Using observations and models to better understand and predict hurricanes
What is the role of convective-scale processes in tropical cyclone intensity change?

Overview

- TC intensity forecasting has shown less improvement than track forecasting
  - Intensity change involves multiscale processes
- Observations **key** component of a balanced approach toward advancing understanding and improving forecasts of TC intensity change
  - *HRD uniquely positioned to contribute to this effort through a combination of data collection and analysis and numerical model experiments*
- **IFEX**: Multi-year field campaign intended to improve TC intensity forecasts
  - Partnership among NOAA (NHC, EMC, AOC) and other government, academic agencies (NASA GRIP, HS3; NSF PREDICT)
  - **Goals**: 1. collect observations that span TC life cycle in a variety of environments for model initialization and evaluation
    2. develop and refine measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment
    3. improve understanding of physical processes important in intensity change for a TC at all stages of its life cycle

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Rogers et al. (2013a)
IFEX Goal 1: Observations for model initialization and evaluation

Synergy of high resolution forecast and airborne observations

Hurricane Isaac (2012)
Positive impact of Tail Doppler radar data on TS Karen intensity forecast

Intensity Forecast for Karen (2012)
Valid 12 UTC 4 October 2013

NHC Forecast Discussion on October 4, 5 PM:

“...THE 12Z HWRF RUN SHOWED CONSIDERABLY LESS INTENSIFICATION WITH KAREN COMPARED TO PREVIOUS RUNS AFTER ASSIMILATING DATA FROM THE NOAA P-3 TAIL DOPPLER RADAR. THIS MARKS THE FIRST TIME DOPPLER RADAR DATA HAVE BEEN ASSIMILATED INTO AN OPERATIONAL HURRICANE MODEL IN REAL TIME. ..”
IFEX Goal 2: Techniques for real-time TC monitoring

Tail Doppler radar from the high-altitude NOAA G-IV aircraft

*Flight track for the G-IV on 15 Sept 2013 in Hurricane Ingrid*

*Doppler-derived wind speed (shaded, m s\(^{-1}\)) and vectors and dropsonde measurements at 1, 6, 12-km altitude for Hurricane Ingrid (2013)*

*Doppler observations will be transmitted in real time this season*
IFEX Goal 3: Improved understanding of TC processes: Role of convective-scale processes

What is the difference in the inner-core structure of intensifying and steady-state hurricanes?

- Analyses obtained from composites of multiple intensifying vs. steady-state hurricanes
- Convective bursts defined as top 1% of vertical velocity distribution at 8 km altitude (5.5 m/s)
- Intensifying cases have more bursts, more inside 2-km RMW compared with steady-state cases
IFEX Goal 3: Improved understanding of TC processes: Role of convective-scale processes

What is the inner-core convective structure of a rapidly-intensifying hurricane?

Airborne Doppler observations of the rapid intensification (RI) of Hurricane Earl (2010)

- Most convective bursts located inside 2-km RMW during this flight
- Updraft core originates from PBL inside RMW, nearly vertical ascent
- Slope of updraft core departs significantly from angular momentum (M) surface
- Peak updraft inside local RMW throughout ascent, in locally high inertial stability regime
IFEX Goal 3: Improved understanding of TC processes: The Tropical Cyclone Diurnal Cycle

Hovmoller: Daily IR Temp Trends (10-yr MH Composite)
IFEX Goal 3: Improved understanding of TC processes: Role of convective-scale processes

How well does HWRF produce microphysics fields in deep convection?

Evaluation of ice microphysics in HWRF simulations

Radar reflectivity (shaded, dBZ) from ER-2 in Bonnie (1998)

Axisymmetric graupel concentration (shaded, $x\times10^{-5}$ kg/kg) at 54 h for idealized HWRF runs using Thompson (left) and operational Ferrier (right) scheme

Flight-level vertical velocity (top, m/s) and ice concentration (bottom red, $x\times10^{-5}$ kg/kg) from midlevel NASA DC-8 aircraft

- Thompson scheme produces graupel at high (12 km) altitudes, but may produce too much
- Ferrier does not produce any graupel at these heights, produces much less overall than Thompson
- Bonnie was an unusual storm; more research needed in a spectrum of cases
Summary

- HRD is advancing the IFEX goals of improving TC intensity forecasting through a combination of observations, modeling, and theory
  - assimilation of airborne Doppler, new radar platforms, research on convection and its role in TC intensity change

- HRD is uniquely positioned to combine these approaches

- Ongoing work will continue to develop and refine our observational and modeling capabilities, covering the spectrum of spatial and temporal scales important in TC intensity change
  - new sampling strategies, model evaluation

- These efforts advance NOAA’s mission of building a Weather-Ready Nation
QUESTIONS?


IFEX Goal 1: Observations for model initialization and evaluation

Spatio-temporal scales targeted by IFEX field experiments

Rogers et al. (2013a)
### IFEX Goal 1: Observations for model initialization and evaluation

**Percentage (%) of on-station aircraft flight hours**

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<th>IFEX 2005-2011</th>
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Rogers et al. (2013a)
IFEX Goal 2: Techniques for real-time TC monitoring

Real-time analyses of TC inner-core structure from airborne radar

Doppler-derived wind speed (shaded, \(m \, s^{-1}\)) and vectors and dropsonde measurements at 1-km altitude for Hurricane Irene (2011)

South-north cross section of Doppler-derived wind speed (shaded, \(m \, s^{-1}\)) through Hurricane Irene (2011)

- Analyses are available within 1-2 h after aircraft lands
IFEX Goal 3: Improved understanding of TC processes: Convective-scale processes

HWRF simulations of the rapid intensification of Hurricane Earl (2010)

2-km axisymmetric wind maximum and coverage of convective bursts between $r^* = 0.5$ and 1

- After bifurcation period, coverage of bursts for Exp. 1826 increases markedly
- Enhanced coverage occurs prior to significant increase in symmetric wind speed
- Transient, limited coverage of bursts for Exp. 1226
IFEX Goal 3: Improved understanding of TC processes: Role of convective-scale processes

Convective burst module in Tropical Storm Gabrielle (2013)

Infrared satellite image and flight track showing 2nd of 3 box patterns flown around convective burst

Contoured frequency by altitude diagram (CFAD) of vertical velocity (shaded, %) for 2nd box pattern

Contoured frequency by altitude diagram (CFAD) of vertical vorticity (shaded, %) for 2nd box pattern

**Convective burst module:**
- Collect Doppler and dropsonde data in vicinity of a convective burst at high time frequency (~30-45 minutes)
- Document structure and evolution of convective-scale properties, e.g., statistics of reflectivity, vertical velocity, vorticity, mass flux over convective/mesoscale time scales
- Quantify impact of convective-scale processes on parent system
- Evaluate and improve HWRF microphysics parameterization
IFEX Goal 3: Improved understanding of TC processes: Role of convective-scale processes

Can high-resolution numerical models capture structural features of RI?

HWRF 3-km simulations of the rapid intensification of Hurricane Earl (2010)

Intensity traces for Hurricane Earl (2010)

Wind speed at 2 km (shaded, m s\(^{-1}\))
Streamlines at 2 km (black), 8 km (white) during bifurcation period
Convective burst locations (red contours)

- Two HWRF runs: initialized at 12 UTC 26 August (Exp. 1226) and 18 UTC 26 August (Exp. 1826)
- Both runs capture early intensity evolution well
- Bifurcation period at 00 UTC 8/30 – RI aborted in Exp. 1226 for 24 h
- More convective bursts inside 2-km RMW in Exp. 1826 during bifurcation period