Umkehr data: comparisons with sondes, microwave and satellite

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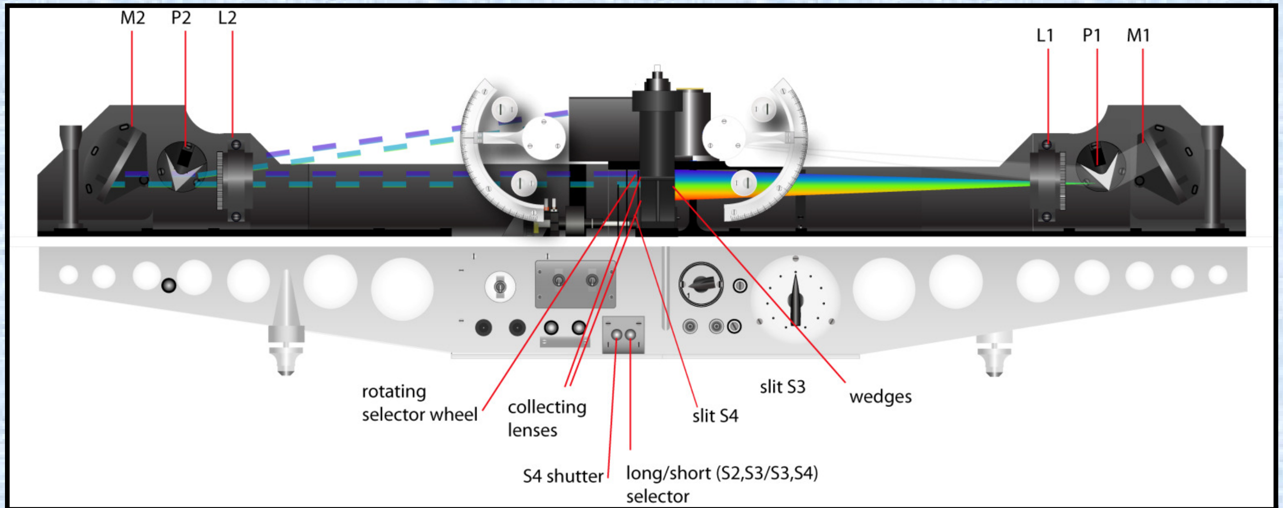
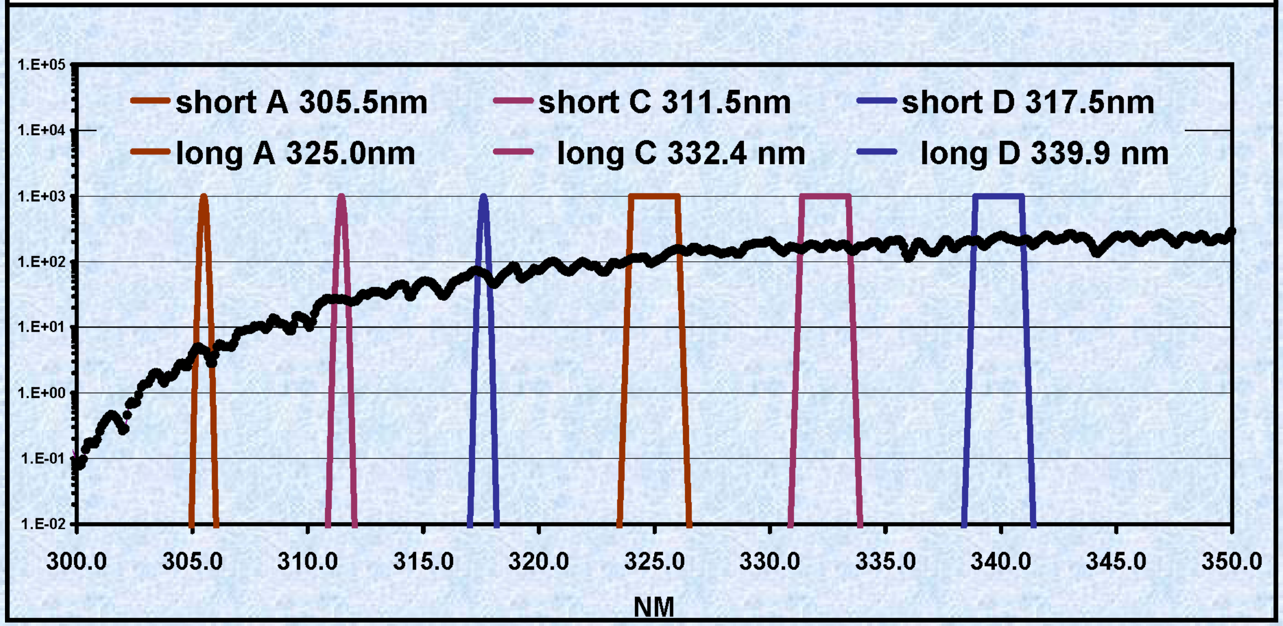
- Measurements of total ozone column by Dobson network for over 50 years (15 stations at ESRL/GMD + world calibration standard)
- Umkehr ozone profile measurements (6 stations) are taken since 1930s (manually) and since 1980s – automated measurements, also 5 automated stations in JMA + 1 at Arosa





Sir G.M.B. Dobson

Götz, H. Dütch, C.Mateer, W. Komhyr, R. Bojkov, J. DeLuisi, B. Evans, D. Quincy, G.McConville, and many others

Walshaw, C. D., "G.M.B. Dobson – The man and his work, Planet. Space Sci., 37, pp.1485-1507, 1989.

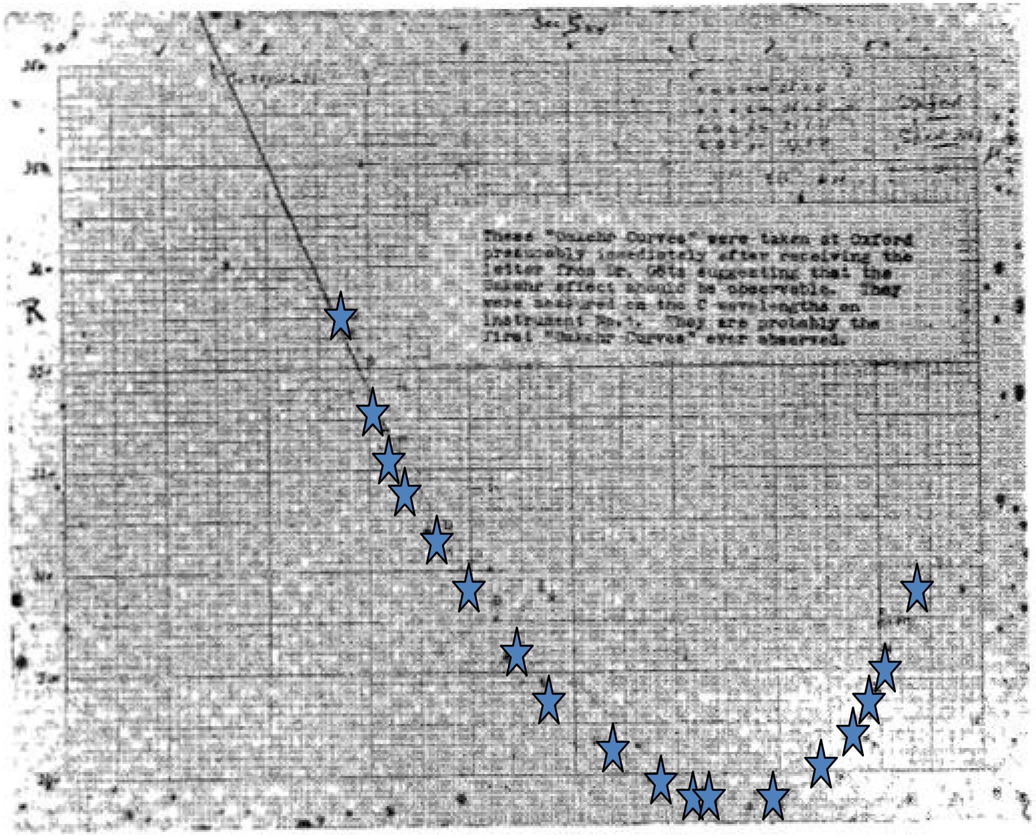
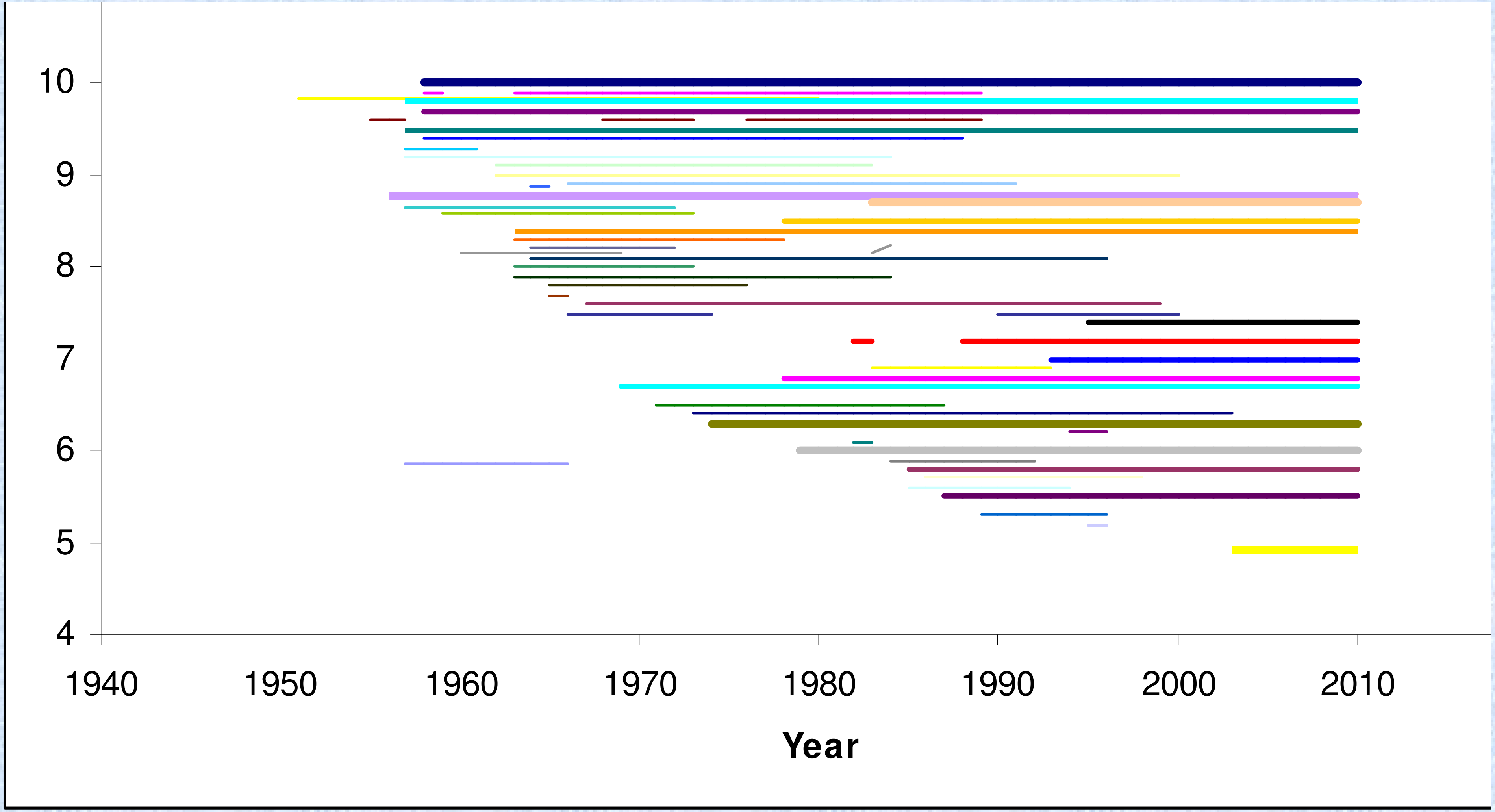


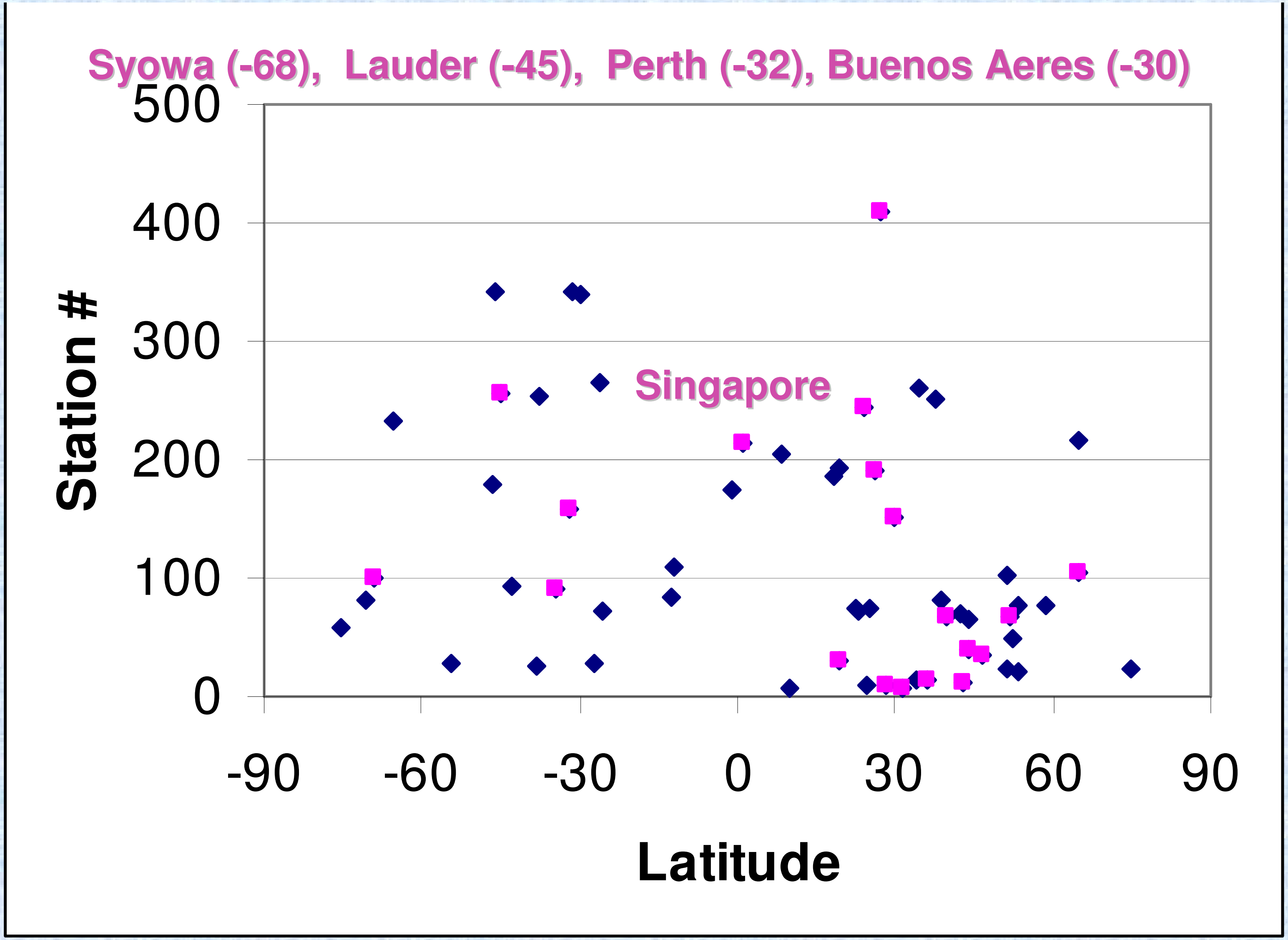
FIG. 6. DOBSON'S FIRST UMKEHR OBSERVATIONS, 25–27 JANUARY 1931.
The typed comment is his. Only a minimum of enhancement has been used on a xerox print of the original graph.

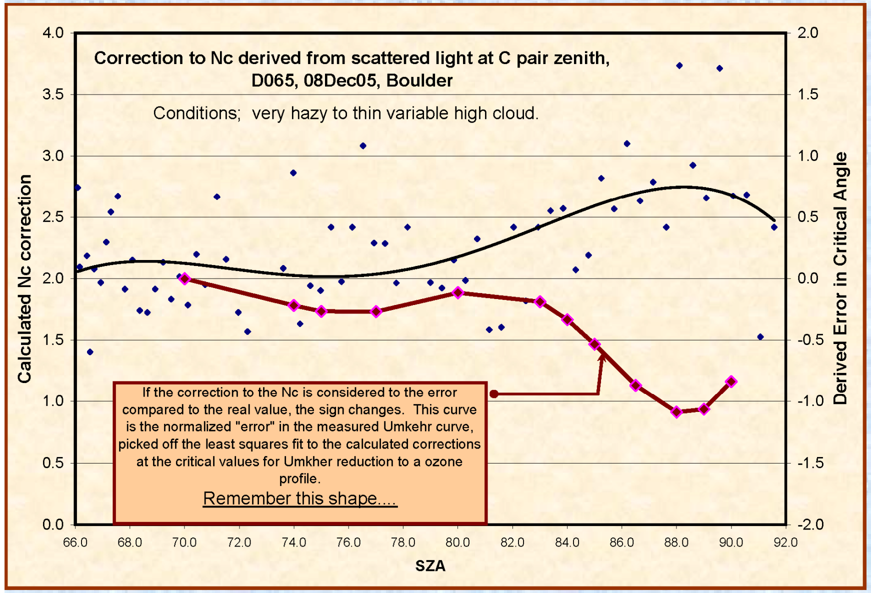
"These "Umkehr Curves" were taken at Oxford presumably immediately after receiving the letter from Dr. Götz suggesting that the Umkehr effect should be observable. They were measured on the C wavelengths on instrument Db 1. They are probably the first "Umkehr" curve ever observed." - G.M.D. Dobson

Umkehr Records (18 up –to-date)

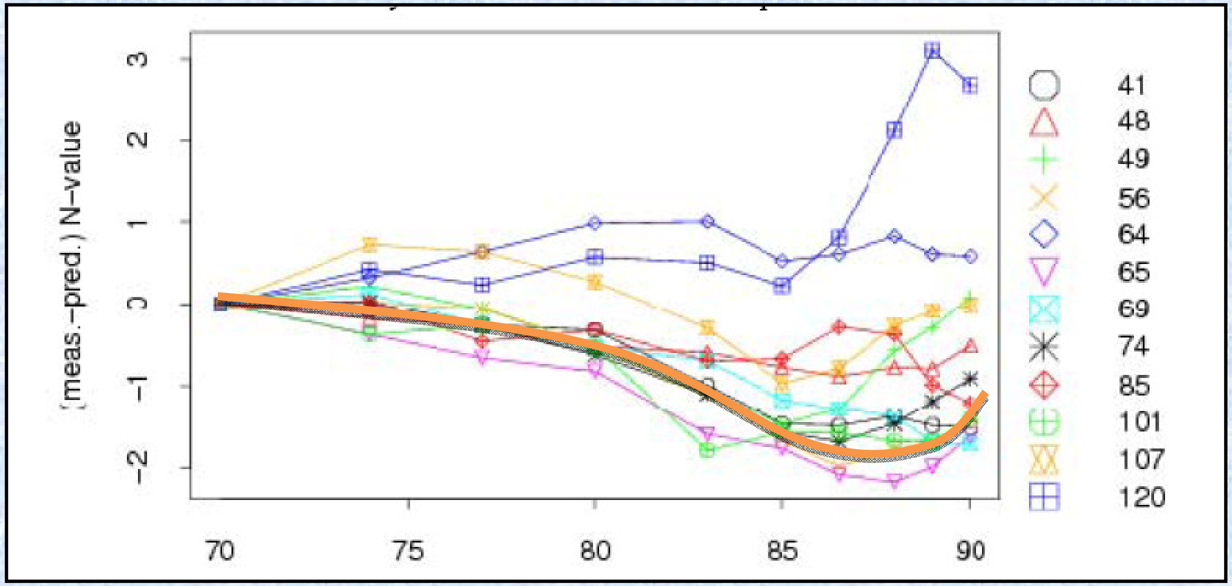


Geographical coverage





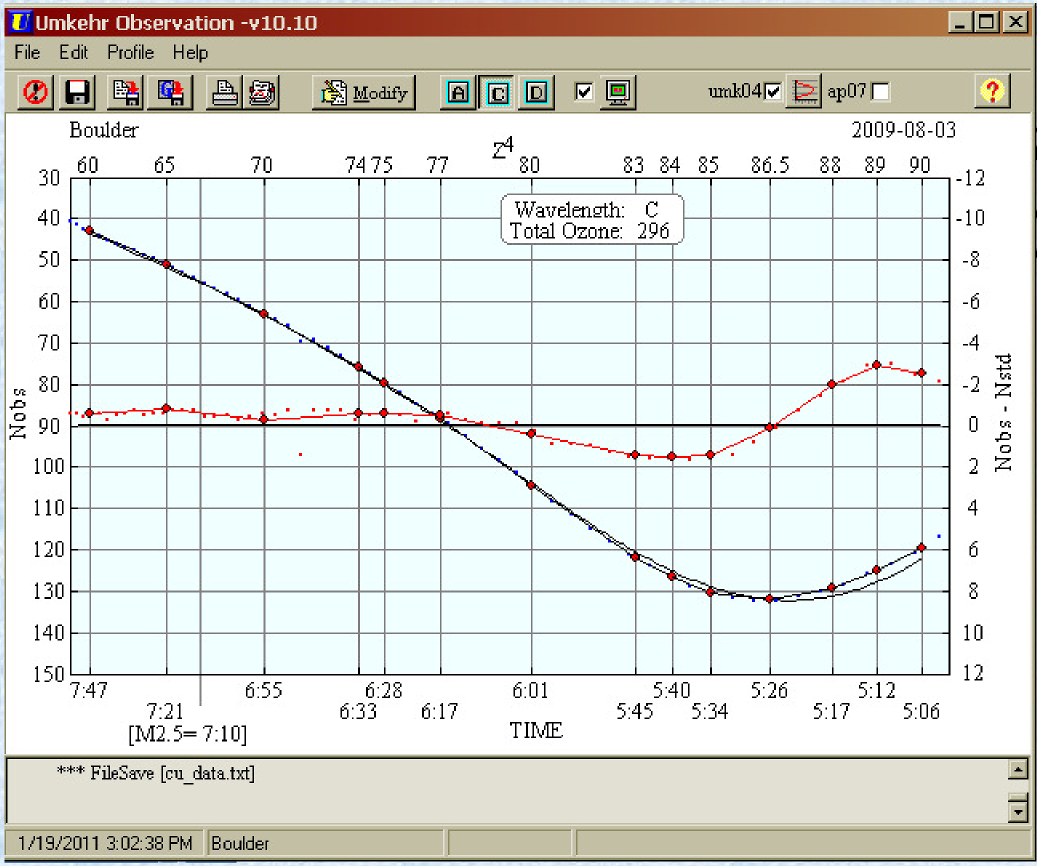
What are we finding? – Investigations in to the effect of internal stray light show similar curve.

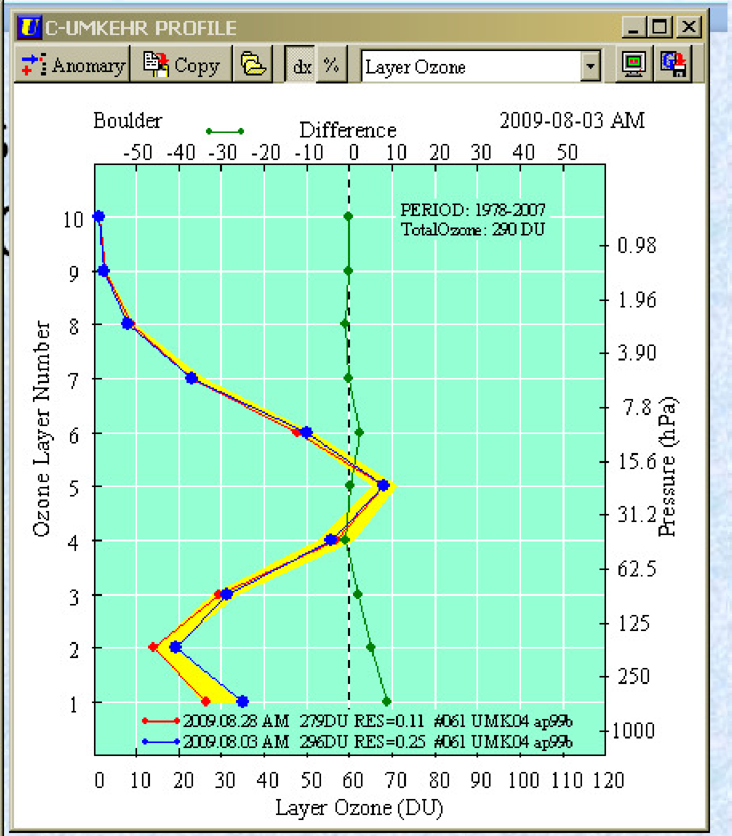


Ozone profile from Umkehr

- Goetz and Dobson (1928) - ozone maximum
- Goetz (1931) – First Umkehr (zenith sky light changes with SZA) - and then profile (4 layers) – manual calculations
- Mateer (1964) – first computerized algorithm
- Optimum statistics method of information retrieval (Rodgers, 1976 and 2000).
- Mateer and DeLuisi (1992) – algorithms for ozone profile retrieval
- Petropavlovskikh (2005) –current algorithm, a priori dependence is minimized for trend analysis

New automated Dobson system:
Boulder since May 2009
MLO since June 2010



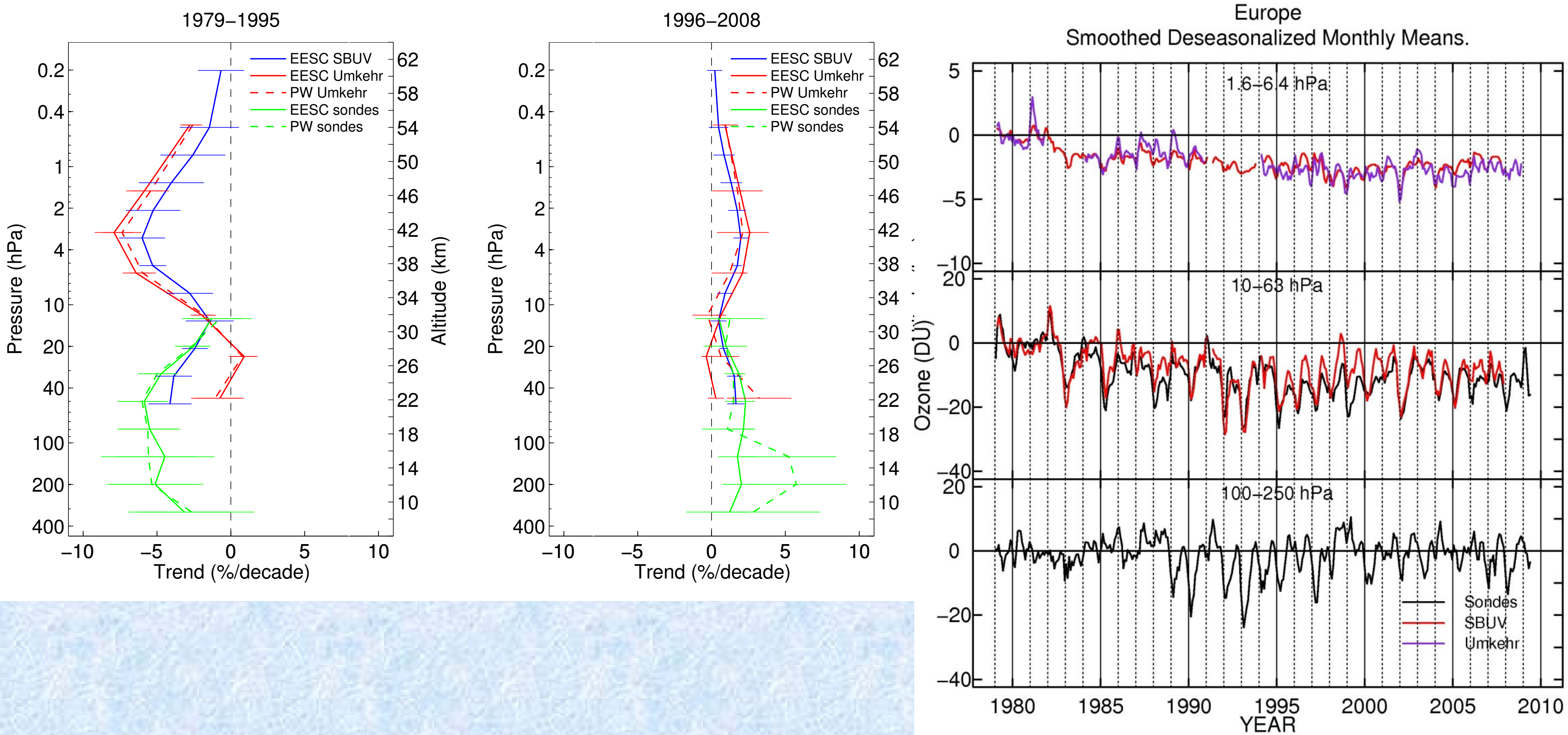


Instant tracking of measurement (plots in real time), remote access, automated recording, easier processing (instant) and re-processing of data

Why do we continue using Umkehr method?

- **Long historical record**
- **The data are easily available**
- **The calibration schemes (Dobson and Brewer) are well defined and documented**
- **Algorithm is well-known and continuous to be developed and refined**
- **Limitations are understood (stray light, vertical resolution, aerosols)**
- **Other methods to determine ozone profiles have other limitations, atmospheric coverage is different, have shorter records**
- **Dobson measurement is relatively cheap**

Differences in derived trends from Umkehr, satellite and sounding data (WMO, Ozone Assessment, 2010).



Presenting data: ozone variability

- **Climatology:**

➢ MLL (McPeters et al, 2006): DU or mixing ratio, 10-degrees latitude averages, monthly averages, and Z-60 (pressure) vertical resolution, also has RMSD information

- **Troposphere:**

➢ Umkehr vs. ozone sounding – Boulder and MLO stations (US)

- **Stratosphere:**

➢ SBUV V.8 (NOAA-9, 11, 16, 17, 18) vs. Umkehr

Belsk (52 N, Poland), Arosa (47 N, Switzerland), OHP (44 N, France), Boulder (40 N, US), MLO (19 N, US), Lauder (45 S, New Zealand) stations

➢ Microwave vs. Umkehr (MLO, USA and Lauder, New Zealand)

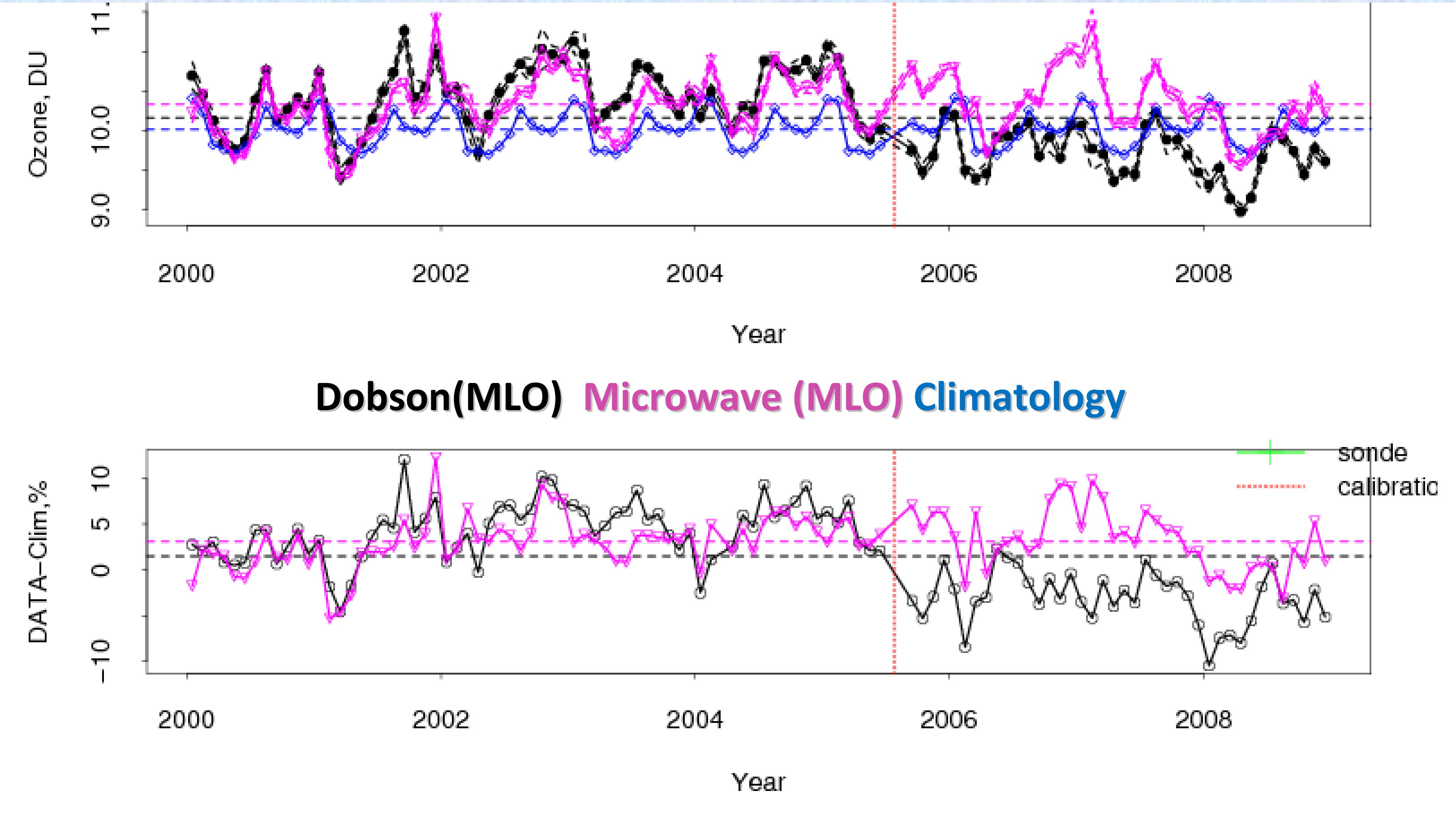
MLO: Umkehr (Dobson and Brewer), Microwave, sounding (Hilo), and SBUV overpass and zonal mean data.

- **Umkehr Dobson** – at MLO, started in 1982, typical frequency of measurements is 22 days per month, automation was done in 1984, thick layers (5 km) with wide AK
- **Umkehr Brewer** – started in 1990s, collected Umkehr data until 2006, variable sampling rates
- **Sounding** – at Hilo, started in 1982, sampling is 4 times a month, high resolution, regularly gets to layer 6.
- **Microwave** measurements started in 1995, <10 km vertical resolution, profile is derived above ~ 30 hPa (20-70 km), multiple measurements per day (diurnal cycle)
- **SBUV (NOAA/2)** V8 data – overpass (+/- 4 degrees in longitude and latitude, and 24 hours), or zonal mean homogenized data (NOAA and NASA), ~ 4 km vertical resolution, low tropospheric sensitivity, series of measurements by different satellites started in 1970s.

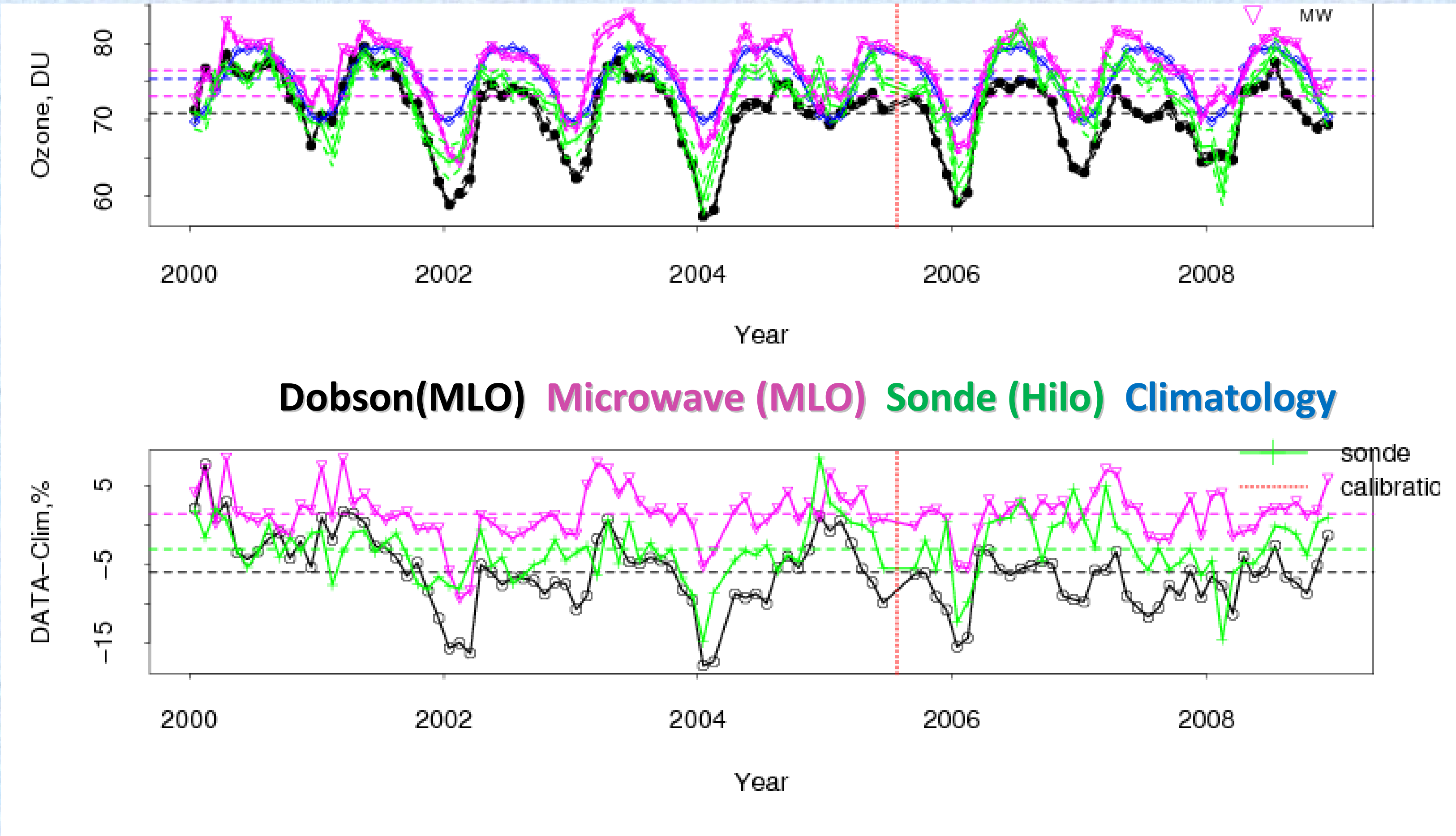
Separation of data in periods (PK): the most recent decade, plenty of data

- **Decade 4: 2000-2009**
- Satellite: NOAA-16, 17, 18 & 19 SBUV/2, SAGE II, SAGE III, POAM, Aura MLS, ACE
- Ground: Umkehr, sonde, microwave, Lidar
- Satellite Data Coverage: SBUV/2 provides full coverage. SAGE and POAM cover only the 1st half. SAGE III has limited coverage. Aura MLS covers only the 2nd half.
- Data Quality: By far the best decade for profile data.

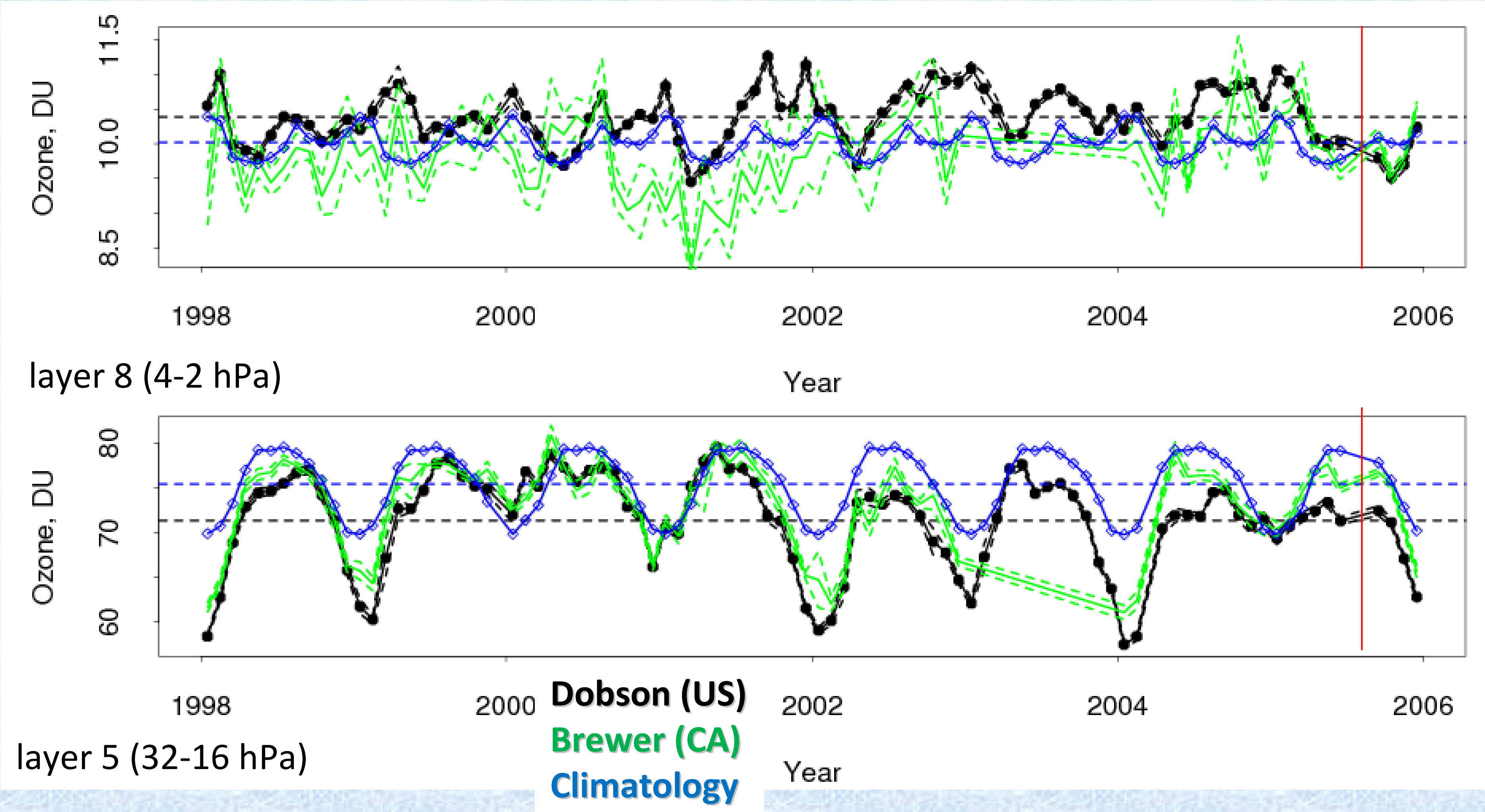
MLO, Microwave (integrated), Climatology and Umkehr, layer 8 (4-2 hPa) 2005 – offset change in Dobson electronics



MLO, Microwave and Sounding (integrated), Climatology, Umkehr, layer 5 (32-16 hPa)



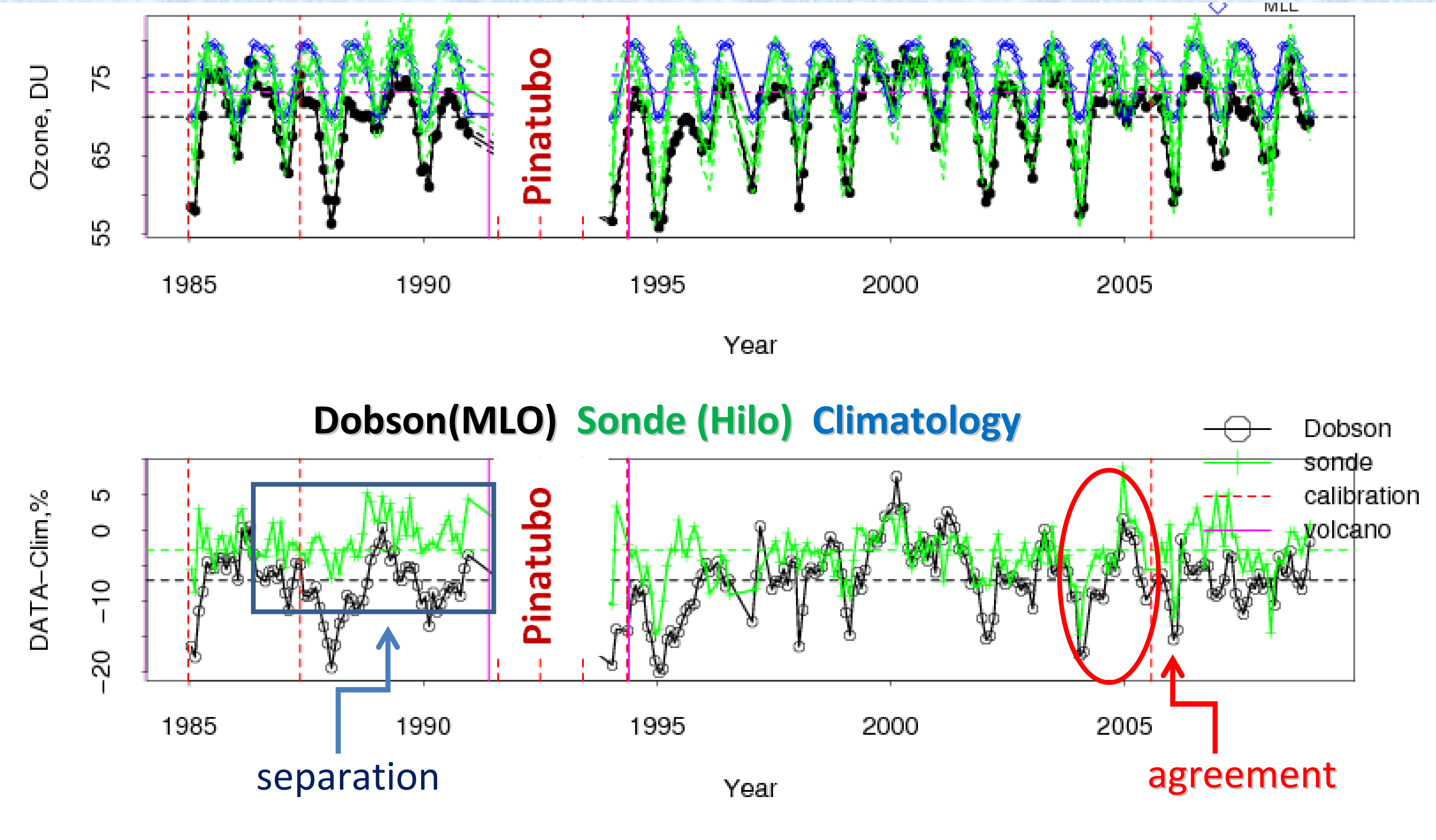
MLO, 1998-2005, **Dobson** and **Brewer** Umkehr



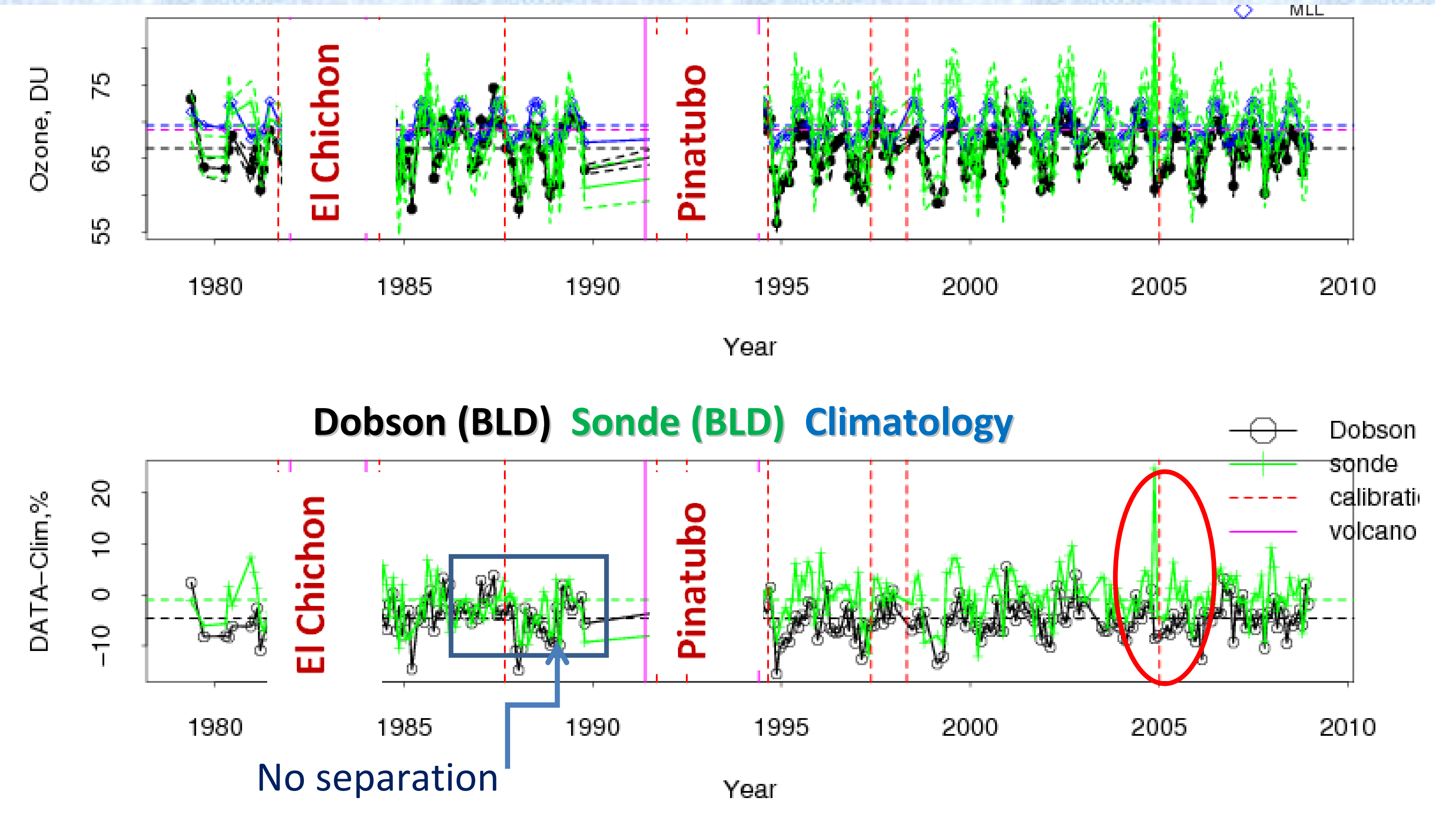
Other periods in Umkehr data (PK)

- **Decade 2: 1980-1989**
- Satellite: Nimbus-7 SBUV, SAGE I, SAGE II, NOAA-9 SBUV/2
- Ground: Umkehr, sonde
- Data Coverage: no significant gaps
- Data Quality: Generally good except NOAA-9. Eruption of El Chichon volcano in April 1982 created problems for ~1 year with some instruments.
- **Decade 3: 1990-1999**
- Satellite: NOAA-9, 11 & 14 SBUV/2, SAGE II, POAM, UARS MLS
- Ground: Umkehr, sonde
- Data Coverage: no significant gaps, except POAM has limited coverage.
- Data Quality: SBUV/2 data are significantly affected by orbital drift. Eruption of Mt. Pinatubo In June 1991 created problems for ~2 years with some instruments.

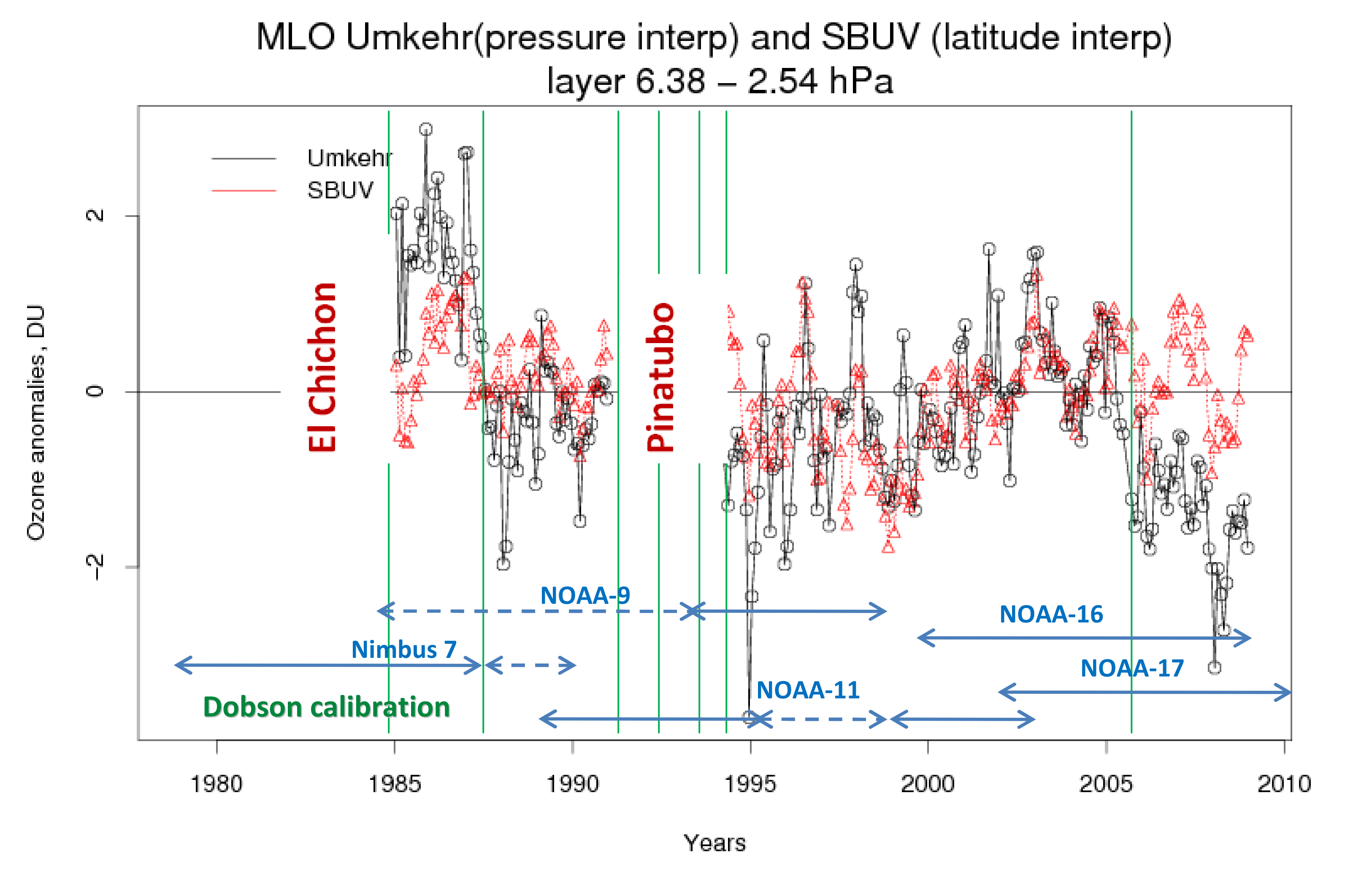
MLO,1985-2008, Sounding (integrated), Climatology, Umkehr, layer 5 (32-16 hPa)



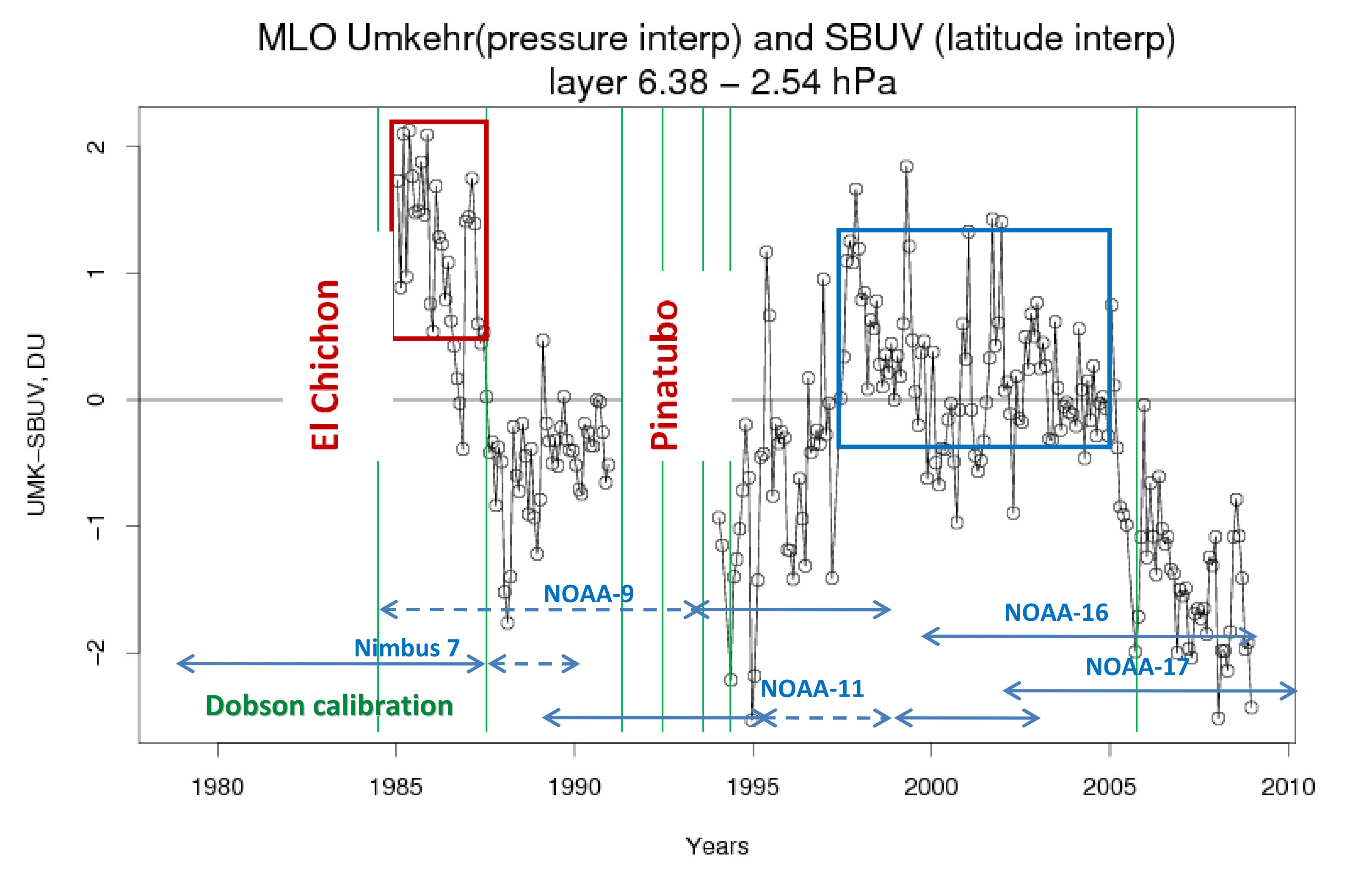
Boulder, 1979-2008, Sounding (integrated), Climatology, Umkehr, layer 5 (32-16 hPa)



MLO, 6-2 hPa, (SBUV V8, zonal-mean, NOAA homogenized), monthly de-sesonalized



MLO, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), SBUV and Umkehr difference



M. Kurylo questions

- *Define the altitude regions over which the Umkehrs are most reliable for determining ozone vertical profile trends:*
  - layers 6 (16-8 hPa), 7(8- hPa), 8 (4-2 hPa) and 8+ (above 4 hPa) (and all others, but they are thick)
  - layers represent information that is smoothed vertically (AK)
  - trends below 16 hPa have to be carefully interpreted when dynamical processes at the lower altitudes could contribute to the vertically smoothed profile layer.

M. Kurylo questions

- *Detailing how long-term stability and quality control is verified for the Umkehrs (Dobson and Brewer)*
  - Intercomparisons and calibration - every 4 years, repairs when needed, wedge density calibration, replacement of filters, measurement of the offset in electronics noise.
  - Regional and world standard instruments (Langley at MLO, Izana) - transfer of the ETC by matching TO measured by the standard instrument
  - Mercury lamp (continuous for Brewer) and standard lamp tests (Dobson monthly, daily for Brewer) to verify spectral shifts and calibration offsets (TO correction)
  - Reports of intercomparisons are submitted to WMO
  - Station-to-station intercomparisons (occasional) and station-to-satellite (regular)

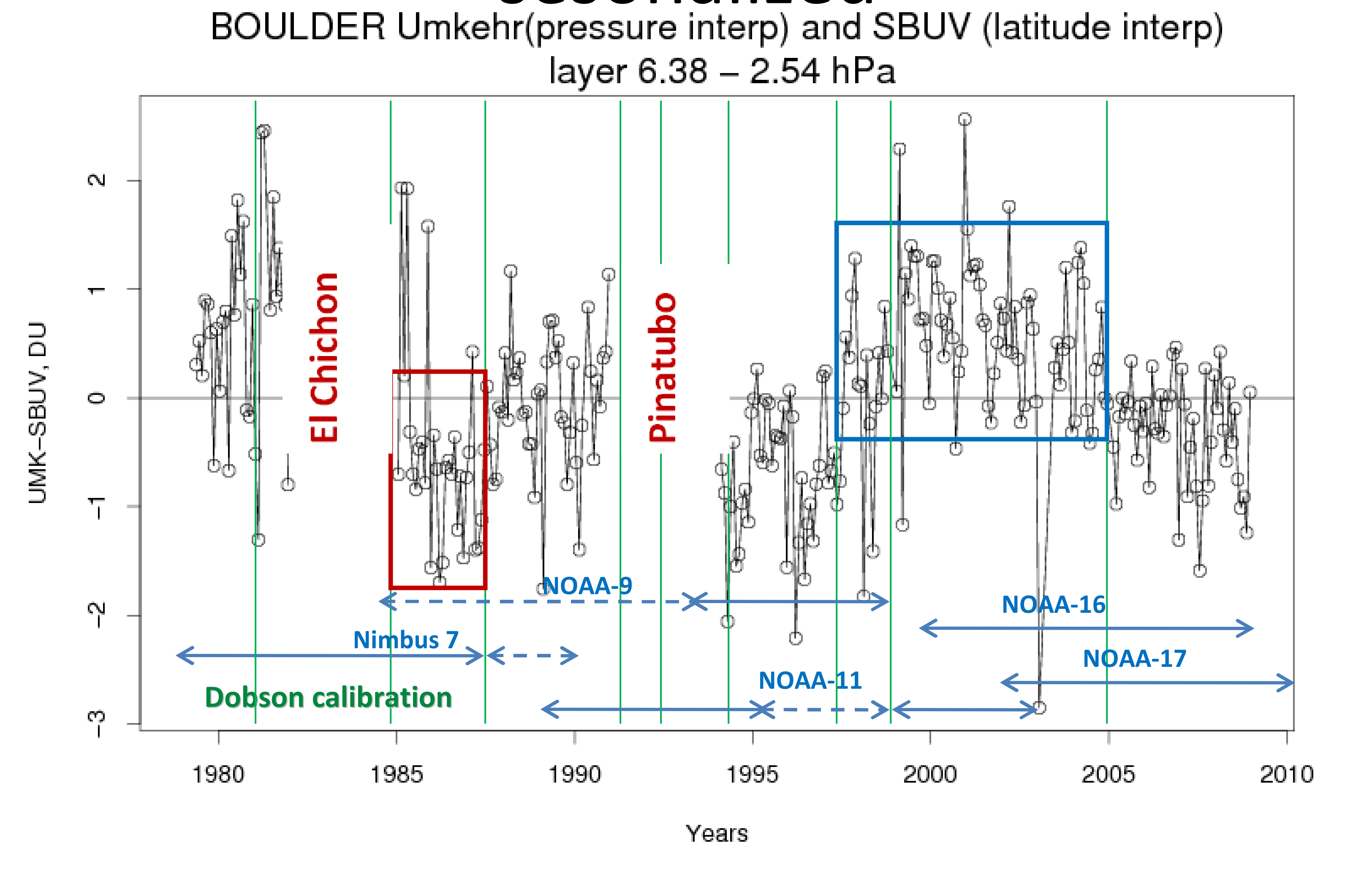
M. Kurylo questions

- *Indicating the level of confidence for long-term vertical trend determinations by various instrument types as established by intercomparisons with other ground instruments and with satellite data:*
  - Not all Dobson or Brewer stations have data quality sufficient for trend analysis – length of the record, lack of information about calibration and change of instrumentation.
  - Comparisons between stations within the same region – stratospheric data are well mixed over lower and middle latitudes, but not near polar vortex
  - Comparisons against SBUV data, sounding and MW over extended periods of time.

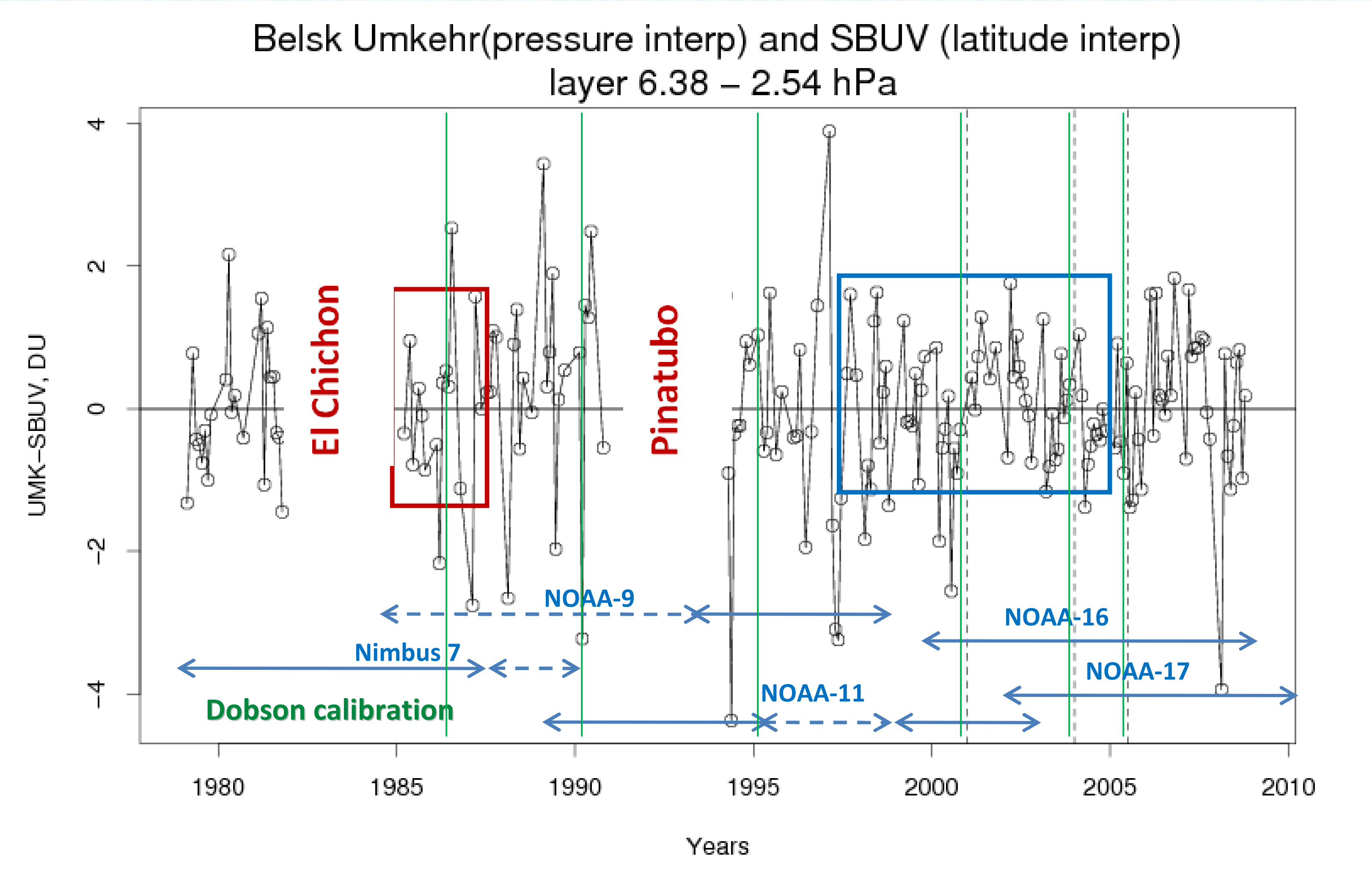
M. Kurylo questions

- Examining how the determination of long-term trends could be “compromised” by geographical gaps in measurement coverage:
  - Combining Umkehr data within the same geographical region
  - Gaps in data during volcanic aerosol interferences with measurements

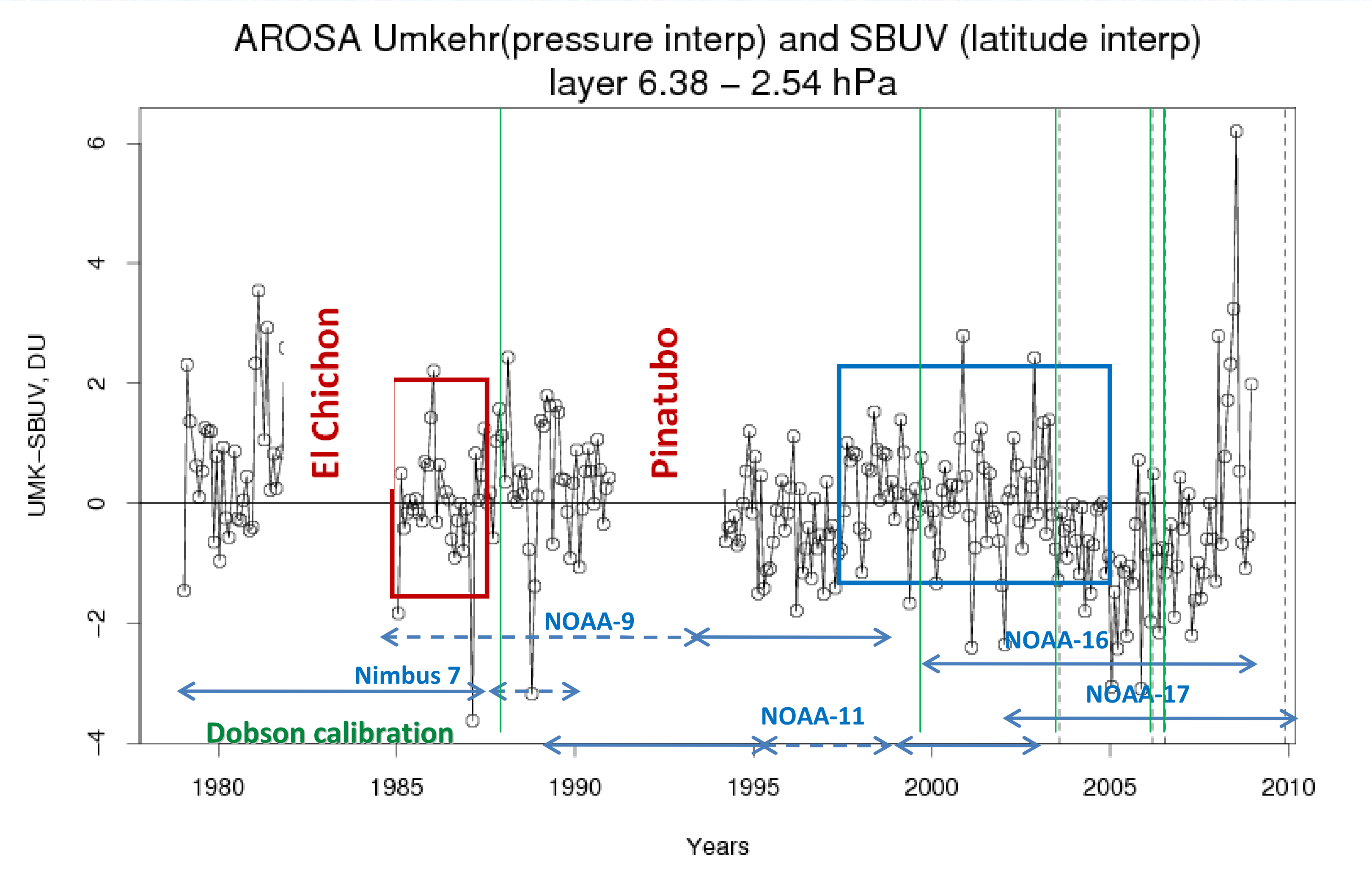
Boulder, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), monthly de-sesonalized



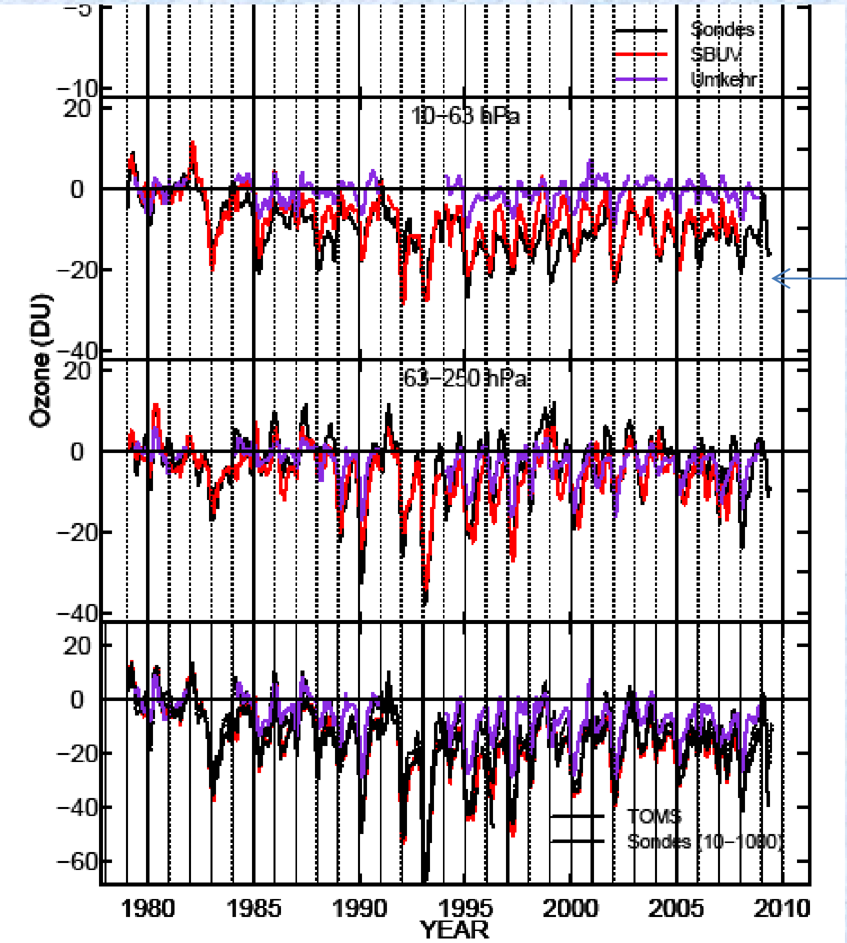
Belsk, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), contd: Umkehr-SBUV

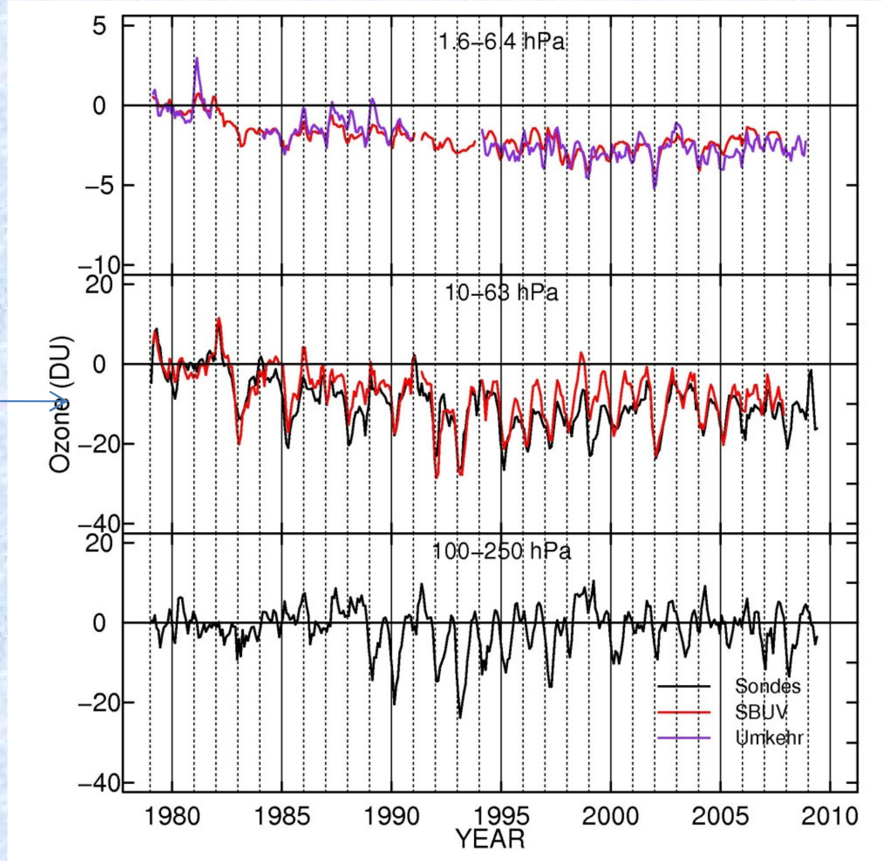


Arosa, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), monthly de-sesonalized



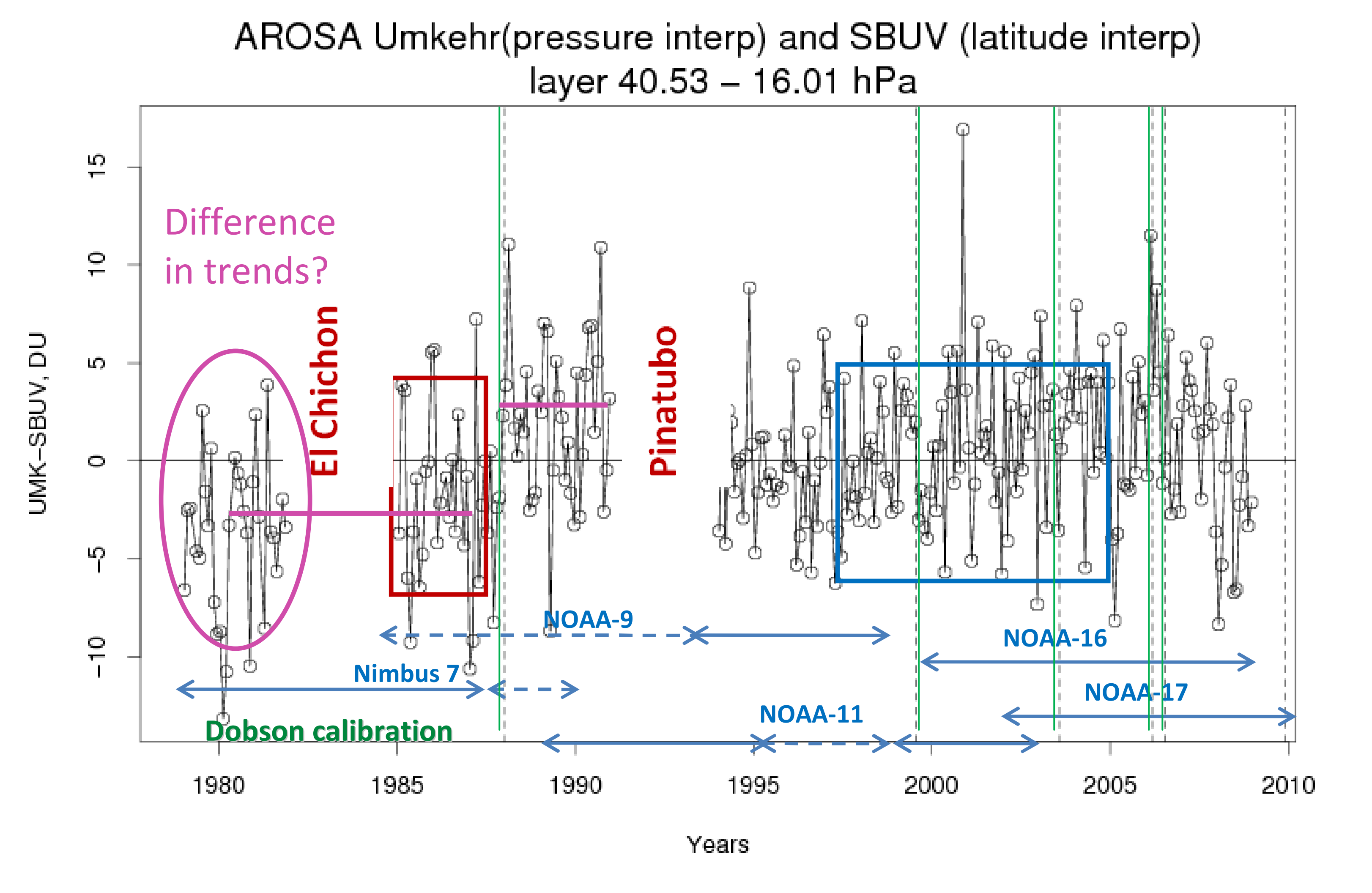
Europe average: SBUV - gridded
Umkehr: Belsk, Arosa and OHP
Sonde: Uccle, Hohenpeissenberg, Payerne



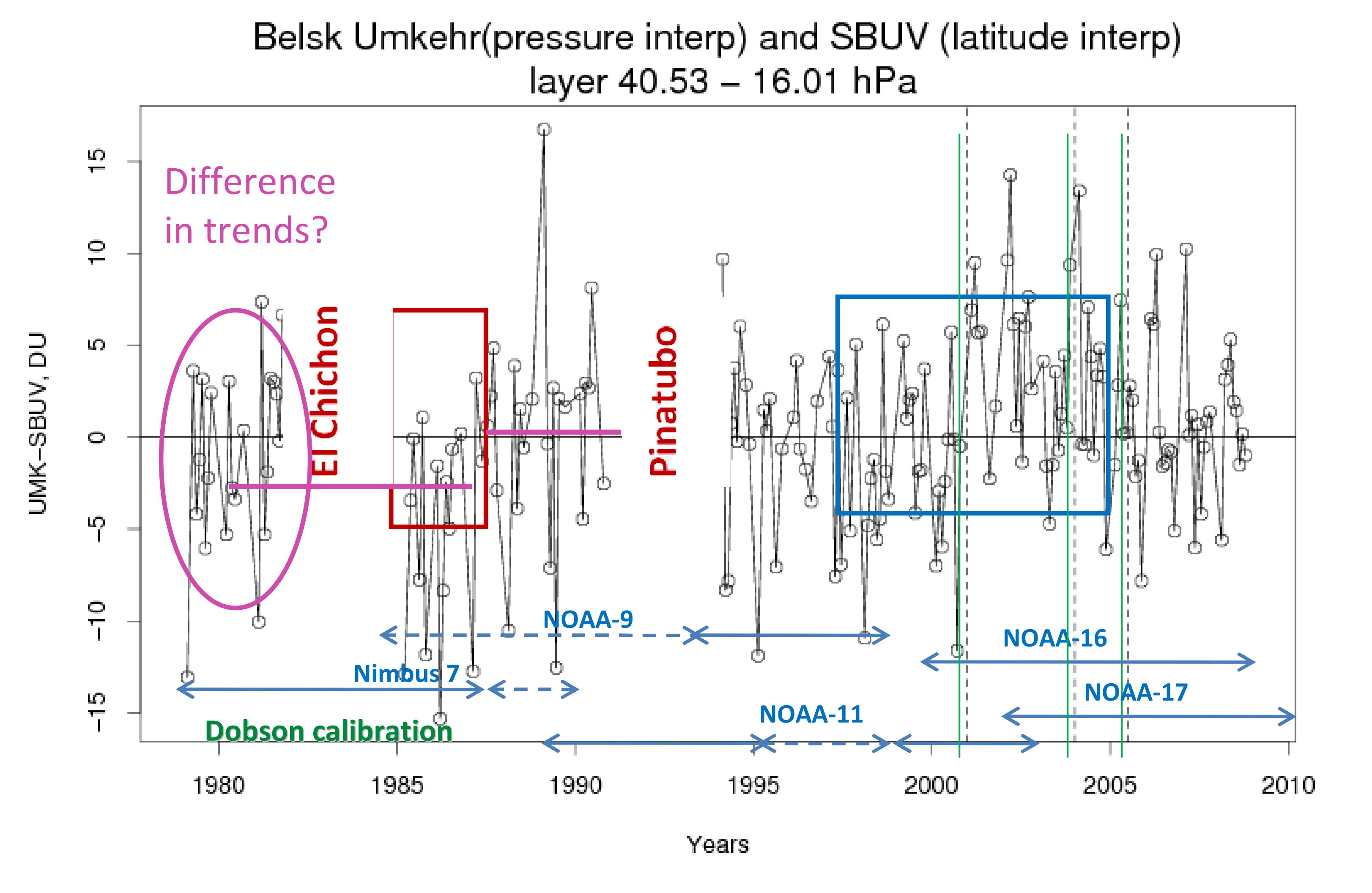


No decline in Umkehr O3 in layer 10-63 hPa, but small trend in sonde and SBUV (gridded and adjusted, Terao and Logan, 2006)

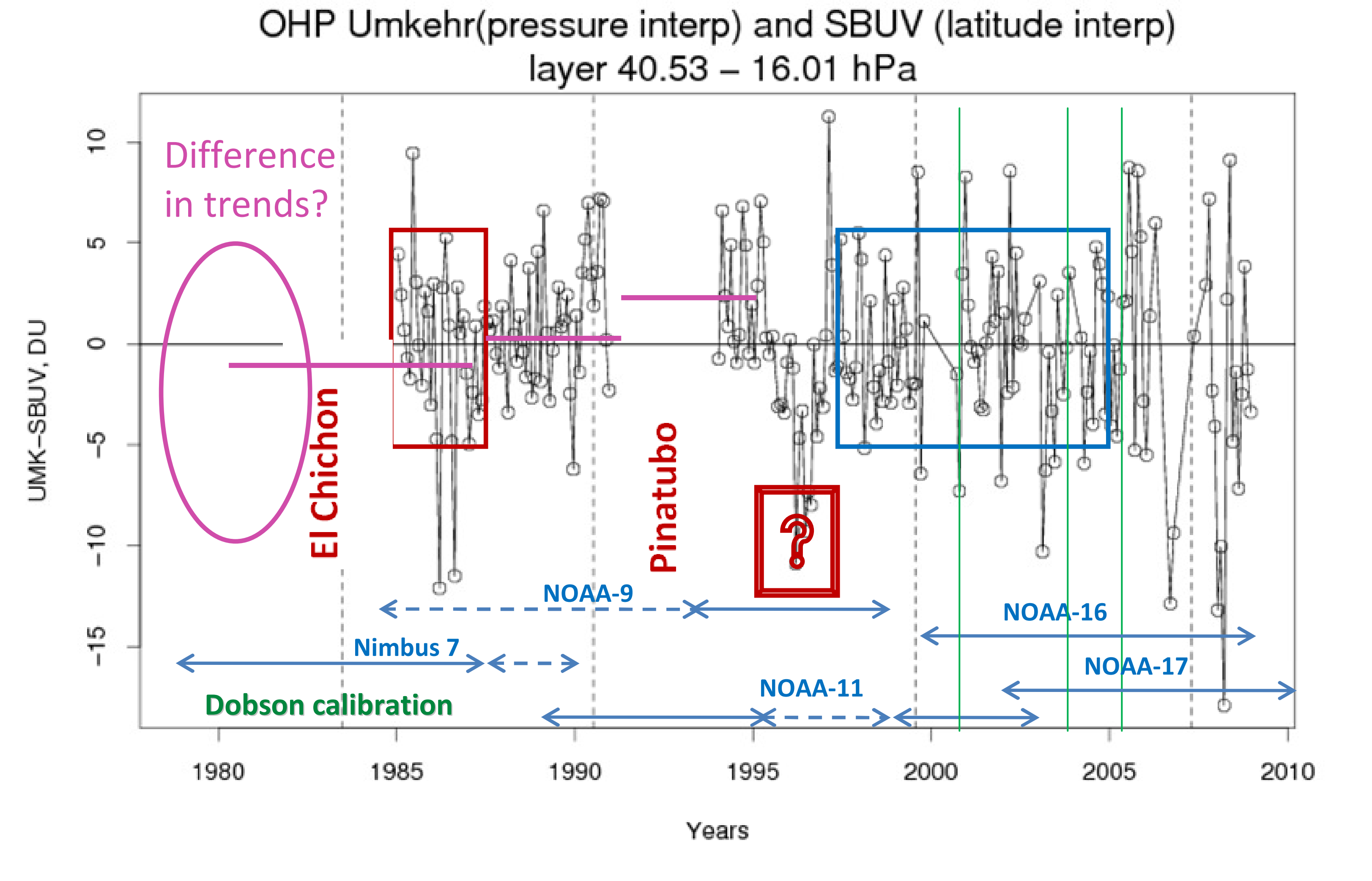
Arosa, 40-16 hPa (SBUV V8, zonal-mean, NOAA homogenized), monthly de-sesonalized



Belsk, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), contd: Umkehr-SBUV



OHP, 6-2 hPa (SBUV V8, zonal-mean, NOAA homogenized), contd: Umkehr-SBUV

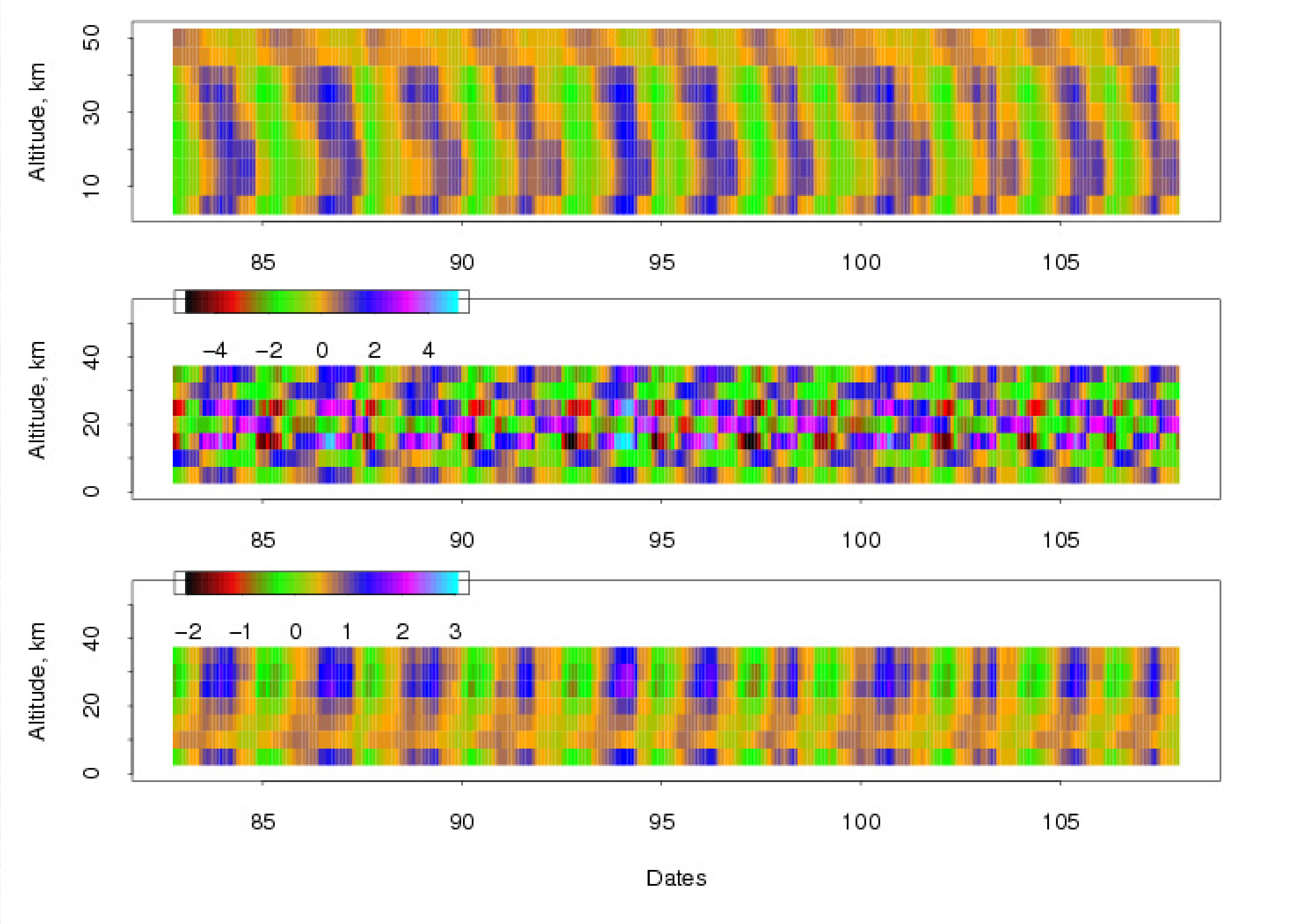


MLO, QBO signal in ozone profile, Dobson and sonde, coincidence <2-day

Umkehr

Sonde

AK*sonde



Questions to consider in preparing the action plan.

- ***What are the needs*** **?**
- Creating databases in different coordinate systems for meeting, the needs of different users
  - Doing it all the time for comparisons with other measurements – but there is no consistent follow up
  - Typically conversions from mixing ratio to DU in pressure coordinate system
- Procedures for homogenizing existing vertically resolved ozone measurements from different sources:
  - Monthly mean data, and uncertainties of the measurement and retrieval
  - Compare data after subtracting individual seasonal cycles (stray light or diurnal change differences)
  - Corrections for diurnal changes
  - Using calibration/instrument replacement records
  - Overlapping data from different instruments (stray light issues, different wavelengths)
  - Assessment of how the algorithm differences can affect the retrieval
  - Characterization of instruments for band-passes, stray light, wavelength registration

Questions to consider in preparing the action plan.

- **(a) what is being done**: calibration of instrument, daily checks for stability of measurement (lamps), measurement of electronics noise (amplifier), measurements of NiSO4 filter degradation
- **(b) what could be done**: better optical characterization of instruments, measurements of individual band-passes and stray light contributions, polarization characteristics of Brewer optical system, ETCs, transfer of calibration, better tacking of NiSO4 filter degradation
- **(c) what should be coordinated and how** ?

  Including aspects such as:
- **will there be a core measurement again?**
  - yes for Dobson, however funding for NEUBrew measurements is scarce (no base funding, except for the NPP support and occasional EPA support)
- **what should be used for validation, what for trends?**
  - Umkehr data in stratosphere can be used for both validation and trends
- **what are good ways to merge time series?**
  - Use the data with the most of the global coverage and correct it using ground-based and remote-sensing data.
- **how can this be assessed?**
  - Through continuing monitoring and validation excersize.

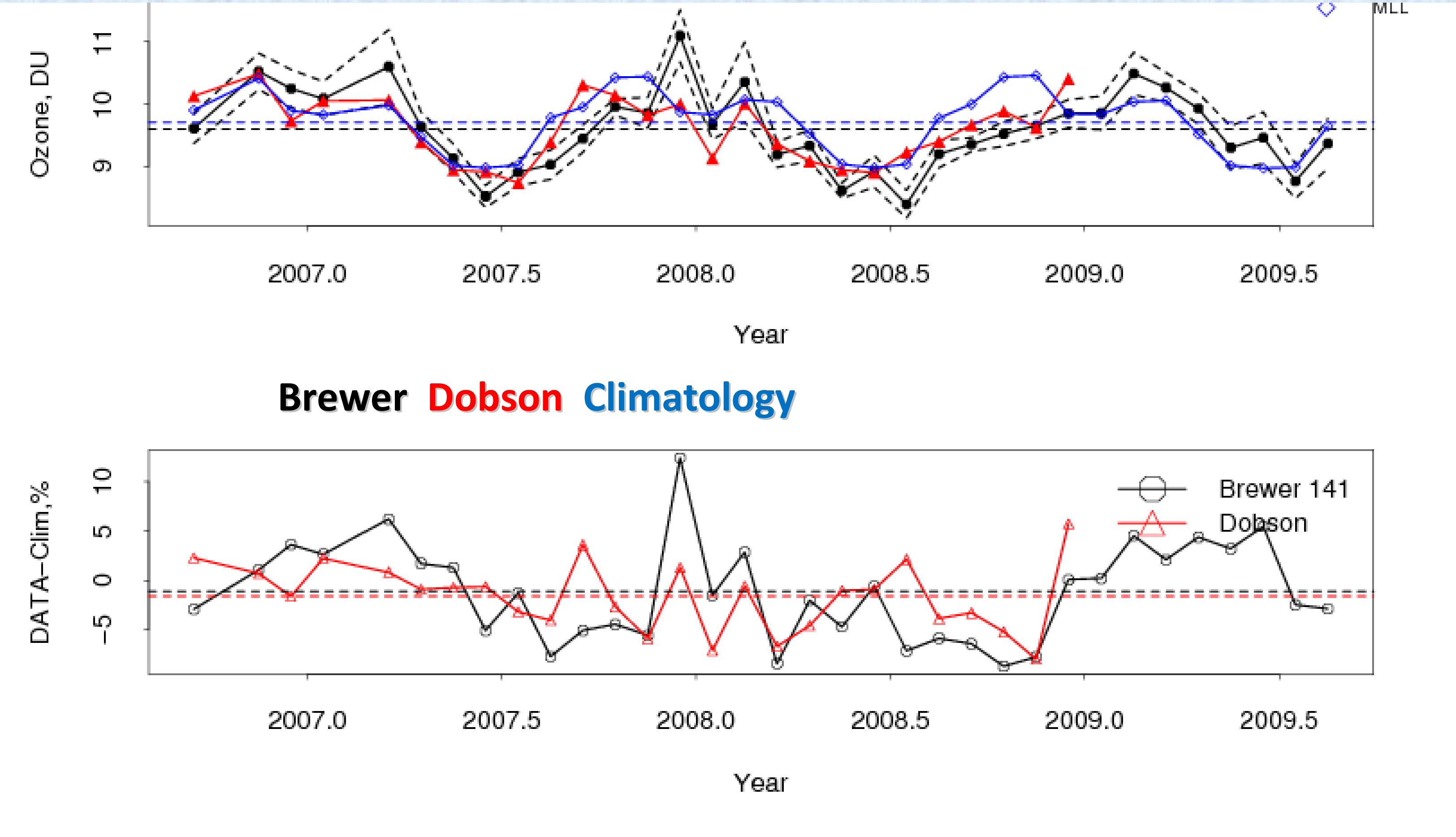
Questions to consider in preparing the action plan.

- **Decide how this initiative should be organised**
- leaders, work plan, communication, end product
- **Funding issues:** What is already funded, what activities (would) need additional funding ?
-
- ***Who can do what ?***
- **Coordination ?**
- **Meetings of subgroups in 6 months ?**
- **Next plenum meeting: in one year. Where?**
- **Product of coordinated activity ?**
- **Time planning and planned termination of the activity?**

Why do we continue taking and looking at Umkehr data?

- **Well-maintained and self-consistent record** easily available from archives
- **Long historical record** (back to 1957, some even earlier, but unknown quality)
  - Satellites measurements began in 1970s
  - Sondes records started in 1960s.
  - Microwave started in 1990s.
- **Calibration**: well established for Dobson and Brewer instruments
  - ➢ Ratio (Dobson) or weighted average (Brewer) vs. Absolute (tropospheric aerosols, albedo)
  - ➢ N-tables for Dobsons (optical instrumental characterization)
  - ➢ Records are kept at regional calibration centers, also as published reports at WMO, archiving information at WOUDC (future)
  - — Satellites are hard to calibrate (different platforms, orbits, not sufficient overlaps)
  - — Sondes have changes in solutions, types of instruments, procedures, chamber tests
  - — Microwave - two levels of calibration: hourly, under computer control, and manually, three times per week. Black bodies at known ambient and cryogenic temperatures are used in the calibration procedures.
- **Stratospheric aerosol interference** – large errors, but a short-lived effect (~6 months)
  - The same problem for satellites and other remote-sensing instruments, SO2 and aerosol interference in sounding in troposphere
- Umkehr data provide **reliable information in layer 8 (40-45 km)**
  - Sonde data do not reach 40-km altitude
  - New methods (Microwave, IR) have shorter records and limited coverage

Boulder, 2006-2009, 4-2 hPa, Brewer (NEUBrew), Dobson and climatology



Boulder, 2006-2009, 32-64hPa, climatology, sounding (4/month) and Brewer (20/month)