# Impact of $O_3$ cross-sections on satellite total $O_3$ retrievals using GDOAS/GODFIT.

**Christophe Lerot and Michel Van Roozendael**

*Belgian Institute for Space Aeronomy (BIRA-IASB)*

*Meeting on $O_3$ cross-sections*
*23-25 March 2010 – WMO (Geneva)*

aeronomie.be

christl@oma.be

# Available cross-section data sets

- **Bass and Paur (BP)**: only in Huggins Bands, resolution: ~ 0.1nm
- **Brion, Daumont and Malicet (DBM)**: high resolution (~0.015 nm)
- **Burrows et al. (GOME FM)**: GOME resolution (0.15 nm)
- **Bogumil et al. (SCIAMACHY FM)**: SCIAMACHY resolution (0.22 nm) (→ not directly applicable to GOME)
- **Gür et al. (GOME-2 FM)**: GOME-2 resolution (0.24 nm) (→ not directly applicable to GOME and SCIAMACHY)

christl@oma.be

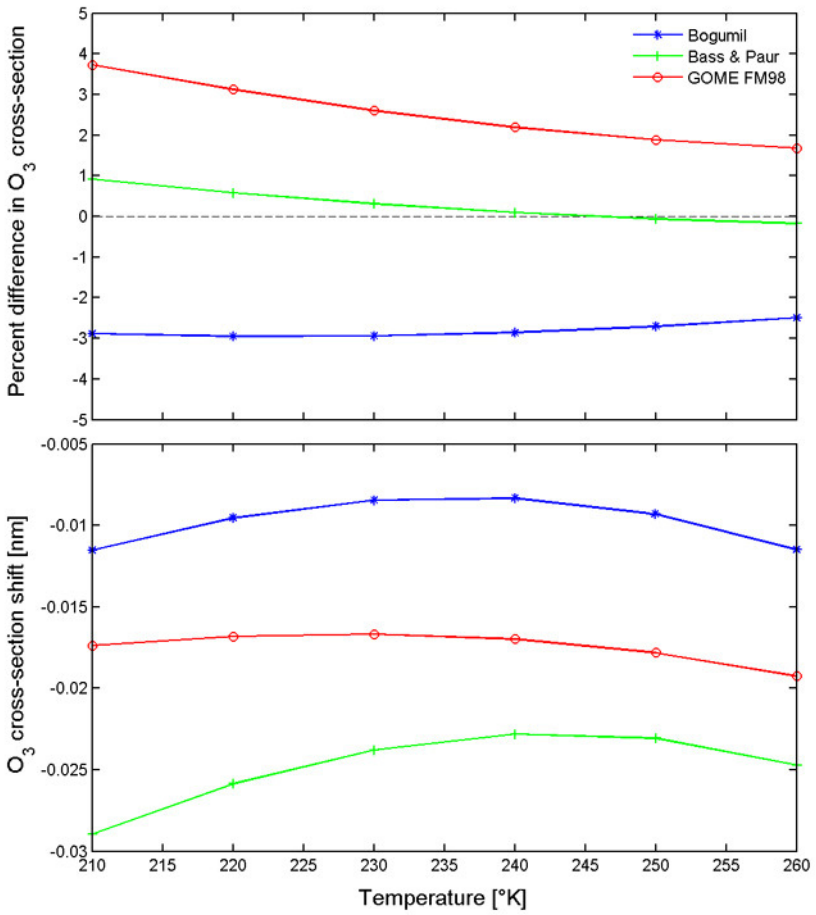
# Total $O_3$ retrievals

- Spectral region of interest: Huggins bands **(325 nm – 335 nm)**.
- Retrievals based on the **Differential Optical Absorption Spectroscopy** (DOAS) technique: only the **differential structures** are important.
- The criteria to judge of the quality of a data set are:
  - Absolute accuracy of « differential structures »,
  - Accurate wavelength registration,
  - Characterisation of the temperature dependence,
  - Level of noise.

➔ **Focus on the BP, DBM and GFM** data sets applied to GOME, SCIAMACHY and GOME-2 instruments.

christl@oma.be

# Direct comparison in the 320-340 nm interval




- Reference: DBM
- SCIAMACHY resolution
- Quadratic parameterisation (T°)
- Simultaneous fit of two parameters: shift and scale.
- Mean amplitude of differential cross-sections:
  - -BP and DBM in good agreement.
  - -Differences ranging from 2 to 3% between GFM and DBM.
- Important shift applied to GFM and BP to match DBM.

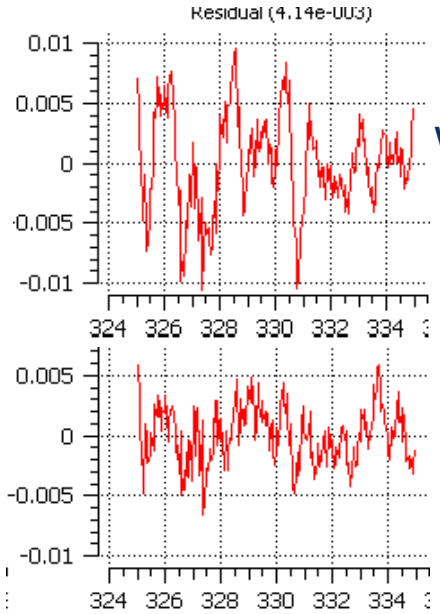
christl@oma.be

# Wavelength registration

**Ozone theme meeting 2009**:

- The fit residuals may indicate possible issues in the wavelength registration of cross-sections.
- BP and GFM need to be shifted to improve the fit quality.
- DBM shows good wavelength registration.
- Results consistent with Weber et al.

*Fit residuals - BP*




w/o shift

shifted

*Pre-shift to apply to reference data sets*

| | |
|---|---|
| DBM | --- |
| Bass and Paur | +0.023 nm |
| GOME FM | +0.017 nm |

aeronomie.be

christl@oma.be

# Total $O_3$ retrieval algorithms used at BIRA

**GDOAS:**

- Total $O_3$ retrieved in **2 steps**: Slant column retrieval followed by an air mass factor to convert it into a total column.
- **Approximation**: Wavelength dependency of the photon path length is neglected. Not valid anymore at very high SZA (>80°)
- Very fast.
- Algorithm used for ESA operational algorithms **GDP 4** and **SGP 3** (GOME, SCIAMACHY, GOME-2).

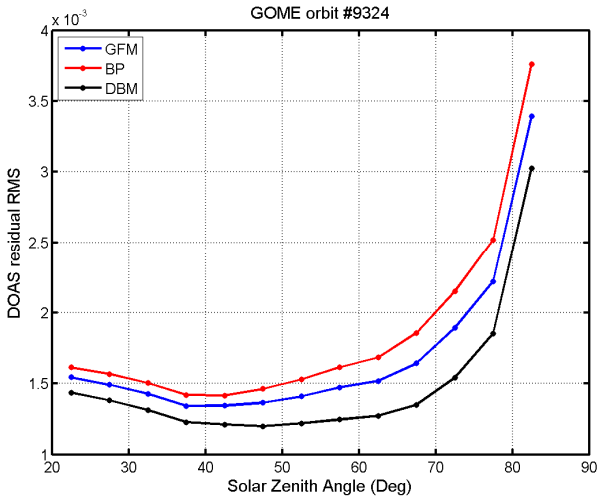
**GODFIT:**

- **Direct fitting** of the $O_3$ vertical column.
- Radiances simulated at each wavelength of the fitting window and compared to measured radiances.
- **Closer to the Physics**.
- More time-consuming.
- Algorithm under implementation for next GOME Data processor **GDP 5**.

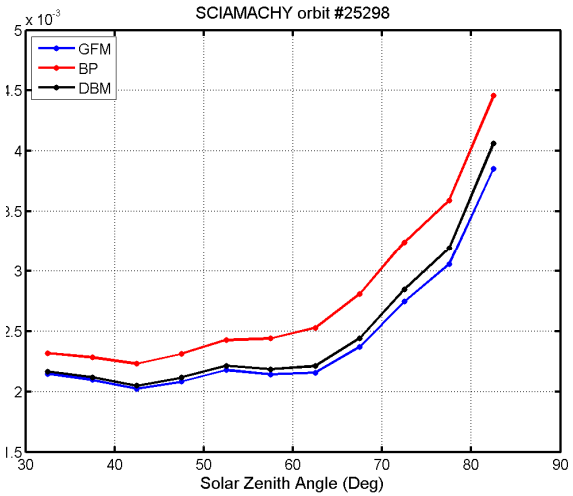
christl@oma.be

# Impact on the DOAS fit quality

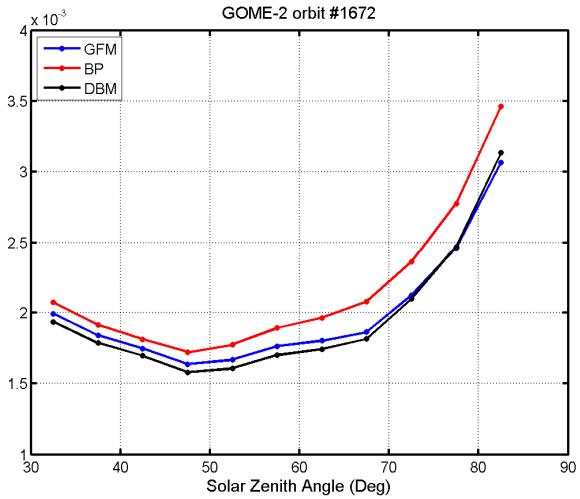
***GOME***




***SCIAMACHY***




***GOME-2***

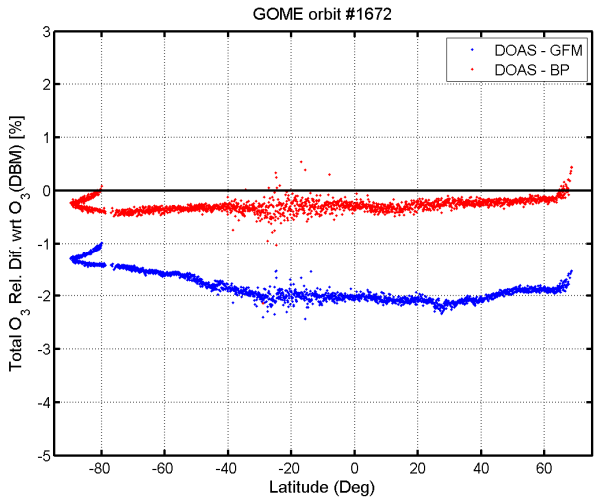



- Bass and Paur data systematically lead to poorer fits.
- DBM gives the smallest residuals for GOME retrievals.
- GOME FM and DBM data perform similarly for SCIAMACHY and GOME-2.

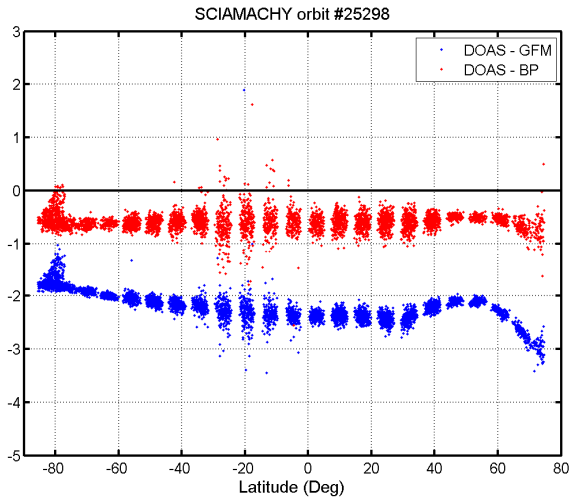
christl@oma.be

# $O_3$ relative differences w.r.t. DBM

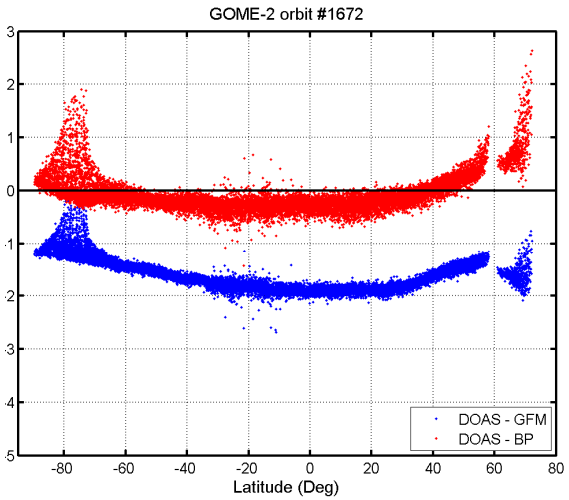
## GOME




## SCIAMACHY




## GOME-2




- The $O_3$ columns retrieved with DBM and BP are in good agreement (±1%).
- The $O_3$ columns retrieved with GOME FM are 2% lower.

christl@oma.be

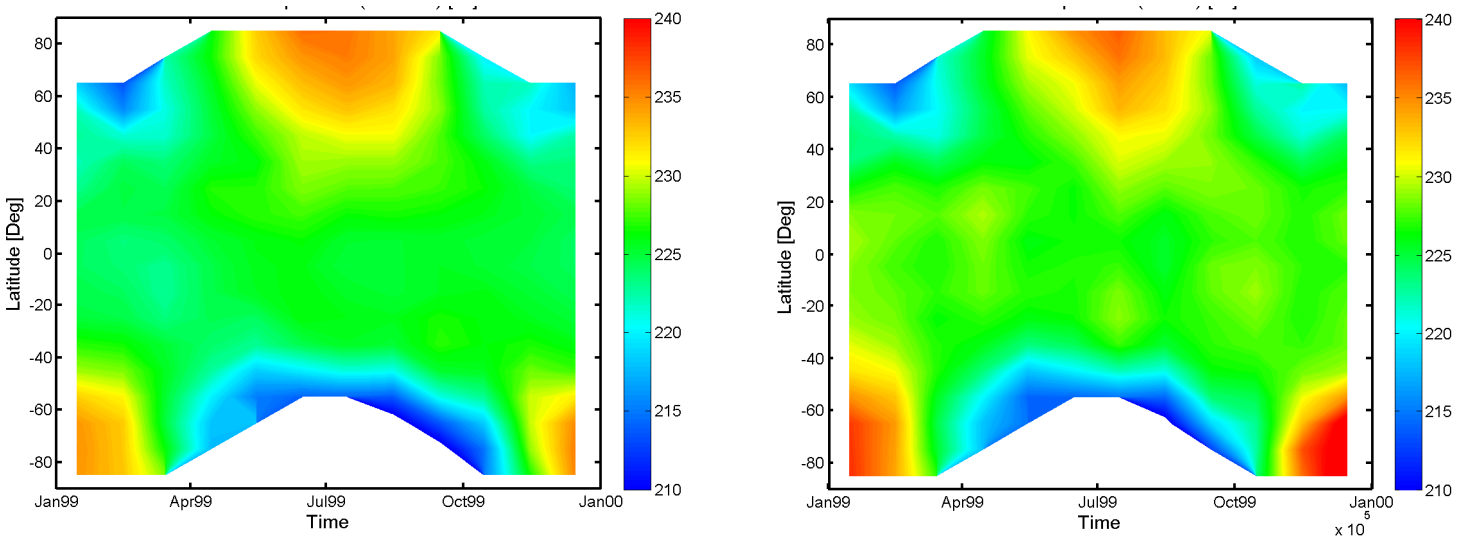
# $O_3$ relative differences w.r.t. DBM

**Effective temperature**: *Mean atmospheric temperature weighted by the $O_3$ concentration profile.*

➔ GDOAS: retrieved by fitting the $O_3$ cross-sections at 2 temperatures.

➔ GODFIT: **T-shift procedure**: The a-priori atmospheric T° profile is adjusted to match at best the observed $O_3$ absorption. The effective temperature is calculated a-posteriori.

*ECMWF* *T-shift*



christl@oma.be

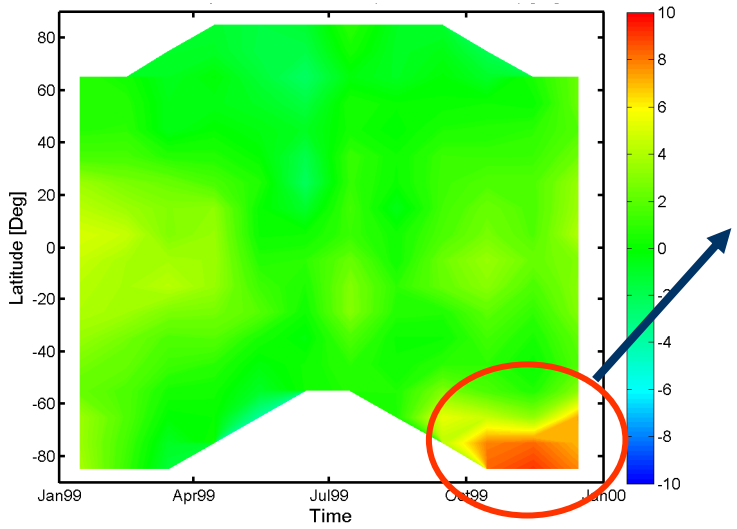
# $O_3$ relative differences w.r.t. DBM

**Effective temperature**: *Mean atmospheric temperature weighted by the $O_3$ concentration profile.*

➔ GDOAS: retrieved by fitting the $O_3$ cross-sections at 2 temperatures.

➔ GODFIT: **T-shift procedure**: The a-priori atmospheric T° profile is adjusted to match at best the observed $O_3$ absorption. The effective temperature is calculated a-posteriori.

*Differences*



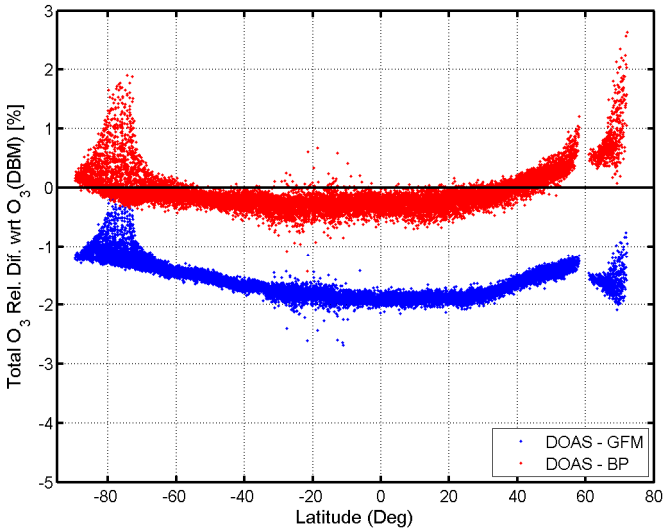

The ECMWF ERA-40 data set is known to underestimate the T° in $O_3$ hole conditions.

christl@oma.be

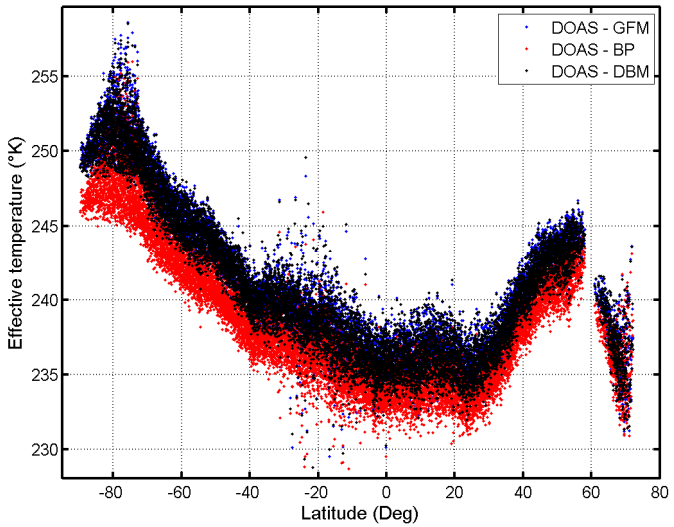
# $O_3$ relative differences w.r.t. DBM

## GOME-2

### *$O_3$ Differences*




### *Effective T°*

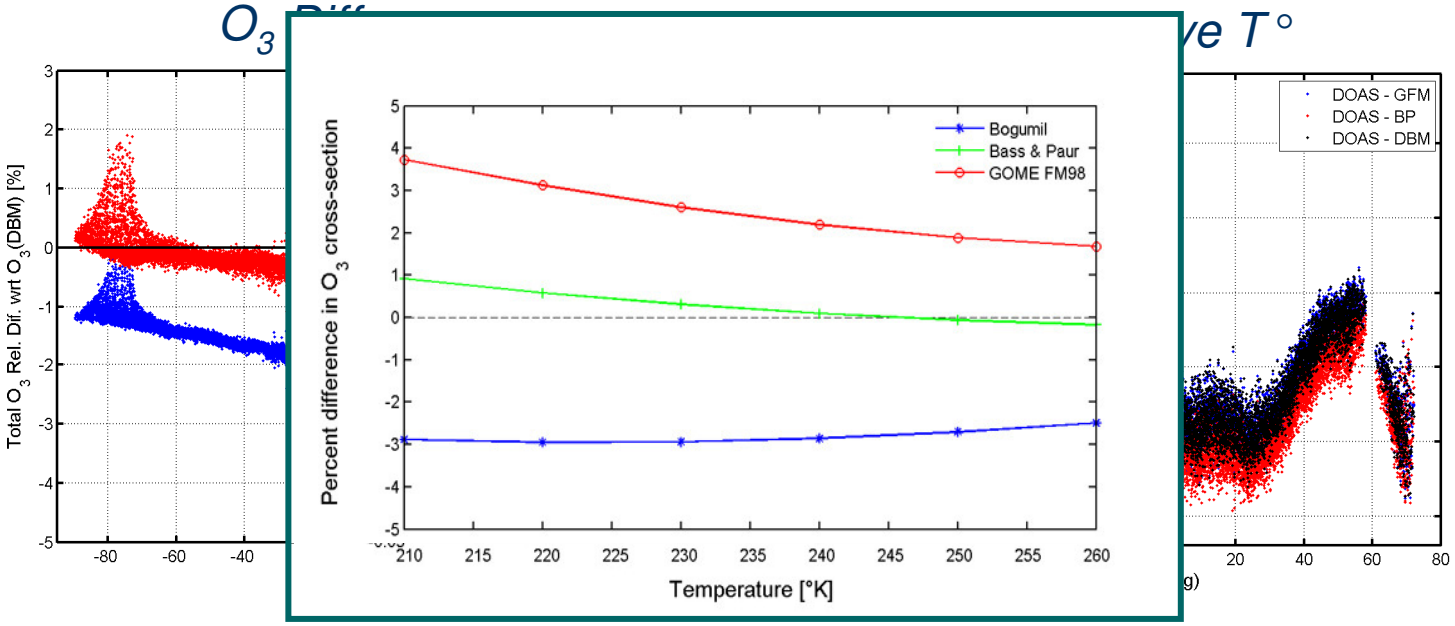



aeronomie.be

christl@oma.be

# $O_3$ relative differences wrt Brion et al.

GOME-2




↳ Changing the reference $O_3$ cross-section leads to $O_3$ differences depending on the effective temperature.

christl@oma.be

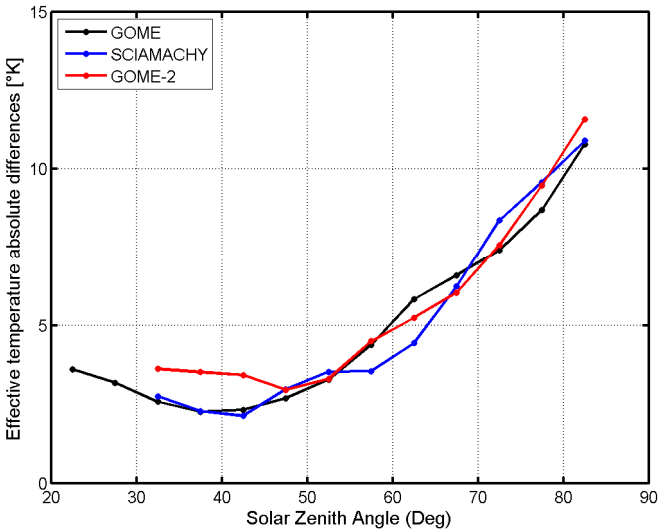
# DOAS vs Direct Fitting

DOAS approximation no longer valid at large SZA!!

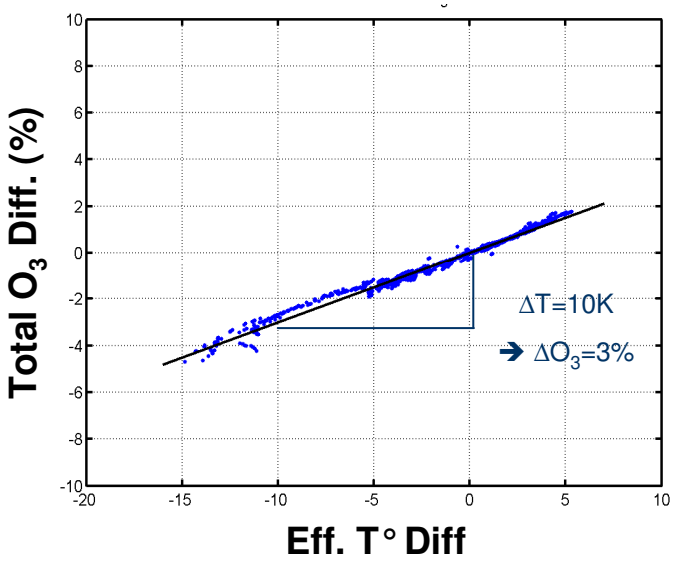
↳ Impact on retrieved effective T° and $O_3$ ??

***DOAS - Direct fitting***

Effective temperature Diff.




Total $O_3$ column Diff. vs Eff. T° Diff.




↳ The DOAS technique leads to effective temperatures and total columns too high, especially at high SZA.

aeronomie.be

christl@oma.be

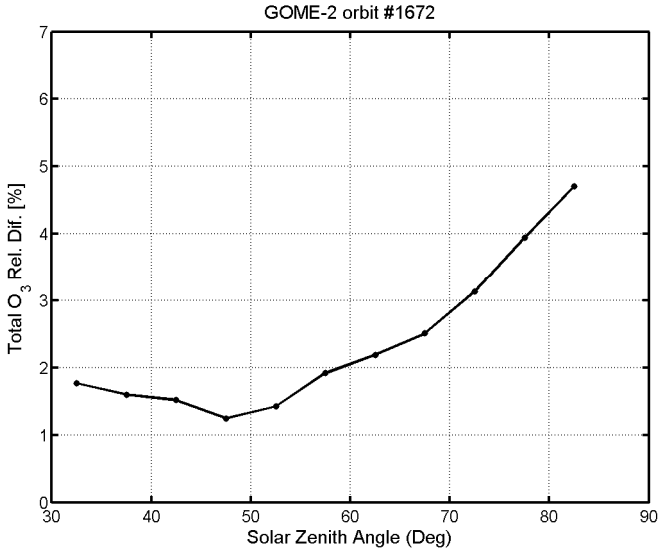
# DOAS vs Direct Fitting

DOAS approximation no longer valid at large SZA!!

↳ Impact on retrieved effective T° and $O_3$ ??

***DOAS - Direct fitting***

Total $O_3$ column Diff. for GOME-2




↳ The DOAS technique leads to effective temperatures and total columns too high, especially at high SZA.

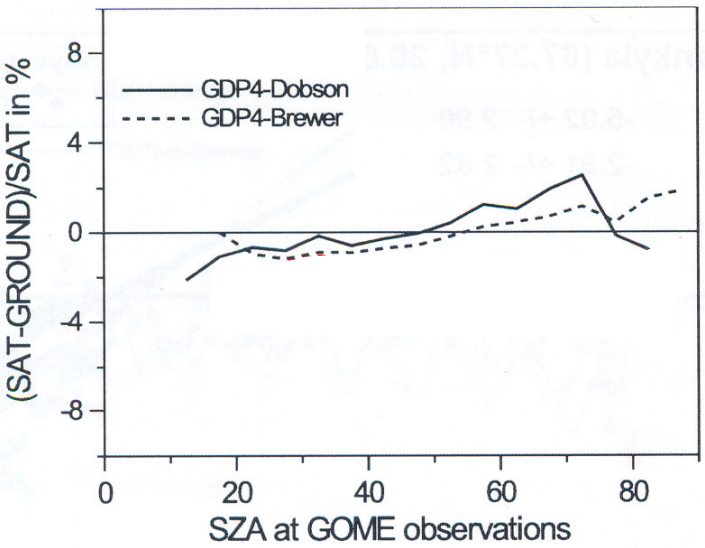
christl@oma.be

# DOAS vs Direct Fitting

**GDP 4:** - Based on GDOAS

- Uses the **GOME FM** data as a baseline
- Validation (Balis et al, 2007) shows global good agreement with ground-based data, but a significant SZA dependence in the differences.

*SZA dependency of GDP4-GB differences*

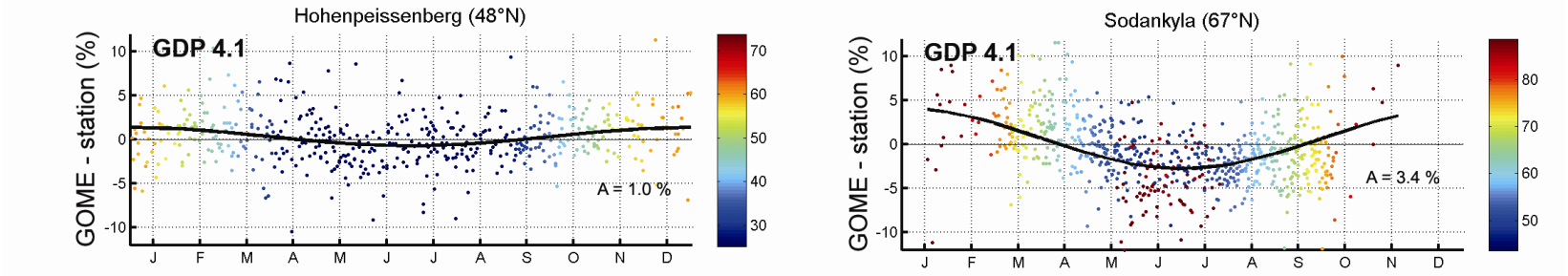



- Global compensation between overestimation effect due to bias in Effective T° (DOAS limitation) and underestimation effect due to bias in GFM cross-sections.
- At low SZA: Underestimation effect dominates.
- At large SZA: Overestimation effect dominates.

christl@oma.be

# DOAS vs Direct Fitting

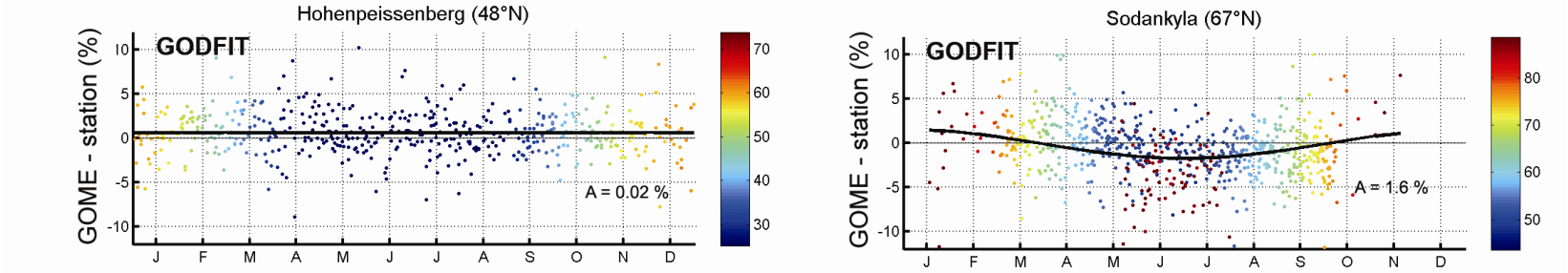
Subsisting seasonalities in GDP4!!




**GODFIT**: Meaningful effective temperature and $O_3$, at any SZA.

➔ No more compensation effect: Using GFM leads to $O_3$ columns too low.

➔ The **DBM** data is our **baseline** for our direct fitting retrievals.




*Lerot et al., IJRS, 2010*

aeronomie.be

christl@oma.be

# Summary

- Focus on the **Huggins bands** for 3 cross-section data sets applicable to satellite total $O_3$ retrievals: Bass and Paur, DBM and Burrows et al. (GOME FM)
- Pre-shifts have to be applied to GFM and BP wavelength grids. The wavelength registration of DBM is the most accurate.
- The fit quality using BP is poorer than with DBM or GFM.
- Mean amplitude of differential cross-sections (320-340 nm):
  - DBM and BP lead to $O_3$ columns in good agreement.
  - GFM leads to lower $O_3$ columns (+ T° dependent bias).
- Direct-fitting retrievals using DBM are closer to "ground-truth" data sets (Brewer/Dobson)
- Changing the $O_3$ cross-sections in an algorithm requires attention as there can be compensation of errors (e.g. DBM applied to GDOAS do **not** lead to better agreement with GB).