Celebrating the First Decade of the NASA/NOAA/DoD Joint Center for Satellite Data Assimilation

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NOAA Center for Weather and Climate Prediction

College Park, MD

September 13, 2012

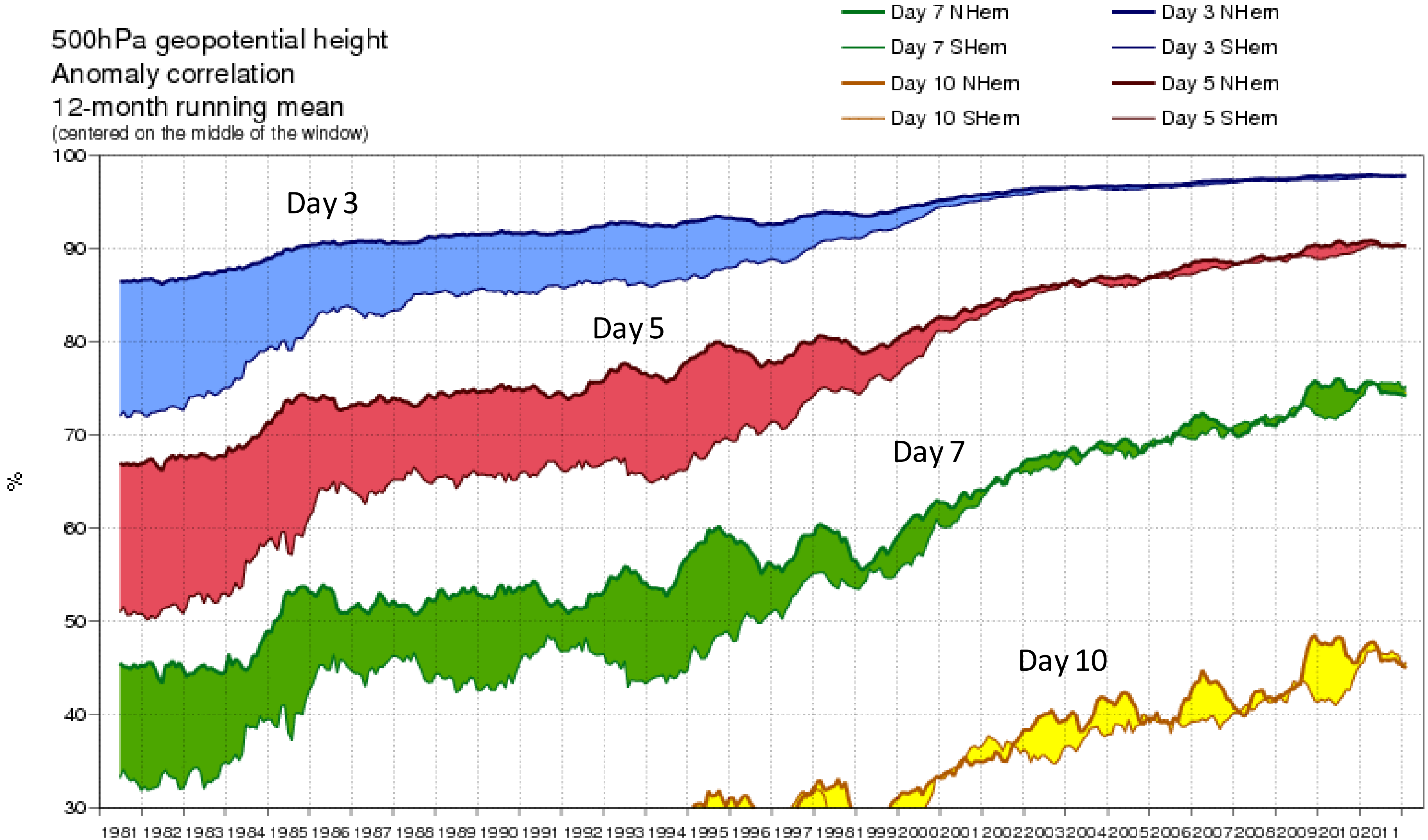
Welcome to the
NOAA Center for Climate and Weather Prediction

Outline

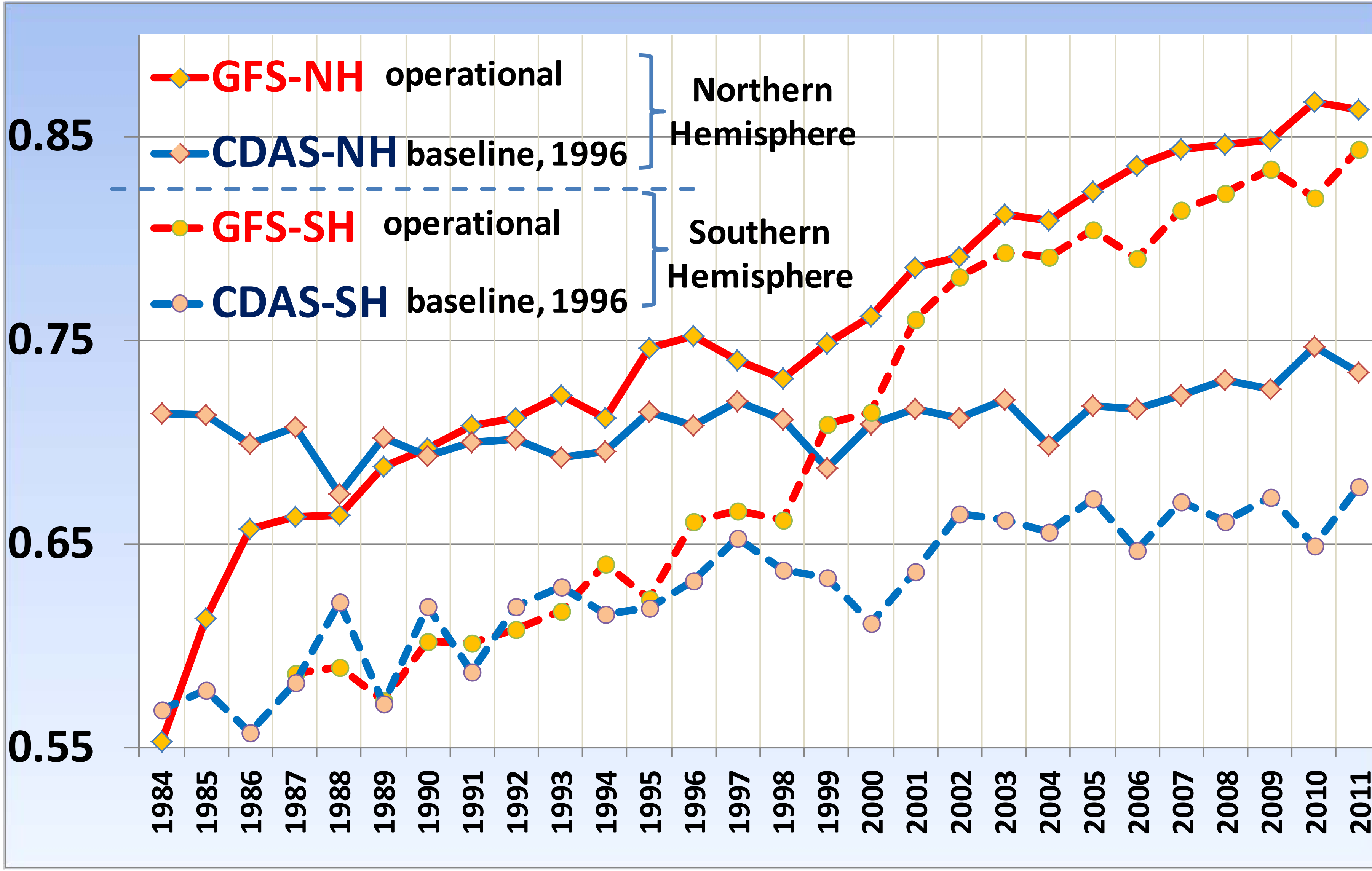
- Celebrating Accomplishments in Weather Prediction
- Transformation of the Forecast Process
- Importance of the JCSDA; Helping to solidify the R2O process
- Ongoing opportunities/challenges
- Summary

Celebrating Accomplishments in Weather Prediction

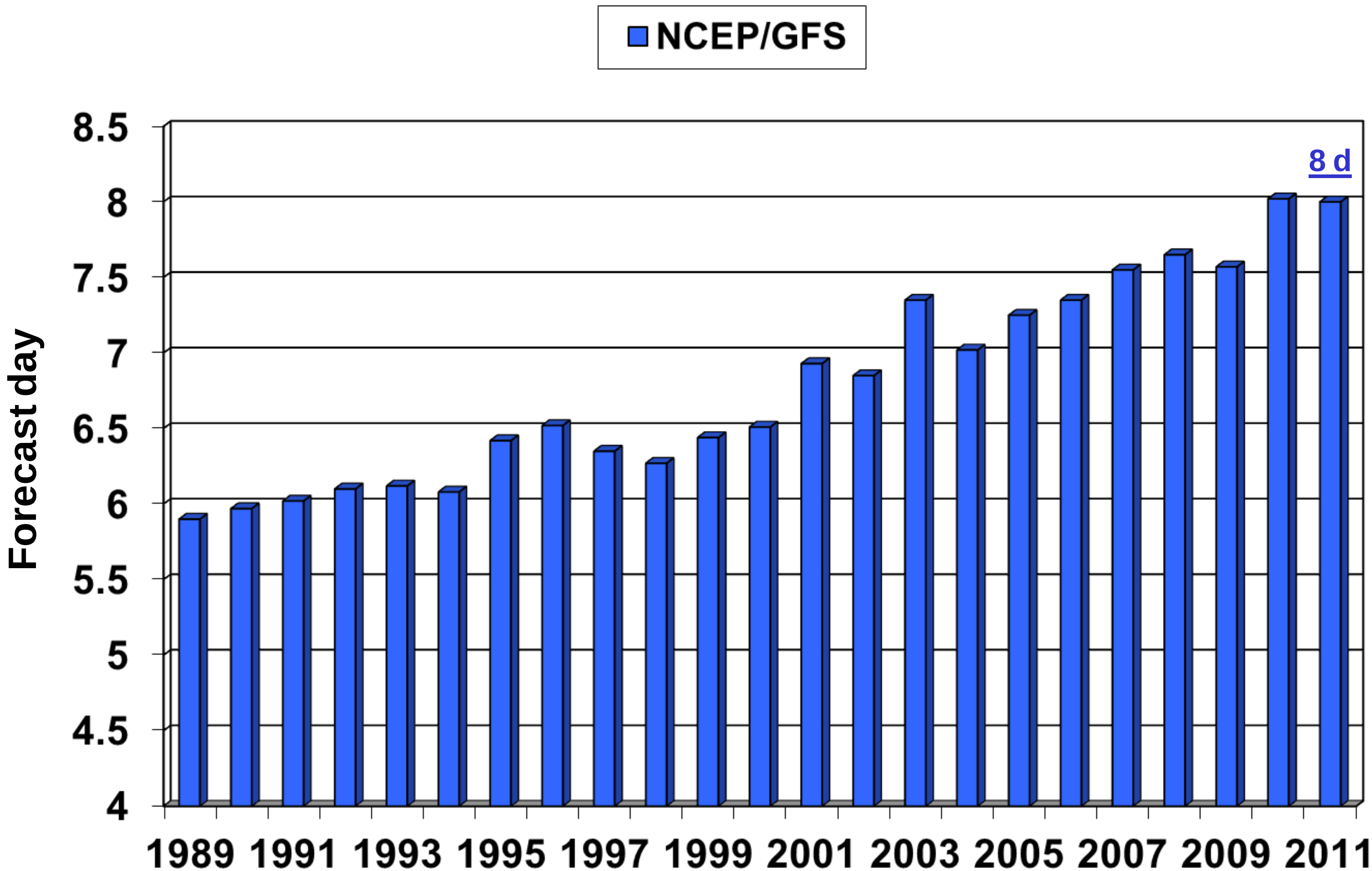
ECMWF


500hPa geopotential height
Anomaly correlation
12-month running mean
(centered on the middle of the window)
Day 7 NHem
Day 7 SHem
Day 10 NHem
Day 10 SHem
Day 3 NHem
Day 3 SHem
Day 5 NHem
Day 5 SHem
Day 3
Day 5
Day 7
Day 10
%
100
90
80
70
60
50
40
30
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

Annual Mean 500-hPa HGT Anomaly Correlation at Day 5
NCEP Global Forecast System



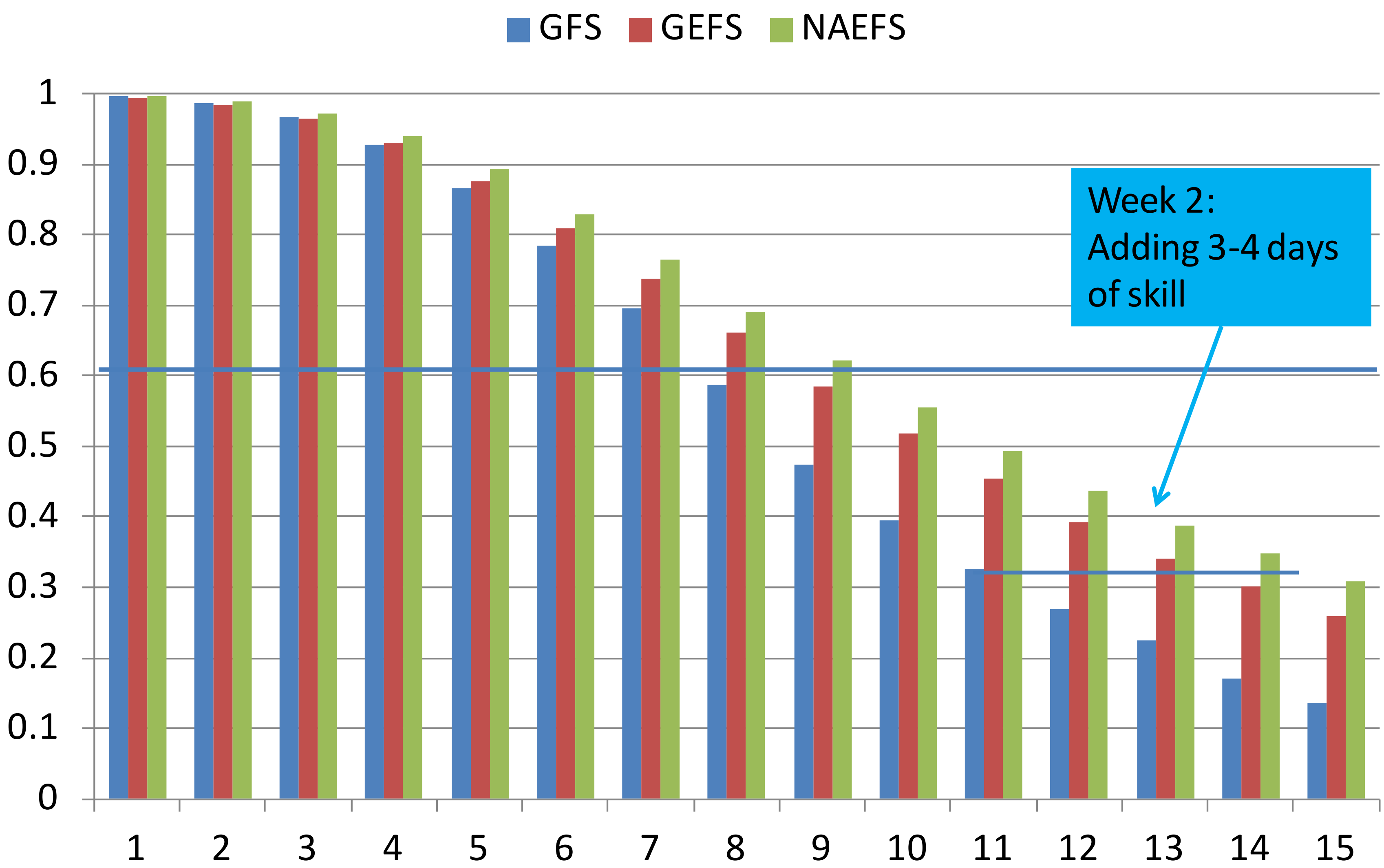
Day at which forecast loses useful skill (AC=0.6)
N. Hemisphere 500hPa height calendar year means



North American Ensemble Forecast System (NAEFS)

Impact on NH Anomaly Correlation for 500hPa Height

Period: September 1st – November 30th 2011



Rapidly Developing Pacific Storm: Not Predicted

13-14 November 1981

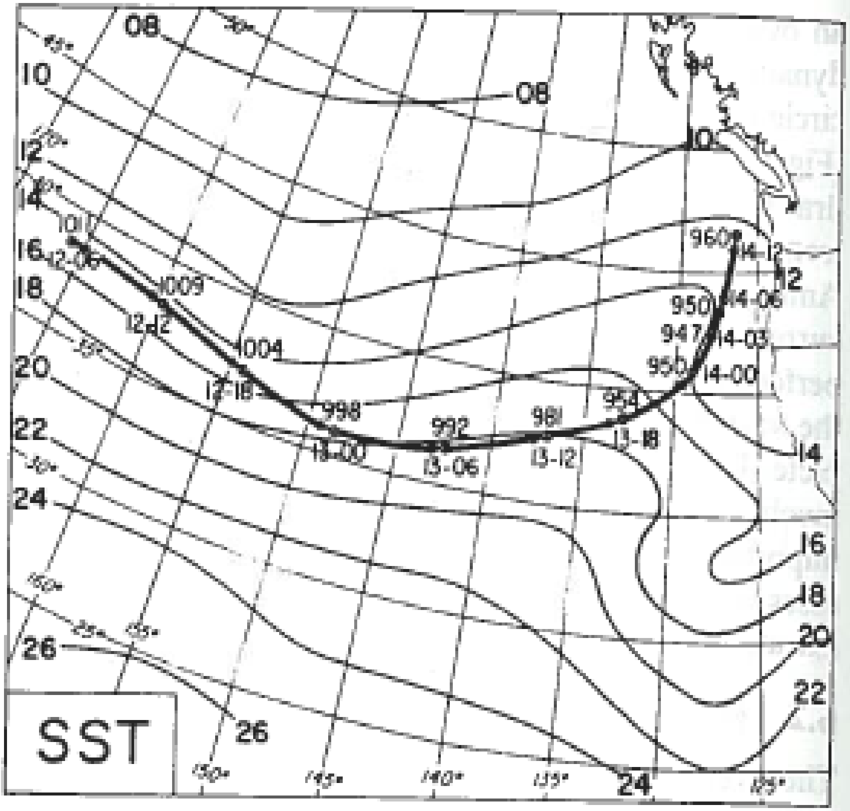


FIG. 6.4. Storm track for an intense oceanic cyclone. The 6-h positions and corresponding central pressures are marked for the period from 06 UTC 12 November to 12 UTC 14 November. Light solid lines are sea-surface temperature (°C)

Reed and Albright, MWR, 1986

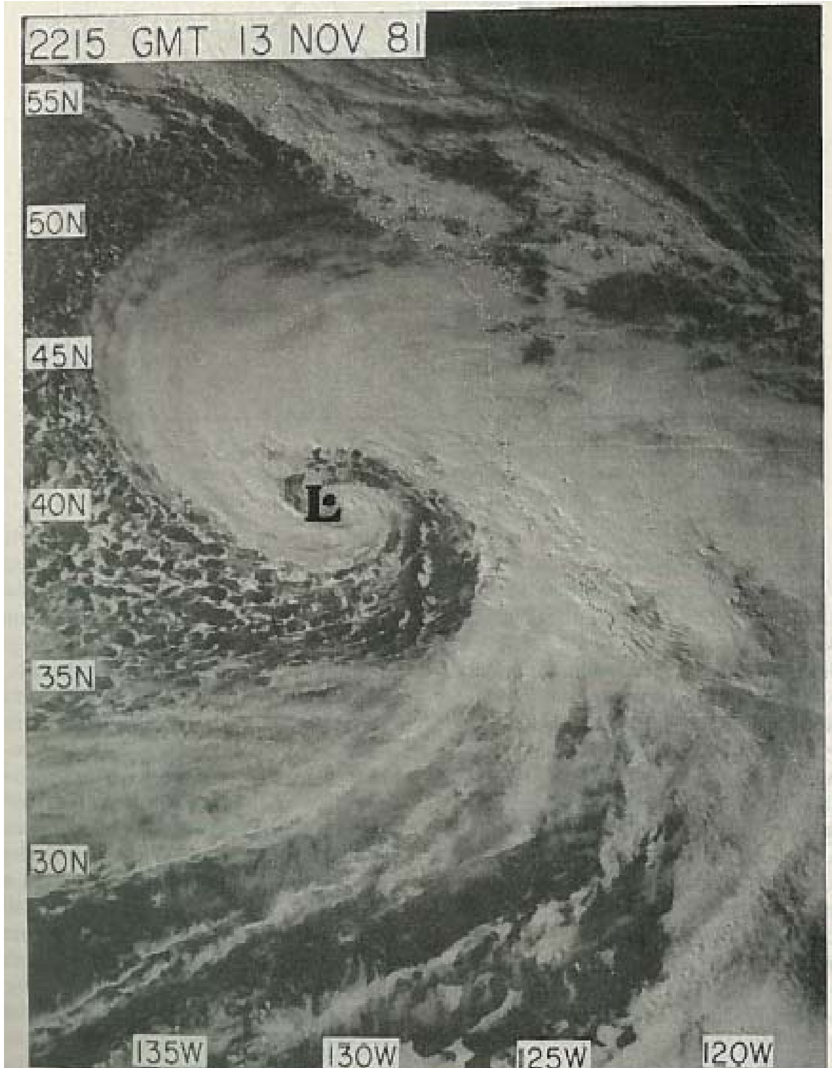
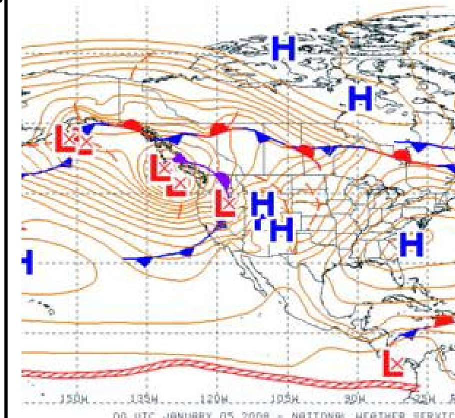


FIG. 10. GOES-W visible image 2215 GMT 13 November 1981.

January 3-7, 2008
West Coast Rain/Snow Event

- Snowfall in CA mountains of up to 10 feet.
- Many locations with multiple feet of snow.
- Localized flooding caused by heavy rains at lower elevations
- Rainfall amounts 2-10 inches.

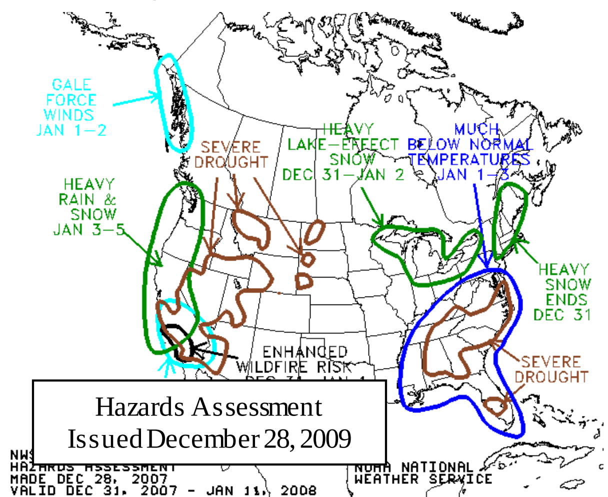
00Z 5 January, 2008



3 Weeks Prior to Event

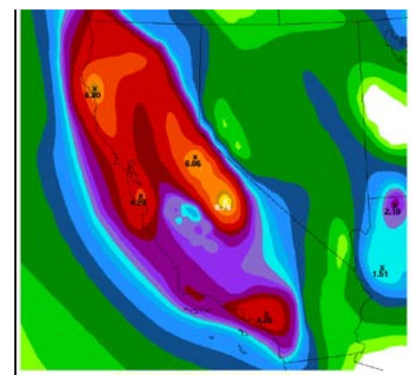
MJO Update: **issued by Climate Prediction Center**
December 24, 2007
"Some *potential exists for a heavy precipitation event* tied to tropical convection by week 3 … along *the west coast of the US* "

6 Days Prior to Event



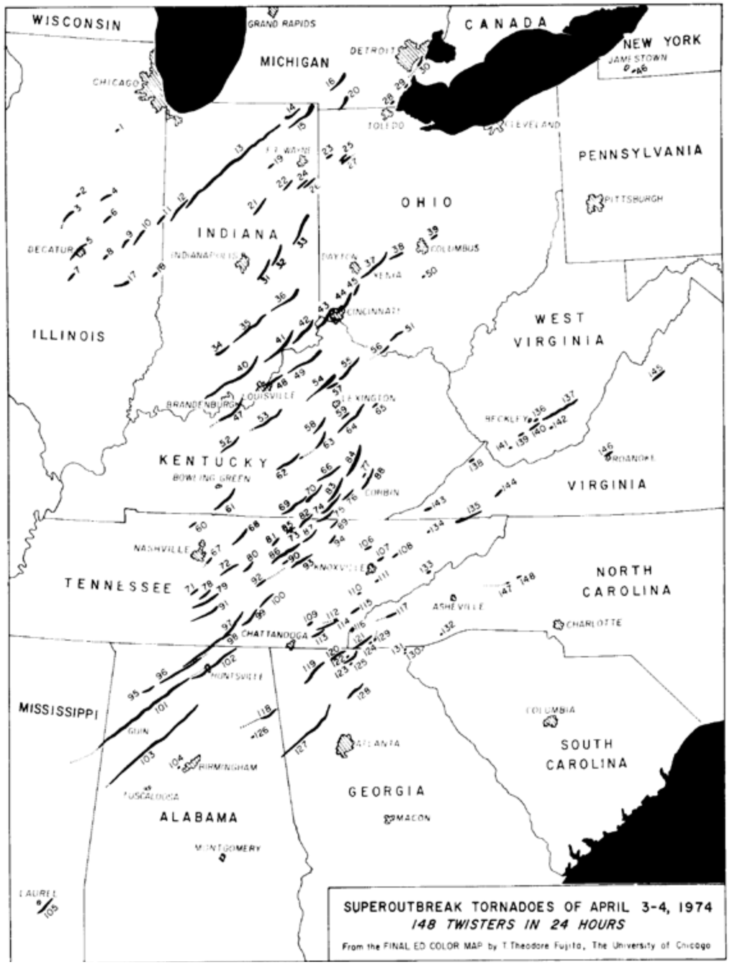
Hazards Assessment
Issued December 28, 2009

4 Days Prior to Event

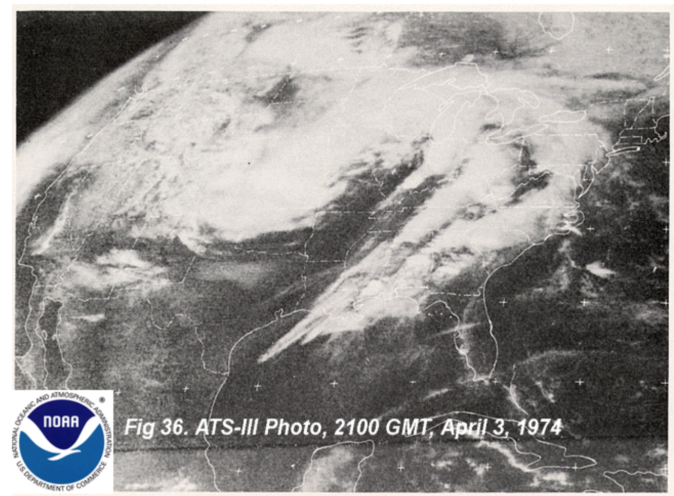


HPC 48-h QPF ending 00Z 6 Jan
Issued 00Z 1 Jan
Day 4-5 forecast

April 3-4, 1974 Super Outbreak

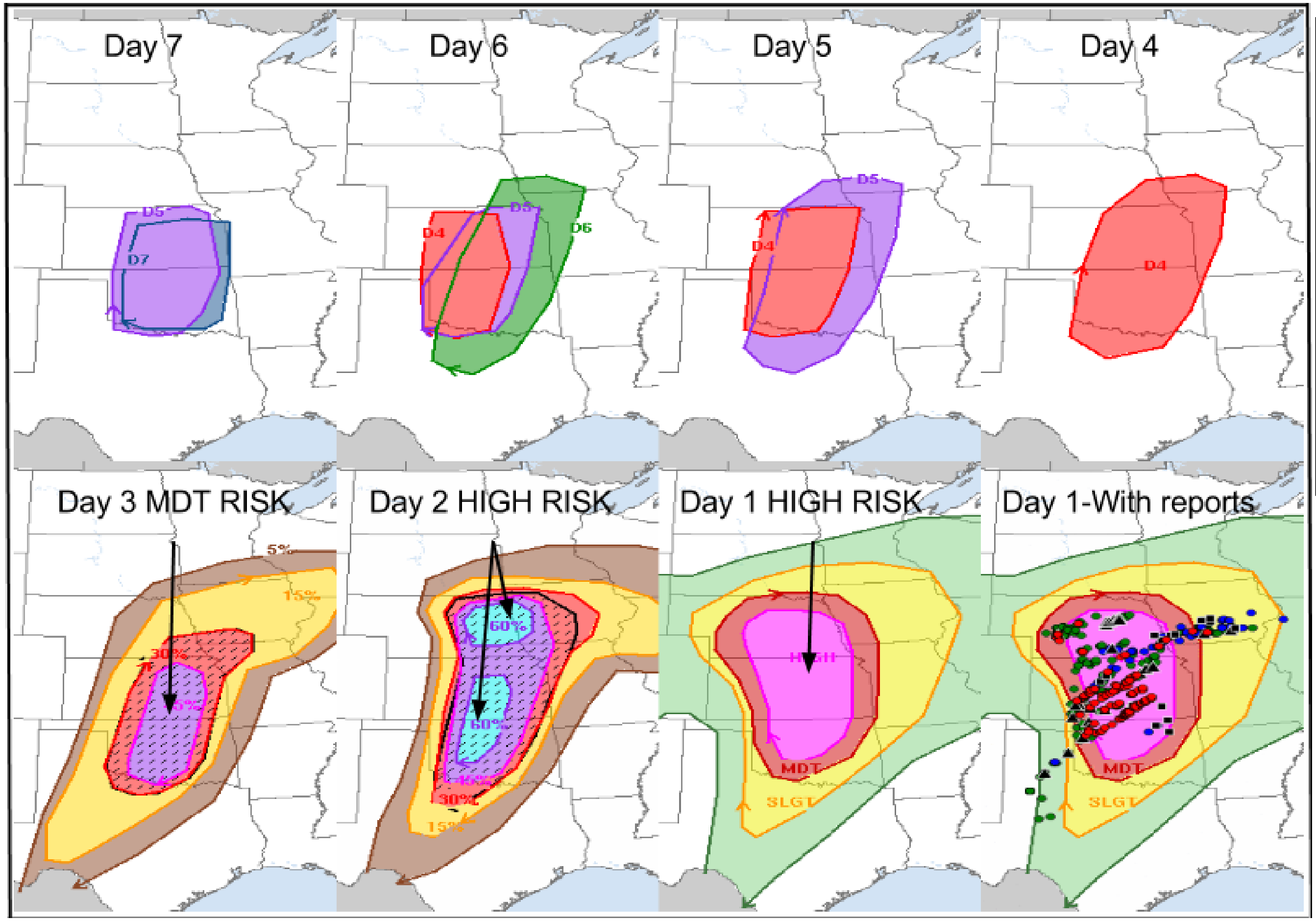


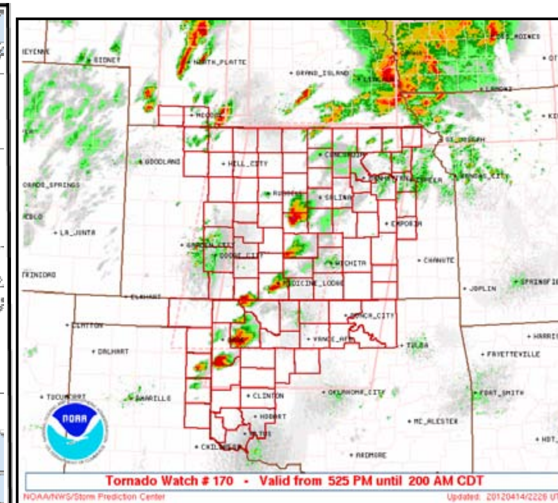
Tornado Tracks
12Z April 3 – 12Z April 4, 1974



- 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

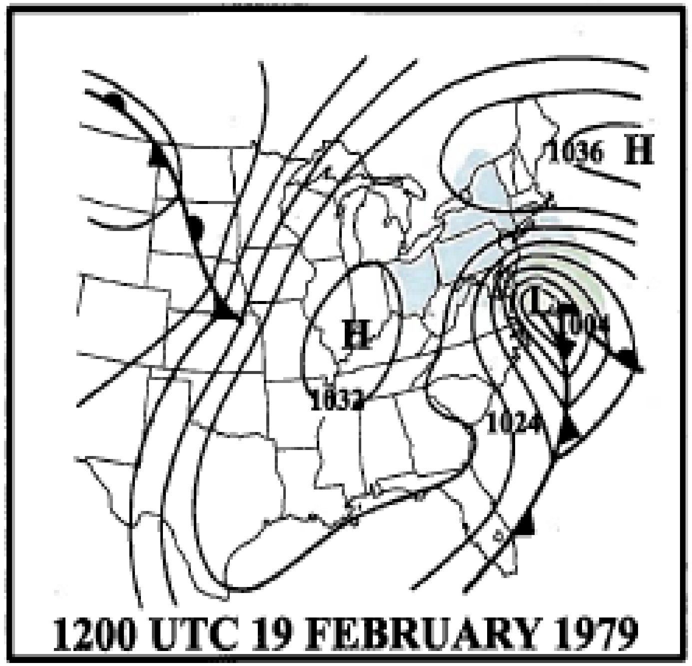
14 April 2012 Great Plains Outbreak





- 60 Tornadoes (1 EF4, 3 EF3 & 3 EF2)
- 6 Fatalities in Woodward, OK near midnight
- Outlook first issued 7 days in advance; Moderate Risk 3 days in advance; High Risk 2 days in advance (only 2nd time)
- Preliminary NWS average warning lead time (Tornadoes) : 20.1 minutes.

Presidents’ Day Storm 18-20 February, 1979



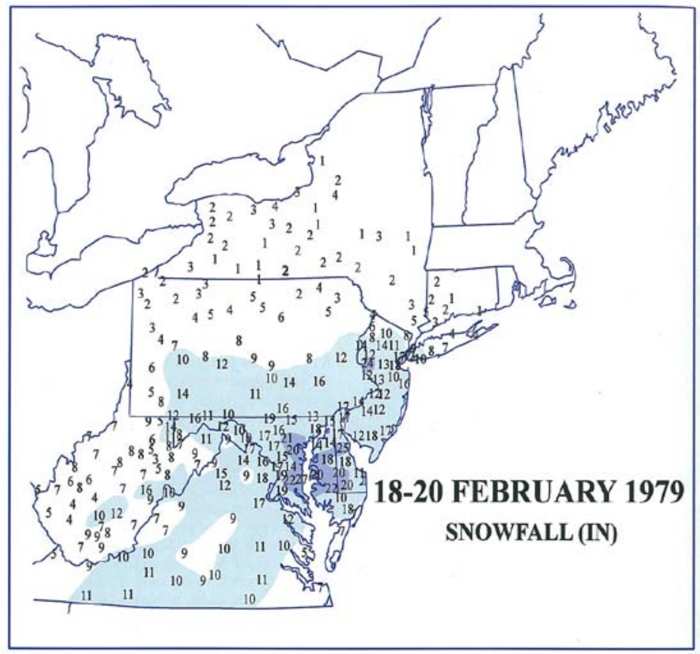
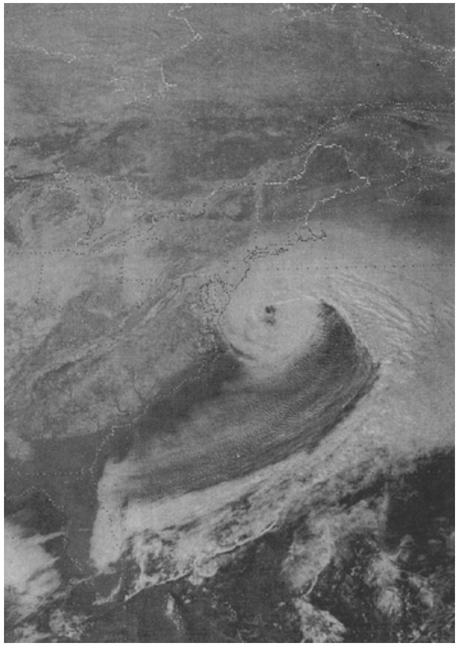


FIG. 10.18-1. Snowfall (in.) for 18–20 Feb 1979. See Fig. 10.1-1 for details.

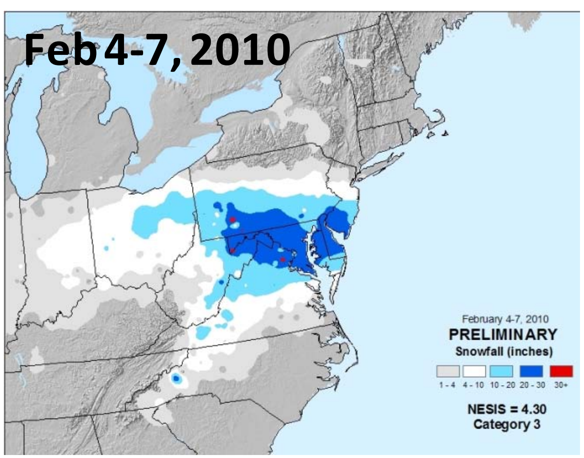


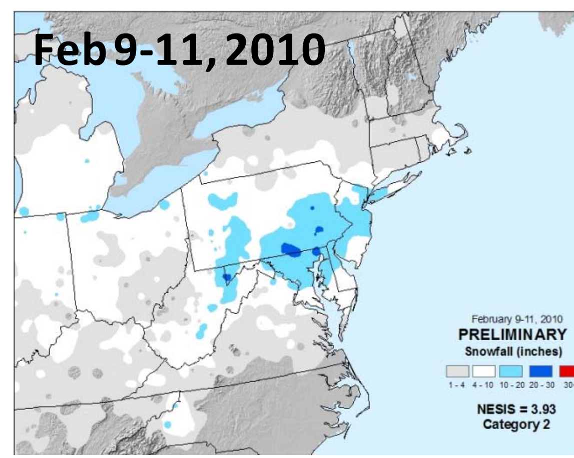
1830Z 19 Feb 1979

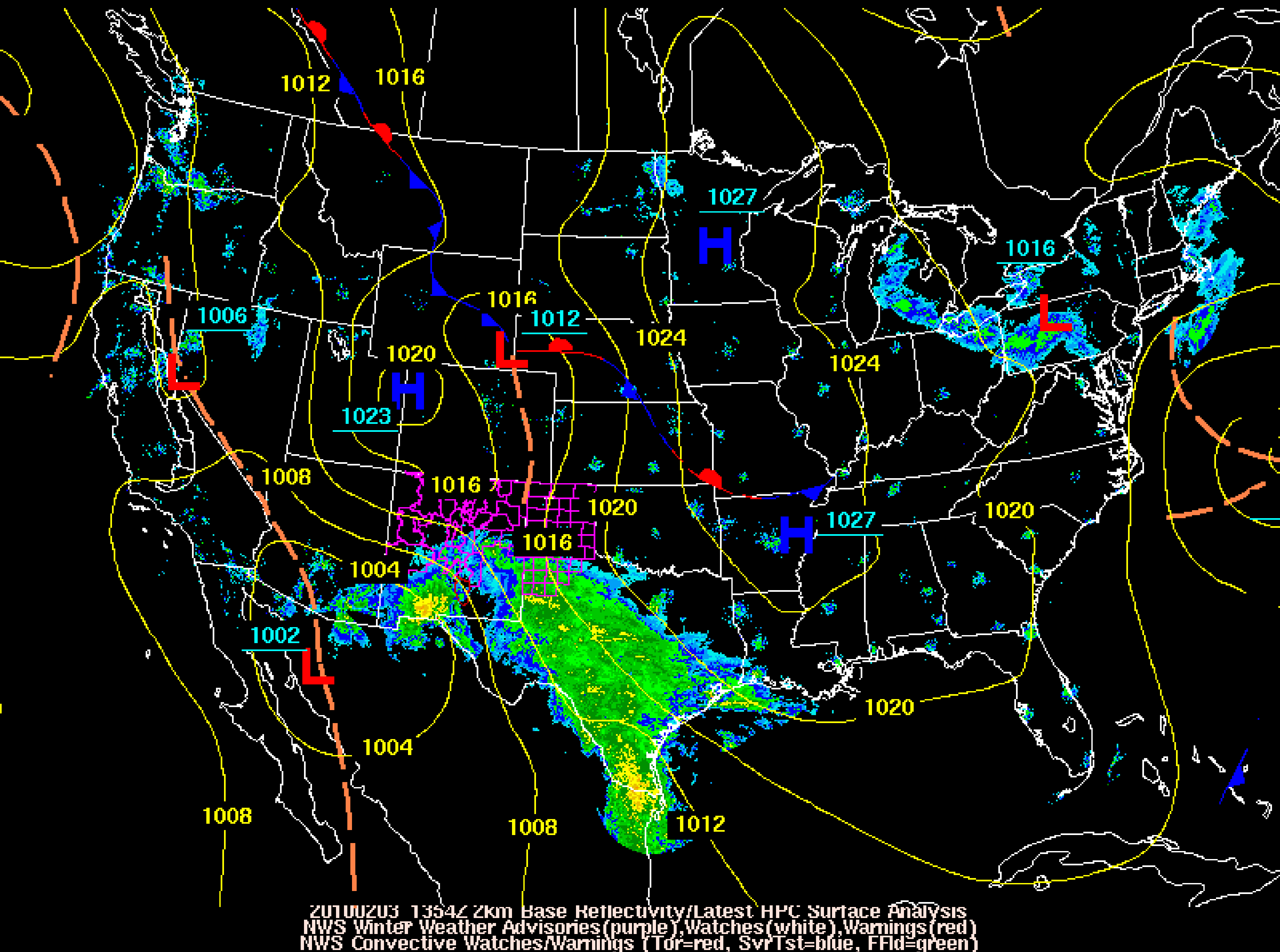
- 22 inches of snow buries Washington D.C. area
- Rapid cyclogenesis off the coast
- Not predicted even hours in advance

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



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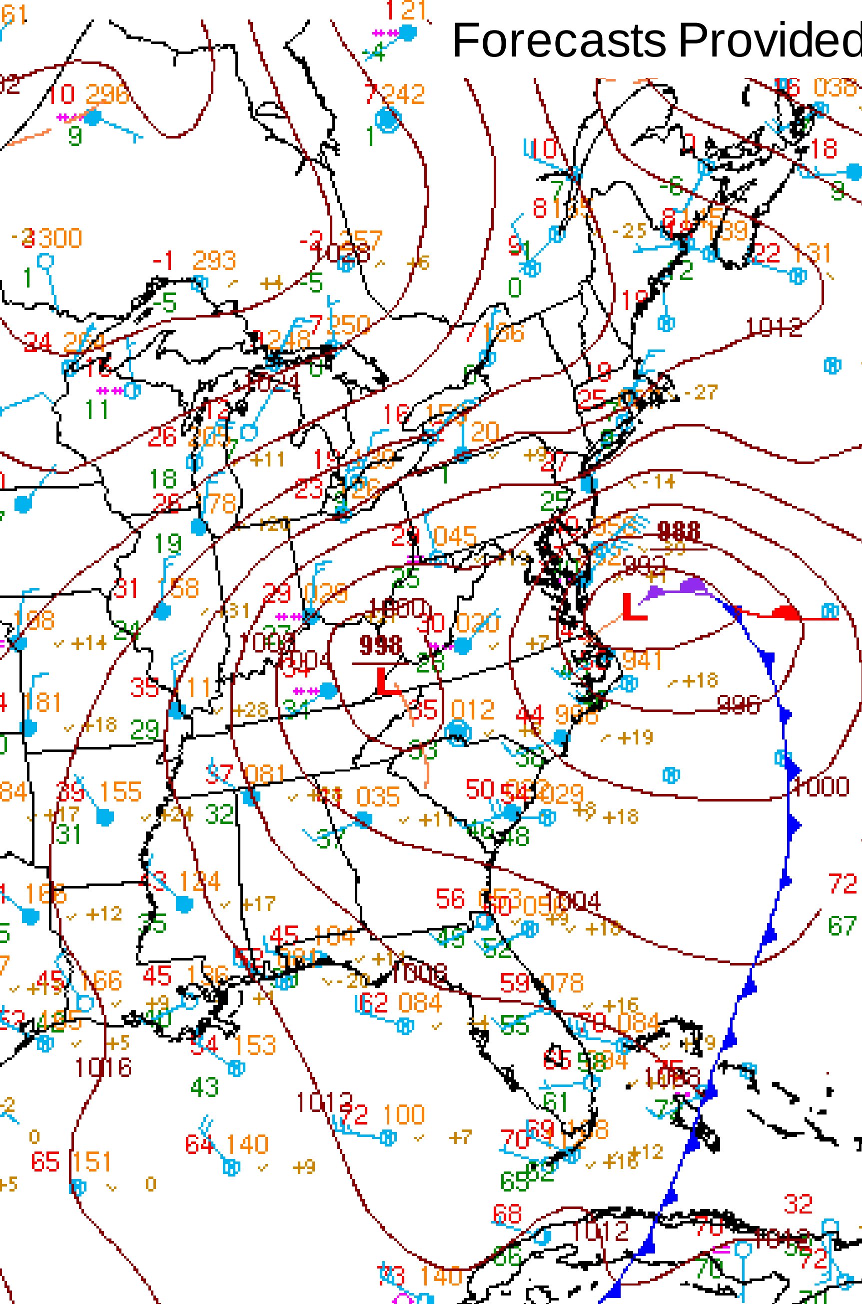
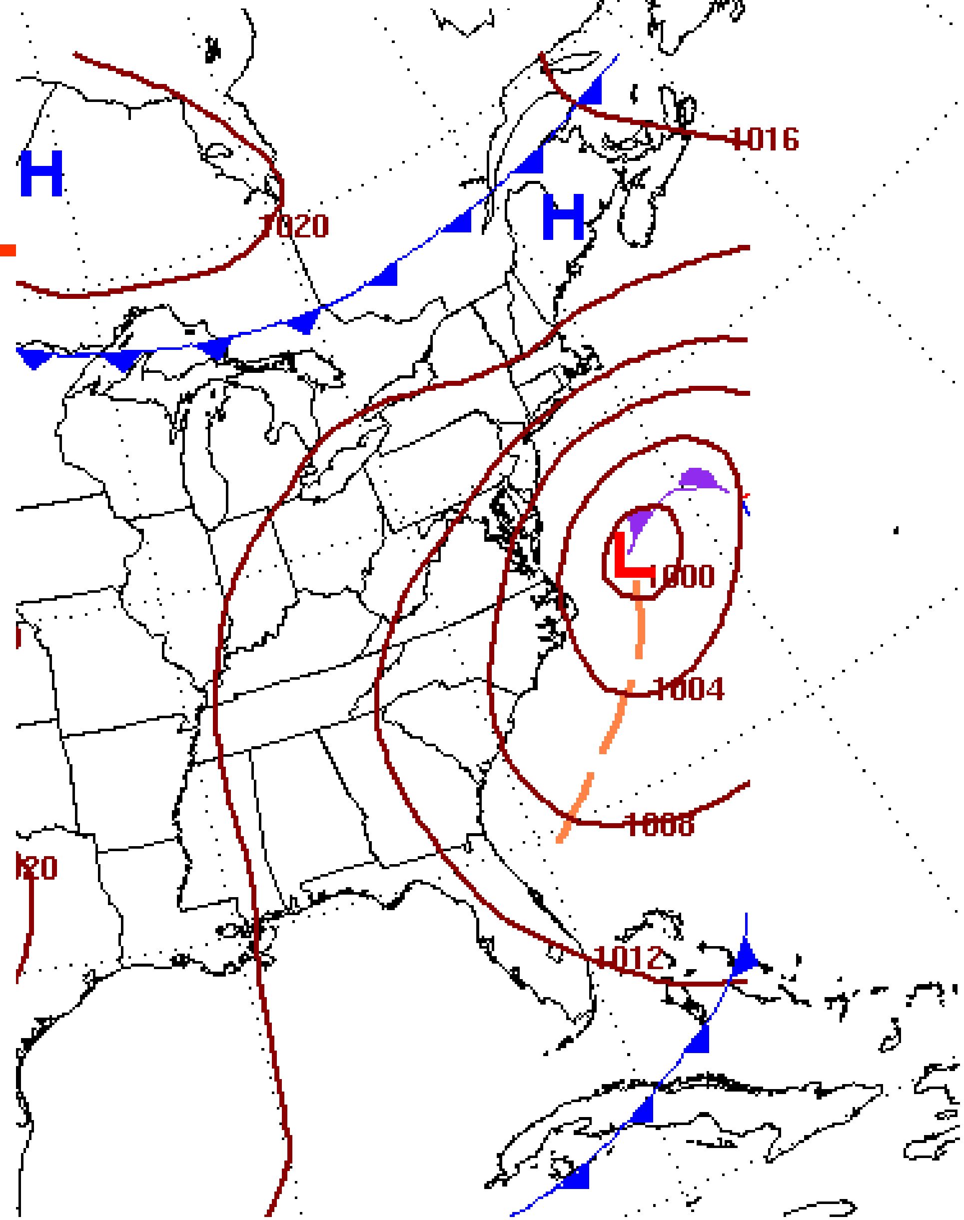
20100203 1354Z 2km Base Reflectivity/Latest HPC Surface Analysis
NWS Winter Weather Advisories(purple),Watches(white),Warnings(red)
NWS Convective Watches/Warnings (Tor=red, SvrTst=blue, FFld=green)

Forecasts Provided by Hydromet Prediction Center



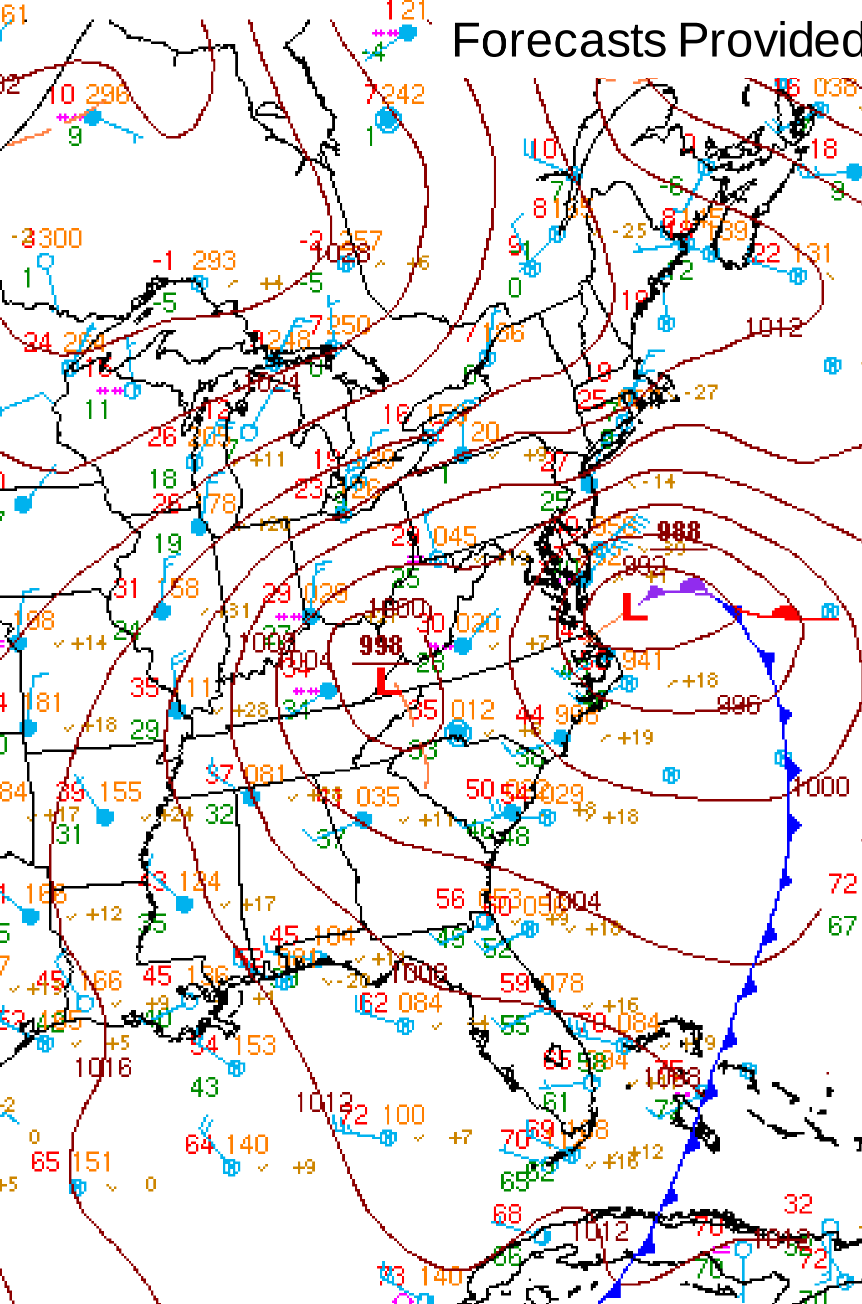
Surface Analysis



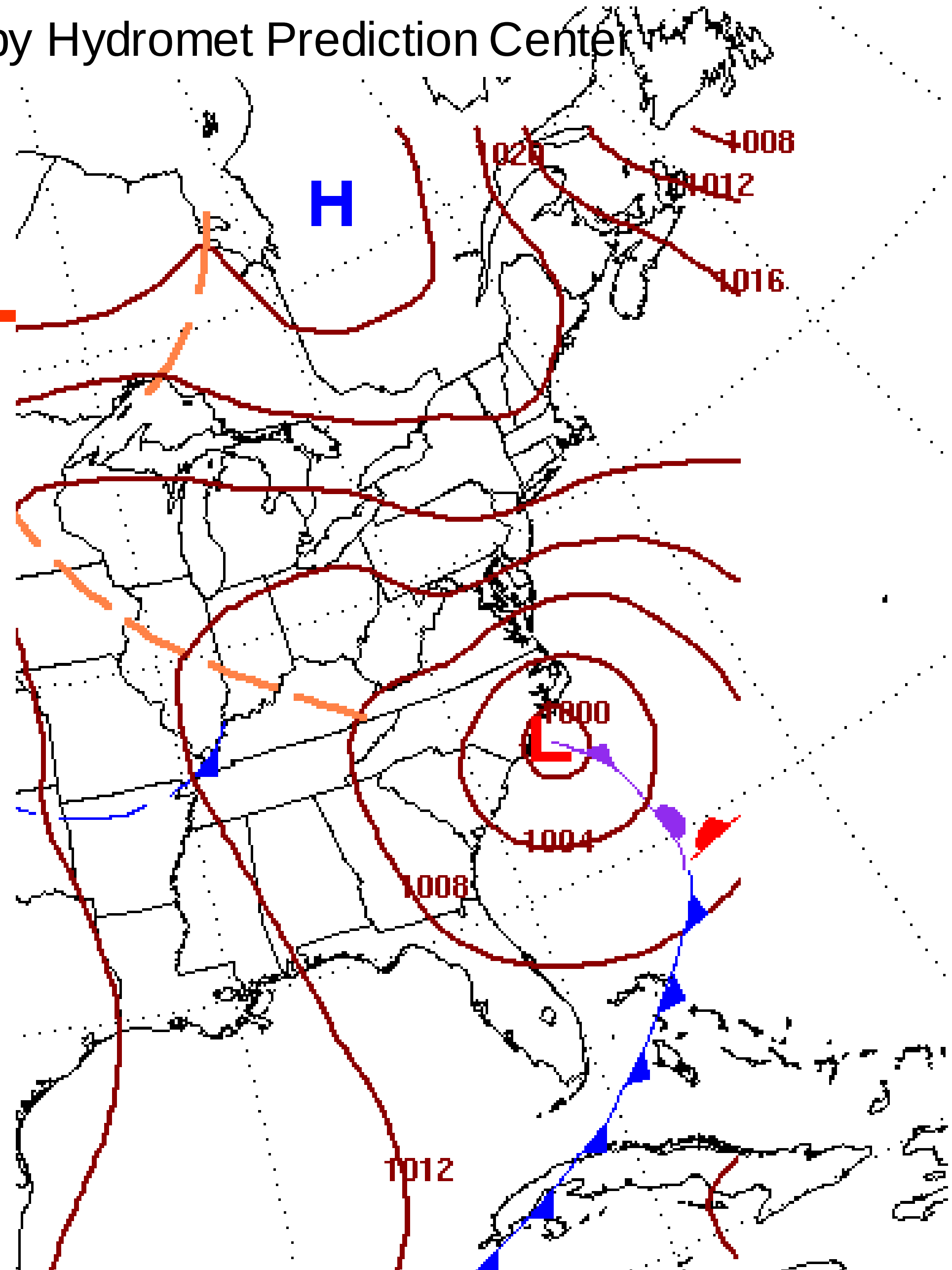
Seven day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



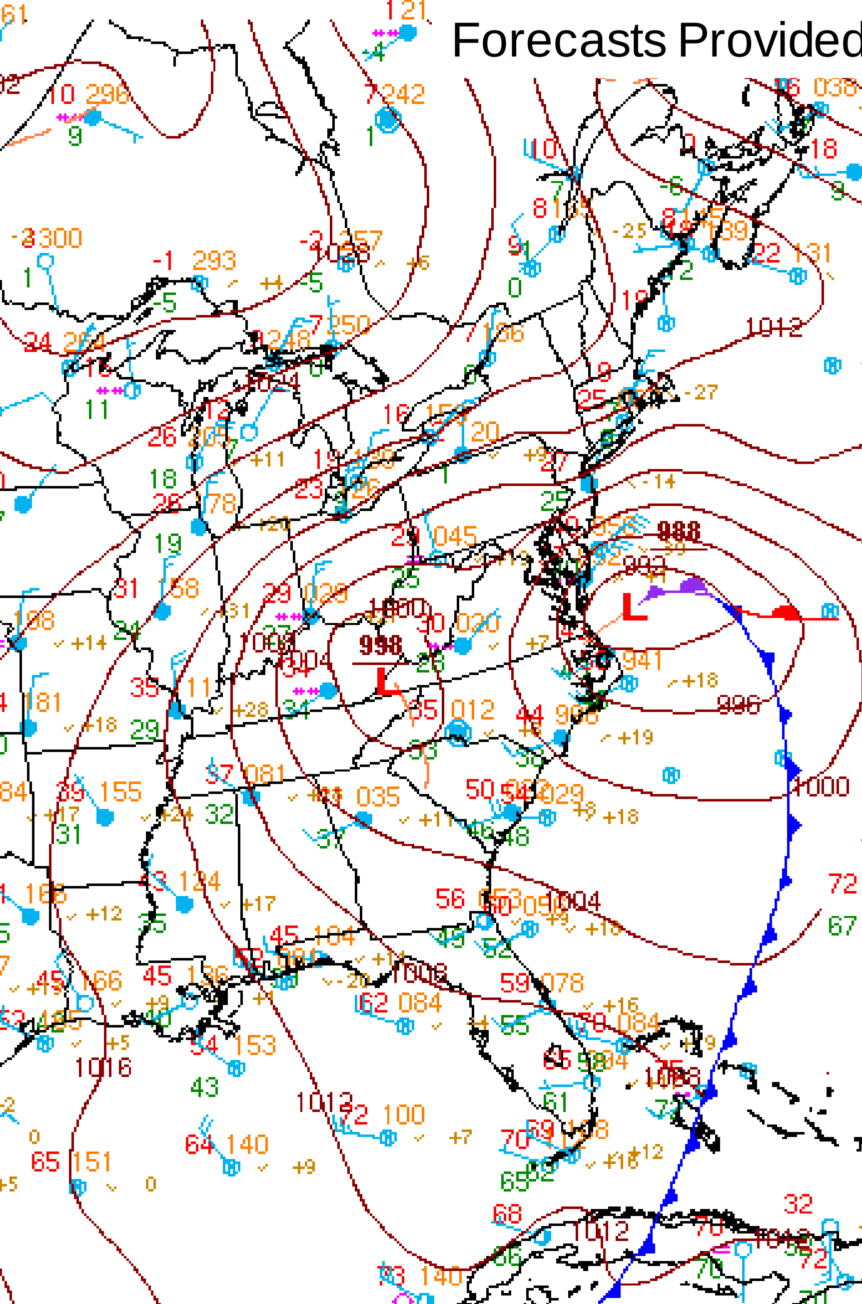
Surface Analysis



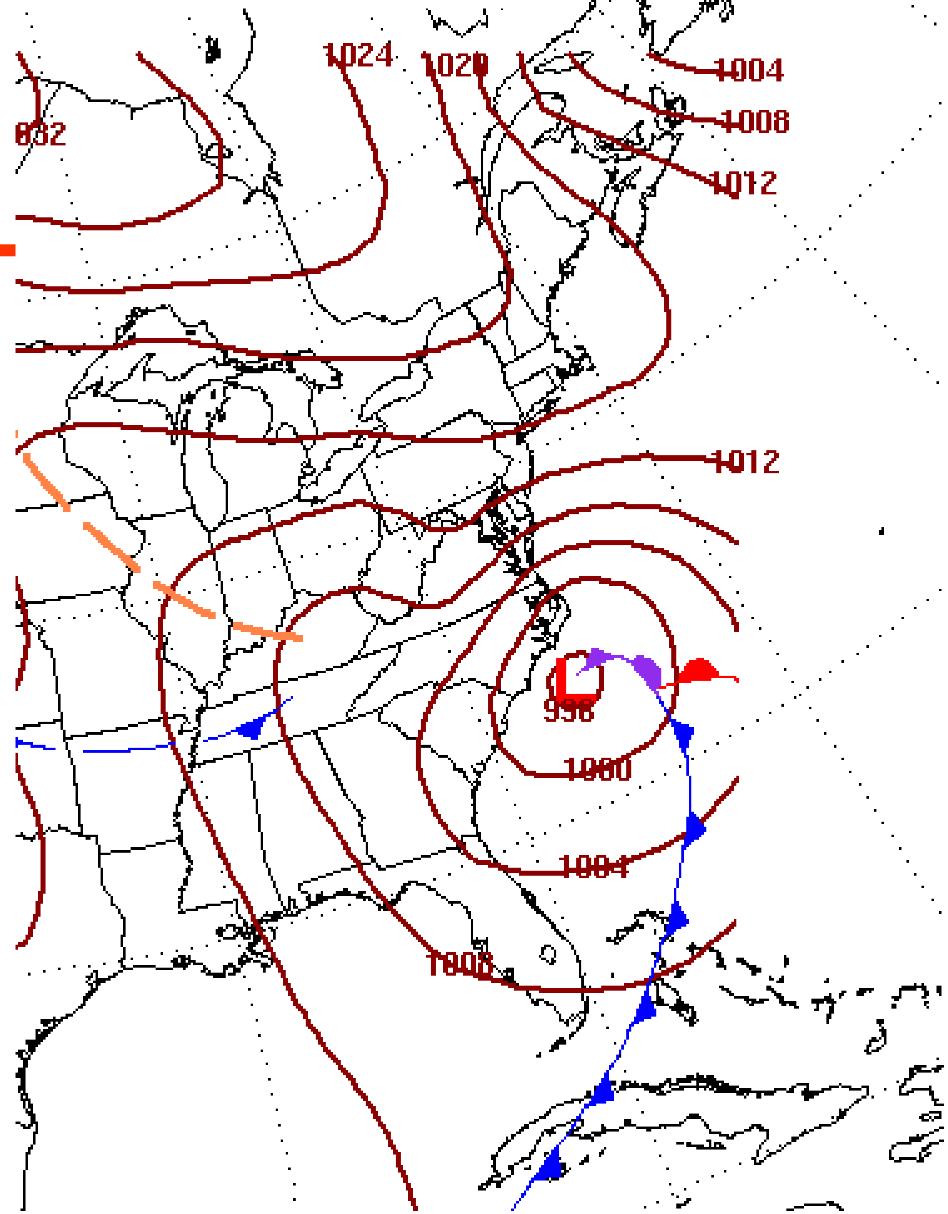
Six day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



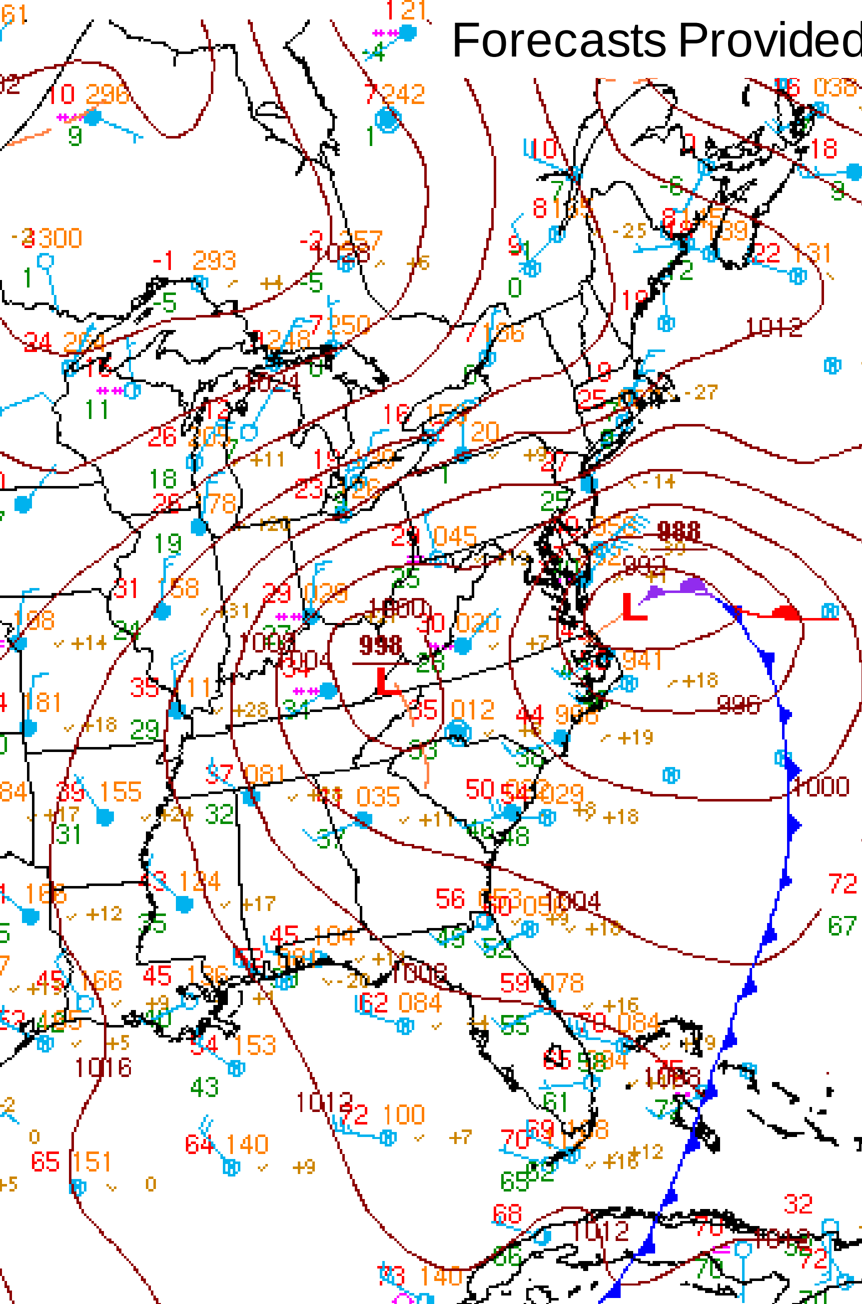
Surface Analysis



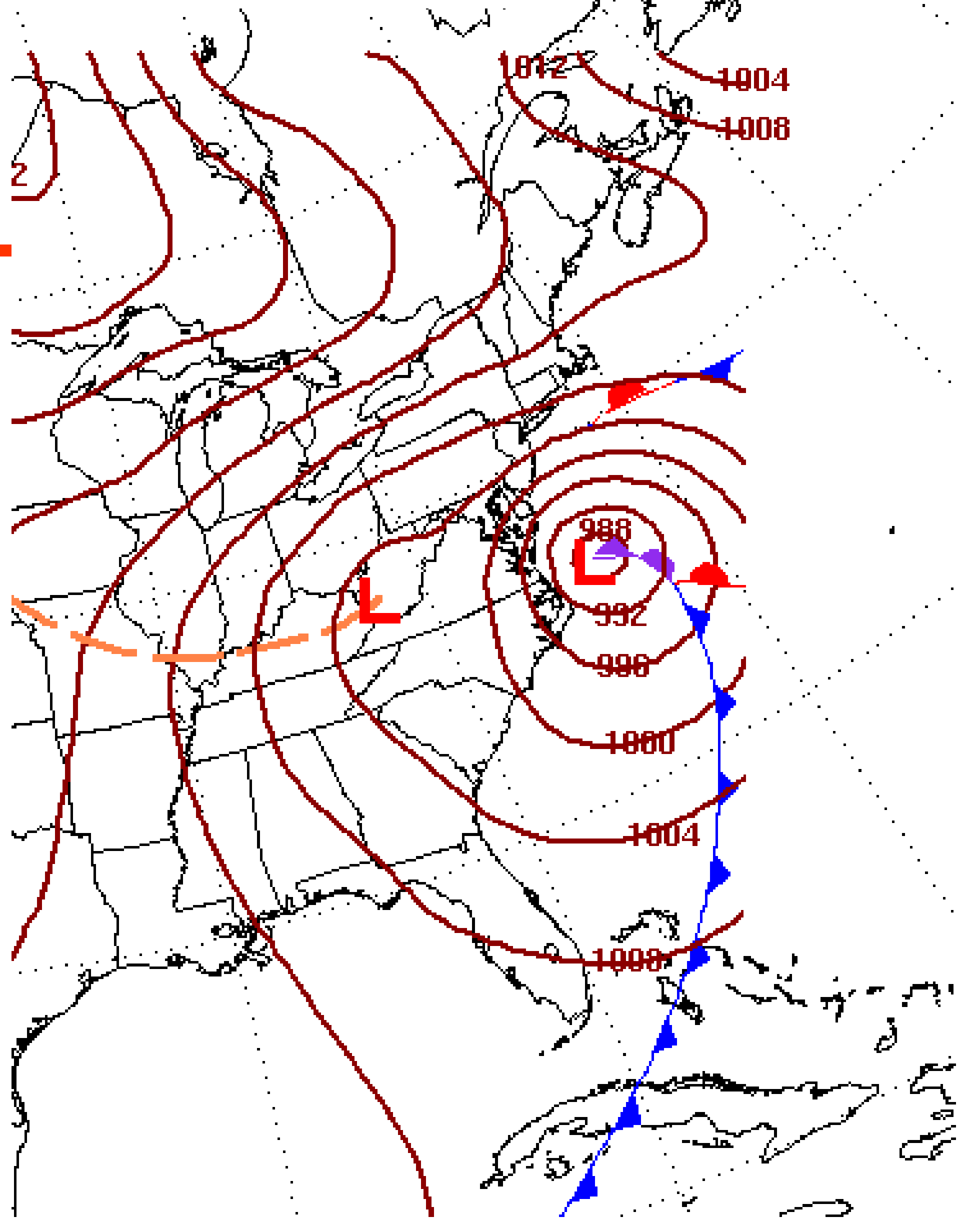
Five day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



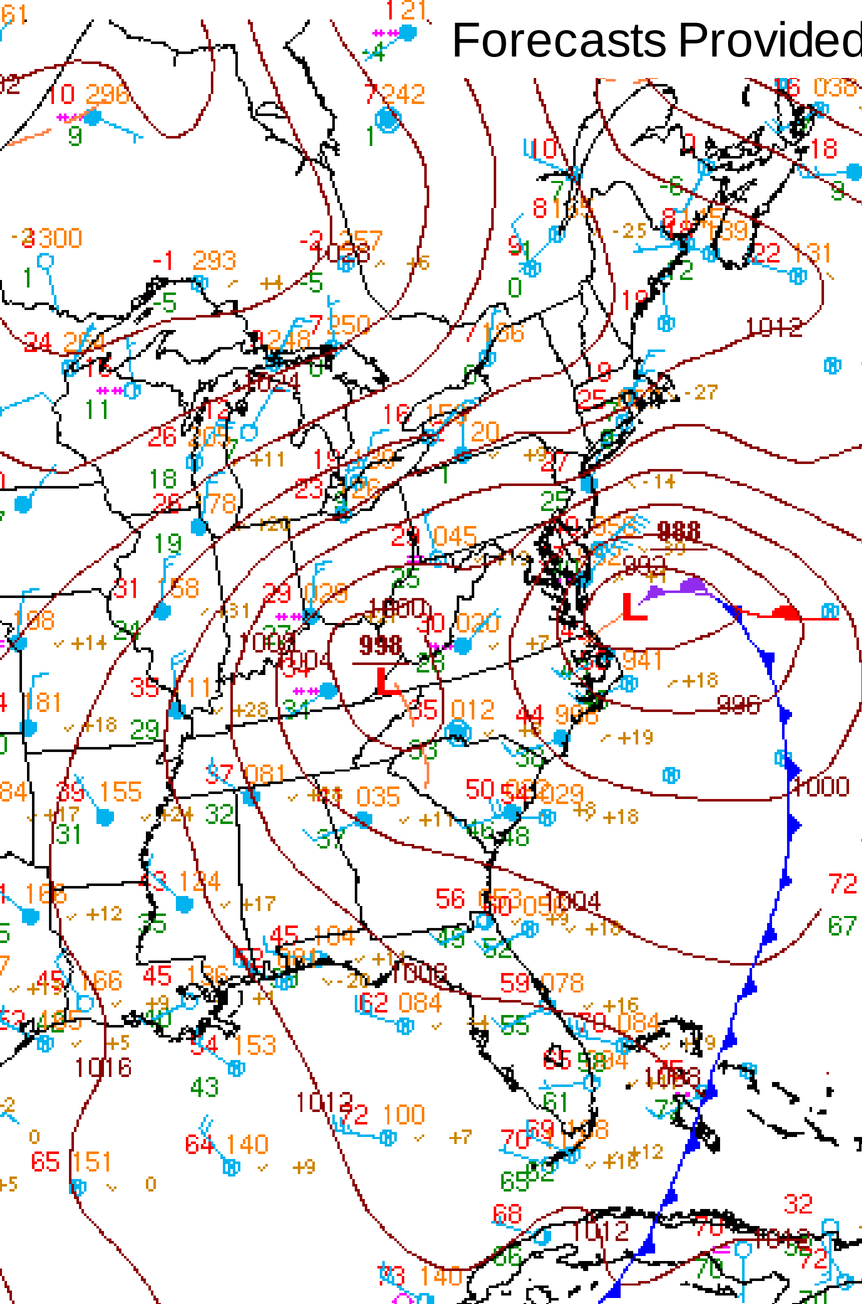
Surface Analysis



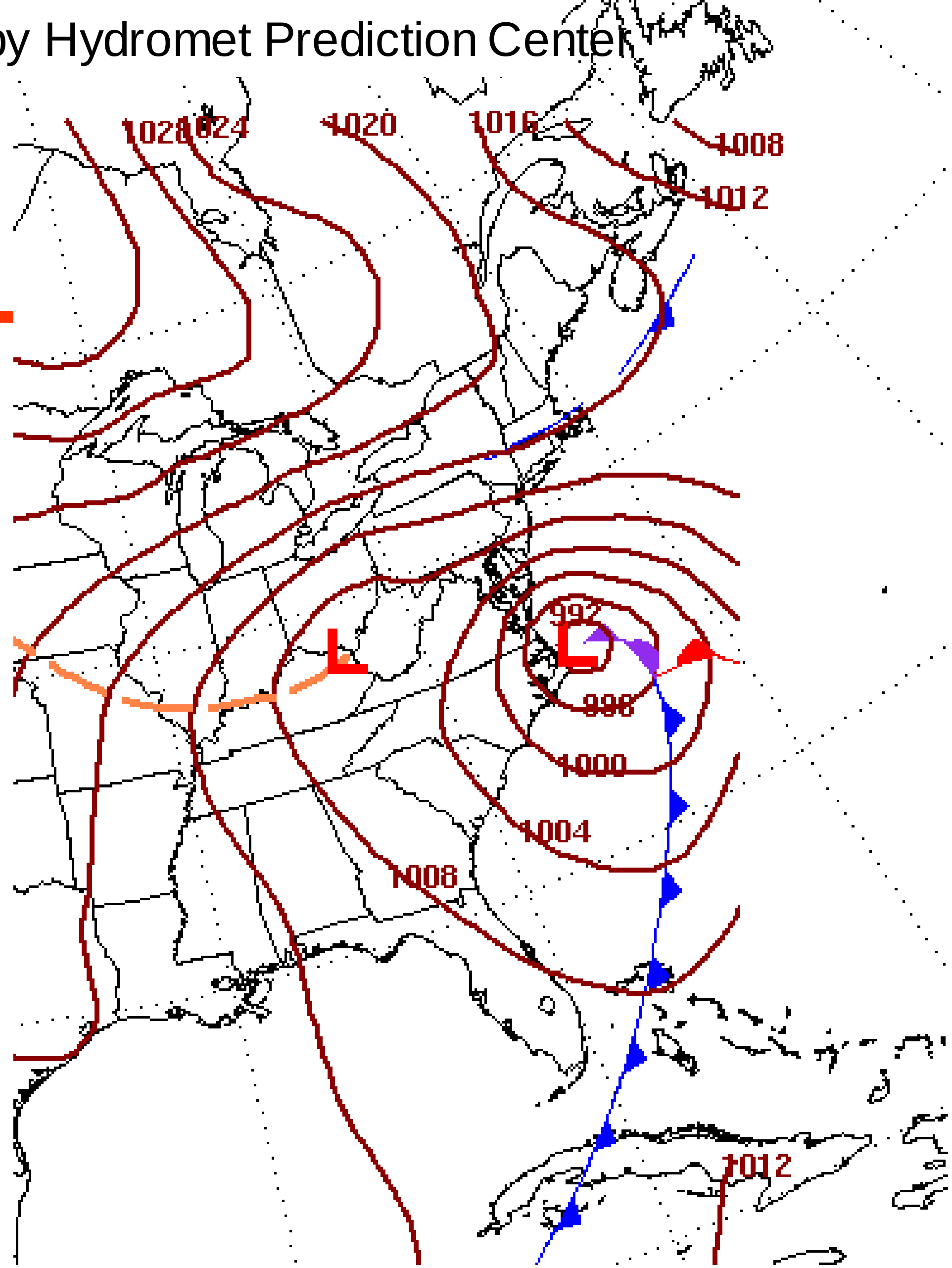
Four day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



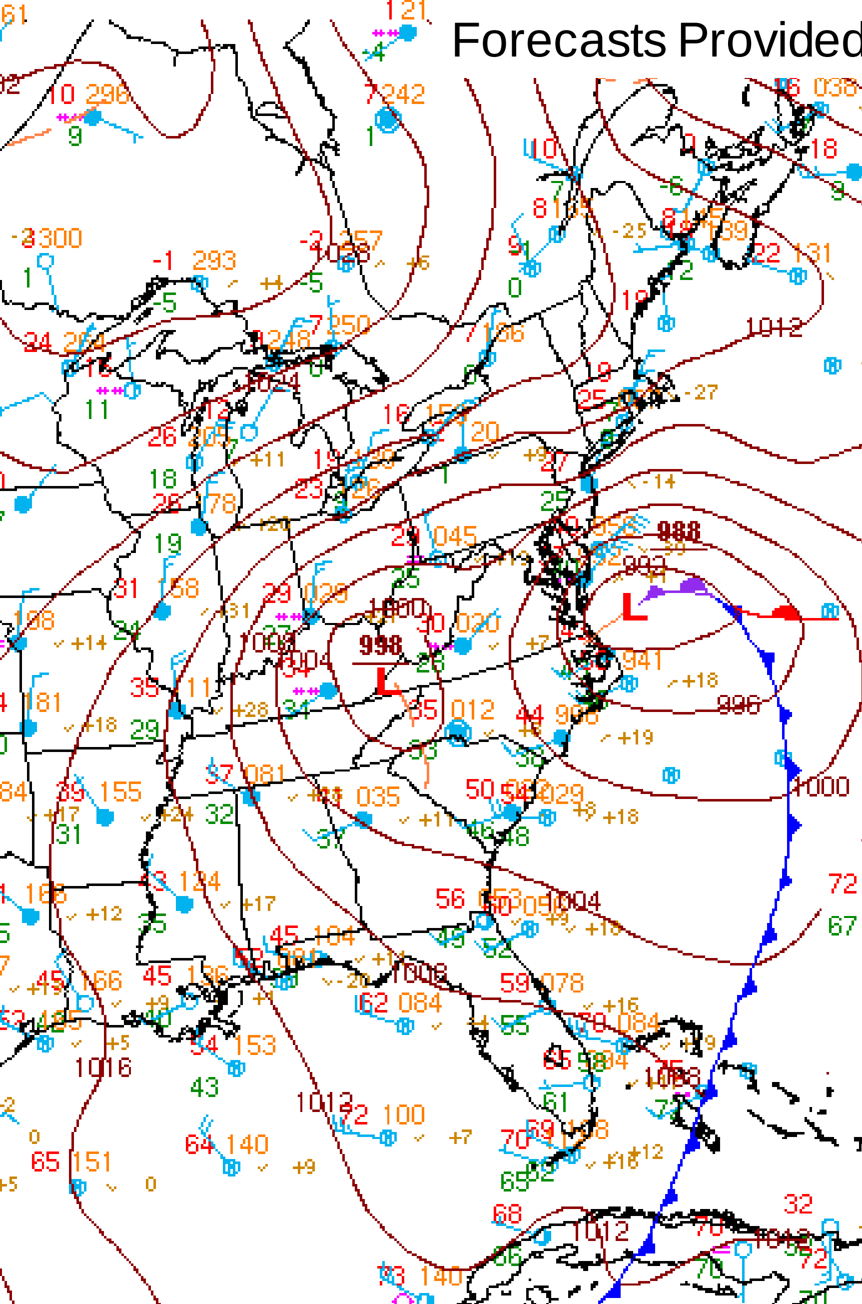
Surface Analysis



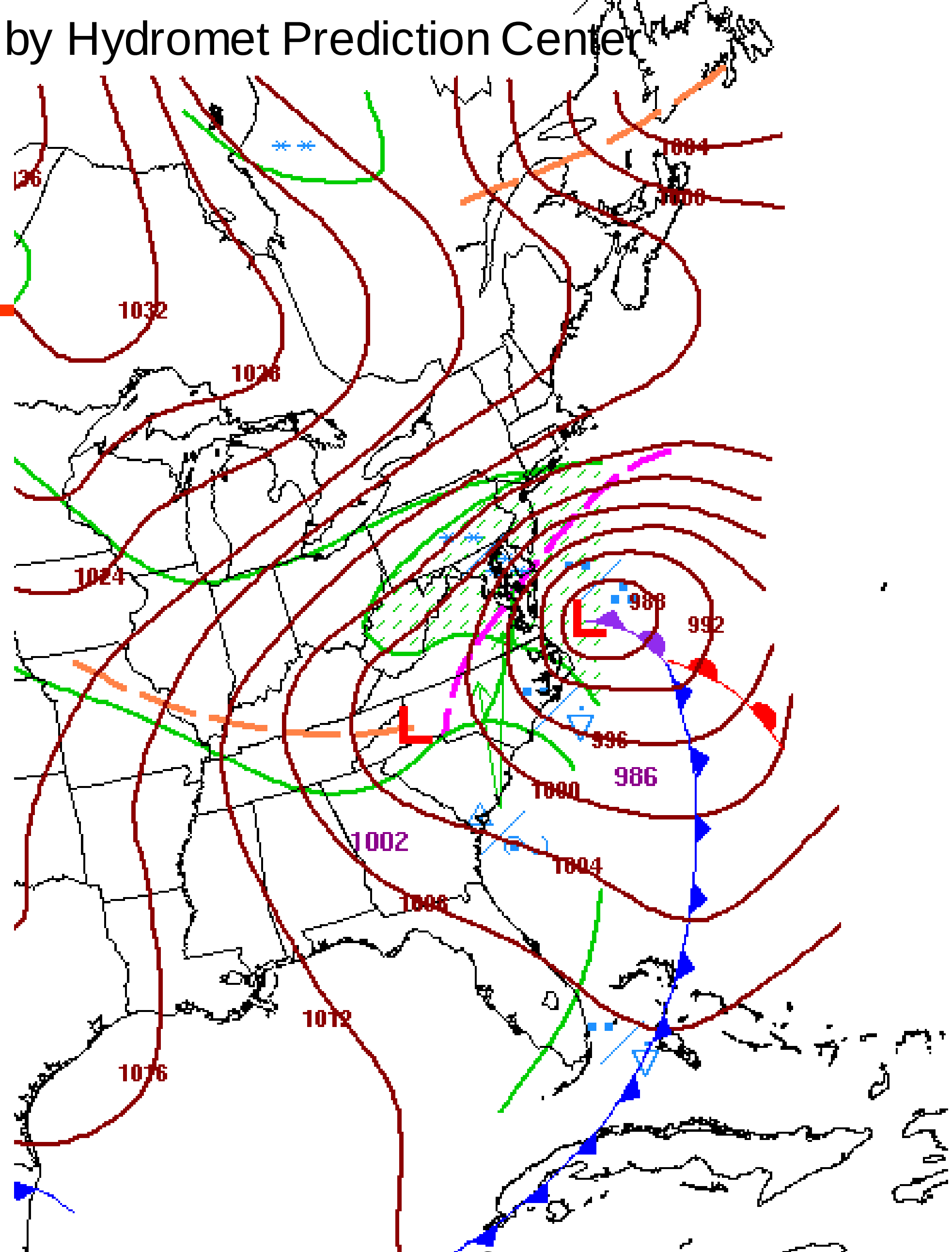
Three day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



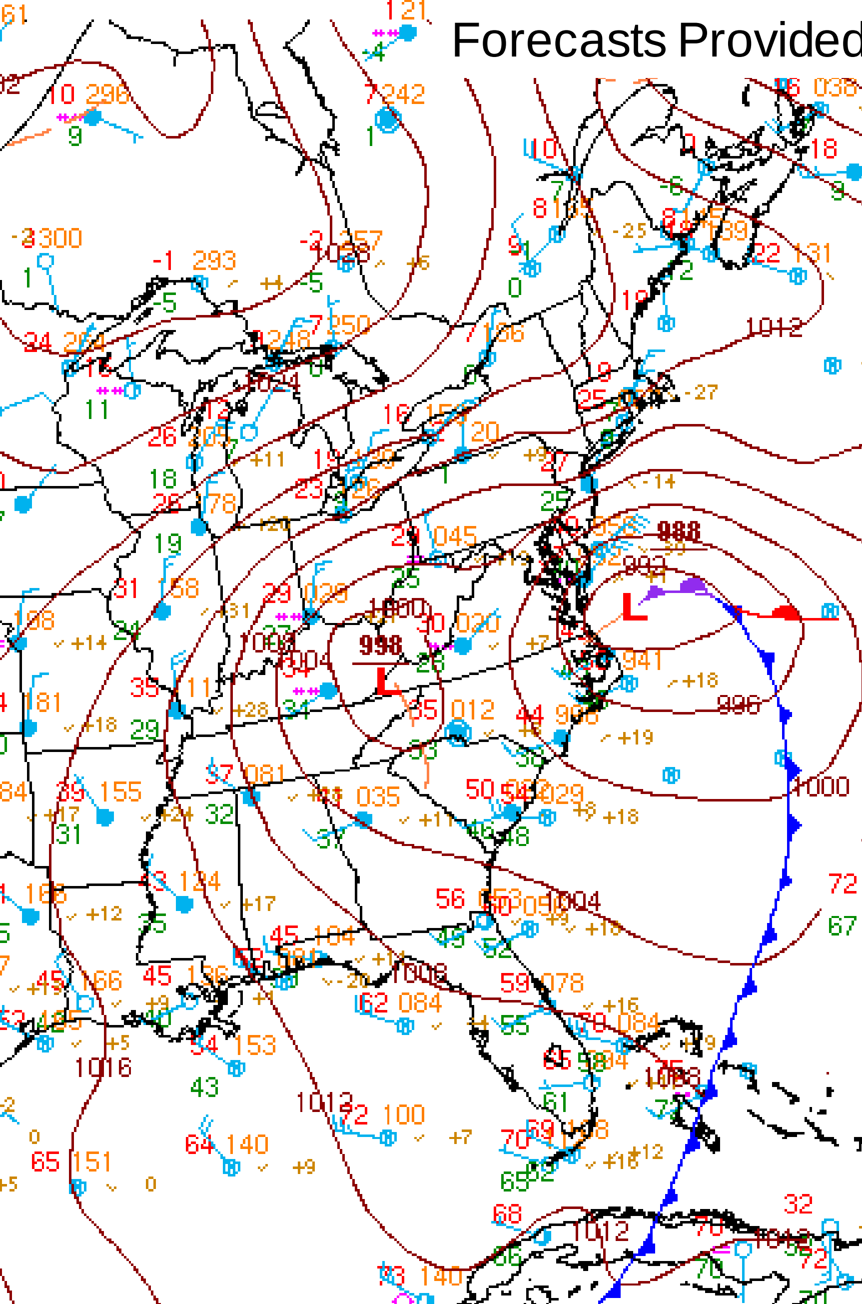
Surface Analysis



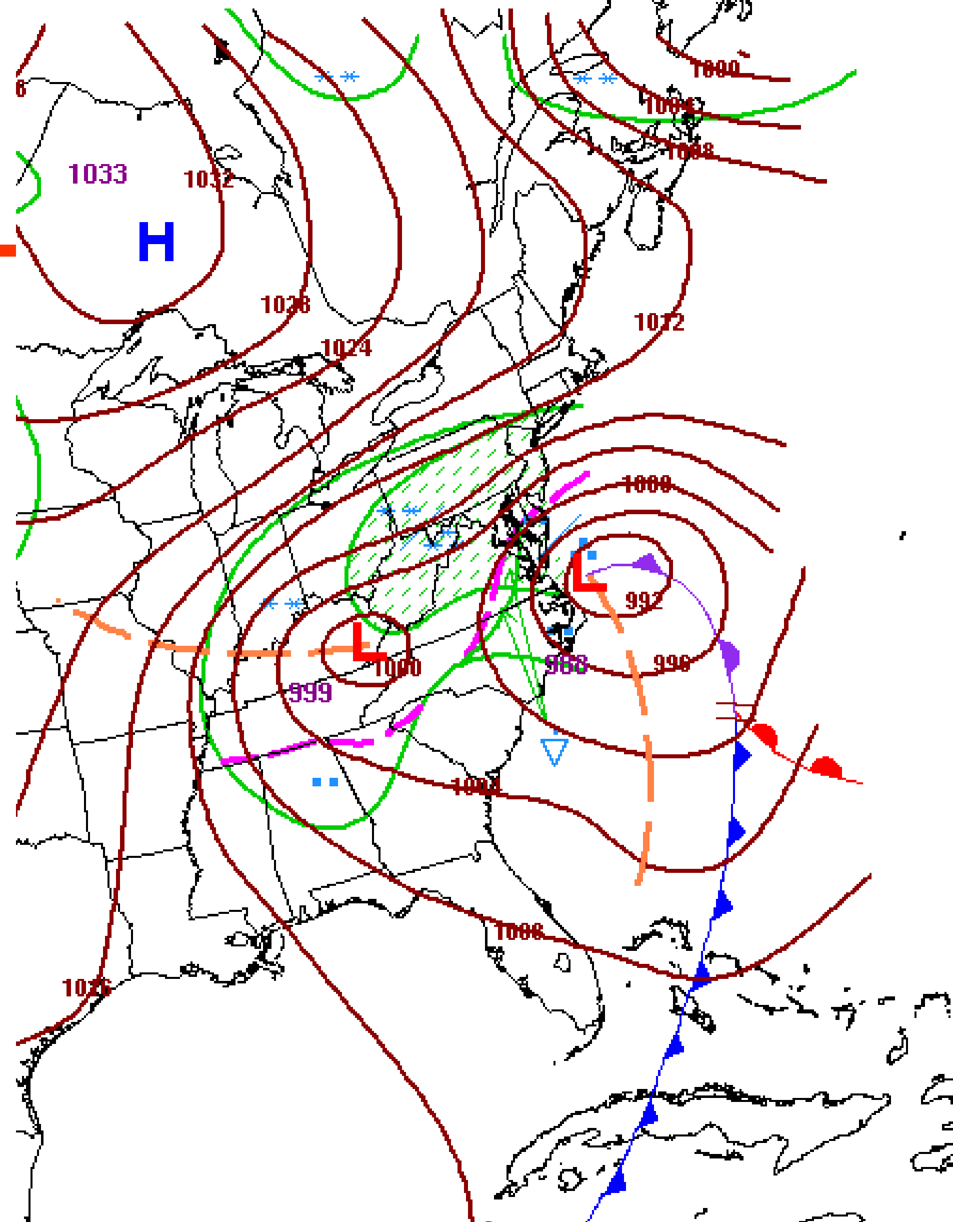
Two day forecast

Valid 12Z February 6, 2010

Forecasts Provided by Hydromet Prediction Center



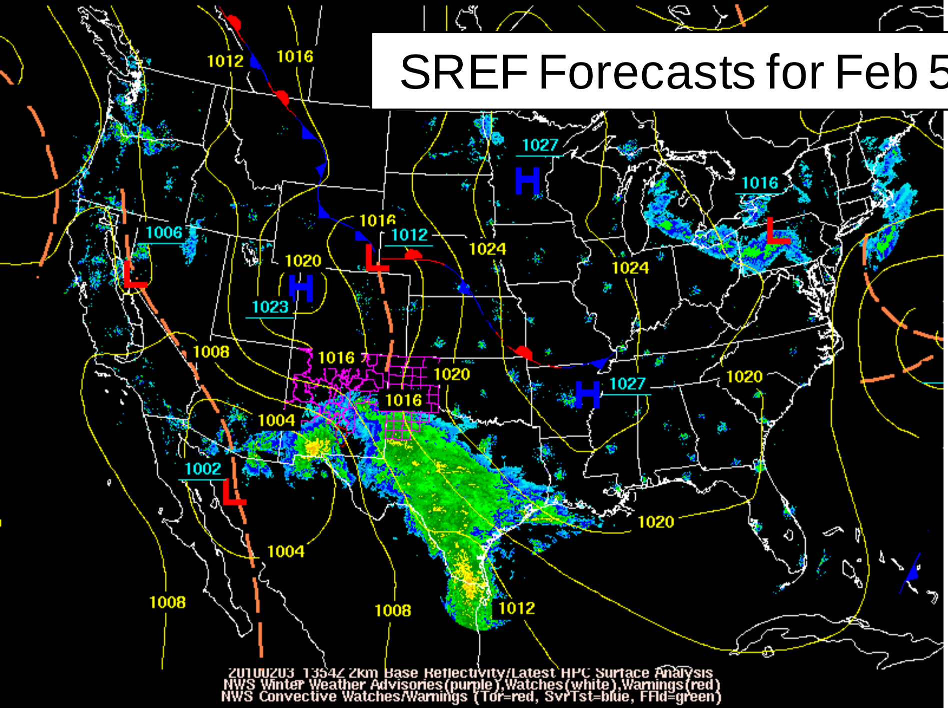
Surface Analysis

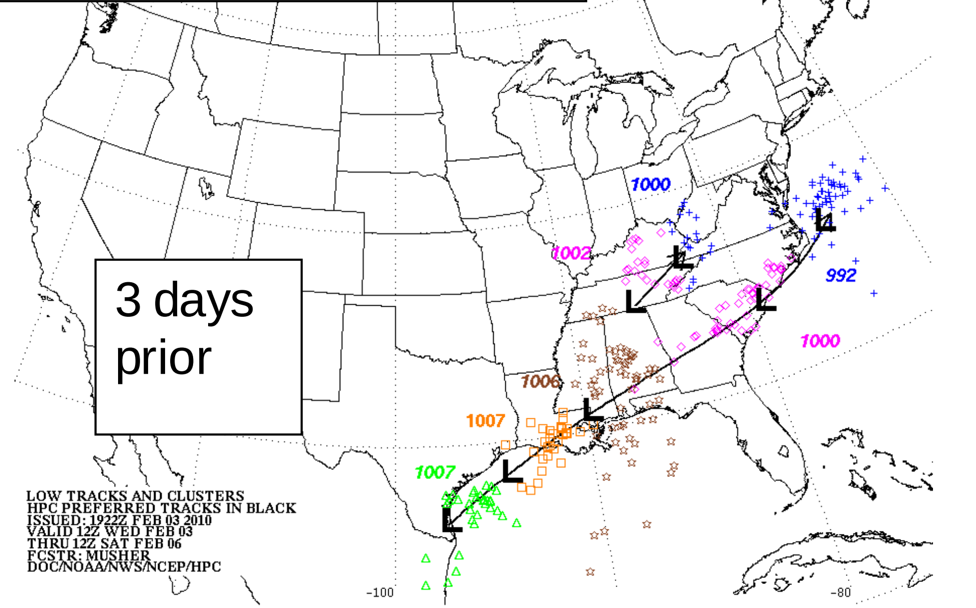


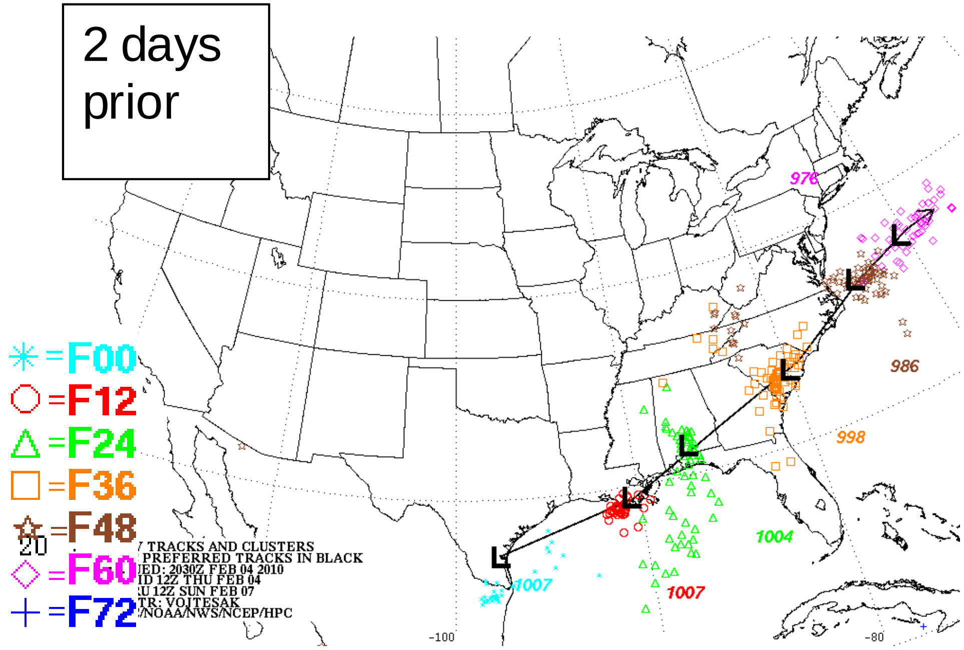
One day forecast

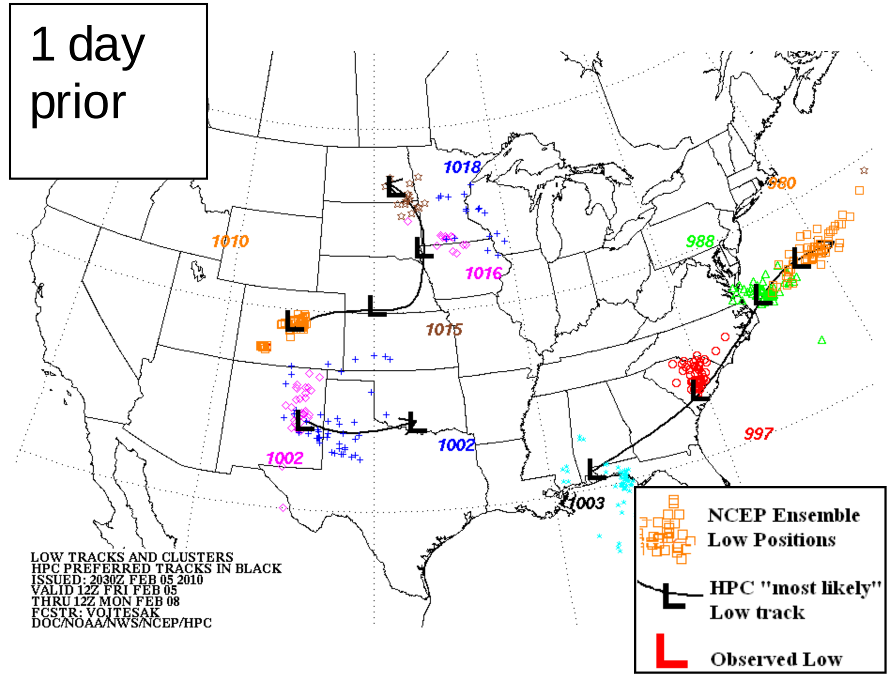
Valid 12Z February 6, 2010

SREF Forecasts for Feb 5, 2010: “Snowmageddon”

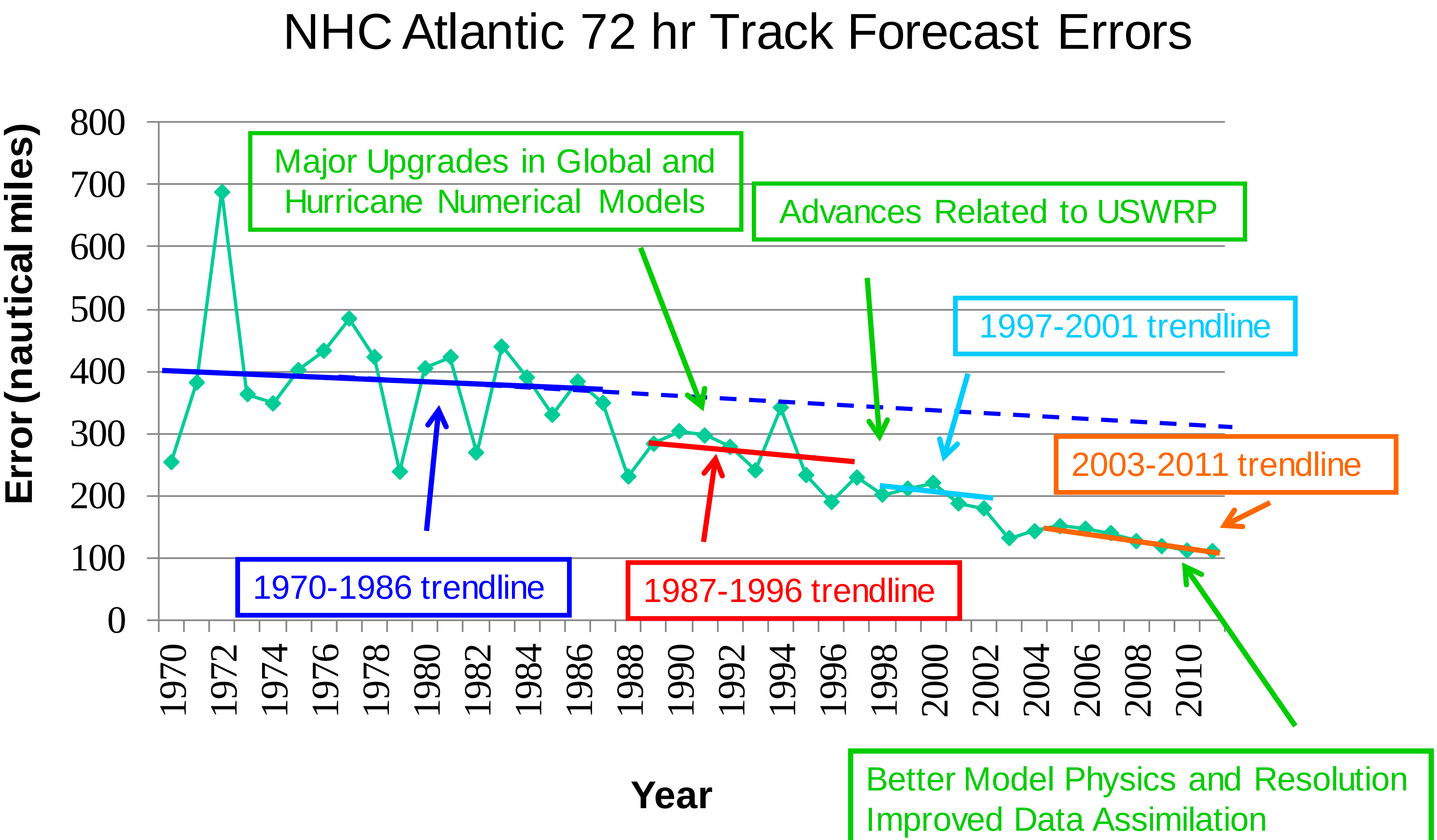








Hurricane Prediction Skill

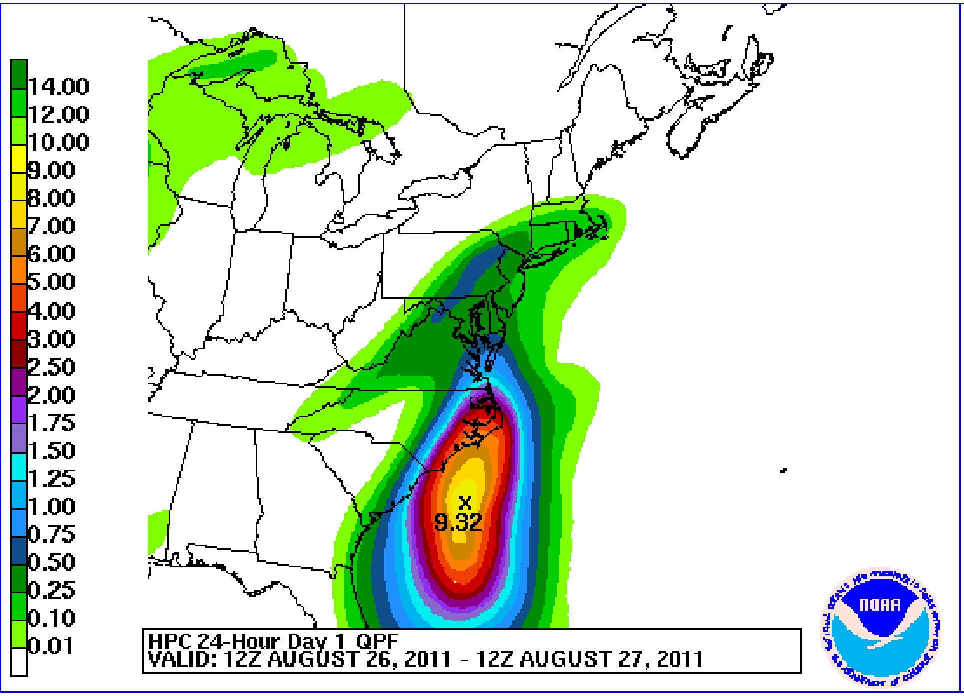


Hurricane Irene Track Forecast

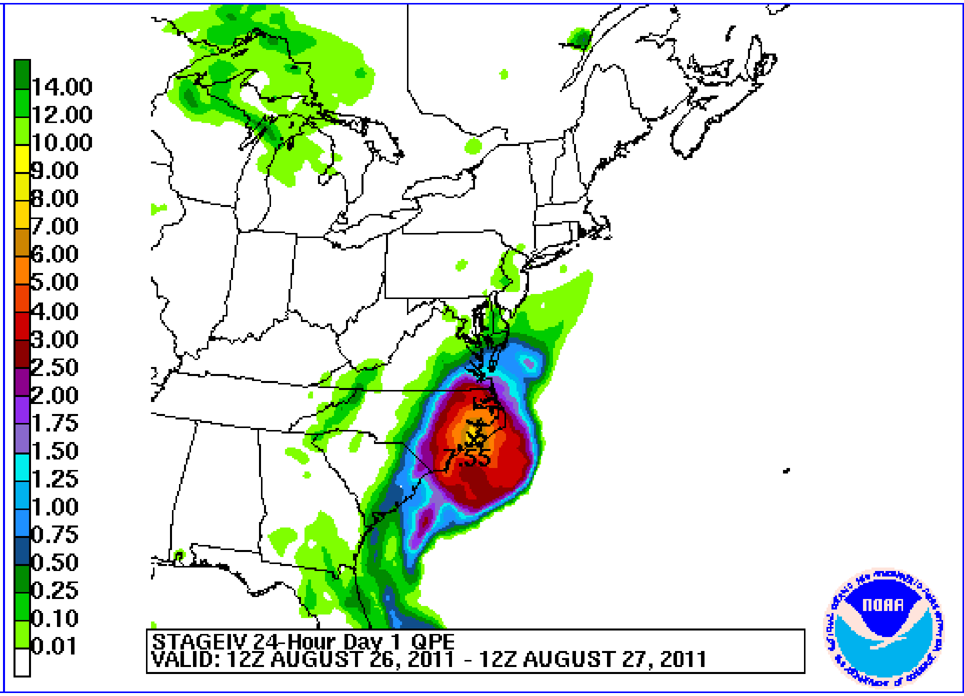
August 20, 2011 – August 27, 2011

Hurricane Irene Precipitation

Precipitation Forecast Loop



Precipitation Verification Loop

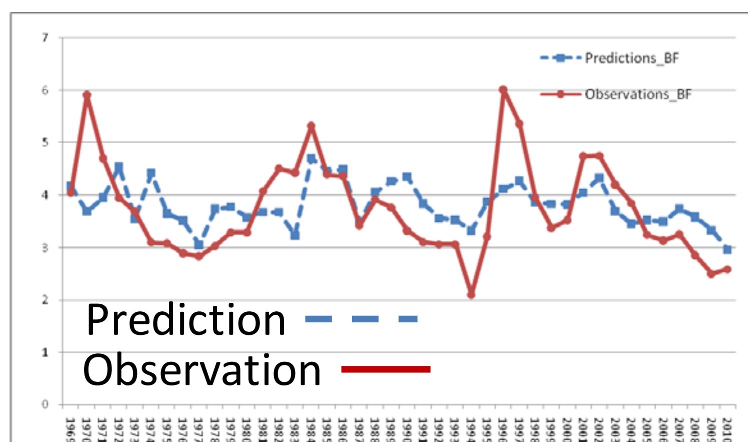


August 26 – 29, 2011

Summary of Predictive Skill

- Now provide predictions with “useful skill” out to Day 8
- Through use of ensembles, provide forecasts/uncertainties for extreme events out to Day 8
- Decision makers now using forecasts as a foundation of Decision Support Services
- Prediction capabilities being applied in non-traditional areas (health, alternative energy, water/air quality, ecosystems, …)

Meningitis Incidence Rate in logarithmic form - Case of Burkina Faso
Base Period: 1968-2005

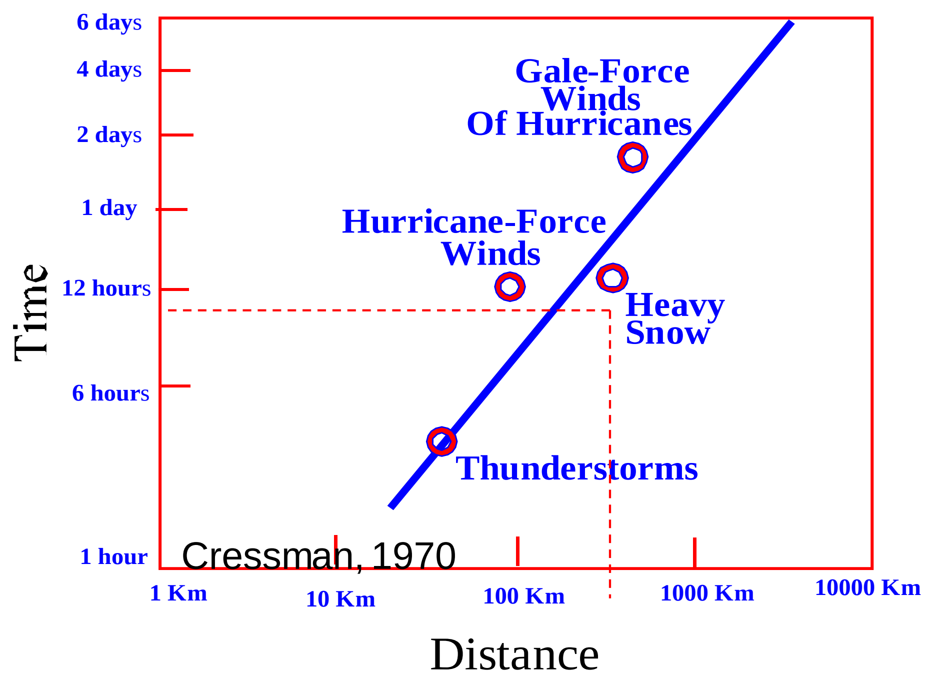


Yaka et al., 2008

Transformation of the Forecast Process:

The Advance from Subjective to Model-Based Forecasts

1970s Limits of Predictability



"…abandon research that uses "weather sequences" generated in a computer as bases for deduction about the real atmosphere." C.S. Ramage, 1976: Prognosis for Weather Prediction. *Bull Amer. Meteor. Soc*., 57, 4-10.

1970s → 1980s → 1990s

Despite this opinion, research continued on real-time numerical prediction models and the use of satellite observing systems within those models.

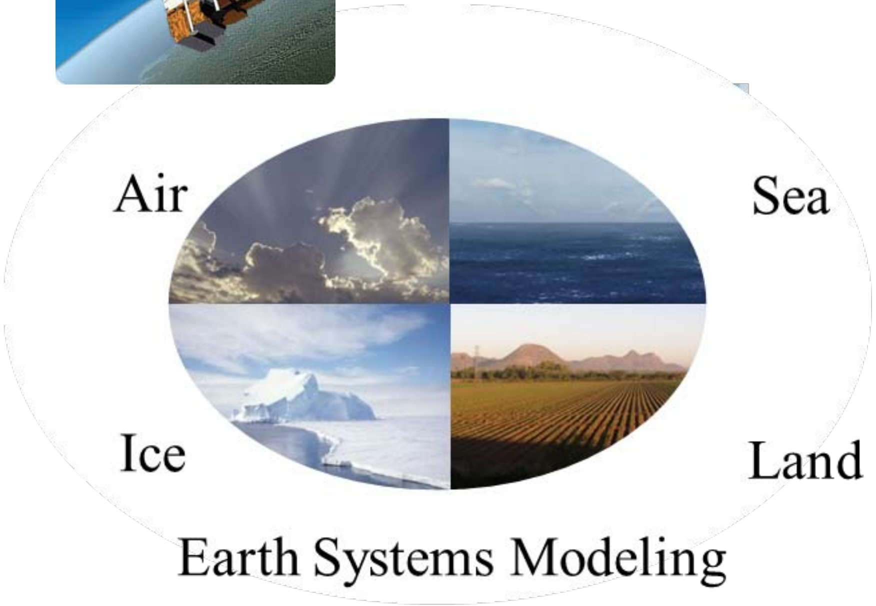
Today: Everything you read, see or hear about weather, climate and ocean forecasts begins with numerical prediction models

Three Major Components of the Numerical Prediction Enterprise

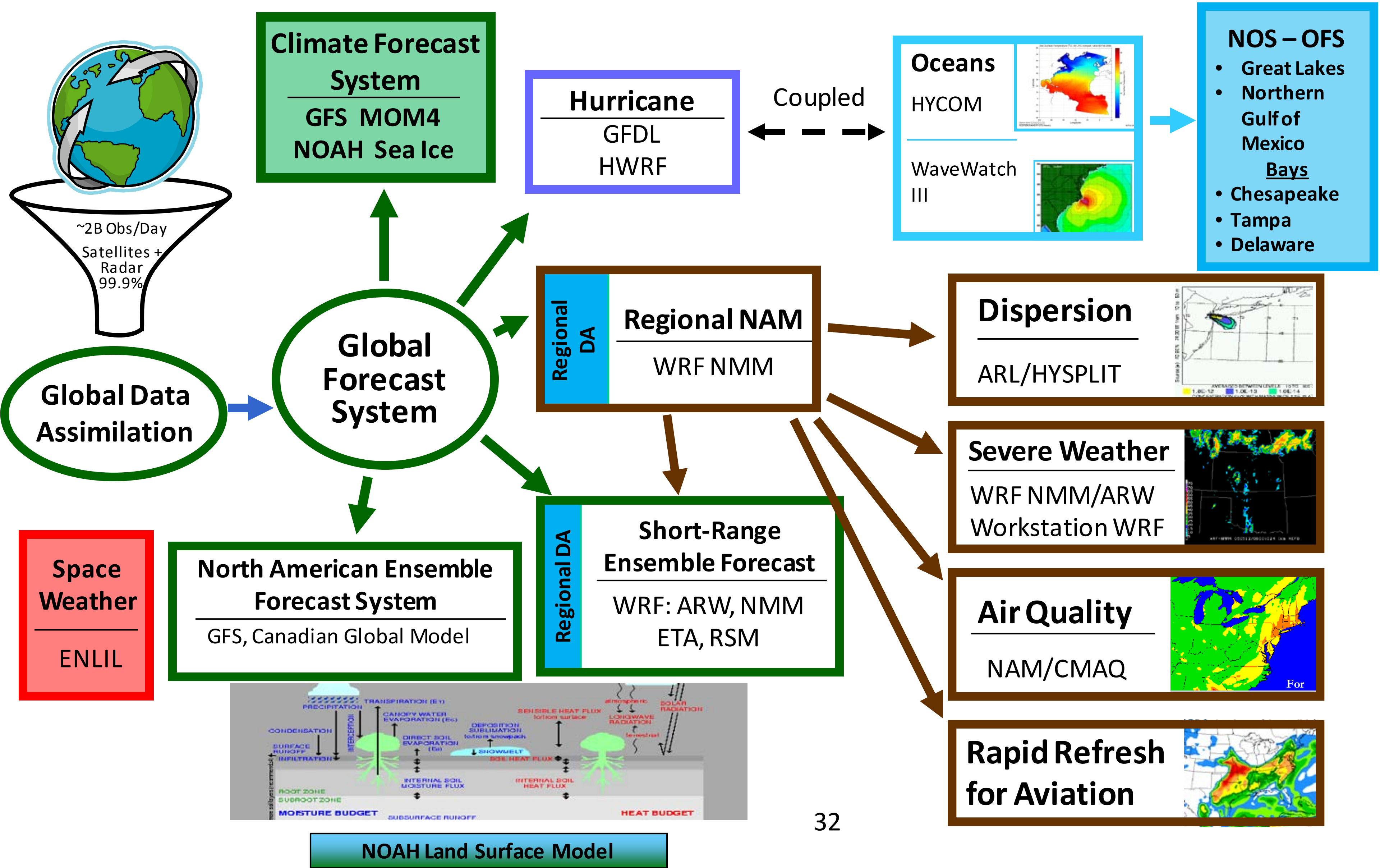
- Global Observing System
- Computers (supercomputers, work stations)
- Data Assimilation & Modeling/Science

Three Major Components Related to NWS/NCEP Operational Numerical Prediction Enterprise

- Observations
  - ~2 billion/day
  - 99.9% remotely sensed, mostly from satellites
    - ~35 different satellites now used including NPP/ATMS
- 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



NOAA's Model Production Suite

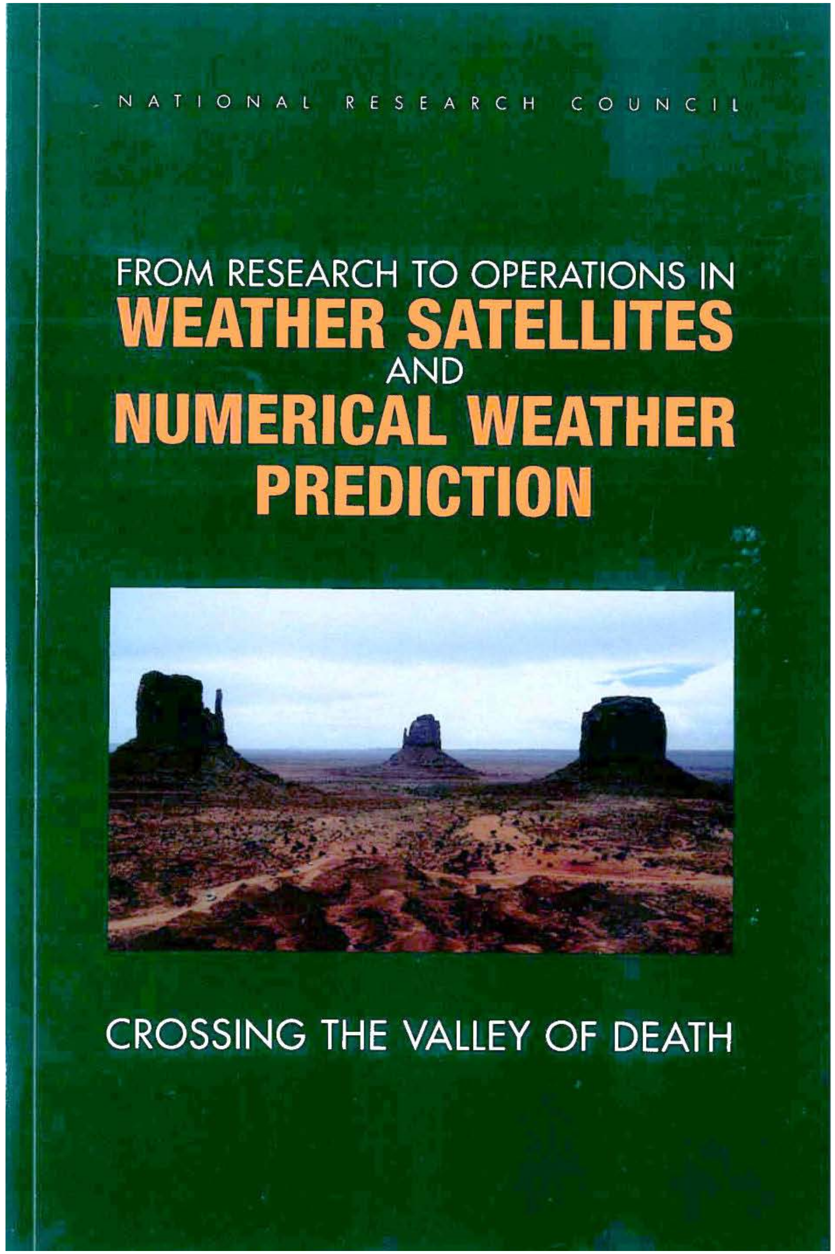


Importance of the JCSDA: Helping to solidify the R2O process for expanded use of satellite data in operational model systems

Circa 1990s

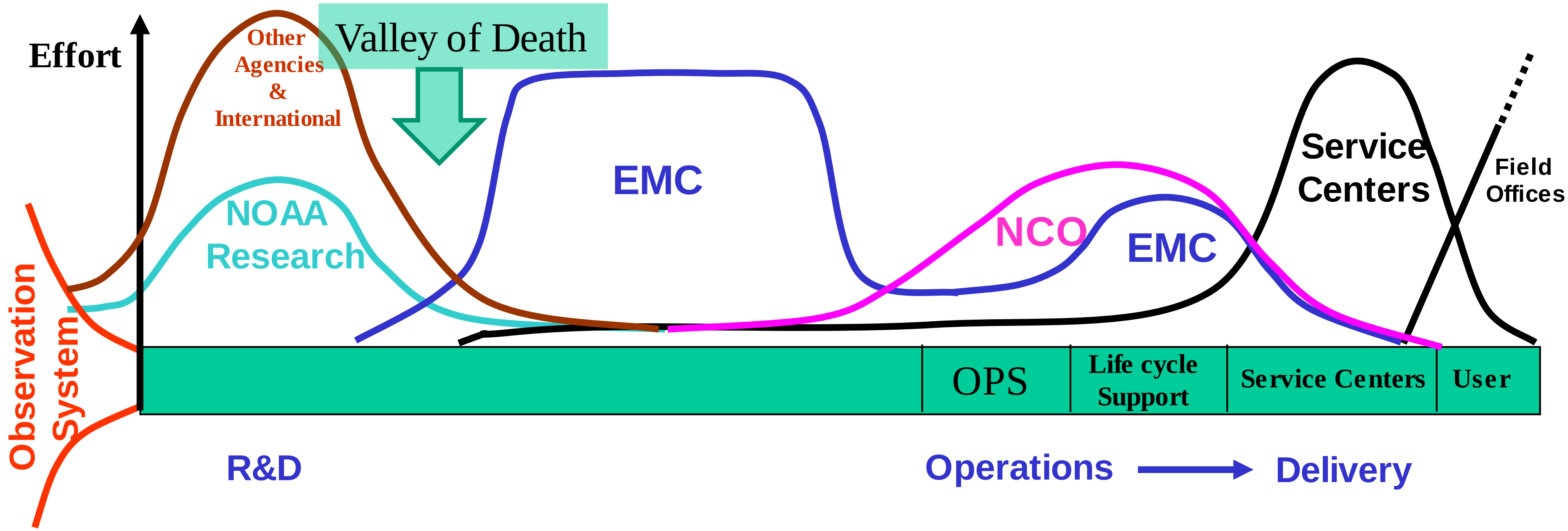
- Increase use of satellite radiances in operational model
- No standards for fast forward radiative transfer scheme
- Taking 2+ years to incorporate <u>operational</u> satellite data into operational numerical models (over 40% of expected lifetime)
- Very little (if any) use of research satellite data in operational models
- Very little exchange among various operational centers, especially within the U.S. Basically, a nonfunctional R2O process

National Research Council Report (2000): Valley of Death



Schematics in the Model Transition Process

EMC and NCO have critical roles in the transition from NOAA R&D to operations



Operations to Research

Transition from Research to Operations

Launch List – Model Implementation Process

Concept of Operations

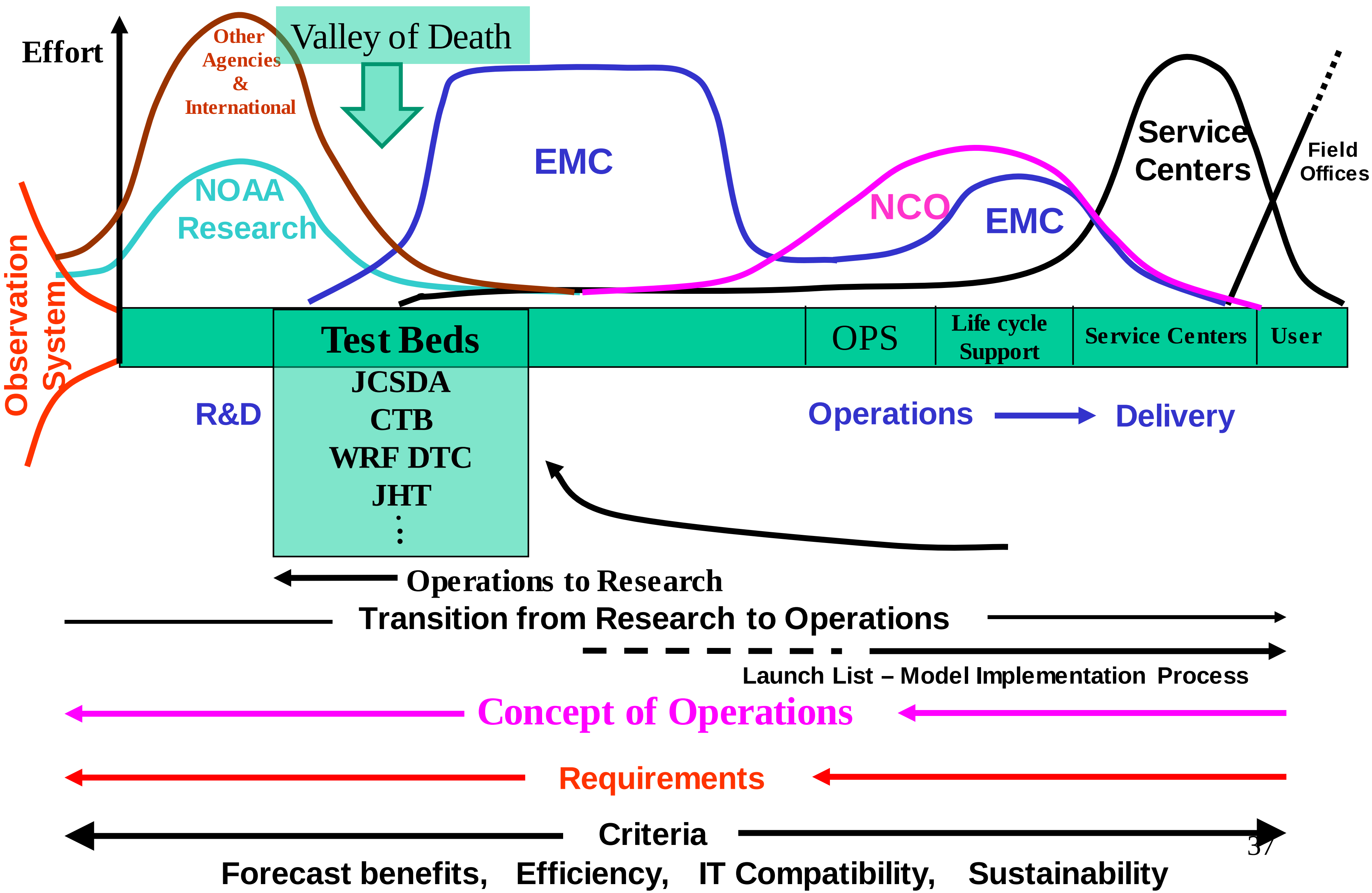
Requirements

Criteria

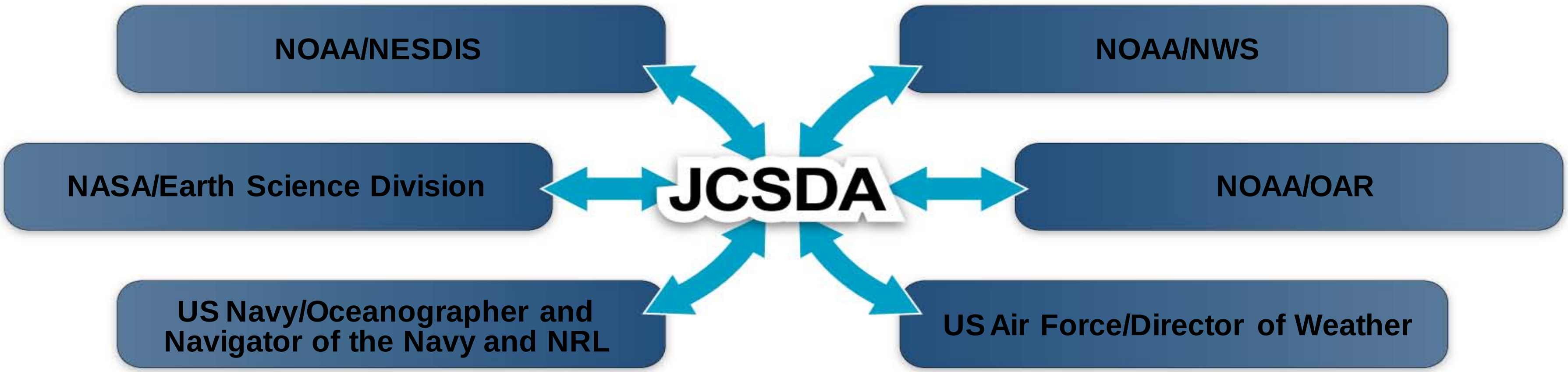
Forecast benefits, Efficiency, IT Compatibility, Sustainability

Schematics in the Model Transition Process

EMC and NCO have critical roles in the transition from NOAA R&D to operations



JCSDA Partners, Vision, Mission



Vision:

An interagency partnership working to become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction

Mission:

…to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction models.

JCSDA History

- NASA/NOAA collaboration (Uccellini, Einaudi, Purdom, MacDonald) initiated in 2000
  - Concern about US leadership in satellite data technology and instrumentation not replicated in user applications, e.g. NWP
  - GMAO (DAO), NCEP and STAR (ORA) – first participants on technical level
  - Emphasis on balanced approach involving
    - Modeling
    - Computing
    - Observational data
  - Need to provide “O2R” infrastructure to research communities

- Inclusion of DoD (NRL Monterey and AFWA) triggered by NPOESS IPO sponsorship of JCSDA starting in 2002
- Science priorities established by Advisory Board
- First permanent Director hired in 2004 (John Le Marshall)
- Memorandum of Agreement at Associate Administrative Level signed May 2008
- NASA/NOAA provide first JCSDA computer in 2011

JCSDA Science Priorities

Overarching goal: Help the operational services improve the quality of their prediction products via improved and accelerated use of satellite data and related research

- Radiative Transfer Modeling (CRTM)
- Preparation for assimilation of data from new instruments
- Clouds and precipitation
- Assimilation of land surface observations
- Assimilation of ocean surface observations
- Atmospheric composition; chemistry and aerosols

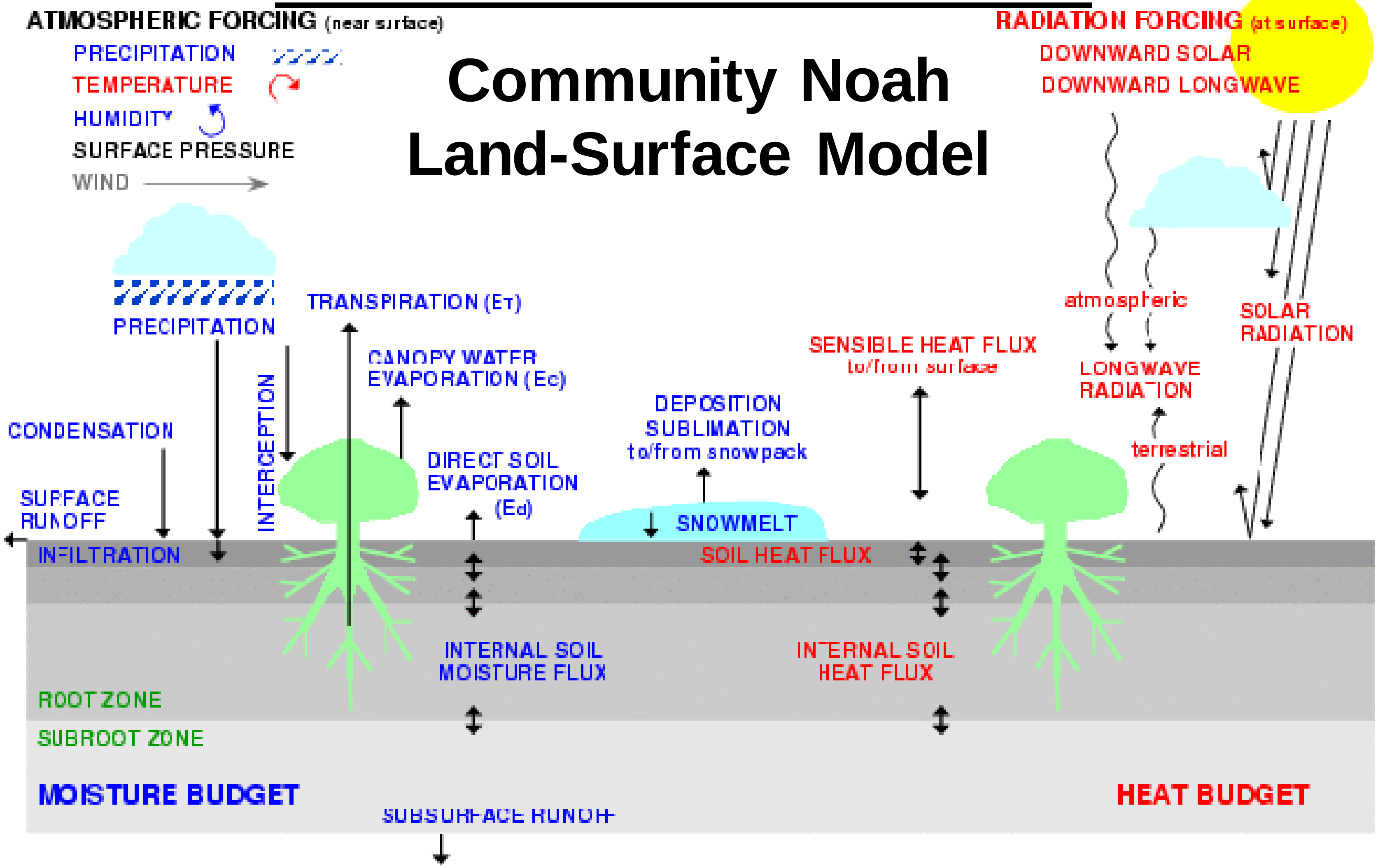
Driving the activities of the Joint Center since 2001, approved by the Science Steering Committee

JCSDA accomplishments

- Common assimilation infrastructure (NOAA, GMAO, AFWA)
- Community radiative transfer model - CRTM (all partners)
- Numerous new satellite data assimilated operationally, e.g. MODIS (winds and AOD), AIRS and IASI hyperspectral IR radiances, GPSRO sensors (COSMIC, GRAS, GRACE), SSMI/S, Windsat, Jason-2,...
- Advanced sensors tested for operational readiness, e.g. ASCAT, MLS, SEVIRI (radiances),...
- Ongoing methodology improvement for sensors already assimilated, e.g. AIRS, GPSRO, SSMI/S,...
- Improved physically based SST analysis
- Adjoint sensitivity diagnostics
  - Applied to GSI/GEOS5 by GMAO
  - Applied to FNMOC by NRL
- Common NOAA/NASA land data assimilation system (NOAA, GSFC, AFWA)

Common Land Data Assimilation

Community Noah Land-Surface Model



STATE VARIABLES

SKIN TEMPERATURE, CANOPY WATER, SOIL TEMPERATURE, SOIL WATER, SOIL ICE, SNOW DEPTH, SNOW WATER

SURFACE PARAMETERS

VEGETATION TYPE, GREEN VEGETATION FRACTION, SOIL TEXTURE, ROUGHNESS, ALBEDO, SLOPE FACTOR

ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm

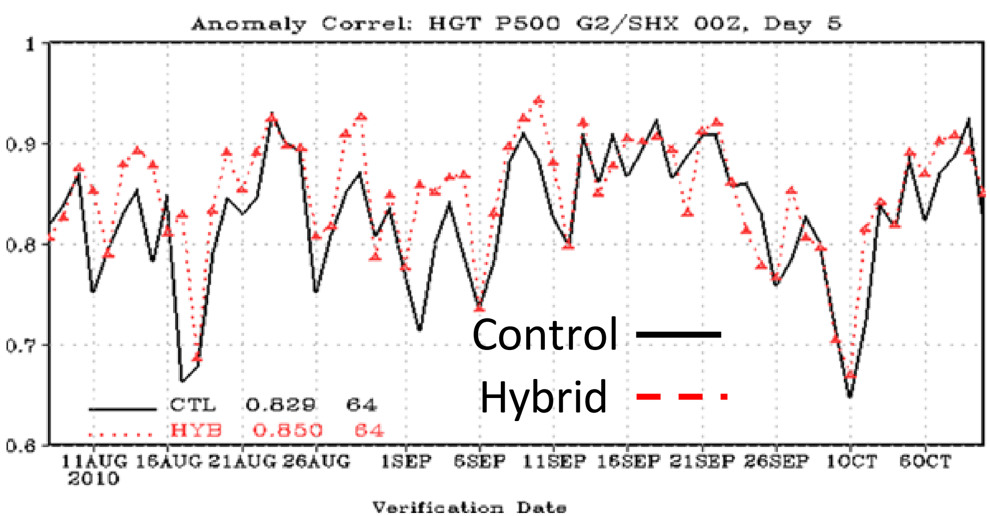
Used operationally at NCEP; initialized through Land Information System (led by GSFC) – Christa Peters-Lidard (GSFC)

JCSDA accomplishments (II)

- OSE capability illustrating importance of satellite data
- OSSE capability in support of COSMIC-2, JPSS, GOES-R, Decadal Survey and other missions
- Comprehensive suite of data impact experiments for all major observing systems using NCEP GFS
- New supercomputer at GSFC (jointly funded by NASA and NOAA, installed and operated by NASA for the Joint Center)
- Part of NOAA/NESDIS-funded supercomputer (S4) located at UW Madison available for JCSDA investigators
- Hand-off to NCEP of NPP ATMS data assimilation capability (collaboration between EMC, NESDIS, NASA, JCSDA); implemented in operations on May 22 2012, 7 months after launch
- Science Enhancements to CRTM
  - Aerosols and impacts on sounding channels
  - Surface Emissivity for microwave and infrared bands
  - State of the art Line-by-line calculation capability
- Bending angle assimilation for GPSRO

Recent Model/DA Implementations at NCEP

- New EnKF hybrid data assimilation system
  - Implemented at NCEP – based on collective research effort
  - Includes use of NPP advanced microwave sounder – 7 months after launch!
  - Improves the use of GPSRO – bending angle



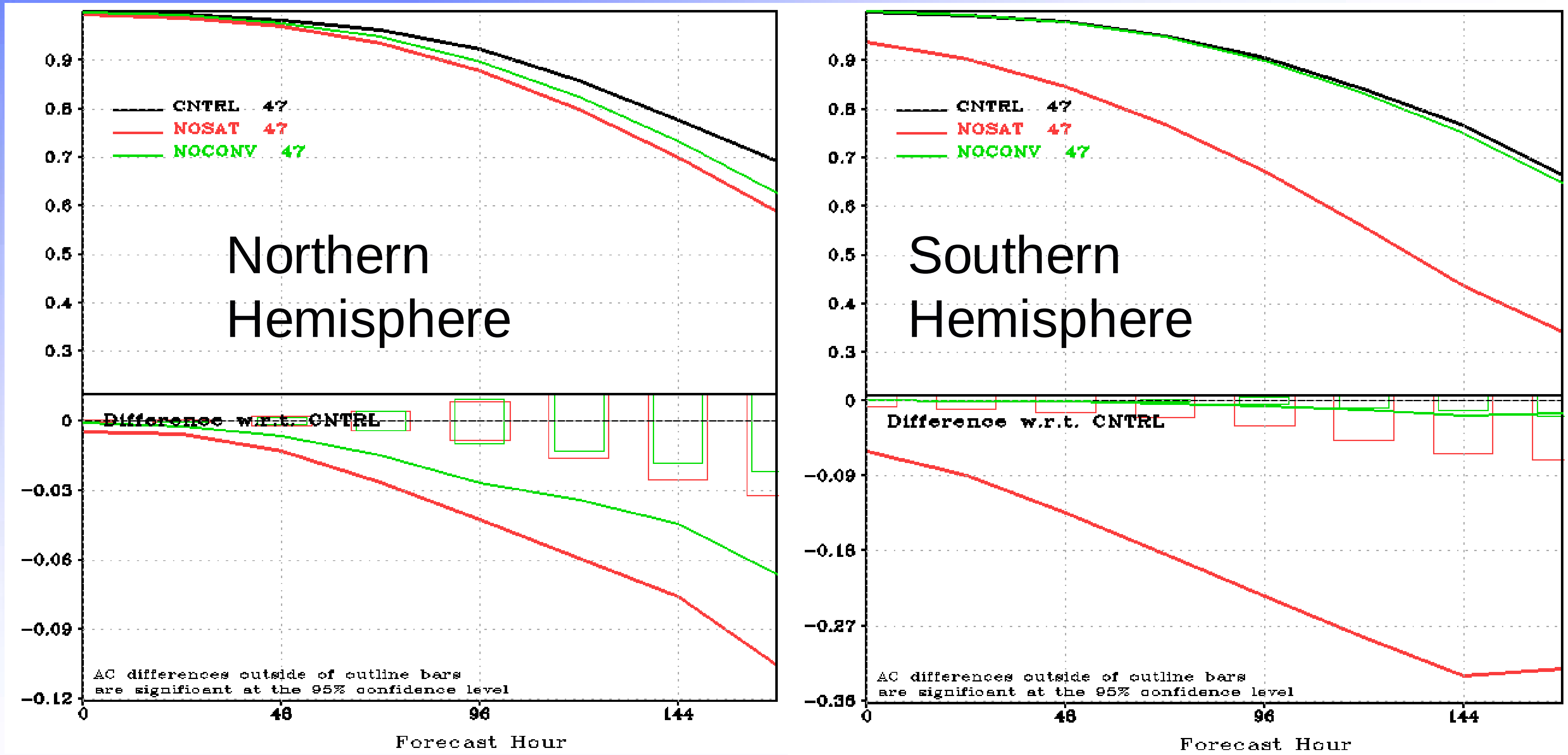
Comparison of 5 day forecast anomaly correlation at 500mb between forecasts from previous analysis system (black) and new hybrid analysis system (red) for period from August – October 2010.

Recent Observation Simulation Experiment on JCSDA Computer System

500 hPa Anomaly Correlations

15 Aug – 30 Sep 2010

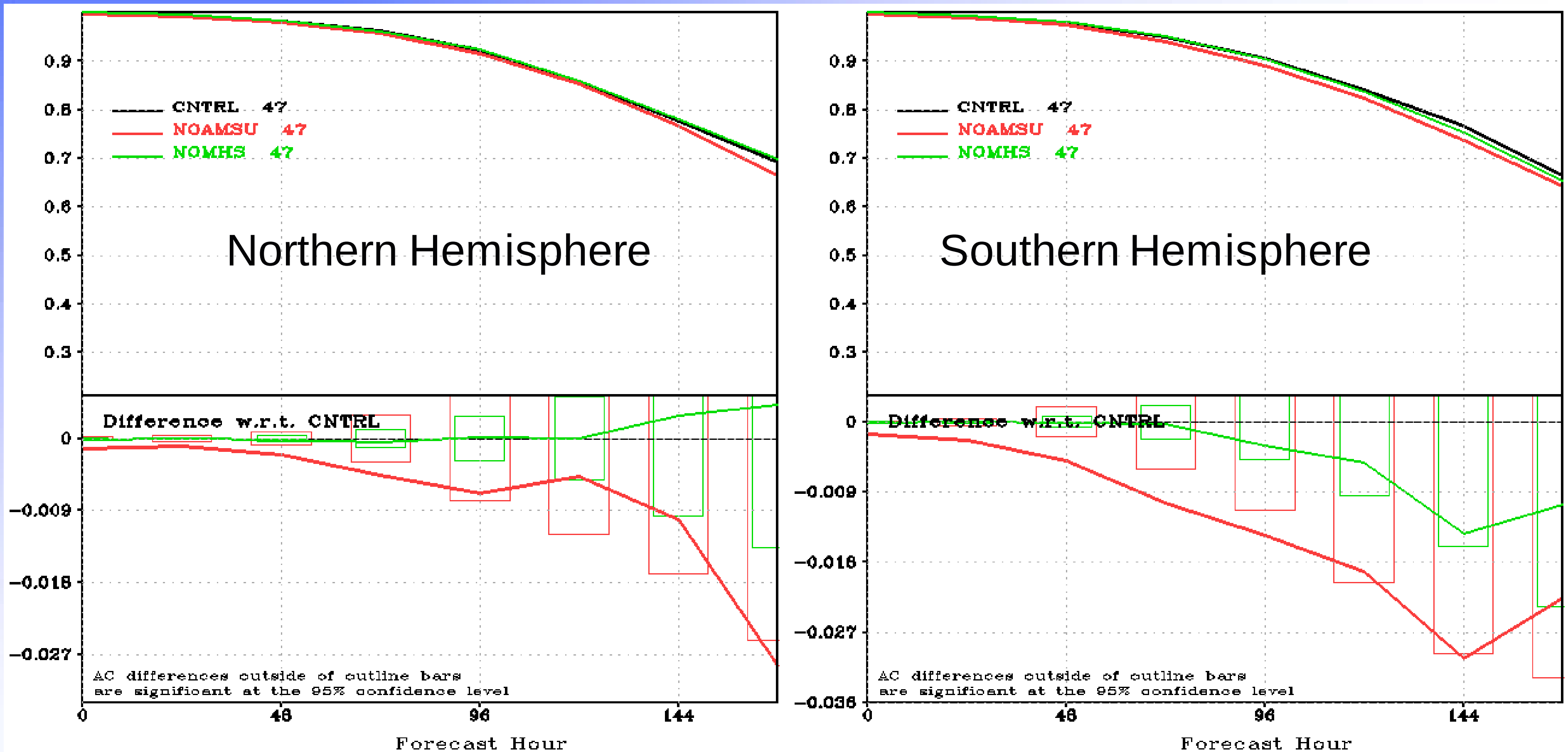
No Satellite / No Conventional Data



Example of OSE diagnostics (J. Jung, 5th WMO Impact Workshop, Sedona 2012)

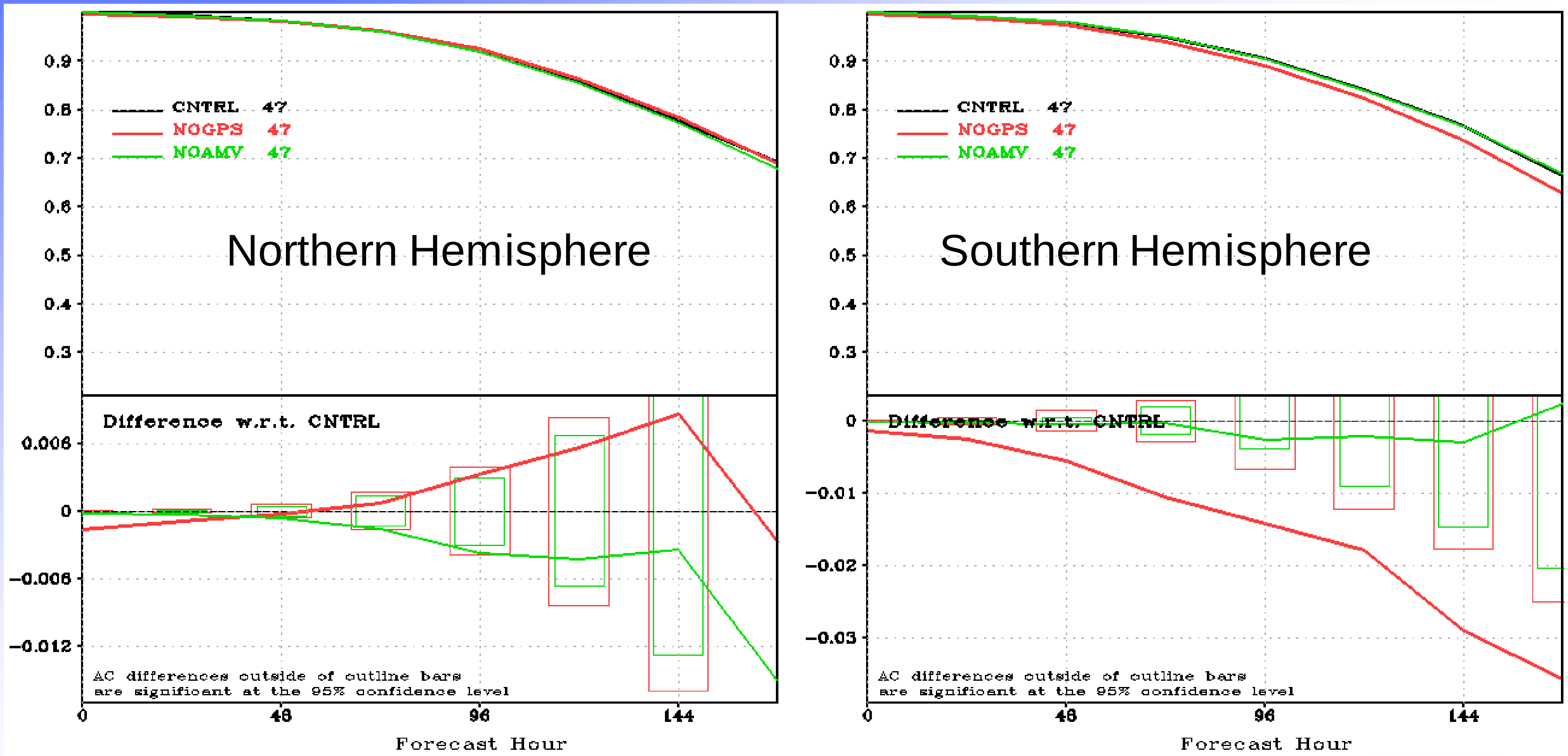
500 hPa Anomaly Correlations
15 Aug – 30 Sep 2010

No AMSU-A / No MHS



500 hPa Anomaly Correlations
15 Aug – 30 Sep 2010

No GPS-RO / No AMV



Summary of JCSDA OSEs

- NCEP operational version of the GDAS (May 2011) at the operational resolution (T574L64) was used on the JCSDA computing system (at GSFC)
- No Satellite / No Conventional data statistics show significant impact
- Impact from individual sensors was less than expected
  - other remaining instruments appear to compensate the loss of any one instrument
- Most instrument types have a positive impact on wind forecasts in the tropics
  - Conventional data, AMSU, AMV, GPS-RO, Aircraft, Rawinsondes

Adjoint Studies Conducted at:

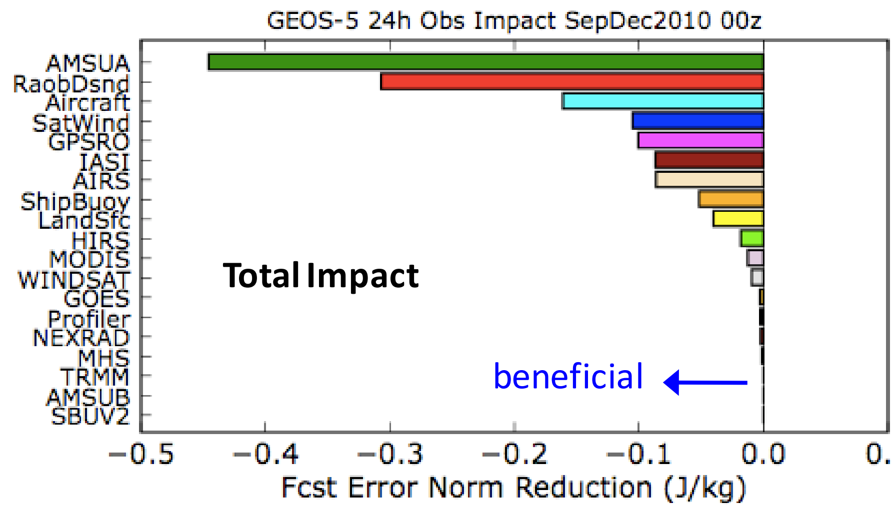
- GMAO
- NRL

Impact of Various Observing Systems in GSI/GEOS-5

01 Sep – 31 Dec 2010 00z

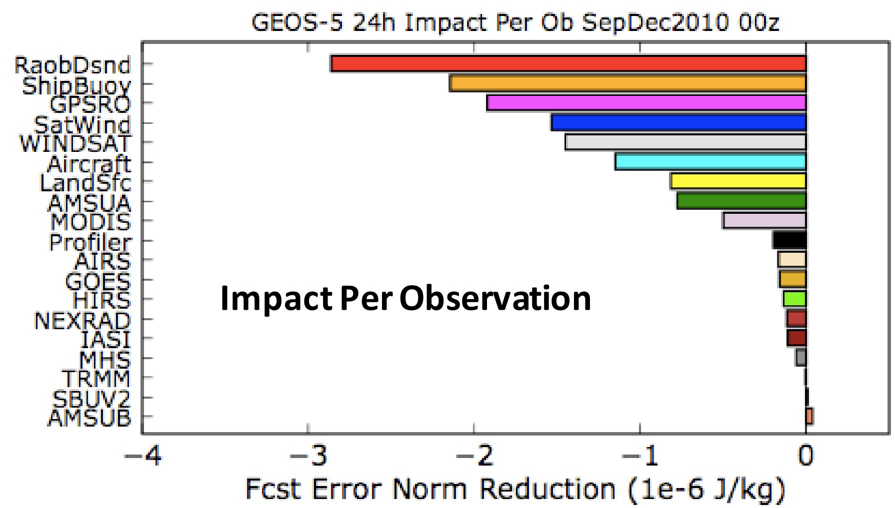
Total Impact

- AMSU-A radiances have the largest impact globally, but conventional data (raob, aircraft) still very important. GPSRO now a significant contributor.



Impact Per Observation

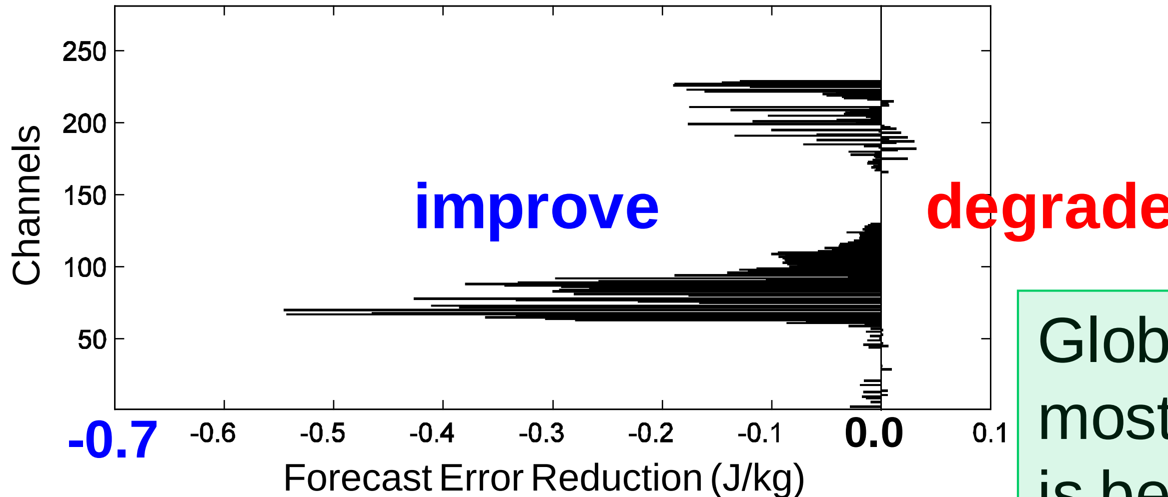
- Raobs get large weight in the analysis and have large IPO. Ship obs are few, but are located where there are few other in-situ data.



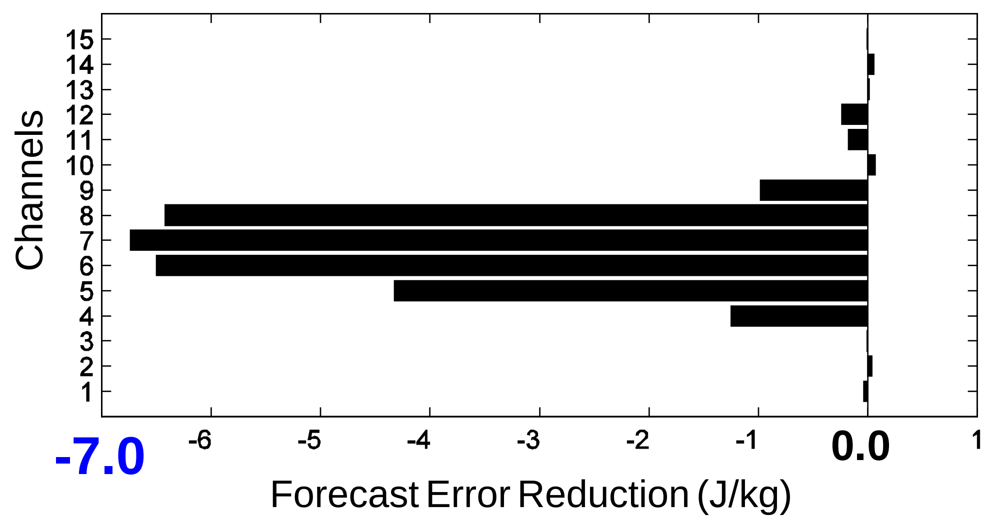
Impact of Satellite Observations by Channel

GMAO GEOS-5 July 2005 00z

AIRS

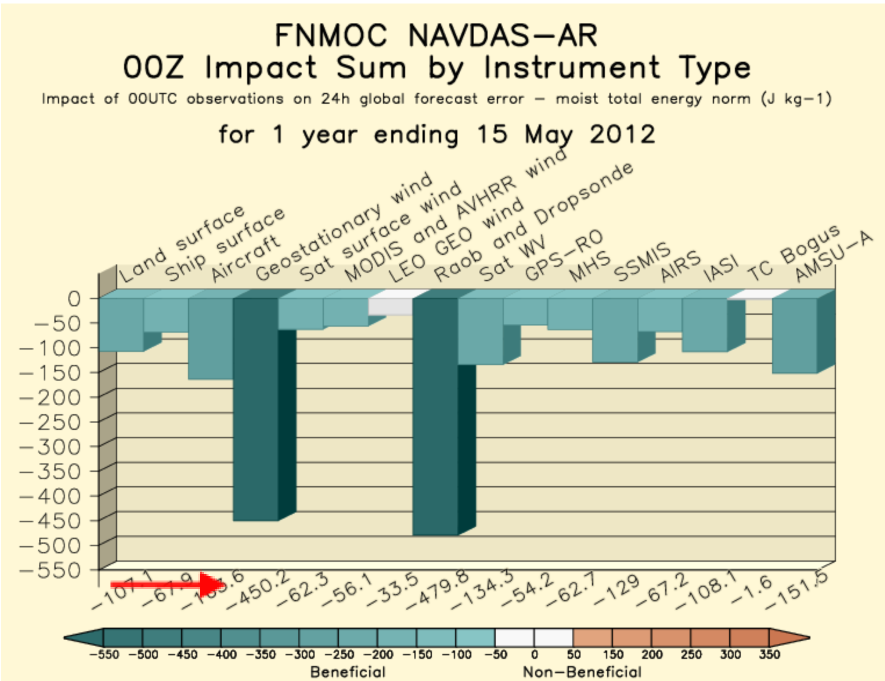


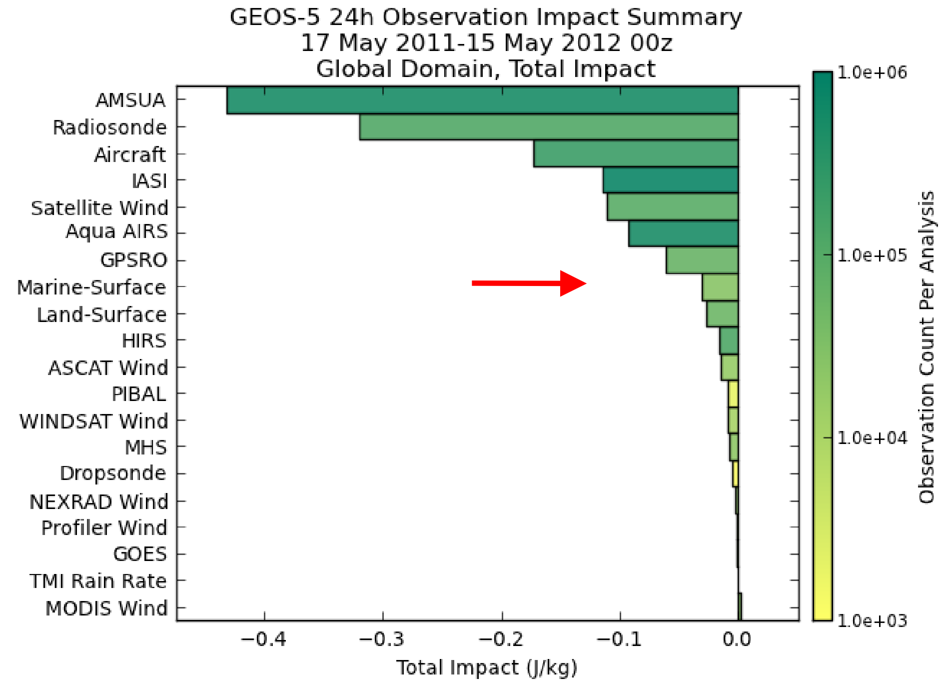
AMSU-A



Global impact of most channels is beneficial on average…with some exceptions

FSD diagnostics (Gelaro, 5th WMO Impact Workshop, Sedona 2012)



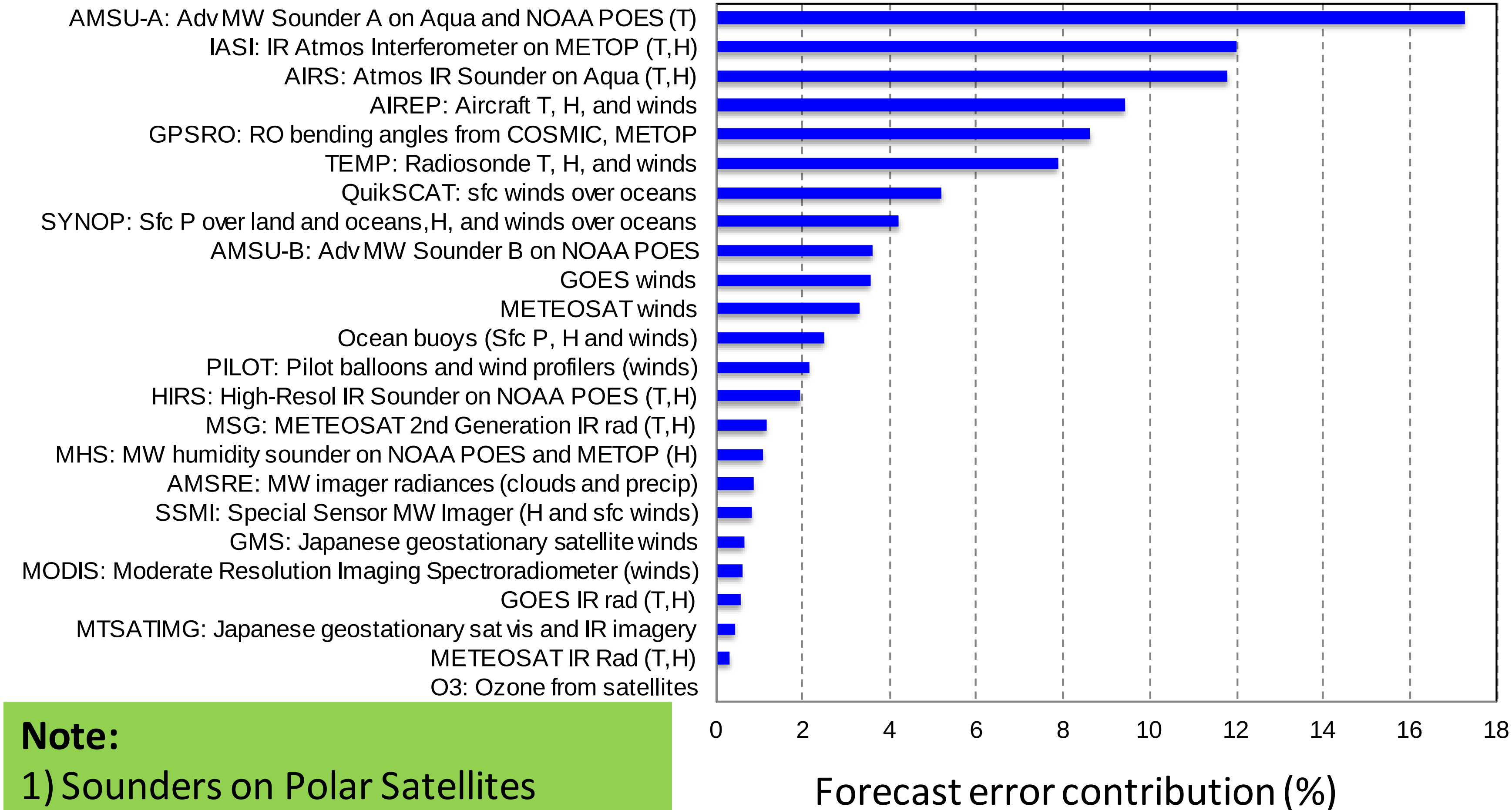


http://www.nrlmry.navy.mil/obsens/fnmoc/obsens_main_od.html

http://gmao.gsfc.nasa.gov/products/forecasts/systems/fp/obs_impact/

Much larger relative impact of AMVs in Navy system compared to NASA's. Note that IASI has moved up in NASA system compared to 2010 (previous slide), and GPSRO has moved down as COSMIC ages/degrades.

Operational ECMWF system September to December 2008. Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.



Note:
1) Sounders on Polar Satellites reduce forecast error most
2) Results are relevant for other NWP Centers, including NWS/NCEP

Courtesy: Carla Cardinali and Sean Healy, ECMWF

Satellite Data Used Operationally

- HIRS sounder radiances
- AMSU-A sounder radiances
- AMSU-B sounder radiances
- ATMS sounder radiances
- AIRS* sounder radiances
- IASI sounder radiances
- GOES sounder radiances
- GOES, Meteosat, GMS winds
- GOES precipitation rate
- SSM/I precipitation rates
- TRMM* precipitation rates
- SSM/I ocean surface wind speeds
- ERS-2* ocean surface wind vectors
- [1]Quikscat* ocean surface wind vectors → ASCAT
- JASON ocean surface altimetry
- AVHRR SST
- AVHRR vegetation fraction
- AVHRR surface type
- Multi-satellite snow cover
- Multi-satellite sea ice
- SBUV/2 ozone profile & total ozone
- MODIS* polar winds
- GPS Radio Occultation
  - COSMIC, METOP/GRAS, GRACE,* SAC-C*, TerraSAR-X*
- SSMIS
- OMI*
- MSG Seviri

* Indicates Research Satellite or Sensor

[1] No longer available

As of September, 2012

Upcoming Satellite Systems

- Research satellite being tested: Aquarius for sea surface salinity
- Operational
  - JPSS: ATMS, CrIS, VIIRS
  - GOESR: ABI, 15 minute full disc coverage
- Research
  - Soil Moisture Active-Passive (SMAP) satellite (launch date: 2014)
  - Global Precipitation Mission (GPM) satellite (launch date: 2014)
- International
  - China FengYun-3 (FY3) satellite (launch date: 2013)

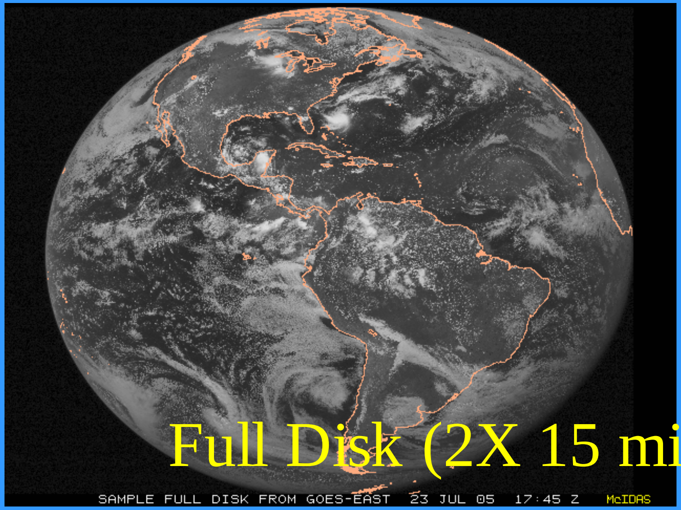
Ongoing Opportunities/Challenges

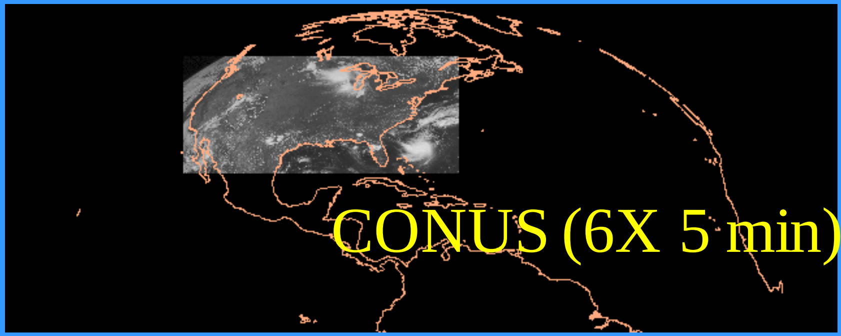
- Getting ready for JPSS!!
  - Plan for potential data gaps
  - Be ready at Day 1
- Getting ready for GOES R – full disc coverage of 16 image channels in 15 minutes
- Expanding new hybrid DA
  - Higher resolution ensemble
  - 4DVAR capabilities w/o adjoint
- OSSEs – advancement of new observing systems (e.g., wind lidar)

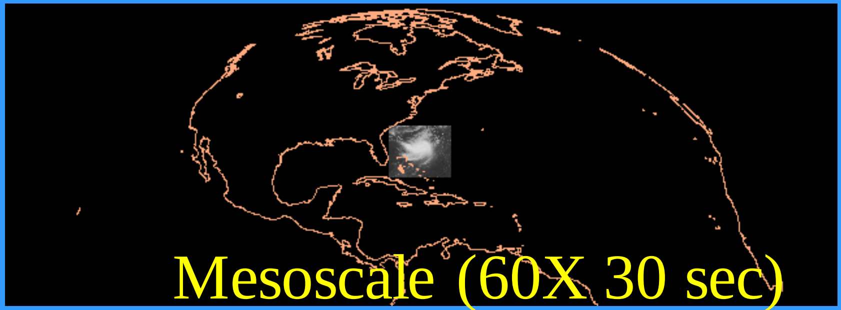
ABI Spectral Bands

Future GOES imager (ABI) band	Wavelength range (µm)	Central wavelength (µm)	Nominal subsatellite IGFOV (km)
1	0.45–0.49	0.47	1
2	0.59–0.69	0.64	0.5
3	0.846–0.885	0.865	1
4	1.371–1.386	1.378	2
5	1.58–1.64	1.61	1
6	2.225–2.275	2.25	2
7	3.80–4.00	3.90	2
8	5.77–6.6	6.19	2
9	6.75–7.15	6.95	2
10	7.24–7.44	7.34	2
11	8.3–8.7	8.5	2
12	9.42–9.8	9.61	2
13	10.1–10.6	10.35	2
14	10.8–11.6	11.2	2
15	11.8–12.8	12.3	2
16	13.0–13.6	13.3	2

ABI Scans (in 30 min)







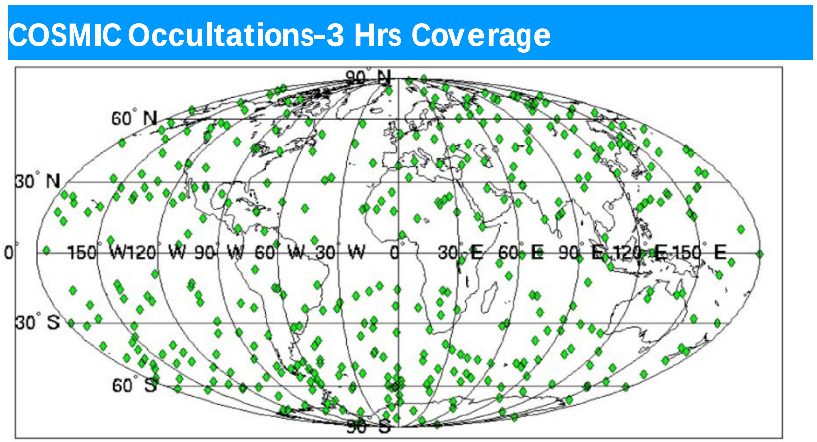
GOES-R ABI offers more bands, more often

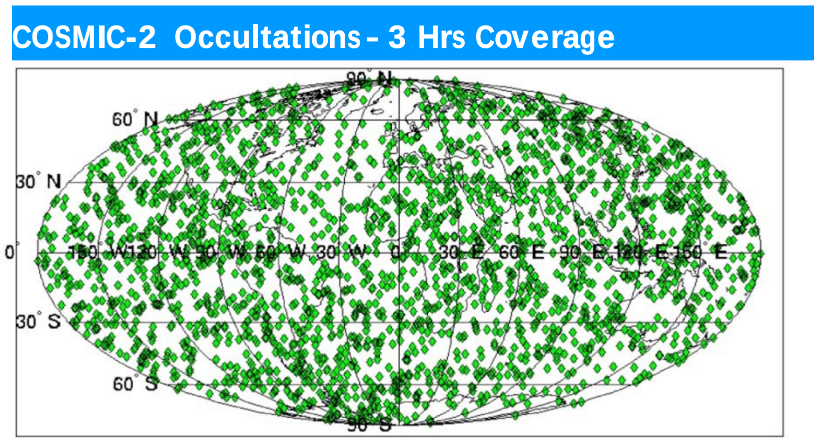
Ongoing Opportunities/Challenges

- Expanding new hybrid DA at NCEP
  - Higher resolution ensemble
  - 4DVAR capabilities w/o adjoint
- Improved DA at FNMOC: 4DVAR
- OSSEs – advancement of new observing systems (e.g., wind lidar)

Ongoing Opportunities/Challenges

- COSMIC 2 – thousands of soundings per day





- Earth Systems: Land, Ocean, Ice
  - Must do for the Earth System what is being done for the atmosphere!!
  - Full inclusion of clouds
- Leveraging total system by research community

Observation = QC → DA → Models → Post Processing

Prediction System

Summary

- Forecasting/prediction has arrived as a fundamental part of our science → expanding throughout the Earth Systems Science community
- Advancing general forecast skill, especially for extreme events; now predict extreme events seven to eight days in advance
- Four fundamental components for today's forecast process
  - Global observing system dominated by satellites
  - Model/DA/Science
  - Computer
  - Forecaster
- JCSDA continues to play a critical role in advancing the use of satellite data within operational forecast models (NOAA & DoD)
  - CRTM
  - Accelerating use of research satellite data/assess data impacts
  - Joint efforts to advance DA
- Major priorities focus on getting ready for JPSS, GOESR, COSMIC2 and other research satellite systems (SMAP, GPM)
- Challenges include expanding the use of satellite data more broadly in operational Earth System Prediction System – use by operational and research communities

Preparing for the American Meteorological Society Annual Meeting

Austin, TX, January 4-10, 2013

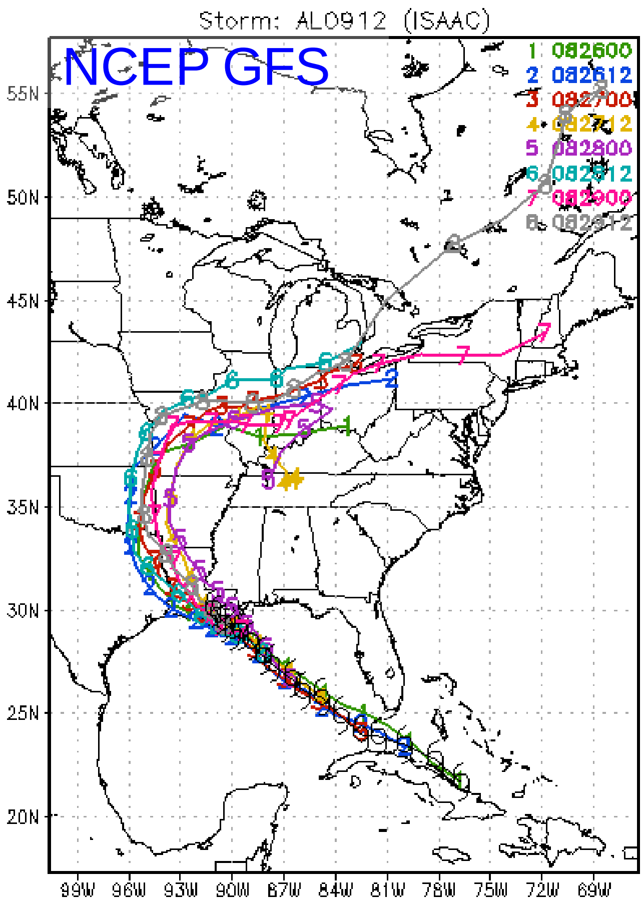
- 2013 AMS Annual Meeting theme:
  - "Taking Predictions to the Next Level: Expanding Beyond Today's Weather, Water and Climate Forecasts and Projections"
  - Designed to build off interdisciplinary partnerships
  - Applications include coastal, health vectors, ecosystem prediction
- An important developing partnership involving the atmospheric-ocean sciences-bio/chem communities
- Completing the "last mile" to expand beyond today's forecasts points to a physical science-social science intersection/overlap, especially for mitigation and adaptation → Decision Support and Services
- Need to keep academic/research communities fully engaged with the AMS
- Special Symposium on the Joint Center for Satellite Data Assimilation – Thursday, January 10

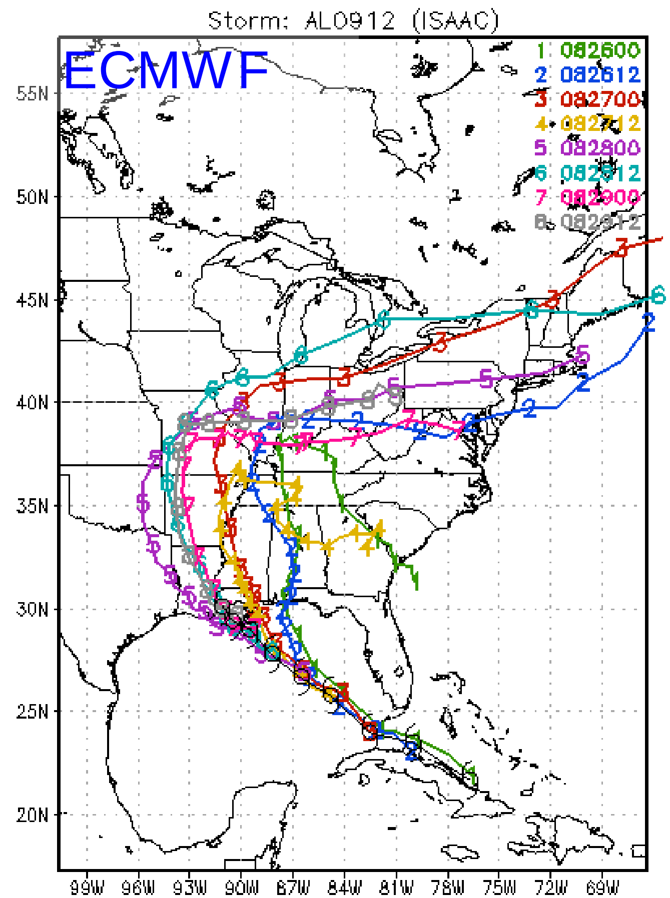
Appendix

Global Model Track Guidance for TS/Hurricane Isaac

Sequence of 5-day 00 and 12 UTC cycle Isaac forecasts

26 August 2012 to 29 August 2012





Hurricane Isaac Precipitation Forecast