



Royal Netherlands  
Meteorological Institute  
*Ministry of Infrastructure  
and Water Management*



# Ozone monitoring from space by TROPOMI

Piet Stammes (KNMI, De Bilt)

On behalf of Pepijn Veeffkind and the  
international TROPOMI team

*"50 years of ozonesonde measurements at Uccle",  
19 Sept 2019*



# First ozone balloon sounding in De Bilt in November 1992

- › Ozone soundings at KNMI began 27 years ago, by the group of Hennie Kelder, inspired by the work at KMI by Dirk de Muer and his team.

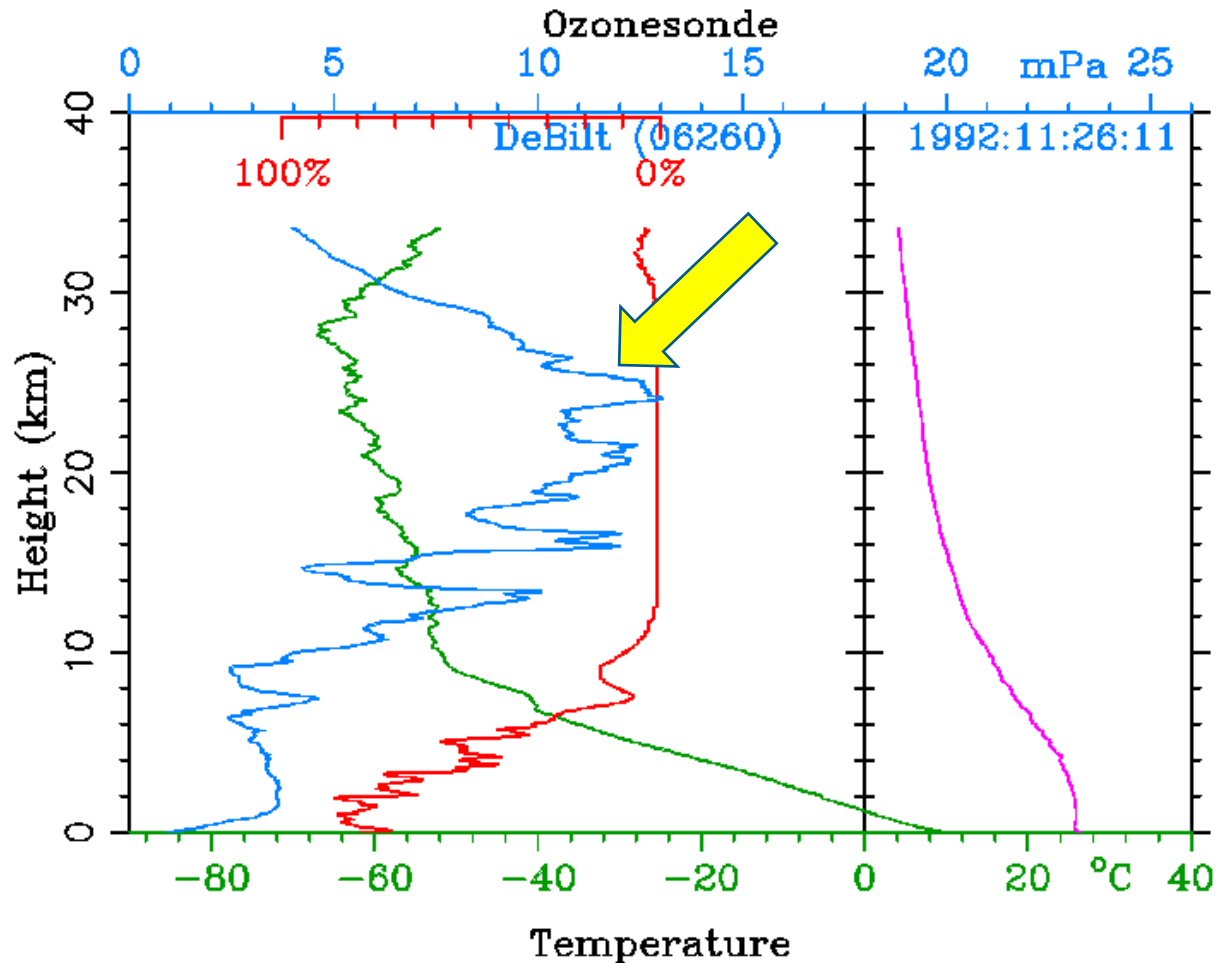


Figure by Marc Allaart (KNMI)



Hennie Kelder

- › 1530 sondes have been launched since 1992.
- › Weekly launches on Thursday.



# Paramaribo

5.8 N, 55.2 W

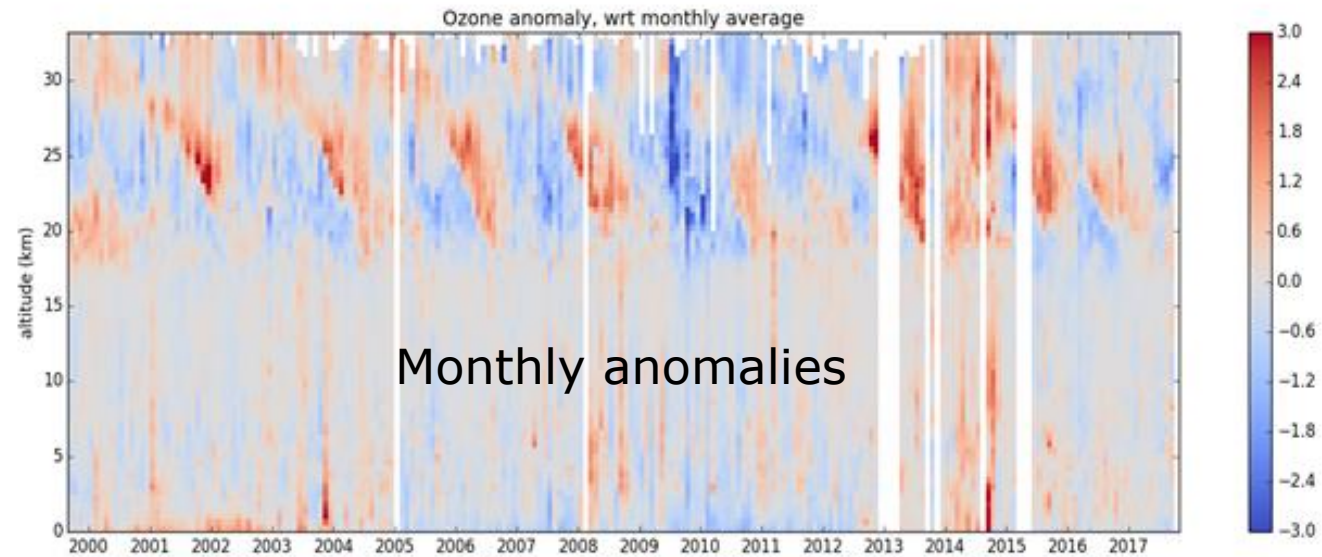
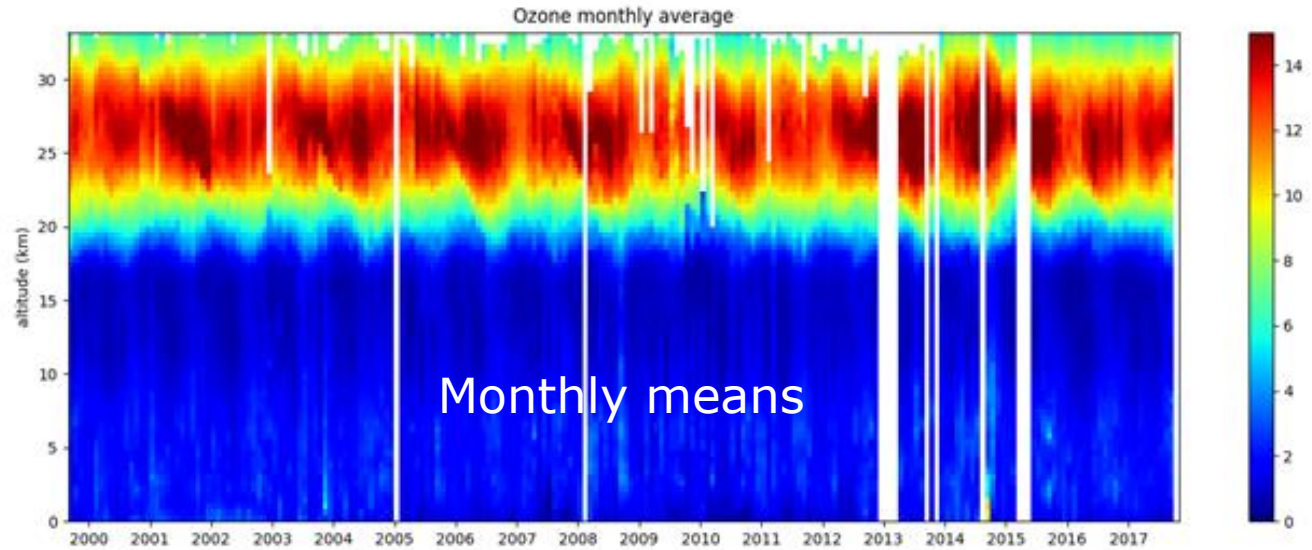


## Paramaribo station:

- › Weekly ozone soundings since August 1999
- › Launched by Meteorological Service of Surinam (MDS)
- › Important station for tropical dynamics and satellite validation
- › Also Brewer and radiation instruments (candidate BSRN station)

# Paramaribo ozone profiles

1999 - 2017



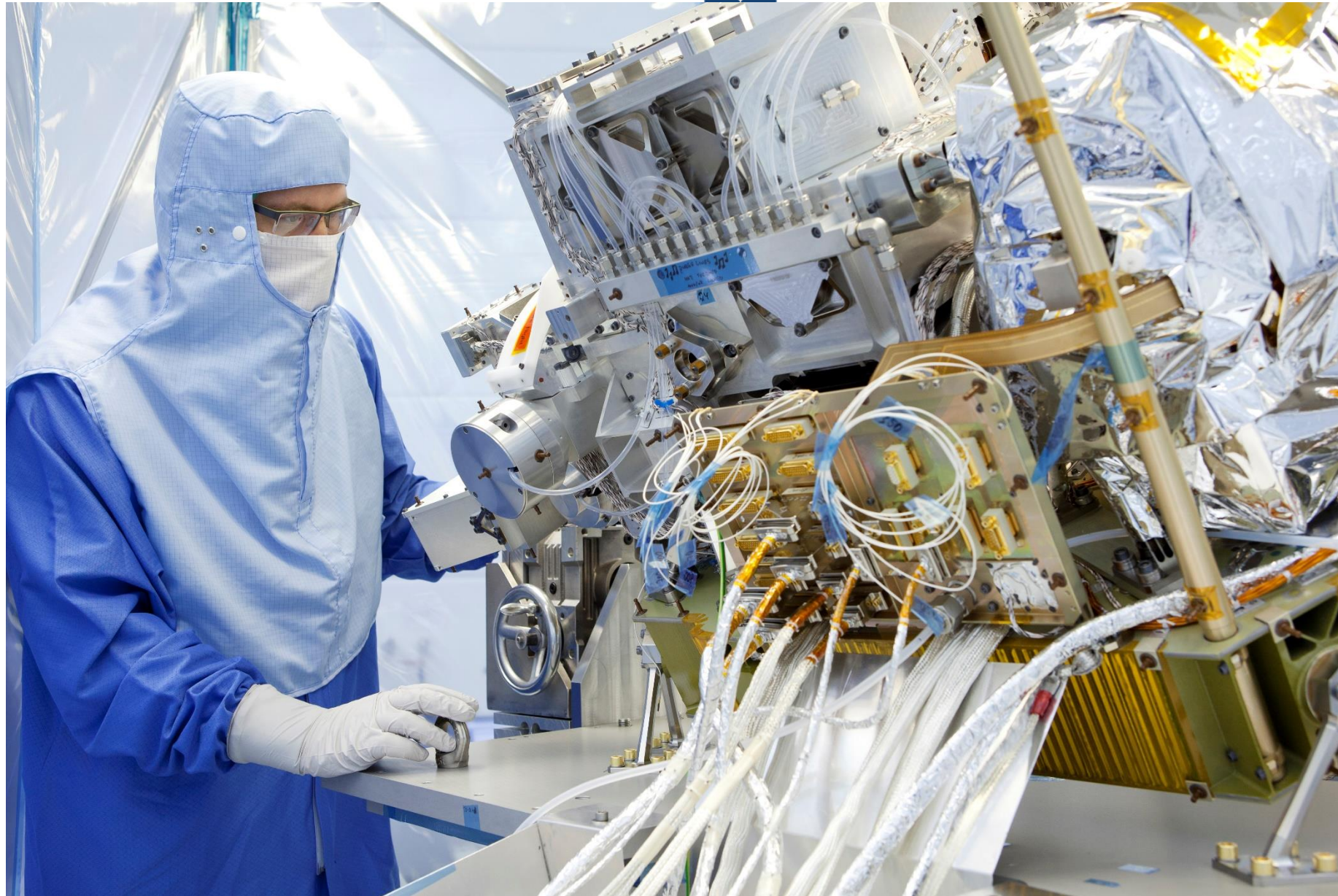
*Work by:*

*Paul Fortuin  
Ankie Piters  
Marc Allaart  
Rinus Scheele  
(KNMI)*



# Overview

1. TROPOMI on ESA/EU's Sentinel-5 Precursor
2. Data products
3. Stratospheric ozone
4. Tropospheric ozone and ozone precursors



Instrument designed and built by TNO and Airbus D&S



## SENTINEL 5 PRECURSOR

Launch	13 October 2017
Launcher	Rockot from Plesetsk Russia
Orbit	Polar Sun synchronous, altitude 824 km
Overpass time	13:30 local time
Mission duration	7 year
Satellite	Airbus Astrobuss-M, height 3,55 m, 5,63 m diameter, mass 820 kg
Payload	Tropospheric Monitoring Instrument (TROPOMI)
Ground stations	Svalbard (Norway), Inuvik (Canada) and Kiruna (Sweden)
Data processing	DLR Oberpfaffenhofen (Germany) KNMI De Bilt (The Netherlands)





# TROPOMI characteristics:



Yesterday, 18 Sept 2019, at 06:20 UT

- > UV, Visible, Near-IR, and Shortwave-IR bands
  - **SCIAMACHY/Envisat heritage**
- > 2D detectors
  - **OMI/Aura heritage**
- > Pixel size 3.5 x 5.5 km<sup>2</sup>
  - **Before 6 August 3.5 x 7 km<sup>2</sup>**
- > Daily global coverage
  - **OMI/Aura heritage**





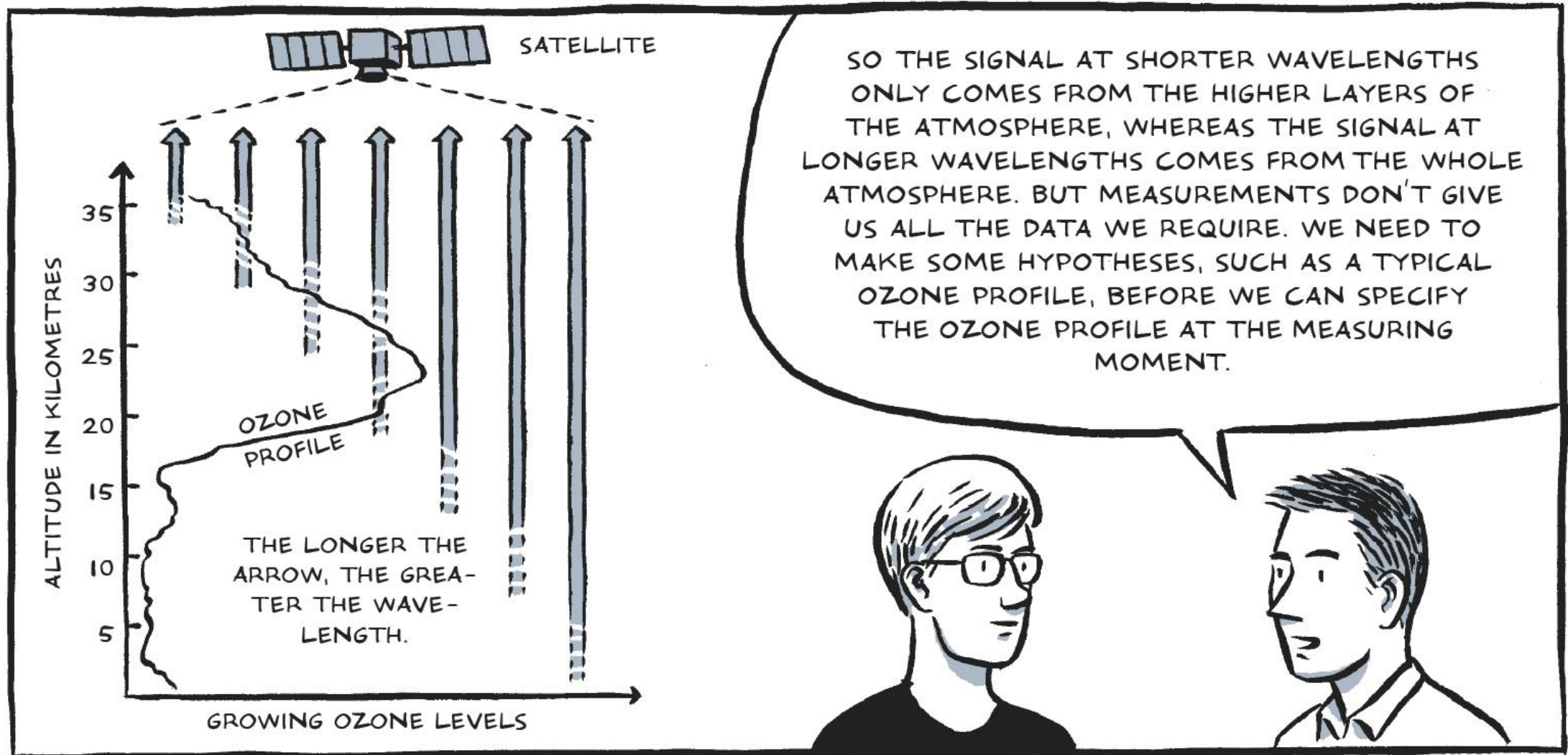
# TROPOMI data products



Product	Spectrometer	Application
<b>O<sub>3</sub> - Ozone</b>	UV, UVIS	Ozone layer, UV forecast, Weather forecast
<b>NO<sub>2</sub></b>	UVIS	Air quality
<b>CO</b>	SWIR	Air quality
<b>CH<sub>2</sub>O</b>	UVIS	Air quality
<b>CH<sub>4</sub> - methane</b>	SWIR	Climate
<b>SO<sub>2</sub></b>	UVIS	Air quality, Volcanos
<b>Aerosols</b>	UVIS, NIR	Air quality, Climate, Volcanos
<b>Clouds</b>	UVIS, NIR	Climate
<b>UV-Index</b>	UVIS	UV forecast

The TROPOMI algorithms are developed by a consortium of institutes from the Netherlands, Germany, Belgium, United Kingdom and Finland.

# Explanation of ozone profile retrieval





# TROPOMI UV spectrum (bands 1 & 2)

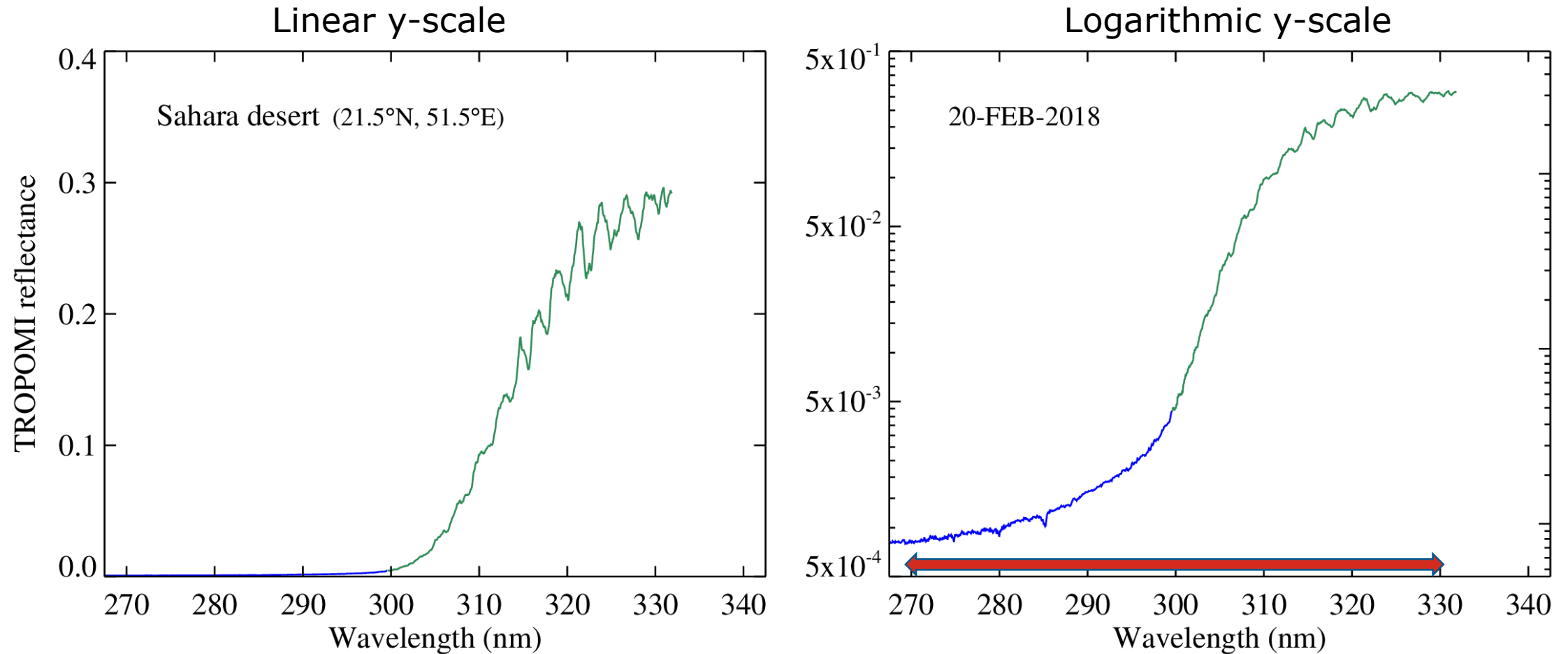


Figure by Gijs Tilstra, KNMI

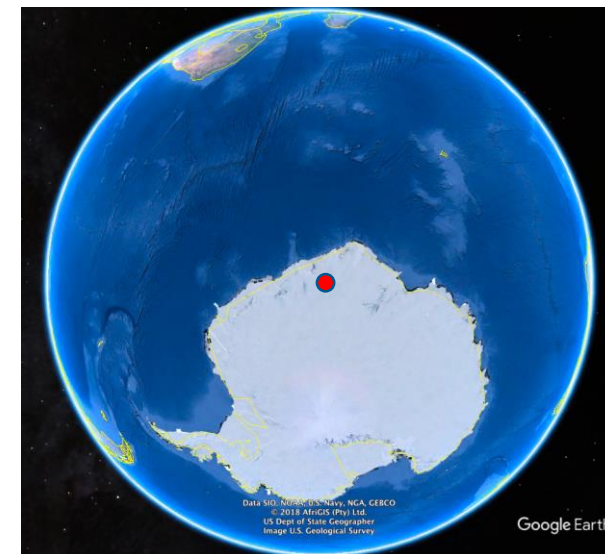
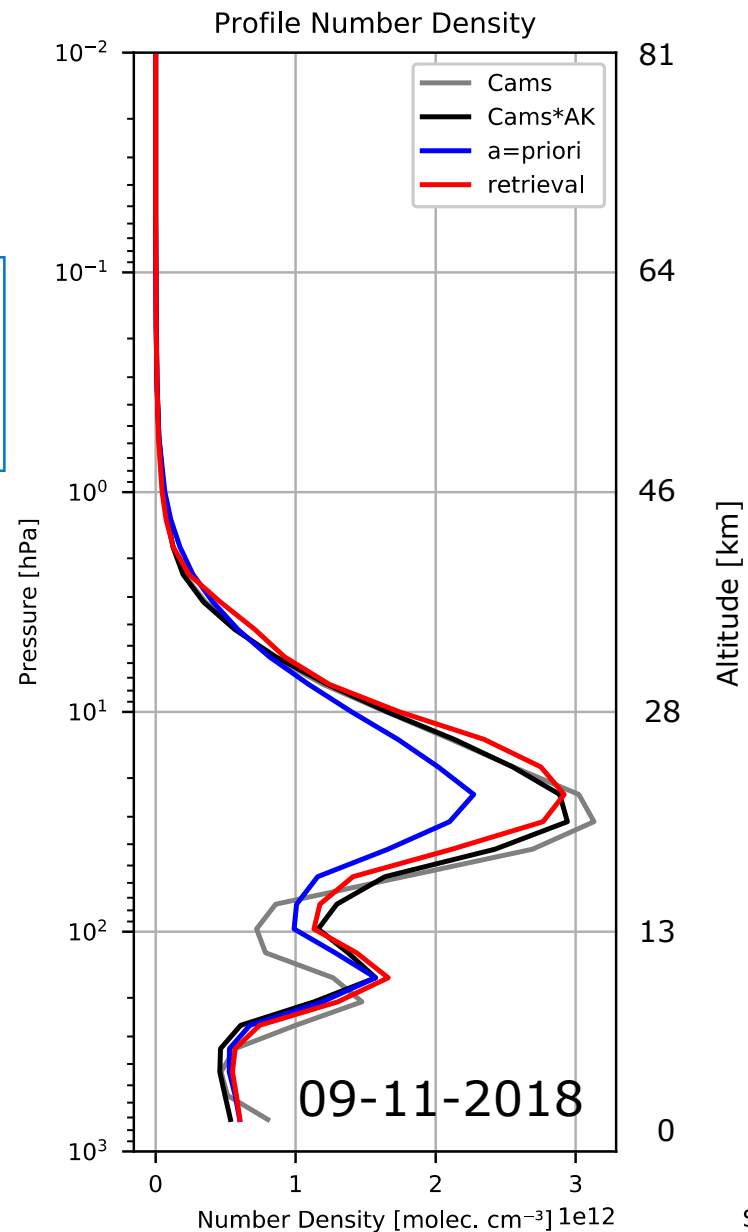
The entire spectrum of **270-330 nm** is used for ozone profile retrieval. This spectrum is on *one* detector.



# Ozone Profile

The O3 profile algorithm uses an a-priori profile based on sonde data.

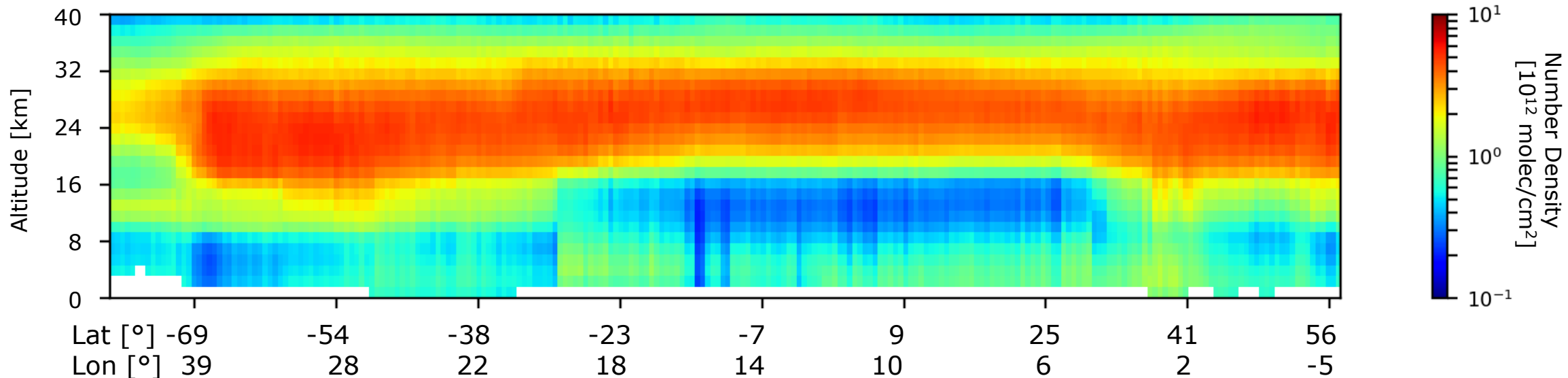
*Work by Pepijn Veefkind  
and Johan de Haan*



Pixel size for ozone profiles is about 25 x 25 km<sup>2</sup>



# Ozone Profile slice from SH to NH

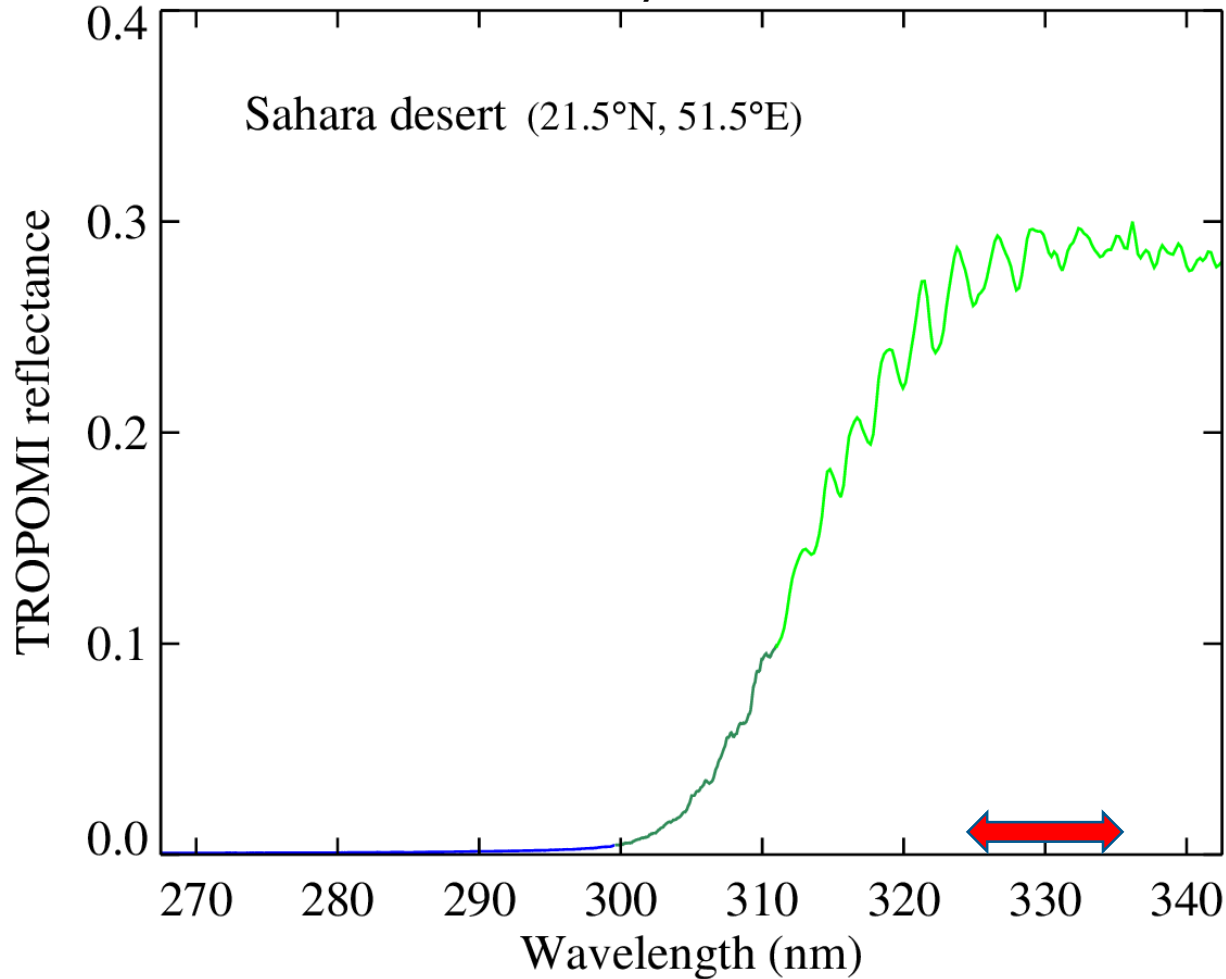


TROPOMI measures 77 slices at the same time

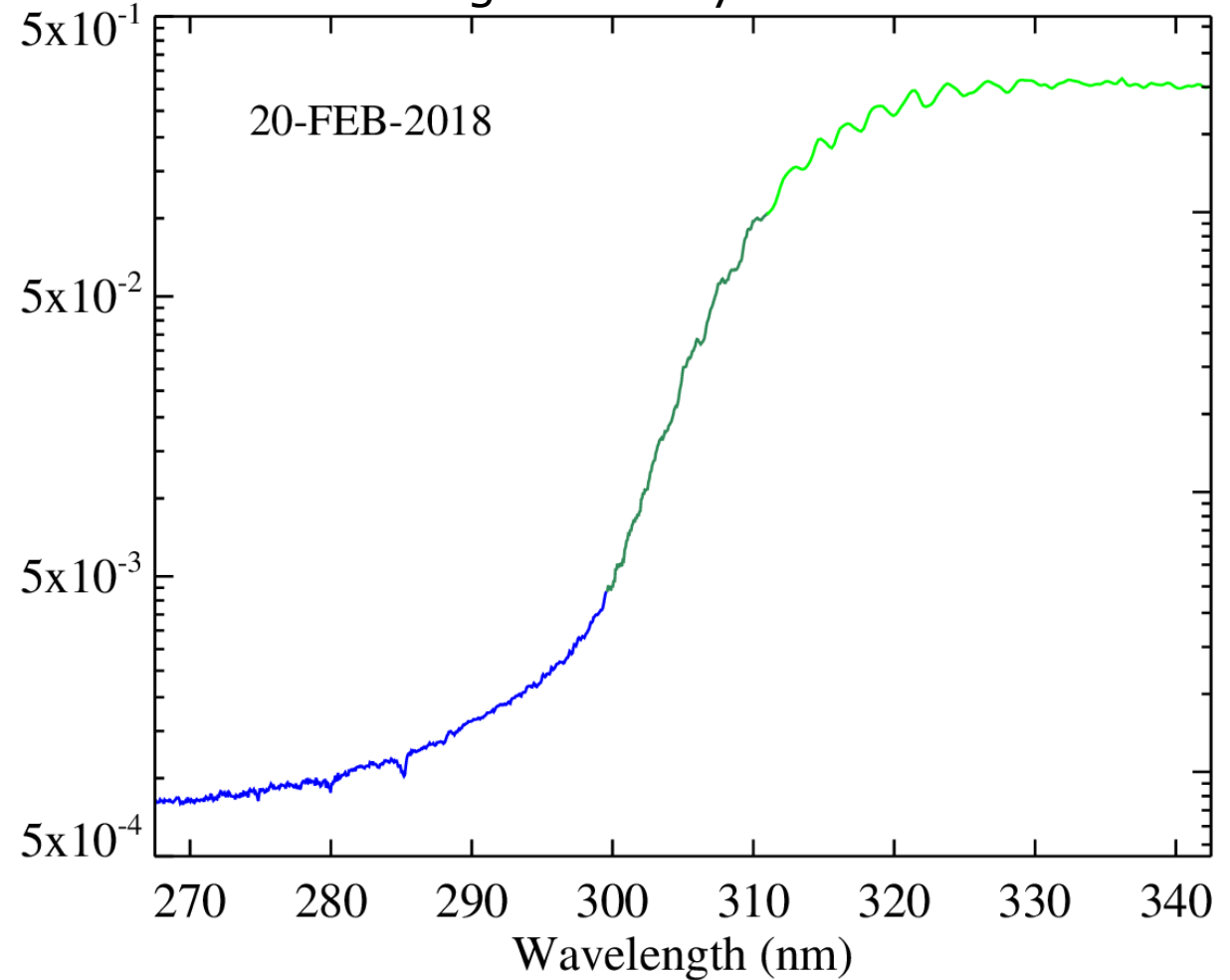
*Figure by Pepijn Veefkind, KNMI*

# TROPOMI UV spectrum (bands 1, 2 & 3)

Linear y-scale



Logarithmic y-scale

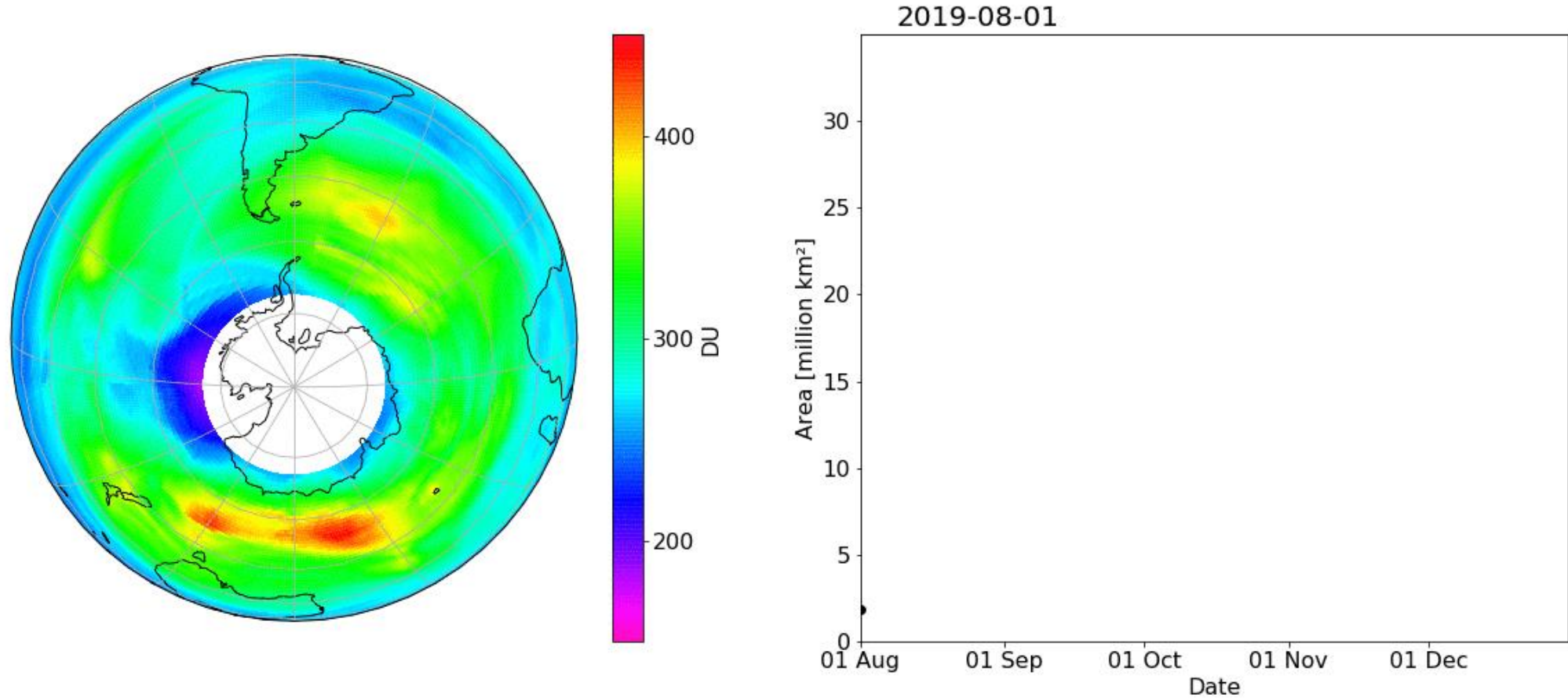


Total ozone retrieval uses the range from **325 – 335 nm**



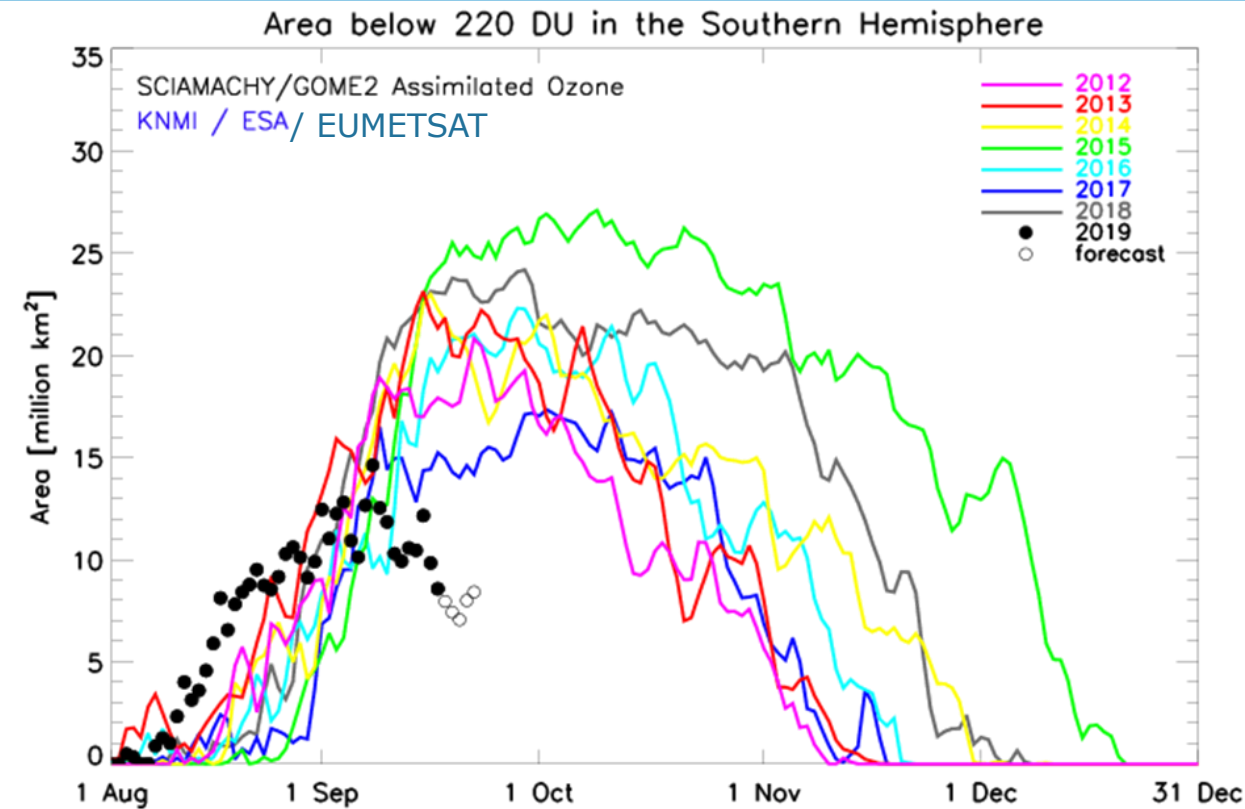
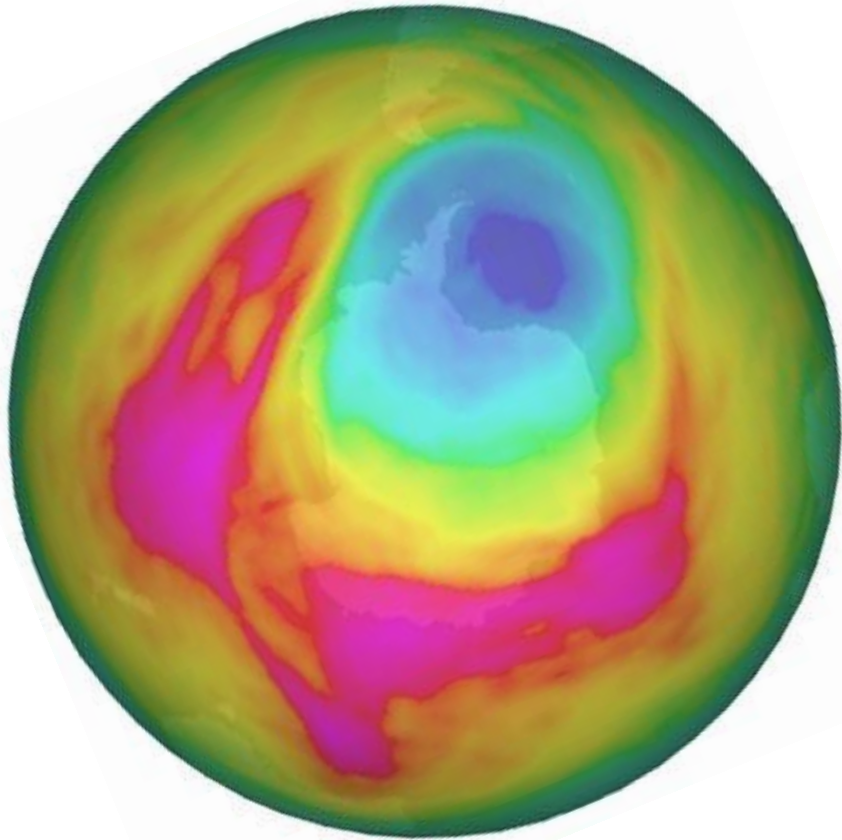
# Total ozone

Sentinel 5 Precursor, total ozone, DLR-BIRA



*Figure by Klaus-Peter Heue, DLR*

# Antarctic ozone on 19 Sept 2019



Forecast from temis.nl - ozone bulletin



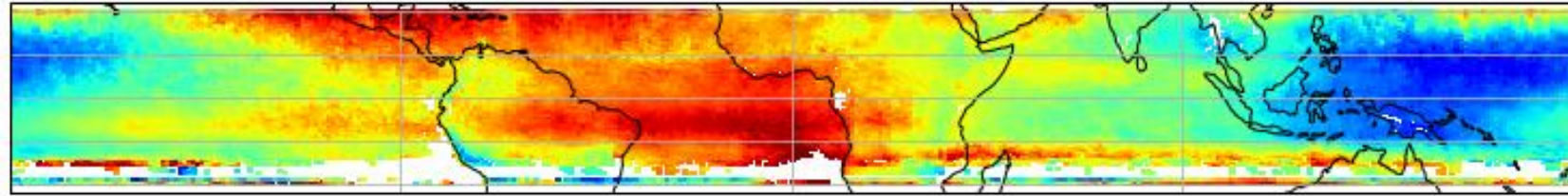


JJA, 2019

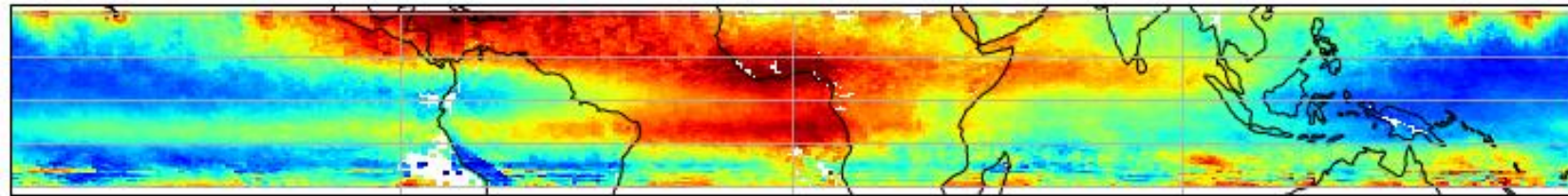
# Tropical tropospheric ozone

CCD method

Tropical tropospheric ozone for August 2019



Tropical tropospheric ozone for July 2019



Tropical tropospheric ozone for June 2019

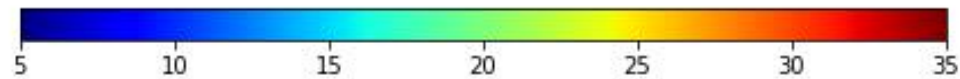
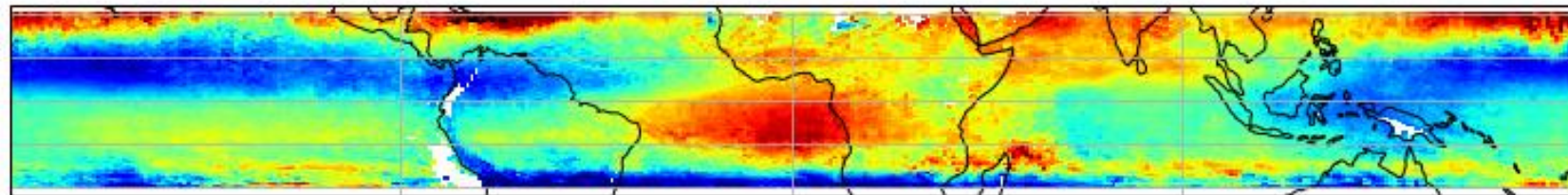
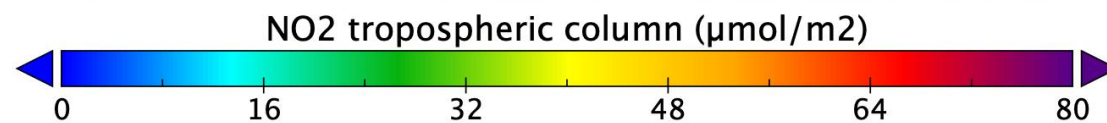
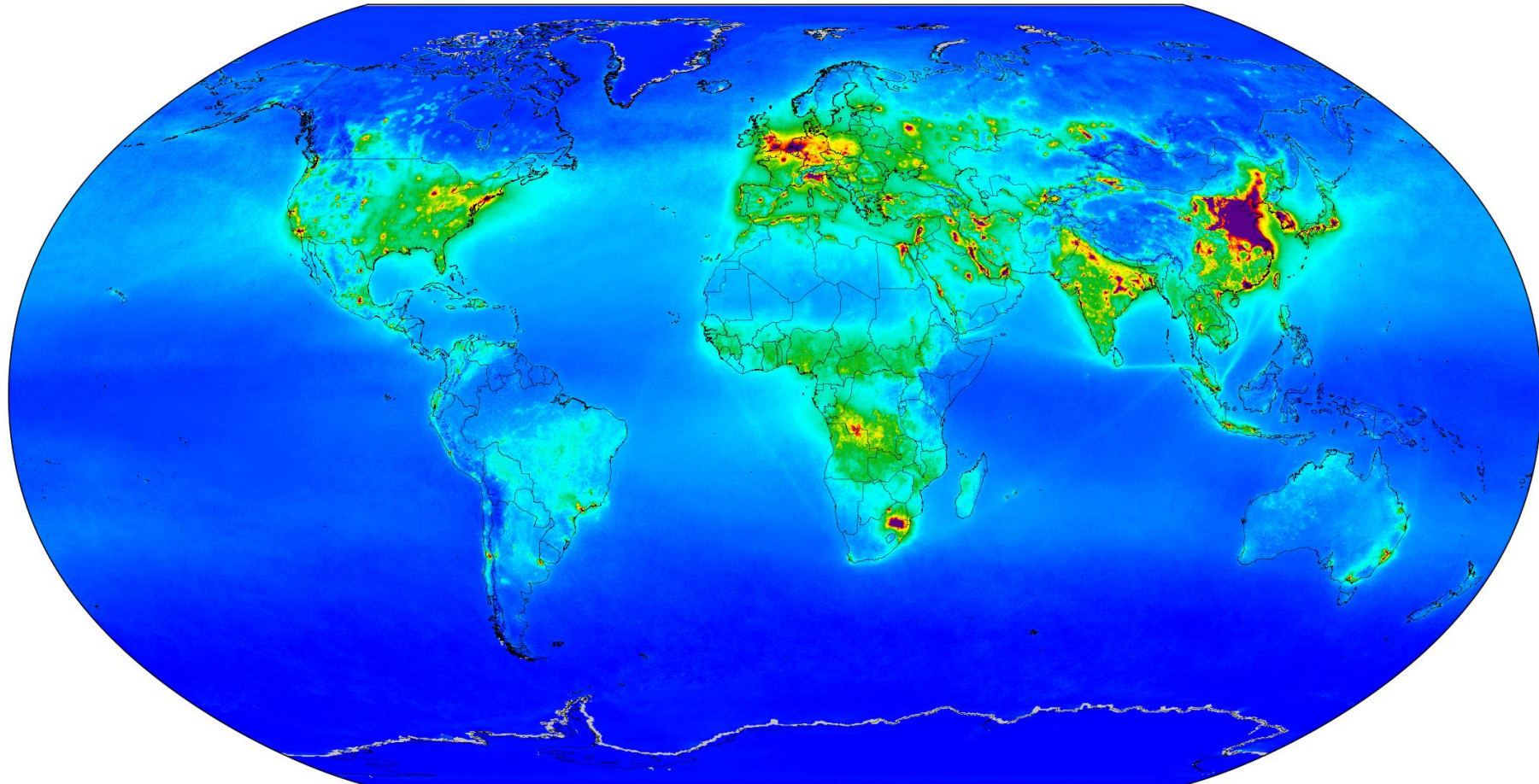


Figure by Klaus-Peter Heue, DLR



# Tropospheric Ozone Precursors: NO<sub>2</sub>

S5P NO<sub>2</sub> one-year mean, April 2018 – March 2019

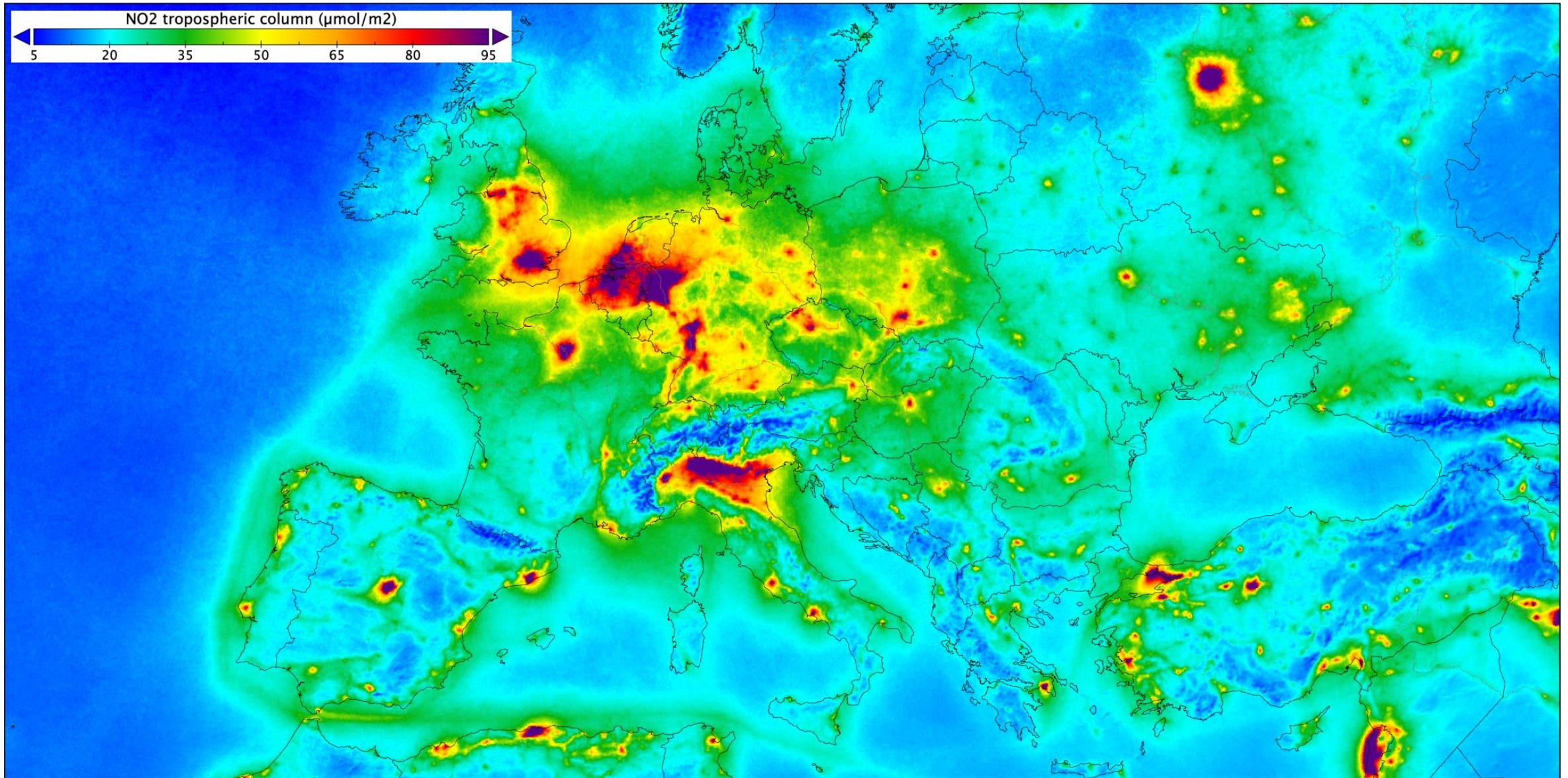


*Figure by Henk Eskes, KNMI*



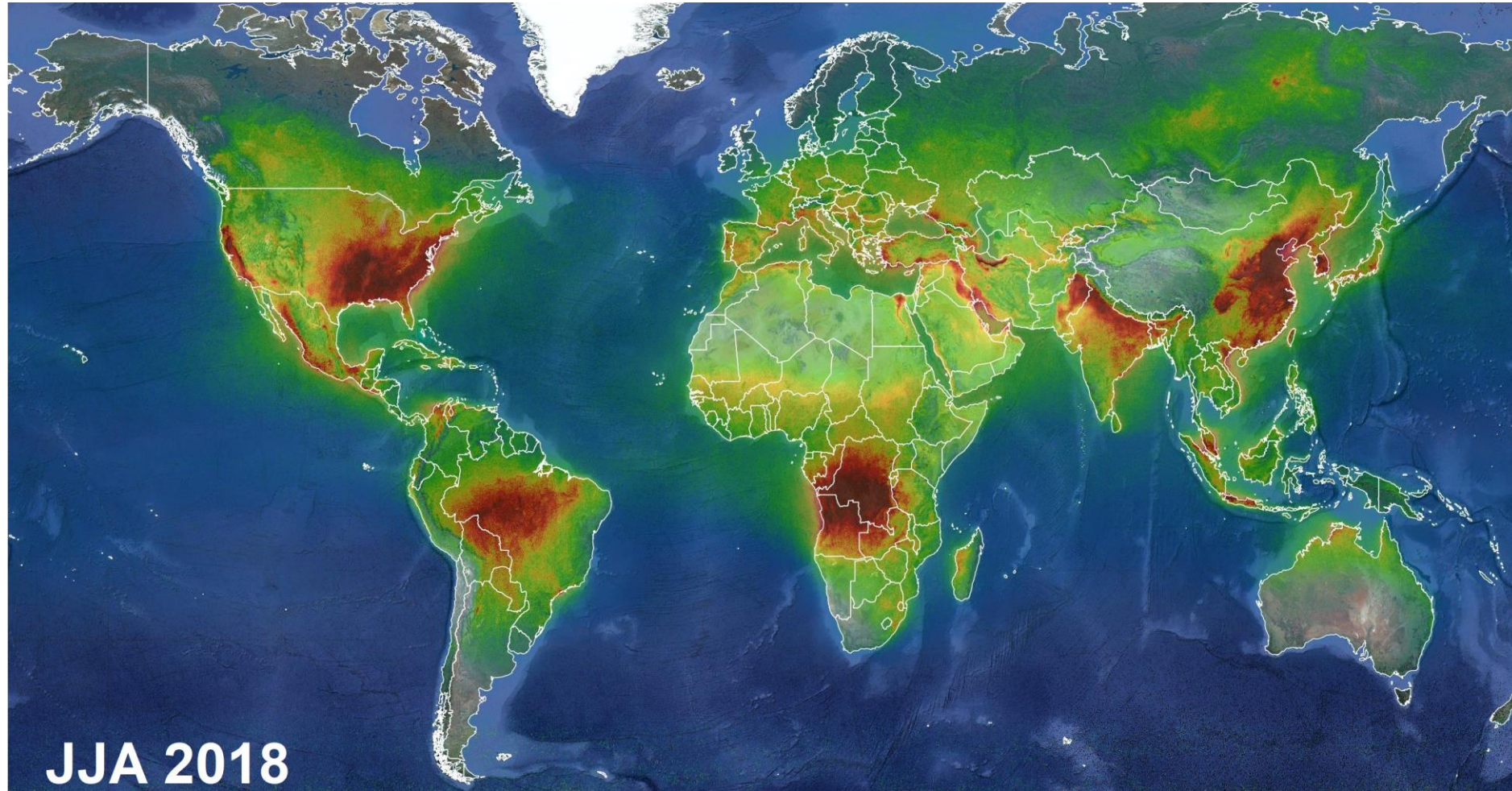
# Tropospheric Ozone Precursors: $\text{NO}_2$

*Figure by Henk Eskes, KNMI*





# Tropospheric Ozone Precursors: HCHO



BIRA-IASB / DLR / ESA

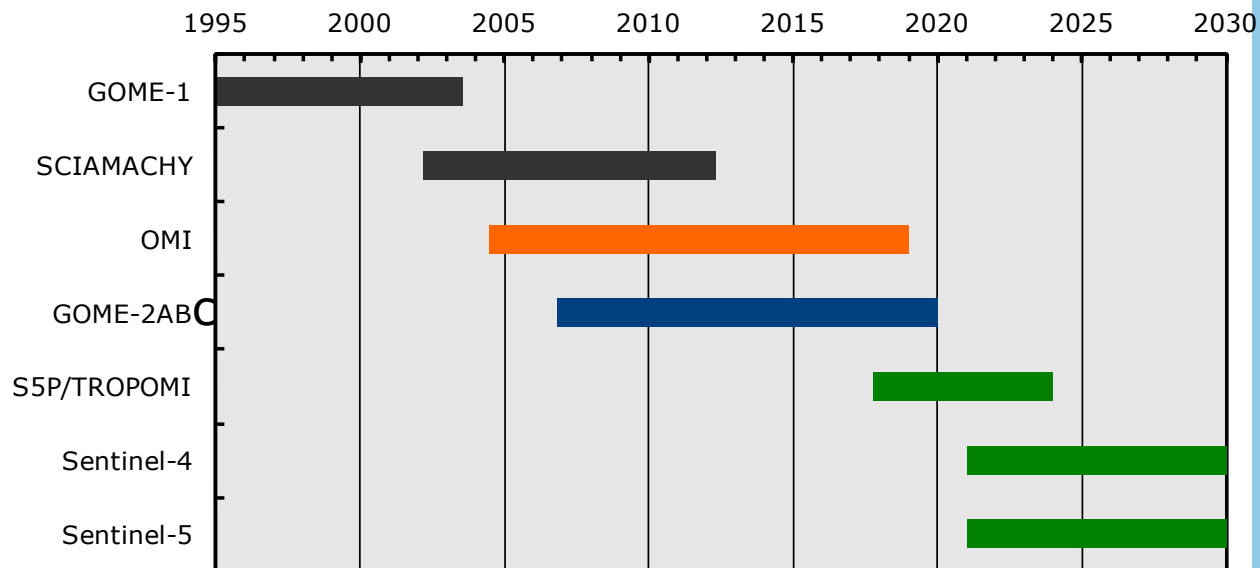
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S5p TROPOMI HCHO Tropospheric Columns  $10^{15}$  molec.cm<sup>-2</sup>





# Continuity



# Conclusions

- > TROPOMI is a game-changer in atmospheric composition measurements from space
- > ... due to its large spectral coverage, small pixel size, and high sensitivity
- > Release of TROPOMI ozone profile product in Feb 2020 (together with L1b version 2)
- > The global network of ozone sonde stations is used for validation, which is coordinated by BIRA.



Thank you for your attention

**Congratulations to KMI !**