On the Difference between Total Ozone Measured by Dobson and Brewer Spectrophotometers

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1) Dobson vs. Brewer at several European stations

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- trend

correction for the effective ozone temperature:

- *no correction*
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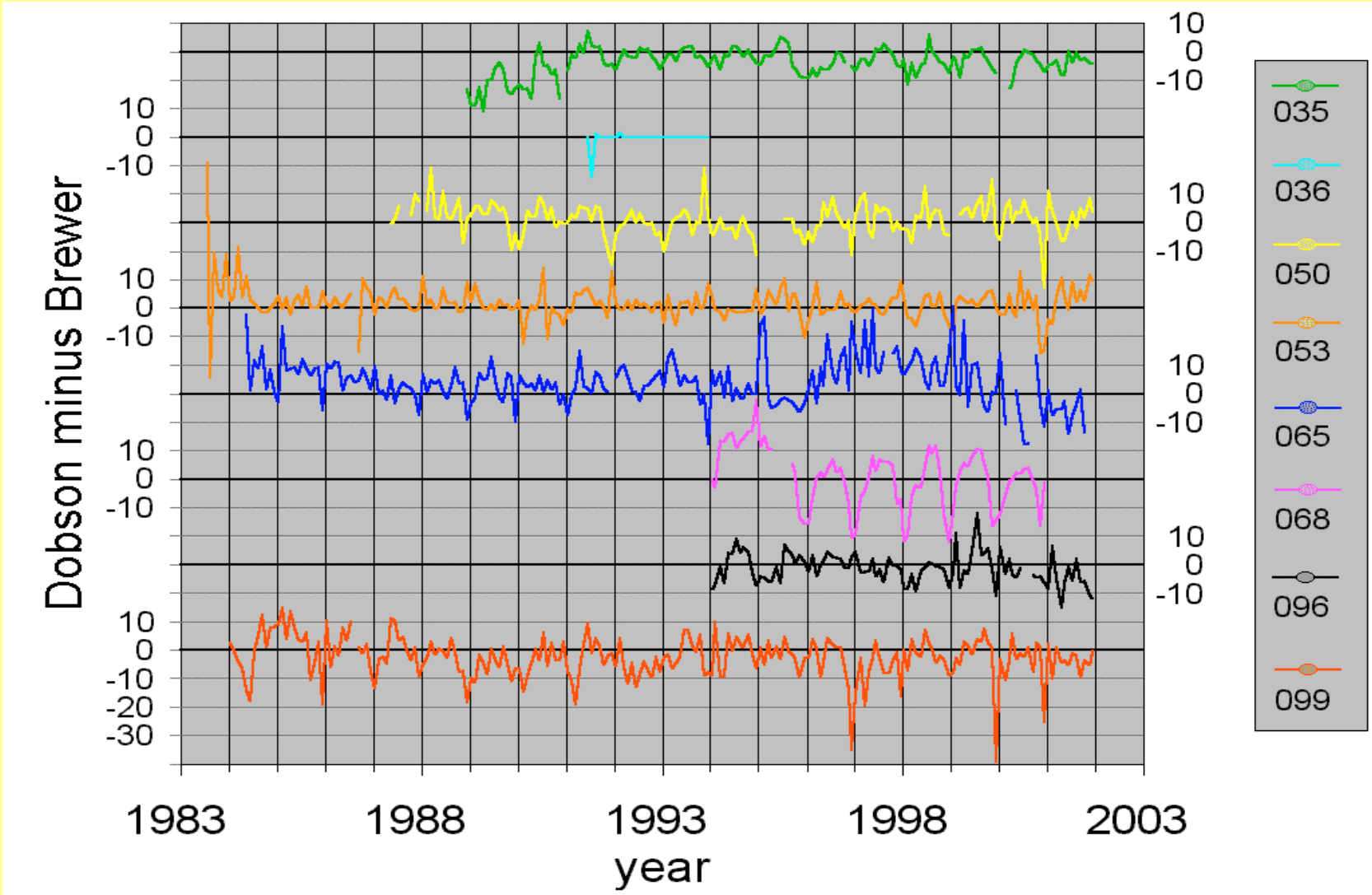
- *new correction*

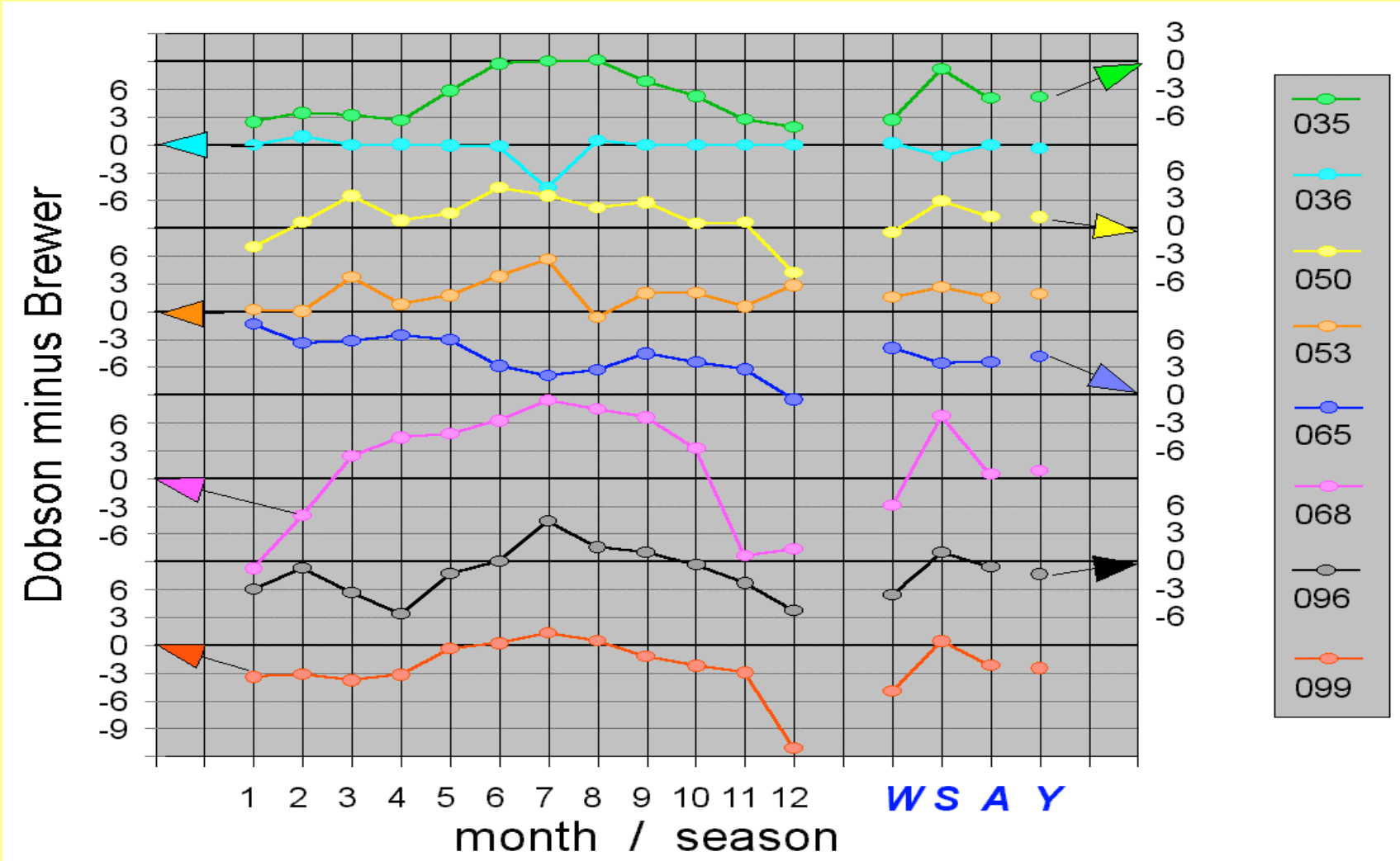
2) Effect of limited number of daily measurements on an accuracy of monthly means

Dobson - Brewer: time series of monthly means



035: Arosa, Switzerland; **050:** Potsdam, Germany; **068:** Belsk, Poland; **096:** Hradec Kralove, Czechia; **099:** Hohenpeissenberg, Germany; **036:** Camborne, UK; **053:** Uccle, Belgium; **065:** Toronto, Canada

Dobson - Brewer: mean annual cycle



W = DEC+JAN+FEB+MAR+APR; ***S*** = MAY+JUN+JUL; ***A*** = AUG+SEP+OCT; ***Y*** = whole year.

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Dobson - Brewer: trends [D.U. / year]

[096] Hradec Králové:	b = – 0.54 ± 0.24;	p = 0.025	*
[099] Hohenpeissenberg:	b = – 0.24 ± 0.10;	p = 0.014	*
[035] Arosa (since 1989):	b = + 0.32 ± 0.10;	p = 0.003	**
(since 1991):	b = – 0.31 ± 0.09;	p = 0.001	***
[050] Potsdam	b = – 0.10 ± 0.10;	p = 0.342	
[053] Uccle	b = – 0.16 ± 0.08;	p = 0.038	*
(since 1985)	b = – 0.03 ± 0.07;	p = 0.596	
[065] Toronto	b = – 0.20 ± 0.11;	p = 0.086	

*	P-level < 0.05
*	P-level < 0.01
***	P-level < 0.001

Correction of Dobson and Brewer data for the effective ozone temperature

- **effective ozone temperature (T_{O3eff}) =**

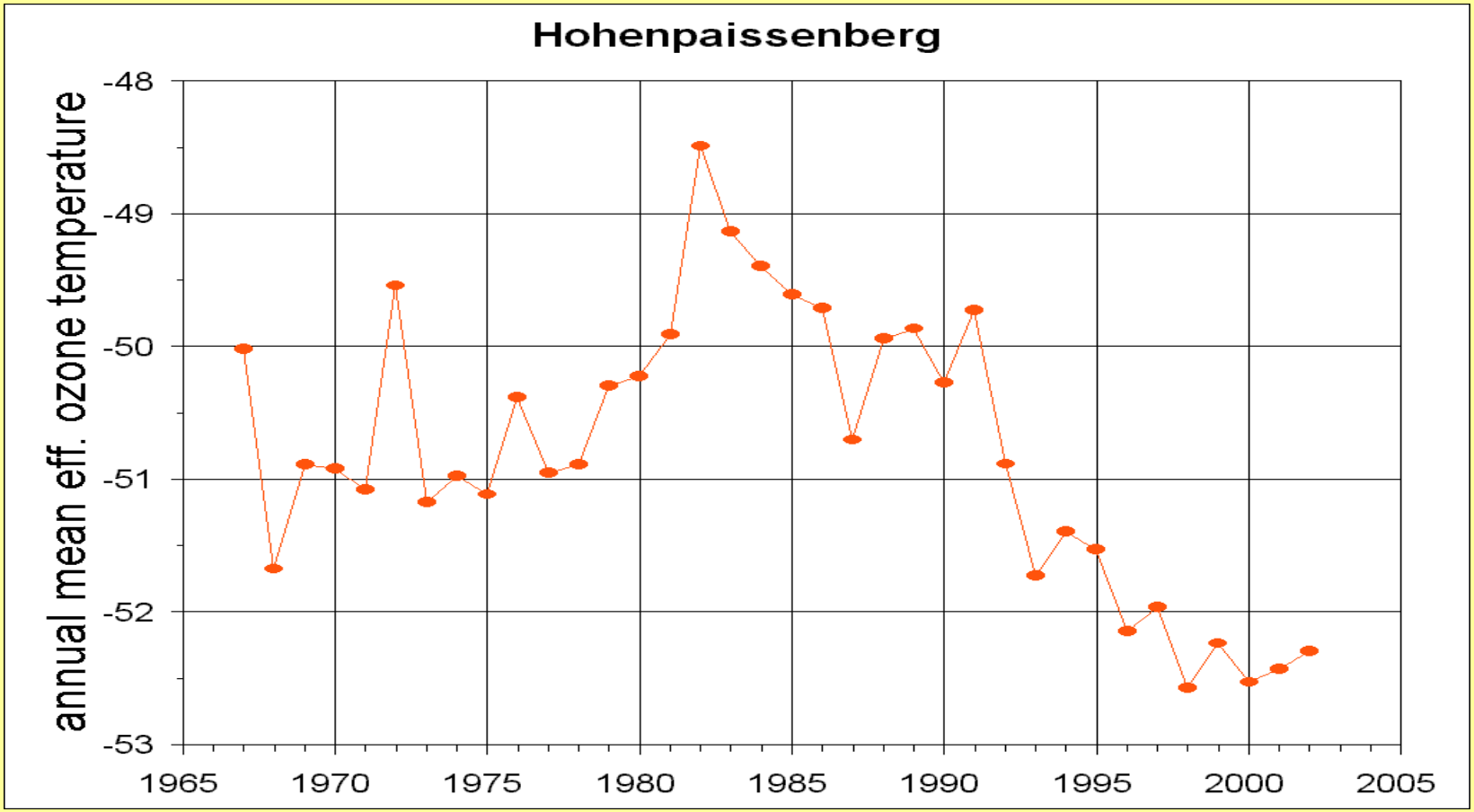
  weighted mean temperature of the atmosphere
  (weight = partial ozone pressure)

- **corrections according to Kerr et al. (1988):**

  $$\text{Brewer}^* = \text{Brewer} \times [1 - 0.0007 \times (T_{O3eff} + 46.3)]$$

  $$\text{Dobson}^* = \text{Dobson} \times [1 - 0.0013 \times (T_{O3eff} - 46.3)]$$

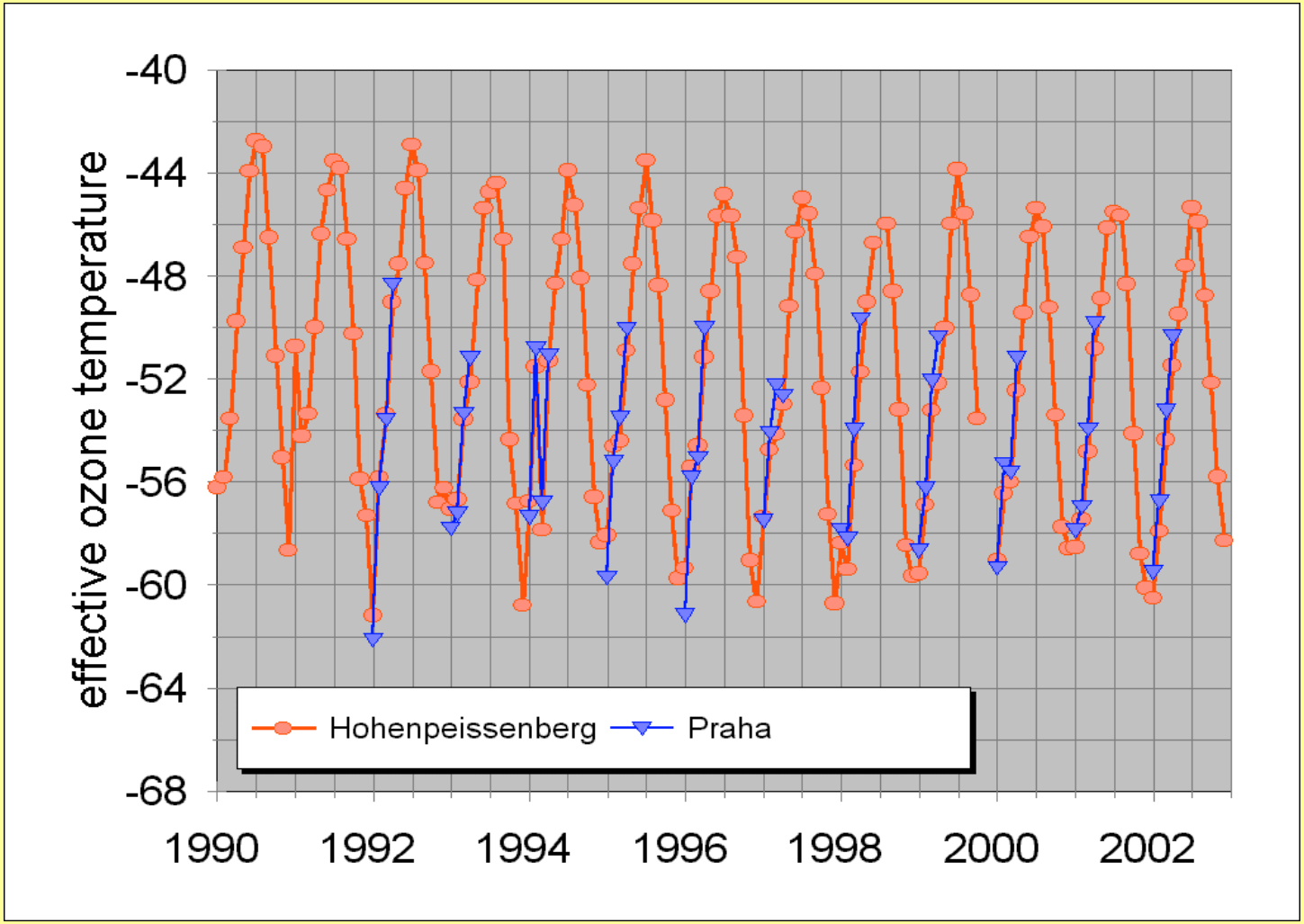
effective ozone temperature: annual means



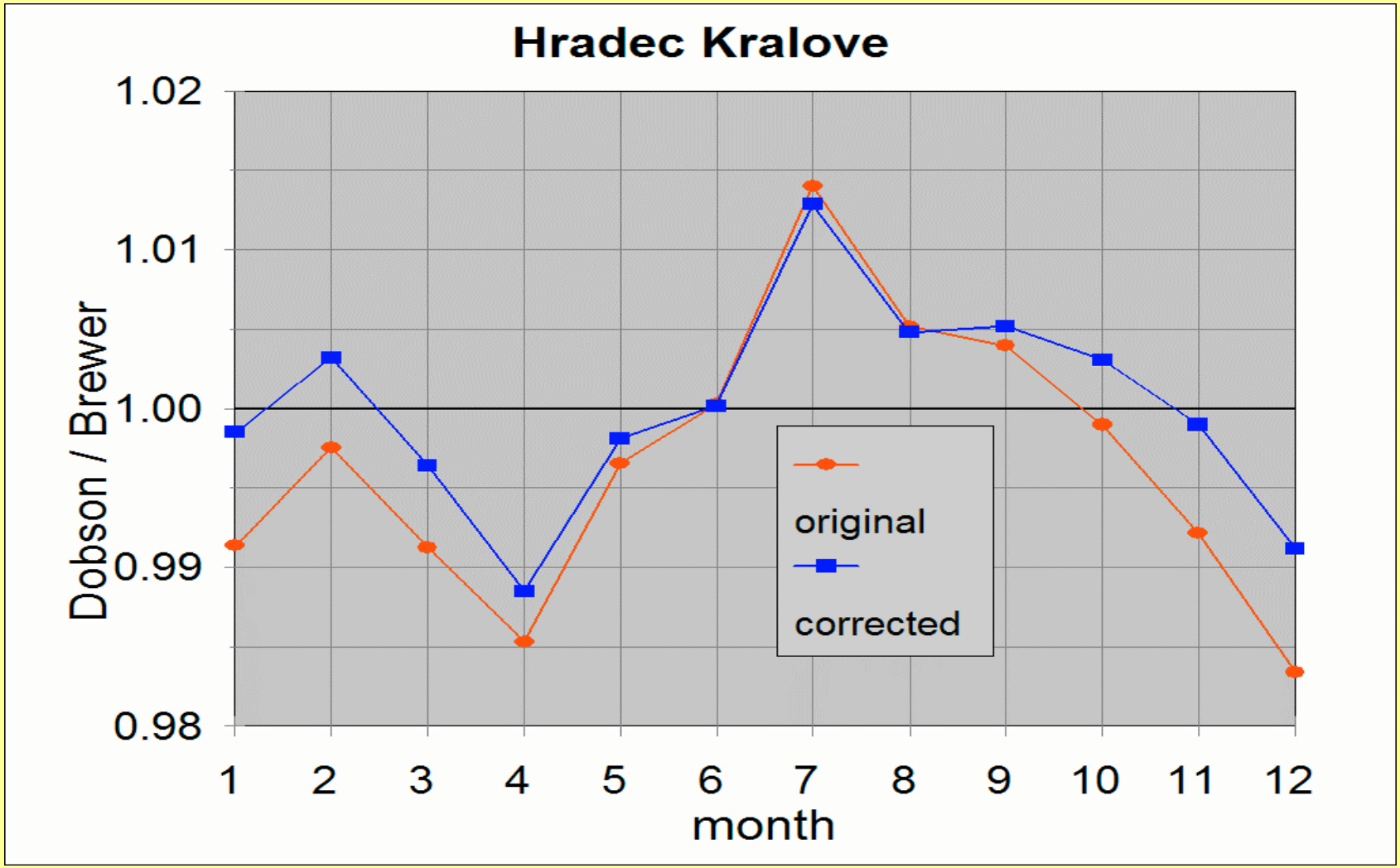
trend:

1967-2002:	-0.04507 ± 0.015262;	P-value = 0.0057
1994-2001:	-0.15599 ± 0.037369;	P-value = 0.0059

Effective ozone temperature:
Prague vs. Hohenpeissenberg (monthly means)

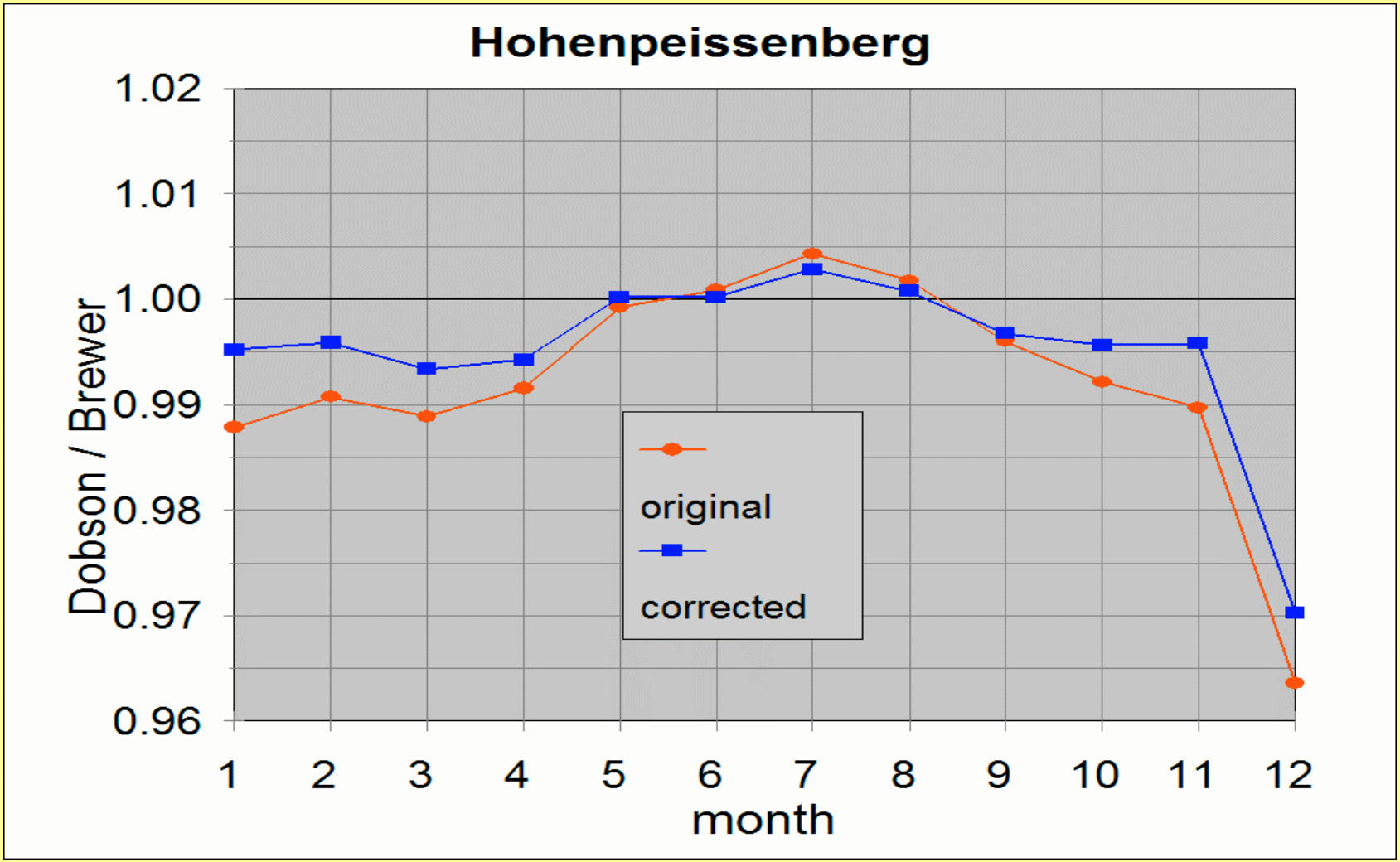


Dobson/Brewer: Annual cycle



corrected = Kerr's correction is applied

Dobson/Brewer: Annual cycle



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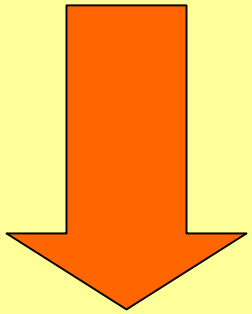
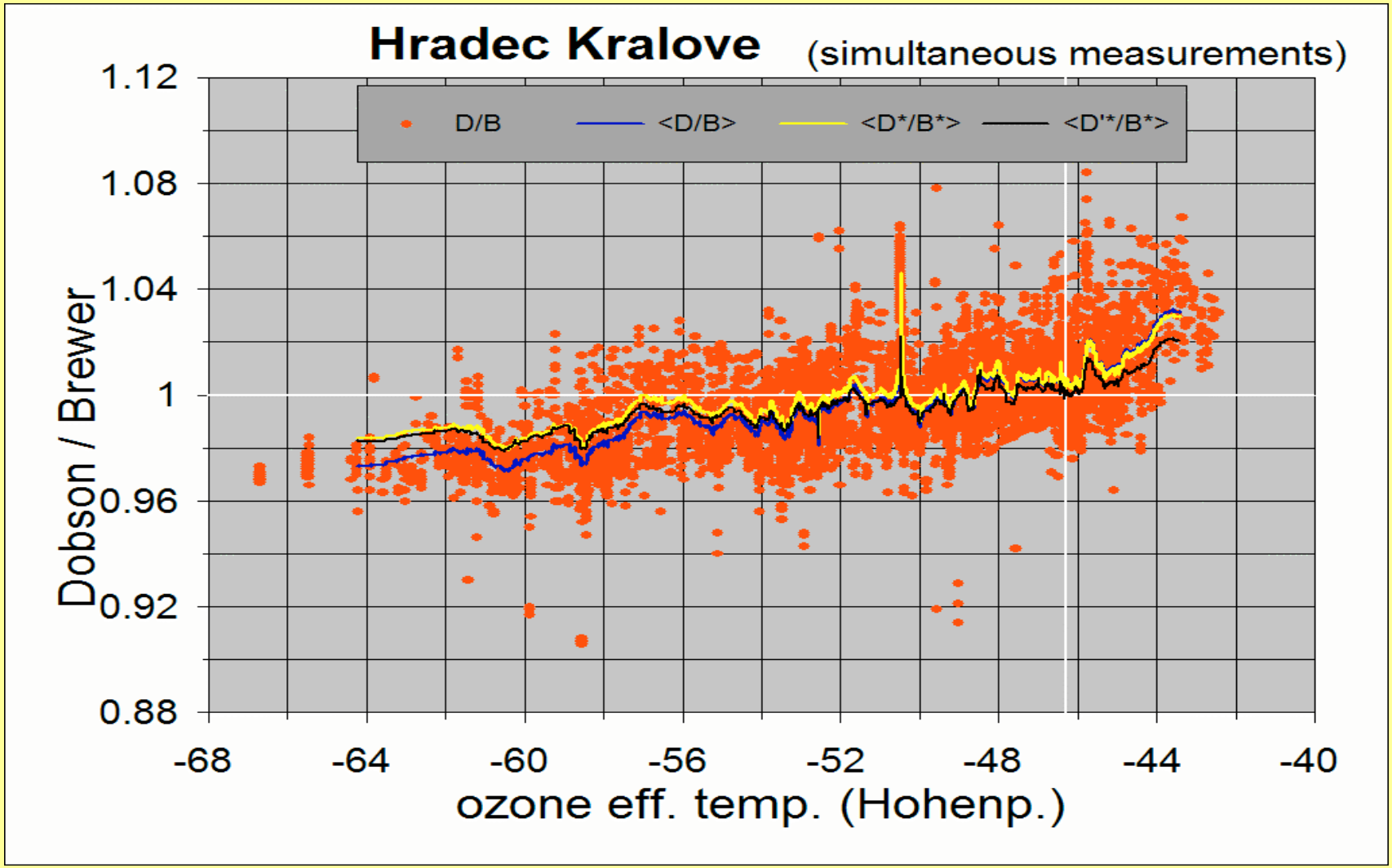


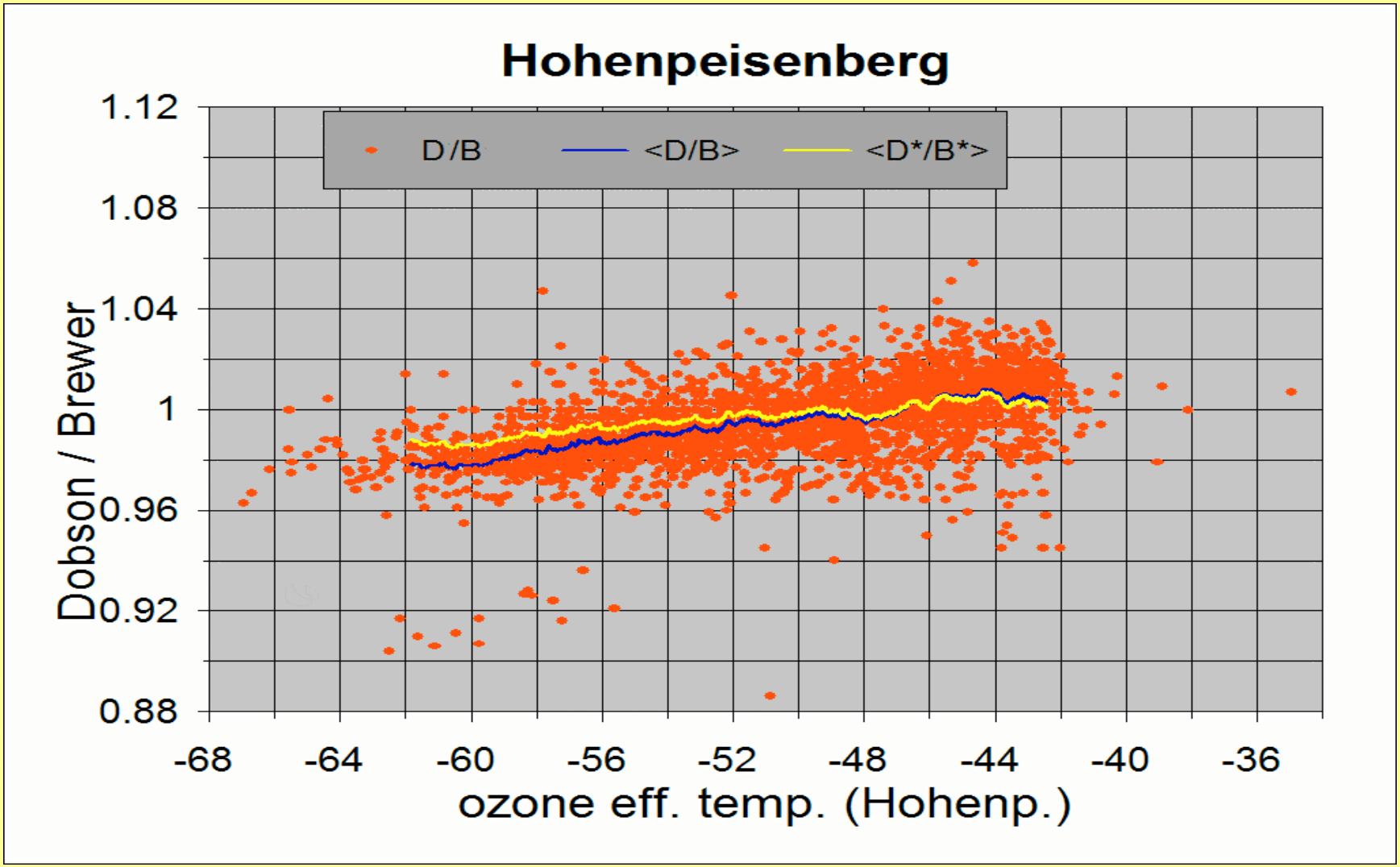
Is the Kerr's correction for the effective ozone temperature sufficient ?

Dobson/Brewer vs. effective ozone temperature



D/B: ratio of uncorrected daily values; **<D/B>:** smoothed; **<D*/B*>:** daily values were corrected for the eff.ozone temp. and smoothed; **D'*:** corrected for SO2 and eff.oz.temp.

Dobson/Brewer vs. effective ozone temperature



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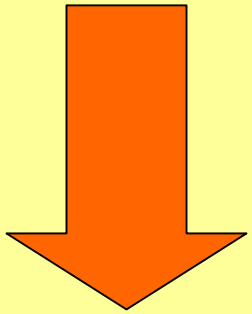


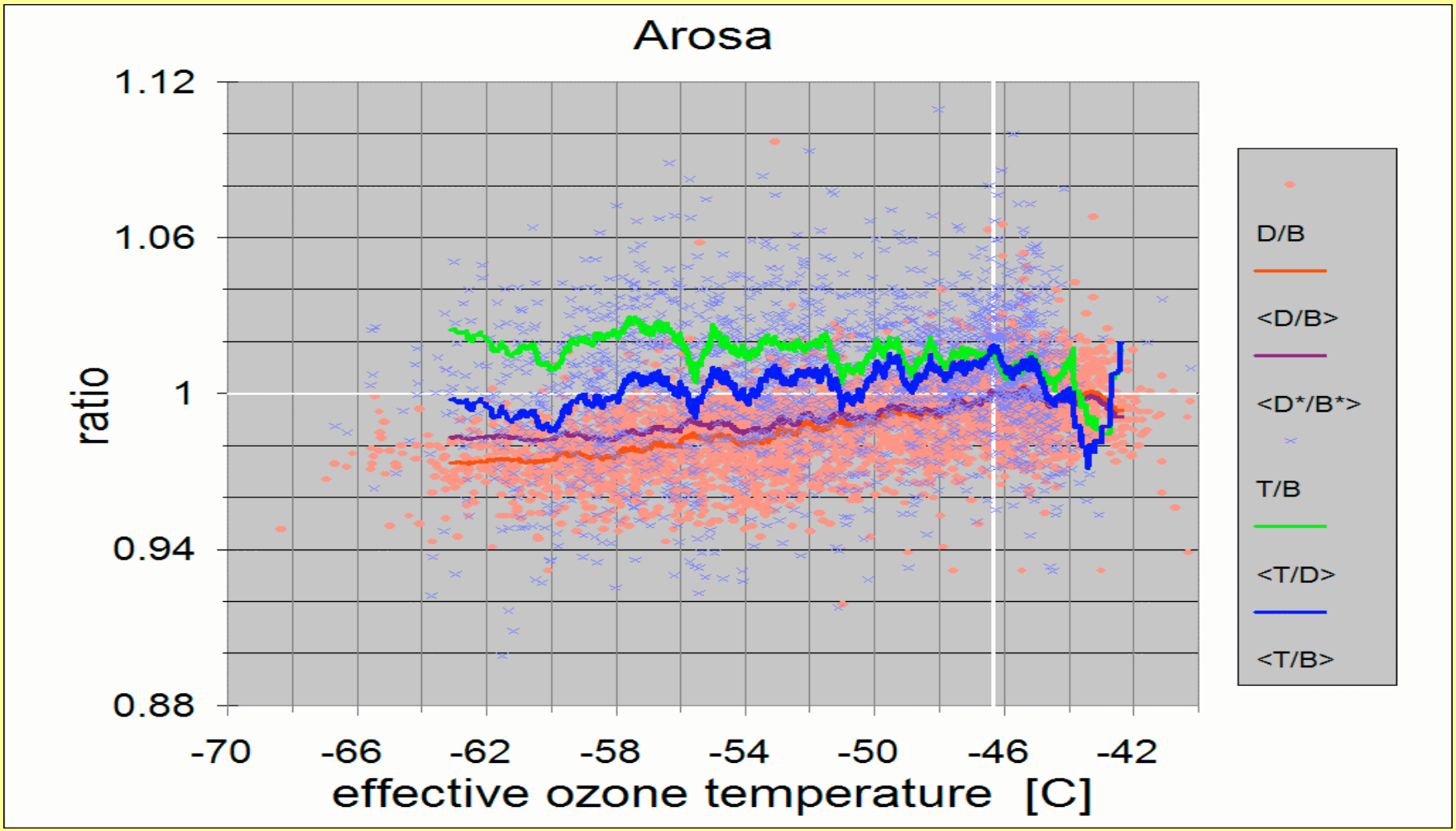
better correction is needed !

new correction
for the effective ozone temperature

$$\text{Brewer}^{**} = \text{Brewer} \times [1 - \mathbf{QB} \times \mathbf{0.0007} \times (T_{O3eff} + 46.3)]$$

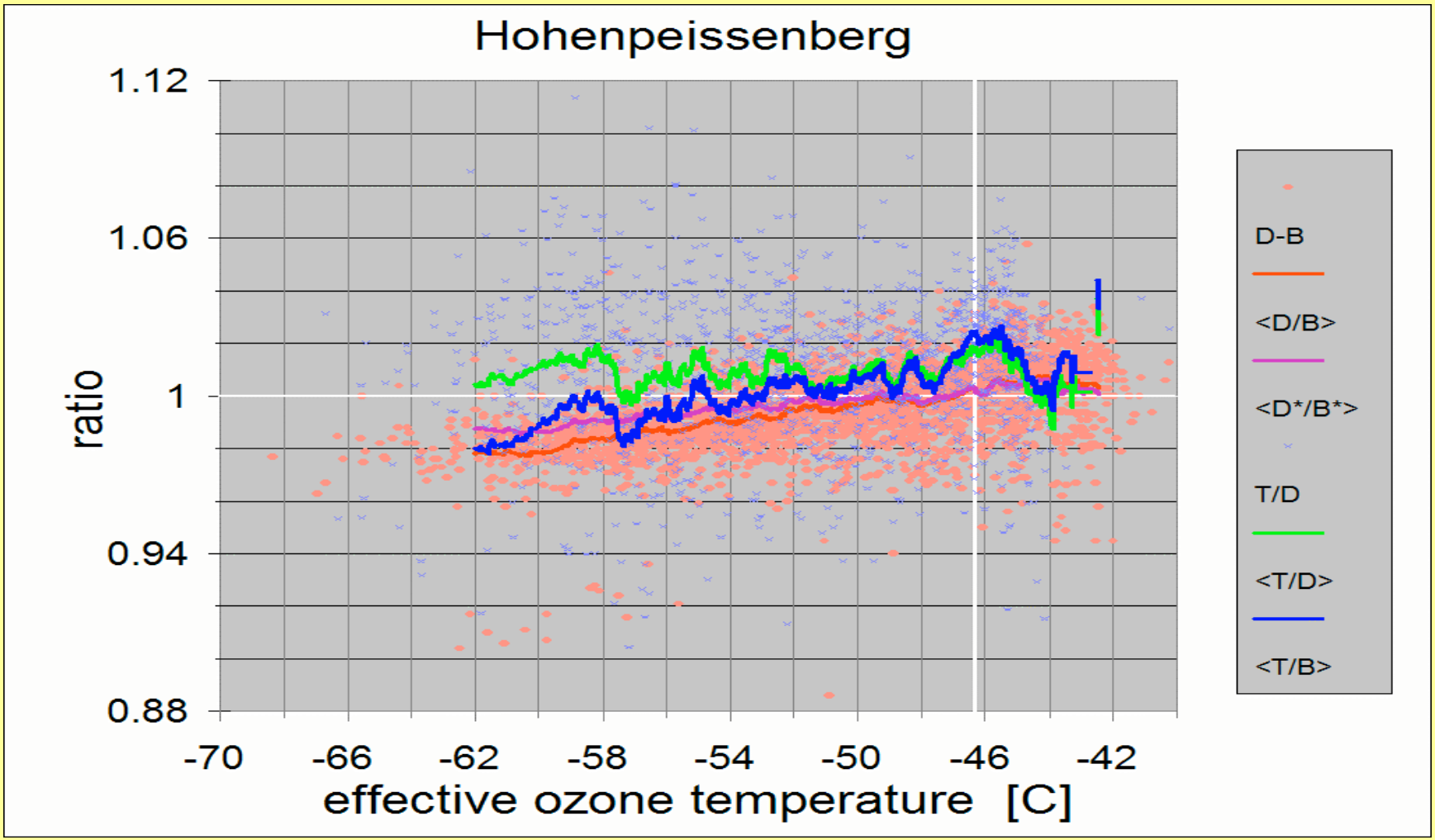
$$\text{Dobson}^{**} = \text{Dobson} \times [1 - \mathbf{QD} \times \mathbf{0.0013} \times (T_{O3eff} - 46.3)]$$

engagement of TOMS data



D/B: ratio of uncorrected daily values; **<D/B>:** smoothed; **<D*/B*>:** daily values were corrected for the eff.ozone temp. and smoothed; **T/B:** TOMS/Brewer (daily values); **<T/D>:** TOMS/Dobson (smoothed); **<T/B>:** TOMS/Brewer (smoothed)

engagement of TOMS data



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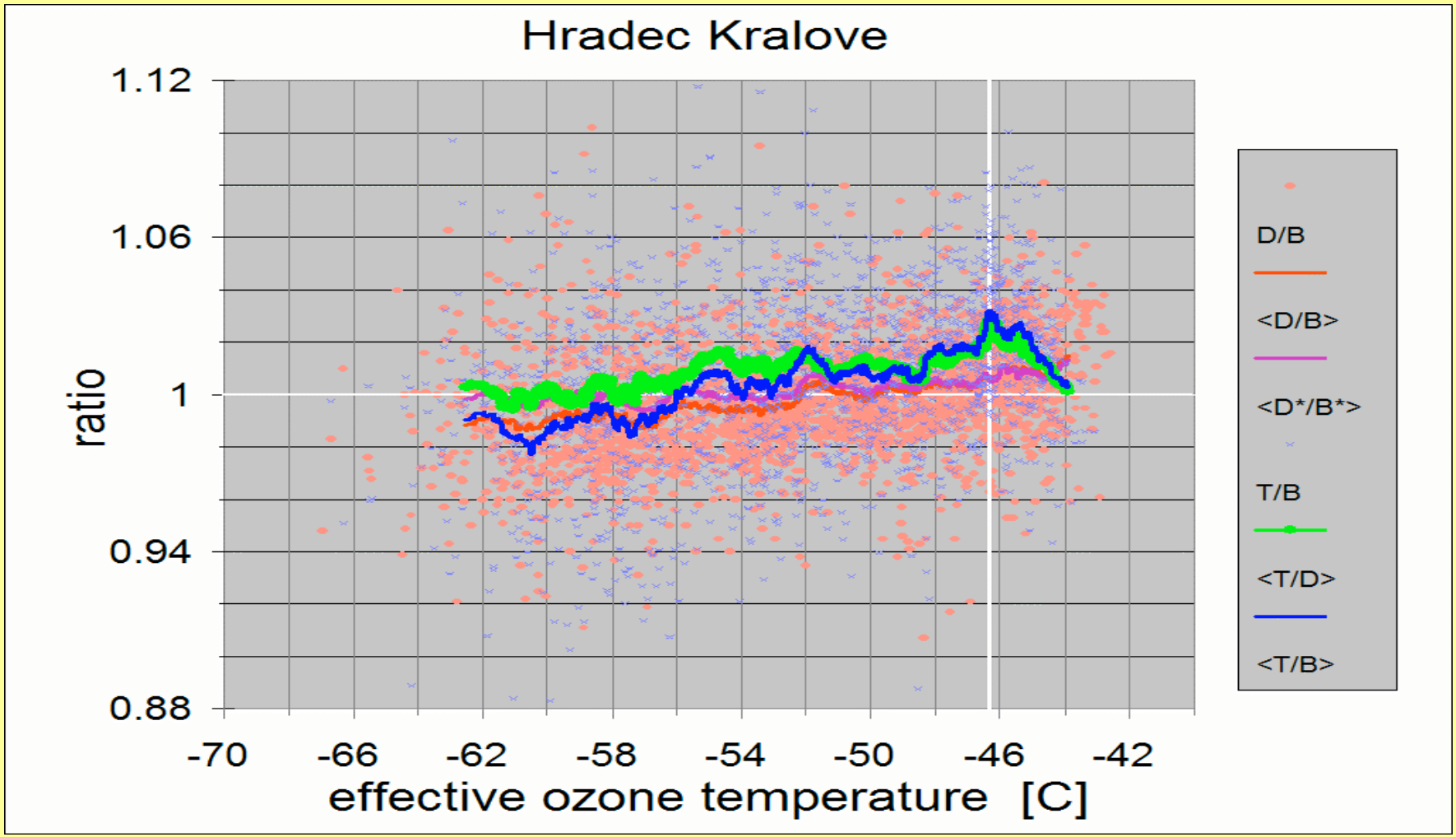

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new correction for effective ozone temperature

$$\text{Brewer}^{**} = \text{Brewer} \times [1 - \mathbf{QB} \times \mathbf{0.0007} \times (T_{O3eff} + 46.3)]$$

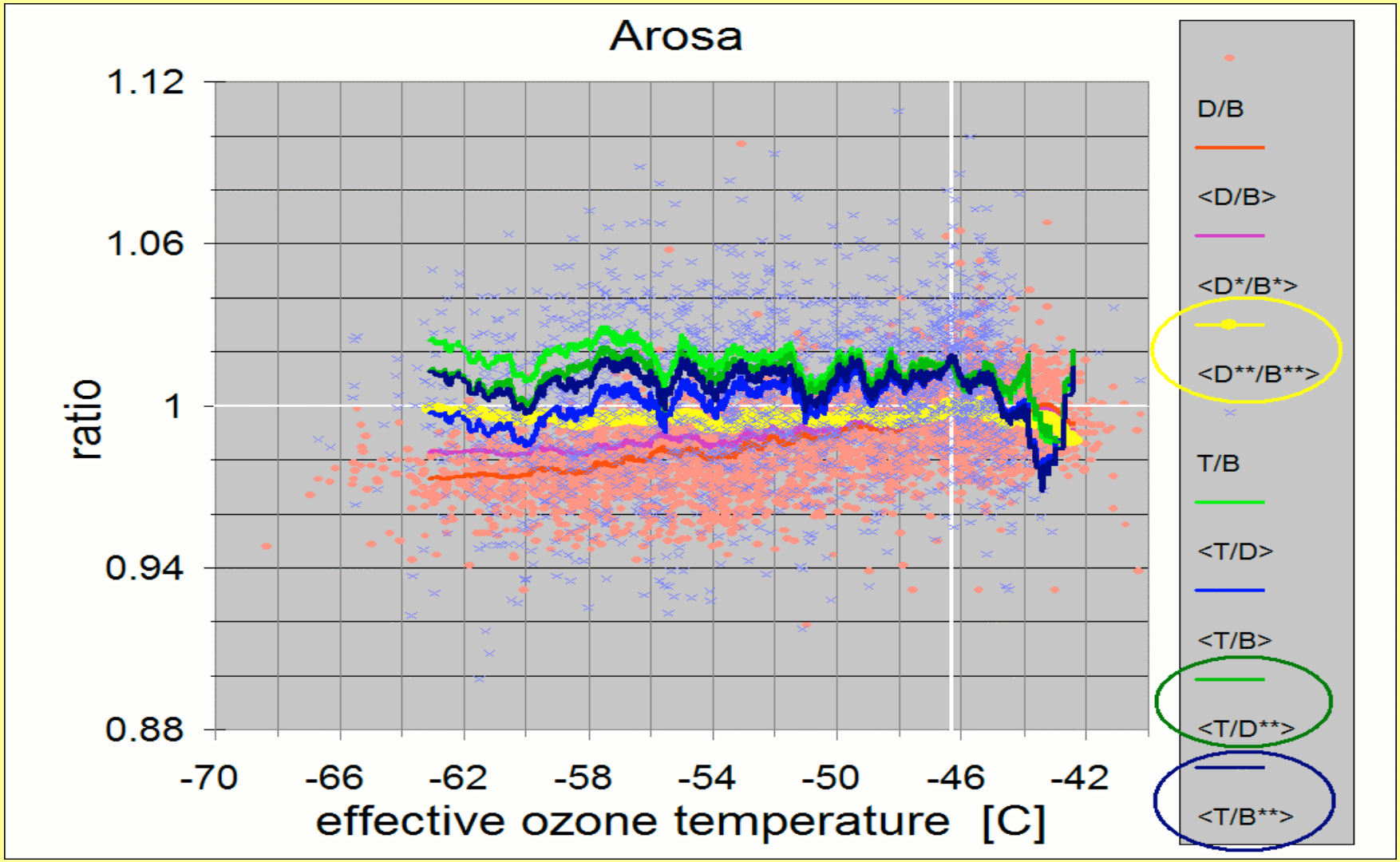
$$\text{Dobson}^{**} = \text{Dobson} \times [1 - \mathbf{QD} \times \mathbf{0.0013} \times (T_{O3eff} + 46.3)]$$

optimal values for QB and QD:

	QB	QD	Q*
Arosa	-1.3	0.5	2.5
Hradec Kralove	-3.0	-0.7	2.0
Hohenpeissenberg	-2.0	0.0	2.3

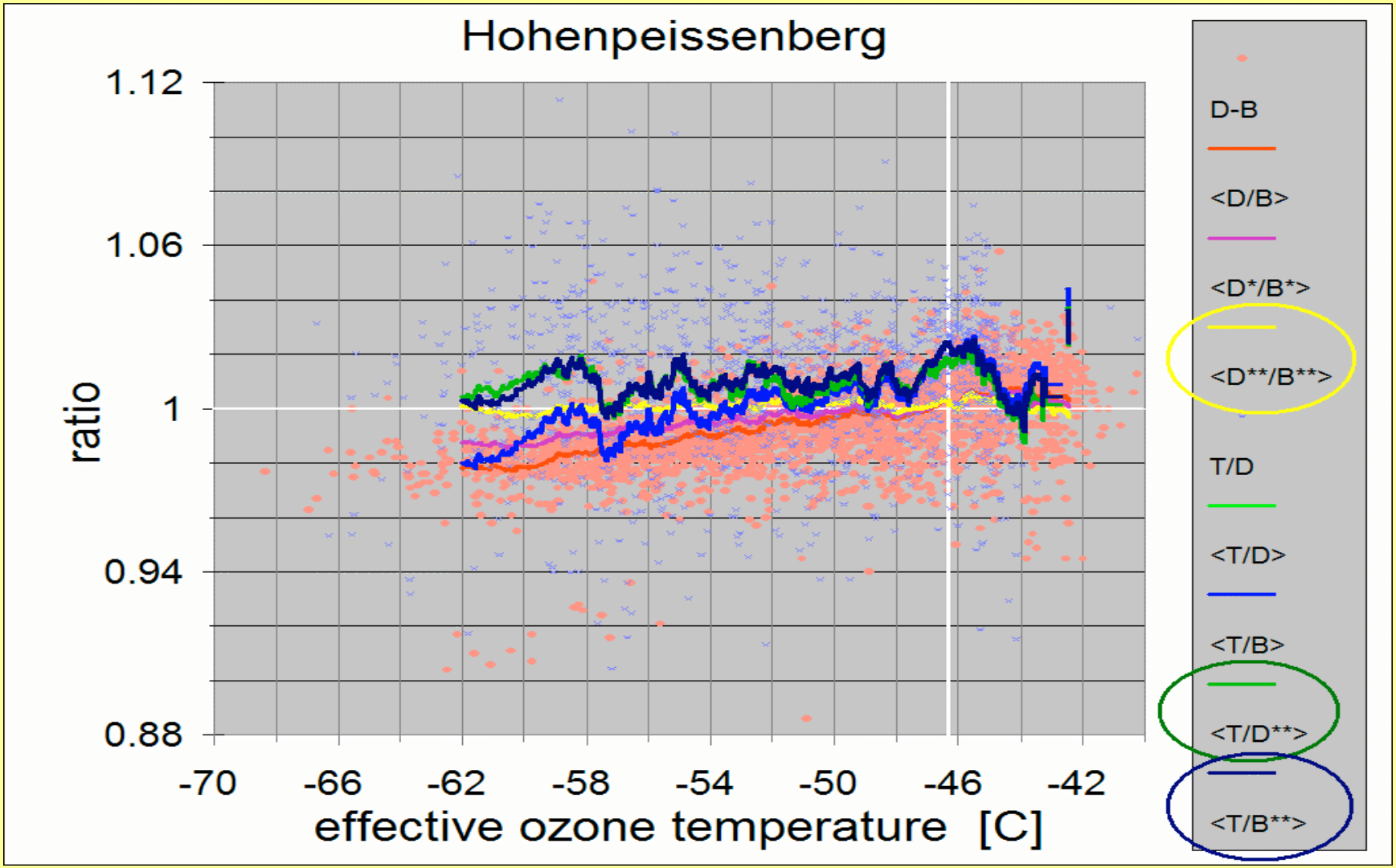
Q* is the common value for QB and QD which will remove the dependence of Dobson**/Brewer** ratio on eff.ozone temp (but the dependences of TOMS/Dobson and TOMS/Brewer on the eff.ozone temp. will not be removed)

updated correction coefficients



the circled (in the legend box) lines relate to new correction coefficients applied on the Brewer and Dobson data

updated correction coefficients



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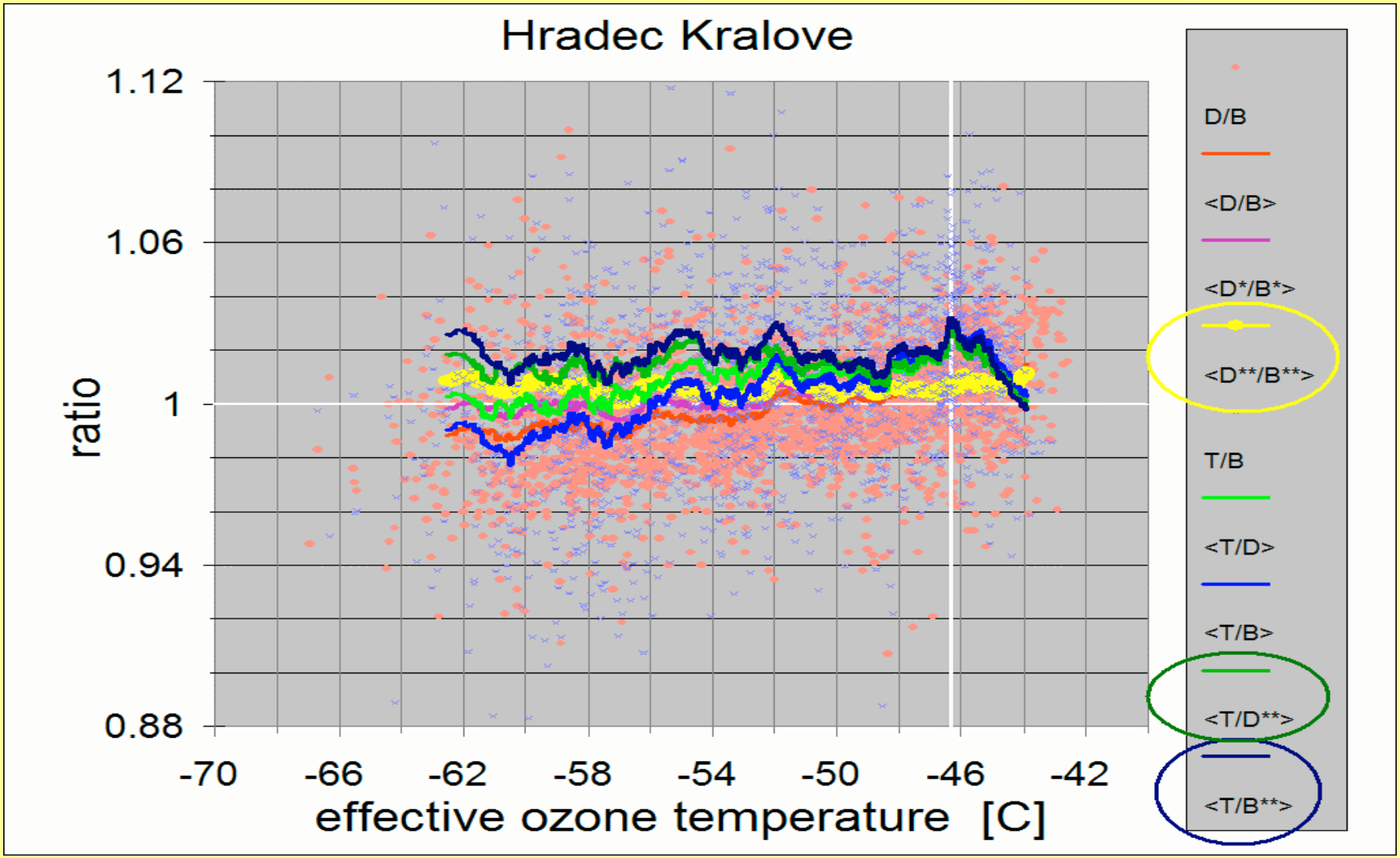
updated correction coefficients



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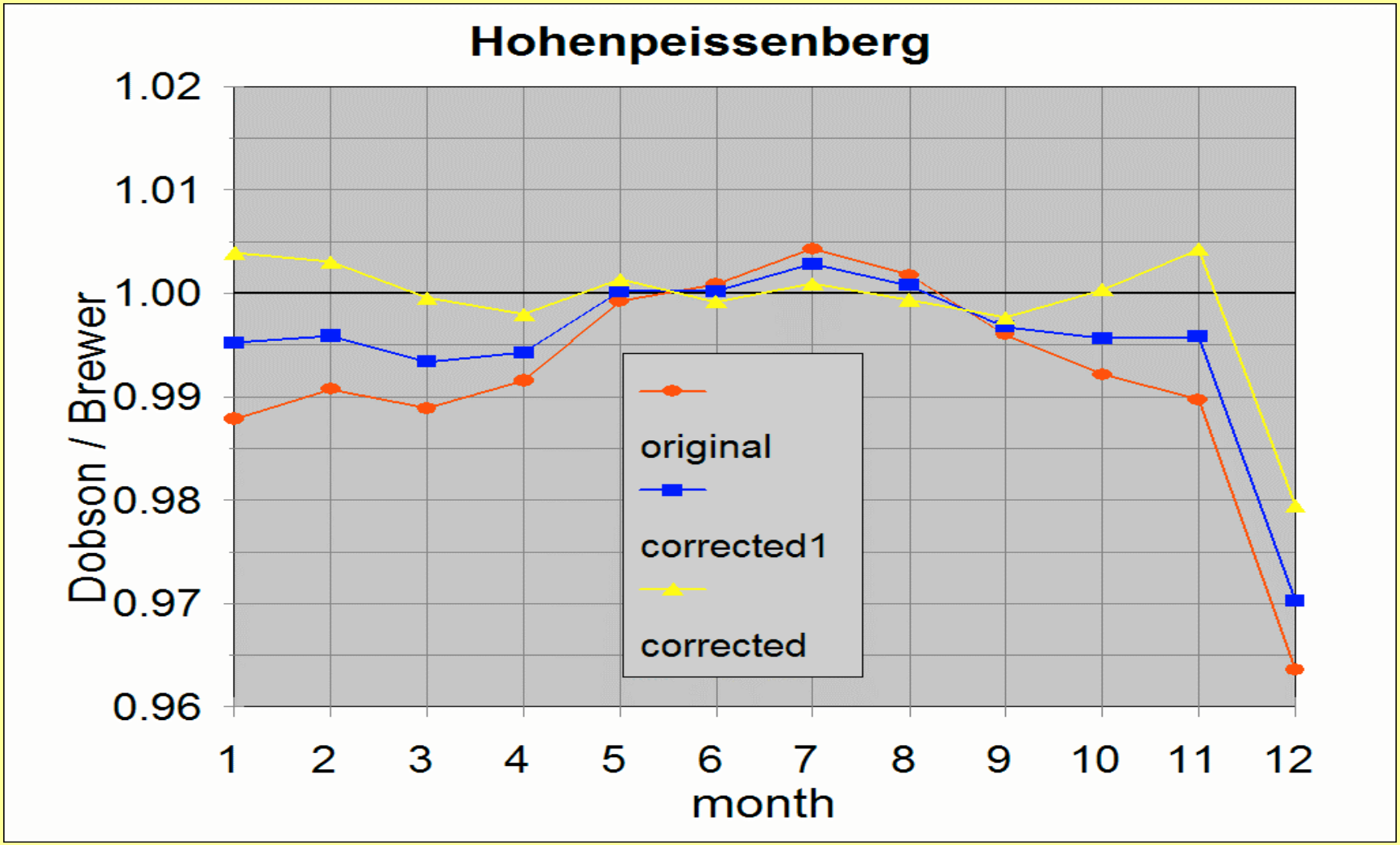
Dobson / Brewer: annual cycle



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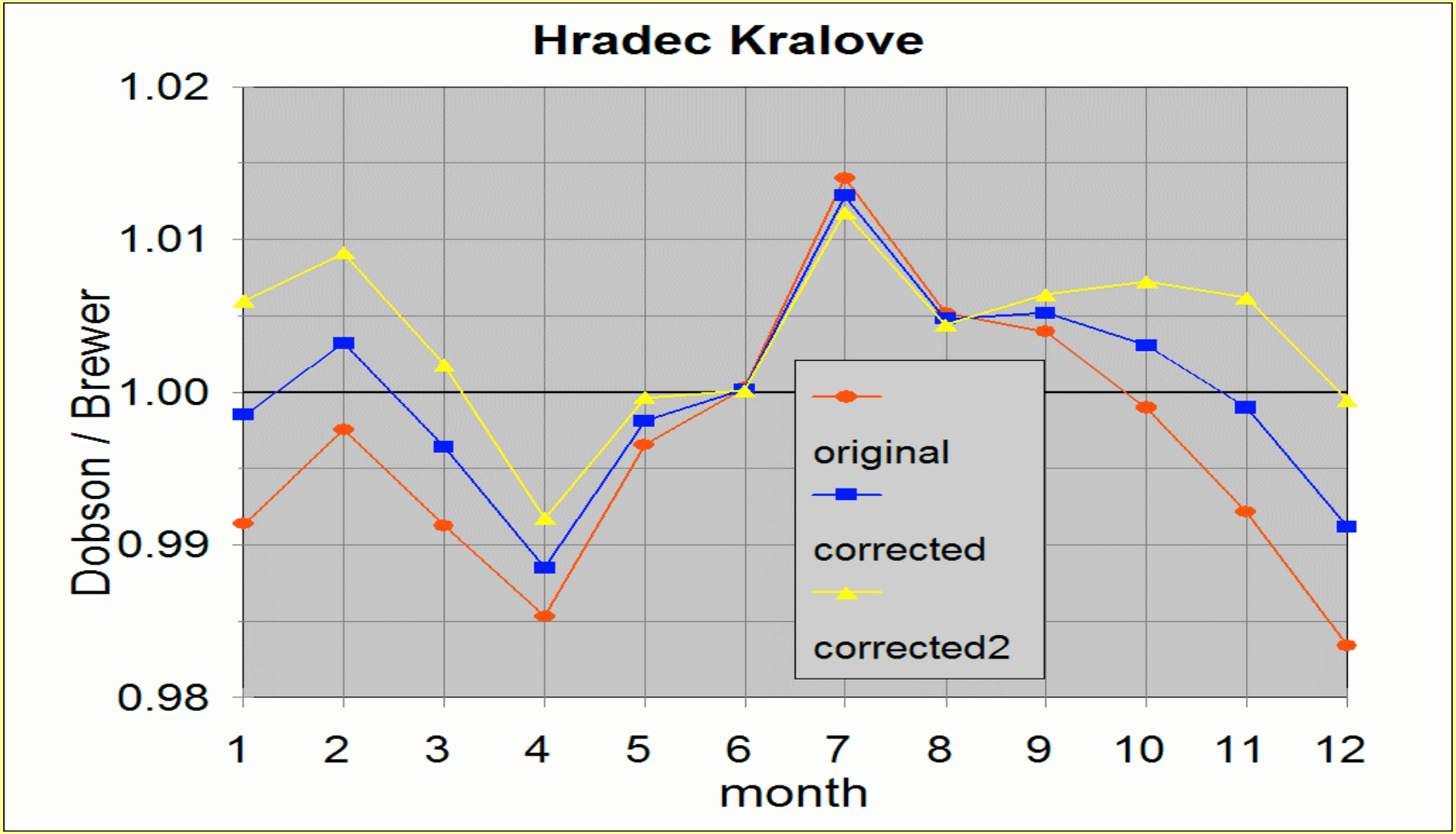
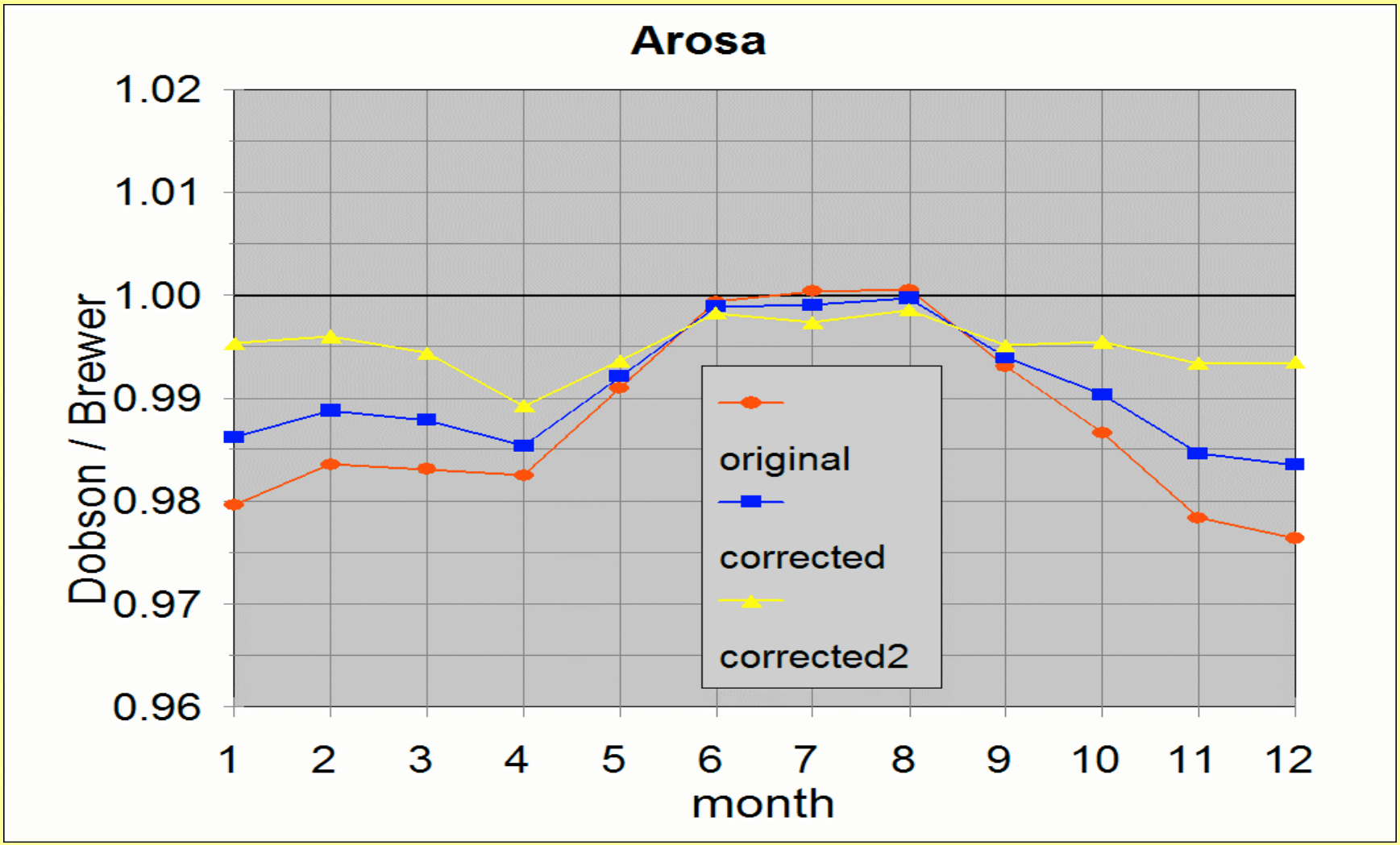


red: data were not corrected for effective ozone temperature; **blue:** the Kerr's correction is applied; **yellow:** new correction coefficients are applied

Dobson / Brewer: annual cycle



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Dobson - Brewer: trends [D.U. / year]

	not corrected data	new correction applied
[096] Hradec Králové:	b = – 0.54 ± 0.24;	– 0.45 ± 0.22
[099] Hohenpaissenberg:	b = – 0.24 ± 0.10;	– 0.16 ± 0.09
[035] Arosa (since 1991):	b = – 0.31 ± 0.09;	– 0.22 ± 0.07

conlusions *(of the first part?)*

- **Dobson/Brewer shows:**
  - annual cycle
  - trend
  - significant correlation with effective ozone temperature
- **Kerr's corrections is not sufficient**
- **modified correction coefficient**
  - removes correlation with eff. O3 temperature
  - reduces trend and annual cycle of Dobson/Brewer ratio
- **problem:** can we consider TOMS data independent on both Dobson and Brewer data??? ***(no!)***

Part 2: Effect of limited number of daily measurements on an accuracy of monthly means

- **<u>motivation</u>: Ground- based measurements of total ozone are not available for all days in a month** [as they are taken (mainly with the Dobson spectrophotometer) only at suitable weather condition]**.**

  The question stands, what is the error of the monthly mean total ozone estimated from incomplete set of daily values?

method (Monte Carlo):

1. **30 daily values are randomly sampled from normal $N(\mu,\sigma^2)$ distribution;** These values represent the daily total ozone values during a month. (μ,σ) are mean and standard deviation of total ozone values in a single month

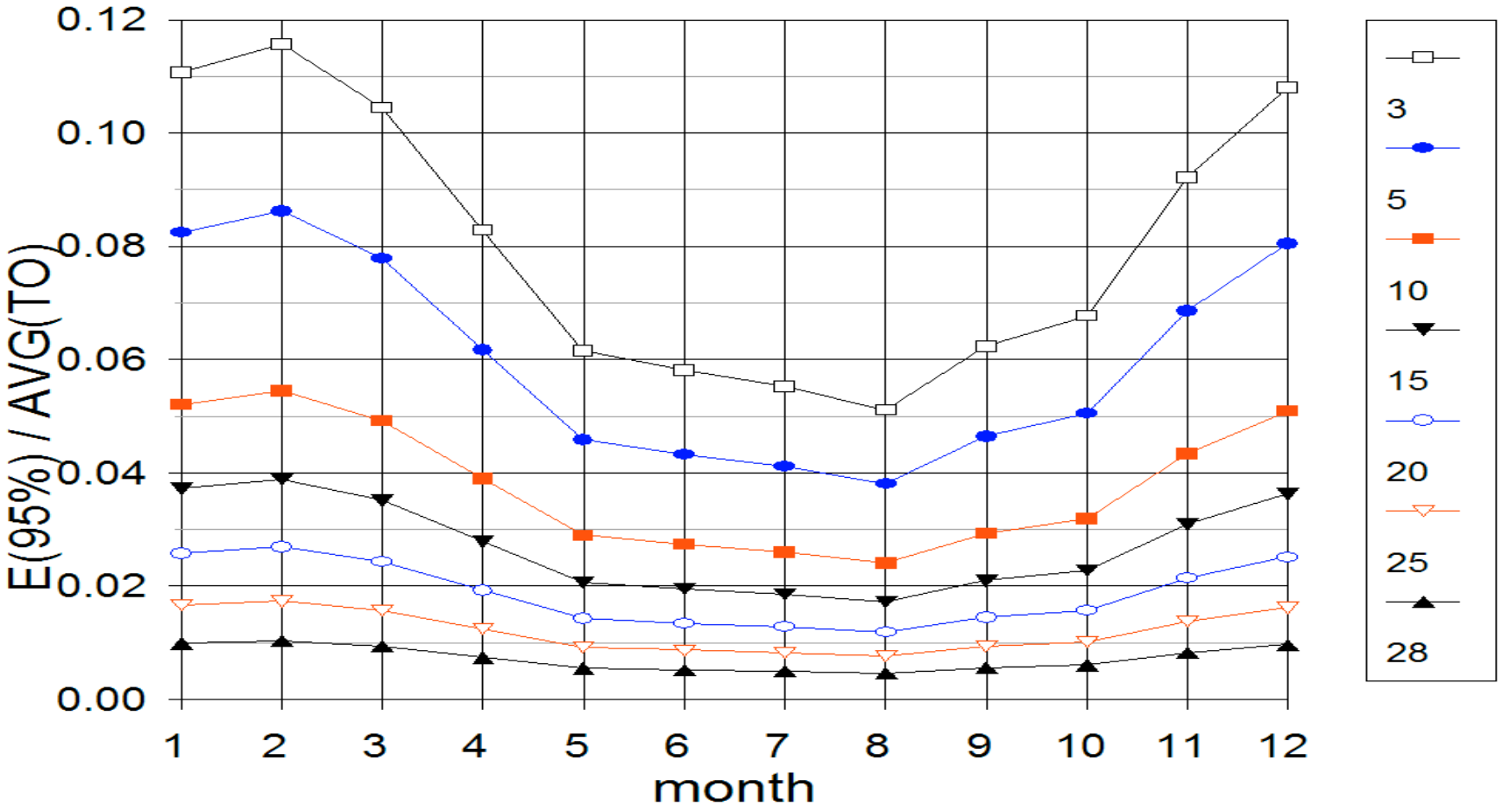
2. ***n* values (*n* < 30) are selected from $\{x_i\}$:** $\{x_{i1}, \ldots, x_{in}\}$. This subset represents the available values of standardised daily total ozone.

3. **Averages of the two sets and their difference are calculated**: $X = \text{avg}\{x_1, \ldots, x_{30}\}$, $X_n = \text{avg}\{x_{i1}, \ldots, x_{in}\}$, $D = X_n - X$. The difference represents the error of the monthly mean estimated from a limited set of the daily ozone values.

4. **Steps 1-3 are repeated many times** (e.g.: $N = 10000$) and the mean, μ_n (should be insignificantly different from zero), **and standard deviation, σ_n, of *D* are calculated**.

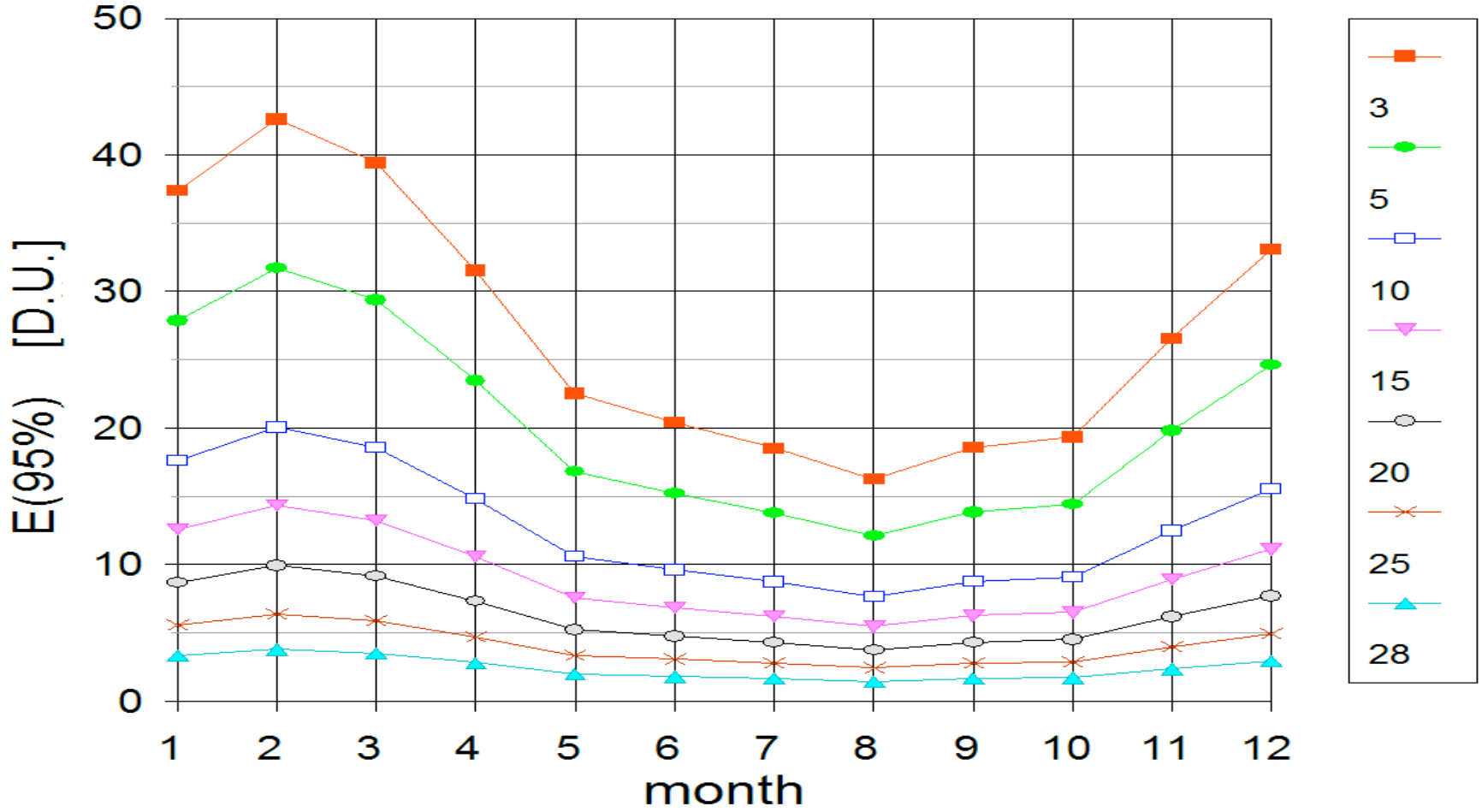
s_n(D) is proportional to **σ** *(which differs for individual months)* and depends on n (σ_n decreases with n increasing and diminishes to zero for n = 30), this uncertainty differs for individual months and number of available daily ozone values.

half-width of 95% confidence interval (in which the monthly mean of total ozone lies with 95% probability)



Assumption: *D* has approximately a normal distribution

half-width of 95% confidence interval (in which the monthly mean of total ozone lies with 95% probability)

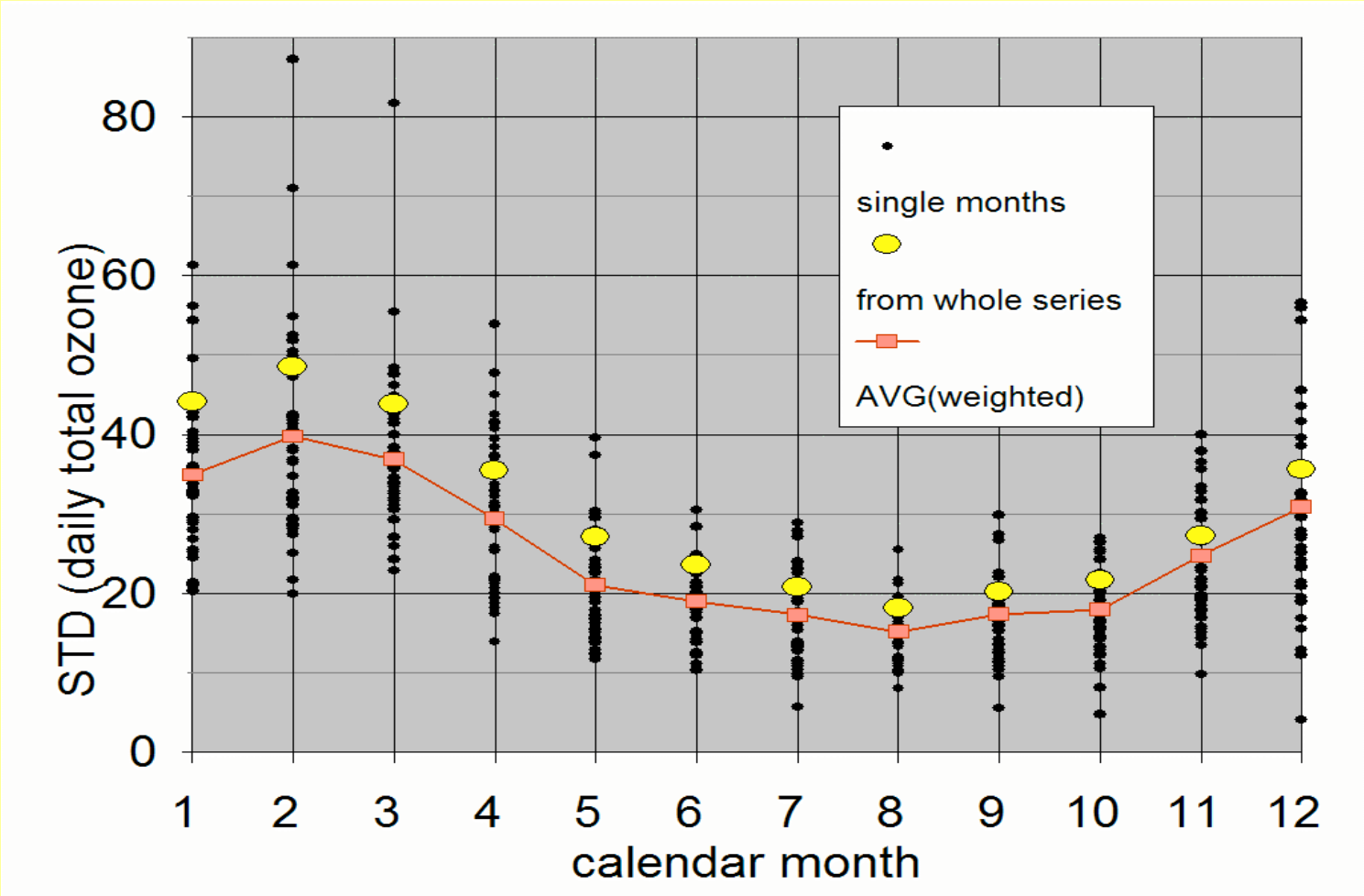


Assumption: *D* has approximately a normal distribution

Number of measured daily total ozone required for a half-width of 95% confidence interval being lower then 1%, 2%, 3% and 5% of a monthly average total ozone

month	1%	2%	3%	5%
1	29	24	19	11
2	26	22	17	10
3	29	24	18	10
4	27	20	14	7
5	25	16	10	5
6	24	15	9	4
7	24	14	9	4
8	23	13	8	3
9	24	16	10	5
10	26	17	11	5
11	27	21	15	8
12	29	24	18	11

Standard deviations of daily total ozone values in Hradec Králové (1961-2002)



AVG(weighted) is average standard deviation of daily total ozone in a single month (weighted average from the black dots); **yellow circles** represent standard deviation of daily values in a given month calculated from the whole time series (1961-2002)