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

Zoltan Toth

Environmental Modeling Center
NOAA/NWS/NCEP
USA

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)

Land-based radar

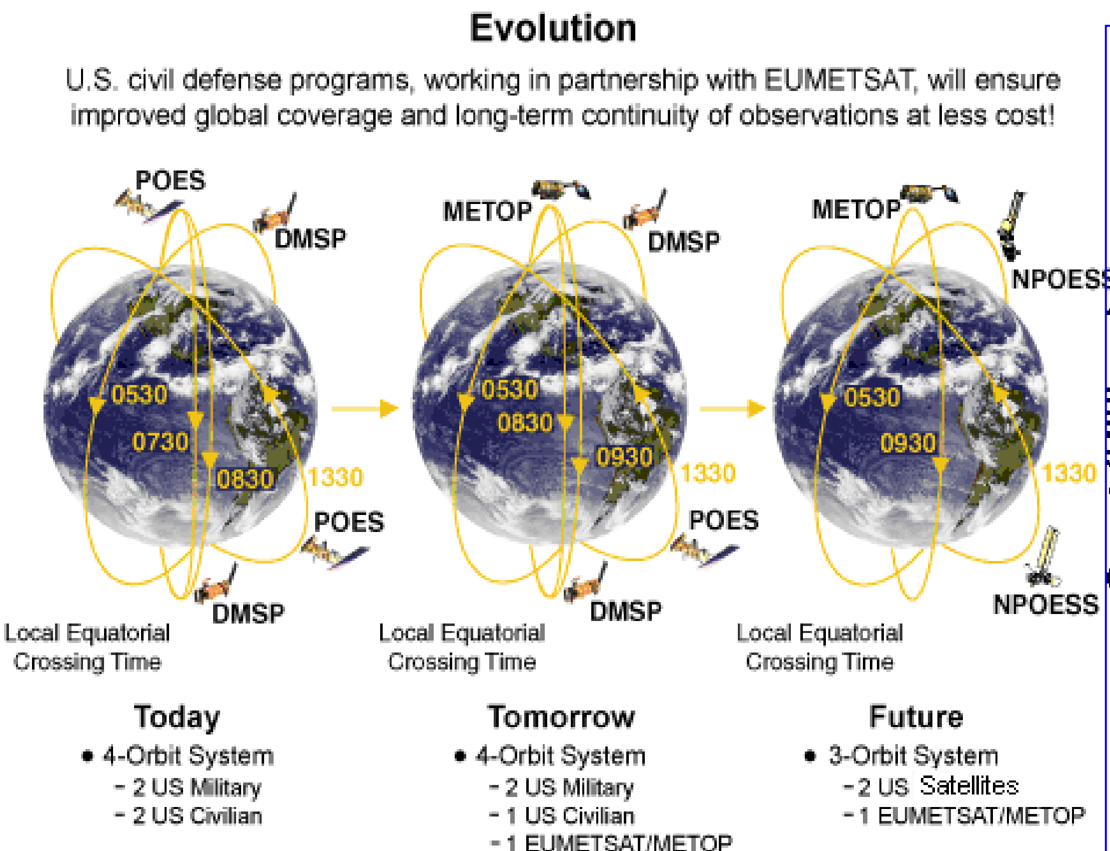
Great advances in Remote sensing

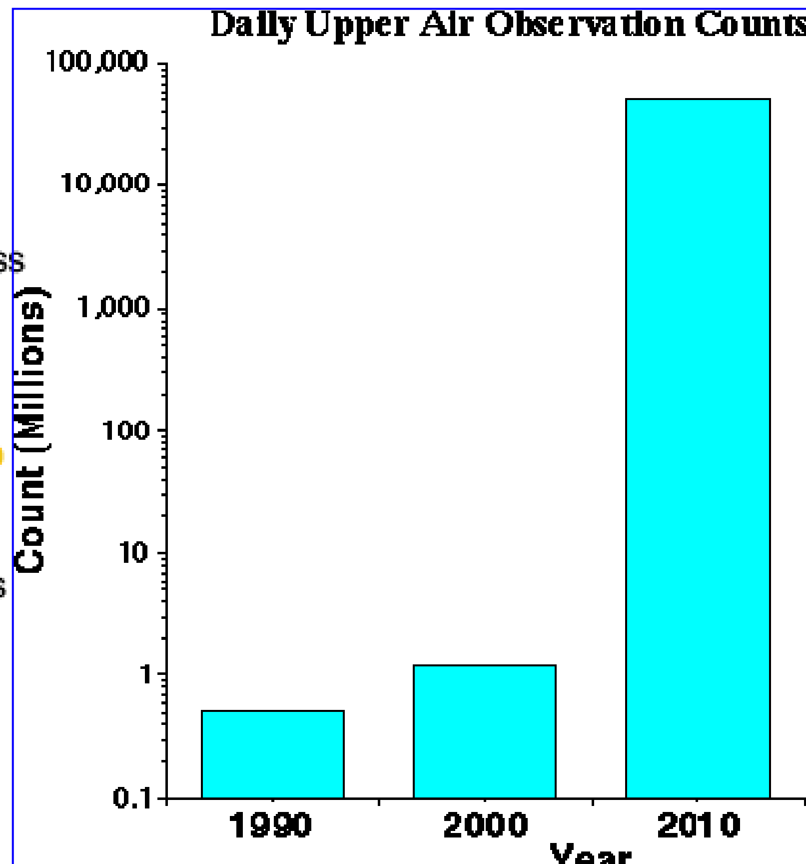
Ocean buoy
(In situ)

OBSERVING THE CURRENT STATE – *SPACE-BASED SYSTEMS*

Enormous technological advances
New observing platforms
New observing instruments

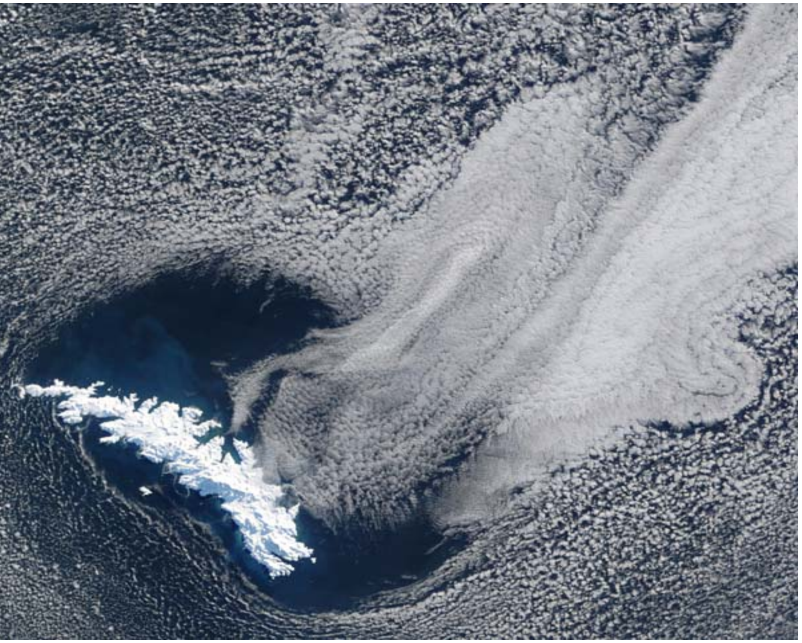
Vast increase in number of observations





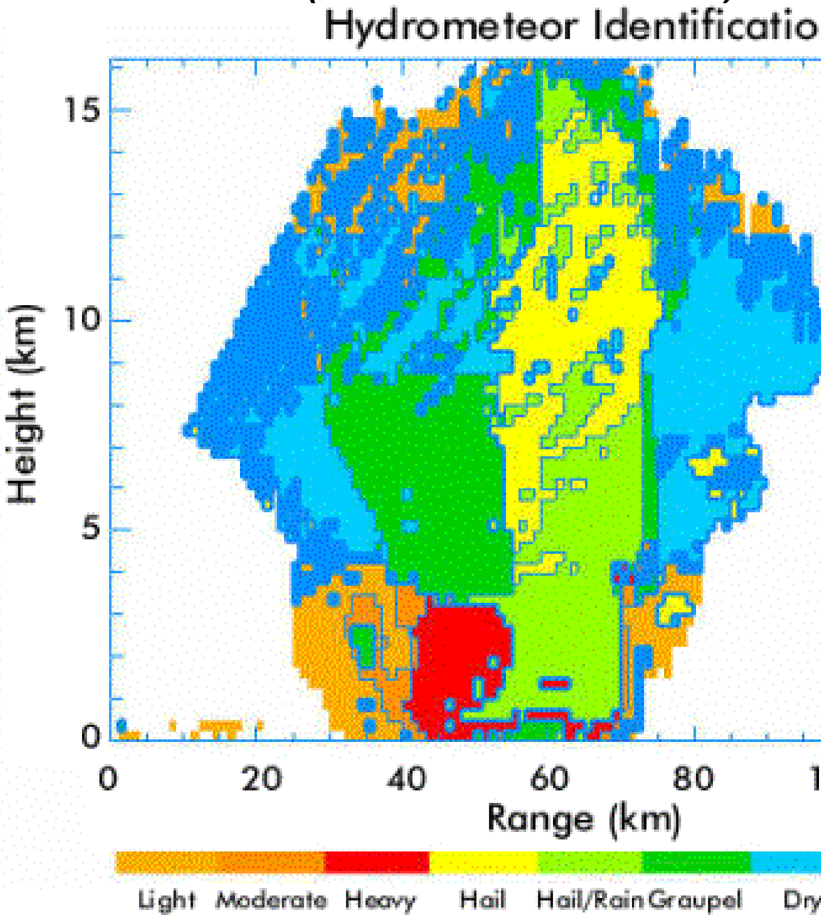
OBSERVING THE CURRENT STATE –

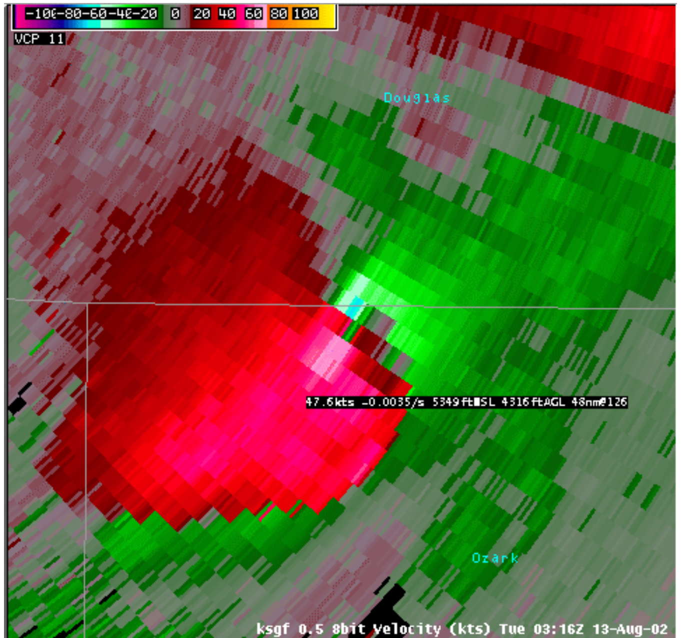
REMOTELY SENSED "IMAGES", INSTEAD OF "DATA POINTS"



Satellite imagery

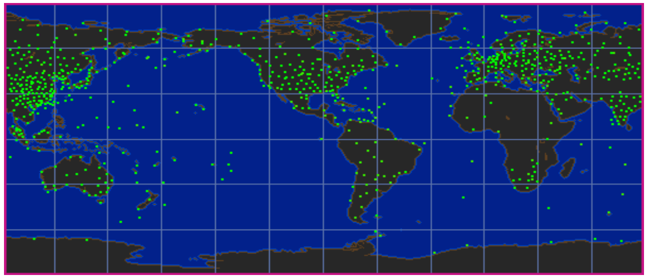
Precipitation type (Radar derived)



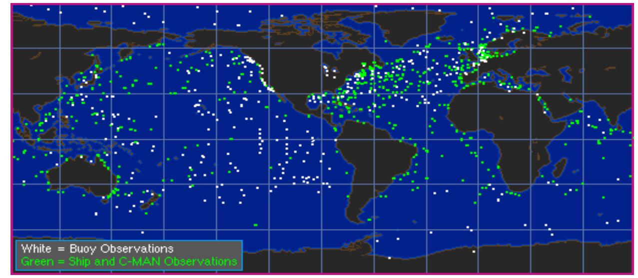


Wind speed (Radar)

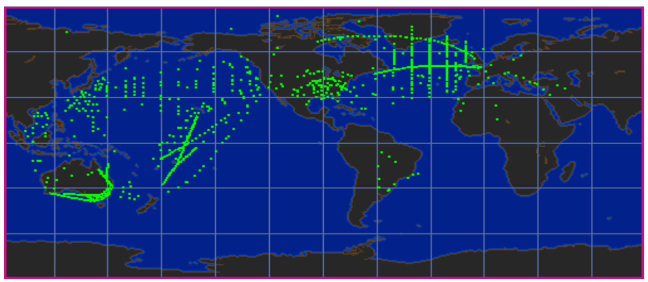
Global Observations 12 UTC
6 hour window



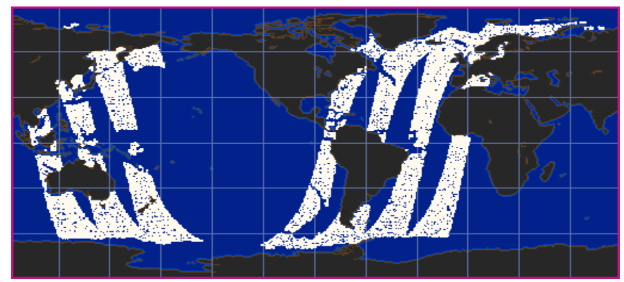
Global Rawinsondes



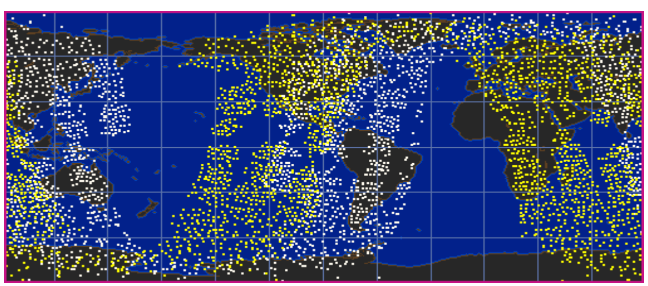
Marine Obs -- 12 Hour Total



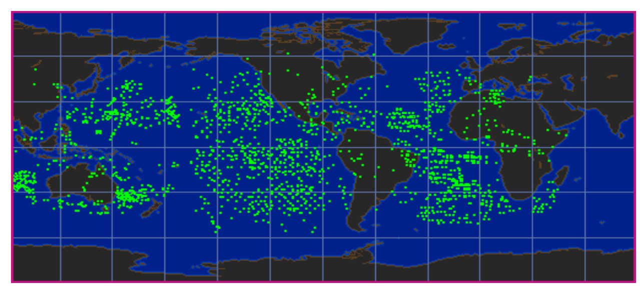
Aircraft Wind/Temp Reports



DMSP Imager – Sfc winds/PW



Polar Satellite Radiances (2 sat)



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

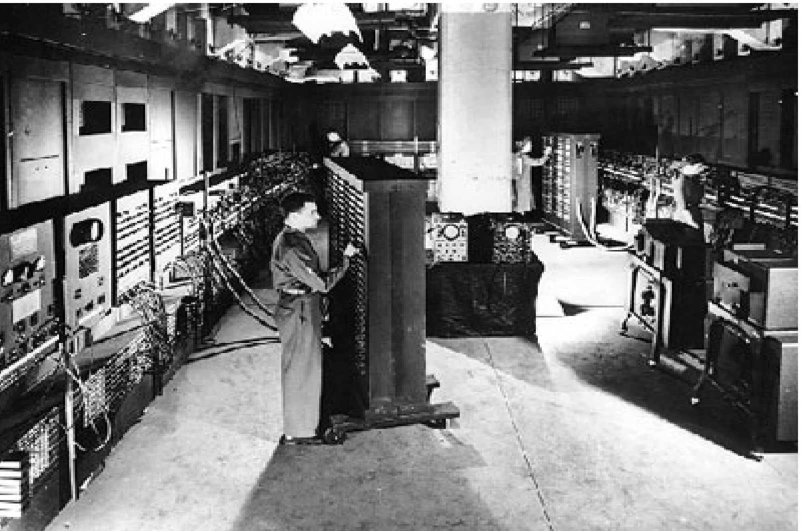
HOW OBSERVATIONS ARE USED?

DATA MUST BE MOLDED INTO STANDARD FORMAT

ENORMOUS TECHNOLOGICAL EVOLUTION

"Weather factory" of the past: Manual analysis

Computing machines (1950s)



Supercomputers

HOW OBSERVATIONS ARE USED?

DATA MUST BE MOLDED INTO “MODEL” FORMAT

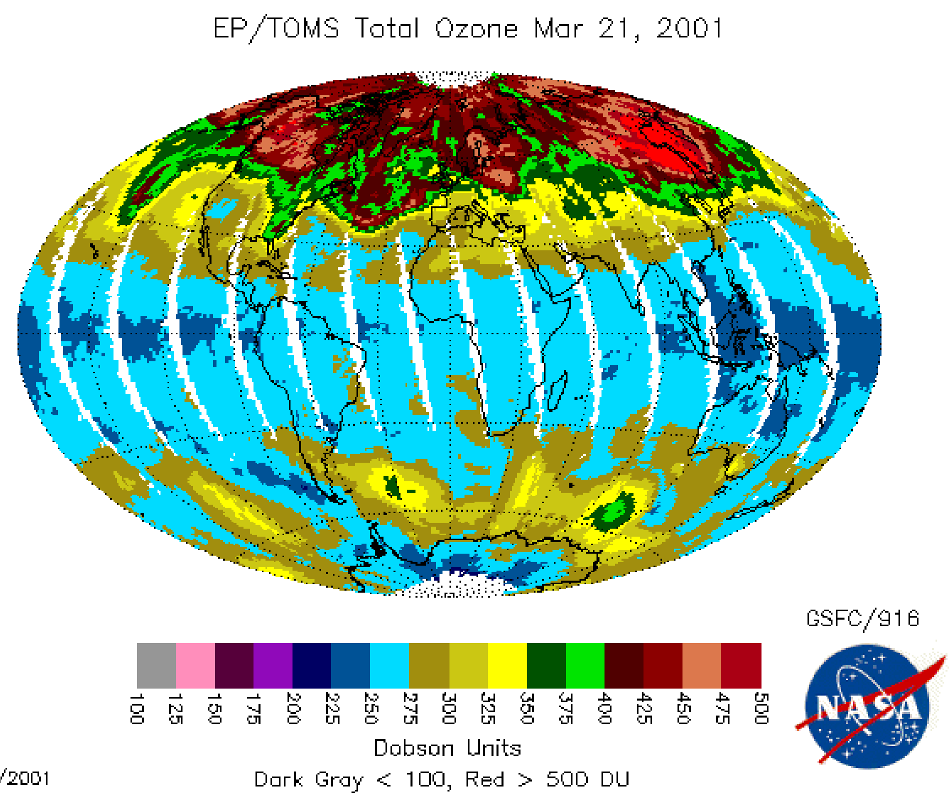
Data assimilation combines observed & model forecast data

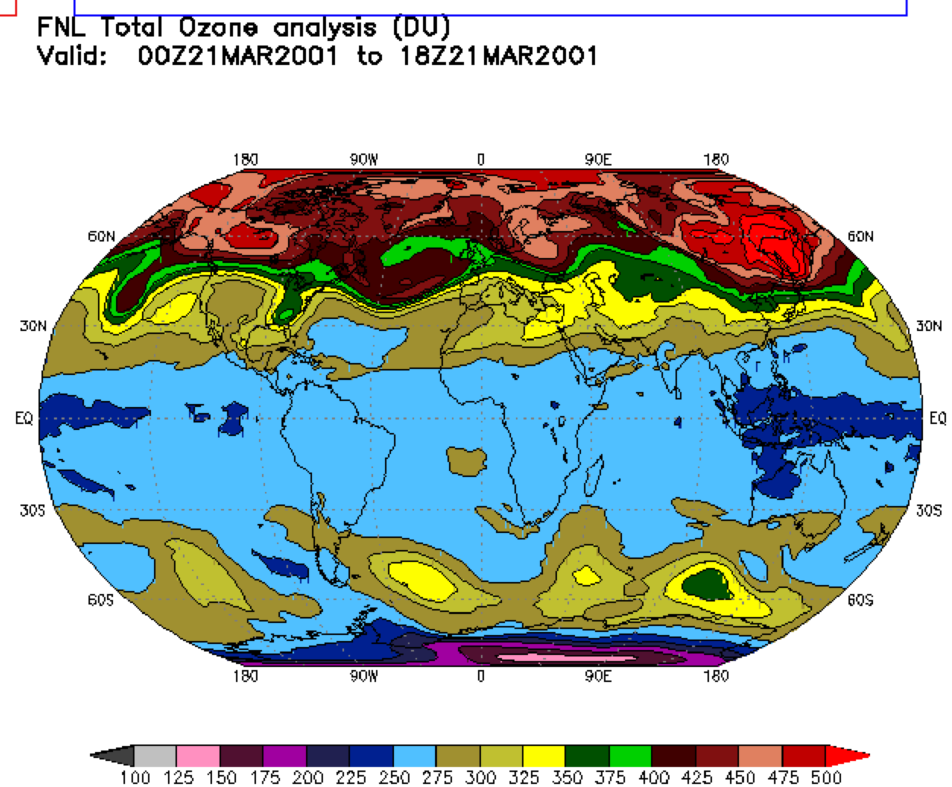
Raw data

- Intermittent
- Noisy
- Not suitable for numerical model

Assimilated data:

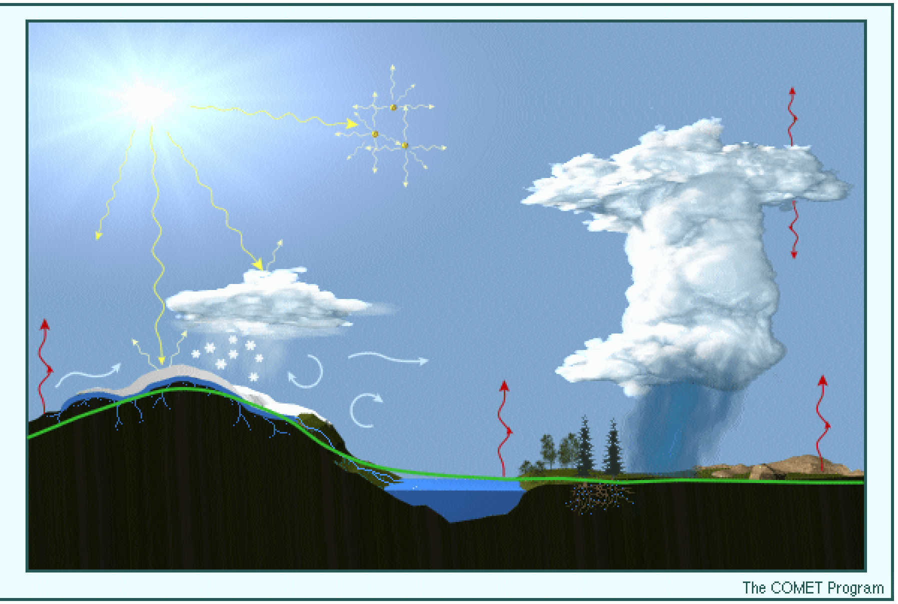
- Continuous
- Smooth
- Provides model initial state





HOW CURRENT STATE GETS PROJECTED INTO FUTURE?

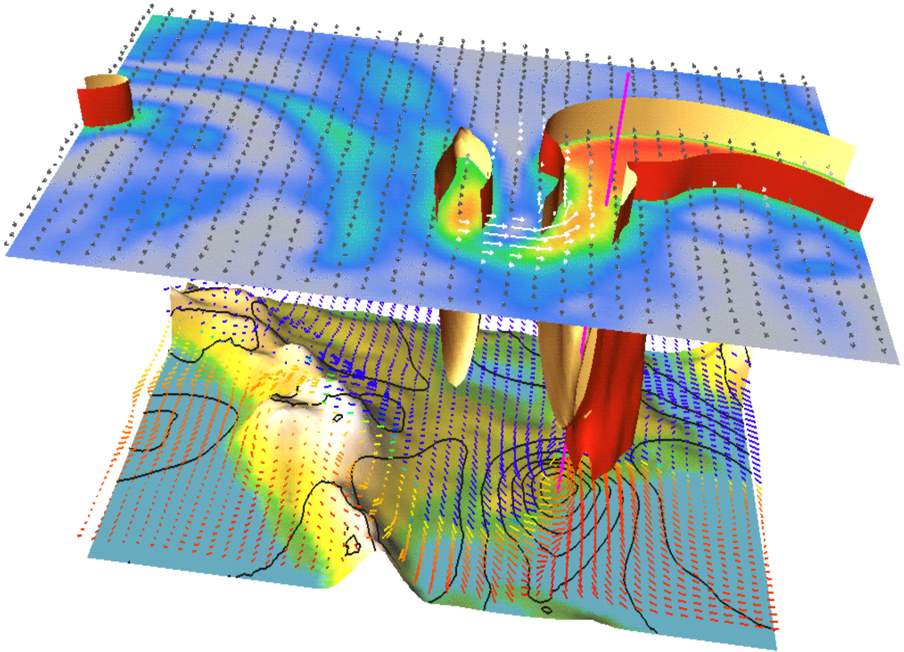
NUMERICAL WEATHER PREDICTION



Use Newton's laws of physics, plus thermodynamics

Synoptic forecasting of past

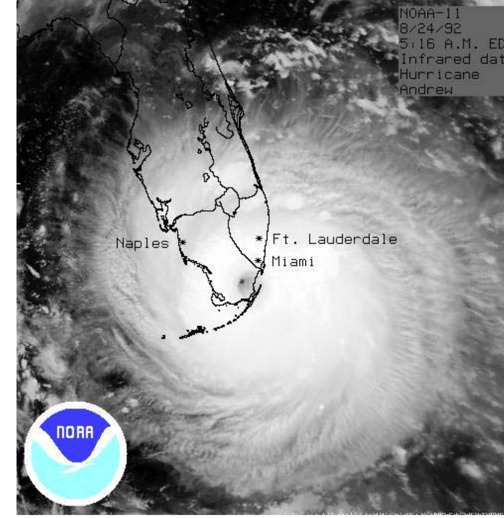
Numerical model calculations on 3-dimensional grids

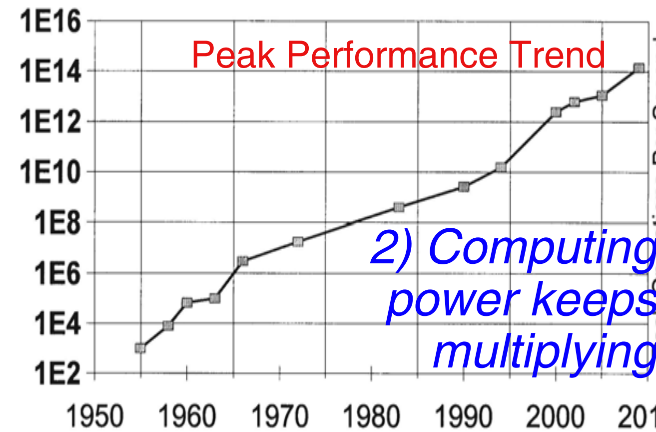


STATUS OF WEATHER FORECASTING

5) Trust of society earned

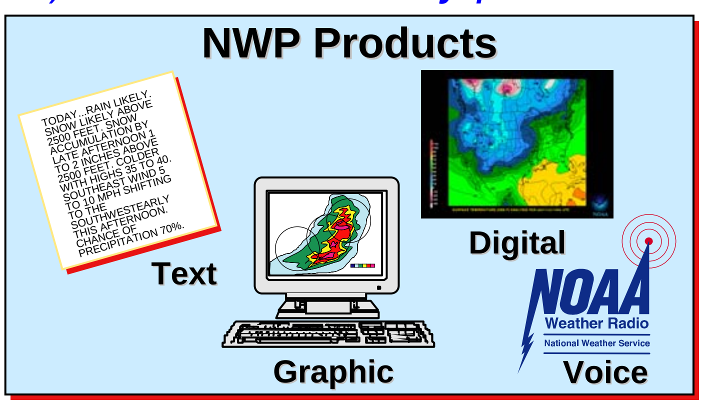
1) Observing techniques improve



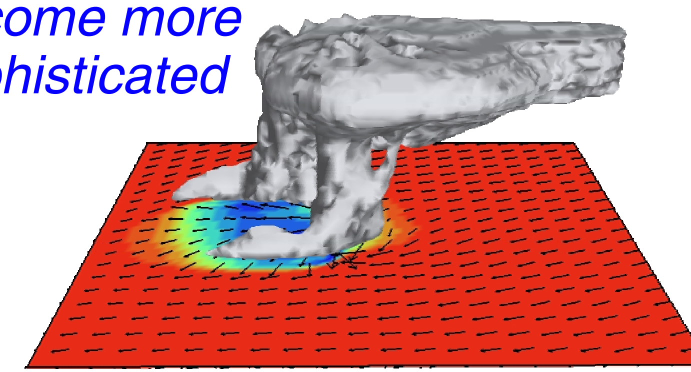


2) Computing power keeps multiplying

4) More user friendly products



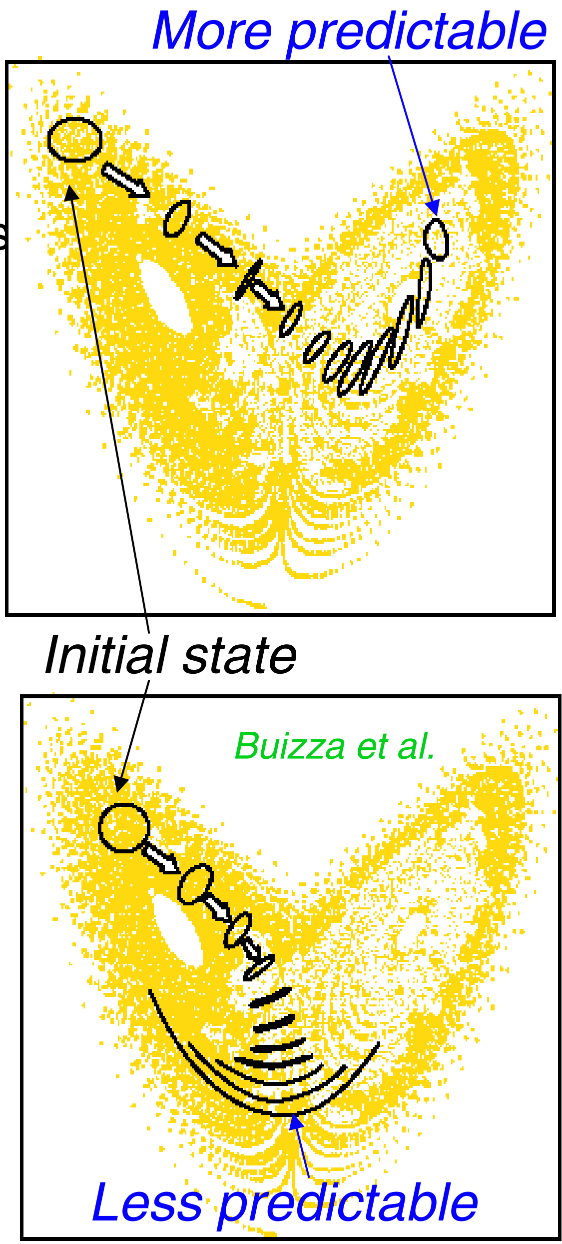
3) Numerical models become more sophisticated



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

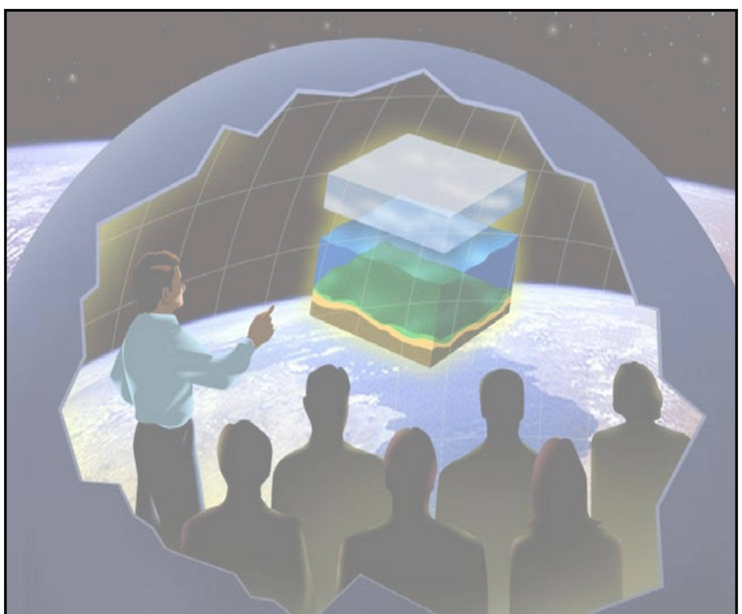
LIMITS REMAIN - NEED PROBABILISTIC APPROACH

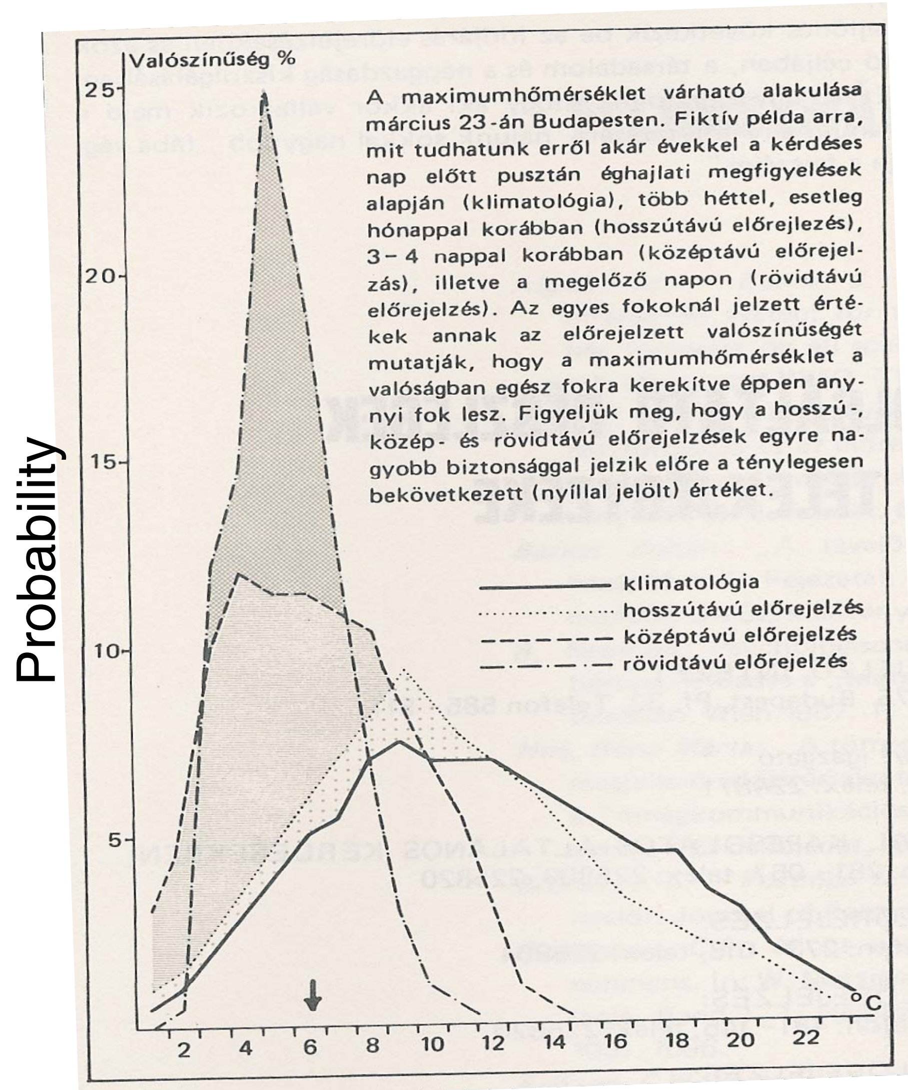
HOW TO DEAL WITH FORECAST UNCERTAINTY?

- 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**

How forecast uncertainty can be communicated?

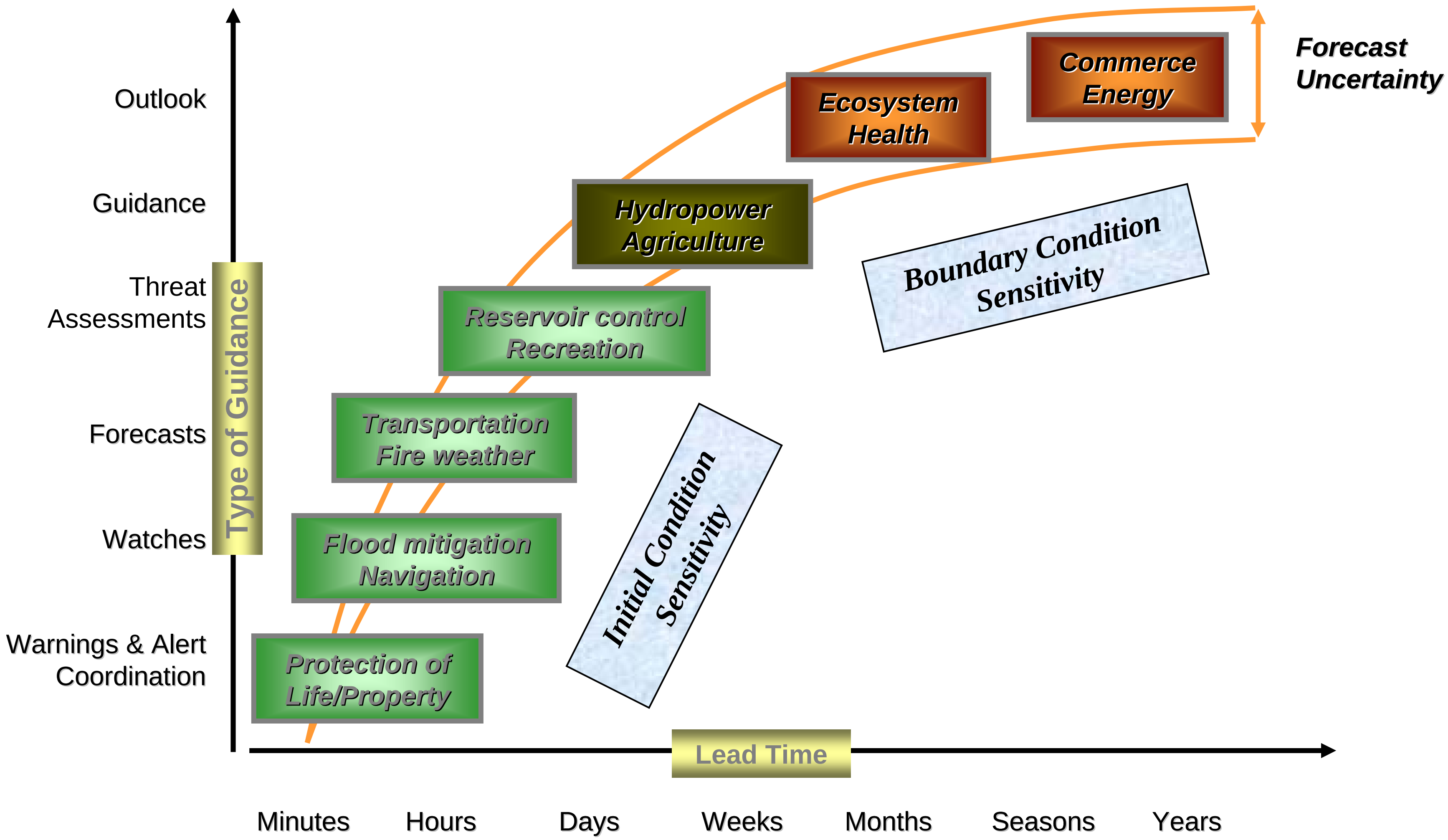
Do users need to know about uncertainty in forecasts?





THE PROBABILISTIC APPROACH

SOCIO-ECONOMIC BENEFITS OF SEAMLESS WEATHER/CLIMATE FORECAST SUITE



THE MAKINGS OF A WEATHER FORECAST – *EVER IMPROVING, BUT ALWAYS IMPERFECT*

- 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"*

REPRESENT FORECAST UNCERTAINTY – PROBABILISTIC FORMAT