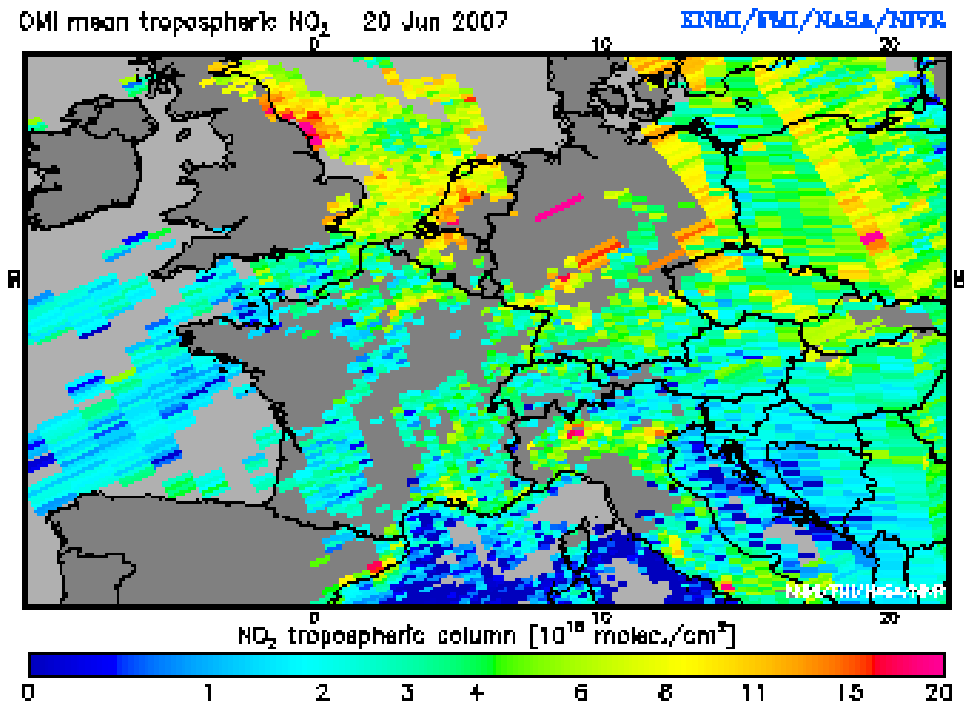
A global map showing atmospheric model results with a color scale from blue (low) to red (high). A black box highlights the European region, which is shown in a larger, more detailed inset map at the bottom left. The inset map shows a prominent red and yellow area over the North Atlantic and Europe, indicating high values in the model output.

European developments on atmospheric modeling and future satellite missions

Dr. Pieter F. Levelt
Royal Netherlands Meteorological Institute
KNMI
The Netherlands

GMES: Global Monitoring of the Environment and Security

- European part of GEO (EU counterpart of USGEO)
- Two axes approach (satellite data provision and use of satellite data):
 - Infra structure and use of satellite data for Atmospheric Service (EU GEMS & ESA PROMOTE & GAS)
 - Provision of satellite data for operational monitoring of the atmosphere (Sentinels 4 (GEO) & 5 (LEO))



OMI NRT NO2 June 20, 2007



Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft



Global and regional Earth-System (atmosphere) Monitoring using Satellite and in-situ data (GEMS)

- Integrated Project of the 6th EC Framework Programme
- part of the GMES (EC&ESA) Atmosphere theme
- 31 consortium members
- 4 years (started in March 2005)
- coordinated by the European Centre for Medium-Range Weather Forecasts
ECMWF



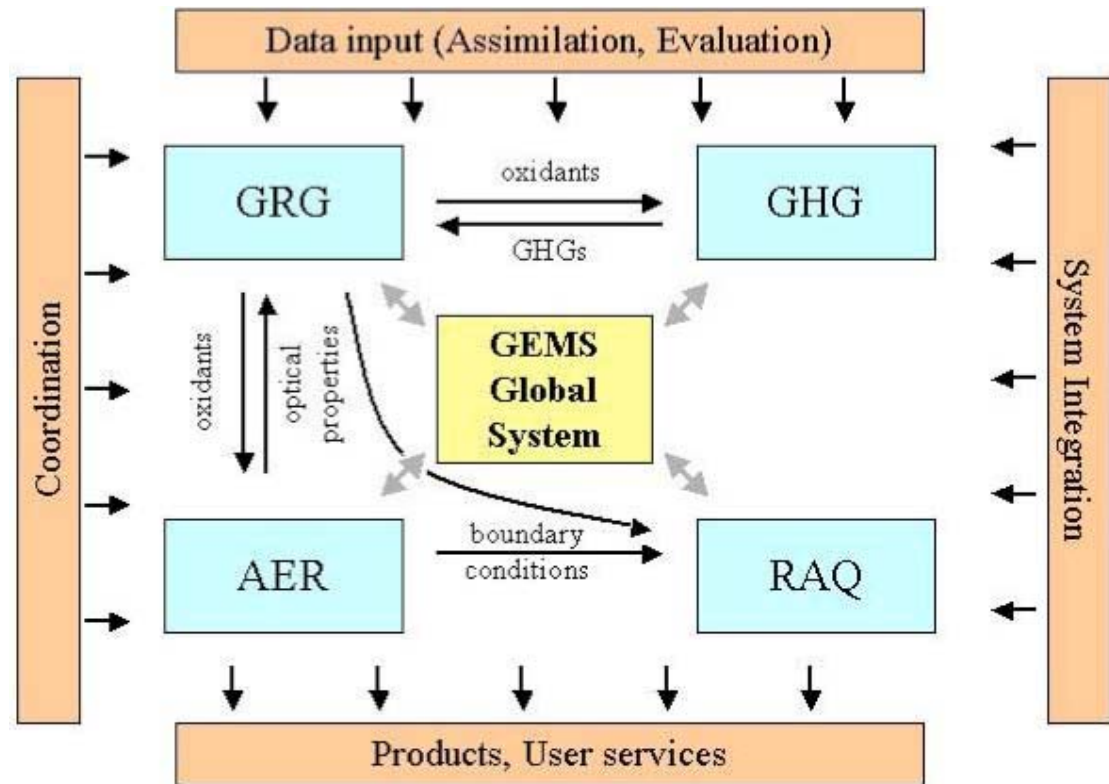
The GEMS Project

Global & regional Earth-system Monitoring using Satellite and in-situ data
EU 6FP, GMES, 2005-2009, 31 partners

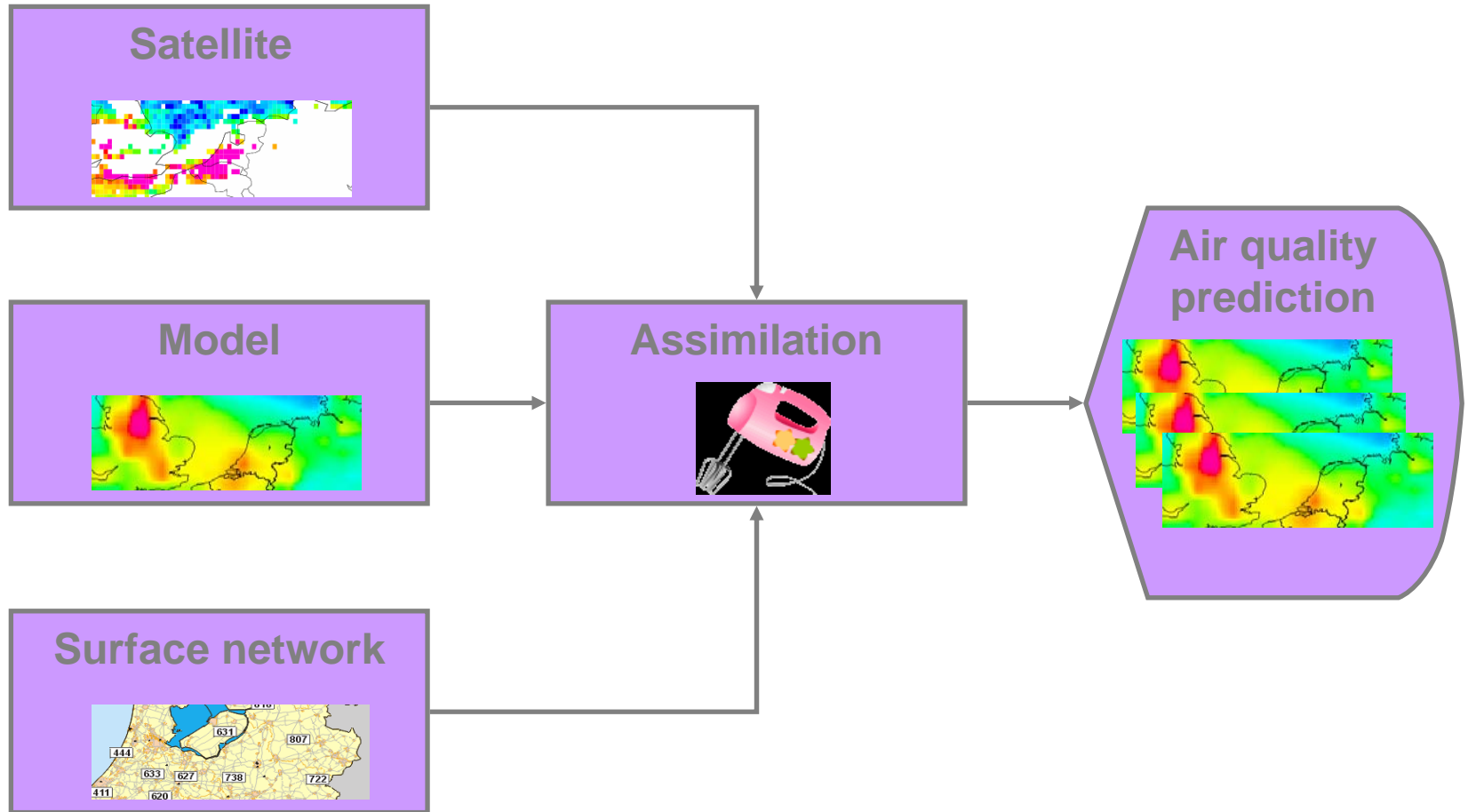
Subprojects:

- Greenhouse gases
- Reactive gases
- Aerosols
- Regional air quality

First (trial) reanalysis
(period 2003/2004)
will start at end of 2006



The aim



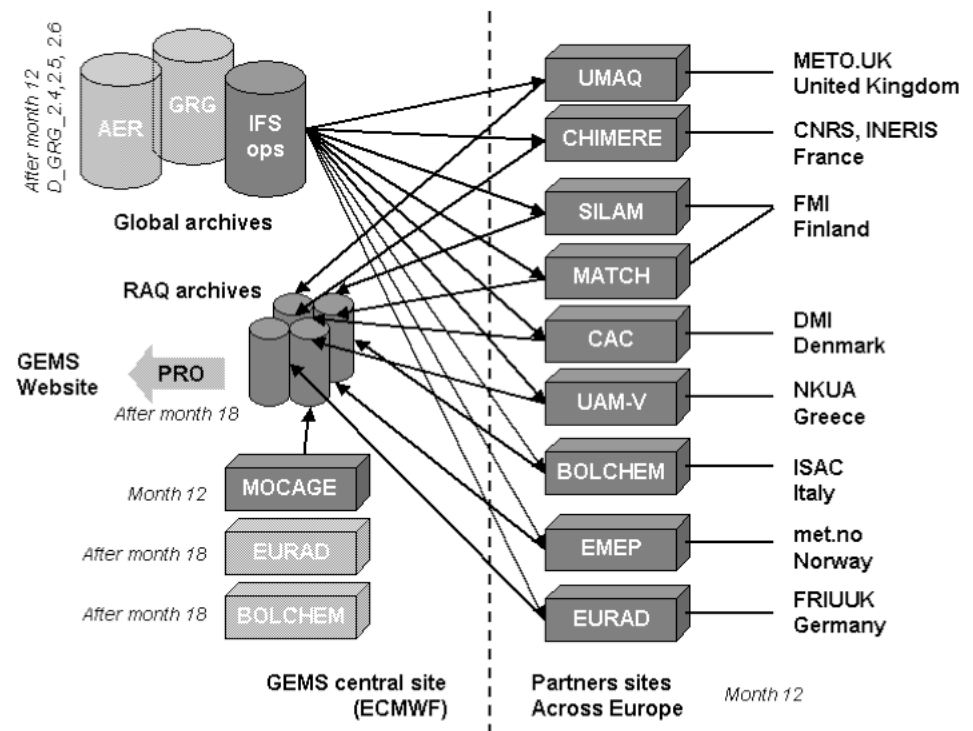
GEMS: Regional air quality subproject

Aspects:

- Many of the European regional AQ modelling groups involved
- Intercomparison of 11 European RAQ models on GEMS website
- Boundary conditions from GRG, AER
- Chemical assimilation at the regional scale (surface observations)
- NRT access to surface data
- Ensemble forecasts

OMI and GEMS-RAQ:

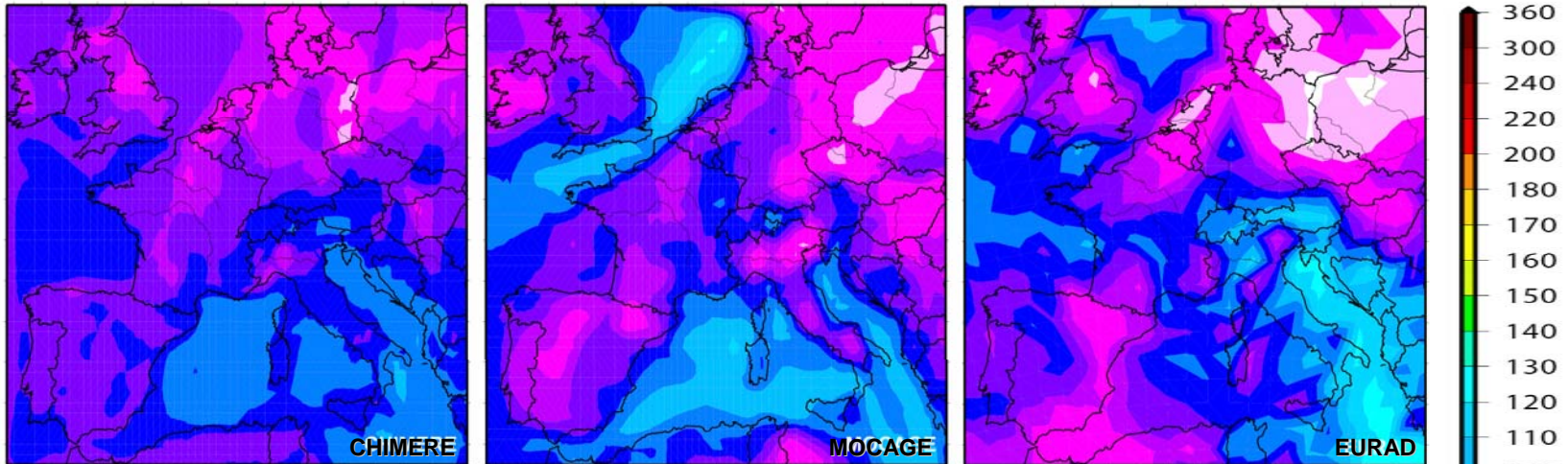
- OMI nrt NO₂ will be included in intercomparison
- OMI NO₂ products available for assimilation in RAQ models



Forecast from three European air quality model systems



daily maxima of surface ozone [$\mu\text{g}/\text{m}^3$] for 20/10/2006



CHIMERE (CNRS-INSU and INERIS)



MOCAGE (Météo-France)



EURAD (Rhenish Institute for Environ. Research, Univ. Köln)

GMES Atmospheric Service (GAS-Pilot Service)

December 5 and 6, 2006 EU workshop on GAS in Brussels

Results:

- Implementation team to be installed
- Issue a space call including GAS

- **GEMS** and **PROMOTE** prepare **MACC** proposal lead ECMWF, deadline proposals: 19 June 2007
 - Budget 15 M€
- Subject: Activity 9.1.2 GMES Atmospheric Services
 - **Developing pre-operational service capabilities in new application fields (Atmosphere and Security)**

Overview recent European satellite instruments for tropospheric measurements

GOME

Launched April 1995 (ESA's ERS-2)

*First total ozone data, 11 Jan 07
courtesy Eumetsat / DLR*

SCIAMACHY

Launched February 2002 (ESA's ENVISAT)

KNMI is involved in all 4 solar backscatter satellite projects

OMI

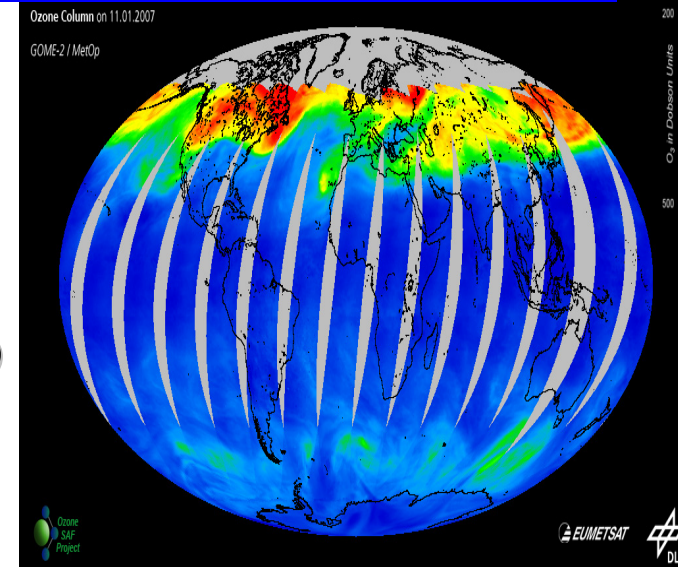
Launched July 2004 (NASA's EOS-Aura)

GOME-2

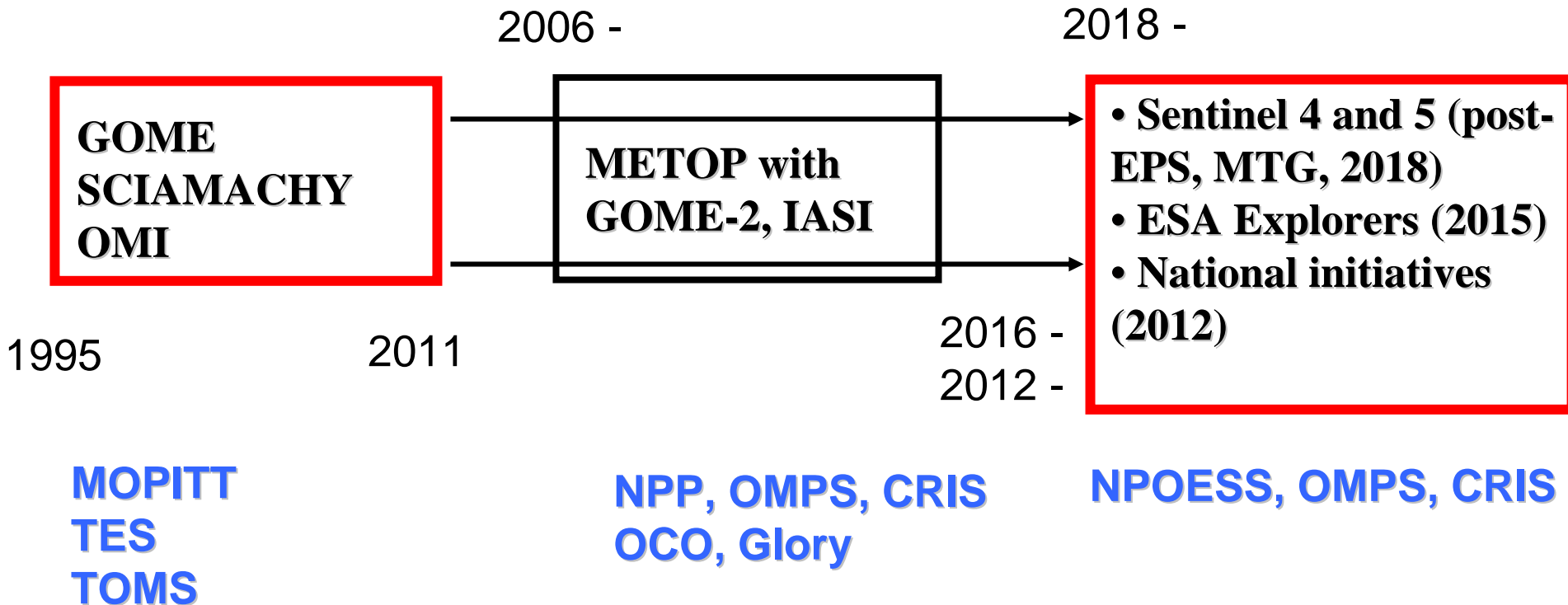
Launched October 2006 (EUMETSAT's METOP-1)

IASI

Launched October 2006 (EUMETSAT's METOP-1)



European & US satellite instruments for air quality



Red = present or planned European missions with air quality data

Black = European atmospheric composition missions

not optimal for air quality

Initiatives and plans for air quality/climate exploring and monitoring satellite missions

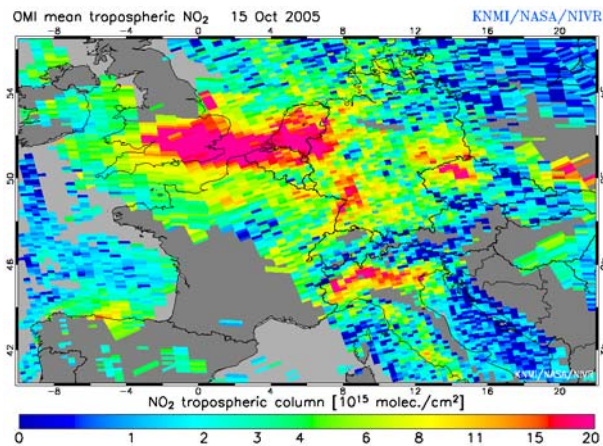
- **ESA**
 - Earth Explorer program
 - Sentinels 4 and 5: Capacity study 1 and 2, operational monitoring atmospheric chemistry based on user requirements.
- **EUMETSAT**
 - Post EPS and MTG
- **National initiatives**
 - Air quality and climate monitoring : NL, Fi, Belgium, UK, etc.
 - **TROPOMI/TROPI (Dutch led initiative):**
Nadir looking UV/VIS/NIR/SWIR instrument on small platform

ESA EOEP Program (EE7, estimated Launch 2014/2015): The Six Candidate Core Missions for phase 0 study

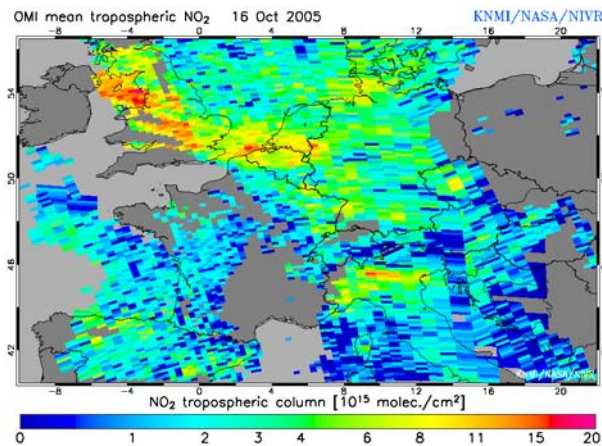
- **BIOMASS: A BIOMASS Monitoring Mission for Carbon Assessment**
- **TRAQ: Tropospheric composition and Air Quality**
(Lead-Investigator: P.F. Levelt; co-Lead: C. Camy Peyret)
- **PREMIER: PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation,**
- **FLEX: FLuorescence Explorer**
- **A-SCOPE: Advanced Space Carbon and Climate Observation of Planet Earth**
- **Core-H2O: Cold Regions Hydrology High-resolution Observatory**

TRAQ Science Questions

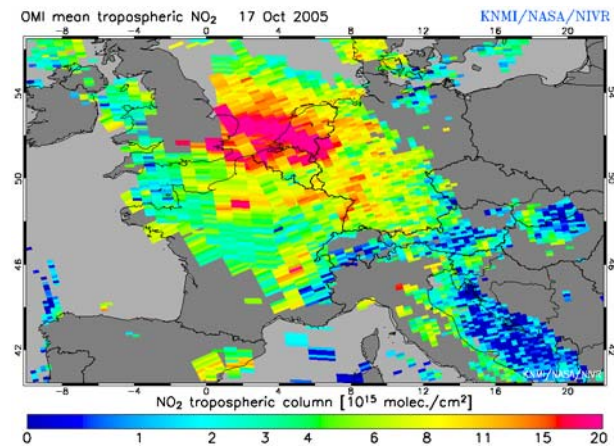
- How fast is air quality changing on a global and regional scale?
- What is the strength and distribution of the sources and sinks of trace gases and aerosols influencing air quality and climate?
- What is the role of tropospheric composition in global change?



Saturday 15 October 2005



Sunday 16 October 2005



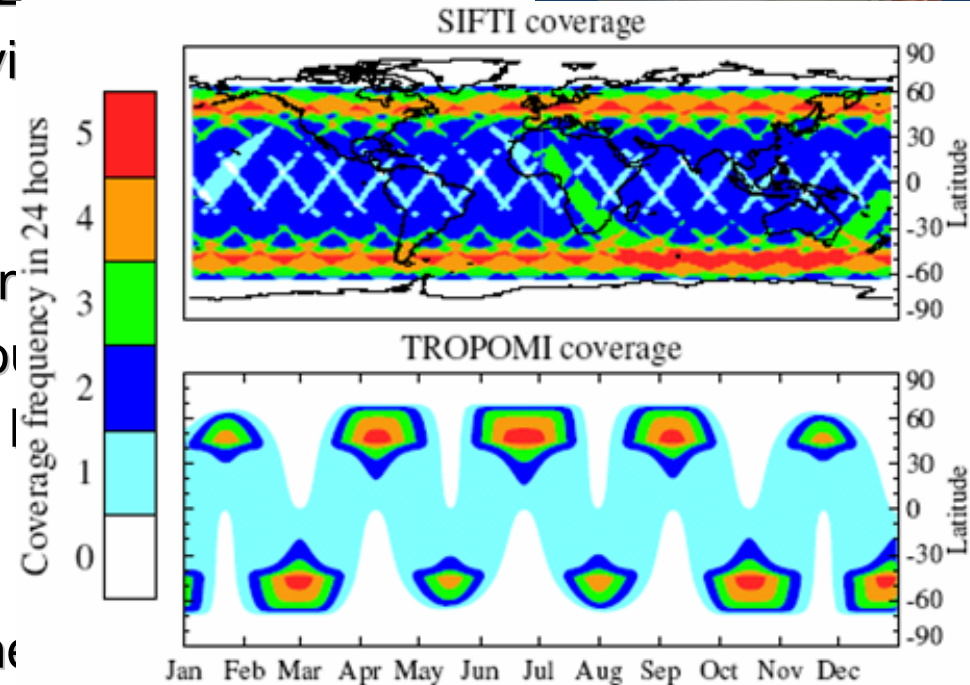
Monday 17 October 2005

ESA explorer mission candidate TRAQ Payload

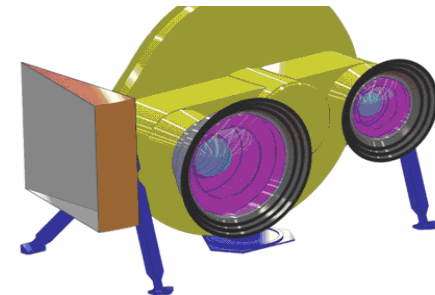
TROPOMI: Backscatter instrument (trop) columns of O₃, NO₂, SO₂, HCHO, aerosols & CO and CH₄.
Swath 2600, 10 x 10 km²
Heritage: Aura-OMI, Envi



SIFTI (FTIR): O₃, CO, CH₄: trop column
intelligent pointing for cloud
Swath 2000 km, 10 x 10 km²
Heritage: IASI



OCAPI: POLDER type of instrument
AOD, single scattering albedo (ω_0), Air quality index (AQI), aerosol sizes and aerosol type.
Swath 2000 km, 5 x 5 km²
Heritage: POLDER, PARASOL



GMES Sentinels 4&5

Eumetsat

Meteosat Third Generation

- Detailed UV-VIS instrument studies during phase 0
- Instrument not considered at system level
- Will not be followed in phase A

Post-EPS

- Many atmospheric composition instruments considered
- Highest priority : UV-VIS-NIR-SWIR and TIR spectrometers

Eumetsat – ESA cooperation

- It is planned to merge Sentinels 4&5 with Eumetsat atmospheric composition programme.
- Funding is open.

- **Goals:**

- **Operational monitoring of the atmosphere in preparation of the Sentinel missions 4 & 5**
- **Integrated approach in line with IGACO, ground-based, in situ and satellites**

- **CAPACITY 1: 3005 – 3006 (KNMI lead, ESA J. Langen)**

- **Main goal : to identify gaps in current / planned operational system and identify system/instrument requirements**

Recommendations from CAPACITY 1

In line with IGACO to implement a system of GEO and LEO satellites:

1. Implement 1 LEO satellite with UV-VIS-SWIR payload for **global air quality and climate protocol monitoring** with small pixel sizes as soon as possible
2. Perform trade-off between GEO + LEO and LEO constellation in inclined orbit, and implement complete air quality & climate protocol monitoring mission
3. Consolidate choice and requirements of instruments for UT/LS mission for climate and ozone NRT and assessment applications, and implement the mission

- **Goals:**

- **Operational monitoring of the atmosphere in preparation of the Sentinel missions 4 & 5**
- **Integrated approach in line with IGACO, ground-based, in situ and satellites**

- **CAPACITY 1: 3005 – 3006 (KNMI lead, ESA J. Langen)**

- **Main goal : to identify gaps in current / planned operational system and identify system/instrument requirements**

- **CAPACITY 2: 3007 - 3008 (KNMI lead, ESA J. Langen)**

- **Main goal: to perform sensitivity and retrieval studies for several operational systems and perform trade-offs, including user's perspective (workshop).**

CAPACITY-2: Study objective

Defining the **air quality and climate protocol monitoring** parts of GMES Sentinels 4 and 5.

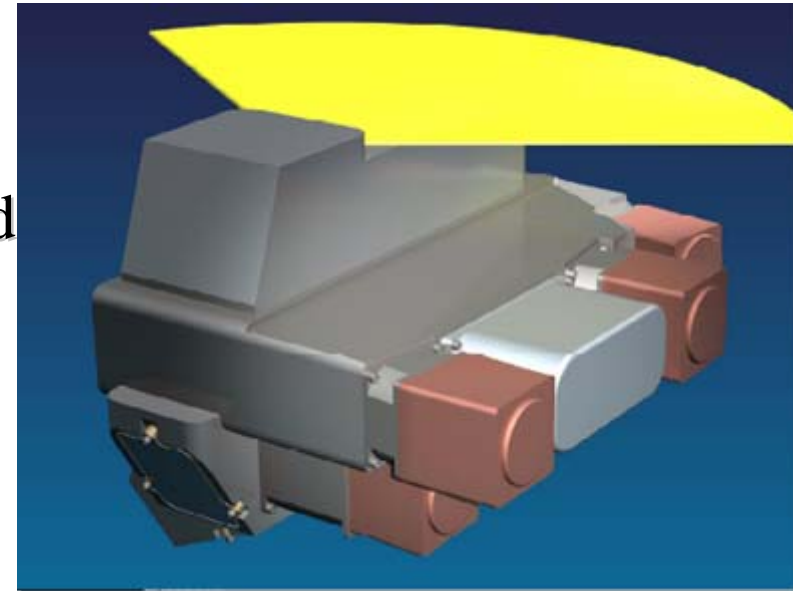
Key issues:

- Identification and quantification of **meteorological and possibly other auxiliary data requirements** and their priority compared to chemical data requirements
- Trade-offs between **different observation strategies** (spectral ranges, polarisation, direction etc.) for aerosol and several gaseous species
- **Quantitative mapping of geophysical observation requirements onto instrument performance requirements** and a review of the implementation-critical requirements
- Quantitative assessment of requirements for **spatio-temporal sampling** taking into account contamination of nadir-viewing observations by cloud
- Contribute from the **user's perspective** to the trade-off between different orbit options

**ESA (J. Langen) KNMI | (Project leader) | RAL | U. Leicester | SRON | FMI
BIRA-IASB | CNR-IFAC | Noveltis (LPMAA, ULB) | U. Koeln**

TROPOMI (TROPI)

- Successor of OMI en SCIAMACHY
- Successful collaboration between KNMI, SRON, TNO and DS.
- Consists of the OMI channels and added to that channels for CO, CH₄ and the O₂-A band (cloud detection and surface albedo)
- Due to TROPOMI's
 - smaller ground pixel size than OMI's and
 - improved correction for clouds the troposphere can be measuredWith improved accuracy



< 10 x 10 km² ground pixel

PI : Dr. P.F. Levelt, KNMI
Co-PI: Prof. Dr. I. Aben, SRON

- TROPOMI type of instrument part of TRAQ, Sentinels, National initiative for a precursor mission
- TROPOMI also Called TROPI in USA (decadal survey)

Conclusions

- **European satellite instruments** : key information on ozone/UV, climate and air quality
- **Infrastructure and user services** (ESA Promote and EU funded project GEMS, GAS): will result in more users.
- **Next decade: satellite part will be significantly reduced in capacity in Europe**. The perspectives after 2018 are more positive. National initiative for a precursor/bridging mission.

There is a **shared European responsibility** for GMES and hence for a mature satellite component & user services - decisions in the near future by ESA, EU, EUMETSAT and national efforts

Cooperation across the Atlantic - ?

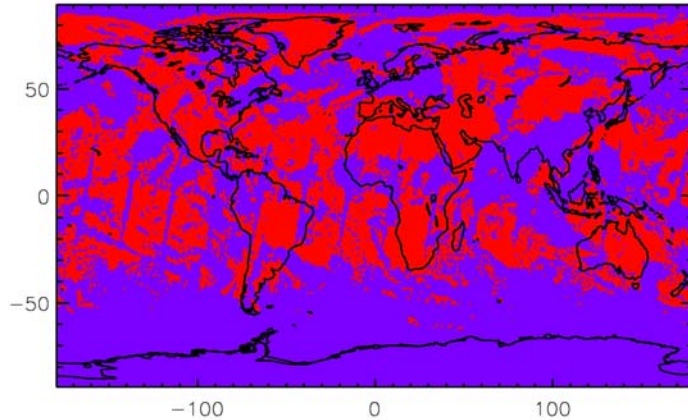
GEO Meeting Cape town November 2007 ideas:

- Diurnal cycle NO₂: SCIA/OMI
- NRT Exhibit based on a.o. OMI data

Back-Up

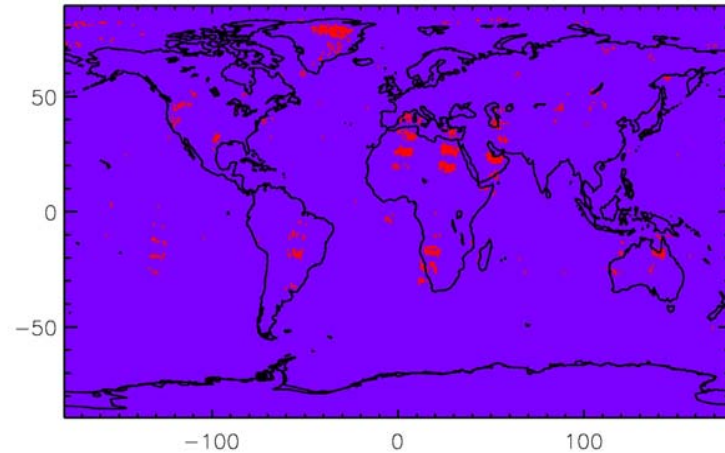
One (1) day cloud-free sampling :

TROPOMI (polar orbit)



10 km x 10 km
2300 km swath (**2600 km**)

SCIAMACHY CO and CH₄

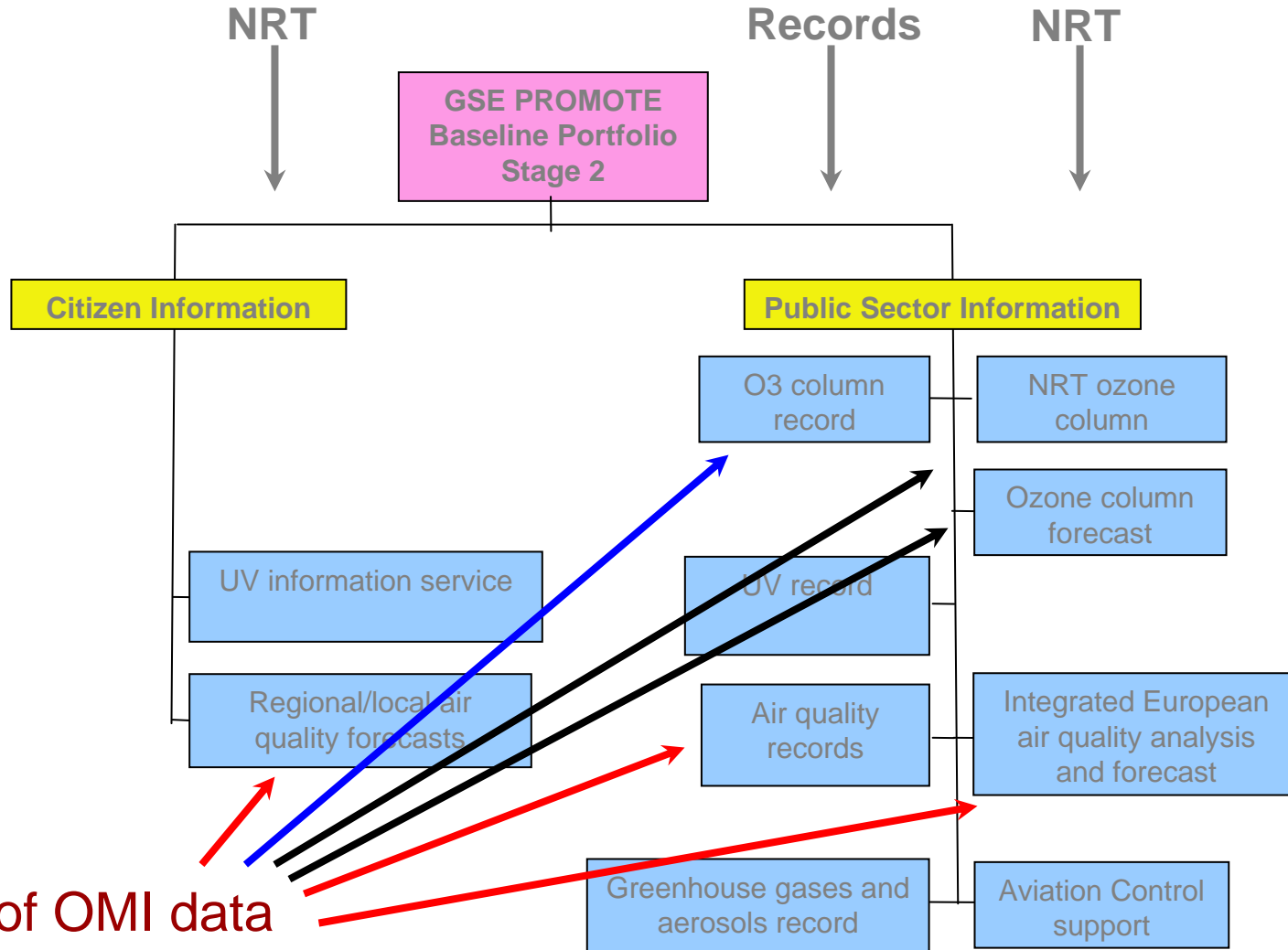


120 km x 30 km
960 km swath

based on MODIS observations (polar orbit, 2300 km swath)

**TROPOMI : as many cloud-free observations in a few days as
SCIAMACHY in one year !! (CO,CH4)**

OMI and PROMOTE



Use of OMI data

ESA Capacity 1 study, 2003-2005

Led by KNMI

- **Operational monitoring atmospheric chemistry, user requirements**

integrated approach in line with IGACO, ground-based, in situ and satellites

- **Main gaps in current / planned operational system**
 - High temporal/spatial resolution space-based measurements of tropospheric (PBL) composition for application to Air Quality
 - Climate gases (CO₂, CH₄ and CO) and aerosol monitoring with sensitivity to the PBL
 - High vertical resolution measurements in the UT/LS region for Ozone layer and Climate applications

Observation Techniques and Mission concepts for Atmospheric Chemistry

AO/1-5163/06/NL/HE
("CAPACITY-2")

Kick Off

ESA, ESTEC, 18 April 2007,
Joerg Langen, ESA

**KNMI (Project leader) | RAL | U. Leicester | SRON | FMI
BIRA-IASB | CNR-IFAC | Noveltis (LPMAA, ULB) | U. Koeln**