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Progress on Tropospheric Ozone Retrievals at RAL

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STFC – Rutherford Appleton Laboratory

ESA CCI O3

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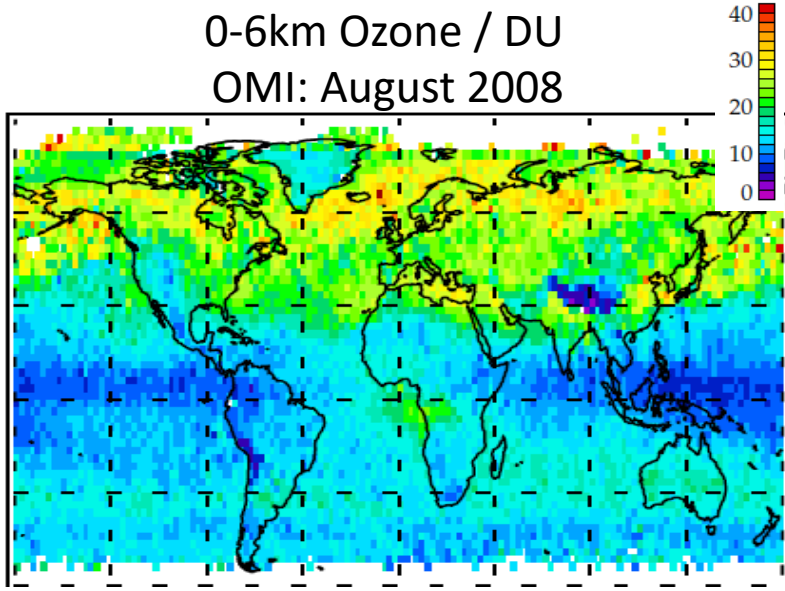
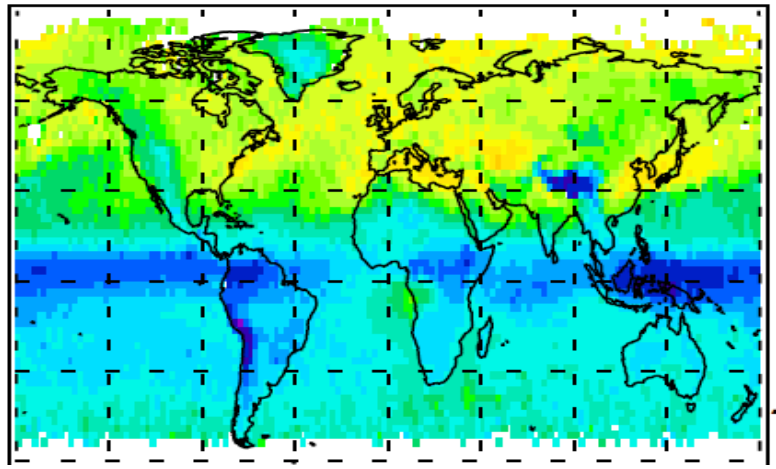
Overview

- RAL scheme developed in UK-NCEO / ESA-CCI to produce ozone profile data from nadir –uv sounders:
  - ~5 degrees of freedom for profile
  - Combines stratospheric ozone from Hartley band <307nm with tropospheric ozone from Huggins bands temperature dependence (320-334nm) via precise fit to spectral structure
- Multi-year data sets produced for CCI and C3S from GOME, GOME-2, SCIAMACHY, OMI
- Defining the tropospheric ozone scheme for Sentinel4 and Ozone profile scheme for Sentinel 5
- Presentation to outline:
  - Status of ESA-CCI / C3S multi-satellite data, focusing on tropospheric time-series
  - New work on tropospheric ozone from TIR sounders IASI+ CrIS (towards joint uv+IR retrieval)
  - Ozone changes in summer 2018 vs 2017 over Europe

0-6km Ozone / DU
OMI: August 2008



MACC (with averaging kernel)



CCI Time-series of 0-6km Ozone / DU

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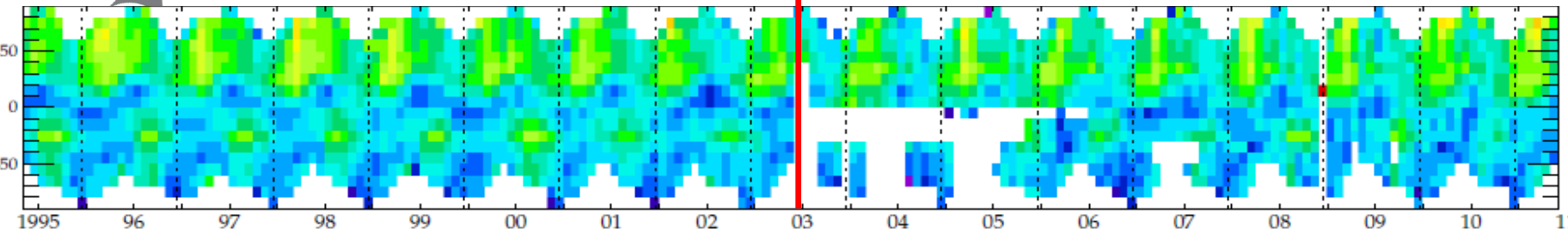
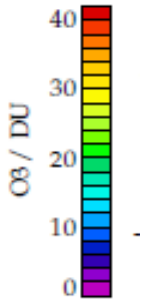
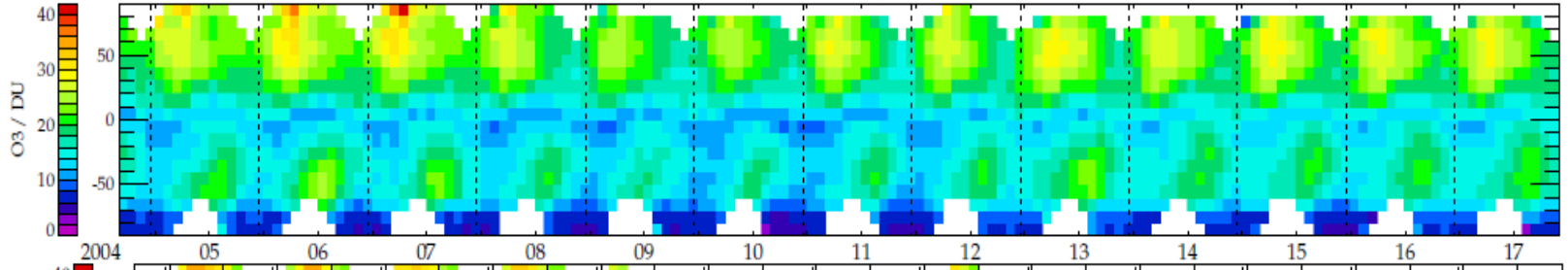
Tape recorder failure, much reduced coverage



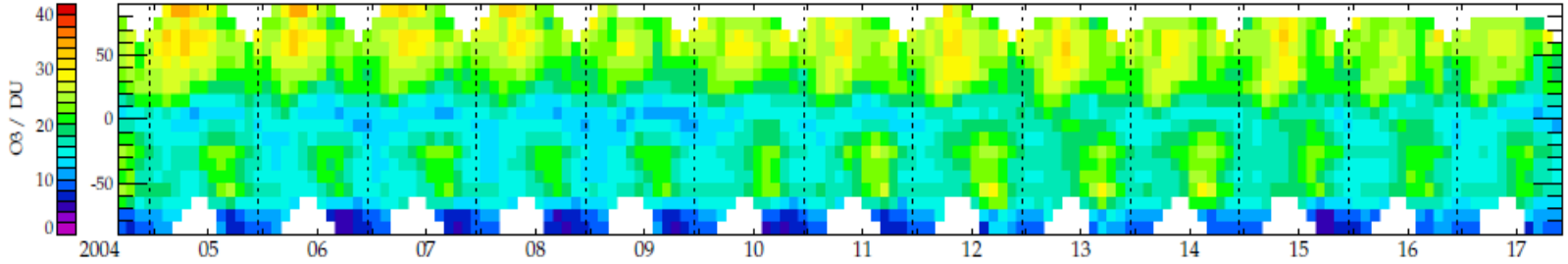
GOME-1



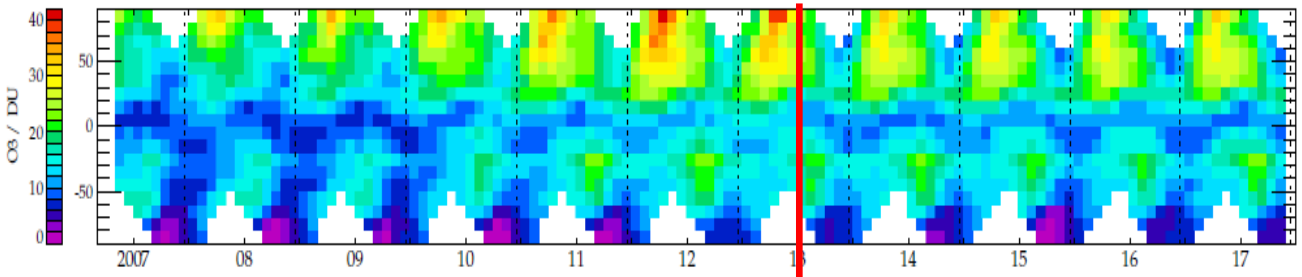
CAMS/MACC (sampled as OMI)



OMI



GOME-2 (Metop A)



Time vs latitude Hovmoller plots for GOME-1, OMI, GOME-2 produced for CCI Compared to ECMWF/CAMS

Change to from 1920 to 960km swath

RAL Infra-red Microwave Sounder (IMS) for IASI + ASMU + MHS

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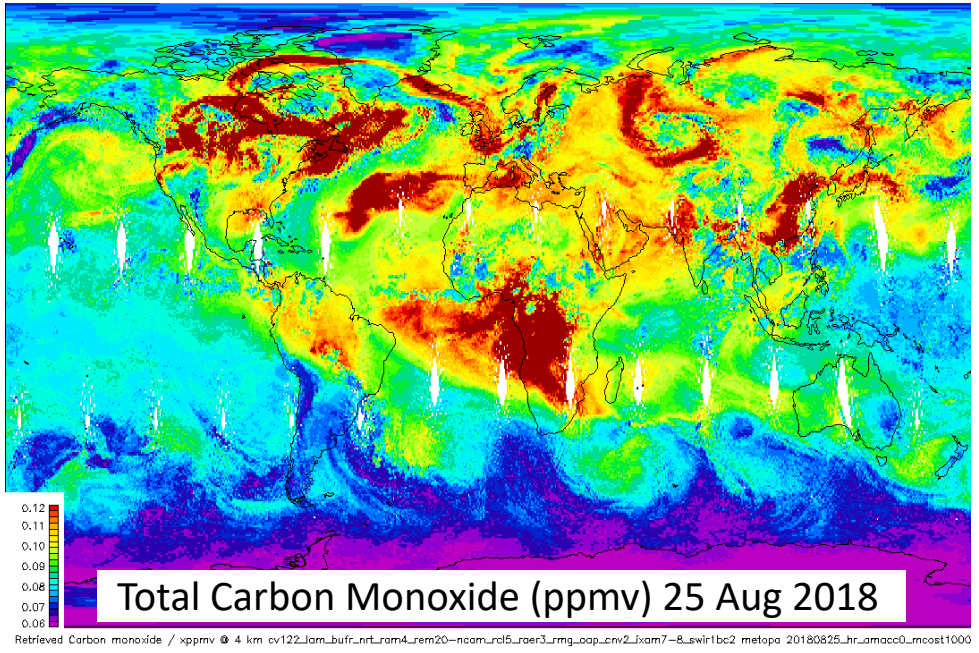
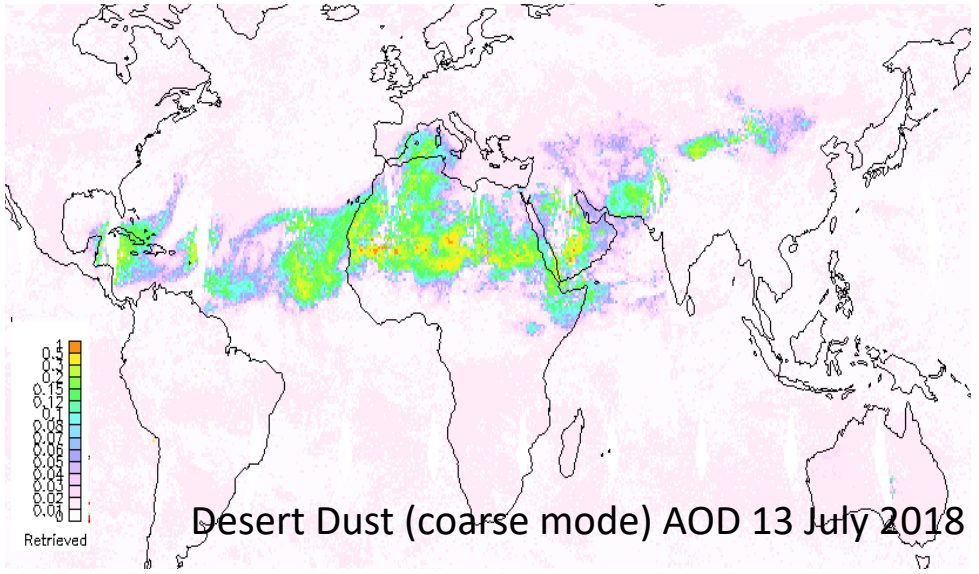
- Optimal estimation (OE) scheme for IASI using RTTOV as fast radiative transfer model
  - Based on Eumetsat operational IASI OE scheme for **temperature, water vapour** and **ozone**, extended via study:
  - Add info from microwave sounders (AMSU+MHS)
  - Joint fit of **surface spectral emissivity** and **cloud**
- Recently new features of RTTOV 12 exploited to extend retrieval to IASI SW band and model aerosol
- Channel selection + other settings now optimised for ozone
  - State vector extended to fit also **CO, NH3, HNO3, SO2, CH3OH, HCOOH**
  - **dust + H2SO4 aerosol**
- Operated in (almost) near-real time
- Used to define temperature and spectral emissivity (and H2SO4 aerosol) for separate methane retrieval

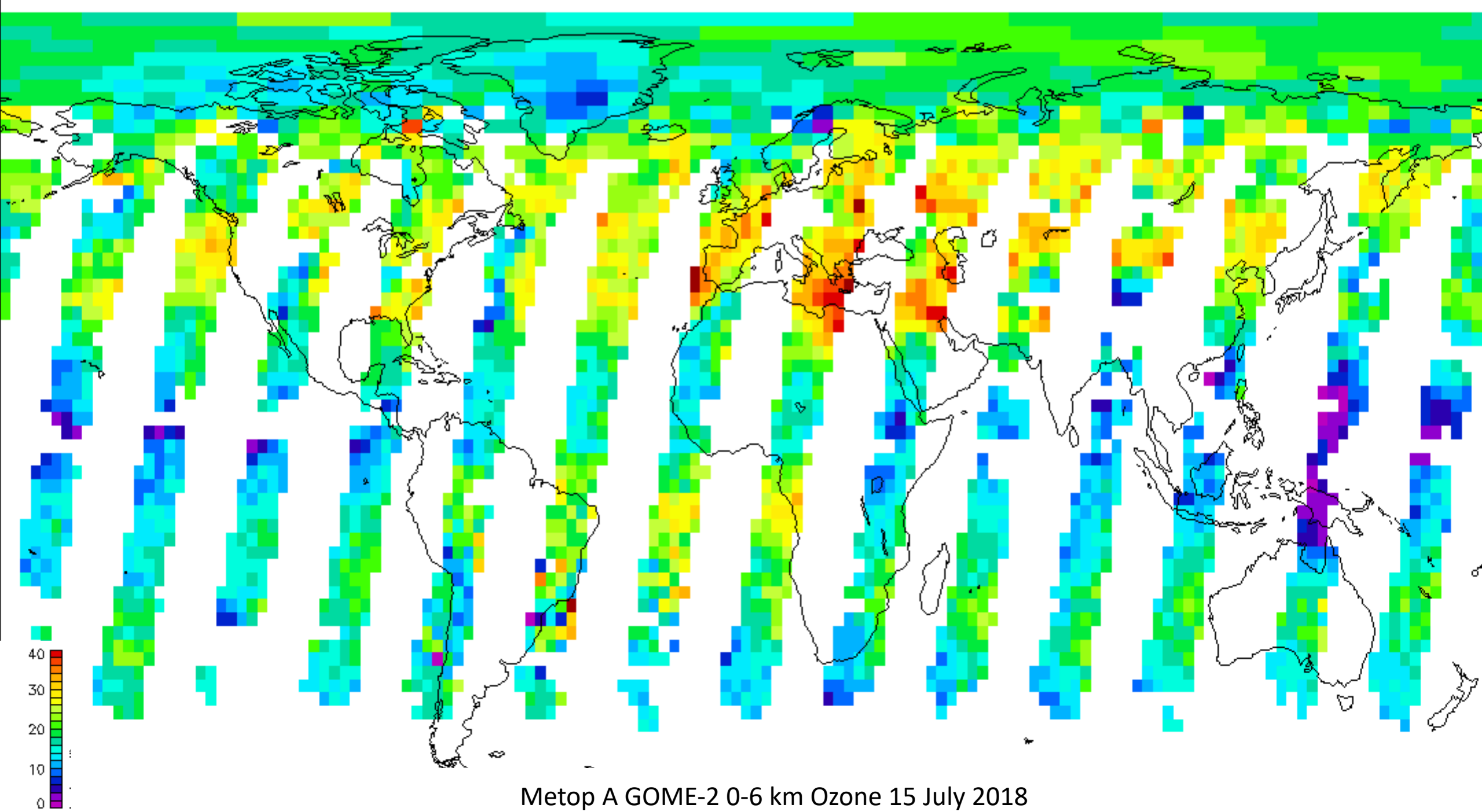
- *Very recently IMS has been successfully applied to NPP CrIS, in preparation for joint retrievals (O3, CO, CH4 with S5P)*



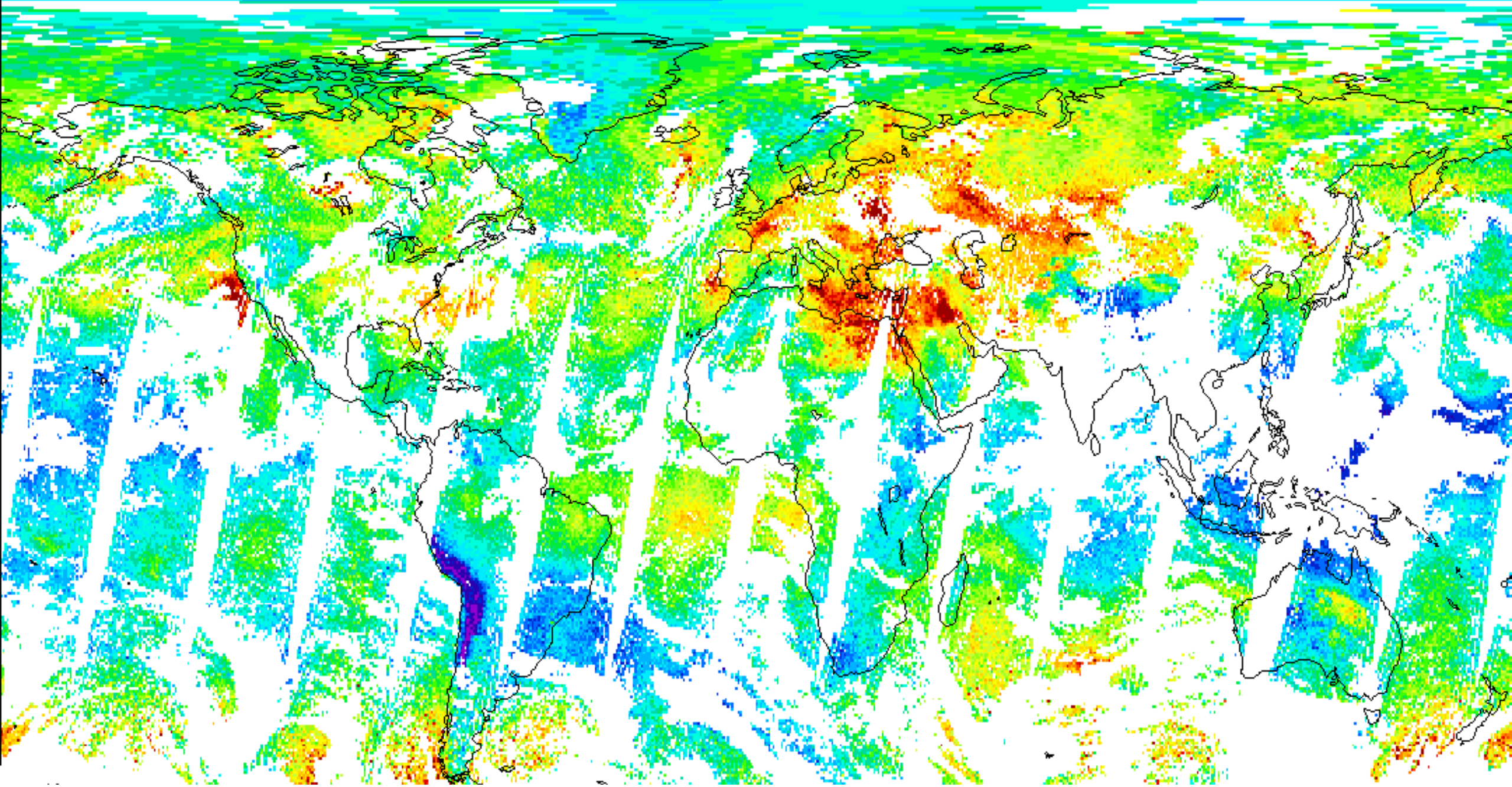
Total Carbon Monoxide (ppmv) 25 Aug 2018



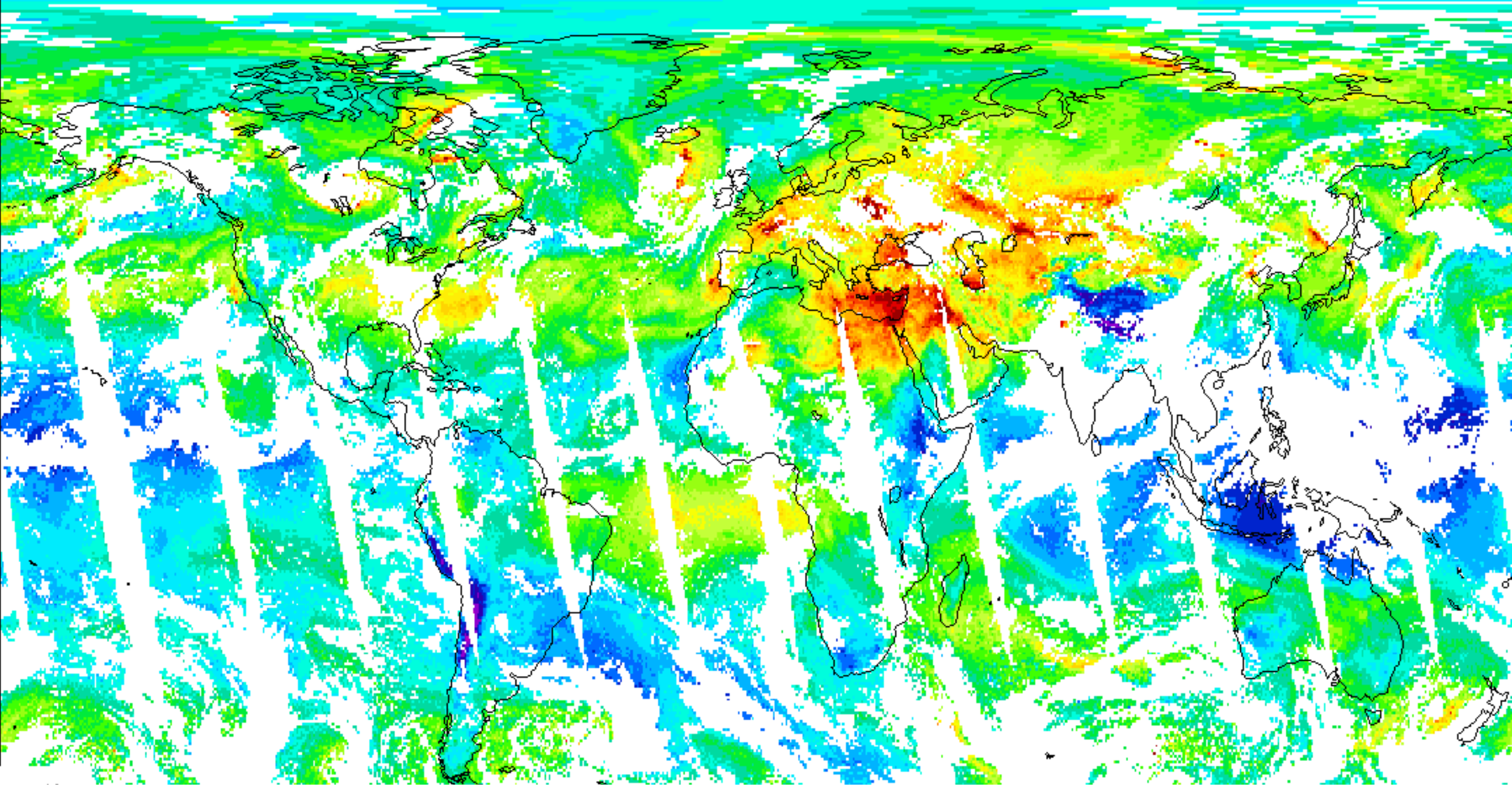
Desert Dust (coarse mode) AOD 13 July 2018



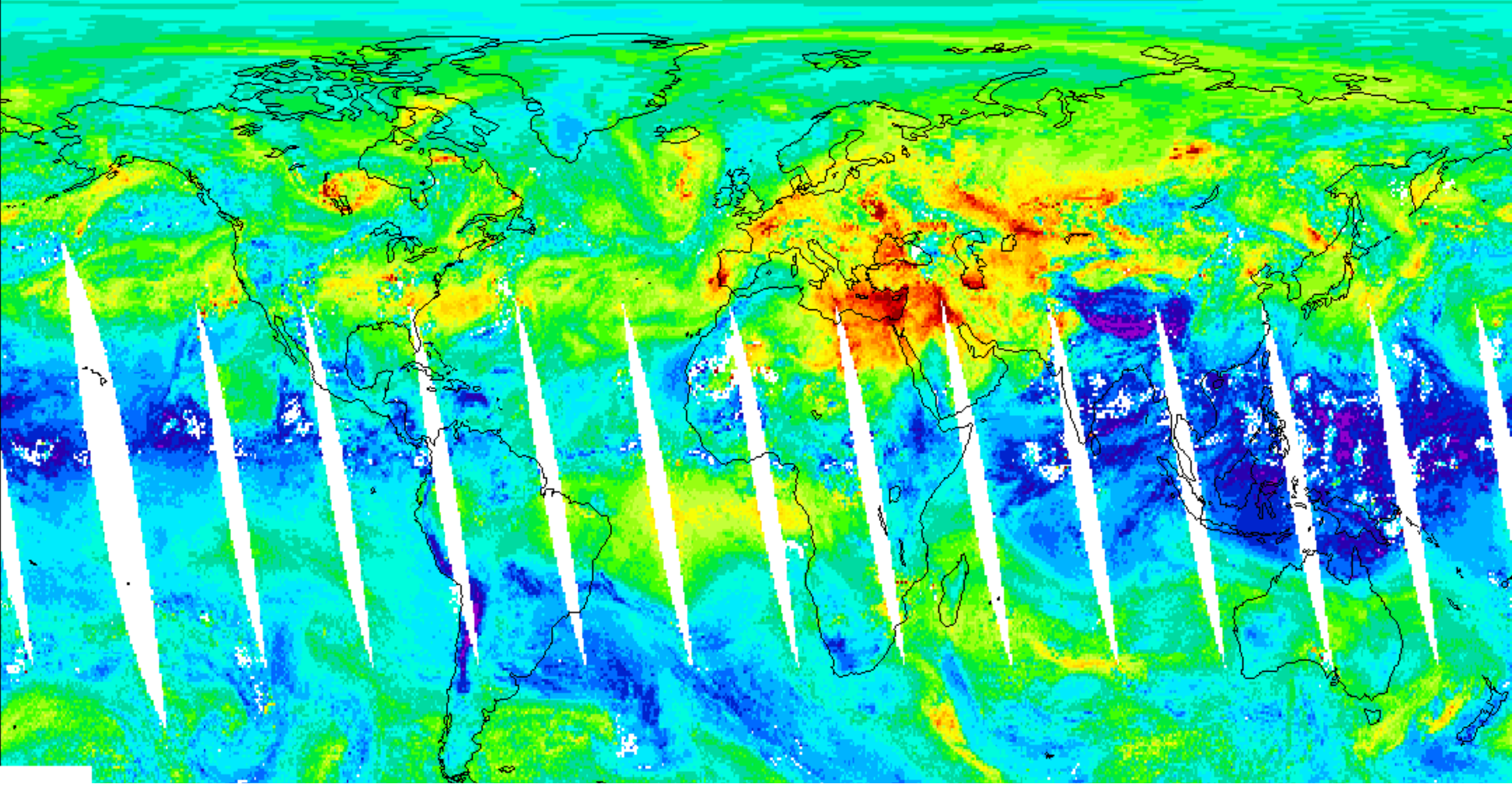
Metop A GOME-2 0-6 km Ozone 15 July 2018



Metop A IASI 0-6 km Ozone 15 July 2018



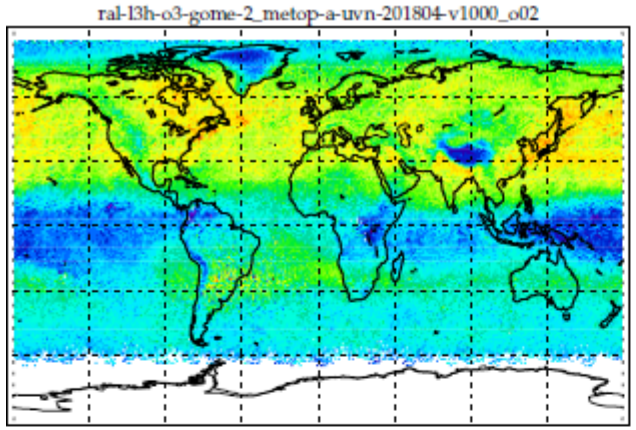
Suomi-NPP CrIS 0-6 km Ozone 15 July 2018

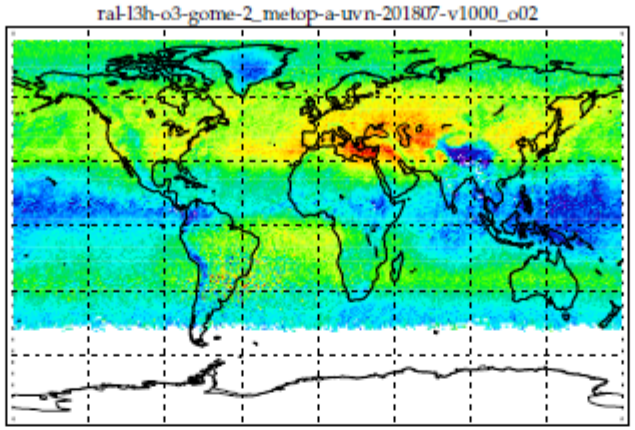


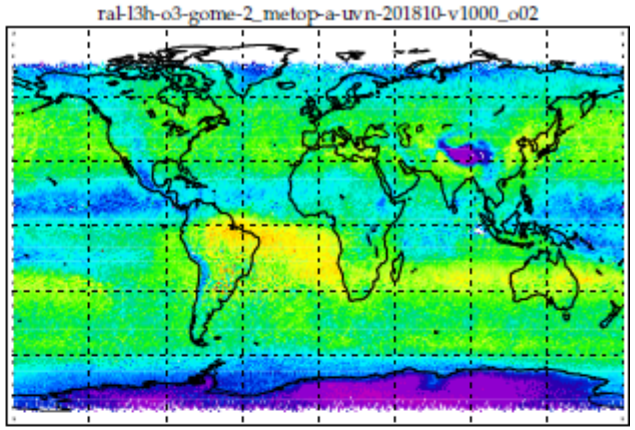
Suomi-NPP CrIS 0-6 km Ozone 15 July 2018 (no cloud screening)

April 2018 | July 2018 | October 2018

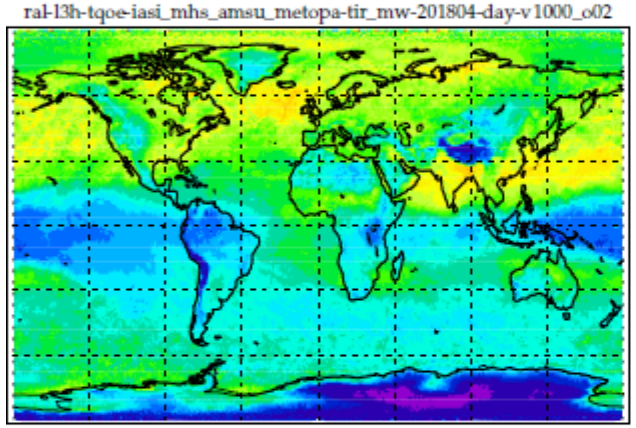
GOME-2

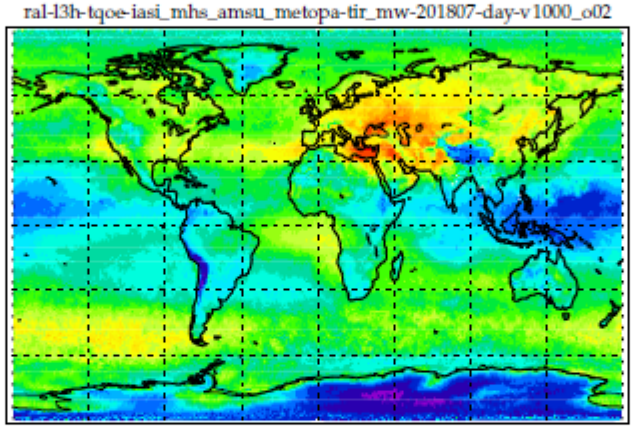


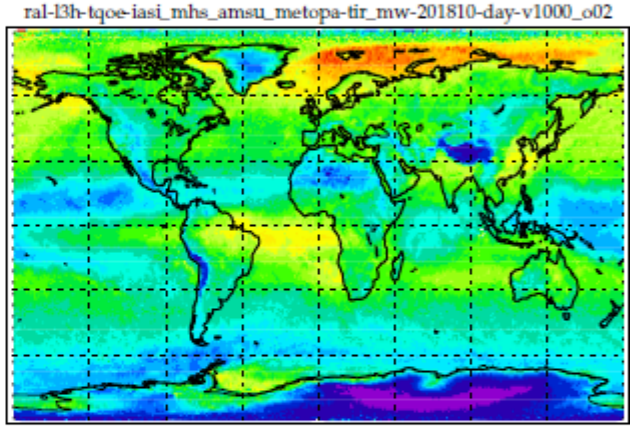




IASI







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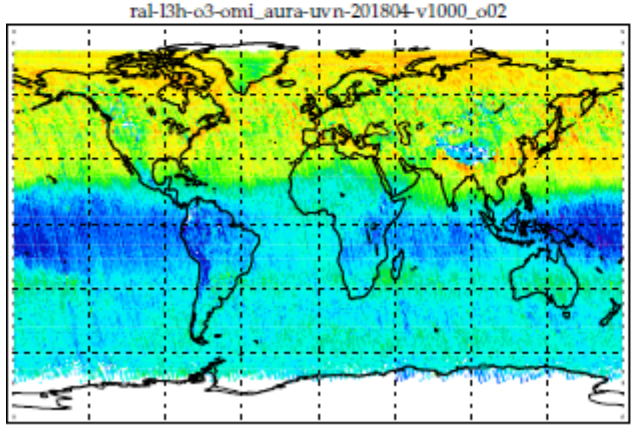
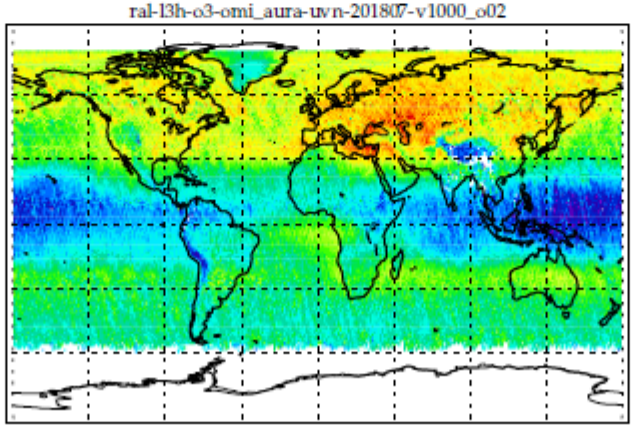
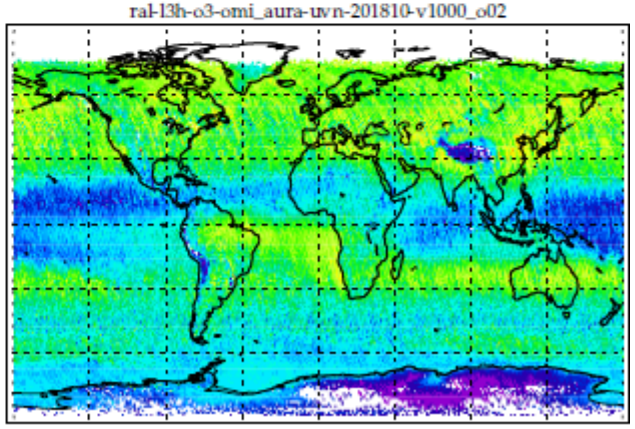
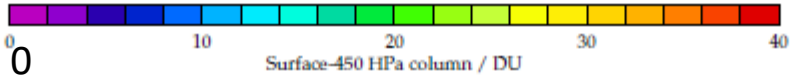








0 40

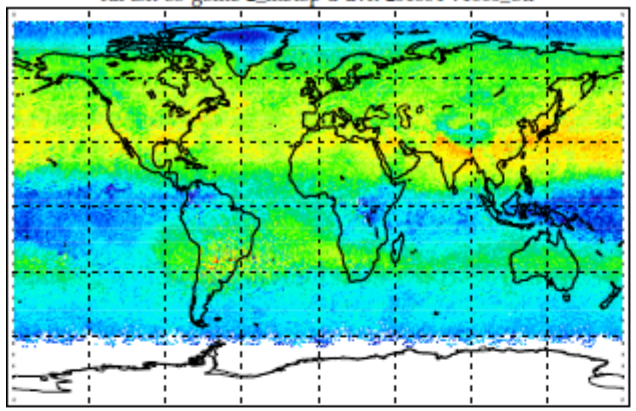
Data for ACVC Comparison

Surface – 6km
Sub-column
(DU)

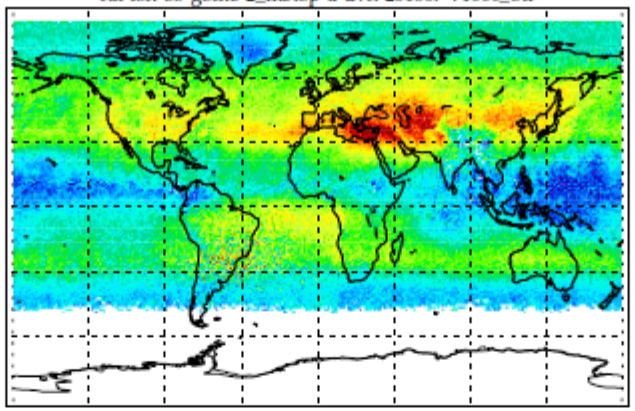
April 2018 | July 2018 | October 2018

GOME-2

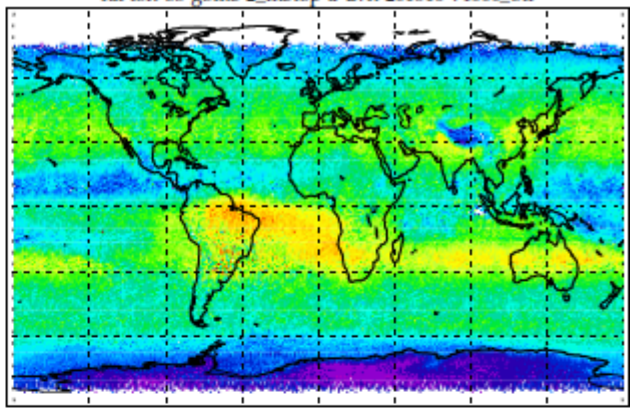
ral-l3h-o3-gome-2_metop-a-uvn-201804-v1000_otr



ral-l3h-o3-gome-2_metop-a-uvn-201807-v1000_otr

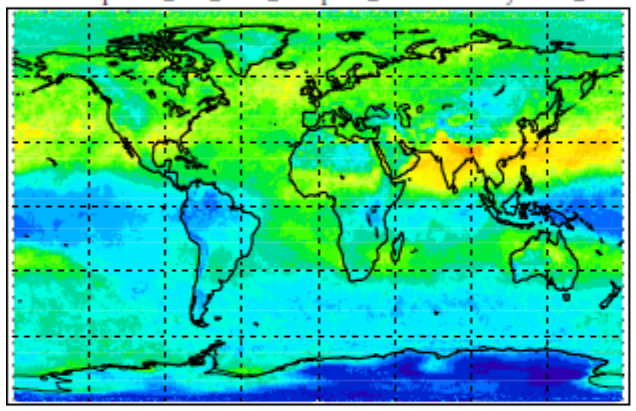


ral-l3h-o3-gome-2_metop-a-uvn-201810-v1000_otr



IASI

ral-l3h-tqoe-iasi_mhs_amsu_metopa-tir_mw-201804-day-v1000_otr



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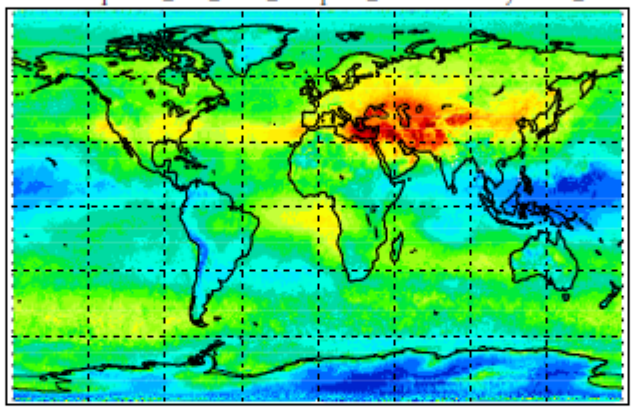

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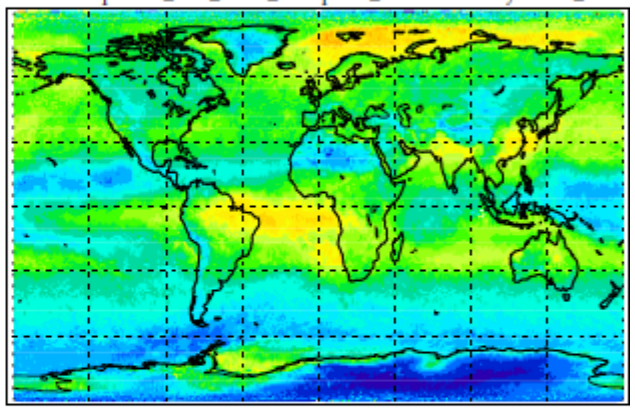
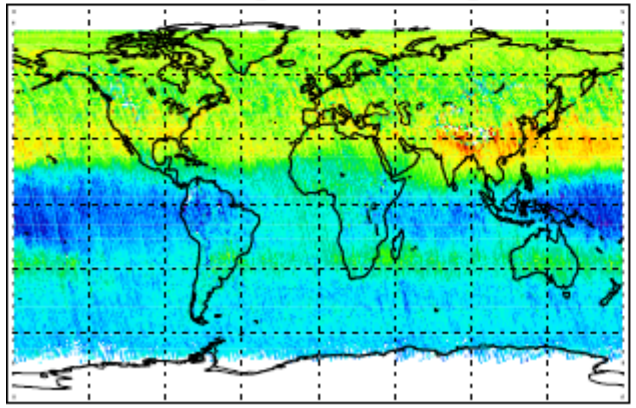
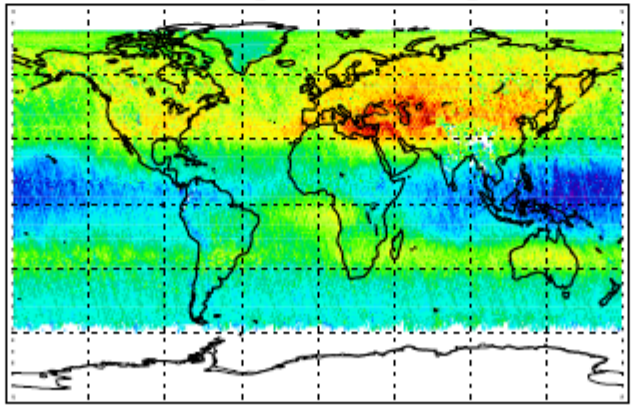


OMI

ral-l3h-o3-omi_aura-uvn-201804-v1000_otr



ral-l3h-o3-omi_aura-uvn-201807-v1000_otr



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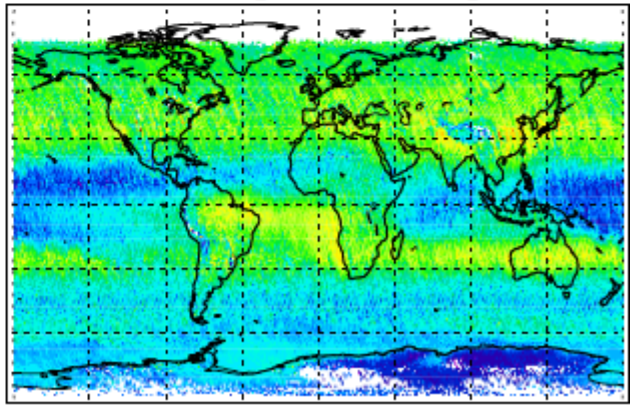

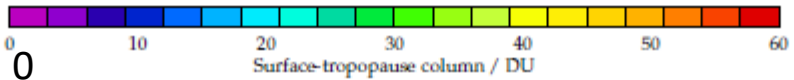

0 60

Data for ACVC Comparison

Surface – tropopause Sub-column (DU)

Estimated from 0-6km retrieval:

1. Convert to sub-column average vmr
2. Scale by column of air up to WMO lapse-rate tropopause

(~ assume fixed vmr in troposphere)

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0-6km Ozone changes over Europe noticed in GOME-2 near-real time system

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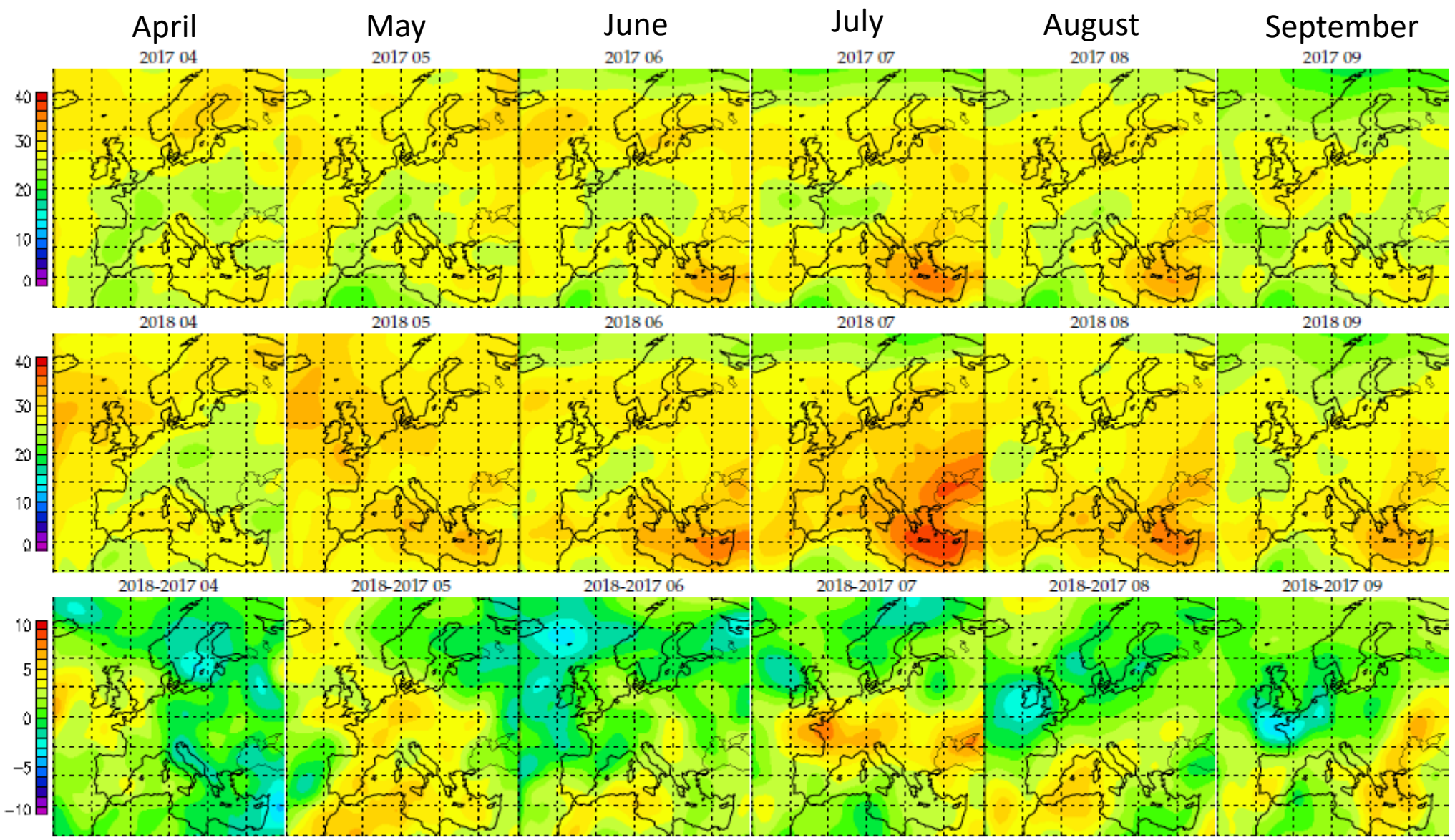
0-6km
Sub-column
DU



0-6km Monthly Ozone changes 2018-2017: Metop A GOME-2, IASI + OMI

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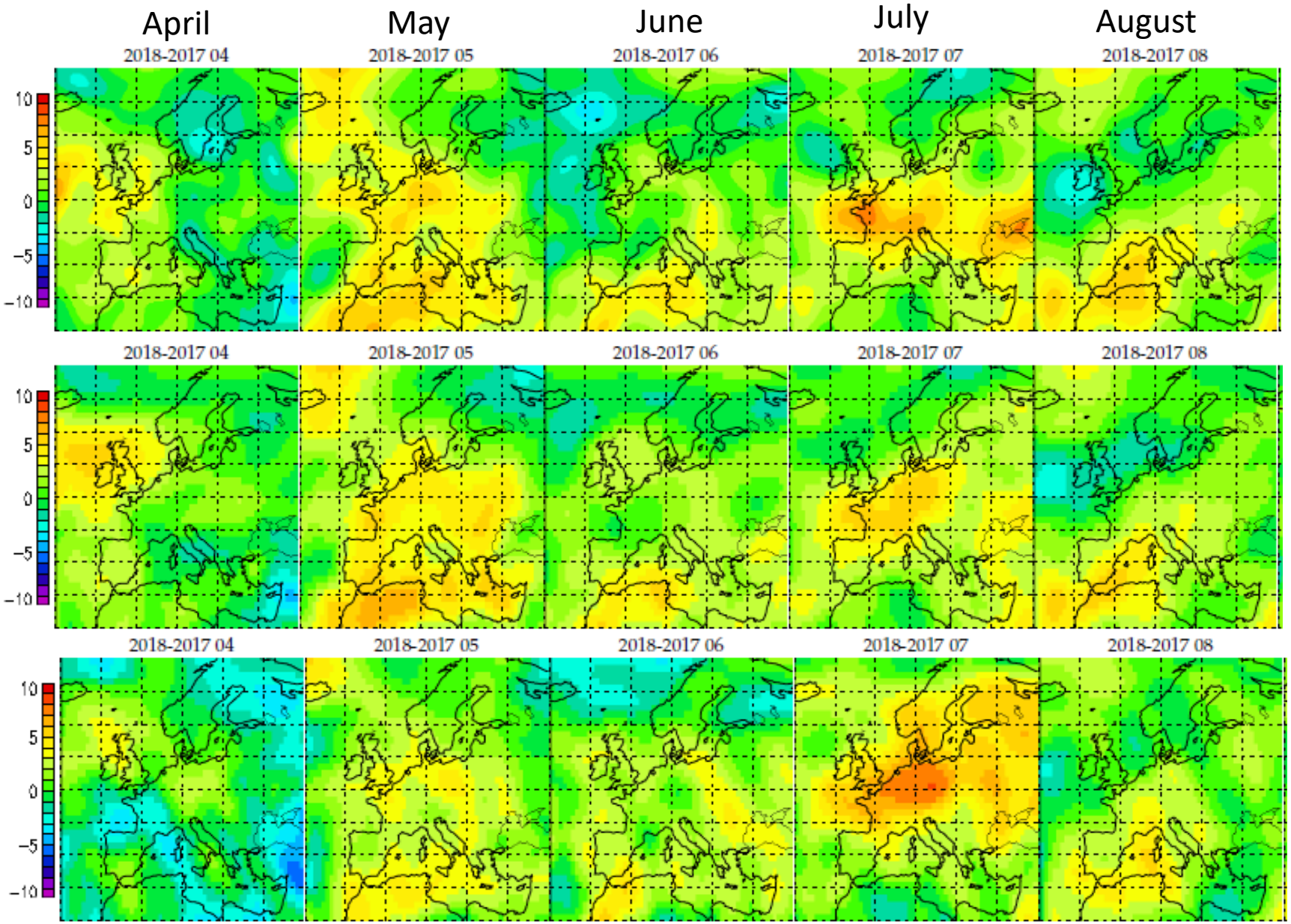
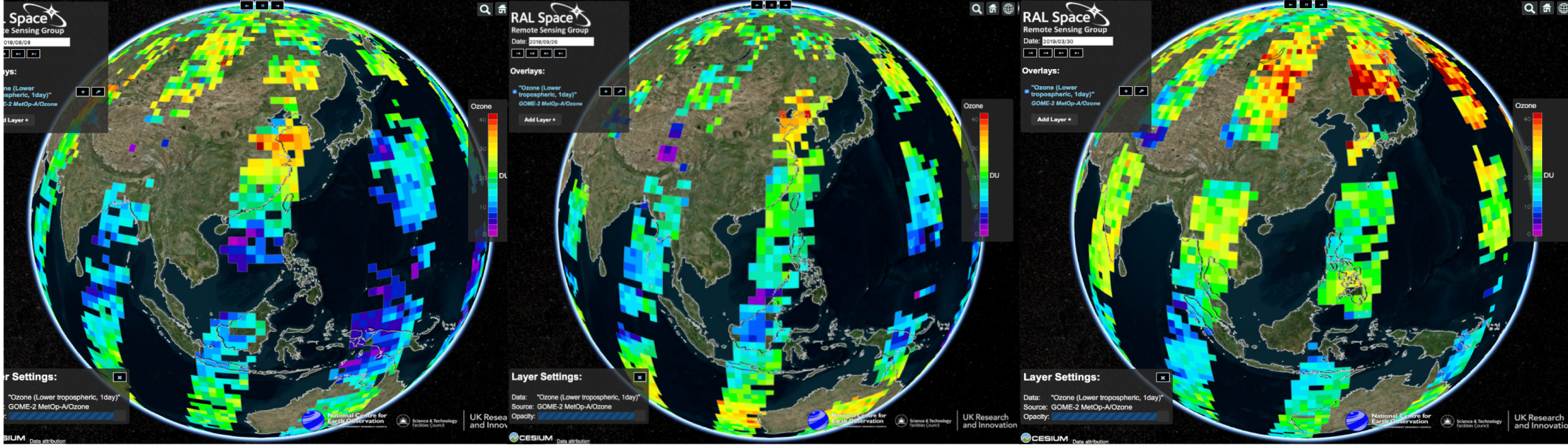


Changes linked to differences in surface T + other trace gases including methanol (IASI) and fomaldehyde (GOME2) + Strat-trop exchange.

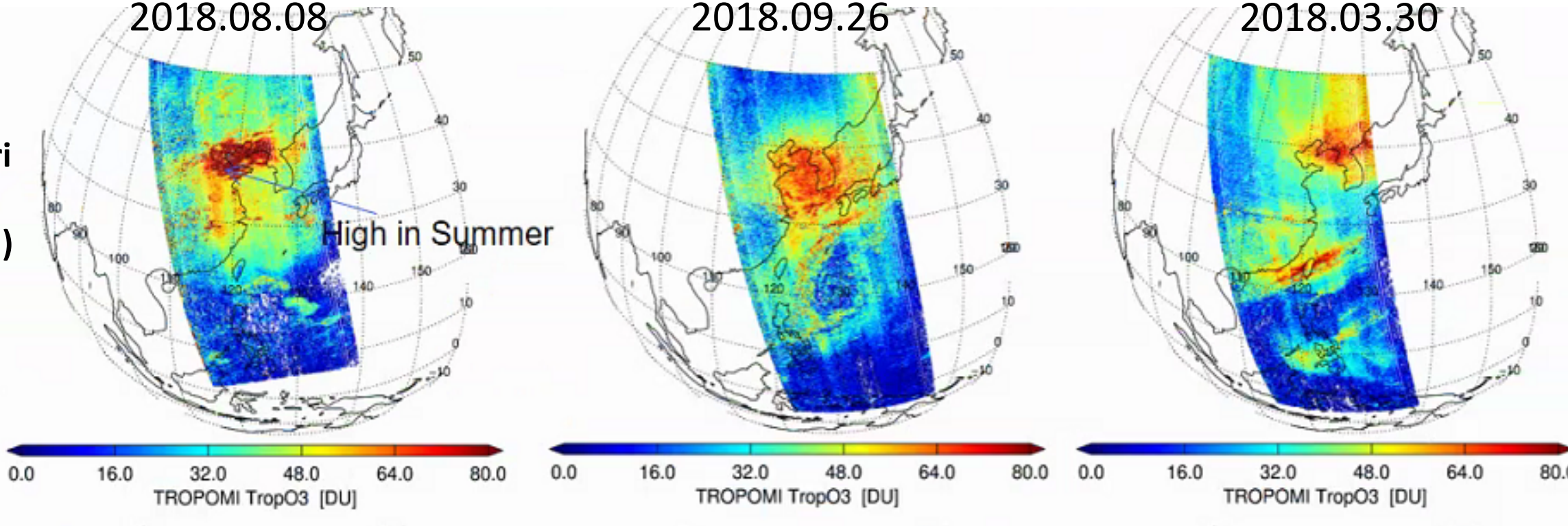
Investigation under way via TOMCAT model simulations in collaboration with R. Pope, M. Chipperfield @ Univ. Leeds

RAL GOME-2 From Protype NRT System



2018.08.08 2018.09.26 2018.03.30

GEMS S5P tropospheric Ozone (Jhoon Kim)



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Summary & Future Work

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- Multi-year global data sets on height-resolved ozone spanning troposphere and stratosphere produced from uv sounders for EU C3S Ozone
  - GOME-1 1995- 11, SCIA 2002-12, OMI 2004-18, GOME-2A 2007-18 & GOME-2B 2013-17
  - Improvements to *uv-only* scheme to be implemented for future C3S data production
- RAL IASI scheme recently improved for ozone and now also working for NPP-CrIS

- Near-term R&D:
  - Further investigation of Summer 2018 vs 2017 in collaboration with Univ. Leeds (TOMCAT model)
  - Diagnose & mitigate factors limiting tropospheric ozone retrieval from uv sounders
    - Awaiting improved L1 data for SCIAMACHY + GOME-2 Metop B
  - Apply uv-only scheme to GOME-2 Metop C and Sentinel-5P
  - Implement combined **IR** + **UV** for MetOp GOME-2+IASI & Sentinel-5P+CrI
    - Sentinel 5P + CrIS also being developed for CO & CH4 (D. Knappet ESA fellowship in collab with SRON)
  - Further work on **visible** band for GOME-2 (then TEMPO) → *resolve near-surface layer*
- Implementation of scheme as operational processor for Sentinel 4 and 5 under way

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MetOp-A methanol and surface temperature 2018 – 2017 difference in monthly means

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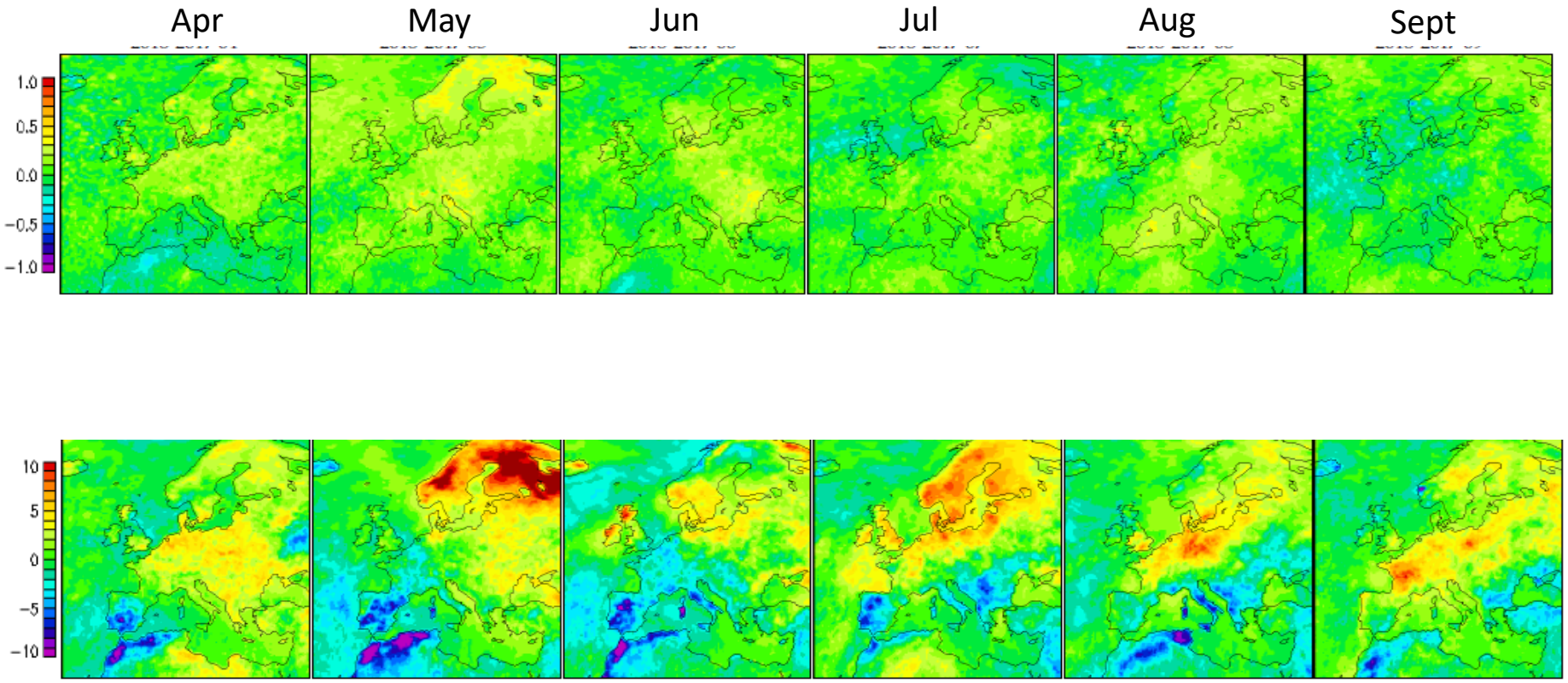

ΔCH_3OH (ppbv) 2018-17

ΔT_s (K) 2018-17

- Methanol and surface temperature jointly retrieved with other variables from IASI (+MHS & AMSU) on MetOp
- 2018-2017 difference maps indicate methanol generally higher over Scandinavia, W.Europe in 2018
- Higher methanol associated with higher surface temperatures, particularly over Scandinavia in May 2018.
- AVHRR false colour images also indicate less snow cover over Scandinavia in May 2018 than 2017

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GOME-2A (TEMIS) formaldehyde
2018 – 2017 difference in monthly means

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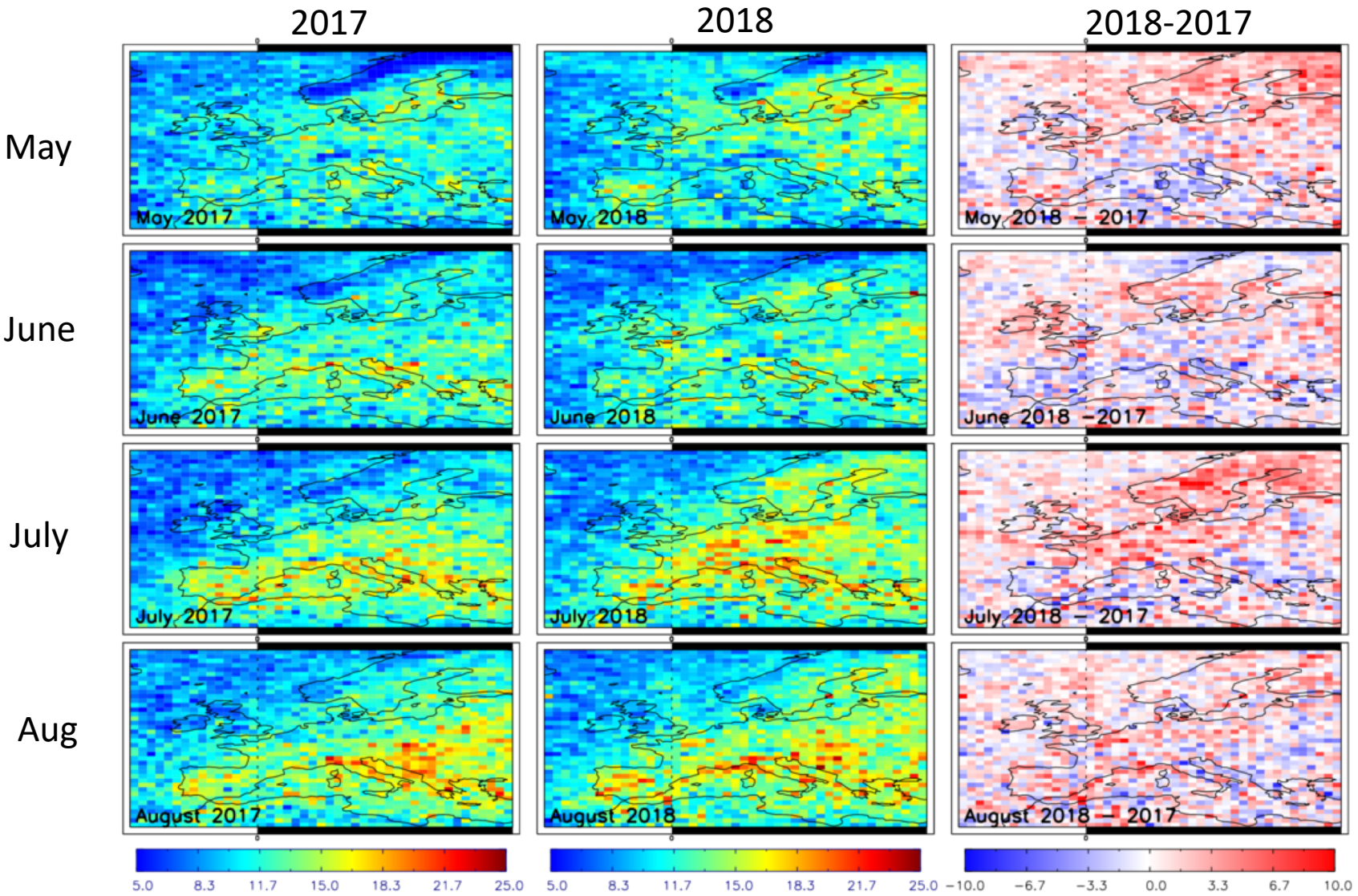
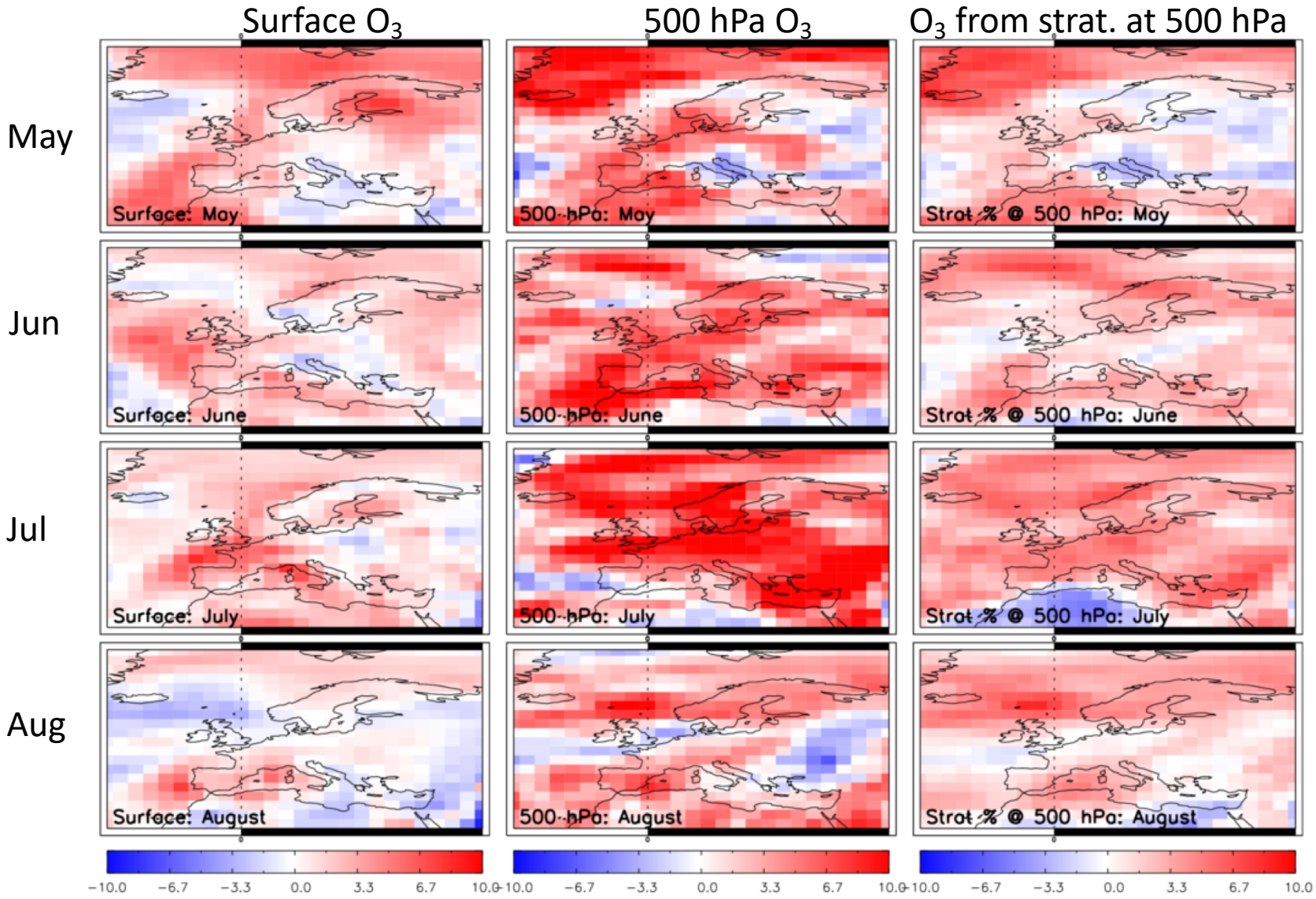


10^{15} molecules/cm^2

TOMCAT Control Simulation (2018-2017)

UNIVERSITY OF LEEDS



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Summer 2017 & 2018 AVHRR false colour images

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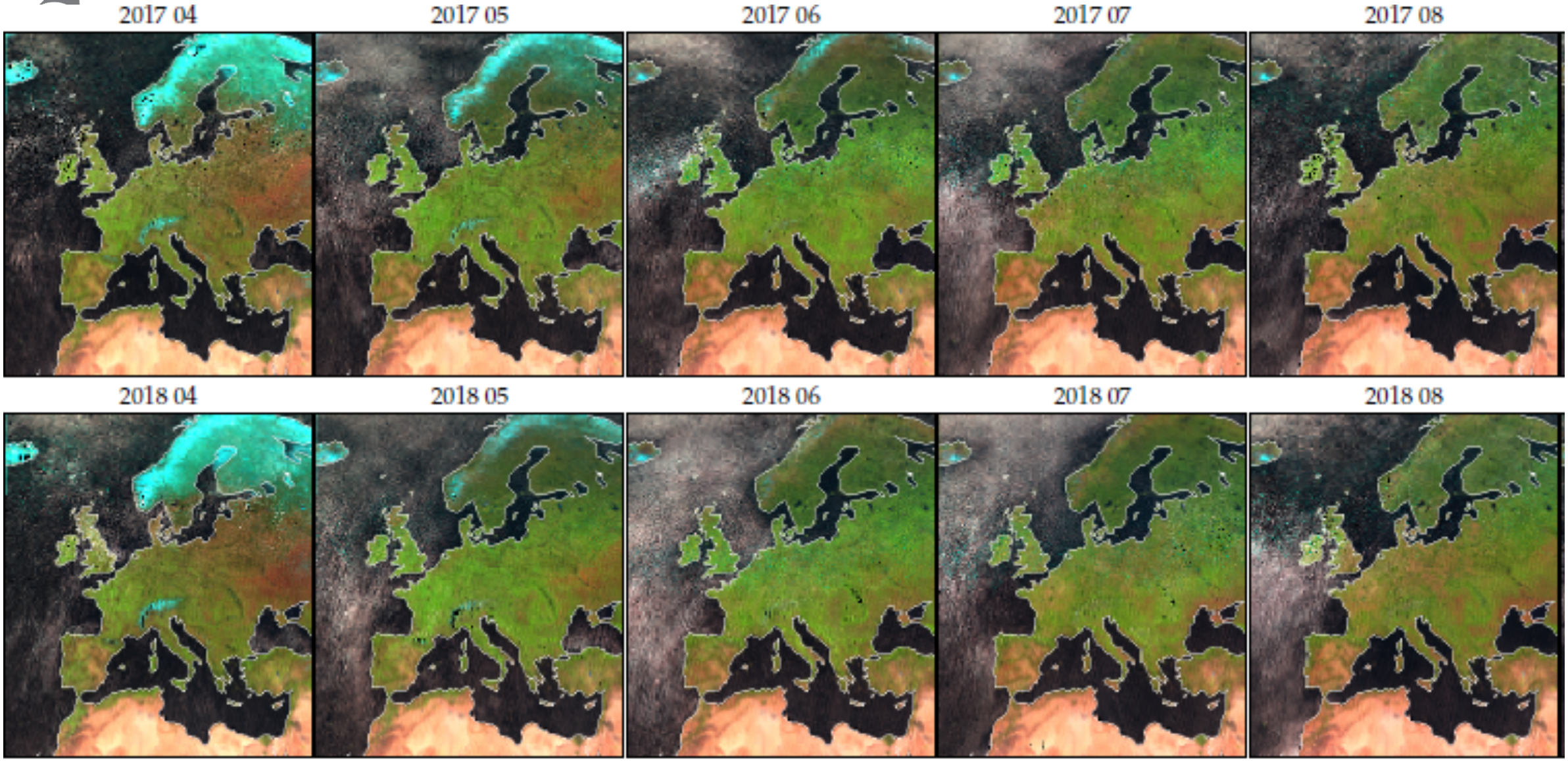

- Snow cover over Scandinavia less extensive in May 2018 than 2017

Ozone Time series (from RAL IMS scheme cf CAMS

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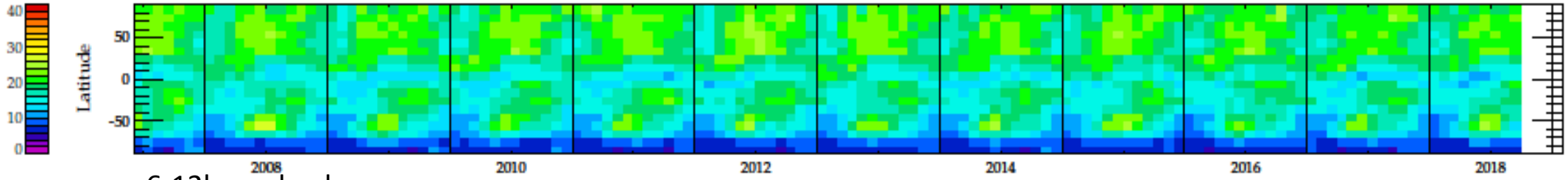
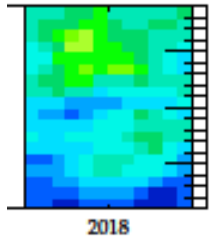
IASI (Metop A)

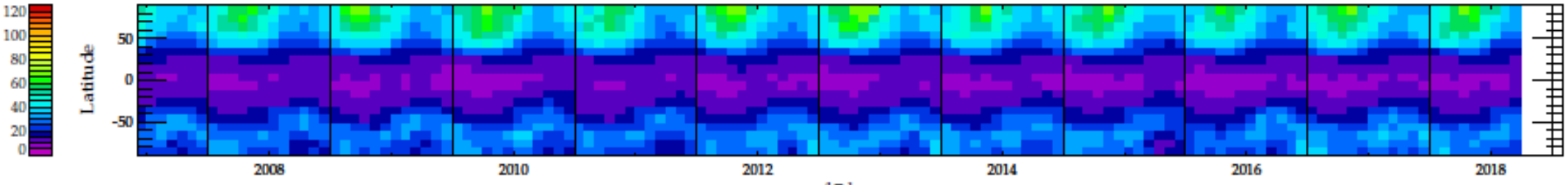
0-6km subcolumn

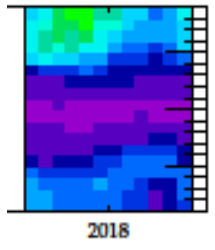


CrIS



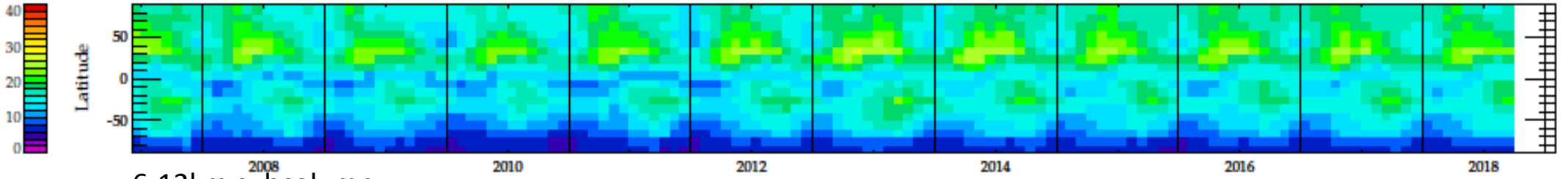
6-12km subcolumn



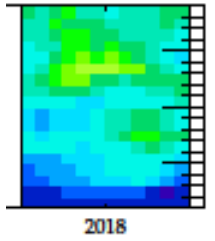


CAMS with Aks for IASI (Metop A)

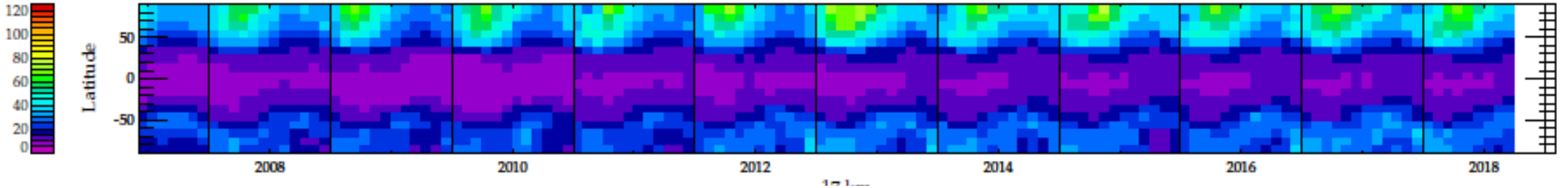
0-6km subcolumn

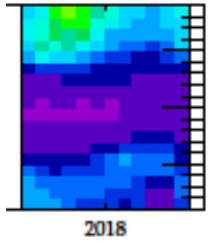


CAMS x AK CrIS



6-12km subcolumn

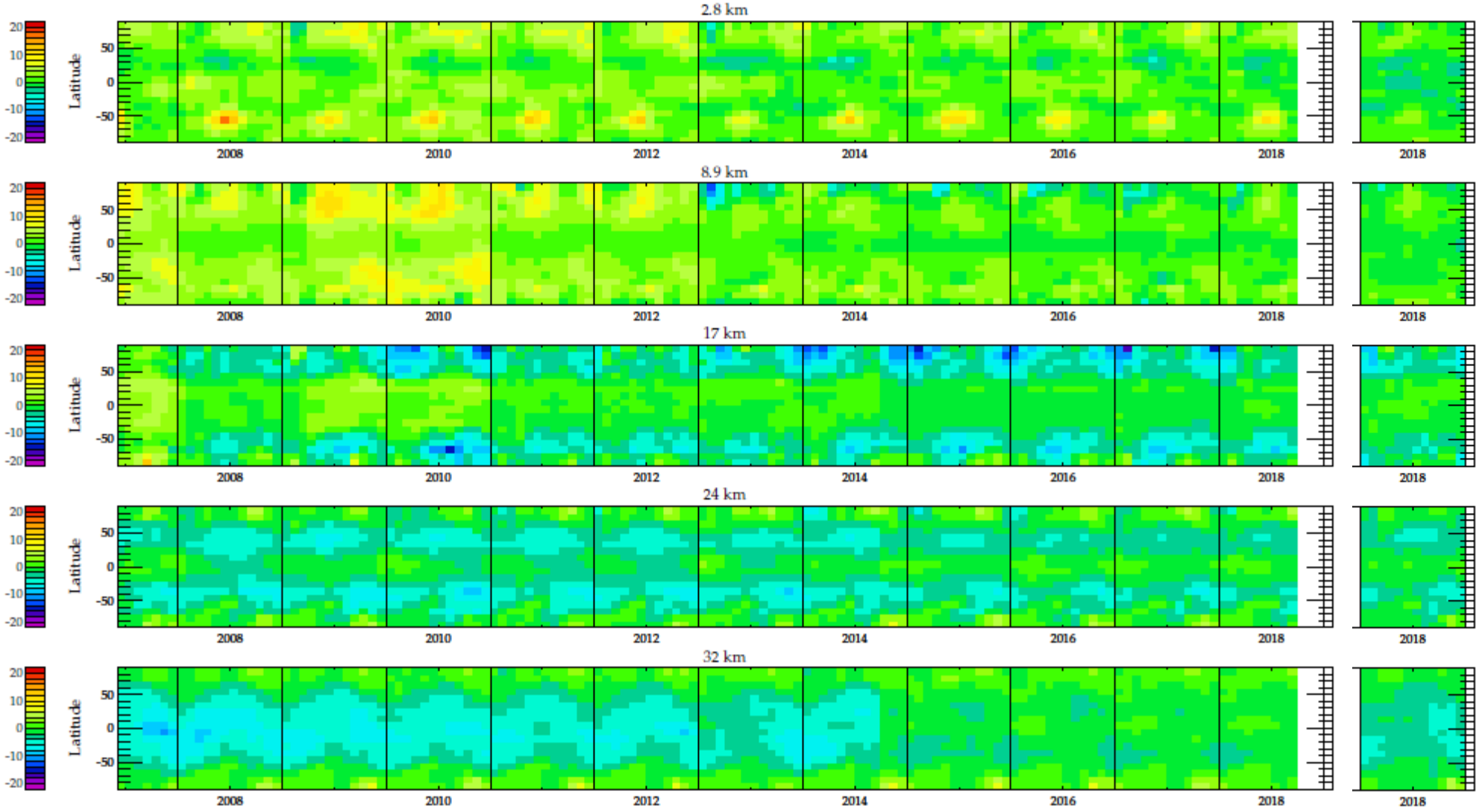




Mean (Retrieved – CAMS_x_AK)

IASI (Metop A)

CrIS



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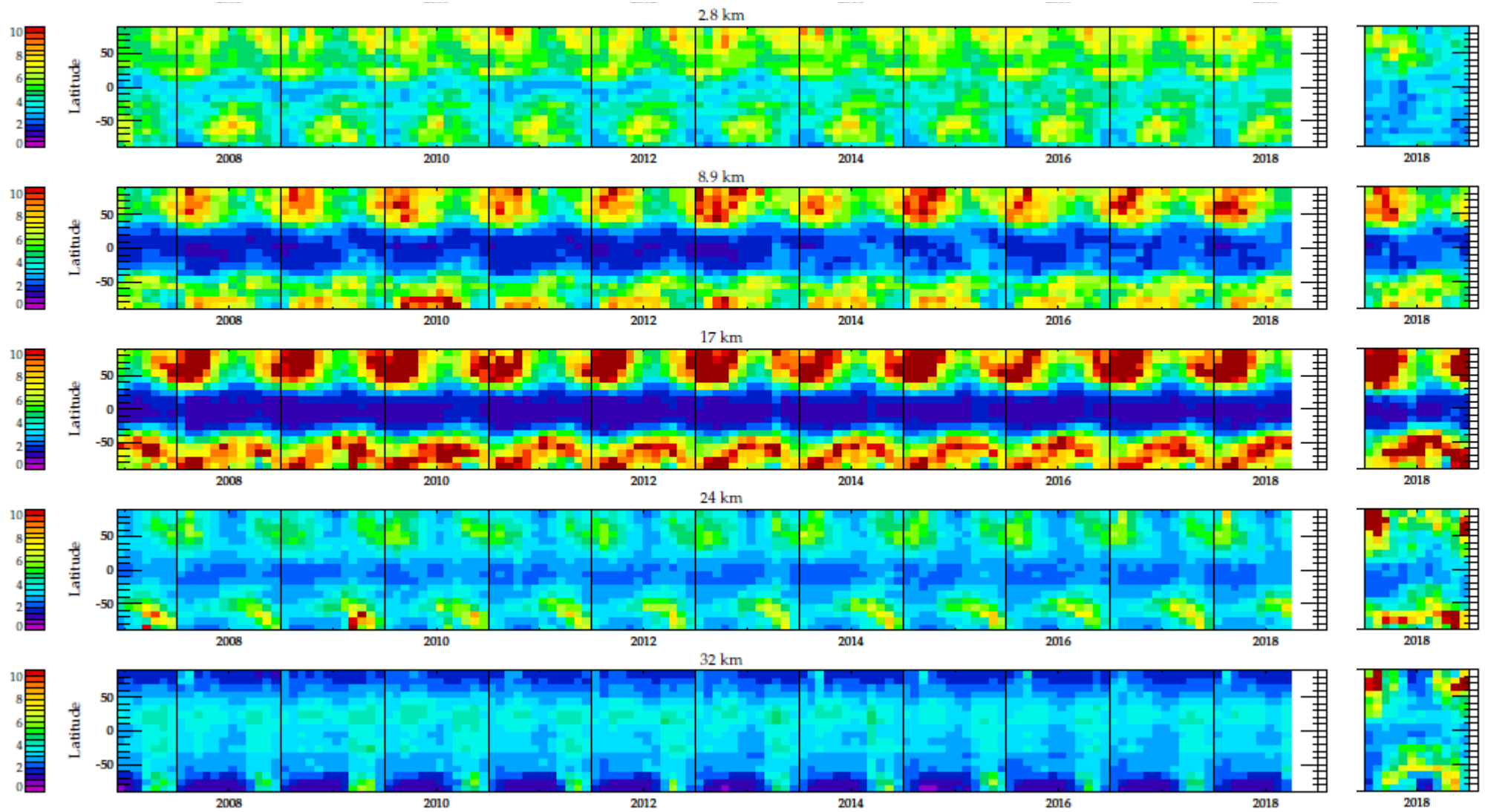
Std.dev. (Retrieved – CAMS_x_AK)

IASI (Metop A)

CrIS



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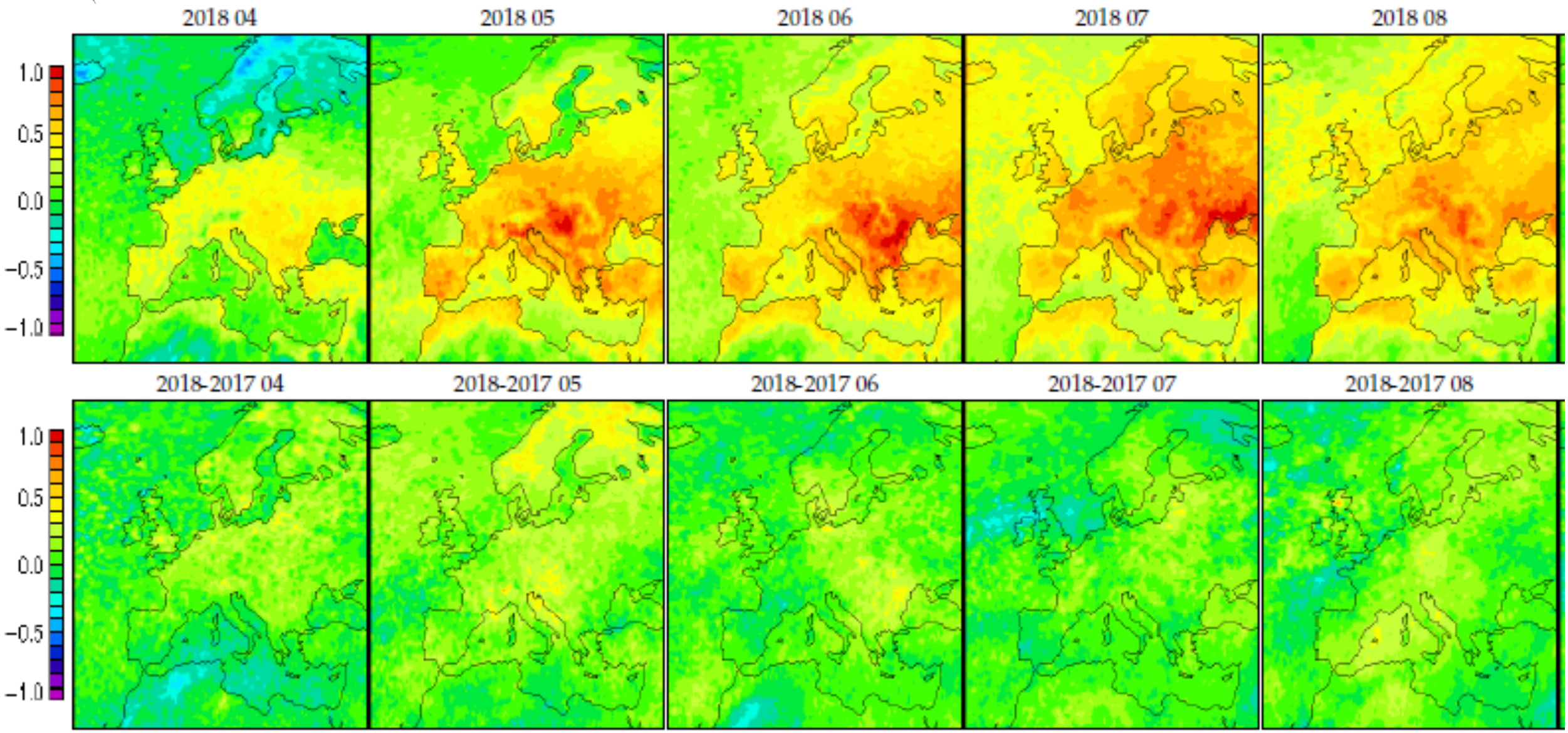

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Total xCO (ppmv)

15 July 2018