→ 3rd ADVANCED COURSE ON RADAR POLARIMETRY

SAOCOM-CS Mission and ESA Airborne Campaign Data

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Objectives of presentation

- Introduce a new type of ESA SAR mission with Polarimetrice, Interferometric and Bistatic measurement capabilities
- Present ESA airborne SAR campaigns which provide a useful source of data for SAR training and new science development

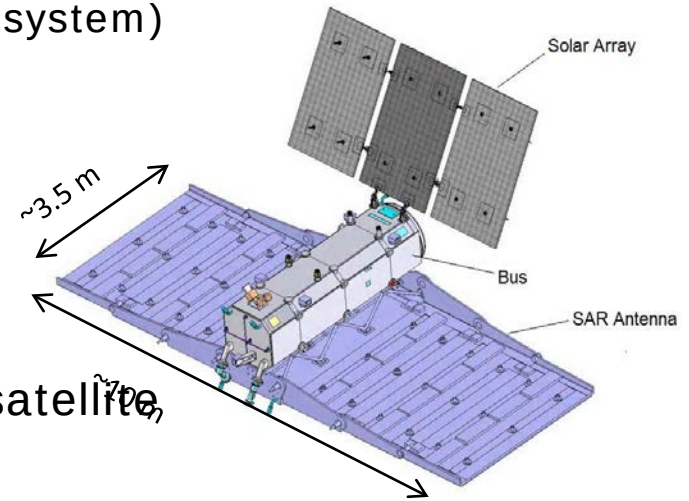
Overview

- SAOCOM Companion Satellite Mission (a new type of SAR mission)
  - Background
  - Mission Capabilities
  - Mission Science
- ESA airborne campaigns
  - Background and objectives of campaigns
  - Example SAR campaigns
  - Access to Data

The SAOCOM Mission

- The Argentinian Space Agency CONAE - with contributions from ASI - is developing an L-band SAR mission

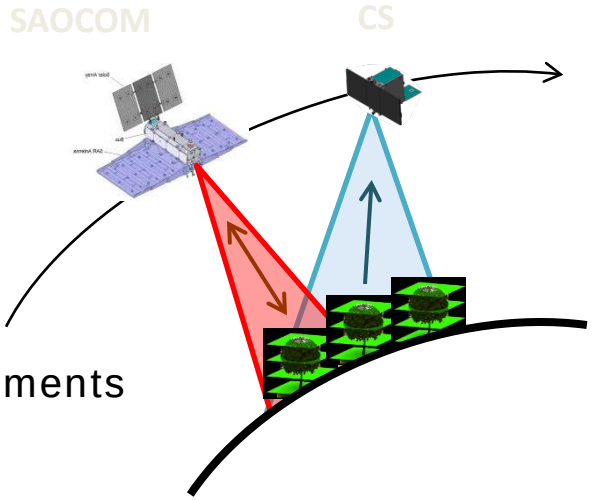
- 2 satellites SAOCOM-1A/1B flying in constellation with COSMO-SkyMed (forming toegther the SIASGE L+X-band SAR system)
  - ✓ 619.6 km altitude, incidence angle range 17.5^0 – 50^0
  - ✓ L-band SAR at 1275 MHz, bandwidth up to 50 MHz
  - ✓ peak RF transmit power 3.1 kW
  - ✓ antenna dimensions 10 m x 3.5 m
  - ✓ fully polarimetric, interferometric capabilities
  - ✓ multiple modes (Strip, TOPS)



- In 2013, CONAE offered ESA to launch a small satellite together with SAOCOM 1B

- ESA, together with European experts and CONAE have assessed the feasibility to fly a passive add-on satellite in formation with SAOCOM to enhance the science return (condition for cooperation from CONAE)

SAOCOM-CS Description



- <u>"Companion Satellite" ("SAOCOM-CS")</u>
  - ✓ receive-only, dual-pol L-band SAR satellite
  - ✓ (close) formation with SAOCOM
  - ✓ SAOCOM as illuminator
- <u>Complement science return of SAOCOM</u>
  - ✓ New radar science: tomography, bistatic measurements
  - ✓ mapping of biomass and structure of boreal forests by SAR tomography (mission driver)
  - ✓ several imaging geometries (baselines and angles) for experimental applications
  - ✓ Detailed studies by POLIMI, DLR and CSL to confirm mission science program
- <u>Launcher & schedule constraints</u>
  - ✓ Falcon-9, available volume: cylinder, 1.5 m diameter x 1.4 m height
  - ✓ max. total launch mass: ca. 400 kg
  - ✓ tight schedule imposes maximum reuse of existing equipment / high TRL

Science snd Observation Geometry

- Four configurations w.r.t baselines and viewing geometry
- Three science mission phases: tomographic, bistatic, specular

Tomographic phase

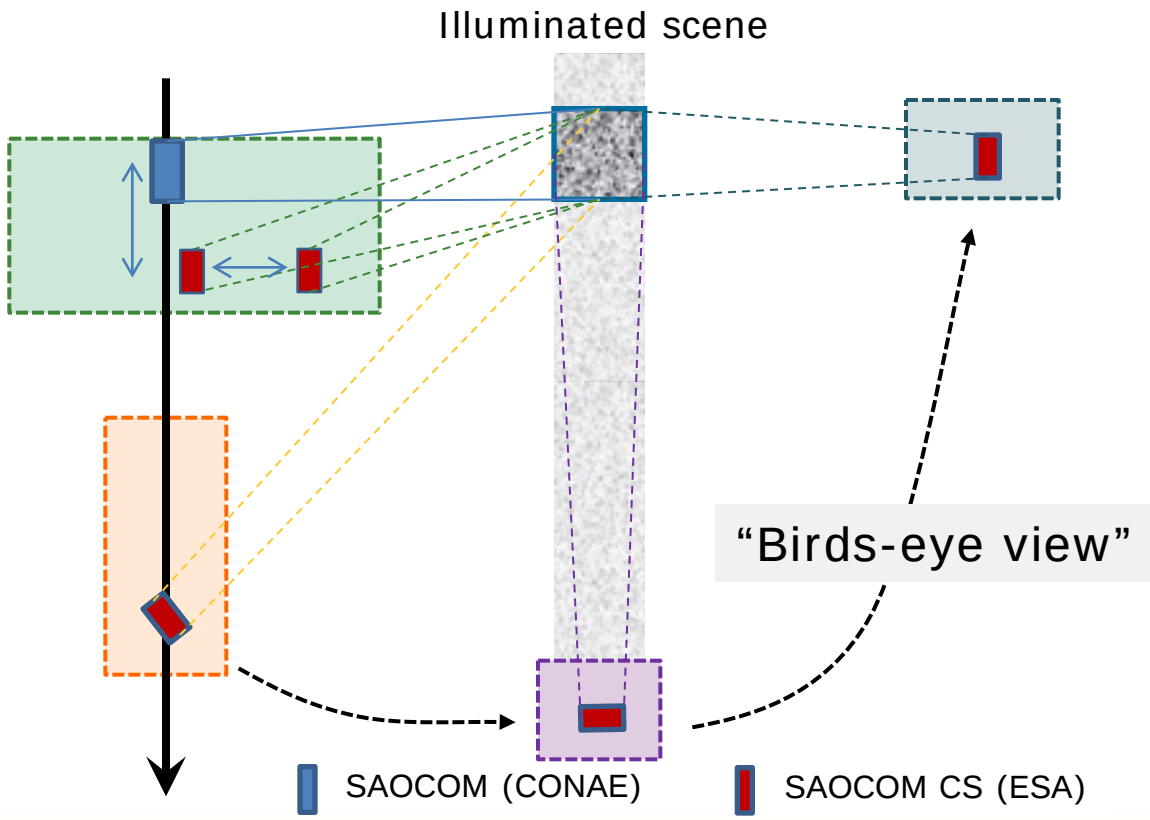
- ✓AT baseline < 6 km
- ✓XT baseline varies ~1–6 km
- ✓Science mission driver
- ✓Duration ~2.5 years

Bistatic 1, Bistatic 2

- ✓ AT baseline < 250 km
- ✓ Small XT baseline (phase 1)
- ✓ Large XT baseline (phase 2)
- ✓ Duration ~2 years

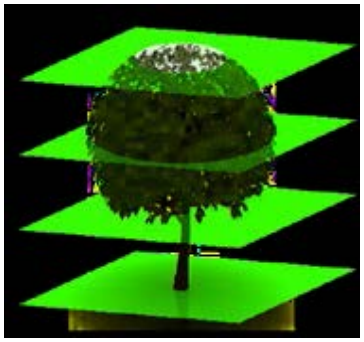
Specular phase

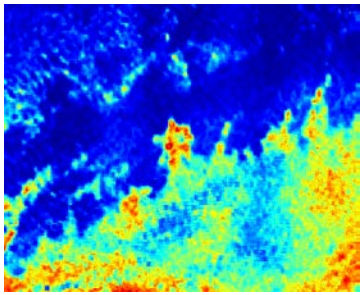
- ✓ Experimental
- ✓ Short duration



Science objectives

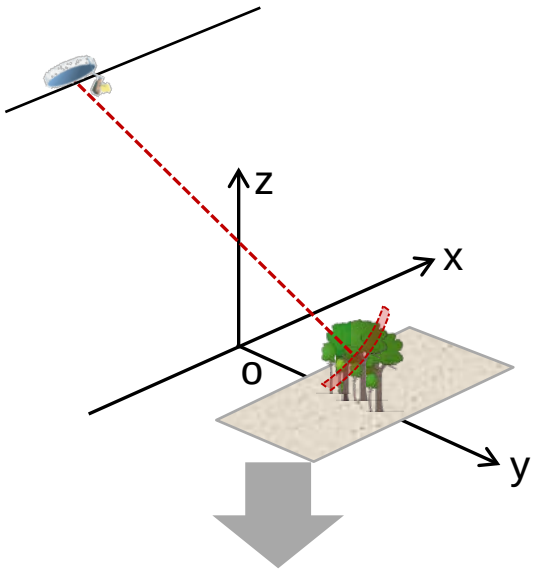
- **Tomographic Configuration**
  - **Boreal forest structure (mission science driver)**
  - Tropical forest structure (experiment)
  - Ice subsurface feature mapping (experiment)
- **Bistatic interferometry and radar signatures**
  - Dense persistent scatterers (PS) for urban environments (demonstration)
  - Bistatic interferometry for surface motion and land cover properties (demonstration)
  - Soil moisture (experiment)
  - Desert subsurface mapping (experiment)
- **Specular configuration**
  - Soil moisture (experiment)



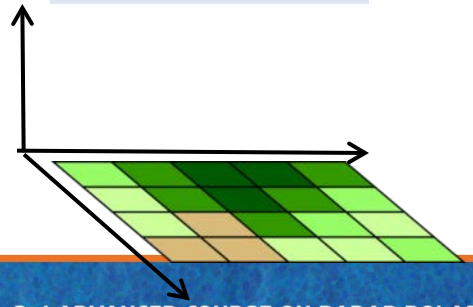


SAOCOM + SAOCOM-CS - 3 independent types of information depending on geometry & baselines

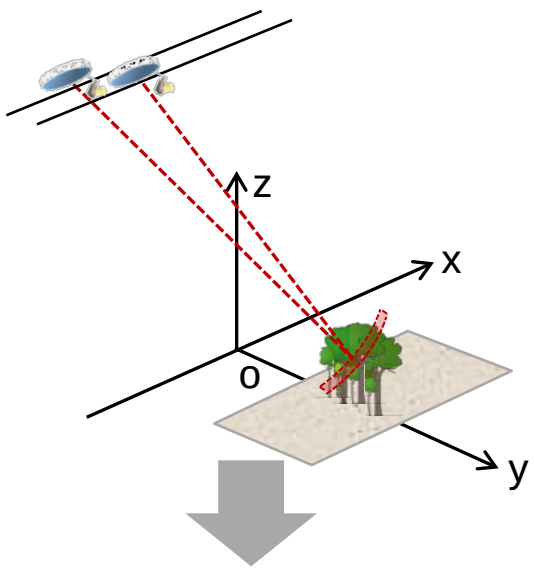
PolSAR
(SAR Polarimetry)



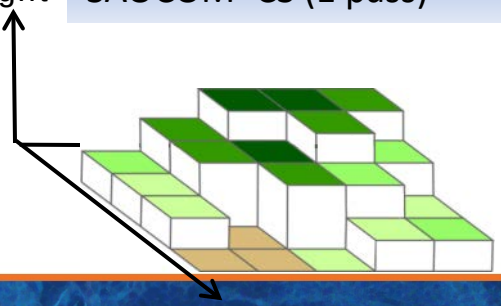
SAOCOM only



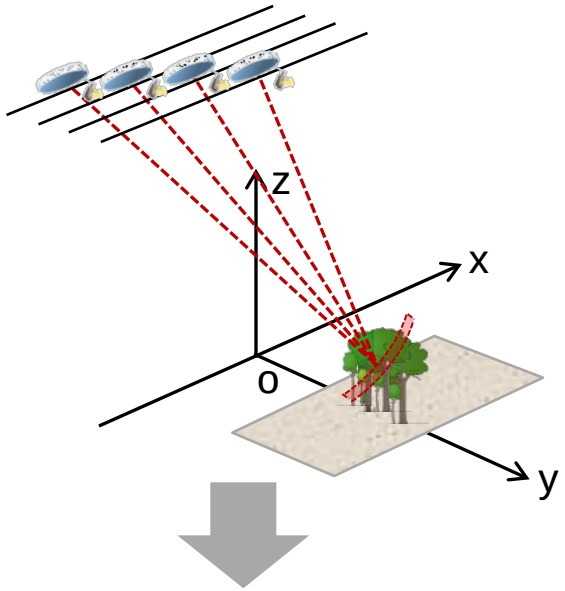
PolInSAR
(Polarimetric SAR Interferometry)



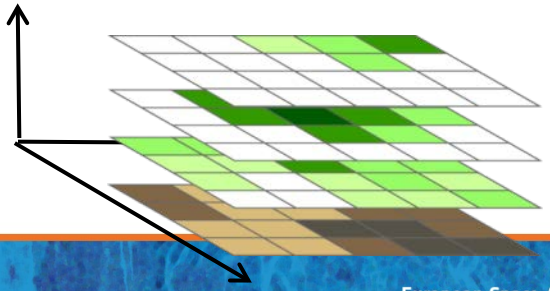
SAOCOM+CS (1 pass)



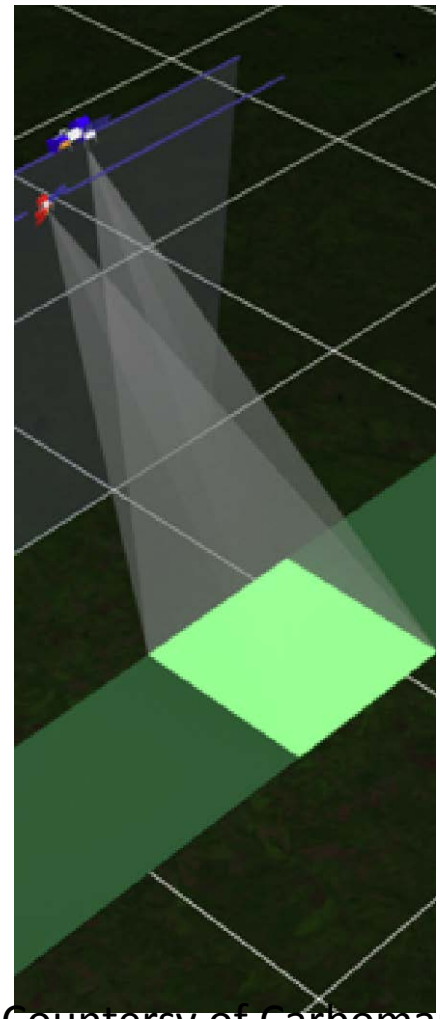
Tomo SAR
(SAR Tomography)



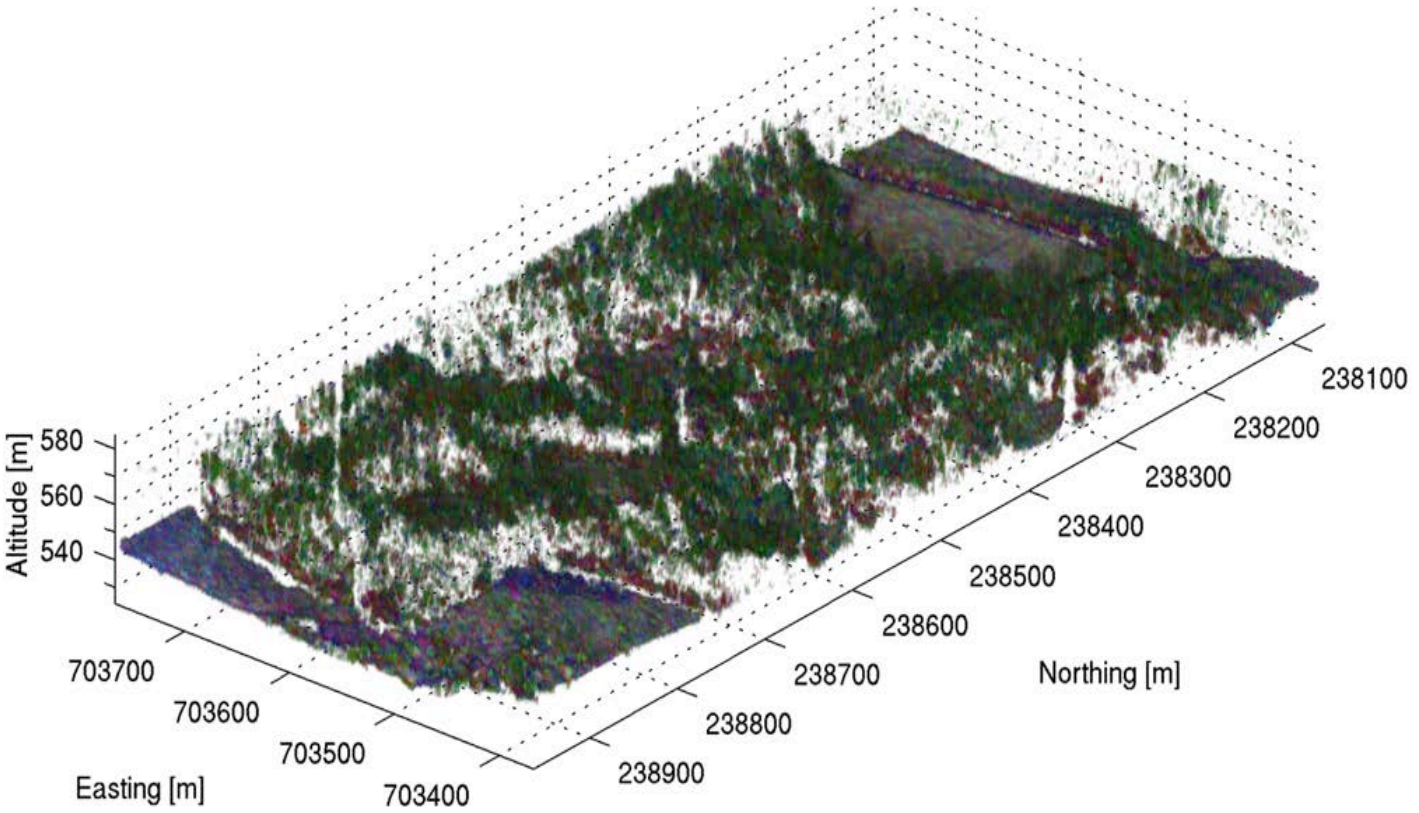
SAOCOM+CS (>1 passes)



Example forest structure product



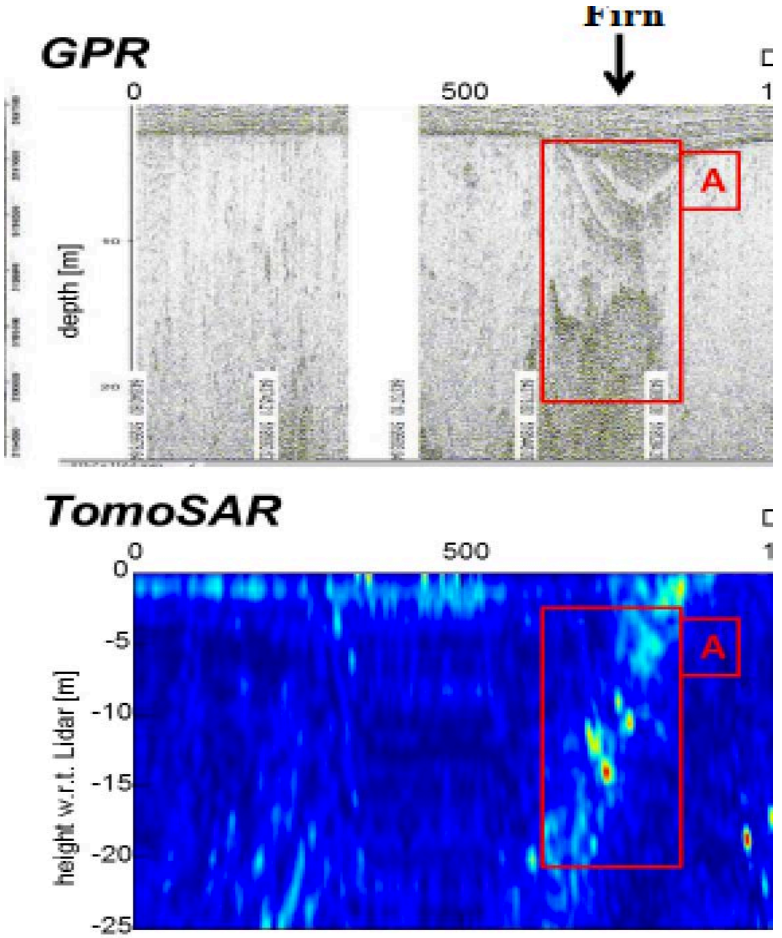
Countersy of Carbomap UK



(Frey & Meier, 2011)

Example ice subsurface product

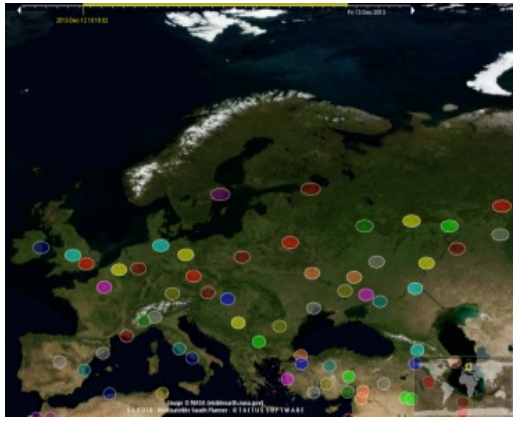
Tabaldini (POLIMI)
Nagler (ENVEO)



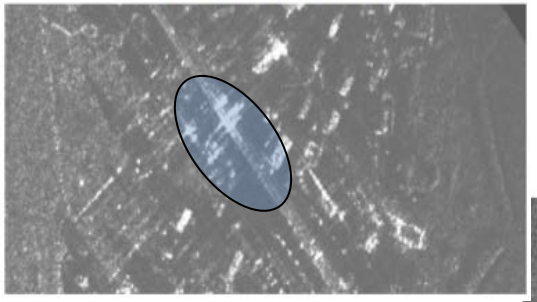
Example bistatic product

- Urban interferometric applications based on persistent scatterers or PSs
- Phase-changes in PSs are related to movement of buildings and ground beneath (e.g. subsidence)
- Bistatic measurements improve density of PSs and urban motion estimates because:
  - Remove spatial saturation due to dihedral & trihedral scatterers
  - Allow identification of additional PS sources (i.e. fill in gaps)

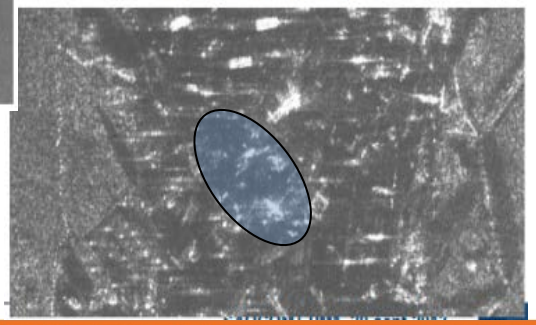
Major Urban Centres (Europe/World)



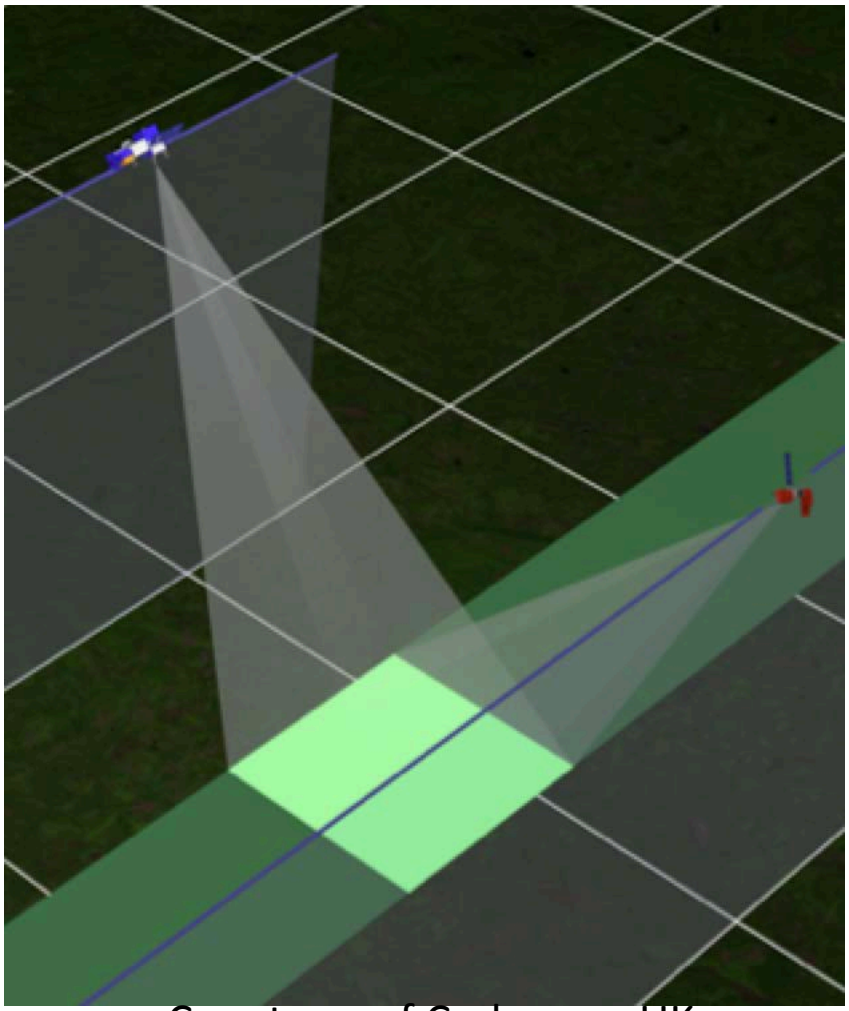
MONOSTATIC



BISTATIC 70^0



Example specular product



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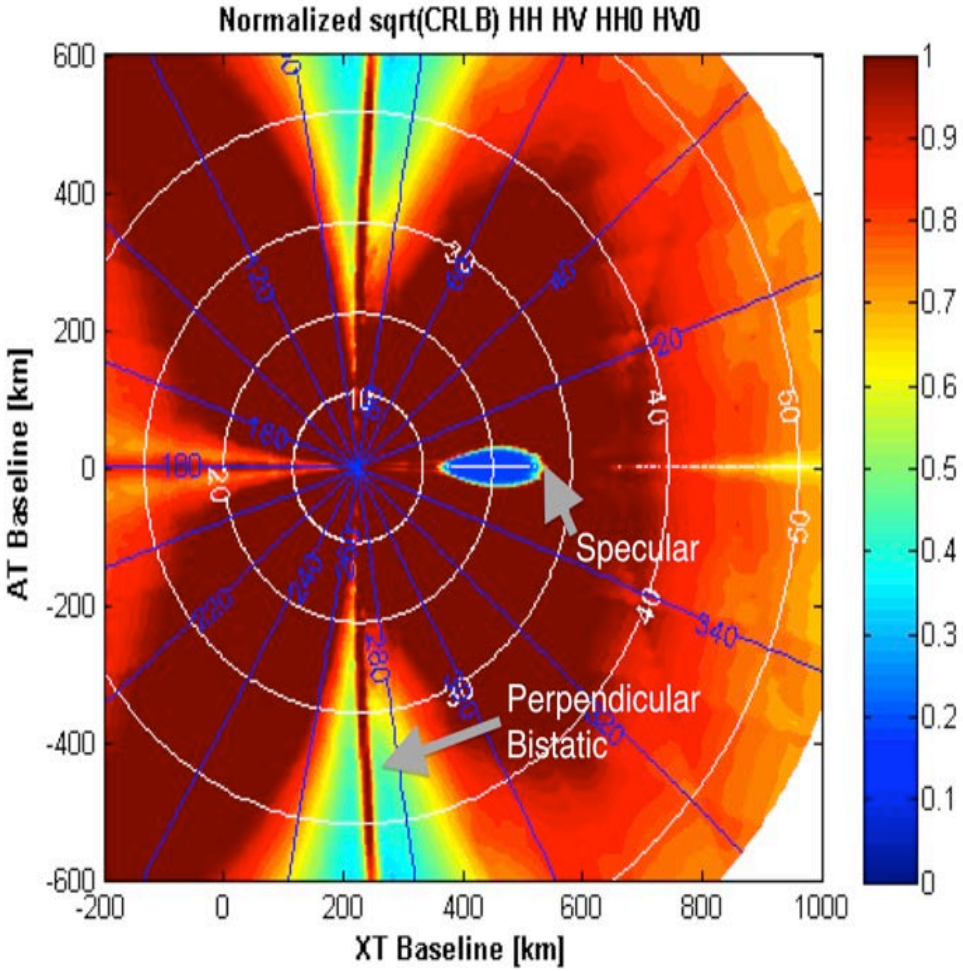
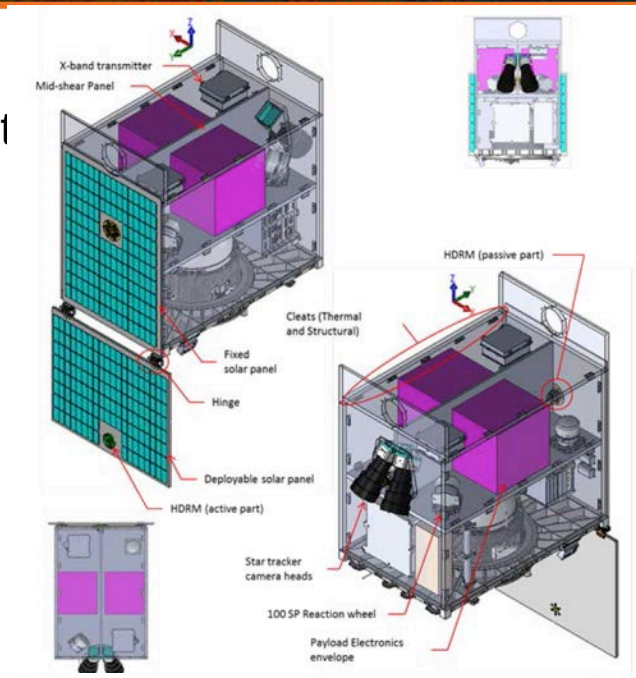
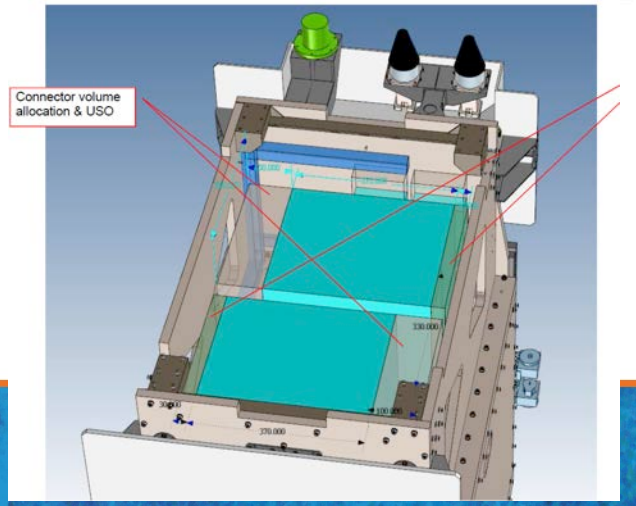


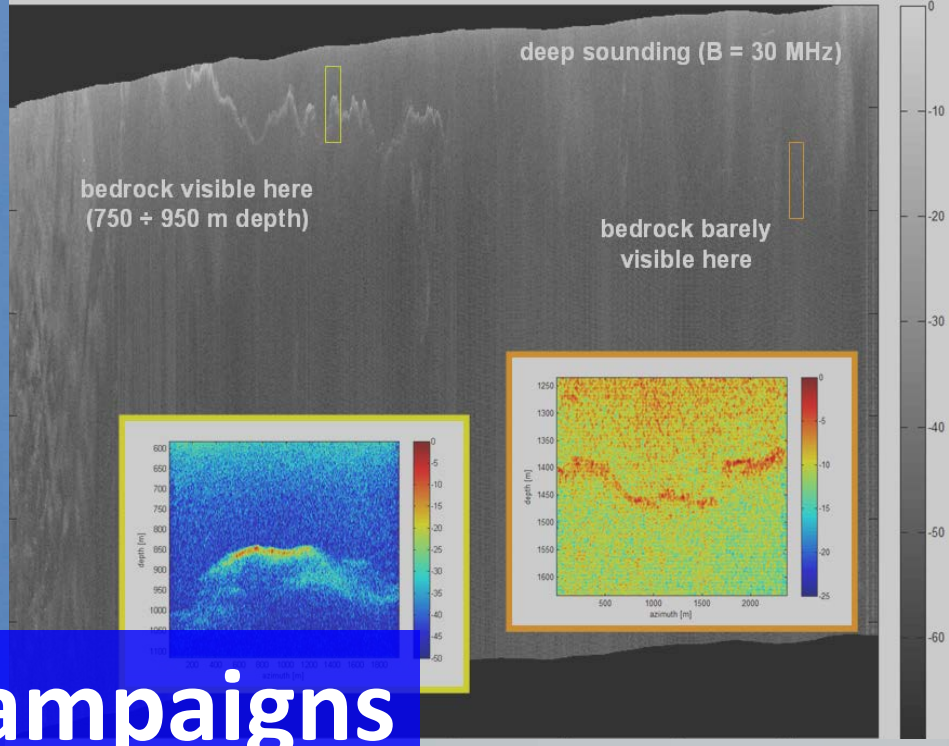
N. Pierdicca

Mission Implementation

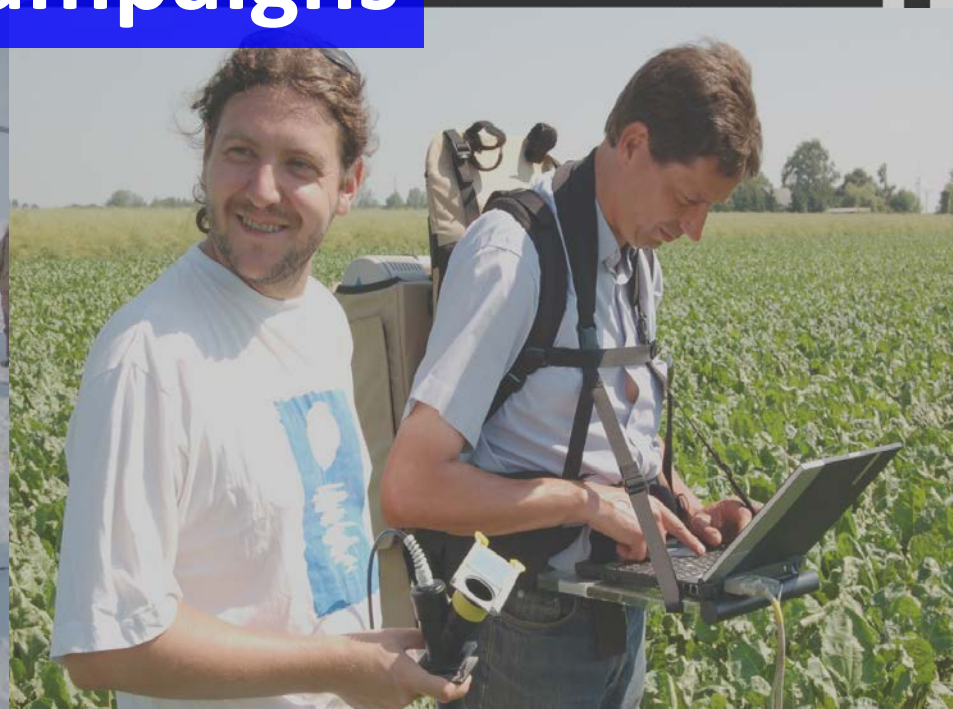
- SAOCOM-CS mission characteristics
  - ✓ 5m resolution/6 minutes of operation per orbit
  - ✓ 3 x 1m antenna
  - ✓ Formation flying with 3 main geometries (tomographic, bistatic and specular)
  - ✓ 400kg wet mass
  - ✓ Launch as co-passenger on Falcon-9
- Ground Segment
  - Mission Control Centre (core of flight operations segment)
  - Two X-band ground stations for science data downlink
  - A (distributed) PDGS for science data processing
- Short development schedule (ready for launch by 2nd half 2018)





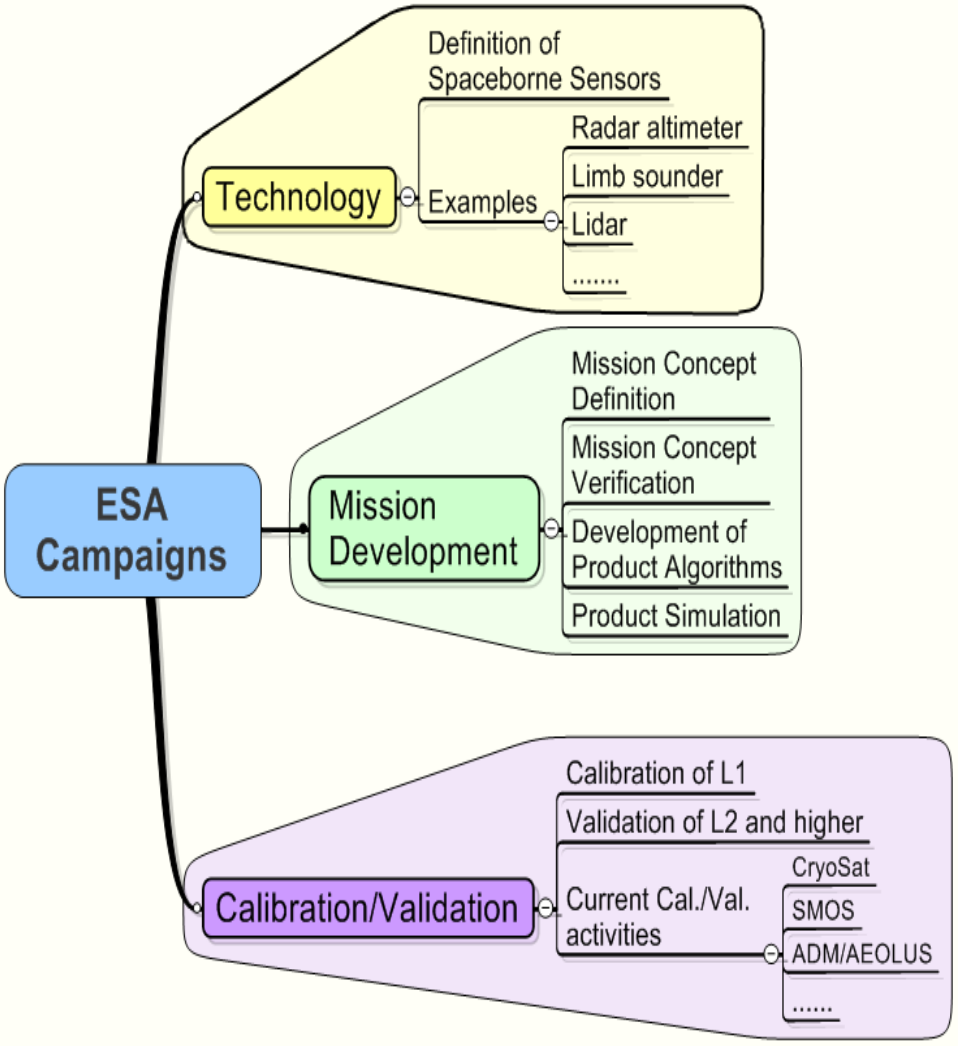


ESA Campaigns



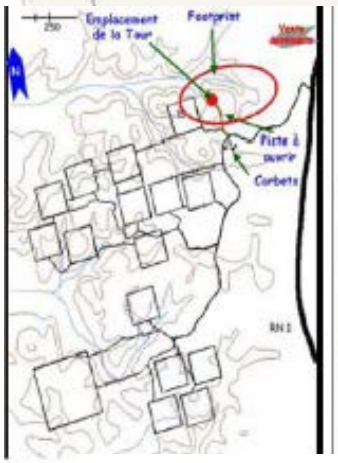
Programmatic Background

- Programme started in 1981
  - 100+ campaigns as of 2015
  - 5-6 campaigns/year
- Strategic objectives:
  1) Support to EO programs
  2) Improved access to airborne instrumentation and data in Europe
  3) Partnerships with national and international organisation ESA Campaigns Programme addresses all phases of ESA missions
- Campaign activities address three main areas: technology, mission development and calibration/validation

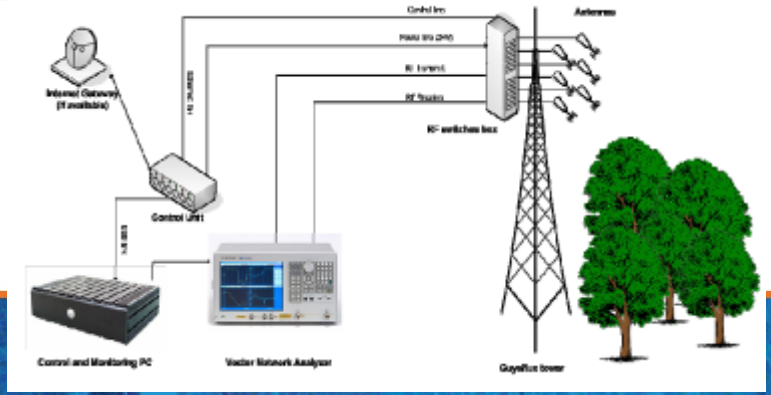


ESA airborne SAR campaigns - overview

1. ESA airborne campaign activities addressing forest biomass generally executed in framework of future mission concepts
   a. TerraSAR-L (up to 2004)
   b. EE7 BIOMASS (2005 to present)
2. In addition we address PolInSAR workshop recommendations where possible
3. Main campaign datasets to date
   a. Indonesian Radar Experiment (Indrex-2) over tropical forests in Borneo in 2004 with DLR
   b. BioSAR-1,-2 and -3 over boreal forests in Sweden (DLR, ONERA)
   c. TropiSAR 2009 over tropical forest in French Guyana (ONERA)
   d. TropiScat scatterometer measurements in French Guyana (CESBIO, ONERA, POLIMI)
4. Campaign datasets generally include well-documented airborne and ancillary data (e.g. lidar, ground biomass estimates, tree height data)



Paracou



Example campaign: TropiSAR 2009 (1)

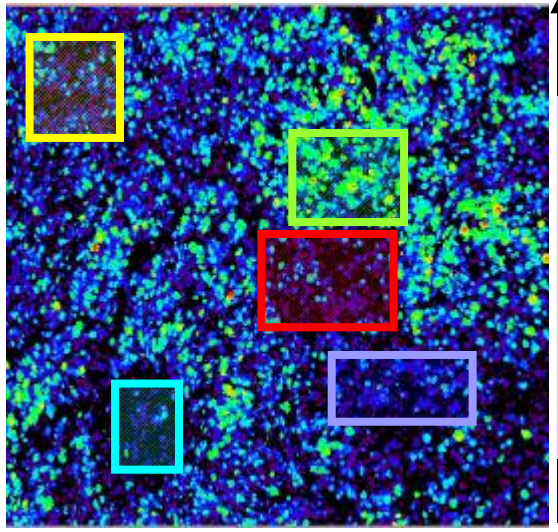
- **Aims**
  - Support BIOMASS Phase-A
  - Collect reference radar at P- and L-band over tropical forests
  - Quantify temporal decorrelation to support mission orbit selection
  - Provide basis for forest biomass retrieval algorithm
  - Assess product validation methodology
- **Experiment details**
  - Collaboration with CNES and French national programmes (GUYAFOR) in French Guyana
  - Airborne acquisitions using SETHI and Falcon-20 (ONERA)
  - Coincident ground and laser altimeter measurements

Example campaign: TropiSAR 2009 (2)

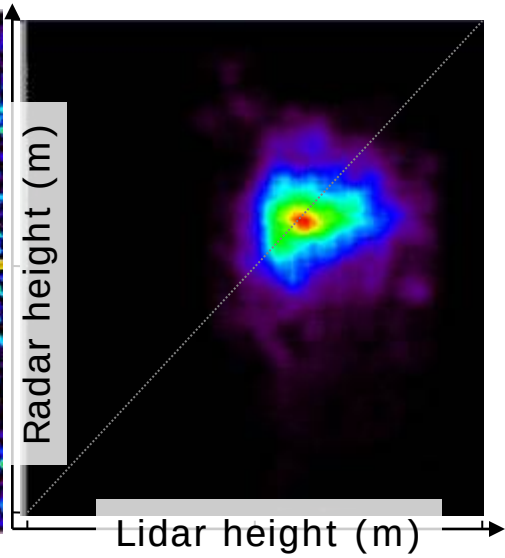
3. Outcome

- Development of airborne SAR processing chain (capacity building)
- 60 acquisitions processed and delivered in Q1/11
- Data analysis indicates:
  - moderate temporal decorrelation at P-band over tropical forests
  - Feasibility of forest height retrieval in tropics
  - Importance of terrain correction
  - Consolidated dataset input to BIOMASS scientific support/End-to-end studies

P-band radar height map

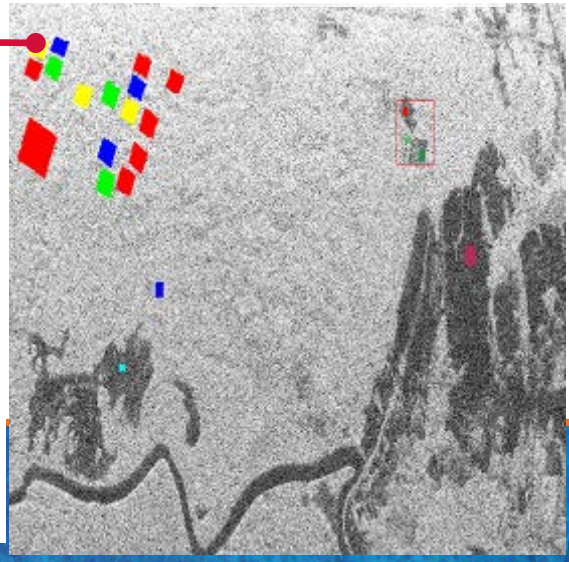


Height validation vs lidar



Radar database

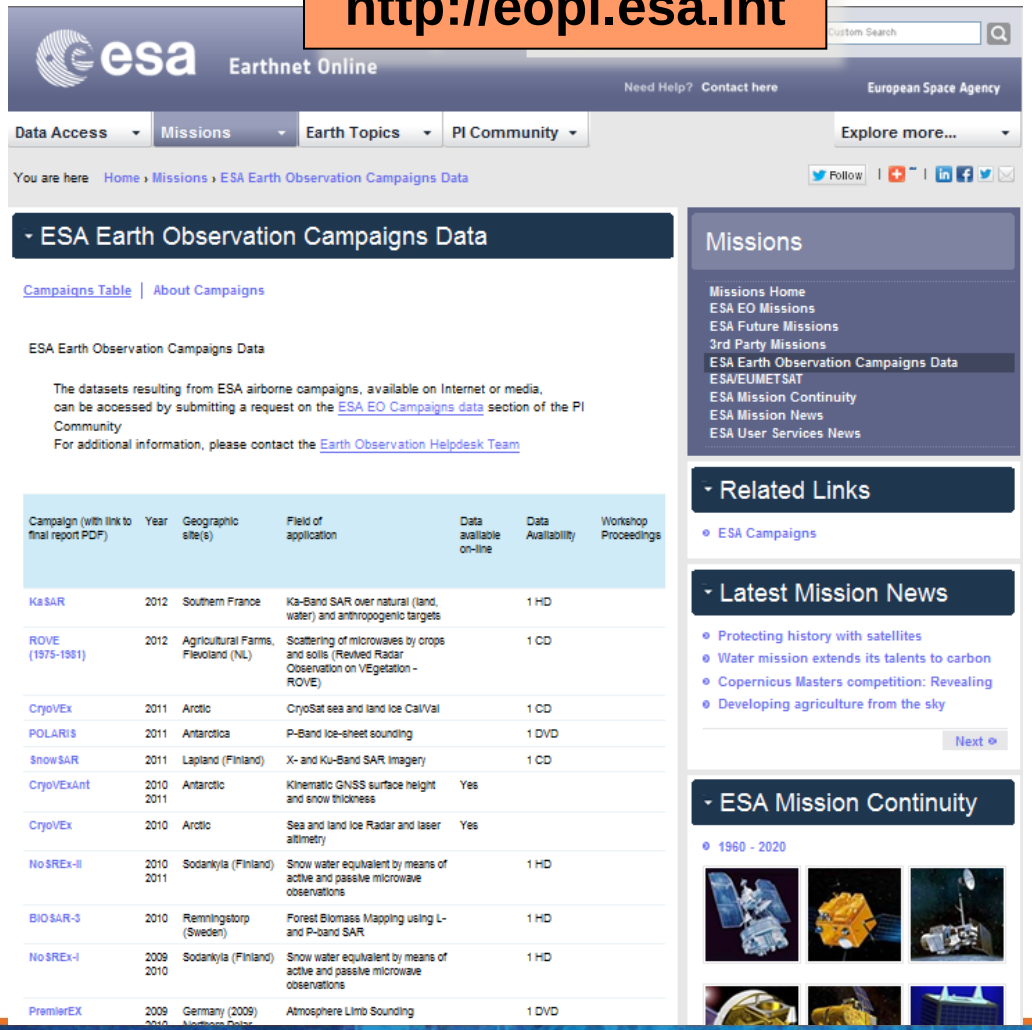
Stand ID	β^0_{hh}	β^0_{hv}	β^0_{vh}	β^0_{vv}	γ^0_{hh}	γ^0_{hv}	γ^0_{vh}	γ^0_{vv}	σ^0_{hh}
01	-8,81	-13,32	-13,19	-8,84	-10,36	-14,89	-14,76	-10,40	-13,44
02	-8,88	-13,46	-13,34	-8,82	-10,40	-15,00	-14,88	-10,36	-13,55
03	-7,79	-12,27	-12,23	-8,05	-9,58	-14,05	-14,01	-9,83	-12,77
04	-7,36	-12,06	-12,04	-7,47	-9,47	-14,15	-14,13	-9,56	-13,10
05	-6,14	-10,93	-10,82	-6,05	-8,45	-13,25	-13,14	-8,39	-12,34
06	-5,14	-9,95	-9,90	-5,03	-7,83	-12,64	-12,59	-7,74	-11,88
07	-6,87	-11,07	-11,57	-6,67	-9,14	-13,95	-13,85	-8,94	-13,00
08	-6,43	-11,32	-11,21	-6,51	-8,67	-13,52	-13,42	-8,72	-12,57
09	-6,32	-10,66	-10,58	-6,01	-8,92	-13,29	-13,21	-8,62	-12,52
10	-3,99	-8,86	-8,83	-4,11	-6,98	-11,85	-11,81	-7,10	-11,21
11	-5,05	-9,54	-9,44	-4,75	-7,67	-12,15	-12,05	-7,35	-11,36
12	-4,19	-9,05	-8,98	-4,20	-7,21	-12,05	-11,98	-7,20	-11,40
13	-7,52	-12,21	-12,14	-7,68	-9,24	-13,95	-13,87	-9,42	-12,63
14	-8,02	-12,24	-12,21	-7,74	-10,00	-14,23	-14,20	-9,76	-13,10
15	-6,01	-10,48	-10,35	-5,80	-8,60	-13,01	-12,88	-8,36	-12,14
16	-7,28	-12,34	-12,32	-7,53	-9,08	-14,13	-14,11	-9,32	-12,87



Access to ESA Campaign Data

- ESA campaign data available to interested PIs
  - Formatted and documented datasets
  - Data Inventory
  - Final report with full description of campaign activity and analyses
- Final report accessible directly through web
- Access to datasets provided through Category 1 mechanism (short proposal incl. identification of desired datasets)
- Currently 56 campaign datasets available

http://eopi.esa.int



Conclusions

- SAOCOM-CS a small satellite SAR mission with highly innovative measurements from space (example of R & D satellite)
- ESA has organised a number of airborne SAR campaigns in past 15 years in support of spaceborne missions (BIOMASS, SAOCOM-CS, TerraSAR-L, Sentinel-1)
- A number of airborne SAR datasets available to the science community via campaign database