The Advancement of Weather Forecasting from an Art to a Science: Today’s Prediction Capability of Extreme Weather, Short-term Climate and Water Events

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Annual Conference of the Prognostics and Health Management Society
Minneapolis, MN
September 26, 2012
Outline

• “The Weatherman is not a Moron”
• Recent Examples of Predicting Extreme Events
• The Transformation of Weather Prediction from an Art to a Science
• Essential Components of Numerical Predictions
• The Future is Now: Extending Prediction Capabilities into Decision Support Services
• Summary
IN THE HOCUS POCUS REALM OF PREDICTING THE FUTURE, WEATHER FORECASTING STANDS OUT AS AN AREA OF GENUINE, MEASURABLE PROGRESS. YOUR OWN EXPERIENCE MAY DIFFER. BY NATE SILVER

THE WEATHERMAN IS NOT A MORON
“The Weatherman is not a Moron”

• Weather prediction has progressed when most other predictions have failed
• Progress can be “measured”/verified in a quantitative way
• Prediction capabilities include uncertainty and have already been integrated into key decision support
From the inside, the National Centers for Environmental Prediction looked like a cross between a submarine command center and a Goldman Sachs trading floor.

Quoted from “The Weatherman is not a Moron” New York Times Magazine, September 9, 2012
Recent Examples of Predicting Extreme Events
Rapidly Developing Pacific Storm: Not Predicted
13-14 November 1981

Reed and Albright, MWR, 1986
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.

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

Issued December 28, 2009

4 Days Prior to Event

00Z 5 January, 2008

HPC 48-h QPF ending 00Z 6 Jan
Issued 00Z 1 Jan
Day 4-5 forecast
April 3-4, 1974 Super Outbreak

- 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

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

- 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 heavy snow 3-5 days in advance
- States implement COOP plans, airlines cancel flights, retail industry pre-stocks shelves
White cone – 2003
Blue cone - 2010

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.
Hurricane Prediction Skill

National Hurricane Center
Atlantic 72 Hr Track Forecast Errors

Error (nautical miles)

Year

1970-1986 trendline
1987-1996 trendline
1997-2001 trendline
2003-2011 trendline

Major Upgrades in Global and Hurricane Numerical Models
Advances Related to USWRP

Better Model Physics and Resolution
Improved Data Assimilation
Background: The Transformation of Weather Prediction from an Art to a Science
Forecasting in the ‘30s, ‘40s, ’50s
When Forecasting was an “Art”

Data
- Surface – every six hours
- Regional to global extent

Forecast Process
- Subjective – based on analogs, experience
- Manually intensive
- Based on data from one level
Today’s Forecast Process

Data
- Multi-faceted
- Increasingly remotely-sensed

Forecast Process
- Objective
- Based on numerical models
- Initialized with a “cube” of data
- Forecast made out to week 2

Ongoing Opportunities
- Public-Private
- Earth System Model approach
- Assimilation of satellite data
The Essential Components of the Numerical Prediction Enterprise
Everything you read, see or hear about weather, climate and ocean forecasts is based on NCEP numerical prediction models.

Three Essential Components of the Numerical Prediction Enterprise

- Global Observing System
- Computers (supercomputers, work stations)
- Data Assimilation & Modeling/Science
Three Essential 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/backup 15 minute switchover
    - 73 trillion calc/sec – IBM Power 6
  - 2013
    - 146 trillion calc/sec – IBM iDataPlex Intel/Linux
Global Observing Critical for Successful Numerical Weather Prediction
Nonhydrostatic Multiscale Model (NMM-B)

Regional Domain (12 km) – 84 hrs
Embedded Mesoscale (6, 4 & 3 km) – 60 hrs
Incident Directed-[Fire Wx] (1.5 & 1.33 km) – 36 hrs

Lake Superior
Model Production Suite

We are Now Running “Earth System” Prediction Models

- Predictions Driven by Global Observing Systems
- Real-time operations require world’s largest computers
- BIOLOGY/CHEMISTRY NOW BEING INCLUDED
NOAA’s Model Production Suite

Climate Forecast System
- GFS
- MOM4
- NOAH Sea Ice

Global Forecast System
- Regional NAM
  - WRF NMM

Regional DA

Short-Range Ensemble Forecast
- WRF: ARW, NMM
- ETA, RSM

Hurricane
- GFDEL
- HWRF

Coupled

Dispersion
- ARL/HYSPLIT

Severe Weather
- WRF NMM/ARW
- Workstation WRF

Air Quality
- NAM/CMAQ

Rapid Refresh for Aviation

Space Weather
- ENLIL

Global Data Assimilation

~2B Obs/Day Satellites + Radar 99.9%

North American Ensemble Forecast System
- GFS, Canadian Global Model

NOS – OFS
- Great Lakes
- Northern Gulf of Mexico Bays
- Chesapeake
- Tampa
- Delaware

NOAA’s Model Production Suite

NOAH Land Surface Model
Computing Capability
“reliable, timely and accurate”

- Current computers
  - IBM Power6
  - 73.1 trillion calculations/sec
  - 2 billion observations/day
  - 27.8 million model fields/day
  - Primary: Gaithersburg, MD
  - Backup: Fairmont, WV
  - Guaranteed switchover in 15 minutes

- Next generation computer: by Oct 2013
  - IBM iDataPlex Intel/Linux
  - 143 trillion calc/sec
  - Primary: Reston, VA
  - Backup: Orlando, FL

Web access to models as they run on the CCS
The Future is Now!
Extending Prediction Capabilities into Decision Support Services

• Need to Quantify Uncertainty

• Introduction of Ensemble Forecasting
Numerical Weather Models (NWP) and Ensemble Systems

- Numerical weather models...
  - All forecasts contain errors (either in physics or initial analysis) that increase with time
  - Doubling time of small initial errors ~1 to 2 days
  - Maximum large-scale (synoptic) predictability ~10 to 14 days

- Ensembles...
  - A collection of models providing information on a range of plausible forecasts, statistical measures of confidence, and extend predictability
  - Ensemble Model runs provide a range or “envelope” of solutions
  - The spread of solutions can be used to provide probabilities or “confidence” limits for any forecasts

Weather forecasting: It’s impossible to be certain all of the time!
The Forecaster’s Dilemma

Initialization  Forecast Possibility #1  Forecast Possibility #2

Today  Four Days Later
An Ensemble of Possibilities

Ensembles provide an envelope of solutions (and probable “best solutions”) representing possible storm tracks, storm intensity and precipitation amount/type.
SREF Forecasts for Feb 5, 2010: “Snowmageddon”
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 GNP¹
• Federal disaster declared; facilitates snow removal, and faster recovery!

¹Some 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.
Extending Prediction Models into Nontraditional Areas

- Coupled Models: Atmosphere – Ocean – Land → provide opportunities for ecosystem prediction: beach/water quality, health, "critters"

Regional Earth System Modeling

Coupling models and linking products
Satellite chlorophyll image with possible HAB areas shown by red polygon(s).

Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Southwest Florida
Monday, 27 August 2012
NOAA Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service

Relies on satellite imagery, field observations, models, public health reports and buoy data to assess and predict bloom conditions, location and movements.
Summary

• Weather forecasting has made a revolutionary change in the past 50 years
  – One of the top intellectual achievements of the 20th century
• 4 main components of the modern forecast process
  – Global observations -- Numerical models/service
  – Super computers -- Highly educated forecasters
• Can now routinely predict weather/extreme events days to a week (plus) in advance
• Linking forecasts to decision-making across a wide spectrum of users and decision makers
  – Big challenges remain – quantifying uncertainty being one of them
• Transforming weather forecasts to “impact-based forecasts” for Decision Support Services → especially emergency management community
• Need to approach from an interdisciplinary perspective, physical and social scientists
• Expand prediction into non-traditional areas: air/water quality, ecosystems, health vectors – based on an interdisciplinary Earth System approach
THANK YOU
Appendix
Predicting Health Vectors
Malaria Field Program in Niger

Wassila Thiaw - CPC African Desk Team Leader
Malaria Field Campaign in Niger

- Pond near Banizoumbou
- Observing mosquito Larvae in the pond
- CDC Light trap
- Well in Zindarou
Rainfall and Malaria
Weekly Cases in Niger from 2001 to 2003

Solid blue: GPCP Precipitation
NCEP Reanalysis employed to develop a meningitis prediction system in Burkina Faso

Yaka et al., 2008
Relationships between high impact weather and outbreaks of cholera

Linkages between environmental parameters and cholera outbreaks
Understand influence of weather and climate on cholera outbreaks
Develop early warning systems for water borne disease outbreaks
WHO; WMO; National Health Institutions; National Met & Hydrologic Services

There is now strong evidence that climate variability has a major influence on the cycles of cholera outbreaks.

Studies have shown that cholera has a marked seasonality associated with the rainfall season, especially in coastal countries.

The peak of epidemic outbreaks are preceded by an increase in sea surface temperature and rainfall.

2005 Cholera outbreak and Precipitation in Dakar, Senegal
Drought and Food Security Planning

Weekly Climate Risk Bulletins

• Objective: Support USAID/Food for Peace

• Facilitate decision making on issues related to food security.

• Enable USAID for other risk management strategies, such as humanitarian relief efforts

Weekly Weather Summary and Outlook For Darfur Humanitarian Relief Effort