European developments on atmospheric modeling and future satellite missions

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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):
  - Infrastructure 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))
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
Satellite

Model

Surface network

Assimilation

Air quality prediction

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 [ug/m3] for 20/10/2006

CHIMERE (CNRS-INSU and INERIS)
MOCAGE (Météo-France)
EURAD (Rhenish Institute for Environ. Research, Univ. Köln)
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)

**SCIAMACHY**
Launched February 2002 (ESA’s ENVISAT)

**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)

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

**KNMI is involved in all 4 solar backscatter satellite projects**
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

- **1995 - 2011**
  - GOME
  - SCIAMACHY
  - OMI

- **2006 - 2011**
  - METOP with GOME-2, IASI

- **2016 - 2018**
  - Sentinel 4 and 5 (post-EPS, MTG, 2018)
  - ESA Explorers (2015)
  - National initiatives (2012)

- **2012 - 2016**
  - MOPITT
  - TES
  - TOMS

- **2016 - 2018**
  - NPP, OMPS, CRIS
  - OCO, Glory

- **2018 -**
  - NPOESS, OMPS, CRIS

Red = present or planned European missions with air quality data
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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
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?
TROPOMI: Backscatter instrument (trop) columns of O₃, NO₂, SO₂, HCHO, aerosols & CO and CH₄.
Swath 2600, 10 x 10 km²
Heritage: Aura-OMI, Envisat

SIFTI (FTIR): O₃, CO, CH₄: trop columns and profiles with intelligent pointing for cloud free pixels.
Swath 2000 km, 10 x 10 km²
Heritage: IASI

OCAPI: POLDER type of instrument:
AOD, single scattering albedo ($\omega_0$), 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 measured With improved accuracy
- TROPOMI type of instrument part of TRAQ, Sentinels, National initiative for a precursor mission
- TROPOMI also Called TROPI in USA (decadal survey)

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

< 10 x 10 km² ground pixel
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)

SCIAMACHY CO and CH₄

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

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)
GSE PROMOTE
Baseline Portfolio
Stage 2

Air quality records
Public Sector Information
NRT ozone column
Ozone column forecast
Integrated European air quality analysis and forecast
Aviation Control support

UV record
Air quality records
Greenhouse gases and aerosols record

Use of OMI data

UV information service
Regional/local air quality forecasts

OMI and PROMOTE
http://www.gse-promote.org
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 (CO$_2$, CH$_4$ 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

ESA Capacity 1 study, 2003-2005
Led by KNMI
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