1. Analysis and Reanalysis Products

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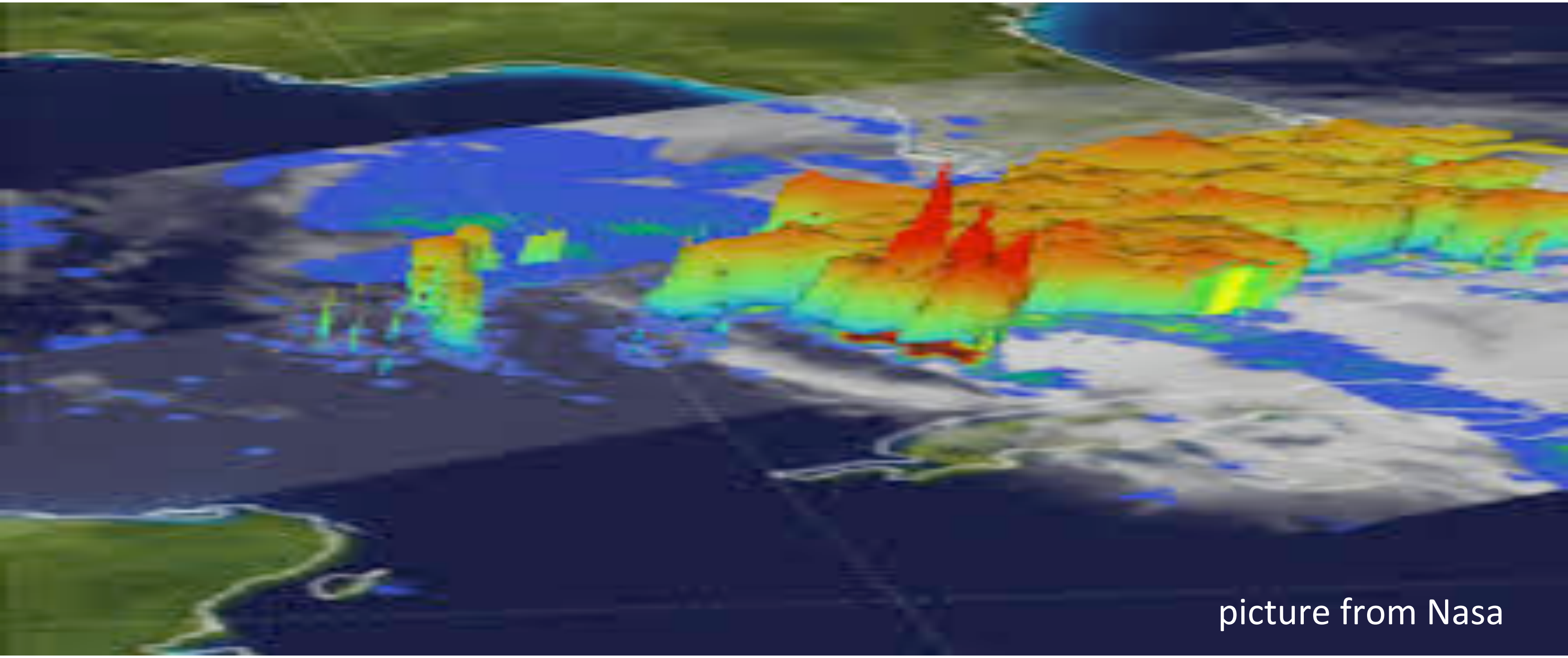

Climate impacts on society

- Climate impacts are multifaceted and can occur over many timescales
  - Severe weather: floods, droughts
  - Impacts on health:
    - Vector borne diseases
    - Heat stress
    - parasites
    - Food security
  - Infrastructure, economy, sea level rise...
- But how can we get climate data for the present day?

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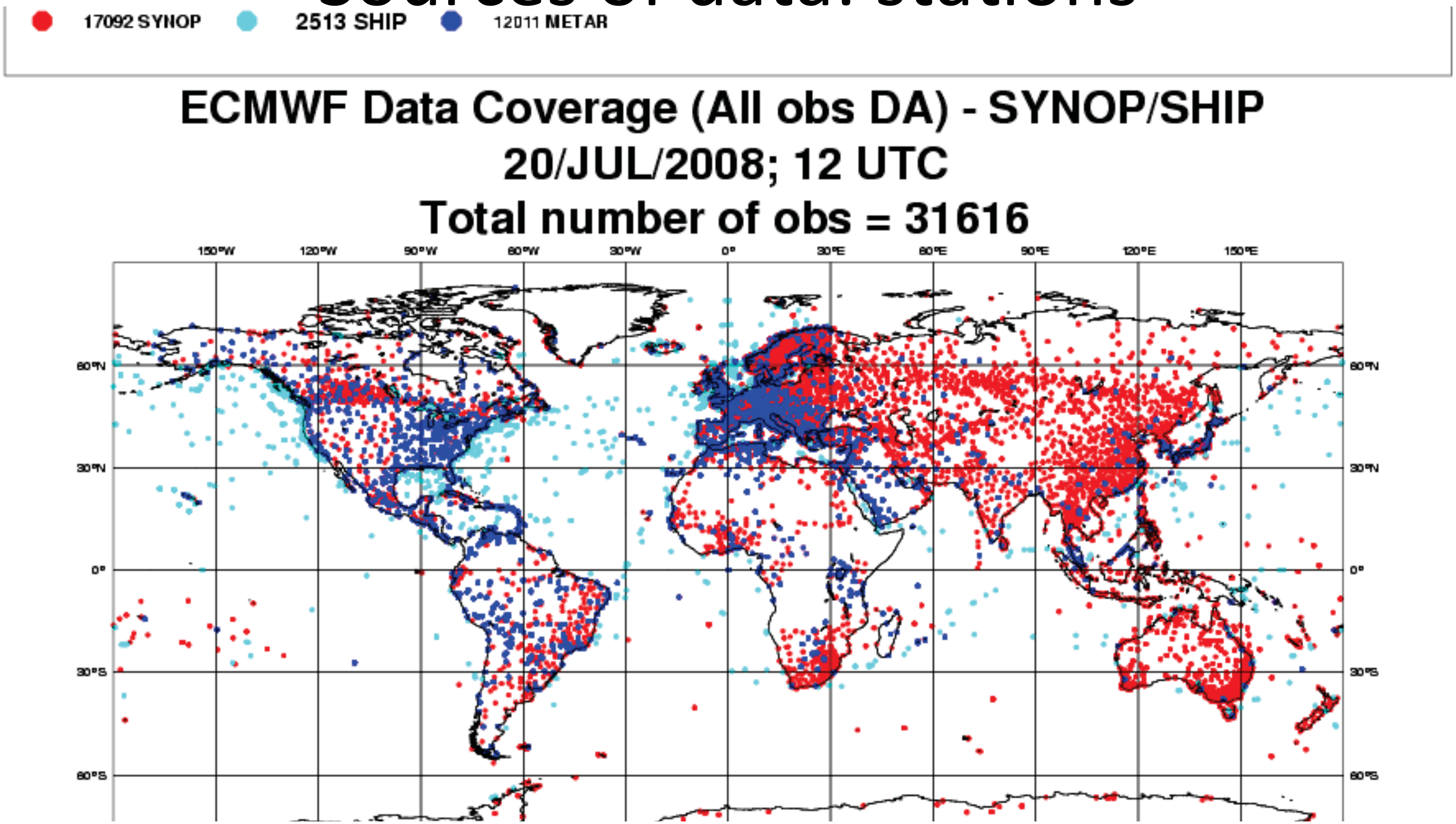
Sources of data: stations



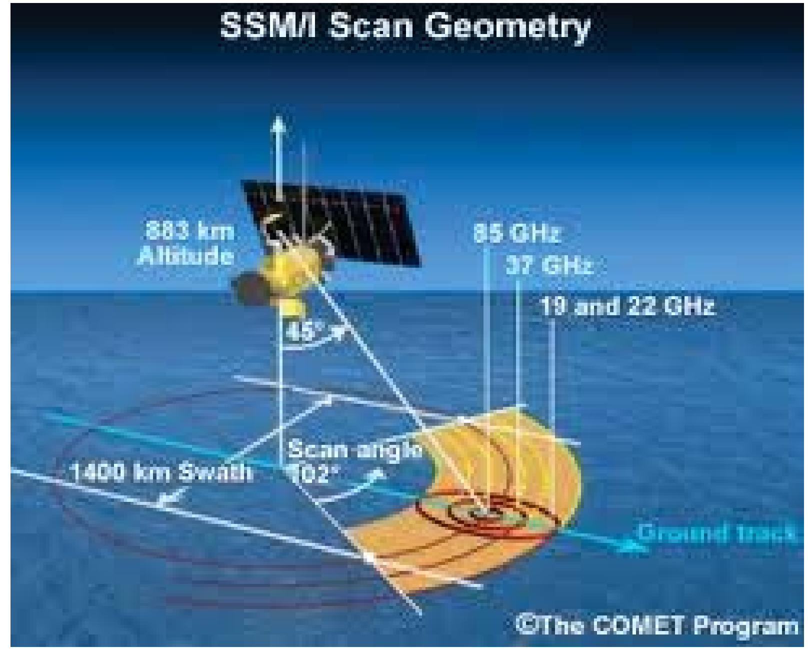
Station Data: Advantages and Disadvantages

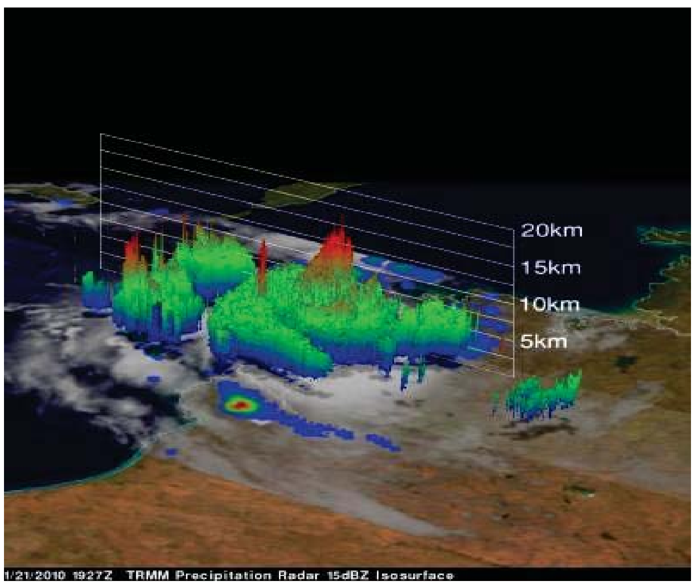
- Full array of variables
- Locally representative

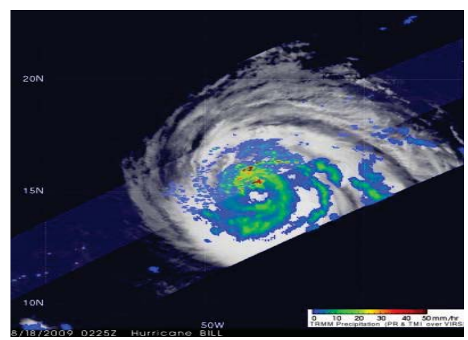
- Not often available locally
- Potentially data gaps, handling of bad data
- Representativeness over complex terrain

Satellite Data

- Surface Temperature
- Precipitation
- Humidity
- Winds

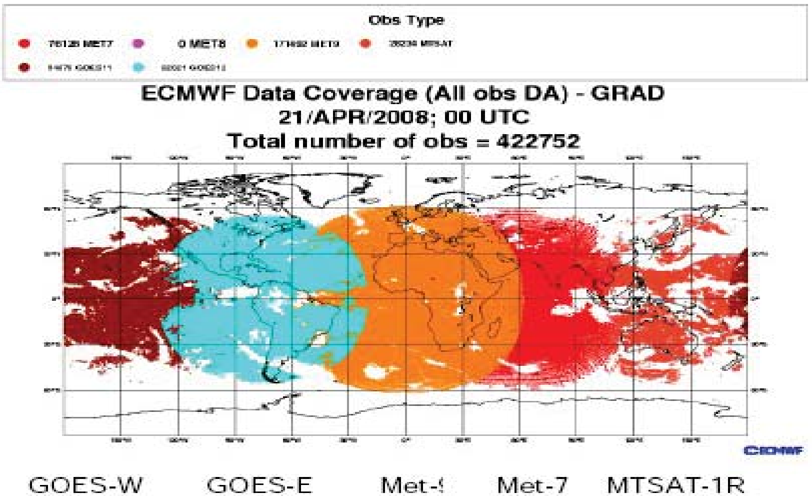




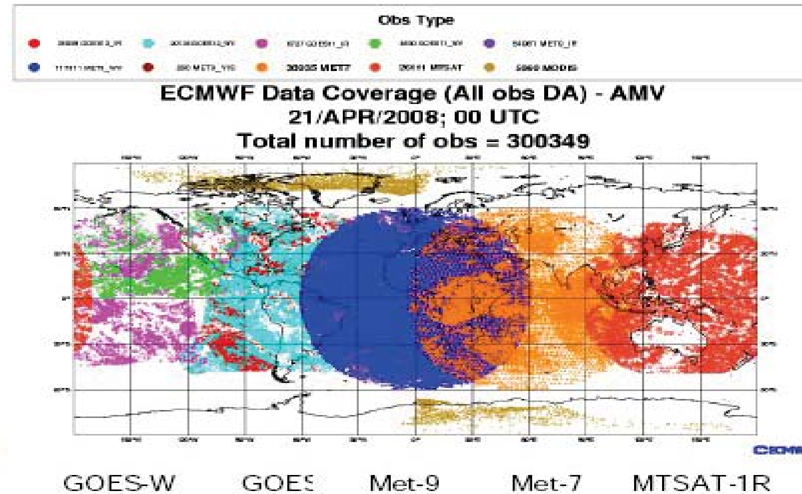


For Satellite – coverage can be less of an issue (polar or geostationary – resolution, swathe, return times)

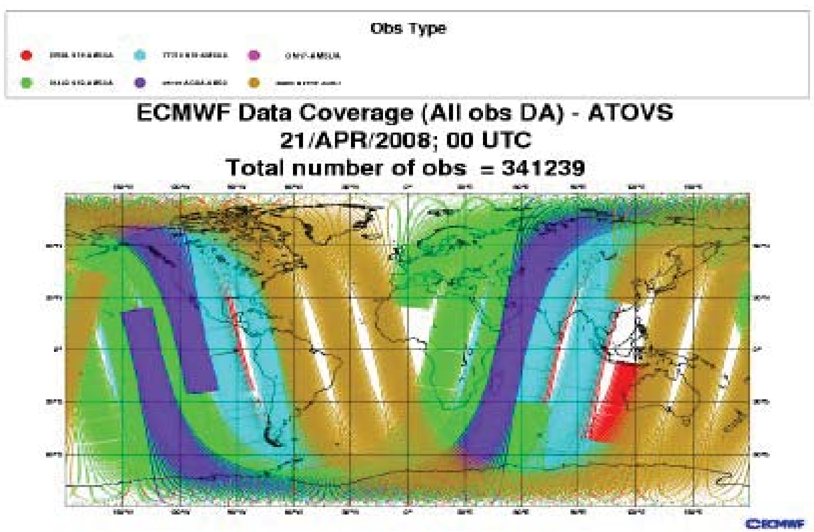
Clear-sky radiances



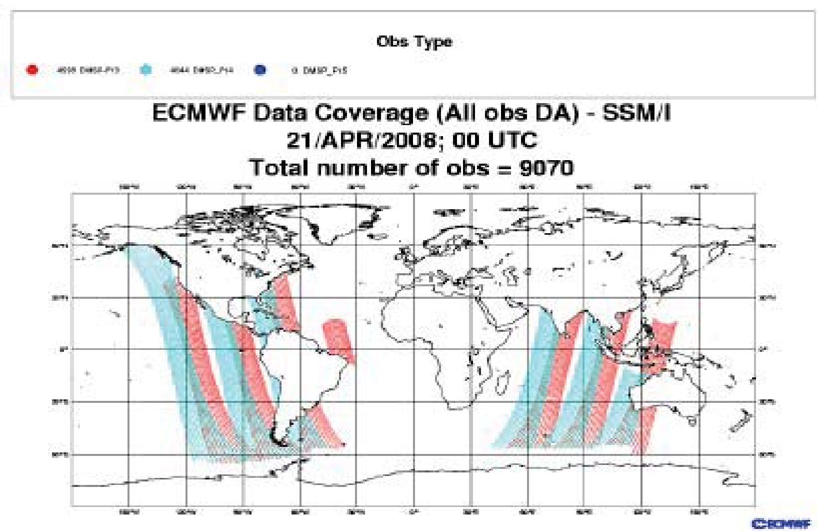
Atmospheric Motion Vectors



AMSU-A



SSM/I



Satellite – advantages and disadvantages

- Good spatial and/or temporal coverage (depending on swathe, scan, orbit...)
- Only way to get regional information in conventional data-sparse regions

- Large uncertainties
- Temperature is skin temperature
- Problems for clouds, aerosols, insects etc
- Vertical resolution of atmospheric variables poor
- Problems in many retrievals mechanisms over land

Wide Choice of retrievals: e.g. Precipitation

- GPCP – 1995 daily (1 deg), 1979 monthly (2.5 deg) – not real-time. Mix of IR and raingauge
- CMAP – Similar to GPCP – monthly only at 2.5deg
- CMORPH – 2003-present, realtime. 30 mins. based on microwave channels, using IR to provide temporal resolution. 25/8km.
- FEWS – daily, only over Africa, using gauge if nearby, otherwise combination of IR/microwave channels, 11km resolution. Realtime, 2000-present.
- TRMM – 25km resolution, 1998-present, 3 hourly.
  - 2A25 – precip radar product – not gridded
  - 3B42 – merged, radar, IR and microwave using gauge calibration – realtime

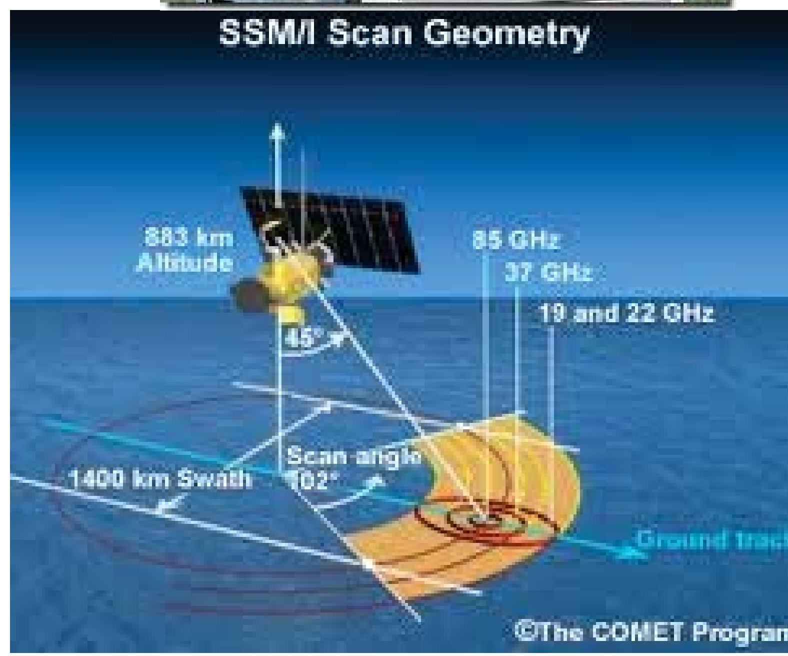
What to use?
What is best?

But some variables in contrast are difficult to get directly from Satellite

- Surface temperature: reliable over oceans using microwave. Some products over land, but uncertainty is large and not available daily
- Winds: reasonable over oceans using scatterometer data, surface winds over lands not possible. Upper level winds from feature tracking (cloud, humidity) but uncertainties high.
- Humidity: near surface only indirectly.
- Take home message: most (near) surface variables **over land** very difficult to infer from remote sensing

Take home messages

- Station data are good where they exist, but they require careful treatment
- Satellite data useful for a regional view, but uncertainties are large, not all parameters are available, and the retrieval techniques are often obscure.



A supplement source of climate information: analysis and reanalysis

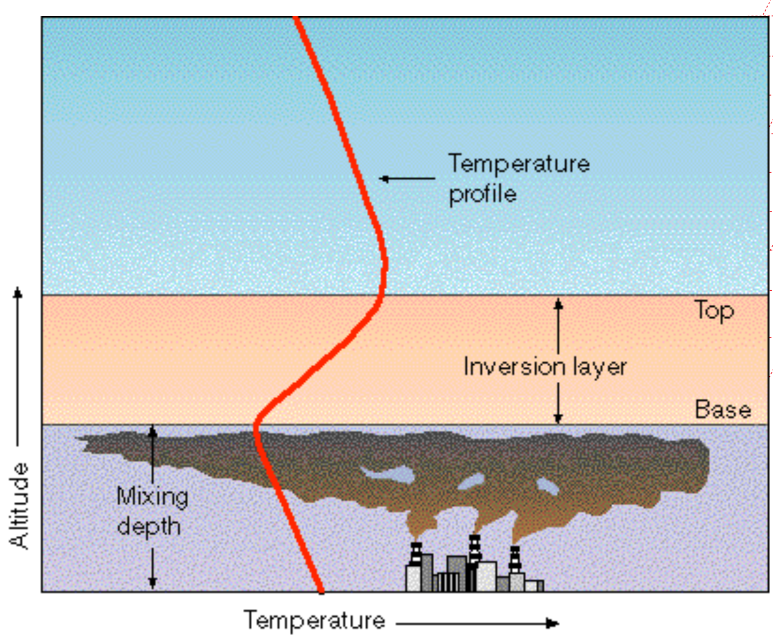
- To make forecasts of the future weather, knowledge of the present state is required
- This "picture" of the atmosphere needs to be "balanced" – Simple spatial and temporal interpolation of observations doesn't work
- Hence the development of analysis systems

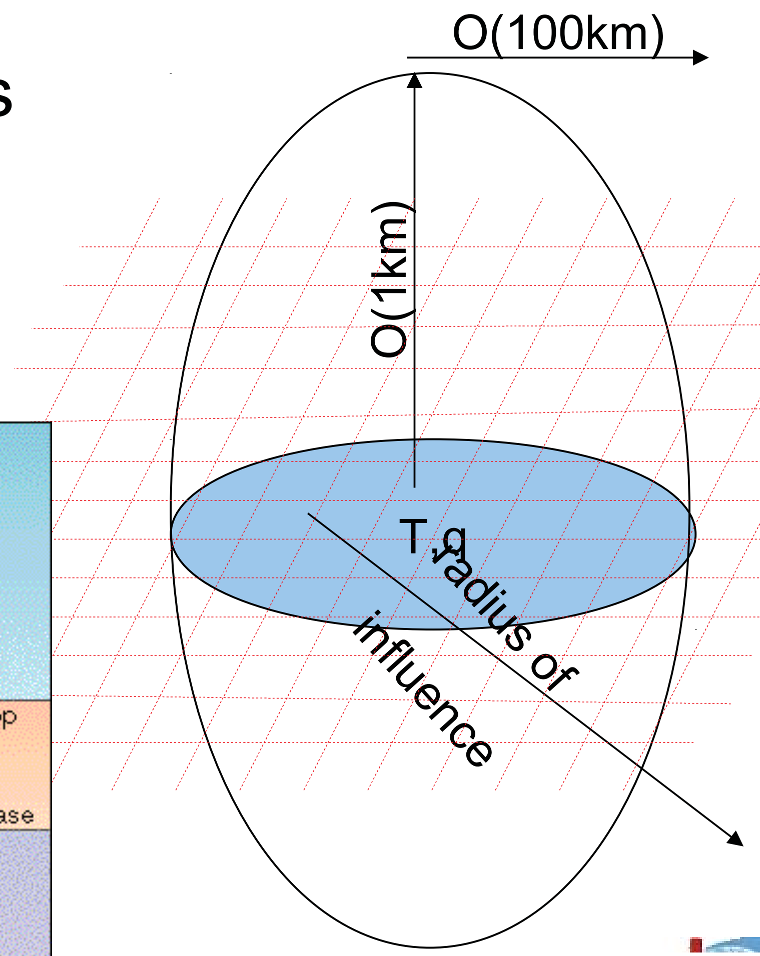
Aim of “Data Assimilation” System

- To take a wide variety of variables (not necessarily model variables)...
- ...from a wide variety of instruments...
- ...with vastly different measurement densities...
- ...taking care to reject bad measurements...
- ...and combine them into an assessment of the atmospheric state, that is near balance with the forecast model “climate”
- Sounds Easy?

Data assimilation

- Radius/distance of influence for each observation type needs to be defined
- Not obvious: e.g. Inversions, fronts etc.



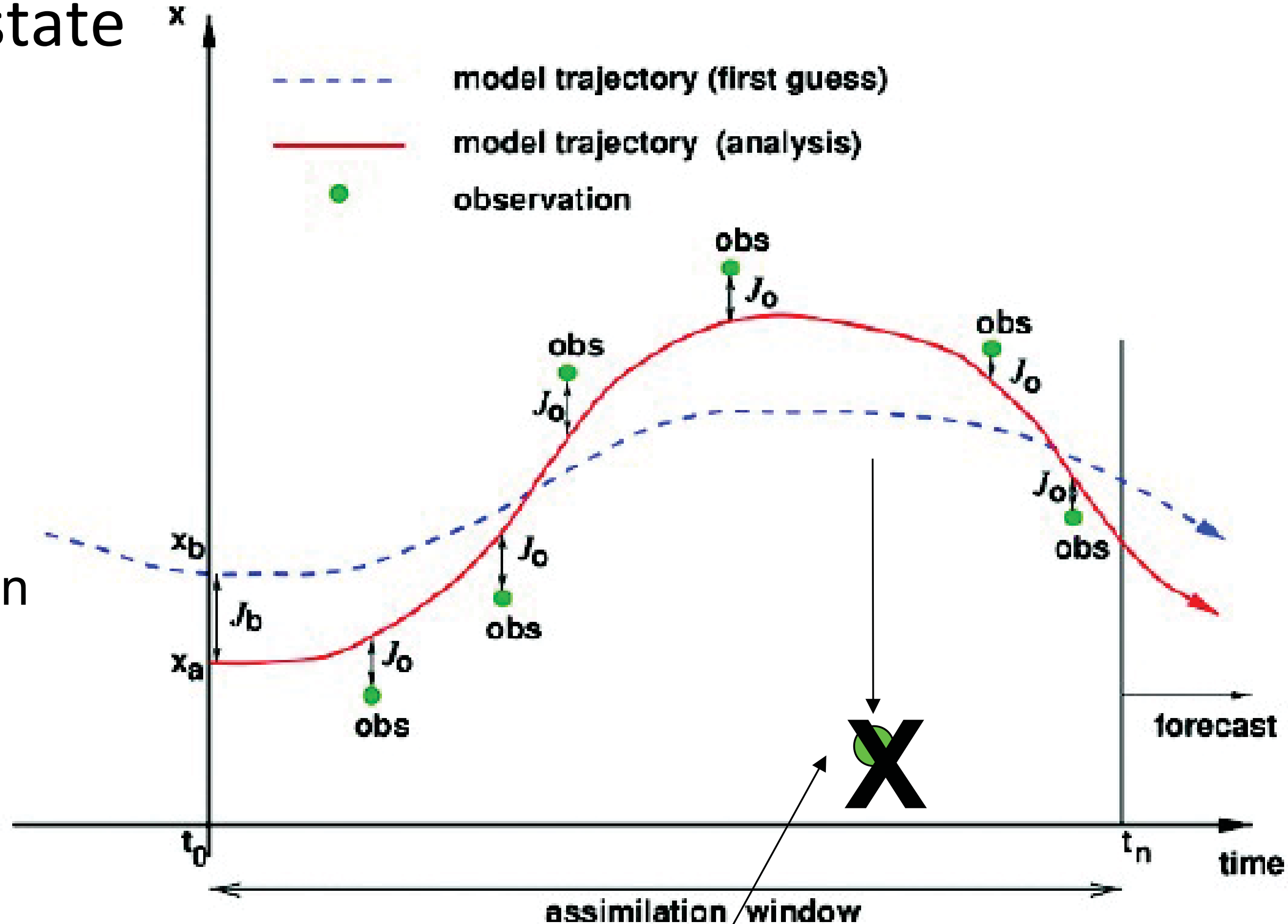


Use of a forecast model is required to obtain balanced state

from Marta Janiskova

4DVAR assimilation

Goal: define atmospheric state x(t0) such that the “distance” between the model trajectory and observations is minimum over a given time period

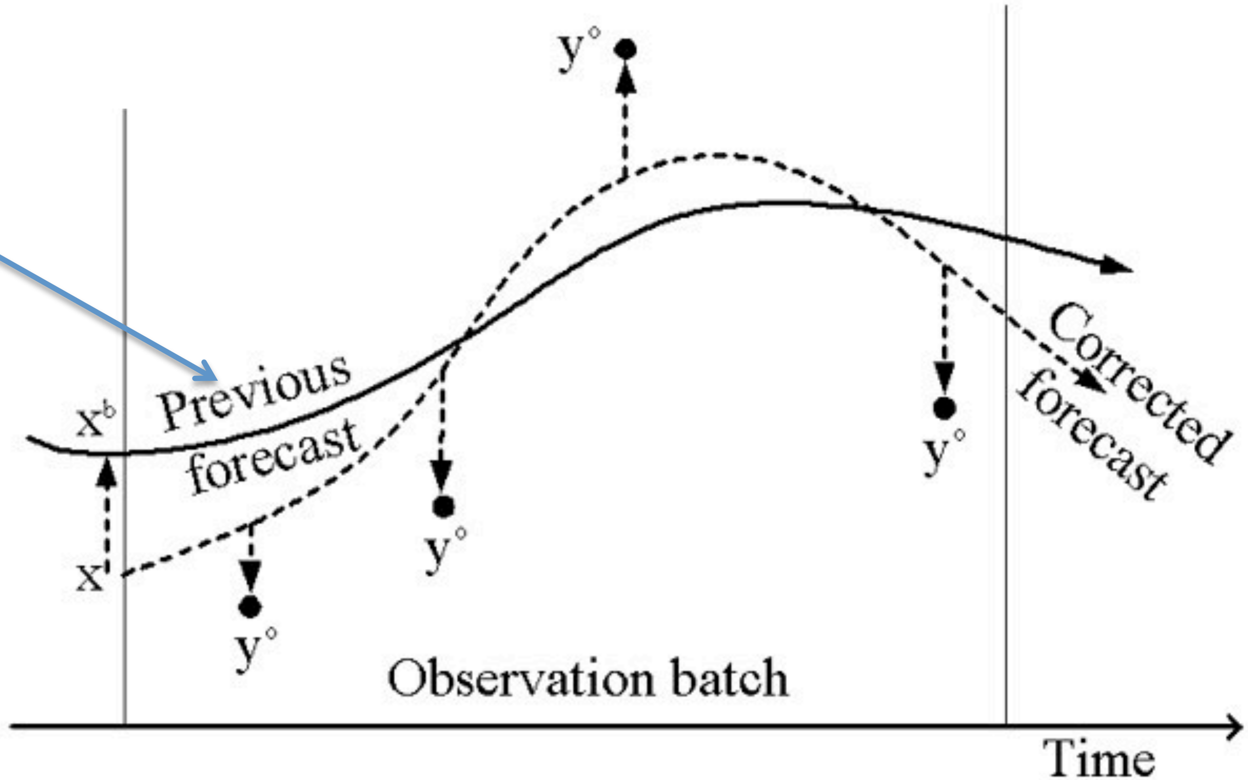


Note that the quality of the forecast model is important for a good analysis!

Observations “too far” from the background forecast are rejected as unreliable!!!

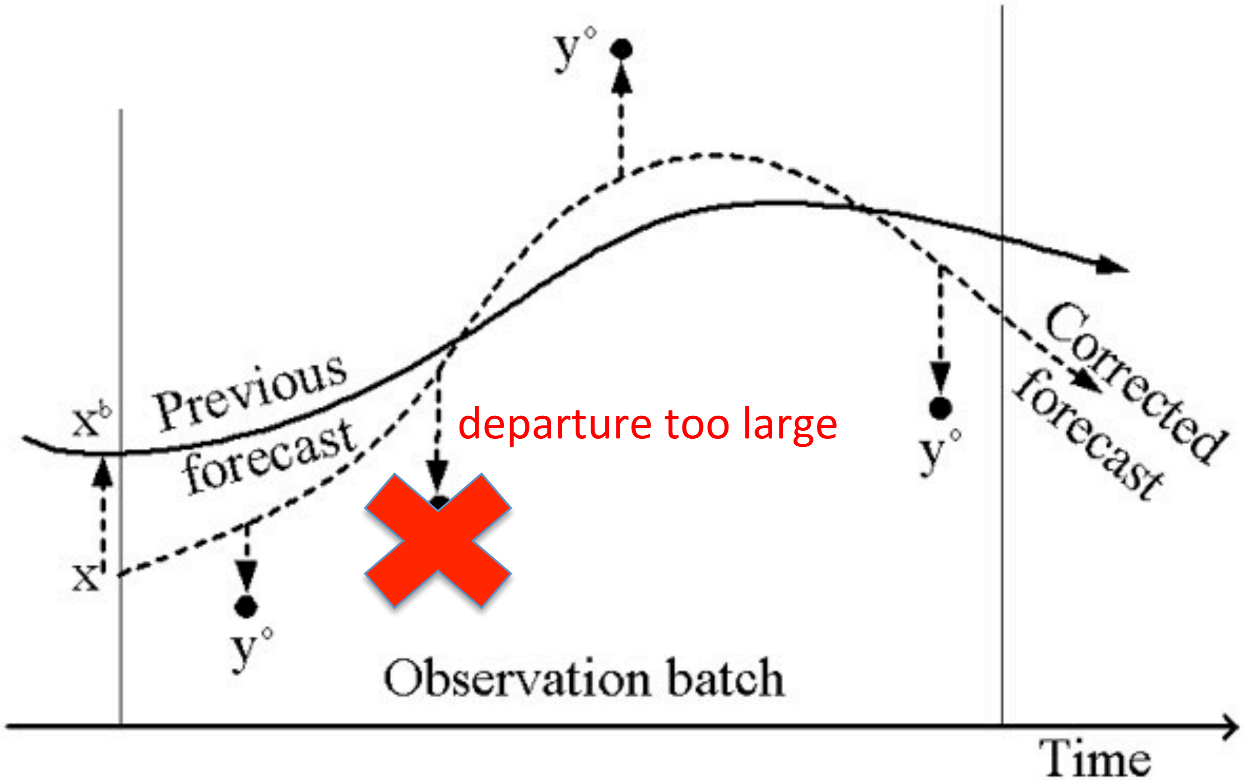
recipe in a nutshell

1. Make a short forecast from previous "analysis", call the "control"



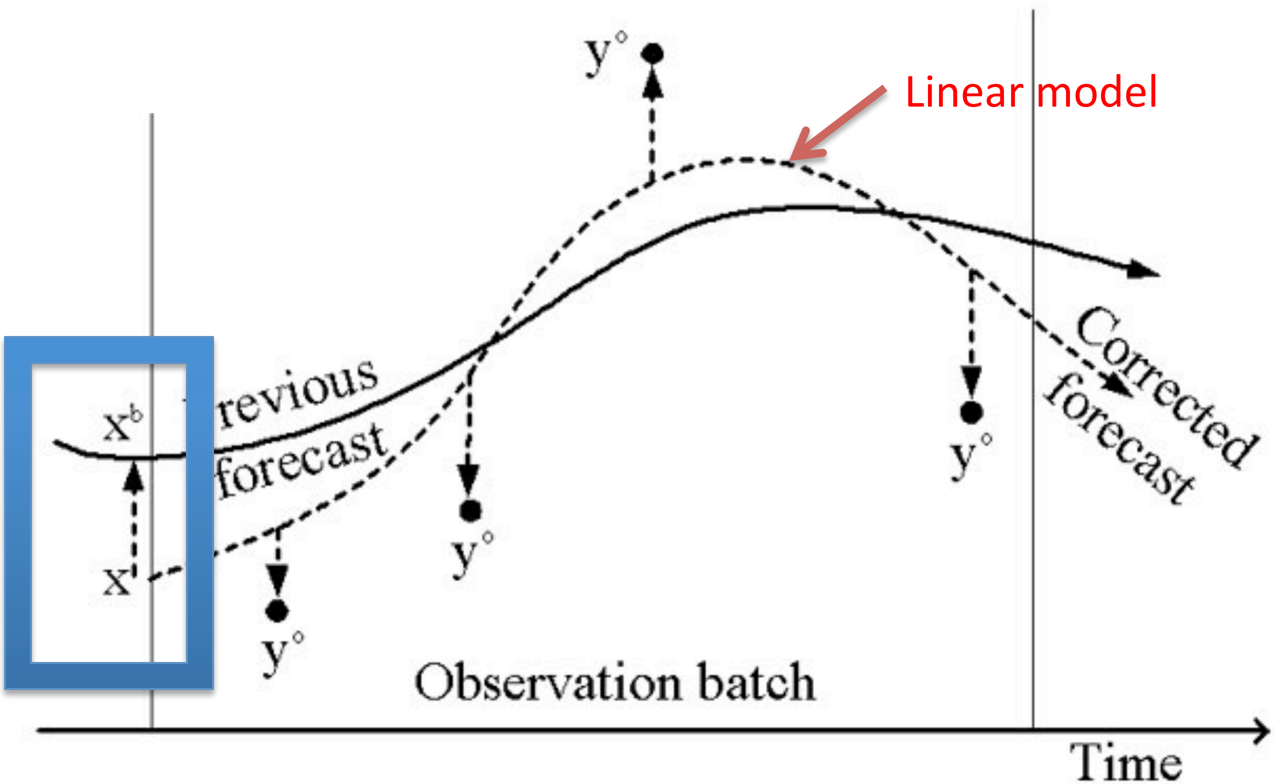
recipe in a nutshell

2. Throw out "bad" data automatically



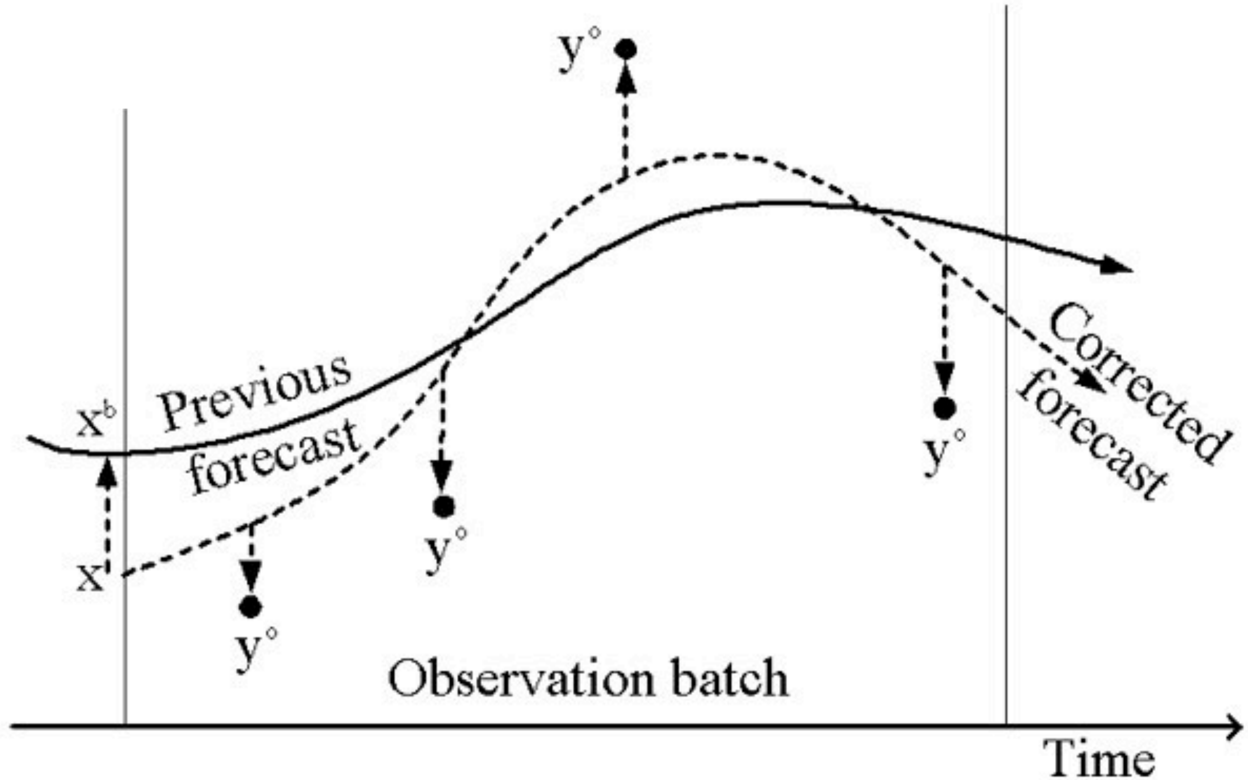
recipe in a nutshell

3. Using a clever technique, find set of initial condition perturbations that minimize the departure of a revised LINEAR forecast from **both** the control and the set of “good” observations (translate model to observation space where necessary)



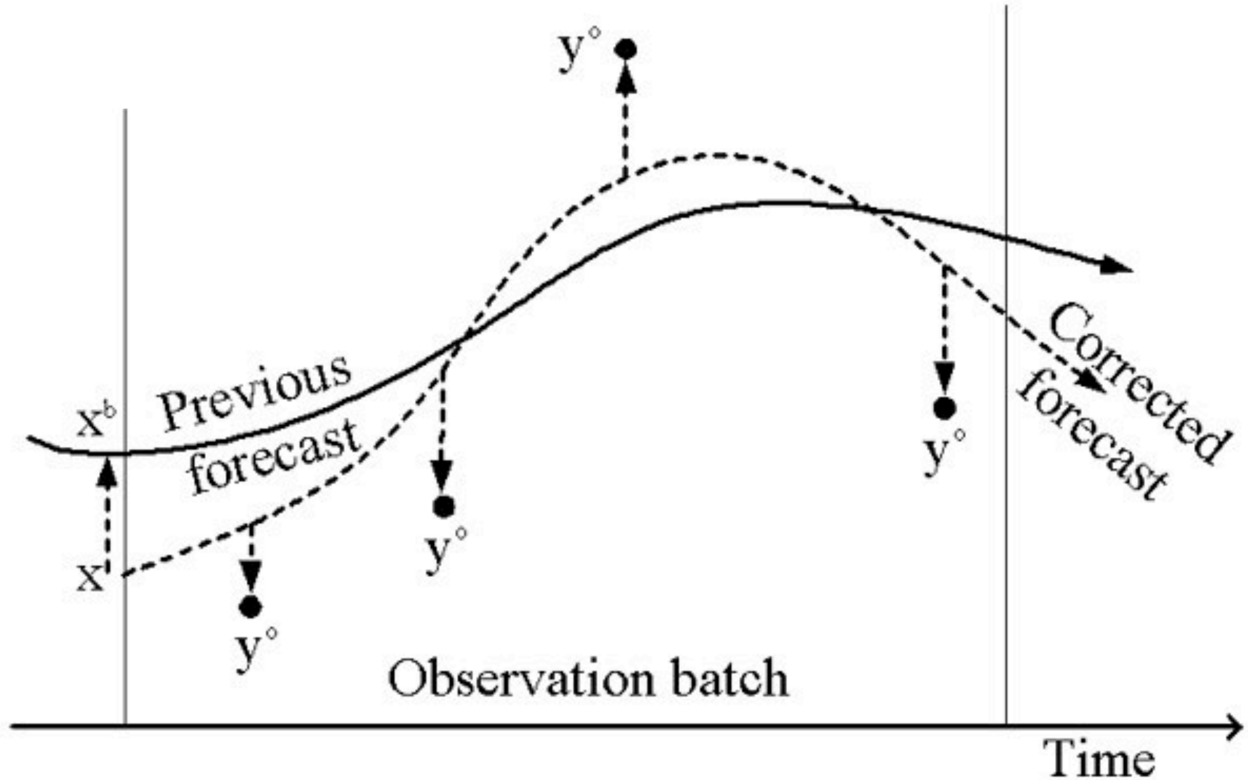
recipe in a nutshell

4. Perform revised "control" forecast starting from this new initial condition



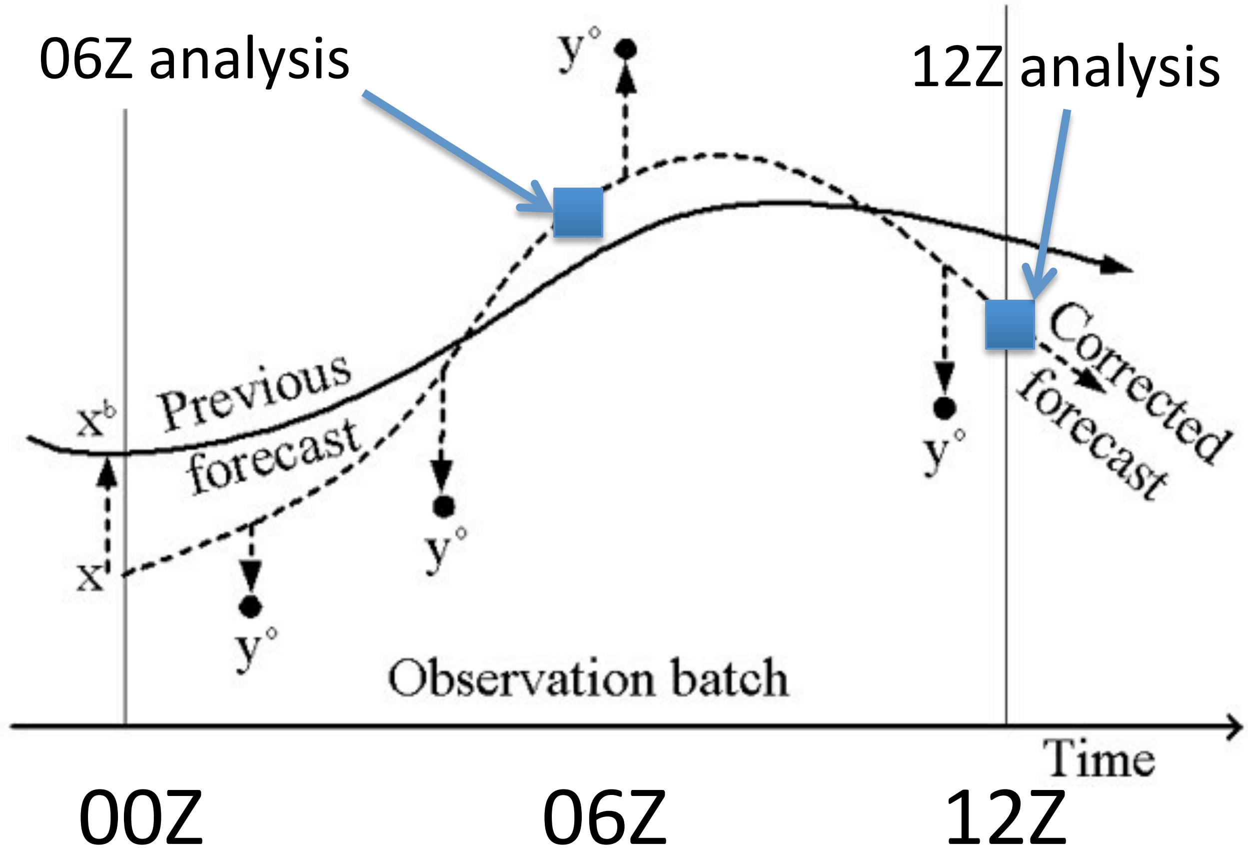
recipe in a nutshell

5. Repeat step 1-4 until (if!) the process converges (e.g. 3 cycles)



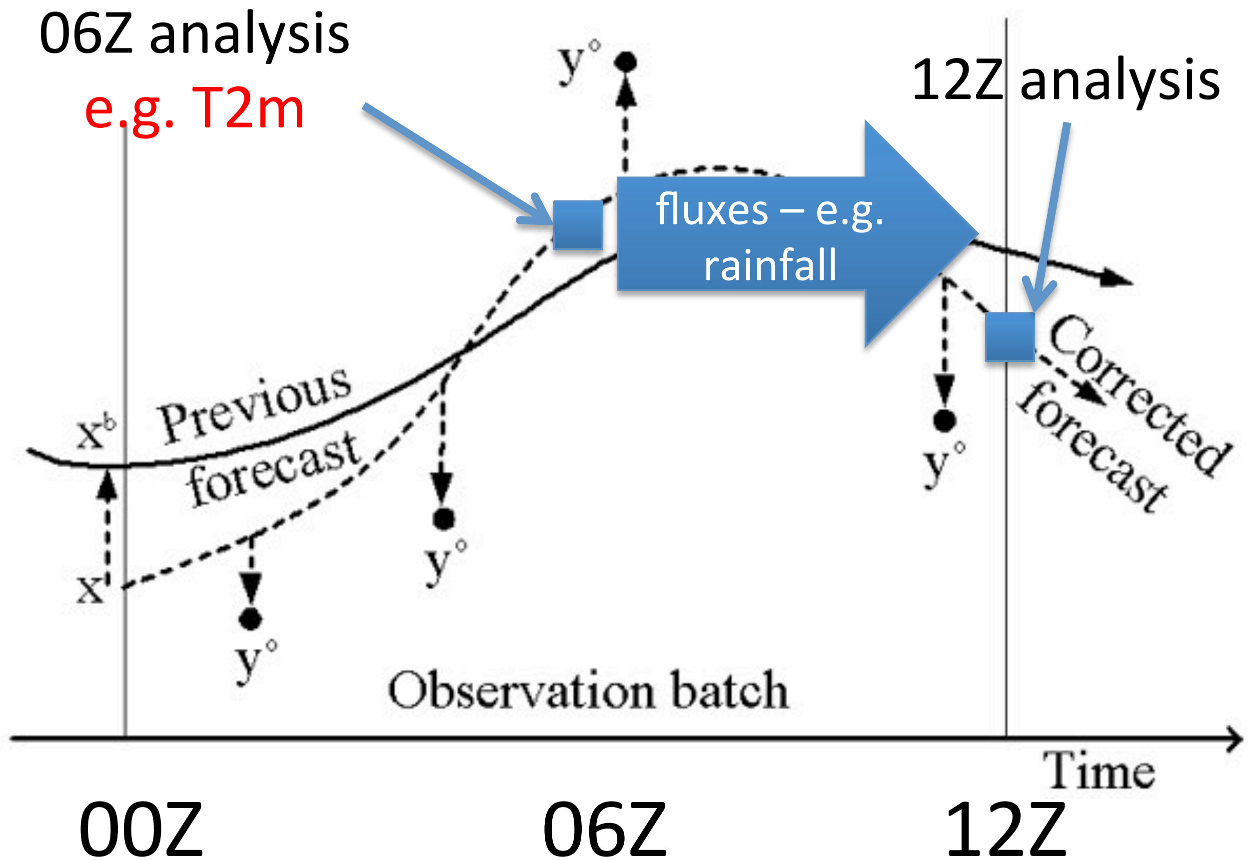
recipe in a nutshell

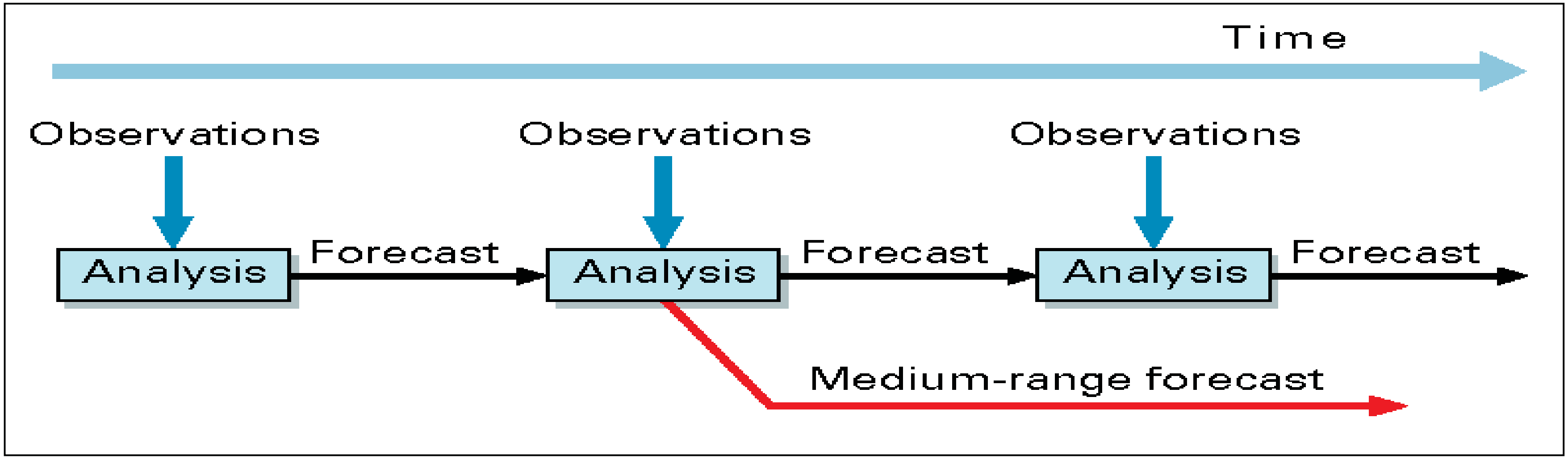
6. Now take any time point of the final “control” and use this as the “analysis”



Fluxes and instaneous fields

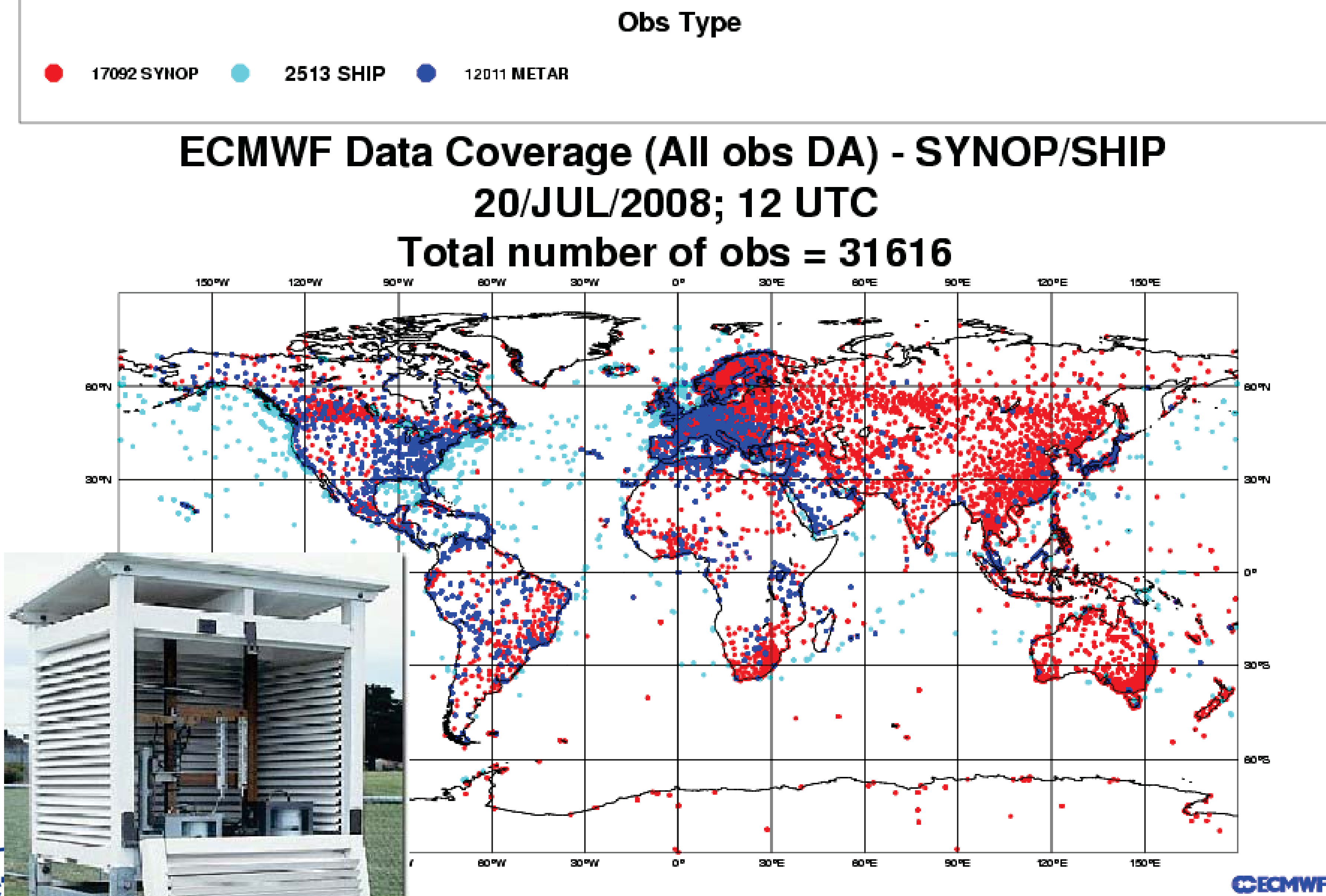
- Instaneous fields such as temperature are taken from the “analysis”
- Pointless to do this for fluxes as can not calculate water and energy budgets – these are obtained from short-range forecasts (0-24hrs)





- Observations are used to “correct” errors in the short forecast from the previous analysis time.
- At ECMWF, every 12 hours 4 – 8,000,000 observations are assimilated

DATA USED: Pressure, humidity during day
SYNOP T,q also used for soil moisture analysis

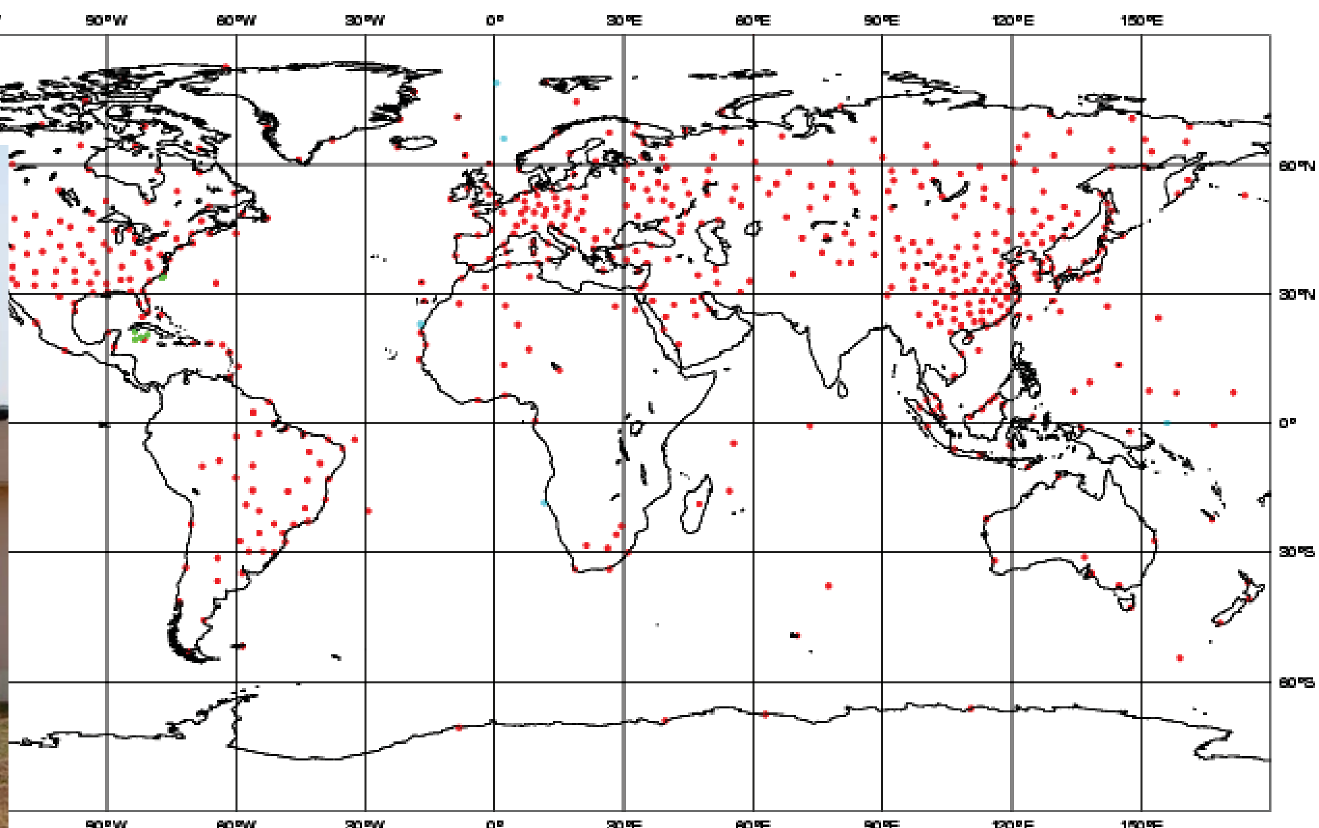


DATA USED: T,q,u,v – humidity to 300 or 100hPa

Obs Type

573 LAND
5 SHIP
7 DROPSONDE
0 MOBILE

ECMWF Data Coverage (All obs DA) - TEMP
20/JUL/2008; 12 UTC
Total number of obs = 585

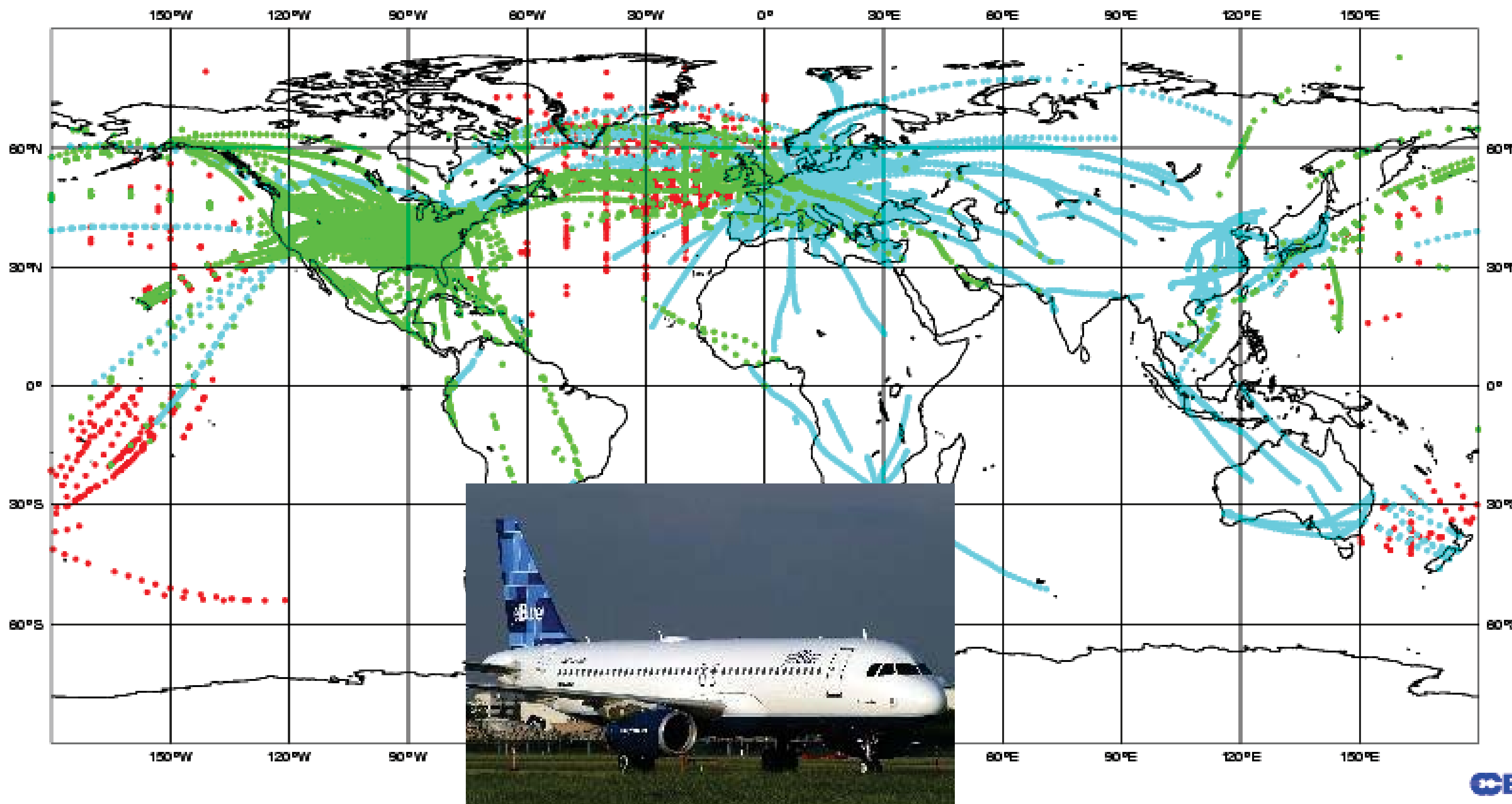


DATA USED: Temperature, winds (mozaic humidity research product)

Obs Type

18035 ACARS

ECMWF Data Coverage (All obs DA) - AIRCRAFT
20/JUL/2008; 12 UTC
Total number of obs = 50089



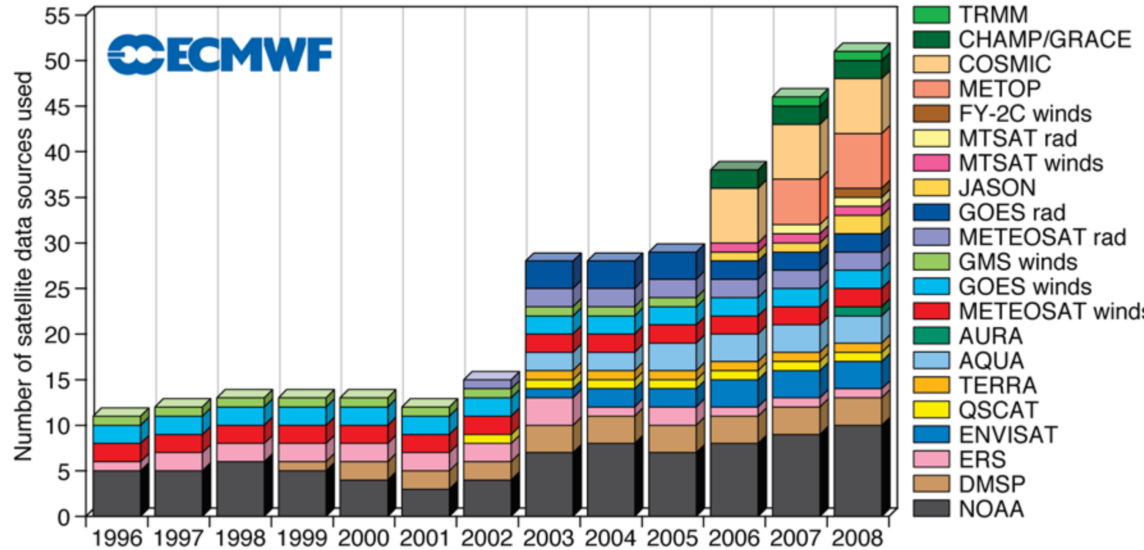
ECMWF

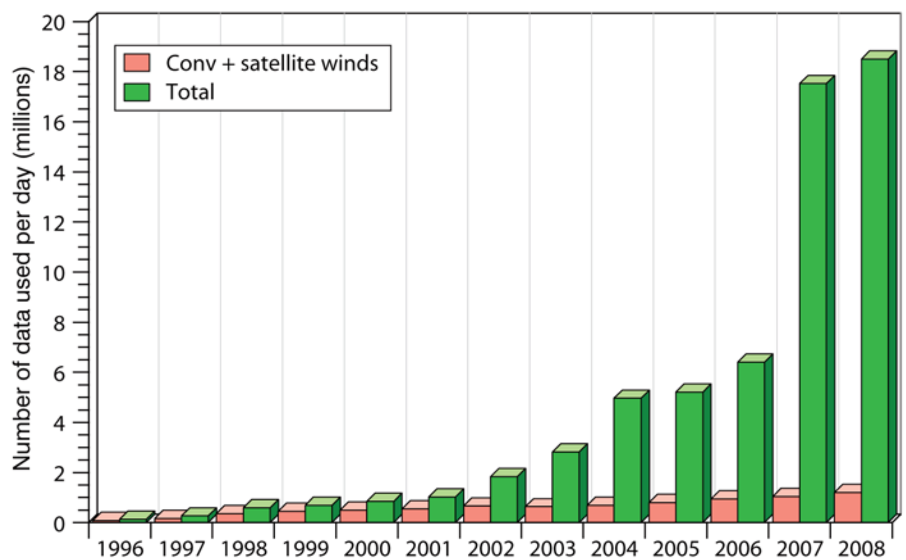
Satellite data used at ECMWF

A key factor for the advance in NWP is increase availability of satellite data.

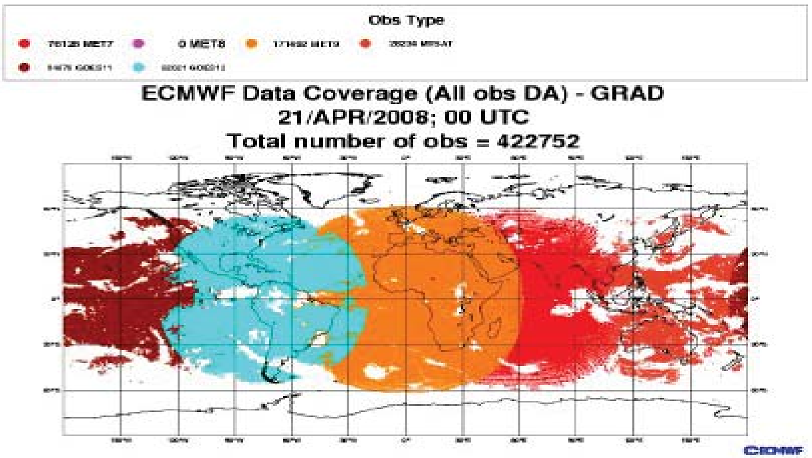
In 2008, ~ 300 million satellite observations from ~ 50 instruments have been received daily (top).

At ECMWF, ~ 6% of the available observations (~18 of the ~300 million) have been used daily (bottom).



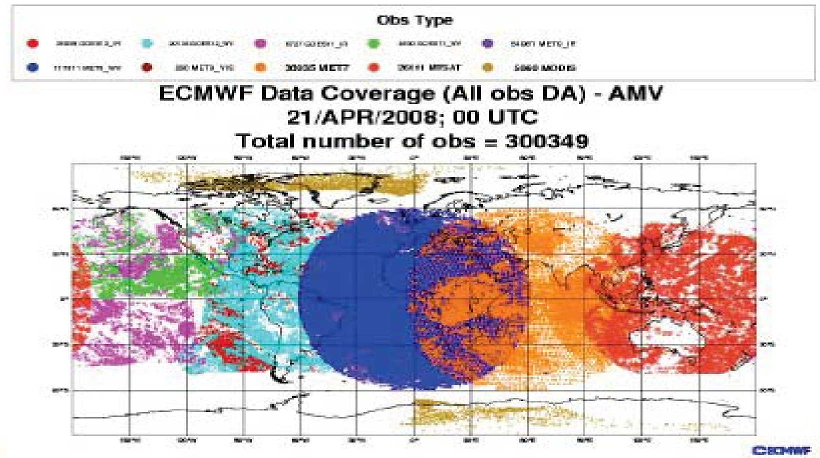


Clear-sky radiances



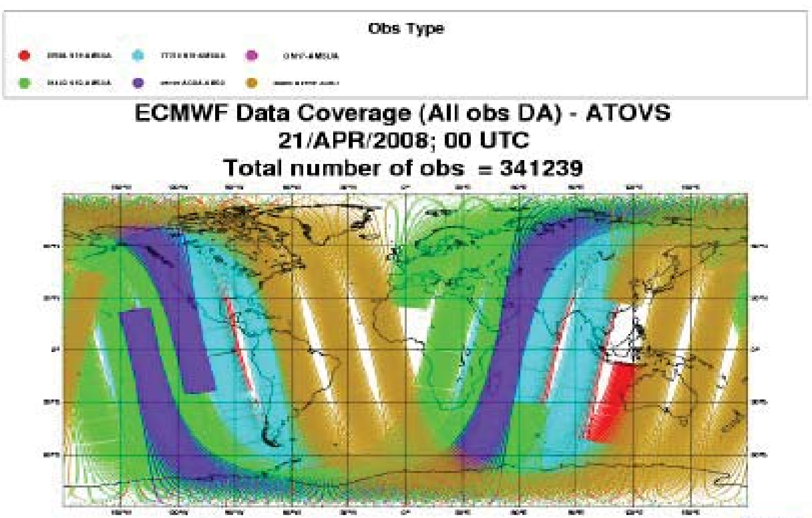
GOES-W GOES-E Met- Met-7 MTSAT-1R

Atmospheric Motion Vectors



GOES-W GOES Met-9 Met-7 MTSAT-1R

AMSU-A



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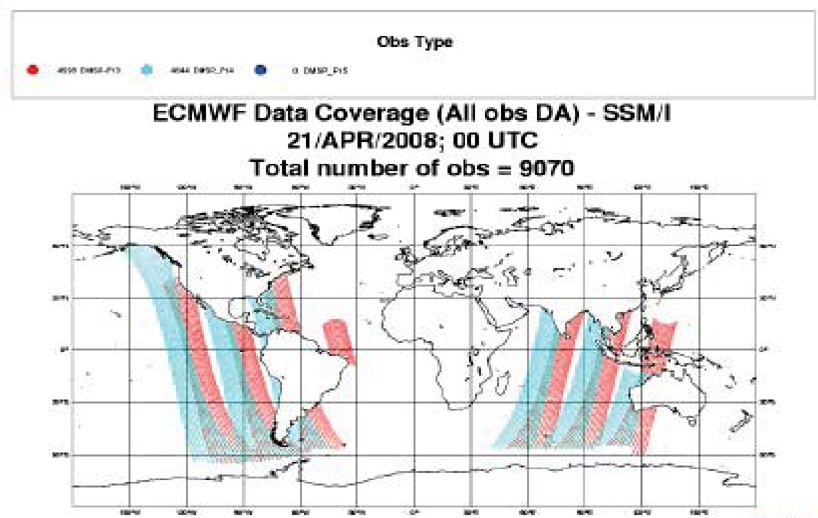
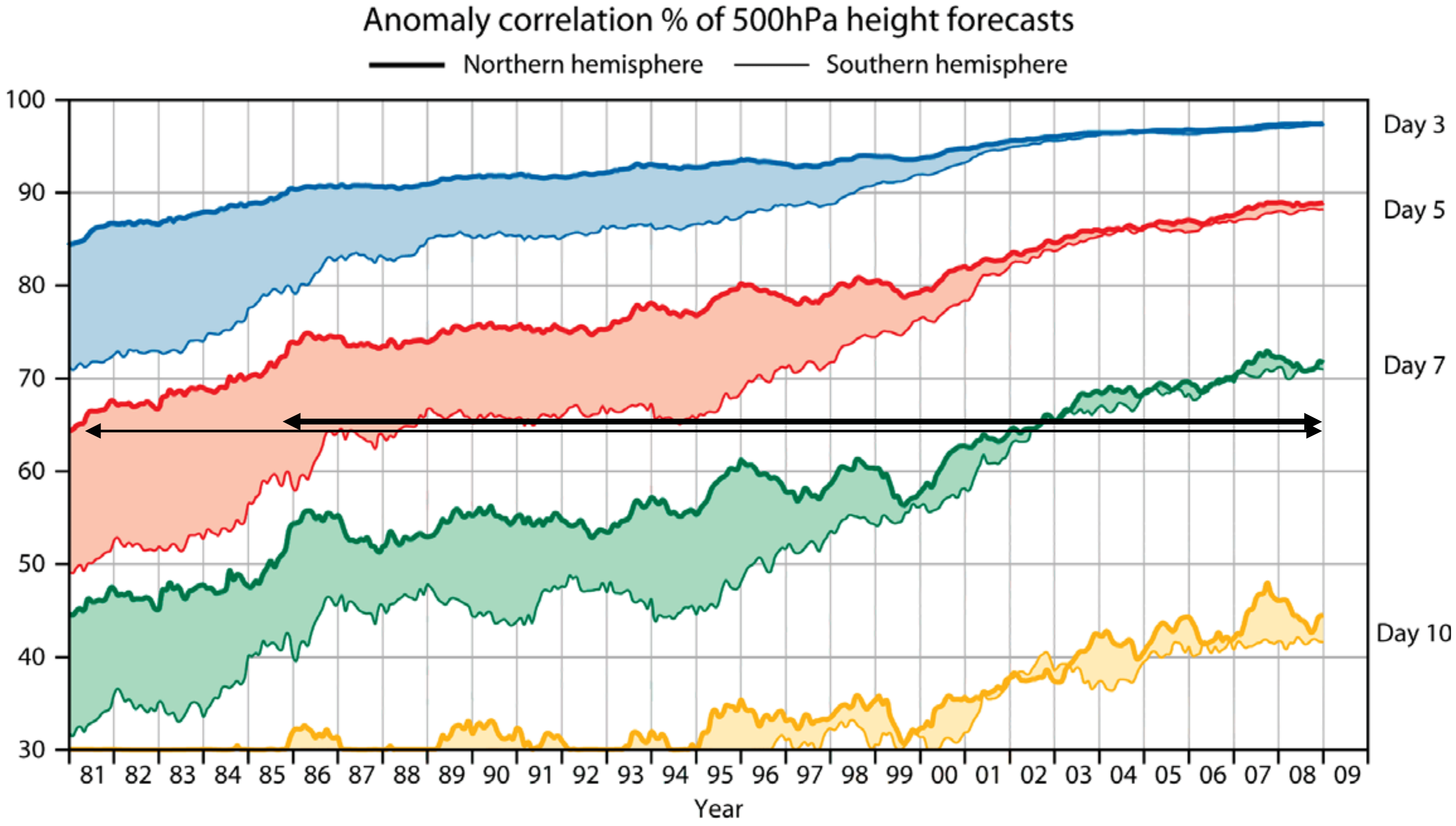


Evolution of ECMWF scores over NH and SH for Z500

- Over NH (SH) a day-7 single forecast of the upper-air atmospheric flow has the same accuracy as a day-5 in 1985 (day-3 in 1981).
- Note that Satellite data now implies equally good FC in NH and SH



Some common misconceptions

- Very little information concerning clouds or precipitation is directly assimilated into the model
- Clouds in the analysis are a model product from the model physics, their location/properties determined by temperature, humidity and dynamics.
- Thus the parameters most important for impacts modelling (e.g. esp. temperature and precipitation) are all influenced by the model physics even in the analysis

Advantages of analysis system

- all observations contribute to all variables
- Poor data can be automatically "sifted"

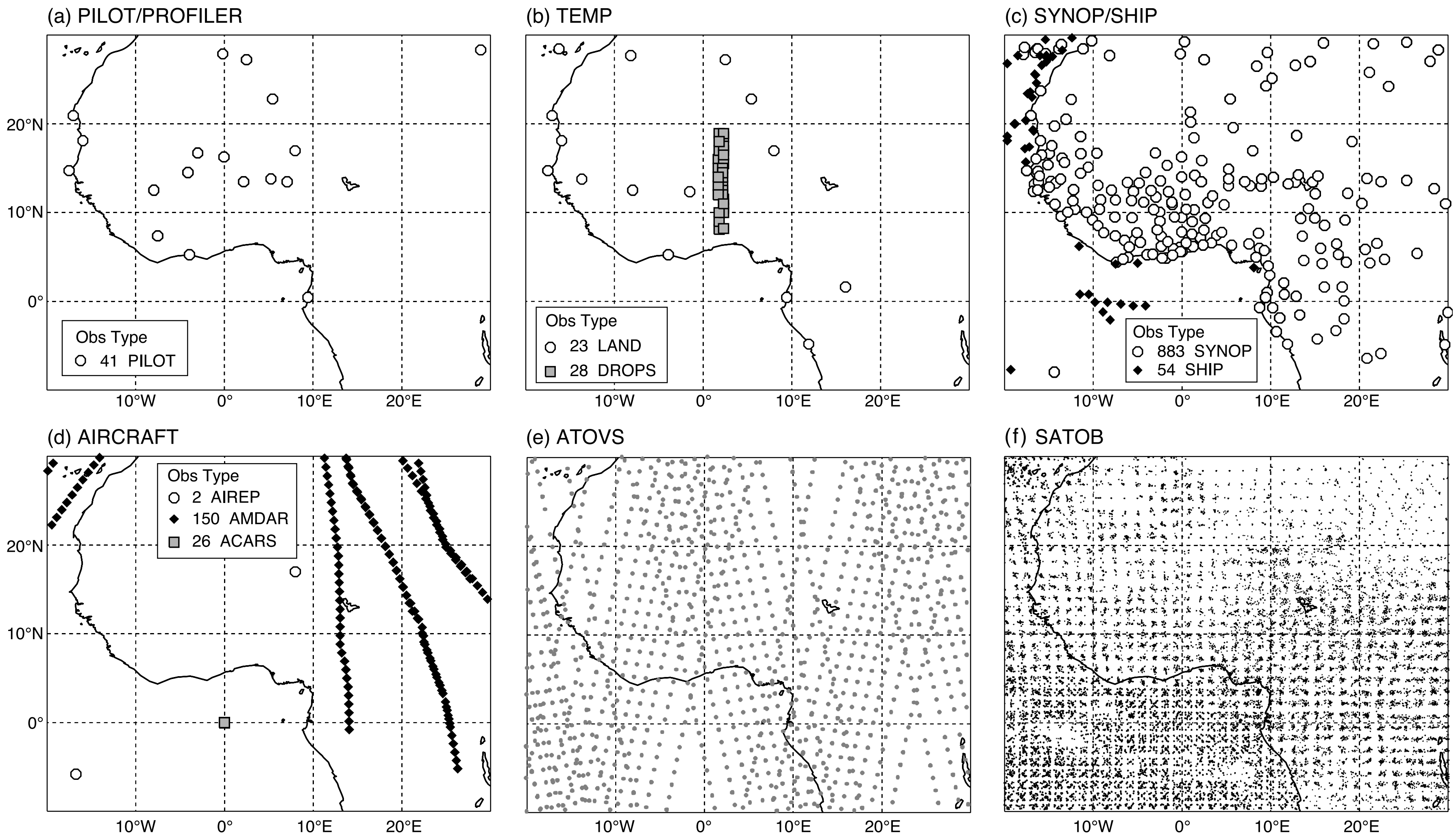
Example: Data denial experiments conducted over West Africa by Tompkins et al. 2003 QJRMS:

TABLE 2. DATA DENIAL EXPERIMENTS

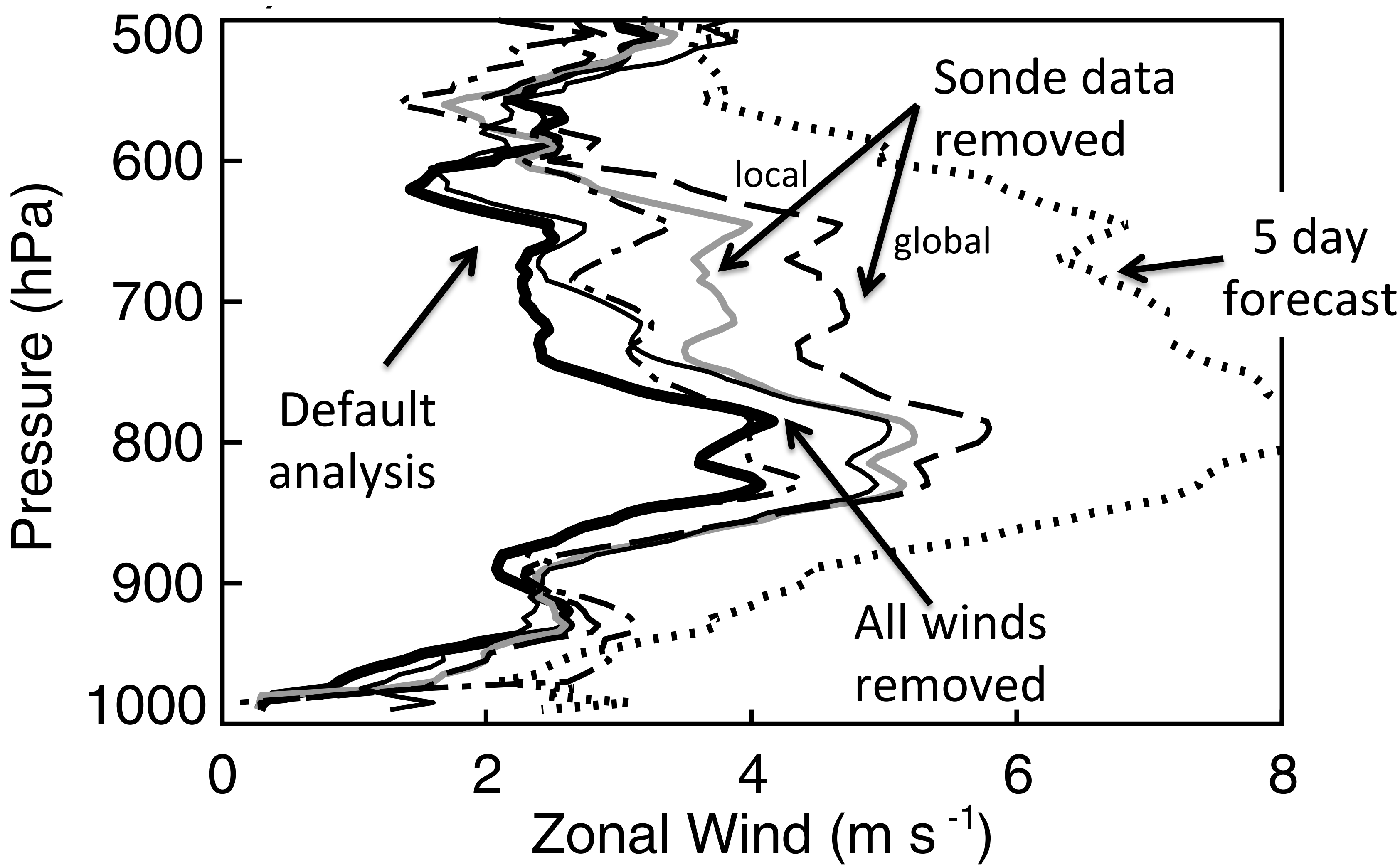
Experiment	Data denied	Region
1	Radiosonde, pilot and aircraft	Local
2	Radiosonde, pilot and aircraft	Global
3	Satellite	Local
4	Surface SYNOP and drift sondes	Local
5	All wind information	Local

'Local' implies the region 0 to 30°N and from 30°W to 60°E.

Observations assimilated in 2000



Root mean square wind errors – compared to independent data



Conclusion: Sonde **temperature** information more important for **wind** analysis than **winds**!

But what is REanalysis?

- Operational forecasting systems change their systems 3 or 4 times a year
  - New observation sources to be incorporated
  - Improvements to the physics in the forecast models
  - Improvements to the data assimilation techniques.
- This means that the analyses are not "coherent" in time
  - e.g. Could a temperature trend be due to changes in data and/or assimilation system
- One way to improve the coherency in reanalysis: The same system is run for all past dates.

ICTP

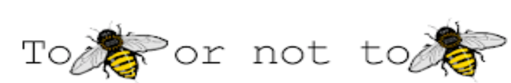
To analysis or reanalysis – that is the question?

Analysis

- Latest operational system
- High resolution
- Latest observation suite
- Model and observations change over time
- Not easily available
- Ideal for recent case study

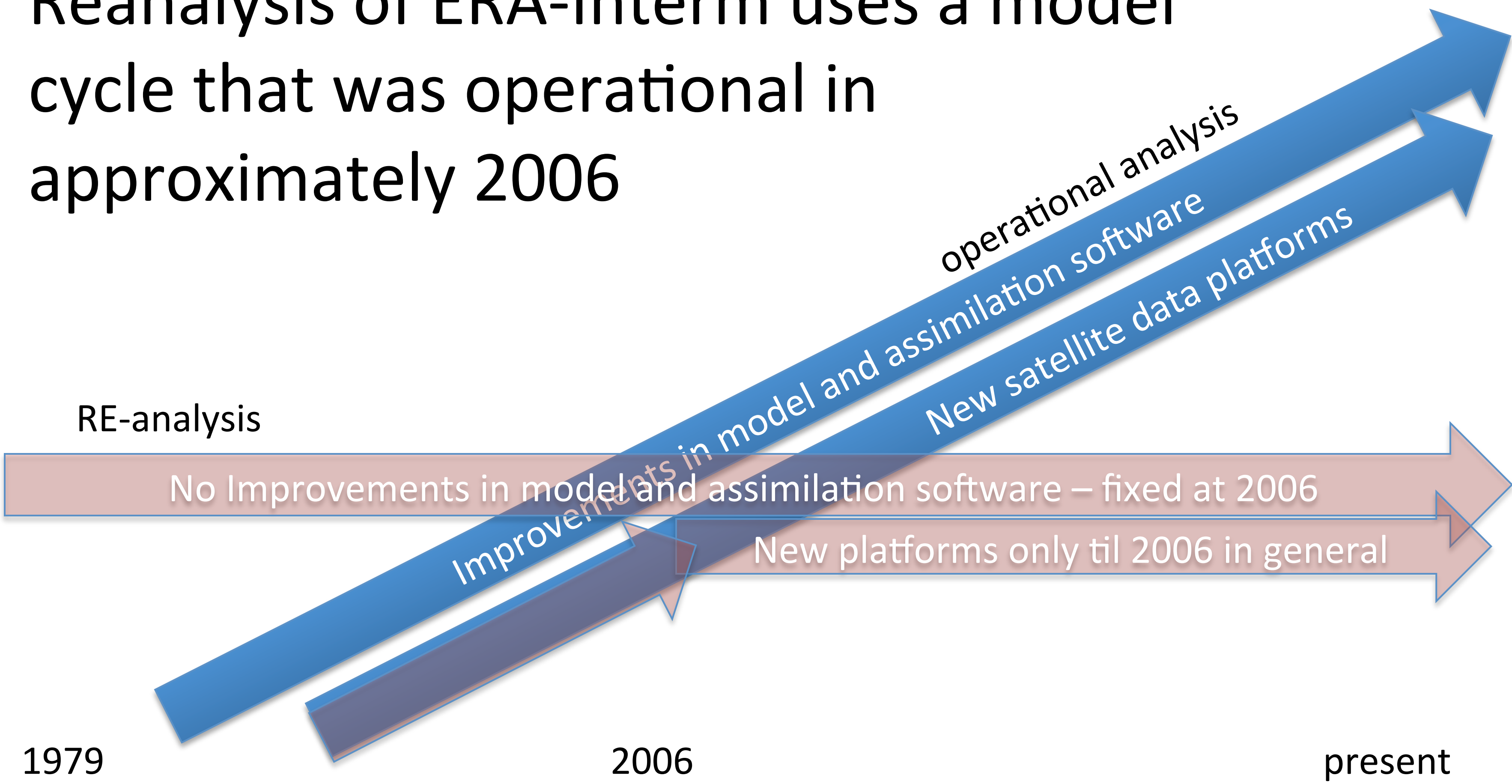
Reanalysis (e.g. ERAI)

- Using same model system, rerun for long period
- More continuity, although observations change over time
- Low resolution
- Obsolete model (ERAI from 10 years ago)
- Ideal for long term study



To give you an idea

- Reanalysis of ERA-40 uses a model cycle that was operational in 2000
- Reanalysis of ERA-Interm uses a model cycle that was operational in approximately 2006



Take home messages

- Analysis products are a useful supplement to observations
- Instantaneous fields are directly from the model analysis. Fluxes are from a short-range forecast.
- For recent case studies much better to use the analysis than reanalysis (higher resolution and better system)

http://apps.ecmwf.int/datasets/data/interim_full_daily/

- We will now try to download some fields using the reanalysis server
- and post-process them using cdo