# Valdidation of GOME total ozone retrieved using WF-DOAS

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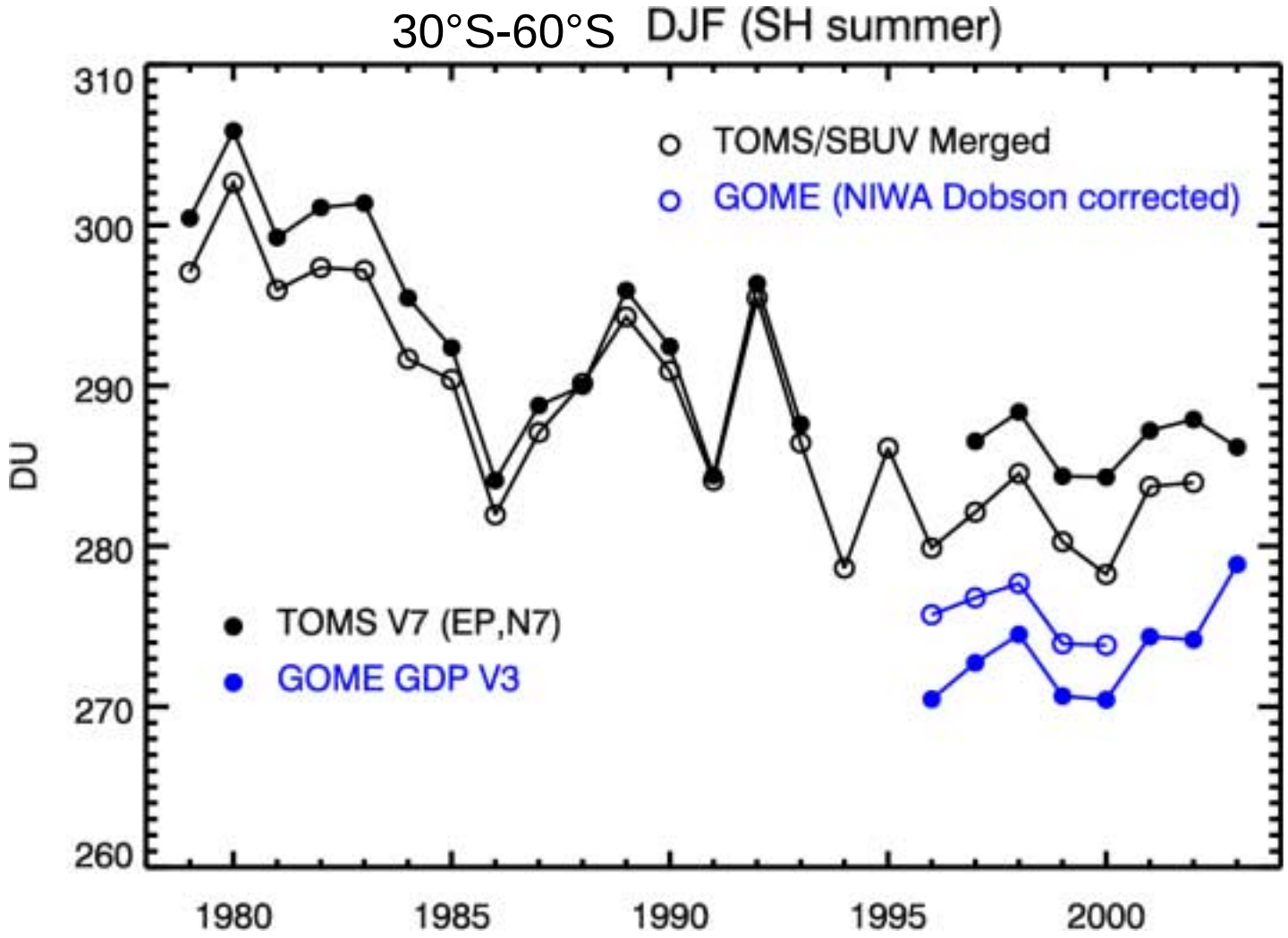
**Quadrennial Ozone Symposium 2004 (QOS04), Kos, Greece, 1-8 June 2004**

## Status before QOS04



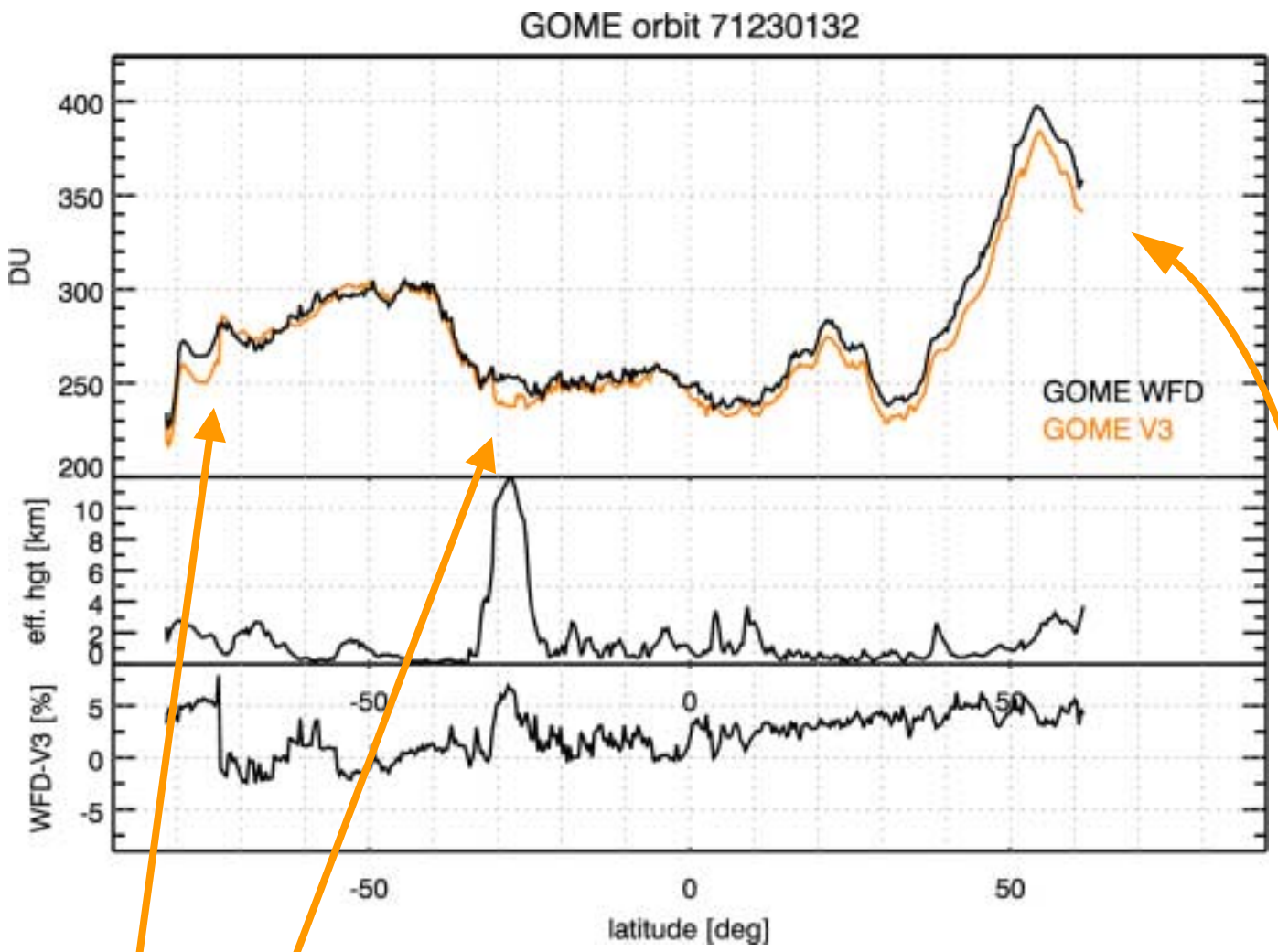

→ **Need for improved data version: TOMS/SBUV V8 & GOME V4**

# Weighting-Function-DOAS (WFDOAS)

$$\ln \frac{I_{obs}}{F_{obs}} = \ln\left(\frac{I}{F}\right)_{\text{mod}} + \left.\frac{d \ln(I/F)}{d\text{TOZ}}\right|_{\text{mod}} \cdot \left(\text{TOZ}_{fit} - \text{TOZ}_{\text{clim}}\right) + \cdots + P$$

- Taylor expansion of optical depth spectrum around climatological total ozone ($TOZ_{clim}$)

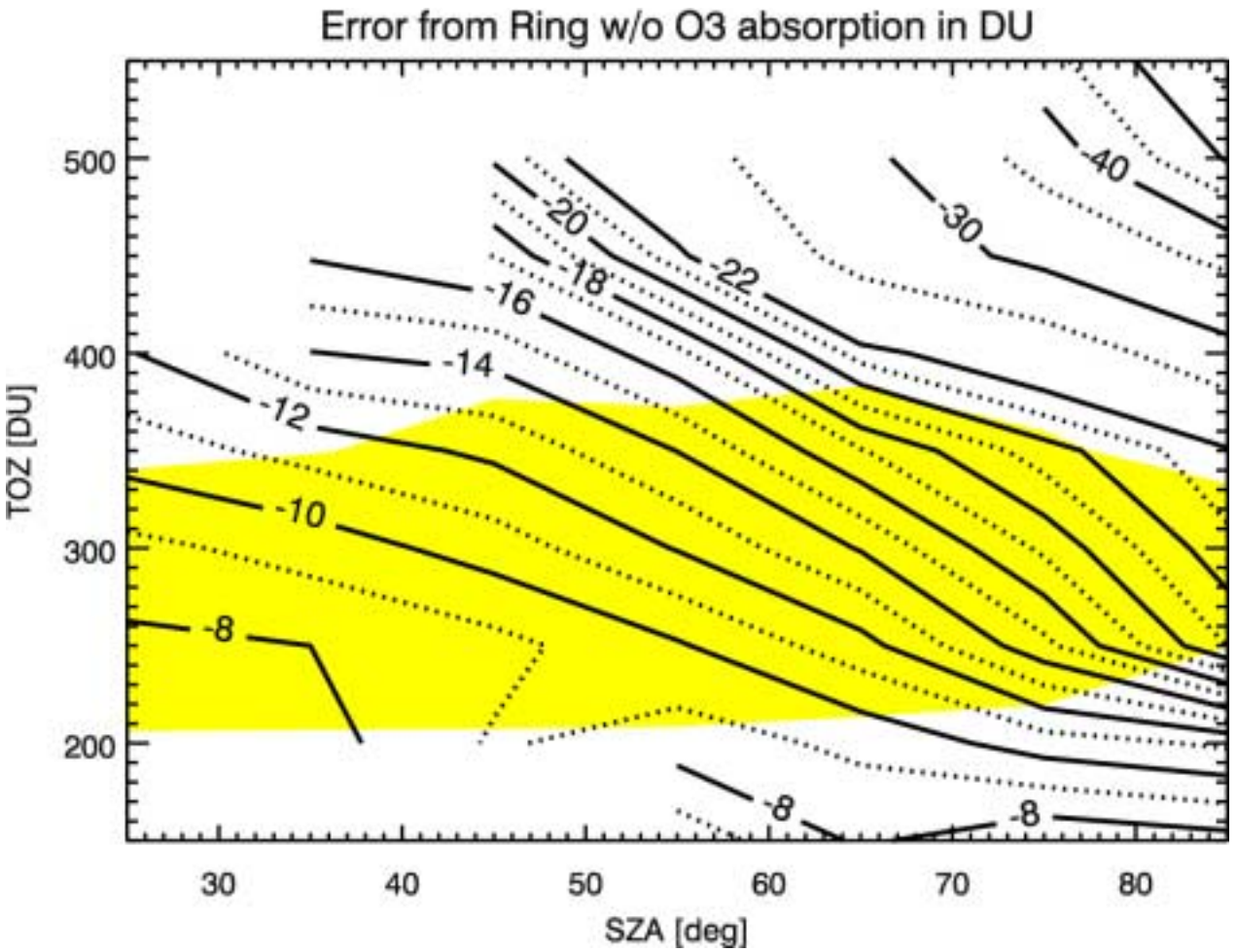
  - ➔ **Mod**elled radiative transfer quantities: **reference OD and weighting function**
    - parameterised by : TOZ, eff. albedo, eff. scene height, viewing geometry
  - ➔ Climatological ozone from **TOMS V7 profile shape climatology** (Wellemeyer et al. 1997)
  - ➔ Main feature of WF-DOAS:
    - Improved Raman correction (accounting for variable ozone dependent contribution to **Ring effect**)
    - temperature weighting function included (**ozone temperature correction**)
    - **Cloud cover and effective scene height** from oxygen A-band absorption (Koellemeijer et al. 2001) including ghost vertical column correction
    - **Effective UV albedo** (surface reflectance) from 377nm
    - Spectral fitting window: 326.6-335nm




Use of UV effective albedo

higher sensitivity to clouds

variable ozone dependent contribution to rotational Raman scattering




➔Neglect of ozone contribution to Raman correction: up to 10% error for GOME total ozone

113 GOME orbits from Mar, Jun, Sep, and Dec 1997

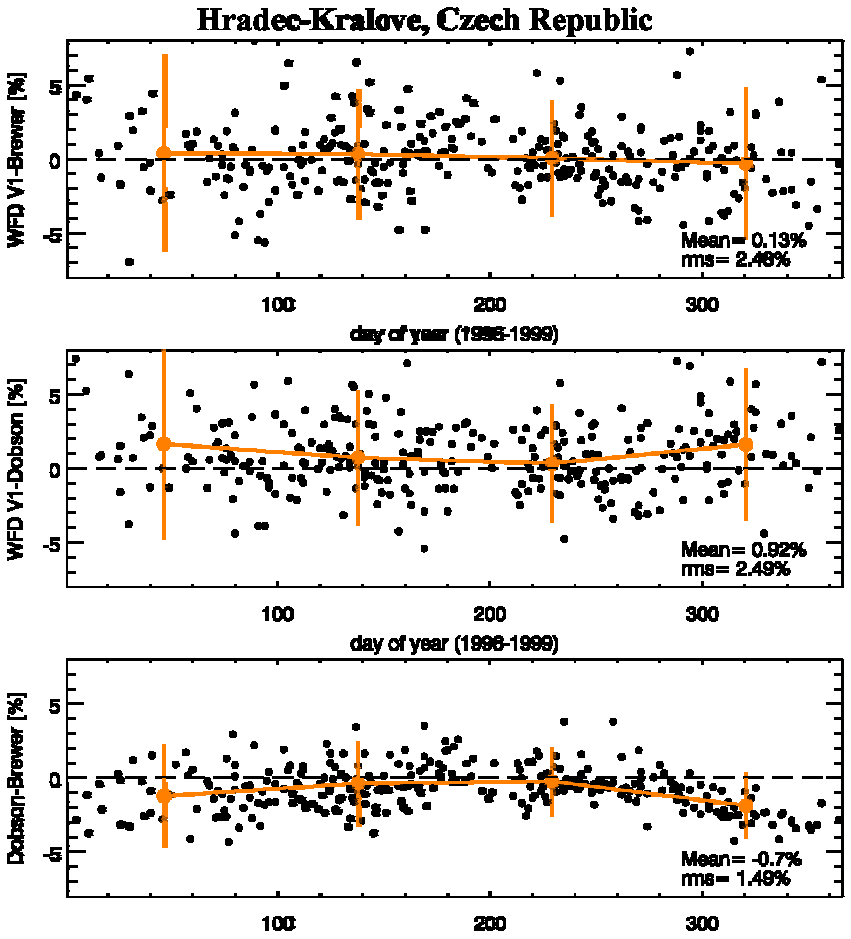
# Global Error Budget

| Error Source | Percent Error |
|---|---|
| *A priori Errors* | |
| profile shape: $O_3$ and $T$ | 1% below 80°SZA<br>5% beyond 80°SZA |
| profile shape (climate zone) | 2% below 80°SZA<br>5% beyond 80°SZA |
| effective albedo | ~ 1.5% |
| effective height | 1% |
| *LUT Interpolation error* | |
| albedo | 0.30% |
| altitude | 0.25% |
| relative Azimuth Angle | 0.05% |
| line-of-sight | 0.02% |
| solar Zenith Angle | 0.2% below 89°SZA |
| ozone | 0.1% below 80°SZA<br>1.5% beyond 80°SZA |
| *Other errors* | |
| enhanced absorbing aerosol loading | -1% |
| polarisation correction error | 0.5% (1) |
| enhanced non-absorbing aerosol loading | <0.3% |
| ground Al diffuser plate error | ~0.3% (1) |
| signal-to-noise ratio | 0.3% (1) |
| pseudo-spherical approximation | 0.3% (1) |
| GVC error w.r.t. GVC | 25% |
| GVC error w.r.t total ozone | 0.15% |
| *Error impact if not applied in WF-DOAS* | |
| Fraunhofer fit (Kurucz) | ~+2% |
| Bass-Paur vs. GOME FM98 $O_3$ cross-section | 2% (2) |
| Ring ozone filling–in | +2% |
| $I_o$ effect | -0.2% |

- Detailed error investigation as part of ESA Project GOTOCORD
- **Overall precision of WFDOAS**
  - **➔3% for <80°SZA**
  - **➔5% for >80°SZA**
- For more details on algorithm visit **Poster 189 Weber et al.**

**(1) de Beek et al. (2003)**
**(2) GDP V3 VALREPORT (2002)**

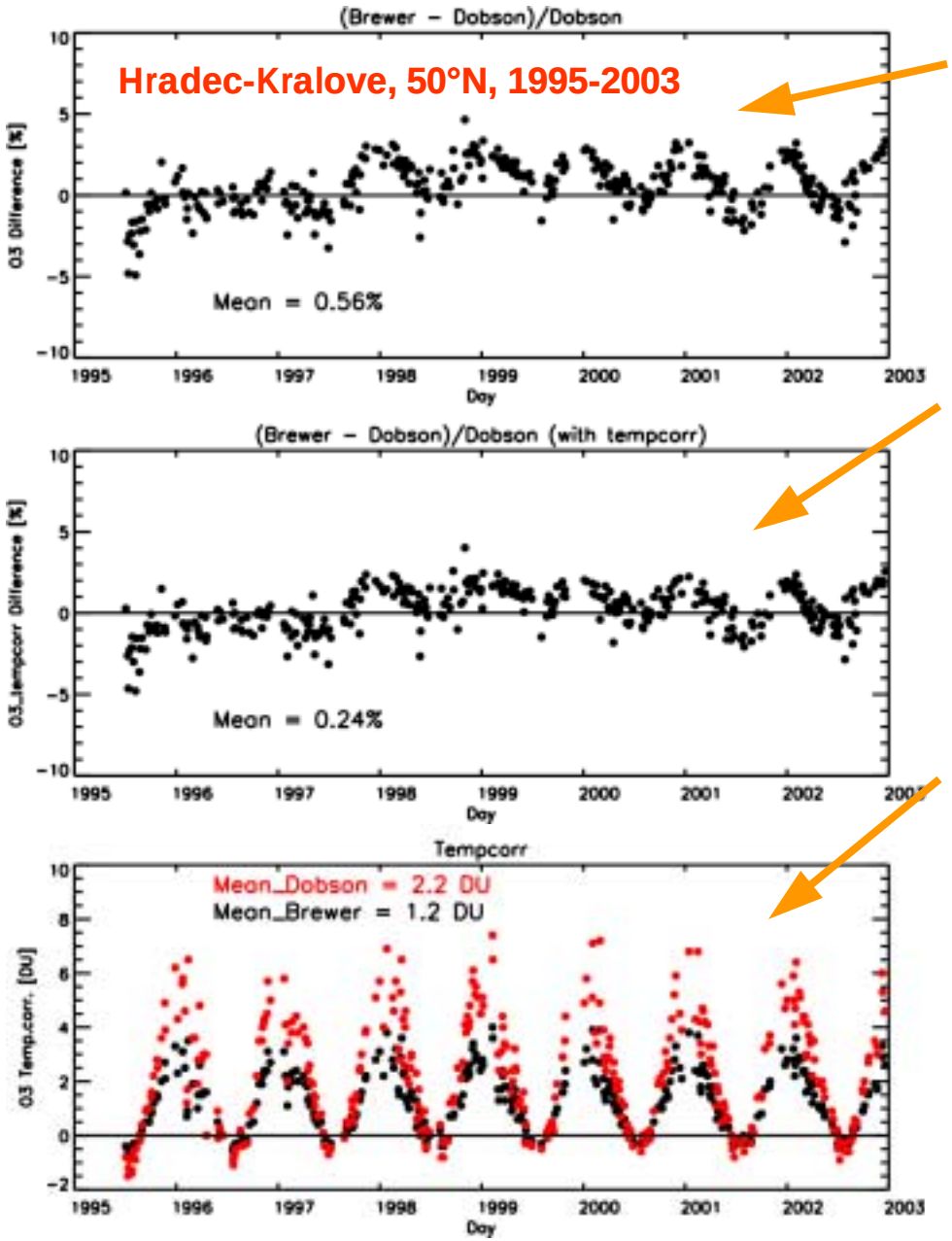
# Brewer-Dobson-GOME intercomparison




- Brewer and Dobson averages from same day
- About 300 matches with GOME in 1996-1999

- **WFDOAS V1**
  - ➔ with Brewer little seasonal variation (±0.5%)
  - ➔ fall/winter higher than Dobson
- **Dobson/Brewer**
  - ➔ Brewer in fall/winter higher than Dobson (1-2%)

# Ozone temperature correction: Dobson/Brewer




- Standard Dobson/Brewer retrieval (WMO/GAW) uses fixed ozone cross-section temperature (Dobson: 226.9K)
- Brewer & Dobson pair, simultaneous measurements within 10 min
- **Ozone weighted temperature** determined from sonde ascents at Hohenpeissenberg used in retrieval from simultanous Brewer/Dobson
- Fall/winter correction of up to **+4 DU** (Brewer) and **+8 DU** (Dobson) with respect to standard retrieval
- Remaining differences may be due to straylight at high SZA (errors goes in the same direction as ozone temperature error)

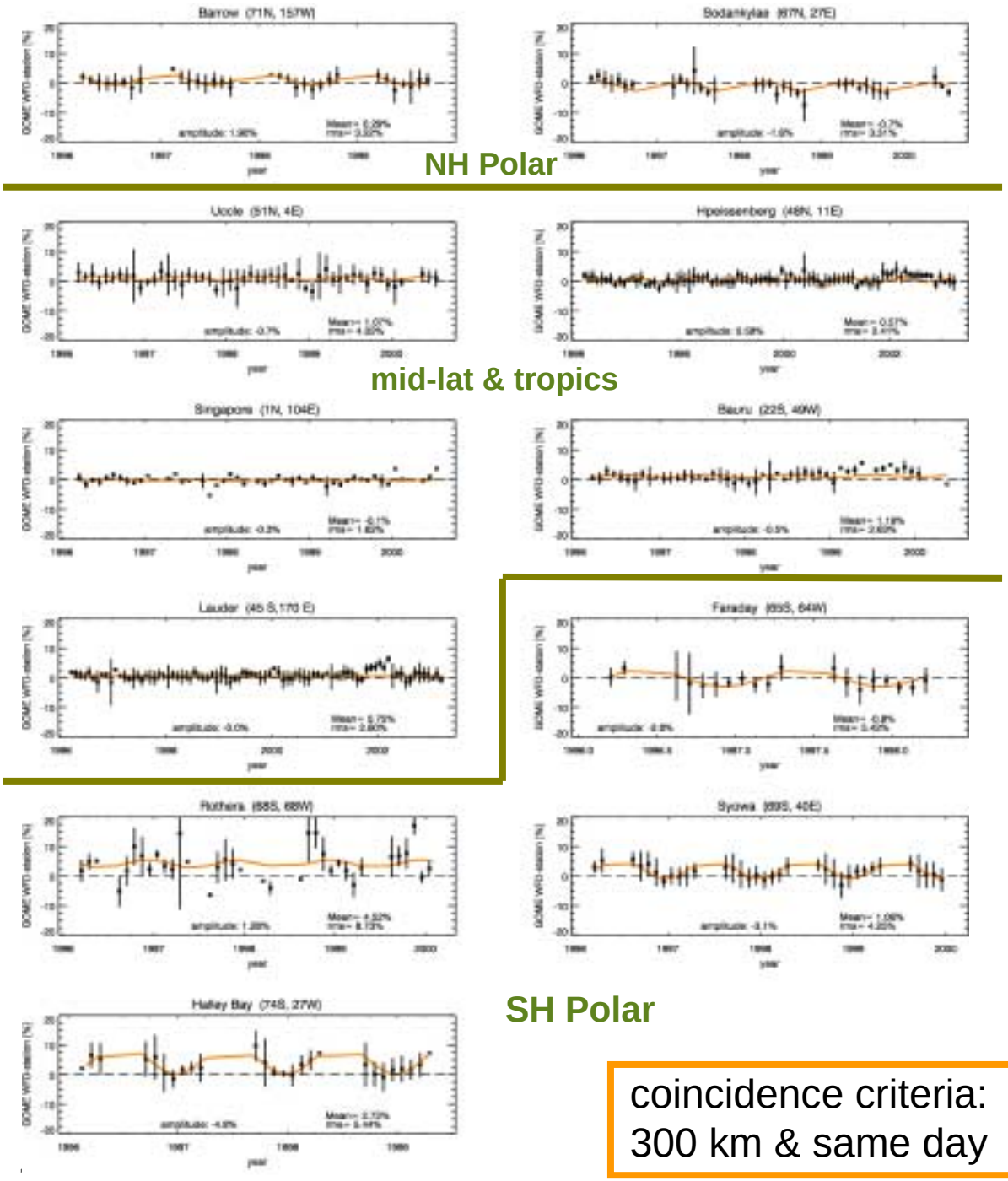
# Comparison with temperature corrected Dobson/Brewer

| Hradec-Kralove | mean | I | II | III | IV |
|---|---|---|---|---|---|
| WF-DOAS - Brewer [%] | 0,13 | 0,5 | 0,3 | 0,1 | -0,4 |
| WF-DOAS - Brewer T corr [%] | -0,24 | -0,2 | 0,1 | 0,1 | -1,1 |
| WF-DOAS - Dobson [%] | 0,93 | 1,7 | 0,7 | 0,3 | 1,1 |
| WF-DOAS - Dobson T corr [%] | 0,23 | 0,4 | 0,4 | 0,3 | 0,3 |

season

➔ Better agreement with Brewer than with Dobson if no ozone temperature correction is applied (GAW/WMO standard retrieval)

➔ Excellent agreement with both Dobson and Brewer when correct ozone temperature is used in groundbased retrieval




coincidence criteria:
300 km & same day

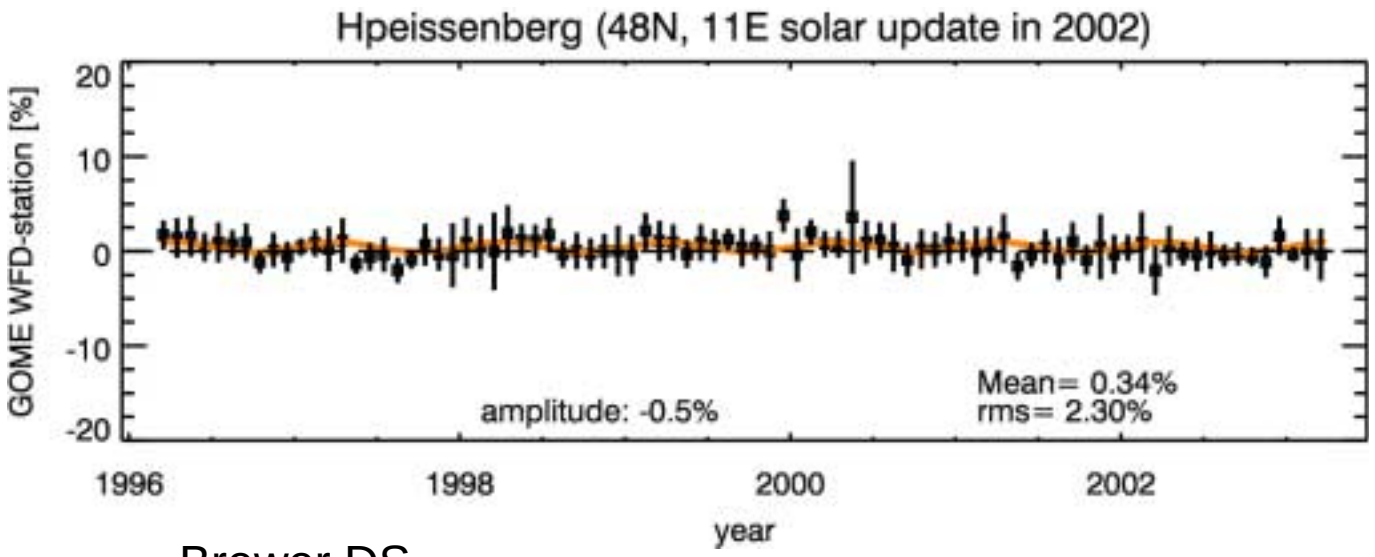
## Comparison of WFDOAS with groundbased data (Brewer/Dobson/SAOZ/M124)

**~56 stations**

- mid-latitudes and tropics good agreement to within 1% and little seasonal variation (cosine amplitudes below 0.5% in general)
- At polar latitudes differences of up to +4 to +8% in winter (dependent on individual stations)

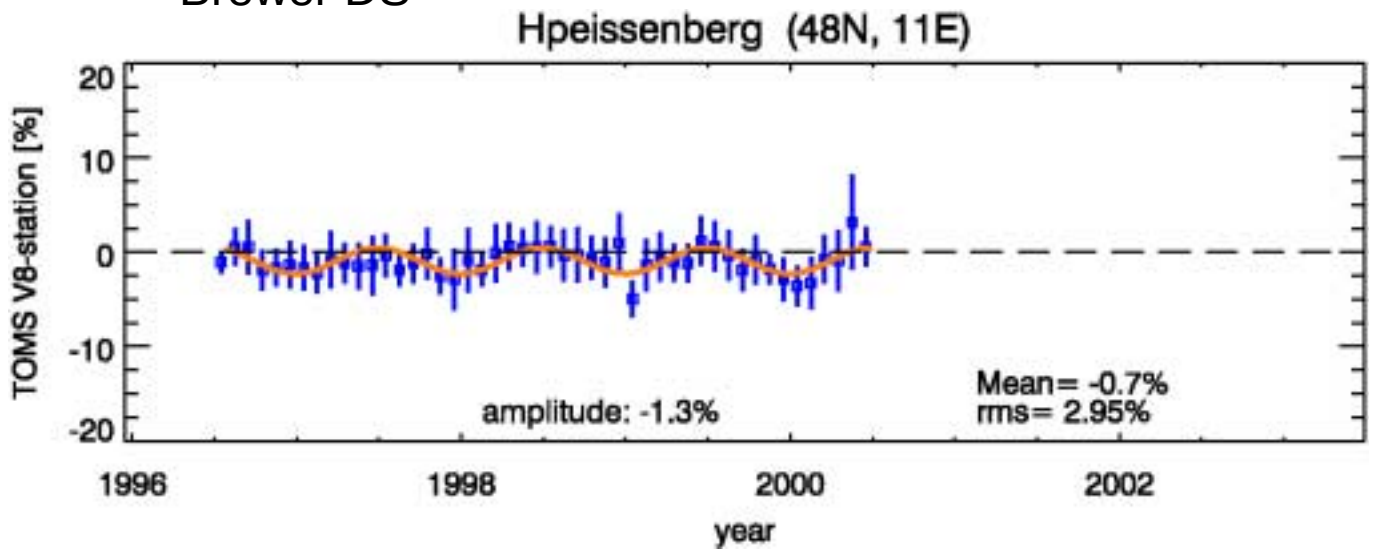
# GOME WFDOAS & TOMS V8

**GOME**




Brewer DS

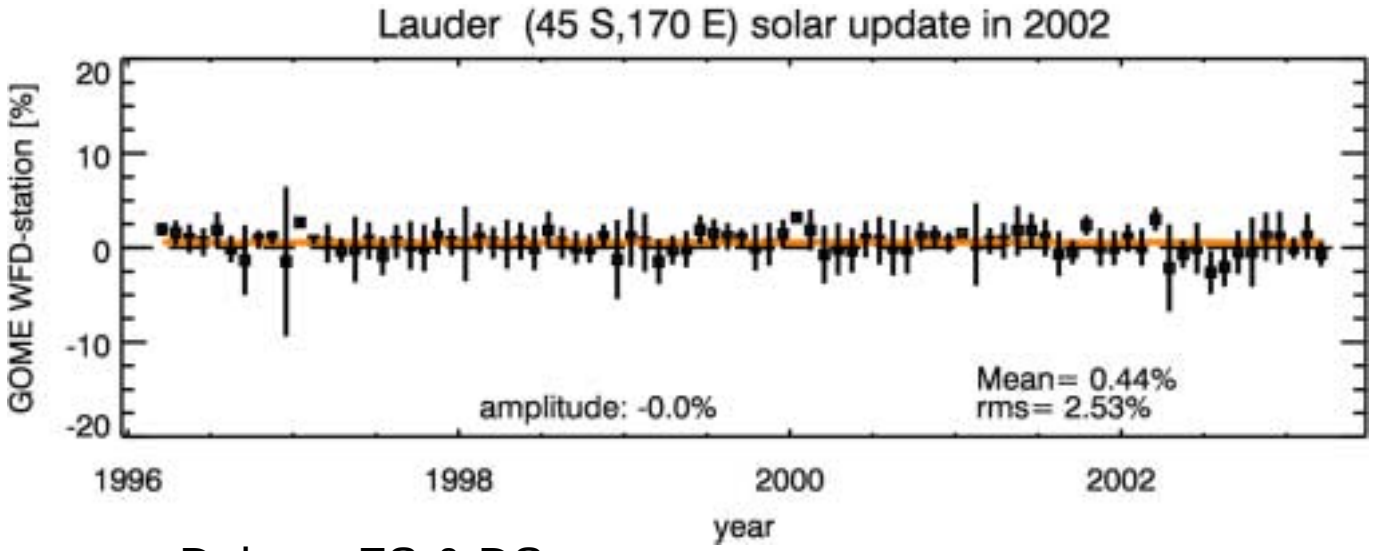
**TOMS**




Thanks to H. Claude & Ulf Köhler, MOHp

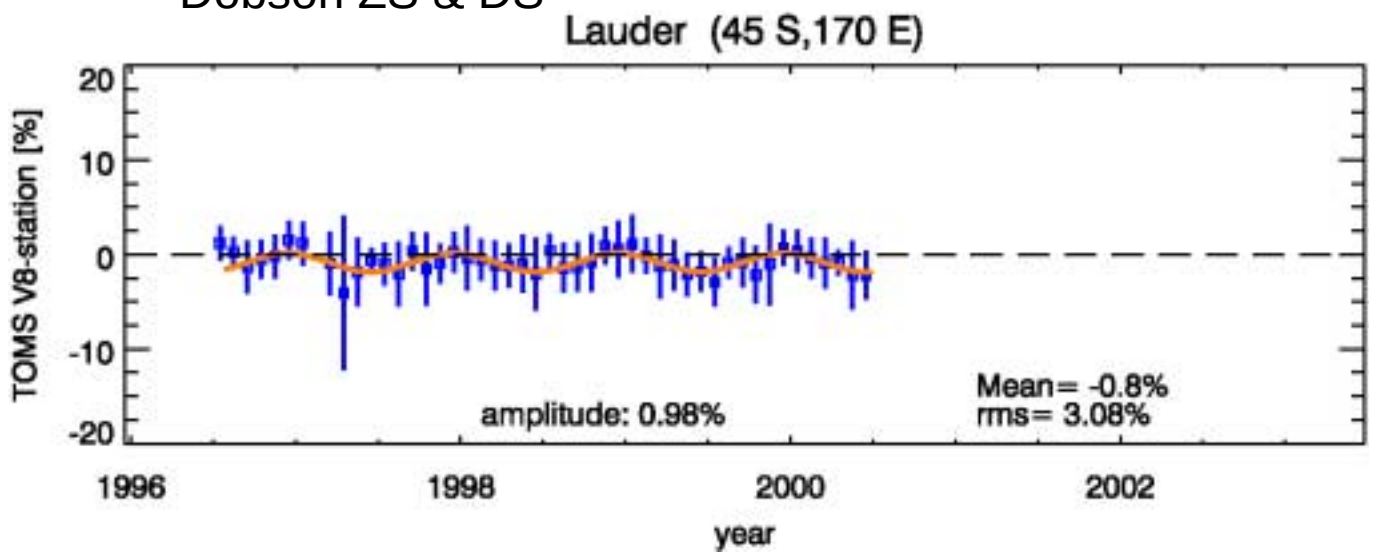
# GOME WFDOAS & TOMS V8

**GOME**




Dobson ZS & DS

**TOMS**

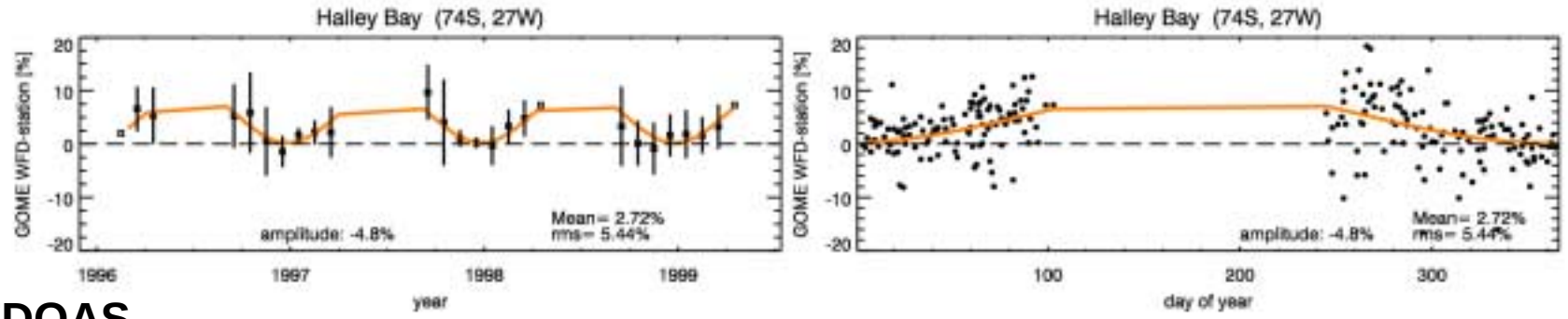



Thanks to Bob Evans, NOAA

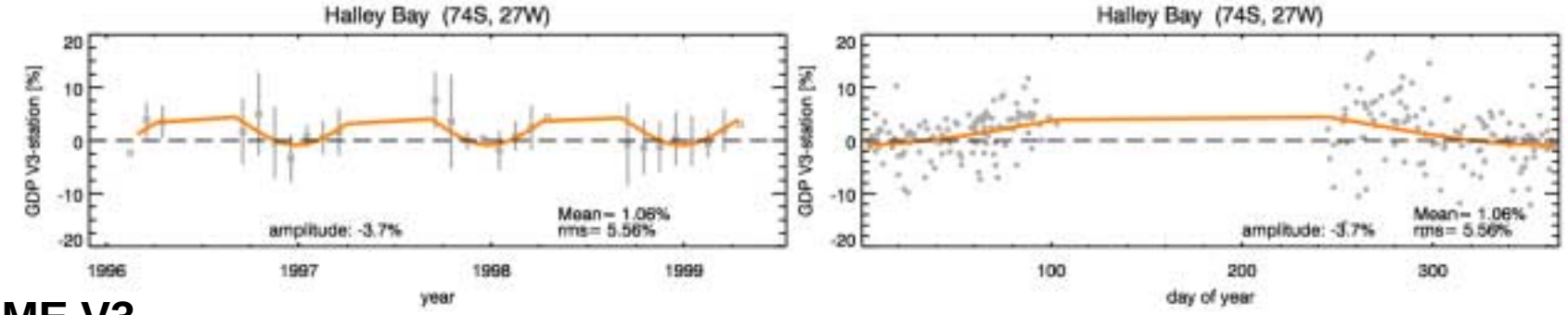
# Validation with WOUDC database (Statistics)

| region | # stations | mean bias | 1σ RMS | max seasonal bias (±1σ) | min seasonal bias (±1σ) |
|---|---|---|---|---|---|
| 60°N-90°N | 5 | -0.3% | 4.7% | 6% (±6%) | -2%(±3%) |
| 25°N-60°N | 17 | -0.4% | 3.9% | 0% (±5%) | -1%(±3%) |
| Europe | 8 | 0.0% | 3.7% | 0% (±5%) | 0%(±3%) |
| Russia | 13 | -1.4% | 5.3% | 2% (±6%) | -3% (±5%) |
| Tropics | 7 | 0.5% | 2.9% | | |
| 25°S-60°S | 6 | 0.1% | 4.1% | 0% (±4%) | 0% (±4%) |
| 60°S-90°S | 4 | 1.3% | 8.6% | 5% (±10%) | 0% (±4%) |

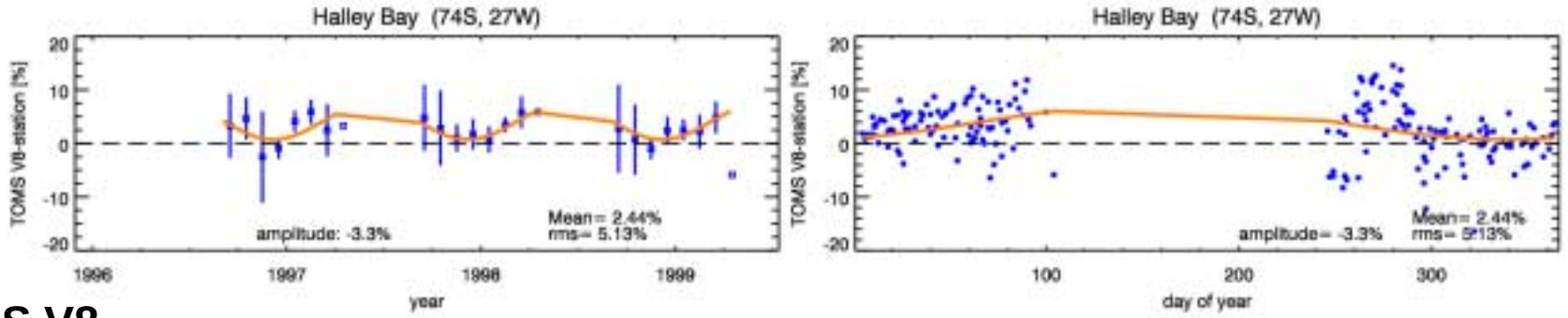
# Halley Bay, Antarctica, 74°S, Dobson




**WFDOAS**



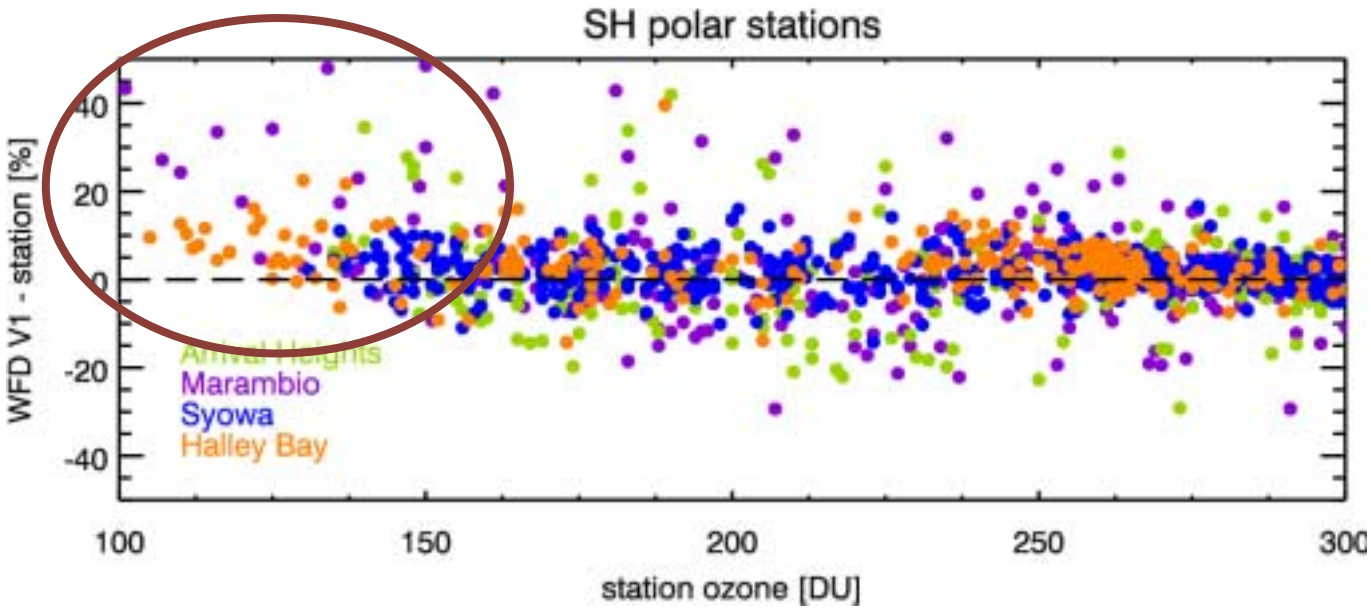

**GOME V3**

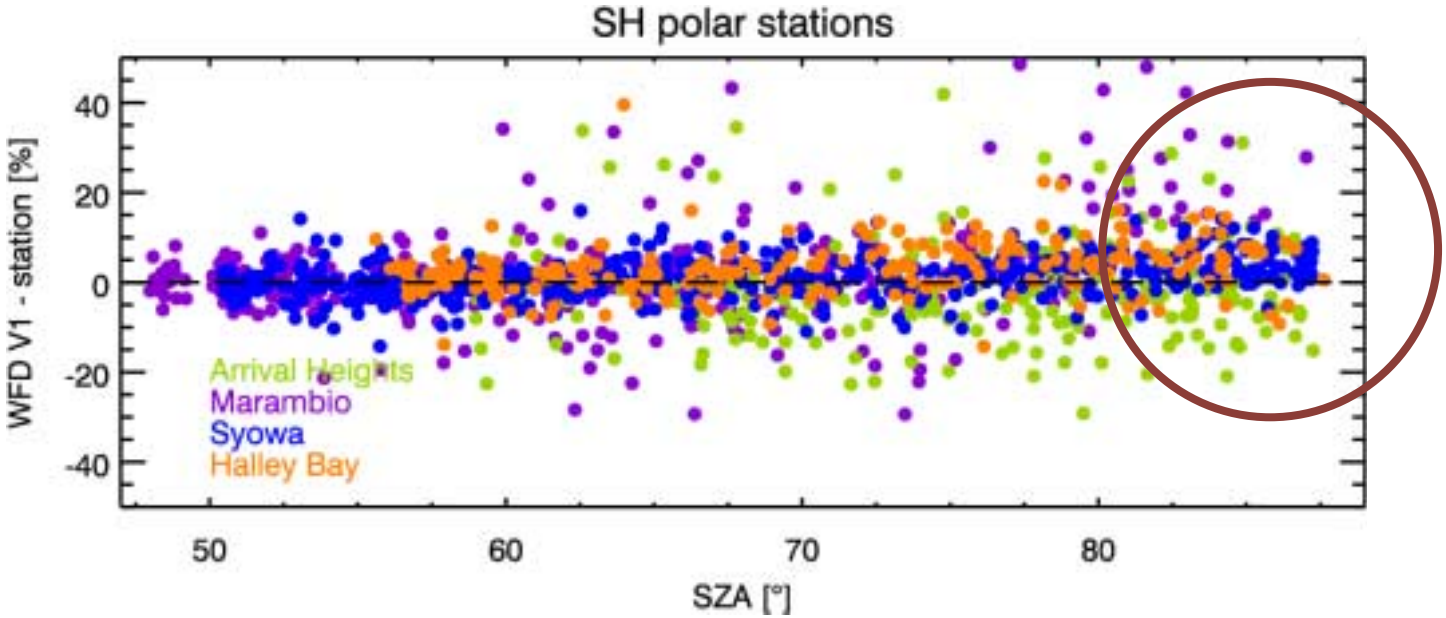



**TOMS V8**

14/weber@uni-bremen.de

# Antarctic observations



# Conclusions

- ➔ Excellent agreement to within ±1% with groundbased Dobson/Bewer measurements with negligible seasonal variation of less than ±0.5%
- ➔ Better agreement with Brewer than Dobson (WMO-GAW standard retrieval) if no ozone temperature correction is applied to groundbased data
- ➔ In polar region and at high solar zenith angle bias of +4% to +8% is observed, about half of the difference may be explained by lack of ozone temperature correction and stray light in ground based data (see TOMS Fairbanks campaign)
- ➔ Reprocessing of GOME data for 1995-2004 with WFDOAS until end of summer (watch *www.iup.physik.uni-bremen.de/GOME* for updates)
- ➔ Adaptation of algorithm to SCIAMACHY (2002-present) currently underway

# Publications

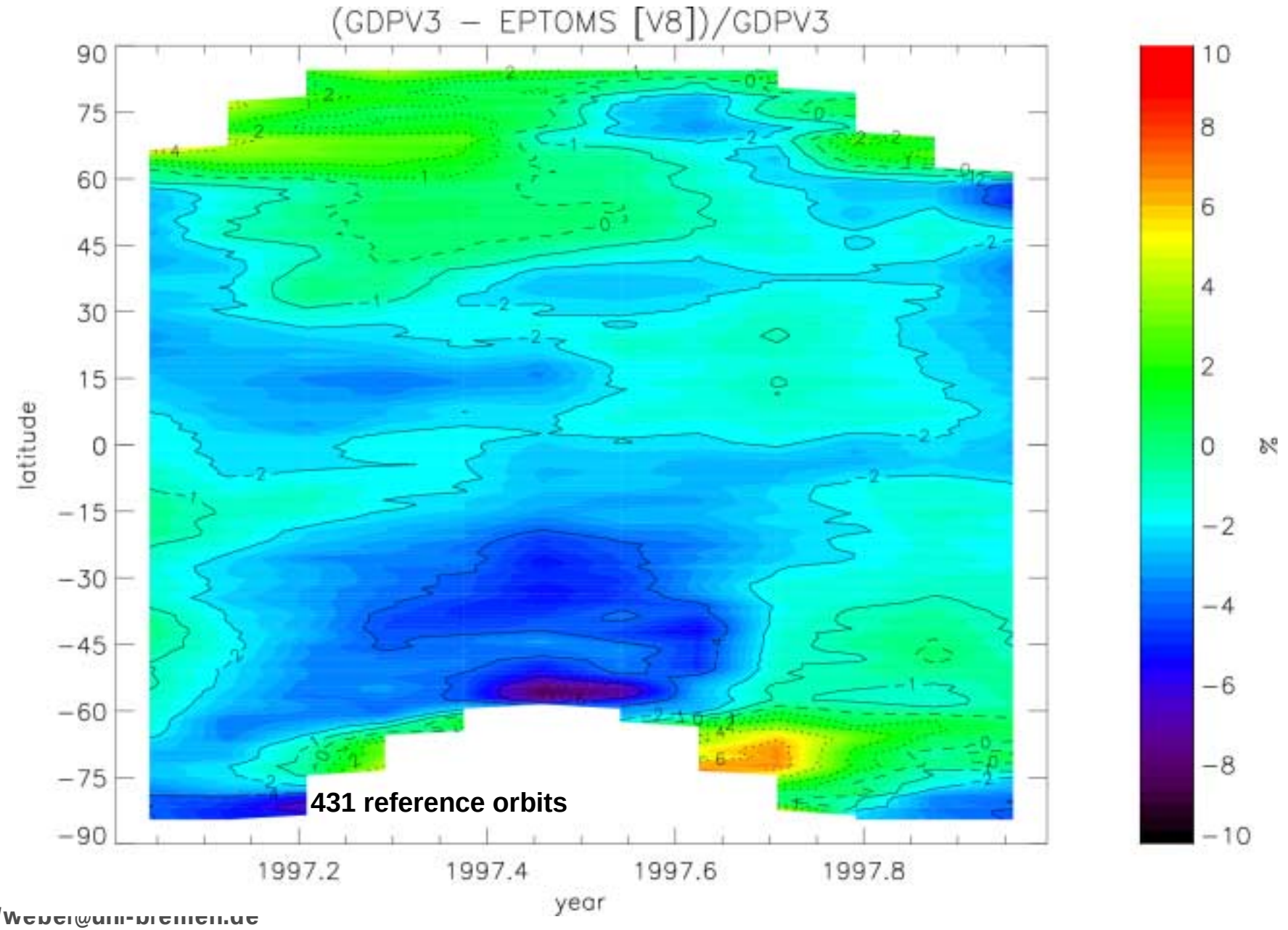
- M. Coldewey-Egbers, M. Weber, L. N. Lamsal, R. de Beek, M. Buchwitz, and J. P. Burrows, A novel total ozone algorithm for backscatter UV using the weighting function DOAS approach, *Atmos. Chem. Phys. Discuss.,* submitted.

- M. Weber, L. N. Lamsal, M. Coldewey-Egbers, K. Bramstedt, J. P. Burrows, Pole-to-pole validation of GOME WFDOAS total ozone with groundbased data, *Atmos. Chem. Phys. Discuss.,* submitted

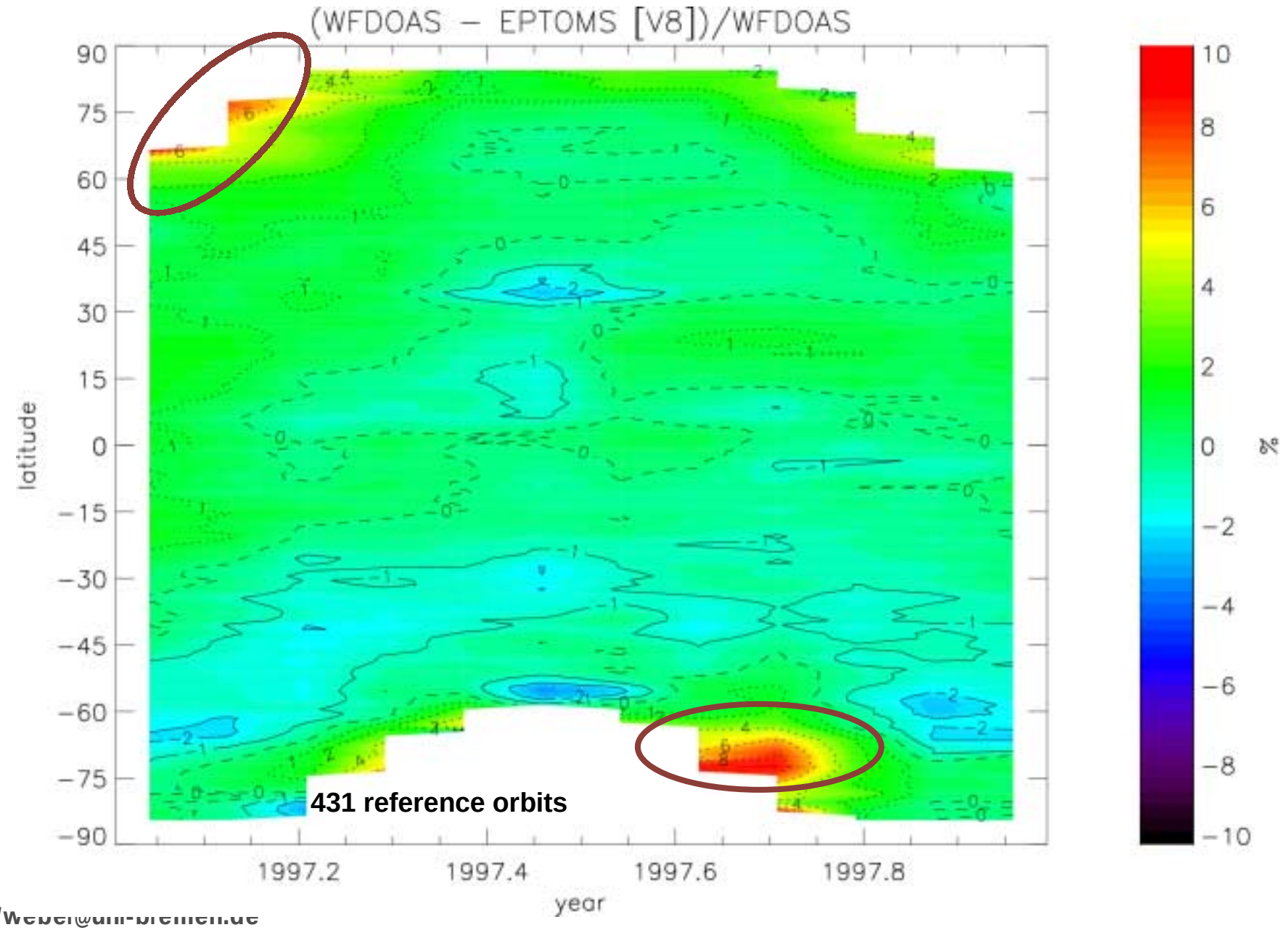
➔ www.iup.physik.uni-bremen.de/~weber/papers

➔ www.copernicus.org/EGU/acp/acp.html

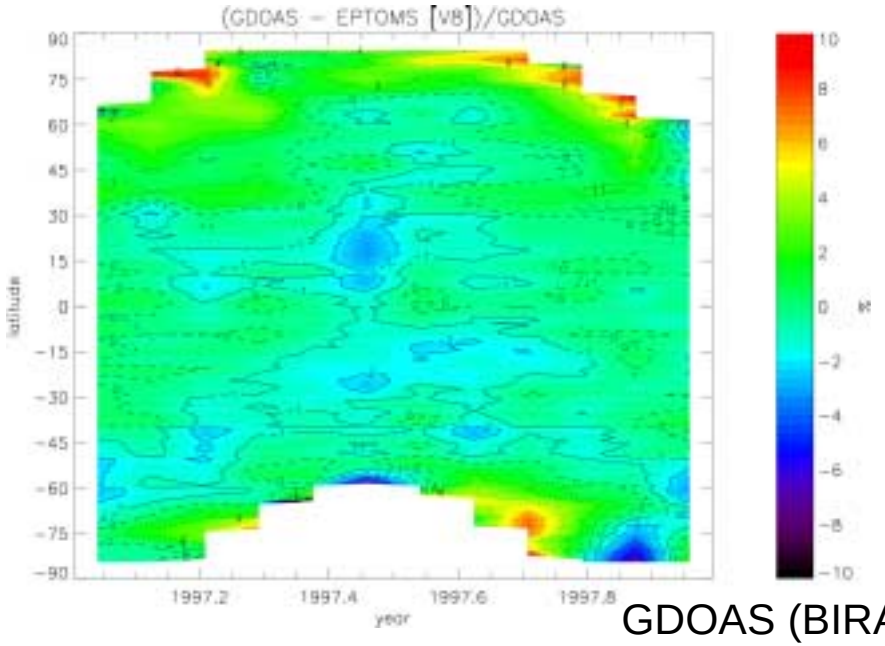
# Comparison GOME V3 with TOMS V8



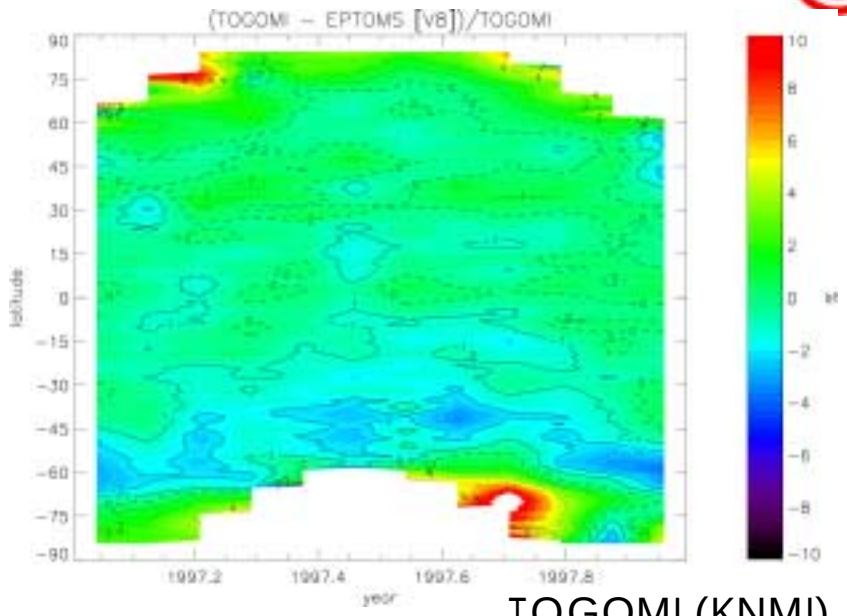
# Comparison of WFDOAS with TOMS V8



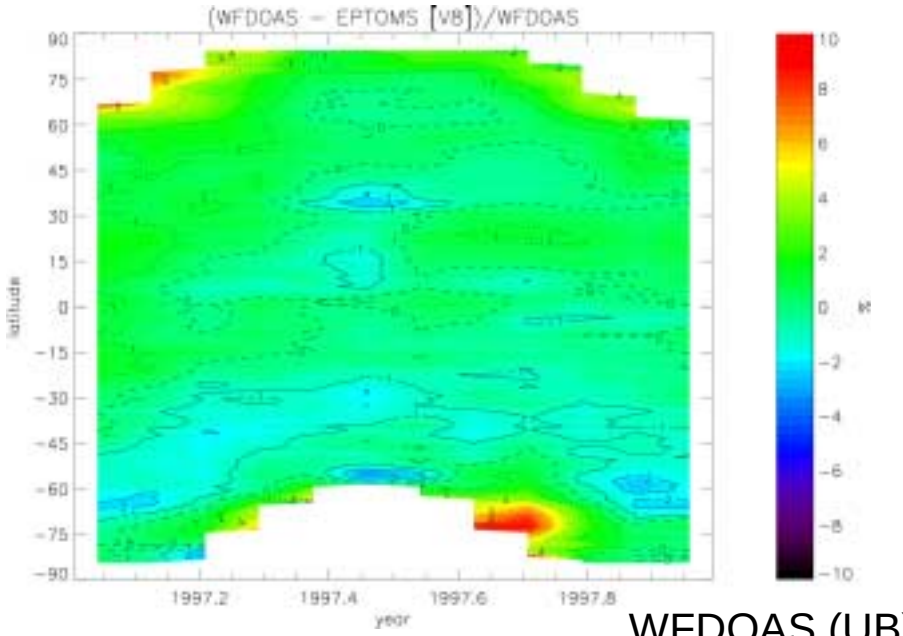
# Three GOME algorithms (three ESA studies)




GDOAS (BIRA)



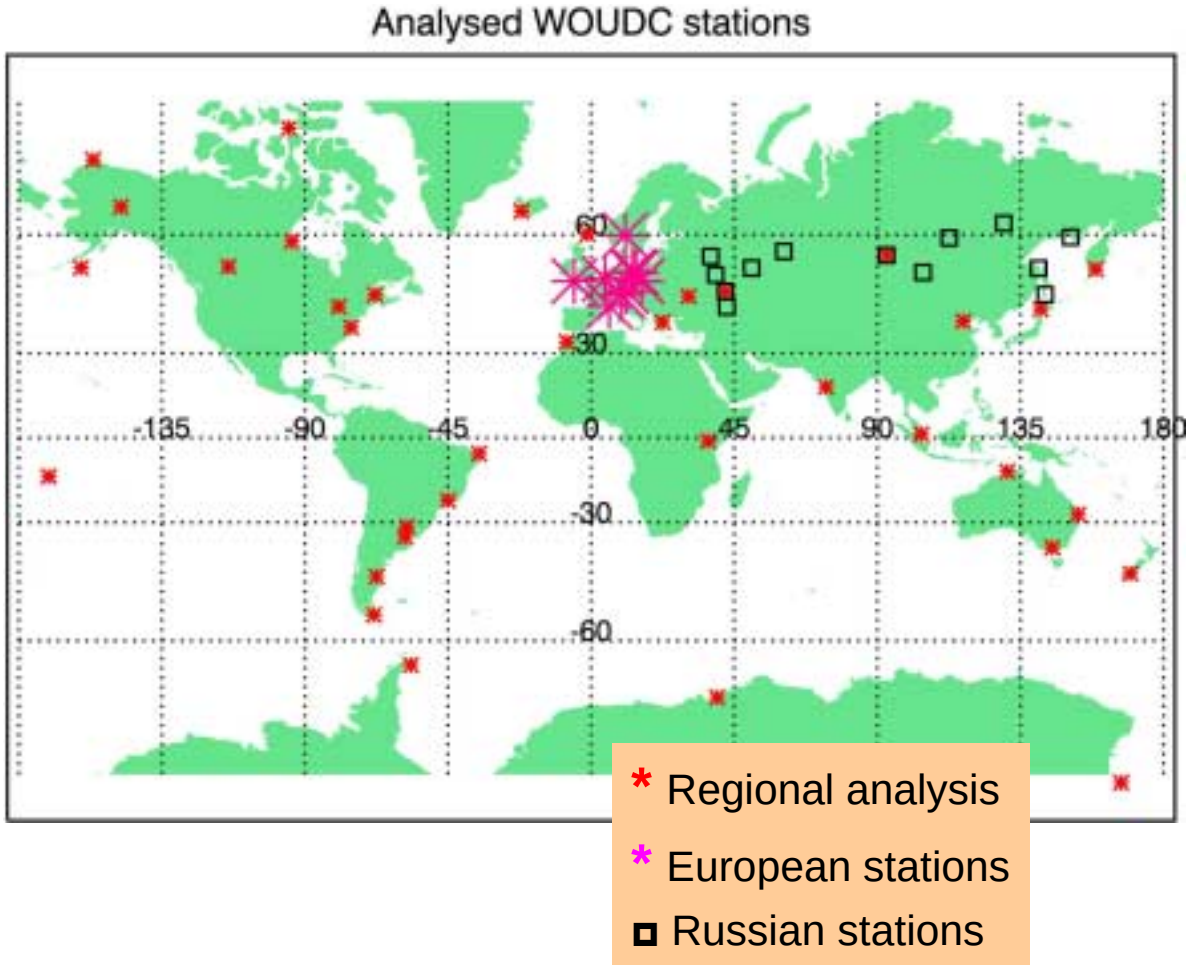

TOGOMI (KNMI)




WFDOAS (UB)

- Three algorithms in excellent agreement to each other
- Positive bias at high solar zenith angles in polar region for all three algorithms
- ESA management decision:
  - ➔ GDOAS will be official GOME V4

# WOUDC overview




- 56 stations (45 for global statistics + 11 Russian stations)
  - ➔Uneven distribution (NH midlatitude dominates)
  - ➔regional analysis in 30° wide latitude bands
    - NH polar
    - NH mid latitudes
    - tropics
    - SH mid latitudes
    - SH polar
  - ➔Separation between Russian (M124) and Europe (Dobson/ Brewer)

Collocation criteria:
300km collocation radius
same day