Sentinel-5 Precursor Validation Plan Approach

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1) ESA/ESTEC

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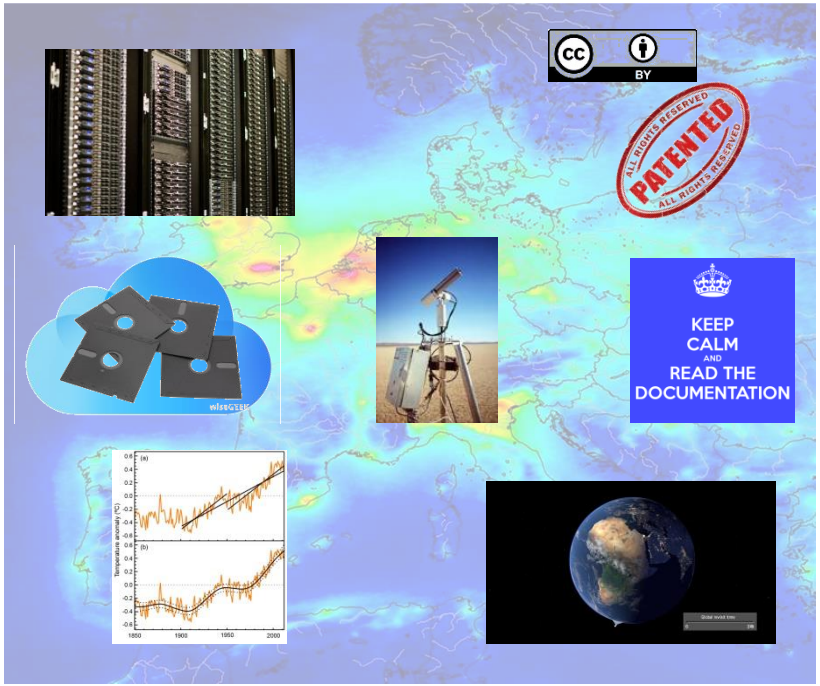
Satellite Data Quality

Fit for Purpose = Data Quality Requirements fulfilled

- Data Availability
- Data Continuity
- Data Coverage
- Data Policy
- Data Documentation
- Data Curating
- **Data Representativity**

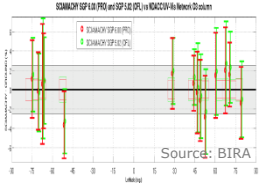
Geophysical Validation

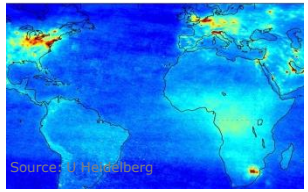


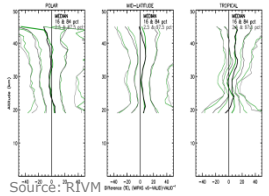
Ensure Data Quality through Validation …

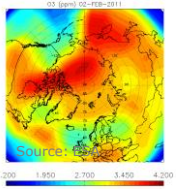
Validation is the process of assessing, by **independent** means, the quality of the data products as derived from the (satellite) system outputs.

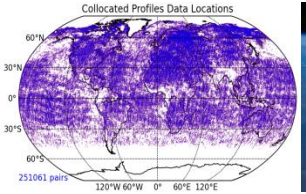
Geophysical validation ensures that the quality of geophysical products derived from the (satellite) system is properly assessed by independent means and via **quantification of the uncertainties** at any stage of the product processing chain.

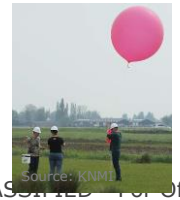


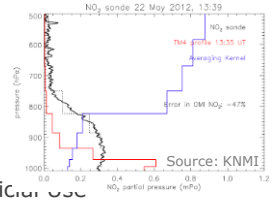


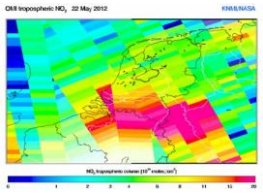


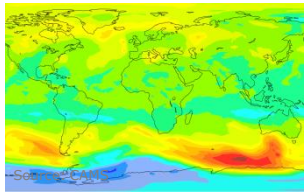


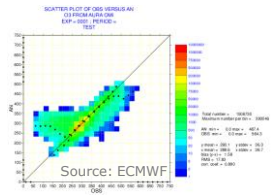


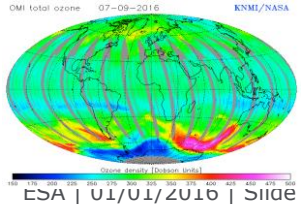












… throughout the mission phases

Commissioning Phase (E1): 0-6 months

- Initial assessment of Level 1 and 2 data quality
- Verification of consistency with correlative measurements

Exploitation Phase (E2-F): 0.5-7 years

- Consolidation of product quality information in terms of accuracy and precision estimates
- Continuous product quality monitoring and algorithm maintenance
- Continuous monitoring of instrument characteristics
- Re-assessment of validation needs

Sentinel-5 Precursor Validation Team (S5PVT) - Approach

Key Stakeholders are ESA, Validation teams and national funding agencies … and data users

1. Announcement of Opportunity 4Q2014
   - Detailed Validation Requirements
   - Proposals reviewed by External Experts
   - Letters of Acceptance → Funding Agencies

2. 1st pre-Launch S5PVT Workshop 4Q2015
   - 36 projects > 150 datasets
   - Consolidate Proposal information
   - Prepare Validation Implementation Plan
   - Review Validation Requirements

3. Science Validation Implementation Plan
   - Linking all S5PVT activities
   - Including a risk assessment
   - Living document

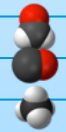
4. 2nd pre-Launch S5PVT Workshop (date TBD)
   - Review S5P and Validation Projects
   - Ground Segment Interface Testing

5. Routine Validation Activities during S5P operations

Validation Requirements: coverage

- **"Global"** coverage of correlative measurements
- **Polluted areas** for air-quality assessments, in particular urban sites and biomass burning
- Sites important to address **specific themes or target issues**, e.g., gradients, clouds, specific emissions (industrial, household, traffic, volcanic, …)
- **Background observations** in pristine locations, e.g., high altitude observations, remote sites

Validation Requirements: L2 Product Performance

Parameter	Data Product	Vertical Resolution	Accuracy	Precision
Ozone 	Ozone Profile	6 km	10-30%	10%
	Total Ozone	total column	3.5-5%	1.6-2.5%
	Tropospheric Ozone	trop column		
NO_2 	Stratospheric NO_2	strat column	<10%	0.5e15
	Tropospheric NO_2	trop column	25-50%	0.7e15
SO_2 	SO_2 enhanced	total column	30%	0.15-0.3 (0.06-0.12) DU
	Total SO_2	total column	30-50%	1-3 (0.4-1.2) DU
Formaldehyde 	Total HCHO	total column	40-80%	1.2e16 (4e15)
CO	Total CO	total column	15%	<10%
Methane	Total CH_4	total column	1.5%	1%
Cloud 	Cloud Fraction	total column	<20%	0.05
	Albedo (Optical Thickness)	total column	<20%	0.05 (10)
	Cloud Height (Pressure)	total column	<20%	<0.5 km (<30hPa)
	SNPP VIIRS Cloud data			
Aerosol 	Aerosol Layer Height	total column	<100hPa	<50hPa
	Aerosol Type	total column	~1 AAI	<0.1 AAI
Surface UV	Provided by FMI in frame of the Finnish Sentinel Collaborative Ground Segment			

S5P Validation Team

Validation Contributions

S5PVT

S5P Mission Performance Center

(Validation) Data Bases

evdc

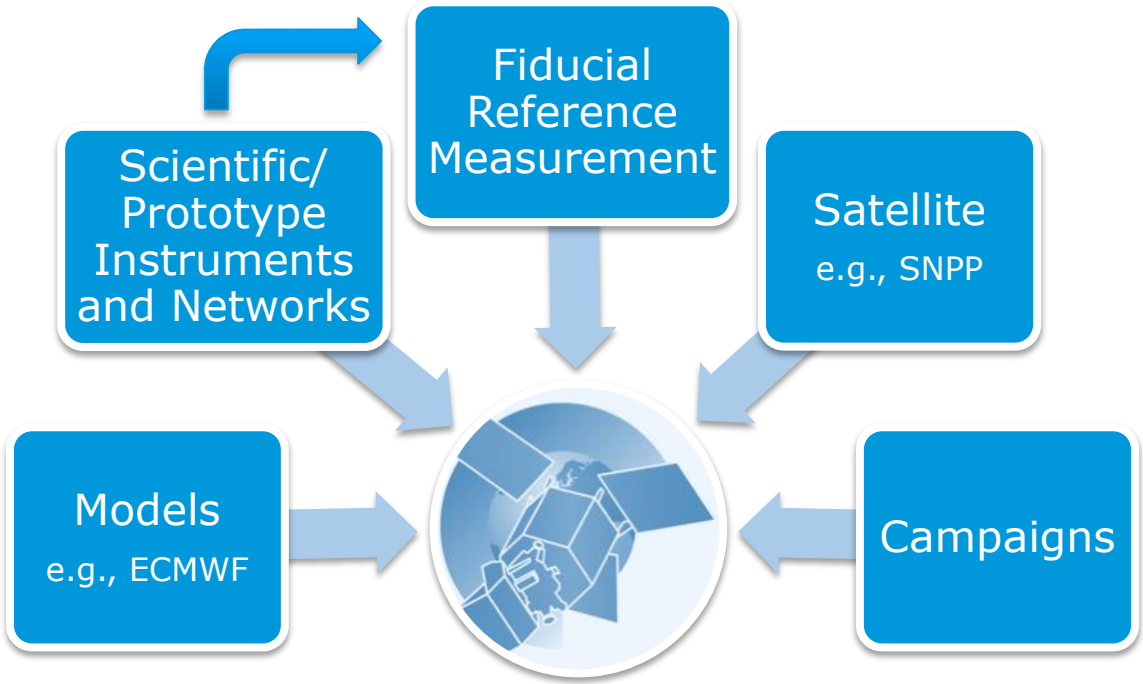
Atmosphere Monitoring Service

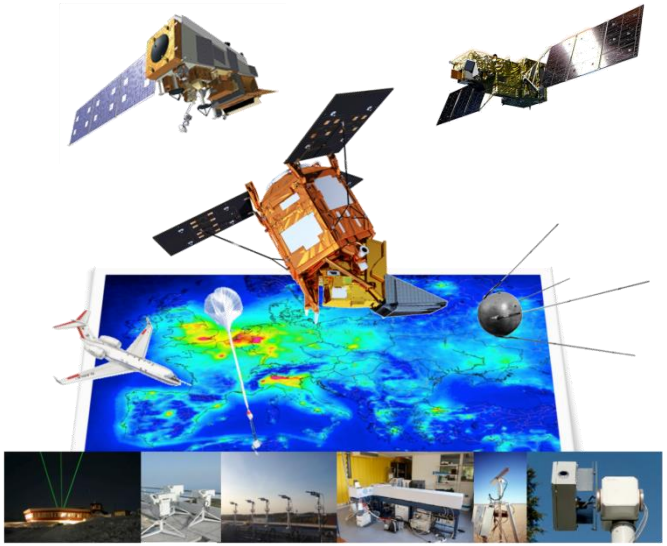
External Validation Teams

ESA Activities

FRM4DOAS
FRM4GHG
Pandonia

Validation Sources





Fiducial Reference Measurements

FRM is the suite of ground-based measurements that provide the maximum Return On Investment for a mission by delivering the required confidence in the data products for users (QA4EO)

FRM4GHG, U Bremen

- IR instrument intercomparisons and best practice development for GHG measurements
- Key: TCCON and NDACC IR WG

Infrastructure support to stations/laboratories:

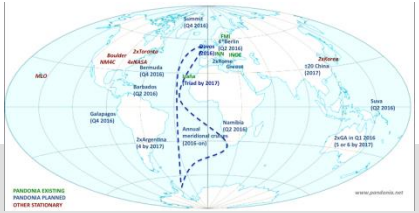
- Support annual European Brewer calibration campaigns (AEMet, Izaña)
- Calibration laboratory upgrades: PMOD/WRC, PHOTON/RIMA (AERONET)
- Direct support to Eureka (aircraft, infrastructure)

FRM4DOAS, BIRA-IASB

- MaxDOAS algorithm and processing harmonisation
- Preparation of an air quality intercomparison campaign, CINDI-2
- Focus on NDACC UV-Vis WG

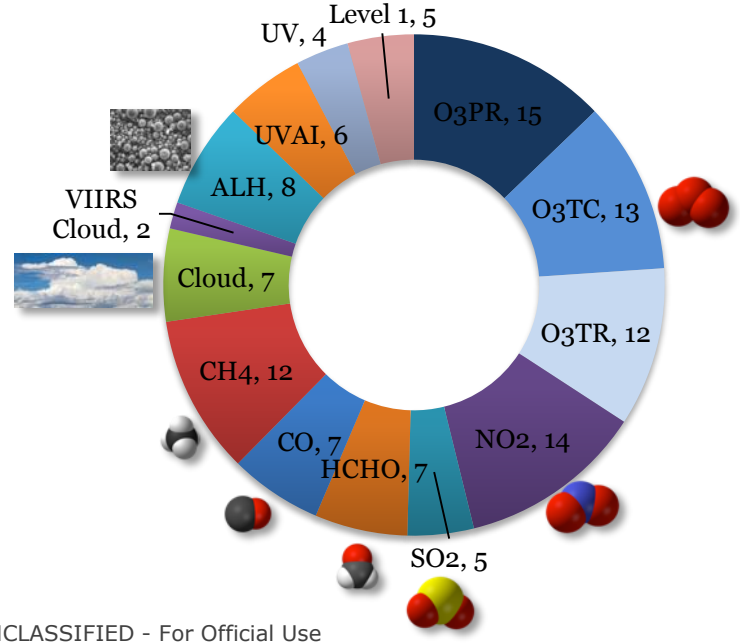
Pandonia Network, Luftblick

- Further development of the Pandora systems
- Calibration in cooperation with U. Innsbruck (Austria), AEMet (SP), PMOD/WRC (CH) and NPL (UK)
- Network of existing instruments with ~30 new operational instruments by the end of 2017

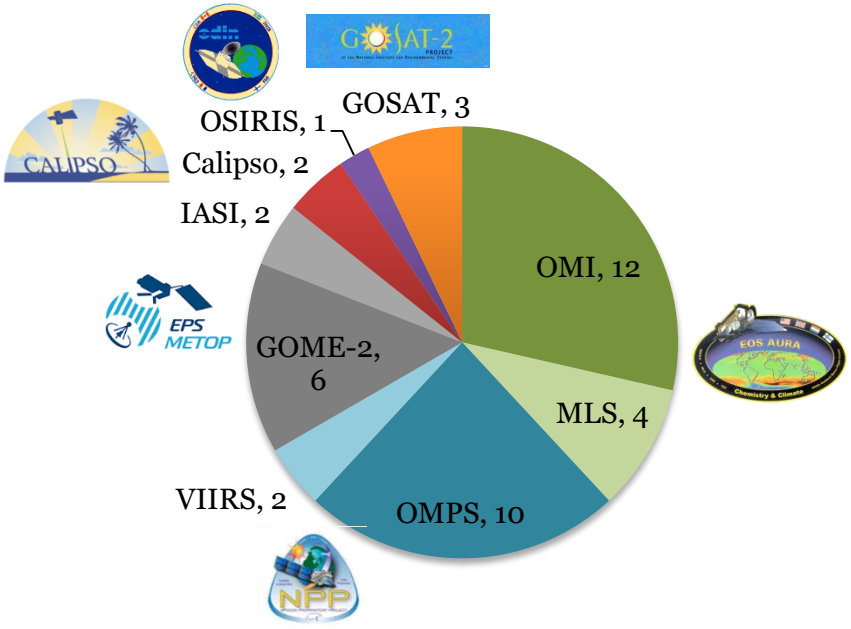


S5PVT Projects coverage …

… of operational products

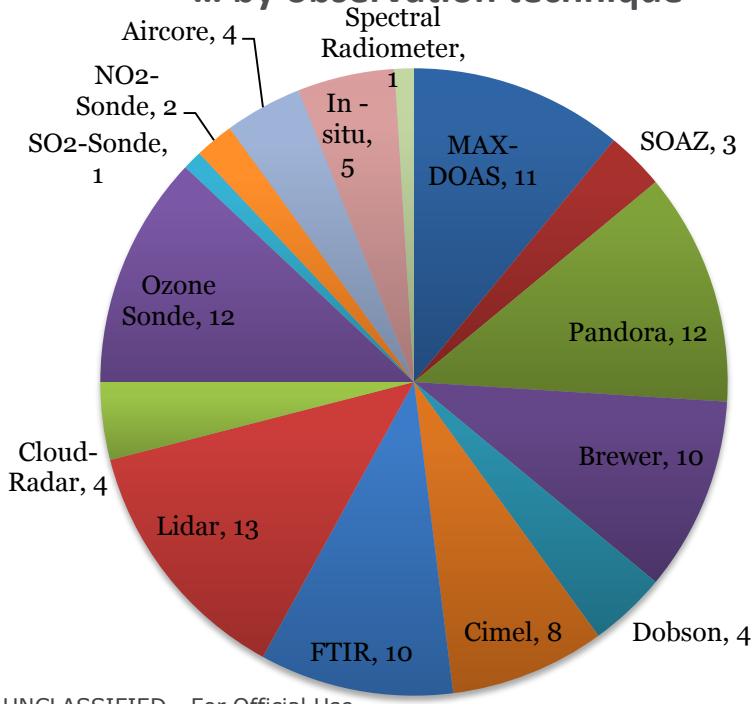


… of correlative satellite obs.

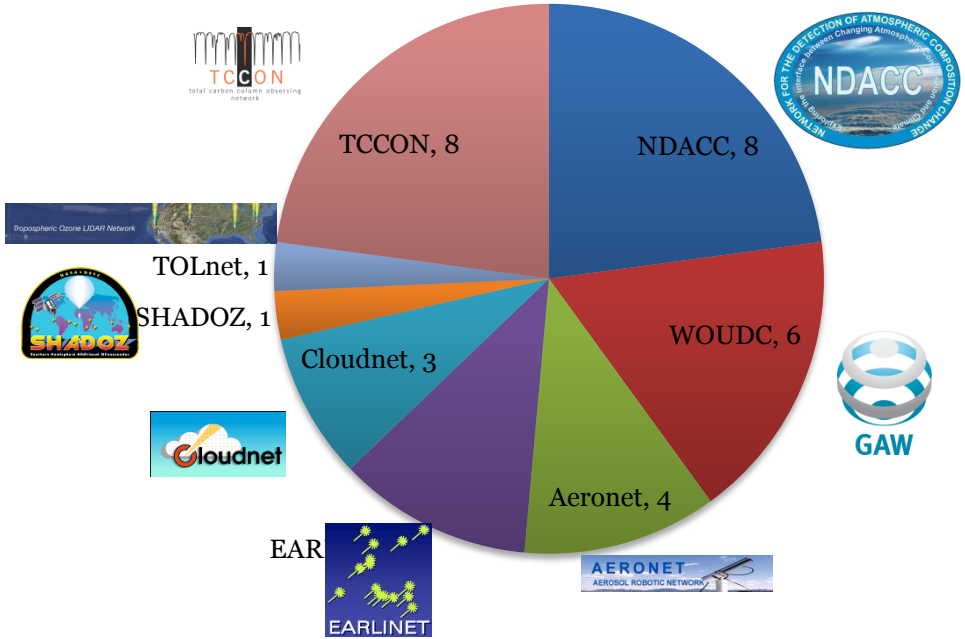


S5PVT Projects coverage …

… by observation technique



… of observation networks



Risk Assessment: Risk Factors and Weights

Schedule:	**Risk related to the overall planning of the project with respect to the S5P mission schedule.**	**33%**
Budget:	**Risk related to the budget currently allocated and the funding outlook.**	**33%**
Manpower:	**Risk relates to the availability of critical expertise and manpower (e.g., potential loss due to end of PhD program or retirement)**	**8.3%**
Infrastructure:	**Risk related to the status and availability of the infrastructure (e.g., development schedule, planning or aging)**	**8.3%**
Data:	**Risk related to the availability of validation data to the S5PVT along the mission**	**8.3%**
Dependencies:	**Risk related to dependencies of the project on partners external to the validation projects**	**8.3%**

➔ p_j = weighted probability that project j succeeds

Risk Assessment: Global Picture

N = number of projects
$\bar{P}$ = 1/N Σ_j p_j = average probability
P = Σ_j pj = measure for overall confidence

Requirements		Pre-Launch			Comiss.			Year 1			Year 2			Year > 2			Overall		
		$\overline{P_{j,k}}$	$P_{j,k}$	N	$\overline{P_{j,k}}$	$P_{j,k}$	N	$\overline{P_{j,k}}$	$P_{j,k}$	N	$\overline{P_{j,k}}$	$P_{j,k}$	N	$\overline{P_{j,k}}$	$P_{j,k}$	N	$\overline{P_{j,k}}$	$P_{j,k}$	N
Total and enhanced Sulphur Dioxide Total Column (SO2)																			
VAL-SO2-01	Enhanced Total Column Accuracy: 30%	93%	5,6	6	77%	4,6	6	91%	4,6	5	90%	4,5	5	86%	4,3	5	86%	4,3	5
VAL-SO2-02	Enhanced Total Column Precision: 0.15-0.3 (0.06-0.12) DU	93%	5,6	6	77%	4,6	6	91%	4,6	5	90%	4,5	5	86%	4,3	5	86%	4,3	5
VAL-SO2-03	Total Column Accuracy: 30-50%	93%	5,6	6	77%	4,6	6	91%	4,6	5	90%	4,5	5	86%	4,3	5	86%	4,3	5
VAL-SO2-04	Total Column Precision: 1-3 (0.4-1.2) DU	93%	5,6	6	77%	4,6	6	91%	4,6	5	90%	4,5	5	86%	4,3	5	86%	4,3	5
VAL-SO2-05	Validation of a-priori vertical tropospheric SO2 profile.	94%	1,9	2	91%	1,8	2	92%	1,8	2	92%	1,8	2	83%	1,7	2	83%	1,7	2
VAL-SO2-06	Validation in volcanic plume environment (degassing and eruptive volcanoes) in particular plume height.	94%	2,8	3	92%	2,8	3	93%	2,8	3	93%	2,8	3	85%	2,6	3	85%	2,6	3
VAL-SO2-07	Regions with significant SO2 pollution.	92%	3,7	4	70%	2,8	4	91%	2,7	3	89%	2,7	3	87%	2,6	3	87%	2,6	3
VAL-SO2-08	Nominal and high SO2 load conditions to validating all algorithm branches	95%	1,9	2	92%	1,8	2	92%	1,8	2	92%	1,8	2	81%	1,6	2	81%	1,6	2

Risk Assessment: Findings

Risk analysis preformed for the S5PVT projects with support of the validation teams:

Ozone profile and total column well covered, except spatial representativity and specific environmental conditions

Tropospheric ozone, NO_2 and formaldehyde well covered, but lacking global validation and in the tropics

Clouds and aerosol layer height well covered

Most validation capabilities are stable along the mission lifetime

SO_2 lacks redundancies and validation capabilities for high SO_2 pollution

AAI validation against other satellites only

CO and methane validation not fully secured, in particular as a result of funding issues for validation

Level 1b lack any redundancy and covering only UV/VIS

Lessons Learnt

- Define upfront detailed and specific Validation Requirements, with L2 experts
- Perform risk analysis of Validation program including schedule and budget of individual projects
- … do not start too early (nor too late)

Next Steps

ESA validation activities restart when launch date is confirmed

- Latest status of S5P and Validation Projects
- 2nd Pre-launch Validation Workshop
- Update Science Validation Implementation Plan
- Test of Ground Segment interfaces

Following S5P launch

- First L1b and L2 for validation towards end of commissioning (L+6 months)
- Routine Validation Activities with dedicated S5P Cal/Val Workshops