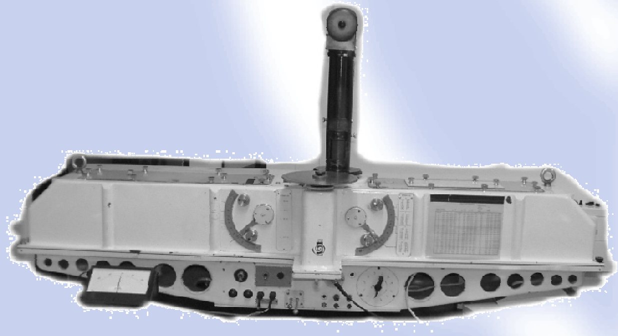
25 Years of Total Ozone Observations

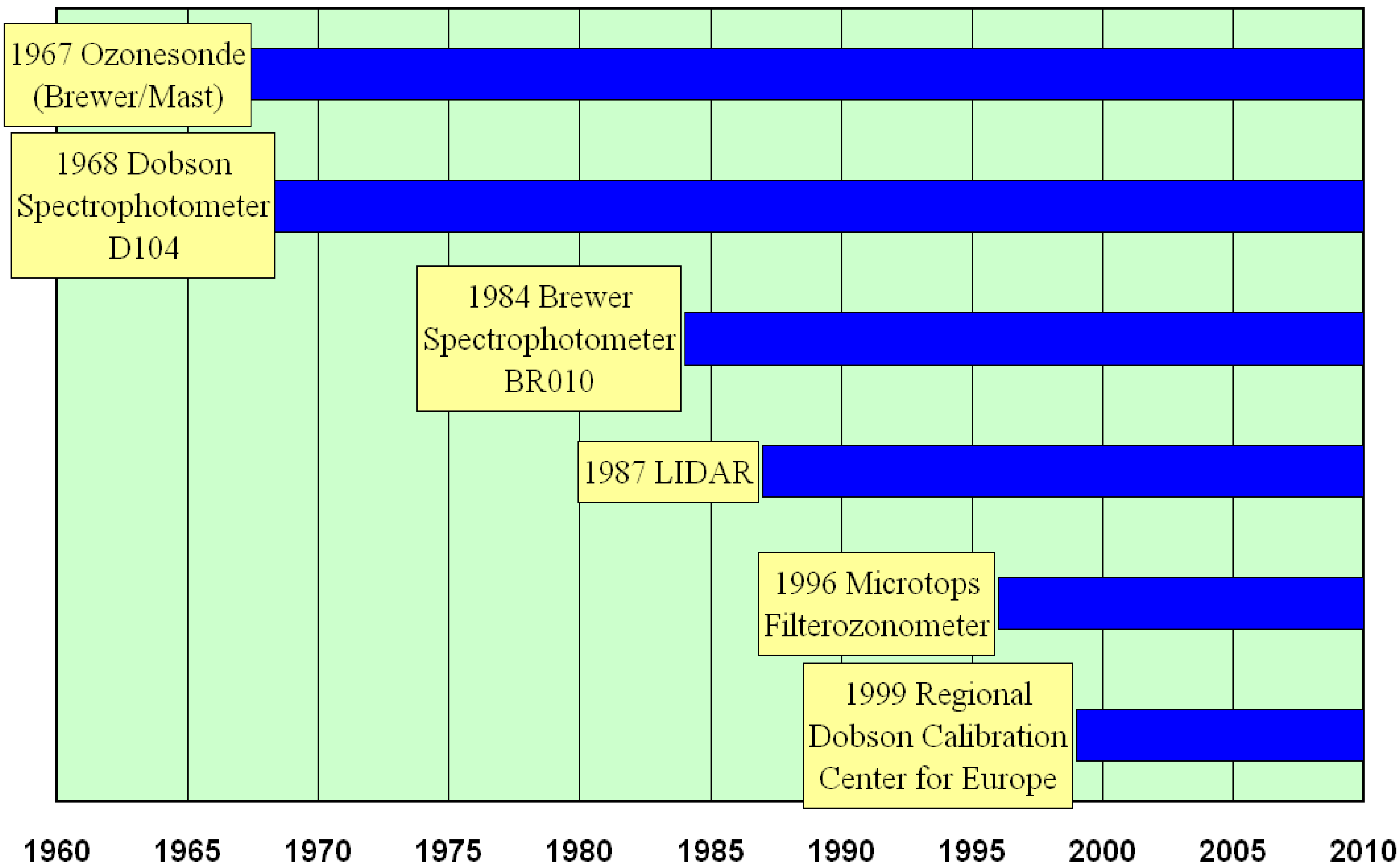
at Hohenpeissenberg

with Dobson and Brewer Spectrophotometer



(Ulf Köhler)

Ozone Observation Programm at MOHp



Measurement principle of both spectrophotometer types Dobson and Brewer:

General principle of observation:

- Measurement of solar UV radiation in at least two wavelengths
  (short with strong, long with weak ozone absorption

General principle of calculation:

-simplified equations:

$$O3(Dobson) = \frac{N_0 - \log(\frac{I_1}{I_2})}{\alpha * \mu} - Rayleigh - Mie$$

$$O3(Brewer) = \frac{M(9) - F_0}{\alpha * \mu}$$

$\log(\frac{I_1}{I_2})$ & M(9) = measured signal

N0 and F0 ≡ Extraterrestrial Constants ETC's

α = Ozone absorption coefficient for wavelength pair(s) (Dobson) or combination (Brewer)

μ = relative optical path through the ozone layer (ozone slant path OSP)

Rayleigh is atmospheric scattering / Mie is particle (e.g. aerosols) scattering (~ 0 for double wavelength pairs)

Possible error sources and effects on ozone value:

- Measured signal: due to electronical (e.g. EMI) or optical „noise“ (e.g. internal or external straylight)
→ variable error with higher values when signal to noise ratio is getting small (e.g. at low sun) which is seen as μ-depending error („drop off“ of ozone values at lower sun)
Single monochromators worse than double monochromators (internal straylight)
Dobson worse than Brewer due to larger field of view (more skylight around sun)

- N0 and F0: not optimal („wrong“) calibration, that means ETC‘s are not correctly determined
→ variable error with smaller values at low sun as divided by μ

- μ: wrong calculation of the OSP (e.g. wrong assumption of the height of O3-layer)
→ error becomes larger, when sun is low: is seen is μ-depending error

-α: incorrect ozone absorption coefficients (wrong optical alignment of the instrument or „too old values“)
→ bias with a constant factor
or incorrect due to variable effective O3-layer temperature (not -46^{O} C as nominal value for the currently valid Bass/Paur absorption coefficients)
→ bias with variable values depending on difference between nominal and effective temperatur is mostly seen as seasonal oscillation since ozone layer temperatures fluctuates correspondingly

-Mie-scattering: high turbidity enhances external straylight (see first item)
→ ozone drop off at low sun, but earlier than under clear air conditions

Which of these effects can be seen

in the Hohenpeissenberg long term records

obtained with

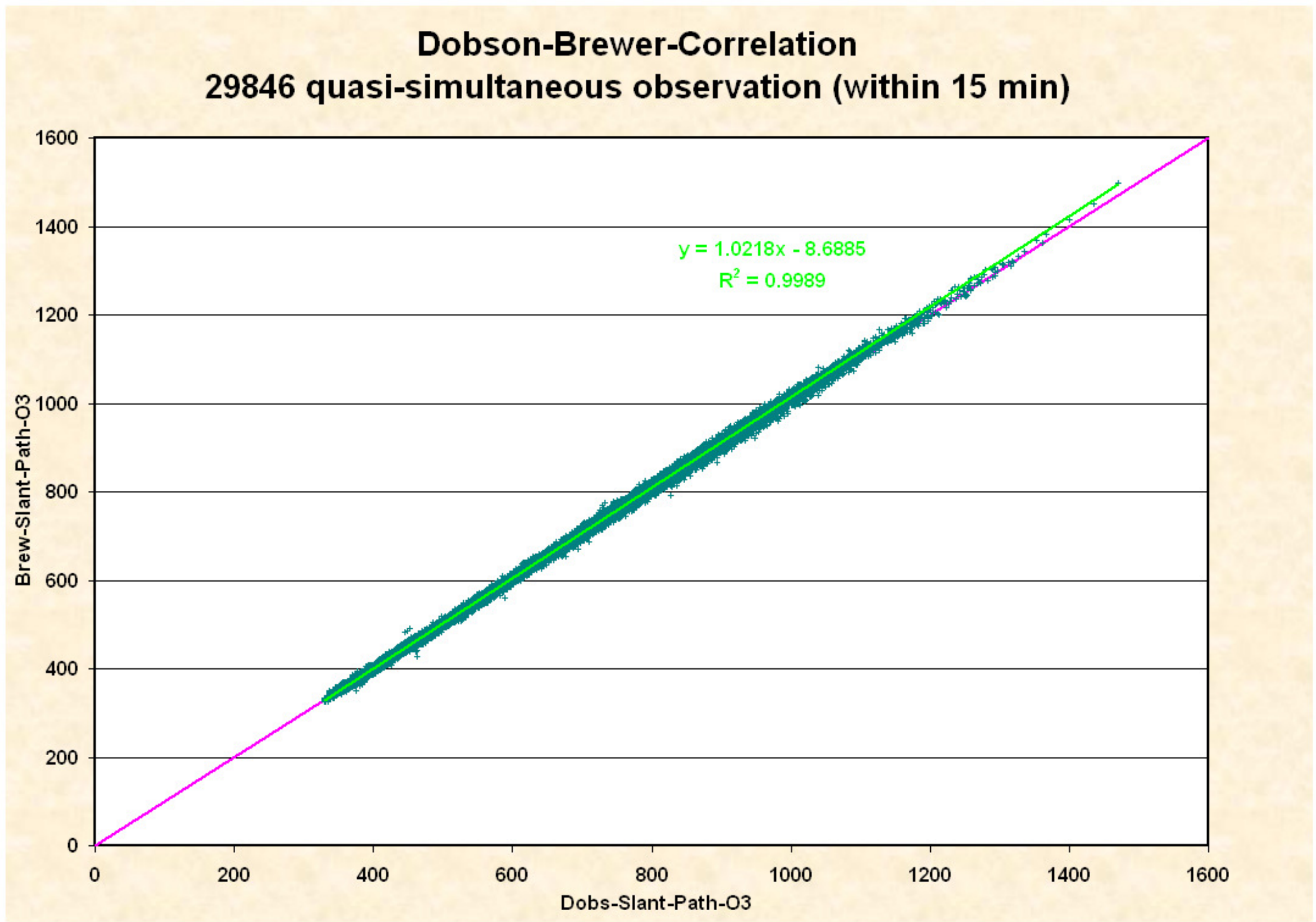
Dobson spectrophotometer No. 104

and

Brewer spectrophotometer No. 010 (# II)

???????????????????

Long Term Intercomparison between Dobson No. 104 and Brewer No. 010 – Individual Observations



Data base – 29846 individual observations within 15 minutes:

In principle good agreement!

Better at high sun and low O3 (small OSP)

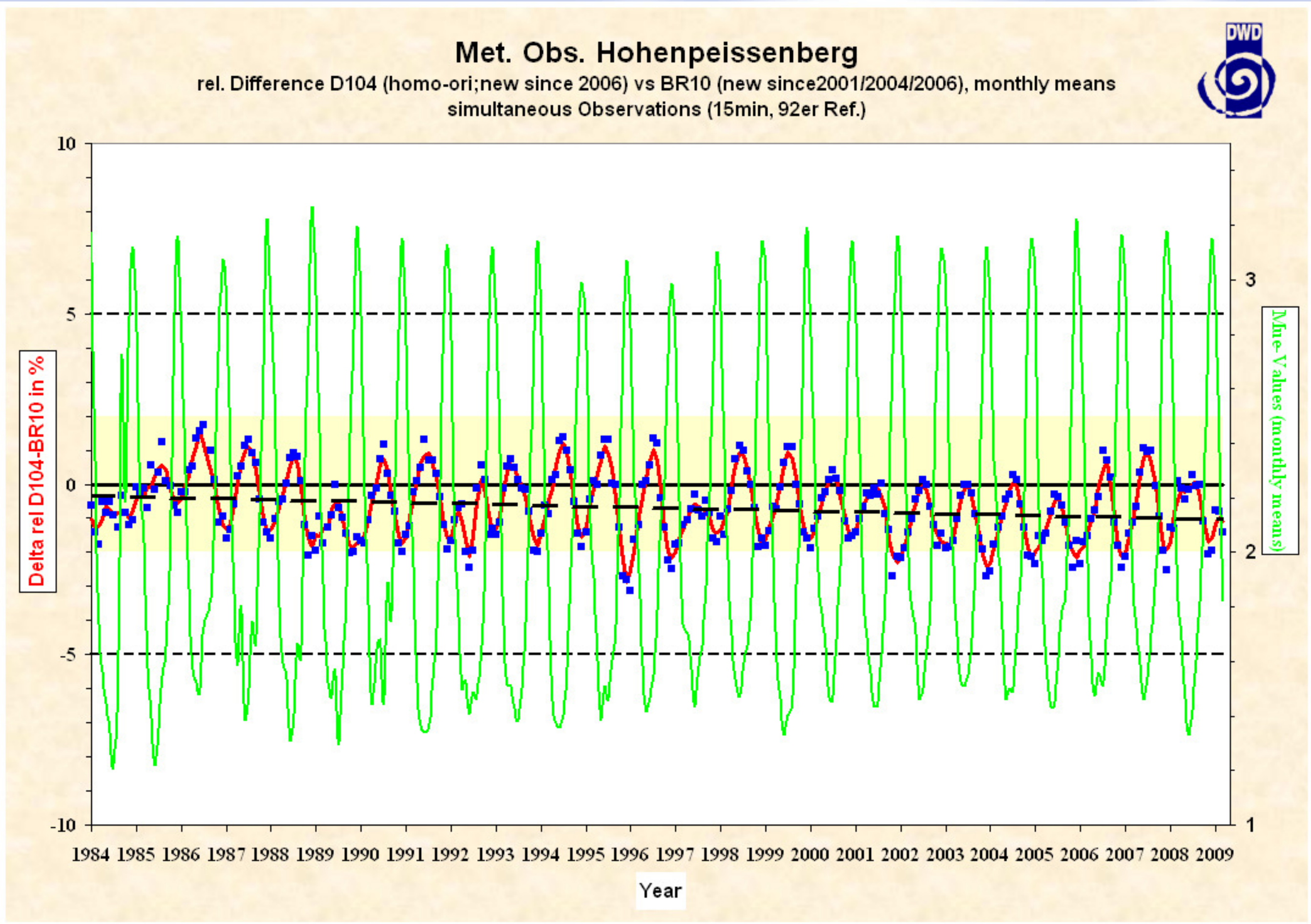
Large OSP values represent observations during winter and spring season (low sun or thick ozone layer): larger difference!

Brewer higher than Dobson!

Possible explanation?

Next slide:
same data –
different presentation

Long term Intercomparison between Dobson No. 104 and Brewer No. 010 – Monthly Means

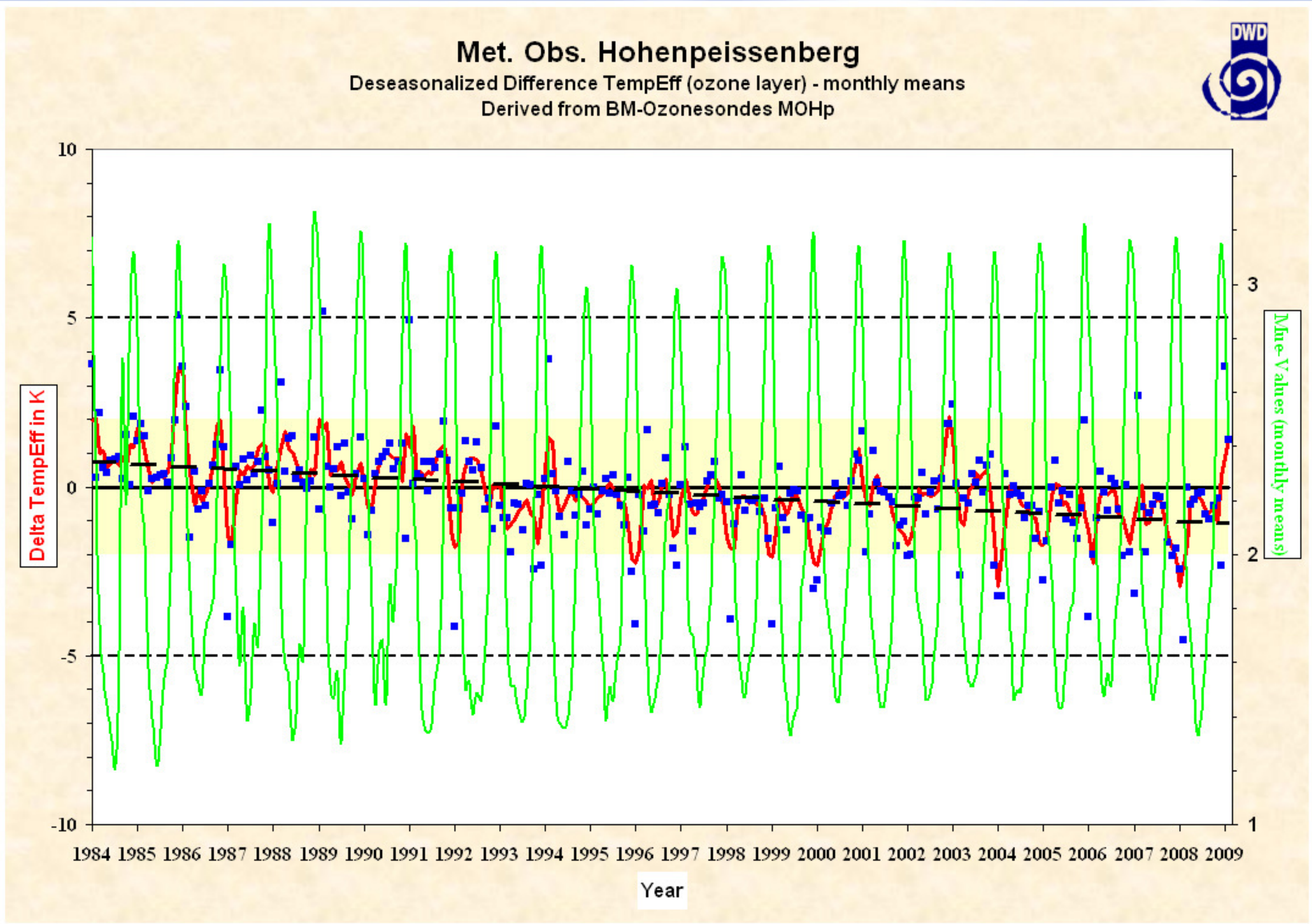


<u>Time series of monthly means of the individual observations</u>

Evident patterns:

- Annual oscillation (well-known in the Dobson-Brewer community): Amplitude of 2-3%
- Mean difference: Bias approx. -0.7%
- Small trend: -0.5% in 25 years
- Some anomalies in the first years may be due to often change of Brewer abs.coeff.

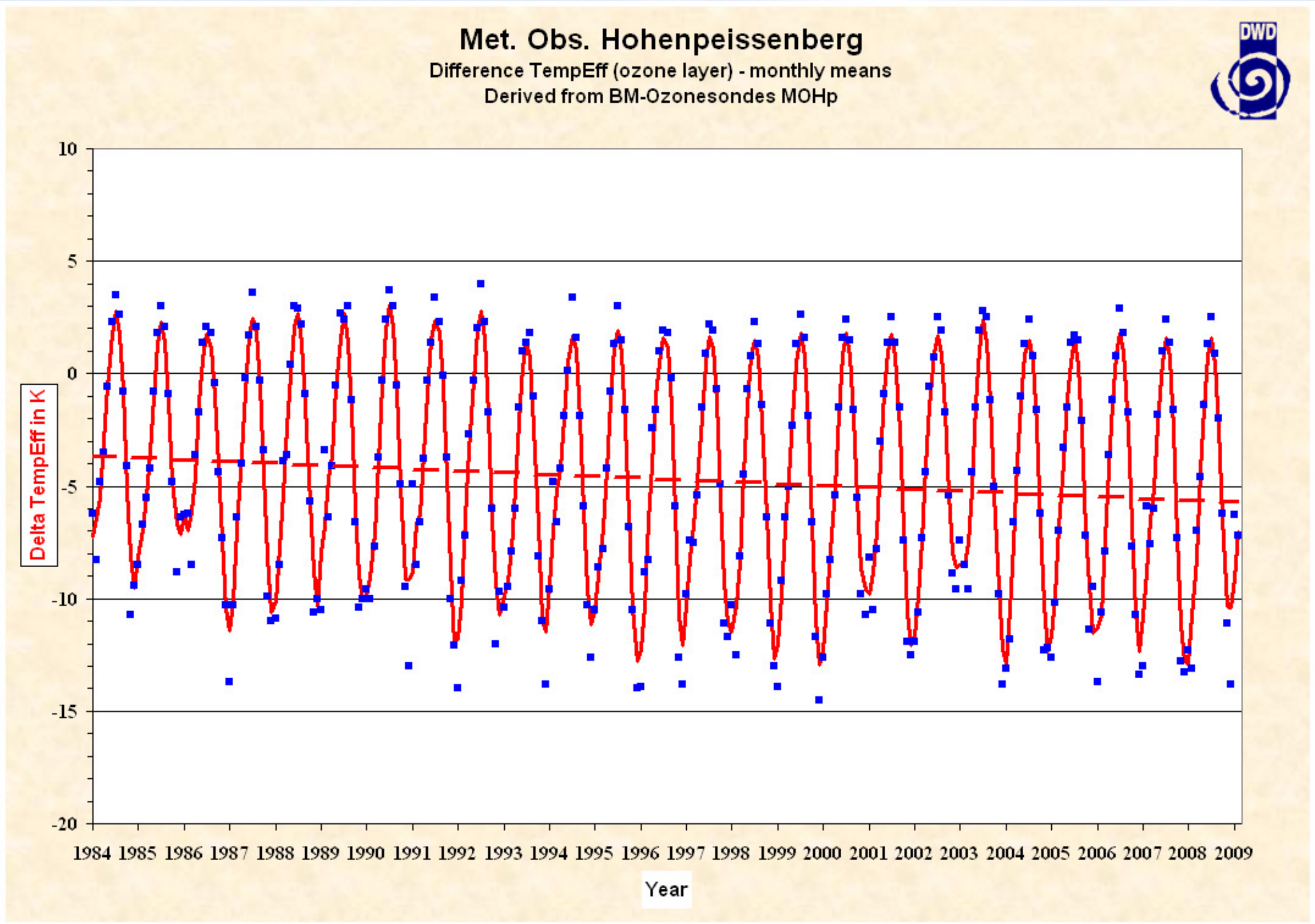
One Major Reason for the Observed Pattern
Effective Temperature of the Ozone Layer



Deseasonalized time series of the effective temperature in the ozone layer shows high variability from month to month and from year to year incl. a significant trend:

- cooling of the stratosphere due to climate change

One Major Reason for the Observed Pattern
Effective Temperature of the Ozone Layer



- Mean Difference:
  Eff. Temp. approx. -4.6 K lower than -46º C (nominal temperature used for B/P

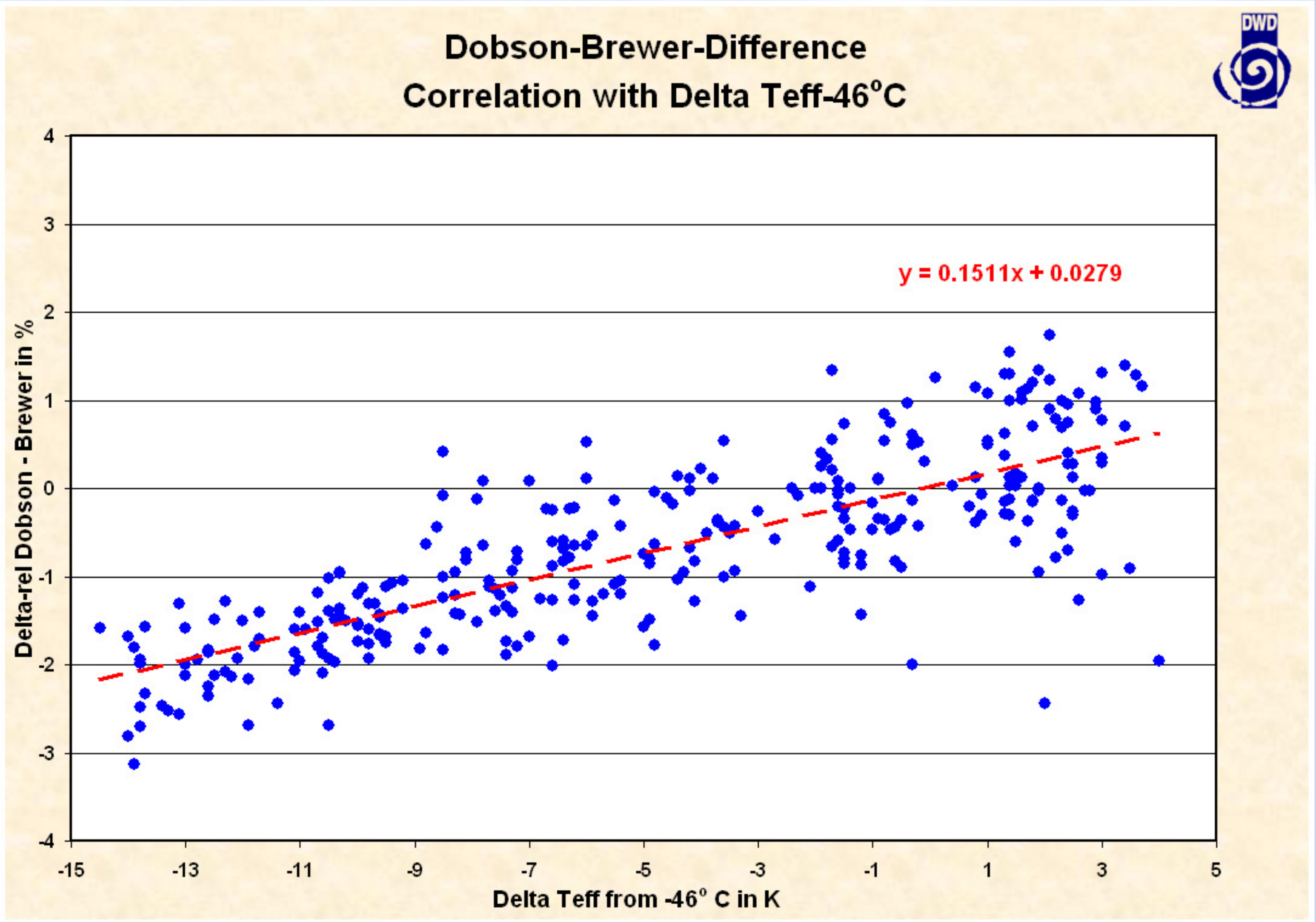
- Evident Trend:
  -2 K in 25 years
  →

Resulting in (using Kerr's finding about Delta Dob-Brew Absorption Coefficients = -1.25% per 10K):

- Mean Difference:
  -0.6% (from -0.7%)
  Residual -0.1% can be explained by mue-effect

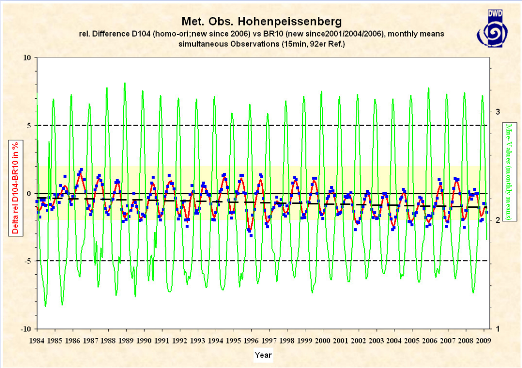
- Small Trend:
  -0.25% in 25 years
  (from -0.5% in 25 years)

One Major Reason for the Observed Pattern
Effective Temperature of the Ozone Layer

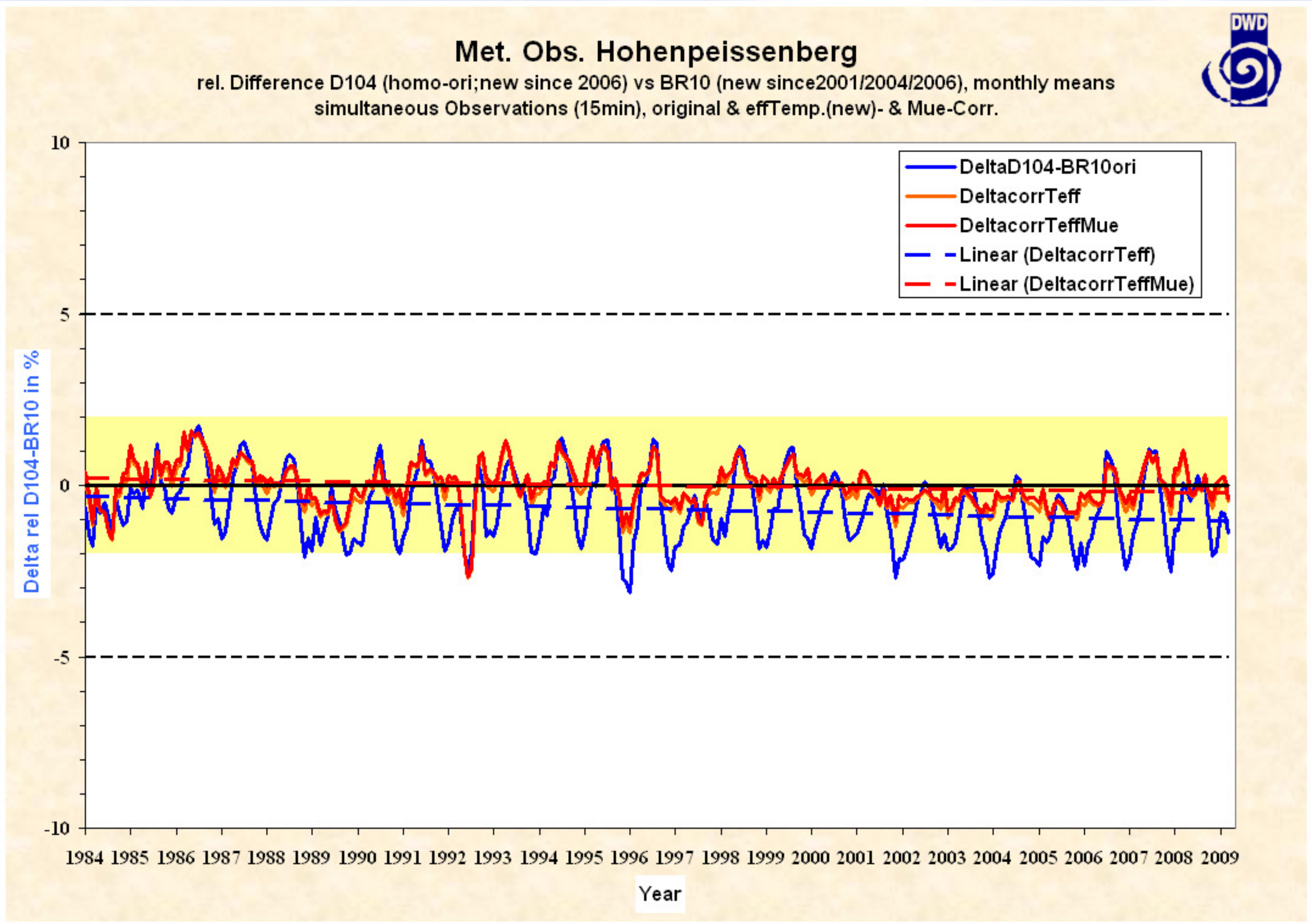


Good Correlation between Deviation of the Effective Temperature of the Ozone Layer from the Nominal Value -46° C (used for Bass/Paur) and the relative Difference Dobson – Brewer.

Outliers might be explained by temporary miscalibration or malfunction (not more than 1%)



Application of Corresponding Corrections on the Monthly Means of the Delta-Rel Dobson - Brewer



- Amplitude of Oscillation:
  Significant Reduction

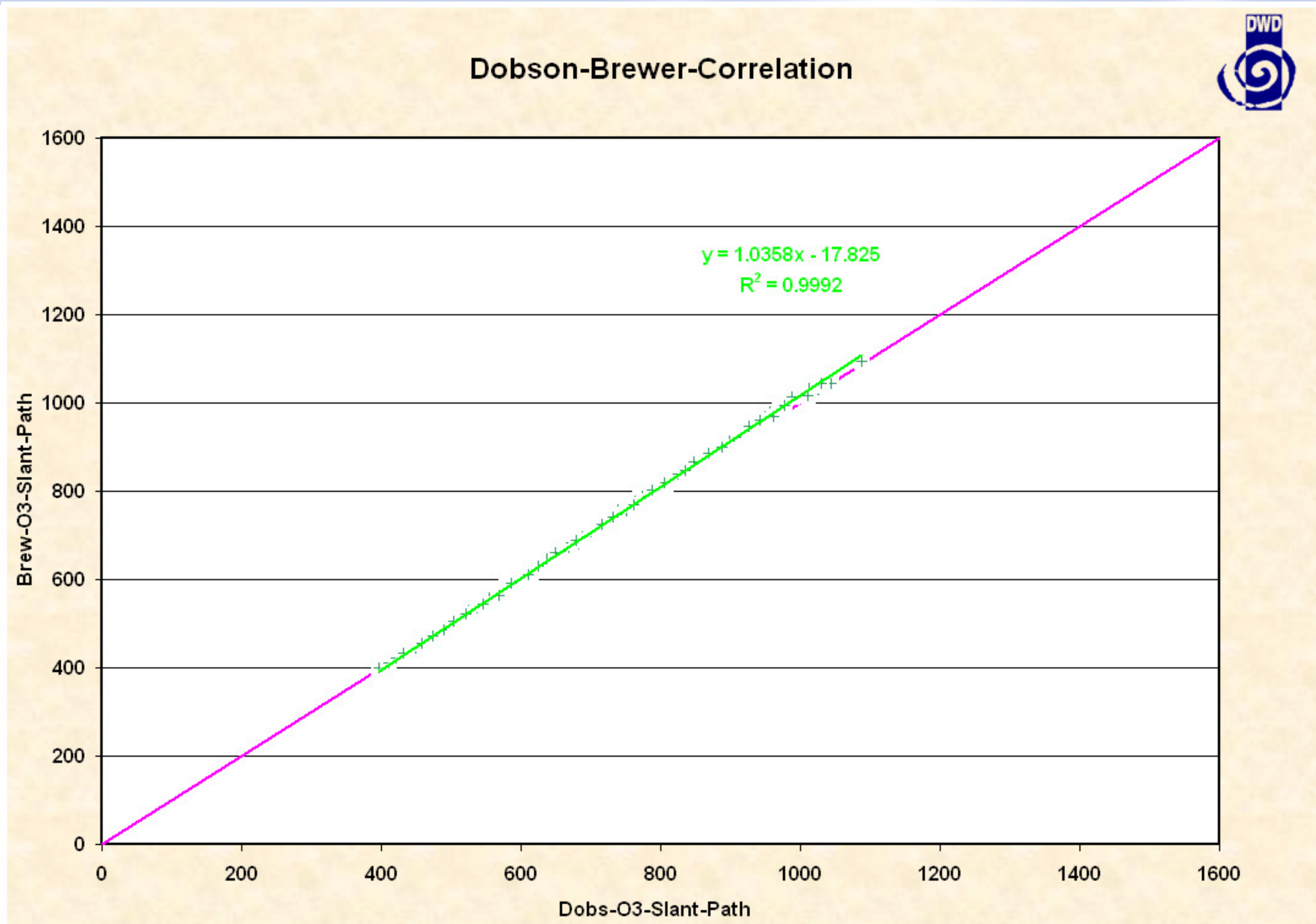
- Mean Difference:
  Bias approx. Zero

- Remaining Trend:
  Evidently smaller

Residual of Amplitude:
Probably caused by Straylight Effects (needs more investigations)

Residual of Trend: ?
(Differences in Calibration Levels of Standard Instr.?)

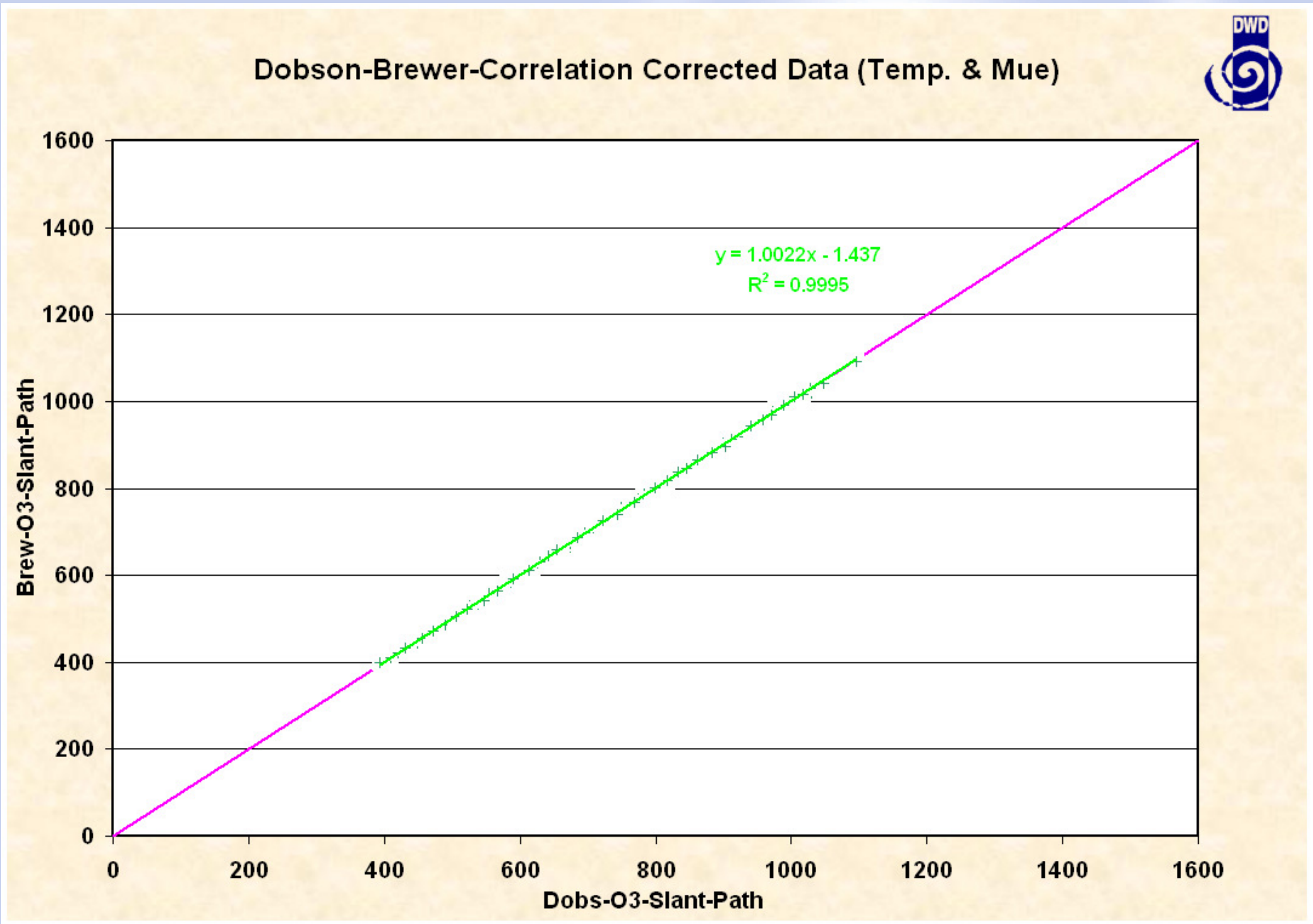
Improvement of the Agreement between Dobson and Brewer Data Records by Means of the Correlation



As reminder: original data

As monthly means

Improvement of the Agreement between Dobson and Brewer Data Records by Means of the Correlation



Corrected data:

Very good agreement

Finally

Demonstration of the effects of different calibration and correction methods by means of „historical“ data

(published in a JAC paper in 1986)

Comparison D014 and B017 on two days of cal. service for B010 in 1984

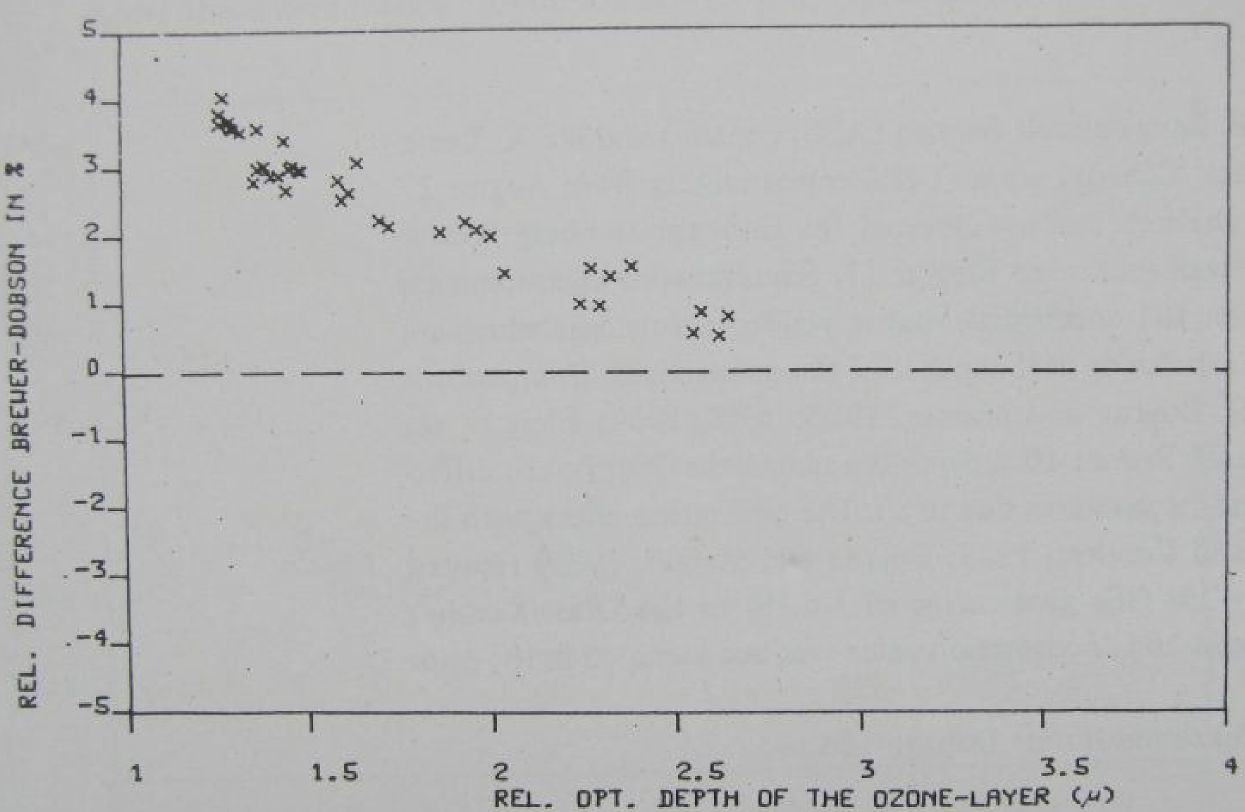


Fig. 2. Relative difference Brewer 17 – Dobson 104. Original data. (α_{AD} = 1.388, ΔN_{AD} = –0.018).

Original data
(after Vigroux):

- large difference with

- strong mu-dependence

Comparison D014 and B017 on two days of cal. service for B010 in 1984

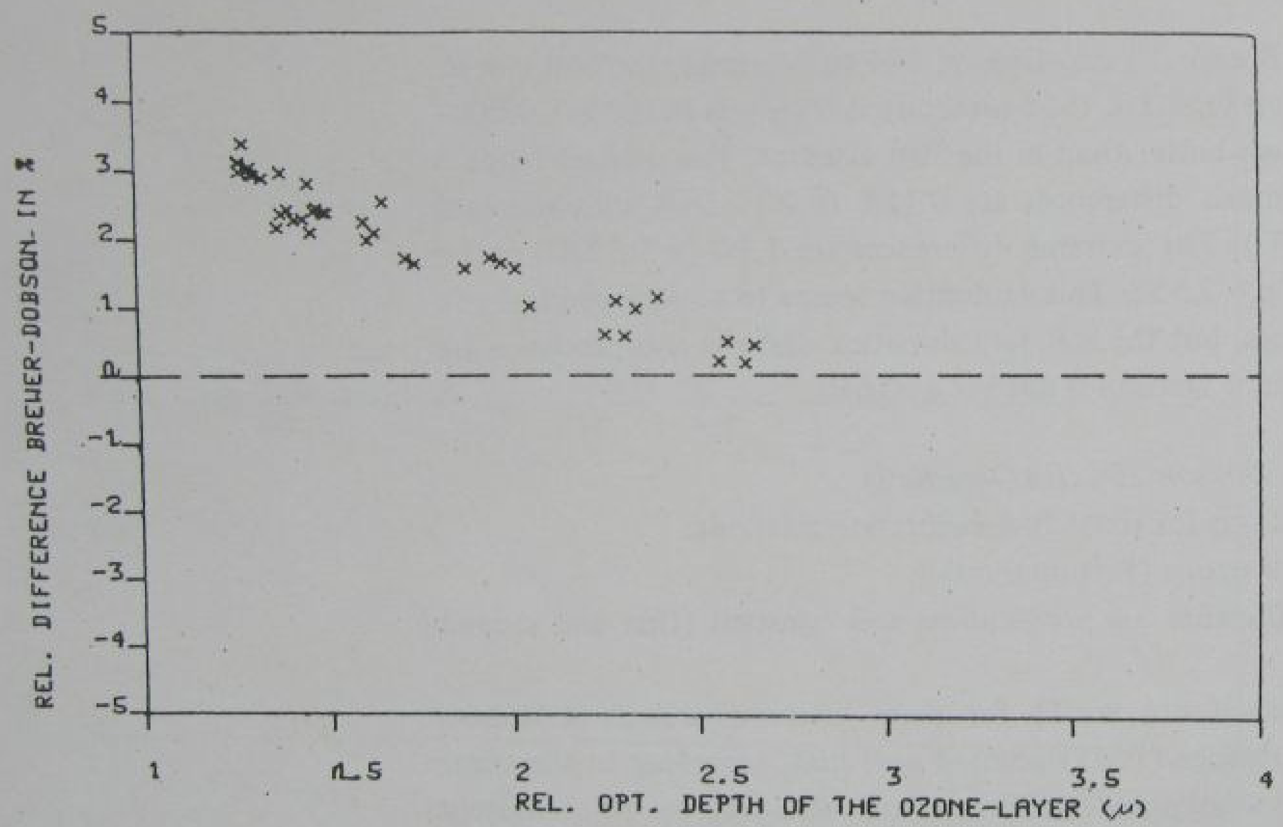


Fig. 3. Relative difference Brewer 17 – Dobson 104. Calibration of Dobson 104 by special direct sun observation (α_{AD} = 1.388, ΔN_{AD} = 0.0143).

Corrected data
(using a kind of Langley):

- smaller difference with

- strong mu-dependence

Comparison D014 and B017 on two days of cal. service for B010 in 1984

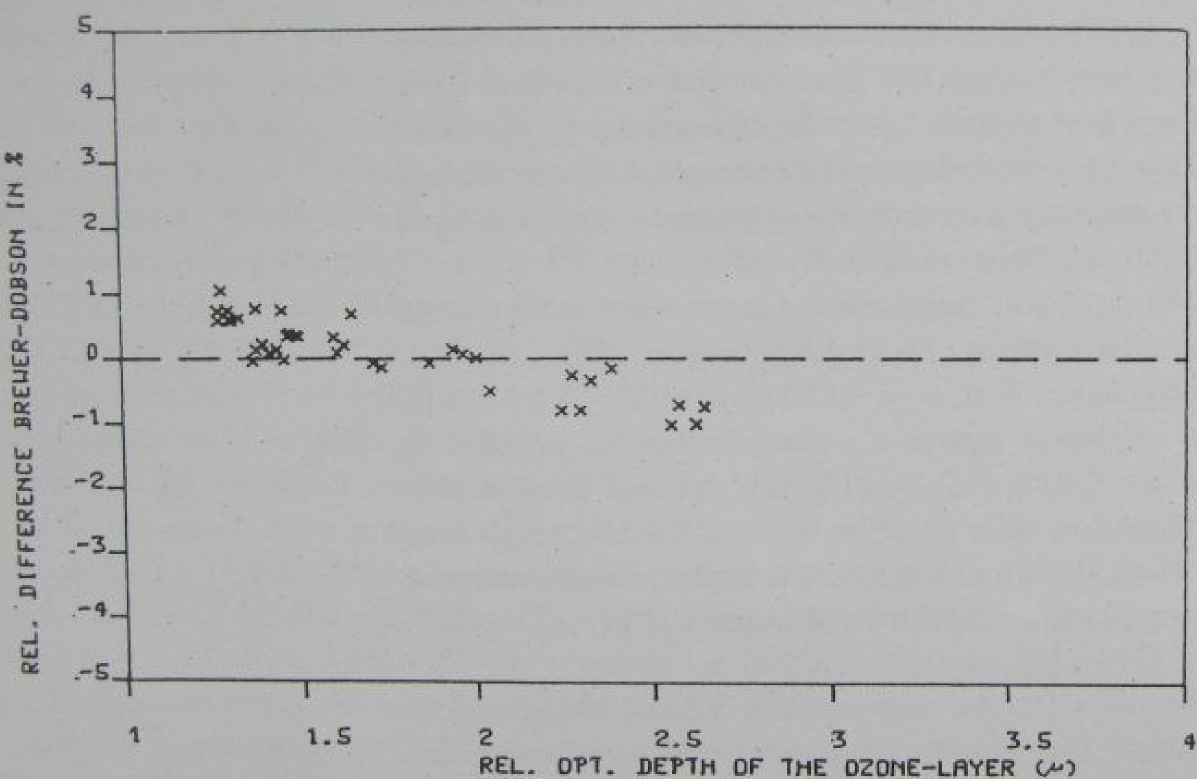


Fig. 4. Relative difference Brewer 17 – Dobson 104. Calibration of Dobson 104 by direct comparison with Brewer 17 (α_{AD} = 1.388, ΔN_{AD} = −0.0004).

Corrected data (direct intercomparison):

- mean difference = 0

- still mu-dependence

Comparison D014 and B017 on two days of cal. service for B010 in 1984

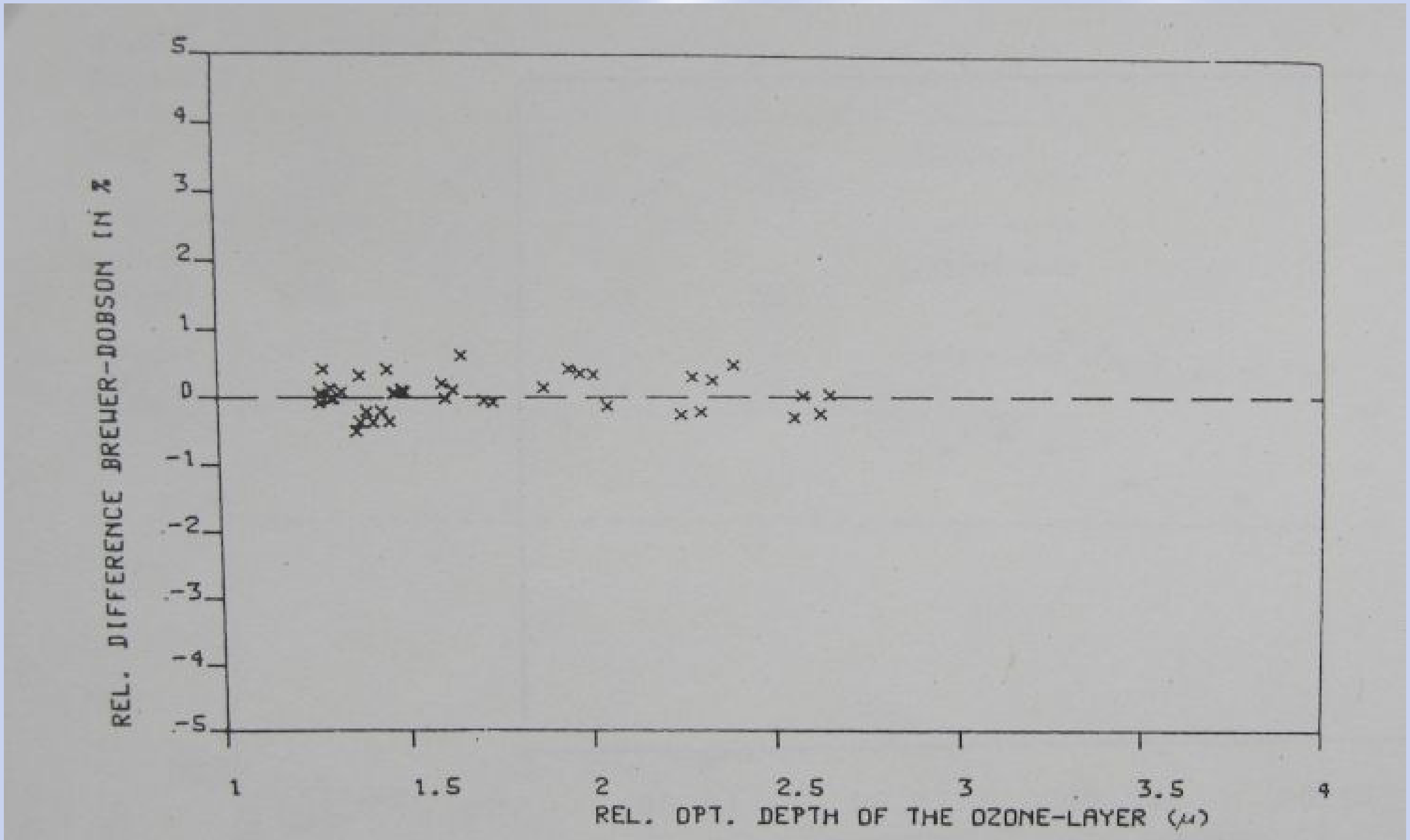


Fig. 5. Relative difference Brewer 17 – Dobson 104. Calibration of Dobson by the EAC-method ($\alpha_{AD} = 1.417$, $\Delta N_{AD} = 0.0163$).

Corrected data (effective α for Dobson = two point calibration):

- no bias

- no mu-dependence

- Abs. coeff. = Bass/Paur

Conclusion / Summary

- Agreement between well calibrated Dobson and Brewer not too bad with well-know patterns

- Reasons for these patterns known to a large extent (temperature dependence, straylight etc.)

- Possible corrections in data processing like use of effective temperature of the ozone layer yield significant improvement

- Possible improvement in data production: e.g. reduction of straylight

- Two point calibrations (abs.-coeff.‘s and ETC‘s) sometimes helpful, but should be used carefully (normally not applied to Dobsons): only instrumental changes in the optical properties can explain a shift of the abs.-coeff.

- Good knowledge of temperature dependence of the new x-sections needed to assess the effect on the abs.-coeff.‘s for Dobsons and Brewers

The End – Thank You !!!