



# ECMWF-CAMS Products

Atmosphere Monitoring

Richard Engelen  
ECMWF



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## Part I

- Brief History and Information for EU Copernicus programme
- Climate Change Service (C3S)
- Atmosphere Monitoring Service (CAMS)

## Part II

- How do we produce our forecasts
- Modelling with focus on aerosol
- Satellite observations
- Data assimilation
- Reanalysis
- User interaction



ATMOSPHERE MONITORING



MARINE ENVIRONMENT MONITORING



LAND MONITORING



CLIMATE CHANGE



EMERGENCY MANAGEMENT



SECURITY



Copernicus  
Europe's eyes on Earth



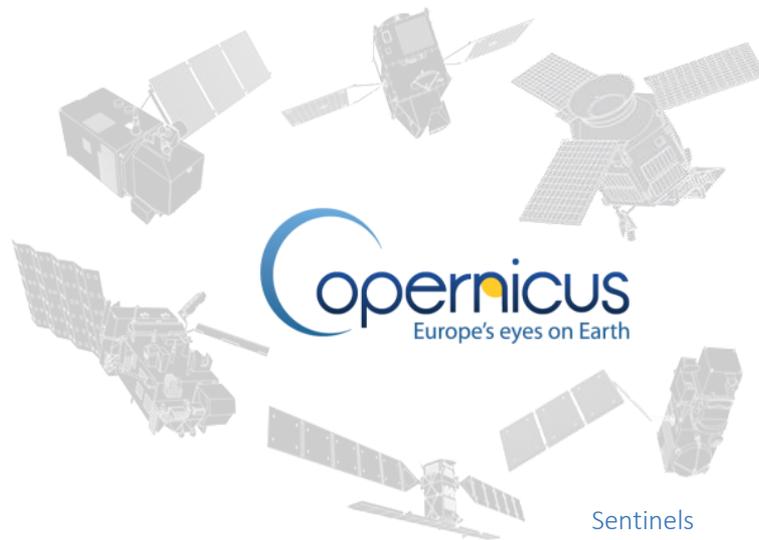
**Copernicus** is the European Union's revolutionary Earth Observation and Monitoring programme, looking at our planet and its environment for the ultimate benefit of all European citizens

**User-driven with free and unrestricted data access**

**Sustained and operational**



Services



Sentinels



Atmosphere  
Monitoring

## A little bit of history

- **1998** Baveno Manifesto: birth of the Global Monitoring for Environment and Security programme
- **2008** GMES Forum in Lille launches first GMES services
- **2012** Name changed to the Copernicus programme
- **2014 – 2020** operational Copernicus services as part of the Multi-annual Financial Framework





Climate  
Change

## The Copernicus Climate Change Service (C3S)

**Supporting scientists, policy makers and businesses by providing authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide.**



Climate  
Change

## The Copernicus Climate Change Service (C3S) mission

To support European adaptation and mitigation policies by:

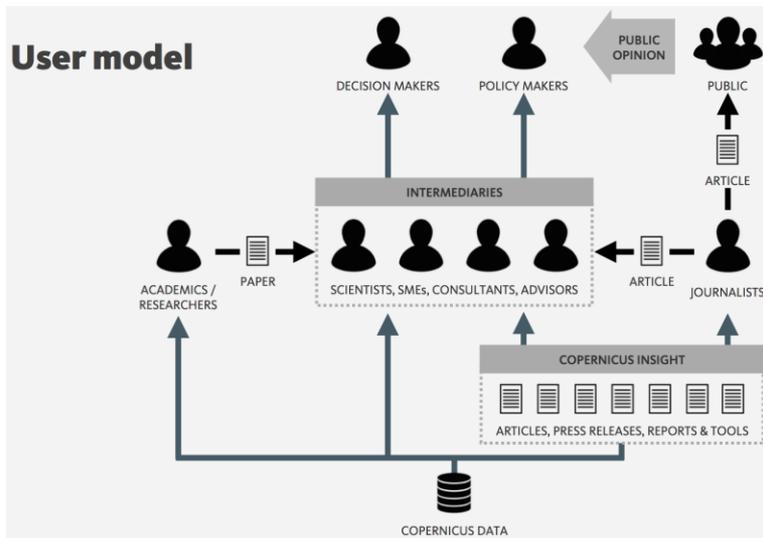
- Providing consistent and authoritative information about climate
- Building on existing capabilities and infrastructures
- Stimulating the market for climate services in Europe





Climate  
Change

# Who are the users and what do they want?



## User needs

- Find relevant data
- Content is reliable and trustworthy
- Download data in appropriate form
- Download data they can use/need
- Know they can use data legally
- Keep up to date about tenders
- Get help with data
- Know about the programme (inc. longevity)
- See Case studies of previous uses
- See high level overviews of information
- Keep up to date with relevant content
- Find content appropriate to area of work
- Have a well structured explicit press area
- Easy to access contact details
- High quality assets

	Scientists, academics, and researchers	SMEs and consultants	Policy advisors and influencers	Journalists
Find relevant data	x	x	x	
Content is reliable and trustworthy	x	x	x	x
Download data in appropriate form	x			
Download data they can use/need	x	x		
Know they can use data legally	x	x		
Keep up to date about tenders	x	x		
Get help with data	x	x		
Know about the programme (inc. longevity)		x		x
See Case studies of previous uses		x	x	
See high level overviews of information			x	
Keep up to date with relevant content			x	x
Find content appropriate to area of work			x	
Have a well structured explicit press area				x
Easy to access contact details				x
High quality assets				x



Climate  
Change

## A one-stop Climate Data Store

We are building a store.

We are putting products on the shelves.

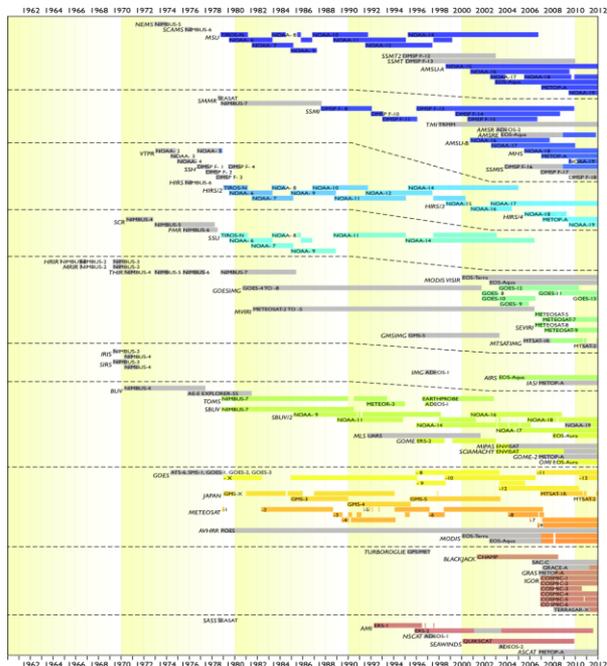
Soon we will open the door to customers.



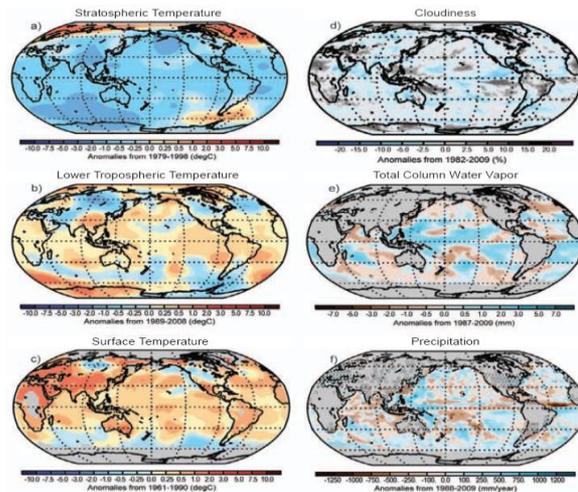


Climate  
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# Access to observations and climate reanalyses



Earth system models

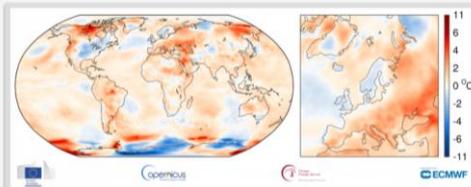




# Monthly reports on the state of the climate

## Surface air temperature for August 2017

home » resources » data analysis » average surface air temperature analysis » monthly maps » Surface Air Temperature For August 2017

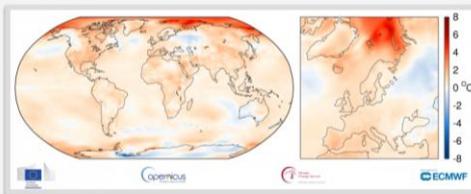


Surface air temperature anomaly for August 2017 relative to the August average for the period 1981-2010. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

[Download the original image](#)

August 2017 was warmer than the 1981-2010 average over much of Europe. It was particularly warm over the south and east of the continent, where wildfires continued to trouble several countries and sustaining water supplies remained a challenge in places. Temperatures continued to be below average over the north-west.

Unusually warm summer conditions prevailed over the western USA and western and northern Canada, although central and eastern North America was not as warm as usual for August. Temperatures were much above average over parts of the Middle East and eastern Siberia. Most other continental areas were also warmer than average. Temperatures were well below average over much of Antarctica, although pronounced warm anomalies occurred where the surrounding winter sea-ice cover was lower than usual.



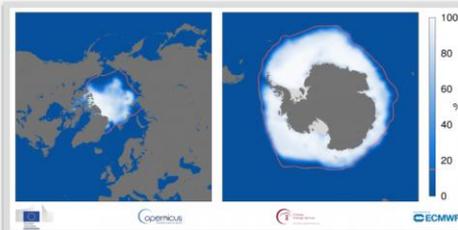
Surface air temperature anomaly for September 2016 to August 2017 relative to the average for 1981-2010. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

[Download the original image](#)

Average temperatures for the twelve-month period from September 2016 to August 2017 were:

- most above the 1981-2010 average in the Arctic;
- much above average offshore of West Antarctica, over much of North America, and over south-western Europe, the Middle East, north-western and central Africa, and eastern and southern Asia;
- higher than average over most other areas of land and ocean;
- lower than average over only a few oceanic and land areas.

## Sea-ice cover for August 2017



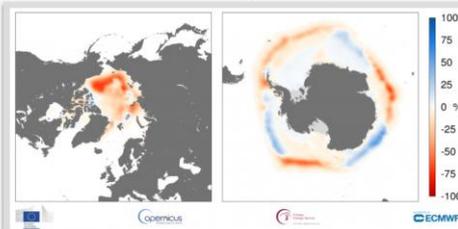
Sea-ice cover for August 2017. The pink line denotes the climatological ice edge for August for the period 1981-2010. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

[Download the original image](#)

Sea-ice was much less widespread in August 2017 than in the average for August from 1981 to 2010.

Arctic sea-ice was either absent or at a lower concentration than normal almost everywhere. Ice cover was especially below average in a region extending outwards into the Arctic Ocean from the Beaufort Sea and the East Siberian Sea.

Antarctic sea-ice cover was also lower than average overall. It extended less to the north than is normal for August in all but one sector, although concentrations close to the northern limit of sea-ice were also higher than average in two other sectors.

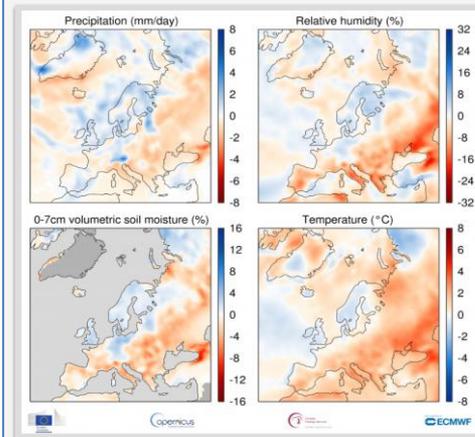


Sea-ice cover anomaly for August 2017 relative to the August average for the period 1981-2010. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

[Download the original image](#)

## Precipitation, relative humidity and soil moisture for August 2017

The surface hydrological variables are more difficult to observe and analyse than surface temperature. The surface hydrological variables page explains more about the reliability of the data and information presented here, including comparisons with alternative datasets. The data on soil moisture is currently of qualitative rather than quantitative value. This summary is intended to provide European and near-global views of conditions for the month. Specific information for many countries can be found on the websites of their weather or climate services.



Anomalies in precipitation, the relative humidity of surface air, the volumetric moisture content of the top 7 cm of soil and surface air temperature for August 2017 with respect to August averages for the period 1981-2010. The darker grey shading denotes where soil moisture is not shown due to ice cover or climatologically low precipitation. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

[Download the original image](#)

August 2017 was in general drier than the 1981-2010 average over south-western and central Europe, in terms of surface atmospheric relative humidity and the moisture content of the soil. Temperatures were also well above average over this part of the continent. The distribution of precipitation was more mixed. Rainfall totals were particularly high over the Alps, where relative humidity and soil moisture were above average. The month was also generally wetter than normal over northern Europe, in terms of precipitation, relative humidity and soil moisture. *Use the color bar to see the normal over part of this region.*



Climate Change

# Access to seasonal forecast data and products







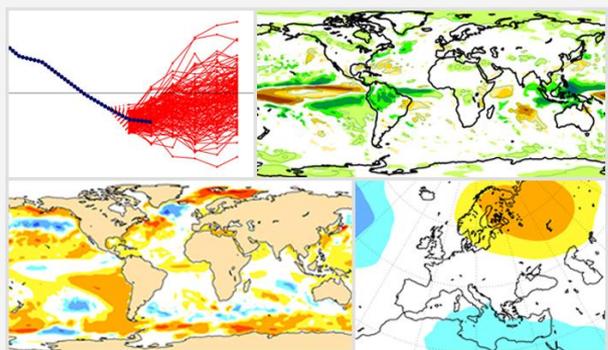
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[PRODUCTS](#)
[SERVICES](#)
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## Seasonal forecasts

home > products



The Copernicus Climate Change Service (C3S) is developing seasonal forecast products, with a target publication date of 15<sup>th</sup> of each month. These products are based on data from several state-of-the-art seasonal prediction systems.

The current proof-of-concept phase includes **graphical forecast products** for a number of variables (air and sea-surface temperature, atmospheric circulation and precipitation); the forecasts are updated every month and cover a time range of 6 months. The interface to the list of products offers links to maps or timeseries for the forecast variables, and the facility to navigate the full set of graphics. Multi-system combinations, as well as predictions from the individual component systems, are available.

The centres currently providing forecasts to C3S are **ECMWF, The Met Office and Météo-France**; at a later stage **Deutscher Wetterdienst** and **Centro Euro-Mediterraneo sui Cambiamenti Climatici** will be added to the list.

- AVERAGE SURFACE AIR MONTHLY MAPS
- MONTHLY SEA-ICE MA
- HYDROLOGICAL CLIM
- CLIMATE REANALYSIS
- SEASONAL FORECAST

### NEWS

16 Jul 2017  
C3S releases powerful ne "encyclopaedia" for public

03 Mar 2017  
#OpenDataHack @ECMWF uses of open data

03 Mar 2017  
C3S holds its inaugural G

26 Jan 2017  
Copernicus at the 4th Int on Energy & Meteorology

06 Dec 2016  
Report Reassesses Variat

[More News](#)

### EVENTS

13 Nov 2017

Base time | Map type (forecasts and skill measures) | Area | Product results

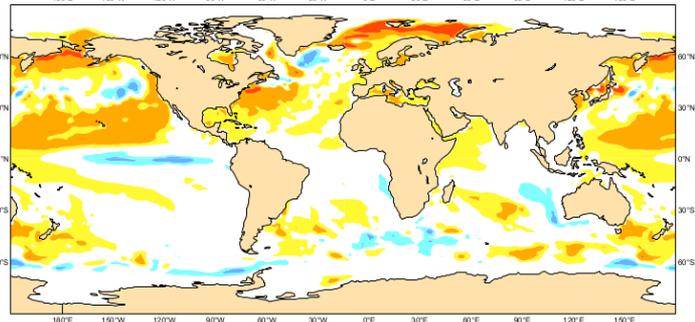
### C3S multi-system seasonal forecast

#### Mean forecast SST anomaly

Nominal forecast start 01/08/17  
Variance-standardized mean

ECMWF/Met Office/Météo-France  
NDJ 2017/18

- <-2.0°C
- 2.0,-1.0
- 1.0,-0.5
- 0.5,-0.2
- 0.2,0.2
- 0.2,0.5
- 0.5,1.0
- 1.0,2.0
- >2.0°C



Oct 2017

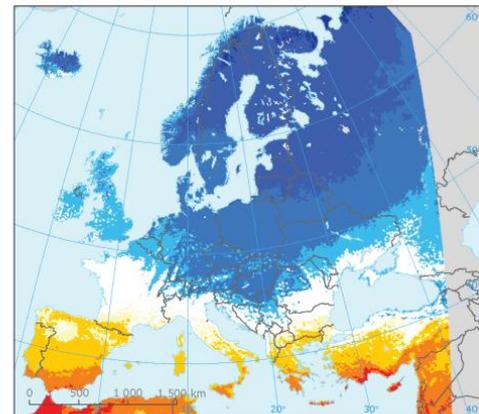
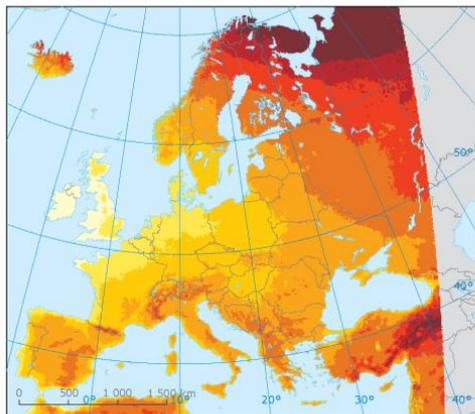
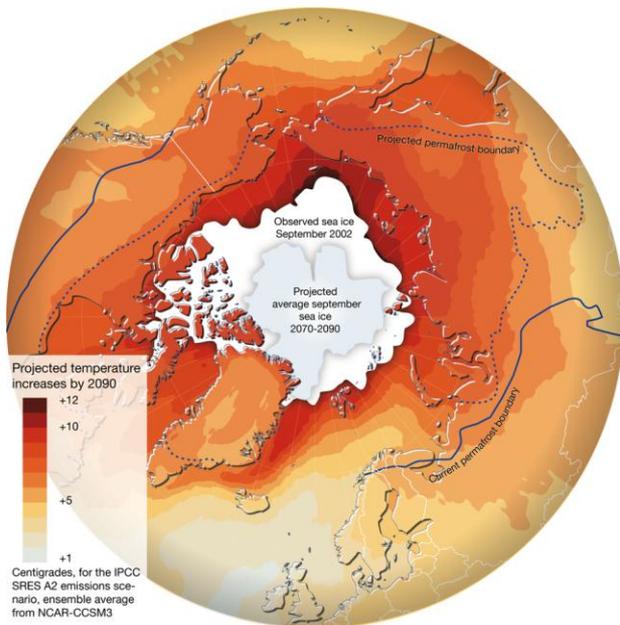
VT: [play button]



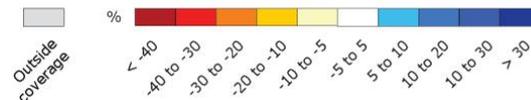
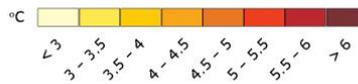




# Access to climate model simulations



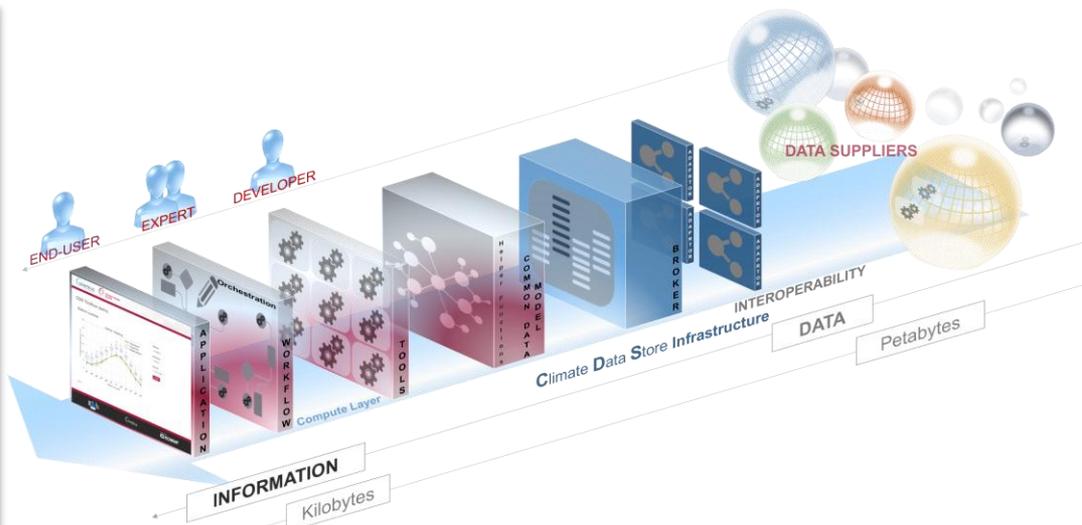
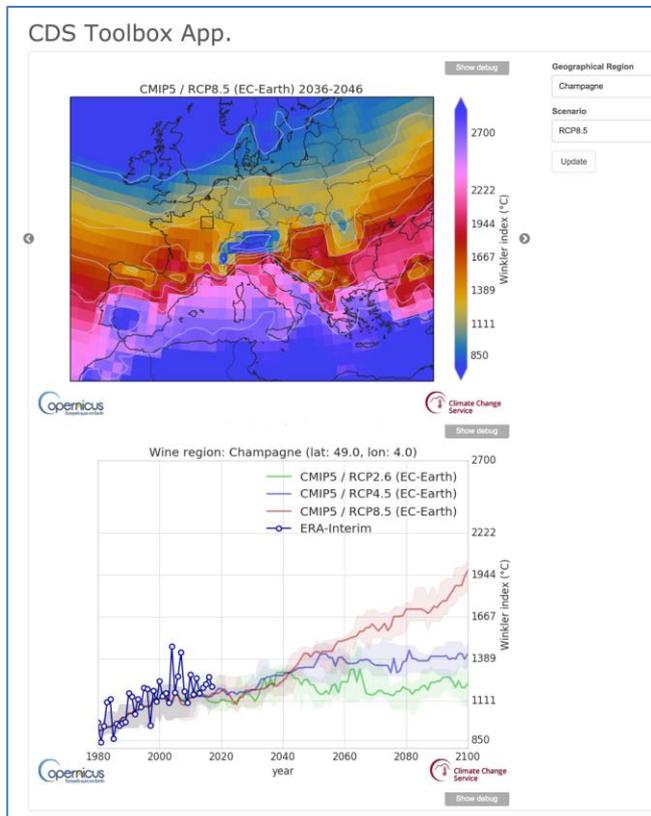
Projected changes in annual mean temperature (left) and annual precipitation (right)





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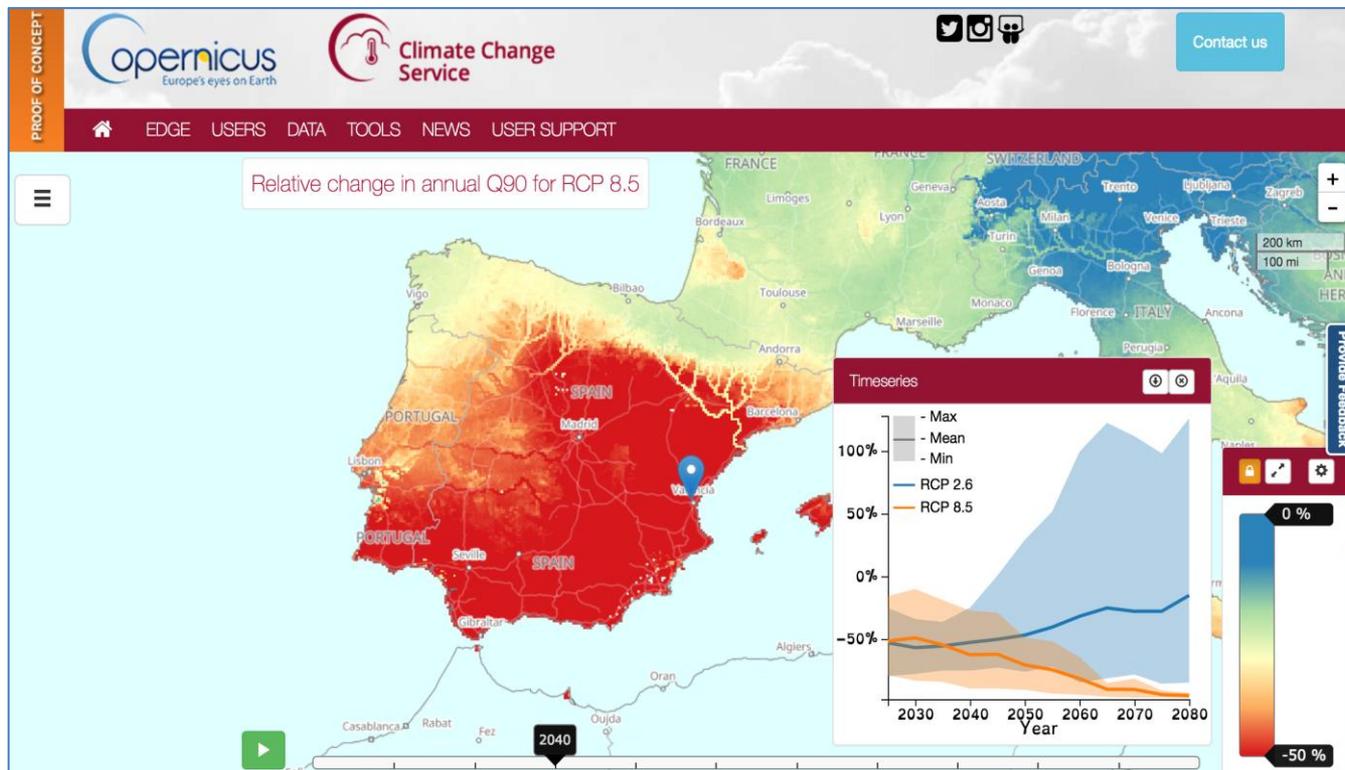
# Access to tools, workflows and applications





Climate  
Change

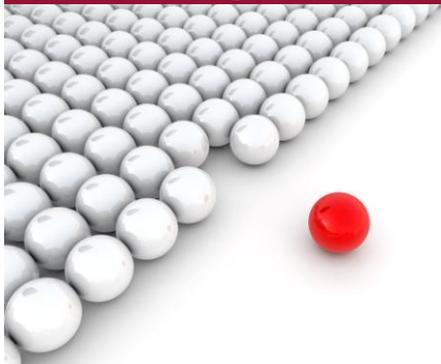
# Sectoral indicators and tools to support adaptation





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## Challenges in communication



- Communicating climate science
- New kid on the block
- Unfamiliar territory for ECMWF



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# Successes in communication

Leonardo DiCaprio Retweeted

**WMO | OMM** @WMO · Jan 5  
2016 hottest year on record, per @CopernicusEU #ClimateChange. 0.2°C above 2015, 1.3°C above 1880. Warm #Arctic. [bit.ly/2iHGwzc](http://bit.ly/2iHGwzc)

**ANNUAL GLOBAL SURFACE AIR TEMPERATURE AVERAGE SURFACE AIR TEMPERATURE FROM 1880 TO 2016**

WMO

Annual average temperature

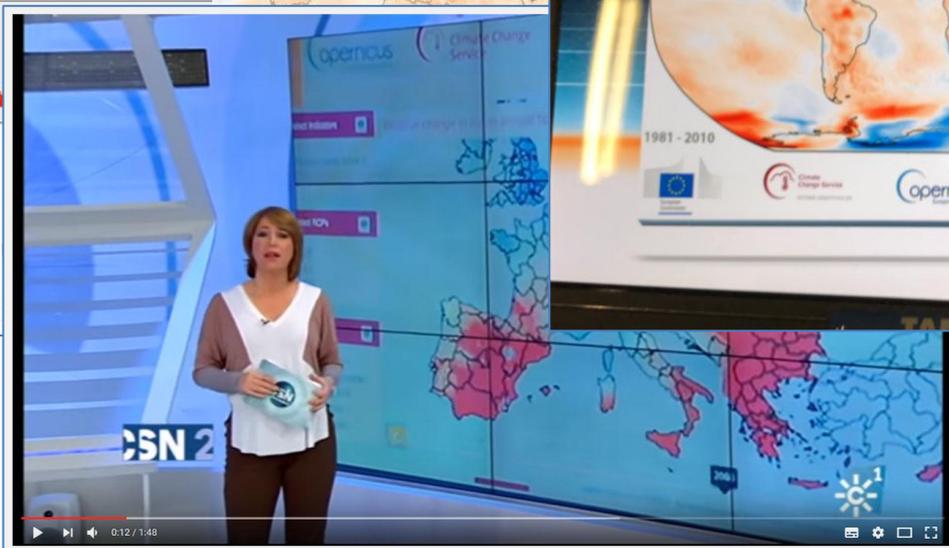
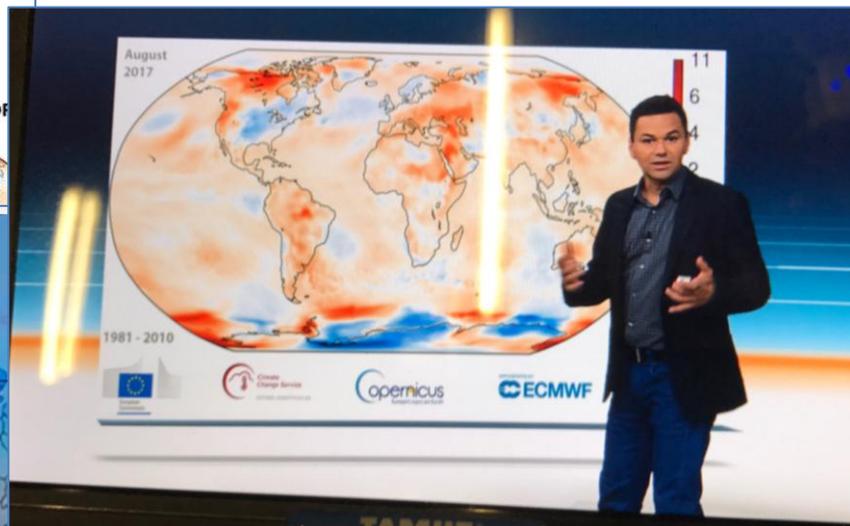
Change in industrial

30 1900 1920

at Climate Change Service, ECMWF, for data from 1979; Centre for Global Monitoring and WMO for historical data prior to 1979.

Copernicus EU and

67





Climate  
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## Why we do it





Atmosphere  
Monitoring

# Copernicus Atmosphere Monitoring Service



**Providing policy makers, businesses, scientists and citizens alike with reliable information about atmospheric composition.**

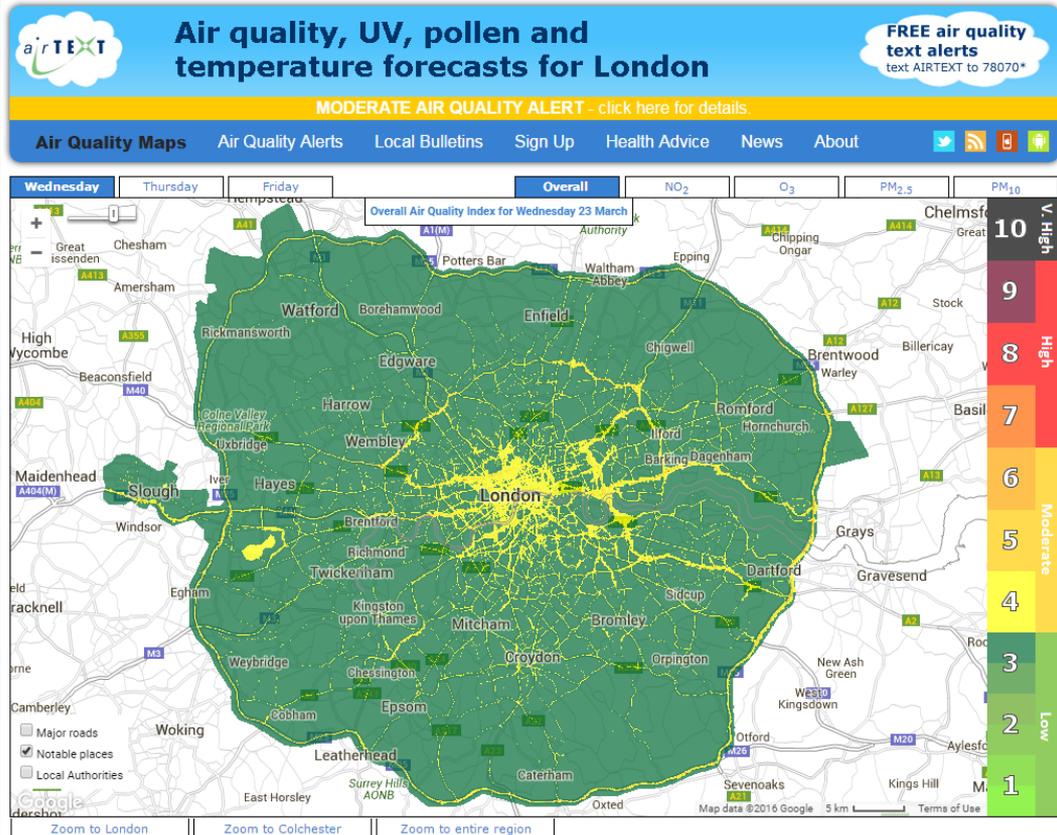


**Building up knowledge and boosting informed decision-making on topics such as air quality, health, solar energy, weather and climate.**



Atmosphere  
Monitoring

# Existing services: *airTEXT*



Free air pollution, UV, pollen and temperature forecasts for Greater London and the South East.

Currently provides free air quality alerts to more than 15,000 subscribers.

Local forecast models need information on how much pollution flows into and out of the domain to provide an accurate service.

**CERC**





## Existing services: SunSmart



The SunSmart phone app offers users daily alerts on ultraviolet (UV) radiation peaks and current readings wherever they are in Australia.

It can also provide alerts to users on how much and when they need to reapply sunscreen depending on their coverage and skin type.

Interpolated observations provide information for today.

Using forecasts of UV, SunSmart can provide warnings in advance.





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How can CAMS help?



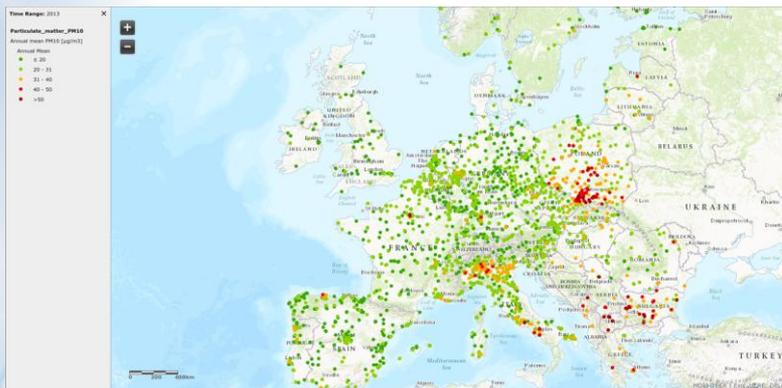
Atmosphere  
Monitoring Service

[atmosphere.copernicus.eu](https://atmosphere.copernicus.eu)



Atmosphere  
Monitoring

# CAMS: Adding value to observations



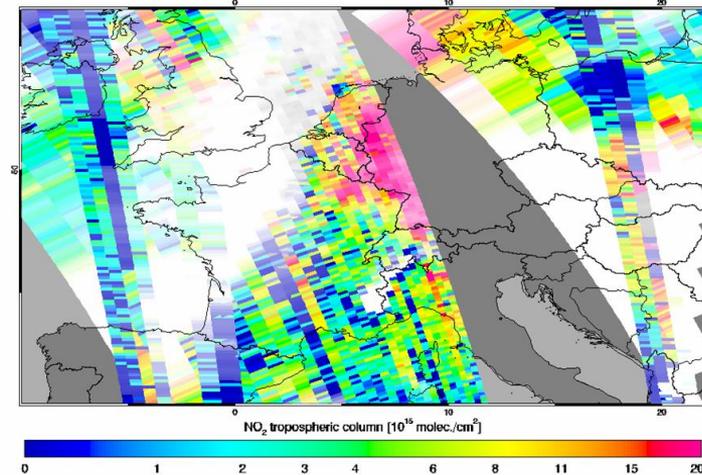
**In-situ  
observations**

European Environment Agency



OMI NRT tropospheric NO<sub>2</sub> 12 Nov 2016

KNMI/NASA



**Satellite observations**

**CAMS adds value to today's observations, providing consistent information anywhere in Europe (and the rest of the world).**

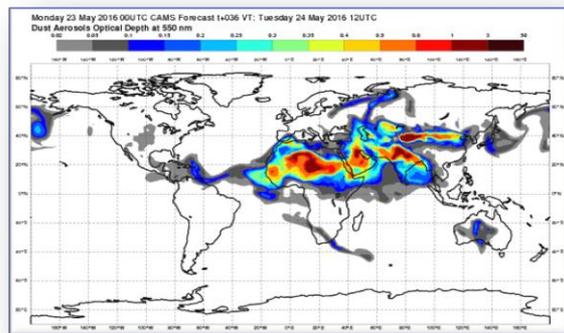
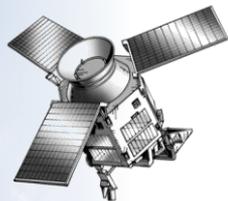
**CAMS forecasts allow you to anticipate the situation of tomorrow.**



# CAMS Service Chain

Atmosphere  
Monitoring

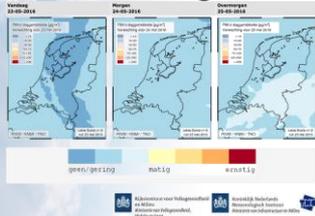
Space Agencies



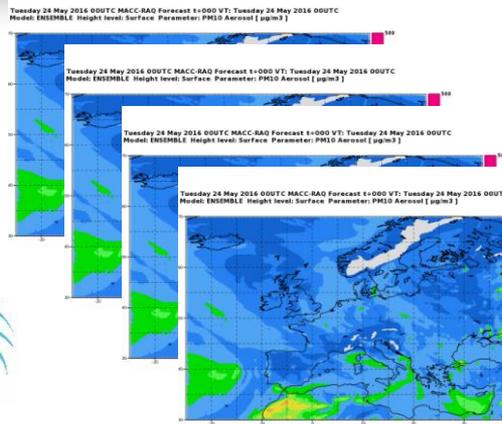
In-situ observations



National agencies



SMEs



Citizens



Scientist

S







# User question: solar energy

Atmosphere  
Monitoring

## Energy firm: What is a cost-effective place to build our solar power plant?

**CAMS McCLEAR SERVICE FOR ESTIMATING IRRADIATION UNDER CLEAR-SKY**

The CAMS McClear irradiation service delivers time series of irradiation that would be observed in a specific site in the world under clear-sky conditions, with a time step ranging from 5 min to 1 month. The global, direct and diffuse horizontal irradiation, as well as the beam normal irradiation are provided. The time coverage of the data is from 2004-01-01 to current day-2.

The research leading to these results has received funding from the European Union's Horizon Framework Programme (FP7) (2007-2013), under grant agreement no. 218767 (MACC project, 2009-2012), no. 281578 (MCC2-01 project, 2011-2014) and from the European Union's Horizon Framework Programme (FP8) (2024-2031), under grant agreement no. 431840 (MCC2-02 project, 2024-2031). The service is part of the Copernicus Atmosphere Monitoring Service (CAMS).

[Learn more](#)

**McClear**

Latitude (in 1-IMP):  Select point on map  Start time from:  Time reference:

Longitude (in 1-IMP):  Select point on map  End date (set to today):  Include default into an irradiance (0: no)

Altitude (in meters, Automatic if empty):  Time Step:  Output Format:

ECMWF Copernicus logo



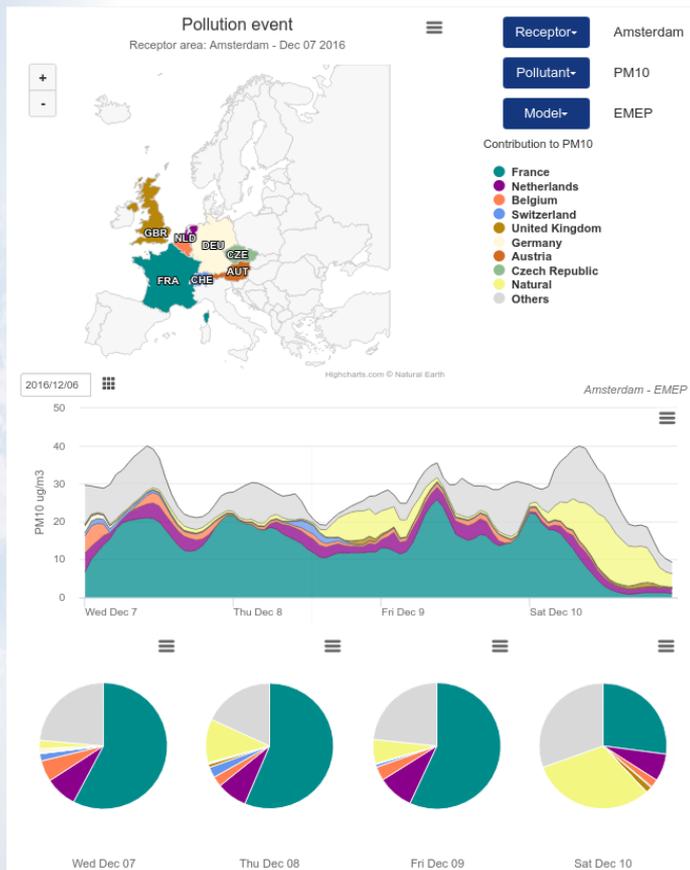
© BMU

### CAMS solar radiation

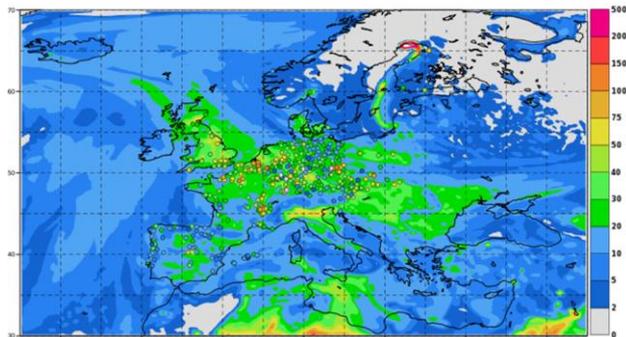
- 2004 – current
- 1-minute resolution
- Clear-sky and total sky global, direct and diffuse radiation at surface



## National Environment Agency: Where did PM<sub>10</sub> come from during the latest pollution event?



Tuesday 06 December 2016 00UTC CAMS Verification t+012 VT: Tuesday 06 December 2016 12UTC Observations + LOTOS-EUROS Forecast Surface PM10 Aerosol [  $\mu\text{g}/\text{m}^3$  ]

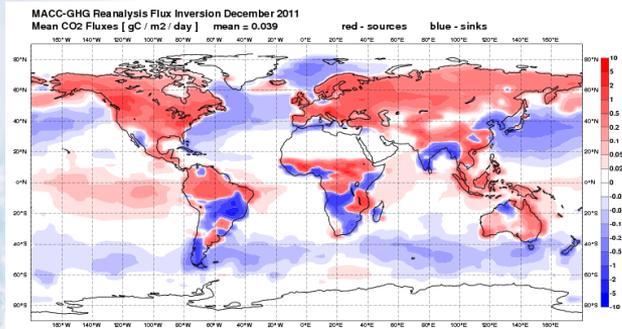


### CAMS policy tools

- Source-receptor calculations and emission scenarios
- Daily and on-demand
- Main regulatory pollutants
- 10 km spatial resolution

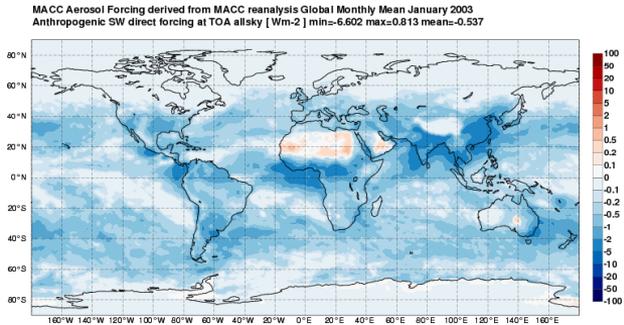


Scientist: what has been the impact of greenhouse gases and aerosol on the Earth's climate over the last few decades?



## CAMS greenhouse gas flux estimates

- CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O
- Decadal time series



## CAMS radiative forcing

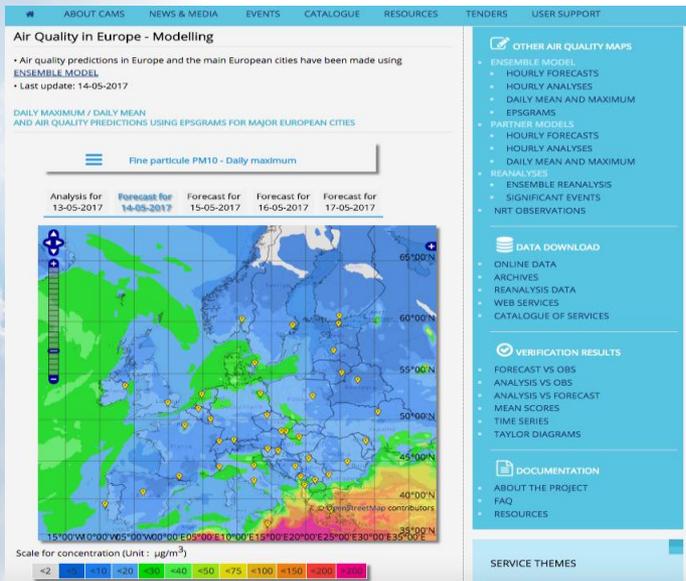
- Direct and indirect radiative forcing of aerosol and greenhouse gases
- Decadal time series



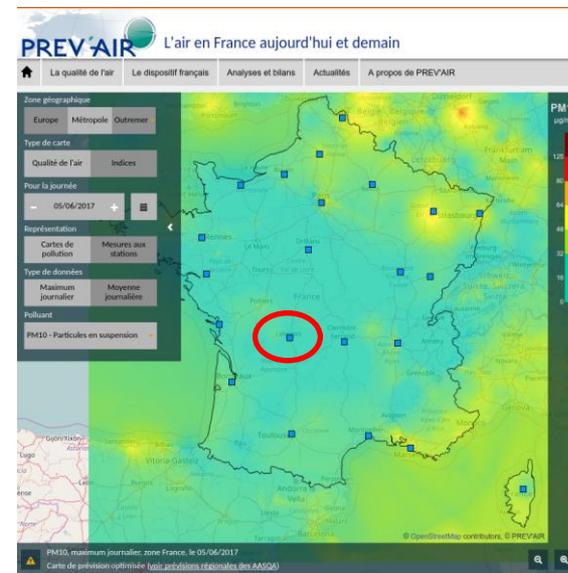
# User question: what's the forecast?

Atmosphere  
Monitoring

## French citizen: What will be the air quality in Limoges tomorrow?



CAMS provides background air quality forecast maps, but more importantly boundary conditions for national forecast models.



### CAMS regional forecasts

- Daily 4-day forecast using forecast model ensemble
- 10 chemical pollutants + pollen
- 10 km spatial resolution



Atmosphere  
Monitoring

# CAMS Portfolio



Portfolio	Product groups
A. Regional products	European AQ NRT analyses
	European AQ NRT forecasts
	European AQ interim reanalyses
	European AQ reanalyses
B. Global products (troposphere and stratosphere)	Global atmospheric composition NRT analyses
	Global atmospheric composition NRT forecasts
	Global atmospheric composition reanalyses
C. Supplementary products	Policy support products
	Solar radiation
	Greenhouse gas fluxes
	Climate forcings
D. Emissions products	Anthropogenic emissions
	Fire emissions

CAMS delivers the portfolio of products outlined in the Delegation Agreement with the EC



Search

Reset

### PRODUCT FAMILY

- Global forecasts
- Global reanalyses
- Global analyses
- Regional analyses
- Regional forecasts
- Climate forcings
- Anthropogenic emissions
- Solar radiation
- Greenhouse gas fluxes
- Fire emissions
- Policy support

### PARAMETER FAMILY

- Aerosol
- Greenhouse gas
- Reactive gas
- Radiation
- Fire

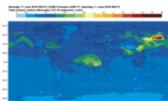
### PARAMETER

- Sulfates concentration
- Organic carbon concentration
- Black carbon concentration
- Sea-salt concentration
- Dust concentration
- PM10

### CURRENT FILTERS:

Product family: Global forecasts

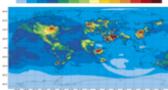
Total results: 5



### Global forecasts of chemical species - carbon monoxide

This service provides daily forecasts of chemical species observations

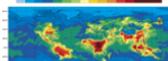
Parameter: Carbon monoxide



### Global forecasts of chemical species - dioxide

This service provides daily forecasts of chemical species observations

Parameter: Nitrogen dioxide

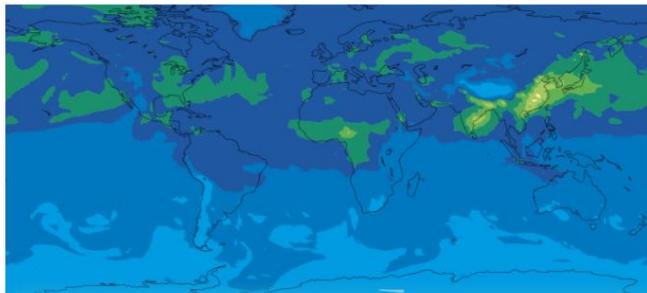


### Global forecasts of assimilated chemical species - formaldehyde

More details

## Global forecasts of chemical species - carbon monoxide

[Back to index](#)



This service provides daily forecasts up to 5 days of chemical species

**Theme:** Air quality and atmospheric composition  
**Product family:** Global forecasts  
**Parameter:** Carbon monoxide  
**Geographical area:** ( -180, 180, -90, 90 )  
**Time coverage:**  
**Metadata:** XML



Data download



Verification results



Validation reports



Plots



Documentation



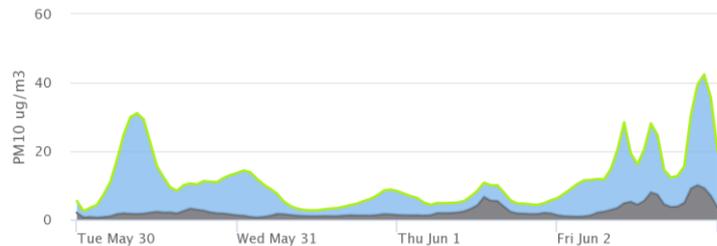
Contact us



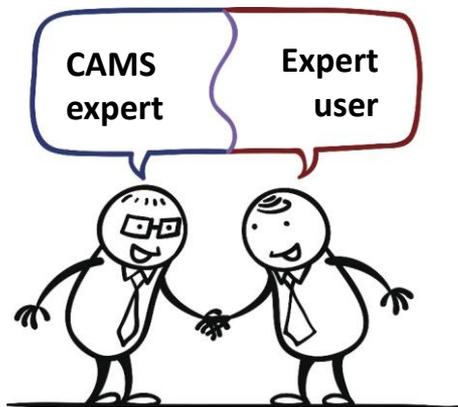
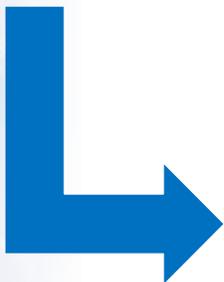


Atmosphere  
Monitoring

# Using CAMS data



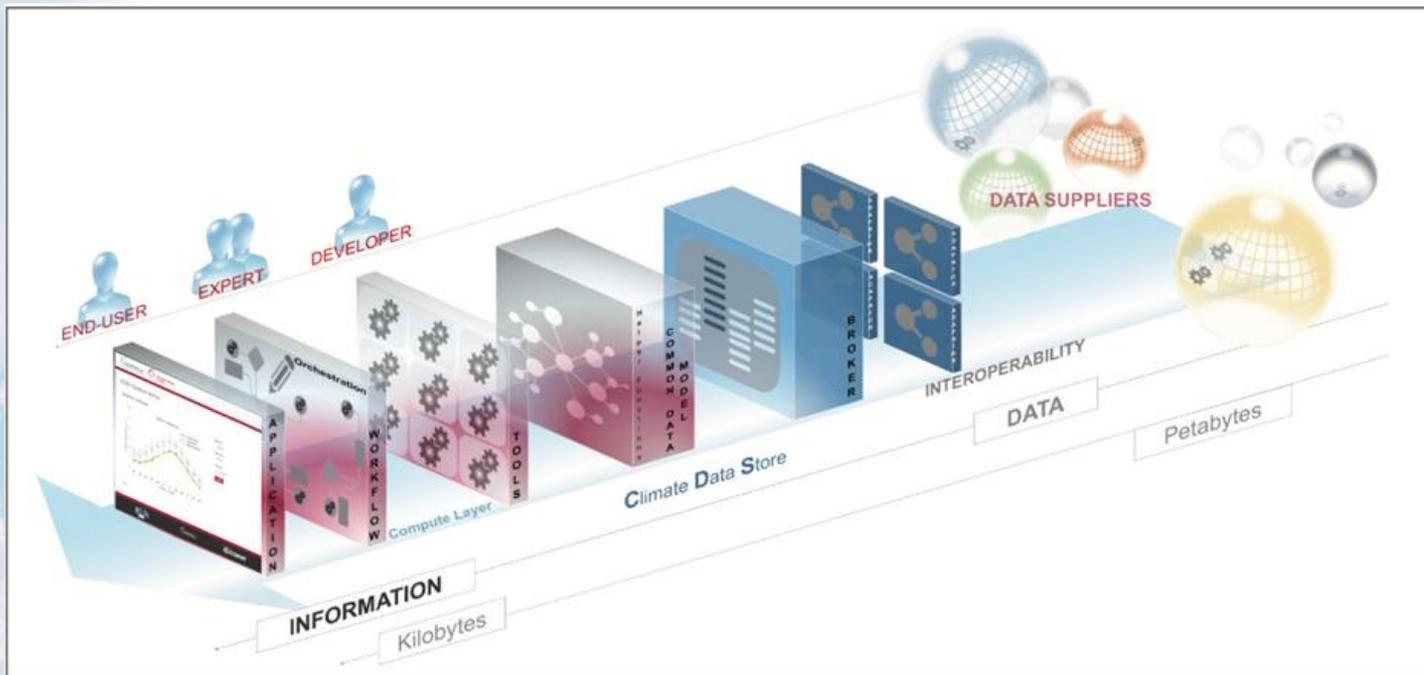
CAMS forecast charts and policy tools



Downstream applications



# Looking forward: Data Platforms



C3S and CAMS are putting in place a distributed data platform with consistent workflow and tools for all products.

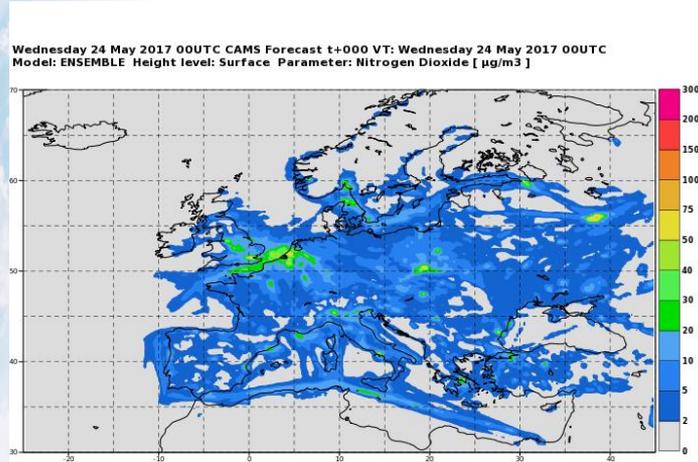
Together with EUMETSAT and the Marine Service this will be expanded to also include access to other Copernicus data and provide cloud computing facilities.



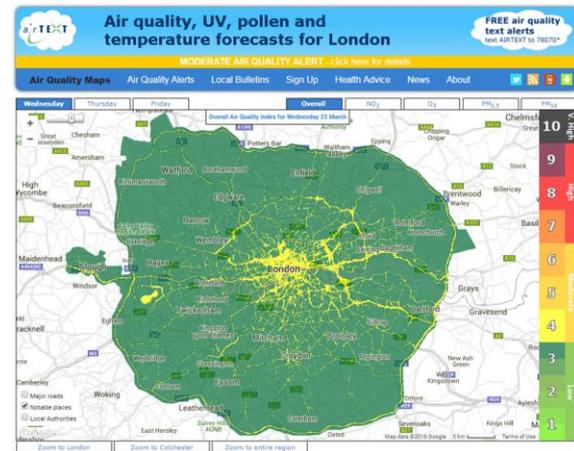
# Use Case: AirText

AirText (CERC) uses daily air quality forecasts from the CAMS regional model ensemble to provide the boundary conditions for their local air quality forecast model.

This ensures better local forecasts and also allows them to market their service in other cities in Europe.



CAMS regional forecast



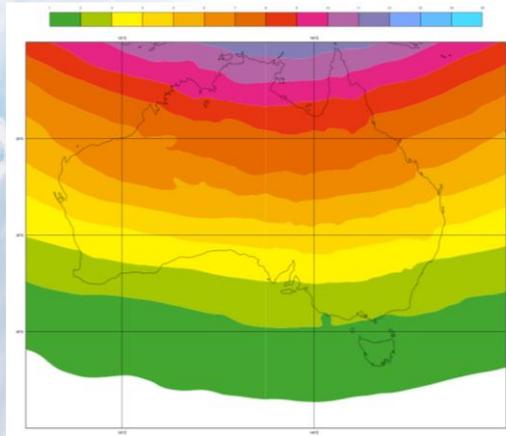
AirText London warnings



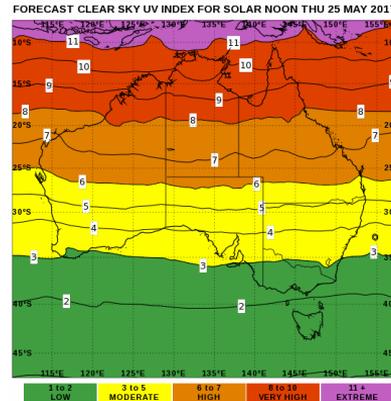
# Use Case: SunSmart

Atmosphere  
Monitoring

In Collaboration with the Australian Bureau of Meteorology, SunSmart uses CAMS UV-Index forecasts every day to feed their smartphone App with the required information, providing an improved service to their customers.



CAMS UV forecast



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Generated using Copernicus Atmosphere Monitoring Service information 2017.

Bureau of Meteorology



Cancer Council Victoria



# Use Case: CitySol

Atmosphere  
Monitoring

Noveltis is using a CAMS Use Case contract to adapt their system to use satellite-based solar radiation information instead of local measurements.

This allows them to easily adapt their service for different cities in France and potentially the rest of Europe.





Atmosphere  
Monitoring

To summarize



Atmosphere  
Monitoring Service

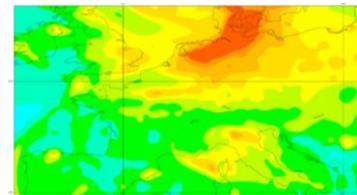
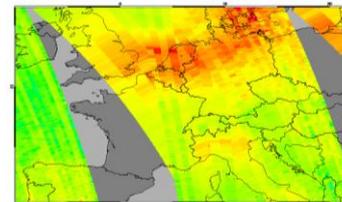
[atmosphere.copernicus.eu](https://atmosphere.copernicus.eu)

**User-driven**

**Free and unrestricted data access**

**Making observations more meaningful to you**

**Provide information for past, present and future**





Atmosphere  
Monitoring

# Part II

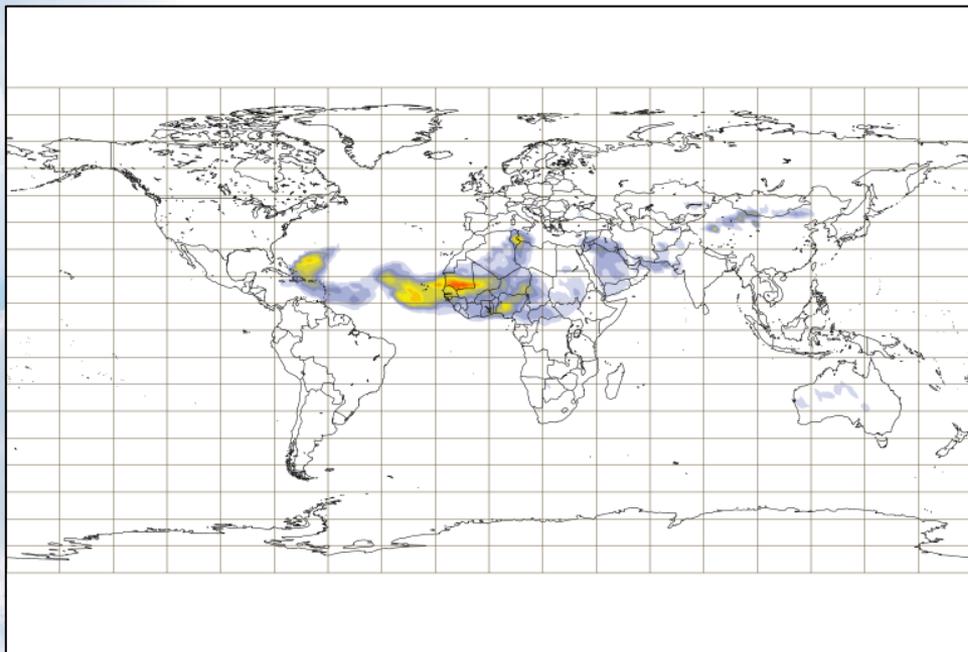
How we combine observations and models to provide accurate forecasts: data assimilation.



Atmosphere  
Monitoring

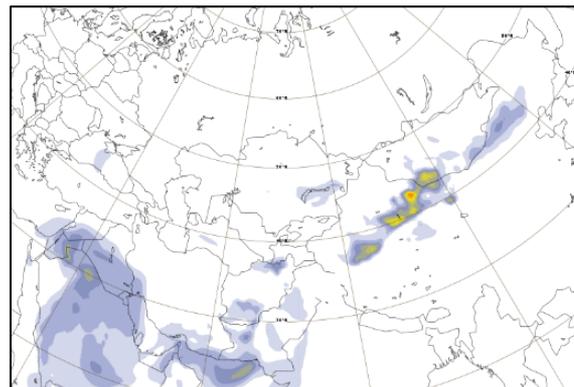
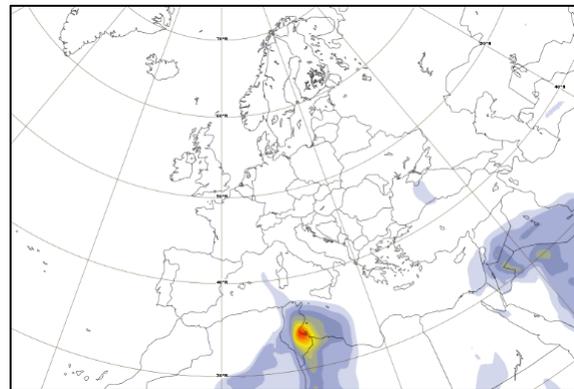
# Twice-daily forecasts from global system

## 5-day forecasts @ 40 km resolution



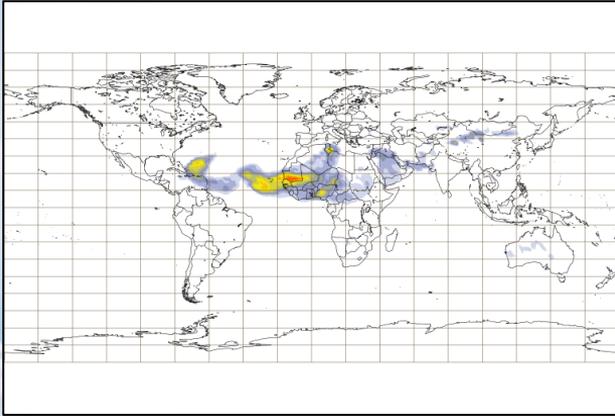
0.1 0.16 0.23 0.29 0.36 0.42 0.49 0.55 0.61 0.68 0.74 0.81 0.87 0.94 3

DOD



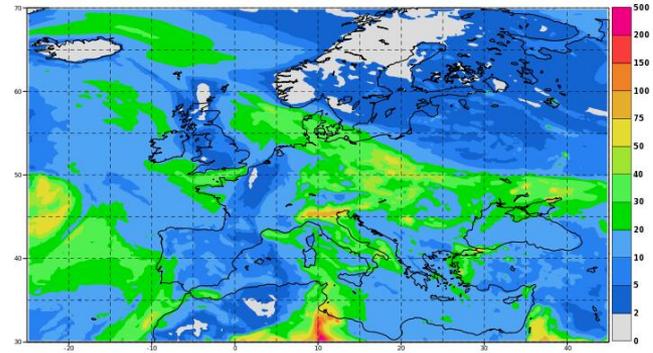


40 km



10 km

Friday 20 October 2017 00UTC CAMS Forecast t+003 VT: Friday 20 October 2017 03UTC  
Model: ENSEMBLE Height level: Surface Parameter: PM10 Aerosol [  $\mu\text{g}/\text{m}^3$  ]



The CAMS global system provides boundary conditions for the daily CAMS regional ensemble forecasts.

**Boundary conditions are also available for CAMS users running regional models for other domains.**



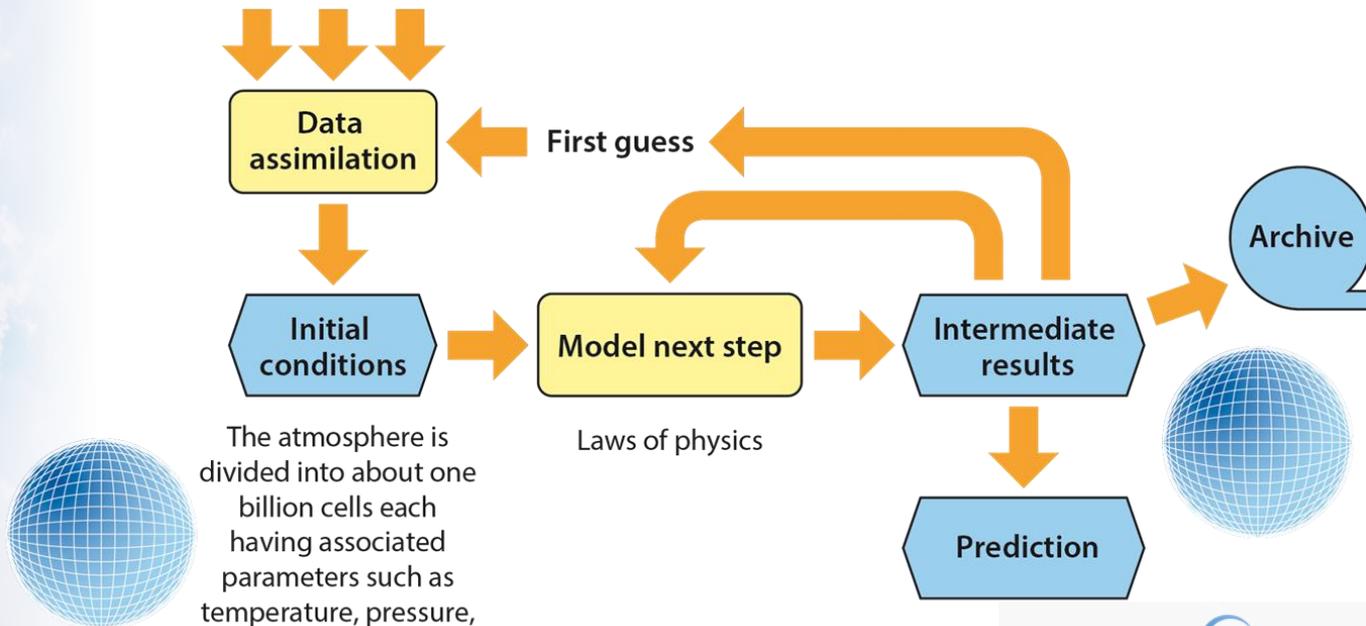
# Global production



Approximately 20 million observations

Every 12 hours, observations are acquired, pre-processed, quality controlled, and assimilated.

Every 12 hours a global 5-day forecast is produced, checked and disseminated.





# Atmospheric composition modelling

Atmosphere  
Monitoring

*Radiation and clouds*

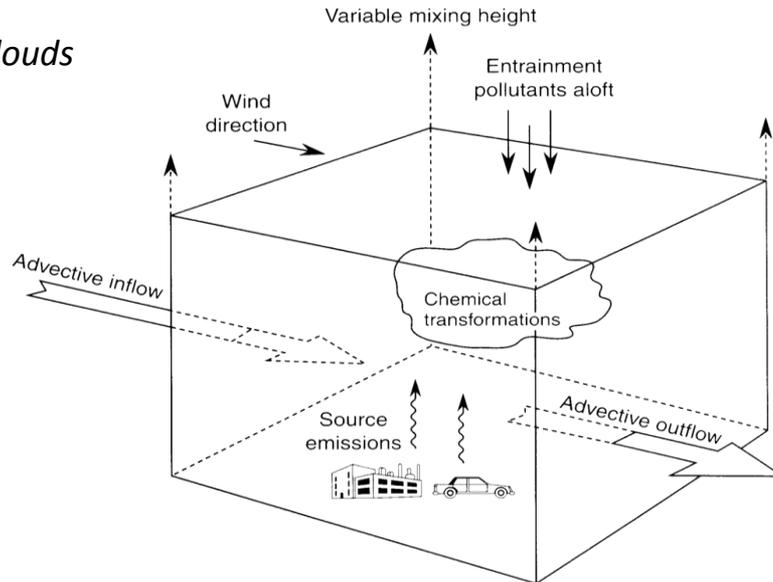
*Turbulent mixing  
and convection*

*Advection*

*Wet deposition*

*Sedimentation*

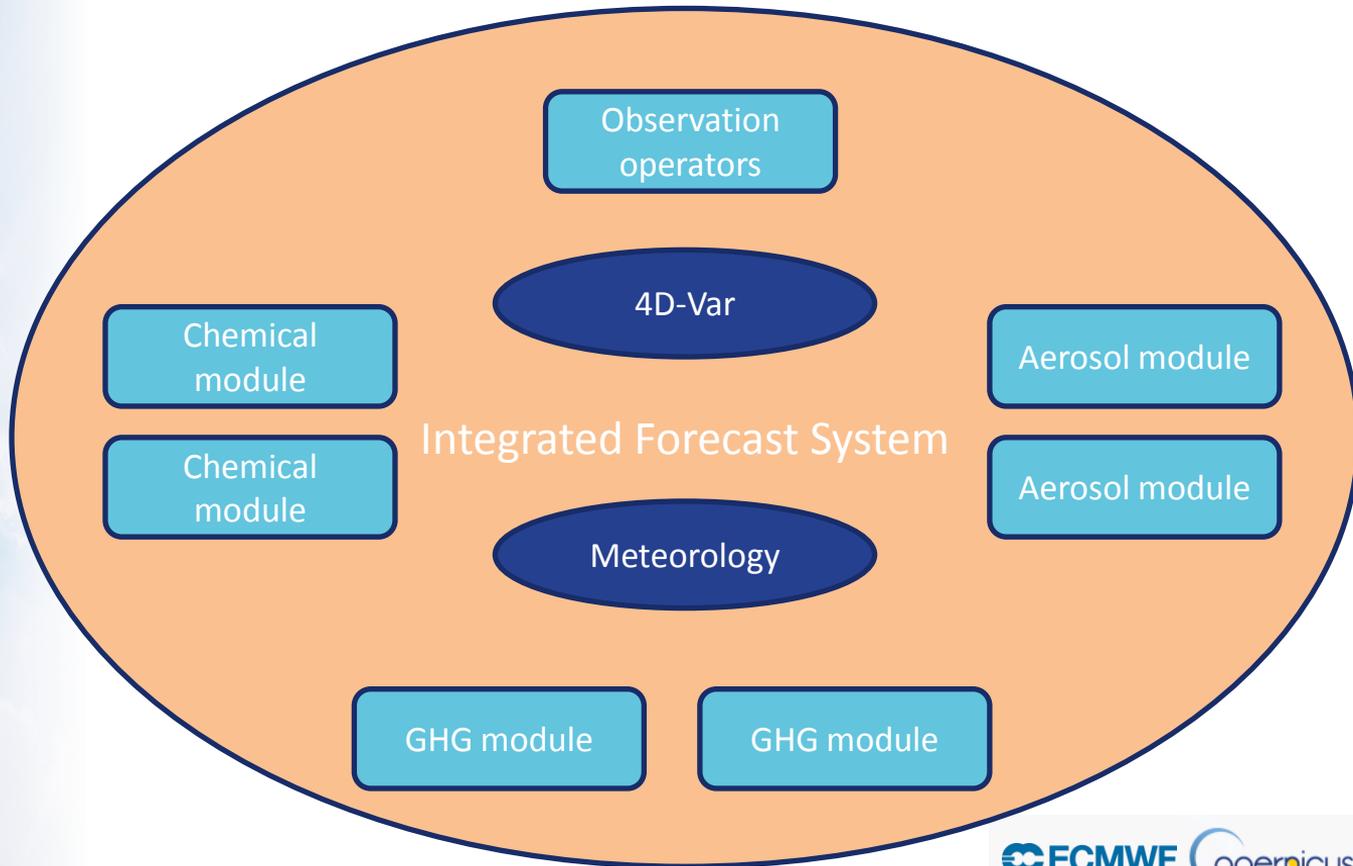
*Homogeneous and  
heterogeneous chemistry,  
including photochemistry*



*Biogenic and anthropogenic  
emissions*

*Aerosol processes*

*Dry deposition*



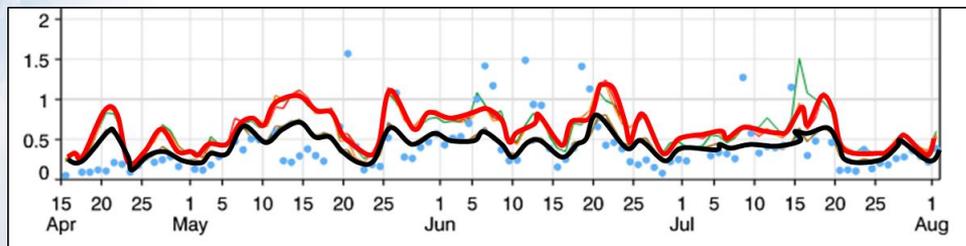


## Under the aerosol hood

Dust emissions are based on the bare soil fraction, soil moisture content, wind speed above a threshold and a regionally-defined constant source potential (Morcrette et al. (2009), Ginoux et al. (2001)).

Online dry deposition velocities for all aerosol species as a function of particle size, surface friction, roughness length and soil type, following Zhang et al (2001).

Data assimilation uses observations from MODIS and PMAp to constrain total Aerosol Optical Depth. This means that speciation and size distribution are provided by model.

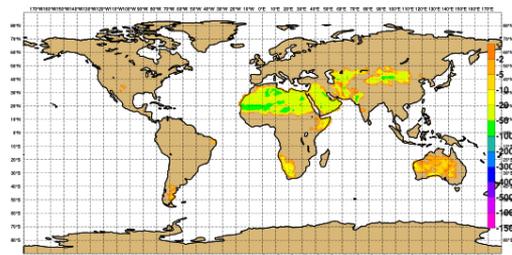
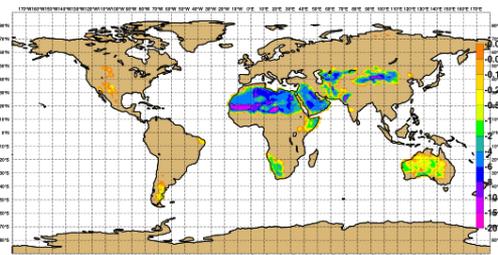
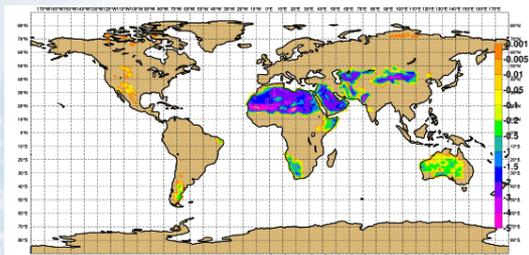


Total AOD at the Tamanrasset (Algeria)  
AERONET station

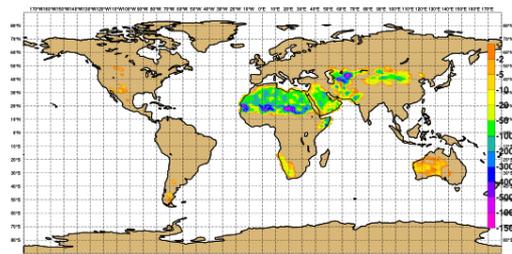
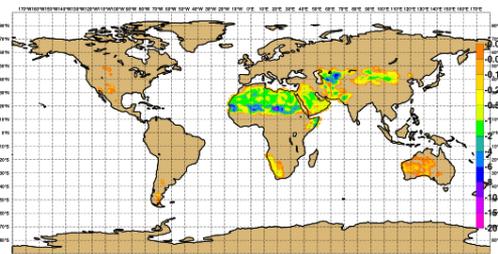
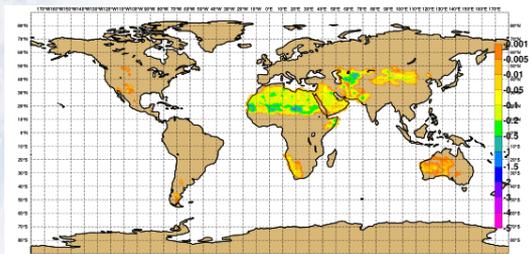


A new dust emission scheme is adapted from Nabat et al. (2012, ACP), which itself uses the work of Zakey et al. (2006, 2008), based on Marticorena and Bergametti (1995).

Old



New

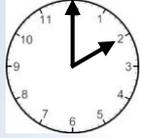


Redistribution of aerosol over size bins.



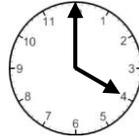
Atmosphere  
Monitoring

# Operational timeliness



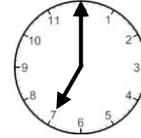
## Space

GOME-2 observes  
the atmosphere



## AC-SAF/EUMETSAT

Retrieves O<sub>3</sub>, NO<sub>2</sub> & SO<sub>2</sub>  
concentrations



## ECMWF

Global data assimilation  
and forecast for the  
next 5 days



## 7 regional centres

Regional air quality  
forecast



## Meteo-France

Model ensemble  
processing



## Anywhere

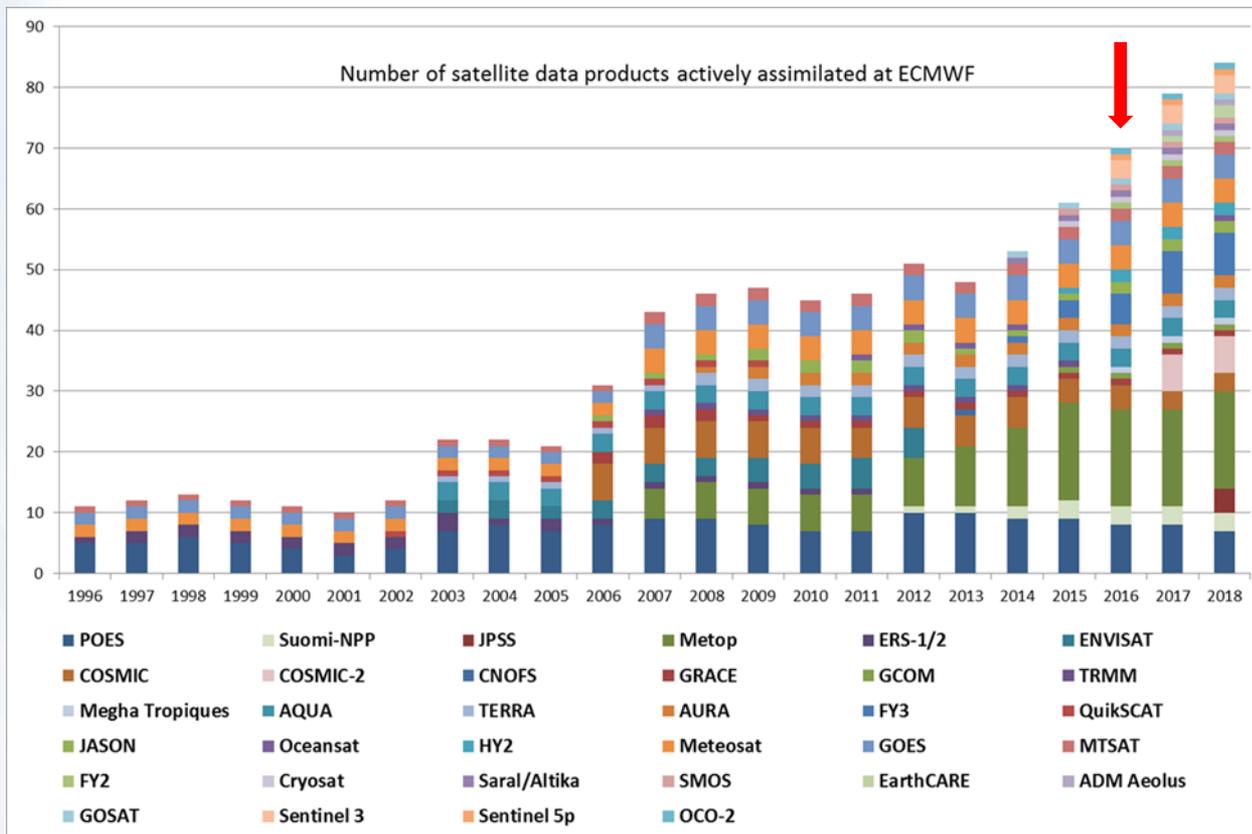
Daily AQ forecast for  
Europe for the next 4  
days





# Satellite data used

Atmosphere  
Monitoring



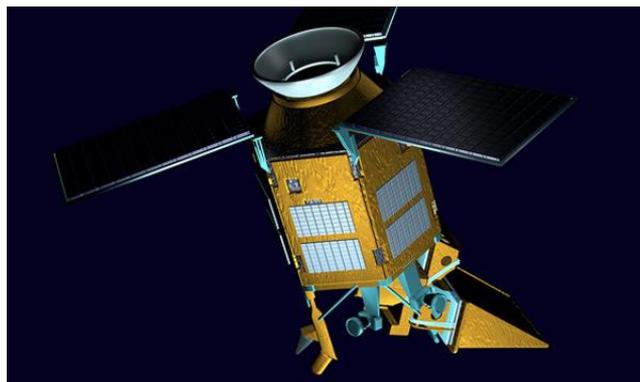


# European stage

Atmosphere  
Monitoring



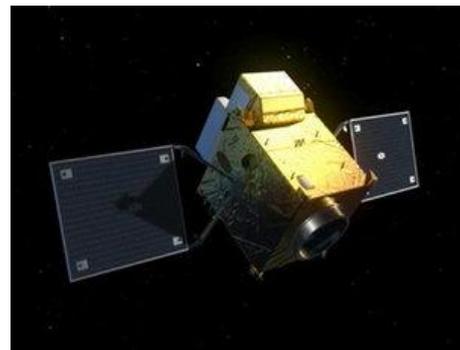
IASI & GOME-2 (and PMAp)



Sentinel-5p



Sentinel-5

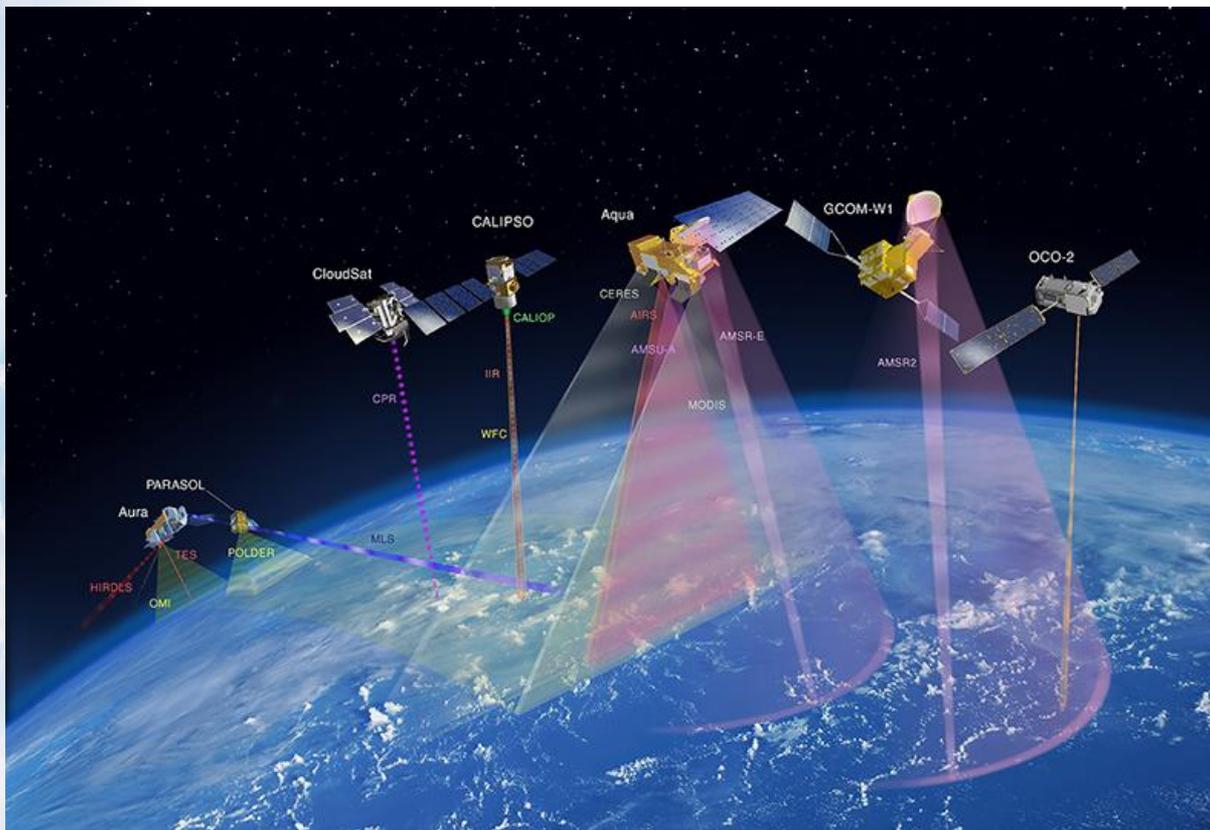


Sentinel-4





# Which instruments do we use?



The A-train



# Current satellite data usage

Species	Instruments
Global system	
O <sub>3</sub>	OMI, SBUV, GOME-2, MLS, OMPS, S5p
CO	IASI, MOPITT, S5p
NO <sub>2</sub>	OMI, GOME-2, S5p
SO <sub>2</sub>	OMI, GOME-2, S5p
Aerosol	MODIS, PMAp, VIIRS, S3
CO <sub>2</sub>	GOSAT, OCO-2
CH <sub>4</sub>	GOSAT, IASI, S5p
GFAS fire emissions	MODIS, GOES, SEVIRI, VIIRS, S3

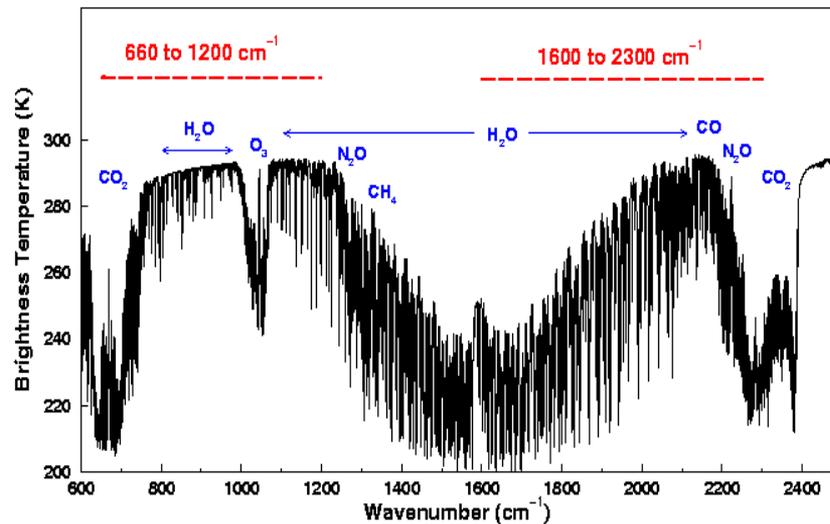
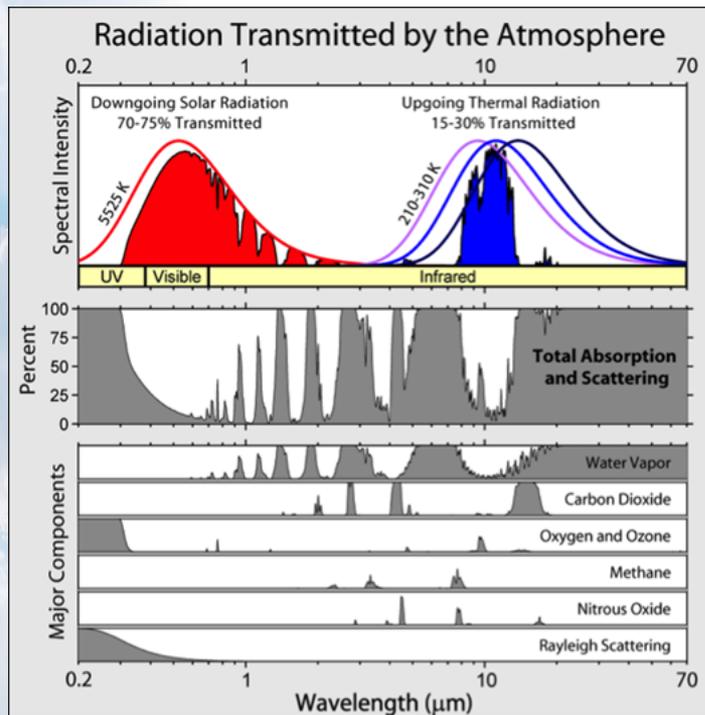




# What we actually observe from satellites

Atmosphere  
Monitoring

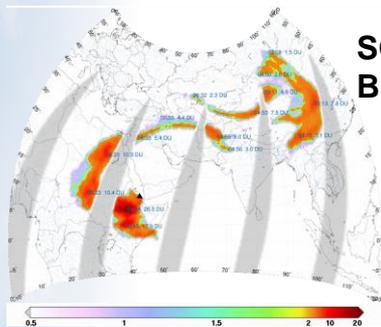
There is a wealth of information available in the observed radiances.



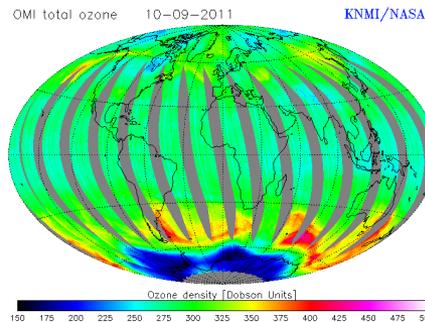
Many trace gases can be measured in the UV-VIS, infrared, and microwave parts of the spectrum.



# Some examples

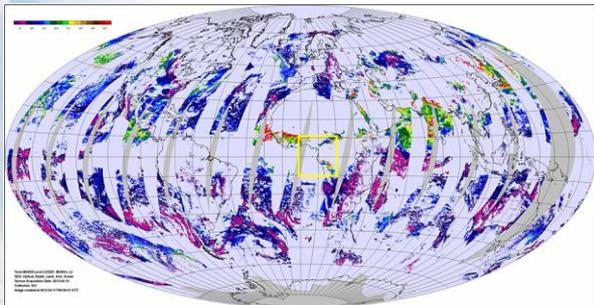


**SO<sub>2</sub>, GOME-2, SACS,  
BIRA/DLR/EUMETSAT**



**O<sub>3</sub>, OMI, KNMI/NASA**

**Aerosol Optical Depth, MODIS, NASA**



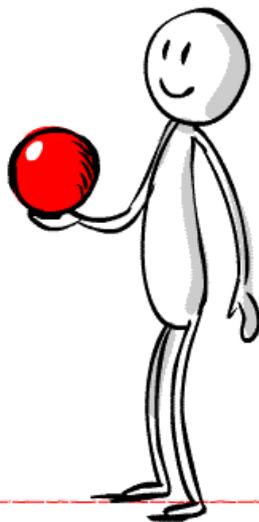
**NO<sub>2</sub>, OMI, KNMI/NASA**

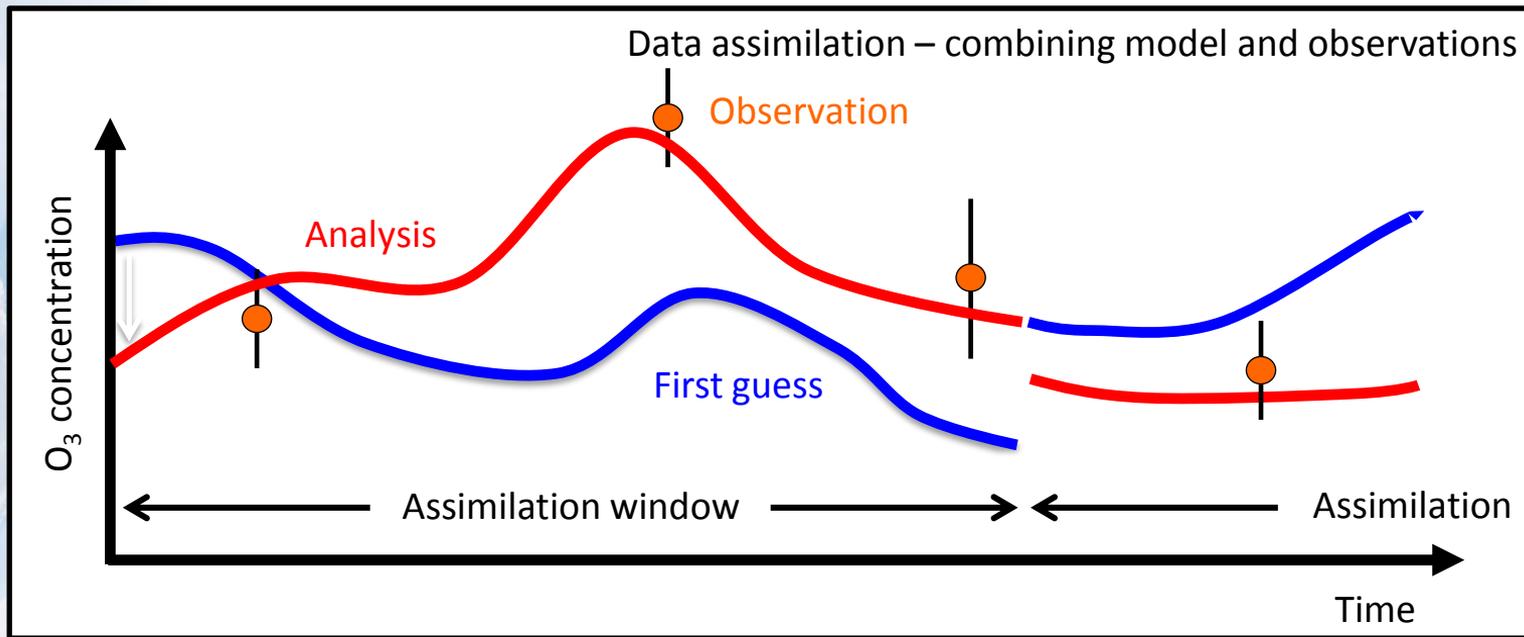
Atmospheric composition observations traditionally come from UV/VIS measurements. This limits the coverage to day-time only. Infrared/microwave are now adding more and more to this spectrum of observations (MOPITT, AIRS, IASI, MLS, MIPAS ...)



Atmosphere  
Monitoring

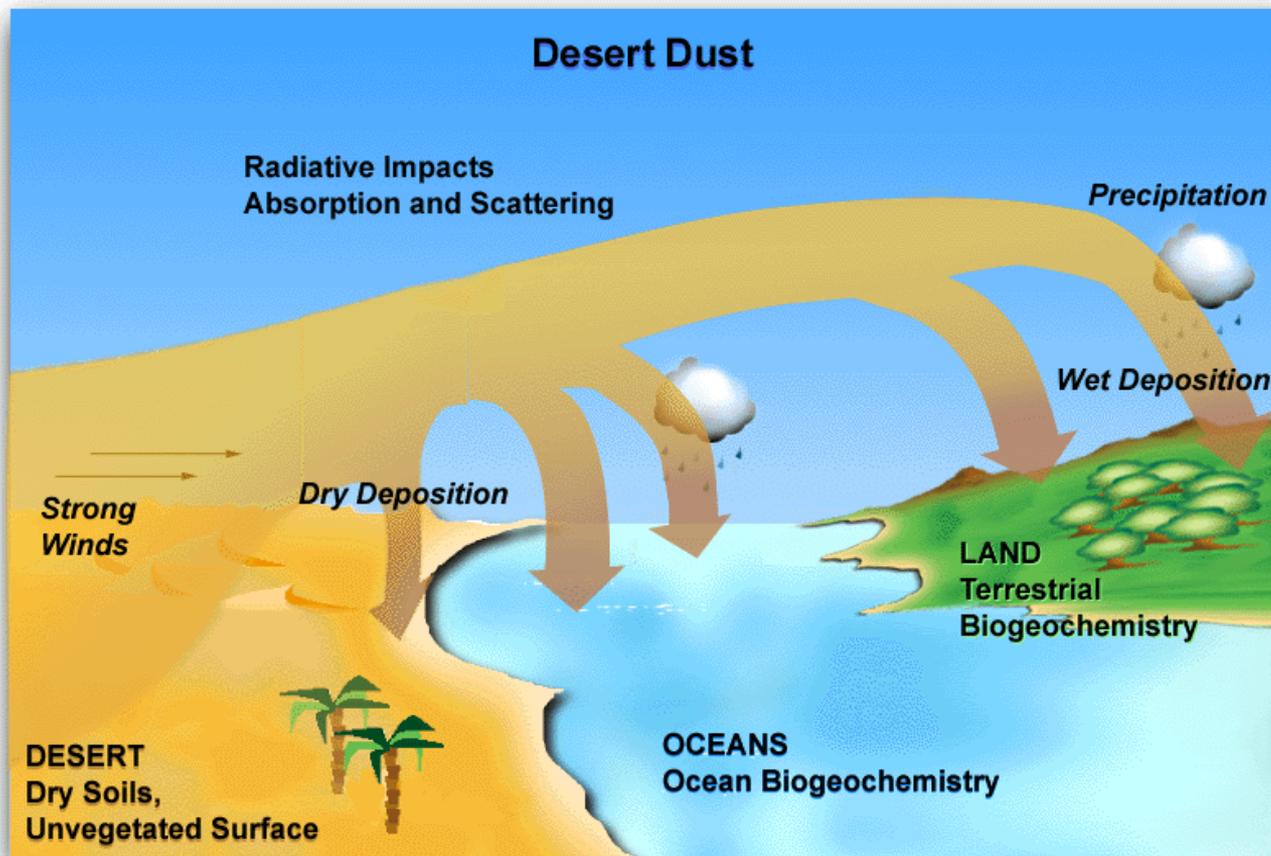
# Data assimilation







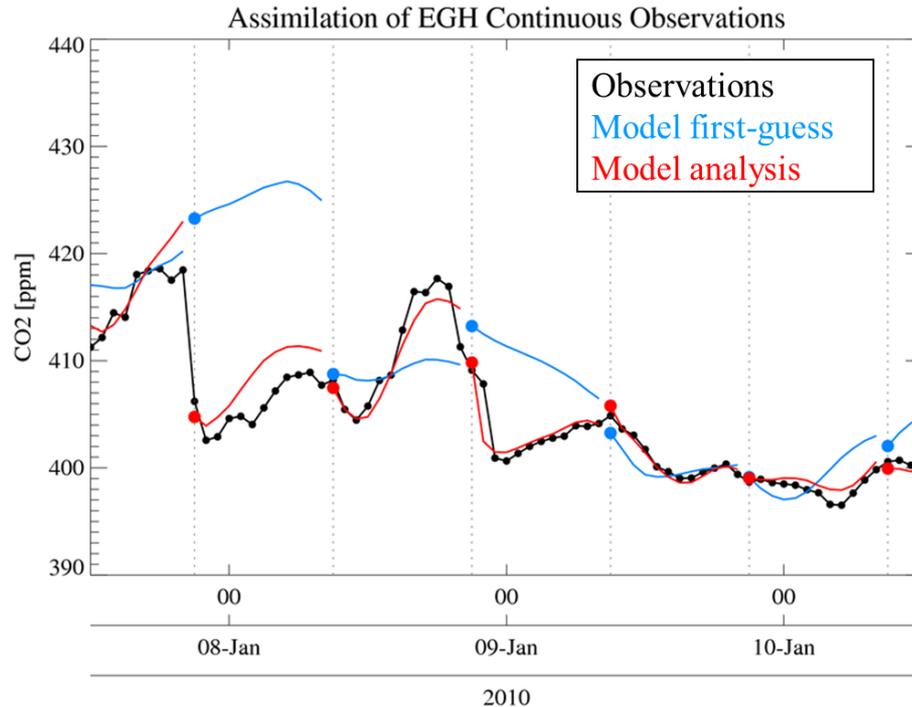
# Dust as an example





# Boundary condition problem – CO<sub>2</sub>

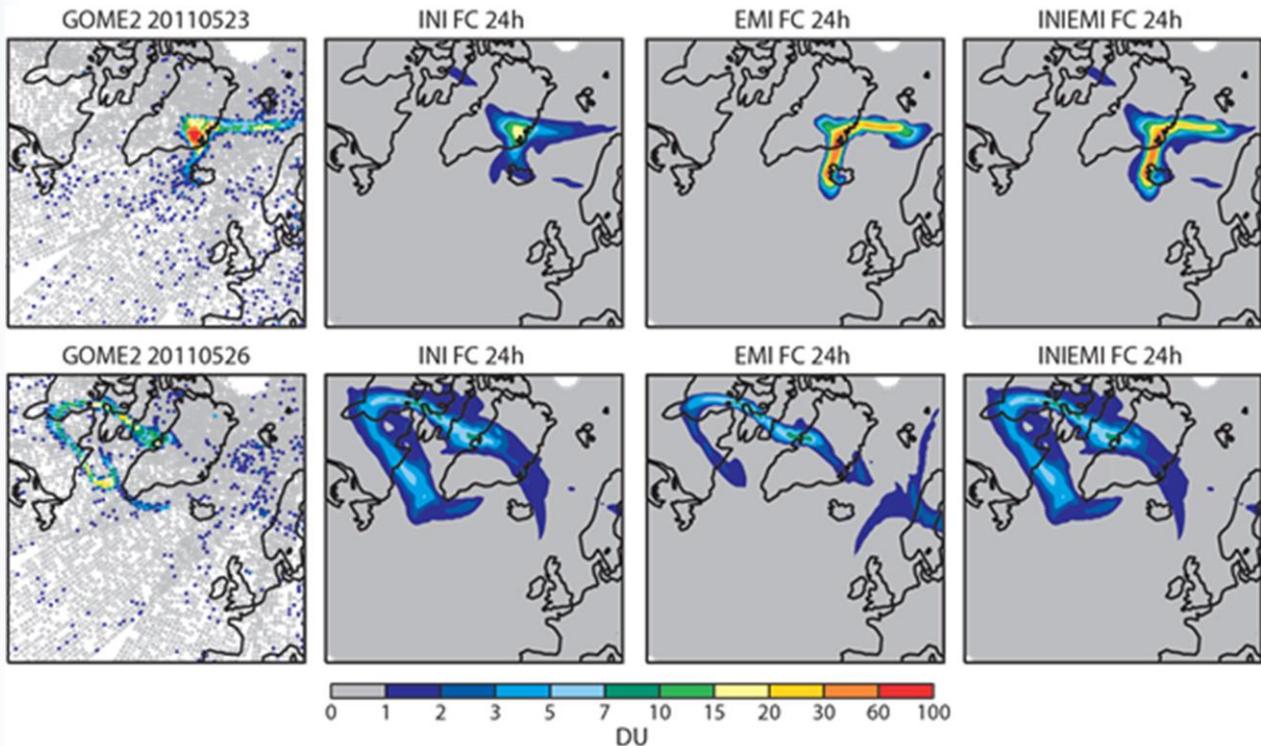
Atmosphere  
Monitoring



For atmospheric composition, the boundary conditions are very important (surface fluxes, emissions,...).



# Another example: volcanic eruptions



Both initial conditions and emissions are important to get it right



## Issues with Observations

- Little or no vertical information from satellite observations. Total or partial columns retrieved from radiation measurements. Weak or no signal from boundary layer.
- Fixed overpass times and daylight conditions only (UV-VIS) -> no daily maximum/cycle
- Global coverage in a few days (LEO); often limited to cloud free conditions; fixed overpass time.
- Retrieval errors can be large; small scales not resolved



# NRT data coverage for reactive gases

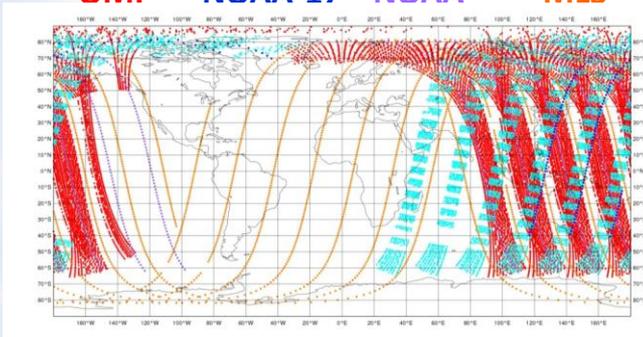
## Ozone

SCIA  
OMI

SBUV/2  
NOAA-17

SBUV/2  
NOAA-

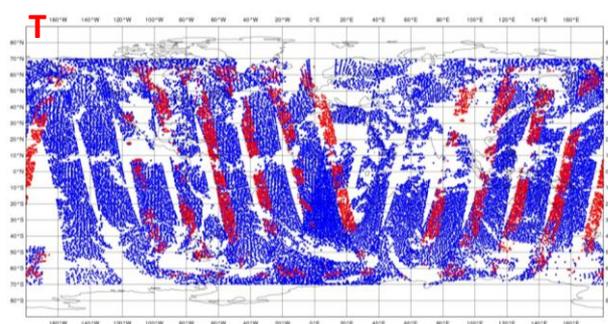
MLS



MOPIT

CO

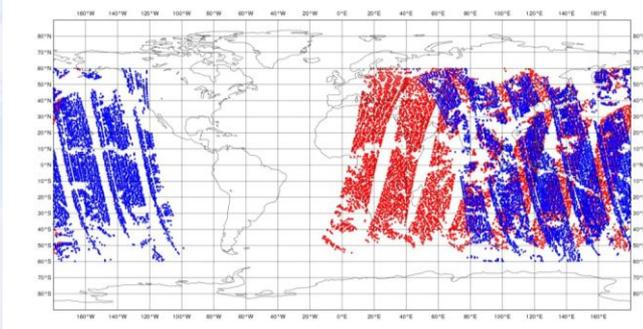
IASI



OMI

NO2

GOME-2

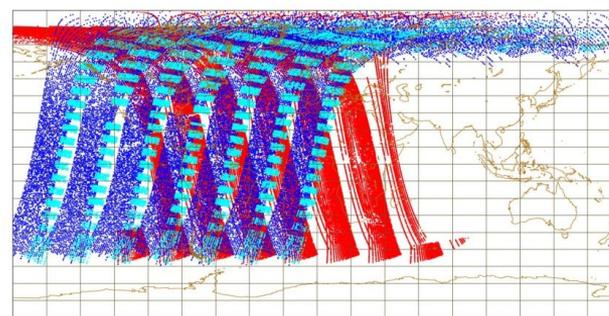


OMI

SCIA

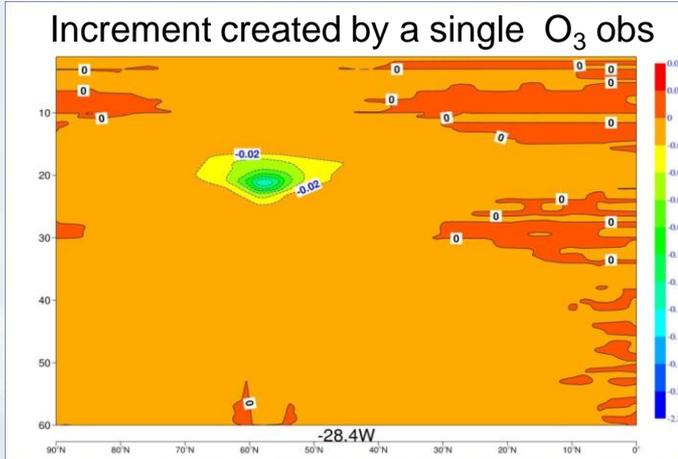
SO2

GOME-2





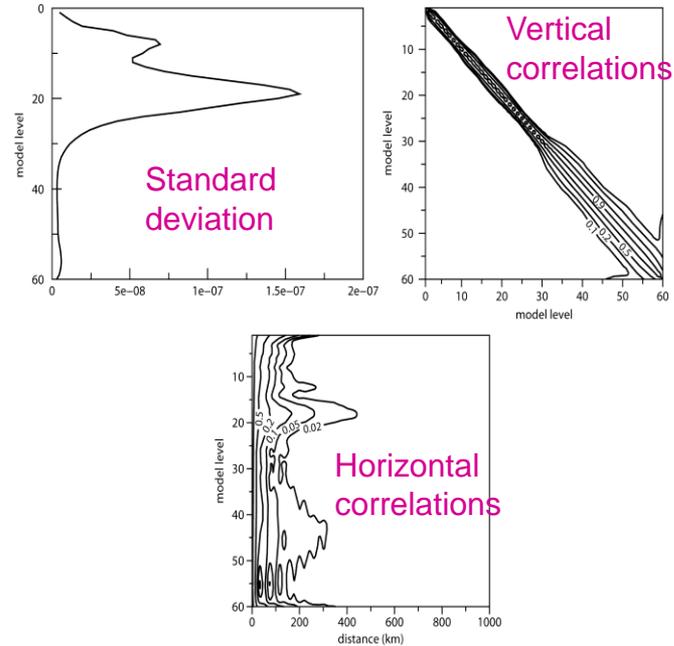
# Single total column O<sub>3</sub> observation



Ozone observation of 247 DU, 66 DU lower than background

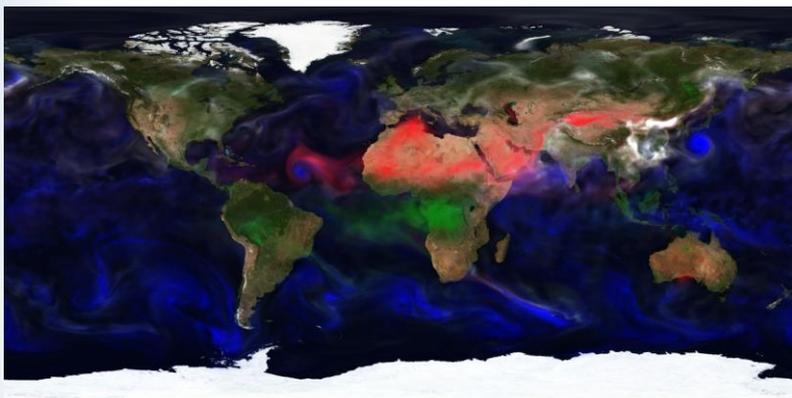
Profile data are important to obtain a good vertical analysis profiles

## Ozone background errors

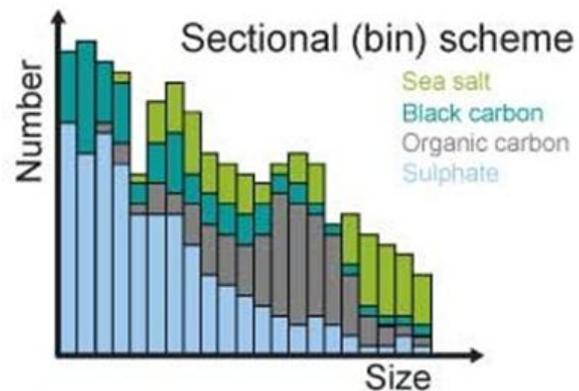
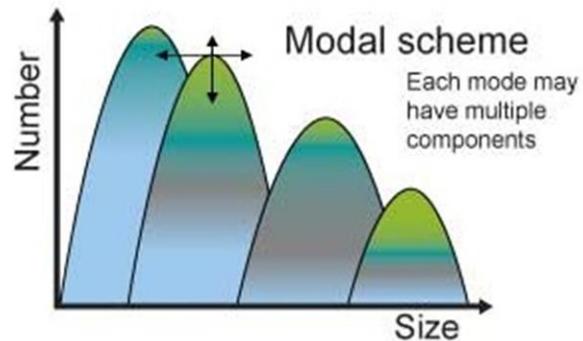
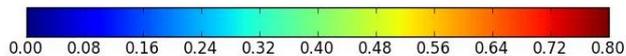
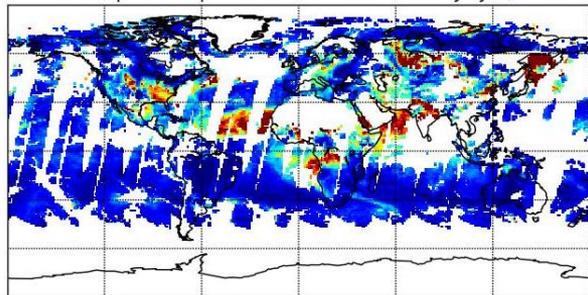




# What is the problem with aerosol?

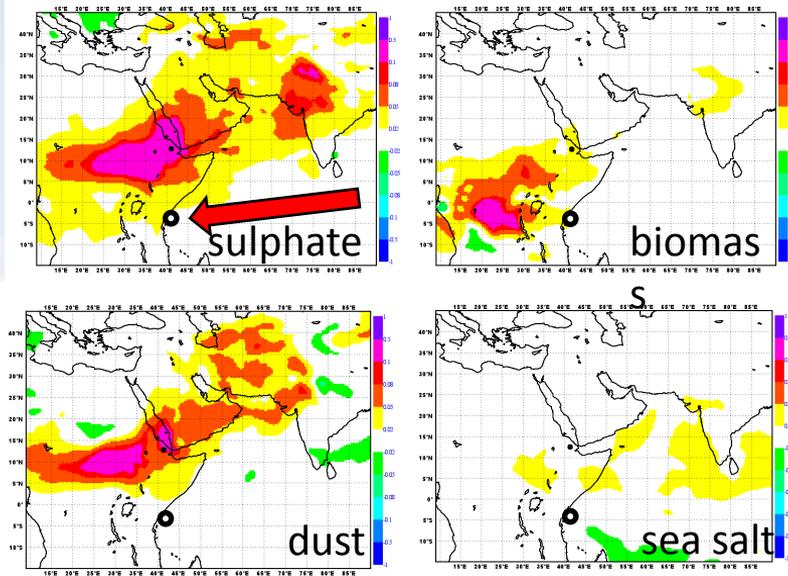


MODIS Optical Depth Land And Ocean Mean July 1, 2012





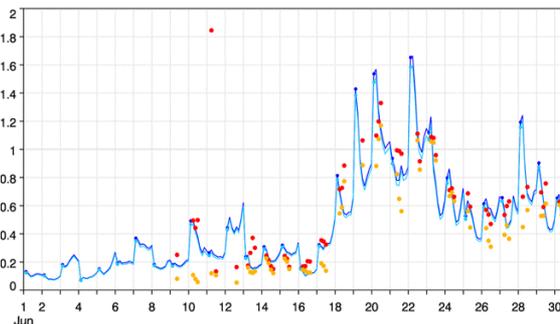
# Example for wrong aerosol attribution



The MACC/ECMWF aerosol model does not contain stratospheric aerosol yet, so the observed AOD was wrongly attributed to the available aerosol types.

Eruption of the Nabro volcano in 2011 put a lot of fine ash into the stratosphere. This was observed by AERONET stations and the MODIS instrument.

ICIPE-Mbita - AERONET

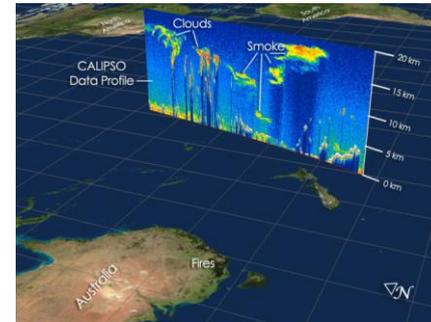
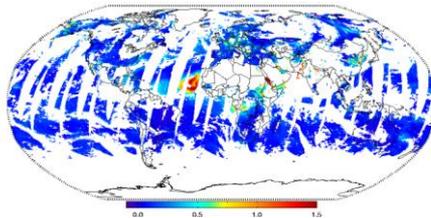
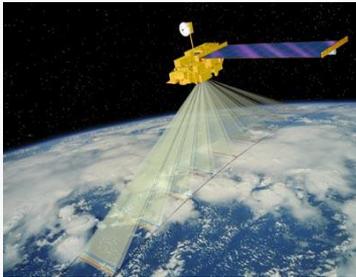


- MACC AOD analysis
- AERONET total AOD
- AERONET fine mode AOD



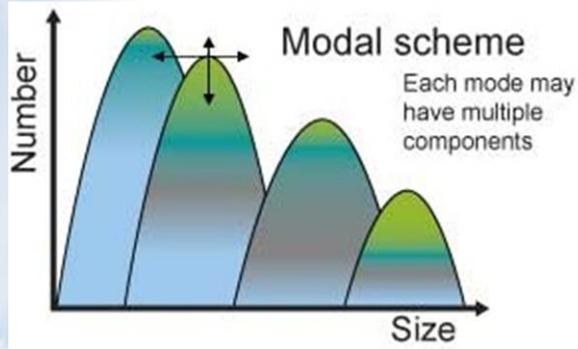
# Constraining aerosol

**“The most comprehensive approach to monitoring intercontinental smoke transport is to use MISR to observe smoke injection height near source fires, OMPS to track plumes over long distances, MODIS to measure aerosol loading, and CALIOP to capture a vertical profiles of smoke plumes” - Hongbin Yu, University of Maryland.**

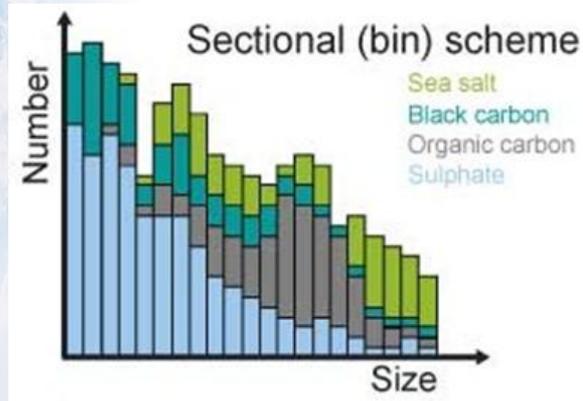




# What is the problem with aerosol?



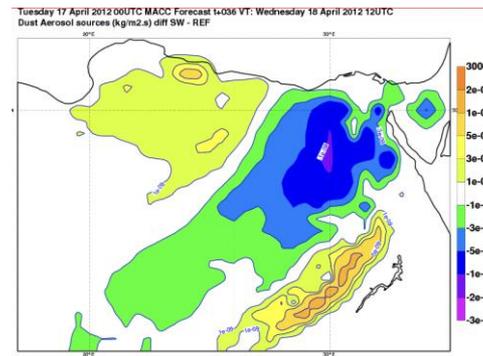
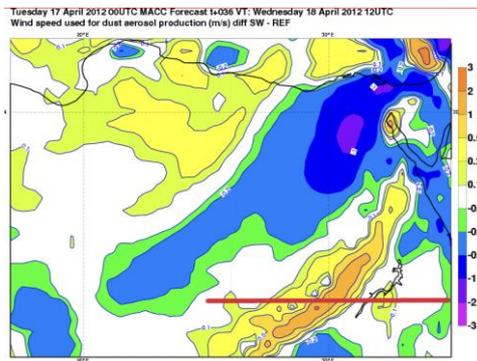
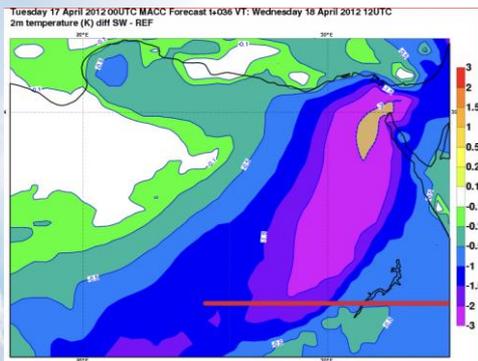
Aerosol schemes are not straightforward to translate from one model to another.



This poses a challenge for using boundary conditions for regional or local models.



# Aerosol-meteorology feedbacks



S. Rémy et al., 2015

The dust aerosol in a dust storm affects the local boundary meteorology through short-wave and long-wave radiation effects. This in turn can influence the dust source.



# Reanalysis and real-time analyses

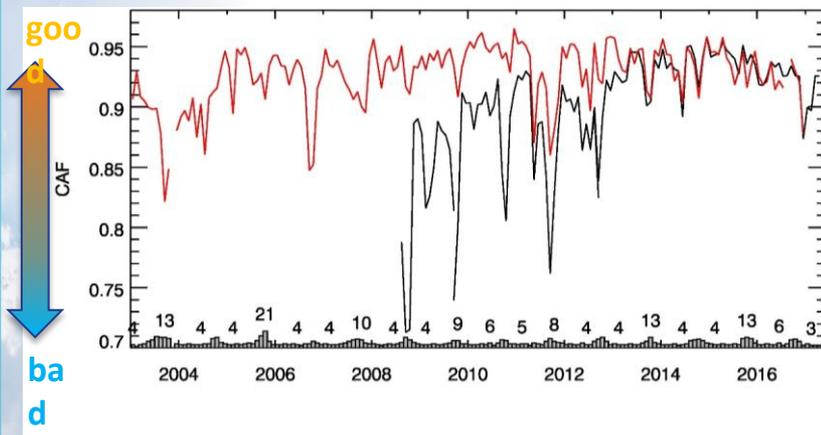
- Real-Time CAMS system (twice-daily analysis and 5-day forecast):
  - Evolves with time: Usually 2 model updates per year
  - Horizontal and vertical resolution can change
  - Observation usage changes
  - Emission data sets might change (e.g. change from GFED to GFAS fire emissions)
- Reanalysis (retrospective):
  - Consistent long term dataset produced with one model version
  - Consistent emissions
  - Consistent, reprocessed data sets
  - Gridded continuous presentation of atmospheric composition combining model and satellite retrievals in an optimal way
  - Can be used for trend analysis



# Evolution of NRT system

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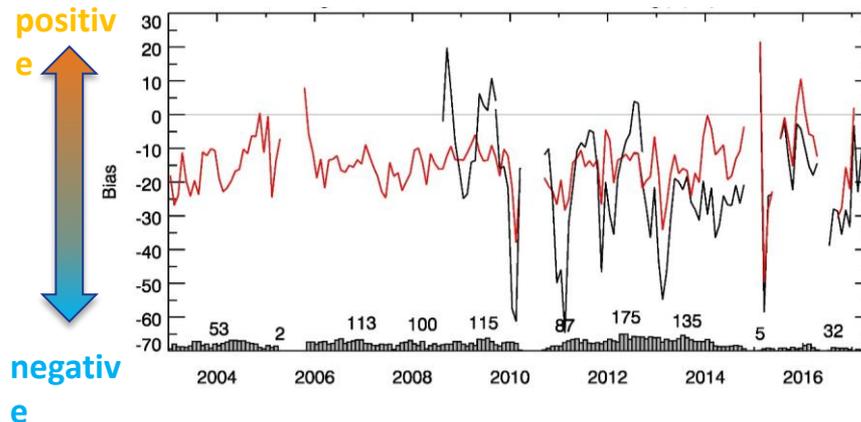
## O3 score at Neumayer station



- More consistent timeseries in reanalysis
- NRT timeseries shows model evolution and problems in earlier years

— CIRA (CAMS Interim Reanalysis)  
— NRT CAMS analysis

## CO bias (1000-700 hPa) at Frankfurt





# Datasets used in CAMS reanalysis

Atmospher

Moni

- OMI Aura
- SCIAMACHY Envisat
- SCIAMACHY Envisat
- MOPITT Terra
- AATSR Envisat
- MIPAS Envisat
- SCIAMACHY Envisat
- SBUV/2 NOAA-18
- SBUV/2 NOAA-17
- SBUV/2 NOAA-16
- SBUV/2 NOAA-14
- OMI Aura
- MLS Aqua
- GOME ERS-2
- MODIS Terra
- MODIS Aqua

Observation overview: {'Experiment': 'GN29', 'Type': 'MFB', 'Obs.Groups': 'RESAT'}



RESAT

RESAT Averaging Kernels



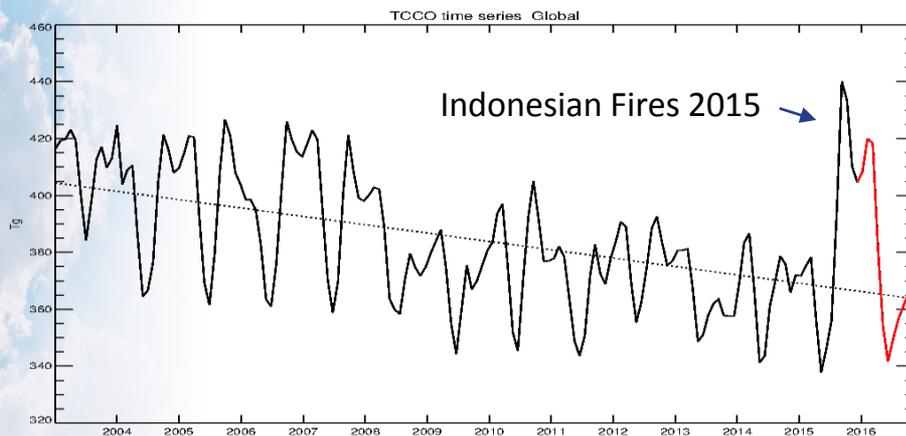


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# GLOBAL Trends of CO burden

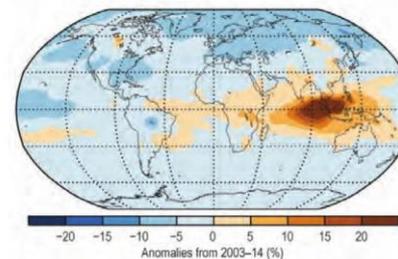
## CAMS interim Reanalysis

GLOBAL CO Burden in Tg 2003-2016

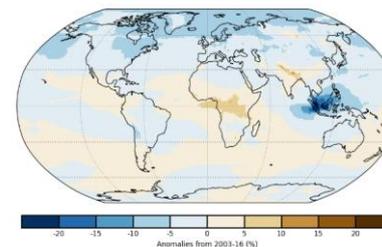


### Anomaly (%) 2015

(ac) Carbon Monoxide

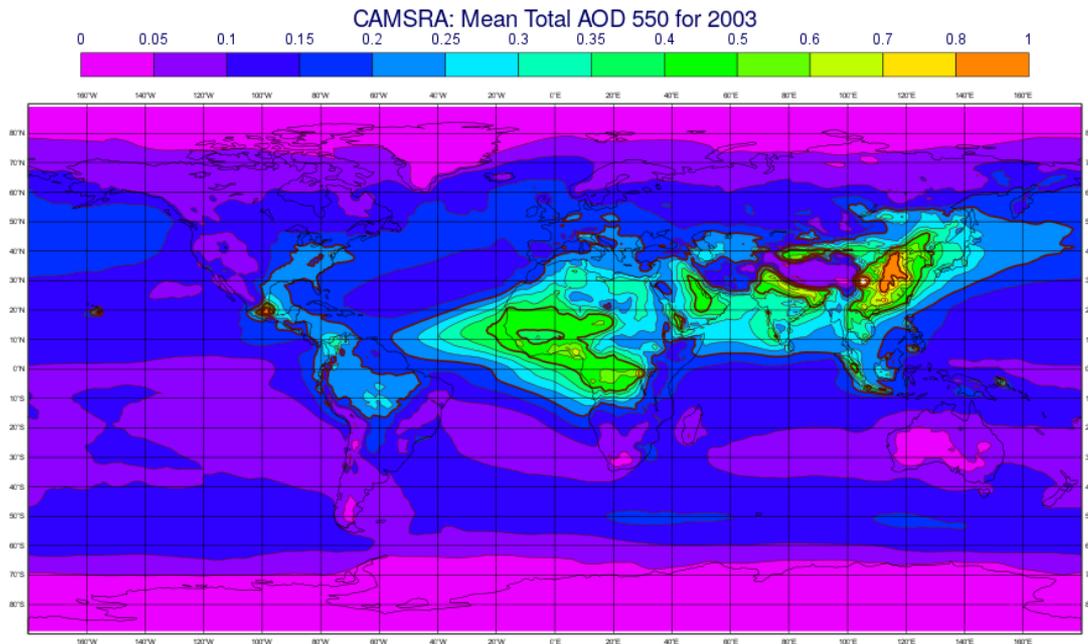


### Anomaly (%) 2016



Flemming and Inness, BAMS State of Climate 2015





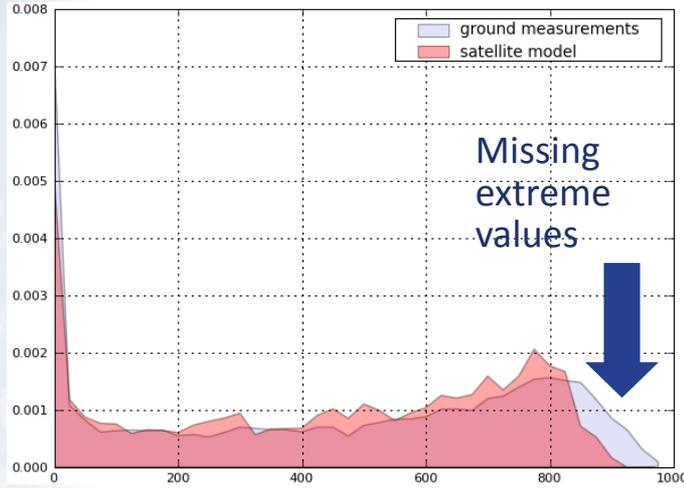
- New reanalysis currently in the process of being produced by CAMS
- Will cover the period 2003-current day
- First data will be released in Autumn 2017
- Current aim is to have full data released in early 2018



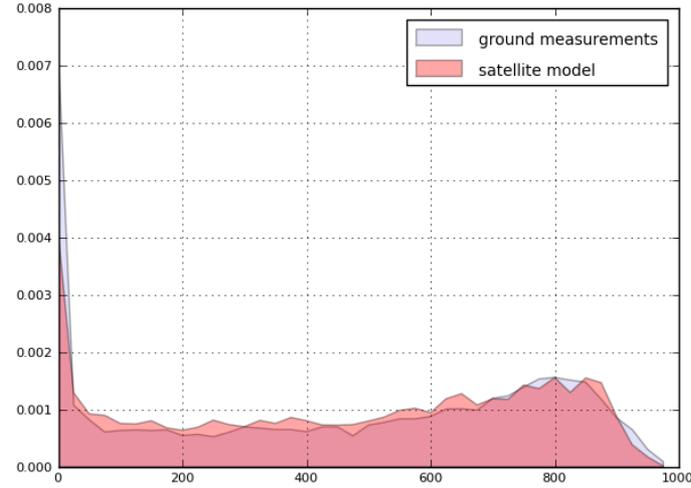
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# Support for solar energy applications

AOD monthly climatology



GEMS AOD daily values



Direct normal irradiance [W/m<sup>2</sup>]

**Climatology databases do not allow correct representation of direct normal irradiance distribution**

GeoModel

SME, Bratislava, SK



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# CAMS User Support Gateway

ABOUT CAMS NEWS & MEDIA EVENTS CATALOGUE RESOURCES TENDERS HELP & SUPPORT



## Knowledge Base

Find answers to your questions



## Documentation

Global, regional, supplementary and emissions products



## Validation

Global, regional, supplementary and emission products



## Operational Users

System upgrades, technical info and data access



## Your Enquiry Portal

Login to submit and monitor the live status of your enquiry, interact directly with our Support team and keep track of all your past requests



Sign up to our mailing lists



Field Campaign Support

## SERVICE THEMES

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

## ANALYSES

European Air Quality  
Fire Monitoring  
Reactive Gases  
Aerosols

## FORECASTS

Reactive Gases  
Aerosols  
European Air Quality  
Ozone Layer  
CO<sub>2</sub>





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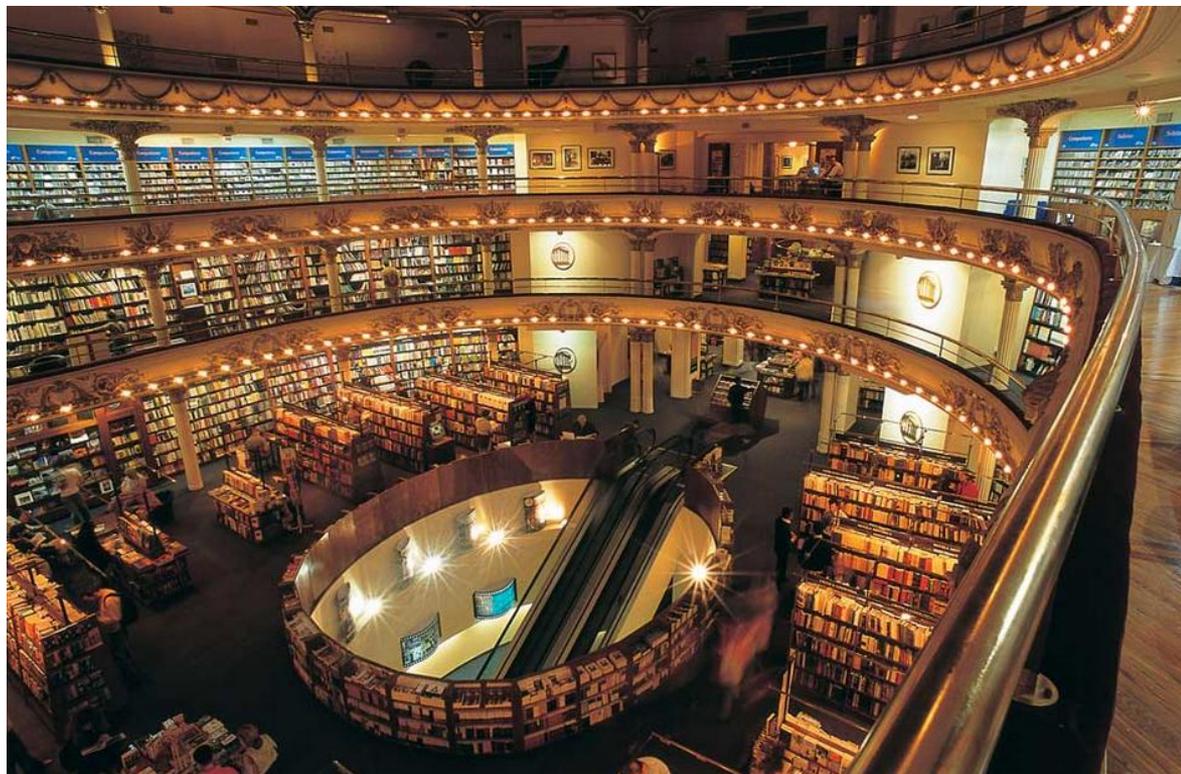
## CAMS User Support Service in a nutshell

- ✓ Dedicated to aid CAMS data discovery, dissemination, understanding and use by all users
- ✓ Provides a central communication tool (JIRA Service Desk)
- ✓ Promotes an extra source of information through its Customer Portal integrated Knowledge Base



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# Levels of Support





Pages / Copernicus Knowledge Base

Edit
 Save for later
 Watch
 Share
 ⋮



## CAMSiRA, the CAMS interim Reanalysis

Created by Karl Hennermann, last modified on Apr 27, 2017



### What is CAMSiRA?

CAMSiRA is a global reanalysis data set of atmospheric composition (AC), produced by the Copernicus Atmosphere Monitoring Service (CAMS). At the time of writing (March 2017) CAMSiRA already covers the period 2003–2015 and data for 2016 is in production. CAMSiRA will then continue to run close to near-real-time.

The CAMSiRA data is made available as an interim product until a comprehensive CAMS Reanalysis, planned for 2017/18, becomes available.

For further information on CAMSiRA please see: [Flemming et al \(2017\) The CAMS Interim Reanalysis of Carbon Monoxide, Ozone and Aerosol for 2003–2015, Atmos. Chem. Phys., 17, 1945-1983, 2017.](#)

### How to access CAMSiRA data

CAMSiRA data is hosted on ECMWF's Meteorological Archiving and Retrieval System (MARS).

**Users with direct access to MARS** can access the CAMSiRA data on MARS as `stream=oper, class=mc, expver=eac3`. `eac3` has the following CAMS fields:

```

levtype=ml
type=an
time=0000to/1800/by/6
type=fc
time=0600,1800
step=0,3,6,9,12
param=aermr01,aermr02,aermr03,aermr04,aermr05,aermr06,aermr07,aermr08,aermr09,aermr10,aermr11,aermr12,co,go3,hno3,n2o5,no,no2,o3,pan,q,so2 # ! ( same aerosols but fewer chemical species than gbst)

```

levtype=pl





The search function below currently does not work.  
Copernicus data users please [search on the Copernicus Knowledge Base](#).  
We apologise for the inconvenience.

ECMWF

## Requests

Any status  Created by anyone  Any request type  Search for requests

Type	Reference	Summary	Service desk	Status	Requester
	CUT-64	Testing C3S new portal	CAMS and C3S Training	WAITING FOR SUPPORT	Anabelle Guillory
	CUT-25	download error	CAMS and C3S Training	OVER TO SPECIALIST SU...	Anabelle Guillory
	CUT-23	Testing for training demonstrations - IGNORE	CAMS and C3S Training	RESOLVED AND CLOSED	Anabelle Guillory

1-3 of 3

Create Cancel

I am looking for CAMS data for Warsaw.  
Thank you,  
CUS Demo user



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## Why should you contact us?

1. We want to help!
2. It is in part through User Support that we build and consolidate our reputation
3. Tell your friends about us – the best advertising we can have is a loyal customer spreading the word about how great our services are!
4. Send us your user stories
5. We want to grow our services for your benefit



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## W h a t t o r e m e m b e r

- User Support Gateway page on CAMS website
- Levels of support
- We're happy to help and with a smile! 😊



Atmosphere  
Monitoring

and finally ...

**"Coming together is a beginning.**

**Keeping together is progress.**

**Working together is success."**

<http://atmosphere.copernicus.eu>

The screenshot shows the Copernicus Atmosphere Monitoring Service website. At the top, there is a navigation bar with the Copernicus logo and 'Atmosphere Monitoring Service' text. Below the navigation bar is a large banner image of a landscape under a bright sun. The main content area is divided into three columns: 'IN FOCUS' with a 'CAMS General Assembly' article, 'CATALOGUE' with a 'EUROPEAN AIR QUALITY' map, and 'NEWS' with several recent news items. A search bar is located in the top right corner.

Twitter

The screenshot shows a Twitter feed on a mobile device. The top tweet is from Copernicus ECMWF (@CopernicusECMWF) mentioning a blog post about peatland fires in Southeast Asia. The second tweet is from Copernicus ECMWF (@CopernicusECMWF) dated 18/09/2015, mentioning the Copernicus Atmosphere Monitoring Service tracking Asia's haze. The bottom of the screen shows the Twitter navigation bar with icons for Home, Notifications, Messages, and Me.

Newsletter

The screenshot shows an email newsletter from Copernicus Atmosphere Monitoring Service. The header features the Copernicus logo and the service name. The main content includes a satellite image of Earth with a satellite in orbit. Below the image, there is a paragraph of text explaining the newsletter's purpose and the services provided. At the bottom, there is a section titled 'SAVE THE DATE' for the '1st CAMS General Assembly' held from June 14-16, 2016, in Valencia, Spain.

# Follow us!



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[www.copernicus.eu](http://www.copernicus.eu)

