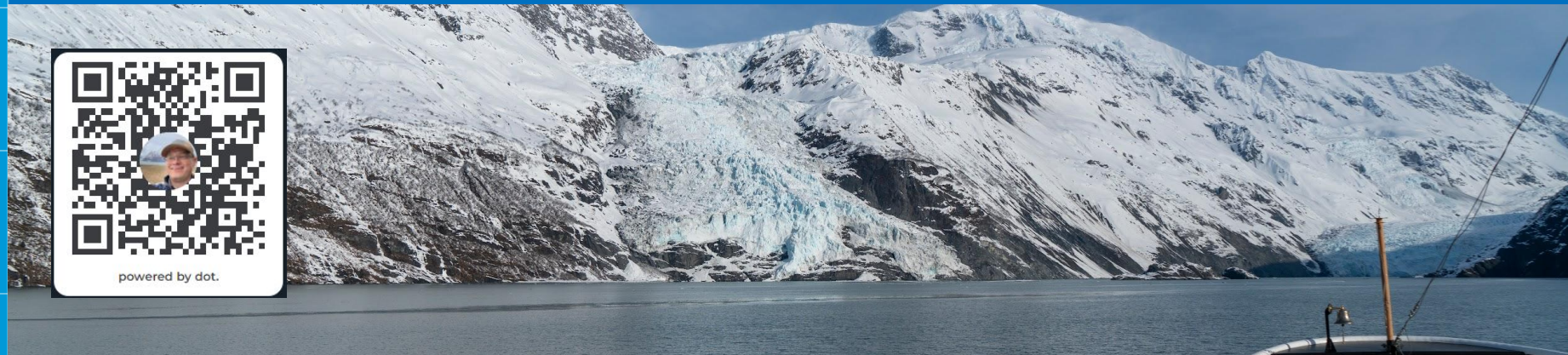
NOAA
National
Weather
Service

2024 Mission Briefing

National Tsunami Warning Center



National Tsunami Warning Center Staff Profile

11: Duty Scientists (Tsunami Watch)

4 : Information Technology/ Electronic Support

1 : Administrative Support

4 : Management

NWS Tsunami Program Staffing Profile

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About 40 personnel between

Operational Watch, Support, & Management

- National Tsunami Warning Center
- Pacific Tsunami Warning Center

Focus areas:

Geophysics, Oceanography, Physical Science, Geology, Communications & Emergency Management, Computer science / IT, Electronics, Observation Systems

Program Management & Support

- International Tsunami Information Center
- NWS Headquarters staff

Tsunami events in the last 4 years

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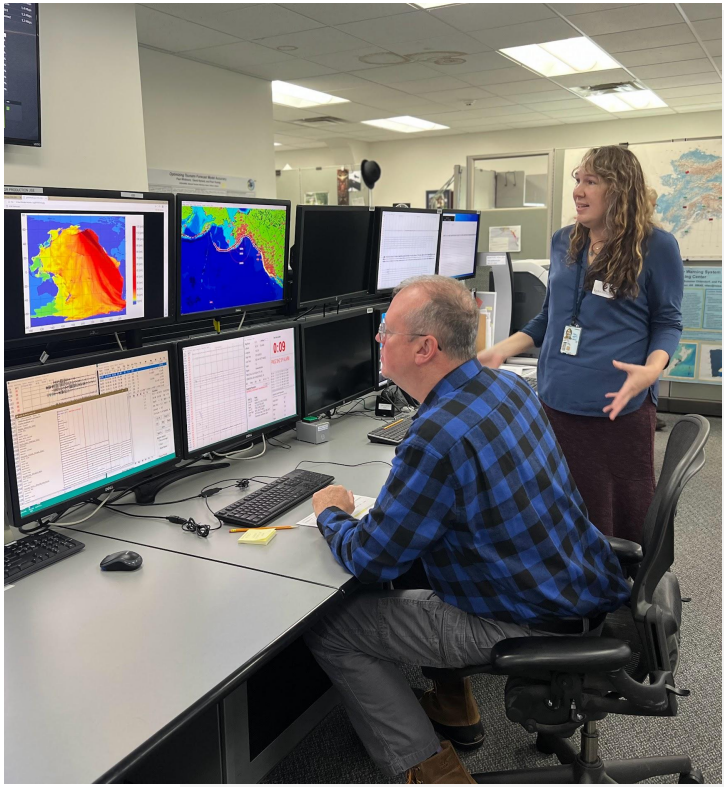
Close call events that ***don't*** reach alert/message status are critical decision events, too.

10-08-2023	M5.0 Izu Islands, Japan
07-16-2023	M7.4 Sand Point, Alaska
02-06-2023	M7.8 Turkey
03-16-2022	M7.3 Honshu, Japan
01-15-2022	Hunga Tonga- Hunga Ha'apai eruption
08-12-2021	M8.1 South Sandwich Islands
07-29-2021	M8.2 Chignik /Perryville, Alaska earthquake
03-04-2021	M8.1 Kermadec Islands earthquake
02-10-2021	M7.9 Loyalty Islands earthquake
10-19-2020	M7.6 Sand Point, Alaska earthquake
07-22-2020	M7.8 Simeonof, Alaska earthquake



Barry Arm, AK, landslide tsunami

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Well-known threat:

Landslides in glacial fjords within Prince William Sound may create local tsunamis.

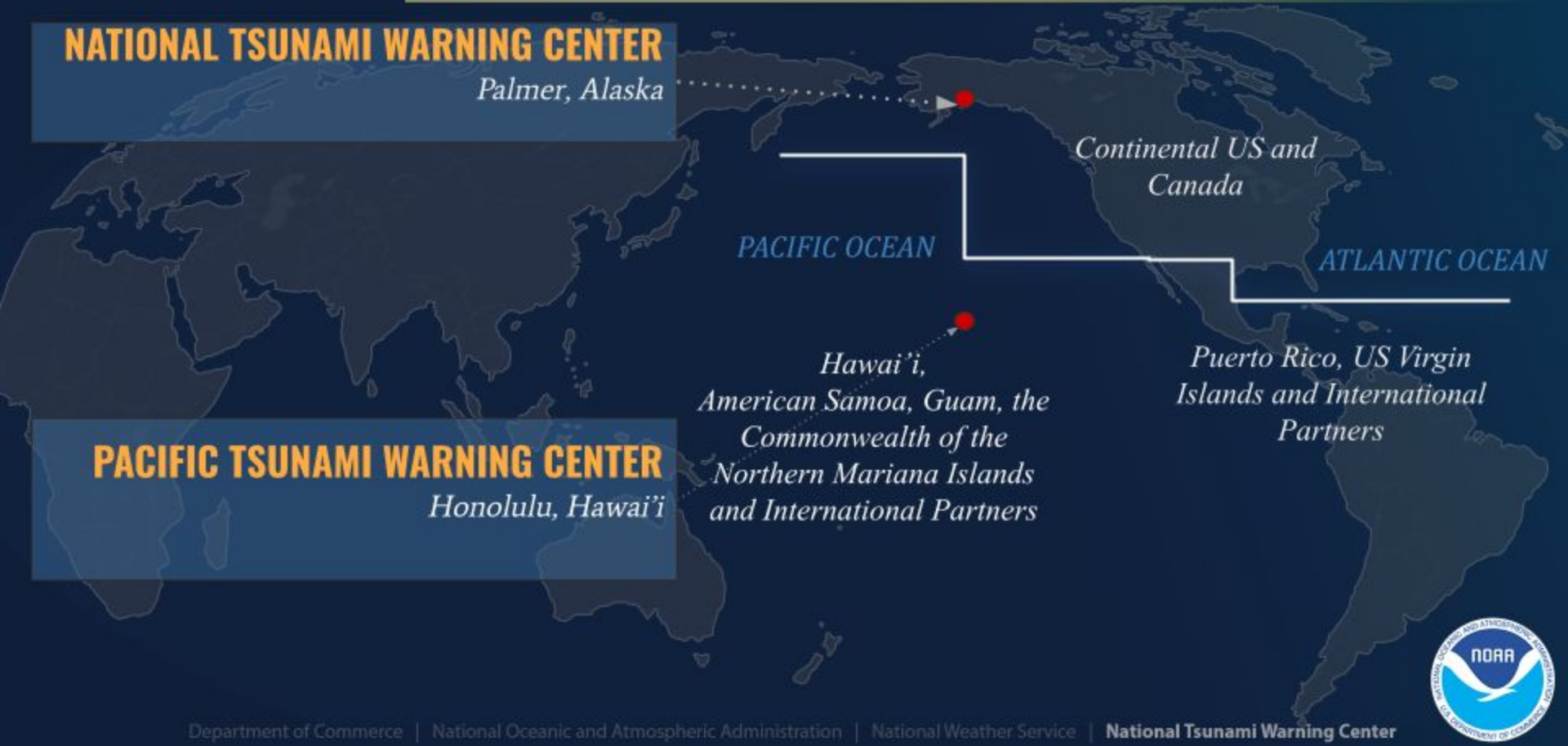
The Barry Arm landslide is **~500 Million cubic meters** of rock that could create a tsunami reaching Whittier, Alaska, in about 20 minutes.

Barry Arm Landslide: May 2021

https://dggs.alaska.gov/hazards/barry-arm-landslide.html

NATIONAL TSUNAMI WARNING CENTER
Palmer, Alaska
tsunami.gov

CONTINENTAL ALERTING RESPONSIBILITY



NTWC informs Federal and State partners

Who serve their local communities and coastlines

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NORTH AMERICAN COAST

PACIFIC

- Alaska
- *Canada
- Washington
- Oregon
- California

ATLANTIC

- Maine
- Massachusetts
- Rhode Island
- Connecticut
- New York
- New Jersey
- Delaware
- Maryland
- Virginia
- North Carolina
- South Carolina
- Georgia
- Florida
- Alabama
- Mississippi
- Louisiana
- Texas

Governance: Tsunami Warning and Research Act

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United States Code Title 33
Navigation and Navigable Waters Chapter 45
Tsunami Warning and Education
Sections 3201 - 3208

Tsunami forecasting and warning program.

National tsunami hazard mitigation program.

Tsunami research program.

Global tsunami warning and mitigation network.

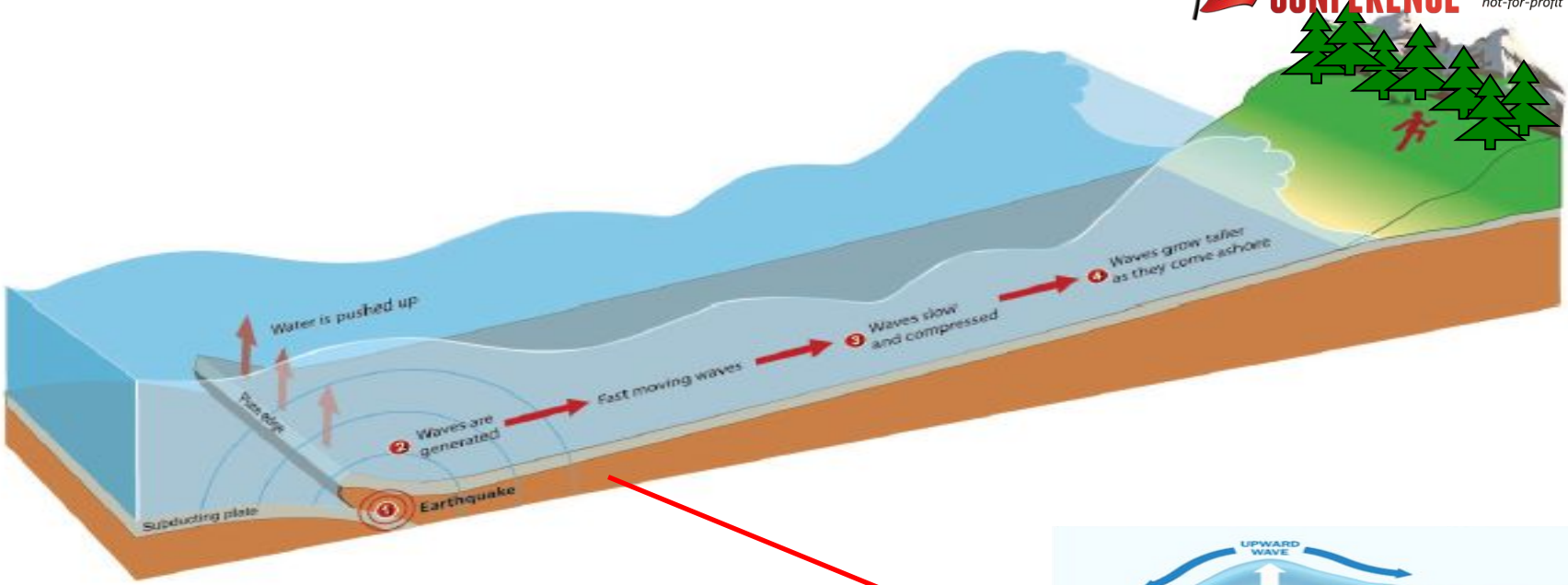
Tsunami Science and Technology Advisory Panel.

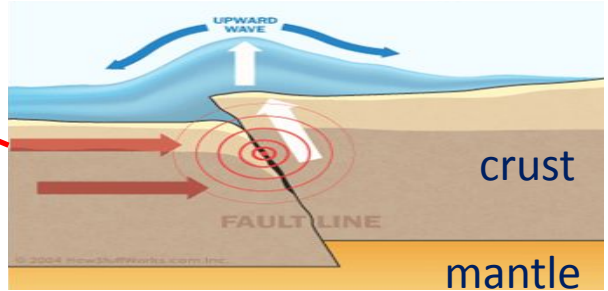
Authorization of appropriations.

Outreach responsibilities.

Tsunami partners organize through NTHMP

How does a tsunami form?





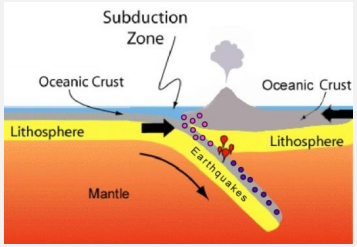
Tsunami sources

~85% of tsunamis are caused by earthquakes.

[The Tsunami Warning Centers are designed to alert for this threat].

The remaining ~15% comes from landslides, volcanic eruptions, meteors, and meteotsunamis (weather), and other significant water disruptions.

[The Tsunami Warning Program has special procedures for some of these events. Additional work is required to adequately detect, analyze, forecast, and alert for these threats].



The June 13, 2013, meteotsunami was generated by this weather system

Hazards associated with tsunamis

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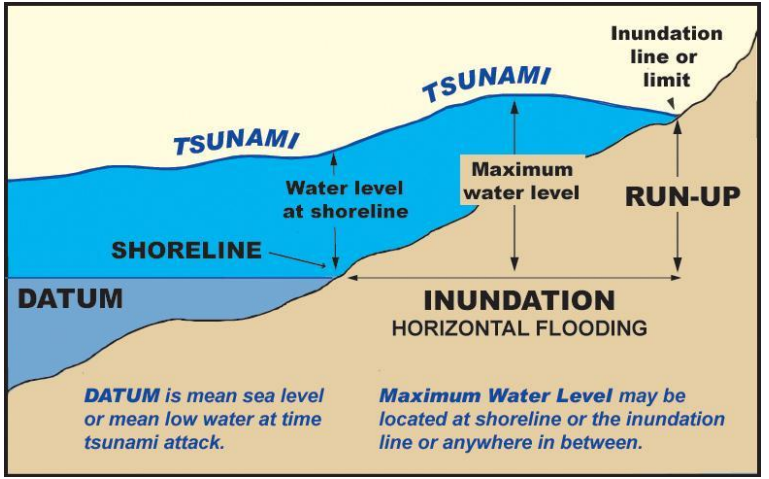
Coastal flooding/ inundation

- Tsunamis can also travel up low-lying coastal waterways
- Tsunami arrival at high tide will be worse than at low tide
- Subsidence during the earthquake will result in more inundation



Strong Currents

- Danger from even "small" or distant source tsunamis
- Change in shipping channels and harbors

Santa Cruz Harbor, 2011: 13 knot current

Santa Cruz harbor, California damage:
$16 M harbor infrastructure
$60 M personal property

Hunga Tonga-Hunga Ha'apai eruption and tsunami damage during a Tsunami Advisory January 15, 2022

TSUNAMI IMPACTS

Sound a lot like storm surge impacts

PLAN FOR THE TSUNAMI CARD- IT'S IN THE DECK

and might not stay at the bottom of the pile

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FOLLOWING A SIGNIFICANT SEISMIC OR NATURAL EVENT,
THE NATIONAL TSUNAMI WARNING CENTER
HAS

5 MINUTES

TO ANALYZE AND ISSUE AN ALERT OR NO THREAT- MESSAGE

NOAA TSUNAMI
National Tsunami Warning Center

TSUNAMI ALERTS

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Alert level	Action	Hazard	
WARNING	Get to high ground or inland IMMEDIATELY! Follow evacuation signage	DANGER! A TSUNAMI IS IMMINENT. Flooding & dangerous currents	3+ feet or 1+ meter
ADVISORY	Stay out of the water and away from the shore	STRONG CURRENTS & DANGEROUS WAVES! In or near coastal waters	1 - 3 feet or 0.3 - 1 meter
WATCH	Prepare to take action. Monitor local TV, radio, social media, NOAA weather radio	A TSUNAMI IS POSSIBLE. Arrival time is several hours away. Prepare now. Alert level may change.	Prepare
INFORMATION STATEMENT	NO action needed	NO tsunami impact expected.	Relax

THREAT MESSAGE: Issued for International Partners; NOT for U.S. Coasts

NATIONAL TSUNAMI WARNING CENTER
Palmer, Alaska
tsunami.gov

TSUNAMI FORECASTS NEED TIME

1) SIGNIFICANT EARTHQUAKE OR LANDSLIDE
(WHICH DISTURBS A SIGNIFICANT VOLUME OF WATER)

2) WAVE REACHING A DEEP-WATER SENSOR:
DART BUOY

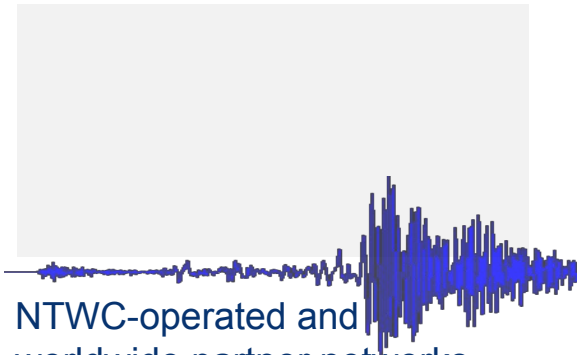
FORECAST

3) WAVE REACHES THE COAST :
COASTAL TIDE STATION OR TSUNAMI GAUGE

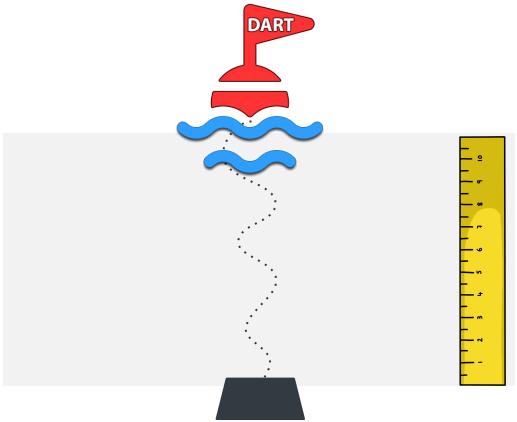
OBSERVATION

C O N F I D E N C E

Observation networks inform tsunami alert decisions



NTWC-operated and worldwide partner networks detect local and global earthquakes



NOAA-operated DART underwater pressure sensors plus worldwide partner-supported networks detect deep-ocean water changes indicating a tsunami is present

NTWC-operated stations plus NOAA and worldwide-supported tide gauges networks measure a tsunami once it reaches the coast

2022: Unusual tsunami currents damage harbors

- **Tsunami means “harbor wave”**
- Resonating waves create fast currents that can be dangerous to impossible to navigate
- Currents change the harbor channels
- Damage to vessels and docks is likely
- Vessels underway may encounter debris and hazards to navigation

3 Years since Aleutian Islands M8.6 earthquake and tsunami

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HILO, Hawai'i 1946, April Fool's Day Tsunami, and Scotch Cap Tsunami

60 Years since the Great Alaska Quake: M9.2

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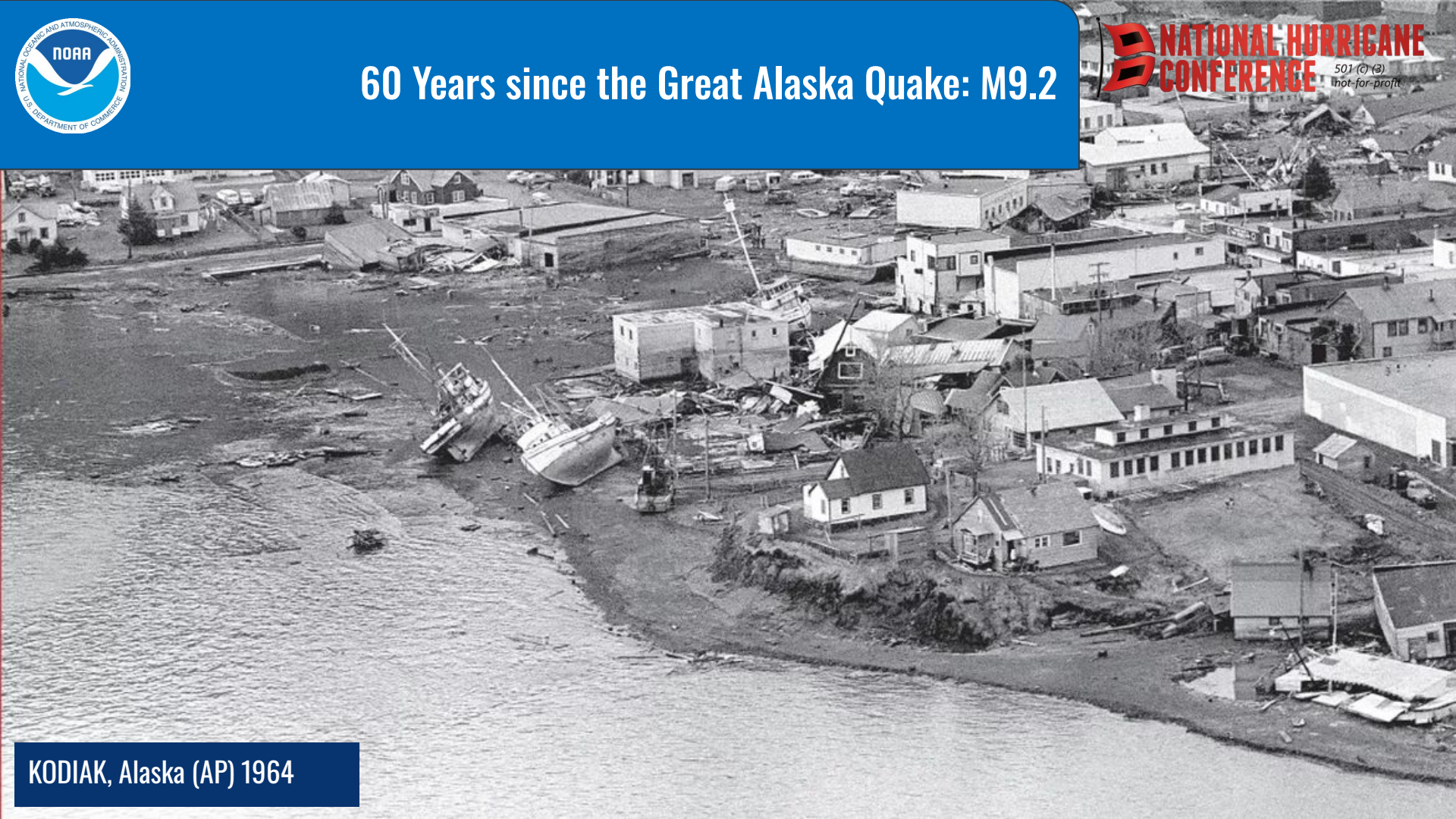

KODIAK, Alaska (AP) 1964

20 Years since the Sumatra M9.1 earthquake & tsunami

South-West suburb of Banda Aceh, Indonesia. Village of Lampisang (US Navy) 2004

13 Years since the Tohoku M9.0 earthquake & tsunami

Damage near Rikuzentakata, Japan.
Mass Communication Specialist 3rd Class Alexander Tidd, U.S. Navy

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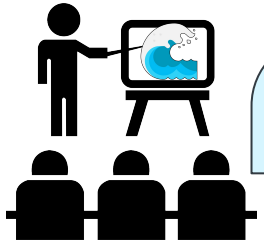
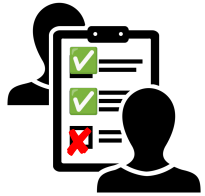
Tsunami event is a small part of the cycle



TSUNAMI EVENT RESPONSE
(hours/days)
Tsunami Decision Support
Science & Forecasts + Alerts & Communication



Preparation (years)
Monitoring, Source Detection & Description
Education, Outreach, Exercises

Physical Science
+
Social Science

Assessment (months)
Post-Event Assessment, Feedback, Needs
Post-Event Assessment, Feedback, Needs

Improvement (months/years)
R20/02R, R&D, Innovation
Applied Social Science, Alerting Refinement

Research Community

Contacts

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Tsunami
Warning
Center

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The Climate Prediction Center: Mission overview and the Global Tropics Hazards (GTH) Outlook

Jon Gottschalck

Chief, Operational Prediction Branch
NOAA / NWS / Climate Prediction Center

National Hurricane Conference
March 26, 2024
Orlando, FL

CPC Mission

Deliver real-time products and information that predict and describe climate variations on timescales from weeks out to a year

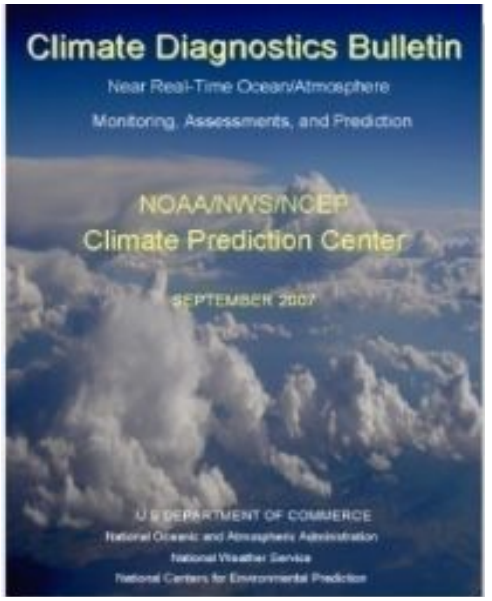
Thereby promoting effective management of climate risk and a climate-resilient society

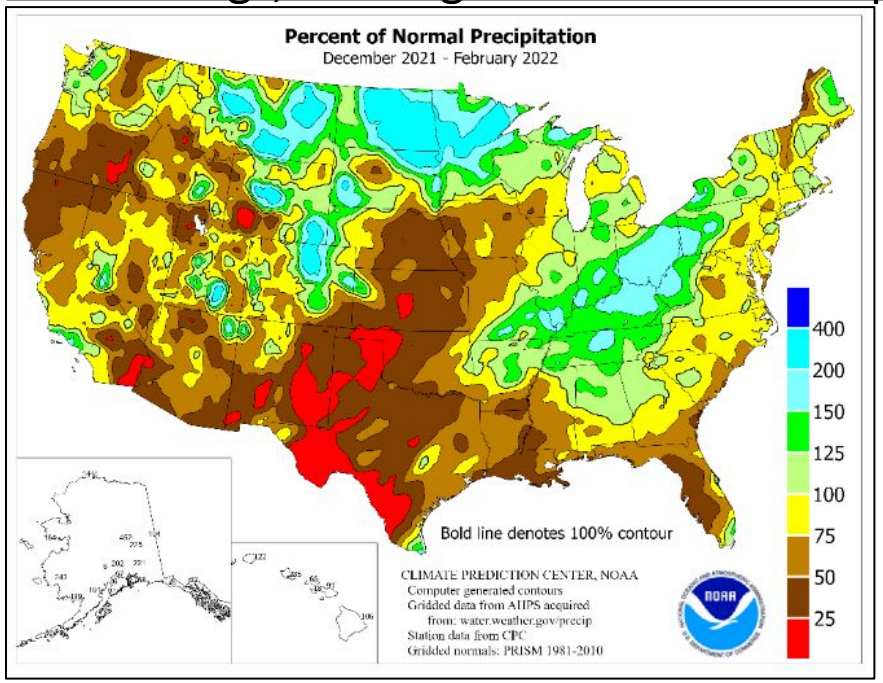
https://www.cpc.ncep.noaa.gov/

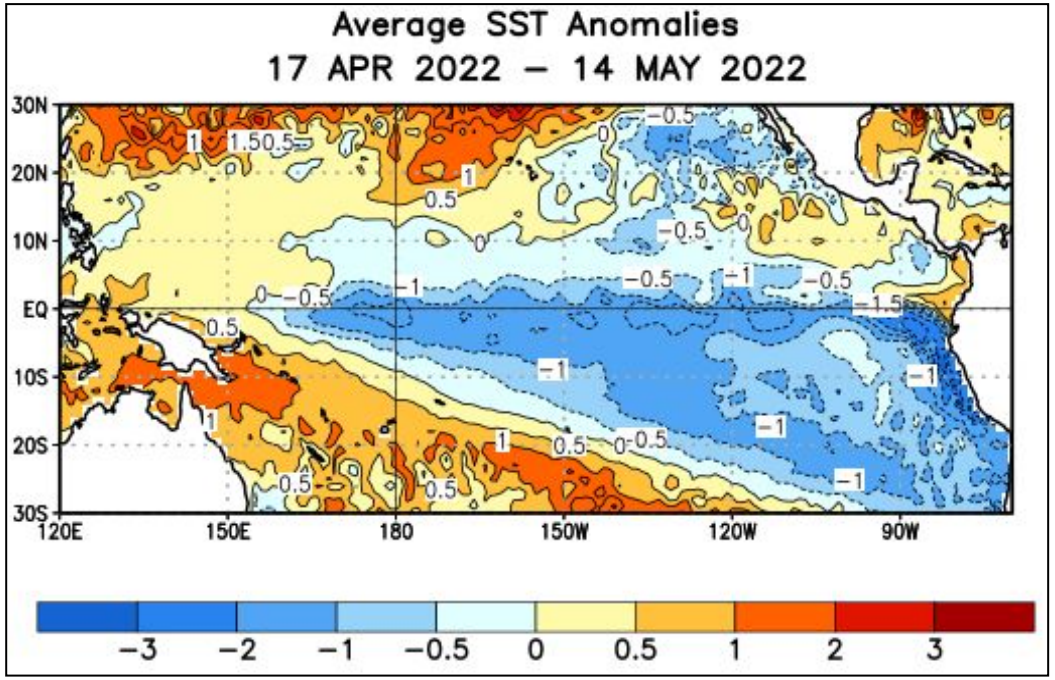
Both domestic and international presence

CPC Mission – Monitoring Services

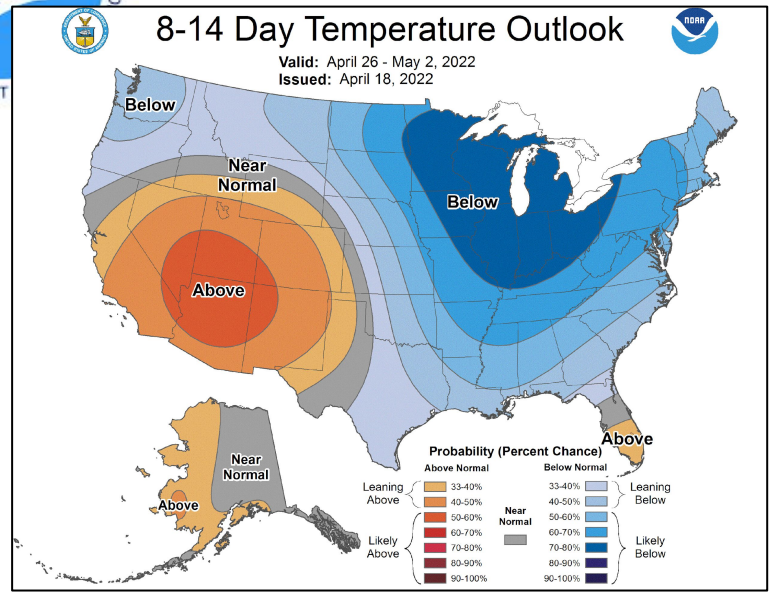
- U.S. Drought Monitor
  - ✔ Co-produced with other agencies including USDA
- Satellite and Gauge Precipitation
- Surface Temperature
- Atmospheric and Ocean reanalysis
- Monitor common types of Climate Variability:
  - ✔ ENSO, MJO, NAO, AO, PNA, stratosphere
- ENSO Diagnostic Discussion
- Briefings, training for NWS field and partners, stakeholders

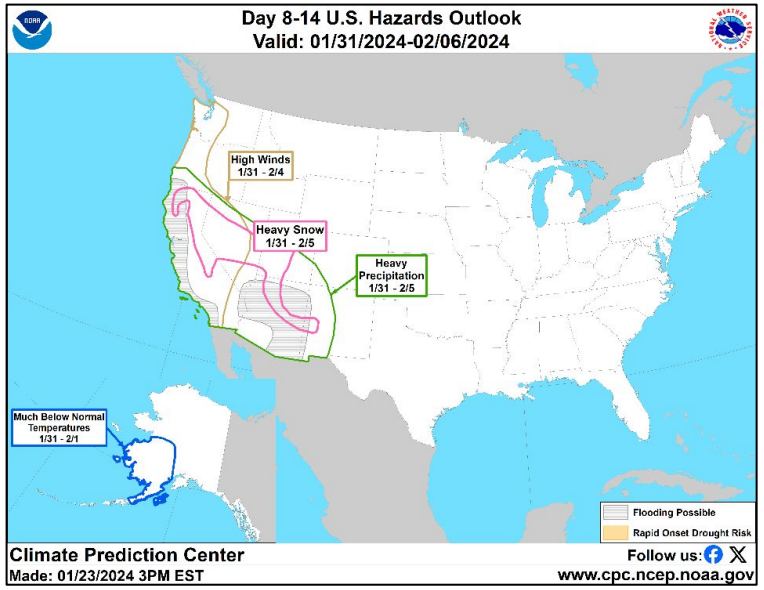


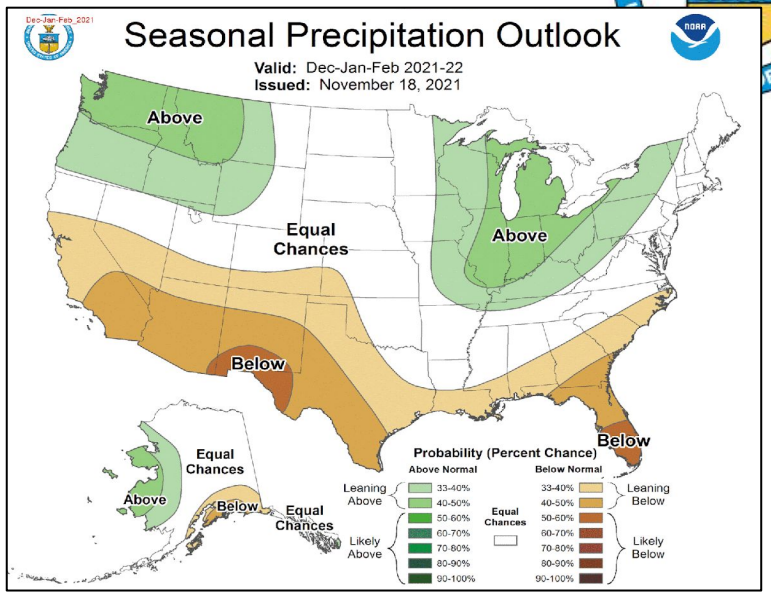


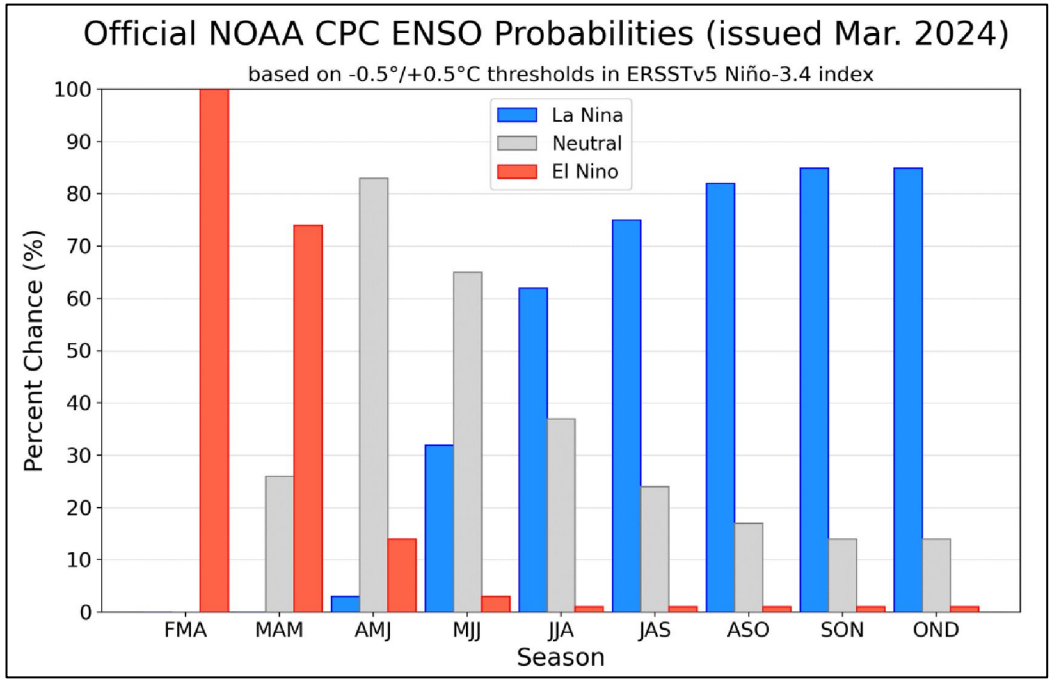


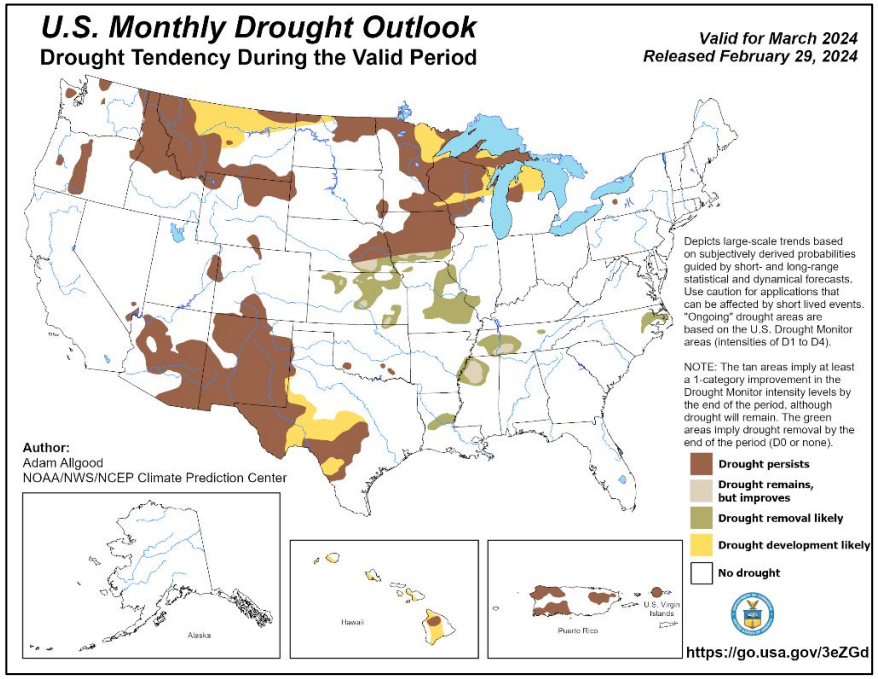
CPC Mission – Forecast Products and Services





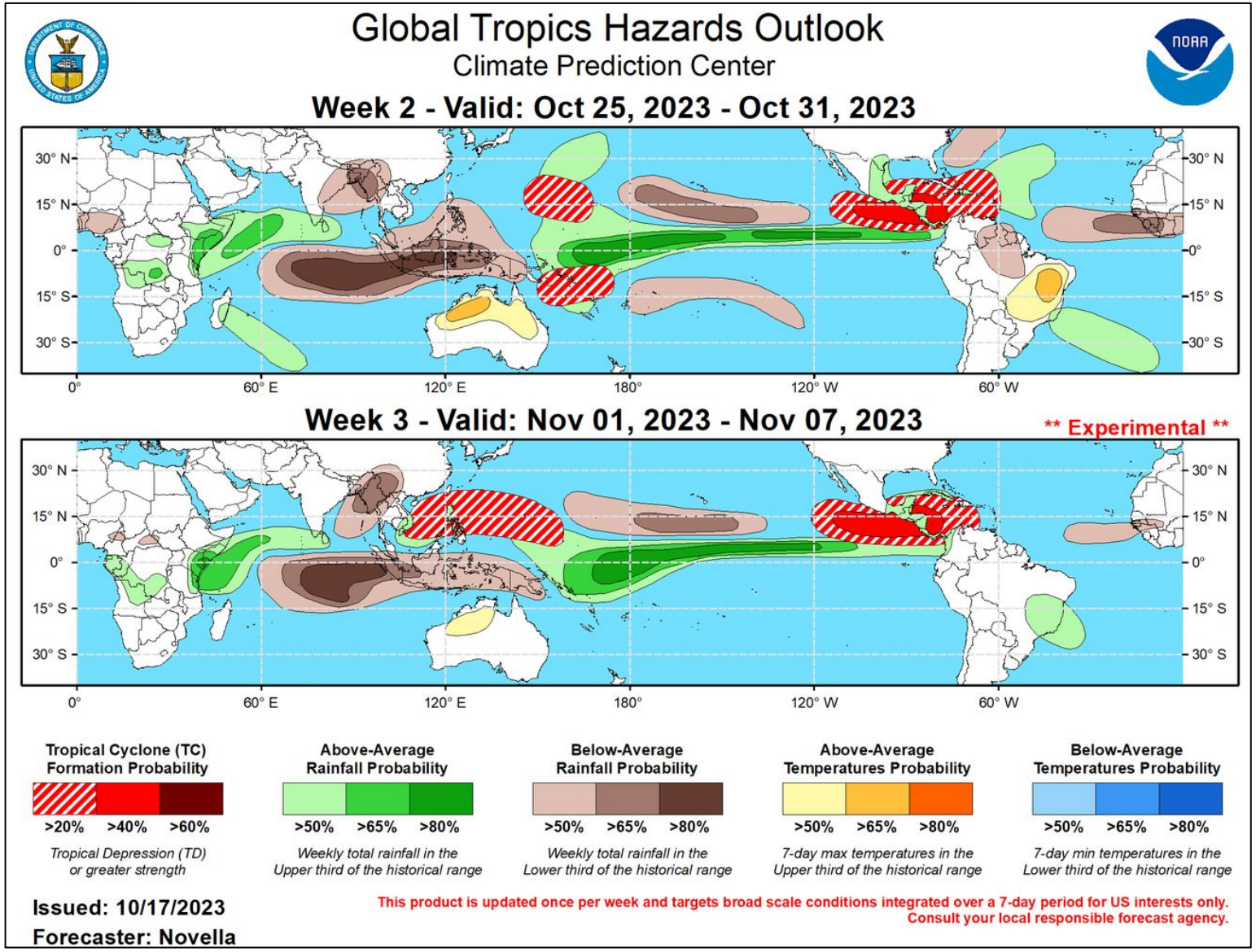






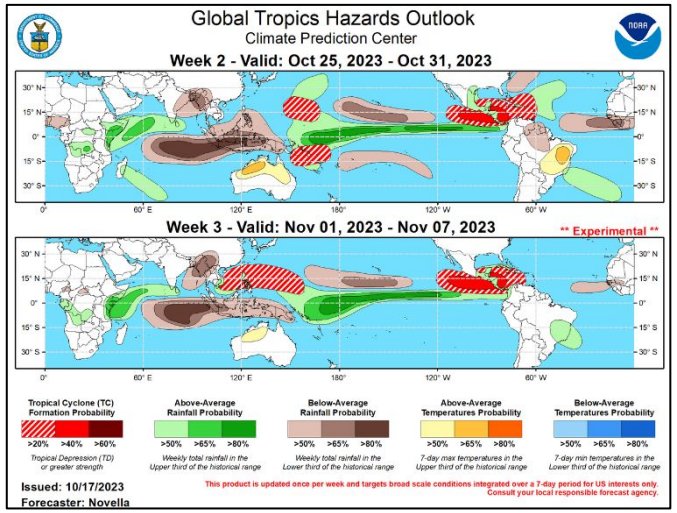
Global Tropics Hazards (GTH) Outlook

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghaz/index.php



- ✔ **Forecast elements include:**
  - ❑ Hazardous weekly precipitation
  - ❑ Hazardous extreme heat/cold
  - ❑ Favored TC genesis regions
- ✔ **Forecast Format:**
  - ❑ Targets Weeks 2-3
  - ❑ Probabilistic

Global Tropics Hazards (GTH) Outlook



✔ Goal:

- ✔ Monitor and assess changes in anomalous tropical rainfall, winds, other extremes and communicate this information to NWS and other forecasters
- ✔ Provide situational awareness, early watch for potential tropical related hazards such TCs, subseasonal rainfall departures, monsoon impacts, etc.
- ✔ Support sectors of the U.S. economy (finance, emergency management, energy, agriculture, WRM) that have both domestic and foreign interests

✔ Stakeholders:

- ✔ NWS, NOAA, Federal, state and local government, aid organizations, emergency management entities

GTH Outlook Discussion

Last Updated - 03/19/24

Valid - 03/27/24 - 04/09/24

A robust MJO event continues to unfold, with the enhanced convective phase now crossing the Western Pacific. During the past week or so, widespread enhanced convection overspread the eastern Indian Ocean and western Maritime Continent, which is a departure from the weakening ENSO base state. Dynamical models are in good agreement with tight ensemble clustering that strong MJO activity continues to propagate eastward from the Western Pacific and into Western Hemisphere over the next two weeks, though it should be noted that the forecasted phase speed is on the fast end of the MJO frequency range . As the suppressed phase of the MJO is moving into the Maritime Continent, this tends to suppress tropical cyclone (TC) activity in the Australia and South Pacific regions, which have been active recently.

One TC formed over the last week. On March 15 TC Megan formed in the Gulf of Carpentaria. It intensified quickly, reaching category 1 strength, and came ashore into northern Australia on March 18. The Joint Typhoon Warning Center (JTWC) expects Megan to dissipate in the next day or so, but indicate that the system will be closely monitored for signs of regeneration.

Consensus among the model ensembles depicts the MJO in phases 8 and 1 during week-2, which would slightly favor TC genesis in the southwest Indian Ocean. This is also supported by the ECMWF extended range TC genesis forecast, so a slight risk (>20% probability) for TC genesis is posted east of Madagascar. The MJO in phase 8 or 1 tends to suppress TC activity for the Australia and South Pacific regions, which have been quite active lately. Model solutions diverge by week-3 but generally still indicate eastward propagation of the MJO signal into the Indian Ocean, which would once again begin to favor TC genesis off the northwest coast of Australia for week-3.

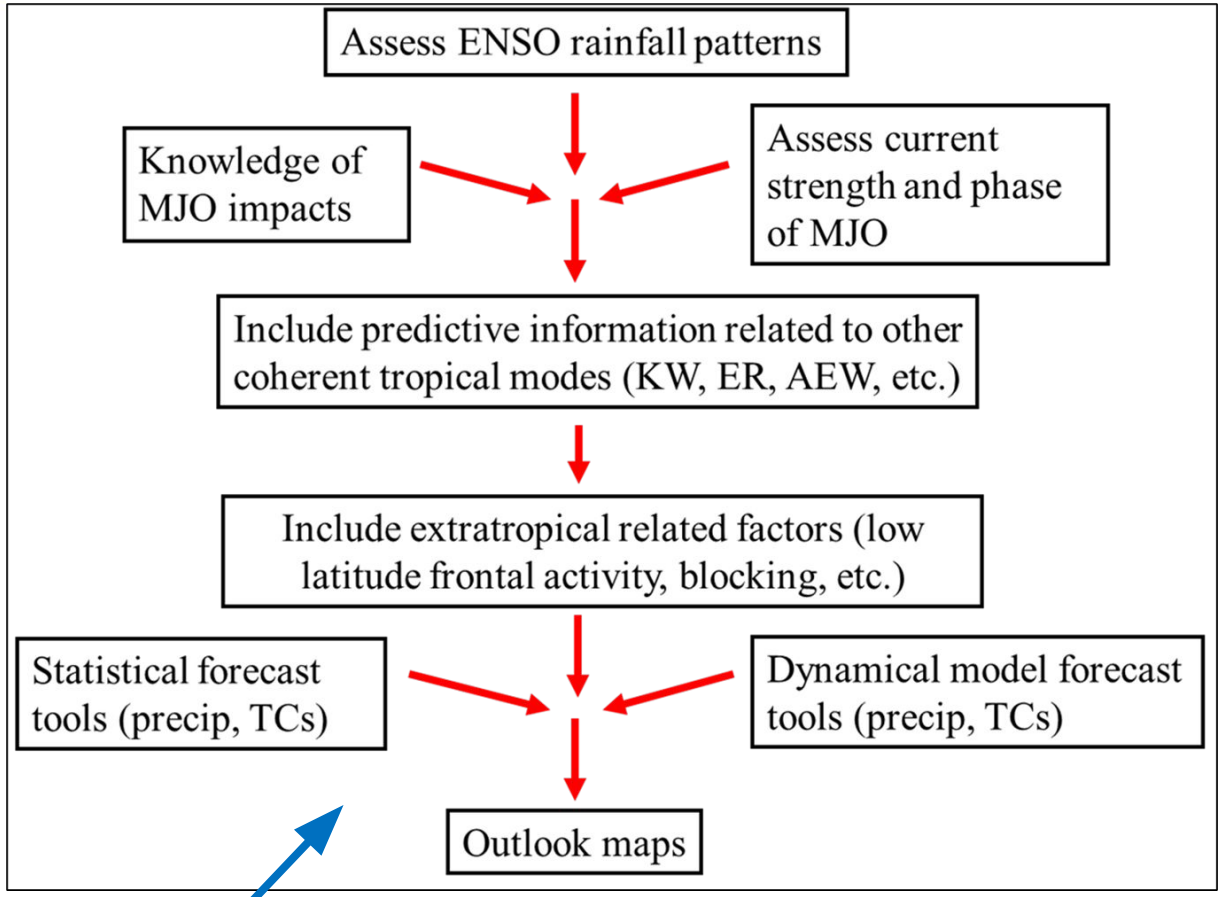
GIS Ready Formats

Hazard	Week-2	Week-3
Tropical Cyclone Formation Probability	KMZ KML SHP	KMZ KML SHP
Enhanced Precipitation Probability	KMZ KML SHP	KMZ KML SHP
Suppressed Precipitation Probability	KMZ KML SHP	KMZ KML SHP
Above Average Temperatures Probability	KMZ KML SHP	KMZ KML SHP
Below Average Temperatures Probability	KMZ KML SHP	KMZ KML SHP

Tropical Cyclone Only GTH Map
Precipitation Only GTH Map
Temperature Only GTH Map
Lines Only GTH Map

Latest Product (PDF Format)
Latest Briefing (PDF Format)
GTH Archive

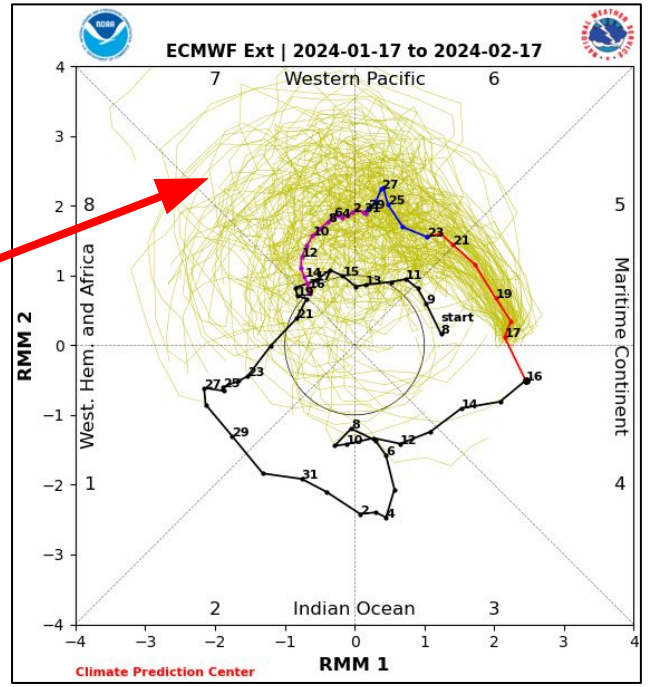
Global Tropics Hazards (GTH) Outlook



Factors considered and utilized as part of the outlook process

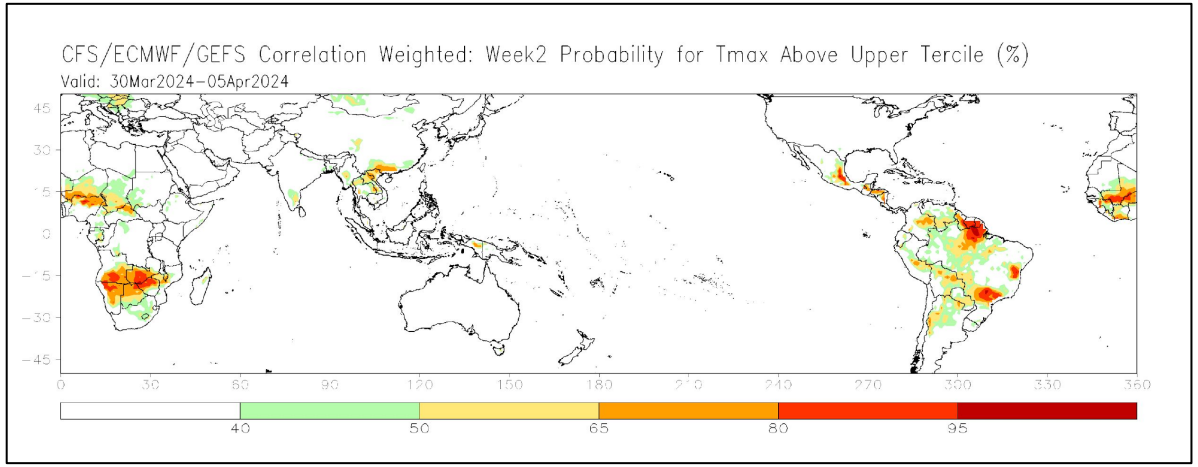
- ✔ Forecasters use a variety of climate monitoring and forecast guidance products -- both dynamical model and statistical methods
- ✔ ENSO, Madden-Julian Oscillation (MJO) and other subseasonal tropical variability are physical drivers

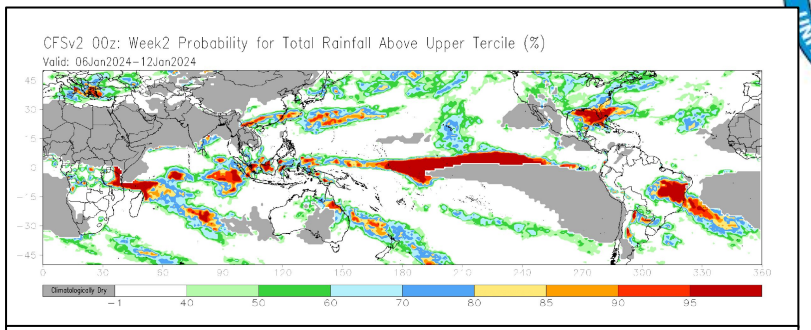
MJO index forecast from ECMWF for the next 1-4 weeks

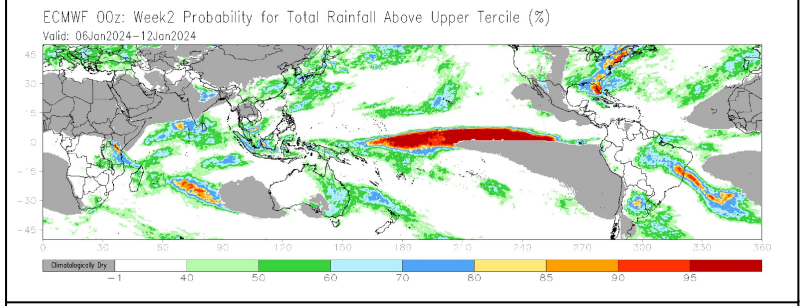


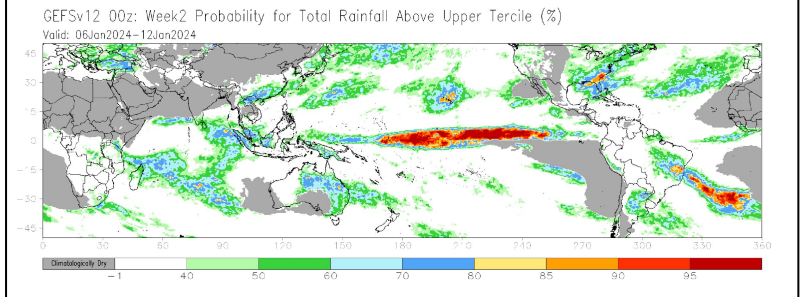
Global Tropics Hazards (GTH) Outlook

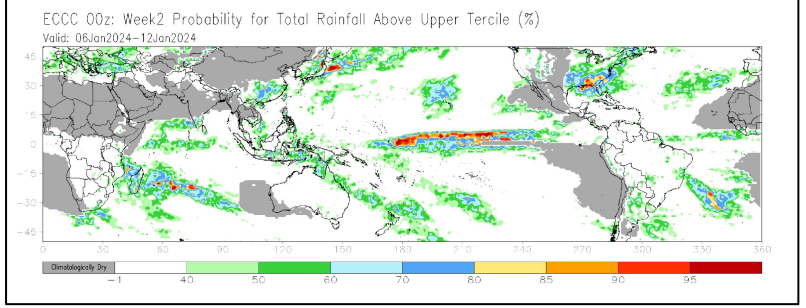
- ✔ Dynamical model guidance from several operational ensemble model systems
- ✔ Post processed (bias-corrected, calibrated)
- ✔ Forecast systems utilized:
  - NCEP Climate Forecast System (CFS)
  - NCEP Global Ensemble Forecast System (GEFS)
  - ECMWF Ensemble Prediction System (EPS)
  - Environment Climate Change Canada (ECCC) Global Ensemble Prediction System (GEPS)







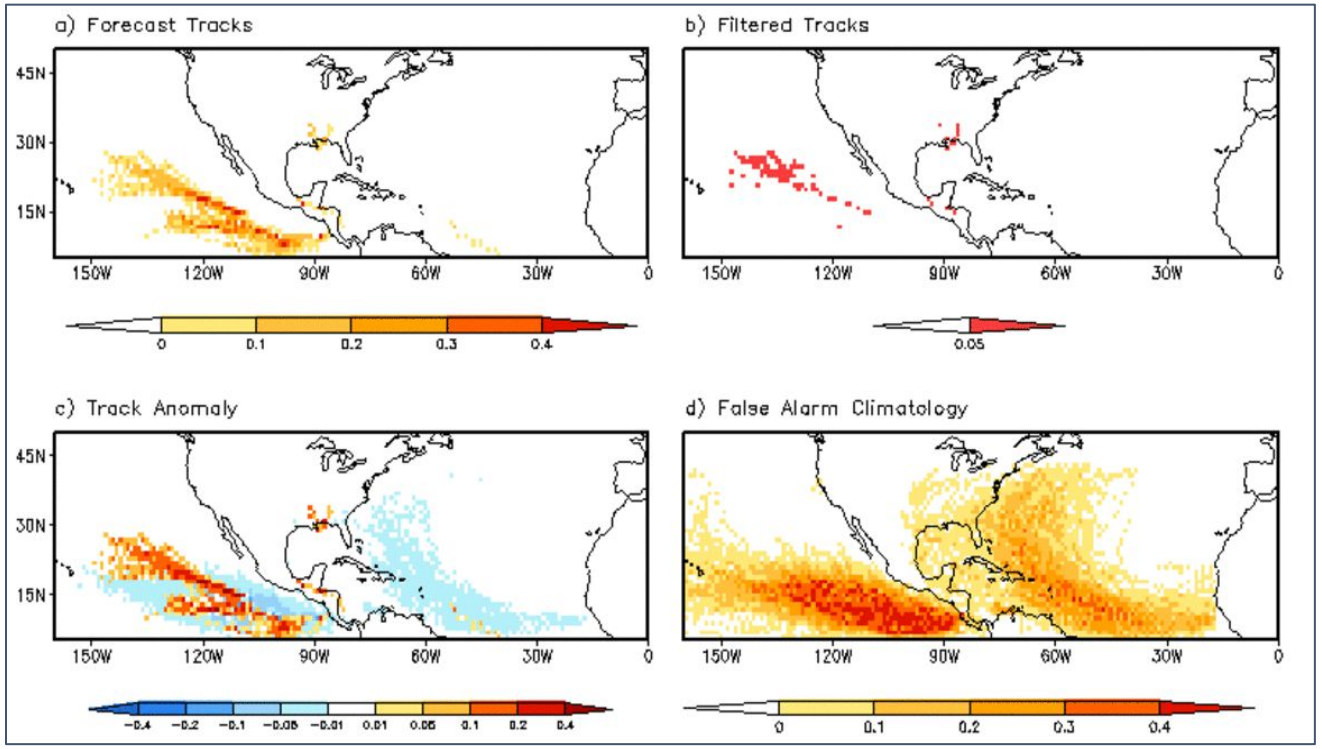


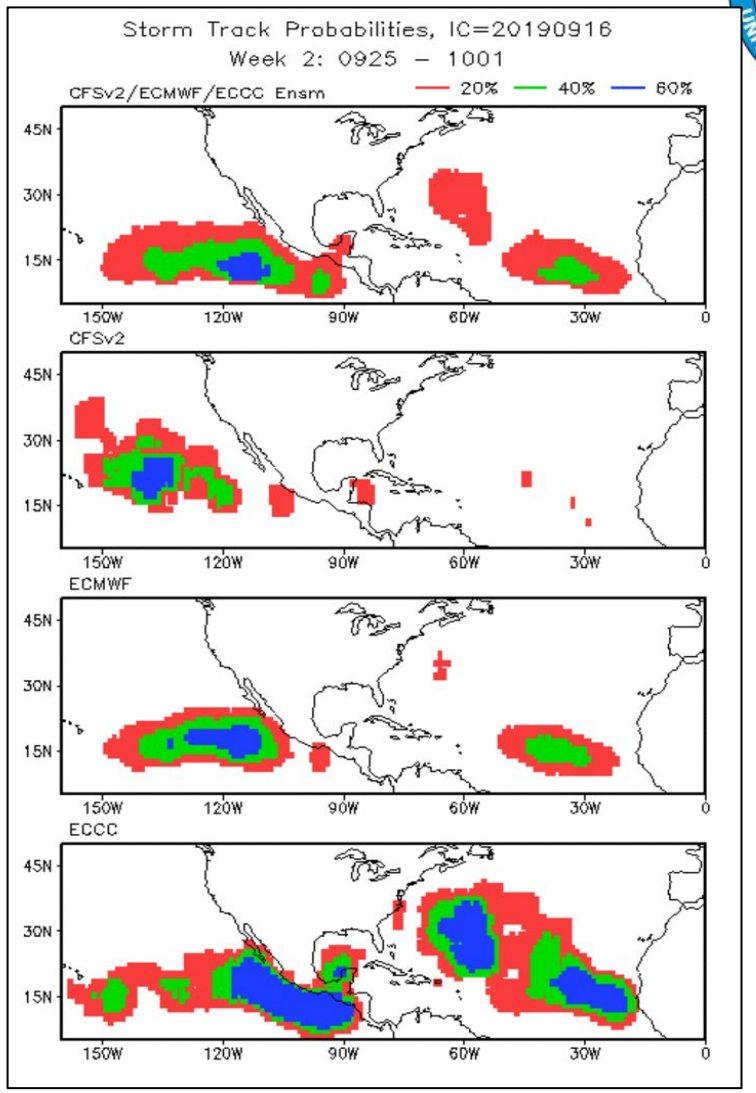


Global Tropics Hazards (GTH) Outlook

Tropical Cyclone Detection / Tracking

- Method based on Camargo and Zebiak (2002)
- Detection thresholds model based on reforecasts
- Verification: HURDAT2 and JTWC Best Track Data



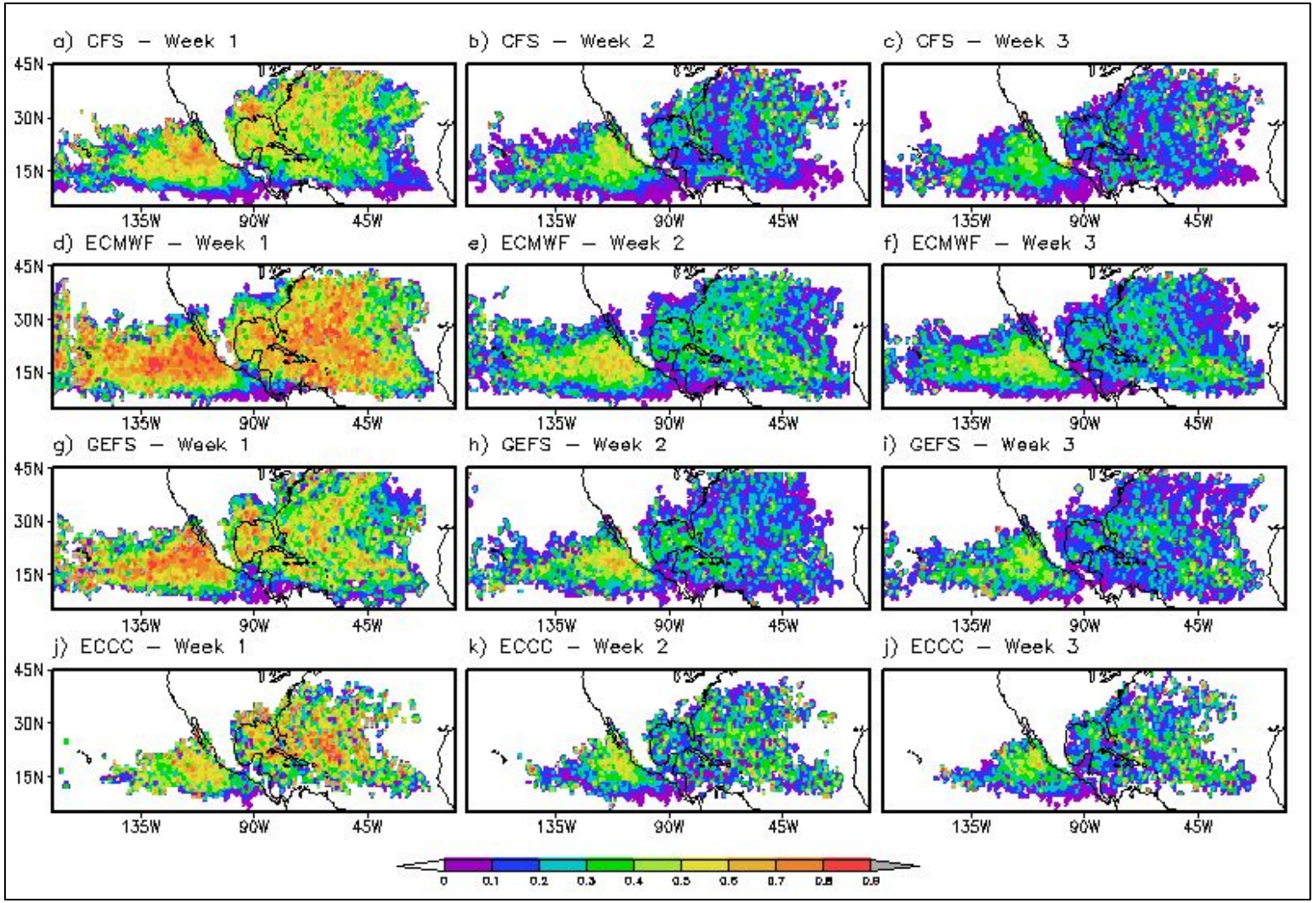


Forecast tracks

Probabilities (Each model, multi-model)

Global Tropics Hazards (GTH) Outlook

- ✔ Critical Success Index (CSI):
  - CSI = a / (a+b+c)
    - a = Hits
    - b = False Alarms
    - c = Misses
- ✔ Reforecast overlap period:
  - 2000-2012
- ✔ ECMWF, GEFSv12 perform the best in this sample
- ✔ EPAC shows higher forecast skill than NATL
- ✔ Some skill remains during Week 3

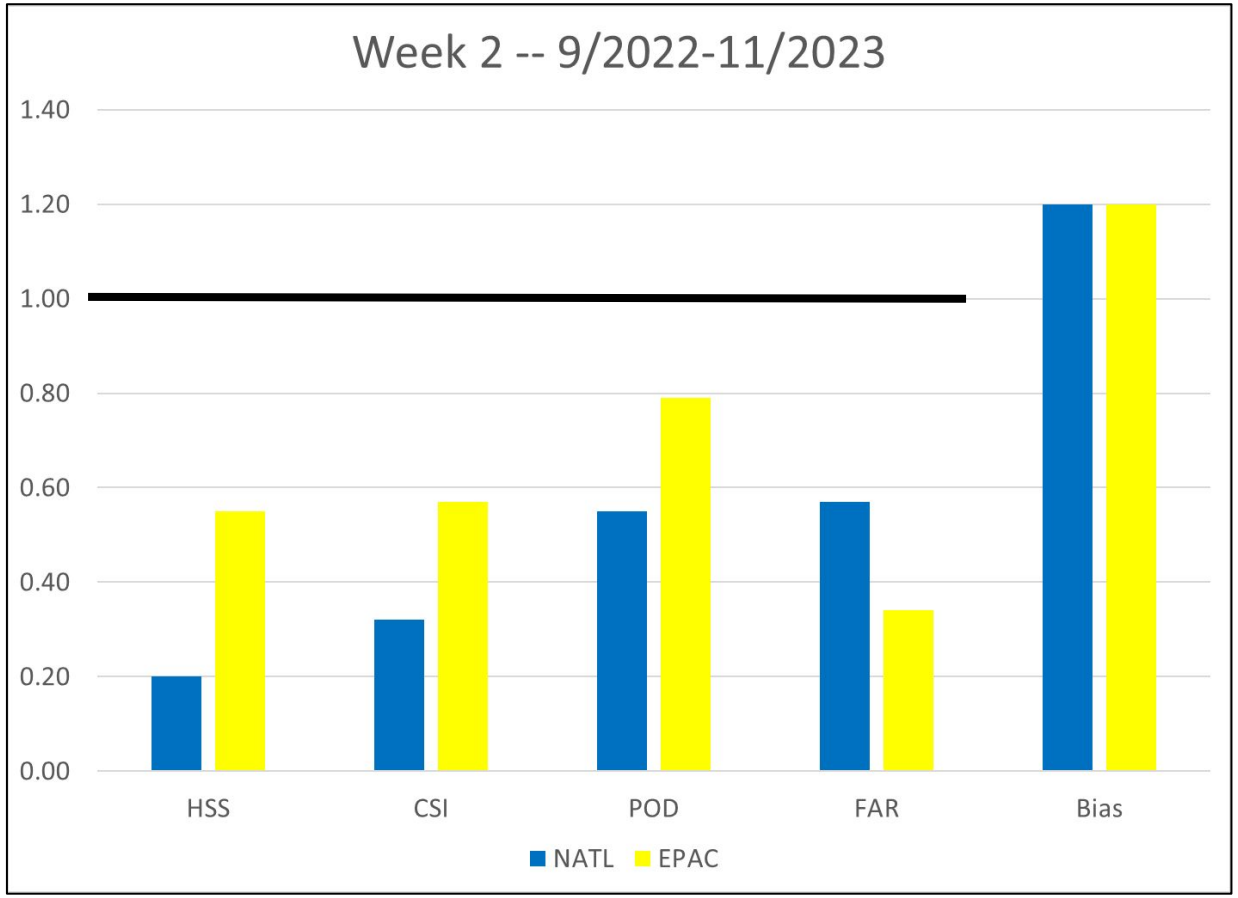


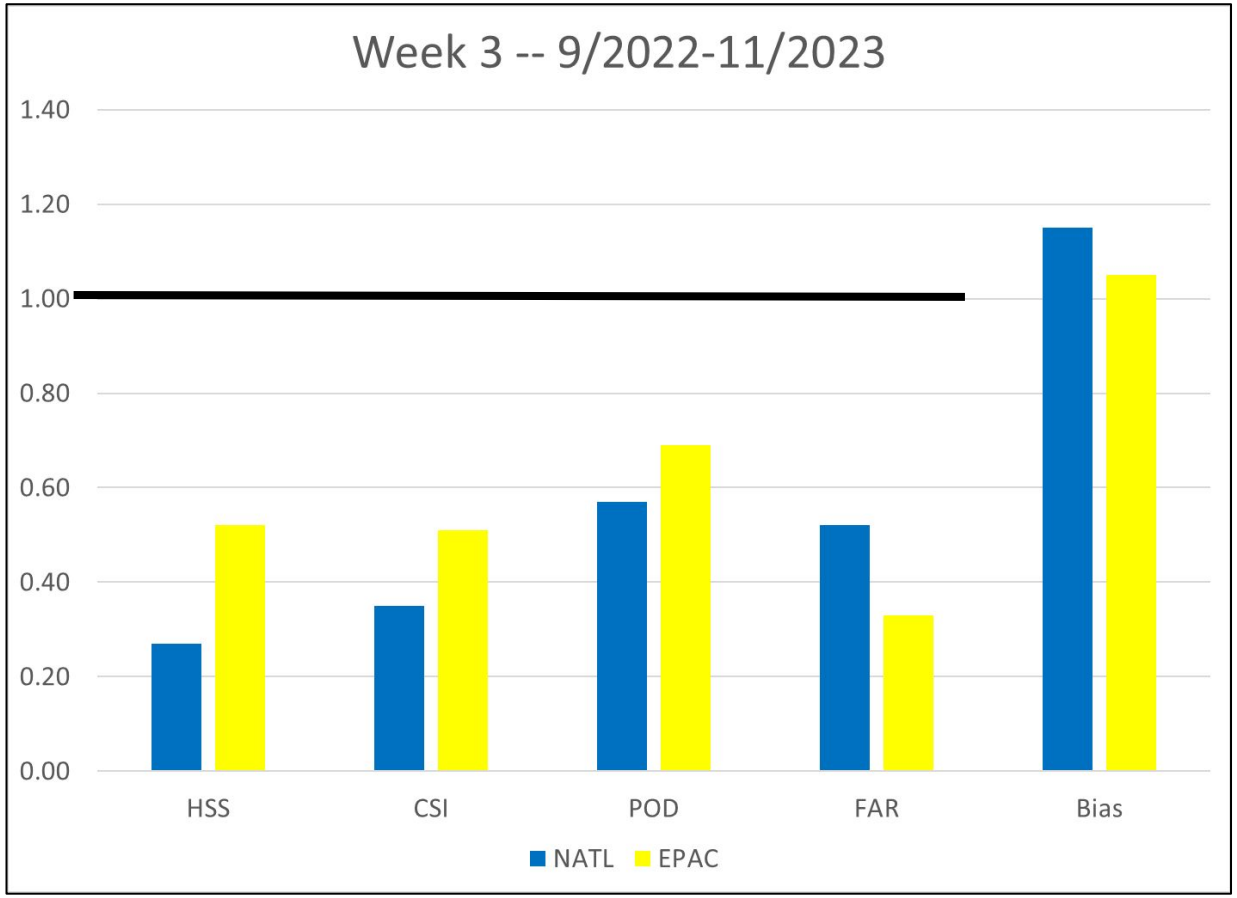
Global Tropics Hazards (GTH) Outlook

CPC Week 2-3 GTH Official Outlook to Date

Heidke Skill Scare	= (a + d) – *E* / (n - *E*)
Critical Success Index	= a / (a + b + c)
Probability Of Detection	= a / (a + c)
Accuracy	= (a + d) / n
False Alarm Rate	= b / (a + b)
Bias	= (a + b) / (a + c)

Forecast \ Observed	YES	NO
YES	A	B
NO	C	D





Summary

- ✔ CPC produces many domestic and global monitoring products as well as outlook products that span from Week 2 out to approximately 1 year
- ✔ The CPC Week 2-3 probabilistic GTH outlook was first released on September 13, 2022 with Week 3 currently experimental in nature
- ✔ The GTH outlook attempts to target “forecasts of opportunity” that can be identified to provide above-normal lead time, confidence for potential high impact events related to tropical cyclones
- ✔ Increased lead time and confidence can play an important role in situational awareness, early decision making and possible mitigation of weather/climate risk

Thank you for your time and attention

Jon.Gottschalck@noaa.gov

Global Tropics Hazards (GTH) Outlook

Some applications and product uses of the GTH outlook and live briefing from stakeholders

Stakeholder Feedback

Focusing on stakeholder benefits and feedback from FEMA, DoD and state/city emergency management offices are below:

From FEMA: "NWS staff use the GTH extensively in the WPAC and SPAC to drive confidence/uncertainty messaging to FEMA leadership regarding prepositioning of assistance teams and resources, and advance travel planning. Typically, FEMA leadership will begin pulling triggers during HIGH or MEDIUM chances in your outlooks or TCFA's, especially if in phase with high probabilities in the GTH"

Domestic use includes usage by city management offices (as noted by the New Orleans Director of Homeland Security and Emergency Preparedness in 2019). "We review and utilize the product for advance planning and situational awareness purposes such as with festivals (> 150 per year). Have discussions with organizers and can ask for more detailed emergency plans and contingencies from them, can help us determine what level of support we are going to provide as far as incident command, and what requests of support we ask from our local WFO."

Operational use of the CPC Global Tropical Hazards Outlook in the Emergency Management Community: Comments from the Director of the Office of Homeland Security and Emergency Preparedness of the City of New Orleans

CPC Stakeholders Workshop
College Park, MD September 2019

Victor Murphy

A Conversation with Collin Arnold, Director of New Orleans GOHSEP

- "It also allows us to determine what level of support to provide we need to provide with regard to incident command and needing additional support from the local WFO."
- "A week 3/week 4 outlook would be another tool at our disposal. I've found the GTHO to be pretty accurate and I'm glad to be on the call each week."

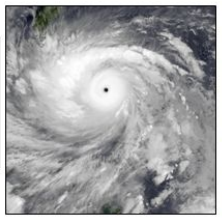
Stakeholder Feedback

Maritime interests: "The GTH gives OTSR a 1 to 2 week heads-up on potential TC formation areas, to aid planning ahead with possible ship routing concerns generating a running list of ships transiting through tropical development areas to watch and can result in diverts or advisories."

"The GTH also is used as a long-range planning tool often for Trans Pacific aircraft flights. One of the many real world examples was during Super Typhoon Trami in 2018 when we were able to afford our commanders adequate lead time for planning asset relocation and base safety measures for equipment and personnel."

"The precipitation and temperature outlooks are used for humanitarian aid purposes and in a contingency planning in these scenarios similar to USAID and the Red Cross."

GTH outlook used for guidance, situational awareness information for recovery efforts (i.e., after a high impact event is just as important)



Stakeholder Feedback

Spaceflight Meteorology Group
June 2012, sent by SMG Chief, Frank Brody

"Recent outlooks highlighting the Gulf of Mexico for tropical cyclone development were very accurate. This gave SMG valuable early insight into what may unfold in the Gulf and Caribbean. Following one of these GTM briefings, I used the global outlook chart to brief NASA Johnson Space Center that tropical cyclone potential would be increasing the following week …"

Linda Spuler, the NASA/JSC Emergency Preparedness Manager, made this comment:

"As Emergency Preparedness Manager for the Johnson Space Center, I greatly appreciate the long range tropical outlook. The information is extremely valuable to me. I use it to brief Center management on potential activity in the gulf, and it allows me to help JSC proactively prepare for potential events instead of just reacting to events as they occur. Kudos to the NWS for providing a tool that concisely shows a lay person areas of interest to focus upon.

Organization Feedback

NWS HQ Leadership Team – GOES Satellite Operations Decision

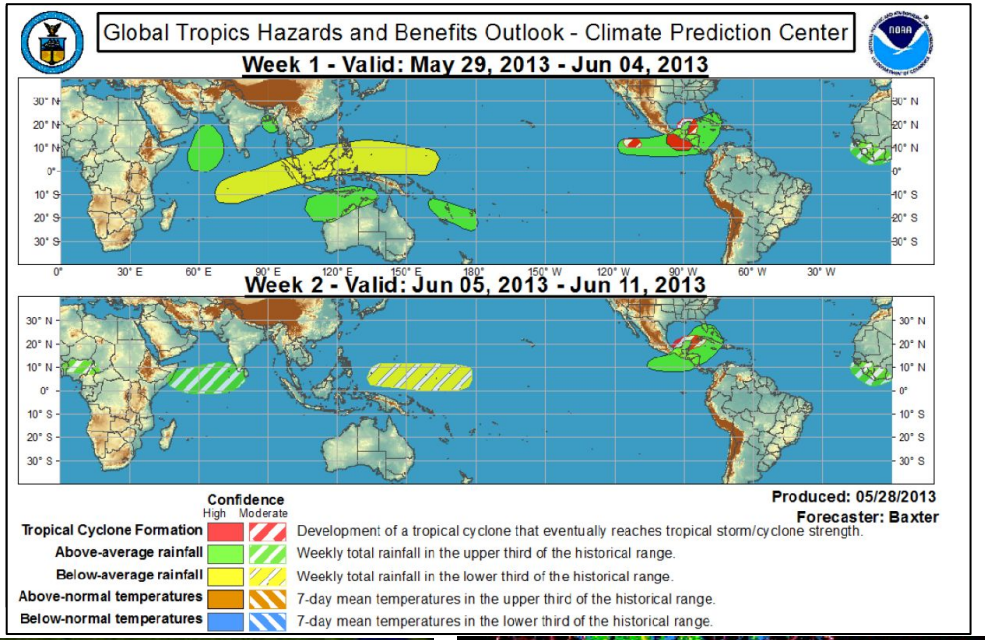
June 7, 2013 communication with then NWS Director Louis Uccellini

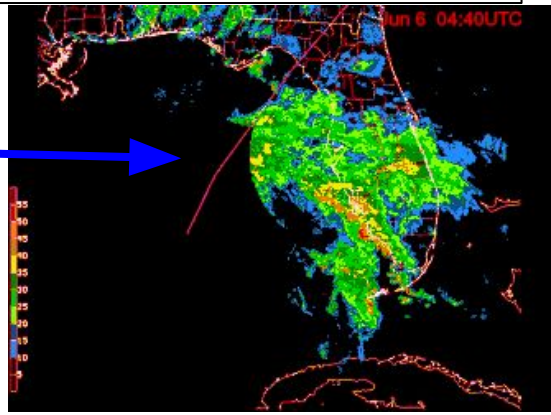
Regarding Tropical storm Andrea – briefing late May 2013

All,

During the morning NWS leadership briefing, Louis took time to comment on how much he and the staff there appreciated **the lead time provided by our GTH outlook 2 weeks in advance for tropical cyclogenesis in the NW Caribbean and southern Gulf of Mexico** for Tropical storm Andrea, **along with the likely flooding rains across Florida**. At the time he pushed the product up the chain to NOAA leadership and it actually **resulted in an adjustment to the GOES-13 to GOES-14 transfer of operations schedule** (i.e., they wanted to make sure they had reliable satellite coverage for operational entities in the southeast U.S.).

He personally congratulated CPC on this outlook and communication and just wanted folks to know this.





NATIONAL WEATHER SERVICE

Community-Based Model Development at NCEP/EMC for Operational Weather Prediction

Avichal Mehra[1]

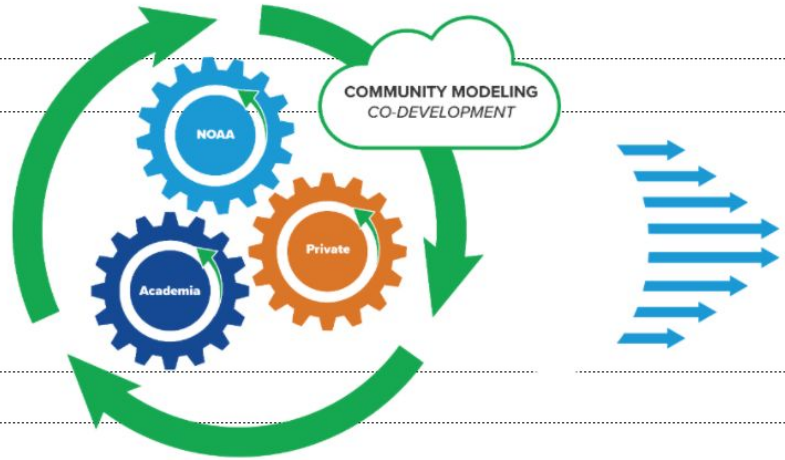
[1]*Chief, Coupled Modeling Division at NOAA/NWS/EMC, College Park, MD*

2024 National Hurricane Conference
March 25-28 2024, Orlando, FL

- **Acknowledgements**
  - All of the outstanding scientists and engineers at the Environmental Modeling Center, and Collaborators within NOAA, at other Federal agencies, Academia, and the Private Sector
- **Reference**
  - EMC 5-Year Implementation Plan

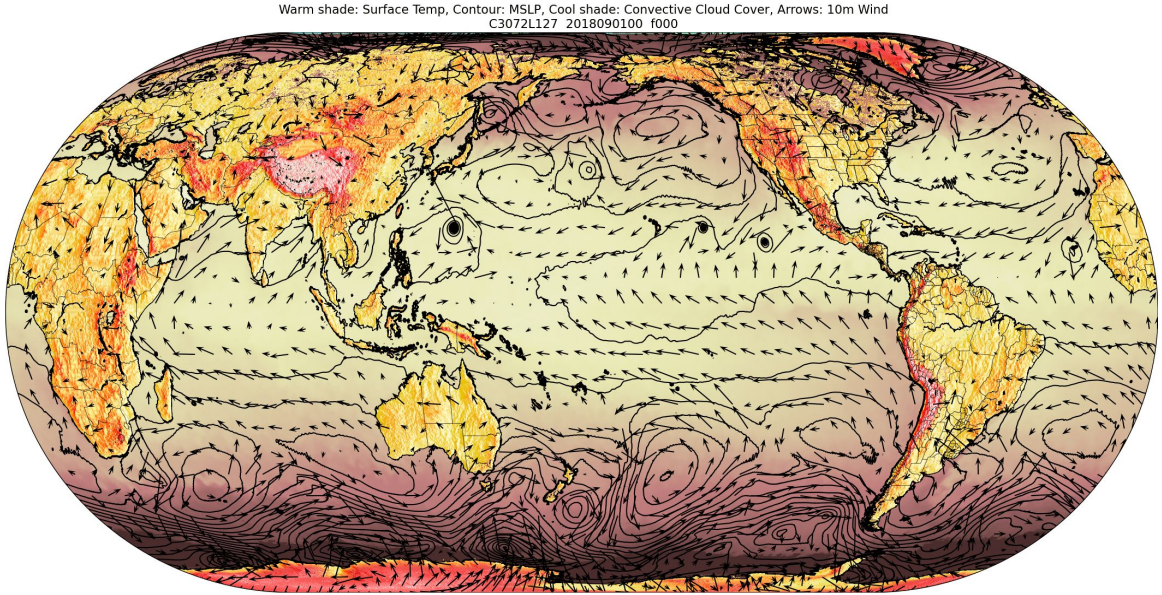
Evolution of NCEP Modeling Suite into UFS Apps

NPS Modeling System	Current Version	FY2022 - FY2027	UFS-based Version	UFS Application
Global Weather, Waves & Global Analysis	GFS/ GDASv16.2	Unified Forecast System (UFS)	GFS/ GEFS/SFS	UFS Medium Range & Sub-Seasonal
Global Weather and Wave Ensembles, Aerosols	GEFSv12			
Short-Range Regional Ensembles	SREFv7			
Global Ocean & Sea-Ice	RTOFSv2			UFS Marine & Cryosphere
Global Ocean Analysis	GODASv2			
Seasonal Climate	CDAS/ CFSv2			UFS Seasonal
Regional Hurricane 1	HWRFv13		HAFS	UFS Hurricane
Regional Hurricane 2	HMONv3			
Regional High Resolution CAM 1	HiRes Window v8		RRFS/WoF	UFS Short-Range Regional HiRes CAM & Regional Air Quality
Regional High Resolution CAM 2	NAM nests/ Fire Wxv4			
Regional High Resolution CAM 3	RAPv5/ HRRRv4			
Regional HiRes CAM Ensemble	HREFv3			
Regional Mesoscale Weather	NAMv4			
Regional Air Quality	AQMV6			
Regional Surface Weather Analysis	RTMA/ URMA v2.8		3DRTMA/ URMA	
Atmospheric Transport & Dispersion	HySPLITv7		HySPLIT	UFS Air Quality & Dispersion
Coastal & Regional Waves	NWPSv1.3		RWPS	UFS Coastal Waves
Great Lakes	GLWUv1.0.3		GLWU	UFS Lakes
Regional Hydrology	NWMv2.1		NWM	UFS Hydrology
Space Weather 1	WAM/IPEv1		WAM/IPE	UFS Space Weather
Space Weather 2	ENLILv1			



Global Coupled Prediction Systems

MRW/S2S: Building a Six-Way Global Coupled Unified Forecast System For future GFS, GEFS and SFS



UFS Earth System Model Components:

- FV3 (Atmosphere)
- MOM6 (Ocean)
- CICE6 (Sea Ice)
- WW3 (Waves)
- NOAH-MP (Land)
- GOCART (Aerosols)

A fully coupled UFS serves as a foundation for future operational global forecast systems at NOAA/NWS/NCEP ranging from weather to subseasonal to seasonal scales.

GFSv17 Development Priorities

- Coupled forecast model (atm, land, ocn, ice, wav)
- Improved DA with marine JEDI
- Physics improvements including Noah-MP land model and Thompson Microphysics
- Unstructured Wave grids w/2-way coupling
- Higher resolution (9-km target)
- Improve on known issues in GFSv16
- Consolidation of NCEP production suite
  - GODAS combined in Coupled GDAS
  - Retirement of NAM and RAP

GEFSv13 Development Priorities

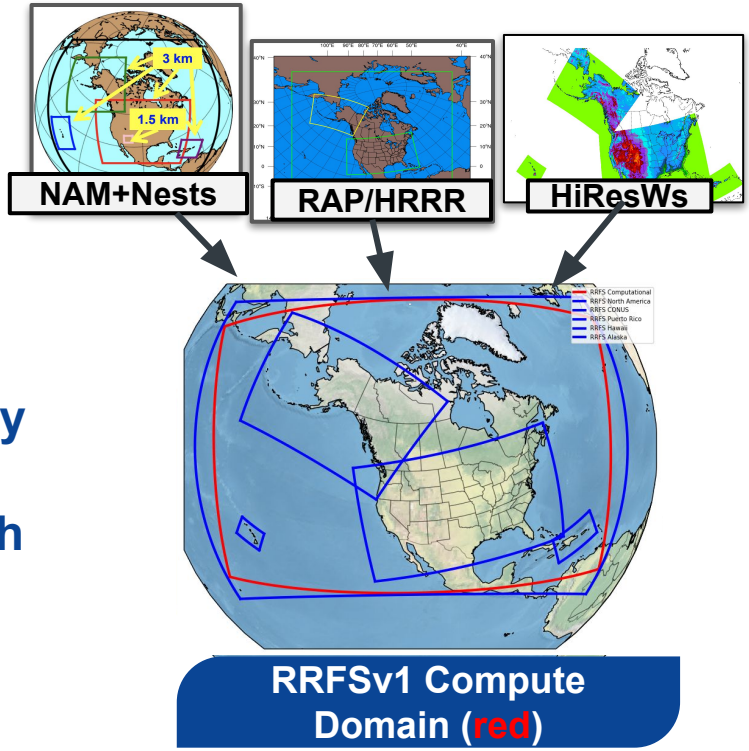
- Have the same model configuration as of GFSv17 (Latest UFS coupled forecast model)
- Include interactive aerosols in all ensemble members
- Early cycle EnKF analysis for ensemble initial perturbations
- Advanced model stochastics for all component models
- Reanalysis/reforecast
- 30 years reforecast to support forecast calibration (and training)
- Extend forecast length to 48 days
- Improve on known issues in GEFSv12
- Consolidation of NCEP production suite
  - Retirement of SREF

Regional Prediction System

Rapid Refresh Forecast System (RRFS)

A UFS Application

- FV3 dynamical core Limited Area Model
- Hourly updated
- 3 km grid spacing over North America
- 65 vertical layers
- Hybrid 3DEnVar assimilation (30 members)
- Includes Smoke & Dust
- Deterministic forecasts to *at least* 18h every hour
- Deterministic & Ensemble forecasts to 48+h every 6 hours



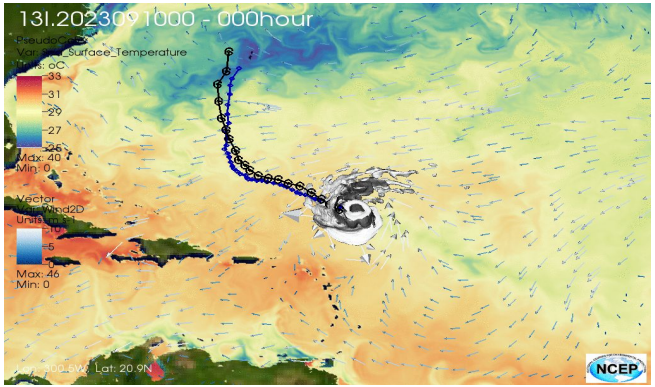
Hurricane Analysis and Forecast System

Hurricane Analysis and Forecast System (HAFS v1)

- HAFS is NOAA's new hurricane modeling system within the Unified Forecast System (UFS) framework which was **implemented operationally in June 2023**
- HAFS is a results of multi-year R2O collaboration between NWS's Environmental Modeling Center and OAR's AOML/Hurricane Research Division and other UFS partners
- HAFS has atmosphere-ocean-wave coupling, improved data analysis and physics, and provides detailed outputs following the storm

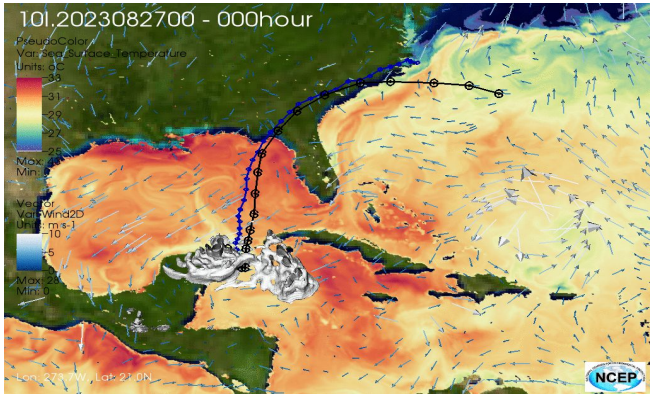
Hurricane Lee, 13L, 20230910 00Z

HFSA



Hurricane Idalia, 10L, 20230827 00Z

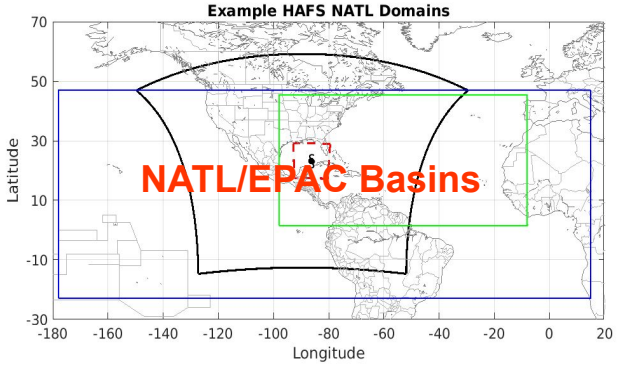
HFSB

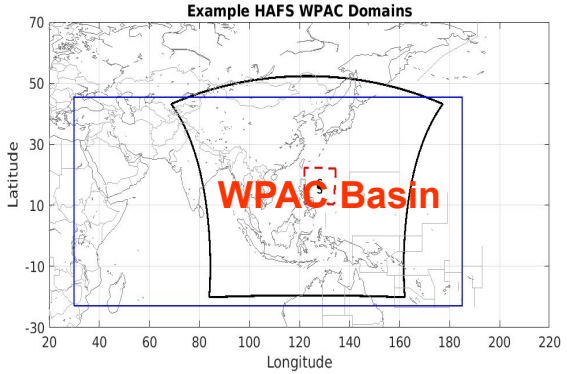


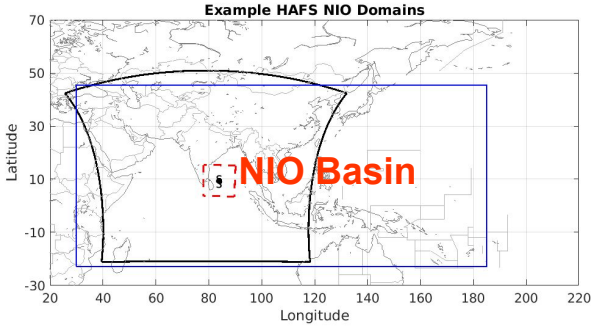
NCEP's Operational Hurricane Modeling Systems

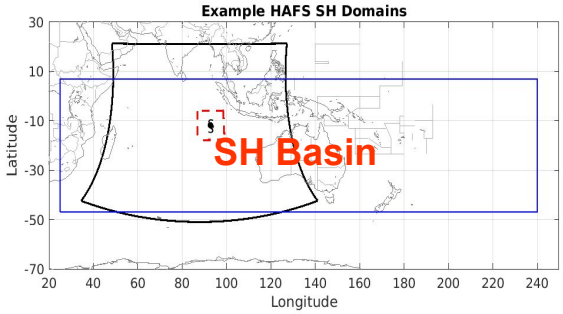
	HWRF Operational since 2007	HMON Operational since 2017	HAFS-A Operational Since 2023	HAFS-B Operational Since 2023
System and Infrastructure	NMM E-grid NCEP coupler 13.5/4.5/1.5 km L75	NMM B-grid NCEP Coupler 18/6/2 km L71	**FV3 dyn-core** **CMEPS** 5.4/1.8 km L81	**FV3 dyn-core** **CMEPS** 6/2 km L81
Data Assimilation	3DEnVar Self-cycled DA for priority TC	No DA	**4DEnVar**	**4DEnVar**
Vortex Initialization	Vmax > 25 kt warm-cycled VI	Vmax > 25 kt warm-cycled VI	Vmax > 40 kt warm-cycled VI	Vmax > 40 kt warm-cycled VI
Ocean/Wave Coupling	POM/WW3 RTOFS	HYCOM RTOFS	MOM6/WW3 RTOFSv2	HYCOM RTOFSv2
CONOPS	Global Basins Maximum slots: **3**	NHC Basins Maximum slots: **3**	Global Basins Maximum slots: **7**	NHC basins Maximum Slots: **5**

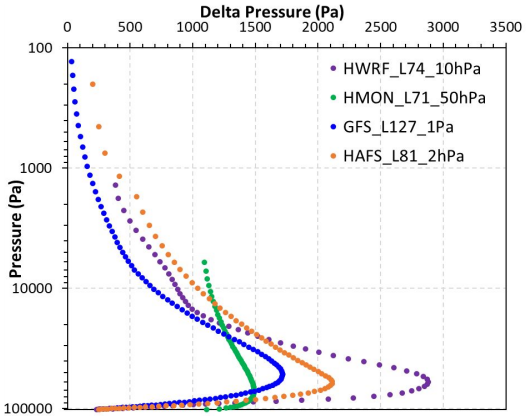
Configurations: HAFS vA runs in all Global Basins

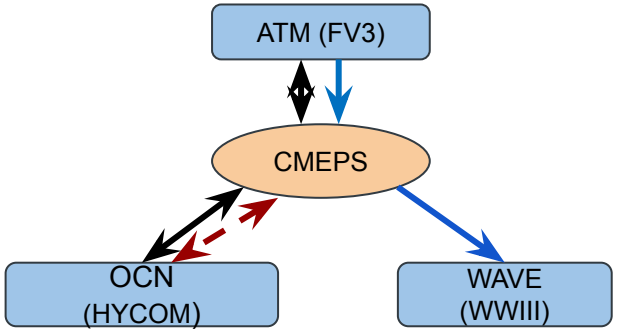






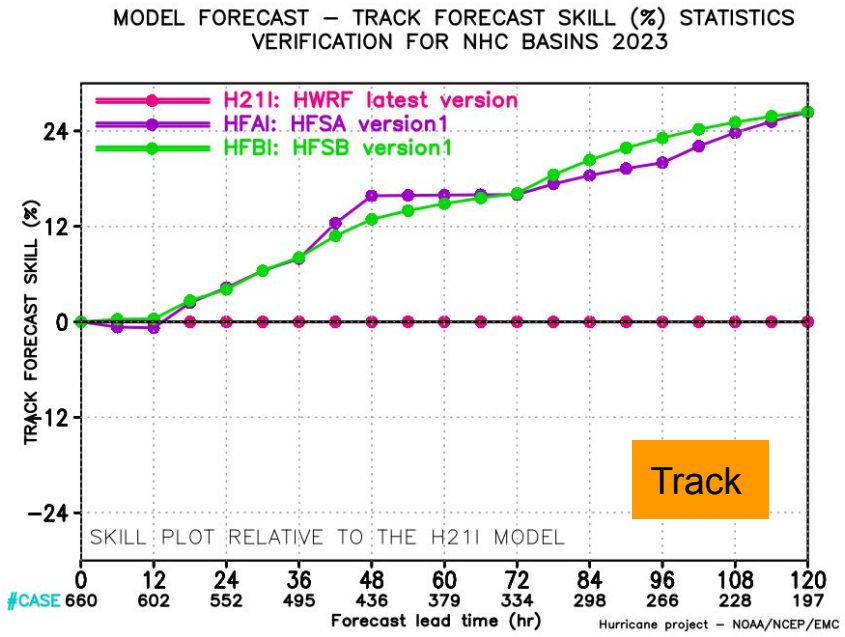






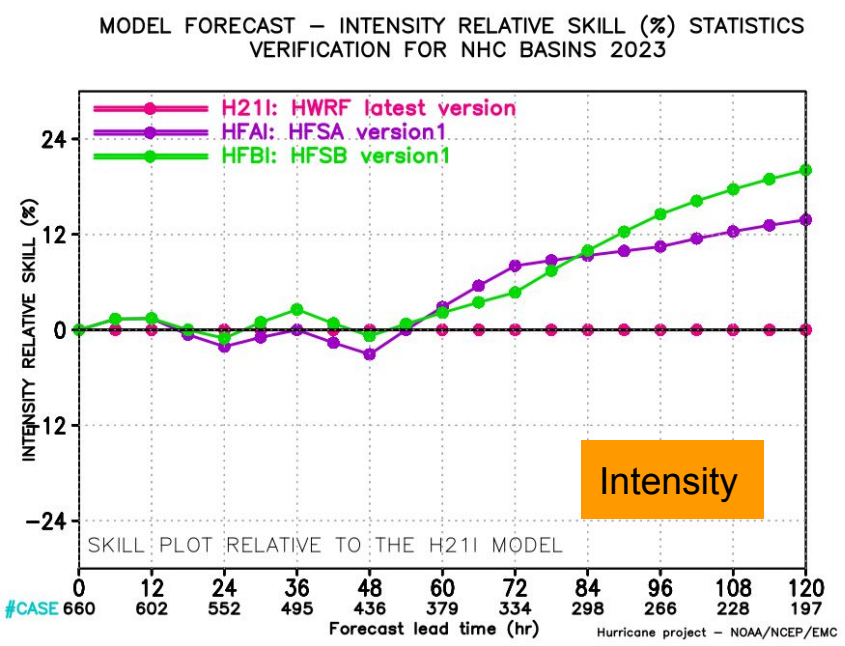
NOAA's New Generation Hurricane Model HAFS Forecast Skills Relative to Legacy HWRF

All 2023 Storms in NHC Basins



Improvement

Degradation



Timeline for HAFS v2 Transition to Operations

05/01 to 07/31, 2023 Complete	08/01-10/31, 2023 Complete	11/01/23-01/15/24 code development - code freeze 01/16-03/30, 2024 3-year retros and NHC evaluation	03/31-06/30, 2024 Planned	~July 1, 2024
HAFS IOC and planning for real time experiments	HAFS real time Experiments	HAFS v2 baseline Evaluation and developments	HAFSv2.0 implementation	

Testing two configurations:

- High resolution domains
- Improving model physics
- Improved Vortex initialization and Inner-core data assimilation
- T&E to select optimal configurations

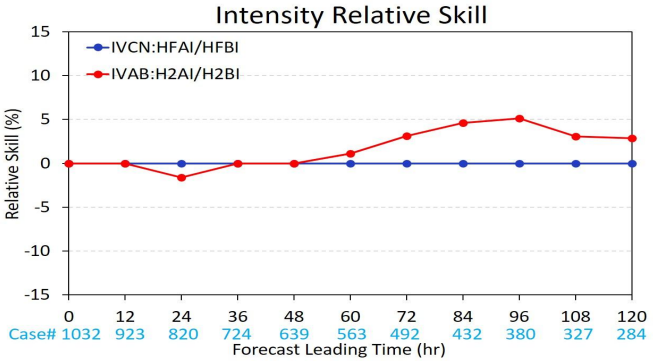
Highlights HAFS v2.0

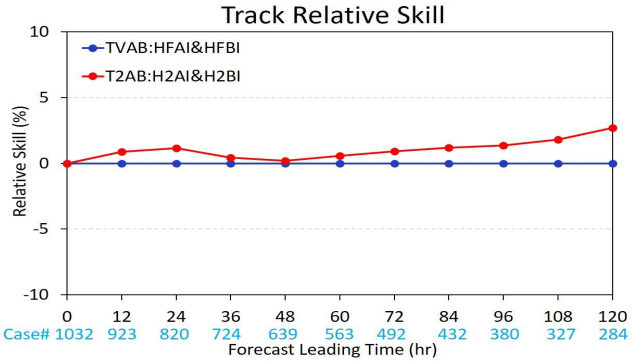
- Higher resolution for HAFSA
- MOM6 coupling for HAFSA
- High-density meso AMVs DA
- Improved vortex relocation
- Improved physics
- Code modernization and optimization
- Model efficiency and stability

NCO implementation

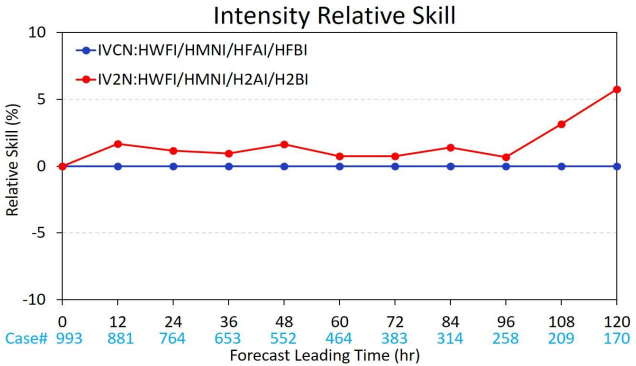
Consensus Skill: HAFSv2 vs HAFSv1

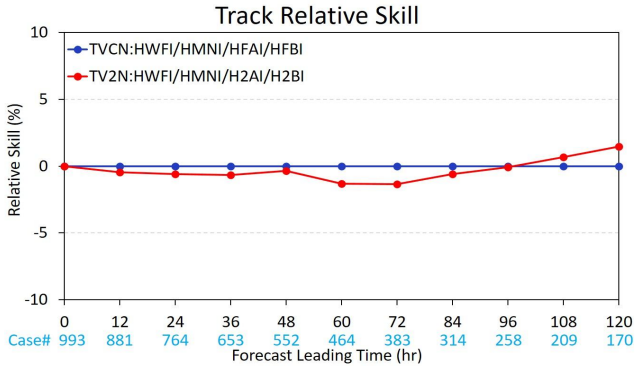
NATL BASIN





EPAC BASIN





Intensity: DSHP, LGEM, HWRF, HMON, HAFSA, HAFSB, CTCI

Track: AVNO, EGRR, HWRF, HMON, HAFSA, HFSAB, EMXI, CTCI

Development Roadmap for Hurricane Modeling Systems

Target Annual Upgrades

HAFSv2

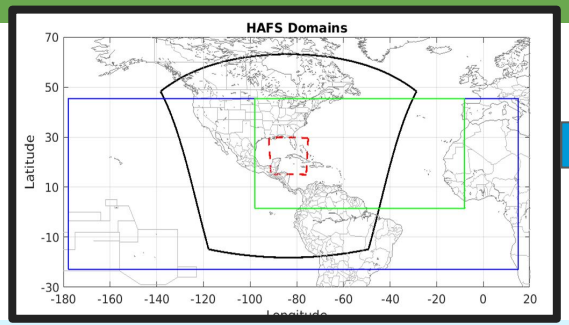
- Storm-centric with one moving nest
- Improved vortex initialization
- Flight-level obs. for priority storms
- 4DEnVar using GDAS ensemble
- TC-calibrated Physics based on UFS physics suites
- Atm/Ocn Coupled System, one-way Wave

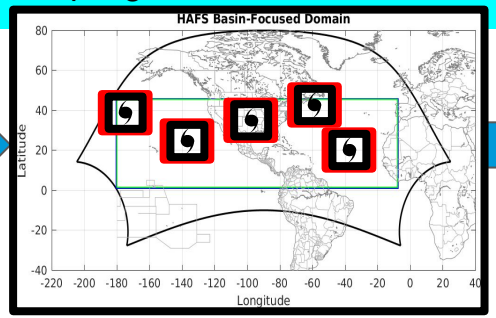
Near future plans

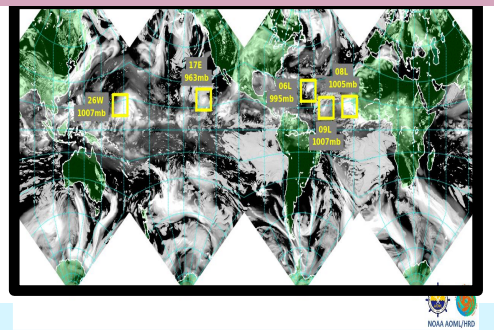
- Multiple moving nests in a basin-centric domain
- Sophisticated VI, GSI and/or AI and/or dynamics-based VI
- High-frequency, self-cycled 4DEnVar, weakly coupled Atmos/Ocean DA, All-sky, explore JEDI-based DA
- Scale-aware model Physics suitable for high res. model
- Three-way HAFS/MOM6/WW3 coupling

Long term plans

- Multiple moving nests with cloud-resolving resolutions in a global model framework
- Multi-scale, coupled DA
- High temporal and spatial resolution of in-situ atms/ocn obs
- AI-based sub-kilometer model physics
- Hurricane Ens. Prediction System
- High res. products, tornadoes, inundation and flooding







Application of AI/ML for Operational NWP

Current/Planned AI/ML Activities at NCEP/EMC

Observations	Data Assimilation	Forecast	Post/Product
Radiosonde processing	Physics emulation	AC Accelerated Transport	Wave Systems
Satellite Thinning	Improved Background	Atmospheric Chemistry Emulator	Air Quality Bias Correction
AMV super-observations and error estimation	Background Error Covariances	Physics Suite Emulation	Sub-Seasonal/ Seasonal forecast products
Conventional / Aircraft quality control	CRTM emissivity modeling	Radiation Parameterizations	
Observation Anomaly Detection	High-resolution background downscaling and emulation	Ensemble Forecasting / Forecast Model Emulation	
	Radiance bias correction	Fire emissions for sub-seasonal to seasonal predictions	

Real Time forecasts using Google deepmind Graphcast ML model emulator

Evaluation results of GraphCast, a high-resolution model presented by *Lam et al., 2023* (0.25 degree resolution, 37 pressure levels), trained on ERA5 data from 1979 to 2017.

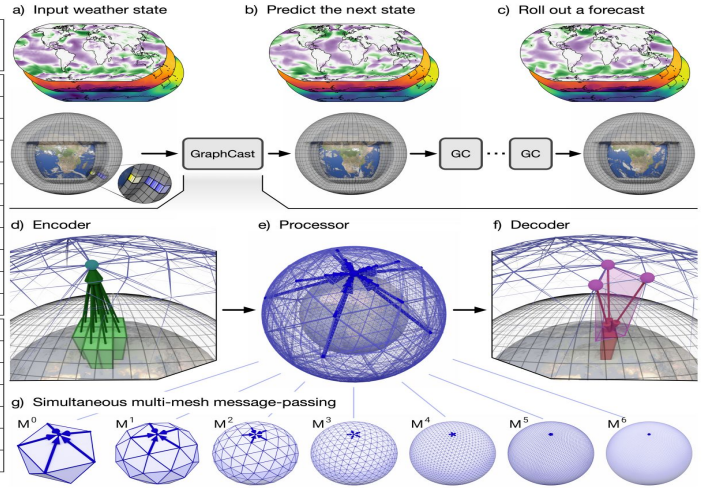
Status:

- Able to run GraphCast with ERA5 data on NOAA cloud

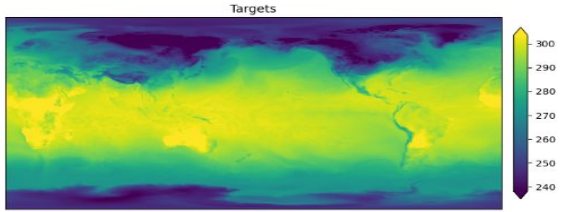
EMC's Plan:

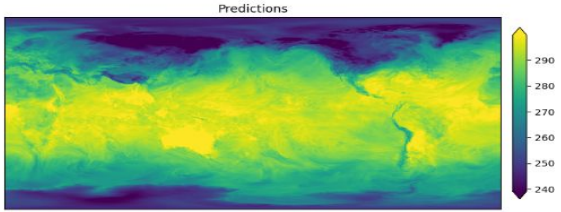
- Run GraphCast in real time with GDAS analysis
- Train GraphCast with GEFSv12 reanalysis and run ensemble forecast.

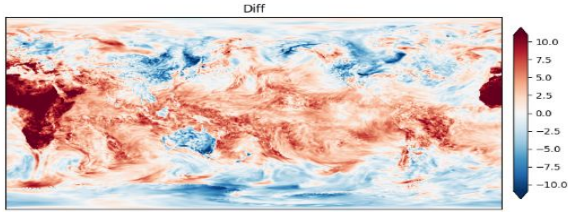
Variable name	Role (accumulation period, if applicable)
Geopotential	Input/Predicted
Specific humidity	Input/Predicted
Temperature	Input/Predicted
U component of wind	Input/Predicted
V component of wind	Input/Predicted
Vertical velocity	Input/Predicted
2 metre temperature	Input/Predicted
10 metre u wind component	Input/Predicted
10 metre v wind component	Input/Predicted
Mean sea level pressure	Input/Predicted
Total precipitation	Input/Predicted (6h)
TOA incident solar radiation	Input (1h)
Geopotential at surface	Input
Land-sea mask	Input
Latitude	Input
Longitude	Input
Local time of day	Input
Elapsed year progress	Input



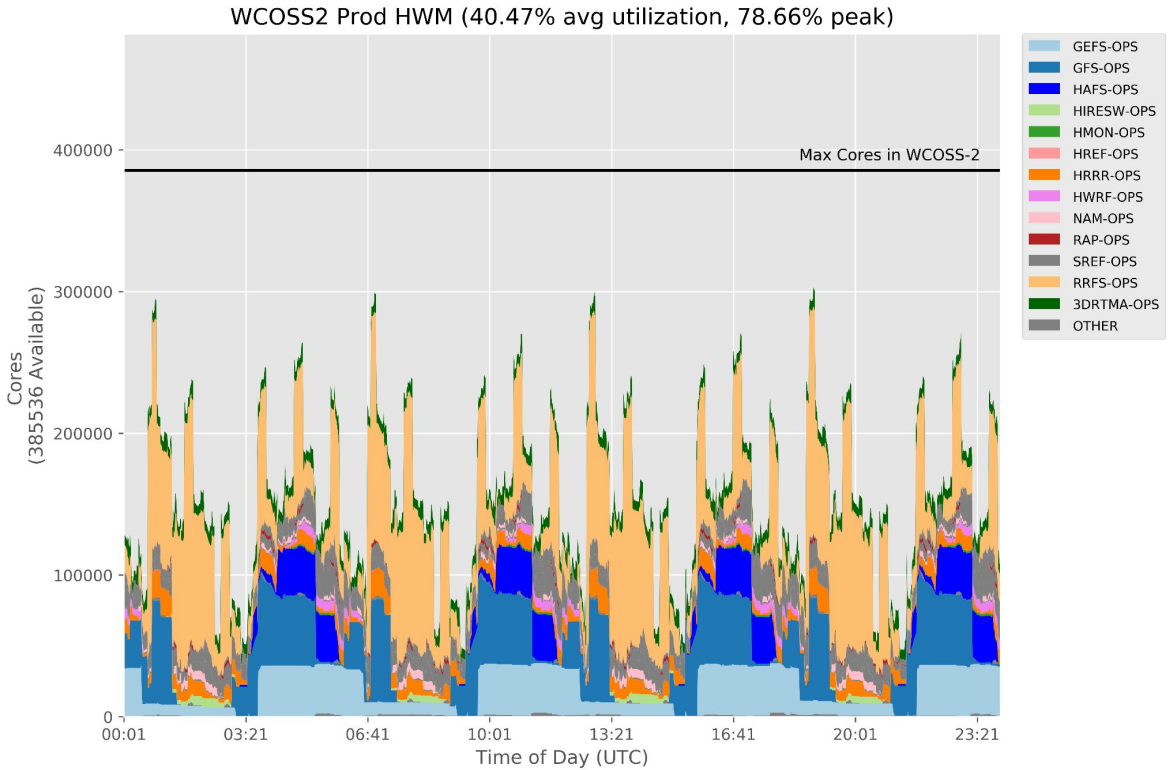
2m_temperature, 6:00:00

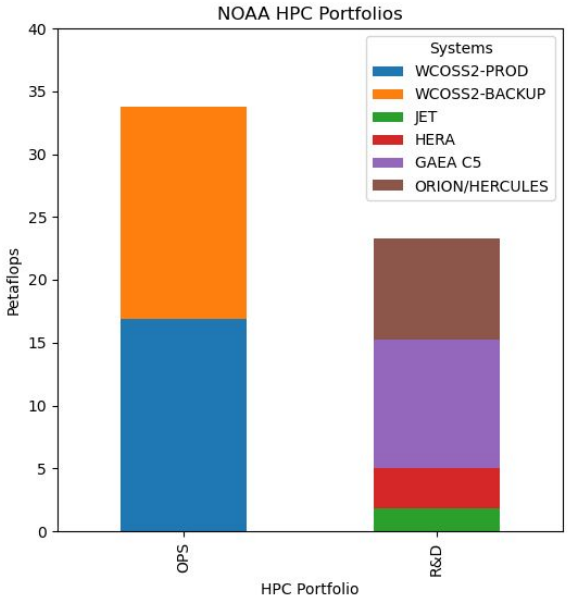






Challenges: HPC Resources





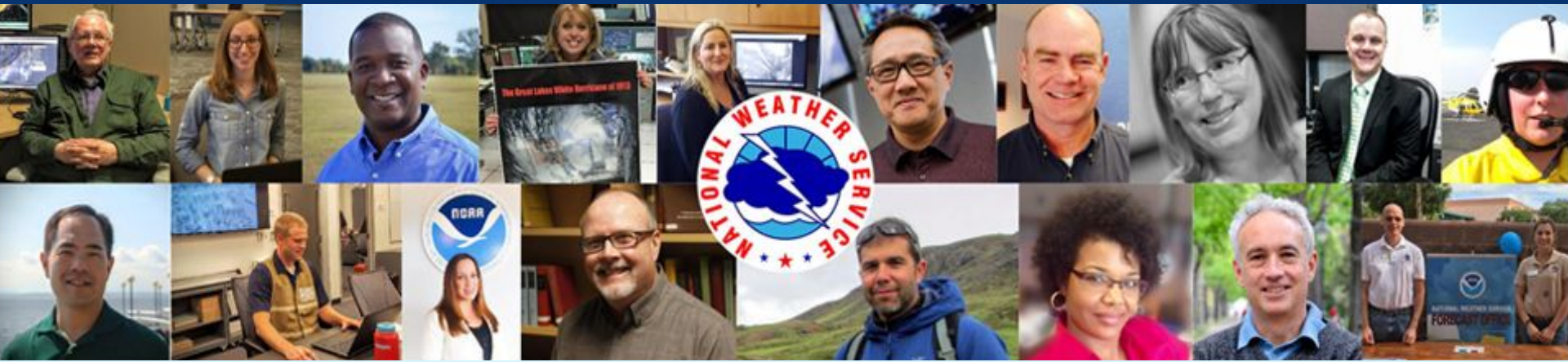
** Significant increase in R&D HPC is anticipated from DRSA, BIL, and IRA; still may be insufficient for R2O

Imagine a World ….

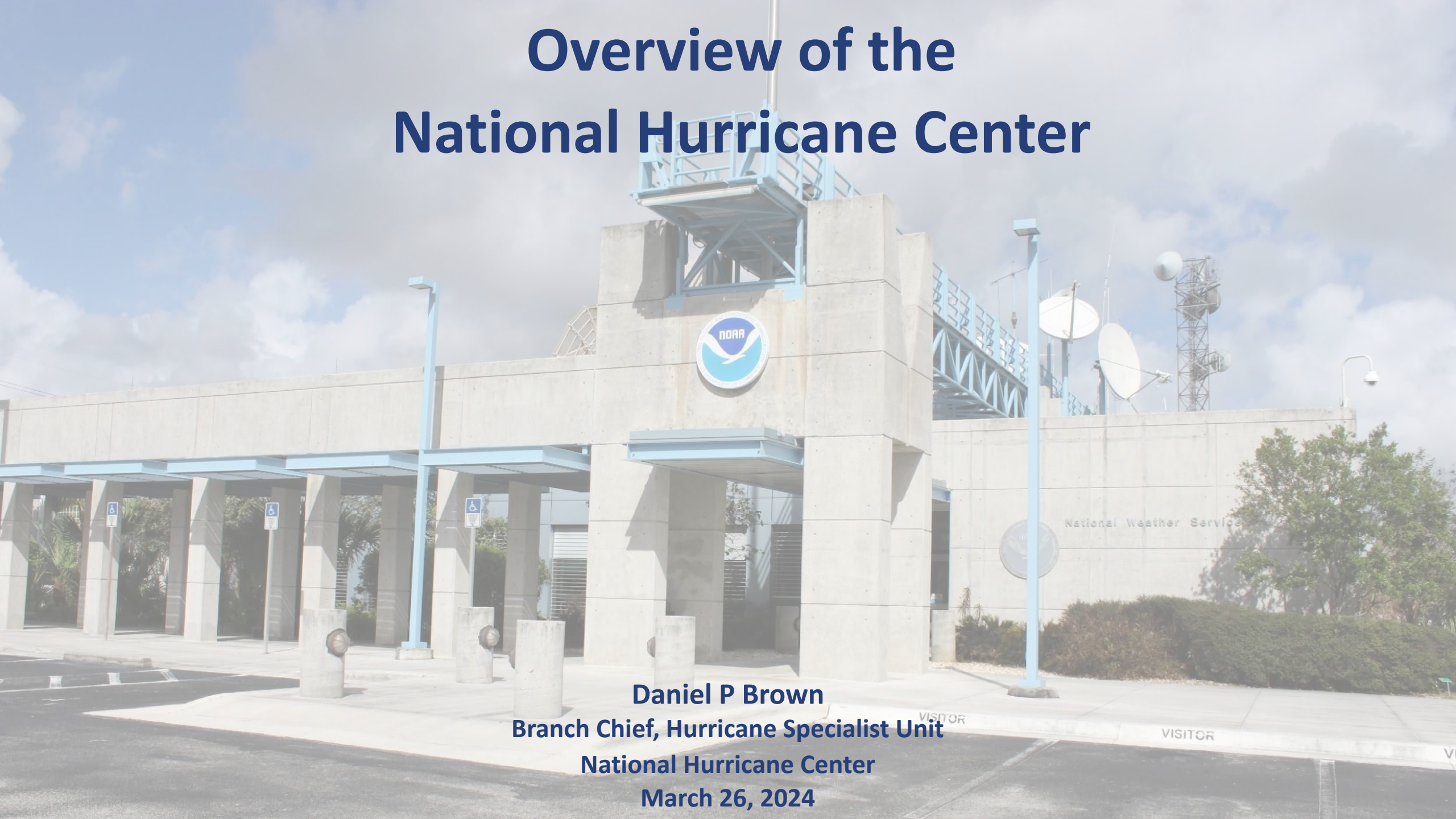
*

- Operational Production Suite backbone of continuously assimilating comprehensive coupled Earth System Model
  - “Digital Twin” - constant update of global state and innovation of training data **
- Regular prediction systems (e.g., 2/day global, hourly CAM) and ad hoc (hurricane, fire, dispersion, etc)
- Variety of approaches - deterministic, ensemble-based, surrogate systems trained on reanalysis and backbone
- Cloud-based systems to accommodate HPC requirements as-needed

Thank you!



Overview of the National Hurricane Center

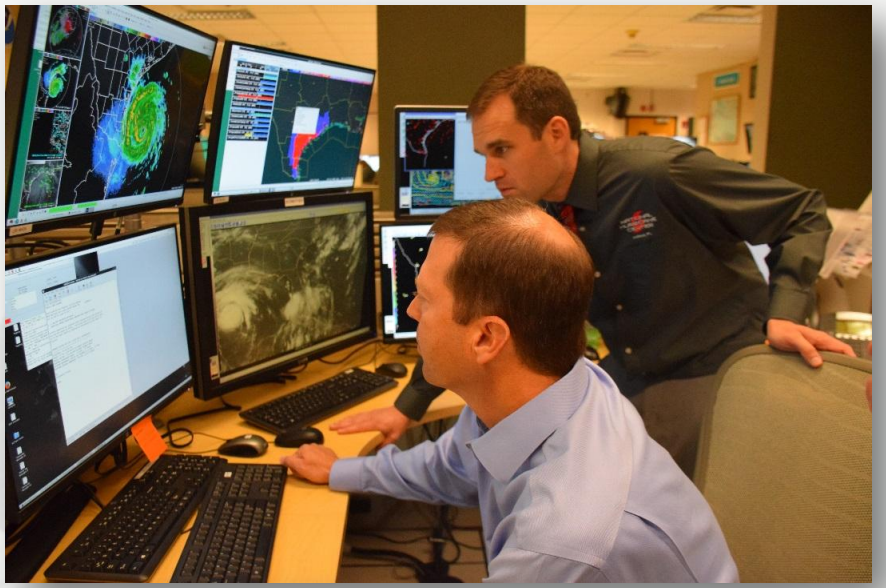


Daniel P Brown
Branch Chief, Hurricane Specialist Unit
National Hurricane Center
March 26, 2024

The Mission

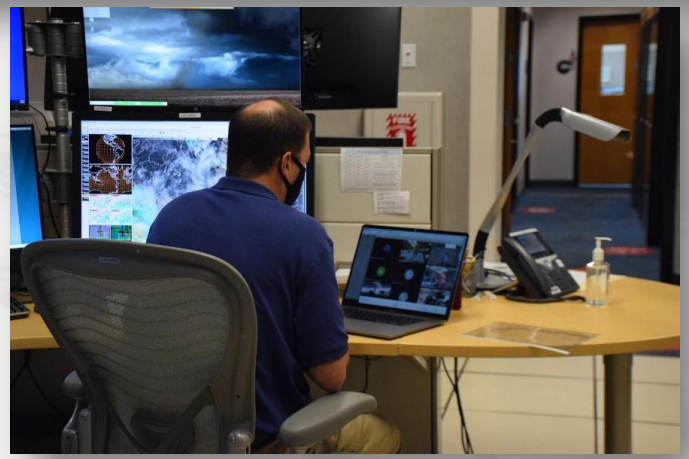
Mission:

Save lives, mitigate property loss, and improve economic efficiency by issuing the best watches, warnings, and forecasts of hazardous tropical weather and by increasing understanding of these hazards.



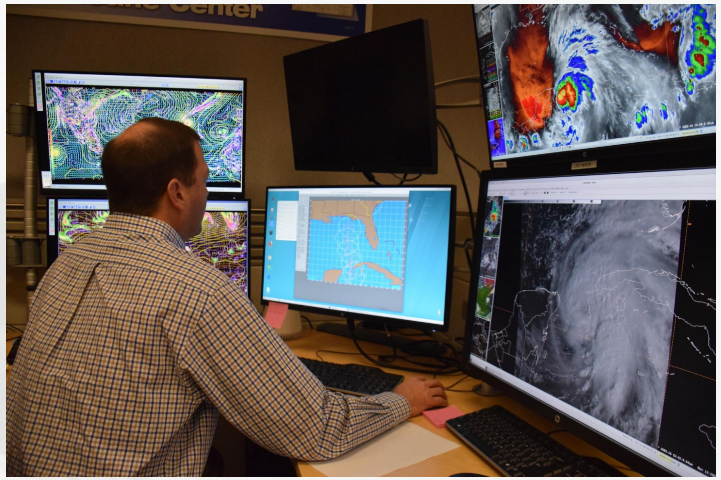
Vision:

To be America's calm, clear and trusted voice in the eye of the storm, and with our partners, enable communities to be safe from tropical weather threats



The People

- ~46 NHC government positions across four work units
- Around 15 contractors
- Also host to:
  - U.S. Air Force Reserves outpost (coordinating hurricane aircraft reconnaissance)
  - Federal Emergency Management Agency (FEMA) Hurricane Liaison Team
  - NOAA Corps Officer
  - Navy hurricane forecaster
  - Occasional visiting scientists and students



The Operating Units

Hurricane Specialist Unit (HSU) - 11 forecasters

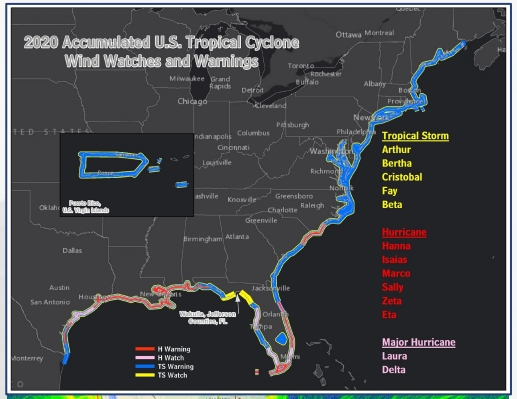
- Develop, coordinate (domestically and abroad) and issue tropical cyclone forecasts and warnings
- Enhance response through a public awareness program and training for emergency managers, meteorologists and the media

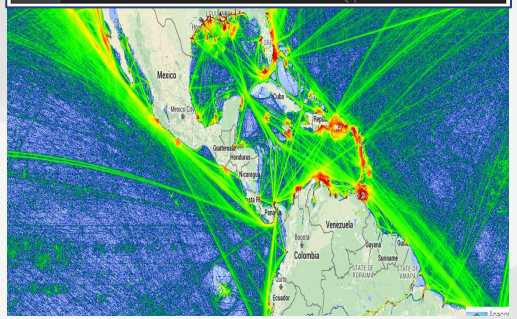
Tropical Analysis and Forecast Branch (TAFB) - 18 forecasters

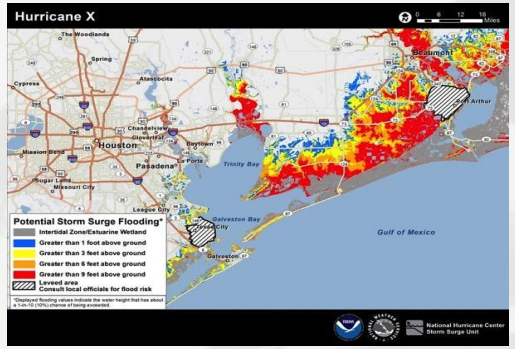
- Produce and issue gridded, text and graphical marine analyses, forecasts and warnings for the tropical Atlantic and northern East Pacific
- Provide satellite analyses and support to the HSU

Technology and Science Branch (TSB) – 10 meteorologists

- NHC Storm Surge Unit
- Help maintain NHC's operational information technology systems
- Advance the Center's forecast skill and scientific credibility





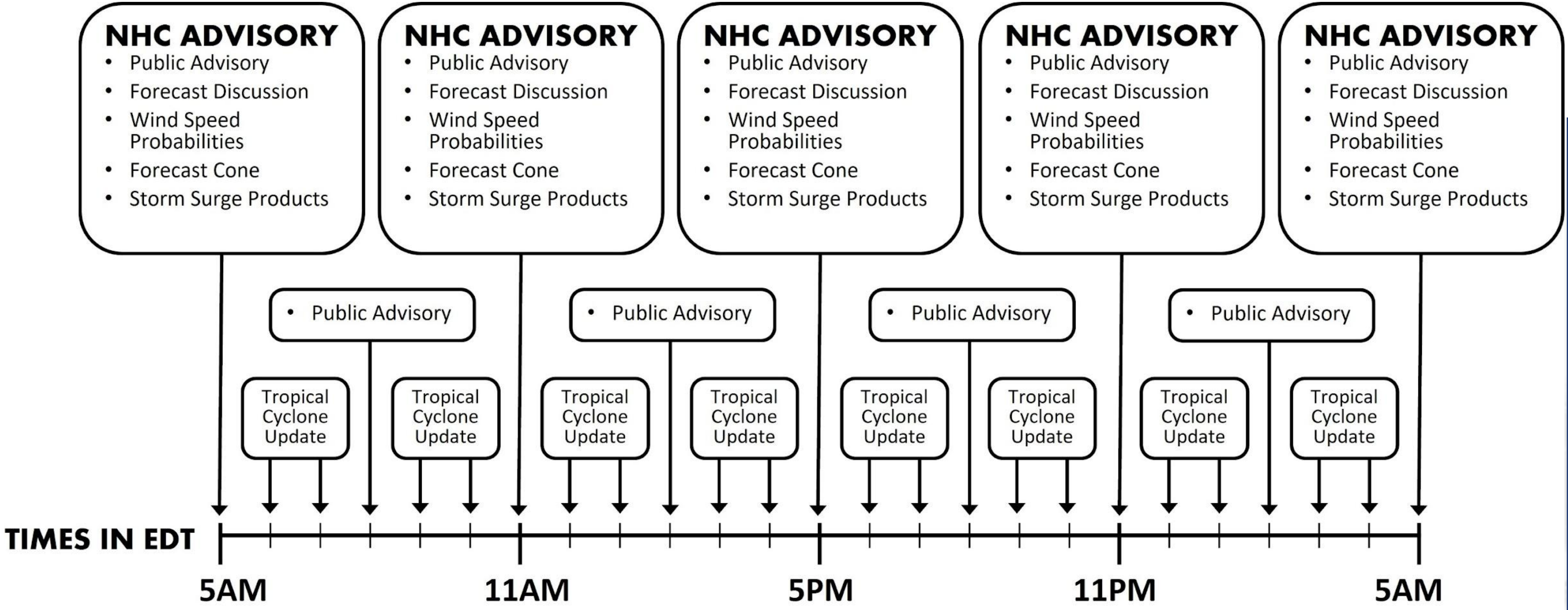


The Facility

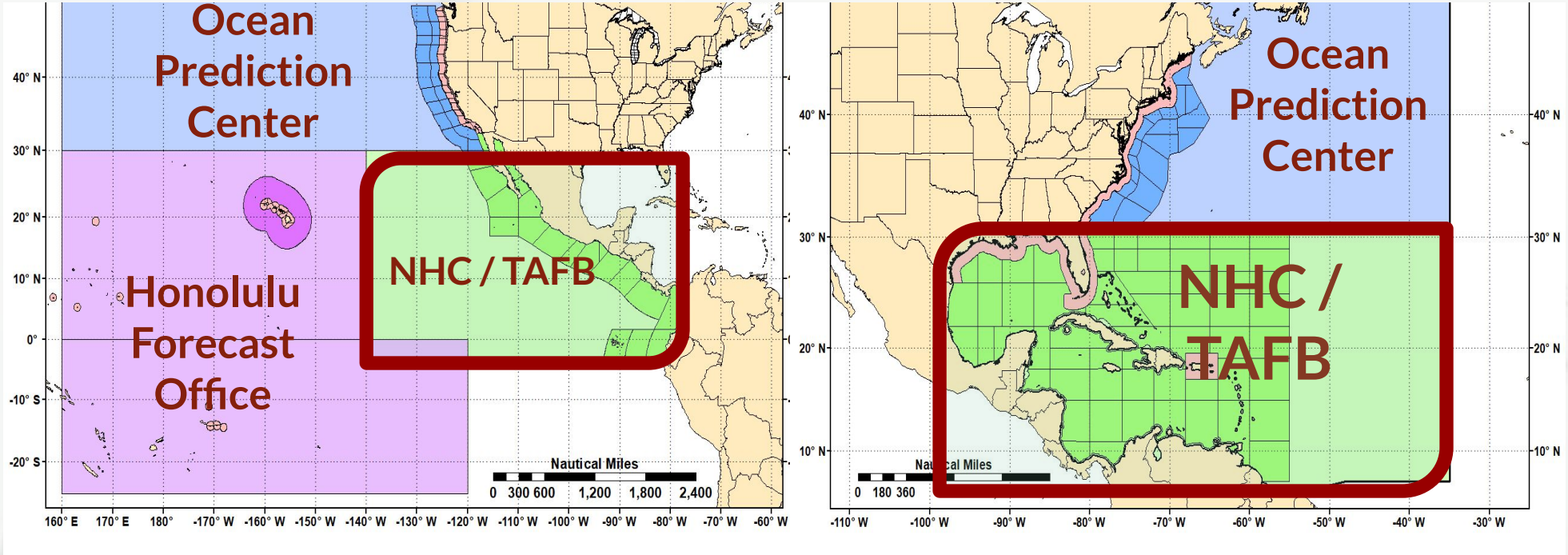
- Opened in 1995
- 25,000 square ft
- Design team included Herb Saffir
- Rest five feet above flood plain
- 10-inch thick walls made from 3000 cubic yards of concrete, reinforced with 45 miles of steel reinforcing rods
- More than 50 miles of electrical and communications wiring
- Also houses the NWS Miami Weather Forecast Office

A Look at Operations

Hurricane Specialist Unit
Pace of Information Flow



Tropical Analysis and Forecast Branch Providing Life-Saving Marine Forecasts



- 80% of all traded goods globally are carried by sea
- In 2018, the American Blue Economy contributed $373 billion to the nation's Gross Domestic Product (GDP), supporting 2.3 million jobs
- Maritime commerce is expected to triple by 2030

TAFB Products and Operations

- 24/7/365 Operations – about 100 graphical, text, and gridded products issued each day
  - Surface analysis, Tropical Weather Discussions, Wind/Wave Forecasts, High Seas and Offshore Waters Forecasts
- Routinely provide ”spot” forecasts and decision-support briefings to the U.S. Coast Guard
  - TAFB provided 157 spot forecasts & more than two dozen live briefings in 2023
- Also perform Dvorak “classifications” and assist HSU with international collaboration

HIGH SEAS FORECAST
NWS NATIONAL HURRICANE CENTER
1030 UTC FRI OCT 02 2015

SUPERSEDED BY NEXT ISSUANCE IN 6 HOURS

SEAS GIVEN AS SIGNIFICANT WAVE HEIGHT...WHICH IS THE AVERAGE HEIGHT OF THE HIGHEST 1/3 OF THE WAVES. INDIVIDUAL WAVES MAY BE MORE THAN TWICE THE SIGNIFICANT WAVE HEIGHT.

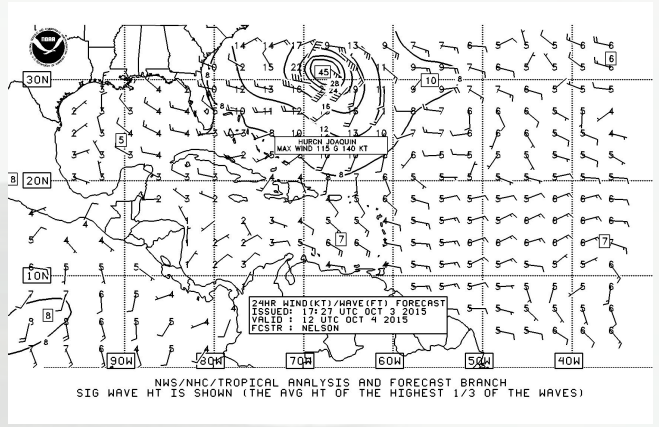
PAN PAN

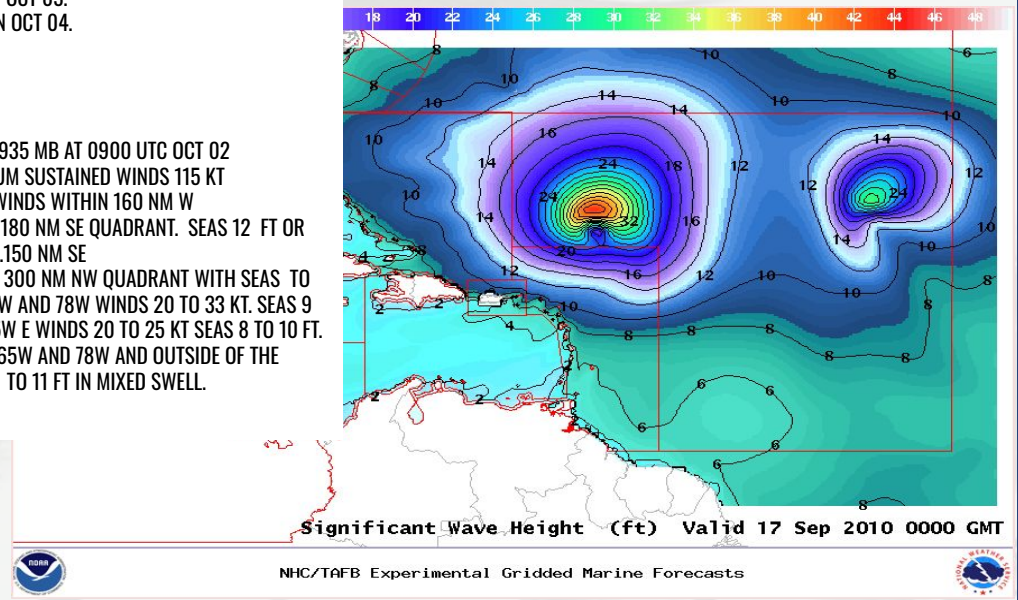
ATLANTIC FROM 07N TO 31N W OF 35W INCLUDING CARIBBEAN SEA AND GULF OF MEXICO.

SYNOPSIS VALID 0600 UTC FRI OCT 02.
24 HOUR FORECAST VALID 0600 UTC SAT OCT 03.
48 HOUR FORECAST VALID 0600 UTC SUN OCT 04.

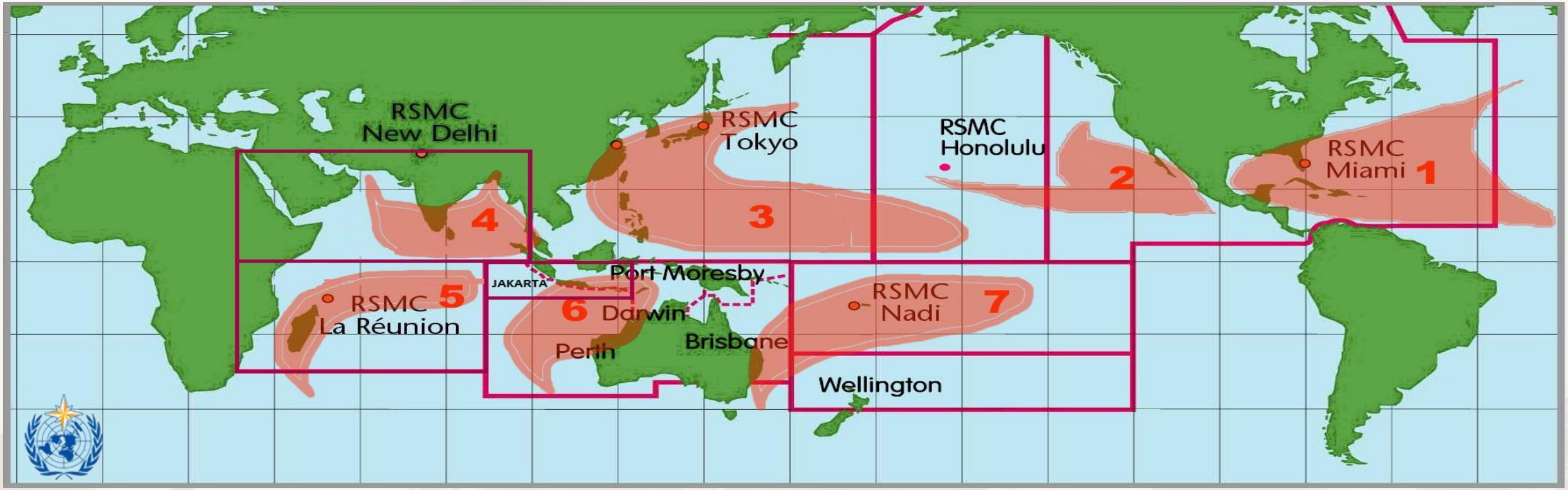
.WARNINGS.

...HURRICANE WARNING...
.HURRICANE JOAQUIN NEAR 23.3N 74.7W 935 MB AT 0900 UTC OCT 02 MOVING NW OR 315 DEG AT 3 KT. MAXIMUM SUSTAINED WINDS 115 KT GUSTS 140 KT. TROPICAL STORM FORCE WINDS WITHIN 160 NM W SEMICIRCLE...140 NM NE QUADRANT AND 180 NM SE QUADRANT. SEAS 12 FT OR GREATER WITHIN 400 NM NE QUADRANT...150 NM SE QUADRANT...120 NM SW QUADRANT...AND 300 NM NW QUADRANT WITH SEAS TO 39 FT. ELSEWHERE S OF 28N BETWEEN 70W AND 78W WINDS 20 TO 33 KT. SEAS 9 TO 12 FT. N OF 28N BETWEEN 70W AND 75W E WINDS 20 TO 25 KT SEAS 8 TO 10 FT. REMAINDER OF AREA N OF 21N BETWEEN 65W AND 78W AND OUTSIDE OF THE BAHAMAS WINDS 20 KT OR LESS. SEAS 8 TO 11 FT IN MIXED SWELL.





International Collaboration
World Meteorological Organization



NHC is one of 7 Regional Specialized Meteorological Centers (RSMC) that produce and coordinate tropical cyclone forecasts for various ocean basins.

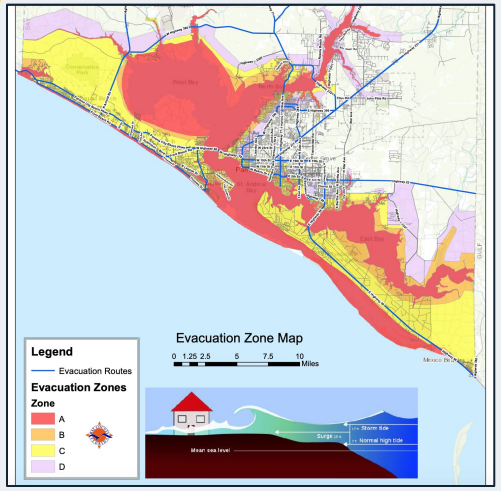
International Collaboration Highlights

- NHC provides forecasts and guidance on watches and warnings to 28 WMO member nations
- NHC hosts and teaches two-week workshop on tropical cyclones for international government meteorologists
- NHC Director serves as Chairman of the WMO RA-IV Hurricane Committee. Annual meeting updates the Region's "Hurricane Operational Plan"
- U.S. conducts annual Caribbean Hurricane Awareness Tour
- Storm surge projects

NHC Supporting the Nation's Emergency Managers

Timeline – Years Before

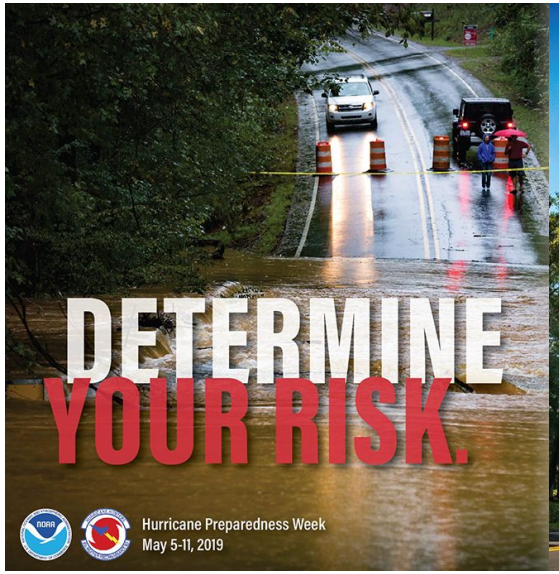
- Storm Surge Vulnerability Mapping
  - Work conducted by NHC's Storm Surge Unit and funded by FEMA
  - Drives the Nation's evacuation zones
- Evacuation Studies
  - Work conducted by U.S. Army Corps of Engineers
  - Results in "Clearance Times" – how long will it take to evacuate population
- Training
  - Hurricane preparedness classes for state and local emergency managers

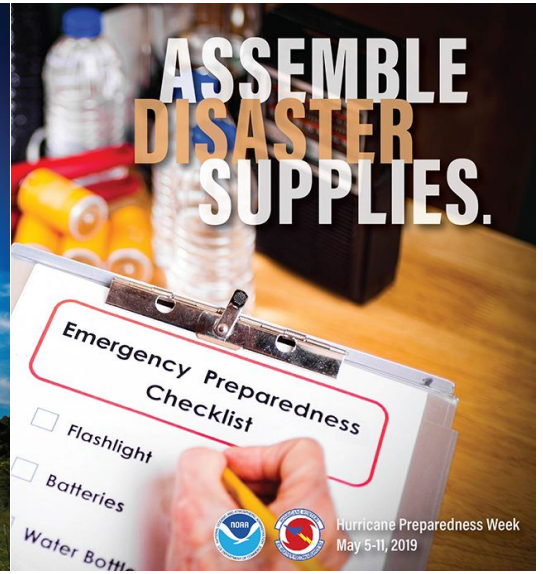


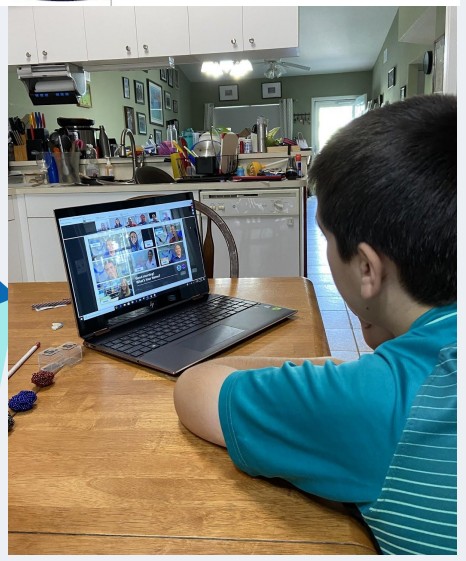
NHC Supporting the Nation's Emergency Managers

Timeline – Months Before

- **Battle is won during the off season**
  - Encourage readiness & personal preparedness
    - Exercises (Federal/State Partners)
    - State/local hurricane conferences
    - Hurricane Awareness Tour
    - National Hurricane Preparedness Week







NHC Supporting the Nation's Emergency Managers

Timeline – Days Before

- NHC supports all levels of governmental emergency managers
- **FEMA Activates the Hurricane Liaison Team**
  - Supports response operations through rapid exchange of critical information
  - NHC supports video teleconferences with FEMA and other Federal Agencies
  - VTCs with state emergency operations center
  - Responding to emergency management questions and concerns from all levels
- **Operational Support for U.S. Coast Guard**
  - TAFB provides live briefings with Districts 7 and 8

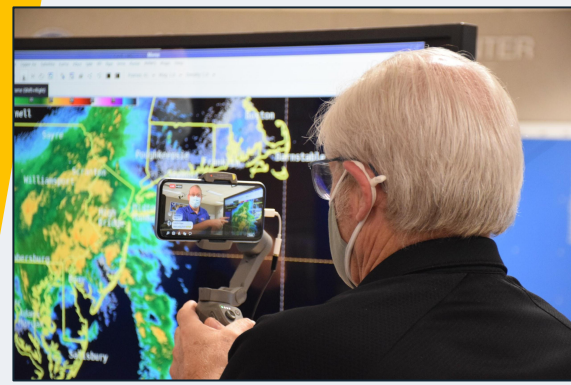
NHC Supporting the Nation's Emergency Managers

Timeline – Hours to Days Before

- **NHC Media Pool**
  - Activated whenever a U.S. hurricane watch or warning is in effect
  - Conduct interviews with local and national media

- **Social Media**
  - NHC provides Key Messages
  - Warning and hazard-based information and safety messaging
  - Facebook Live to highlight threats

- **Collaborate Watches/Warnings**
  - NWS Weather Forecast Offices
  - International Meteorological Services



Questions/Comments

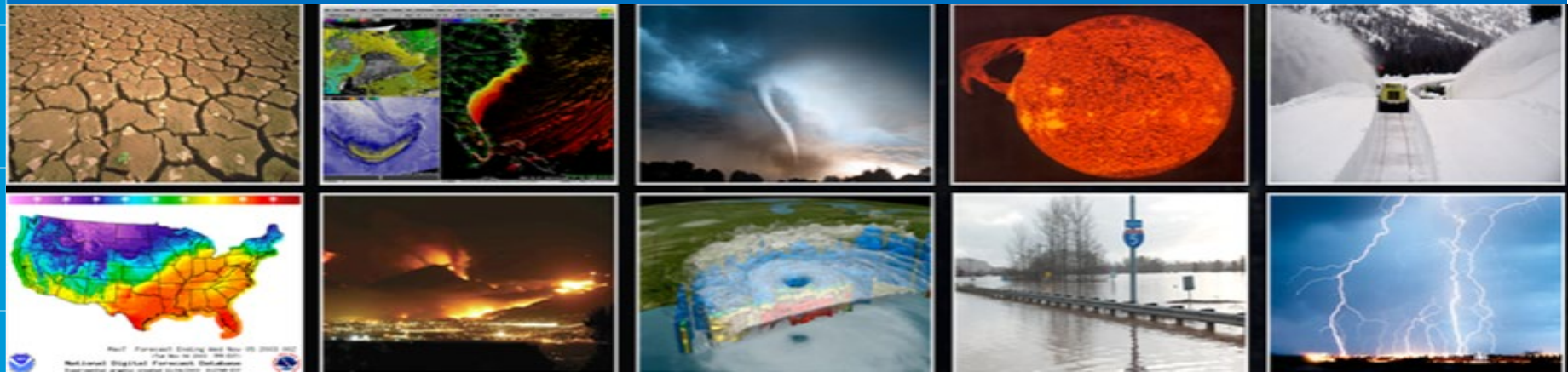
Contact: daniel.p.brown@noaa.gov

Ocean Prediction Center

Michael Folmer, PhD
Warning Coordination Meteorologist

Special Thank You:
Casey Joseph, Forecaster/Outreach Focal Point
Darin Figurskey, Operations Forecast Branch Chief
LTJG Thomas Cervone-Richards, NOAA Corps

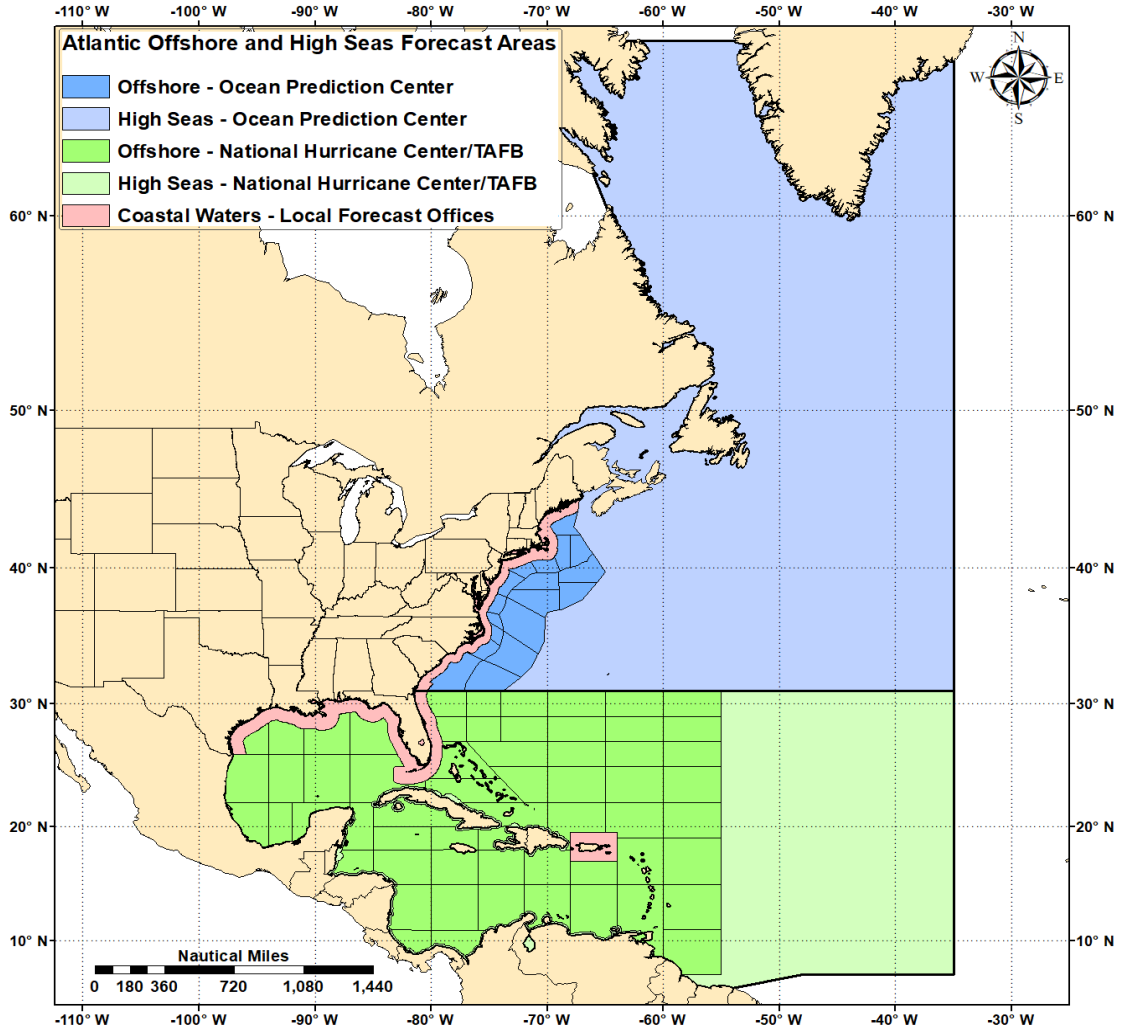
NOAA
National
Weather
Service



Atlantic Forecast Area

Offshore and High Seas

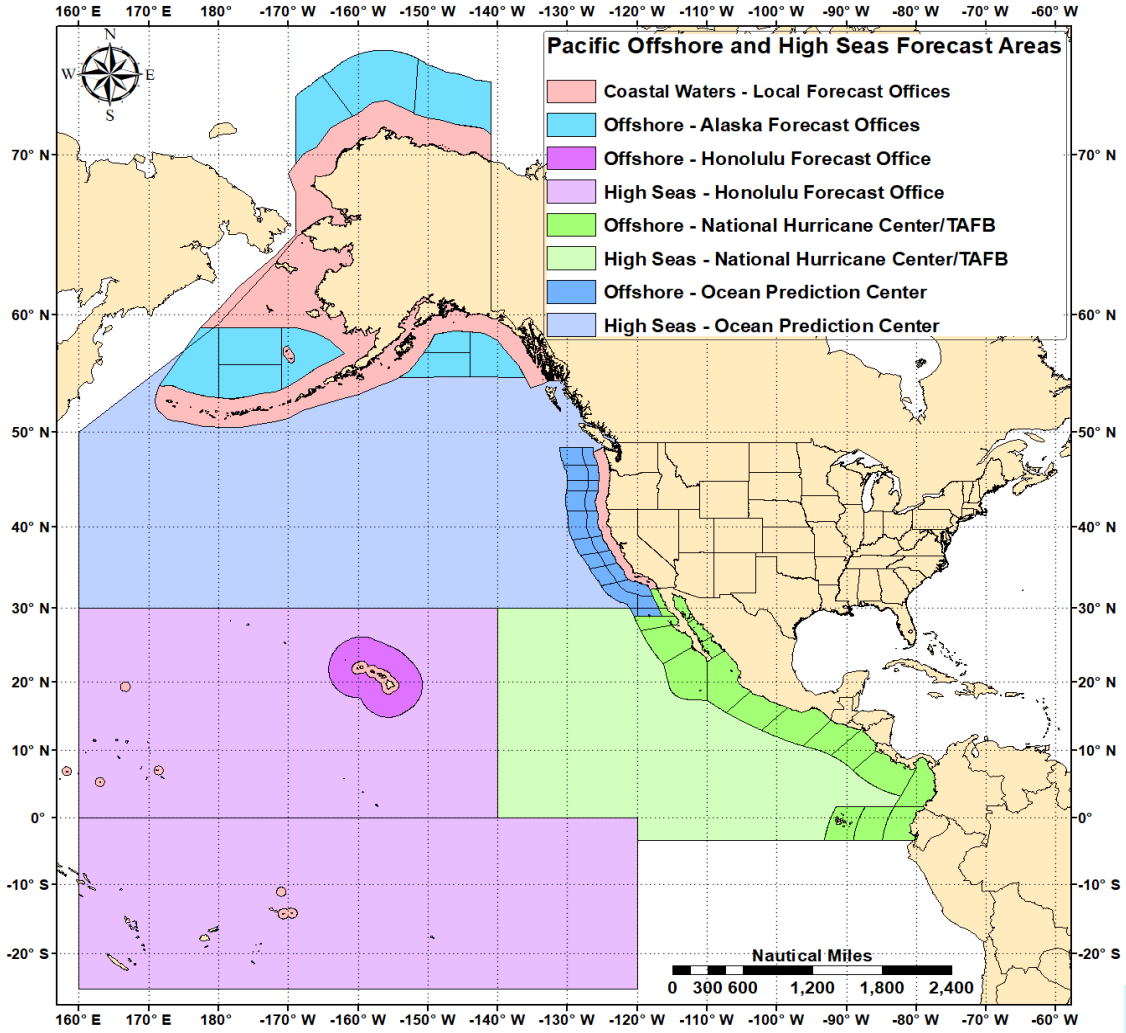
(radiofax charts to Europe and Africa)



Pacific Forecast Area

Offshore and High Seas

(radiofax charts to Asia)

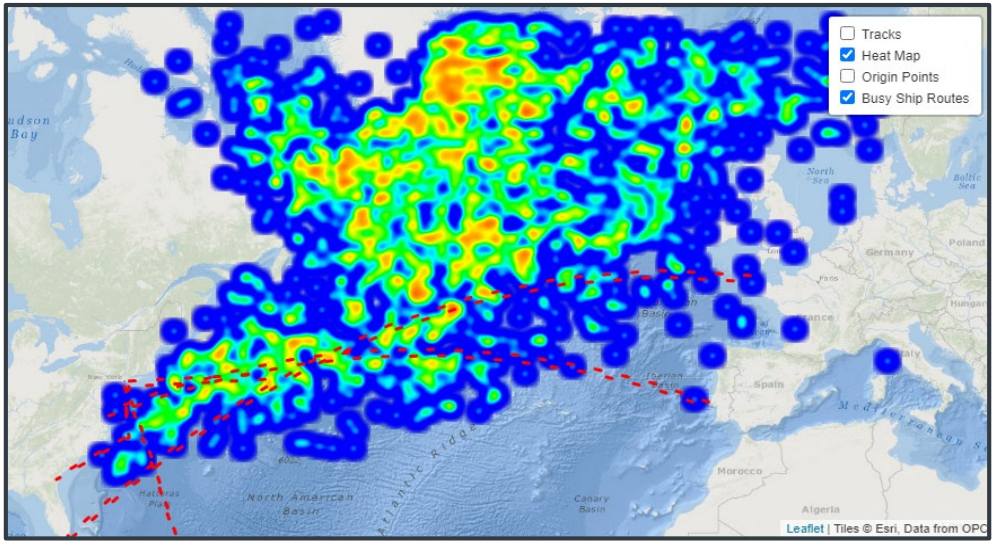


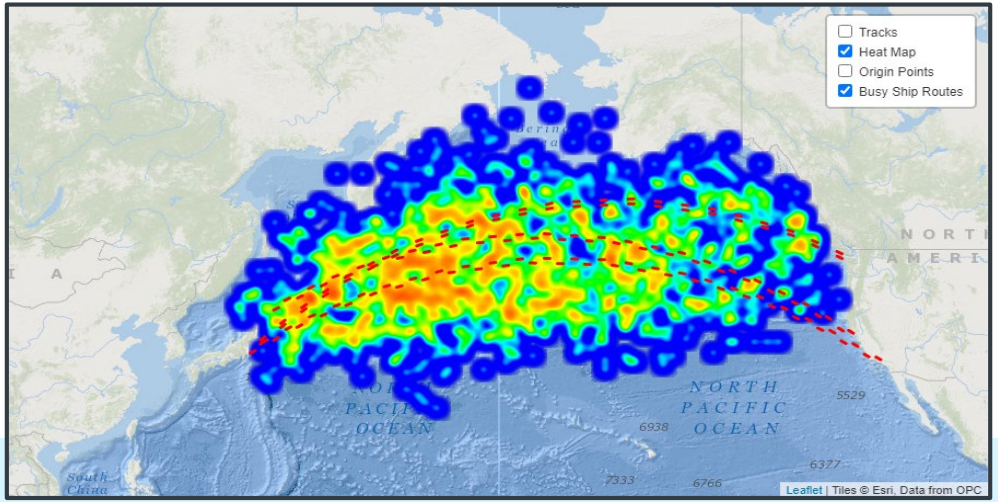
Why?

Heat Maps of extratropical hurricane-force lows in the Atlantic and Pacific since 2005.

Atlantic average, 45

Pacific average, 38





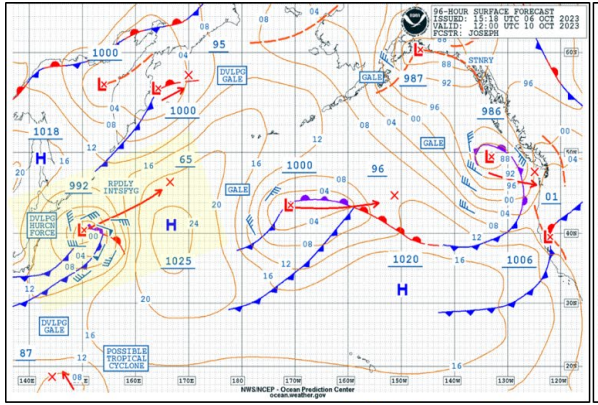
Climatology

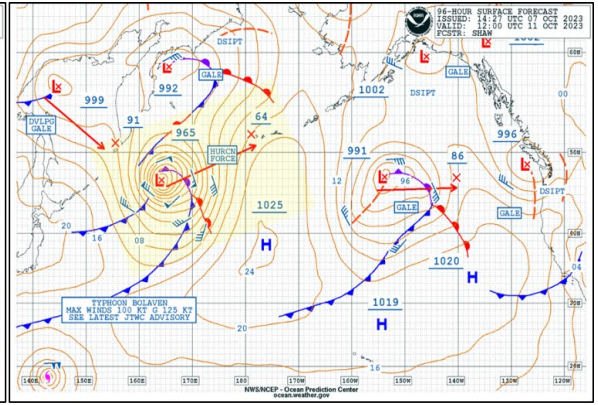
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	SEASON TOTALS
2005-2006	0	0	3	2	2	3	3	5	9	6	0	0	33
2006-2007	1	0	0	3	4	6	8	13	20	7	1	3	66
2007-2008	0	0	1	0	6	5	10	9	6	4	1	0	42
2008-2009	0	0	1	3	7	3	13	11	4	6	2	1	51
2009-2010	0	0	0	0	6	2	7	6	8	1	0	0	30
2010-2011	0	0	0	1	4	4	1	3	13	4	1	1	32
2011-2012	0	0	0	2	4	5	11	7	3	7	1	0	40
2012-2013	0	0	0	0	5	5	5	13	7	4	3	0	42
2013-2014	0	0	0	0	2	5	14	9	10	5	1	0	46
2014-2015	0	0	1	2	2	6	9	14	8	11	4	0	57
2015-2016	1	1	0	0	4	1	11	11	11	7	2	1	50
2016-2017	0	1	0	1	4	1	12	10	10	9	2	0	50
2017-2018	0	0	1	1	4	4	9	9	7	8	3	1	47
2018-2019	0	0	0	2	4	7	7	8	9	4	3	1	45
2019-2020	0	0	0	3	3	4	9	9	6	3	4	1	42
2020-2021	0	0	0	3	3	8	4	6	8	7	2	1	42
2021-2022	0	0	0	3	3	3	11	13	11	10	1	1	56
	0.1	0.1	0.4	1.5	3.9	4.2	8.5	9.2	8.8	6.1	1.8	0.6	45.4

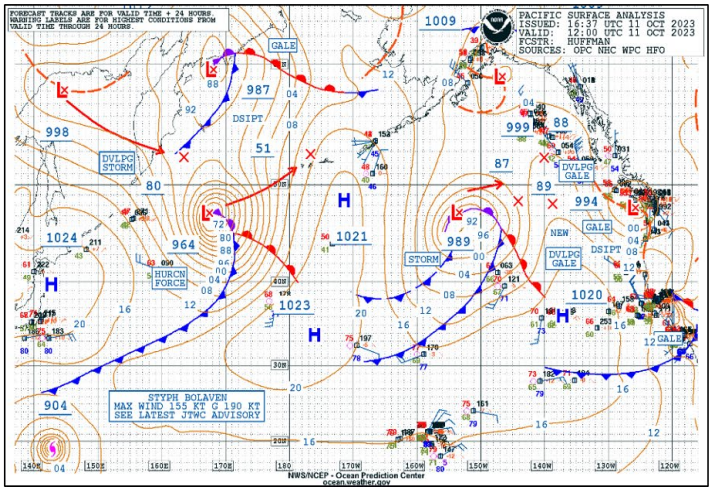
Monthly totals of unique hurricane force lows in the Atlantic

Avoidance

October 11, 2023



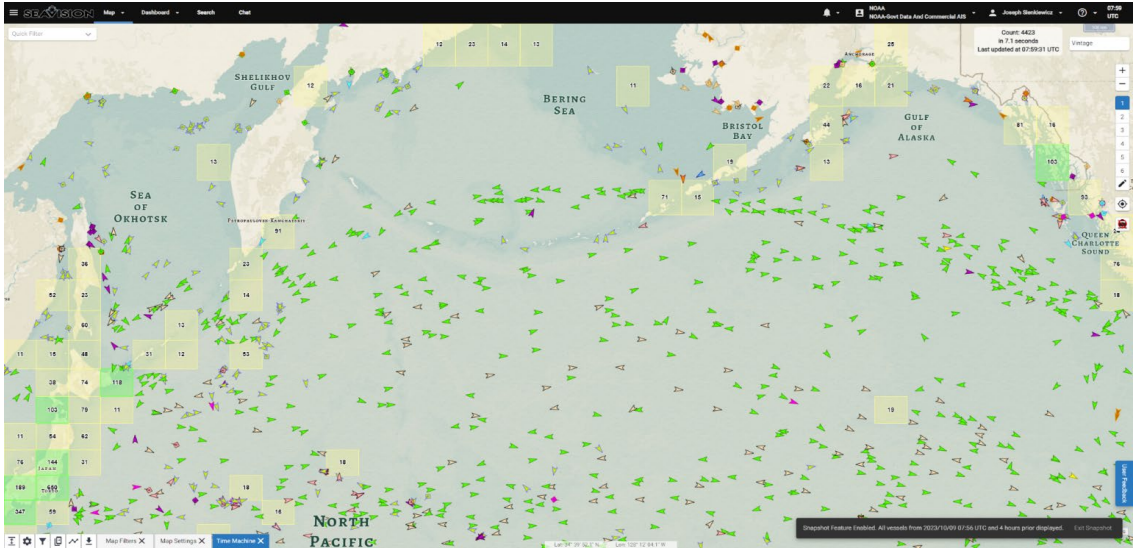


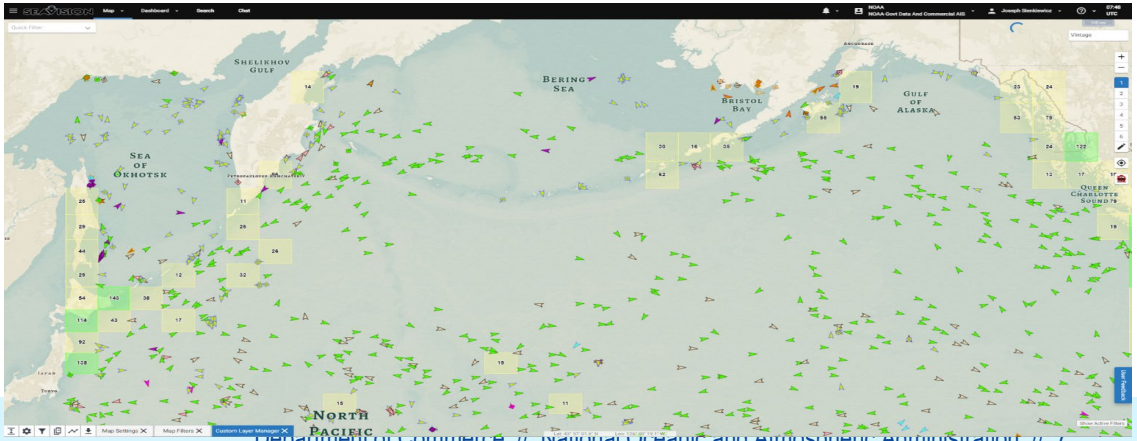


Avoidance

October 9, 2023 (top)

October 11, 2023 (bottom)





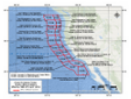
graphics courtesy SeaVision

Over 150 products each day

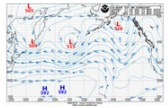
What We Do

https://ocean.weather.gov

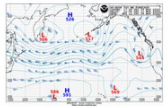
Pacific Text Forecasts

Offshore Waters Forecasts *description*	 Live Map	Washington and Oregon waters Updated: Wed, 09-Nov-2022 15:30:31 UTC California waters Updated: Wed, 09-Nov-2022 15:31:04 UTC
NAVTEX Coastal & Offshore Waters Forecasts *description*	 Live Map	Astoria, OR: Canadian Border to Pt Saint George, CA Updated: Wed, 09-Nov-2022 17:34:10 UTC San Francisco, CA: Pt Saint George, CA to Pt Piedras Blancas, CA Updated: Wed, 09-Nov-2022 17:31:56 UTC Cambria, CA: Pt Piedras Blancas, CA to Mexican Border Updated: Wed, 09-Nov-2022 17:31:47 UTC
High Frequency Voice Broadcast for Offshore Waters (VOBRA) *description*	 Live Map	Washington and Oregon Waters Updated: Wed, 09-Nov-2022 15:32:30 UTC California waters Updated: Wed, 09-Nov-2022 15:32:47 UTC
High Seas Forecasts *description*		North Pacific Ocean Updated: Wed, 09-Nov-2022 16:12:30 UTC East and Central North Pacific Ocean (Metarea XII) Updated: Wed, 09-Nov-2022 17:26:13 UTC

Pacific Graphical Forecasts



24-hour 500 mb
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:29:21 UTC
More 500 MB images



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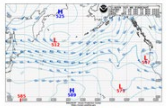

72-hour 500 mb
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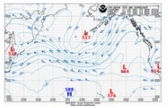

96-hour 500 mb
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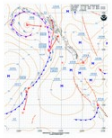
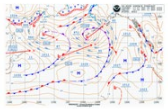
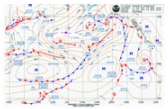
More 500 MB images



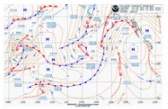
24-hour surface
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:04:43 UTC



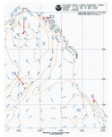
48-hour surface
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:08:14 UTC



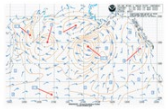
72-hour surface
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:59:17 UTC



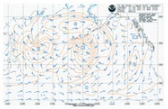
96-hour surface
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 14:27:11 UTC



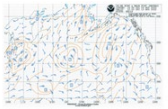
24-hour wind & wave
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:36:41 UTC



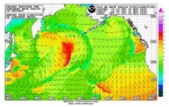
48-hour wind & wave
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 17:49:28 UTC



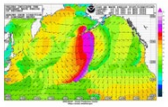
72-hour wind & wave
Loop: [3] [7] [14] Days
Updated: Tue, 08-Nov-2022 17:59:04 UTC



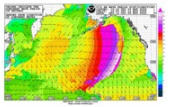
96-hour wind & wave
Loop: [3] [7] [14] Days
Updated: Wed, 09-Nov-2022 14:57:06 UTC



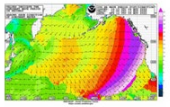
24-hour wave period & direction
Loop: [3] [7] [14] Days



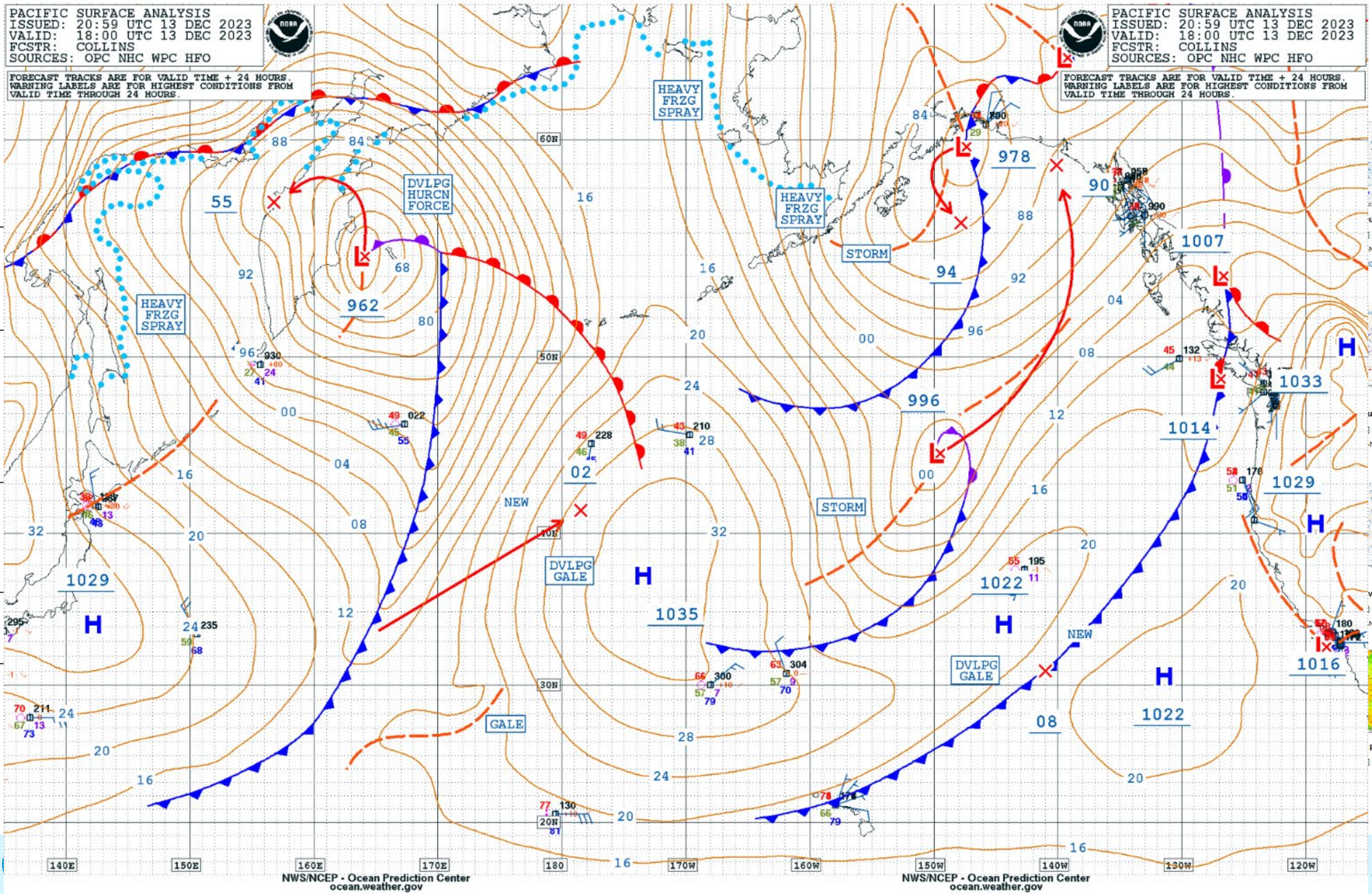
48-hour wave period & direction
Loop: [3] [7] [14] Days



72-hour wave period & direction
Loop: [3] [7] [14] Days



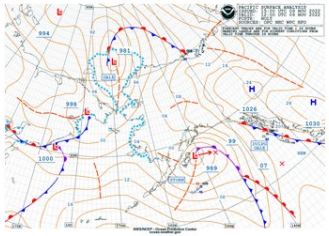
96-hour wave period & direction
Loop: [3] [7] [14] Days



PACIFIC SURFACE ANALYSIS
ISSUED: 20:59 UTC 13 DEC 2023
VALID: 18:00 UTC 13 DEC 2023
FCSTR: COLLINS
SOURCES: OPC NHC WPC HFO
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM
VALID TIME THROUGH 24 HOURS.
HEAVY FRZG SPRAY
DVLPG HURCN FORCE
STORM
DVLPG GALE
GALE
NEW
NWS/NCEP - Ocean Prediction Center
ocean.weather.gov

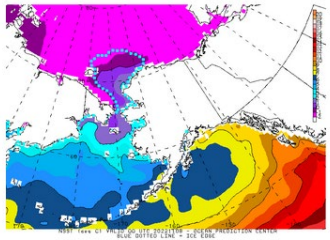
What We Do

Alaska/Arctic Analysis



Latest Surface Analysis

Updated: Wed, 09-Nov-2022 15:10:18 UTC



Latest SST/Ice Edge Analysis

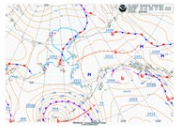
Updated: Tue, 08-Nov-2022 23:10:39 UTC

Alaska/Arctic Graphical Forecasts

24-hour surface

Loop: [3] [7] [14] Days

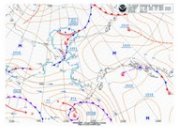
Updated: Wed, 09-Nov-2022 07:24:56 UTC



48-hour surface

Loop: [3] [7] [14] Days

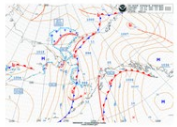
Updated: Wed, 09-Nov-2022 06:10:57 UTC



72-hour surface

Loop: [3] [7] [14] Days

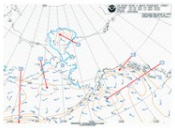
Updated: Tue, 08-Nov-2022 17:27:03 UTC



96-hour surface

Loop: [3] [7] [14] Days

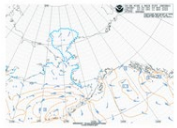
Updated: Wed, 09-Nov-2022 14:27:49 UTC



Loop: [3] [7] [14] Days

24-hour wind & wave

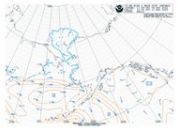
Updated: Wed, 09-Nov-2022 06:33:35 UTC



Loop: [3] [7] [14] Days

48-hour wind & wave

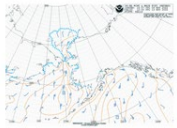
Updated: Wed, 09-Nov-2022 06:39:59 UTC



Loop: [3] [7] [14] Days

72-hour wind & wave

Updated: Tue, 08-Nov-2022 17:59:03 UTC



Loop: [3] [7] [14] Days

96-hour wind & wave

Updated: Wed, 09-Nov-2022 14:57:46 UTC

U.S. National Ice Center
NOAA component = OPC Ice Services Branch

https://usicecenter.gov

U.S. National Ice Center
Mission and Organizational Alignment

The U.S. National Ice Center provides global to tactical scale ice and snow products, ice forecasting, and related environmental intelligence services for the United States government.

Tri-agency organization composed of:

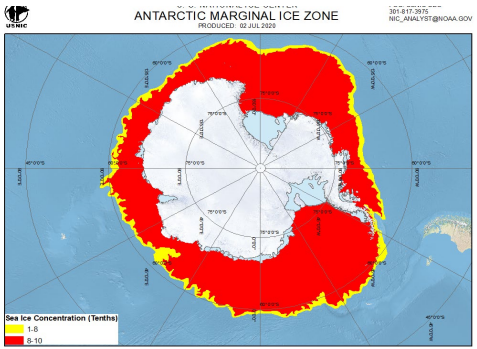
<u>NOAA component:</u>
NWS Ocean Prediction Center Ice Services Branch

<u>Navy component:</u>
Fleet Weather Center Norfolk, Naval Ice Center

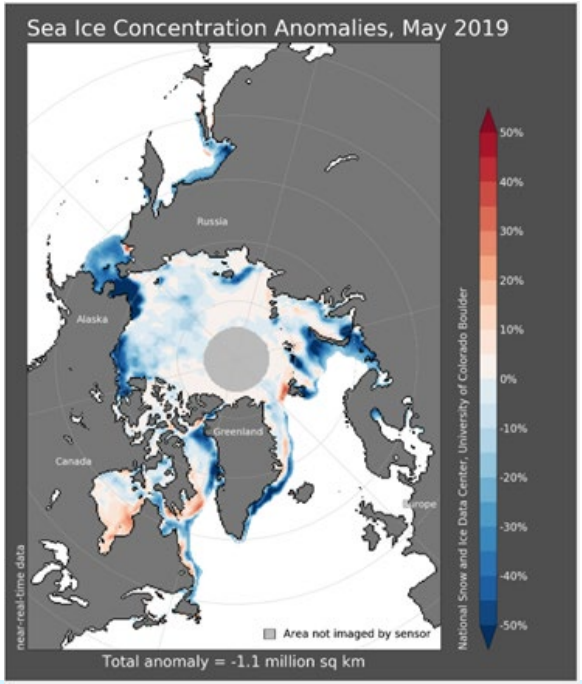
<u>USCG component:</u>
Office of Waterways and Ocean Policy, Mobility and Ice Operations Division

Ice Services

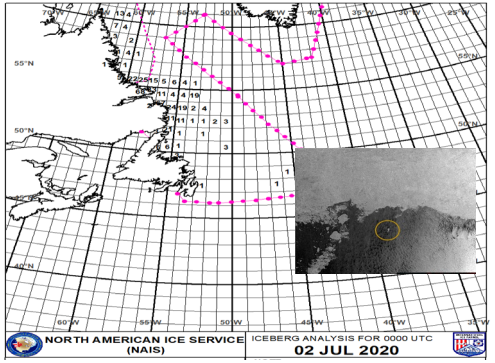
Ice Extent and Change

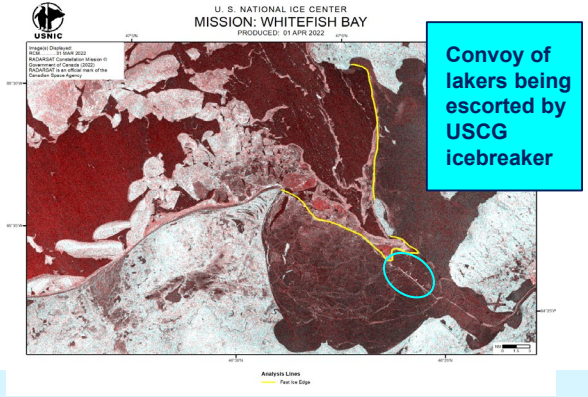


Ice Concentration and Thickness

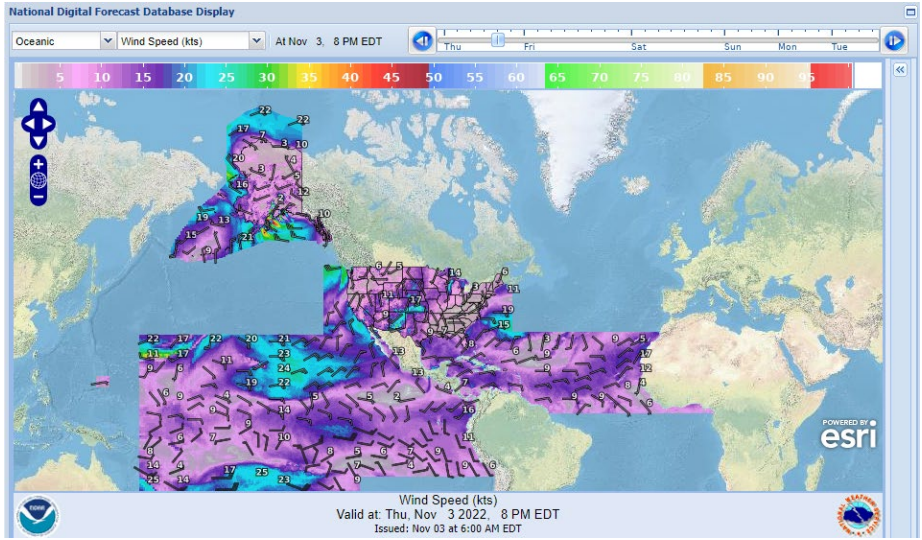


Icebergs and Ice Routing

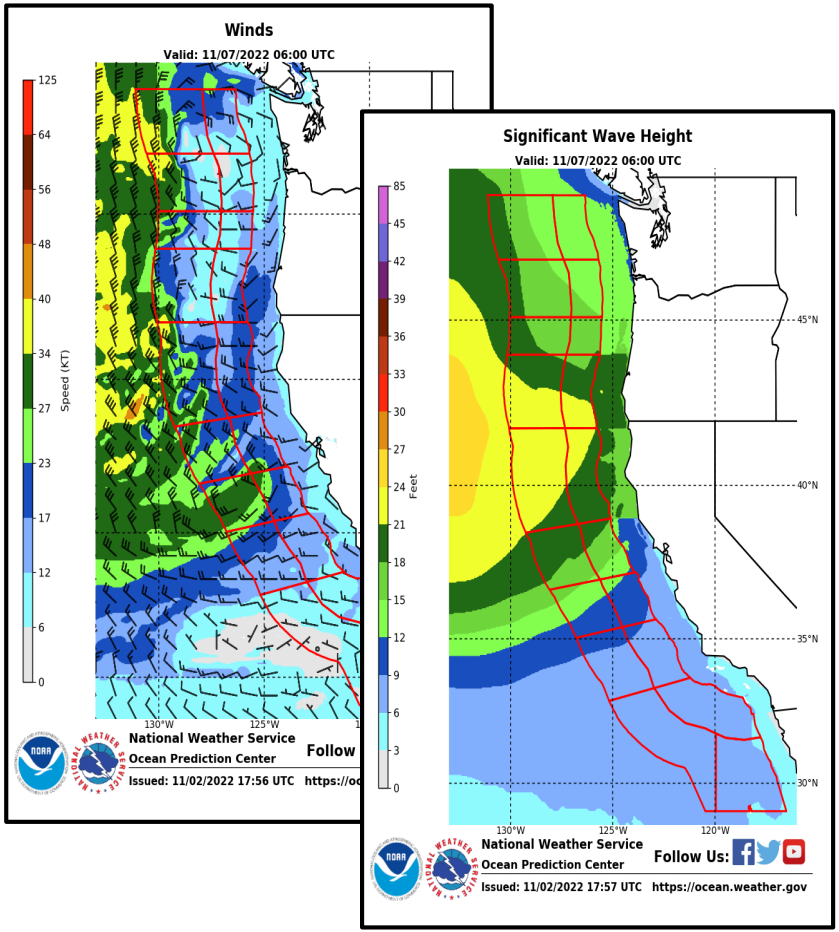




What We Do



National Digital Forecast Database (NDFD)
https://www.weather.gov/mdl/ndfd_info
https://digital.weather.gov/

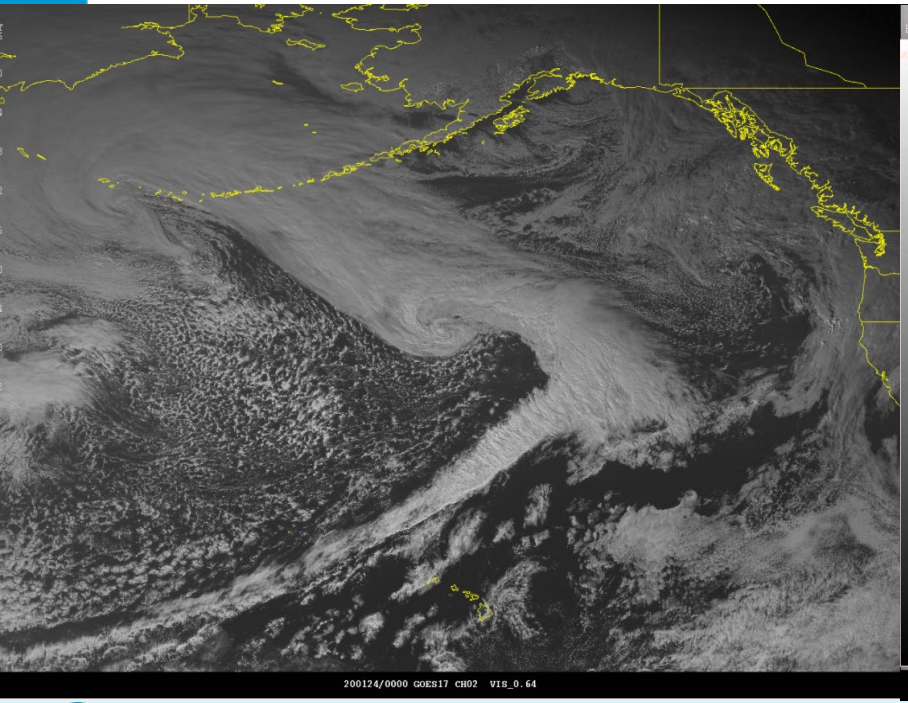


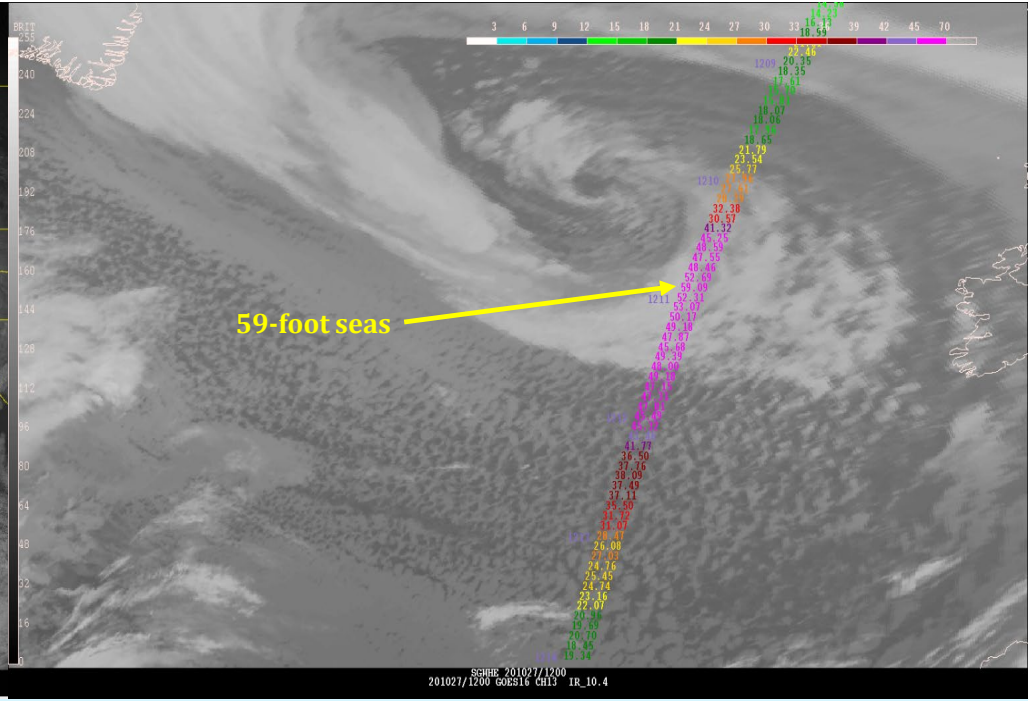
Top: oceanic domain of the NDFD, forecast, November 4, 2022, 0000 UTC
Upper Right: wind and wave forecasts, November 7, 2022, 0600 UTC

How We Do It

Satellite imagery

L: visible image, Pacific, January 24, 2020, 00 UTC
R: infrared image + altimeter, Atlantic, October 27, 2020, 12 UTC

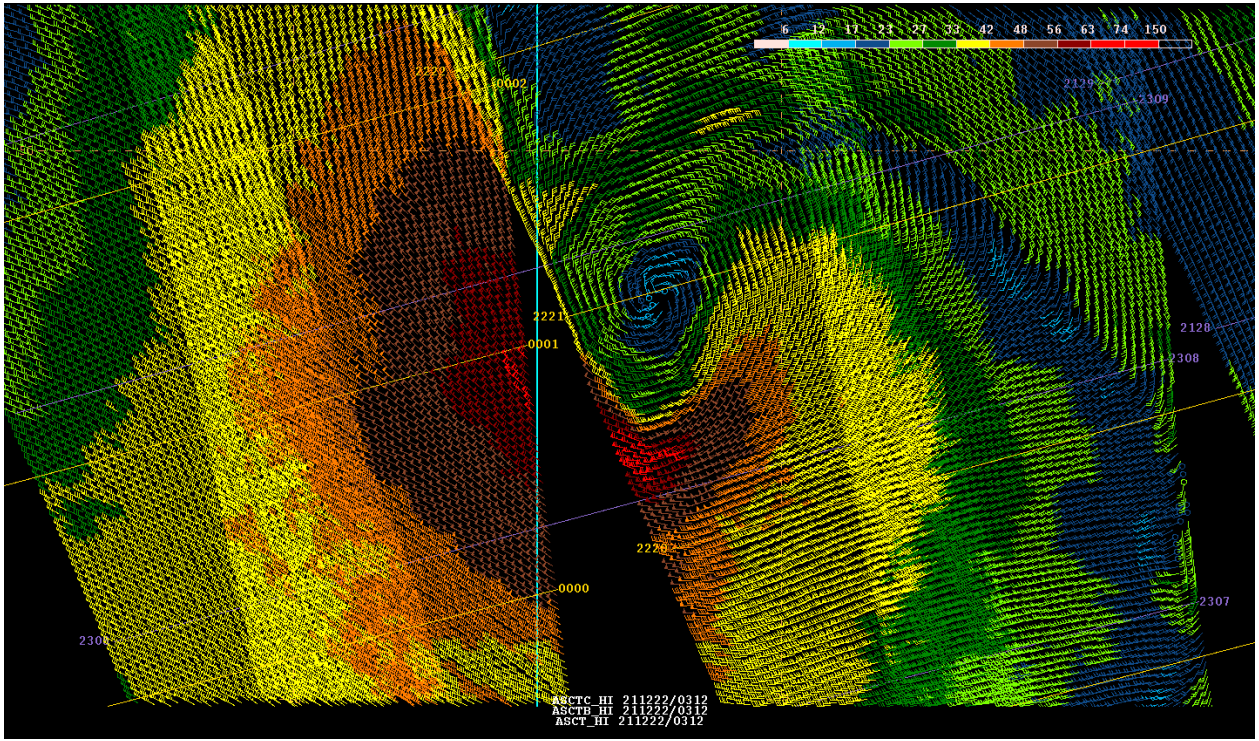




How We Do It

Satellite imagery

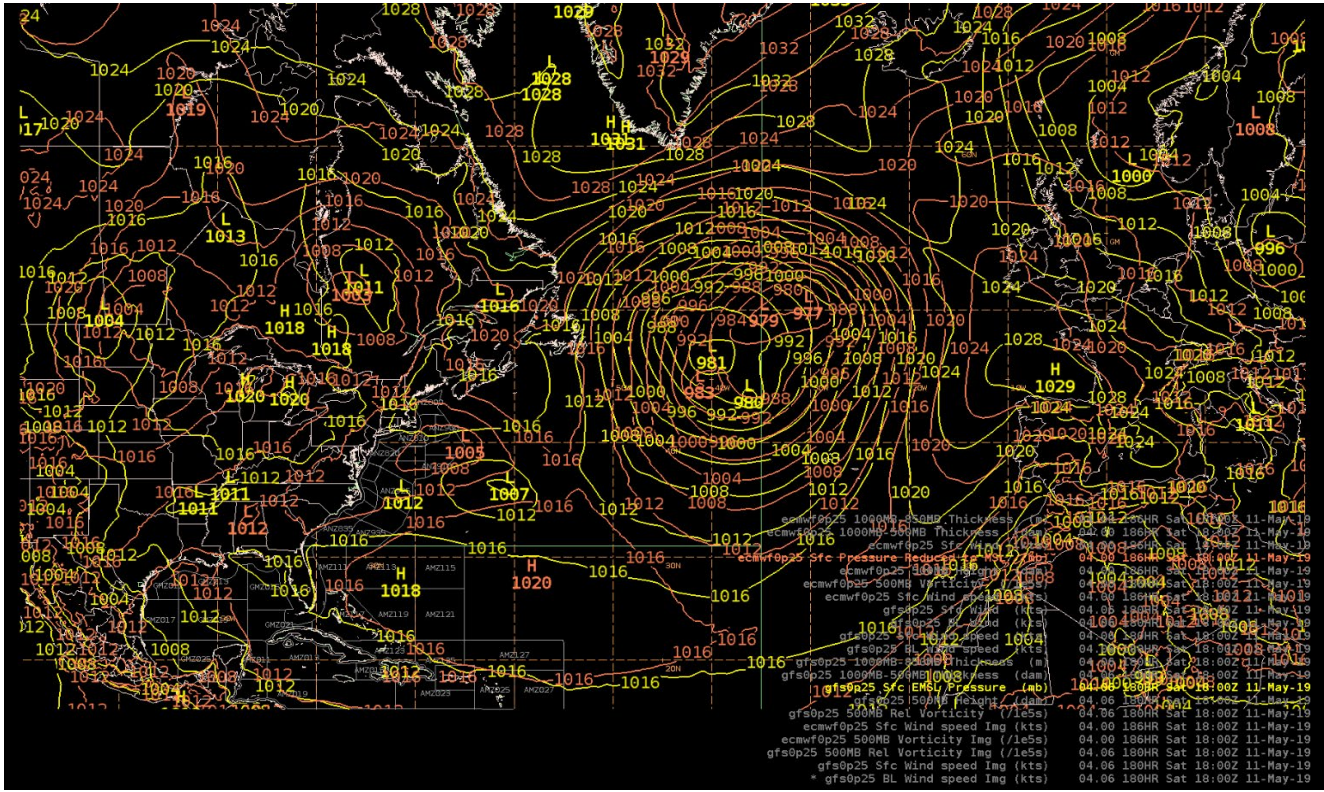
Scatterometer data, December 22, 2021, from ~0000 UTC



How We Do It

Global Forecast System (GFS)
and
European Centre for Medium-Range
Weather Forecast (ECMWF)

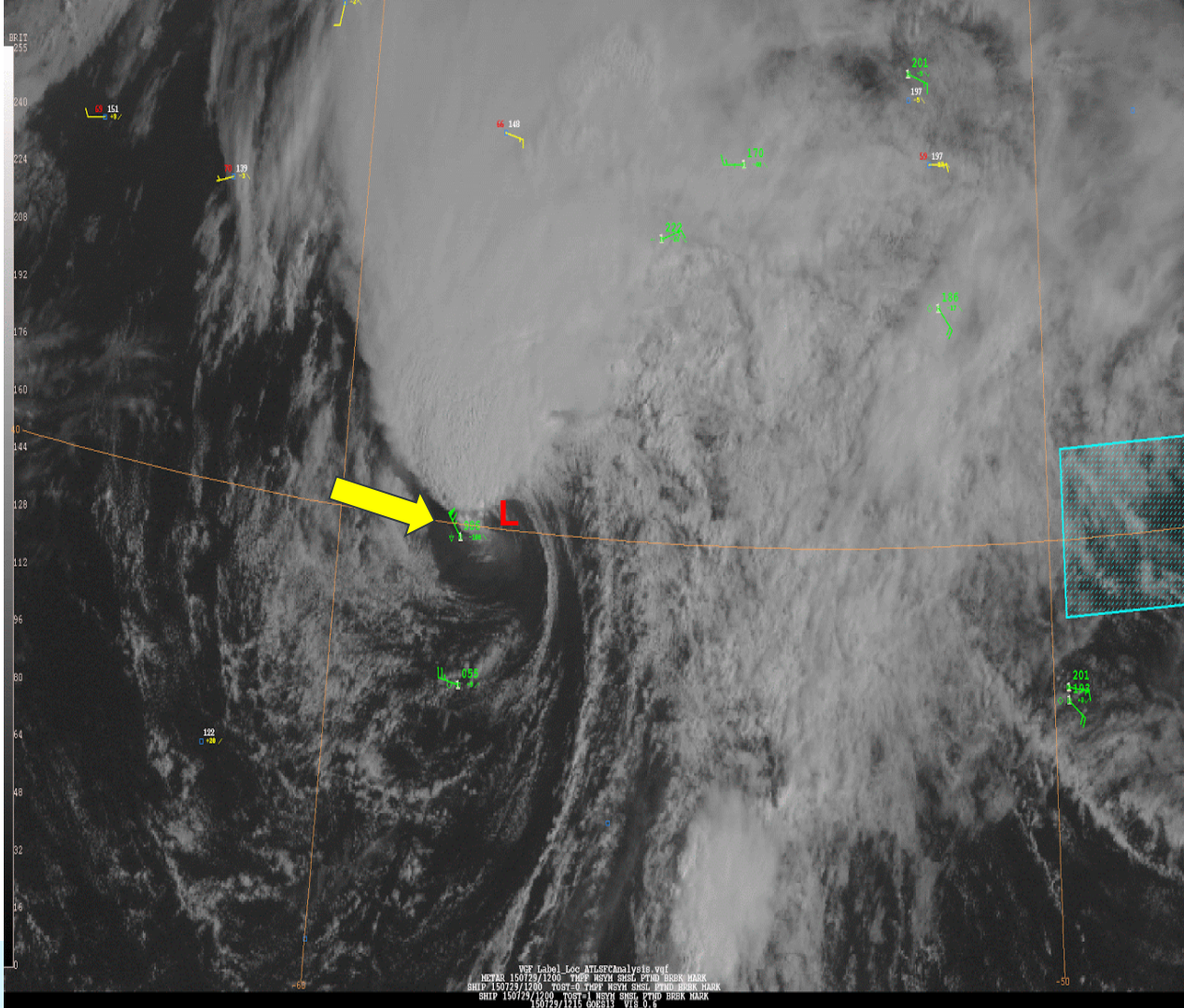
Surface pressure
180 hour / 186 hour forecast
May 11, 2019



Observations

Satellite imagery

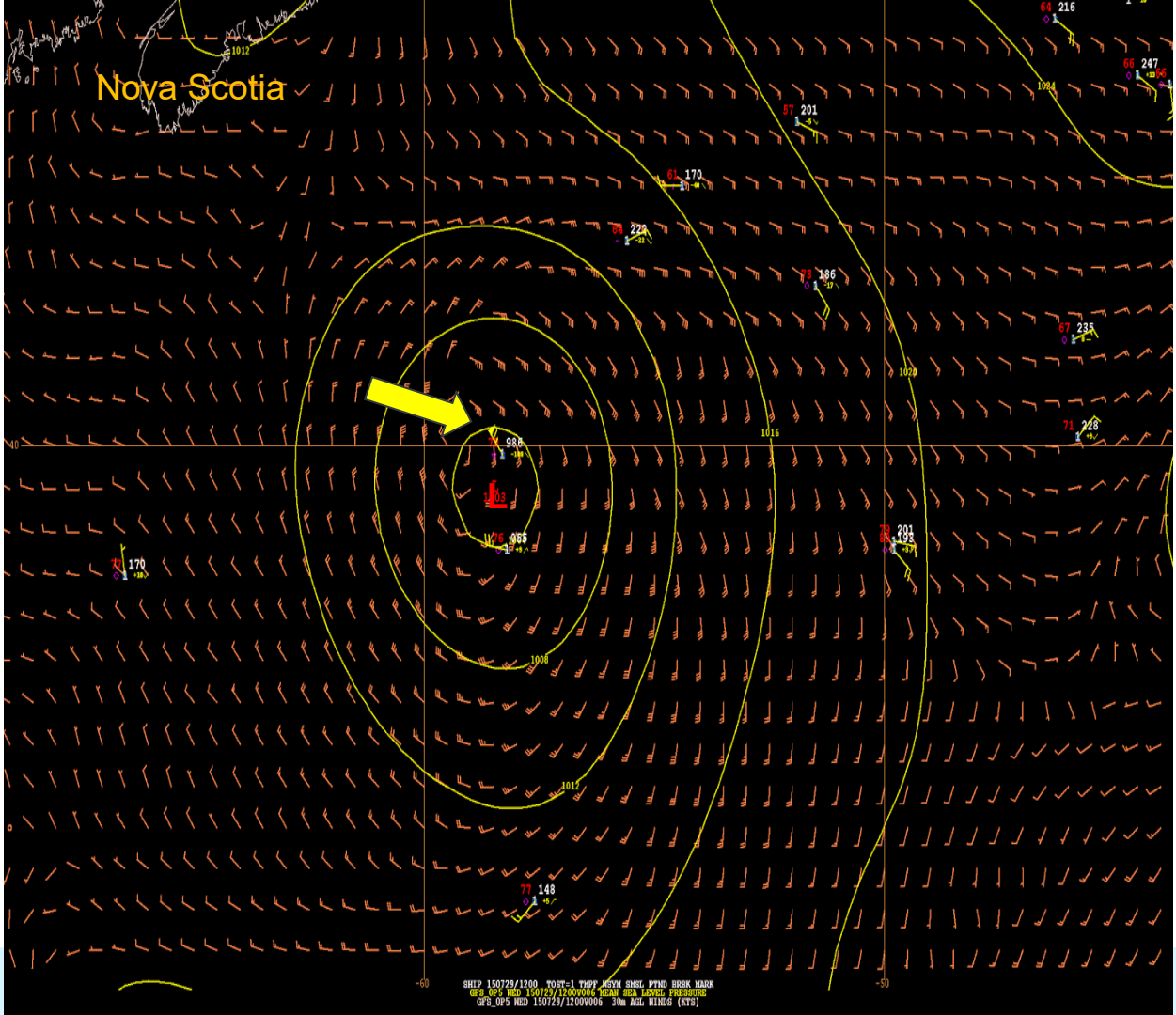
Visible image, July 29, 2015, 12 UTC

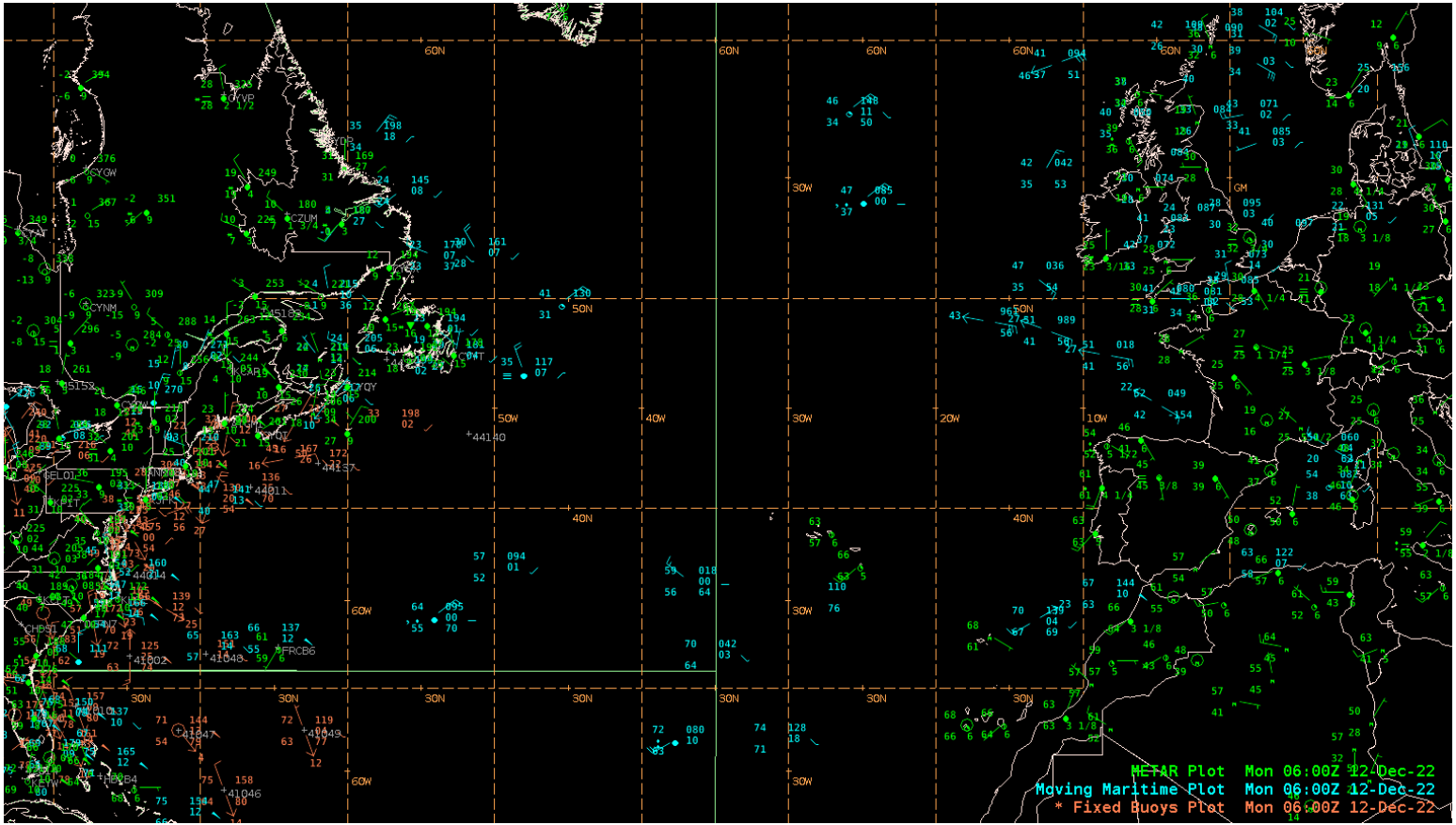


Observations

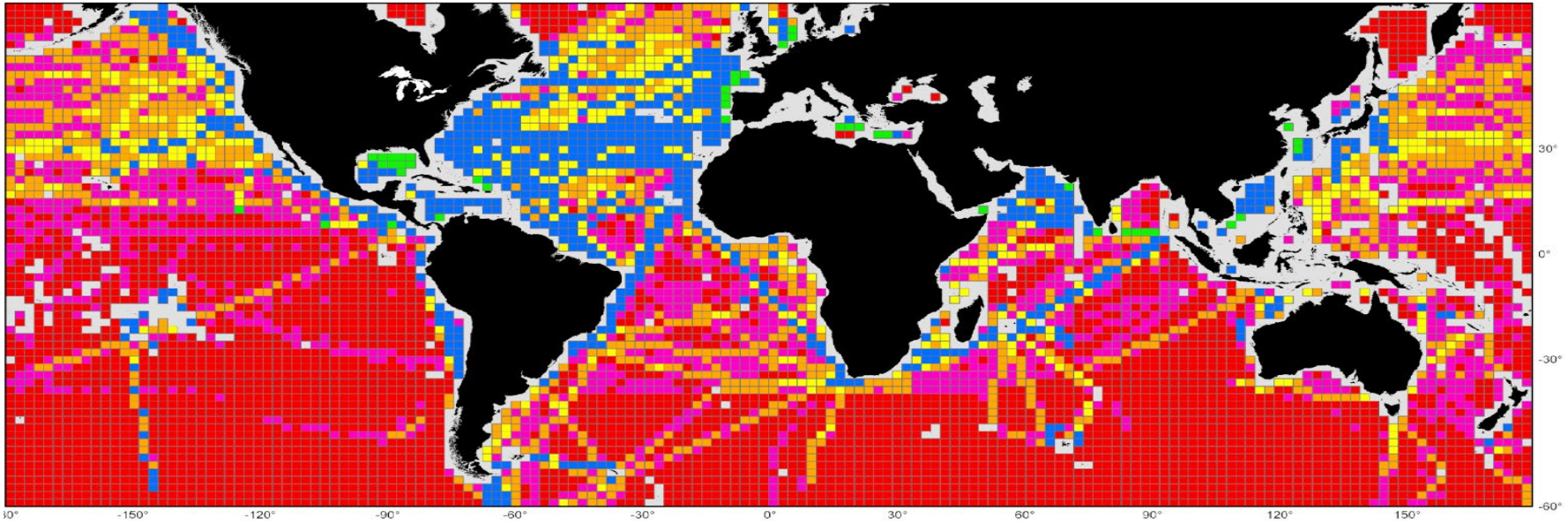
Global Forecast System (GFS)

Six-hour forecast, July 29, 2015, 12 UTC




METAR Plot Mon 06:00Z 12-Dec-22
Moving Maritime Plot Mon 06:00Z 12-Dec-22
* Fixed Buoys Plot Mon 06:00Z 12-Dec-22

Observations - We Need Them!



OceanOPS

No or insufficient amount of VOS data

Minimum to good amount of VOS data

December 2022

Voluntary Observing Ships (VOS)

Data Source: GTS/Meteo-France

Decision Support Services

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Storm Warning

Today (12/11)

KEY MESSAGES:

CALL TO ACTION: Vessels planning to be in the area should execute avoidance plans.

- A strong cold front will continue to push east farther offshore of the East Coast today, trailing low pressure moving northeast from New England into southeast Canada.
- By late morning, storm-force conditions will occur from about 36.5N to 44N east of 69W. Hurricane-force wind gusts will also occur, especially in vicinity of the Gulf Stream.
- Storm-force conditions will move well east into the north Atlantic late this afternoon into this evening.
- Widespread seas over 20 feet will be in place late this morning north of 36N and east of about 71.5W. Maximum seas will approach 30 feet especially in and near the Gulf Stream from about 37N to 40N between 66W and 70W. These very high seas will also shift east into the north Atlantic this evening.
- Winds and seas will be higher in and near any thunderstorms, mostly concentrated along and ahead of the strong cold front.

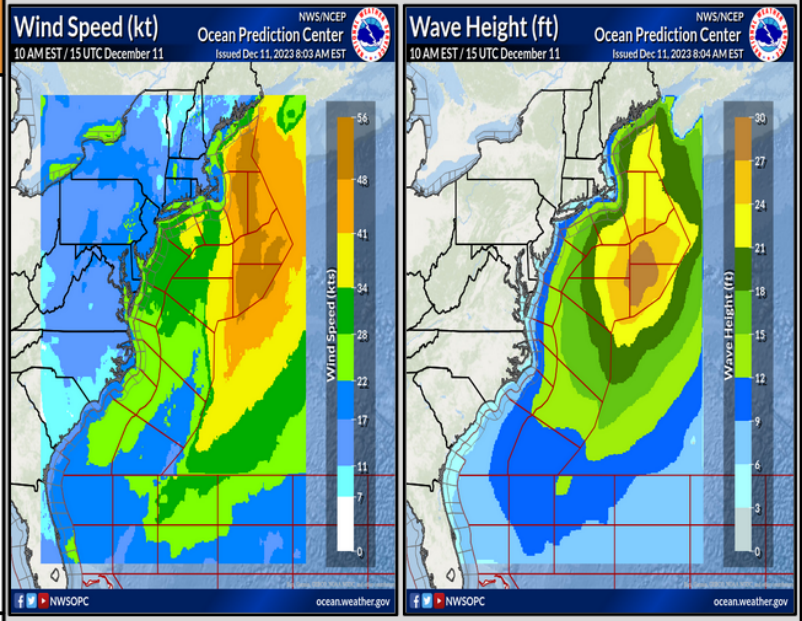
WRN WEATHER-READY NATION

ISSUED: 14 UTC December 11, 2023

@NWSOPC
@NHC_Atlantic

Outlook for the Western Atlantic

East Coast N of 31N to 65W



Wind Forecast (L, kt) and Wave Forecast (R, ft) Valid 10 AM / 15 UTC Monday, December 11, 2023

Decision Support Services

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Gale Warning

Thursday (11/23) through Friday (11/24)

KEY MESSAGES:

CALL TO ACTION: Vessels in the area should use caution or make avoidance plans depending on your vessel type and cargo.

- Behind a front, and also between lower pressure near the coast and inland and higher pressure offshore centered off of the Pacific Northwest, an area of sustained gale-force winds will occur late tonight through Friday.
- The gales should be off of the northern California and far southern Oregon coasts, mainly from about Point Reyes north to between Point St. George and Cape Blanco. The chances for gales diminish Friday night.
- Areas of 12-foot seas off of the Pacific Northwest today will shift south tonight, increasing to 15 to 20 feet off of the northern California coast Thursday.
- 12-foot seas will build south offshore of much of the California coast Thursday night, with 12-foot seas also building back north off of the Pacific Northwest late Friday and Friday night.

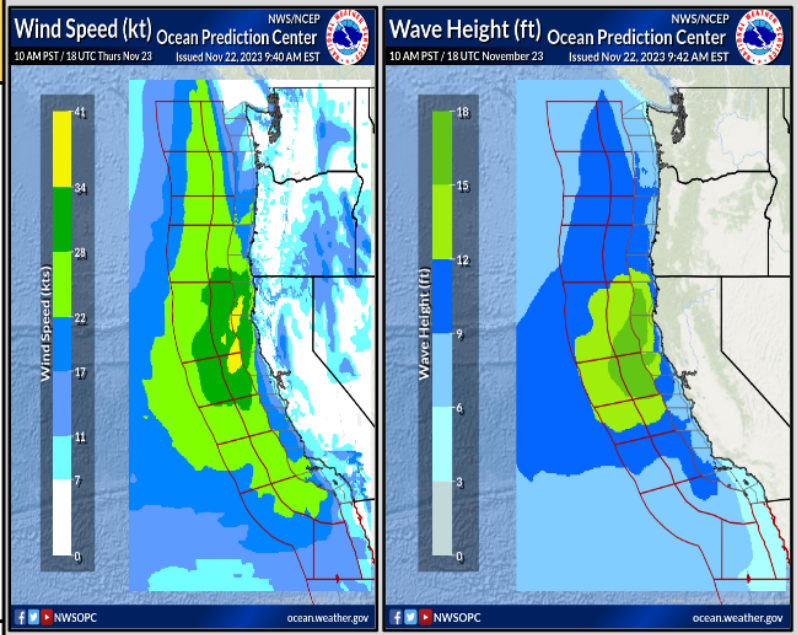
WRN WEATHER-READY NATION

ISSUED: 16 UTC November 22, 2023

@NWSOPC
@NHC_Pacific

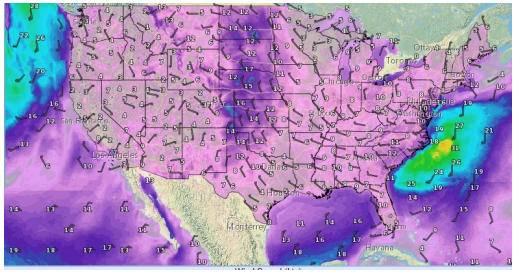
Outlook for the Pacific Ocean

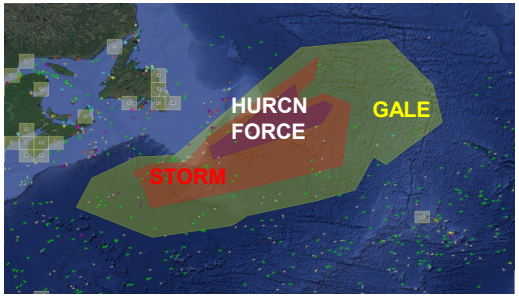
From 30N to 50N E of 133W



Wind Speed Forecast (L, knots) and Wave Height Forecast (R, feet) Valid 10 AM PST / 18 UTC Thursday, November 23.

Future of High Seas Forecasts?






```
HIGH SEAS FORECAST FOR METAREA XII
NWS OCEAN PREDICTION CENTER WASHINGTON DC
1145 UTC THU NOV 03 2022

CCODE/1:31:12:01:00/AOW+POR/NWS/CCODE
SUPERSEDED BY NEXT ISSUANCE IN 6 HOURS

SEAS GIVEN AS SIGNIFICANT WAVE HEIGHT...WHICH IS THE AVERAGE
HEIGHT OF THE HIGHEST 1/3 OF THE WAVES. INDIVIDUAL WAVES MAY BE
MORE THAN TWICE THE SIGNIFICANT WAVE HEIGHT.

ONLY YOU KNOW THE WEATHER AT YOUR POSITION. REPORT IT TO THE
NATIONAL WEATHER SERVICE. EMAIL US AT
VOSOPS@NOAA.GOV(LOWERCASE).

SECURITE

PACIFIC N OF 30N AND S OF 67N E OF A LINE FROM BERING STRAIT
TO 50N 160E

ALL FORECASTS VALID OVER ICE FREE FORECAST WATERS

SYNOPSIS VALID 0600 UTC NOV 03.
24 HOUR FORECAST VALID 0600 UTC NOV 04.
48 HOUR FORECAST VALID 0600 UTC NOV 05.

.WARNINGS.

...STORM WARNING...
.LOW 61N146W 985 MB MOVING S 05 KT. FROM 56N TO 60N E OF
163W...ALSO FROM 50N TO 57N BETWEEN 131W AND 136W WINDS 25 TO 40
KT. SEAS 10 TO 19 FT.
.24 HOUR FORECAST LOW 59N145W 993 MB. FROM 52N TO 59N BETWEEN
148W AND 162W WINDS 30 TO 45 KT. SEAS 9 TO 18 FT.
.48 HOUR FORECAST LOW 56N136W 992 MB. WITHIN 660 NM W AND 420 NM
S QUADRANTS WINDS 35 TO 50 KT. SEAS 14 TO 26 FT. ELSEWHERE E OF
A LINE FROM 59N160W TO 53N160W TO 50N150W TO 42N124W WINDS 25 TO
40 KT. SEAS 8 TO 16 FT.

...STORM WARNING...
.W OF A LINE FROM 52N163E TO 46N160E WINDS TO 25 KT. SEAS TO 9
FT.
.24 HOUR FORECAST LOW 53N160E 996 MB. FRONT WILL EXTEND FROM LOW
TO 50N161E TO 40N153E. WITHIN 120 NM E OF FRONT WINDS 35 TO 50
KT. SEAS 12 TO 21 FT. ELSEWHERE WITHIN 300 NM E OF FRONT WINDS
25 TO 40 KT. SEAS 8 TO 13 FT.
.48 HOUR FORECAST LOW 50N167E 1003 MB. FRONT WILL EXTEND FROM
59N170E TO LOW CENTER TO 42N163E TO 36N156E. WITHIN 120 NM E OF
FRONT N OF 47N WINDS 35 TO 50 KT. SEAS 14 TO 23 FT. ELSEWHERE
WITHIN 300 NM E OF FRONT WINDS 25 TO 40 KT. SEAS 8 TO 16 FT.

...STORM WARNING...
.LOW 38N178E 995 MB MOVING E 10 KT. WITHIN 180 NM NW QUADRANT
WINDS 35 TO 50 KT. SEAS 16 TO 25 FT. ELSEWHERE WITHIN 480 NM N
AND 300 NM W QUADRANTS WINDS 25 TO 40 KT. SEAS 10 TO 18 FT. ALSO
FROM 31N TO 48N BETWEEN 175W AND 169E WINDS 20 TO 30 KT. SEAS 8
TO 14 FT.
.24 HOUR FORECAST LOW 39N179W 997 MB. WITHIN 240 NM N AND 180 NM
W QUADRANTS WINDS 35 TO 50 KT. SEAS 17 TO 27 FT. ELSEWHERE
WITHIN 300 NM N AND NW OF A LINE FROM 44N165W TO 40N179W...ALSO
WITHIN 360 NM NW...300 NM SW AND 120 NM SE QUADRANTS WINDS 25 TO
40 KT. SEAS 10 TO 18 FT.
.48 HOUR FORECAST LOW 37N179W 1001 MB. FROM 40N TO 45N BETWEEN
175W AND 176E...AND FROM 33N TO 44N BETWEEN 175E AND 179W WINDS
25 TO 40 KT. SEAS 12 TO 21 FT.

...GALE WARNING...
```

Storm (Low, Front, Area, Line) -- TAFB (Gap Winds), OPC

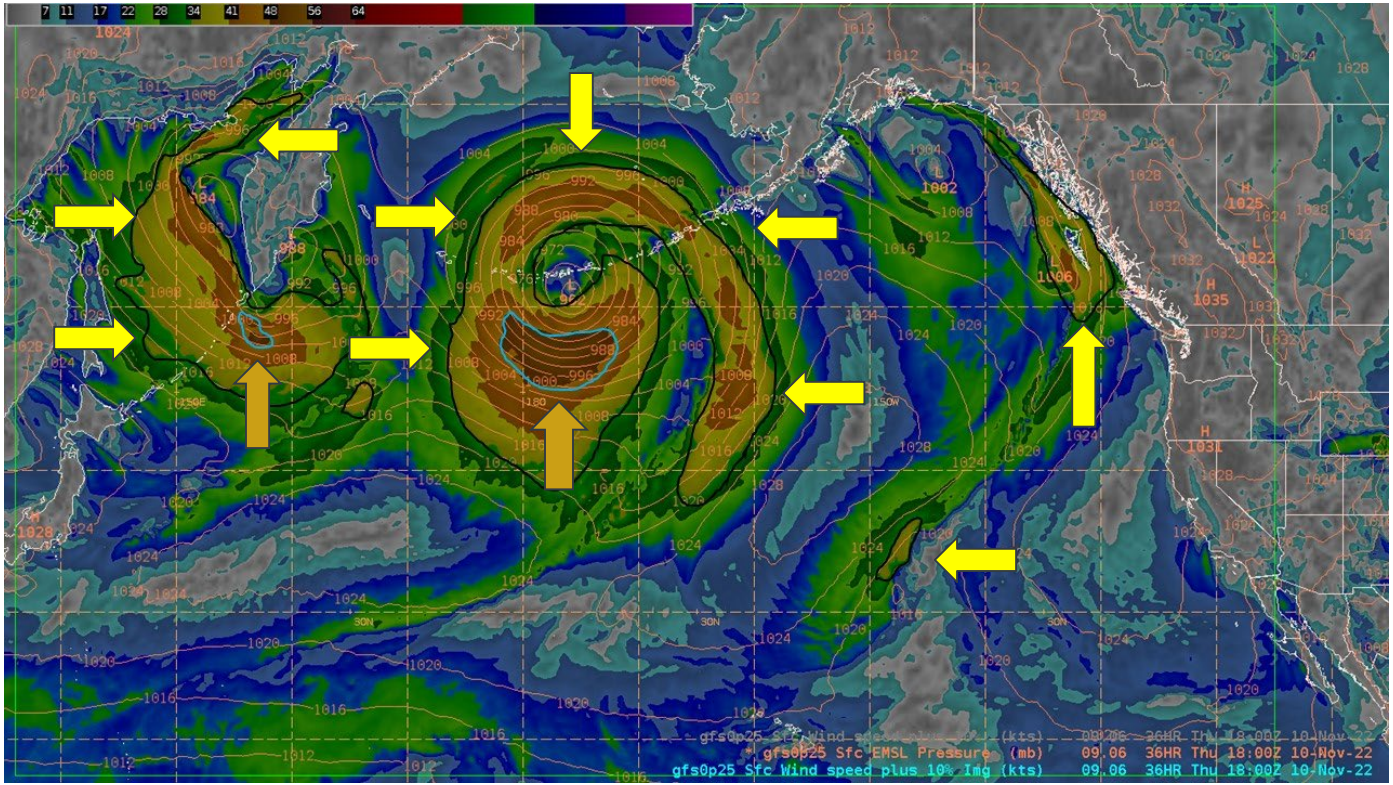
Event Level Parts	Example
eventHeader	WARNING 2020-00012: STORM
issueTime	ISSUED 1745 UTC TUE JUL 14 2020
initialDetails	.WITHIN 47N55W 46N51W 44N45W 47N55W WINDS 40 TO 50 KT.
forecastDetails	.24 HOUR FORECAST WITHIN 47N55W 46N42W 45N52W 44N44W 47N55W. WINDS 40 TO 50 KT. .48 HOUR FORECAST WITHIN 48N56W 46N41W 46N52W 45N45W 48N56W. WINDS 40 TO 50 KT.

Gale (Low, Front, Area, Line) -- TAFB (Gap Winds), OPC

Event Level Parts	Example
eventHeader	WARNING 2020-00012: GALE
issueTime	ISSUED 1745 UTC TUE JUL 14 2020
initialDetails	.WITHIN 47N55W 46N51W 44N45W 47N55W WINDS 30 TO 40 KT.
forecastDetails	.24 HOUR FORECAST WITHIN 48N56W 46N41W 46N53W 46N47W 48N47W 53N49W 56N52W 48N56W. WINDS 30 TO 40 KT. .48 HOUR FORECAST WITHIN 49N57W 47N42W 47N54W 47N48W 49N48W 54N50W 57N53W 49N57W. WINDS 30 TO 45 KT.

Need to Serve Mariners with 21st Century Information

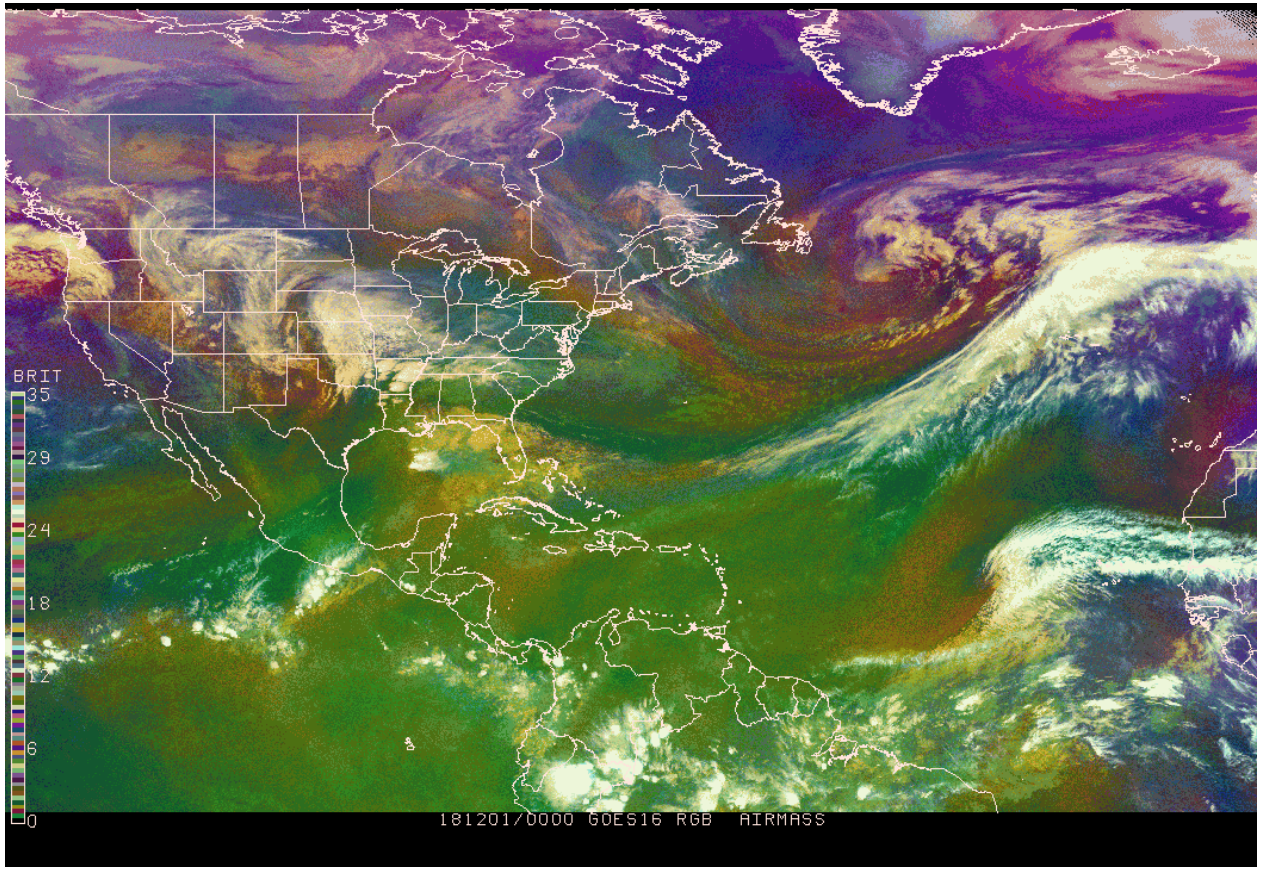
GFS 36-hour forecast, valid November 10, 2022, 18 UTC



Save the Date!

- A great opportunity for forecasters and researchers that specialize in marine weather and associated hazards to interact and learn from industry partners and customers in-person and virtually.

Thank you!



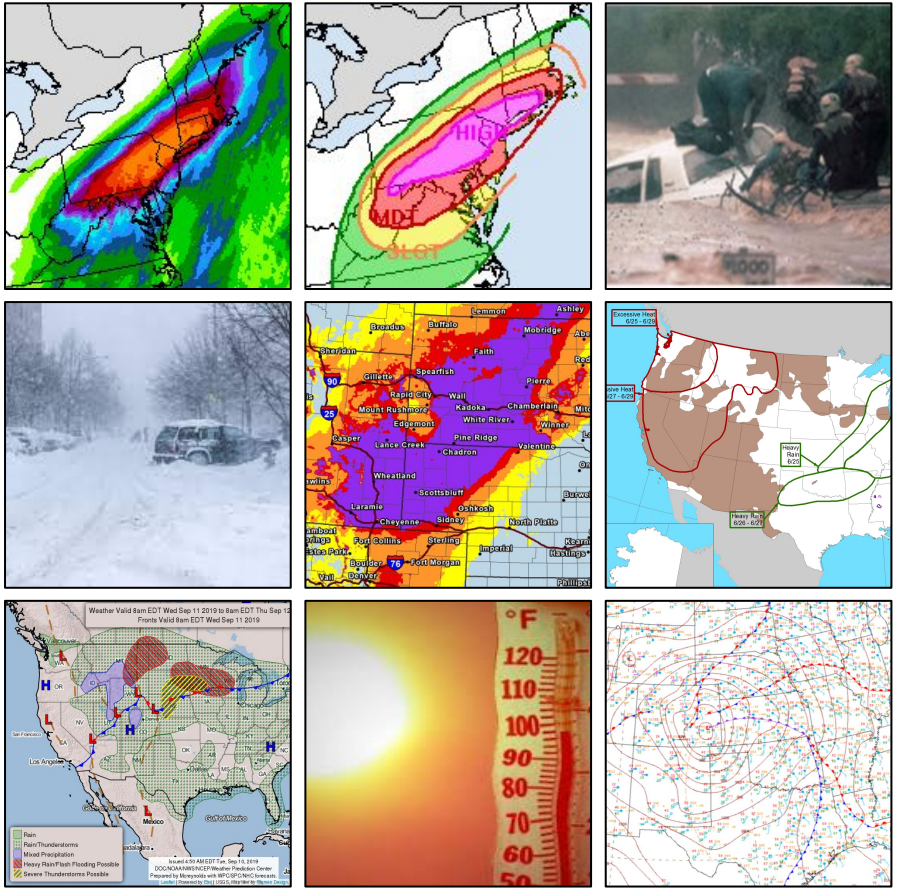
Michael Folmer

michael.folmer@noaa.gov

Overview of the Weather Prediction Center

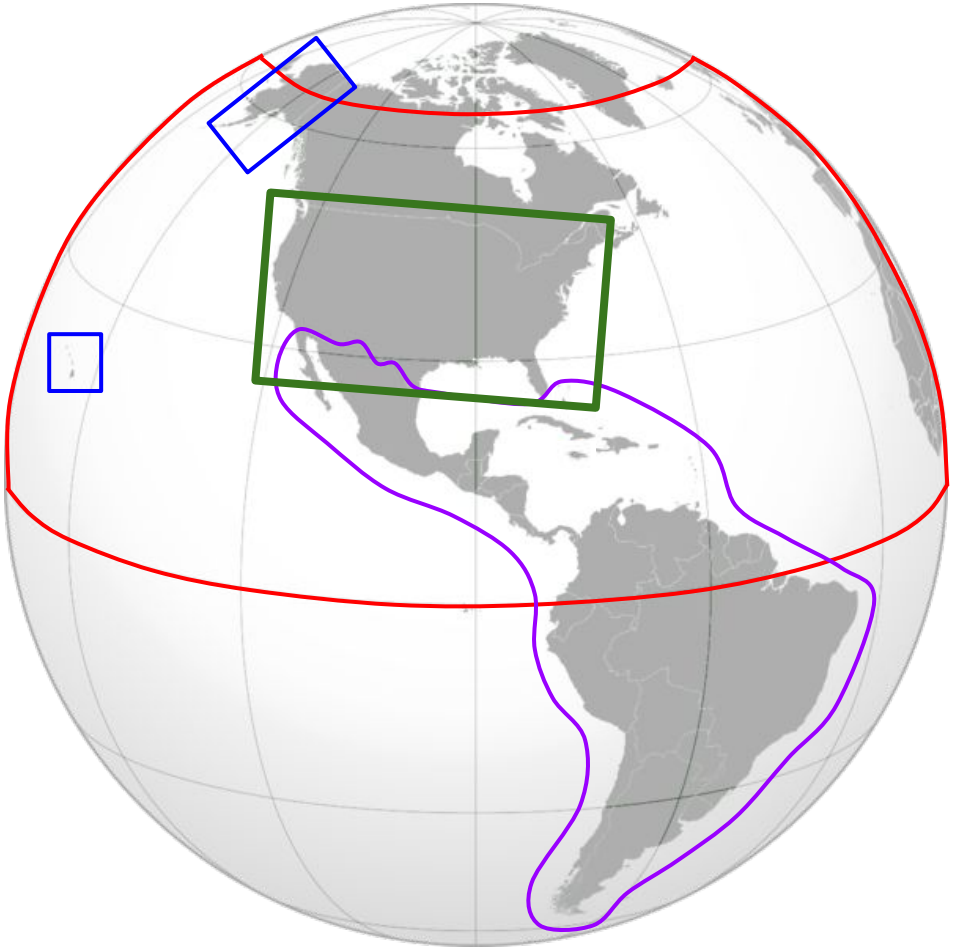
Alex Lamers, Warning Coordination Meteorologist
NOAA/NWS Weather Prediction Center

2024 National Hurricane Conference
March 26, 2024 | Orlando, FL



What do we do?

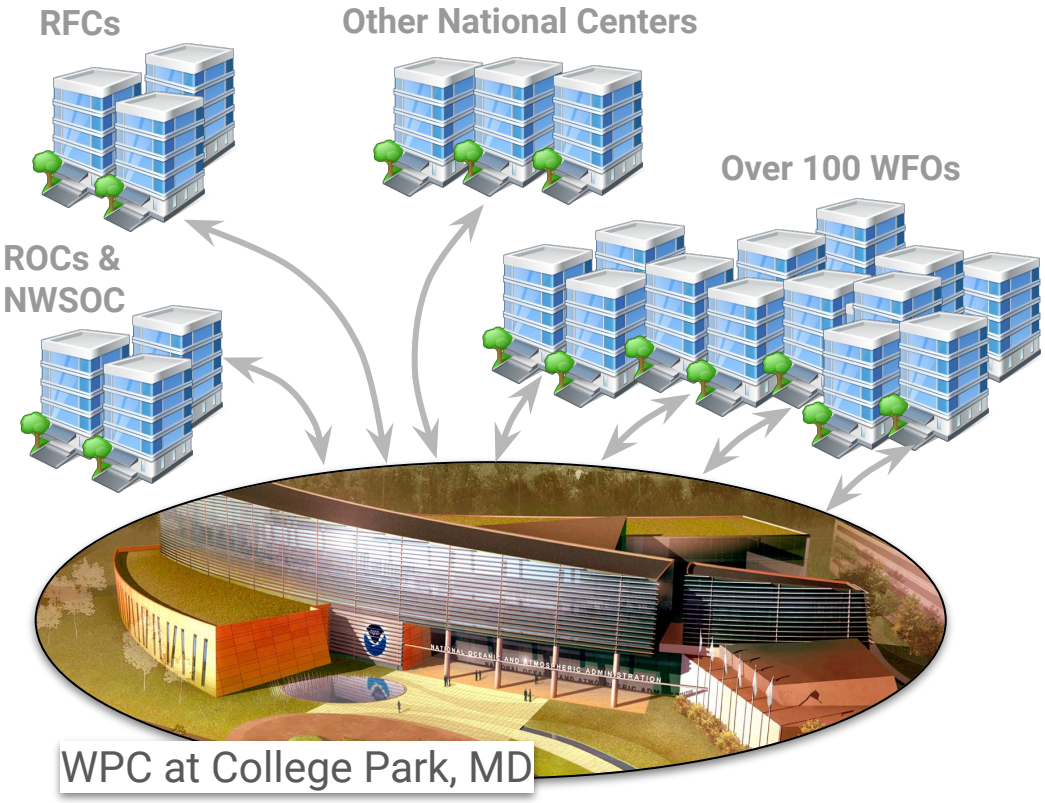
- **Short answer: a lot!**
- Precipitation forecasting expertise including rainfall and snow/ice
- Growing role in extreme temperatures, from heat to cold
- Foundation of the national weather story
- Continuing the 150+ year legacy of surface weather map analysis
- Backup for Nat'l Hurricane Center



Where do we do it?

- CONUS: multitude of forecasts
- OCONUS: Alaska medium range and Hawaii forecast discussion
- Tropical cyclone rainfall statements with NHC and CPHC
- International Desk trains forecasters from Central and South America and the Caribbean

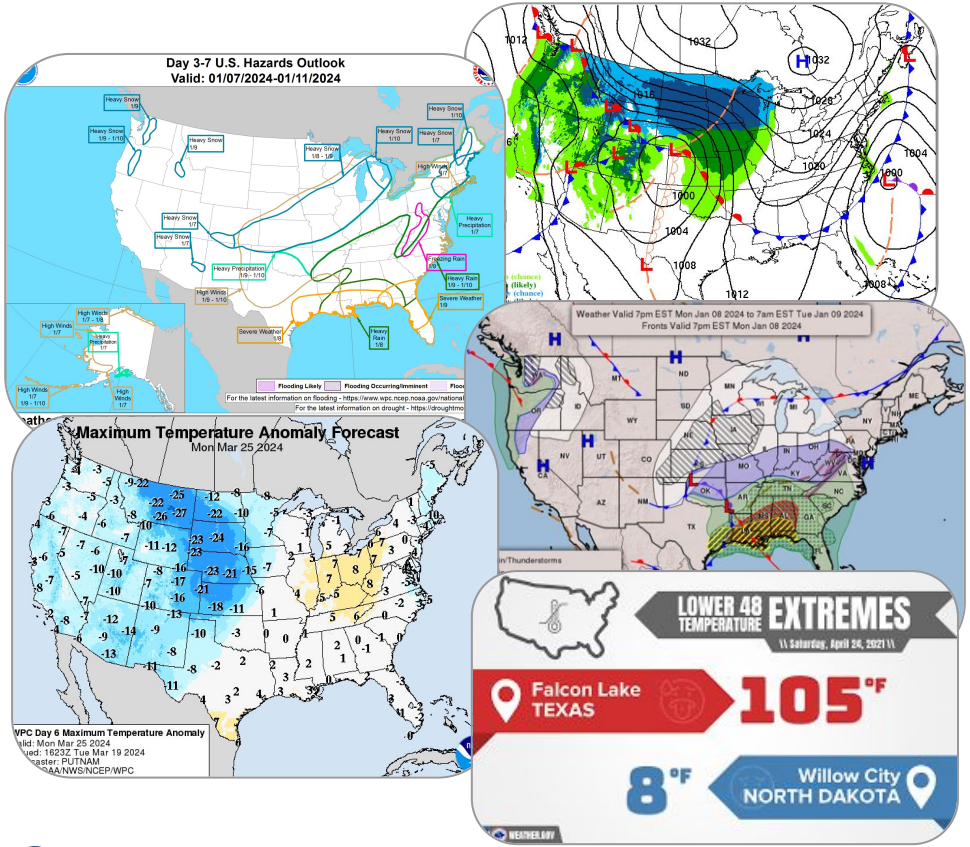
Nerve Center for National Weather Coordination



- On any given day we are in communication with just about every field office around the country
- In particular, collaboration focused on precipitation
- Fundamentally, there are inputs from all levels of the agency in the products you see on our website
- Co-located with OPC, NWS Ops Center, and NWS Senior Duty Meteorologist

Foundation of the National Weather Story

- Basic weather maps and forecast charts that show the expected weather and major fronts and pressure systems
- Hazardous weather outlooks that synthesize official forecast information from other NWS centers and sources
- Contextual information such as potential temperature records and anomalies
- National extremes and summaries of major weather events



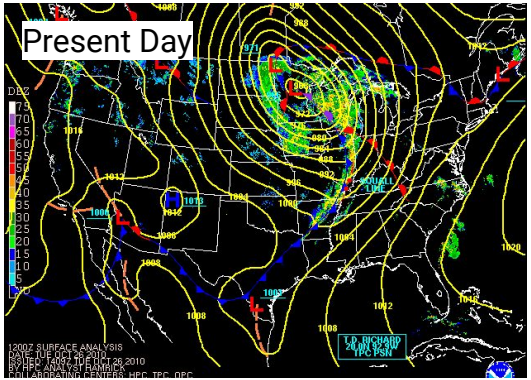
Deep Roots Mapping the Nation's Weather

Smithsonian Image Archive

Signal Service Office in D.C. (1872)

HOW IT STARTED

HOW IT'S GOING



It's **IN OUR DNA** to bring together many bits of information into a ***coherent national weather story***. You can trace this practice back over 150 years to the U.S. Army Signal Service and an early Smithsonian observing network that got its start in the 1840s.

Motivation and Mission

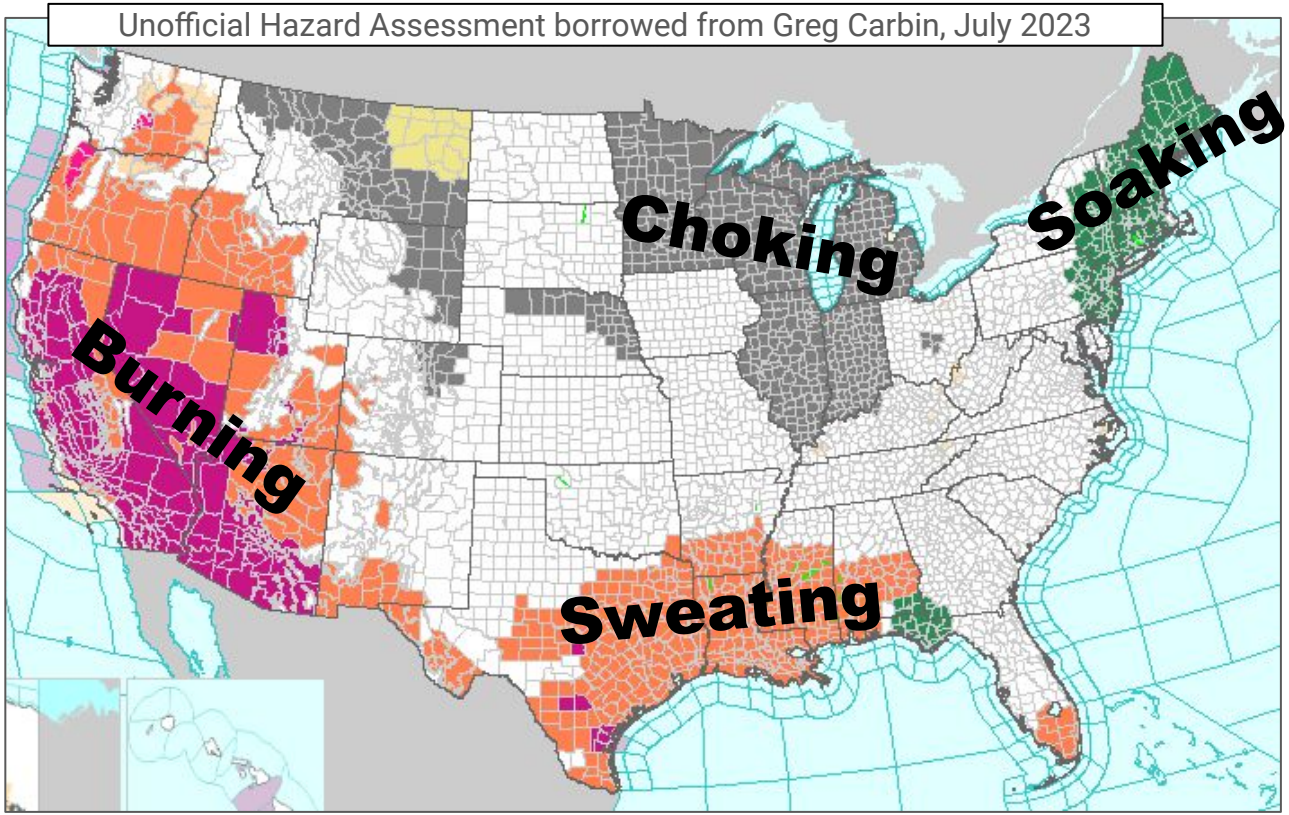
U.S. Leading Cause of Weather-Related Fatalities
(NWS and CDC stats agree, although not exact numbers)

Extreme Temps

Next Highest Cause of Weather Fatalities (NWS)

Flooding

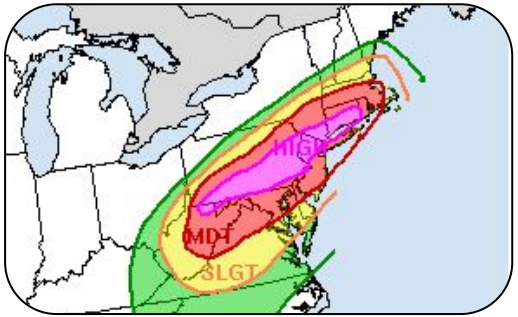
From new WPC roadmap: we "champion the prediction of rain storms, winter storms, and extreme temperature events for the protection of life and property"



Helping You Find The Problem Spots

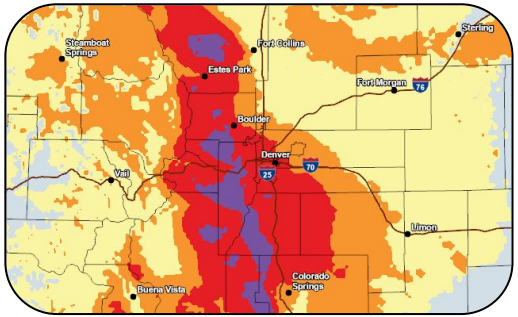
This is just the tip of the iceberg! We have more products that are focused on extreme precipitation and temperatures.

Excessive Rainfall Outlook



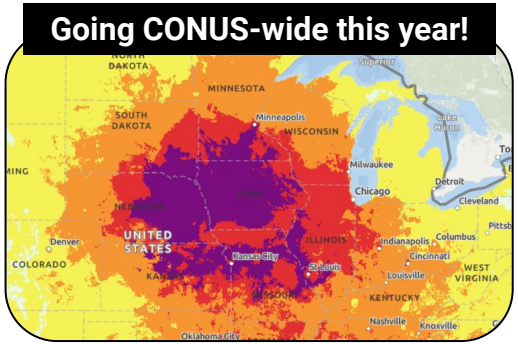
Translating rainfall forecast into a likelihood of flash flooding, based on factors like rainfall rate, preceding rain, historical context.

Winter Storm Severity Index



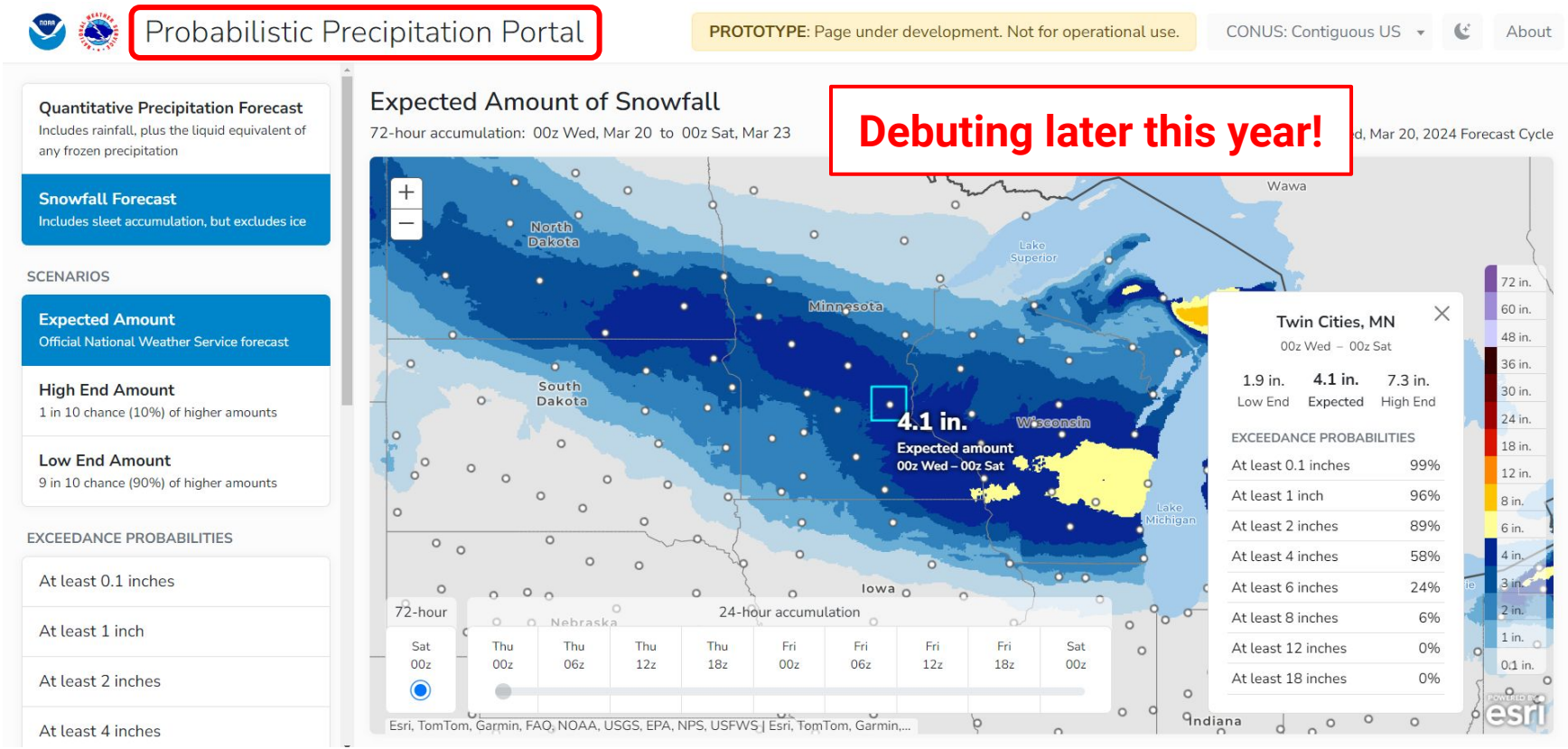
Translating the official NWS forecast of snow, ice, wind, etc. into a potential societal impact – in other words, how disruptive?

HeatRisk



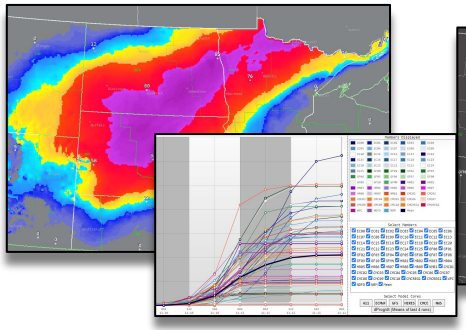
Translating the official NWS temperature forecast into how unusual this level of heat is. Correlated with health impacts.

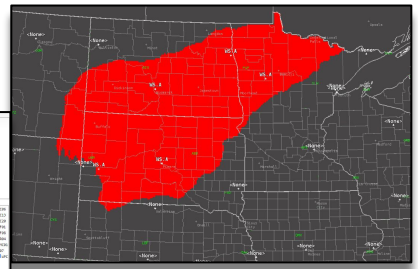
Advancing Probabilistic Forecasting

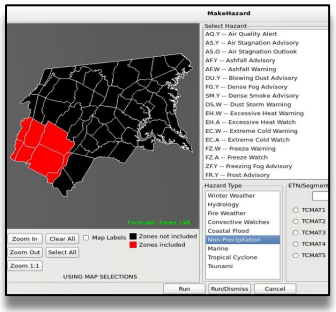


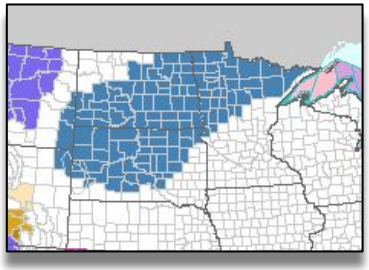
Probabilistic Approaches to Hazard Decisions

Collaborative Winter Storm Watch Experiment testing a methodology for Watch area recommendation from WPC to local NWS forecast offices…









WPC leverages ensemble info…

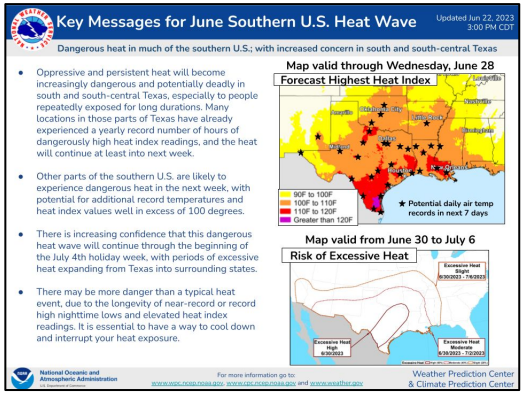
…to produce a first guess area.

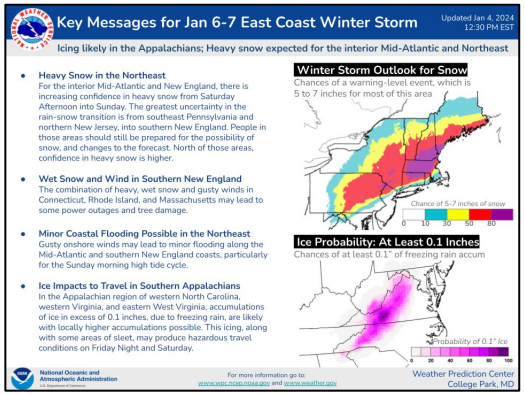
WFOs use it for collaboration and decisions…

…resulting in consistent final common picture

The goal is to leverage the strengths of ensemble systems and WPC winter expertise and pair it with local decision-making and understanding at a critical juncture pre-event

Key Messages Graphics

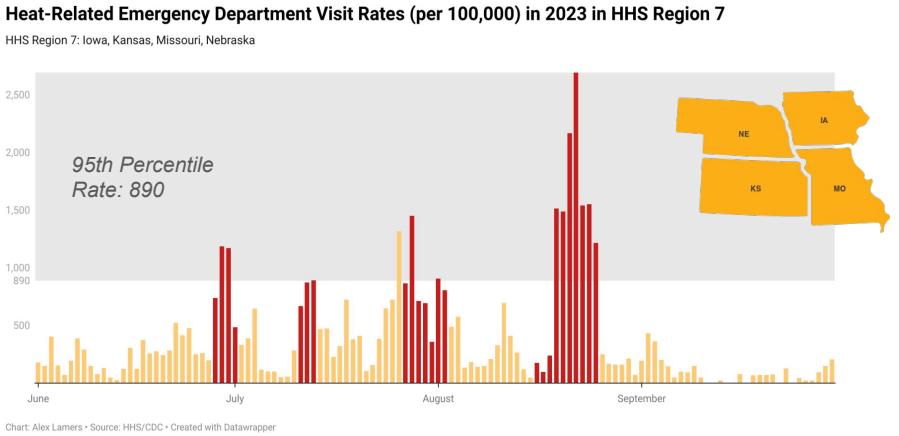




- Available now for winter storms, cold snaps, heat waves
- Heat graphics integrated into Heat.gov
- Collaboration across time scales with the Climate Prediction Center for longer lead time
- Aiming for regional-scale, warning-level events

Impact verification: we DID see major spikes in heat emergency department visits when we had Key Messages in effect.

Example for HHS Region 7 to right.



Stay Engaged! How to Get In Touch…

- We want to hear from you!
- What works and what doesn't?
- Ongoing social science study of our web page and precipitation products to improve user experience
- Do our synthesis products tell you what you need to know about the national weather story?
- What do you need to be ready for extreme temperatures and precipitation?
- What lead times do you need for major preparedness actions for those types of events? Studies for hurricane evacuations, but more opaque to us for other situations.

QR Code: Digital Business Card with my Contact Info

Alex Lamers
alex.lamers@noaa.gov

Operations at the National Water Center

Jason Elliott
Service Coordination Hydrologist, Water Prediction Operations Division
Office of Water Prediction | National Water Center

Office of Water Prediction / National Water Center

- The Office of Water Prediction (OWP) operationally supports and delivers science-based, integrated, consistent, timely, reliable and accurate operational water resources monitoring, prediction and diagnostic information to the Nation.

Key Functions

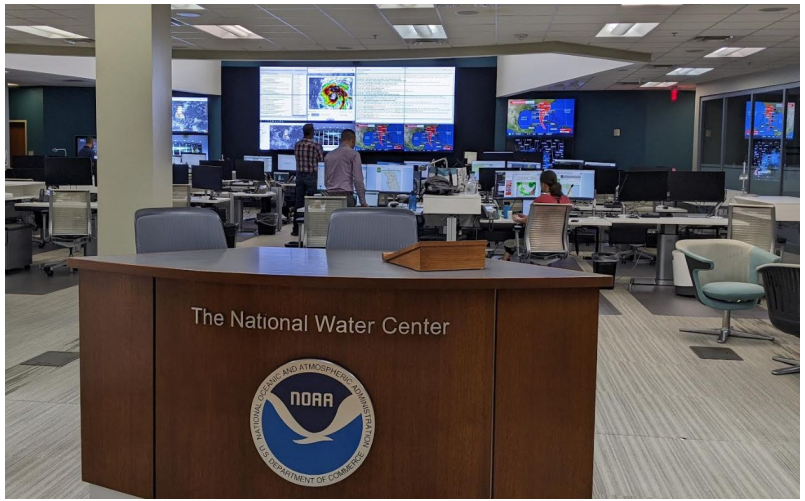
- National Water Model
- Visualization Services
- Validation and Development
- Emerging Services & Training
- Operations and Decision Support Services
- ...and more!

NWC Operations

- The role of the Operations Division within the National Water Center is to determine, coordinate, and deliver the National-level hydrologic picture
  - We do this through products and services, mostly still experimental

- Current operating hours:
  5:00 AM CT → 8:30 PM CT (can extend)

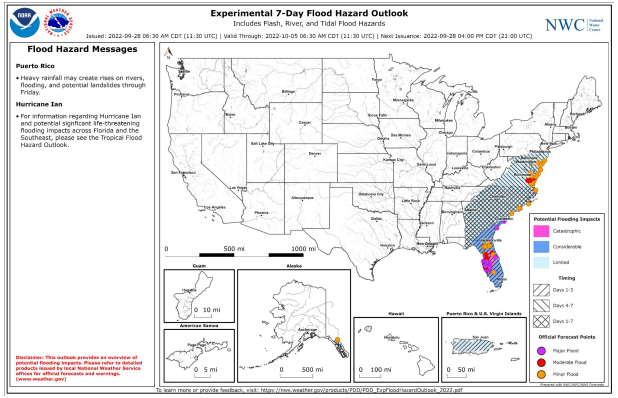
- Current staffing (about ⅔ of 'full' staffing):
  2 Senior Hydrologists
  4 Lead Hydrologists
  7 Hydrologists
  2 Winter/Remote Sensing Scientists
  3 GIS Specialists
  2 Technical Support Staff
  4 Managers

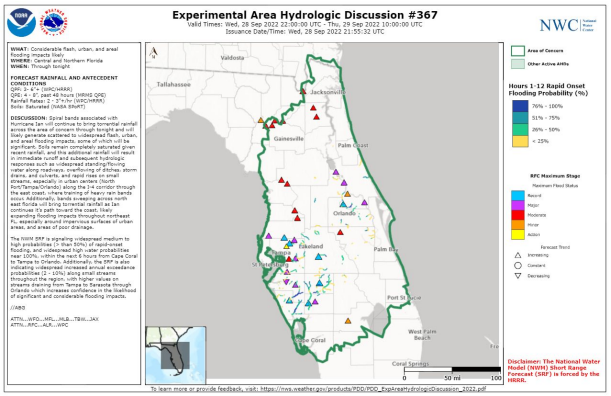


NWC Public Products (currently experimental)

https://www.weather.gov/owp/operations

Flood Hazard Outlook **FHO**	Area Hydrologic Discussion **AHD**	Nat'l Hydrologic Discussion **NHD**
National overview of potential flood impacts in the next seven days	Localized overview of areas with rapid onset flood potential in the next 0-18 hours	Descriptive narrative of current and forecast hydrologic conditions during the next ten days





National Hydrologic Discussion - EXPERIMENTAL
NWS National Water Center - Tuscaloosa AL
1015 AM CDT WED SEP 28 2022

.Synopsis…

Hurricane Ian likely to produce widespread considerable flooding impacts across the Florida Peninsula, southern Georgia, and coastal South Carolina, and limited impacts across portions of the Southeast and southern Mid-Atlantic… Localized flooding impacts possible in Puerto Rico…

.Discussion…

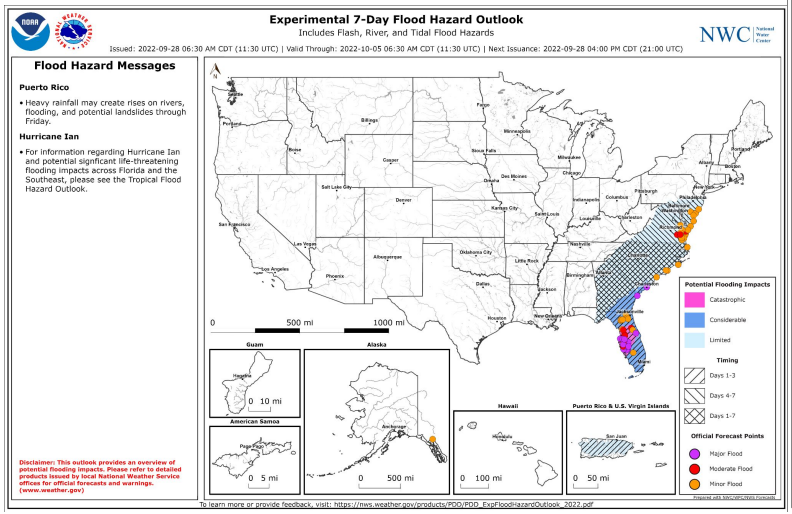
.Hurricane Ian…

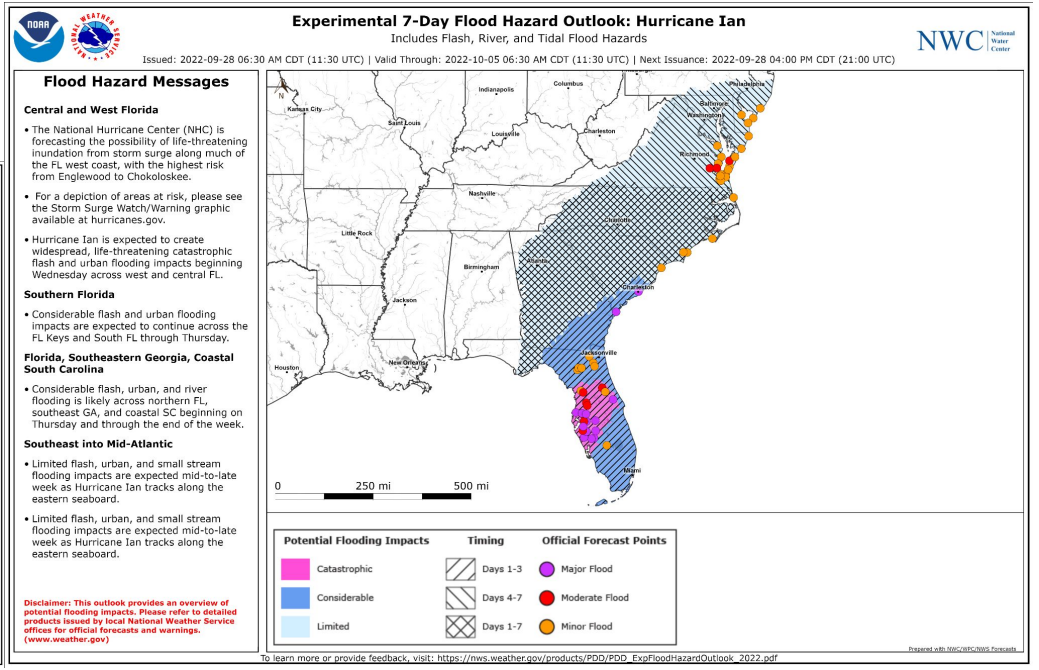
Hurricane Ian will continue impacting much of central and southern FL today and will generate moderate to major river flooding, including record major flood forecasts across portions of the Southeast later this week based on the latest forecast from the NHC. Despite some remaining uncertainty in Ian's forecast track, confidence is high for catastrophic life-threatening flooding impacts for portions of central FL, considerable flooding impacts for the rest of the FL Peninsula, southern GA, and coastal SC, and limited flooding impacts across much of the Southeast and southern Mid-Atlantic. The latest QPF from WPC indicates rainfall associated with Ian will continue over the Florida Keys, South FL and throughout much of the Peninsula through day 2 (Thu) and spread further into the Southeast and southern Mid-Atlantic late on day 2 - 5 (Thu - Sun). Rainfall amounts continue come into better agreement ahead of Ian's pending landfall; current forecast rainfall amounts from WPC include 12 - 18" with local amounts up to 24" for central and northeast FL, 6 - 8" for the FL Keys and south FL, and 4 - 8" for eastern GA and coastal SC. With two feet of rainfall possible in the central portion of FL, any municipality's storm sewer system will be challenged and hydrologic impacts will likely be felt in urban, suburban, and exurban environments outside of floodplains.

The National Hurricane Center is also forecasting the possibility of life-threatening inundation from storm surge along much of the FL west coast, with the highest risk from Marco Island to Tampa Bay. For a depiction of areas at risk, please see the Storm Surge Watch/Warning graphic available at hurricanes.gov.

Flood Hazard Outlook (Experimental)

- Issued (soon to be) twice daily – at 4 PM / 7 AM CDT; 3 PM / 7 AM CST
- During tropical operations, a specially-zoomed visualization of the outlook, with further detailed Flood Hazard Messages, is also produced at the same times

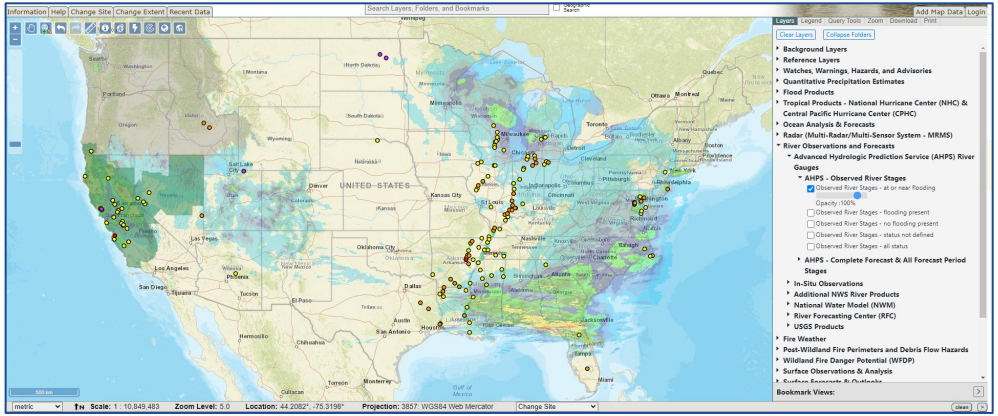


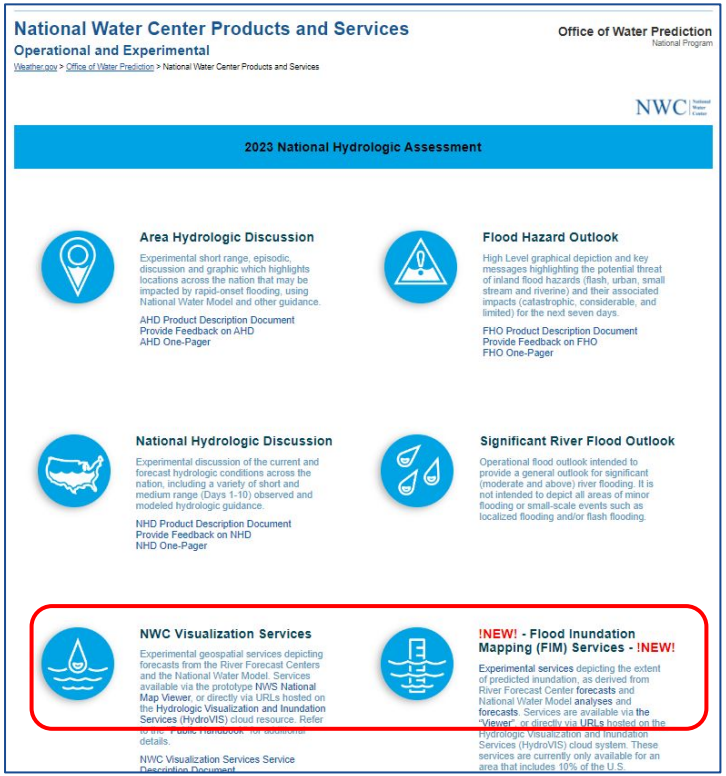


Experimental Services (Publicly available)

NWS GIS Viewer

https://www.weather.gov/owp/operations



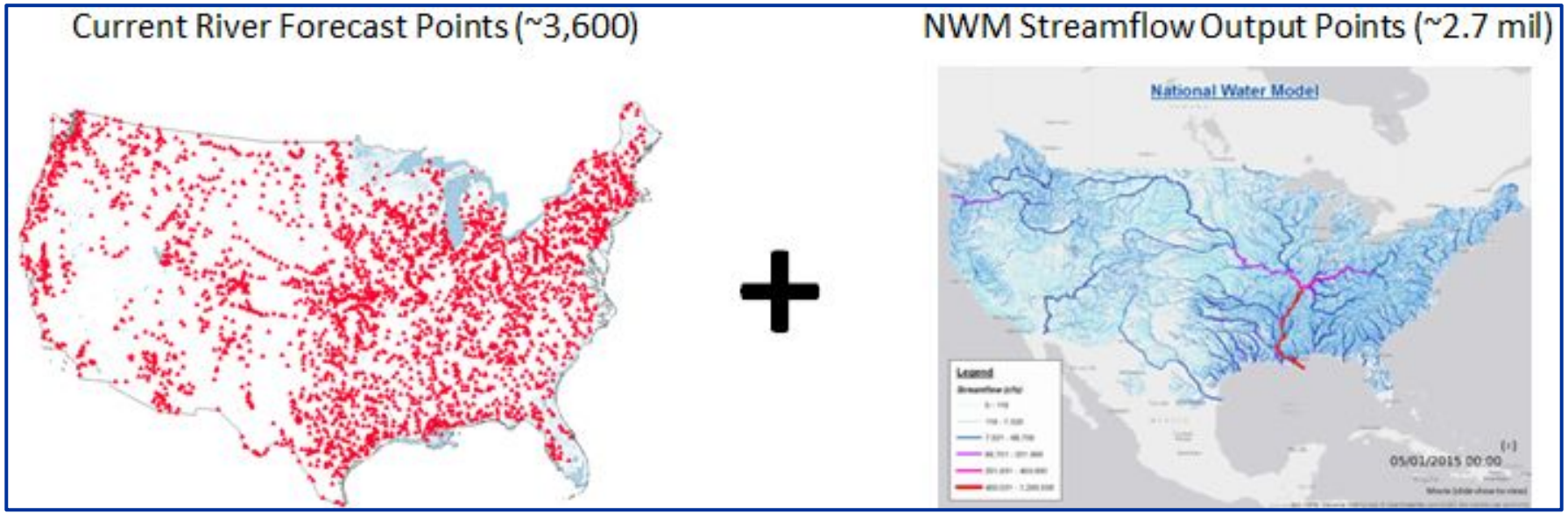


- **Both the suite of NWC Visualization Services and the publicly-available inundation mapping services are available through the NWS GIS Viewer**

https://viewer.weather.noaa.gov/water

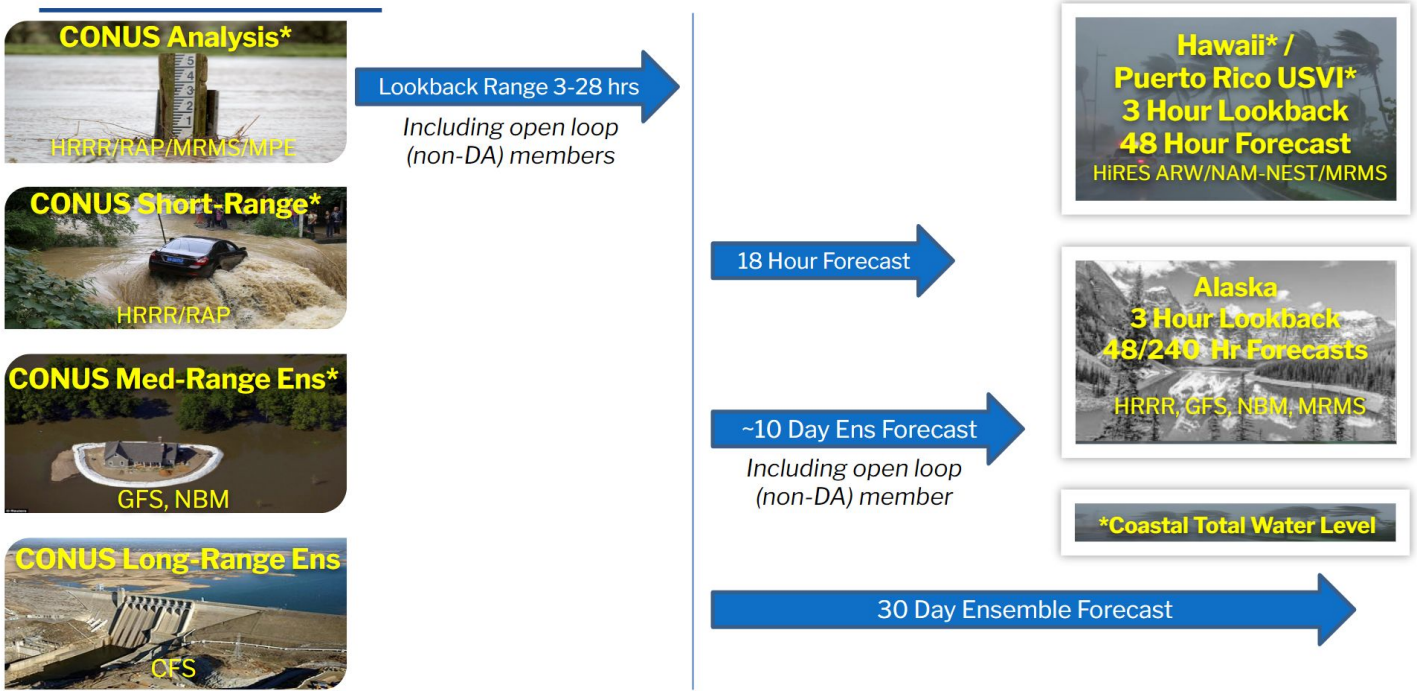
National Water Model

- NWM is a hydrologic model that simulates observed and forecast **streamflow**
- *Complements* official NWS river forecasts provided at approximately 3,600 locations across the CONUS with a very fine spatial and temporal scale and a large spatial coverage (3.2 million river reaches/3.6 million river miles)



National Water Model Operational Cycles

- Visit https://water.noaa.gov/about/nwm



NWS Flood Inundation Mapping Implementation Services

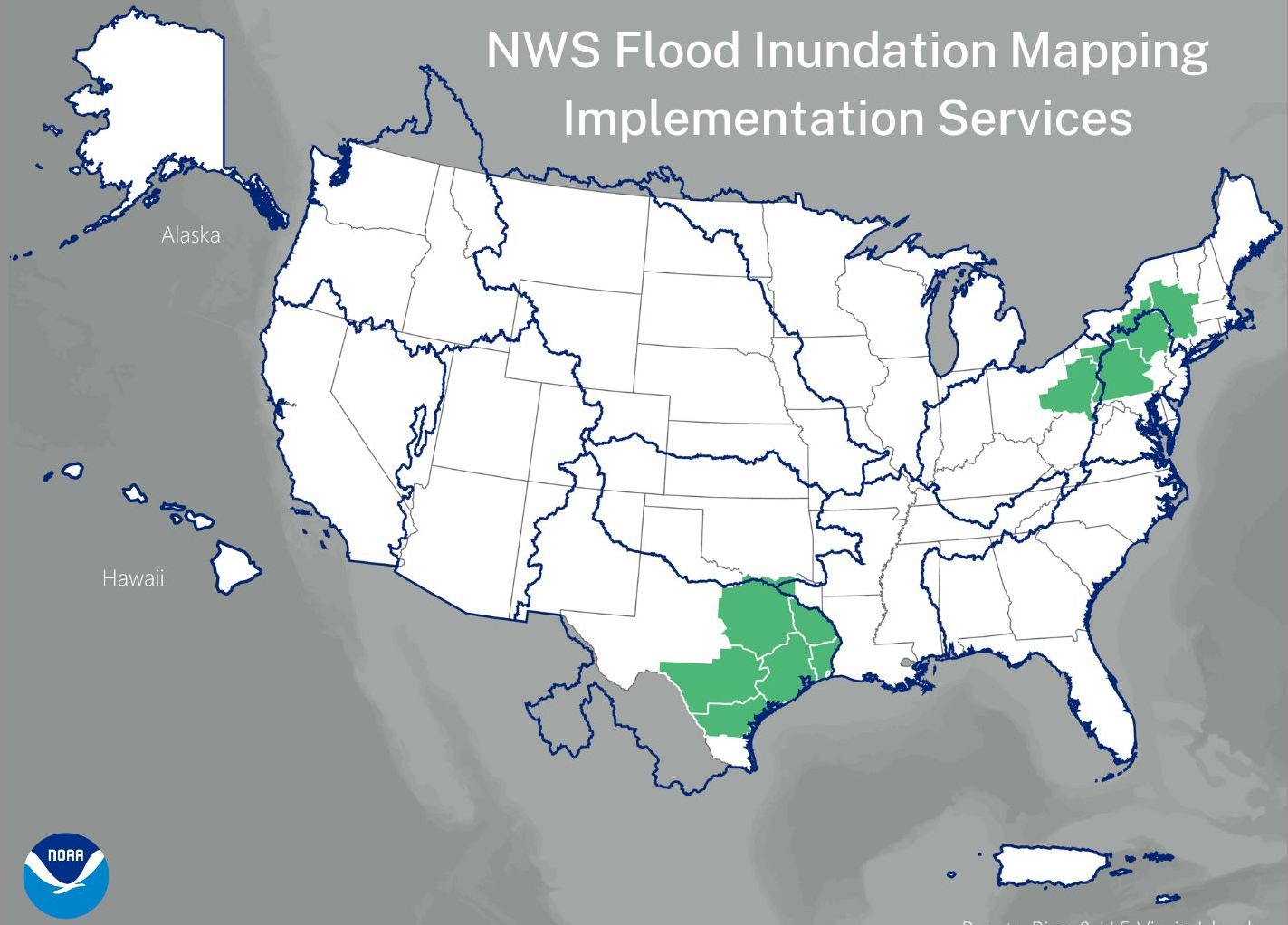
Map Legend

Population served by **October 2023**.

NWS County Warning Areas

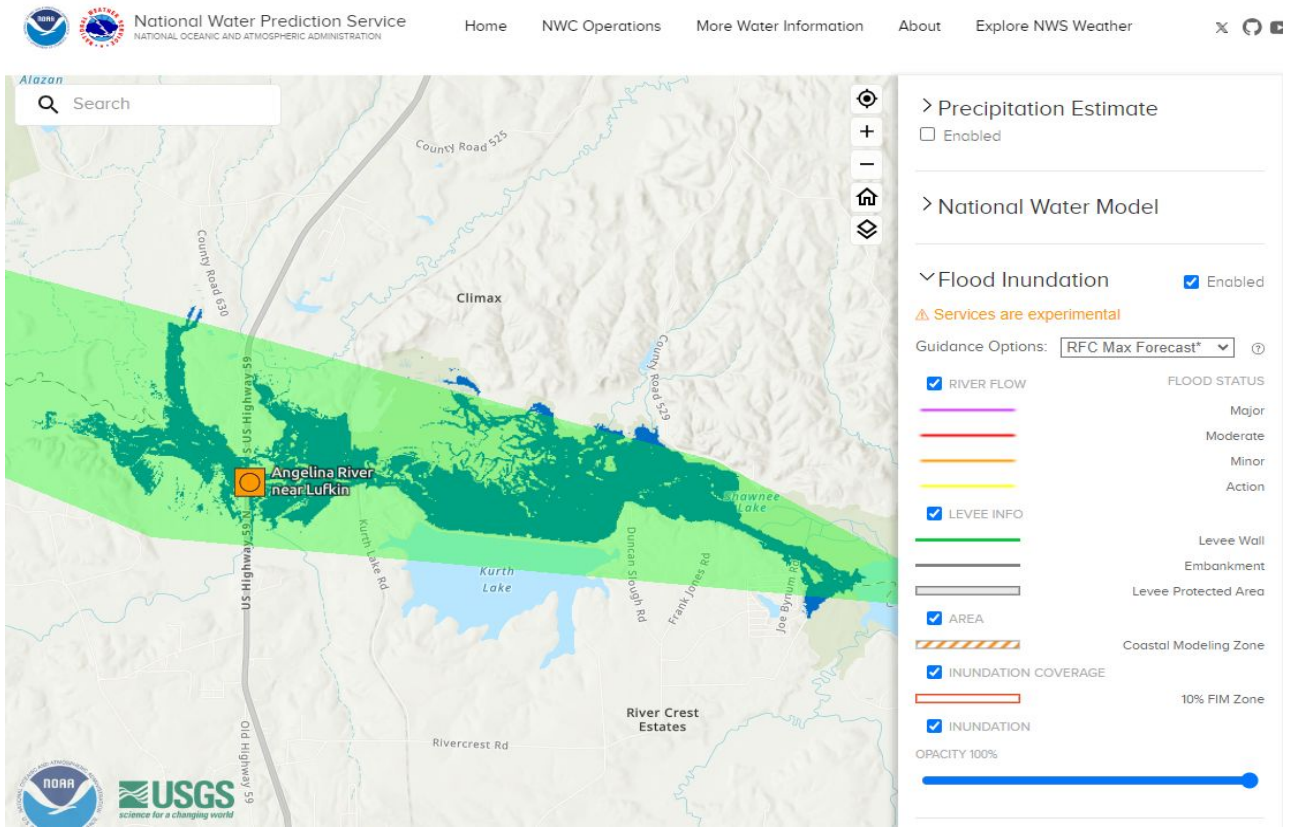
NWS River Forecast Center Boundaries

Over the next 3 years, the **National Weather Service's National Water Center** will work in coordination with **NWS River Forecast Centers, Weather Forecast Offices**, and other Federal partners to release forecast flood inundation mapping services to the Nation.



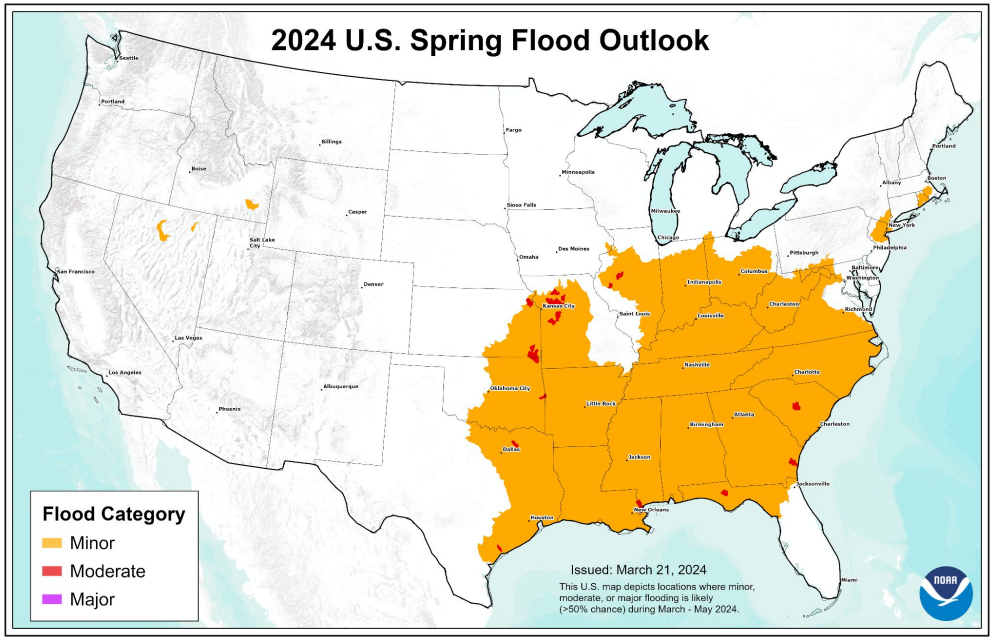
National Water Prediction Service

- **Coming tomorrow!**
- **New, modernized viewing platform for all NWS hydrologic information**
- **Will include the experimental FIM services currently on the NWS GIS Viewer**
- ***Join us tomorrow for additional info***



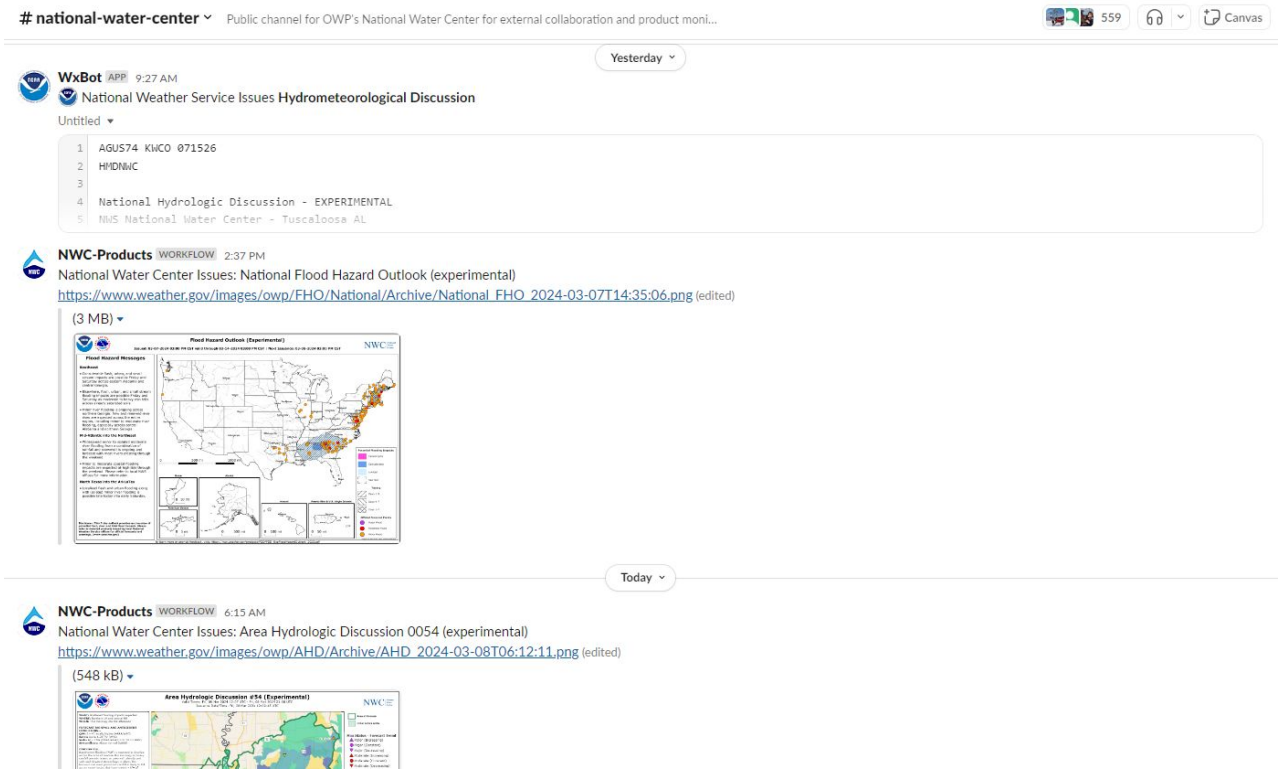
Other NWC Operations Functions

- Include, but are not limited to:
  - The annual NOAA National Hydrologic Assessment
  - Service Status Monitoring
  - Review of Flood Inundation Mapping for intel
- Coordination with other federal agencies in the water space
- Interaction with the remainder of the NWS (field & National centers)
- New initiatives under development include longer-range products and water resources operations and products



We are on NWSChat, powered by Slack!

- **Search for national-water-center**
- **Channel is open to all to join**
- **Products post here routinely, along with occasional other items**
- **Local needs are best served by your local NWS office; we are available for larger scale needs**



Product-only channel also available (no chats): **national-water-center-datafeed**

NOAA

OWP | OFFICE OF WATER PREDICTION

Thank You!

Jason Elliott

jason.elliott@noaa.gov

https://water.noaa.gov

TC TORNADO BASICS and SPC GUIDANCE

Roger Edwards and Matt Elliott

Storm Prediction Center

Norman, Oklahoma

National Hurricane Conference

26 March 2024

TC TORNADO FACTS & CLIMATOLOGY

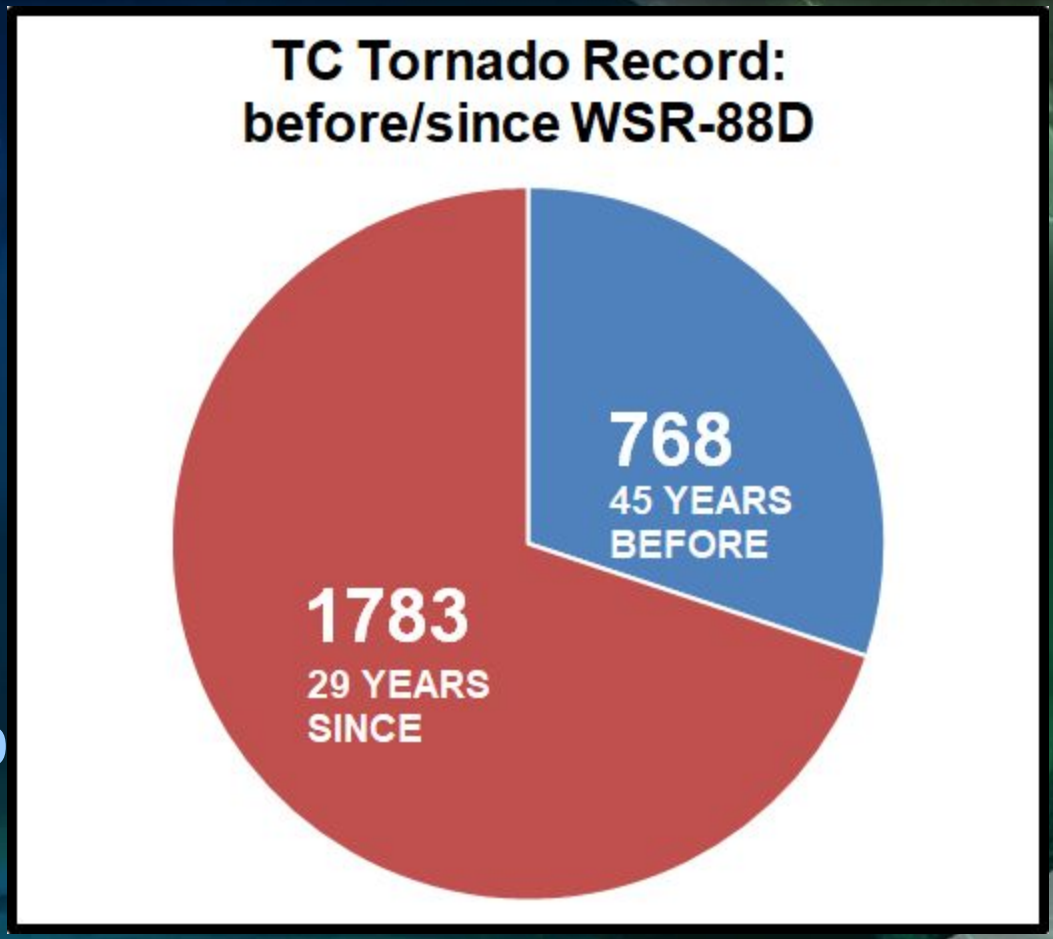
- MOST COMMON: Outside 50-kt wind radius
- NNW-NE-SE of center (deep-shear-related)
- Most common and damaging from mini-supercells
- Occasionally reported from non-supercell radar features (weak – EF0-EF1)
- Sharp decrease >500 km from coasts
- Clear diurnal preference, but still occur at night
- Occur over water and can move ashore
- In every stage of classification (MH, H, TS, TD, low)
- Detailed discussion in Edwards (2012), EJSSM
  Still valid w/some new research since

TC TORNADO FACTS & CLIMATOLOGY

WSR-88D and SPC TCTOR era: 1995 onward

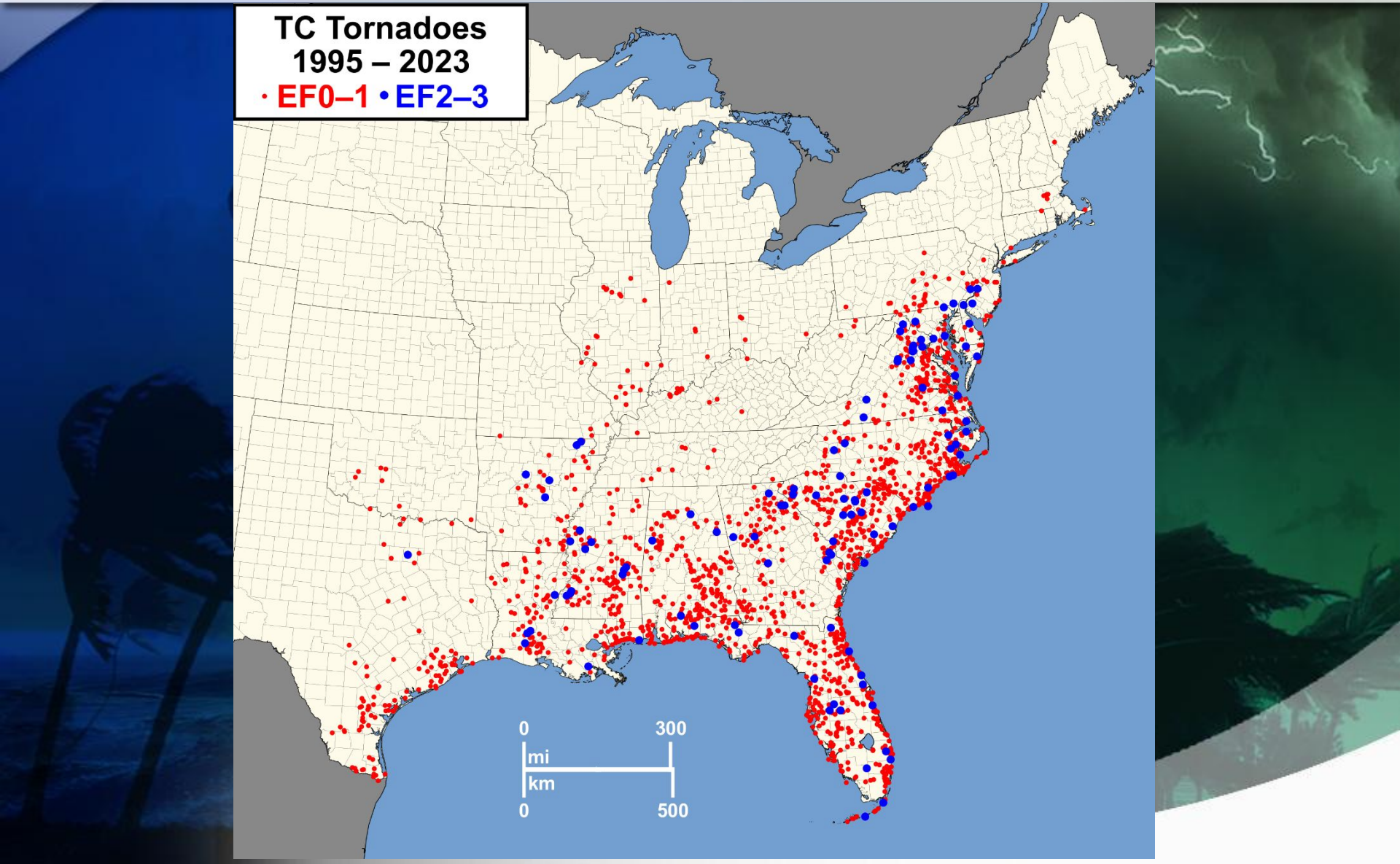
Many more weak TC tornado reports,

Many more TC tornado reports TOTAL

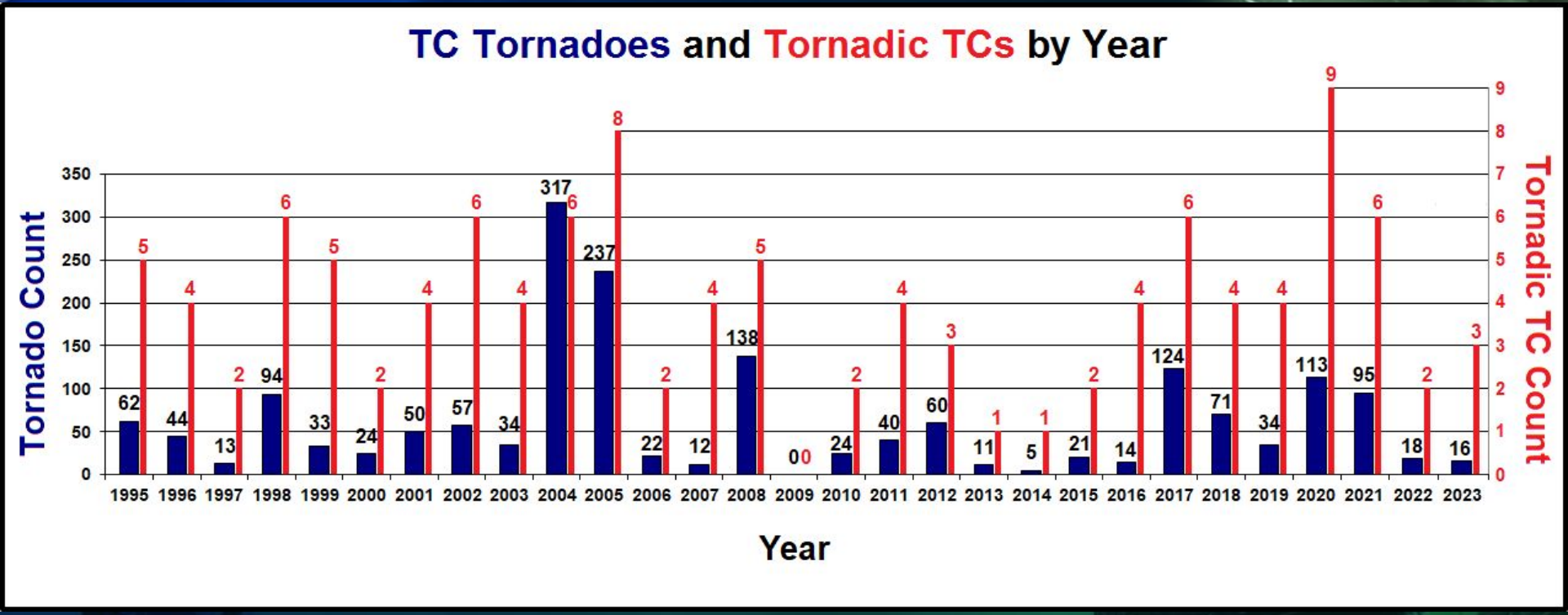


Pre-88D data from Schultz and Cecil (2009)

TC TORNADO FACTS & CLIMATOLOGY

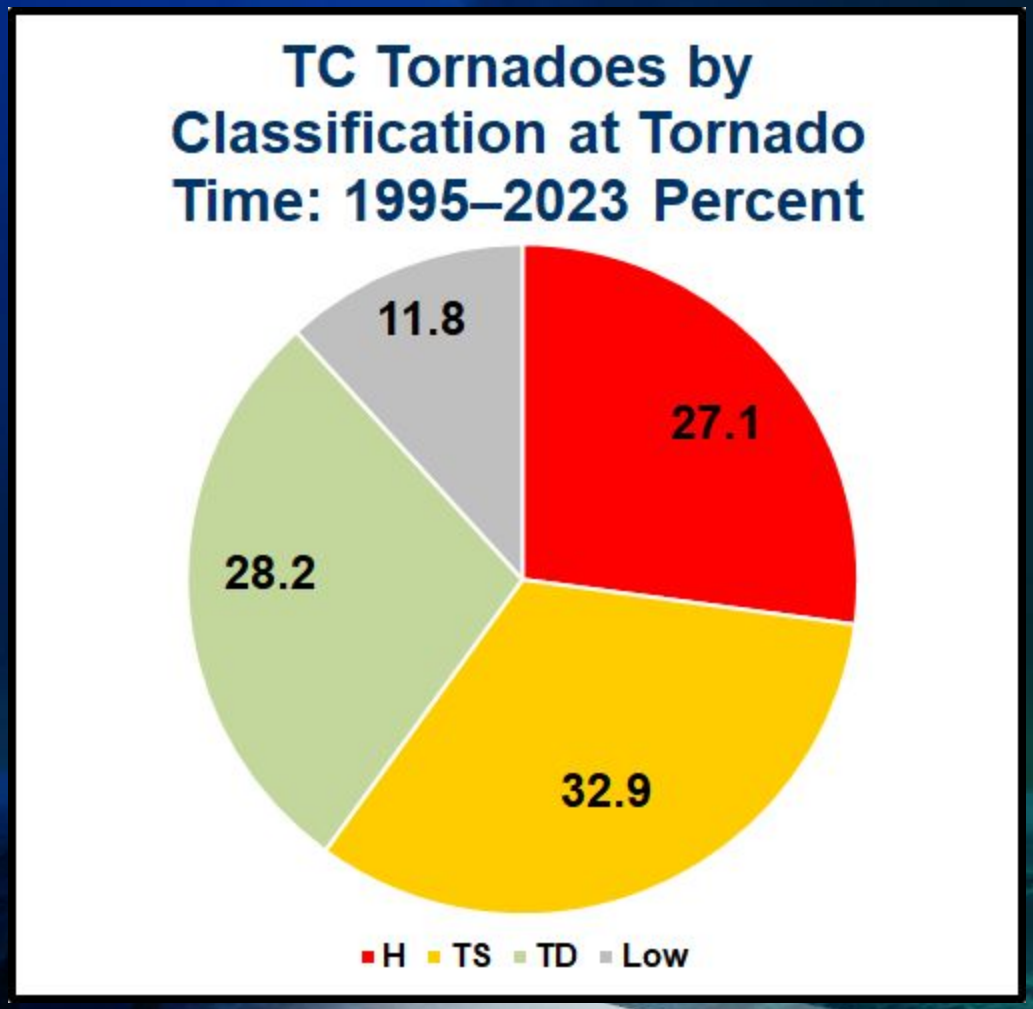


TC TORNADO FACTS & CLIMATOLOGY



Highly variable year-to-year in WSR-88D era

TC TORNADO FACTS & CLIMATOLOGY



TCTOR DATA: TC strength at tornado time (from HURDAT)

TC TORNADO FACTS & CLIMATOLOGY

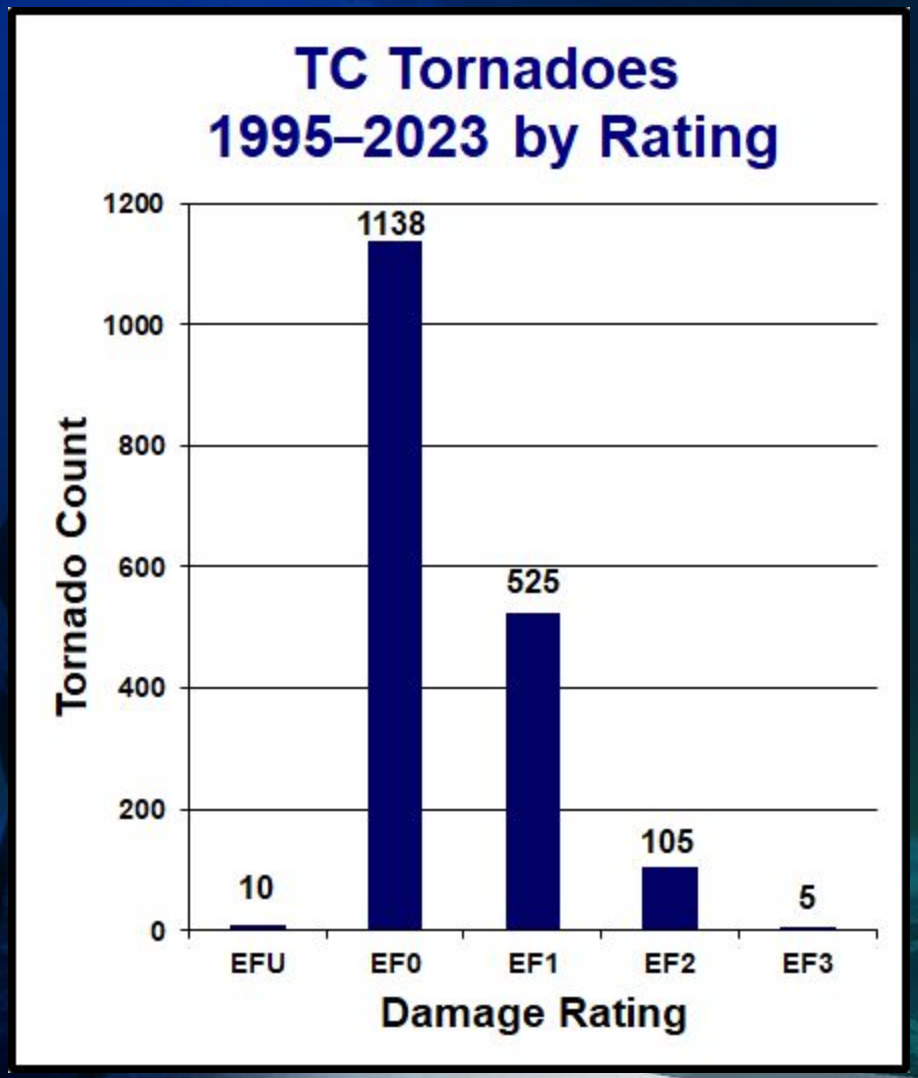
TROPICAL CYCLONE	YEAR	TORNADO REPORTS
H Ivan	2004	118
H Beulah	1967	115
H Frances	2004	103
H Rita	2005	98
H Katrina	2005	59
H Andrew	1992	56
H Harvey	2017	52
TS Fay	2008	50
H Gustav	2008	49
H Georges, TS Cindy	1998, 2005	48

TOP-10 LIST

From TCTOR and pre-1995 formal references

Peak classification

TC TORNADO FACTS & CLIMATOLOGY

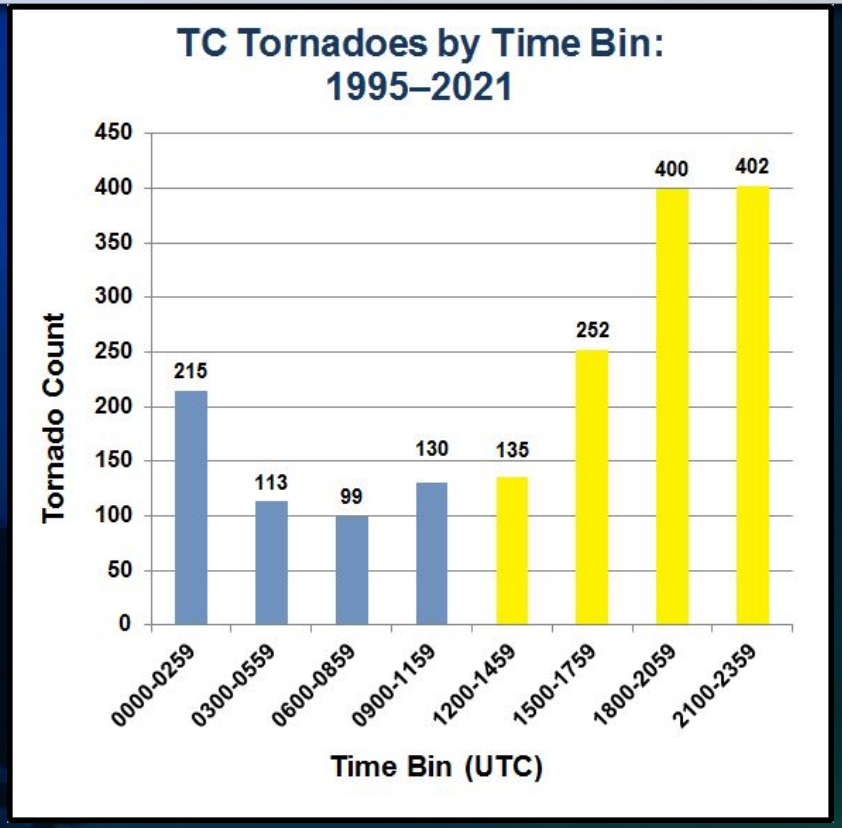


(E)F-scale rating

NOT “TORNADO INTENSITY”

(Edwards et al. 2013 damage-rating paper, BAMS)

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS



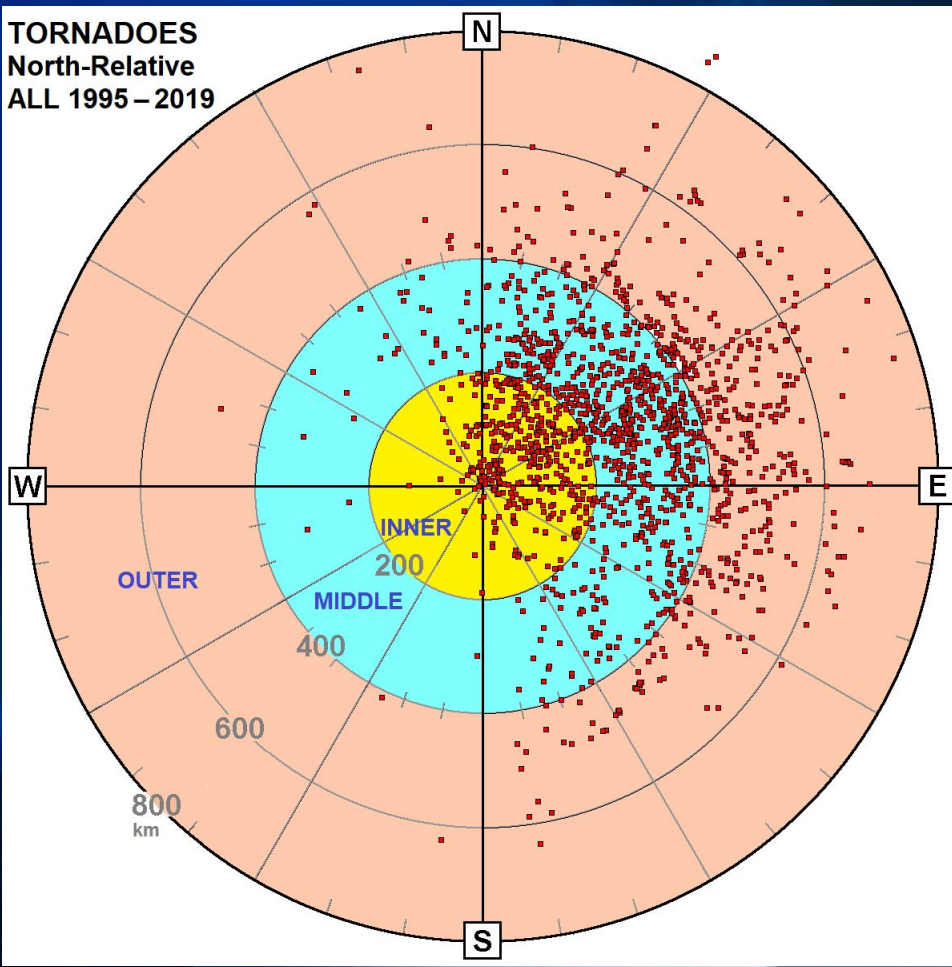
DAYTIME FAVORED

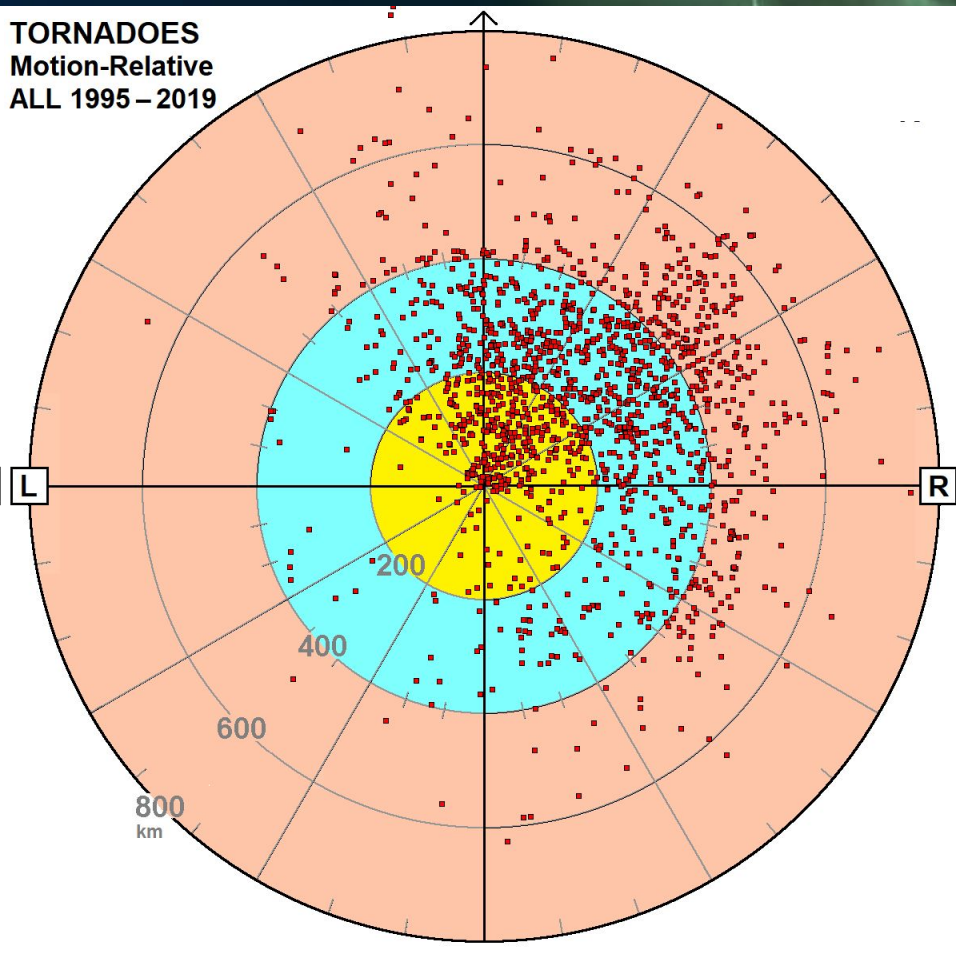
PHYSICAL BASIS BEHIND CLIMATOLOGY:

In deep moist environment, subtle warming under cloud cover or in clear slots greatly increases CAPE.

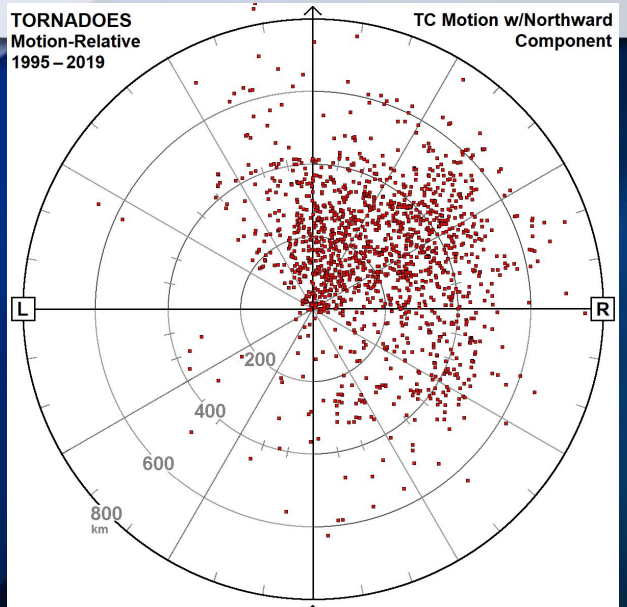
CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

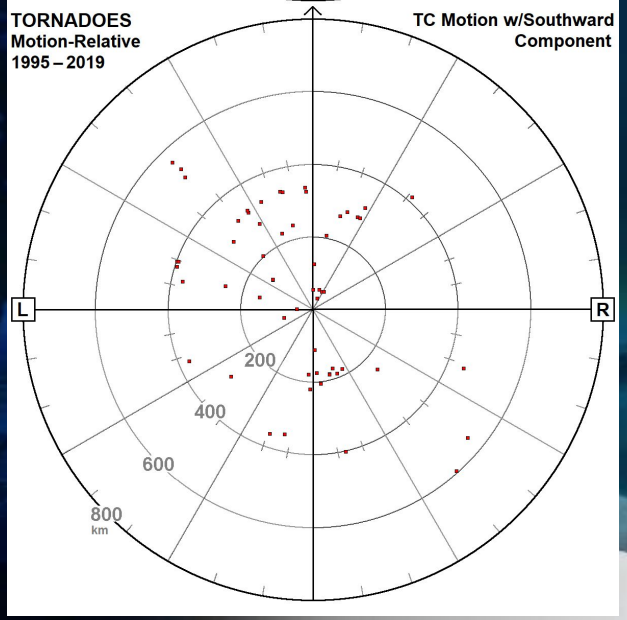
AZRAN of TCTOR events from center





CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS



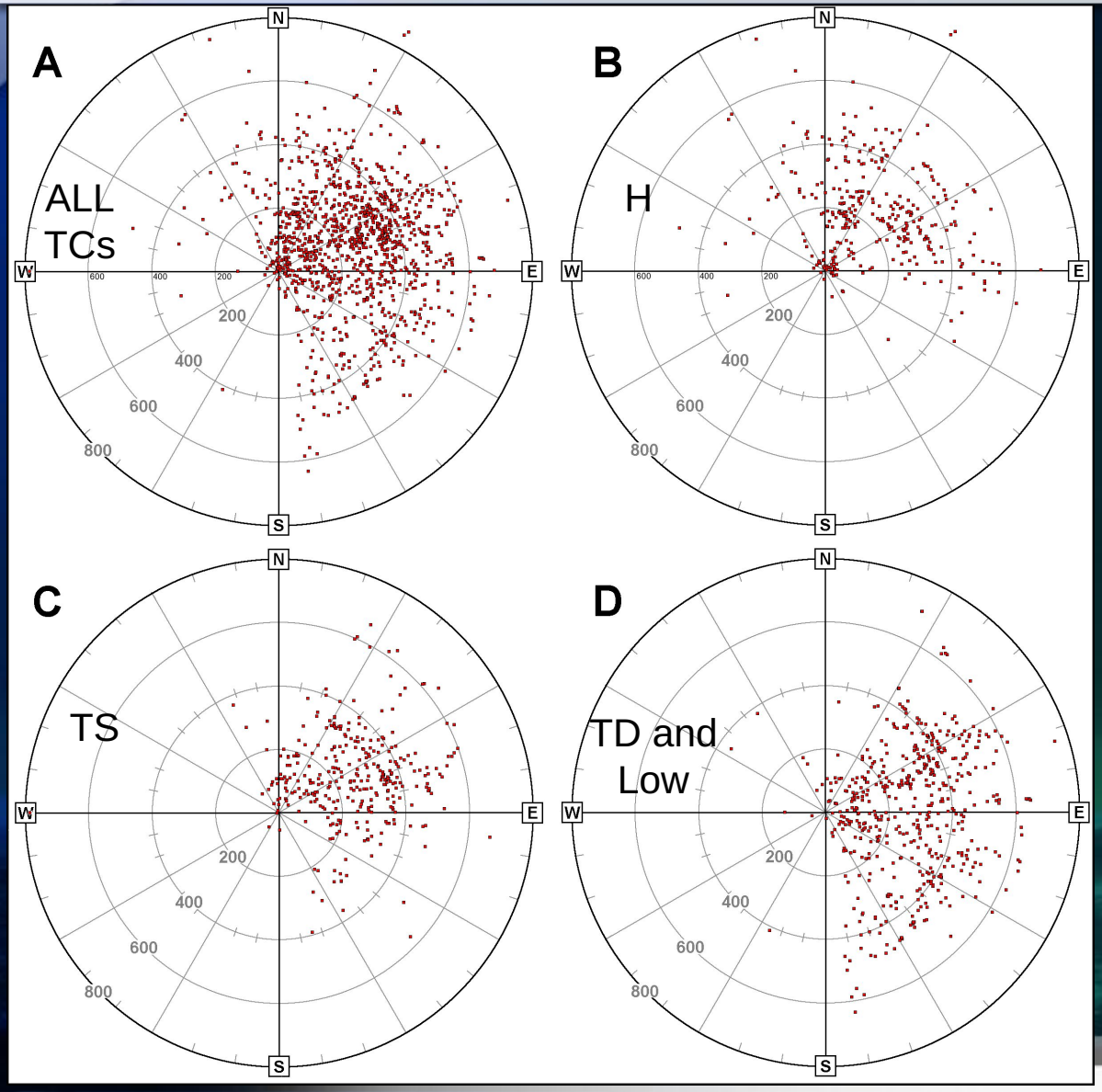


Motion-relative AZRAN of TCTOR events from center: Northward translation component

HOW MOTION-RELATIVE FAILS

Motion-relative AZRAN of TCTOR events from center: Southward translation component

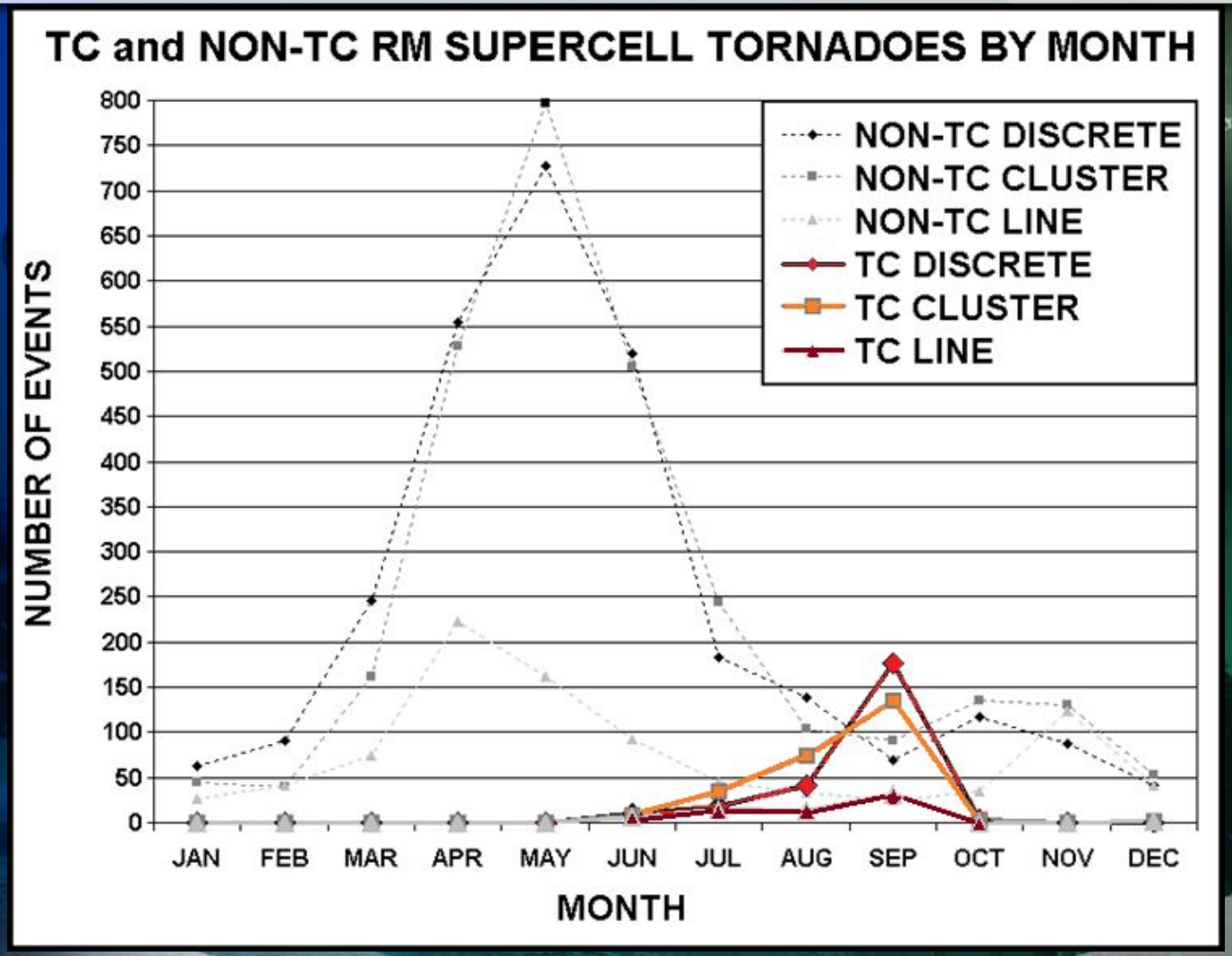
CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS



Tornadoes more common in SE sectors as TCs weaken...WHY?

...greatly due to that sector's being over water when most are mature hurricanes!

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS



data from Edwards et al. (2012)

REVIEW ARTICLE for MORE DETAILS

Edwards, R., 2012: Tropical cyclone tornadoes: A review of knowledge in research and prediction. *Electronic J. Severe Storms Meteor.*, **7** (6), 1–61.

Electronic Journal of
SEVERE STORMS METEOROLOGY

Tropical Cyclone Tornadoes: A Review of Knowledge in Research and Prediction

ROGER EDWARDS
NWS Storm Prediction Center, Norman, Oklahoma

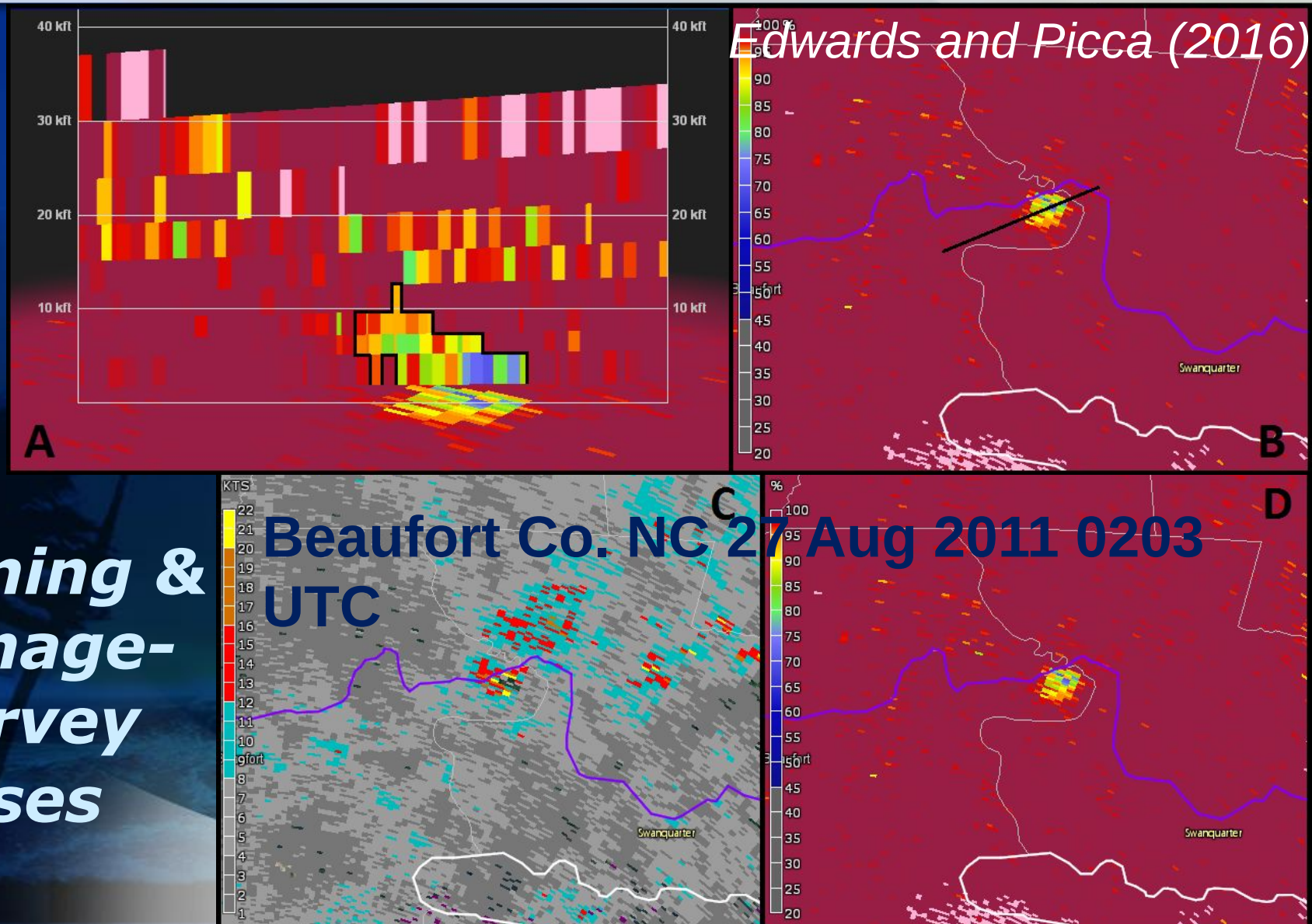
(Submitted 18 August 2011; in final form 7 September 2012)

ABSTRACT

The scientific documentation and investigation of tropical cyclone (TC) tornadoes has spanned portions of ten decades, but has been missing a documentary overview of topical knowledge accumulated to any given point in that time span. This review article summarizes the evolution of TC tornado-related literature from the perspectives of crucial historic tornadoes, climatology, distribution patterns, applied research into their environments, remote and environmental observations, forecasting practices, and numerical simulations at various scales. Discussion of the future of TC tornado research and prediction includes several testable hypotheses, along with potentially beneficial tools soon to be available to operational forecasters.

Available at EJSSM, SPC Publications web site
and (internal access) SPC Formal Science Library

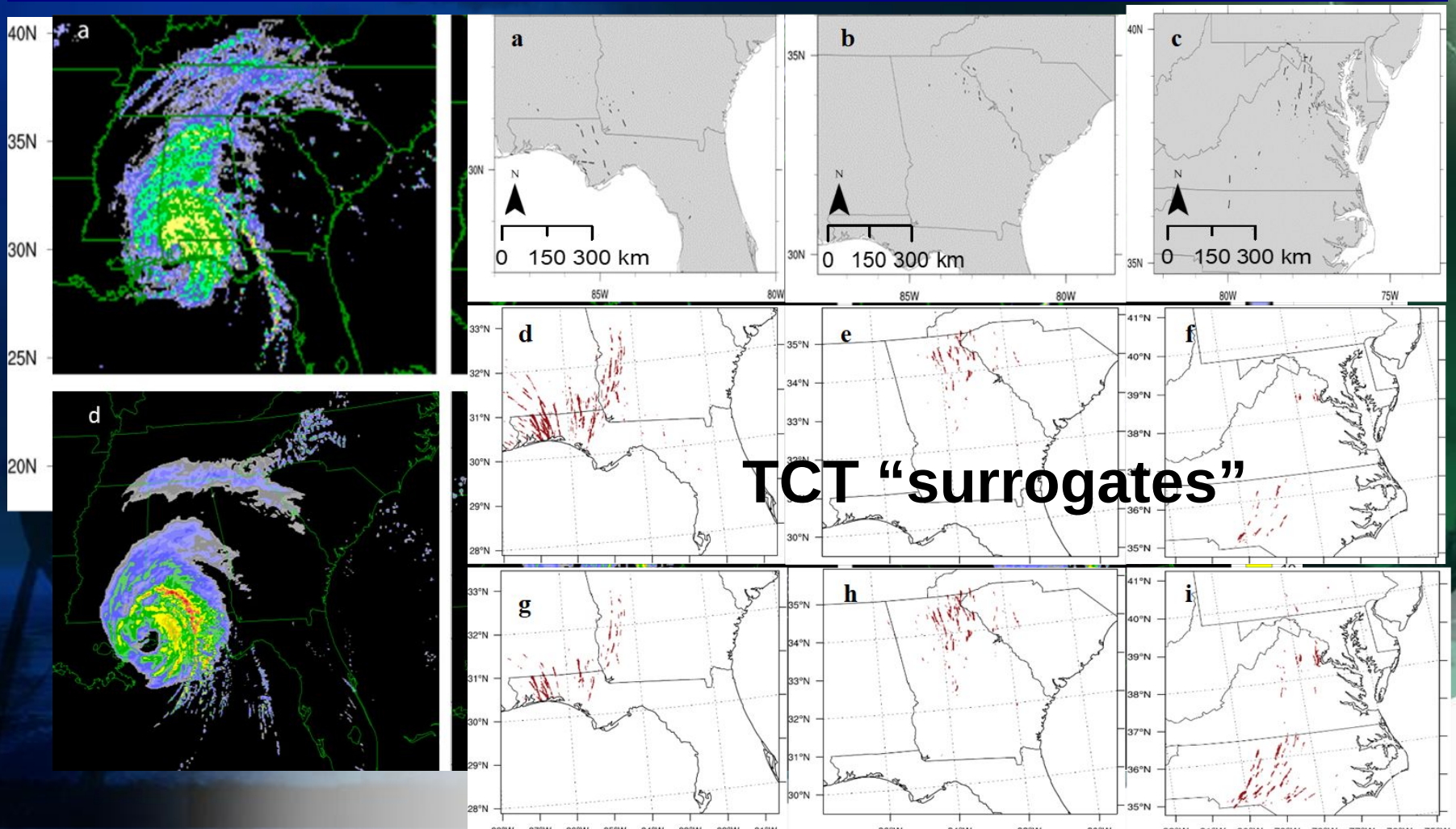
KEY RESEARCH SINCE 2012 REVIEW



Warning & damage-survey uses

KEY RESEARCH SINCE 2012 REVIEW

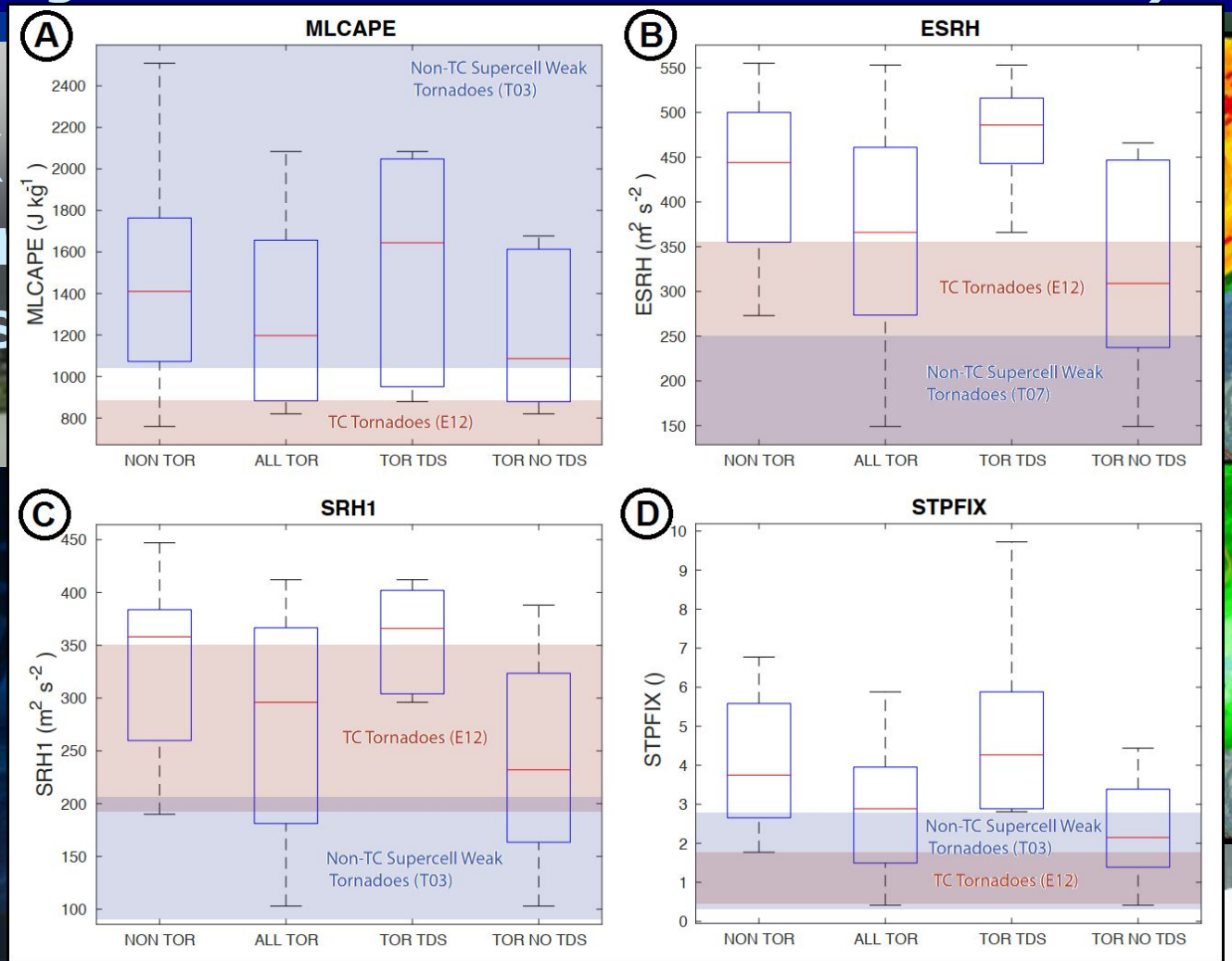
Promising app. of hi-res CAM NWP (Carroll-Smith et al. (2019, EJSSM): Successful WRF simulation of Ivan (2004)

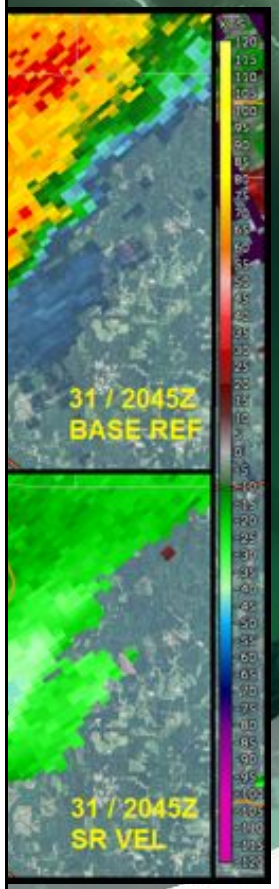


KEY RESEARCH SINCE 2012 REVIEW

Ongoing applications of Harvey findings (Nowotarski et al., including several SR-WFO collaborators and me)

SE TX
respo
issues

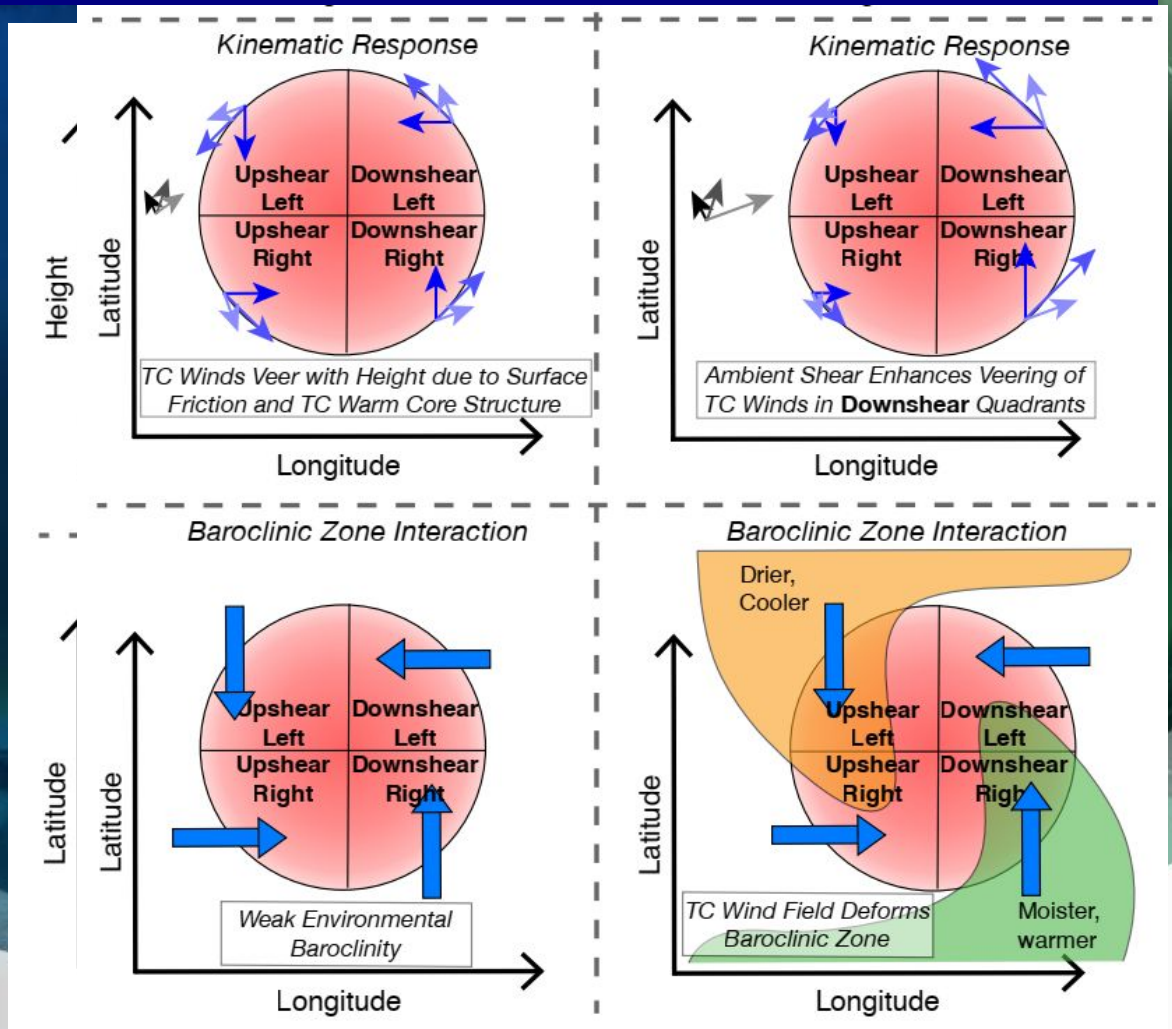




KEY RESEARCH SINCE 2012 REVIEW

Stronger-sheared TCs lead to more tornadoes and explain why they occur downshear right (usually NE quad).

(Schenkel et al. 2020)



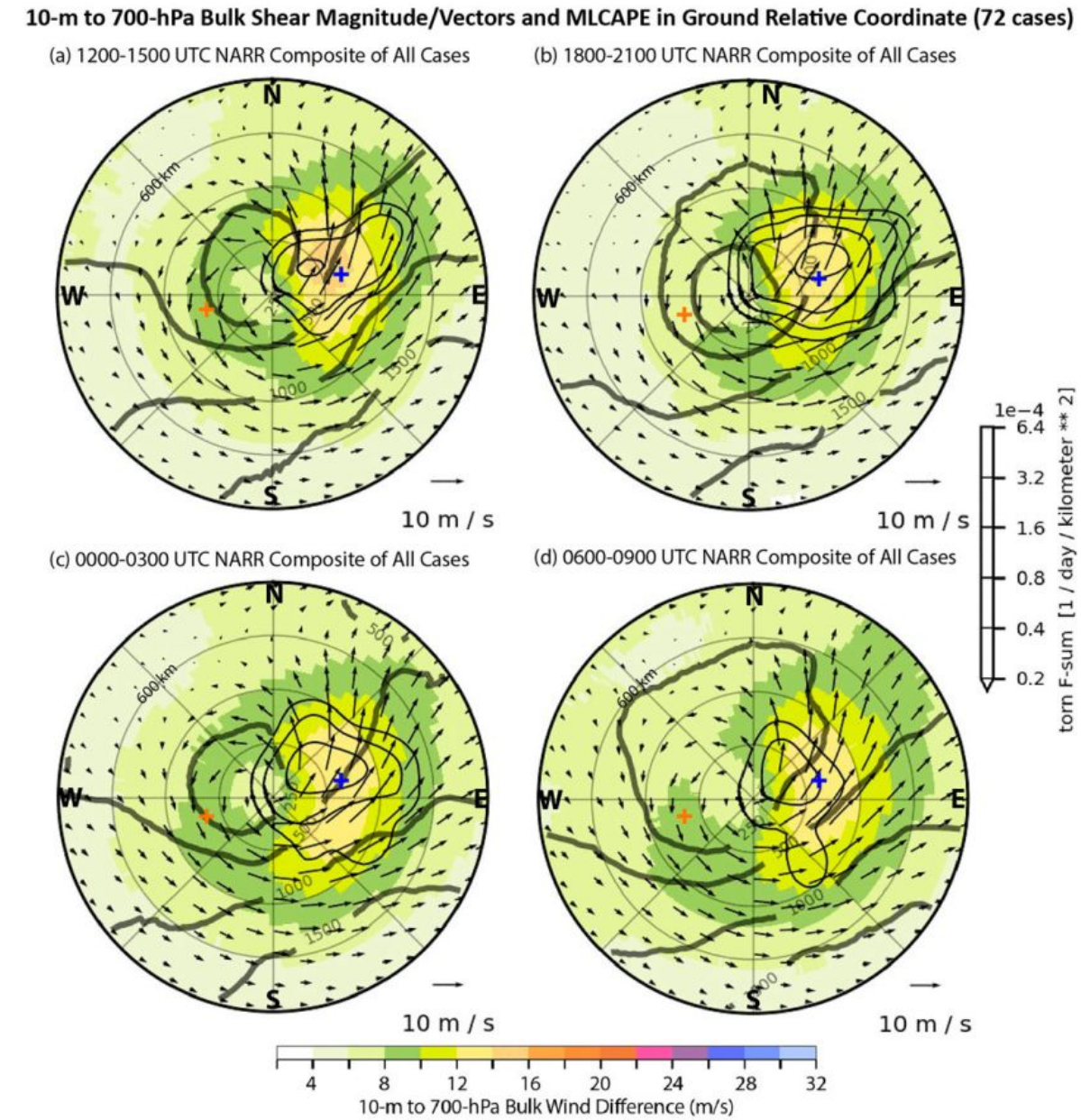


FIG. 8. Diurnal cycle of 10-m–700-hPa BWD magnitude (color shading) and vectors, MLCAPE (250, 500, 1000, and 1500 J kg^{-1} contours in bold gray), and the F-sum tornado density field (thin black contours with values indicated at right) for n = 72 ALL-CASES composite in ground-relative coordinates. The color-coded cross symbols indicate the locations of the composite soundings, and time series presented in Figs. 9 and 10, respectively.

TCTOR density vs. CAPE & sfc-700-mb BWD (Trier et al. 2023)

TCTORs max out at all hours where sfc-700-mb "shear" intersects CAPE gradient. That's NE-SE of center!

TC TORNADO FORECASTING CONCEPTS

Shifting from climatology-based and empirical to

INGREDIENTS-BASED THINKING

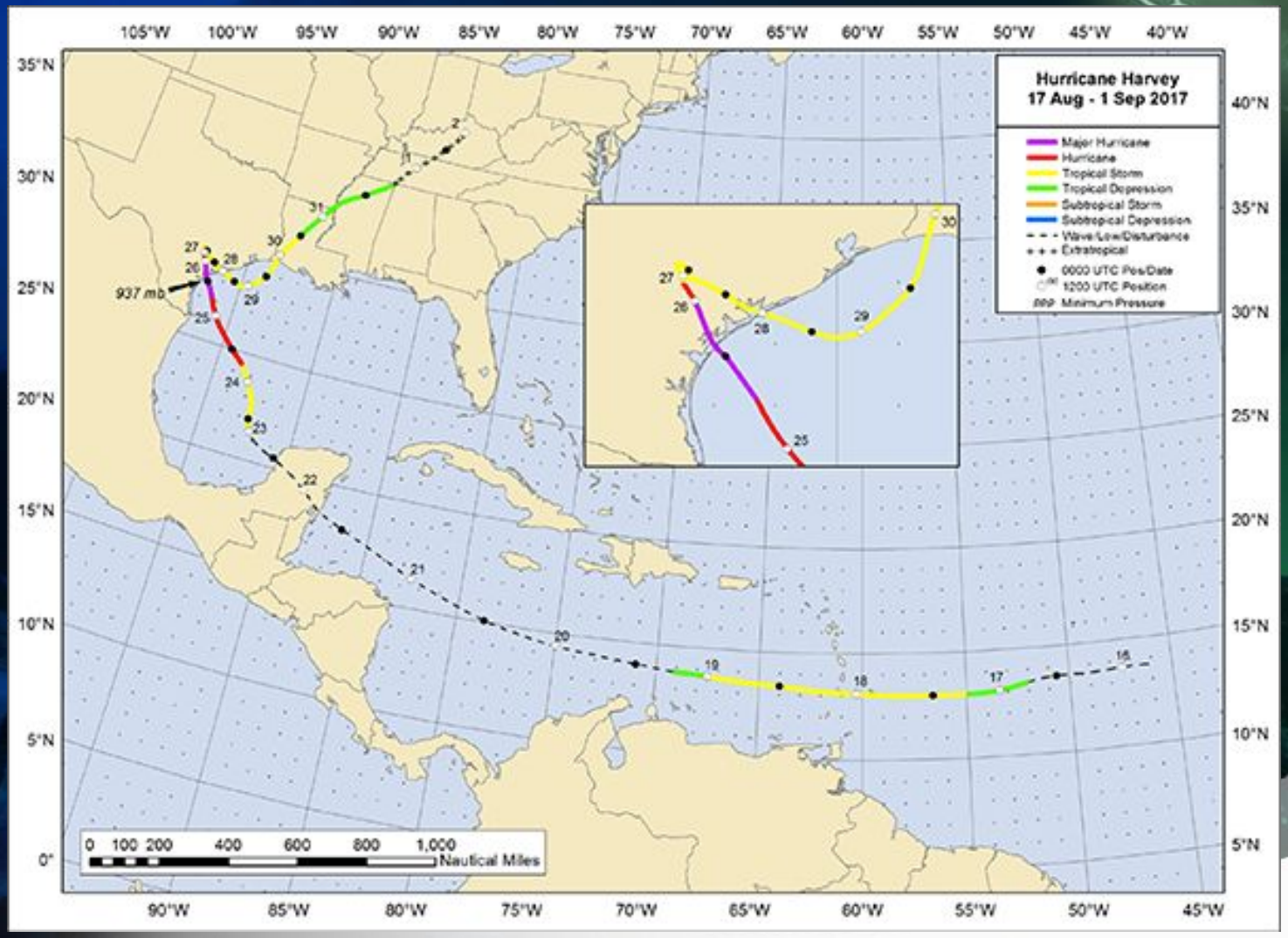
For supercells in midlatitude systems and tropical cyclones!

- **MOISTURE: usually no problem**
- **INSTABILITY: helps to have diurnal heating with large antecedent BL theta-e to offset weak lapse rates aloft**
- **(source for) LIFT: Spiral bands, embedded boundaries concentrate threat on mesoscale and smaller – MINDFUL HAND ANALYSIS is CRUCIAL!**
- **VERTICAL SHEAR: Peak hodographs in climatologically favored N-NE-SSE sector (thanks, ambient shear!)**

Edwards 2012

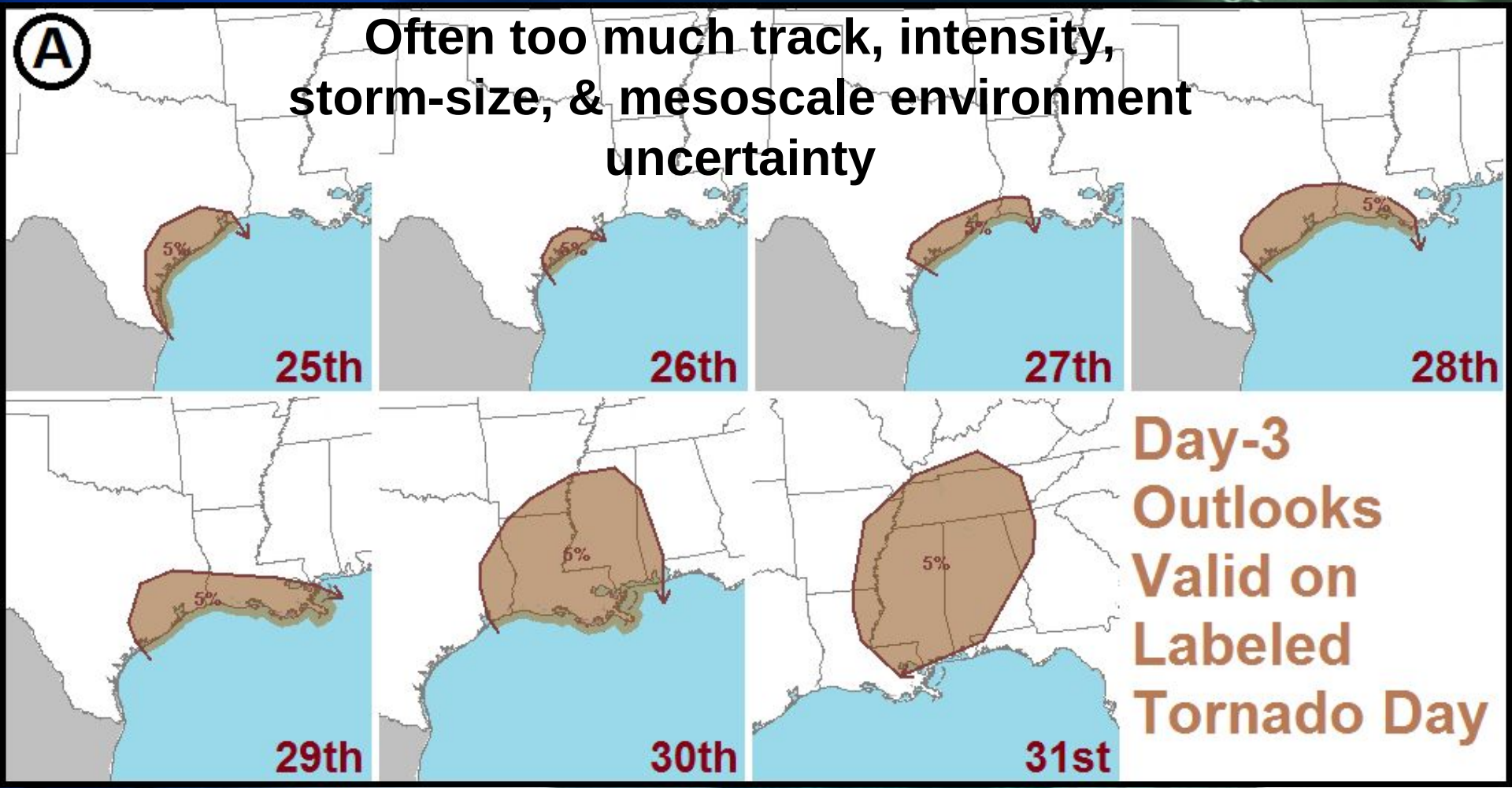
SPC OUTLOOK-SEQUENCE CASE

HARVEY-17



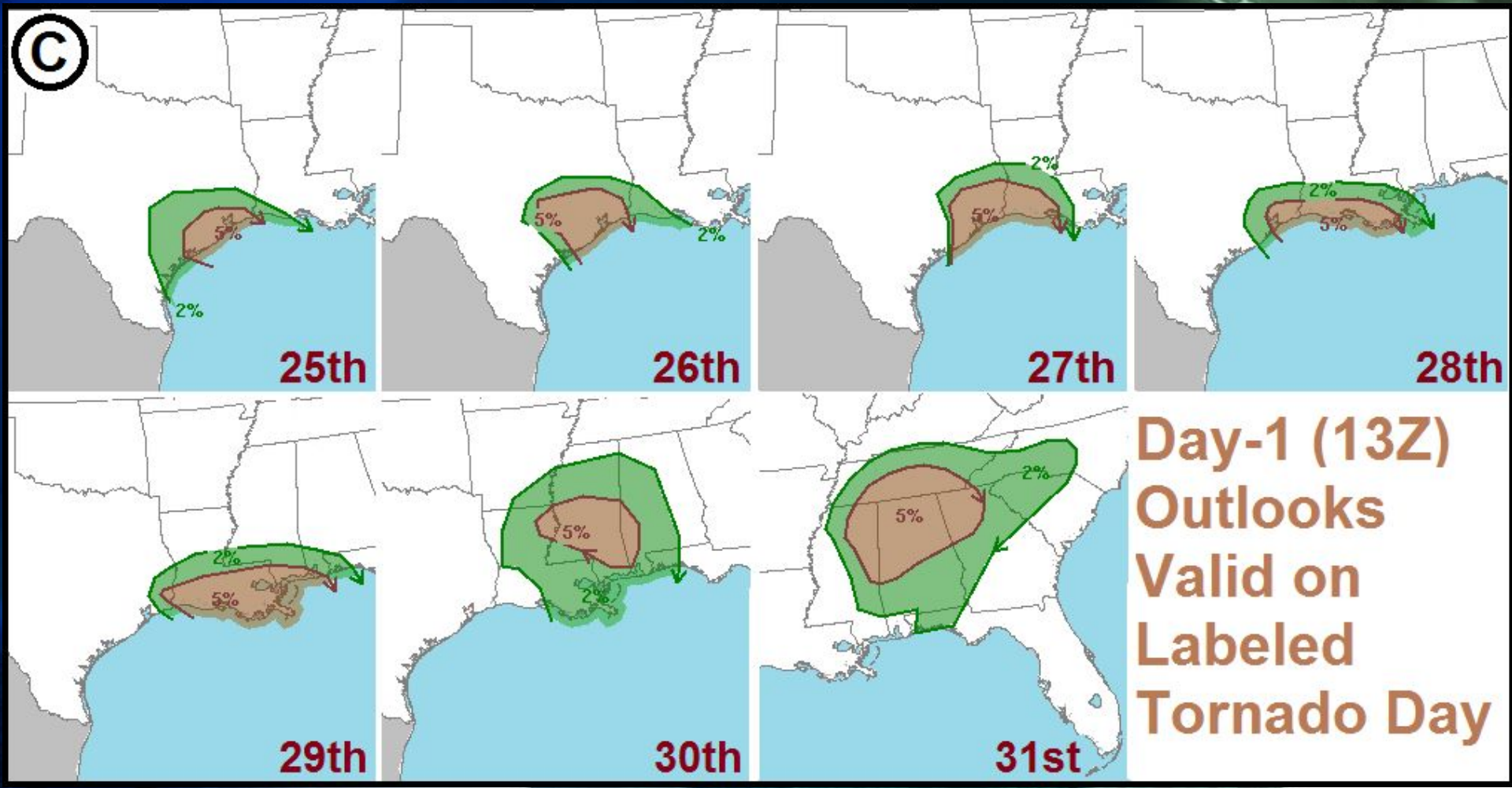
SPC OUTLOOK EXAMPLES FOR TCs

OUTLOOKS (Day-3 examples for HARVEY-17)



SPC OUTLOOK EXAMPLES FOR TCs

OUTLOOKS (Day-1 examples for HARVEY-17)



SPC OUTLOOK-SEQUENCE CASE

HARVEY-17

ZCZC MIATCPAT4 ALL
TTAA00 KNHC DDHHMM

BULLETIN
Hurricane Harvey Advisory Number 22
NWS National Hurricane Center Miami FL AL092017
400 PM CDT Fri Aug 25 2017

...MAJOR HURRICANE HARVEY BEARING DOWN ON THE TEXAS COAST...
...CATASTROPHIC FLOODING EXPECTED DUE TO HEAVY RAINFALL AND STORM SURGE...

SUMMARY OF 400 PM CDT...2100 UTC...INFORMATION

LOCATION...27.5N 96.5W
ABOUT 60 MI...95 KM ESE OF CORPUS CHRISTI TEXAS
ABOUT 60 MI...100 KM S OF PORT OCONNOR TEXAS
MAXIMUM SUSTAINED WINDS...125 MPH...205 KM/H
PRESENT MOVEMENT...NW OR 325 DEGREES AT 10 MPH...17 KM/H
MINIMUM CENTRAL PRESSURE...941 MB...27.79 INCHES

WATCHES AND WARNINGS

CHANGES WITH THIS ADVISORY:

The Tropical Storm Warning has been discontinued south of Port Mansfield, Texas.

The Storm Surge Watch has been discontinued south of Port Mansfield, Texas.

The government of Mexico has discontinued the Tropical Storm Watch north of Boca de Catan.

SUMMARY OF WATCHES AND WARNINGS IN EFFECT:

A Storm Surge Warning is in effect for...
* Port Mansfield to High Island Texas

A Hurricane Warning is in effect for...
* Port Mansfield to Sargent Texas

A Tropical Storm Warning is in effect for...
* North of Sargent to High Island Texas

A Storm Surge Warning means there is a danger of life-threatening inundation from rising water moving inland from the coastline in the indicated locations. For a depiction of areas at risk, please see the National Weather Service Storm Surge Watch/Warning Graphic, available at hurricanes.gov. This is a life-threatening situation.

A Hurricane Warning means that hurricane conditions are expected somewhere within the warning area, in this case within the next few hours. Preparations to protect life and property should already be complete.

Interests in southwest Louisiana should continue to monitor the

HAZARDS AFFECTING LAND

RAINFALL: Harvey is expected to produce total rain accumulations of 15 to 30 inches and isolated maximum amounts of 40 inches over the middle and upper Texas coast through next Wednesday. During the same time period Harvey is expected to produce total rain accumulations of 5 to 15 inches in far south Texas and the Texas Hill Country over through southwest and central Louisiana. Rainfall of this magnitude will cause catastrophic and life-threatening flooding.

STORM SURGE: The combination of a dangerous storm surge and the tide will cause normally dry areas near the coast to be flooded by rising waters moving inland from the shoreline. The water is expected to reach the following heights above ground if the peak surge occurs at the time of high tide...

N Entrance Padre Island Natl Seashore to Sargent...6 to 12 ft
Sargent to Jamaica Beach...5 to 8 ft
Port Mansfield to N Entrance Padre Island Natl Seashore...3 to 5 ft
Jamaica Beach to High Island...2 to 4 ft
Mouth of the Rio Grande to Port Mansfield...1 to 3 ft
High Island to Morgan City...1 to 3 ft

The deepest water will occur along the immediate coast near and to the northeast of the landfall location, where the surge will be accompanied by large and destructive waves. Surge-related flooding depends on the relative timing of the surge and the tidal cycle, and can vary greatly over short distances. For information specific to your area, please see products issued by your local National Weather Service forecast office.

WIND: Tropical storm conditions are occurring in portions of the hurricane and tropical storm warning areas, and hurricane conditions are expected to begin within the hurricane warning area in the next few hours. Tropical storm conditions are likely to persist along portions of the coast through at least Sunday.

SURF: Swells generated by Harvey are affecting the Texas, Louisiana, and northeast Mexico coasts. These swells are likely to cause life-threatening surf and rip current conditions. Please consult products from your local weather office.

TORNADOES: A few tornadoes are possible through Saturday near the middle and upper Texas coast into far southwestern Louisiana.

NEXT ADVISORY

Next intermediate advisory at 700 PM CDT.
Next complete advisory at 1000 PM CDT.

$$
Forecaster Berg

NNNN

Tornado Statement provided by the SPC

SPC OUTLOOK-SEQUENCE CASE

HARVEY-17

25 August 2017

SPC Convective

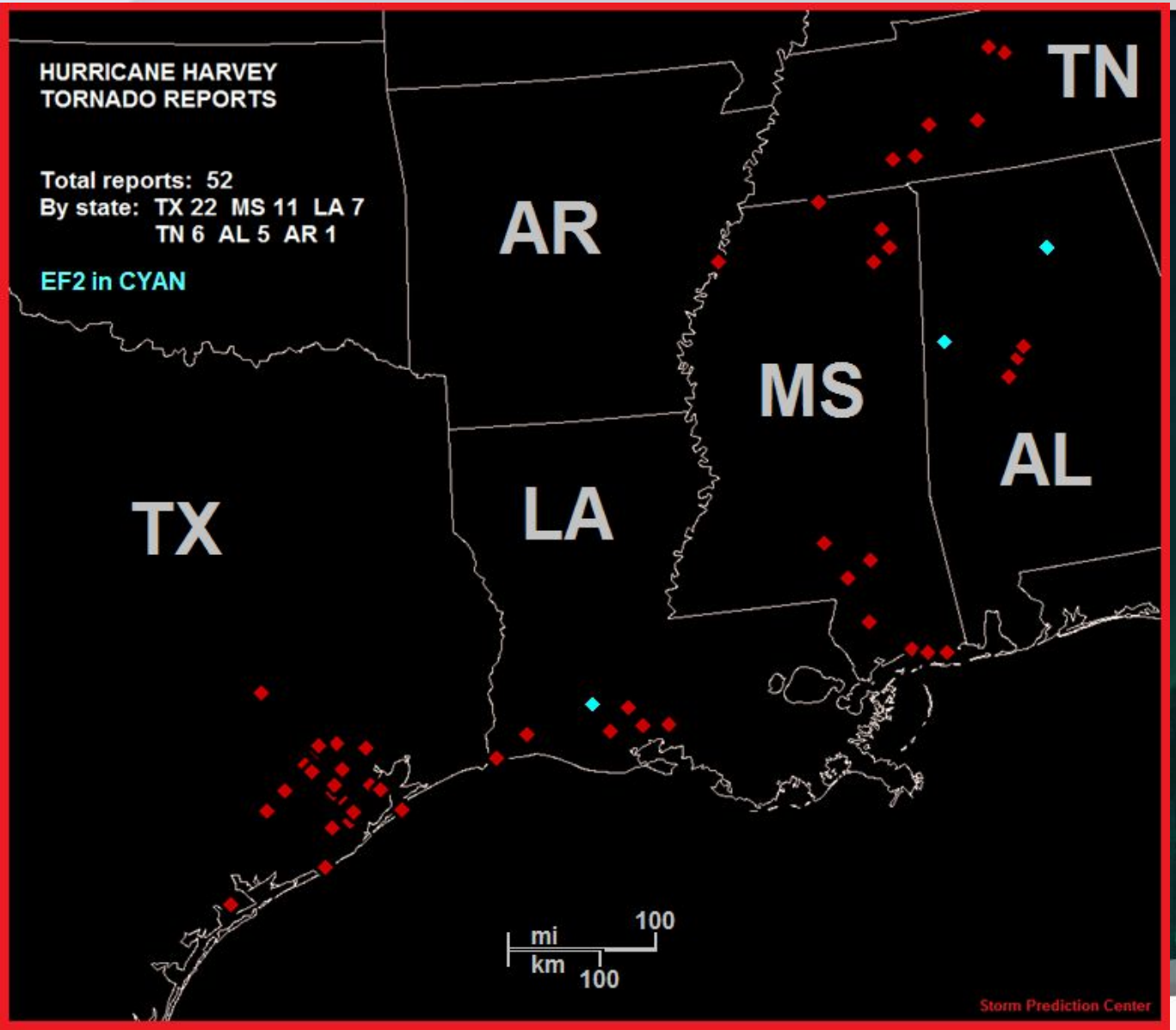
Category 4 Hurricane

Social Media

"Just a Slight Risk (Level 2 of 5) with a Category 4 Hurricane?"

Reminder: The SPC is forecasting the severe weather risk from tornadoes, wind, or hail from embedded thunderstorms

IMPACT EXAMPLE (ATMOSPHERE)

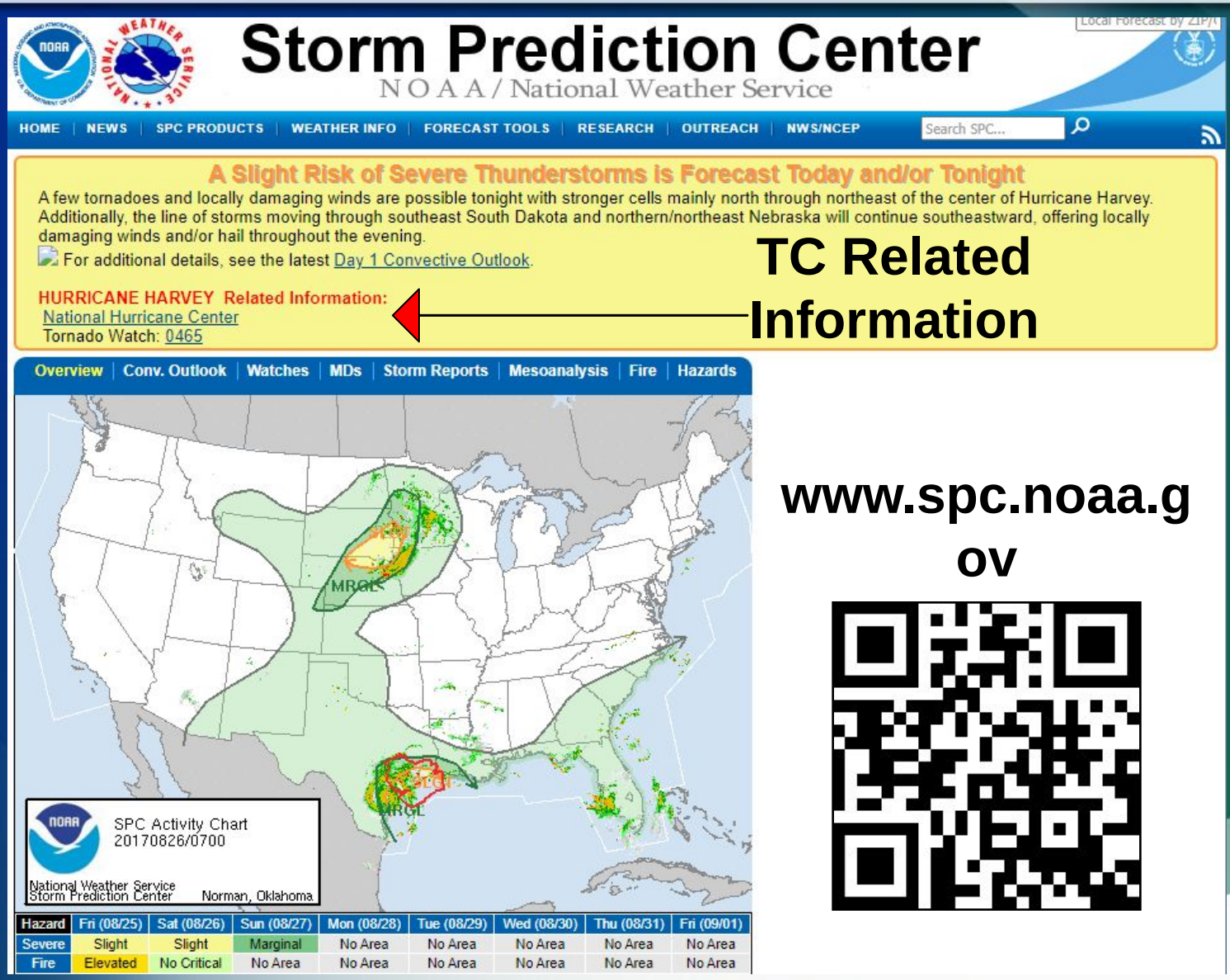


HARVEY-17

RECORD DURATION:

7 DAYS COMBINED

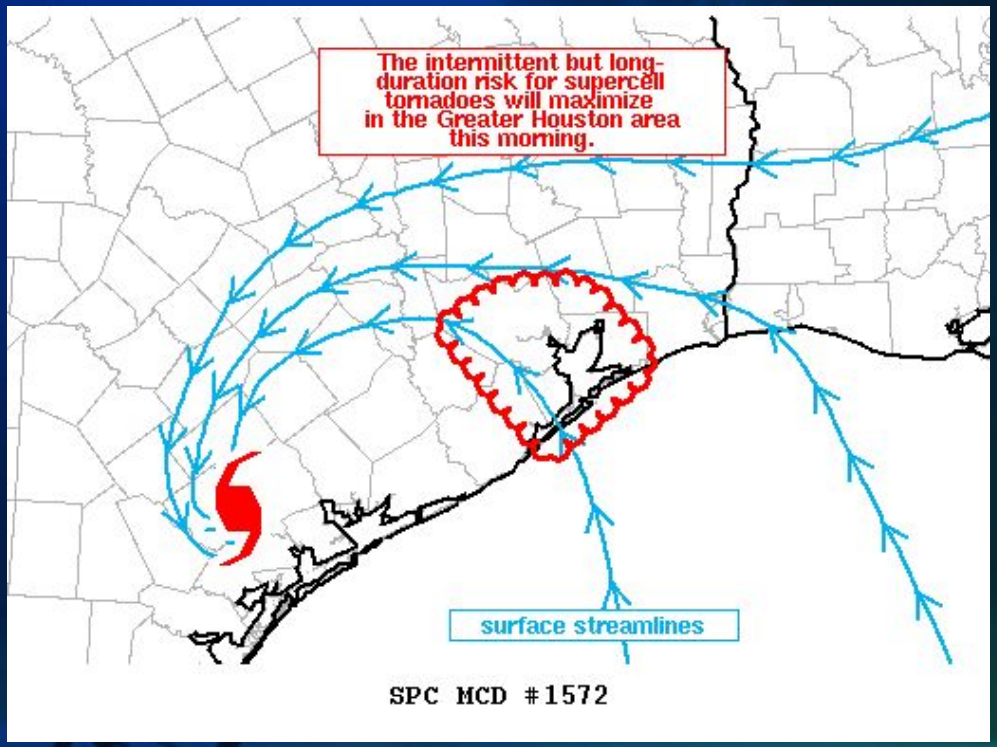
SPC WEBSITE INFO FOR TCs



www.spc.noaa.gov

MESOSCALE DISCUSSION EXAMPLE for TCs

HARVEY-17



Mesoscale Discussion 1572
NWS Storm Prediction Center Norman OK
0649 AM CDT Sat Aug 26 2017

Areas affected...the Galveston Bay/Greater Houston area

Concerning...Tornado Watch 467...

Valid 261149Z - 261345Z

The severe weather threat for Tornado Watch 467 continues.

SUMMARY...The intermittent but long-duration risk for short-lived supercell tornadoes will maximize in the Galveston Bay/Greater Houston area this morning.

DISCUSSION...The latest subjective surface streamline analysis implies low-level convergence is focused across the Galveston Bay vicinity. Surface observations also show temperatures in the lower 80s degrees F from Brazoria County to Houston Hobby and east-northeast to Beaumont. Dewpoints are ranging from the upper 70s to around 80 at the coast. As a result, buoyancy is maximized in the discussion area compared to areas farther inland and closer to the center of Harvey. Time trends in the KHGX VAD suggest a decrease in hodograph size has occurred during the past few hours with 0-1 km SRH less than 50 m2/s2 according to observed storm motions. Nonetheless, the moist-tropical airmass will support intermittent low-level rotation with the strongest updrafts embedded within convective bands and clusters for the next several hours.

..Smith.. 08/26/2017

...Please see www.spc.noaa.gov for graphic product...

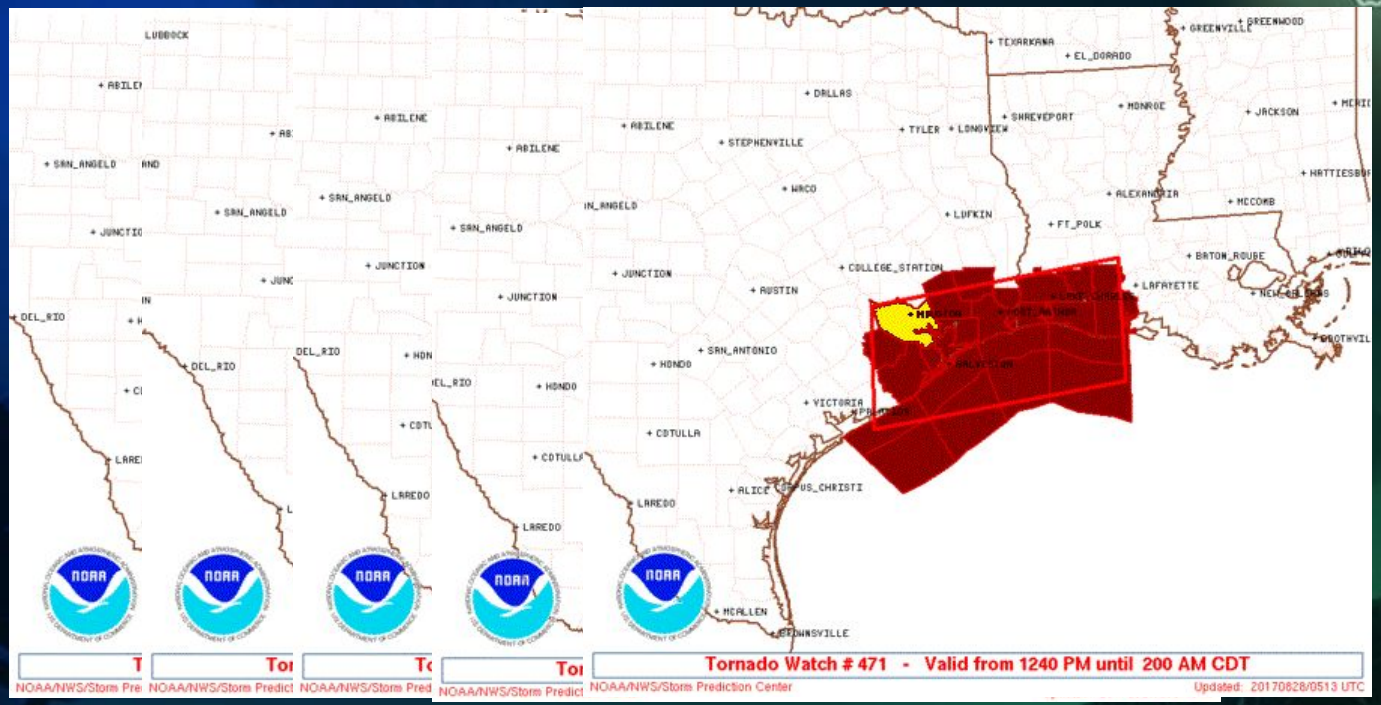
ATTN...WFO...LCH...HGX...

LAT...LON 29799582 30059540 30099479 29579430 29019506 29799582

PRECEDES and/or UPDATES TORNADO WATCH

TORNADO WATCH EXAMPLES for TCs

HARVEY-17 – EXTREME DURATION



CITY of HOUSTON: 60 HOURS in TORNADO WATCHES

WFO WARNING AREA: 96 HOURS

WHILE IN RECORD RAIN & FLOODING

Contacts:

Roger.Edwards@NOAA.gov
(former NHC meteorologist)

Matthew.Elliott@NOAA.gov
(SPC WCM)

Aviation Weather Center Operations

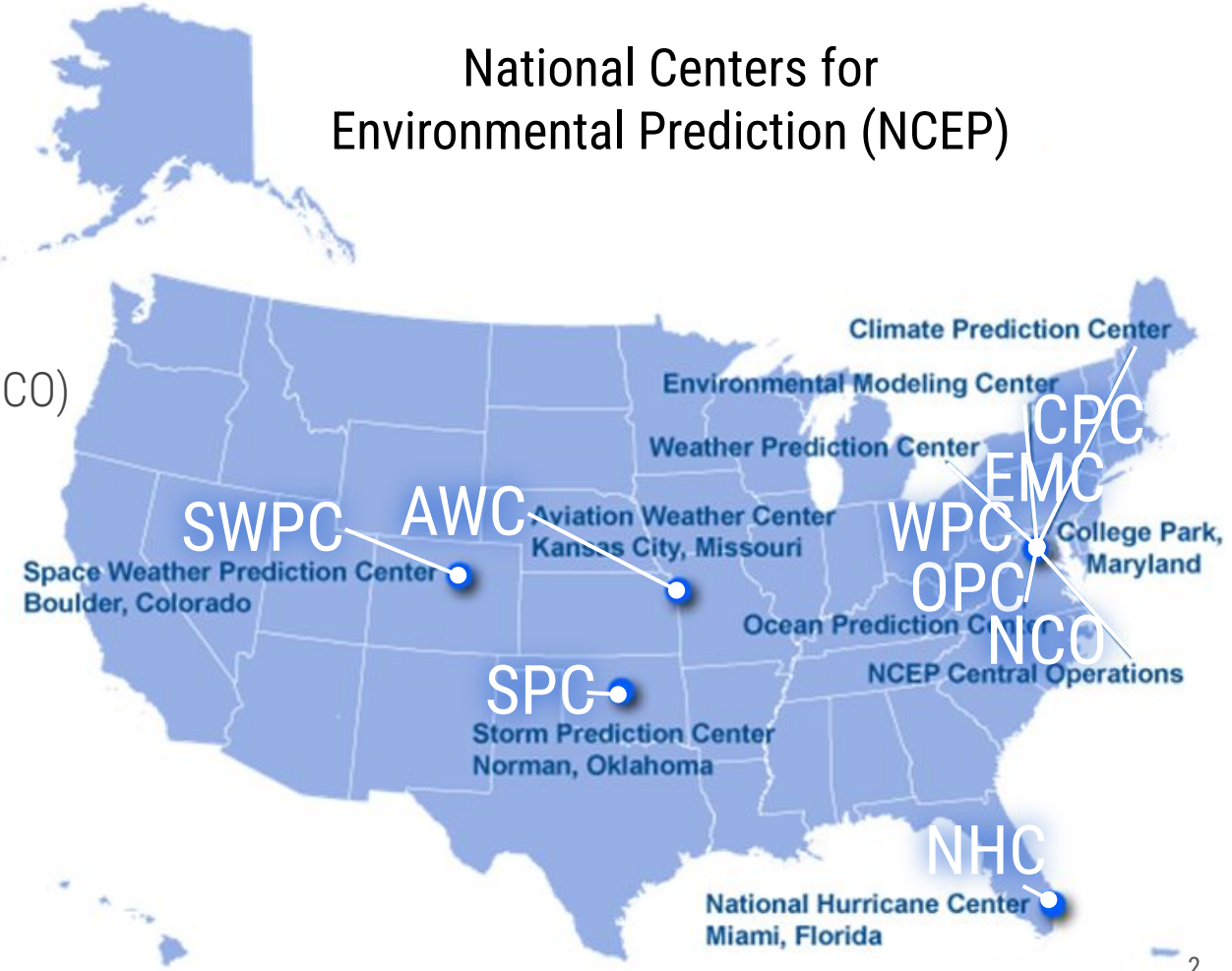
Kansas City, MO

Amanda Martin - Acting Warning Coordination Meteorologist

National Centers for Environmental Prediction (NCEP)

9 Specialized Centers

- Aviation (AWC)
- Climate (CPC)
- Modeling (EMC)
- Supercomputing & data flow (NCO)
- Hurricanes (NHC)
- Oceans (OPC)
- Severe storms (SPC)
- Space weather (SWPC)
- Hydrometeorology (WPC)



http://www.weather.gov/jetstream/nws/ncep.html

Aviation Weather Center

www.aviationweather.gov

OUR MISSION STATEMENT

The Aviation Weather Center delivers consistent, timely and accurate weather information for the world airspace system.

We are a team of highly skilled people dedicated to working with customers and partners to enhance safe and efficient flight.

OUR VISION

To be the trusted authority and leading innovator for aviation weather information.

A Brief History of Aviation Weather Forecasting

1961 USAF Air Weather Service issues the **first official forecast of clear air turbulence**

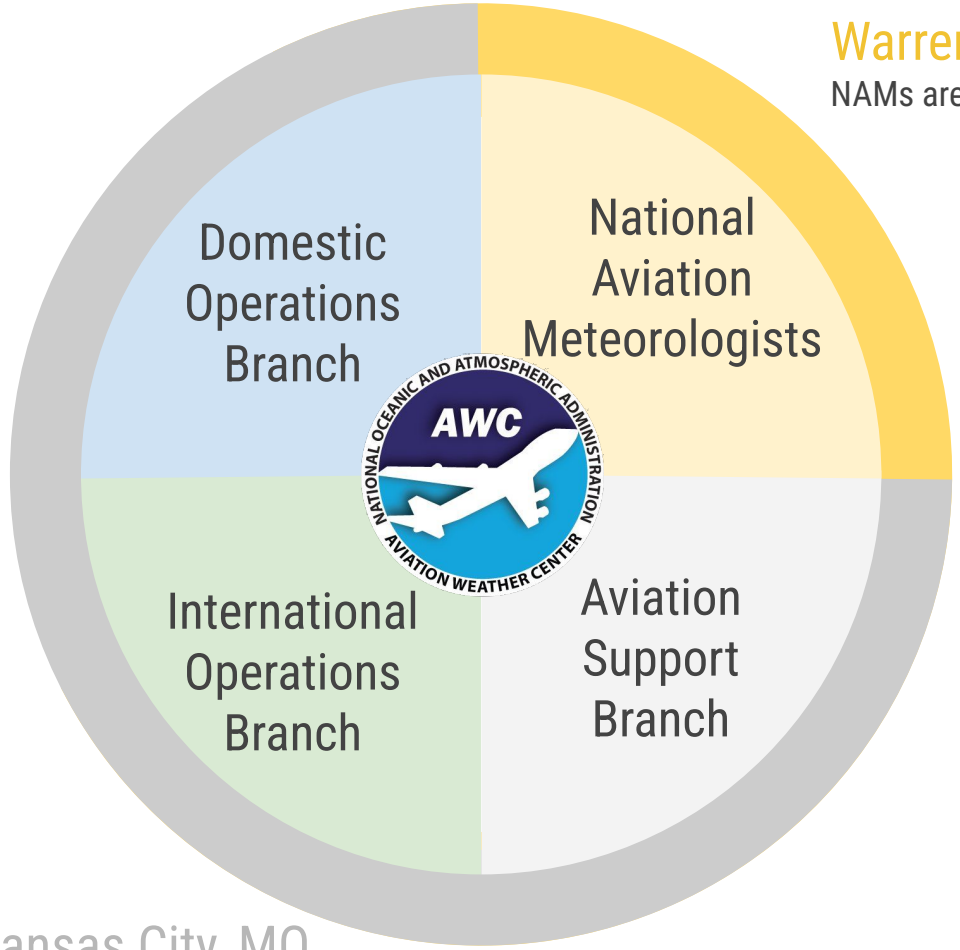
1977 **Crash of Southern Airlines 242** in New Hope, GA kills 72. NTSB recommends "procedures for the timely dissemination of all available severe weather information by controllers"

1978 **Convective SIGMET unit established** within the National Severe Storms Forecast Center. NWS meteorologists stationed in **13 ARTCCs**

1981 NWS meteorologists now stationed in **all 21 ARTCCs**. That partnership continues today

1982 National Aviation Weather Advisory Unit (NAWAU) is formed. Renamed to **AWC** in 1995

Structure of AWC



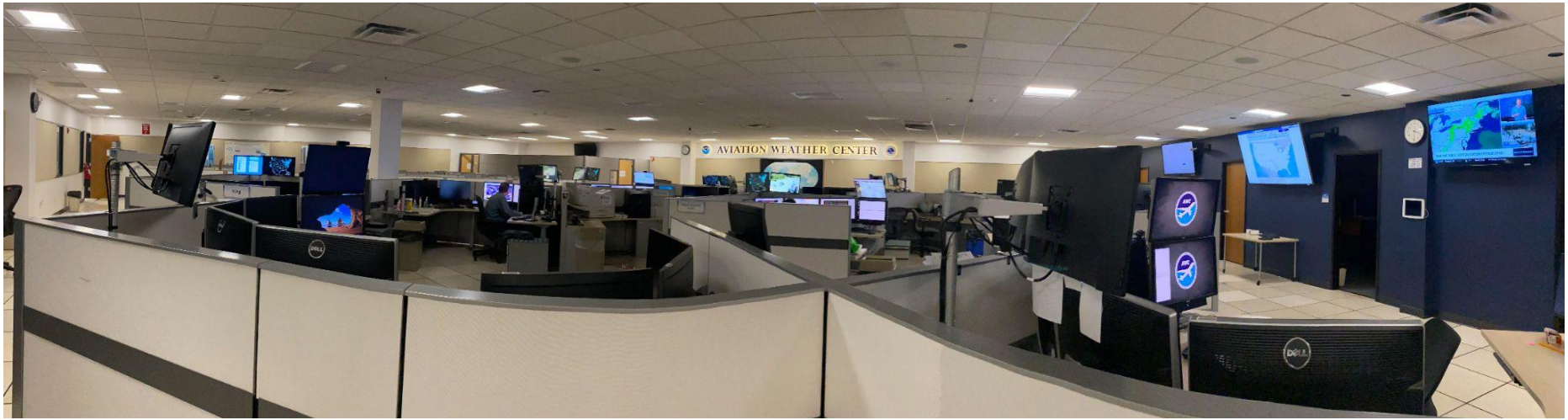
Warrenton, VA

NAMs are embedded with the FAA at the ATCSCC

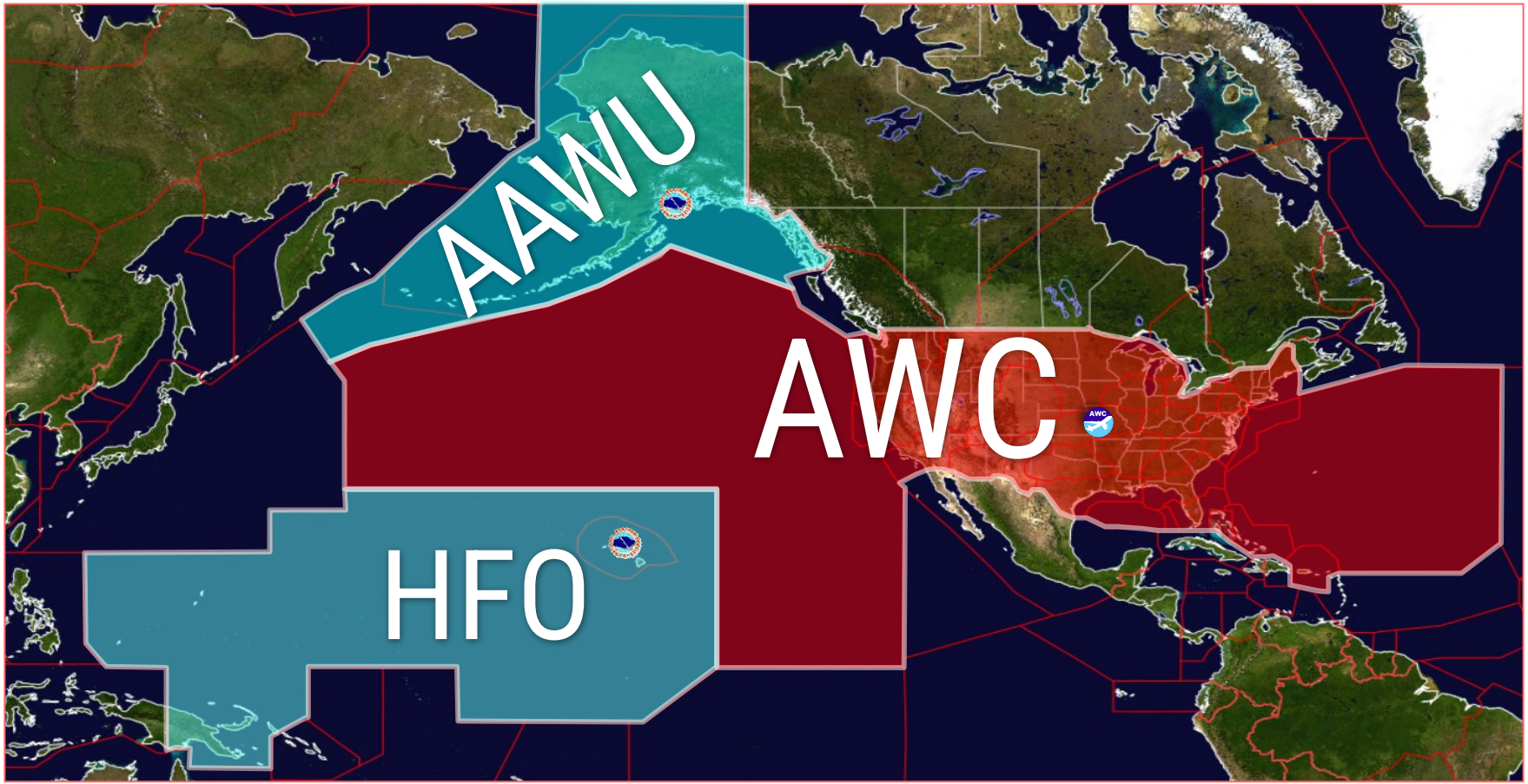
- 4 branches
- 2 locations
- ~80 people
  - Forecasters
  - Researchers/developers
  - IT staff
  - Administrative support staff
  - Managers & supervisors
  - NOAA Corps Officer

Kansas City, MO

Most AWC staff are based here

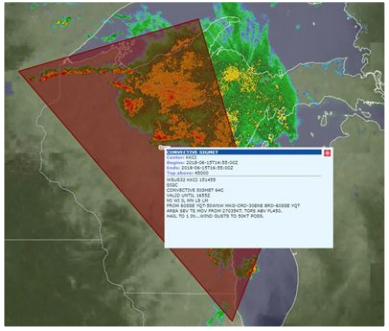


Kansas City, MO

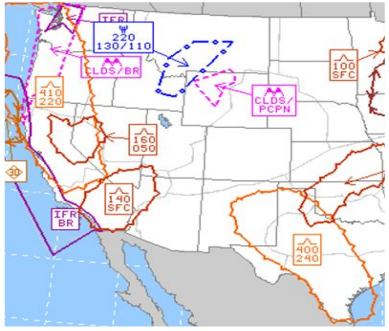

AAWU
AWC
HFO

Aviation Weather Center Operations

Domestic Operations

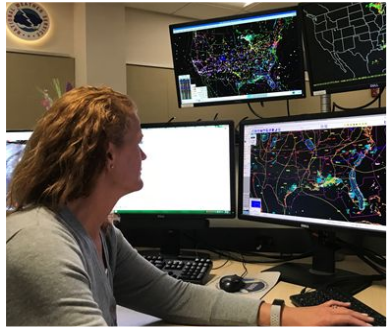


SIGMETs
CONUS · Coastal waters



AIRMETs · TFM convective forecast · Low-level SIGWX

CWSUs · Airlines · FAA

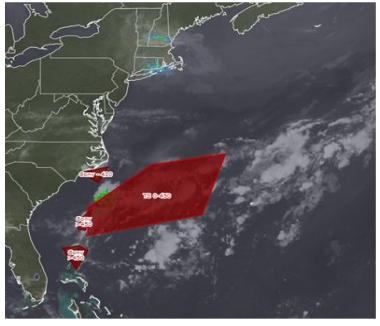


Convective SIGMET · TCF · Turbulence · Icing · Clouds & visibility

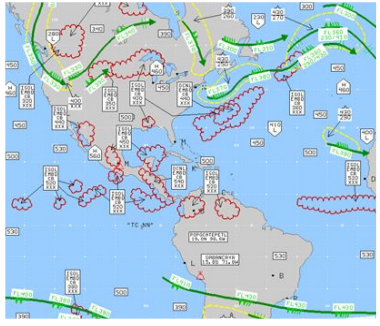
AVIATION WARNINGS	AVIATION FORECASTS	COLLABORATION	DESKS

International Operations

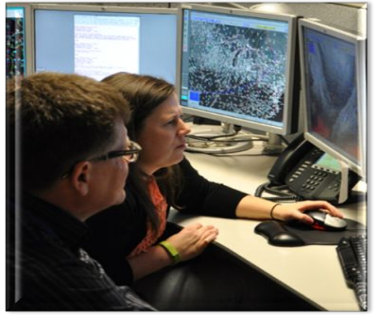
Atlantic · Pacific
Gulf of Mexico & Caribbean



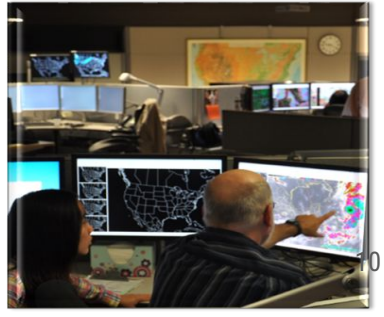
Global Significant Weather (SIGWX) · Area Forecasts for Gulf of Mexico & Caribbean



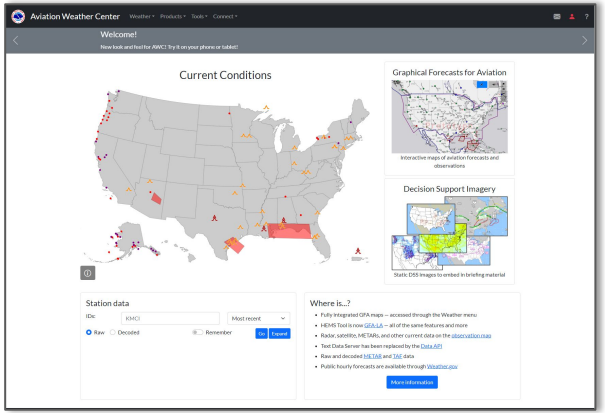
International meteorological services



Tropical · SIGWX North · SIGWX South



Aviation Weather Center Support Branch



PRODUCTS & SERVICES

Graphical Forecasts for Aviation (GFA) · WAFS Internet File Service (WIFS) · Computer models · Operational shift fill-in

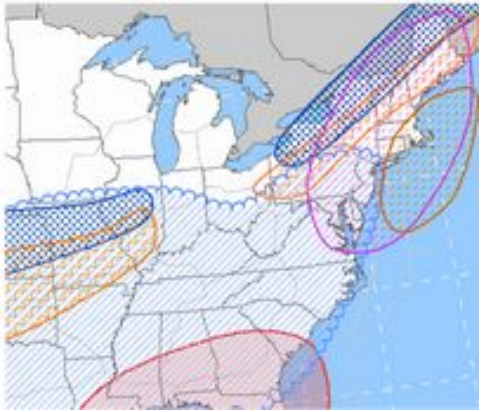
DATA, TECHNOLOGY, & INFRASTRUCTURE

IT architecture & security · Production systems · Data management · Support for remote forecast operations

SCIENCE & TECHNOLOGY

Aviation Weather Testbed (AWT) · Aviation Weather Research Program · Research initiatives

National Aviation Meteorologists (NAMs)



DECISION SUPPORT

Embedded with FAA decision makers · Balance air traffic demand with capacity · Fully integrated & coordinated weather decision support

NAS ASSESSMENT

Conduct post-event reviews · Debriefings · Improve safety, efficiency, and decision making for the National Air Space (NAS)

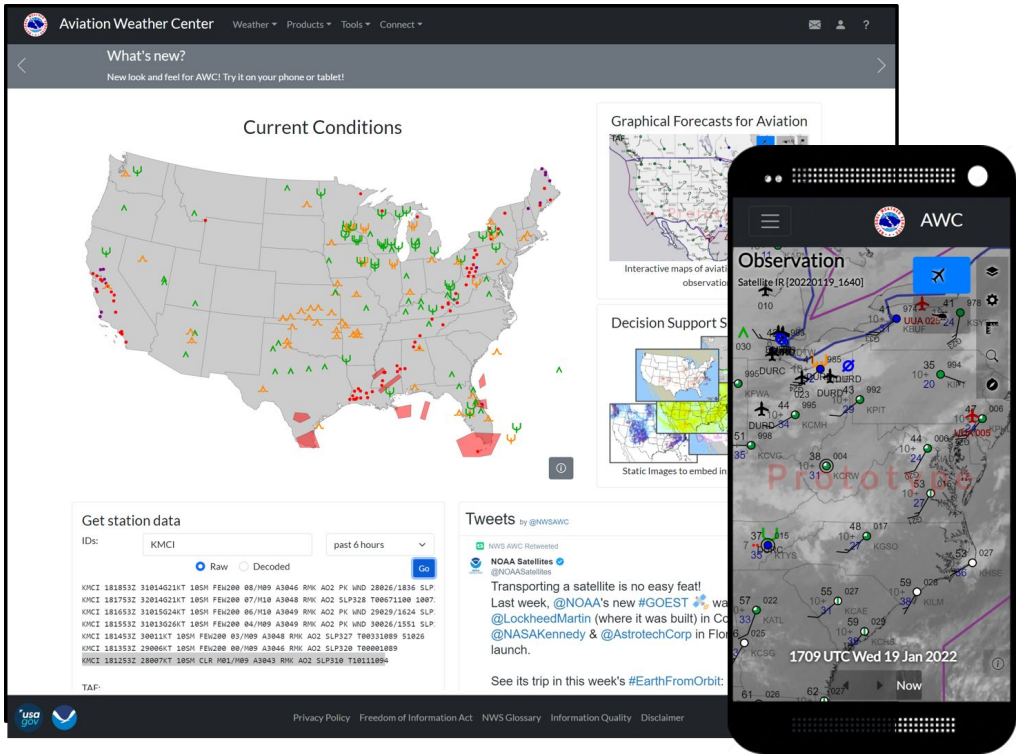
PERTI ACTIVITIES

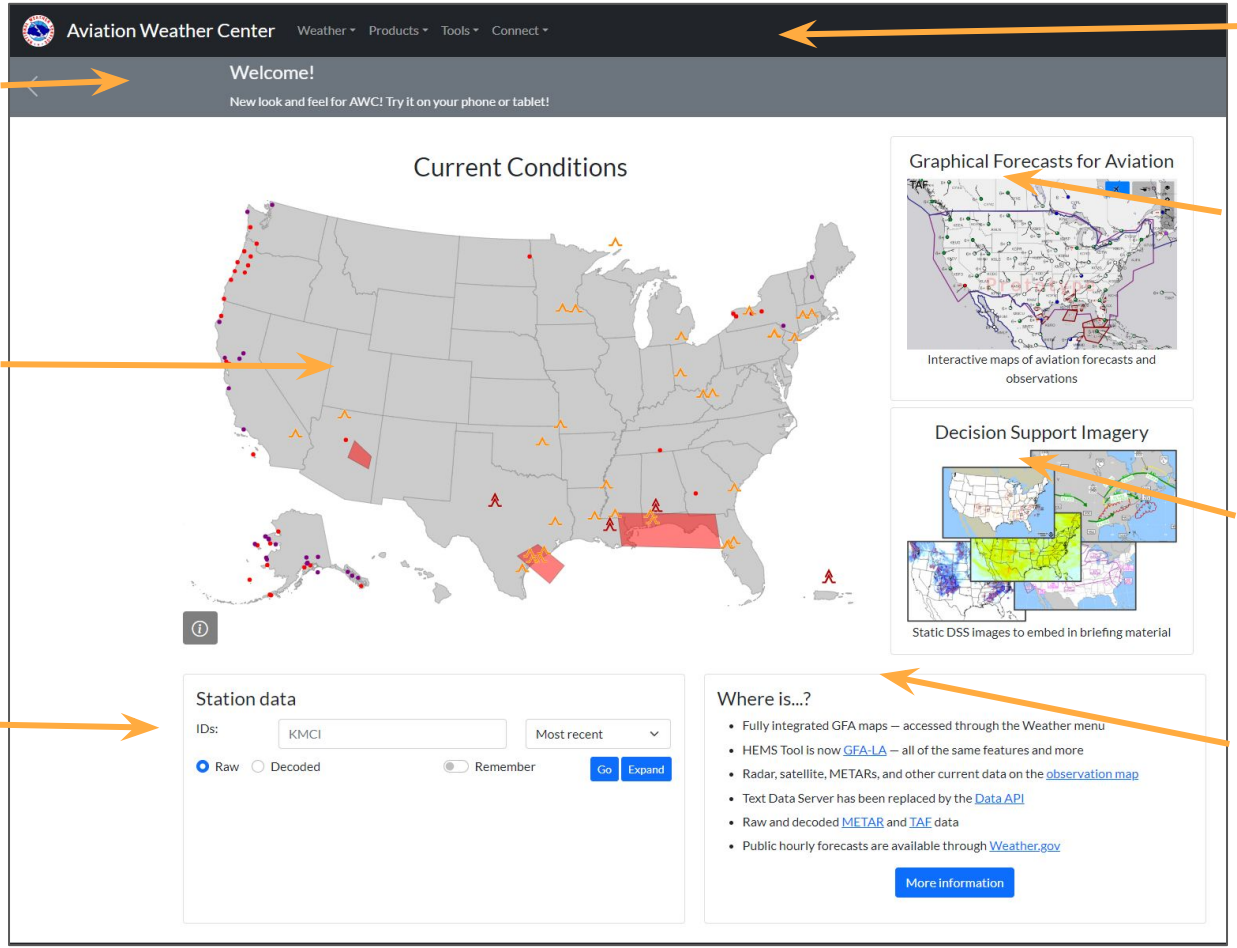
NAMs are involved in the FAA's broader strategic efforts to Plan, Execute, Review, Train, Improve

AviationWeather.gov

New look and feel for aviationweather.gov

- Mobile-first design
- Consistent navigation across all pages
- Focus on in-house aviation products
- Updated Graphical Forecasts for Aviation (GFA)





Messages/news (scrolling)

Navigation bar

Quick view of aviation weather conditions (click to go to GFA)

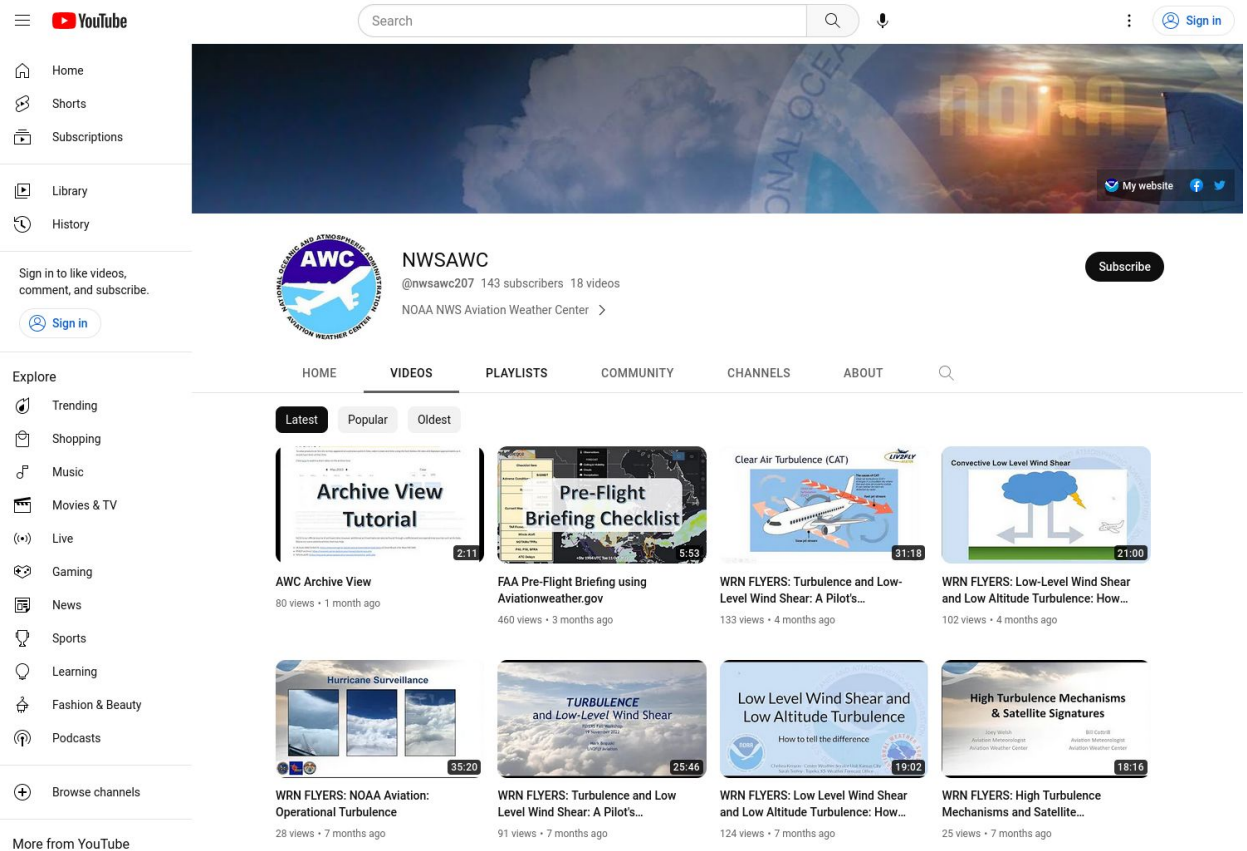
Link to GFA

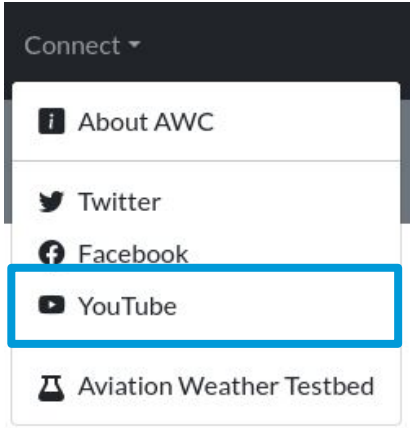
Link to dedicated DSS imagery

Quick access to station data

Help area

Youtube Tutorials



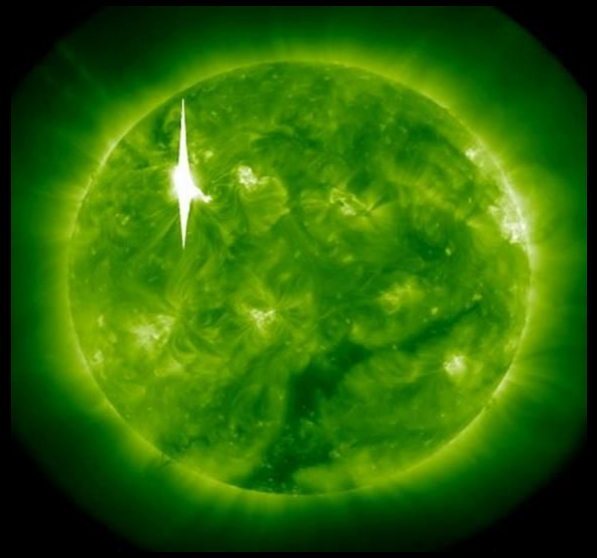


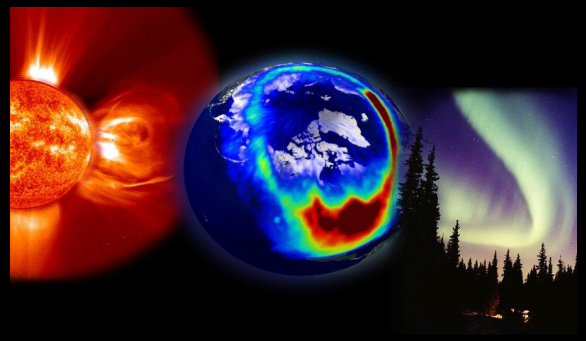
Thank you!

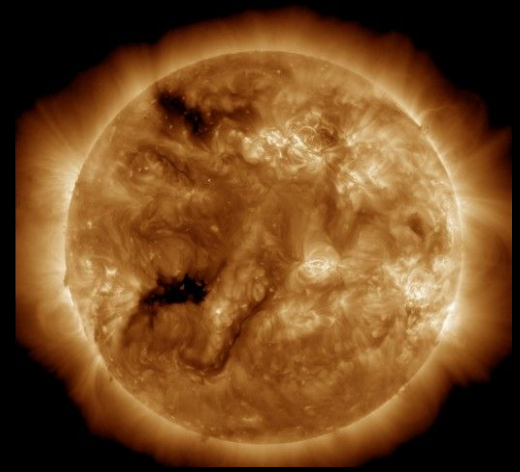
Questions?

Amanda.Martin@noaa.gov
aviationweather.gov

Space Weather Prediction Center (SWPC) Support for Communications



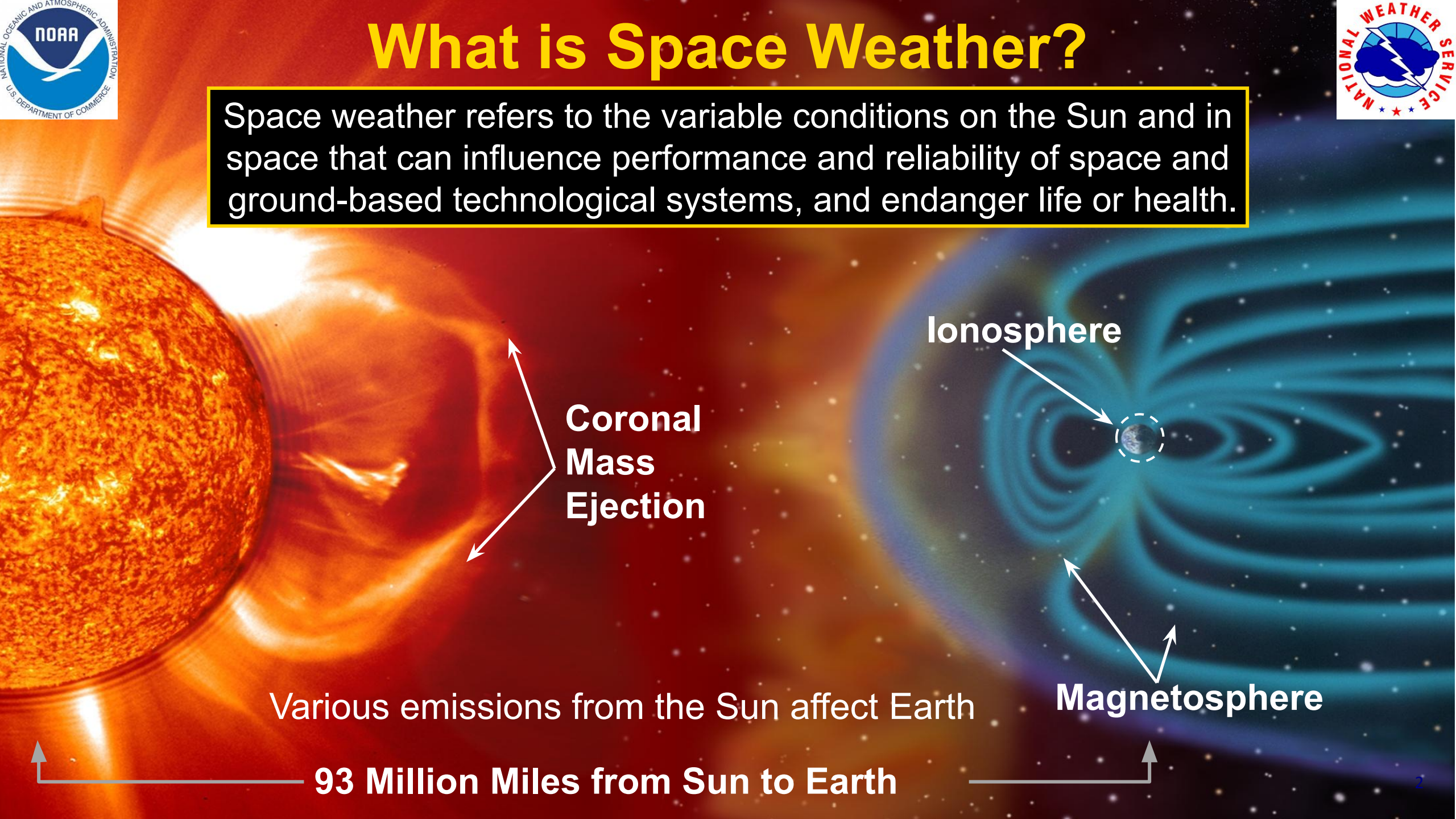




SWPC: "Safeguarding Society with Actionable Space Weather Information"

What is Space Weather?

Space weather refers to the variable conditions on the Sun and in space that can influence performance and reliability of space and ground-based technological systems, and endanger life or health.

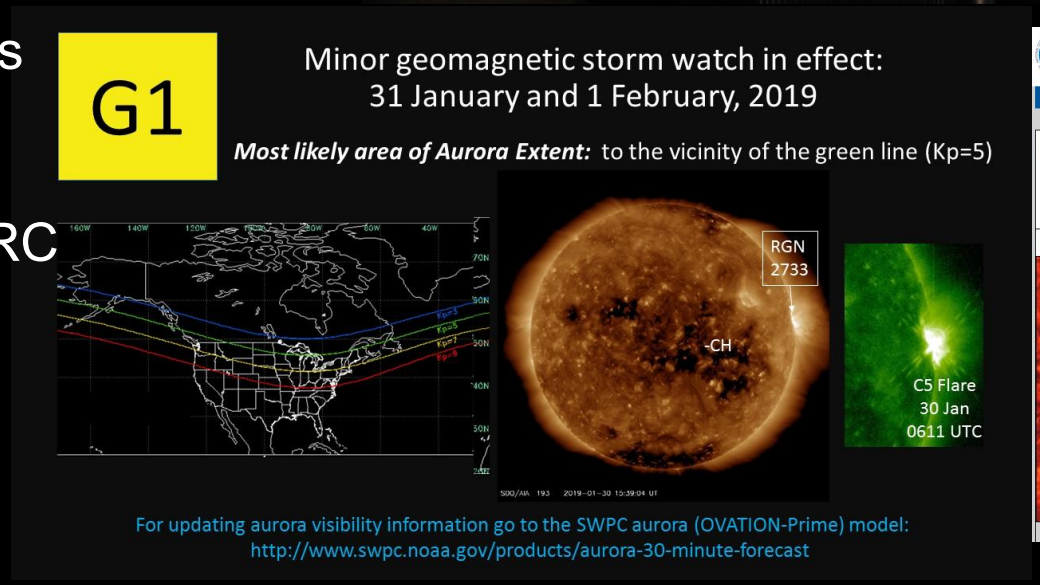


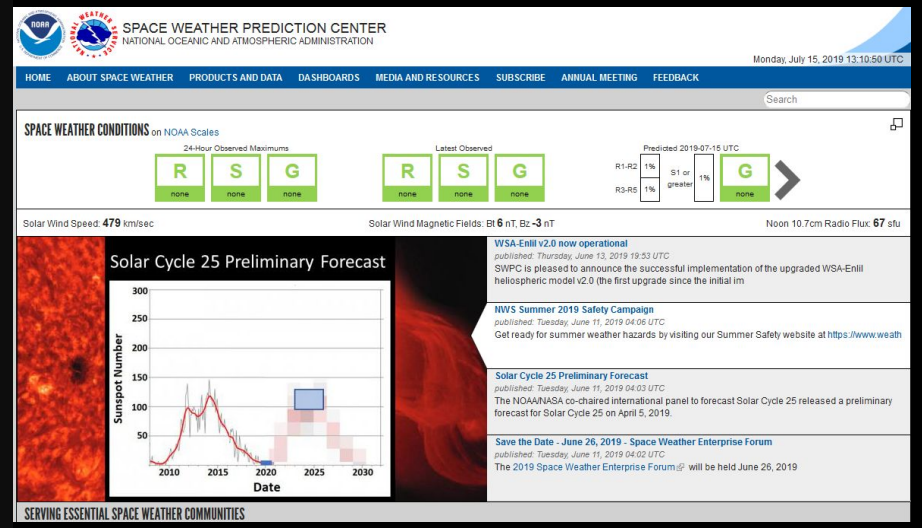
SWPC Forecast Operations (SWFO)

Operations, systems & data monitoring, forecasting, watches/warnings & Alerts, IDSS, etc.

Staffed 24 hours 7 days a week – just like any NWS forecast office

Core partnerships with USAF, NASA, FEMA, NERC





Focus areas

(3 primary activity types SWPC forecasts)

Impacts & Phenomena Based Forecasts

Solar Radiation Storms **(S-scale) :** related to *Solar Proton Events*

Solar Radiation Storm Warnings and Alerts

HF Radio Blackouts **(R-scale):** as related to *Solar Flares*

Solar Flare Alerts

Geomagnetic Storms **(G-scale):** as related to origin source *Coronal Mass Ejection* (CME), *Coronal Hole* (CH)

Geomagnetic Storm Watches, Warnings, and Alerts

Sunspots & Solar Cycle

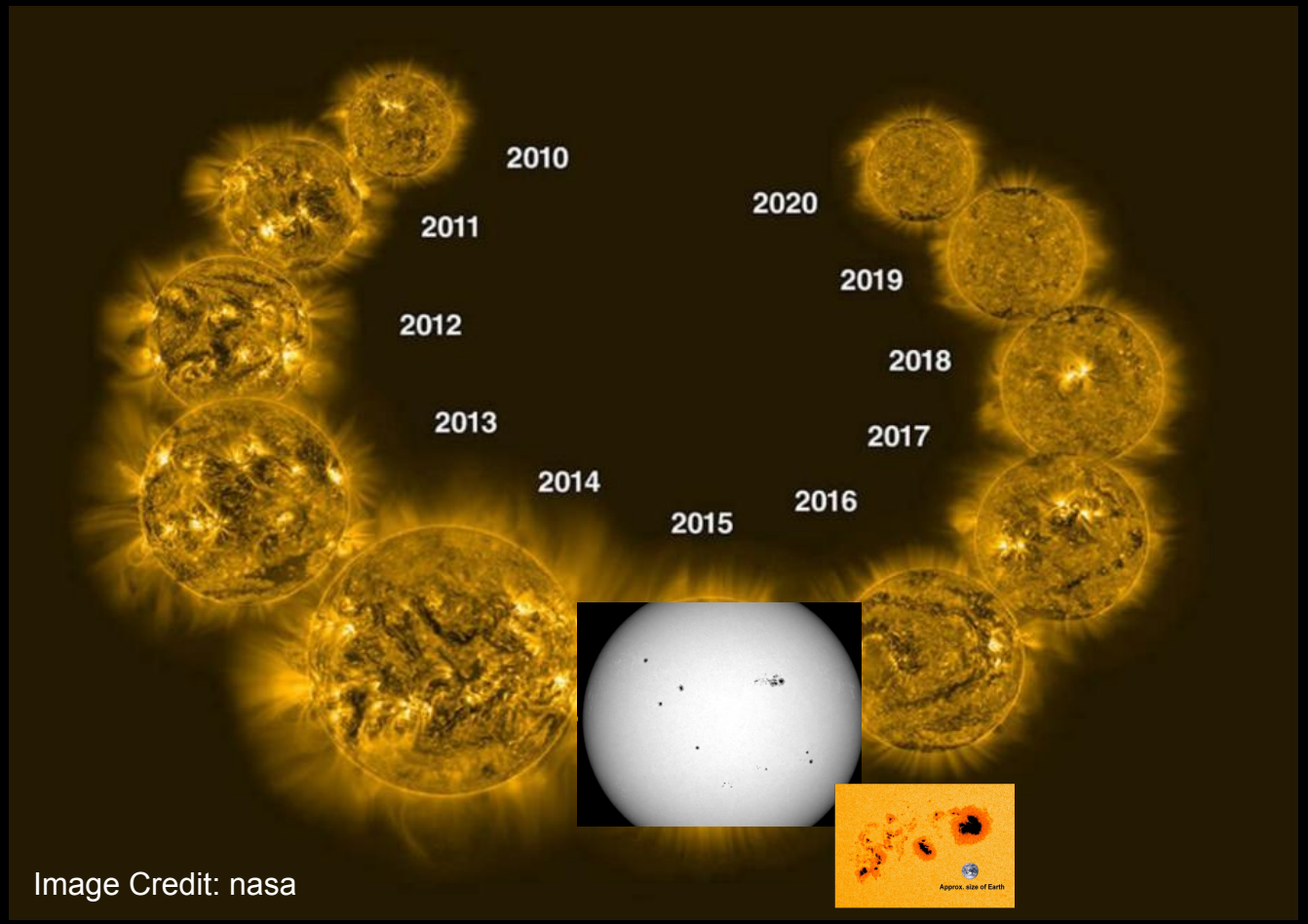
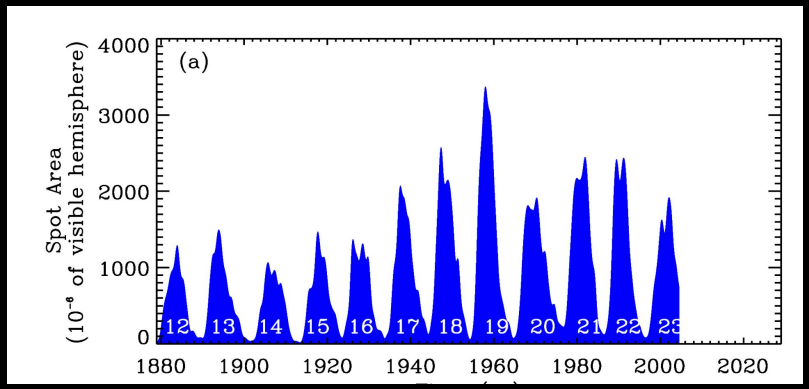
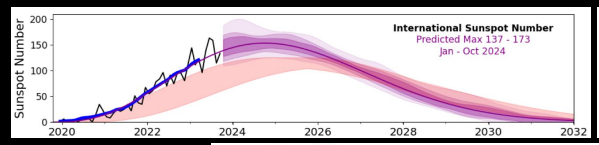
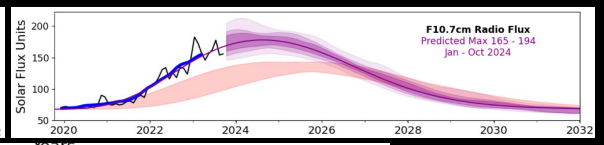


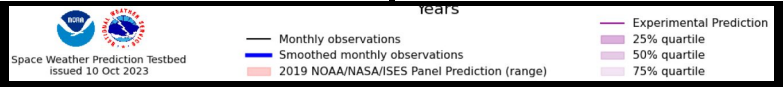
Image Credit: nasa

The highest sunspot numbers (most sunspots) are correlated with solar maximum. This is part of the 11-year solar cycle. Solar maximum is when we have increased chance of Severe & Extreme events









Solar Flares

Location of a flare on the Earth-facing disk does not matter. The affect on Earth's **sunlit** side ionosphere is immediate.

Dec 31st

Their strength is measure in **X-ray** energy from a space weather package on the GOES satellites and the strength relates to geographic area of impact to our ionosphere.

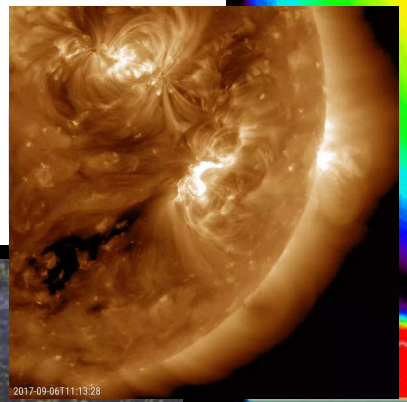
When Significant Space Weather and Catastrophic Terrestrial Weather come together – Sep 2017

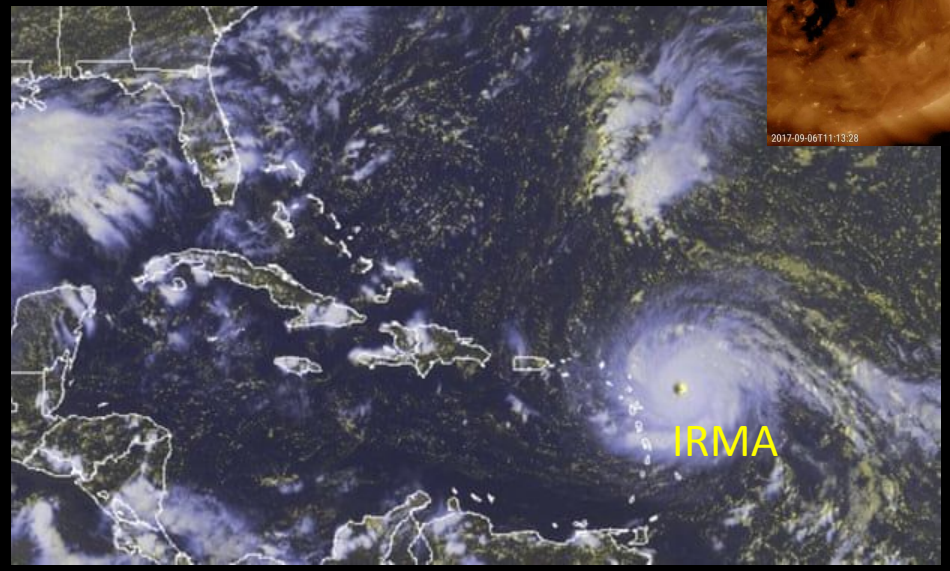
EOS NEWS ▾ NEWS FROM AGU JOURNALS ▾ TOPICS & DISCIPLINES ▾ OPINIONS ▾ BLOGS AGU'S CENTENNIAL

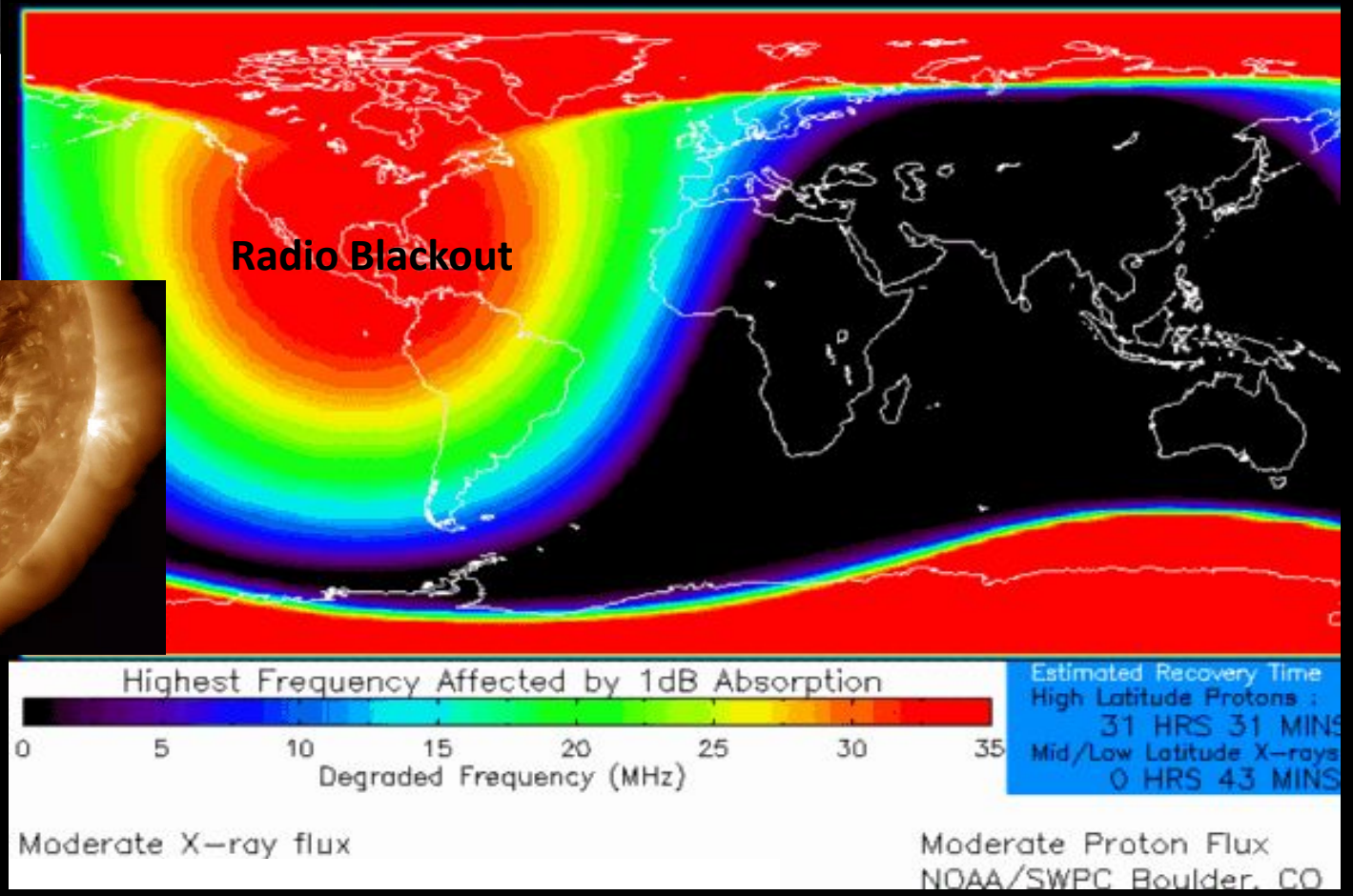
SPACE SCIENCE & SPACE PHYSICS Scientific Press Releases

Solar Flares Disrupted Radio During 2017 Hurricane Irma

On 6 September 2017, as Category 5 Hurricane Irma hit the Caribbean's Leeward Islands, and Tropical Storm Jose hovered in the wings, another storm erupted on the Sun.







HF Radio Comm from the Caribbean Islands (Ham Radio in particular) was nearly impossible during the hurricane disasters & crisis response for several hours. Hurricane Watch Net & Aviation Communication notably impacted.

Frequency (Radio) Bursts

Strongest Solar Flare of this Solar Cycle

Updated
2023 Dec 14
1900 EST

WHAT: Multiple Aviation Communication Impacts Associated with this Event

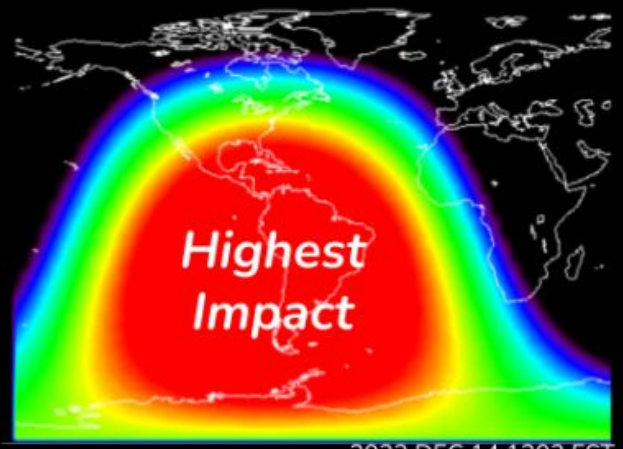
Amazing Event - likely one of the largest solar radio events ever recorded

Radio communication impacts between approximately 1200 - 1400 EST Thu

CWSUs report degraded communications across Nation
- ZKC, ZMP, ZAU, ZNY, ZOB
- "... Never seen anything like this..." - ZOB

Possible Earth-directed Coronal Mass Ejection (CME) being analyzed

Dec 14th

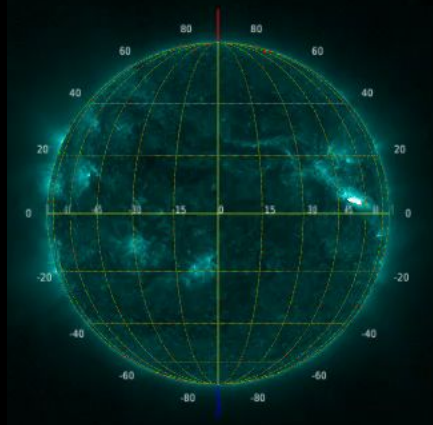


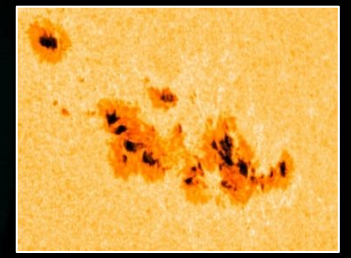
2023 DEC 14 1202 EST

National Oceanic and Atmospheric Administration

Safeguarding Society with Actionable Space Weather Information

Space Weather Prediction Center;
Boulder, CO



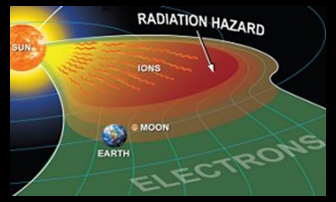


Can make radio communication difficult or unclear on frequencies other than HF bands. Additional Air Traffic Control (ATC) bands impacted dramatically on higher communication bands over U.S. - problem on 14 Dec! Could also be issue for urban environment communication repeater systems. Also, concern for military assets and interests.

Solar Radiation Storms

Feb 9-13th

We talk with NASA every day about threat of these events

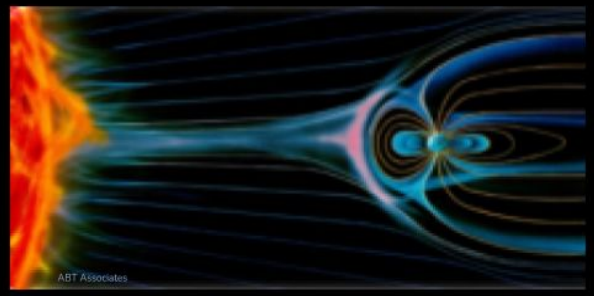


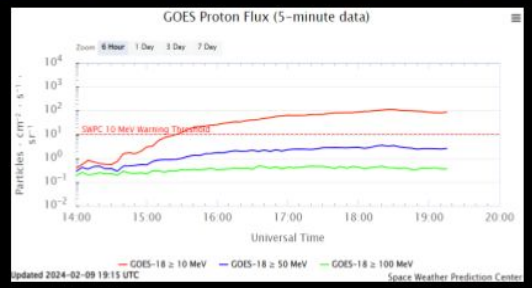
Solar Radiation Storm Event

S1 S2

Updated 2024 Feb 09 1435 EST

WHAT: A Solar Energetic Particle Event is in Progress





EVENT:
A solar radiation storm occurs when charged particles are accelerated by processes at or near the Sun and arrive in enough quantity at Earth. S2 levels are less common, while S1 storms are not uncommon

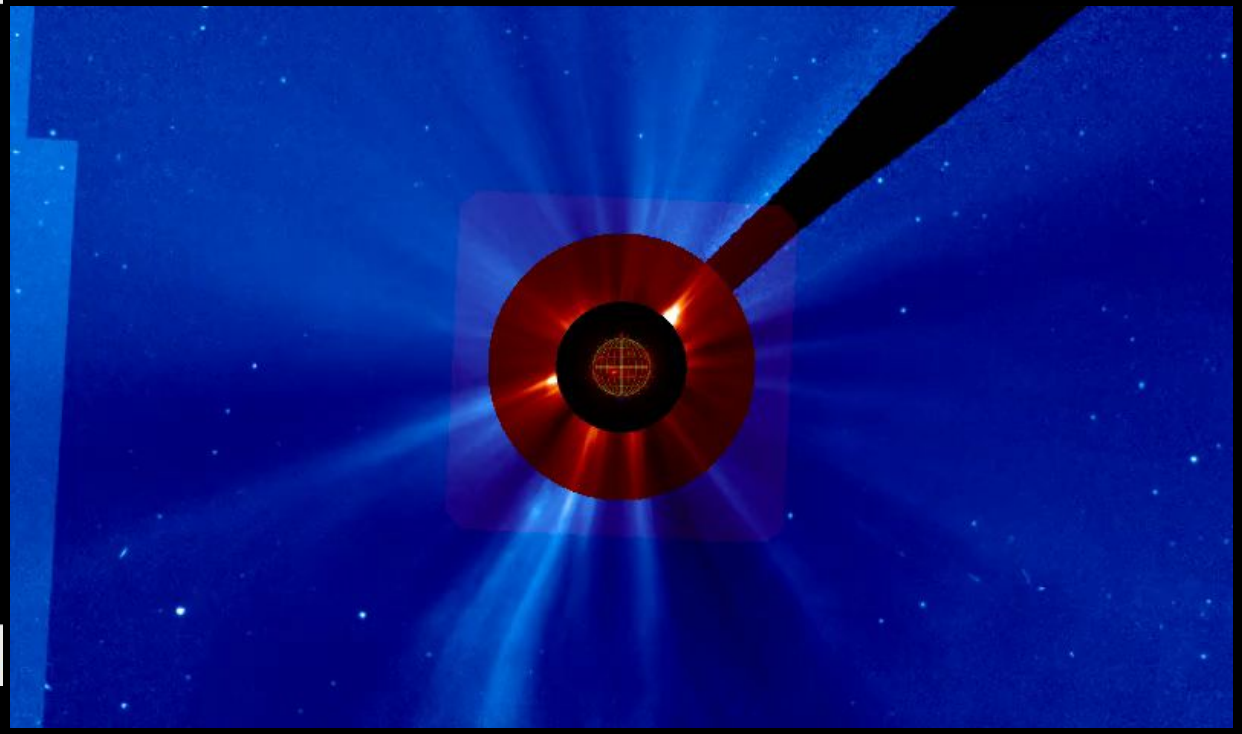
TIMING:
The S1 event first began at 09/1530 EST and is expected to last to at least 10/0100 EST. The event reached an initial peak at S2 levels at 09/1325 EST

EFFECTS:
Degradation to HF communications in the polar regions; possible risk to space launch and satellites; high flying interests along polar routes should monitor the situation for updates. The general public need not be concerned.

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Safeguarding Society with Actionable Space Weather Information

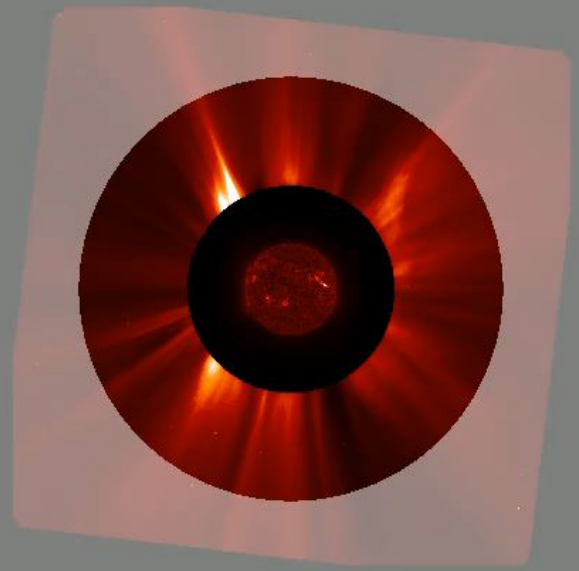
Space Weather Prediction Center; Boulder, CO



Can adversely affect aviation – increased radiation exposure risk to astronauts and perhaps aircrews at high altitudes near polar regions; relates to long HF communication outages extending from polar regions; can delay space launch and cause increased risk of anomalies to satellites

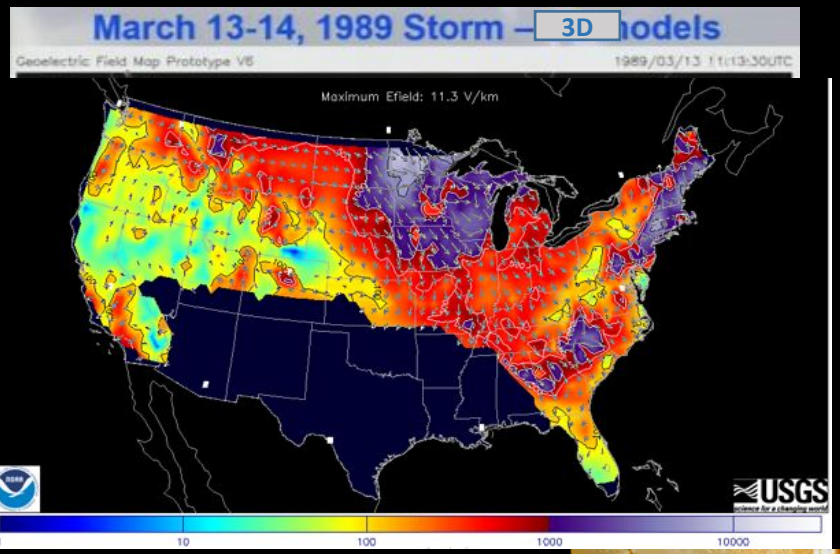
Coronal Mass Ejections (CME)

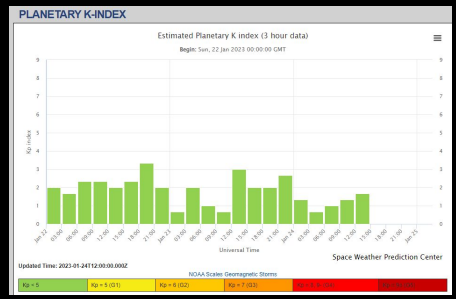
Tremendous expulsions of solar and embedded magnetic fields. Their impact to our magnetosphere can cause major changes resulting in **Geomagnetic Storms**

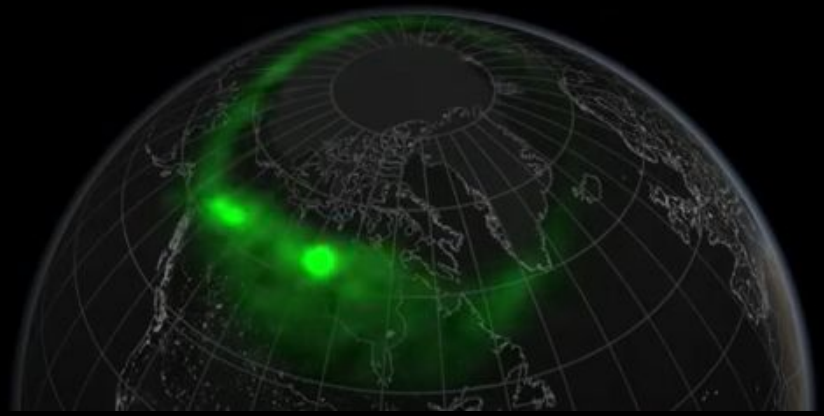


Fastest Earth-directed CMEs can get here is in 15 hours. Usually, they are slower and take 2 to 4 days.

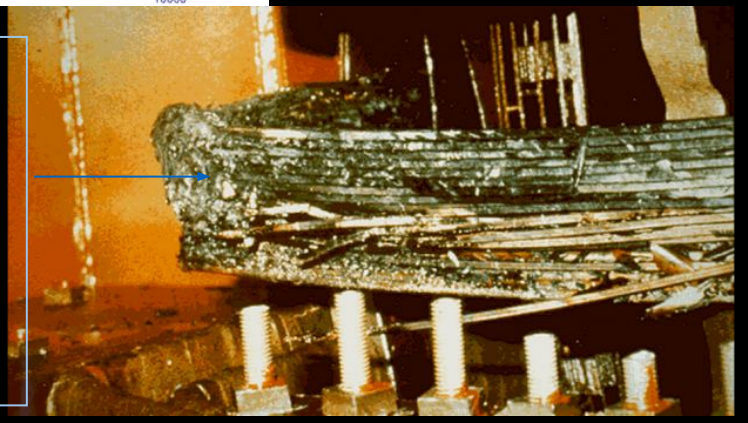
Geomagnetic Storms





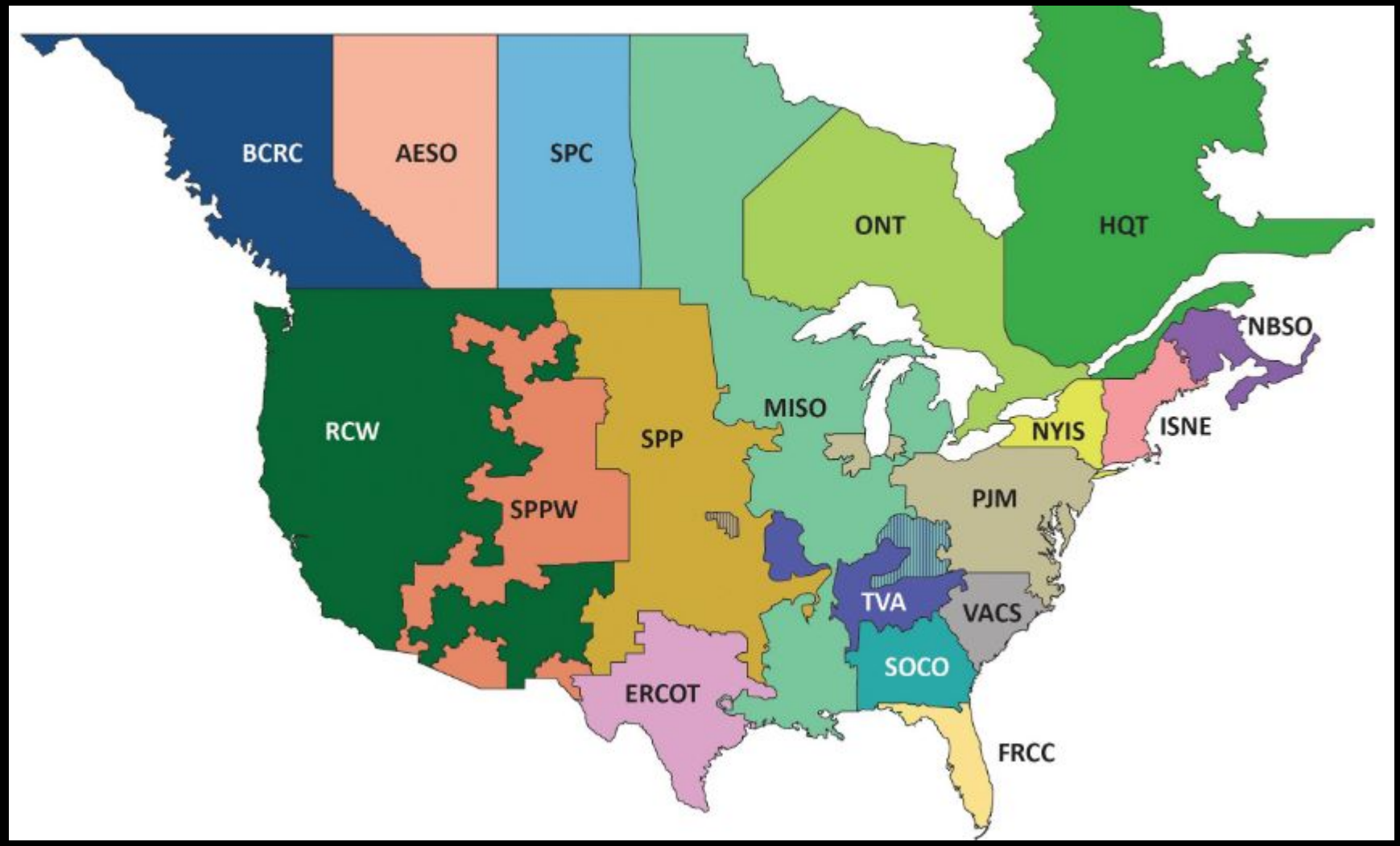


Severely damaged Salem New Jersey Nuclear Plant GSU Transformer



Can produce problematic geomagnetic induced currents on the power grid systems… and can lead to ionosphere storms that can cause scintillation, electron density changes that may impact SATCOM, GNSS, HF MUF depressions, satellite drag, and more… even well after the Geomagnetic Storm is done

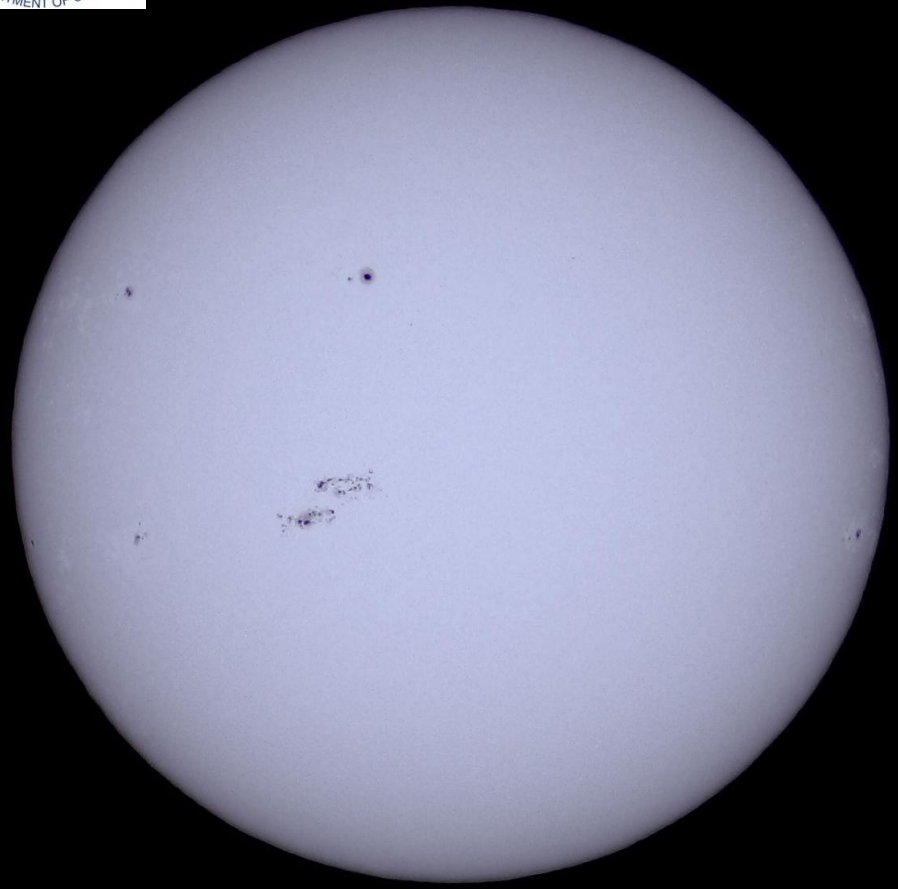
Reliability Coordinators (RC) throughout the two major and three minor Interconnections

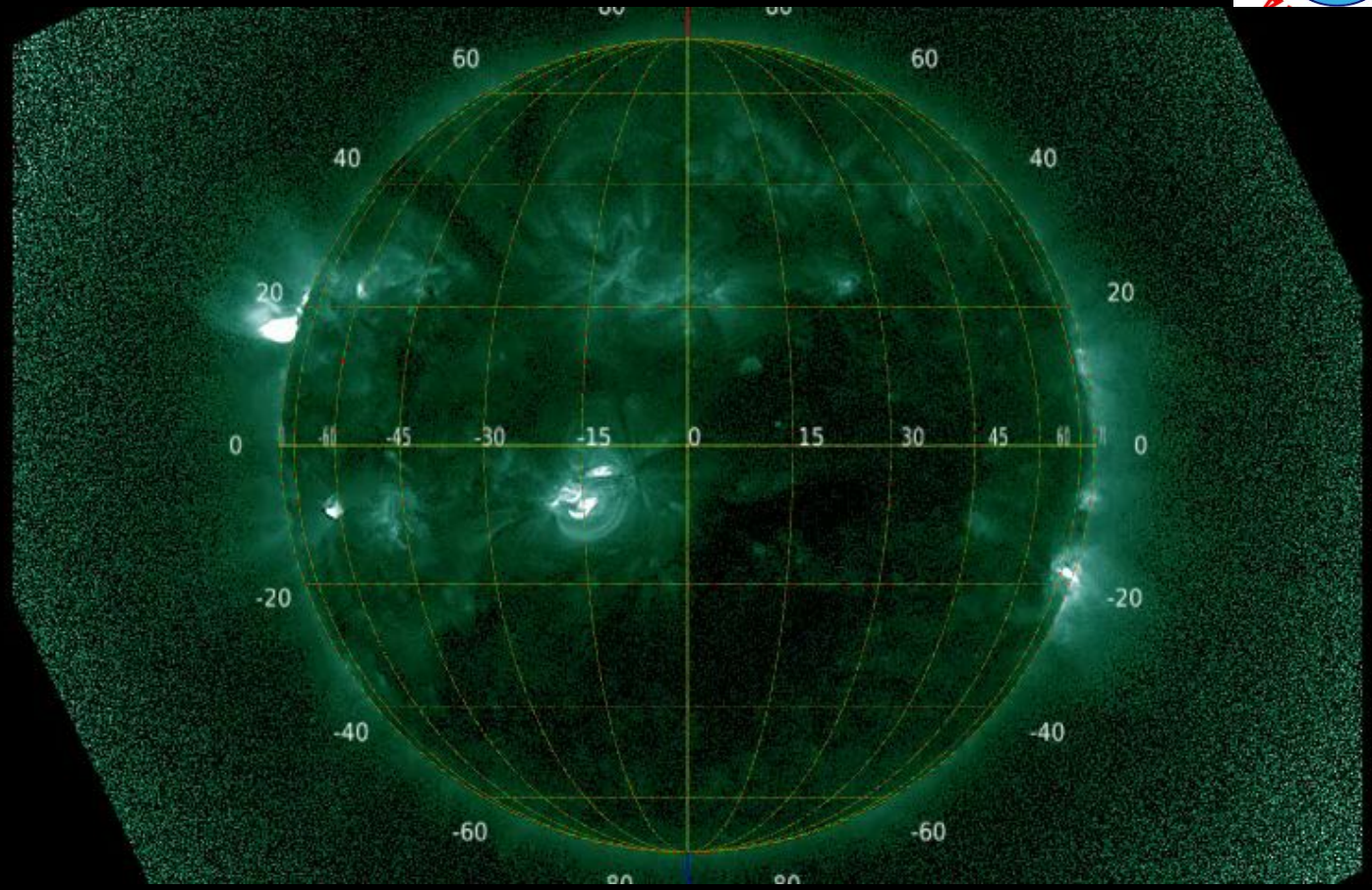


Mitigating Power Outage Potential to our Interconnected Power Grid:
NERC Hotline Call

All RC's are on the NERC hotline call when we initiate the NERC hotline call beginning at G3

22 March 2024 – Sunspots/Flares





Massive and magnetically complex active region sunspot group to the south and a much smaller and moderately complex active region sunspot group to the north. The northern spot group erupted with an X1 (R3) long duration flare (few hours). The southern group also flared shortly afterwards. SWPC forecasters made calls to NASA and Oakland ATC when flare activity reached M5 (R2).

22-23 March 2024 – CME/Radiation Storm

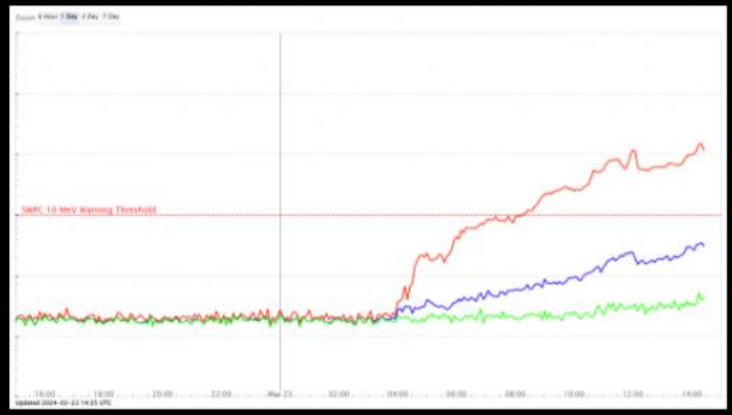
MODERATE Solar Radiation Storm Event S2

WHAT: A Solar Energetic Particle Event is in Progress

EVENT:
The greater than 10 MeV proton flux became enhanced following an X1.1 flare at 23/0133 UTC. Solar radiation storms at S1-S2 (Minor-Moderate) levels have been observed.

TIMING:
S1 (Minor) levels were observed beginning at 23/0815 UTC, and S2 (Moderate) levels began at 23/1405 UTC.

EFFECTS:
Degradation to HF communications in the polar regions; possible risk to space launch and satellites; high flying interests along polar routes should monitor the situation for updates. The general public need not be concerned.



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Space Weather Prediction Center; Boulder, CO

Several hours later, energetic particles (protons) arrive at GOES-16/18. SWPC forecasters call NASA/SRAG among others. About 6 hours later, imagery from the NASA coronagraph at L1 (1 million miles from Earth) captures the associated CME departing the Sun. It is a full halo and SWPC forecasters begin analyzing and modelling the CME for anticipated Earth arrival timing and intensity. Speed over 1000 km/s (fast)

24 Mar - Geomagnetic Storms

Geomagnetic Storm Levels Continue

G1 G2 G3 G4

Updated 2024 Mar 24 4:15pm EDT

WHAT: CME progression continues and the effects are anticipated to linger into 25 March

EVENT:

A coronal mass ejection (CME) that departed the Sun Friday evening, 22 March, reached Earth this morning and continues it progression and geomagnetic storm levels to at least G3 are expected through Sunday evening, 24 March.

TIMING:

Changes in the strength of the geomagnetic storm levels will occur due to variations in solar wind as the CME continues to pass over Earth.

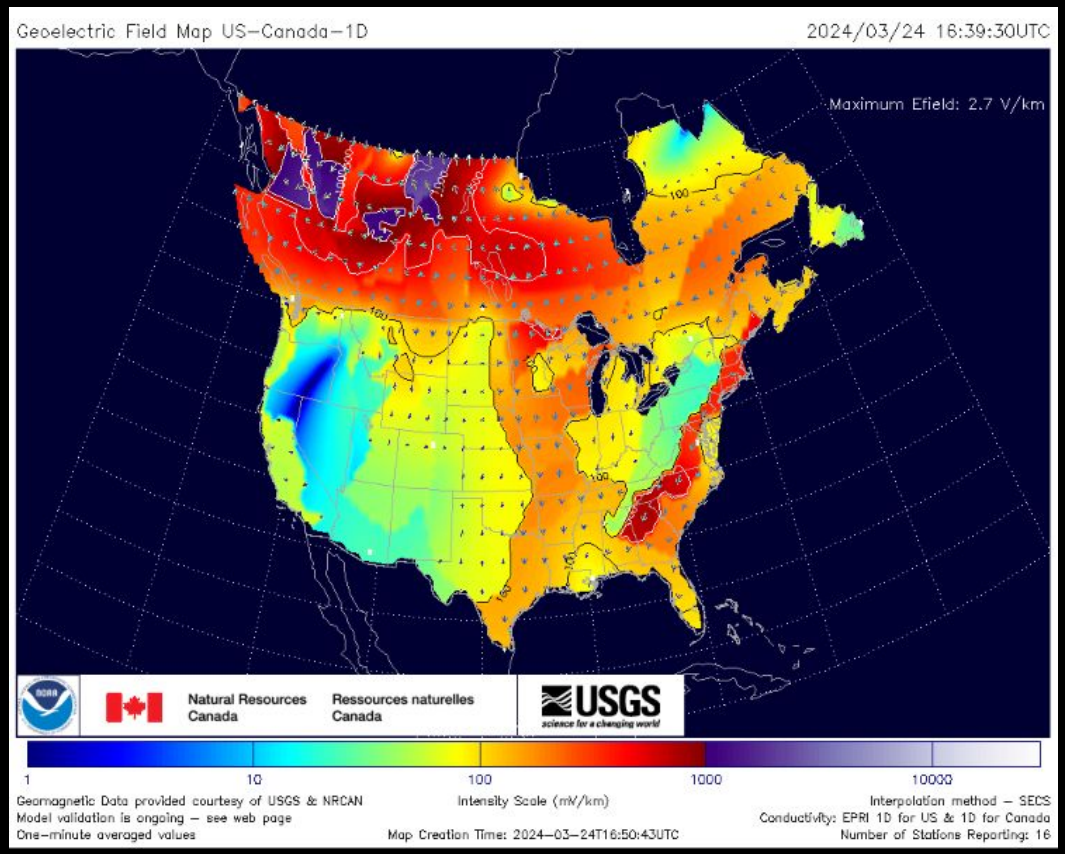
EFFECTS:

G1 through G4 levels have been reached so far with this CME related activity and should G4 levels be reached tonight, the aurora may become visible over much of the northern half of the country, and maybe as far south as Alabama to northern California.

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

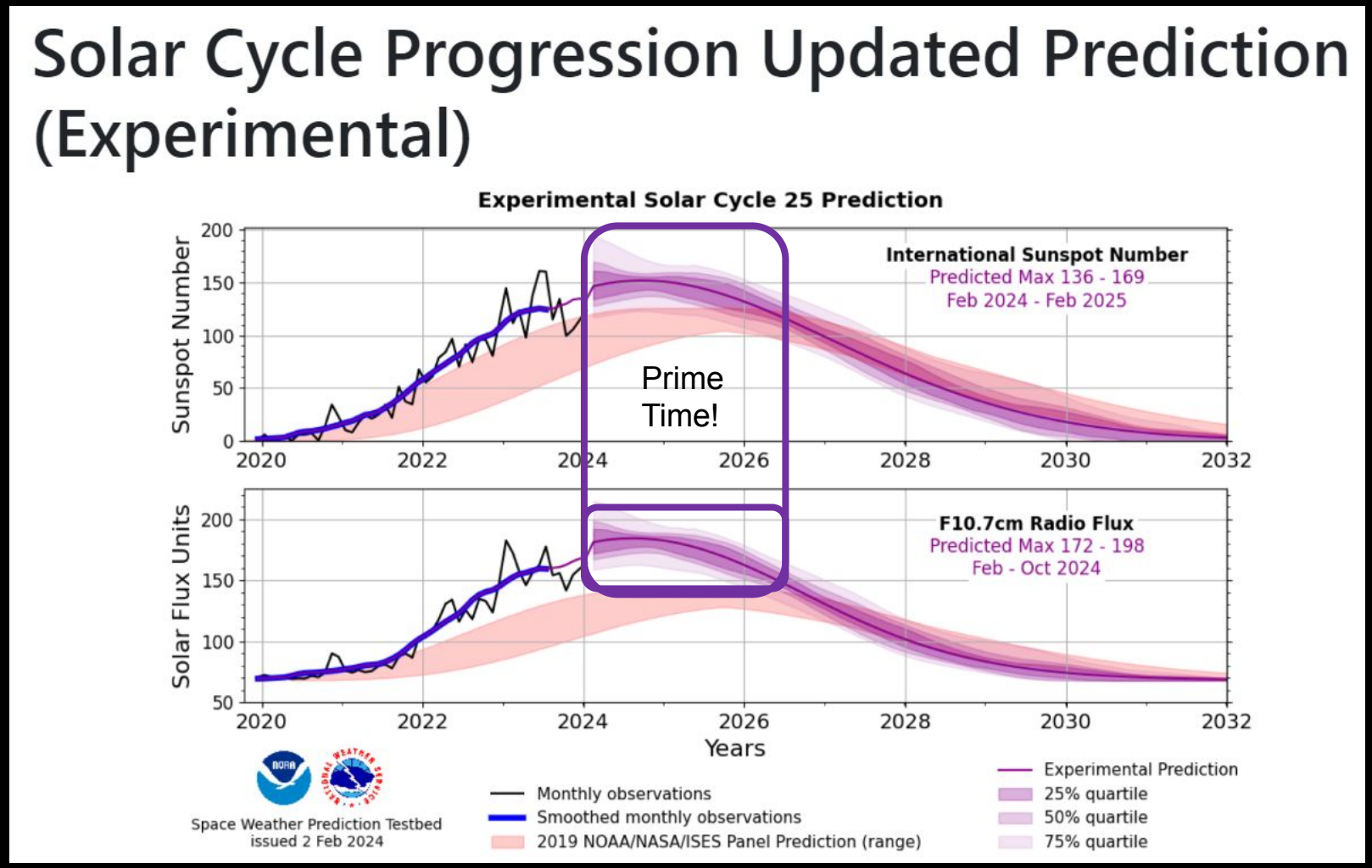
Safeguarding Society with Actionable Space Weather Information

Space Weather Prediction Center; Boulder, CO

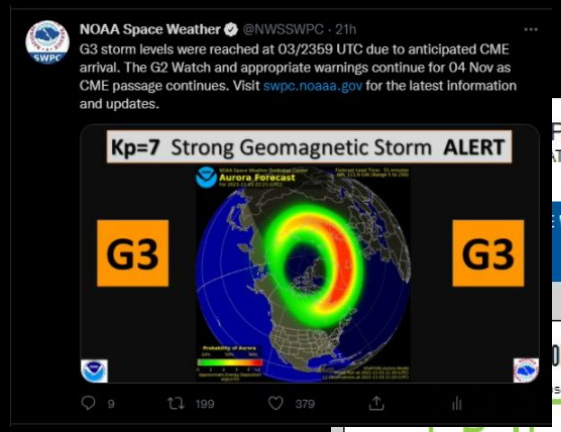


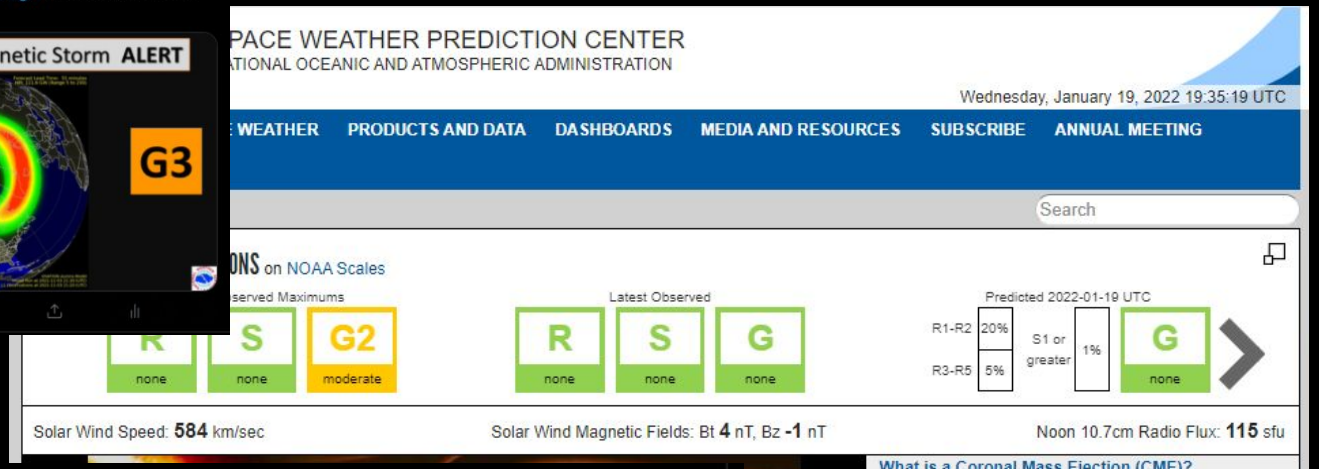
CME shock arrives at L1 as observed by DSCOVR/ACE spacecraft. SWPC forecasters issue Sudden Impulse warning for benefit of the power grid. Decent SI observed less than 30 minutes later. Geomagnetic responses rapidly escalate and SWPC forecasters begin calling specific transmission operation centers, Oakland ATC, NASA/SRAG, NWS SOC. At G3 (NERC Hotline Call), at G4 – FEMA WOC and Denver MOC contacted.

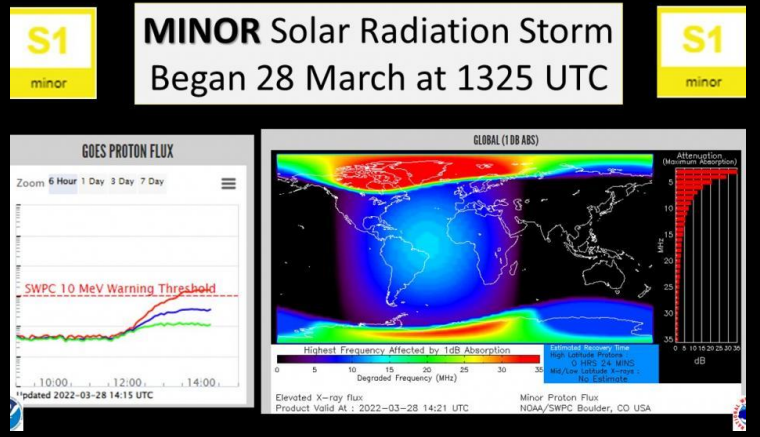
Current Solar Cycle 25 is ramping up; currently above the original forecast margin of error

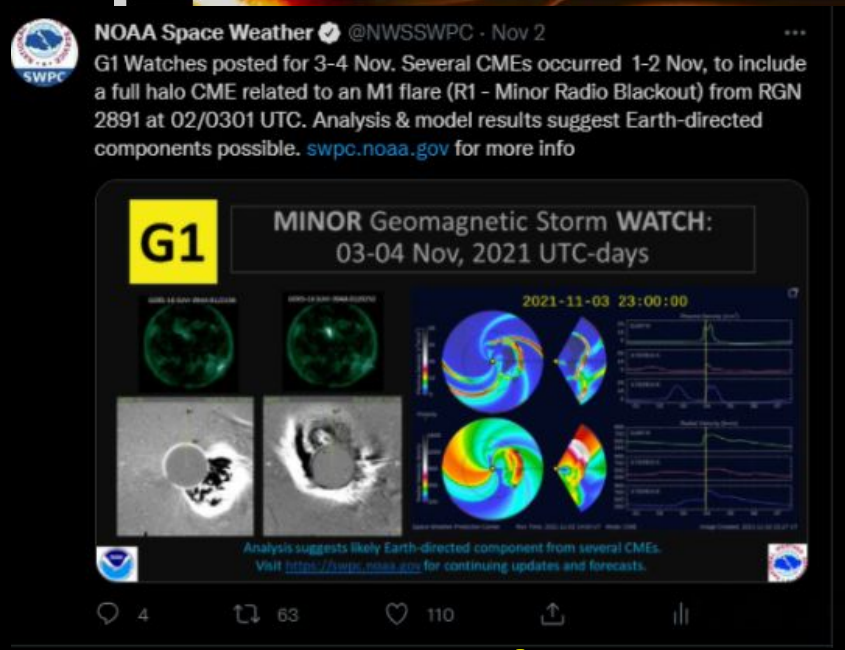


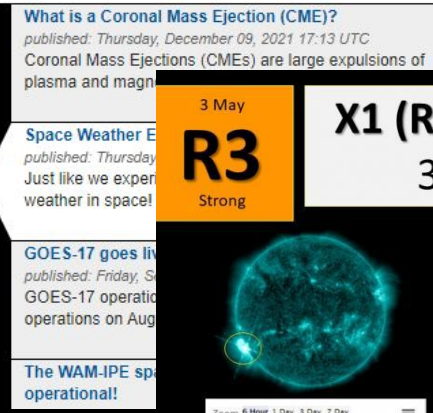
How to **STAY** Informed





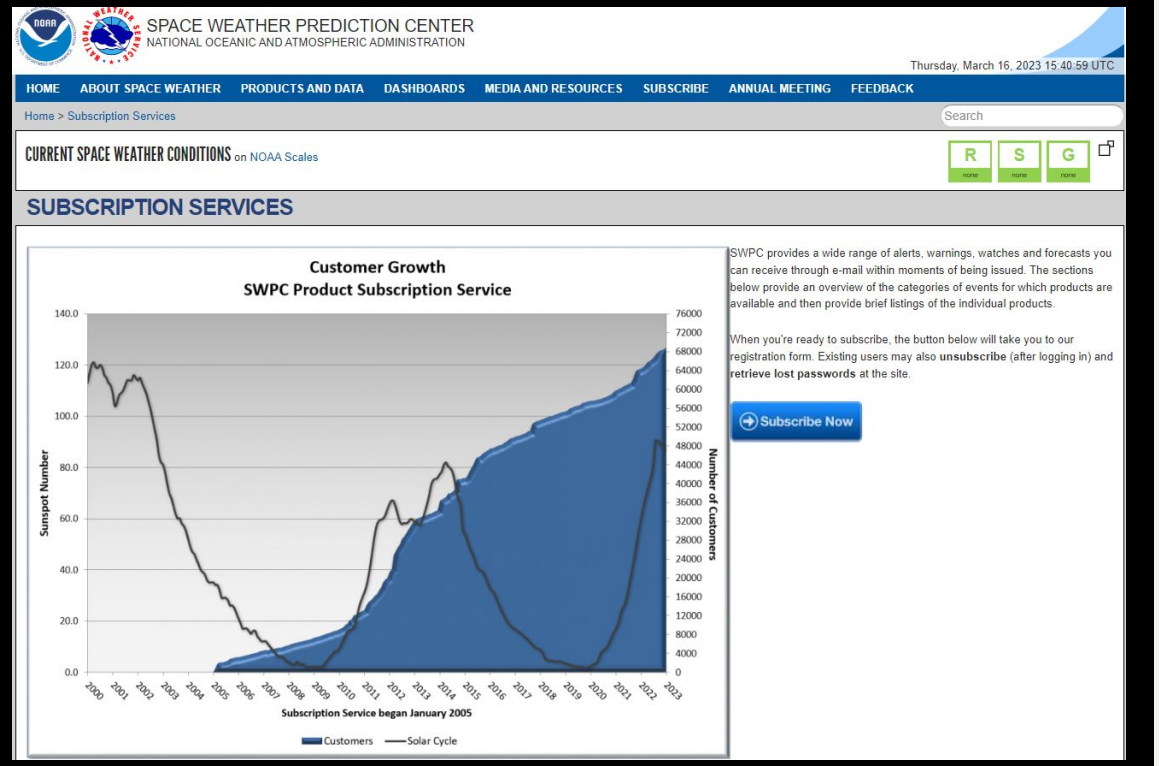


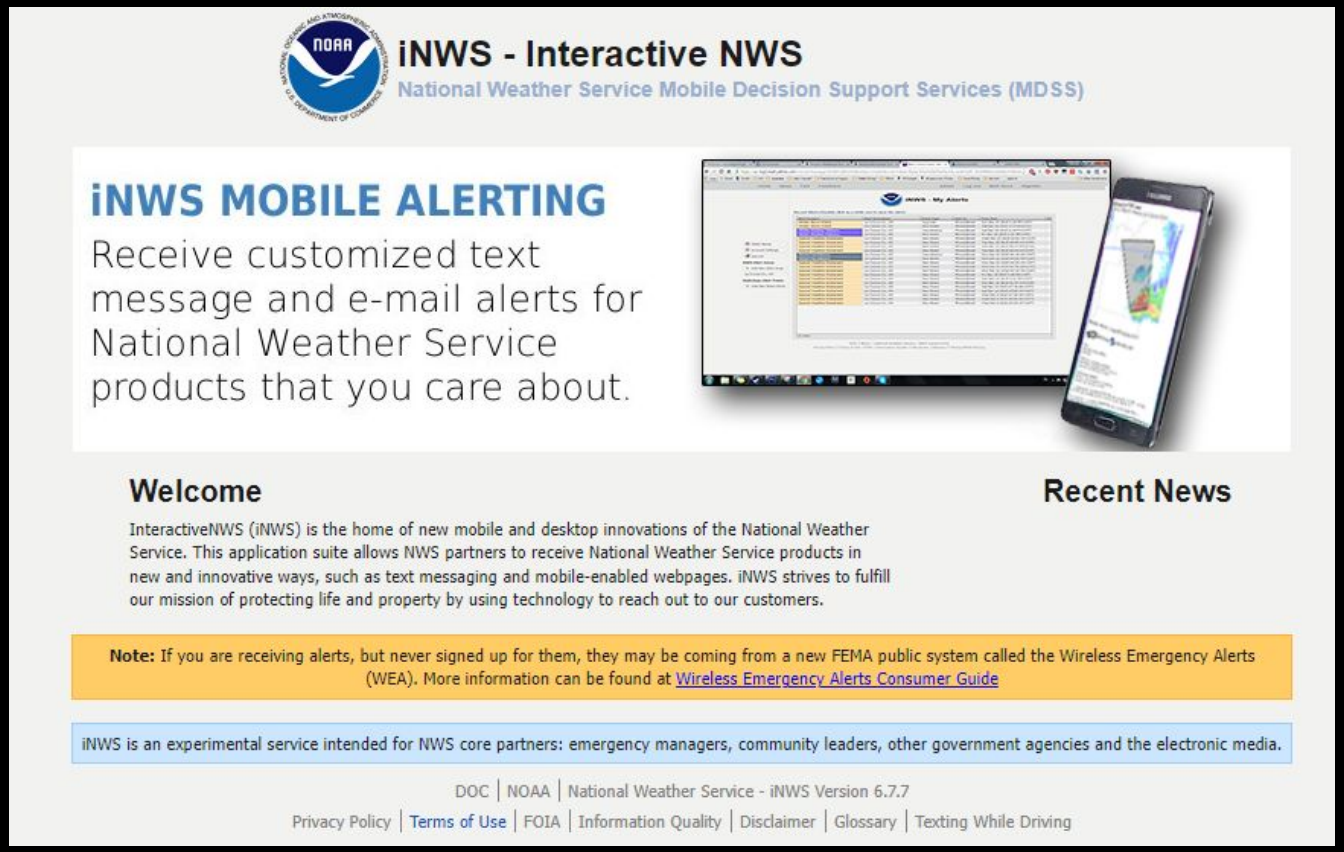




Webpage: swpc.noaa.gov

How to **GET** Informed





SWPC PSS for direct emails of many various products and WWA

*NWS INWS for direct text messages and/or emails of primary WA

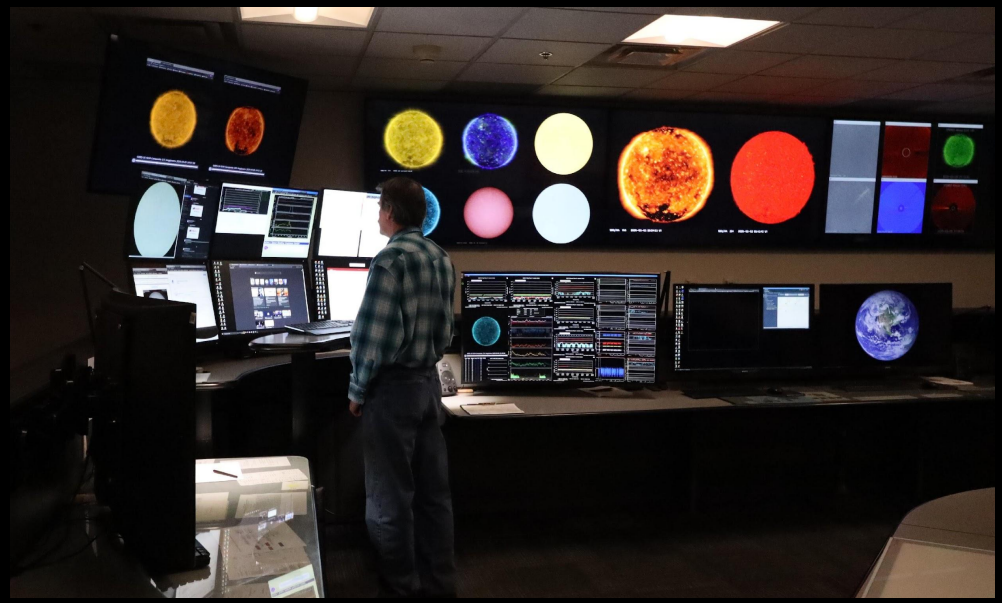
*experimental service intended **only for NWS core partners, EMs, and other government agencies**

Thank You!

POC for your questions or needs

- Use your NWS WFO WCMs when possible for basic, general information; but for more specific needs or expertise, contact SWPC

Shawn Dahl – SWPC Service Coordinator
shawn.dahl@noaa.gov



"Safeguarding Society with Actionable Space Weather Information"