# Global Methane Retrievals from IASI and combination with S5P

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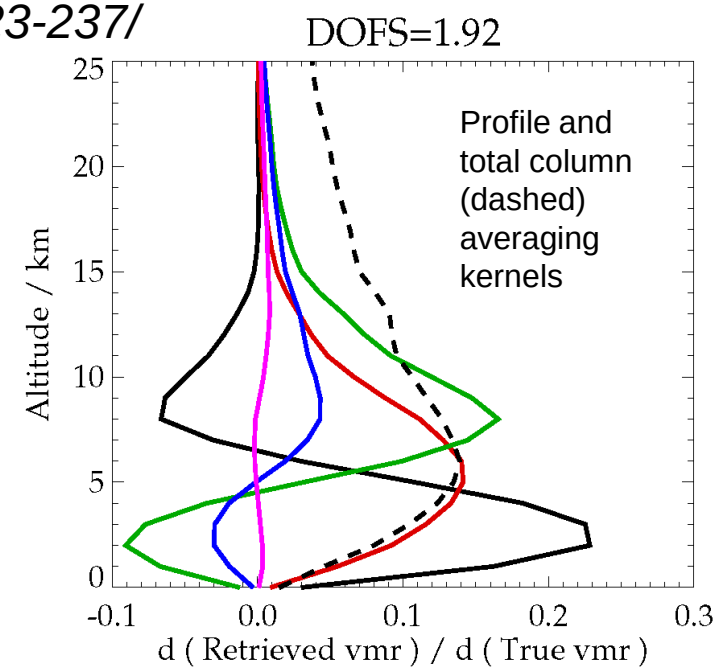
UKRI Science and Technology Facilities Council
RAL Space
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Background

- IASI is the thermal infra-red (TIR) spectrometer on MetOp, observing at relatively high spatial resolution (12km), day and night, globally over land and ocean.
- The RAL methane scheme, developed via UK national funding (NCEO) + Eumetsat studies, uses optimal estimation to retrieve height resolved information from IASI measurements in the 7.9µm band with typically ~2 degrees of freedom for signal and sensitivity extending into the lower troposphere (Siddans et al 2017).
  - *Independent validation: Dils et al, https://amt.copernicus.org/preprints/amt-2023-237/*
- Recently developments via *ESA Methane+* project (led by SRON) include
  - Detailed validation and intercomparison with model ground-based, airborne and S5P data
  - Use of the data in inverse modelling (by TNO and DLR)
  - Development of joint TIR+SWIR product, combining information of IASI and S5P to gain profile information within the troposphere
- New *ESA Smart-CH4* project to re-evaluate + improve spectroscopic data + further use via inverse modelling



# Development and Validation via ESA Methane+ Project

- Metop B processed for first time, focussing on overlap with S5p (April 2018 onwards) Metop-B dataset from January 2018 to March 2021
- Dataset was validated by comparison to CAMS, ATOM, AirCore, TCCON, S5P:
- Various improvements implemented:
  - Relaxed prior constraint (improves trends previously affected by prior constraint)
  - Improvements to input temperature retrievals; better cloud, aerosol and surface modelling.
    - Uses separate RAL Infra-red Microwave Sounder (IMS) retrievals – see presentation 3.2.4 by L.Ventress.
  - Improvements to assumed nitrous oxide profiles (based on latest ACE-FTS and CAMS data)
  - Update to latest Hitran spectroscopy, including line mixing (via LBLRTM)
  - Remaining spectroscopic errors corrected via
    - *Residual spectral patterns* included in the retrieval itself.
    - *Post-hoc empirical correction at very low water vapour amount*
- Metop A re-processed with improved scheme using Eumetsat reprocessed L1

https://methaneplus.eu/

SRON Netherlands Institute for Space Research

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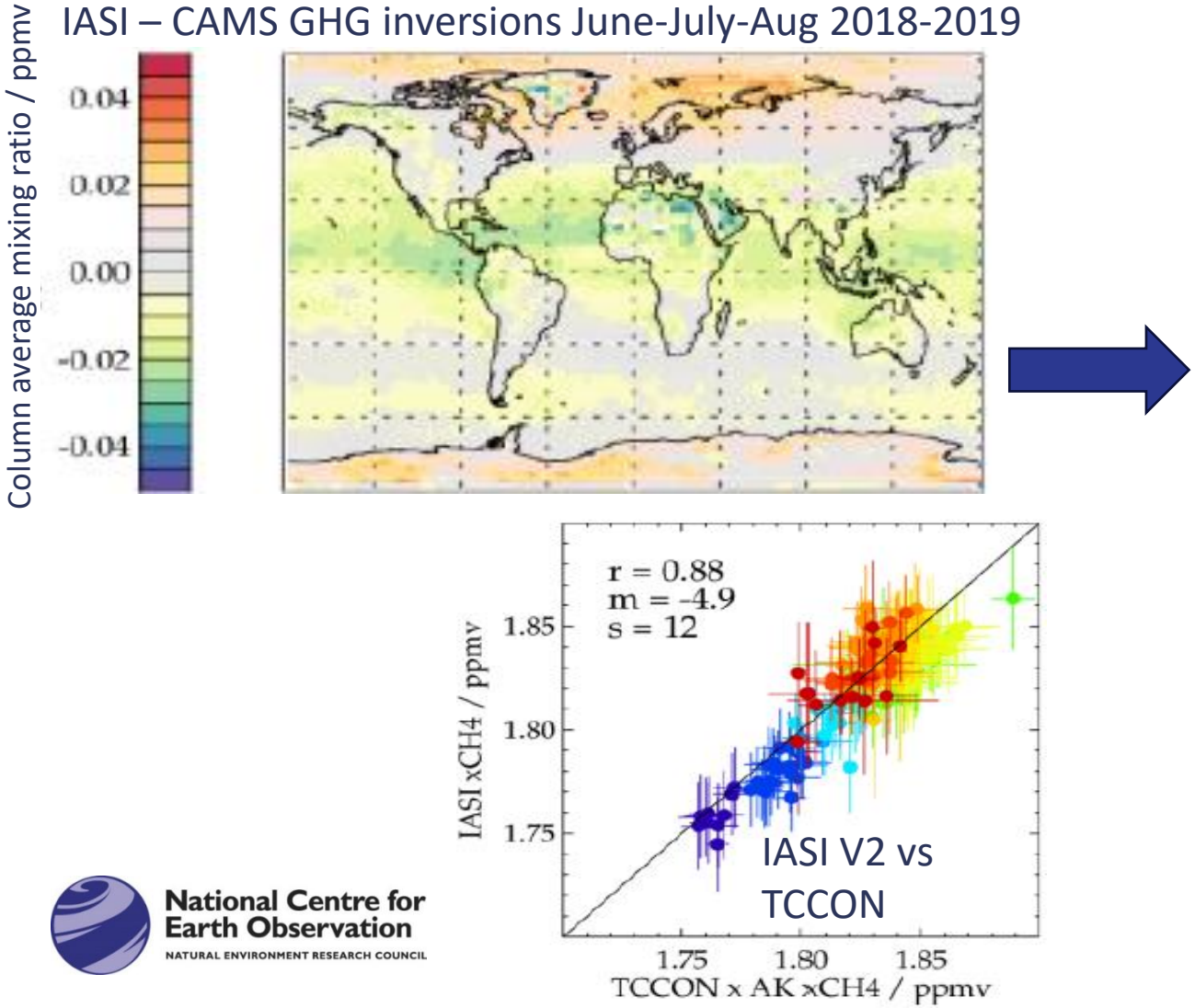
# RAL IASI V2 vs V3 Data (improvement via Methane+)

**Current version 2.0 (in CEDA archive)**

https://dx.doi.org/10.5285/4bbcb1722f2842c1b0a5ebc19160a863

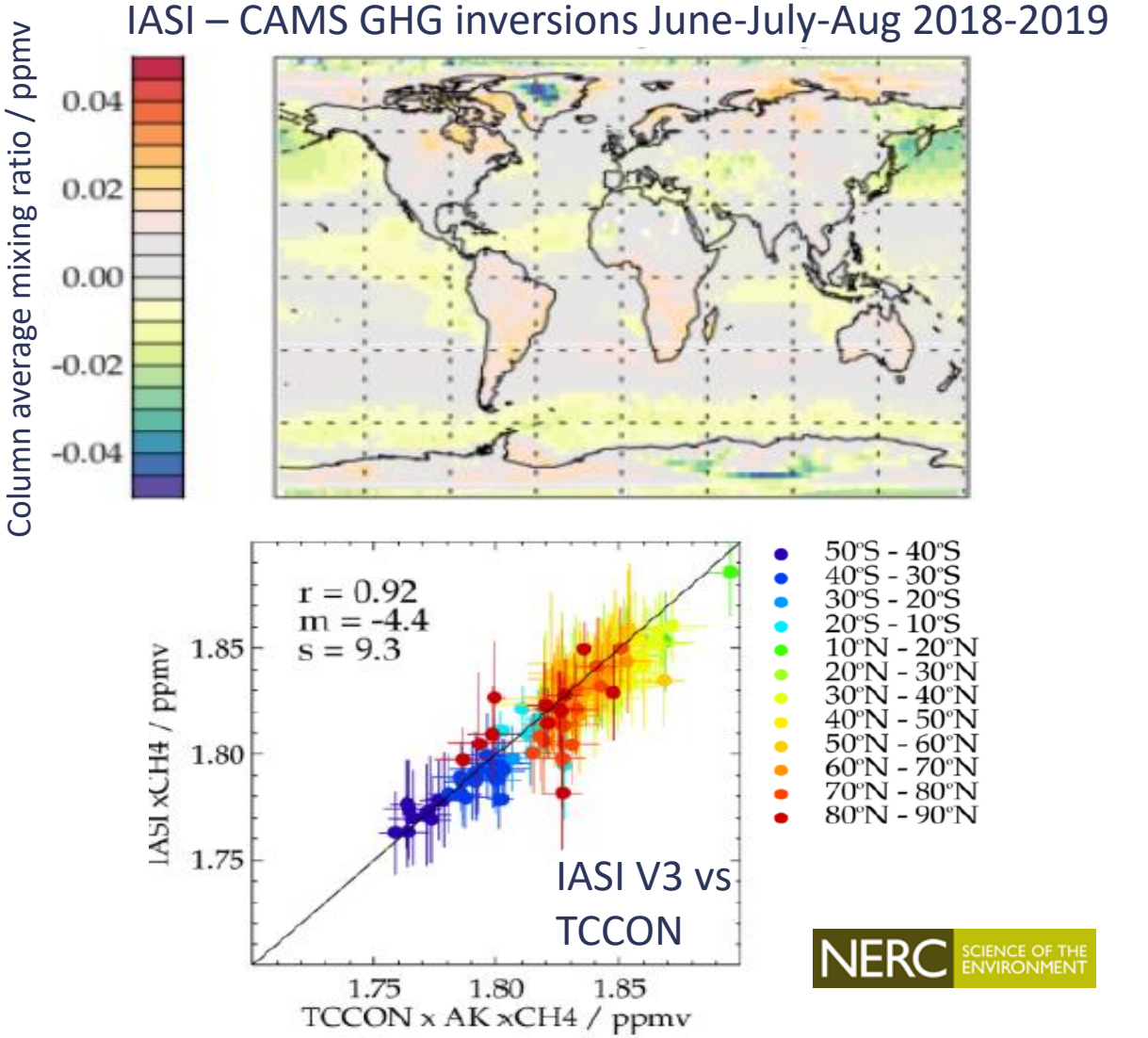
IASI – CAMS GHG inversions June-July-Aug 2018-2019




**New version 3.0 after Methane+**

Soon to be archived for public access…

IASI – CAMS GHG inversions June-July-Aug 2018-2019

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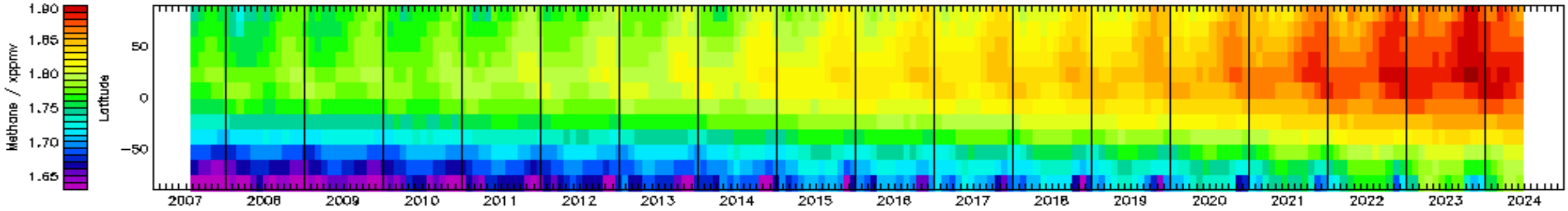
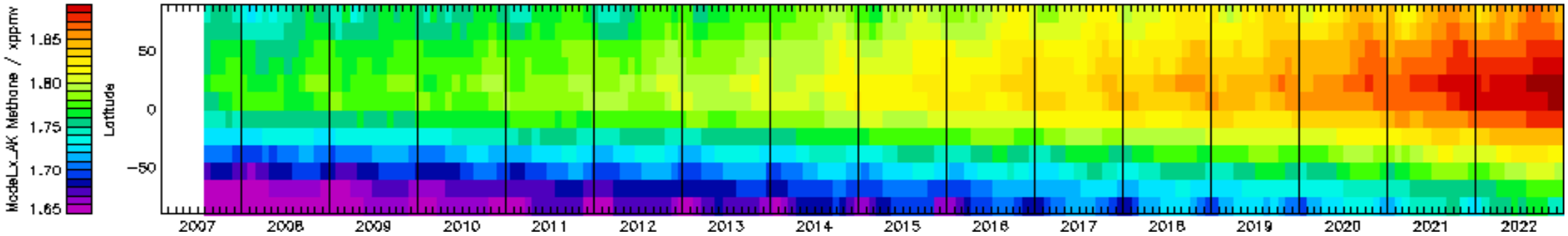
# Zonal mean total column average methane timeseries 2007-2024

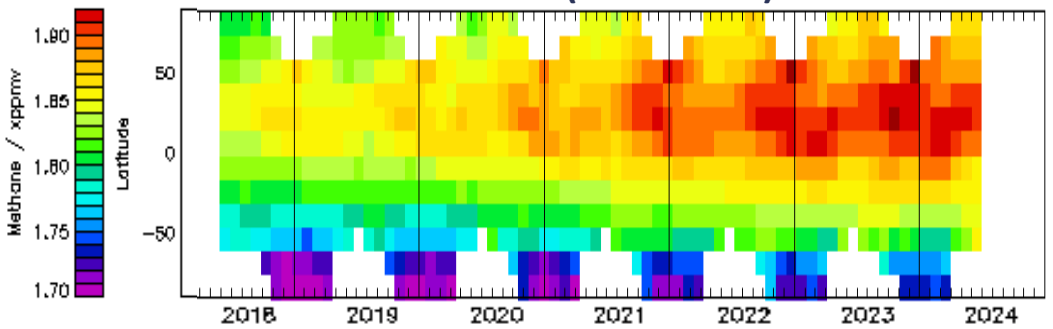
## IASI Metop A+B




## CAMS GHG surface only flux inversion v19r1 (2007-2019), +v22r1 (2020-2022)



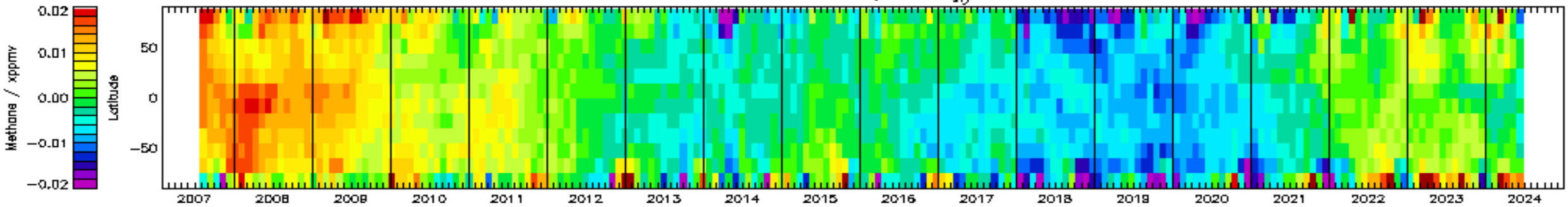

## S5P (2018-2024)



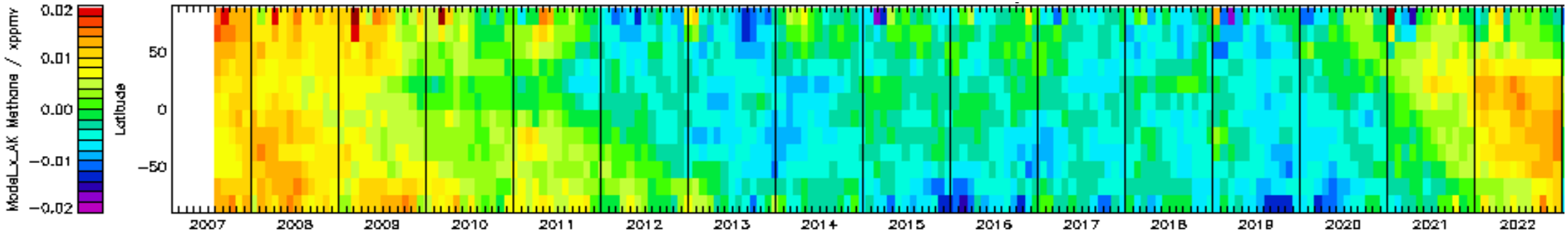

NB spatial sampling of S5P very different, especially at high latitude !

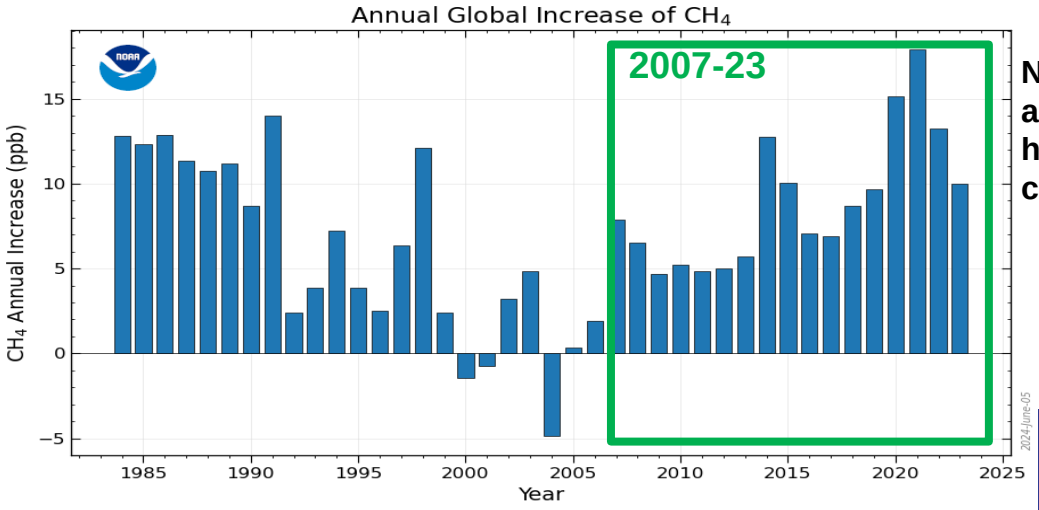
# *Detrended de-seasonalised anomaly* of total column average methane 2007-2024

**IASI Metop A+B**



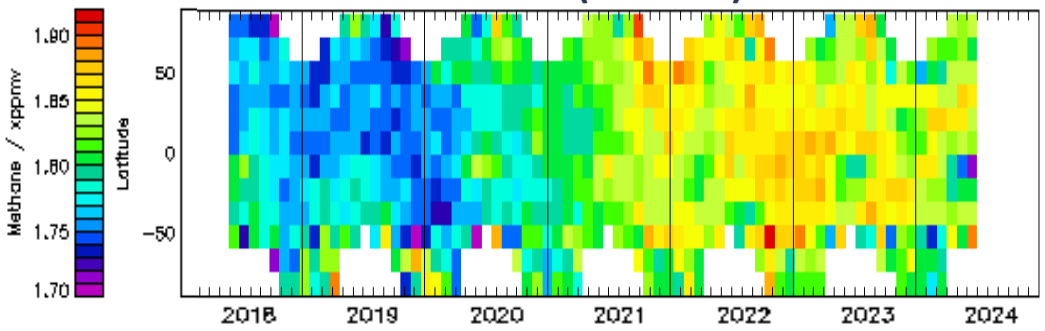

**CAMS GHG surface only flux inversion v19r1 (2007-2019), +v22r1 (2020-2022)**




**NOAA ground-based air sampling sites: https://gml.noaa.gov/ccgg/trends_ch4/**

**S5P (2018-24)**

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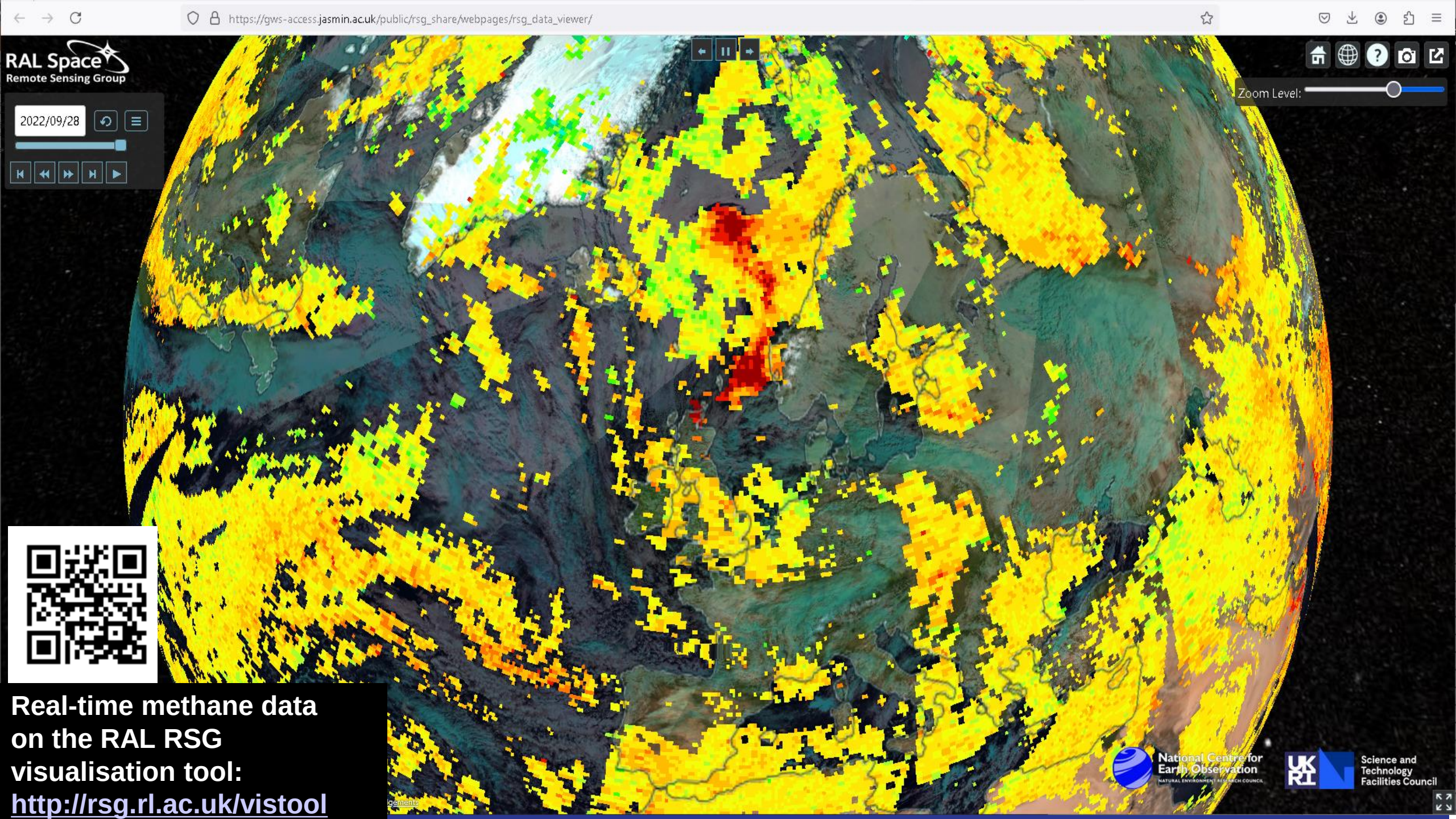
https://gws-access.jasmin.ac.uk/public/rsg_share/webpages/rsg_data_viewer/
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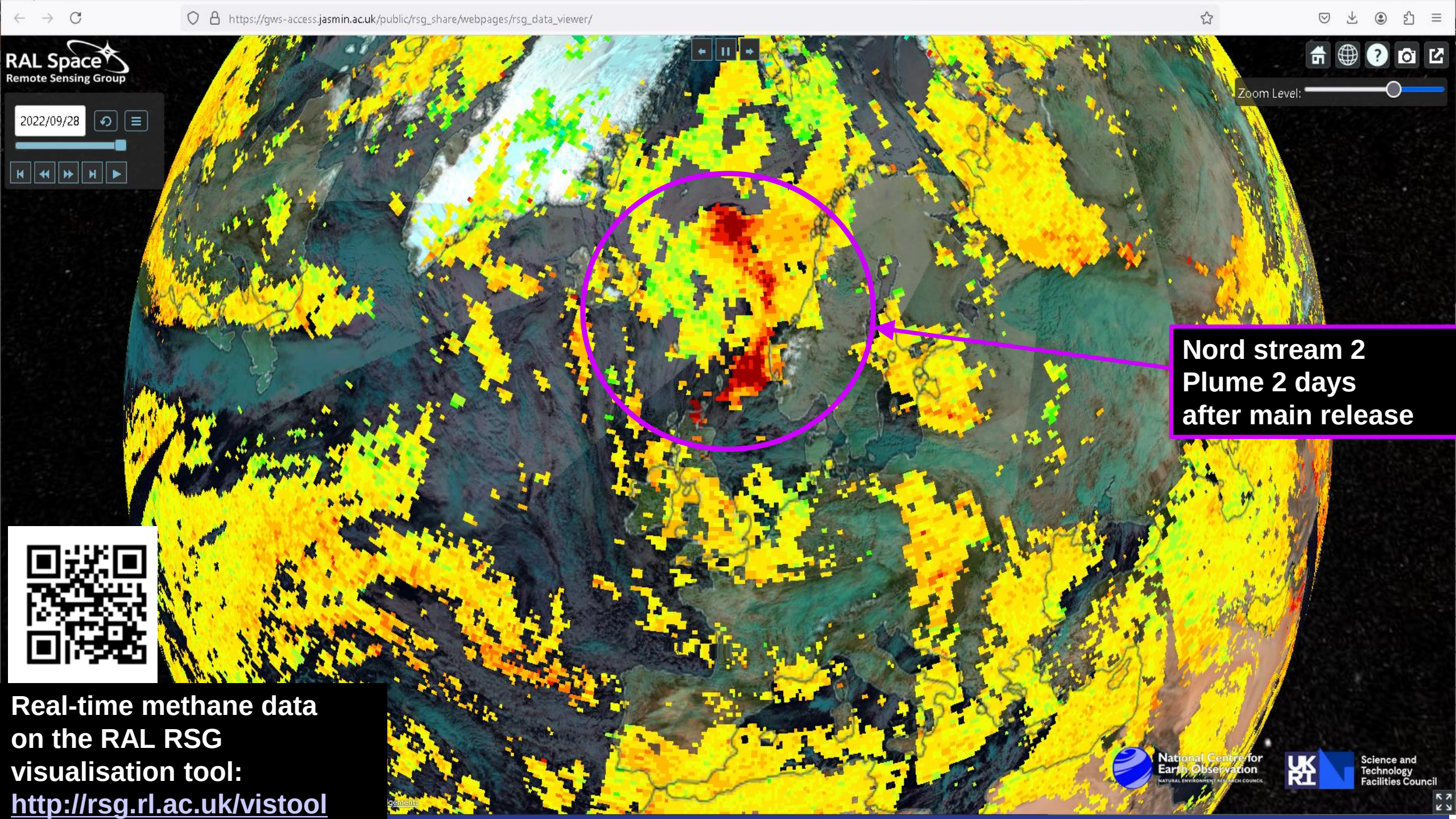
2022/09/28
Zoom Level:
National Centre for Earth Observation
Science and Technology Facilities Council
Real-time methane data on the RAL RSG visualisation tool:
http://rsg.rl.ac.uk/vistool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Zoom Level:
Nord stream 2
Plume 2 days
after main release
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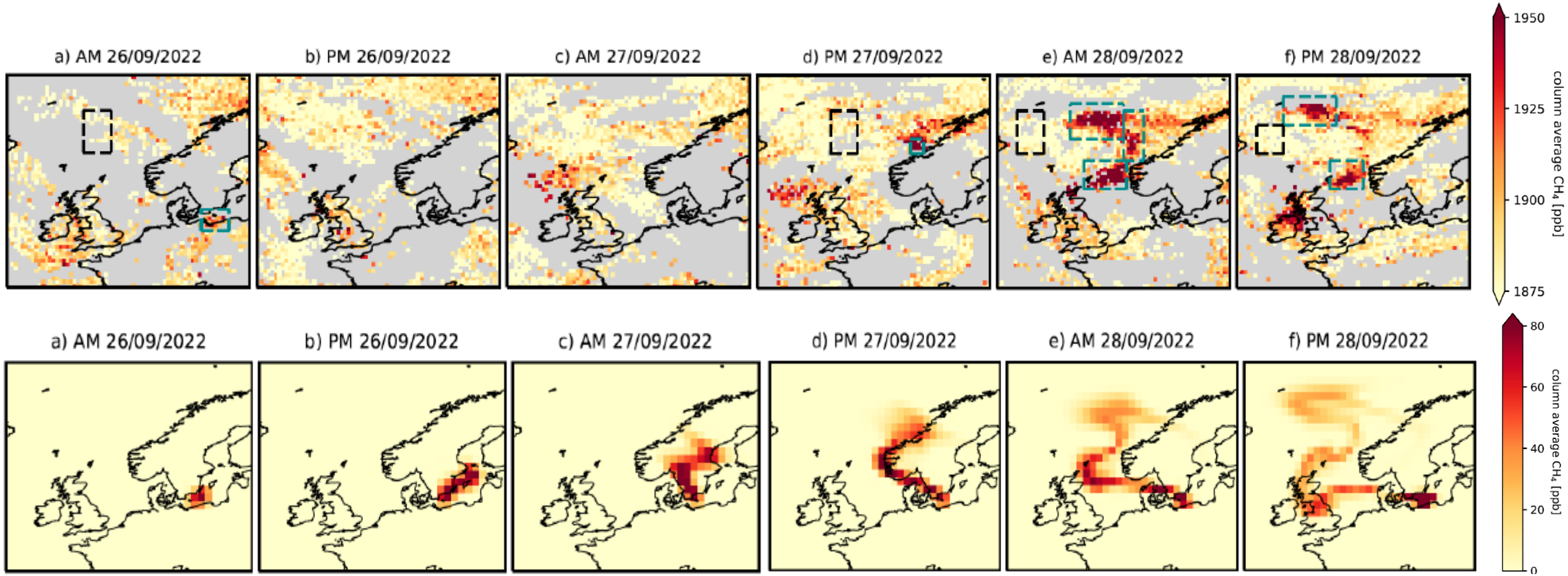
National Centre for
Earth Observation
Science and
Technology
Facilities Council

https://doi.org/10.5194/egusphere-2023-1652
Preprint. Discussion started: 23 November 2023


# Quantifying large methane emissions from the Nord Stream pipeline gas leak of September 2022 using IASI satellite observations and inverse modelling

Chris Wilson[1,2], Brian J. Kerridge[3,4], Richard Siddans[3,4], David P. Moore[5,6], Lucy J. Ventress[3,4], Emily Dowd[2], Wuhu Feng[2,7], Martyn P. Chipperfield[1,2], John J. Remedios[5,6]

UNIVERSITY OF LEEDS




Total mass of CH4 emitted during the first two days: 215 - 390 Gg. *Results feeding into UNEP-IMEO Sythesis Paper*

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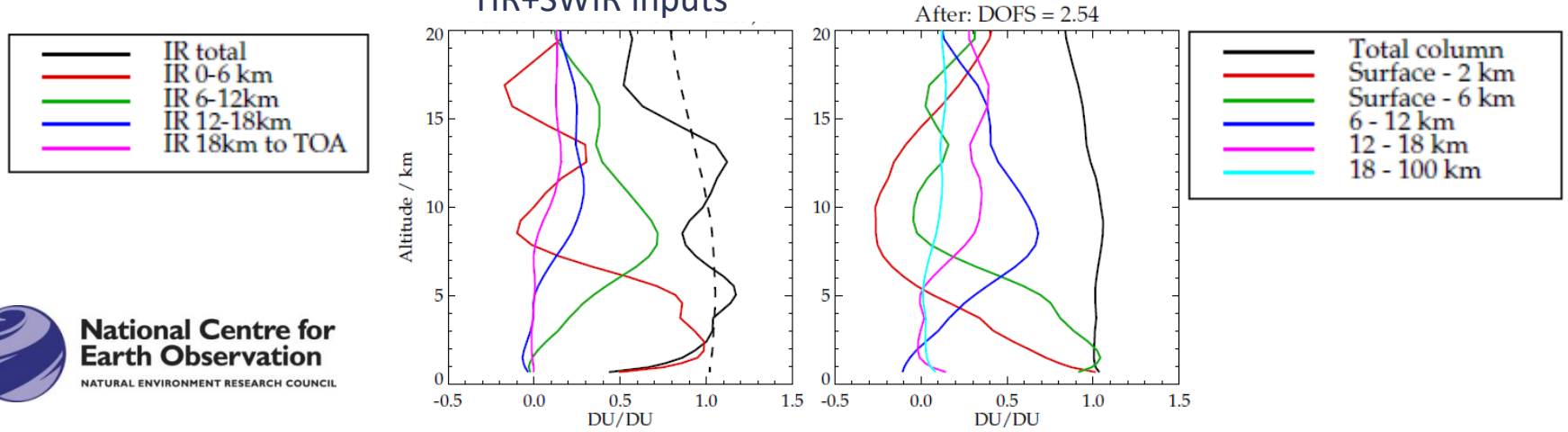
# Combined IASI and S5P Retrievals

- "L2-L2" combination approach developed to combine S5P total column measurements (Operational V2, Lorente et al 2022) with IASI retrieved sub-columns
- Approach uses optimal estimation, treating the individual retrievals as "measurements", accounting for respective averaging kernels and using a common simple prior constraint:
- Latitude and month dependent bias correction (based on comparisons to CAMS flux inversion) is applied to both IASI and S5P before the combination is carried out.
- Approach leads to total column from combined scheme be closely constrained to match SWIR total column and upper layer tend to follow the TIR; *Lower tropospheric layers take information from both.*

Averaging kernels of TIR+SWIR inputs

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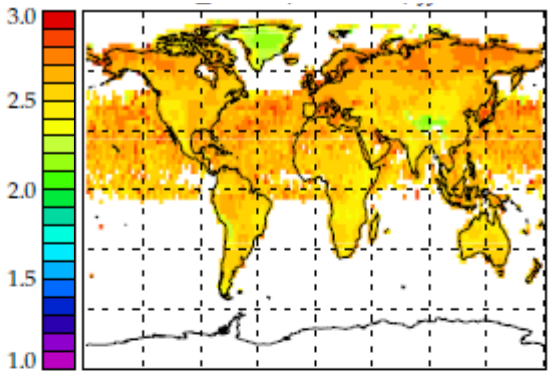
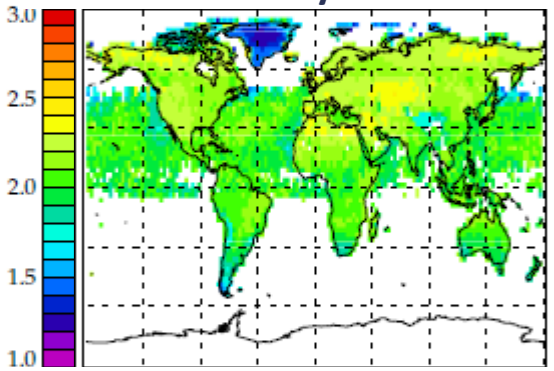
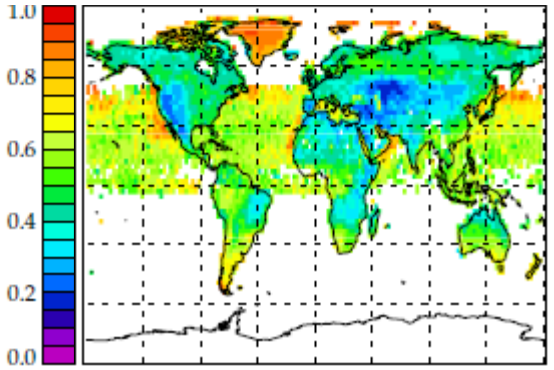
Combined retrieval degrees of freedom (DOFS)



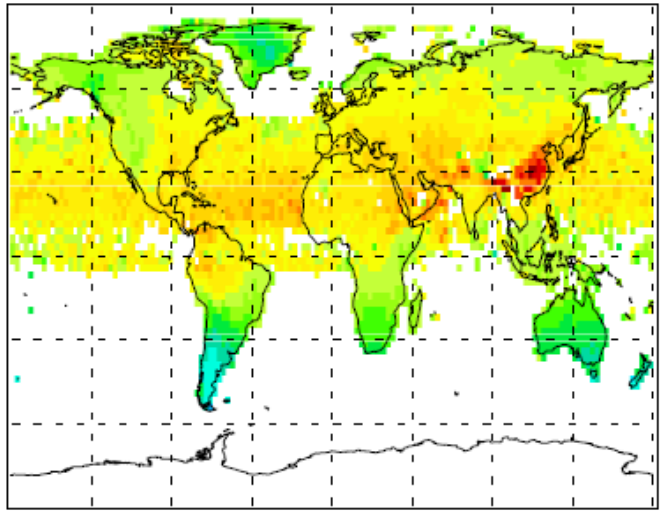
IASI only DOFS



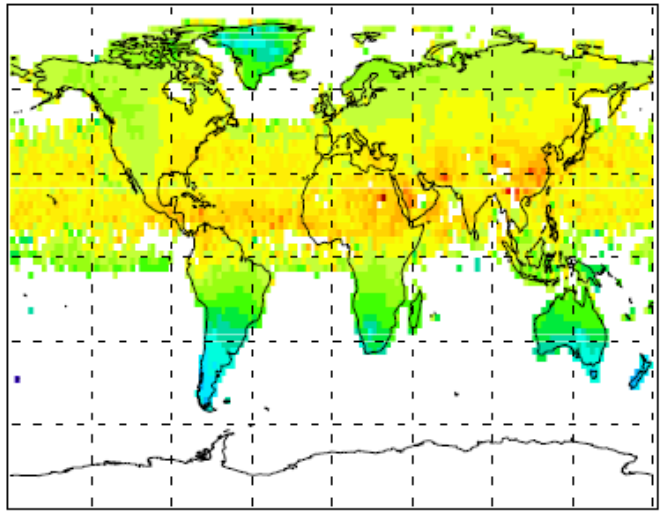
Combined - IASI DOFS difference

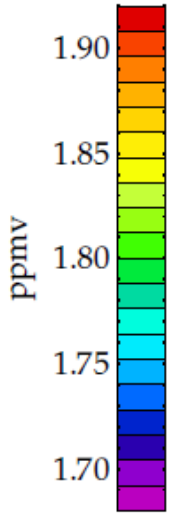


S5P Column Average

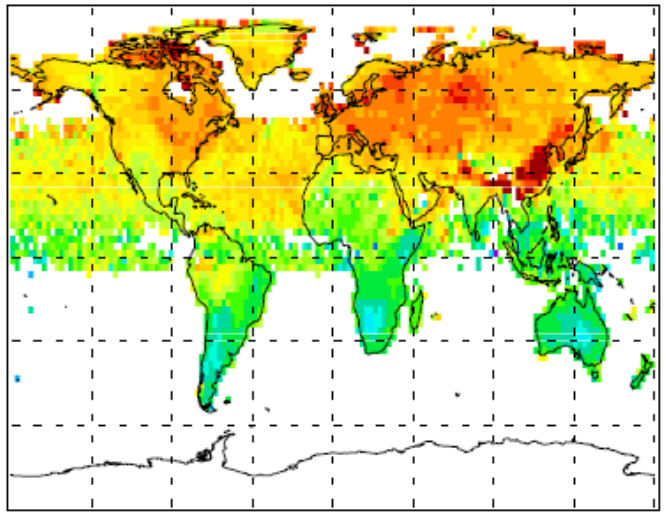


IASI Column Average

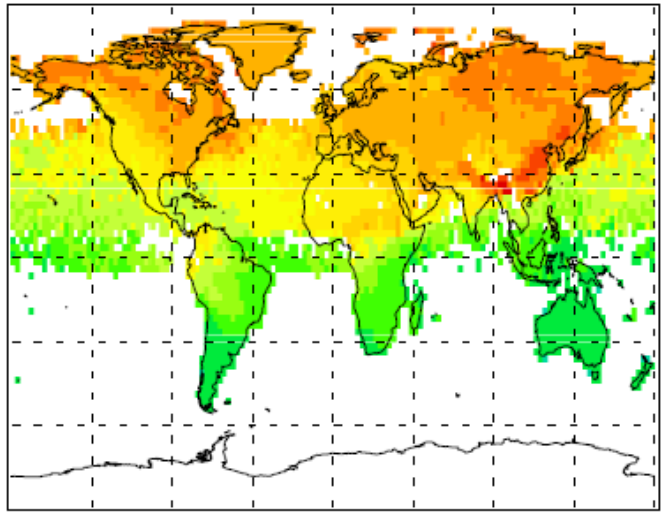




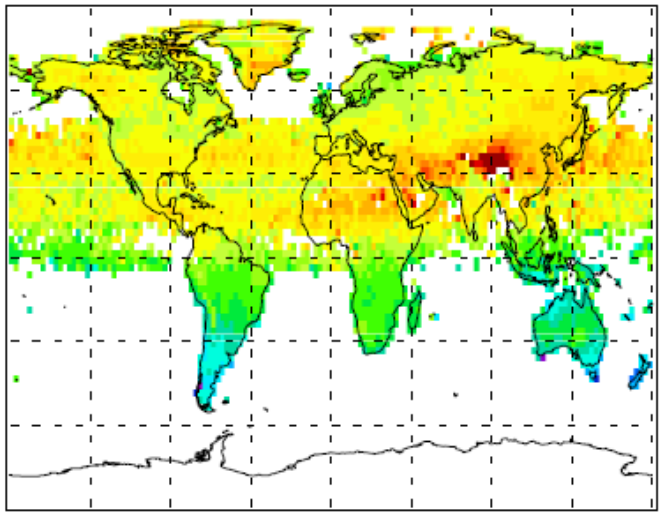

Combined 0-6 km sub-column



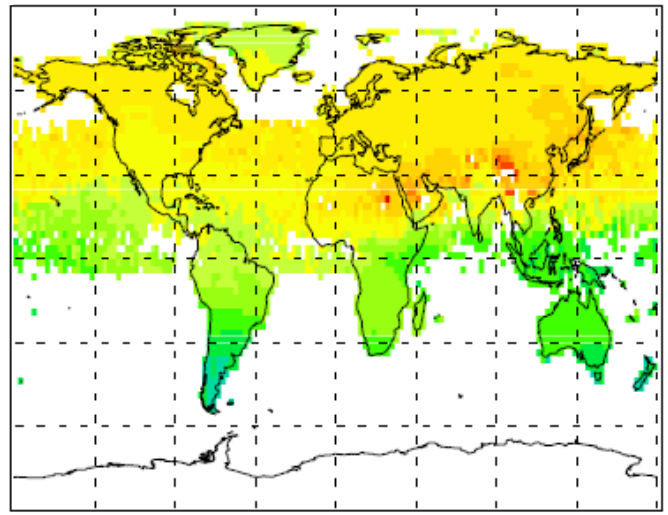
CAMS 0-6 km sub-column

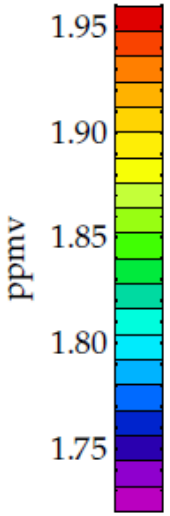


Combined 6-12 km sub-column



CAMS 6-12 km sub-column






Seasonal averages for June-July-August 2018+2019

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Joint retrieval assigns positive anomalies in S5P (presumably related to emissions), which are not seen by IASI into 0-6km layer.

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# Summary / Further work



- New (V3) RAL IASI dataset has been produced & validated cf ground based and airborne data, extensively compared with S5P and CAMS GHG surface-only flux inversion v19r1 and test data assimilated in TM5 flux inversion (ESA Methane+; UK NCEO/EOCIS)
- Data from 2007-present will soon be archived for public access on CEDA, superseding the existing V2 data.
- Data also produced in near-real time and can be visualised online via **http://rsg.rl.ac.uk/vistool**

  → *The only satellite observation and mass estimate of the main Nordstream plume*
  *(C.Wilson et al, in preparation, ACP; S.Harris et al, UNEP Nordstream Synthesis Report, in review, Nature)*
- Results still limited by spectroscopy / detailed radiative transfer issues

  → Strongest features in methane $n_4$ band ~1300cm-1 to add profile information but yet to be fitted accurately.

  → Spectroscopy + line-by-line calculations to be revisited (with Spascia) in ESA SMART-CH4 project. (Builds on findings of previous ESA TIR spectroscopy study and recent updates to radiative transfer codes.)
- Lower (<6km) and upper (>6km) troposphere layers resolved well by IASI-S5P combination; variability in near surface (0-2km) appears high compared to CAMS.

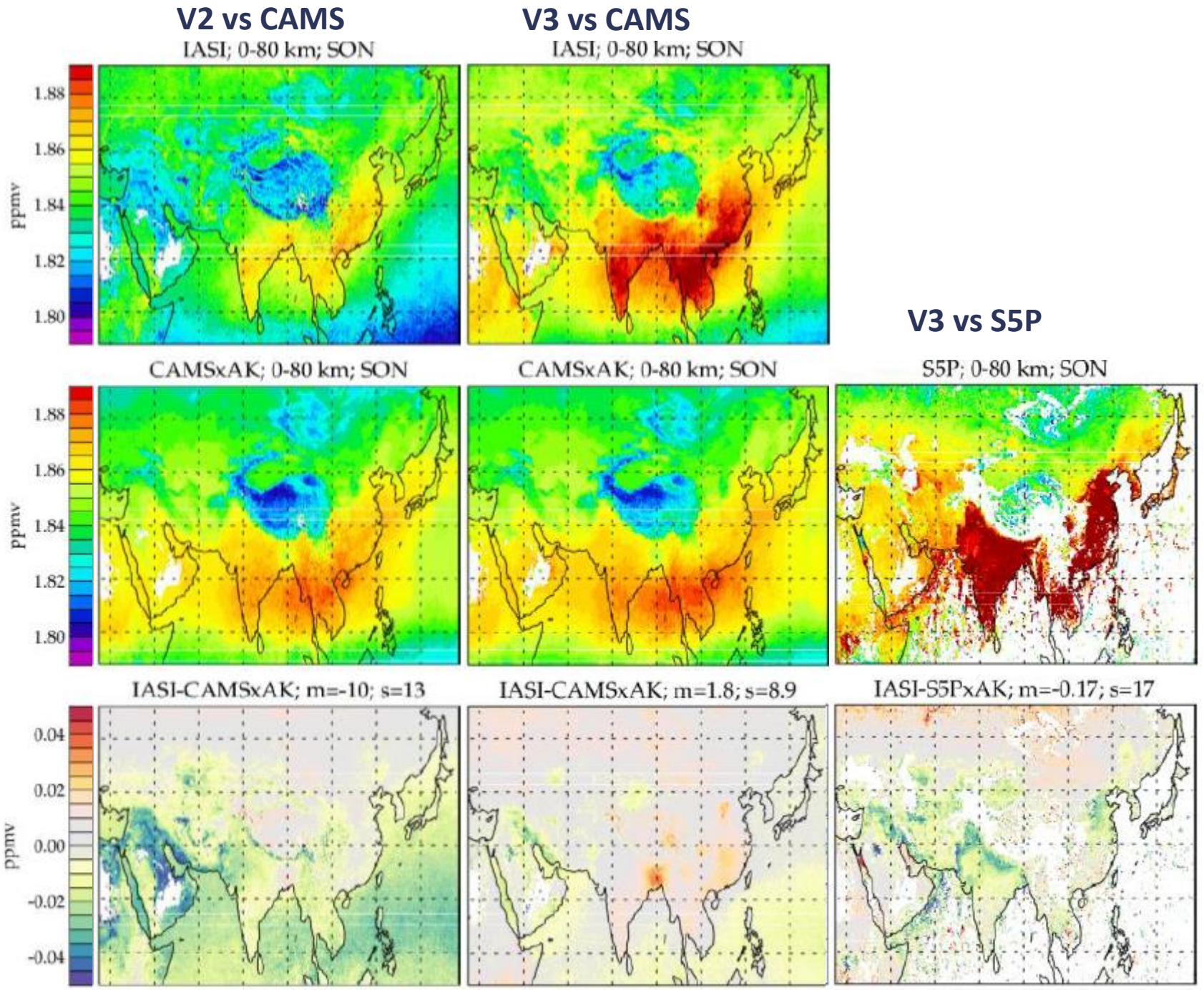
  → More *profile* validation data needed to adequately validate satellite height-resolved retrievals.
- IASI+S5P retrievals also limited by co-location (due to different orbits).

  → Metop 2nd Generation to provide co-located SWIR (S5) and TIR (IASI-NG) with greater potential

**Detailed comparisons over regions:**
**Asia**
**(Sept-Oct-Nov 2018-19)**

Bias cf CAMS reduced + spatial features more similar to CAMS
Real difference over Bangladesh

S5P sees more (near surface) emission in Indo-Gangetic plain



## M+V2BC combined retrievals: 0-2km sub-column (SON)

**S5P+ IASI**

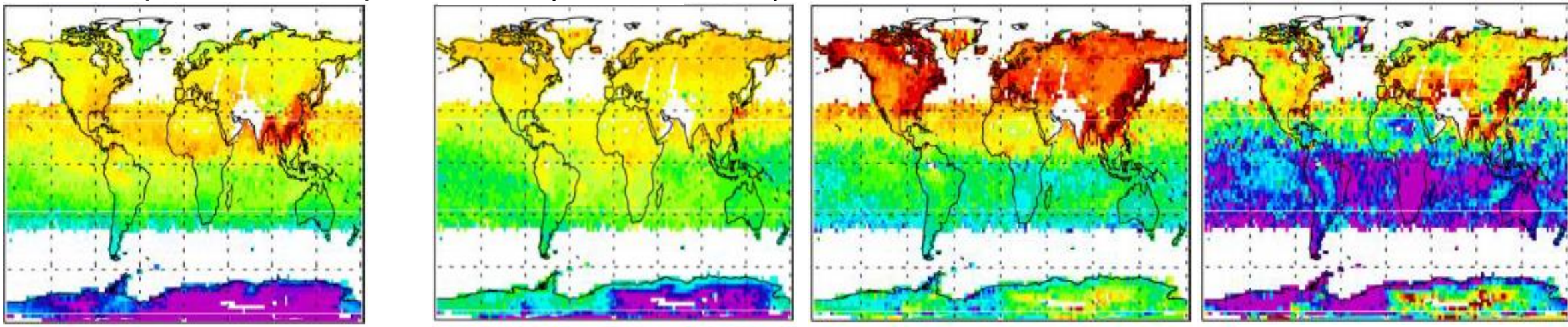
Sept+ Oct+Nov 2018+19

Total column (S5P dominates)

6-12km (IASI dominates)

0-6 km

0-2 km



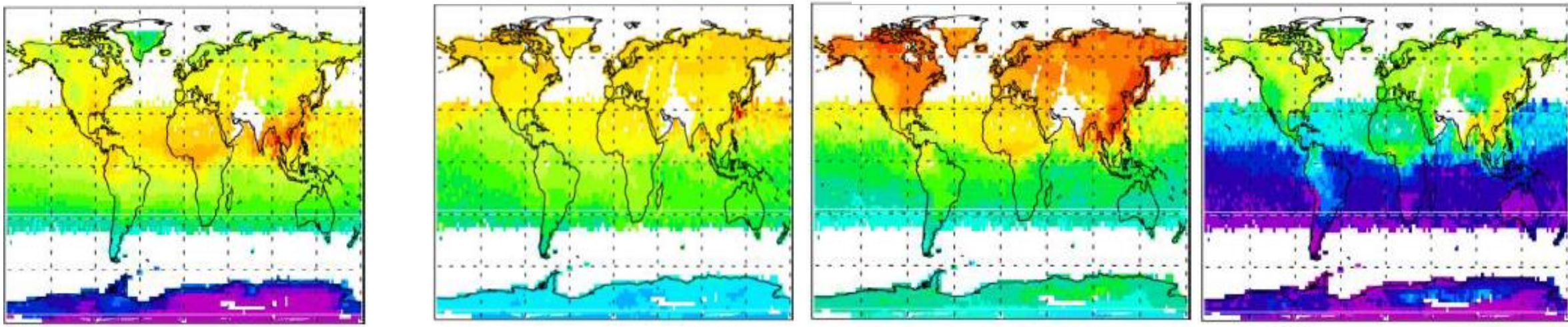
**CAMS GHG Inver-sion**

Total column

6-12km

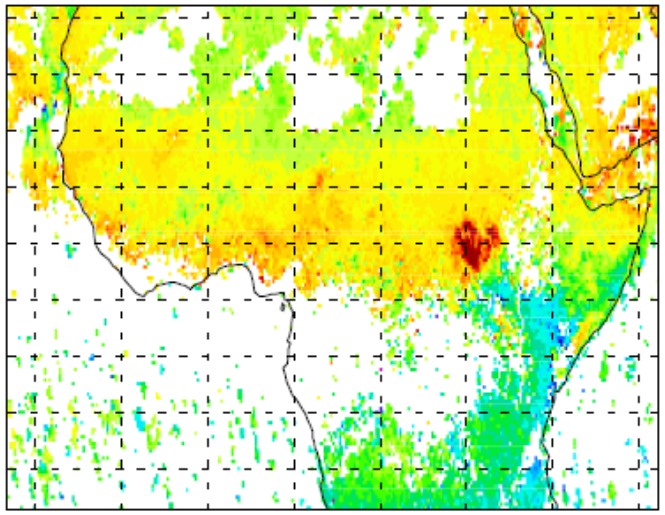
0-6 km

0-2 km

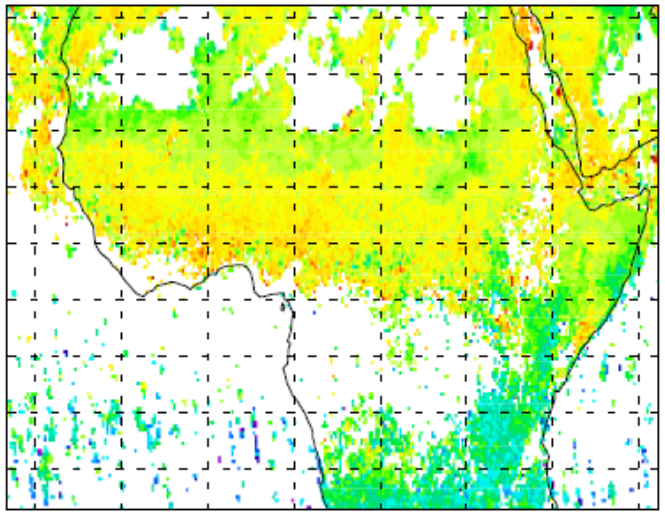


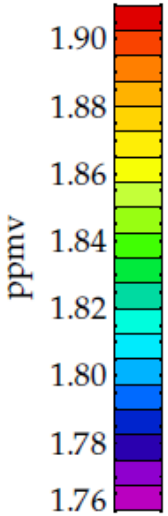
# IASI+S5P Joint retrieval inputs

S5P Total column Average



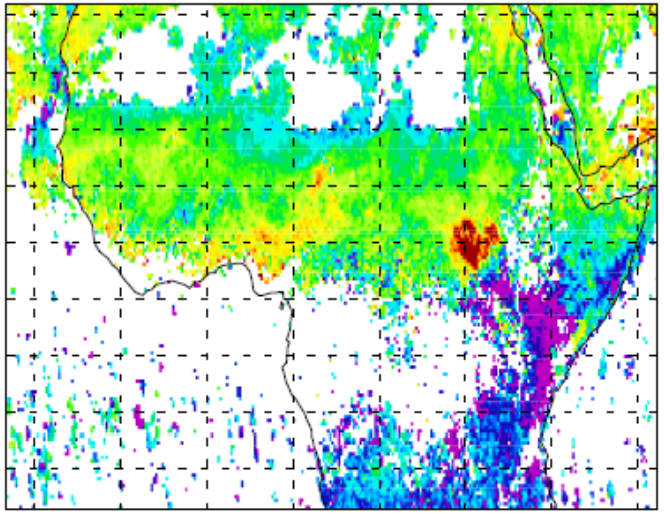
IASI Total column Average



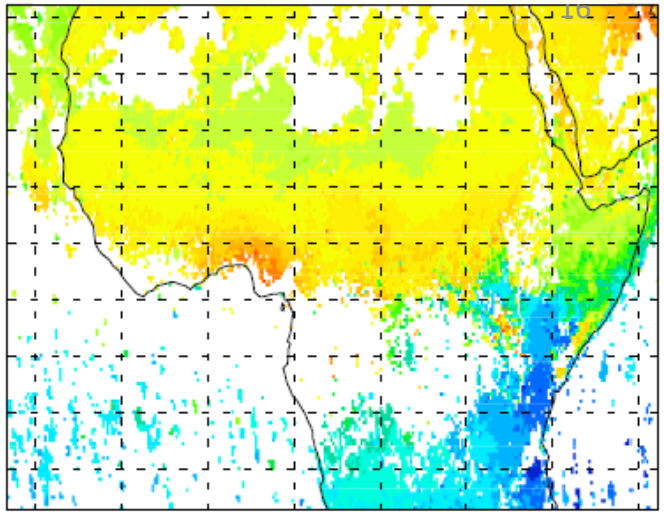



# Joint retrieval outputs (Cf CAMS flux inversion)

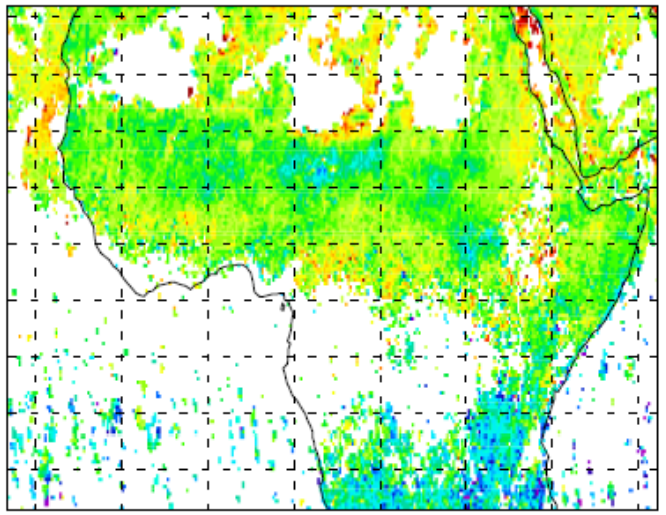
Combined 0-6 km sub-column



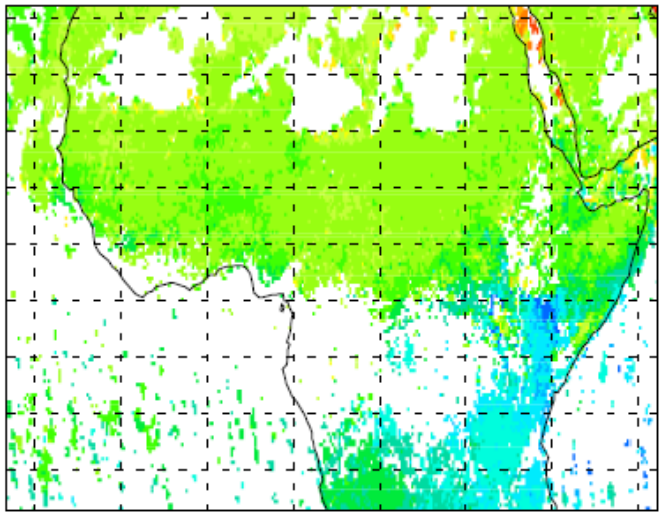
CAMS 0-6 km sub-column

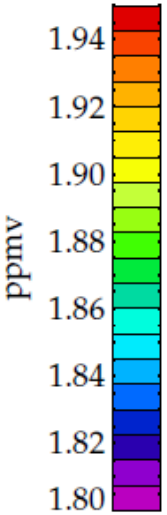


Combined 6-12 km sub-column



CAMS 6-12 km sub-column






Seasonal averages for September-October-November 2018+2019

Enhancement associated with emissions from Sudd wetlands assigned entirely to 0-6km layer.