# CAPACITY*

## OPERATIONAL ATMOSPHERIC CHEMISTRY MONITORING MISSIONS 2010-2020

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*** Composition of the Atmosphere: Progress to Applications in the user CommunITY**

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# Overview

- Introducing the ESA CAPACITY study
- Applications and User Requirements
- Some differences with IGOS-IGACO
- Measurement strategy and identified satellite level-2 data requirements
- Missing space elements in the 2010-2020 time period
- Mission concepts and measurement techniques for operational Air Quality applications
- Conclusions

# The CAPACITY strategy

- Envision a global monitoring system for atmospheric composition that integrates *space and ground-based* observations with models
- Collect the relevant operational applications and produce an inventory of user and geophysical data requirements (satellite and ground-based) per application
- Identify the missing space elements in the 2010-2020 time frame, concurrent with the operational use of MetOp, NPOESS and geostationary platforms
- Recommend measurement techniques and conceive possible mission concepts

## Study overview

| | | |
|---|---|---|
| ➢ | Consortium formation | November 2002 |
| ➢ | ‘CAPACITY’ proposal | January 2003 |
| ➢ | Kick off | October 2003 |
| ➢ | User consultation workshop | January 2004 |
| ➢ | Mid-term review / user feedback | August 2004 |
| ➢ | Final presentation | June 2005 |
| ➢ | Final report | October 2005 |

## Key team

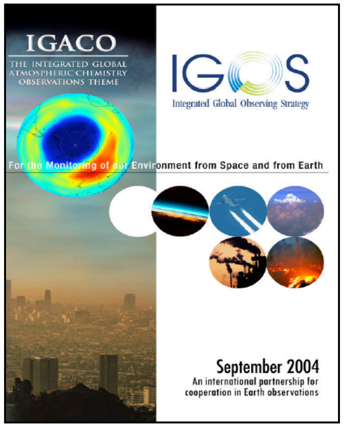
KNMI, Rutherford Appleton Laboratory, Univ. Bremen, Univ. Leicester,
EADS-Astrium, Alcatel Space,
+ wide range of consultants (users, modellers, retrieval experts)

## Website (ESA workshop; final report and documents)

http://www.knmi.nl/capacity

# Basic Ingredients

- CAPACITY workshop January 2004
- Environment and climate protection protocols, directives, etc. (EU & International)
- ESA GMES service element PROMOTE
- EU GMES-GATO report
- EUMETSAT user consultation process in the frame of geostationary program MTG (2015+)
- IGOS-IGACO Theme report =>
- Long-term observation requirements from WMO, GCOS, WCRP, IGBP, …
- Various scientific ESA studies
- Various EU framework research projects, e.g., Evergreen ($CH_4$, $CO$, $CO_2$)



# Environmental themes, data usage, applications

| Environmental Theme / Data usage | Ozone Layer & Surface UV radiation | Air Quality | Climate |
|---|---|---|---|
| **Protocols** | UNEP Vienna Convention; Montreal and subs. Protocols<br>CFC emission verification<br>Stratospheric ozone, halogen and surface UV distribution and trend monitoring | UN/ECE CLRTAP; EMEP / Göteborg Protocol; EC directives EAP / CAFE<br>AQ emission verification<br>AQ distribution and trend monitoring | UNFCCC Rio Convention; Kyoto Protocol; Climate policy EU<br>GHG and aerosol emission verification<br>GHG/aerosol distribution and trend monitoring |
| **Services** | Stratospheric composition and surface UV forecast<br>NWP assimilation and (re-) analysis | Local Air Quality (BL); Health warnings (BL)<br>Chemical Weather (BL/FT)<br>Aviation routing (UT) | NWP assimilation and (re-) analysis<br>Climate monitoring<br>Climate model validation |
| **Assessment**<br><br>**(lower priority for operational mission)** | Long-term global data records<br>WMO Ozone assessments<br>Stratospheric chemistry and transport processes;<br>UV radiative transport processes<br>Halogen source attribution<br>UV health & biological effects | Long-term global, regional, and local data records<br>UNEP, EEA assessments<br>Regional & local boundary layer AQ processes;<br>Tropospheric chemistry and long-range transport processes<br>AQ source attribution<br>AQ Health and safety effects | Long-term global data records<br>IPCC assessments<br>Earth System, climate, rad. forcing processes; UTLS transport-chemistry processes<br>Forcing agents source attribution<br>Socio-economic climate effects |

# Some differences with IGOS-IGACO

- ***CAPACITY*** is on operational applications; it gives somewhat lower priority to science questions

- ***IGACO*** data requirements have not been specified per application. Instead, distinction has been made in a **group-1 (existing systems)** and **group-2 (next generation systems)** set of observables

- ***IGACO*** has four themes, ***CAPACITY*** three. The fourth theme of ***IGACO*** is the **oxidising capacity**, which in ***CAPACITY*** has been integrated in the "assessment" of the three other themes

- ***IGACO*** requirements are given on a per species and atmospheric domain basis, but the rationale behind each of the quantitative requirements has not been detailed in the ***IGACO*** report as in the ***CAPACITY*** study

# Strategy to Data Requirements

- Specify for each parameter the (threshold) **resolution and revisit time requirements per atmospheric domain** on the basis of the observed spatial and temporal variability
- Define a **measurement strategy** the different role of satellite data, ground-based networks and atmospheric models for each theme/user type combination
- Investigate the role of **data assimilation** for uncertainty requirements, also in relation with the established resolution and revisit time requirements and sampling/coverage
- Define the **auxiliary data** requirements for the applications.
- Examine and try to understand differences with several existing tabulated data requirements

# Strategy Air Quality Protocol Monitoring – example

## Role of Satellite Measurements

- Interpolation of surface networks in the PBL
- Boundary conditions for regional AQ models
- Tropospheric background and long-range transport
- Application to inverse modeling of surface emissions

## Role of Surface Networks

- EU Framework Directives (surface concentrations)
- National Emission Ceilings (concentration monitoring to derive emissions)
- Gothenburg protocol on ground-level ozone
- Ship emissions (operational ship monitoring coastal waters)
- A representative network for surface concentrations and emissions in Europe
- Satellite and model validation, also by boundary layer profiling (LIDARS, Towers)

## Auxiliary data

- Meteorology from NWP centers including surface data
- Emission inventories and estimates on sinks

# Summary of identified operational satellite data products for Air Quality

| Observable | User(s) | Domain(s) |
|---|---|---|
| $O_3$ | all | PBL/Troposphere |
| $NO_2$ | all | PBL/Troposphere |
| CO | all | PBL/Troposphere |
| $SO_2$ | all | PBL/Troposphere |
| $CH_2O$ | all | PBL/Troposphere |
| Aerosol OD | all | PBL/Troposphere |
| Aerosol Type | all | PBL/Troposphere |
| $H_2O$ | all except protocol | PBL/Troposphere |
| $HNO_3$ | all except protocol | PBL/Troposphere |
| $N_2O_5$ | all except protocol | PBL/Troposphere |
| PAN / Org. nitrates | all except protocol | PBL/Troposphere |
| Surface UV albedo | all except protocol | Surface |

# Summary of identified operational satellite data products for Ozone layer / surface UV

| Observable | User(s) | Domain(s) |
|---|---|---|
| $O_3$ | all | Stratosphere, Troposphere |
| UV solar spectrum | all | Top-of-Atmosphere |
| UV aerosol optical depth | all | Troposphere |
| UV aerosol absorption optical depth | all | Troposphere |
| Spectral UV surface albedo | all | Surface |
| | | |
| $H_2O$ | NRT, assessment | Stratosphere |
| $N_2O$ | NRT, assessment | Stratosphere |
| $CH_4$ | NRT, assessment | Stratosphere |
| $CO_2$ | NRT, assessment | Stratosphere |
| $HNO_3$ | NRT, assessment | Stratosphere |
| Volcanic aerosol | NRT, assessment | Stratosphere |
| | | |
| CFC-11 | assessment | Stratosphere |
| CFC-12 | assessment | Stratosphere |
| HCFC-22 | assessment | Stratosphere |
| ClO | assessment | Stratosphere |
| BrO | assessment | Stratosphere |
| $SO_2$ | assessment | Stratosphere |
| Aerosol surface density | assessment | Stratosphere |
| PSCs | assessment | Stratosphere |
| HCl | assessment | Stratosphere |
| $ClONO_2$ | assessment | Stratosphere |
| $CH_3Cl$ | assessment | Stratosphere |
| HBr | assessment | Stratosphere |
| $BrONO_2$ | assessment | Stratosphere |
| $CH_3Br$ | assessment | Stratosphere |

# Summary of identified operational satellite data products for Climate

| Observable | User(s) | Domain(s) |
|---|---|---|
| $CH_4$ | C1 | PBL, Troposphere |
| $CO_2$ | C1 | PBL, Troposphere |
| CO | C1 | PBL, Troposphere |
| $NO_2$ | C1 | PBL, Troposphere |
| $O_3$ | C1 | PBL, Troposphere |
| Aerosol OD | C1 | PBL, Troposphere |
| Aerosol absorption OD | C1 | PBL, Troposphere |
| $H_2O$ | C2, C3 | Troposphere, Stratosphere |
| $O_3$ | C2, C3 | Troposphere, Stratosphere |
| $CH_4$ | C2, C3 | Stratosphere |
| $CO_2$ | C2, C3 | Stratosphere |
| $N_2O$ | C2, C3 | Stratosphere |
| Aerosol optical properties | C2, C3 | Stratosphere |
| Cirrus optical properties | C2, C3 | Troposphere |
| $HNO_3$ | C3 | Troposphere, Stratosphere |
| $NO_2$ | C3 | Stratosphere |
| $SF_6$ | C3 | Stratosphere |
| Cl compounds | C3 | Stratosphere |
| $N_2O_5$ | C3 | Stratosphere |
| PAN | C3 | Troposphere |
| CO, HCs, $CH_2O$, $H_2O_2$ | C3 | Troposphere |

# 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

# Mission concepts for Air Quality (1)

**System options**

- A sun-synchronous LEO platform and a GEO platform to satisfy spatio-temporal sampling requirements over Europe

- A constellation (~3) in inclined LEO to satisfy spatio-temporal sampling requirements globally at mid-latitudes

- A sun-synchronous LEO to complement Metop and NPOESS diurnal sampling with a mid-afternoon orbit

# Mission concepts for Air Quality (2)

**Instrumentation**

**(1) combined solar backscatter and thermal IR sounding**

- combination to provide optimal PBL sensitivity for $O_3$, CO
- solar backscatter to provide column information on $NO_2$, $SO_2$, HCHO, aerosols at daytime with PBL sensitivity
- thermal IR to provide in addition nitrogen reservoir species (e.g., $HNO_3$, PAN, organic nitrates, $N_2O_5$), at day and night

**(2) solar backscatter sounding only**

- Column information on $O_3$, $NO_2$, CO, $SO_2$, HCHO, aerosol OD at daytime

## Mission concept for Climate Protocol Monitoring

**System:** A sun-synchronous LEO platform
**Instrumentation:** UV-vis-SWIR spectrometer for $O_3$, $NO_2$, $CH_4$, CO, aerosol
- Thermal IR functionality by IASI
- $CO_2$ immature for an operational mission

# Key conclusions of the CAPACITY study w.r.t operational Air Quality missions

- User requirements for nine application areas have been addressed in detail
- A consistent set of satellite level-2 data requirements has been compiled for each application area
- The system for Air Quality should target user requirements on global coverage as well as optimal regional temporal sampling
- A trade-off is recommended between the three system options for Air Quality
- The climate protocol mission has important overlap with the global Air Quality mission – a combined implementation may turn out most efficient
- A limb-component could complement the nadir observations also for Air Quality