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The TROPOMI surface UV radiation product

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Surface UV radiation and its many roles

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- Thanks to **Montreal Protocol**, large increase in UV radiation has been avoided.
- **Climate change** affects on surface UV radiation levels, e.g. effect of changes in clouds, aerosols, surface albedo and total ozone.
- **Plant, terrestrial and aquatic ecosystem** response to changes in UV radiation and climate.
- Variability in UV is related **health effects**: skin cancer, cataract, immunosupression, vitamin D deficiency
- Research on-going to study the role of UV on globally spread **infection diseases** like influenza, COVID-19
- UV is linked to air quality and atmospheric chemistry via OH production and **oxidation.**
- UV linked to **carbon cycle**, e.g., methane sink in the troposphere and inducing CO_2 production from thawing permafrost.
- UV-radiation has recently been suggested to GCOS to be considered as an essential climate variable.

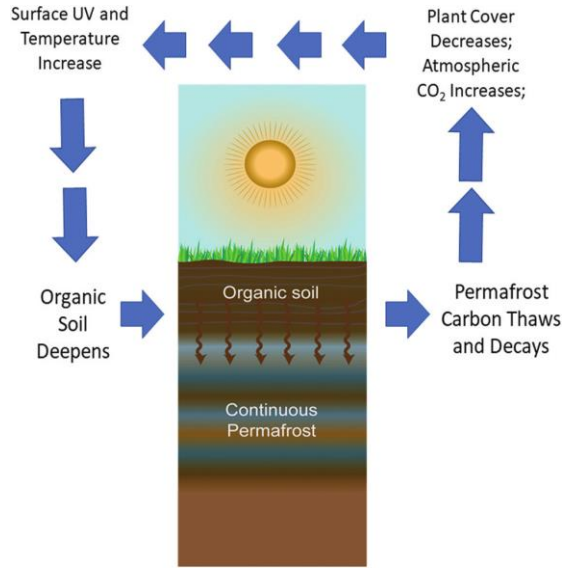
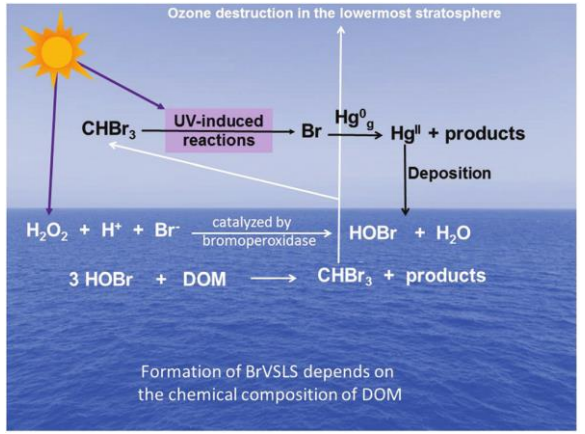


Fig: UV radiation induces carbon dioxide production from organic carbon released by thawing permafrost



Example of biogeochemical reaction affected by UV radiation.

Figs Ref. Bernhard et al. 2020, Environmental effects of stratospheric ozone depletion, UV radiation and interactions with climate change: UNEP Environmental Effects Assessment Panel, update 2019 Photochem. Photobiol. Sci., 2020, 19

S5P / TROPOMI UV

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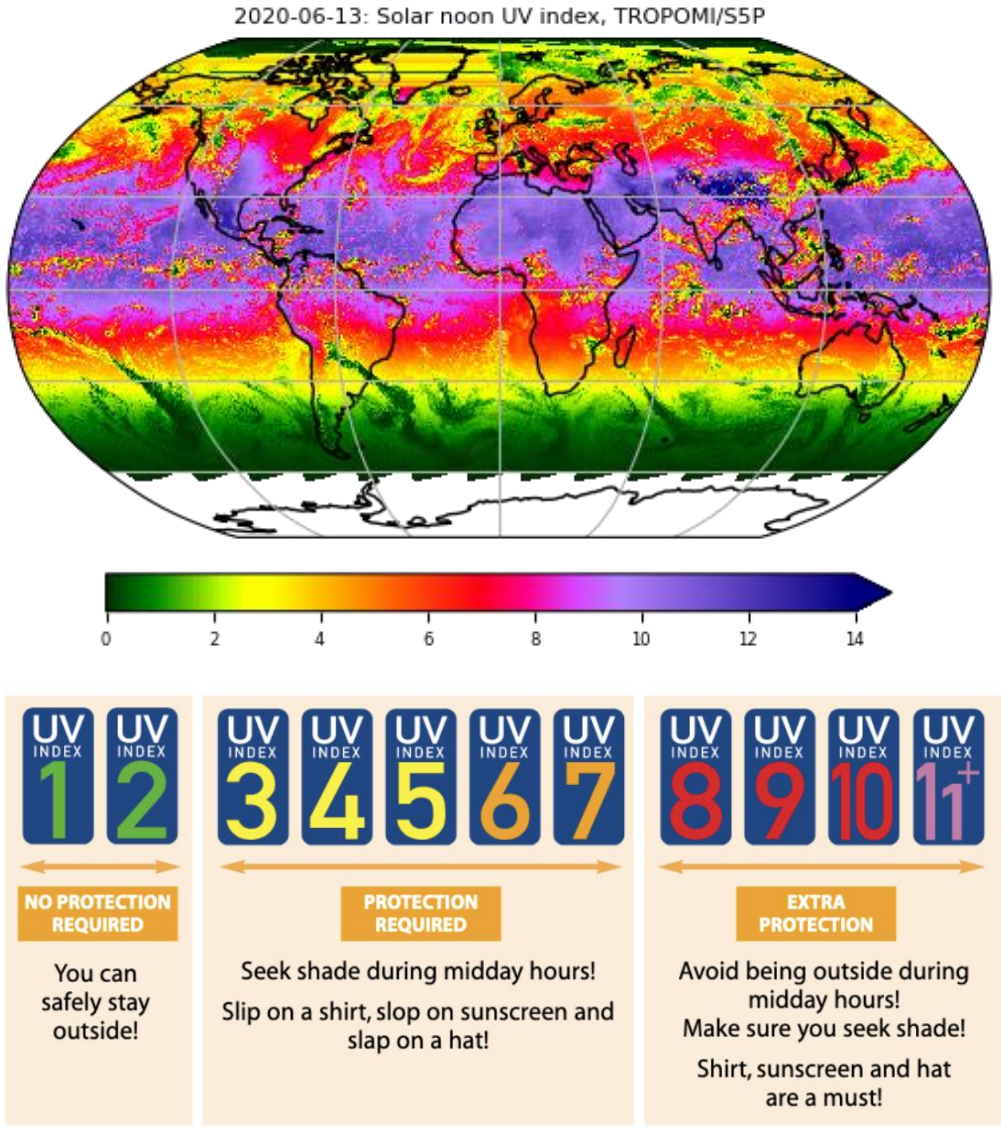
- UV radiation reaching the Earth's surface can be estimated by radiative transfer modelling using satellite data of total column ozone together with cloud, aerosol and surface properties as input.
- Surface UV products derived from polar orbiting satellites cover the whole globe and complement traditional ground-based measurements.
- S5P/TROPOMI surface UV radiation product is provided operationally as an in-kind contribution to S5P mission by the Finnish Meteorological Institute (FMI).
- TROPOMI UV data set continues UV time series of TOMS, OMI and GOME/GOME-2 . The overpass time is close to OMI overpass time.
- Both offline and NRT products are processed.

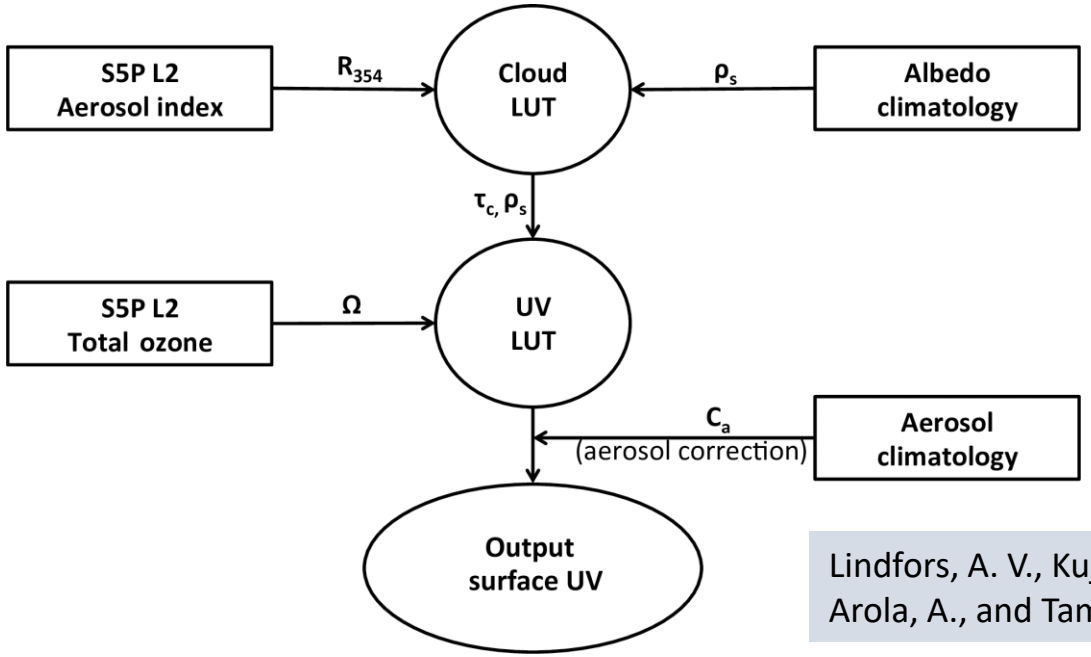


Algorithm and product

Input data:

- **Total column ozone** from TROPOMI L2 product
- **Reflectance at 354 nm** form TROPOMI Aerosol index product for retrieving cloud optical depth.
- **Surface albedo** and **Absorbing aerosol** correction factors from climatology.

To speed up processing radiative transfer computations are approximated with pre-computed Look-up-Tables.



TROPOMI UV product:

- Overpass and solar noon **irradiance** at 305, 310, 324 and 380 nm
- Overpass and solar noon **Erythemal dose rate**
- Overpass and solar noon **Vitamin D weighted dose rate**
- Erythemally weighted daily dose
- Vitamin D weighted daily dose
- Daily accumulated irradiances at 305, 310, 324 and 380 nm
- Overpass and solar noon **UV index**
- + all these for clear sky
- Quality flags

Lindfors, A. V., Kujanpää, J., Kalakoski, N., Heikkilä, A., Lakkala, K., Mielonen, T., Sneep, M., Krotkov, N. A., Arola, A., and Tamminen, J.: The TROPOMI surface UV algorithm, Atmos. Meas. Tech., 11, 997–1008,

Validation vs. ground-based measurements

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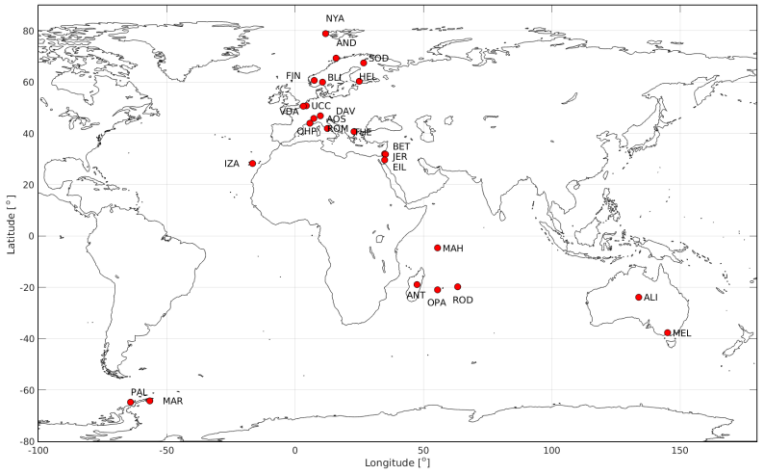
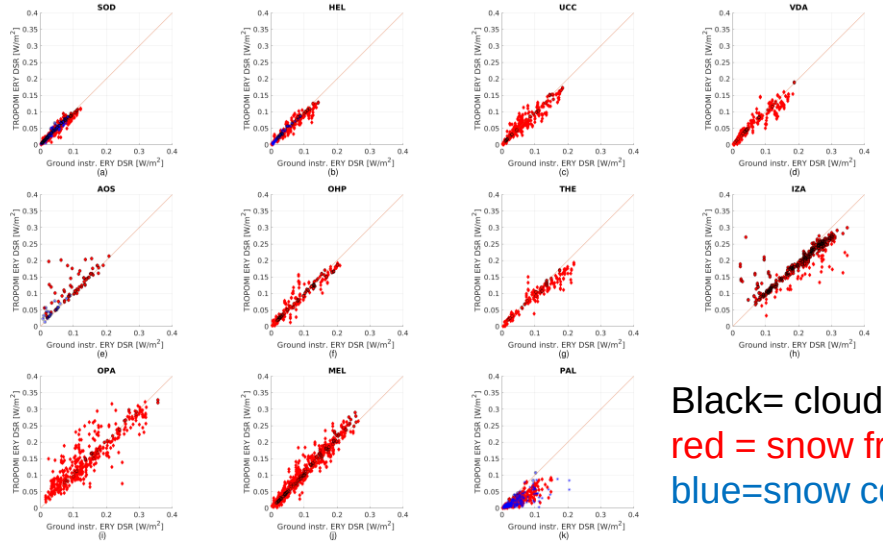
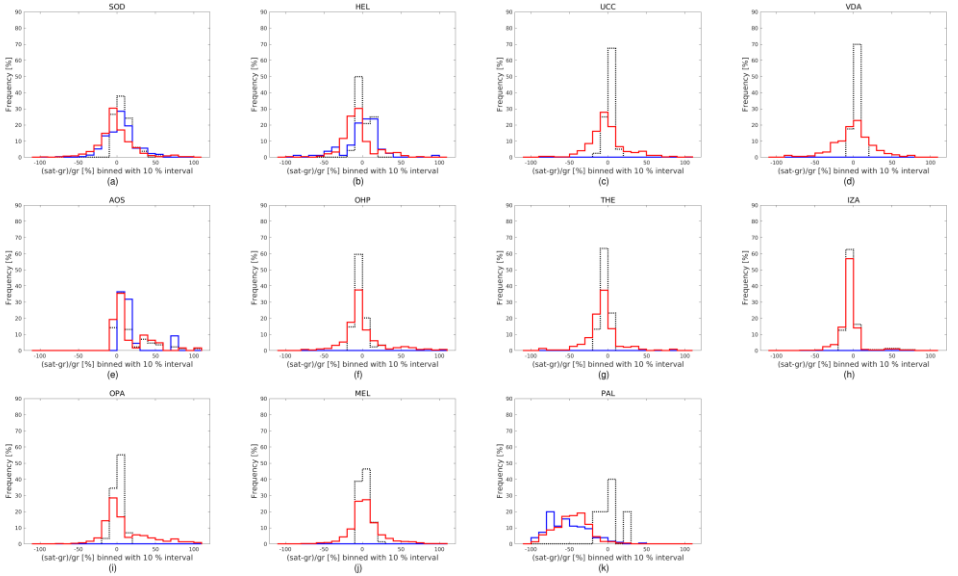
- TROPOMI UV product validation presented in Lakkala *et al.* 2020
- Validation of erythemal UV dose rate, erythemal daily dose and irradiances at selected wavelengths (1.1. 2018 – 31.8. 2019)
- 25 ground based validation sites located in arctic, subarctic, temperate, equatorial and Antarctic areas.
- Overall good results, and in agreement with the quality flags which indicate increased uncertainties in the data due to heterogeneous surface albedo and rough terrain.





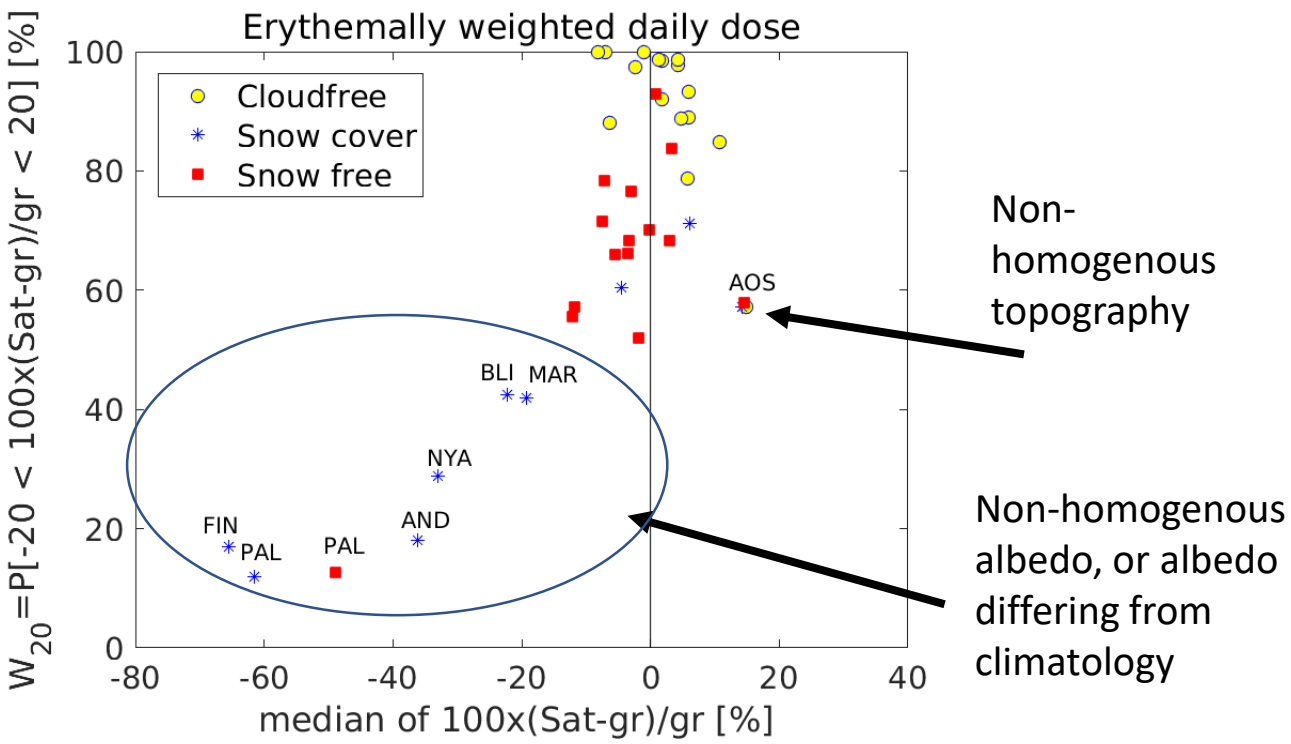
Black= cloud free
red = snow free
blue=snow cover



Lakkala et al, Validation of the TROPOspheric Monitoring Instrument (TROPOMI) surface UV radiation product, Atmos. Meas. Tech., 13, 6999–7024, 2020

Summary of validation

- For snow free surface, most of the TROPOMI data agreed within ±10% with ground-based data.
- For all UV parameters larger differences found at challenging conditions related to non-homogeneous topography, non-homogeneous surface albedo, or surface albedo differing from the albedo climatology used by the TROPOMI UV algorithm.
- UV product will be re-processed along with the mission re-processing.
- Improvement for surface albedo planned.

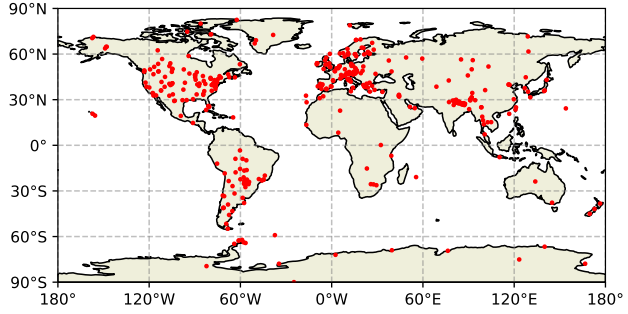


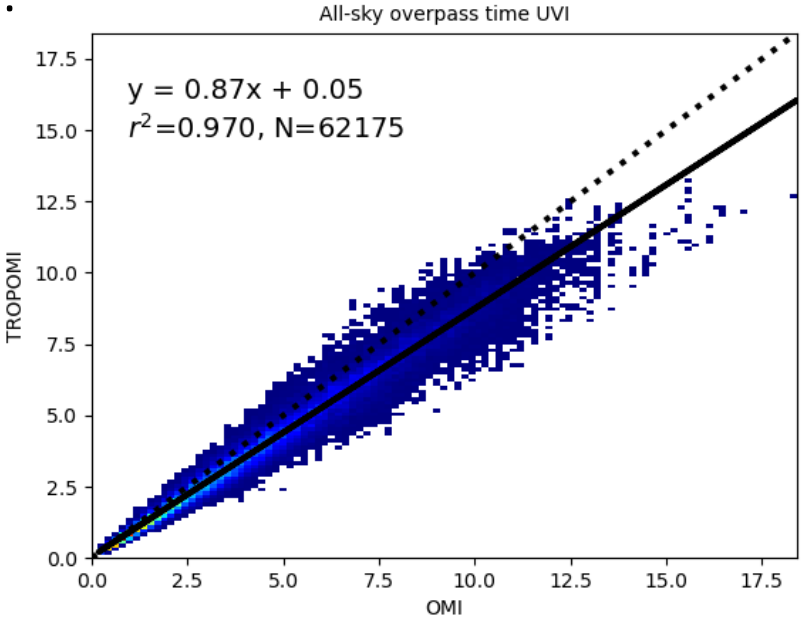
Portion of agreement within 20% vs Median difference

Lakkala et al, Validation of the TROPOspheric Monitoring Instrument (TROPOMI) surface UV radiation product, Atmos. Meas. Tech., 13, 6999–7024, 2020

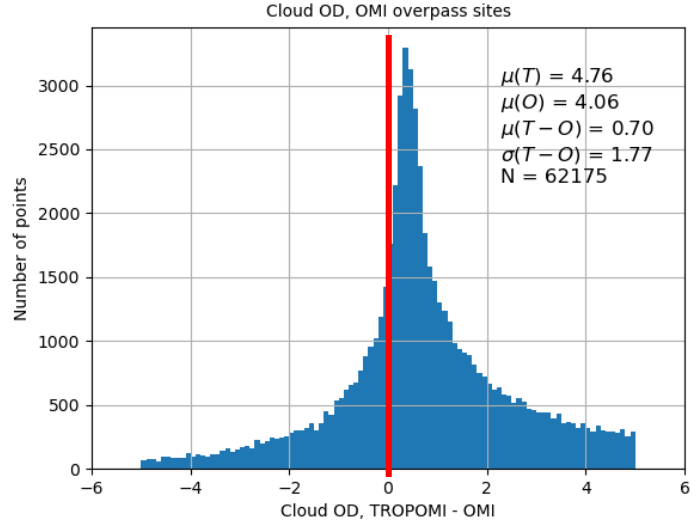
TROPOMI - OMI intercomparison at AVDC sites

- TROPOMI overpass time UV index data were compared with OMI data at the 391 OMI overpass sites given in the Aura Data Validation Center (AVDC).
- Time period: 16 Nov 2017 – 15 Oct 2020
- Scatter plot indicate very good correlation between the instruments and that TROPOMI UVI is somewhat smaller than OMI. Difference at mean level 12%.
- This is in agreement with the larger cloud optical depth and total ozone seen by TROPOMI.

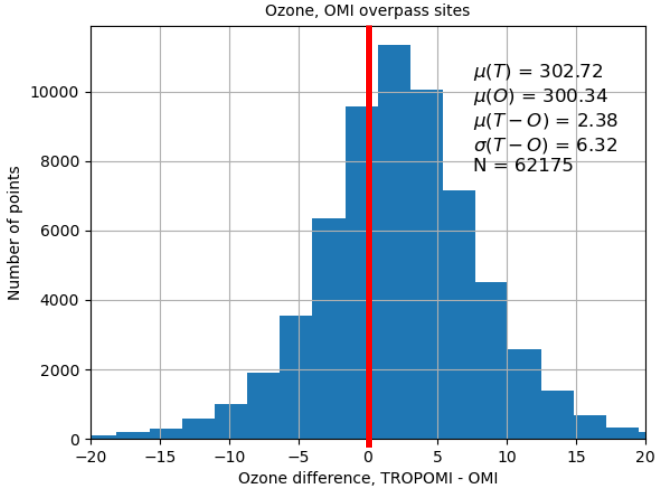




Lakkala et al,, 2020



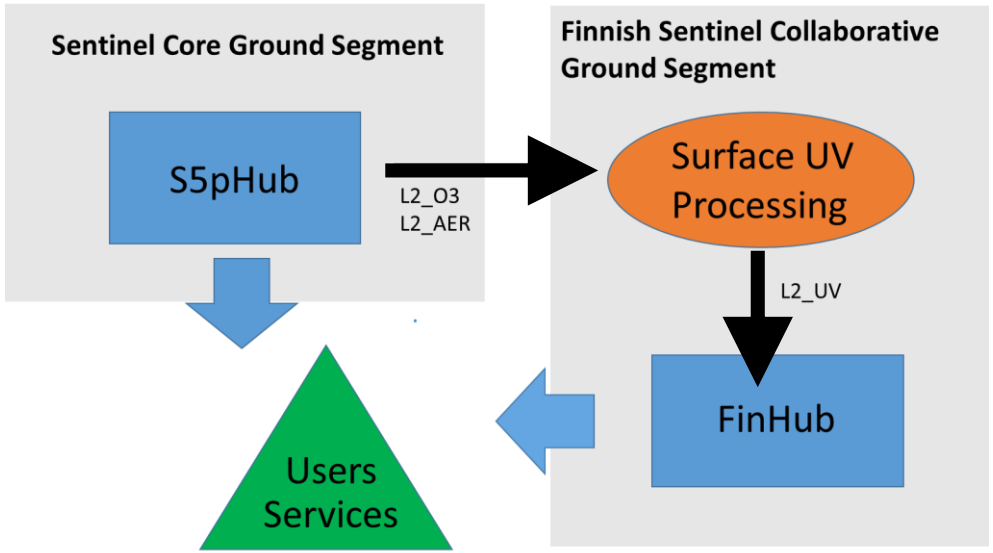
Difference in **cloud optical depth**: TROPOMI sees clouds thicker than OMI

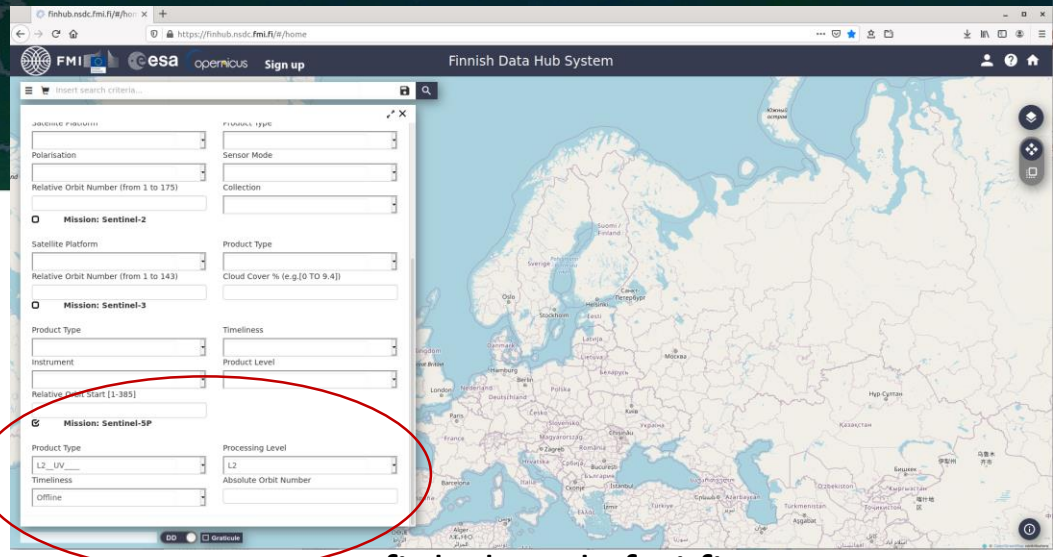


Difference in ozone: TROPOMI **total ozone** is slightly (ca. 1 %) larger than OMI

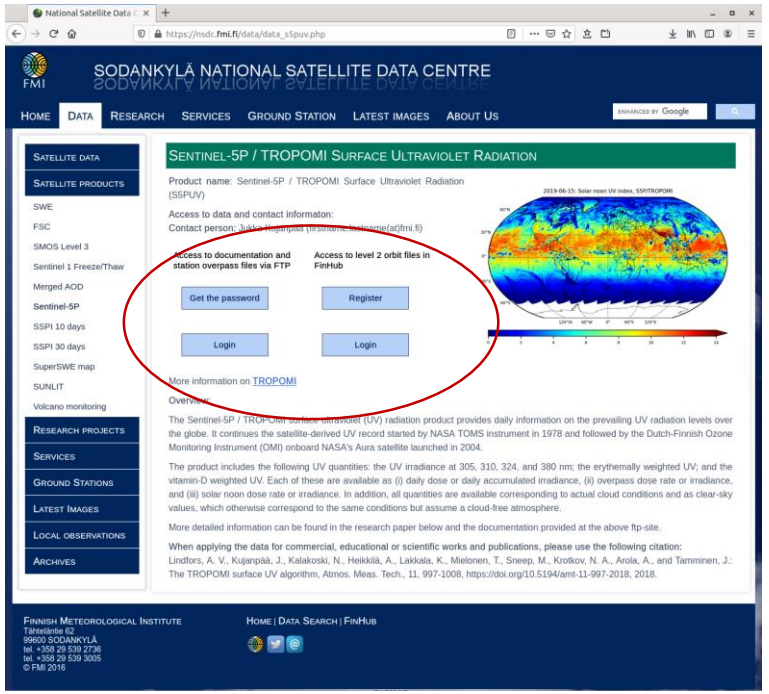
Processing, archiving and distribution

- The TROPOMI UV product is processed and archived at the Finnish Sentinel Collaborative Ground Segment in Sodankylä, Finland.
- **Offline UV product L2 orbit files** are available at Finnish Data Hub (FinHub) exposing the standard Sentinel data discovery and download options provided by the Data Hub Software (DHuS)
- **NRT, overpass and product documentation** are available at ftp site. Access can be obtained from the product web page at the Sodankylä National Data Center: https://nsdc.fmi.fi/data/data_s5puv.php





finhub.nsdc.fmi.fi



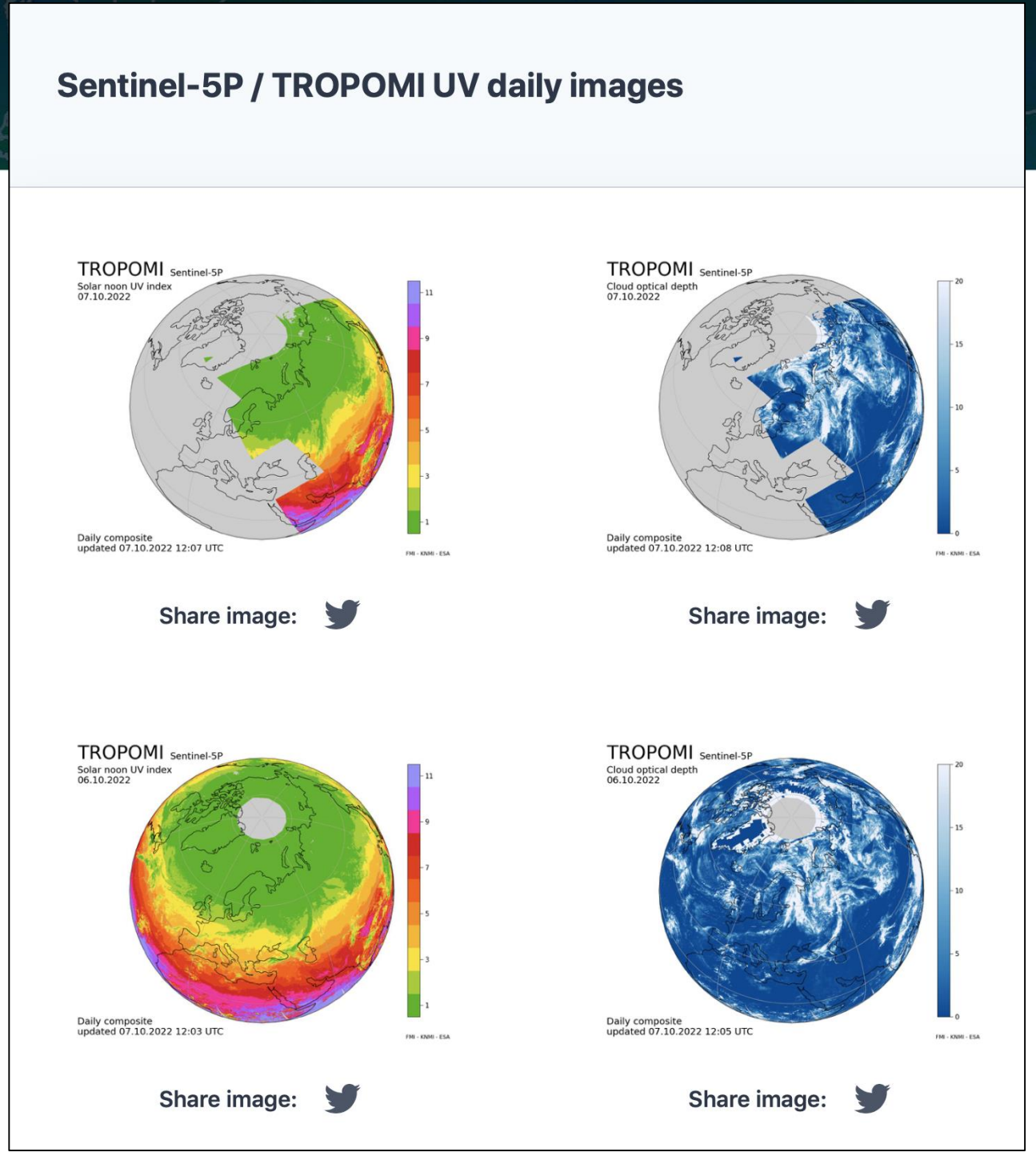
https://nsdc.fmi.fi/data/data_s5puv.php

NRT data

NRT daily images

sampo.fmi.fi/s5puv/

Improvement suggestions welcome!



Record–breaking increases in Arctic UV in spring 2020

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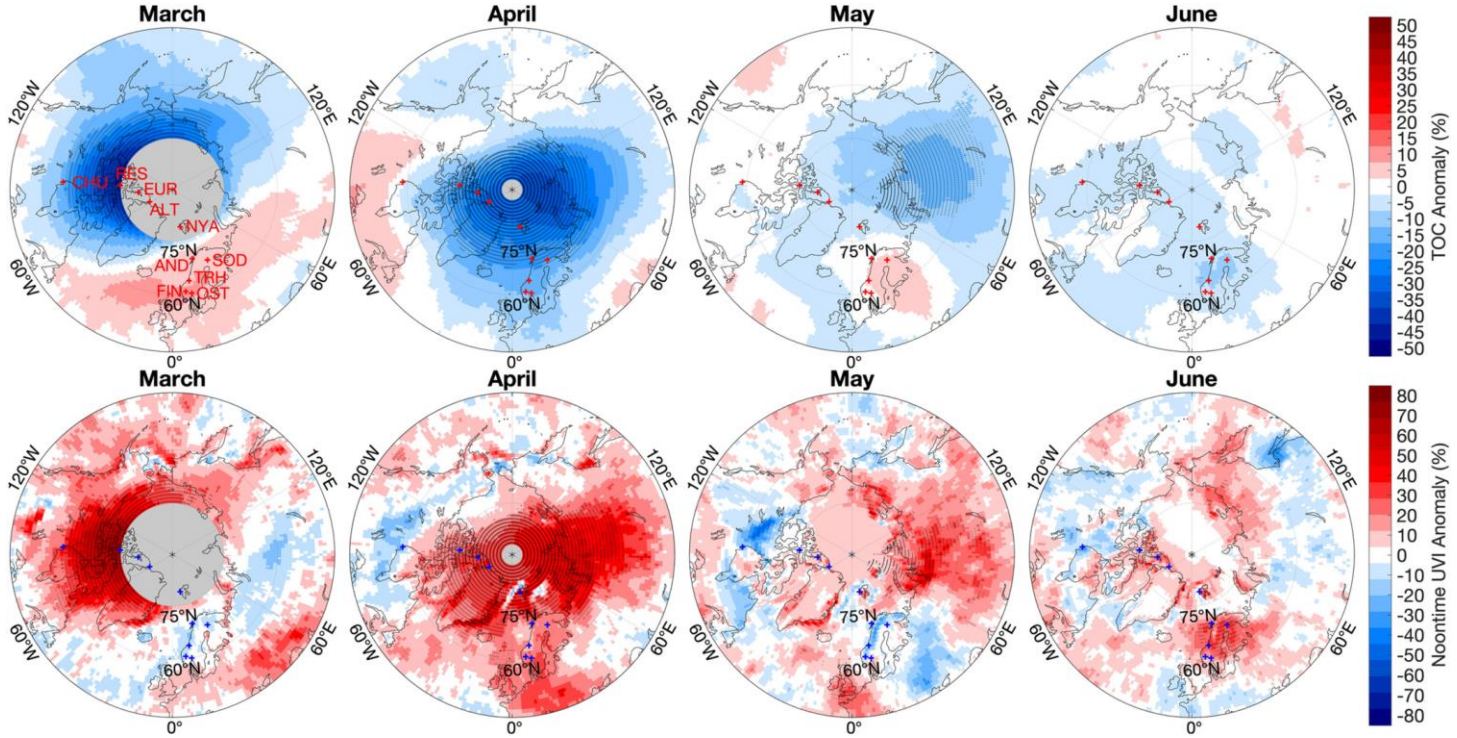
- Record-breaking low total ozone over the Arctic in March and April 2020 led to unprecedently large increases of UV radiation at Earth's surface (Bernhard et al., GRL, 2020)
- OMI ozone and UV radiation in 2020 compared to historical record 2005 – 2019.
- Monthly average UVI anomalies in March and April between 30 – 70% in large parts.
- In northern Canada, the average UVI for March was 75% larger than usual.

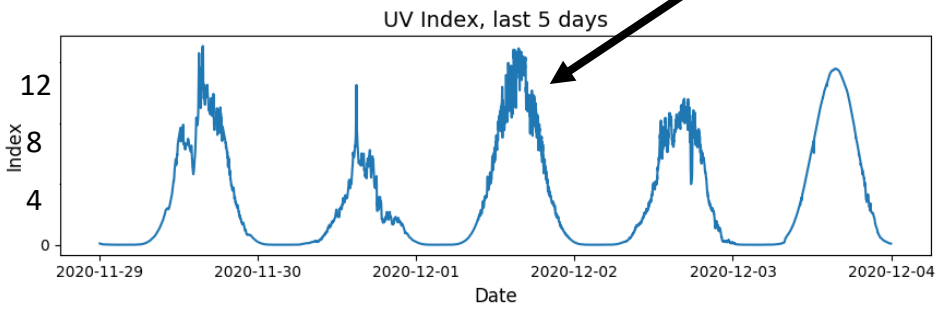


Spatial deviations of monthly average TOCs and UVIs for March, April, May, and June 2020 from the historical (2005–2019) mean estimated from OMI data.

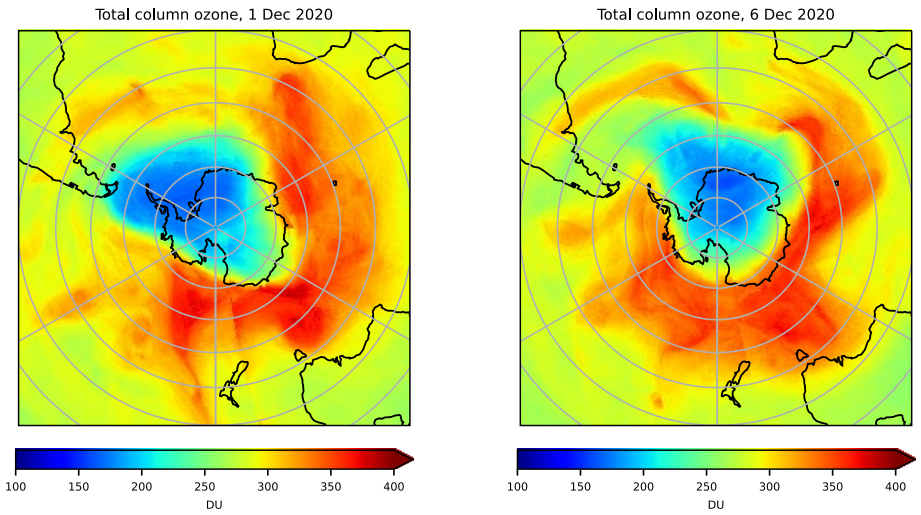
Bernhard, G. H., Fioletov, V. E., Grooß, J.-U., Ialongo, I., Johnsen, B., Lakkala, K., et al. (2020). Record-breaking increases in Arctic solar ultraviolet radiation caused by exceptionally large ozone depletion in 2020. *Geophysical Research Letters*, 47, e2020GL090844. https://doi.org/10.1029/2020GL090844

High Antarctic UVI in early December 2020

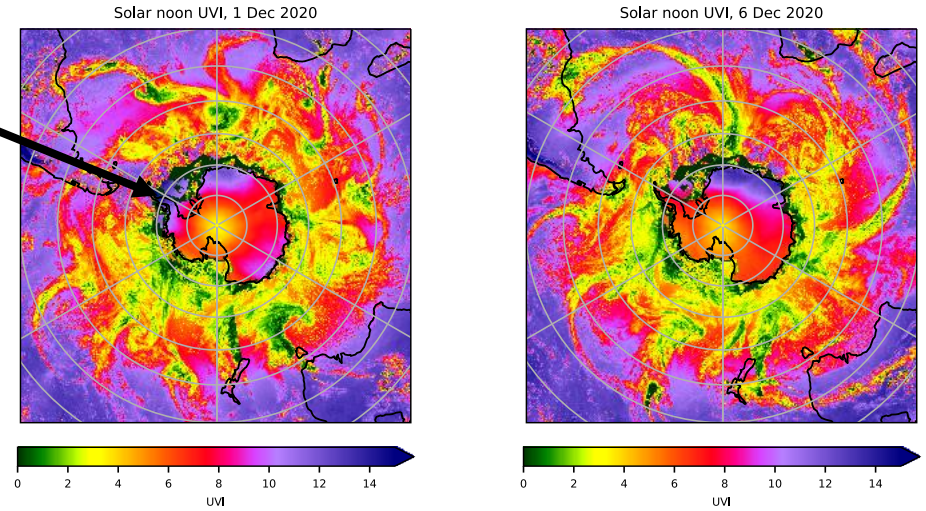
- In 2020, Antarctic polar vortex and the resulting low total ozone values persisted unusually long until December, close to the Southern Hemisphere midsummer.
- As a result, exceptionally high UV index values, typical to tropics, were observed in the costal areas of Antarctica in early December
- This was seen in the TROPOMI surface UV product, and by ground-based measurements in Marambio (64.23 S, 56.63 W)



UV Index measured by GUV-radiometer during 29 Nov - 3 Dec 2020 (instrument owned by Finnish Meteorological Institute (FMI), measurements are made in collaboration with FMI and Servicio Meteorológico Nacional, Argentina).



TROPOMI total column ozone (product by DLR/ESA/EU Copernicus, image FMI)



TROPOMI surface UV product, Solar noon UV index

Summary

- Surface UV radiation is important parameter for atmospheric chemistry, biosphere, health, carbon cycle and climate.
- Global TROPOMI UV radiation data products are processed from the beginning of the mission.
- Offline data are available from Sentinel FinHub
- NRT data available from FTP site.
- Re-processing expected next year (TBD).
- To-Do with ESA: linking FinHub data to S5P-Hubs and commonly used data browsers.
- To-Do: Develop long time UV-data record by combining OMI and TROPOMI UV data records. Long overlap of the two products is valuable.