

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)

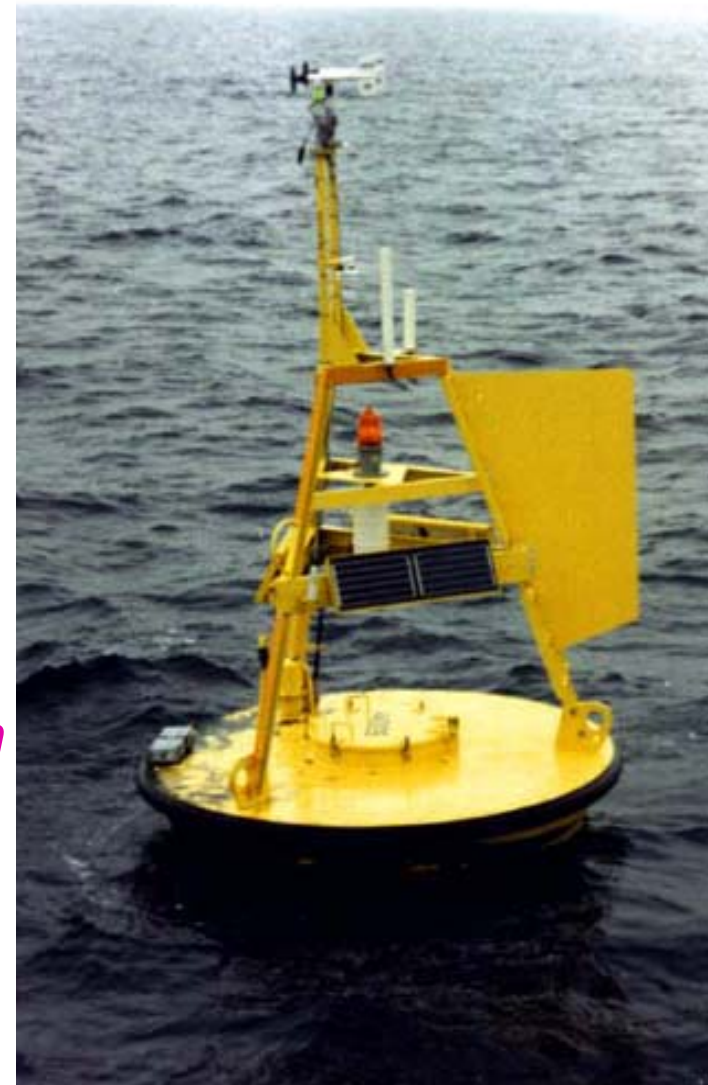


Land-based radar



*Great advances in
Remote sensing*

Ocean buoy
(In situ)



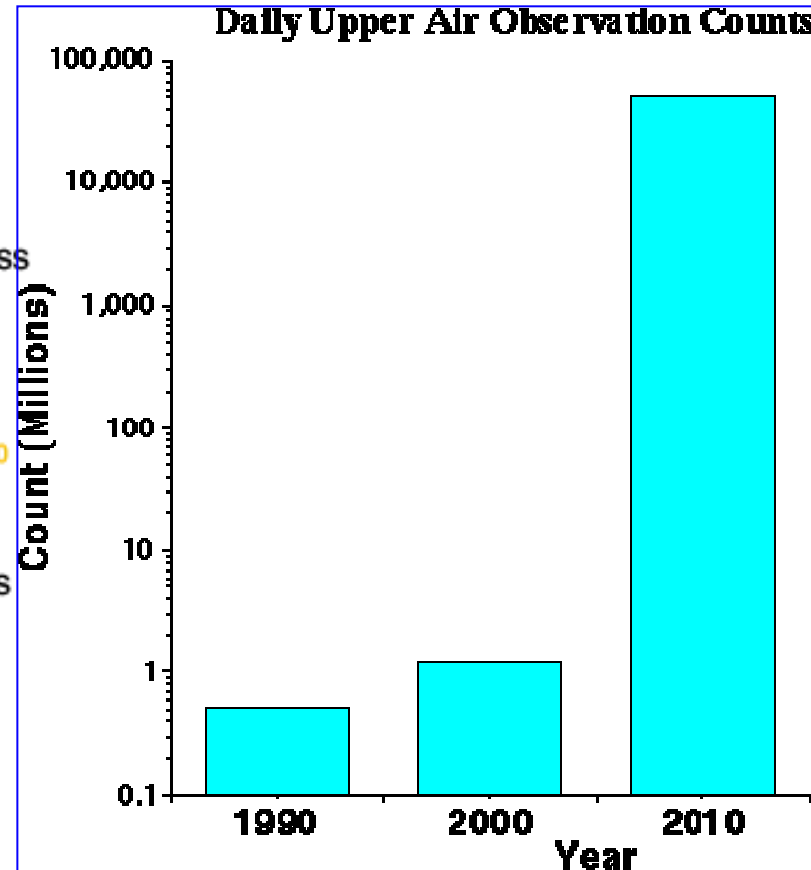
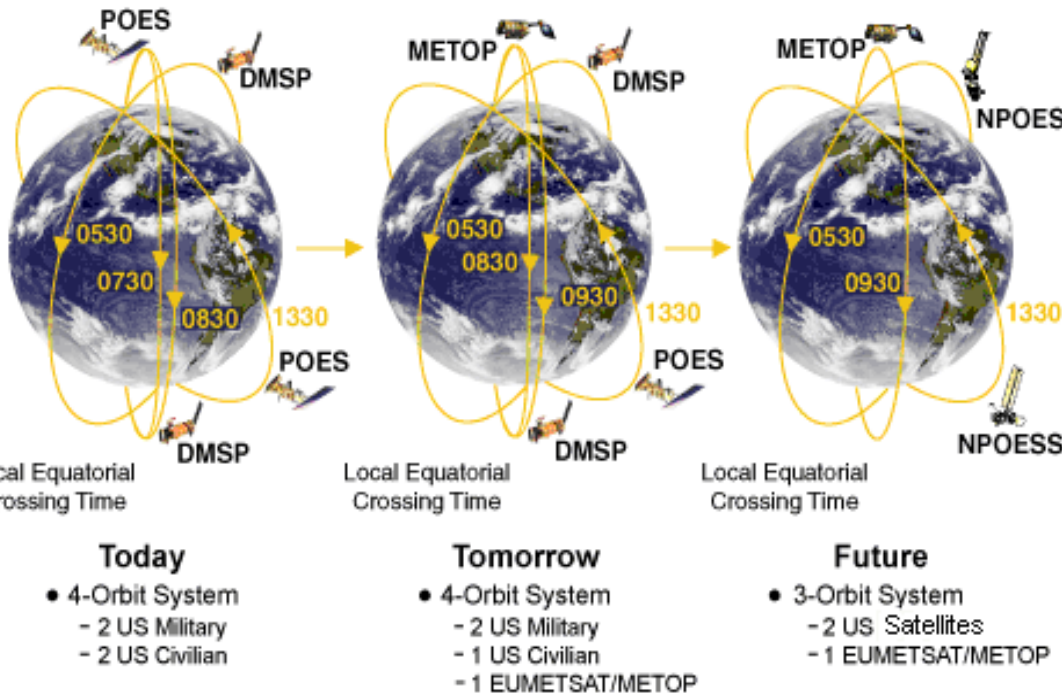
OBSERVING THE CURRENT STATE – SPACE-BASED SYSTEMS

Enormous technological advances
New observing platforms
New observing instruments

Vast increase in number
of observations

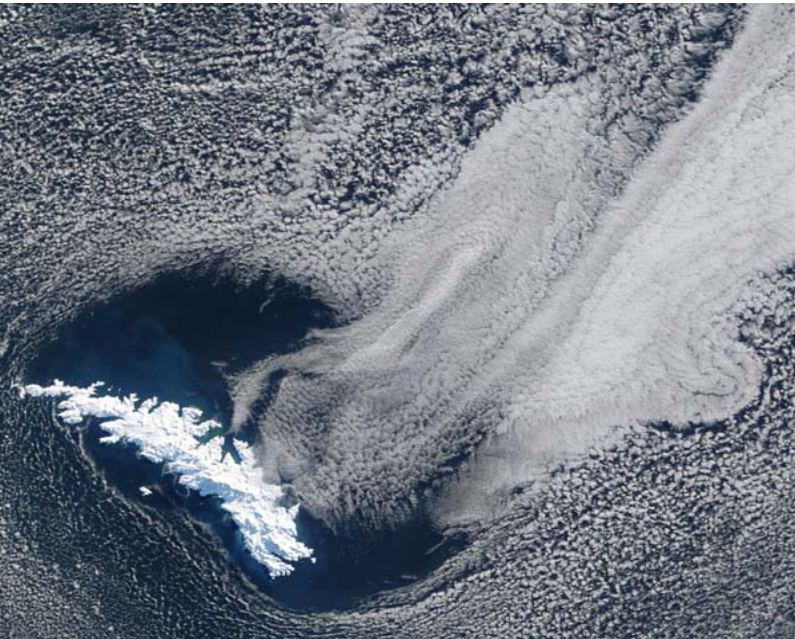
Evolution

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



OBSERVING THE CURRENT STATE –

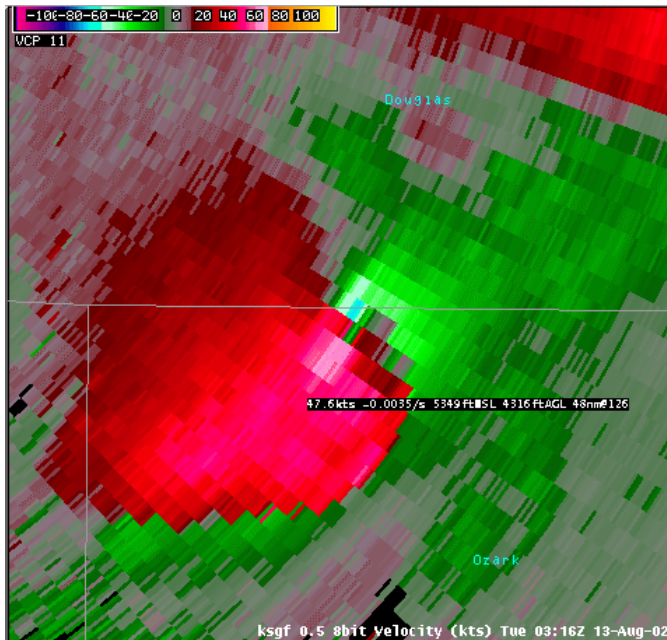
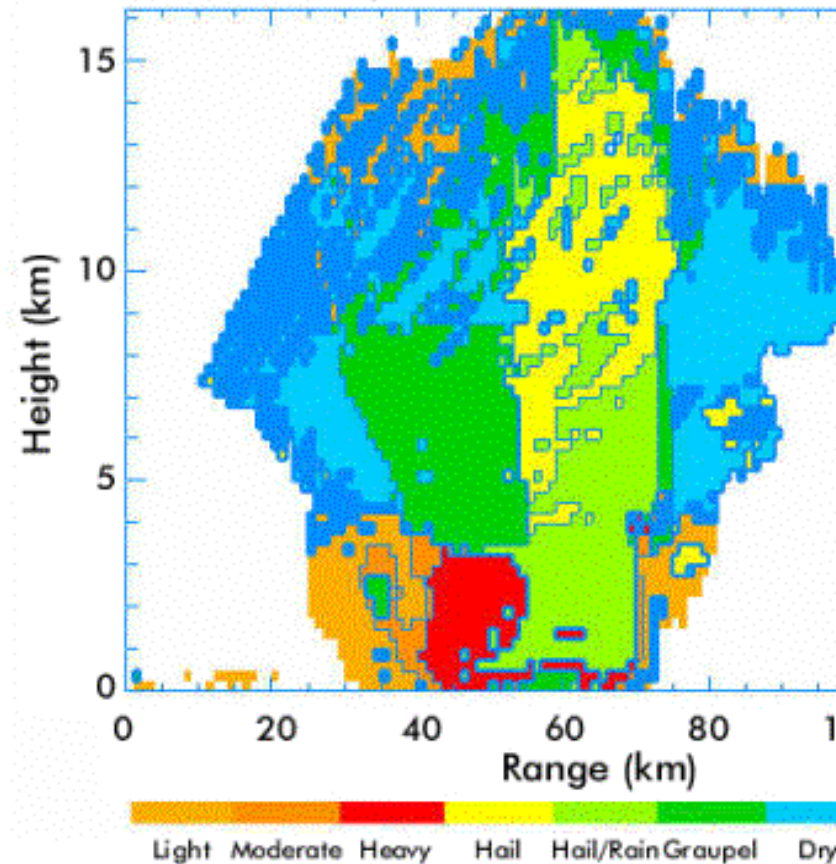
REMOTELY SENSED “IMAGES”, INSTEAD OF “DATA POINTS”



Satellite
imagery

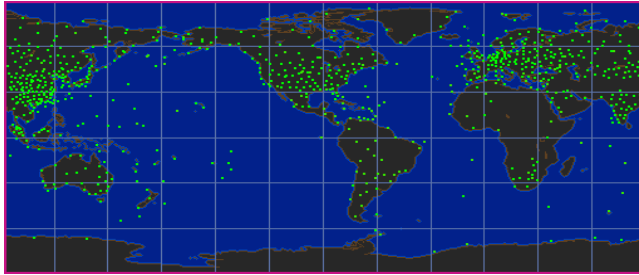
Precipitation type
(Radar derived)

Hydrometeor Identification

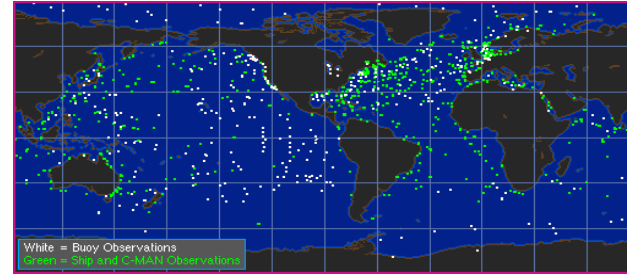


Wind speed
(Radar)

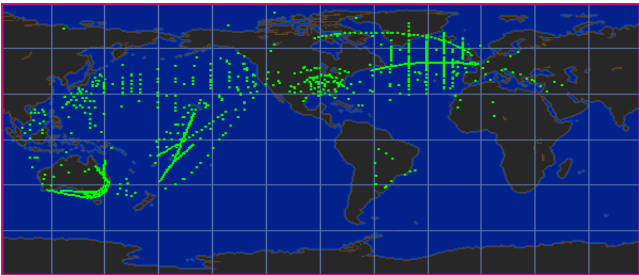
Global Observations 12 UTC 6 hour window



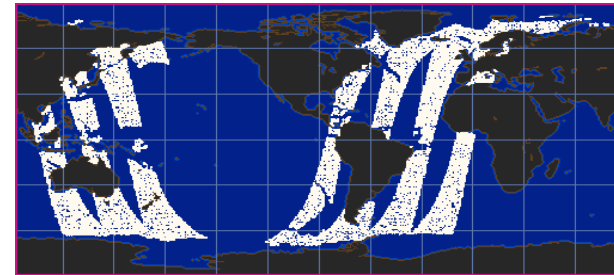
Global Rawinsondes



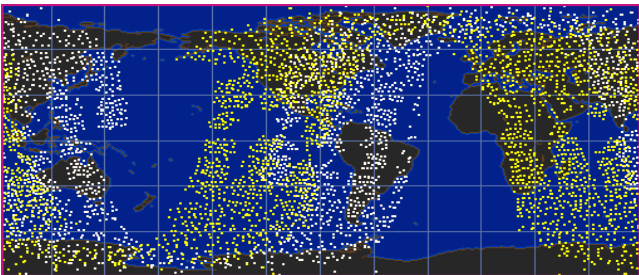
Marine Obs -- 12 Hour Total



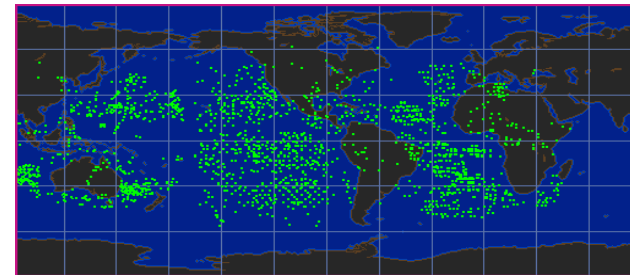
Aircraft Wind/Temp Reports



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

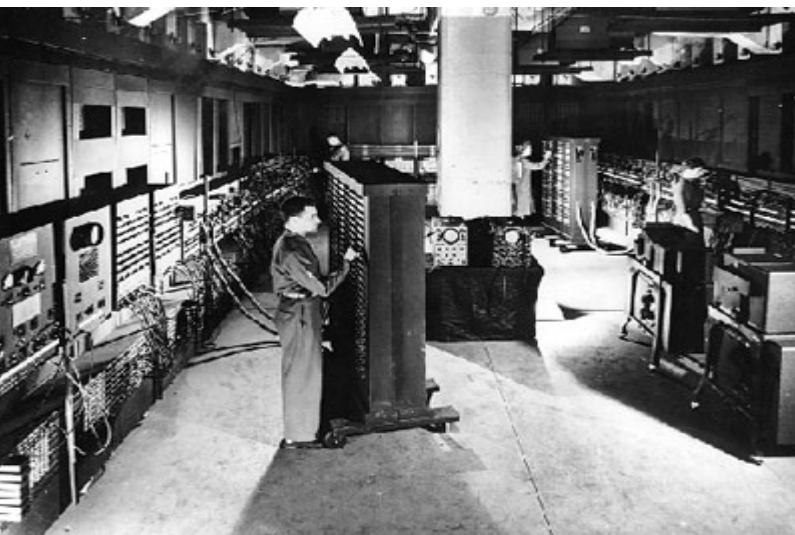
ENORMOUS TECHNOLOGICAL EVOLUTION



“Weather factory” of the past: Manual analysis

Computing machines (1950s)

Supercomputers



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

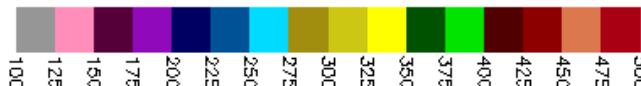
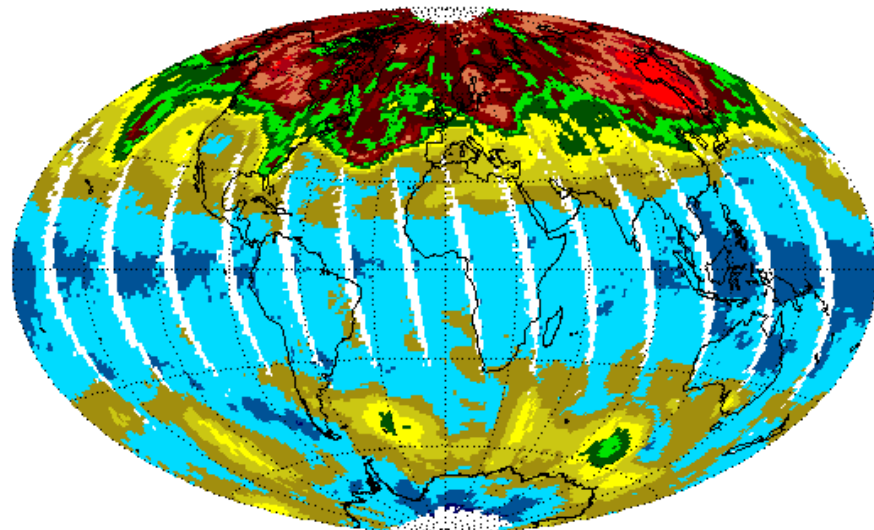
Raw data

- Intermittent
- Noisy
- Not suitable for numerical model

Assimilated data:

- Continuous
- Smooth
- Provides model initial state

EP/TOMS Total Ozone Mar 21, 2001

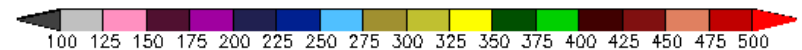
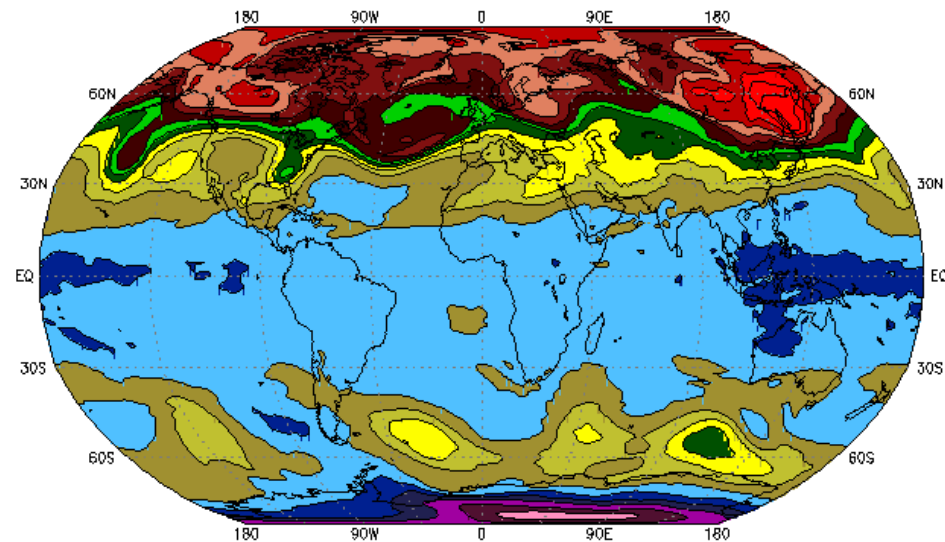


Dobson Units
Dark Gray < 100, Red > 500 DU

GSFC/916

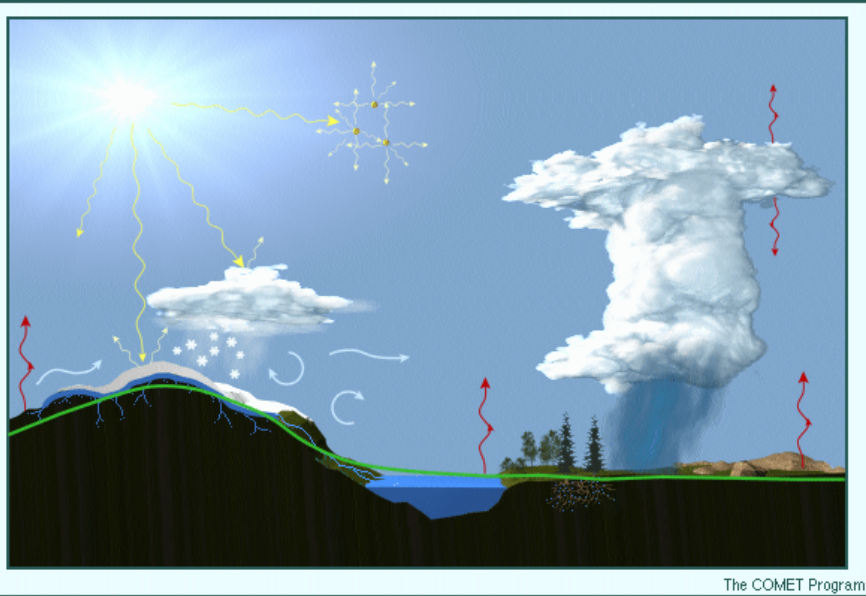


FNL Total Ozone analysis (DU)
Valid: 00Z21MAR2001 to 18Z21MAR2001



HOW CURRENT STATE GETS PROJECTED INTO FUTURE?

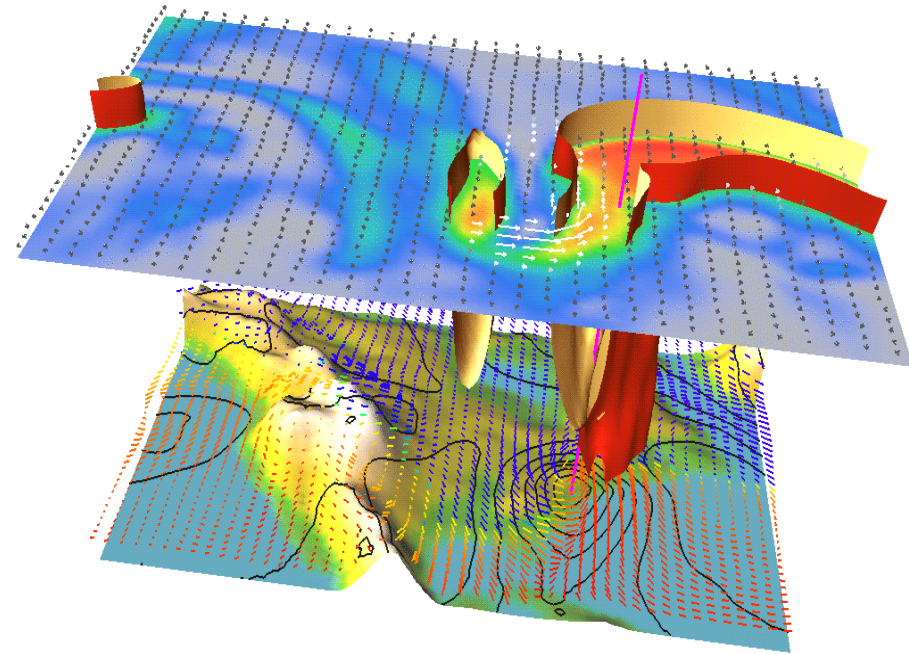
NUMERICAL WEATHER PREDICTION



*Use Newton's laws of physics,
plus thermodynamics*

*Numerical model calculations
on 3-dimensional grids*

Synoptic forecasting of past



STATUS OF WEATHER FORECASTING

5) Trust of society earned



4) More user friendly products

NWP Products

TODAY... RAIN LIKELY. SNOW LIKELY ABOVE 2500 FEET. SNOW BY ACCUMULATION BY LATE AFTERNOON TO 1 INCHES. SOLDER TO 2700 FEET. COLDER TO 40. WITH HIGHS 35 TO 40. SOUTHEAST WIND 5 TO 10 MPH SHIFTING TO THE WESTEARLY SOUTH AFTERNON. CHANCE OF PRECIPITATION 70%.

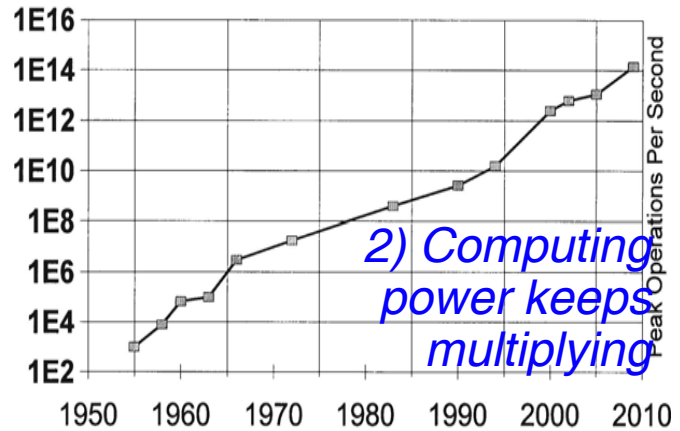
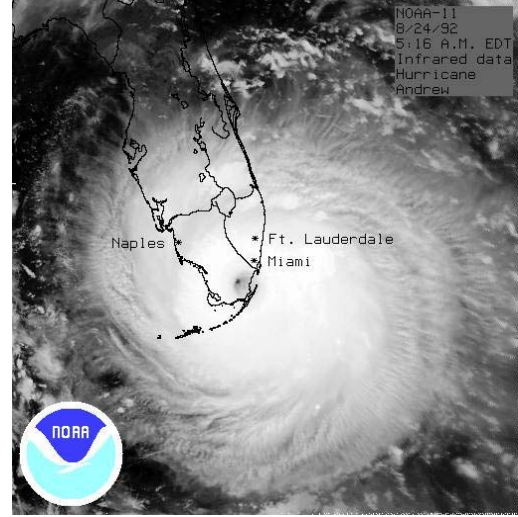
Text

Graphic

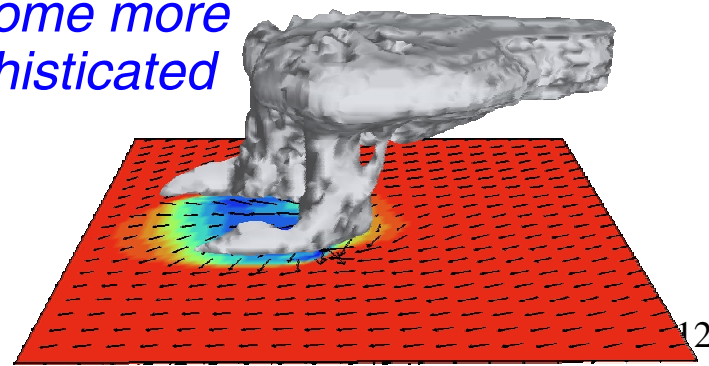
Digital

Voice

1) Observing techniques improve



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

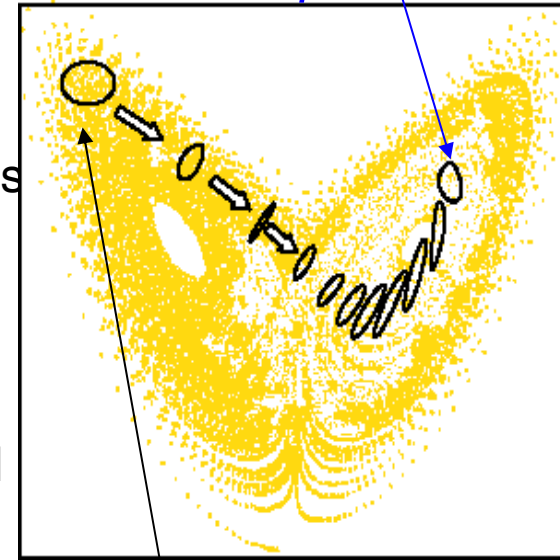
Numerical model is imperfect

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

Atmosphere is chaotic

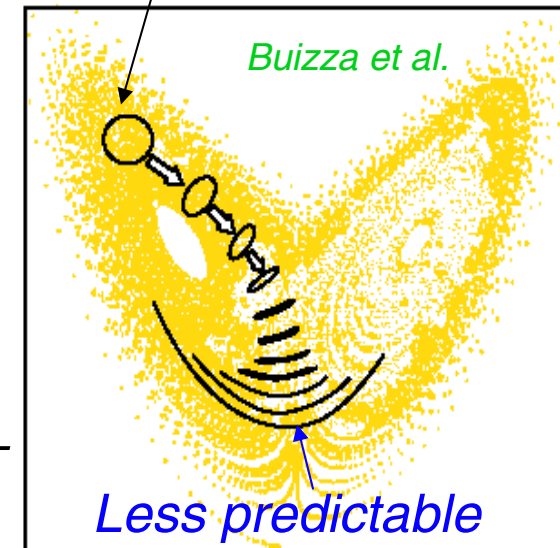
- Small errors amplify rapidly
 - Forecasts lose skill with increasing lead time
 - Loss of skill is case specific

More predictable



Initial state

Buizza et al.



Less predictable

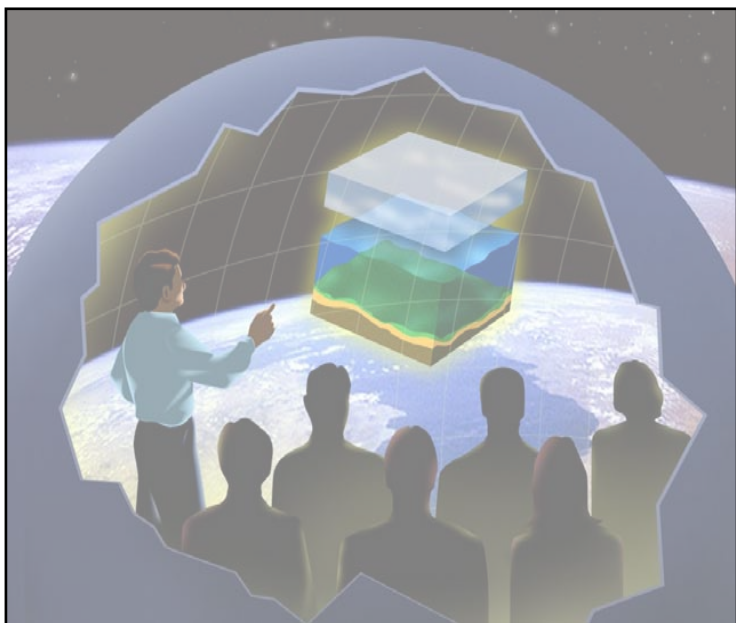
*THOUGH SKILL IN FORECASTS EVER INCREASES –
LIMITS PUSHED FURTHER OUT IN TIME*

LIMITS REMAIN - NEED PROBABILISTIC APPROACH

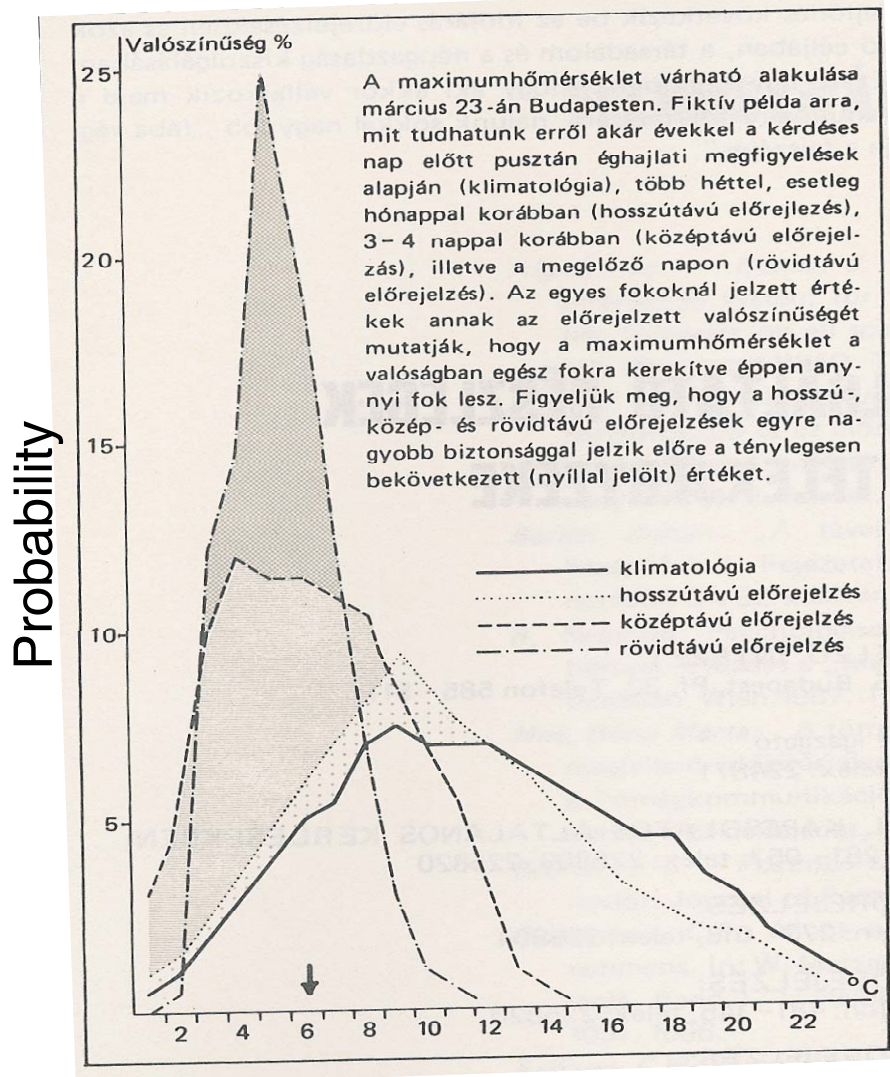
HOW TO DEAL WITH FORECAST UNCERTAINTY?

- 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?

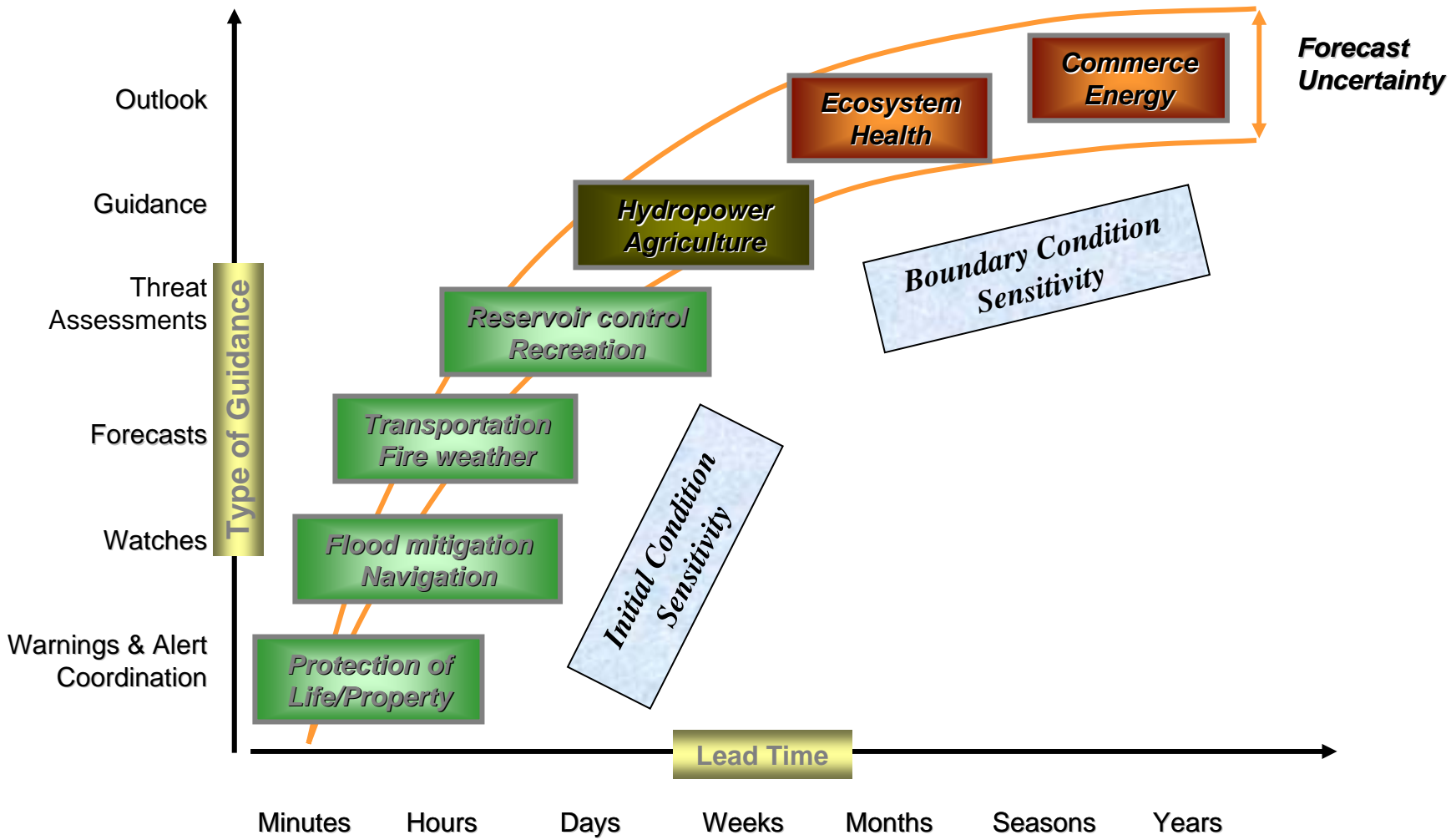


How forecast uncertainty can be communicated?



THE PROBABILISTIC APPROACH

SOCIO-ECONOMIC BENEFITS OF SEAMLESS WEATHER/CLIMATE FORECAST SUITE



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

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REPRESENT FORECAST UNCERTAINTY – PROBABILISTIC FORMAT