

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



Atmosphere Monitoring

Mark Parrington (mark.parrington@ecmwf.int)

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





S u m m a r y

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



Atmosphere
Monitoring

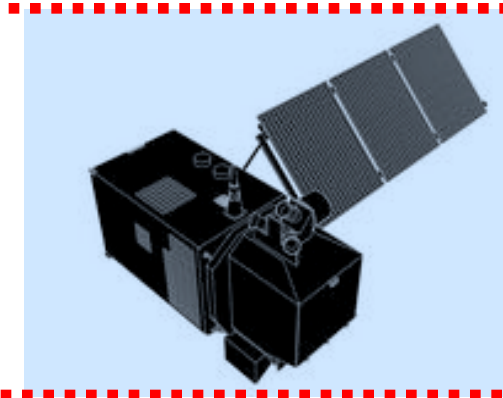
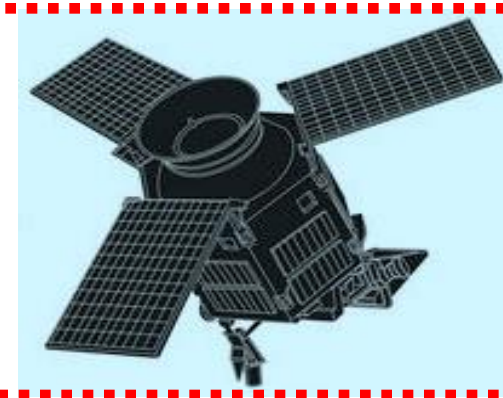
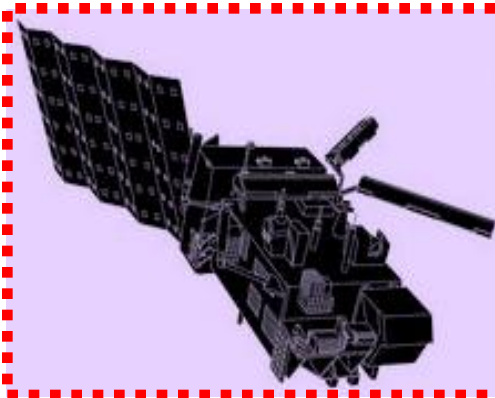
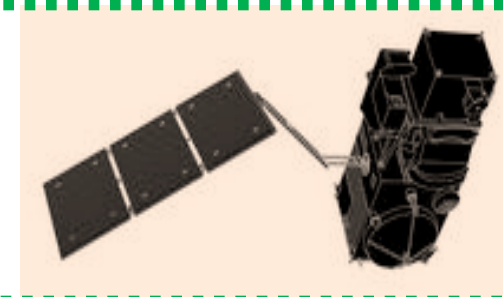
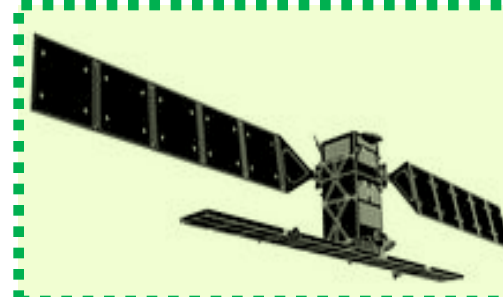
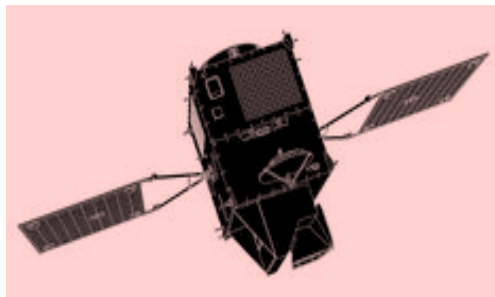
Copernicus: A Flagship European Programme



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

The Sentinels

Burnt area/FRP observations



Atmospheric composition/Air quality observations

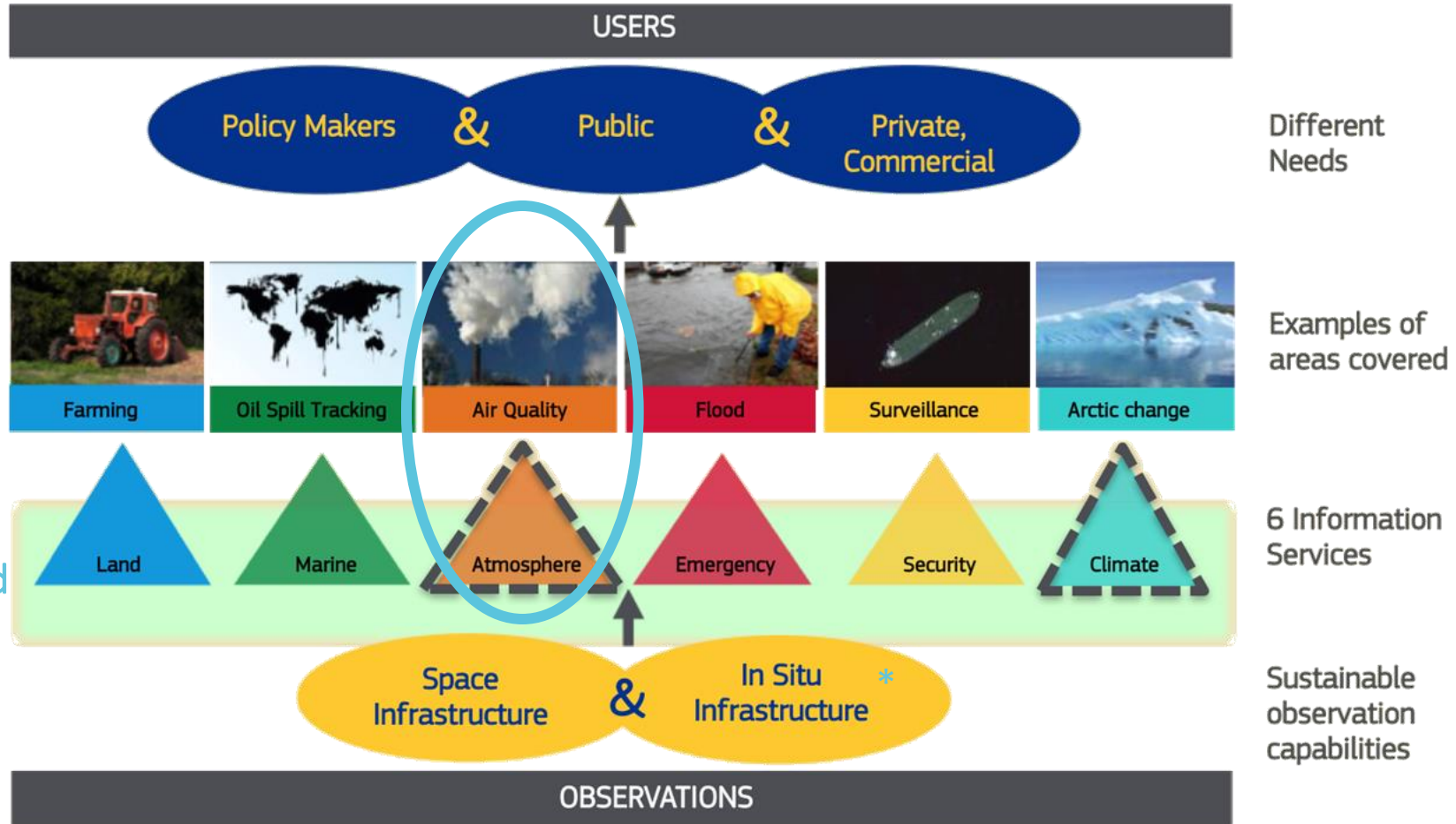


is harnessing world leading science and technology to equip society to understand and adapt to our changing environment



Atmosphere
Monitoring

THE COPERNICUS VALUE-ADDING CHAIN



 Services led by ECMWF

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



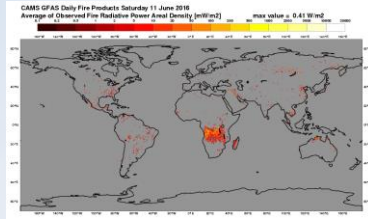
Atmosphere Monitoring

CAMS Services

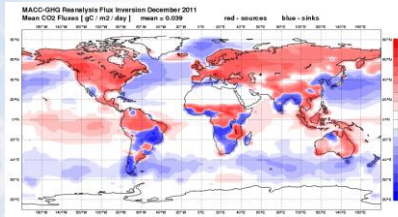
Space Agencies



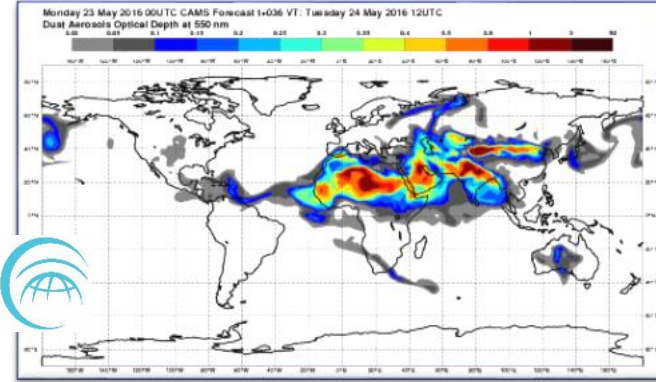
In situ observations



Fire emissions



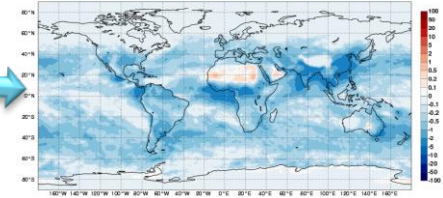
GHG fluxes



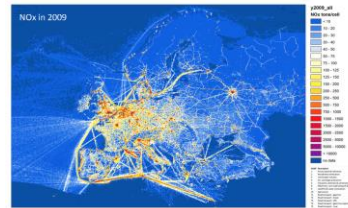
Global



Solar radiation



Climate forcing



Anthropogenic emissions

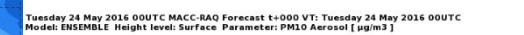
Tuesday 24 May 2016 00UTC MACC-RAQ Forecast t+000 VT: Tuesday 24 May 2016 00UTC Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [µg/m3]



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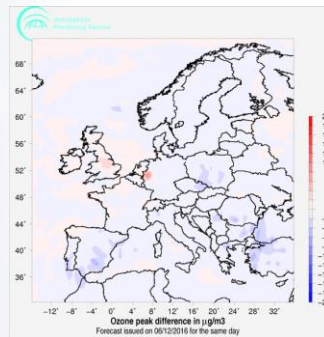
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Tuesday 24 May 2016 00UTC MACC-RAQ Forecast t+000 VT: Tuesday 24 May 2016 00UTC Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [µg/m3]



Policy



Regional

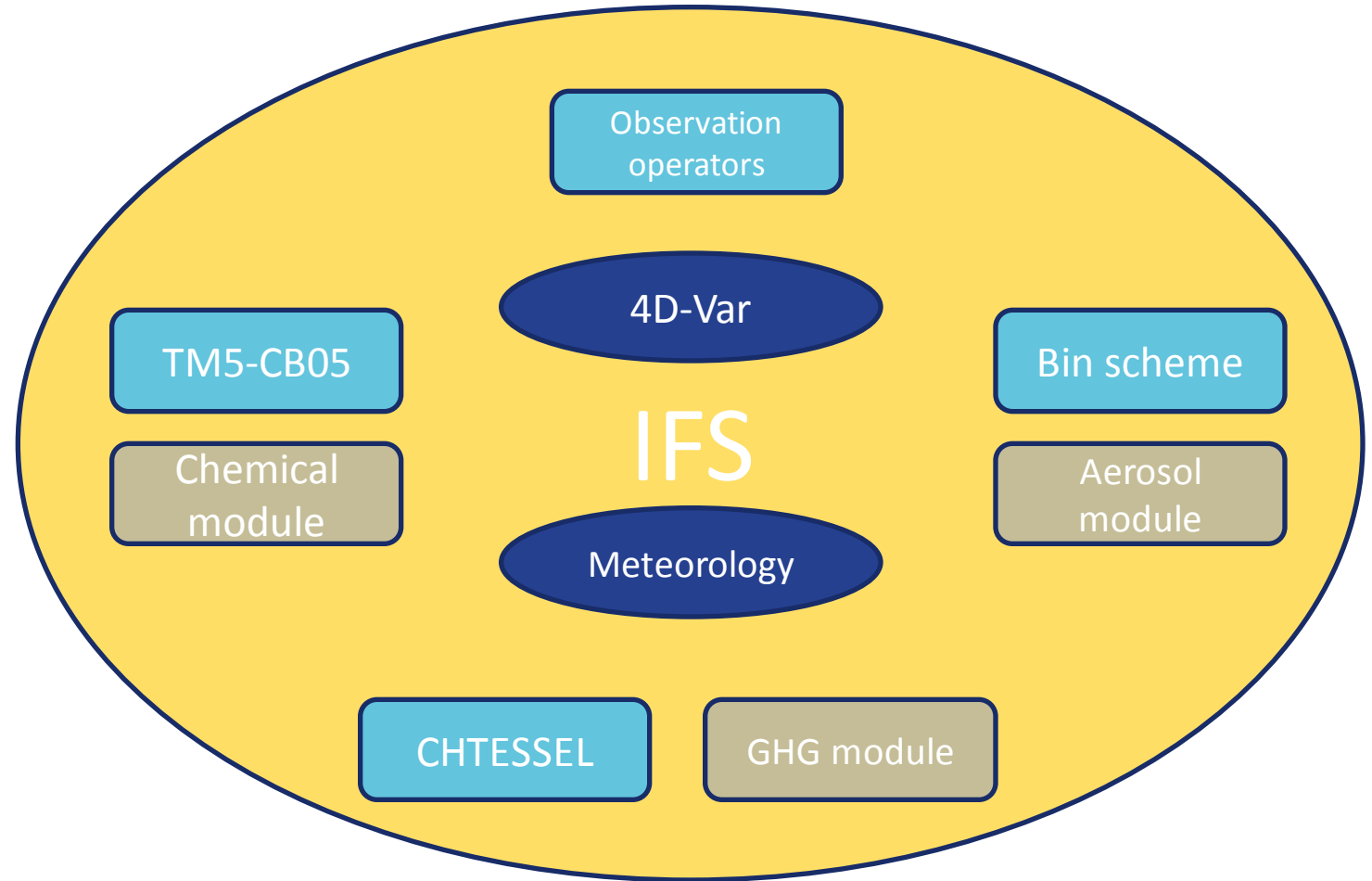




Atmospheric science in the ECMWF Integrated Forecast System (IFS)

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

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





Atmos
Monit

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.

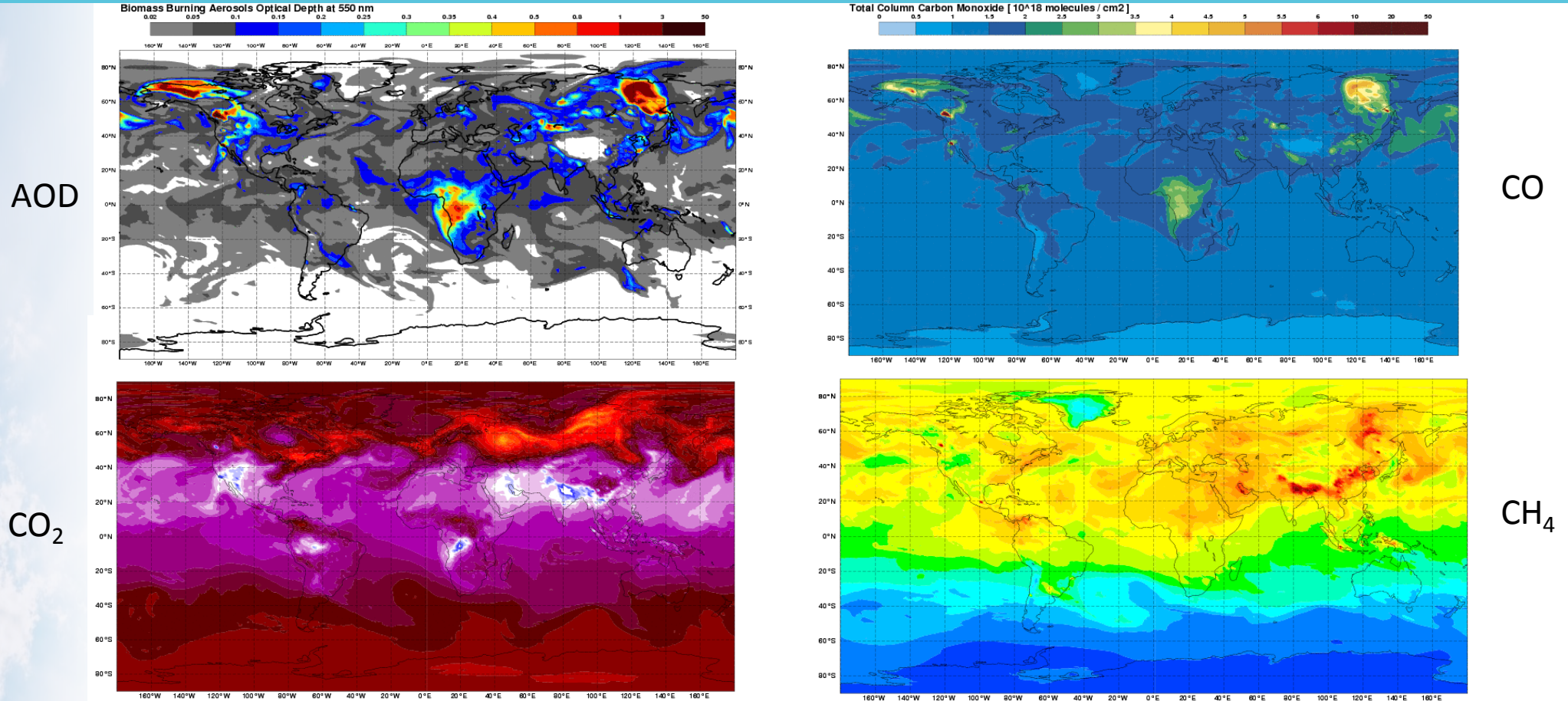
Control runs (with no data assimilated) and forecasts (initialised from analyses) are also produced in CAMS.

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

Composition data additional to thousands of assimilated meteorological data.



Current analysis/forecast configuration



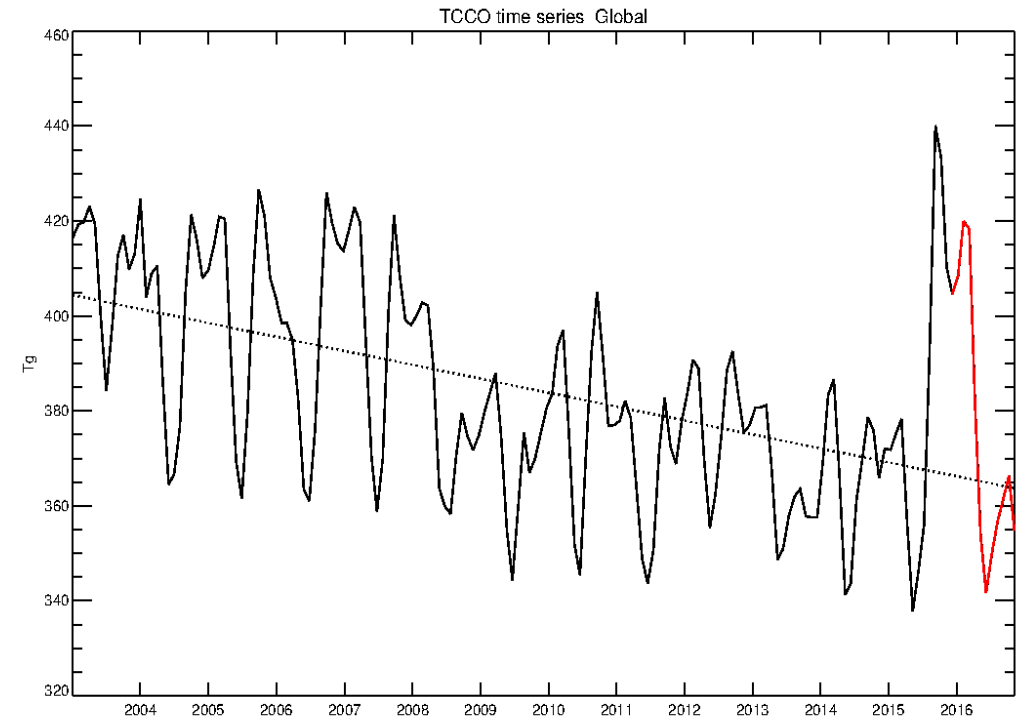
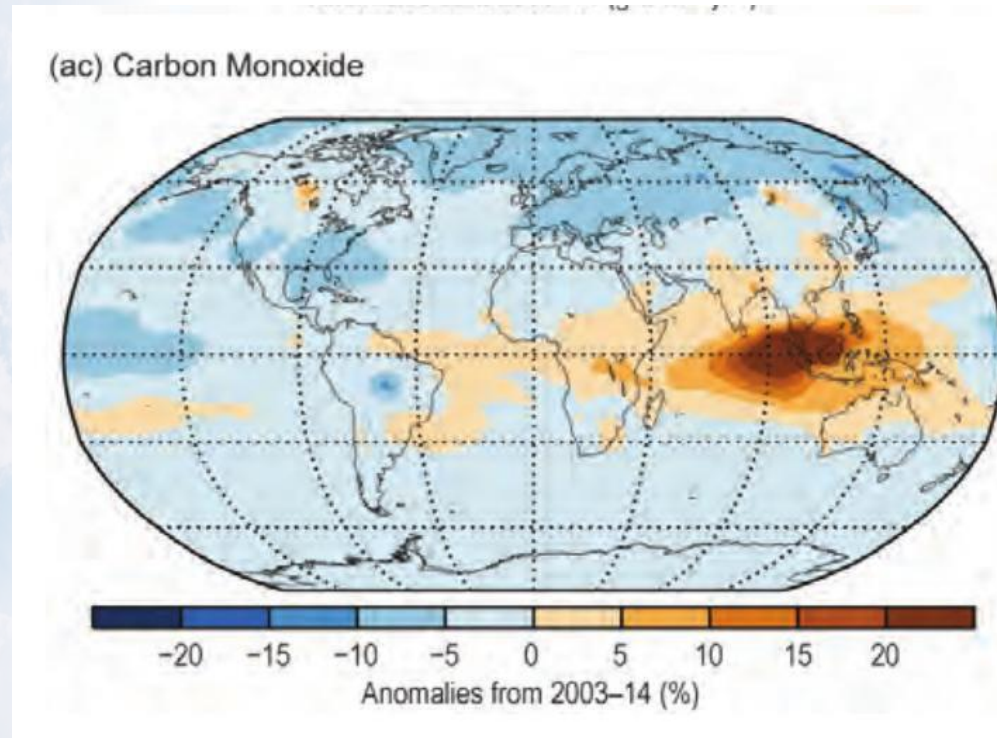
- 40 km horizontal resolution at 60 model levels; two 5-day forecasts at 00z and 12z UTC each day
 - Aerosols (AOD and concentration): biomass burning, dust, sea salt, sulphate
 - Reactive gases: CO, HCHO, NO₂, O₃, SO₂.
- 9 km horizontal resolution at 137 model levels; one 5-day forecast per day (CO₂, CH₄, linear CO)

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



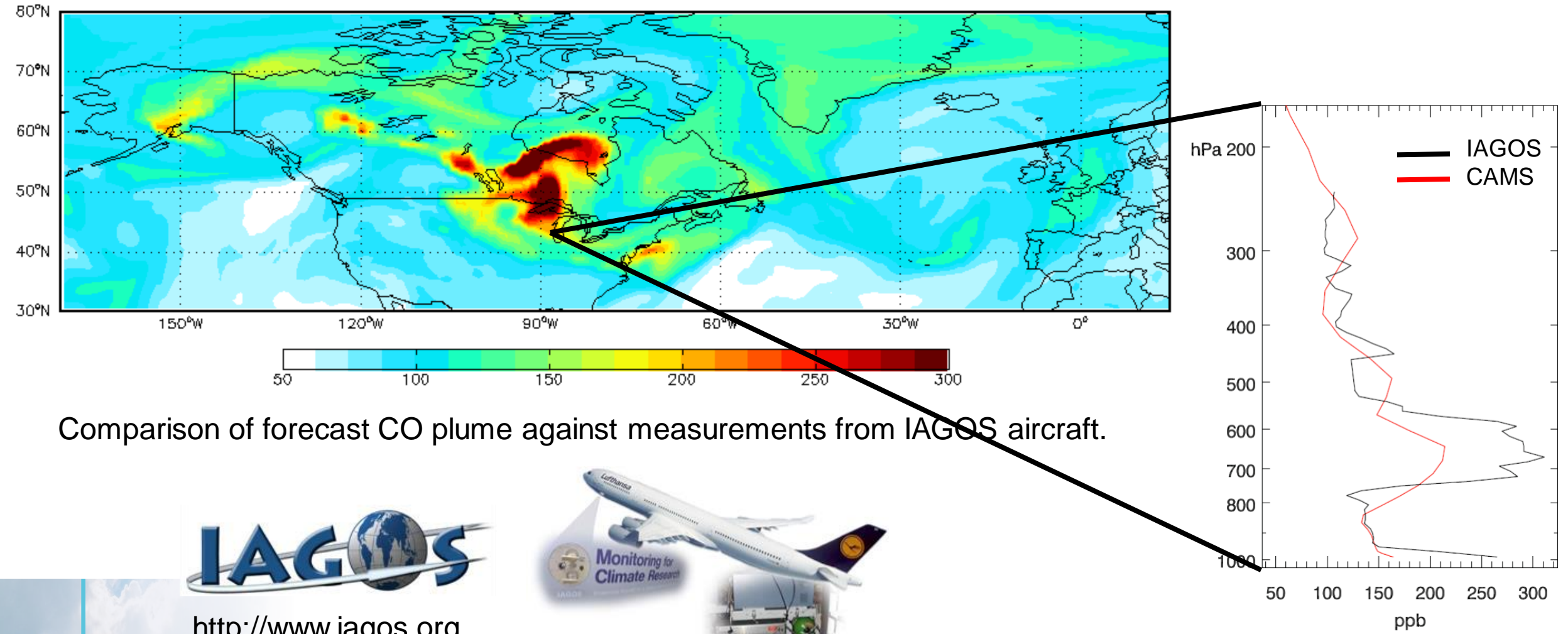
Monitoring of Atmospheric Composition: CAMS interim (re-)analysis

- 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.



Long-range transport of Canadian wildfire emissions to Europe

Chicago, 3 July 2015

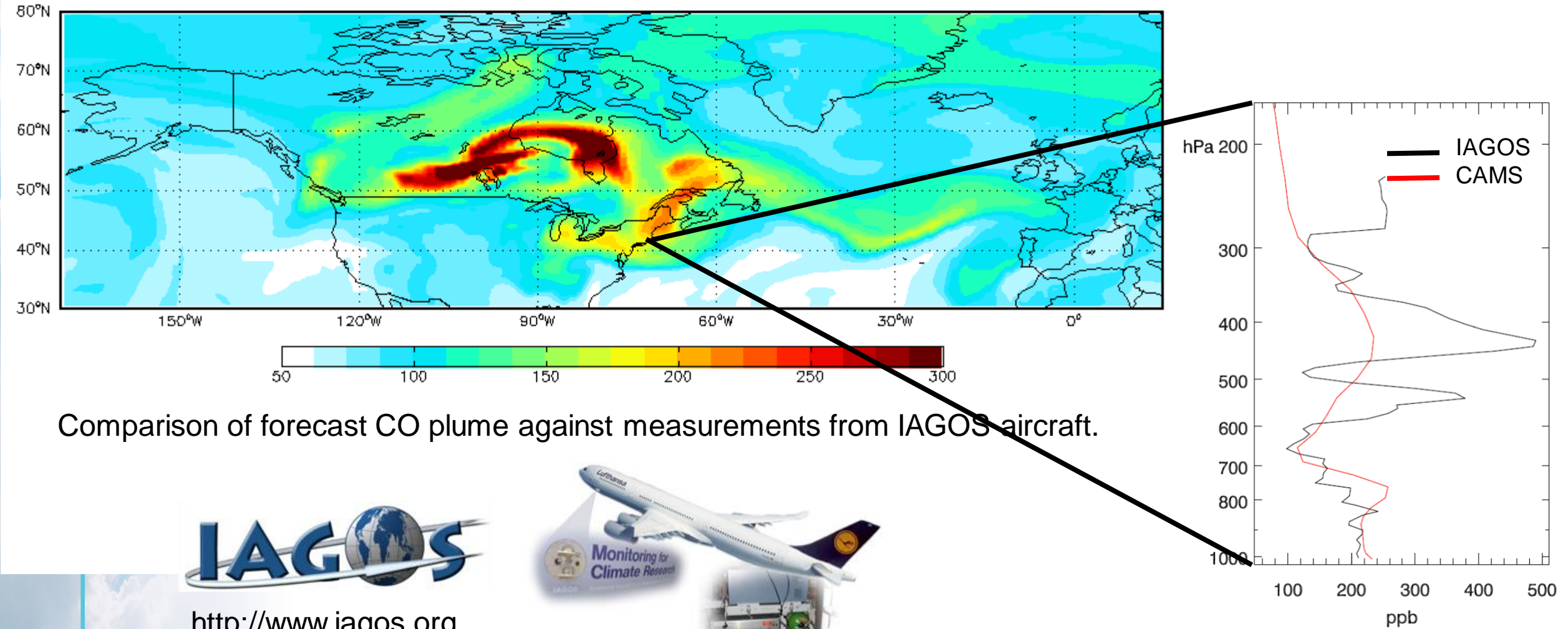


Comparison of forecast CO plume against measurements from IAGOS aircraft.



Long-range transport of Canadian wildfire emissions to Europe

New York, 5 July 2015



Comparison of forecast CO plume against measurements from IAGOS aircraft.

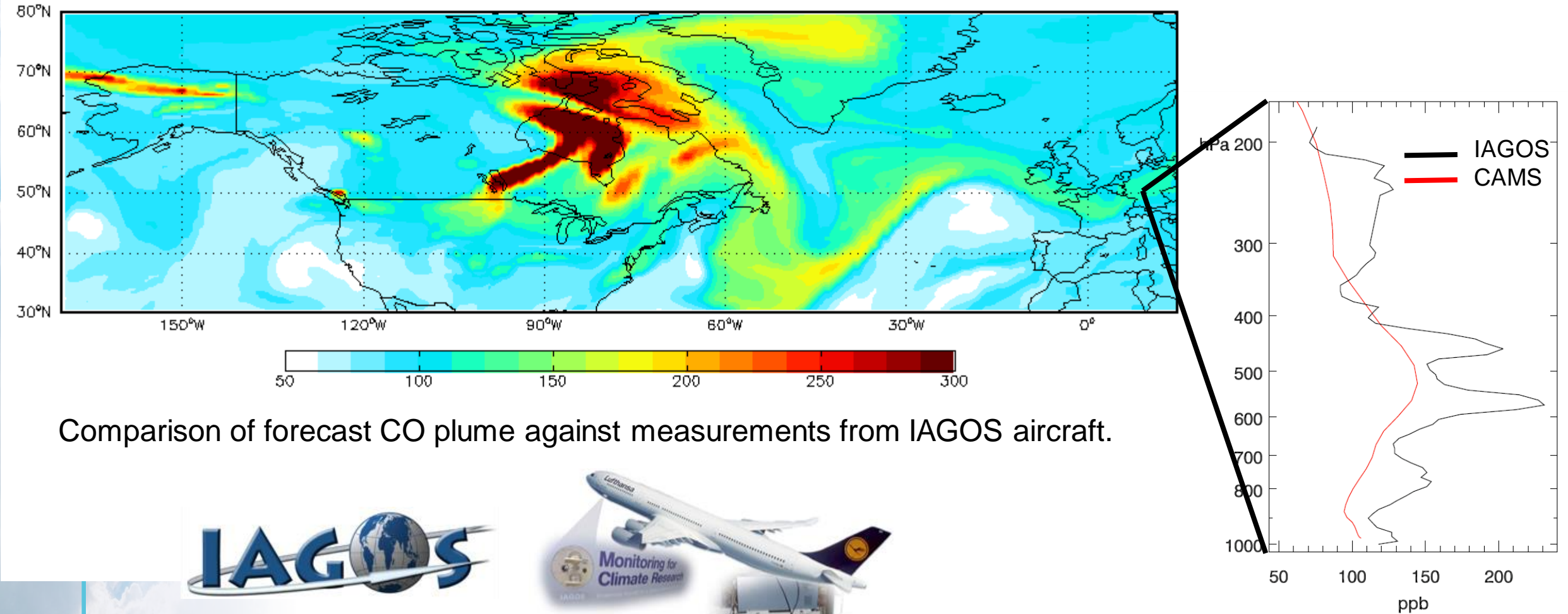


<http://www.iagos.org>



Long-range transport of Canadian wildfire emissions to Europe

Frankfurt, 8 July



Comparison of forecast CO plume against measurements from IAGOS aircraft.



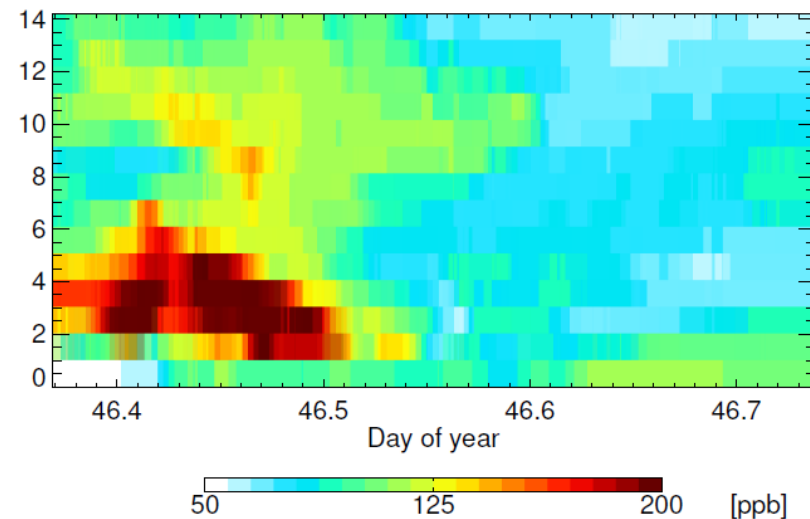
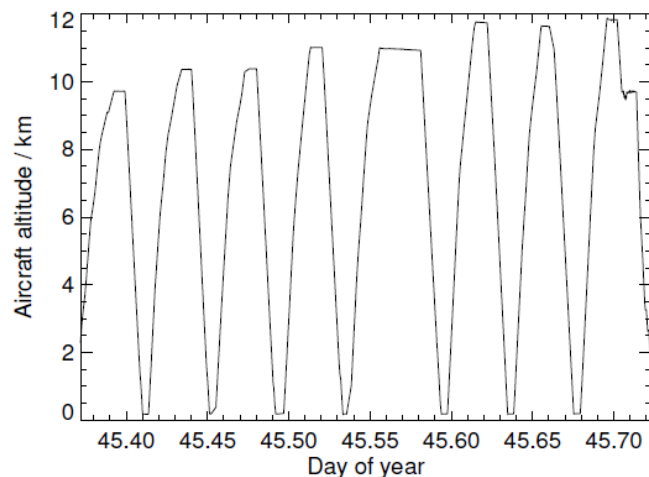
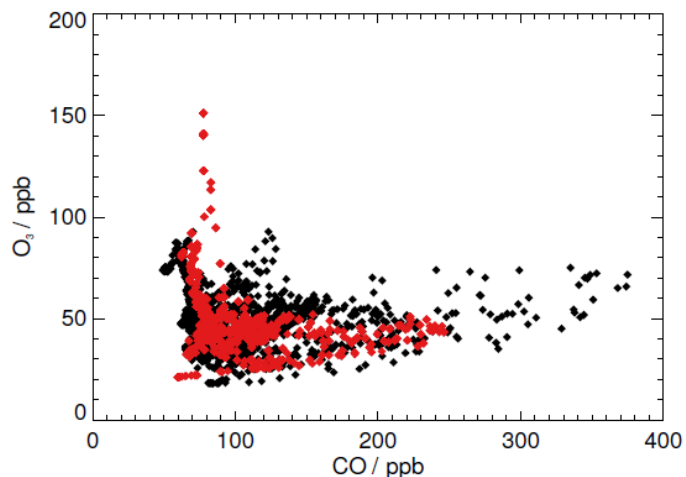
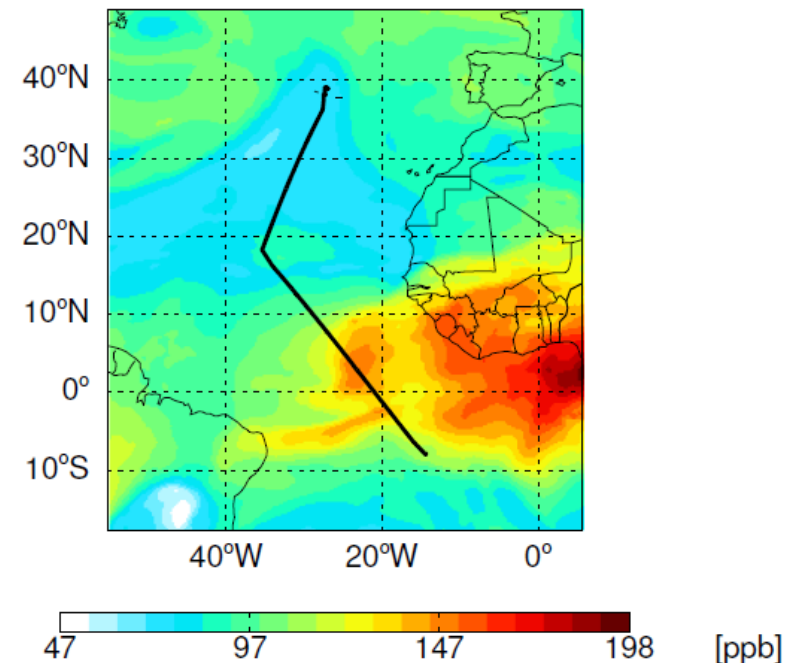
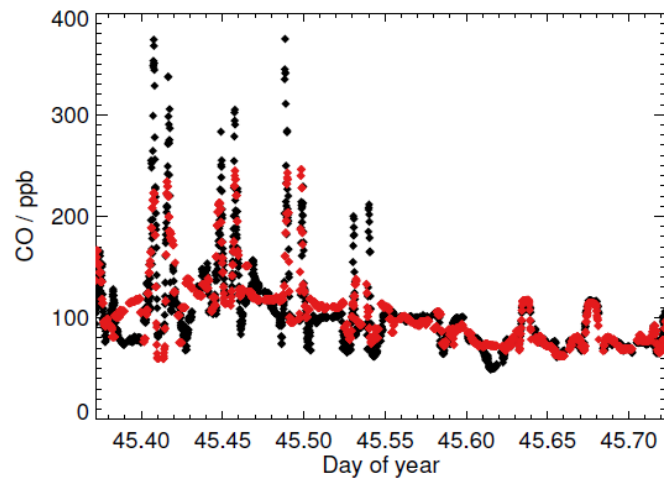
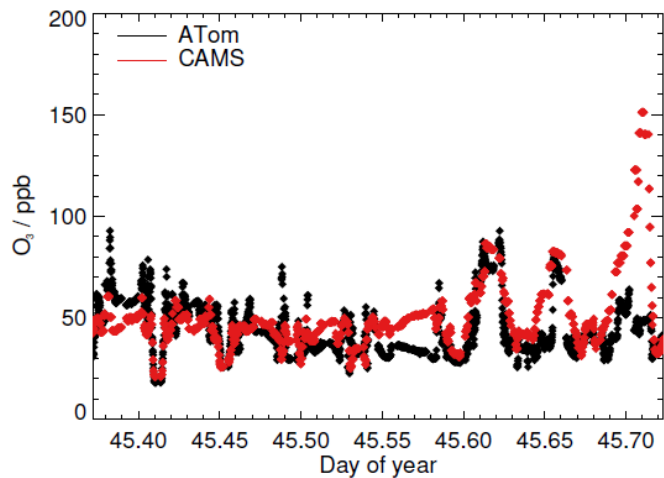
<http://www.iagos.org>





Long-range smoke transport to tropical Atlantic

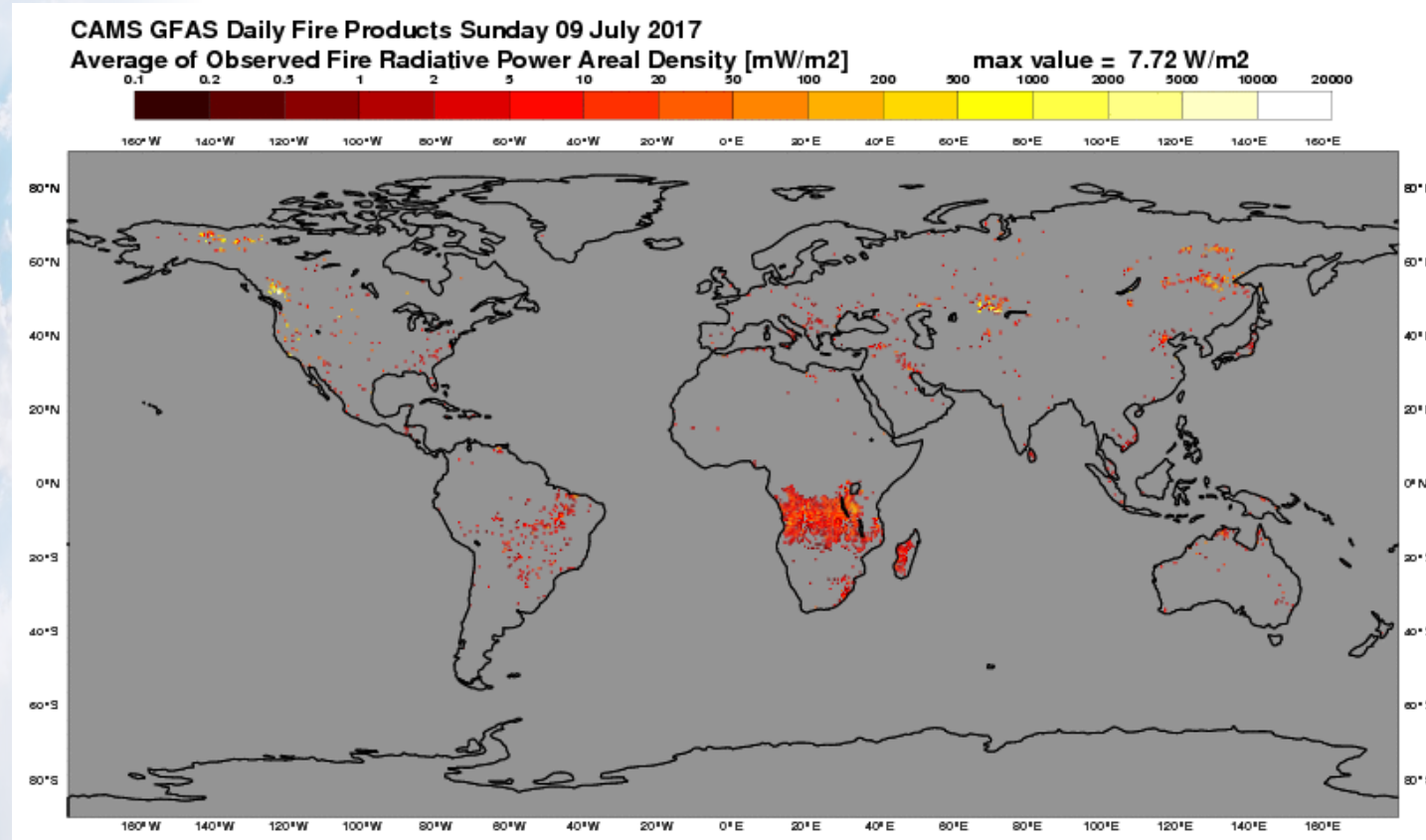
ATom-2 data vs. CAMS IFS forecast: 15 February 2017





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.

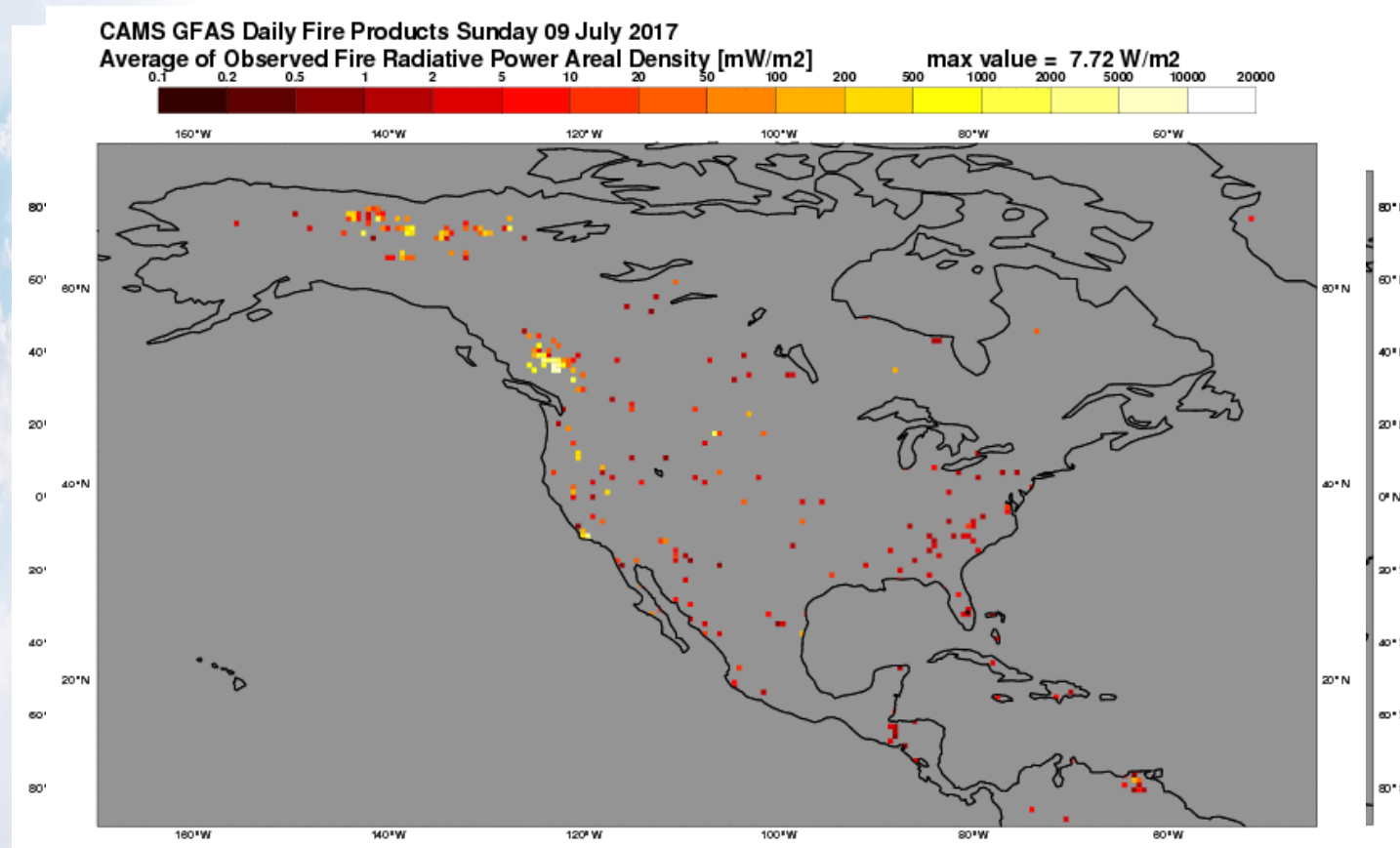


Latest GFAS global fire activity, 9 July 2017



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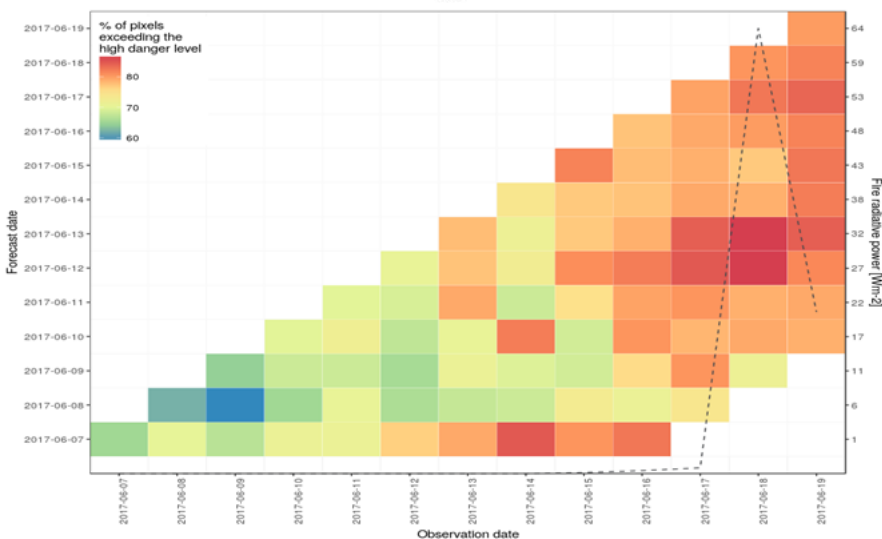
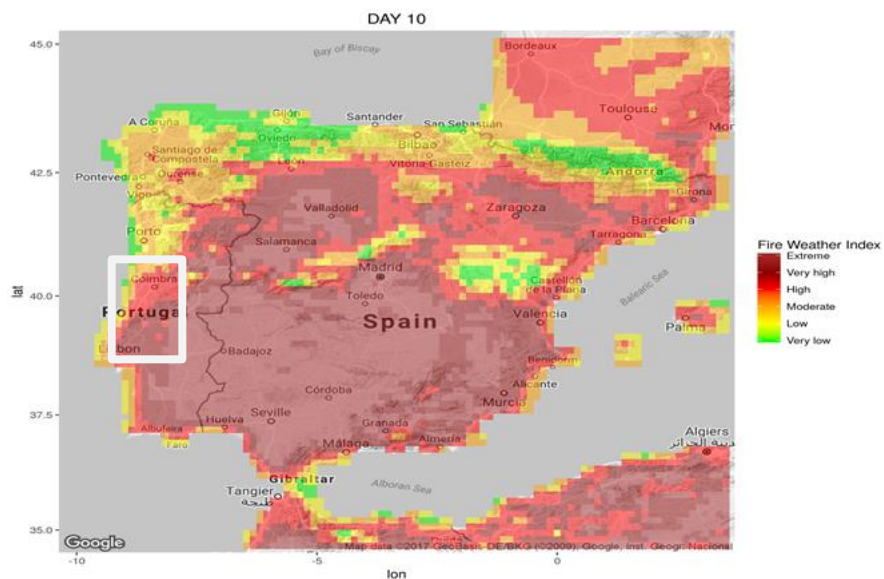


Latest GFAS N American
fire activity, 9 July 2017

Forest fires Portugal 17-18 June 2017

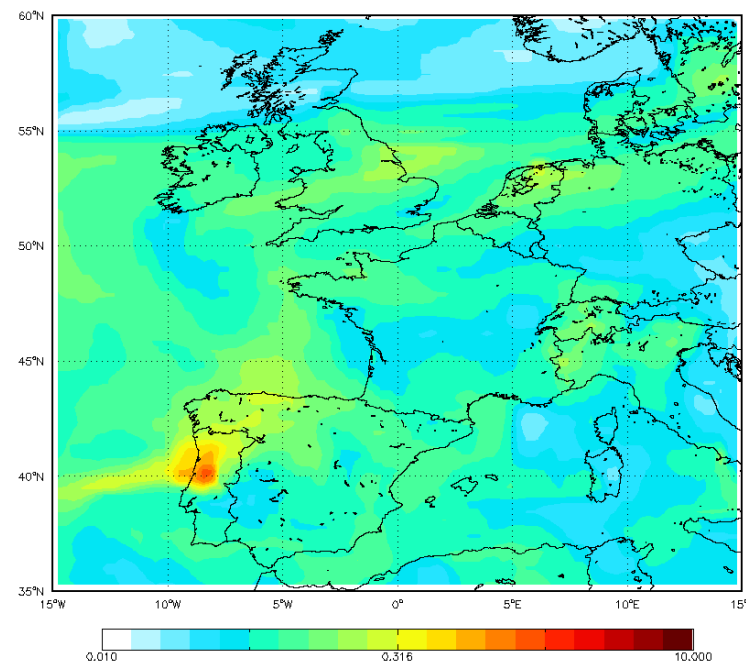
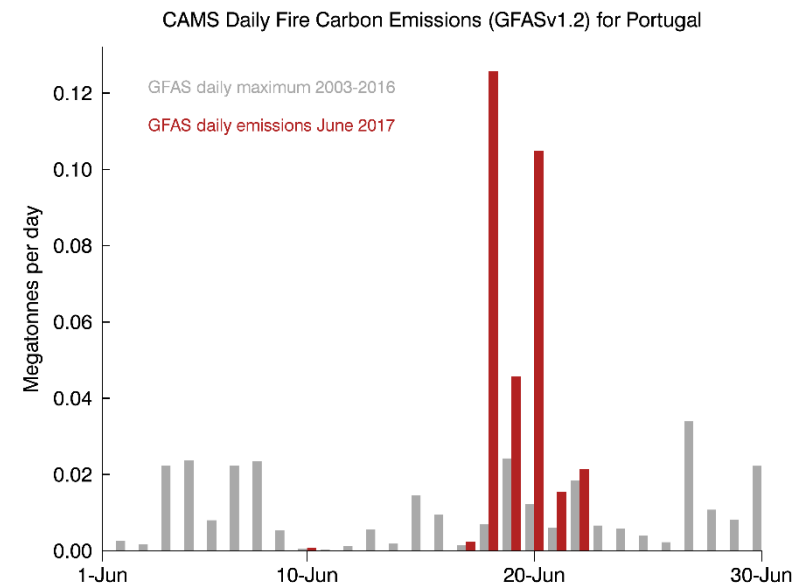
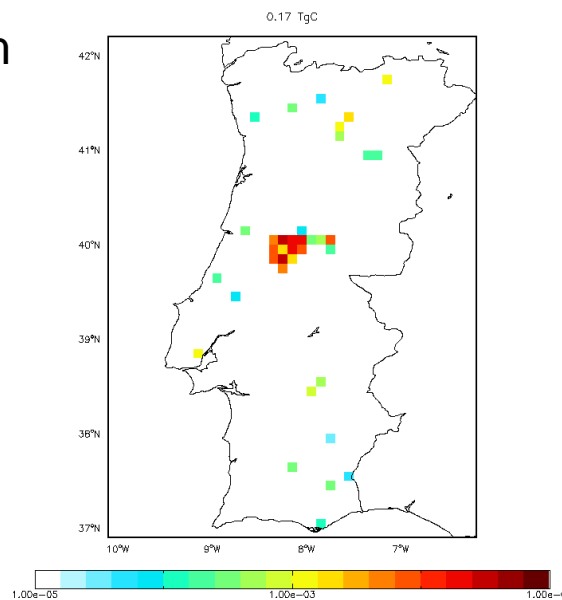
Clear signal for extreme fire danger conditions from 10 days before the event

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



M-RANGE WEATHER FC

Observed emissions (CAM5)



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



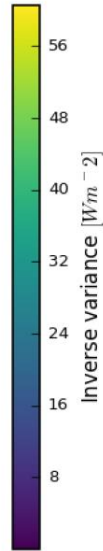
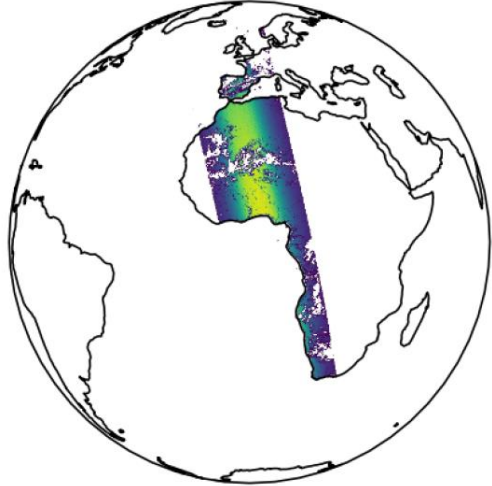
GFAS developments

- 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

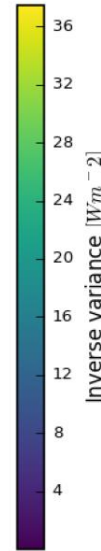
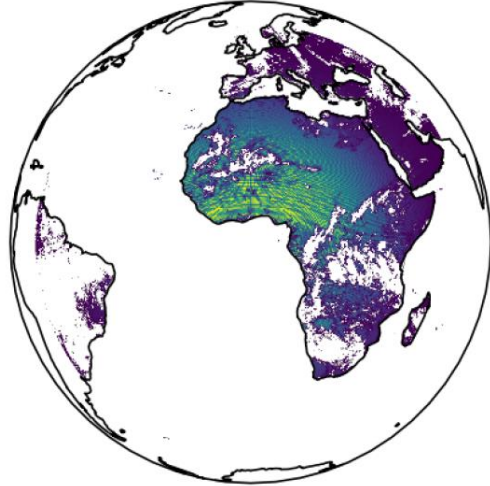


New FRP gridding algorithm

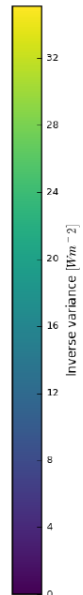
MODIS hourly inverse variance



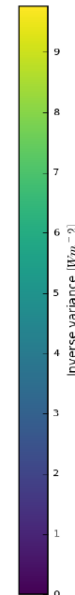
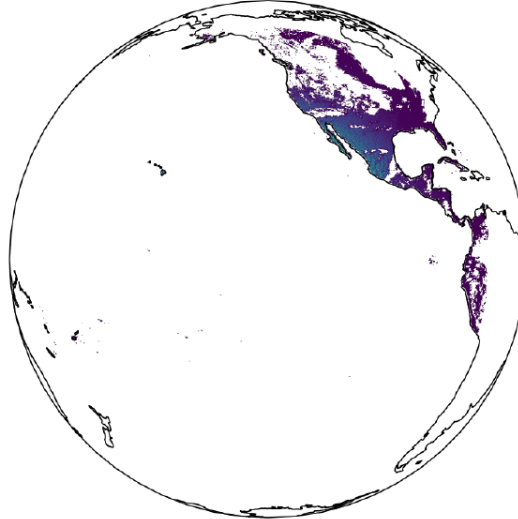
SEVIRI hourly inverse variance



GOES EAST hourly inverse variance



GOES WEST hourly inverse variance

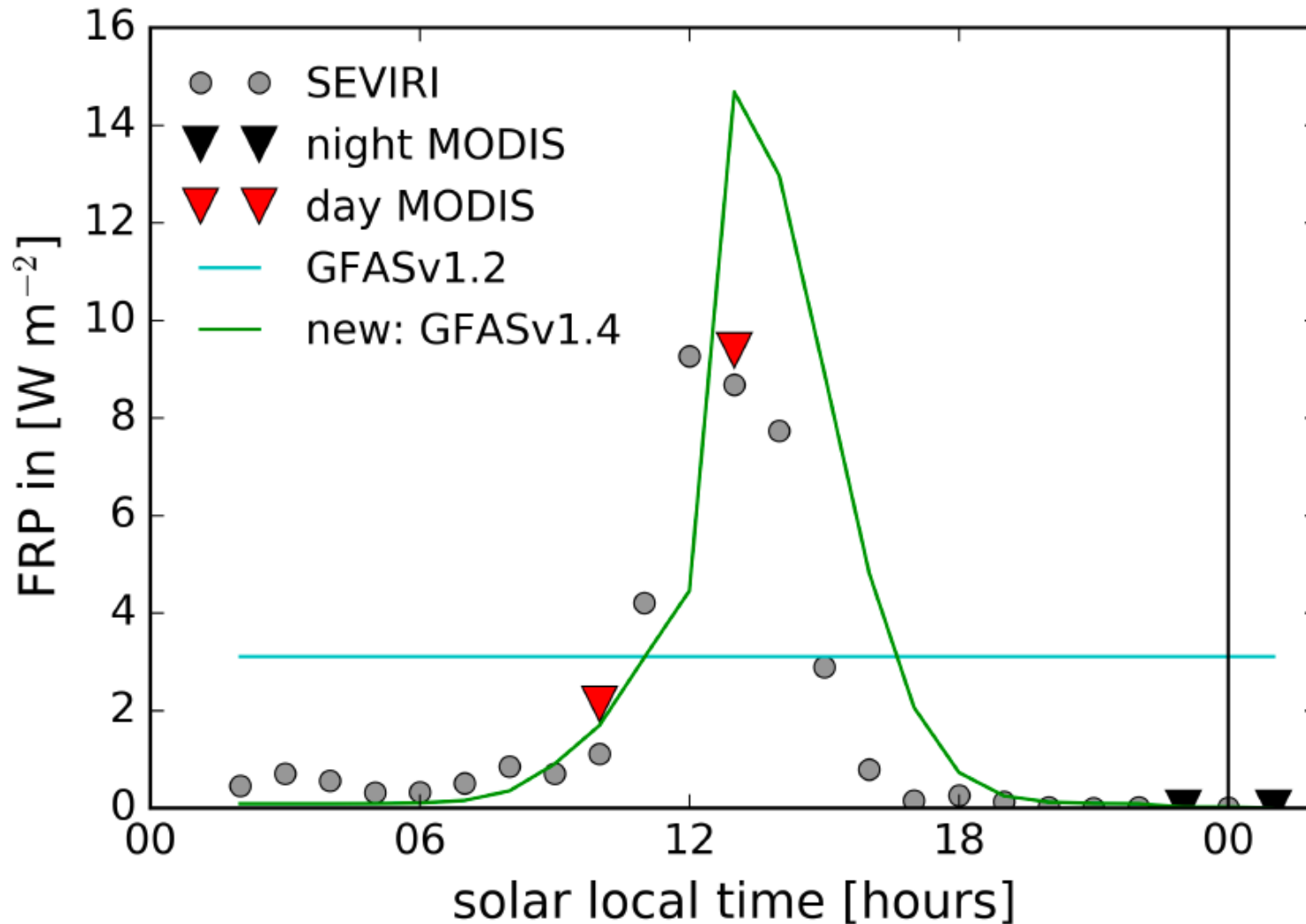


- 5 satellites in GEO and LEO
 - Terra/Aqua MODIS (currently actively used in GFAS)
 - SEVIRI
 - GOES-E/W
 - Himawari-8 (in development)
- FRP error estimates
 - based on S/N
 - detection threshold
- Atmospheric correction (MODIS)

Tadas Nikonovas (KCL)



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)



Dynamic emission factors

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

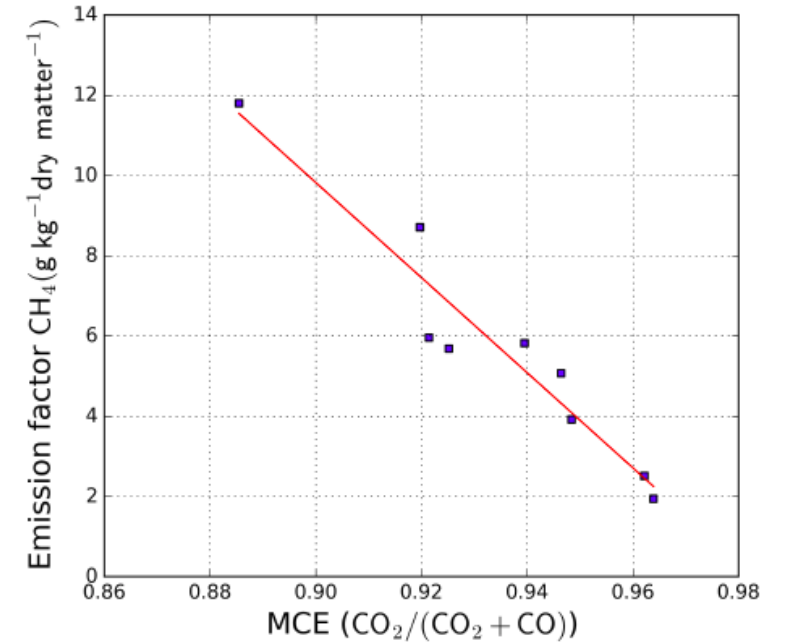
Relate linearly MCE variability

with

Soil Moisture variability



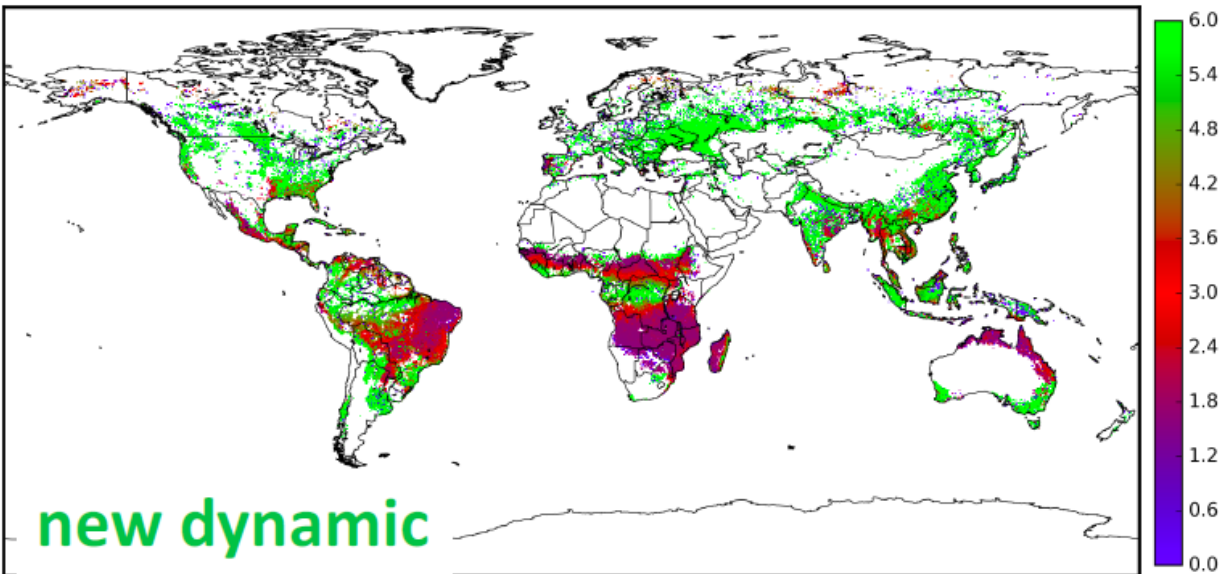
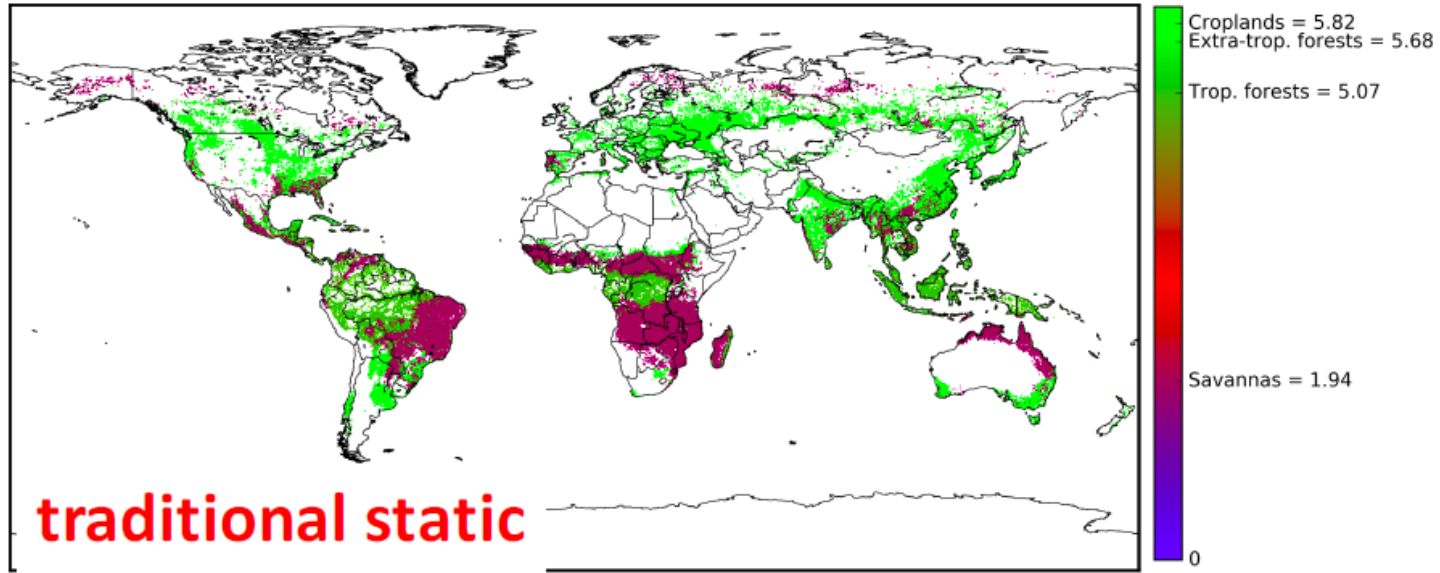
Allow for spatio-temporal variability of EFs



Yannis Bistinas, Guido van der Werf (VUA)



Spatial variability of CH₄ emission factors



Yannis Bistinas, Guido van der Werf (VUA)



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)



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)



- 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

atmosphere.copernicus.eu/catalogue#/

Most Visited Most Visited ECMWF Livelink Mail

Copernicus Europe's eyes on Earth Atmosphere Monitoring Service

Search Search

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PRODUCT FAMILY ▲

PARAMETER FAMILY ▲

PARAMETER ▲

Open links in a new window

CURRENT FILTERS:

Product family: Global analyses Parameter family: Aerosol

Total results: 5 BETA

Global analyses of aerosol concentrations - sea-salt (3 bins)

This service provides daily global analyses of aerosol concentrations

Parameter: Sea-salt concentration #1

More details Data Download

Global analyses of aerosol concentrations - dust (3 bins)

This service provides daily global analyses of aerosol concentrations

More details Data Download

Products found

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

CAMS online catalogue search

<http://atmosphere.copernicus.eu/catalogue>

The screenshot shows a web browser window with the URL `atmosphere.copernicus.eu/catalogue#`. The page header includes the Copernicus logo and the Atmosphere Monitoring Service logo. A navigation menu contains links for ABOUT CAMS, NEWS & MEDIA, EVENTS, CATALOGUE, RESOURCES, TENDERS, and USER SUPPORT. The main content area is titled "Catalogue" and features a search bar with the text "Global forecasts of aerosol optical depth at 550 nm - organic carbon". A "Back to index" link is located to the right of the title. Below the title is a world map showing biomass burning aerosol optical depth at 550 nm. The map is color-coded according to a scale from 0.02 to 50, with a color gradient from dark blue to dark red. The map is titled "Sunday 28 August 2016 00UTC CAMS Forecast t+036 VT: Monday 29 August 2016 12UTC Biomass Burning Aerosols Optical Depth at 550 nm". To the right of the map, there is a description of the service: "This service provides daily global forecasts up to 5 days of optical depth (AOD) at 550 nm". Below the description, there are several key-value pairs: "Theme: Air quality and atmospheric composition", "Product family: Global forecasts", "Parameter: Organic carbon AOD", "Geographical area: (-180, 180, -90, 90)", "Time coverage:", and "Metadata: XML". At the bottom of the page, there are five icons representing different actions: "Data download", "Verification results", "Validation reports", "Plots", and "Contact us". The footer includes the Copernicus logo, the European Commission logo, and social media icons for Twitter, Facebook, and Google+.

CAMS online catalogue search results

atmosphere.copernicus.eu/global-near-real-time-data-access

Search

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Opennicus Europe's eyes on Earth Atmosphere Monitoring Service

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Global Near-Real-Time Data Access

Home » USER SUPPORT » Operational Info

Data Access Options

Currently CAMS provides its global NRT analyses and forecasts in two different ways:

Interactive data access to full dataset (ECMWF data server)

Select parameter

- Black Carbon Aerosol Opt
- GEMS Total column ozone

batch data access using ECMWF Web API web services;
GRIB and NetCDF format;
from July 2012;

Operationally supported routine daily access (ECMWF FTP server)

```
305280 May 14 20:18 z_macC...
305280 May 14 20:16 z_macC...
207096 May 14 20:14 z_macC...
305280 May 14 20:17 z_macC...
207096 May 14 20:18 z_macC...
305280 May 14 20:18 z_macC...
207096 May 14 20:21 z_macC...
305280 May 14 20:16 z_macC...
```

recommended for operational usage;
batch access using FTP protocol;
GRIB and NetCDF format;
three latest forecasts kept online;

Data Licence

The CAMS data access is governed by the following [licence terms](#).
CAMS is very interested to hear about your use of the data. Please [contact us](#) for further information.

- SERVICE DESK
- DOCUMENTATION
- VALIDATION
- MAILING LISTS
- OPERATIONAL INFO

SERVICE THEMES

- AIR QUALITY & ATMOSPHERIC COMPOSITION
- CLIMATE FORCING
- OZONE LAYER & UV
- SOLAR RADIATION
- EMISSIONS AND SURFACE FLUXES

ANALYSES

European Air Quality

CAMS online catalogue search results



Type of level

- Model levels
- Pressure levels
- ▶ Surface

Atmospheric composition

- Reanalysis
- Near-real-time
- Global Fire Assimilation System

About

- Conditions of use
- Documentation

Navigation

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See also...

- Access Public Datasets
- General FAQ
- WebAPI FAQ
- Accessing forecasts
- GRIB decoder

CAMS Near-real-time

Please [login](#) before retrieving data from this dataserver.

Select date

Select a date in the interval 2012-07-05 to 2016-08-24

Start date: End date:

[Reset](#)

Select a list of months

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2013 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2014 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2015 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2016 | | | | | | | | | | | | | | | | | | | | | | | | | |

[Select All](#) or [Clear](#)

Select time

00:00:00 06:00:00 12:00:00 18:00:00

[Select All](#) or [Clear](#)

Select step

0 3 6 9 12 15 18 21 24 27 30 33 36
 39 42 45 48 51 54 57 60 63 66 69 72 75
 78 81 84 87 90 93 96 99 102 105 108 111 114
 117 120

[Select All](#) or [Clear](#)

Select parameter

2 metre dewpoint temperature 2 metre temperature
 10 metre U wind component 10 metre V wind component
 Albedo Black Carbon Aerosol Optical Depth at 550nm