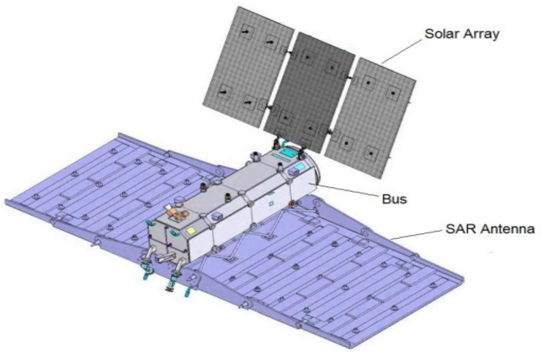
Business from technology



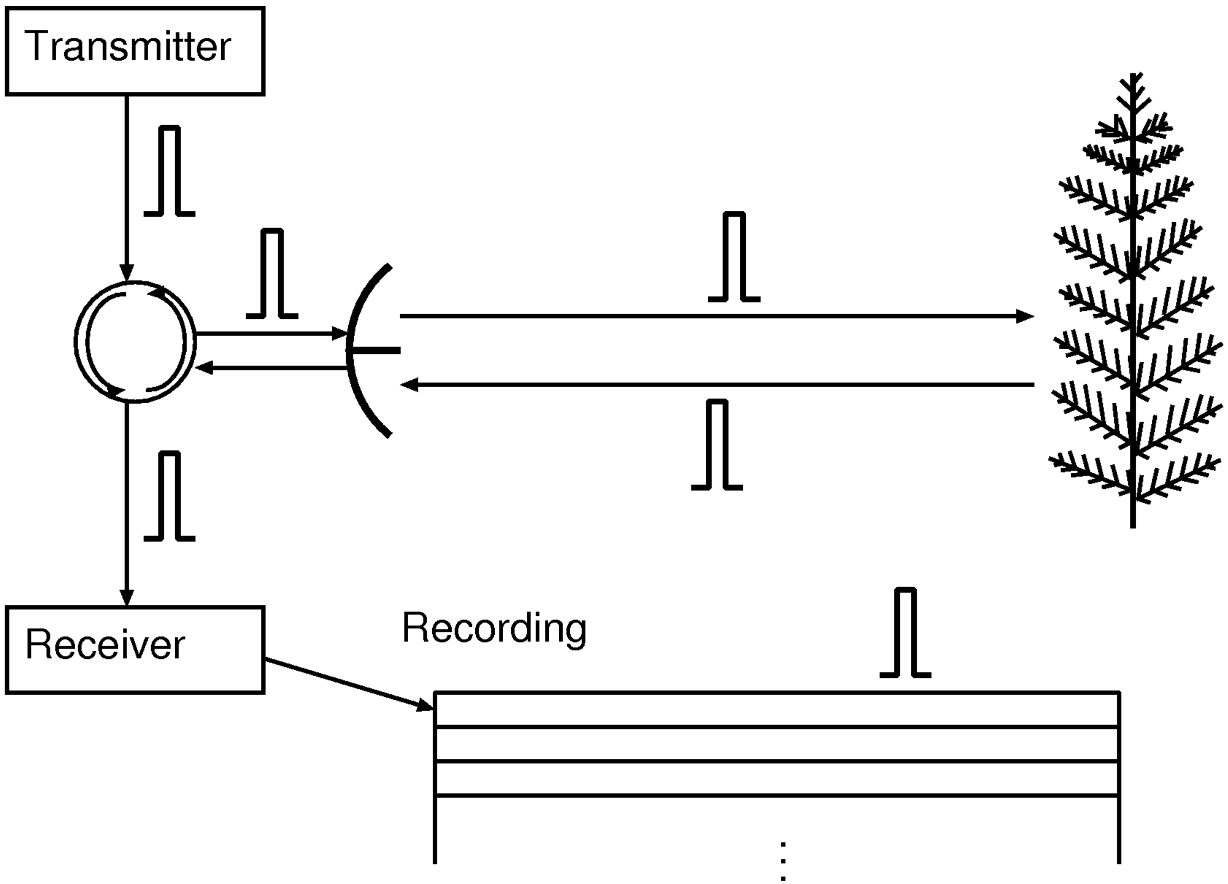
SAOCOM Companion Satellite (CS)

Compiled by Tuomas Häme

Oct 30, 2014

VTT Technical Research Centre of Finland

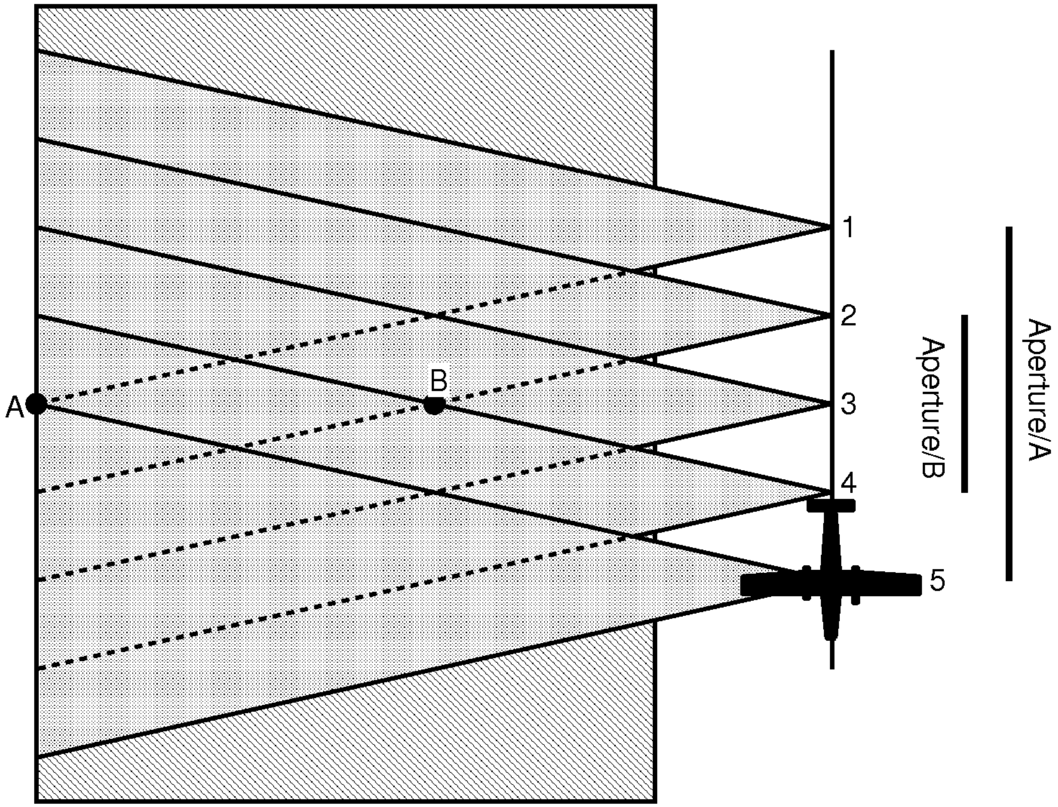
What is Radar



- Acronym from words "RAdio Detection And Ranging"
- Implies measurement from the sensor to the target
- A pulse is sent
- The return signal recorded as a function of time
- Intensity of the signal = power, P
- Square root of P = amplitude

Courtesy of Yrjö Rauste, VTT

Synthetic Aperture Radar



- In real aperture radar, the resolution along track is the better the longer antenna is used
- In synthetic aperture radar (SAR) a long synthetic aperture is constructed by combining the registered echoes from several pulses along the track
- Matched filtering in SAR processing
- Raw data (level 0) is useless without a SAR processor

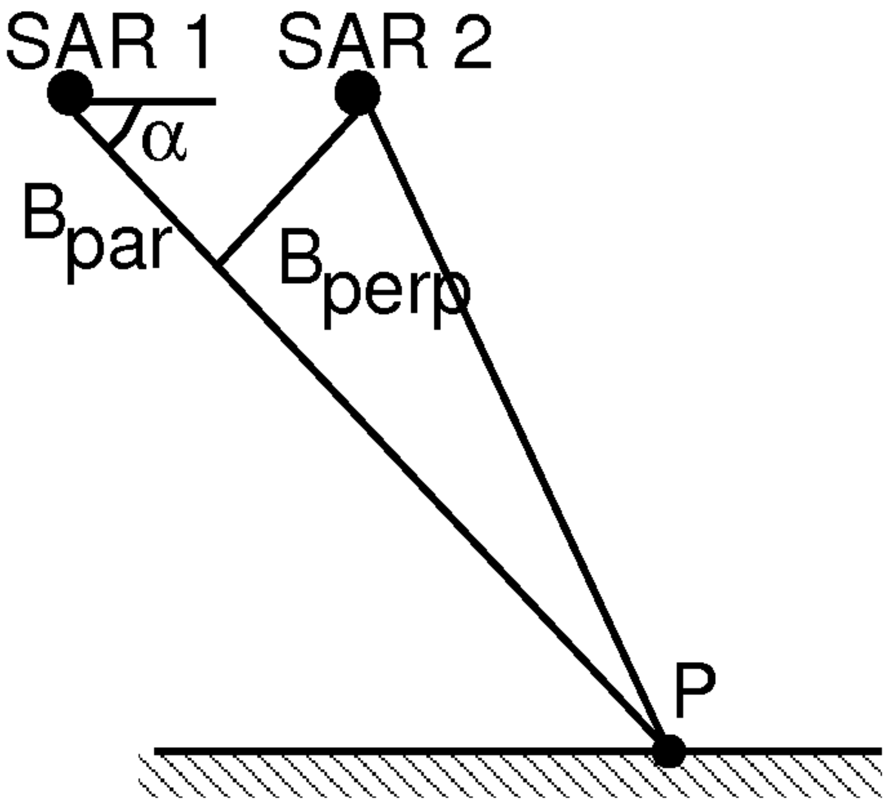
Courtesy of Yrjö Rauste, VTT

Radar Frequencies

- For historical reasons (military secrecy, allocation of frequency bands in the electromagnetic spectrum), a common practice to refer to radar frequencies is by "radar band":
- X-band: wavelength approximately 3 cm, frequency approximately 10 GHz (Giga Herz)
- C-band: 6 cm, 5 GHz
- **L-band: 23 cm, 1.3 GHz - SAOCOM**
- P-band: 63 cm, 0.5 GHz
- K_u-band: 2 cm, 15 GHz (in some old real-aperture radars)

Courtesy of Yrjö Rauste, VTT

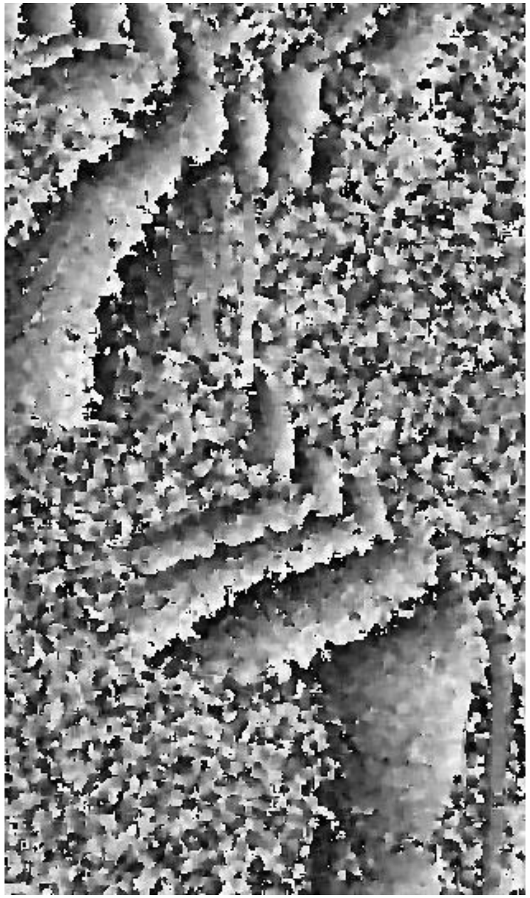
SAR Interferometry



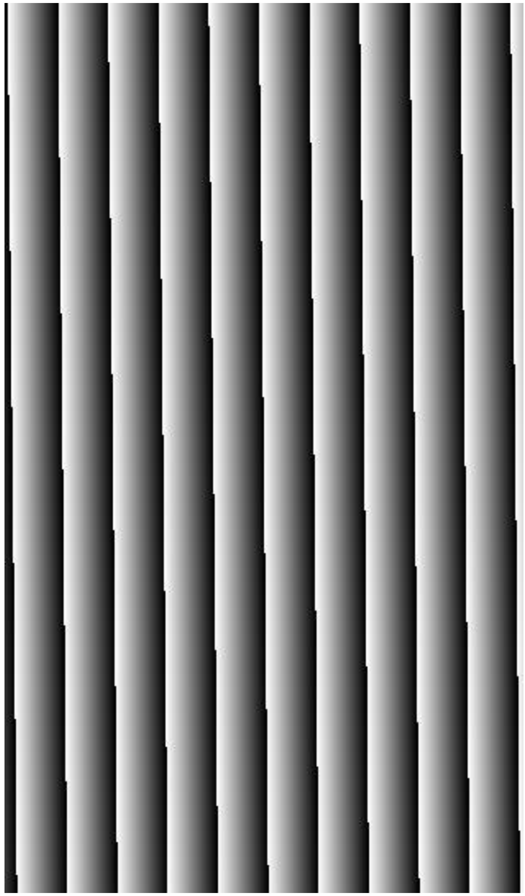
- The change in orbit positions between two over-flights forms a baseline
- The perpendicular baseline component B_{perp} causes a phase shift between the SAR scenes as a function of pixel elevation

Courtesy of Yrjö Rauste, VTT

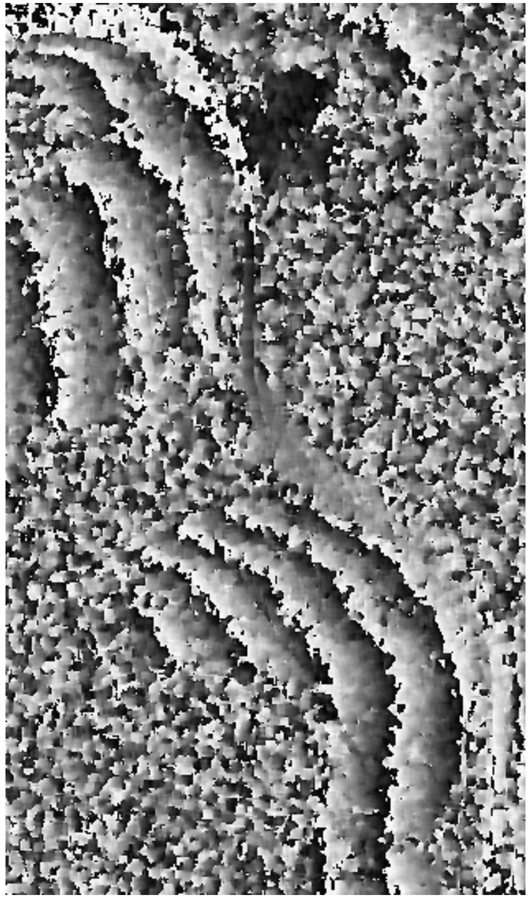
Interferometry/Example on Elevation Mapping



Without flattening



Phase computed for ellipsoid



Ellipsoid-flattened

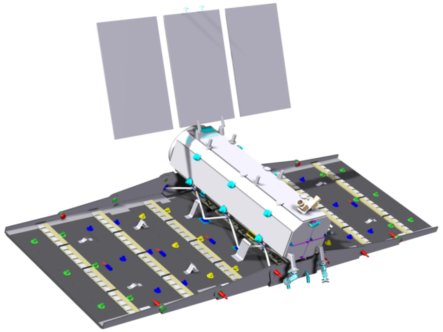
- Effects of the changes on interferogram phase caused by an ellipsoidal earth are computed and then corrected
- Fringes separated by $H_{2\pi}$ (in this case 12.65 m) in elevation

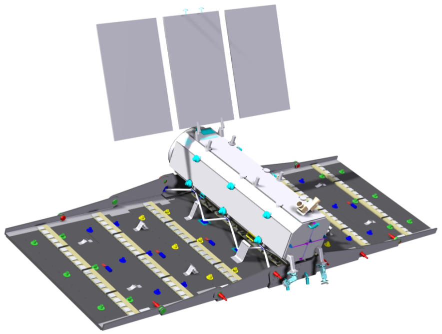
TerraSAR-X data

Courtesy of Yrjö Rauste, VTT

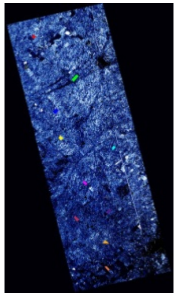
SAOCOM Mission

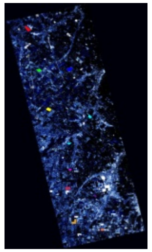
The SAOCOM 1 Mission is composed of two satellites, SAOCOM 1A and SAOCOM 1B, presently under development. Both satellites are equally designed and each one carries a full polarimetric L-band SAR instrument

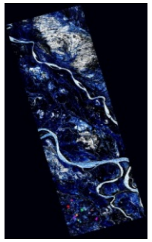




This mission has as main driver the generation of Soil Moisture Maps over the Pampas Region in Argentina, with the aim of providing an essential quantitative input of the soil moisture content for giving support to agricultural and hydrological applications (SAOCOM Strategic Applications).

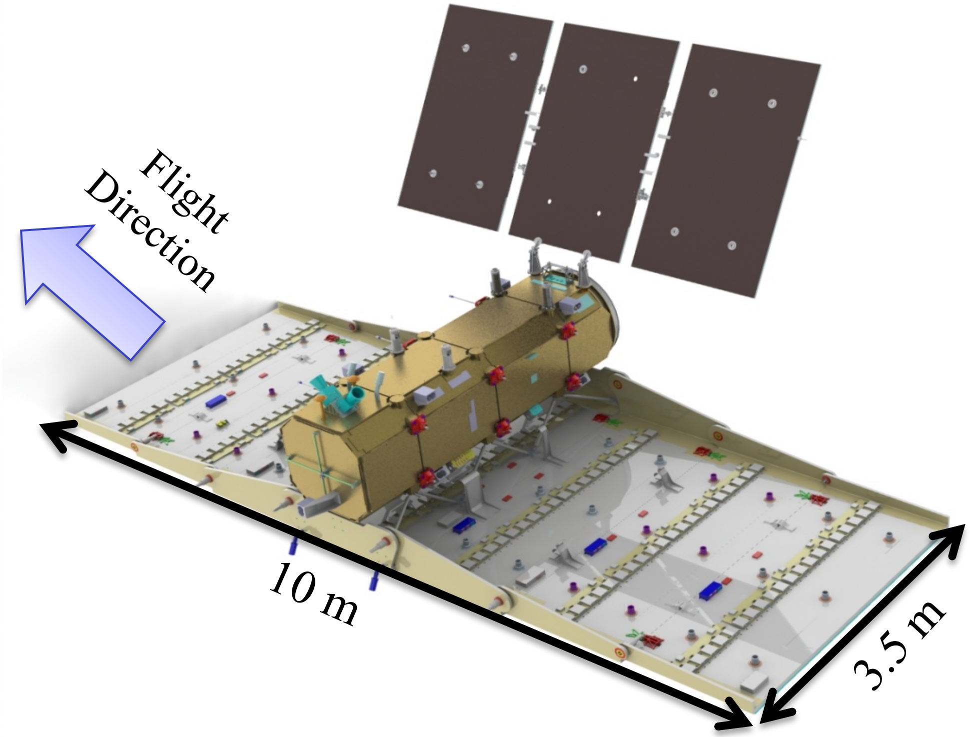






Courtesy of Laura Frulla, Gladys Rodriguez Ortega, Jorge Milovich, Marc Thibeault (ST), CONAE

SAOCOM SAR Instrument

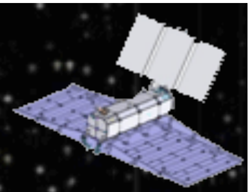


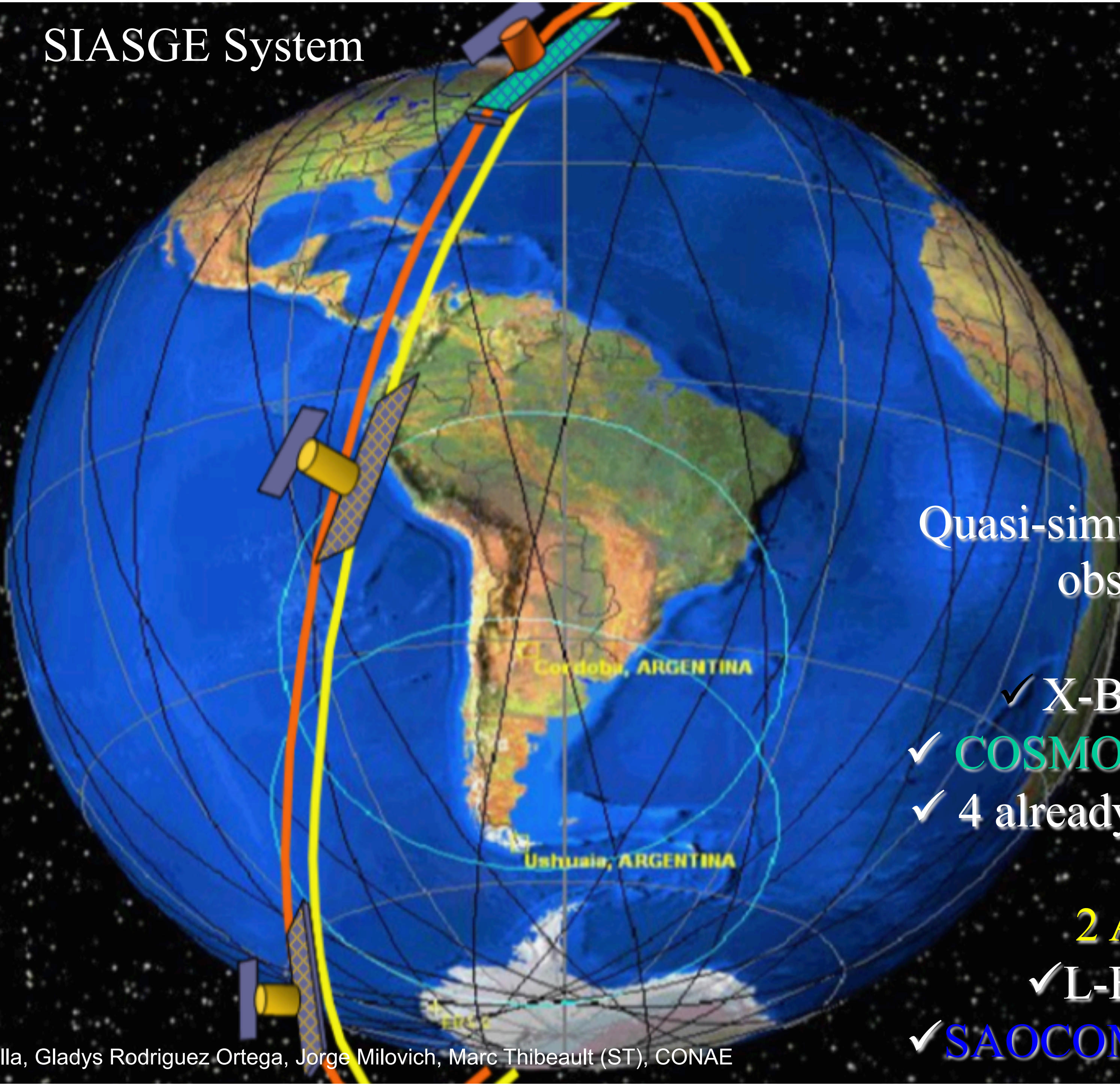
MAIN CHARACTERISTICS

- L-Band SAR
- Right looking SAR
- Left looking capability
- 10m x 3.5m active phased array antenna with 140 TRMs
- TOPSAR & Stripmap acquisition modes
- Single, dual and quad polarization operative modes
- More than 2600 beams
- Satellite Weight: ~3 tons
- Solar Array area: ~13 m^2

Courtesy of Laura Frulla, Gladys Rodriguez Ortega, Jorge Milovich, Marc Thibeault (ST), CONAE

SIASGE System





Quasi-simultaneous observations

4 Italian

- ✓ X-Band SAR
- ✓ COSMO SkyMed
- ✓ 4 already in orbit

2 Argentine

- ✓L-Band SAR
- ✓SAOCOM 1A, 1B

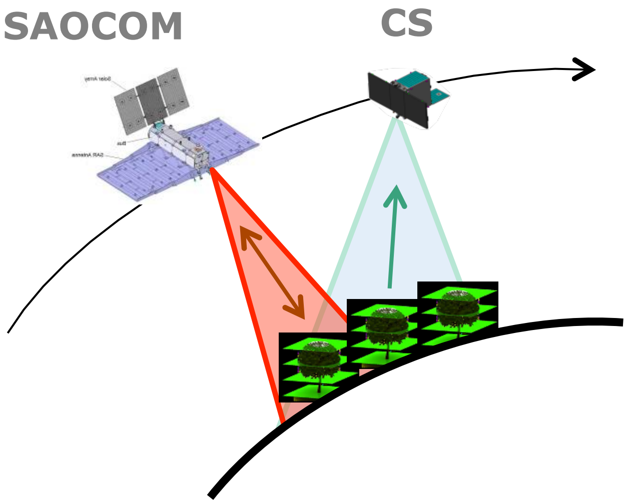
Courtesy of Laura Frulla, Gladys Rodriguez Ortega, Jorge Milovich, Marc Thibeault (ST), CONAE

Nominal Modes Features

acquisition mode	polarization mode	swath width	spatial resolution	minimum incidence angle range
StripMap	SP: HH or HV or VH or VV	> 40 km	< 10 m	21° - 50°
	DP: HH/HV or VV/VH	> 40 km	< 10 m	21° - 50°
	QP: HH/HV/VH/VV	> 20 km	< 10 m	20° - 35°
TOPSAR Narrow	SP: HH or HV or VH or VV	> 150 km	< 30 m	25° - 45°
	DP: HH/HV or VV/VH	> 150 km	< 30 m	25° - 45°
	QP: HH/HV/VH/VV	> 100 km	< 50 m	20° - 35°
TOPSAR Wide	SP: HH or HV or VH or VV	> 350 km	< 50 m	25° - 45°
	DP: HH/HV or VV/VH	> 350 km	< 50 m	25° - 45°
	QP(1): HH/HV/VH/VV	> 220 km	< 100 m	20° - 35°
	CL-POL: RH/RV or LH/LV	> 350 km	< 50 m	25° - 45°

Courtesy of Laura Frulla, Gladys Rodriguez Ortega, Jorge Milovich, Marc Thibeault (ST), CONAE

Development of a companion to SAOCOM Mission - overview



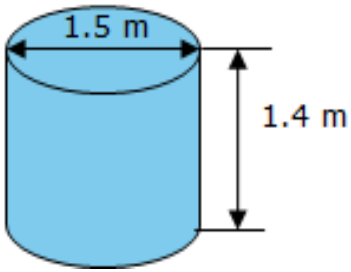
- TangoSat "Companion Satellite" ("SAOCOM-CS")
  - ✓ receive-only, dual-pol L-band SAR satellite
  - ✓ (close) formation with SAOCOM
  - ✓ SAOCOM as illuminator
- Complement science return of SAOCOM
  - ✓ new radar science: tomography, bistatic measurements
  - ✓ mapping of biomass and structure of boreal forests by SAR tomography
  - ✓ several imaging geometries (baselines and angles) for experimental applications
  - ✓ detailed studies by POLIMI, DLR and CSL confirmed preliminary mission science program
- Launcher & schedule constraints
  - ✓ 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

Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

System Definition

Launch with Falcon-9 as secondary payload.

MAS-5 launcher adapter.



Dynamic envelope

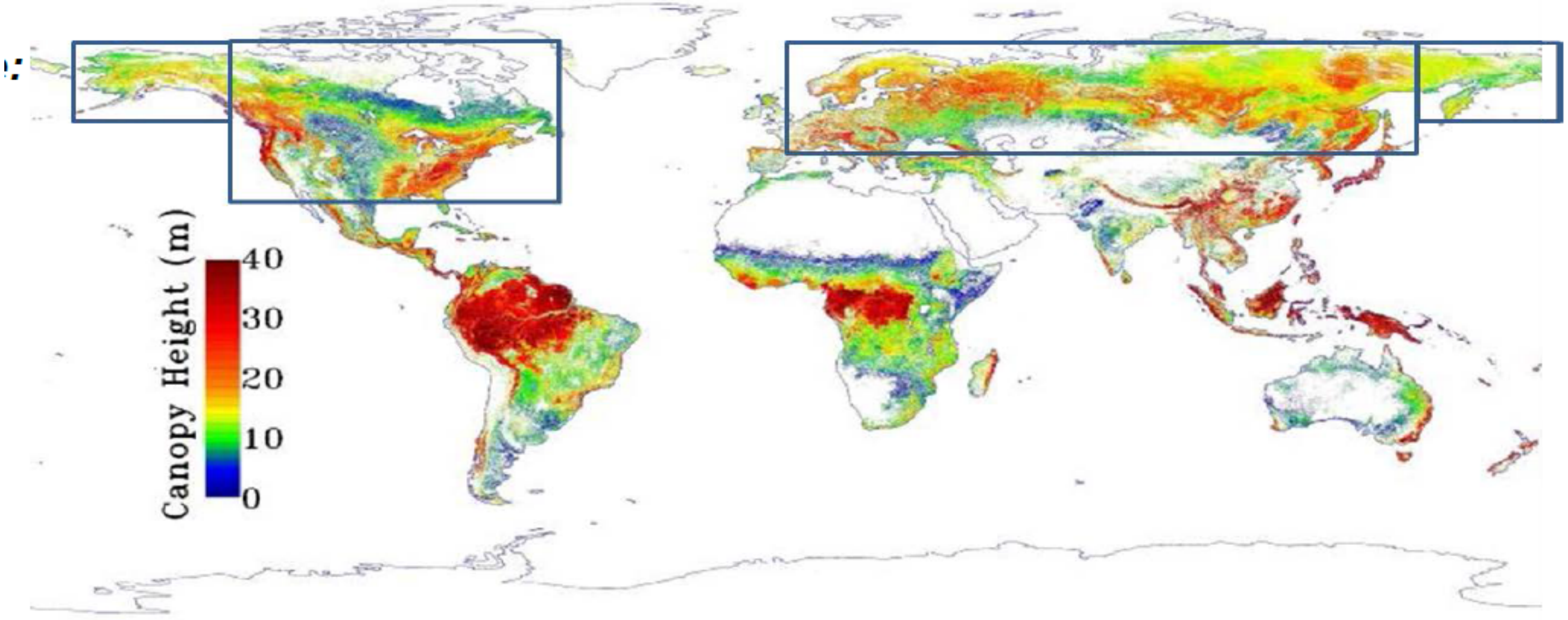
Max mass: ca 400 kg

- Small platform
- Planar deployable antenna
- Reuse/Adaptation of Central electrons

- Available technology
- High TRL
- Design heritage

Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

SAOCOM CS Science Mission Driver: Boreal forest structure

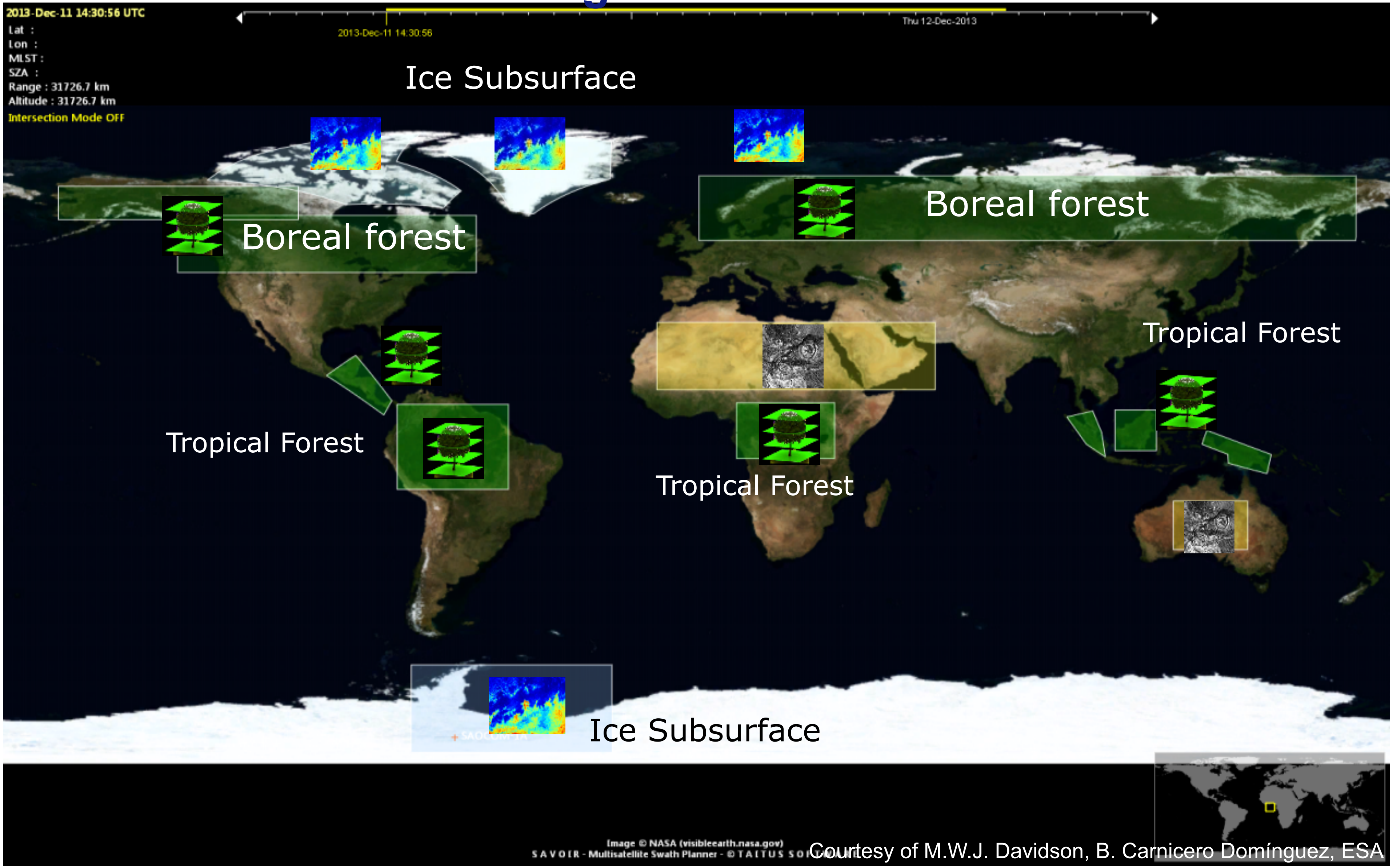


Attractive science goal for SAOCOM CS mission

- Forest structure provides valuable information including forest biomass/carbon resources
- Fill in SOTR restricted areas
- Complements ESA BIOMASS Explorer Mission and other mission concepts NASA L-band SAR/JAXA PalSAR/DLR Tandem-L

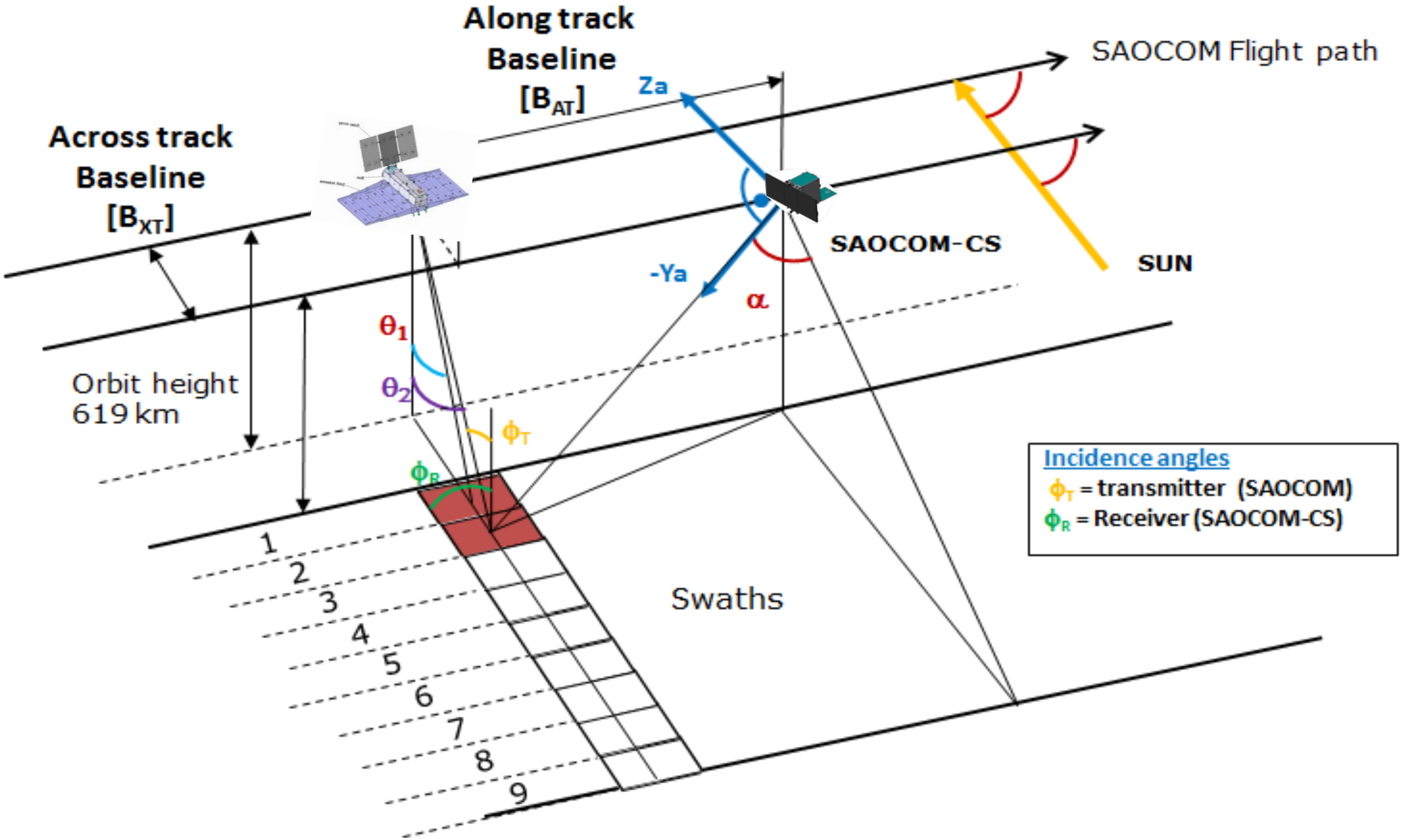
Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Tomographic Science Applications and Coverage for SAOCOM CS



Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Observation Geometry



Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Science and Observation Geometry

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

Tomographic phase

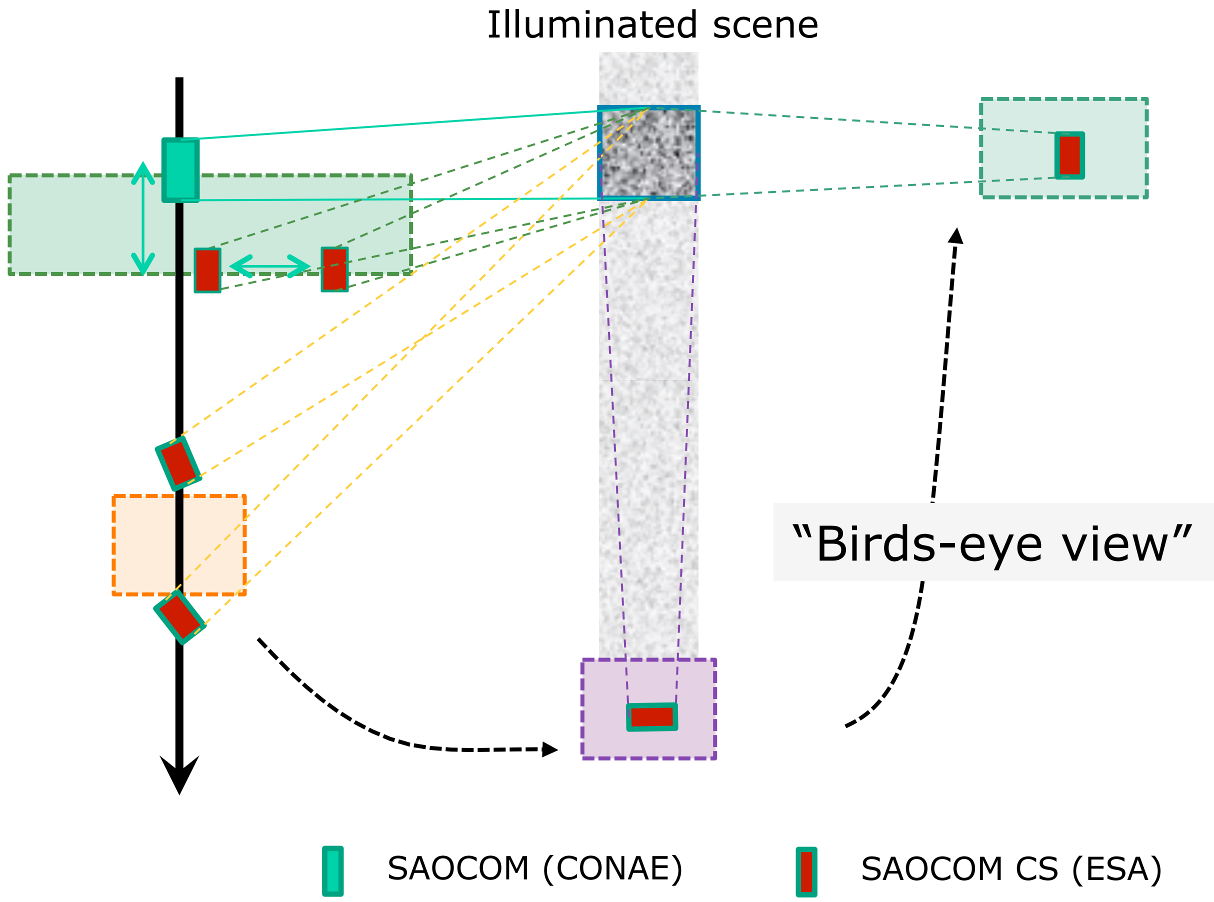
✓**AT baseline < 6 km**
✓**XT baseline varies ~1–6 km**
✓**Science mission driver**
✓**Duration ~2.5 years**

Bistatic 1, Bistatic 2

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

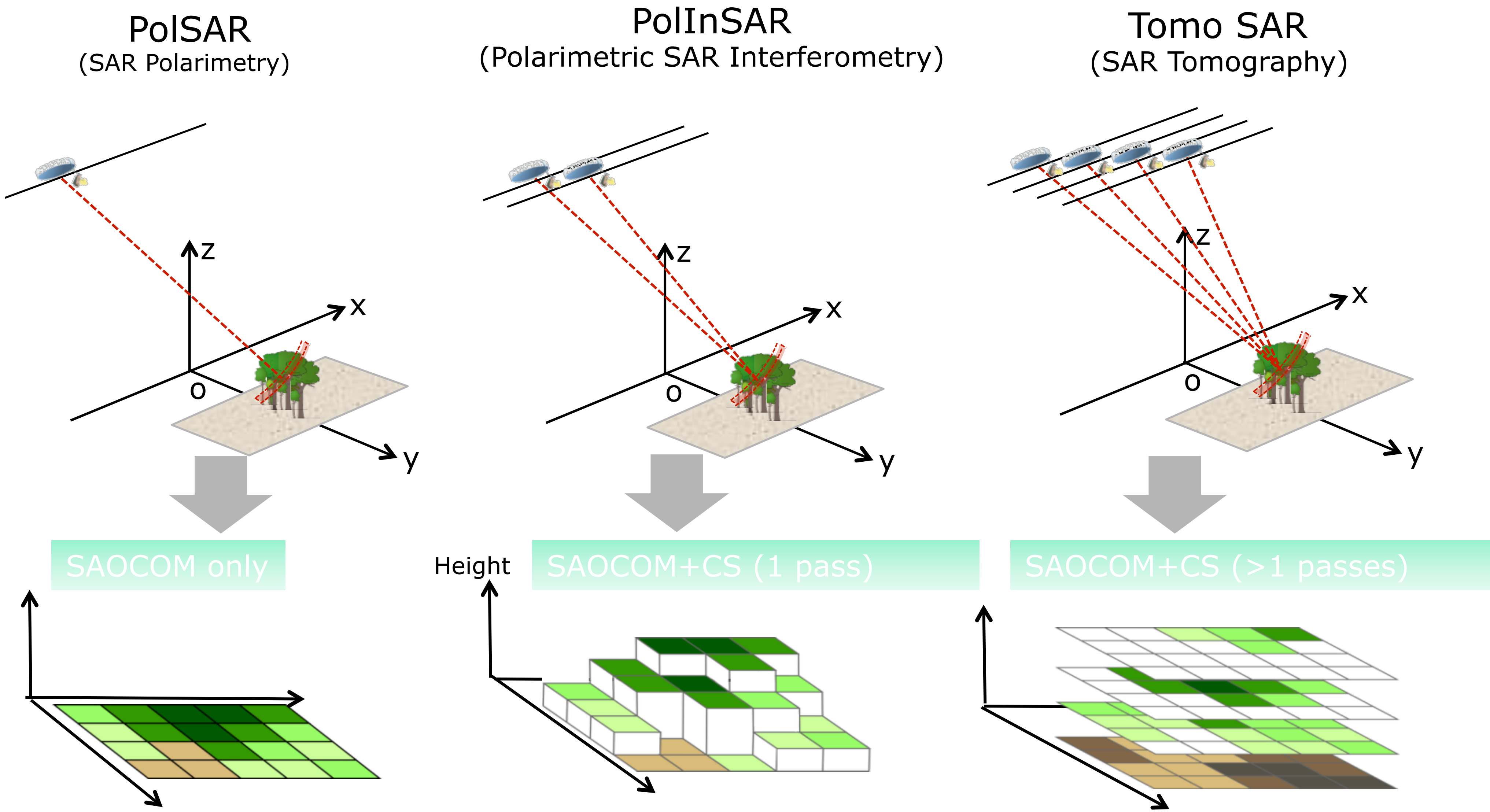
Specular phase

✓ **Experimental**
✓ **Short duration**



Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

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



Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Overview: Mission Timeline and Baselines

Science Cycle	Science Target	Days	RC	SAOCOM Inst. mode	AT Baseline	XT Baseline
TC1	Boreal forest/Tomography	160	10	SM/DP/Swath2	<= 6km	<= 1200m (RC1), <=6km (RC2-9), <= 1200m (RC10)
TC2	Boreal forest/Tomography	160	10	SM/DP/Swath2	<= 6km	<= 1200 at 55N (RC1), <=6 km (RC2-9), <= 1200m (RC10)
TC3	Tropical Forest Structure/Height	320	20	SM/DP/Swath2	<= 6km	<= 600m at 0N (RC1) <= 12km (RC2-RC19) <= 600m (RC20)
TC4	Ice subsurface structure	160	10	SM/FP	<= 6km	<= 1km at 70N (RC1) <= 6km (RC2-9) <=1km (RC10)
TC5	Desert subsurface structure/super resoltuion	80	5	SM/FP	<= 6km	<=800m at 10N (RC1) <= 2km (RC2-4) <=800m (RC5)
BS2	Dense PS inteferometry	480	30	SM/DP/Swath2	50km	0km
BS3	Ocean currents	80	5	SM/DP/Swath2	9km	<= 300m
BS4	Bistatic Interferometry	160	10	SM/FP	50-250km	0km
BS5	Bistatic Interferometry	80	5	TBC	250km	260km
SP	Specular	80	5	TBC	Close to 0km	520km at SAOCOM height (specular)

Tomographic Phase (880 days)

Bistatic Phase (720 days)

Specular Phase (160 days)

Science Days: 1760
Science Years: 4.82

Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Imaging Modes & L1b performance

- small antenna height limits access to near range swaths
  - ✓ 2 swaths in quad-pol mode
  - ✓ 2 nominal (+2 experimental) swaths in dual-pol mode
- stripmap mode selected due to best geometric resolution (single look)

Resolution (az x rg): 6 x 10 m^2 (quad-pol) and 5 x 10 m^2 (dual-pol)

Swath	Q1	Q2	D1	D2	D3	D4
PRF (Hz)	3479	3434	1839	1796	2150	1856
Start (^{0})	17.6	19.5	20.7	24.9	29.1	33.7
End (^{0})	19.6	21.5	25.1	29.2	33.9	38.4
Chirp (MHz)	44.7	40.5	38.3	32.2	27.9	24.4
B_{dop} (Hz)	> 1050		> 1250			

625 km altitude

- full range of altitudes considered
- radiated peak power 3.1 kW, RF losses 4.2 dB
- calculations limited to tomographic phase (small AT baselines)

Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

Conclusions

- SAOCOM-CS represents a new mission concept with attractive elements
  - ✓ high degree of R&D with respect to novel radar measurements (tomography, bistatic, specular) and processing techniques
  - ✓ short development schedule (ready for launch by 2018)
  - ✓ Demonstrator for more operational-oriented - but still cost-effective - SAR convoy missions e.g. with Cosmo or Sentinel-1
  - ✓ collaboration between Agencies and with the science community
- Studies have demonstrated principle mission feasibility and science return
- Investigations are on-going, follow-on activities initiated:
  - ✓ Phase A/B1 system (platform, accommodation of payload and in launcher) studies (kicked-off July 2014)
  - ✓ Parallel activities on payload, science, processing, and operations on-going or planned to start
  - ✓ Confirmation of mission by ESA member states expected early 2015

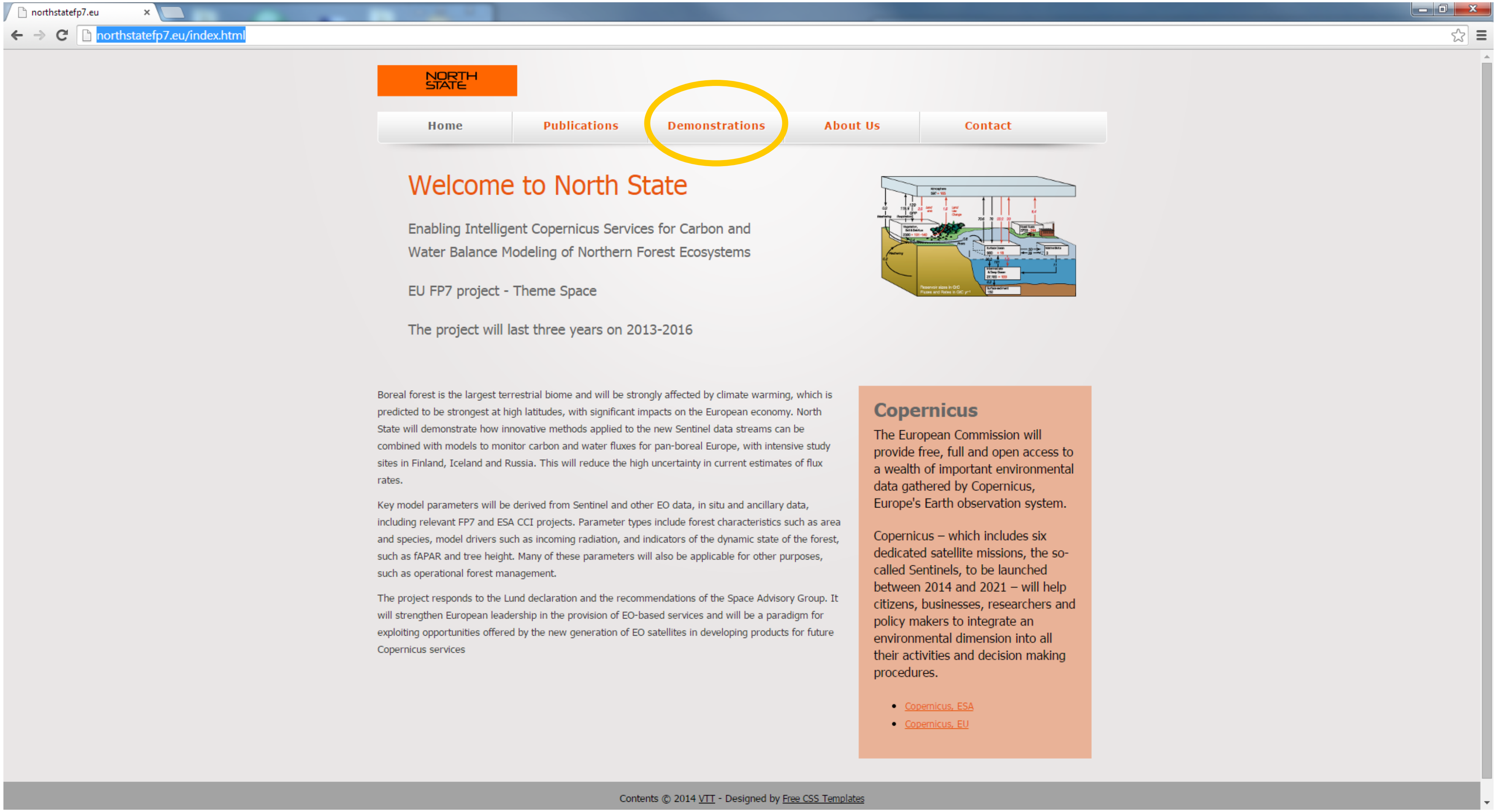
Courtesy of M.W.J. Davidson, B. Carnicero Domínguez, ESA

ADD-on:

SENTINEL-1 MOSAIC FROM FINLAND

Sentinel-1 mosaic from Finland

http://northstatefp7.eu/index.html



http://northstatefp7.eu/demonstrations.html

NORTH STATE

Home | Publications | Demonstrations | About Us | Contact

Our Gallery

North State will demonstrate how innovative methods applied to the new Sentinel data streams can be combined with models to monitor carbon and water fluxes for pan-boreal Europe.

The most important variables to be estimated based on EO-data and applied in carbon and water balance models are:

- Fraction of Absorbed Photosynthetically Active Radiation (fAPAR)
- Leaf area index (LAI)
- Forest area
- Plant functional type (or tree species)
- Tree height
- Snow cover
- Phenology; start and end of growing season
- Logging events
- Biomass (or growing stock volume)
- Peatland extent

The rationale of the introduction of the EO based variables in the modelling comes from the need to calibrate the models and assess their accuracy. Many of these variables will also be applicable for other purposes including relevant FP7, Horizon 2020, and Climate Change Initiative (CCI) of ESA projects.

Sample products

Examples of the products. **Data policy**

Date	Name	Description
27.10.2014	Finland, mosaic	Mosaic of Sentinel 1 images from October 2014.

North State study sites

North State has four sites for intensive studies, see below. Additionally, the model input variables will be estimated and models applied over European boreal and