GMES Sentinels 4 and 5 Mission Requirements

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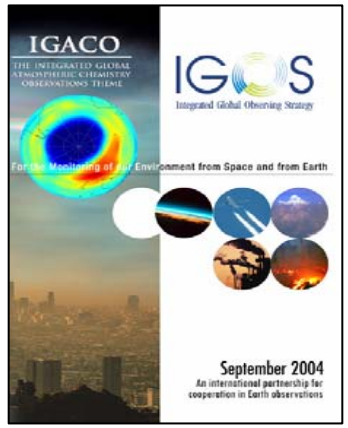
Sources of user and observational requirements for operational atmospheric chemistry



- IGOS-IGACO Theme report
- EU GMES-GATO report
- EU FP projects, e.g. Create-Daedalus, Evergreen
- Eumetsat user consultation in the frame of MTG
- Environment and climate protection protocols, directives etc. (EU, international)
- GCOS implementation plan, WCRP-SPARC long-term observation requirements
- GMES service element PROMOTE
- ESA studies on CO_2 monitoring
- ESA study on atmospheric chemistry observation requirements (research)
- CAPACITY workshop Jan. ’04

… many useful inputs, but …

… we need a set of requirements …

- for each environmental theme
- for each application type
- self-consistent
- sufficiently complete to perform trade-offs between space mission concepts
- following an integrated observation strategy (IGACO) considering ground, airborne and space observations and assimilation / models

… and we need to perform the reality check.

Launched dedicated study “CAPACITY” on quantitative requirements for operational atmospheric chemistry monitoring missions

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

Measurement strategy - example: climate protocol monitoring

Role of Satellite Measurements

- Concentration monitoring for inverse modeling of CH_4, CO_2, CO and NO_2 emissions
- Global concentration distributions of the mentioned gases, O_3 and aerosols

Role of Surface network

- Greenhouse gases trend monitoring (CO_2, CH_4, N_2O, SF_6, CF_4, HFCs)
- Weekly surface concentrations and total columns from a representative network.
- Validation of satellite measurements
- Concentration monitoring for inverse modeling of CH_4, CO_2, CO and NO_2 emissions
- Tropospheric O_3: sondes, lidar and surface data;
- Tropospheric aerosol optical depth and aerosol absorption optical depth
- Trend monitoring for ozone depleting substances with climate forcing: (H)CFCs.

Auxiliary data

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

Observational requirements – example: AQ NRT satellite

B2-S	Theme:	Air Quality
	Category:	Near-Real Time Data
	Type of Observations:	Satellite

Requirement / Data Product	Driver	Height Range	Horizontal resolution (km)	Vertical resolution (km)	Revisit Time (hours)	Uncertainty
O3	Air Quality Forecast; UV actinic fluxes	PBL	5 / 20	--	0.5 / 2	10%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	25%
		Total Column	50 / 100	--	12 / 24*3	5%
NO2	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	10%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
CO	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Ttropospheric Column	5 / 20	--	0.5 / 2	25%
		Total Column	5 / 20	--	0.5 / 2	25%
Aerosol OD	Air Quality Forecast; UV actinic fluxes	PBL	5 / 20	--	0.5 / 2	0.05
		FT	5 / 50	--	0.5 / 2	0.05
		Ttropospheric Column	5 / 20	--	0.5 / 2	0.05
		Total Column	5 / 20	--	0.5 / 2	0.05
Aerosol Type	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	< 10% mis-assignments
		FT	5 / 50	--	0.5 / 2	< 10% mis-assignments
		Ttropospheric Column	5 / 20	--	0.5 / 2	< 10% mis-assignments
		Total Column	5 / 20	--	0.5 / 2	< 10% mis-assignments
H2O	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	10%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	10%
		Total Column	5 / 20	--	0.5 / 2	10%
SO2	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
CH2O	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
HNO3	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
N2O5 (night)	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	50%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
PAN	Air Quality Forecast	PBL	5 / 20	--	0.5 / 2	20%
		FT	5 / 50	1 / 3	0.5 / 2	20%
		Tropospheric Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
		Total Column	5 / 20	--	0.5 / 2	1.3e15 molec cm-2
Spectral UV surface albedo	UV actinic fluxes	Surface	5 / 20	--	24 / 24*3	0.1

Geographical coverage requirements

Ozone Layer & Surface UV radiation	**global**
Air Quality	**threshold : Europe + surrounding areas** (e.g. monitoring of EC directives and national AQ legislation, short-term air quality forecast) **target : global** (monitoring, assessment and forecast of global air quality, the oxidising capacity, and the quantification of continental in/outflow)
Climate	**global**

Assessment of existing and planned missions – quick summary

Current status of observational system in 2010-2020 :

MetOp / EPS	GOME-2, IASI
NPOESS	OMPS, CRIS

GOME-2 and OMPS

- designed for stratospheric ozone monitoring
- considered appropriate for this purpose
- some contribution to NWP
- contributions to tropospheric applications very limited, due to insufficient temporal sampling (~ 1/week/geo-location cloud-free) and too coarse horizontal resolution

IASI and CRIS

- main products: T, greenhouse gases (H_2O, O_3, CH_4, N_2O) and CO
- vertical profiles of H_2O; vertical resolution for tropospheric O_3, CO
- sensitivity decreasing towards planetary boundary layer (main interest)

Main gaps in current / planned operational system

- **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 and climate applications**
- High temporal/spatial resolution space-based measurements of tropospheric (PBL) composition for application to **air quality**

(in line with IGACO findings)

Mission concept for climate protocol monitoring applications (lower troposphere)

System: sun-synchronous LEO platform

Instrumentation: UV-vis-SWIR spectrometer for O_3, NO_2, CH_4, CO, aerosol

Mission concept for ozone and climate applications in the UTLS

System: sun-synchronous LEO platform with a limb-sounder, formation flying with Metop or other new mission with nadir-viewing instruments in order to support their tropospheric data products

Instrumentation options:

either mm-wave (MASTER derivative) or mid-IR (AMIPAS derivative)

Mission concept for air quality

Instrumentation options:

1) combined solar backscatter and thermal IR sounding
2) solar backscatter sounding only

Mission concept for air quality - system options

Driving requirements (protocol monitoring, forecast) :

Revisit time **0.5 – 2 h** **Spatial resolution 5 – 20km**

System options:

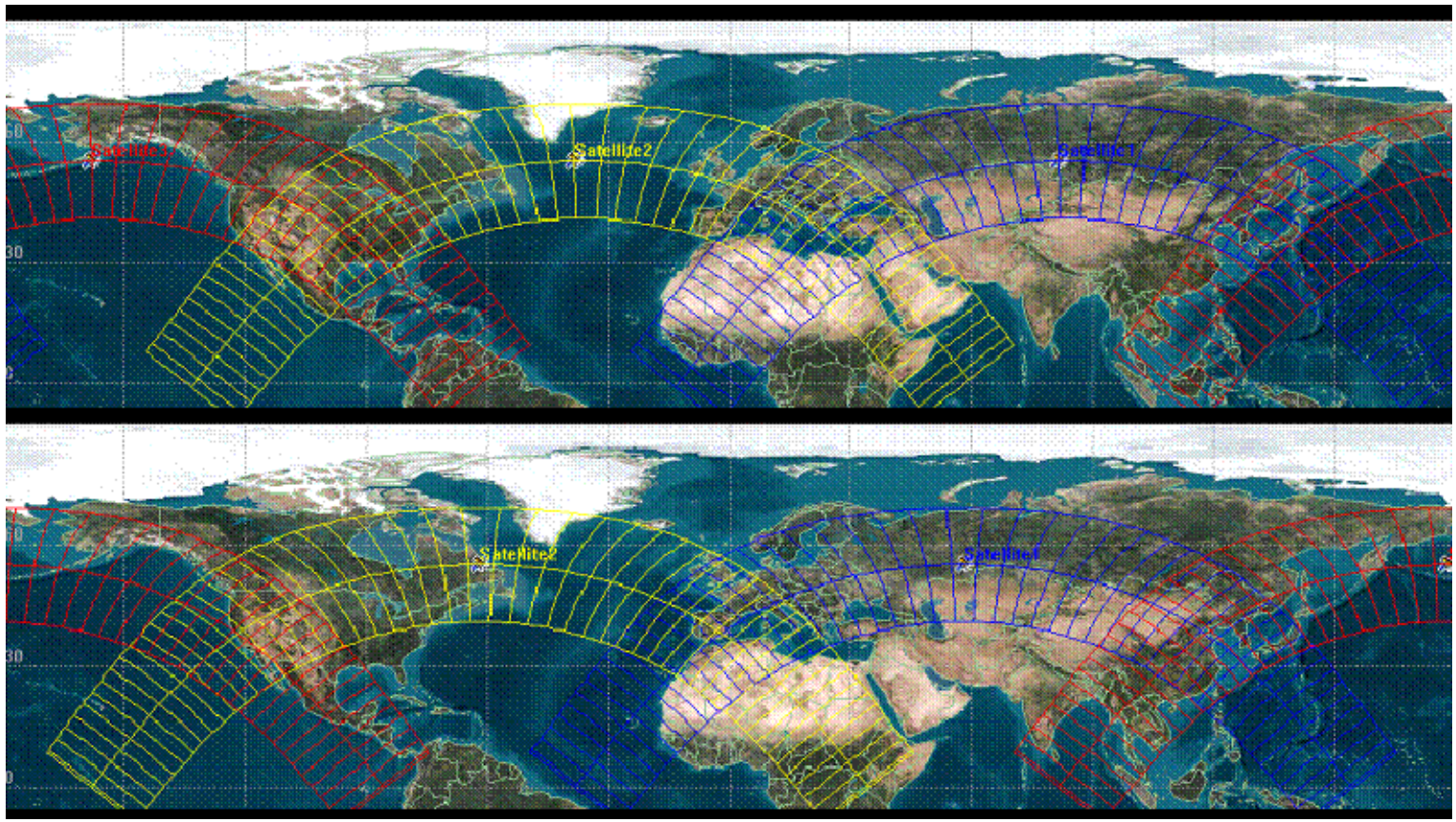
A 1 geostationary satellite to satisfy spatio-temporal sampling requirements over Europe, and

1 LEO satellite in sun-synchronous orbit for global pollution transport (Convention on long-range transport of air pollutants, medium-range forecast)

B a constellation of 3 satellites in inclined LEO to satisfy spatio-temporal sampling requirements globally at mid-latitudes, with reduced sampling at low latitudes. High orbit desirable to maximise latitude range.

C 1 satellite in sun-synchronous LEO, with local time defined to complement Metop and NPOESS diurnal sampling (afternoon orbit)

3 satellites at 900km, 125º inclination (two consecutive orbits)



each of the 3 satellites will cover Europe at 5 subsequent orbits

➡ full day (+night) coverage with 1.7hours revisit time

Conclusions

1. Choice between system options for air quality mission

   (1 GEO + 1 LEO vs. 3 inclined LEO's)

   depends on technical and scientific trade-offs still to be performed.

2. Meanwhile, 1 LEO satellite with UV-VIS-SWIR payload for global air quality is part of both options and can be developed without delay.

3. The climate protocol monitoring mission should be combined with the LEO air quality mission (large overlap in requirements)

4. After selection of air quality system option, either 1 GEO or remaining two LEO's to be added.

5. Consolidate choice and requirements of instrument for UTLS mission for climate and ozone NRT and assessment applications, and implement the mission

Thank you !

Air quality:

LEO constellation as a replacement for GEO ?

- GEO mission has best spatio-temporal sampling over Europe
- GEO mission only complete with additional LEO platform covering hemispheric pollution transport (CLRTAP convention)
- GEO mission fulfils temporal sampling requirement only over Europe – air quality services not available for most polluted regions (e.g. Asia)

- LEO constellation (3 satellites) provides quasi-global coverage with good temporal sampling
- LEO constellation can more easily fulfil radiometric and pointing requirements
- LEO constellation redundancy easier (loss of one satellite leads to degraded mission instead of complete failure; identical satellites; cheaper launch)