

Overview of the ONR Tropical Cyclone Intensity Program and Future Plans

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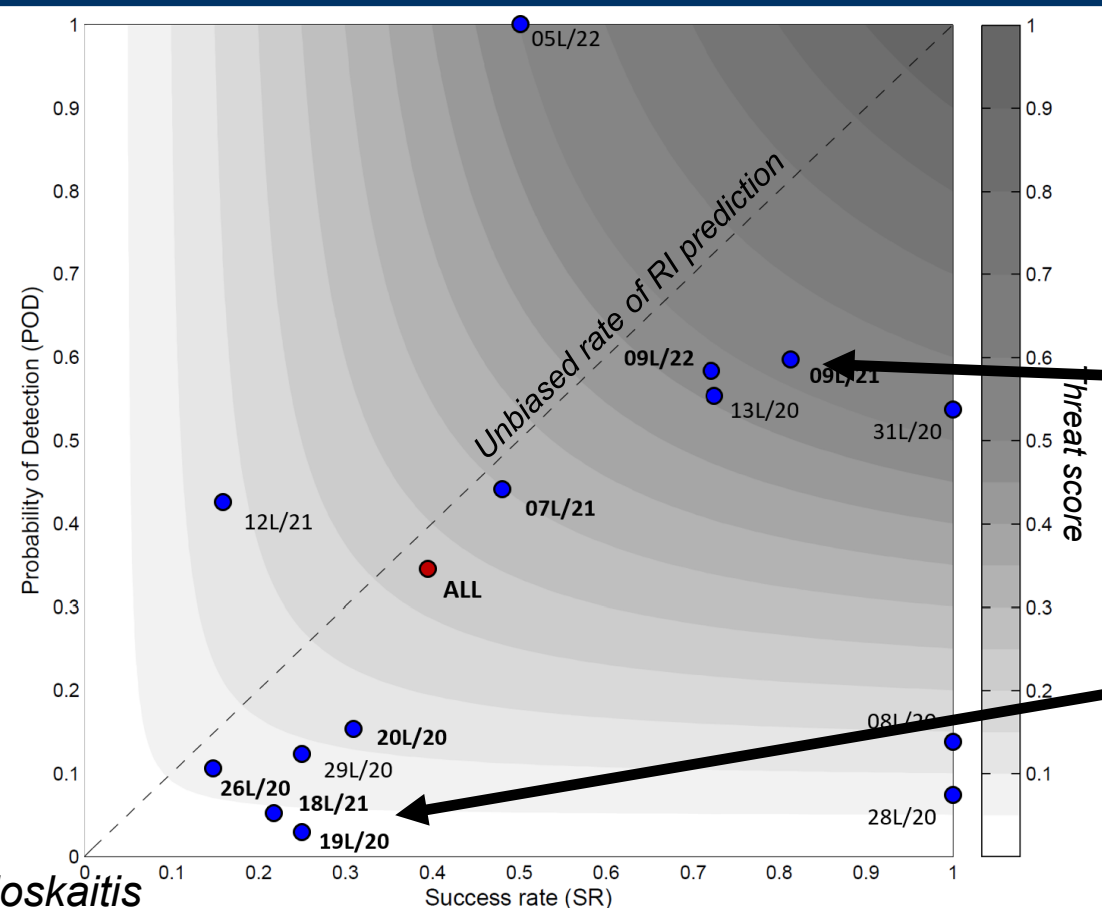
²U.Miami/CIMAS – NOAA/AOML/HRD, ³NOAA/HRD, ⁴ONR

Tropical Cyclone Rapid Intensity Campaign

ONR Program

- Identify the key processes and predictability barriers governing the rapid intensification (RI) of tropical cyclones (TCs). Special focus on: i) onset of RI, ii) boundary layer and cloud microphysics processes
- Field measurements conducted in close collaboration with NOAA IFEX (2020) and APHEX (2021-22)

2020 - 2022 Atlantic Storm-by-Storm RI performance



2020 TCRI storms

- 19L: Sally*
- 20L: Teddy*
- 26L: Delta*

2021 TCRI storms

- 06L: Fred
- 07L: Grace*
- 08L: Henri
- 09L: Ida*
- 12L: Larry*
- 18L: Sam*

2022 TCRI storms

- 06L: Earl
- 07L: Fiona
- 09L: Ian*
- 13L: Julia
- 15L: Lisa

*TCRI storms with observed RI (blue), which are shown in **bold** in plot at left

The best CTCX RI forecasts are for storms with a prolonged period of RI with peak intensity $\geq$ Cat4, and a medium-to-large inner core. Ida (09L/21) and Ian (09L/2022) are examples.

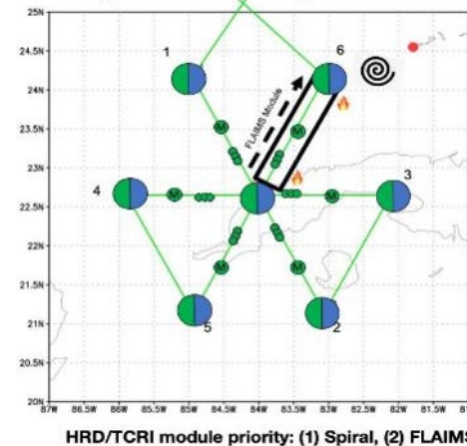
However, CTCX does not perform well for all storms with a prolonged period of RI and high peak intensity. CTCX scored poorly for Delta (26L) and Sam (18L), which both had a very small inner core during RI.

Tropical Cyclone Rapid Intensity Campaign Summary

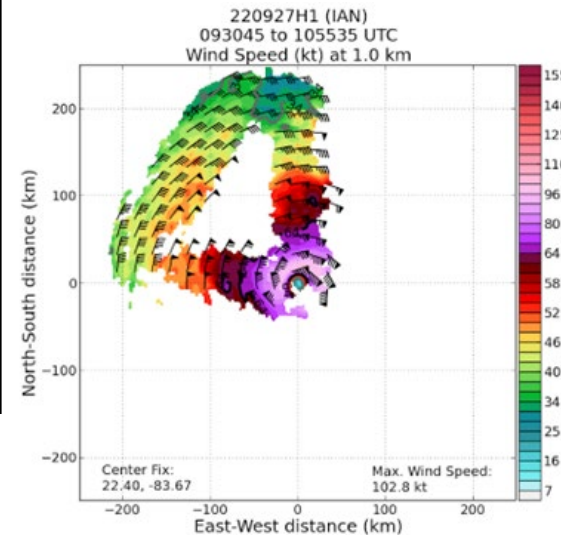
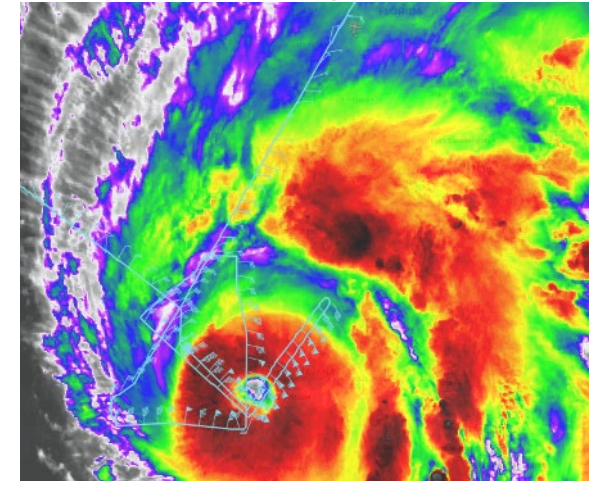
- Conducted in collaboration with NOAA APHEX TCRI P3 flight hours and extra drops on P3 & G-IV
- Scheduled roles serving from mid-July thru Oct
 - Science leads, Forecasters, Flight Planners
- 2020: Sally, Teddy, Delta
 - 159 dropsondes deployed, additional modules
- 2021: Fred, Grace, Henri, Ida, Larry, Sam
 - 257 dropsondes deployed, additional modules
- 2022: Earl, Fiona, Ian, Julia, Lisa
 - 266 dropsondes deployed, additional modules
 - Windborne balloon sampling
- 2020-2022: Deployed 186 AXBTs
- Added flight modules for many storms
 - Microphysics, gravity waves, vortex tilt, etc.

Hurricane Ian 27 Sep 2022

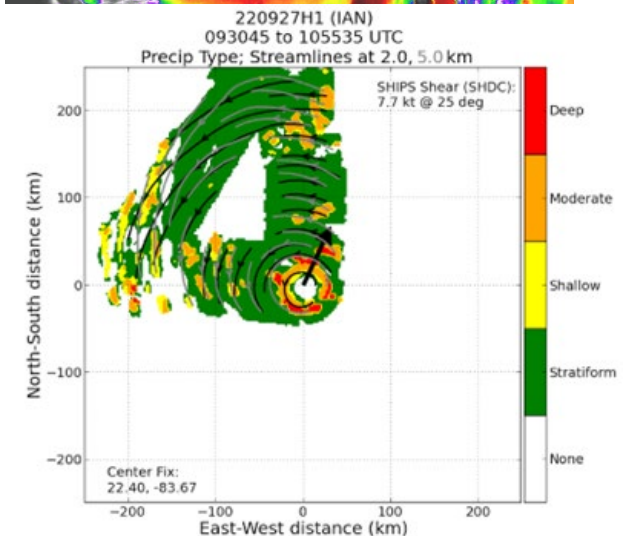
N42 flight into Ian: 27 Sep, 2022 H1



N42 final flight track



TDR winds at 1 km

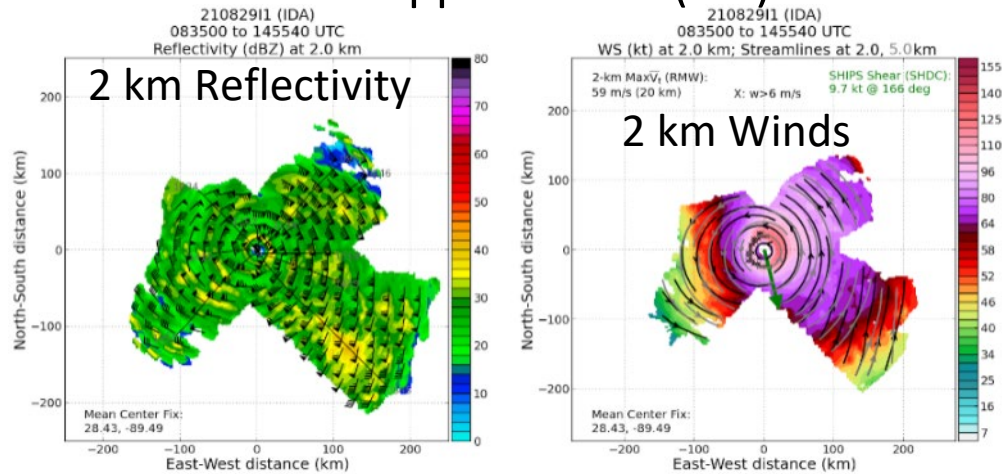


Precip mode from first TDR analysis

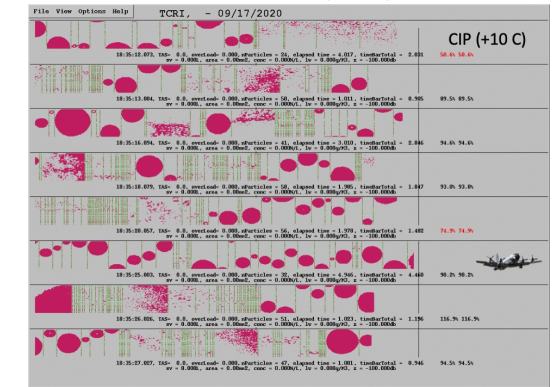
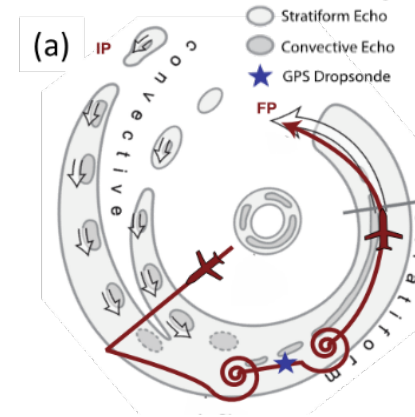
Hurricane Field Program (APHEX & TCRI)

Observing Systems Highlights

P-3 Tail Doppler Radar (Ida)



Cloud Imaging Probe (CIP) Microphysics

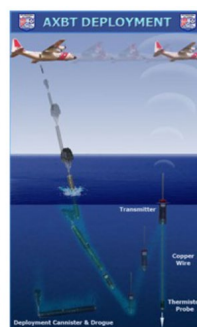
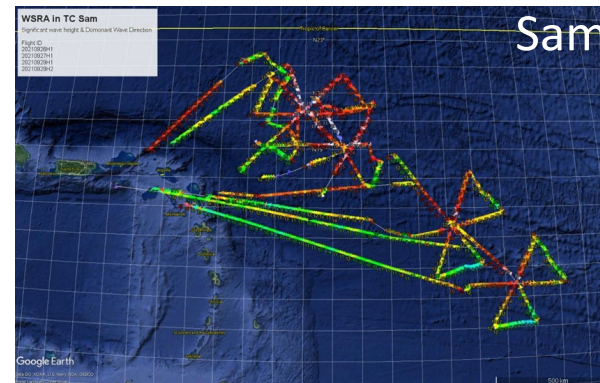
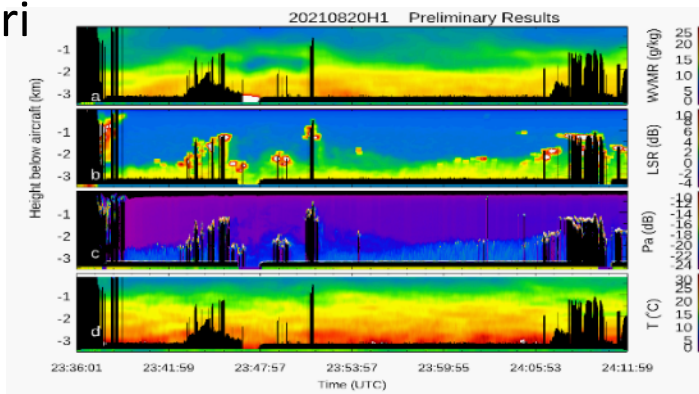


Hydrometeors transition from water to ice as the P-3 flies through and above the freezing level.

Compact Rotational Raman Lidar (CRL) Wide Swath Radar Altimeter (WSRA)

Dropsondes and AXBTs

Henri

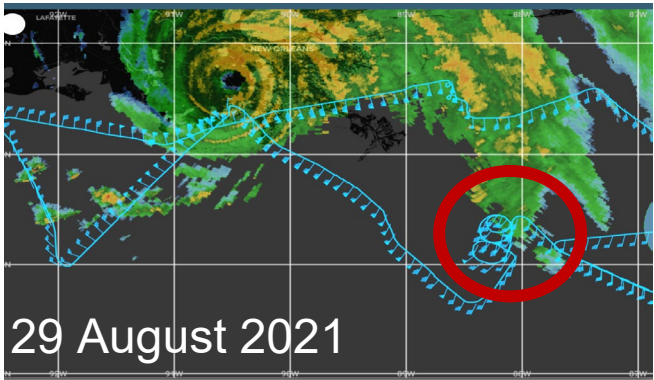


Data: 3-D temperature, water vapor, clouds, aerosols
Resolution: 45 m vertical, 100-1000 m horizontal

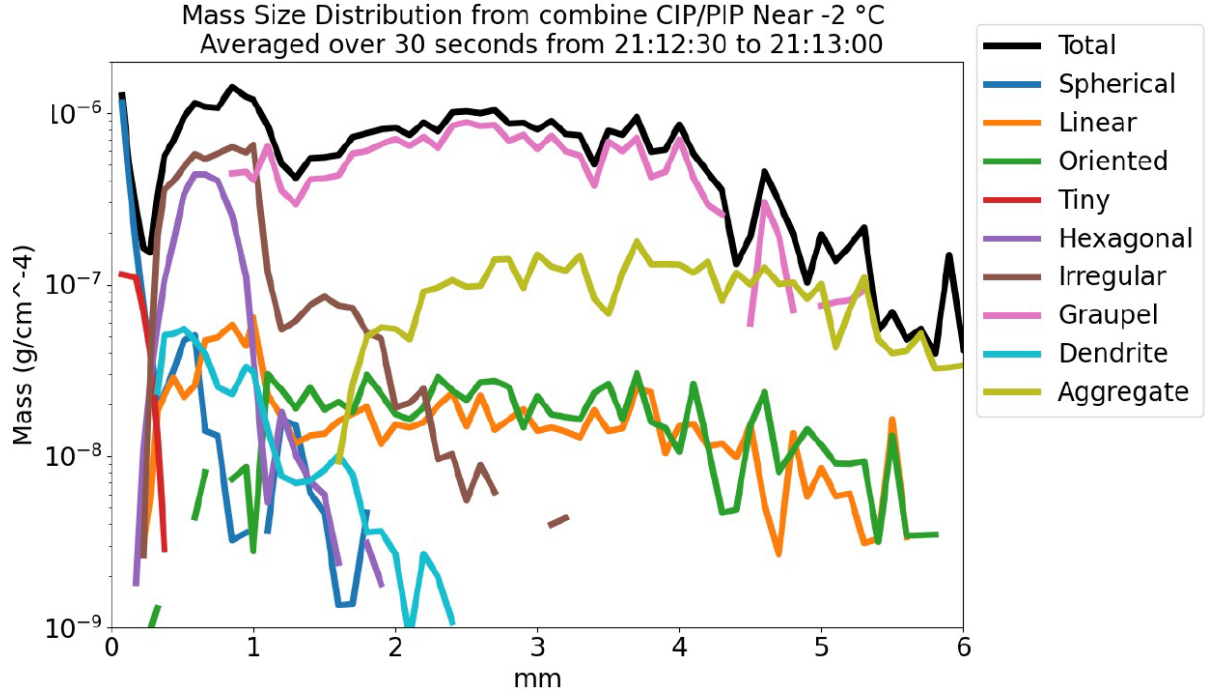
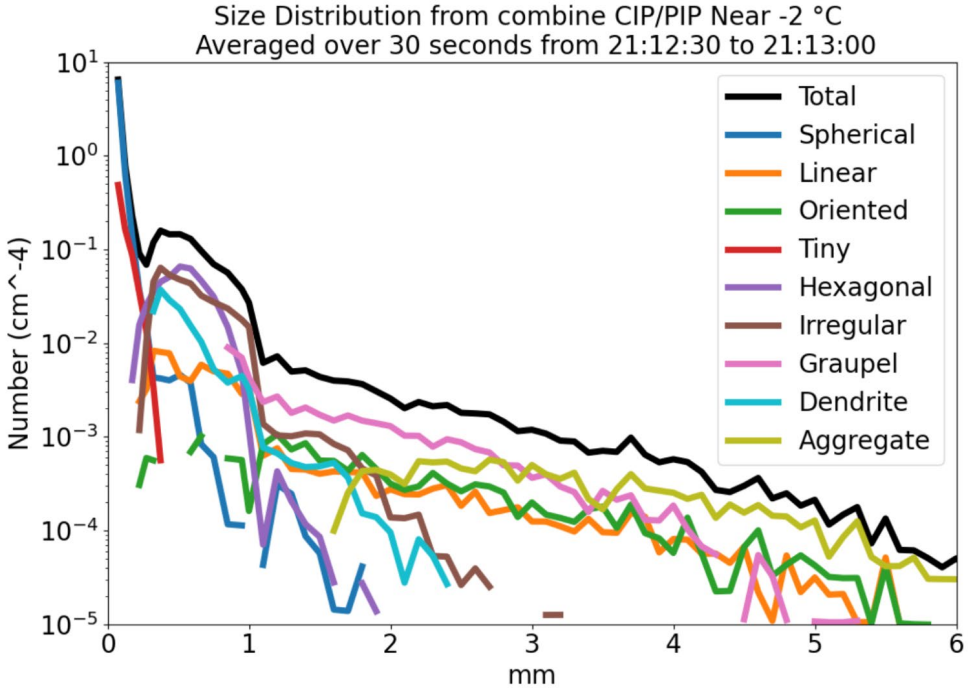
Data: significant wave height, ocean directional wave spectra, & rain rate

Dropsonde: Winds, pressure, height, temp, RH
AXBT: Ocean temperature, salinity, depth

Hurricane Ida P3 track and microphysical spiral



- Sample size and habit distribution near -2 C
- Numerous spherical particles below 0.2 mm (likely supercooled droplets)
- High concentrations of pristine ice (plates, dendrites) and possible rimed ice (irregular) near 1 mm
- Graupel and aggregates dominate distribution > 1 mm

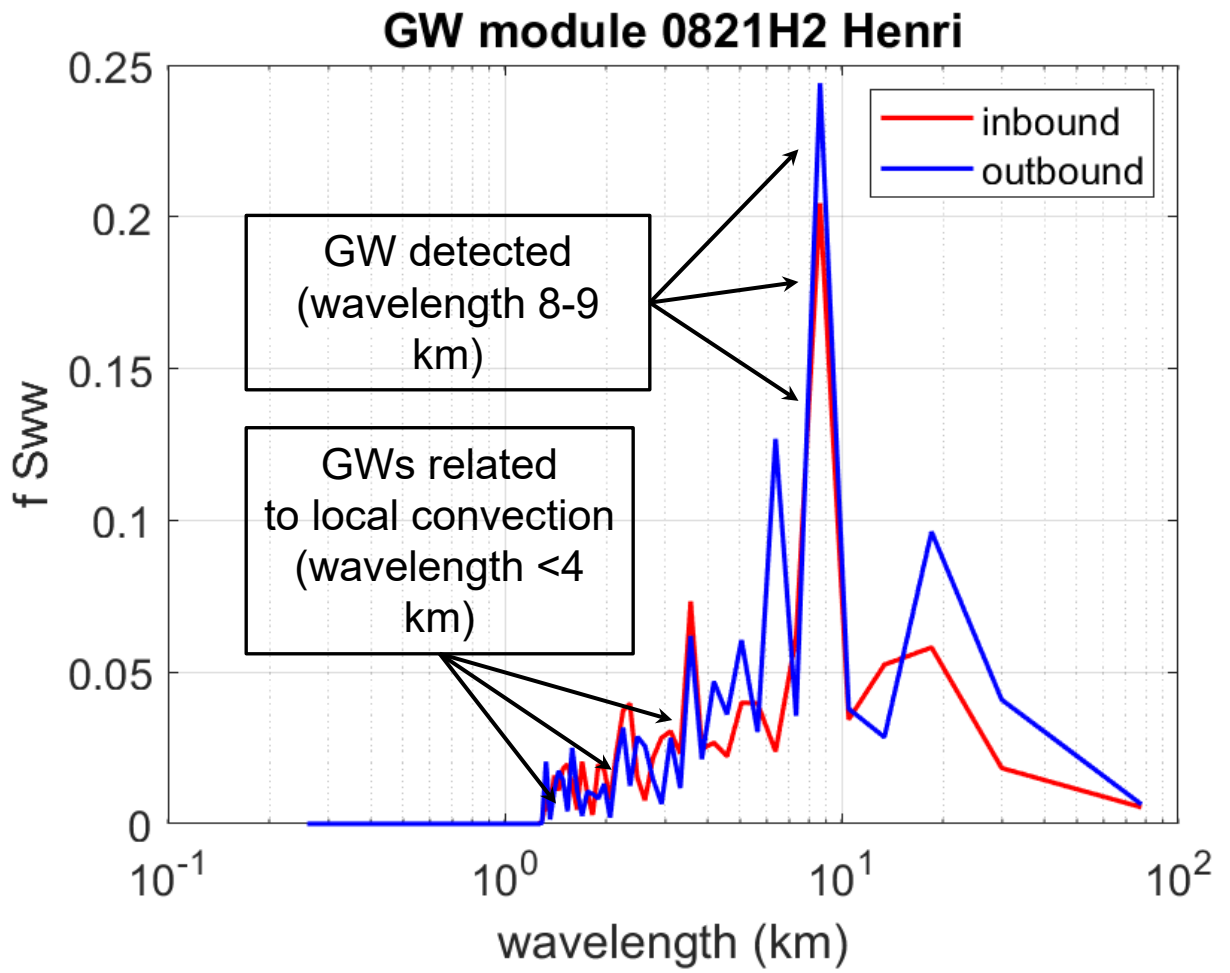
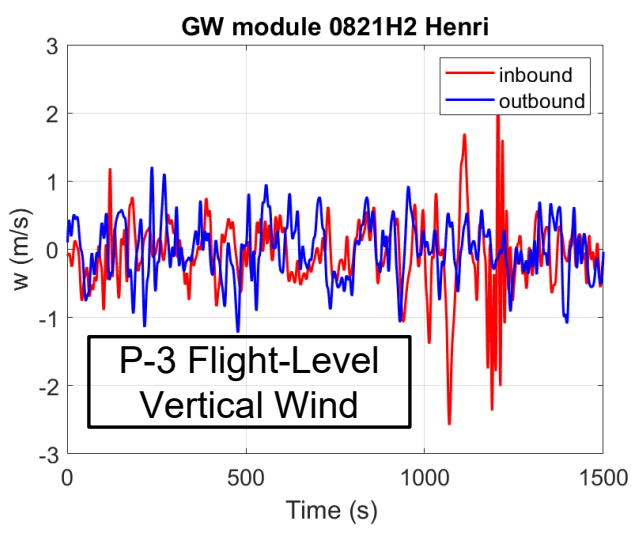
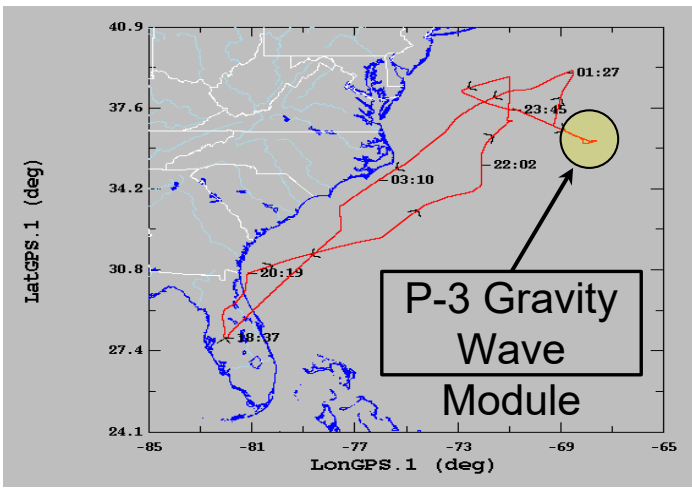


Michael Bell, Alex DesRosiers, and Chelsea Nam (Colorado State Univ.)

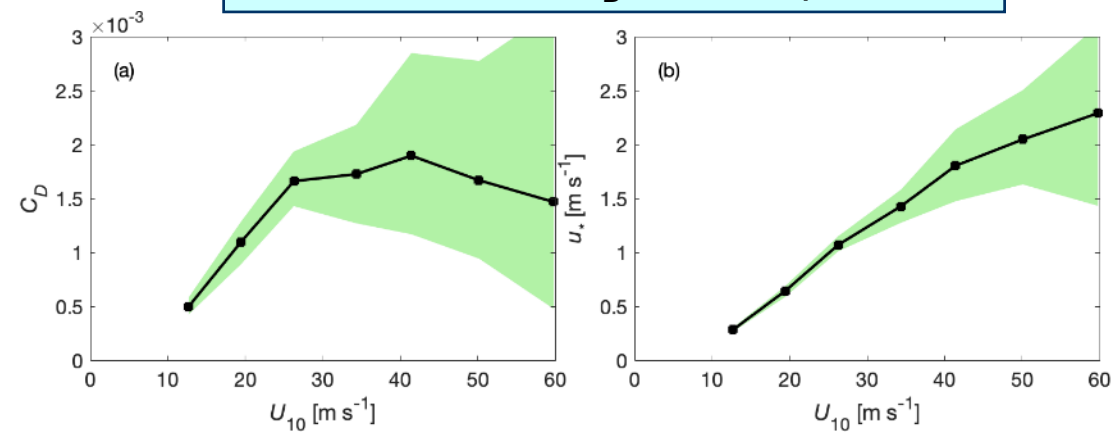
Gravity Waves and TCs

TCRI Research Highlights

Goal: use P-3 flight-level data to examine GWs in early-stage TCs and how they relate to TC intensity

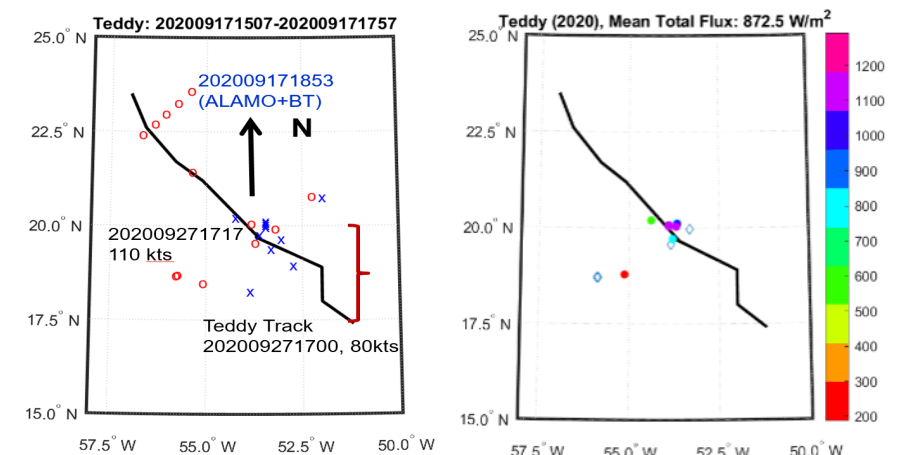


Uncertainties in C_D from Dropsondes



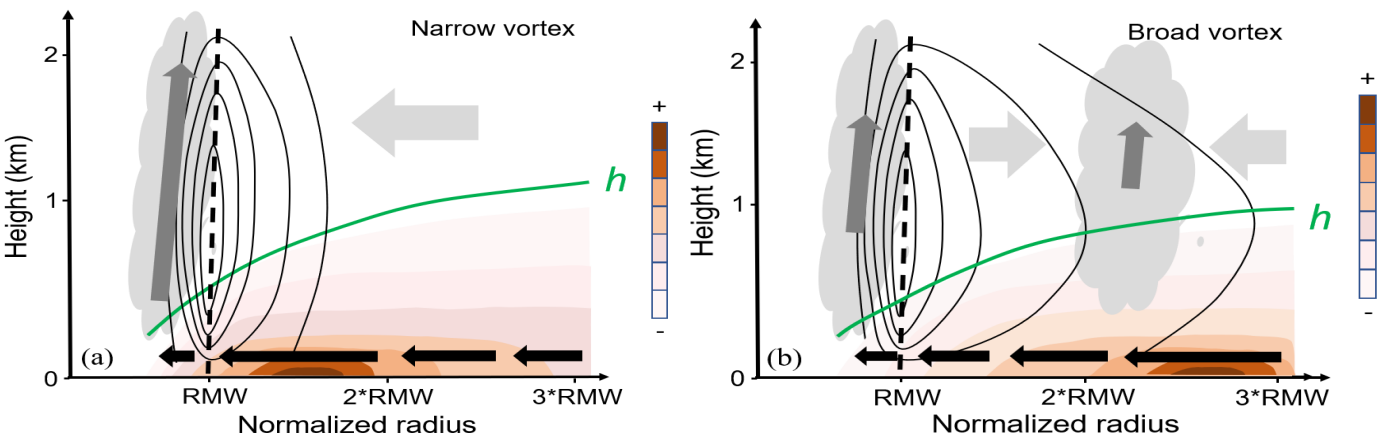
David Richter (U. Notre Dame), Charlotte Wainwright, Chibueze Oguejiofor

Air-Sea Interaction Studies



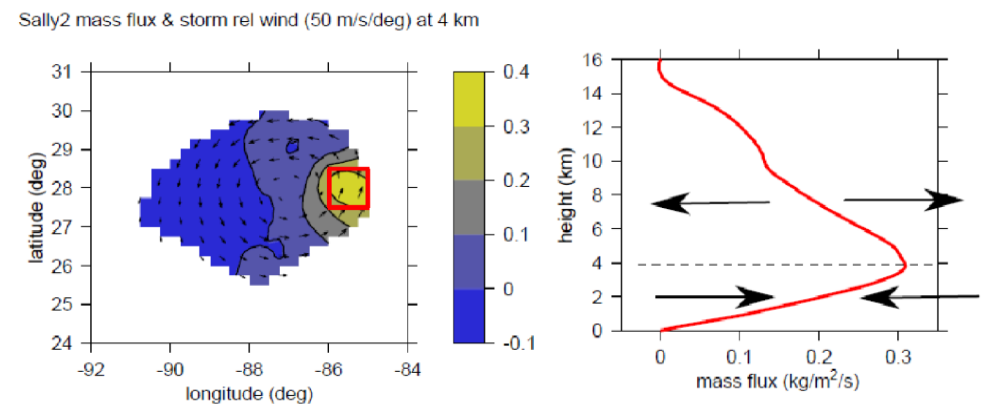
Sue Chen (NRL), Cliff Watkins (NRC), Jun Zhang (NOAA/HRD)

Doppler Profile Observations of the Boundary Layer



Jun Zhang, Rob Rogers, Paul Reasor (NOAA/HRD)

Thermodynamics of Rapid Intensification

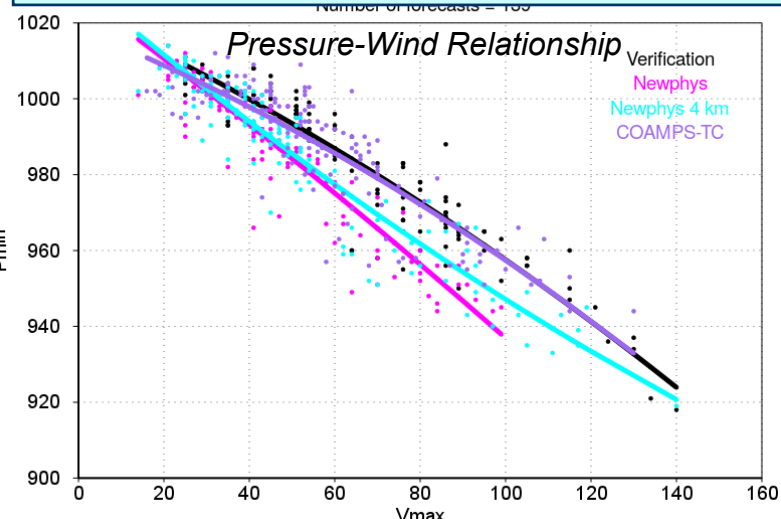


Dave Raymond and Zeljka Fuchs-Stone (New Mexico Tech)

TC Rapid Intensification Modeling Studies

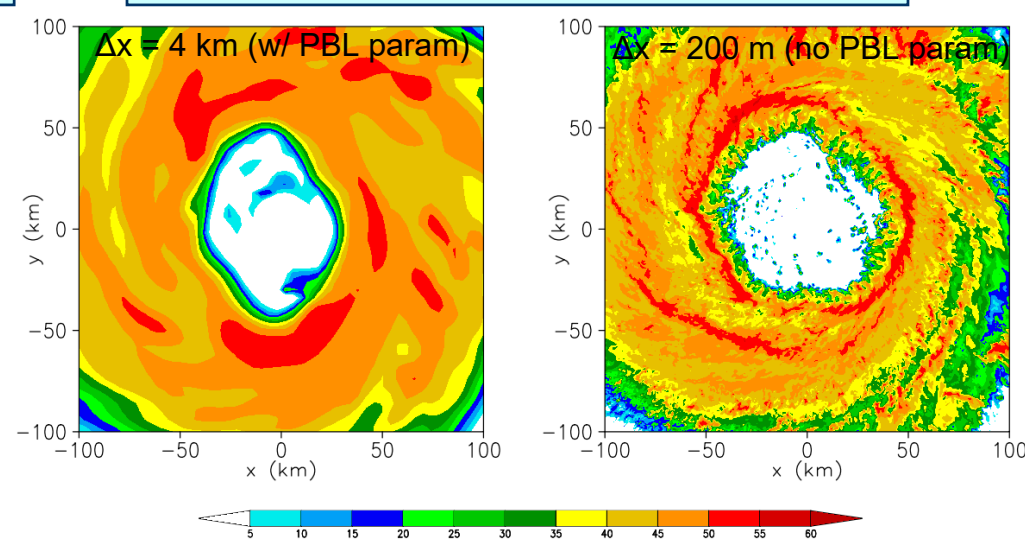
TCRI Research Highlights

ECMWF & COAMPS-TC Comparisons



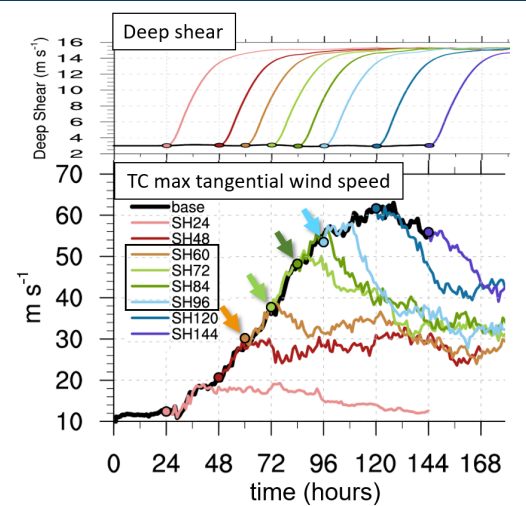
Sharan Majumdar (UM), Linus Magnusson (ECMWF),
Peter Bechtold (ECMWF), James Doyle (NRL)

Large Eddy Simulation



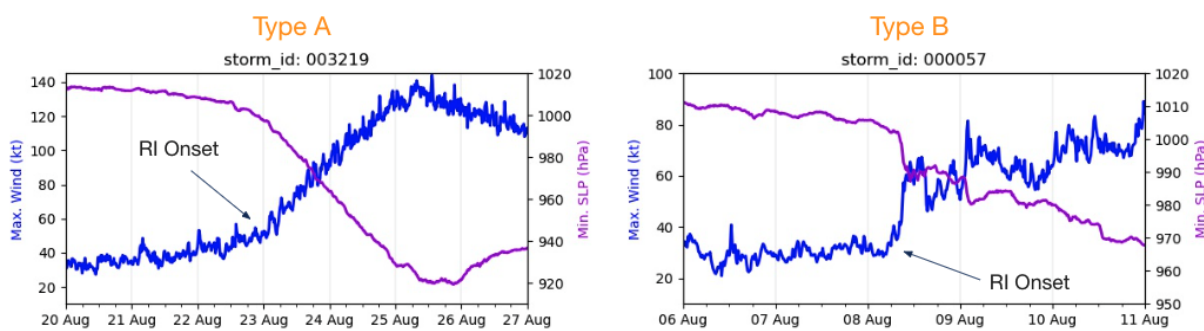
George Bryan (NCAR)

Intensity-Dependent Response to Increasing Vertical Wind Shear



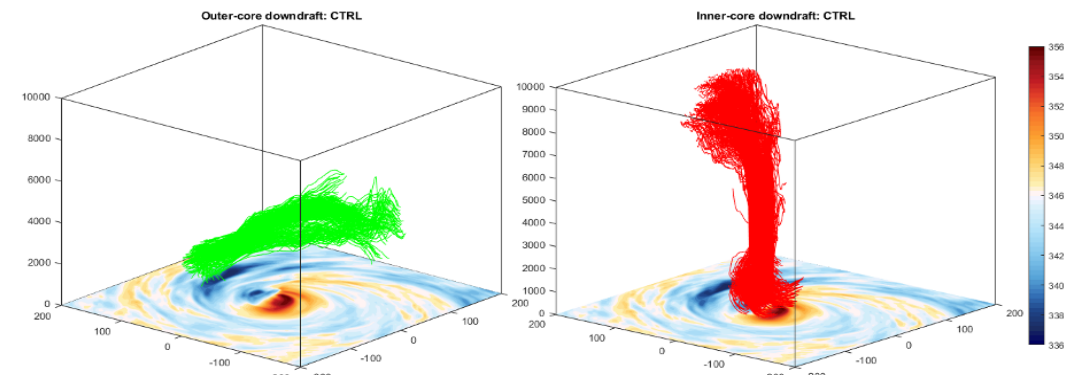
Pete Finocchio (NRL), Rosimar Rios-Berrios (NCAR)

Two-Modes of Rapid Intensification using a Global CAM



Falko Judt (NCAR)

Downdraft Ventilation



Chau Lam Yu and Brian Tang (U. Albany)

Tropical Cyclone Rapid Intensity DRI

Summary

- **ONR TC Rapid Intensification Program**
 - Observational and modeling studies highlight complex processes related to the boundary layer, microphysics, and the environment that influence the characteristics of TC rapid intensification.
 - Next phase will concentrate on research and publications with continued focus on:
 - Onset of intensification and RI
 - Boundary layer and microphysics processes
 - Vertical wind shear, tilt, and intensification onset
- **ONR-NRL-NOAA Collaborative Observing Plans**
 - ONR will continue to support additional observations (dropsondes) and add-on flight modules of opportunity independent of the TCRI program
 - NRL-ONR will continue to collaborate with HRD and APHEX to support field missions
 - Synergy with ONR Moisture and Aerosol Gradients / Physics of Inversion Evolution (MAGPIE) centered on Barbados focused on the marine boundary layer (Navy Twin Otter and NOAA P3)
- **FY24 Multidisciplinary Research Program of the University Research Initiative (MURI)**
 - “Reexamining Ocean Effects on Atmospheric Wind Drag and Enthalpy Flux”
 - <https://www.nre.navy.mil/work-with-us/funding-opportunities/fy24-department-defense-multidisciplinary-research-program>