Tropospheric ozone column dataset derived by combination of TROPOMI and limb satellite measurements

Viktoria Sofieva, Risto Hänninen, Monika Szelag, Mikhail Sofiev, Hei Shing Lee, Johanna Tamminen

Finnish Meteorological Institute

Christian Retscher

ESA/ESRIN

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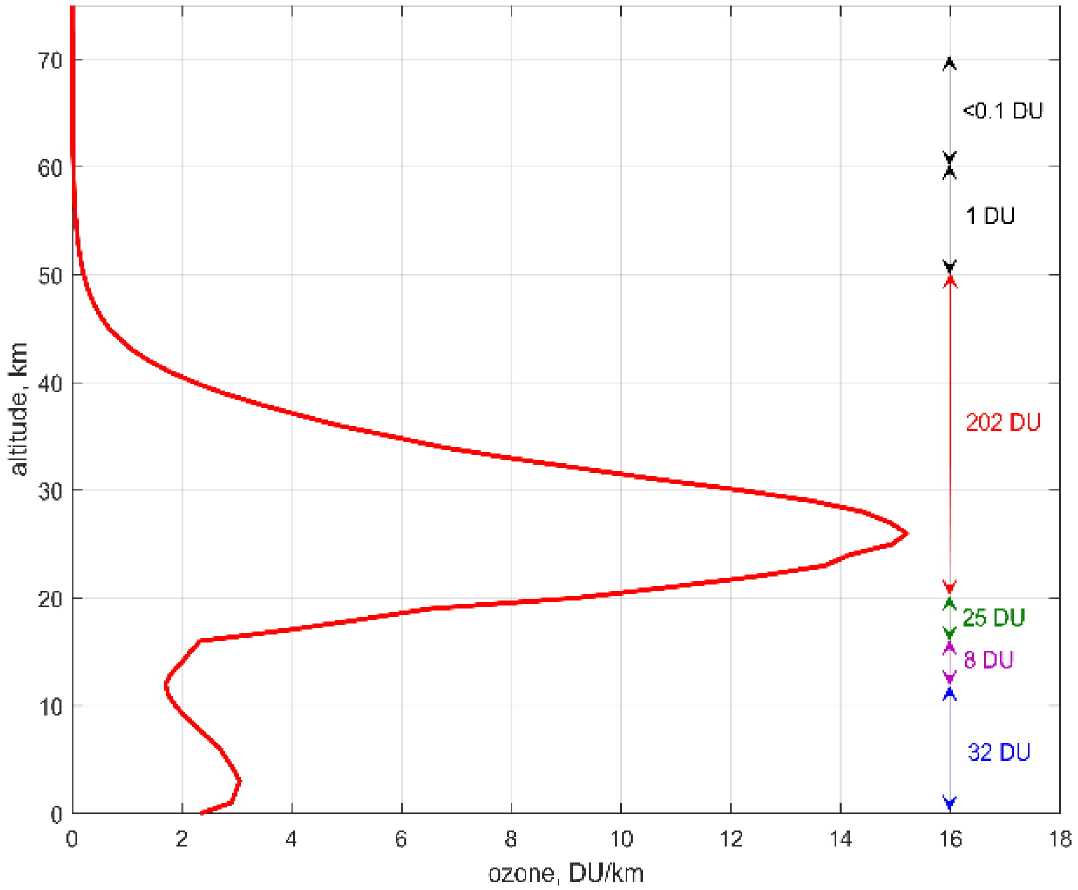
Synergy of Using Nadir and Limb Instruments for Tropospheric ozone monitoring

- Scientific objective:

  Application of residual method to create tropospheric ozone column data

  - TROPOMI combined with MLS, OMPS-LP, OSIRIS
  - OMI combined with MLS, GOMOS, MIPAS, SCIAMACHY, OSIRIS, OMPS-LP

- Novelty and challenge: stratospheric ozone is estimated using data from several satellite instruments
- Residual method: the ozone in the UTLS has nearly the same abundance as the lower tropospheric ozone, both much smaller than stratospheric ozone column
- We used the FMI CTM SILAM for various feasibility studies, optimal data interpolation, and improvements in the UTLS



Tropospheric ozone column by residual method: methodology in general

1

- Clear-sky total ozone column from nadir instruments (TOC)

2

- creating high-horizontal resolution stratospheric ozone column by combining ozone profiles from several limb instruments (SOC)

3

- TrOC= TOC- SOC

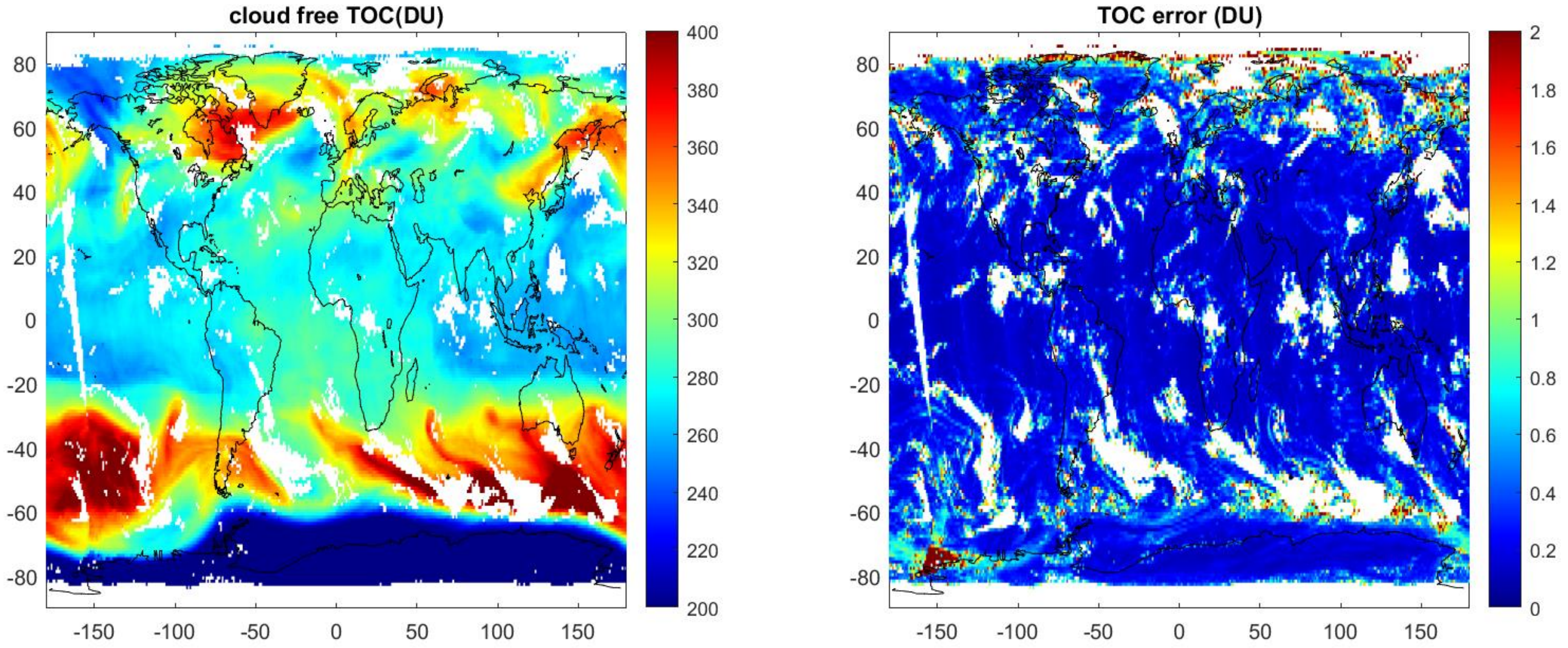
1°x1° spatial resolution

Daily TrOC → Averaging → Monthly mean TrOC

Gridded clear-sky TOC from nadir data

- Clear sky: cloud fraction <0.2
- Simple averaging in 1°x1° spatial bins

- Random uncertainties: $$\sigma^2 = \frac{1}{N}\sum_i \sigma_i^2 + \frac{1}{N}\mathrm{var}(\rho_i)$$

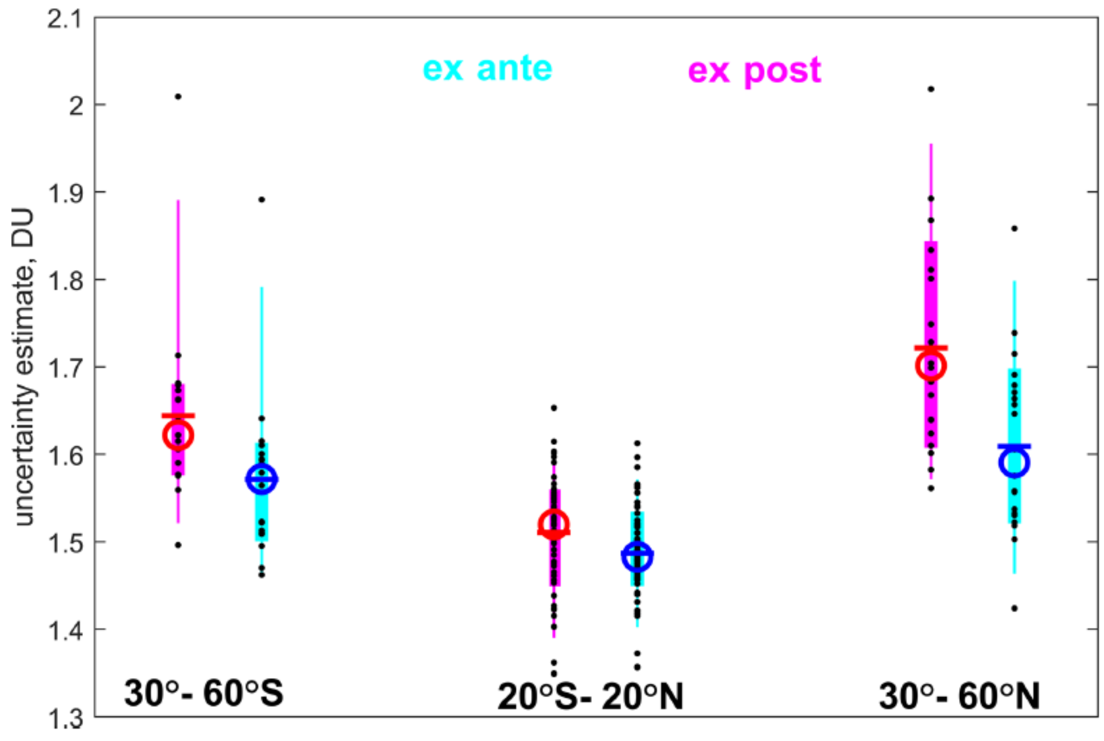


TROPOMI Level 3 total ozone column data (left) and random uncertainty (right) for 1 October 2018

TROPOMI TOC random uncertainties have been validated

Thanks to small pixel size of TROPOMI, the a-posteriori estimate of random uncertainties using the structure function method is possible

TROPOMI TOC random error estimates are realistic for clear-sky measurements



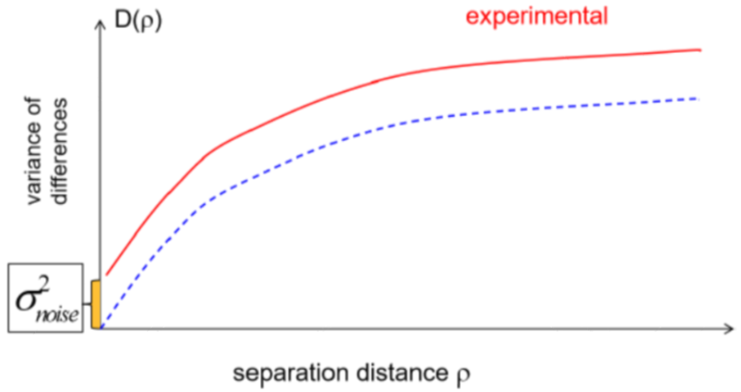


Figure 1. The schematic representation of the structure function estimated from noisy measurements.

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A method for random uncertainties validation and probing the natural variability with application to TROPOMI on board Sentinel-5P total ozone measurements

Viktoria F. Sofieva[1], Hei Shing Lee[1,2], Johanna Tamminen[1], Christophe Lerot[3], Fabian Romahn[4], and Diego G. Loyola[4]

[1]Space and Earth Observation Centre, Finnish Meteorological Institute, Helsinki, Finland
[2]Atmospheric Sciences Department, University of Helsinki, Helsinki, Finland
[3]Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium
[4]German Aerospace Centre (DLR), Remote Sensing Technology Institute, Oberpfaffenhofen, Germany

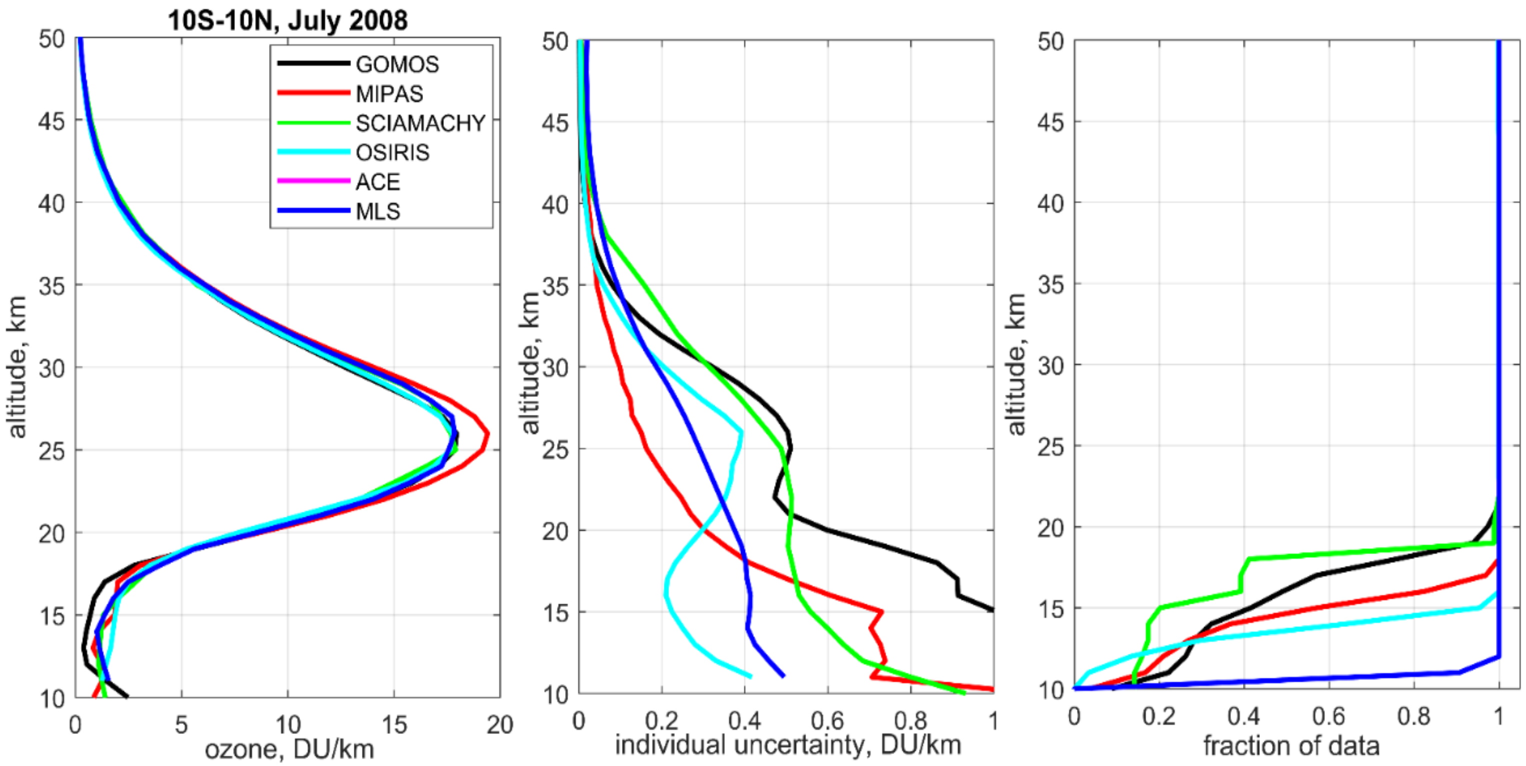
Correspondence: Viktoria F. Sofieva (viktoria.sofieva@fmi.fi)

Limb satellite data

- All datasets are from the HARMonized dataset of Ozone profiles(HARMOZ) developed in ESA Ozone_cci
- Accuracy and coverage in the UTLS is limited

Table 1. Information about the datasets used in the analyses

Instrument/ satellite	Processor, data source	Time period	Local time	Estimated precision	Profiles per day
OSIRIS/ Odin	USask v5.10	2011 – present	6 a.m., 6 p.m.	2-10%	~250
GOMOS/ Envisat	ALGOM2s v1.0	2002 – 2011	10 p.m.	0.5–5 %	~110
MIPAS/ Envisat	KIT/IAA V7R_O3_240	2005 – 2012	10 p.m., 10 a.m.	1–4%	~1000
SCIAMACHY/ Envisat	UBr v3.5,	2002- 2012	10 a.m.	1-7%	~1300
OMPS/ Suomi NPP	USask 2D v1.1.0,	2012- present	1:30 p.m.	2-10%	~1600
MLS/Aura	NASA v. 4.2	2004- present	1: 45 a.m and p.m.	1-7 %	~3500



Homogenized and interpolated dataset of ozone profiles

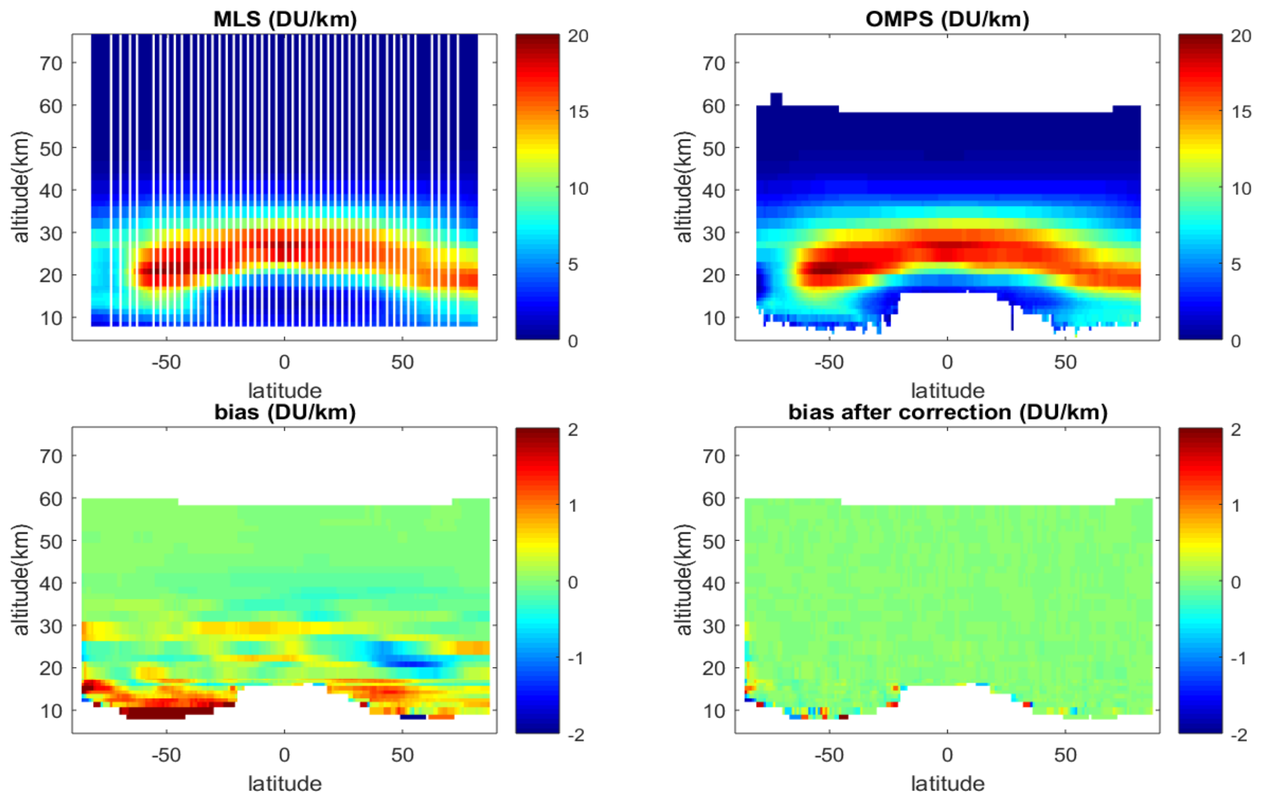
Homogenization of ozone profile data from the limb satellites

Interpolation of the limb profiles from each day to 1°x1° horizonal grid

A smooth transition to the adjusted model data below the tropopause

Homogenization

- Bias correction
  - MLS is reference
  - Biases are evaluated for each month
- Validation/ a posteriori estimation of random uncertainties



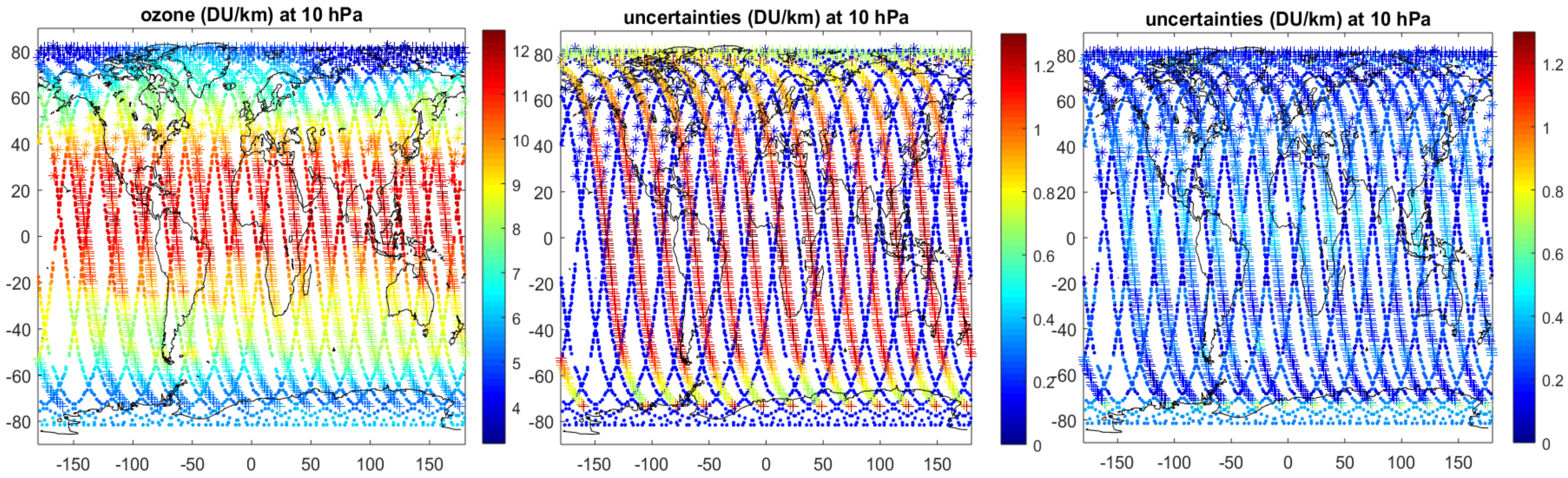
$$\sigma^2_{ex-poste} = s^2 - \sigma^2_{nat}$$

A-posteriori uncertainty

Sample variance

Natural variability from SILAM

$$\Delta = \sigma_{ex-poste} - \sigma_{ex-ante}$$

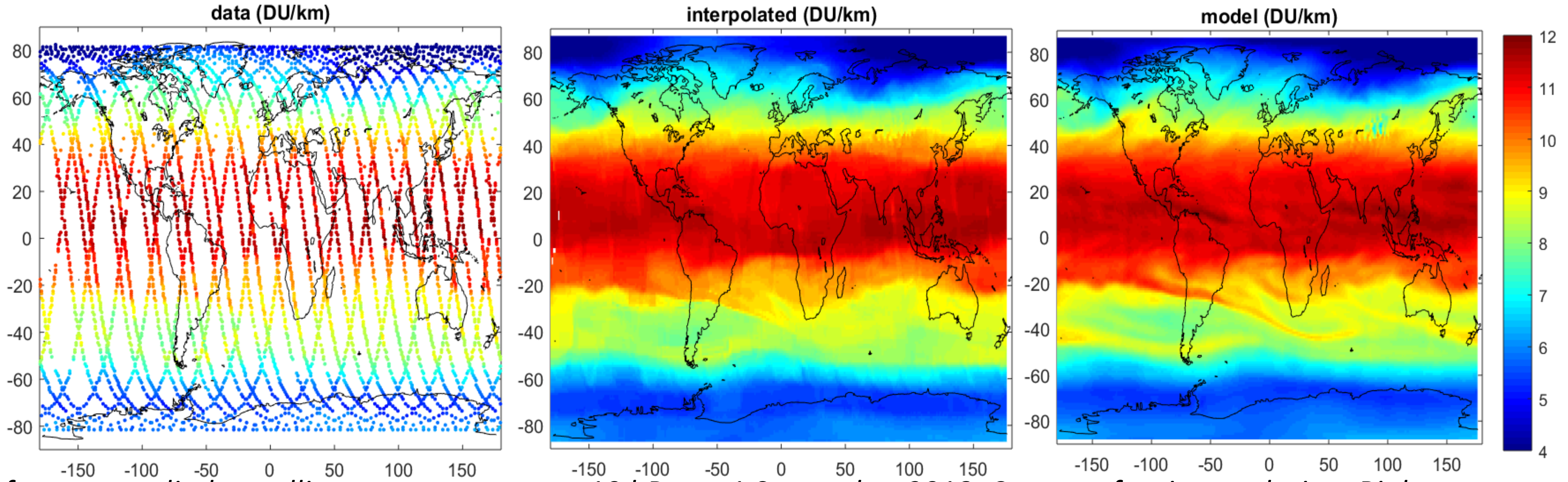


Horizontal interpolation

- A kriging-type interpolation at each pressure level
  - Weighted mean of data in a neighborhood
  - Weights are inversely proportional to total uncertainties
  - The mismatch uncertainties are estimated using the SILAM model

$$x(\mathbf{r}) = \sum_i w_i x(\mathbf{r}_i),$$

$$\sigma^2_{tot,i} = \sigma^2_{noise,i} + D(\mathbf{r}_i - \mathbf{r})$$



Left: ozone at limb satellite measurements at 10 hPa on 1 September 2018. Center: after interpolation. Right: corresponding adjusted SILAM ozone field at the same pressure level.

Transition to the model profiles in the troposphere

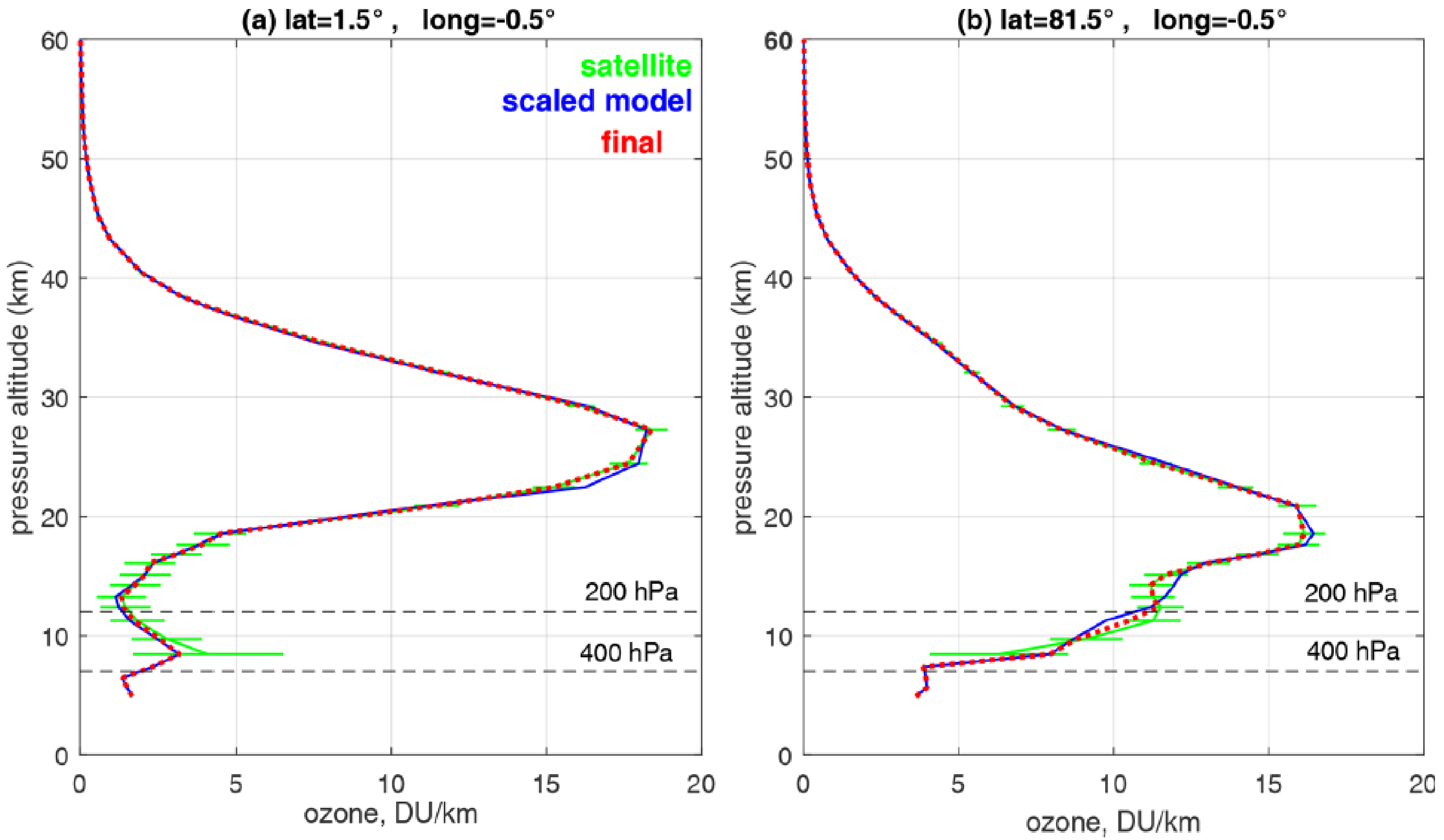
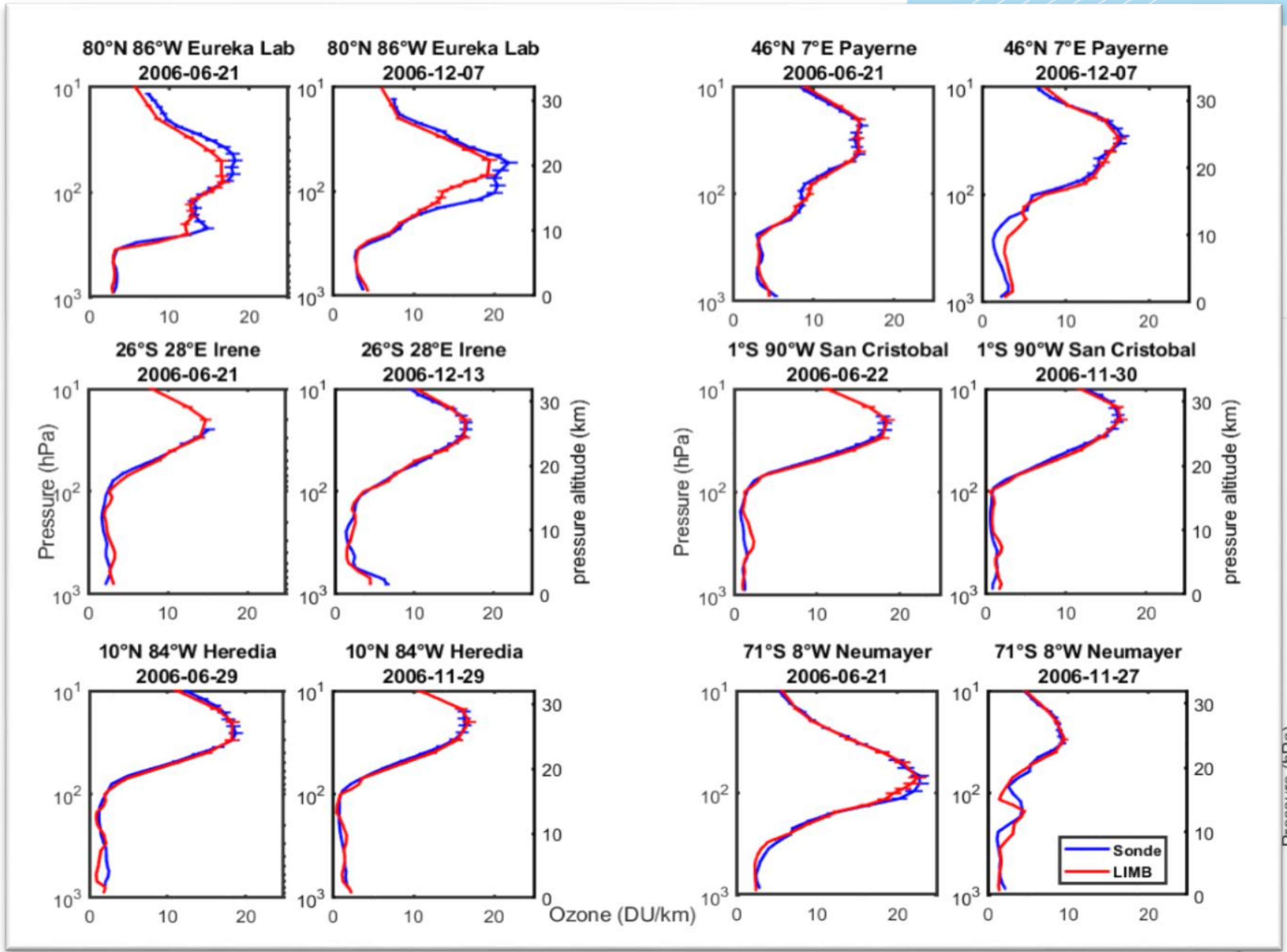
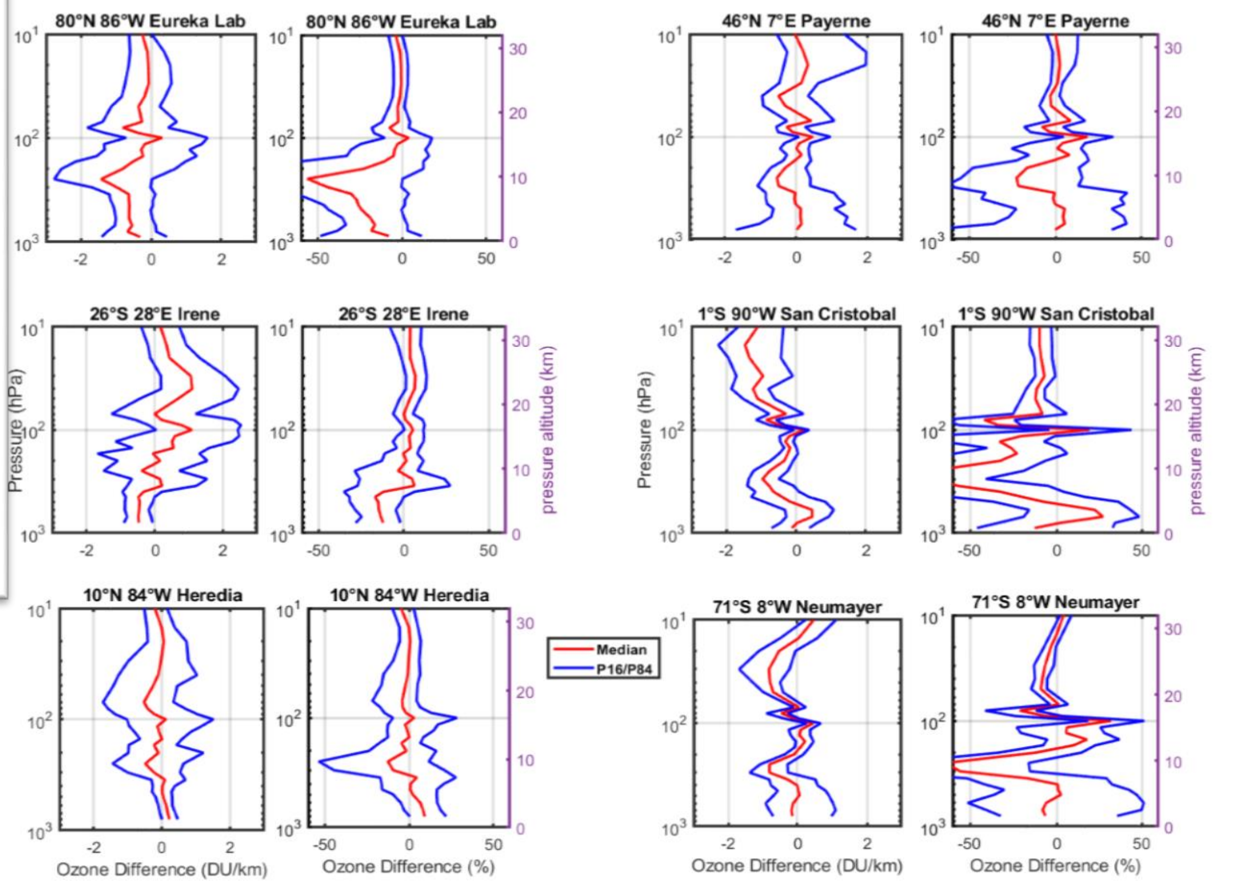


Illustration of transition to model-adjusted profiles at lower altitudes for tropical (left) and polar region (right)

- Satellite data have limited accuracy, non-homogeneous and rather sparse coverage below the tropopause
- We extended the satellite-based ozone profiles to lower altitudes by using the smooth transition to the adjusted SILAM profiles
- The linear transition is performed in such a way that above 200 hPa the profile follows fully the experimental data and below 400 hPa - fully the model data.

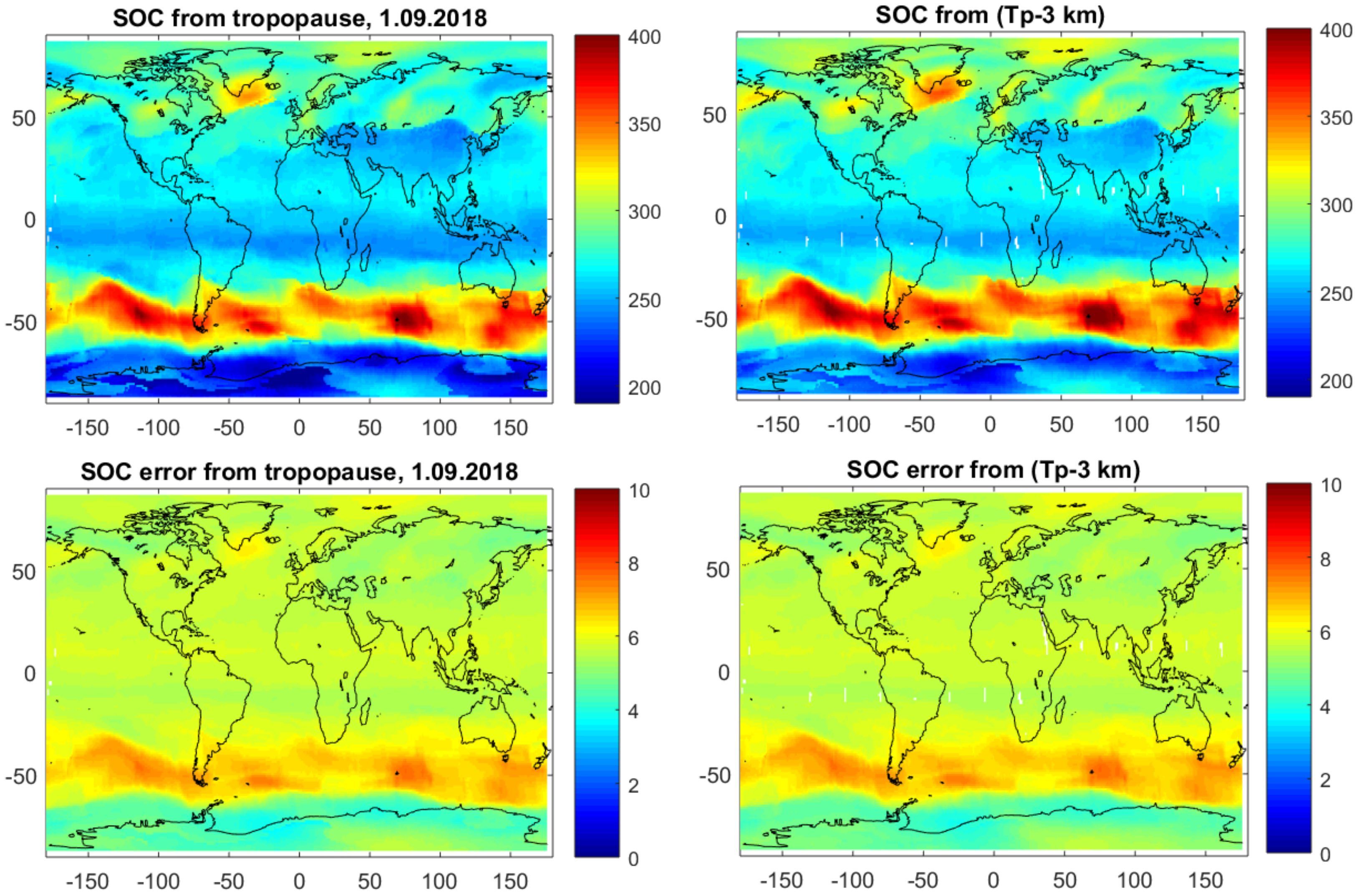
Validation of ozone profiles against ozonesondes





- The biases are small in both stratosphere and the troposphere;
- the inter-percentile range of differences is a few percent in the stratosphere and in the range of 10-50 % in the UTLS and the troposphere.

Stratospheric ozone column and uncertainties

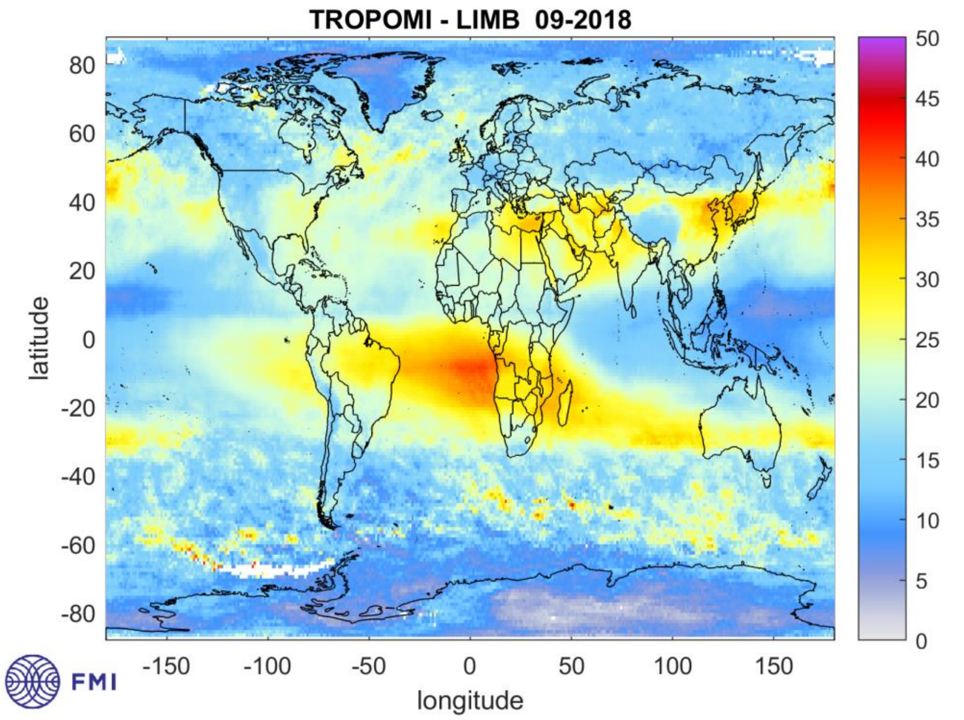


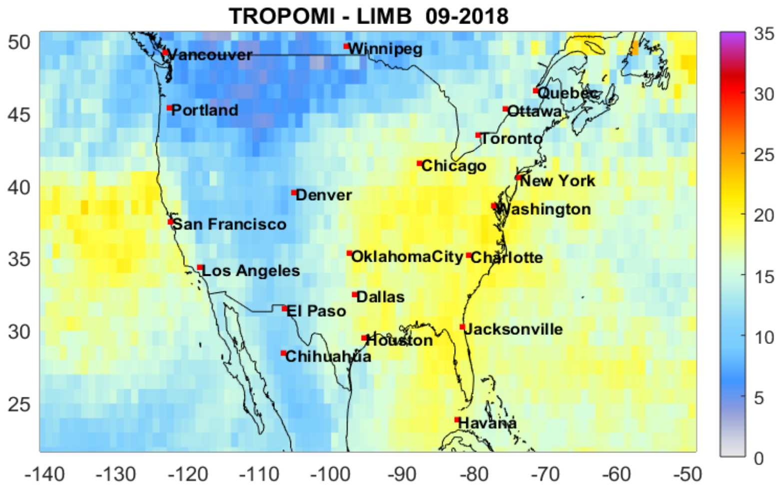
Computing the stratospheric ozone column from the high-resolution profiles is rather straightforward. The integration can be done from the tropopause upwards (we use 55 km as the upper integration limit), or from a certain altitude level.
In our analyses, we use 3 km below the tropopause as a lower limit.

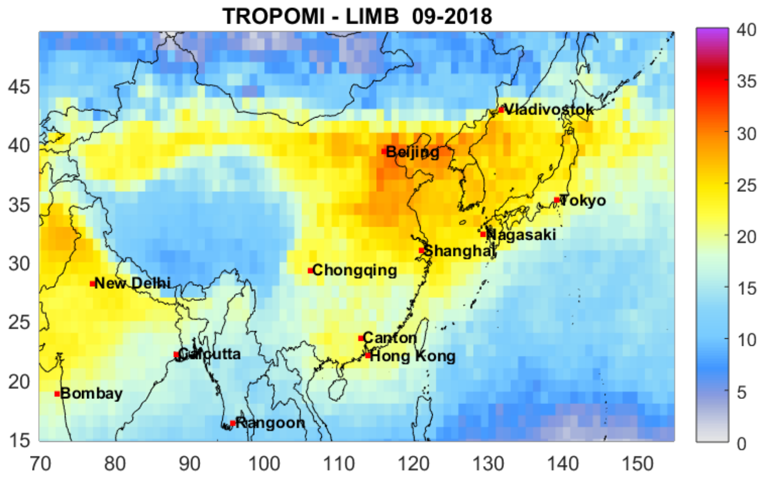
Stratospheric ozone column, SOC, (DU) from tropopause (left top) and from 3 km below the tropopause (right top) computed from 1°x1° merged (homogenized and interpolated) limb ozone profiles. The corresponding uncertainties are shown in bottom panels.

Results

- Monthly 1°x1° global tropospheric ozone column datasets
  - OMI-LIMB
  - TROPOMI-LIMB
- The global distributions of tropospheric ozone exhibit enhancements associated with the tropospheric sources

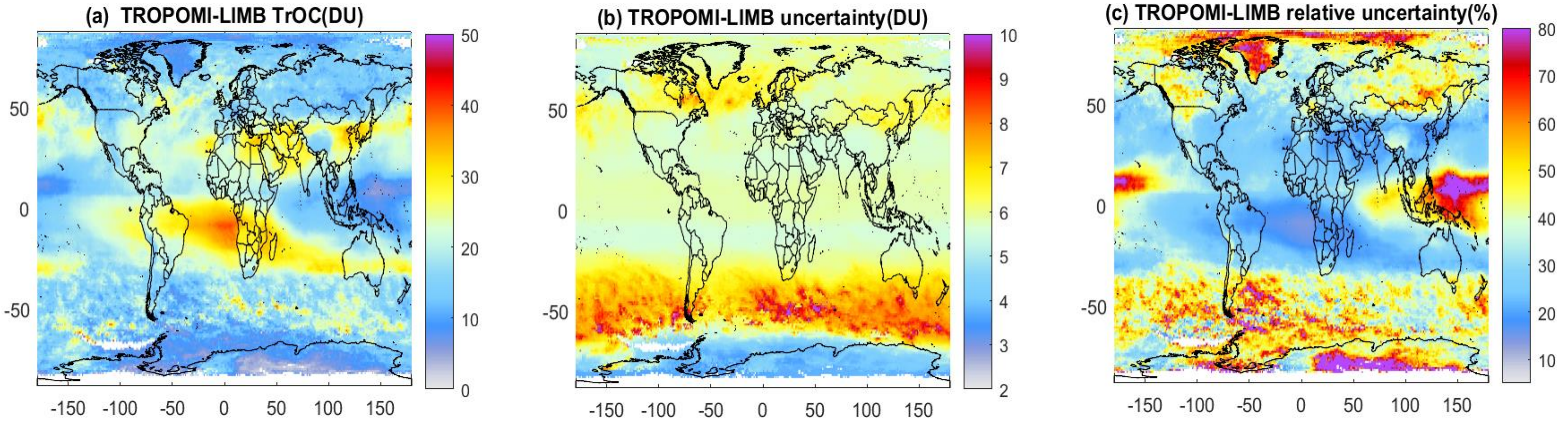




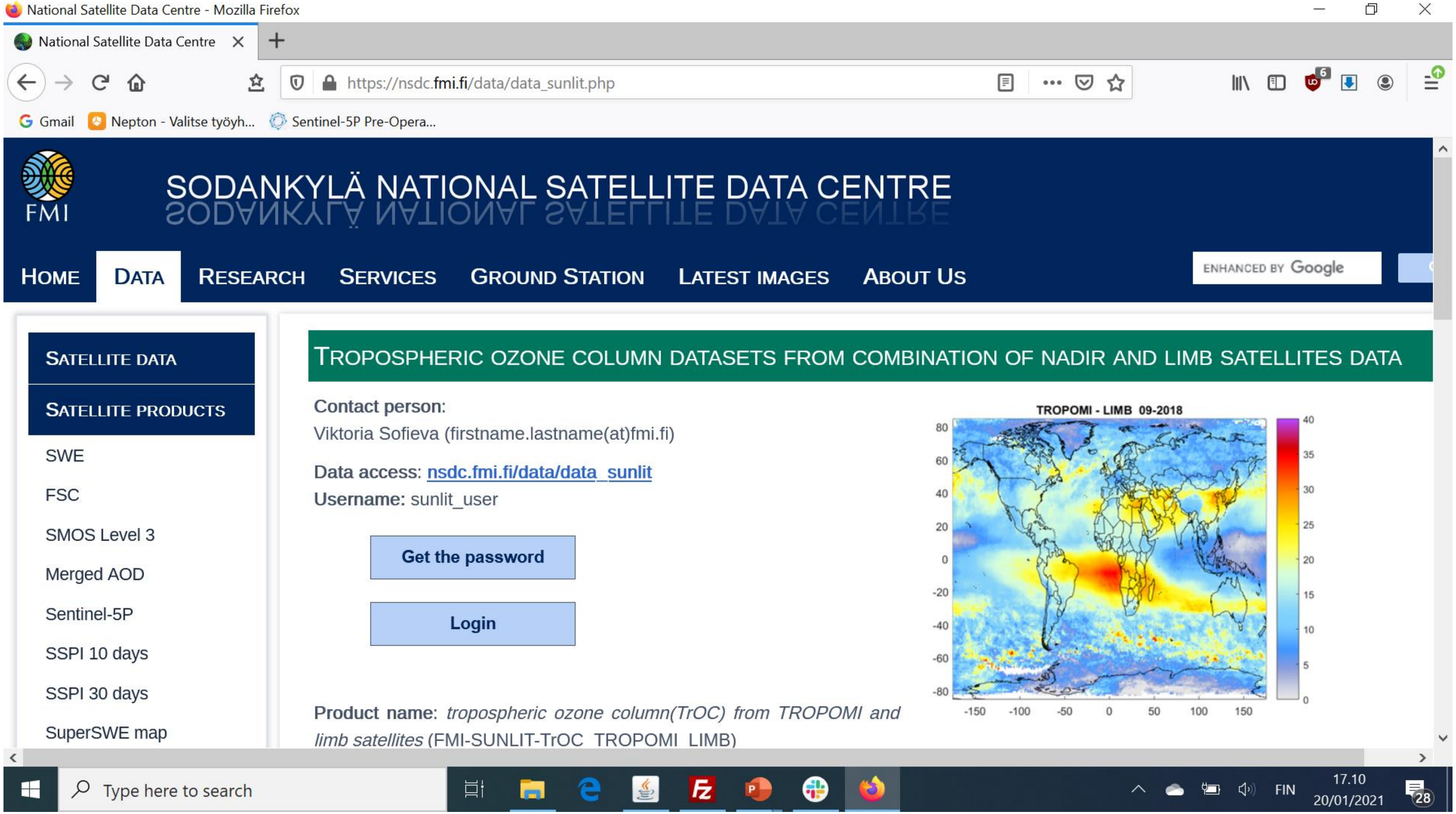


Associated uncertainties of tropospheric ozone

- Uncertainties are estimated via error propagation through the all steps of the inversion
- Typical uncertainties of TROPOMI-LIMB tropospheric ozone are 4-8 DU



Data access: https://nsdc.fmi.fi/data/data_sunlit.php



Main datasets

- Monthly 1°x1° global tropospheric ozone column dataset using OMI and limb instruments
- Monthly 1°x1° global tropospheric ozone column dataset using TROPOMI and limb instruments
- Daily 1°x1° interpolated stratospheric ozone column from limb instruments

THANK YOU!

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Synergy of Using Nadir and Limb Instruments for Tropospheric Ozone Monitoring (SUNLIT)

Viktoria F. Sofieva[1], Risto Hänninen[1], Mikhail Sofiev[1], Monika Szelag[1], Hei Shing Lee[3,4], Johanna Tamminen[1], and Christian Retscher[2]

[1]Finnish Meteorological Institute, Helsinki, Finland
[2]ESA/ESRIN, Frascati, Italy
[3]Institute for Atmospheric and Earth System Research/Physics, University of Helsinki, Helsinki, Finland
[4]Helsinki Institute of Sustainability Science, University of Helsinki, Helsinki, Finland

Correspondence: Viktoria F. Sofieva (viktoria.sofieva@fmi.fi)