Global reanalysis: Some lessons learned and future plans

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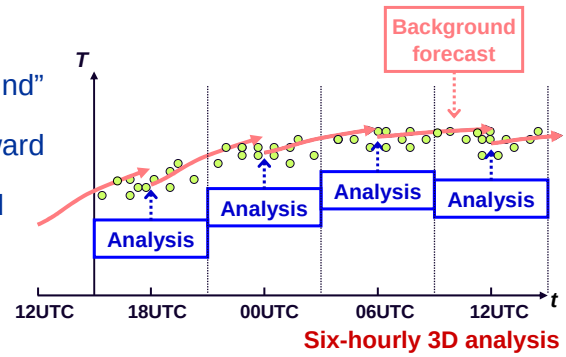
With thanks to Per Kållberg and many other colleagues from ECMWF and Partners in ERA-40

Reanalysis

- **Data assimilation has been developed primarily to provide initial conditions, "analyses", for operational numerical weather forecasts**
- **Quality of operational analyses varies over time largely because of changes in data assimilation systems**
- **Reanalysis:**
  - applies a fixed, modern data assimilation system to multi-decadal sets of observations
  - generates a sequence of atmospheric and land/ocean/ice surface conditions every few hours throughout the period
  - provides complete, gridded data sets for use in a wide variety of applications

Data assimilation

- **combines information from**
  - Current observations
  - A short-range "background" forecast that carries forward the information extracted from prior observations
  - Statistics
  - Dynamical and physical relationships



- **to produce the "most probable" estimate of the atmospheric state (and some estimate of uncertainty)**

The quality of reanalyses is affected by:

- **The quality of the assimilation system**
  - The assimilating model (atmosphere, ocean waves, land state)
  - The analysis system
- **The characteristics of the observing system**
  - The type, accuracy and coverage of observations, changes over time in particular
- **The prescribed boundary conditions**
  - Sea-surface temperature and sea-ice distribution
  - Land-surface state (vegetation, lakes, …)
- **The specified atmospheric composition**
  - Greenhouse gases, aerosols, …

Primary global reanalyses

- **NCEP/NCAR**
  - 1948 – *present* by NCEP with NCAR data supply
- **ERA-15**
  - 1979 – 1993 by ECMWF
- **NCEP/DOE (Reanalysis-2)**
  - 1979 – *present* by NCEP with DOE funding
- **ERA-40**
  - 1957 - 2002 by ECMWF and partners (including NCAR)
- **JRA-25**
  - 1979 - 2004 by JMA (including observations from ERA-40)

Changes to the observing system

1940s: Establishment of network of Atlantic and Pacific Weather Ships

1957: Radiosonde network enhanced in Southern Hemisphere for International Geophysical Year

1973: NOAA-2 – First operational sounding of temperature and humidity from polar-orbiting satellite

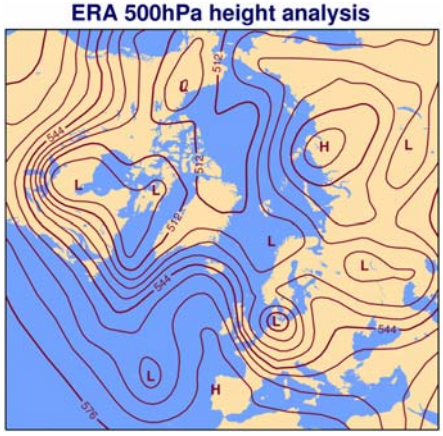
1979: Improved sounding from polar orbiters
Winds from geostationary orbit
More data from commercial aircraft
Drifting buoys

Today: Additional satellite, aircraft and buoy data
Poorer radiosonde coverage (but better quality data)

00UTC 1 February 1953

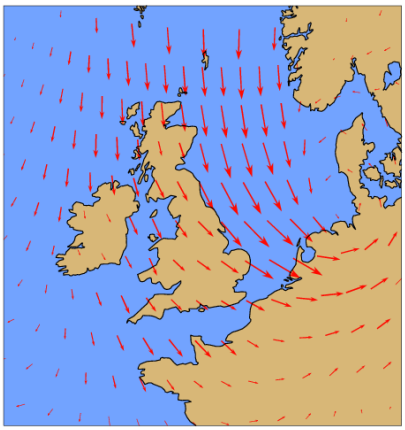
The Netherlands' gift to ECMWF

ERA 500hPa height analysis

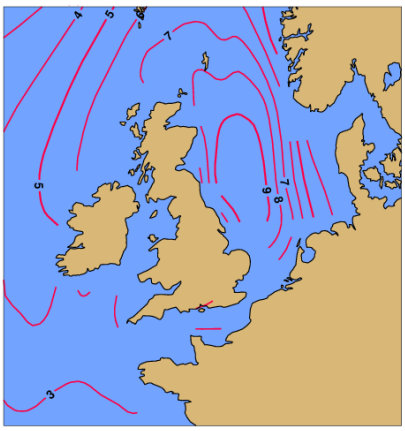


00UTC 1 February 1953

10m wind ⟶ 25ms^{-1}

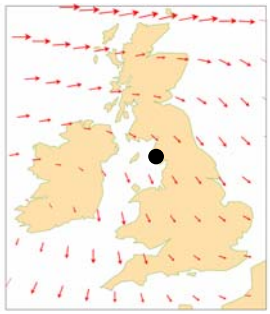


Significant wave height (m)



Re-analyses for time of Windscale nuclear reactor fire

12UTC 11 October 1957

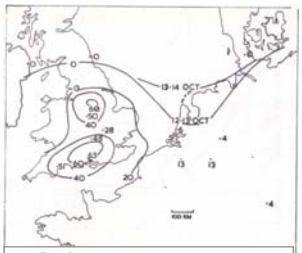


6UTC 12 October 1957

24h from 9UTC 11 Oct

Iodine-131 measurements

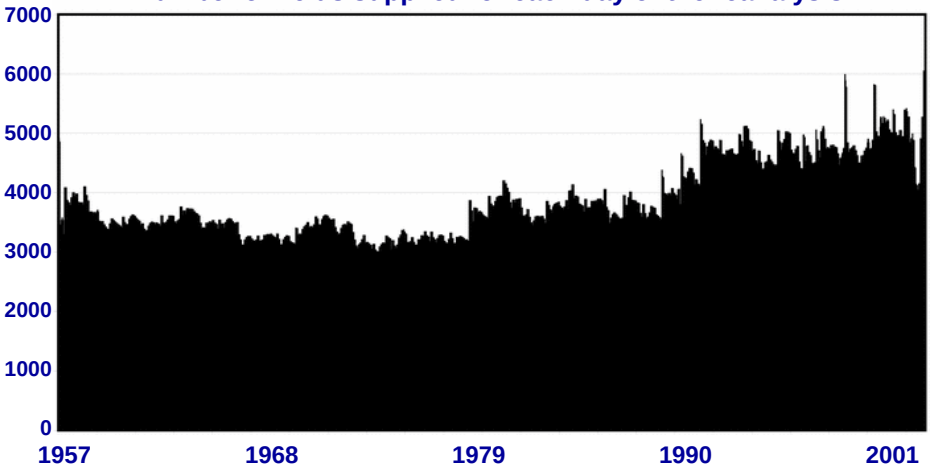
Crabtree(1959)
Quarterly Journal
Royal Met Soc



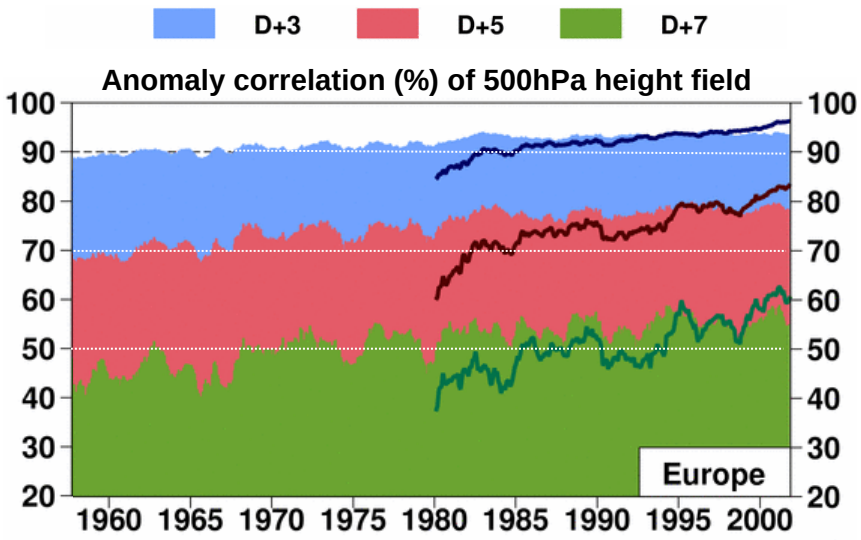
48h from 9UTC 12 Oct

2.5^{O} data supplied by public server (to Dec 2003)

Number of fields supplied for each day of the reanalysis



Accuracy of forecasts from ERA-40 and ECMWF operations



Non-satellite data supplied by NCAR/NCEP for ERA-40

Radiosonde and pilot	
China	1957-1962
Raobs	1957-1967
Countries, US Control, France, Misc	1957-1978
Russia	1960-1978
TD52	1960-1971
TD53	1957-1969
TD54	1957-1968
ON20	1962-1972
US Navy	1966-1973
GATE/TWERLE	1974-1976
USAF, ON29	1973-1978
Surface	
TD13, TD14, USSR	1957-1973
USAF	1967-1976
ON124	1976-1978
COADS	1957-1999
USSR snow depth	1966-1990
Automatic Antarctic	1980-1998
Aircraft	
Australian	1971-1978
US Navy	1970-1978
ON20	1962-1972
Sadler	1960-1973
Rean-1	1957-1961
	1973-1978
Cloud Motion Winds	
ON20	1967-1972
Rean-1	1973-1978

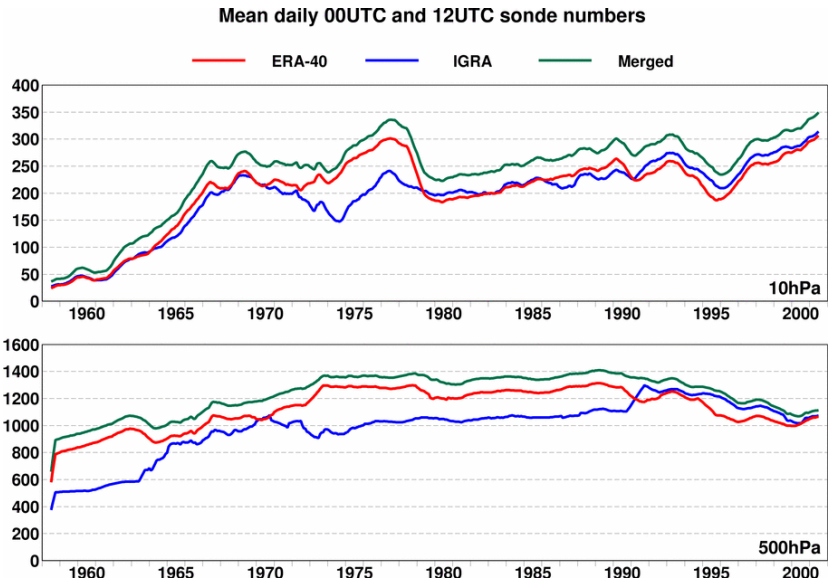
NCAR's current upper-air datasets (J. Comeaux)

DESCRIPTION	PERIOD	ERA-40
C-CARDS Raobs	1949-1965	
CARDS 542	1946-1947	
China R & P	1954-1962	1957-1962
Countries R & P	1946-1993	1957-1978
French R & P	1948-1979	1958-1978
GATE R & P	1974	
Line Island	1967	
MIT Raobs	1958-1963	1958-1963
Navy Kunia	1966-1969	
Navy Spot Soundings	1966-1973	1966-1973
NCEP ADP	1973-Cont	1980-1994
NCEP B3	1962-1972	1962-1972
Permanent Ship	1973-1980	

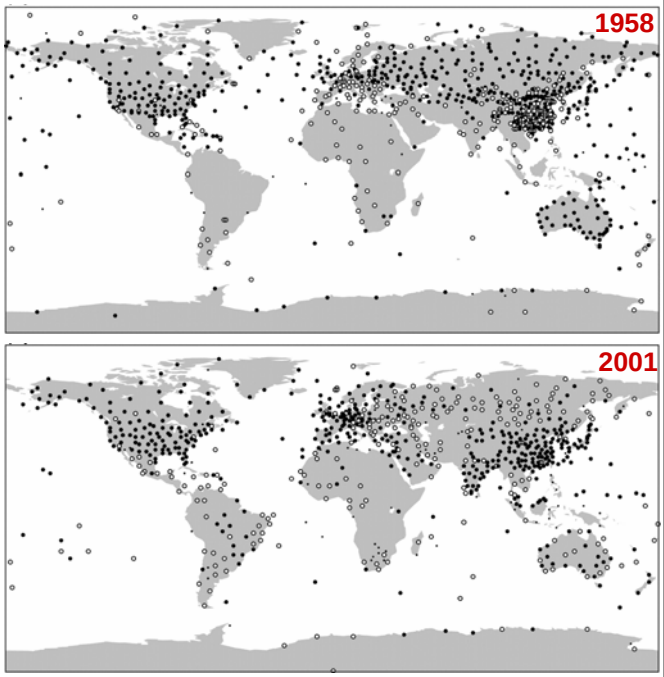
NCAR's current upper-air datasets (J. Comeaux)

DESCRIPTION	PERIOD	ERA-40
Ptarmigan Drops	1950-1961	
Russian NP	1950-1991	
Russian Ship	1947-1990	
Russian Upper Air	1960-1990	1960-1978
Scherhag Raobs	1954-1962	
South African	1961-1967	
TD390 Raobs	1943-1962	
TD52 Pibals	1922-1971	1957-1971
TD53 Pibals	1919-1969	1957-1969
TD54 Raobs	1943-1974	1957-1973
TWERLE	1975-1976	1975-1976
US Control	1946-Cont	1958-1978
USAF Upper Air	1973-1980	

NCDC's Integrated Global Radiosonde Archive



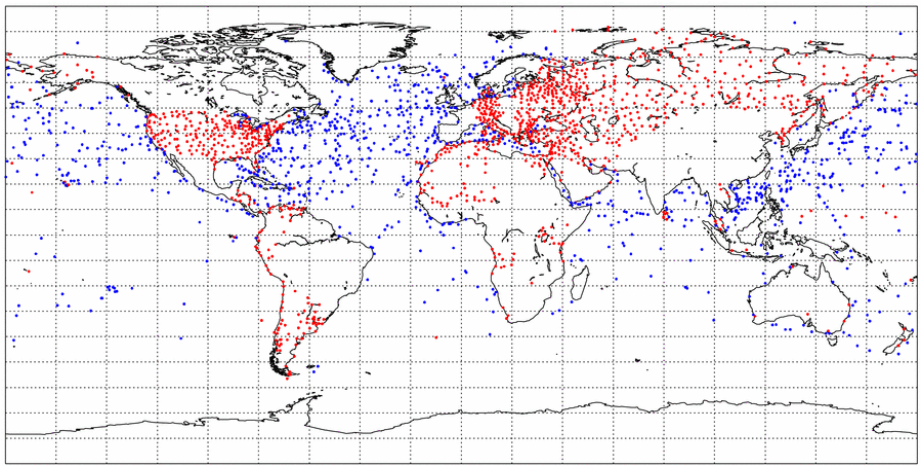
Radiosonde coverage



Average number of soundings per day: 1609

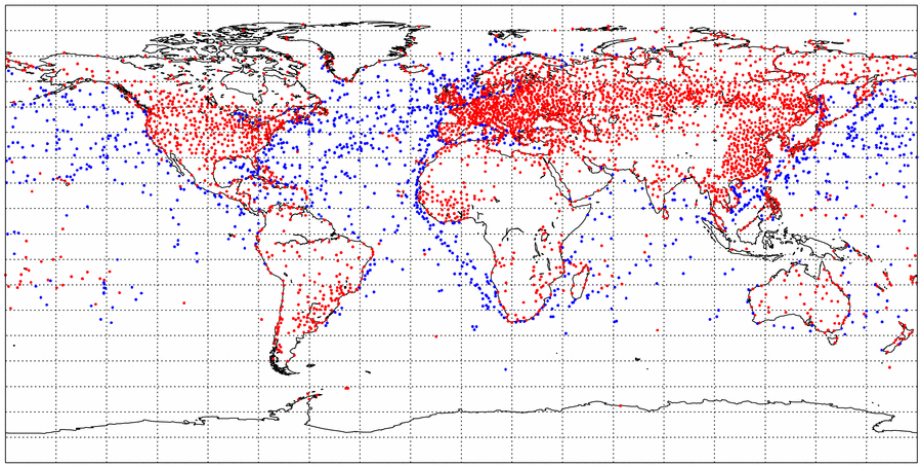
Average number of soundings per day: 1189

ERA-40 SYNOP and SHIP coverage



9-15UTC 1 July 1966

ERA-40 SYNOP and SHIP coverage



9-15UTC 1 July 1967

SYNOP sources for NCEP/NCAR reanalysis (J.Woollen, NCEP)

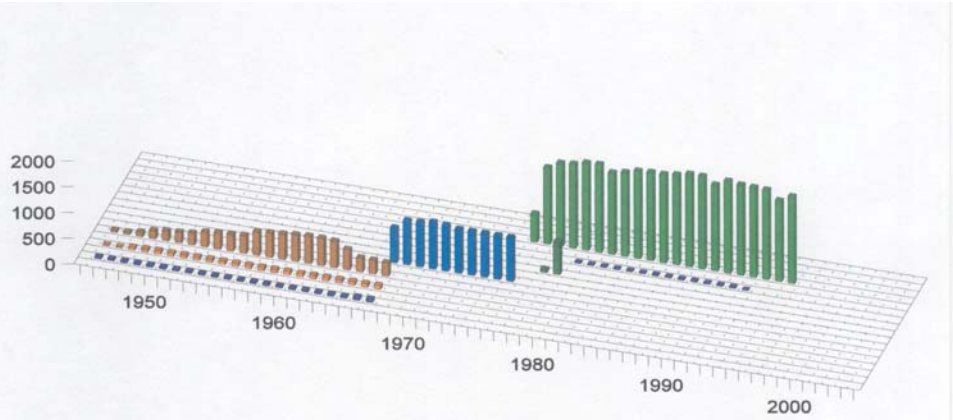
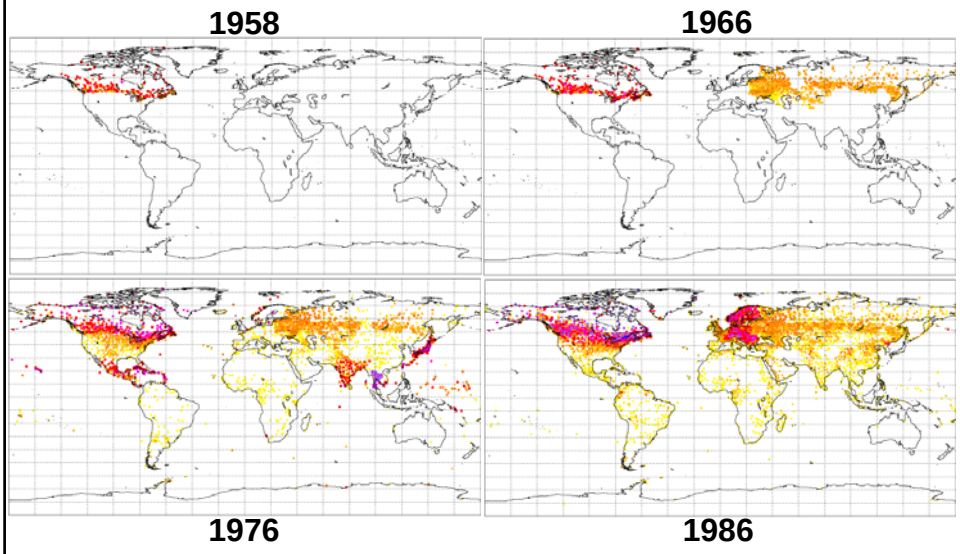
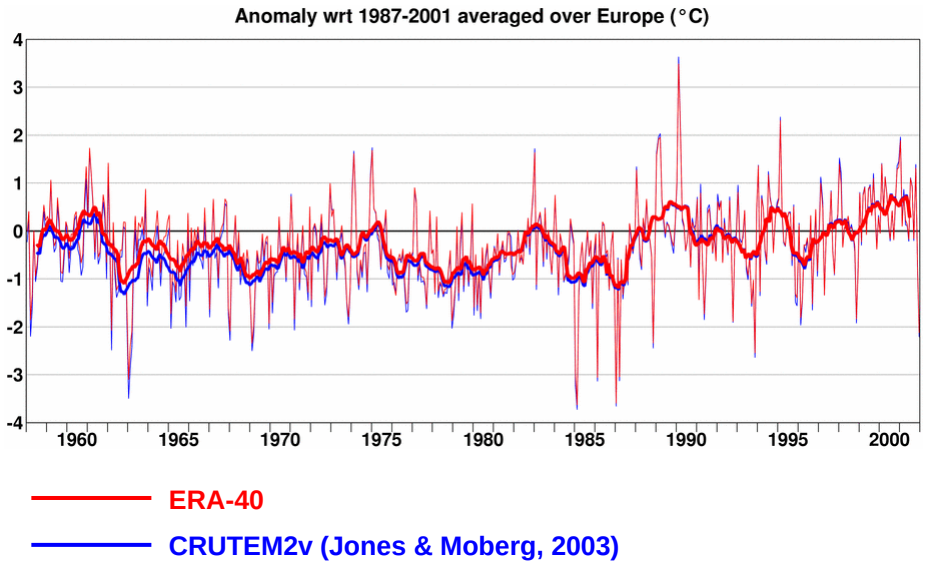


Figure 3. Land surface inventory. From back to front, in megabytes; NMC, ICEB, FGGE, USAF, TD13, TD14, USSR.

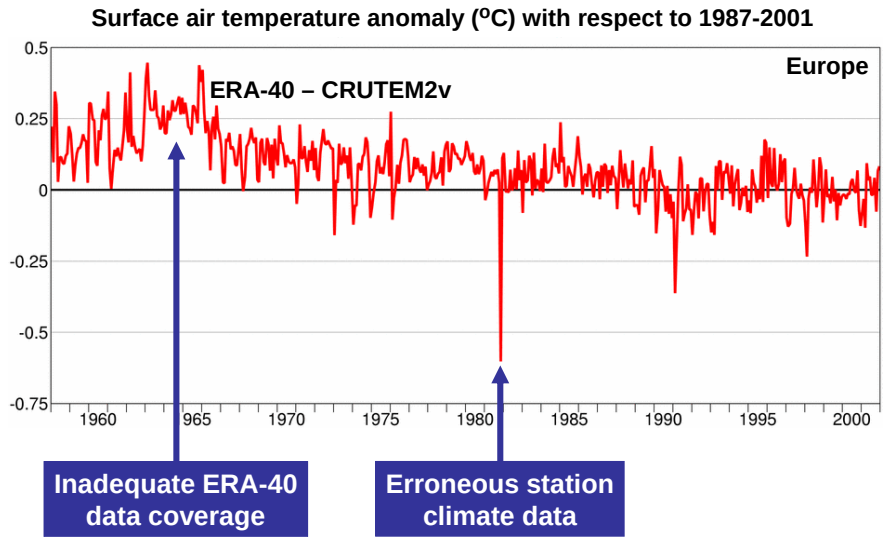
Snow-depth data available for ERA-40



Trend and variability in two-metre temperature

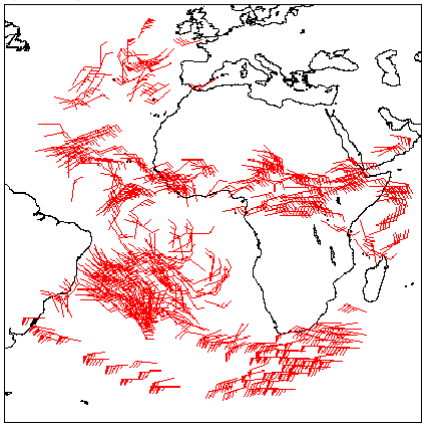


Identification of data problems: a land example

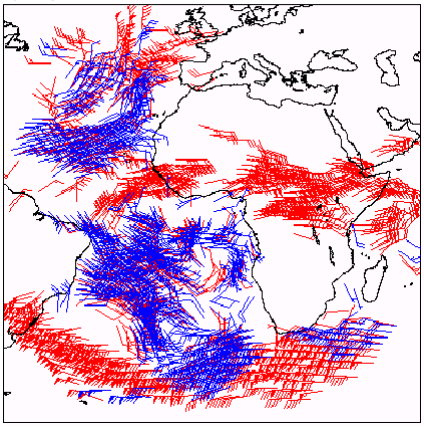


EUMETSAT's reprocessed METEOSAT-2 winds

a) Old operational IR data



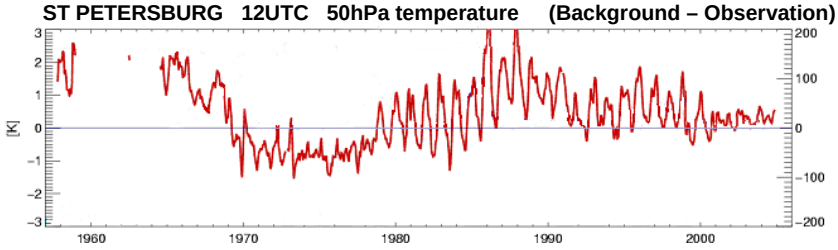
b) Reprocessed ELW data, IR and VIS



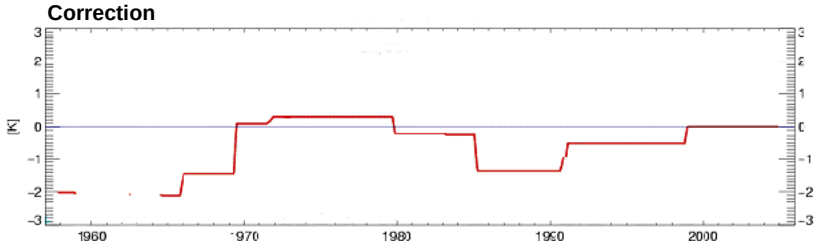
EUMETSAT is reprocessing data from later METEOSATs

Radiosonde bias correction using ERA-40 feedback (Haimberger, 2005)

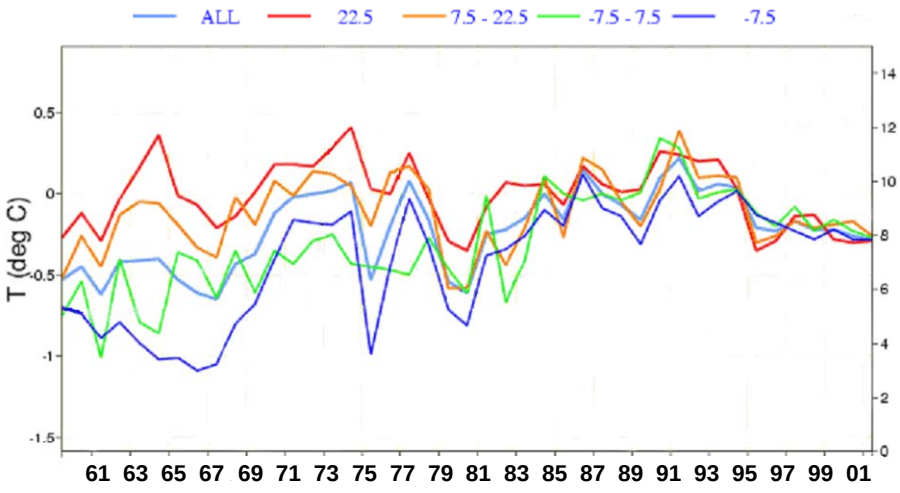
ST PETERSBURG 12UTC 50hPa temperature (Background – Observation)



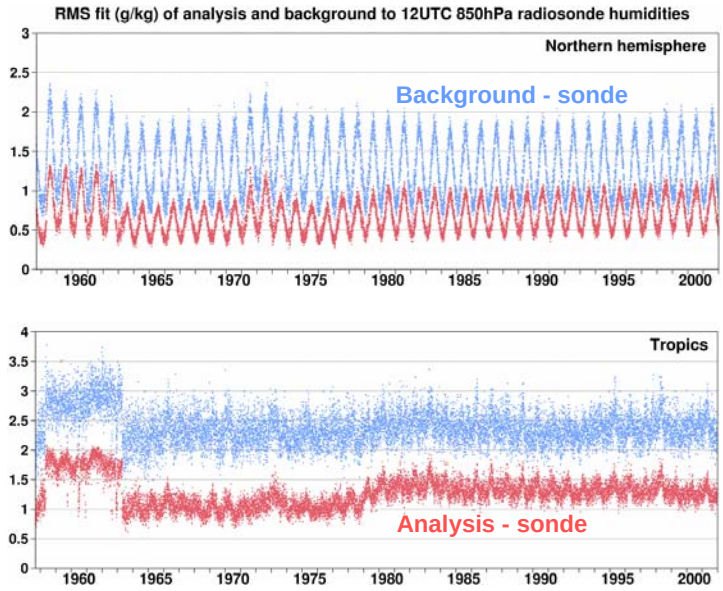
Correction



(Obs- background) for UK radiosonde temperatures at 100hPa as a function of solar angle



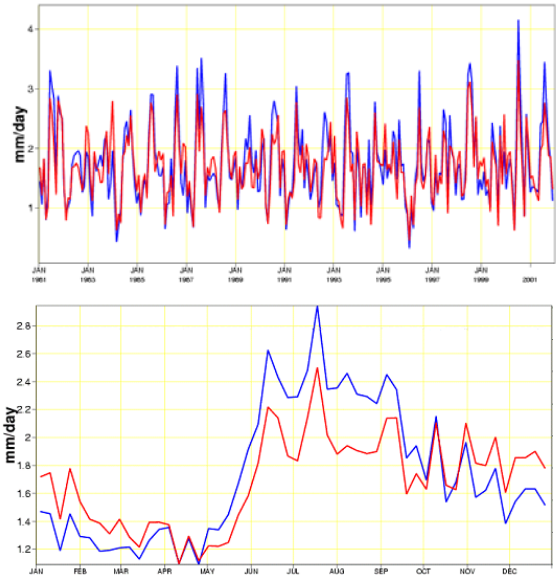
850hPa specific humidity differences

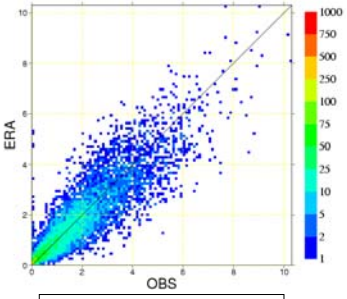


Precipitation over the Baltic catchment area (1981-2001)

OBS ERA-40

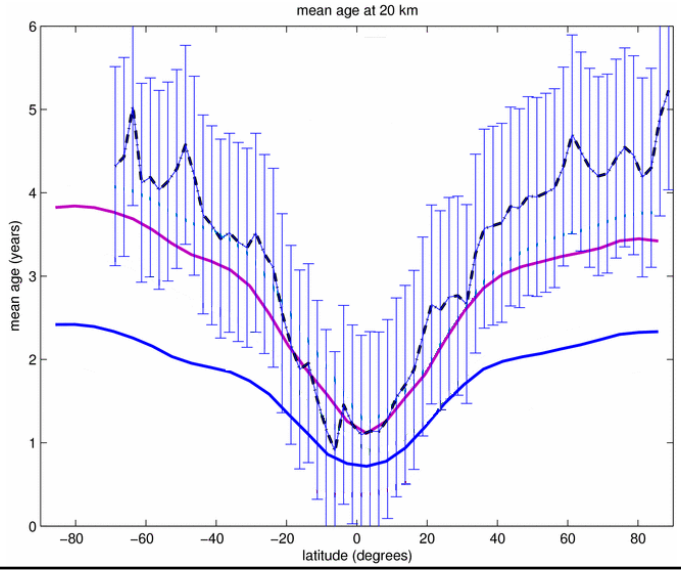
(Ulf Andrae)





Stratospheric age of air simulations with a chemical transport model

(Beatriz Monge Sanz, Martyn Chipperfield)



From CO_2 and SF_6 measurements

New reanalysis

ERA-40

Plans for global reanalysis

ECMWF

- **An interim global reanalysis**
  - will cover 1989-2009, starting soon
  - will have higher horizontal and vertical resolution than ERA-40
  - will use 4D-Var and latest version of forecasting system
  - will address several problems in ERA-40 analyses
  - will provide baseline for further developments, including constituent analysis
- **A new extended global reanalysis**
  - ERA-65/75 (1938/48-2012) to begin in 2010
  - experimentation for pre-1989 periods will be done with interim system
  - preparatory work on observational database is a major task
  - subject to funding

Plans for global reanalysis

Japan Meteorological Agency

- **JCDAS (JMA CDAS)**
  - JRA-25 (1979-2004) will be continued in near real time
- **2nd Japanese reanalysis (JRA-50)**
  - will cover 1958-2010 and be completed by 2012

USA

- **NOAA CDC**
  - Reanalysing 1938-1948 using only surface-pressure obs
- **NASA GMAO**
  - MERRA will cover 1979- …. ; 1970s will also be studied
- **New NOAA (NCEP/CDC/NCDC) programme**
  - ~1950- ….
  - ....