Atmosphere Monitoring

The Copernicus Atmosphere Monitoring Service

Richard Engelen & Stijn Vermoote
ECMWF

Copernicus
Europe's eyes on Earth

European Commission

The EU Copernicus programme

Atmosphere Monitoring

Sentinels

Observations feeding into value-added Services

- Atmosphere
- Climate
- Land
- Marine
- Emergency
- Security

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

User-driven with free and unrestricted data access

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Copernicus Atmosphere Monitoring Service

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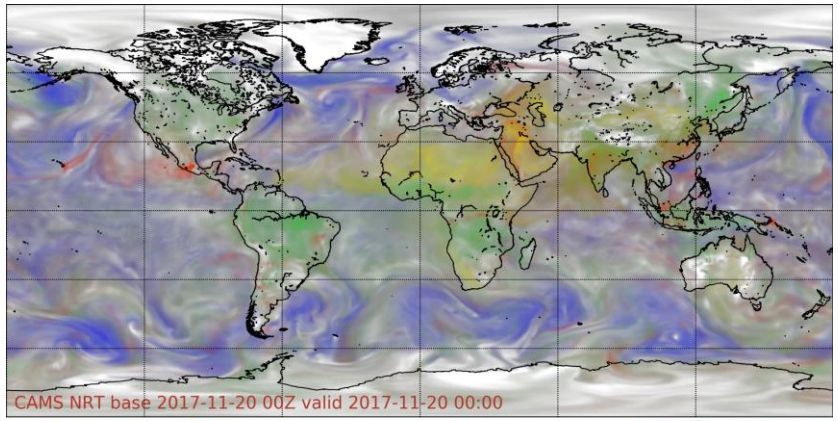
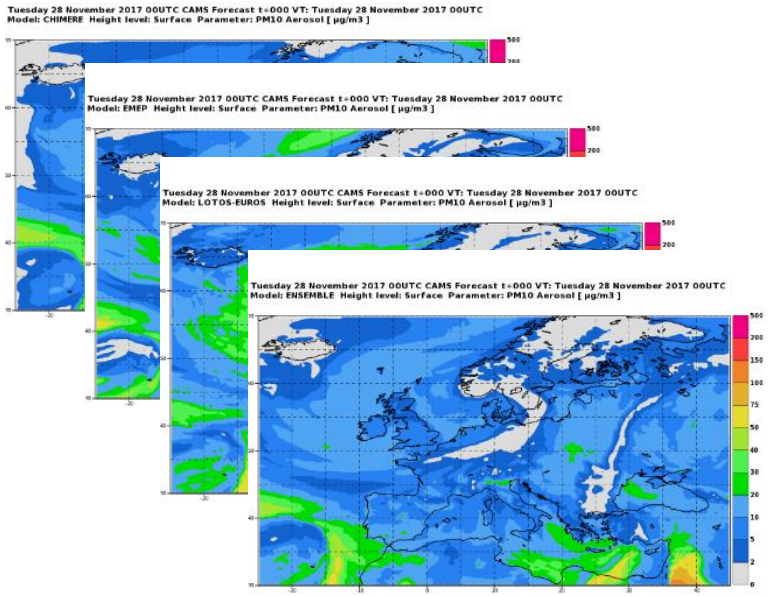
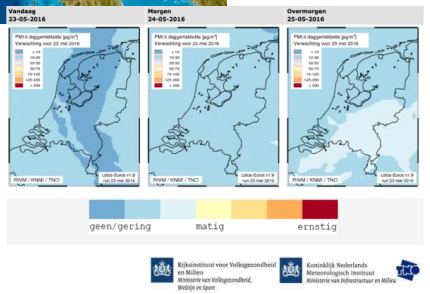


Transforming satellite observations into user-driven services.





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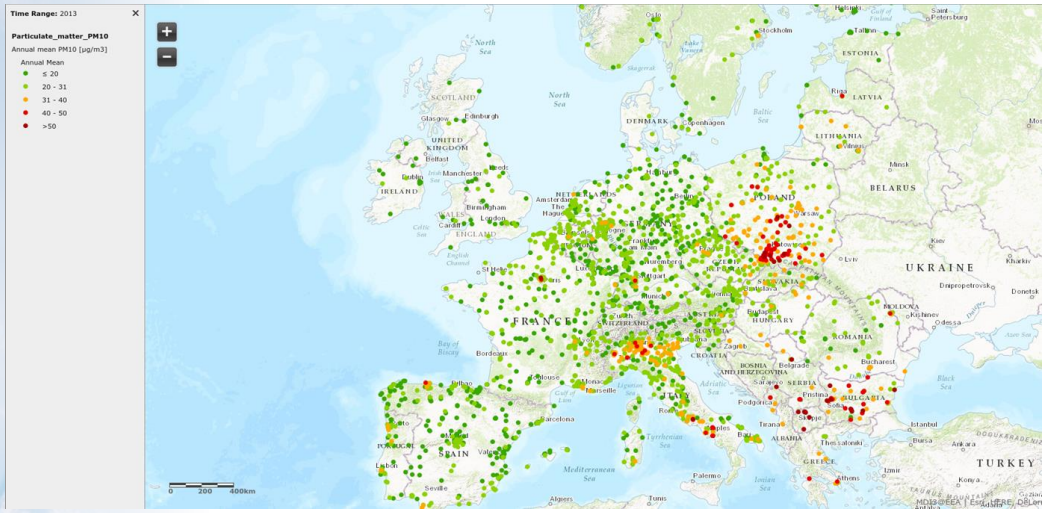
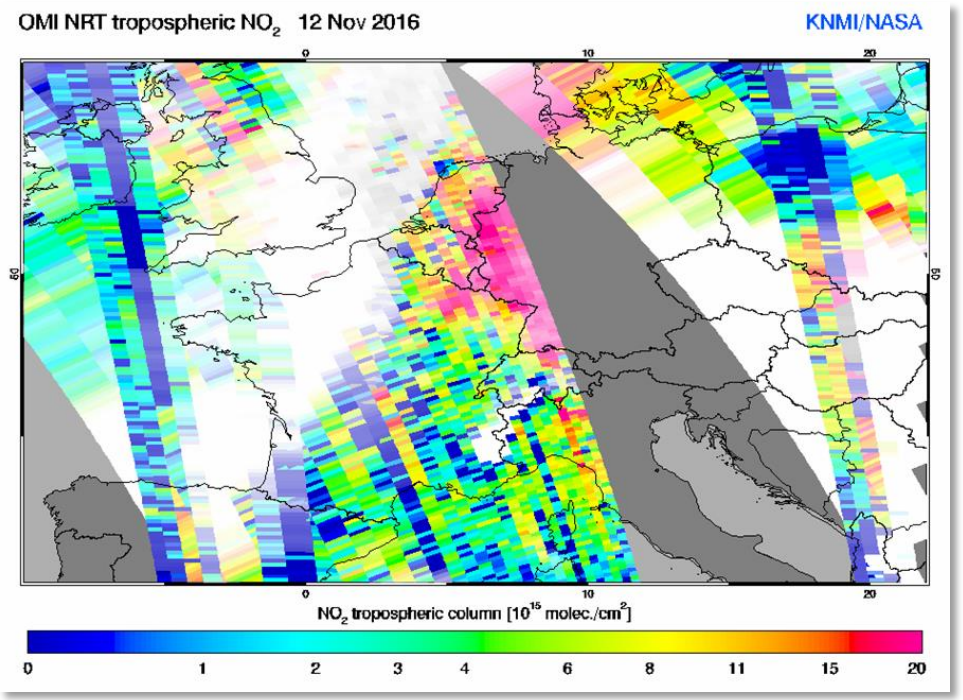
CAMS: Adding value to observations



In-situ observations

European Environment Agency



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.

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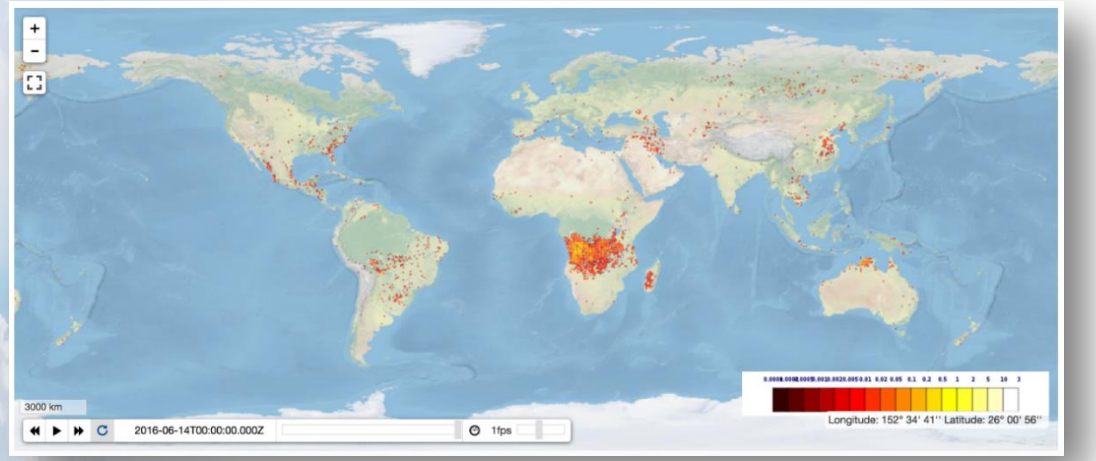
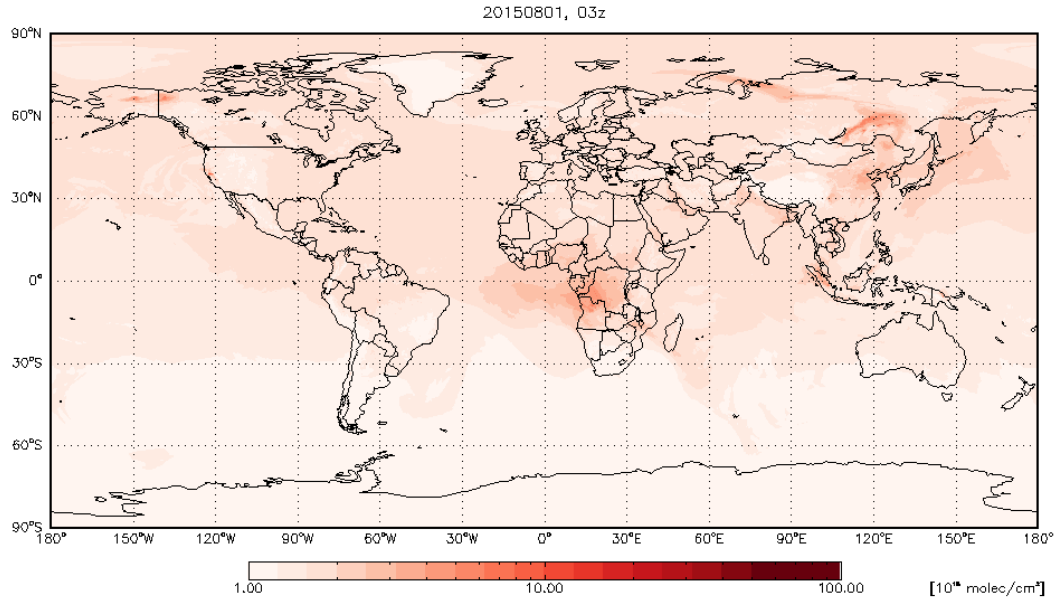
Global monitoring and forecasts

Newspaper: Will the smoke from wildfires in Indonesia affect air quality in our country later this week?



CAMS satellite-based Fire emissions (GFAS)

- daily estimates
- Aerosols, chemical species and greenhouse gases



CAMS global forecasts

- twice-daily 5-day forecasts
- Aerosols, 13 chemical pollutants, CO_2 & CH_4
- 40 km spatial resolution

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Global reanalysis

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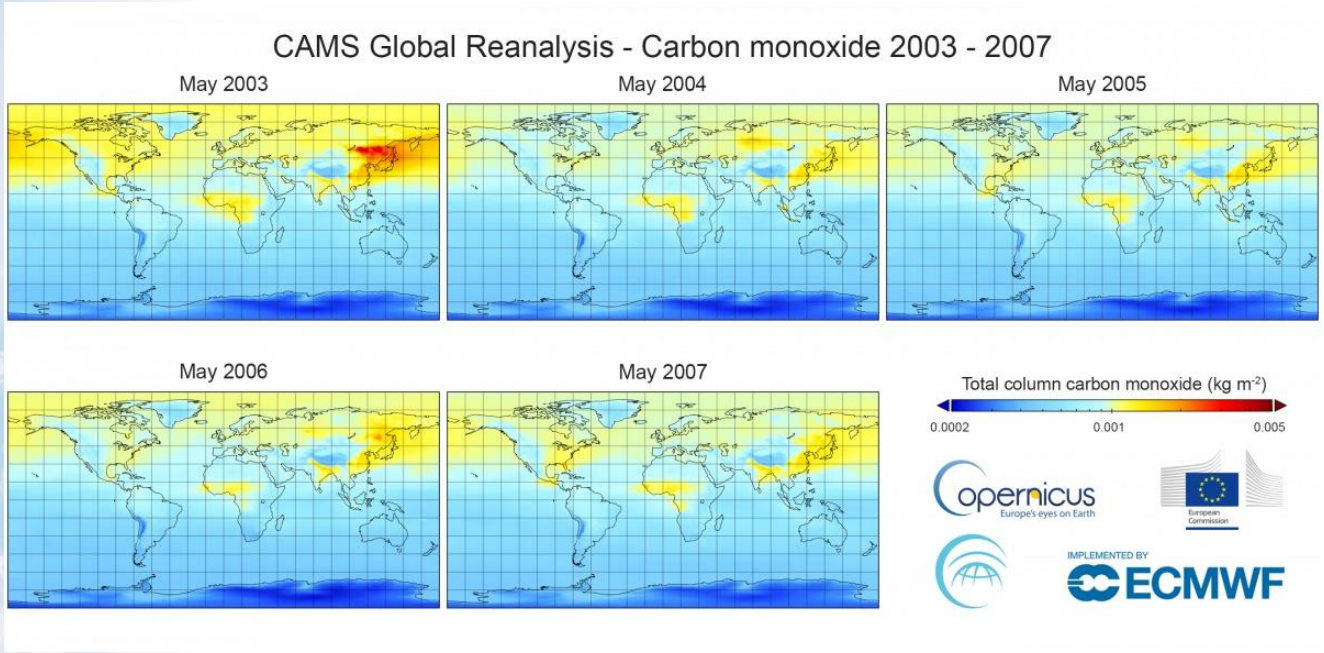
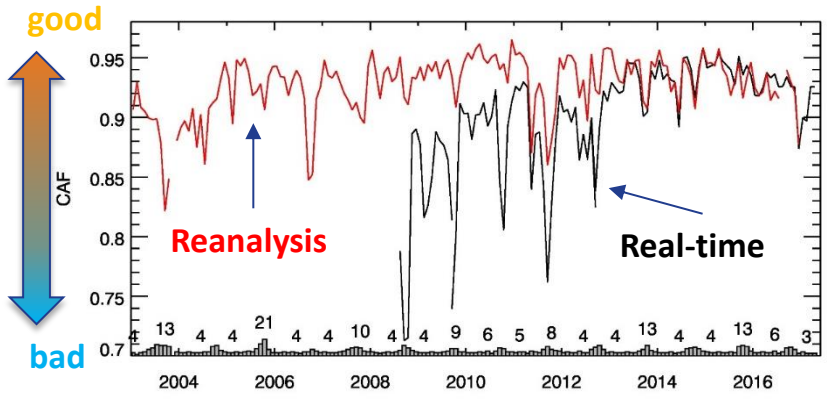
Scientist: I need a consistent well-documented data set to look at trends.



Release of full data set in September/October 2018.

O3 score at Neumayer station



CAMS global reanalysis

- 2003 – 2016, with new years being added
- Aerosols, 13 chemical pollutants, CO_2 & CH_4
- 80 km spatial resolution

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Regional forecasts

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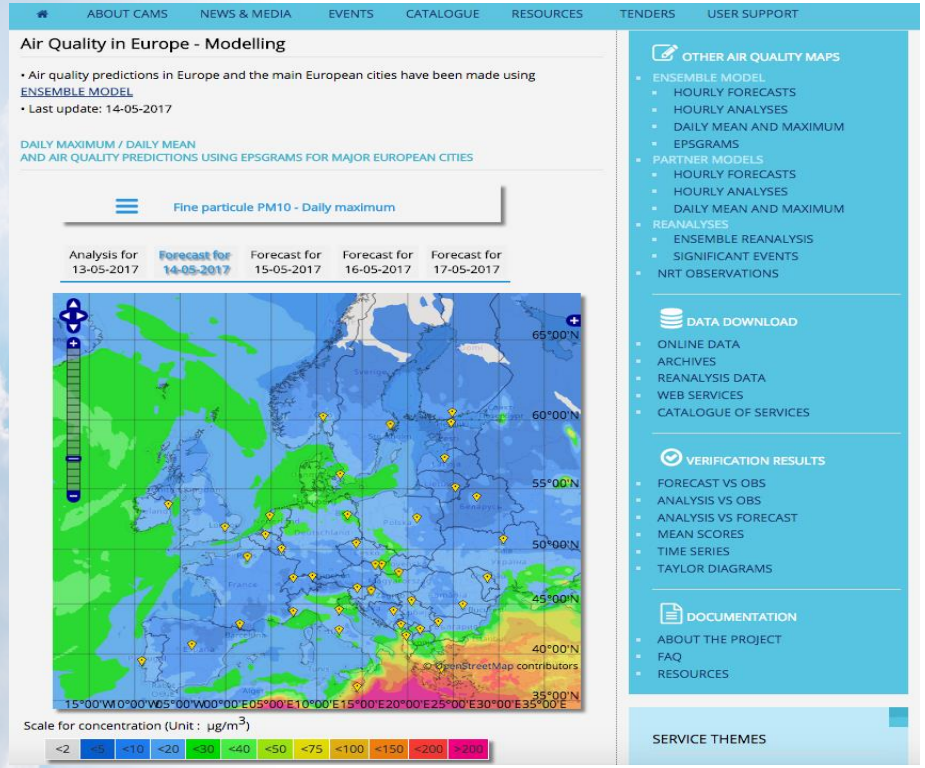
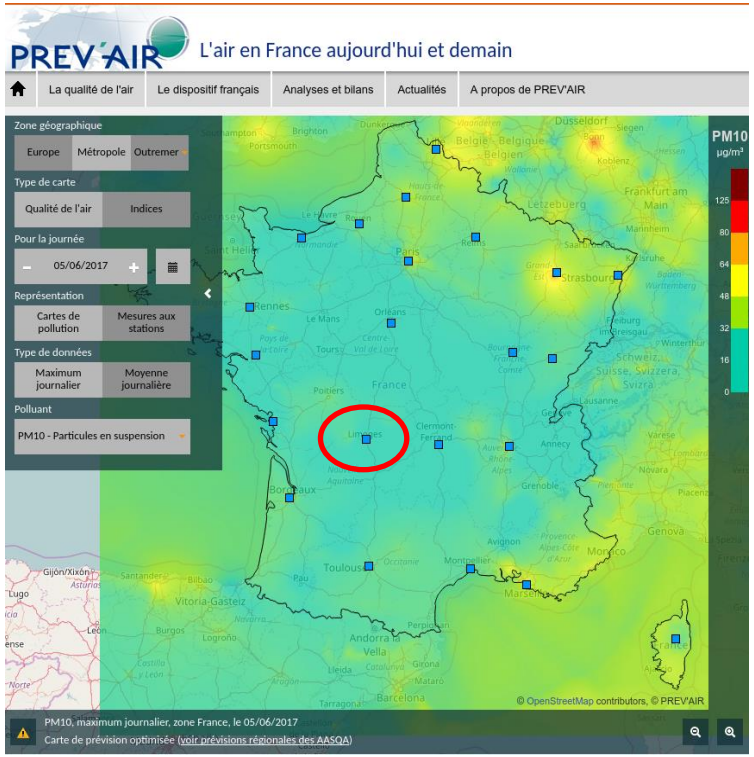
French citizen: What will the air quality in Limoges be tomorrow?



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

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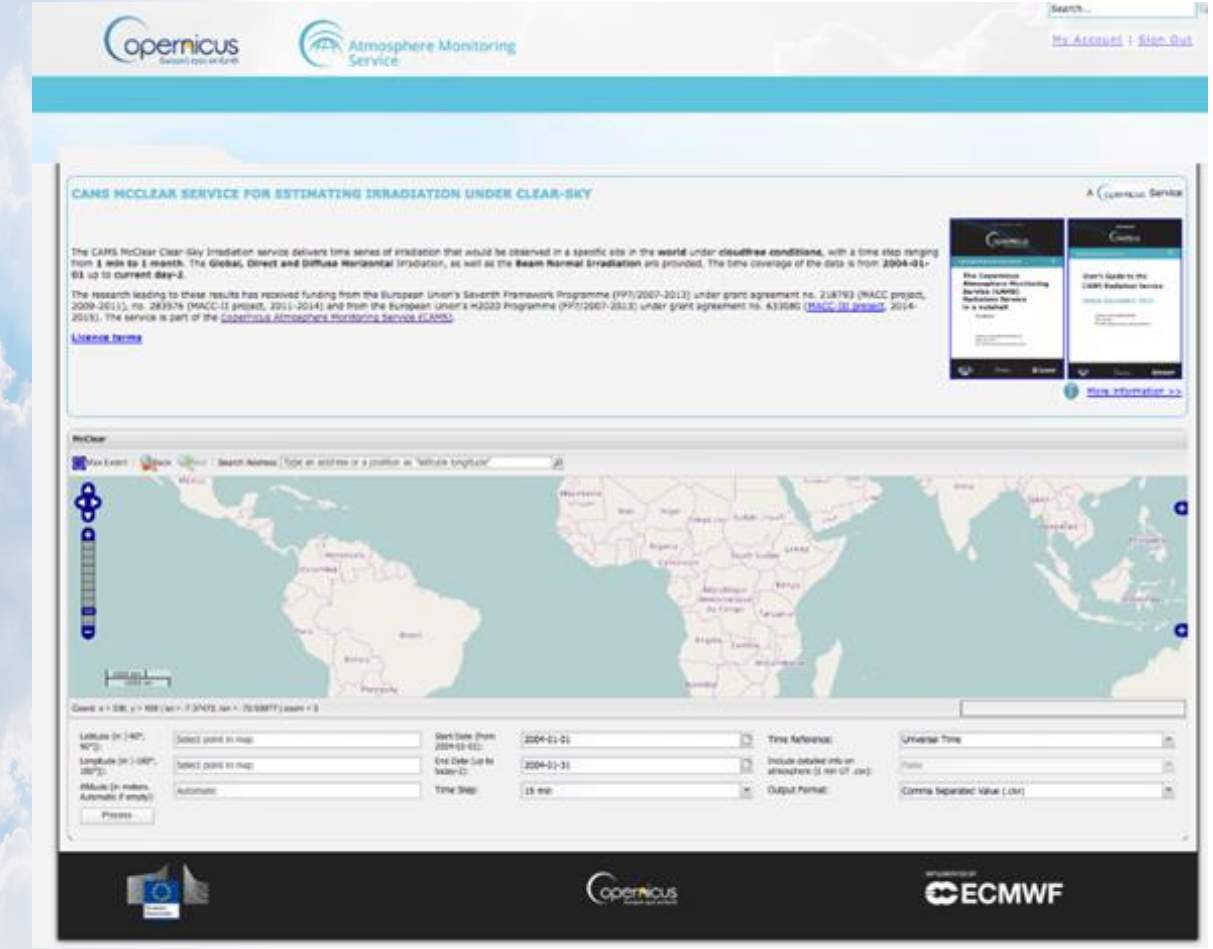
Solar energy

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



CAMS solar radiation

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

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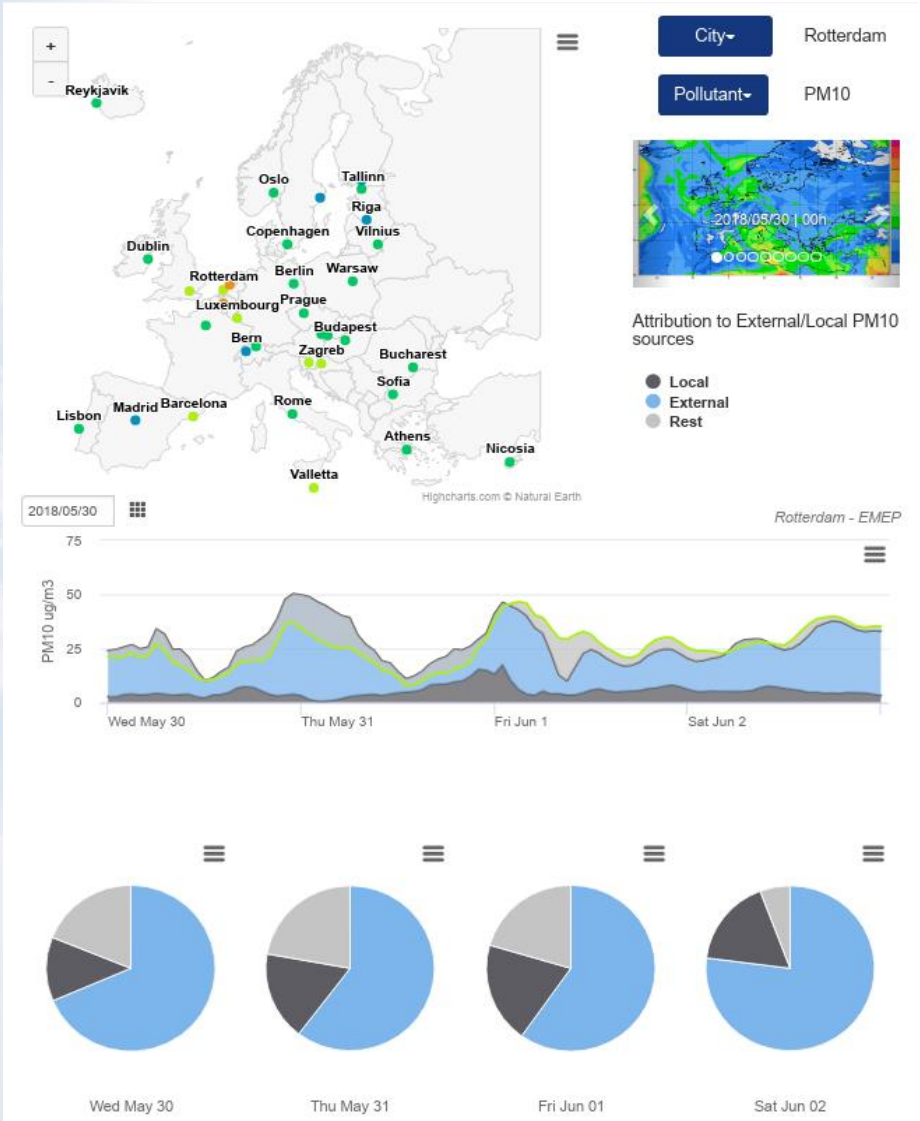
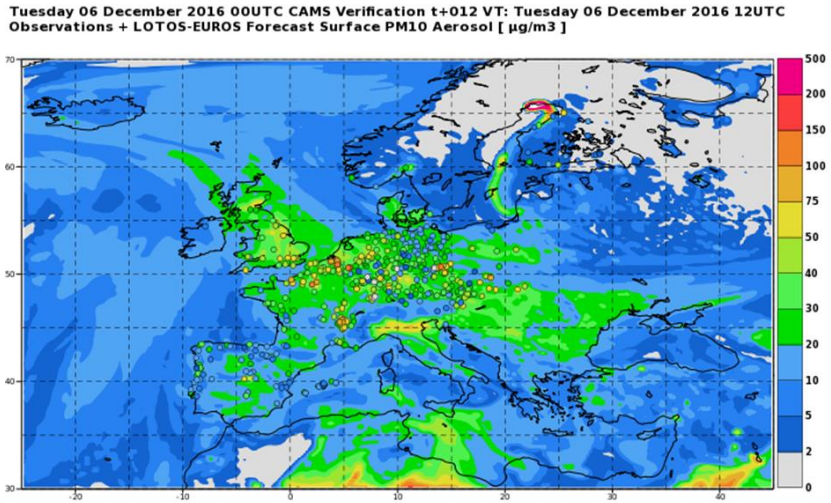
Policy tools

National Environment Agency: Where did PM_{10} come from during the latest pollution event?





CAMS policy tools

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

Emissions

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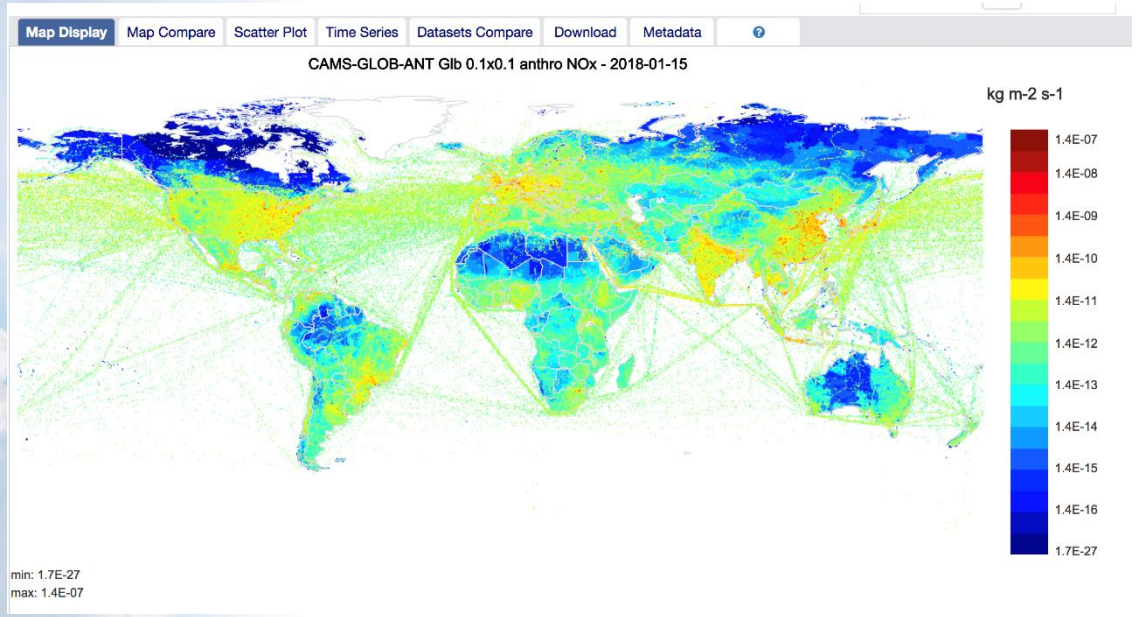
Air quality forecaster: Where do I get consistent up-to-date emission data sets?

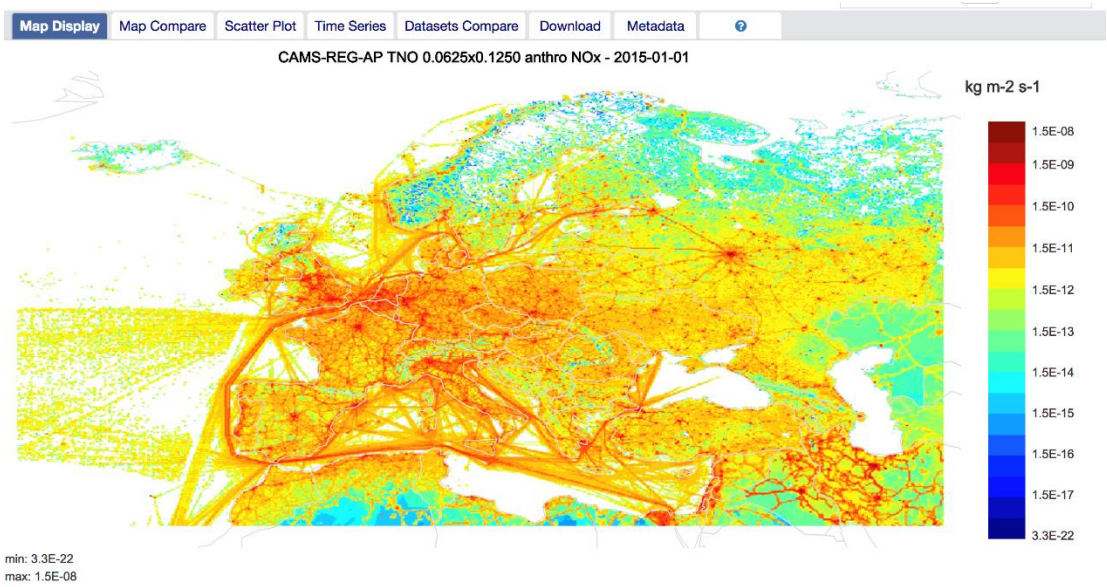


CAMS global emissions

- Anthropogenic emissions
- Ship emissions
- Natural emissions
- Biogenic emissions
- Volcanic emissions

CAMS regional emissions

- European anthropogenic emissions - air pollutants
- European anthropogenic emissions - greenhouse gases



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Climate monitoring

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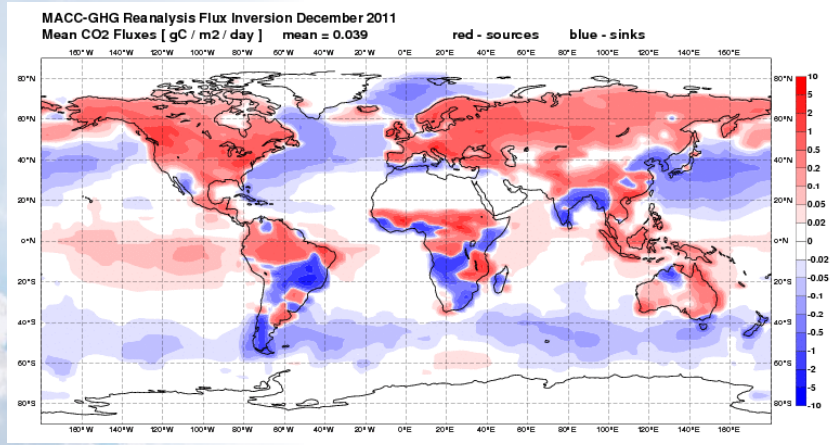
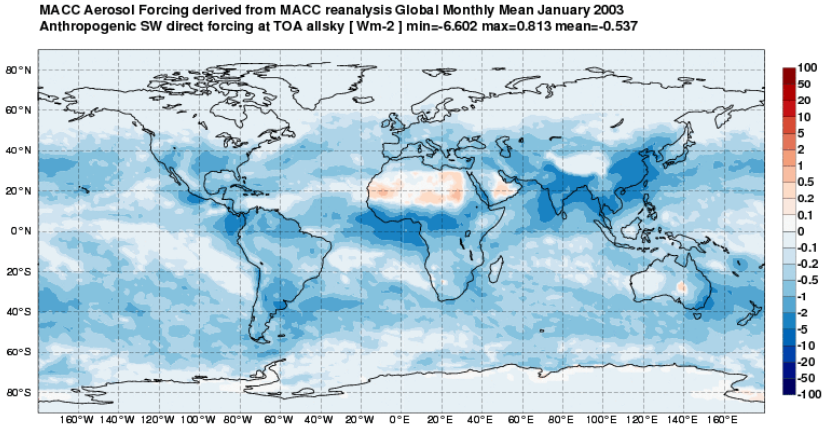
Scientist: what has been the impact of greenhouse gases and aerosol on the Earth's climate over the last few decades?





CAMS greenhouse gas flux estimates

- CO_2, CH_4 and N_2O
- Decadal time series

CAMS radiative forcing

- Aerosol-radiation radiative forcing based on global reanalysis
- Aerosol-cloud radiative forcing based on global reanalysis
- Radiative forcing of CO_2 and CH_4 based on global reanalysis
- Radiative forcing of tropospheric and stratospheric O_3 based on global reanalysis

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CAMS Portfolio

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Portfolio	Product groups
A. Regional products	Real-time analyses
	Real-time forecasts
	Interim annual reanalyses
	Annual reanalyses
B. Global products	Real-time analyses
	Real-time forecasts
	Reanalyses
C. Supplementary products	Policy support products
	Solar radiation
	Greenhouse gas flux inversions
	Climate forcings
D. Emissions products	Anthropogenic emissions
	Fire emissions
	Natural emissions

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

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Documentation & validation

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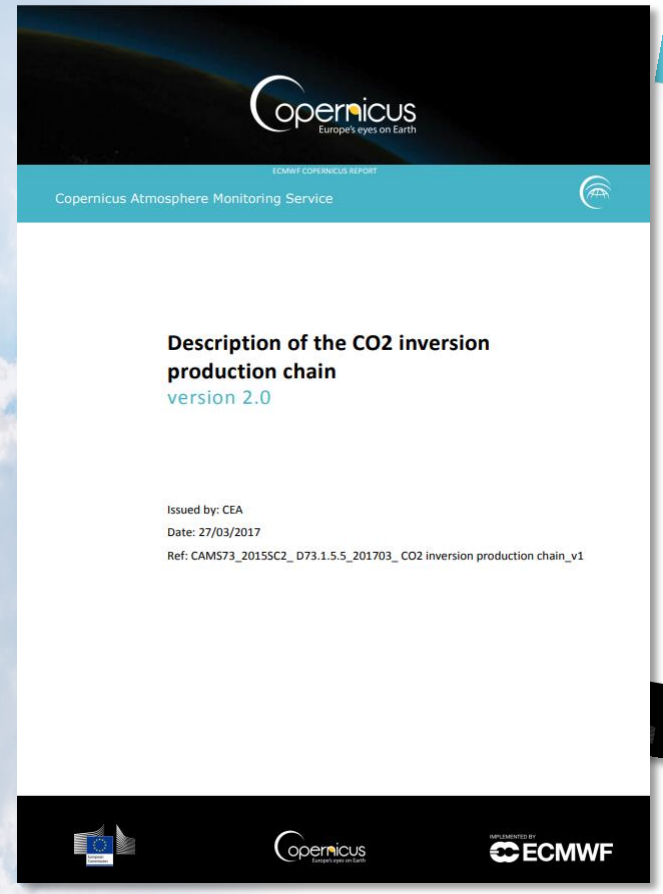

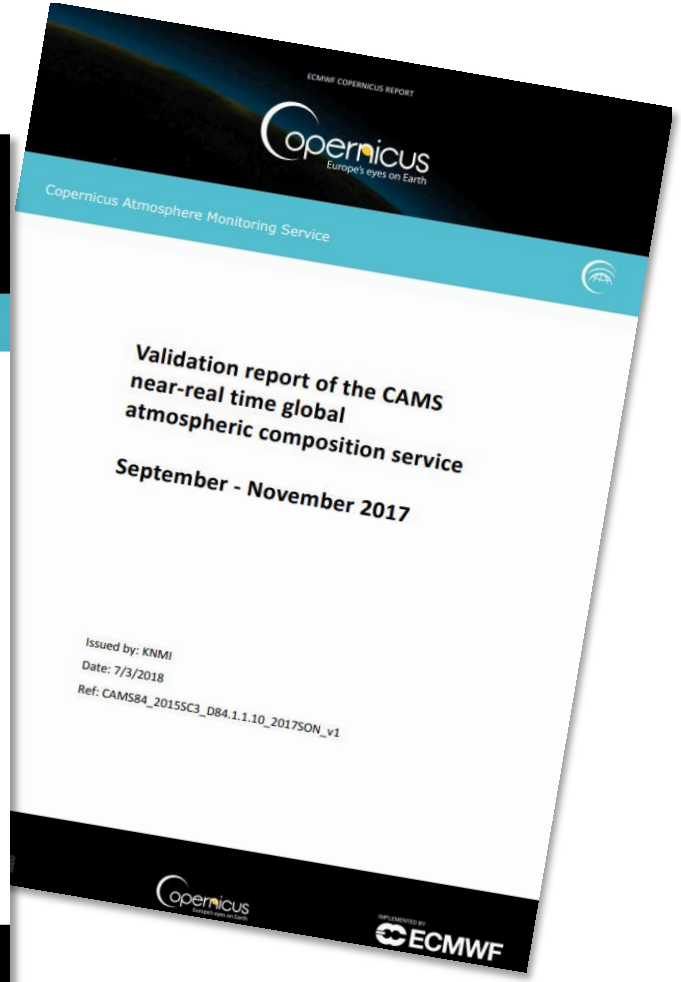

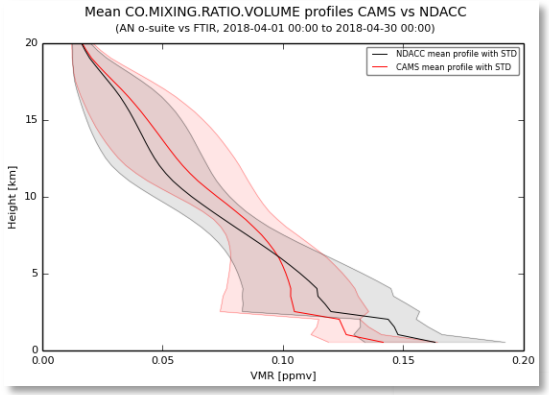

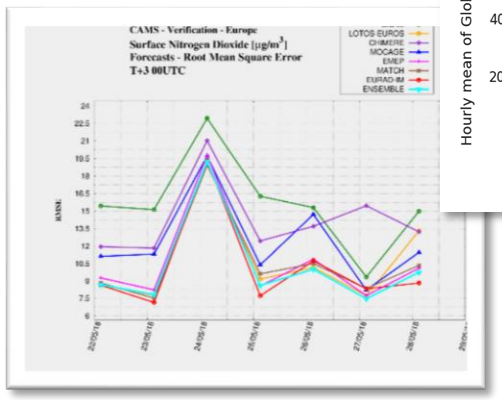

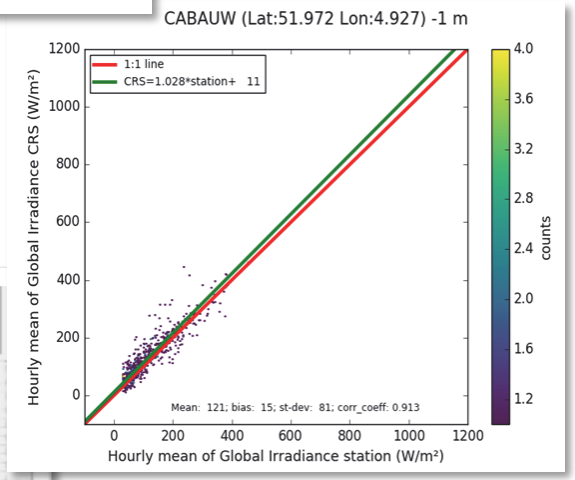

CAMS provides detailed information about how its products are produced and how good the quality is.

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Accessing the Products

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ABOUT CAMS | NEWS & MEDIA | EVENTS | CATALOGUE | RESOURCES | TENDERS | USER SUPPORT

Search

Reset

PRODUCT FAMILY

- [x] 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
- [x] Reactive gas
- [ ] Radiation
- [ ] Fire

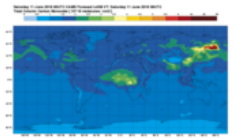
PARAMETER

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

CURRENT FILTERS:

× Product family: Global forecasts × Pa

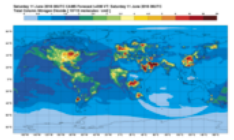
Total results: 5



Global for chemical monoxide

This service prov chemical species observations

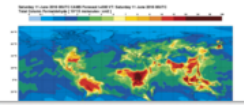
Parameter: Car



Global for chemical dioxide

This service prov chemical species observations

Parameter: Nitr

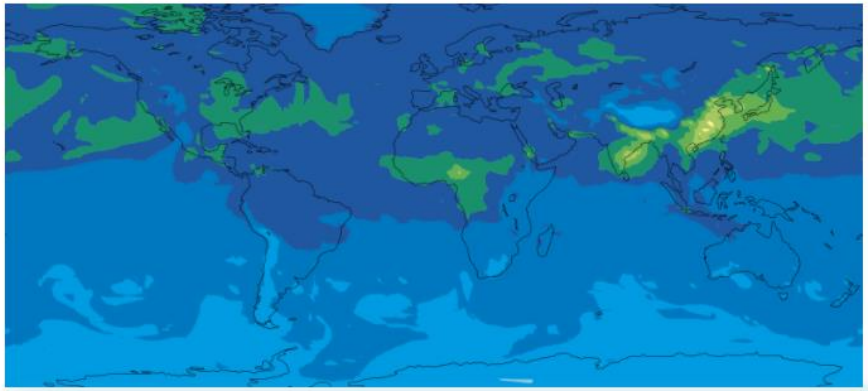


Global forecasts of assimilated chemical species - formaldehyde

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

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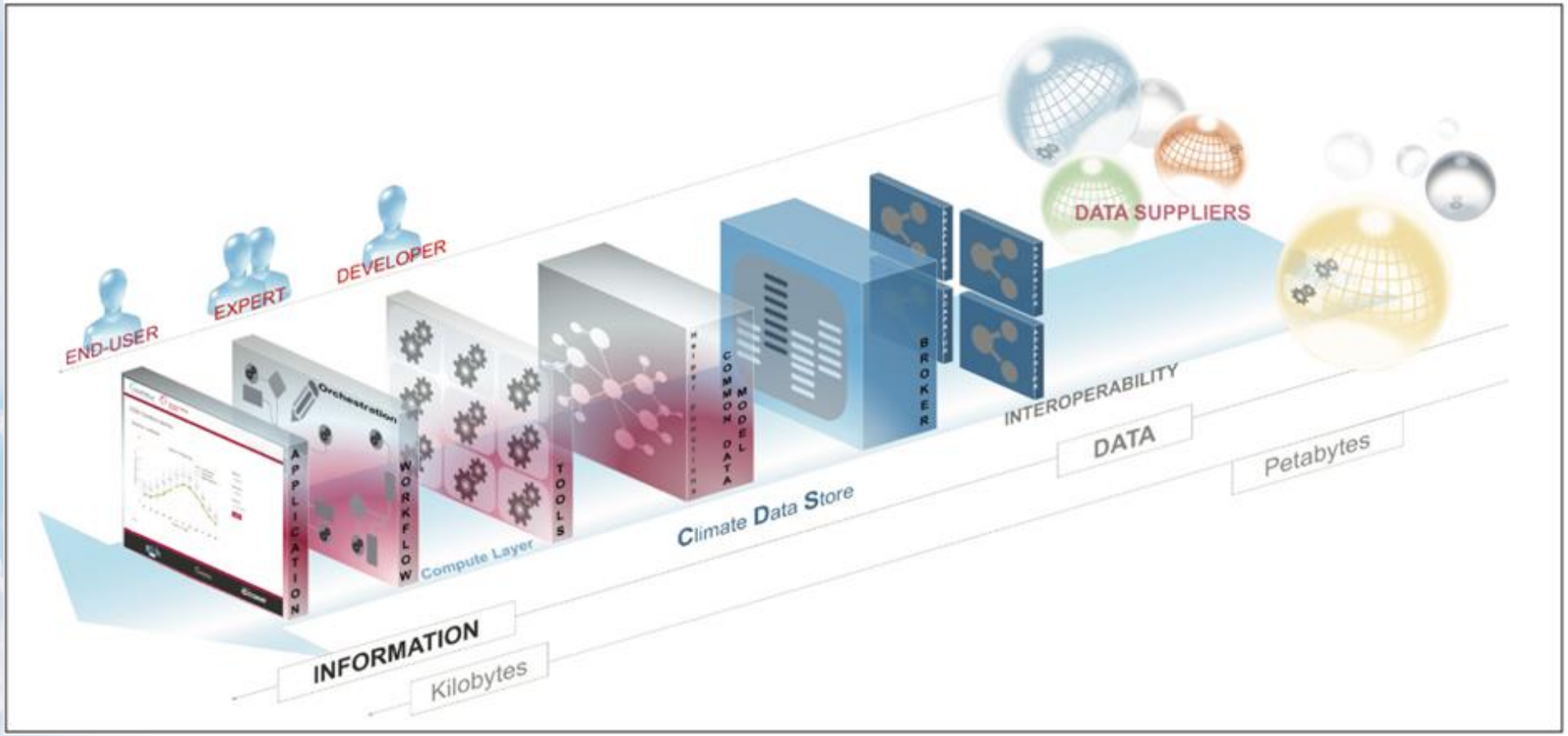
Looking forward: Data Platforms



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.

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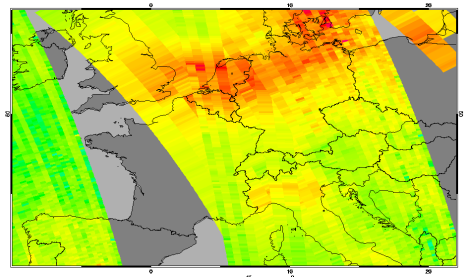
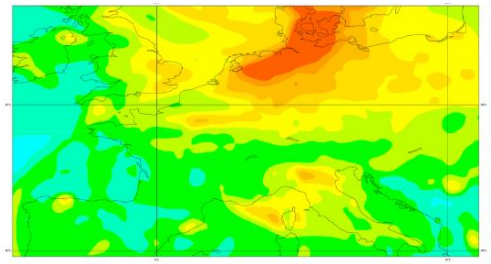
To summarize

Atmosphere Monitoring Service

atmosphere.copernicus.eu





User-driven

Free and unrestricted data access

Making observations more meaningful to you

Provide information for past, present and future

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How CAMS data is used

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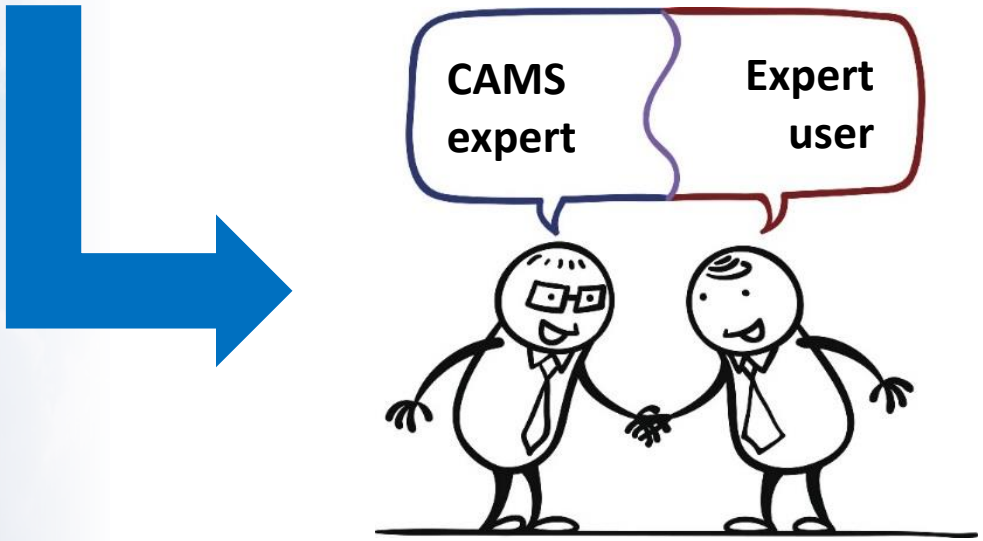
CAMS: big data for local applications

CAMS provides big data with the corresponding technical and scientific expertise to support expert users.

In doing so, we allow the CAMS information to reach millions of users in and outside Europe.



Downstream applications

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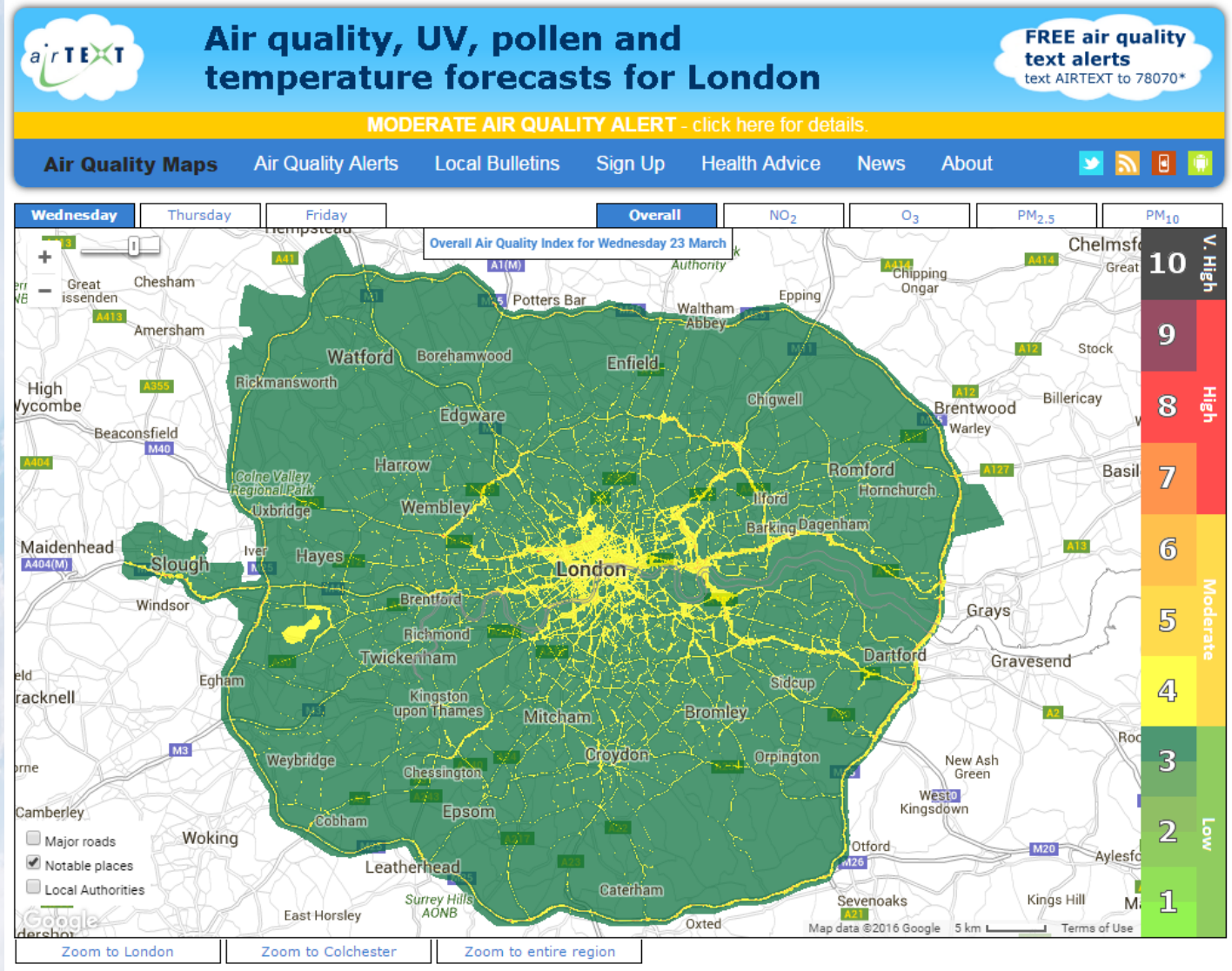

Free air pollution, UV, pollen and temperature forecasts for Greater London and the South East.

Local forecast models need information on how much pollution flows into and out of the domain to provide an accurate service.
This is provided by CAMS European air quality forecasts.

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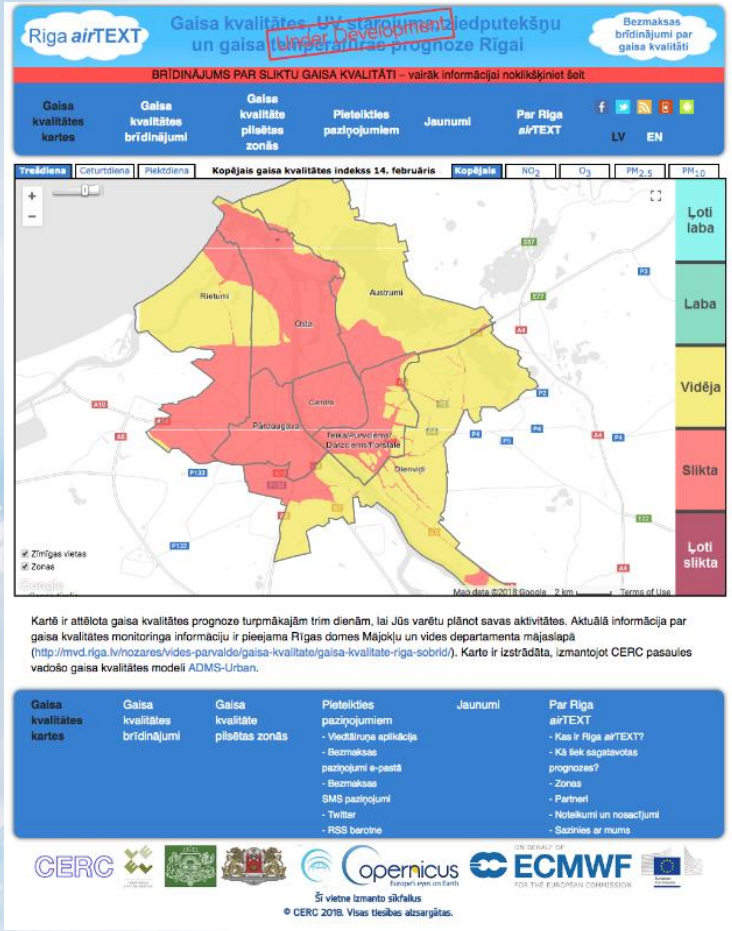
airTEXT: Business model



AirText Riga

Business model

- The service is free for its users, citizens in the city or region (e.g., 15,000 subscribers in London)
- The city or region authorities pay a set-up fee followed by an annual maintenance fee
- The public economic benefit from the investment in airText comes from improvements to health and well-being in Riga.
- airText brings wider public awareness of air pollution and therefore helps to build public support for action to improve air quality.
- airText will directly enable users with particular vulnerabilities to better manage their health conditions.

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Mon Toit Solaire

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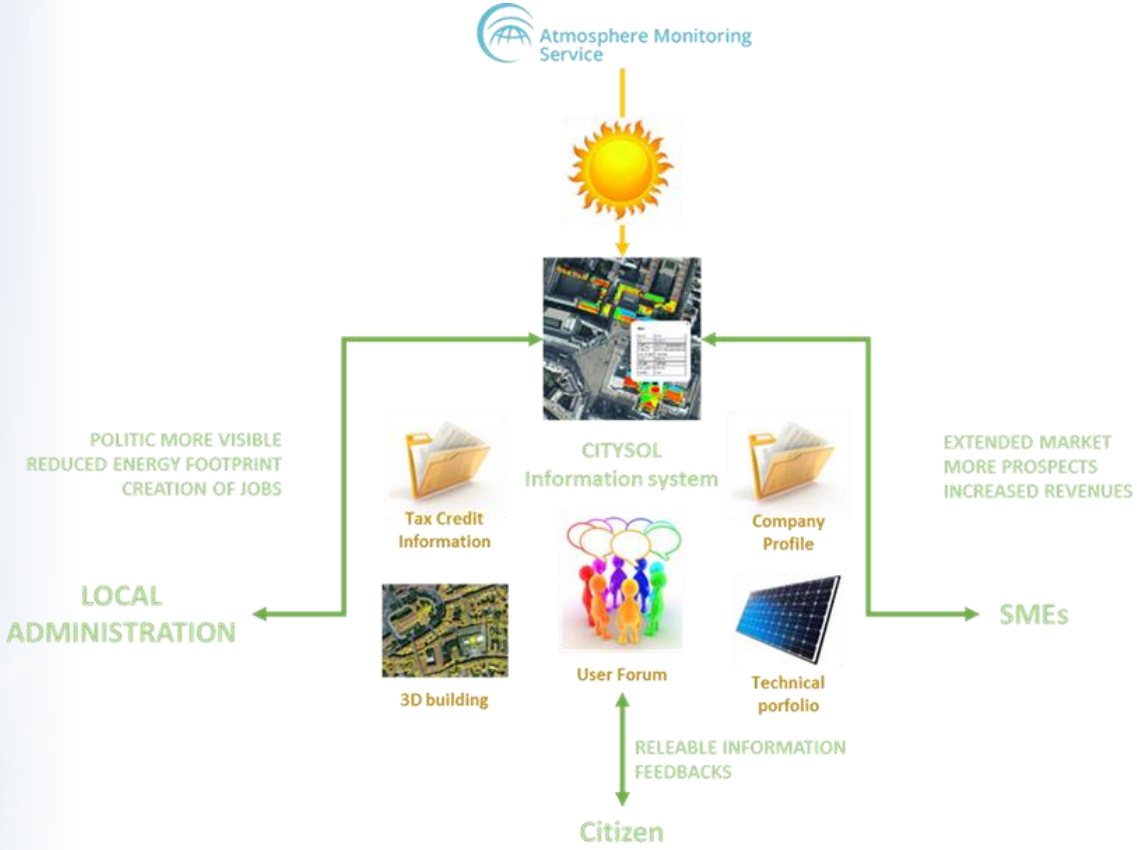

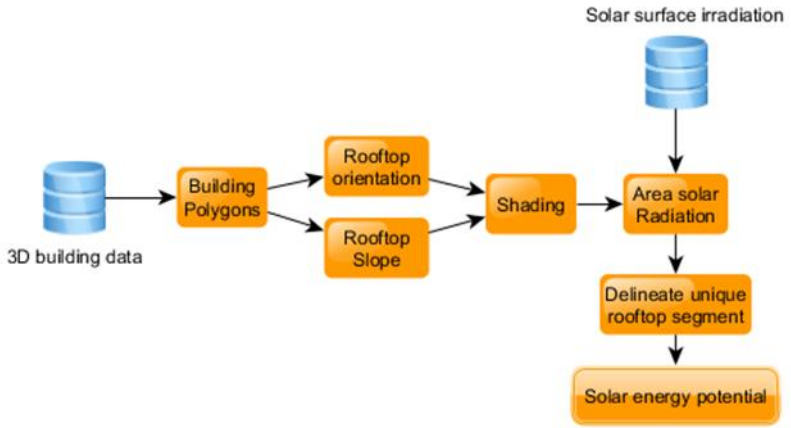

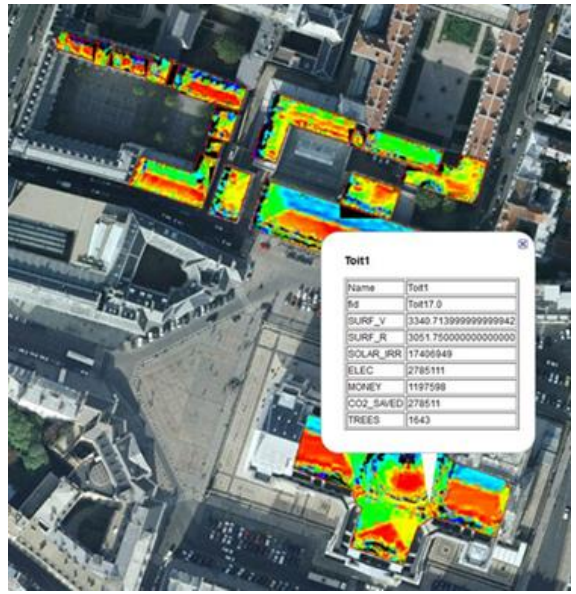

Mon Toit Solaire provides a web-based decision support system for the development of rooftop photovoltaic solar panels.

CAMS provides the satellite-based time series of available solar radiation for the specific location, taking into account the amount of clouds and aerosols.

Mon Toit Solaire: Business model

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Business model:

- Free for users (landlords, citizens)
- City authorities pay set-up and maintenance fees
- Local PV installers pay a broker percentage for being included in the service web site

- Stimulate the use of solar PV panels on rooftops in the city as part of green energy strategy

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ATMOSYS - CAMS

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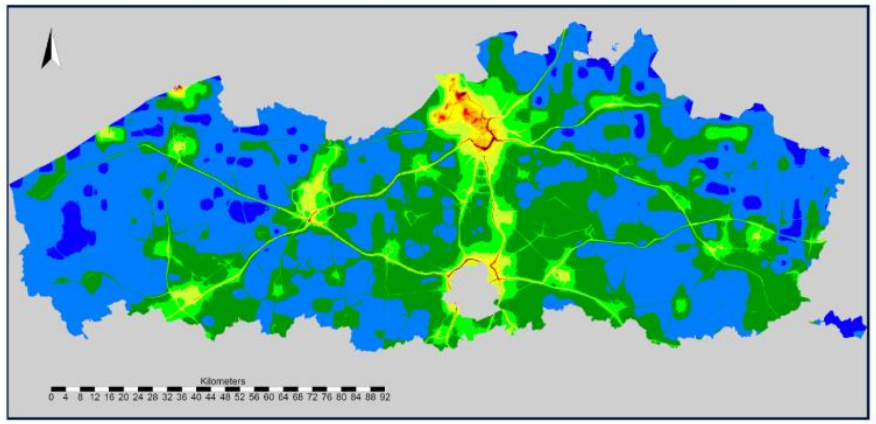
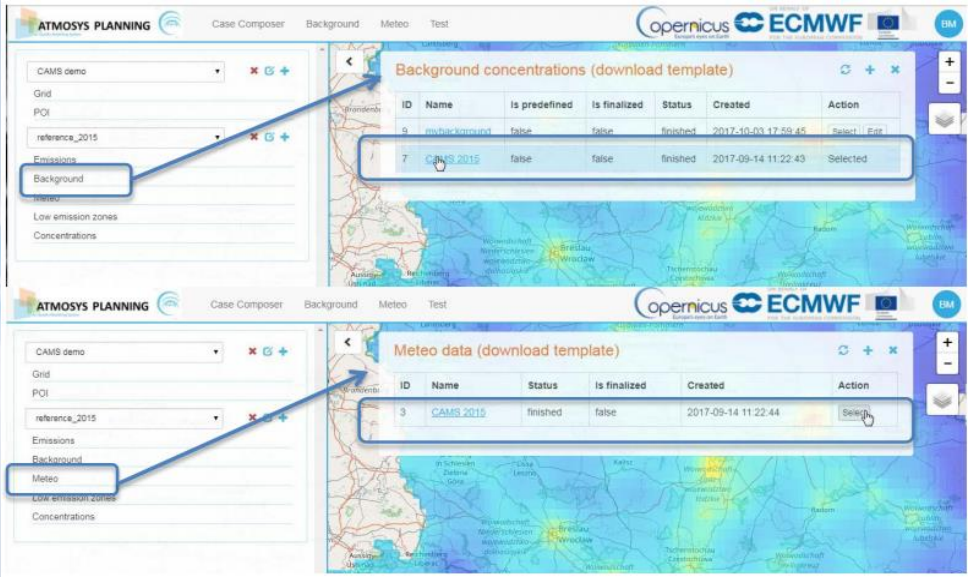
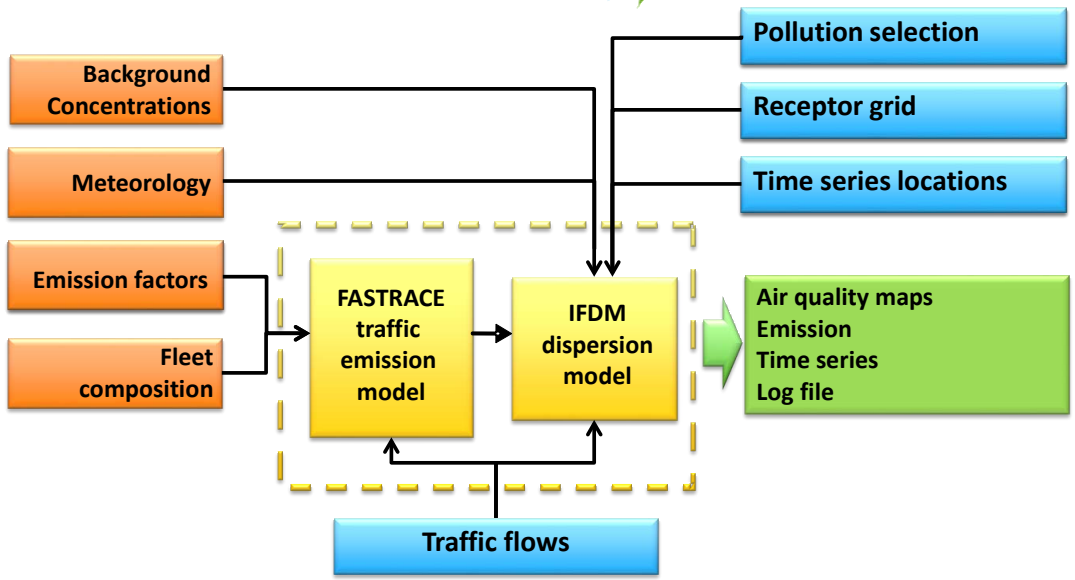


2015 - jaargemiddelde NO_2 ($\mu g/m^3$)





VITO developed a web application for the Flemish Environmental Agency to calculate road traffic emission scenarios in support of regional air quality management.

Using CAMS European air quality reanalysis data, they can much easier implement their service in other parts of Europe.

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ATMOSYS-CAMS: Business model

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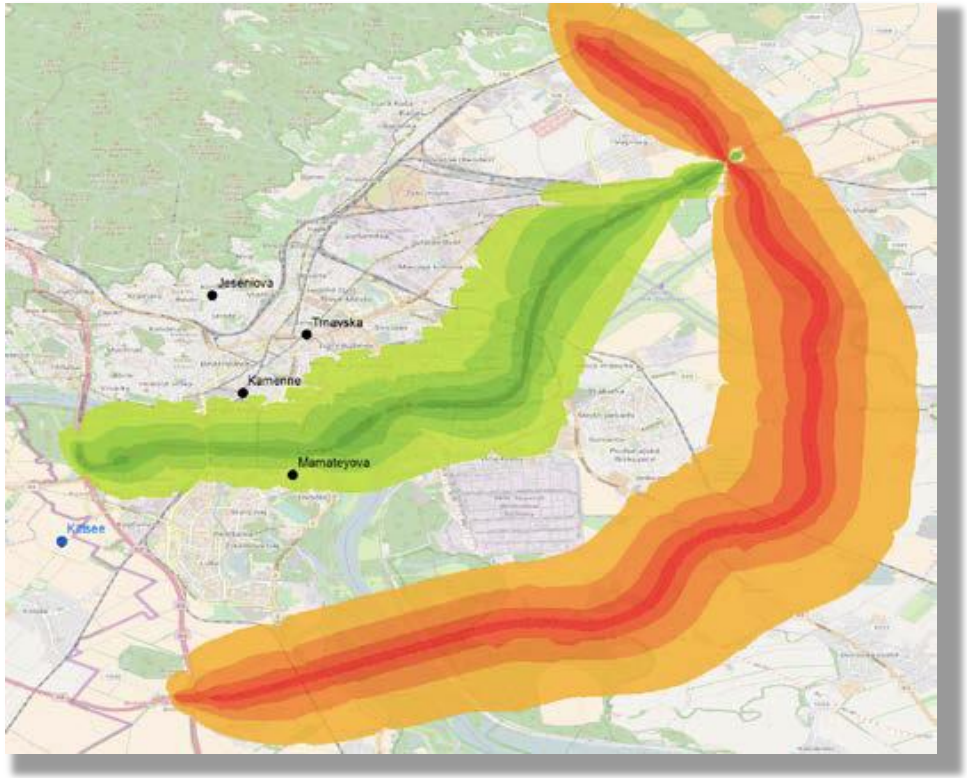
Business model:

- Users: national and regional governmental environmental agencies that do not have sufficient tools required to assess and report on air quality and evaluate planning and local emission reduction scenarios
- Over the past 6 years the application has been used for 40 studies by various Flemish agencies
- Extended service is now being tested and promoted in Slovakia, Poland, Italy and Portugal. Outcome will determine pricing model.

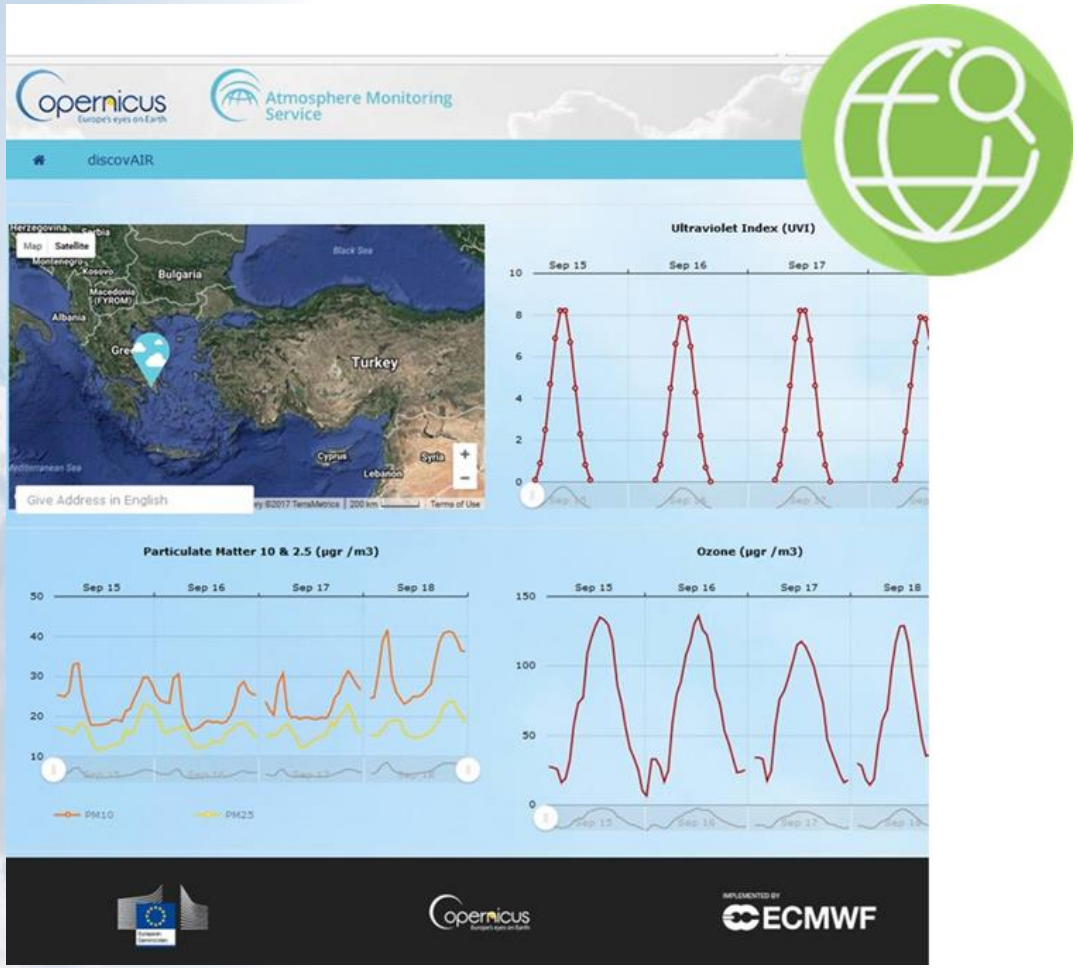


Example of impact of new bypass road on NO2 levels in Bratislava

DiscovAIR

Atmosphere Monitoring

NATIONAL OBSERVATORY OF ATHENS
more than 170 years contribution to research and society



DiscovAir
powered by Copernicus

Based on the weather and other environmental conditions, DiscovAir provides location-specific, personalised advice and alerts for comfort and health.
DiscovAir enhances your trips, travels and days out.

CAMS European air quality forecasts are used to provide the up-to-date information on air pollution, pollen, UV and dust.

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DiscovAIR: Business model

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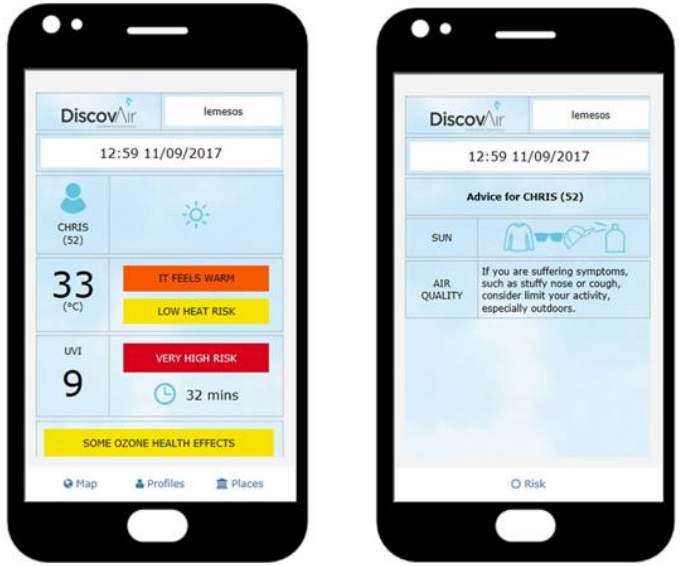
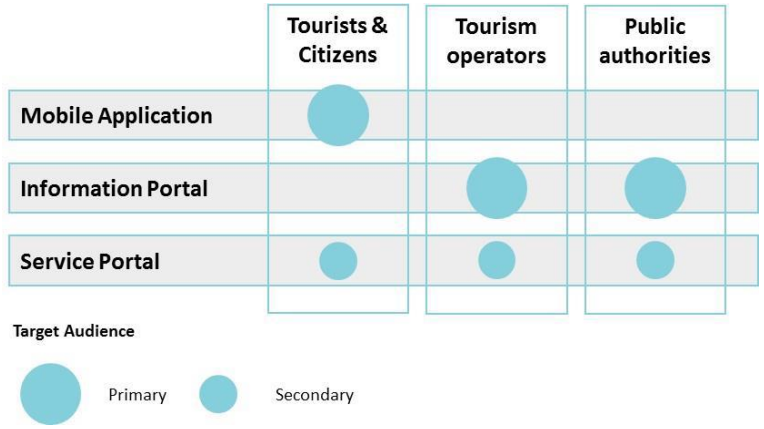
Business model:

- Users: tourists & citizens, tourism operators and public authorities
- Revenues through e.g., premium version of smartphone app and advertising on mobile and web apps.
- Intention to expand the product beyond the borders of Greece and Cyprus. The service can be applicable to all EU countries and beyond; this is ensured through the utilisation of CAMS products.





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PASYFO

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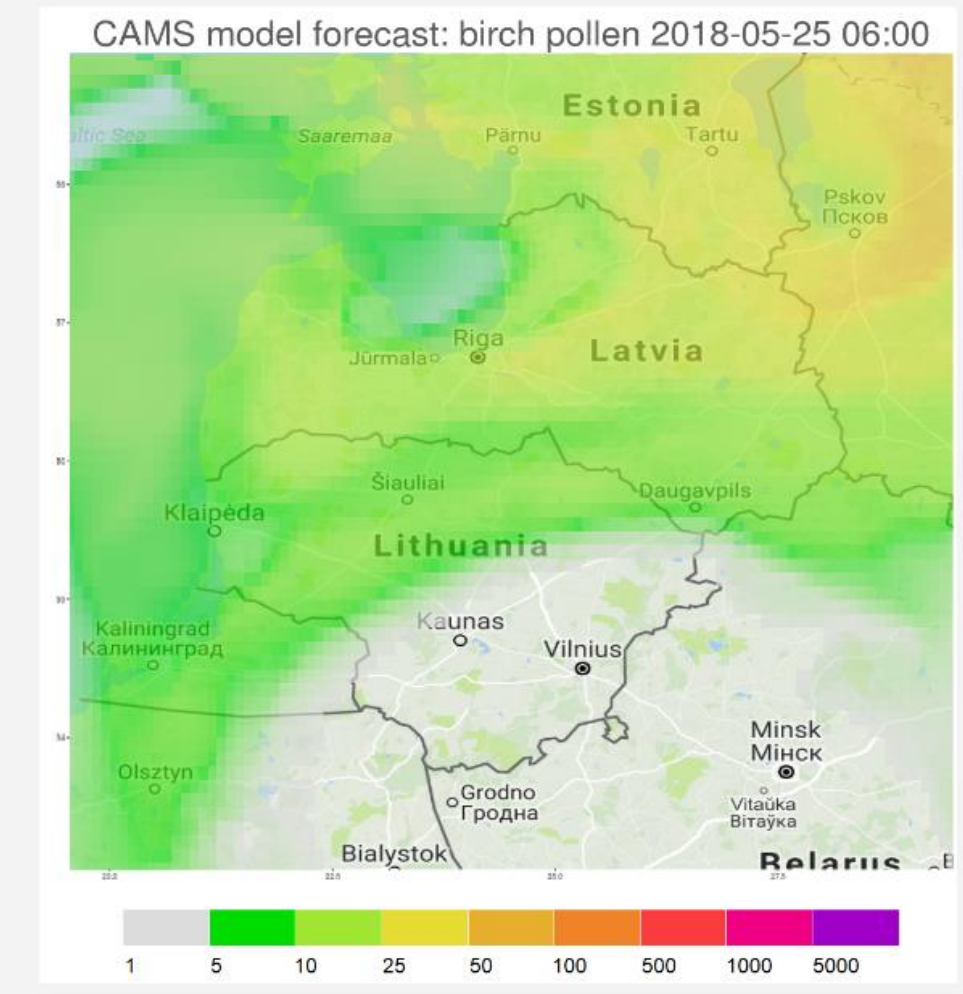

The aim of PASYFO is to provide a high-resolution regional system for predicting the personal allergy symptoms of pollen-sensitive people using personalised sensitivity information.

CAMS European pollen forecasts are used to provide the up-to-date information on pollen for the European domain.

CAMS Use Cases

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- **PRINCIPLE**: Based on market analysis, the Use Case will develop and demonstrate end-to-end applications (product, software or service) based on CAMS products.

- **OBJECTIVE**: Stimulate innovative ideas and support the development of downstream applications.

- **SELECTION CRITERIA**:
  - innovative use of one or more CAMS products,
  - the sustainability of the application business plan,
  - the potential for increasing the use of CAMS services and reaching out to wider communities,
  - the quality and value for money of the proposals.

- **Expected SCOPE and IMPLEMENTATION of USE CASE** :
  - cover a single application (tenderers may submit other separate proposals covering other applications) using 1 or more CAMS products
  - design and development phase (duration between 3 and 6 months);
  - market trial phase (duration between 12 and 24 months)
  - Max. price: 95kEUR (additional in-kind contributions possible)

Multiplication factors

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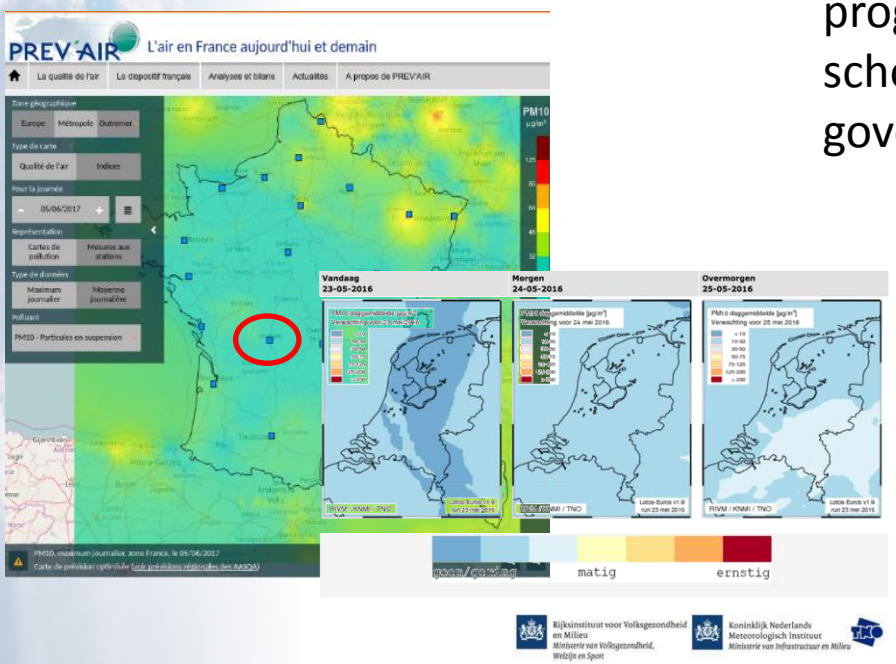
Plumelabs

~ 500,000 downloads

Part of the Australian SunSmart programme, working with schools, workplaces, and local governments.

Euronews

~ 9 million viewers in December 2017



National AQ forecasts

Millions of viewers

The success of CAMS relies on the success of the downstream applications.

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Looking ahead – CAMS post-2020

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THE CONTEXT

Four main aspects to take into account:

- The planned evolution of the Copernicus Space Infrastructure: Sentinel-4 (2022…), Sentinel-5 (2023…)
- Its further evolution: proposed CO_2 mission “Sentinel-7”…
- CAMS outstanding expressed User Requirements
- Mid-term review, surveys & economic impact analysis (PwC…)

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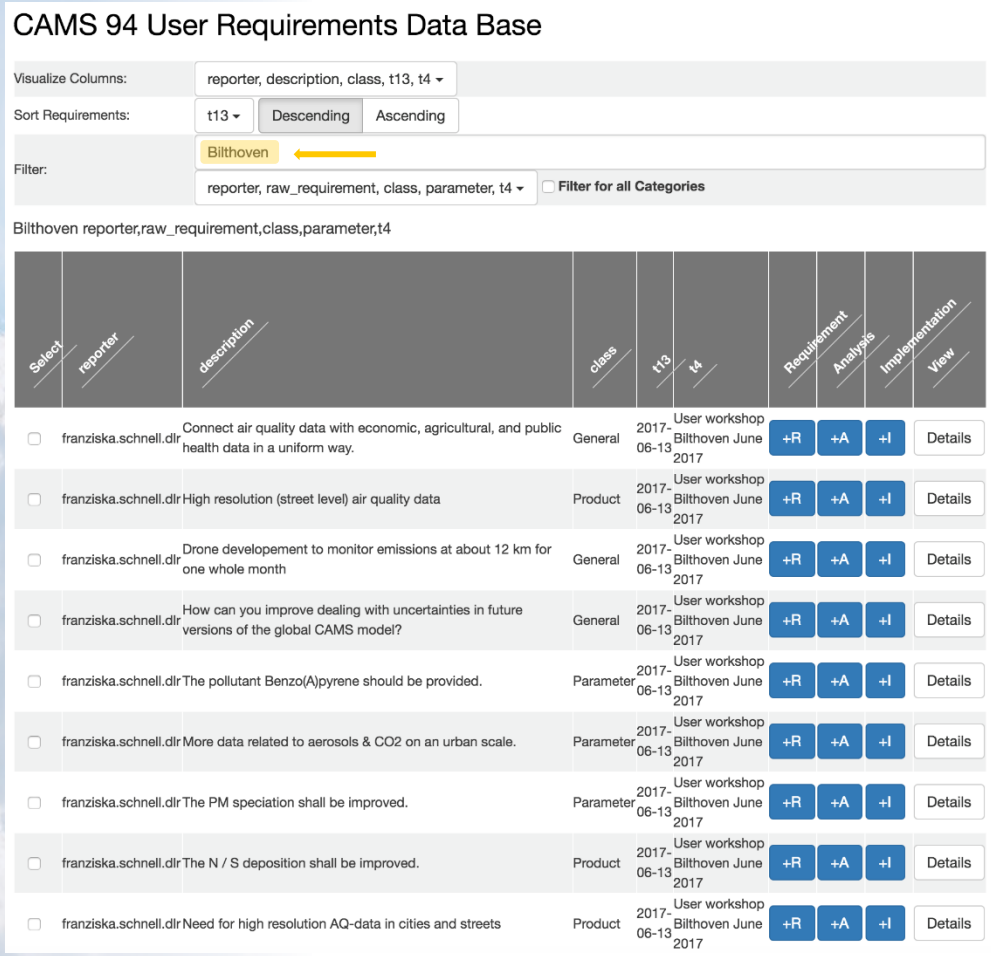
HOW DO WE KNOW WHAT USERS NEED?

The CAMS User Requirements Database:

- Main objective is to ensure detailed traceability
- Residual requirements from precursor projects have been loaded and new requirements are continually added (user events, service desk…)



URDB

Similar requirement	Number repeated
Provide high spatial resolution AQ data	10
Provide sub-setting / OGC interfaces for download (regional)	9
Extend historic length of reanalysis	6
Provide regions, cities source apportionment	5
Accompany atmospheric composition with meteorological data	5
User forum	5
User survey / online questionnaire	5
Provide uncertainties with the data	4
Provide daily AQ forecasts earlier in the morning	4
Provide interim reanalysis earlier	4
Provide multi-annual regional air quality datasets	4

Analysis

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OUTLINE

- **Improve global products**
  - **reliable air quality information anywhere on the planet**
- **Improve regional products**
  - **local air quality and exposure information anywhere in Europe**
- **(Near-Real-Time) anthropogenic emissions monitoring**
- **Deposition fluxes**
- **Past & Future Air Quality**
- **New Copernicus CO_2 service**

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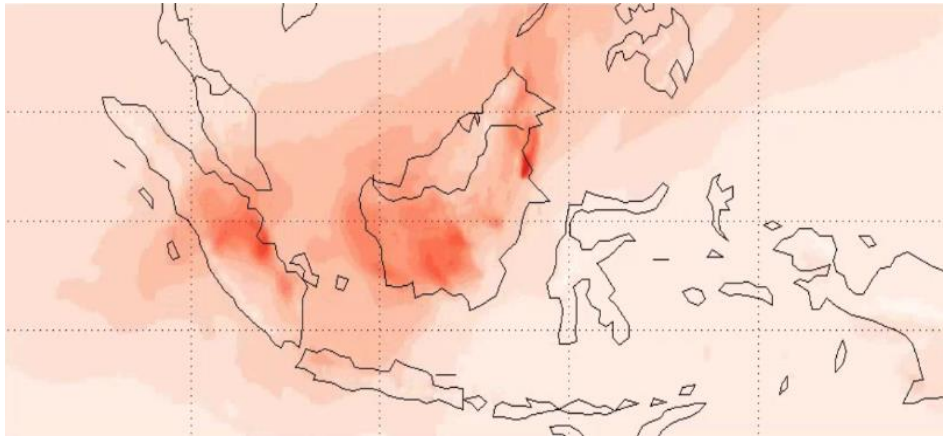
REFERENCE INFORMATION WORLDWIDE

Users demand **higher resolution** to enable Air Quality and solar applications **anywhere** on the planet.

Users demand **uncertainty** information.

S-5 (and S-4 over Europe) will **strengthen** atmospheric composition operational capabilities.



WMO WHO

- Higher global resolution (scale of hot spots / megacities) in order to feed directly local air quality applications
- Global cloudy sky solar radiation using geostationary instruments and model in between (monitoring and forecasts)?
- Estimate uncertainty with each product: single model with perturbations? Model with different chemical packages? Ensemble of Data Assimilation? Statistical perturbation schemes (emissions, parameters…)?

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ENHANCE REGIONAL PRODUCTS

Sentinel-4 is a **game changer** for European Air Quality .

Users demand **uncertainty** information.

Plant species	Popular name	Allergenicity of Pollen		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Corylus	Hazel bush	Moderate to high	TREES												
Alnus	Alder	Moderate to high													
Cupressaceae	Cypress, Juniper	Moderate													
Populus	Poplar	Low													
Acer	Maple	Low to moderate													
Salix	Willow	Low													
Fraxinus	Ash tree	Moderate to high													
Betula	Birch	Very high													
Carpinus	Hornbeam	Low to moderate													
Platanus	Plane tree	Moderate to high													
Juglans	Walnut tree	Low to moderate													
Quercus	Oak tree	Moderate													
Morus	Mulberry	Insufficiently studied													
Fagus	Beech tree	Low to moderate													
Tilia	Linden	Very low													
Dactylis	Cocksfoot		GRASS												
Poaceae	Grass	Very high													
Triticum	Wheat	Moderate to high													
Cannabaceae	Cannabis, hop	Low	WEEDS												
Plantago	Plantain	Low to moderate													
Rumex	Sorrel	Moderate to high													
Urticaceae	Nettle	Low													
Chenopodiaceae	Cindarella	Low to moderate													
Artemisia	Wormwood	Very high													
Ambrosia	Ragweed	Very high													

- Higher regional resolution? Challenge: getting closer to exposure while respecting downstream sector. “Copernicus to national” uptake support scheme.
- Bigger/better ensemble (dozen models in Europe). Perturbations within each model in the ensemble (cost/benefit)?
- More pollen species

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DEDICATED SCHEME FOR NATIONAL UPTAKE

There's a **deadlock** between:

- the agreed "boundary" between CAMS and downstream air quality applications in Europe (no higher resolution than 8-10km);
- the strongly expressed requirement by several national environment agencies to be able to use CAMS very directly (higher resolution please!).

Vision: the national official air quality forecast information in "all" EU MS is based on CAMS products and benefits from support/coordination from CAMS

Proposed **solution**:

- set-up a scheme similar to the use cases (CAMS_95) so that targeted downscaling developments can be supported in each EU country without making it a CAMS service component.
- Build a "contract" with each Member State's agency in charge of Air Quality management to define appropriate downscaling chain (depends strongly on local context/expertise –no one-for-all solution). Scientific & technical support provided by CAMS. Of course, MS can decide to delegate contract to private sector.

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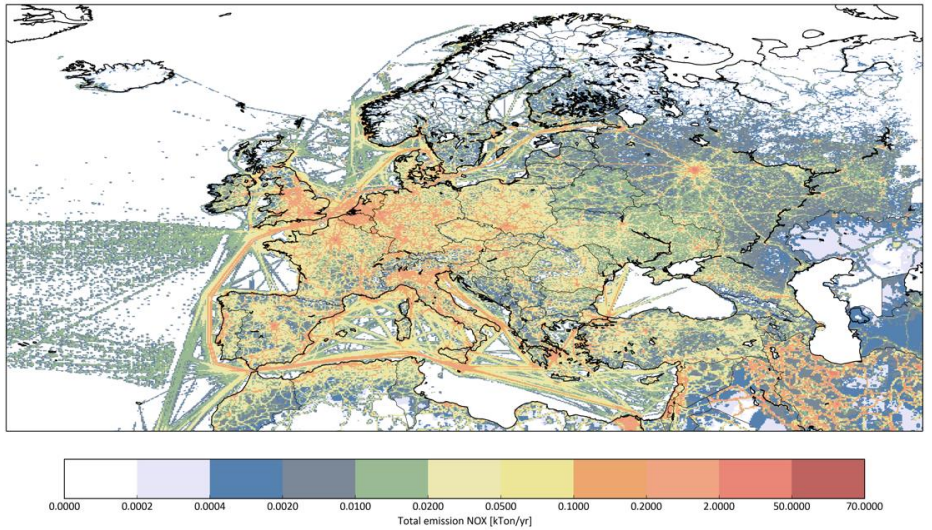
EMISSIONS MONITORING

The **quantification of emissions** is crucial for monitoring the effectiveness of abatement strategies (short- to long-term) and consolidating bottom-up reported estimates.

Hourly NO_2 emissions will (probably) be THE "headline" application for Sentinel-4

Priority (joint with C3S): **CO_2 emissions from fossil fuel combustion**



- Significant methodological developments needed, some common and some specific to the different compounds (e.g. lifetime of species, top-down/bottom-up hand-shaking, combine *in situ*, ground based and satellite)
- Targets: NO_2, anthropogenic CO_2, CO (tracer of all combustion processes)

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DEPOSITION FLUXES MONITORING

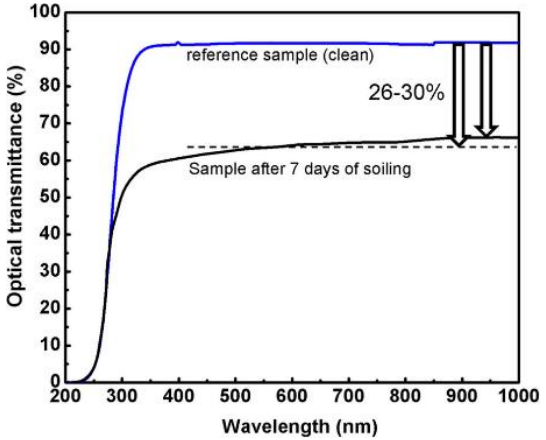
This is a long-standing user demand. Still very much a research area, but **feasible to aim for operations post-2020** (currently = experimental).

A significant number of potential application areas: climate policy, forestry, agriculture/crops, biodiversity, solar panels (soiling)...

Liaison needed with the Climate Change, Land Monitoring and Marine Services

- deposition of NO_x
- deposition of SO_x
- deposition of aerosol (soiling)
- deposition of ozone

Solar energy



Agriculture

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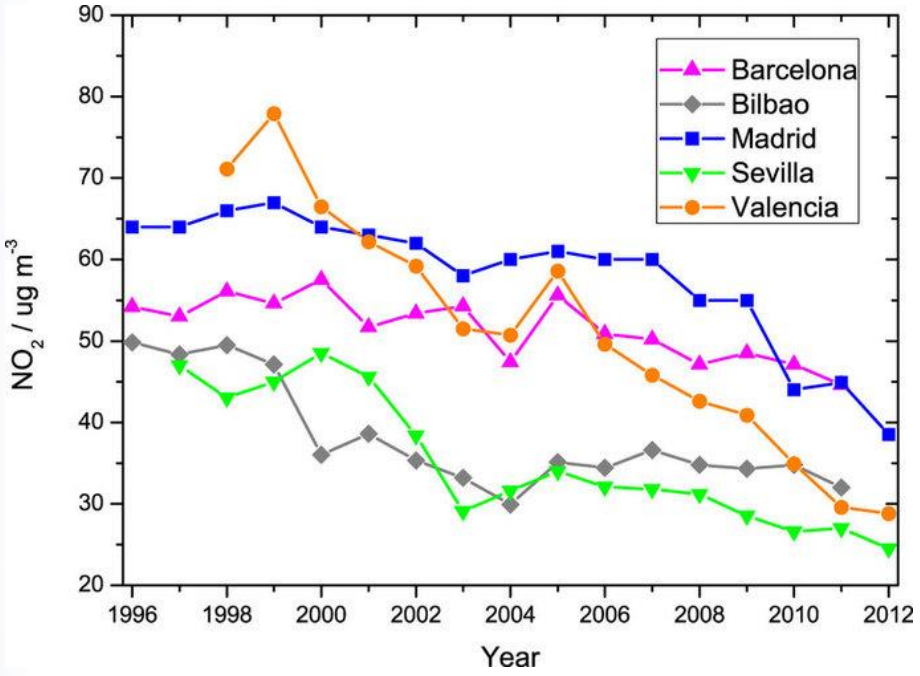
PAST ATMOSPHERIC COMPOSITION

Pre-industrial reference needed for climate forcings

Use of a **different reference** than 18th or 19th century (1980s)?

Past 10/15 years or more is a recurring user requirement (health applications in particular)

Limited by **past observing capacity** for air quality and atmospheric composition



- global pre-industrial 1750/1850s?
- extend CAMS global reanalysis in the past: to 1980's (ozone, AOD) or before (model only)? Joint activity with C3S, including interactive aerosol.
- extend annual CAMS regional reanalyses in the past to ~2000?

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FUTURE ATMOSPHERIC COMPOSITION

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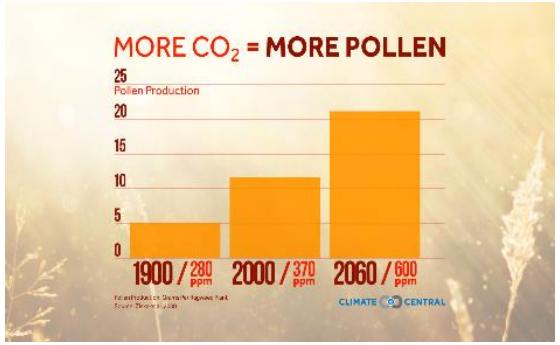
Outstanding user requirements

"Interesting" horizons could be **2030's** (emissions reduction target), **2050's** (climate has changed) and **2080's-2100's** (climate has changed further)

Largely same infrastructure as for current global and regional products but **future climate projections needed** (incl. emissions)

- global future "time slices"
- regional future "time slices"
- would feed several C3S Sectoral Information Systems (health, energy…)



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Copernicus Monitoring and Verification Support (MVS) capacity

Precision & Accuracy

Detection of emitting hot spots such as megacities or power plants

Monitoring the hot spot emissions to assess emission reductions of the activities

Assessing emission changes against local reduction targets to monitor impacts of the NDCs

Assessing the national emissions and changes in 5-year time steps to estimate the global stock take

Spatial and temporal resolution

Implementation of CO_2 MVS

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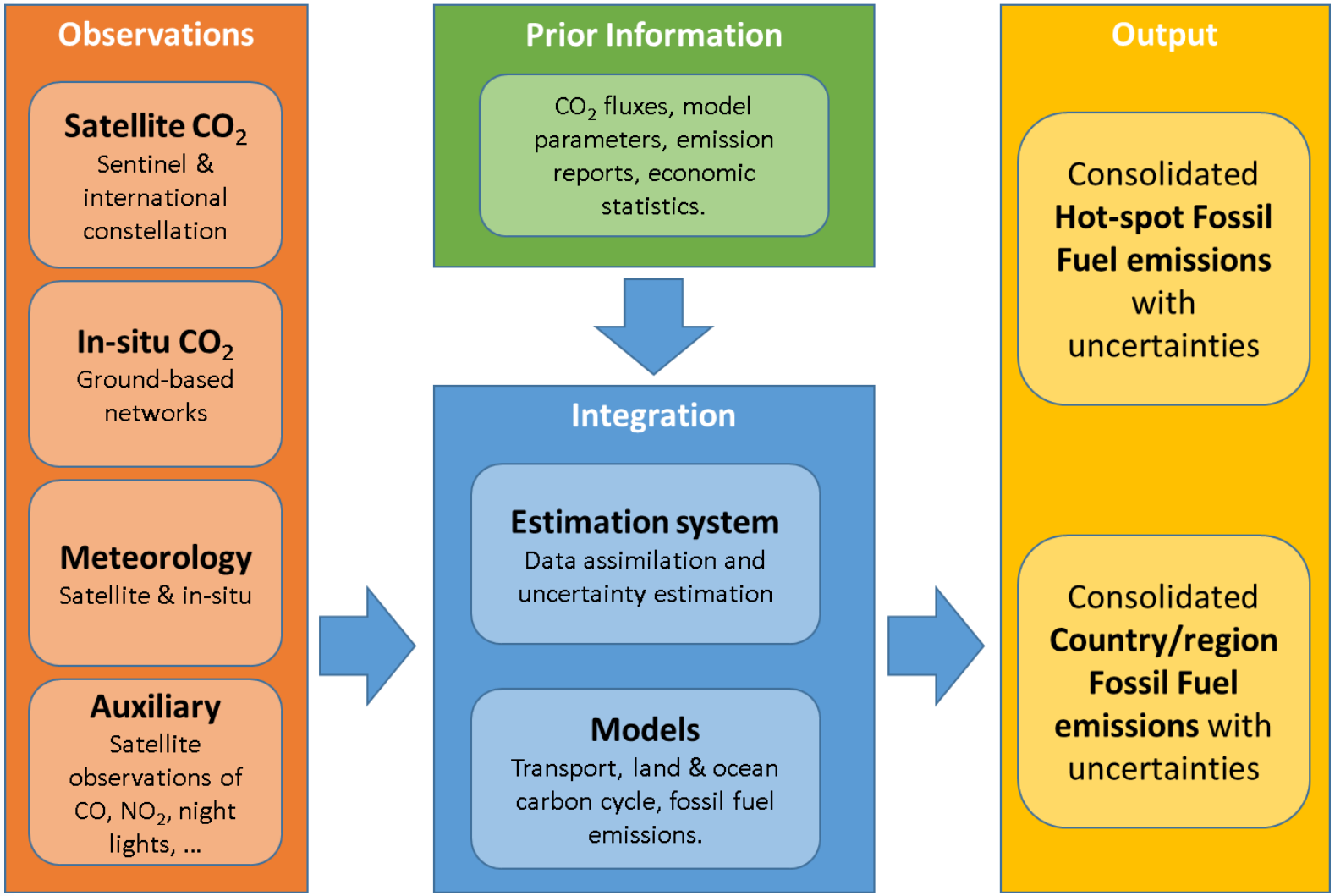

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Expected timeline of service development

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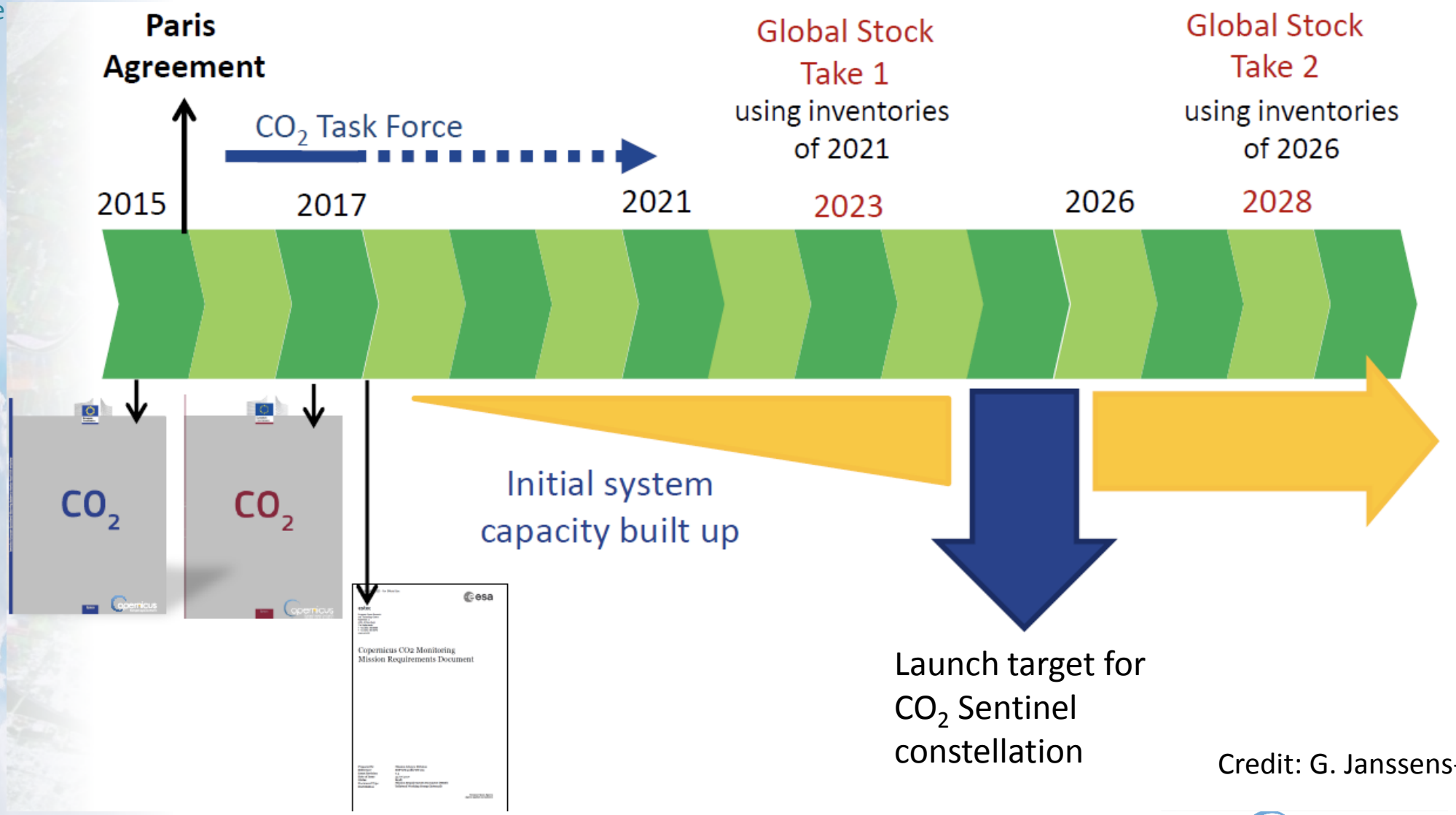

Credit: G. Janssens-Maenhout

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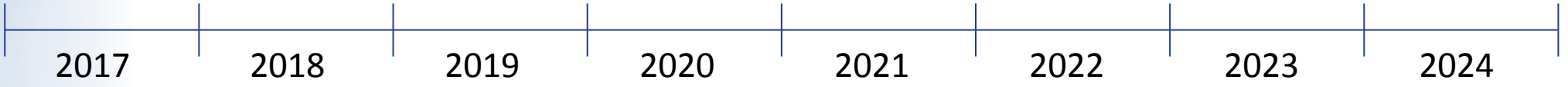
Towards an operational service

International context: IG3IS, GEOCARBON...



CHE (H2020; lead: ECMWF)

H2020 Call SPACE-5-EO-2019
(ambition: ECMWF lead)

CO_2 pre-operational service

VERIFY (H2020; lead: CEA; ECMWF in charge of "blueprint" of the operational system)

? Supporting R&D effort (FP9)

+ other relevant R&D projects (H2020 and nationally funded)

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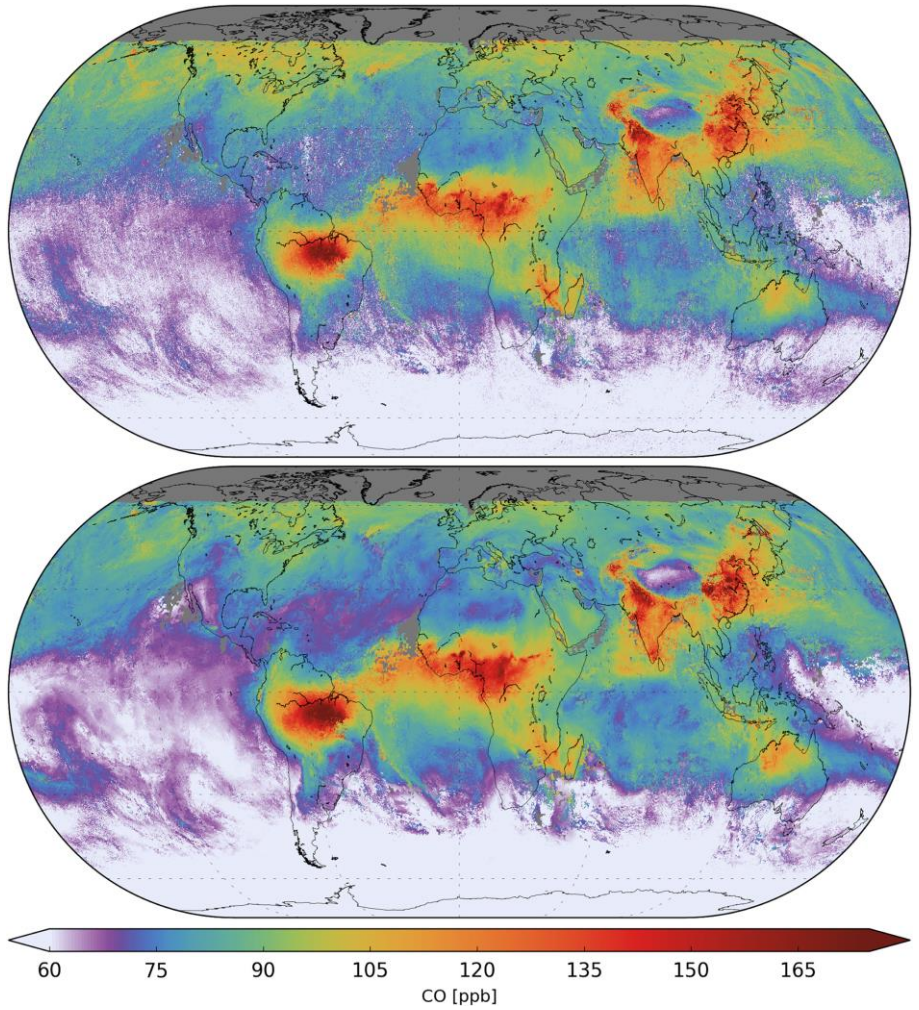
Back to the present

Borsdorff et al.,2018



Sentinel-5p is the first Sentinel mission that will be used in CAMS.

Unprecedented spatial resolution and accuracy will improve CAMS forecasts and open up new opportunities to get a better handle on air quality issues.

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