Building Weather Ready Nations - The New International Need
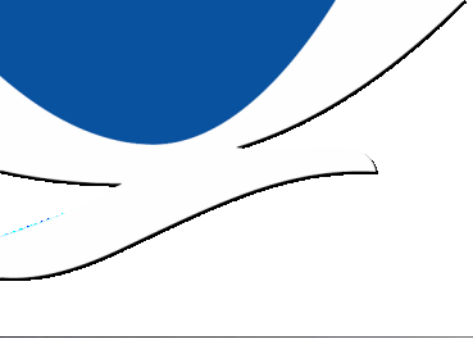
Dr. Louis W. Uccellini

Director, National Weather Service

NOAA Assistant Administrator for Weather Services

September 4, 2018: Eötvös Loránd University

4th PannEx Workshop

Budapest, Hungary

Outline

- Background

- Why the urgency for change?

- Building a Weather-Ready Nation

- So how are we doing?

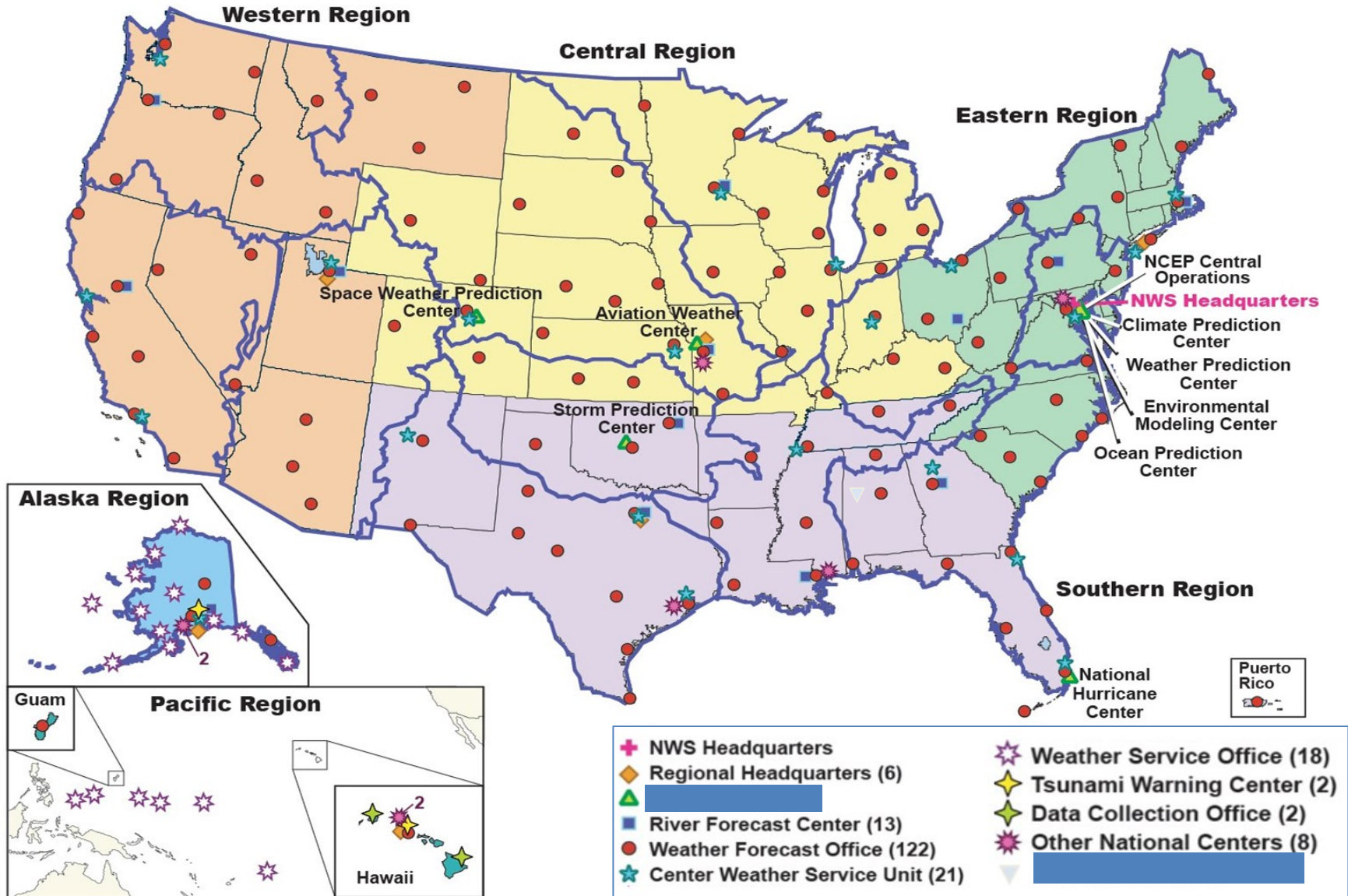- Building Weather Ready Nations (WRNs)
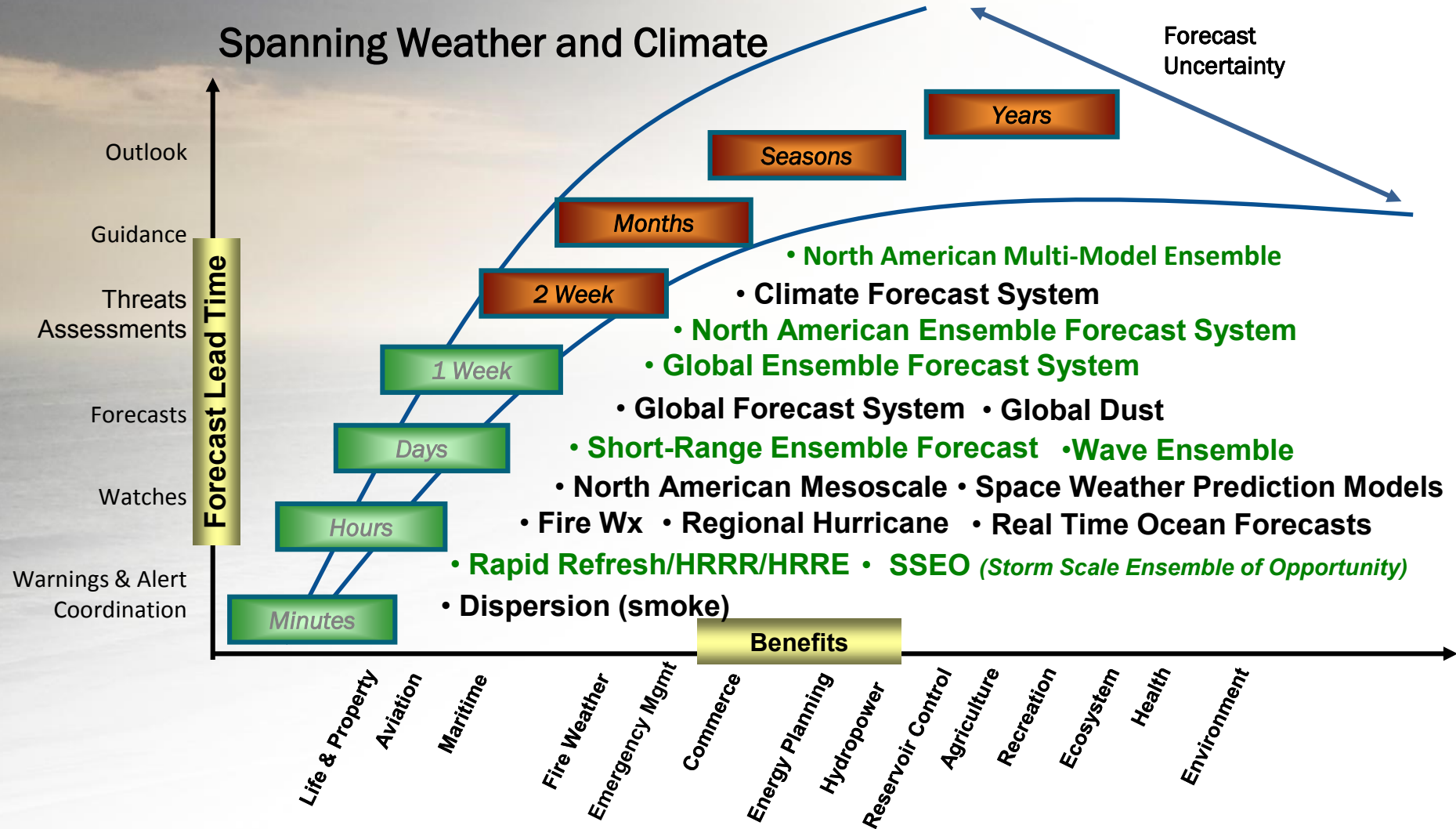
Background

MISSION

Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and the enhancement of the national economy.
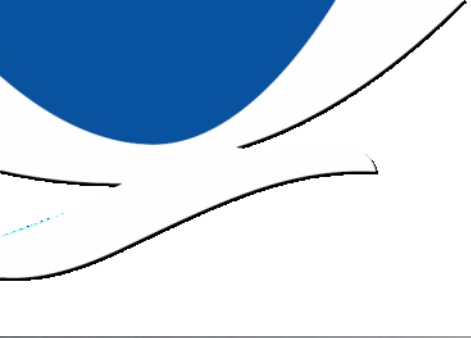
NWS Operations
Community Based Services

Western Region

Central Region

Eastern Region

NCEP Central Operations

NWS Headquarters

Space Weather Prediction Center

Climate Prediction Center

Aviation Weather Center

Weather Prediction Center

Environmental Modeling Center

Storm Prediction Center

Ocean Prediction Center

Alaska Region

Southern Region

Guam

Puerto Rico

Pacific Region

National Hurricane Center

Hawaii

Symbol	Legend	Symbol	Legend
✚	NWS Headquarters	✰	Weather Service Office (18)
◆	Regional Headquarters (6)	✩	Tsunami Warning Center (2)
△		✦	Data Collection Office (2)
■	River Forecast Center (13)	✸	Other National Centers (8)
●	Weather Forecast Office (122)	▽	
✦	Center Weather Service Unit (21)		

Seamless Suite of Forecasts From Mesoscale to S2S Increasingly Based on Multi-Model Ensembles

Spanning Weather and Climate

Forecast Uncertainty

Forecast Lead Time

- Outlook
- Guidance
- Threats Assessments
- Forecasts
- Watches
- Warnings & Alert Coordination

Years

Seasons

Months

2 Week

1 Week

Days

Hours

Minutes

- **North American Multi-Model Ensemble**
- **Climate Forecast System**
- **North American Ensemble Forecast System**
- **Global Ensemble Forecast System**
- **Global Forecast System** • **Global Dust**
- **Short-Range Ensemble Forecast** • **Wave Ensemble**
- **North American Mesoscale** • **Space Weather Prediction Models**
- **Fire Wx** • **Regional Hurricane** • **Real Time Ocean Forecasts**
- **Rapid Refresh/HRRR/HRRE** • **SSEO** *(Storm Scale Ensemble of Opportunity)*
- **Dispersion (smoke)**

Benefits

Life & Property, Aviation, Maritime, Fire Weather, Emergency Mgmt, Commerce, Energy Planning, Hydropower, Reservoir Control, Agriculture, Recreation, Ecosystem, Health, Environment

6

Why the Urgency for Change

Increasing Societal Vulnerability to Environmental Hazards

Average Year

26,000 Severe Storms

6 Atlantic Hurricanes

1,300 Tornadoes

5,000 Floods

Loss Events in the US (1980-2015)

Munich RE

Number

Geophysical events — Meteorological events — Hydrological events — Climatological events
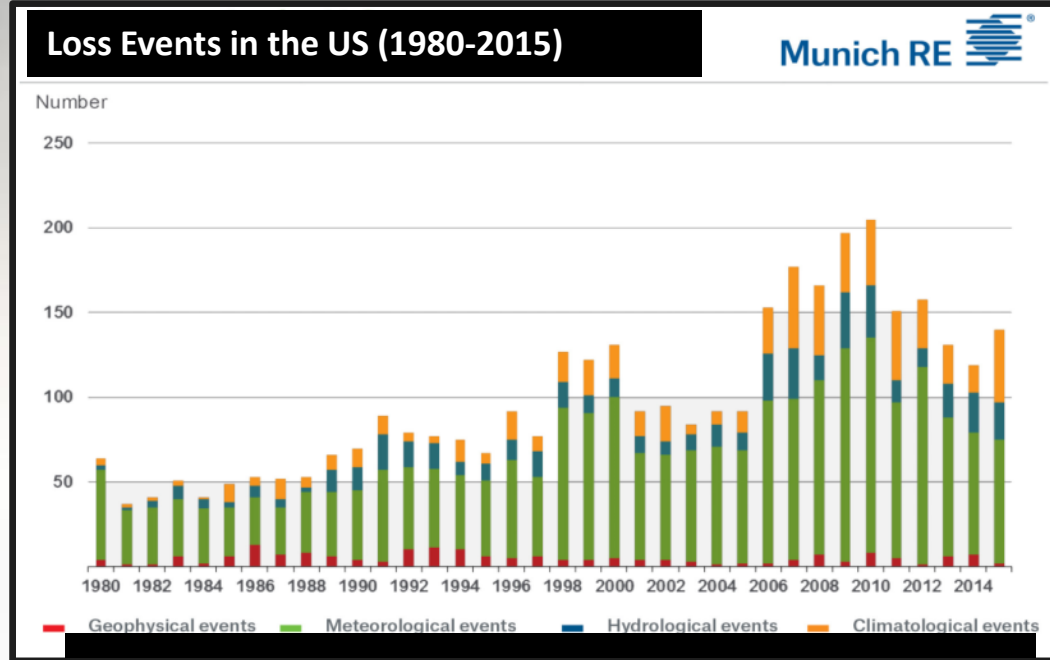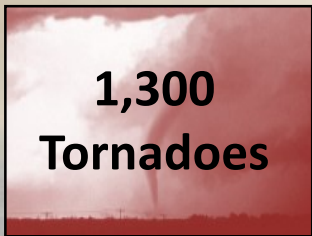
4 out of 5 Americans live in counties that have been declared weather-related disaster areas in the past six years*

Meanwhile we are now predicting extreme events out to a week in advance!

Factors contributing to increased vulnerabilities

✓ **Increasing population in vulnerable areas**

✓ **More infrastructure at risk to extreme events**

✓ **Signs of climate change**

- **Sea-level rise**
- **Increasing extreme precipitation events**
- **Record monthly temperatures**

*Source: Environment America

8

Extreme One-Day Precipitation Events Contiguous 48 States, 1920-2015
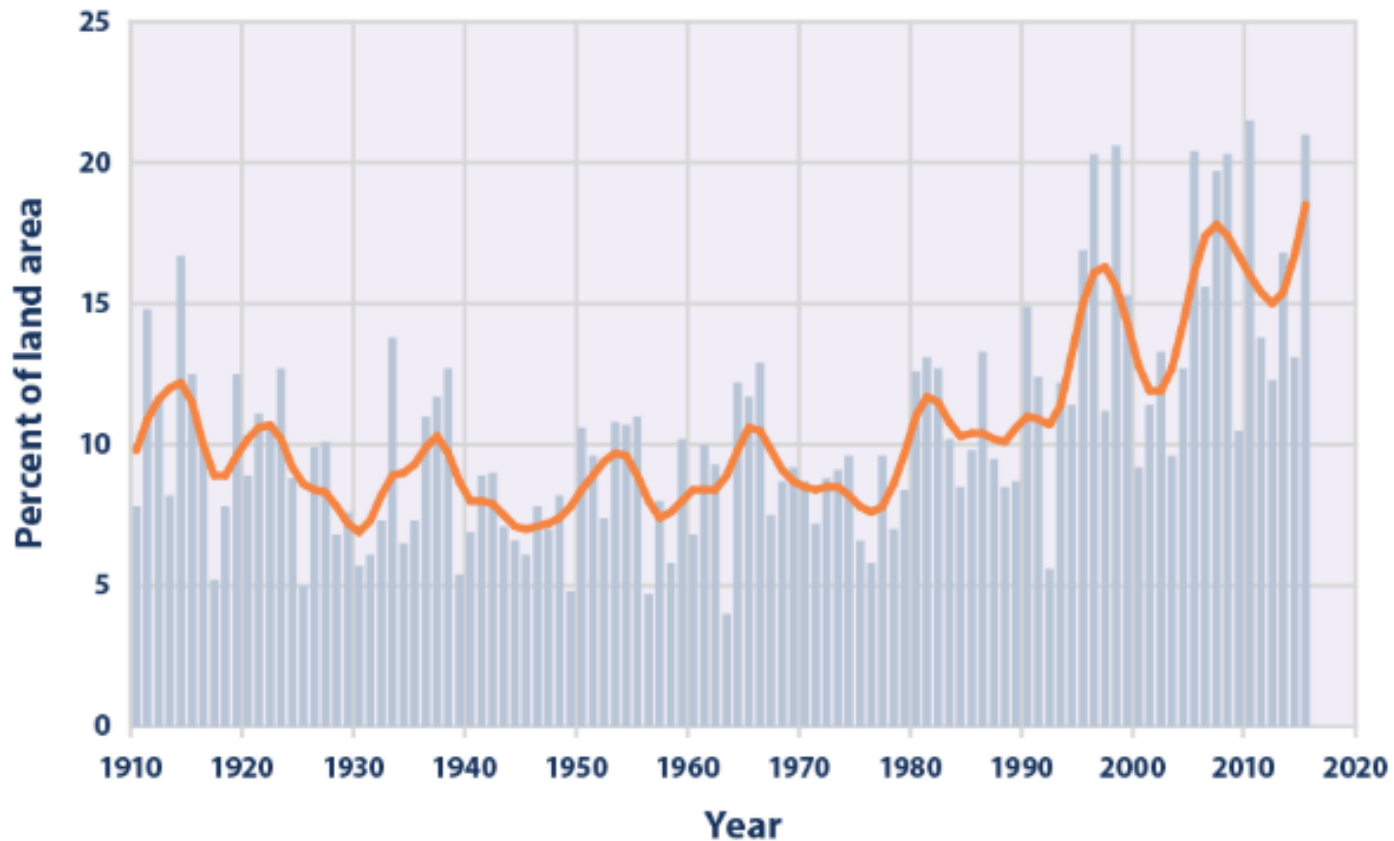
This figure shows the percentage of the land area of the contiguous 48 states where a much greater than normal portion of total annual precipitation has come from extreme single-day precipitation events.

The bars represent individual years, while the line is a nine-year weighted average.

Extreme Rain Events

Rainfall for 2-3 Days

**August 23, 201[?]
Hilo, HI: Hurric[?]**

National Weather Service
Weather Prediction Center
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Devastating Ellicott City, Maryland Flash Flood - Sunday, May 27, 2018
Update: 9 am EDT, Monday, May 28, 2018
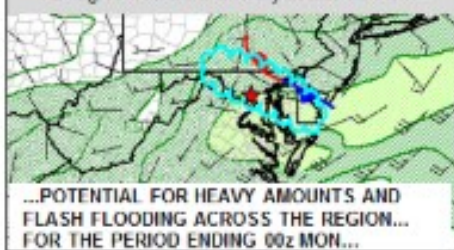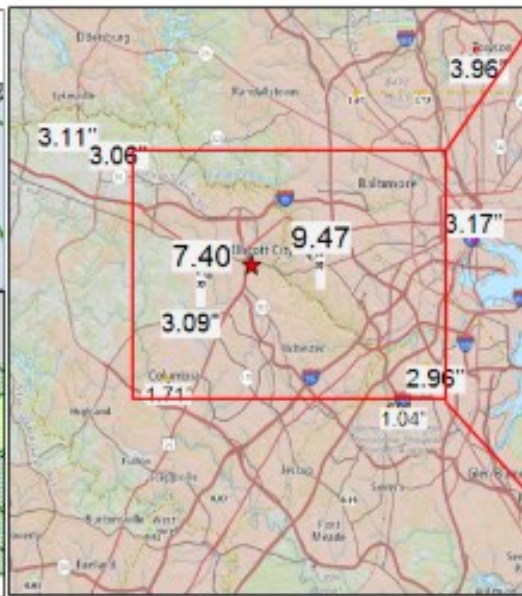
WPC outlooks and discussions for the affected area (marked by red star) ahead of the event

- **Predi[?]**

- **Under predicted by a factor of 3**
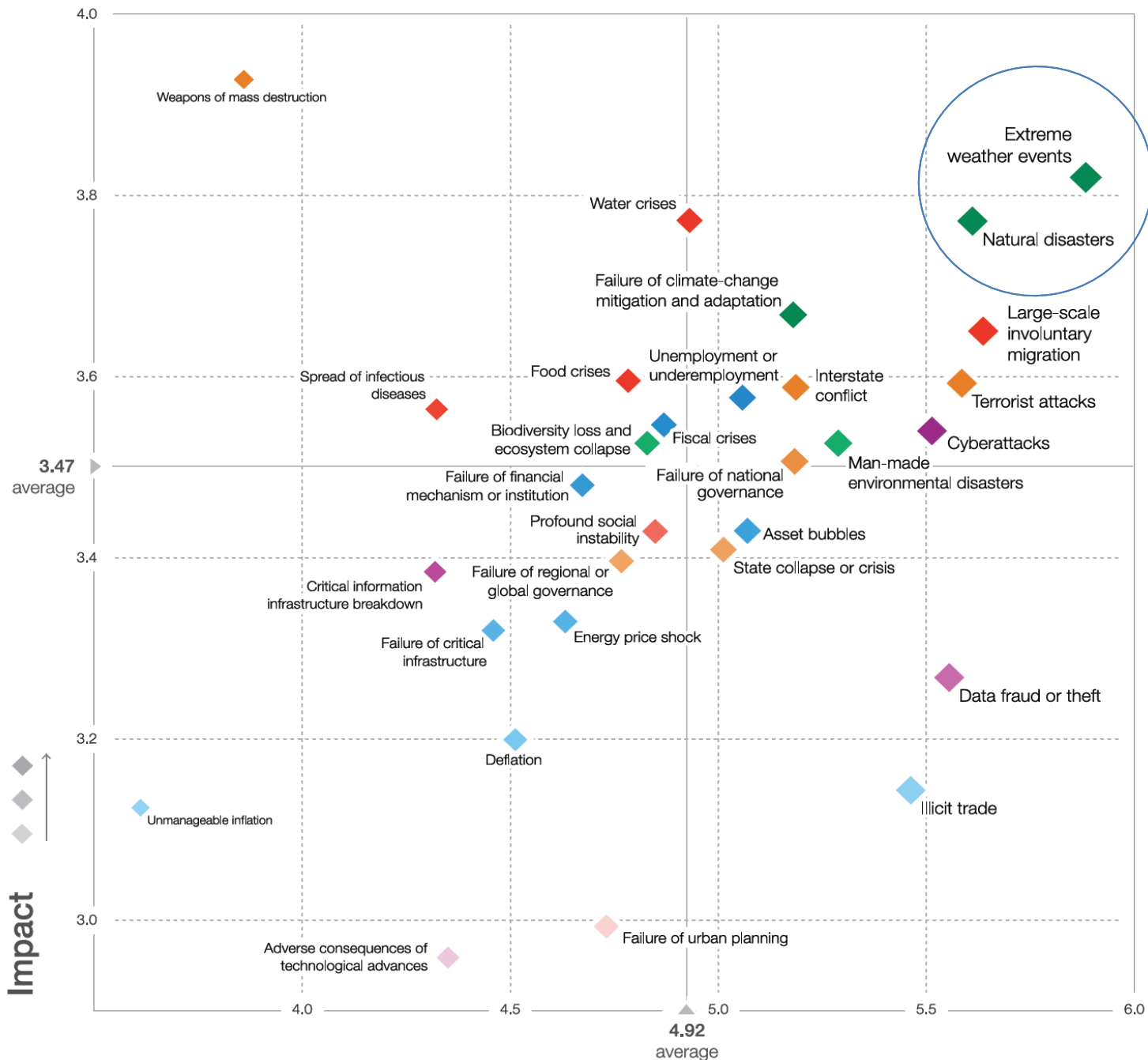
- **Major impacts on infrastructure**

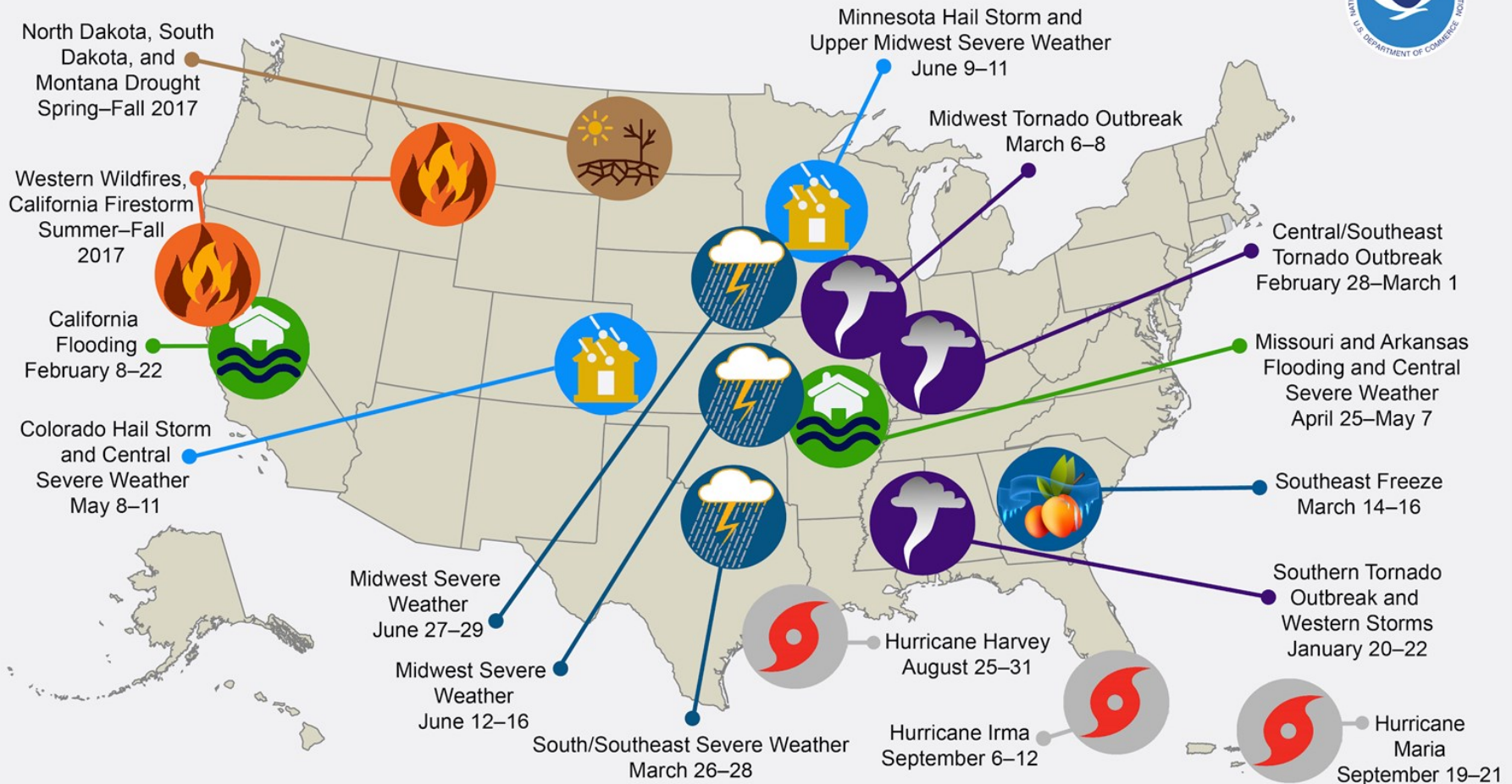**August 21, 2018:
Madison, WI**

Global Risks Landscape

World Economic Forum Davos 2018

Global Risks Landscape scatter plot. Horizontal axis: Likelihood (4.0 to 6.0), with 4.92 average. Vertical axis: Impact (3.0 to 4.0), with 3.47 average.

- Weapons of mass destruction
- Extreme weather events
- Natural disasters
- Water crises
- Failure of climate-change mitigation and adaptation
- Large-scale involuntary migration
- Spread of infectious diseases
- Food crises
- Unemployment or underemployment
- Interstate conflict
- Terrorist attacks
- Biodiversity loss and ecosystem collapse
- Fiscal crises
- Cyberattacks
- Failure of financial mechanism or institution
- Failure of national governance
- Man-made environmental disasters
- Profound social instability
- Asset bubbles
- Critical information infrastructure breakdown
- Failure of regional or global governance
- State collapse or crisis
- Failure of critical infrastructure
- Energy price shock
- Data fraud or theft
- Deflation
- Unmanageable inflation
- Illicit trade
- Adverse consequences of technological advances
- Failure of urban planning

2017: 16-billion dollar events
Totaling 306 billion in damages - a U.S. record

U.S. 2017 Billion-Dollar Weather and Climate Disasters

North Dakota, South Dakota, and Montana Drought Spring–Fall 2017

Western Wildfires, California Firestorm Summer–Fall 2017

California Flooding February 8–22

Colorado Hail Storm and Central Severe Weather May 8–11

Minnesota Hail Storm and Upper Midwest Severe Weather June 9–11

Midwest Tornado Outbreak March 6–8

Central/Southeast Tornado Outbreak February 28–March 1

Missouri and Arkansas Flooding and Central Severe Weather April 25–May 7

Southeast Freeze March 14–16

Southern Tornado Outbreak and Western Storms January 20–22

Midwest Severe Weather June 27–29

Midwest Severe Weather June 12–16

South/Southeast Severe Weather March 26–28

Hurricane Harvey August 25–31

Hurricane Irma September 6–12

Hurricane Maria September 19–21

This map denotes the approximate location for each of the 16 billion-dollar weather and climate disasters that impacted the United States during 2017.

Comparing Severe Weather Outbreaks

Super Outbreak :	April 3-4, 1974	April 27-28, 2011
Summary:	150 tornadoes across 13 states	~200 tornadoes across 16 states
Number and Strength:	6 F-5 tornadoes, 24 F-4	4 EF-5 tornadoes, 11 EF-4
Tornado Track Length:	2500 miles	2500 miles
Tornado Time:	50 hours	50 hours
Outbreak forecast :	"Indications" provided night before	4-6 days prior
Warning lead time:		~24 minutes
Fatalities:	316	314

Building a Weather Ready Nation: "A Vital Conversation"

December 2011 Workshop in Norman, OK

- Focus on the "last mile": delivery of warnings

- Assess and update warning dissemination strategy

- Integrate social and physical science

  - Is the message delivered equal to the message received?

  - Impact-based Forecast and Warnings for a wide range of decision makers (from 'organized' to 'loosely coupled' to 'individuals')

- Improved outreach and education

The Job Doesn't End with Forecasts and Warnings

"*First, it should be understood that forecasts possess no intrinsic value. They acquire value through their ability to influence the decisions made by users of the forecasts.*"

"What is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting"
  – *by Allan H. Murphy; Weather and Forecasting (June 1993)*
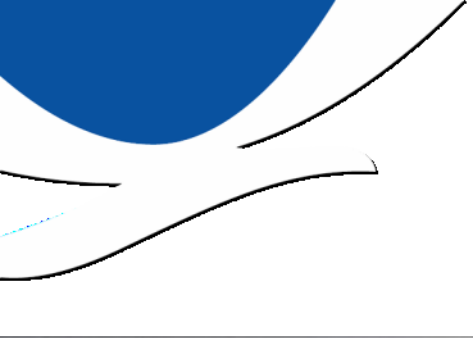
Building a Weather-Ready Nation

Becoming a Weather-Ready Nation is about **building community resiliency in the face of increasing vulnerability** to extreme weather, water and climate events.

Touching every county every day.
Supporting national security and public safety.

"Ready, Responsive, Resilient"

Better forecasts and warnings   *Actionable environmental intelligence*

Consistent products and services

Involves the entire US Weather, Water and Climate Enterprise WORKING TOGETHER

We have 8200+ WRN Ambassadors

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Becoming a Weather-Ready Nation Relies on the NWS Connecting Forecasts to Decisions Based on

Generating forecasts and warnings **+** **Connecting those forecasts/warnings with partner decision-making process** **=** **Impact-based Decision Support Services**

Practice, practice, practice!

Realizing Intrinsic Value and Mission Success

Embed

Trust

The best hydrometeorological forecasting in the world

Develop relationships / know partner needs

"Ready, Responsive, Resilient"

Impact-Based Decision Support Services

- Now authorized by **Federal Law**:

  The 2017 Weather Research and Forecasting Innovation Act authorized the NWS to address "increasing IDSS needs...at the Federal, State, local, Tribal Nations..." "within current resources"

- Recent review shows that 94% of IDSS provided at local levels for all service areas - demands sustained local presence.

The Complexity of supporting decision processes in the United States that save lives and property

- We have rediscovered Alexis de Tocqueville(1835):

  - "The Europeans accustomed to finding a functionary* always at hand to interfere with all he undertakes...reconciles himself with difficulty to the <u>complex mechanisms</u> of the administration of the townships...in the United States."

  - de Tocqueville referring to his discovery that nearly all the decisions for the public welfare/safety in the United States are made at local levels – town halls – not the states – not the federal (central) government!

  * From the national/central government

As we have found with WRN – not much has changed

**Rhode Island: "Storm Ready State" celebration
39 Townships Make The Decisions (February 2, 2018)**

With Governor Gina Raimondo

**NWS has committed itself to serving the "complex mechanism"
of local decision makers who save lives**

What Does it Mean for the NWS and its Workforce ?

Building a Weather- & Water-Ready Nation will change the way we work–and change the nature of our products:

- Becoming more oriented toward Earth System Sciences (atmosphere, ocean, land, cryosphere)
- Incorporating Social Science - ensure message delivered equals message received for desired outcomes (e.g. How to describe and display "storm surge?")
- Understanding decision makers and their "shifting risk preferences" before/during/after an event
  - *"Organized" – Government (NWS Focus Area)*
  - *"Loosely Coupled" – Social Organizations*
  - *"Organic" – Individuals*
- Connecting observations/forecasts/warnings to "Key Decision Points" in all service areas
- How we measure success: determining intrinsic value of the forecast and IDSS

Hurricane Arthur
Potential Storm Surge Mapping
'Best Guess, Worst Case Scenario'

NHC Experimental Potential Storm Surge Flooding Map
Tropical Storm ARTHUR (2014) Advisory 7
From 11 AM EDT Wednesday July 02 to 04 PM EDT Saturday July 05

2-5 July 2014
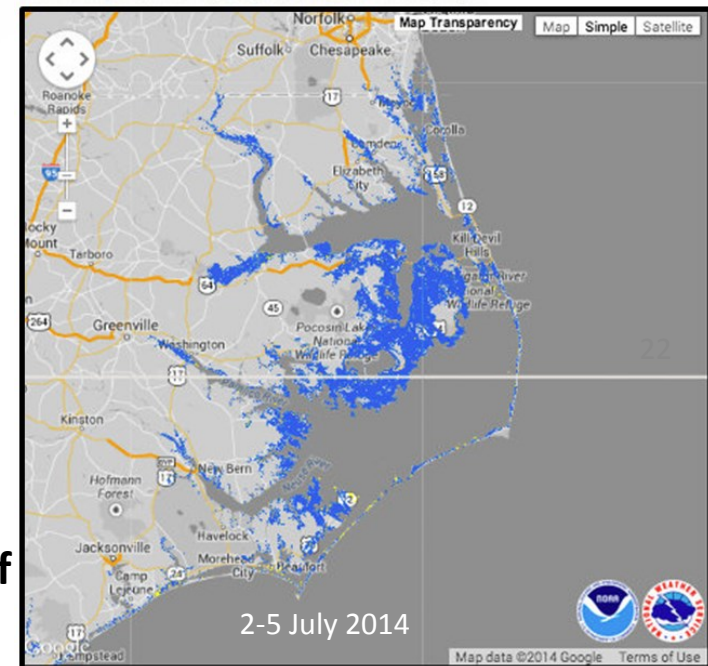
The NWS must evolve to complete these goals
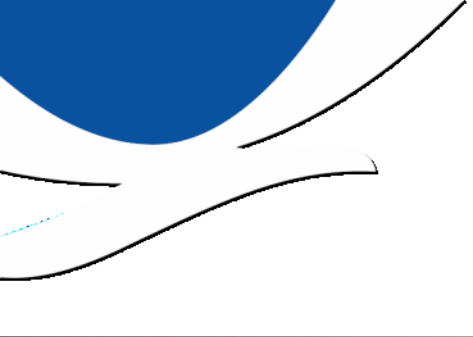
So how are we doing?

Post Christmas Storm (Dec. 25-28, 2015): The Spectrum of IDSS

Preparedness

Federal and State Actions

- Increased level of coordination across federal, state and local jurisdictions before, during, and after the event
- Maintained situational awareness through NWS and liaison briefings (as early as Dec 22)
- Alerted response teams and assets for possible activation or deployment (over holiday weekend)
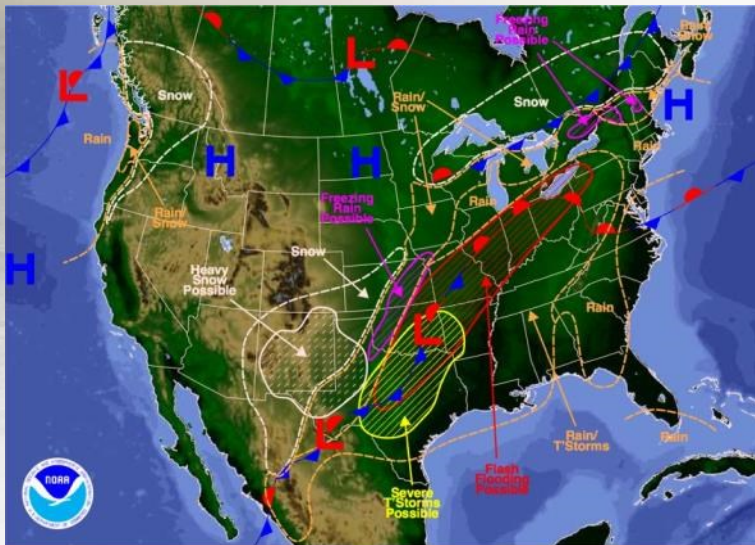
Weather Forecast for Sat, Dec 26, 2015, issued 4:29 PM EST
DOC/NOAA/NWS/NCEP/Weather Prediction Center
Prepared by Santorelli based on WPC, SPC and NHC forecasts

Immediate Response

Tornadoes

- Federal, state, local mobilized for widespread impact
- WFO Fort Worth made preliminary tornado tracks working with SR-ROC and liaisons;
- FEMA analyzed impacts to support activation and deployment decisions

Blizzard

- State and local municipalities mobilized to address road conditions, open shelters, on call for emergencies

Flooding

- Emergency Response Specialist (ERS) deployed to FEMA VII Regional Response Coordination Center
- NWS embeds with state EOCs, with FEMA, highlighted greatest flood risk to support staging operations over large domain

Photo: News Channel 10 – Amarillo, TX

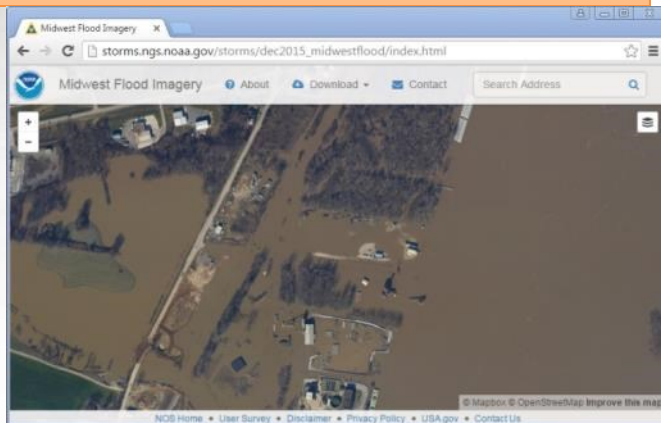Photo: St. Louis Post Dispatch

States of Emergency Declared
Dec 27: TX/NM/MO; Dec 28: OK; Dec 29: IL; Dec 30: MS/LA

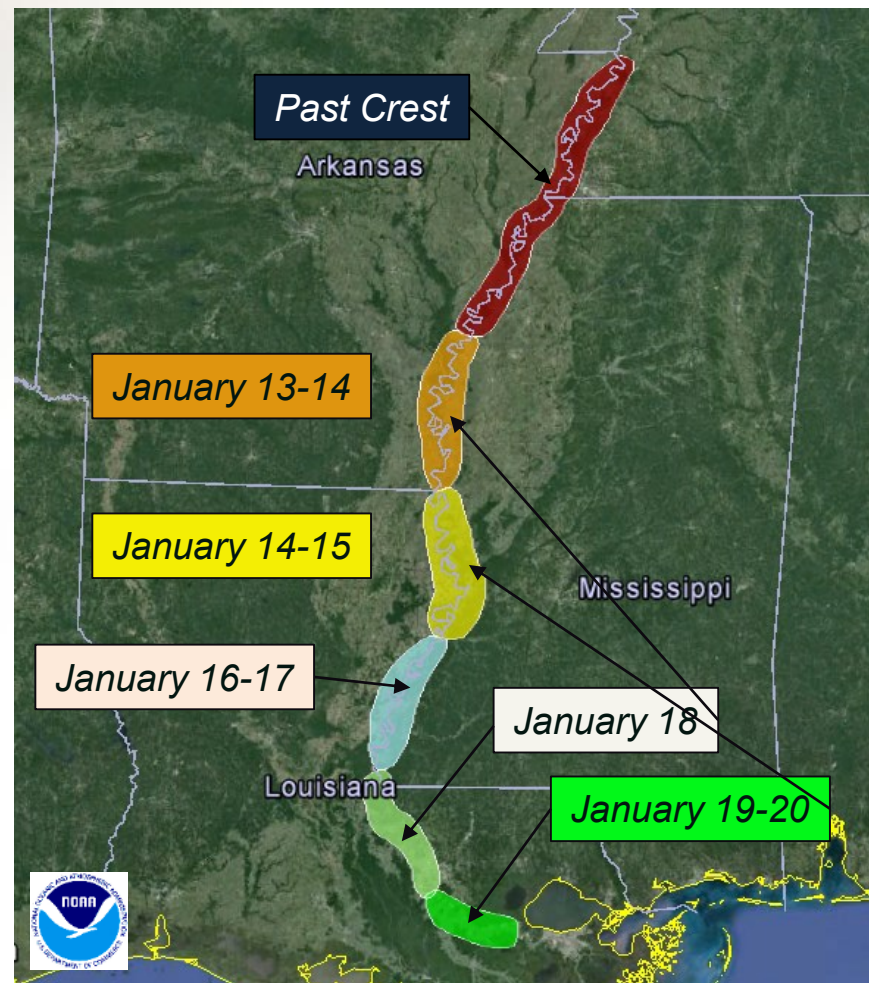# Post Christmas Storm (Dec. 25-28, 2015): The Spectrum of IDSS

Response and Recovery

Long-Duration River Flooding

- NOAA Liaison provided location and timing of peak crests along affected rivers:
  - to help FEMA and states define when NOAA and interagency remote sensing capabilities should be executed
  - imagery captured real-time visual impacts during worst conditions to support NWS RFC operations as well as inform disaster declaration (recovery) decisions
- NWS Central and Southern Regions worked closely with FEMA Regions and States to define the events for declaration requests
- Central Region ROC continues to provide IDSS for debris removal operations in southern Missouri

NOAA King Air Aircraft

Past Crest

Arkansas

January 13-14

January 14-15

January 16-17

January 18

Mississippi

January 19-20

Louisiana

Appreciation for IDSS

"I want to first fully thank the dedicated professionals here at the National Weather Service for providing us with the most updated forecast briefing this afternoon and for their continued hard work as part of the effort to protect lives and property. Folks here are incredibly professional. We rely on them, and they don't let us down. We tremendously appreciate, especially over the holidays, how they're always there and always helpful, doing the best they can to help law enforcement and others."

Missouri Governor Jay Nixon following the 2015 December Holiday storm and January 2016 Flooding

1153Z Jan 21, 2016 2km Base Reflectivity/Latest WPC Surface Analysis
NWS Winter Weather Advisories(purple),Watches(white),Warnings(red)
NWS Convective Watches/Warnings (Tor=red, SvrTst=blue, FFld=green)
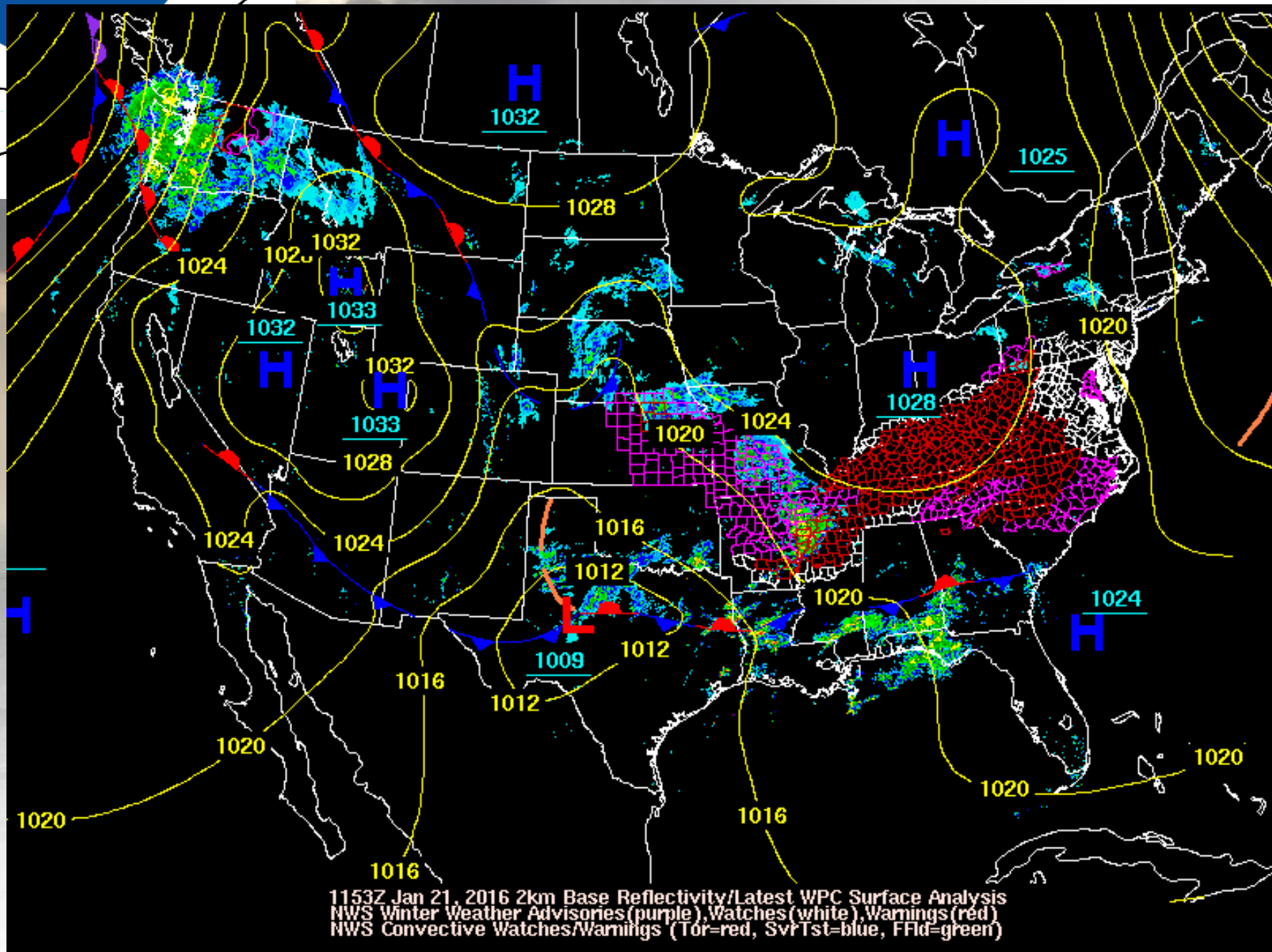
January 2016 Blizzard & Coastal Storm: Connecting All of the Pieces

Jan 15 - 18	Jan 19	Jan 20	Jan 21	Jan 22
Medium range products begin identifying snowstorm threat for the end of next week	Confidence increasing	Partner Coordination/ Briefings	Fed./state/local govts make critical decisions **before** the snow begins	Snow begins in the Mid-Atlantic
NWS offices begin briefing partners on potential storm	Partner Coordination/ Briefings	**Blizzard Watches Issued**		Snow forecast adjusted to include NYC in Blizzard Warning
	Media interviews	Media interviews	Blizzard Warnings Issued	
			Flights Canceled	Schools/Govt Close Roads Closed
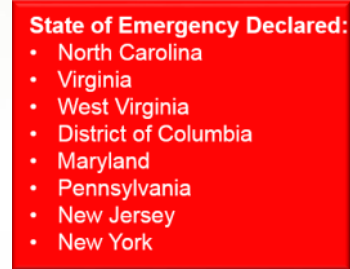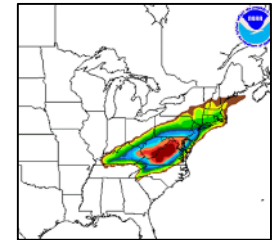
State of Emergency Declared:
- North Carolina
- Virginia
- West Virginia
- District of Columbia
- Maryland
- Pennsylvania
- New Jersey
- New York

1 pm: Press Briefing

Connecting All the Pieces

2013 Snowstorm

2016 Snowstorm

Long Island Expressway

With NWS Decision Support

The Past

Without NWS Decision Support
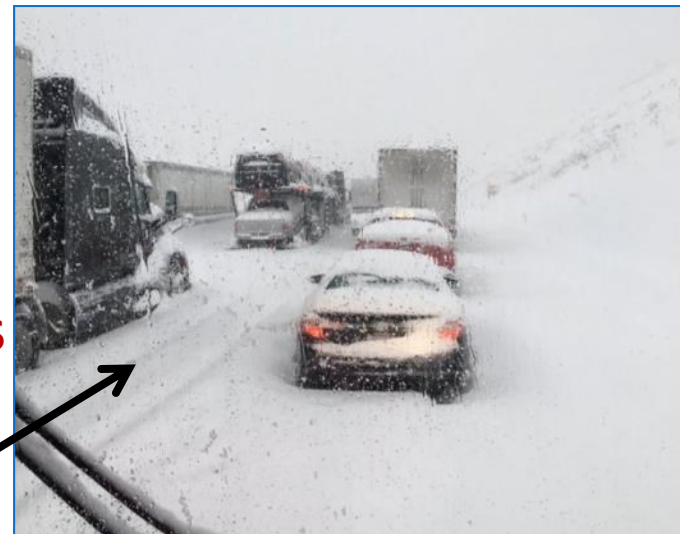
Pennsylvania Turnpike

2017 East New Orleans Tornado

Date :	February 7, 2017
Strength:	EF-3
Track Width:	1/3 mile
Tornado Track Length:	10 miles
Warning lead time:	~33 minutes
Injuries	33
Fatalities:	**0**

- NWS local outreach and preparedness activities <u>over a 4-year period</u>
- Deep relationships with Emergency Managers/WRN Ambassadors
- Dissemination of forecasts and warnings
- Public awareness
  - Daytime event, visual confirmation, schools sheltered
- Collaborative forecast preparations within NWS and the larger enterprise a success
  - **Over 100 meetings and table-top exercises held in the city in the year preceding event**
- IDSS provided days in advance of the tornado

GOES-16 (Engineering Check-Out in 2017)
Harvey Rapid Intensification

31

1 0001 G-16 IMG   2 25 AUG 17237 181525 00755 00620 01.00

CIRA/RAMMB
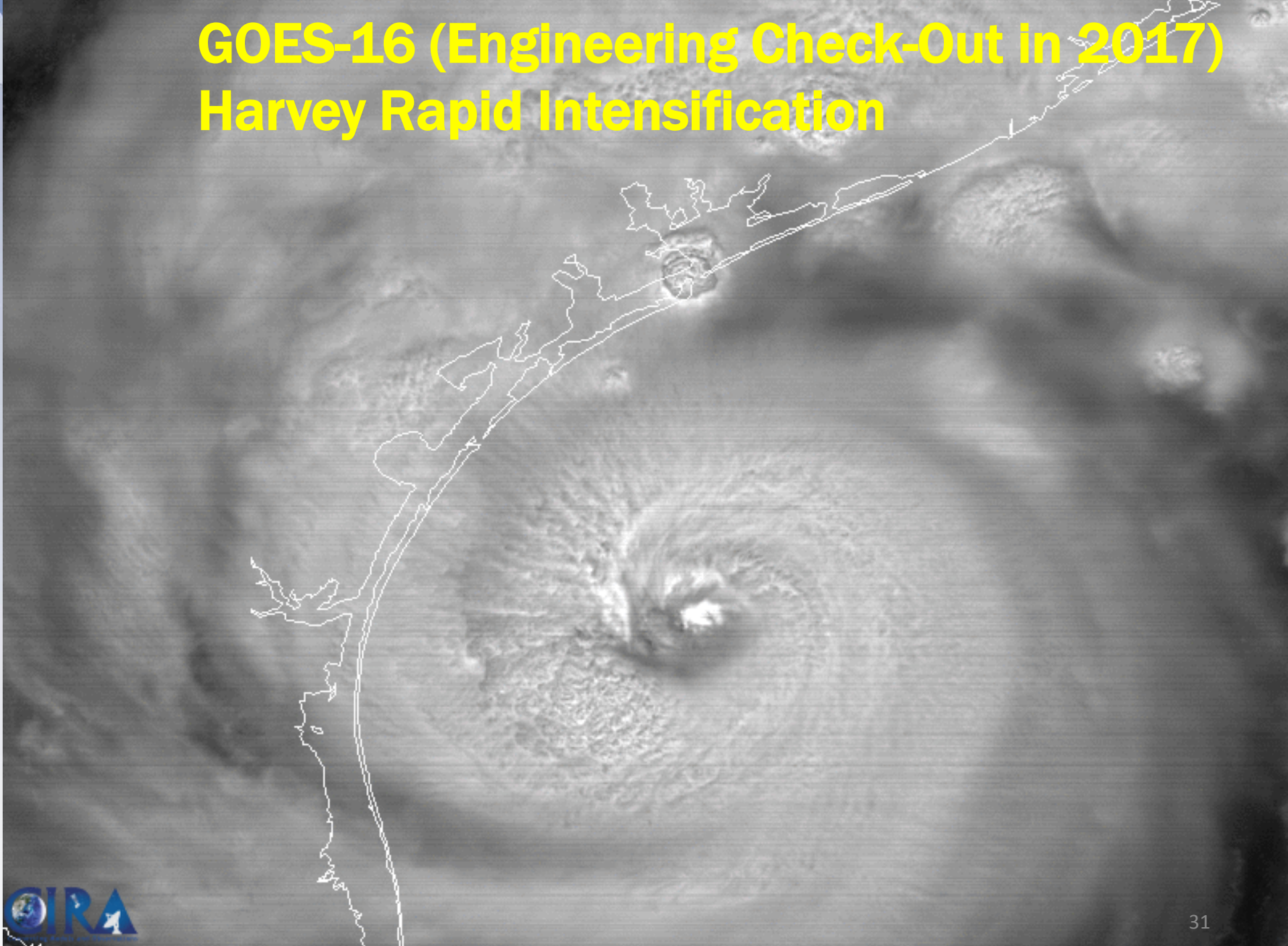
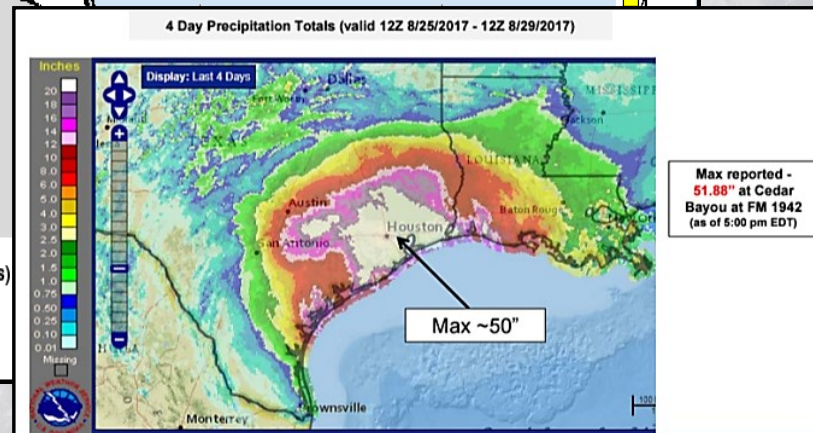# Harvey: WPC 5-Day Rainfall Forecast

Issued Monday, August 28, 2017

"The breadth and intensity of this rainfall are beyond anything experienced before and catastrophic flooding is now underway and expected to continue for days. 50 inches will be possible by end of the week."
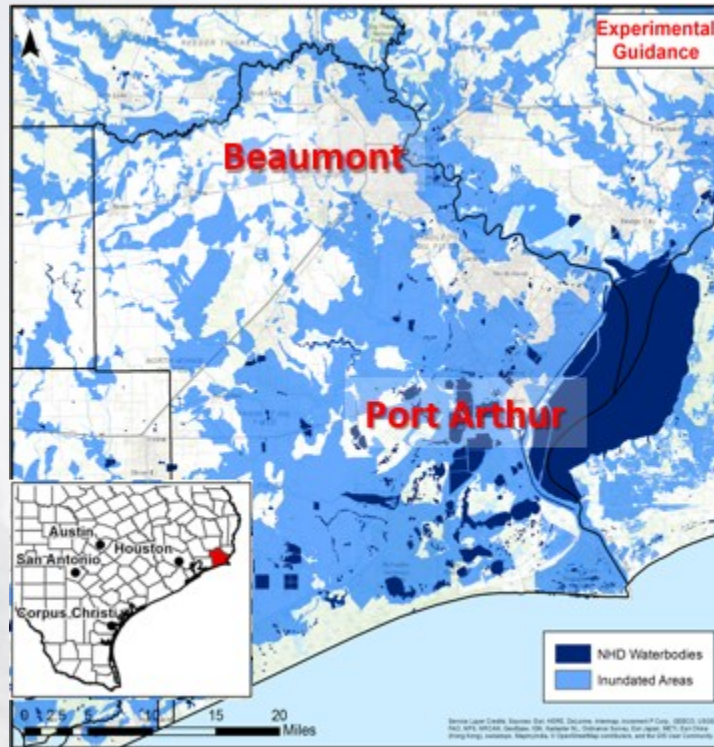
- WPC Forecast Discussion

WPC briefing to FEMA
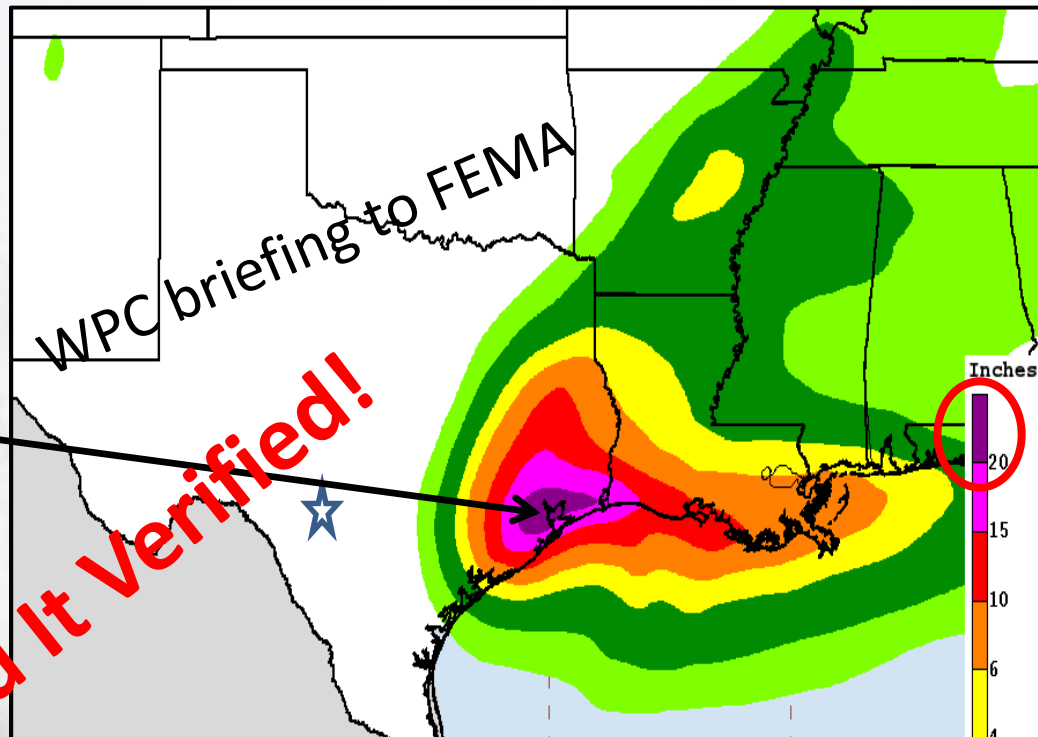
And It Verified!

Inches

Tropical Storm HARVEY
120-hour Day 1-5 Rainfall Forecast (inches)
Created 7:17 AM CDT Mon Aug 28 2017
Valid 7:00 AM CDT Mon Aug 28 2017
through 7:00 AM CDT Sat Sep 2 2017
NOAA/NWS/NCEP/WPC

4 Day Precipitation Totals (valid 12Z 8/25/2017 - 12Z 8/29/2017)

Display: Last 4 Days

Inches

Max reported - 51.88" at Cedar Bayou at FM 1942 (as of 5:00 pm EDT)

Max ~50"

Harvey: Experimental National Water Model (NWM) Guidance

- **Flood inundation maps based on NWM forecast using 5-day quantitative precipitation forecast**

- **Texas Department of Emergency Management needed information on exisiting and maximum possible flood extent**

- **Maps supported emergency management efforts to stage supplies in non-flooded areas and to target relief efforts**
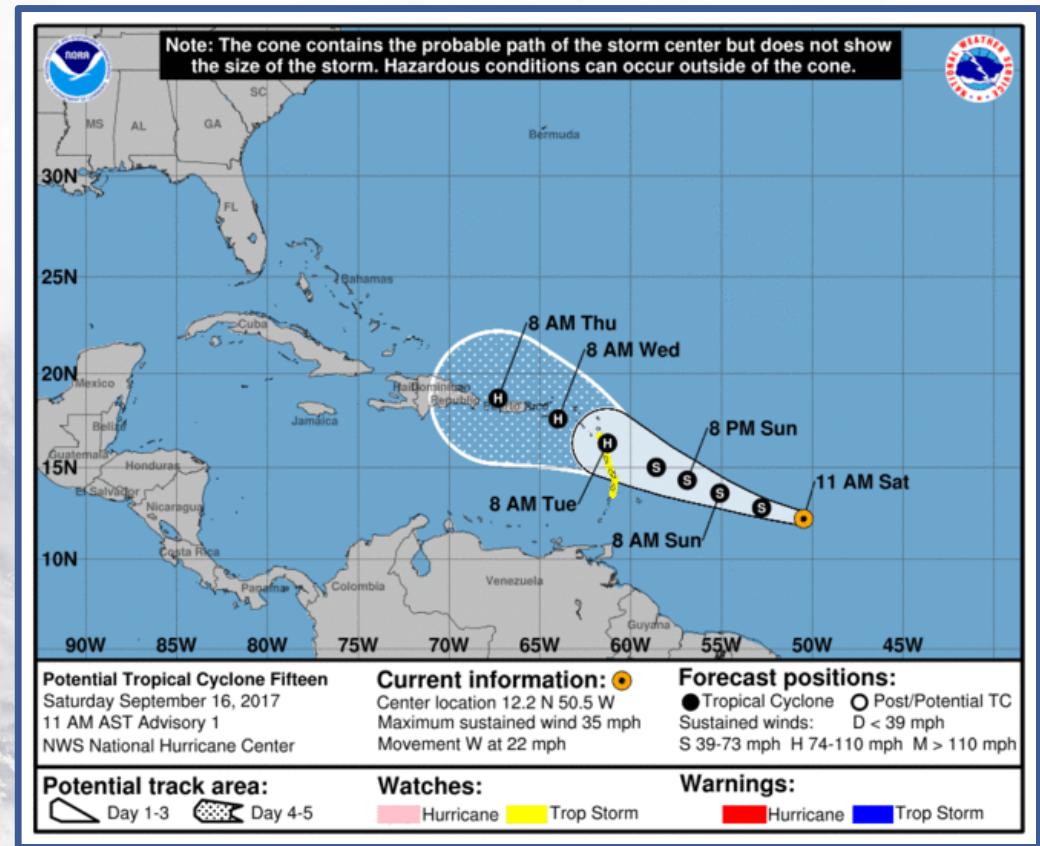
Irma

- ✓ Models predicted Irma becoming a hurricane before the tropical depression formed in the eastern Atlantic.

- ✓ NWS indicated threat for southeastern U.S. 8-10 days in advance

- ✓ Sharp right turn to the north was expected based on strong ensemble agreement
  - Exact turn with regard to the FL peninsula was uncertain; but confidence was high enough to alert Southeast U.S. and focus on Florida.

- ✓ **Florida Governor declared a State of Emergency on Monday, six and a half days before landfall**

- **Forecast for the right turn verified!**
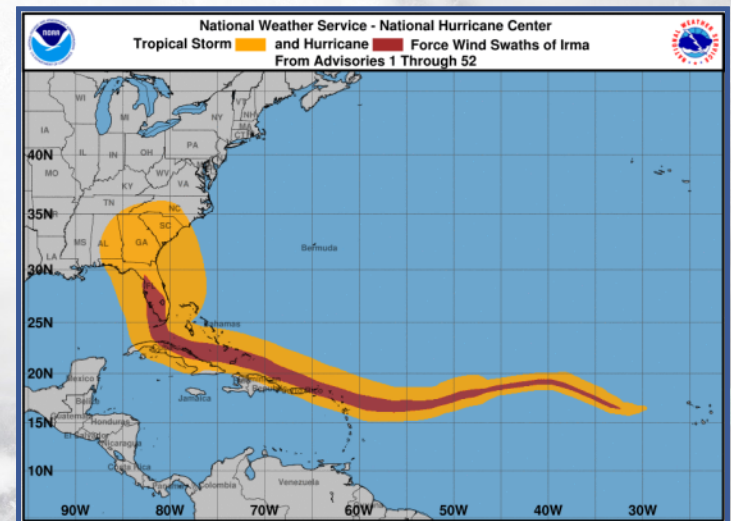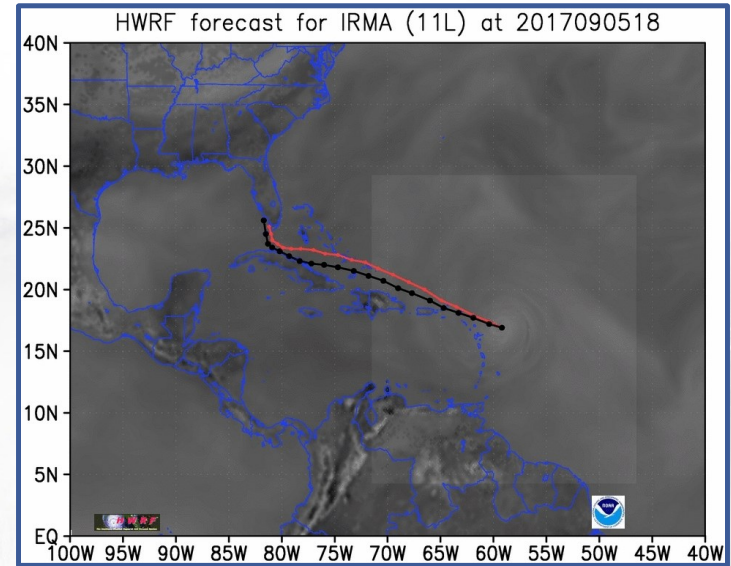
Forecasts and Impact Decision Support Services (IDSS)
Maria

- ✓ Track forecasts for Maria were very accurate
  - GFS had the best track forecast stats
  - Intensity forecasts proved challenging
- ✓ 5, 4, 3 …. day forecasts had Maria tracking over Puerto Rico
  - Strong winds and heavy rainfall were the main threat
  - IDSS --> 5 days in advance
- ✓ Email briefings every 3 hours with partners 3 days in advance of landfall in Puerto Rico
  - Briefings to FAA and military to coordinate evacuations
- ✓ IDSS provided during the extended recovery phase

Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

Potential Tropical Cyclone Fifteen
Saturday September 16, 2017
11 AM AST Advisory 1
NWS National Hurricane Center

Current information: ⊙
Center location 12.2 N 50.5 W
Maximum sustained wind 35 mph
Movement W at 22 mph

Forecast positions:
● Tropical Cyclone ○ Post/Potential TC
Sustained winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110 mph

Potential track area: ◻ Day 1-3 ▨ Day 4-5
Watches: ▮ Hurricane ▮ Trop Storm
Warnings: ▮ Hurricane ▮ Trop Storm

Forecasting Improvements Over the Past 25 Years

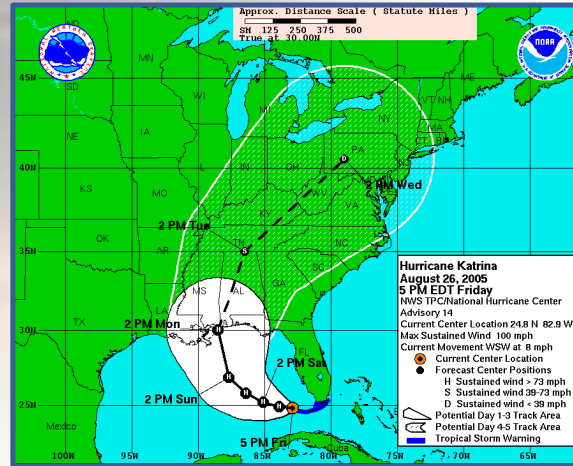## Andrew 1992


Brian Norcross

Katrina 2005

Irma 2017

➢ Policy: Global models not used for official forecast

➢ GFS did capture an "L" with one or two closed isobars - considered a success!

➢ Policy changed after Andrew

➢ Accelerated use of models for 5-day forecasts

➢ Model runs captured intensification/track - broad "cone of uncertainty"

➢ Intensity changes advertised 1-2 days in advance – still a major challenge
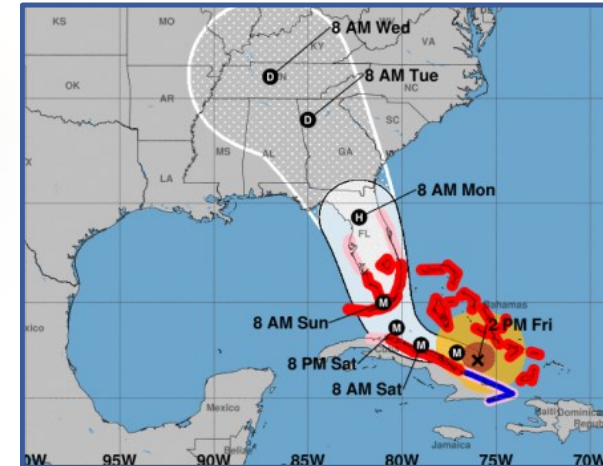
➢ 10-day model runs used to track Irma:
  ➢ development of storm as a wave exited Africa
  ➢ right turn in the track predicted as storm approached Florida

➢ Still have issues nailing down the details
  ➢ Small track changes approaching Florida
  ➢ Rapid intensity changes

Impact Based Decision Support Services Improvements

Andrew 1992

Katrina 2005

Harvey/Irma/Maria 2017

- NHC connected with National/State EMs

- FEMA/National Recovery assets <u>not</u> prepositioned

- Slow to react to natural disasters

- National response tempo took ▮▮▮▮ LANDFALL to recognize impact and then rise up to meet the challenges

- NHC connection with National/State EMs expanded

- <u>Variable connectivity</u> with local, state/parish EM community

- National pre-coordination of response was problematic in some states

- Recovery, supplies overwhelmed

- Entire NWS connected to National, State, Local Emergency and Water Resource Managers

- Strong connection (embedding) <u>at every government level, especially at the local level</u>

- All hands on deck to support field structure before, during, and after events –NWS surges resources where needed!!

- Ready-Set-Go with EM community <u>7 days in advance of landfall</u>

- CONSISTENT messaging of forecasts and impacts to all partners

Impact Based Decision Support
Days Prior to Landfall

	HARVEY AUG 17 – SEPT 1	IRMA AUG 30 – SEPT 12	MARIA SEPT 16 – SEPT 20
External Partner Engagements: Briefings to Emergency Managers	7	11	5
Embedded with Emergency Operation Centers	7	6	3
"All Hands on Deck" – Internal Staffing Surge to Effected Offices	3	6	4
Internal Collaboration Calls (Centers, WFO, RFC, CWSU)	4	5	4

US Deaths :   **88**   **97**   **>2900***

* - estimated and predominately post-storm

How do we Measure Success?

One of the bigger challenges for those who hold us accountable to realize the intrinsic value of our forecasts and warnings is how we measure success (economic, societal, reduced deaths/injuries) and document increased preparedness.

"Partnership with the NWS has revolutionized the EM community from one that reacts to events to one that proactively prepares and stays ahead of extreme events." - Eric Waage

Director of Emergency Management, Hennepin County Minnesota
Northern Plains Winter Weather Workshop, November 2016

Florida's unusually long red tide is killing wildlife, tourism and businesses

RED TIDE

Red tide in Florida and Texas is caused by the rapid growth of a microscopic algae called *Karenia brevis*. When large amounts of this algae are present, it can cause a harmful algal bloom (HAB) that can be seen from space. NOAA issues HAB forecasts based on satellite imagery and cell counts of Karenia brevis collected in the field and analyzed by NOAA partners.

Why Should You Care?

Red tide in Florida and Texas produces a toxin that can have harmful effects for marine life. For people, the toxin can become airborne and cause respiratory issues and eye irritation. These symptoms can be more severe for people with serious respiratory issues such as asthma.

N. Pleasant Palm Beach ▶

◀ S.Pleasant Palm Beach

Making Choices

State and local resources are available to help beachgoers find beaches and coastal areas that are not impacted by Red tide, but are still nearby.

Ecological Predictions by NOS
IDSS Provided Through Local NWS WFOs

Dead fish line the beaches of Panama City. Photo: Randy Robinson

Weather Ready Nations (WRNs) Pilot Program

- IDSS is viable and useful for all countries
- NWS develops pilots with USAID/OFDA and encourages participation from other WMO Members
- WRNs pilots (2-3 years each) share IDSS lessons learned and best practices
- 6 WRNs pilot projects: El Salvador, Guatemala, Costa Rica, Barbados, S. Africa, Indonesia (w/Met Office)
- Upcoming: Croatia (September 2018) and Sri Lanka (January 2019)

Weather Ready Nations

The Weather Ready Nations (WRNs) demonstration projects, supported by USAID/OFDA and NOAA, represent a paradigm shift in how we think about weather forecasting. We are:

Moving from just what the weather *will be*
- 6 inches of rain
- 40 mph winds

To also include what the weather *will do*
- Roads flooded
- Communities cut off
- Power lines down

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Disaster managers and traditional weather forecasting agencies must work closely together to create an impact-based forecast

Disaster management agencies contain detailed geographic spatial information on the vulnerabilities of local communities. These agencies traditionally lead in the warning of communities at risk.

Forecasters using the latest science based weather predictions decide on the likelihood of an impact, and together with disaster managers decide on an appropriate warning level according to the risk matrix.

Risk Matrix
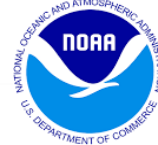
The Process

- **Disaster Managers and Forecasting Weather Agencies jointly develop hazard matrices (thunderstorm, snow).**

- **Forecasters compile science based weather predictions.**

- **Disaster management agencies provide detailed geographic spatial information on the potential for human and economic losses.**

- **Forecasters decide on the likelihood level and together with disaster managers agree on an appropriate warning level according to the risk matrix.**

- **Forecasters and Disaster managers coordinate to issue a warning.**

- **Disaster Managers and Forecaster coordinate to monitor progress and share situation reports .**

Summary

- The US NWS is leading the US Weather, Water, Climate Enterprise in Building a Weather-Ready Nation (BWRN) and now involving 8200+ WRN Ambassadors and organizations across the U.S.

- We are now moving beyond the forecast and warning -- connecting these to decision makers at the Federal, State, Local and Tribal Nation.

- Building a Weather-Ready Nation and providing increased IDSS and the Federal, State, Local, and Tribal Nation level authorized by the Weather Act that was signed into law in April, 2017.

- Initial successful outcomes -- effective life and property saving decisions have energized the NWS workforce and all core partners. Demand for IDSS continues to increase across all service areas.

- Changing the nature of the workforce includes Earth System Science & Social Science

- Spreading the Gospel! With USAID, OFDA and WMO members, 6 Pilot Projects to Build Weather Ready Nations (WRNs) are currently underway, with 2 more in development.

Thank You