

What We Learned from the 2019 Atlantic Hurricane Season

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Karthik Ramanathan, Ph.D.

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Meet Today's Presenters



Peter Sousounis, Ph.D.

VP and Director of Climate Change Research



Karthik Ramanathan, Ph.D.

AVP and Principal Engineer

Today's Agenda

Season Overview and Climate Signals

Hurricane Dorian

- Meteorology Insights
- Event Modeling and Ground Truthing

Climate Change Impacts

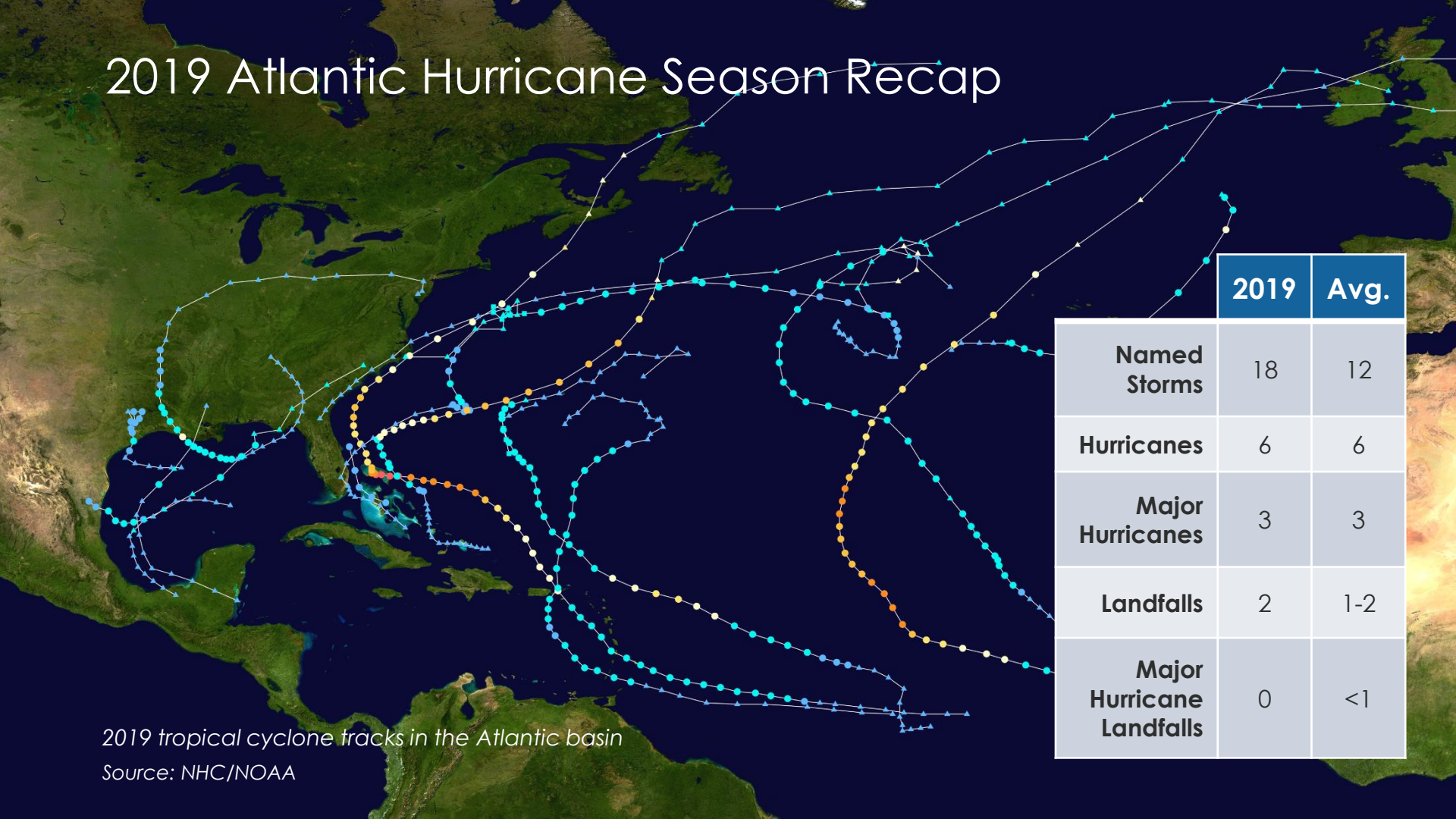
Hurricane-Induced Flood Modeling

Hurricane Contest Results

Q&A

Season Overview and Climate Signals

2019 Atlantic Hurricane Season Recap

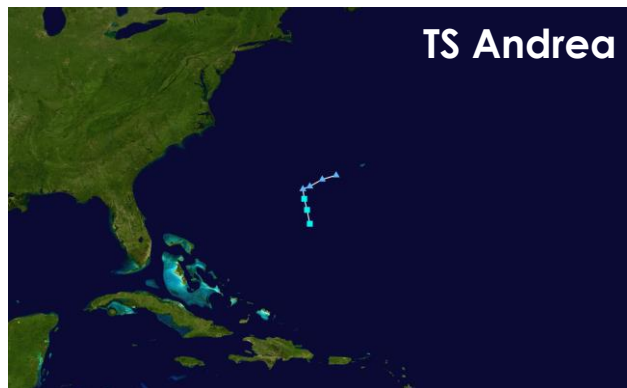


2019 tropical cyclone tracks in the Atlantic basin

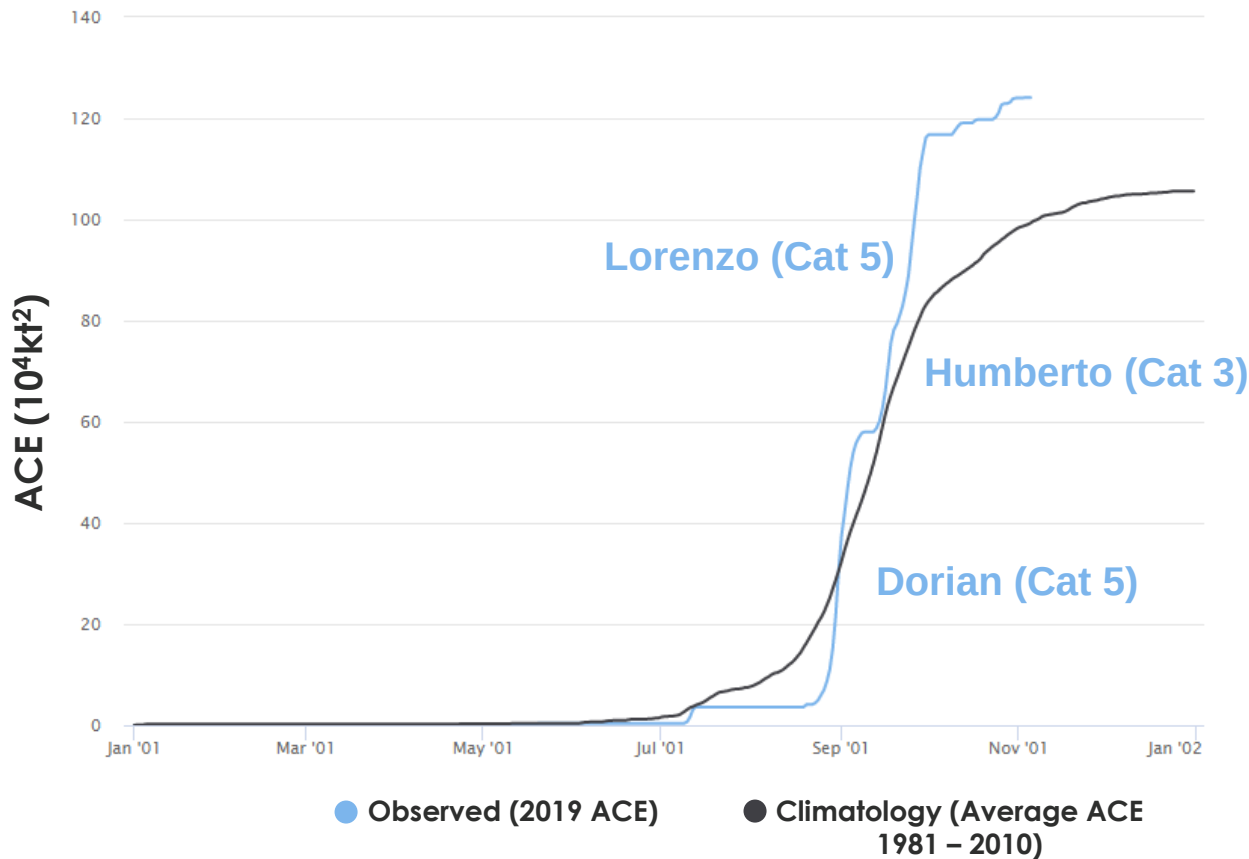
Source: NHC/NOAA

	2019	Avg.
Named Storms	18	12
Hurricanes	6	6
Major Hurricanes	3	3
Landfalls	2	1-2
Major Hurricane Landfalls	0	<1

Noteworthy Storms of 2019



Accumulated Cyclone Energy (ACE): Above Normal Once Again



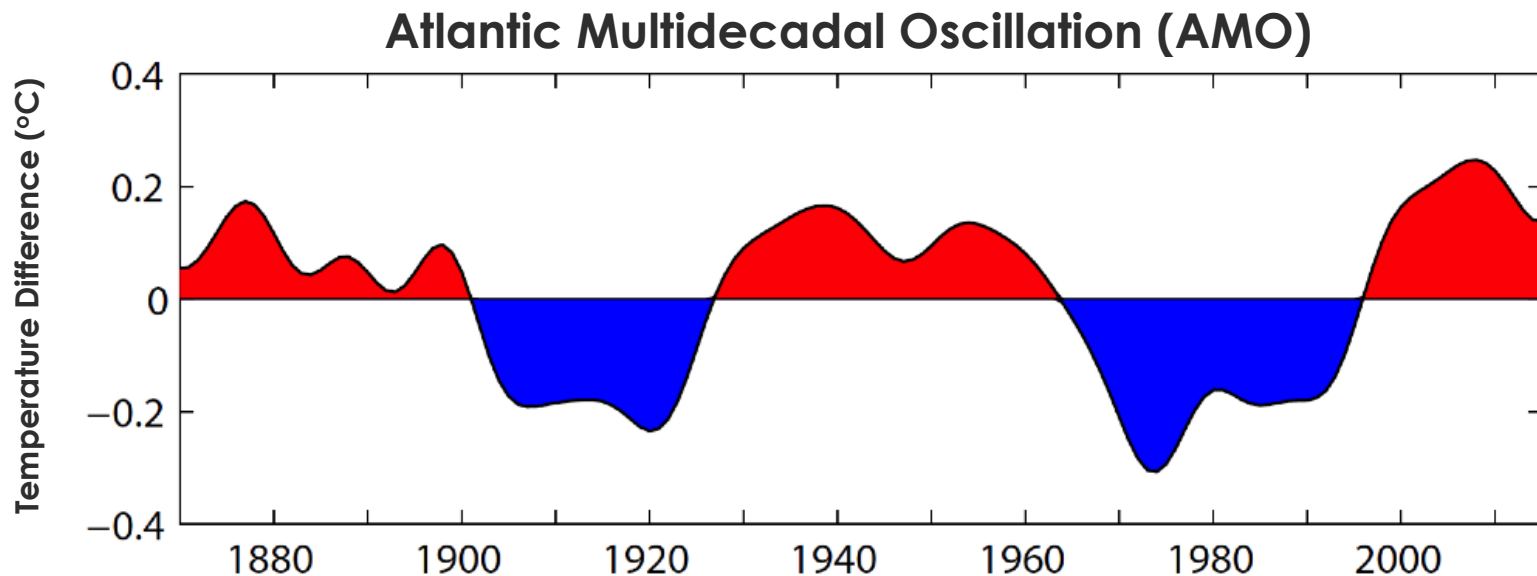
Early Season Forecasts Were Actually More Accurate

- Early season forecasts were for average activity
- August updates maintained status quo
- Season ended slightly above average

Forecaster		May	August	Actual
TSR		12/6/2/88	13/6/2/100	18/6/3/130
CSU		14/6/2/100	14/7/2/105	
NOAA		12/6/3/111	13.5/7/3/135	

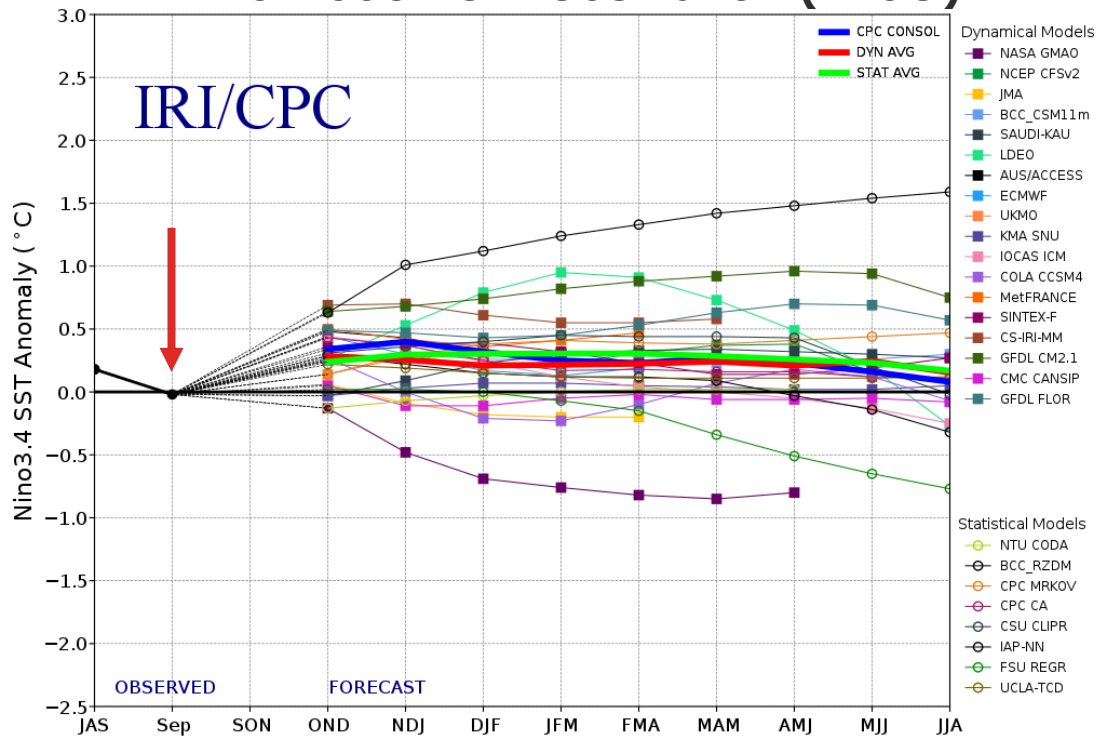
Named storms/Hurricanes/Major Hurricanes/ACE

Climate Influences

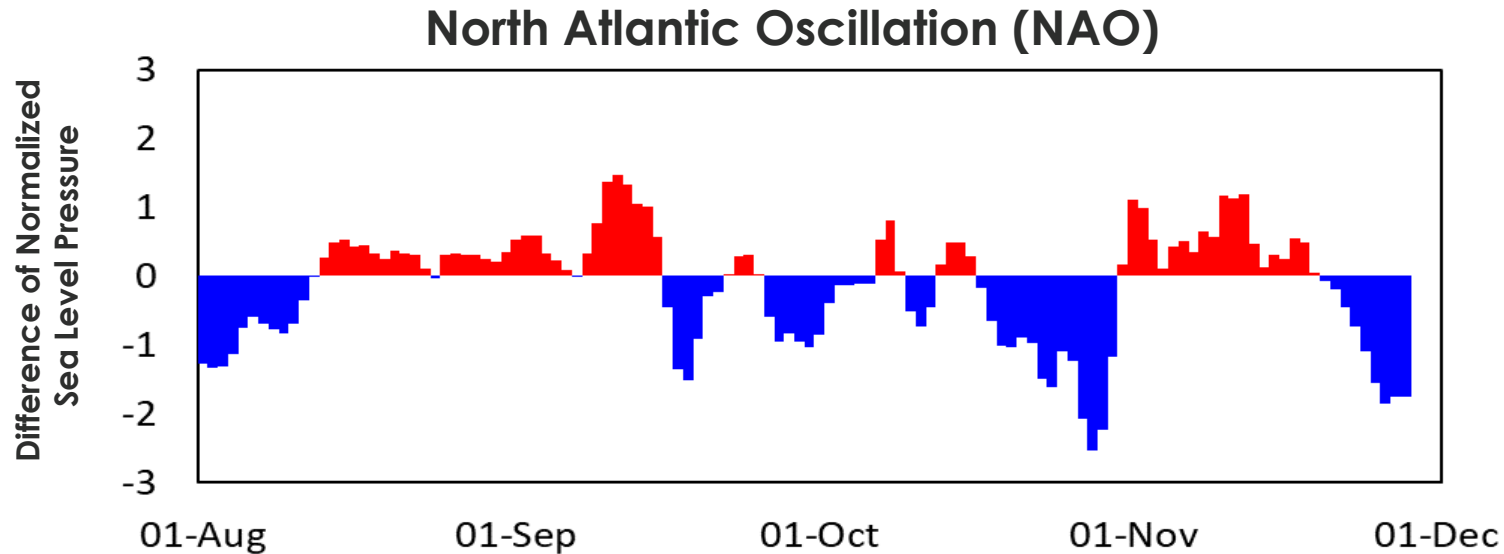


Climate Influences

El Niño – Southern Oscillation (ENSO)

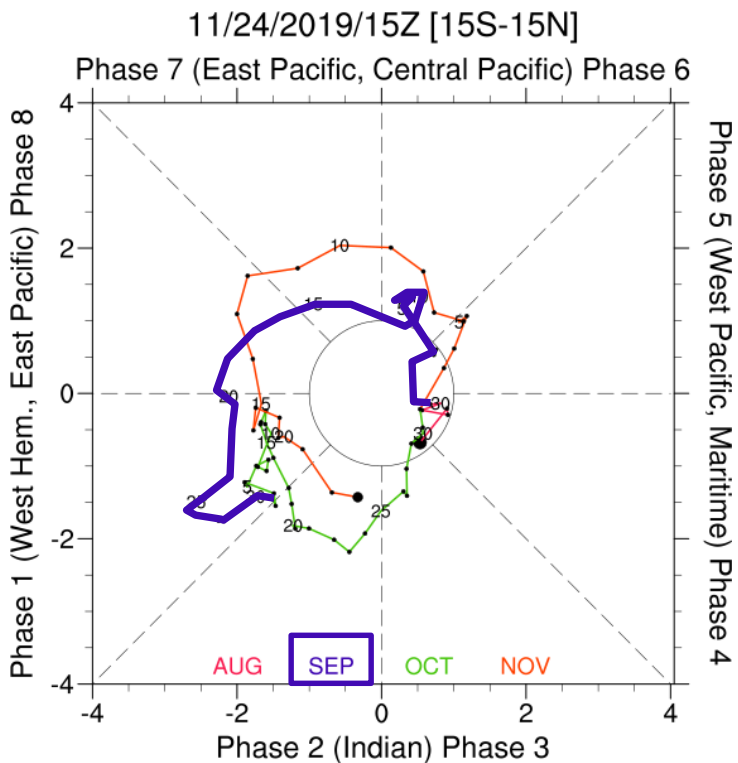


Climate Influences



Climate Influences

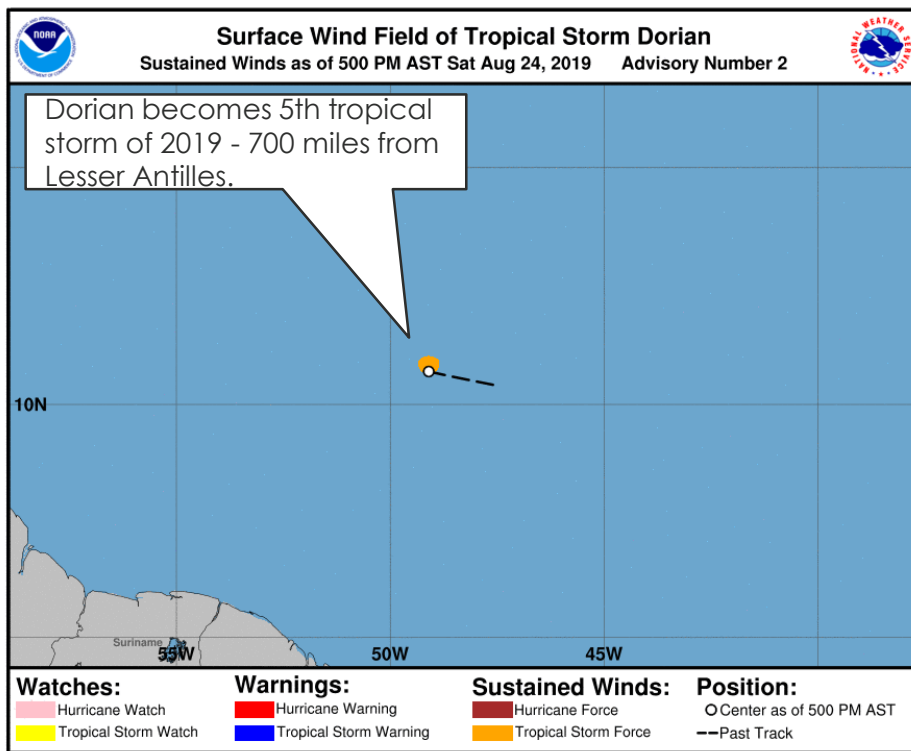
Madden Julian Oscillation (MJO)



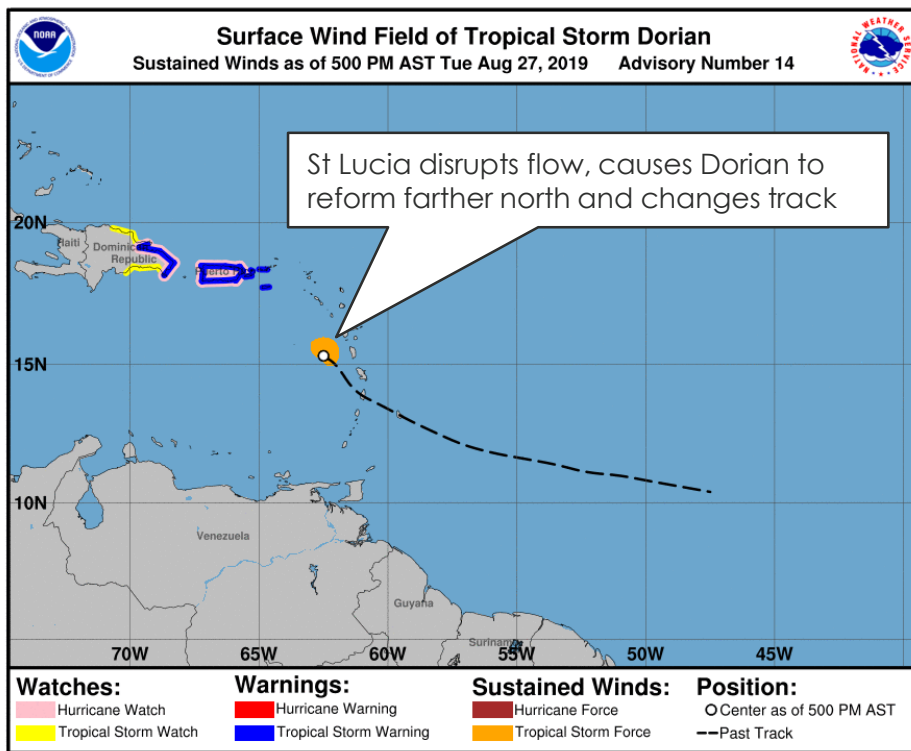
Hurricane Dorian

Meteorology Insights

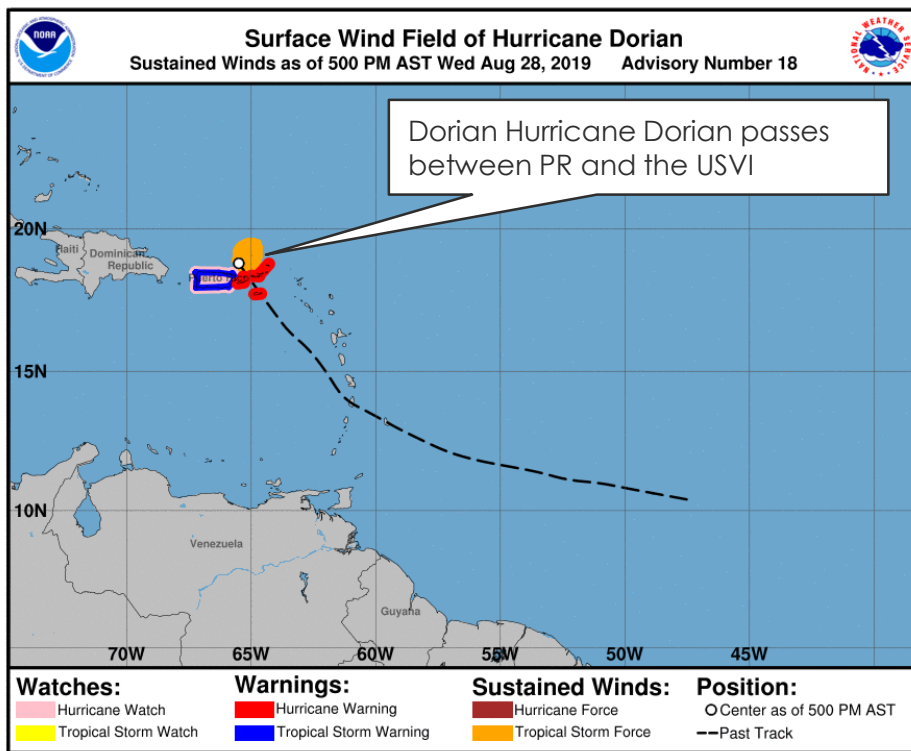
Dorian's Trek Across the Atlantic



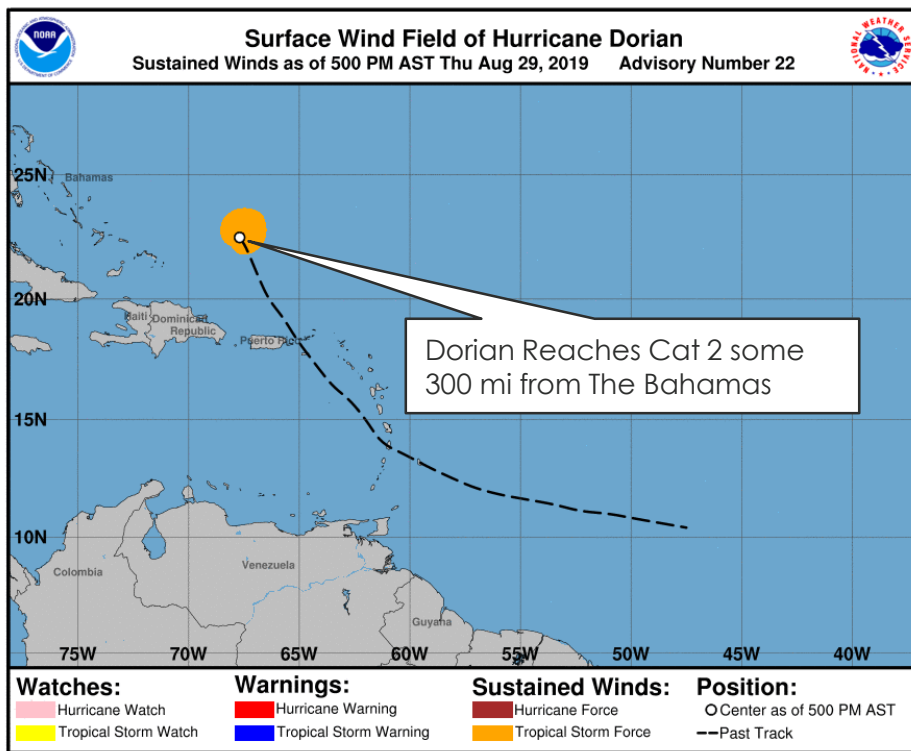
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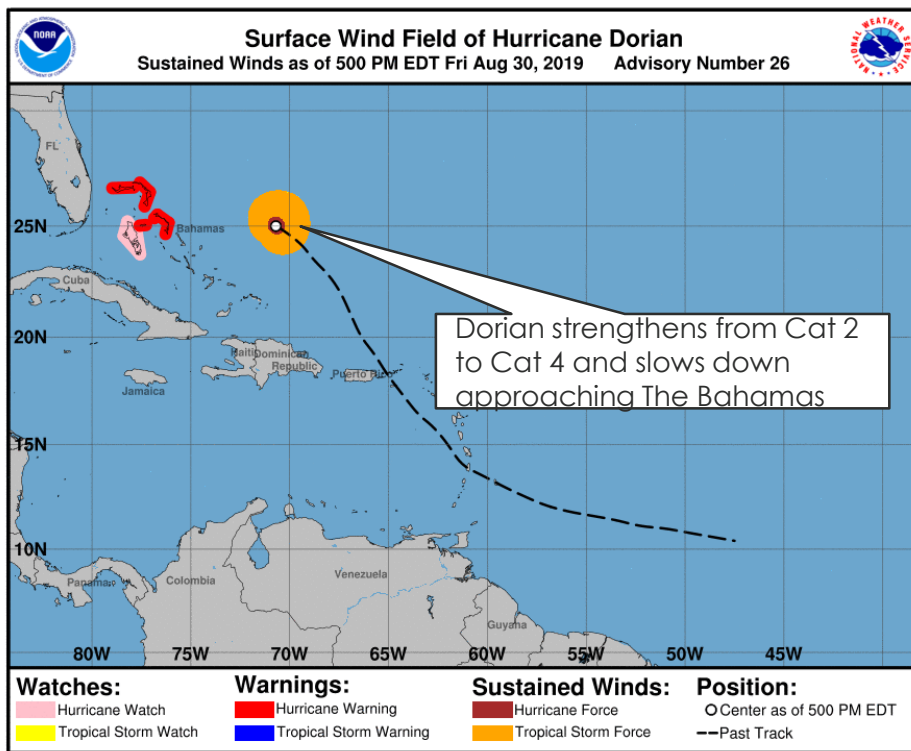
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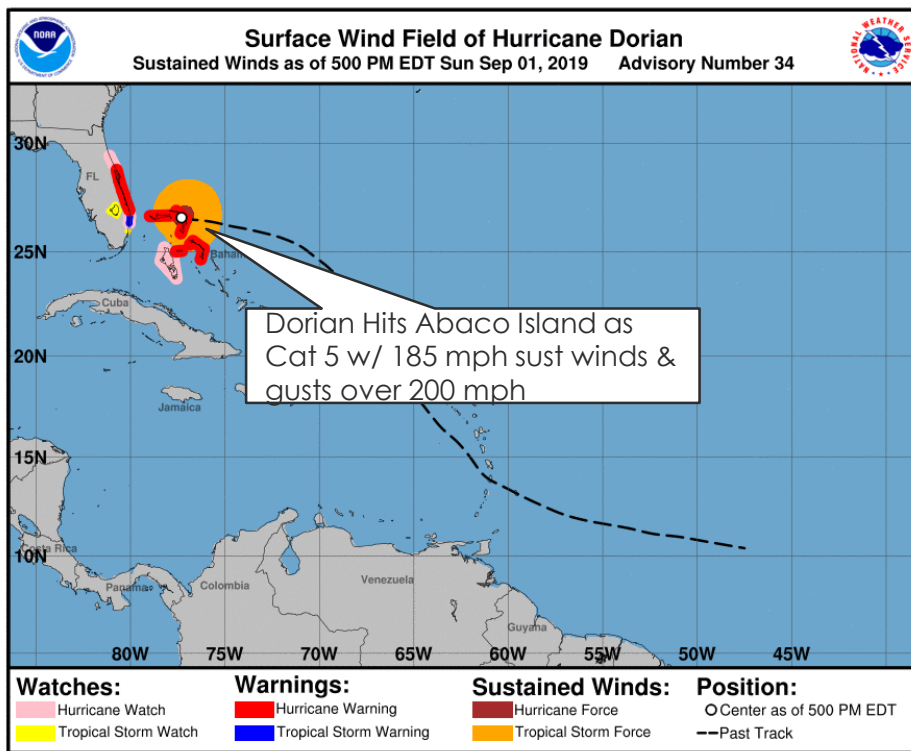
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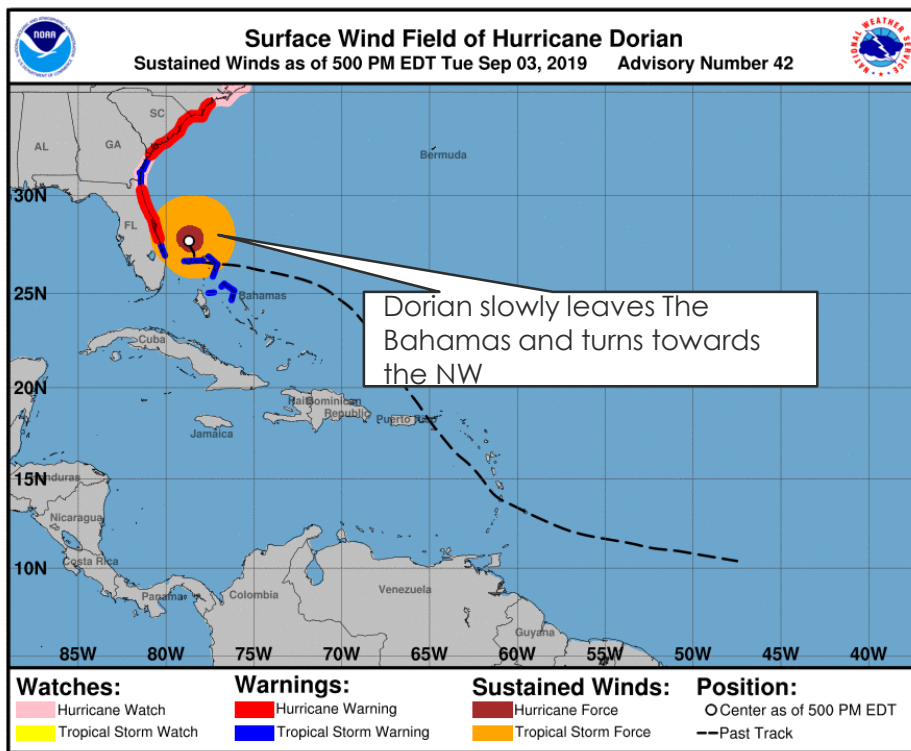
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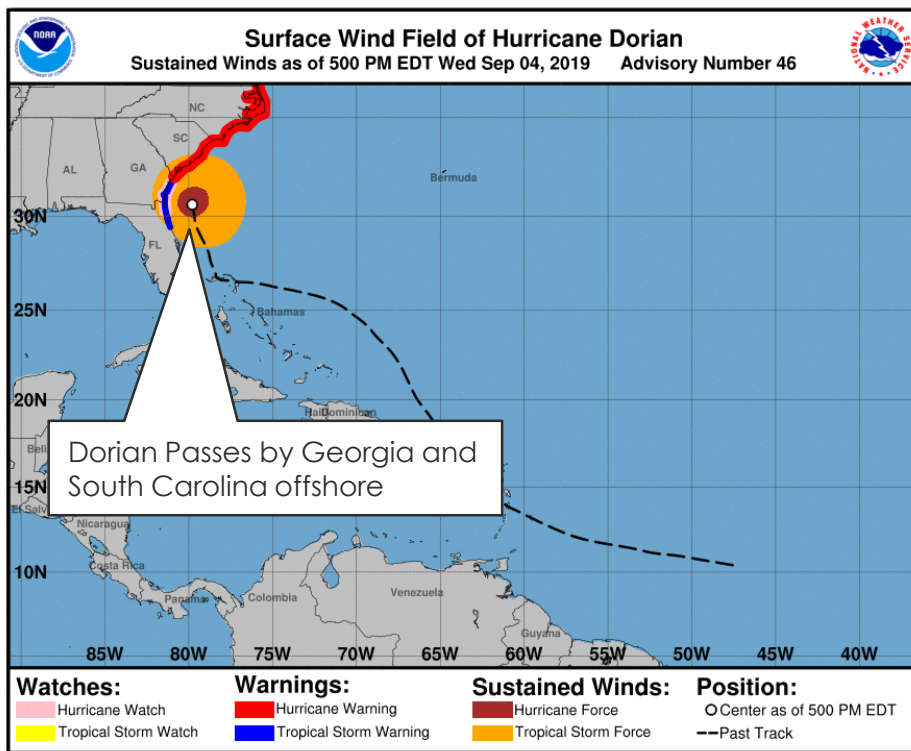
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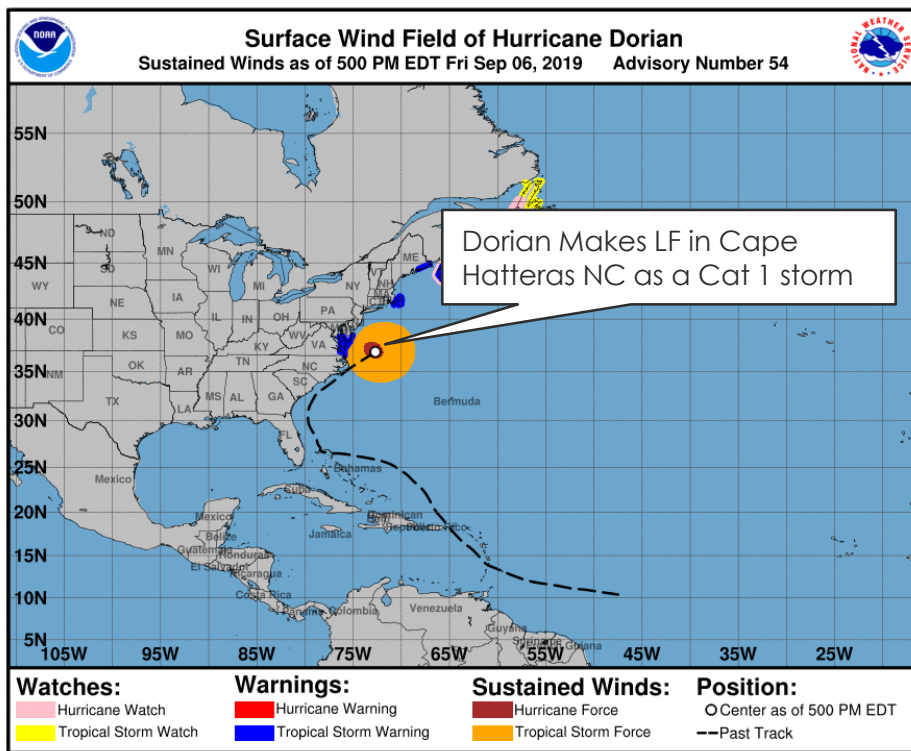
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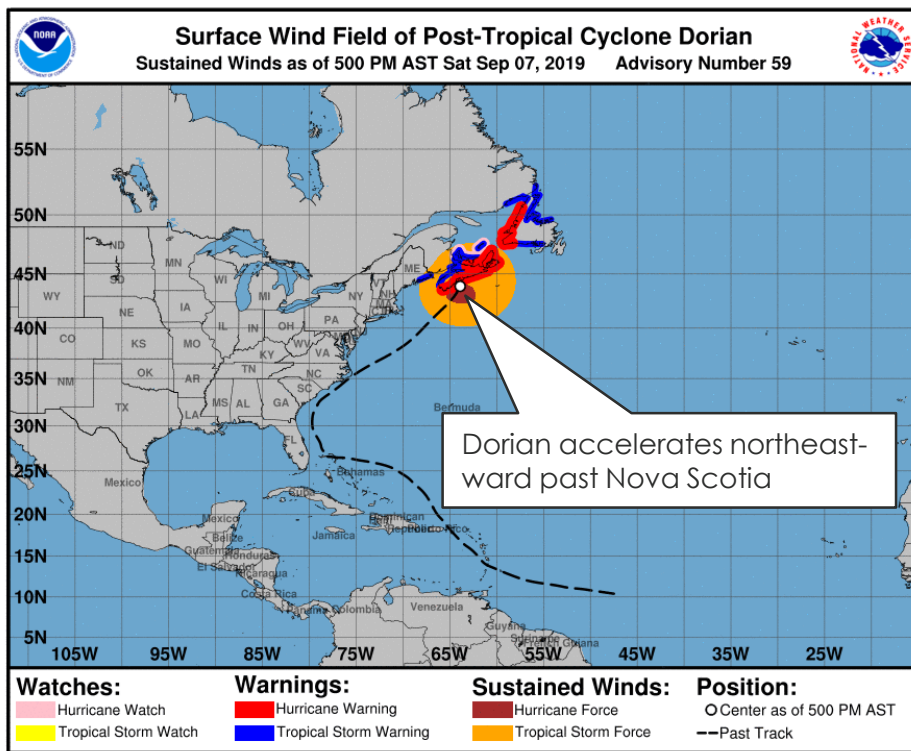
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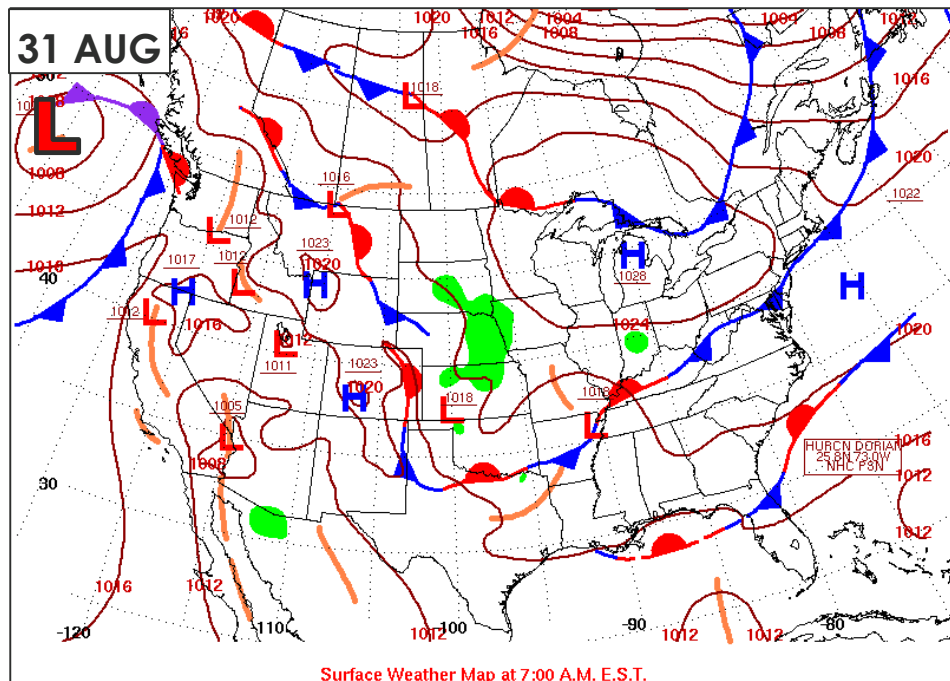
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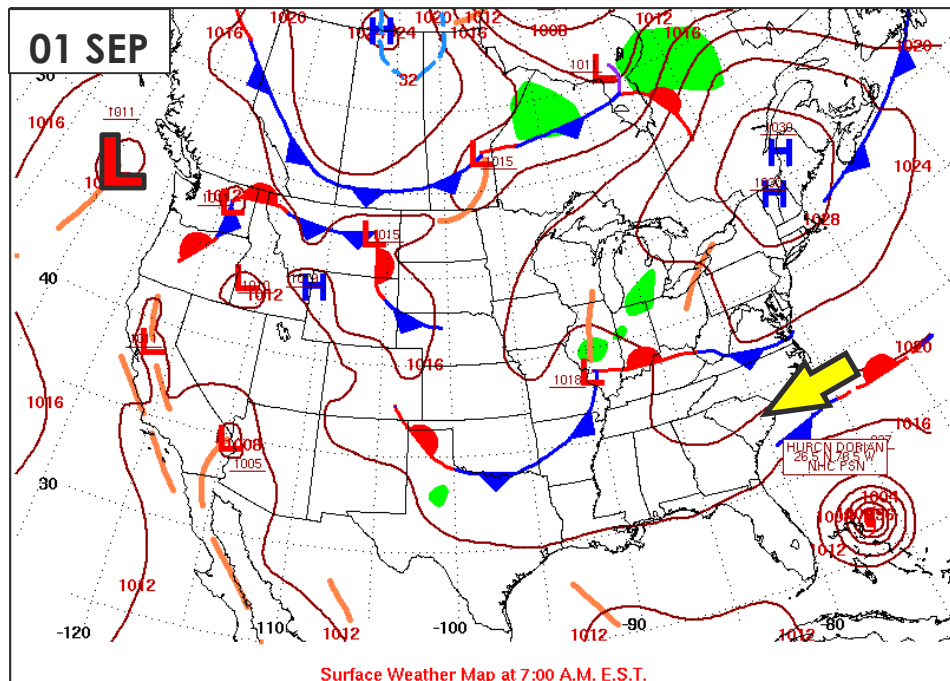
A Timely Cold Front Spared Florida



- Just three days before Dorian struck the Bahamas, the forecast was for it to hit Florida
- Low pressure off the coast of British Columbia ultimately redirected Dorian northeastward
- As Dorian stalled, high pressure that could have steered Dorian into Florida moved out of the way
- The next cold front, attached to the low that swept across Canada, took care of business

Daily surface weather maps for period Aug 31 to Sept 8, 2019

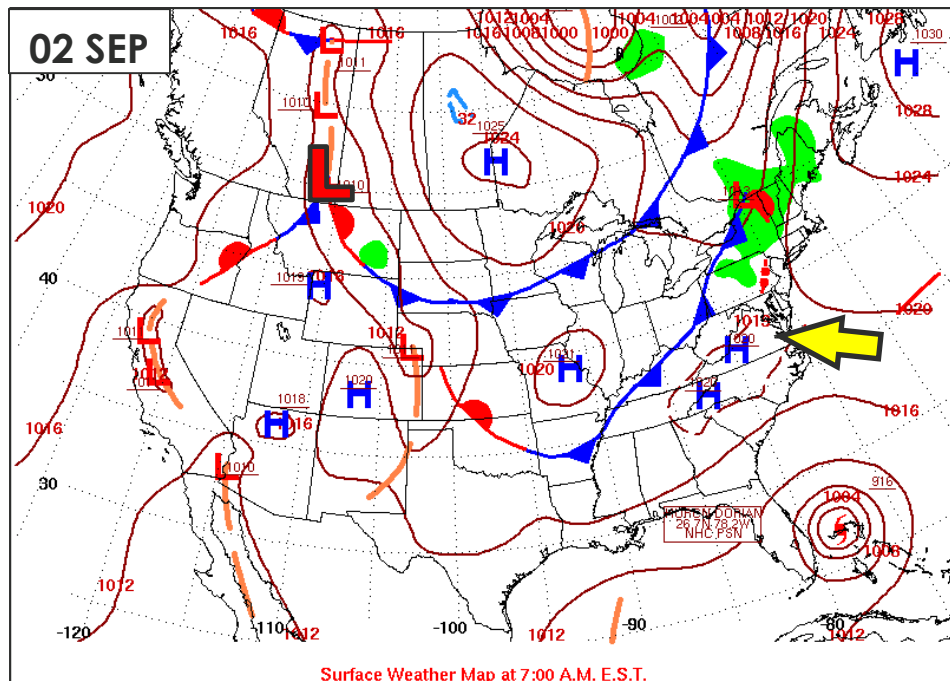
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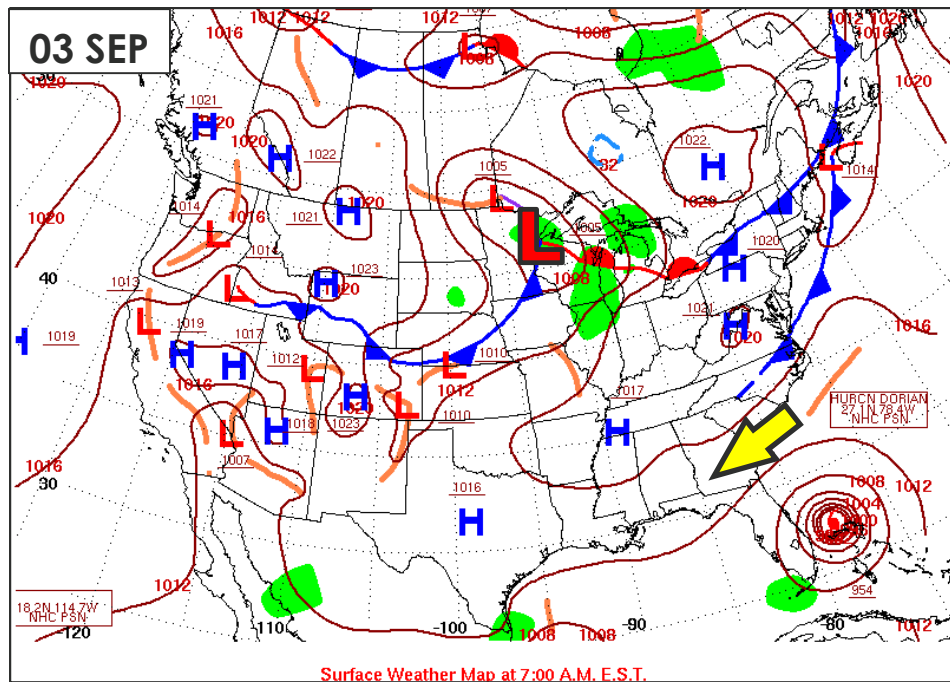
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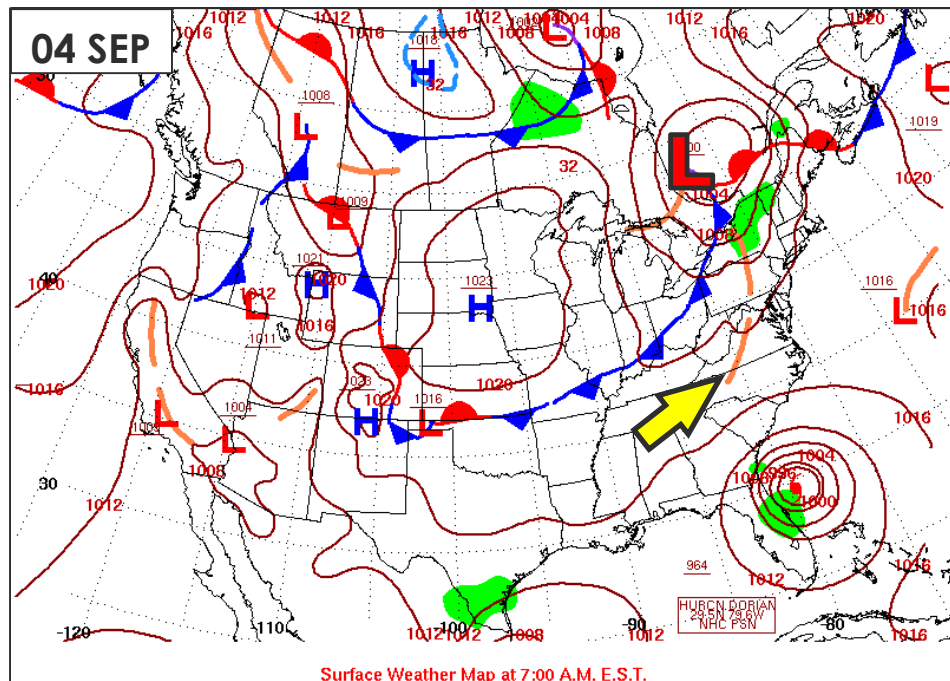
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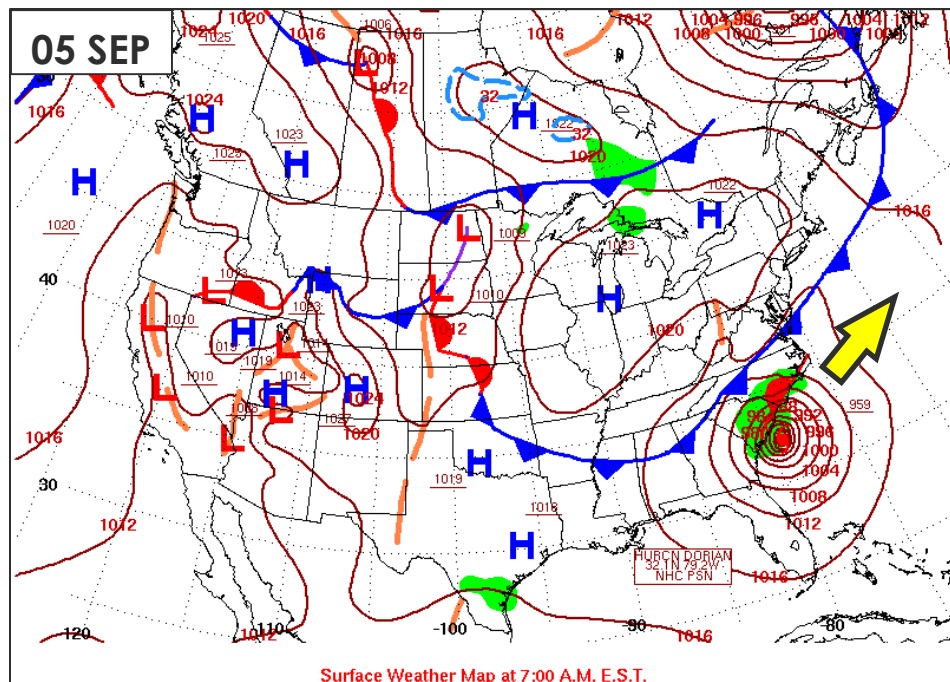
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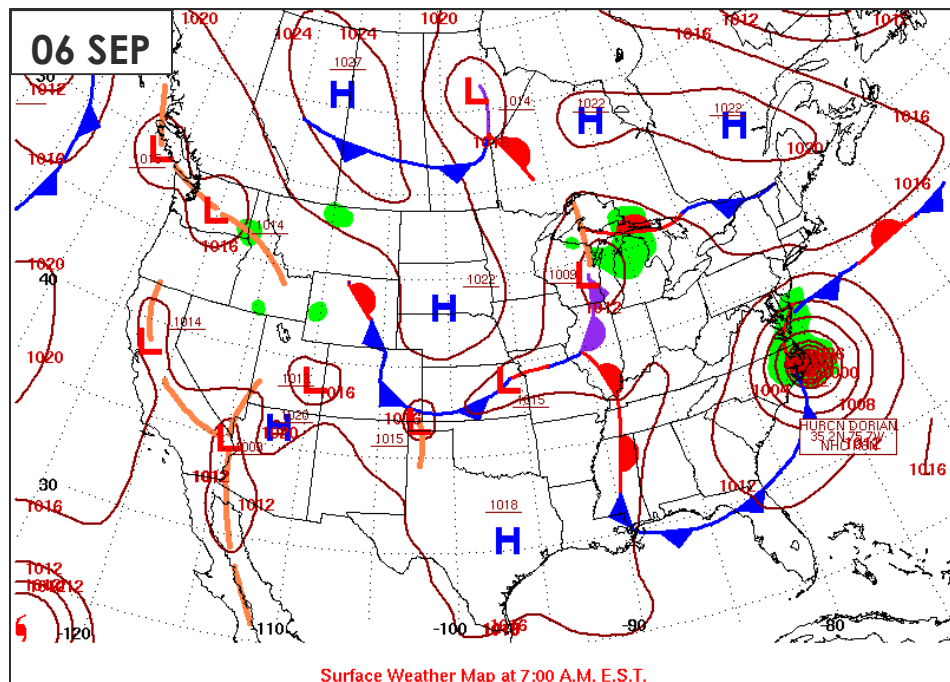
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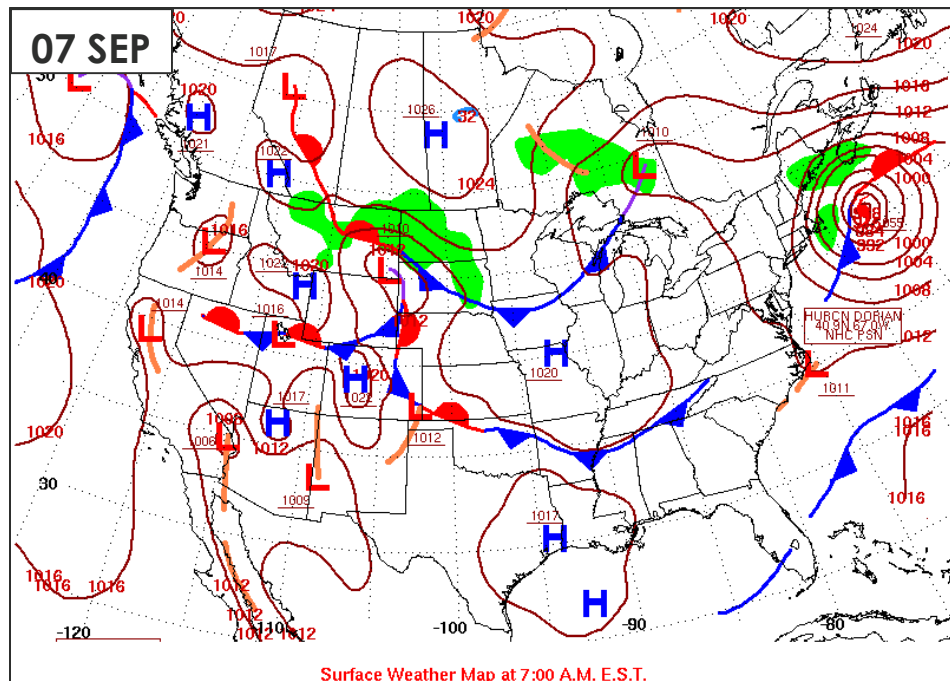
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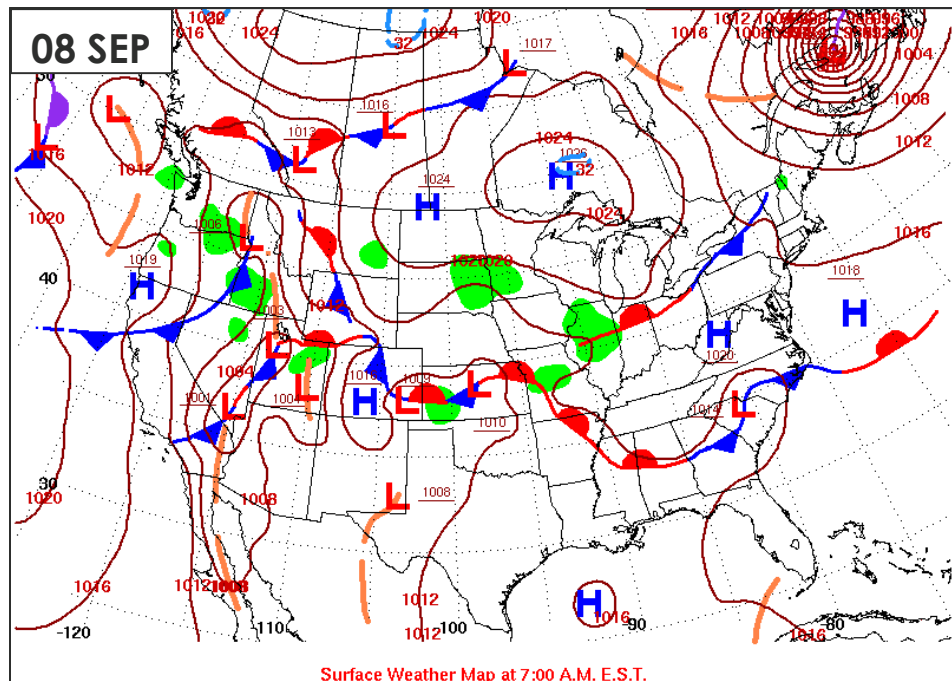
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Dorian in Perspective

- Most intense tropical cyclone on record to strike the Bahamas (185 mph sustained winds)
- Tied for most intense landfalling storm with Labor Day Hurricane of 1935
- Not the most intense tropical cyclone ever in the Atlantic; Hurricane Allen still holds the record at 190 mph
- Fifth Atlantic Basin Category 5 storm in four years
- Third consecutive year that a storm moved across land at less than 5 mph

Marsh Harbour, Abaco, Bahamas

Source: AIR

Hurricane Dorian

Event Modeling and
Ground Truthing



Dorian's Damage



Dorian spared the U.S. Virgin Islands and Puerto Rico: very few reports of damage



Minor impacts in the Lesser Antilles: reports of street flooding

Dorian's Damage



Dorian's impact on the U.S.:
flooding and limited tornado
damage along the Outer
Banks, North Carolina

Observational Hazard Constraints

National Oceanic and Atmospheric Administration's
National Data Buooy Center
Center of Excellence in Marine Technology

Home About Us Contact Us

Storm Special! View the latest observations near [Atlantic Tropical Storm Fernand](#), [Atlantic Hurricane Dorian](#) and [East Pacific Hurricane Juliette](#).

Station SPGF1 - Settlement Point, GBI, Bahamas

Owned and maintained by National Data Buooy Center
C-MAN Station
SutroN XPERT payload
26.704 N 78.995 W (26°42'16" N 78°59'41" W)

Site elevation: 1.5 m above mean sea level
Air temp height: 6.1 m above site elevation
Anemometer height: 6.6 m above site elevation
Barometer elevation: 2.7 m above mean sea level

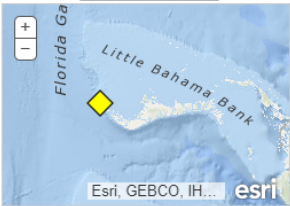
[Latest NWS Marine Forecast](#)
[Important Notice to Mariners](#)
[Search And Rescue \(SAR\) Data](#)
[Meteorological Observations from Nearby Stations and Ships](#)

Sector pictures are available for this station at [0](#), [45](#), [90](#), [135](#), [180](#), [225](#), [270](#), [315](#) degrees.

(SECTOR PHOTOS ARE NOT IN REAL-TIME AND ARE NOT UPDATED!)

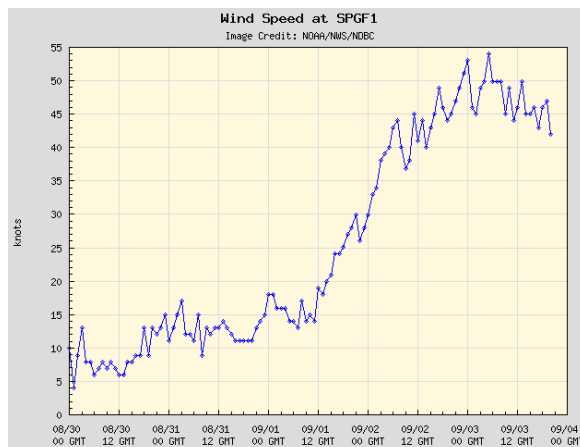


Oceans

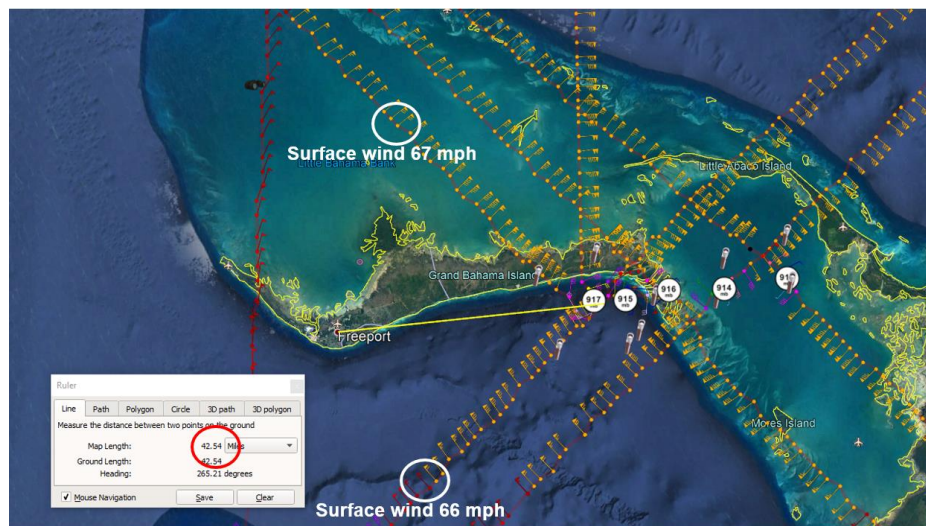
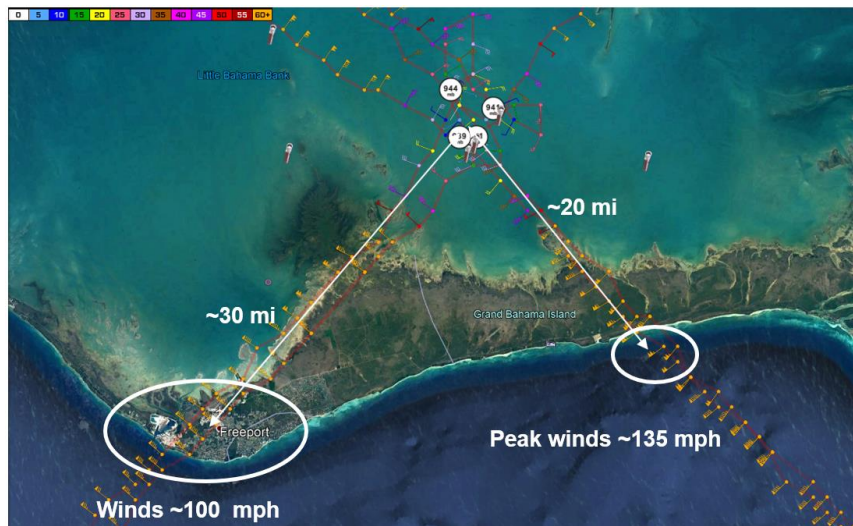


Large icon indicates selected station. [Disclaimer](#)
♦ Stations with recent data
♦ Stations with no data in last 8 hours (24 hours for tsunami stations)

Station SPGF1 at Settlement Point (western tip of Grand Bahama) recorded full passage of Dorian without failure, estimating sustained wind speeds in excess of 55 knots (approx. 70 mph)



Insights from SFMR Data over Freeport, Grand Bahama

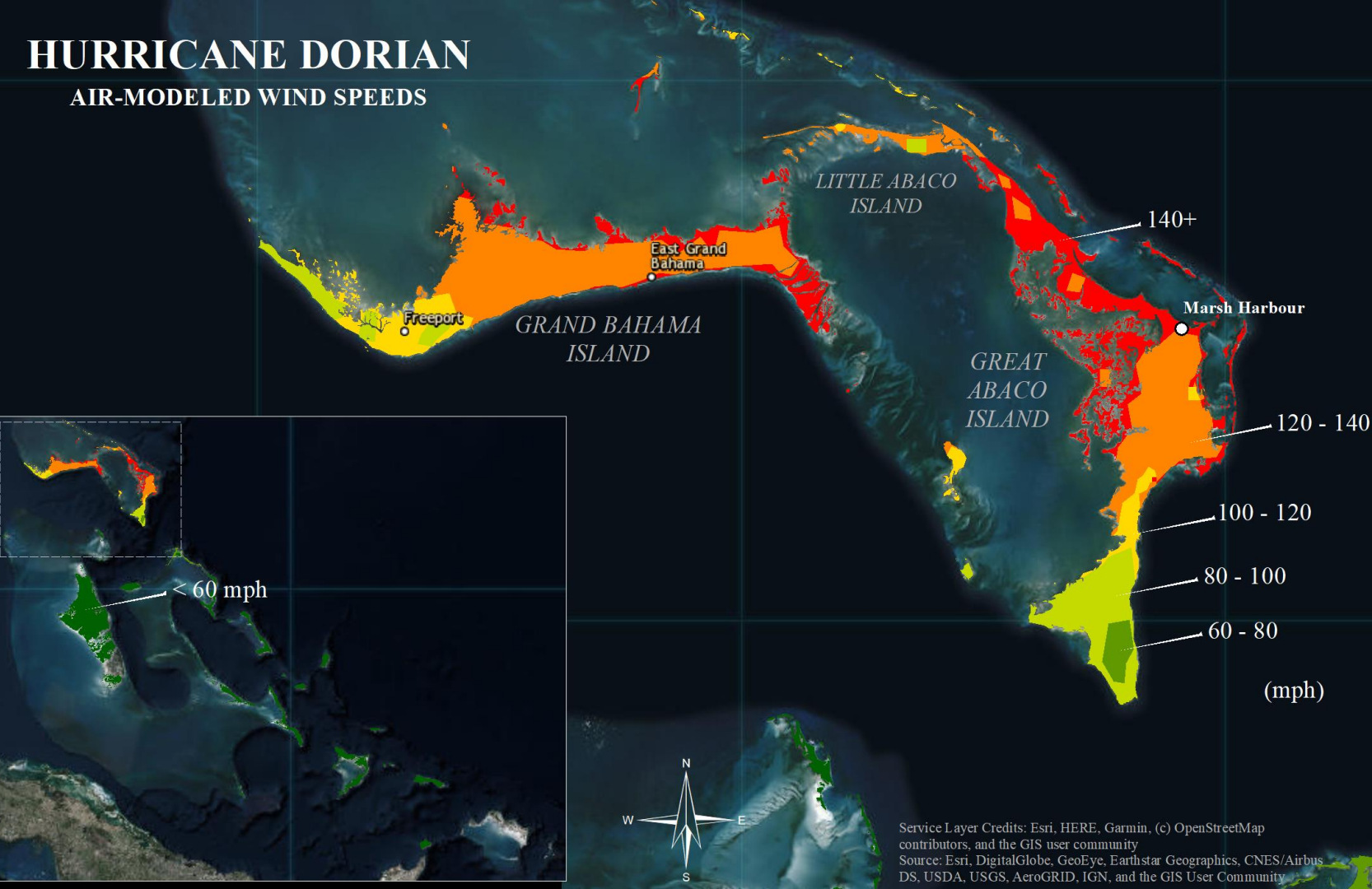


Observations and analysis suggest local wind speeds of approximately 100 mph

Visual interpolation of SFMR-based wind speed observations in Freeport for a time slightly later as storm tracked west, but still close to peak intensity

HURRICANE DORIAN

AIR-MODELED WIND SPEEDS



Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Source: AIR

Near total
destruction in
Central Abaco by
Hurricane Dorian
(2019)



Performance of Gable Roofs

Set of row houses in Treasure Cay
Treasure Cay, Abaco, Bahamas



Source: AIR

Performance of Gable Roofs

Treasure Cay, Abaco, Bahamas

Source: AIR



Hip Roofs Stayed on Buildings, But with Questionable Performance

Central Abaco, Bahamas

Source: AIR



Asphalt Shingle Roofs Suffered Significant Damage

Grand Bahama Island, Bahamas

Source: AIR



BISHOP MICHAEL ELDON SCHOOL

Clay Tile Roofs Were Faulty and Often Lacked Positive Connection to Roof Decking



Grand Bahama Island, Bahamas

Source: AIR

Standing Seam Metal Roofs Were Far Better Performers



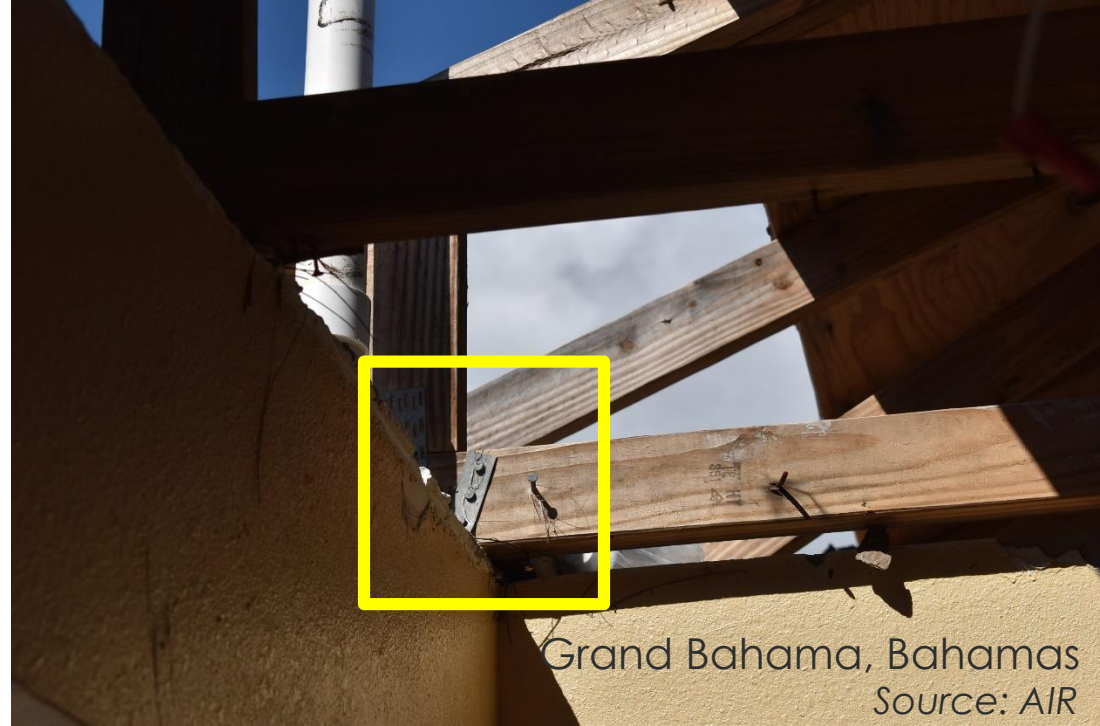
Grand Bahama Island, Bahamas

Source: AIR

- Properly installed metal roofs performed much better in comparison to other roof cover types – still saw lots of damage
- Widespread presence of opening protection and hurricane clips

Marsh Harbour, Abaco,
Bahamas

Source: AIR



Grand Bahama, Bahamas
Source: AIR

Widespread presence of opening
protection and hurricane clips

Bermuda Style Roof Covers Performed Relatively Well

Marsh Harbour, Abaco,
Bahamas

Source: AIR



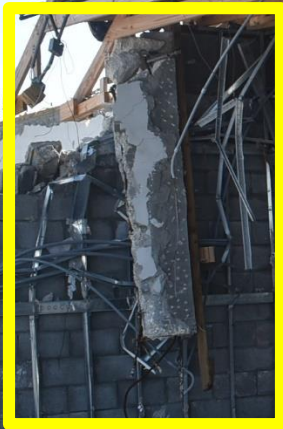
Wood Frame Construction

Central Abaco, Bahamas

Source: AIR



Masonry Construction



Commercial establishment housing a bank in
Marsh Harbour, Abaco, Bahamas

Source: AIR

Mixed Construction Fared Poorly



Central Abaco, Bahamas

Source: AIR

Light Metal Structures Were Obliterated



Remnants of the Treasure Cay Police Station
Treasure Cay, Abaco, Bahamas

Source: AIR

Significant Losses to Contents and Business Interruption

Remnants of the factory floor at the Bahamian Brewery, Freeport, Grand Bahamas

Source: AIR



Source: AIR

Remnants of the factory floor
at the Bahamian Brewery,
Freeport, Grand Bahamas



Source: AIR

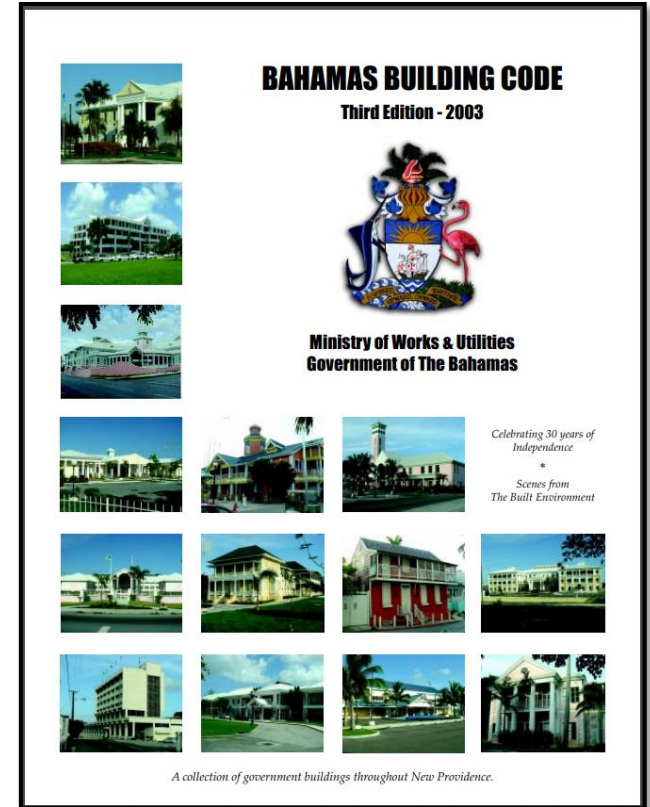
Significant Losses to Contents and Business Interruption

Bahamian Brewery
Freeport, Grand Bahama
Source: AIR



Looking at Damage from a Building Code Perspective

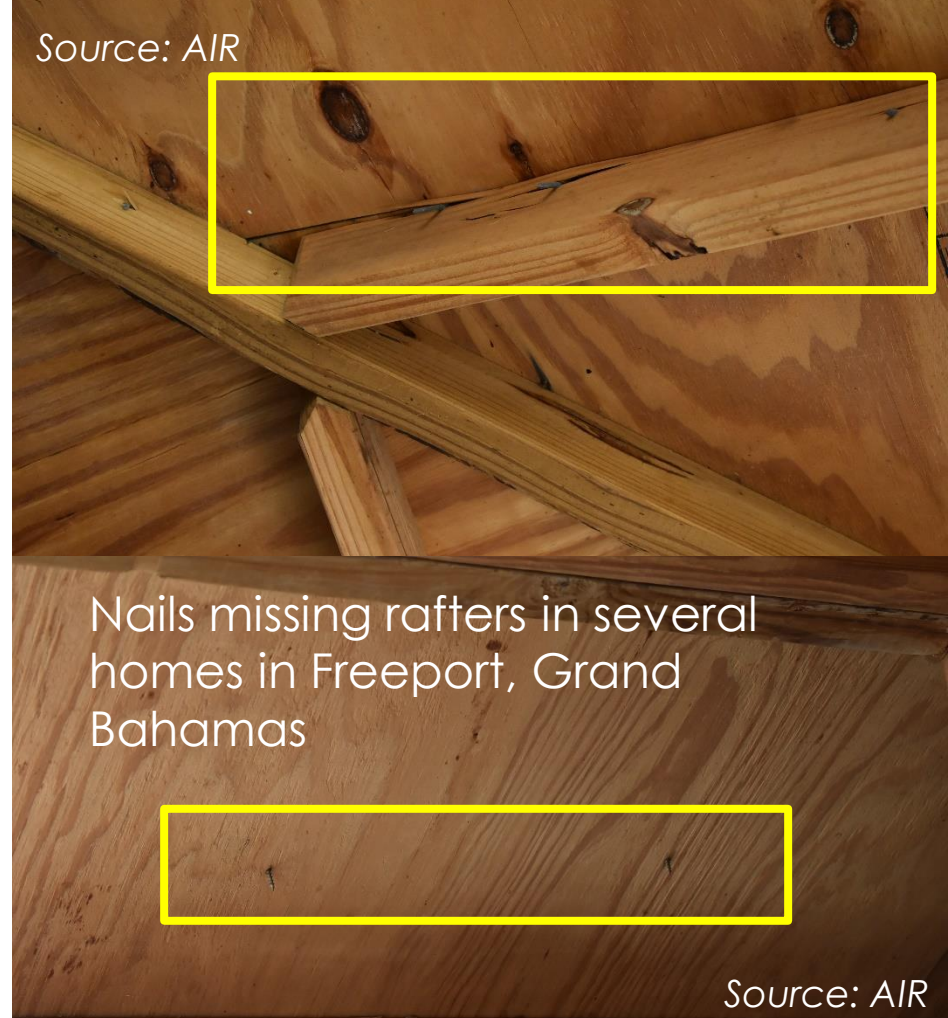
- Bahamas Building Code (BBC) was first implemented in the early 1970s
- BBC was updated in 1987 in line with South Florida Building Code
- Latest edition of BBC as of 2003:
 - Wind design to 150 mph
 - Exposure D
 - Requirement for hurricane shutters



Enforcement of Building Codes and Workmanship Continues to Be a Concern

- BBC lacks important provisions for minimum spacing of fasteners for roof decking, load concentration at ridges, member edges, and overhangs
- Lack of resources and personnel, in addition to geography, contributes to less stringent inspections

Source: AIR



Nails missing rafters in several homes in Freeport, Grand Bahamas

Source: AIR

Damage to Pleasure Boats

Central Abaco, Bahamas
Source: AIR



Damage to Automobiles

Freeport, Grand Bahama,
Bahamas
Source: AIR



Damage to Automobiles

Central Abaco, Bahamas

Source: AIR



AIR estimates industry insured losses
resulting from Hurricane Dorian in
the Caribbean will be between
USD 1.5 billion and USD 3 billion

Affected Caribbean Territories

Bahamas, Barbados, British Virgin Islands, Dominica, Guadeloupe, St. Kitts & Nevis, Martinique, Montserrat, Puerto Rico, St. Lucia, U.S. Virgin Islands

Preview of Enhancements to the AIR Tropical Cyclone Model for the Caribbean



Damage to an ocean front home in
2019 Hurricane Dorian
Central Abaco, Bahamas

Source: AIR

Historical and Stochastic Catalogs

- Extended years of historical data validates model frequency
 - Updates will address minor spatial biases in intensity
- Addition of new historical events:



**2014 Hurricane
Gonzalo**



**2016 Hurricane
Matthew**



**2017 Hurricane
Irma**



**2017 Hurricane
Maria**

Vulnerability Enhancements

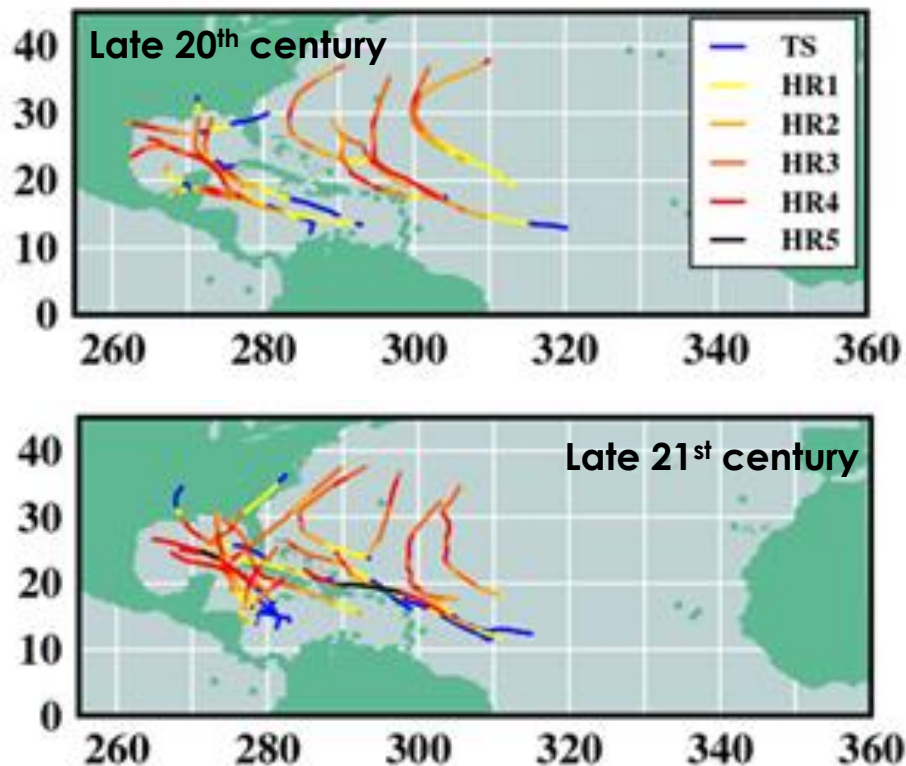
- Comprehensive assessment of spatial and temporal variation in vulnerability across 29 countries for traditional risks
- Vulnerability of industrial facilities
- Addition of several new lines of business



Climate Change Impacts

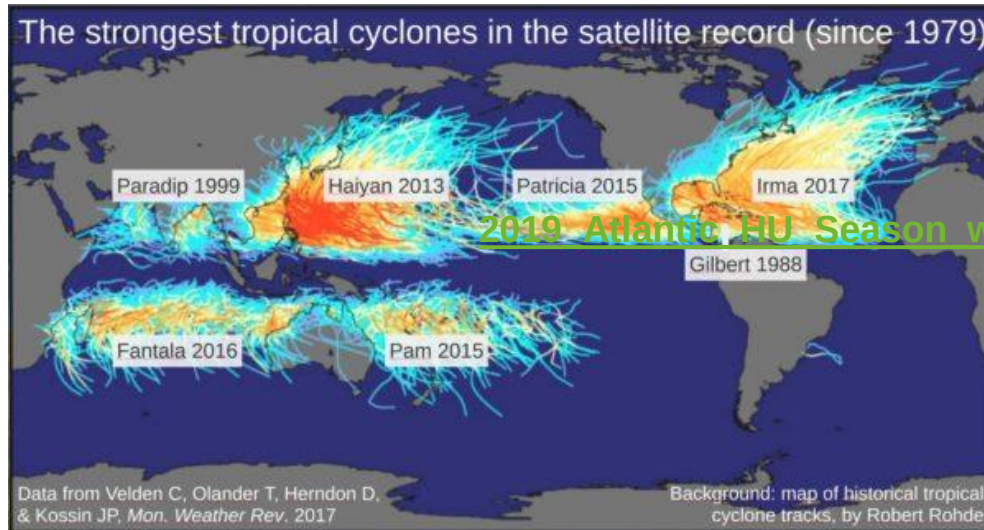
- Storm frequency and intensity
- Landfall probability
- Slowdown and other factors

Climate Change Will Likely Mean More Cat 4s and 5s

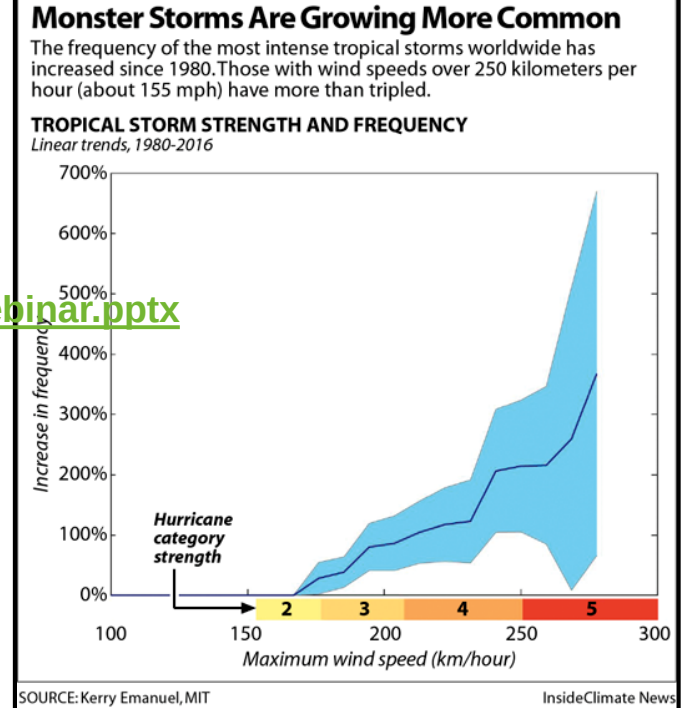


- GCMs do show an increase in Cat 4s and 5s by later this century
- Overall decrease in TC numbers
- Storm surge threat will increase
- Precipitation will increase

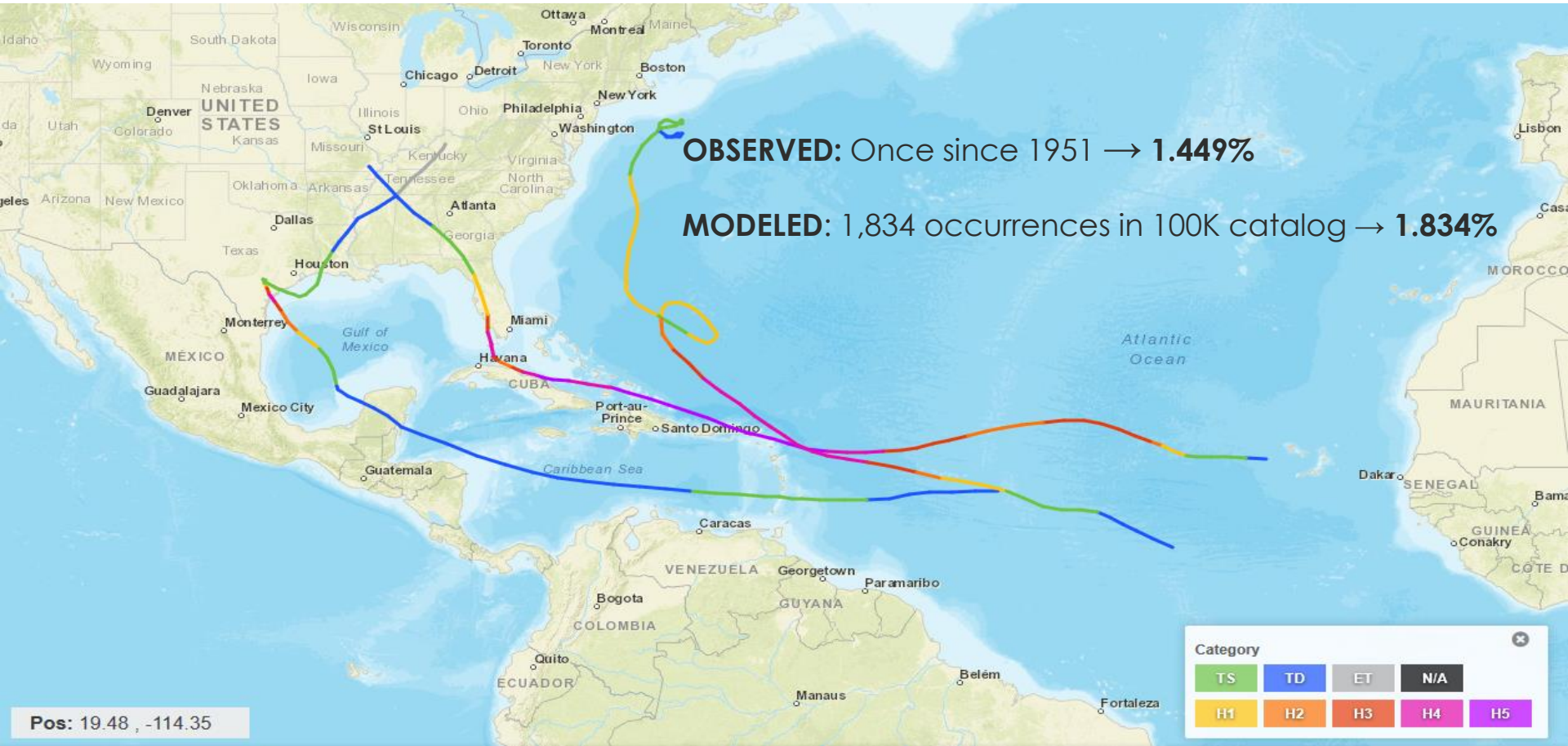
Historical Record Shows Stronger Storms (TCs) Are Increasing in Frequency



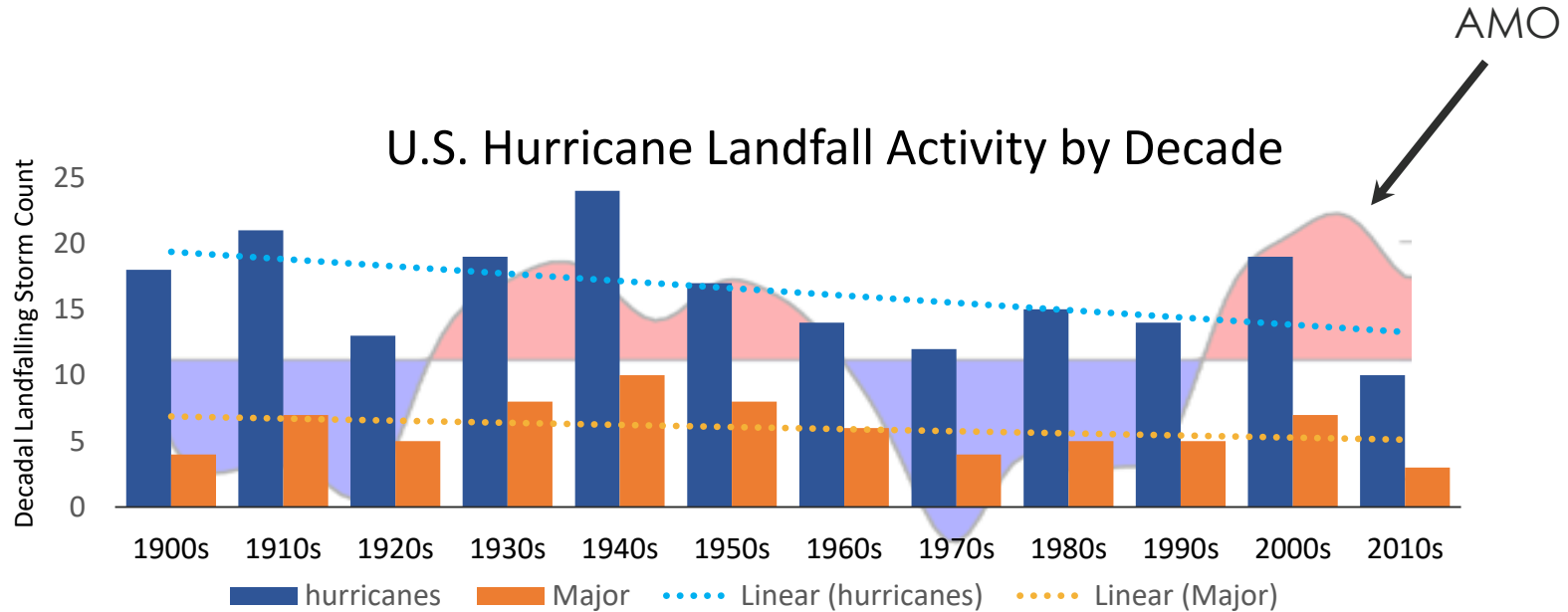
2019 Atlantic HU Season webinar.pptx



What Is the Probability of 3 Consecutive Cat 4s?



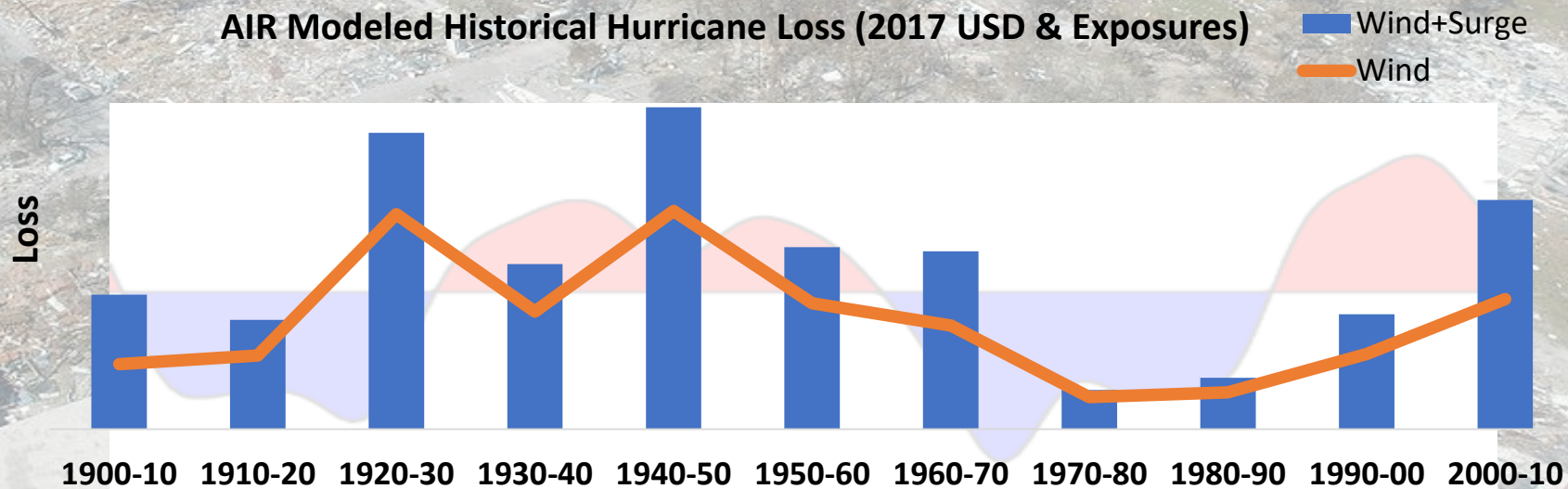
U.S. Landfalling Hurricane Activity Shows Influence from AMO



Negative slope in decadal hurricane landfall count
likely related to asymmetry of AMO

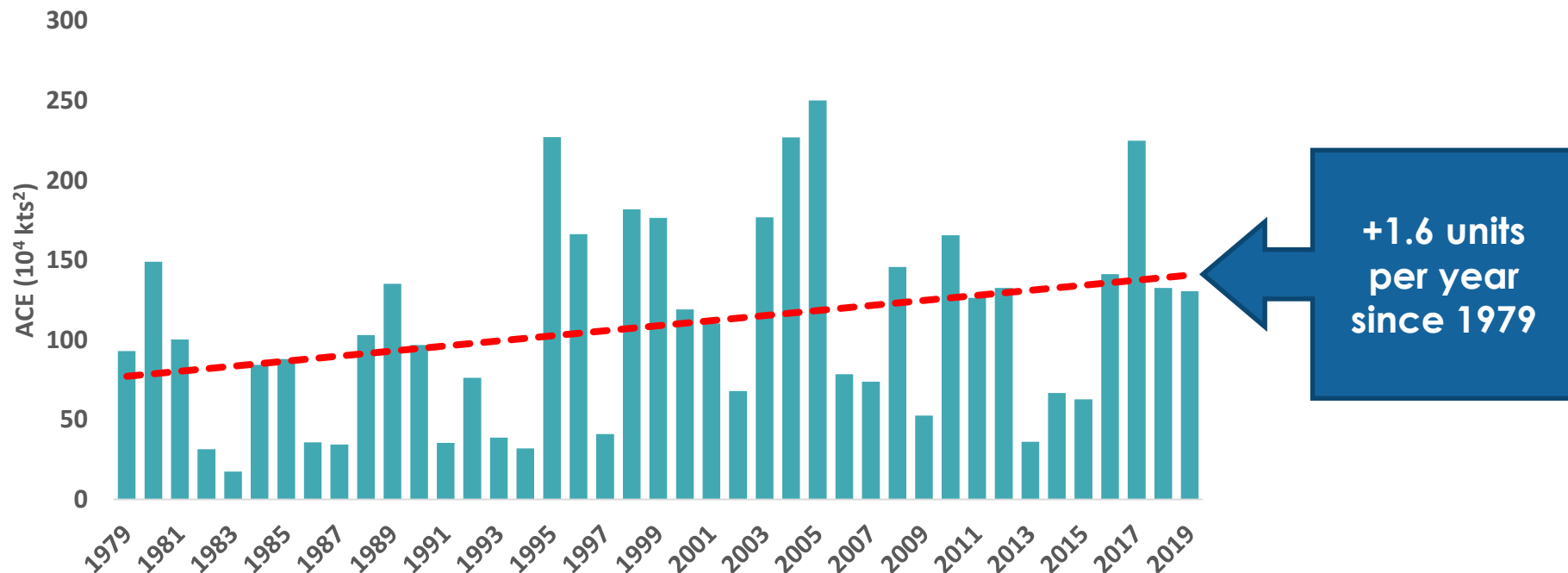
Hurricane Losses Show Similar AMO Dependence

AIR Modeled Historical Hurricane Loss (2017 USD & Exposures)



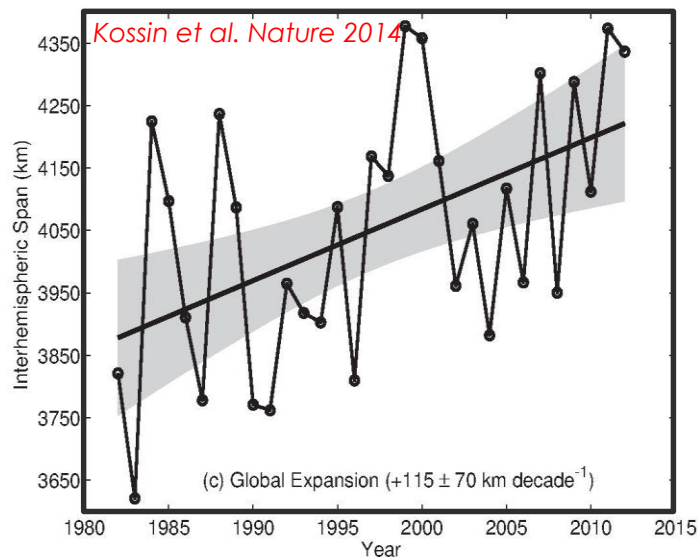
Some Other Hurricane Features Are Showing Trends

Atlantic Basin Accumulated Cyclone Energy (ACE)



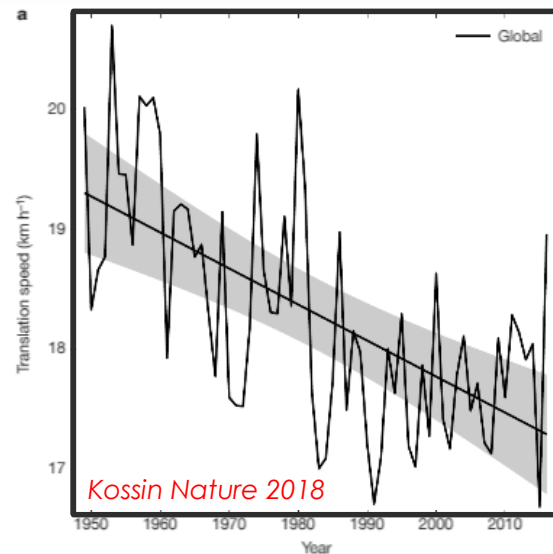
Some Other Hurricane Features Are Showing Trends

The latitude of **Lifetime Maximum Intensity (LMI)** has been changing significantly



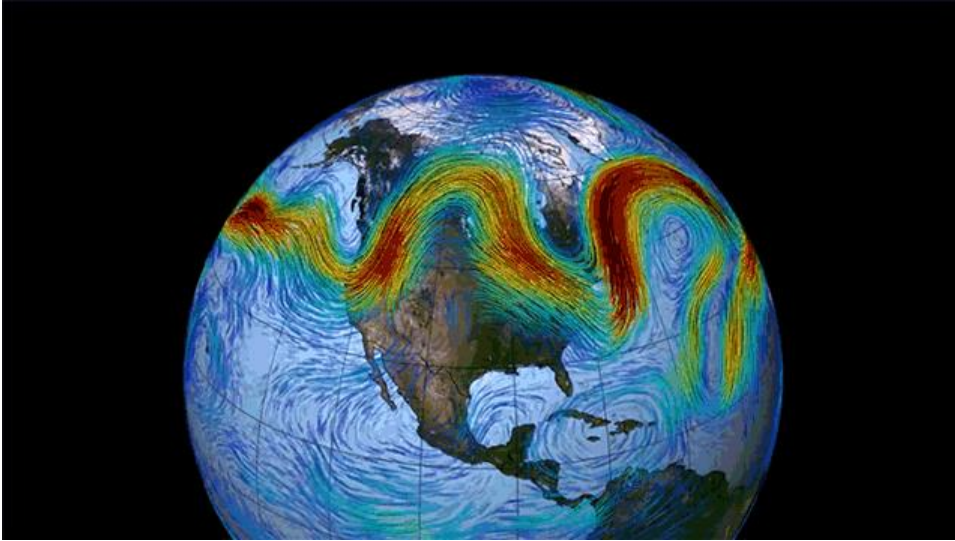
**0.5° latitude per decade
per hemisphere**

Storms have been **slowing down**



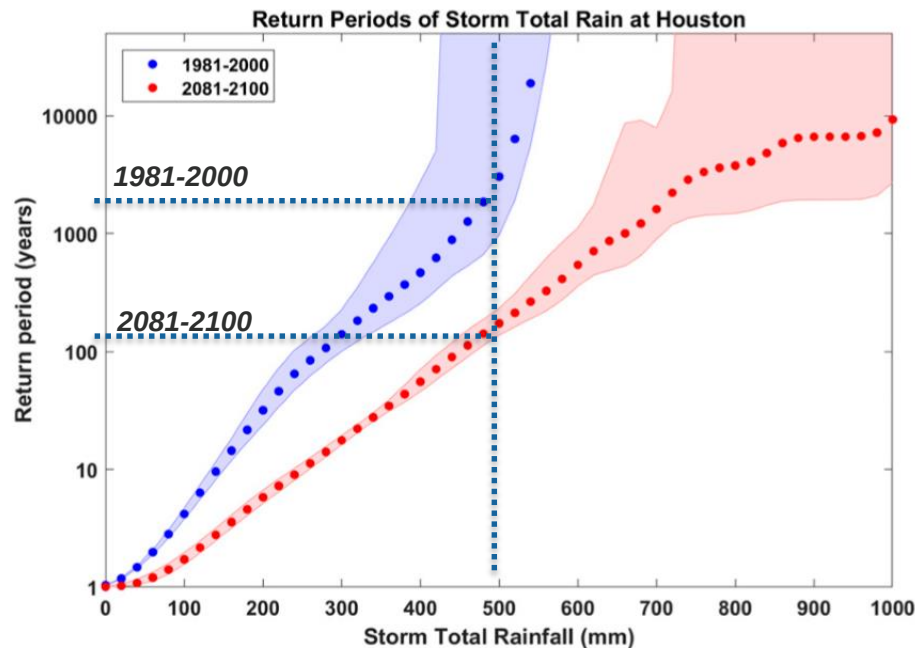
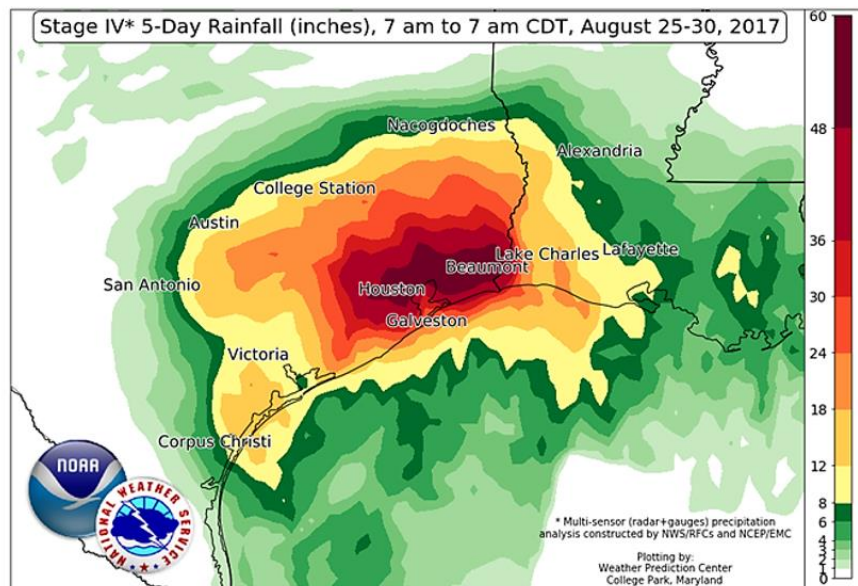
10-15% over water; 25% over land

An Explanation for Slowdown and More Weather Extremes



- Arctic ice melt has reduced the pole- to-equator temperature difference
- Large planetary waves that normally move slowly around the earth may move more slowly or become trapped, and amplify

Slowdown Played a Role in Harvey's Record Rainfall

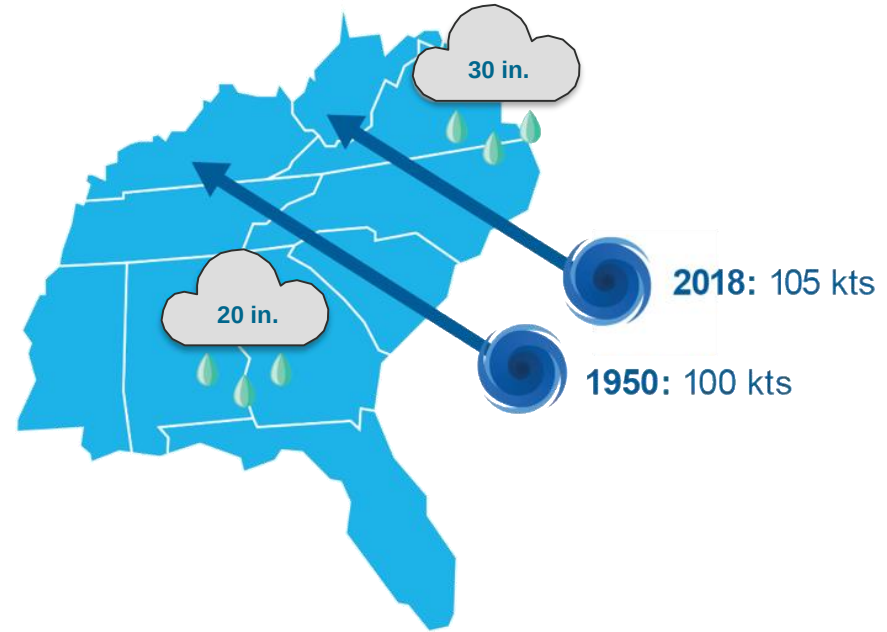


Triple Threat for Hurricane Precipitation Is in the Future

Impact on Hurricane Florence

Increased Intensity	5%
Increased Moisture	7%
Decreased Forward Speed	-25%

$$1.05 \times 1.07 / 0.75 = \sim 1.50$$



Historical record shows trend in forward speed, latitude of maximum intensity, and intensity

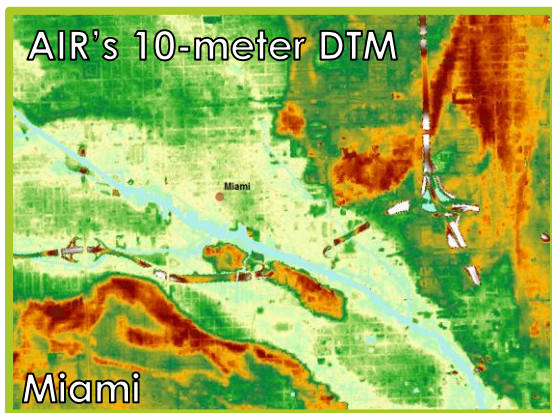
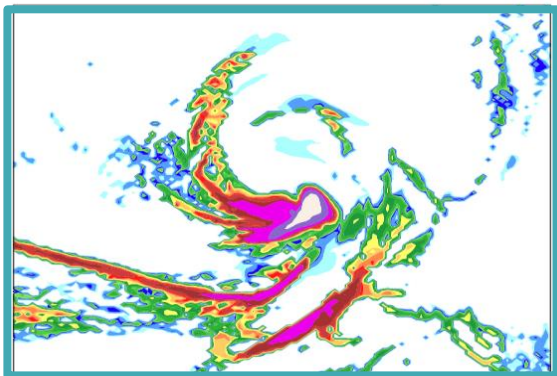
Key Climate Change Takeaways

- Hurricane activity will likely increase in frequency and intensity
- Recent historical record supports the result in world's basins but not certain about Atlantic
- Other trends such as increases in latitude of Lifetime Maximum Intensity and decrease in forward speed show up in historical record and can be physically explained
- Highest confidence in precipitation and storm surge increases



Hurricane-Induced Flood Modeling

Inland Flooding Enhancements in Both Models



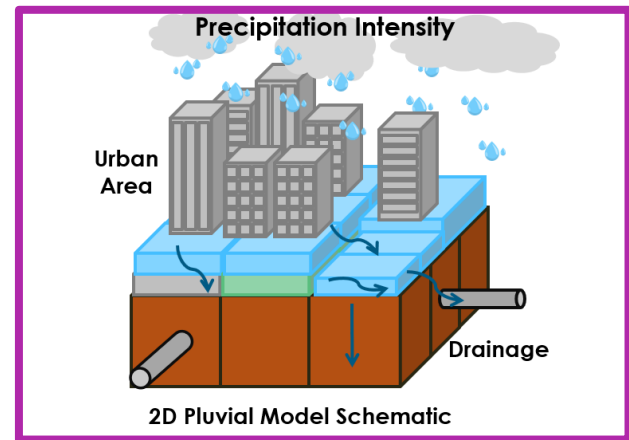
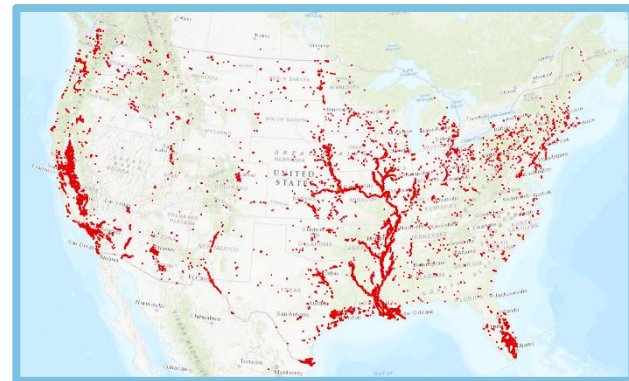
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Precipitation is
simulated using fully
coupled GCM-NWP

Enhanced 10-meter
high-resolution Digital
Terrain Model

Extensive levee
data set

Flooding is simulated
using a physically
based 2D model



Flood Vulnerability Enhancements

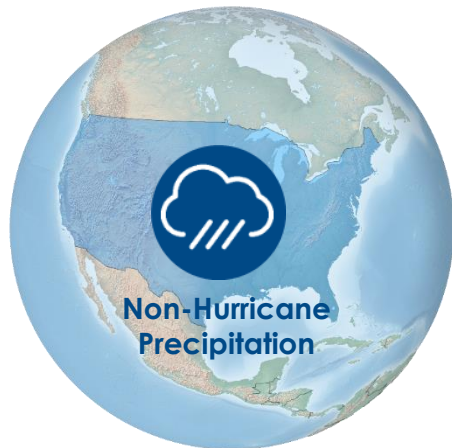
- Component-level framework to estimate the vulnerability of traditional risks
- Overhaul of the vulnerability of industrial facilities
- Addition of several new lines of business to be consistent with AIR's U.S. hurricane model
- Model validated using several loss data sets from sister companies within Verisk, NFIP, and clients

Leverage Touchstone's Flexibility to Capture Several Views of Risk

Hurricane Model



Inland Flood Model



Flood Risk

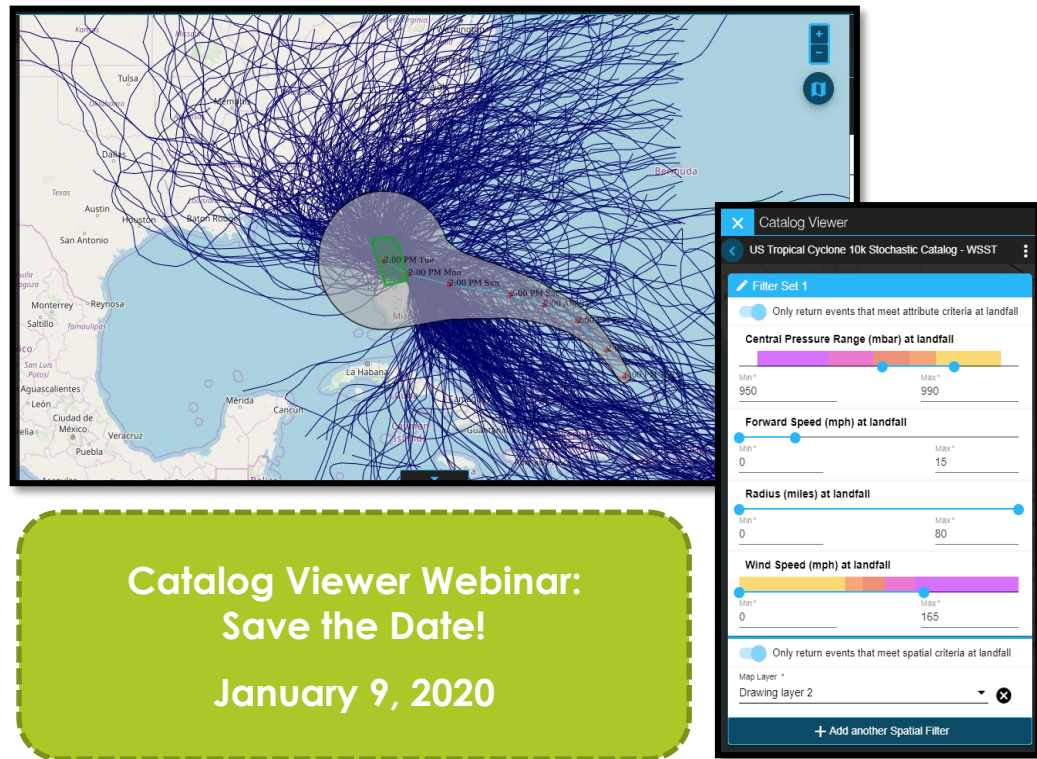
Storm Surge

Hurricane Precipitation-Induced Flooding

Non-Hurricane Precipitation-Induced Flooding

Introducing Catalog Viewer

- Web-based and cloud-native
- Access full tracks and intensity footprints for all stochastic events in catalog (incl. SSEs)
- Customize events to your portfolio
- Automate your workflows and simplify reporting
- Easily export data to Touchstone® and Touchstone Re™



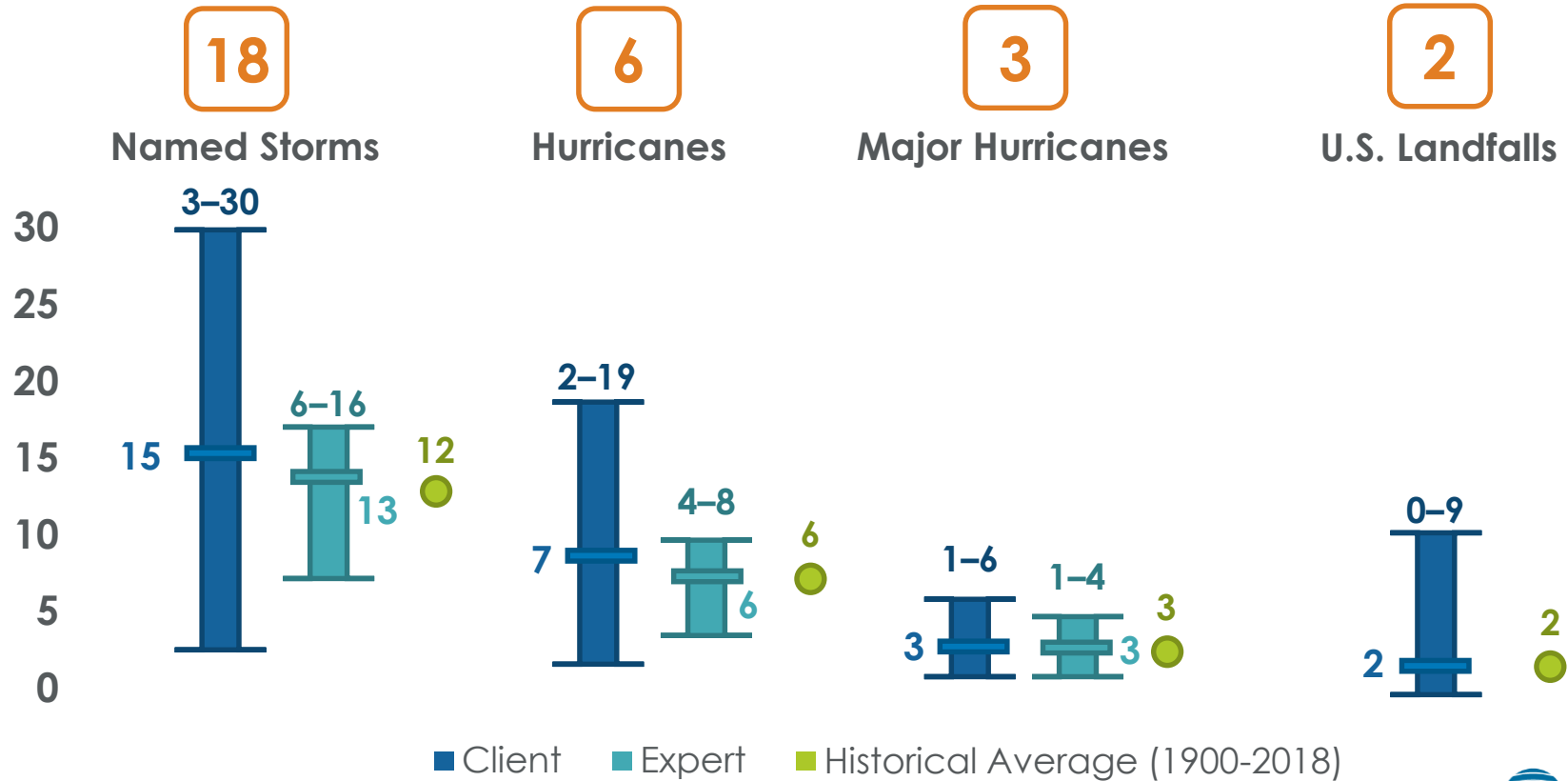
Top 3 Takeaways

While 2019 was an average season in many ways, it only takes one major storm – like Dorian – to cause catastrophic and record-setting damage

AIR continues to explore the impact of climate change on hurricane activity in this and other seasons, deeply analyzing trends and signals to continuously validate our modeling methodology

Innovative analytics tools ensure your organization can effectively evaluate and manage risk from hurricane, flood, and many other catastrophic perils

2019 AIR Hurricane Contest: Who Are the True “Experts?”



Thank You!

A recording of today's webinar and the slide deck will be distributed shortly.

Thank you for submitting your questions online; they helped to shape today's content!

If your question isn't covered during Q&A, please reach out to your account rep or email airconference@air-worldwide.com.