GENERAL DESCRIPTION OF THE WEATHER FORECAST PROCESS
WITH EMPHASIS ON FORECAST UNCERTAINTY

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Acknowledgements: Steve Lord, David Helms, Geoff DiMego, NWS/OST, John Derber

http://wwwt.emc.ncep.noaa.gov/gmb/ens/index.html
THE MAKINGS OF A WEATHER FORECAST – WHAT WE NEED FOR PREPARING A USEFUL FORECAST?

• Assess current weather situation
  – Before we can look into future, understand what is happening now
  – “Initial condition”

• Digest observational information
  – Bring observed data into “standard” format
  – “Data assimilation”

• Project initial state into future
  – Based on laws of physics
  – “Numerical Weather Prediction” (NWP) model forecasting

• Apply weather forecast information
  – Statistical post-processing
  – “User applications”
OBSERVING THE CURRENT STATE – SURFACE-BASED SYSTEMS

Land surface synop station (In situ)

Ocean buoy (In situ)

Land-based radar

Great advances in Remote sensing
OBSERVING THE CURRENT STATE – SPACE-BASED SYSTEMS

Enormous technological advances
New observing platforms
New observing instruments

Vast increase in number of observations

Evolution
U.S. civil defense programs, working in partnership with EUMETSAT, will ensure improved global coverage and long-term continuity of observations at less cost!

Today
- 4-Orbit System
  - 2 US Military
  - 2 US Civilian

Tomorrow
- 4-Orbit System
  - 2 US Military
  - 1 US Civilian
  - 1 EUMETSAT/METOP

Future
- 3-Orbit System
  - 2 US Satellites
  - 1 EUMETSAT/METOP

Daily Upper Air Observation Counts

<table>
<thead>
<tr>
<th>Year</th>
<th>Count (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>0.1</td>
</tr>
<tr>
<td>2000</td>
<td>1</td>
</tr>
<tr>
<td>2010</td>
<td>100,000</td>
</tr>
</tbody>
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Local Equatorial Crossing Time

DMSP

POES

METOP

NPOESS
OBSERVING THE CURRENT STATE – REMOTELY SENSED “IMAGES”, INSTEAD OF “DATA POINTS”

Precipitation type (Radar derived)

Satellite imagery

Wind speed (Radar)
Global Observations 12 UTC
6 hour window

Global Rawinsondes

Aircraft Wind/Temp Reports

Polar Satellite Radiances (2 sat)

Marine Obs -- 12 Hour Total

DMSP Imager – Sfc winds/PW

Satellite Winds
OBSERVING THE CURRENT STATE – HOW LARGE AN AREA WE NEED TO OBSERVE?

• Coherent weather systems (fronts, cyclones)
  – Travel with relatively low speed (<50 km/hr)
• Influence of observations spreads through “downstream development”
  – Can advance at speed of upper level jet stream (~150 km/hr)
• For extended-range prediction, large areas must be observed
UNCERTAINTY IN ASSESSING CURRENT WEATHER

Despite great advances, uncertainty in state of atmosphere remains

• Not all aspects of atmosphere observed
  – Coverage is intermittent in
    • Time
    • Space
  – Not all variables observed

• Existing observations are not perfect
  – Instruments have different kinds of errors:
    • Random
    • Systematic
  – Point-wise measurements not representative for model grid-boxes
HOW OBSERVATIONS ARE USED?
DATA MUST BE MOLDED INTO STANDARD FORMAT
ENORMOUS TECHNOLOGICAL EVOLUTION

“Weather factory” of the past: Manual analysis

Computing machines (1950s)  Supercomputers

3.7 Billion Times Faster in 50 Years
HOW OBSERVATIONS ARE USED?

DATA MUST BE MOLDED INTO "MODEL" FORMAT

Data assimilation combines observed & model forecast data

**Raw data**
- Intermittent
- Noisy
- Not suitable for numerical model

**Assimilated data:**
- Continuous
- Smooth
- Provides model initial state
HOW CURRENT STATE GETS PROJECTED INTO FUTURE?

NUMERICAL WEATHER PREDICTION

Use Newton’s laws of physics, plus thermodynamics

Numerical model calculations on 3-dimensional grids

Synoptic forecasting of past
STATUS OF WEATHER FORECASTING

1) Observing techniques improve

2) Computing power keeps multiplying

3) Numerical models become more sophisticated

4) More user friendly products

5) Trust of society earned

NO LIMITS TO WEATHER FORECASTING?
LIMITS IN WEATHER FORECASTING

- **Initial state is imperfect**
  - Problems with observations and data coverage
  - Problems with assimilating the data
    - Imperfect statistical and numerical forecast methods
    - Random (and systematic) errors

- **Numerical model is imperfect**
  - Limited resolution
    - Processes represented in model must be truncated
      - Spatially
      - Temporally
      - Physically
  - Systematic (and random) errors

- **Atmosphere is chaotic**
  - Small errors amplify rapidly
    - Forecasts lose skill with increasing lead time
    - Loss of skill is case specific

THOUGH SKILL IN FORECASTS EVER INCREASES – LIMITS PUSHED FURTHER OUT IN TIME
LIMITS REMAIN - NEED PROBABILISTIC APPROACH
HOW TO DEAL WITH FORECAST UNCERTAINTY?

• No matter what / how sophisticated forecast methods we use
  – Forecast skill limited
  – Skill varies from case to case
• Forecast uncertainty must be assessed by meteorologists

Do users need to know about uncertainty in forecasts?

How forecast uncertainty can be communicated?
THE MAKINGS OF A WEATHER FORECAST – EVER IMPROVING, BUT ALWAYS IMPERFECT

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REPRESENT FORECAST UNCERTAINTY – PROBABILISTIC FORMAT