Wildfire emissions and atmospheric composition forecasting in the Copernicus Atmospheric Monitoring Service

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Atmosphere Monitoring

2017 IBBI Workshop
Boulder, CO, USA, 10-11 July 2017

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Summary

- Overview of Copernicus and Atmosphere Monitoring Service
  - Copernicus Programme
  - CAMS system, inputs and products
- Global Fire Assimilation System
  - Current status
  - Future developments

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Copernicus: A Flagship European Programme

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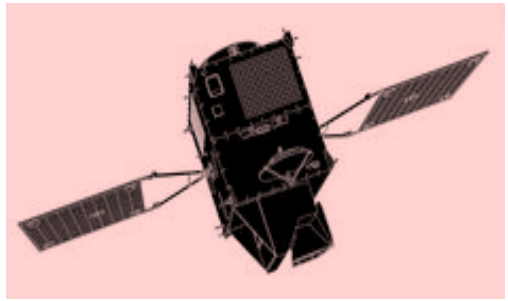
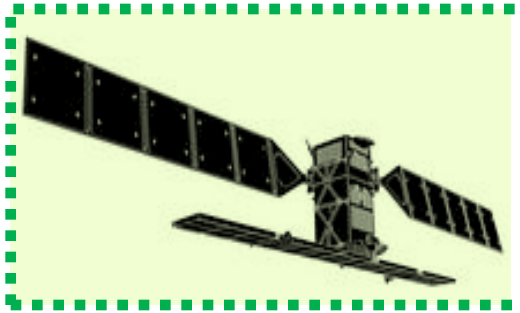
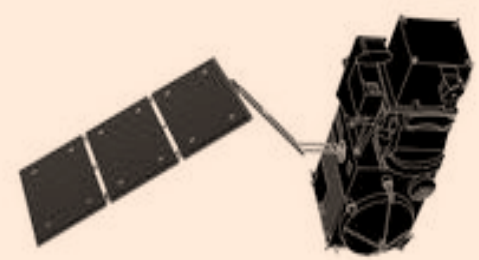
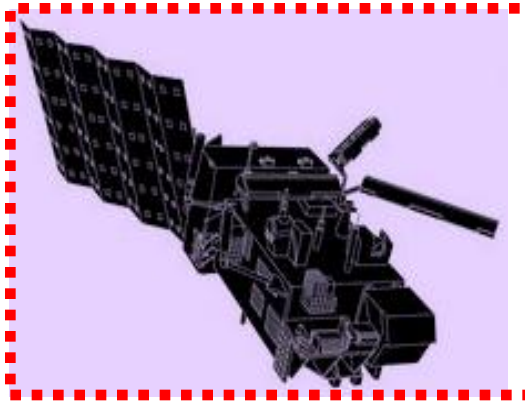
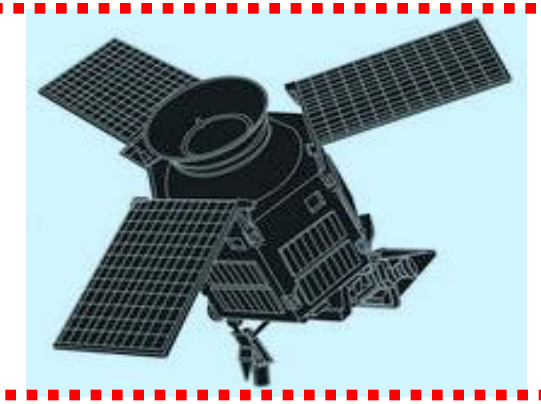
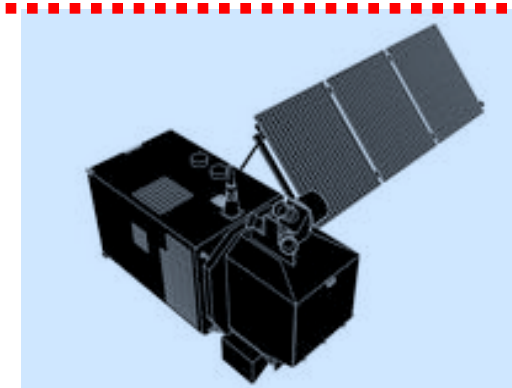
EU's efforts on climate change stretch beyond ambitious carbon reduction commitments

Copernicus
Europe's eyes on Earth

is harnessing world leading science and technology to equip society to understand and adapt to our changing environment

The Sentinels

Burnt area/FRP observations

Atmospheric composition/Air quality observations

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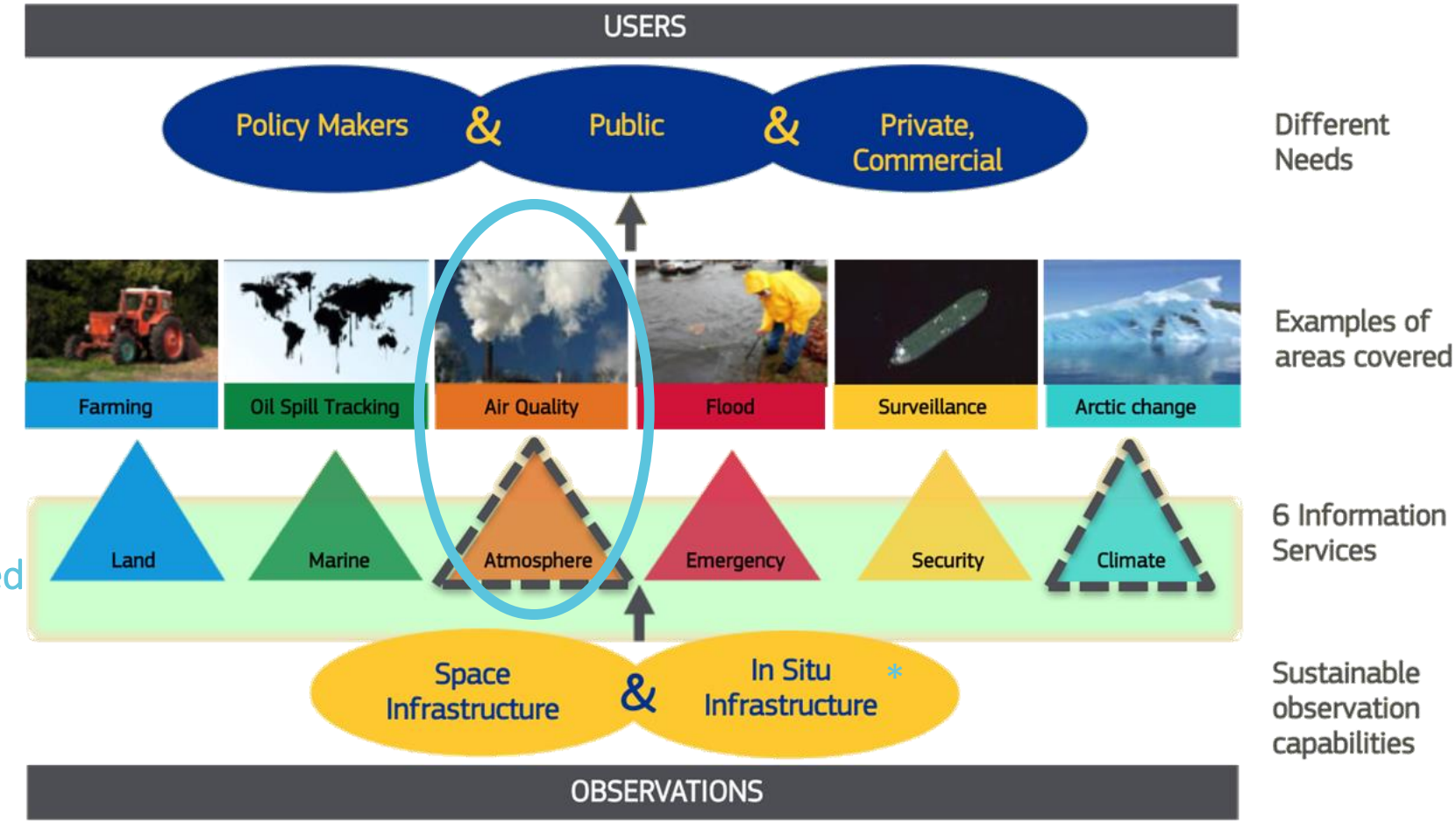
THE COPERNICUS VALUE-ADDING CHAIN



Services led by ECMWF

* Mostly based on the principle of subsidiarity from EU Member states

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CAMS Services

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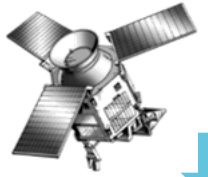
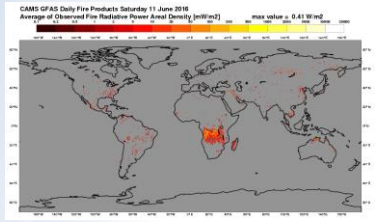
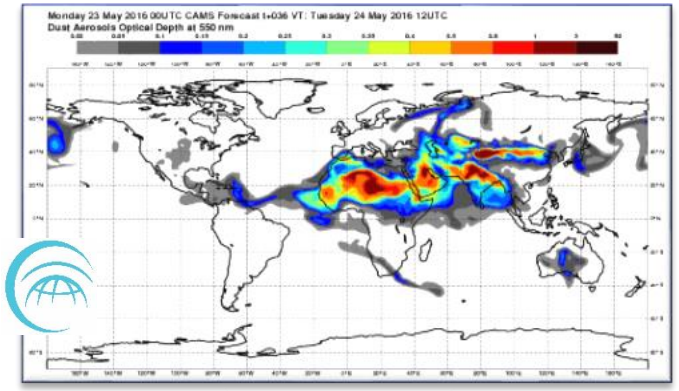
Space Agencies



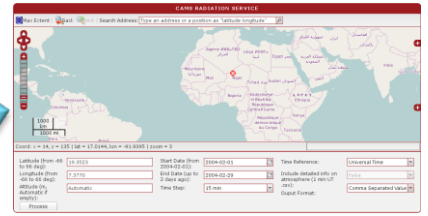
In situ observations



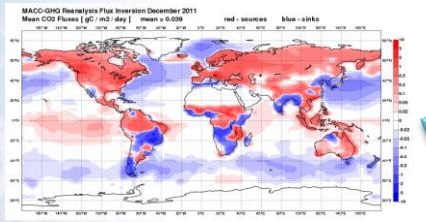
Fire emissions



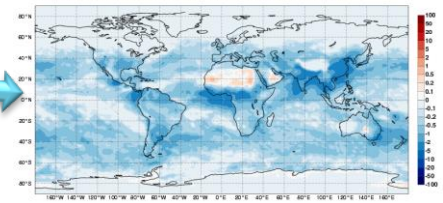
Global



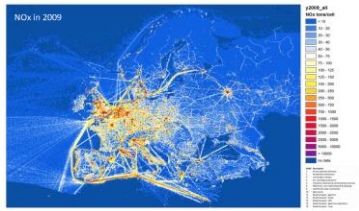
Solar radiation



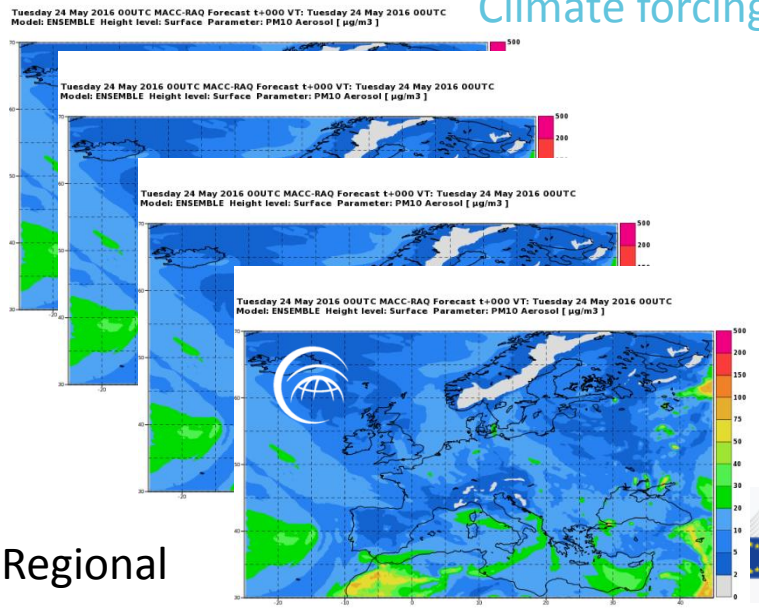
GHG fluxes



Climate forcing

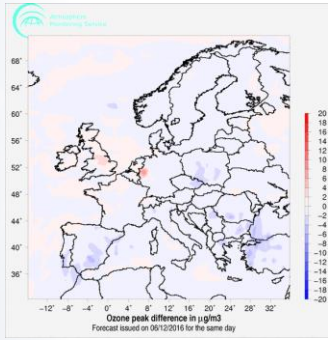


Anthropogenic emissions



Regional

Policy



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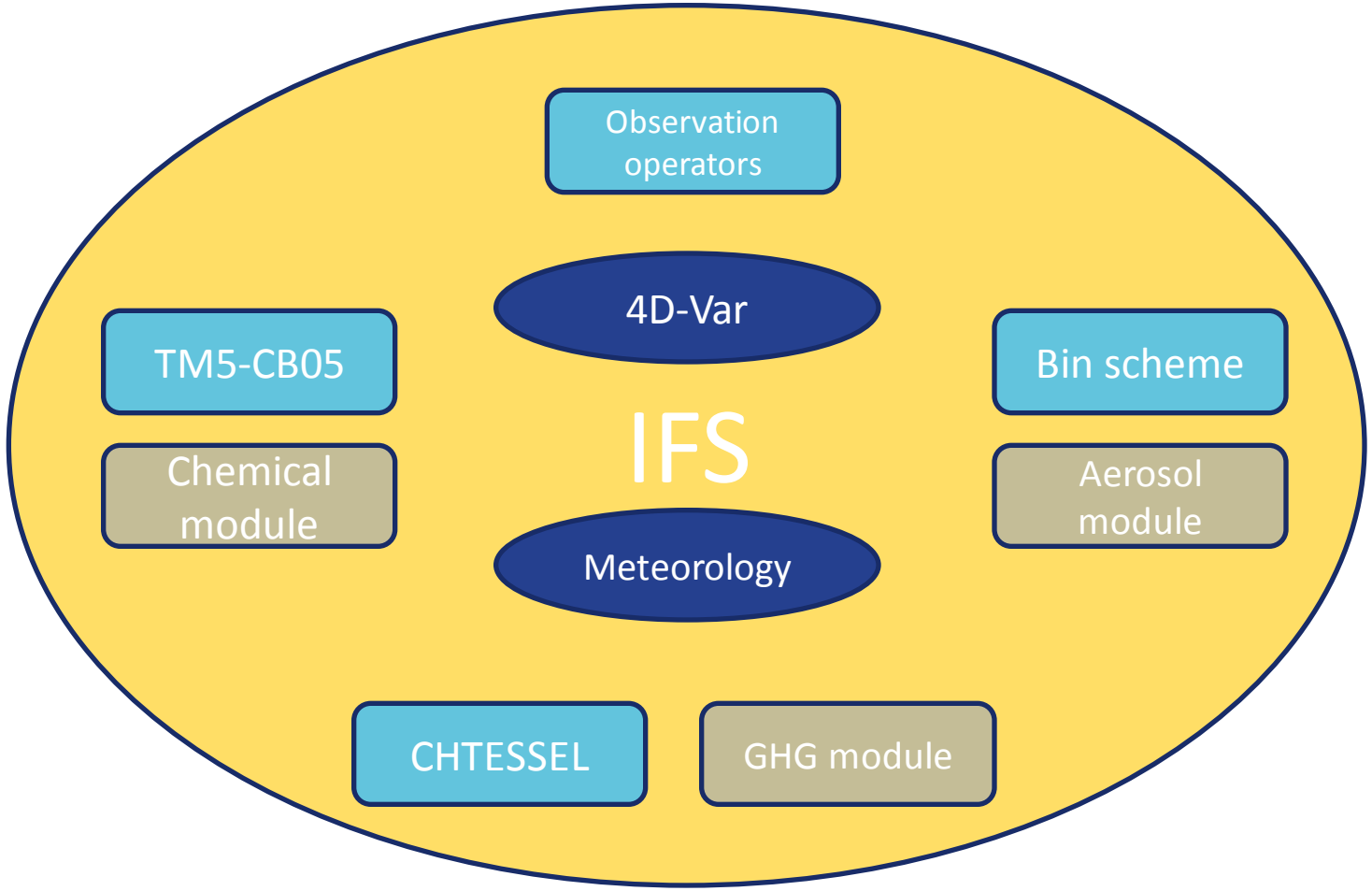
Atmospheric science in the ECMWF Integrated Forecast System (IFS)

The CAMS global production system is the ECMWF Integrated Forecast System (IFS).

IFS is the full NWP forecasting and data assimilation system of ECMWF



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Near-real-time satellite data usage

Species	Instruments
Global system	
O_3	**OMI**, **SBUV**, **GOME-2**, **MLS**, **OMPS**, S5p
CO	**IASI**, **MOPITT**, S5p
NO_2	**OMI**, **GOME-2**, S5p
SO_2	**OMI**, **GOME-2**, S5p
Aerosol	**MODIS**, **PMAp**, VIIRS, S3
CO_2	**GOSAT**, **OCO-2**
CH_4	**GOSAT**, **IASI**, S5p
Assimilated **Monitored** Future	
GFAS fire emissions *Geostationary platform	**MODIS**, **GOES-E/W***, **SEVIRI***, S3, VIIRS, HIMAWARI-8*, GOES-R*

A wide-range of atmospheric composition satellite observations are assimilated in the IFS to produce daily analyses.

Control runs (with no data assimilated) and forecasts (initialised from analyses) are also produced in CAMS.

CAMS data used for field campaign planning and evaluating special events.

Composition data additional to thousands of assimilated meteorological data.

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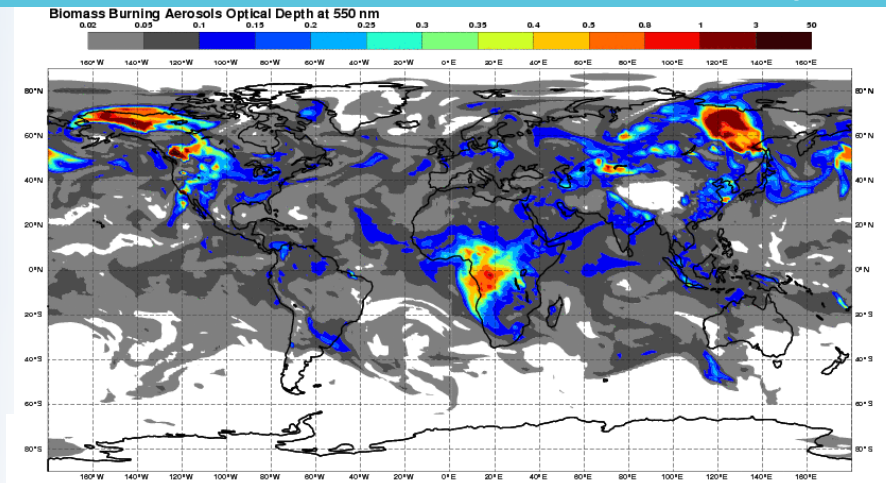
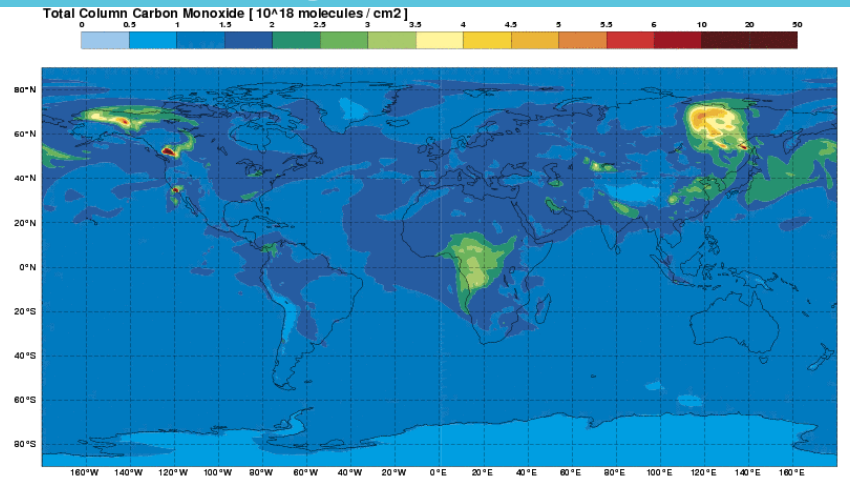
Current analysis/forecast configuration

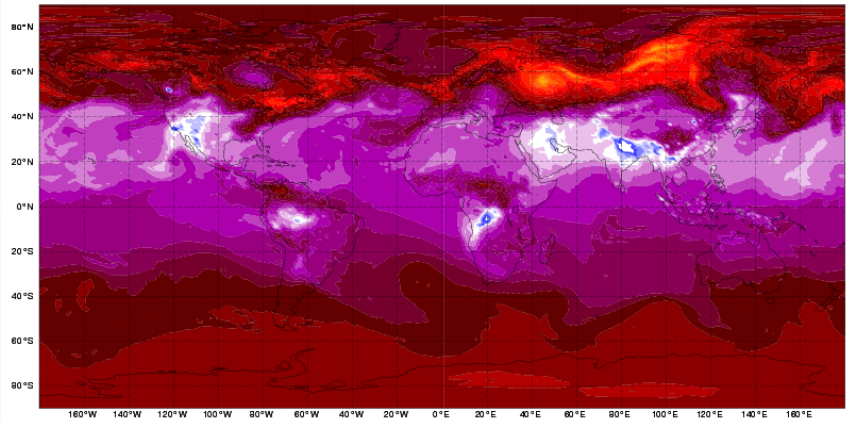
AOD



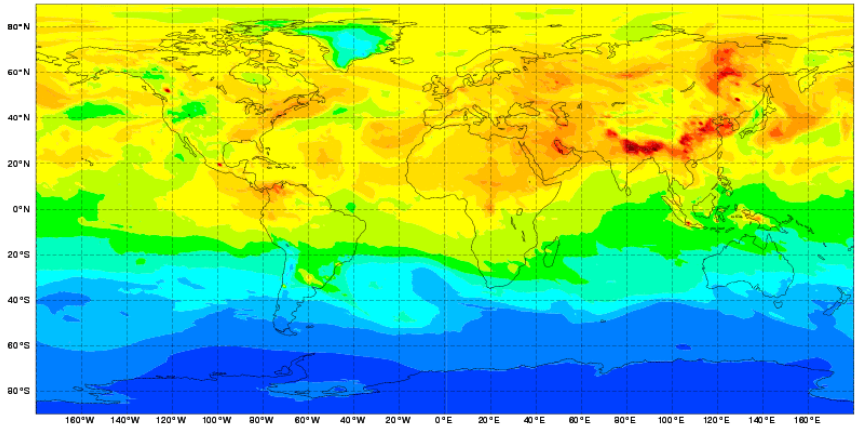
CO



CO_2



CH_4



- 40 km horizontal resolution at 60 model levels; two 5-day forecasts at 00z and 12z UTC each day
  - Aerosols (AOD and concentration): biomass burning, dust, sea salt, sulphate
  - Reactive gases: CO, HCHO, NO_2, O_3, SO_2.

- 9 km horizontal resolution at 137 model levels; one 5-day forecast per day (CO_2, CH_4, linear CO)

http://apps.ecmwf.int/datasets/data/cams-nrealtime/levtype=sfc/

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Monitoring of Atmospheric Composition: CAMS interim (re-)analysis

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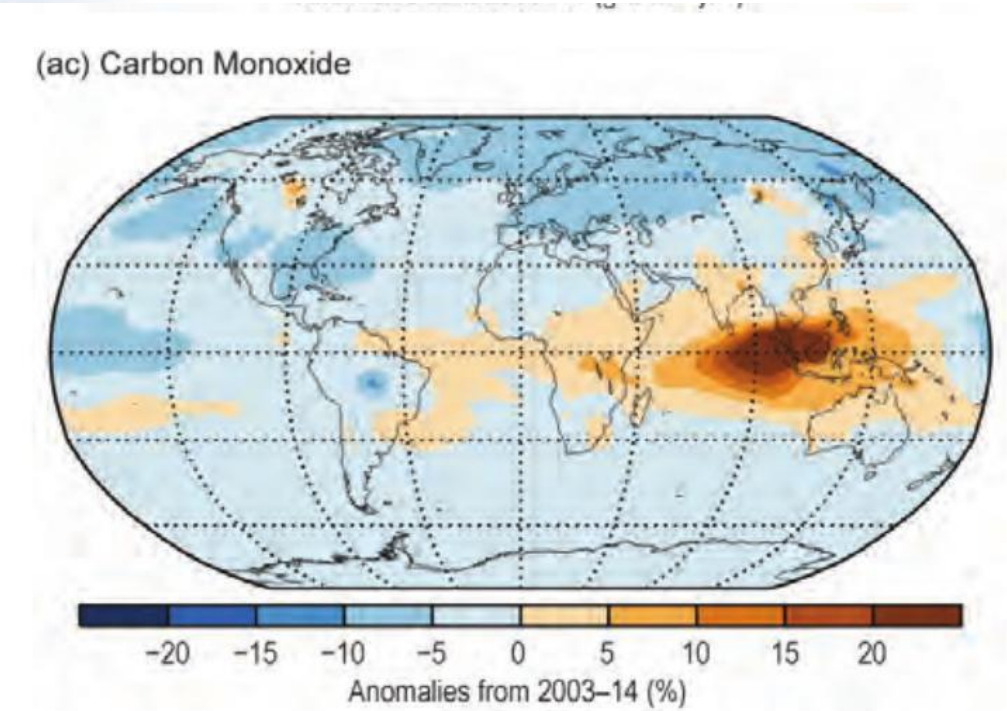
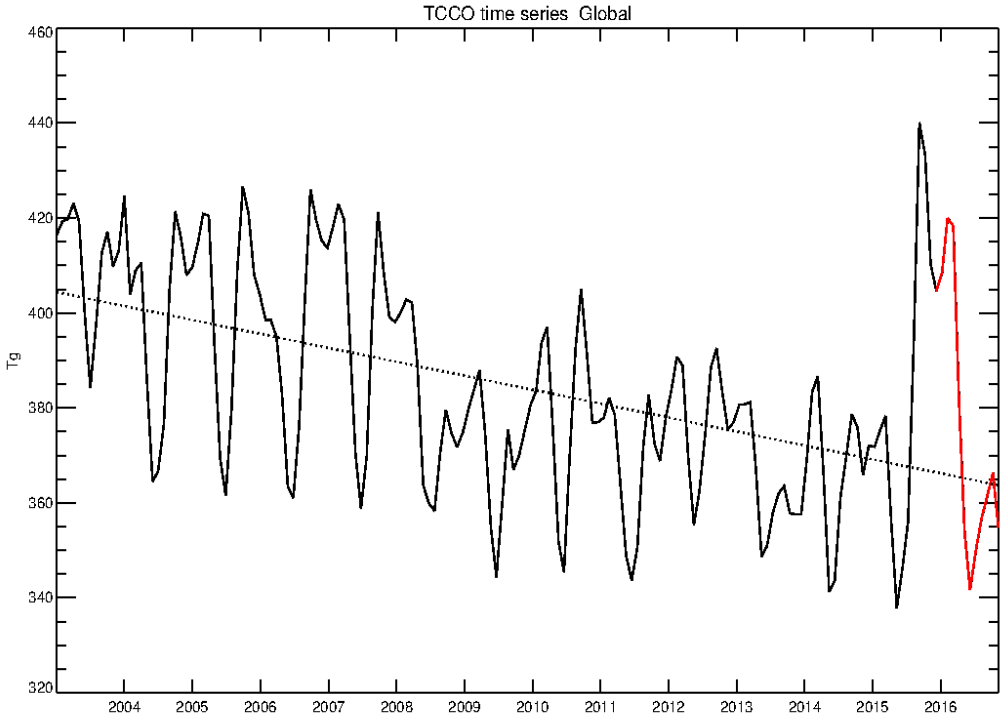
- Reanalyses provide long-term, consistent time series of the chemical state of the global atmosphere.
- CAMS interim reanalysis available 2003-2016.
- New reanalysis incorporating new model developments and satellite products now running.
- Example shows trend of global CO burden.

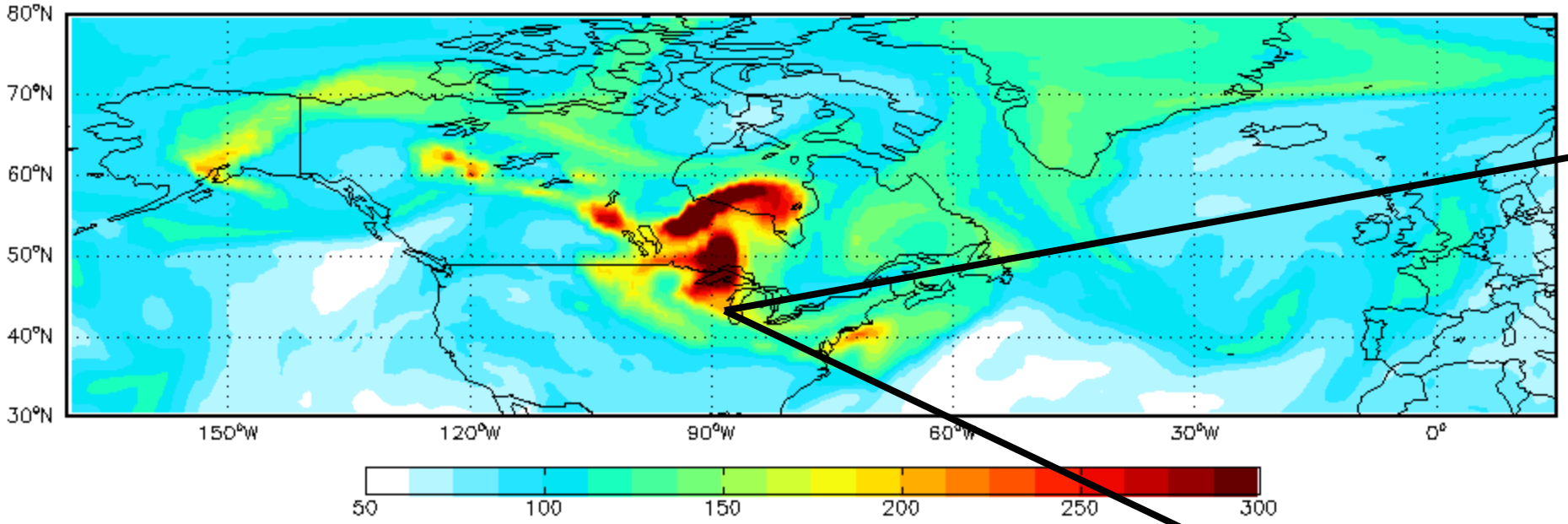


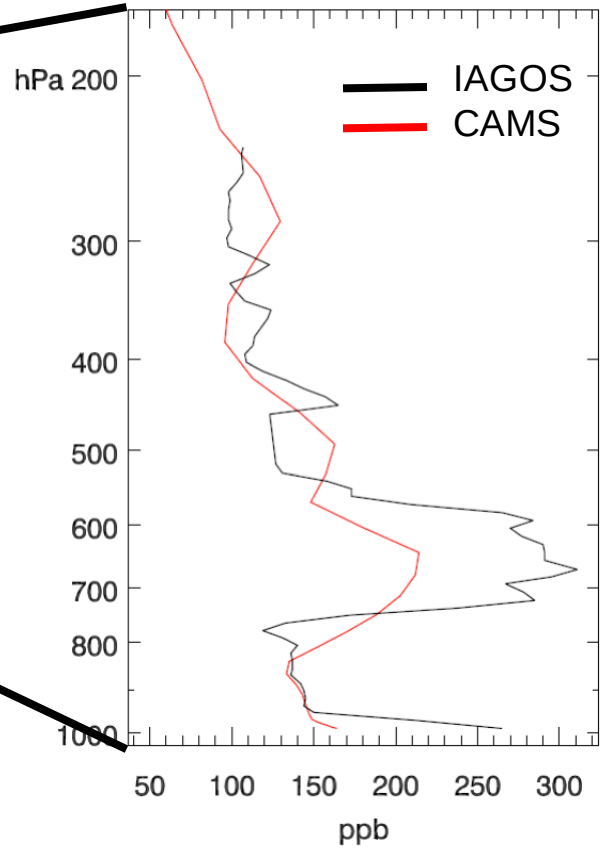


Flemming and Inness, BAMS State of Climate 2015

Long-range transport of Canadian wildfire emissions to Europe

Chicago, 3 July 2015



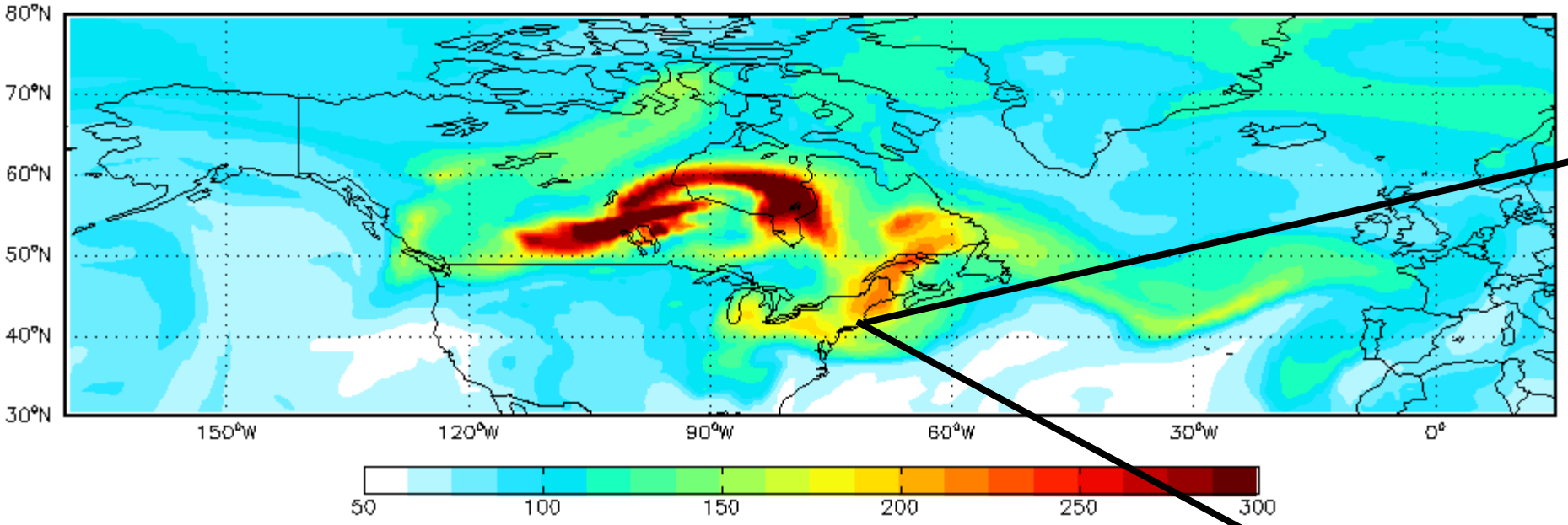


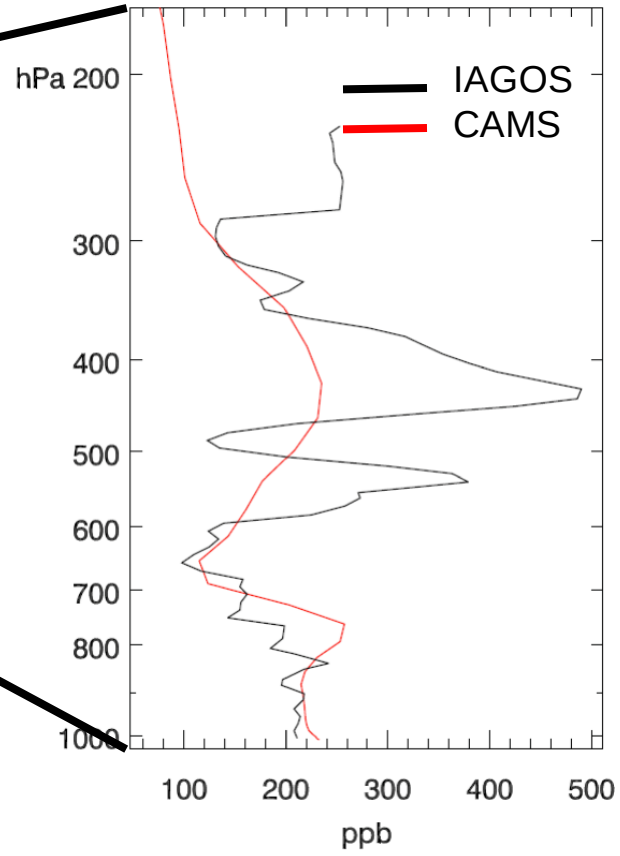
Comparison of forecast CO plume against measurements from IAGOS aircraft.

http://www.iagos.org

Long-range transport of Canadian wildfire emissions to Europe

New York, 5 July 2015





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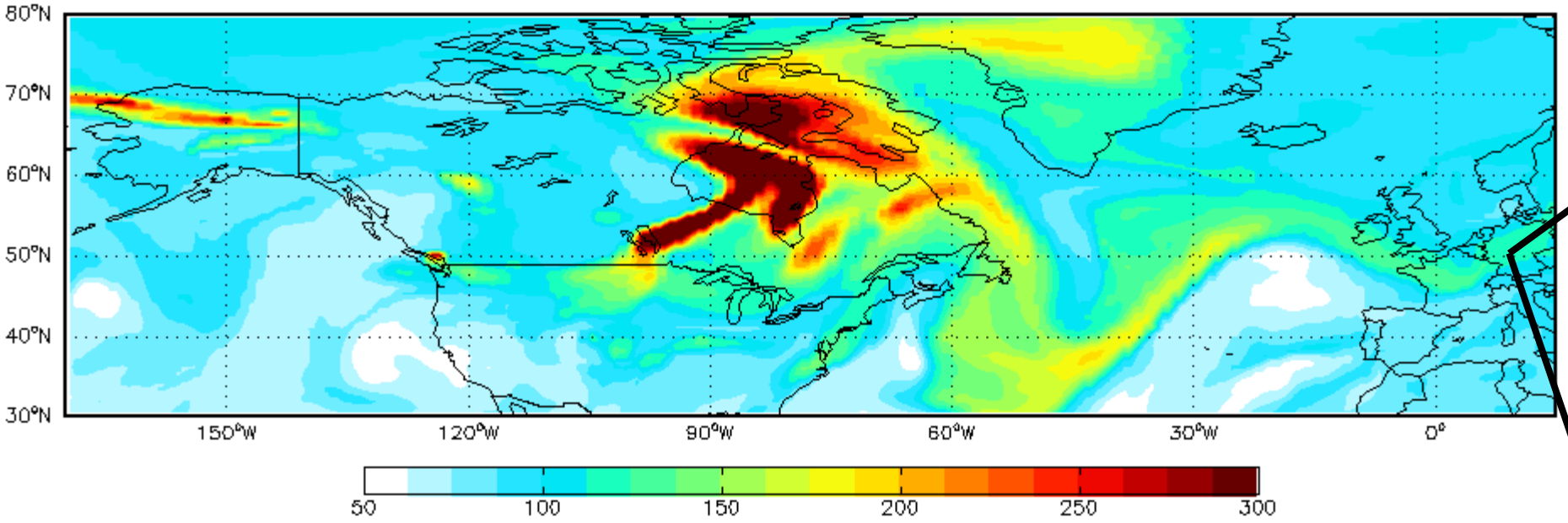
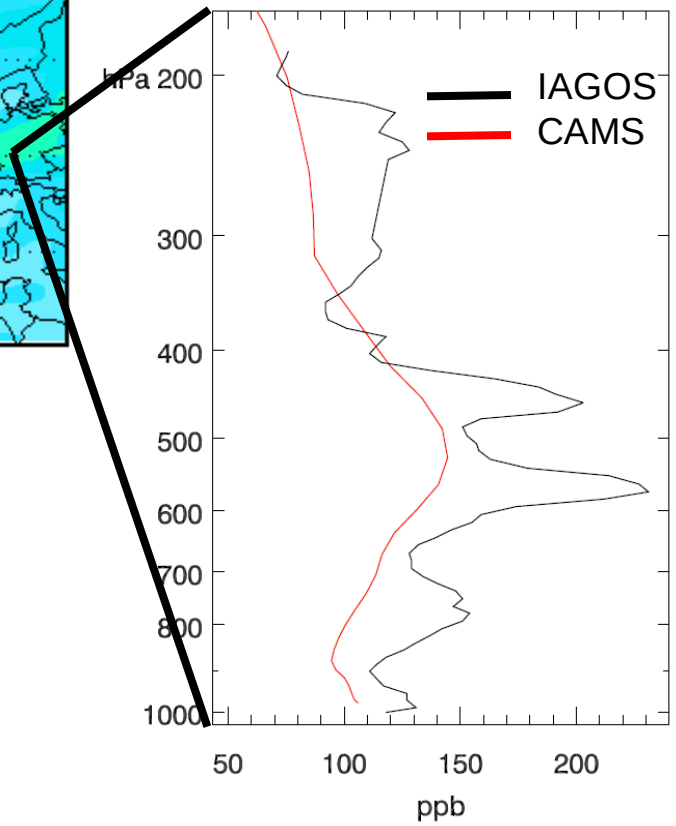
Long-range transport of Canadian wildfire emissions to Europe

Frankfurt, 8 July





Comparison of forecast CO plume against measurements from IAGOS aircraft.

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Long-range smoke transport to tropical Atlantic

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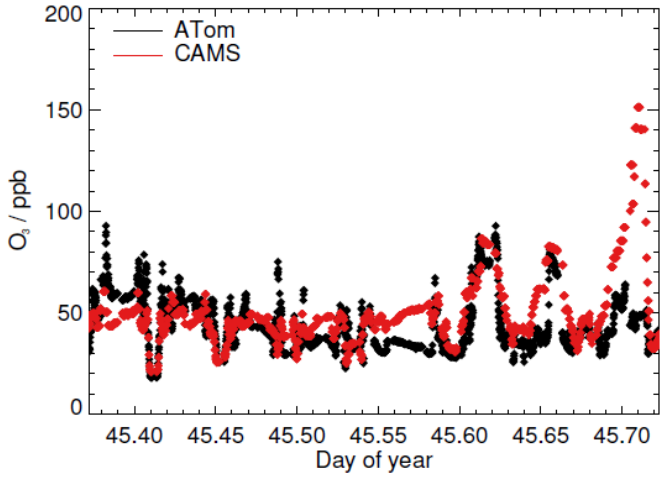
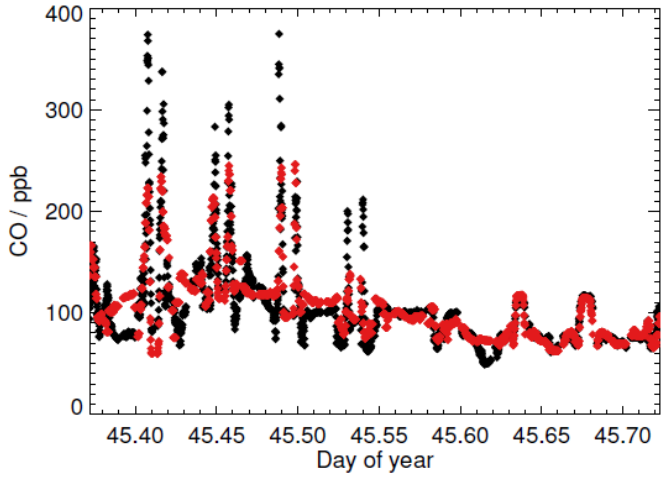
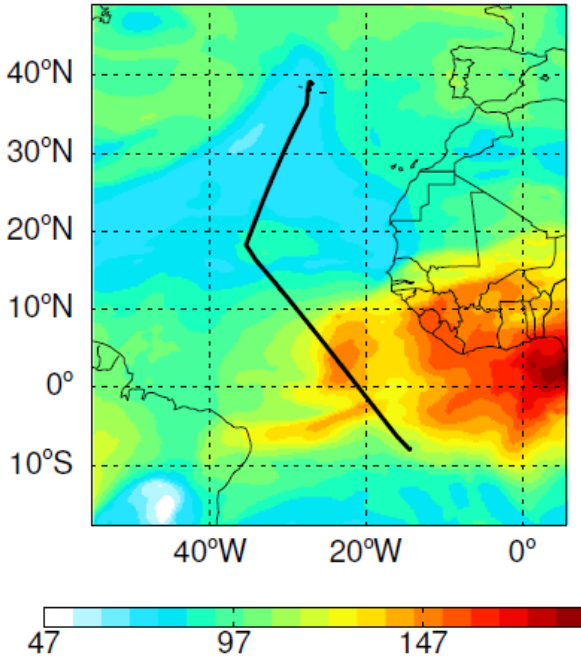
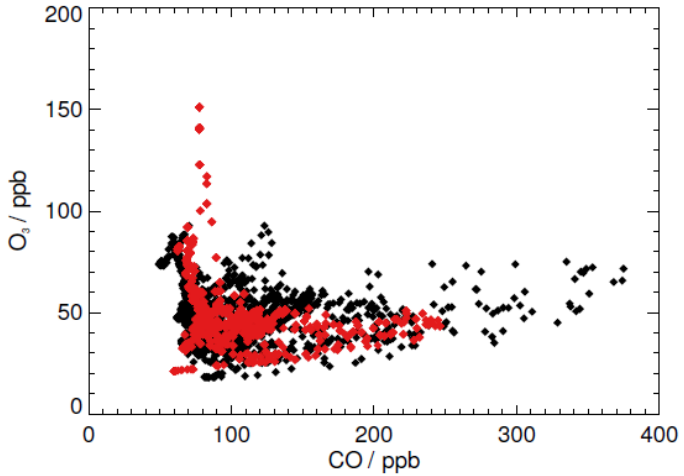
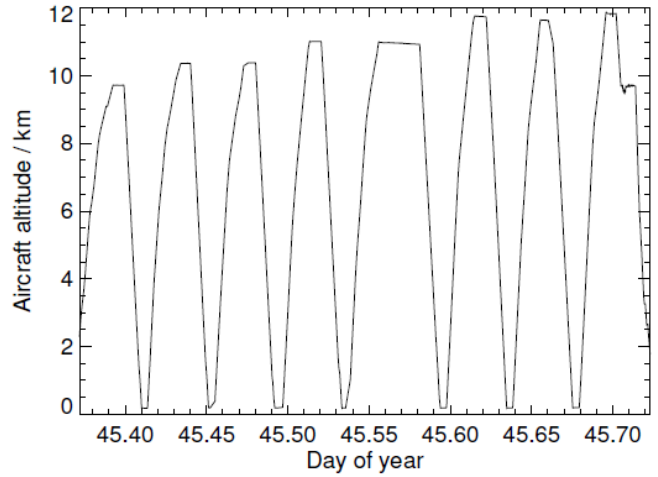
ATom-2 data vs. CAMS IFS forecast: 15 February 2017

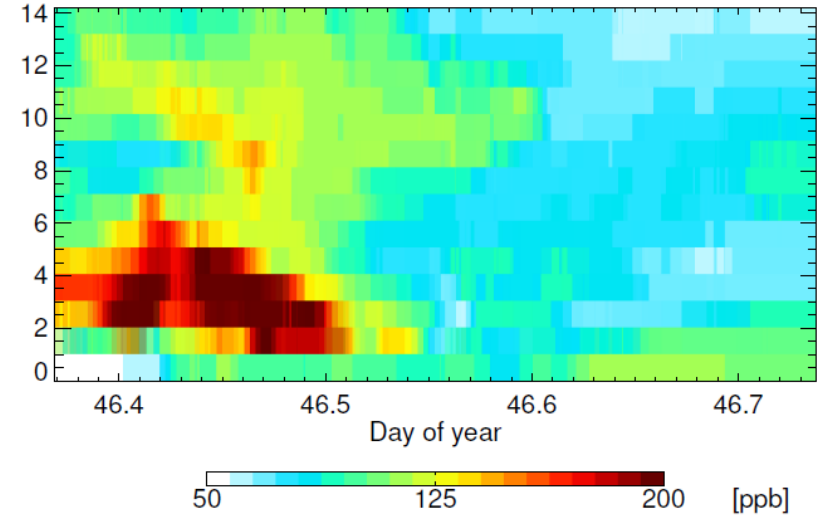












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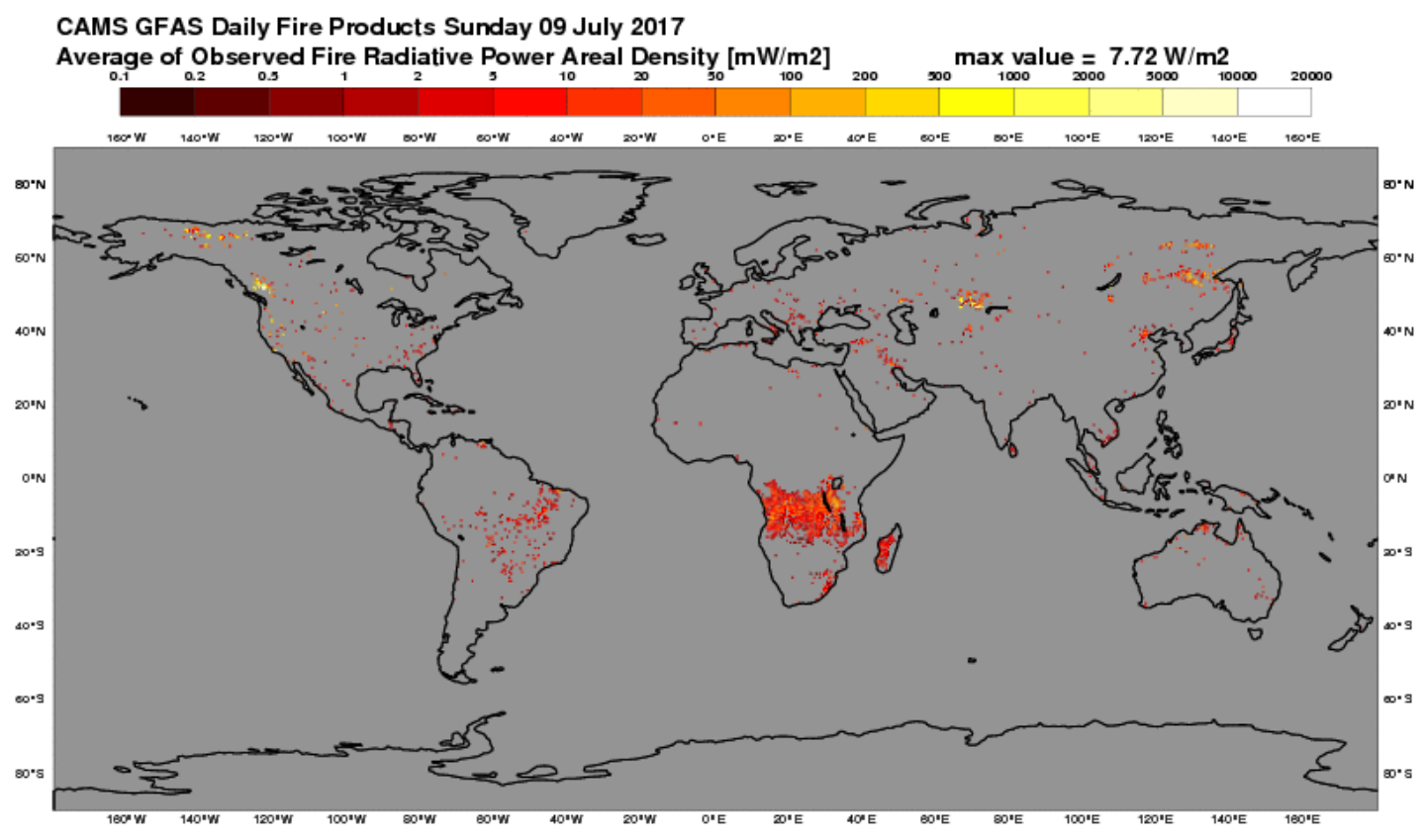
Estimating global fire emissions

- Global Fire Assimilation System (GFAS; http://apps.ecmwf.int/datasets/data/cams-gfas/)
- Uses satellite observations of Fire Radiative Power (FRP)
- Daily global coverage at ~10km resolution
  - 1-day behind NRT (diurnal cycle coming soon)
- Emissions of aerosols and gases estimated using factors dependent on vegetation type.



Latest GFAS global fire activity, 9 July 2017

Atmosphere Monitoring

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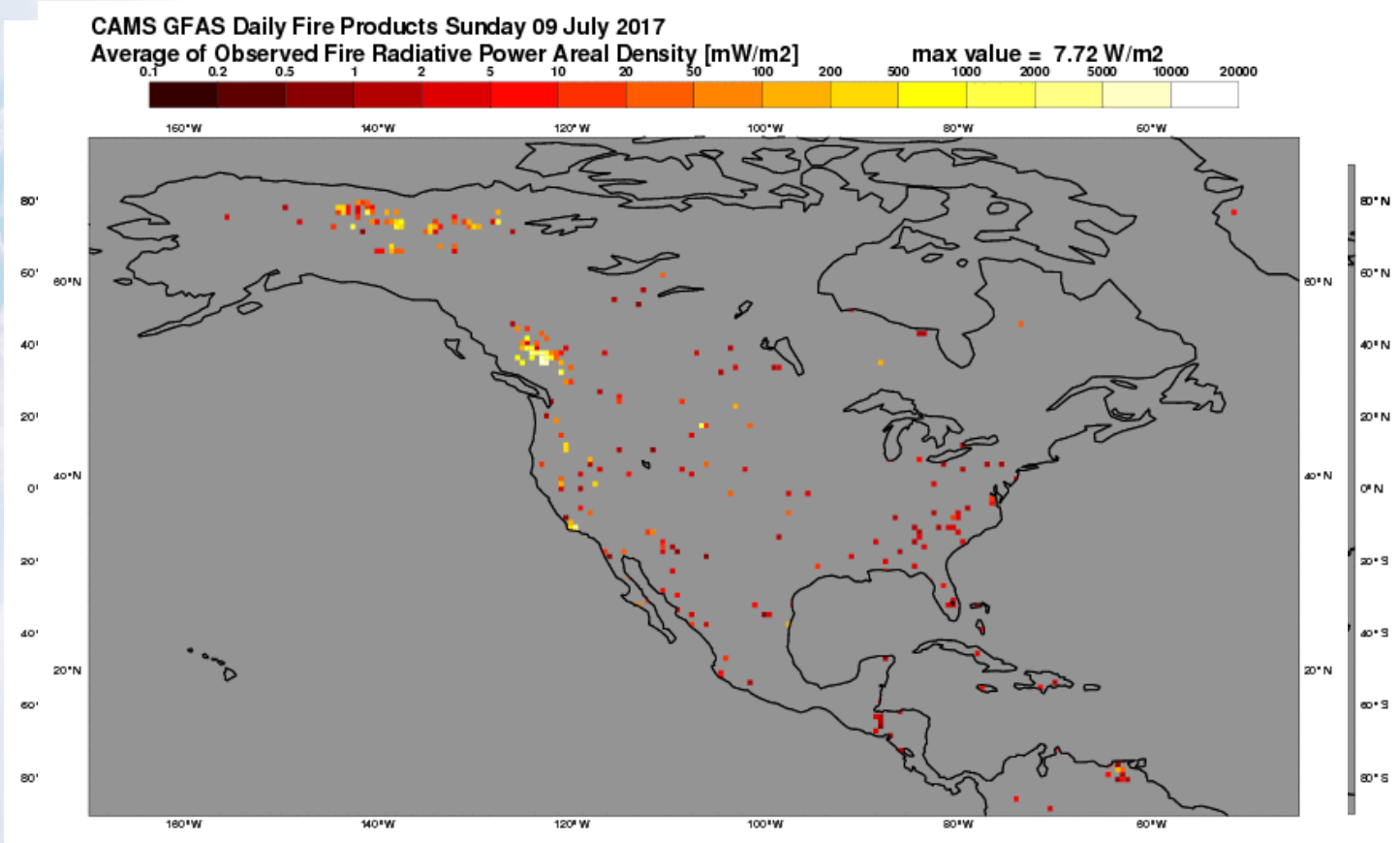
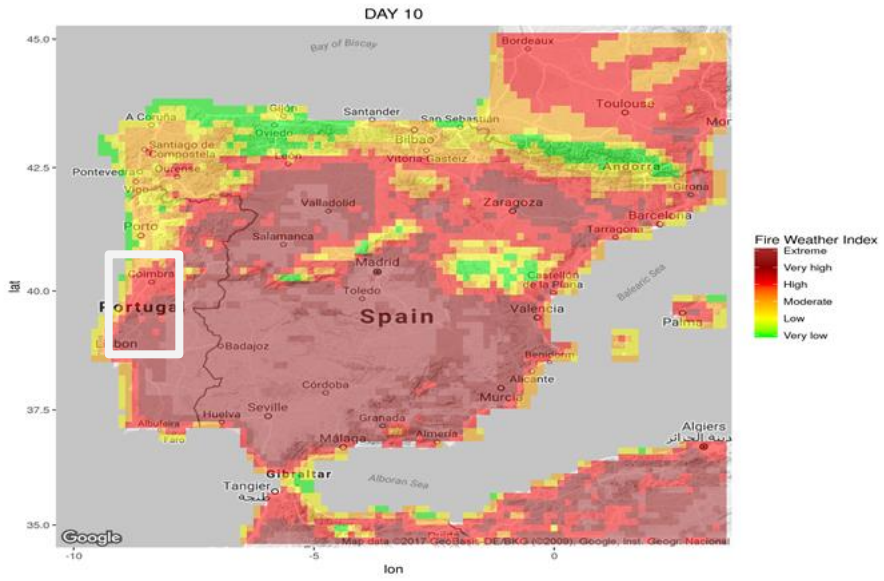


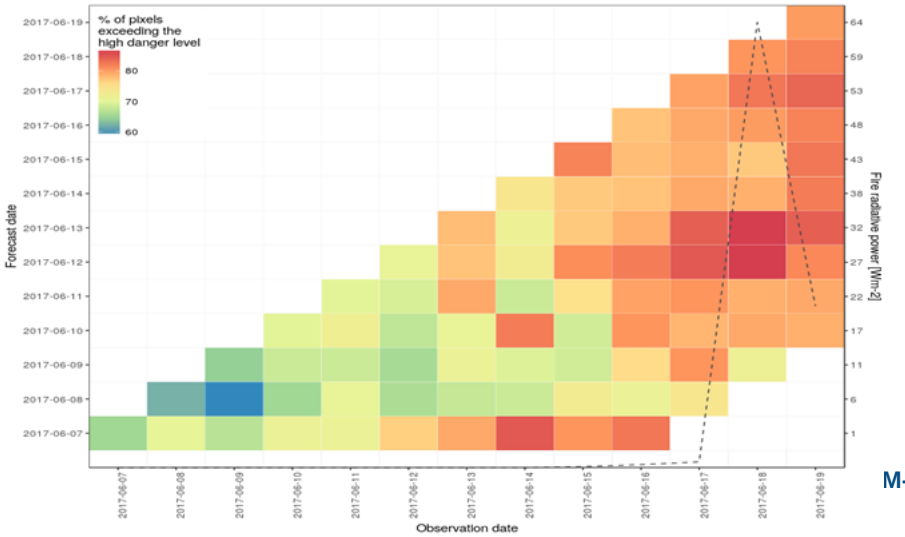
Latest GFAS N American fire activity, 9 July 2017

Forest fires Portugal 17-18 June 2017

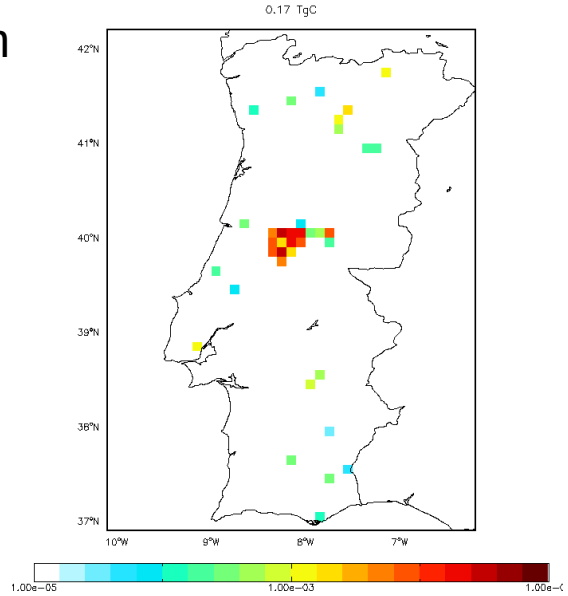
Clear signal for extreme fire danger conditions from 10 days before the event

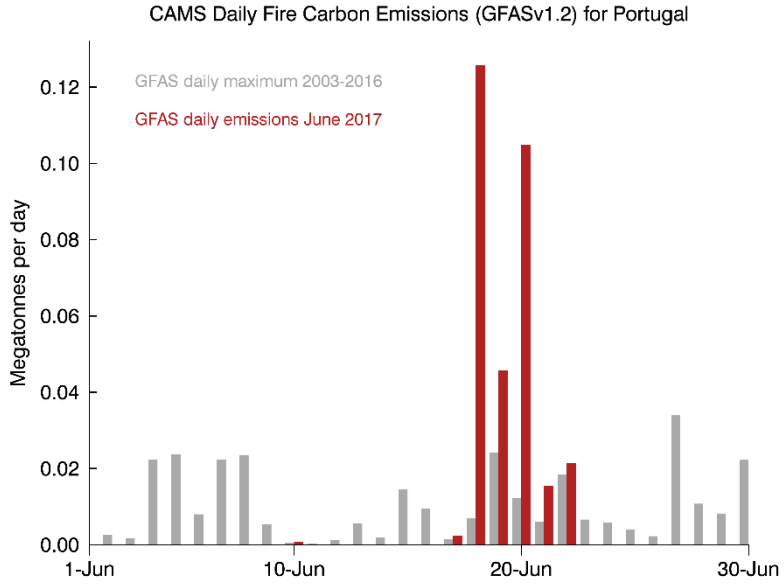
c/o Francesca Di Giuseppe & Claudia Vitolo (ECMWF)

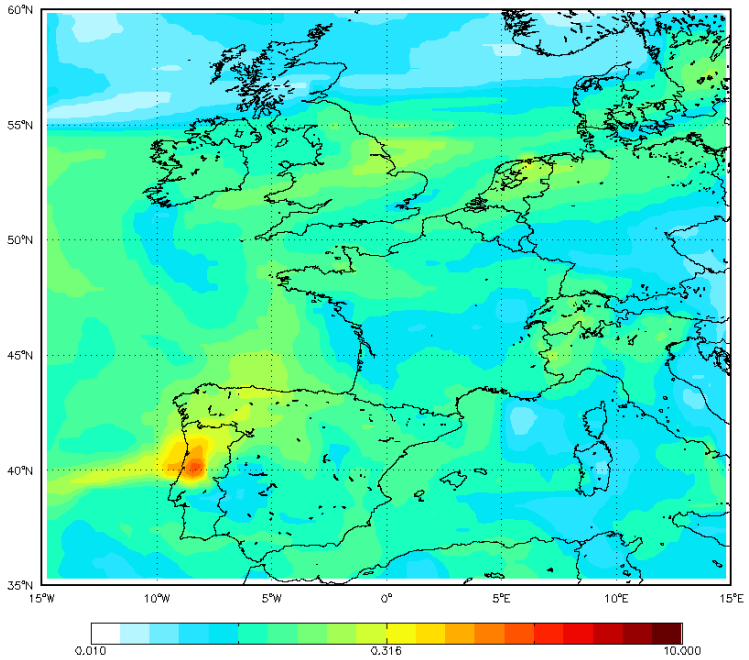




Observed emissions (CAMS)







CAMS operational forecast of organic matter AOD initialized 20 June 2017 at 00 UTC

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GFAS developments

- CAMS developments are supplied under contracts issued to external organizations.
  - GFAS development consortium led by Johannes Kaiser includes MPI-C, KCL, VU Amsterdam, IPMA
- Hourly time resolution
- Production every hour within 5 hours of observation
- Assimilation with underlying model of diurnal cycle
- Quantitative error characterization of satellite FRP products
- FRP provision from Himawari-8
- Assimilation of FRP from
  - GEO satellites
  - Sentinel 3, VIIRS
- Dynamic emission factors
- FRP forecasting

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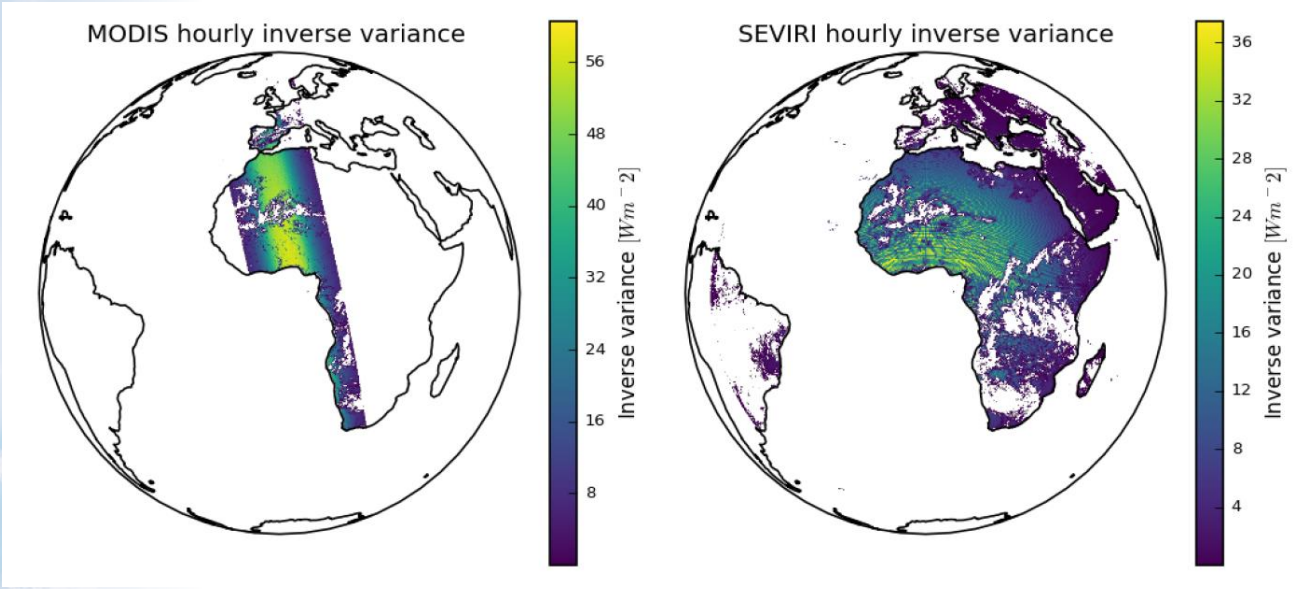
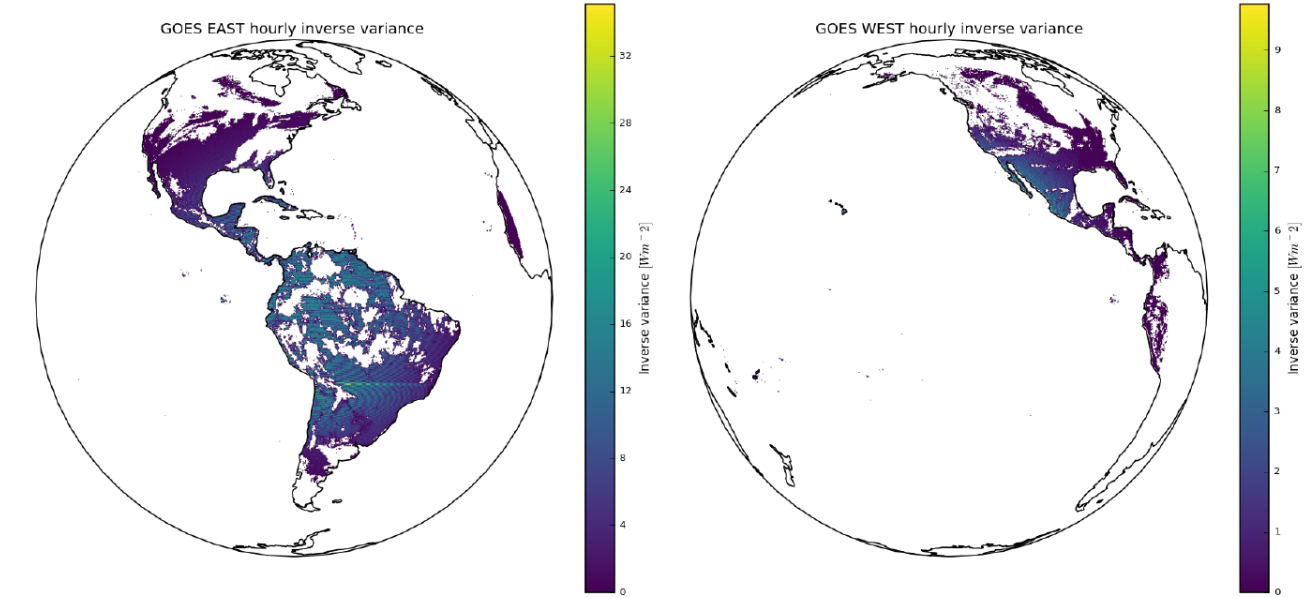
New FRP gridding algorithm





- 5 satellites in GEO and LEO
  - Terra/Aqua MODIS (currently actively used in GFAS)
  - SEVIRI
  - GOES-E/W
  - Himawari-8 (in development)
- FRP error estimates
  - based on S/N
  - detection threshold
- Atmospheric correction (MODIS)

Tadas Nikonovas (KCL)

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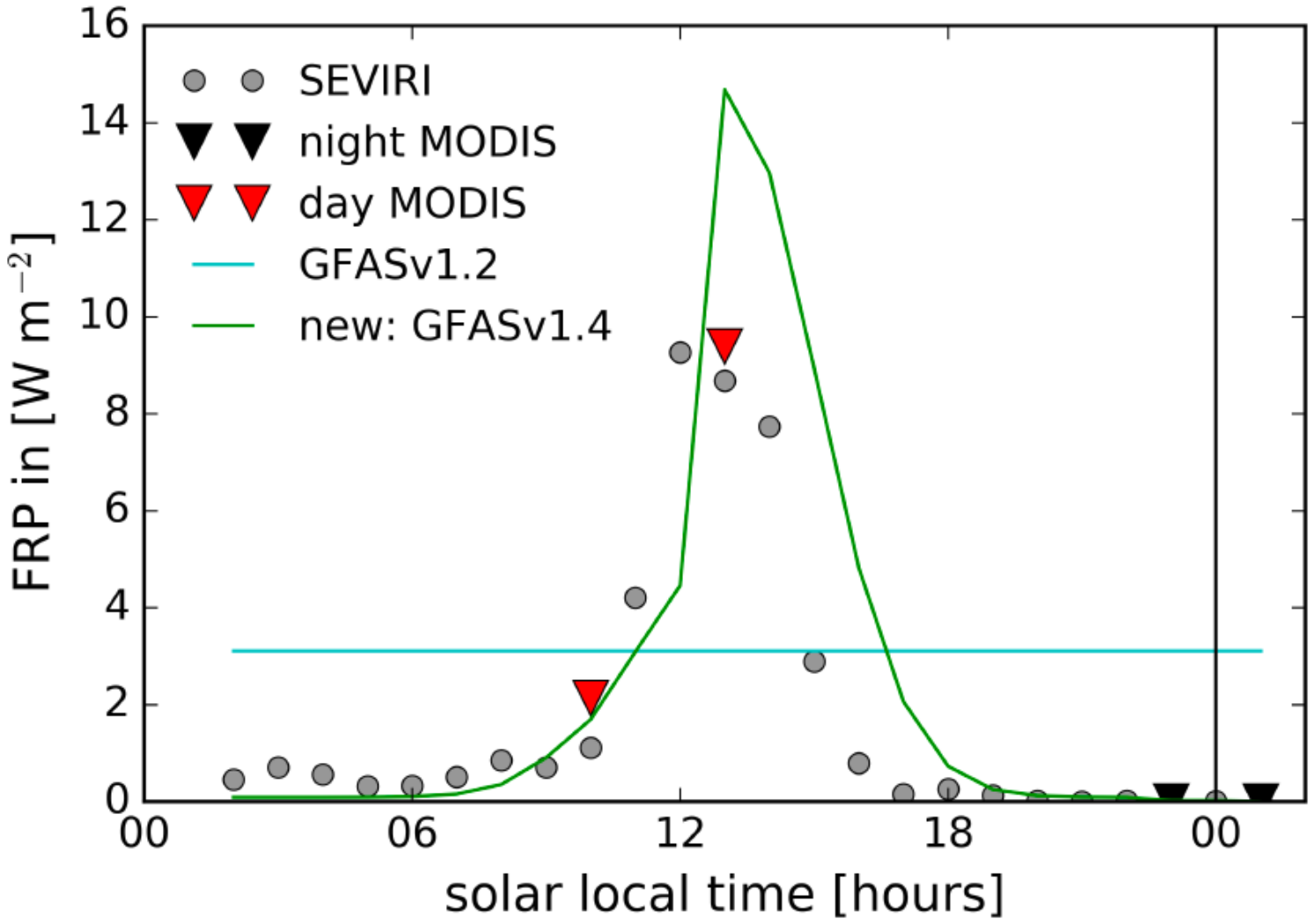
Hourly resolution with diurnal cycle



- Requirement to account for hourly FRP variability with sparse observations from LEO satellites.
- Diurnal cycle parametrization from analysis of
  - nighttime base FRP
  - daytime peak FRP
- New hourly-resolution FRP implemented and being tested in operational GFAS suite.

Imke Hueser, Johannes Kaiser (MPI)

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Dynamic emission factors

Modified Combustion Efficiency is a proxy for the ratio of emissions from flaming and smouldering vegetation
--> **Directly related to EFs.**

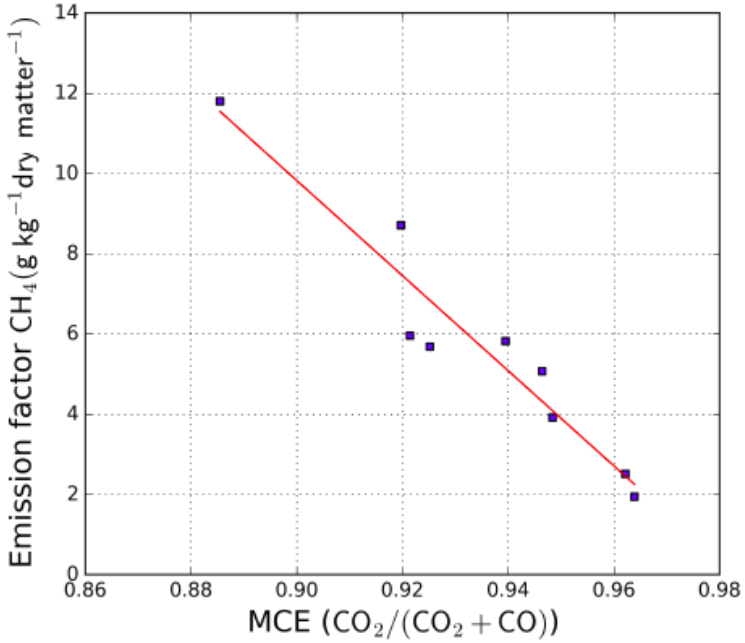
Relate linearly MCE variability

with

Soil Moisture variability

↓

Allow for spatio-temporal variability of EFs



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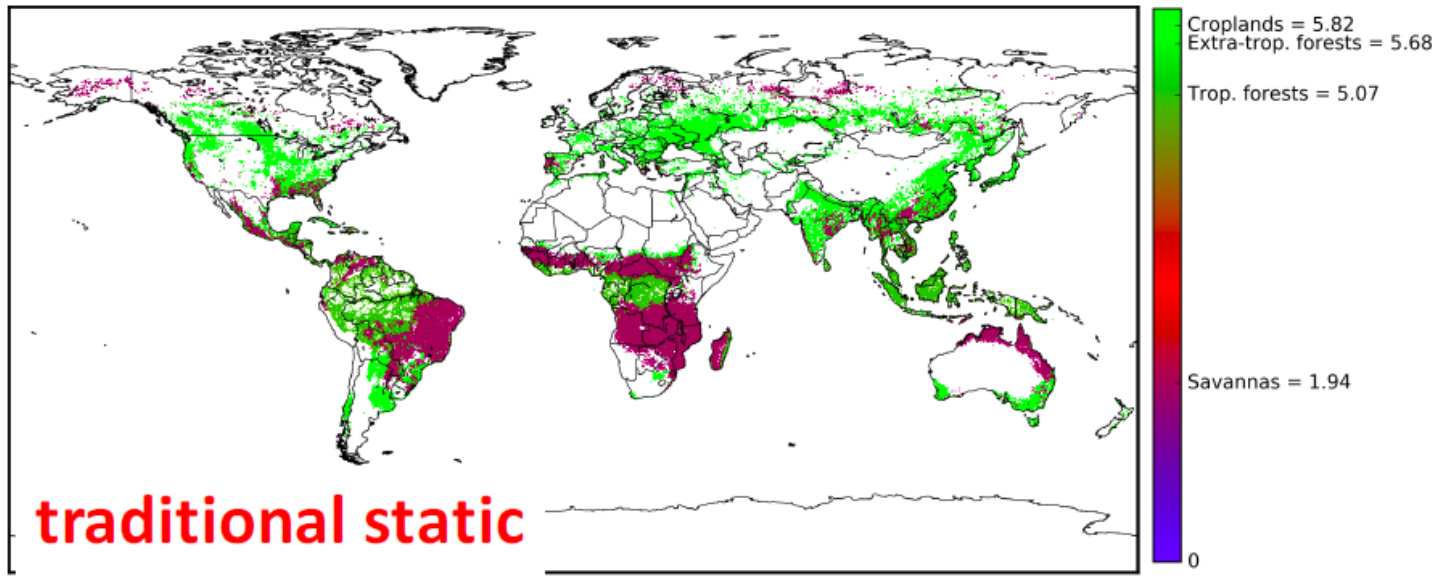
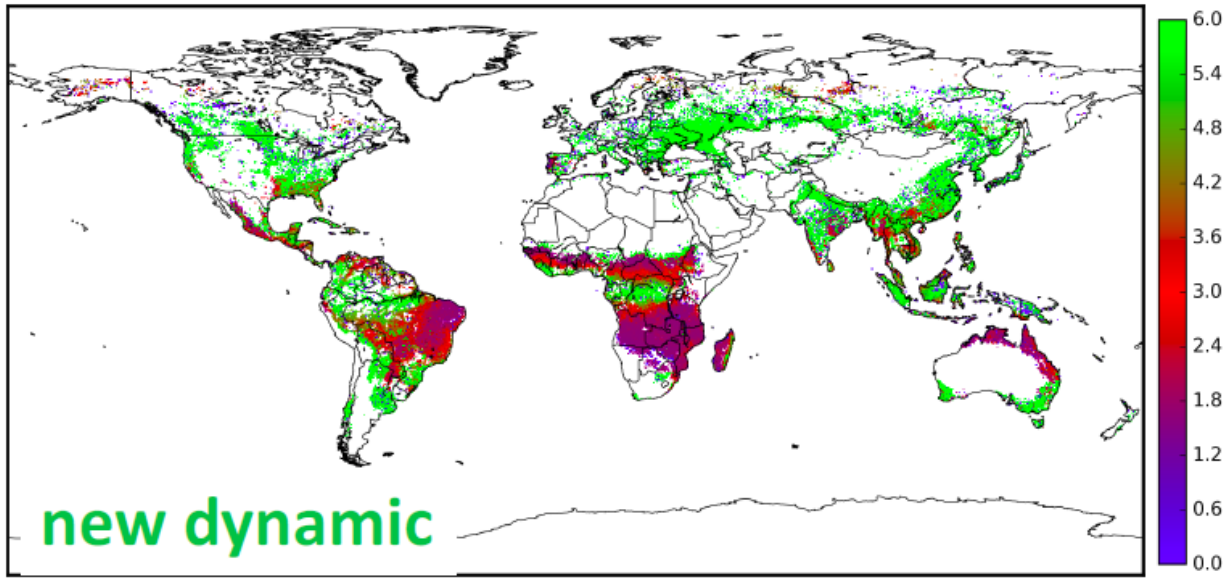
Spatial variability of CH4 emission factors





Yannis Bistinas, Guido van der Werf (VUA)

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Wildfire FRP forecasting

- Motivation: current 5-days forecasts of atmospheric composition assume persistent fire emissions throughout.
- Goal: apply meteorological forecast information to modulate FRP over the course of the forecast.
- Investigating fire activity (FRP) forecasting in different fire affected land cover types using logistic regression (LR), over a 5-day period
  - LR models built using met. and FWI data, and known fire statistics.
  - Probability estimates from LR models used to determine when/if fire activity observed on the first forecast day should be extinguished during days 1-5 of the forecast.
  - Evaluating LR model skill vs. persistence for all fire activity and large fire activity.

Mark de Jong (KCL)

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Summary part 1/2

- Wildfire emissions are an integral part of the atmospheric composition forecasts in CAMS
- Current implementation (GFASv1.2) provides long-term (2003-present), daily, global emissions estimates at 0.1 degree resolution
- New and future developments will greatly improve GFAS and wildfire products available through CAMS
  - In situ, near-field, measurements of fire emissions vital to evaluating and improving global atmospheric composition models
- GFAS developments sub-contracted to an external consortium led by MPI-C
  - Johannes Kaiser, Imke Hueser, Berit Gehrke (MPI-C, Germany)
  - Martin Wooster, Tadas Nikonovas, Mark de Jong, W. Xu, J. He (KCL, UK)
  - Isabel Trigo, Sandra Coelho (IPMA, Portugal)
  - Guido van der Werf, Yannis Bistinas (VU Amsterdam, Netherlands)

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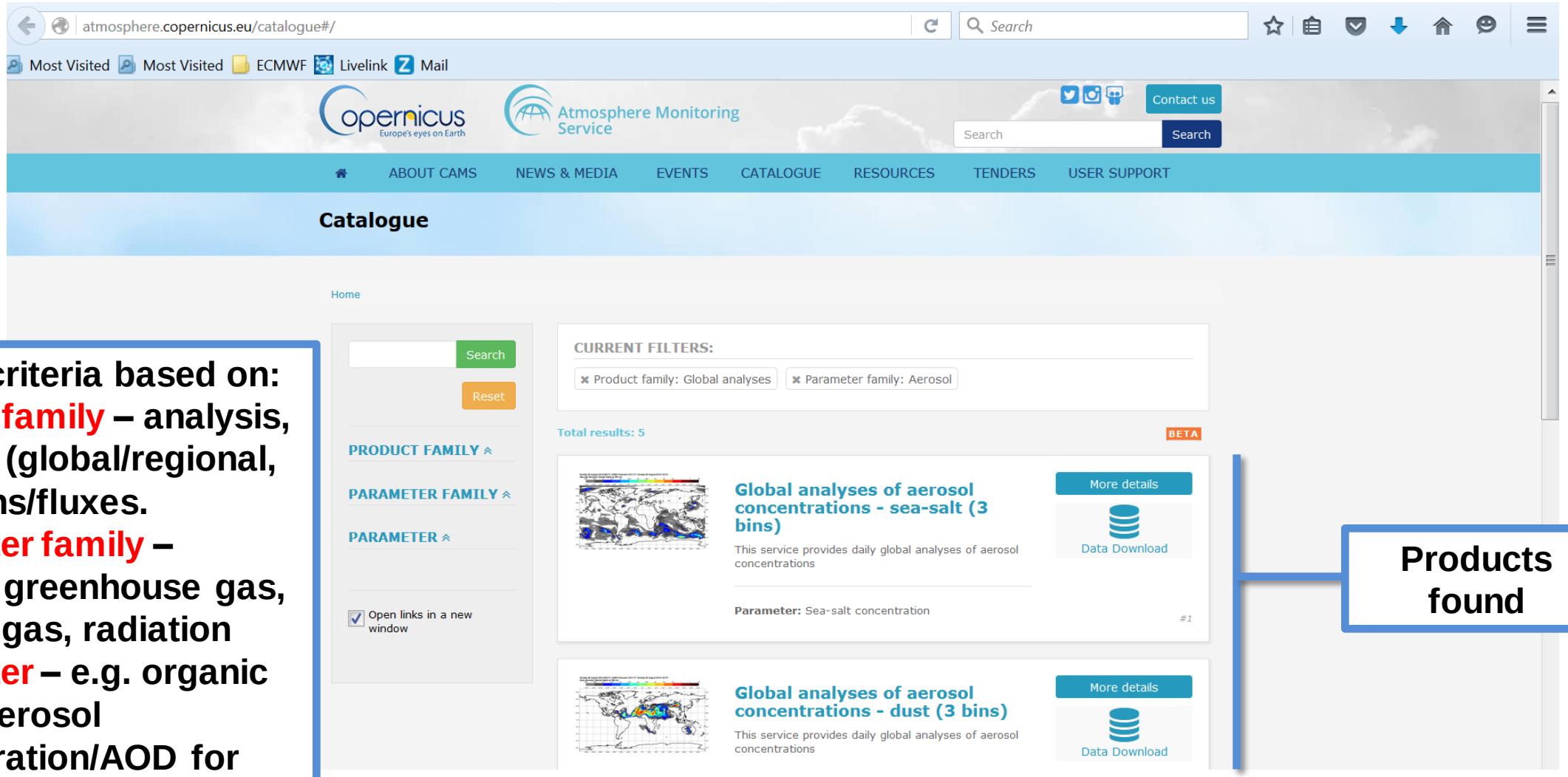
Summary part 2/2

- Copernicus Atmosphere Monitoring Service operational since August 2015.
  - Built on ~10 years development under GEMS and MACC pre-operational “research” projects.
  - Brings together a wide range of models and observations for monitoring and forecasting global and regional atmospheric composition.
  - All data are free and open for everyone to access.
  - http://atmosphere.copernicus.eu http://macc-raq-op.meteo.fr http://climate.copernicus.eu

    @Copernicus_ECMWF @Copernicus_EU
- Acknowledgments
  - Anna Agustí-Panareda, Alessio Bozzo, Johannes Flemming, Antje Inness, Sebastien Massart, Zak Kipling, Melanie Ades, Luke Jones, Richard Engelen, Vincent-Henri Peuch (ECMWF)
  - CAMS Global and Regional Production Teams

CAMS online catalogue search

http://atmosphere.copernicus.eu/catalogue



Search criteria based on:
Product family – analysis, forecast (global/regional, emissions/fluxes.
Parameter family – aerosol, greenhouse gas, reactive gas, radiation
Parameter – e.g. organic matter aerosol concentration/AOD for smoke

Products found

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CAMS online catalogue search

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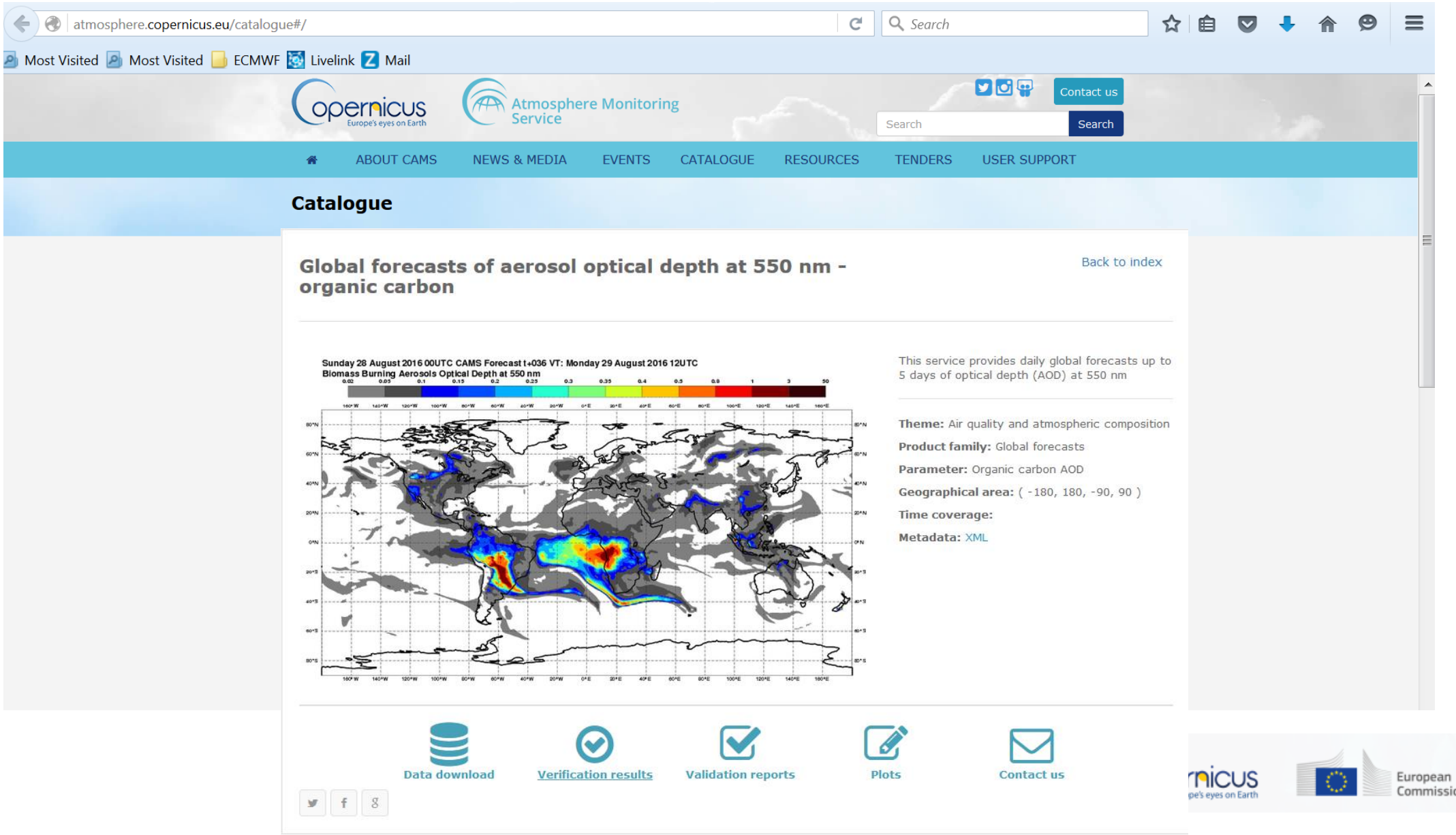
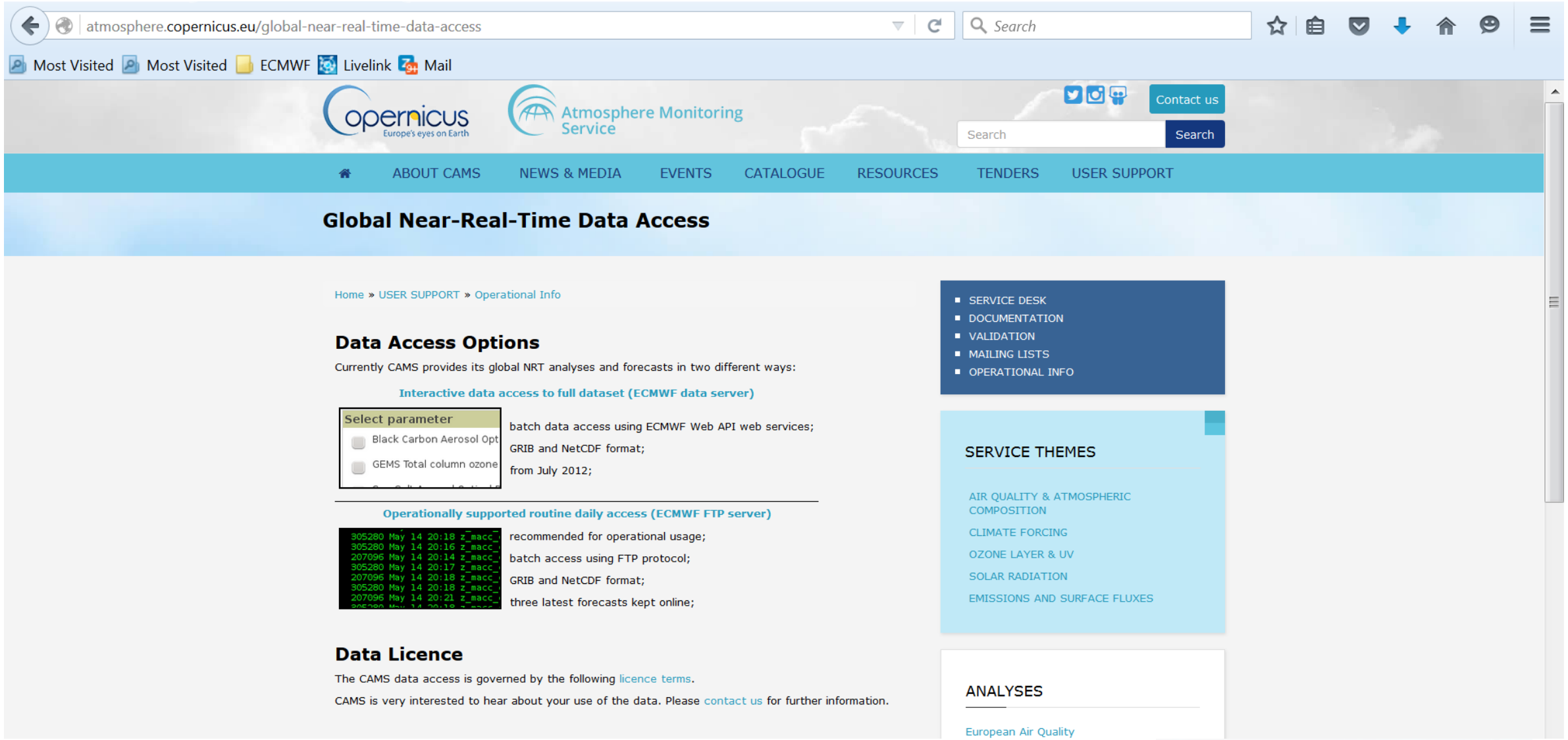


CAMS online catalogue search results



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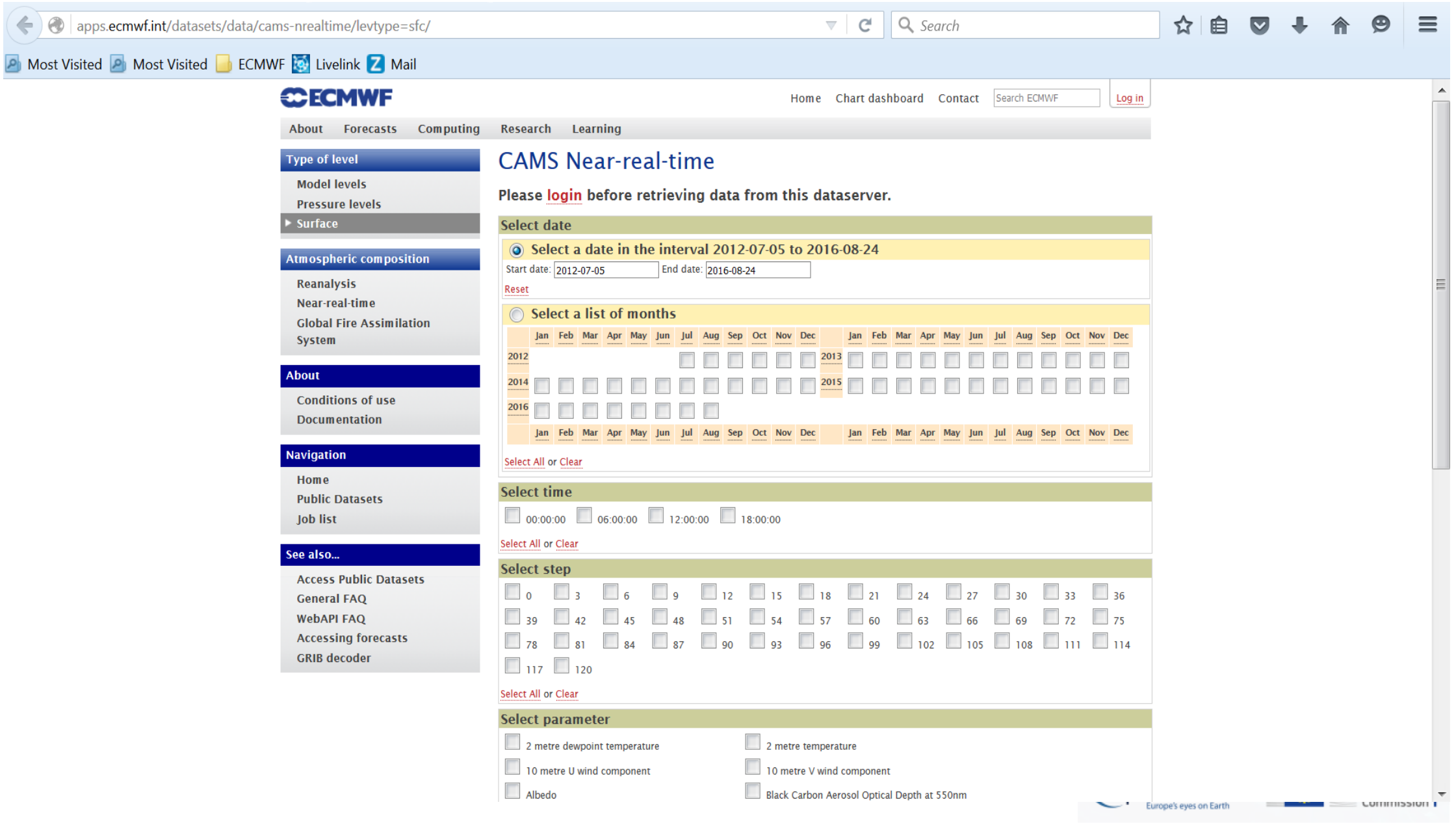
CAMS online catalogue search results