Satellite Monitoring of Air Pollution from Polar and Geostationary Orbit: Activities in RAL Space Remote Sensing Group

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NERC's National Centre for Earth Observation (NCEO)

STFC Air Quality Network, Jan 2020 @York

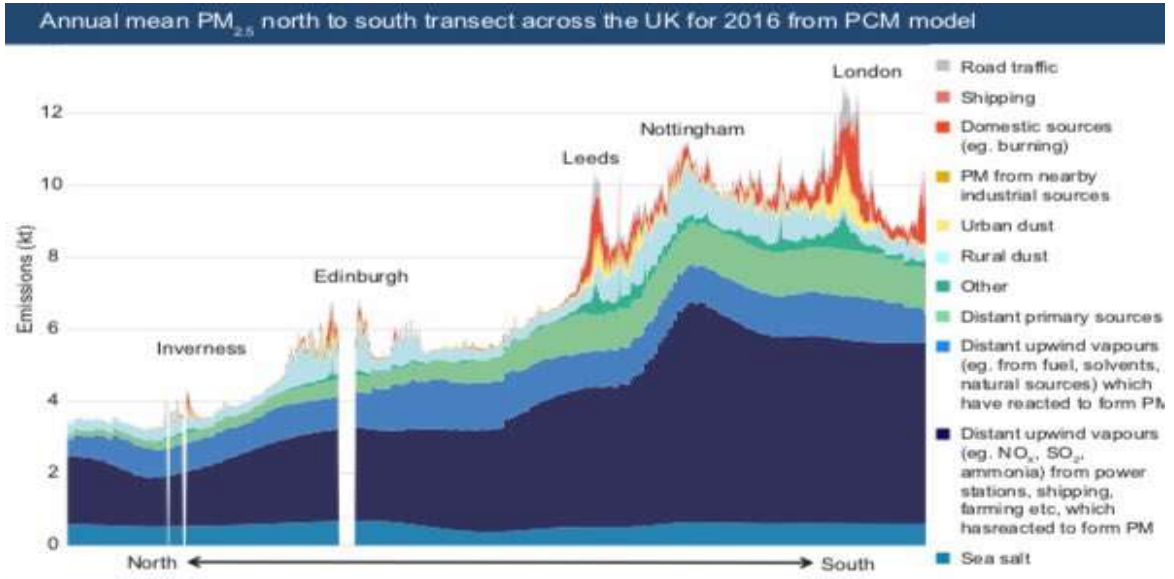
Satellite data role in Air Quality

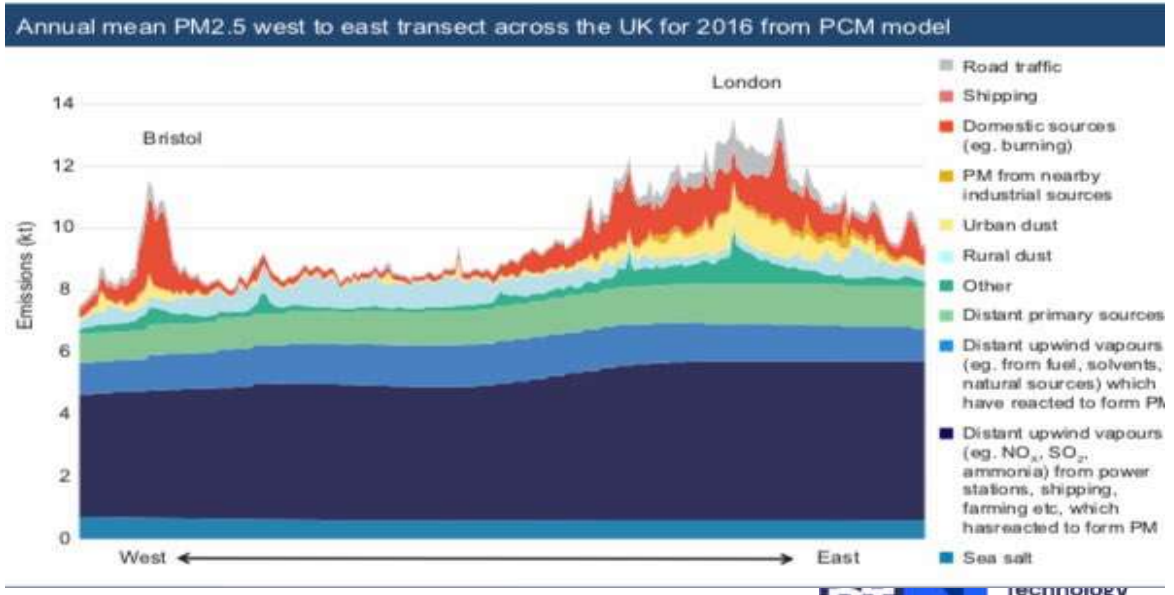
- DEFRA Clean Air Strategy Report 2019 noted majority of 'UK' annual mean PM2.5 from "distant transport" of precursors

- Satellite observations can provide largescale information
  - Transport into/out of domain
  - Help constrain systems

- Relation to AQ @surface-2m from 800+ km away?
  - Variable: product & weather dependent
  - Clouds
  - Spatial/Temporal resolution limits

➢ Useful in combination with (not in place of) in situ observations and models.





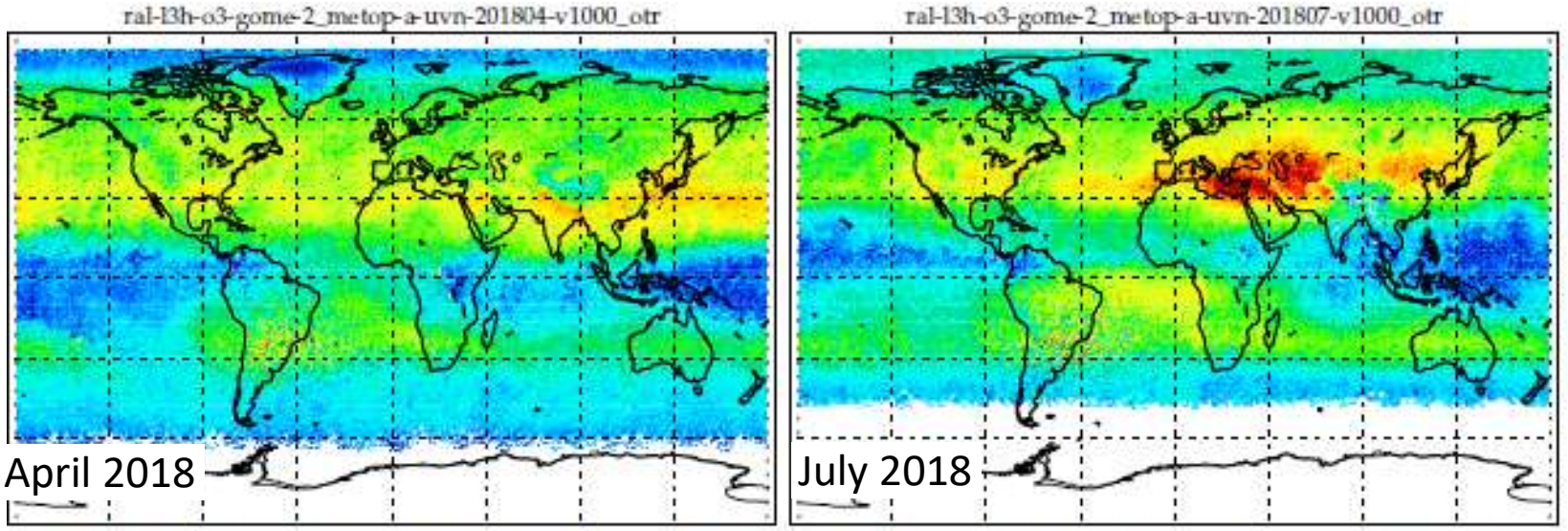
RAL Space Remote Sensing Group: Activities related to air-quality

- State-of-the-art schemes developed in UK NCEO to produce global distributions of ***tropospheric trace gases*** from current satellite missions:
  - ***Tropospheric ozone*** *from UV/Vis spectrometers (Metop GOME-2, OMI)*
  - ***Tropospheric methane, CO & ammonia + other trace gases, water vapour, temperature and ozone profiles from MetOp IR & microwave sounders***
  - *Combined wavelength schemes in development to leverage lower troposphere* O_3, *CO &* CH_4
- Scheme developed also for ***aerosol*** and cloud from satellite *imagers (including Sentinel-3 in polar orbit and MSG SEVIRI in geostationary orbit)* in co-operation with U. Oxford,
- Production of ***multi-year global datasets*** on ozone, aerosol (cloud & water vapour) for ESA's Climate Change Initiative/EU Copernicus Climate Change Service
- Development of ***near-real time*** pilot system on STFC-JASMIN
- Ozone processor code development underway for Sentinels 4 & 5 (2022-40)

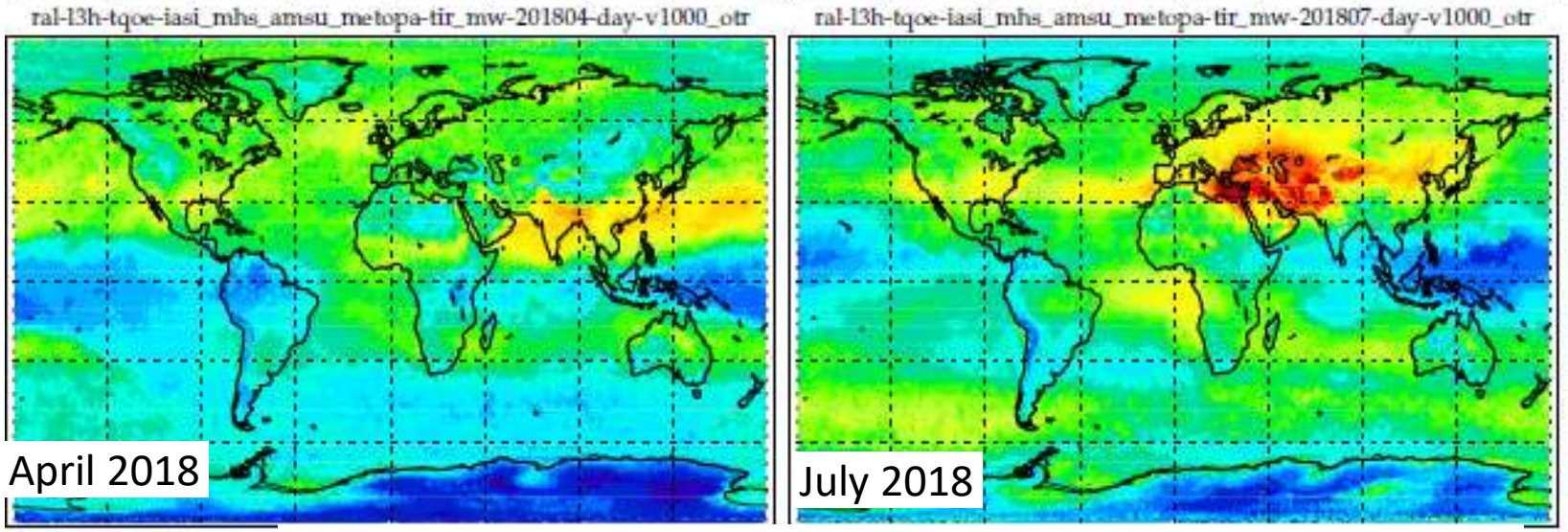
Tropospheric Ozone from Metop UV + IR sounders

RAL Space

GOME-2
UV spectrometer



IASI
IR spectrometer



Tropospheric ozone from 20+years LEO uv sensors: GOME, GOME-2, OMI, SCIAMACHY.
(NCEO/ESA CCI/EU C3S)

Recently developed scheme for thermal IR sounder IASI, which gives broadly consistent results, though vertical sensitivity of UV and IR differ

Now working (CCI+) on combinations which can add vertical information:

- UV+IR: *better resolution in UT/LS*
- UV+Visible (Chappuis): *sensitivity near ground*

National Centre for Earth Observation
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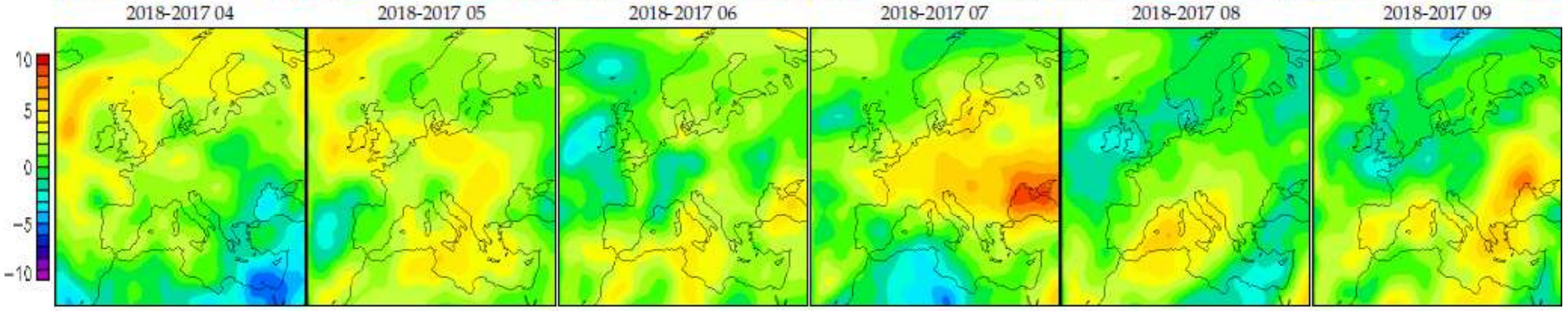
UKRI Science and Technology Facilities Council

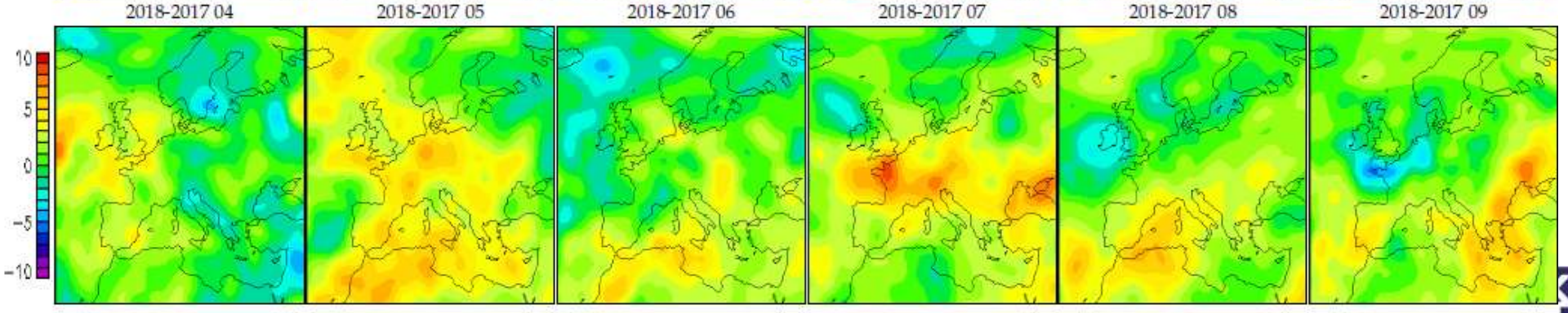
NRT Summer 2018 Ozone [0-6km]: GOME-2 & IASI

- 2 ozone schemes – UV & IR
  - Different vertical sensitivities, broad consistencies
  - Combining (+Visible) -> Improved UT/LS and Near Surface Sensitivity

IASI: Co-located GOME-2 (Metop A): 1.5 deg smoothed

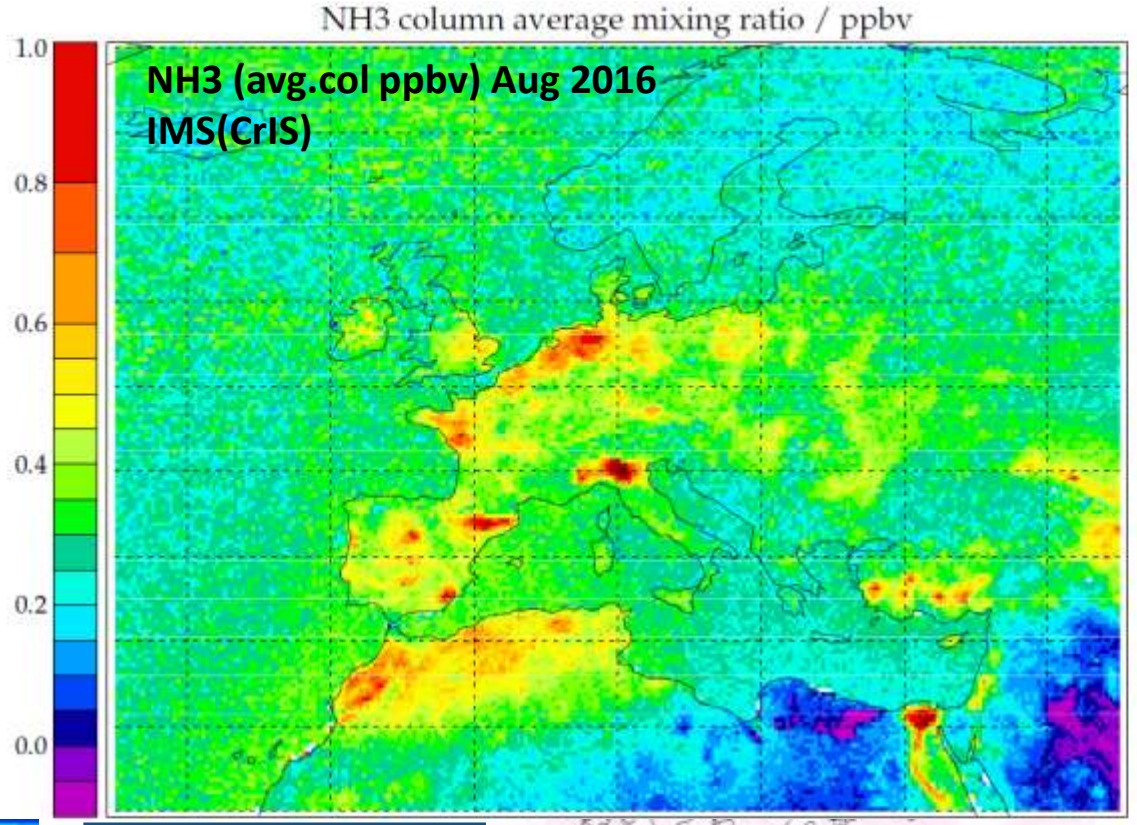


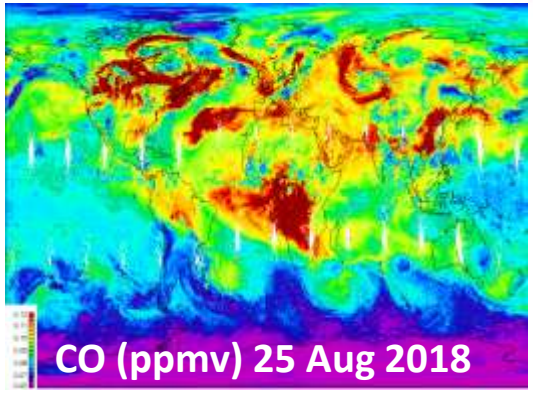
GOME-2 (Metop A): 1.5 deg smoothed

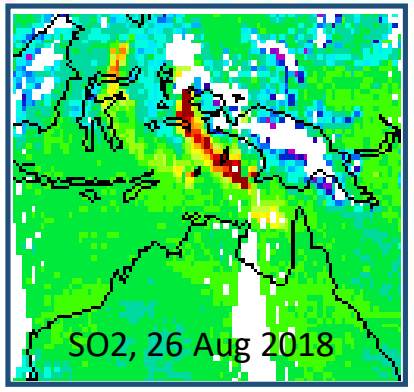


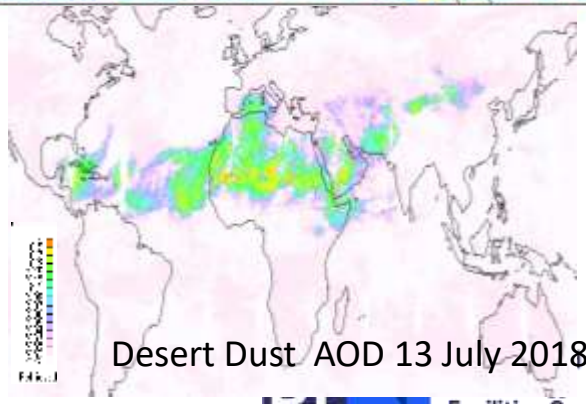
RAL Infra-red + Microwave Sounder scheme (IMS)

- Optimal estimation scheme developed for Metop sounders
- Retrieves:
  - Temperature + water vapour profiles
  - Surface spectral emissivity
  - Cloud optical depth, height, radius
  - Desert dust and sulphuric acid aerosol optical depth
  - ***Carbon monoxide, ammonia, sulphur dioxide, methanol, formic acid, nitric acid***
- So far applied to
  - Metop IASI + AMSU/MHS
  - Suomi-NPP CrIS + ATMS
    - Co-located with Sentinel 5P
    - High spatial sampling + signal to noise than IASI
    - Orbit time (13:30) favours sensitivity near surface





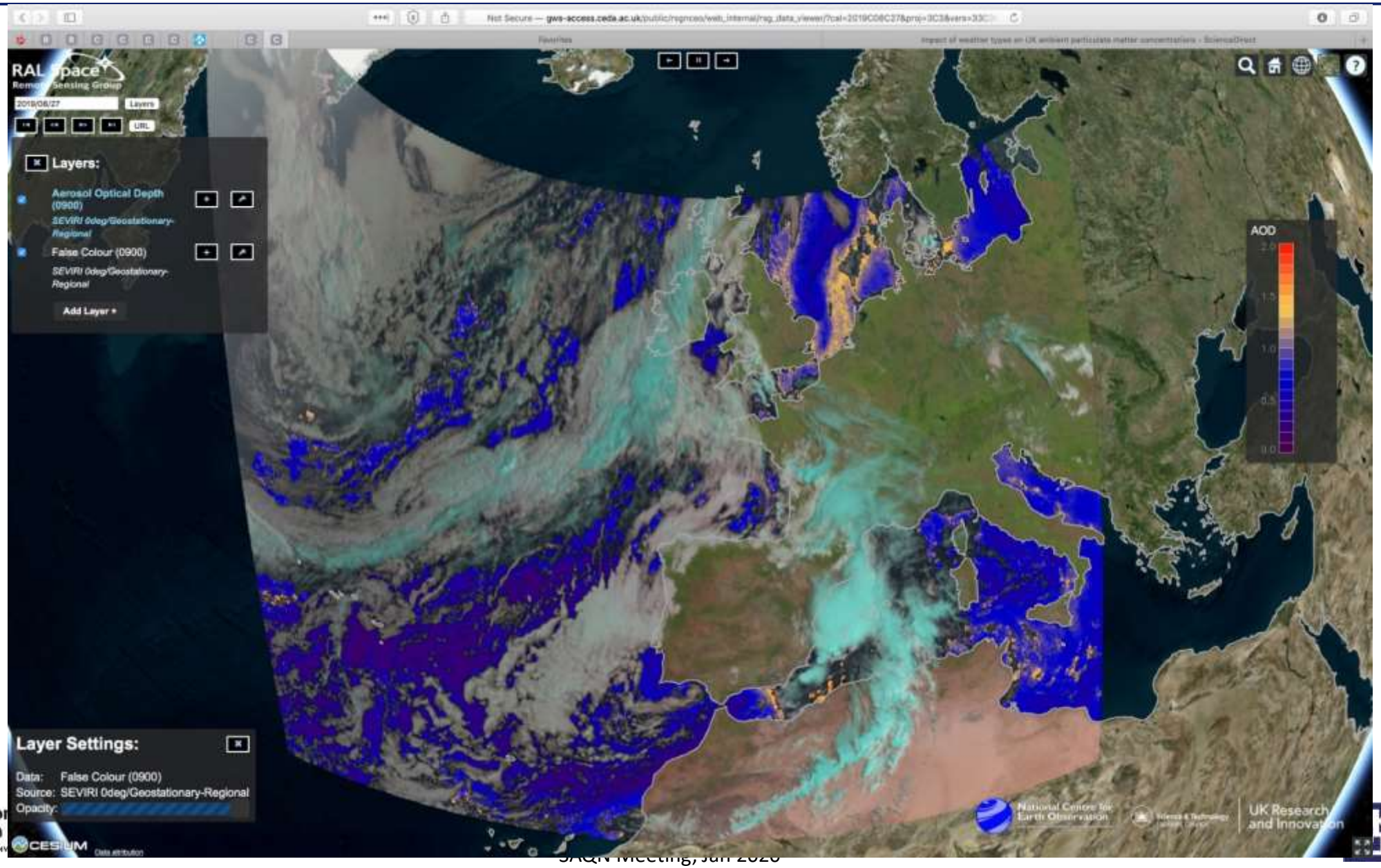




Examples

- Aerosol from Europe from SEVIRI
- Indonesia field campaign (Sept. 2019)
- Long range transport from Siberian/Canadian fires
  - NASA FIRE-AQ: Maps of CO plumes (July 2019)
- Australian fires (Jan 2020)

NRT: European Aerosol 2019/08/27: 0900



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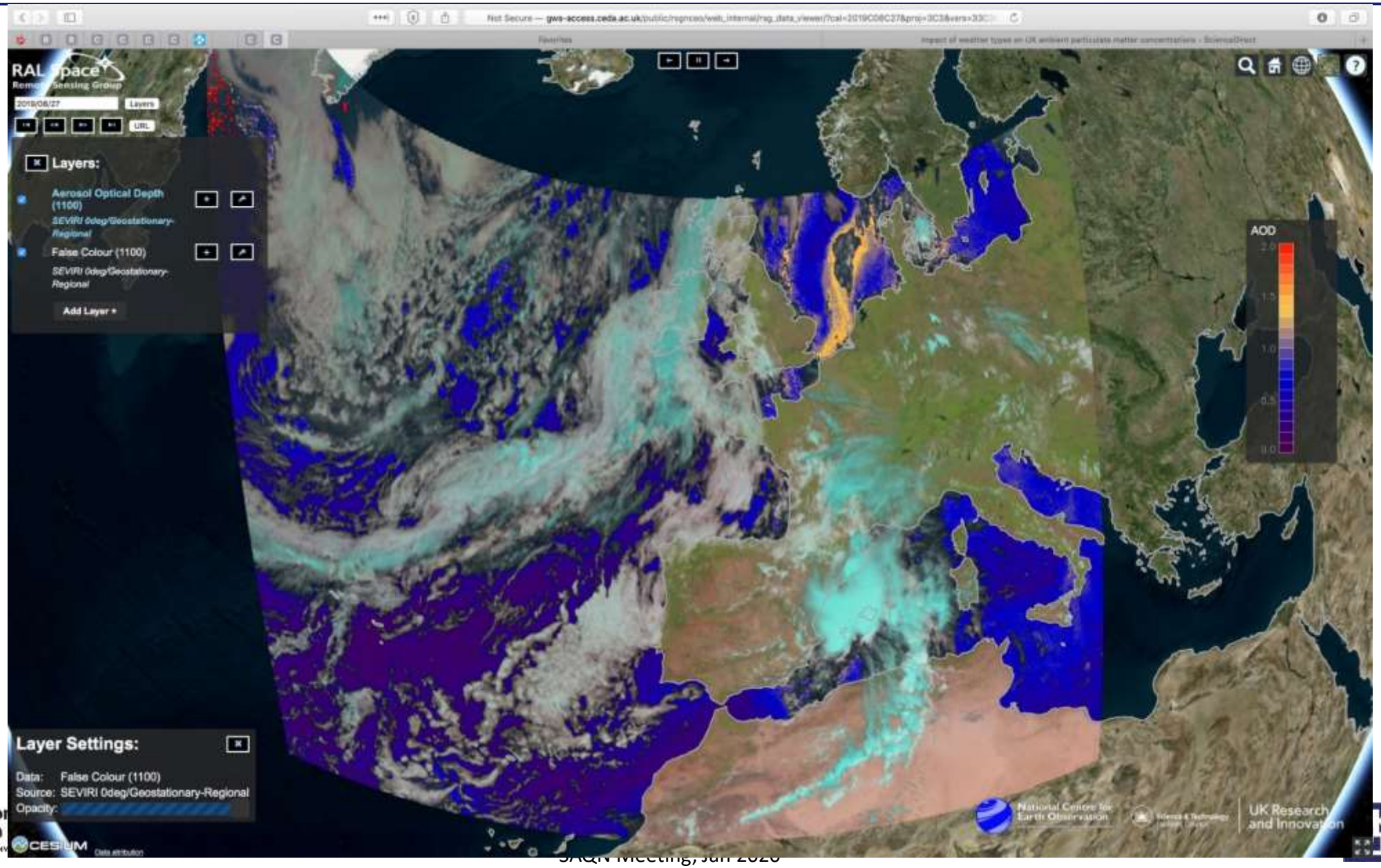
NRT: European Aerosol 2019/08/27: 1100



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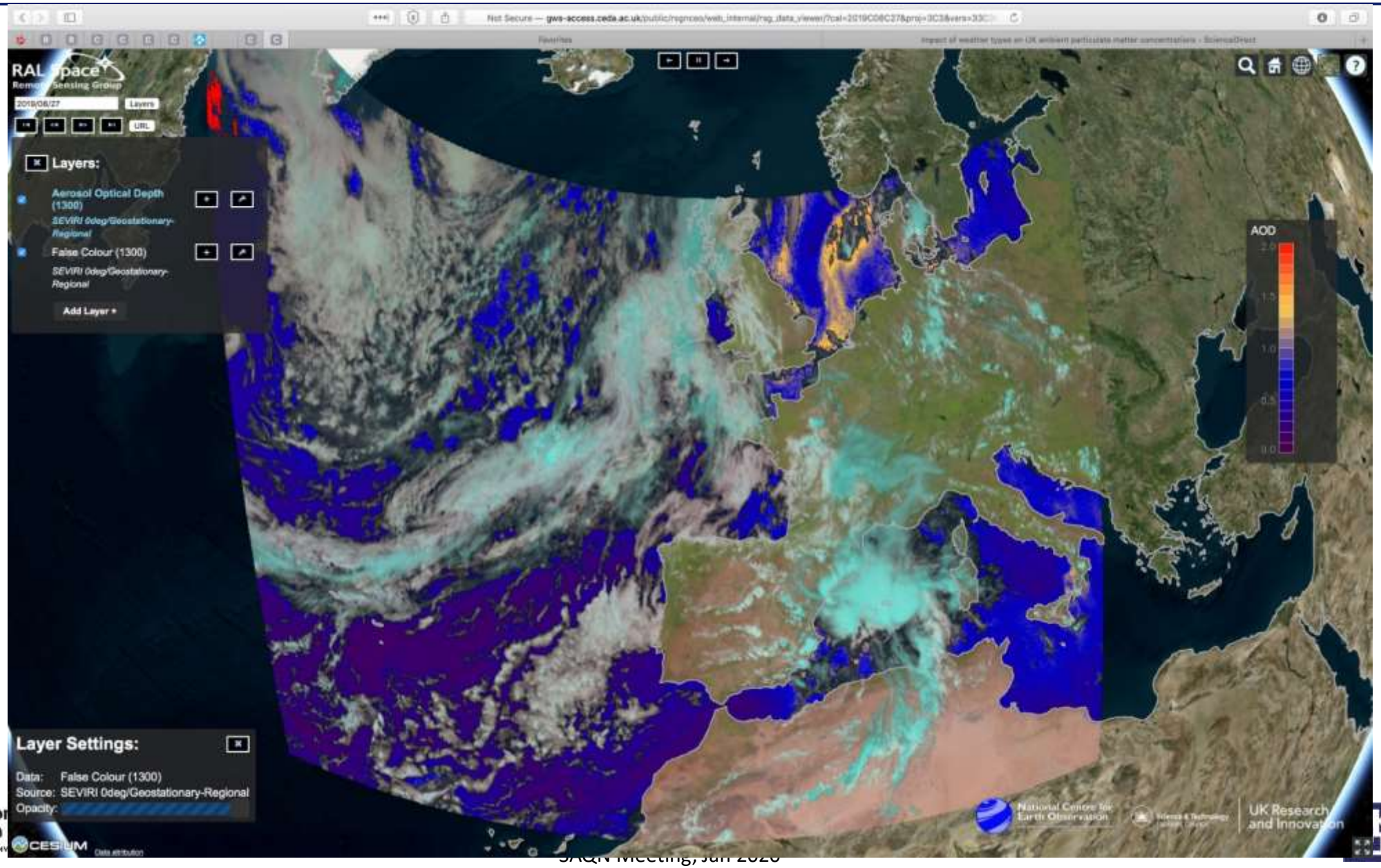

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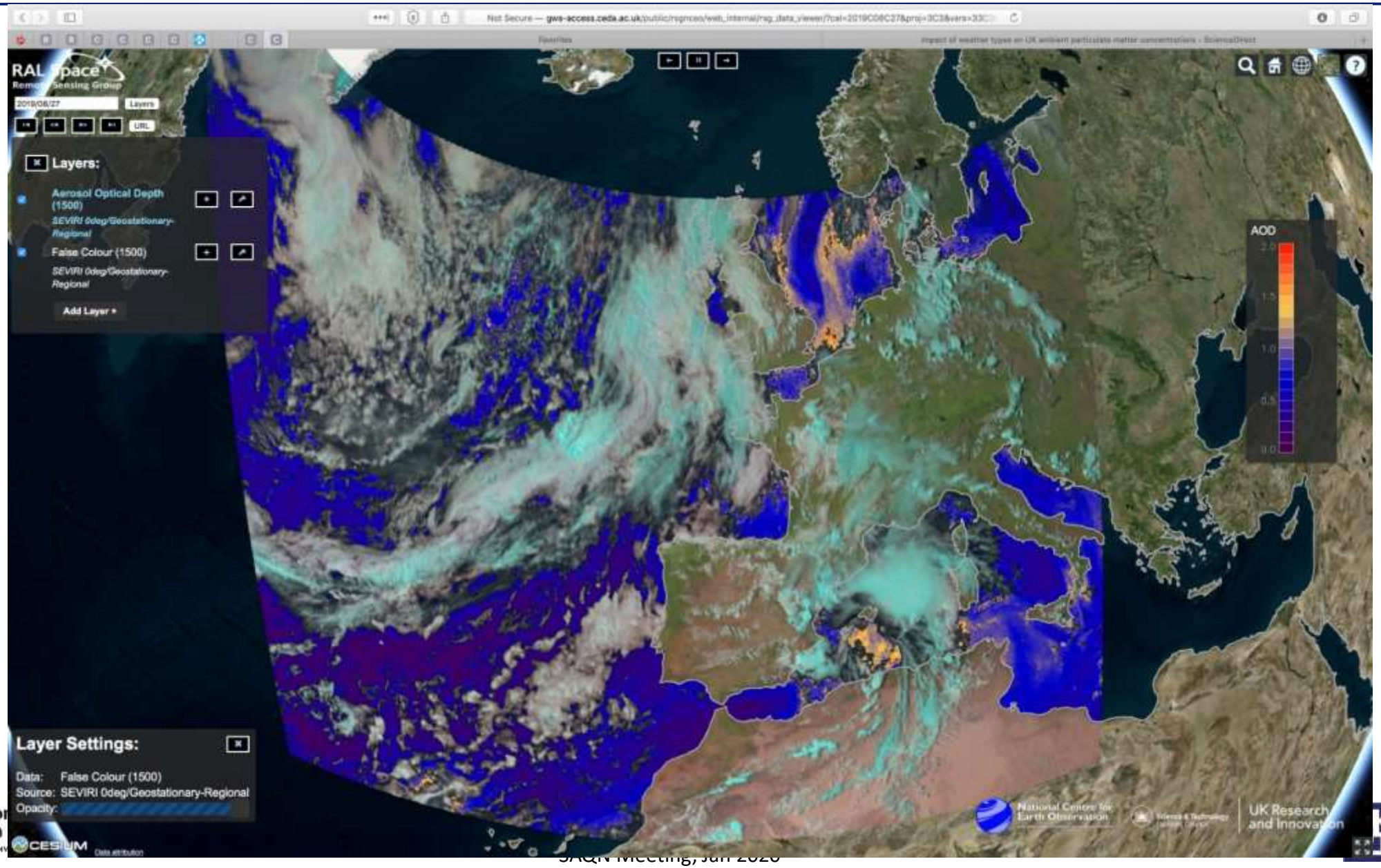
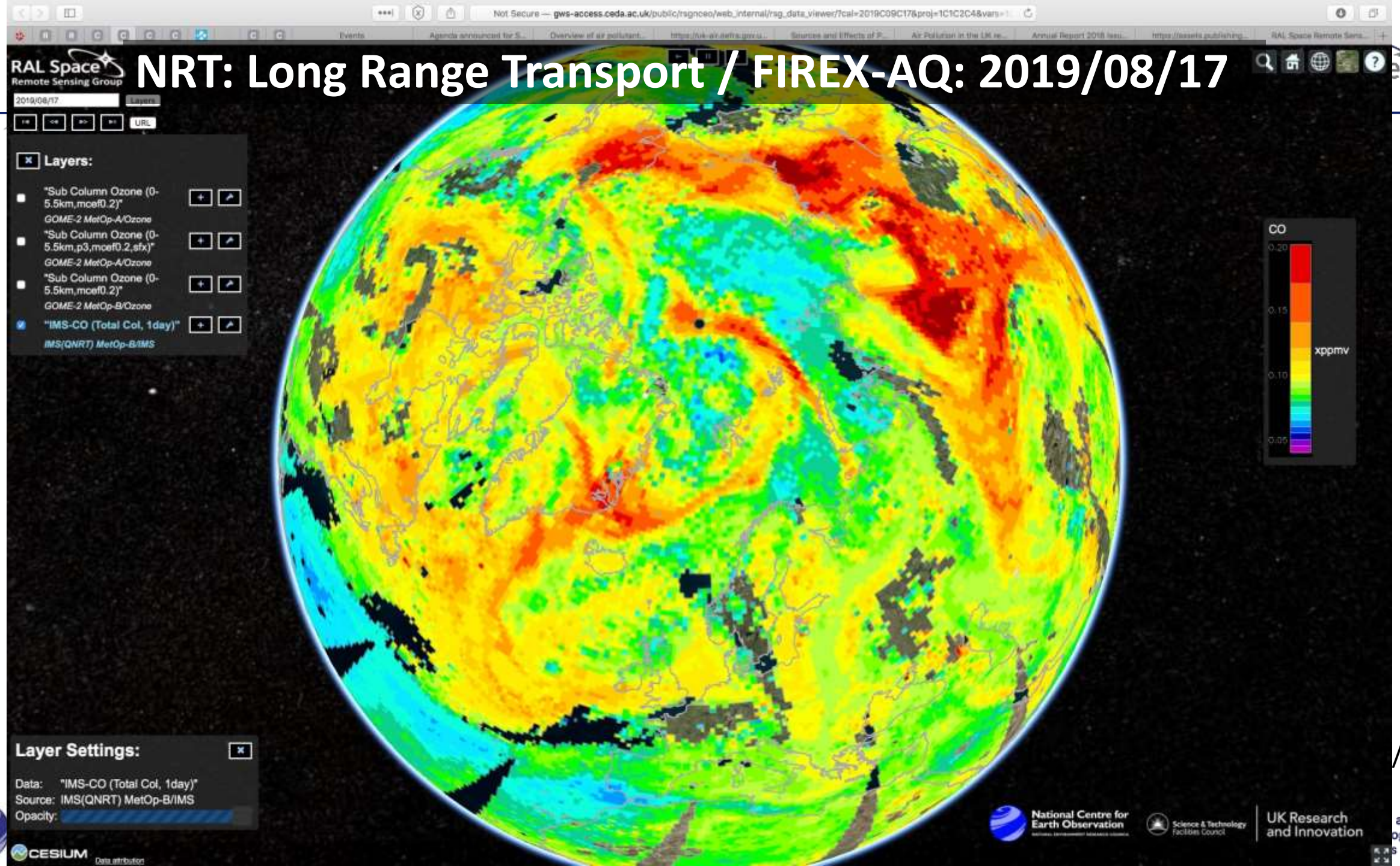
NRT: European Aerosol 2019/08/27: 1500



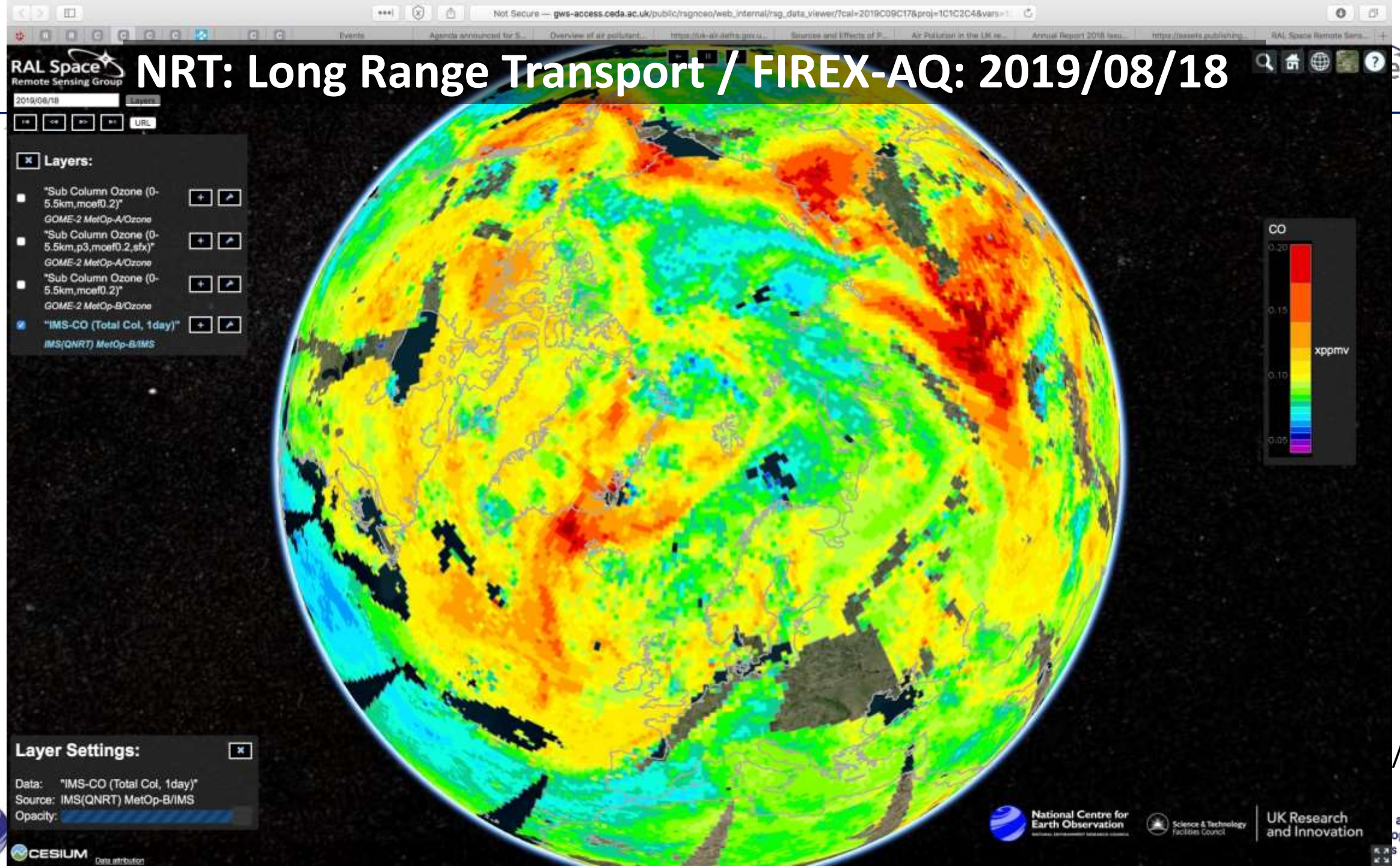
Indonesian Fires 2019: 20 September

Elisa Carboni in Indonesia with colleagues from King College London and Indonesia.

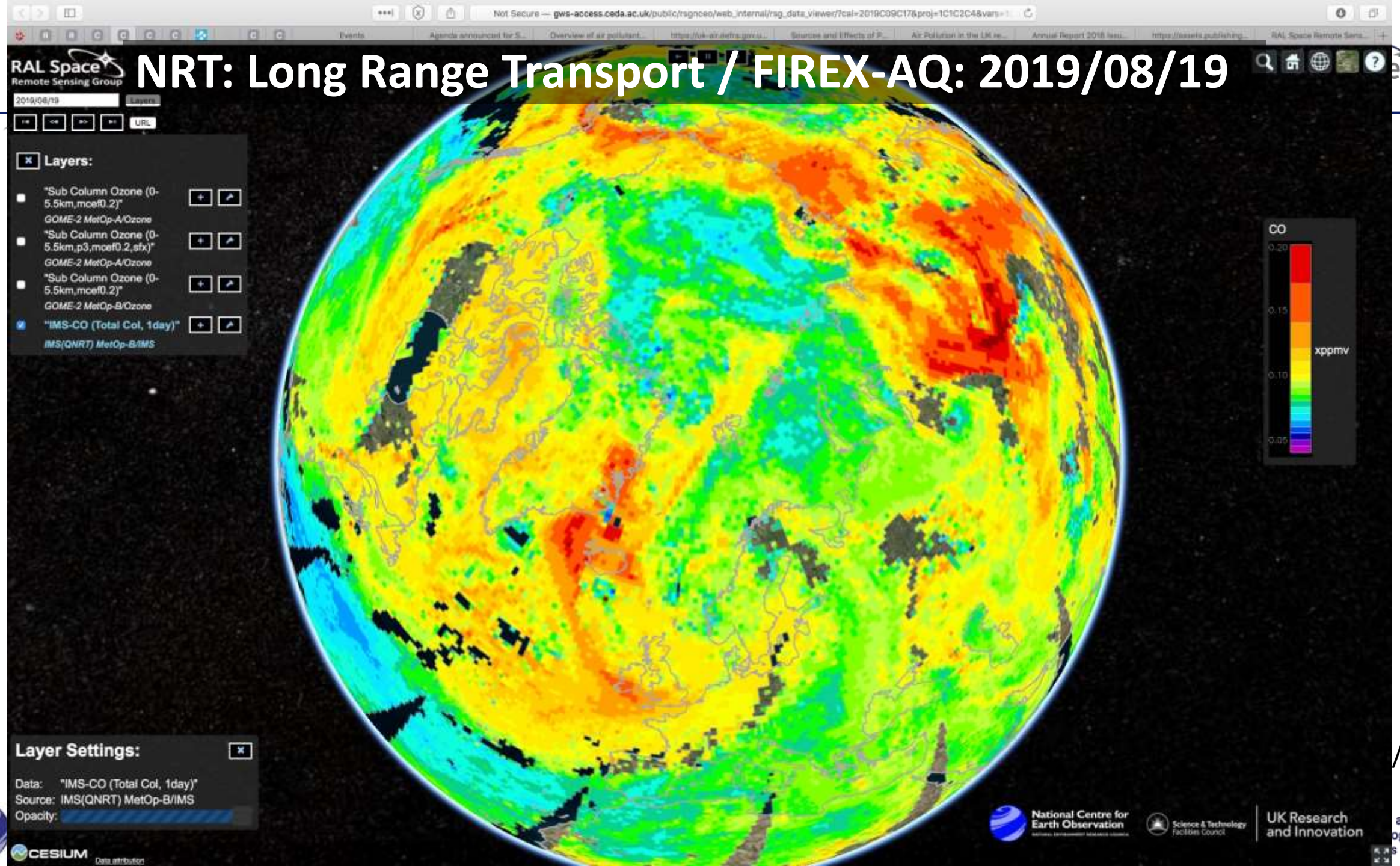
NRT: Long Range Transport / FIREX-AQ: 2019/08/17



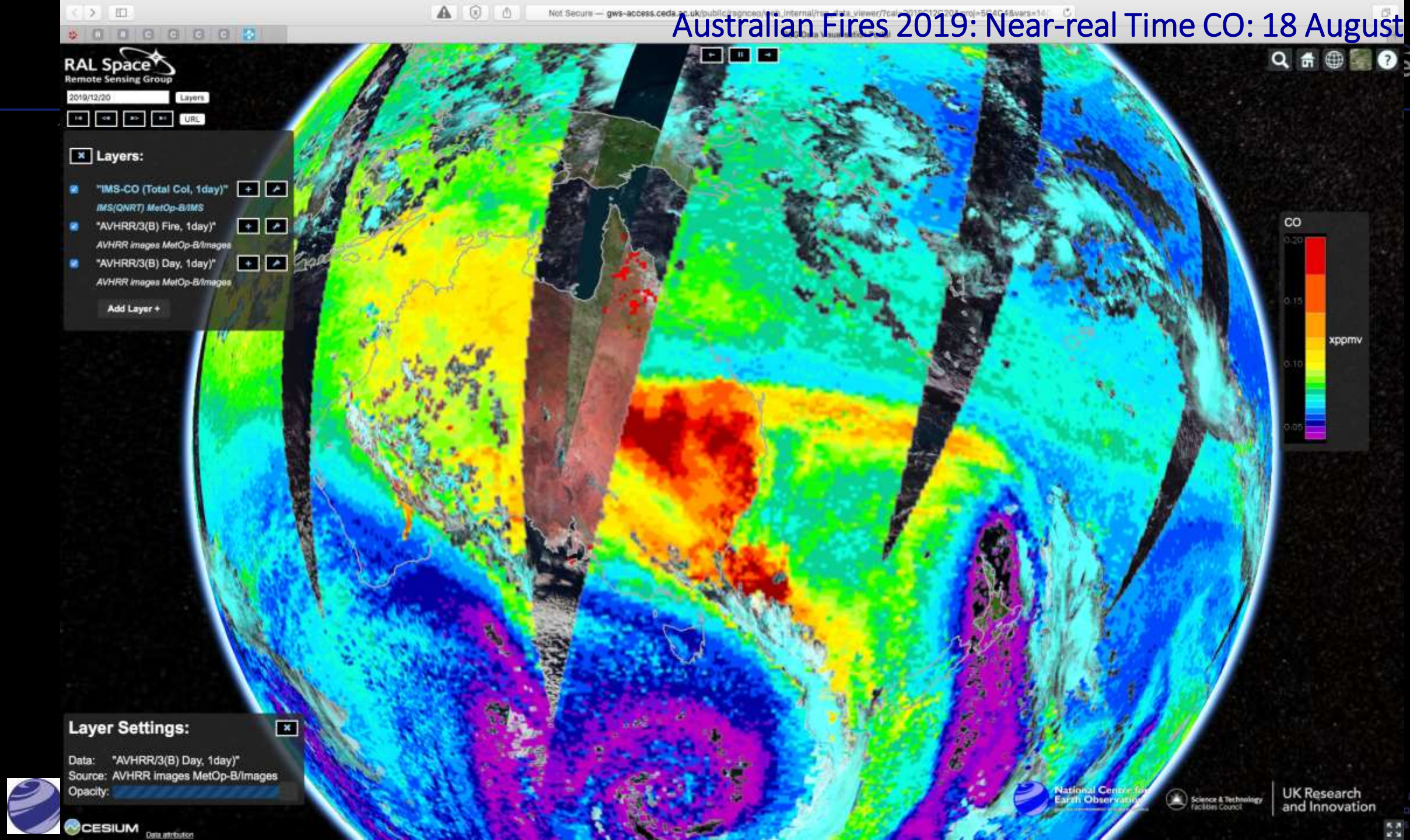
NRT: Long Range Transport / FIREX-AQ: 2019/08/18



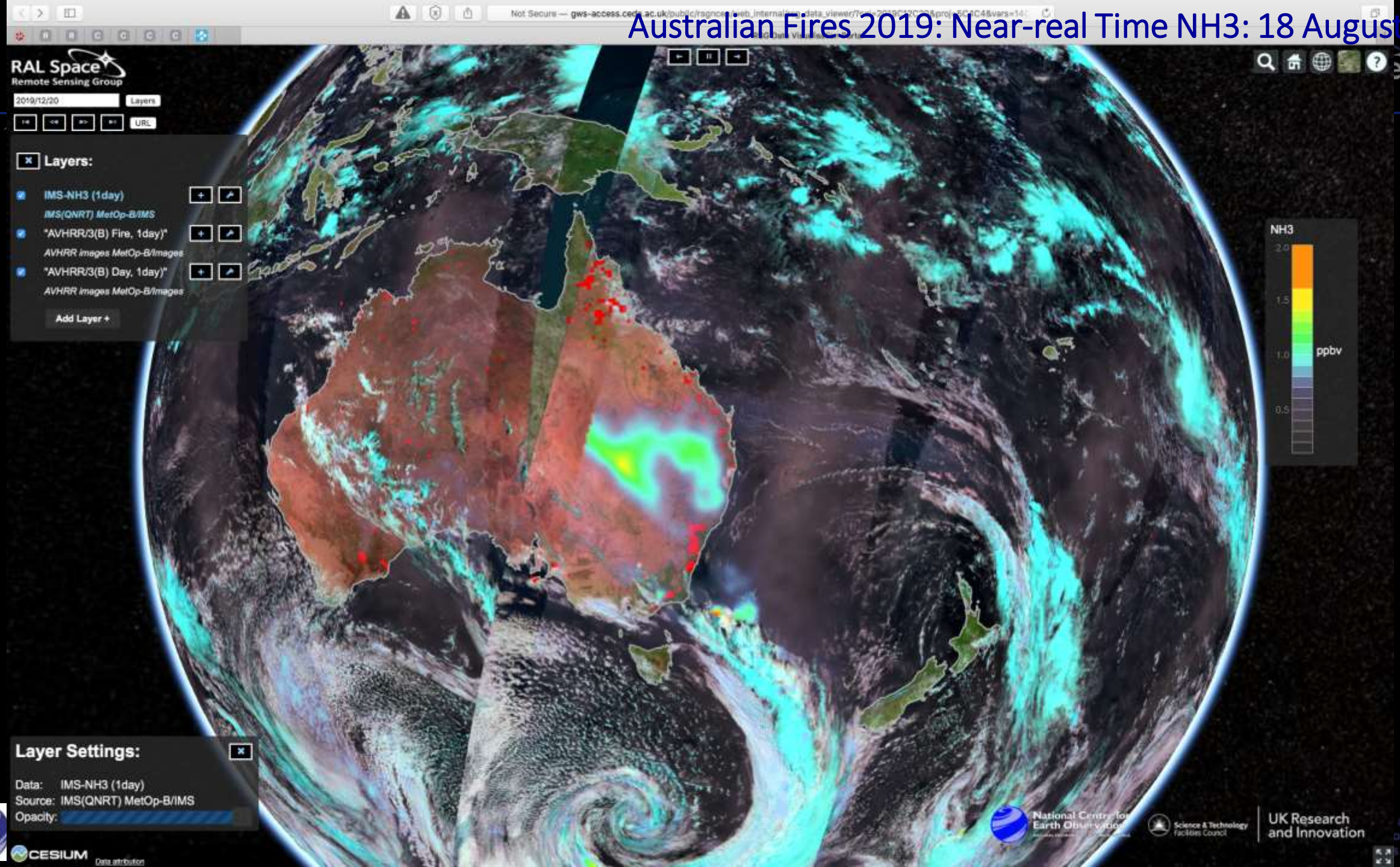
NRT: Long Range Transport / FIREX-AQ: 2019/08/19



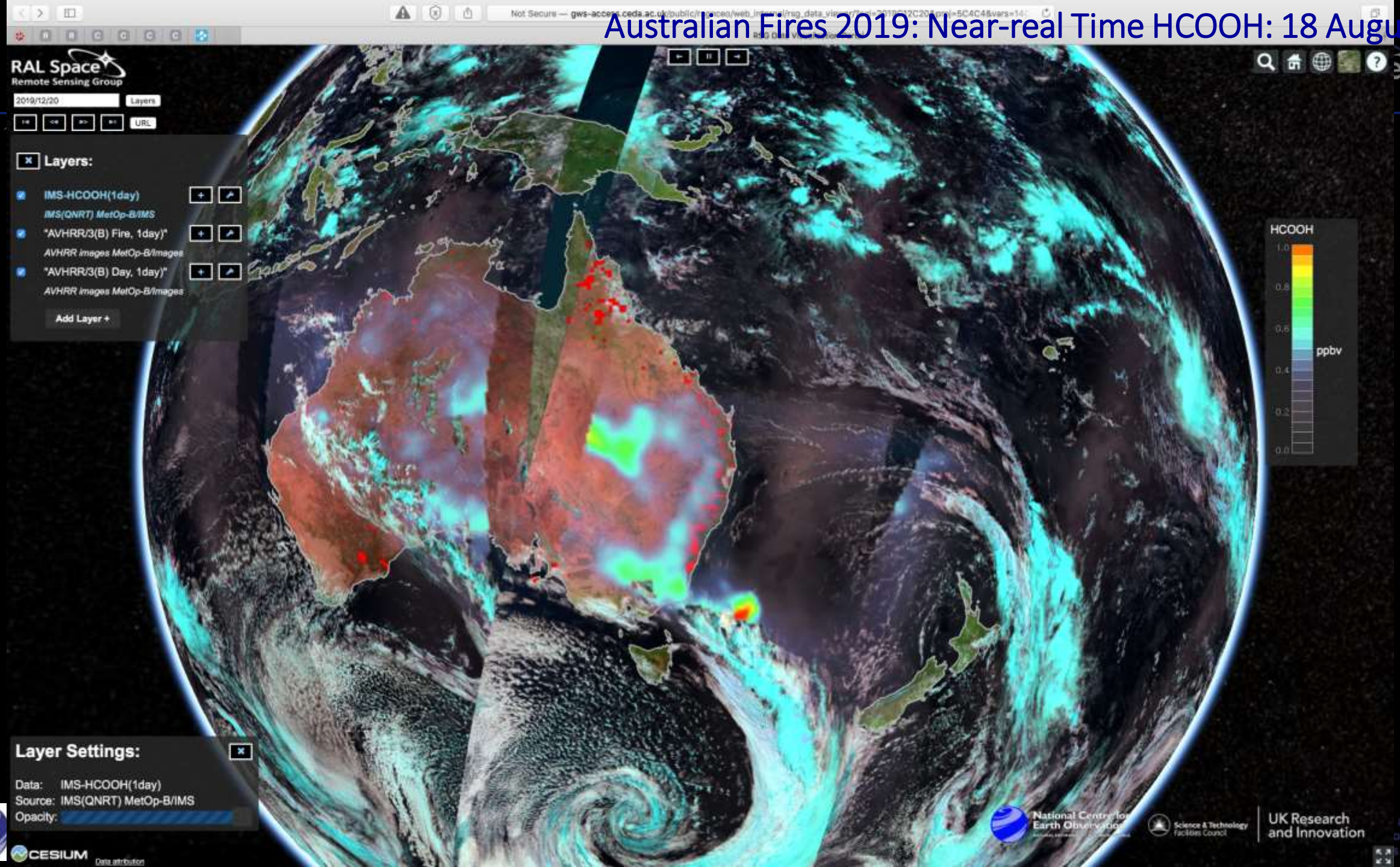
Australian Fires 2019: Near-real Time CO: 18 August



Australian Fires 2019: Near-real Time NH3: 18 August



Australian Fires 2019: Near-real Time HCOOH: 18 August



Satellites Summary

- Satellite observations can provide largescale information

- STFC-RAL Space AQ satellite products:
  - Long term records: NCEO, ESA CCI & EU C3S
  - Near Real Time:
    - LEO: daily, ~3hr from observation (O3, CO, NH3, SO2, …)
    - GEO (Aerosol): 15min sampling, ~1.5hr delay
  - Ongoing developments:
    - O3 – UV+IR+Vis: Improve vertical *resolution* & *sensitivity* in troposphere
    - NH3 – DEFRA-NCEO study: Improve products
    - Aerosol - multi-temporal GEO: Improve over land
    - New sensors: Sentinel 5P, S4, S5, +NASA, Korean, Chinese, … (LEO+GEO)
      - Future UK scale - HAPs (High Altitude Platforms)

➢ Satellites can provide useful additional information in combination with (not in place of) in situ observations and models.

Thank you for your attention

http://www.ralspace.stfc.ac.uk/remotesensing

Contact: remotesensing@stfc.ac.uk

ESA – CCI Ozone Nadir product:

http://www.esa-ozone-cci.org/?q=node/164

EU – C3S Ozone Nadir product:

http://cds.climate.copernicus.eu

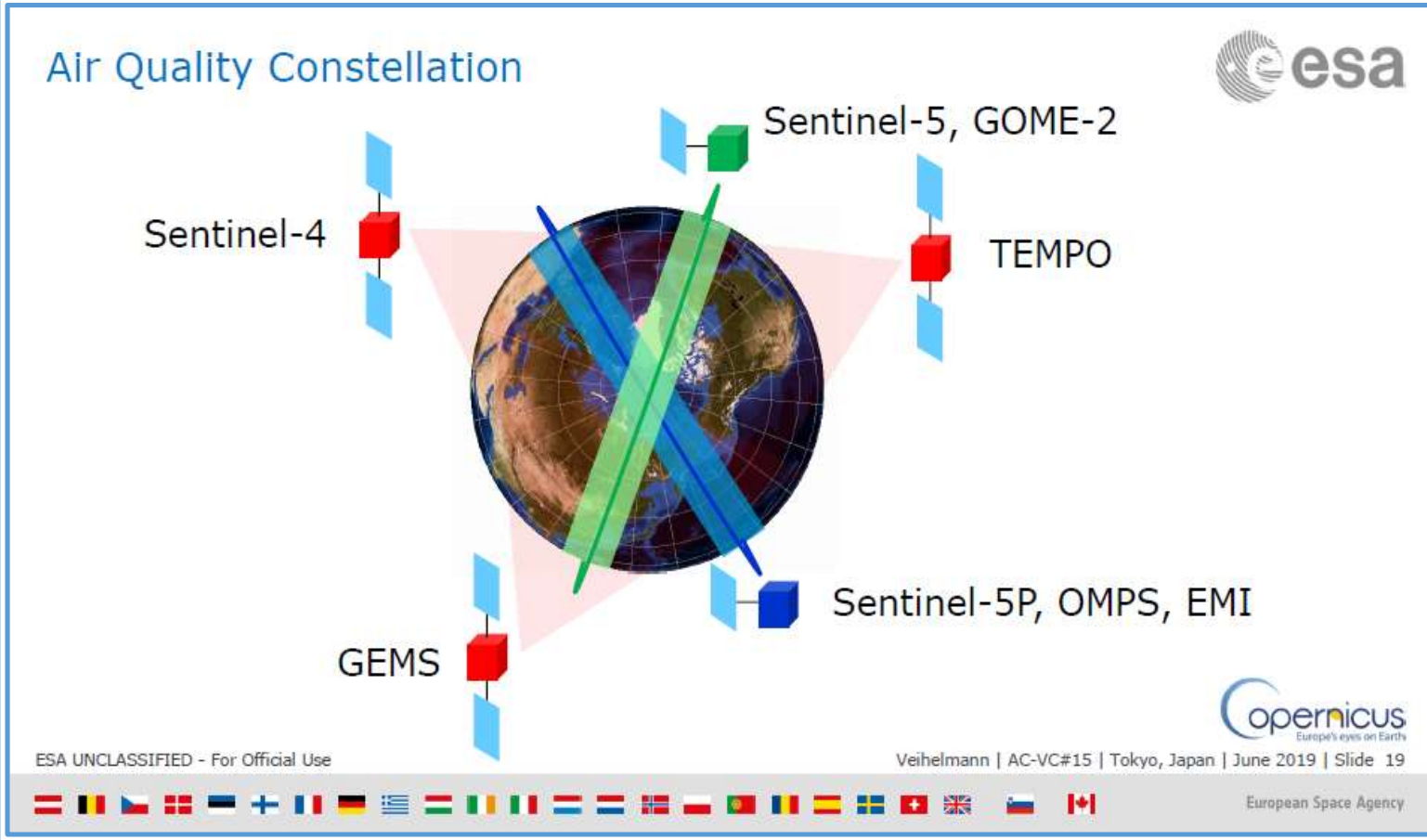
Acknowledgments:

NERC/NCEO, ESA, EUMETSAT, UKSA, EU-C3S, ECMWF for data & support

CEDA – JASMIN-CEMS for use of computer infrastructure

Operational Processor Development

- RAL RSG Involved in the ESA projects to develop the operational processors for
  - Sentinel 4: Geostationary UV/vis nadir spectrometer on MTG
  - Sentinel 5: Polar orbiting UV/vis spectrometer on Metop 2nd Gen
- In both cases, RAL responsibility for development of ozone profile / tropospheric ozone product
- Sentinels 4+5 part of wider "Air-quality constellation" which also includes TEMPO (US) and GEMS (S.Korea)



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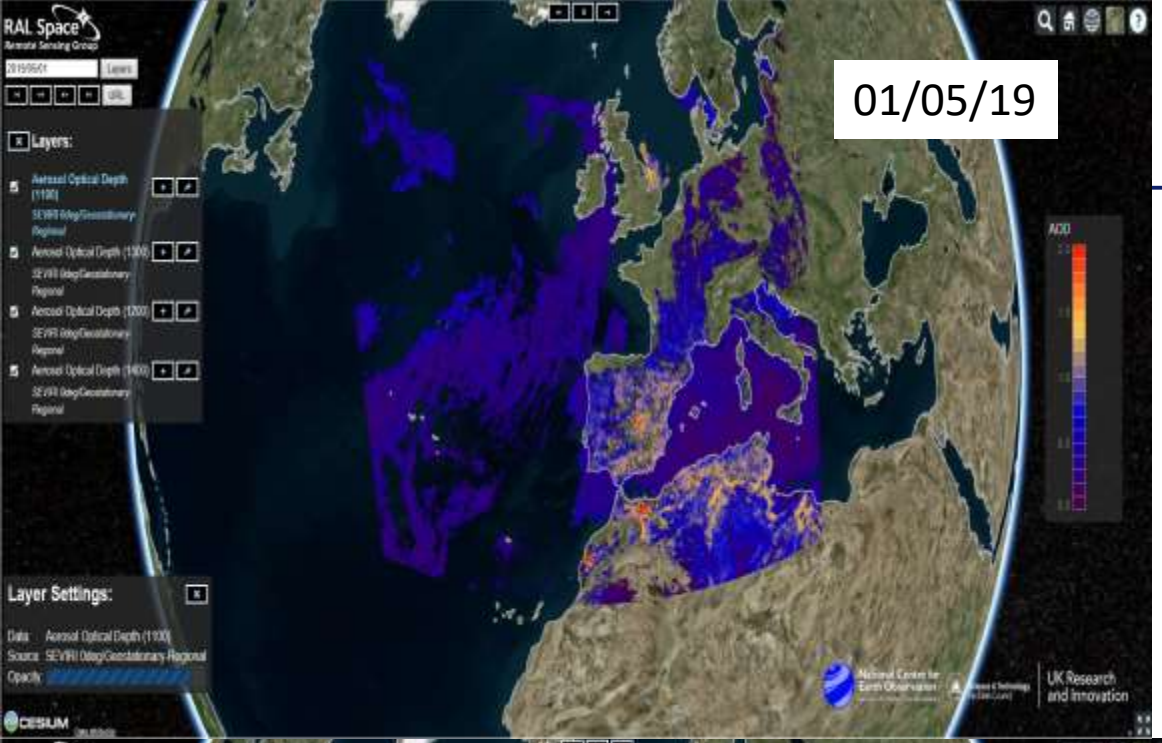
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Remote Sensing Group
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SEVIRI 0deg/Geostationary-Regional
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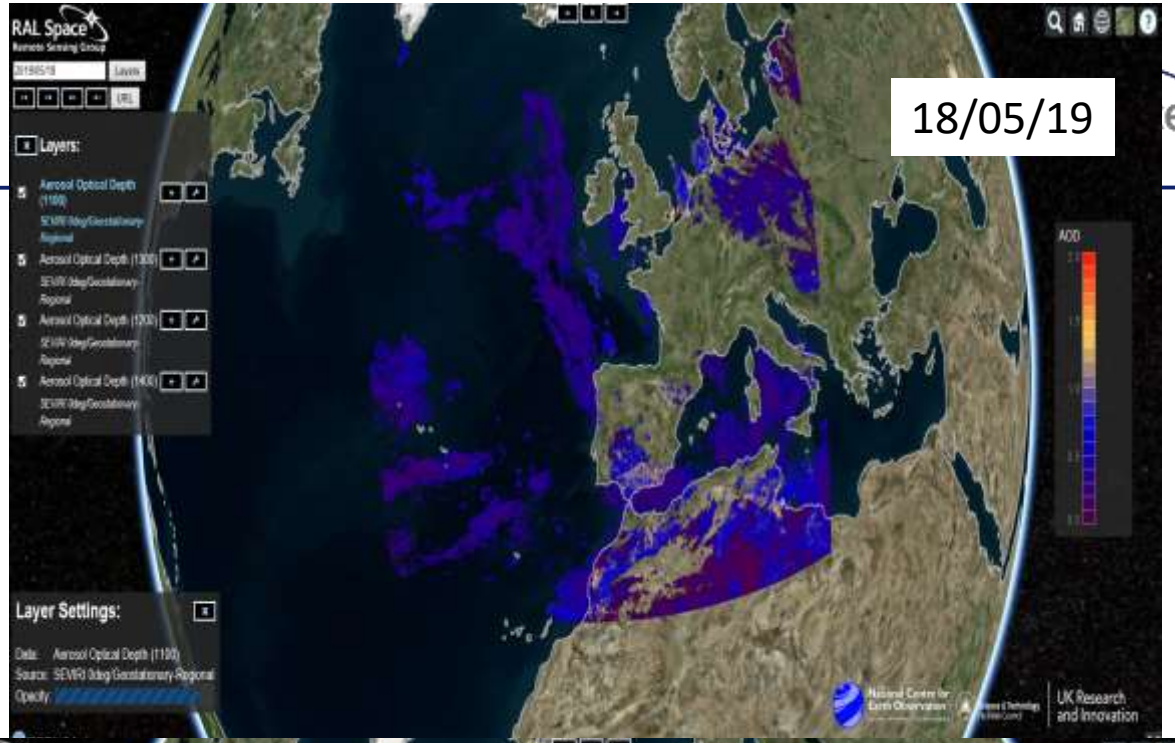
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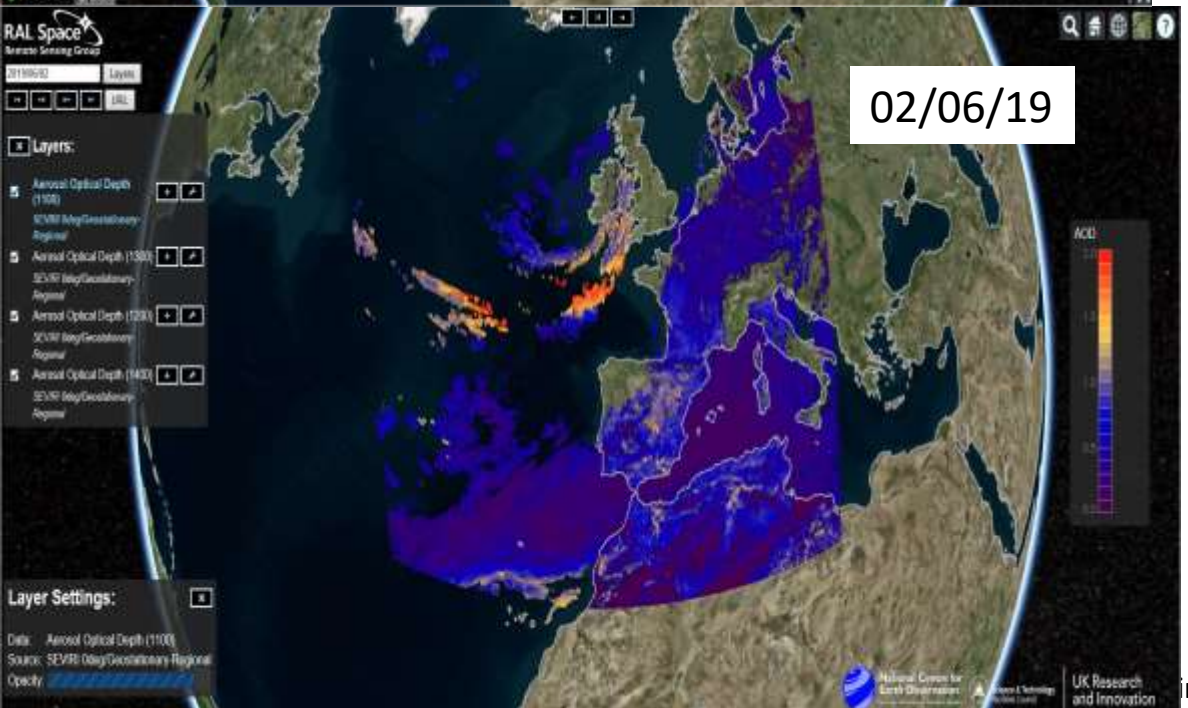
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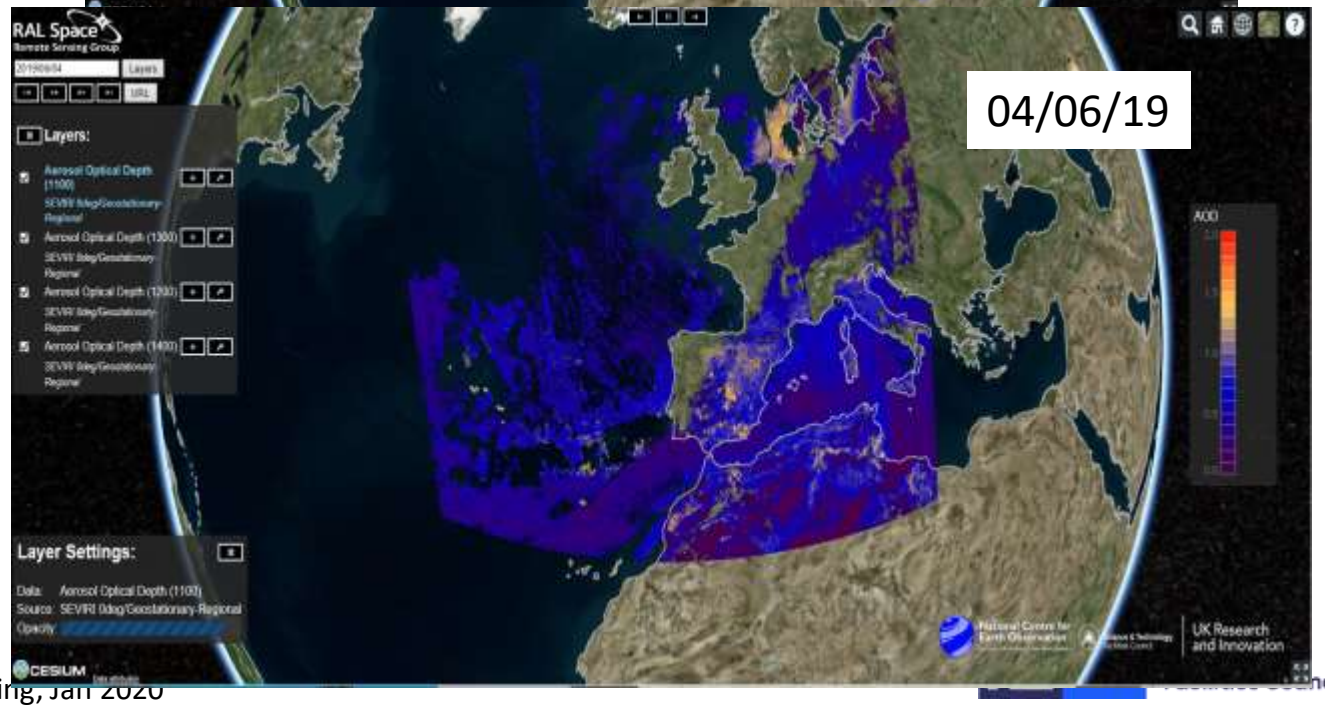
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