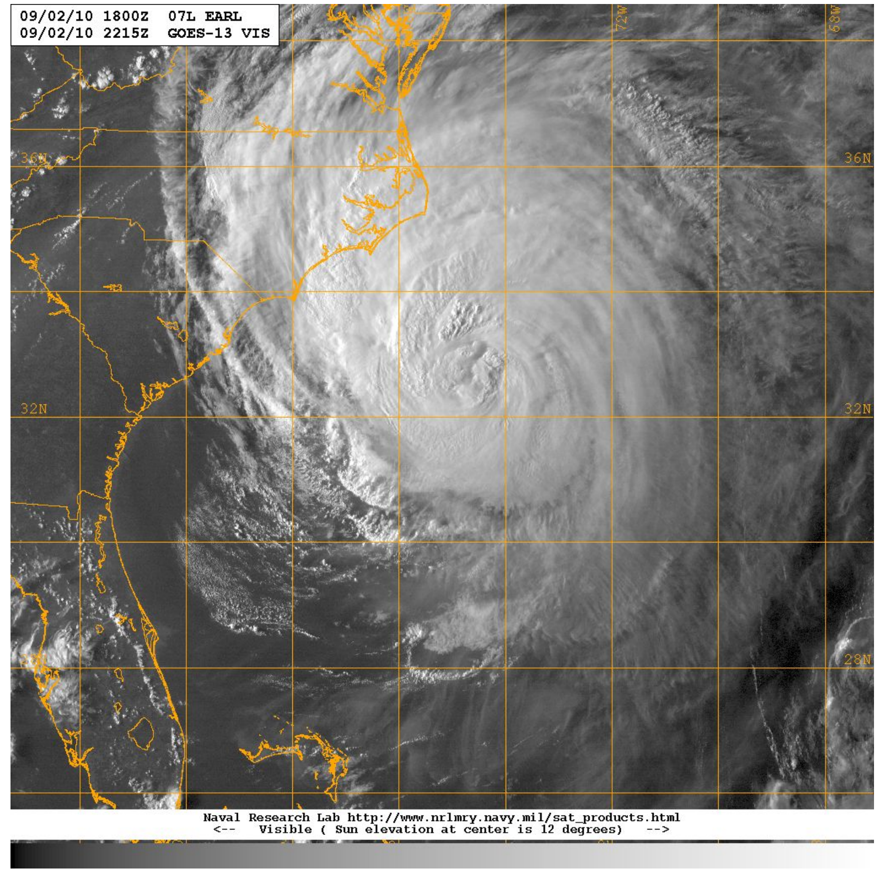
t +48 hr: 2 kt @113 deg

t +72 hr: 13 kt @214 deg

J. Dunion

Earl: 01 Sep 2010 1203 UTC





<u>SHIPS Deep Layer Shear:</u>

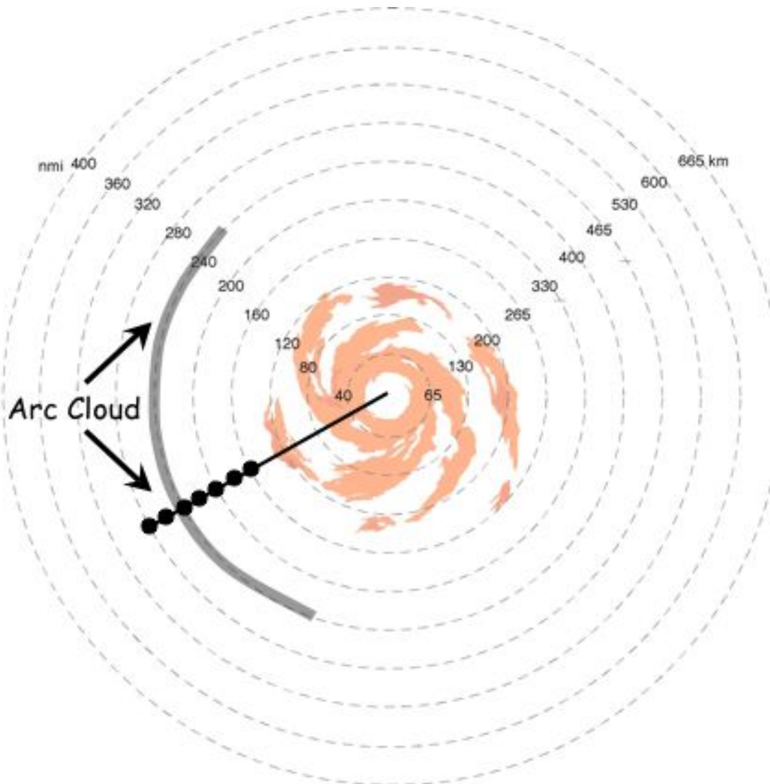
t +24 hr: 13 kt @190 deg

t +48 hr: 24 kt @198 deg

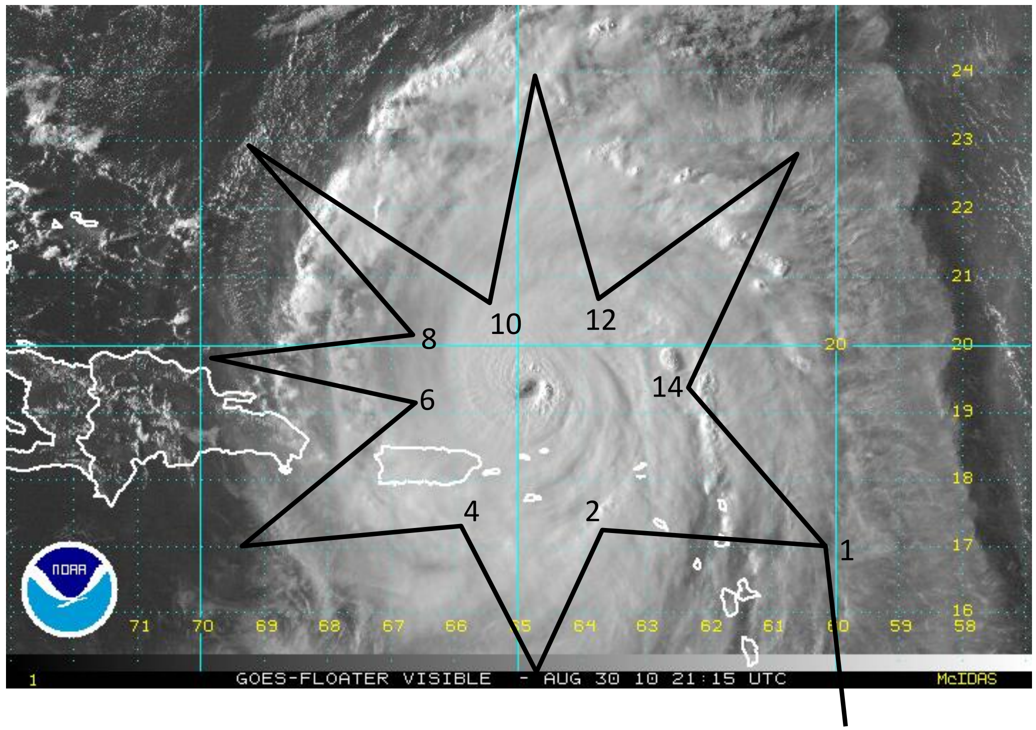
t +72 hr: 22 kt @216 deg

J. Dunion

Dry Air Intrusion Experiment



GPS dropsonde transects across the arc cloud feature (~20 nm spacing)



Modified G-IV star pattern to emphasize sampling in upshear semicircles/quadrants

J. Dunion

Sylvie Lorsolo and Jason Dunion – Doppler Wind LIDAR Modules

Doppler Wind Lidar (DWL) Module

DWL Instrument

• Pulsed 2-micron coherent-detection Doppler wind profiling lidar system (DWL);

•NOAA-42; Status?

• Includes a compact, packaged, coherent Doppler lidar transceiver and a biaxial scanner >> enables scanning above, below and ahead of the aircraft;

• Transceiver emits 2 mJ eyesafe pulses at 500 Hz;

• DWL operating wavelength (~2 microns) >> Mie Scattering >> instrument requires aerosol scatterers in the size range of ~1+ microns;

• Detect winds and aerosols both above (up to ~14 km in the presence of high level cirrus) and below (down to ~100 m above the ocean surface) the aircraft flight level (typically 3-5 km);

• Vertical resolution: ~50 m; Horizontal spacing: ~2 km for u, v, and w wind profiles;

• Anticipated data void region ~300 m above and below the aircraft;

• Retrievals within and below optically thin or broken clouds are frequent; limited capability in the presence of deep, optically thick convection;

J. Dunion

HBL Small-Scale Turbulent Processes Module

Primary IFEX Goal: 2 - Develop and refine measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment

Principal Investigator(s): Sylvie Lorsolo and David Emmitt

Objectives

- Identify and document the physical characteristics of small-scale features of the hurricane boundary layer (HBL) and estimate their impact on the kinematics and the thermodynamics of the HBL;
- Provide data allowing retrieval of turbulent characteristics of the HBL and assess the energy distribution within the HBL and the vertical and lateral energy transport associated with HBL small-scale turbulent processes.

Links to IFEX:

- This experiment supports the following NOAA IFEX goals:
- **Goal 1**: Collect observations that span the TC lifecycle in a variety of environments;
- **Goal 2**: Development and refinement of measurement technologies;
- **Goal 3**: Improve our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle;

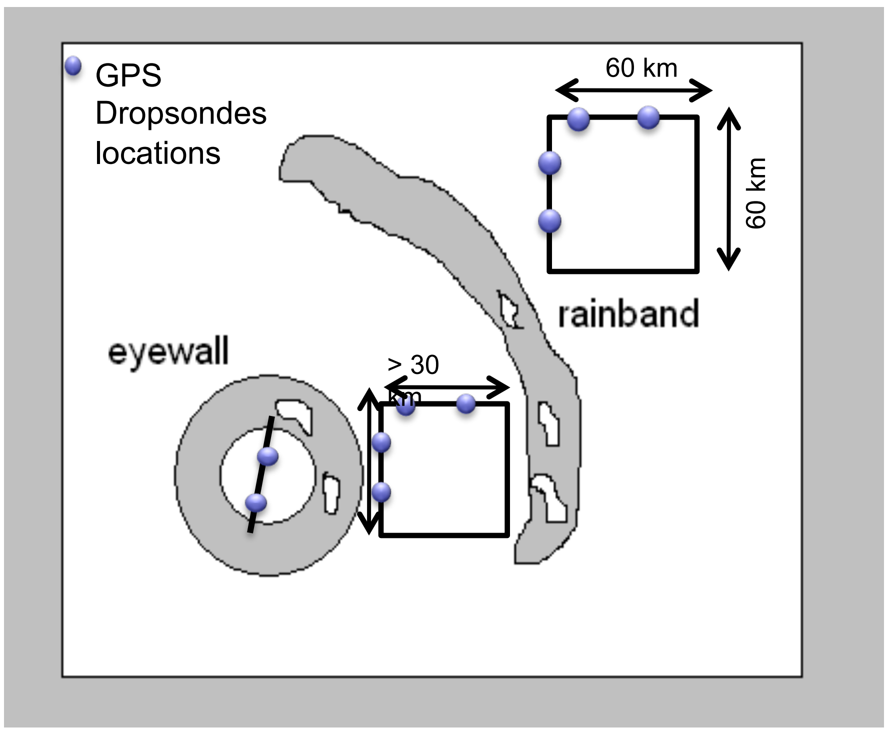
HBL Small-Scale Turbulent Processes Module

Experiment Description

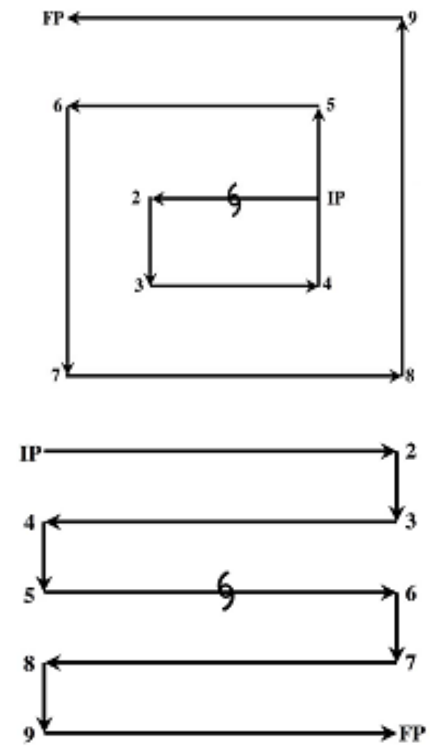
***Objective #1:* Identify and document the physical characteristics of small-scale features of the hurricane boundary layer (HBL) and estimate their impact on the kinematics and the thermodynamics fields of the HBL**

Option 1: Box transect

Tracks



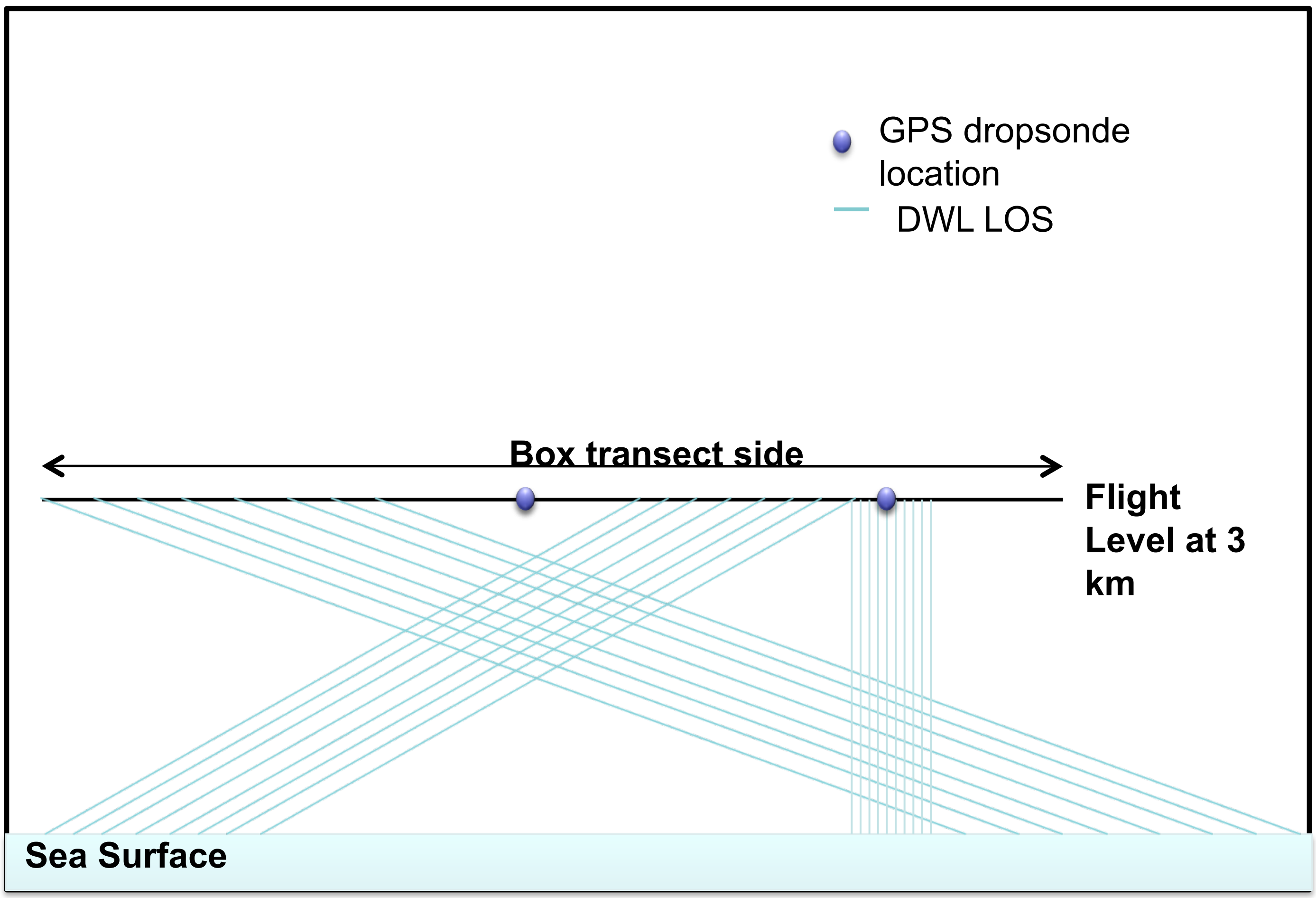
Option 2: Square-spiral or lawnmower pattern



S. Lorsolo

HBL Small-Scale Turbulent Processes Module

Scanning Strategy: Forward, Aft, Nadir (FAN)

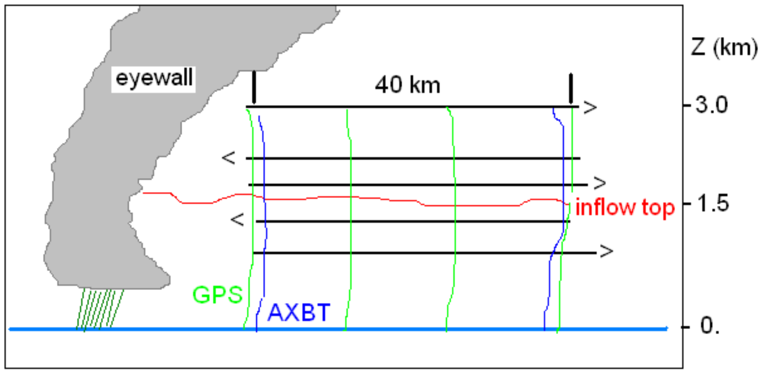


S. Lorsolo

Objective #2: Provide data allowing retrieval of turbulent characteristics of the HBL and assess the energy distribution within the HBL and the vertical and lateral energy transport associated with HBL small-scale turbulent processes

Option 1: Stepped decent (cf. Hurricane Boundary Layer Entrainment Flux Module, Zhang and Barnes)

Track

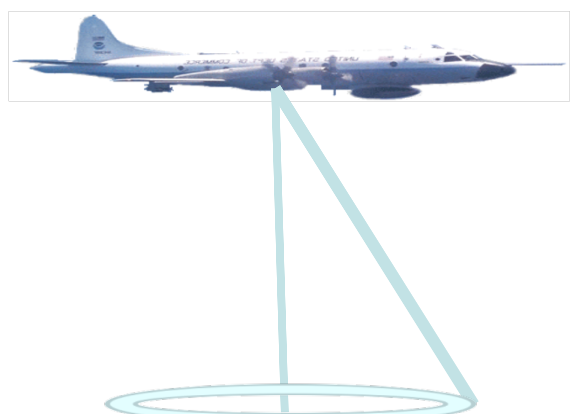


Scanning strategy : FAN

Option 2: Multiple patterns option

If the stepped decent pattern is not possible, the DWL will use the conical scan strategy and TKE will be computed following Lorsolo et al. (2010).

Scanning strategy: Conical scans



S. Lorsolo

DWL SAL Module

Primary IFEX Goal: 3 - Improve our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle

Principal Investigator(s): Jason Dunion and David Emmitt

Objectives

- Characterize the SAL's suspended dust and mid-level jet (~600-800 mb) by the P3DWL along the edges of TC inner core or AEW convection to improve our understanding of interactions between the SAL and tropical convection;
- Observe possible impingement of the SAL's mid-level jet and suspended dust along the edges of the storm's (AEW's) inner core convection (deep convection);
- Test the capabilities of the P3DWL to sample aerosols and the SAL jet in the near-storm environment

Links to IFEX:

- This experiment supports the following NOAA IFEX goals:
- **Goal 1**: Collect observations that span the TC lifecycle in a variety of environments;
- **Goal 2**: Development and refinement of measurement technologies;
- **Goal 3**: Improve our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle;

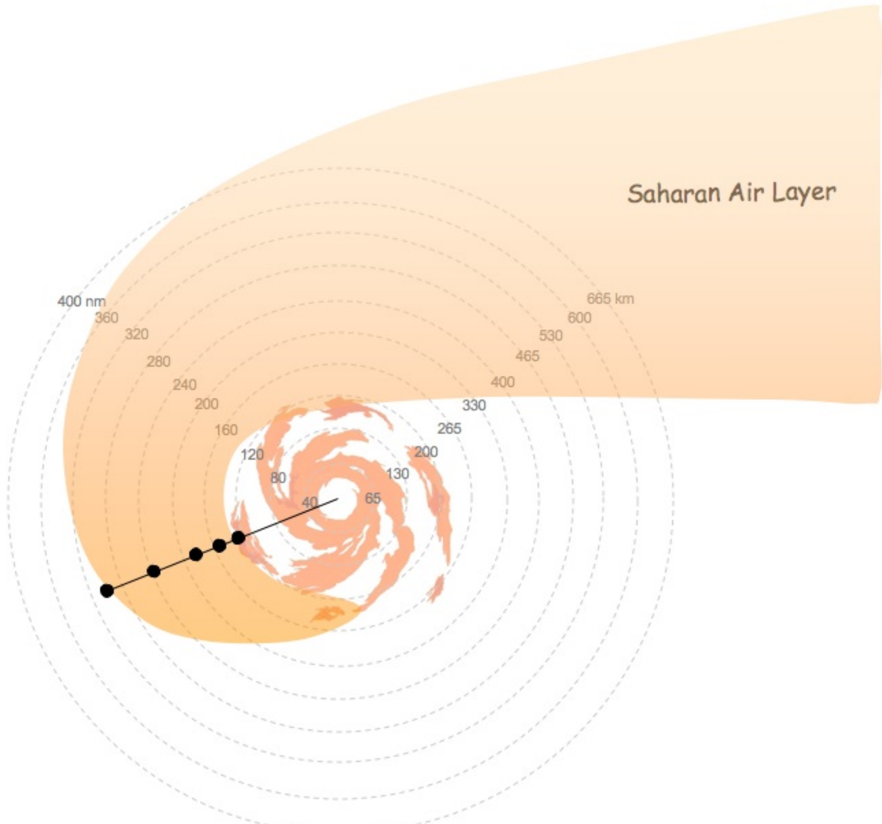
Coordination with other HRD Experiments/Modules:

- This module can be conducted during the ferry to/from the storm during any NOAA-43 mission

J. Dunion

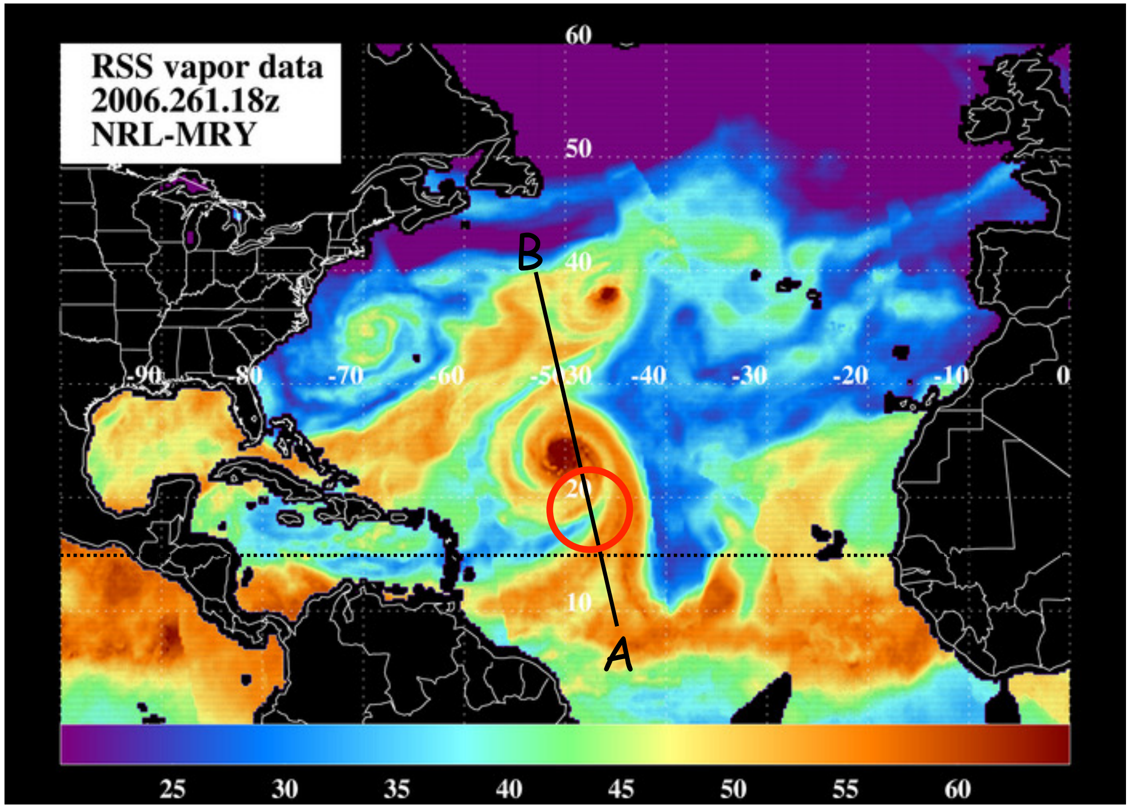
Doppler Wind Lidar (DWL) Module

Option 2: SAL Module (NOAA-43)



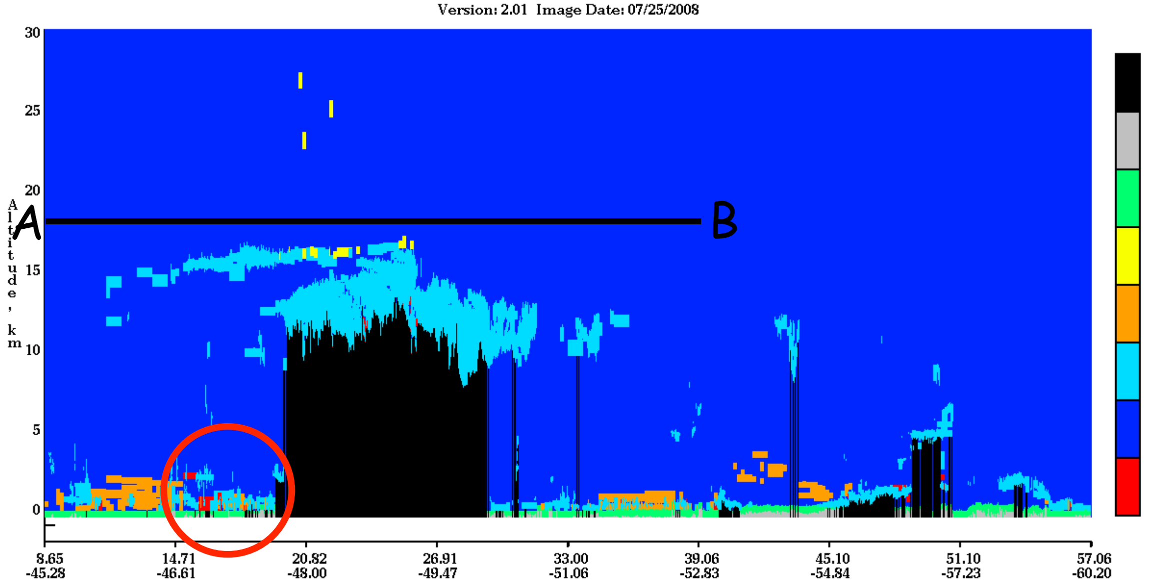
- Transect to/from the storm
- DWL & dropsondes concentrated at fringes of the "inner core"
- Outbound preferred (500 mb or as high as possible);
- DWL: down looking, full sector scanning

J. Dunion



Vertical Feature Mask Begin UTC: 2006-09-18 16:39:58.2152 End UTC: 2006-09-18 16:53:26.8622

Version: 2.01 Image Date: 07/25/2008

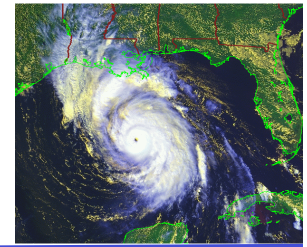


Feature Type: 0 = low/no confidence, 1 = clear air, 2 = cloud, 3 = aerosol, 4 = stratospheric feature, 5 = surface, 6 = subsurface, 7 = no signal (totally attenuated)

J. Dunion

Nick Shay – Gulf Sampling Experiment

Plans: Ocean Profiling Over the BOEMRE Moorings During TC Passage (Shay, Uhlhorn and Jaimes)

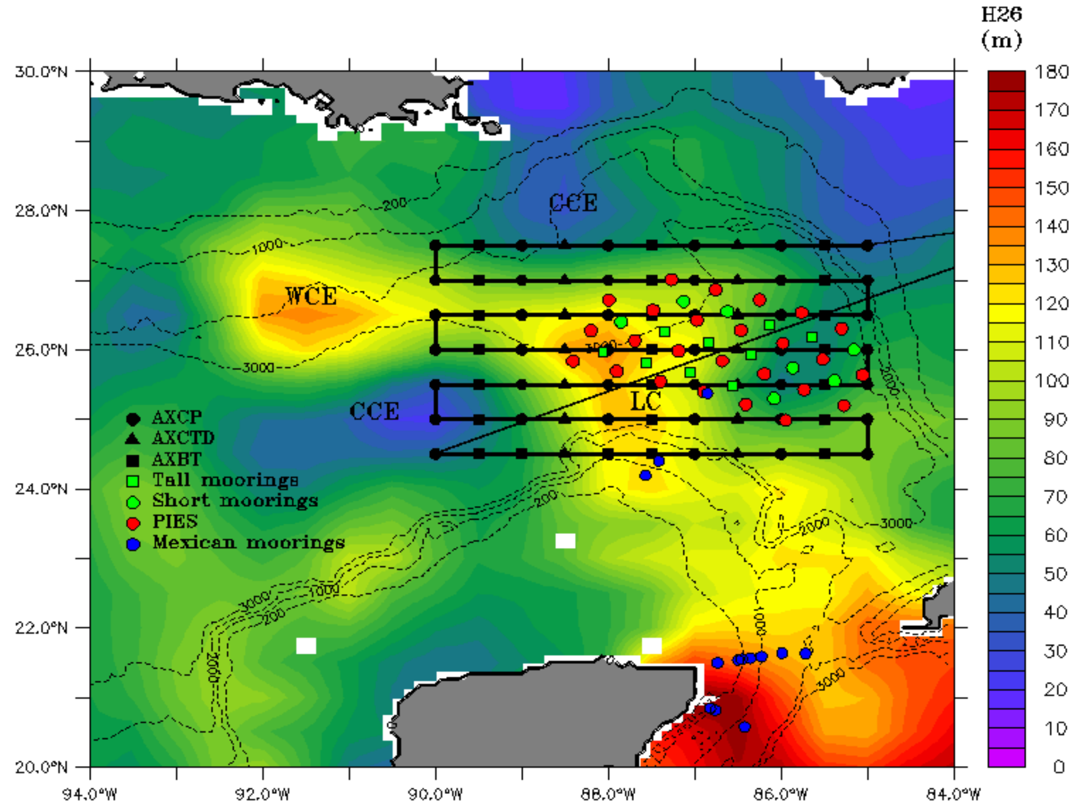


Goal: To observe and understand the LC response to the near-surface TC wind Structure.

Specific objectives are:

1. Determine the oceanic response of the LC to TC forcing; and,

2. Influence of the LC response on the TC's boundary layer and intensity change.

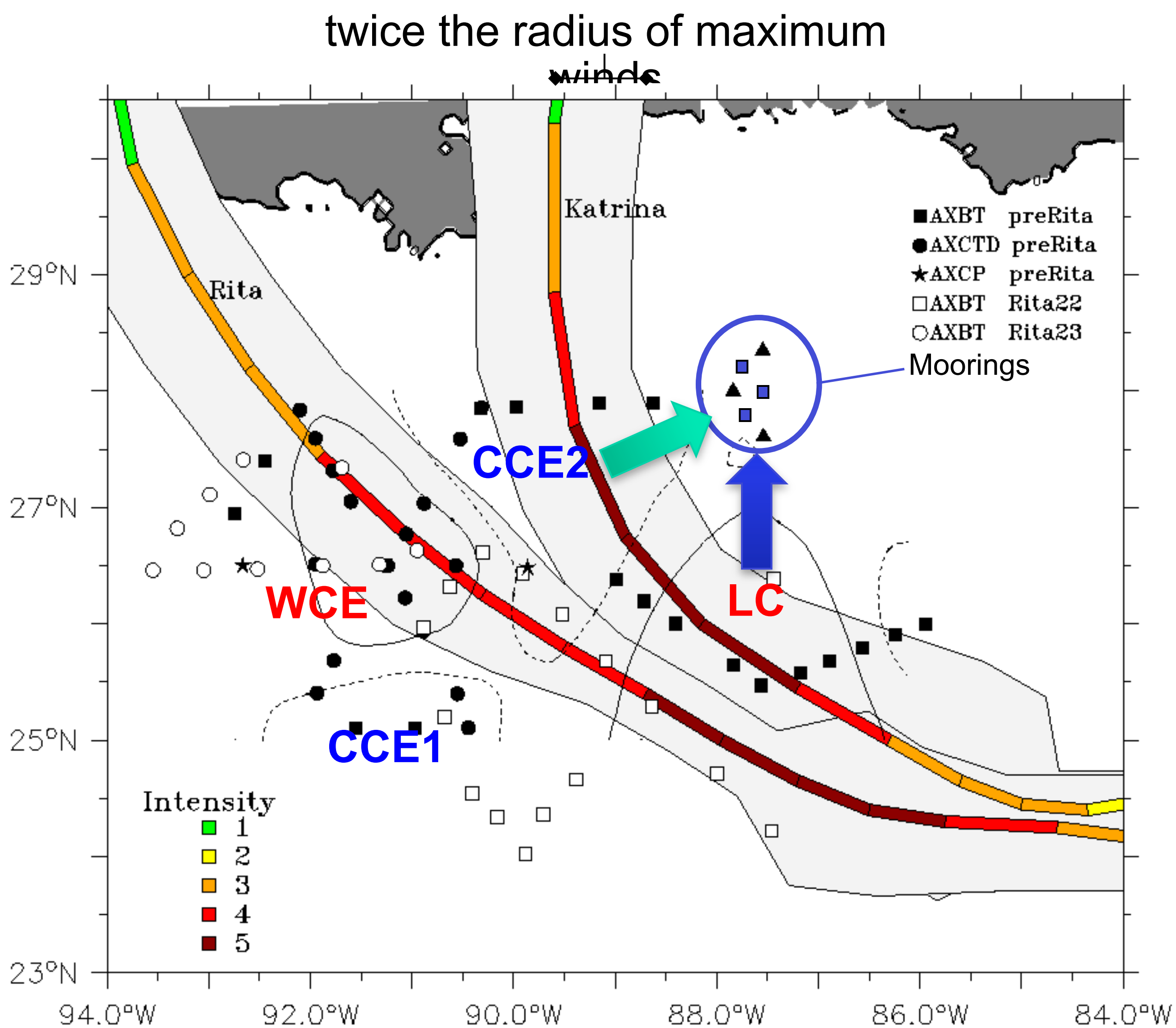


3. Approach: AXCP, AXCTD and AXBT sampling before, during and after with GPS sondes deployed at the AXCP locations during the storm from both aircraft.

4. A preseason flight to calibrate altimetry and use to initialize ocean models at NCEP.

Observational data (From 2005 Ocean Snapshots)

- **Seawater temperature and conductivity data from four airborne experiments.**
- **Mooring data: velocity, temperature, and conductivity at ~10 m intervals.**



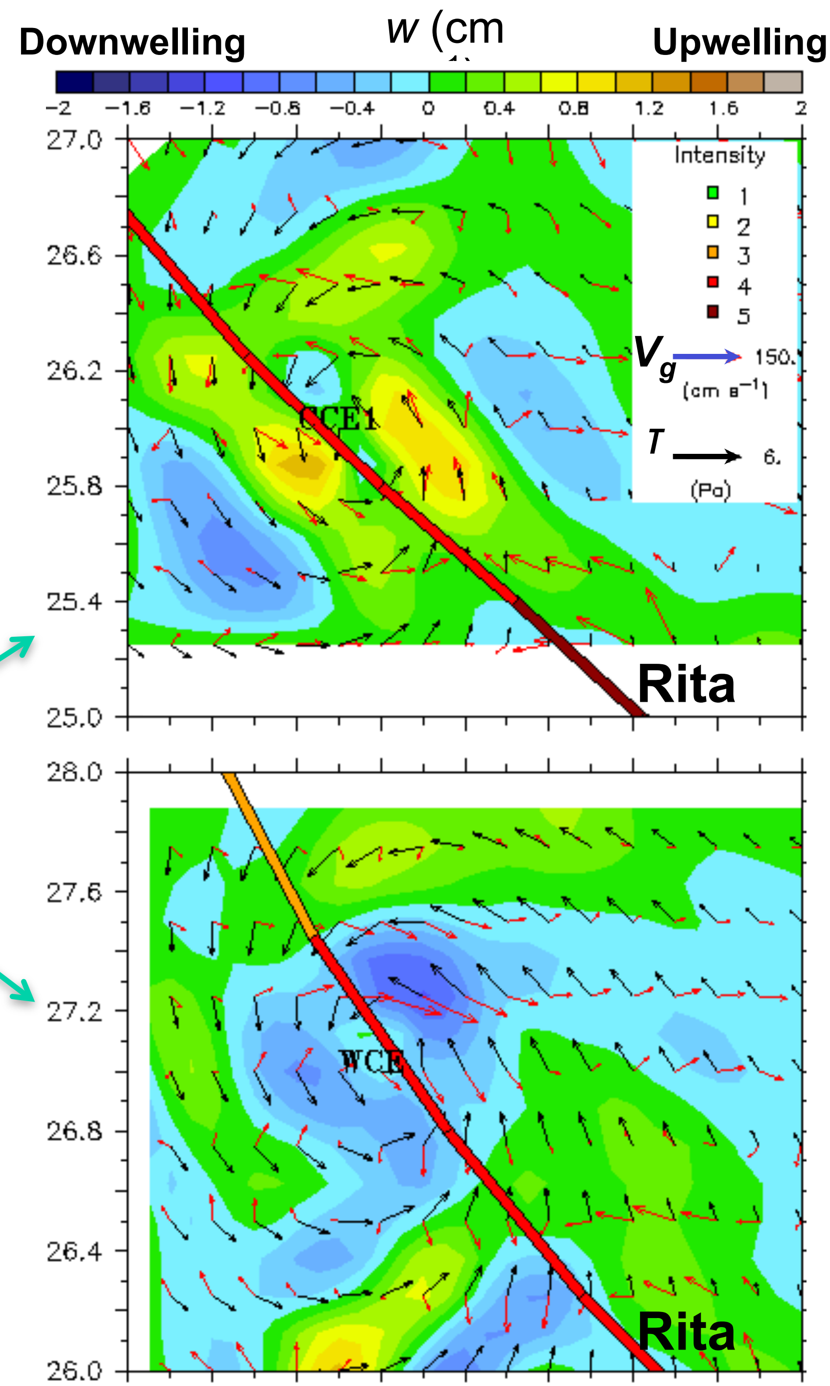
(Jaimes and Shay 2009, 2010, 2011 a,b)

Motivation: TC-induced upwelling in geostrophic eddies (theory)

OML vorticity balance (Stern 1965):

$$\underbrace{\frac{\partial}{\partial z}\mathbf{k}\cdot\nabla\times\theta_s}_{\text{wind stress curl}} + \underbrace{f\,\frac{\partial w_b}{\partial z}}_{\text{vortex stretching}} = \underbrace{\mathbf{V}_b\cdot\nabla\zeta_g}_{\text{frictional horizontal advection}}$$

$$w = \underbrace{-\frac{1}{f}\left(\frac{\partial\tau_y}{\partial x}-\frac{\partial\tau_x}{\partial y}\right)_0}_{w_E} - w_b(0) = \frac{\mathbf{k}\times\boldsymbol{\tau}}{\rho_0 f^2}\cdot\nabla\zeta_g$$



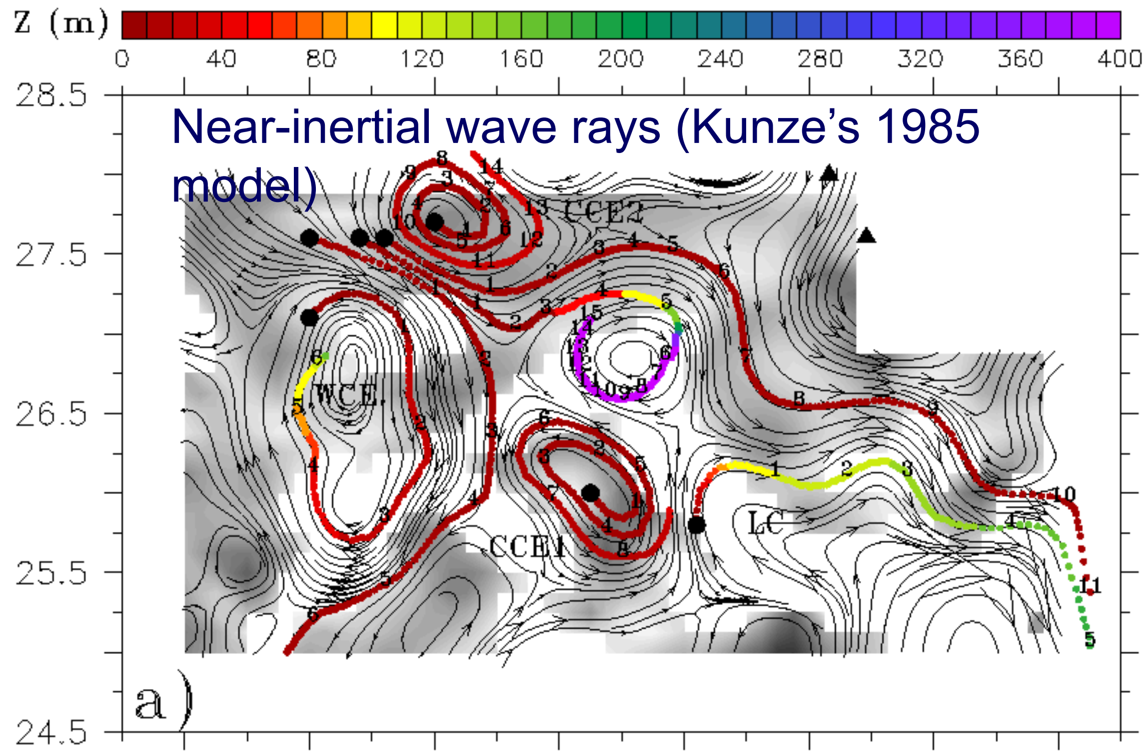
- **Upwelling under the storm's eye in CCEs.**
- **Downwelling under the storm's eye in WCEs.**

Jaimes and Shay (MWR, 2009)

Ray Tracing: Dispersion of forced near-inertial waves in geostrophic flow

In addition to *f* and *N*, geostrophic vorticity affects the kinematic properties of near-inertial waves.

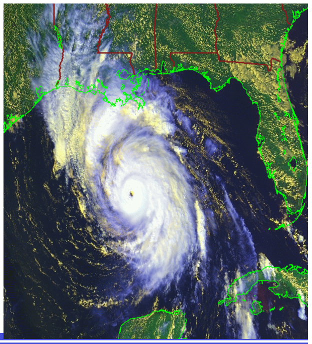
- **WCEs: kinetic energy leakage from the OML into the thermocline.**
- **CCEs: trapping of kinetic energy in the upper ocean.**



contours are geostrophic flow lines from post Katrina airborne data

Jaimes and Shay 2010

Summary: Ocean-Atmosphere Analysis Plans (with AOML HRD, PhOD and NCEP/EMC)



Test new ocean data acquisition system for NOAA WP-3Ds working with AOC as part of HFIP.

Conduct BOEMRE Loop Current Dynamics Study program during a TC with NOAA IFEX over the Gulf of Mexico and eddy shedding region basin.

Process ocean data (and combine with moored and possible drifter data) to assess the oceanic response (Jaimes and Shay 2009, 2011; Uhlhorn and Shay 2011) and estimate air-sea fluxes during hurricane passage following Shay and Uhlhorn (2008).

Resolve the wind-driven current (near-inertial response) in the LC and eddy field (Jaimes and Shay , JPO, 2010).

Provide data to modelers in near real time to properly initialize ocean model and determine ocean model performance using developed metrics (Taylor diagrams, statistical analyses, etc) following Halliwell *et al*. (MWR, 2008; 2011).

Assess boundary layer structures/surface processes from measurements on TC intensity.

Sim Aberson – ET and TC Eye Mixing Experiments

Extratropical Transition Experiment

ET events initiate complex interactions between a TC and the midlatitude flow that lead to sharp declines in hemispheric predictive skill.

Effects include upstream cyclonic development, downstream ridge development associated with the TC outflow, and excitation of Rossby waves leading to downstream cyclone development.

The possibility of high-impact weather from the TC itself and from the results of the ET event, coupled with low predictive skill, makes this an important research topic.

During ET events, rapid structural changes to the precursor TC occur:

Wind, clouds, and precipitation become asymmetric

Frontal systems develop.

Heavy precipitation regions develop, especially in areas of warm frontogenesis well ahead of the TC.

Regions of trapped-fetch waves also develop.

This leads to regions of strong winds and heavy precipitation well away from the TC center, impacting land areas even if there is no landfall.

During ET, storms encounter high shear and low SST, which usually leads to weakening. However, explosive cyclogenesis sometimes occurs, and the intensity changes are poorly forecast.

Improved understanding will contribute to development of conceptual and numerical models leading to improved forecasts and warnings.

Requirements for the Experiment

1. The TC must have been sampled for at least one day prior to the ET event. Regular sampling by the P3s to get structure information from the Doppler radar is required. Previous environmental sampling by the G-IV is helpful, but not required.

2. The TC must have been of at least hurricane intensity during the previous sampling.

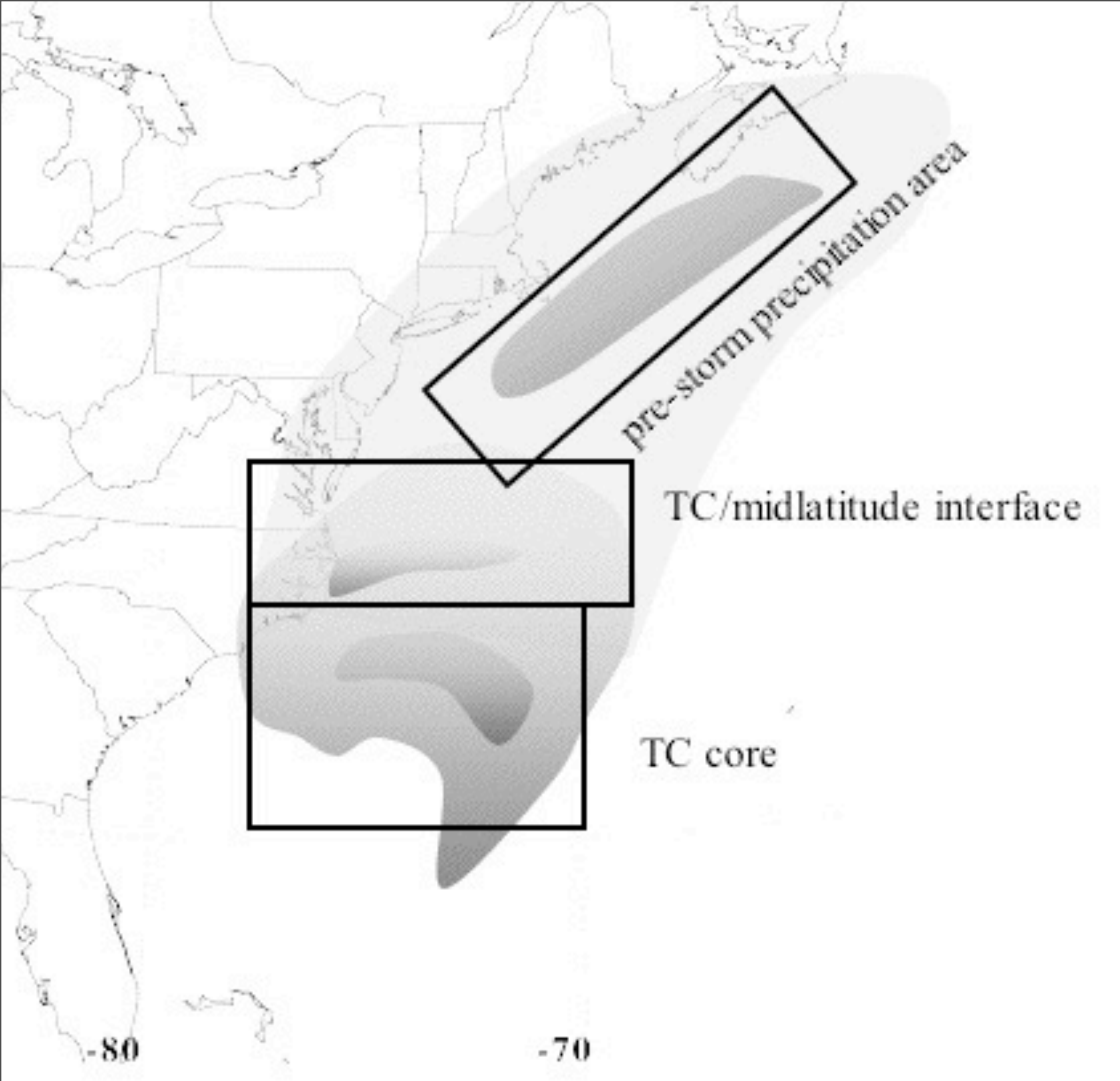
3. The TC must not have had major land interactions during the previous sampling or the proposed experiment.

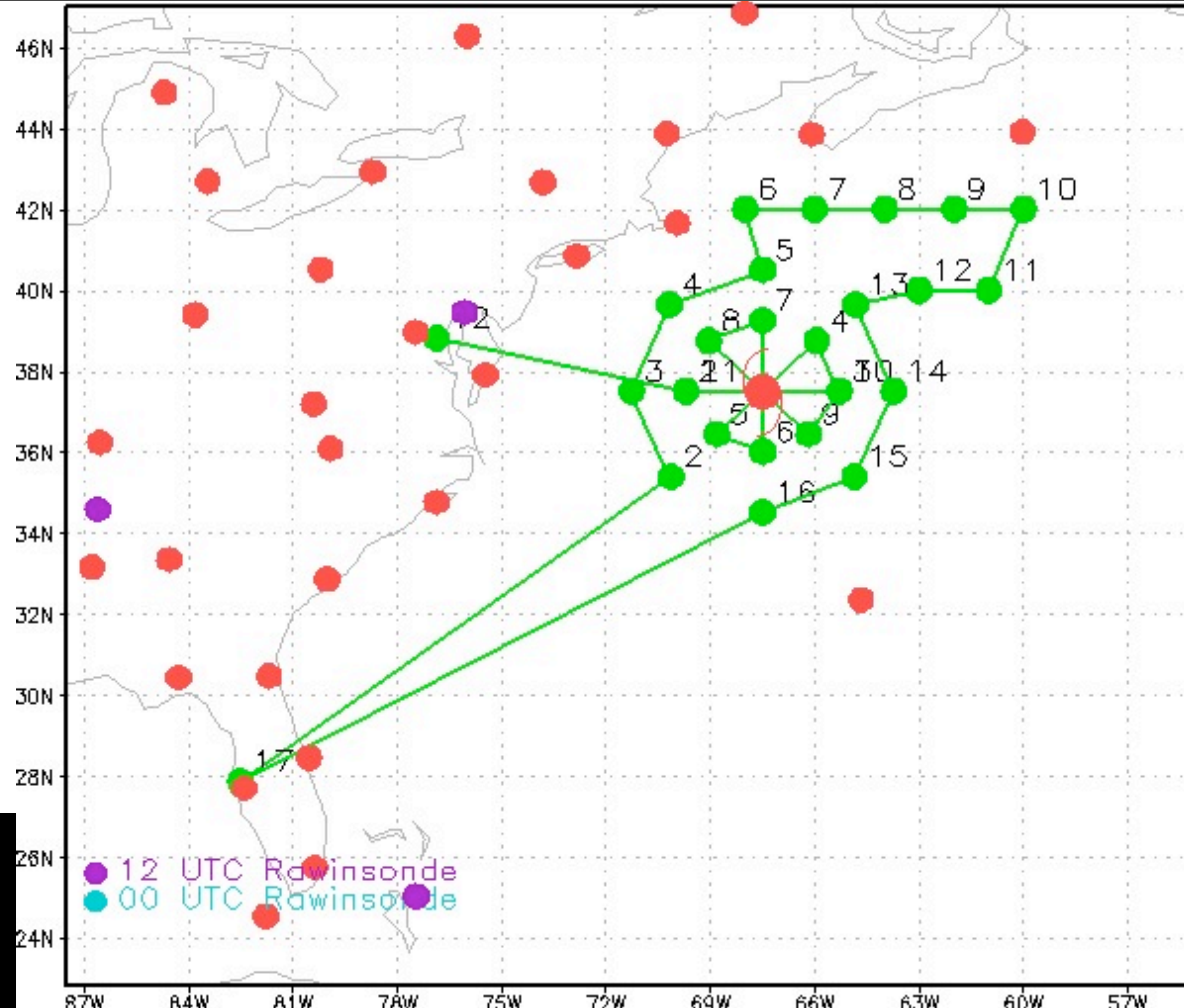
4. Concurrent P3 and G-IV missions are helpful, but not required. Solo P3 missions are good.

Hypothesis/questions

ET depends upon the survival of the TC as it penetrates into midlatitudes in regions of increasing vertical wind shear.

- How is the TC vortex maintained in regions of vertical wind shear exceeding 30 ms^{-1}?
- How is the warm core maintained long after the TC encounters vertical wind shear exceeding 30 ms^{-1}?
- How does vertical shear exceeding 30ms^{-1}alter the distribution of latent heating and rainfall?
- Does vortex resilience depend upon diabatic processes. On subsequent formation of new vortex centers, or by enlisting baroclinic cyclogenesis?
- Does the vertical mass flux increase during ET, as has been shown in numerical simulations?
- Is downstream error growth related to errors in TC structure during ET?
- Is ET sensitive to the sea-surface temperatures?





Proposed flights

P3 will obtain inner-core observations with dropwindsondes (and AXBTs, if possible) at end- and mid-points of legs. Altitude as high as safely possible, within requirements to get WSRA wave data especially on east side.

G-IV will release dropwindsondes every 120 n mi to obtain information in the pre-storm precipitation area and TC/midlatitude interface. Doppler radar, if available, will help determine the kinematic structure of the rainy areas, but is not a requirement.

Tropical Cyclone Eye Mixing Module

Eyewall mesovortices have been hypothesized to mix high entropy air from the eye into the eyewall, thus increasing the amount of energy available to the hurricane. Signatures of such mesovortices have been seen in cloud formations within the eyes of very strong TCs, and from above during aircraft penetrations. However, the kinematic and thermodynamic structures of these features have never been directly observed.

Requirements for the Experiment

1. A TC with a clearly defined visible eye, eyewall, and inversion (interface between cloudy air below and clear air above).

2. The eye diameter must be at least 25 n mi for safety.

3. Daytime only.

Aircraft will enter the eye at altitude, descend to the inversion level during a figure-4 pattern, circumnavigate the eye at least 2 n mi inside the visible edge of the eye, then ascend during another figure-4 pattern. Entire pattern takes 0.5 - 1 h.