Hurricane Research at NOAA

Frank Marks
Vision

Advance understanding & prediction of tropical cyclone (TC) track, intensity, & structure change & their impacts utilizing observations, numerical models, & theory

NOAA’s hurricane research focus for >65 years
Current State of the Art
Operational Forecast Performance

NHC Official Average Track Errors
Atlantic Basin Tropical Storms and Hurricanes

NHC Official Average Intensity Errors
Atlantic Basin Tropical Storms and Hurricanes

Courtesy John Cangialosi & James Franklin (NWS/NHC)
How?

Understanding & Prediction of TCs

Observations

Analysis systems

Modeling

Evaluation

Initialization

Impacts

How?
Hurricane Forecast Improvement Program

- Unified approach to guide & accelerate forecast improvements since 2008
  - improve prediction of rapid intensification & track
  - improve forecasts & communication of storm hazards
  - incorporate risk communication research to create more effective products

http://www.hfip.org
Challenge: Hurricane Intensity Forecasting

Multiscale nature of processes are major reason for this difficulty

- Characterizing & understanding these processes & their interactions are key steps in forecast improvement
- Airborne observations provide a unique opportunity to study these processes across scales

Courtesy Robert Rogers (AOML/HRD)
NOAA Intensity Forecast Experiment

- Collect observations over tropical cyclone’s life cycle
- Develop measurement technologies to provide improved situation awareness
- Improve understanding of processes important in intensity change

https://www.aoml.noaa.gov/our-research/hurricane-research-division/hurricane-field-program/
NOAA Hurricane Hunters

https://www.omao.noaa.gov/learn/aircraft-operations
Major Research Areas

Characterize, Understand, & Predict Processes Important to TC Evolution - IFEX

https://www.aoml.noaa.gov/2021-hurricane-field-program-data/

https://www.aoml.noaa.gov/dynamics-and-physics/
2021 Atlantic Hurricane Season

by the numbers

21 Named Storms
Average is 14
Ana Bill Claudette Danny Elsa Fred Grace Henri Ida Kate Julian

7 Hurricanes
Average is 7
Larry Mindy Nicholas Odette Peter Rose Sam Teresa Victor Wanda

4 Major Hurricanes
Average is 3

8 Storms made U.S. landfall

NOAA Hurricane Hunters

467 P-3 & G-IV flight hours

52 Operational (39) & research (13) missions

146 Tail Doppler radar analyses transmitted

Aircraft-Deployed Instruments

1324 GPS dropsondes

131 Airborne eXpendable BathyThermographs (AXBTS)

8 ALAMO Floats (AOML/PhOD & Navy)

https://www.aoml.noaa.gov/2021-hurricane-field-program-data/
Major Research Areas

Improve representation of TC structure

TDR data combined with satellite-detected lightning in **AWIPS-II** during Hurricane **Lane (2018)** flights

TDR-derived winds from sequence of passes in Hurricane **Delta (2020)** while rapidly intensifying

Courtesy Robert Rogers (AOML/HRD)
Major Research Areas

Optimize use of Observations to Improve Analysis & Forecasts

Hurricane Elsa 5 July 2021

https://www.aoml.noaa.gov/our-research/qosap-program/

https://www.emc.ncep.noaa.gov/gc_wmb/vxt/HATCF/

Courtesy Zhan Zhang (NWS/EMC)
Major Research Areas

Advance Hurricane Forecast Guidance: HWRF -> HAFS

Hurricane Sam (18L) 00 UTC 26 September 2021

HWRF 72 h

HAFS-B 72 h

HAFS: Moving Nests in Global FV3

https://www.aoml.noaa.gov/hurricane-modeling-prediction/
https://storm.aoml.noaa.gov/basin/?projectName=BASIN
https://www.emc.ncep.noaa.gov/HAFS/HAFSv0p2a/index.php
https://hfip.org/hafs

Courtesy Bill Ramstrom (AOML/HRD)
Major Research Areas

**Improve understanding of intensity change**

- Characterizing Inner-core Structure & Intensity Change
- Intensity Change in Vertical Wind Shear
- Boundary Layer Processes & Air-sea Interactions
- Secondary Eyewall Formation & Replacement Cycles
- Genesis & Development of weak systems

- Most recent research focused on structures associated with intensity change processes
- Research used tail Doppler radar & GPS dropsonde data
- Both composite (multi-case) & case study frameworks
  - Composites provide robustness
  - Case studies can provide temporal evolution

- Low-level center repositioned underneath midlevel center over ~3 h period
- Repositioning consistent with low-level stretching in deep, moderate convection around midlevel center

Courtesy Robert Rogers (AOML/HRD)
Major Research Areas

Characterize, Understand, & Predict Processes Important to TC Landfall Impacts

Hurricane Ida 29 August 2021

DOW Data

Tower Data

https://www.weather.gov/sti/coastalact_elements

Courtesy Forrest Masters (UF), Mike Biggerstaff (OU) & Digital Hurricane Consortium
Emerging Research Areas

Optimize use of upper ocean & air-sea interface observations to improve analysis, forecasts & understanding

Buoys 41044 Measurements for Hurricane Sam
Time of Observation Highlighted | Buoy 41044 2021-09-30 06:02Z | GOES East Band13 enhanced time: 06:02Z

Hurricane Sam
30 September 2021

https://aoml1.geocollaborate.com/follow/index.html

https://www.youtube.com/watch?v=uQM_03zuSAI

Courtesy Dave Jones (StormCenter)

Courtesy Greg Foltz (AOML/PhOD) & Saildrone
Emerging Research Areas

Optimize use of Satellite Observations to Improve Analysis & Forecasts
Emerging Research Areas

Address Hurricane Forecast Guidance Uncertainty: Ensembles

Hurricane Sam 00 UTC 26 September 2021

Courtesy Zhan Zhang (NWS/EMC)

https://www.emc.ncep.noaa.gov/HAFS/HAFSEPS/tcall.php
Emerging Research Areas

Address Hurricane Forecast Guidance Uncertainty: Machine learning models

CNN architecture

Random Forest Architecture

Basic concept of SVM

Courtesy Mu-Chieh Ko (AOML/HRD)
Emerging Research Areas

Improve forecast communication of hazards: Link SBES & Physical Science

Forecasting A Continuum of Environmental Threats (FACETs)

https://wpo.noaa.gov/Programs/FACETs
https://sites.google.com/a/noaa.gov/tropical-roadmap/home?authuser=0

Courtesy Jessica Schauer (NWS)
Questions?

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http://www.hfip.org
https://noaahrd.wordpress.com/
https://www.aoml.noaa.gov/hurricane-research-division/
REDDIT AMA
Hurricanes FAQ