ESA Perspective on Airborne Campaigns for EO

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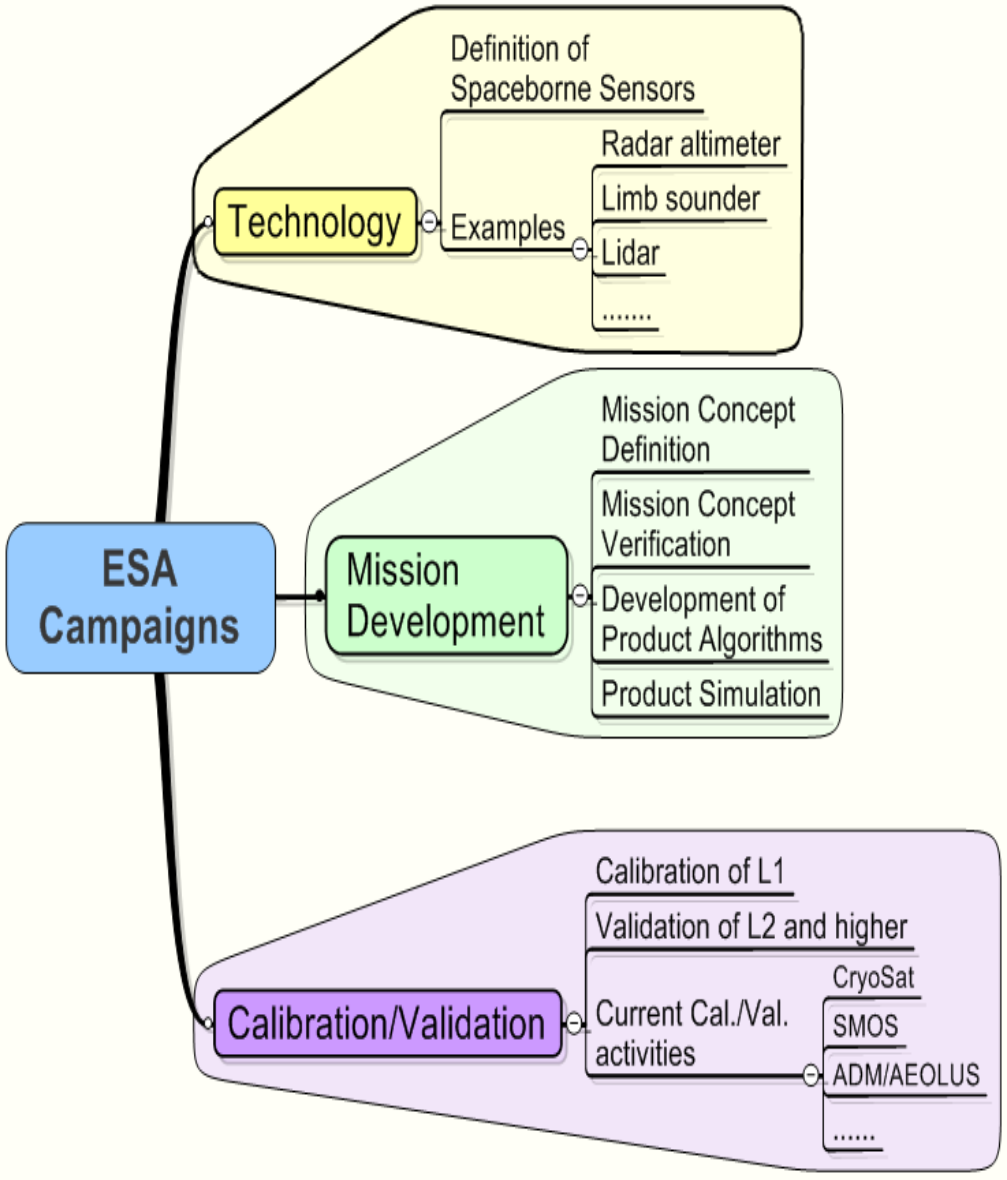
Why are ESA Earth Observation campaigns required ?

1. Explore EO possibilities before going to space
2. Prove EO measurement concepts work
3. Develop interpretation methodology
4. Develop calibration approach
5. Develop validation methods using independent data
6. Simulate data products (pre-launch)
7. Validate results using independent data
8. Develop applications

Close range observation during new development phase

Programmatic Background

1. **ESA campaign activities started in 1981**
    a. 125 campaigns as of September 2015 (+5 since last report)
    b. Typically 4-7 campaigns/year
2. **Strategic objectives:**
    a. Support to EO programs
    b. Transnational access to airborne facilities in member states
    c. Partnerships with national and international organisations
3. **Campaign activities address three main areas:**
    a. Technology
    b. Mission development
    c. Calibration/validation
4. **Campaign data archive supporting science and applications**

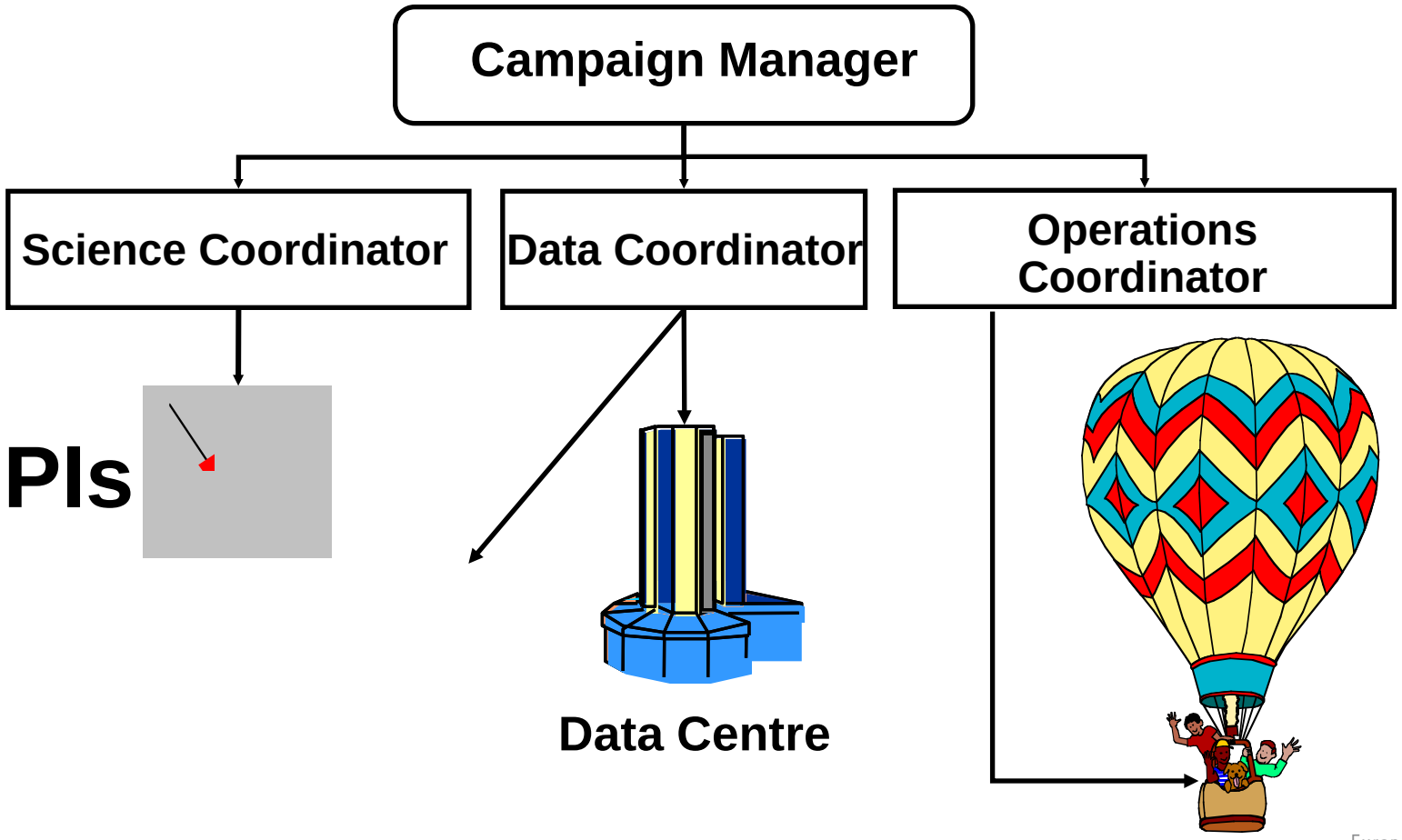


Campaigns for different project phases

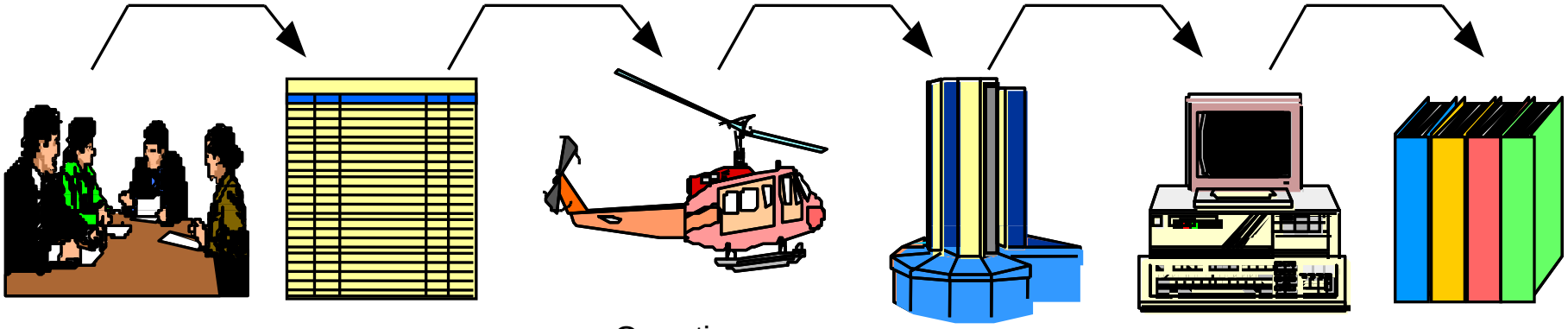
1. ESA campaigns are performed during full life cycle of a typical ESA space mission
2. Different types of campaigns are performed during specific phases of a space mission (concept, feasibility, development and operations)

	Pre-Phase A	Phase A Feasibility	Phase B Design	Phase C/D Development	Phase E1 Commissioning	Phase E2 Operation	Data Archive
Technology	X	X					
Mission Development (Geophysical)	X	X	X	X			
Mission Development (Simulation)	X	X	X	X			
Cal/Val				X	X	X	
Science/ Applications						X	X

Typical campaign organisation



Campaign Phases



Experiment Definition

Mission Definition

Operations and data acquisition

Data Processing

Data Analysis

Publication of results

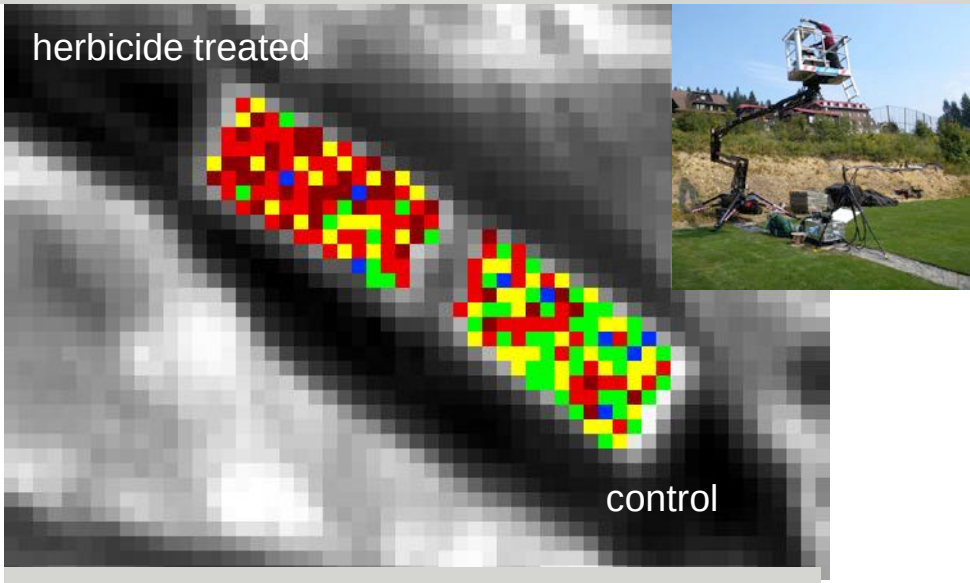
Instruments and airborne platforms

1. ESA develops ground/airborne instruments to support mission definition
    a. EMIRAD (airborne L-band radiometer)
    b. SnowScat(Ku-band ground scatterometer)
    c. MARSHALS (airborne μwave limb sounder)
    d. ASIRAS (Ka-band radar altimeter)
    e. SnowSar (X & Ku Band SAR)
    f. A2D (Doppler Wind Lidar at 355 nm)
    g. …….2.
2. ESA does not own or operate aircraft
3. Infrastructure and non-ESA instruments secured through contractual arrangements

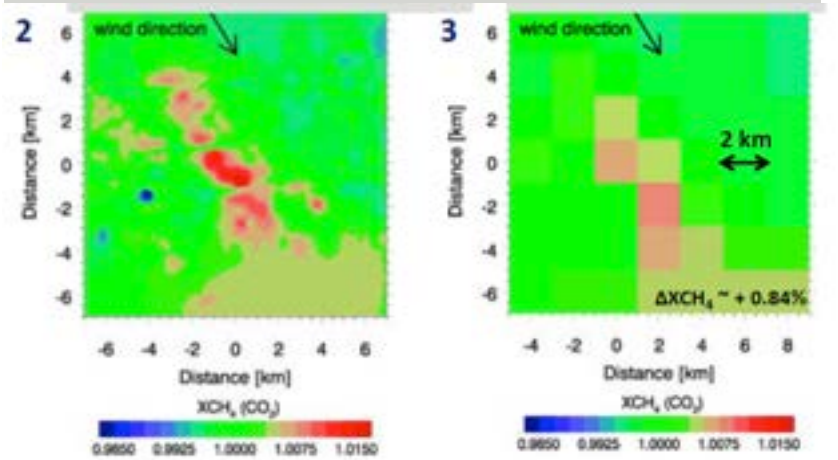
Recent developments (1 of 2)

1. **Key role of campaigns in preparation of future EO missions (up to Phase-0/-AB1)**
    a. Campaigns directly support preparation and documentation of EE8 candidate missions (FLEX, CarbonSat)
    b. New campaign initiatives supporting a number of future mission concepts (e.g. SAOCOM-CS/Convoy or Companion concepts)
    c. Several cross-cutting activities addressing multiple missions (e.g. MULTIPLY for EarthCare/ADM and other missions)

Demo of FLEX as vegetation stress mapper



CarbonSat prototype product



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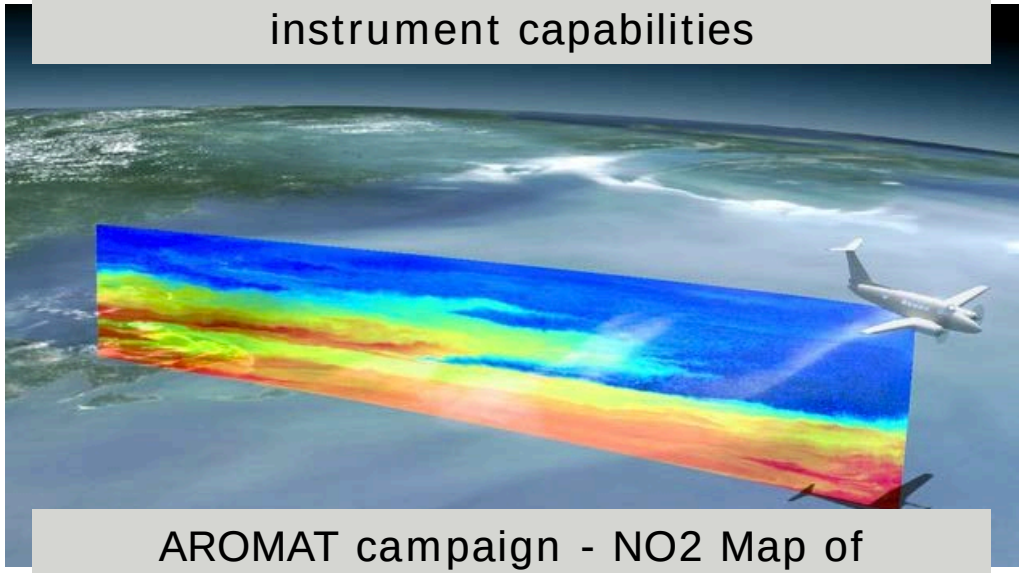
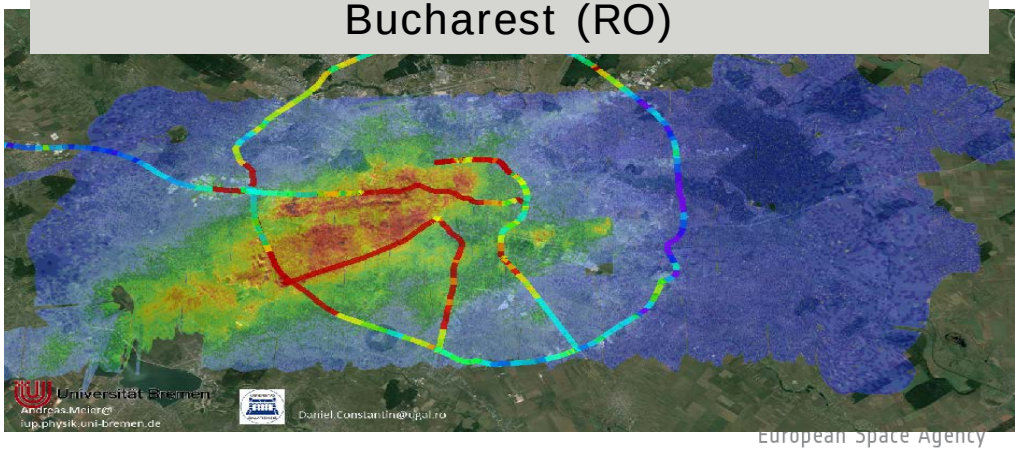
Recent developments

3. **Capacity building in new ESA member states**
    a. HRSL airborne lidar development (RO)
    b. Sentinel-1 soil moisture supersite (PL)
    c. Multimission atmospheric campaign AROMAT-1/-2 (RO)
    d. FLEX-EU and HYPER Processing activities (CZ)
4. **Increasing importance of industry and UAVs/Drones**
5. **International collaboration leading to enhanced campaigns and science return (Member states, EUFAR NASA, NSF…)**

Illustration of future RO MULTIPLY instrument capabilities



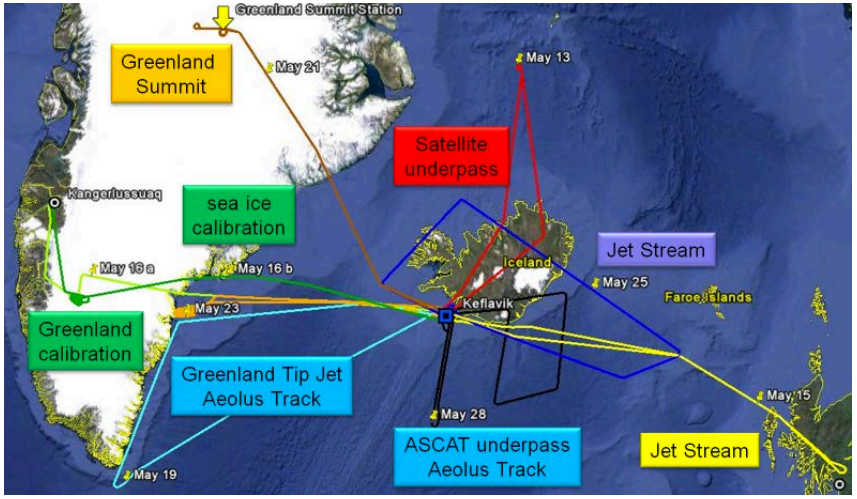
AROMAT campaign - NO2 Map of Bucharest (RO)



ADM / AEOLUS: WindVal

1. **Objectives**
   a. Fill data gaps on Rayleigh and Mie wind observations including highly variable wind conditions and heterogeneous conditions
   b. Extend dataset on response calibrations over ice or land in nadir-pointing mode
   c. Preparation for post-launch validation campaigns (i.e. rehearsal)
2. **Campaign details**
   a. Campaign executed in collaboration with NASA and DLR in May 2015
   b. First time with collocated 4 Wind Lidars on 2 aircrafts
   c. DLR Payload: The ALADIN airborne demonstrator + 2-µm reference wind lidar
   d. Data processing and analyses underway

WindVal campaign team



AROMAT
(Airborne ROmanian Measurements of Aerosols and Trace gases)

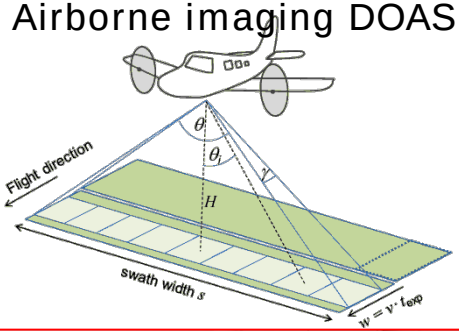
AROMAT combined airborne, satellite and coincident ground activities to provide feedback on key issues related to the definition, performance and product quality of different remotely sensed and in-situ species.

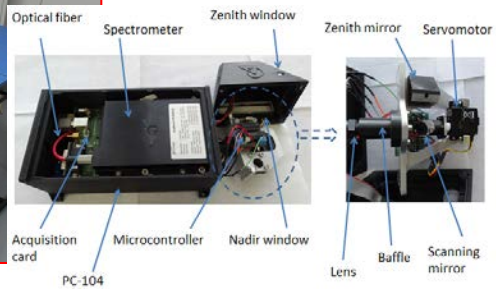
1. Aims:

- to test recently developed airborne observation systems (aircraft + UAV)
- to prepare a larger intercomparison/S5p validation campaign that may be scheduled in the Bucharest area in summer 2016.

2. Instruments:

AirMap Airborne imaging DOAS



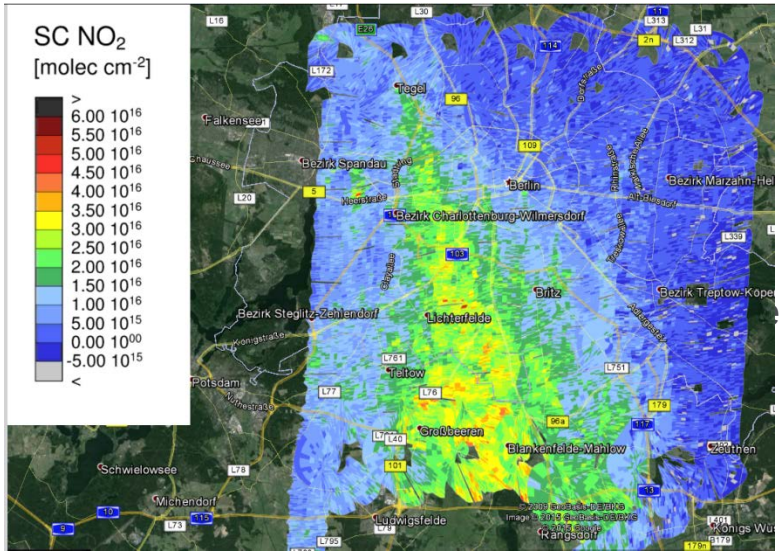


Partners:

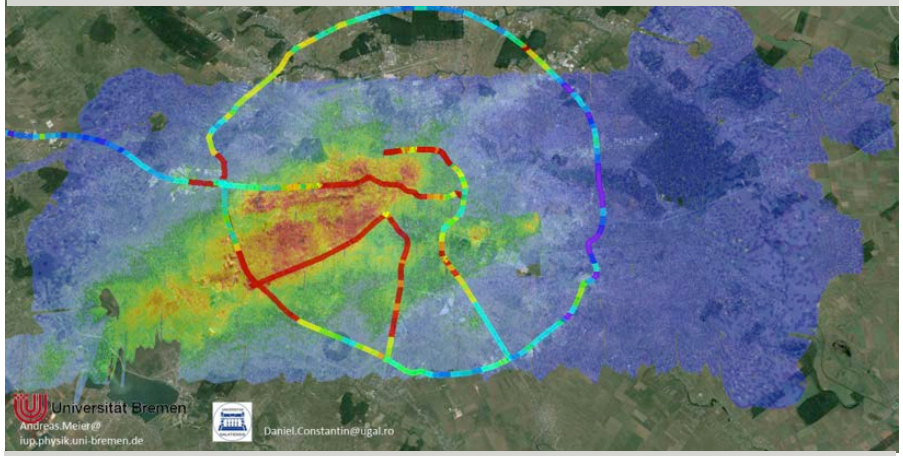
- The Belgian Institute for Space Aeronomy (BIRA, Belgium)
- The Royal Netherlands Meteorological Institute (KNMI, NL)
- University of Bremen (IUP-Bremen, Germany)
- The Institute for Space Sciences of Berlin (ISS-Berlin, Germany)
- The University of Galati (UGal, Romania)
- The National Institute of R&D for Optoelectronics (INOE, Romania)
- Reev River Aerospace (RRA, Romania).

Sentinel-5p / Multimission: AROMAT-1 / -2

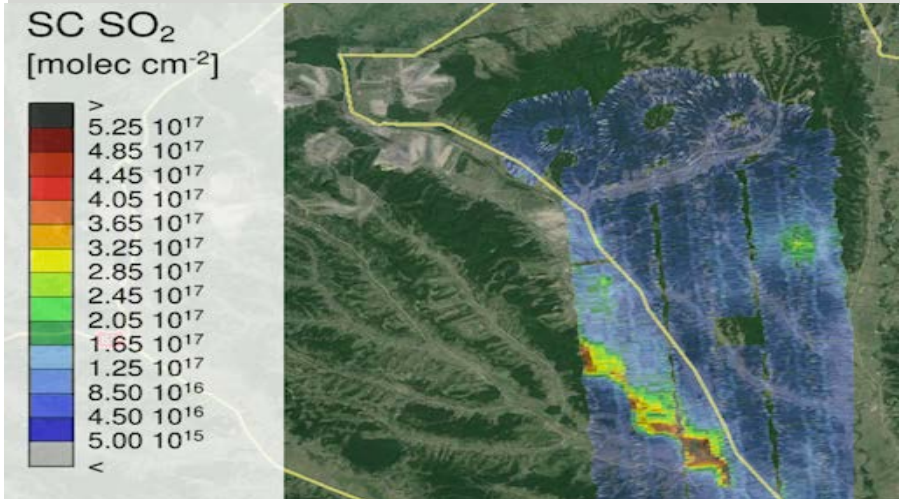
1. **Objectives**
   a. Pre-launch rehearsal campaign to a prepare larger intercomparison/S5p (and others) validation campaign.
   b. To test recently developed airborne observation systems (aircraft + UAV)
   c. Two flight campaigns: 2014 & 2015
2. **Campaign results**



2014 - AirMAP measurements around Bucharest

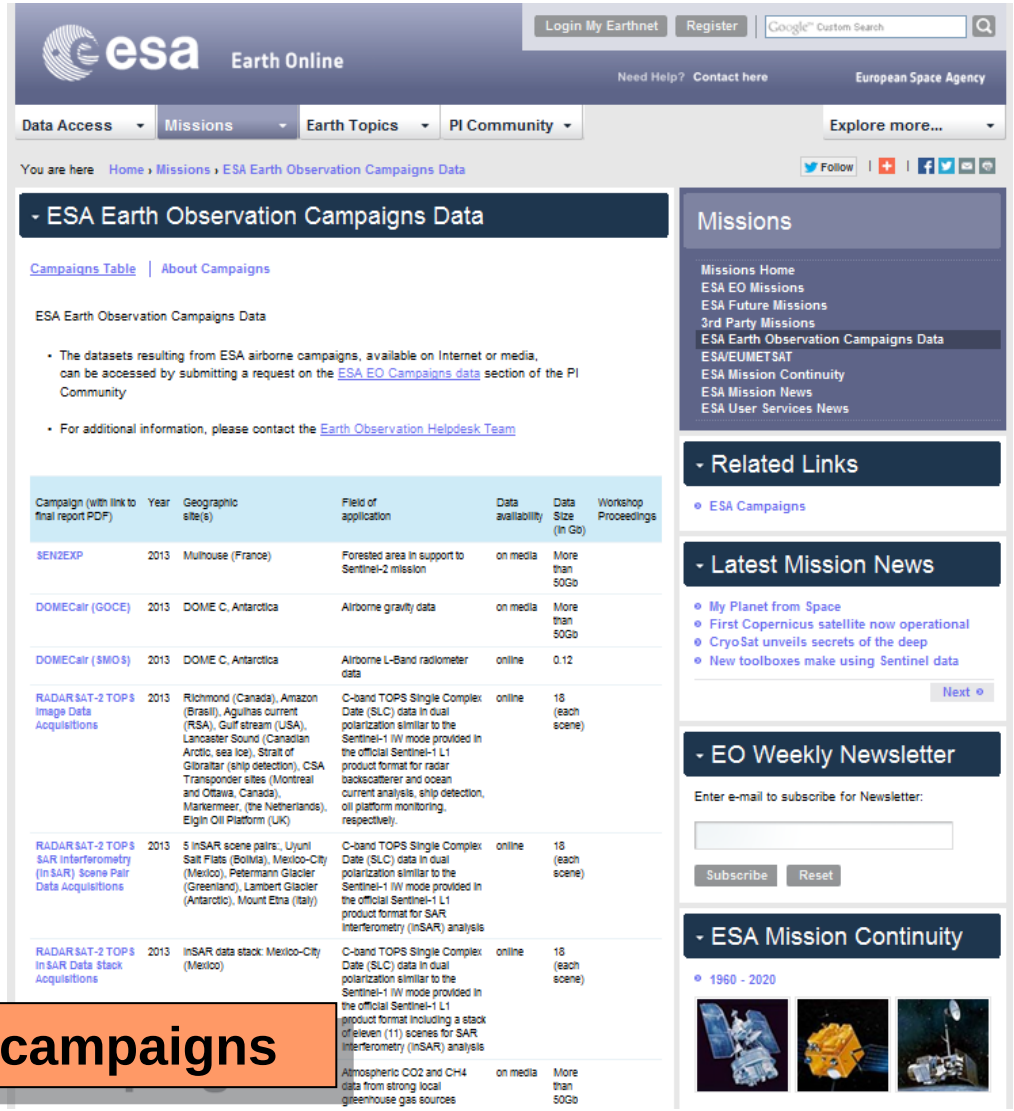


2015 - AirMAP measurements around Turceni



Access to ESA Campaign Data

1. ESA campaign data available to interested PIs
    a. Formatted and documented datasets
    b. Data Inventory
    c. Final report with full description of campaign activity and analyses
2. Final report accessible directly through web
3. Access to datasets provided through Category 1 mechanism (short proposal incl. identification of desired datasets)
4. Currently **64** campaign datasets available



https://earth.esa.int/web/guest/campaigns

SRL:Objectives & Benefits

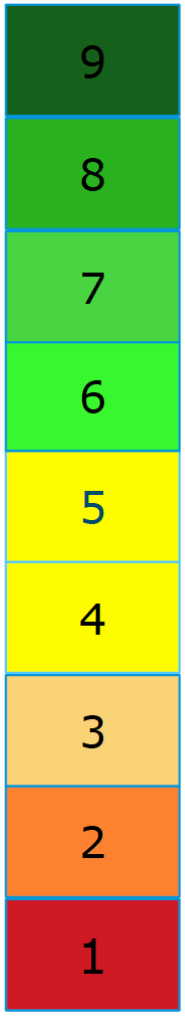
OBJECTIVE:

Provide an objective metric that enables the assessment of the scientific maturity of an EO (candidate) mission and supports a traceable development from Pre-Phase 0 to Phase F

BENEFITS:

- Emphasis on earlier, quantitative scientific preparation of mission concepts as basis for more mature proposals (in pre-Phase 0)
- Supports selection of mission proposals through a standardised and common metric across different missions (and disciplines)
- Provides a standard tool for scientific quality analyses, control, and risk assessment during mission development
- Provides a common metric for end-to-end (E2E) mission performance assessment in all phases
- Provide flexibility to bring in additional scientific expertise
- Independent of scientific discipline

SRLs



Phase F	9	Science Impact Quantification
Phase E2	8	Validated and Matured Science
Phase E1	7	Demonstrated Science
Phase B, C, D	6	Consolidated Science and Products
Phase A	5	End-to-End Performance Simulations
Phase 0	4	Proof of Concept
(Pre –) Phase 0	3	Scientific and Observation Requirements
Pre – Phase 0	2	Consolidation of Scientific Ideas
Pre – Phase 0	1	Initial Scientific Idea

SRLs

SRL	Name (ESA)	Theory	Experiments	Users & Requirement
1	**Scientific Idea**	• A scientific challenge is identified. • The scientific objective is formulated. • A scientific hypothesis is established.	No observational evidence is required.	• The application area is defined. • Interest of the users is identified. • Start defining high-level scientific requirements.
2	**Consolidation of Scientific Idea**	• A scientific theory is formulated. • The physical principle behind the hypothesis is outlined (at least qualitatively).	Experimental evidence supporting the scientific hypothesis.	• Consolidated scientific requirements are established. • A gap analysis with respect to the uniqueness of measurements and observations is performed. • Scientific objective are formulated.
3	**Scientific / Observation Requirements Definition**	• Quantitative theoretical understanding of link between measurement and observation (no software required) is established.	• Initial capability assessment performed.(Information content analysis) • Conceptual measurement technique is established.	• Scientific objective confirmed and approved. • Scientific goal formulated. • Mission objective(s) formulated.
4	**Proof of concept**	• Simulation of measurements based on geophysical parameters (e.g. numerical forward model). • 1st simulated measurements are available.	• First measurement device approximating the instrument is available in case possible for the measurement principle. • Sensitivity of measurements wrt observation is demonstrated.	• Mission objective confirmed and translated into mission requirements and system requirements
5	**End-to-end performance simulations**	• Consolidated retrieval and draft ATBDs (+ prototype) are available	• Demonstrator (e.g. airborne instruments) provides/simulates representative measurements with error budgets, • Draft calibration strategy available.	• First evaluation of observations and / or measurements in applications, • Higher-level products approached.

SRLs

SRL	Name (ESA)	Theory	Experiments	Users & Requirement
6	**Consolidated science and products** (End: launch of sat)	• Operational processor developed and implemented (Level 0, Level 1, and Level 2)	• Test data and sampled data processing • Verification data sets collected • Calibration and validation Plan established	• User studies with simulated or pre-cursor data; • AO call to user community for validation
7	**Demonstrated science** (Commissioning phase)	• First uncertainty analysis	• Cal/Val conducted (L1 and L2) • Early release of first data / demonstrational data are provided • Characterisations of measurements and observations; • Performance vs. specification	• User feedback collected, • Feedback from beta-users received.
8	**Validated and matured science** (Satellite operational declared)	- Full uncertainty analysis - Enhancing scientific understanding	- Systematic validation and quality assurance performed - Operational / nominal processing of measurements and observations	- Science impact quantification, - first performance assessment wrt mission objective - scientific goal evaluation
9	**Science Impact quantification**	- Advancing scientific understanding and addressing its impact for scientific and societal applications	- Generation of long-term data sets - Data fusion	- User impact quantification, - Final performance assessment wrt mission objective - Final performance assessment wrt science objective

Conclusions and general perspectives

1. ESA campaign activities responding directly needs of the EO programmes in efficient and effective way and play a key role in
    a. preparing future EO missions (science, mission requirements, mission definition and reduction of risk)
    b. supporting missions in development (Level-2 product development, preparation of user community, prototype products, mission design and RIDs, PDGS development)
    c. calval for missions in exploitation (validation of mission products and enhanced/new products)
    d. supporting wider science community through the ESA campaign database on the EOPI portal
2. Expanding industrial interest in airborne sensors and activities in the context of UAVs/Drones
3. Expanding international collaboration (NASA, EC e.g. EUFAR, National Agencies) leading to pooling of resources and enhanced science and mission related return (e.g. enabling campaign activities not possible in isolation)