ECMWF Reanalysis: Status and Plans

Dick Dee

Contributions from the ECMWF reanalysis team,
and many colleagues at ECMWF and elsewhere

WCRP 4th International Conference on Reanalyses
7-11 May 2012
Silver Spring, Maryland

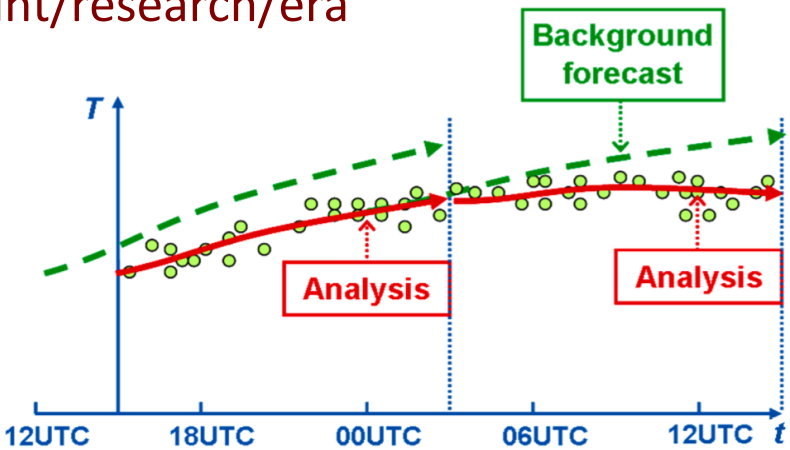
ERA-Interim: Key facts

Data products:

- From 1979 to present, continuing with monthly updates
- 6-hourly upper-air, 3-hourly surface, monthly averages, diagnostics
- Products available at www.ecmwf.int/research/era

Assimilating model:

- ECMWF IFS Cy31r2 (Dec 2006)
- T255 spectral fields; ~79km global
- 60 levels, top at 0.1hPa



4D variational assimilation as used in ERA-Interim

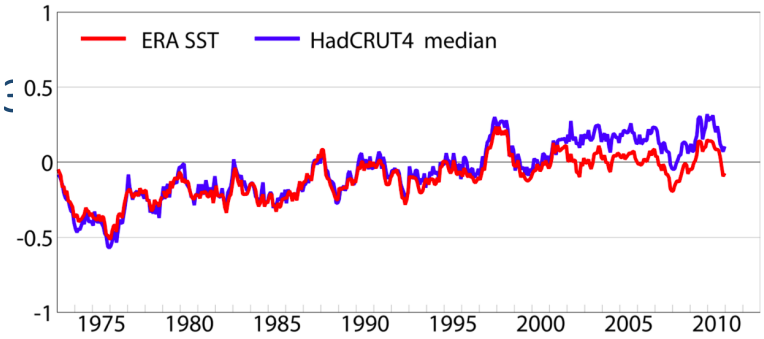
Analysis method:

- 4D-Var with 12-hour analysis window
- Static background error covariances using wavelets
- Variational bias correction of satellite radiances
- 1D+4D-Var assimilation of SSM/I rain-affected radiances

ERA-Interim: Model input data

Surface conditions:

- SST: 5 different products used! Clear shift after 2001.
  - Prior to 2001 as in ERA-40 (HadISST1 then NCEP)
  - After 2001 as in IFS (NCEP then OSTIA)
- Fixed vegetation (USGS GLCC + AVHRR)
- Snow cover from NESDIS, from July 200



Atmospheric forcing:

- Solar constant 1370 W/m^2
- Prognostic ozone, but not coupled to radiation
- Ozone in radiation: Annual cycle based on climatology
- Greenhouse gases: Linear trend from IPCC AR2
- Aerosols: Annual cycle based on climatology + constant background; no evolution of volcanic aerosols

Room for improvement: Presentation by Hans Hersbach

ERA-Interim: Observations

ERA-40 input until 2002, but:

- Direct assimilation of SSM/I clear-sky radiances
- Use of SSM/I rain-affected radiances

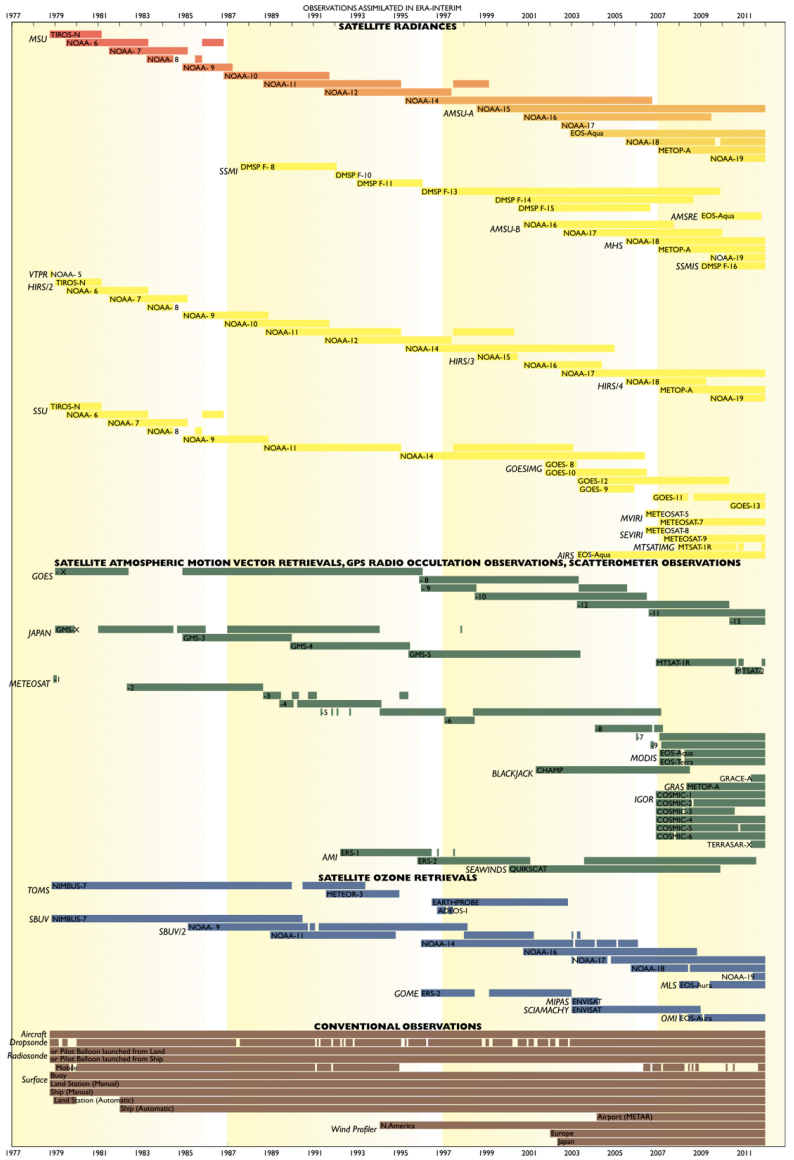
NWP input (GTS) after 2002, but:

- AIRS radiances since April 2003
- No data from TMI, IASI, ASCAT

Some reprocessed satellite data:

- ERS-1,2 wave height data
- A subset of AMV retrievals from EUMETSAT
- Ozone profiles from GOME on ERS-2
- GPS RO bending angles from CHAMP

More on this: Presentation by Paul Poli



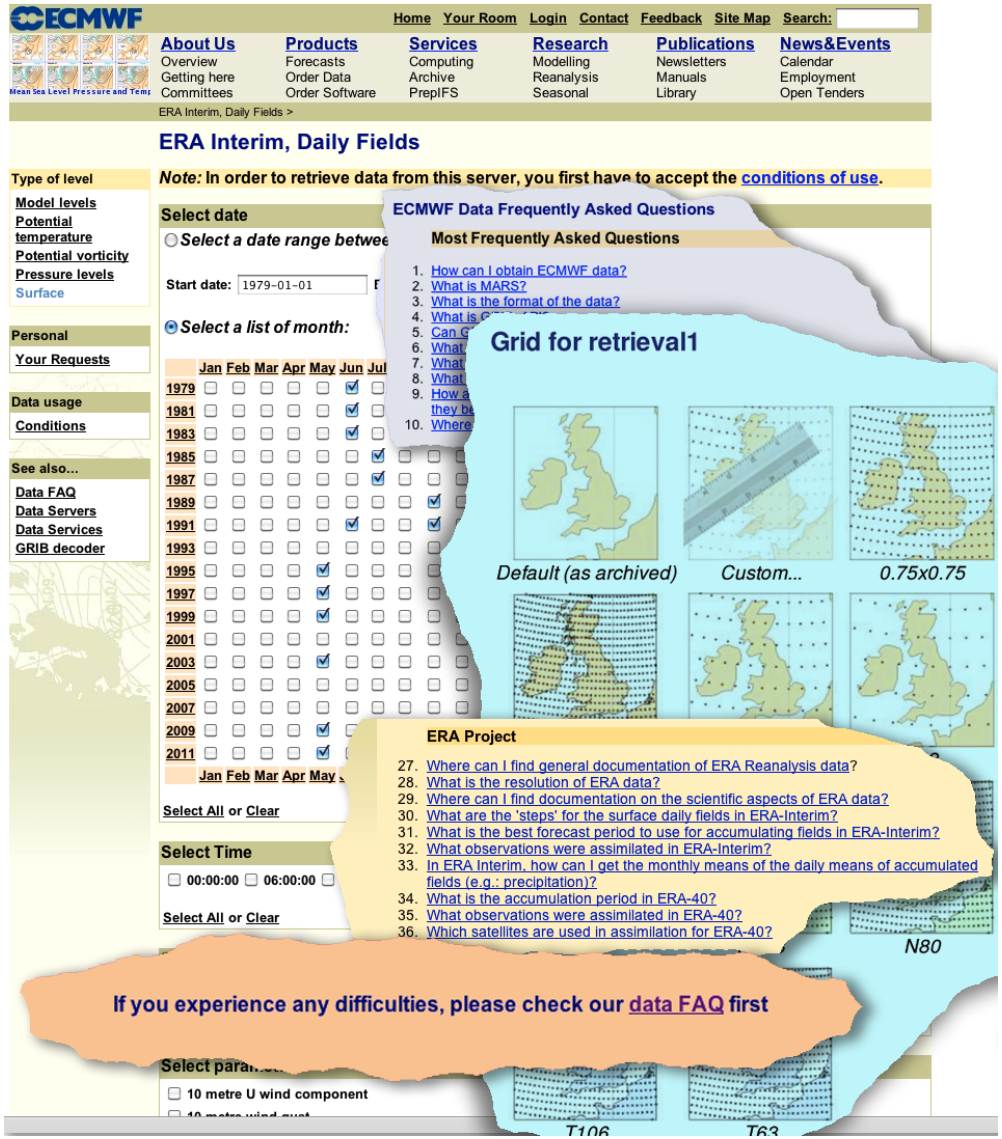
New data server: www.ecmwf.int/research/era

Gridded fields:

- ERA-Interim from 1979
- Data at full horizontal resolution and on model levels
- Options for regional selection and regridding, GRIB or NETCDF
- Less restrictive use conditions

Coming soon:

- Observation Feedback Archive (OFA)
- Dynamic selection of input observations by date, source, instrument, observable
- Filtering options (e.g. QC)
- Basic plots (maps, time series)
- Data retrieval: text or ODB



www.ecmwf.int/research/era

The ERA-Interim reanalysis: configuration and performance of the data assimilation system

D. P. Dee[a]*, S. M. Uppala[a], A. J. Simmons[a], P. Berrisford[a], P. Poli[a], S. Kobayashi[b], U. Andrae[c], M. A. Balmaseda[a], G. Balsamo[a], P. Bauer[a], P. Bechtold[a], A. C. M. Beljaars[a], L. van de Berg[d], J. Bidlot[a], N. Bormann[a], C. Delsol[a], R. Dragani[a], M. Fuentes[a], A. J. Geer[a], L. Haimberger[e], S. B. Healy[a], H. Hersbach[a], E. V. Hólm[a], L. Isaksen[a], P. Kållberg[c], M. Köhler[a], M. Matricardi[a], A. P. McNally[a], B. M. Monge-Sanz[f], J.-J. Morcrette[a], B.-K. Park[g], C. Peubey[a], P. de Rosnay[a], C. Tavolato[e], J.-N. Thépaut[a] and F. Vitart[a]

Q. J. R. Meteorol. Soc. 137: 553–597, April 2011 A

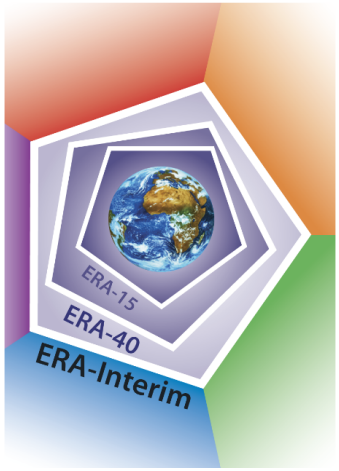
ERA report series

1 The ERA-Interim archive

Version 2.0

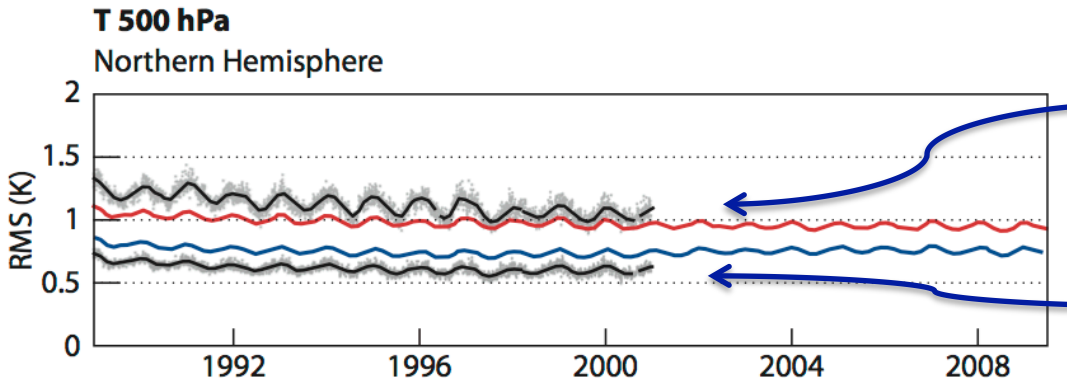
Paul Berrisford, Dick Dee, Paul Poli, Roger Brugge, Keith Fielding, Manuel Fuentes, Per Kållberg, Shinya Kobayashi, Sakari Uppala and Adrian Simmons

Berrisford, P., P. Kållberg, S. Kobayashi, D. P. Dee, S. Uppala, A. J. Simmons P. Poli, and H. Sato, 2011: **Atmospheric conservation properties in ERA-Interim.** *Q. J. R. Meteorol. Soc.*, **137**, 1381-1399.



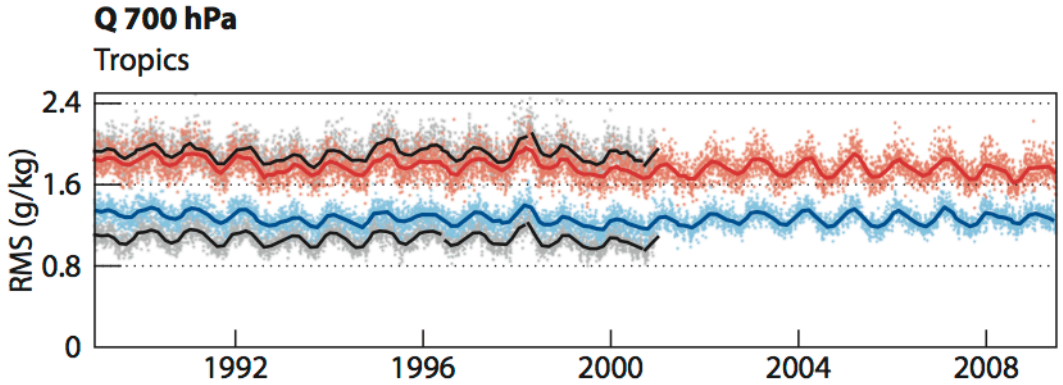
- Poli, P., S. B. Healy, and D. P. Dee, 2010: Assimilation of Global Positioning System Radio Occultation data in the ECMWF ERA-Interim reanalysis. *Quart. J. R. Meteorol. Soc.*, 136, 1972-1990.
- Simmons, A. J., K. M. Willett, P. D. Jones, P. W. Thorne, and D. P. Dee, 2010: Low-frequency variations in surface atmospheric humidity, temperature and precipitation: Inferences from reanalyses and monthly gridded observational datasets. *J. Geophys. Res.*, 115, D01110, doi:10.1029/2009JD012442.
- Kobayashi, S., M. Matricardi, D. P. Dee, and S. Uppala, 2009: Toward a consistent reanalysis of the upper stratosphere based on radiance measurements from SSU and AMSU-A. *Quart. J. R. Meteorol. Soc.*, 135, 2086-2099.
- Dee, D. P., and S. Uppala, 2009: Variational bias correction of satellite radiance data in the ERA-Interim reanalysis. *Quart. J. R. Meteorol. Soc.*, 135, 1830-1841.

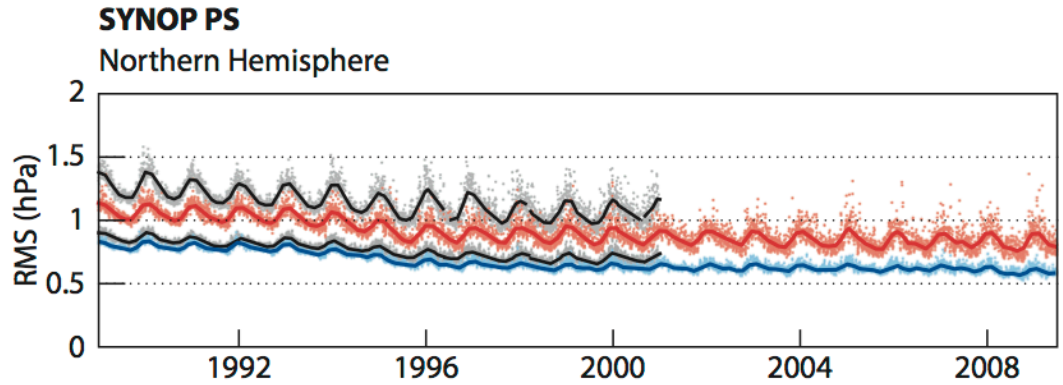
ERA-Interim: Fit to observations



background departures
ERA-Interim, ERA-40

analysis departures
ERA-Interim, ERA-40





ERA-Interim vs ERA-40:

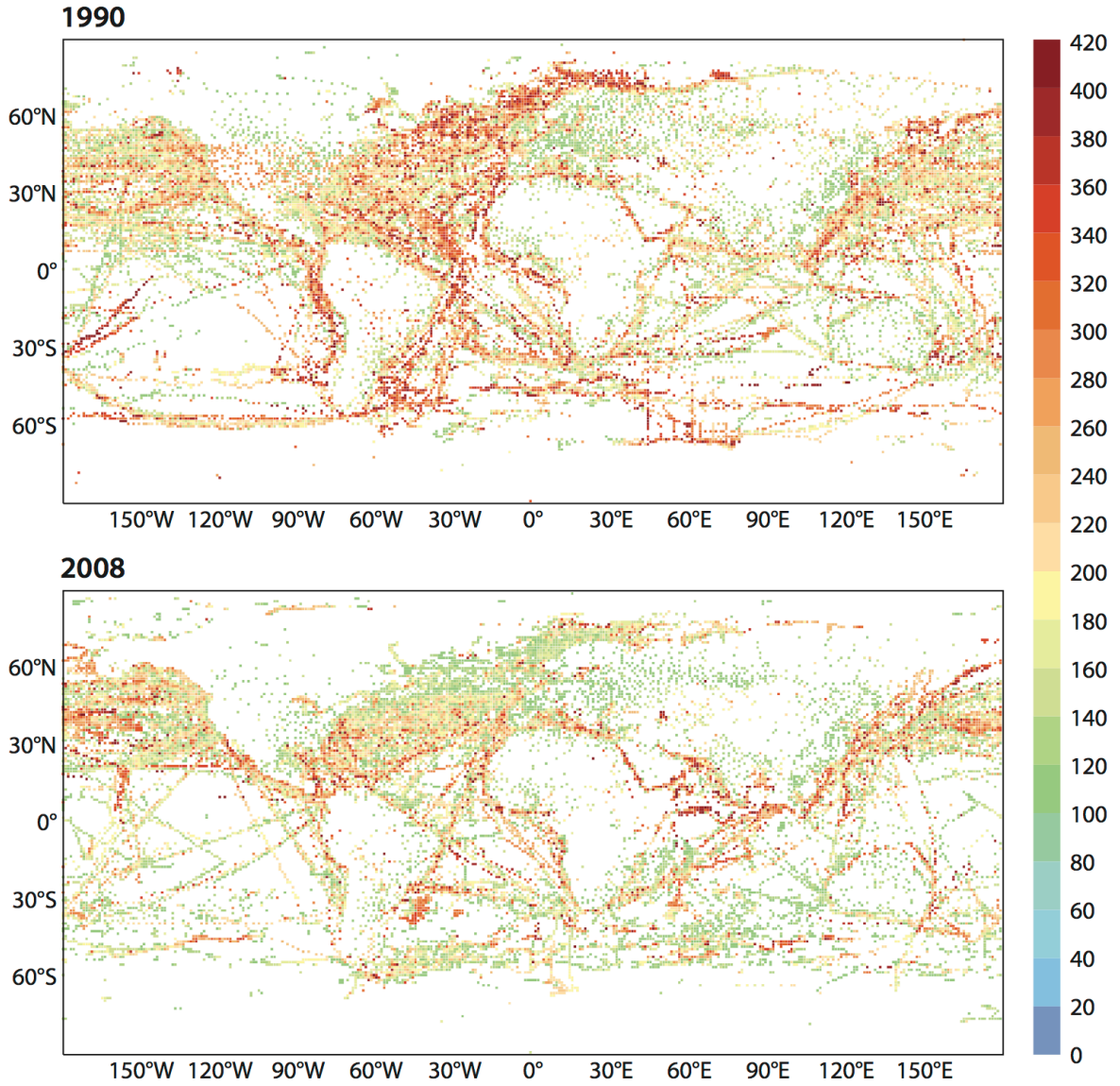
- Reduced background departures
- Reduced analysis increments
- More uniform in space/time/variables

ERA-Interim: Bias correction schemes

- Surface pressure observations:
  - Sequential bias estimation using background departures
  - Separately for each station, ship, or buoy
  - Attempts to prevent impact of model bias
- Temperatures from radiosondes:
  - Off-line break-point adjustments based on ERA-40 departures (RAOBCORE 1.4)
  - Sequential estimation of radiative biases, for groups of stations
- Satellite radiances:
  - Bias estimates updated using the variational analysis (VarBC)
  - Separately for each instrument, channel
  - Based on simple predictor models – i.e. a few parameters per channel

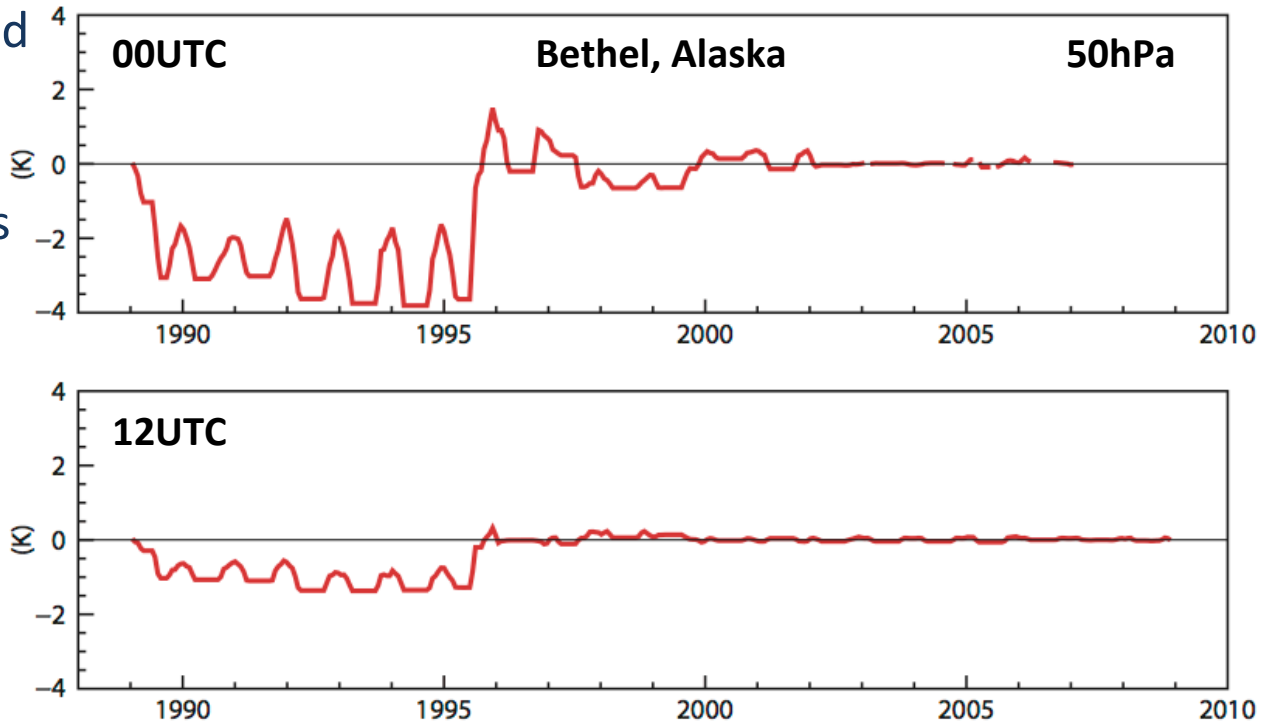
Surface pressure bias corrections

- Shown are rms bias corrections for all data used in 1990 and 2008
- Overall corrections reduce with time
- Some exceptions – e.g. Indian Ocean
- Can these estimates be used to improve the record?
- This scheme to be replaced with VarBC (Paul Poli)



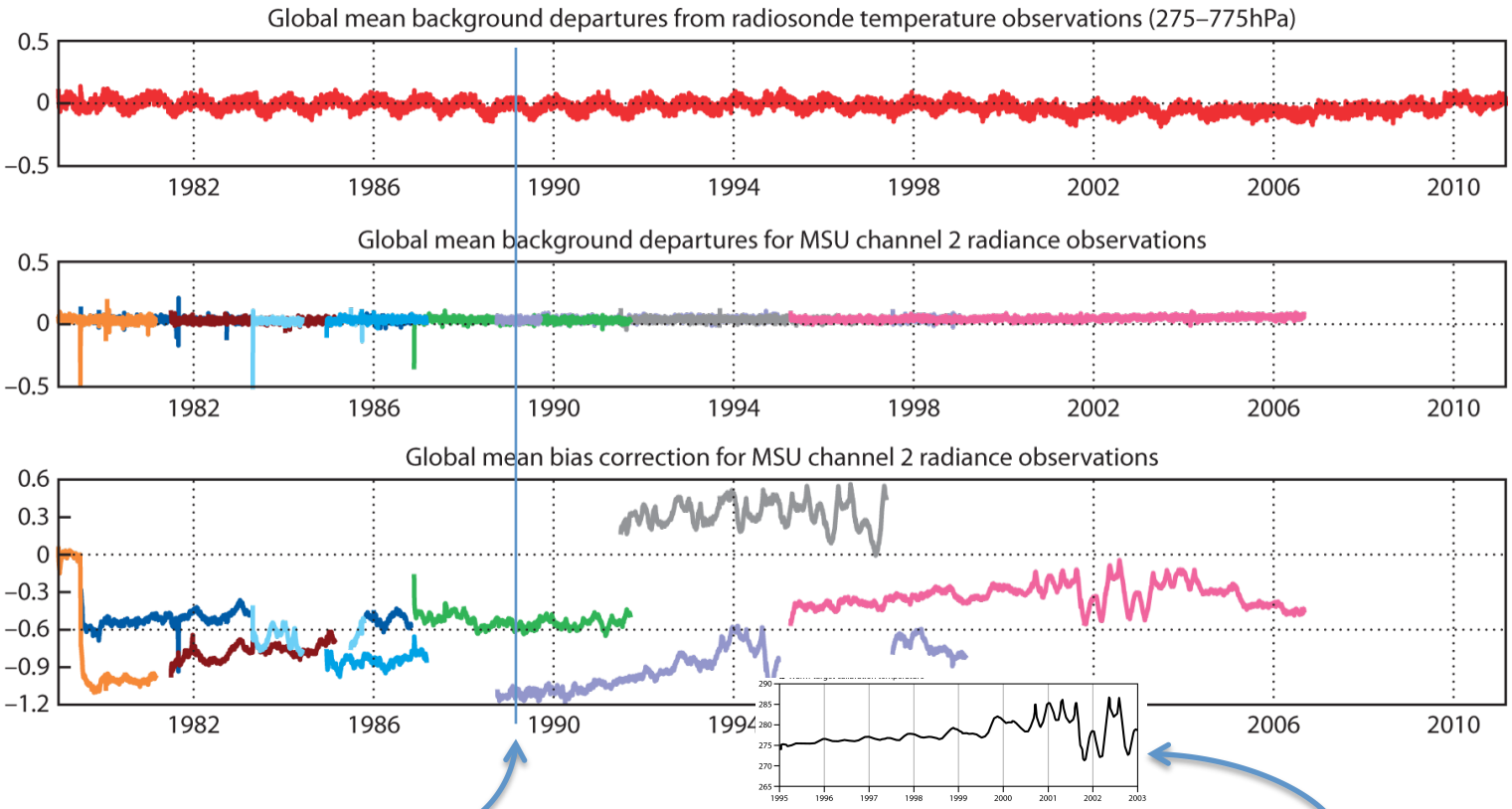
Radiosonde temperature bias corrections

- Daytime (00UTC) and nighttime (12UTC) bias corrections for 50hPa temperatures at Bethel, Alaska
- Large radiation errors at high latitudes, low solar elevation (annual cycle)
- Large shifts in 1989 and 1995 due to equipment changes



More on this: Presentations by Leo Haimberger, Marco Milan

Satellite radiance bias corrections

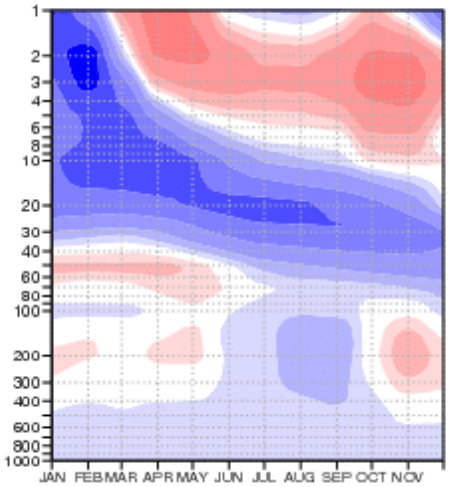


Jan 1989: Transition between two production streams

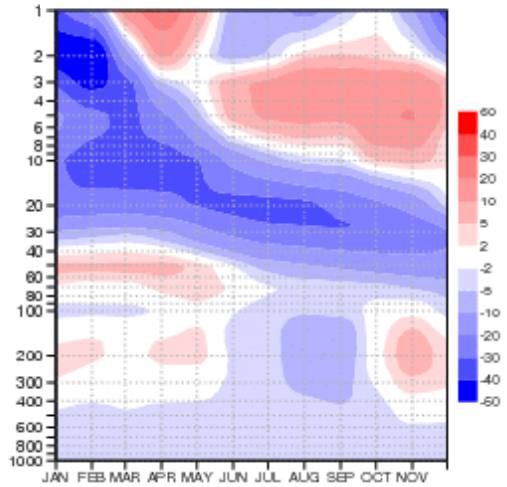
NOAA-14 recorded warm-target temperature changes, due to orbital drift (Grody et al. 2004)

ERA-Interim extension: 1979-1989

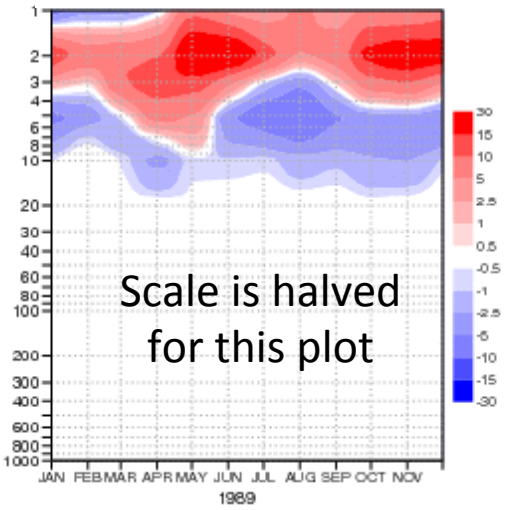
1989, stream 2



1989, stream 1

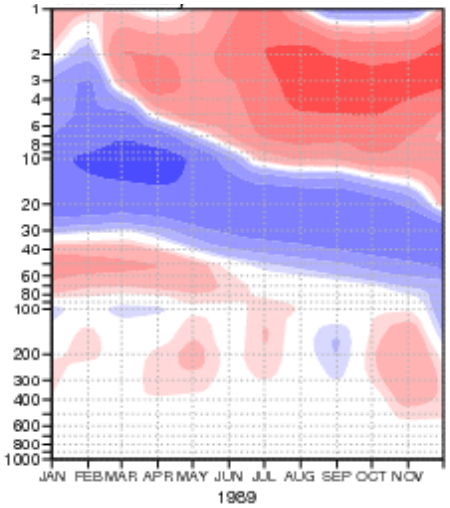


difference

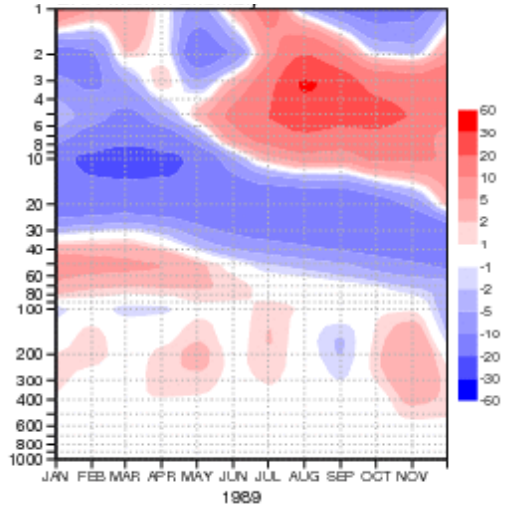


Scale is halved for this plot

anomaly, stream 2



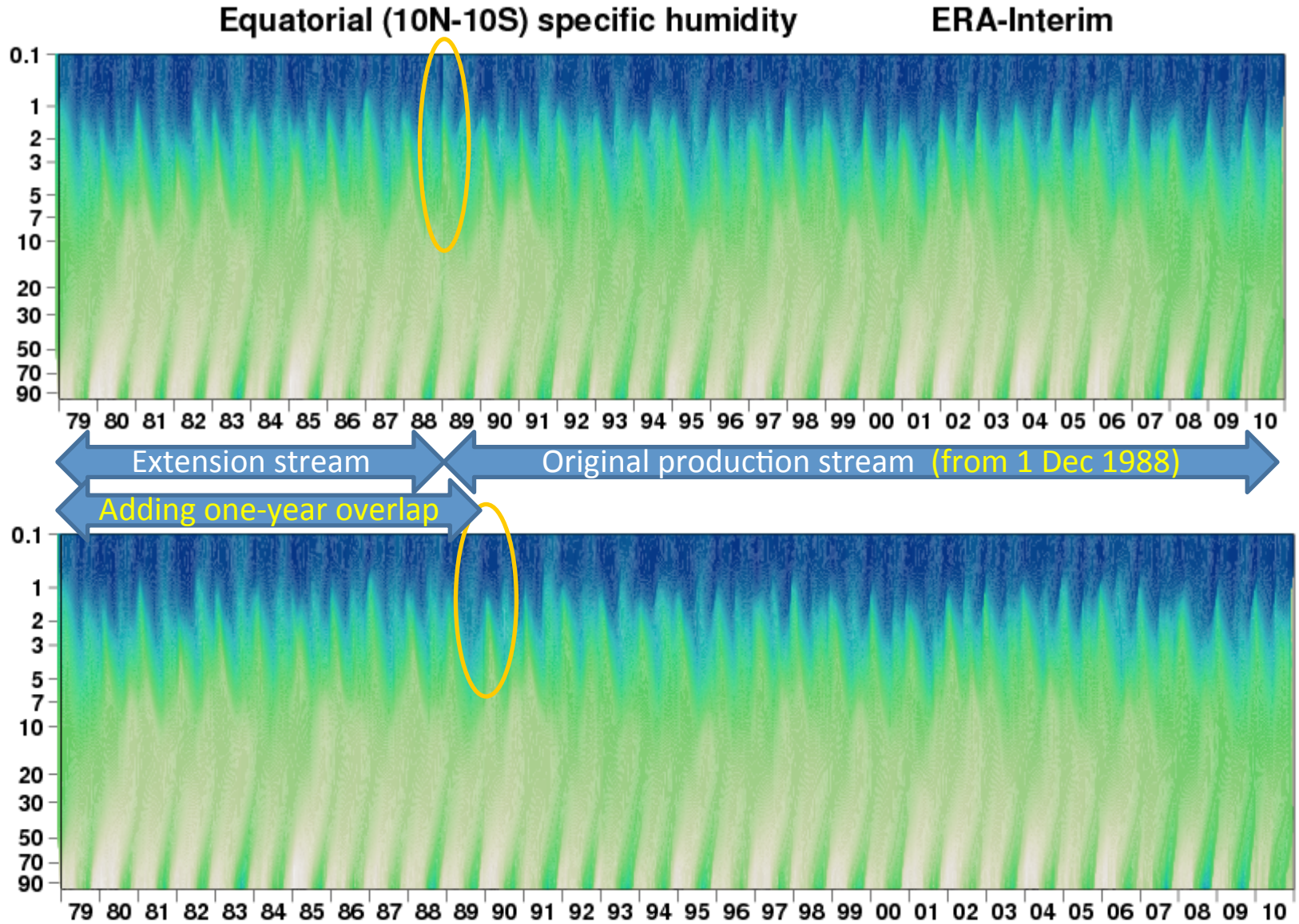
anomaly, stream 1



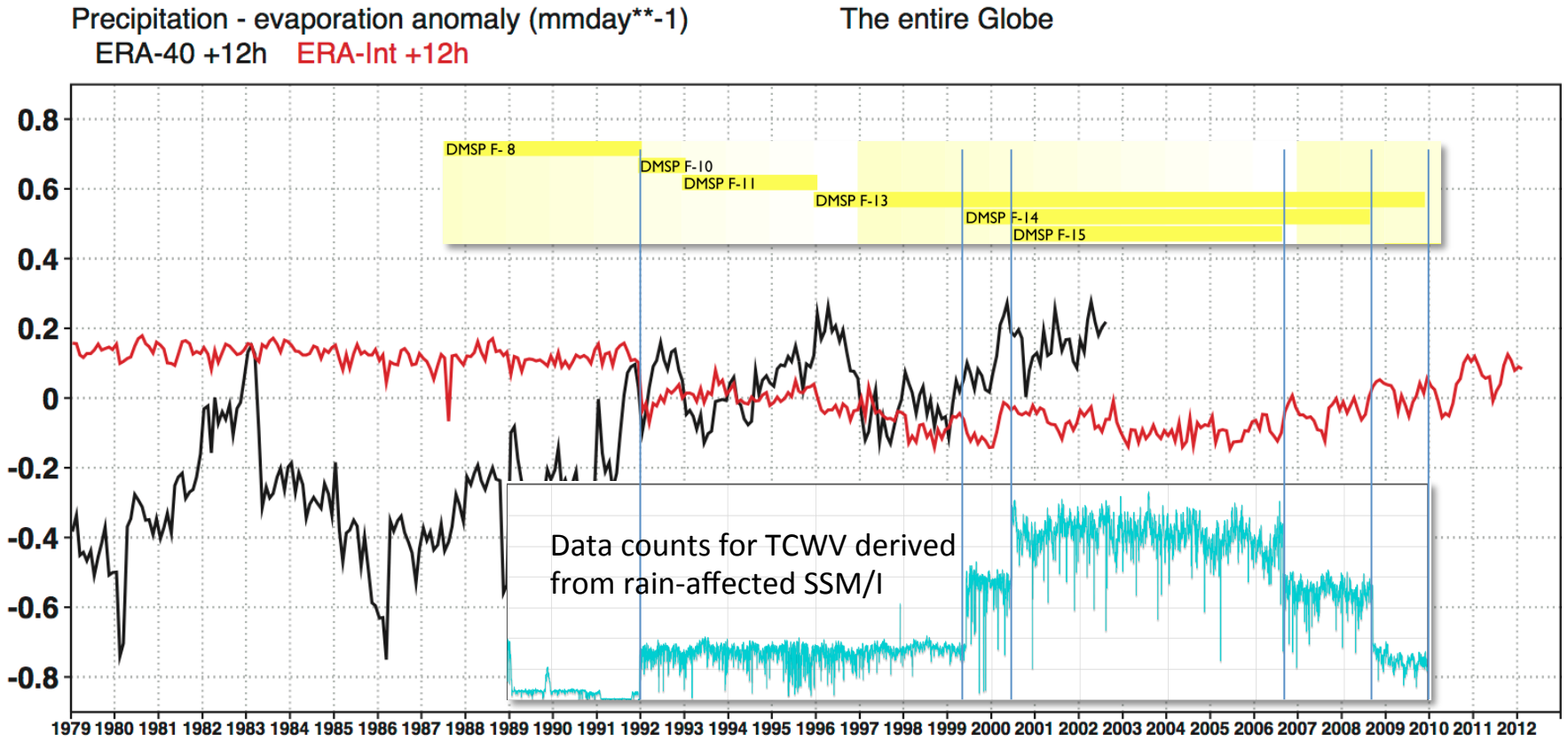
Overlap between two streams:

Zonal mean U (10S-10N)

ERA-Interim extension: 1979-1989



Spurious shifts in global mean precipitation



- Shifts are mainly due to 1D+4D-Var assimilation of rain-affected radiances
- This has been experimentally verified, and is now fully understood *(Geer et al. 2008)*
- The introduction of clear-sky SSM/I does not appear to affect the global mean
- Good prospects for improvement

A fundamental limitation

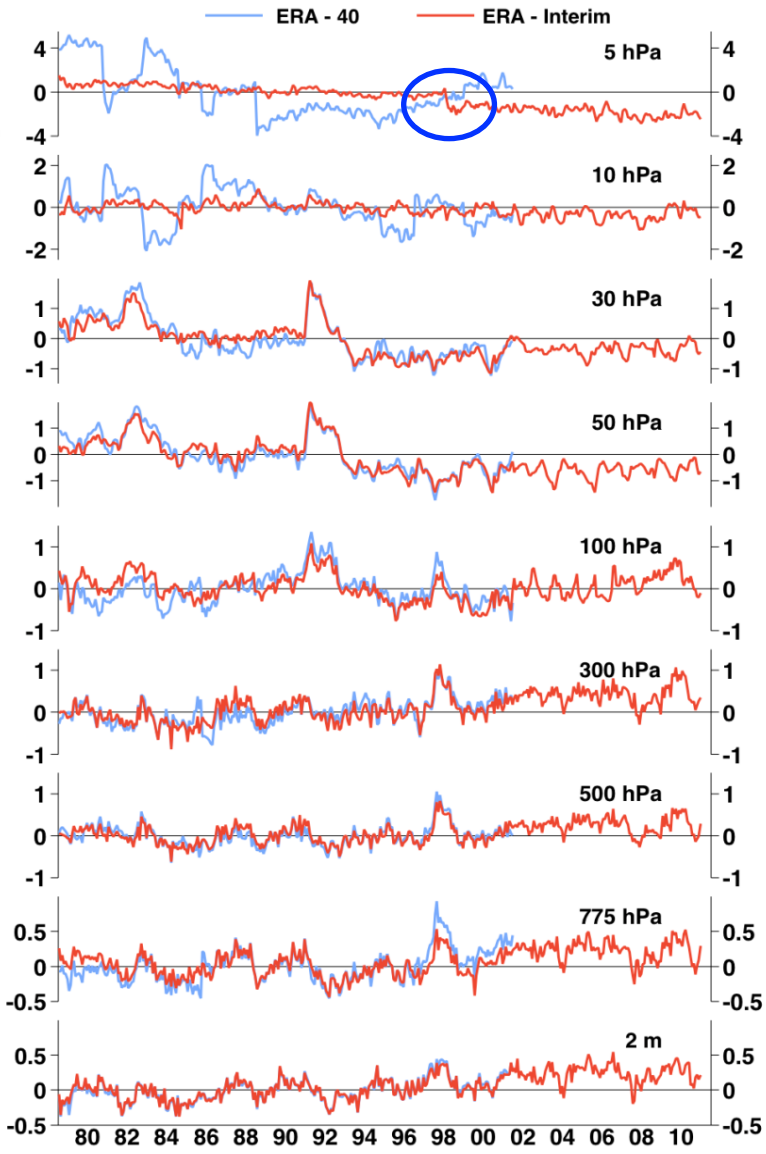
Global temperature anomalies from **ERA-Interim** and **ERA-40**

Upper stratosphere: Large model bias, only partly constrained by SSU prior to 1998, then by AMSU-A

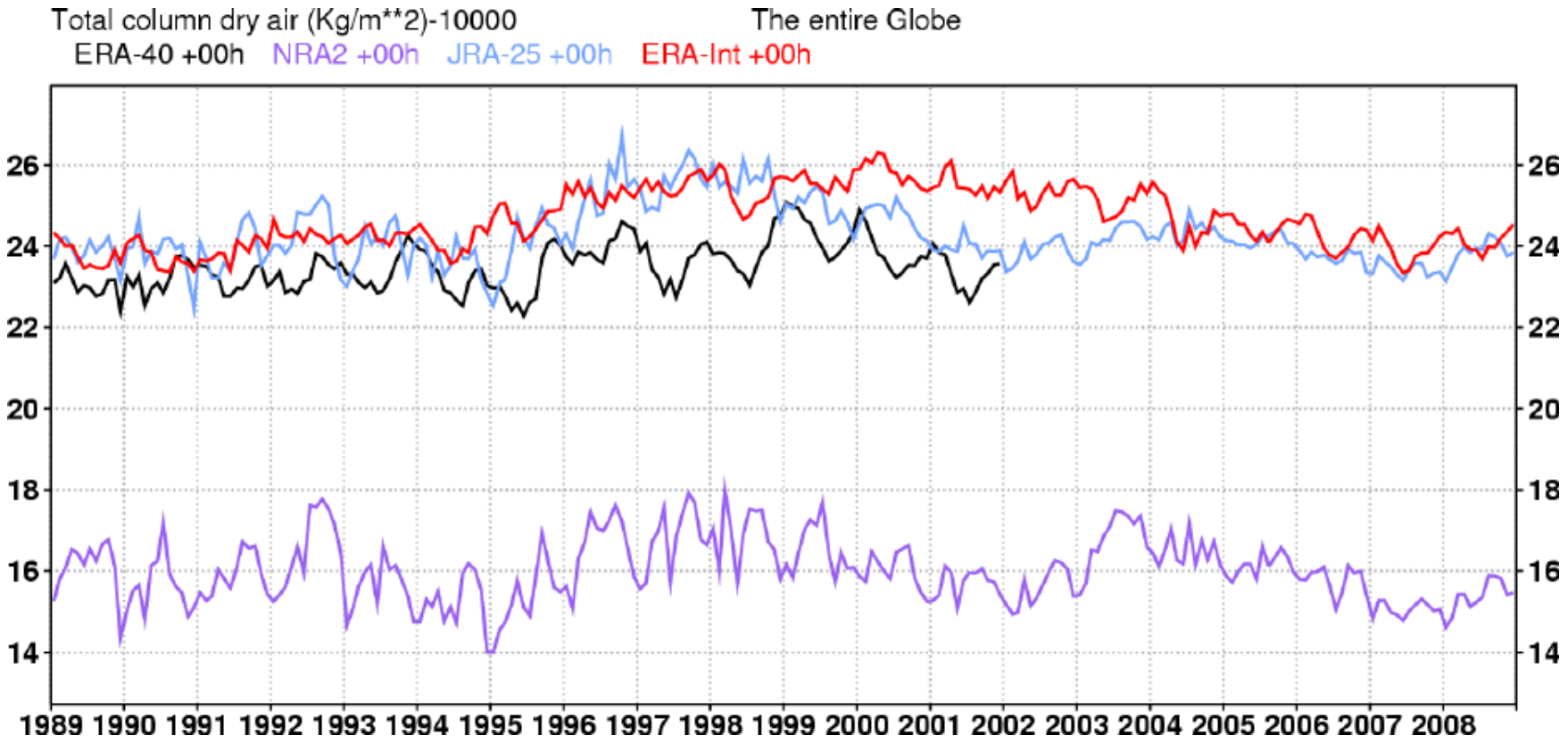
A spurious shift is inevitable in this case

Model biases can be corrected in data assimilation – but that requires accurate observations

Ultimately the accuracy of a reanalysis is limited by available observations

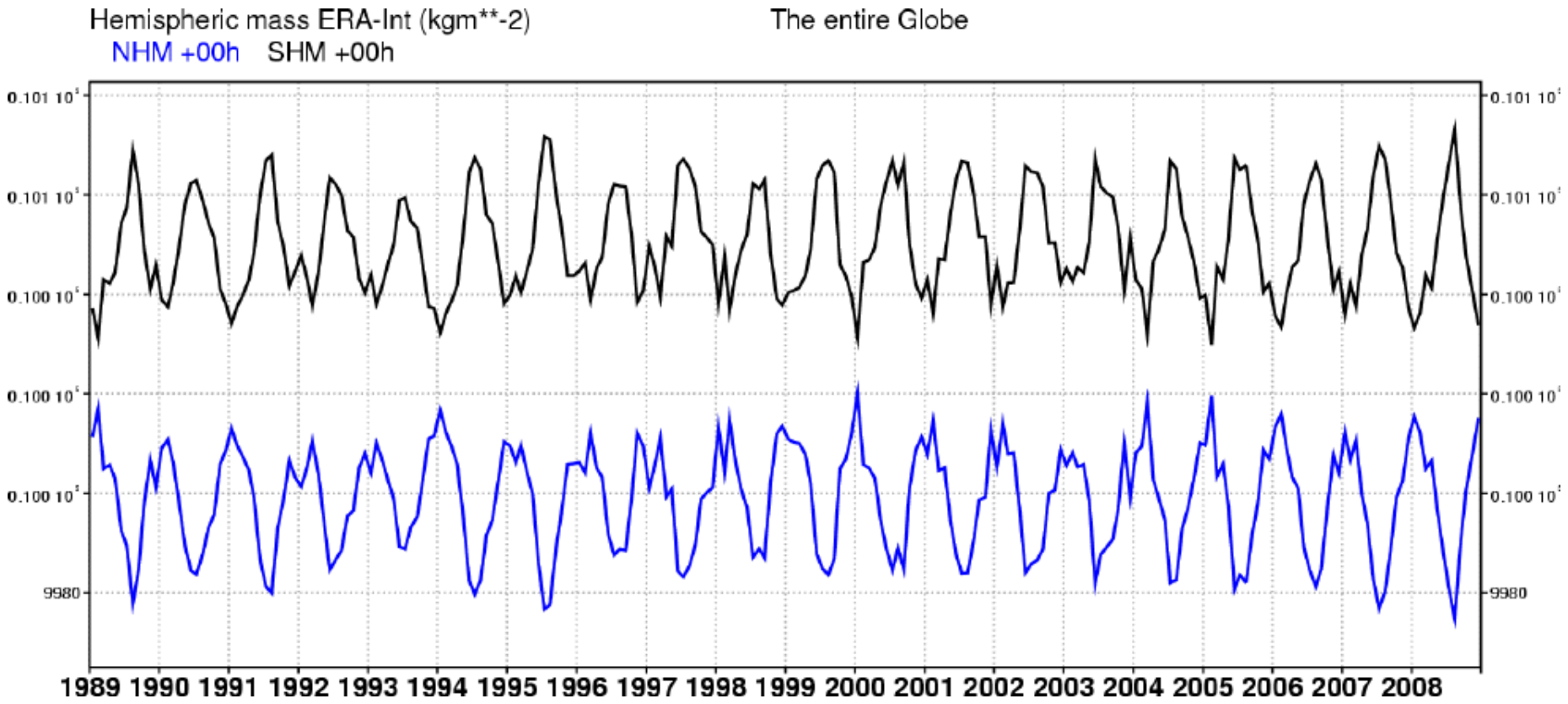


Mass conservation



Variations in mass generally within 0.04%

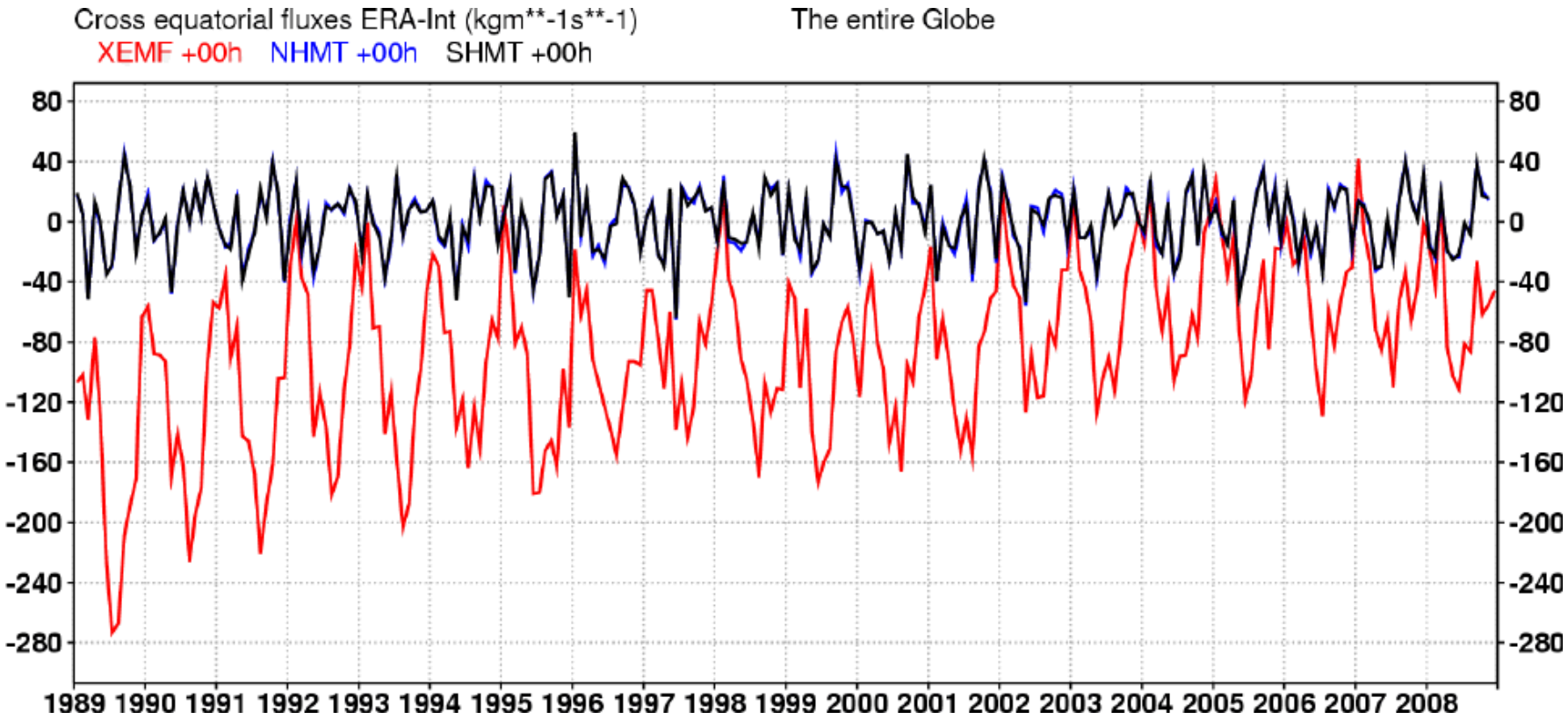
Hemispheric mass variations



Inconsistencies in the mass budget

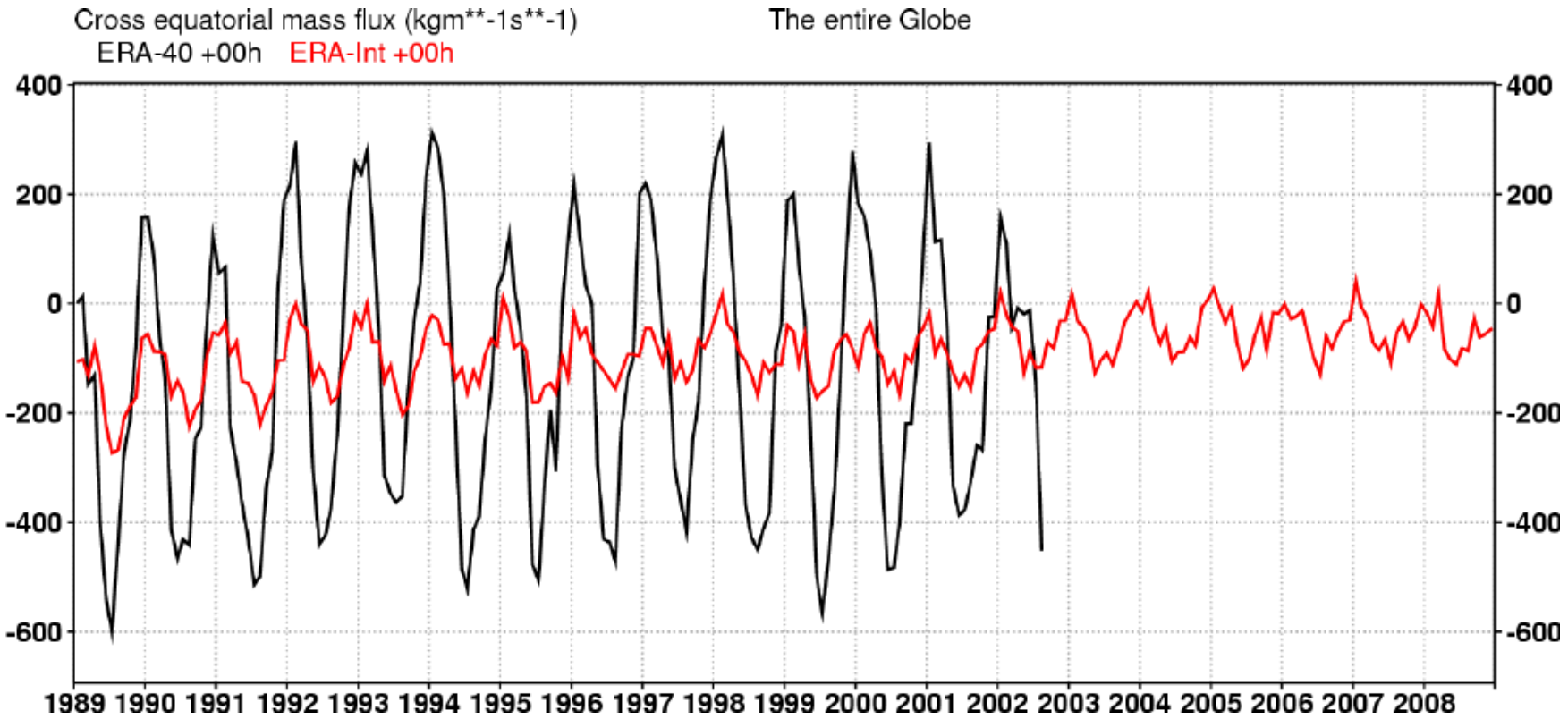
Cross-equatorial mass fluxes computed in two ways:

- using tendencies of the hemispheric mass fields (NH, SH)
- using convergence of vertically integrated mass fluxes



Evidence of improvement

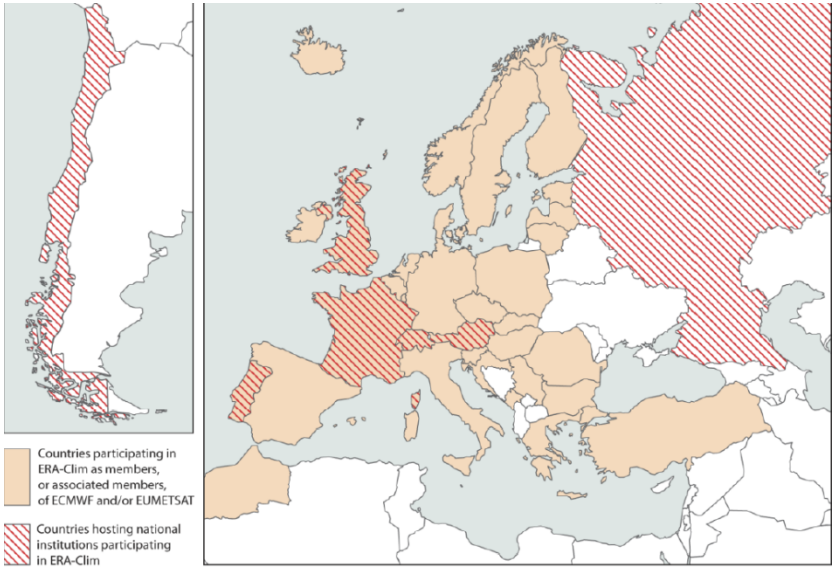
- Consistency much better in ERA-Interim than in ERA-40
- Discrepancy is due to poorly constrained tropical divergent winds
- Improves with time, with the quality of the observing system



Current work at ECMWF: The ERA-CLIM project

ERA-CLIM: A 3-year collaborative research project coordinated by ECMWF, supported by the EU's FP7

Goal: Prepare input observations, model data, and data assimilation systems for a global atmospheric reanalysis of the 20th century – to begin production in 2014



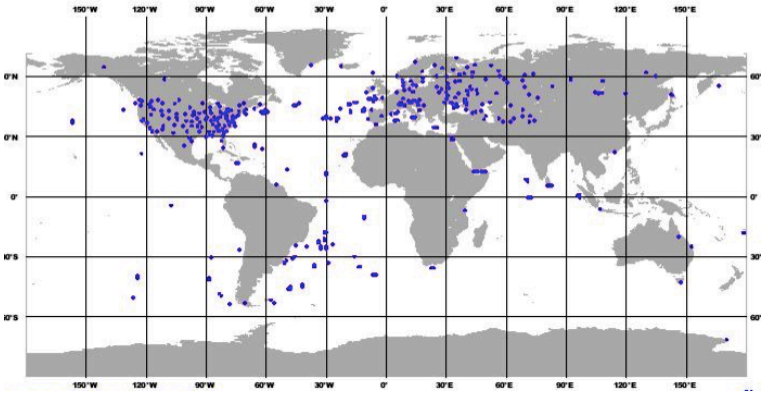
Work plan:

1. Data rescue efforts (in-situ upper-air and satellite observations)
2. Incremental development of new reanalysis products
3. Use of reanalysis feedback to improve the data record
4. Access to reanalysis data and observation quality information

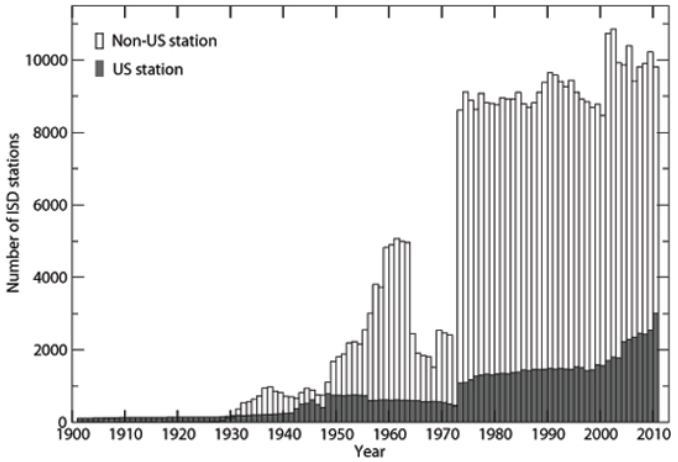
Data rescue: Surface weather observations

Major data collections: ICOADS; ISPD (from 1755); ISD (from 1901)

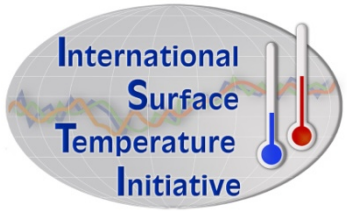
ISPD stations on a random date in 1900



ISD station counts over time

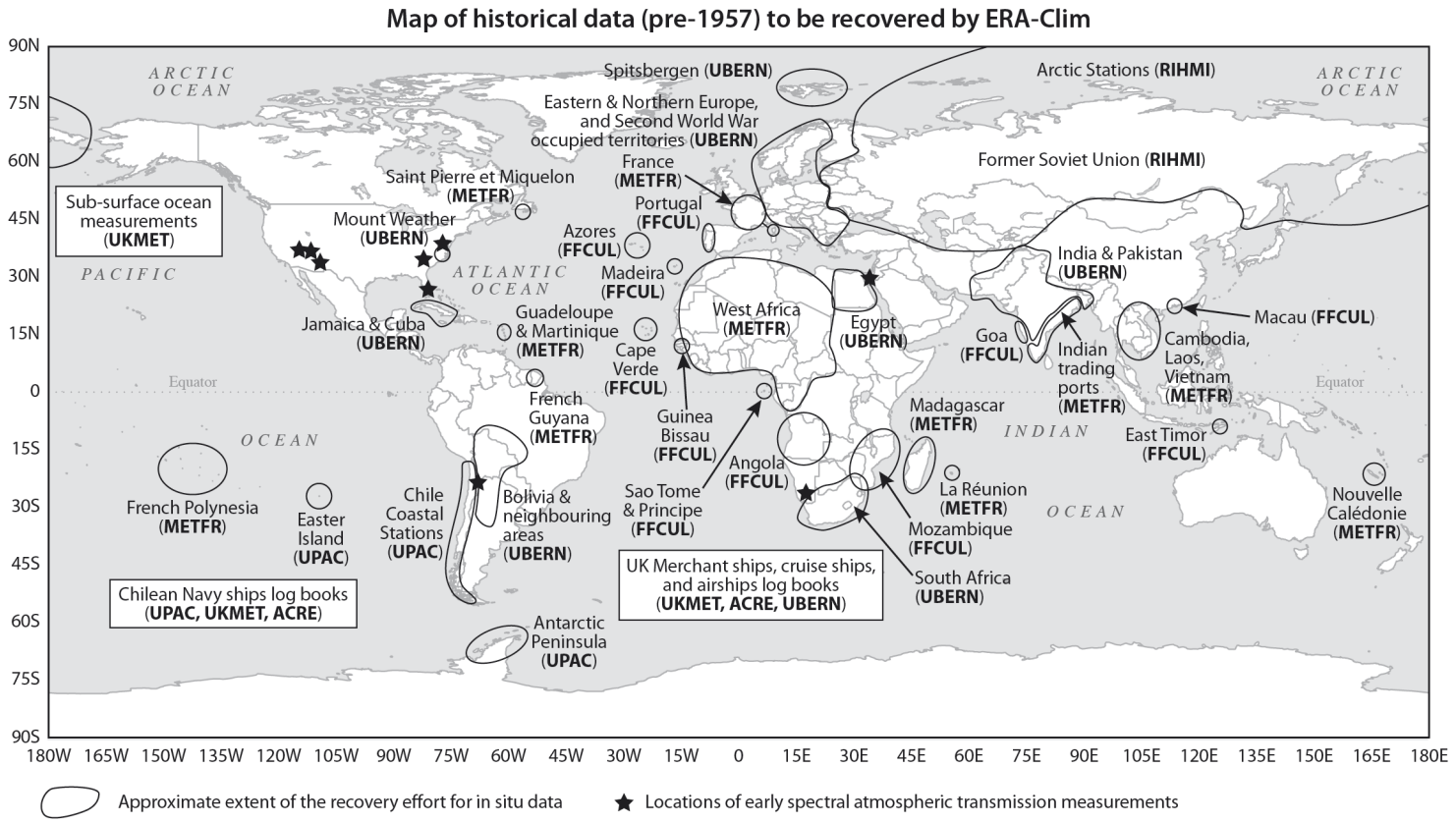


- Poor coverage outside Europe and North America
- Many data not yet in digital form: could easily disappear
- Sub-daily weather observations over land are not well organised (ISTI?)
- More on this: Presentation by Hans Hersbach



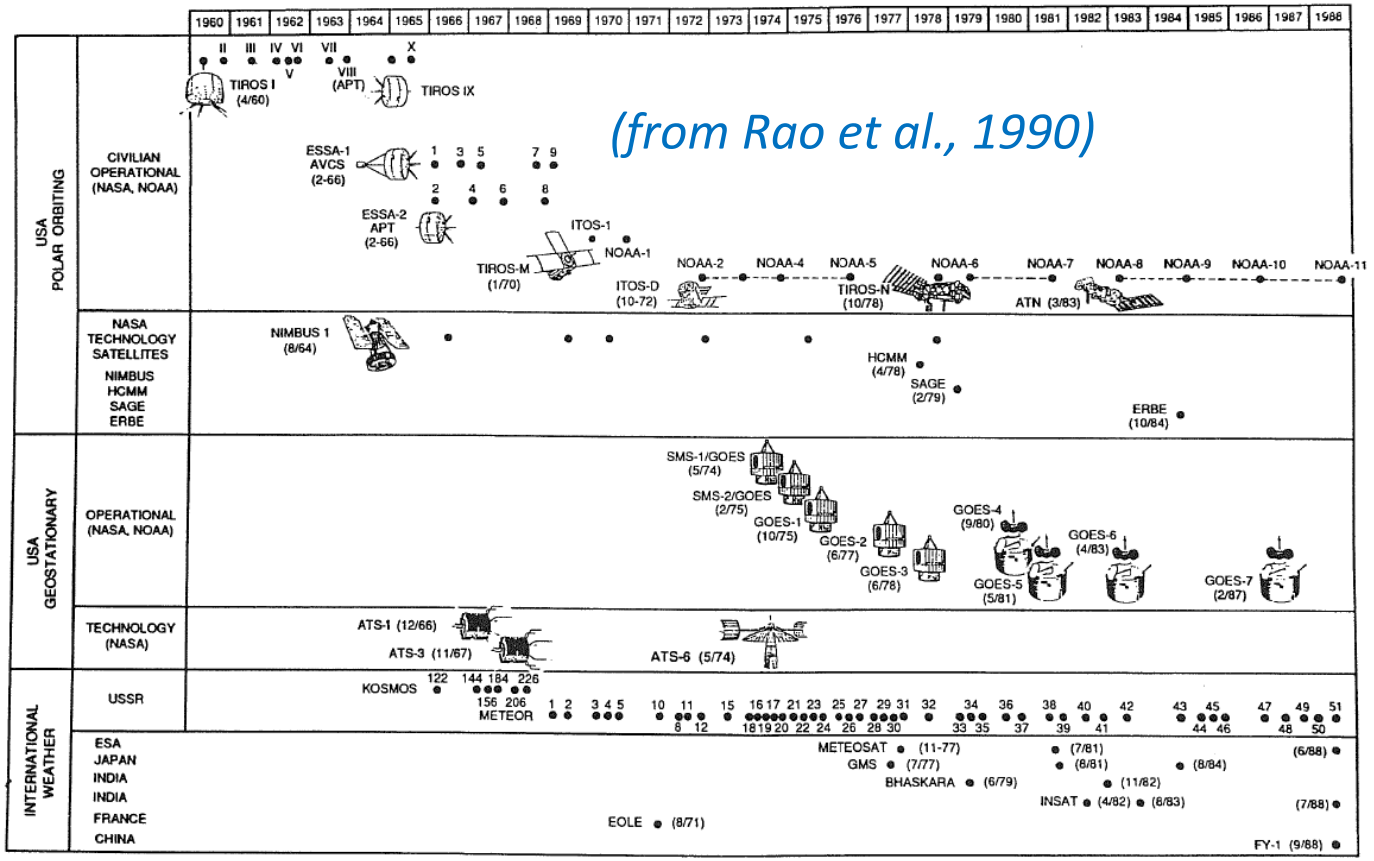
Data rescue in ERA-CLIM: In-situ observations

- Focus on upper-air weather observations in poorly covered regions
- Data rescue, digitisation, and preliminary quality control



Data rescue in ERA-CLIM: Satellite observations

- Can we extend the usable satellite record back to the 1960's?
- Data rescue; development of observation operators; first screening
- More on this: Presentations by R. Saunders, J. Schulz



(from Rao et al., 1990)

ERA-CLIM reanalysis development

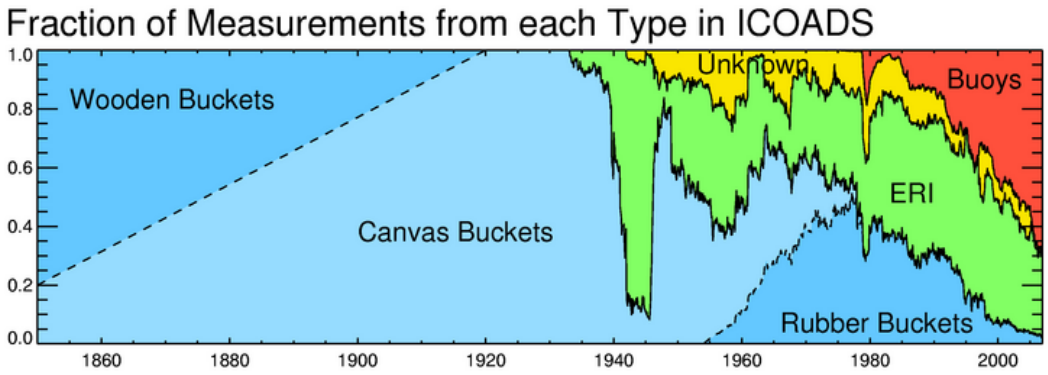
First step: An ensemble of (atmospheric) climate model integrations

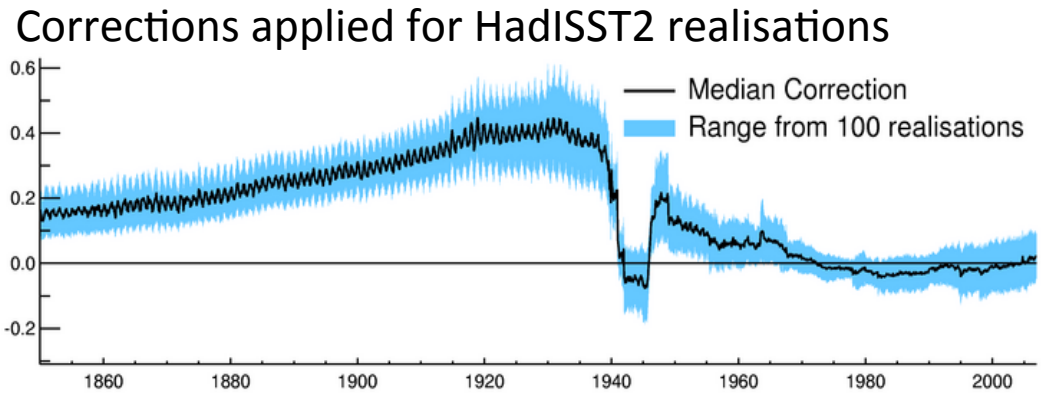
- Atmospheric forcing based on CMIP5 input data
- An ensemble of SST/sea-ice estimates from HadISST2

HadISST2 will provide any number of equally plausible SST reconstructions

Key uncertainties arise from unknown error characteristics of SST measurements

(N. Rayner, MetOffice Hadley Centre)





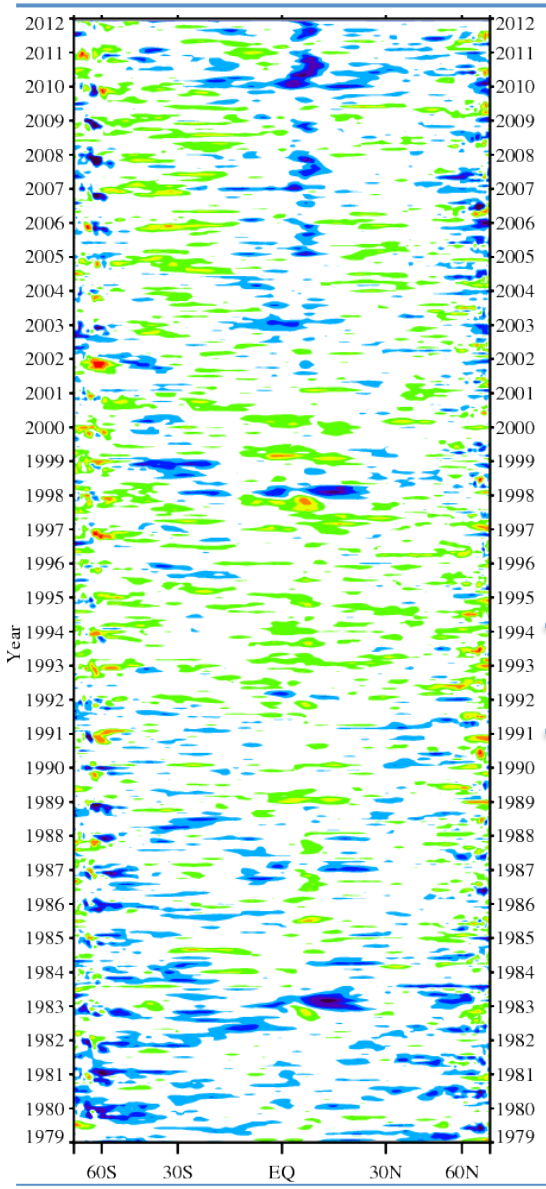
ERA-CLIM reanalysis development

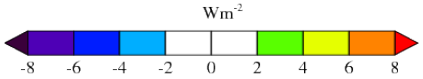
Next: A succession of new reanalysis products

- ERA-20C: 20th Century reanalysis using surface pressure observations only
- ERA-SAT: A new reanalysis of the satellite era (to replace ERA-Interim)

ERA-20CM	Ensemble of model integrations, using HadISST2 and CMIP5 forcing	T159 10 members	
ERA-20C	Reanalysis of surface pressure observations	T159 10 members	Available mid 2013
ERA-20CL	Land-surface only; forced by ERA-20C	T799 10 members	Available mid 2013
ERA-SAT	New reanalysis of the satellite era	T511 To replace ERA-Interim	Available mid 2014

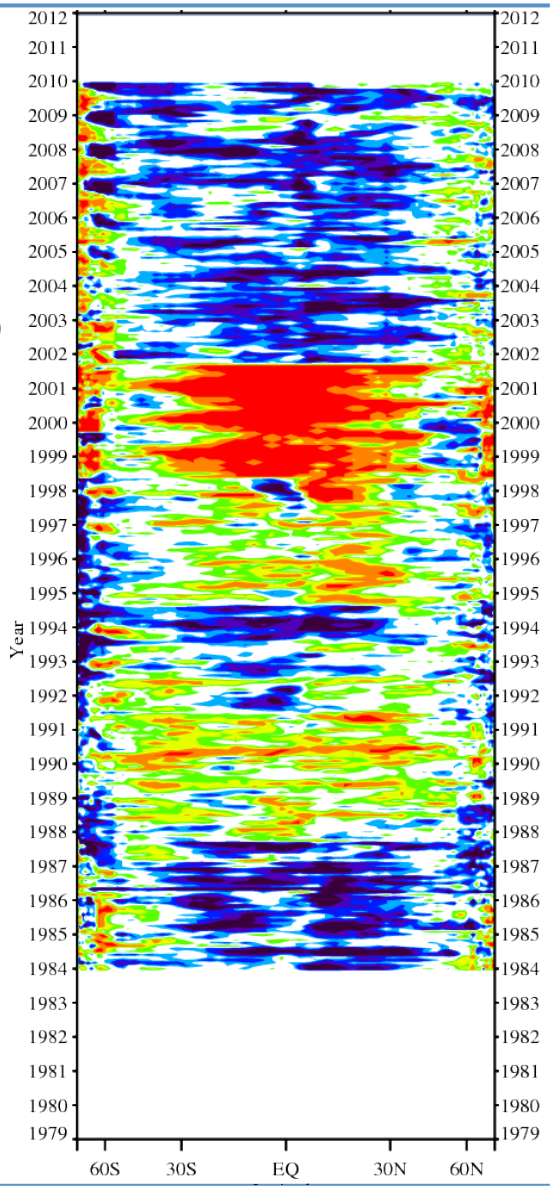
TOA radiation balance





ERA-Interim

ISCCP-FD



No volcanic aerosol in the model

(Michael Mayer)