Validation of GOME WF-DOAS V1

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GOME Total Ozone Column Retrieval Development,
Final Presentation, 3 Dec 2003, Frascati

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Topics

- Introduction (data sources)
- Brewer and Dobson intercomparison
- Long-term validation 1995-2003
- Pole-to-Pole validation (WOUDC)
  - ➔ Polar stations
  - ➔ Mid-latitudes
  - ➔ Tropics
- Conclusion

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Data sources

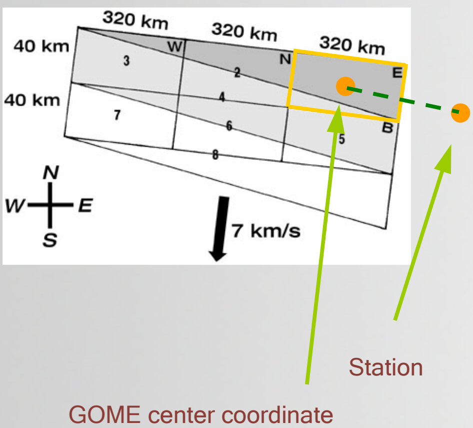
- Separate Brewer and Dobson data sets:
  - ➔Hohenpeissenberg, Germany, 48°N (courtesy U. Köhler, H. Claude)
  - ➔Hradec-Kralove, Czech Republic, 50°N
- Dobson data from Lauder, New Zealand, 45°S (courtesy, Bob Evans, NOAA)
  - ➔Direct sun and zenith sky data
- World Ozone and UV Radiation Data Centre (WOUDC)
  - ➔45 stations from pole-to-pole (+11 Russian stations)
  - ➔Dobson and Brewer data
  - ➔all collocations in the period 1996-1999

GOME WF-DOAS Version 1

- 326.6-335.00 nm
- Fitting parameters
  - ➔Ozone VCD (WF)
  - ➔Temperature shift (WF)
  - ➔Undersampling
  - ➔Ring SCD w/ ozone filling-in
  - ➔NO2 SCD
  - ➔BrO SCD
- Burrows et al. (1999) O3 cross-section, shifted by 0.0017 nm
- Cubic polynomial
- Shift & squeeze (earthshine only)
- Fraunhofer fitting (Kurucz)
- Ghost vertical column (zonal monthly mean TOMS V8)
- A-priori profile shape (TOMS V7)

Collocation Criteria

GOME scan geometry (IT=1.5 sec)



- collocation radius:
  - ➔< 160 km (Brewer-Dobson)
    - ❍ inside GOME pixel
  - ➔< 300 km (WOUDC)
- station & GOME measurements from same day
- nearest neighbor (match/pair) per day

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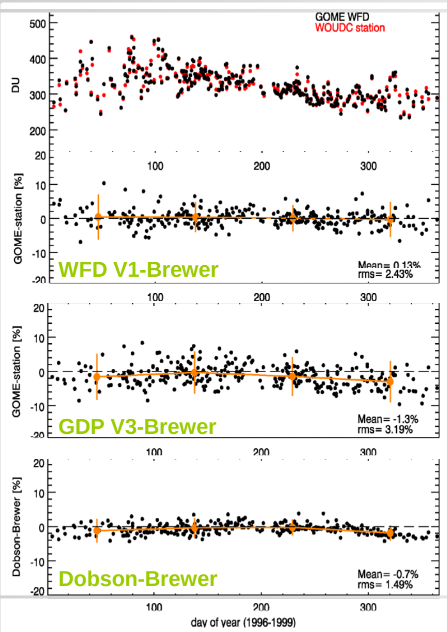
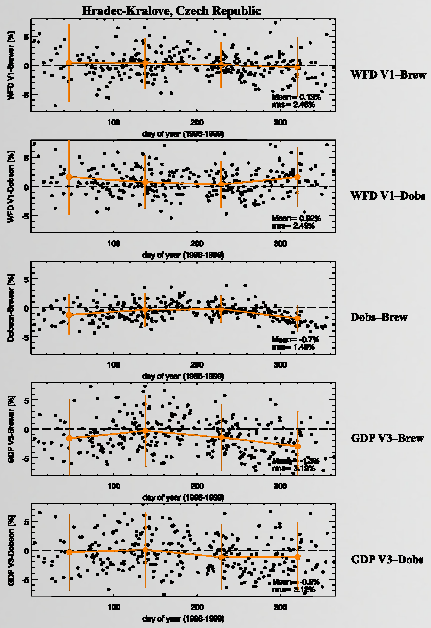
Brewer-Dobson-GOME intercomparison



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

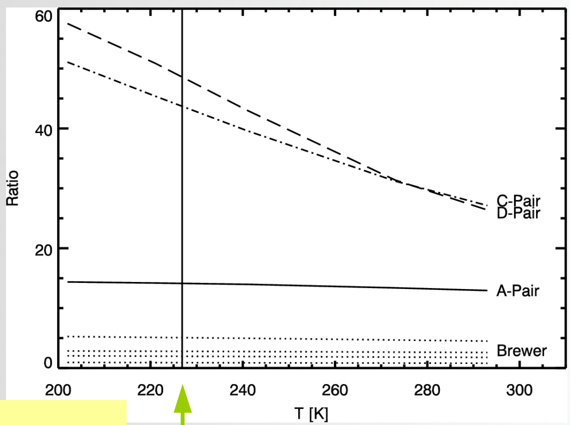
Brewer-Dobson-GOME intercomparison



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

- **WFD V1**
  - ➔with Brewer little seasonal variation (±0.5%)
  - ➔fall/winter higher than Dobson
- **GDP V3**
  - ➔Seasonal cycle with both Dobson and Brewer (±1.5%)
- **Dobson/Brewer**
  - ➔Brewer in fall/winter higher than Dobson (1-2%)

Ozone temperature error in Dobson/Brewer



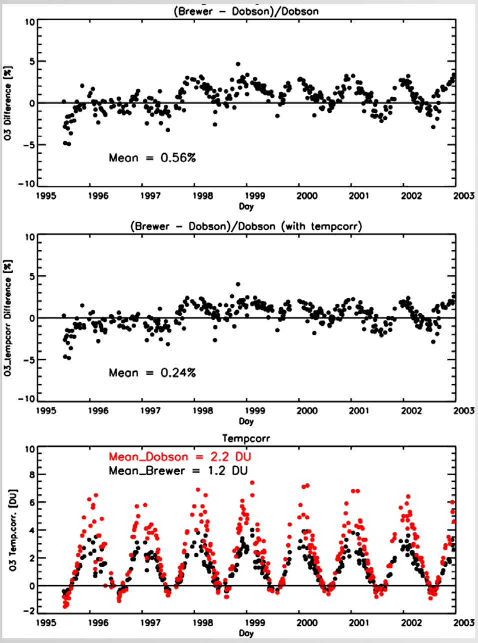
Dobson 1.3%/10K

Brewer 0.7%/10K

Komhyr et al. 1988, Kerr et al. 1988

226.9 K Dobson/Brewer retrieval

Ozone temperature correction: Dobson/Brewer



- ▷ Hradec-Kralove, 50°N 1995-2002
- ▷ Brewer & Dobson pair, simultaneous measurements within 10 min
- ▷ Ozone weighted temperature determined from sonde ascents
- ▷ Fall/winter correction of up to +3 DU (Brewer) and +6 DU (Dobson)
- ▷ Remaining differences may be due to straylight at high SZA

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

Summary: Brewer-Dobson-GOME intercomparison

- WFD V1 shows **little seasonal variation with Brewer** (±0.5%) in Hradec-Kralove and Hohenpeissenberg
- In comparison with **direct sun (DS) Dobson**, WFD V1 has a seasonal cycle of about (±1%)
- **Maximum in differences observed in (fall)/winter** for both Brewer and DS Dobson
- Major part of the differences can be corrected for by using **ozone temperature corrected Dobson and Brewer** data

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Long-term Validation: 1996-2003

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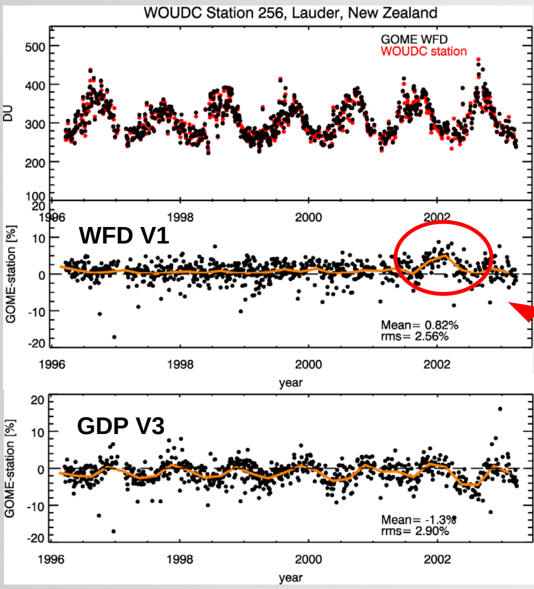
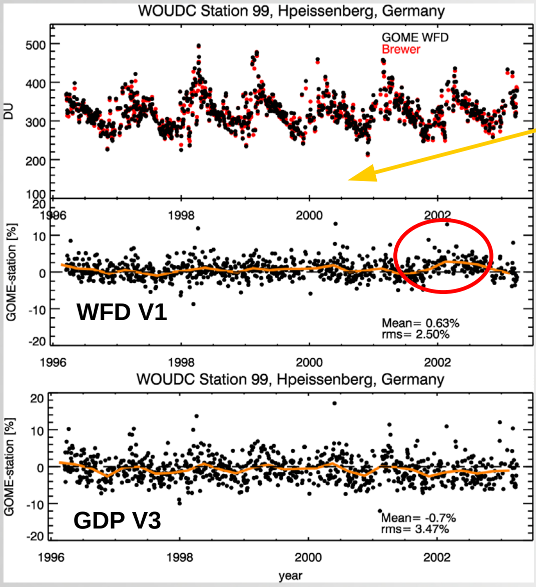


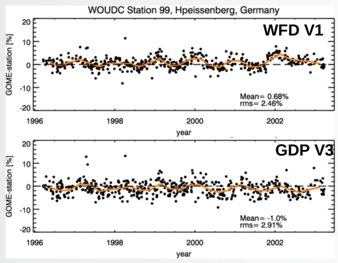
- Lauder, 45°S (NDSC)
- Dobson
  - ➔DS & zenith sky
- Data provided by R.D. Evans, NOAA

No (mean) solar data update Nov 2001-Oct 2002

Long-term Validation (2): 1996-2003



- MOHp, 49°N (NDSC)
- Brewer
  - ➔DS & zenith sky
- Dobson
  - ➔DS only
- Data provided by U. Köhler, DWD



Summary: Long-term validation 1996-2003

- WFD V1 is **very stable with time** and shows no sign of degradation after 2000
- No seasonal cycle is seen with **Lauder, 45°S,** combined DS and zenith sky (ZS) Dobson, the same is true for Brewer in **Hohenpeissenberg (MOHp), 49°N**, seasonal cycle only seen with MOHp DS Dobson (like in Hradec-K.)
- **No hemispheric bias** (Lauder & MOHP)
- Bump observed in 2002, most likely related to the **absence of updated mean solar spectra (October 2001-November 2002**, GDP bug), not seen in GDP V3 (cloud/albedo?)

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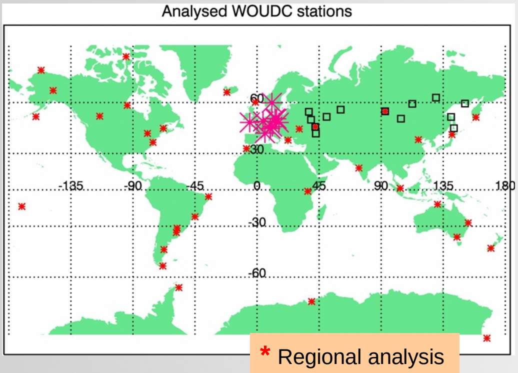
WOUDC overview



* Regional analysis
* European stations
◘ Russian stations

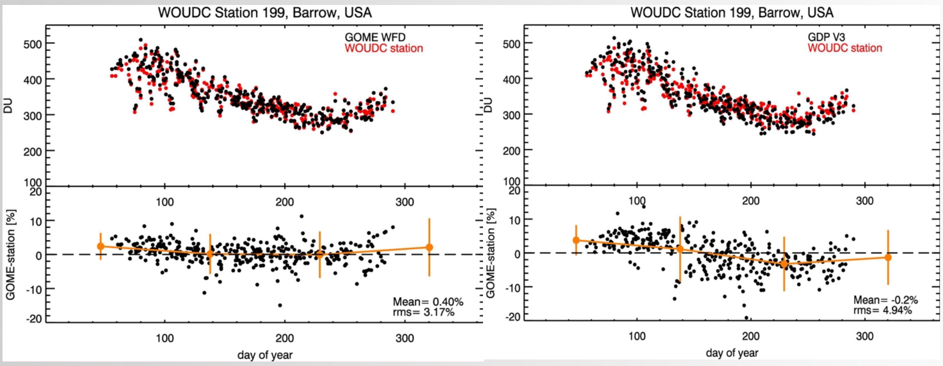
Collocation criteria:
300km collocation radius
same day

- 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)

North polar stations, 60°N – 90°N: 5 stations

Example: Barrow/Alaska, USA, 71.32°N, 156.6°W

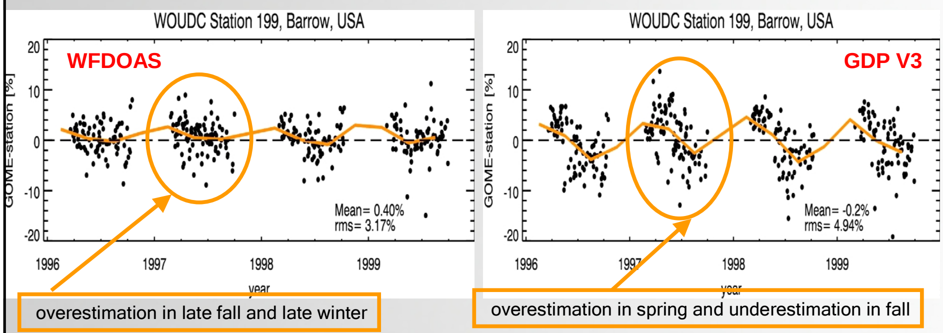
Comparison with WFDOAS | **Comparison with GDP V3**



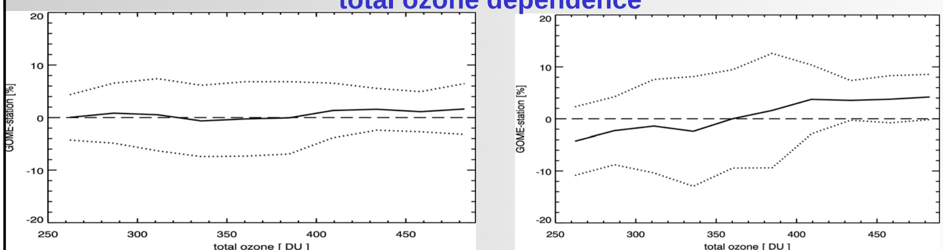
➪ Seasonal cycle in WF-DOAS and GDP V3

➪ lower scatter of WF-DOAS

North Polar Station: Barrow, USA



total ozone dependence



North Polar Station: Barrow, USA

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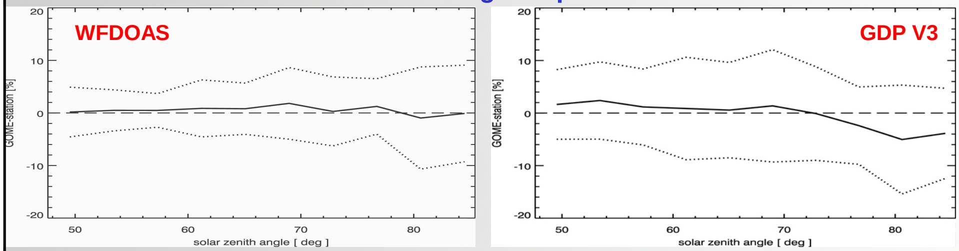
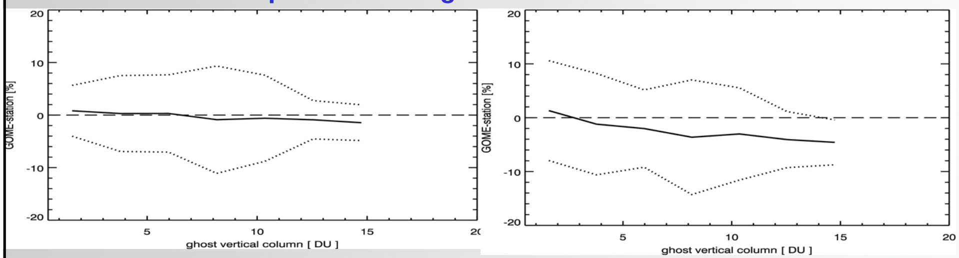
solar zenith angle dependence



dependence on ghost vertical column



North polar stations, Summary of 5 stations

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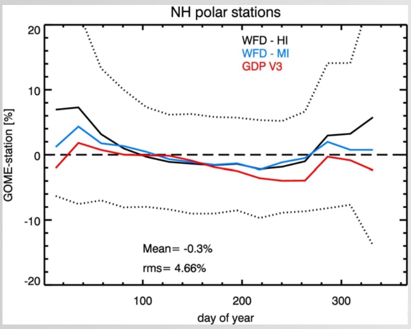

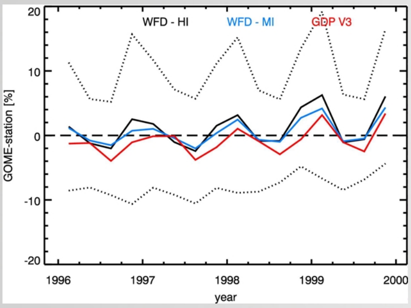

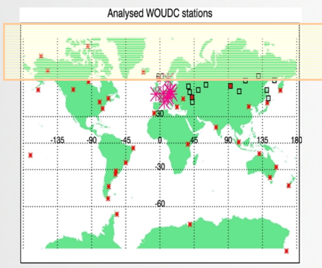

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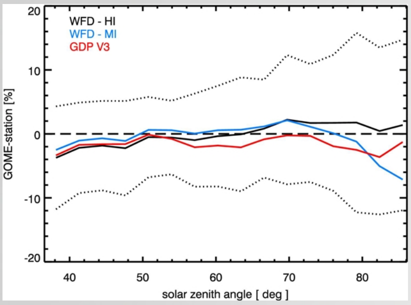
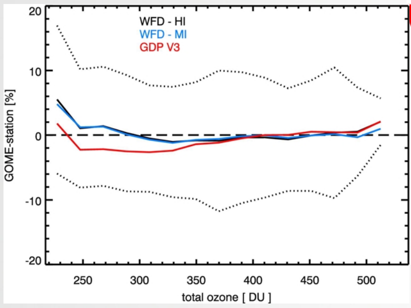
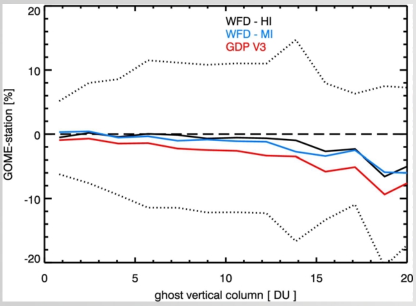
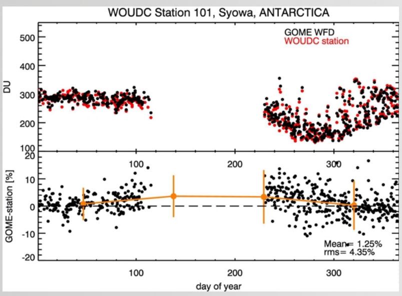


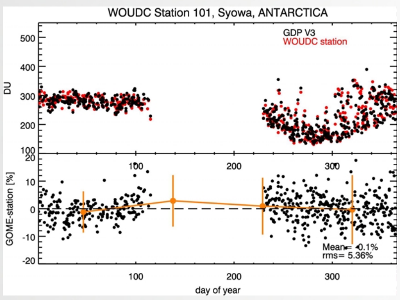


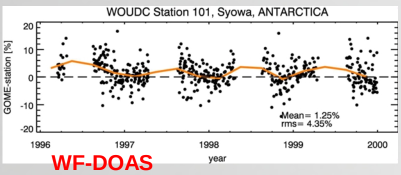


SH polar stations, 60°S – 90°S: 4 stations

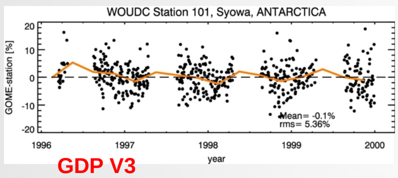
Example: Syowa, ANTARCTICA, 69.0°S, 39.6°E





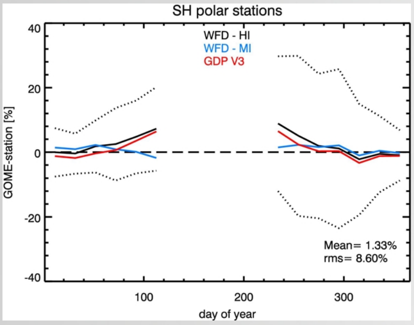


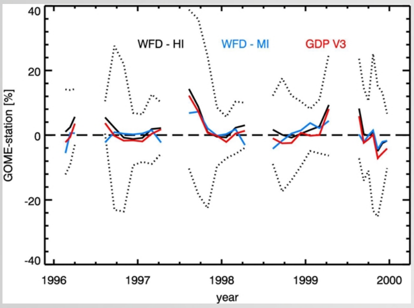
WF-DOAS

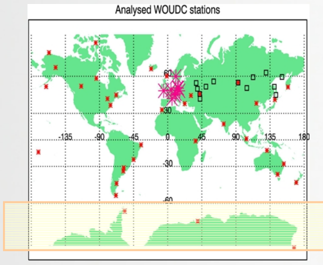


GDP V3

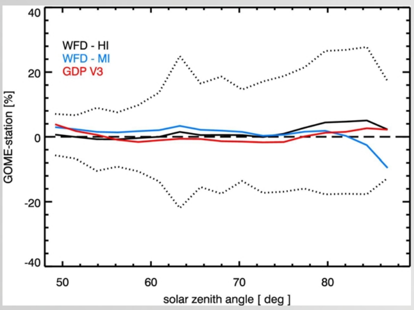
SH polar stations, 60°S – 90°S: Summary

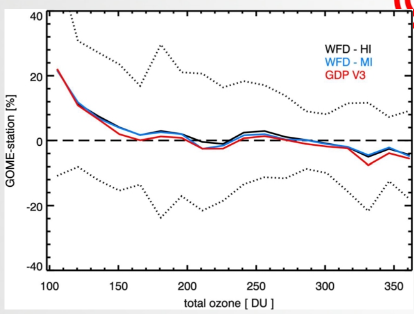


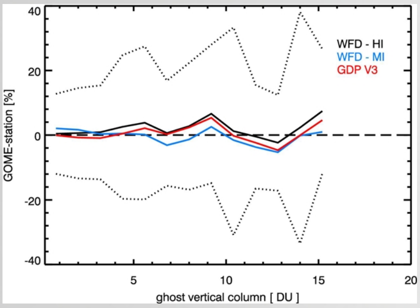




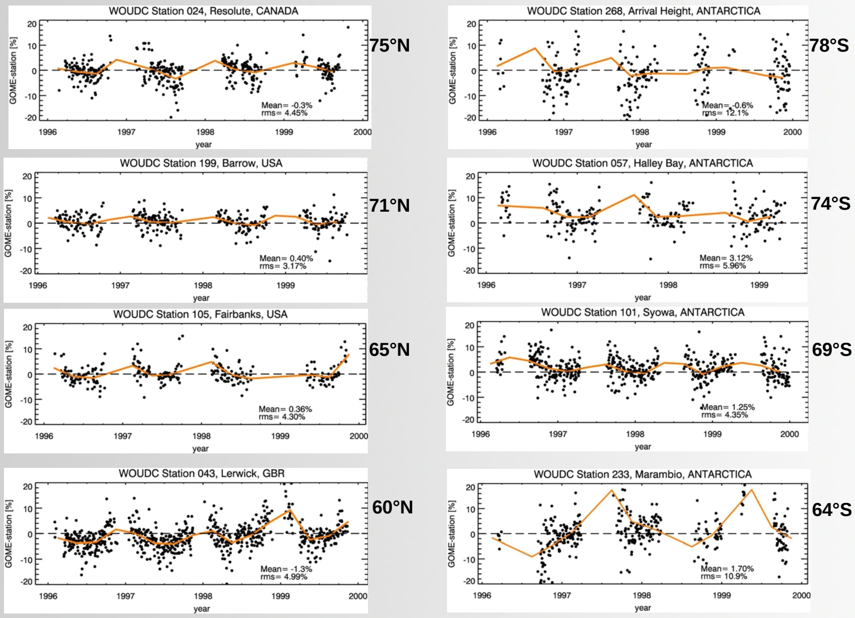
SH polar stations, 60°S – 90°S: Summary







Overview polar stations



TOMS3S-F campaign

Table 4: Overview of results of the spectrophotometric TO_3 measurements of TOMS3-F (Total Ozone Measurements by Satellites, Sondes and Spectrometers at the Fairbanks field campaign), compare text.

Measurement Daily Average	Percent Difference from D83 (AD Direct Sun)	Comments
D63 UAF instrument (AD Direct Sun)	-1.3 +/- 2.0	Near-Simultaneous measurements show a calibration offset of almost -3% at 300 DU (Standard Definition of Calibration Difference)
D63 UAF instrument (CD Direct Sun, 5<μ<2.4)	+3.5 +/-1.3	As CD observations are made mostly at lower sun, these averages are not on the same time periods as the other measurements. The values are both corrected for historic AD-CD difference and actual ozone weighted stratospheric temperature
Brewer B7	+3.1 +/- 1.6	Single Pass Brewer (MK II)
Brewer B85	+3.3 +/- 1.2	Double Pass Brewer (Mk III)
Brewer B171	+3.2 +/- 1.4	NASA Double Pass Brewer (Mk III) with internal scattered light determined
ECC Sonde (SBUV)	+3.8 +/- 5.4	SBUV refers to the method used to account for the unmeasured ozone above balloon burst.
EPTOMS	+0.3 +/- 6.0	EPTOMS has had instrument mechanical problems – the values published in spring 2002 were used for this comparison

Staehelin et al. 2003

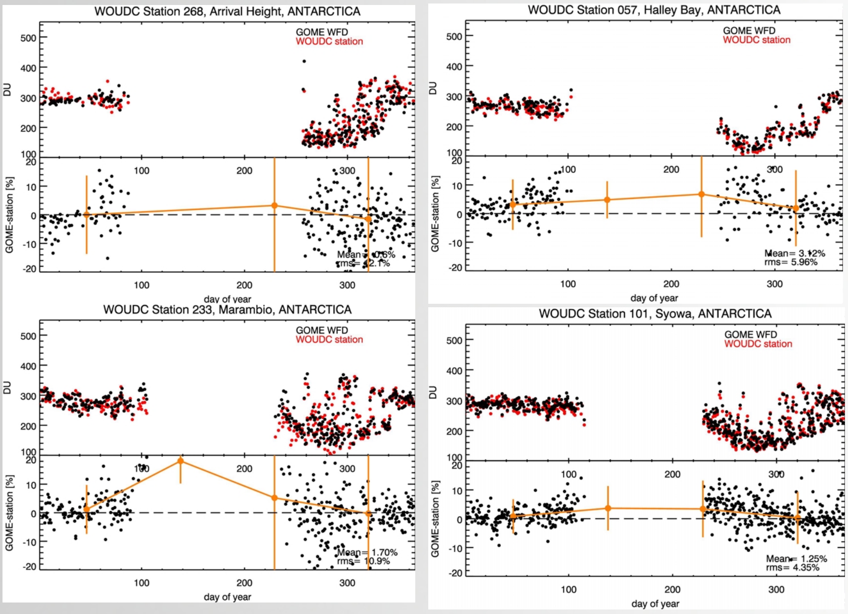
Fairbanks Dobson

EP-TOMS

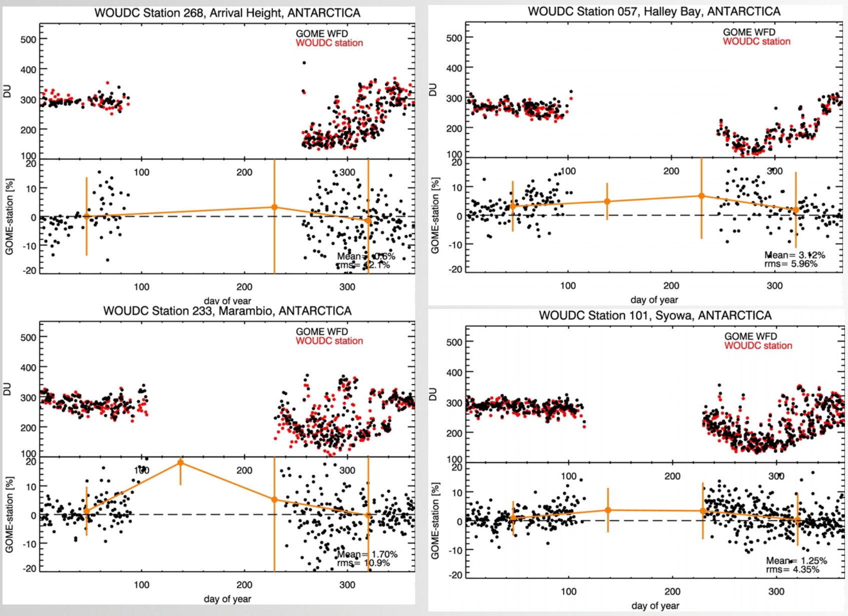
Relative to D83 Dobson travel standard

March/April 2001, high-latitude (64.8°N): Brewer/Sonde +3 to +4% higher than Dobson

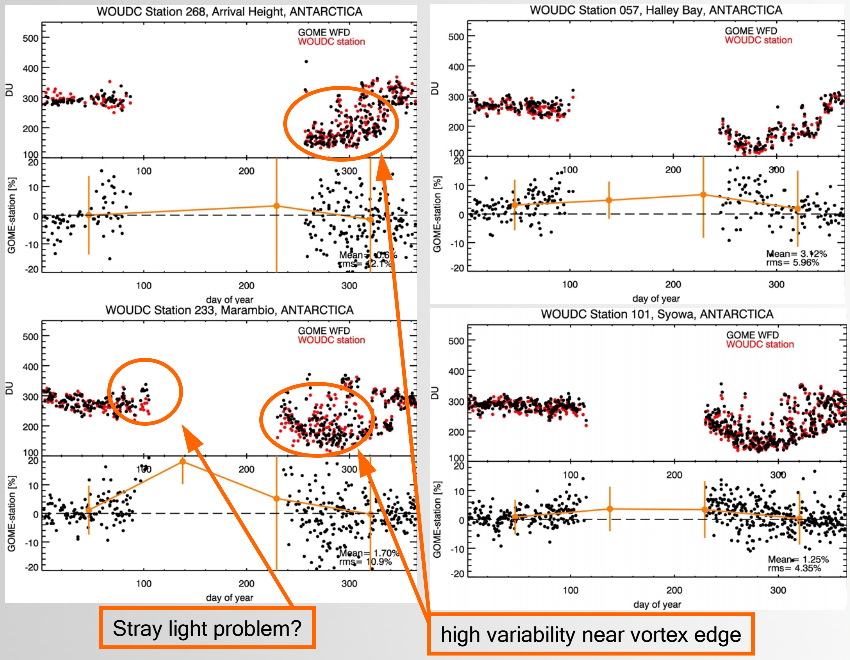
Ozone hole observations



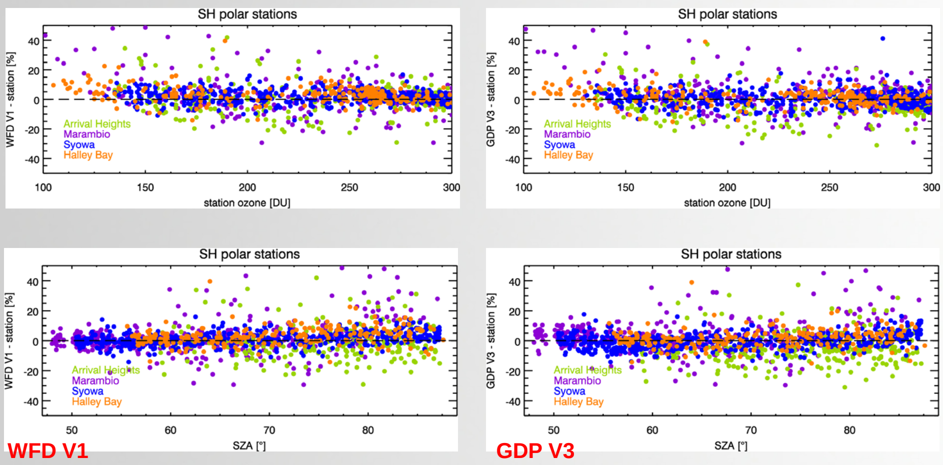
Ozone hole observations



Ozone hole observations



Ozone hole observations



Summary: Polar stations

- WFD V1 shows seasonal cycle of ±1% at Barrow, Alaska (well away from polar vortex)
- Observation of maxima in late fall/late winter (close to polar night) of up to 5% in both hemispheres
- This is consistent with a bias of about 3-5% between Brewer/integrated sondes and Dobson AD pair standard during TOMS3S-F campaign in Fairbanks (March/April 2001)
- Larger deviations can be observed near the polar vortex edge when the ozone field is inhomogenuos (Marimbo, Arrival Heights)
- Overall GDP V3 and WF DOAS rather similar

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  - → Tropics
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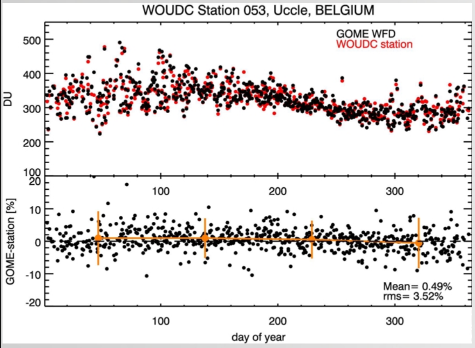
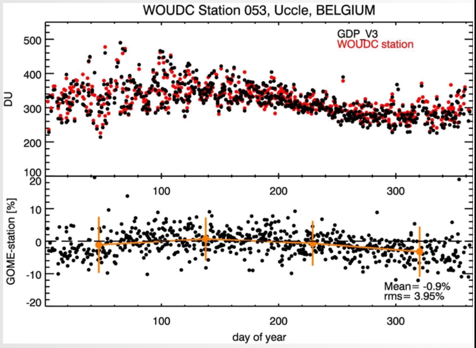
Mid-latitudes, 25°N – 60°N: 17 stations

Example: Uccle /Brussels, BELGIUM, 50.80°N, 4.35°E

Comparison with WFDOAS | **Comparison with GDP V3**

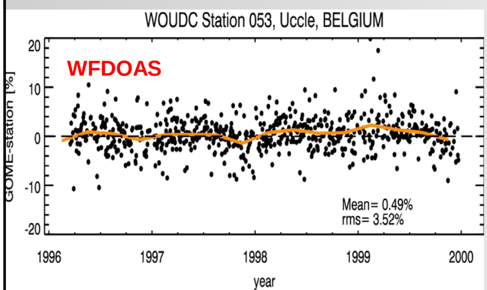


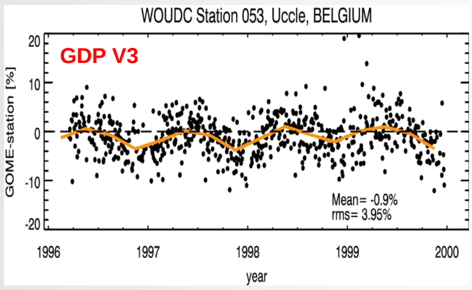


➪ very little seasonal cycle in WF-DOAS

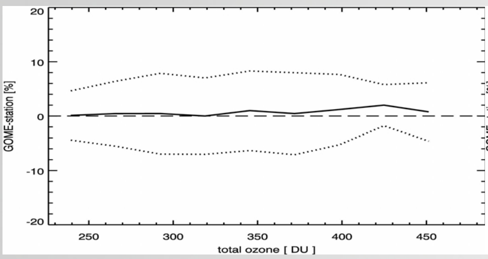
➪ lower scatter of WF-DOAS

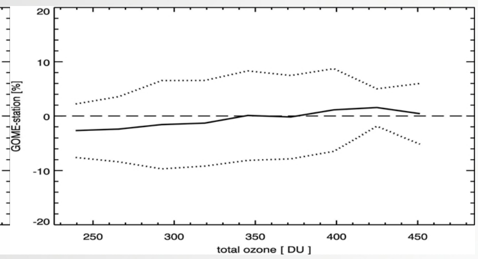
Mid latitude: Uccle, Belgium





Total ozone dependence





Mid latitude: Uccle, Belgium

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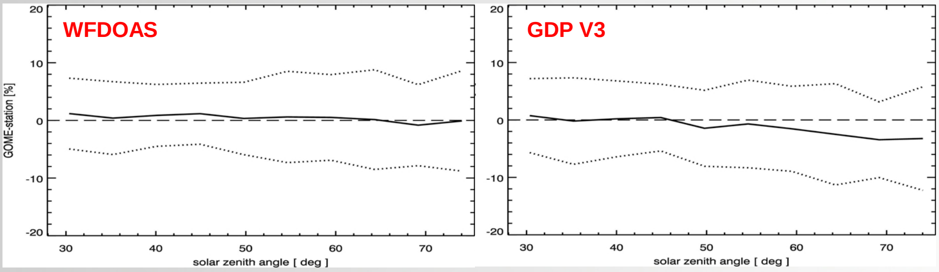
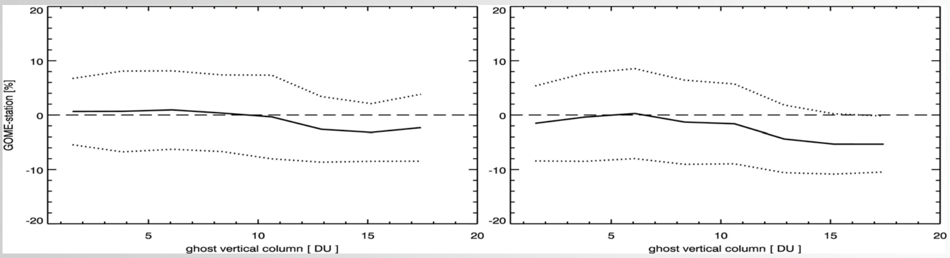
Solar zenith angle dependence



Dependence on Ghost vertical column



European stations

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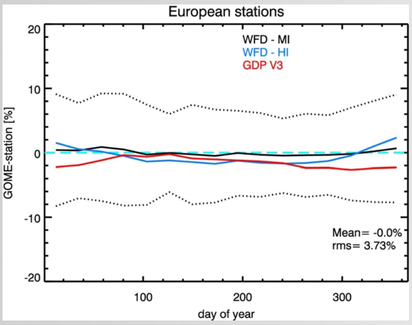
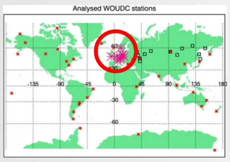
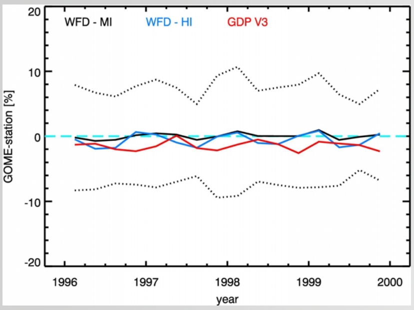
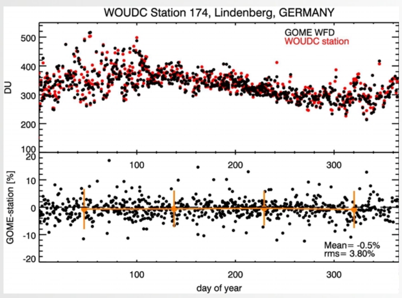
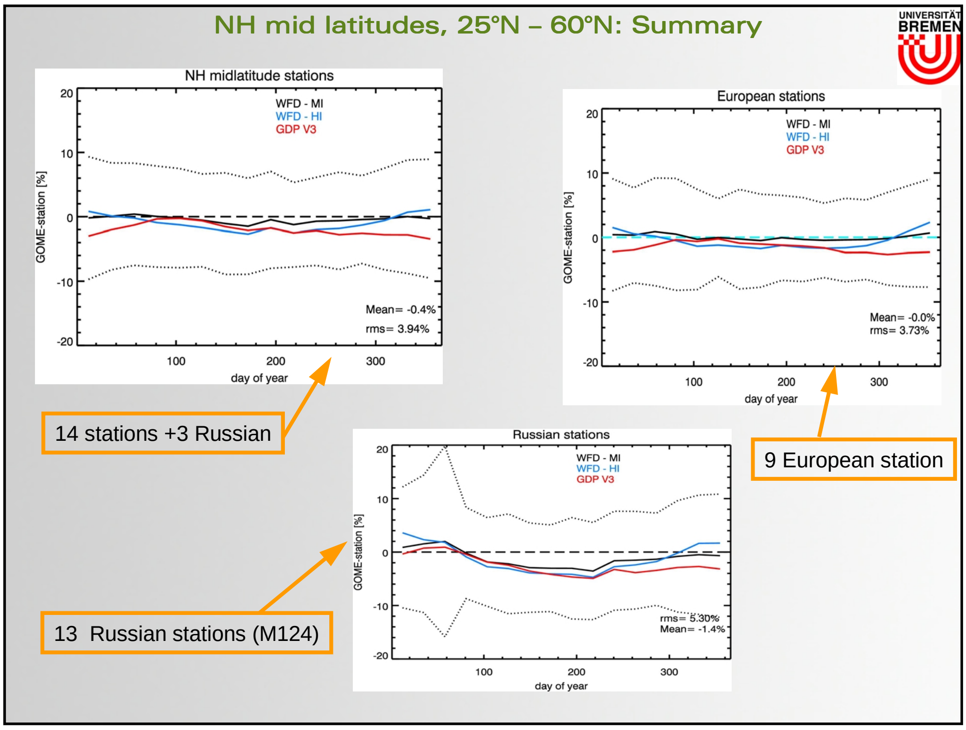




Arosa
Camborne
Heute Province,
Potsdam
Uccle
Hradec Kralove
Hohenpeiss,
Oslo
Lindenberg






NH mid latitudes, 25°N – 60°N: Summary
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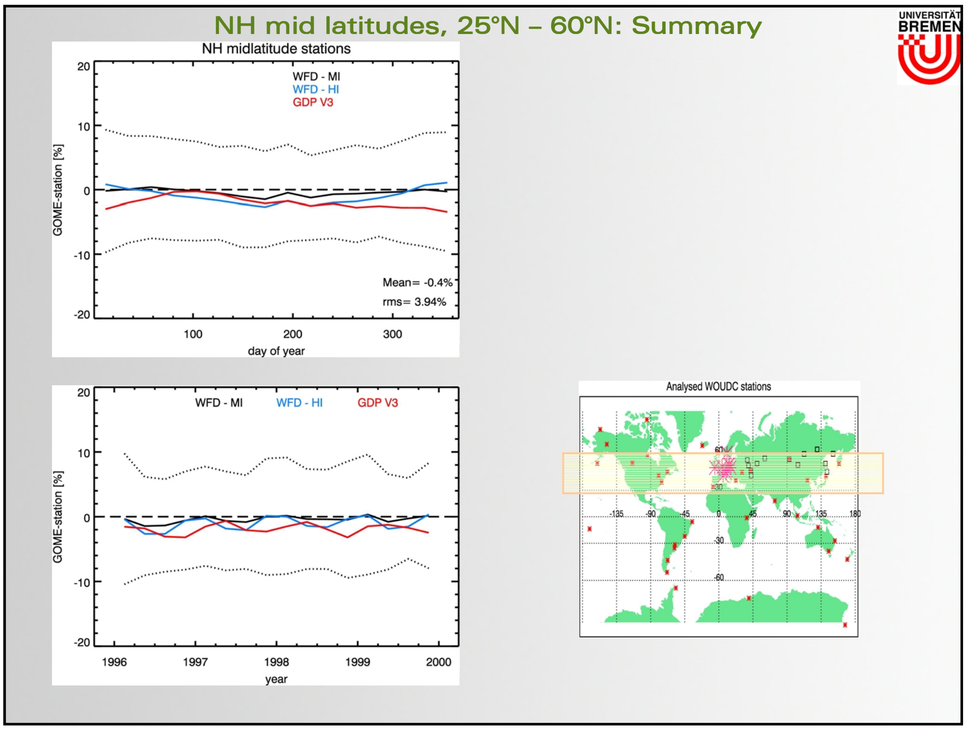
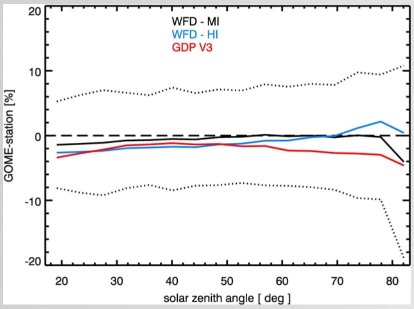
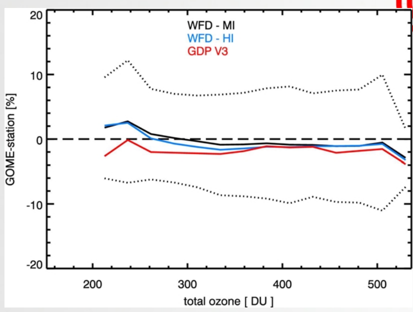
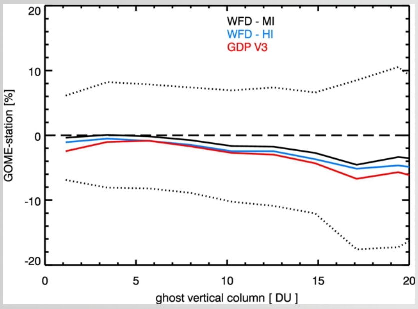
NH midlatitude stations
WFD - MI
WFD - HI
GDP V3
Mean= -0.4%
rms= 3.94%
GOME-station [%]
day of year
14 stations +3 Russian
European stations
Mean= -0.0%
rms= 3.73%
9 European station
Russian stations
rms= 5.30%
Mean= -1.4%
13 Russian stations (M124)


NH mid latitudes, 25°N – 60°N: Summary
UNIVERSITÄT BREMEN
NH midlatitude stations
WFD - MI
WFD - HI
GDP V3
Mean= -0.4%
rms= 3.94%
GOME-station [%]
day of year
year
Analysed WOUDC stations

NH mid-latitudes, 25°N – 60°N: Summary





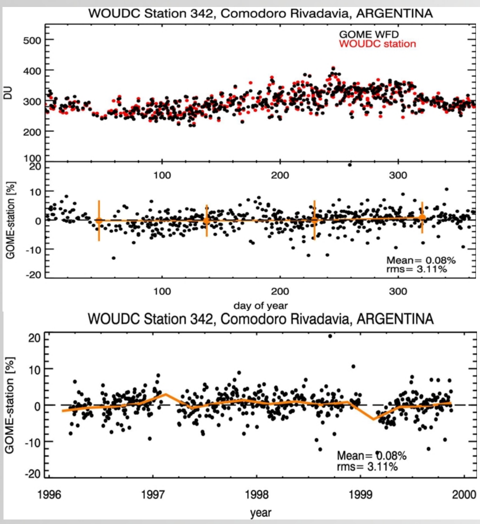


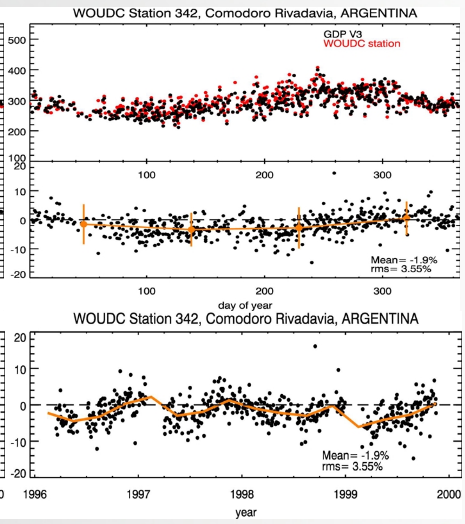
SH mid-latitudes, 25°S – 60°S: 7 stations

Example: Comodoro Rivadavia, ARGENTINA, 45.8°S, 67.5°W

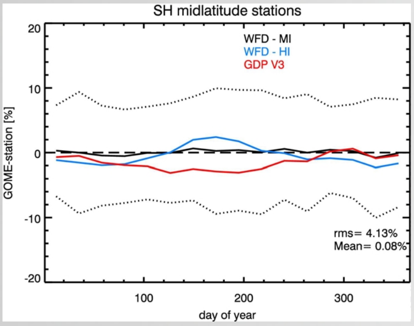
Comparison with WFDOAS

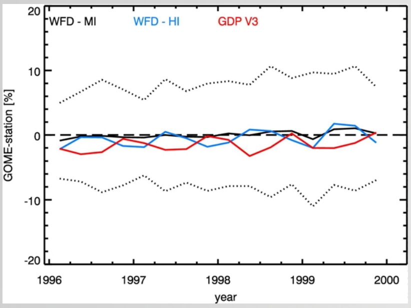
Comparison with GDP V3

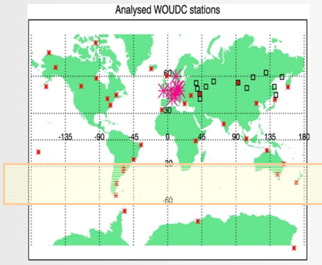




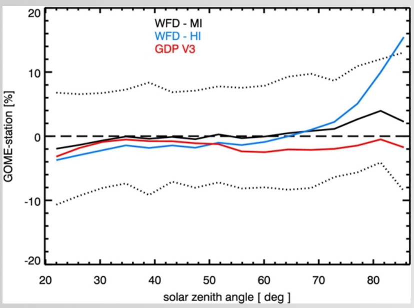
SH mid latitudes, 30°S – 60°S: Summary

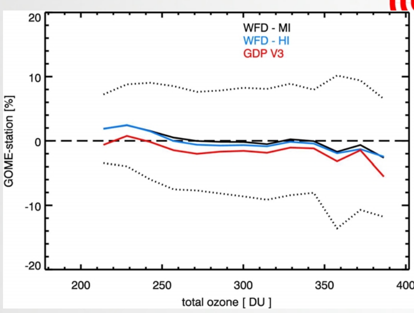


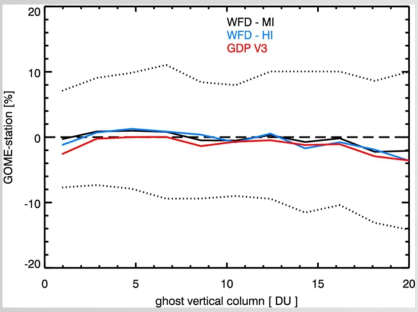




SH mid latitudes, 30°S – 60°S: Summary







Summary: mid latitude stations

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- Weak seasonal cycle with mid-latitude stations (±0.5%, again maxima in fall/winter)
- no significant dependence on SZA and total ozone
- Underestimation of up to 4% under cloudy condition

Tropics, 25°S – 25°N: 7 stations

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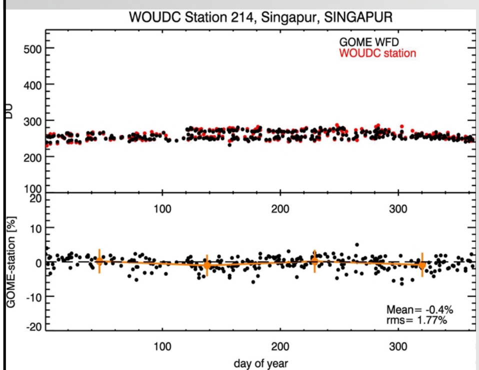
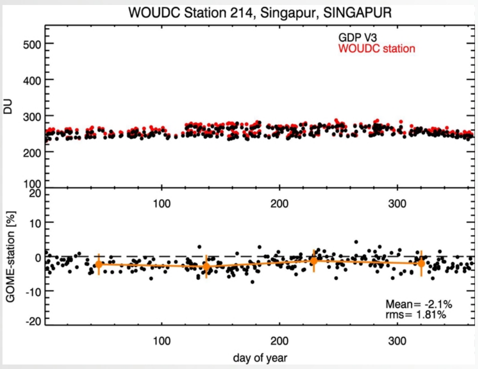
Example: Singapore, SINGAPORE, 1.3°N, 103.9°E

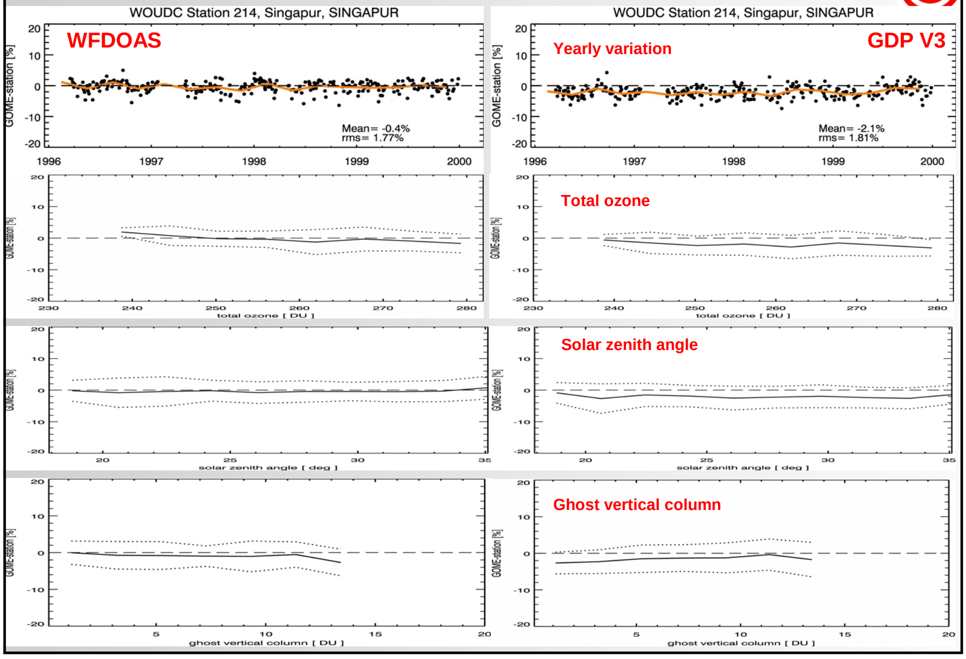
Comparison with WFDOAS



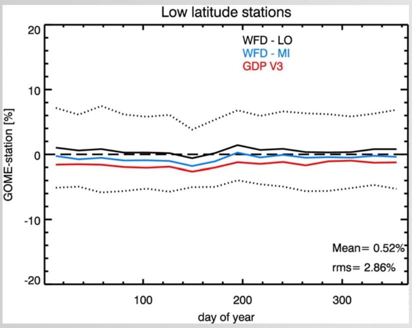
Comparison with GDP V3

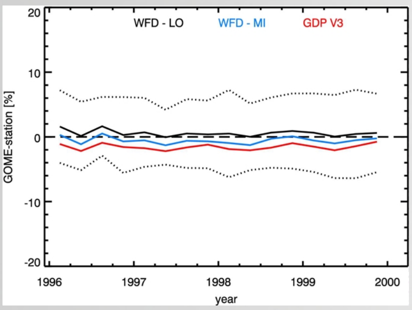


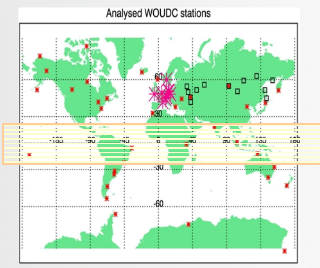
Tropics: Singapore



Tropics, 25°S – 25°N: Summary





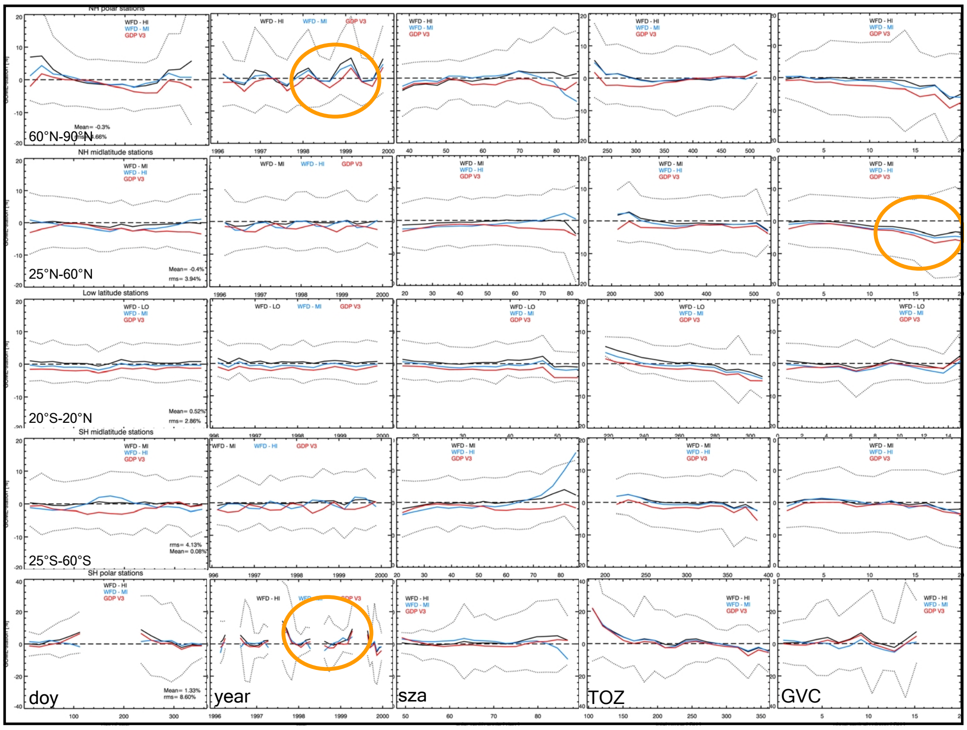


Summary: tropics

- WFD V1 very similar to GDP V3, apart from a bias that is now close to 0% with respect to Dobson (GDP V3 bias: -2%)

Topics

- Introduction (data sources)
- Brewer and Dobson intercomparison
- Long-term validation 1995-2003
- Pole-to-Pole validation (WOUDC)
  - → Polar stations
  - → Mid-latitudes
  - → Tropics
- **Conclusion**



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Conclusion

- At mid- and low latitudes very good agreement with Brewer and Dobson (WOUDC), seasonal cycle signature below ±0.5%, and mean bias below 0.5%

- Stronger seasonal cycle with direct sun Dobson at mid-latitudes
  - ➔ Fixed ozone temperature in standard ground based retrieval
  - ➔ Stray light in Dobson in fall/winter (μ>3.5) / lower SNR in GOME

- At high latitudes in late fall/winter (near polar night period) differences with respect to Dobson can be larger up to 5% (straylight in Dobson/low GOME SNR)

- Significant improvement in the scatter of differences to ground based data as compared to GDP V3

⇨ Combination of changes lead to significant improvement over GDP V3
  - ➔ Ring ozone-filling in
  - ➔ effective albedo & height
  - ➔ Improved wavelength calibration (Fraunhofer fit/cross-section shifts)