Delivering MACC data
What have we learned?

Miha Razinger

Cihan Sahin, Richard Engelen and Xiaobo Yang

Copernicus Climate Data Store workshop
3-6 March 2015

MACC-III is the precursor of the **Copernicus Atmosphere Monitoring Service** and it's the fourth in a series of FP6, FP7 and Horizon 2020 EU R&D projects (since 2005).

The main aim of the series of projects was to develop pre-operational services in the wider field of **atmospheric composition**, which meet the needs of users.

It is coordinated by ECMWF and the consortium comprises 36 partners from 13 countries.

|	
ECMWF	European Centre for Medium-Range Weather Forecasts
EC-DG-JRC	European Commission - Joint Research Centre
EAA	Umweltbundesamt GMBH
BIRA-IASB	Institut d'Aéronomie Spatiale de Belgique
FMI	Ilmatieteen Laitos
ARMINES	Association pour la Recherche et le Développement des Méthodes et Processus Industriels
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
CERFACS	Centre Européen de Recherche et Formation Avancée en Calcul Scientifique
CNRS	Centre National de la Recherche Scientifique
INERIS	Institut National de l'Environnement Industriel et des Risques
MF-CNRM	Météo-France
UPMC	Université Pierre et Marie Curie - Paris 6
DLR	Deutsches Zentrum für Luft - und Raumfahrt e.V.
DWD	Deutscher Wetterdienst
IUP-UB	Universität Bremen
JÜLICH	Forschungszentrum Jülich GMBH
MPG	Max Planck Gesellschaft zur Förderung der Wissenschaften e.V
RIUUK	Rheinisches Institut für Umweltforschung an der Universität zu Köln e.V
ULEI	Universität Leipzig
AA	Academy of Athens
AUTH	Aristotelio Panepistimio Thessalonikis
NUIG	National University of Ireland, Galway
KNMI	Koninklijk Nederlands Meteorologisch Instituut
SRON	Netherlands Institute for Space Research
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek
VUA	Vrije Universiteit Amsterdam
MET.NO	Meteorologisk Institutt
NILU	Norsk Institutt for Luftforskning
IM	Instituto de Meteorologia
AEMET	Agencia Estatal de Meteorologia
SMHI	Sveriges Meteorologiska och Hydrologiska Institut
CERC	Cambridge Environmental Research Consultants Ltd
KCL	King's College London
UKMET	Met Office
ULEIC	University of Leicester
UNIVLEEDS	University of Leeds

European Commission
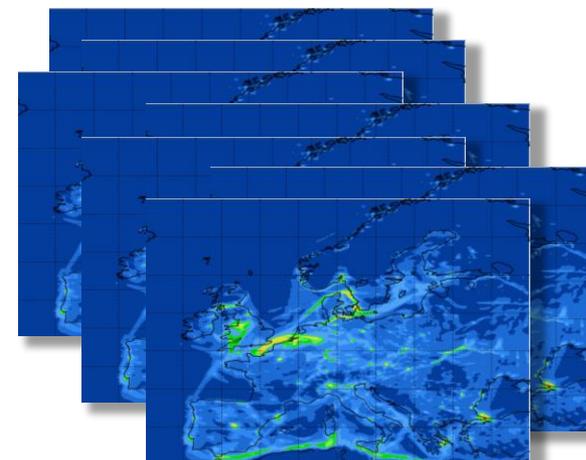
From EO to policy-relevant products
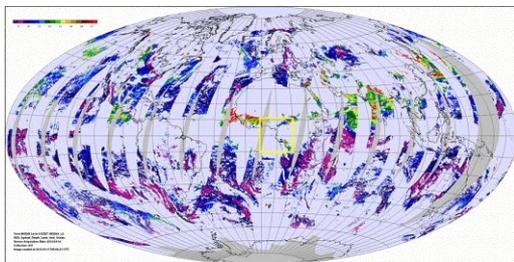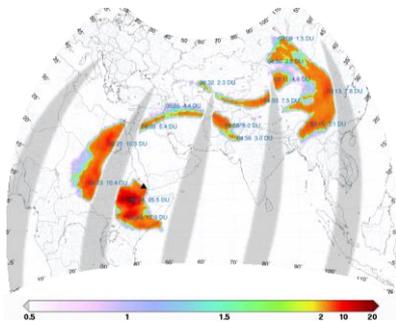
Over 60 EO instruments are assimilated in the global system
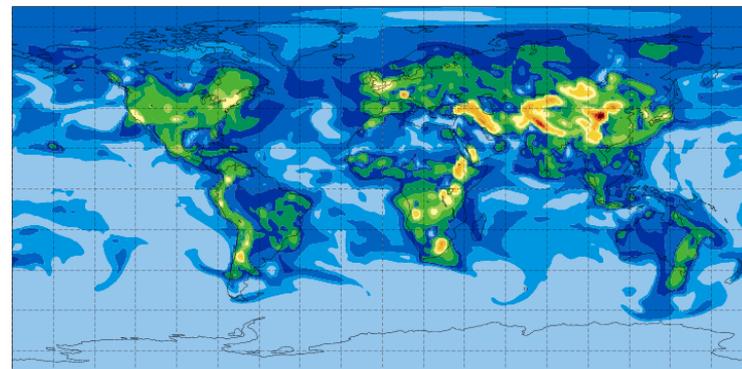
Boundary conditions feed an ensemble of high-resolution European AQ systems (in order to assess uncertainties)
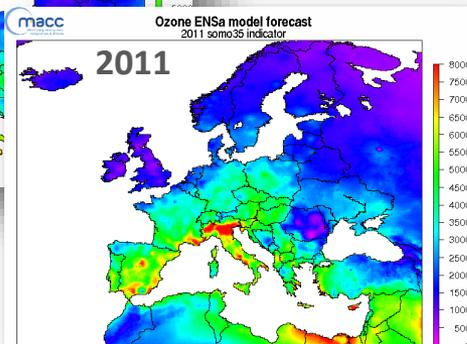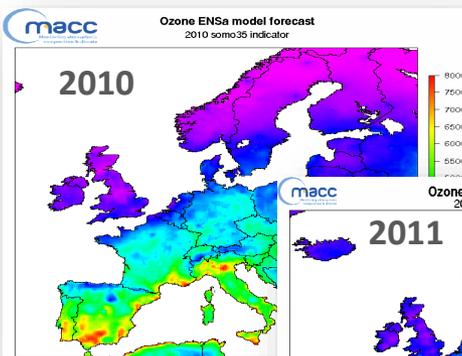
More data are assimilated (in particular hourly surface AQ concentrated by EEA/EIONET)
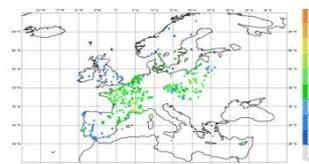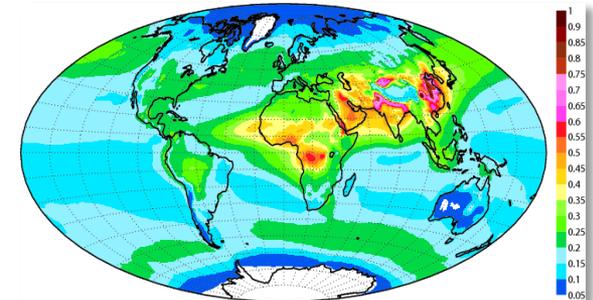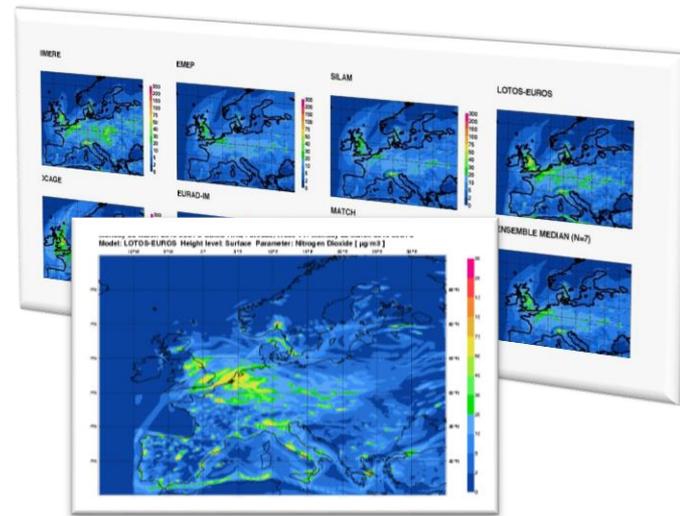
Policy-relevant (here health indicator for ozone) products are delivered. They are "maps with no gaps", which observations alone don't provide and are essential to assess impacts.

http://atmosphere.copernicus.eu

European Air Quality

Global atmospheric composition

Radiation and ozone layer

Surface fluxes: greenhouse gases, fires, emissions (GFAS, MACCity, MACC/TNO)
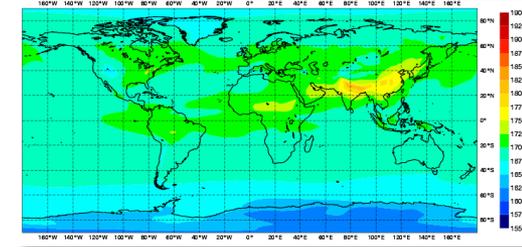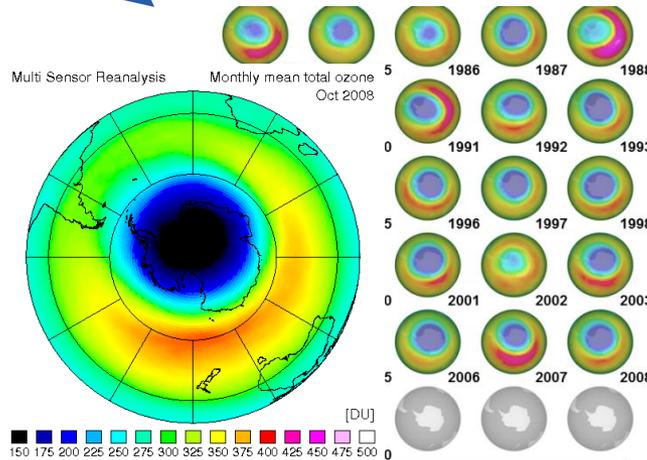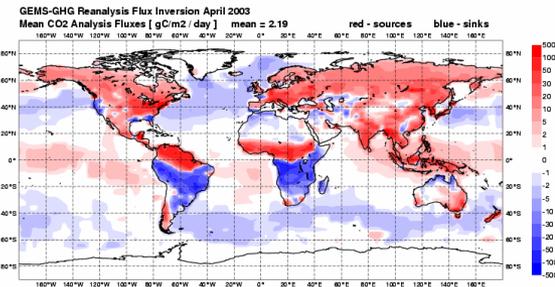
Users

Main products categories	Users
Global NRT Analyses & Forecasts	150 daily users
Regional NRT Analyses & Forecasts	125 daily users
MACC Global Reanalysis 2003-2012	1600 registered users
Solar Radiation	110 users, ~20000 requests/yr

Power users - r...
as part of time-...
AQ modellers, ...
producing publ...
quality apps de...
sector ...).
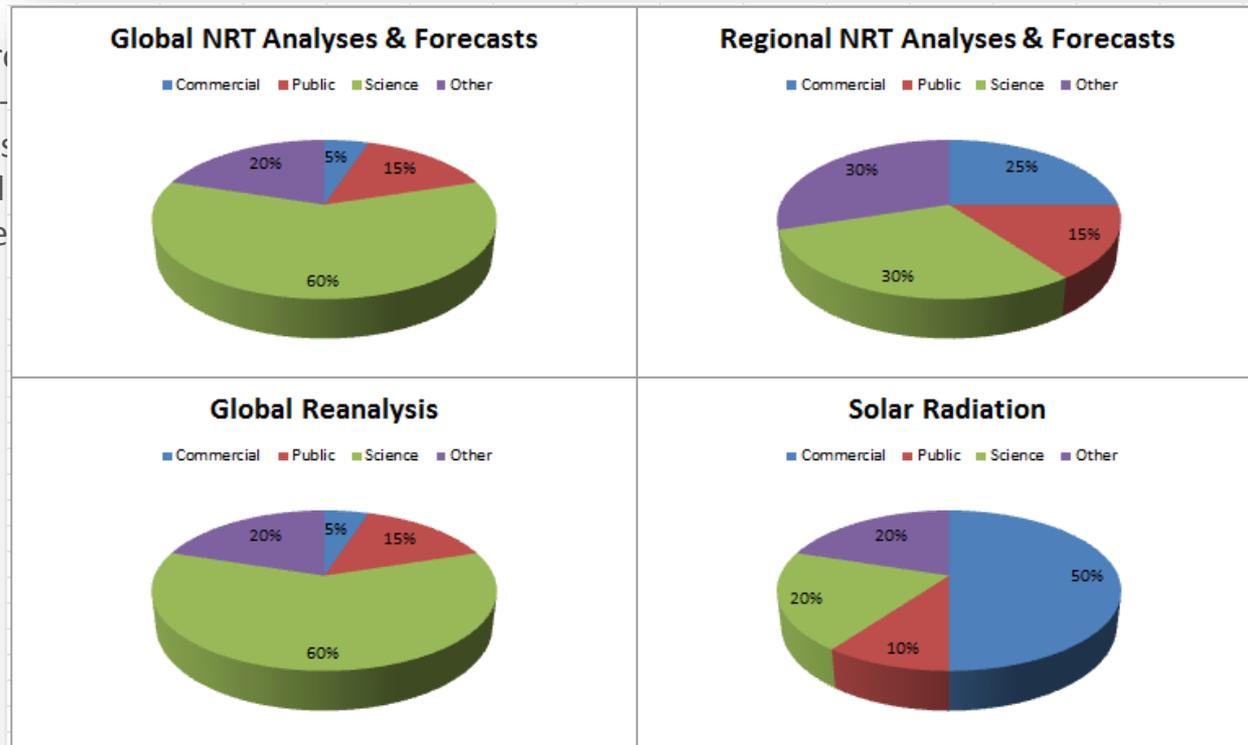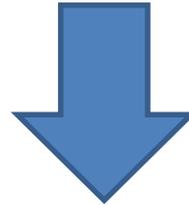
Copernicus Atmosphere Monitoring Service
- Operational delivery of atmospheric composition services
- Global and European regional scale
- Initial period from 2015 – 2020
- ECMWF is in charge of implementation
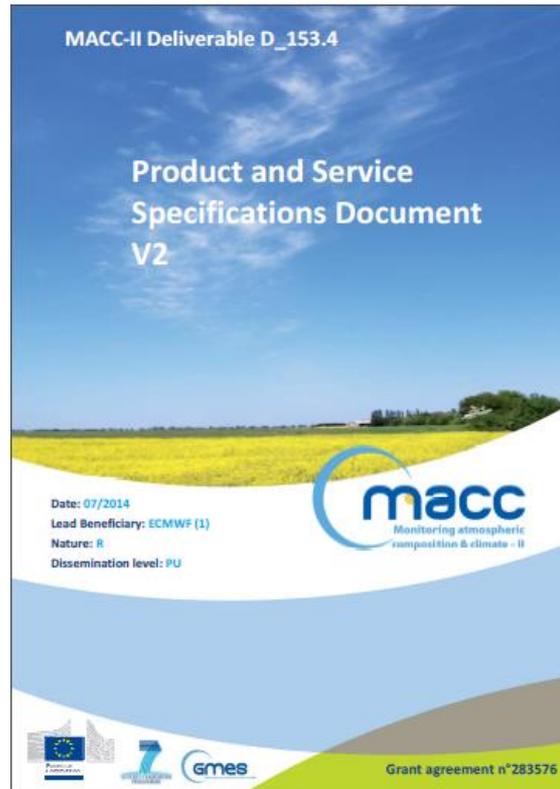
http://atmosphere.copernicus.eu/about/MACCII_Product_and_Service_Specification_20140722.pdf

in total **68** products and services

Anticipating questions from potential users ...

What products and services can I get from MACC?

single entry point

How can I access the data? Where can I find a service?

it depends

How can I read and interpret the data? How can I use a service?

it depends

Where to get information about the quality of a product?

it depends

Is a product suitable for operational usage?

it depends

What am I allowed to do with the data?

single data licence

ECMWF
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Diversity of data producers, number of data formats, large variability of dataset volumes, existing data serving methods

MACC product catalogue

- Start small: comprehensive and up-to-date inventory

- **150** individual products and services accompanied with **description**, **geographical** and **temporal coverage** and links to **access the data**, to **data browsing page**, **documentation**, **validation reports**, **contact points** ...

- Able to export INSPIRE and WMO Core compliant meta data

- Will be used as a source for Catalogue Service for the Web (CSW)

http://atmosphere.copernicus.eu/catalogue

macc — Monitoring atmospheric composition & climate

copernicus

HOME | NEWS | CATALOGUE | PRESS ROOM | ABOUT THE PROJECT | CONTACT US

Home > Catalogue
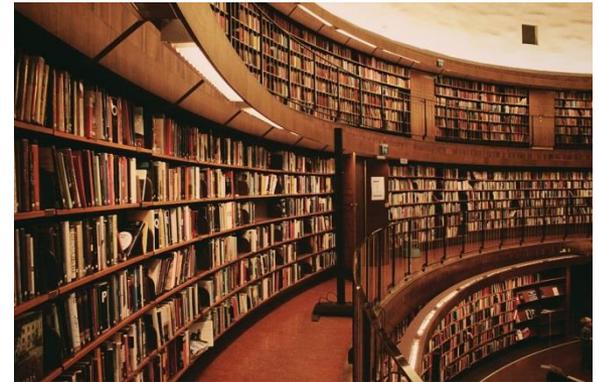
Product	Name	Service Type	Product Family	Parameter	Service Status
Air quality and atmospheric compos ⌄ Reactive gas ⌄ -- Please select a parameter -- ⌄ -- Please select a data type - -- Please select a geograph	European air quality assessment report 2010	Air quality and atmospheric composition	Reactive gas	NO2, Birch pollen, PM2.5, O3, PM10	PRE-OP
	European-scale AQ ozone	Air quality and atmospheric	Reactive gas	O3	PRE-OP
				M2.5, O3,	PRE-OP
					PRE-OP
					PRE-OP
					PRE-OP
					PRE-OP
					PRE-OP

MACC-IFS-MOZ reanalysis of global carbon monoxide   X

Description: This service provides global reanalysis of carbon monoxide using the chemistry of the MOZART model.

MACC Reanalysis Global Monthly Mean January 2003
Surface Carbon Monoxide [ppbv]   mean: 109.80 max: 3677.08

Service type:	Air quality and atmospheric composition	Vertical coordinate:	Potential temperature; Potential vorticity; Model; Surface; Pressure
Product family:	Reactive gas	Time resolution:	Monthly; 3-hourly
Parameter:	CO	Data type:	Reanalysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Verification results Validation reports Contact us XML

a product's details by

Flux inversion delayed-mode of global methane - Atmospheric concentrations ✕

Description: This data provides CH4 atmospheric concentrations based on the estimated surface fluxes in a delayed-mode, based on air mole fraction records from CH4 records from NOAA/ESRL.

MACC Delayed mode Global Monthly Mean June 2009
Surface Methane [ppbv]   mean: 1687.94 max: 8405.67
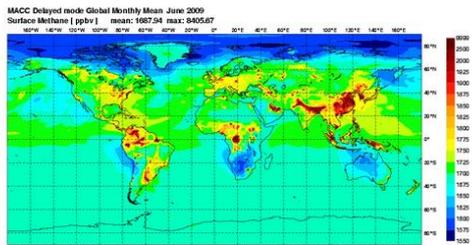
Service type:	Climate forcing; Air quality and atmospheric composition	Vertical coordinate:	Potential temperature; Potential vorticity; Model; Surface; Pressure
Product family:	Greenhouse gas	Time resolution:	Monthly
Parameter:	CH4	Data type:	Analysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Data access Documentation Contact us XML

NRT Biomass burning emissions of carbon and various trace species based on assimilated Fire Radiative Power (FRP) (GFAS) ✕

Description: This service provides daily biomass burning emissions of various aerosol, greenhouse gas, and chemical species based on Fire radiative Power (FRP) satellite observations

MACC Daily Fire Products Thursday 26 February 2015
Average of Observed Fire Radiative Power Areal Density [mW/m2]   max value = 0.40 W/m2

Service type:	Emissions and fluxes	Vertical coordinate:	Surface
Product family:	Fire; Reactive gas; Greenhouse gas; Aerosol	Time resolution:	Daily
Parameter:	Fire Radiative Power	Data type:	Analysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Contact us XML

Flux inversion reanalysis fluxes of global nitrous oxide - Fluxes ✕

Description: This data provides N2O surface fluxes over 12 years, from 1998 to 2009, at 3.75degree x 2.5degree (longitude-latitude) and monthly resolution, based on air mole fraction records from 70 N2O sites plus ship-based and ocean mooring records from NOAA/ESRL, AGAGE, CSIRO, NIES, and Tohoku University.

MACC-GHG Reanalysis Flux Inversion December 2009
Mean N2O Fluxes [gN / m2 / month]   mean = 0.00209   greens - sinks   reds - sources
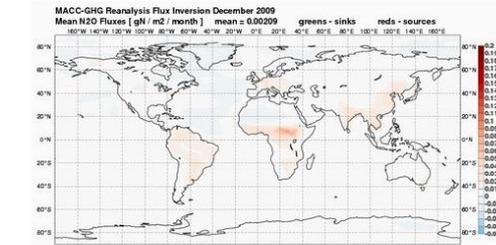
Service type:	Climate forcing; Emissions and fluxes	Vertical coordinate:	Surface
Product family:	Greenhouse gas	Time resolution:	Monthly
Parameter:	N2O	Data type:	Reanalysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Contact us XML

BASCOE NRT global stratospheric analyses ✕

Description: Analyses of stratospheric species using MLS observations in the BASCOE data assimilation system

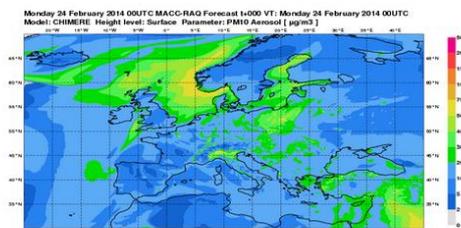o3 [Dobson Units] by BASCOE AMLS_04.03 (dlon*dlat=0.5*0.5 by linear interp)

22-Feb-2015 00:00

Service type:	Ozone and Ultraviolet radiation	Vertical coordinate:	Model
Product family:	Reactive gas	Time resolution:	3-hourly
Parameter:	N2O; HNO3; HOCl; O3; H2O; HCl	Data type:	Analysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Contact us XML

C-IFS-TM5 NRT analyses of global carbon monoxide ✕

Description: This service provides pre-operational daily analyses of carbon monoxide using the C-IFS-TM5 model.

Thursday 26 February 2015 00UTC MACC Forecast t+000 VT: Thursday 26 February 2015 00UTC
Total Column Carbon Monoxide [10^18 molecules / cm2]

Service type:	Air quality and atmospheric composition	Vertical coordinate:	Potential vorticity; Potential temperature; Model; Surface; Pressure
Product family:	Reactive gas	Time resolution:	6-hourly
Parameter:	CO	Data type:	Analysis
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Verification results Validation reports Documentation Contact us XML

ATSR-DV global aerosol ✕

Description: Aerosol optical depth (AOD) retrievals at 555nm from AATSR on ENVISAT
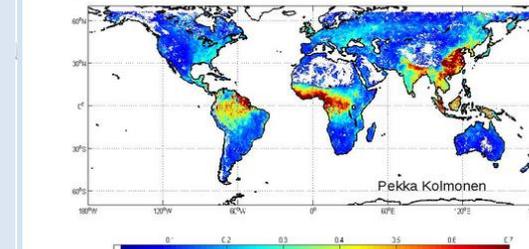
Pekka Kolmonen

Service type:	Air quality and atmospheric composition	Vertical coordinate:	Column
Product family:	Aerosol	Time resolution:	Daily
Parameter:	Total AOD	Data type:	Observations
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Experimental

Links: Plots Data access Contact us XML

European-scale AQ PM10 forecast by CHIMERE ✕

Description: This service provides pre-operational European-scale air quality PM10 forecasts for every hour up to 4 days in advance provided by the CHIMERE model. The maps provided are only representative for large scale phenomena, they cannot reproduce local aspects of air pollution.
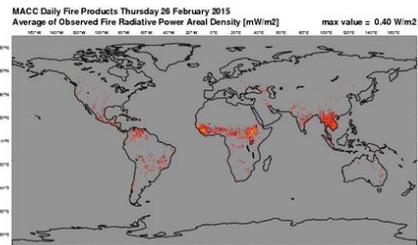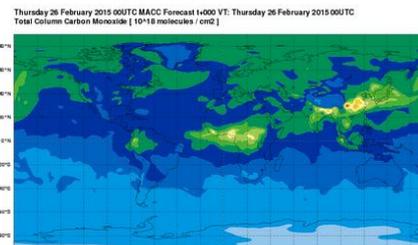
Monday 24 February 2014 00UTC MACC-RAQ Forecast t+000 VT: Monday 24 February 2014 00UTC
Model: CHIMERE Height level: Surface Parameter: PM10 Aerosol [µg/m3]

Service type:	Air quality and atmospheric composition	Vertical coordinate:	500 m; Surface; 3000 m; 1000 m
Product family:	Aerosol	Time resolution:	Hourly
Parameter:	PM10	Data type:	Forecast
Geographical area:	Europe (-25, 45, 30, 70)	Service status:	Pre-operational

Links: Plots Data access Verification results Documentation Contact us XML

TNO-MACC-II European anthropogenic emissions ✕

Description: This services provides anthropogenic emissions for various chemical species for the European domain.

NOx in 2009

Service type:	Emissions and fluxes	Vertical coordinate:	Surface
Product family:	Reactive gas; Greenhouse gas; Aerosol	Time resolution:	Monthly
Parameter:	NOx; SO2; PM2.5; PM10; CH4; NH3; CO; NMVOCs	Data type:	Analysis
Geographical area:	Europe (-25, 45, 30, 70)	Service status:	Pre-operational

Links: Plots Data access Contact us XML

Global solar UV index forecast ✕

Description: This service provides pre-operational daily forecasts up to 5 days for the total sky and clear sky UV index.

Thursday 26 February 2015 00UTC MACC Forecast t+012 VT: Thursday 26 February 2015 12UTC
Total sky UV Index
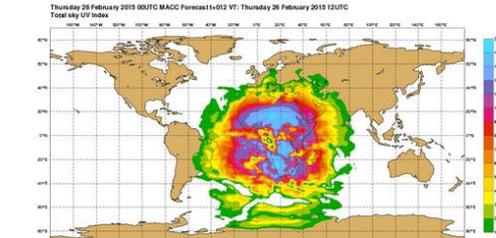
Service type:	Ozone and Ultraviolet radiation	Vertical coordinate:	3-hourly
Product family:	Radiation; Reactive gas; Aerosol	Time resolution:	3-hourly
Parameter:	UV index	Data type:	Forecast
Geographical area:	Global (-180, 180, -90, 90)	Service status:	Pre-operational

Links: Plots Data access Contact us XML

Validation activities

macc Monitoring atmospheric composition & climate

Copernicus

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Air Quality & Atmospheric Composition

Verification of Global Services

Scientific Field Campaign Support

Verification of Regional Services

Validation reports

Today's Forecasts

Reactive Gases

Aerosols

European Air Quality

UV Index

Ozone Layer

CO2

Latest Analyses

Fire Monitoring

Reactive Gases

Aerosols

European Air Quality

Verification of Regional Services

Validation Reports

The regional modelling systems are being validated on a 3-monthly basis. The validation reports are available here:

- Validation reports

Quick-look verification pages

The verification of the MACC-II Regional Air Quality services over Europe is based on comparisons with in-situ surface observations of the following air pollutants: ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and PM10 aerosols. These hourly observational data are delivered to the MACC-II project close to real-time. They are preliminary and not validated and can therefore not be used for checking compliance with air quality regulations or for any purpose other than the evaluation of MACC-II Regional Air Quality products. Detailed information can be obtained from the data owners.

Forecast verfication against in-situ observations

Maps of the forecasts of surface pollutants (ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and PM10 aerosols) produced by each of the 7 individual models or from the ensemble on a 3-hourly basis, overlaid with in-situ observations as coloured dots. Available for the past 30 days.

Analysis verfication against in-situ observations

Maps of the ozone analysis at the surface produced by each of the 7 individual models or from the ensemble on a 3-hourly basis, overlaid with in-situ observations as coloured dots. Available for the past 30 days.

User Support

Documentation

Validation

E-learning

Mailing Lists

Operational Info

Services

Air Quality & Atmospheric Composition

Climate Forcing

Ozone Layer & Ultra-Violet Radiation

Solar Radiation

Emissions & Surface Fluxes

ACCESS CATALOGUE

15
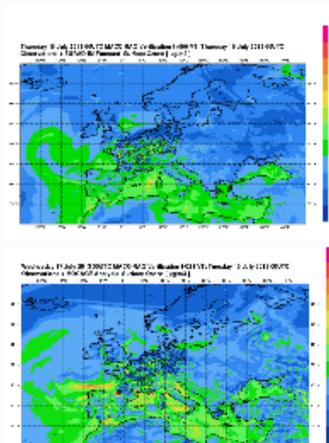
Distributed data access

ECPDS service · FTP servers · WCS servers · WMS servers · Other · API services · ECMWF data servers · Product catalogue
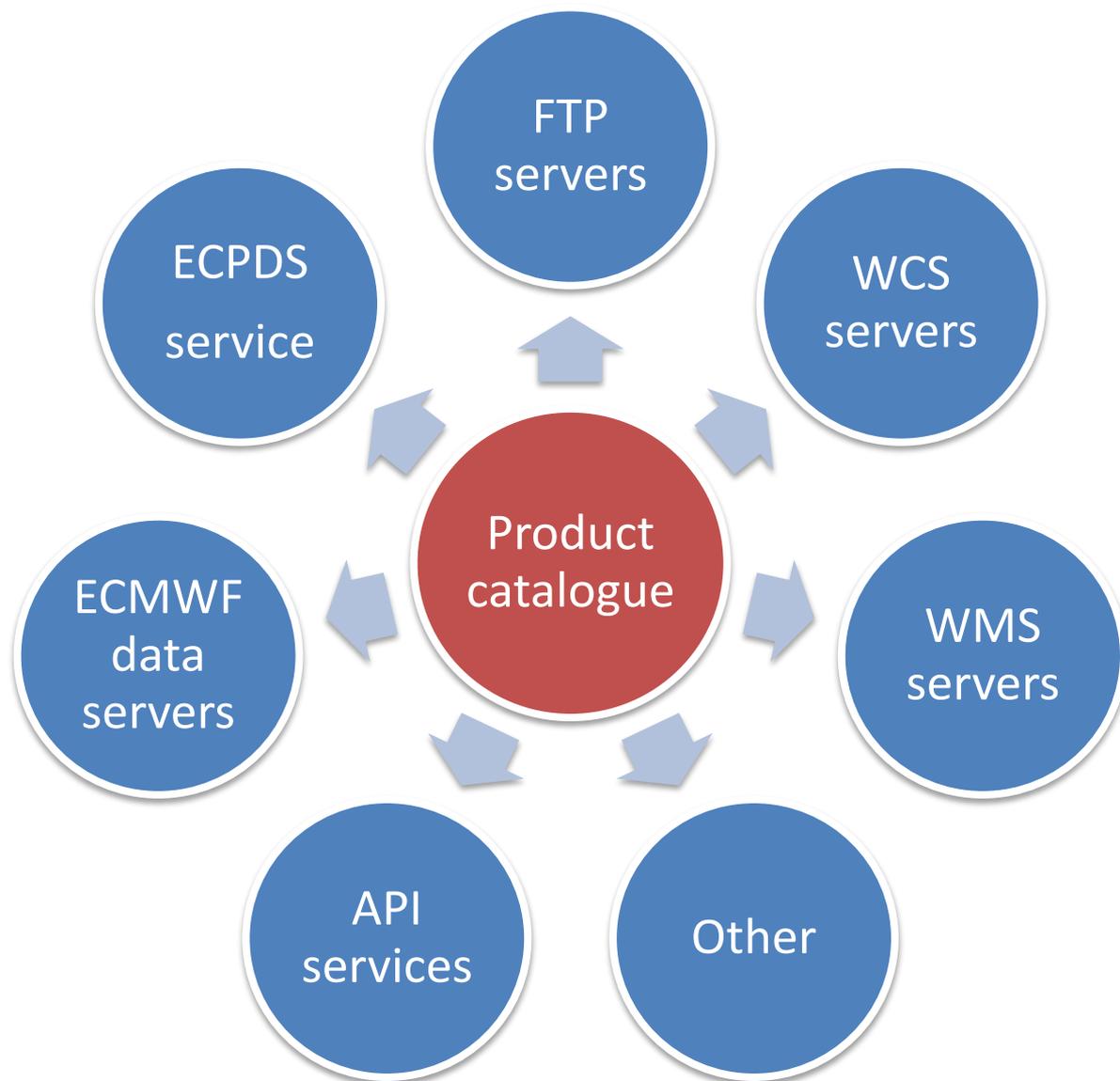
Two examples of delivery systems for the MACC global datasets:

1.   ECMWF data servers

2.   ECPDS data delivery

Delivering global model results

- Hosting the global near-real-time and the reanalysis dataset

- Very capable of serving big volumes of data

- Services build on top of existing and upcoming ECMWF systems

- Most of the data is archived in MARS

- Data volumes: reanalysis 50 GB/day , 22 TB in total, NRT dataset 200 GB/day, 2.5 years, 24 TB

- Not best suitable for data browsing and occasional / light-weight data usage

ECMWF

Type of level
- Model levels
- ▶ Pressure levels
- Surface

MACC Fields
- ▶ Reanalysis
- Near-realtime

About
- Conditions of use

Navigation
- Datasets
- Job list
- Batch access

See also...
- FAQ
- Accessing forecasts
- GRIB decoder

MACC Reanalysis

Select date

○ Select a date in the interval 2003-01-01 to 2012-12-31

Start date: 2003-01-01   End date: 2012-12-31

Reset

○ Select a list of months

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	2004	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2005	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	2006	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2007	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	2008	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2009	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	2010	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2011	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	2012	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Select All or Clear

Select time

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

Select All or Clear

Select step

☐ 0   ☐ 3   ☐ 6   ☐ 9   ☐ 12   ☐ 15   ☐ 18   ☐ 21   ☐ 24

Select All or Clear

Select level and parameter

	1000	925	850	775	700	600	500	400	300	250	200	150	100	70	50	30	20	10	7	5	3	2	1
Carbon monoxide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Divergence	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Formaldehyde	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
GEMS Ozone	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Geopotential	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

ecCharts components

Frontend → Backend → SOA services → Data

Highly available end-to-end service is achieved by:
- Load balancing
- Distributed architecture
- Virtualization
- Service Oriented Architecture (SOA)

ECMWF data servers

- Frontend : JQuery & AJAX based web application
- Backend : Django web framework
- Catalogue of products & User preferences: MongoDB collections of JSON documents
- Distributed Object Caching: Memcached
- SOA components : Bespoke python based framework (with twisted)
- SOA services: mostly in Python and C.
- Data : From MARS (Retrieve to ingest on ecCharts data clusters)
- Data cluster : Data replicated on standard Unix file system.
- Data access: Based on MARS language
- Data related operations : GRIB API

ECPDS data service

- Serves NRT global, global BC and NRT GFAS data streams
- FTP-push and –pull service
- suitable for large data transfers
- 24/7 monitored and supported
- High availability
- Load balance
- Per-dataset, per-user quotas
- Scalable
- User Account Management
- Monitoring Facilities

Successes

- Large and growing user base, in general high level of user satisfaction

- Multi-purpose catalogue: data discovery, MD export, portfolio documents, CSW

- Manage to remain flexible when dealing with a diverse set of datasets and user requirements

- Use of JIRA issue tracking system

Some lessons

- Prescribe (and police) format specification and provide data format validators. Distribute sample code if you want to be certain

- Provide better subsetting services to reduce volume of data that needs to be transferred (subareas, timeseries, vertical profiles ...)

- Value (and headache) of experimental datasets

- Exposing catalogue to web crawlers

Website:

http://atmosphere.copernicus.eu

Contact:

info@copernicus-atmosphere.eu