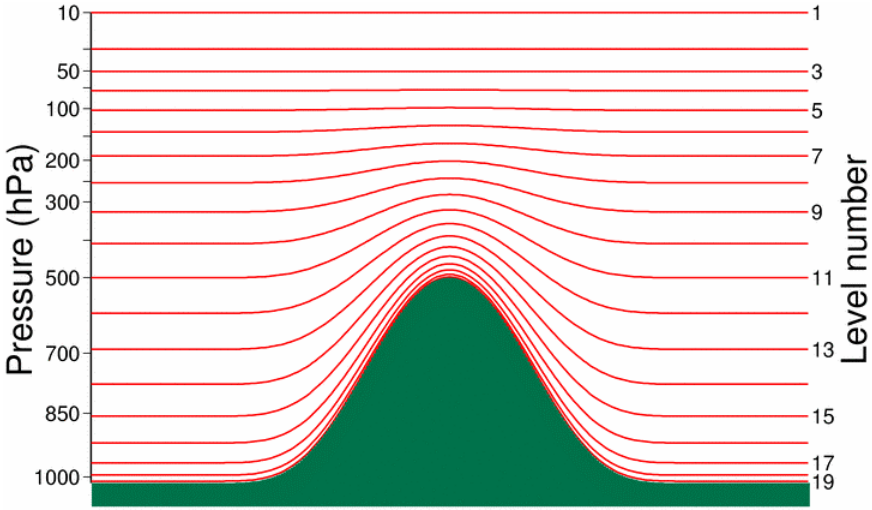
Representation of the stratosphere in ECMWF operations and ERA-40

- History
- Time series of forecast verification statistics
- Wind increments, PV and parametrized gravity-wave drag
- Forecast accuracy: The Antarctic sudden warming of 2002
- Some aspects of ERA-40, and comparison with operations:
  - Temperature trends
  - Bias correction
  - Radiance assimilation
  - Moisture and ozone
  - QBO

with acknowledgements to many at ECMWF

Versions of the operational forecasting system



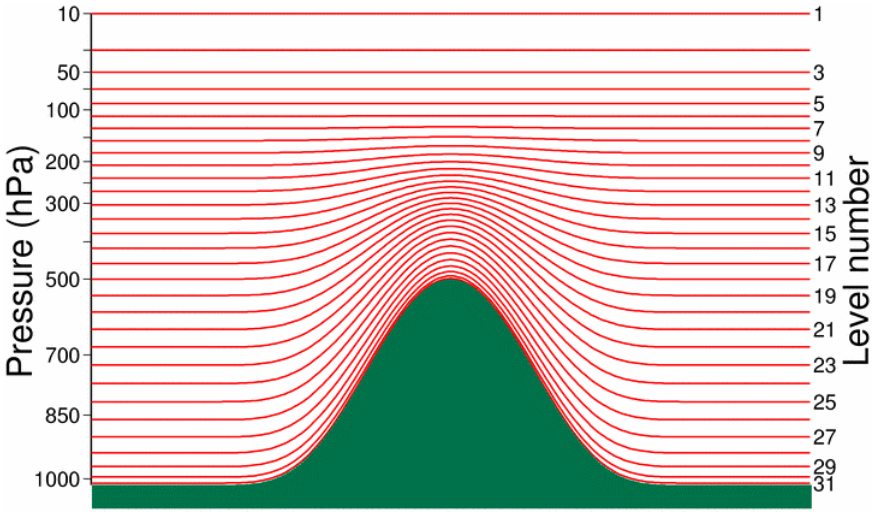
May 1986

19 levels

4 levels above 100hPa

10 hPa top

T106 (~125km) horizontal resolution



September 1991

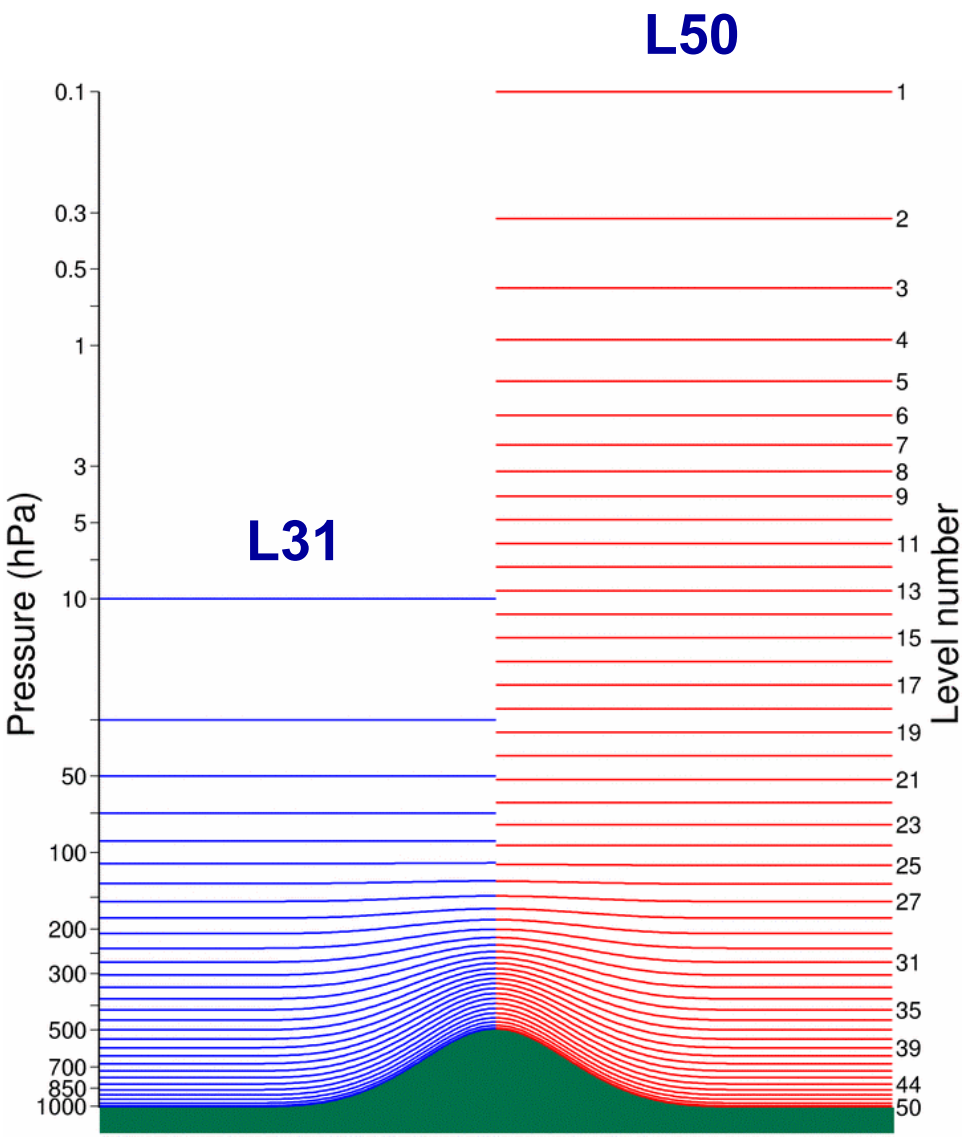
31 levels

5 levels above 100hPa

10 hPa top

T213 (~60km) horizontal resolution

Versions of the operational and reanalysis systems



For ERA-15 (1979-1994):

T106 (~125km) horiz. res.

OI analysis

January 1996

OI analysis replaced by 3D-Var in operations

March 1999

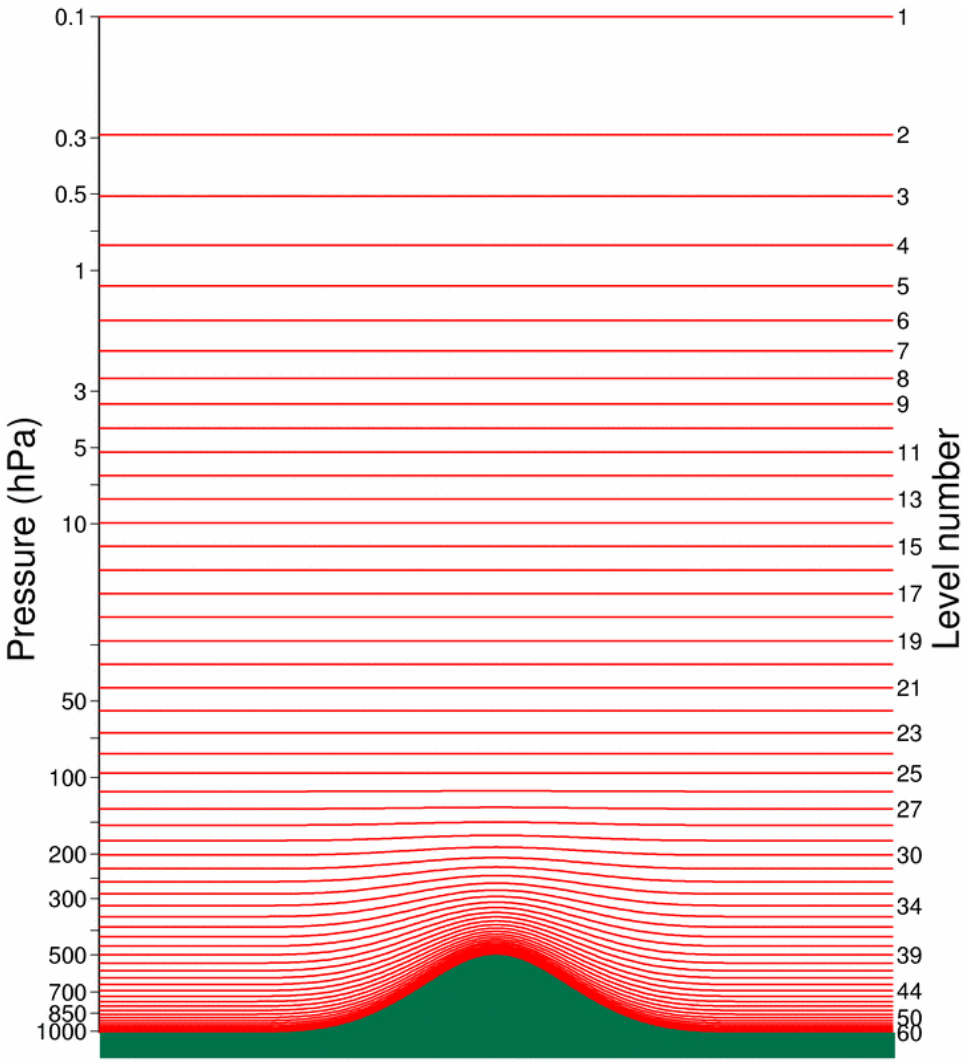
50 levels

24 levels above 100hPa

0.1hPa top

6-hourly 4D-Var analysis

Today's operational and ERA-40 system



Since October 1999:

60 levels

25 levels above 100hPa

0.1hPa top

Since November 2000:

T511 (~40km) horiz. res.

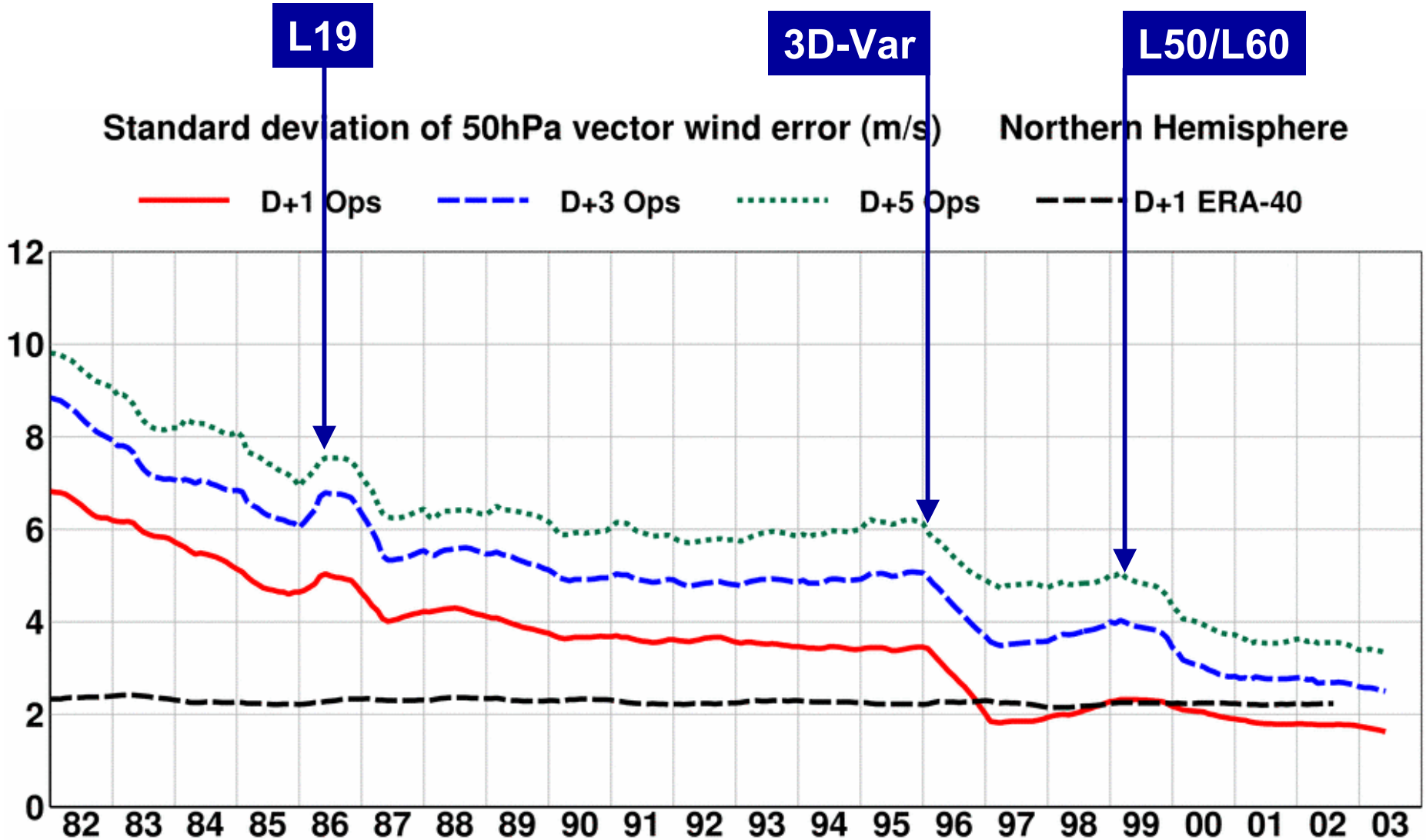
12-hourly 4D-Var analysis

For ERA-40 (1957-2002):

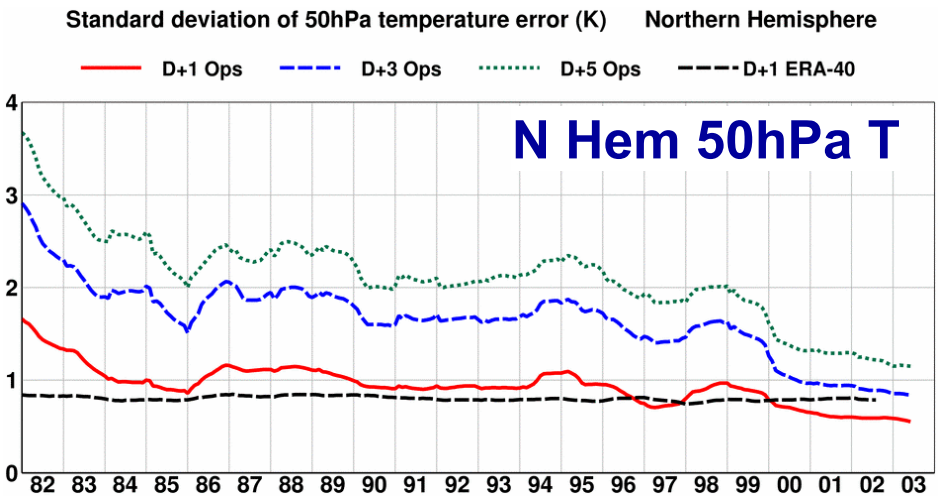
T159 (~125km) horiz. res.

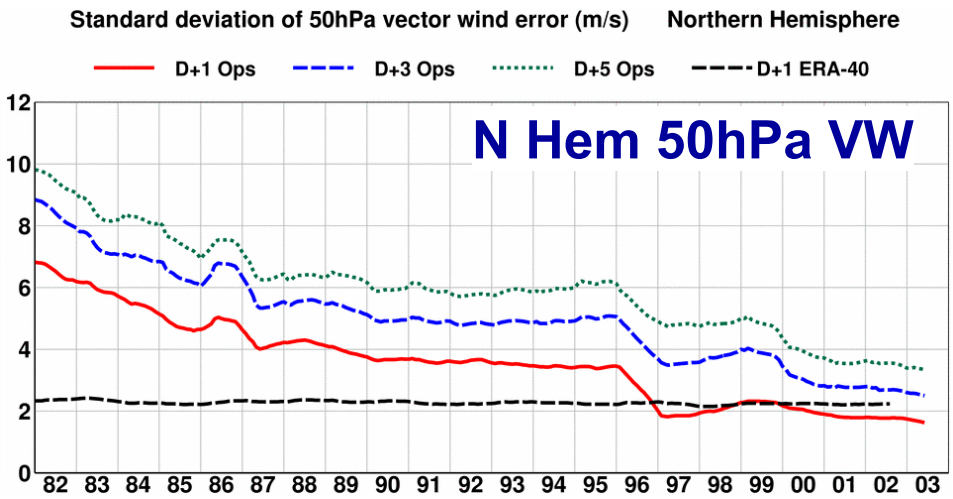
6-hourly 3D-Var analysis

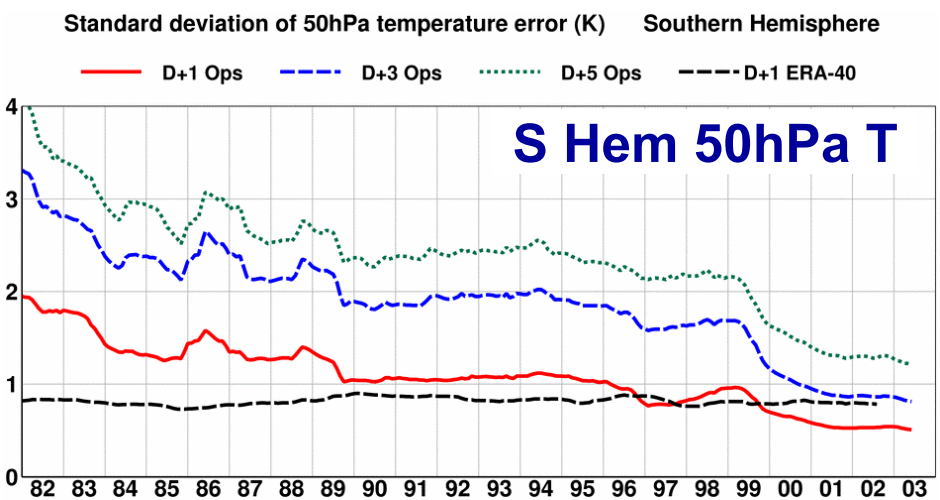
Annual running-mean forecast verification (against analyses)

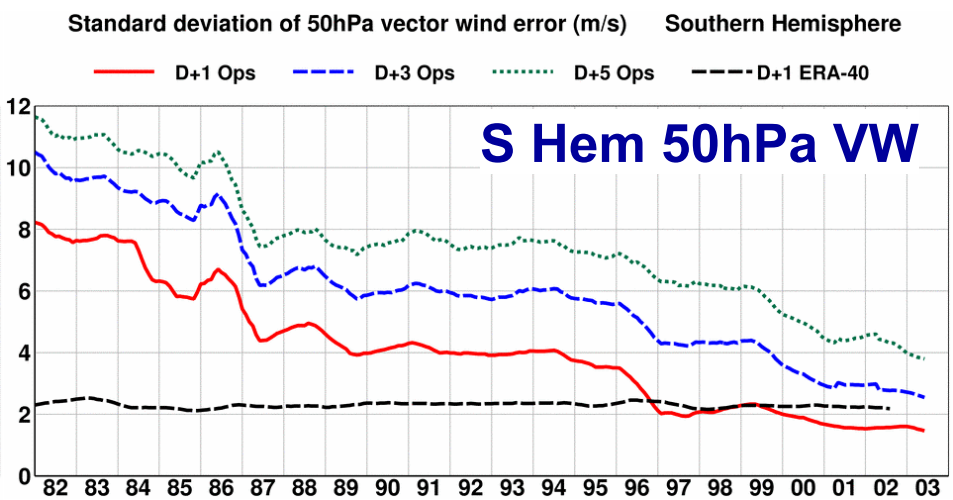


Annual running-mean forecast verifications (against analyses)



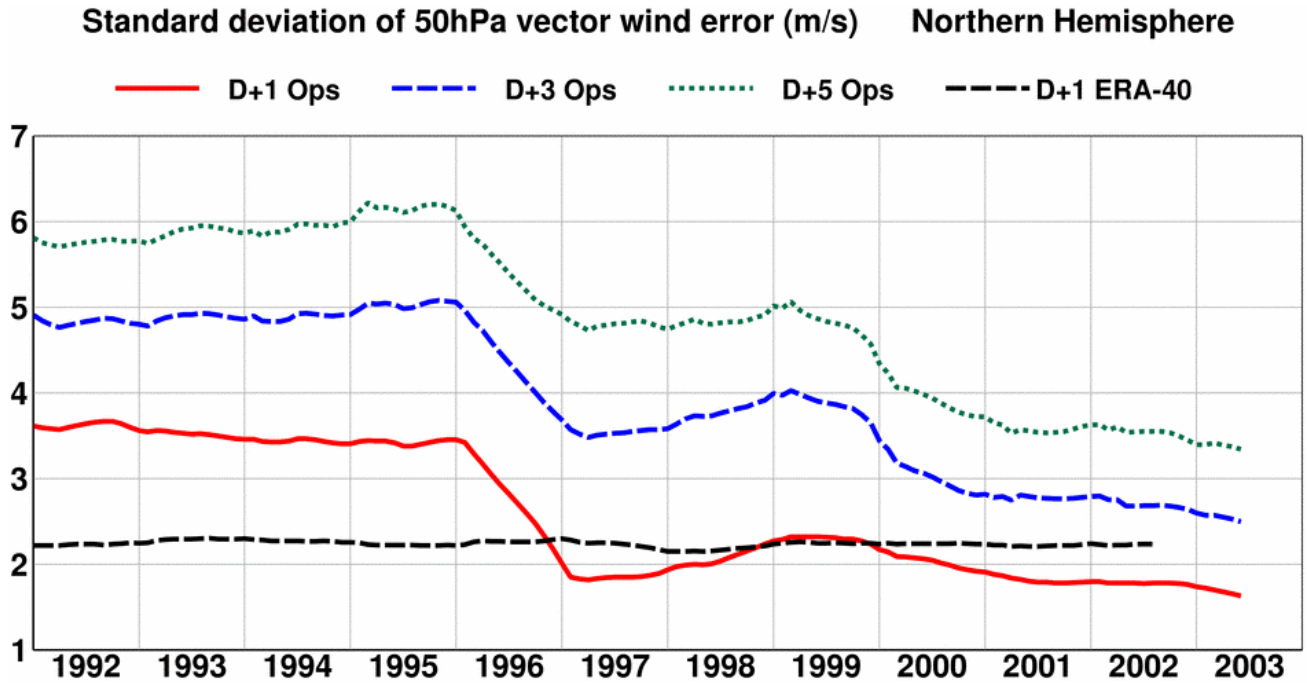




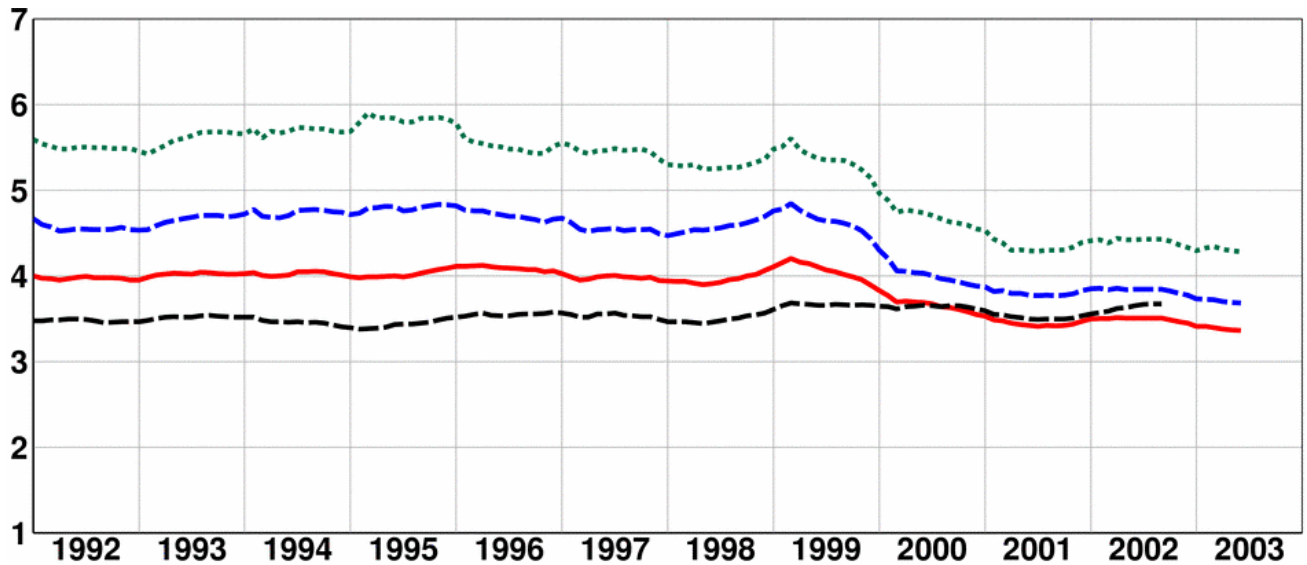


Annual running-mean verification

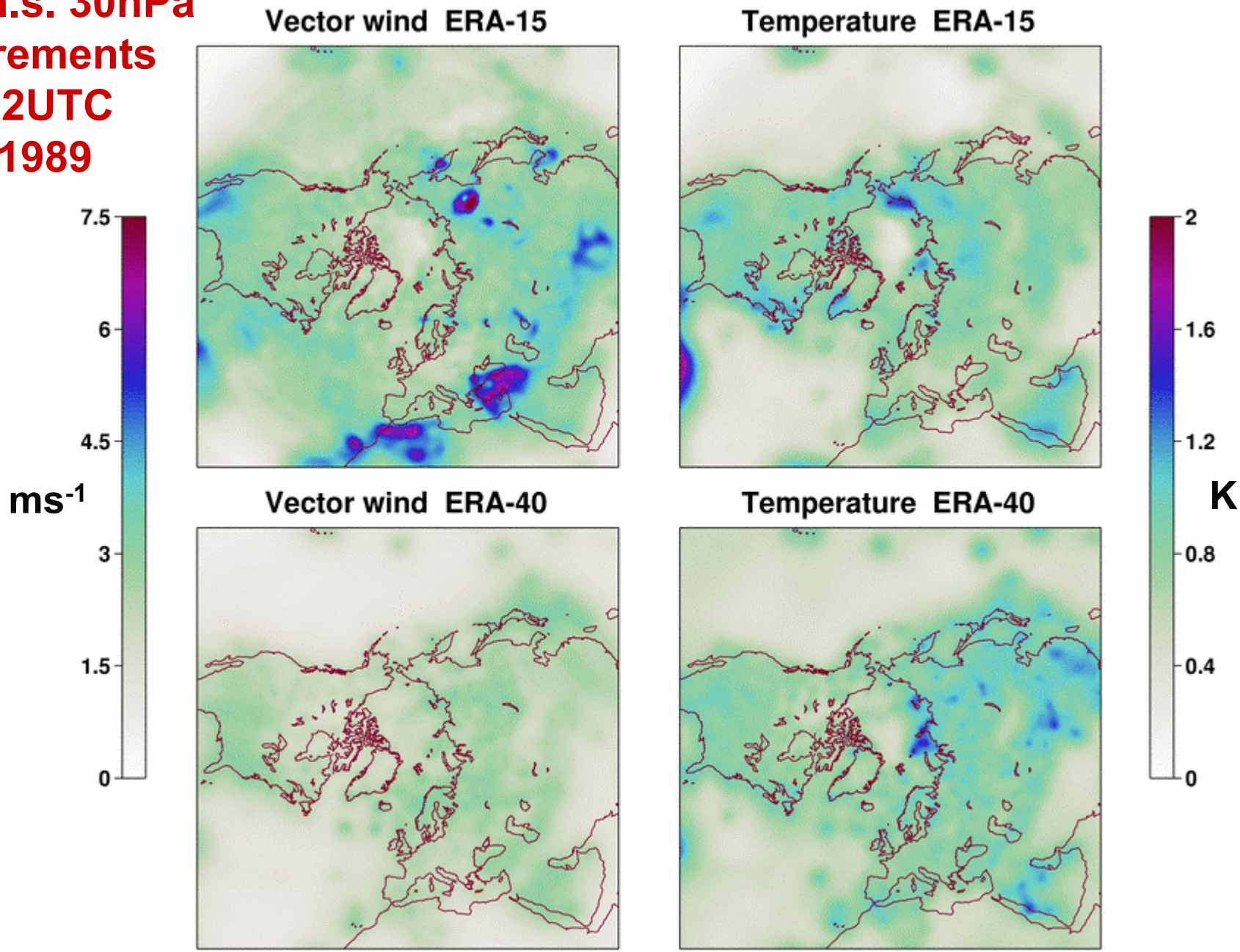
against analyses



against radiosondes

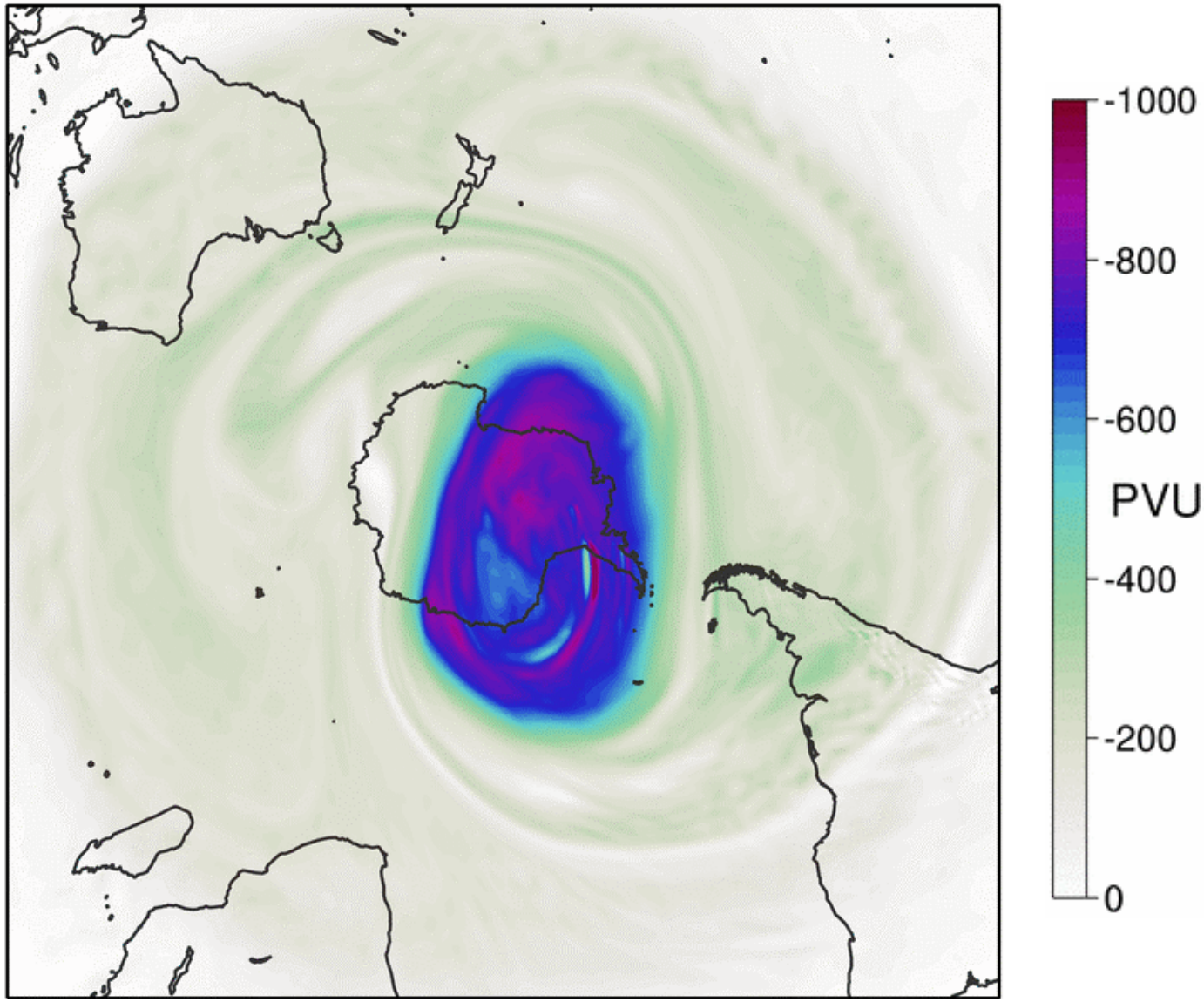


R.m.s. 30hPa increments at 12UTC for 1989

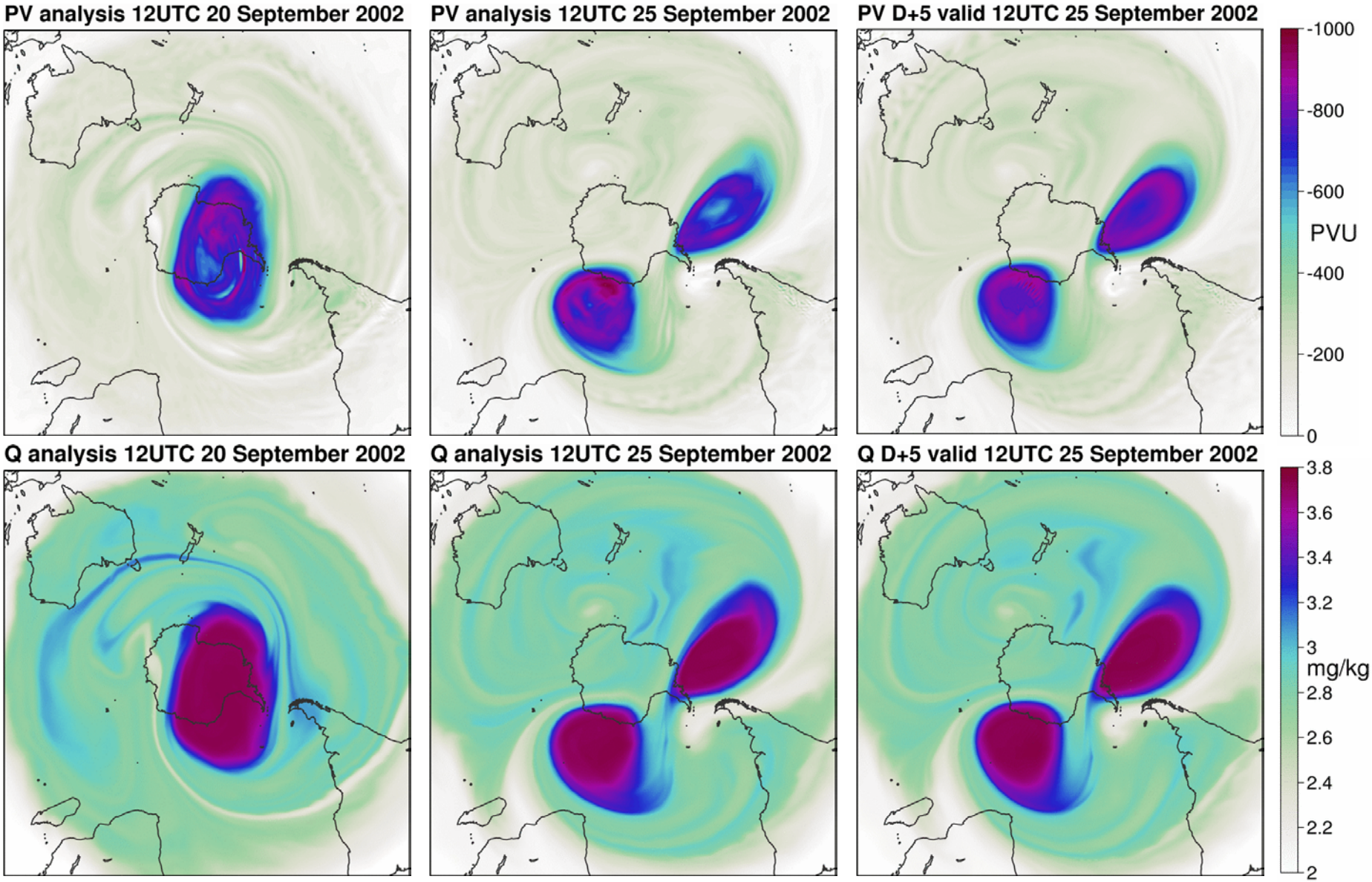


Potential vorticity on 850K isentropic surface

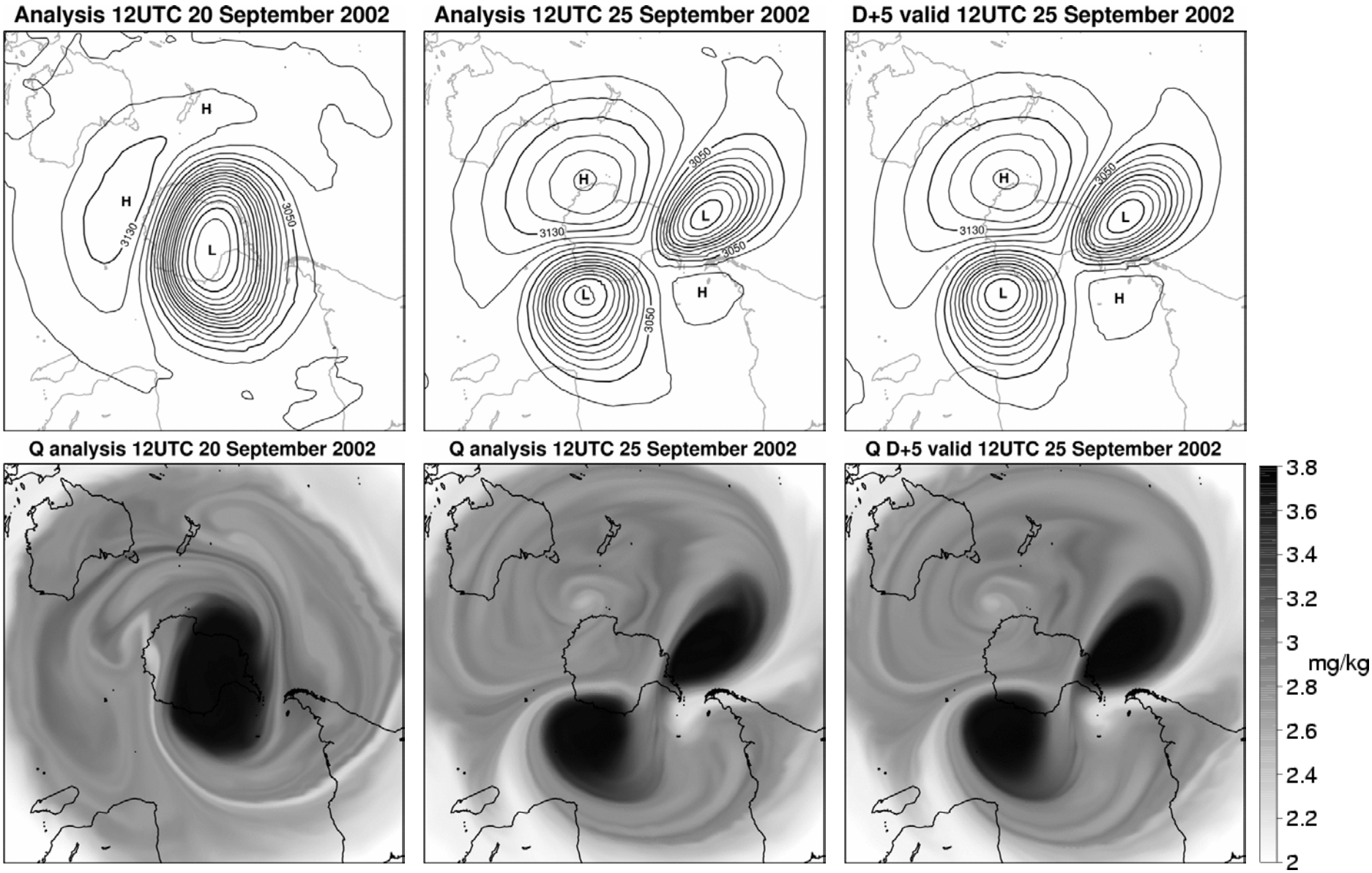
12UTC
20 September
2002



Potential vorticity and specific humidity on 850K isentropic surface

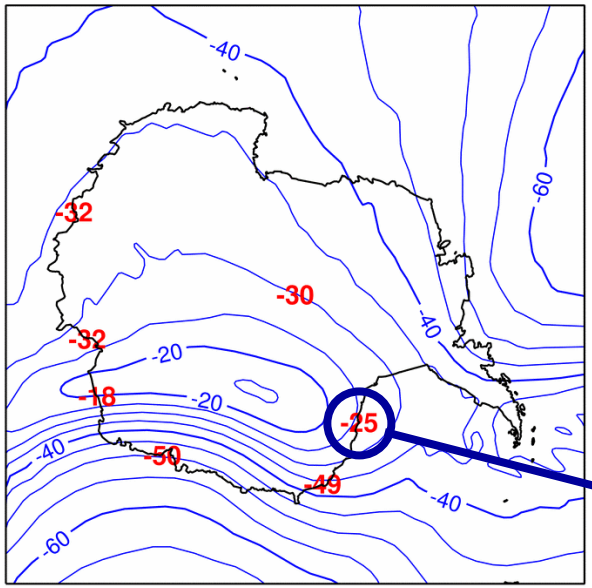


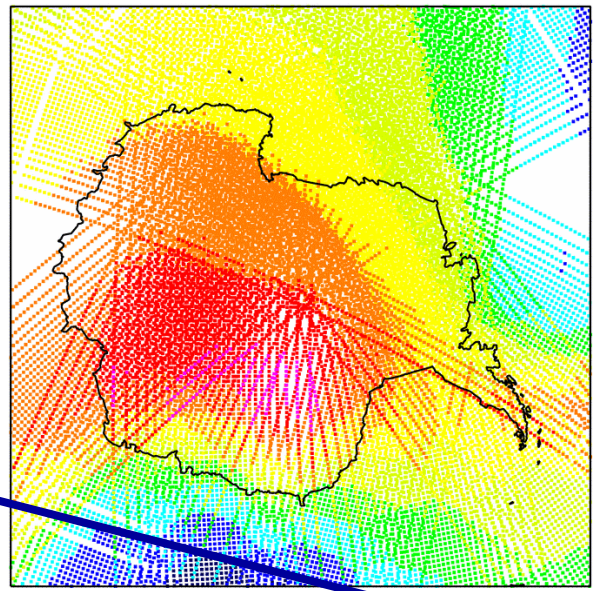
10hPa height and specific humidity on 850K isentropic surface



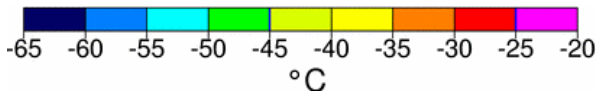
20hPa temperature °C

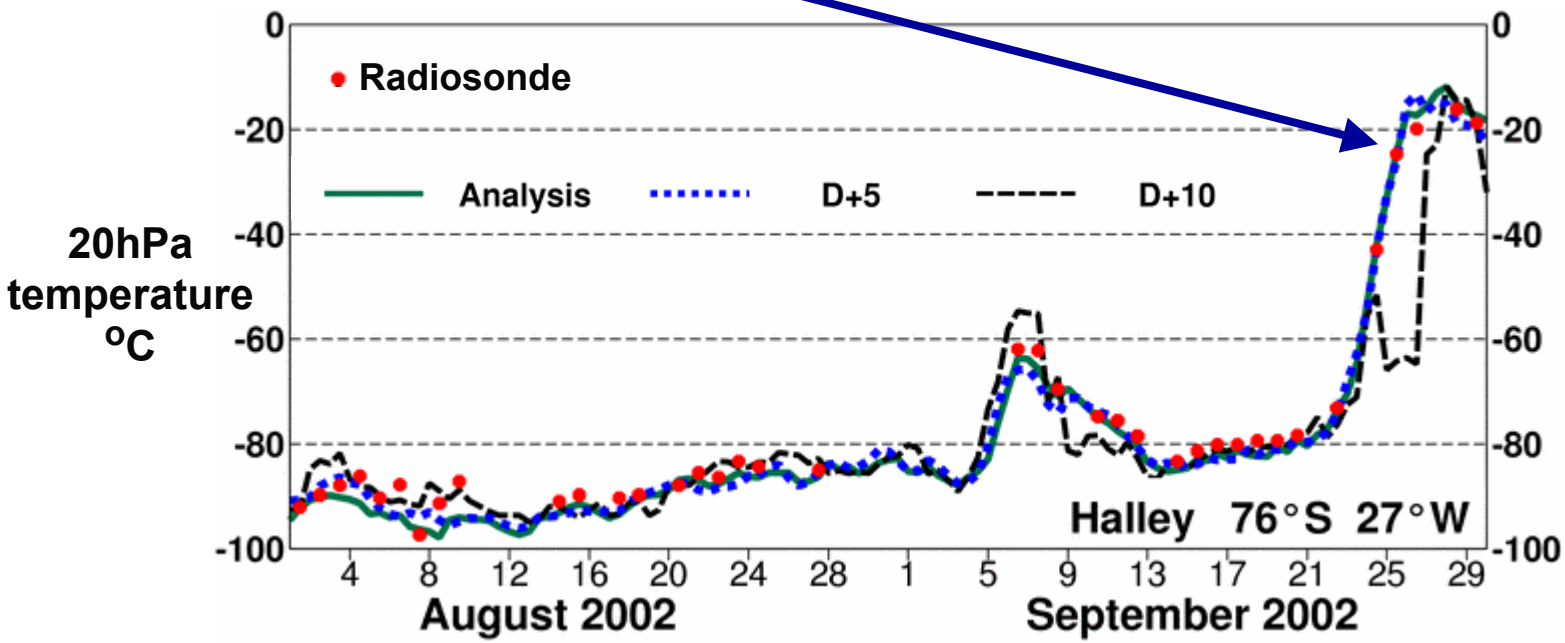
D+5 valid 12 UTC 25 September 2002





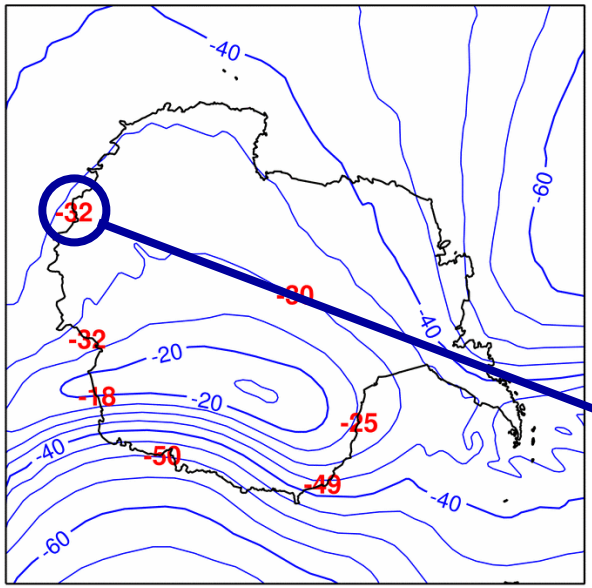
AMSU-A channel-11 brightness temperature 03-15UTC 25 Sept

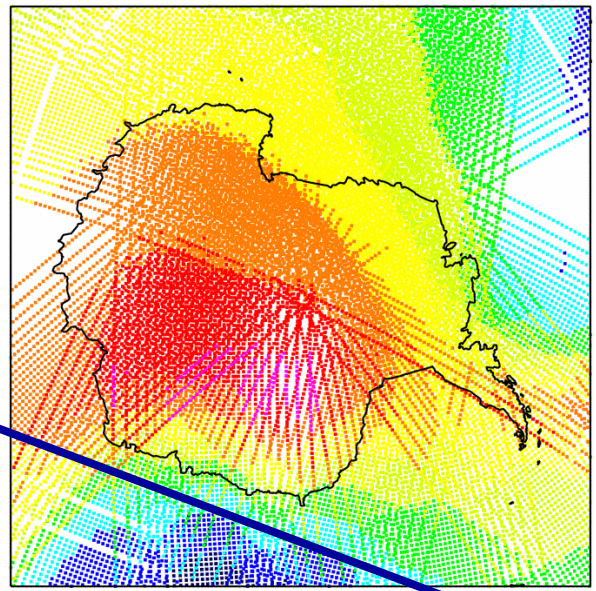




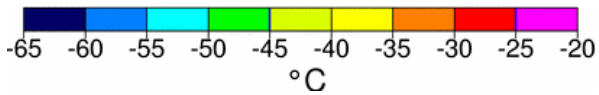
20hPa temperature °C

D+5 valid 12 UTC 25 September 2002

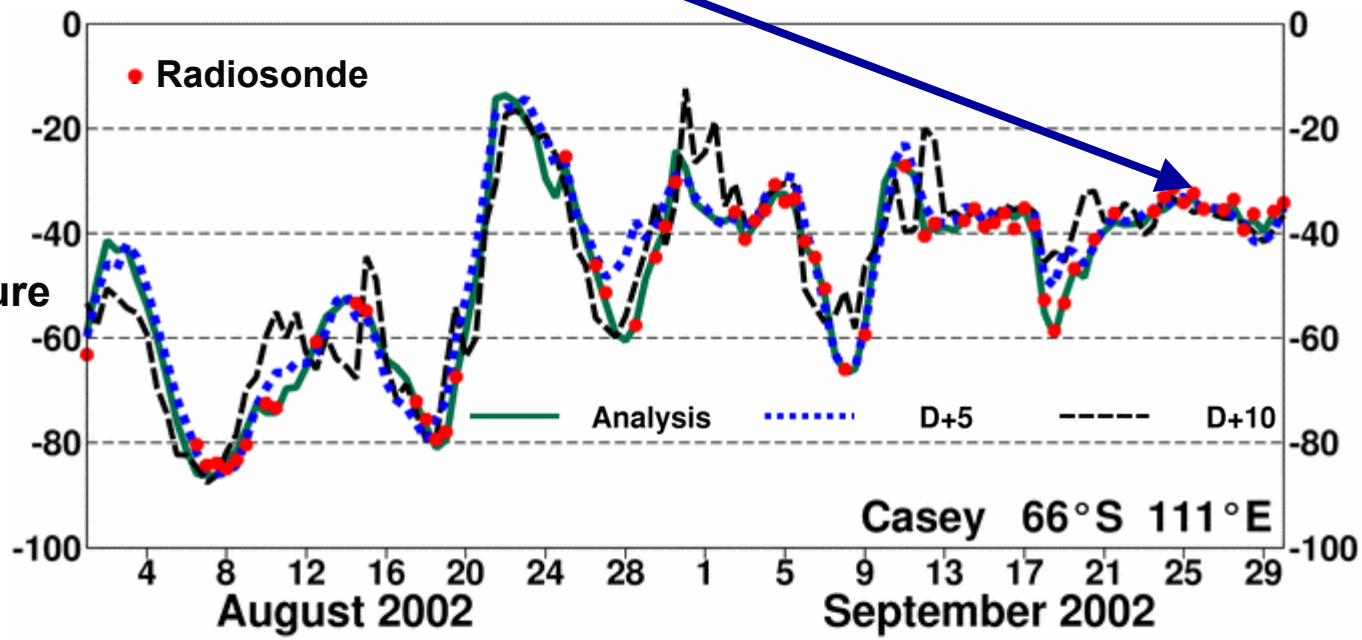




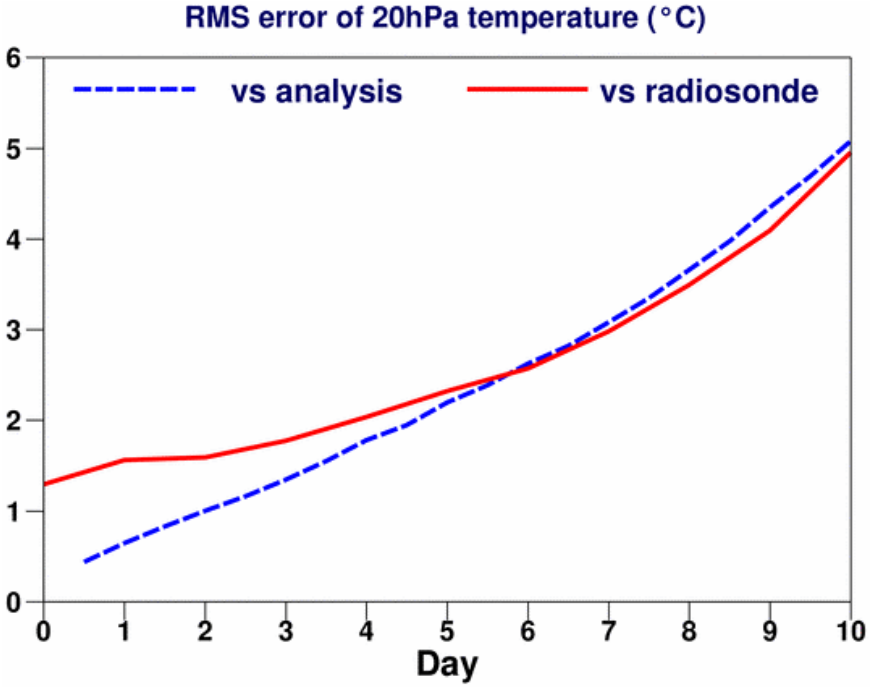
AMSU-A channel-11 brightness temperature 03-15UTC 25 Sept

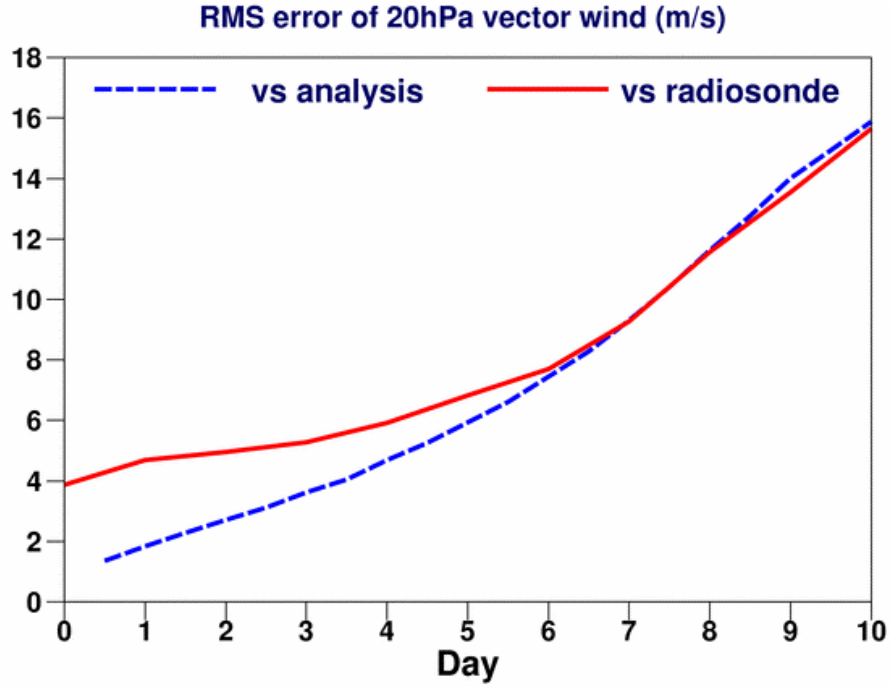


20hPa temperature °C



Verification against analyses and radiosondes
August/September 2002, Southern Hemisphere

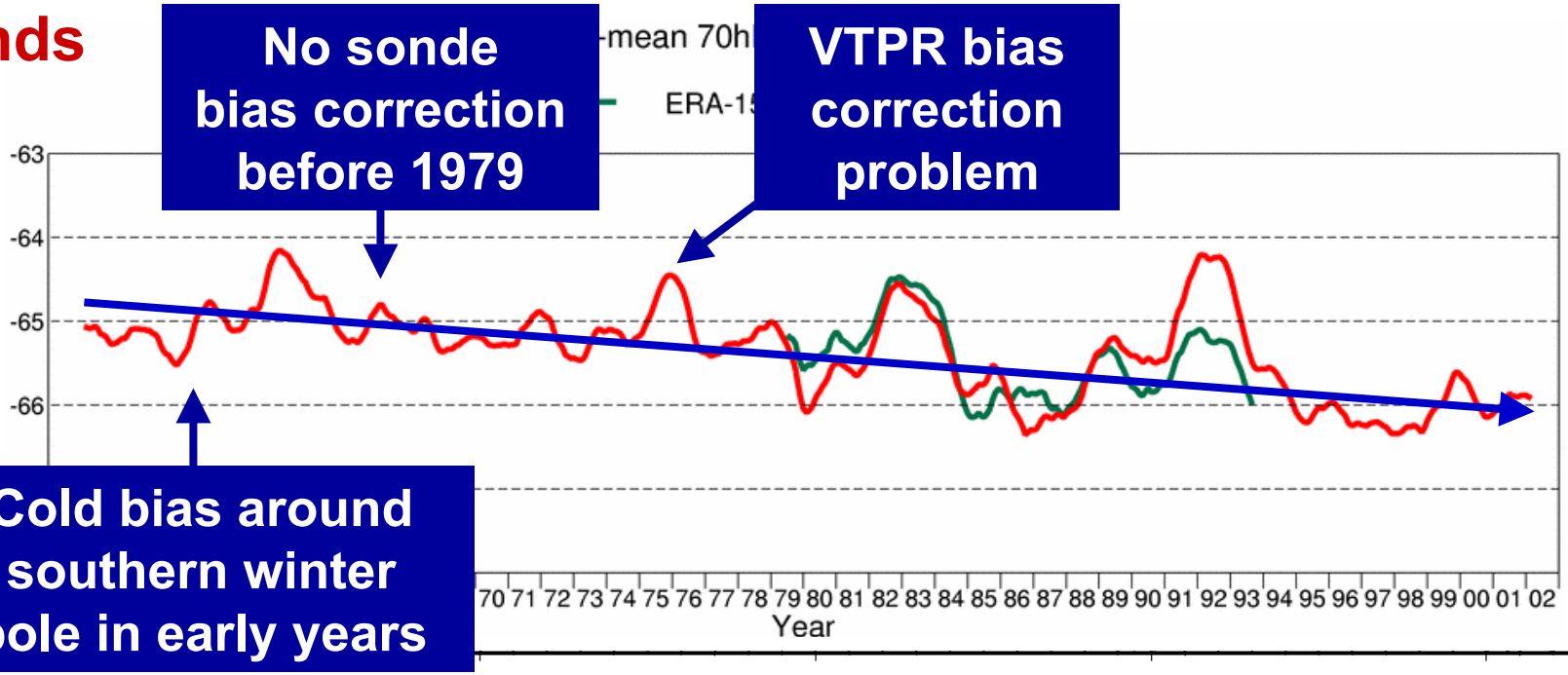


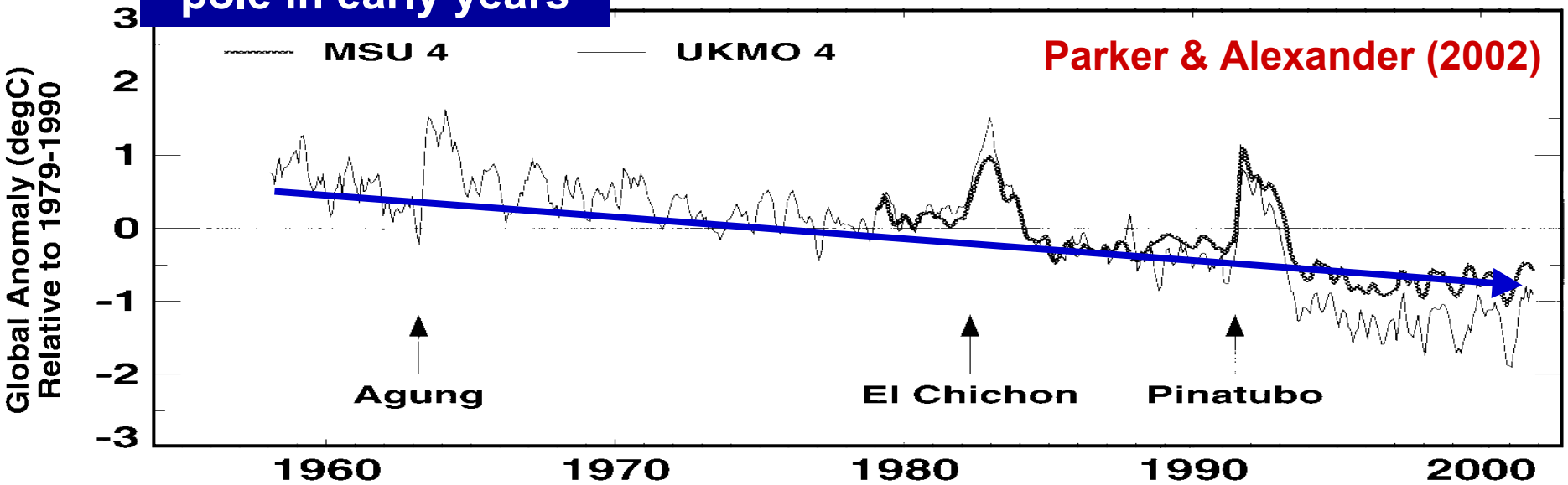


Analysis and short-range forecast error is significantly smaller than radiosonde "observation" error

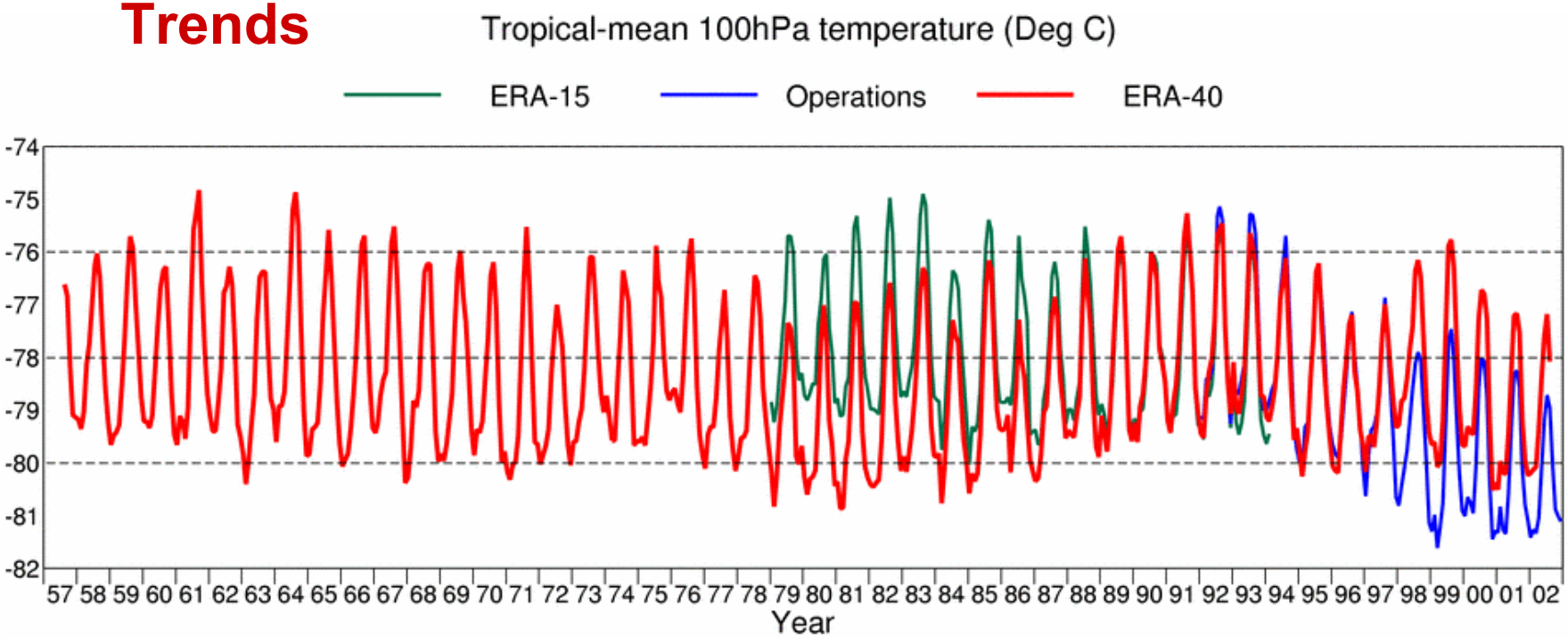
Radiosonde "observation" error includes "errors" in location and time

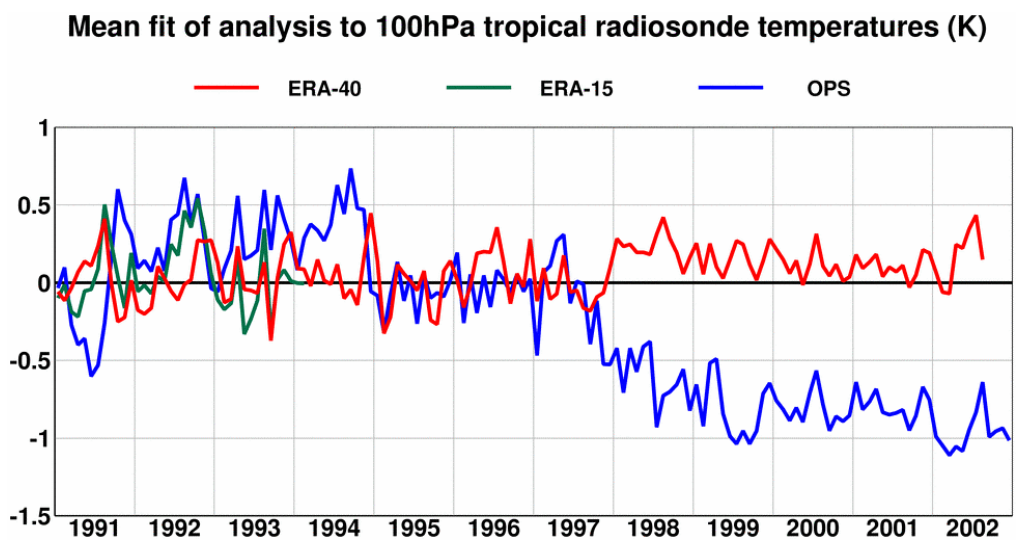
Trends


No sonde bias correction before 1979
VTPR bias correction problem
Cold bias around southern winter pole in early years
-mean 70h
ERA-1
-63
-64
-65
-66
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02
Year

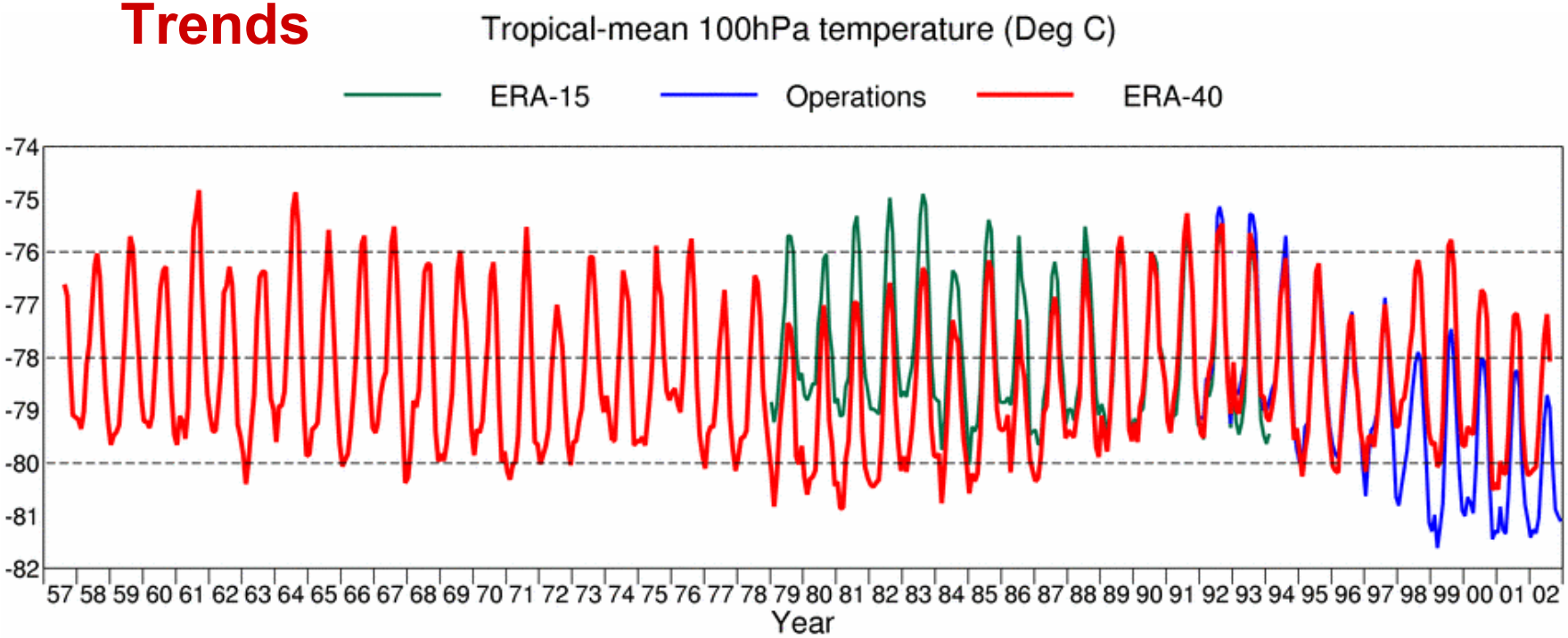

MSU 4
UKMO 4
Parker & Alexander (2002)
Global Anomaly (degC)
Relative to 1979-1990
3
2
1
0
-1
-2
-3
Agung
El Chichon
Pinatubo
1960
1970
1980
1990
2000

Trends

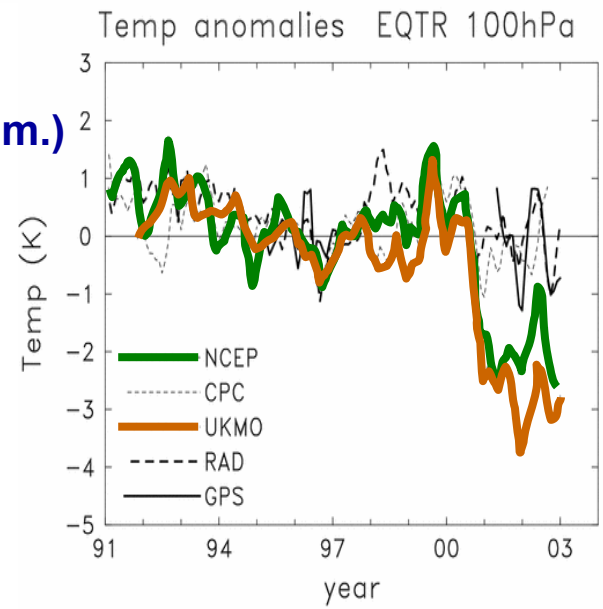

Tropical-mean 100hPa temperature (Deg C)
ERA-15
Operations
ERA-40
-74
-75
-76
-77
-78
-79
-80
-81
-82
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02
Year


Mean fit of analysis to 100hPa tropical radiosonde temperatures (K)
ERA-40
ERA-15
OPS
1
0.5
0
-0.5
-1
-1.5
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002

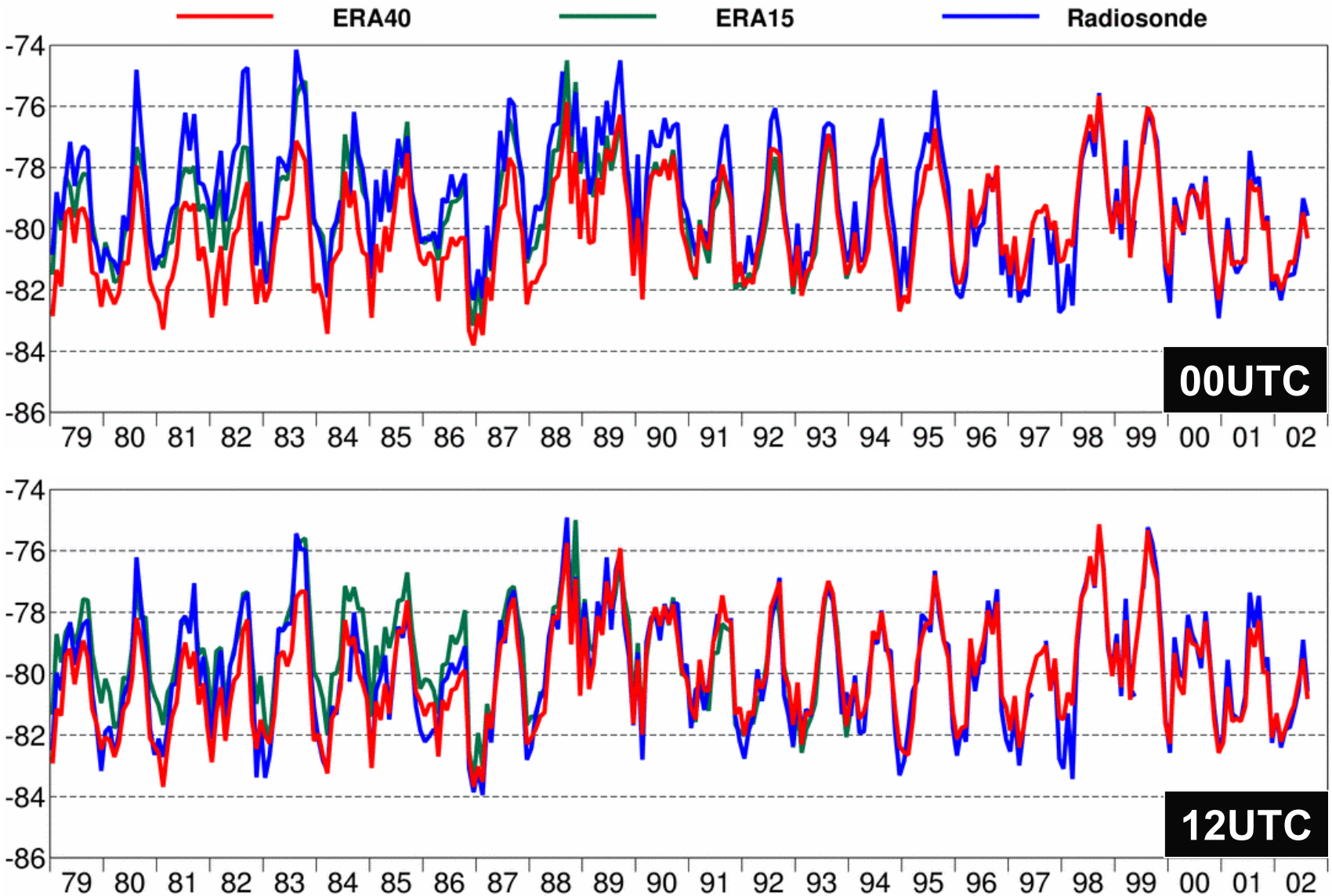
Trends



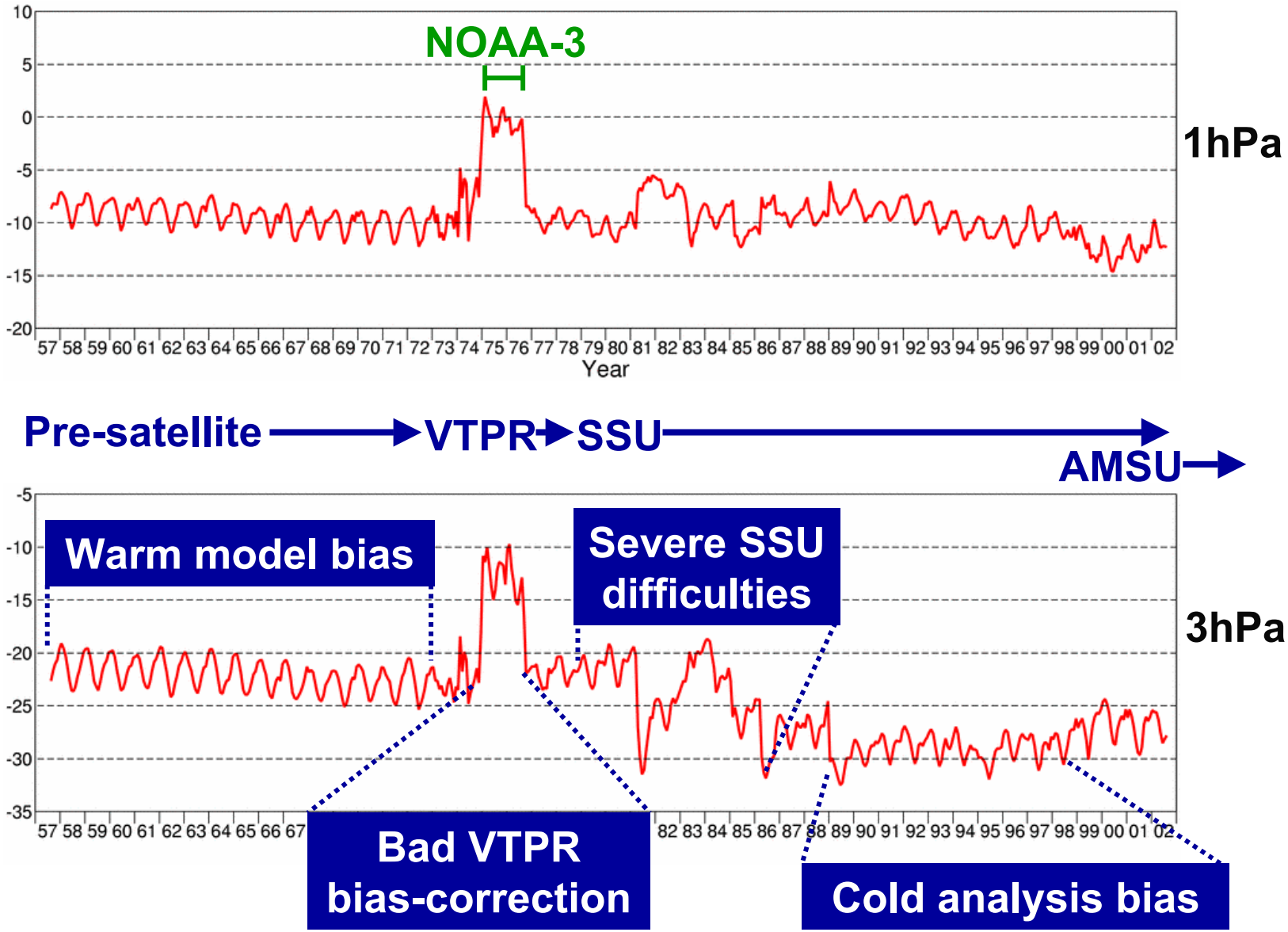
Randel (pers. comm.)



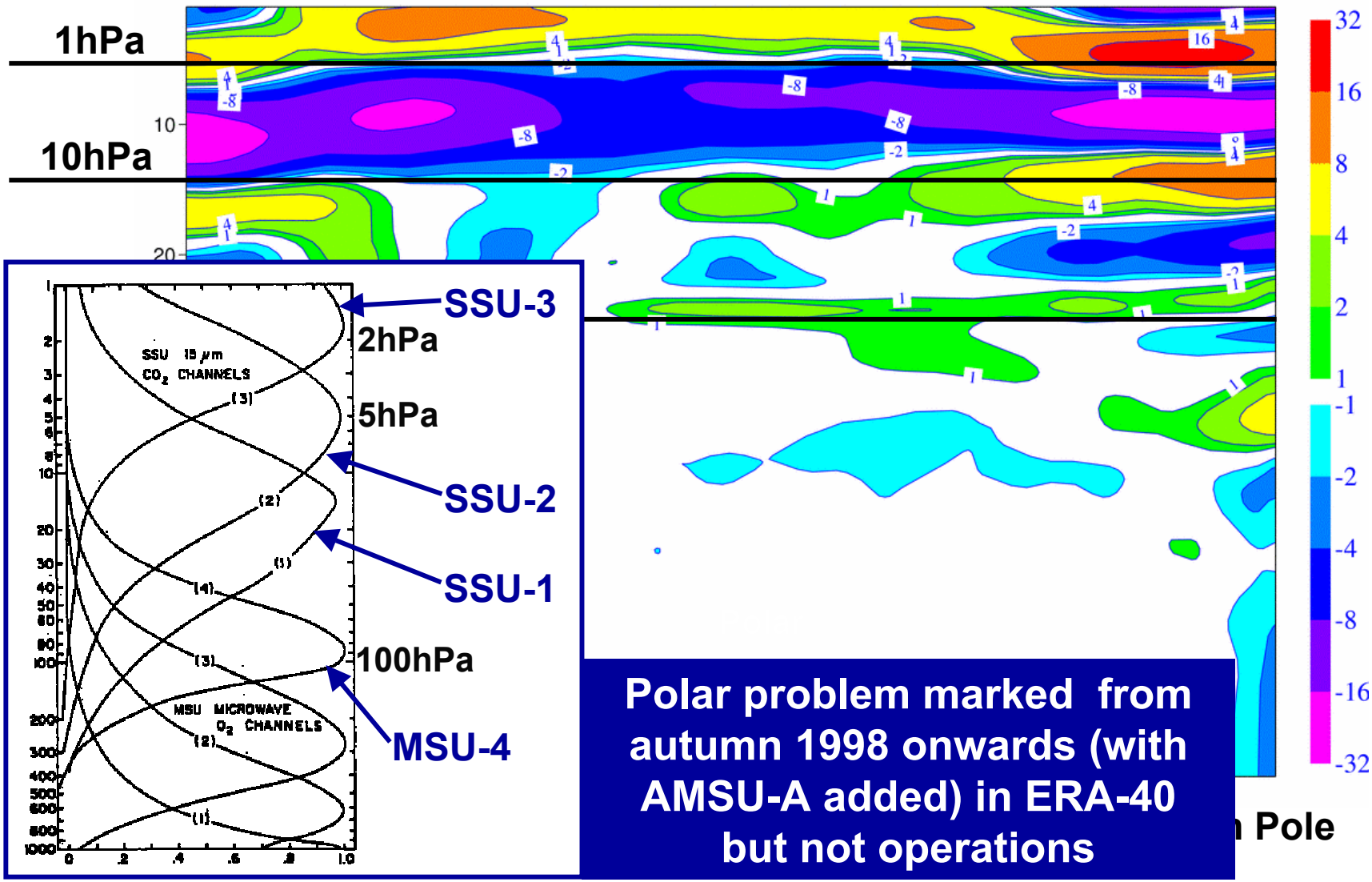
Monthly-mean 100hPa temperatures from re-analyses and radiosondes at 14S 171W (American Samoa)



Global-mean temperature at 1hPa and 3hPa

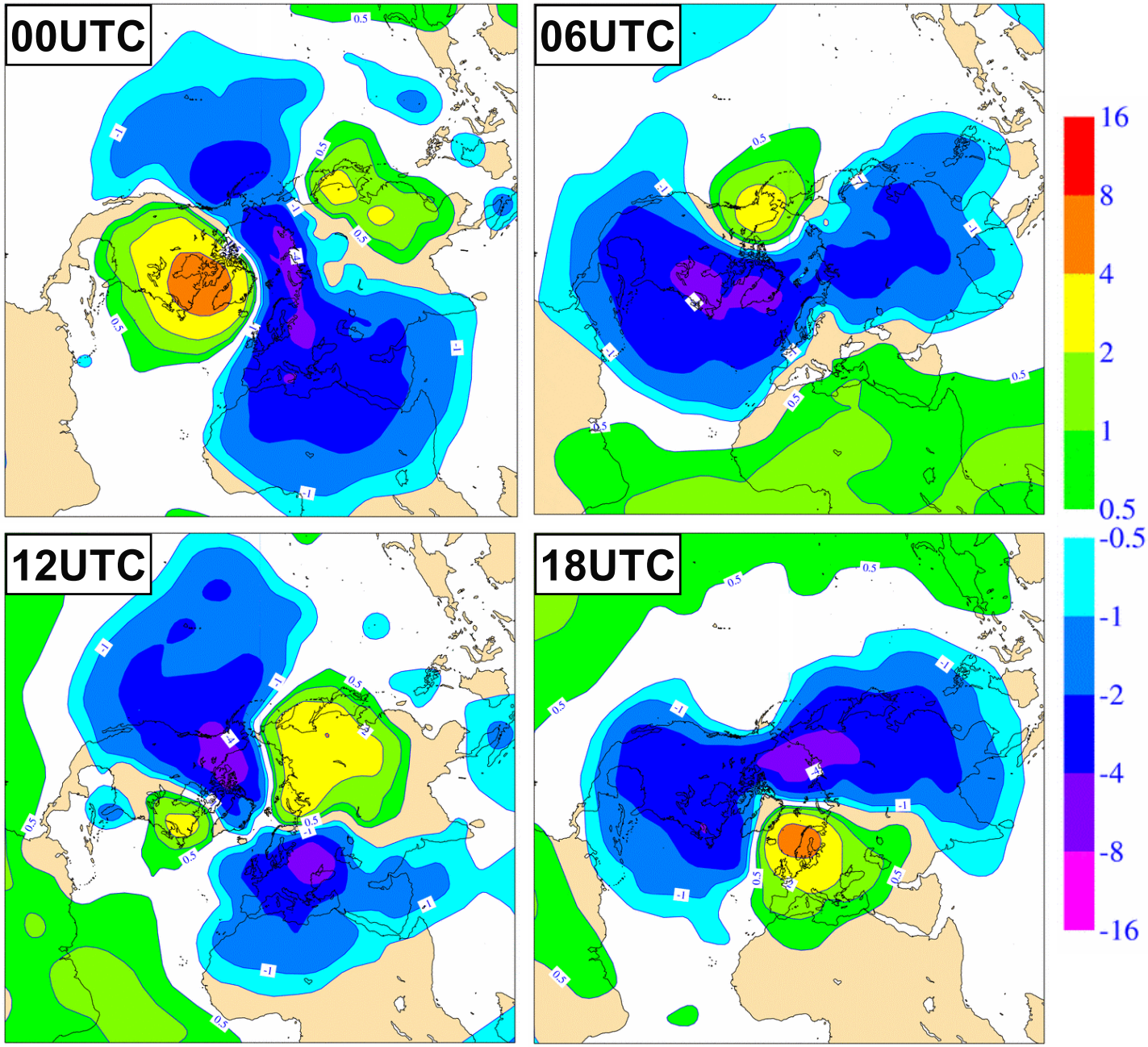


Zonal-mean temperature difference
January 1989 – January 1981



Polar problem marked from autumn 1998 onwards (with AMSU-A added) in ERA-40 but not operations

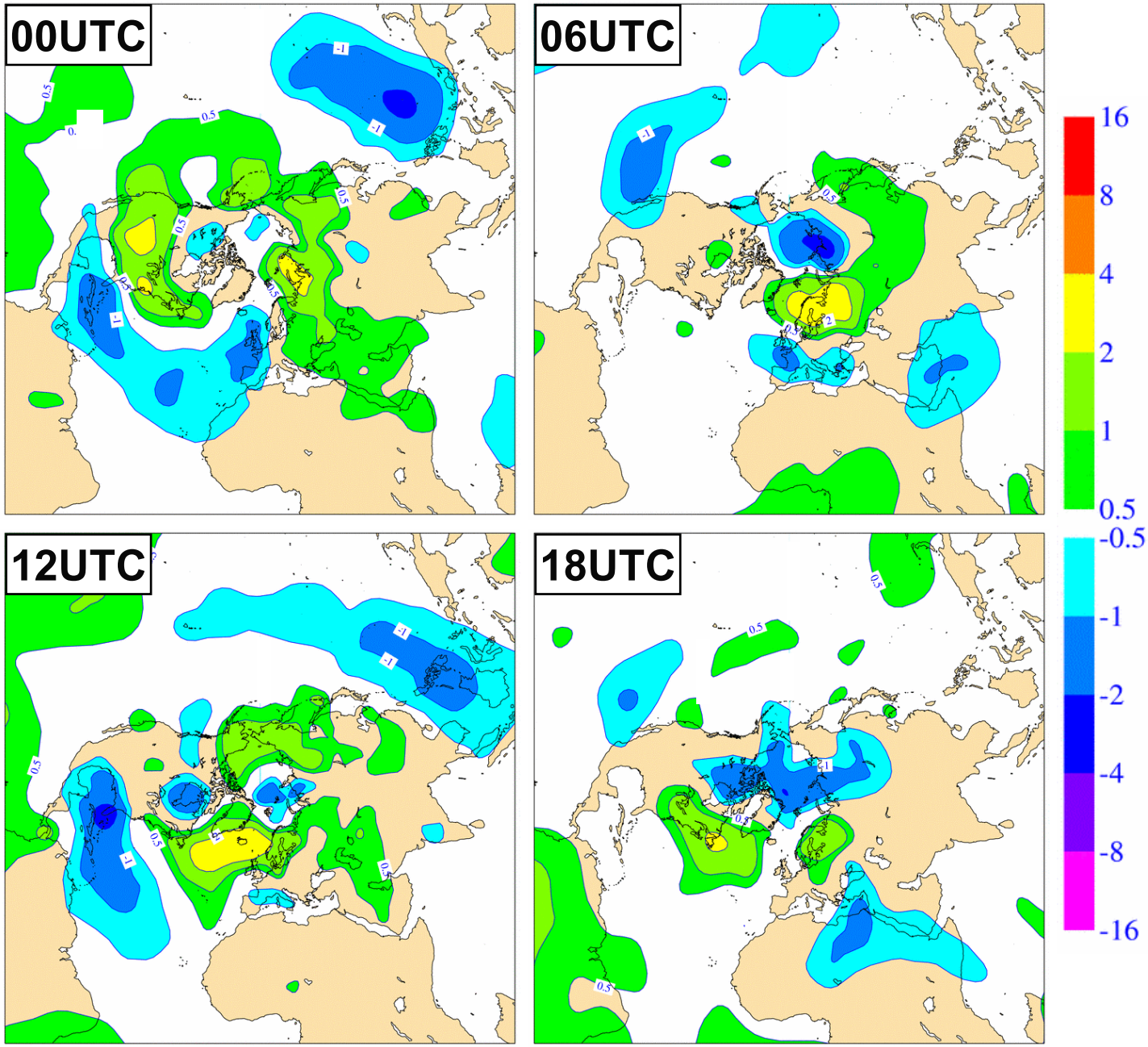
Mean 3hPa temperature analysis increment (K) for January 1989



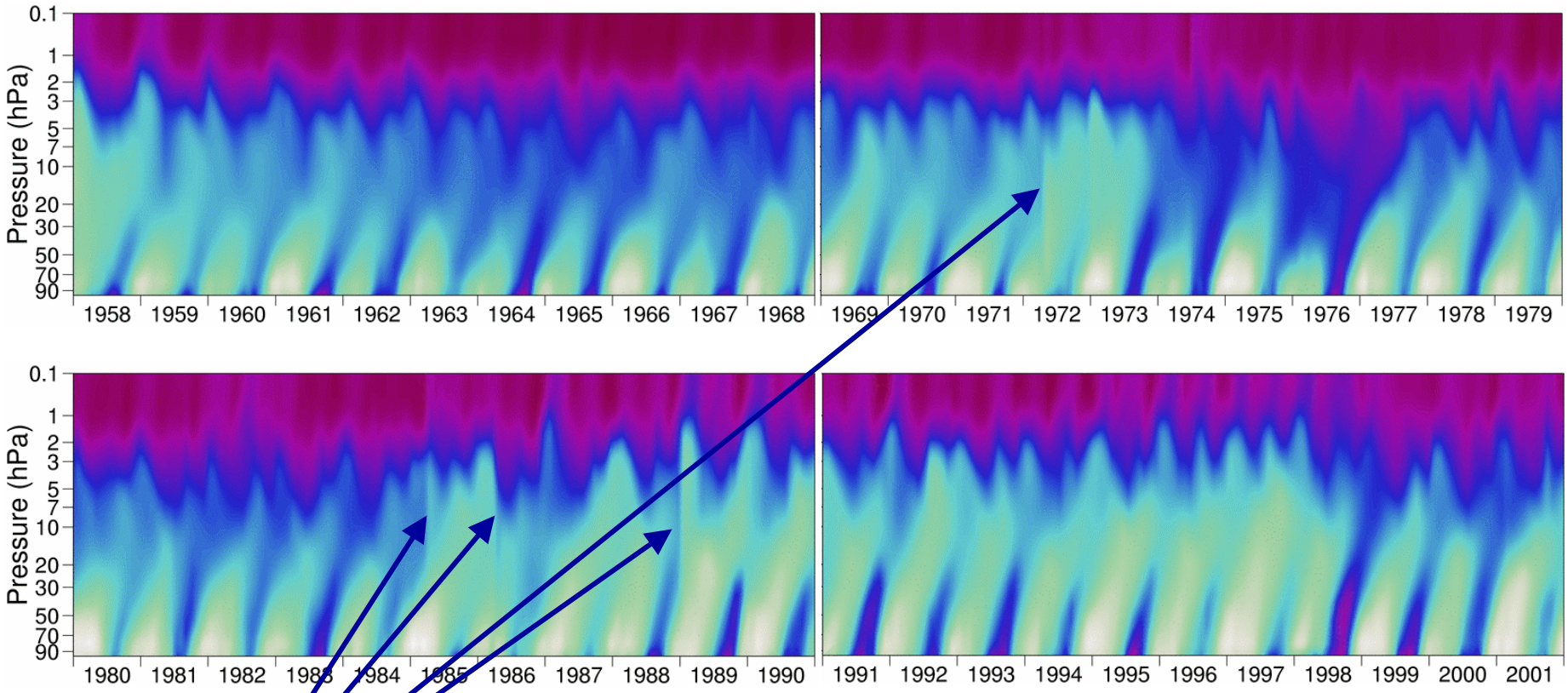
One SSU operational, sampling only one phase of the semi-diurnal tide

Mean 3hPa temperature analysis increment (K) for January 1981

Two SSUs operational

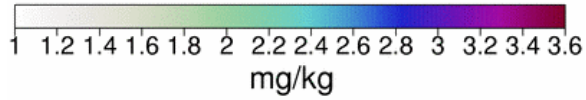


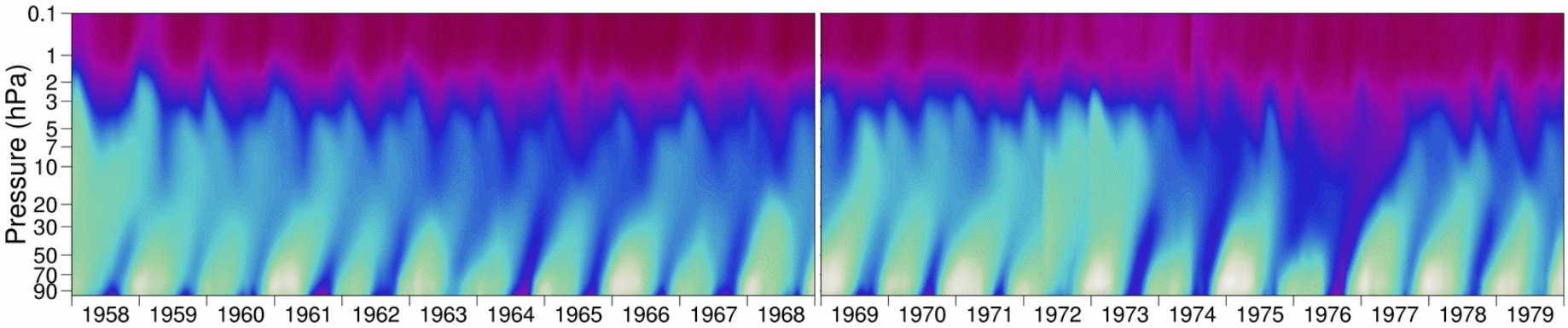
Equatorial specific humidity

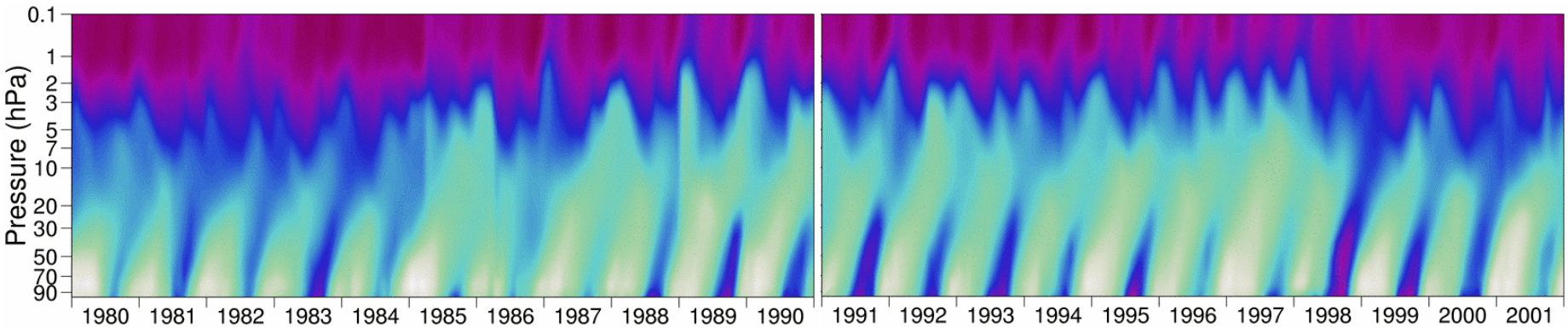


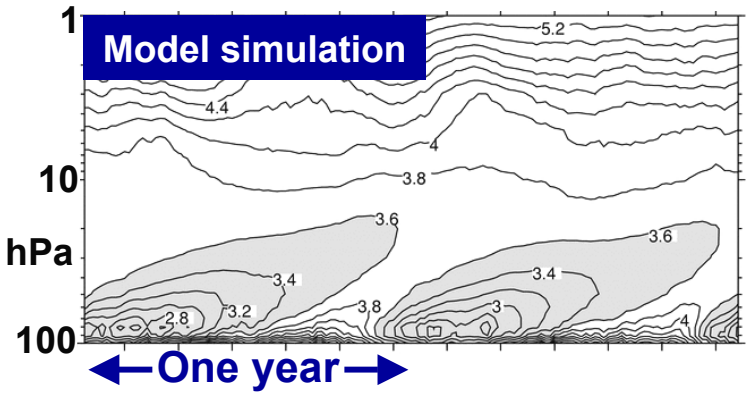
Breaks in production

Equatorial specific humidity

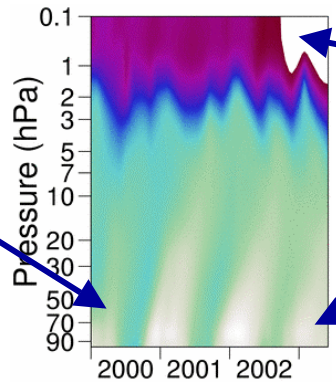








Spurious moistening by analysis until April 2000



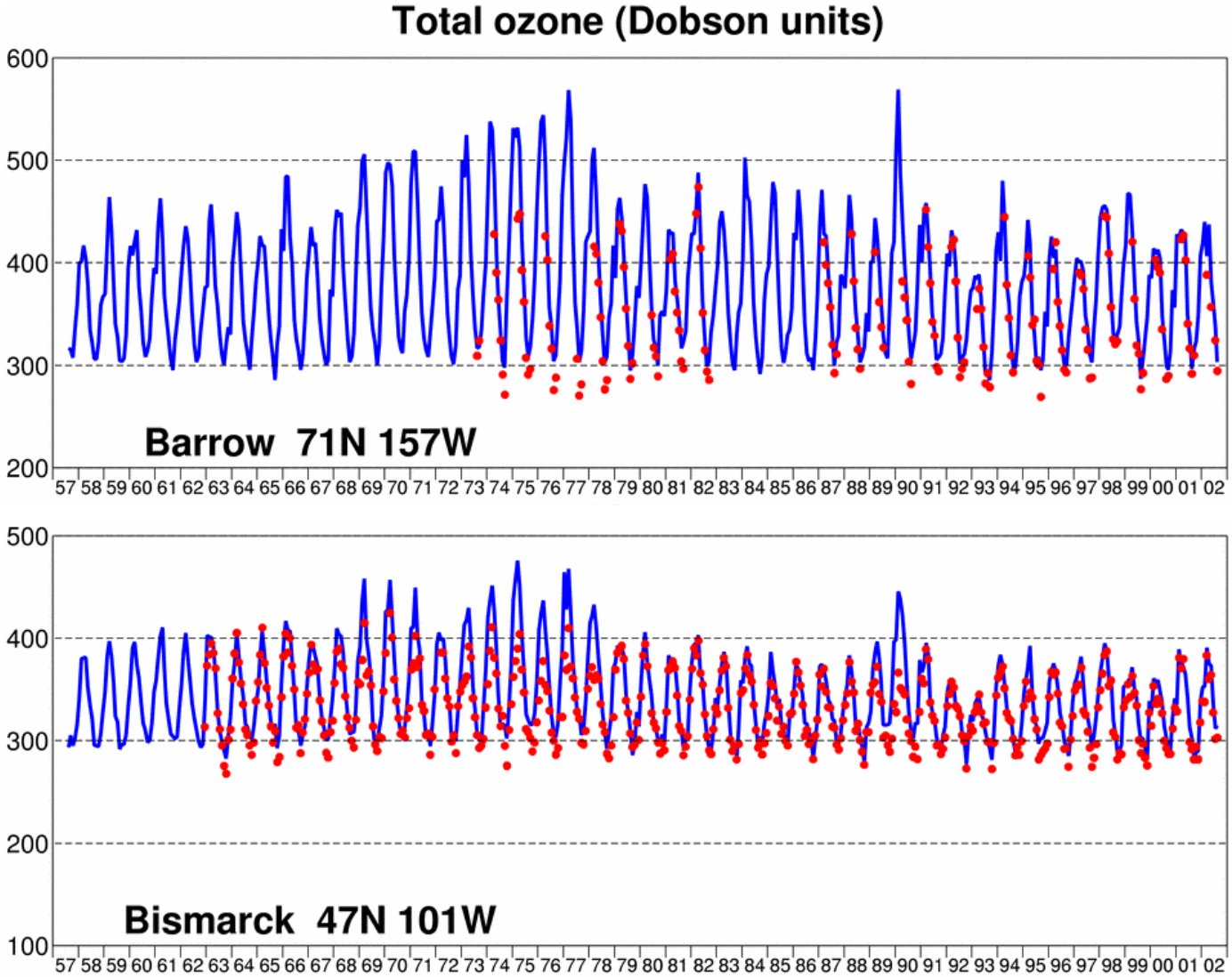
CH_4 oxidation increased in April 2002

Operations

New balance from Jan 2003

Total Ozone (Monthly means from1957 to 2002)

(following Pascal Simon, Météo-France)



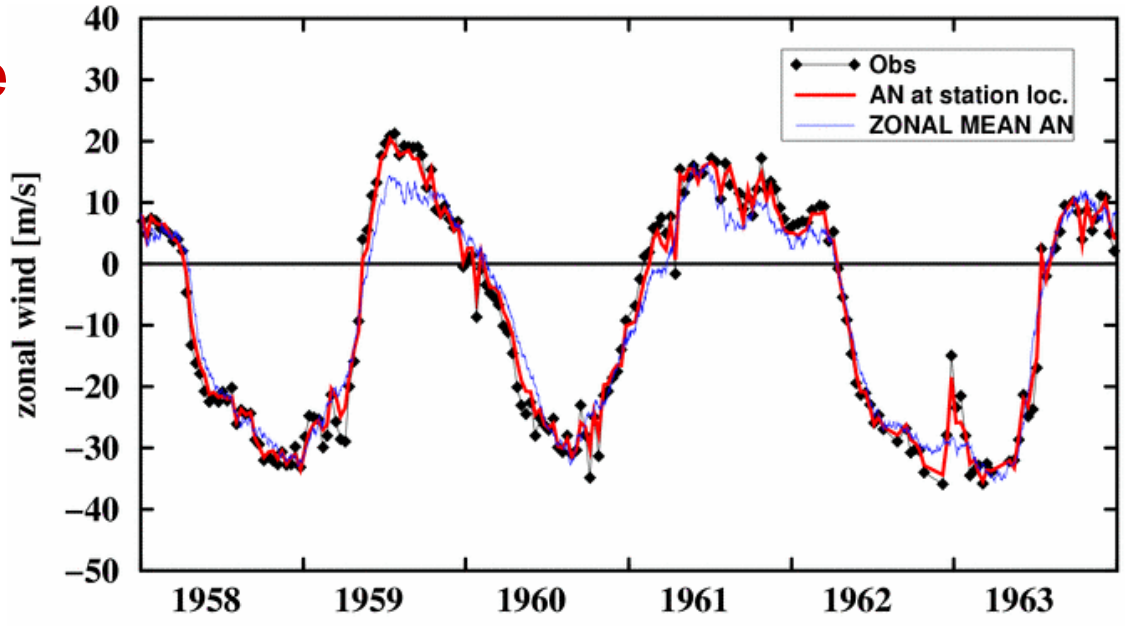
Blue: ERA-40 (TOMS and SBUV data assimilated 1979-1988 and 1991-2002)

Red: Ground-based measurements (NOAA/CMDL)

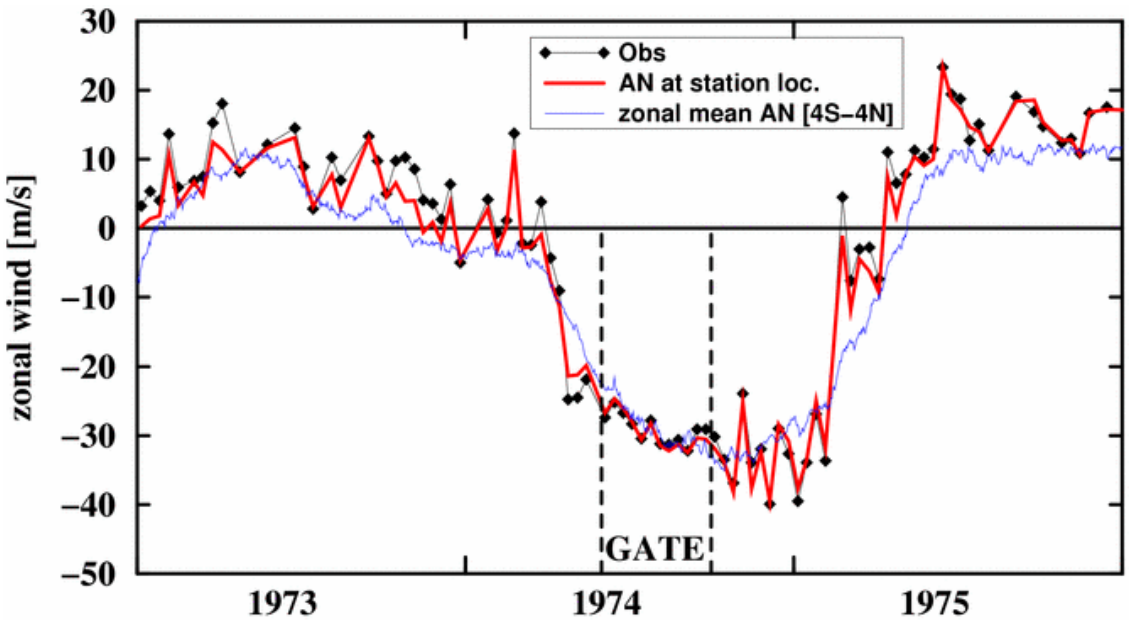
Representation of the QBO

Canton Island
(3S, 171W)

30hPa

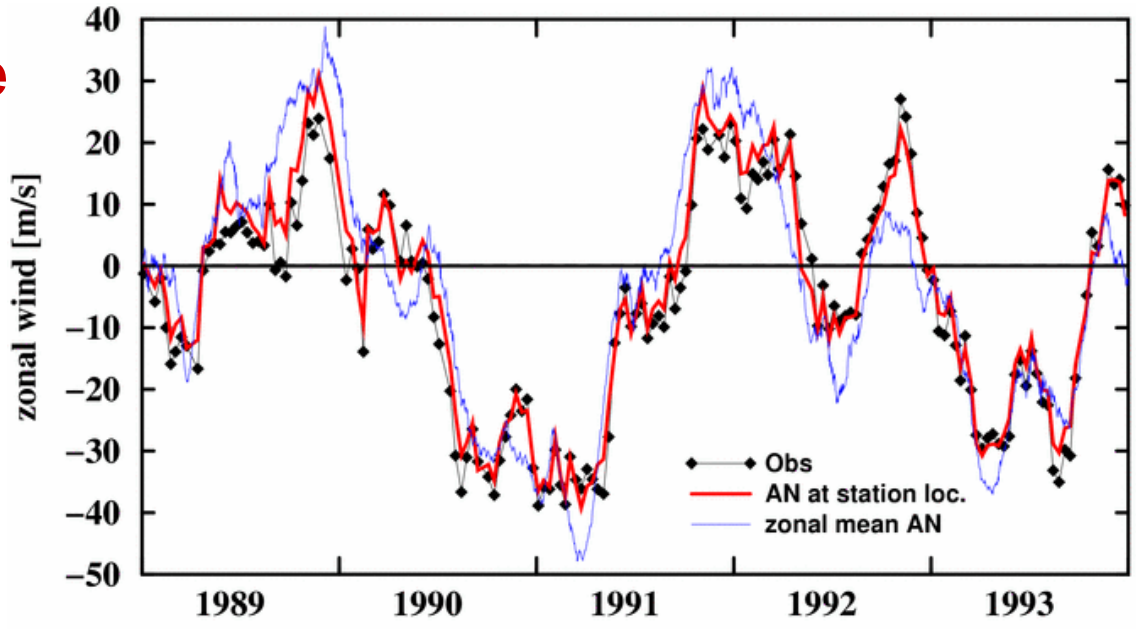


Gan
(1S, 73E)



Representation of the QBO

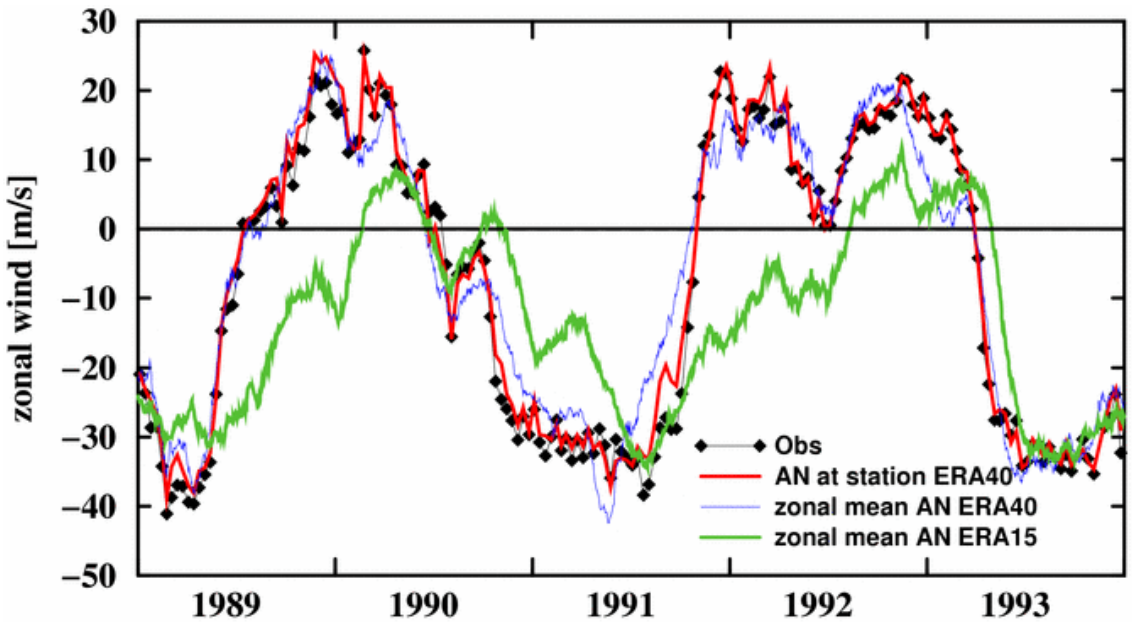
5hPa



Singapore

(1N, 104EW)

10hPa



Conclusions

- Basically a success story (sudden warmings, QBO, …)
- But some problems persist, and new ones are emerging:
  - Model biases (radiation, gravity-wave drag, upper boundary conditions, …)
  - Observation biases (satellite radiances, radiosondes)
  - Fitting of radiances in variational data assimilation
  - Balance of the analysis
  - Humidity
  - Handling of tides
  - Performance of 3D-Var compared with 4D-Var
  - … and others that following speakers and the discussion groups will identify