GOME-type Total Ozone Data Record

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Outline

- GOME-type Total Ozone Data Record
- Climate-Chemistry Models Evaluation
- GDP 5.0
- Outlook

Overview – GOME, SCIAMACHY, and GOME-2

- Passive remote sensing grating spectrometers
- Sun-synchronous and near-polar morning orbit at a height of ~790km

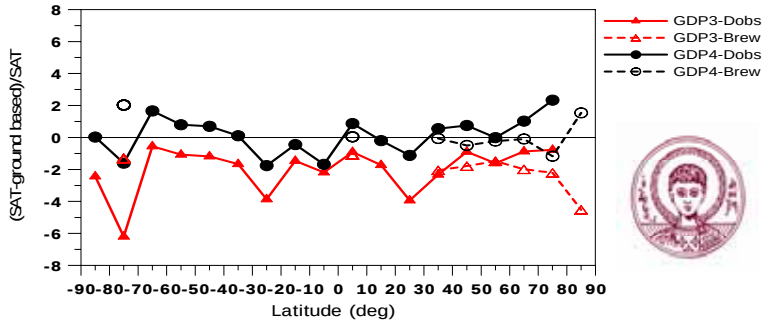
	GOME	SCIAMACHY	GOME-2
Satellite	ERS-2	ENVISAT	METOP-A
Data Availability	06/1995-07/2011	08/2002-present	01/2007-present
Spectral Coverage	240-790 nm	240-2380 nm	240-790 nm
Spectral Resolution	0.2 - 0.4 nm	0.2 – 1.5 nm	0.2 – 0.4 nm
Viewing Geometries	Nadir	Nadir, Limb, Occult.	Nadir
Ground Pixel Size	320 x 40 km^2	60 x 30 km^2	40 x 80 km^2
Swath Width	960 km	960 km	1920 km
Equator Crossing	10:30 a.m. LT	10:00 a.m. LT	09:30 a.m. LT
Global Coverage	3 days	6 days	Almost daily
Repeat Cycle	35 days	31 days	29 days

GOME-type Total Ozone – GDP 4.x Overview

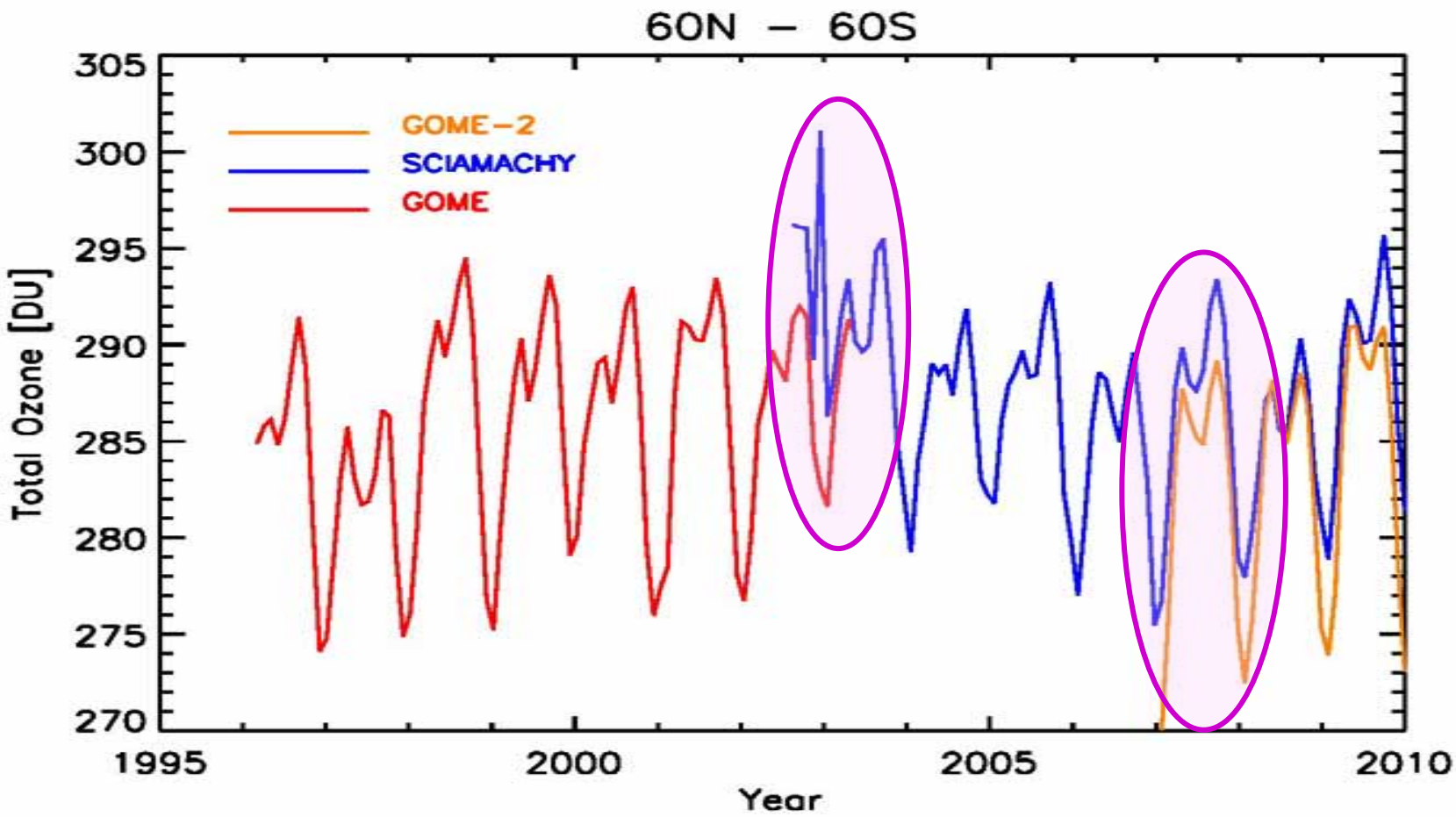
- Two steps GDOAS approach
  - DOAS fit for ozone slant column and effective temperature
  - Iterative AMF/VCD computation using a single wavelength

- Improved O_3 Retrieval
  - Molecular Ring correction (Van Roozendael et al., JGR 2006)
  - On-the-fly RTM simulations LIDORT v3.3 (Spurr, 2003)
  - Cloud correction using OCRA&ROCINN v2.0 (Loyola et al., TGRS 2007)
  - Adaption to SCIAMACHY (Lerot et al., AMT 2009)
  - Intra-cloud, sun-glint and scan angle corrections (Loyola et al., JGR 2011)

- Independent Geophysical Validation
  - D. Balis et al., JGR 2007
  - …
  - Antón et al., RSE 2011
  - Antón and Loyola, JGR 2011
  - Koukouli et al., AMTD 2012

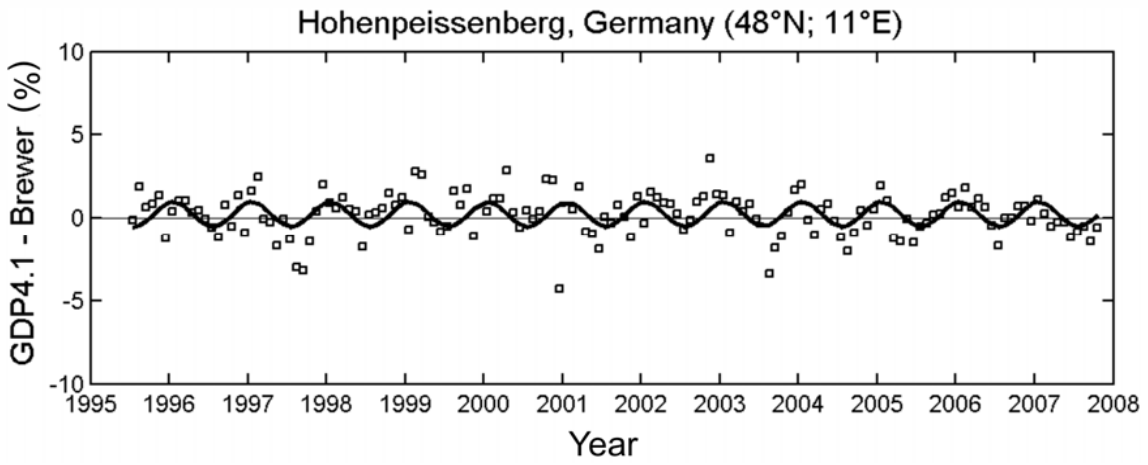


GOME-type Total Ozone – Satellite drifts



GOME-type Total Ozone – Merging Strategy

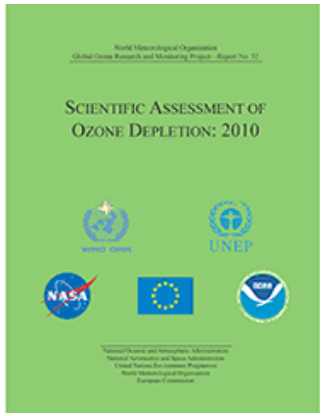
Inter-Satellite Calibration: Select one data set as reference (GOME) and correct others (SCIAMACHY and GOME-2) for spatial and temporal biases and drifts

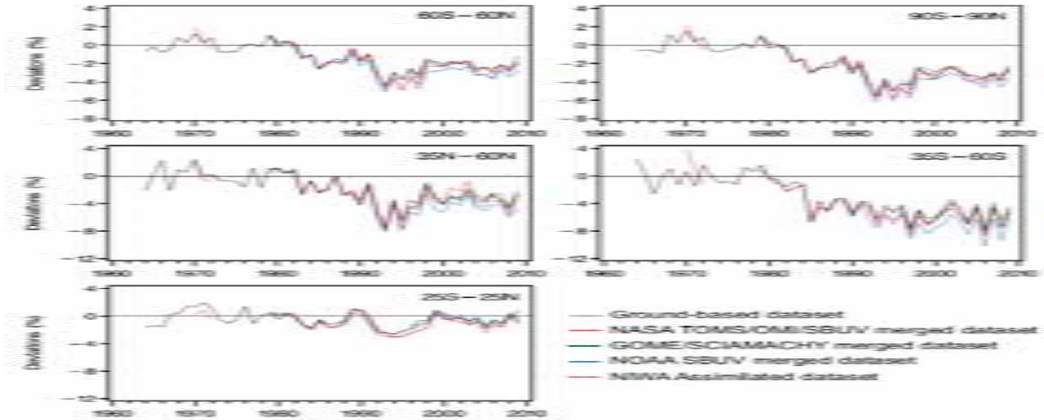


- Pros:
  - self-consistent and independent long-term dataset
  - ground-based data can be used for geophysical validation
  - merged product can be used for climate model evaluation
- Cons: possible drift on absolute accuracy

GOME-type Total Ozone – Merging Strategy (2)

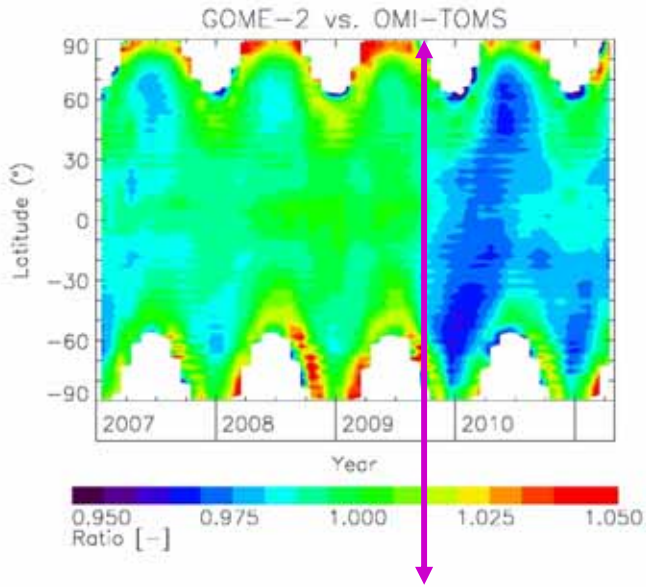
- Alternatives for correcting the spatial and temporal biases and drifts:
  - Polynomial adjustment:
    Loyola D., Coldewey-Egbers M., Dameris M., Garny H., Stenke A., Van Roozendael M., Lerot C., Balis D., Koukouli M., ***Global long-term monitoring of the ozone layer - a prerequisite for predictions***, International Journal of Remote Sensing, vol. 30, no. 15, pp. 4295-4318, 2009



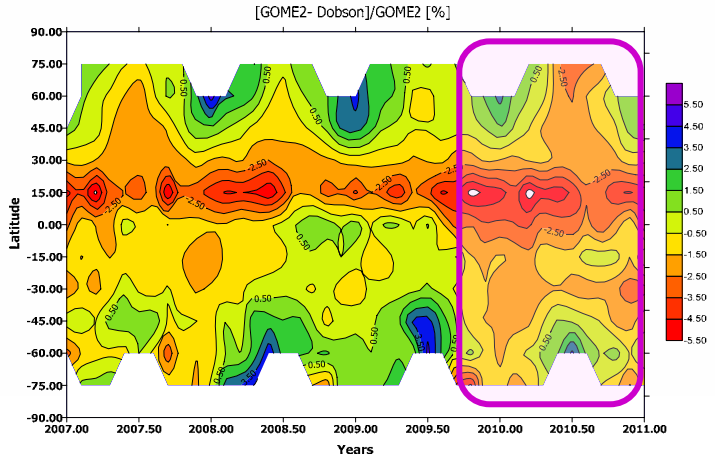


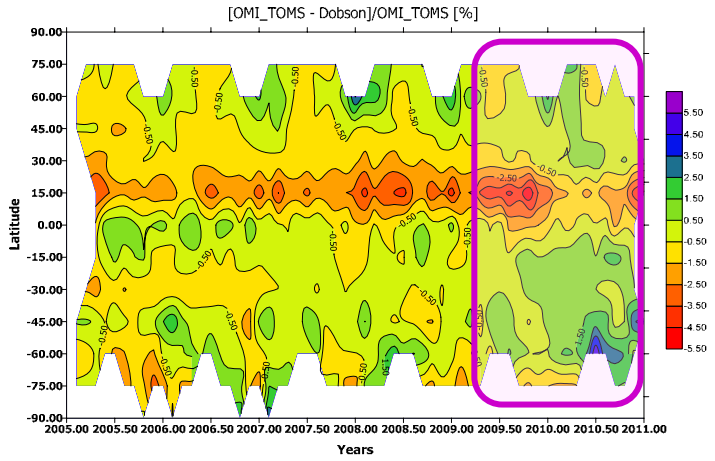
  - Artificial neural network adjustment:
    D. Loyola and M. Coldewey-Egbers, ***Multi-sensor data merging with stacked neural networks for the creation of satellite long-term climate data records***, EURASIP Journal on Advances in Signal Processing, in press, 2012

Total Ozone – GOME-2 and OMI issues in 2009-2011



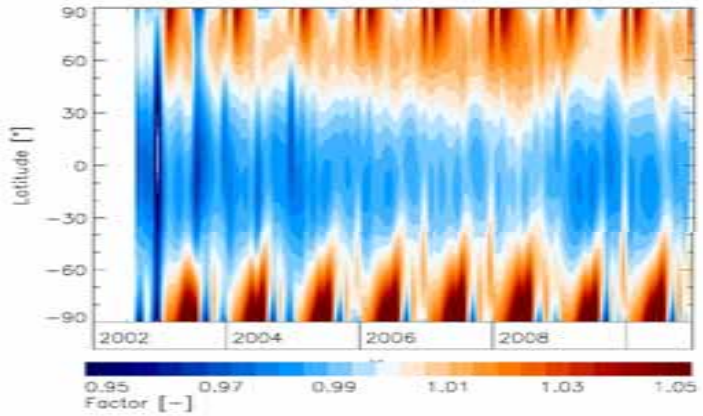
GOME-2 throughput tests



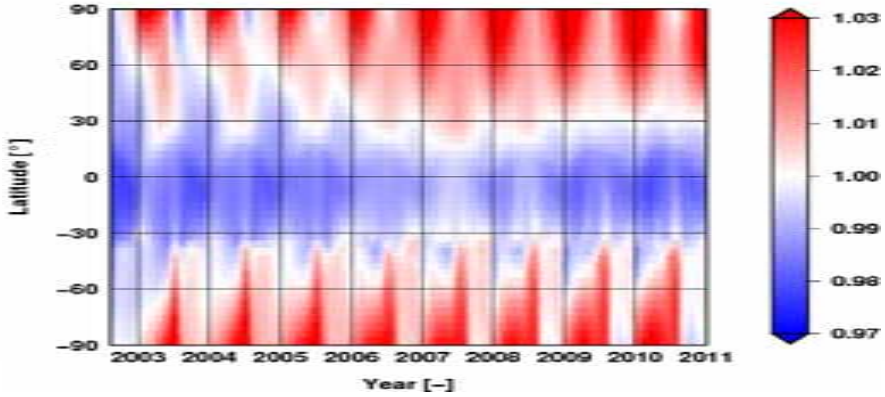


GOME-type Total Ozone – Adjustment Factors

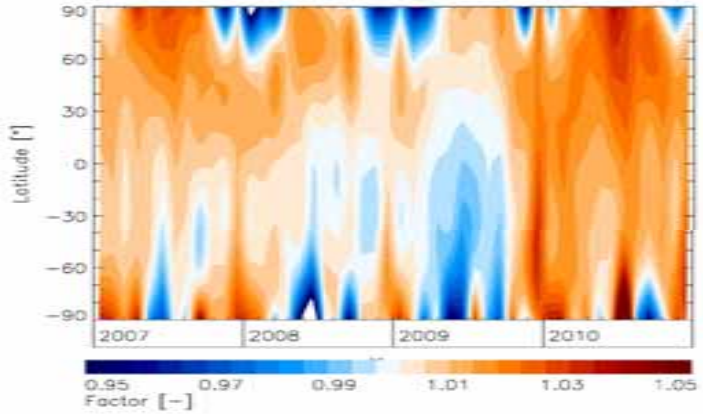
Polynomial adjustment for SCIAMACHY



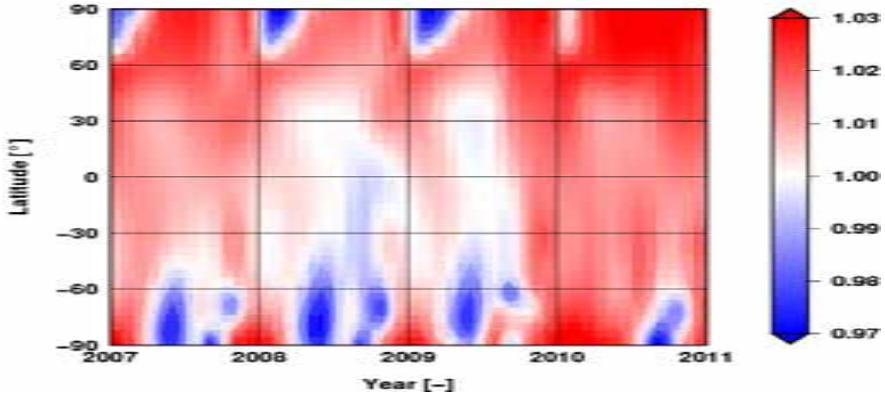
SNN adjustment for SCIAMACHY



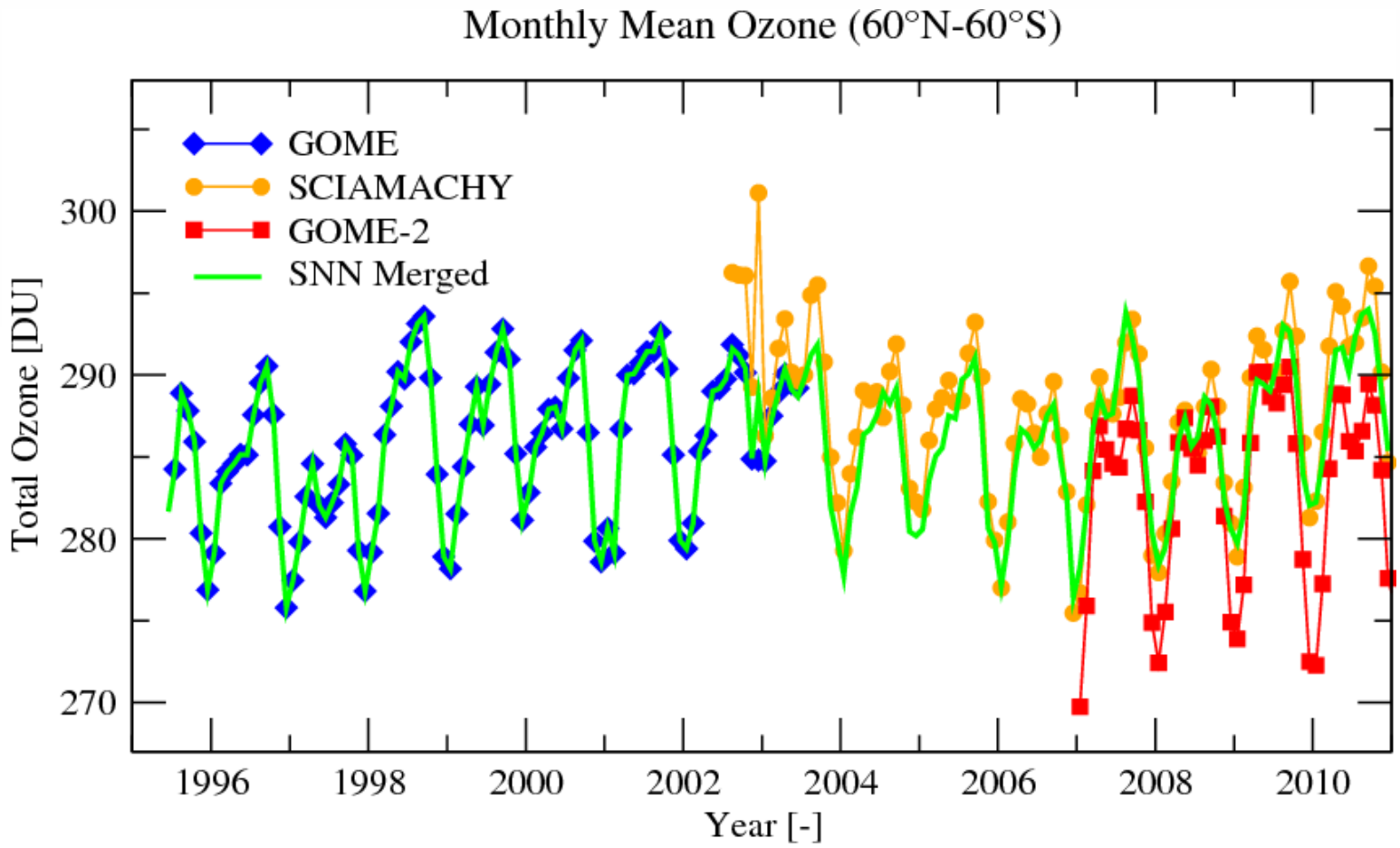
Polynomial adjustment for GOME-2



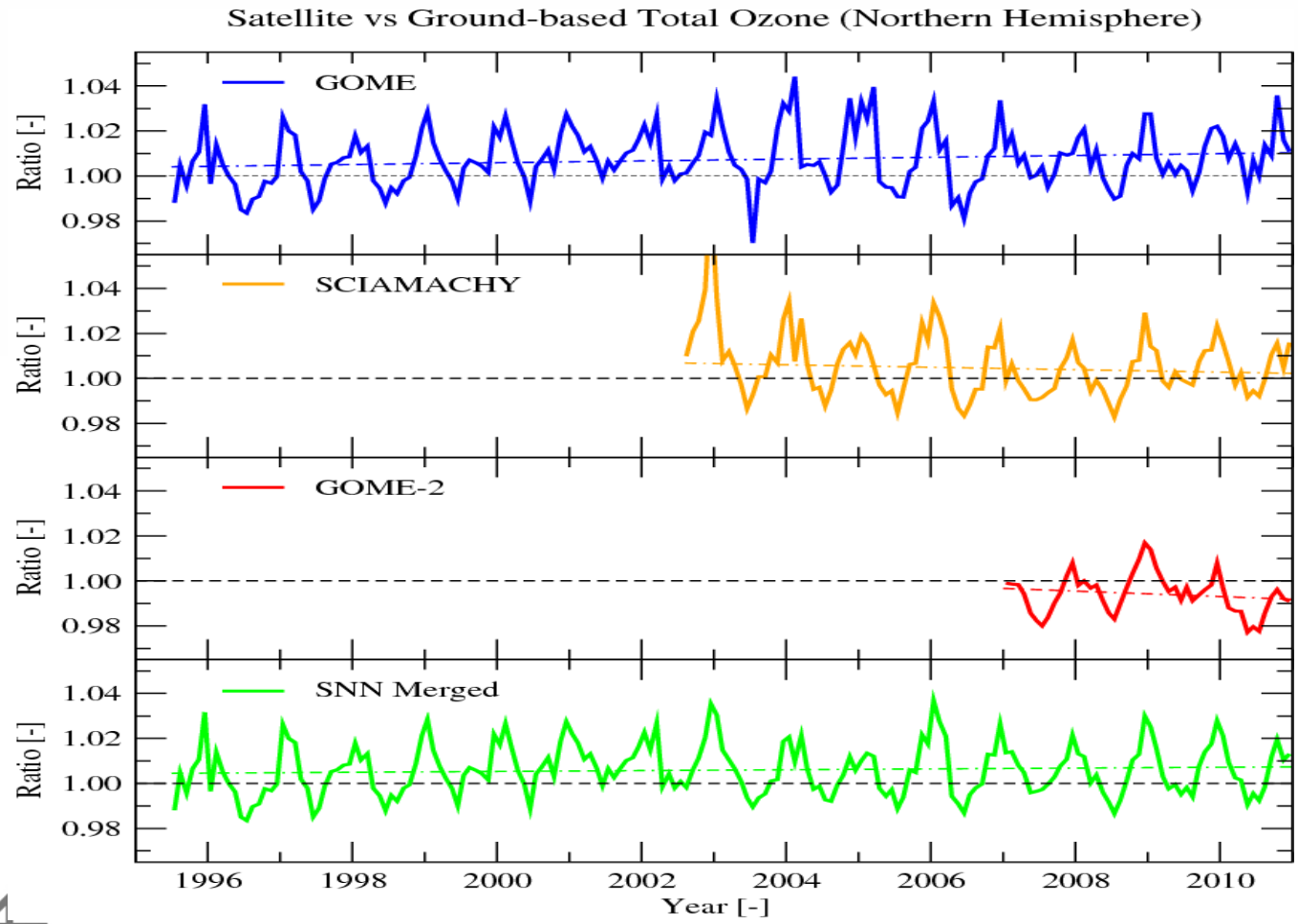
SNN adjustment for GOME–2



GOME-type Total Ozone – Essential Climate Variable



GOME-type Total Ozone – ECV Preliminary Validation



Stability

GOME
0.4±0.2% per decade

SCIAMACHY
-1.5±0.6 per decade

GOME-2
-1.2±1.1% per decade

GTO-ECV
0.2±0.2% per decade

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- **Climate-chemistry Models Evaluation**
- GDP 5.0
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Intercomparison: Data Sets

Satellite Observations

GTO-ECV_v0: GOME-1, SCIAMACHY, and GOME-2, 1995-2009, 1°lat x 1°lon, Loyola *et al*., IJRS, 2009. (http://atmos.caf.dlr.de/gome/gto_ecv.html)

NASA-MOD: TOMS, SBUV(/2), and OMI, 1978-2009, 5°lat x 10°lon, Stolarski and Frith, 2006. (http://acdb-ext.gsfc.nasa.gov/Data_services/merged/mod_data.public.html)

Chemistry Climate Models

E39C-A: ECHAM4.L39(DLR)/CHEM/-ATTILA, 1960-2050, 3.75°lat x 3.75°lon, Stenke *et al*., 2008.

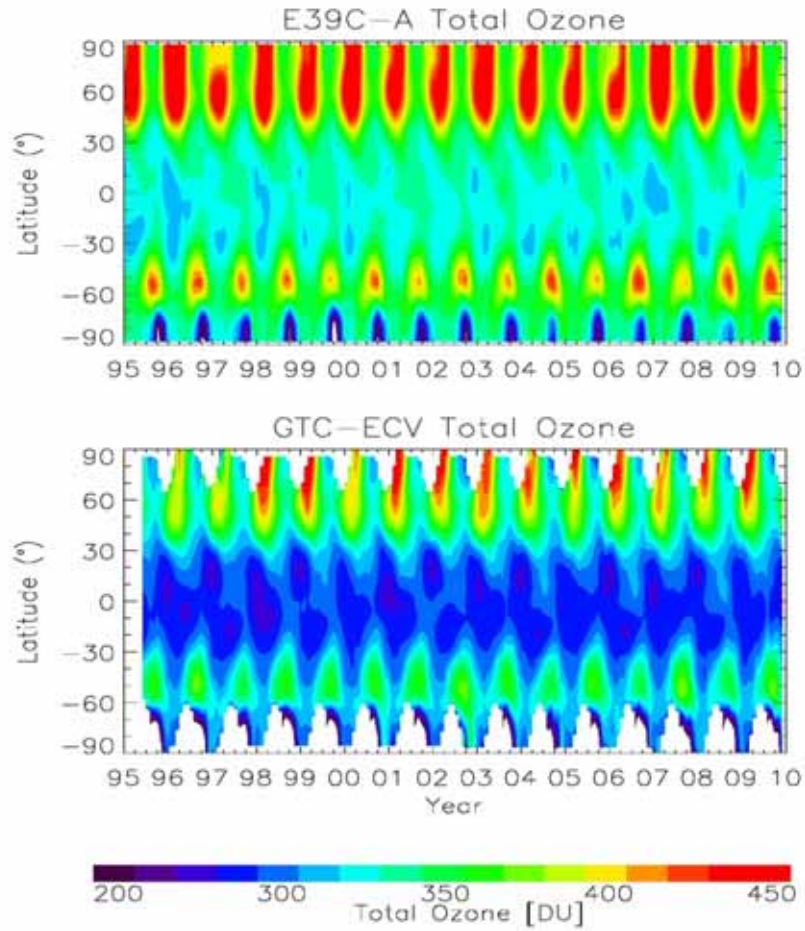
UMUKCA-UCAM: Unified Model / UK Chemistry and Aerosols Module – University of Cambridge, 1960-2100, 2.5°lat x 3.75°lon, Morgenstern *et al*., 2009.

Ground-Data: 32 Brewer and 47 Dobson Stations, 1995-2008, 5°lat x 5°lon, Balis *et al*., 2007.

Total Ozone Comparison – Zonal Means

Model

Satellite



Total Ozone Comparison – Global Distribution

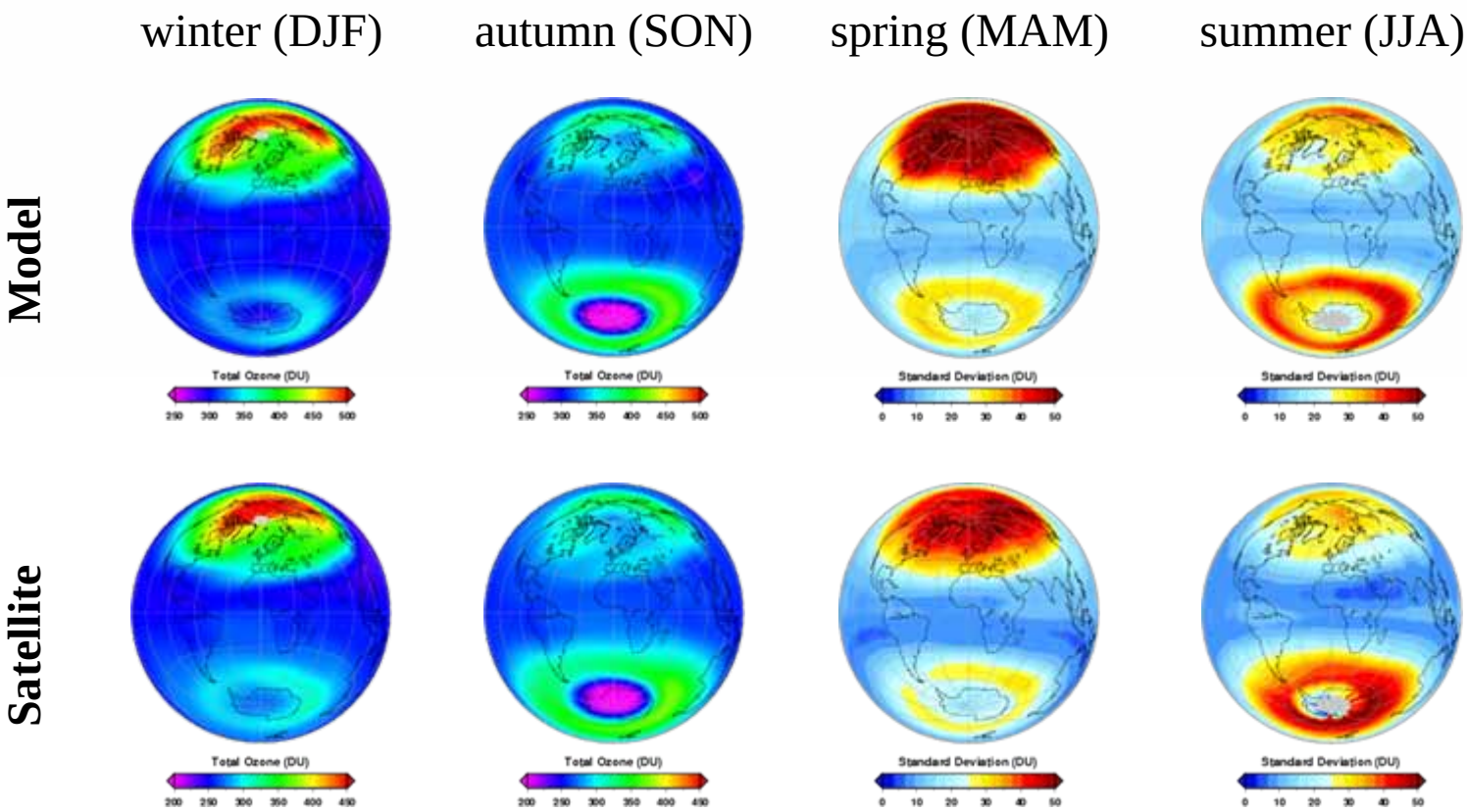


Fig. 6 and 7, Loyola et al., IJRS 2009

Total Ozone Comparison – Decadal Evolution

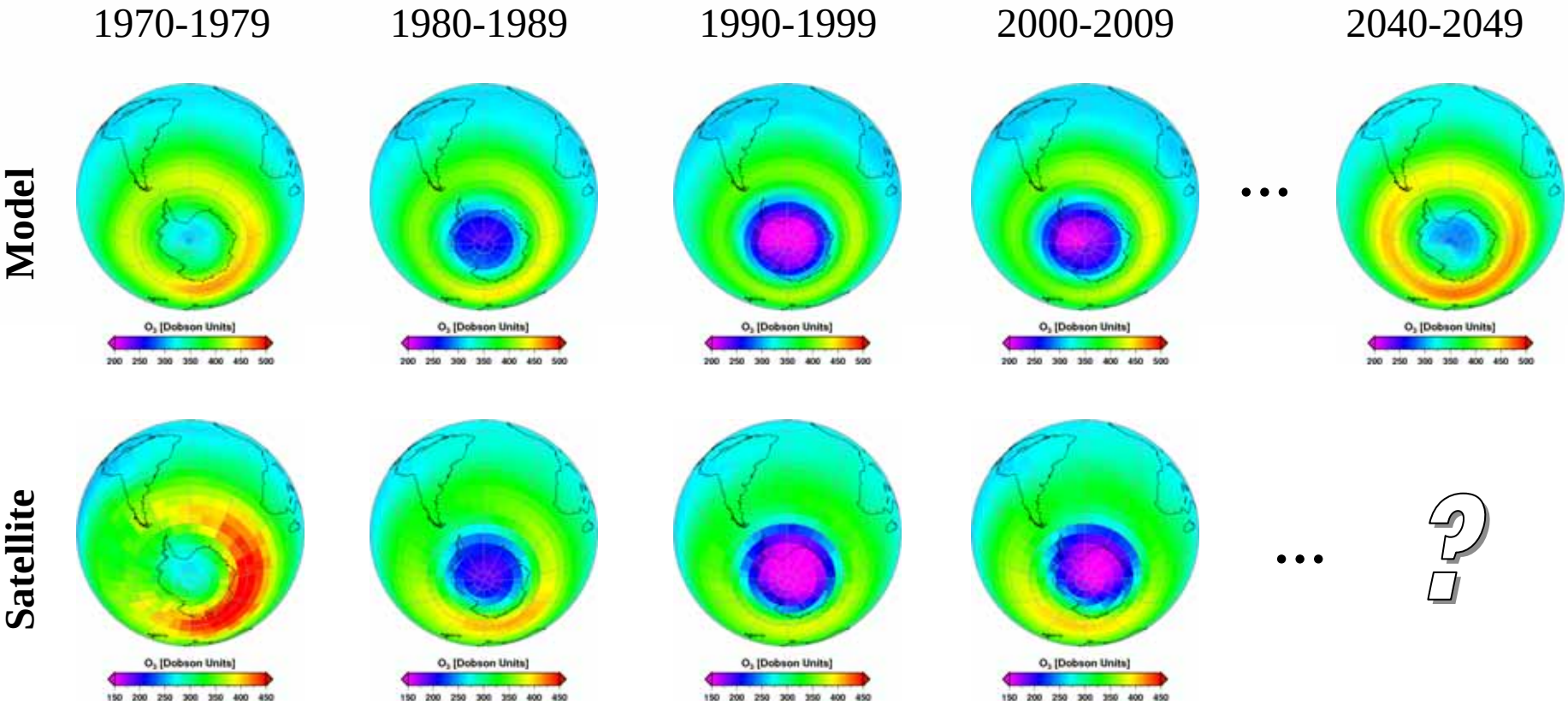
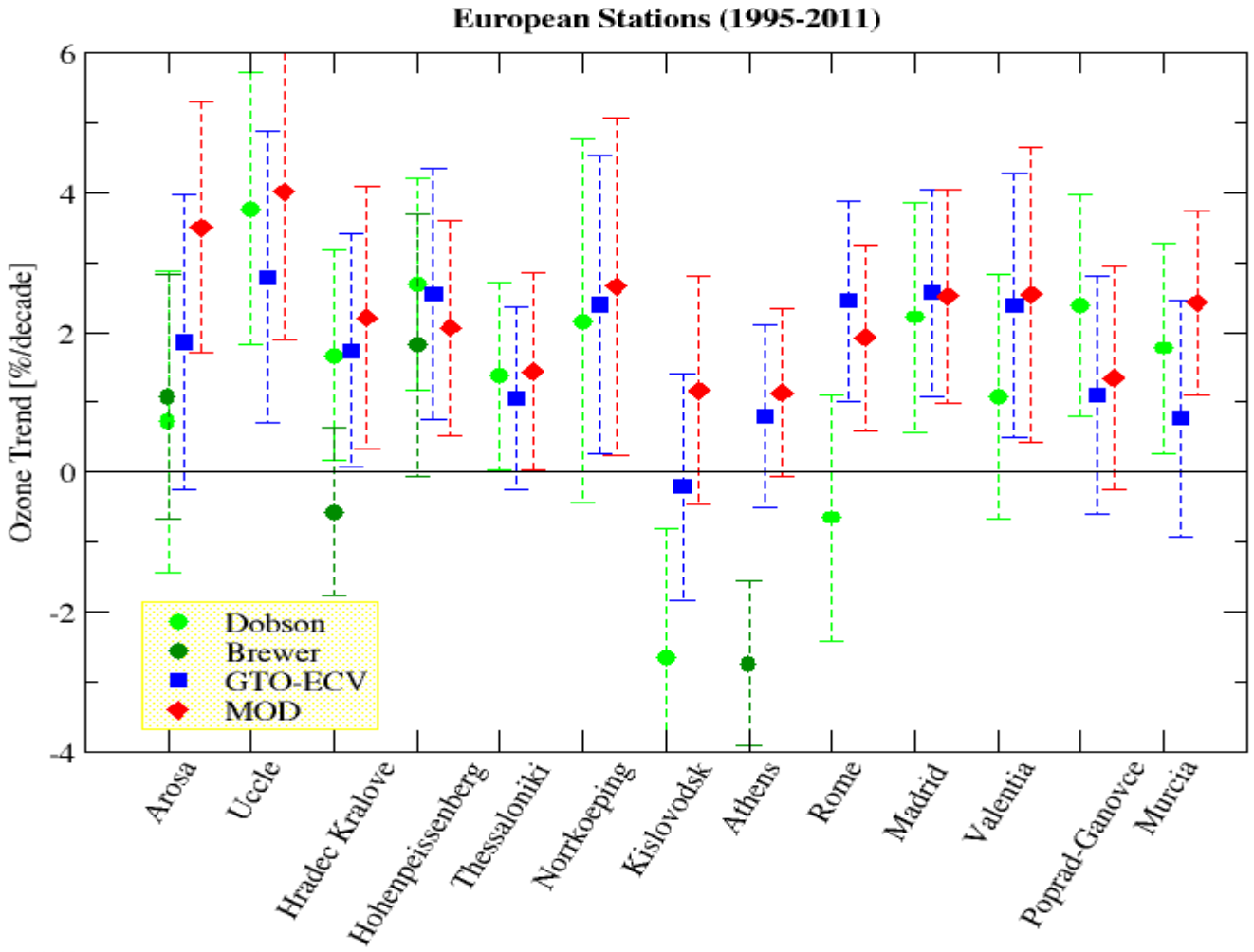


Fig. 12, Dameris and Loyola, Climate change book, 2011

Total Ozone Comparison – Trends



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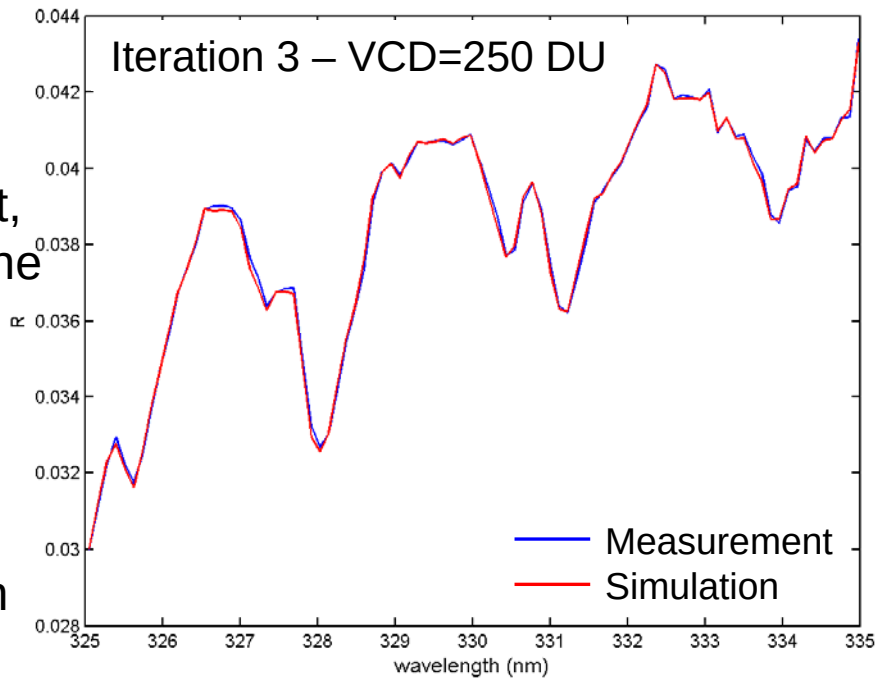
GDP 5.0 – GODFIT Principles

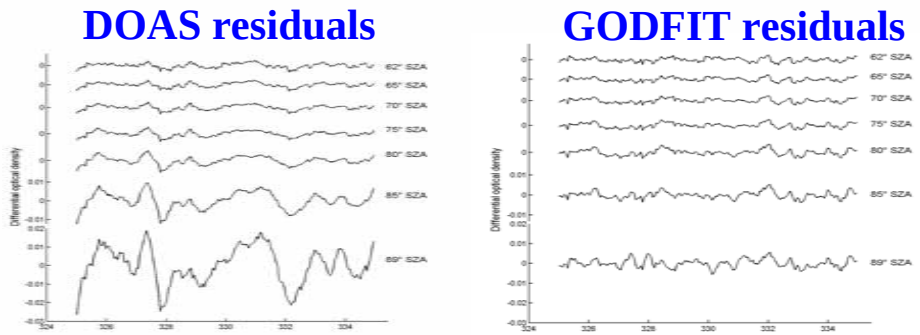
- Direct fit of GOME reflectivity using on-the-fly MS radiative transport calculations (LIDORT)
- Temperature (*T-shift*) adjustment, based on T°-dependence of ozone cross-sections (Brion et al.)
- Parameterised Ring correction
- Cloud correction with v2.0 of OCRA/ROCINN
- Tikhonov regularisation inversion solved with the Levenberg-Marquardt iterative method



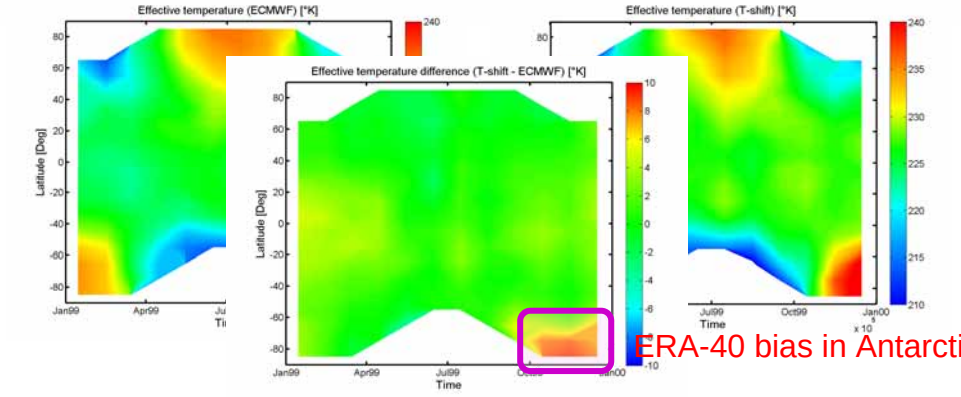
$$R_{\lambda}^{GOME} = I_{\lambda}^{LIDORT}(O_3, A, T_{shift}, f_c, P_c) + E_{Ring}.\sigma_{\lambda}^{Ring}(O_3) + \varepsilon$$

GDP 5.0 – Product Content

- Ozone Total Column

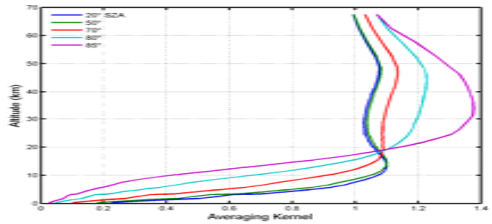


- Effective Temperature

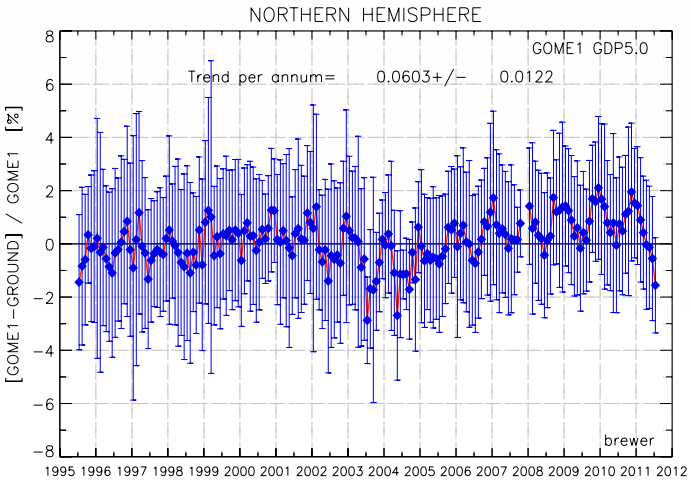


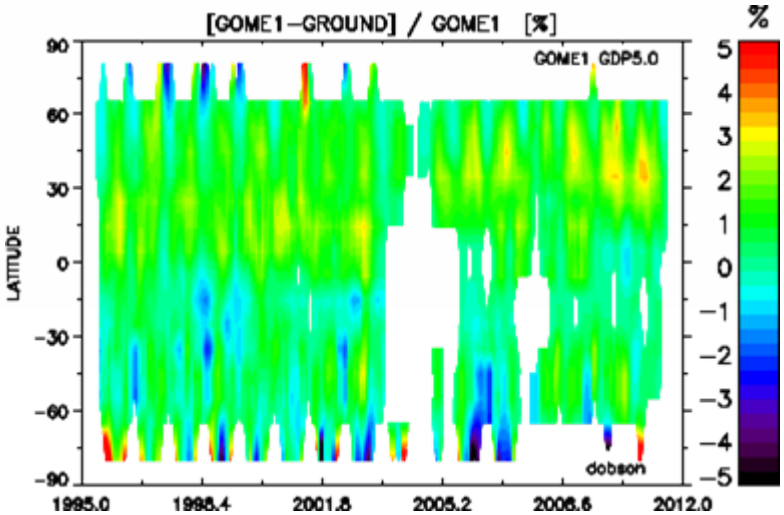
ERA-40 bias in Antarctic vortex

- Averaging Kernels

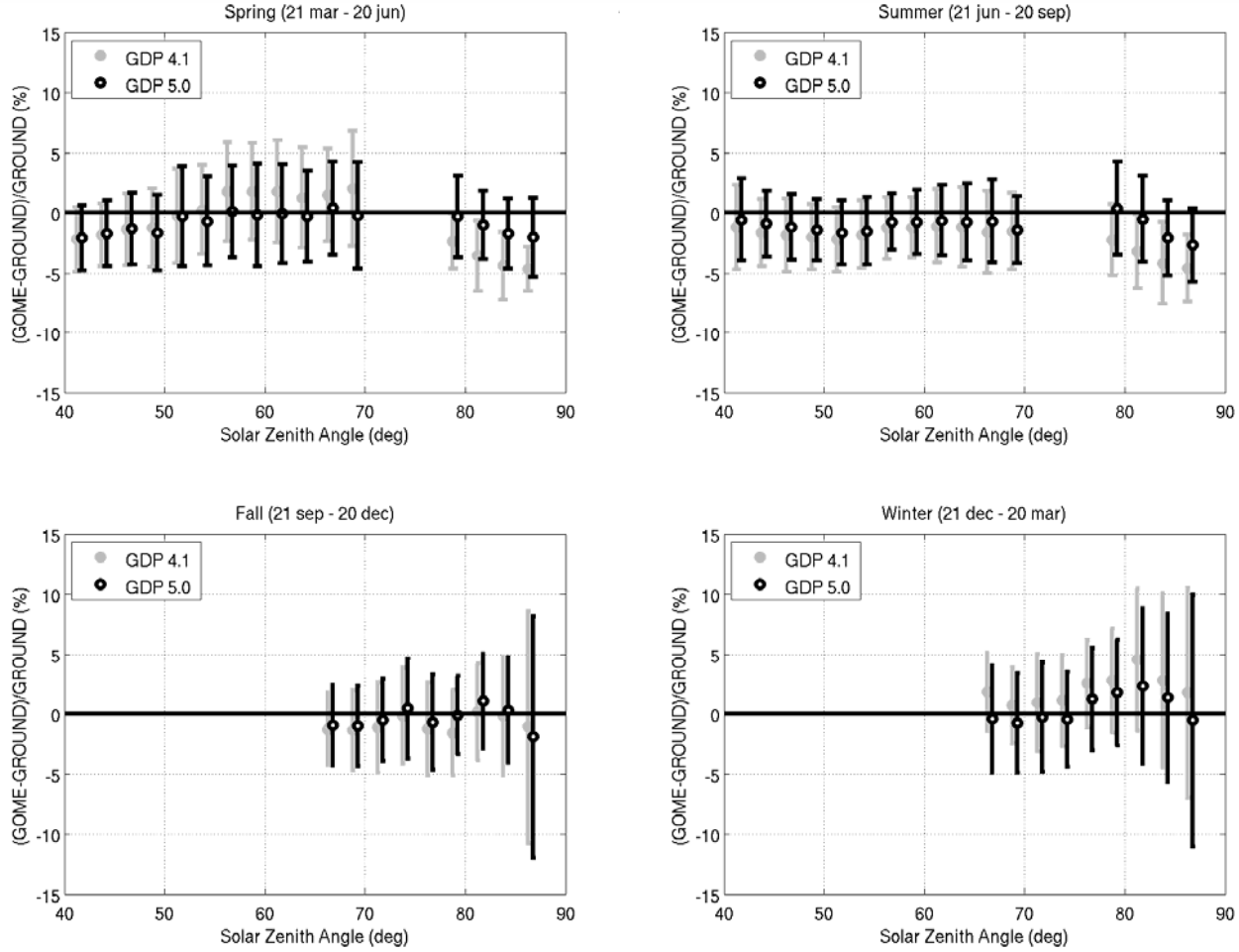


GDP 5.0 – Geophysical Validation



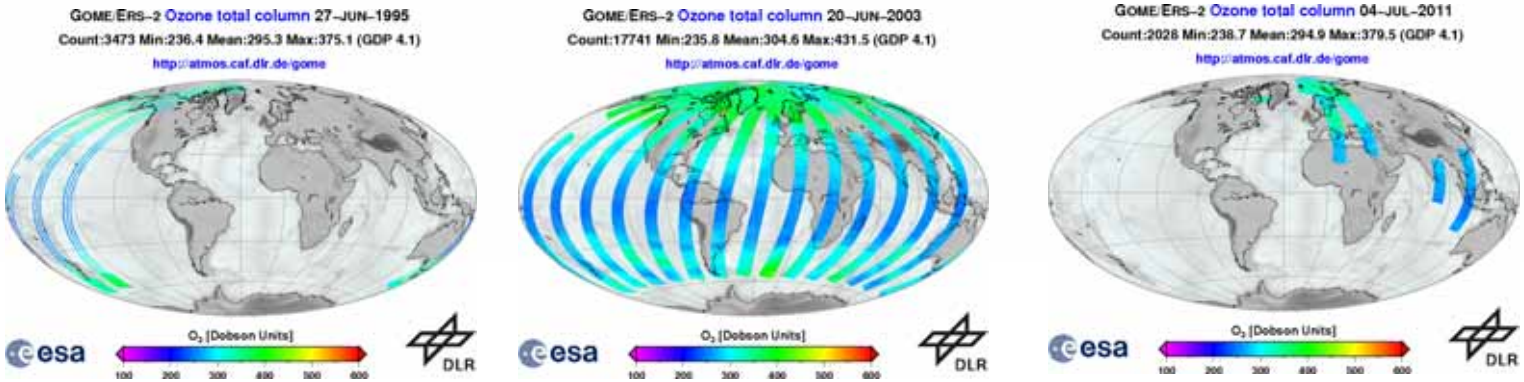


GDP 5.0 – Geophysical Validation (2)



GDP 5.0 – Status

- The complete GOME/ERS-2 data record reprocessed with GDP 5.0



- JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D03305, doi:10.1029/2011JD016471, 2012

Sixteen years of GOME/ERS-2 total ozone data: The new direct-fitting GOME Data Processor (GDP) version 5—Algorithm description

M. Van Roozendael,[1] R. Spurr,[2] D. Loyola,[3] C. Lerot,[1] D. Balis,[4] J.-C. Lambert,[1] W. Zimmer,[3] J. van Gent,[1] J. van Geffen,[1] M. Koukouli,[4] J. Granville,[1] A. Doicu,[3] C. Fayt,[1] and C. Zehner[5]

- GOME GDP 5.0 products, documentation (ATBD, validation report, PUM) and imagery will be delivered in May/June

http://atmos.caf.dlr.de/gome

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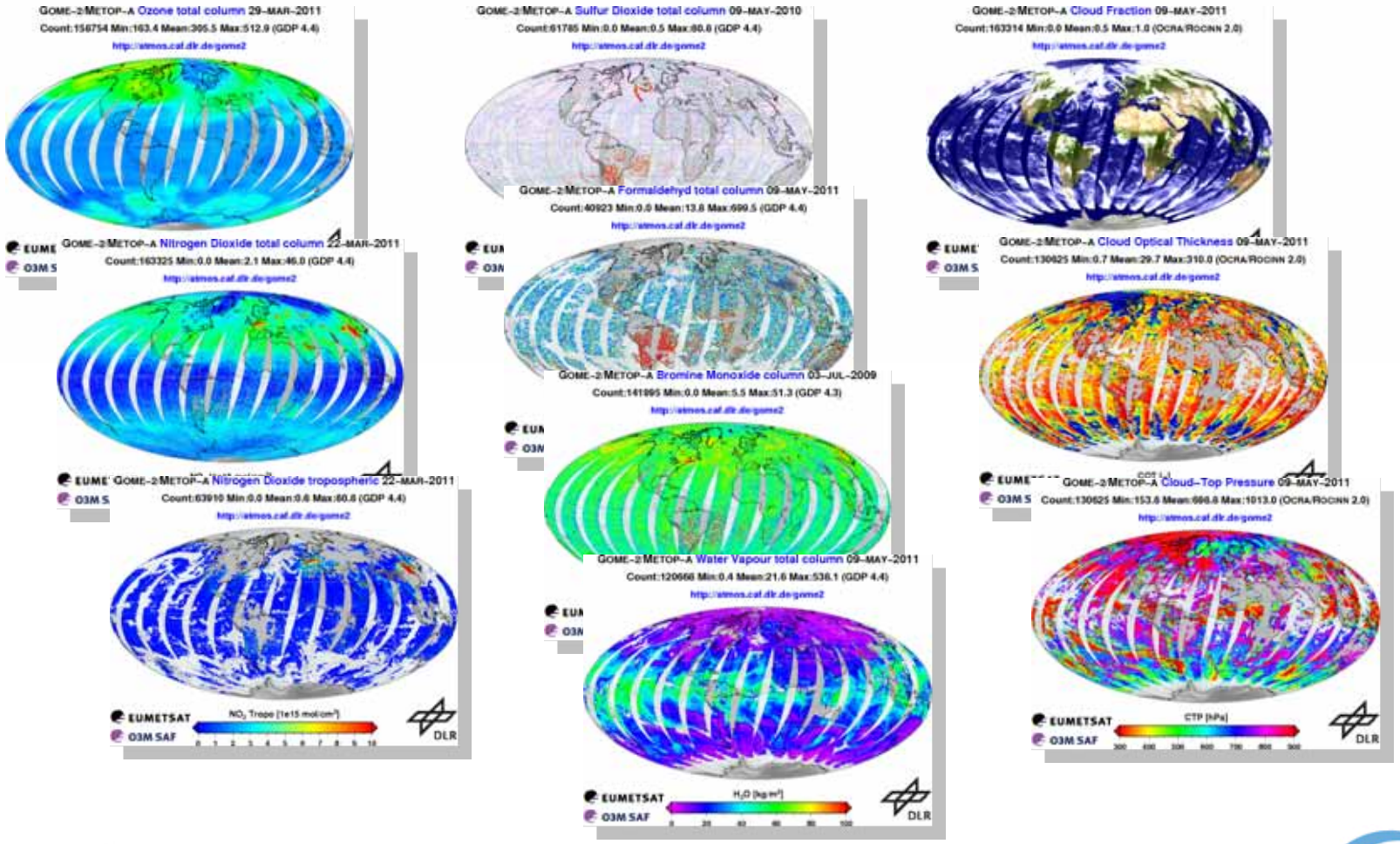
GOME-2 and GMES Atmosphere

O3M SAF

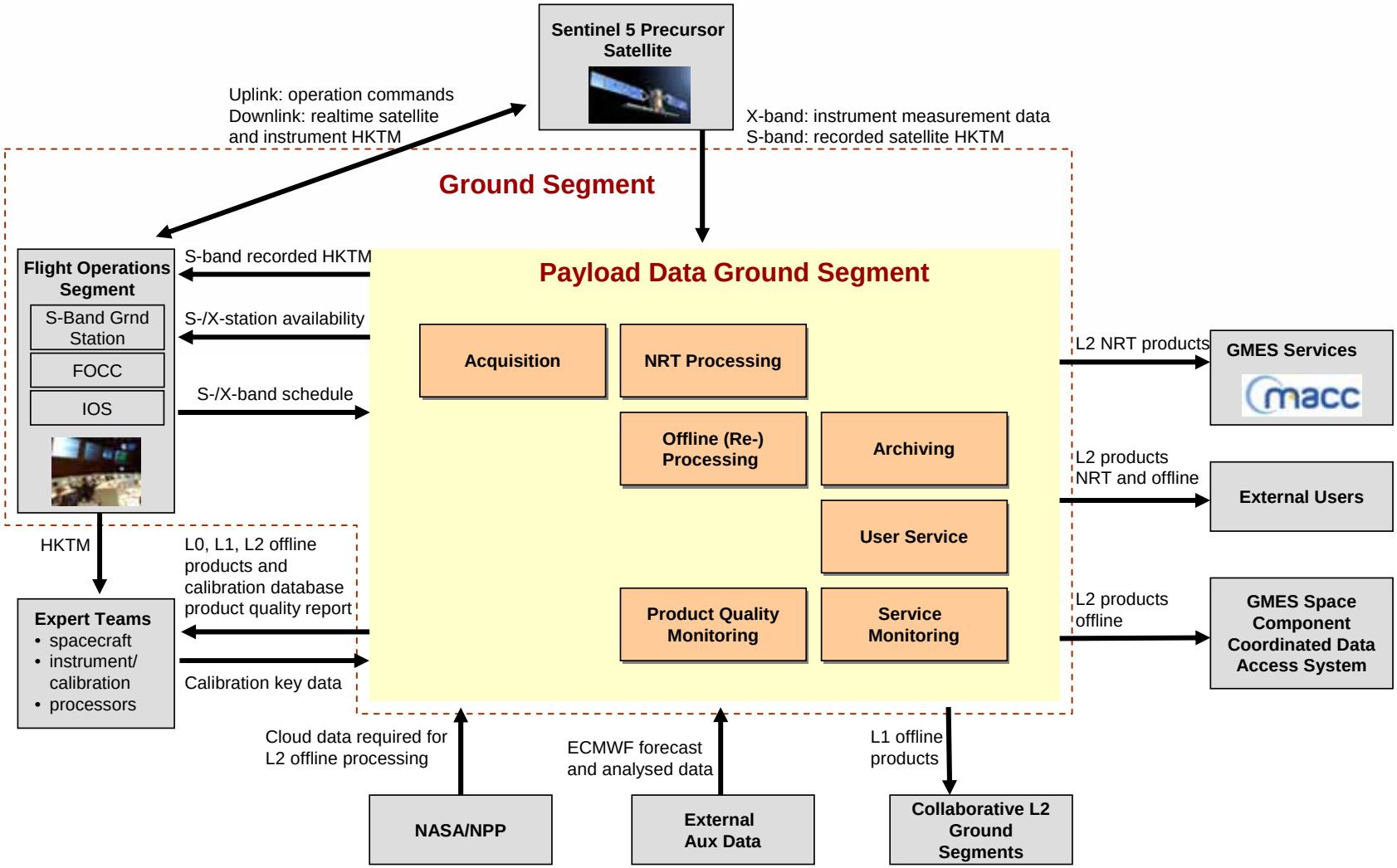


Products
24/7
2h NRT

2007 - 2011

- O_3 tot.
- NO_2 tot.
- NO_2 trop.
- SO_2
- HCHO
- BrO
- H_2O
- Clouds

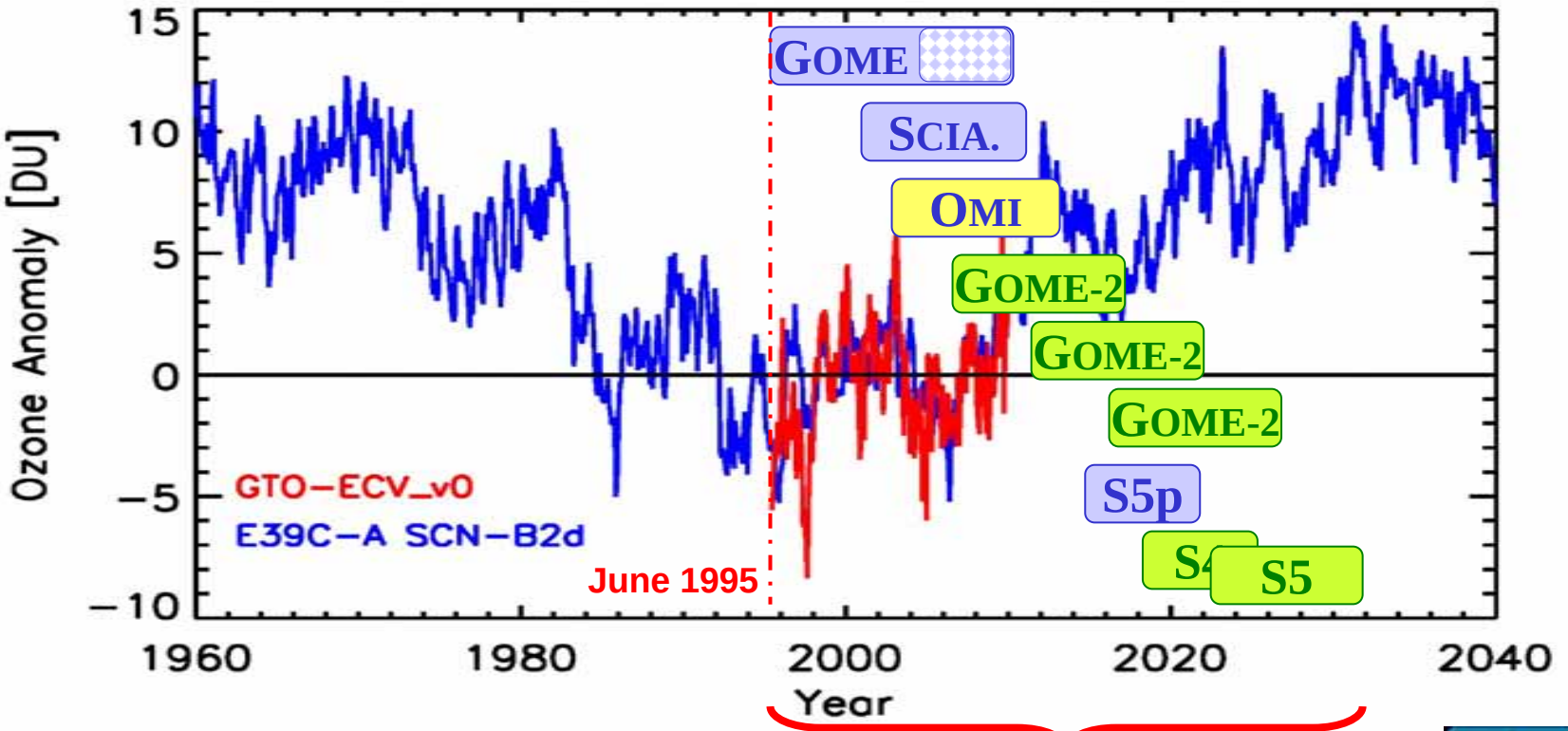
Sentinel 5 Precursor – Payload Segment at DLR



Sentinel 5 Precursor – Level 2 Products

Product Coordinator	Algorithm Prototyping KNMI	Independent Verification IUP	Operational Processor DLR-IMF
O_3 total column	DLR-IMF/BIRA	KNMI	DLR-IMF
O_3 profile (incl. troposphere)	KNMI	RAL/IUP	KNMI
O_3 tropospheric column	IUP	KNMI/DLR-IMF/IUP	DLR-IMF
NO_2 total & tropospheric column	KNMI	IUP/DLR-IMF/MPIC	KNMI
SO_2	BIRA	MPIC/DLR-IMF	DLR-IMF
HCHO	BIRA	IUP	DLR-IMF
CO	SRON	IUP	KNMI
CH_4	SRON	IUP	KNMI
Clouds	DLR-IMF	KNMI/MPIC/IUP	DLR-IMF
Aerosols	KNMI	MPIC/IUP	KNMI
…			

Ozone Long-Term Monitoring with European Sensors



— E39C-A, Stenke et al., ACP 2009

— GOME/SCIAMACHY/GOME-2, Loyola et al., IJRS 2009

ESA Ozone CCI