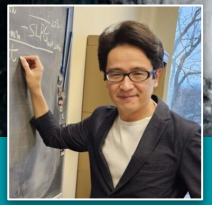
July 29, 2024 | 12:30 – 2:30 p.m. ET

NOAA'S INDUSTRY PROVING GROUNDS SPECIAL WEBINAR

2024 HURRICANE OUTLOOK

Matthew Rosencrans
NOAA Climate Prediction Center

Tom Knutson
NOAA Geophysical Fluid Dynamics Laboratory



Hiroyuki Murakami
NOAA Geophysical Fluid Dynamics Laboratory

Ken Knapp
NOAA National Centers for Environmental Information

Christopher Landsea
NOAA National Hurricane Center

Webinar Logistics

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- If do not wish to be part of the recording, please feel free to drop off.
- Meeting summary, presentation slides and a recording will be available on the NOAA website.

Agenda

- Overview on the NOAA Industry Proving Ground Initiative - ***Mike Brewer***
- NOAA 2024 Hurricane Season - ***Matthew Rosencrans***
- NOAA Hurricane Seasonal Outlooks, Predictions, and Long Term Climate Change - ***Hiroyuki Murakami***
- Climate Change and Hurricane Activity - ***Tom Knutson***
- National Hurricane Center - ***Christopher Landsea***
- Hurricane and Tropical Storm Data at NCEI - ***Christopher Landsea***
- **Break (5 min)**
- **Industry Breakout Sessions**

Welcome / Introduction

Introductions

Mike Brewer
NOAA NCEI, Chief of Information Services, NOAA NCEI and IPG Manager

Jenny Dissen
NOAA Cooperative Institute for Satellite Earth System Studies (CISESS NC)
NC State University

What is the IPG?

Connecting industry to actionable data, products, and services to build climate resilience across the Nation.

- **The Inflation Reduction Act's (IRA's) Industry Proving Grounds (IPG) is a new effort to develop and share actionable climate information and improve the delivery of that information to industry partners.**
- **NOAA–through the National Centers for Environmental Information (NCEI)–is working directly with three major industries to improve information that will allow members to better assess climate risk, improve rapid decision making, and promote long-term resilience in the face of a changing climate.**

NOAA's Industry Proving Grounds Initiative

Workstream 1: Website Development

A "one-stop-shop" for environmental data for the retail sector

Workstream 2: Data Ingestion and Format

Improvements to data availability, accessibility, presentation, and format

Workstream 3: Product Development

Multiple products developed in conjunction with NOAA scientists

Engagement

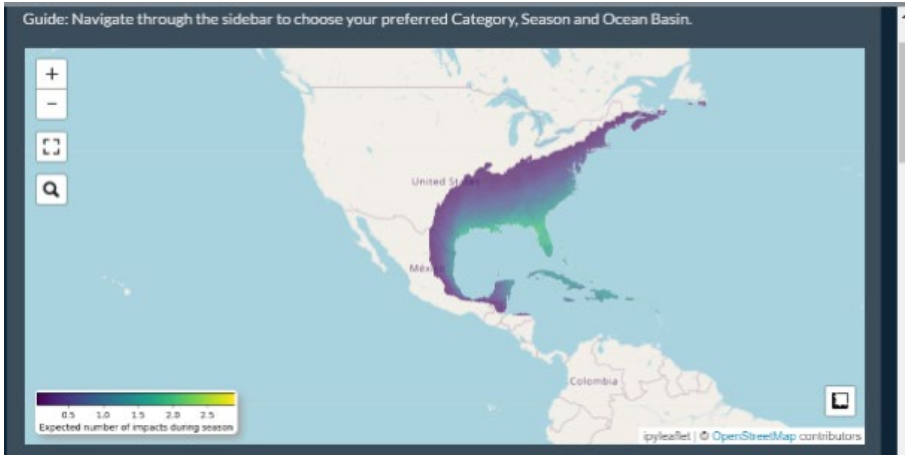
NOAA's Industry Proving Grounds Initiative

Our Commitment	NOAA Desires
• Requested insight into NOAA products, services, and capabilities • Asked to be part of conversations about priorities and future research and development actions • Opportunity to interact directly with NOAA science leads on products and services that impact industries ability to successfully drive commerce • While under the IPG umbrella, also recognizing other long-standing and important partners with similar needs	• Durable improvements in how and what we deliver • Focus future development on impactful information that is useful, usable, and used by industry • Drive resilience, prosperity, and equity now and into future generations

NOAA's Industry Proving Grounds (IPG)

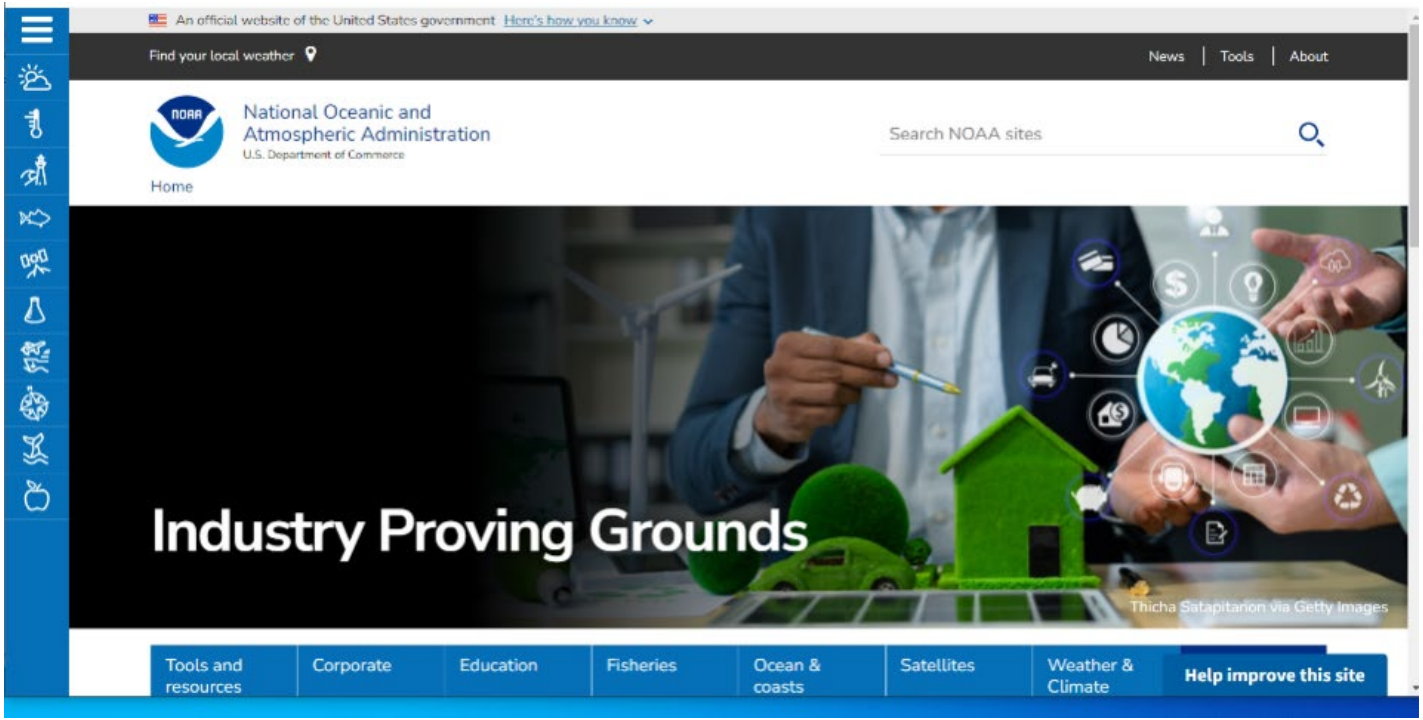
High Risk/High Reward Opportunities

- Working with Dept of Defense and ClimateAI on improving hurricane information.
- Focus on floods, precipitation, and landfalling hurricane outlooks
- Improve specificity of data that could be included in Catastrophe Models and other industry activities and operations
- Build toward co-development with industry partners



AI-informed outlook for landfalling hurricane potential in the next five months

NOAA's Industry Proving Grounds Website



https://www.noaa.gov/climate-industry

2024 Hurricane Season

Matthew Rosencrans

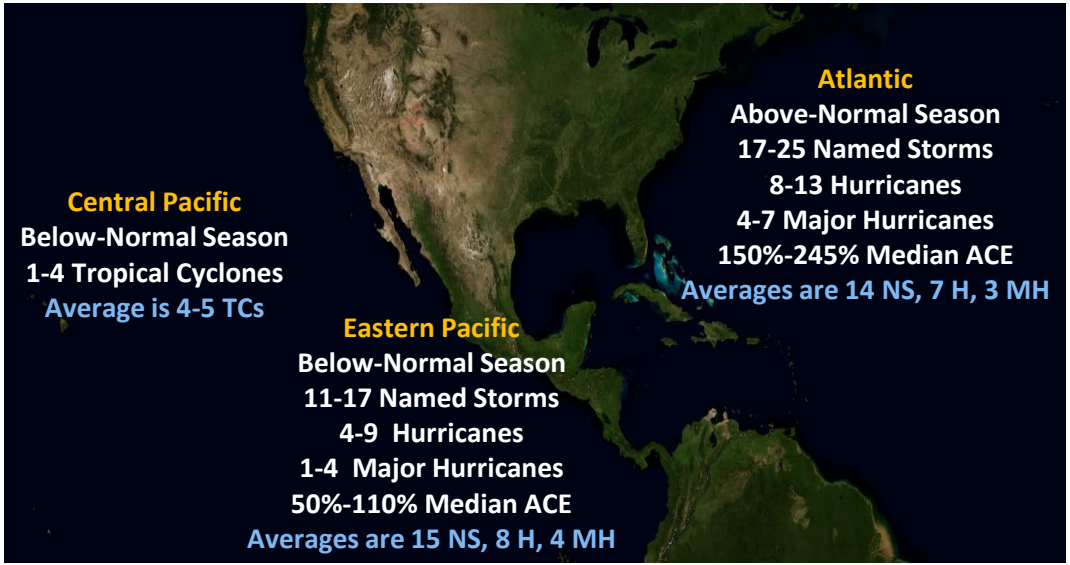
Climate Testbed Director | NOAA Climate Prediction Center

NOAA 2024 Hurricane Season Outlooks

Matthew Rosencrans, Physical Scientist, NOAA/ NWS/ NCEP / CPC

NOAA's 2024 Hurricane Season Outlooks

All ranges of activity are given with a 70% probability.



highest range of NS,H,MH.
2nd for ACE (2010)

n/a	Atlantic	Eastern Pacific	Central Pacific
Above Normal	85%	10%	20%
Near Normal	10%	30%	30%
Below Normal	5%	60%	50%

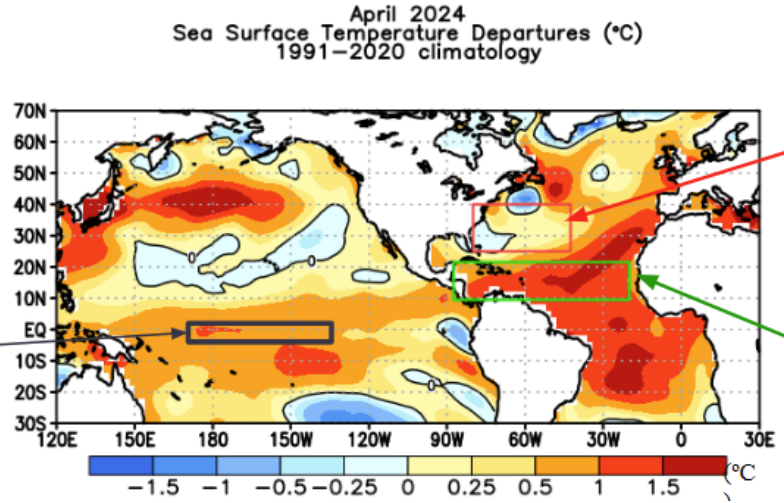
For the Atlantic hurricane season, climate signals and model forecasts indicate that an above-normal season is most likely (**85**% chance), with a 10% chance for near-normal and a 5% chance for a below-normal season. The asymmetry is reflective of the likely complementary impacts of the major climate factors.

For the Eastern and Central Pacific hurricane regions, the outlooks indicate a **below**-normal season is most likely (**60% for East Pacific** and **50% Central Pacific**), with a 30% chance for a near-normal and a 10% chance for an above-normal season (20% for the Central Pacific).

- Accumulated Cyclone Energy (ACE) measures the overall strength of the hurricane season.
- For the Central Pacific, Tropical Cyclones (TCs) include tropical depressions, tropical storms and hurricanes.

These outlooks are for overall seasonal activity. They are not a hurricane landfall forecast.

Recent Sea-Surface Temperature (SST) Anomalies (°C)



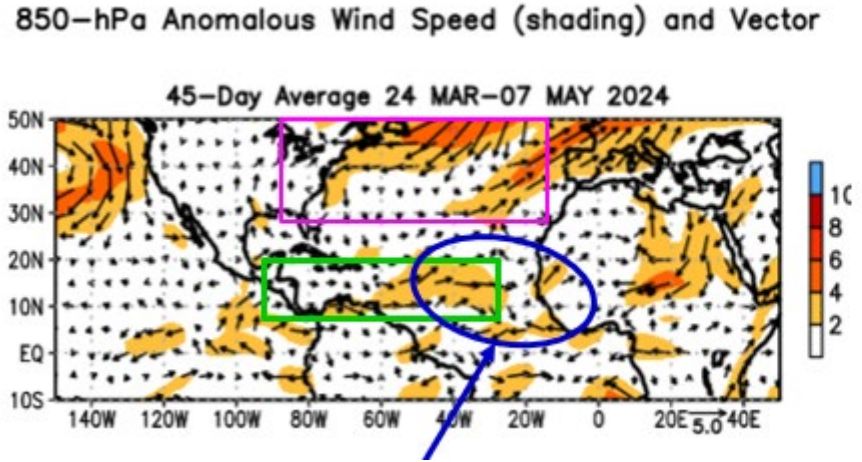
Near-average
Warmer than 2023.

El Niño,
Transition to
La Niña likely

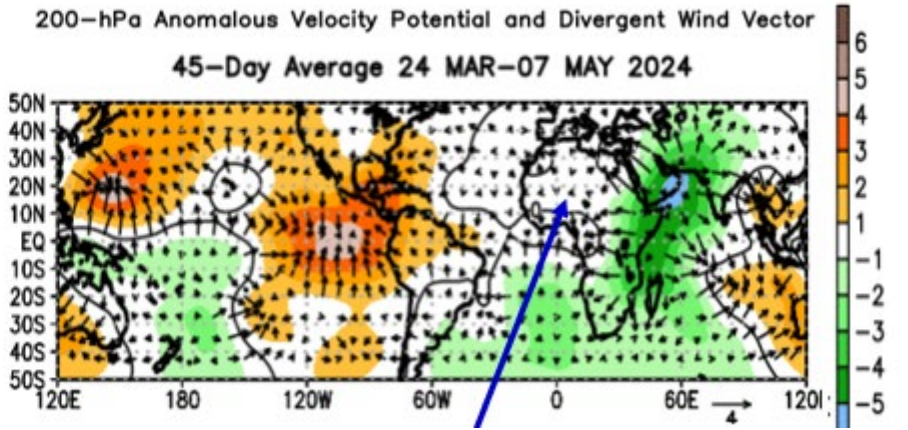
Well above-average
temperatures (+1.22 °C)
Warmer than 2023.

During April, El Niño conditions were present across the central equatorial Pacific Ocean (blue box). A mix of SST anomalies is observed in the off equatorial Pacific. In the Atlantic hurricane MDR (green box), SSTs were well above-average. Strongly above-normal temperatures are evident over much of the eastern North Atlantic with near average SSTs further west. **A warm Atlantic and cool central/eastern Pacific would produce complementary forcings for Atlantic tropical storm and hurricane activity.**

Recent Mid-Level and Upper-Level Atmospheric Anomalies - West African Monsoon



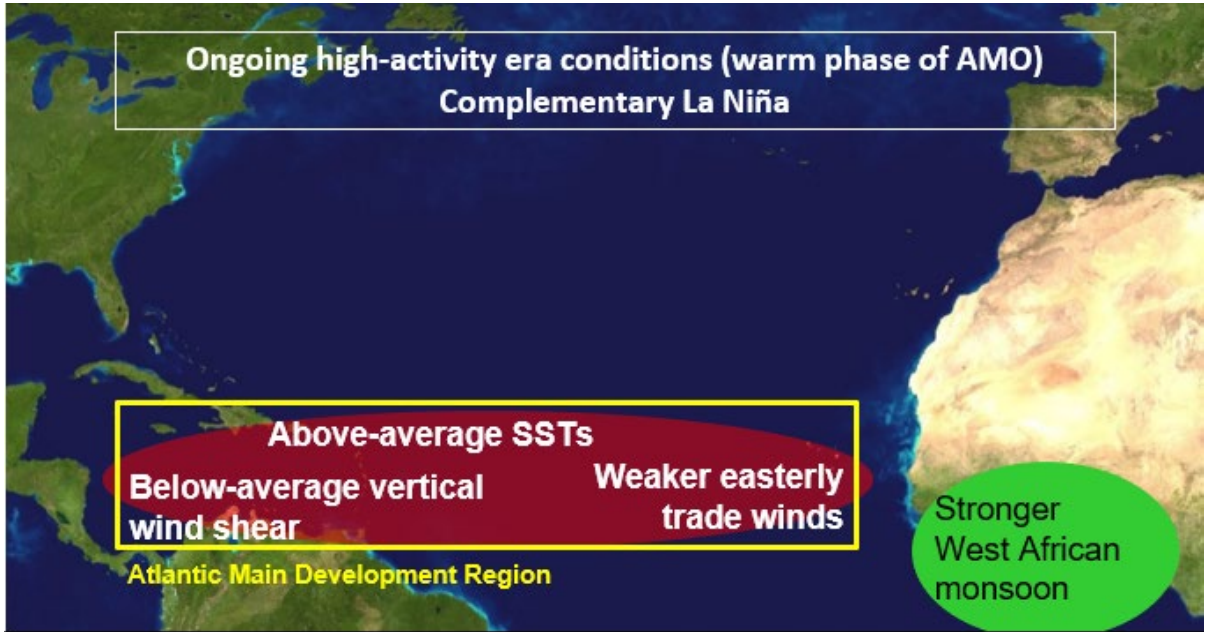
Some westerly anomalies indicate weaker trades/more low-level flow into Western Africa (blue circle).



Near average West African Monsoon

(Left) 850-hPa wind anomalies. Some indications of weakened trade winds evident. Trades are weaker than 2023, closer to 2022/2021, low-level inflow into the West African Monsoon is near normal.
(Right) The upper-level circulation shows little to no signal over Africa, though recent data showed enhanced upper-level circulation features. The variability suggests a more near-normal start to the west African monsoon, or some interaction on intraseasonal time scales.

Expected Atlantic Conditions August-October 2024

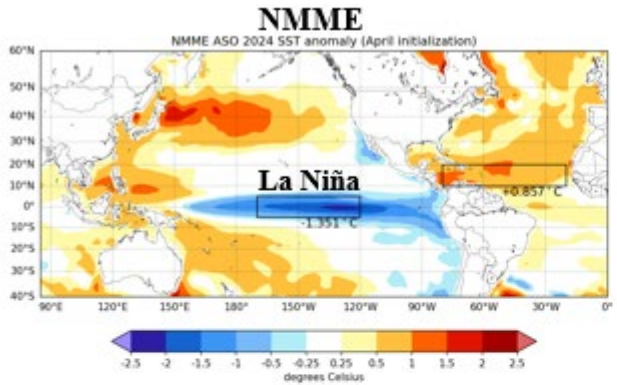


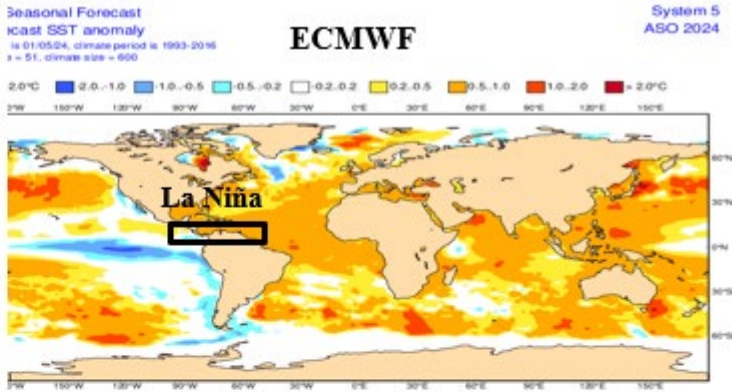
Ongoing high-activity era conditions favor more hurricane activity. These conditions include:
•Above-average sea surface temperatures in the Main Development Region. At or near record warmth.
•Weaker trade winds, weaker vertical wind shear, and stronger West African monsoon.
The predicted La Niña can complement those factors by reducing wind shear and decreasing instability.

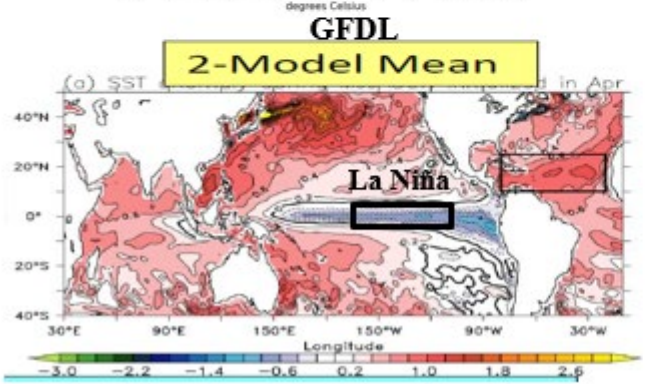
Atlantic Hurricane Season Model Forecast Summary

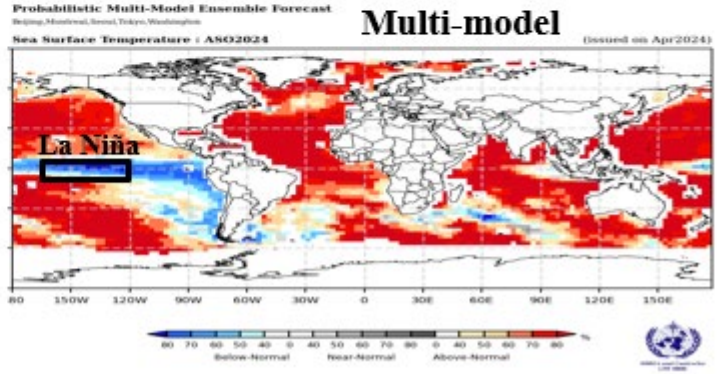
	Model	Named Storms	Hurricanes	Major Hurricanes	ACE (% Median)
Statistical	CPC Regression: Nino 3.4 (-1.7 to 0C) Trailing 5-year Avg MDR-Tropics (0.1 to 0.6C)	19.5-20.2 (19.85)	8-9.1 (8.55)	3.8-4.6 (4.2)	144-192 (168)
Statistical	CPC Binning high-activity era: 5 cases: Nino 3.4 (-1.7 to 0C) MDR SSTA (0.4 to 1C) MDR-Tropics (0.1 to 0.6C)	14-31.56 (22.8)	4.3-14.94 (9.6)	1.9-7.8 (4.8)	89-266 (177)
Statistical	AOML Regression	15-20 (17.5)	9.4-12 (10)	3-6 (4.5)	158-223 (191)
Statistical / Dynamical Hybrid	CFSv2 T128	19-22 (20.5)	10-12 (11)	4-5 (4.5)	174-211 (193)
Statistical / Dynamical Hybrid	NMME (CFSv2, GEM-NEMO, CanCM4i, NCAR)	20-23 (21.5)	10-13 (11.5)	5-6 (5.5)	214-260 (237)
Dynamical	CFS: Hi-Res (Bias adjusted)	15-22 (18.5)	6-11 (8.5)		128-188 (158)
Dynamical	GFDL (SPEAR-MED, HiFLOR-S)	18-25 (21.5)	10-15 (12.5)	3-6 (4.5)	176-254 (215)
Dynamical	ECMWF	18.4-27.2 (22.8)	9.4-16.2 (12.8)		178-331 (254)
Dynamical	UKMET	16-26 (21)	8-14 (11)	2-6 (4)	125-282 (148)
	Guidance Mean	17.2-24.1 (20.7)	8.2-13 (10.6)	3.2-5.9 (4.6)	154-245 (193)
	NOAA Outlook	17-25 (21)	8-13 (10.5)	4-7 (5.5)	150-245 (198)

NMME, ECMWF, GFDL, C3S SST Forecasts



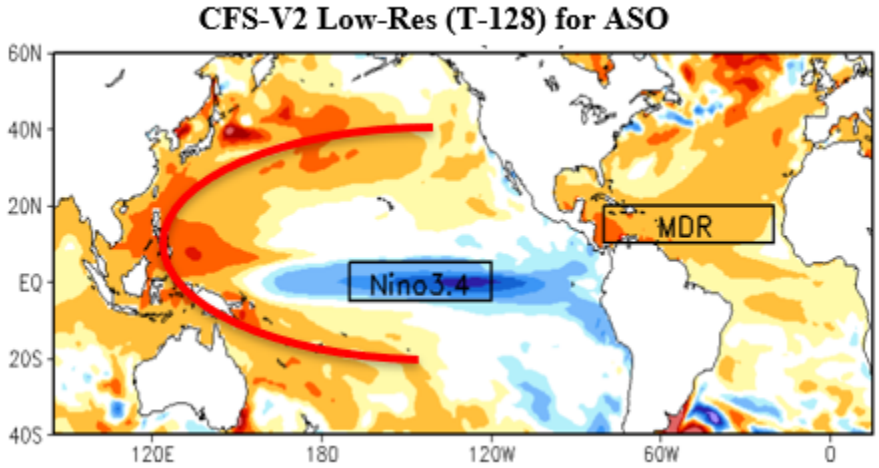


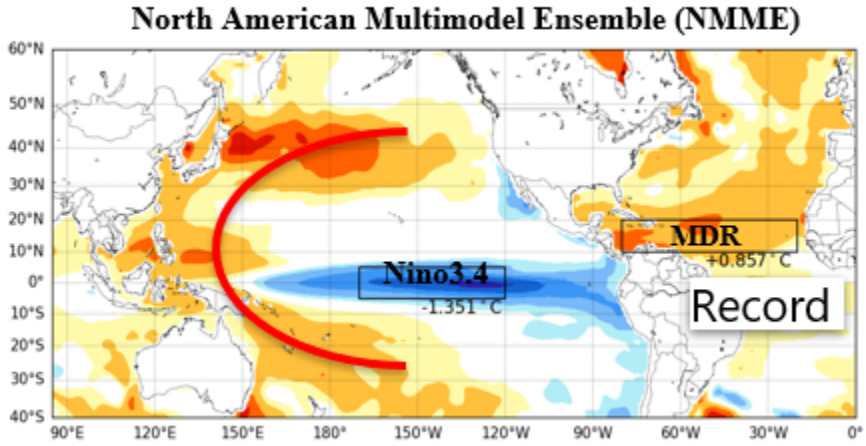




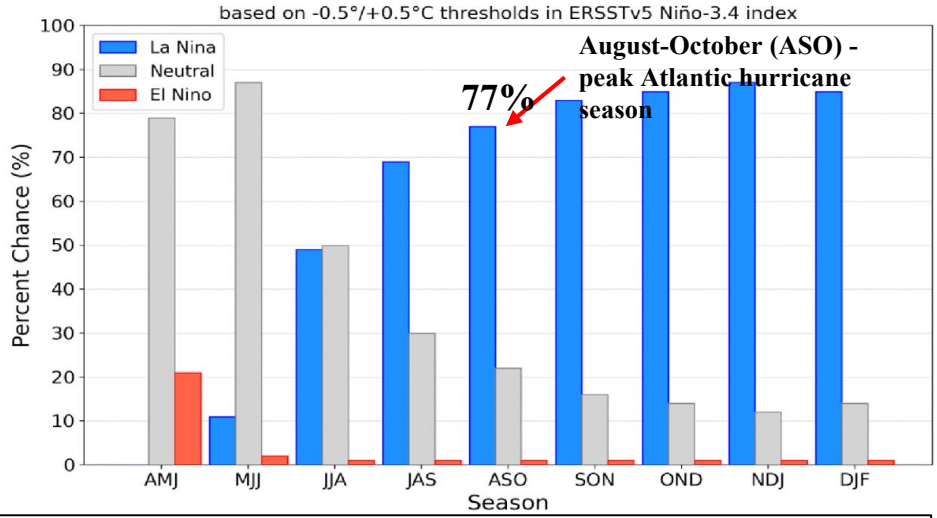
Models call for La Niña and a negative PDO pattern to continue. The official ENSO forecast is for La Niña

Predicted Sea Surface Temperature (SST) Anomalies

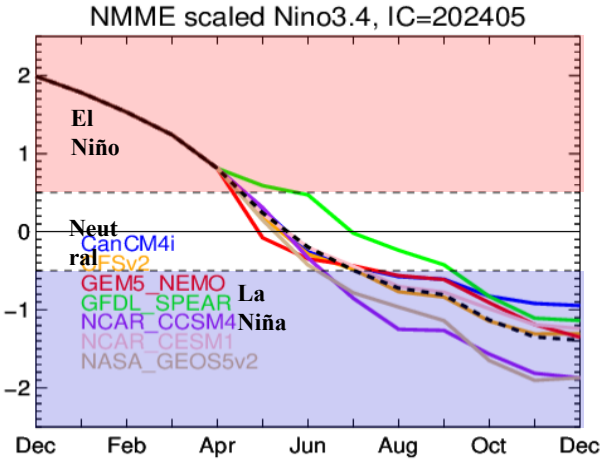




Both the CFS and NMME models are predicting above-average SSTs in the MDR during the peak months (August-October) of the Atlantic hurricane season. Both models are also predicting La Niña during this period.
These conditions would reinforce each other in the Atlantic and the Pacific.



The official CPC forecast issued from May indicates a 77% chance of La Niña during ASO 2024, a 22% chance of ENSO-Neutral, and a 1% chance of El Niño. During JAS, the peak of the East Pacific Hurricane Season, the odds for La Niña are 69%. ENSO forecasts for ASO typically become more reliable as we move through the early summer months. **La Niña favors increased tropical storm/hurricane activity in the Atlantic, decreased in the East Pacific.**



The dynamical model average (dashed black line) predicts La Niña to develop and persist through the peak months of the hurricane season (ASO time period). ENSO forecasts for ASO typically become more reliable as we move through the early summer months.

Caption: (Right) Model predicted seasonal SST anomalies (°C) for the equatorial Pacific Ocean Niño-3.4 region (see inset, between 170°W-120°W, 5°N-5°S). Colored lines correspond to the models indicated at left. NOAA's thresholds for El Niño and La Niña, are shown in pink and blue shading, respectively. Issued by the NOAA Climate Prediction Center (CPC) and consisting of contributing modeling centers (NCEP, ECCC, GFDL, NCAR, NASA). (Left) Seasonal probabilities for El Niño (Red bars), ENSO-neutral (Grey bars), and La Niña (Blue bars). Seasons are indicated by their 3-letter abbreviation (AMJ is April-May-June, etc.). This is issued by the NOAA Climate Prediction Center (CPC) and NOAA associated partners.

NMME-based Hybrid Prediction System; Atlantic Method 1

Bold/underline: Unique to this method Red: New for 2024

- Predictors:

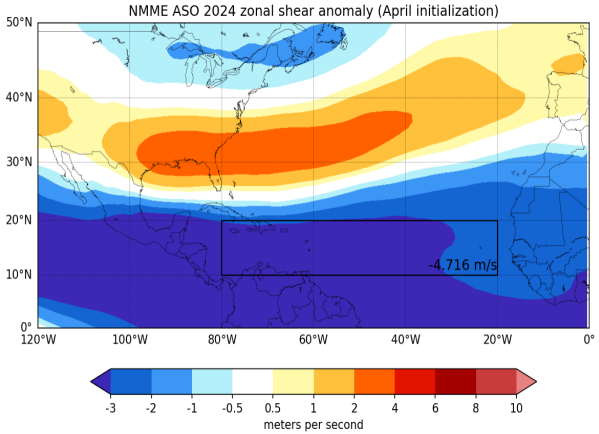
  Forecast wind shear (U_{200}-U_{850}) for ASO over the MDR (10-20°N, 20-80°W)
  and observed SST for the preseason (JFM) over the NATL (55-65°N, 30-60°W)

- Predictands (seasonal total):

  number of anomalous named storms, hurricanes, and major hurricanes

  anomalous percent of median ACE index (1951-2020)

  All are taken with respect to the full 1991-2020 climatology.



- Hindcast data:

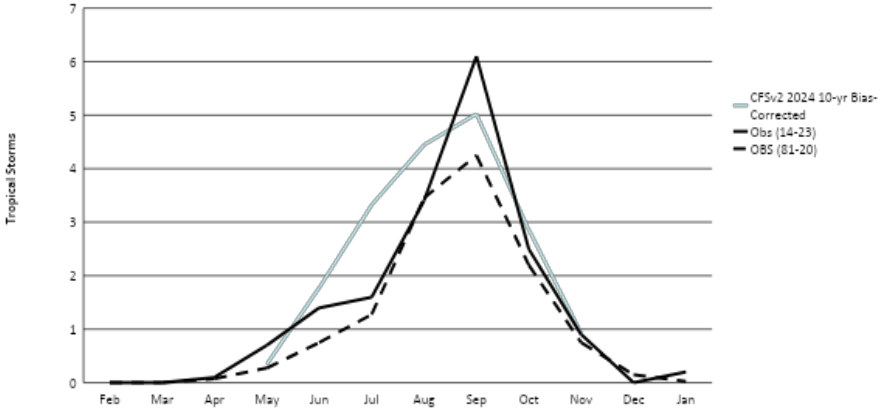
  Period is 1991-2020

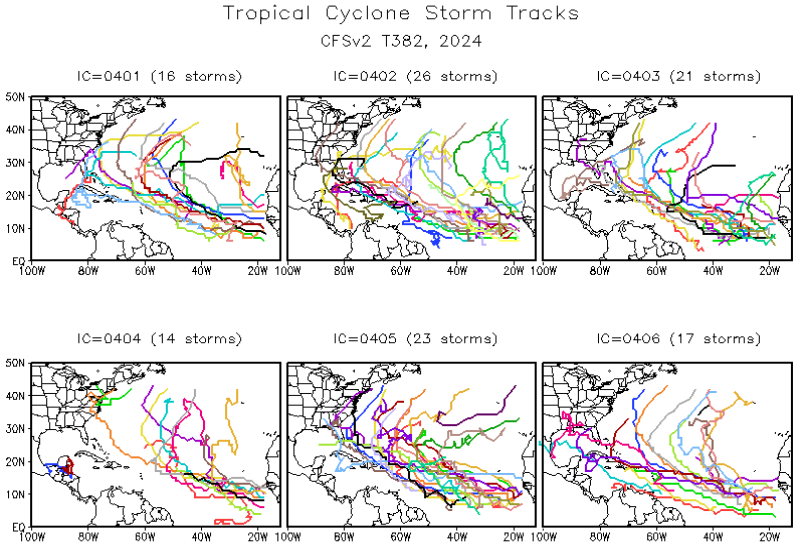
  Models are initialized in April

  Models are CCSM4 (10 members), CESM1 (10), CFSv2 (32), CanCM4i (10), and GEM-NEMO (10)

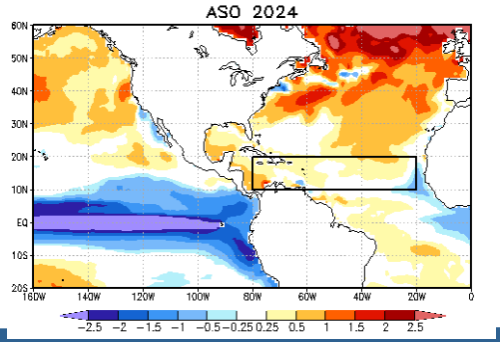
- Hindcast evaluations are performed in a cross-validation mode (leave-one-out)

Hi Resolution CFS

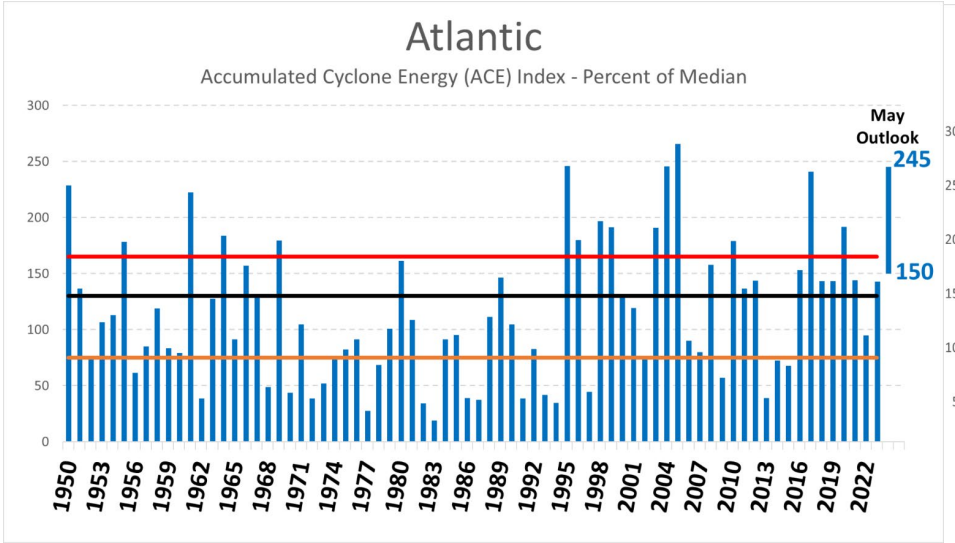


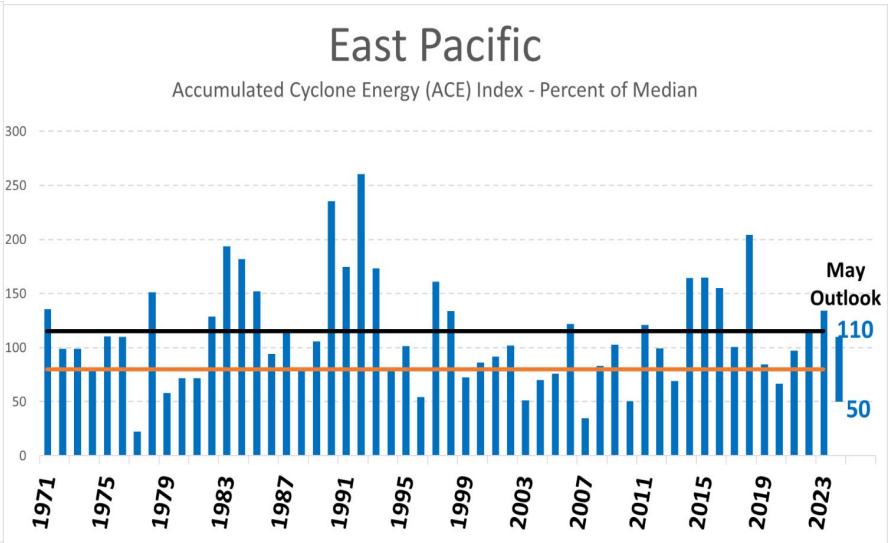


The season will start strong with above-normal activity from June to August and then end the season closer to climatology.



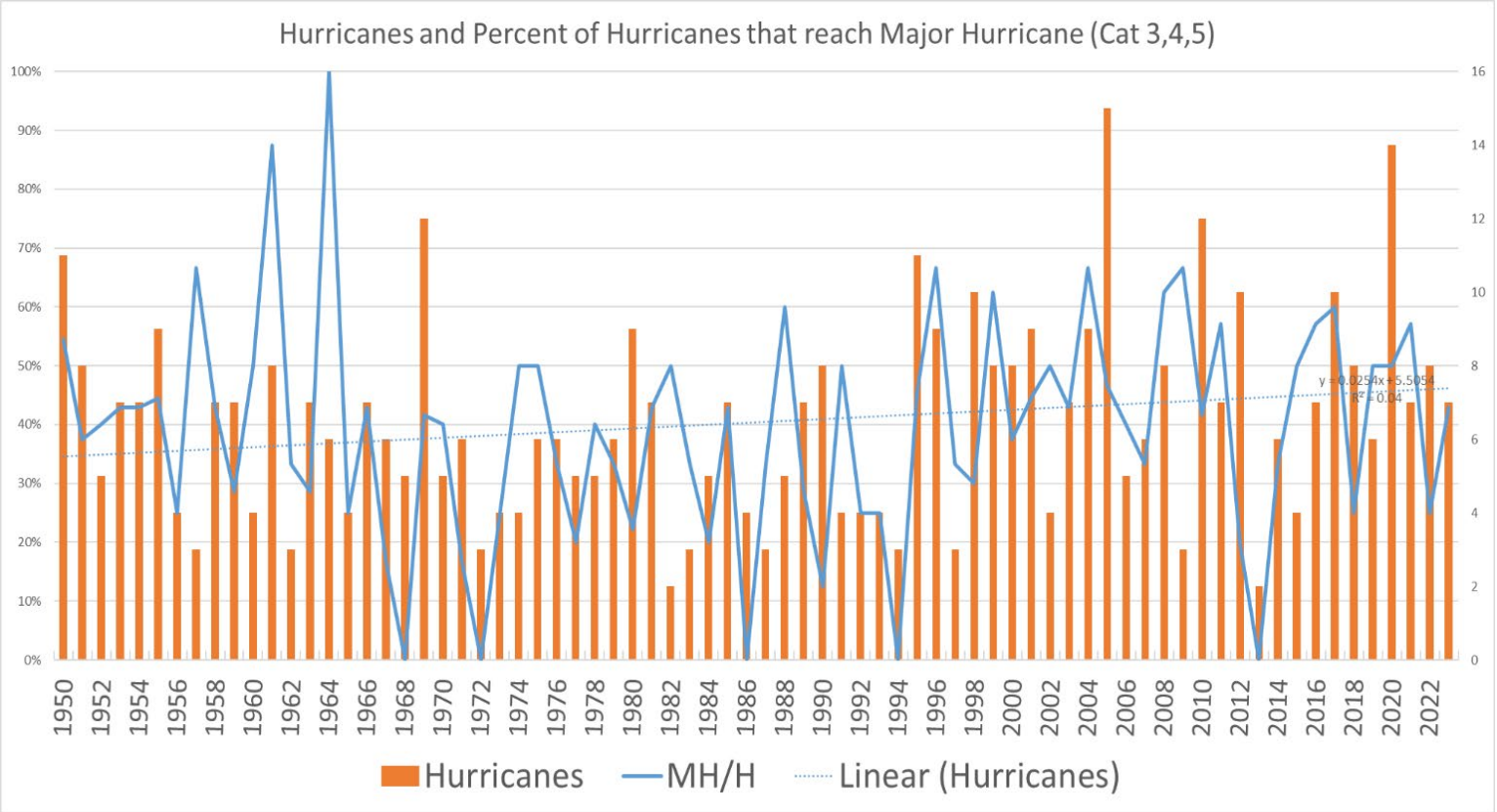
2024 Atlantic and East Pacific Outlooks
Historical Perspective





(Left) NOAA's 2024 Atlantic hurricane season outlook predicts a 70% probability for an ACE range of 150%-245% of the median
(Right) NOAA's 2024 East Pacific hurricane season outlook predicts a 70% probability for an ACE range of 50%-110% of the median.

Caption: Seasonal Accumulated Cyclone Energy (ACE) indices (Blue bars) and NOAA's 2024 outlook range with a 70% probability of occurrence (rightmost column in each panel) are shown for (Left) the Atlantic basin and (Right) the East Pacific basin. Black (orange) lines indicates NOAA's ACE thresholds for classifying hurricane season strength as above (below). For the Atlantic, the 165% threshold (red line) reflects a hyper-active season.


Hurricanes and Percent of Hurricanes that reach Major Hurricane (Cat 3,4,5)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
16
14
12
10
8
6
4
2
0
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
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1972
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1982
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1992
1994
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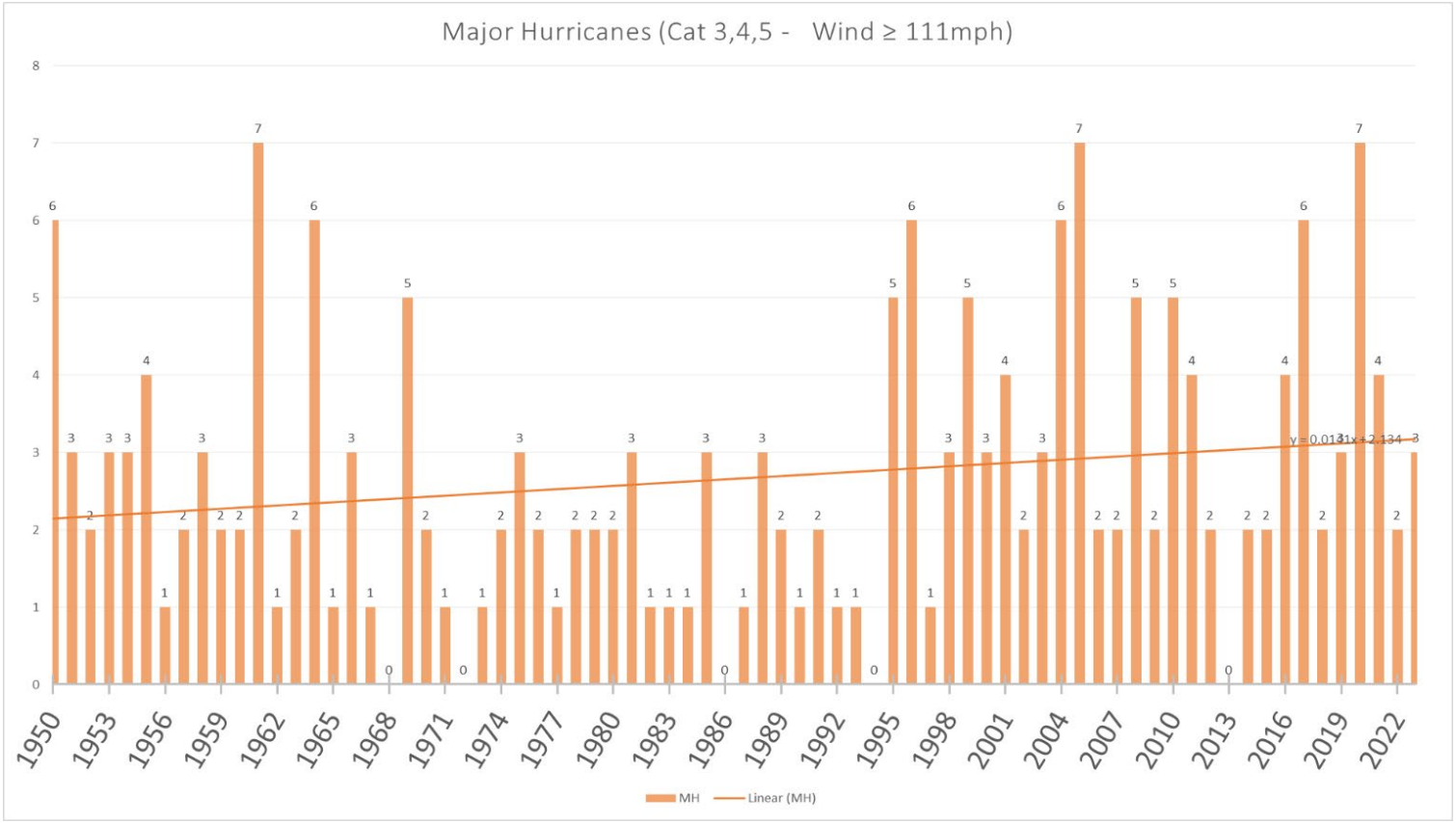
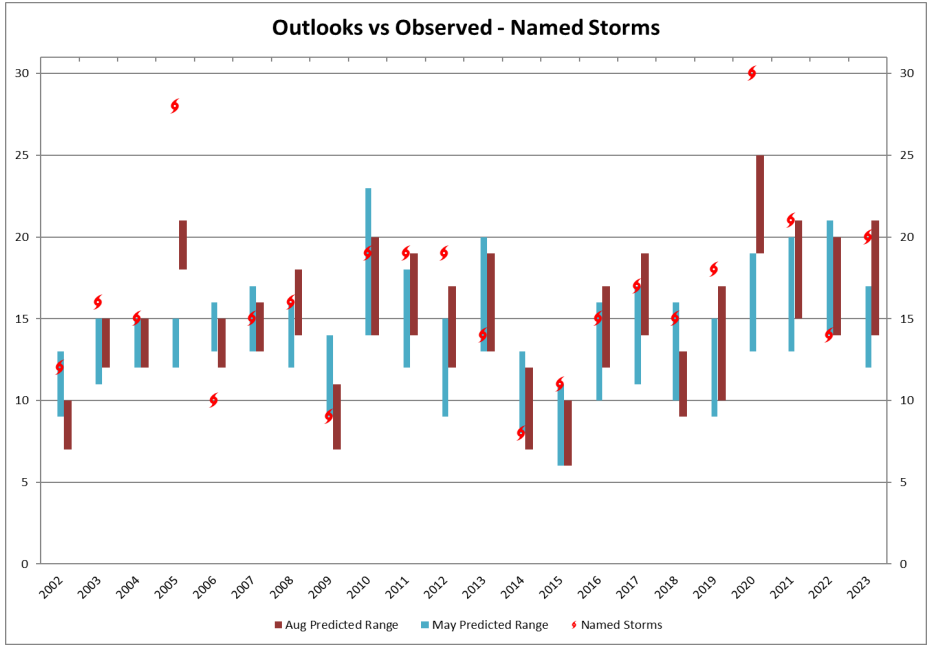
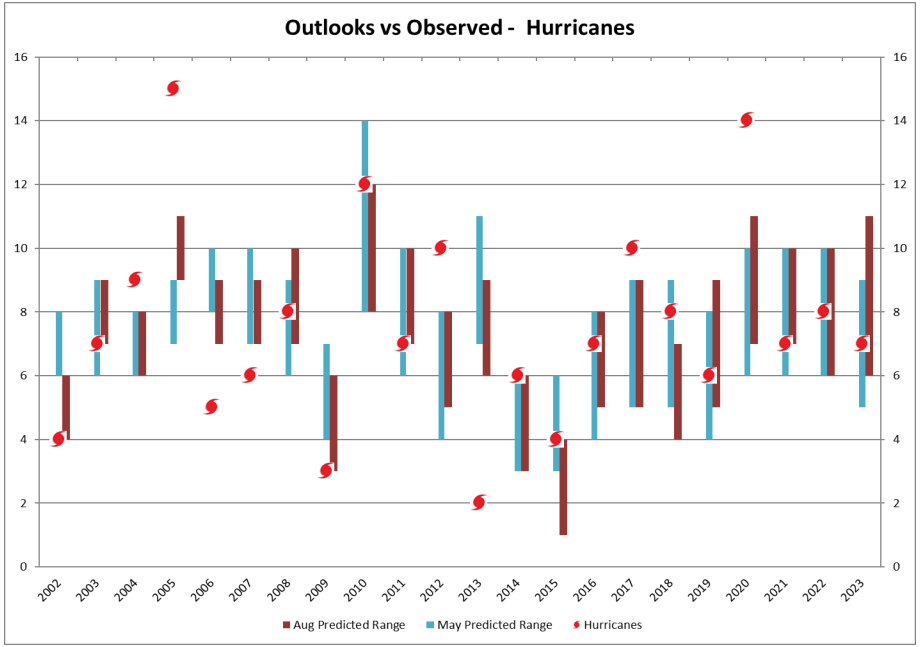
2008
2010
2012
2014
2016
2018
2020
2022
Hurricanes
MH/H
Linear (Hurricanes)


Major Hurricanes (Cat 3,4,5 - Wind ≥ 111mph)
MH
Linear (MH)

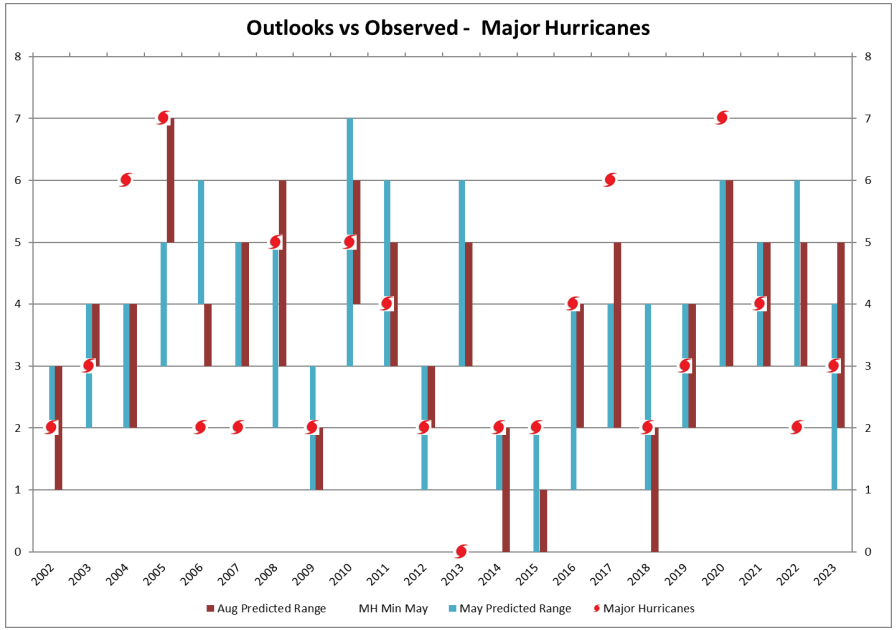
Season Activity and Type	May 2023	August 2023	Actual Observed
Chance Above Normal	30%	60%	Above
Chance Near Normal	40%	25%	
Chance Below Normal	30%	15%	n/a
Total Named Storms	12 - 17	14 – 21	

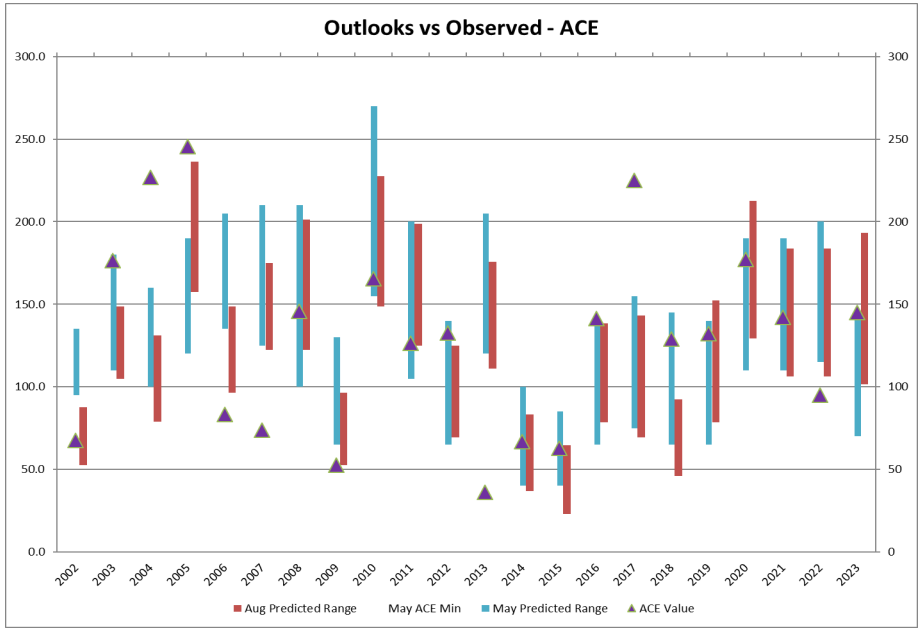
Verification





Verification (1/2)





Verification (2/2)

2009-2023

DATE	All	NS	H	MH	ACE
May - Since 2009	62%	60%	67%	73%	47%
August - Since 2009	65%	67%	67%	67%	60%

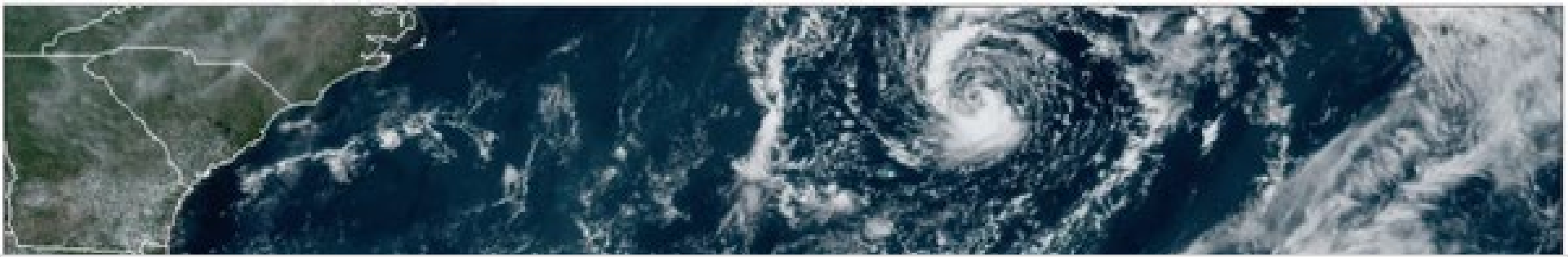
May

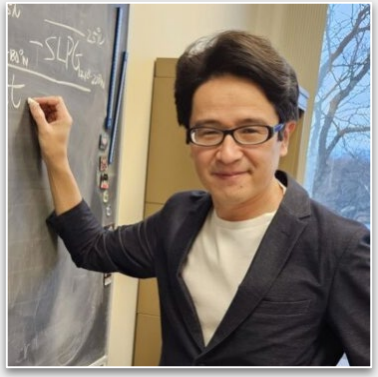
Outlook	NS	H	MH	ACE
stddev	2.7	1.7	1.2	35.3
Range	6.0	4.0	3.0	74.0
bias	-2.6	-0.4	-0.2	-8.1
RMSE	5.4	3.0	1.9	58.7

Aug

Outlook	NS	H	MH	ACE
stddev	3.7	1.9	1.4	44.4
Range	5.0	3.0	2.0	58.2
bias	-1.5	-0.3	0.2	4.4
RMSE	3.7	2.5	1.6	52.5

Obs	NS	H	MH	ACE
stddev	5.2	3.1	1.8	49.8





Hurricane Seasonal Outlooks & Long Term Climate Change

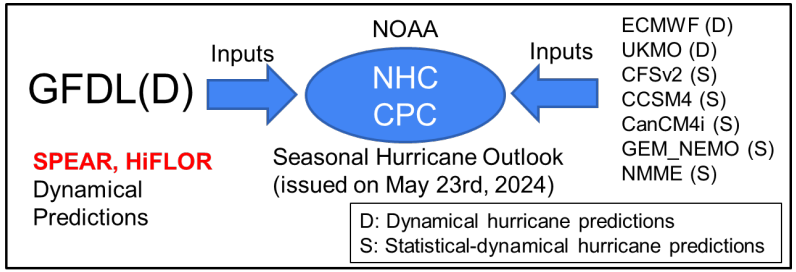
Hiroyuki Murakami

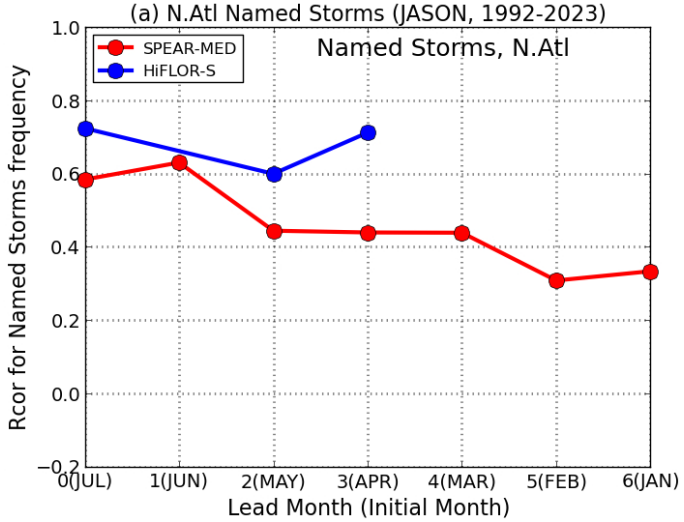
Research Physical Scientist | NOAA Geophysical Fluid Dynamics Laboratory | Seasonal to Decadal Variability and Predictability Division

Experimental Seasonal Hurricane Predictions at NOAA's GFDL

•NOAA-GFDL has been supporting experts at the National Hurricane Center and Climate Prediction Center since 2017 for the hurricane seasonal outlook.

•NOAA-GFDL is the only U.S. institution that provides **dynamical** seasonal hurricane forecasts (**SPEAR and HiFLOR**)



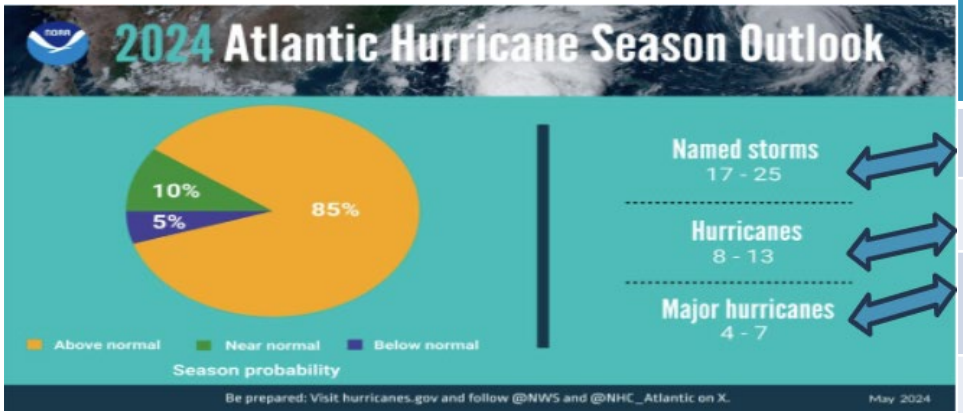


- GFDL's seasonal predictions have demonstrated high skill in forecasting tropical cyclones in the North Atlantic.
- The correlation between observed named storms and predictions from the initial July 1st forecast is +0.7.

Murakami et al. (2024, submitted)

Extremely active hurricane season is predicted for the 2024 summer in the North Atlantic

NOAA's 2024 Seasonal Hurricane Outlook



Predicted from the May 1st GFDL predictions

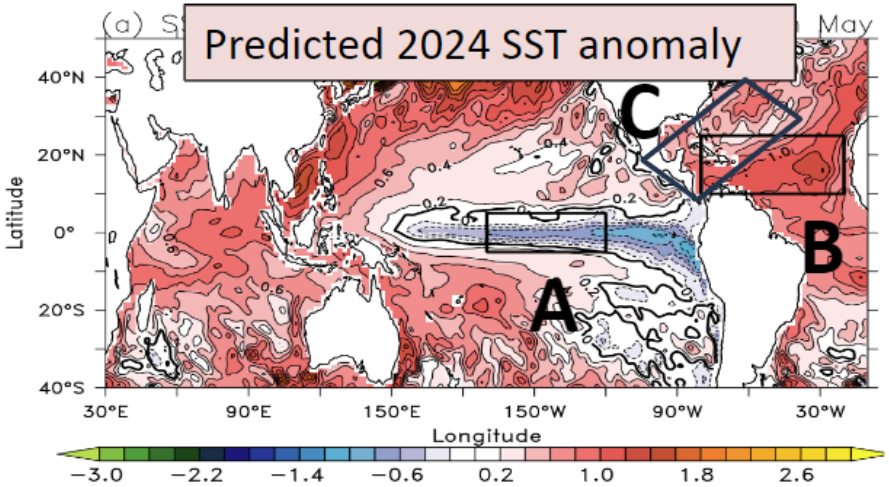
	GFDL predictions	Observed climatology	Anomaly (Standard deviation)
Named Storms	17-23	15	+1.8σ
Hurricanes	9-14	7	+2.4σ
Major Hurricanes	4-7	3	+2.3σ
ACE (10^5 m^2 s^{-2})	4-6	3.2	+1.9σ

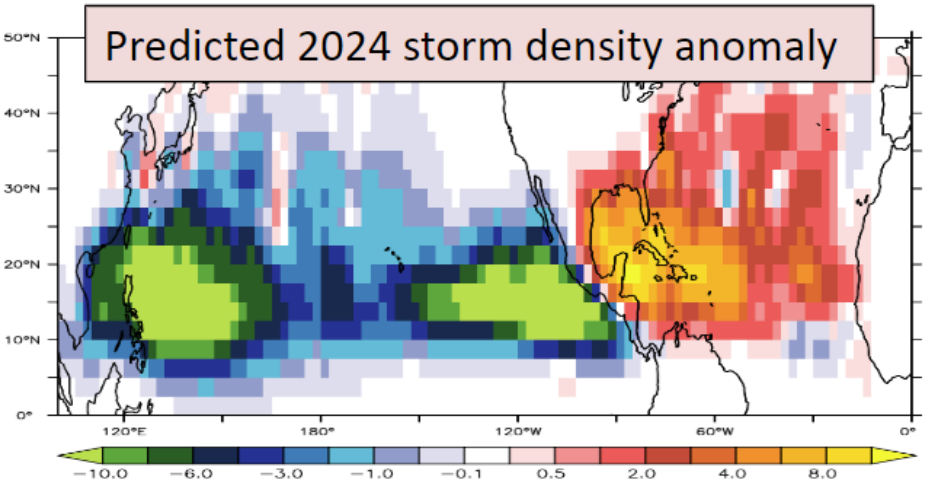
- An extremely active hurricane season is predicted for the summer of 2024 in the North Atlantic
- The GFDL's 2024 hurricane predictions are consistent with NOAA's hurricane seasonal outlook

QUIZ: What causes the predicted active hurricane season in 2024?

The May 1st initial predictions for this summer by the GFDL-SPEAR model

Anomaly relative to the 1992-2023 mean



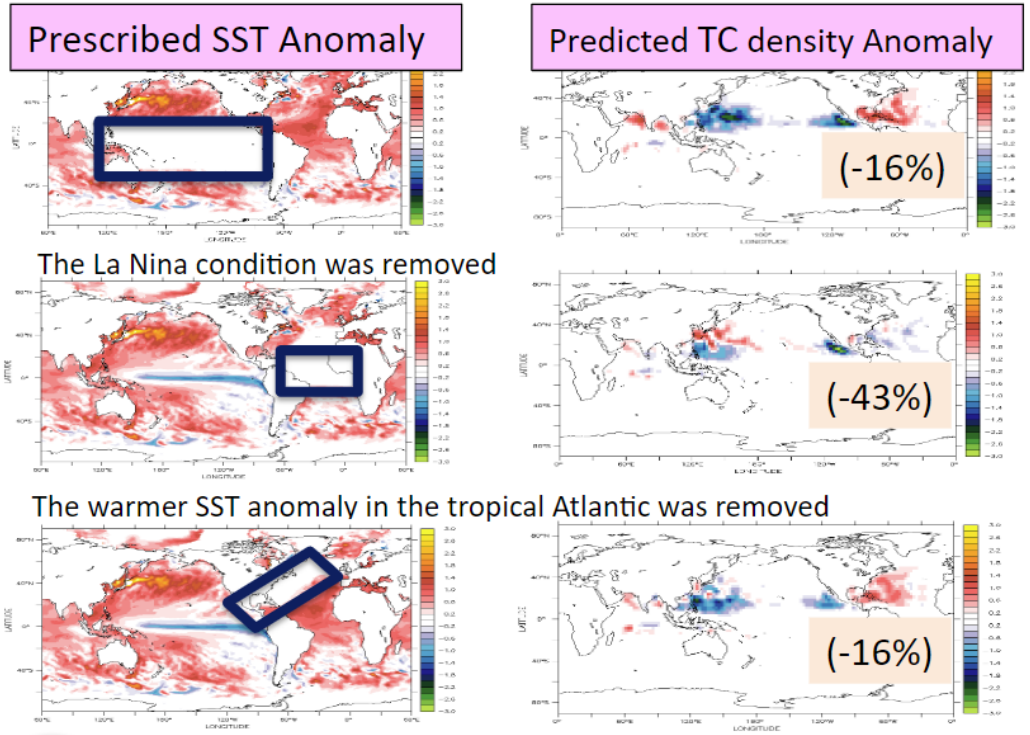


Quiz Options:

A. Developing La Niña?
B. Warmer Tropical Atlantic?
C. Warmer off the coast of North America?

Idealized Seasonal Prediction for the Summer of 2024 by SPEAR

The warmer tropical Atlantic could be a major contributor to the active 2024 hurricane season.



A. La Niña?

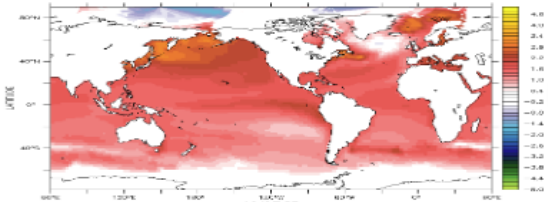
B. Warmer Tropical Atlantic?

C. Warmer off the coast of North America?

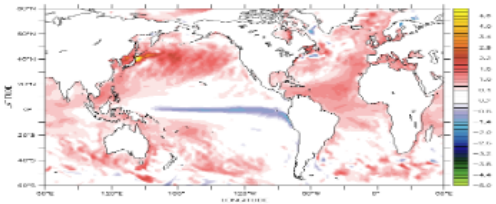
Detailed methodology: Murakami et al. (2018, Science)

What would the future look like if conditions similar to those in 2024 were to happen again?

SSP2-4.5 mean SST change (2081-2100 minus 1991-2010 by CMIP6 models)

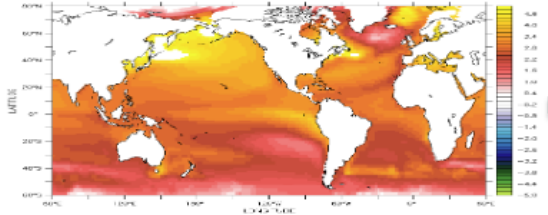


Predicted 2024 SST Anomaly

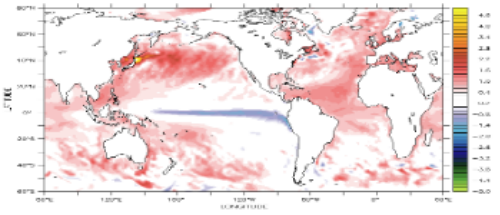


CO_2: 597 ppmv

SSP5-8.5 mean SST change (2081-2100 minus 1991-2010 by CMIP6 models)



Predicted 2024 SST Anomaly



CO_2: 998 ppmv

The current CO_2 level is around 425 ppmv

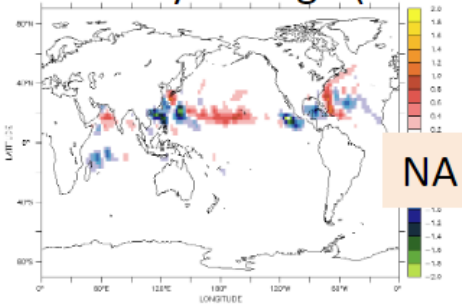
Will we see more active hurricane season than 2024?

Detailed methodology: Murakami et al. (2018, Science)

What would the future look like if conditions similar to those in 2024 were to happen again? (2/2)

SSP2-4.5 mean SST change (2081-2100 minus 1991-2010)

TC Density Change (2090 – 2024)

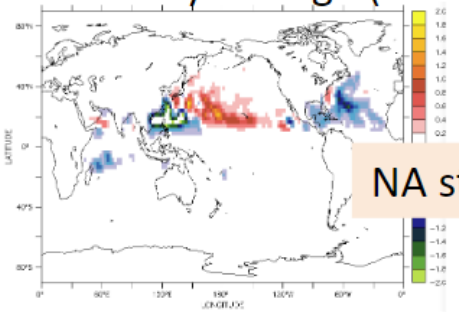


No change under the SSP2-4.5 scenario

NA storms: 0% change relative to 2024

SSP5-8.5 mean SST change (2081-2100 minus 1991-2010)

TC Density Change (2090 – 2024)

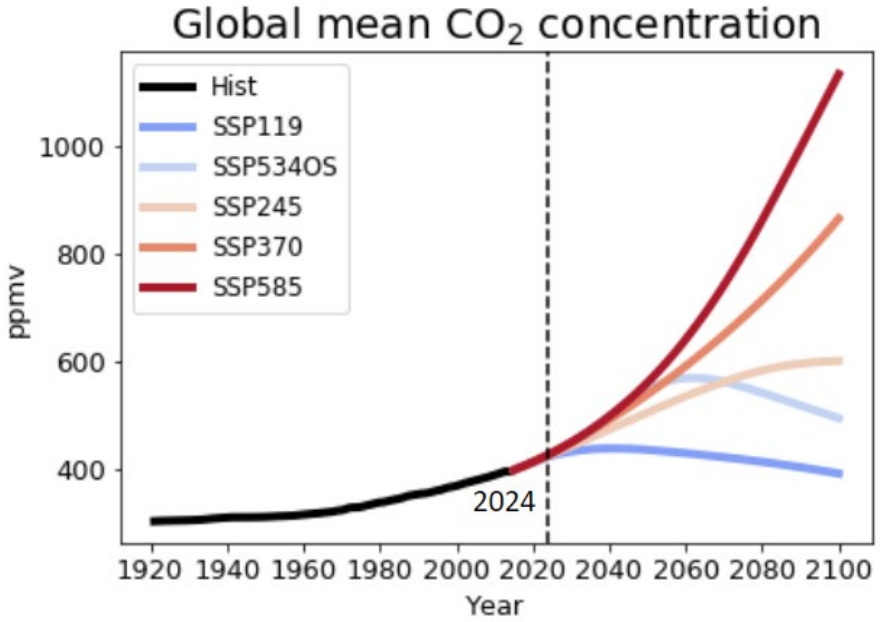


Projected decrease under the SSP2-4.5 scenario

NA storms: -30% change relative to 2024

GFDL-SPEAR tends to project decreased frequency of tropical cyclones in the North Atlantic in the future.

Long-term historical & future simulations by the GFDL-SPEAR model (1/2)



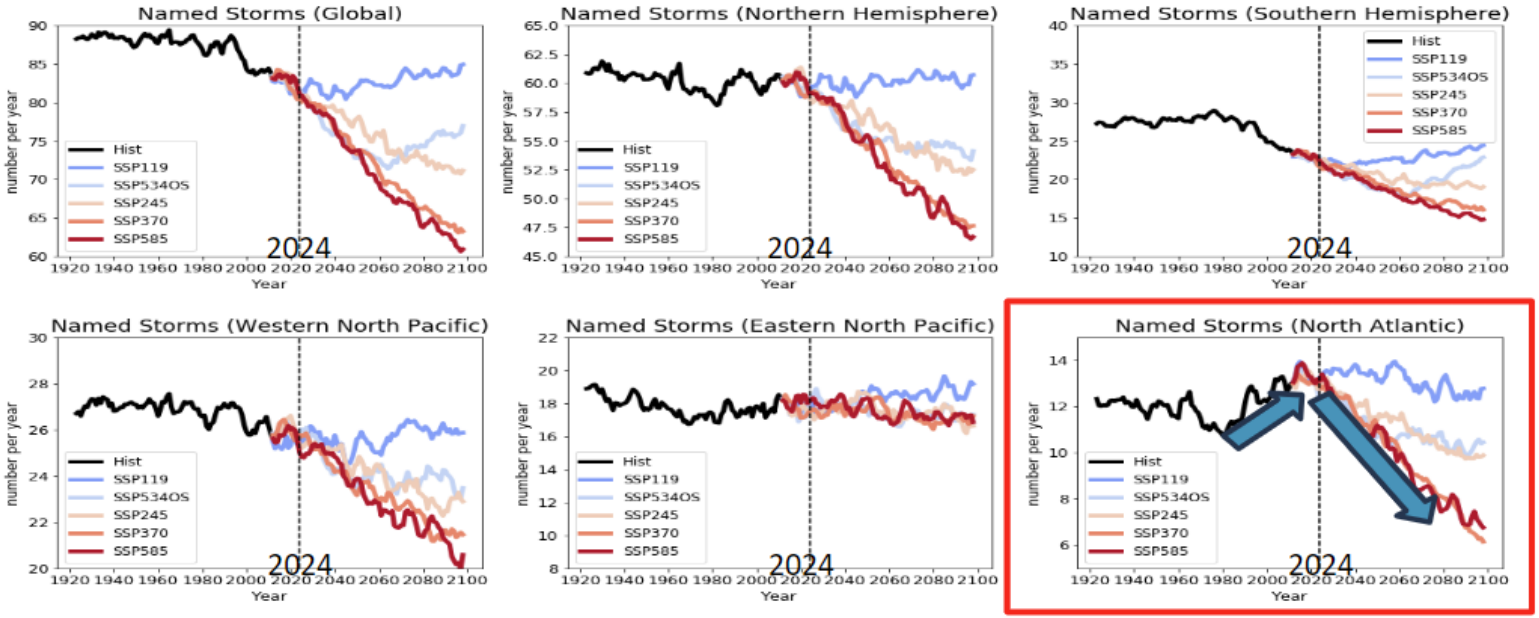
Large-ensemble simulations by the GFDL-SPEAR model

- 30 ensemble member initialized in 1921.
- 1921-2014: Historical forcing (CO_2, Aerosols, etc.)
- 2015-2100: Future forcing under the various SSP scenarios

Murakami et al. (2024, submitted)

Long-term historical & future simulations by the GFDL-SPEAR model (2/2)

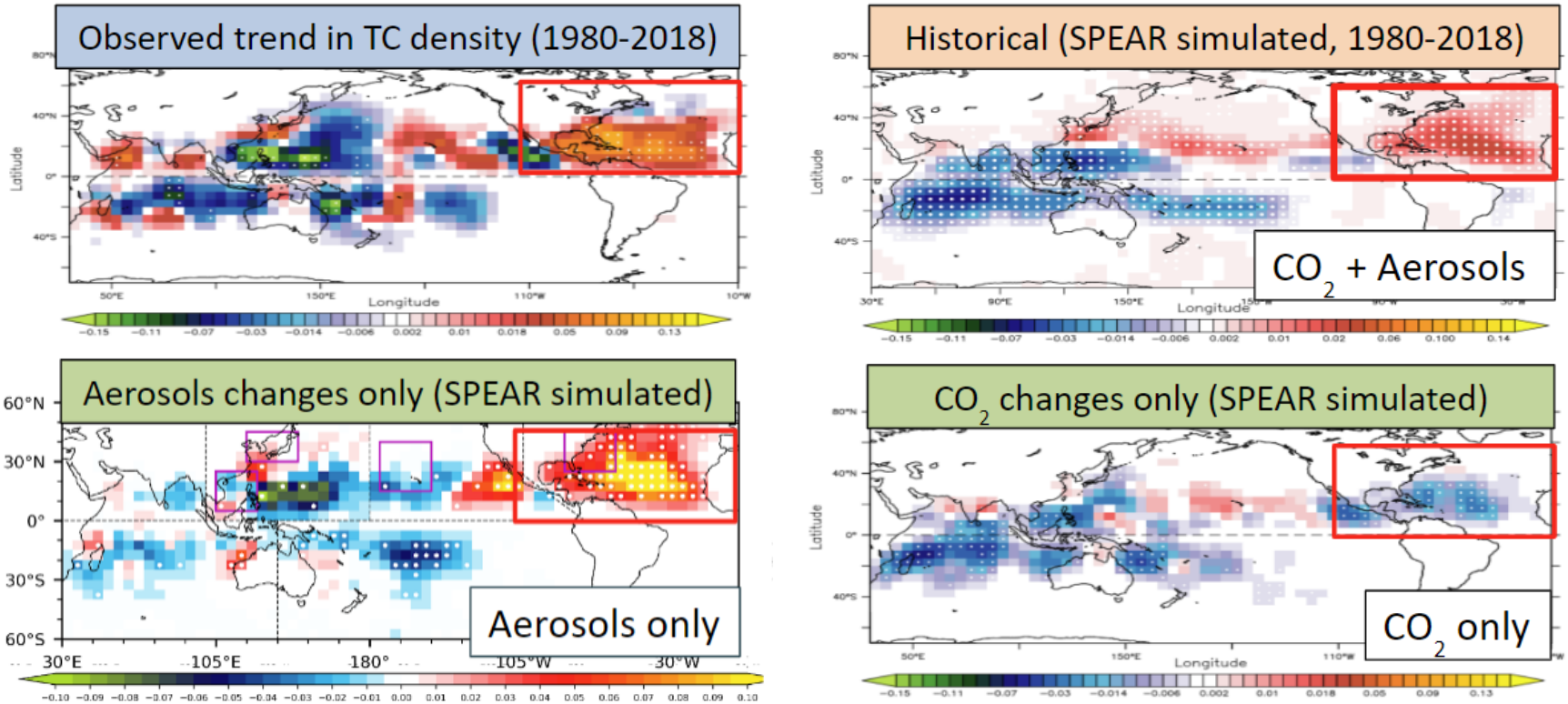
Simulated frequency of named storms (≥ 34 knots)



Murakami et al. (2024, submitted)

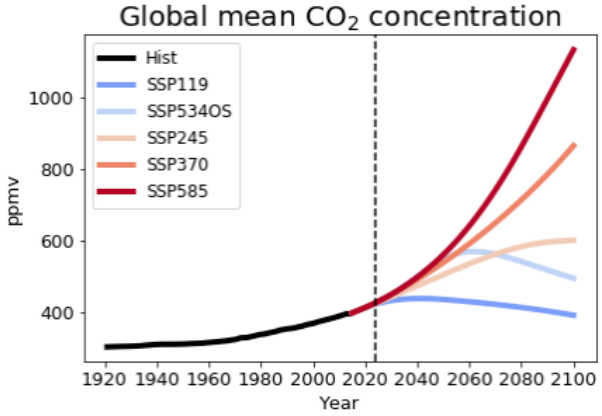
The changes observed in tropical cyclones in the past may not necessarily apply to the future

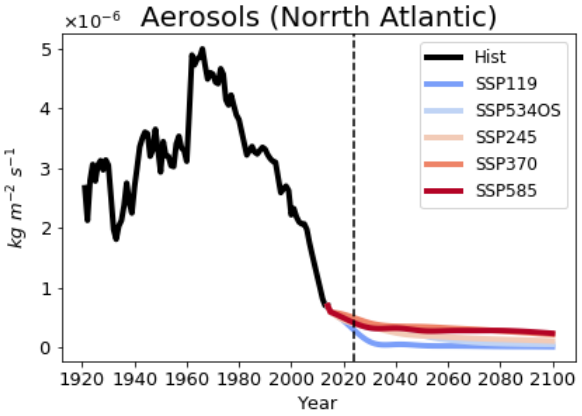
Observed and simulated trends in storm density over the period 1980-2018



Murakami et al. (2020, PNAS), Murakami (2022, Sci. Adv.), Wang et al. (2023, npj. Clim. Atmos)

The past changes in tropical cyclones may not apply to the future





Substantial increases in CO_2 are expected, whereas anthropogenic aerosols over the North Atlantic may not change much in the future.

According to the SPEAR future projections, frequency of tropical cyclones in the North Atlantic is projected to decrease due to the dominant effect of CO_2 .

Murakami et al. (2020, PNAS), Murakami (2022, Sci. Adv.), Murakami (2024, submitted)

Key Takeaways

- GFDL-SPEAR predicts an extremely active hurricane season in the North Atlantic in 2024, consistent with NOAA's hurricane seasonal outlook.
- The predicted active 2024 hurricane season is largely attributed to the anticipated warm sea surface temperatures in the tropical Atlantic Ocean.
- A hurricane season similar to 2024 in the future climate may be less active than 2024.
- SPEAR projects a decrease in the frequency of tropical cyclones in the North Atlantic in the future, primarily due to the dominant effect of increasing CO_2 levels. This trend contrasts somewhat with the past 40 years, which have shown an increased frequency of tropical cyclones, partially attributed to decreased aerosol emissions.

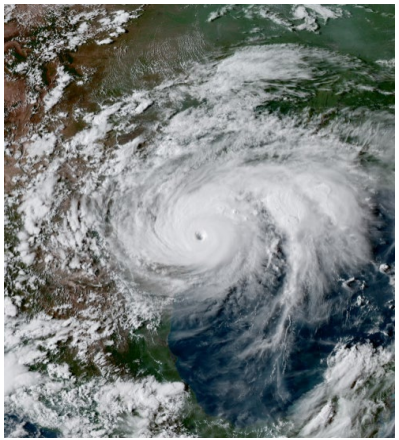
Climate Change and Hurricane Activity

Tom Knutson

Senior Scientist | NOAA Geophysical Fluid Dynamics Laboratory
Division Leader | Weather and Climate Dynamics Division

Atlantic Hurricanes and Climate Change

Thomas R. Knutson
NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ
Former Chair, WMO Expert Team on Tropical Cyclones and Climate Change

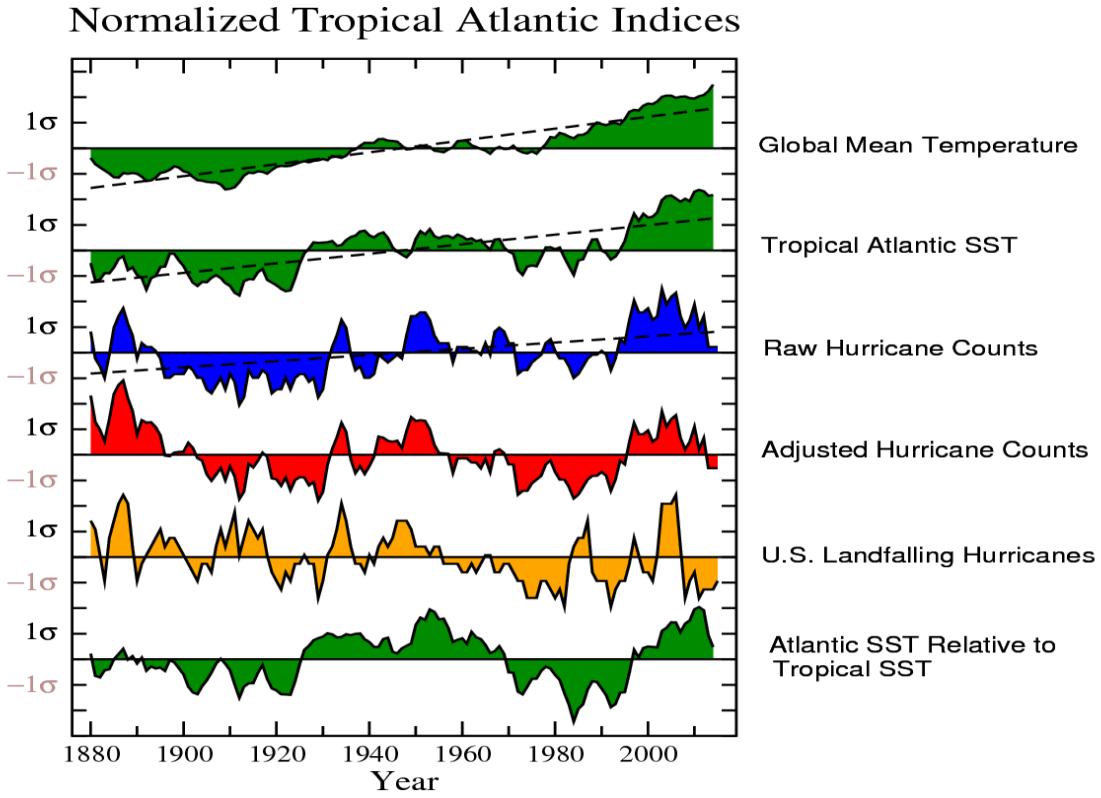


June 2024

My homepage:
www.gfdl.noaa.gov/tom-knutson-homepage

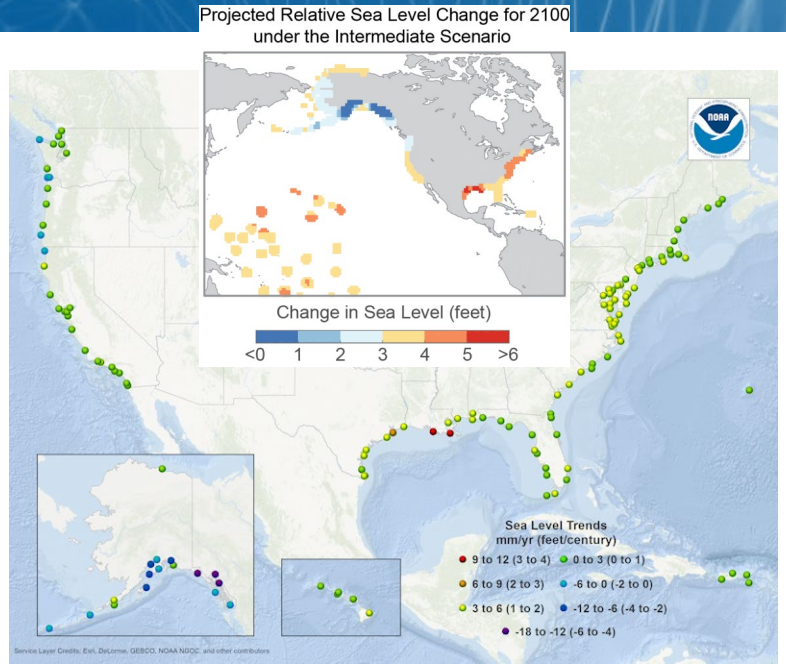
Topical webpage:
https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

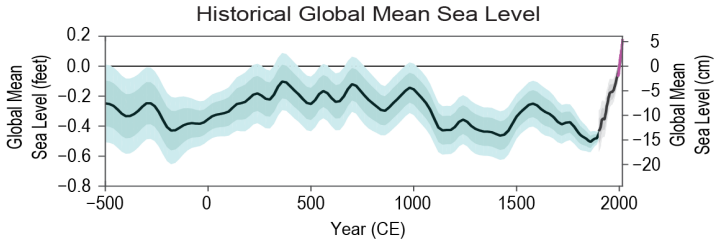
No clear evidence for detectable century-scale trend in Atlantic hurricane frequency



Source: Vecchi and Knutson (2011). Five-ye running means, updated throug 2017.

Sea Level Rise





- Global sea level has risen by about 7–8” inches since 1900, and about 3” since 1993 (very high confidence).
- Human-caused climate change has made a substantial contribution to global sea level rise since 1900 (high confidence).
- Global sea level (relative to year 2000) is very likely to rise by 0.3–0.6 feet by 2030, 0.5–1.2 feet by 2050, and 1.0–4.3 feet (30–130 cm) by 2100 (very high confidence in lower bounds; medium confidence in upper bounds for 2030 and 2050; low confidence in upper bounds for 2100).

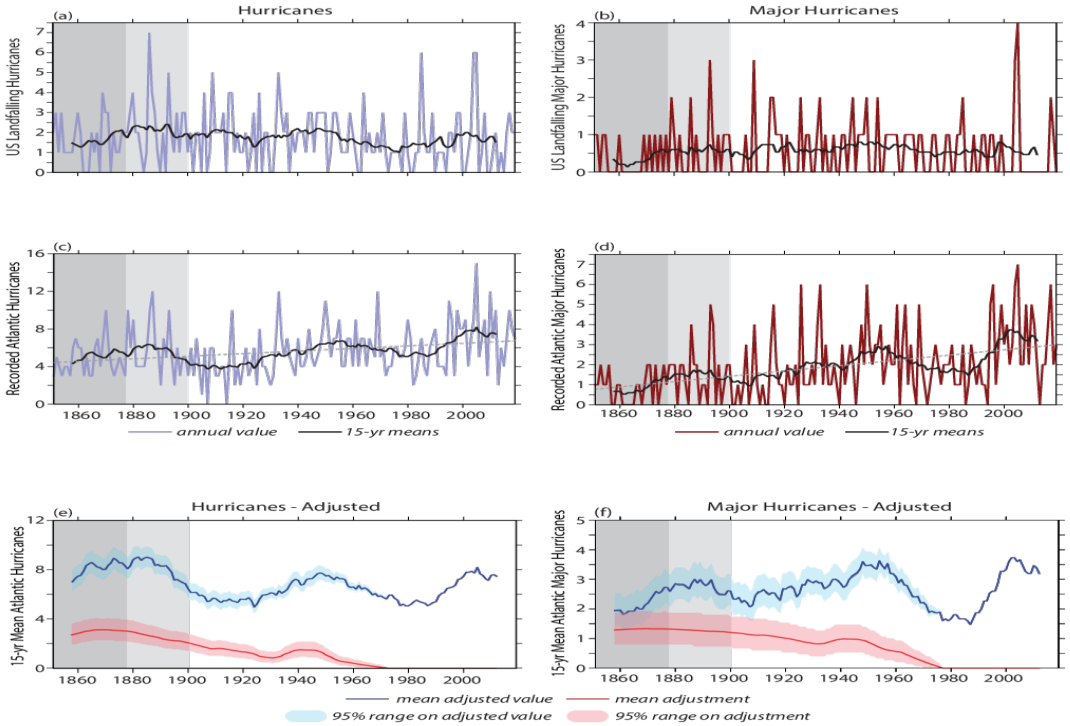
Source: Climate Science Special Report, 2017.

1. U.S. landfalling hurricane and major hurricane counts have no clear trend.
2. Atlantic basin-wide hurricane and major hurricane counts have increasing trends.
3. After adjustment for missing storms, there is no longer a trend in basin-wide counts.

US Landfalling (original data)

Atlantic basin-wide (original data)

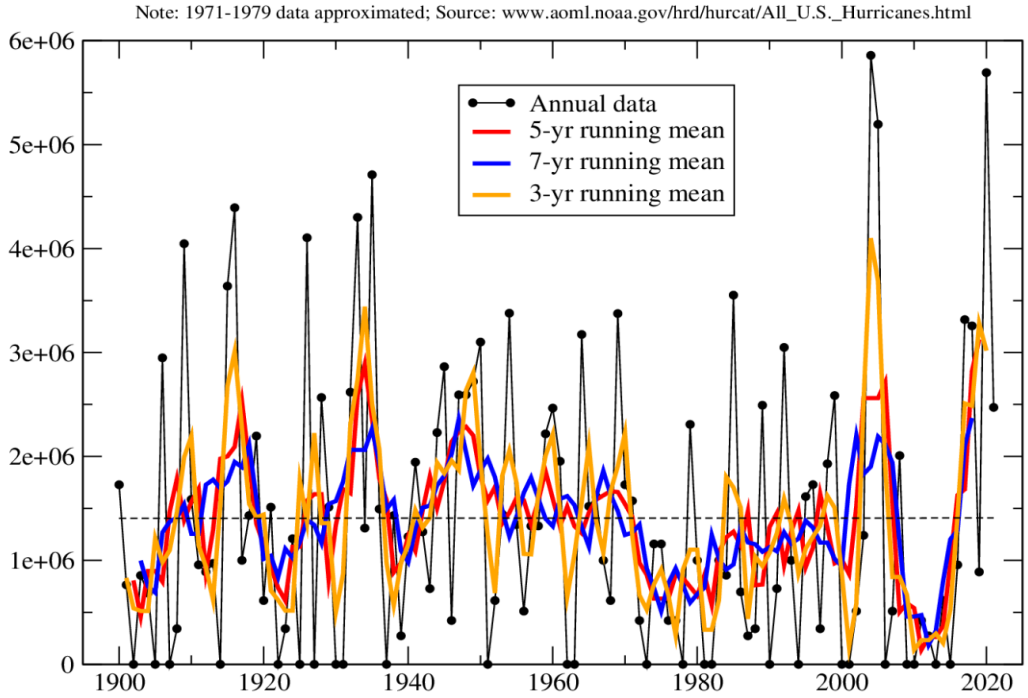
Atlantic basin-wide (adjusted data)



Data through 2019 season.

Source: Vecchi et al. Nat. Comm. 2021.

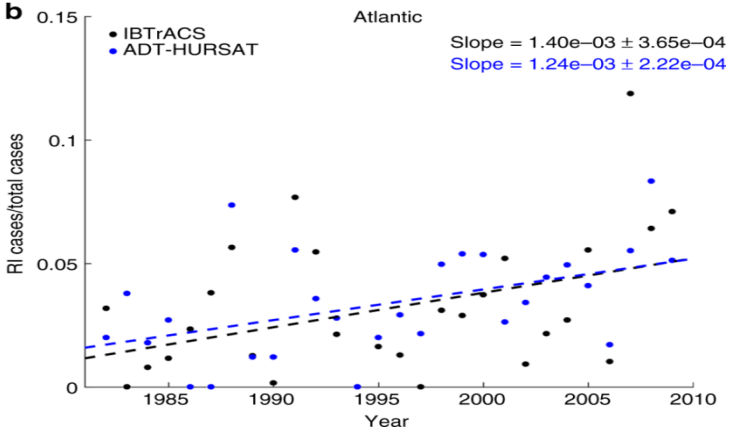
US Landfalling PDI (1901-2021)

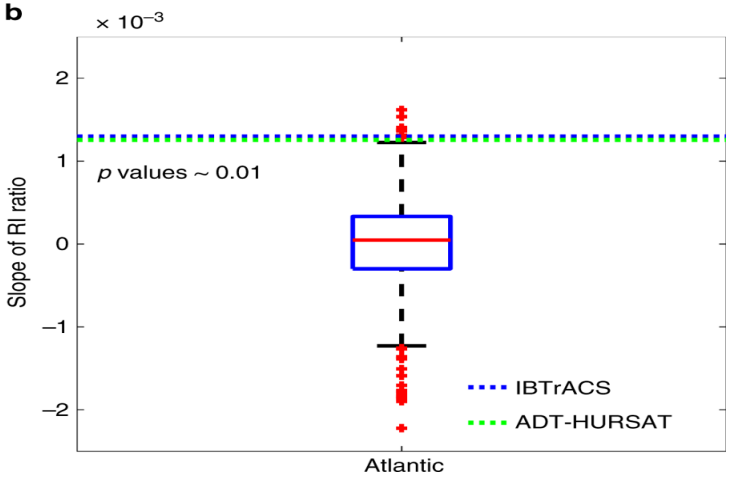


. Landsea (pers. Comm.)

Upward Trend in Atlantic Basin TC **Rapid Intensification** (RI) Ratio (1982-2009)

Comparison of observed trends
(green) vs. modeled natural variability

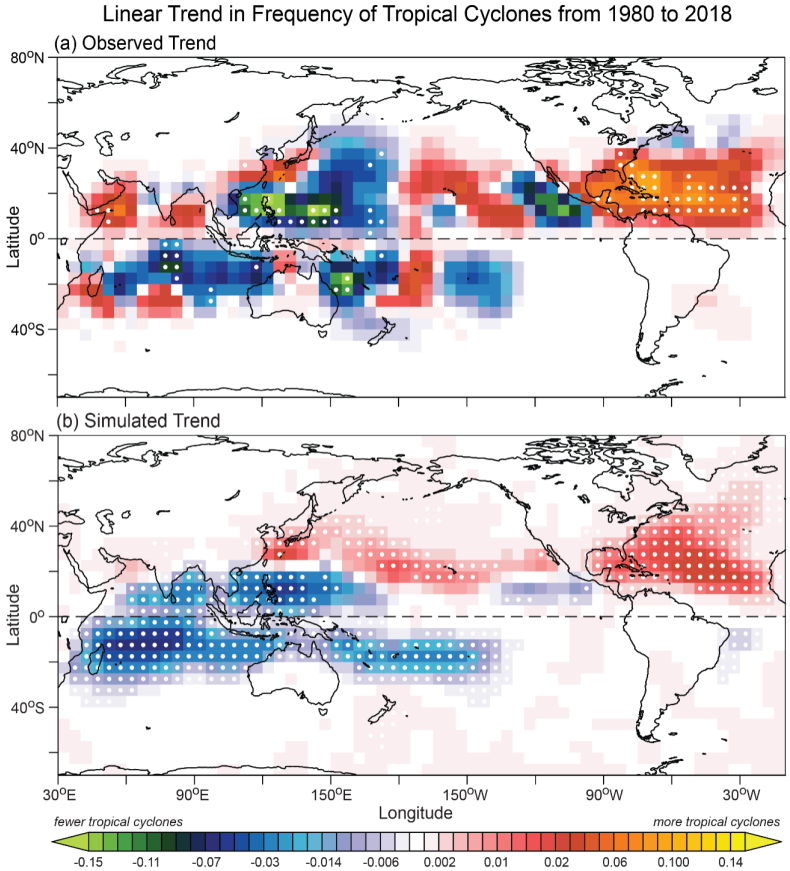




- RI Ratio: # of 24hr intensity changes > 30 knots / total # of 24 hr cases
- Bar-whisker plot: Box: 25th-75th range; whiskers 0.5 to 99.5 percentile range; red + signs are outliers.
- Observed trend (1982-2009) is highly unusual compared to GFDL HiFLOR model's internal variability, but not unprecedented. This is the direction of change expected from modeled human influence.

Bhatia, K.T., Vecchi, G.A., Knutson, T.R. *et al.* Recent increases in tropical cyclone intensification rates. *Nat Commun* **10,** 635 (2019). https://doi.org/10.1038/s41467-019-08471-z

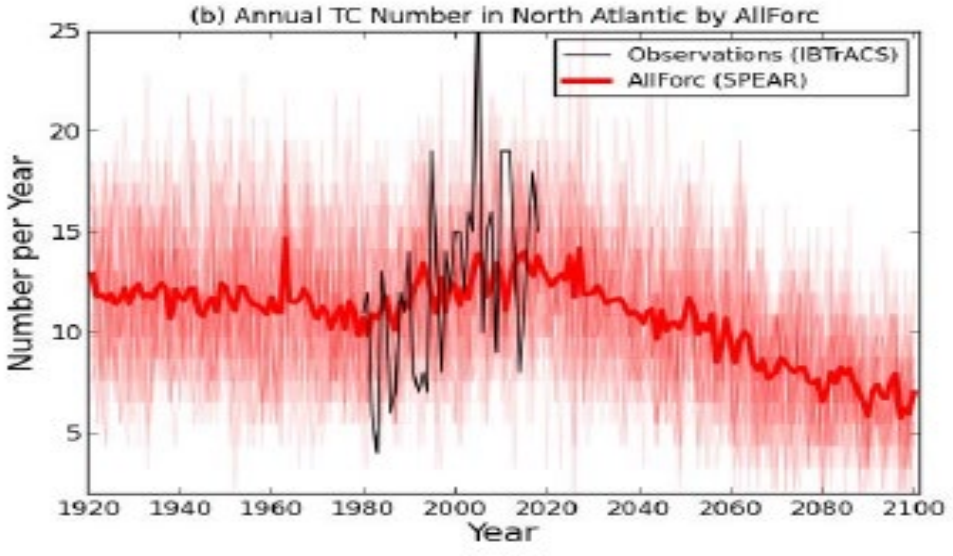
GFDL SPEAR model forced by greenhouse gases and aerosols/volcanic emissions captures trend pattern in tropical cyclone frequency since 1980



Source: Murakami et al. PNAS (2020)

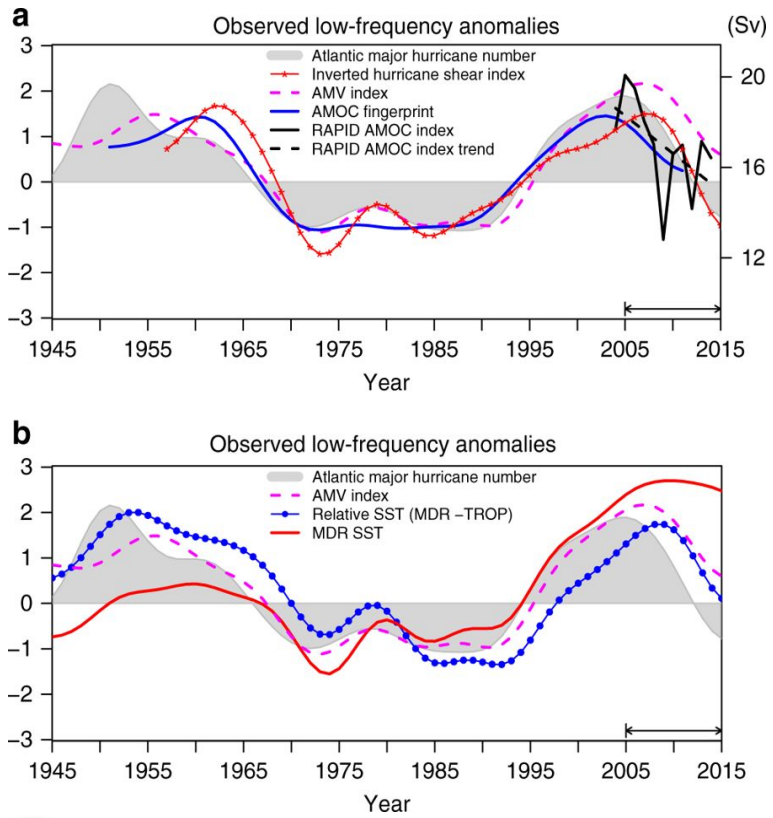
GFDL SPEAR model: Aerosol and volcanic forcing changes produce a temporary rise post-1980 in Atlantic TC frequency… while greenhouse warming produces a long-term decrease.

Implication: linear trends over 1980-2018 in observations in the Atlantic may not be good predictors of future changes due to greenhouse gas-induced warming…



Source: Murakami et al. PNAS (2020)

Atlantic Major Hurricanes since 1945: Strong Multi-decadal Variability (grey shading)

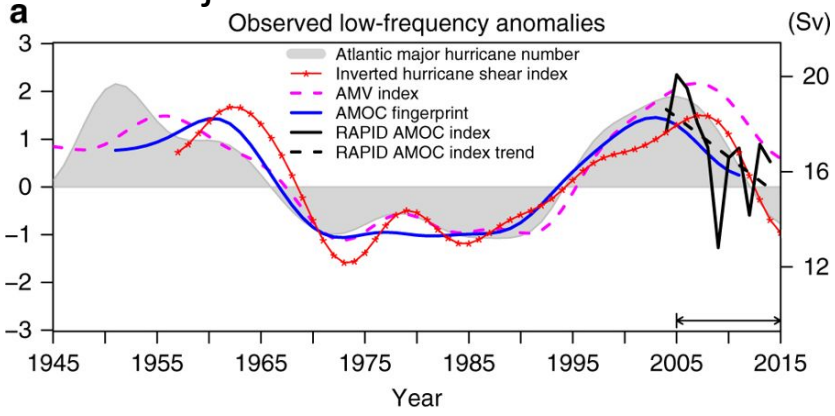


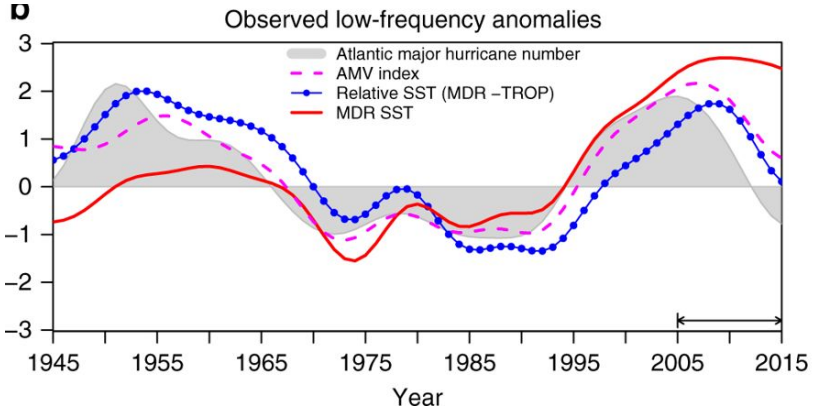
NOTE: The shorter the time-horizon, the more important this variability likely is relative to GHG-induced climate change. Key question: what causes it: aerosol changes? Ocean circulation variability (AMOC)?

AMOC = Atlantic Meridional Overturning Circulation

Yan, X., Zhang, R. & Knutson, T.R. The role of Atlantic overturning circulation in the recent decline of Atlantic major hurricane frequency. *Nat Commun* **8,** 1695 (2017). https://doi.org/10.1038/s41467-017-01377-8

Atlantic Major Hurricanes since 1945: Strong Multi-decadal Variability (grey shading) (2/2)





NOTE: The shorter the time-horizon, the more important this variability likely is relative to GHG-induced climate change. Key question: what causes it: aerosol changes? Ocean circulation variability (AMOC)?

AMOC = Atlantic Meridional Overturning Circulation

Future?

If aerosols were important for 1970s-80s "drought", then hurricane activity may remain high for next few decades.

If internal variability was more important, then we might expect a decline into another "hurricane drought" period.

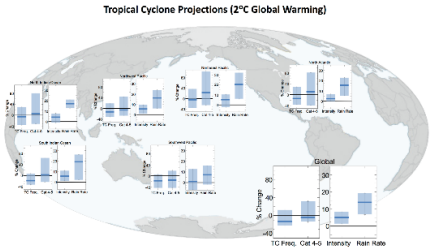
Greenhouse gas influence?

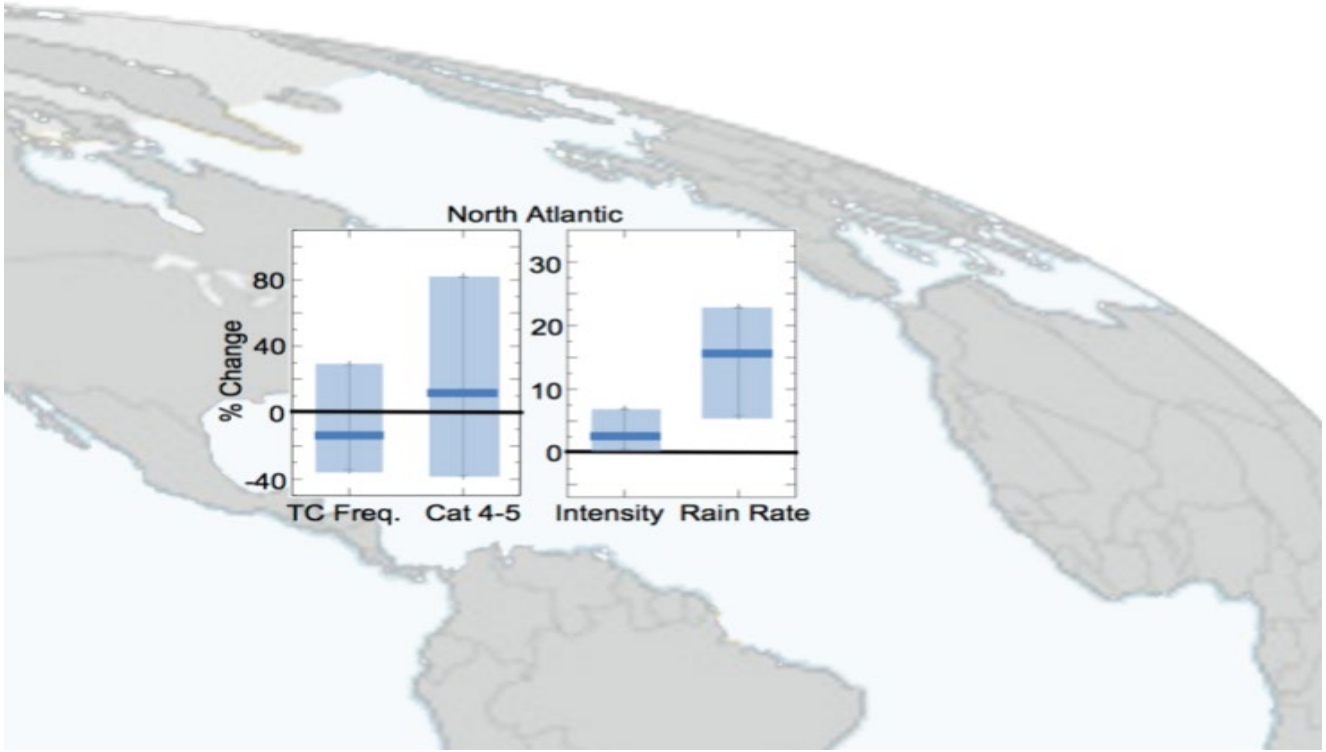
Yan, X., Zhang, R. & Knutson, T.R. The role of Atlantic overturning circulation in the recent decline of Atlantic major hurricane frequency. *Nat Commun* **8,** 1695 (2017). https://doi.org/10.1038/s41467-017-01377-8

Tropical Cyclone Projections for the North Atlantic Basin (for 2°C global warming)

Projected increases:
Rain rates: +14%
TC intensity: +3%

Mixed results across studies for Cat 4-5 frequency and overall TC frequency.





Source: WMO Task Team on TCs and Climate Change., Knutson et al. 2020, *Bull. American Meteorological Society*

Re-Cap: What does historical Atlantic hurricane data show? Interpretations?

Trends since 1901:

- No increase in US landfalling hurricane or major hurricane counts or power dissipation since 1901.
- Attributable human-caused SST warming in tropical Atlantic and Gulf of Mexico.
- Human influence likely contributed to increased multi-day precipitation extremes in eastern Texas, with Hurricane Harvey rains being the most extreme observation.
- Sea level rise worsens coastal flood risk. Human influence was very likely main driver of SLR since 1971.
- Slowing of tropical cyclone propagation speeds over the continental U.S. since 1901; cause not determined

Trends since 1950:

- Multidecadal variations in Atlantic basin major hurricane counts, Main Development Region vertical shear and sea surface temperatures, and possibly the Atlantic Meridional Overturning Circulation (inferred)
  - Causes: Changes in aerosol forcing or internal climate variability are proposed mechanisms
  - Little long-term trend is apparent due to large multidecadal variability (i.e., small GHG signal?)

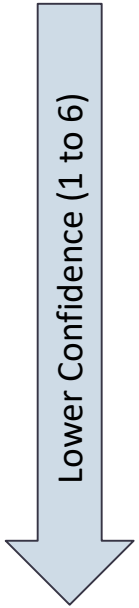
Re-Cap: What does historical Atlantic hurricane data show? Interpretations? (2/2)

Trends since 1980:

- Increase in Atlantic tropical cyclone frequency (Cat 0-5) since 1980 may be temporary and mainly aerosol-reduction driven or due to ocean-driven internal variability. (Greenhouse warming forces a decrease in tropical storms according to the GFDL Spear model (Murakami et al. PNAS 2020)).
- Recent increase in tropical cyclone Rapid intensification occurrence, intensities, and proportion of Cat 3-5 storms globally and over the Atlantic. **Are the Atlantic increases due to an increasing phase of multidecadal variability (internal variability, aerosol reductions) or do they also contain a substantial greenhouse warming component (which would continue)? The answer has implications for the coming few decades….**

Summary – Future Atlantic Hurricane Projections

Tropical cyclone projections for a 2°C global warming [and related observational evidence for detectable/anthropogenic trends]

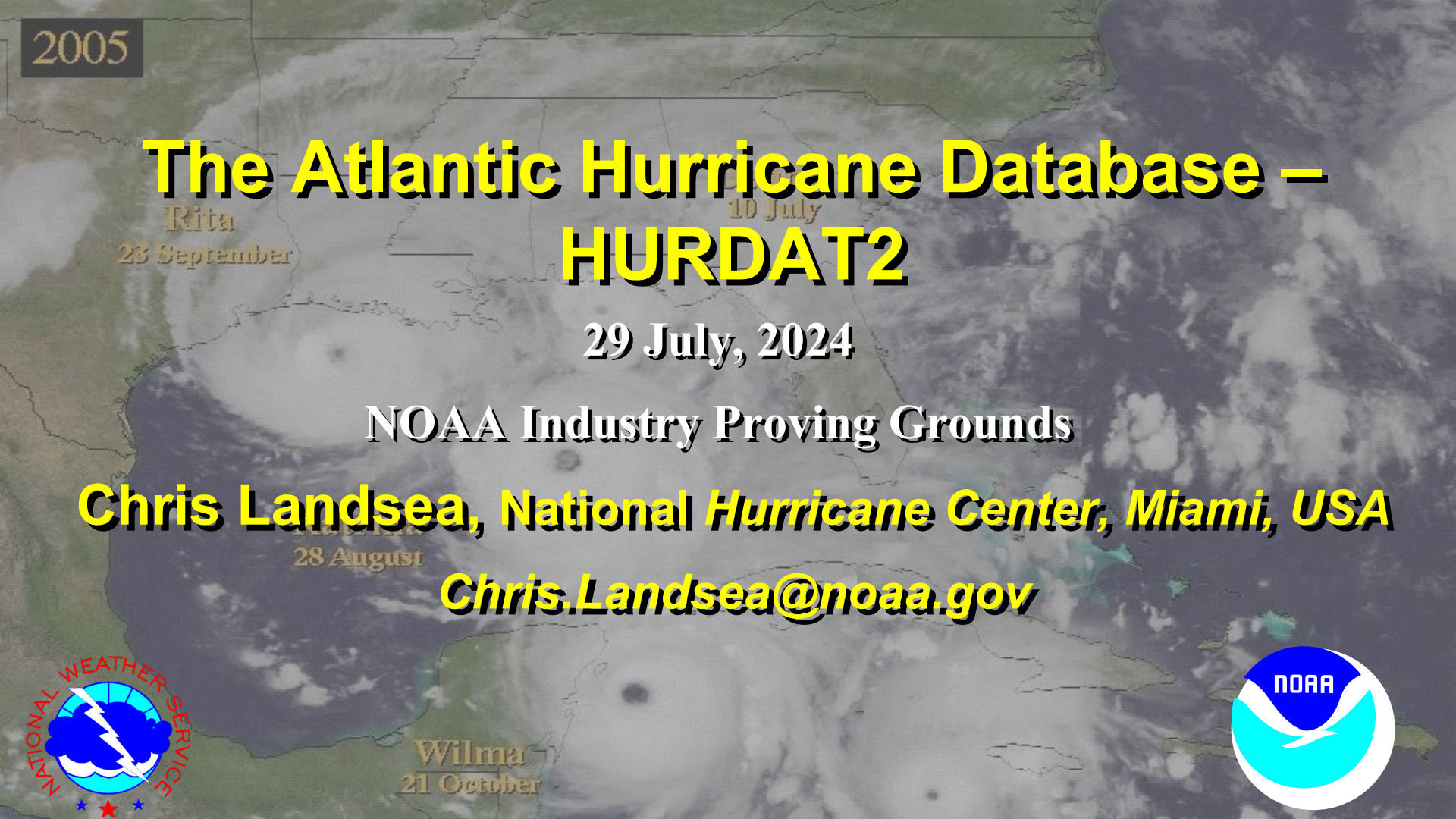


1) **Storm Surge**: sea level rise will lead to **higher average storm inundation levels** for TCs that occur, assuming other factors unchanged. [Attributable anthropogenic SLR trend.]
2) **TC precipitation rates**: *medium-to-high* confidence in an **increase** for the Atlantic basin: +14% for 2°C global warming, or close to the rate of tropical water vapor increase for warming climate. [TC precipitation: No detectable anthropogenic trend; extreme precipitation in general: detectable anthropogenic influence
3) **TC intensity**: *medium confidence* in an **increase** in the Atlantic basin. Magnitude about 3% (range -2 to +11%) for a 2°C global warming. [Observed Rapid Intensification trends may be detectable, but interpretation confounded by multidecadal variability.]
4) **Proportion of TCs that reach very intense (Category 4-5) levels:** *medium confidence* in an **increase** in Atlantic basin. [No long-term trend in reconstructed Cat 3-5 TC fraction.]
5) **Very intense TC frequency (numbers of Category 4-5 hurricanes**): **Mixed results** across studies for the Atlantic basin. [No detection; no century-scale trend in US landfalling major hurricanes or PDI.]
6) **TC frequency (numbers of tropical storms and hurricanes combined): Mixed results** across modeling studies for the Atlantic basin. [No detectable greenhouse warming influence on TC frequency. Recent increase since 1980 may be due to reduced aerosol forcing or to internal (ocean circulation) variability, or both.]

National Hurricane Center

Christopher Landsea

Chief | NOAA National Hurricane Center | Tropical Analysis and Forecast Branch



The Atlantic Hurricane Database – HURDAT2

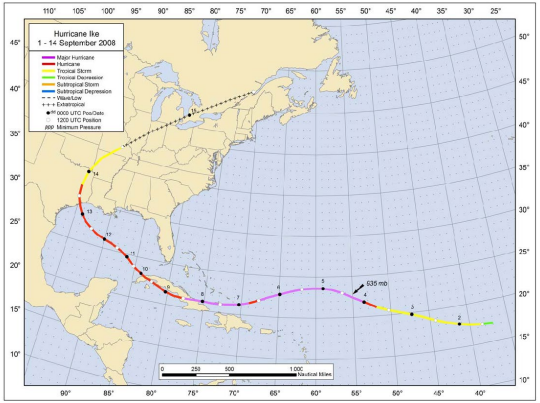
29 July, 2024

NOAA Industry Proving Grounds

Chris Landsea, National *Hurricane Center, Miami, USA*

Chris.Landsea@noaa.gov

HURDAT

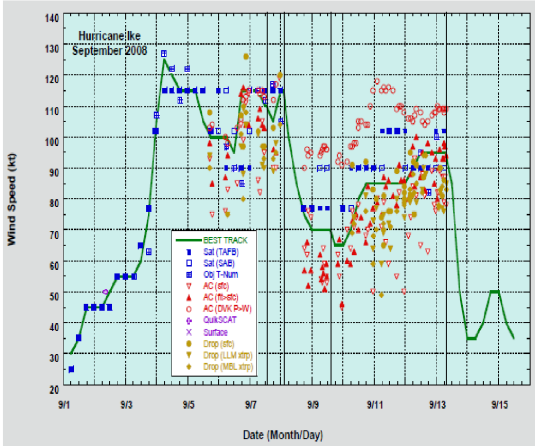


The National Hurricane Center maintains and updates annually the North Atlantic Basin's Hurricane Database (HURDAT)

- Landsea and Franklin, 2013, *Monthly Weather Review*

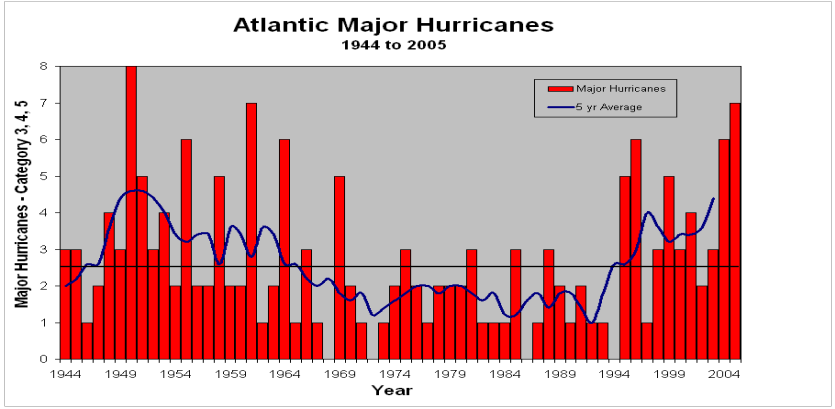
HURDAT provides from 1851 to 2023 for all tropical storms, subtropical storms, and hurricanes every 6 hours (metadata):

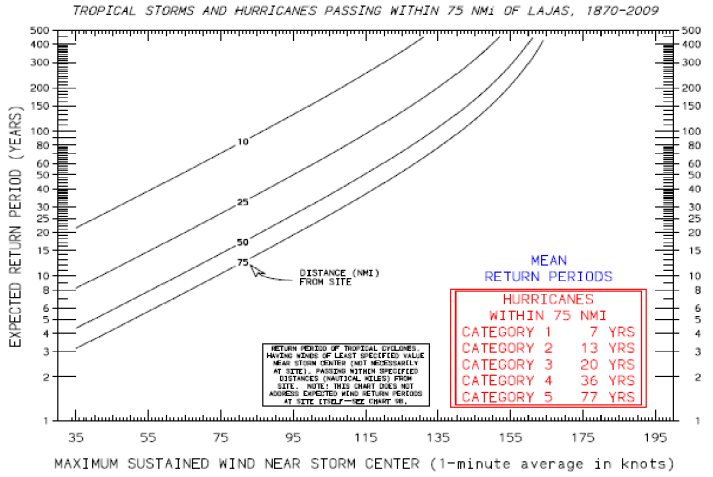
- **Positions** (to nearest 0.1 degree latitude/longitude)
- **Intensity** (1 min surface winds to nearest 10 kt from 1851-1885, 5 kt from 1886 onward)
- **Central pressure** (to nearest 1 mb, when observed)
- **34, 50, and 64 kt wind radii maximum extent** since 2004 (by quadrant, to nearest 10, 5, 5 NM)
- **Radius of Maximum Wind (RMW)** since 2021 (to nearest 5 NM)



HURDAT applications:

- Validation of official and model predictions
- Climate trend assessment – long term trends, seasonal forecasts, etc.
- Building code standards for coastal communities
- Risk assessment for emergency managers (recurrence intervals)

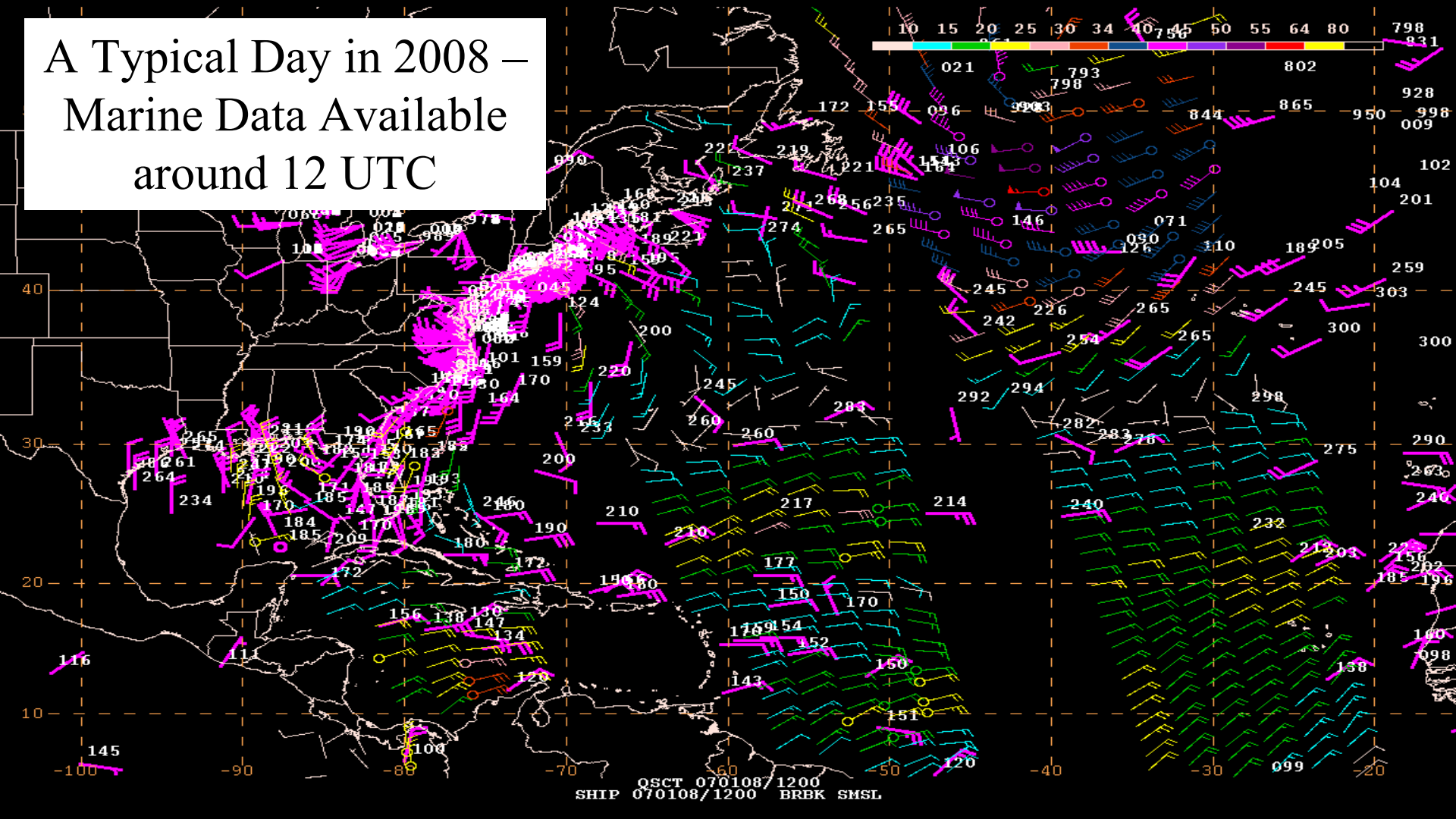


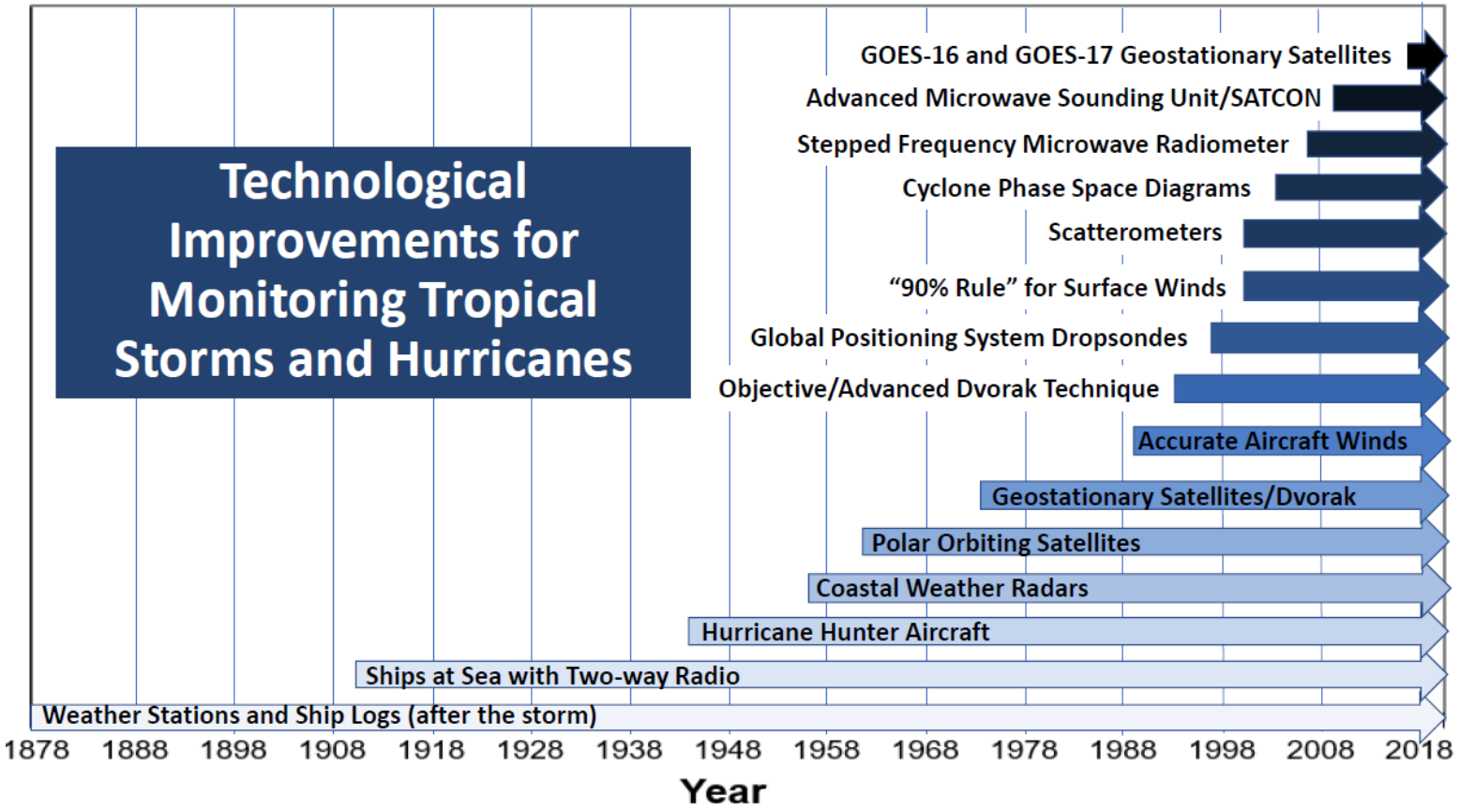



U.S. AIR FORCE


L1 & L2
FY-3 (China)
METEOR 3M (Russian Federation)
850 KM
Terra
NPP
Jason-1
Okean series
GOES-E
(USA)
75W
GOES-W
(USA)
135W
Aqua
QuickScat
TRMM
GEOSTATIONARY ORBIT
SUBSATELLITE
POINT
35 800 km
MTSAT
(Japan)
140E
ENVISAT
METEOR 3M N1
SPOT-5
MSG
(EUMETSAT)
0 Longitude
MSG
(EUMETSAT)
63 E
FY-4
(China)
105E
GPM
ADEOS II
GCOM
GOMS
(Russian Federation)
76E
NPOESS
(USA)
Metop
(EUMETSAT)

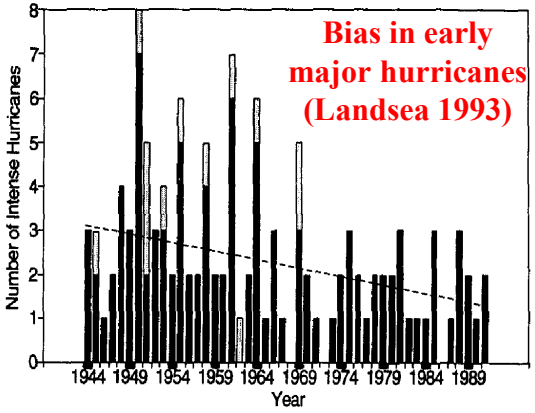
A Typical Day in 2008 – Marine Data Available around 12 UTC




Technological Improvements for Monitoring Tropical Storms and Hurricanes
GOES-16 and GOES-17 Geostationary Satellites
Advanced Microwave Sounding Unit/SATCON
Stepped Frequency Microwave Radiometer
Cyclone Phase Space Diagrams
Scatterometers
"90% Rule" for Surface Winds
Global Positioning System Dropsondes
Objective/Advanced Dvorak Technique
Accurate Aircraft Winds
Geostationary Satellites/Dvorak
Polar Orbiting Satellites
Coastal Weather Radars
Hurricane Hunter Aircraft
Ships at Sea with Two-way Radio
Weather Stations and Ship Logs (after the storm)
1878 1888 1898 1908 1918 1928 1938 1948 1958 1968 1978 1988 1998 2008 2018
Year

Why revise HURDAT?

- HURDAT contains many systematic and random errors
  - 1938 Hurricane: Cat 3 at landfall, but 85kts at last offshore position
- “Missing storms”
- Lack of exact hurricane landfall parameters
- Advances in the understanding of hurricanes and analysis techniques



Atlantic Hurricane Database Re-Analysis Project

http://www.aoml.noaa.gov/hrd/data_sub/re_anal.html

1) 1851 through 1970 (plus 1969's Camille and 1992's Andrew) changes accepted and officially adopted by NHC Best Track Change Committee

2) 1971-1972 have been preliminarily reanalyzed

3) Remainder of 20th Century will be reanalyzed

RE-ANALYSES NEED TO BE CONDUCTED GLOBALLY!!!

Hurricane Data

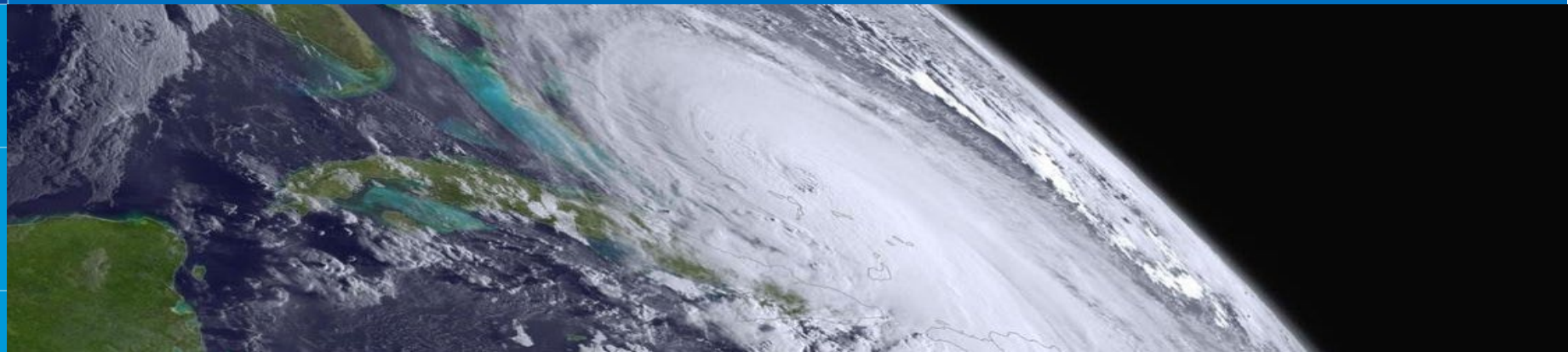
Ken Knapp

Chief | NOAA NCEI Climate Sciences Branch

Hurricane and Tropical Storm Data at NCEI

Kenneth Knapp, NOAA / NCEI

Presented by Christopher Landsea



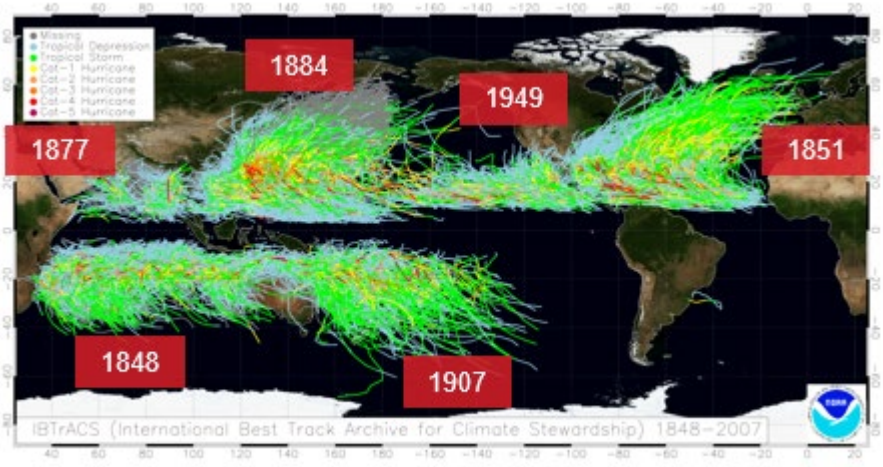
Hurricane and Tropical Storms @ NCEI

- Best Track data (Position & Intensity) - IBTrACS
- Satellite data (IR Imagery) - HURSAT
- Objective Intensity estimates - ADT-HURSAT
- Seasonal and global summaries - NCEI Climate monitoring

IBTrACS:

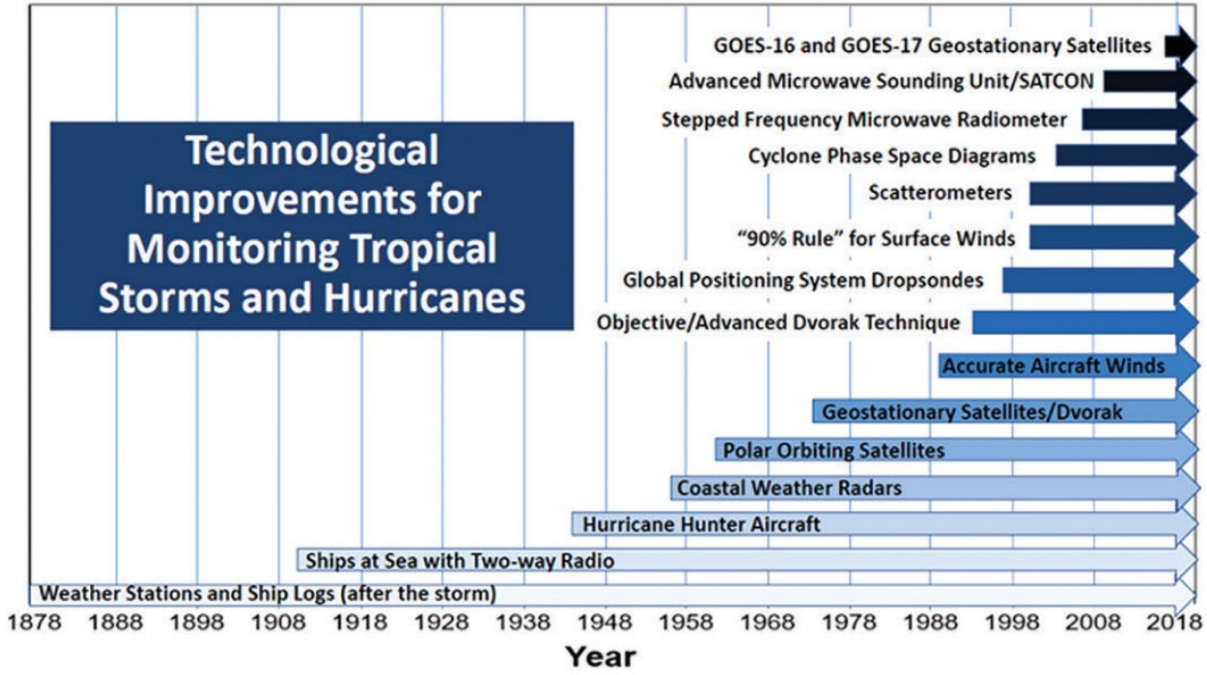
International Best Track Archive for Climate Stewardship

- Collect data from dozens of sources
  - 8 WMO regional forecast centers (NHC, Japan, India, Australia, …)
  - 4 other forecast centers (China, JTWC, HKO, Korea)
  - 4 Historic datasets - Atlases, reanalyses, …
  - 3 real time datasets - NHC, JTWC, …
- 37,500+ tracks from all sources → 13,700+ individual TCs
- Packaged for easy access



IBTrACS: Observation methods and uncertainty

North Atlantic TC Observation Record



Source: C. Landsea, NHC

IBTrACS: Observation methods and uncertainty

Maximum Sustained Wind Speed Uncertainty

Period	SI	NI	SP	WP	EP	NA
Pre 1950						+/- 30
1950 - 1965				+/- 30		+/- 30
1965 -1973	+/- 30	+/- 30	+/- 30	+/- 20	n/a	+/- 20
1973 - 1978	+/- 20	+/- 20	+/- 20	+/- 20	+/- 20	+/- 20
1978 - 1984	+/- 15	+/- 20	+/- 20	+/-20	+/- 20	+/- 15
1984 - 1987	+/- 15	+/- 20	+/- 15	+/-10	+/- 20	+/- 10
1987 - 1995	+/- 15	+/- 15	+/- 15	+/- 15	+/- 15	+/- 10
1995 - 2000	+/- 10	+/- 10	+/- 10	+/- 10	+/- 10	+/- 7

Source: NCEI, IBTrACS Documentation

Table 1 - Qualitative uncertainty level for intensity in wind speeds (knots). Blank boxes imply the level of uncertainty is too difficult to quantify (and possibly larger than 30 knots).

IBTrACS Data Fields

Reports what the agency reports…

- Location (lat, lon)
- Intensity
  - Maximum sustained winds
  - Minimum central pressure
- Wind extent & storm size
  - *Radius of Gales, ROCI, …*
- Gusts
- Eye diameter
- Satellite-derived intensity parameters
- Landfall
- Storm movement - Direction & Speed

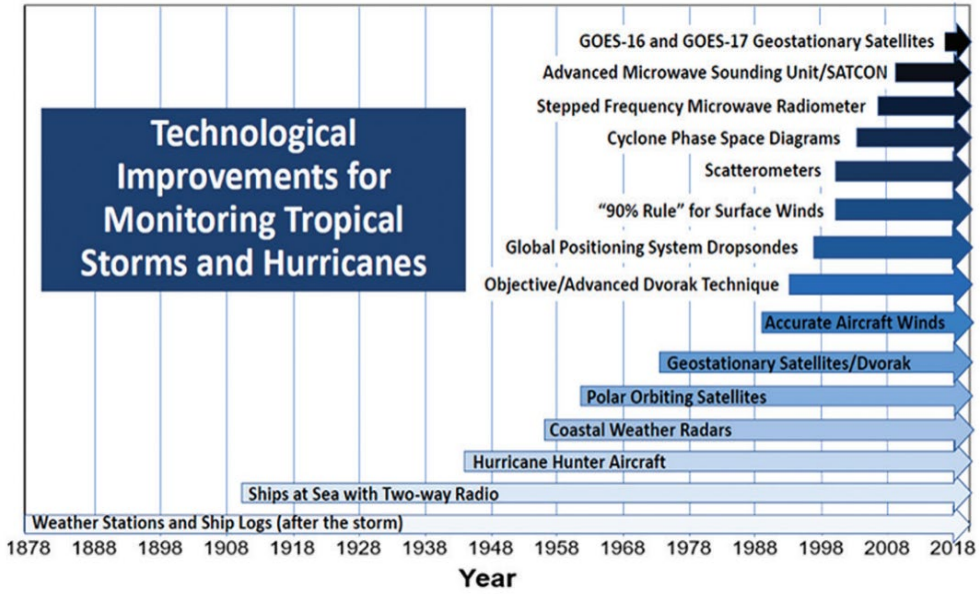
IBTrACS: best track vs. provisional data

- Provisional data
  - updated weekly
  - working best track

- Best Track data
  - updated annually
  - data replaces provisional data
  - represent reanalysis of the storm - long after it occurred
  - produced by forecast agencies
  - improved accuracy of storm attributes

ADT-HURSAT
Automated Dvorak Technique (ADT)

IBTrACS vs ADT-HURSAT



- Homogeneity
- for Entire Period of record…
  - Same algorithm (ADT)
  - Same inputs (HURSAT)
- ADT is state of the art intensity algorithm

Source: C. Landsea, NHC

In closing…

- IBTrACS provides storm characteristics
  - NCEI acts as collector and distributor of data *(in partnership with NHC)*
- HURSAT provides storm imagery for analysis
  - NCEI acts as data producer
- ADT-HURSAT
  - Partnering with Univ. Wisconsin for annual production

Breakout Sessions

Group 1: Retail

Moderator: Jenny Dissen
Support: Alexander Lamb and Noah Benitez Nelson

Group 2: Architecture & Engineering

Moderator: Russ Vose
Support: Morgan Stahl and Adriana Formby-Fernandez

Group 3: Re/insurance

Moderator: Adam Smith
Support: Maggie Coates and Una Darrell

Group 4: Energy

Moderator: Vanessa Escobar
Support: Sydney Luce and Heather Clark

Group 5: Other

Moderator: Mike Brewer and Liz Cox
Support: Joelle Godwin and Bailey Donaldson

Hurricane Expert Breakout Rotation

Name/Time	Group 1: Retail Jenny Dissen	Group 2: A&E Russ Vose	Group 3: Re/insurance Adam Smith	Group 4: Energy Vanessa Escobar
1:55 - 2:02	**Matt**	**Hiro**	**Tom**	**Chris**
2:02 - 2:09	**Chris**	**Matt**	**Hiro**	**Tom**
2:09 - 2:16	**Tom**	**Chris**	**Matt**	**Hiro**
2:16 - 2:23	**Hiro**	**Tom**	**Chris**	**Matt**
Alternate	Matt	Tom	Chris	Hiro

Resources

- This webinar is a part of the NCEI Industry Proving Grounds (IPG) Initiative
  - The IPG specific data and tools can be found on the **NOAA's Industry Page**.
- Looking for more information on hurricanes in 2024?
  - Check out the **NOAA 2024 Hurricane Season Information here**
- See **https://www.noaa.gov/hurricane-prep** for a full hurricane preparedness toolkit
- Visit the **GFDL climate change and hurricanes** page for additional information
- **NOAA State of the Science Fact Sheet**

Thank you!

We appreciate your time and partnership on this effort.

Points of Contact

Mike Brewer NCEI Chief of Climate Information Services Branch Michael.J.Brewer@noaa.gov	**Jenny Dissen** NCEI Retail Sector Lead (NCICS/NCSU) Jenny.Dissen@noaa.gov
Adam Smith NCEI Re/insurance Sector Lead Adam.Smith@noaa.gov	**Russ Vose** NCEI Architecture & Engineering Sector Lead Russell.Vose@noaa.gov