



# NASA High Ice Water Content (HIWC) 2015 Radar Flight Campaign Overview

Prepared by:

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NASA Glenn Research Center & NASA Langley Research Center

## Acknowledgment

this presentation contains material produced by:

Walter Strapp  
Met Analytics, Inc.

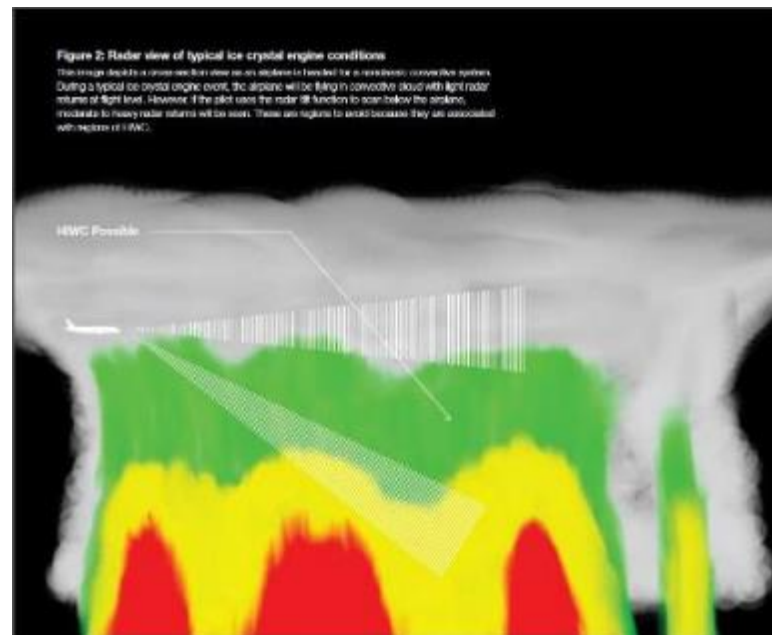
Matt Grzych  
The Boeing Co.

Patricia Hunt & Justin Strickland  
Analytical Mechanics Associates, Inc.

November 12, 2015

# Background

- Commercial pilots report engine power loss and pitot probe events occur in regions that appear to be innocuous
  - In IMC, near convective activity
  - No significant weather on pilot weather radar at flight level (green or black)
  - Only light to moderate turbulence
- Some common observations:
  - Precipitation on windscreen, often reported as rain
  - Total Air Temperature (TAT) probe anomaly
  - Lack of airframe icing
- Current guidance to pilots – Avoid ice crystal icing conditions
  - During flight in IMC, avoid flying directly above significant amber or red radar returns, even with no returns at aircraft altitude.
  - Use the weather radar manual tilt and gain functions to assess weather radar reflectivity below the aircraft flight path



From Grzych, "Avoiding Convective Weather Linked to Ice-Crystal Icing Engine Events", Boeing Aeromagazine QTR1-2010



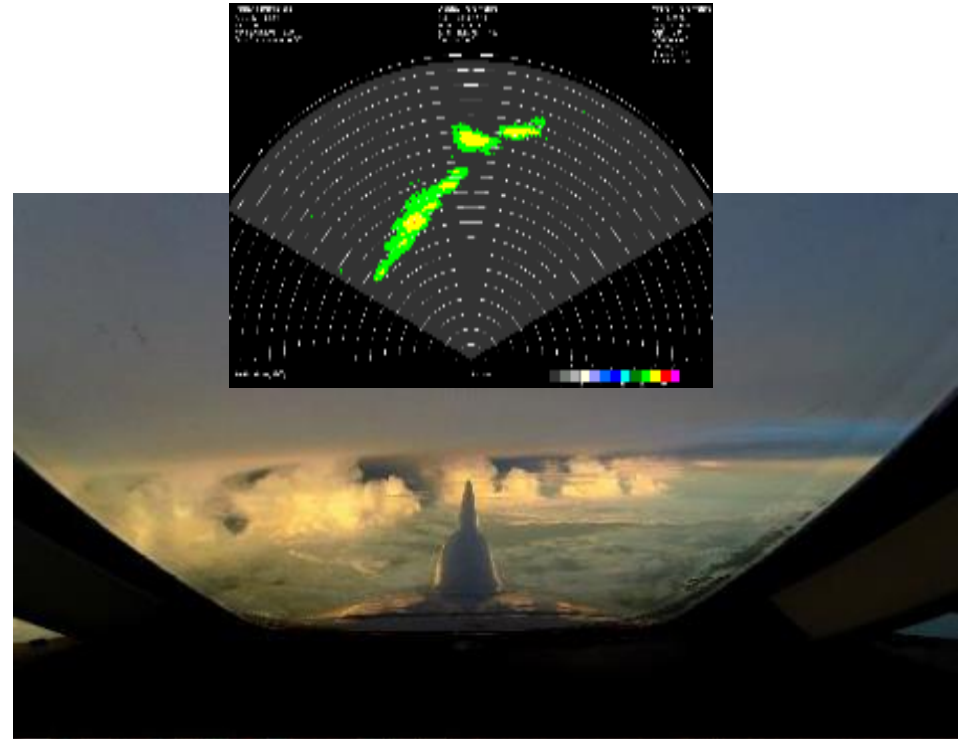
# Background

- In 2014, the High Altitude Ice Crystal – High Ice Water Content (HAIC-HIWC) International Field Campaign flew an instrumented Falcon 20 research airplane into deep convective systems over northern Australia to characterize this environment.



# Background

- One goal that was unfulfilled from the Darwin Campaign was to acquire raw data from the pilot weather radar to develop means to remotely identify regions of HIWC so pilots can divert around the hazard.
  - Onboard remote identification of HIWC regions has a high potential/value to reduce the risk for the current fleet
- NASA and FAA collaborated to conduct the 2015 HIWC RADAR Flight Campaign to acquire data needed to reach this goal
  - Technical support and collaboration from SEA and Met Analytics via contract
  - Technical support from Boeing, Honeywell, Rockwell-Collins via agreements





# NASA HIWC Radar Flight Campaign

## Goal:

- Develop a means to remotely identify HIWC conditions ahead of an aircraft for tactical avoidance decision-making

## Approach:

- Using the NASA DC-8, acquire pilot weather radar I & Q data in deep mesoscale convective systems along with the corresponding in-situ cloud physics data (water content, particle spectra, temperature)
- Data will be used to characterize the response of the radar and develop and test HIWC identification algorithms
- Data may also supplement the database for Part 33 Appendix D/P regulations for engine and air data systems certification and means of compliance testing

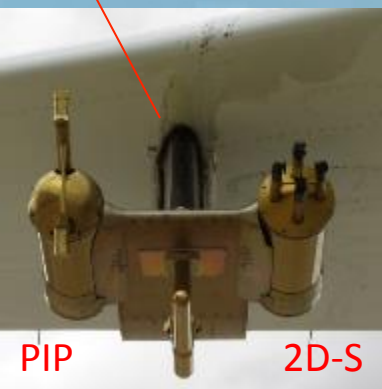
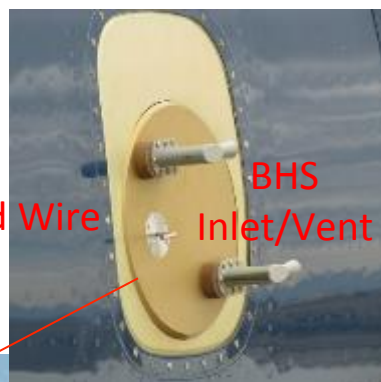
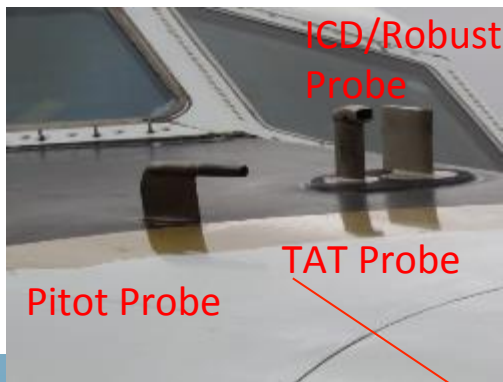
## NASA HIWC Radar Flight Campaign

- Conducted onboard the NASA DC-8 Airborne Science Laboratory
  - 3 week campaign, 80 flt-hours, Ft. Lauderdale, FL, August 10-31, 2015
  - Honeywell RDR-4000 as primary WXR
  - Wing pods for IKP-2 and cloud particle spectra probes
  - Additional fuselage mounted instruments for background humidity, robust TWC, TAT





# Instrumentation



ARIM200

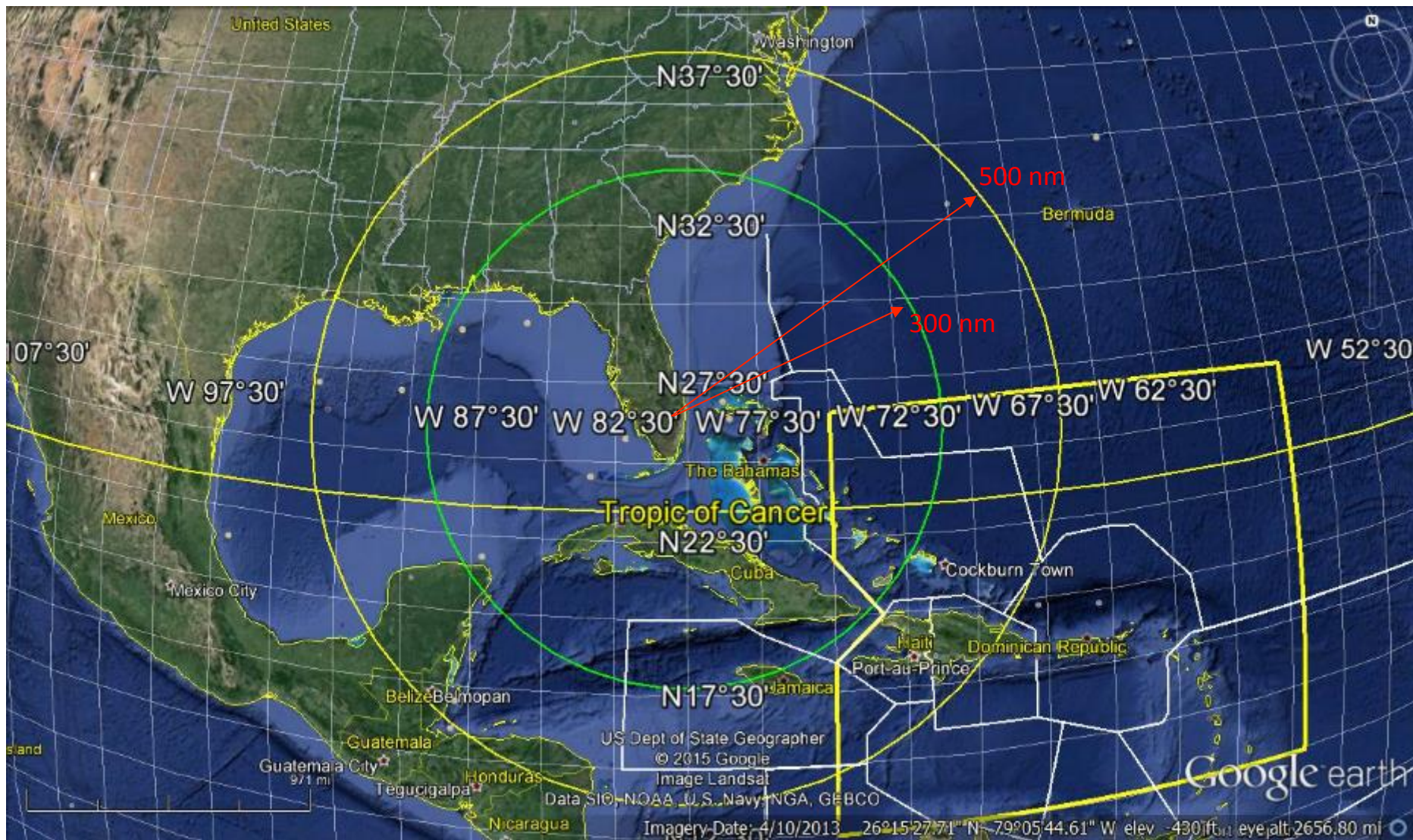


Modified Honeywell RDR-4000





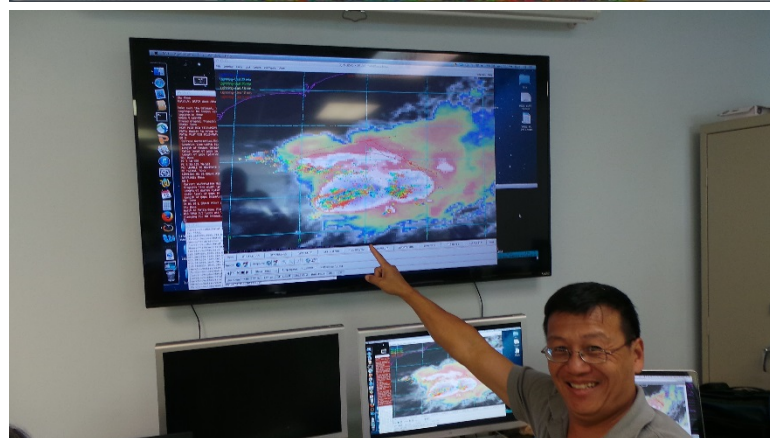
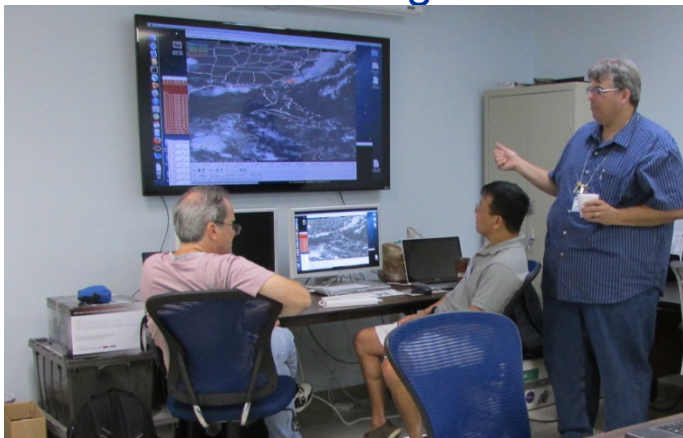
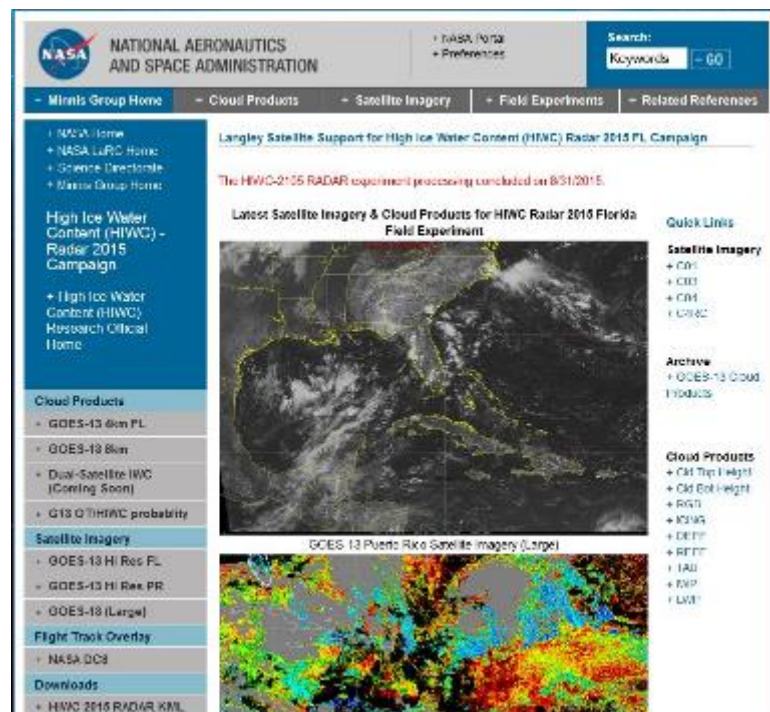
# Operating Area





## Forecast/Nowcast

- Forecast team\* utilized numerical Wx models, Soundings, NASA LaRC Sat products to provide pre-flight wx briefings to define region of interest and timing
- During flights Nowcast team\*\* provided updates to DC-8 utilizing NASA LaRC sat products, lightning network, to refine flight tracks
- Coordination with ATC by Blankenship, Dumont and DC-8 navigators

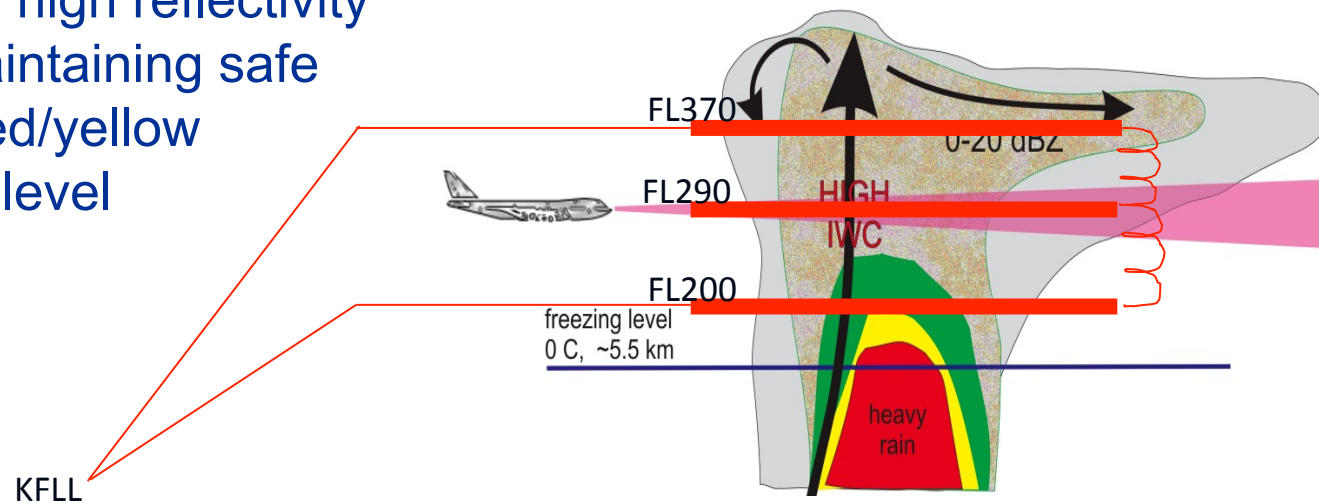
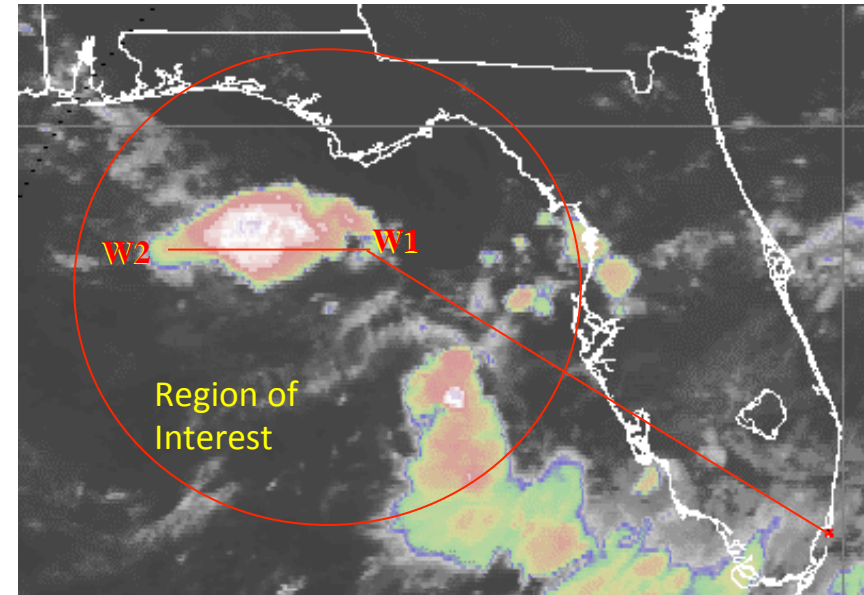


\* Proctor, Grzych, Bernstein, DiVito

\*\* Strapp, Nguyen, Yost, Bernstein

# Sampling Strategy

- Acquire data during level transects at:
  - FL370-FL360 ( $-50\text{C} \pm 3\text{C}$ )
  - FL300-FL290 ( $-30\text{C} \pm 3\text{C}$ )
  - FL210-FL200 ( $-10\text{C} \pm 3\text{C}$ )
- Using satellite imagery, define regions of interest with deep convection
- Overfly areas of high reflectivity below, while maintaining safe distance from red/yellow regions at flight level



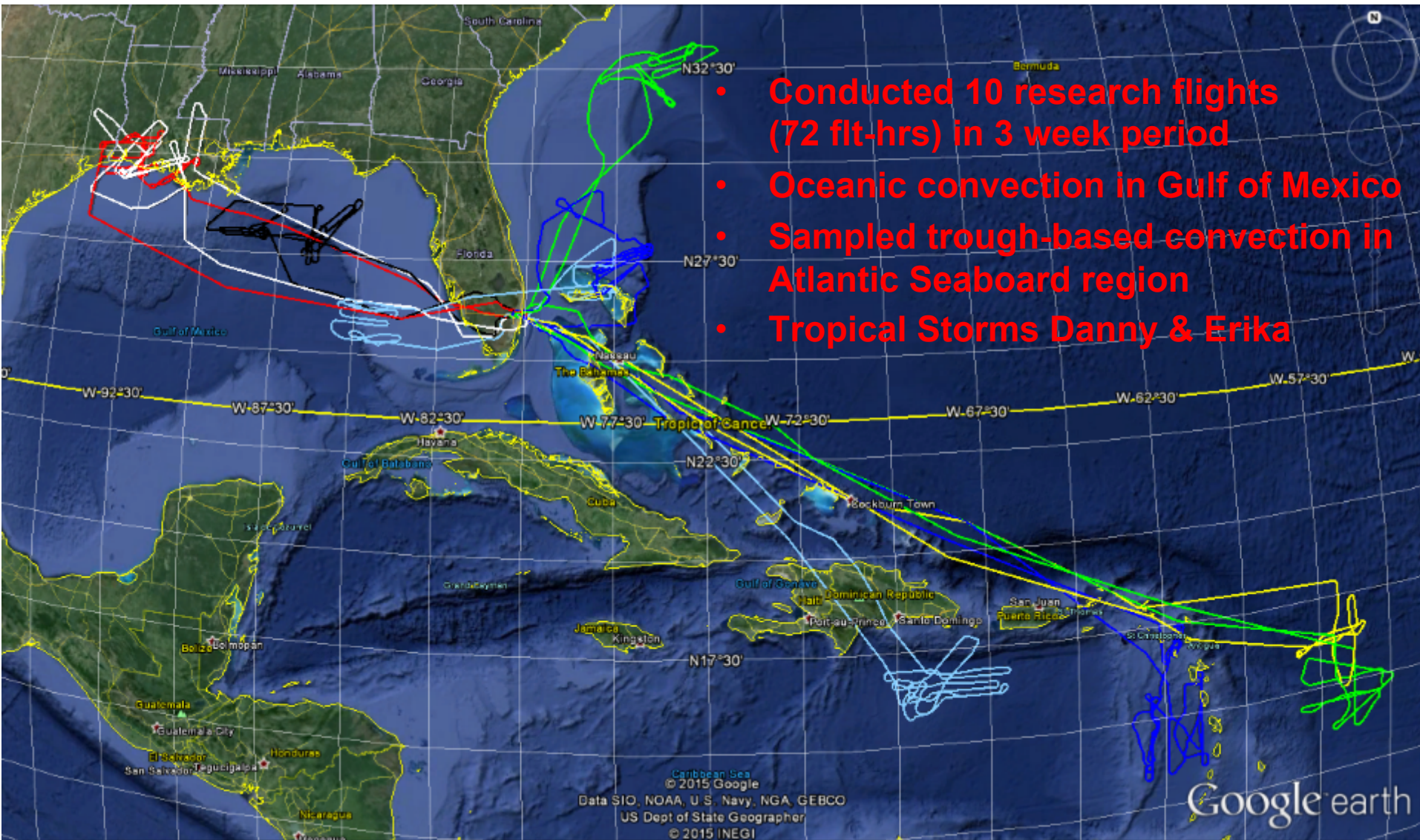


# NASA HIWC Radar Flight Campaign

## *The Outcomes*



# NASA 2015 HIWC Radar Flight Campaign Flight Track Summary





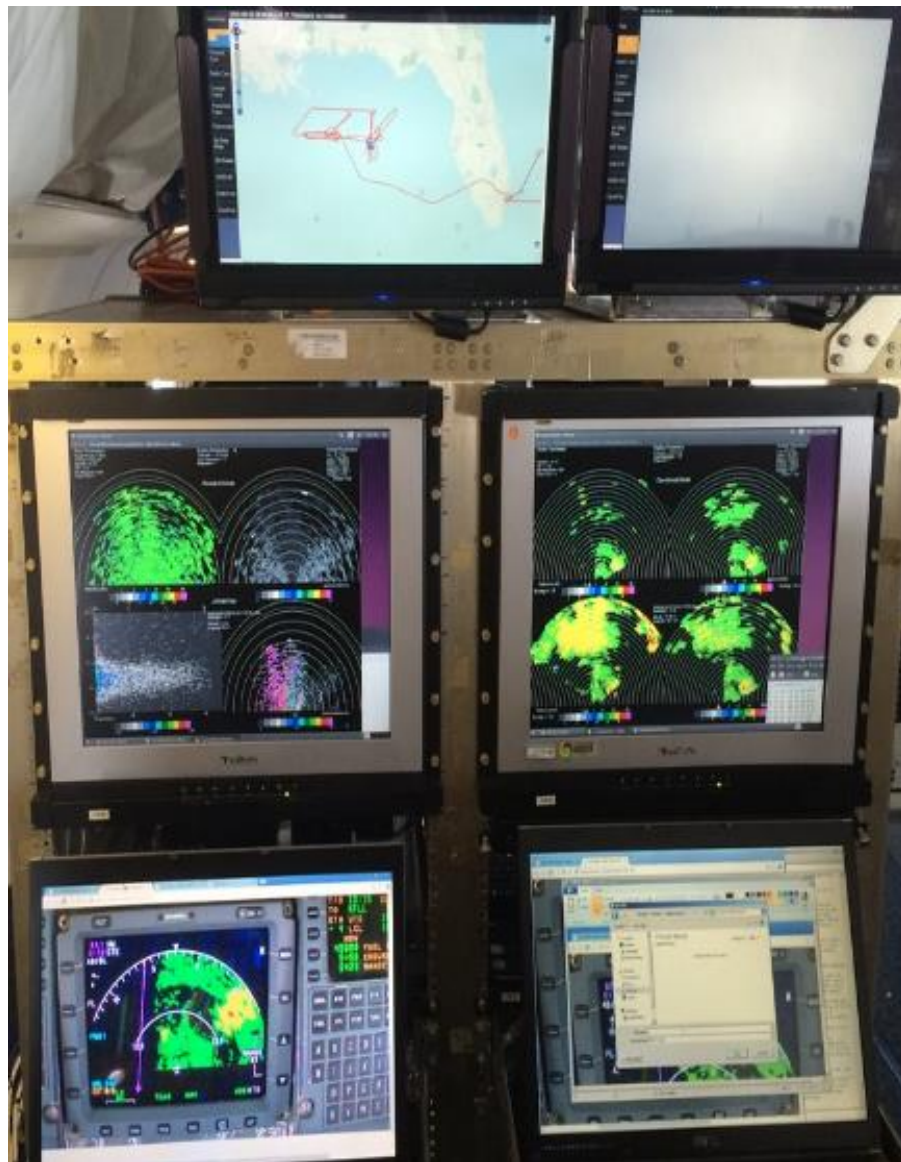


## NASA 2015 HIWC Radar Flight Campaign Flight Record

#	DATE	MIN	IWC	Notable event
ICF	08/08/15	240	-	All Systems Functioning Properly
XIT	08/10/15	300	-	Met Probe Calibration – In Cloud Flight
1	08/12/15	286	2.0	Build-up
2	08/13/15	253	1.5	First Rec TAT Anomaly
3	08/14/15	314	2.0	First Rec Pitot Anomaly
4	08/16/15	424	2.6	Double Pitot Anomaly (-50°C)
5	08/19/15	422	2.2	Double Pitot Anomaly (-30, -40, & -50°C)
6	08/21/15	379	2.7	Coastal HIWC (Gnd Clutter Issues)
7	08/23/15	495	1.7	TS DANNY
8	08/26/15	589	2.8	TS ERIKA
9	08/27/15	598	2.5	TS ERIKA
10	08/28/15	467	3.0	TS ERIKA
XIT	08/30/15	300	-	Return to AFRC

## Notable Events

- Radar:
  - Most HIWC conditions occurred in regions of Yellow (30-40 dBZ) FL radar reflectivity
  - On several occasions HIWC conditions were observed where FL radar reflectivities were green or even black
    - all of these events were regions just downwind (short distances) from convective core and higher reflectivity
  - Many HIWC conditions occurred with regions of high reflectivity below flight level
  - Unfortunately some HIWC events occurred away from radar-based convective cores (signature)

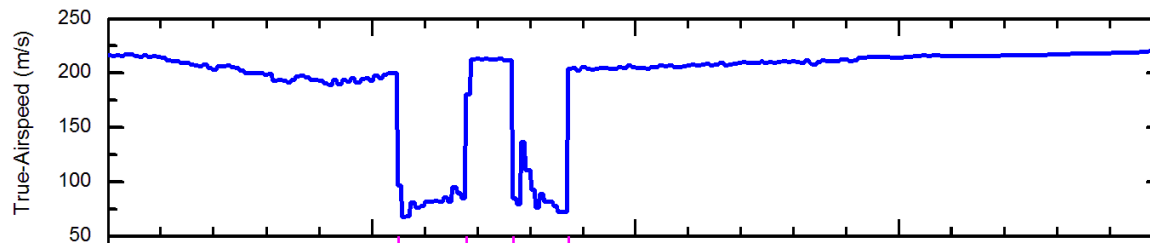


## Notable Events

- Multiple TAT and pitot probe anomalies recorded
  - TAT anomalies occurred with one TAT probe when  $IWC > 1.5$  and  $T_s < -30^\circ\text{C}$ ; no anomalies with another model
  - Numerous pitot anomalies occurred
    - their characteristics varied
    - sometimes innocuous (steady value)
    - other times, indicated airspeed dropped quickly to  $< 100$  knots

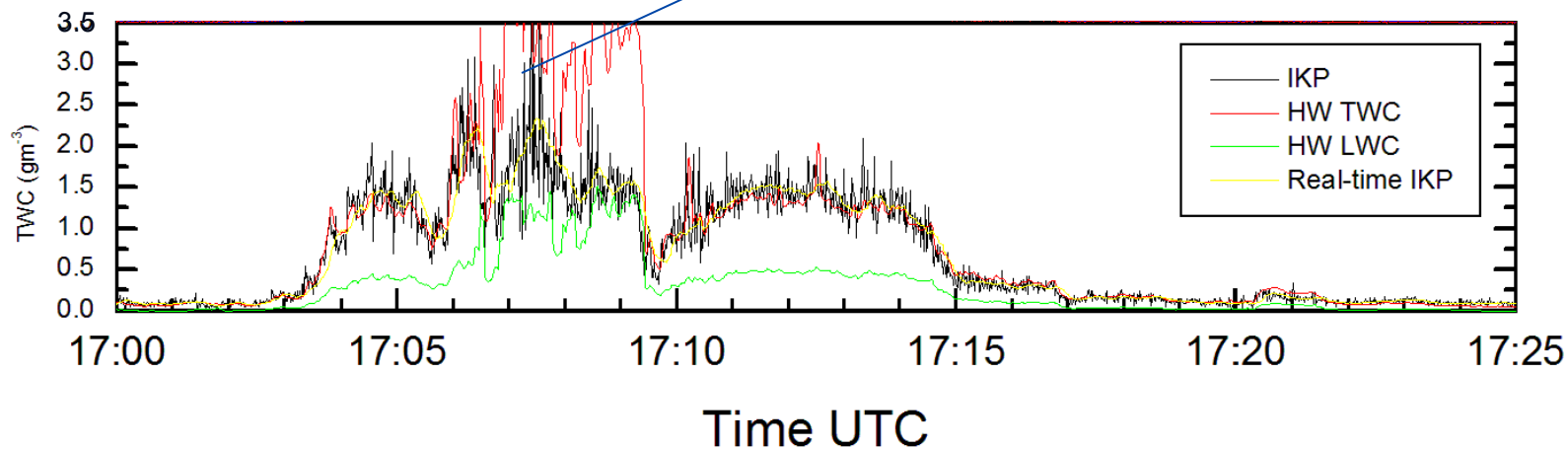
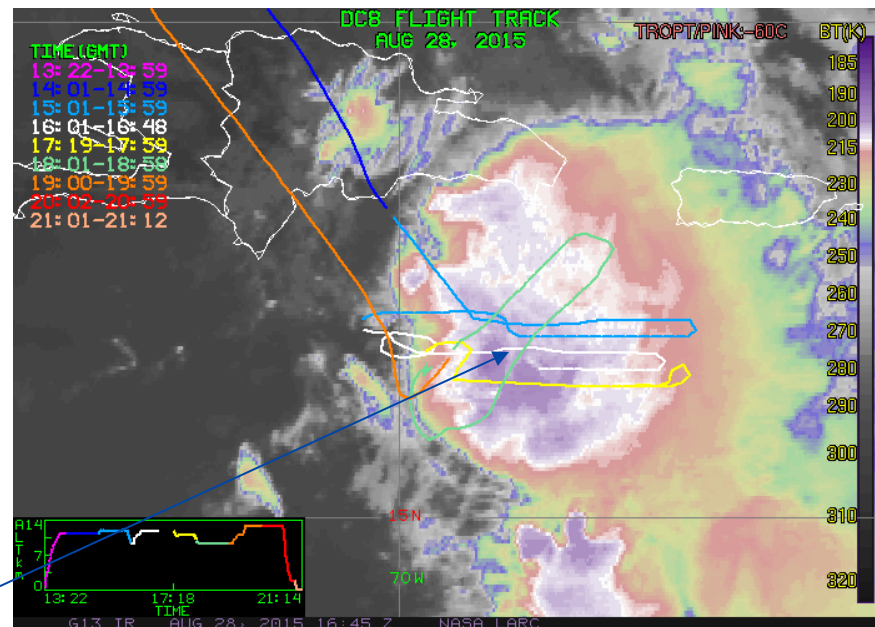


HIWC-RADAR 28Aug15 - Run 1 - v2



## Notable Events

- Tropical Storms Danny and Erika enabled significant data to be collected at  $-50^{\circ}\text{C}$  level
  - 17 runs (approx. 1000 nm) at  $-50^{\circ}\text{C}$
  - Peak IWC at  $-50^{\circ}\text{C}$  was about  $3\text{ g/m}^3$  during Flt 10 (Aug 28)
  - Often in black/green speckled radar
  - Multiple pitot probe failures
  - Multiple tracks <10 min duration with  $\text{IWC} > 1.5\text{ g/m}^3$







# Status

- 500 GB radar data acquired/archived
  - processing underway
- 77 GB in-situ meteorological data acquired/archived
  - Strapp completed rough IKP analysis; other data sets not started
  - EC performing PSD analysis in CY2016
- 4 TB of HD video (windscreen)
  - initial processing completed



## Next Steps

- Complete processing and analysis of radar, IWC, PSD
- Determine correlations between radar, IWC, PSD
  - Is X-band alone sufficient to identify regions of IWC?
- Write up results – end 2016
- Plan for campaign with dual frequency radar – summer 2017



# The HIWC Radar Flight Campaign Team

- **Langley Research Center**
    - Steven Harrah (PI)
    - Robert Neece
    - Fred Proctor
    - Phil Schaffner
    - Larry Goins
    - Patricia Hunt*
    - Justin Strickland*
    - Louis Nguyen
    - Chris Yost
    - Luke Ziemba
    - Ewan Crosbie
  - **Honeywell**
    - David Vacanti
    - Brian Bunch
    - Paul Christianson
    - Bob Jensen
    - Jan Lukas
  - **Rockwell-Collins**
    - Steve Brookshire
    - Kevin Kronfeld
    - Greg Koenigs
    - Tim Etherington
    - Richard Jinkins
  - **Glenn Research Center**
    - Tom Ratvasky (Co-I)
    - Kurt Blankenship
    - Ed Emery
  - **FAA**
    - Tom Bond
    - Chris Dumont
    - Stephanie DiVito
    - Lee Nguyen
  - **SEA**
    - Lyle Lillie
    - Dan Bouley
    - Larry Ching
  - **Met Analytics**
    - Walter Strapp
  - **Boeing**
    - Jeanne Mason
    - Matt Grzych
  - **Leading Edge Atmospheric**
    - Ben Bernstein
  - **Armstrong Flight Research Center**
    - Ed Teets
    - Tim Moes
    - Royce Brown
    - Terrance Dilworth
    - Garry Beauregard
    - Tom Horn
    - Walter Klein
    - Nils Larson
    - Lyndel Lohberger
    - Kevin Mount
    - Herman Rijfkoogel
    - Wayne Ringelberg
    - Scott Silver
    - Donald Bailes*
    - Adam Webster*
    - Mike Delaney*
    - David Van Gilst*
    - David Johnson*
    - Peter Merlin*
    - Greg Pugh*
    - Roger Renfro*
    - Lorenzo Sanchez*
    - Tim Sandon*
- 
- A photograph of a white NASA aircraft on a runway. The aircraft has the NASA logo on its tail. In the background, there is a tall, cylindrical control tower. The sky is overcast.



End of Presentation

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