Geophysical Validation Needs of the Geostationary Air Quality (GeoAQ) Constellation GEMS + Sentinel-4 + TEMPO Linked together by LEO sensors

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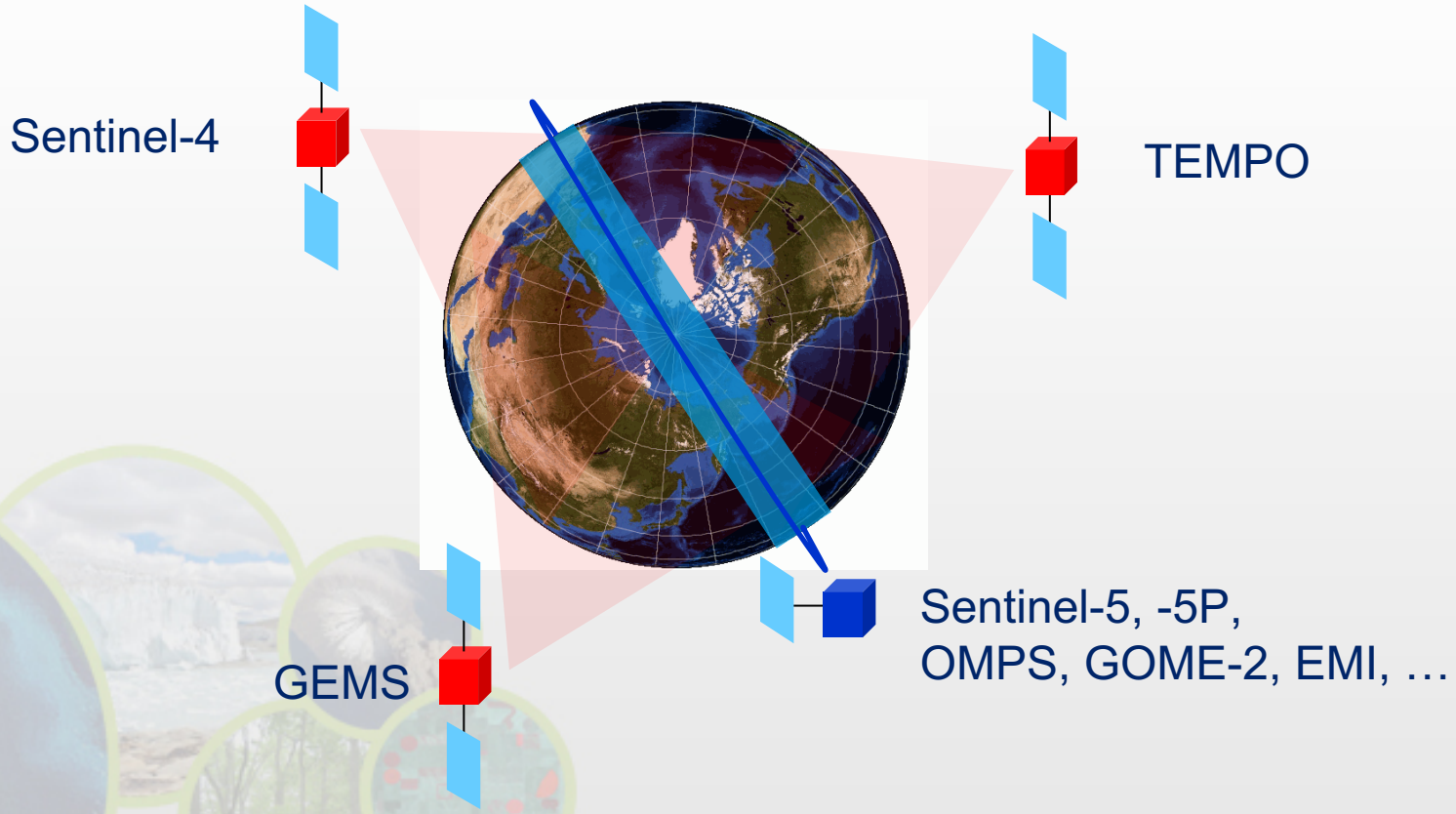
GeoAQ = GEMS + Sentinel-4 + TEMPO + LEO



GeoAQ Validation Needs Document

Geo-AQ Constellation Goals

- Maximize impact of the missions
- Data access & inter-operability
- Consistency of products
- Traceable data quality
- …

GeoAQ Validation Needs Document objective

- Establish inter-mission bias targets
- Identify new validation challenges
- Identify needed validation approaches
- Inventory existing / new reference measurements

➔ **Feedback welcome**

➔ **Target to finalise before summer 2018**

Inter-mission Bias Targets

Product		Uncertainty*			Accuracy* of method	Consistency* heritage data	Agreed bias target*
		GEMS	S4	Tempo			
Solar irrad			2-3%		2-4% consistency of ref spectra, direct comparison	2-5%	1-2%
Earth rad			2-3%		2% acc GSICS inter-cal factors	2-5%	2-5%
Reflect.			2-3%		2%	2-5%	2-5%
O_3	total	3%	3%	3%	1-3%	<1% monthly zonal mean	1%
	strat	5%	-	5%			5%
	trop	20%	25%	10 ppbv			20%
	0-2km	-	-	10 ppbv			
NO_2	total	$1x10^{15}$	-	1×10^{15}			1×10^{15}
	trop	-	30%, 1.5×10^{15}	1×10^{15}		$1\text{-}2\times10^{15}$ (OMI-SCIA), bias in strat 0.5×10^{15}	1×10^{15}
SO_2		$1x10^{16}$	60%, 3×10^{16}	1×10^{16}			1×10^{16}
HCHO		$1x10^{16}$	50%, 1.5×10^{16}	1×10^{16}			1×10^{16}
CHOCHO			50%, 7×10^{14}	4×10^{14}			4×10^{14}
AOD		20%, 0.1	-	0.05			0.05 @ 440 nm

*) in molec/cm^2 unless specified otherwise

New Validation Challenges

- Temporal sampling of diurnal cycle
- Horizontal resolution (S5P forerunner)
- Inter-mission consistency without geographic overlap
- Slant viewing and illumination angles
- Directionality of surface and atmosphere
- Geo-location knowledge
- Vertical distribution of constituents
- Near surface ozone (TEMPO)
- Stratospheric NO_2 correction (S4 lack of clean sector)
- High expectations wrt data quality and availability (➔ FRM, QA4EO)

GeoAQ Geophysical Validation Needs Document Status

4. Validation Needs

4.1. General

4.1.1. Coordination of the Validation Process
4.1.2. Continuity
4.1.3. New Infrastructure or Approaches

4.2. For Each Mission Individually

4.2.1. Level-1b Earth Radiance and Solar Irradiance
4.2.2. Level-2 Systematic Long-term Validation
4.2.3. Total Trace Gas Columns
4.2.4. O_3 Profile
4.2.5. Ozone Trend Monitoring
4.2.6. NO_2 Diurnal Cycle Observation Capability
4.2.7. NO_2 Stratospheric Correction
4.2.8. SO_2 volcanic emission events
4.2.9. Aerosol Optical Depth
4.2.10. Aerosol Layer Height
4.2.11. Emission Source estimation

4.3. Inter-mission Consistency

4.3.1. Solar irradiance
4.3.2. Earth radiance and Reflectance
4.3.3. Inter-calibrated Ground-Based Instruments
4.3.4. LEO satellites as travelling standard for L2
4.3.5. Airborne sensors as travelling standard
4.3.6. Stratospheric Ozone Monthly Zonal Means
4.3.7. Mobile ground-based sensors as travelling standard
4.3.8. Cross Validation of Algorithms
4.3.9. Level-2 Constellation Products Based on a Common set of Algorithms

- Approach
- Domain / scenario
- Correlative data
- Auxiliary data

Example: NO_2 Diurnal Cycle Observation Capability

- Biases with diurnal variation: instrument thermal effects, shortcomings in treatment of the vertical NO_2 profile, aerosols, clouds, the surface reflectance and its directionality.
- Demonstrate that diurnal variation is picked up for a) perfect scene knowledge b) for typical in-flight available scene knowledge
- Airborne NO_2 observations with varying illumination and viewing angles? Comprehensive set of correlative and auxiliary data!

Slides from AV-VC#13

Validation Goals in Phases E1/E2

	Commissioning Phase (E1)	Exploitation Phase (E2)
Level-1b	• In-flight Cal Key Data • System verification and acceptance • Establish data quality	• Maintain data quality • Degradation monitoring • Anomaly detection • Inter-mission consistency
Level-2	• Processor verification and acceptance • First check data quality	• Establish data quality • Maintain data quality • Degradation monitoring • Anomaly detection • Inter-mission consistency

Validation Needs

- NO_2 selected as an example
  - Establish and maintain Data Quality
  - **Validate Diurnal Cycle Observation Capability**
  - **Validate Stratospheric Correction**
  - **Validate Source Estimation**
  - **Verify Inter-Mission Consistency**

Validation Needs for NO_2

Establish and maintain data quality

Systematic validation by operational data quality center

- Domain
  - All conditions, full geographic coverage area, all seasons
- Fiducial Reference Measurements
  - Co-located NO_2 measurements
    - total column (ground based, inter-calibrated network)
    - profile in lower troposphere (ground based, inter-calibrated instrumentation)
  - Cloud fraction, optical depth, height (ground based and met imagers)
  - Aerosol optical depth, type (ground based, inter-calibrated network)
- Other data
  - Surface albedo (climatology, near-real time satellite product)
  - CTM data (NO_2 field)
  - Stratospheric NO_2! From model, OMPS limb, ..?

Validation Needs for NO_2

Validate Diurnal Cycle Observation Capability

Campaign capturing the relevant variations

- Domain
  - Polluted area including sources, limited transport into domain
  - Diurnal evolution of NO2 (sources, processes, transport, sinks)
- Correlative measurements
  - NO_2 with hourly sampling or better
    - total column: high spatial resolution (~1km), various viewing geometries
    - total column: at selected locations
    - profile: lower troposphere, also stratosphere, at selected locations
  - Cloud fraction, optical depth, height
  - Aerosol optical depth, type
  - Surface reflectance directionality (BRF)
- Auxiliary data
  - CTM data (NO_2 sources, sinks, profiles, related species, …)
  - Emission strength (NO/NO_2) diurnal variation

Validation Needs for NO_2

Validate Stratospheric Correction

Dedicated analysis

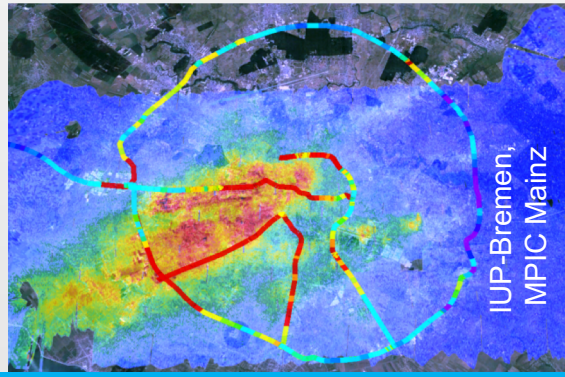
- **Approaches**
  - **use of model forecast**
  - **spatial filtering & interpolation**
  - **clean sector (not available for S4)**
- Domain
  - latitude bands covered by the mission
  - various local times
- Correlative data
  - Stratospheric NO_2! From model, OMPS limb, ..?
  - NO_2 total column

Validation Needs for NO_2

Validate Source Estimation

Campaign dedicated to higher level product

- Domain
  - Similar as for diurnal cycle
  - Polluted area including sources, clean surrounding
- Correlative Measurements
  - NO_2 column and profile reference measurements in domain
  - Near-simultaneous NO_2 profile on domain boundary
  - Cloud fraction, optical depth, height
  - Aerosol optical depth, type
- Compare
  - Inverse modelling of satellite NO_2 data
  - Inverse modelling of correlative NO_2 data
  - Simplistic estimate using divergence theorem
  - Emission estimates



$$\int Source\, dA = \oint \overrightarrow{Flux} \cdot \vec{n}\, ds$$

Validation Needs for NO_2

Verify Inter-Mission Consistency

Various approaches

- LEO missions used as travelling standard
  - Systematic assessment as part of operational QA
  - Dedicated assessment of sub-sets (e.g. best understood, polluted/background, …)
- Stationary inter-calibrated instrumentation
  - Systematic assessment as part of long-term QA
  - Dedicated assessments, e.g. best understood sub-set
- Travelling ground-based and airborne instrumentation
  - Link campaigns
  - Inter-compare instrumentation and algorithms
- Direct comparison of similar targets?
- Comparisons with CTM

Validation Needs for Irradiance

Establish and maintain Data Quality

Systematic validation by operational data quality center

- Comparisons
  - measured reference spectra (ground-based, atmosph. corrected)
  - simulated reference spectra (line lists, models)
  - measured spectra from LEO mission
  - measured spectra from GeoAQ missions
- Monitoring of trends and dependencies
- Global Space-Based Inter-Calibration System (GSICS): verify inter-mission consistency, determine inter-calibration factors

Validation Needs for Radiance and Reflectance

Establish and maintain Data Quality

Systematic validation by operational data quality center

- Comparison with expected signal for known targets
  - bright clouds, dark ocean
  - vicarious calibration targets
  - dark space, moon (S4)
- Monitoring of trends and dependencies
- Inter-comparisons with LEOs used as travelling standard
  - geometry matching
  - bridge goniometry by modelling
- Global Space-Based Inter-Calibration System (GSICS): verify inter-mission consistency, determine inter-calibration factors