Advancing Prediction of Extreme Events

Dr. Wayne Higgins
Director, Climate Prediction Center

NOAA-EPA-WERF-WaterRF-CTC-Noblis
December 17, 2012

Acknowledgments

Louis Uccellini

Robert E. Livezey

Thomas R. Karl

CPC and CSD Staff

Climate.gov Staff

NOAA Climate Adaptation Team

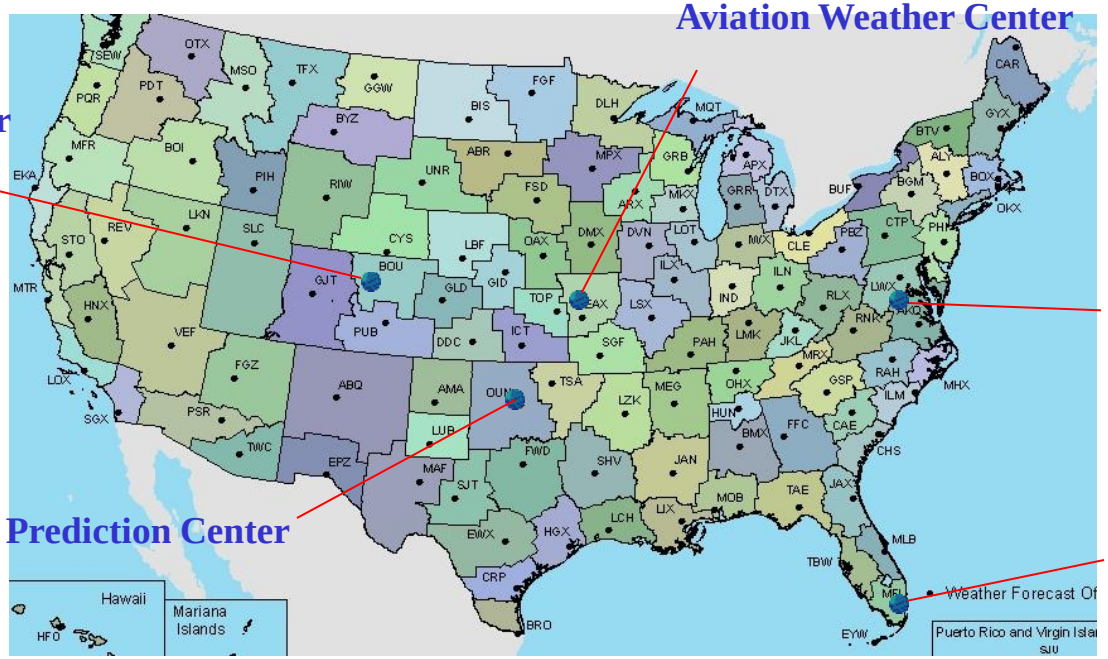
Outline

- National Centers for Environmental Prediction (NCEP)
- Recent Forecast Successes: Contrasting Then and Now
  - *East Coast Snowstorms*
  - *Severe Weather Outbreaks*
  - *Hurricanes*
- A First Look at Hurricane Sandy
  - *Basic Characteristics*
  - *Collaborative Forecast Process*
- Trends in Weather Extremes
  - *Billion Dollar Disasters*
  - *Key Issue: Water Distribution*
  - *Hurricanes in the Atlantic Basin*
- Extras
  - *NOAA Climate Products and Data*

NCEP Supports the NOAA Seamless Suite of Climate Weather and Ocean Products

Organization: Central component of NOAA National Weather Service

Mission: NCEP delivers science-based environmental predictions to the nation and the global community. We collaborate with partners and customers to produce reliable, timely, and accurate analyses, guidance, forecasts and warnings for the protection of life and property and the enhancement of the national economy.

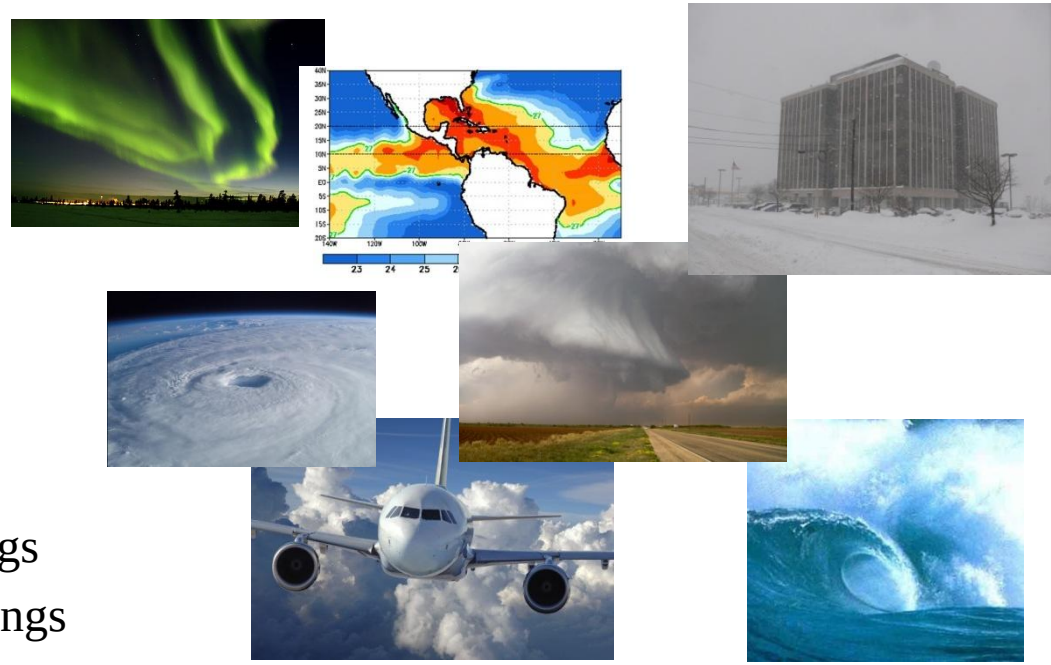


Vision: The Nation's trusted source, first alert and preferred partner for environmental prediction services

What Does NCEP Do?

"From the Sun to the Sea"

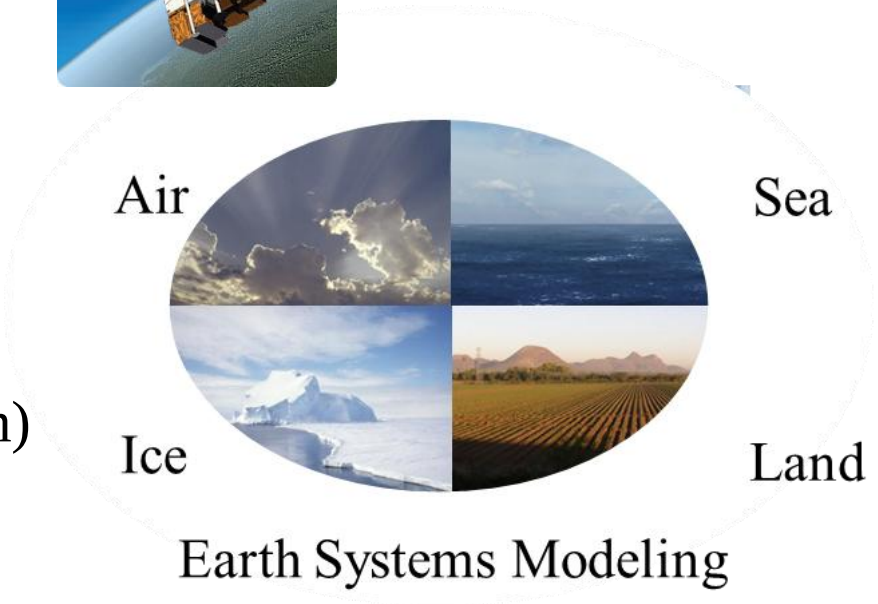
- Solar Monitoring, Warnings and Forecasts
- Climate Seasonal Forecasts
- El Nino – La Nina Forecast
- Weather Forecasts to Day 7
- Extreme Events (Hurricanes, Severe Weather, Snowstorms, Fire Weather)
- Aviation Forecasts and Warnings
- High Seas Forecasts and Warnings



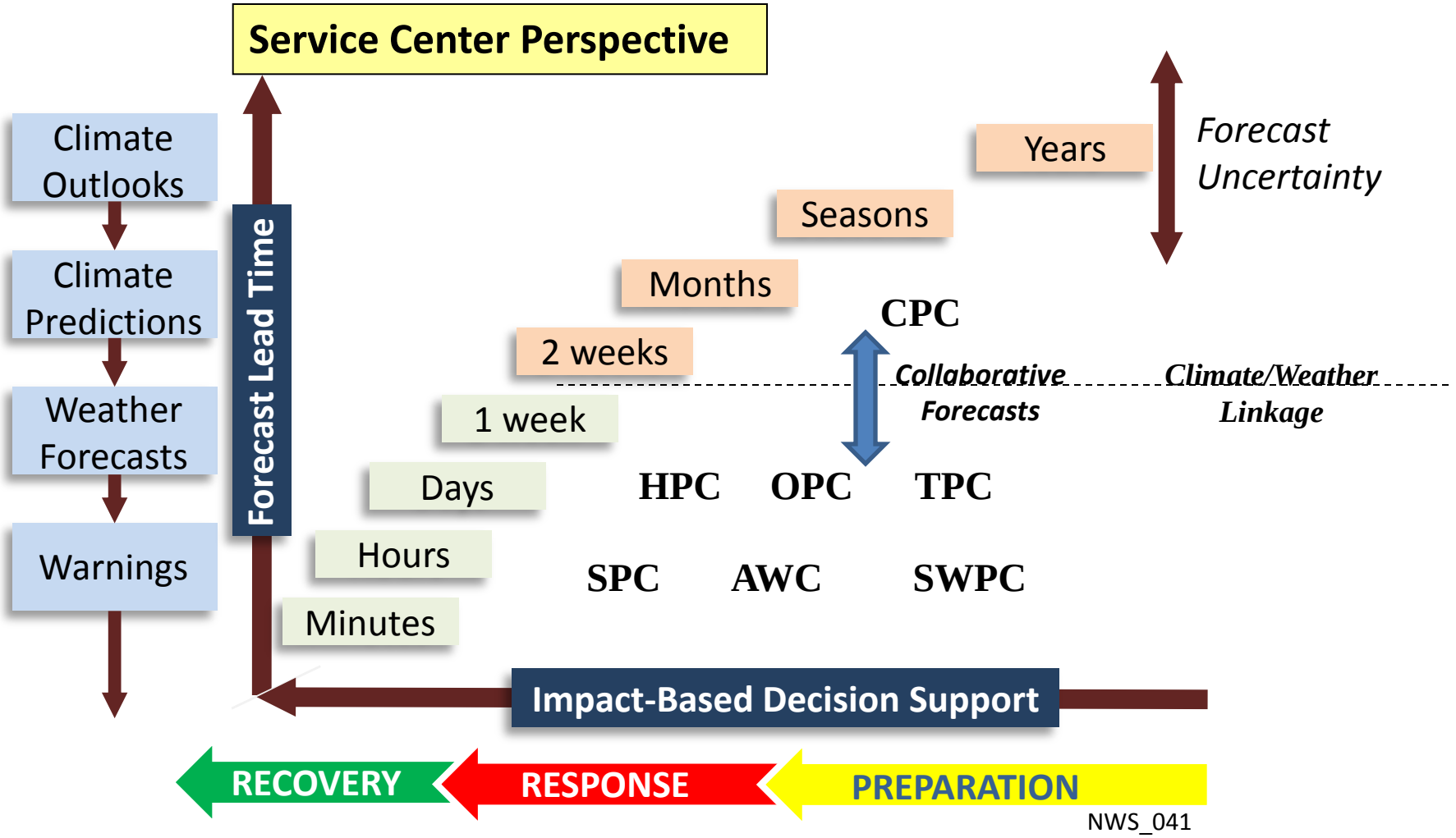
- Model Development, Implementation and Applications for Global and Regional Weather, Climate, Oceans and now Space Weather
- International Partnerships in Ensemble Forecasts
- Data Assimilation including the Joint Center for Satellite Data Assimilation
- Super Computer, Workstation and Network Operations

Three Major Components of Today's Operational Numerical Prediction Enterprise

- Observations
  - ~2 billion/day
  - 99.9% remotely sensed, mostly satellites
- Model
  - Earth System model; coupled
  - Global resolution (27km)
  - North American resolution (4km)
- Computer
  - 2012
    - Primary/backup15 minute switchover
    - 73 trillion calc/sec – IBM Power 6
  - 2013
    - 146 trillion calc/sec – IBM iDataPlex Intel/Linux



NOAA Seamless Suite of Forecast Products Spanning Climate and Weather

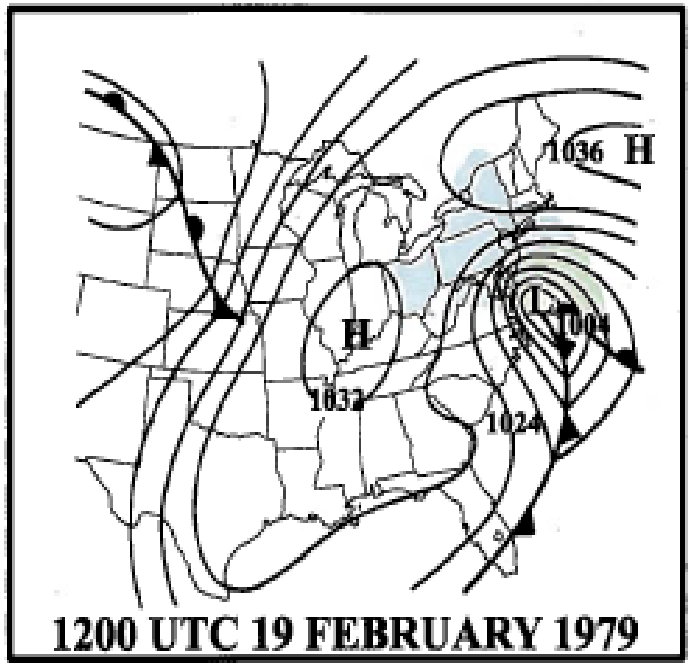


7

Recent Forecast Successes

Contrasting Then and Now

Presidents' Day Storm 18-20 February, 1979



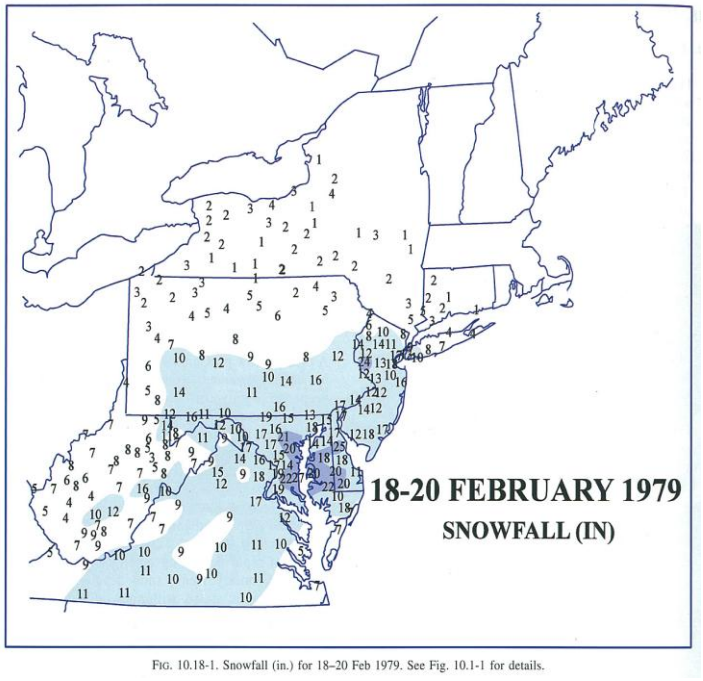
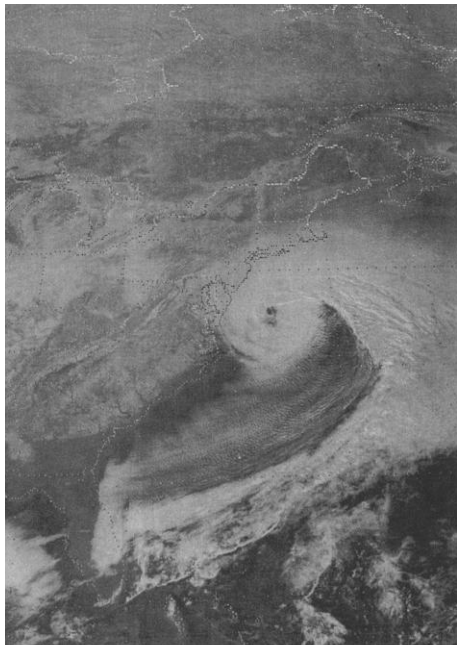


FIG. 10.18-1. Snowfall (in.) for 18–20 Feb 1979. See Fig. 10.1-1 for details.

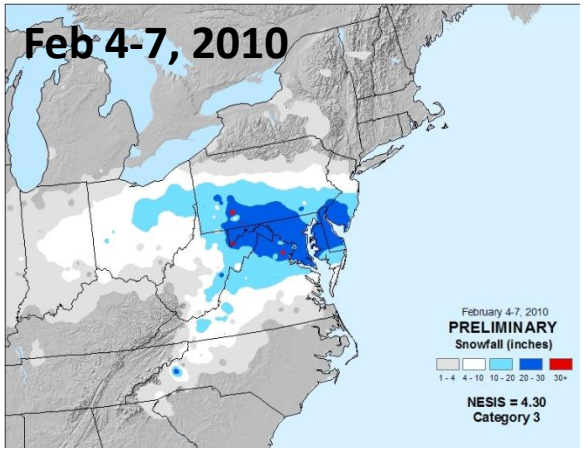


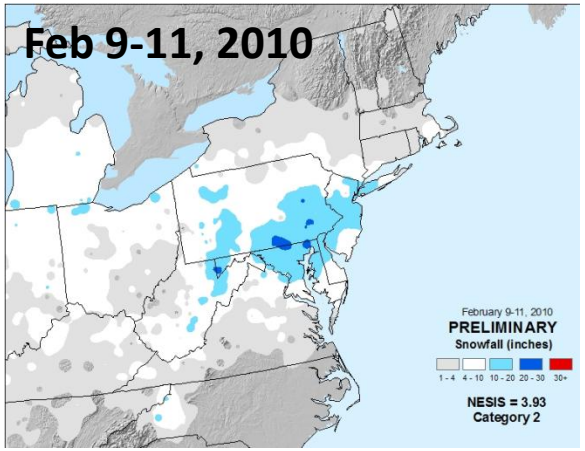
1830Z 19 Feb 1979

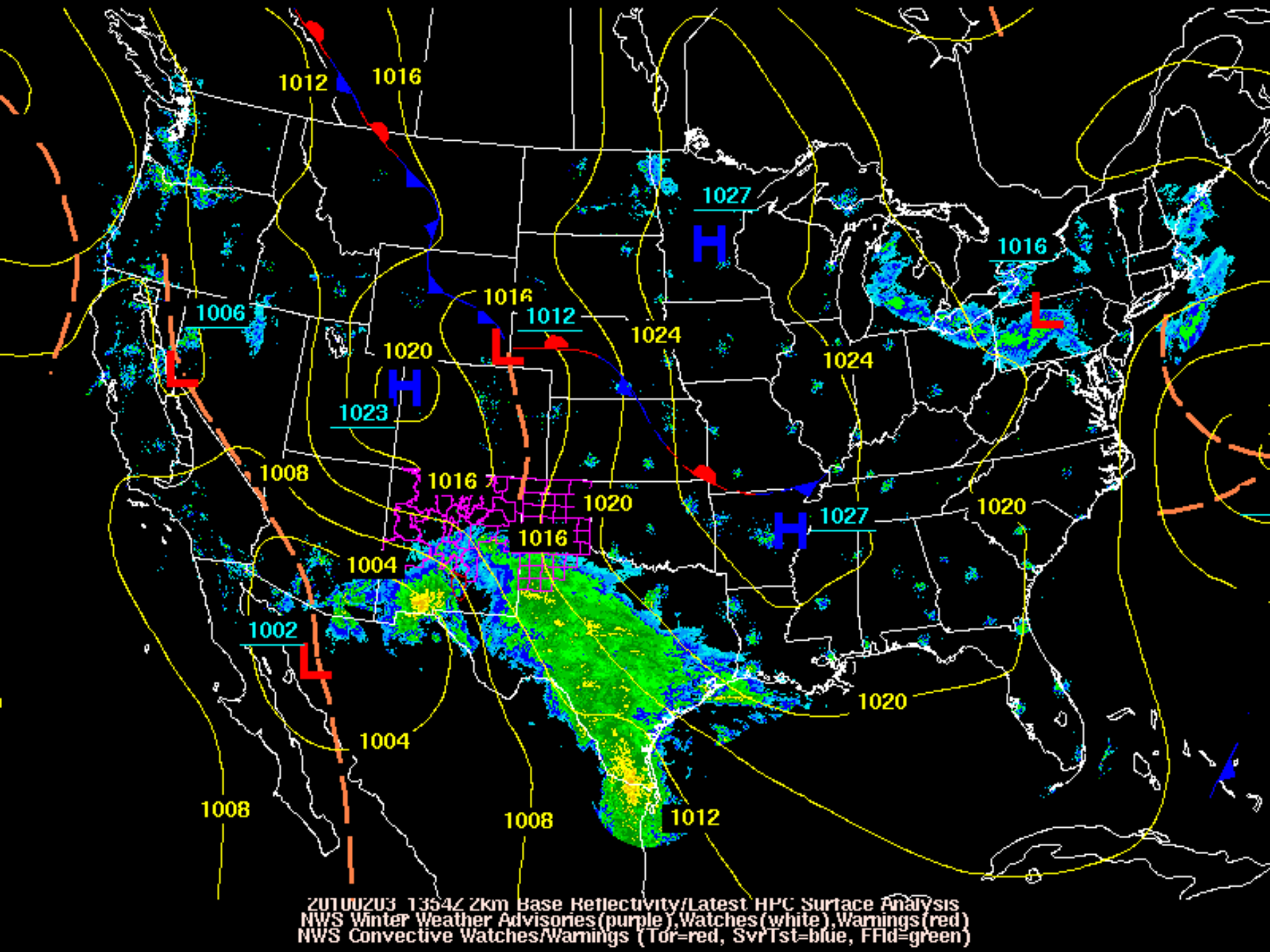
- 22 inches of snow buries Washington D.C. area
- Rapid cyclogenesis off the coast
- Not predicted even hours in advance

February 4-11, 2010: "Snowmageddon"

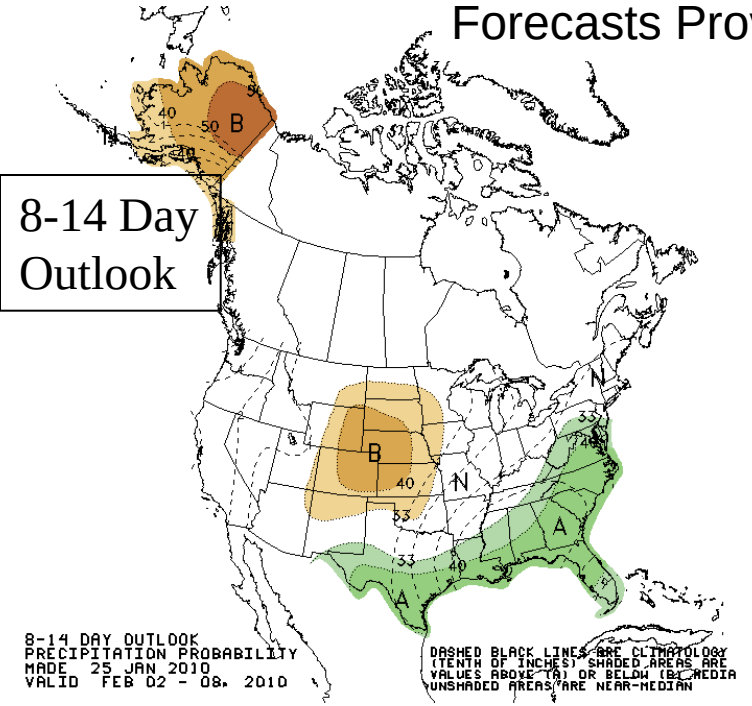
- February 4-7, 2010: massive winter storm paralyzes mid-Atlantic region
  - Locations in Maryland, Pennsylvania, Virginia, and West Virginia recorded more than 30 inches of snow.
  - Washington DC's two-day total of 17.8 inches ranked as the fourth highest total storm amount in history.
  - Philadelphia's 28.5 inches ranked as the second highest amount
  - Baltimore's 24.8 inches ranked as its third highest storm total amount
- Strong blizzard during February 9-11 affects same areas still digging out from earlier storm.
  - Produced as much as 14 inches in the D.C. area, 20 inches in Baltimore, 17 inches in New Jersey, more than 27 inches in Pennsylvania, and 24 inches in northern Maryland.
- Storm system predicted 7+ days in advance; potential for unprecedented heavy snow (up to 3 feet) 3-5 days in advance
- States implement COOP plans, airlines cancel flights, retail industry pre-stocks shelves

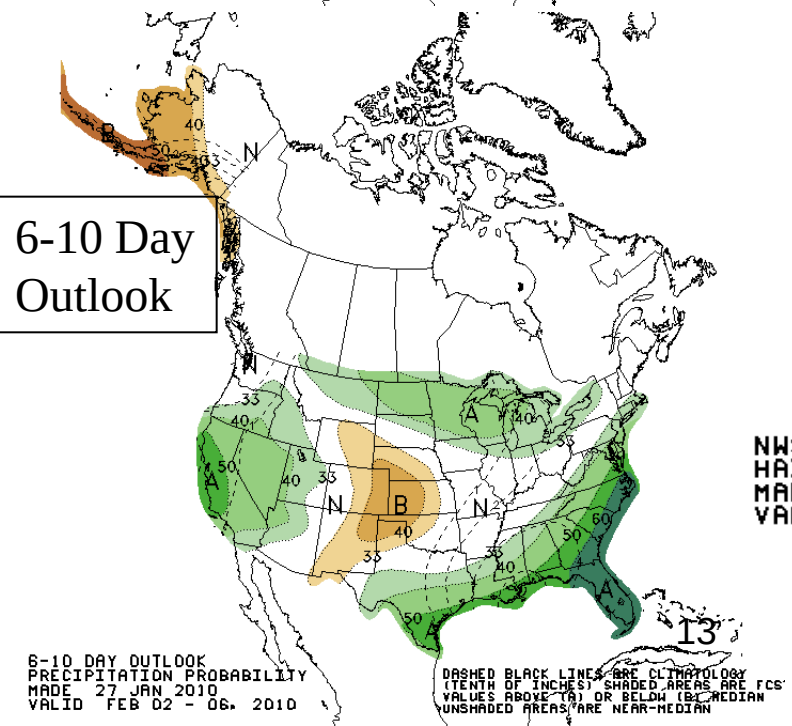


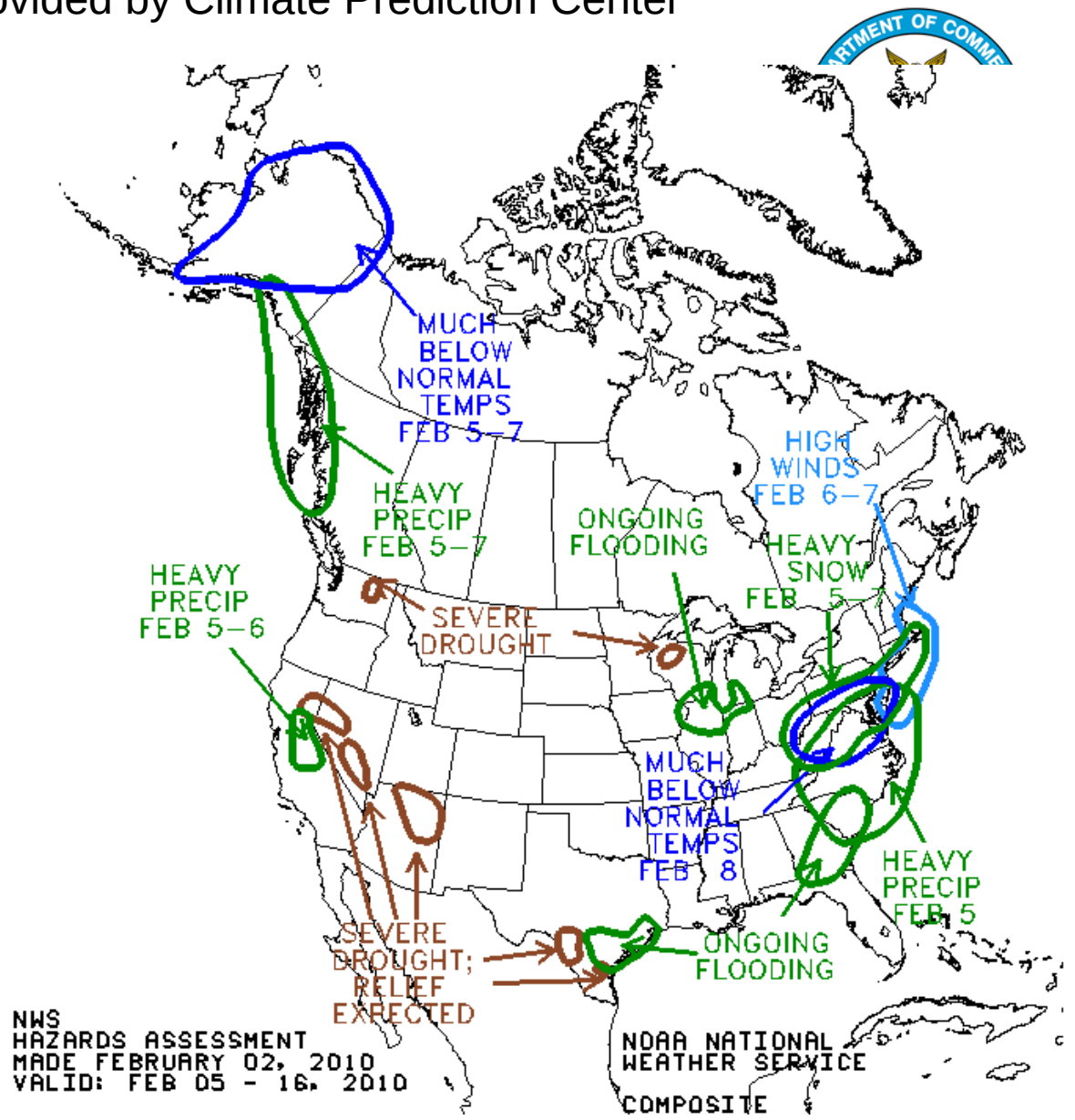



1012
1016
1027
H
1016
L
1006
1012
1024
1024
1020
H
1023
1008
1016
1020
1027
H
1020
1016
1004
1002
L
1020
1004
1008
1008
1012
2010U2U3 1354Z 2km Base Reflectivity/Latest HPC Surface Analysis
NWS Winter Weather Advisories(purple),Watches(white),Warnings(red)
NWS Convective Watches/Warnings (Tor=red, SvrTst=blue, FFld=green)

Forecasts Provided by Climate Prediction Center

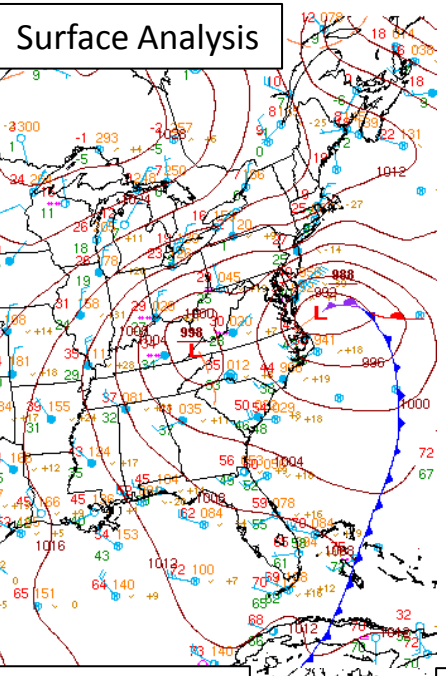


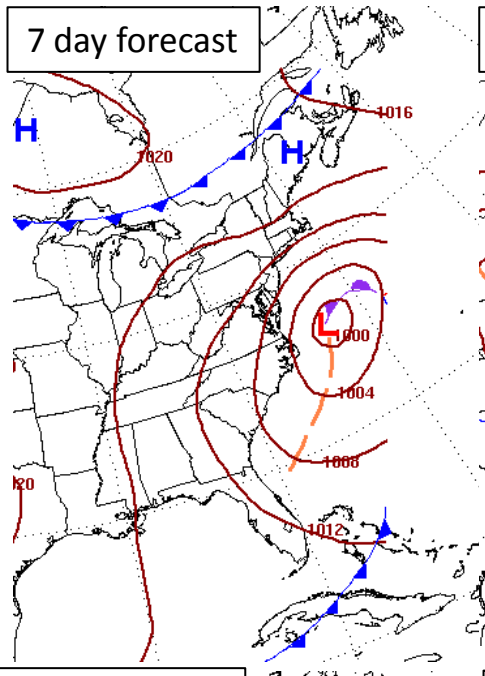


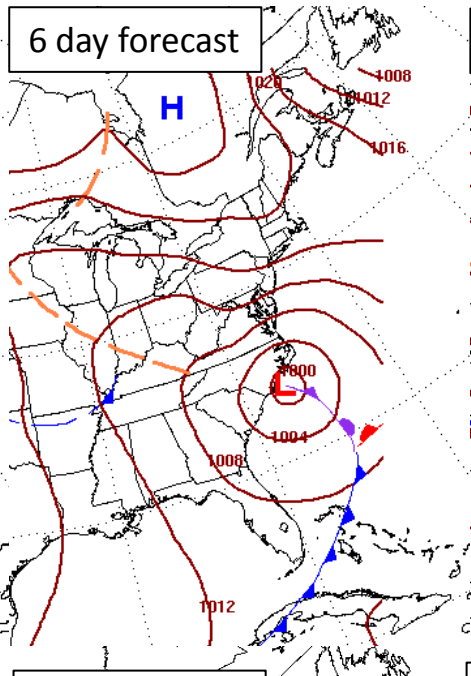


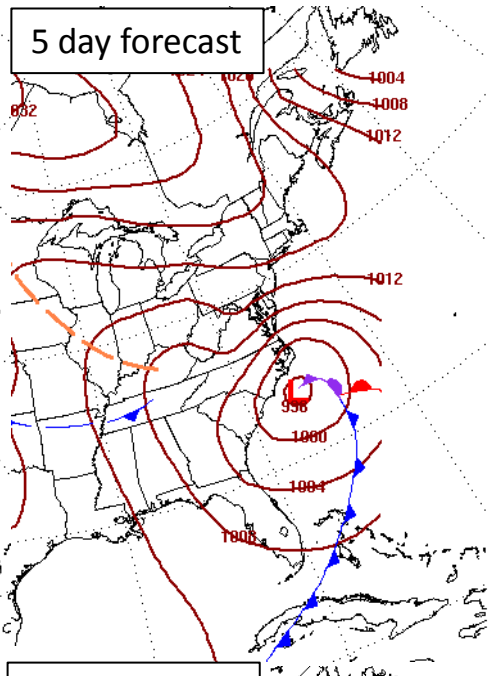
Hazards Assessment

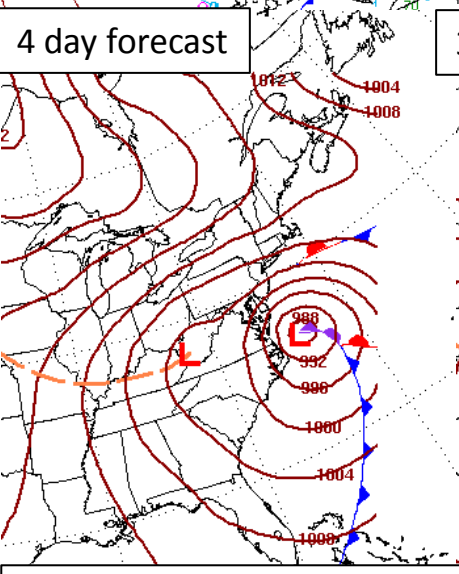
Snowmageddon: All Charts Valid 12Z February 6, 2010

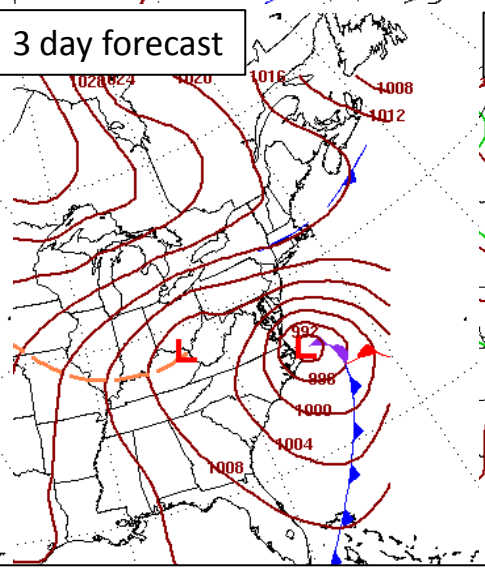


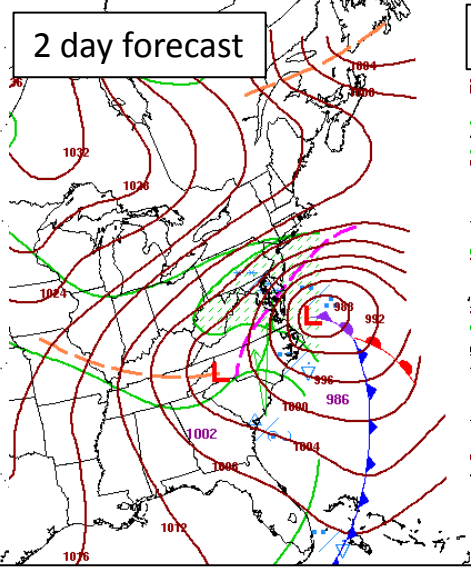


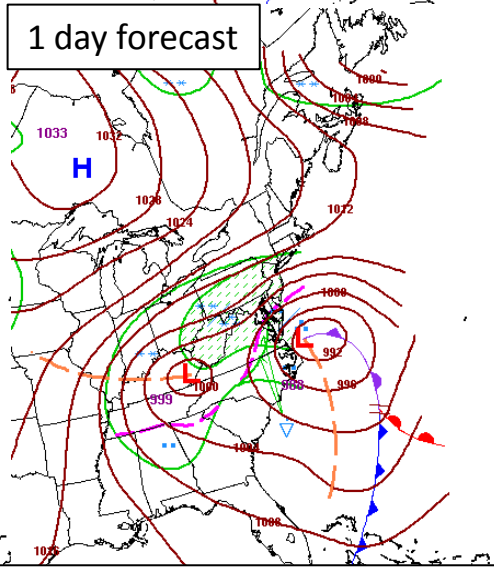












Storm system predicted 7+ days in advance; potential for heavy snow (up to 3 feet) 3-5 days in advance
States implement COOP plans, airlines cancel flights, retail industry pre-stocks shelves

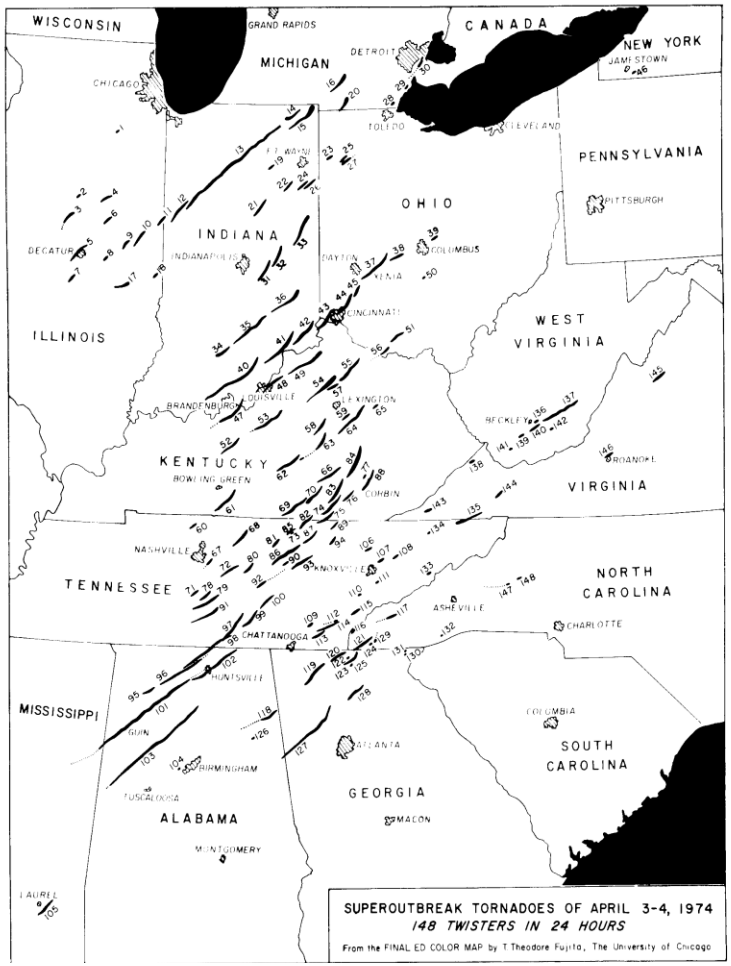
Impacts

"Snowmageddon"

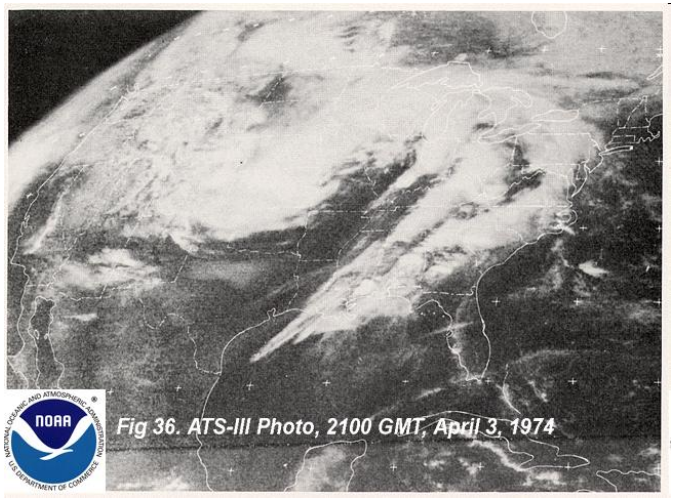
- States declare emergency days before snow
- Airlines cancel thousands of flights at least a day in advance
- Stores adjust to optimize retail sales entire week before the storm
  - Low to no impact on GNP[1]
- Federal disaster declared; facilitates snow removal, and faster recovery!

[1]Some studies (Liscio Reports from 1993-1996) show that major NE snowstorms in the 1990s negatively impacted economic indices for months after the event, including GNP.

April 3-4, 1974 Super Outbreak

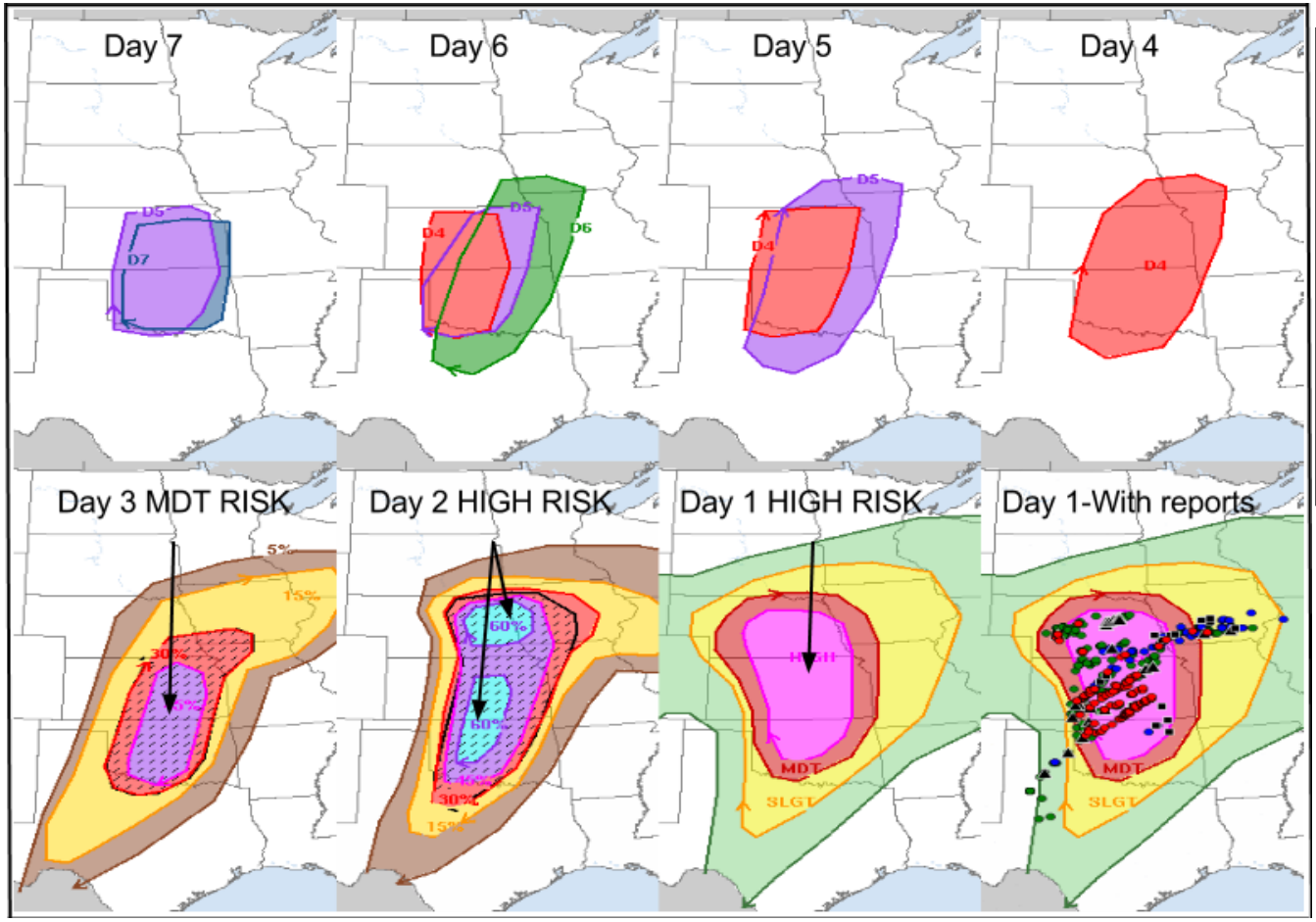


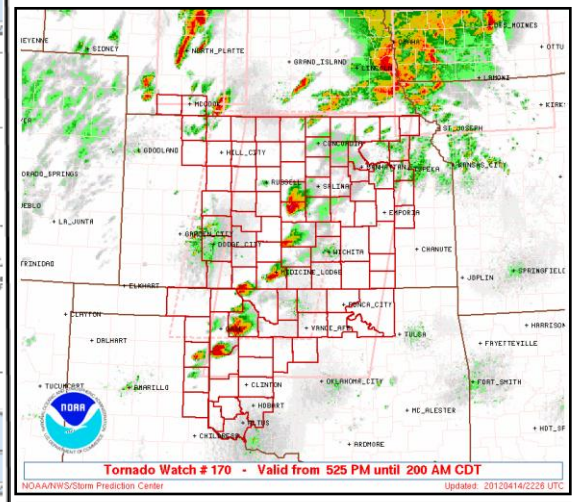
Tornado Tracks
12Z April 3 – 12Z April 4, 1974



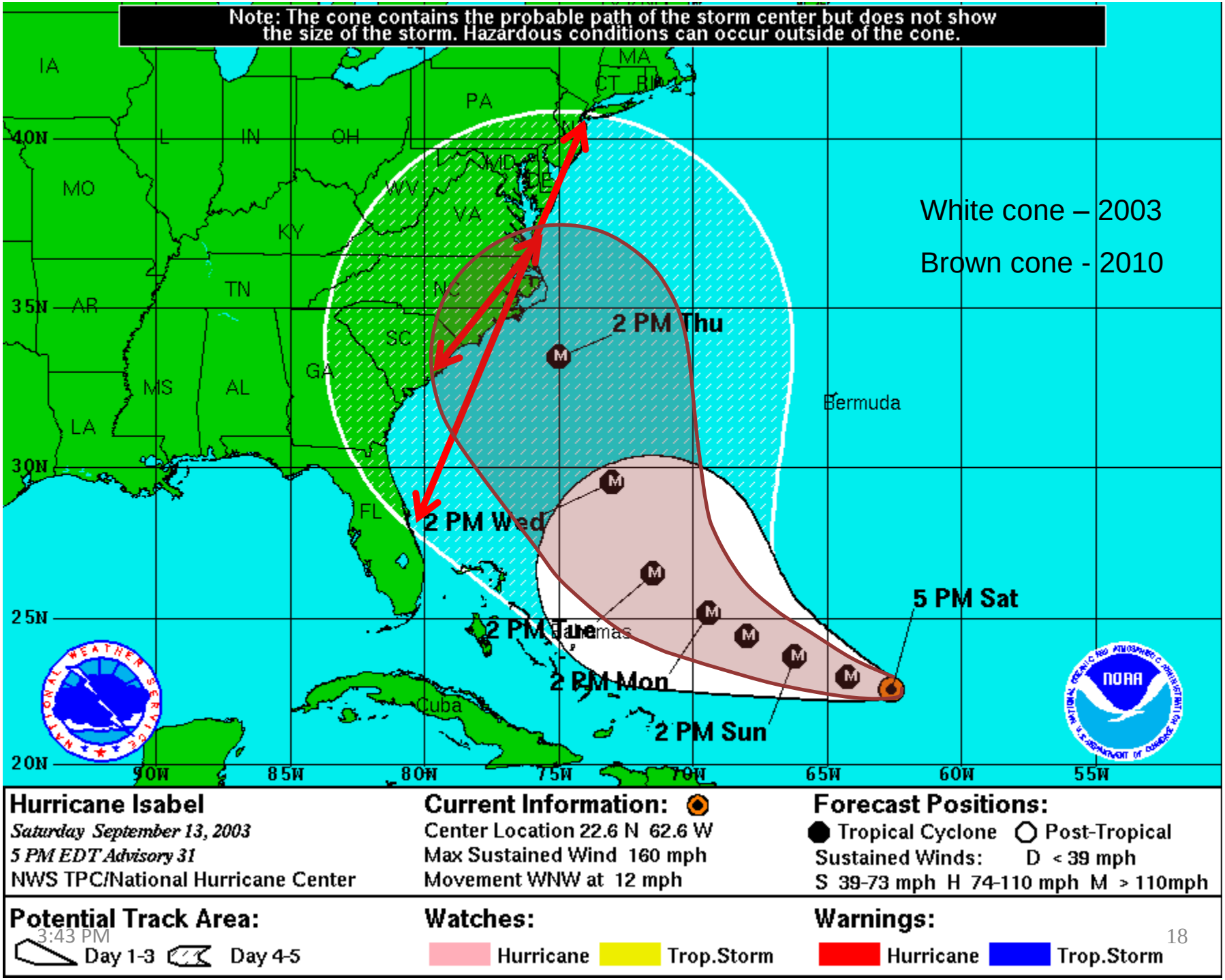
- One of the deadliest tornado outbreaks in the 20th Century (330 fatalities)
- Involved over one-quarter of the country
  - 148 tornadoes in 13 states
- Potential for severe weather was recognized only the afternoon before event
- Magnitude of event not realized until evening news – April 3

14 April 2012 Great Plains Outbreak

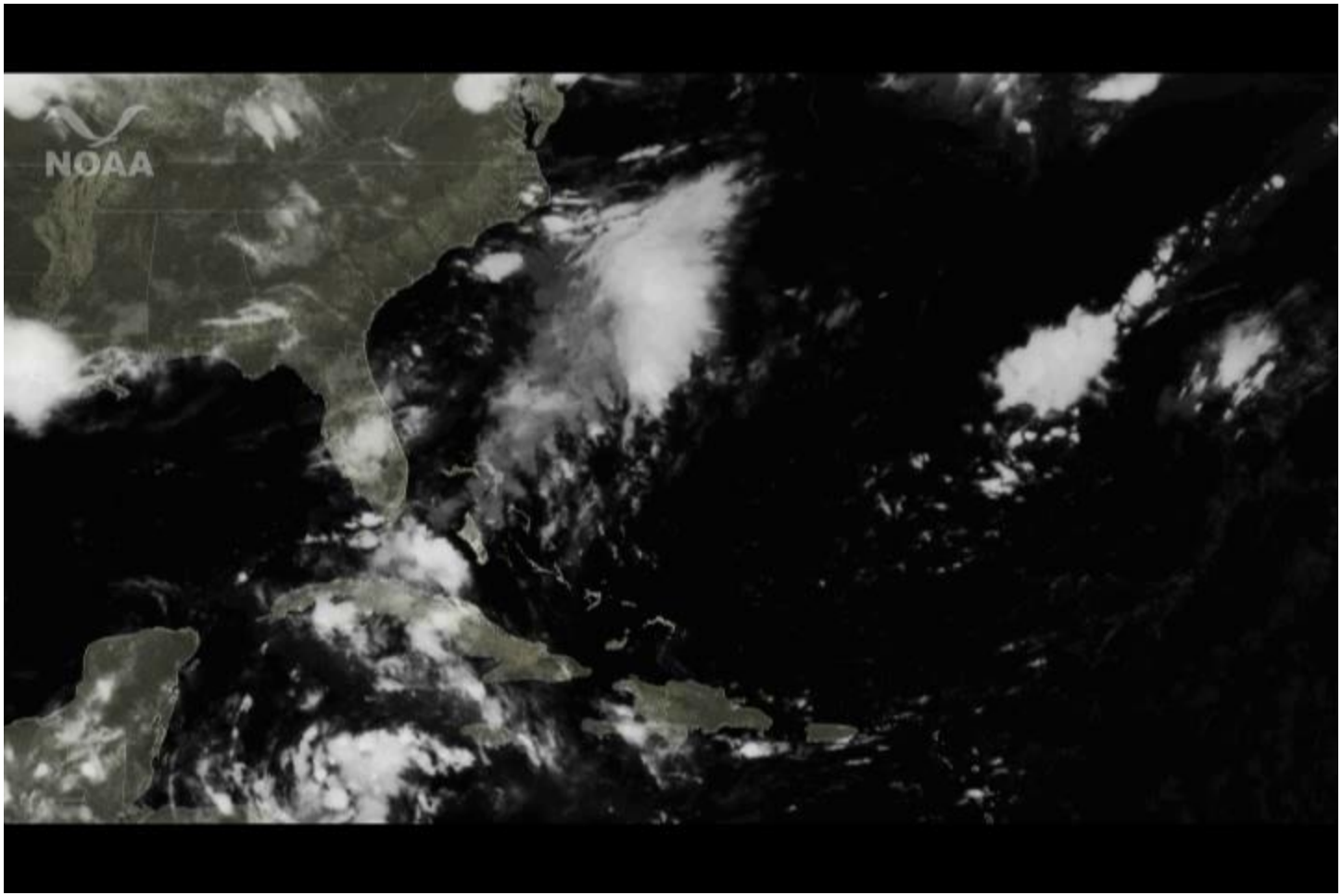




- **60 Tornadoes (1 EF4, 3 EF3 & 3 EF2)**
- **Outlook first issued 7 days in advance; Moderate Risk 3 days in advance; High Risk 2 days in advance (only 2nd time)**
- **NWS average warning lead time (Tornadoes) : 13 minutes**
- **6 Fatalities in Woodward, OK near midnight**
- **FEMA/State/local emergency managers engaged starting 3 days before the event**


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.
White cone – 2003
Brown cone - 2010
2 PM Thu
2 PM Wed
2 PM Tue
2 PM Mon
2 PM Sun
5 PM Sat
Bermuda
Cuba
Bahamas
40N
35N
30N
25N
20N
90W
85W
80W
75W
70W
65W
60W
55W
Hurricane Isabel
Saturday September 13, 2003
5 PM EDT Advisory 31
NWS TPC/National Hurricane Center
Current Information:
Center Location 22.6 N 62.6 W
Max Sustained Wind 160 mph
Movement WNW at 12 mph
Forecast Positions:
Tropical Cyclone
Post-Tropical
Sustained Winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110mph
Potential Track Area:
Day 1-3
Day 4-5
Watches:
Hurricane
Trop.Storm
Warnings:
Hurricane
Trop.Storm

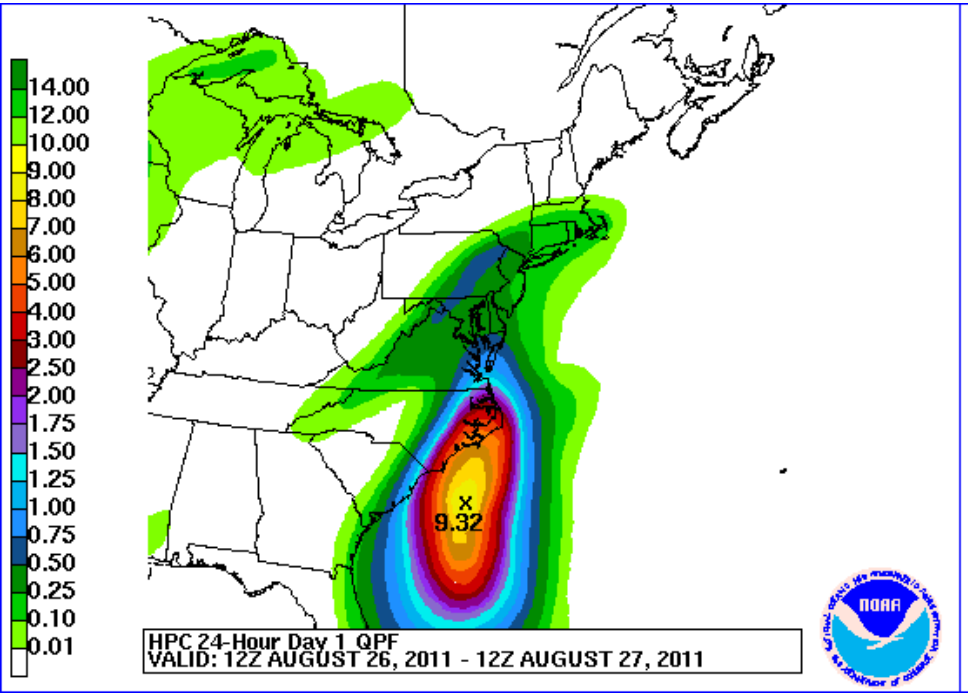
Hurricane Irene Track Forecast



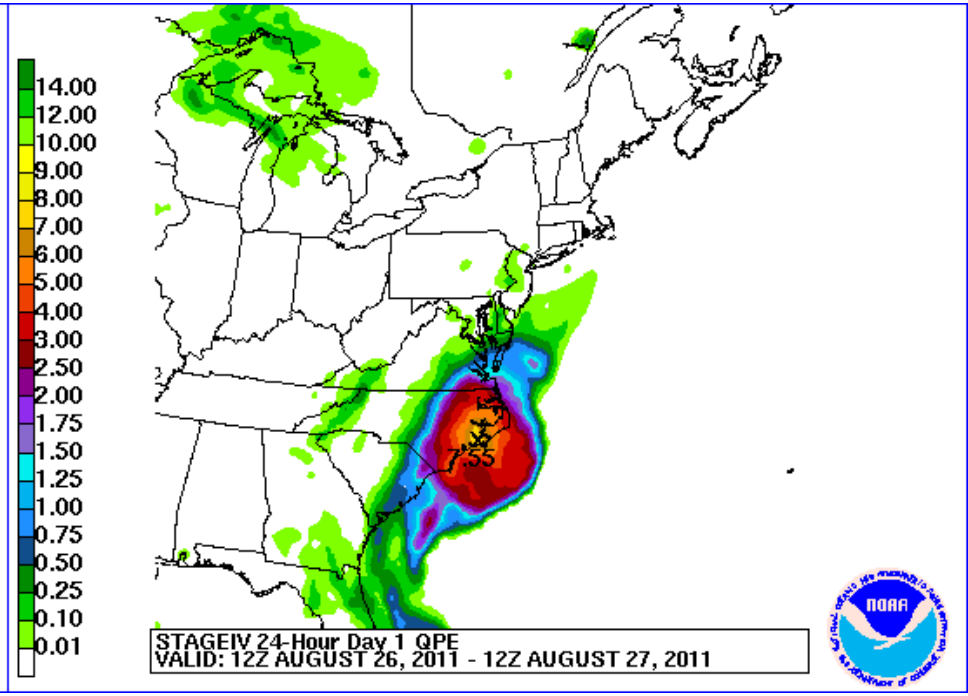
August 20, 2011 – August 27, 2011

Hurricane Irene Precipitation

Precipitation Forecast Loop



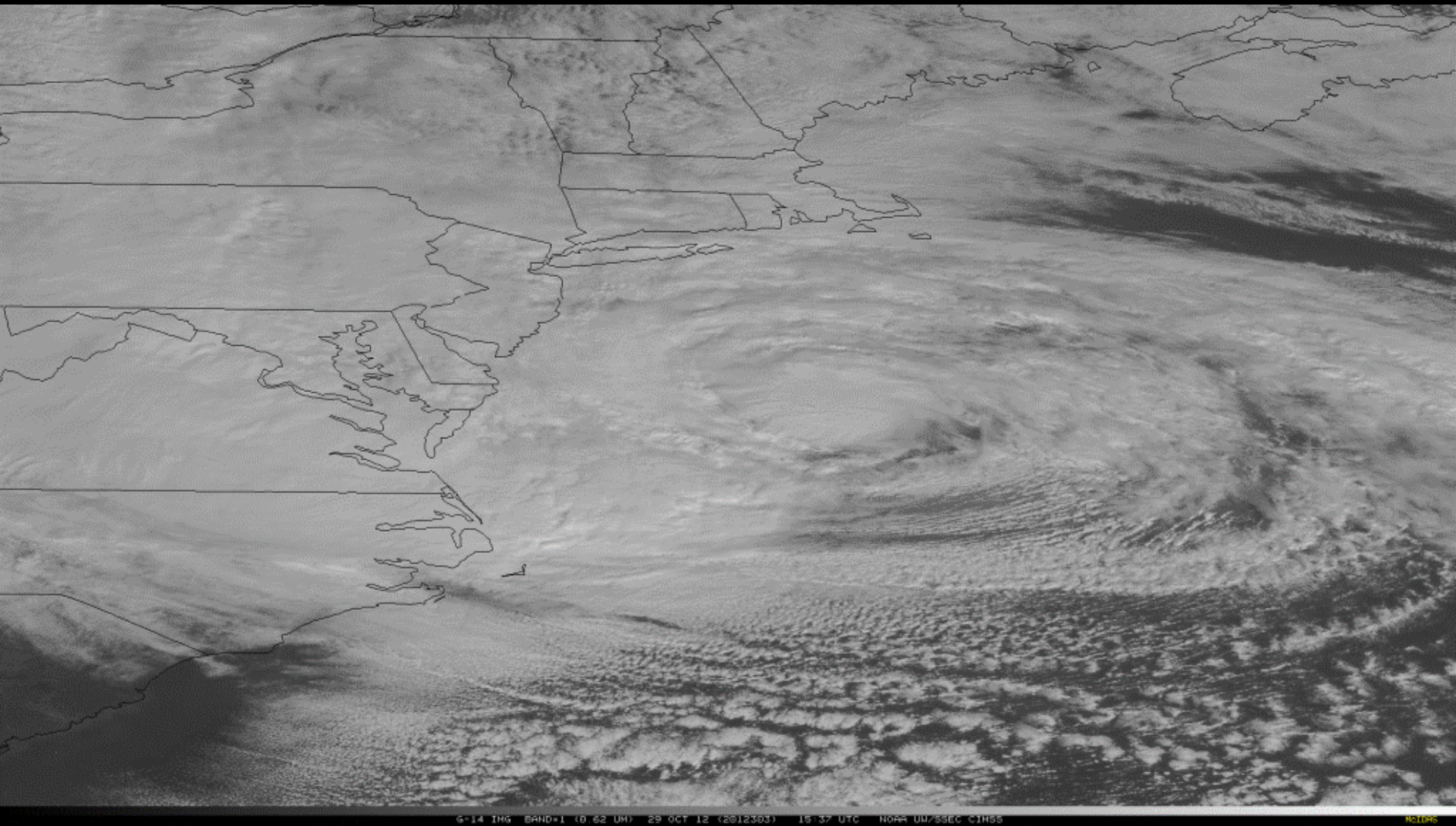
Precipitation Verification Loop



August 26 – 29, 2011

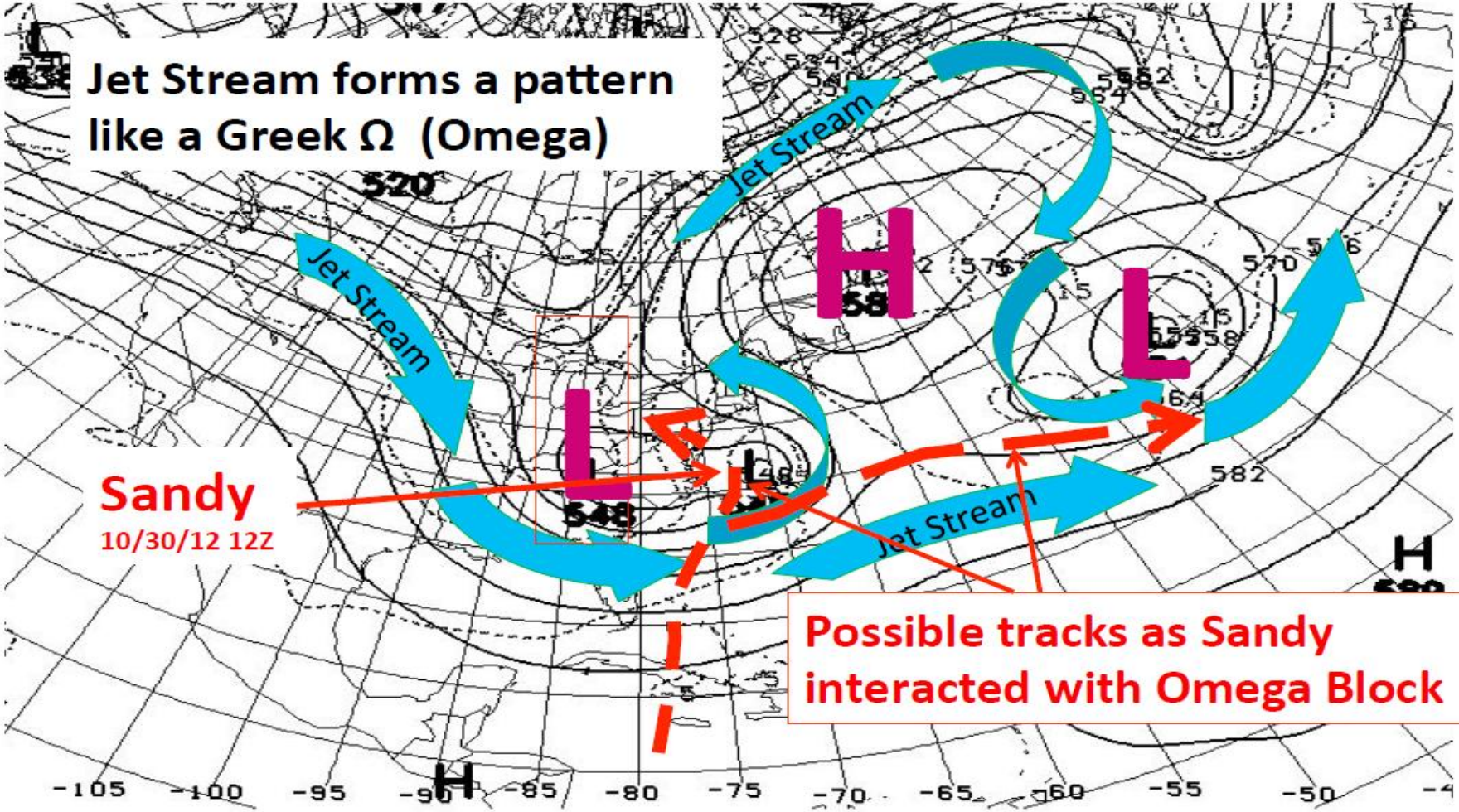
A First Look at Hurricane Sandy

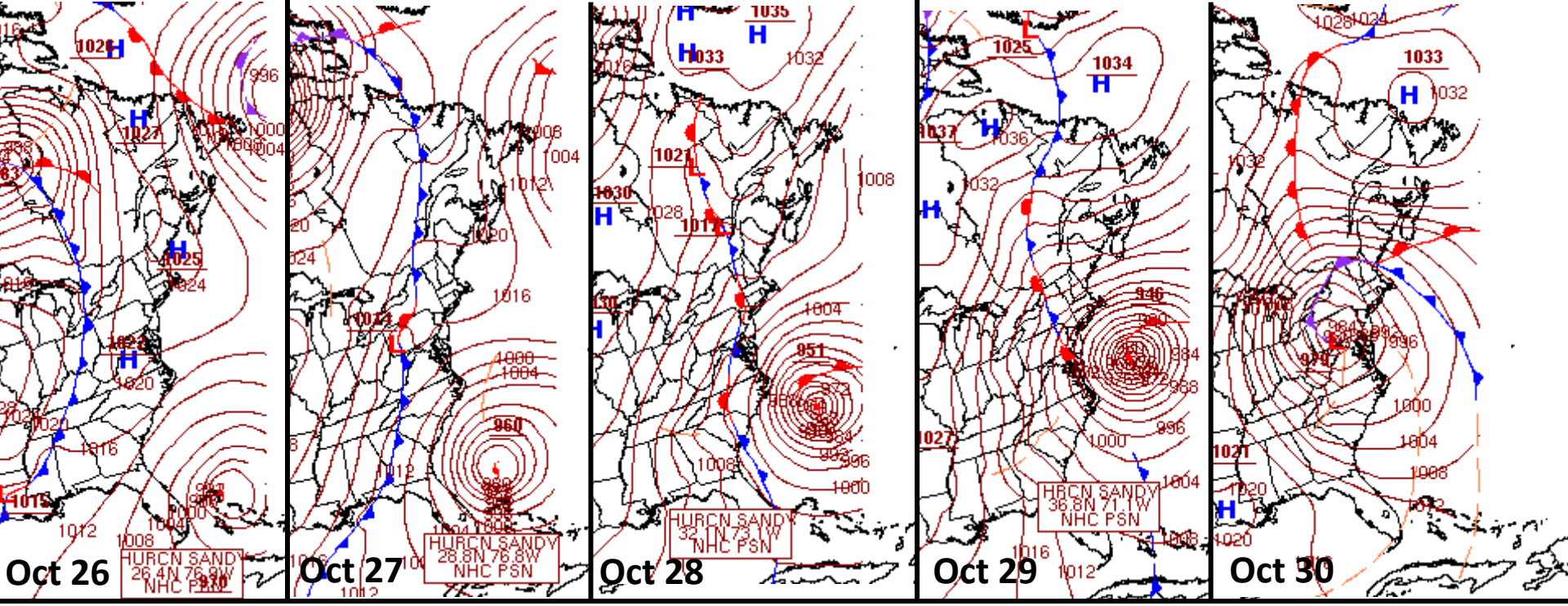
- Basic Characteristics
- Collaborative Forecast Process
- Forecasts & Verification



Hurricane Sandy – GOES-14 SRSO – October 29, 2012 1430-1530 UTC

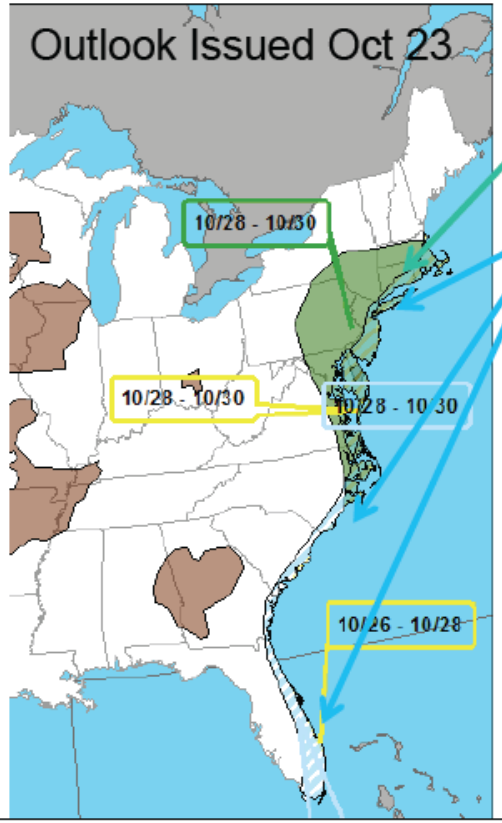
Jet Stream 10/30/12 12Z (Blue)
Uncertainty in Sandy's track





Surface Analysis: Friday October 26 – Tuesday October 30, 2012

Hurricane Sandy: Collaborative Forecast Process

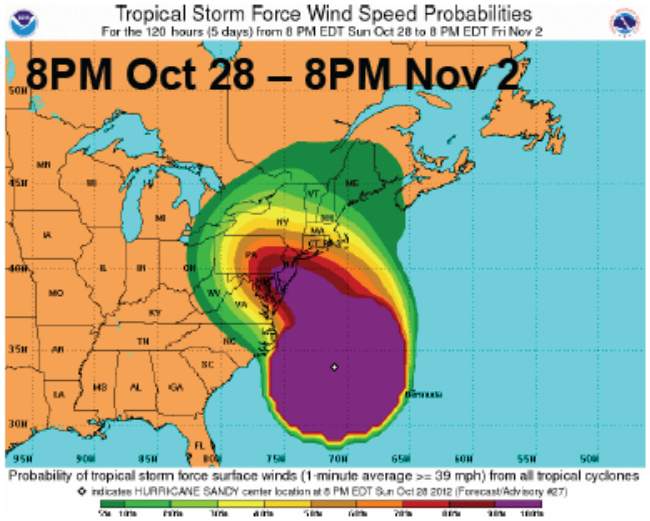


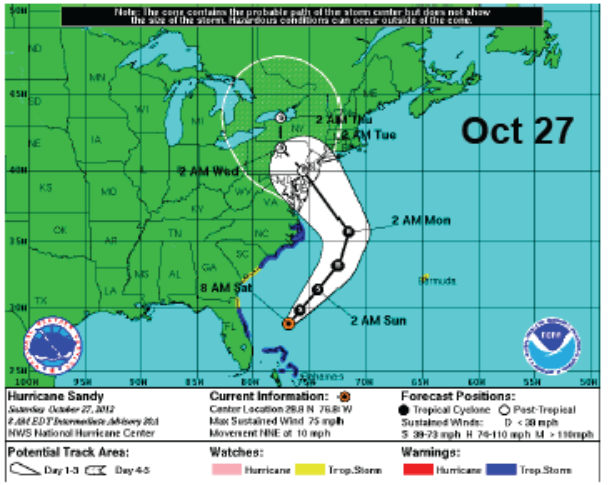
Heavy Rain

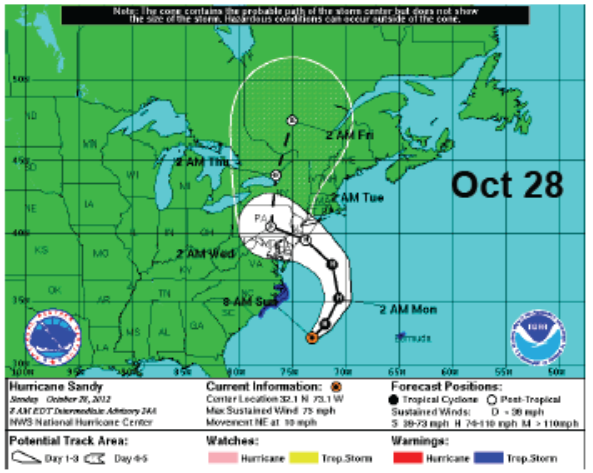
High Winds

- CPC – Outlooks, Hazards Chart, 5 days in advance

- NHC – Hurricane Track/Intensity Forecasts; Wind Speed Probabilities

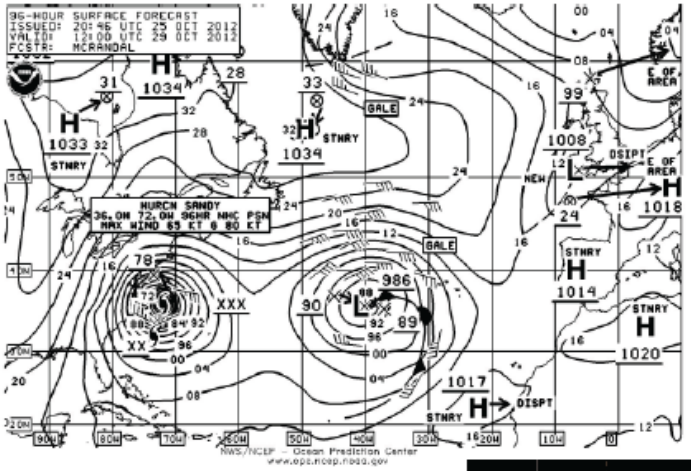




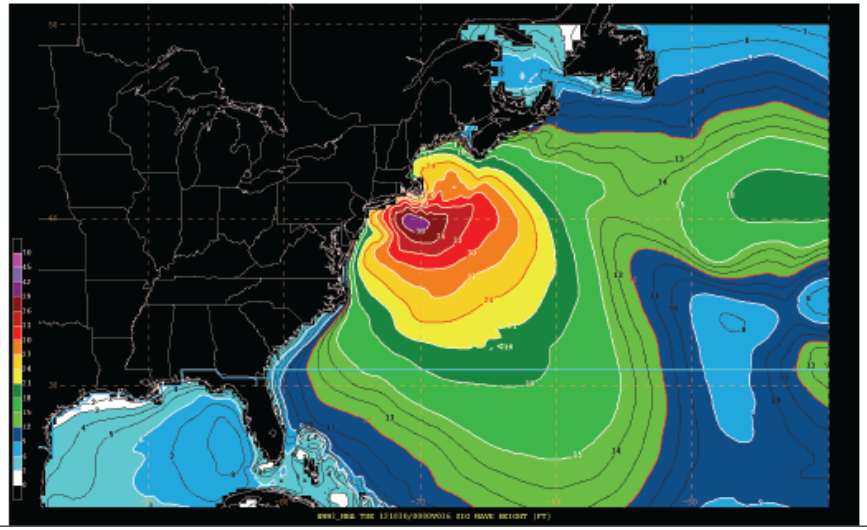


Hurricane Sandy: Collaborative Forecast Process

- OPC – 96 hour surface chart



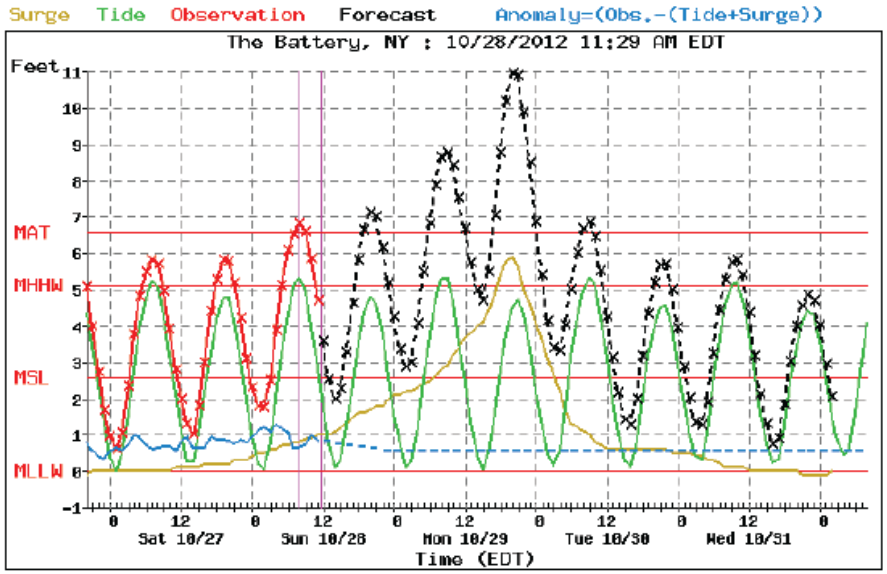
- EMC – Wave Model forecasts

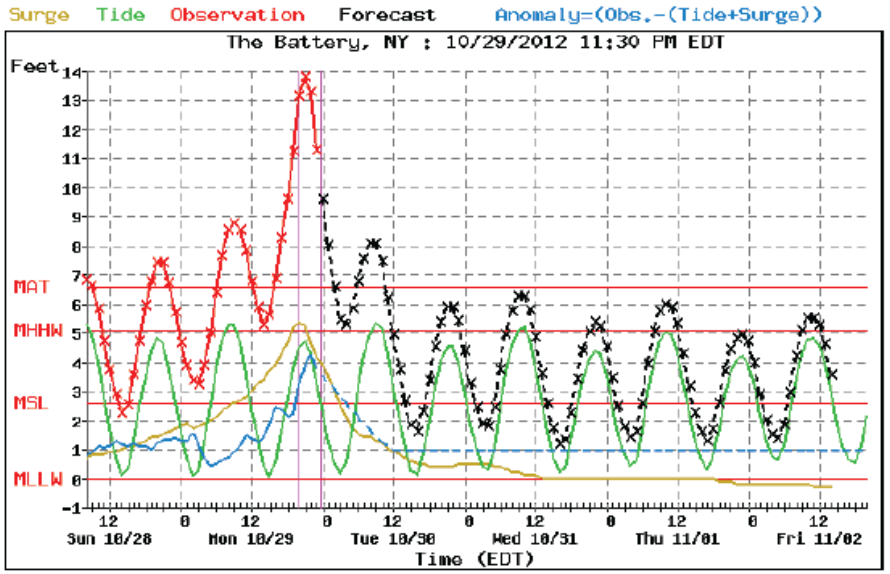


36 hour wave height forecast (ft)

Hurricane Sandy: Collaborative Forecast Process

MDL NWS Surge Forecast:
Forecasts were coordinated among OPC, NHC, local WFOs

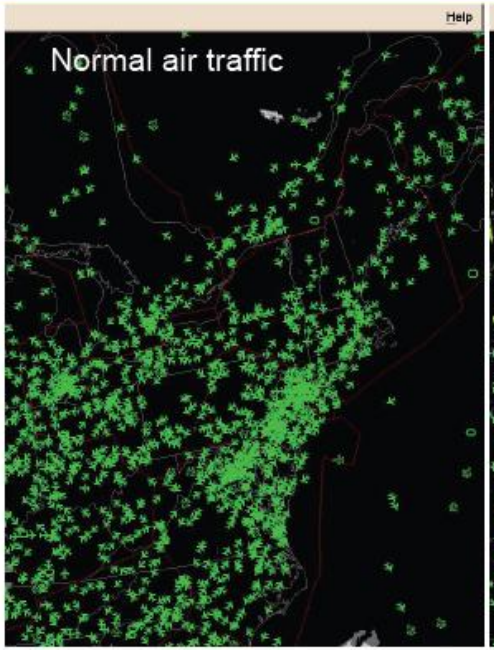


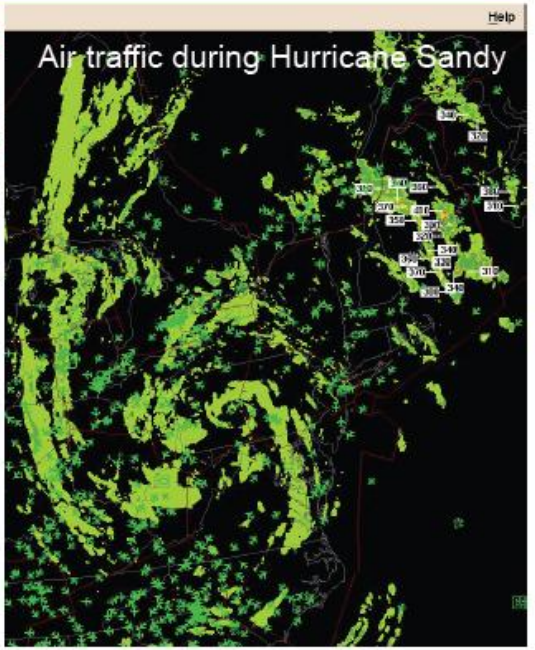


"Life Threatening" statements issued Sunday morning by NHC and called into NYC Emergency Operations Center; NYC initiates evacuations and shut down of public transportation shortly thereafter

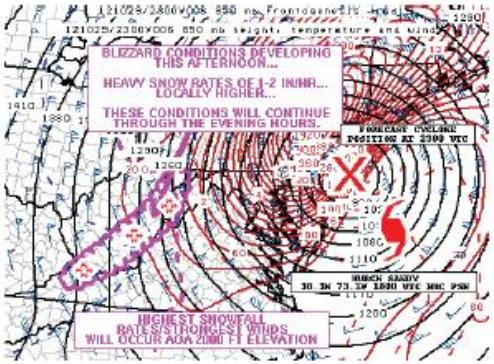
Hurricane Sandy: Collaborative Forecast Process

- AWC – briefings for FAA staff: current weather, timing of impacts at facilities and airports, outlooks for recovery, coordinated with WFOs and CWSUs





- SPC – Mesoscale Discussion highlighting blizzard conditions in the Appalachians



SPC MCD #2091

Hurricane Sandy: Collaborative Forecast Process

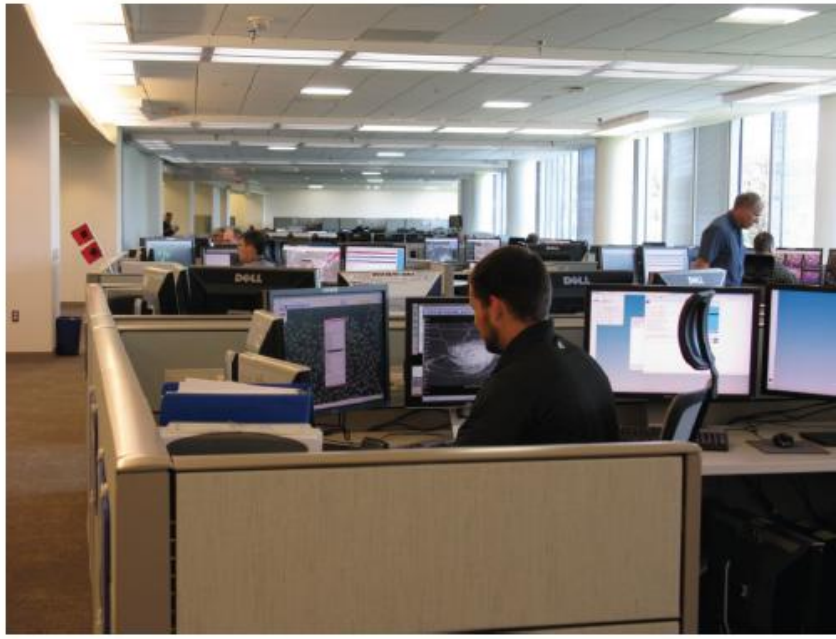
Communication Strategy

- Forecaster collaboration across All NCEP Centers, WFOs and Other NOAA LOs (NESDIS, NOS, OMAO)
  - Specific local forecasts issued by WFOs
  - All special messages and linkages to local emergency centers through WFOs
  - Seamless Consistent Message to Emergency Decision Makers and Public

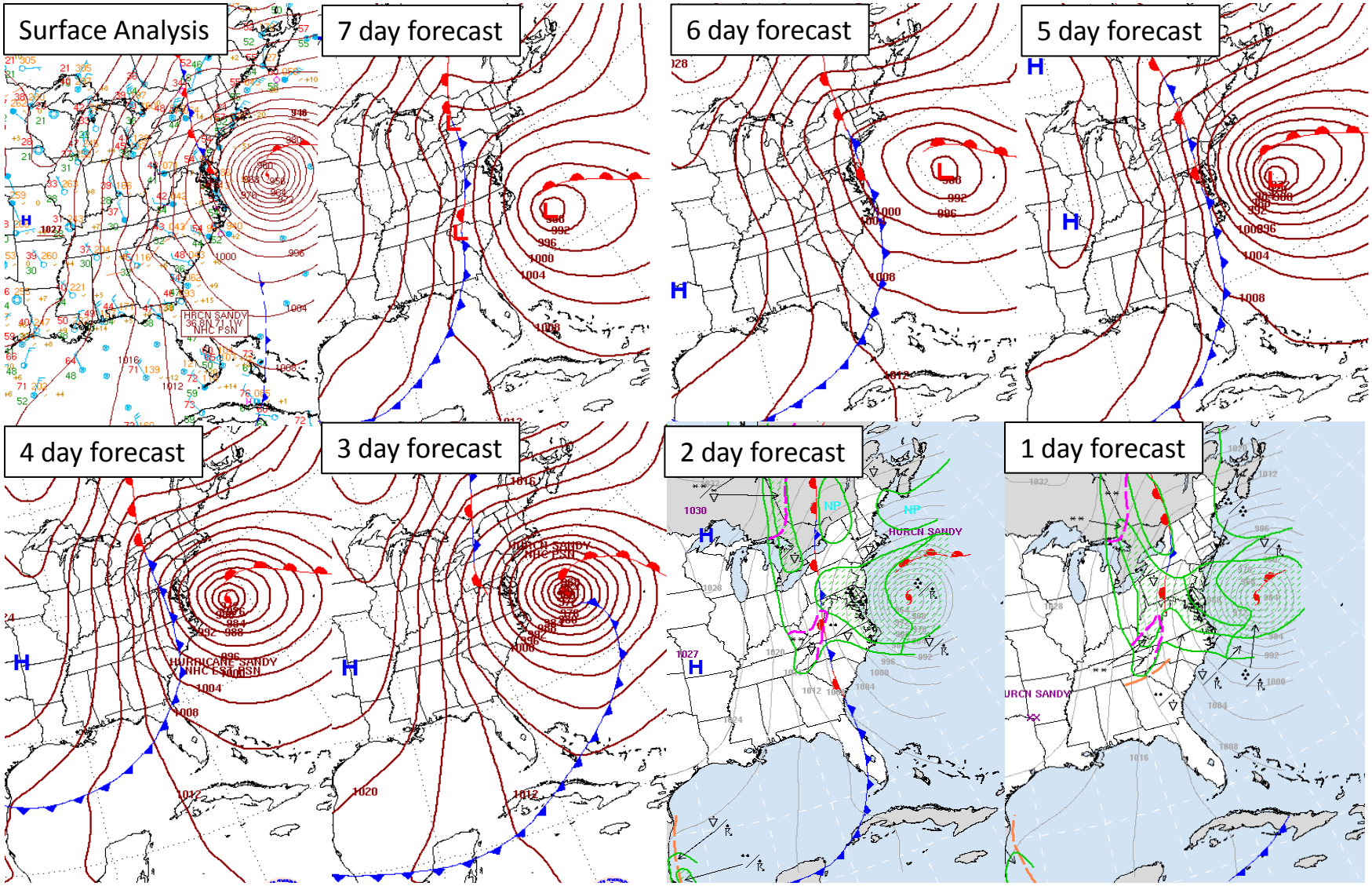
Hurricane Sandy: Collaborative Forecast Process

Communication Strategy

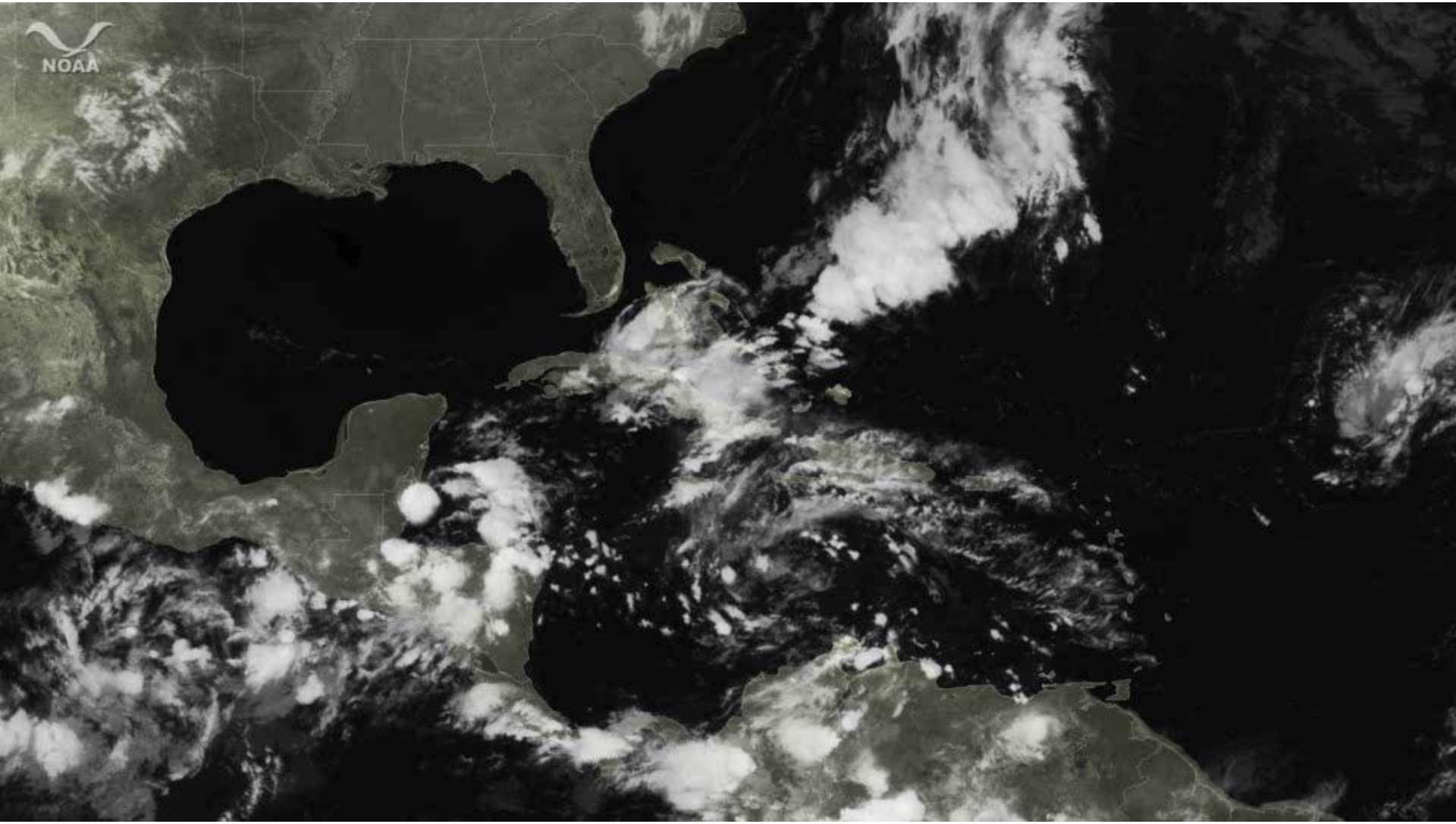
- Messaging Focused on ***Impact***-Based Decision Support Services
  - Unique nature of storm (tropical to extratropical transition
  - Large area affected by strong winds
  - East to west track toward NJ
  - Record surge/inundation in NJ→ NYC→ SE New England
  - Record blizzard in Appalachian Mountains & WV
  - Threats emphasized particularly dangerous storm – "worst case scenario" compared to the Perfect Storm



Hurricane Sandy: All Charts Valid 12Z October 29, 2012



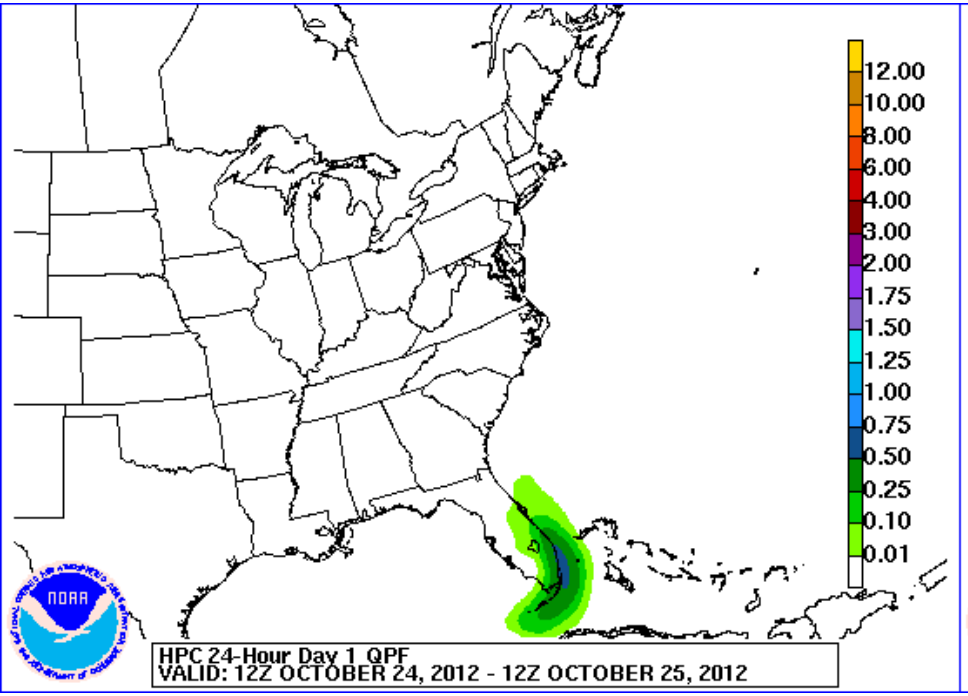
Hurricane Sandy
October 21, 2012 0345Z through October 31, 2012 1315Z



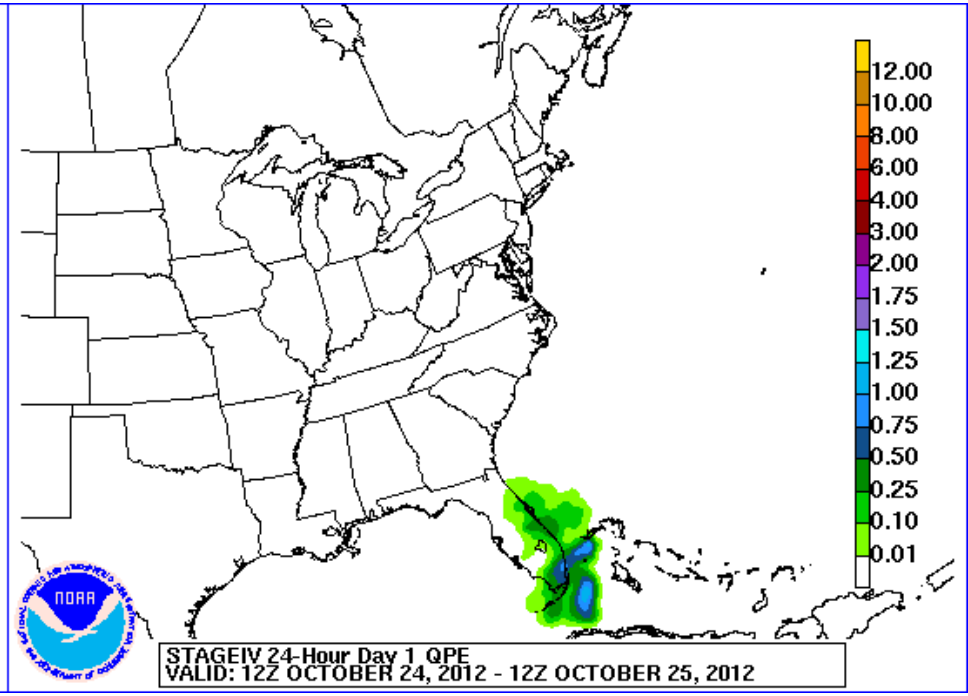
National Hurricane Center's 5 day forecast track issued at 11 a.m. EDT on Thursday, October 25

Hurricane Sandy Precipitation

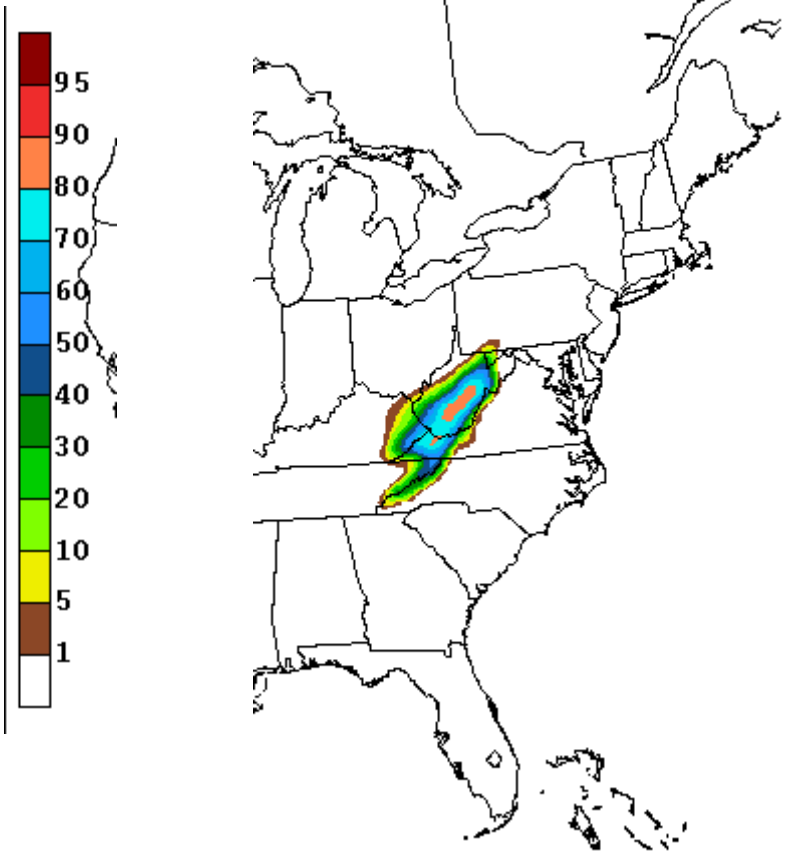
HPC Forecast



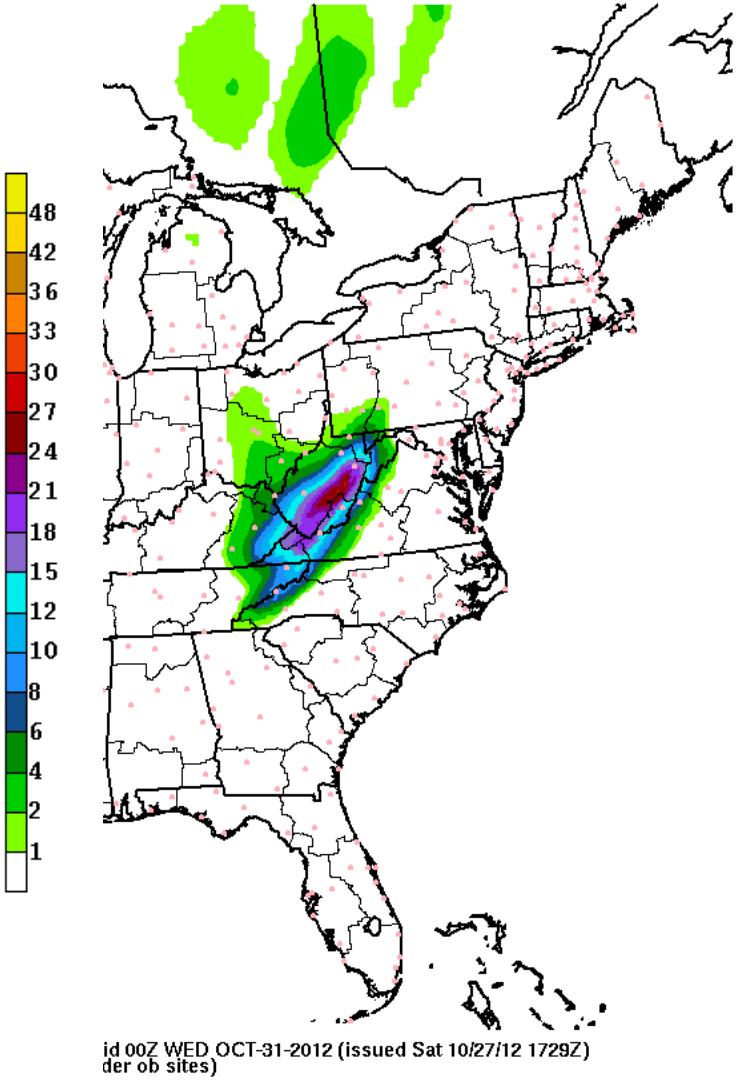
Verification



October 24 – November 1, 2012



Probability of 48 hour snowfall > 12 inches
Issued 2PM, Saturday, Oct 27, 2012
Valid 8PM, Sunday Oct 28 – 8PM Tuesday Oct 30



3 day Snow Accumulation (inches)
Issued 2PM, Saturday, Oct 27, 2012
Valid 8PM Saturday Oct 28 – 8PM Tuesday Oct 30

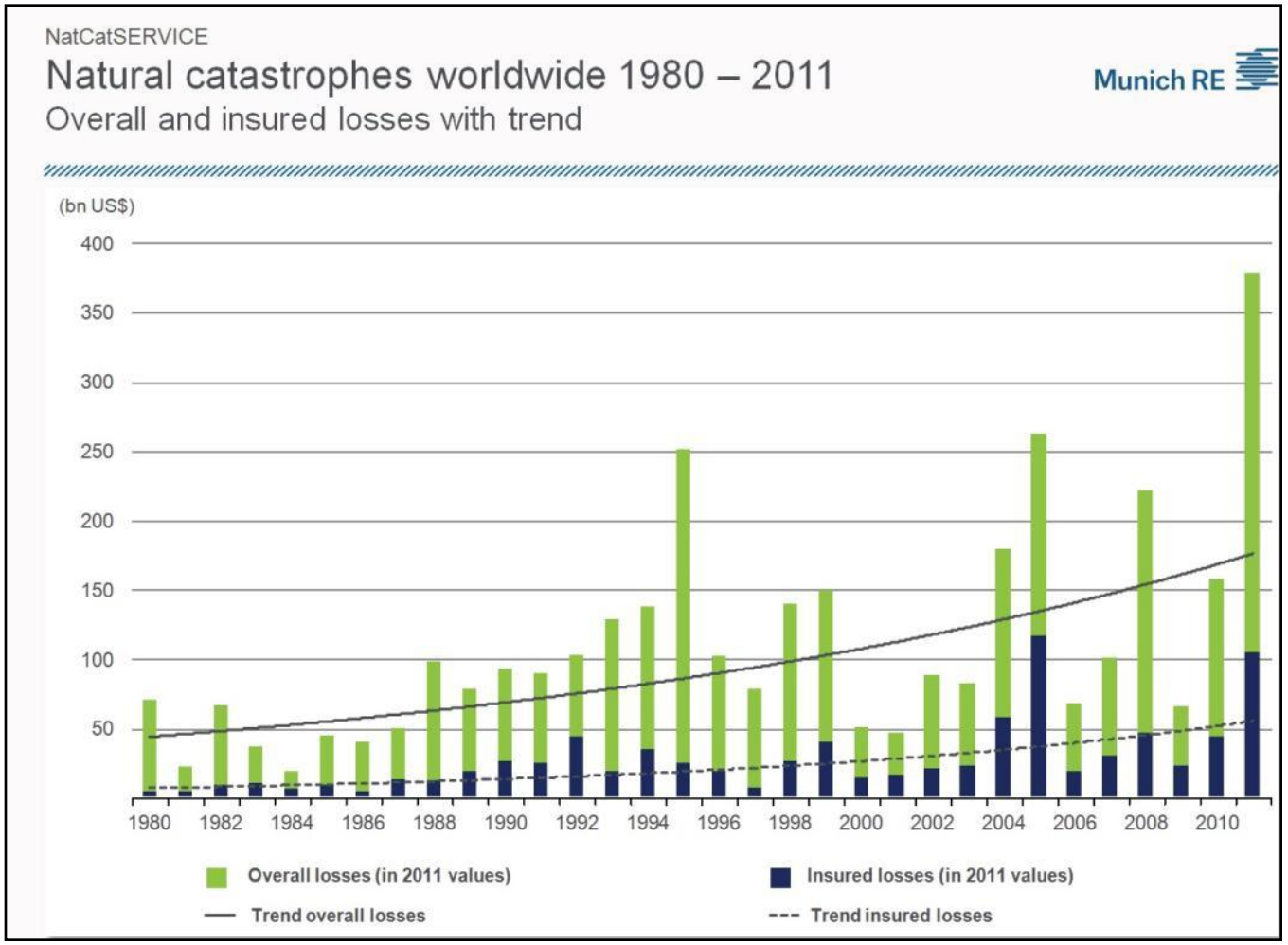
Hurricane Sandy

- Conveyed consistent forecast message on the historic nature and destructive potential for this storm.
  - Westward track
  - Large size
  - Destructive surge (historic levels)
  - Tropical-extratropical transition
  - Heavy precipitation
  - Record setting blizzard conditions
  - Evacuations initiated 60-72 hr in advance
- Beginning Thursday – Friday communicated/coordinated all forecasts with FEMA/emergency management community; NHC provided briefings to the White House
- Media coordination started on Friday and continued through the event
- The forecasts saved lives!

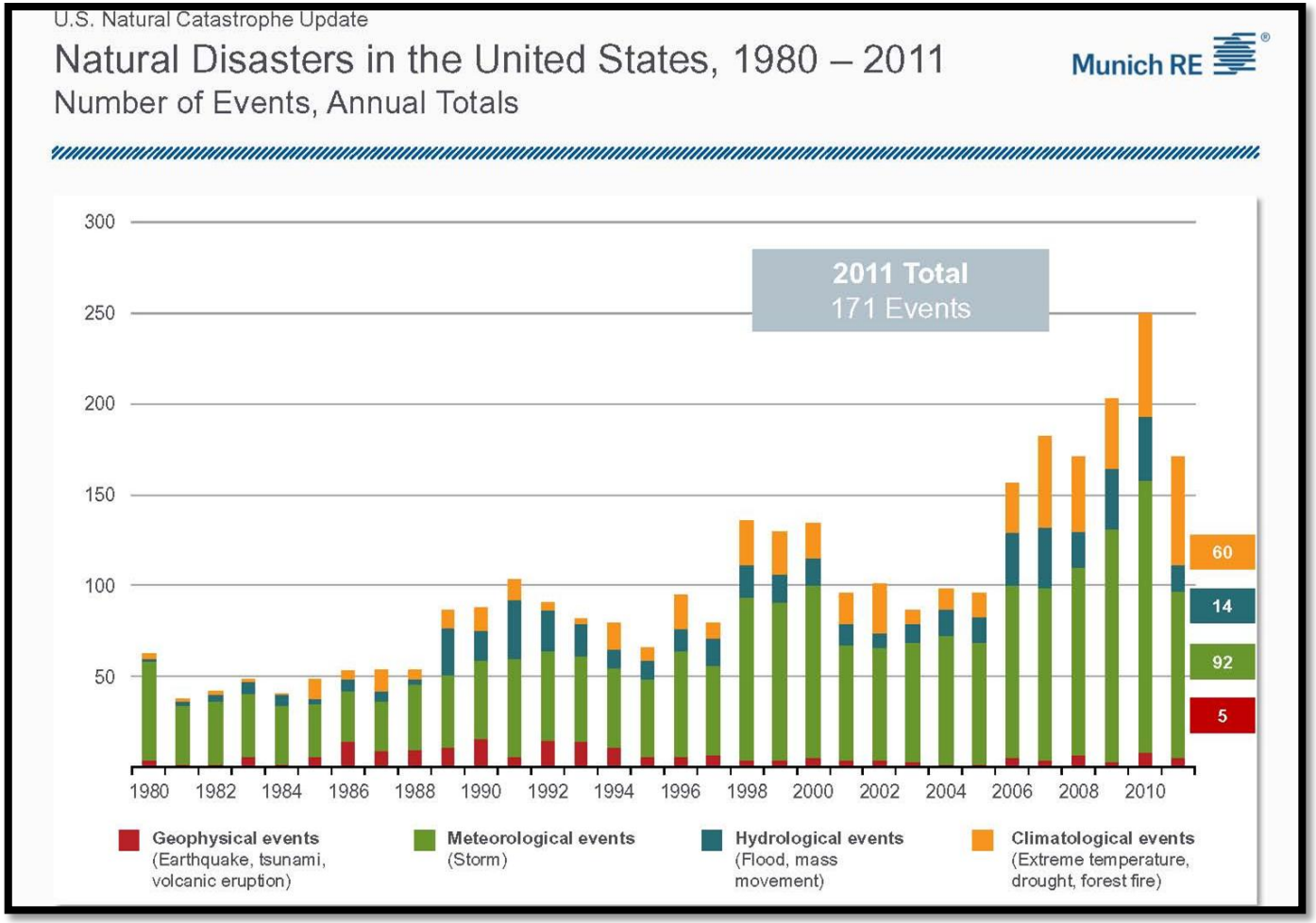
Trends in Weather Extremes

- Billion Dollar Disasters
- Key Issue: Water Distribution
- Hurricanes in the Atlantic Basin

Economic Losses Due to Natural Disasters



Increased Vulnerability to High Impact Events

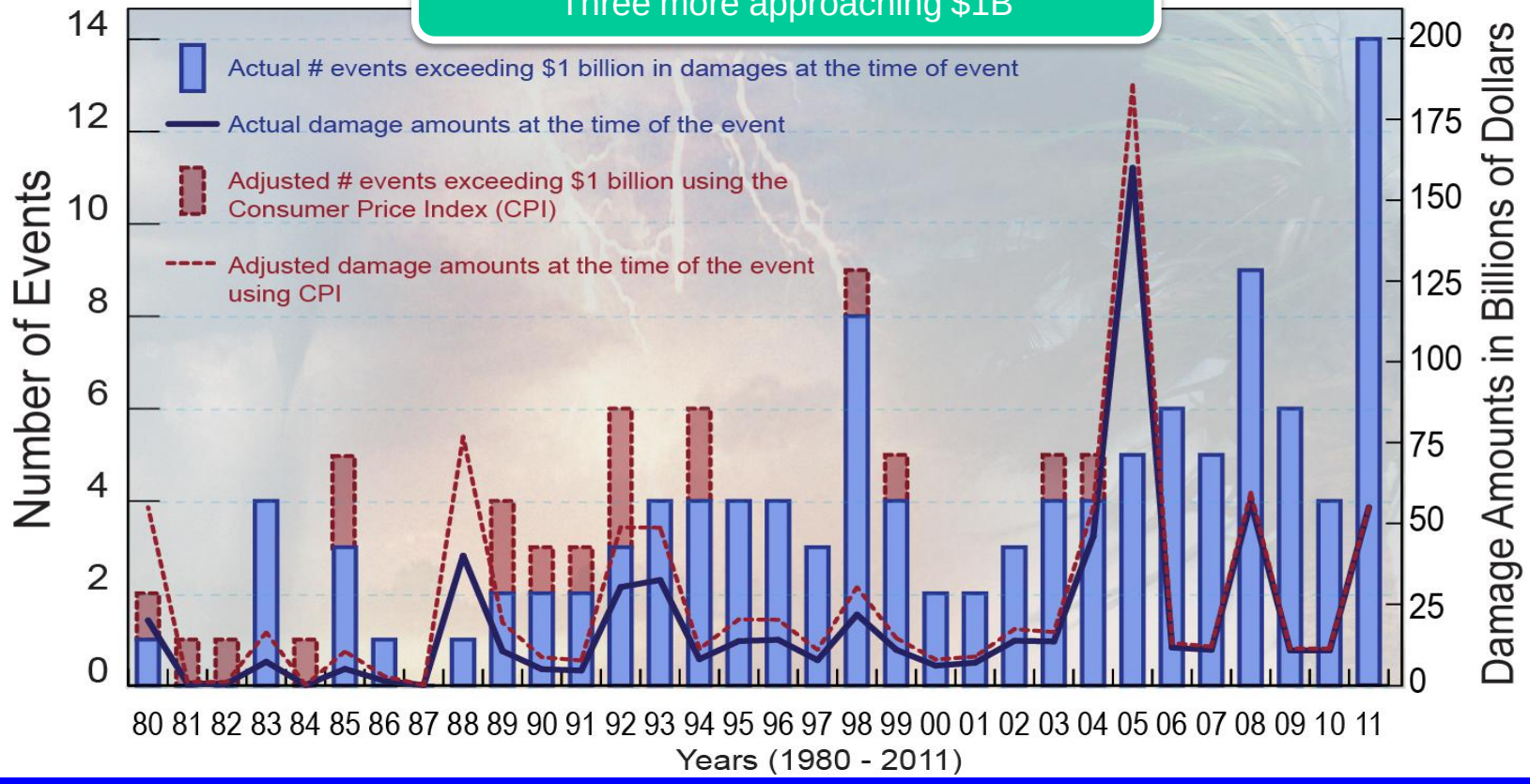


Source: http://www.munichreamerica.com/webinars/2012_01_natcatreview/munichre_iii_2011natcatreview.pdf

Billion Dollar Weather and Climate Disasters

- Since 1980, 114 billion-dollar weather and climate disasters in U.S.
- Total losses since 1980 of billion-dollar disasters exceed $800 billion.
- Is the U.S. becoming more exposed and/or sensitive to severe events?

A Record 14 Disasters in the U.S. in 2011
Three more approaching $1B

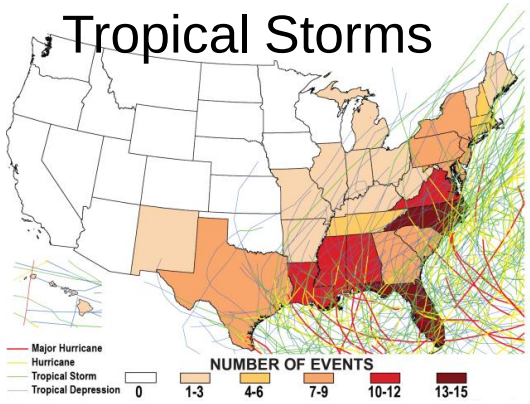


Source: http://www.ncdc.noaa.gov/billions/time-series

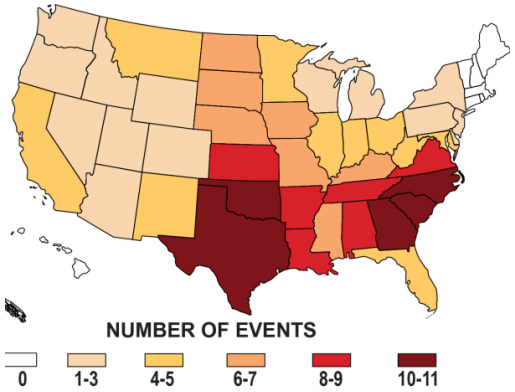
Status of Present Knowledge: *Economic Impacts*

U.S. Billion-Dollar Weather and Climate Disasters: 1980 – 2011

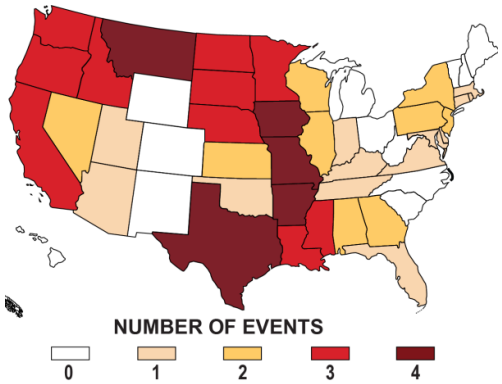
Hurricanes and Tropical Storms



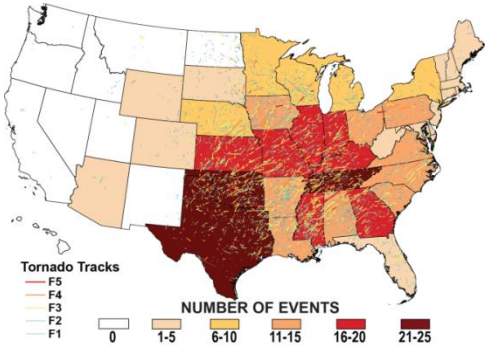
Drought and Heat Wave



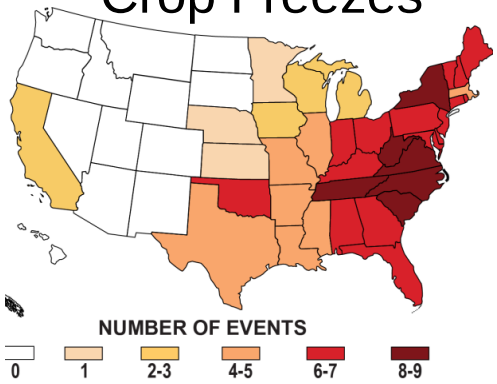
Flooding



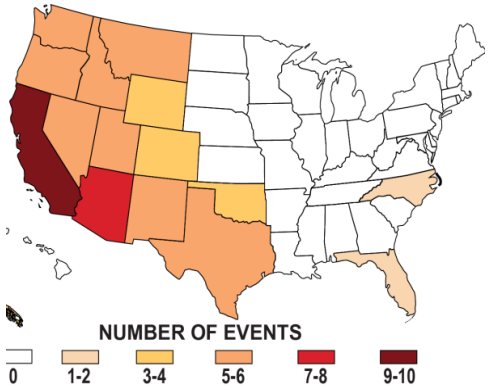
Severe Local Storms and Tornadoes



Winter Storm and Crop Freezes



Wildfires



Source: www.ncdc.noaa.gov/oa/reports/billionz.html

What is at Risk? What Can We Do?


Life and Property


Aviation


Maritime


Space Operations


Forests


Emergency Management


Commerce


Ports


Energy


Hydropower


Reservoir Control

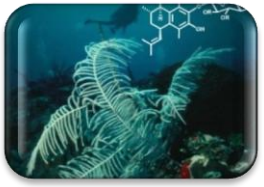

Infrastructure


Construction


Agriculture


Recreation


Ecosystems


Health


Environment

Source: NOAA Climate Adaptation Portfolio

Key Issues: Water Distribution

- Changes in precipitation patterns
- Wildfires
- Snowpack
- Water disputes
- Waterborne diseases

Source: NOAA Climate Adaptation Portfolio

Who is Using NOAA's Water-Related Data and Information?

Source: NOAA Climate Adaptation Portfolio

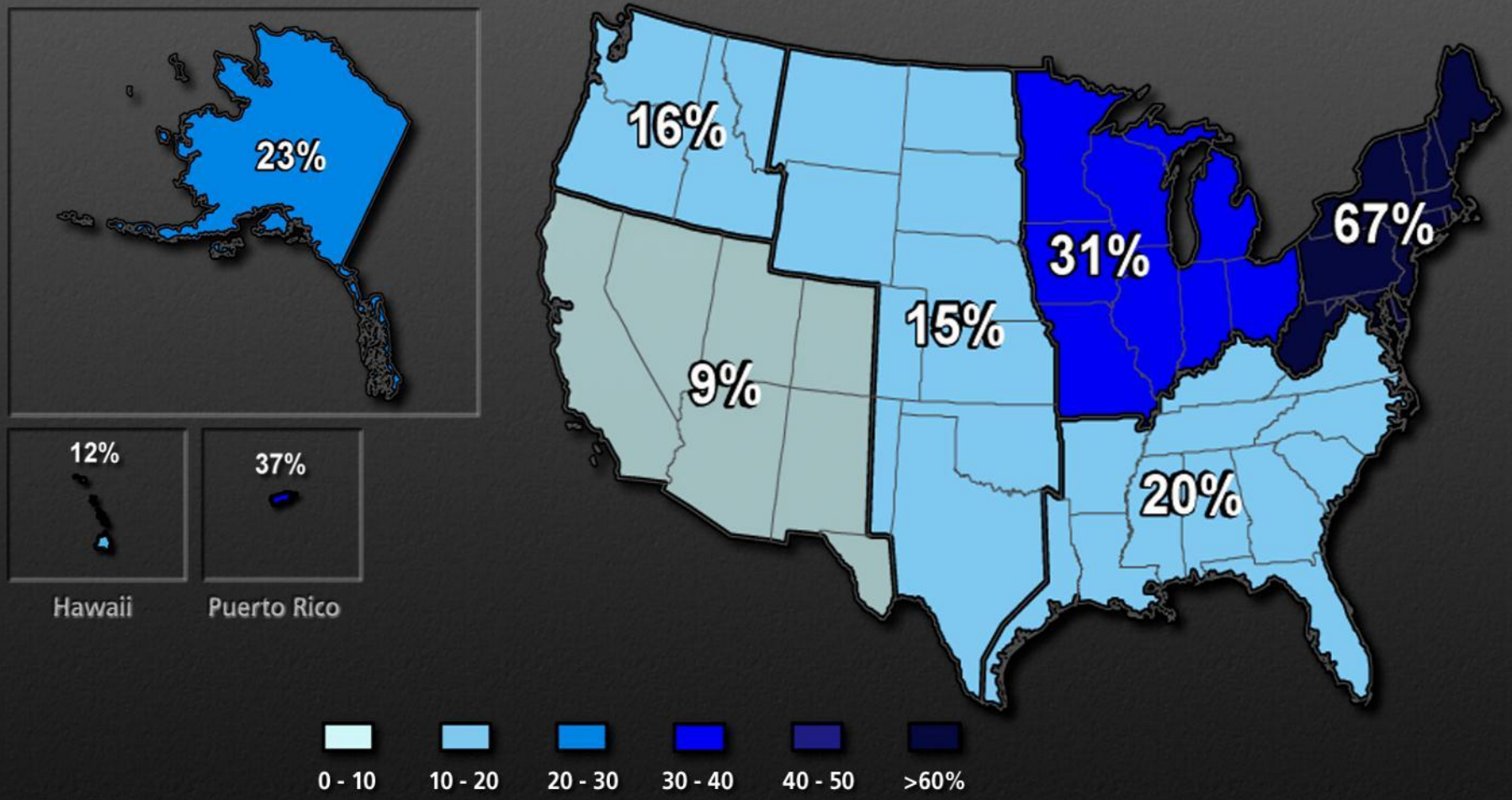
What are People Asking?

- Why / how did this happen?
- Will it happen again? If so, how soon and how often?
- Could the problem get worse in the future?
- What can we do to prevent such events?
- Should we rebuild? Should we relocate?

Source: NOAA Climate Adaptation Portfolio

Increases in Amounts of Very Heavy Precipitation 1958 to 2007

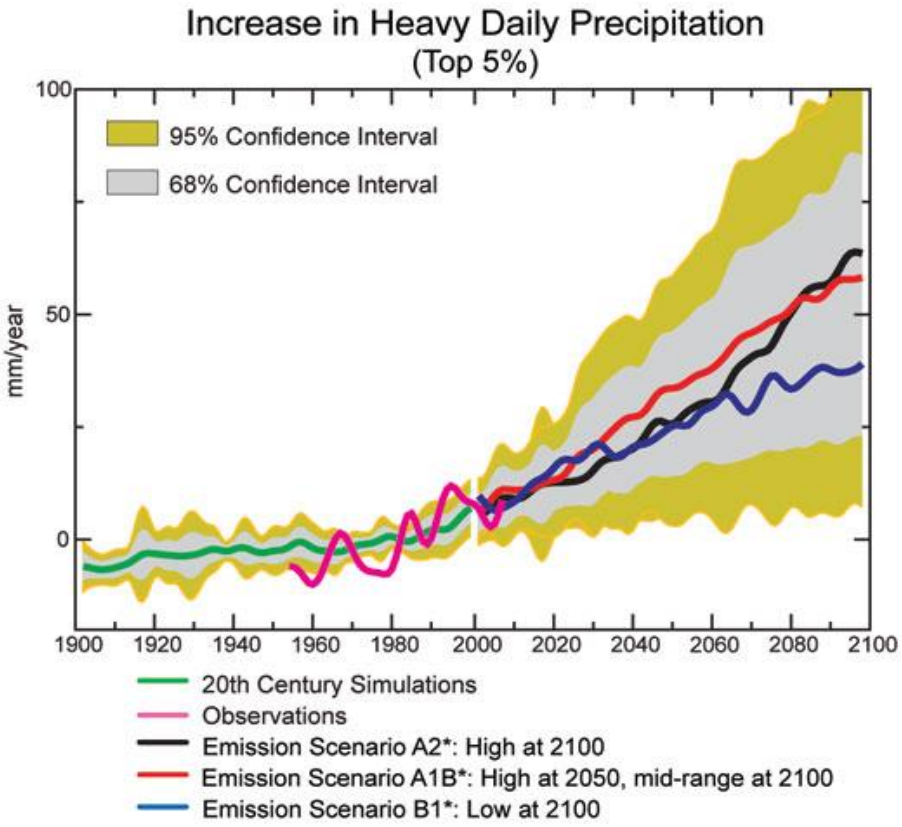
Percent Change



Precipitation Extremes

Projected Changes ----

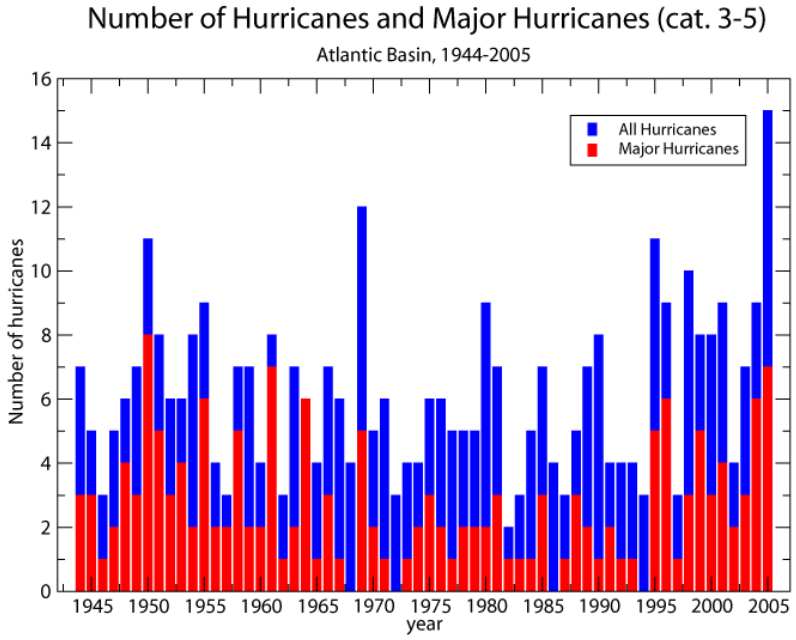
- An increase in precipitation intensity is expected, consistent with the observed increases in atmospheric water vapor (linked to human-induced increases in greenhouse gases).

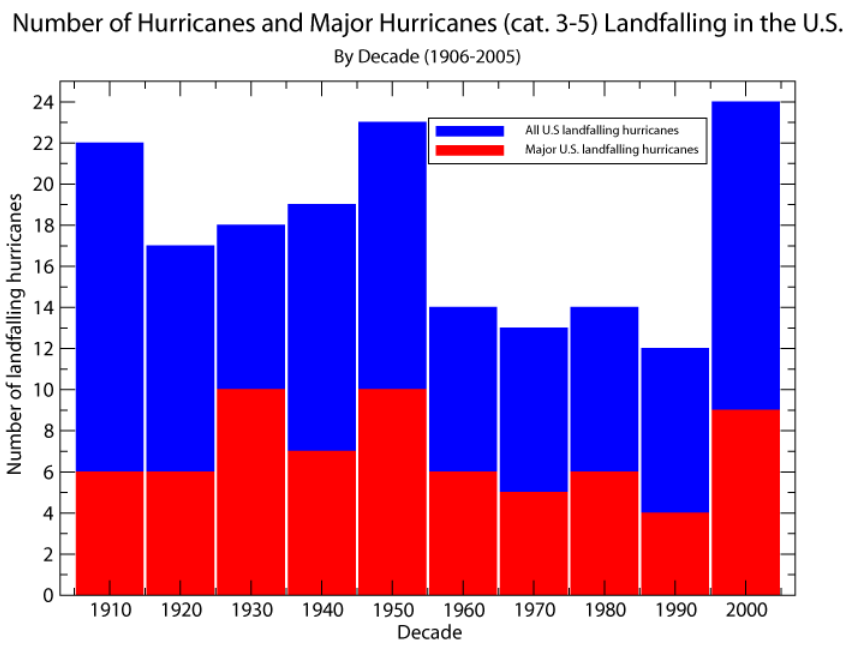


Source: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

Hurricanes in the Atlantic Basin

Observed Changes ----

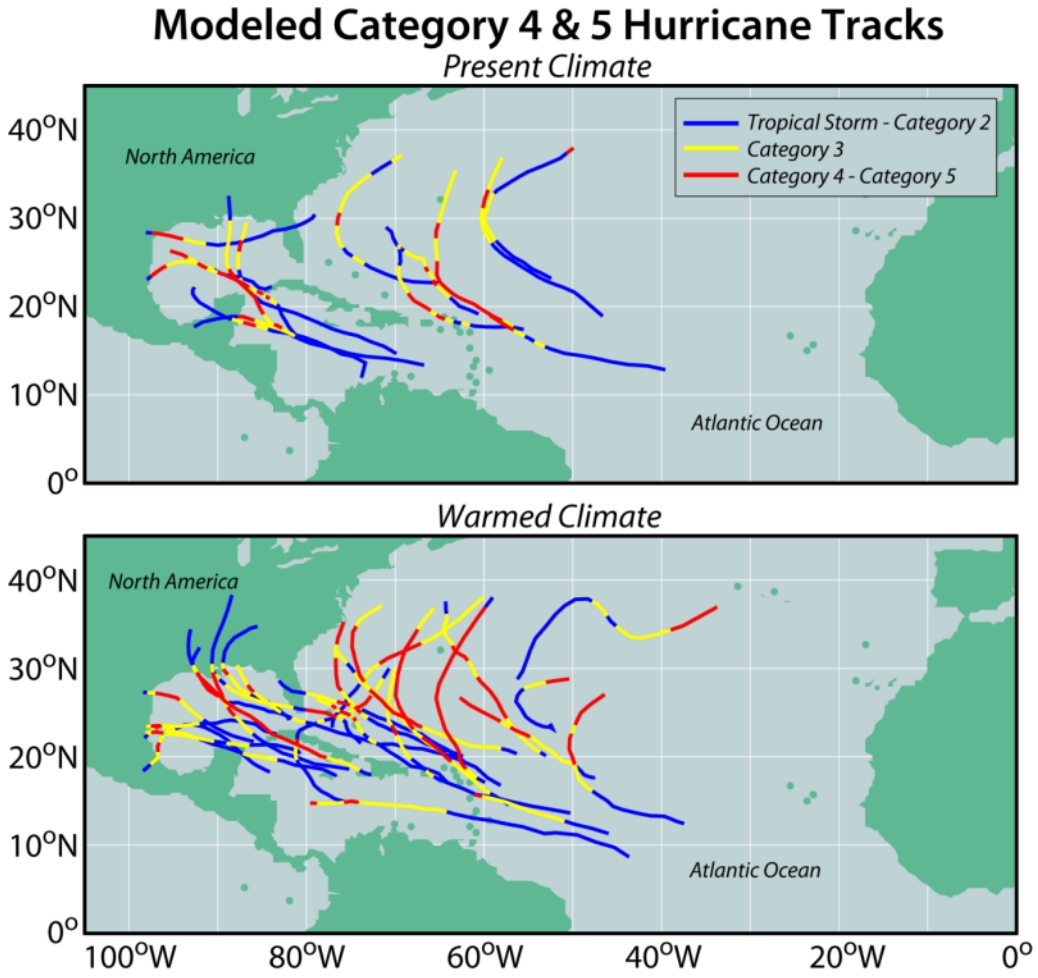




- The increase in hurricane activity since 1995 has precedence. In the historical record
- There is no detectable long-term trend in hurricanes.
- There have been changes in hurricane observation methods (e.g. pre and post satellite era) that complicate the identification of long-term trends

Source : NOAA

Projected Hurricane Patterns in a Warmed Climate



 | Source: http://www.gfdl.noaa.gov/global-warming-and-hurricanes.

NOAA

USGS science for a changing world

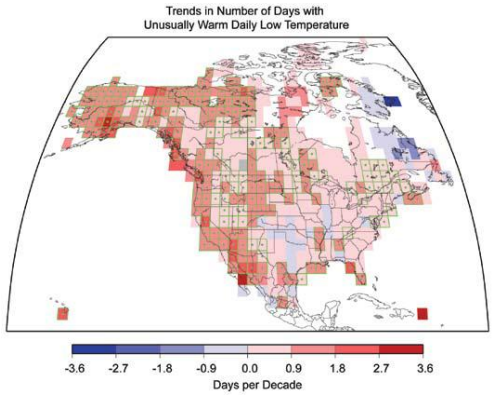
Should we really attribute every extreme event (heat wave, flood, hurricane) to climate change?

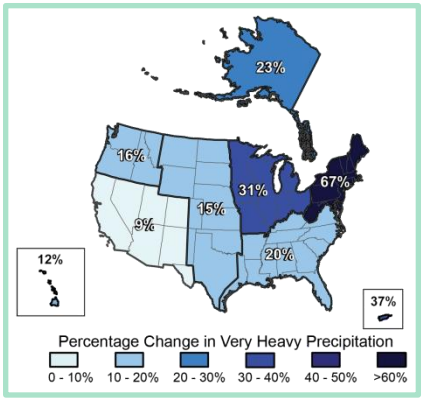
No individual weather event can be attributed to climate change.

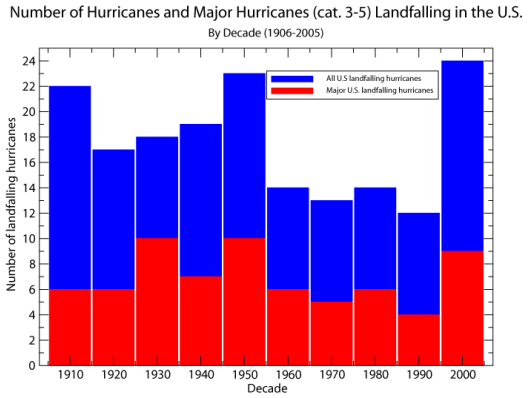
Changes in the number and intensity of some events (e.g. more intense rainfall; warmer winter nights) have strong links to climate change.

Changes in observing systems (e.g. introduction of satellites) have confounded attempts to document trends (e.g. hurricanes over the Atlantic).

Research is ongoing.

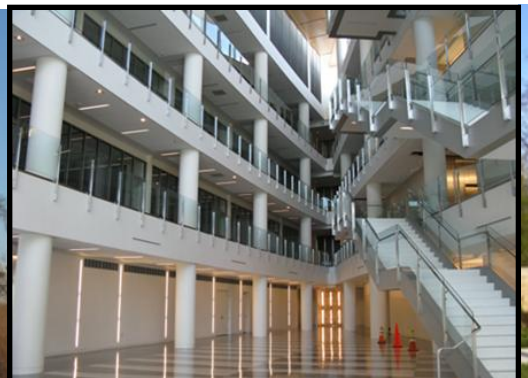






Summary

- The development and application of numerical prediction systems represents one of the top intellectual achievements of the 20th century.
- Making great strides in weather and climate prediction – useful skill out to Day 7 (and beyond), even for extreme events.
- Forecast success heavily dependent on global observing system linked to coupled numerical prediction models.
- Links between trends in green-house gas concentration and trends in weather extremes, including hurricanes, tornadoes, floods, droughts, cold waves, heat waves, etc. have not been fully established.
- Credible extrapolation of trends in extremes depends on future model improvements.

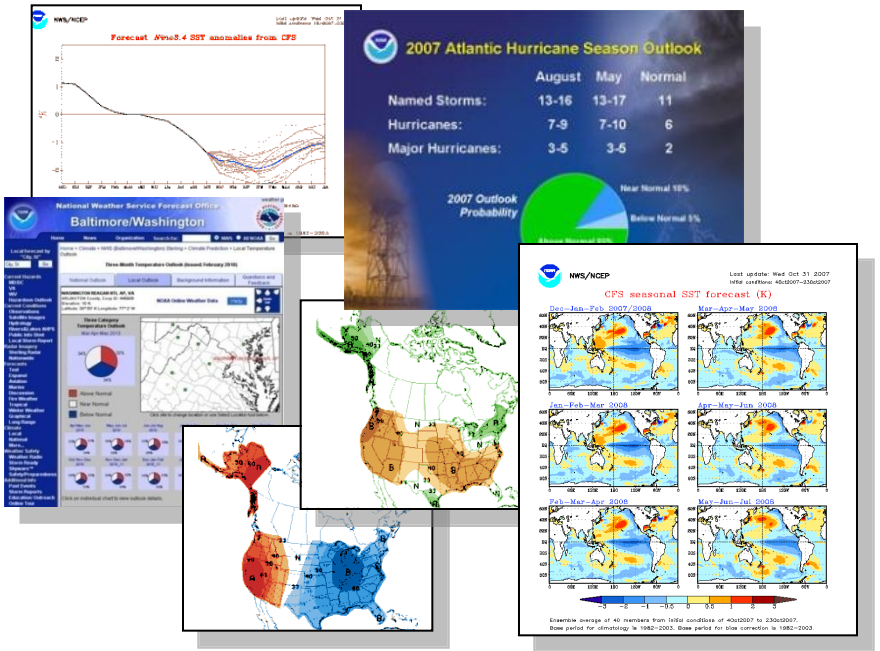




NOAA Climate Products and Data

CPC Prediction and Monitoring Products

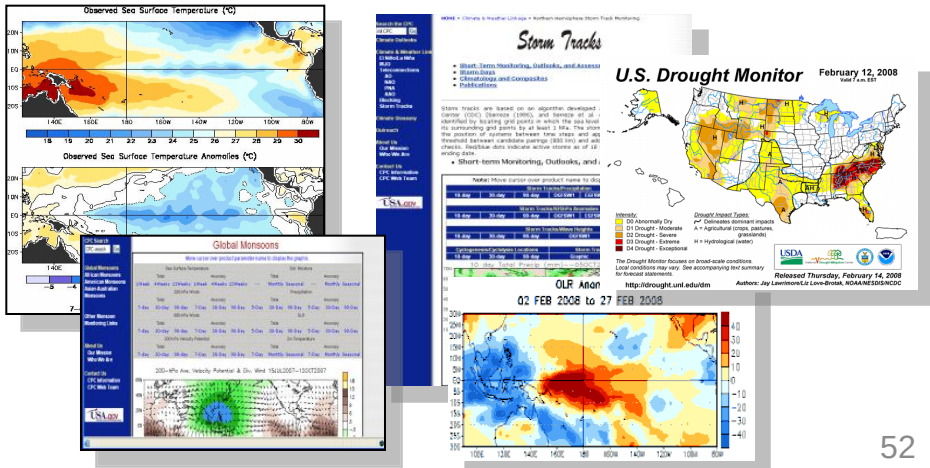
Official Outlooks focused on week-2, monthly, seasonal

- Precipitation & Temperature Outlooks
- Hazards Outlooks (US, Global Tropics)
- Seasonal Drought Outlook
- Seasonal Hurricane Outlooks (Atlantic and Eastern Pacific)
- El Nino / La Nina Prediction

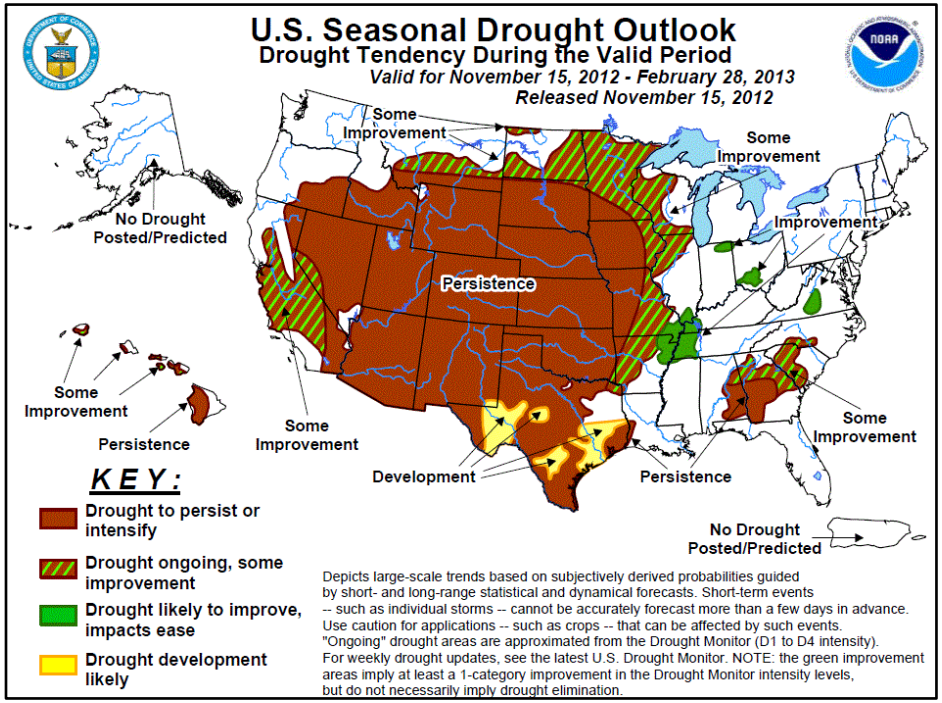


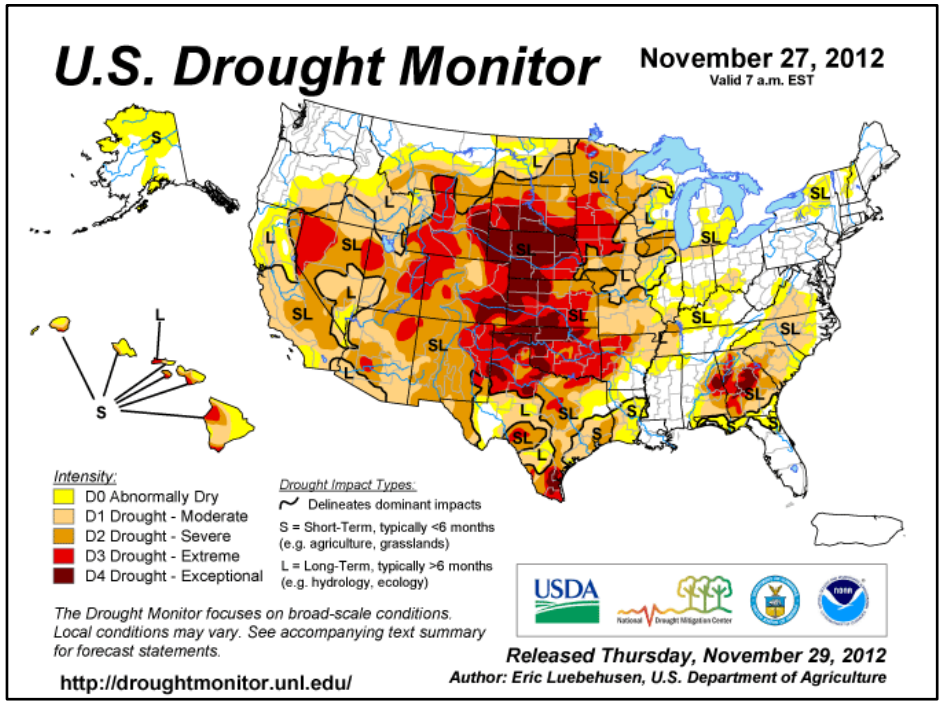
Real-time and historic monitoring of atmosphere, ocean, land surface conditions

- Daily and monthly data, time series, and spatial maps
- Primary modes of climate variability (ENSO, MJO, NAO, PNA, AO,...)
- Storm Tracks and Blocking
- Monsoons
- Precipitation and Surface Temperature
- Drought (US, North America; NIDIS)



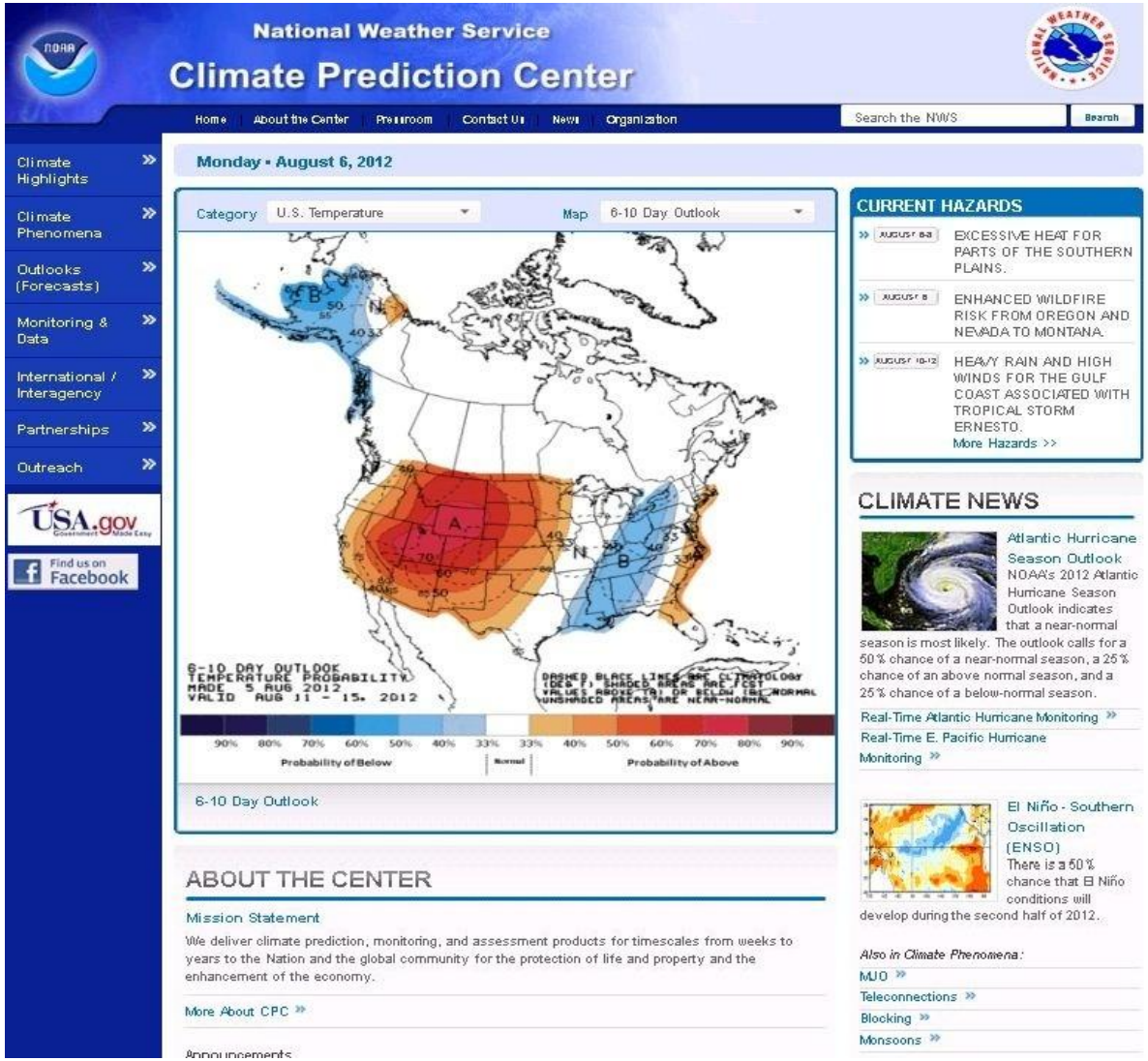
Drought: Tools and Resources





Source: http://www.cpc.ncep.noaa.gov/products/expert_assessment/season_drought.gif.; http://droughtmonitor.unl.edu/monitor.html

Climate Prediction Center Web Site



www.cpc.ncep.noaa.gov

Climate Prediction Center
Example Products

Example Climate Information Products

- Outlooks
  - Extended Range (6-10 day & week-2) – U.S. Temp & Precip
  - Monthly and Seasonal – U.S. Temp & Precip
  - Seasonal Hurricane Outlooks (Atlantic; eastern Pacific)
  - Seasonal Drought Outlook
  - U.S. and Global Tropics Hazards Outlooks
  - El Nino / La Nina prediction
- Tools
  - Dynamical Model Forecasts (e.g. GFS, CFS)
  - Statistical Model Forecasts (e.g. OCN; CCA)
  - National Multi-Model Ensemble
- Real-time Monitoring
  - Global atmosphere, ocean and land surface conditions
  - Primary modes of climate variability (e.g. El Nino / La Nina, Madden Julian Oscillation, Arctic Oscillation)
  - U.S. Drought Monitor
  - Monsoon Monitoring
  - Storm Tracks; Blocking
- Interagency and International
  - Joint Agriculture Weather Facility (Weekly Weather and Crop Bulletin)
  - International Training Desks (Weekly Climate Risk Bulletins)
- Climate Diagnostics and Discussions
  - Monthly Climate Diagnostics Bulletin
  - Monthly ENSO Diagnostics Discussion

Example Climate Data Products

- Surface-Based Analyses
  - Daily Precipitation (U.S. & Global)
  - Daily Temperature (U.S. & Global)
  - Daily Heating/Cooling Degree Days
  - Monthly Snow Cover
- Model Data
  - CFS Reanalysis and Reforecasts
  - Official Outlooks and Verification
- Satellite Data
  - Daily GOES Precipitation Index
  - Daily and Monthly OLR
  - Daily Sea Surface Temperature
  - Daily satellite gauge merge (precipitation)
- Climate Variability Indices
  - Oceanic Nino Index
  - Southern Oscillation Index
  - Teleconnection Indices
  - Palmer Drought Index
- International Desks
  - FEWS-NET

Web Page: www.cpc.ncep.noaa.gov
Point of Contact: Wayne Higgins

National Climatic Data Center
Example Products

Example Climate Information Products

- Tools
  - Climate Data Online – GIS-based map interface
  - Weather and Climate Toolkit
  - Climate at a Glance (U.S. and Global)
- Climate of the U.S.
  - U.S. Climate Normals
  - U.S. Wind Climatology
  - Climate Atlas of the U.S.
- Monitoring
  - Monthly Climate Highlights (U.S. and Global)
  - U.S. Billion-dollar Disasters
  - Drought Portal (U.S., North American, Global)
- Extreme Events
  - U.S. Records
  - Climate Extremes Index, Regional Snowfall Index
  - Annual BAMS Explaining Extremes Report
- Statistical Information
  - Temperature, Precipitation & Drought time series, rankings, maps
- Regional & Sectoral
  - Residential Energy Demand Temperature Index
  - Regional Climate Services
- Assessments
  - International (IPCC)
  - National Climate Assessment
  - Annual BAMS State of the Climate Report

Example Climate Data Products

- Climate Data Records
- Surface-Based Station Data
  - Local U.S. Climatological Data
  - Global Historical Climate Network-Daily
  - U.S. Climate Reference Network
  - National Solar Radiation Database
- Satellite Data
  - Geostationary, Polar-orbiting
- Radar Data
  - NEXRAD, Dual-Polarized
- Model Data
  - Reanalysis, Numerical Weather Prediction, Climate Prediction (CMIP5)
- Weather Balloon Data
  - Integrated Global Radiosonde Archive
- Marine/Ocean Data
  - Multiple global data sets
- Paleoclimate Data
  - Derived from multiple sources
- Severe Weather
  - Storm Events Database, International Best Hurricane Track Archive for Climate Stewardship

Web Page: www.ncdc.noaa.gov

Point of Contact: Tom Karl

Coastal Services Center (CSC)
Example Products and Services

Example Climate Information Products

- Tools
  - Sea Level Rise and Coastal Flood Frequency Viewer
  - Coastal County Snapshots
  - CanVis Visualization Tool
  - Habitat Priority Planner
- Training and Technical Assistance
  - Coastal Adaptation for Coastal Communities
  - Coastal Inundation Mapping
  - Planning for Climate Change
  - Roadmap for Adapting to Coastal Risk
  - Coastal Community Planning and Development
- Publications
  - Marshes on the Move
  - Incorporating Sea Level Change Scenarios at the Local Level
  - Coastal Inundation Mapping Guidebook
  - Understanding Risk Behavior
  - Local Strategies for Addressing Climate Change

Example Climate Data Products

- Elevation Data
  - Topographic and Bathymetric Data Inventory
  - Coastal Lidar Data
- Land Cover Data
  - C-CAP High Resolution and Regional Data
- Data and Information Suites
  - Coastal Climate Adaptation Website
  - Coastal Inundation Toolkit

Point of Contact: Margaret Davidson
For more information:
http://csc.noaa.gov/
http://csc.noaa.gov/digitalcoast/

Climate Program Office (CPO)
Top Products and Services

1. Observations and Monitoring: Develops and sustains global *in situ* climate observing systems; Supports *>50%* of the sustained Global Ocean Observing System; Supports projects that produce datasets essential to international and national climate assessments; Annual *State of the Climate* Report

2. Understanding and Modeling: Over *700* published papers/yr citing CPO support, contributing to growing understanding of climate variability and change; Improved operational systems through CPO-supported research; Field campaigns

3. Informing Decisions: National Integrated Drought Information System (Drought.gov & pilot drought early warning systems); Regional Integrated Sciences and Assessments; Climate training workshops and reports directed to needs of resource managers; Fund National Research Council reports, including *America's Climate Choices*; Provide scientific input, coordination, funding, and sustained engagement for the National Climate Assessment

4. Program Development: Implementation plan for all NOAA climate activities; *176* NOAA Climate and Global Change Postdoctoral Fellows, *35* AMS Graduate Fellows, and *9* Post Docs Applying Climate Expertise (PACE) since inception of programs; New programs (e.g., National Climate Predictions and Projections platform, Deep Argo, Coastal and Ocean Climate Applications)

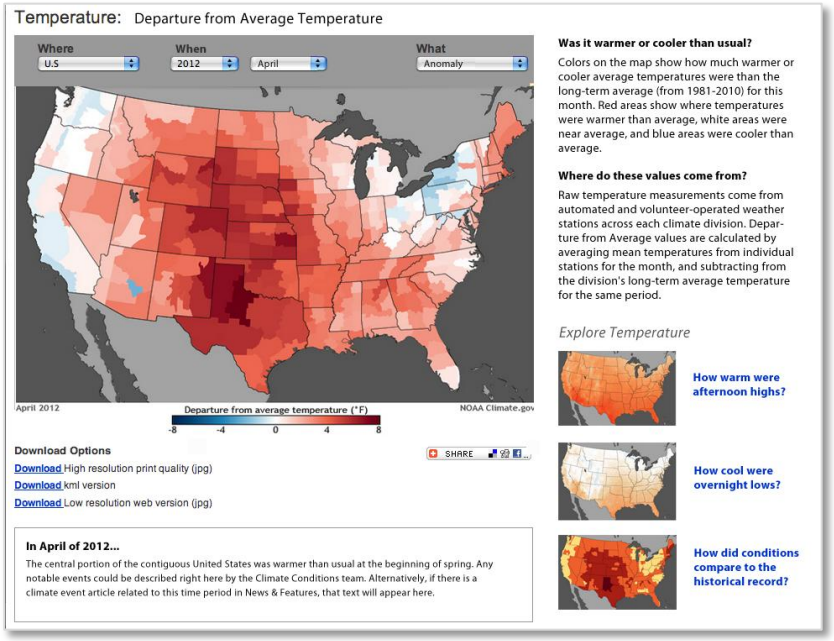
Web Page: www.cpo.noaa.gov

Point of Contact: Rick Rosen (rick.rosen@noaa.gov)

Climate Program Office (CPO)
Top Products and Services

5. NOAA Climate.gov Portal: A public-friend point-of-entry into NOAA's and partners' diverse offerings of climate data and information. We promote public understanding of climate science and the current state of the climate system to enhance public decision-making.

We offer four audience-focused sections with four objectives: **ClimateWatch Magazine** to inform and 'edutain' the climate-interested public; **Data & Services** to simplify discoverability and access to data products; **Education** to help teachers integrate climate science into learning venues; and **Understanding Climate** to provide policy leaders and decision makers with authoritative information resources to help them understand & manage climate-related risks.



New NOAA Climate.gov portal interface design (left) and Climate Conditions concept (right)

Web Page: www.cpo.noaa.gov

Point of Contact: Rick Rosen (rick.rosen@noaa.gov)