Sensing Hazards with Operational Unmanned Technology (SHOUT)

Working Group Meeting

23 January 2015

Objectives

- **Review impact study activities**
- **Review FY 15 deployment plans**
- **Discuss outyear plans and options**

SHOUT Project Objectives

Overall Goal

- **Demonstrate and test prototype UAS concept of operations that could be used to mitigate the risk of diminished high impact weather forecasts and warnings in the case of polar-orbiting satellite observing gaps**

Objective 1

- **Conduct data impact studies**
  - **Observing System Experiments (OSE) using data from UAS field missions**
  - **Observing System Simulation Experiments (OSSE) using simulated UAS data**

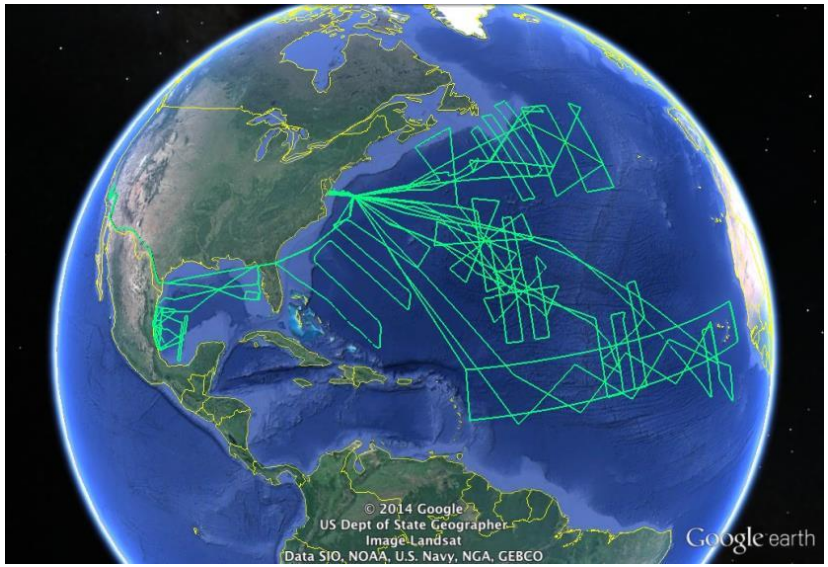
Objective 2

- **Evaluate cost and operational benefit through detailed analysis of life-cycle operational costs and constraints**

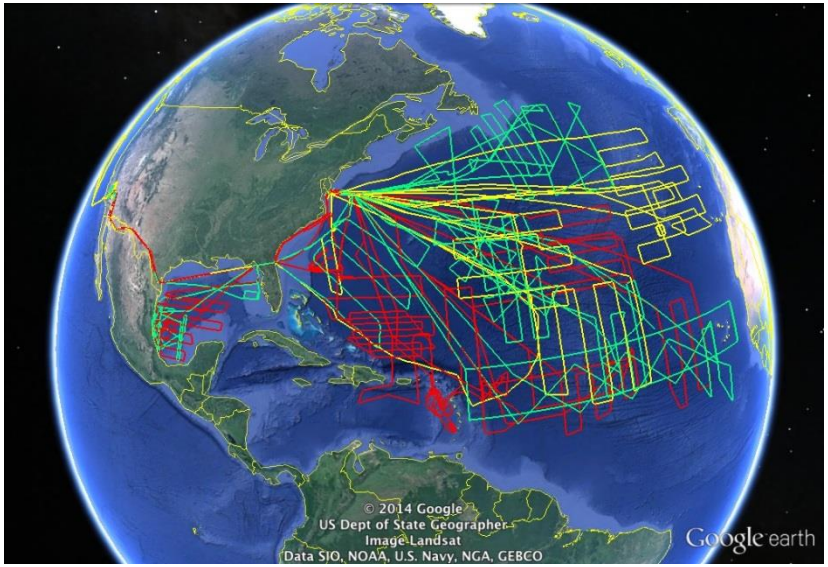
HS3 2014

- **10 Science missions**
- **649 sondes deployed**
- **Second G-IV dropsonde intercomparison**
- **Dedicated NOAA missions and flight plans**

HS3 2014



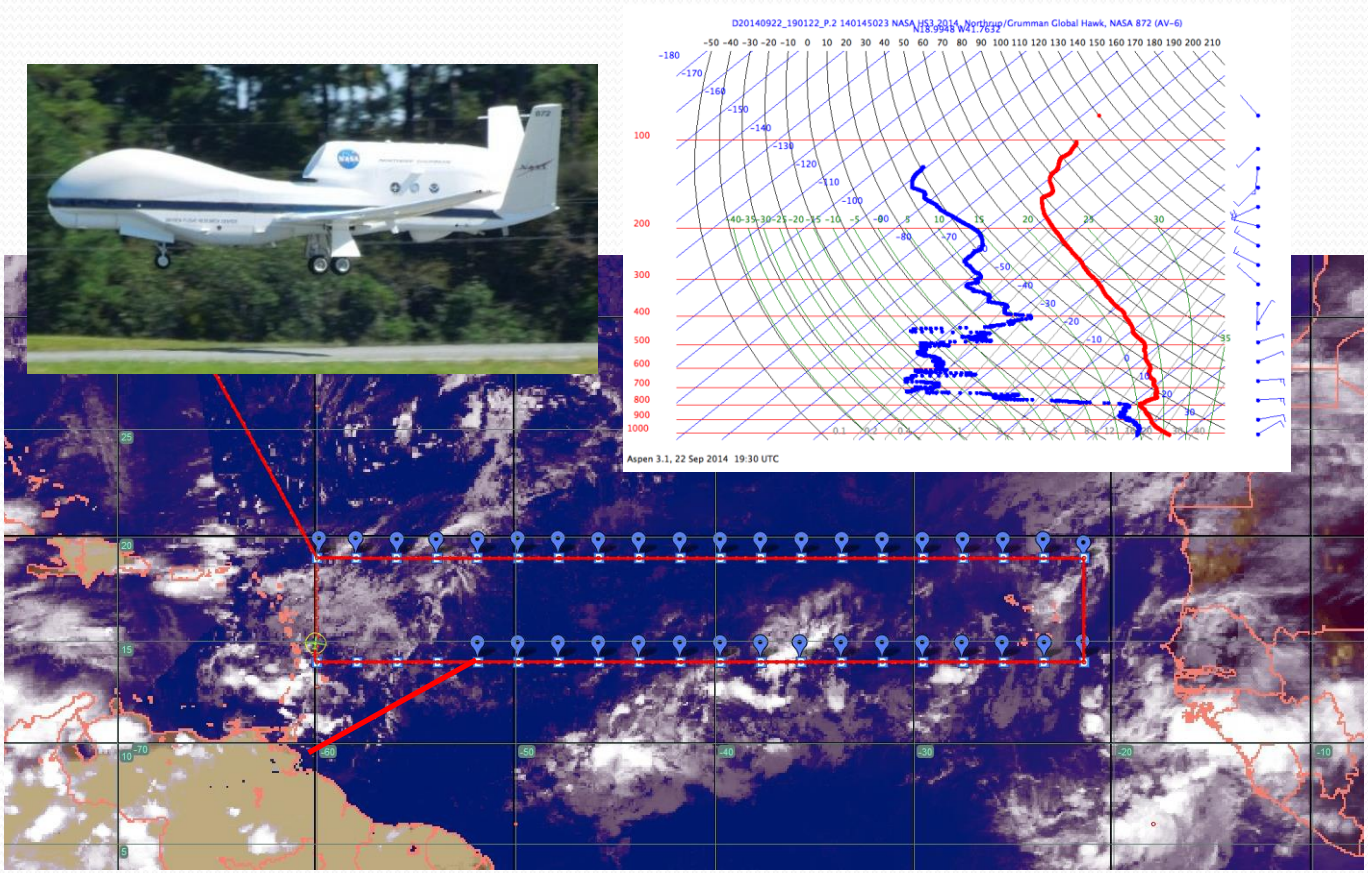
HS3 2012-2014



Graphics Courtesy NASA

NOAA-led Global Hawk Sampling in SHOUT 2014

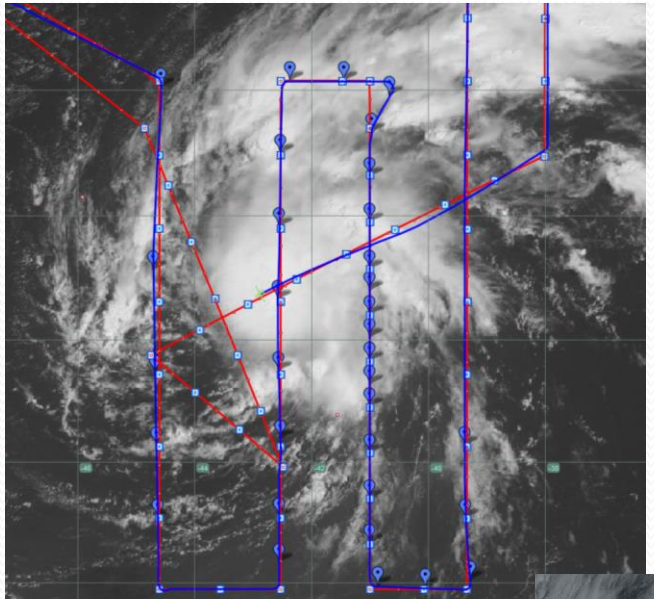
Hurricane Main Development Region (MDR) sampled by NASA Global Hawk on September 22-3 and 28-9 during 2014 HS3/SHOUT campaign



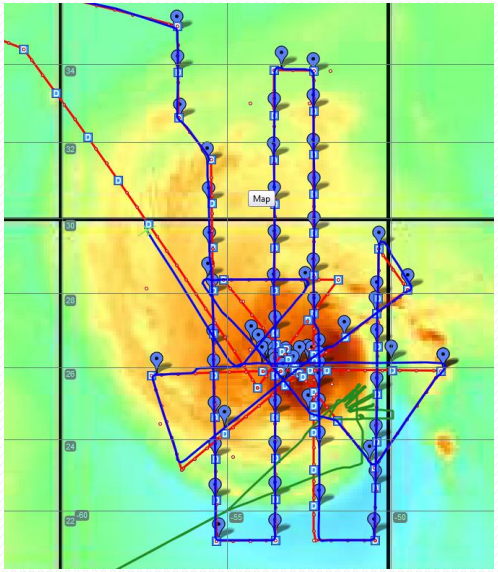
- First systematic sampling of MDR since 1974
- 105 dropsondes deployed and data transmitted to NWS gateway during two 24+ hour missions

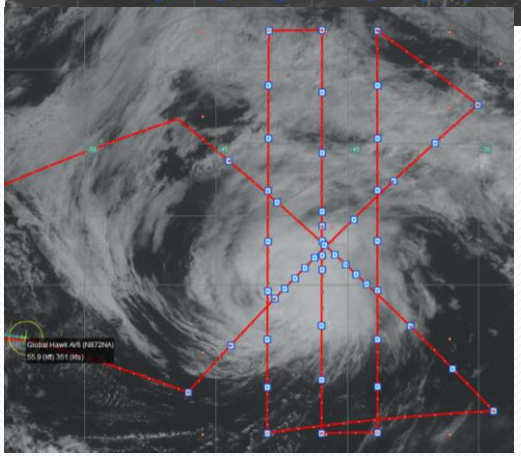
Global Hawk Sampling of Edouard

11 September, Tropical Storm



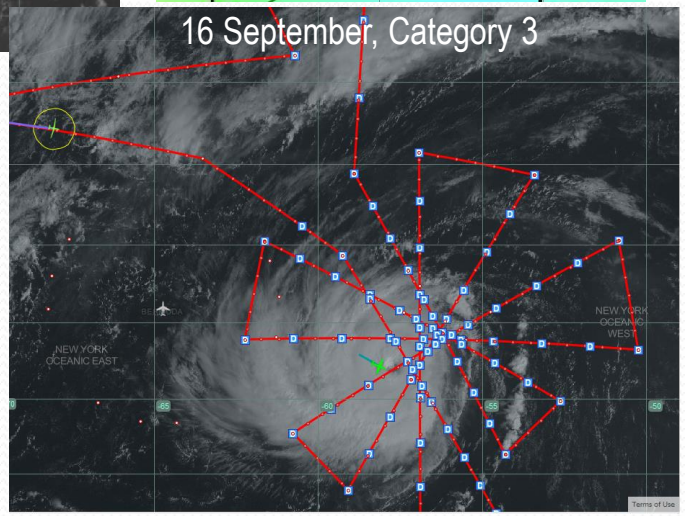
14 September, Category 1





18 September, Decay

16 September, Category 3

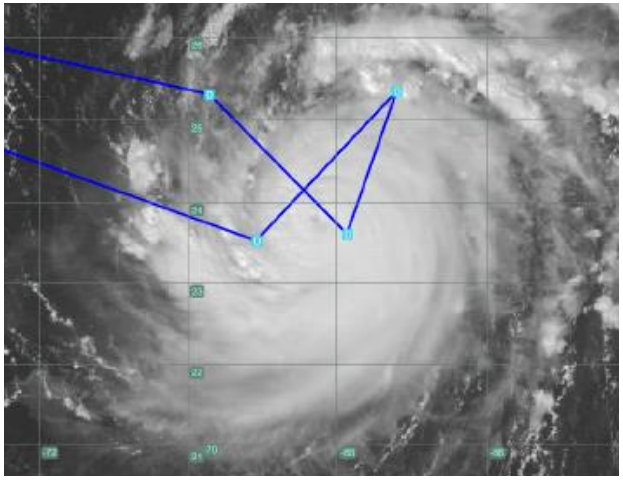


- 282 total dropsondes deployed during more than 58 hours around storm

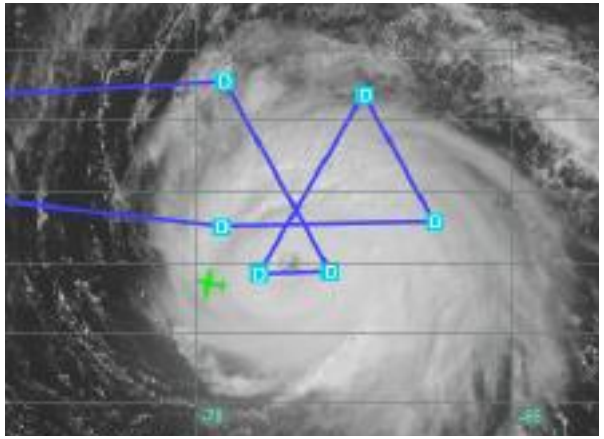
NASA/NRL WB-57 Flights

- **HIWRAP and HIRAD moved to NASA WB-57**
- **Flown in collaboration with NRL testing of high density dropsonde system**
- **Three flights over Hurricane Gonzolo**
- **Data to be available for analysis**

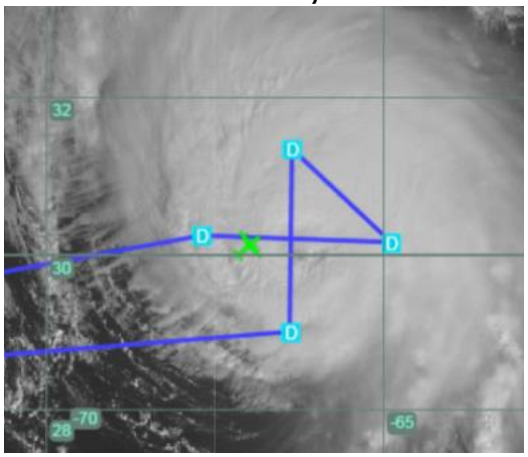
October 15, 2014



October 16, 2014



October 17, 2014



Graphics Courtesy NASA

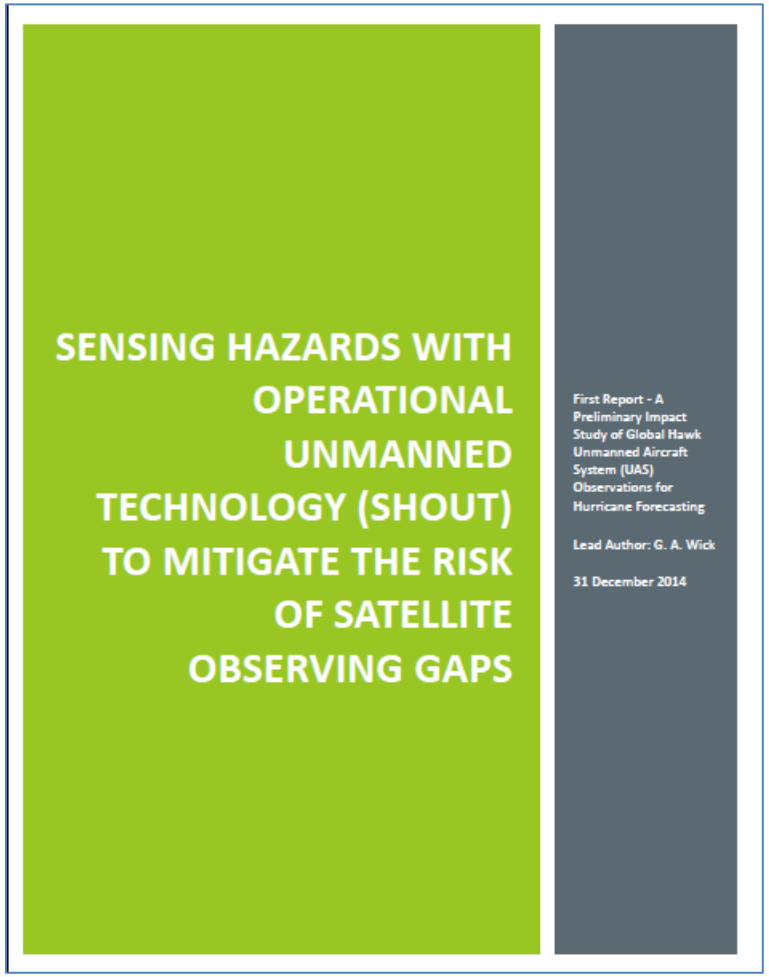
Data Impact Studies

Data Analysis Activities

- Rapid Observing System Simulation Experiment (OSSE)
- Observing System Experiments (OSE)
- Sampling strategies to support both OSSE and OSE activities
- NCEP real-time data utilization
- Data impact analyses

Initial Hurricane Impact Study

- Submitted to DUS 31 December 2014
- Based primarily on observations prior to HS3 2014
- Wide range of studies demonstrate potential for positive impact of observations
- Strong motivation for SHOUT continuation


SENSING HAZARDS WITH OPERATIONAL UNMANNED TECHNOLOGY (SHOUT) TO MITIGATE THE RISK OF SATELLITE OBSERVING GAPS

First Report - A Preliminary Impact Study of Global Hawk Unmanned Aircraft System (UAS) Observations for Hurricane Forecasting

Lead Author: G. A. Wick

31 December 2014

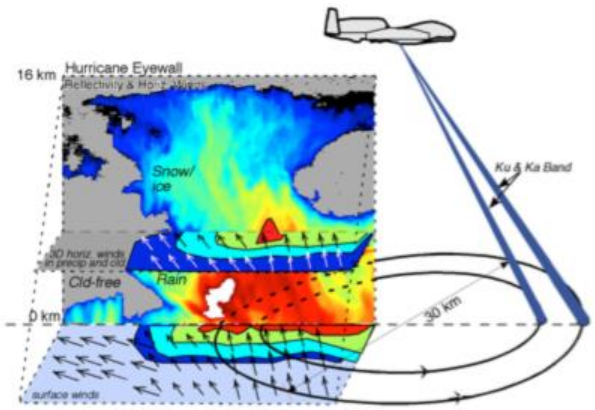
Study Outline

- **External investigations**
- **OSSE studies**
  - **Global**
  - **Regional**
- **Regional OSE studies**
- **Dropsonde assimilation in HWRF**

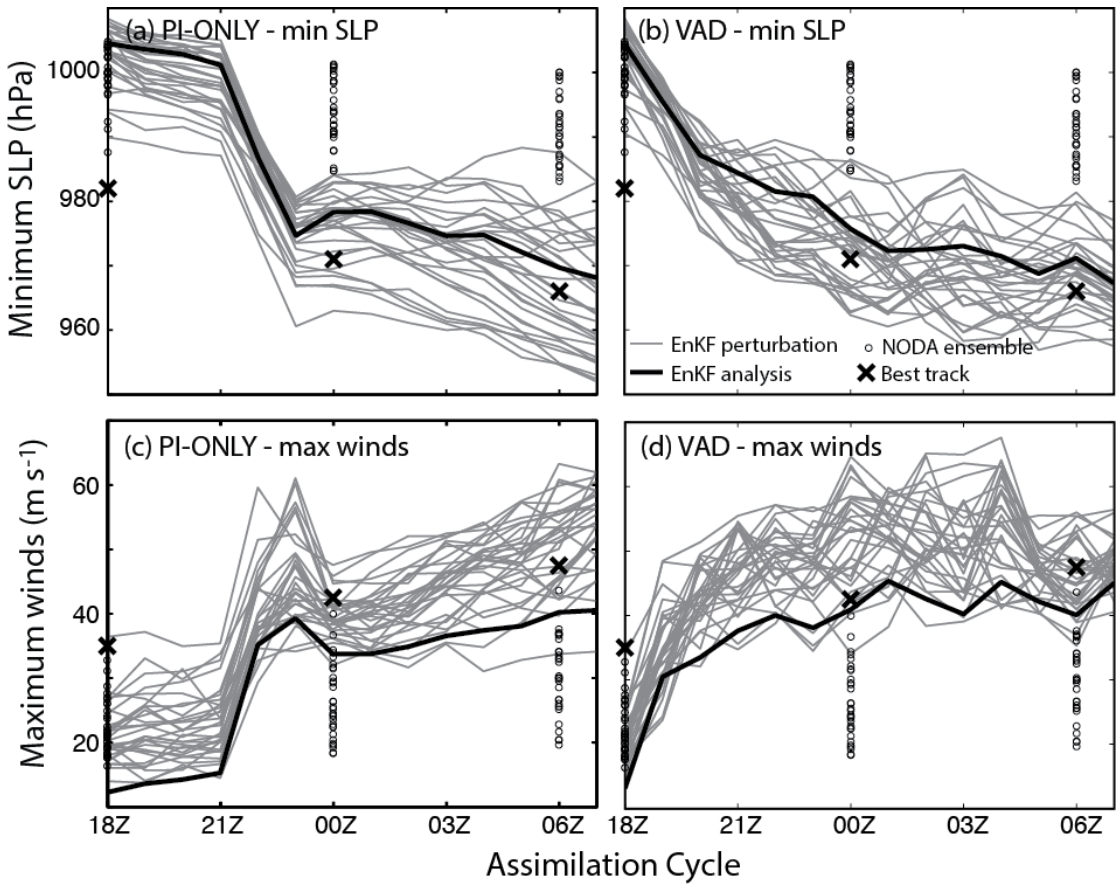
Authors of cited analyses

Altug Aksoy, Robert Atlas, James Doyle, Nikki Privé, Jason Sippel, Vijay Tallapragada, Zoltan Toth, Hongli Wang, Yuanfu Xie

HIWRAP Impact



Courtesy Gerald Heymsfield, NASA GSFC



From Sippel et al., 2014

HIRAD Wind Retrieval, Assimilation for Hurricane Karl

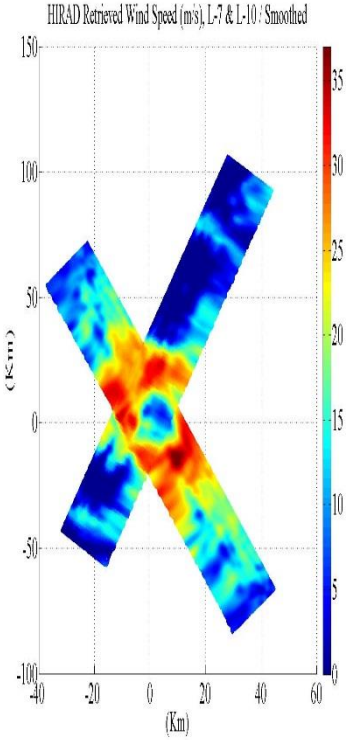
HIRAD Surface Wind maximum likelihood estimation retrievals from Linwood Jones group at U. Central Florida, Aug 2014 (right)

Surface wind field in data assimilation experiments from Jason Sippel at GSFC, Aug 2014 (bottom)

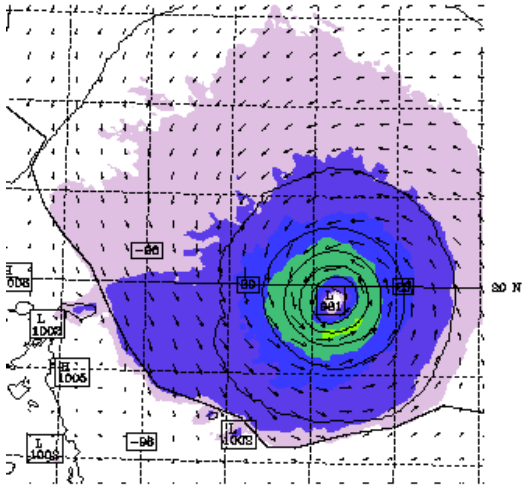
Adding HIRAD (bottom middle) improves characterization of asymmetric nature of wind field, and correctly reduces the horizontal extent of the wind field. Control and Control+HIWRAP experiments had Radii of 50-kt and 34-kt winds too large, compared to Best Track

Best results from assimilating Dropsonde, HIRAD, HIWRAP together

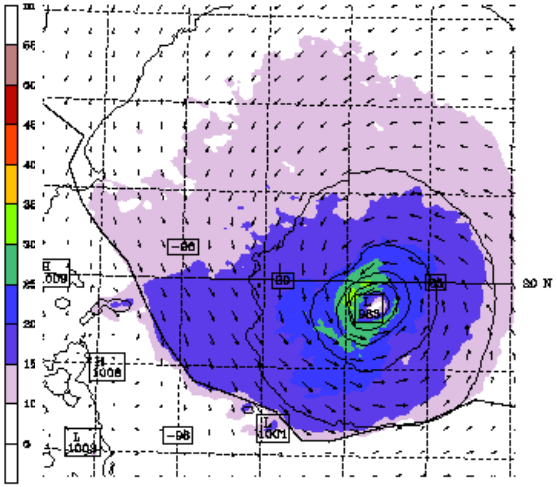
Wind Speed retrievals, from UCF, Aug 2014



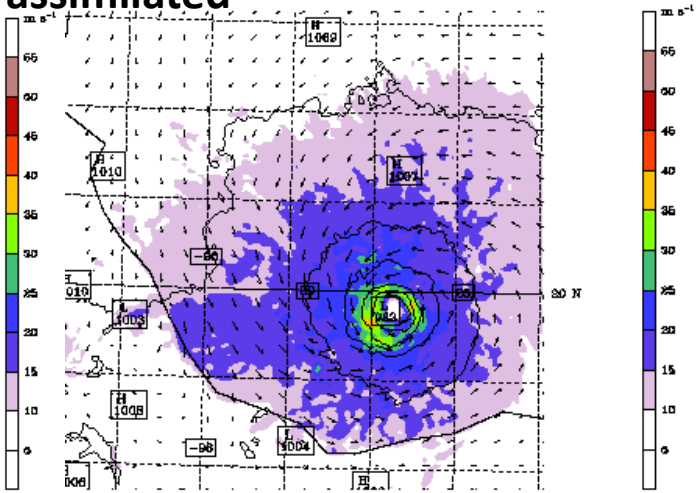
HIWRAP VAD wind assimilated



HIRAD surface wind and HIWRAP VAD wind assimilated

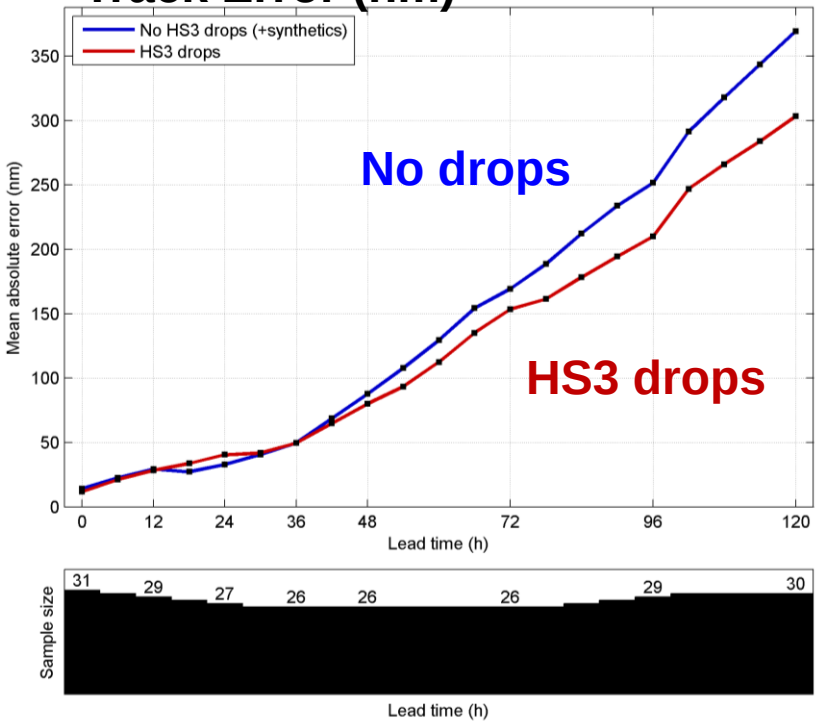


HIRAD surface wind, dropsonde wind, and HIWRAP VAD wind assimilated

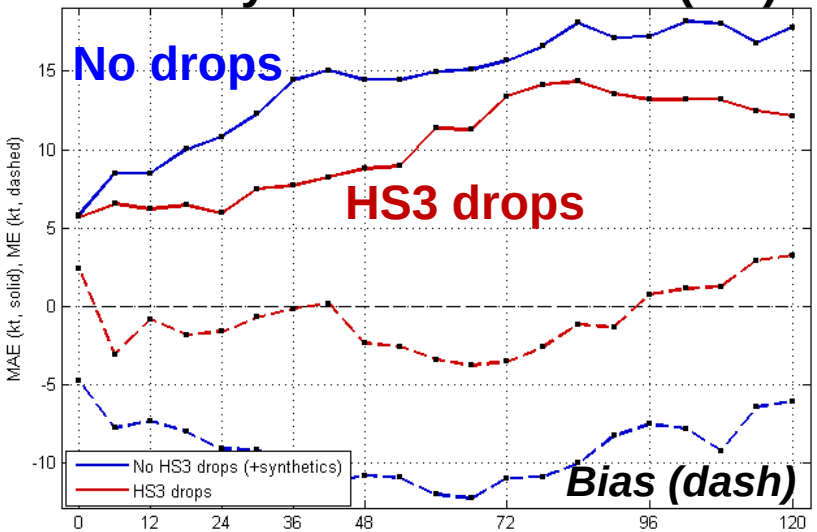


Impact of HS3 Dropsondes for Navy COAMPS-TC Hurricane Nadine Predictions

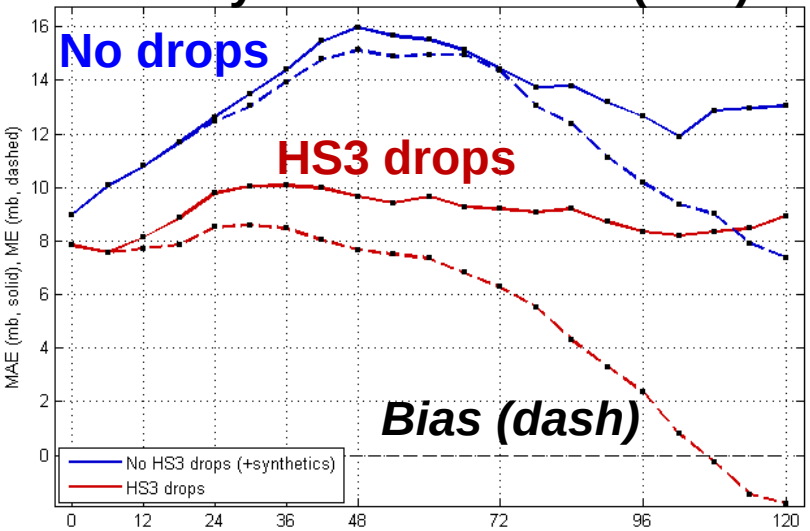
Track Error (nm)



Intensity: Max. Wind Error (kts)



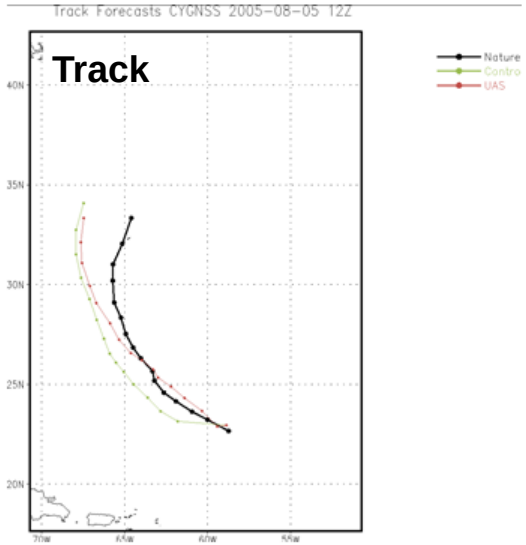
Intensity: Min. SLP Error (hPa)

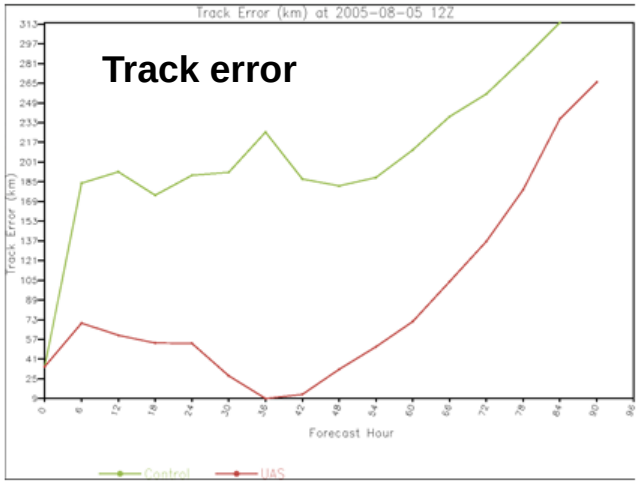


- Dropsonde impact experiments performed for 19-28 Sep. (3 flights)
  - Red: with HS3 drops
  - Blue: No drops with synthetics
- COAMPS-TC Intensity and Track skill are improved greatly through assimilation of HS3 Drops.

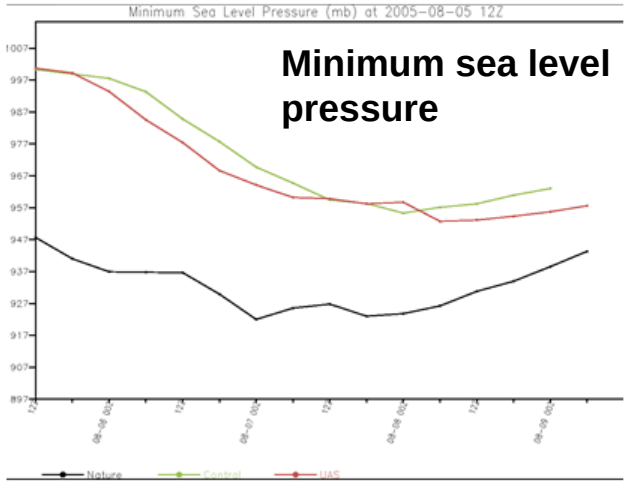
Slide courtesy of James Doyle / NRL

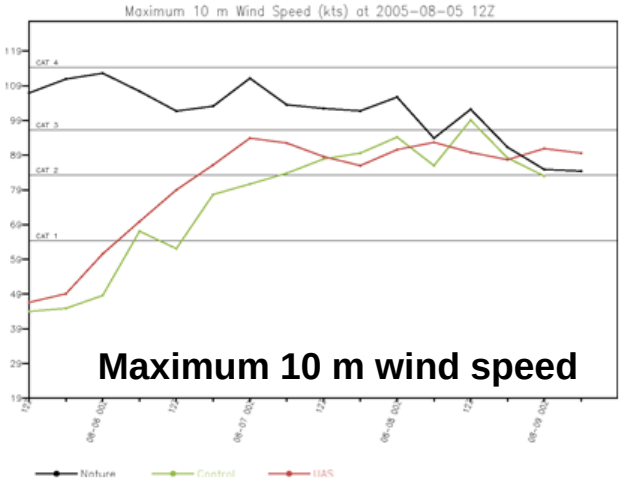
Regional OSSE Results





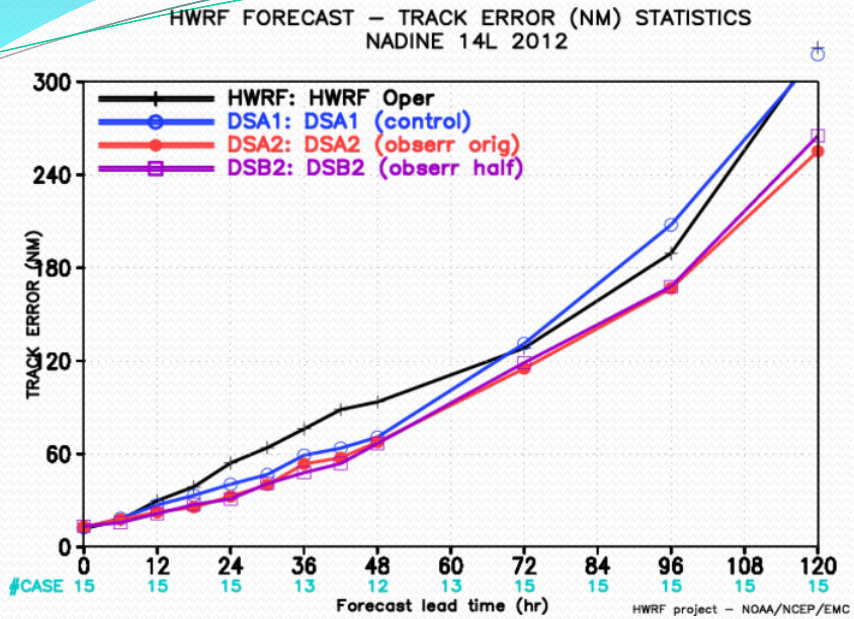
Black: Best track
Green: Control
Red: UAS

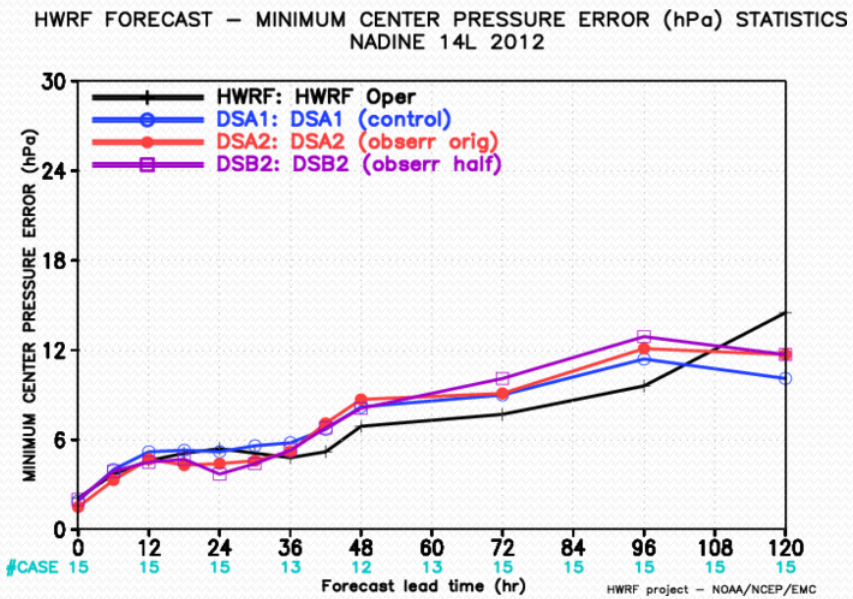


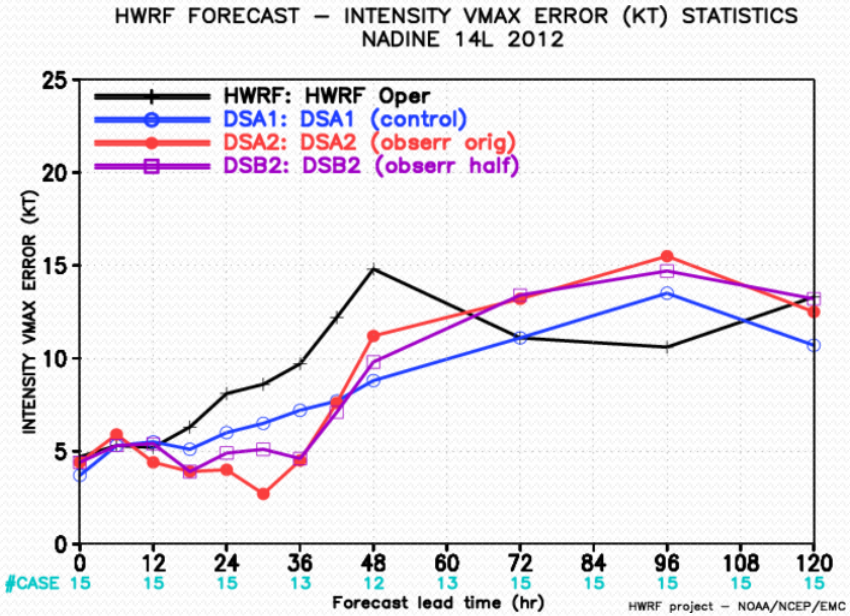


From Atlas et al., 2014

Hurricane Nadine 14L 2012



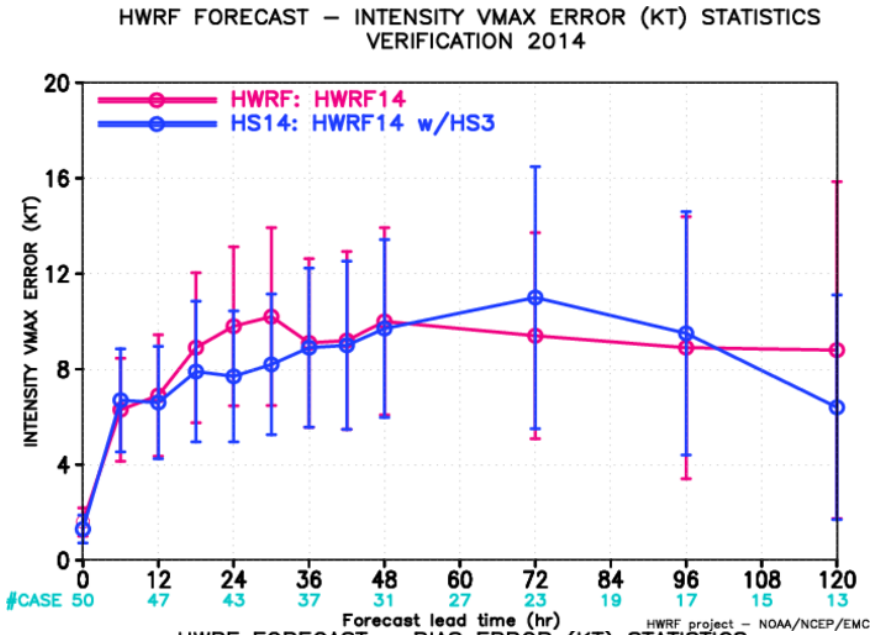


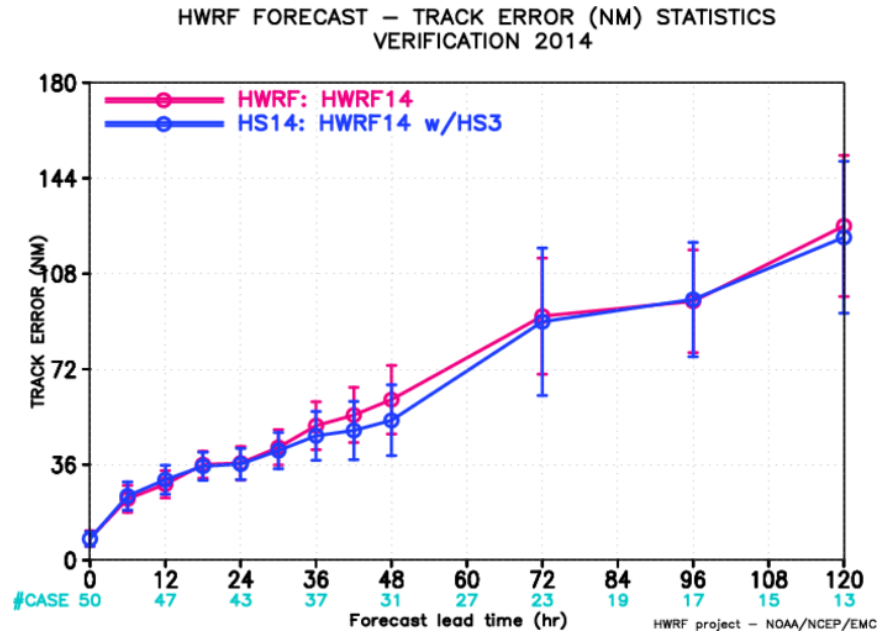


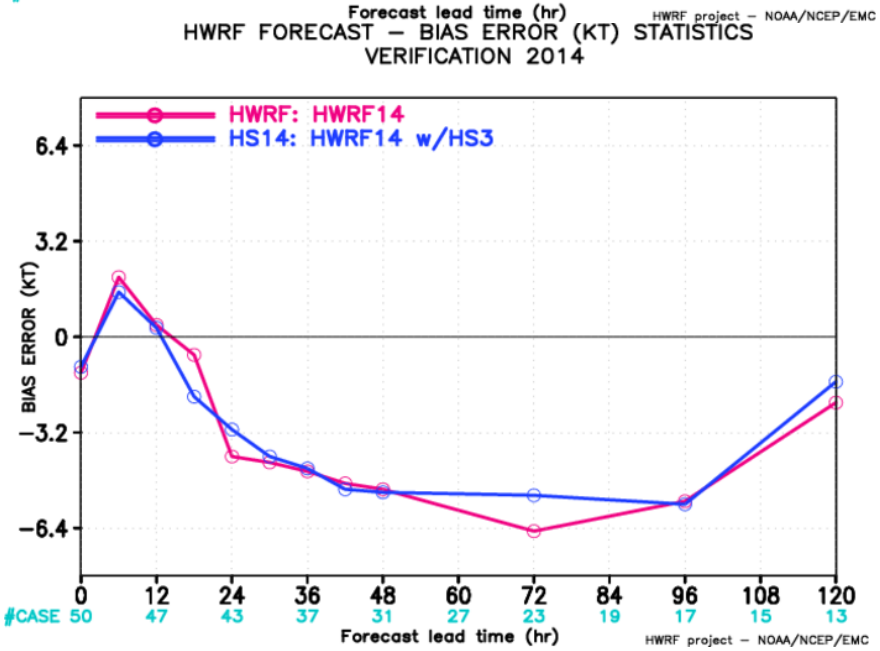
Verification for HWRF forecast from cycles with Global Hawk Dropsondes for H. Nadine (2012):

- Significant improvement in track forecasts compared to control
- Intensity (Vmax) errors improved in the first 36 hrs, degraded afterwards.
- No impact on MSLP forecasts

Slide courtesy of Vijay Tallapragada / NCEP







Cristobal, Dolly, and Edouard with HS3 data

Slide courtesy of Vijay Tallapragada / NCEP

Concluding Assessment

- **Multiple studies all demonstrate a positive impact of new UAS observations when added to existing observing systems**
- **Studies still limited and more work required to establish significant continuing**
- **Largest impact thus far on regional models**
- **Results support continuing observational and modeling studies in SHOUT**

Next Steps

- **New results arriving**
- **More guidance expected on which observations have largest impact**
- **Complete final impact study to be delivered later in SHOUT**

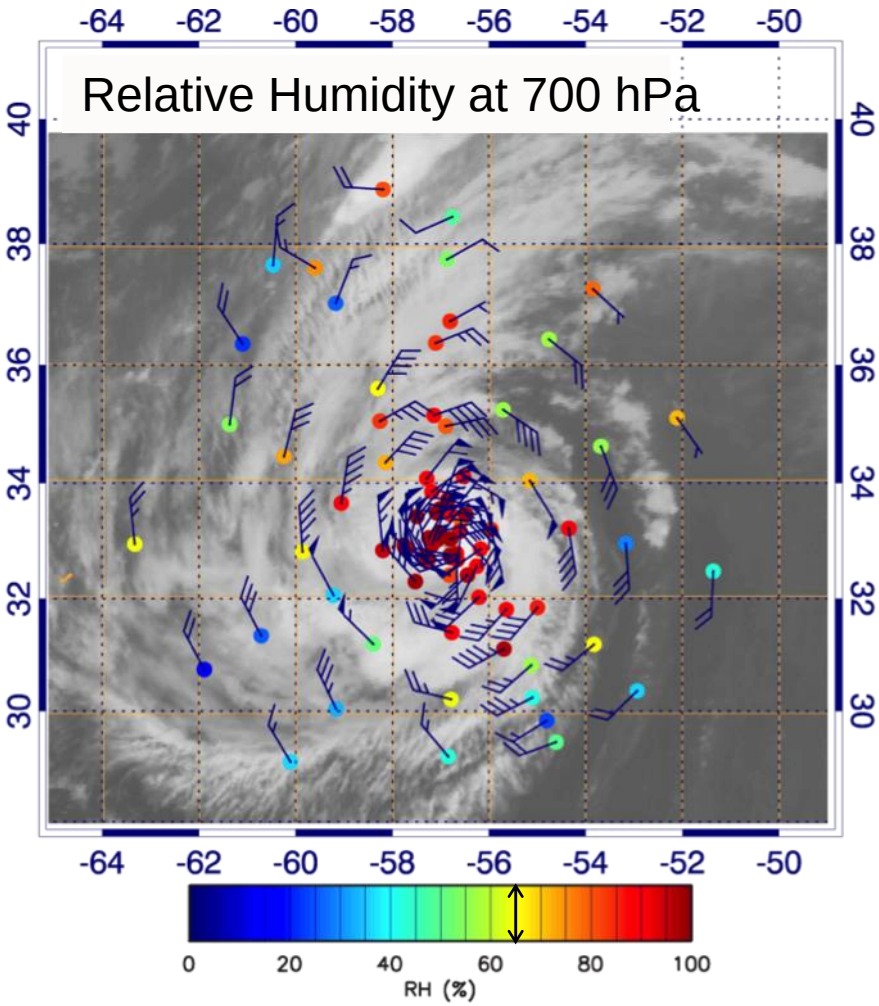
ESRL Data Analysis Team Update

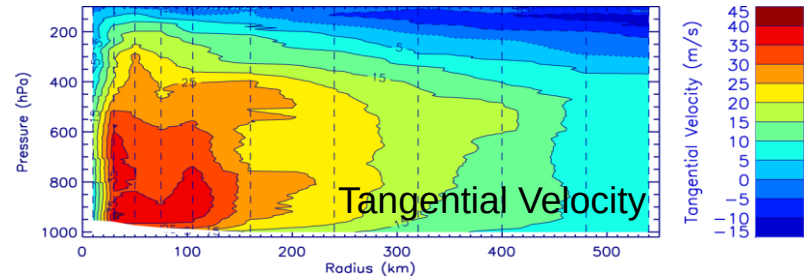
HRD Data Analysis Team Update

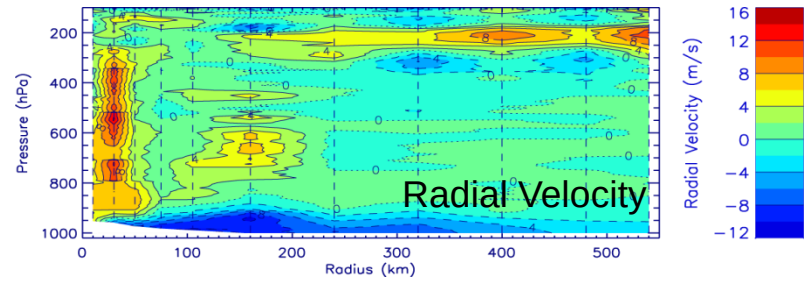
Feedback on Data Analysis?

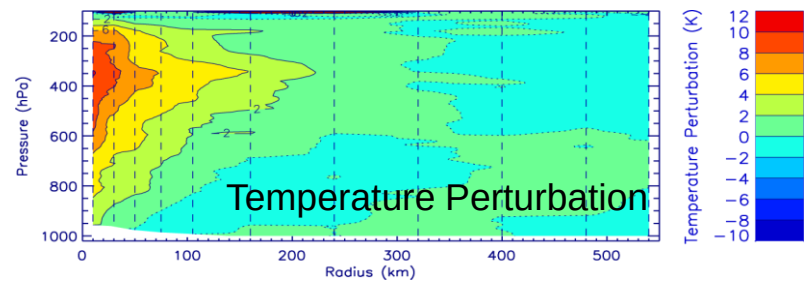
SHOUT FY15 Field Work

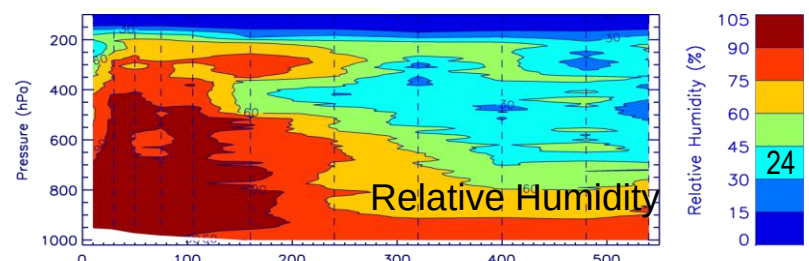
Mission Plans / CONOPS
Hurricane Edouard Sept 16-17







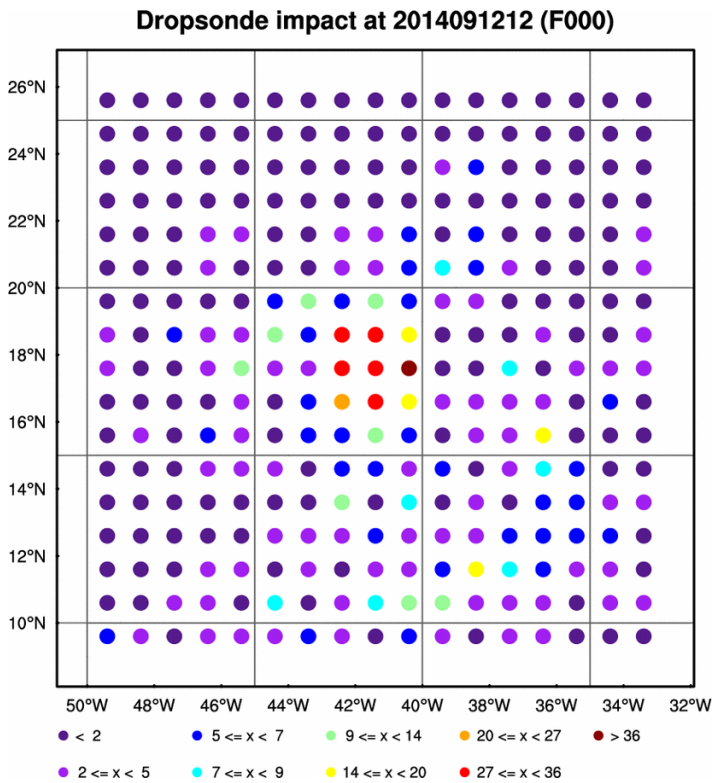


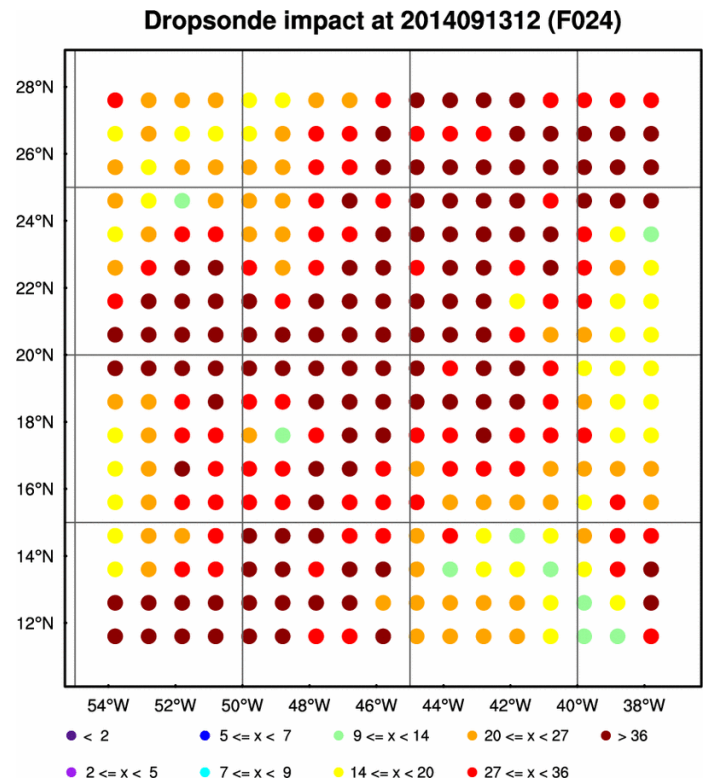


Mission Plans / CONOPS
Targeted Global Hawk GPS Dropsonde Observations

Dropsonde Observation Impact

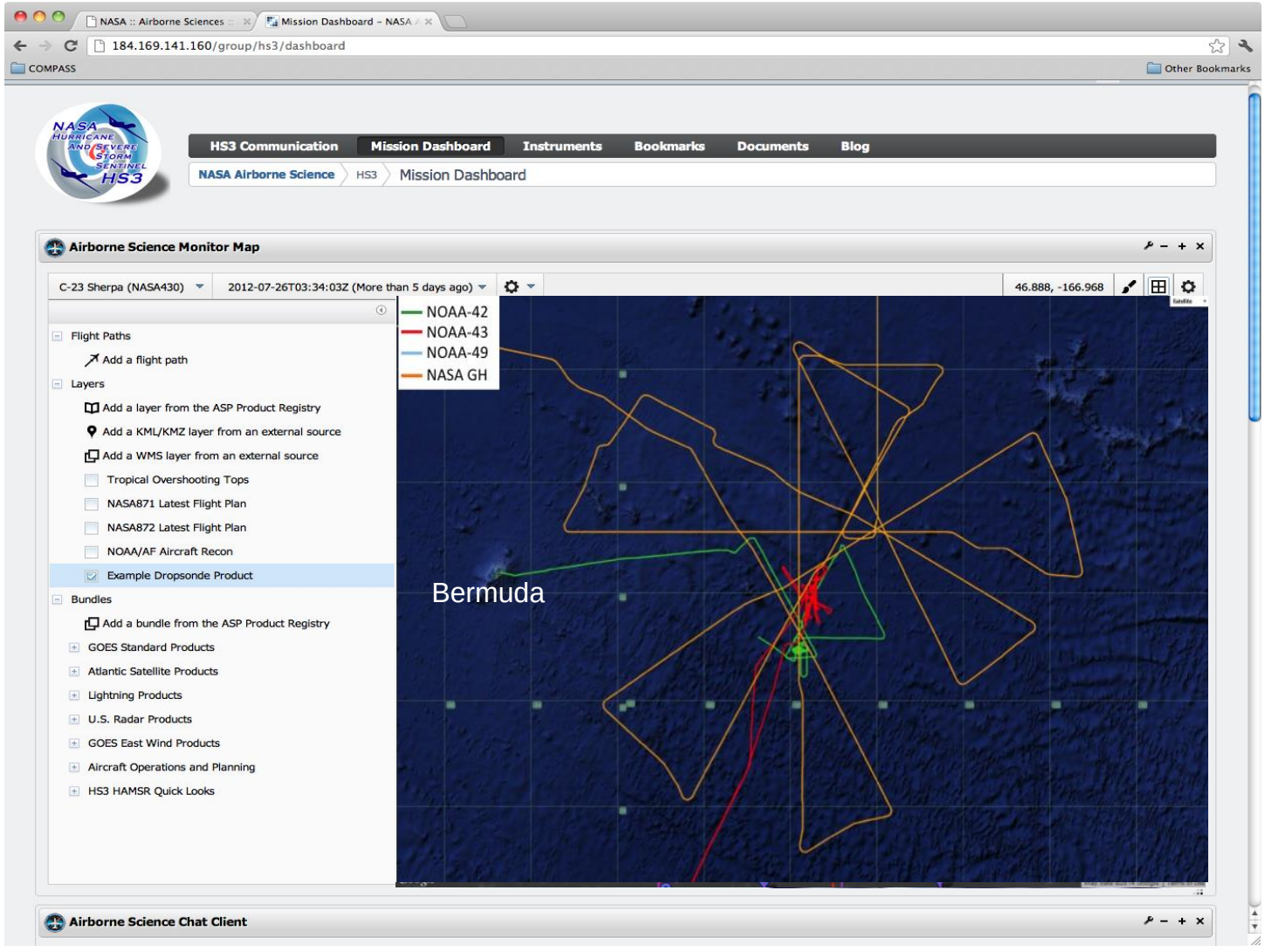
percentage reduction in forecast metric variance (max tangential wind) due to assimilating a dropsonde profile at that location





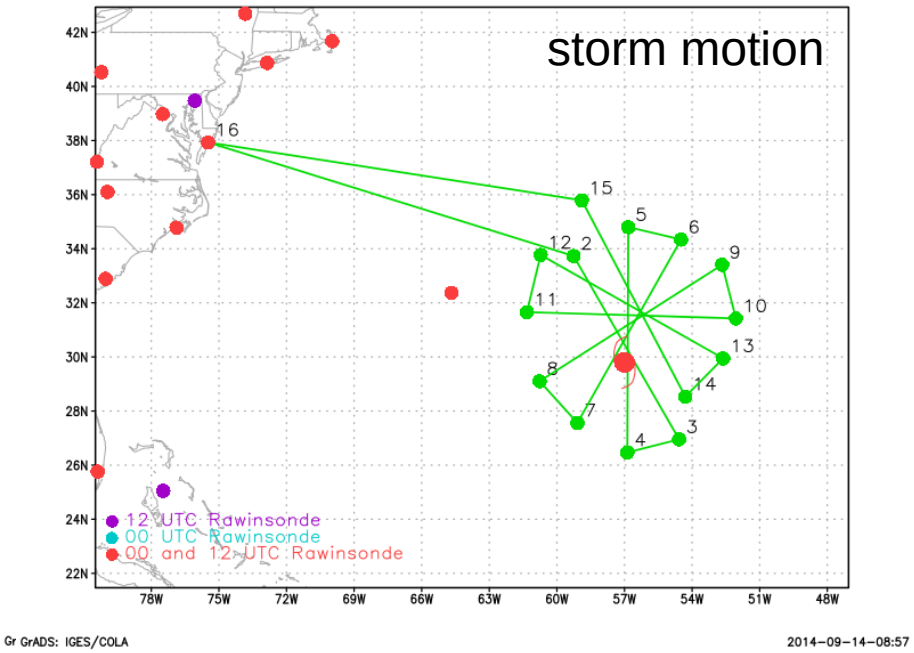
Mission Plans / CONOPS

NASA Mission Tool Suite



Mission Plans / CONOPS
Global Hawk Flight Tracks

- **HRD TKMAP Track Software: Hurricane Edouard 16 Sep 2014**



MISSION PLAN: EDOUARD

Prepared by the Hurricane Research Division File: current1.ftk

Aircraft: N52RF Proposed takeoff: 16/1100Z

TRACK DISTANCE TABLE

#	LAT (d m)	LON (d/m)	RAD/AZM (nm/dg)	LEG (nm)	TOTAL (nm)	TIME (h:mm)
1	WALLOPS			0.	0.	0:01
2S	33 44	59 15	243/330	829.	829.	2:30
3S	26 57	54 35	243/150	474.	1303.	3:56
4S	26 28	56 53	243/180	127.	1429.	4:20
5S	34 48	56 50	243/360	501.	1930.	5:51
6S	34 20	54 29	243/030	119.	2049.	6:13
7S	27 34	59 05	243/210	471.	2521.	7:38
8S	29 06	60 46	243/240	128.	2649.	8:02
9S	33 24	52 40	243/060	490.	3139.	9:31
10S	31 25	52 03	243/090	123.	3262.	9:54
11S	31 40	61 20	243/270	475.	3737.	11:20
12S	33 46	60 43	243/300	131.	3868.	11:45
13S	29 57	52 37	243/120	473.	4341.	13:10
14S	28 32	54 18	243/150	122.	4463.	13:33
15S	35 47	58 54	243/330	495.	4958.	15:03
16	WALLOPS			807.	5765.	17:45

Mission Plans / CONOPS

Inter-Agency Coordination (NOAA IFEX, ONR TCI)

NOAA IFEX

Operations: 01 June – 30 Nov

Aircraft: 1 P-3 Orion; G-IV jet

Goals: multi-faceted (TC track, intensity, structure)

ONR TCI

Operations: 01 July – 31 Oct

Aircraft: NASA WB-57

Goals: TC outflow layer & intensity change

Staffing Status

- **Mission science**
  - Team constructed, distributing funding
  - 6 – 7 members onsite throughout field phase
- **NASA ESPO support planned**
- **Instrument teams**
  - Funding distributed or in work
- **Offsite processing**
  - HRD team identified and funded
- **Pilots**
  - NASA scheduling
  - One shift flown from NASA Armstrong
- **Crew**
  - NOAA supplementing NASA staffing

Interagency Agreement Update (IAA)

- AFRC IAA for Global Hawk Support
  - 5 Year Agreement $5M ceiling cleared
  - First task order cleared ($1.5M)
  - Mod 1 for AFRC deployed operations to WFF in review ($0.58M)
- GSFC IAA
  - 5 year Agreement $2.5M ceiling in review
  - Task order 1 will cover:
    - WFF Field support ($0.125-0.150M)
    - Goddard Science Support ($62.8K)
    - HIWRAP ($0.245M)
- JPL National Space Technology Applications funding through NASA
  - TASK Plan & SOW due 7 Feb
  - HAMSR Support ($0.245M)
- LaRC IAA for HALE alternative analysis in review at NOAA
  - Task order 1($15.5K)

Grants Funded

2014

•CIRES -Simulation Experiments in support of the SHOUT Program ($744,512)

•CIRES -Data Management and Visualization ($235,987)

•CIRES - Mission Support and Analysis ($2,128,163)

•CIRA - NOAA's Observing System Experiments and Observing System Simulation Experiments ($435,107)

•CIRA - Data Management and Visualization ($587,646)

•CIMAS-Improve GH Sampling Strategies to improve TC track and intensity forecast ($1.25M)

2015

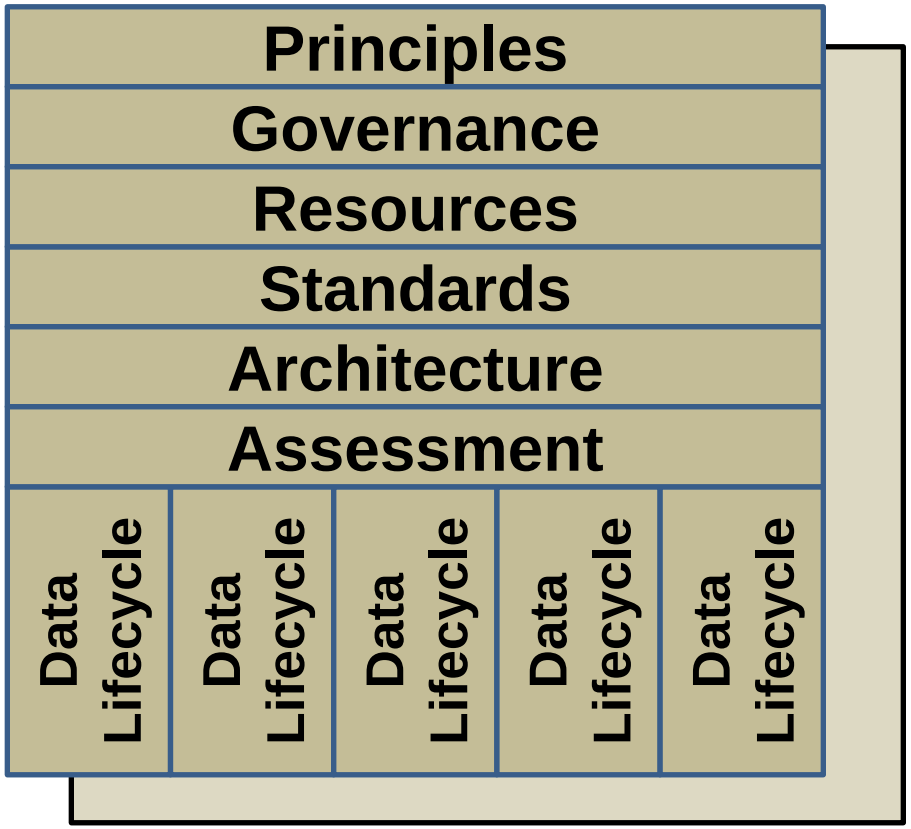
•CIMMS- Real Time Field Mission Science Support ($62.3K) PENDING

SHOUT Data Management Plan
&
Milestones, Metrics, MOSs

John “JC” Coffey
Darien Davis
John Walker

January 2015

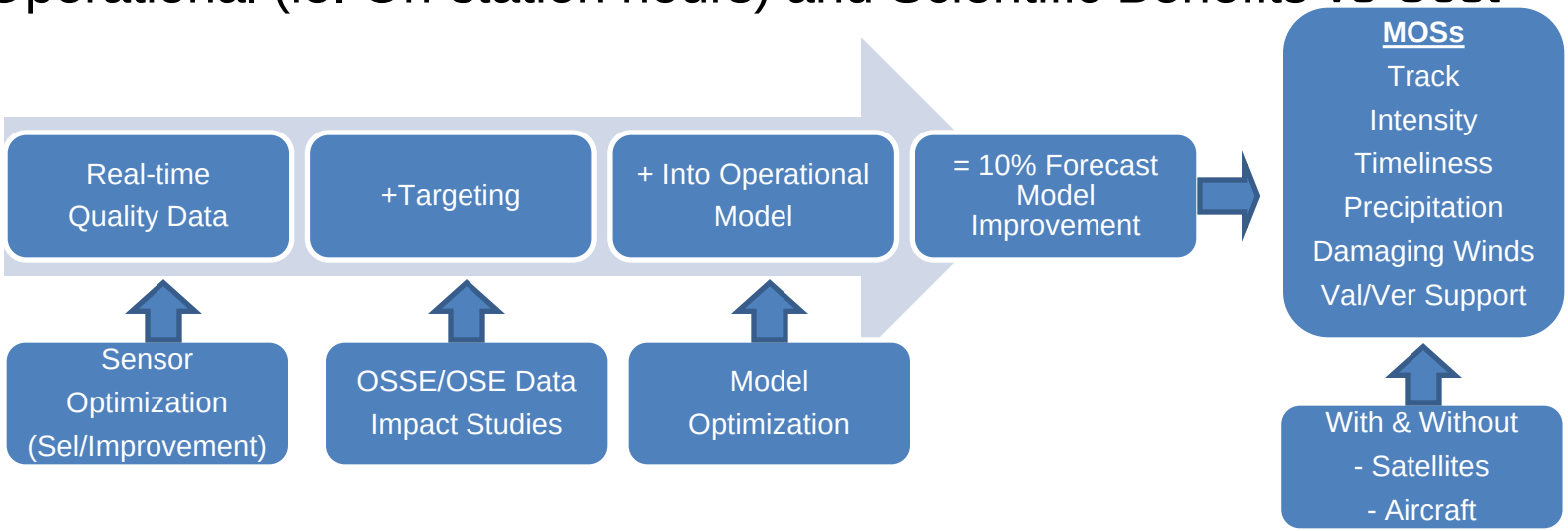
NOAA Environmental Data Management Framework



- Purpose: To organize, guide and support NOAA environmental data management activities.
- Mandate: Science Advisory Board (SAB) recommendation to NOAA.
- https://www.nosc.noaa.gov/EDMC/framework.php

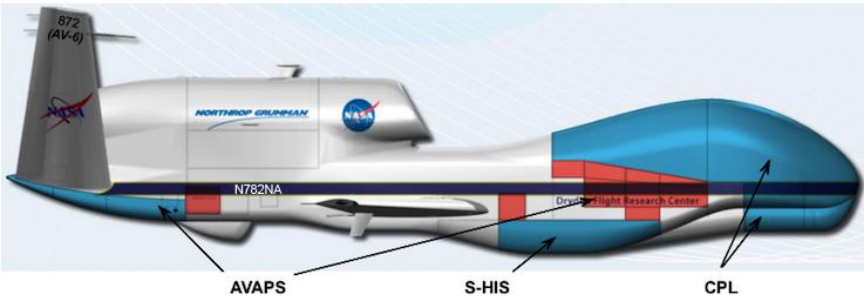
Operational Data Utilization & Optimization Plan

- Pursuing & nurturing close partnership with NCEP
- Dropsonde data transmitted in near real time past two seasons
- Evaluations of dropsonde data impact continues (OSSE/OSE)
- Transmission of priority data through GTS gateway and into the operational model technically feasible during HS3/SHOUT 2014
- Evaluate improvement of model with real-time targeted GH Data
- Operational (ie. On-station hours) and Scientific Benefits vs Cost



NOAA Benefit From NASA Hurricane Severe Storm Sentinel (HS3) in support of SHOUT

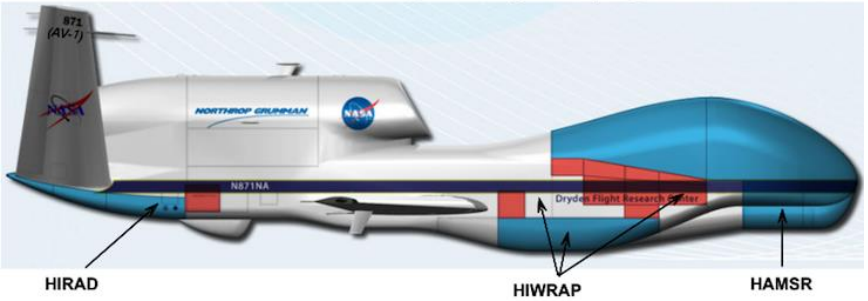
HS3 *Environmental Payload (AV-6) @ WFF '12*



Environment Observations

- **Profiles of temperature, humidity, wind, and pressure (AVAPS)**
- **Cloud top height (CPL)**
- **Cloud top temperature and profiles of temperature and humidity (S-HIS)**

HS3 *Over-Storm Payload (AV-1) @ WFF '12*



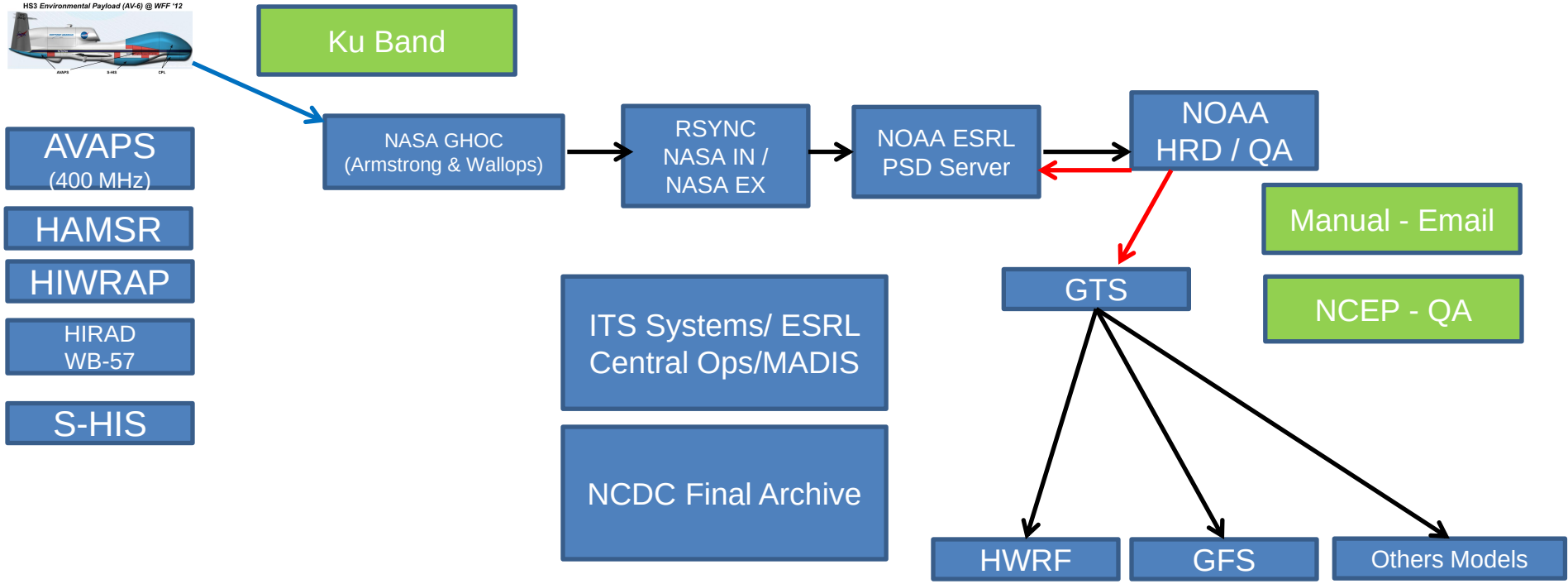
Over-storm Observations

- **Doppler velocity, horizontal winds, and ocean surface winds (HIWRAP)**
- **Profiles of temperature and humidity and total precipitable water (HAMSR)**
- **Ocean surface winds and rain (HIRAD)**

NASA HS3 Environment (AV6) Real-Time Products & Metrics

		Observation Requirement			Timeliness & Usage			Data Metrics			
Sensor/TRL	**Measurements**	**Horizontal Resolution**	**Vertical Resolution**	**Accuracy**	**OSSE/ OSE**	**Real-Time**	**Gateway**	**Models**	**Quality**	**Quantity**	**Archived**
CPL	Attenuating backscatter profiles	1-sec to 1-min Ku Dependent	30 m			YES					
	Cloud Top Height		NA			TBD					
SHIS	IR TB Spectra	2 km	NA			TBD					
	Cloud Top T	2 km	NA			TBD					
	Preliminary Temp Profiles	2 km	1-3 km			YES					
	Preliminary Humidity Profiles	2 km	1-3 km			YES					
TwiLite ?	Doppler Velocity	2 km	250 m			NO					
	Horizontal Winds	4-8 km	250 m			NO					
AVAPS Dropsonde 7/8	Temp Profiles	< 1 km	5-15 m	.5 K	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Humidity Profiles	< 1 km	5-15 m	5%	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Wind Profiles	< 1 km	5-15 m	.5 m/s / 10o	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Pressure Profiles	< 1 km	5-15 m	.1 hPa	YES	YES	GTS	HWRF	VAL	~222 Hrs	

SHOUT Data Flow



- The Optimized SHOUT Data Flow including removal of “sneaker-net” activities.
- No technical constraints for data flow into models.
- Requires socialization with NCEP for data acceptance.
- Real-time flight following at: http://airbornescience.nasa.gov/tracker/

Optimized SHOUT Payload (AV6) Real-Time Products & Metrics

		Observation Require/Cap			Timeliness & Usage				Data Metrics		
Sensor/TRL	**Measurements**	**Horizontal Resolution**	**Vertical Resolution**	**Accuracy**	**OSSE/ OSE**	**Real-Time**	**Gateway**	**Models**	**Quality**	**Quantity**	**Archived**
HAMSR 7/8	Temp Profile	2 km	1 km	.5o K		YES					
	Humidity Profile	2 km	2 km	15-20%		YES					
HIWRAP ? 7/8	Wind Speed	1 km	500 m	2 m/s		TBD					
	Wind Direction	1 km	500 m	15o		TBD					
	Surface Wind Speed	1 km	N/A	2 m/s		TBD					
	Surface Wind Direction	2 km	N/A	15o		TBD					
HIRAD ? 6/7	Surface Wind Speed	N/A	1-2 km	1-5 m/s		TBD					
	Surface Wind Direction	N/A	250 m	N/A		TBD					
AVAPS Dropsonde 7/8	Temp Profiles	< 1 km	5-15 m	.5 K	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Humidity Profiles	< 1 km	5-15 m	5%	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Wind Profiles	< 1 km	5-15 m	.5 m/s / 10o	YES	YES	GTS	HWRF	VAL	~222 Hrs	
	Pressure Profiles	< 1 km	5-15 m	.1 hPa	YES	YES	GTS	HWRF	VAL	~222 Hrs	

- The Optimized SHOUT Payload is being formalized.
- Joint WB-57 flights may enhance payload testing and data val/ver.

SHOUT 2015 Discussion Points

- **Comments on mission plan?**
- **Agreement on dropsonde procurement**
- **Further actions to enable operational data assimilation**

SHOUT FY16/17 Discussion

FY16 Wishlist

- **Potential Deployments**
  - **Arctic/Alaska High Impact Weather Oct-Nov 2015**
  - **Pacific Winter Storm Jan-Mar 2016**

- **Objectives**
  - **Forecast improvement for threats such as extreme precipitation and damaging winds**
  - **Targeted lead times of 3-7 days**

- **Ideally desire OSSE guidance on priorities**

- **Proposed NASA Earth Venture collaborations not funded**

Next Steps – High Impact Weather

Oceanic Storms

- Vertical meteorological profiles observations with HALE
- Low altitude meteorological observations with SMUV and ACL

Floods

- Aerial surveys with medium altitude UAS
- Low altitude aerial surveys and digital elevation mapping with small UASL

Continental Storms

- Storm damage surveys with medium and low altitude UAS
- Low altitude UAS meteorological observations

Fire Weather

- Localized meteorological observations with expendable small UAS

Air Quality

- Vertical air chemistry profiles with balloon-launched UAS
- In situ air chemistry observations with small UAS

NWS & NESDIS Needs

- NWS replacements for Alaska radiosondes
- GOES-R calibration/ validation work with small UAS

Open Discussion

- **Other topics?**
- **Next meeting**

Back Up

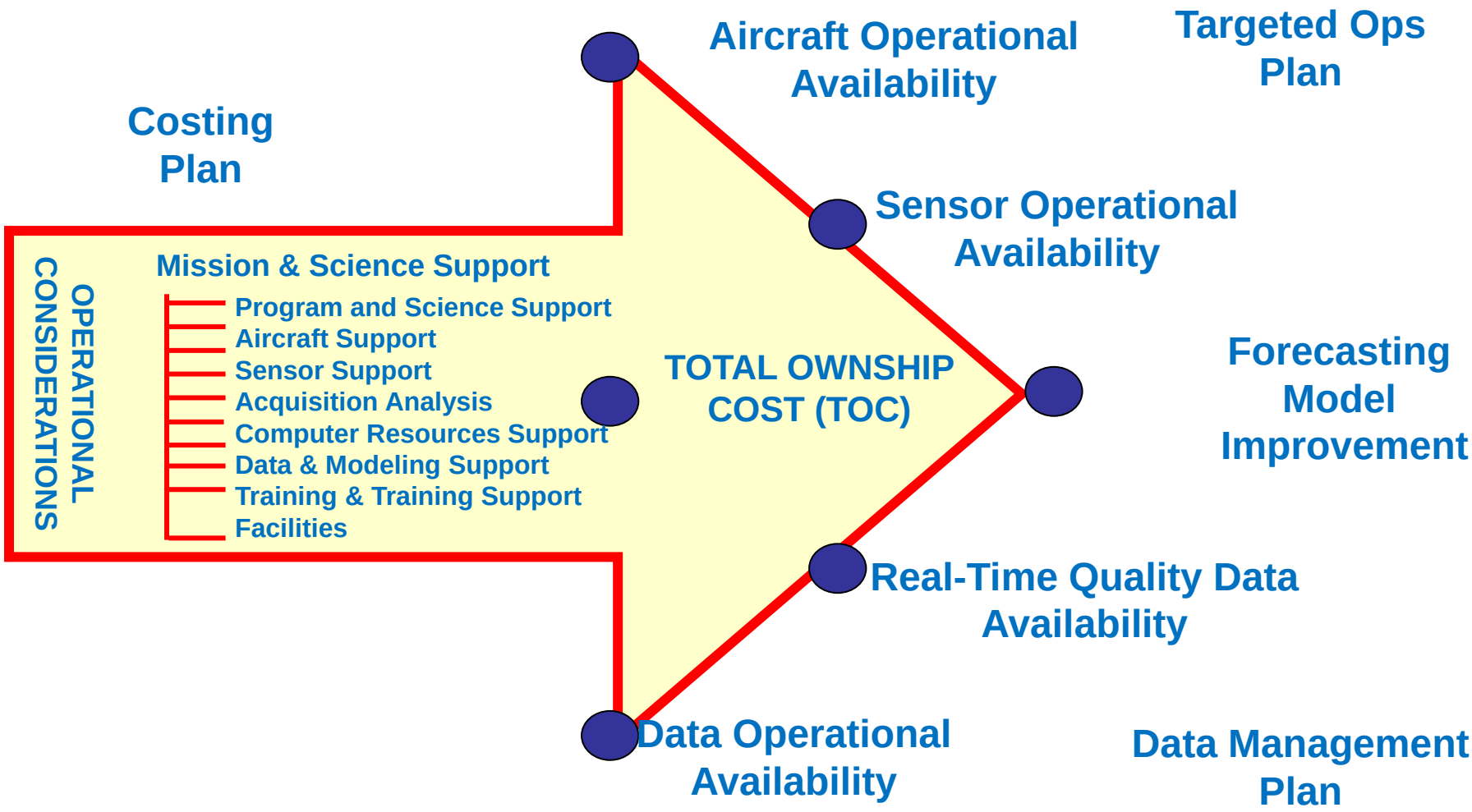
Current Schedule

Data Management Team

Task/Task Lead	Milestone	Deliverable
Develop data lifecycle management plan. (Coffey)	02/28/2015	SHOUT Data Lifecycle plan for UAS instrumentation packages.
Evaluate existing visualization tools. (Stewart)	03/31/2015	Recommendations for which tool to use for each visualization 'realm'.
Develop recommendations for system architecture and implementation plan for UAS data visualization for each 'realm'. (Stewart)	06/30/2015	System architecture and implementation plan for visualization of each 'realm'.
Develop recommendations for UAS data visualization for operational NWS forecasters. (Stewart)	06/30/2015	UAS data visualization system architecture and implementation plan for NWS forecasters.
Develop data discovery and accessibility architecture and implementation plan. (Benjamin & Pratt)	06/30/2015	Plan for data discovery and accessibility architecture for UAS instrumentation package data.
Implementation and delivery of initial data lifecycle management for one UAS instrumentation package. (Wick, Benjamin & Pratt)	06/30/2015	One UAS instrumentation package data set ingested, available for integration, available for visualization, discoverable, and archived for all SHOUT flights.
Initial proof of concept visualization development for one UAS instrumentation package. (Wick & Stewart)	06/30/2015	Proof of concept display reading data from UAS data lifecycle implementation.

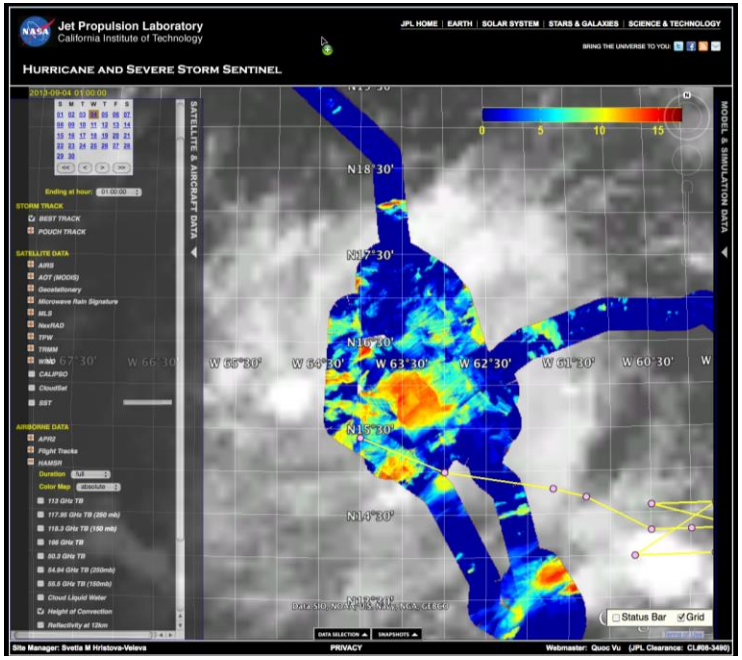
Mission Metrics & MOSs

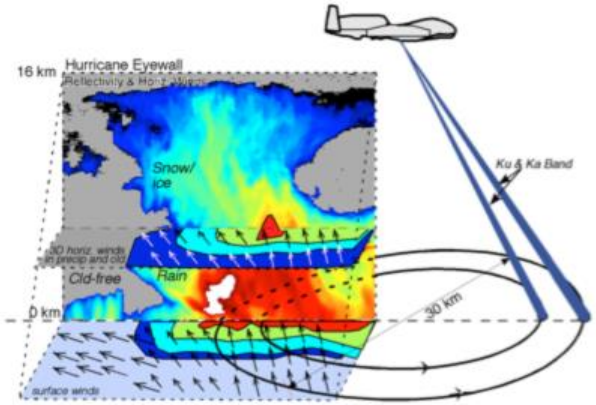
Operational & Scientific Benefits vs Cost



SHOUT 2015 Instruments

- **AVAPS**
  - High-resolution profiles of temperature, humidity and winds
  - Decision required on sonde number (900 currently planned)
- **HAMSR**
  - Passive microwave, AMSU-like sounder
  - Temperature and humidity at ~2 km spatial resolution, 2-4 km vertical resolution
- **HIWRAP**
  - Dual-band Doppler precipitation radar
  - Reflectivity and horizontal winds at 1 km, 500 m resolution

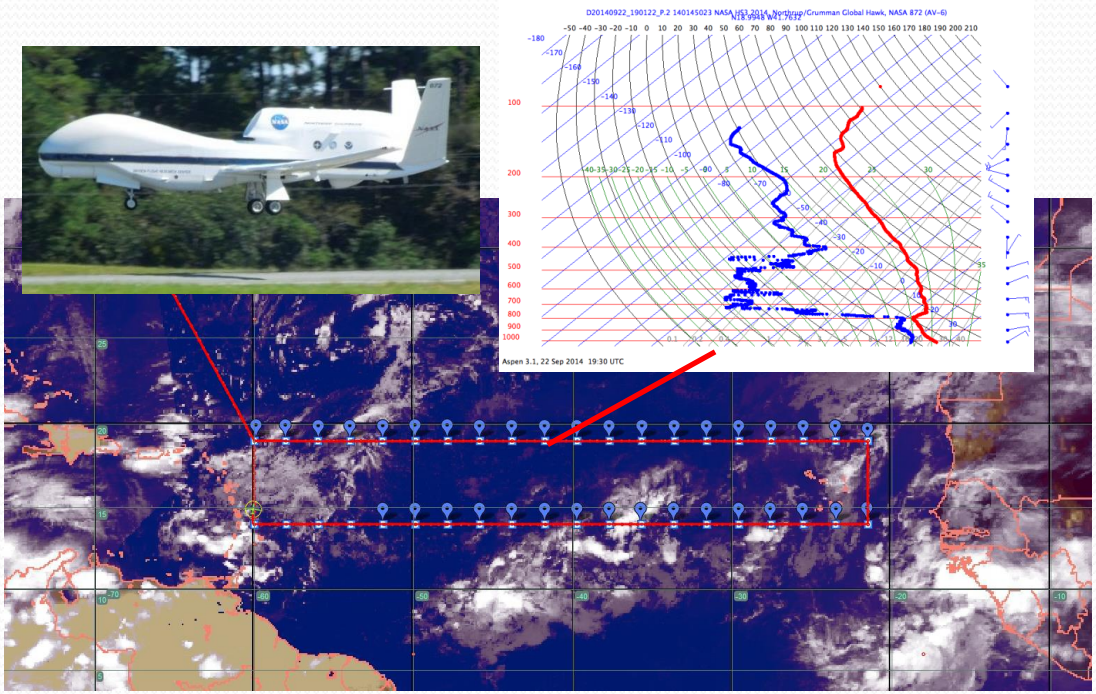




NOAA-led Global Hawk Sampling in SHOUT 2014

Hurricane Main Development Region (MDR) sampled by NASA Global Hawk on September 22-3 and 28-9 during 2014 HS3/SHOUT campaign

- First systematic sampling of MDR since 1974
- 105 dropsondes deployed and data transmitted to NWS gateway during two 24+ hour missions
- Additional measurements from University of Wisconsin infrared sounder and NASA Cloud Physics Lidar

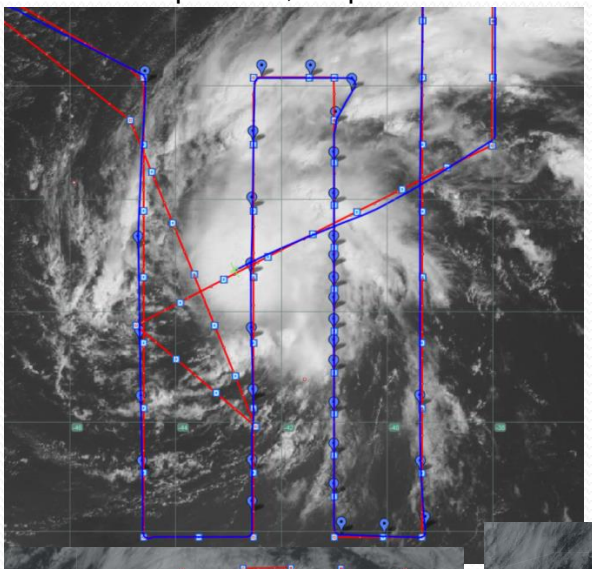


- Enables evaluation of numerical models' representation of tropical atmosphere in region with only satellite observations
- Facilitates comparison with satellite-derived retrievals
- Data to be employed in data-denial studies to determine impact of Global Hawk data on forecasts of the environment in the Atlantic tropical basin
- Complement to other mission flights directly sampling hurricanes and tropical storms

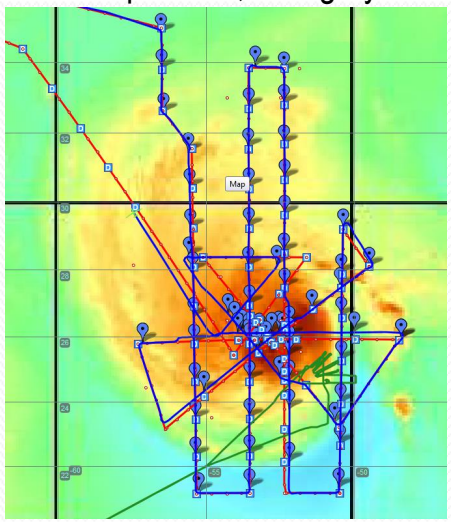
Global Hawk Sampling of Edouard

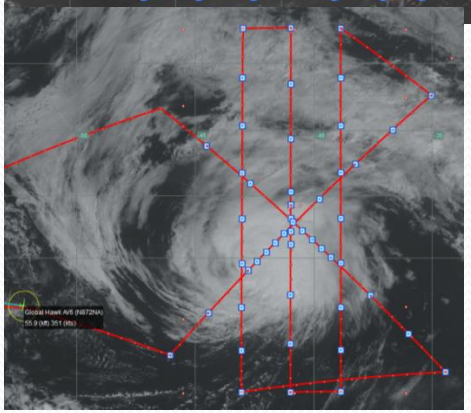
Four flights sampled the complete life cycle of Edouard from tropical storm, to category 1 hurricane, to category 3 hurricane, and to decay into extra-tropical storm

11 September, Tropical Storm

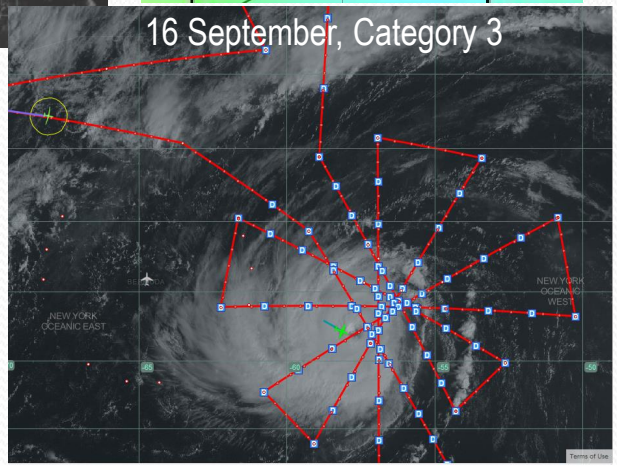


14 September, Category 1





18 September, Decay



- 282 total dropsondes deployed during more than 58 hours around storm
- 16 September flight plan designed and coordinated by NOAA scientists
- Multiple drops into eye and eye wall from Global Hawk altitude
- Key data suggesting rapid intensification on 15 September
- Novel observations documenting storm decay over colder waters
- Data processed in real time, transmitted to NWS gateway, and assimilated in operational WRF model
- Observations will facilitate several forecast impact studies with multiple numerical models