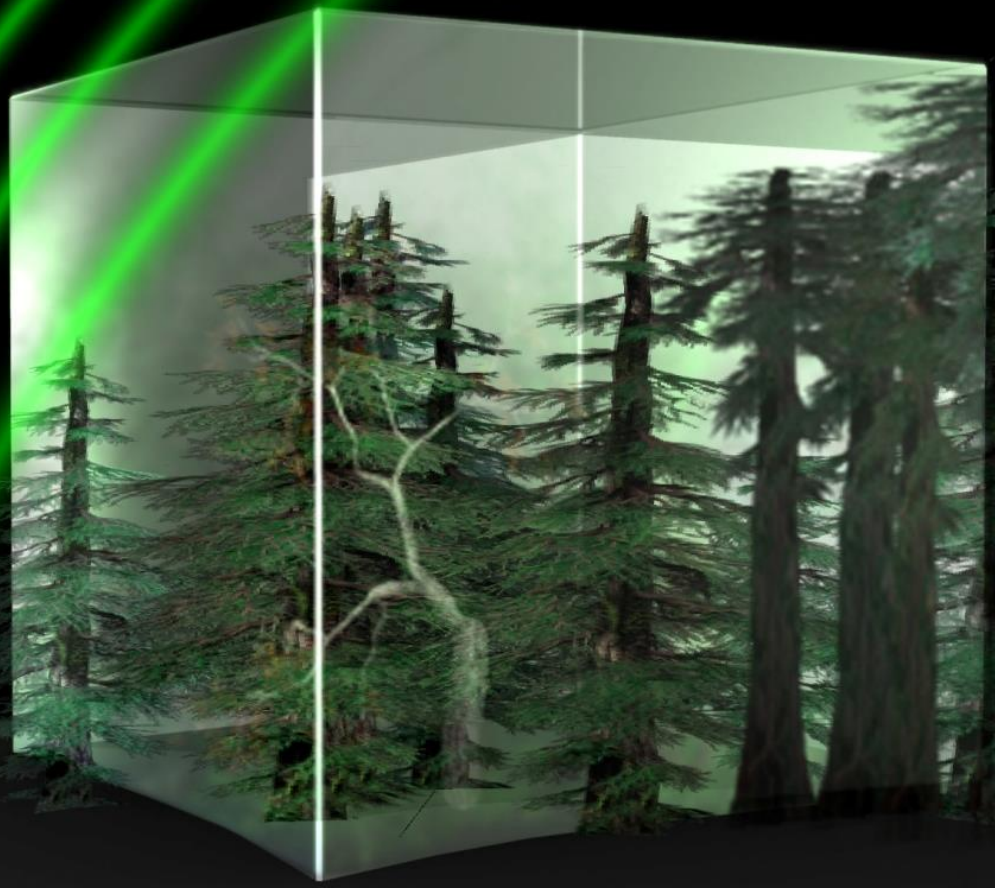
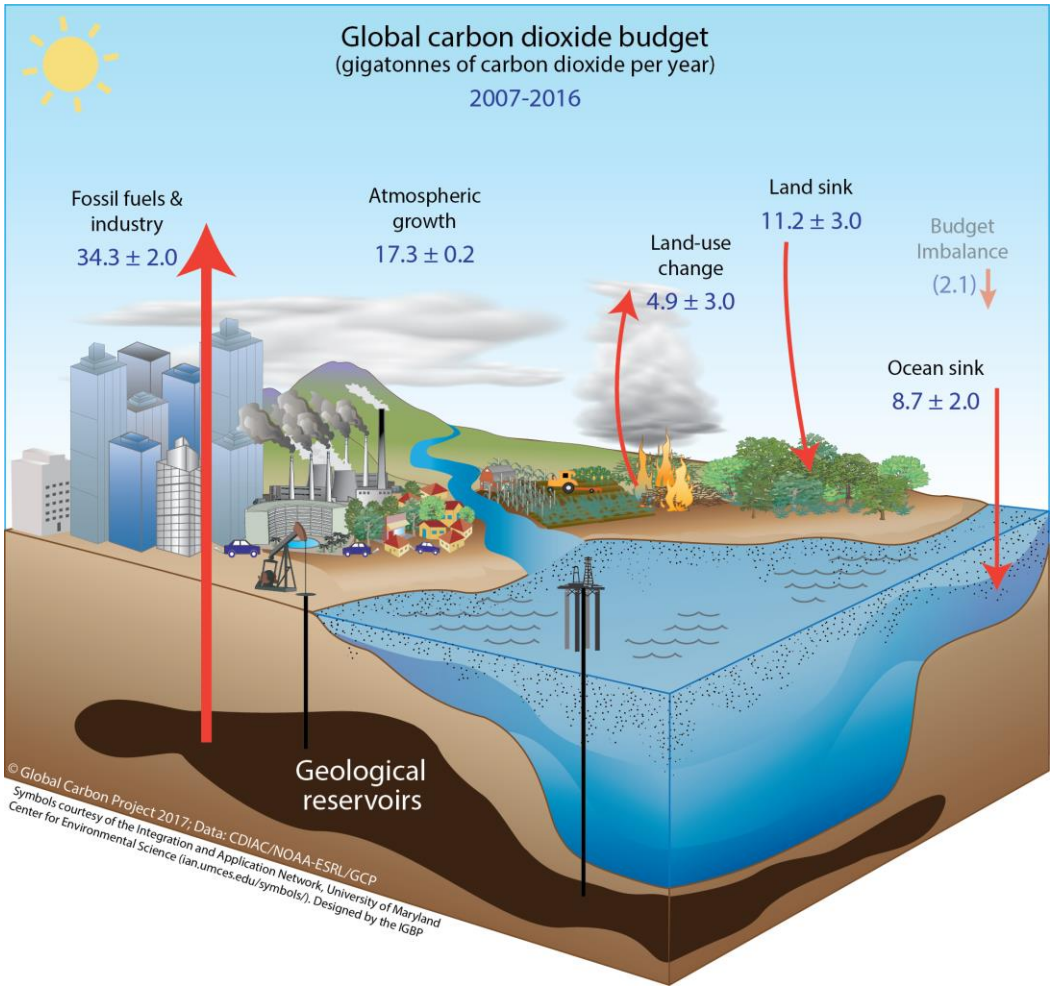
The BIOMASS mission: Quantifying biomass for carbon assessment



Thuy Le Toan
CESBIO, Toulouse, France

The science question: role of forests in the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade **2007–2016 ($GtCO_2$/yr)**

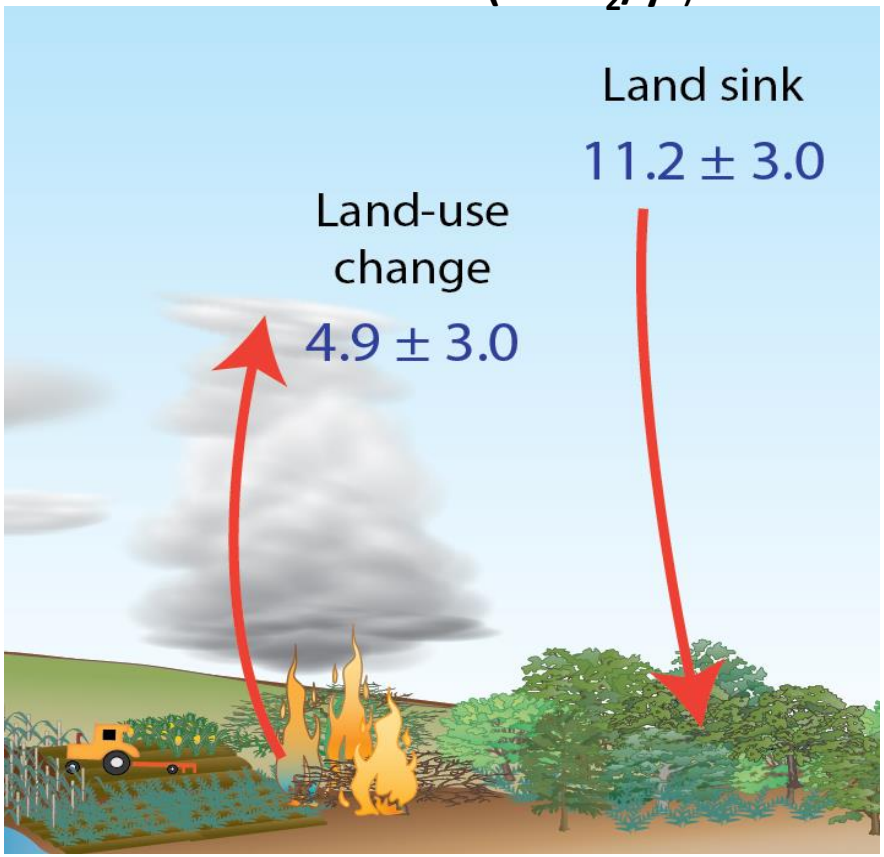


The budget imbalance is the difference between the estimated emissions and sinks.

Source: CDIAC; NOAA-ESRL; Le Quéré et al 2017; Global Carbon Budget 2017

Large uncertainties in terrestrial carbon sources and sinks

2007–2016 ($GtCO_2$/yr)



Science Objective: to reduce uncertainties on the **spatial distribution**, the **quantity** and **dynamics** of **forest carbon stocks, sources and sinks**

The science question

GLOBAL CARBON PROJECT

Fate of anthropogenic CO_2 emissions (2007–2016)

Sources

34.4 $GtCO_2$/yr

88%

12%

4.8 $GtCO_2$/yr

Sinks

17.2 $GtCO_2$/yr

46%

30%

11.0 $GtCO_2$/yr

24%

8.8 $GtCO_2$/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

6%
2.2 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 201

BIOMASS will provide forest biomass, forest height and disturbances

Forest biomass

Above-ground biomass (tons / hectare)

- 4 hectare resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- accuracy of 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}

Forest height

Upper canopy height (meter)

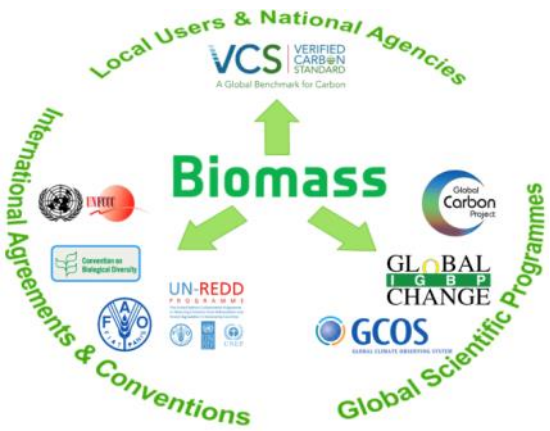
- 4 hectare resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- accuracy of 20-30%

Disturbances

Areas of forest clearing (hectare)

- 0.25 hectare resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- 90% classification accuracy

Mission Overview



USER SEGMENT

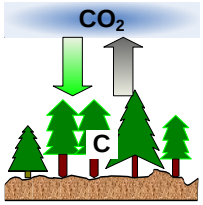
GROUND SEGMENT

Flight Operations Segment

TT&C Station (Kiruna),
Flight Operation Control Centre (ESOC)

Payload Data Ground Segment

Science Data Acquisition Station (Kiruna)
Processing and Archiving Element (ESRIN)



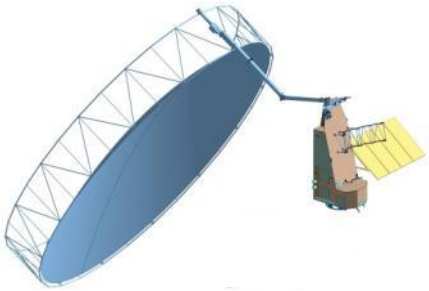
SUBJECT

Terrestrial carbon stock/carbon fluxes by measurement of forest biomass

Biomass Mission Elements

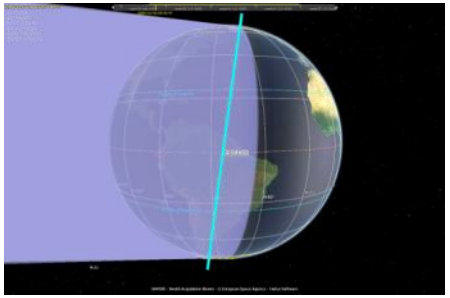
LAUNCHER

Vega



SPACE SEGMENT

Single Spacecraft
Mass: ~1200 kg
Power: ~1500 W
Payload: P-band SAR



ORBIT

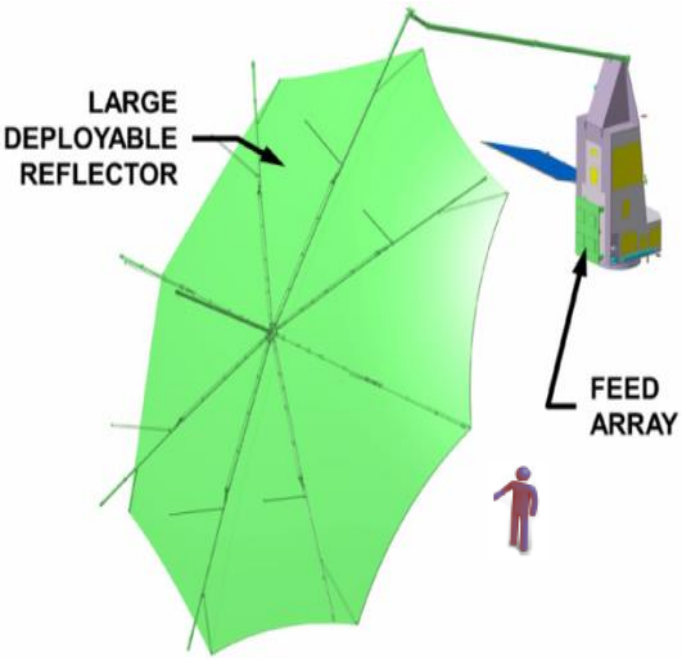
Drifting sun-synchronous
Local time 06:00, 635-672 km,
Repeat cycle: 17 days (Baseline)
3-4 days (Option)

Biomass Mission Concept

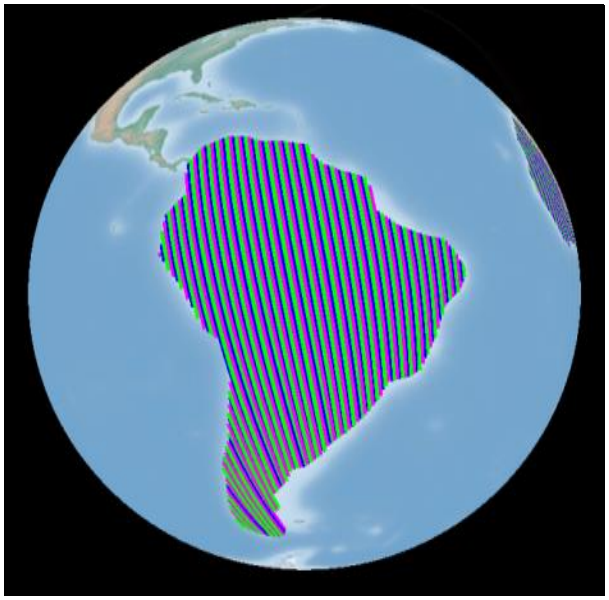
- Single satellite, operated in a polar sun-synchronous orbit
- Full polarimetric P-band (435 MHz) Synthetic Aperture Radar with 6 MHz bandwidth
- Two mission phases: Tomography (year 1), Interferometry (year 2-5)
- Multi-repeat pass interferometry (3 passes in nominal operations) with a 3 days repeat cycle
- Global coverage in ~7 months (228 days) on asc. and des. passes
- 5 years lifetime

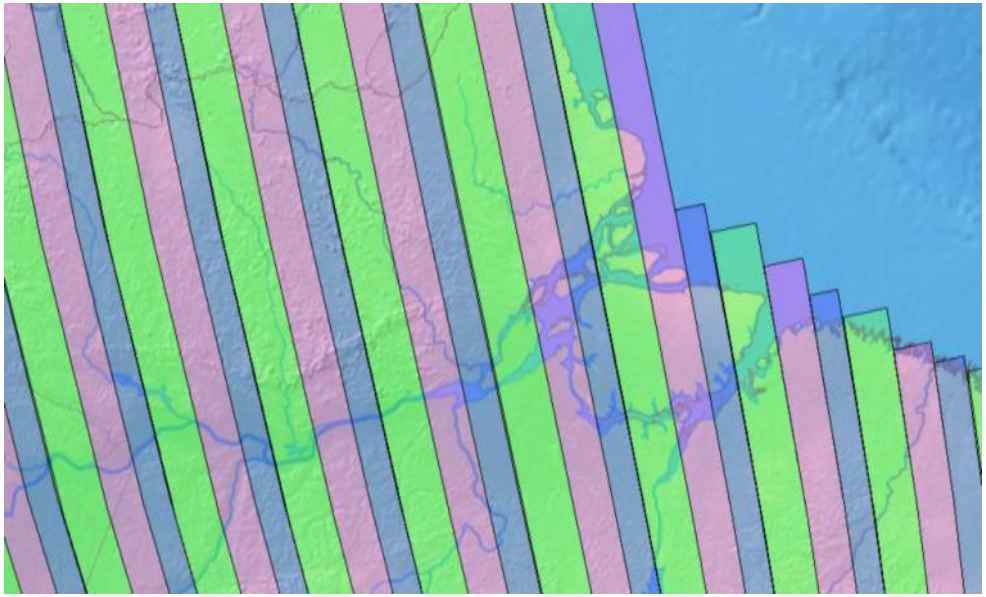
Biomass Mission Performance

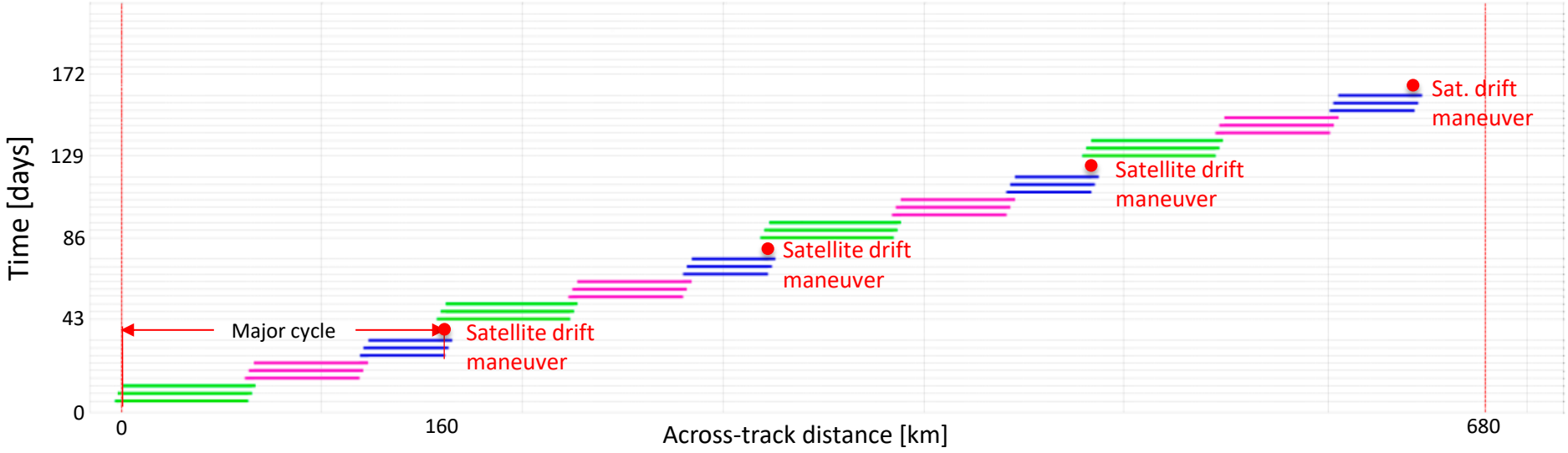
Key Parameters	
Sensitivity (NESZ)	≤ -27 dB
Total Ambiguity Ratio	≤ -18 dB
SLC resolution	≤ 60m x 8m
Dynamic Range	35 dB
Radiometric Stability	≤ 0.5 dB
Radiometric Bias	≤ 0.3 dB
Crosstalk	≤ -30 dB
Channel Imbalance	≤ -34 dB



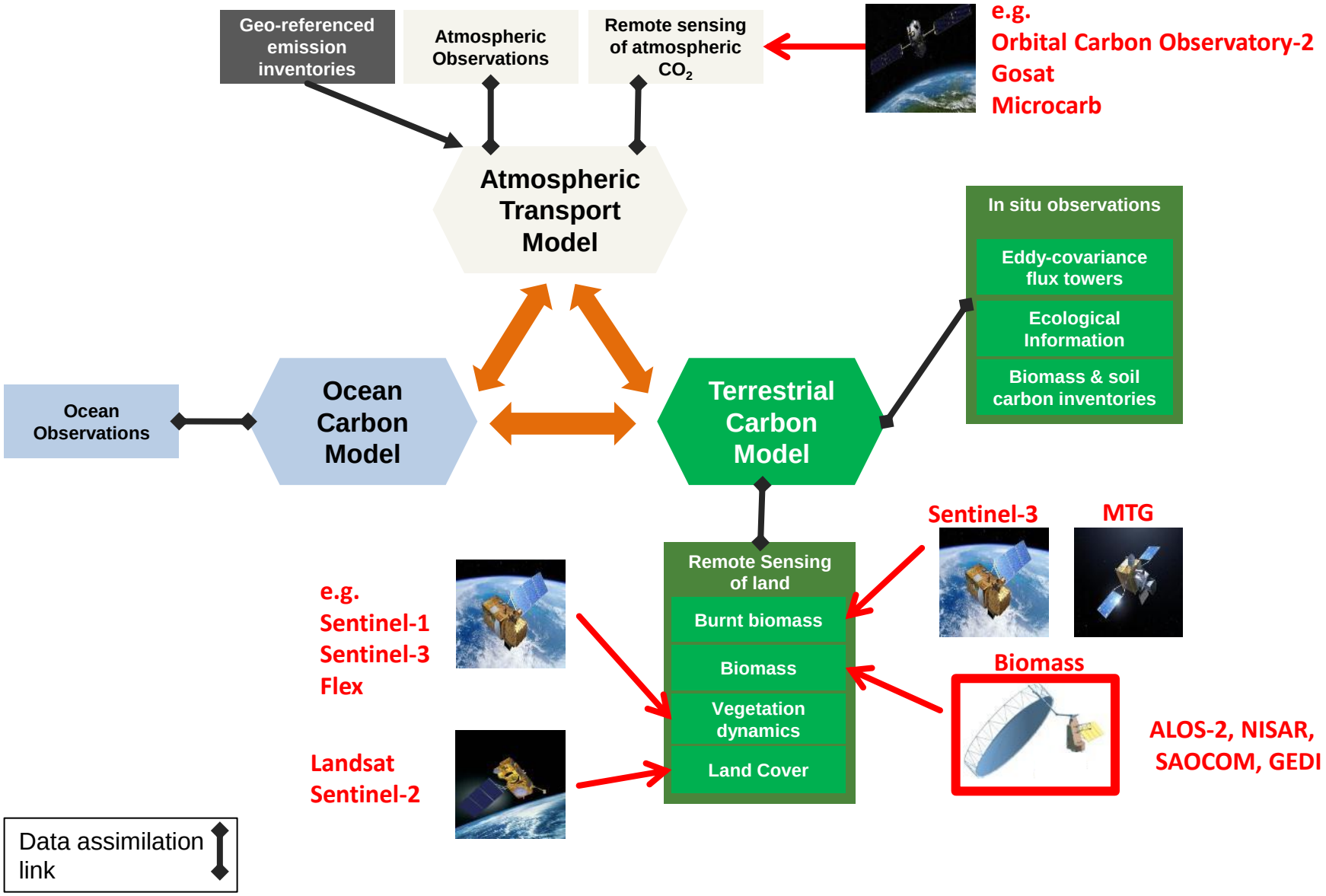
Global Coverage Strategy







Biomass in the Global Carbon Data Assimilation System



Forests are one of the Earth's most precious resources to sustain

Pressing need for forest Information in policy

15 LIFE ON LAND

LIFE ON LAND: WHY IT MATTERS

What's the goal here?

To sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.

Why?

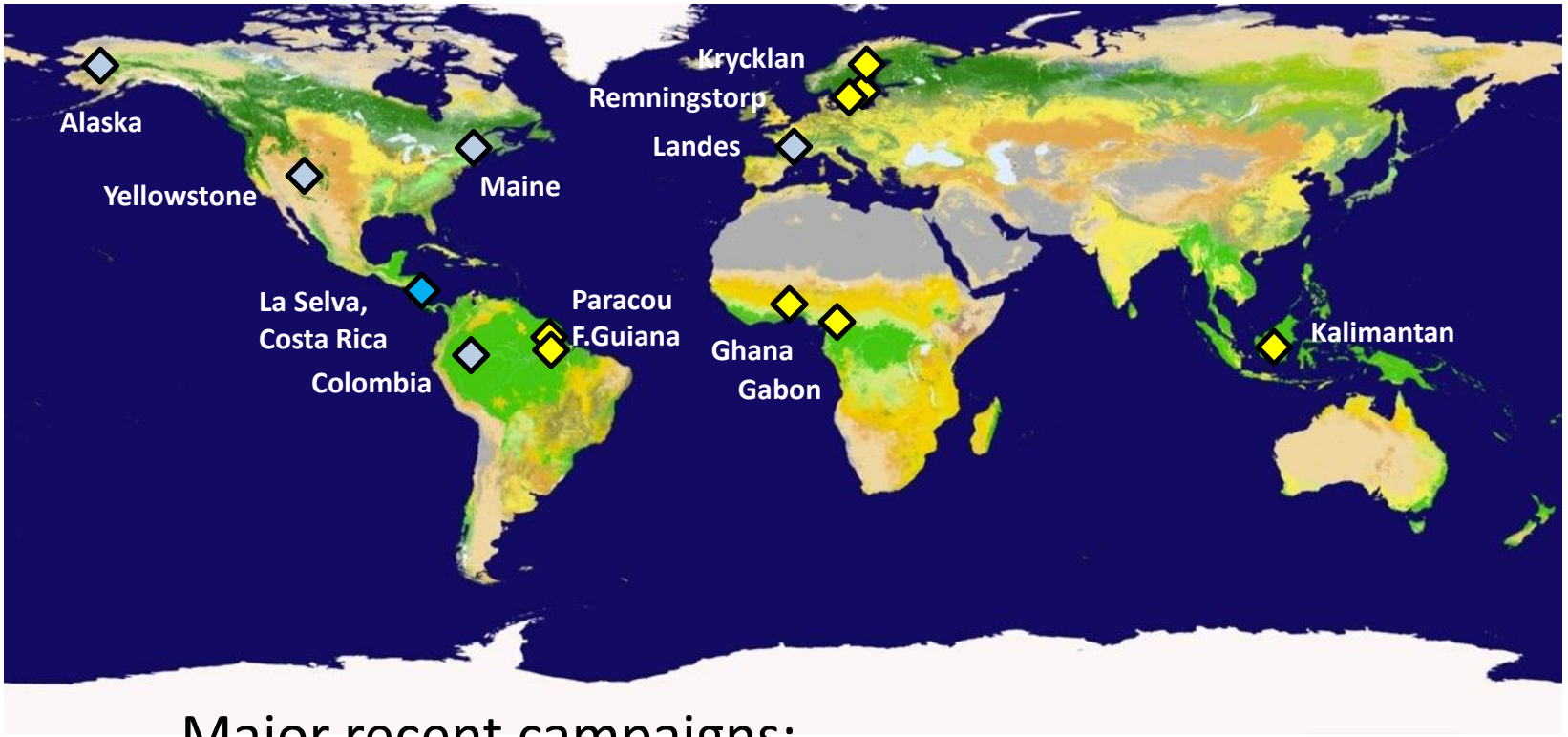
Forests cover nearly 31 per cent of our planet's land area. From the air we breathe, to the water we drink, to the food we eat–forests sustain us.

Think about it. Around 1.6 billion people depend on forests for their livelihood. Almost 75 per cent of the world's poor are affected directly by land degradation. Did you know that forests are home to more than 80 per cent of all terrestrial species of animals, plants and insects? And of the 8,300 animal breeds known, 8 per cent are extinct and 22 per cent are at risk of extinction.

Biodiversity and the ecosystem services it underpins can also be the basis for climate change

Around **1.6 billion** people depend on **forests** for their livelihood.

Campaigns used to develop observation concept

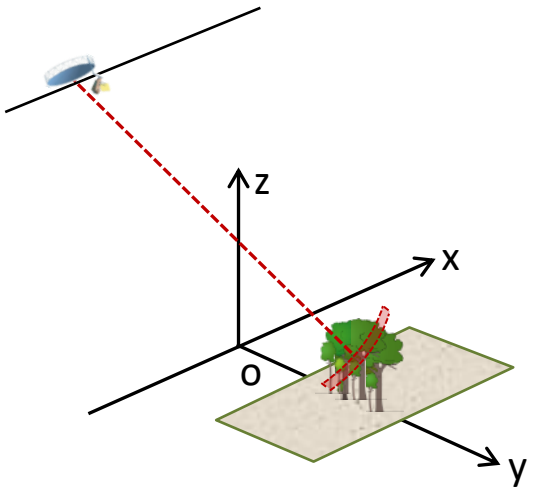


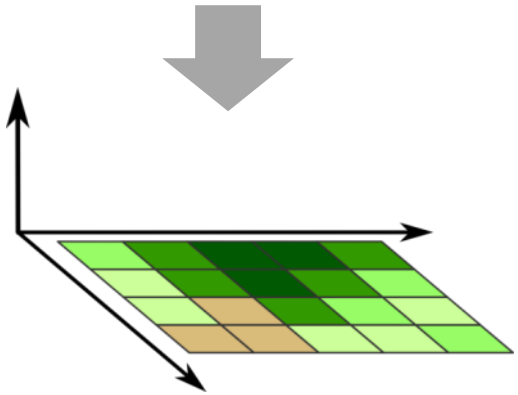
Major recent campaigns:

1. F. Guiana 2009 (TropiSAR), 2011-13 (TropiScat)
2. Gabon (AfriSAR) 2015, 2016
3. Ghana (AfriScat), 2016-2017

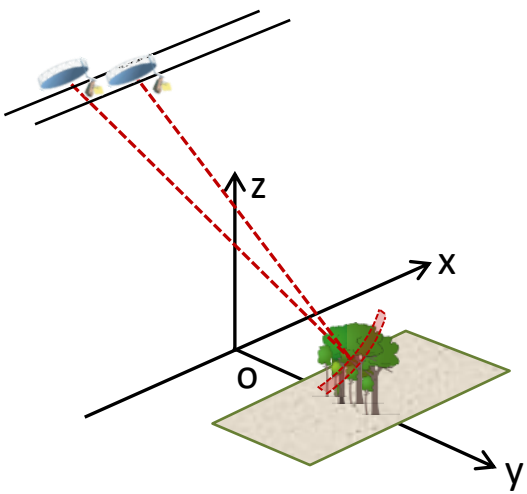
Biomass: a single P-band satellite can deliver 3 independent types of information

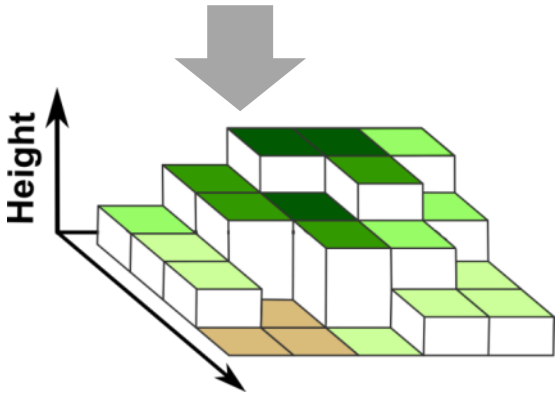
PolSAR
(SAR Polarimetry)



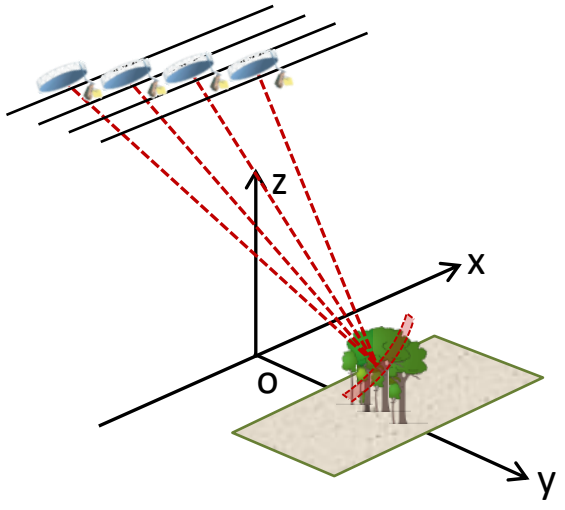


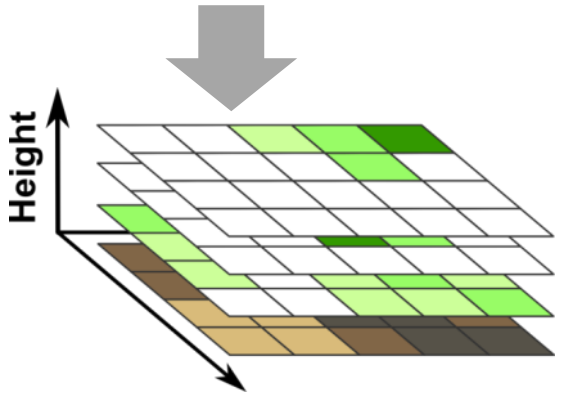
PolInSAR
(Polarimetric SAR Interferometry)





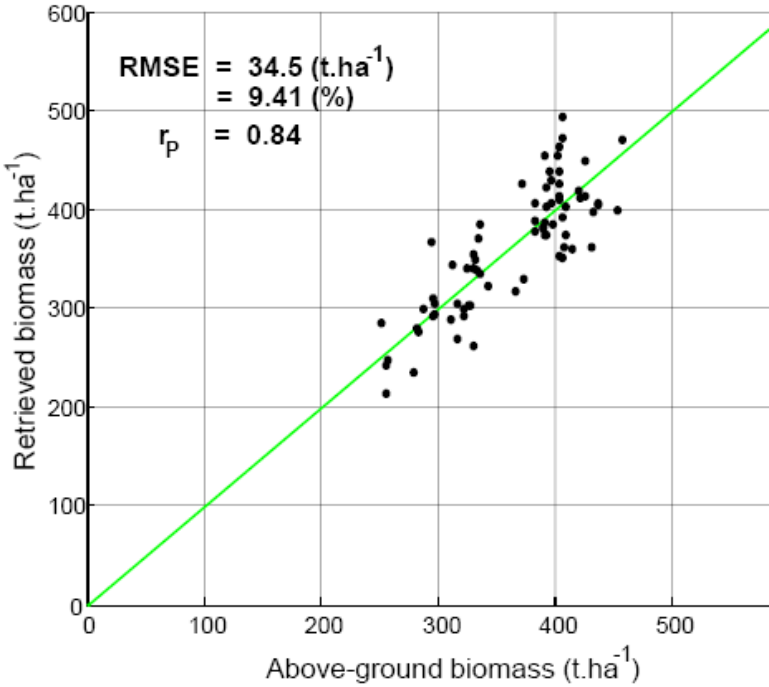
TomoSAR
(SAR Tomography)

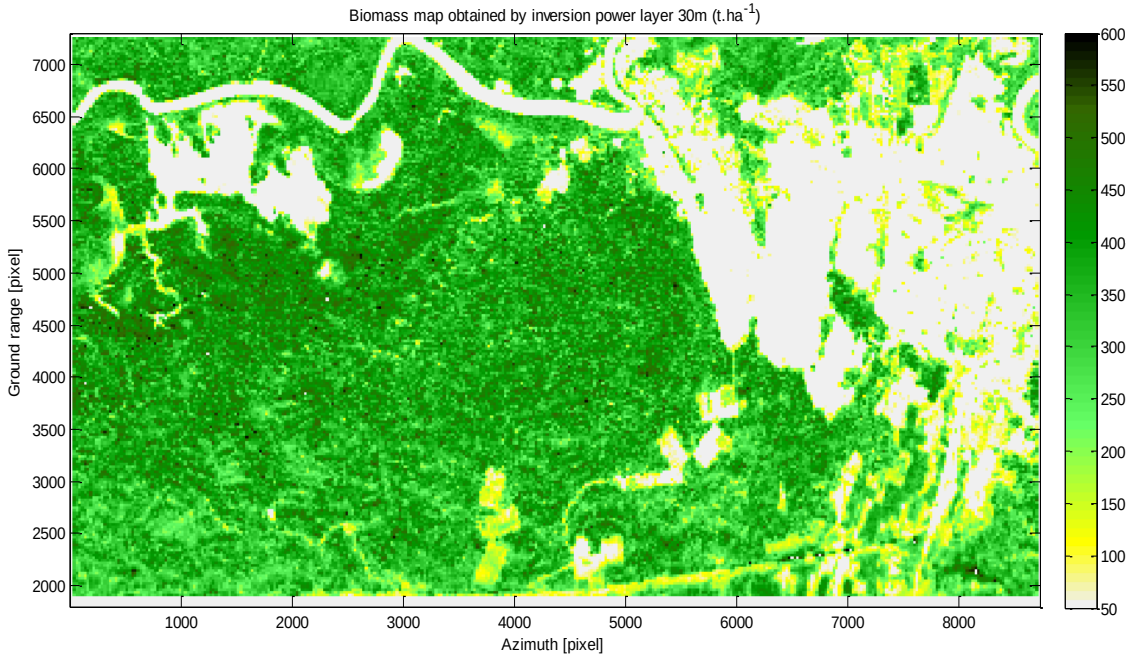




SAR Tomography provides high accuracy biomass maps

P-band SAR image





BIOMASS map at 50 m, by tomography

The recent AfriSAR campaign in Gabon, Africa

1. Testing, comparing algorithms on 4 tropical forest sites
2. P- and L-band PolInSAR and TomoSAR
3. Flights in July 2015 and February 2016 to test seasonal variations
1. NASA collaboration on 2016 flights with the LVIS and UAVSAR systems
2. Other data:
   - Airborne small footprint lidar
   - Plot data
   - Soil moisture
   - TanDEM-X

Sethi-ONERA P-band
(F: 430 Mhz, B: 50 Mhz)

FSAR-DLR P-band
(F: 435 Mhz, B: 50 Mhz)

esa
European Space Agency
Agence spatiale européenne

AGEOS

Parcs Gabon

ONERA
THE FRENCH AEROSPACE LAB

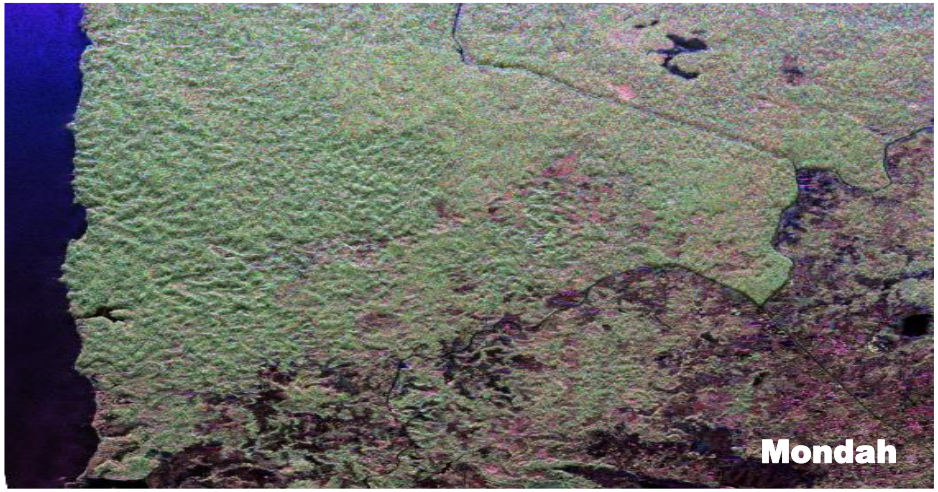
DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

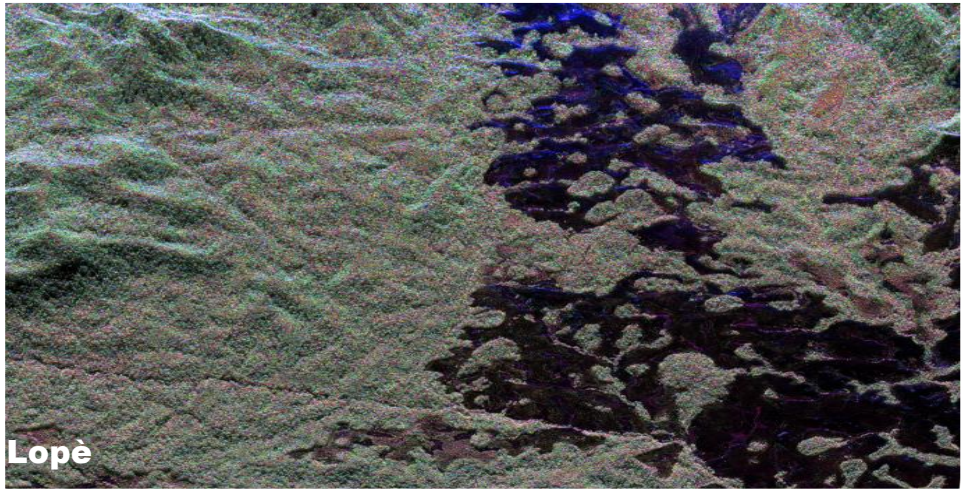
NASA

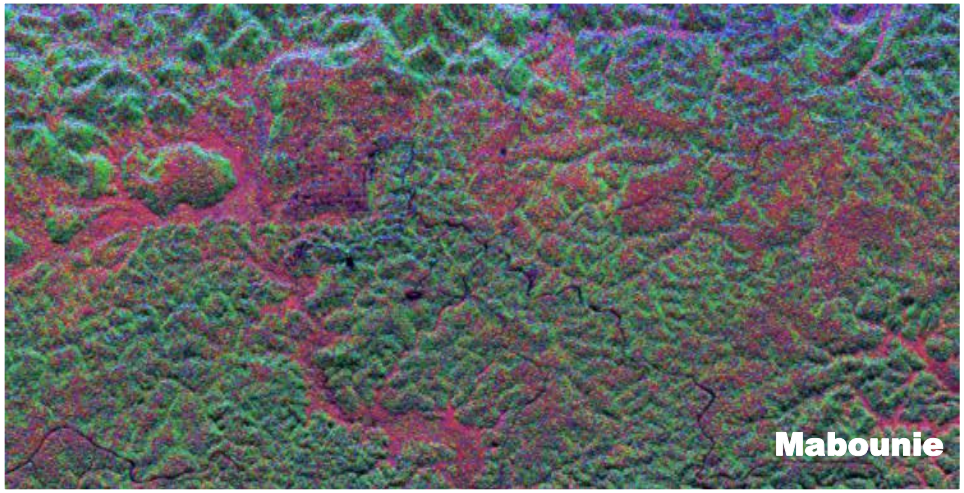
UCL

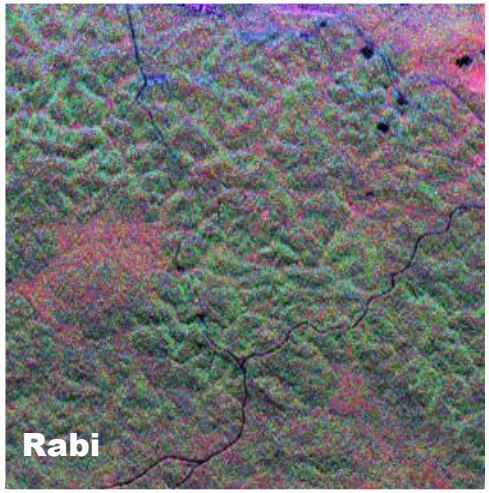
CESBIO

AfriSAR campaign data in Gabon (2016)





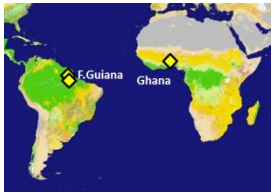




FSAR-DLR

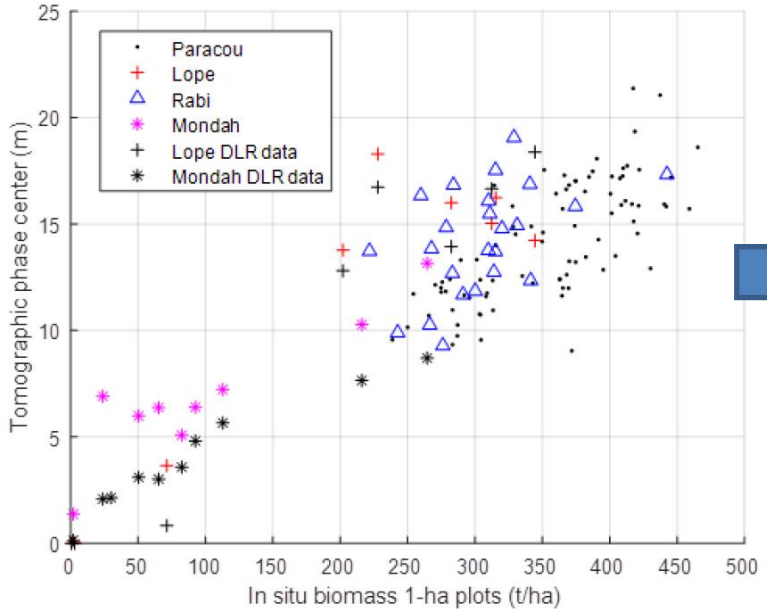
HH+VV HV HH-VV

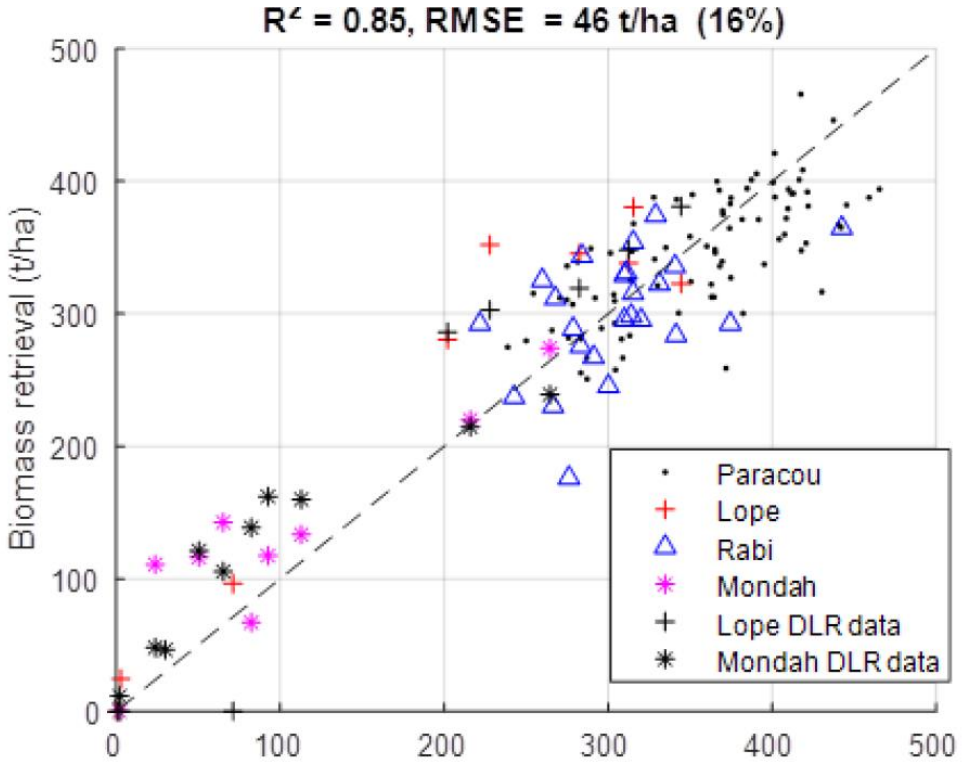
Work in progress: TomoSAR AGB retrieval at various tropical forest sites



Retrieval using HH, VV, HV at 30 m and HV Phase Center

+New AGB indicator: TomoSAR Phase Center





D. Ho Tong Minh, Y.-N. Ngo, I. Moussawi, L. Villard, L. Ferro-Famill,
M. Mariotti d'Alessandro, S. Tebaldini, C. Albinet, K. Scipal , T. Le Toan

Tower based experiments to test long term variation of the SAR measurements

1. Static tower-based radar observing a forest
2. Automatic and systematic acquisitions of fully polarimetric data (HH, HV, VH and VV)
3. Tomographic capability (to have a vertical discrimination of backscattering mechanisms)
4. Associated with in situ measurements

Tropiscat

- **Experiment in French Guiana**
- **Measurements every 15 mn**
- **Started in 2011 , end 2013 (with interruptions)**

Afriscat

- **Experimentna in Ghana**
- **2 x 3 hours per day: 4:30-7:30 am/pm**
- **Started on 20/07/2015, end 4/05/2017**

esa
European Space Agency
Agence spatiale européenne

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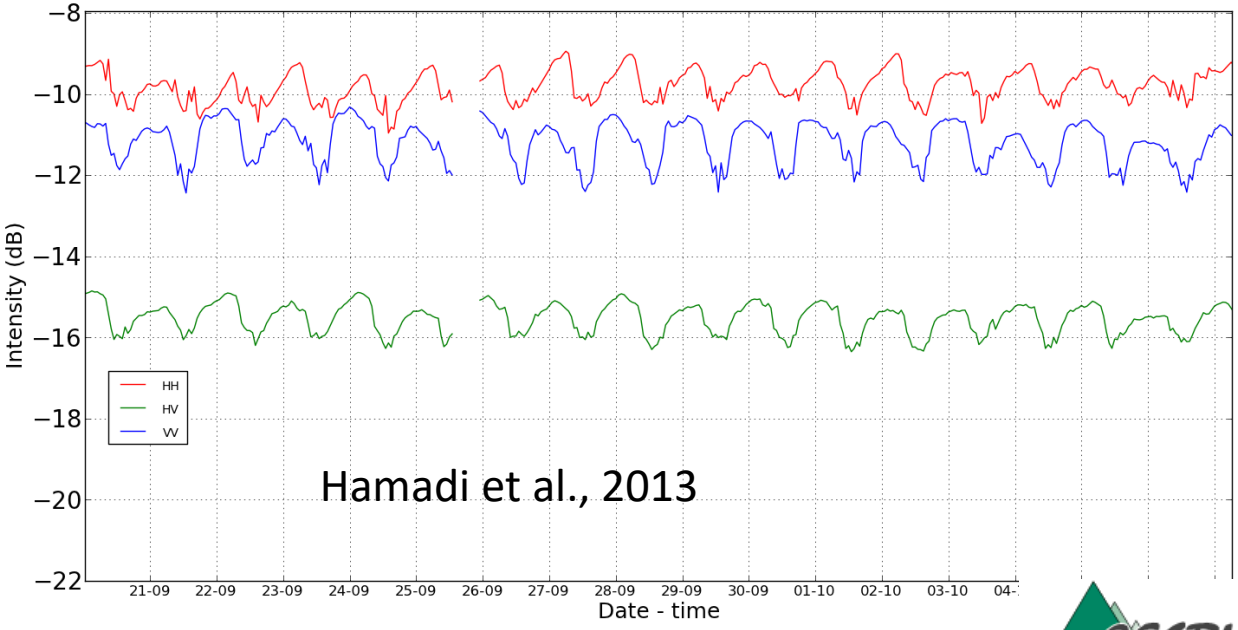
ONERA
THE FRENCH AEROSPACE LAB

POLITECNICO MILANO

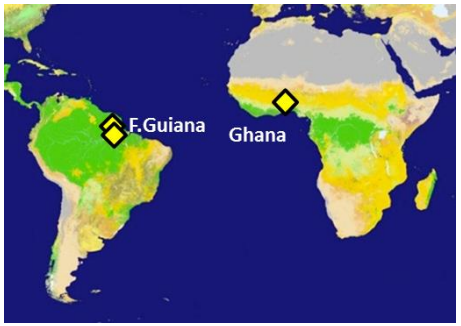
Diurnal cycle of Backscatter Intensity over Paracou forest

TropiScat experiment in French Guiana

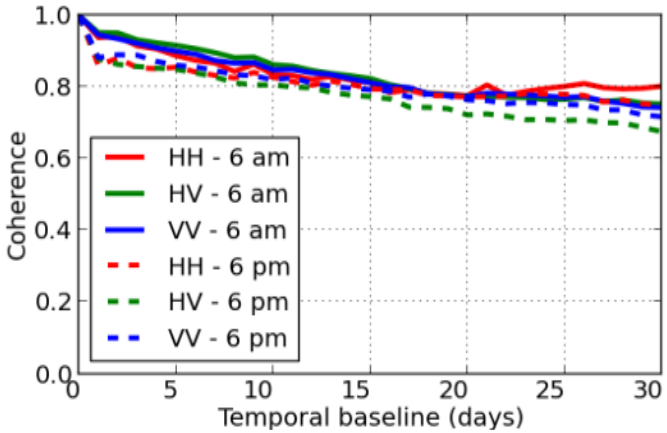
Tour Guyaflux
Equipe Guyafor

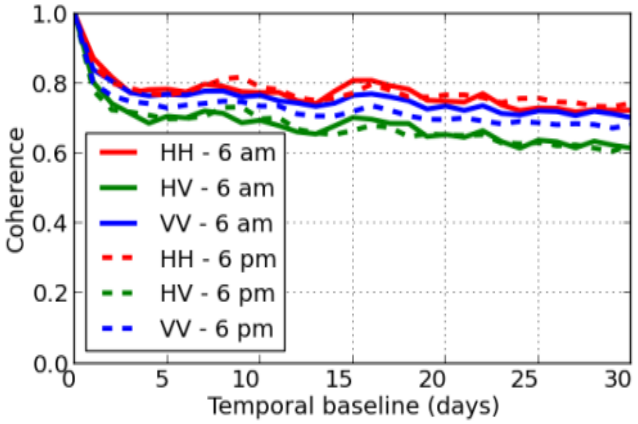


Measure of long term coherence for Biomass repeat pass interferometry

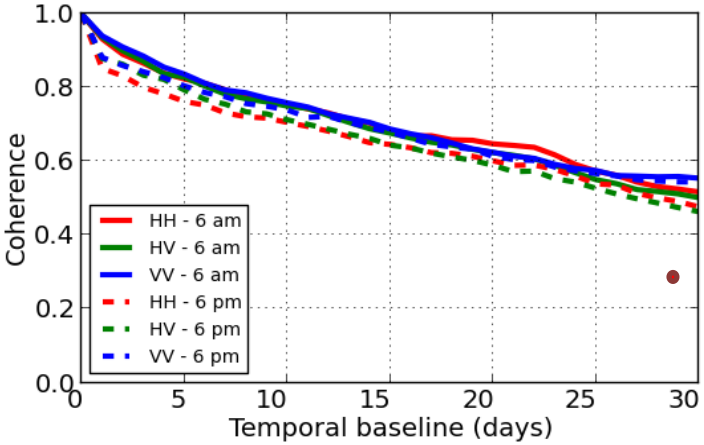


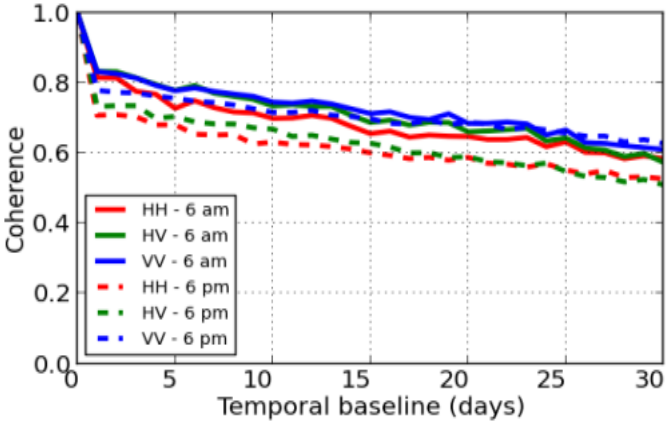
TropiScat (French Guiana)



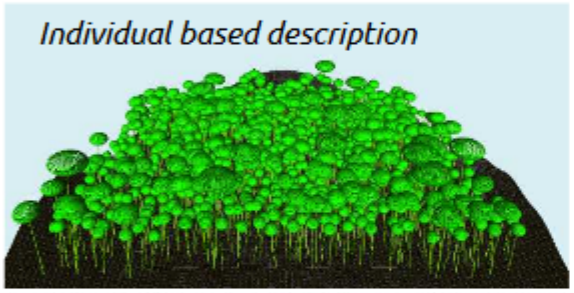


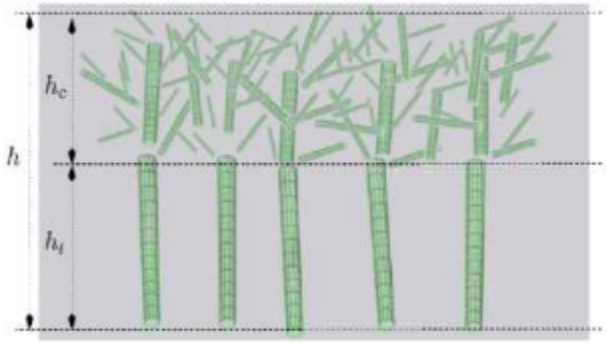
AfriScat (Ghana)



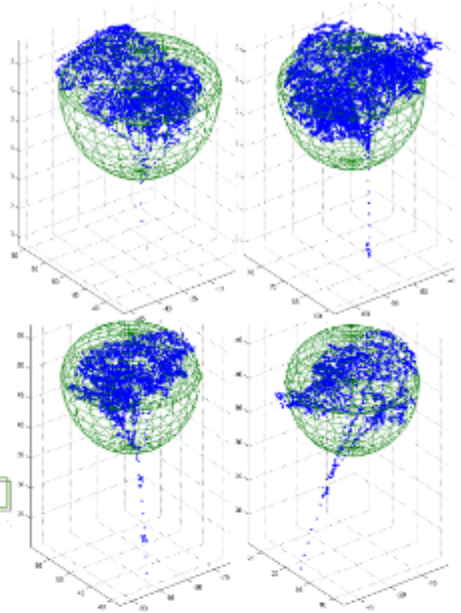


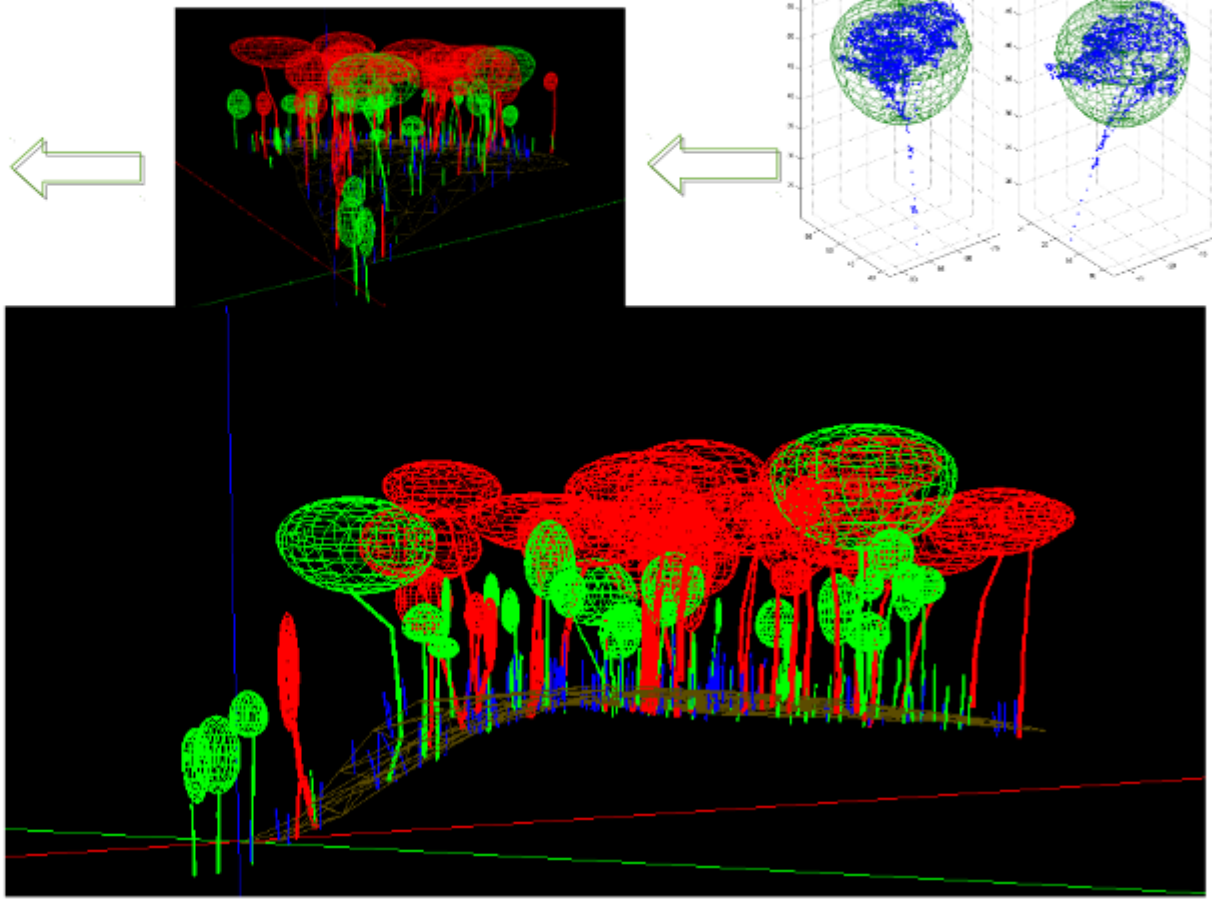
Modelling works using forest description from TLS





Layer based description





CESBIO

Secondary products

Biomass will allow DEM production under dense tropical canopies

TropiSAR data

Huang et al., 2013

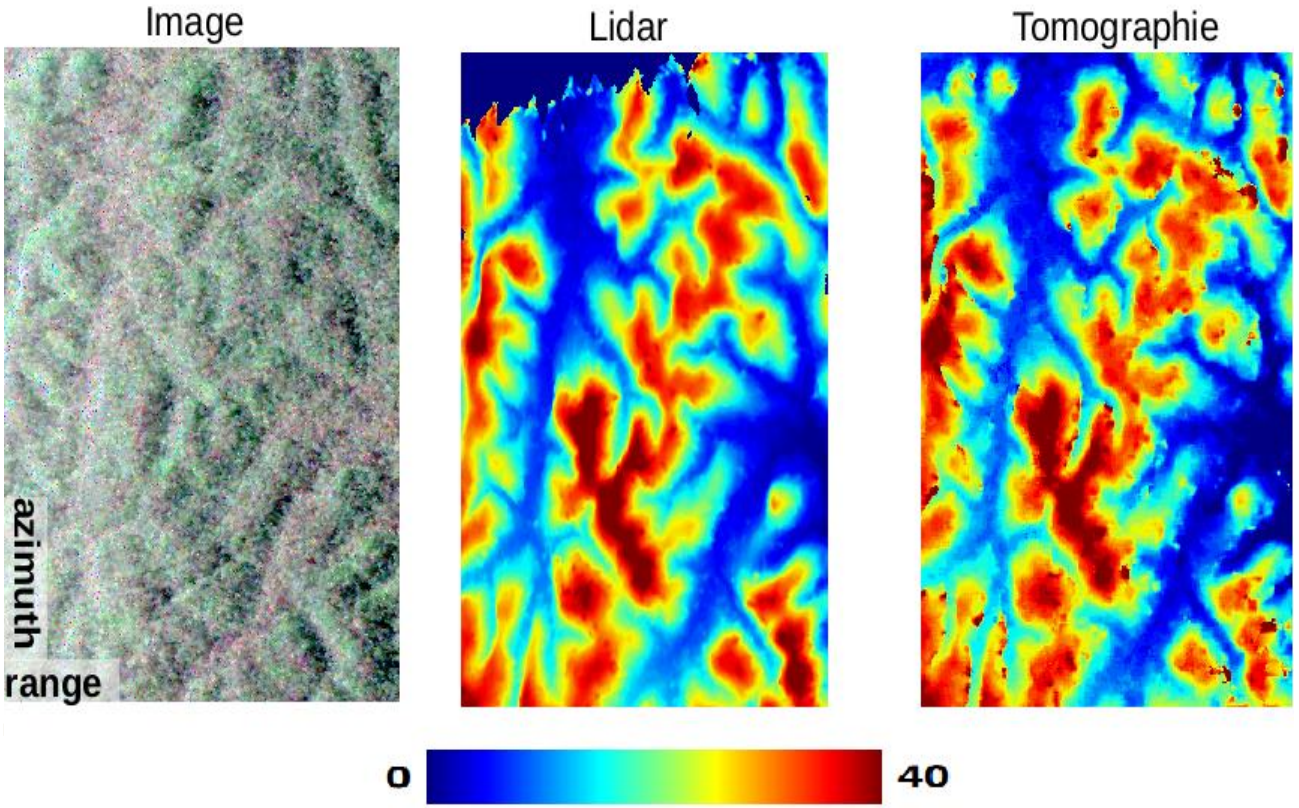
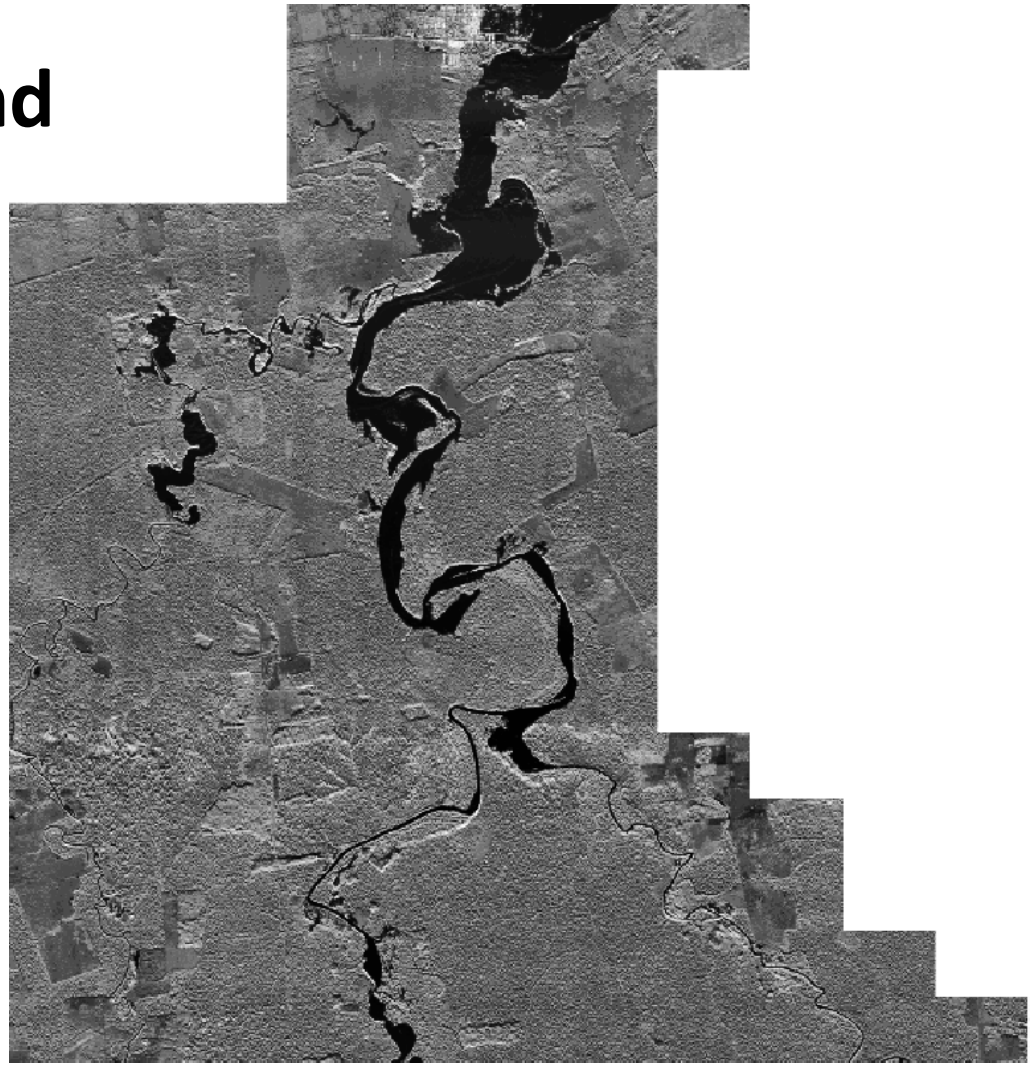


Image by cou

Secondary products

Biomass will allow mapping of inundated forest

X-band

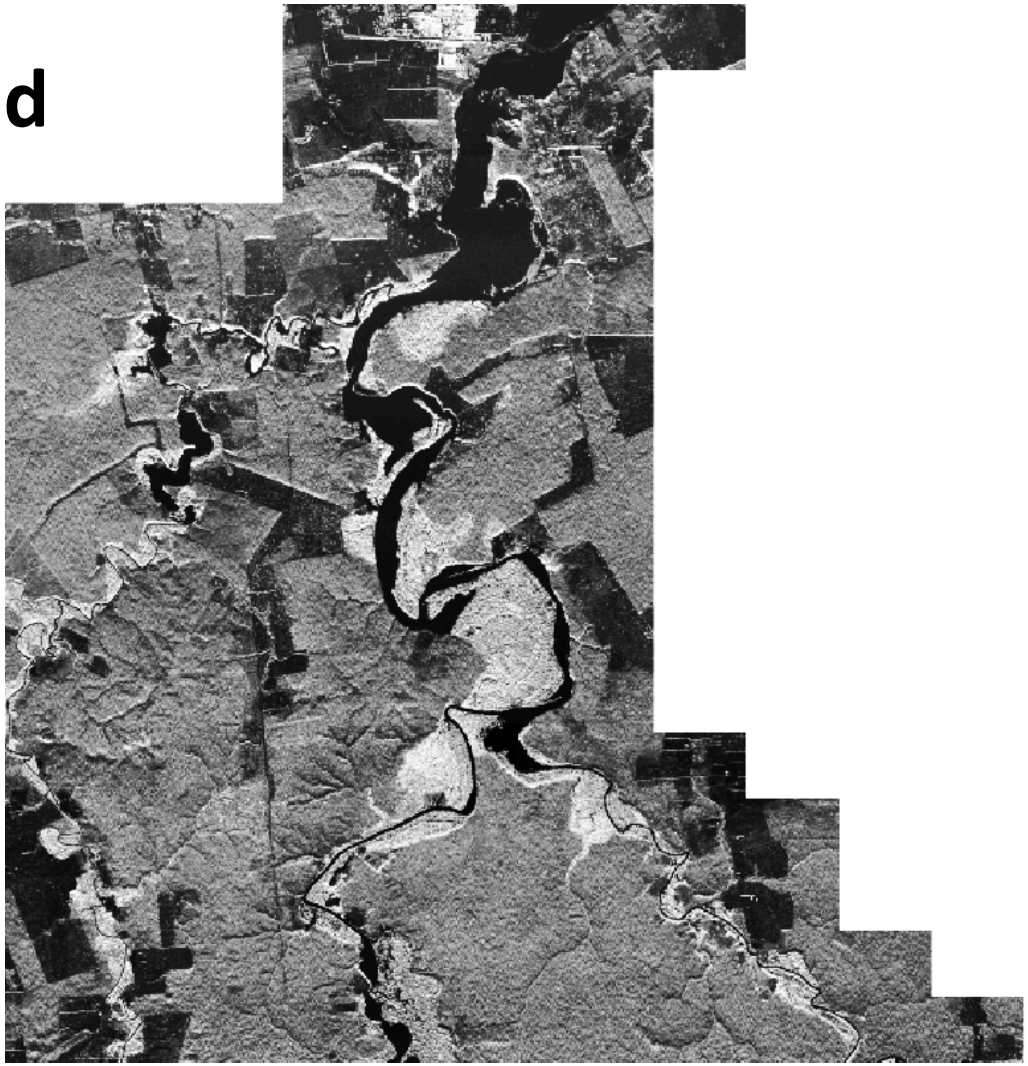


Secondary products

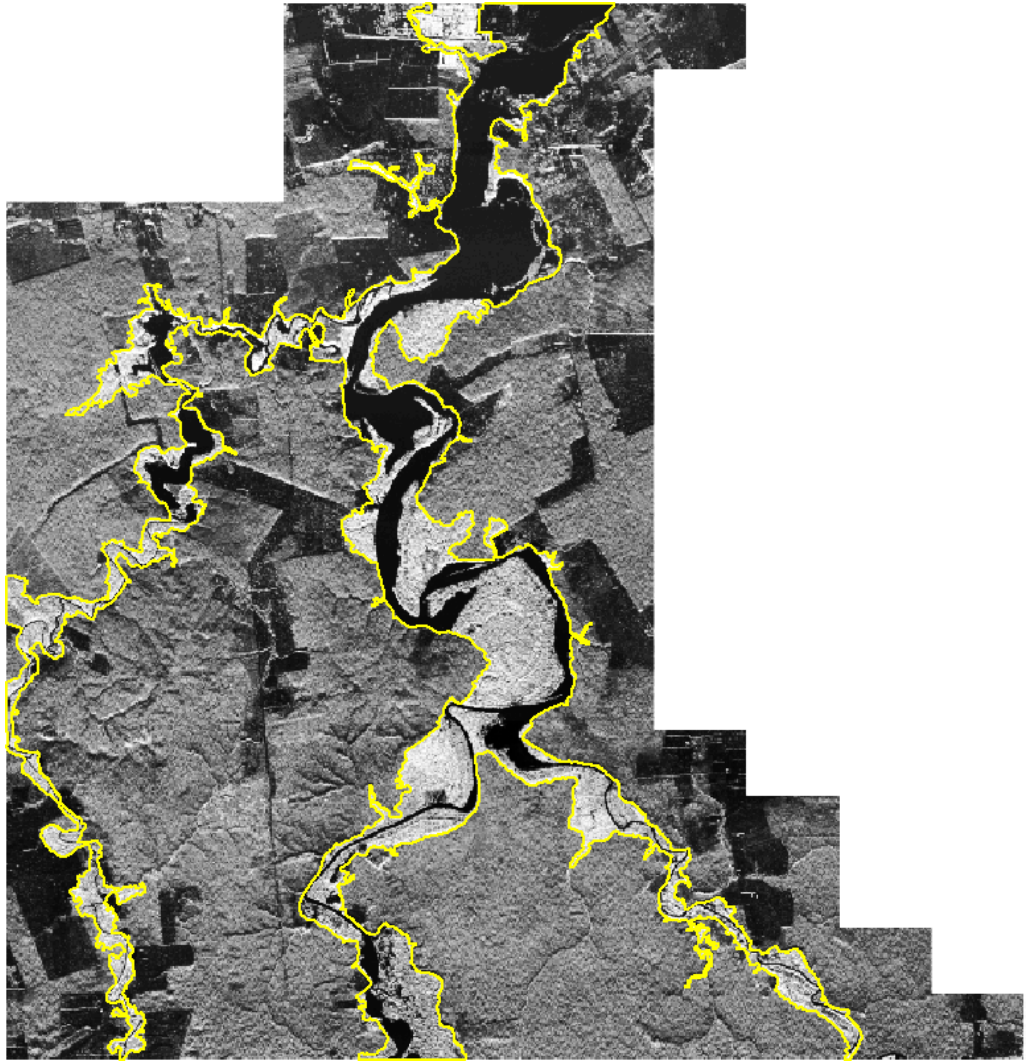
BANDA P

Biomass will allow mapping of inundated forest

P-band



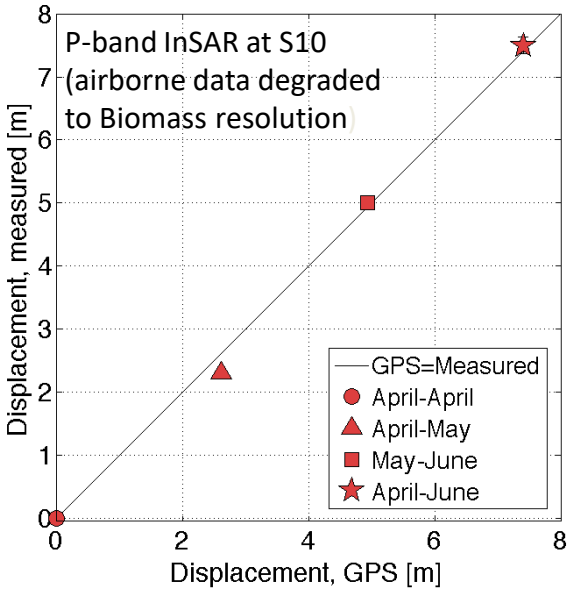
MANCHA DE INUNDAÇÃO ABAIXO DA FLORESTA

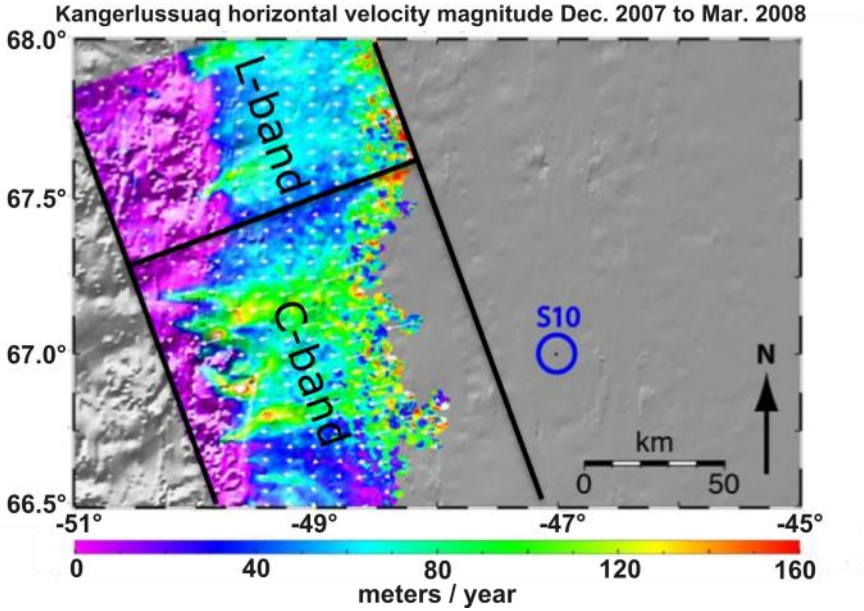


Secondary products

P-band extends the range of measurable glacier and ice sheet velocities

1. P-band is likely to provide better velocity measurements than higher frequencies in areas where the ice does not have crevasses and other features, e.g. above the equilibrium line.
2. It is still unknown if ionospheric scintillations can be corrected with sufficient accuracy.

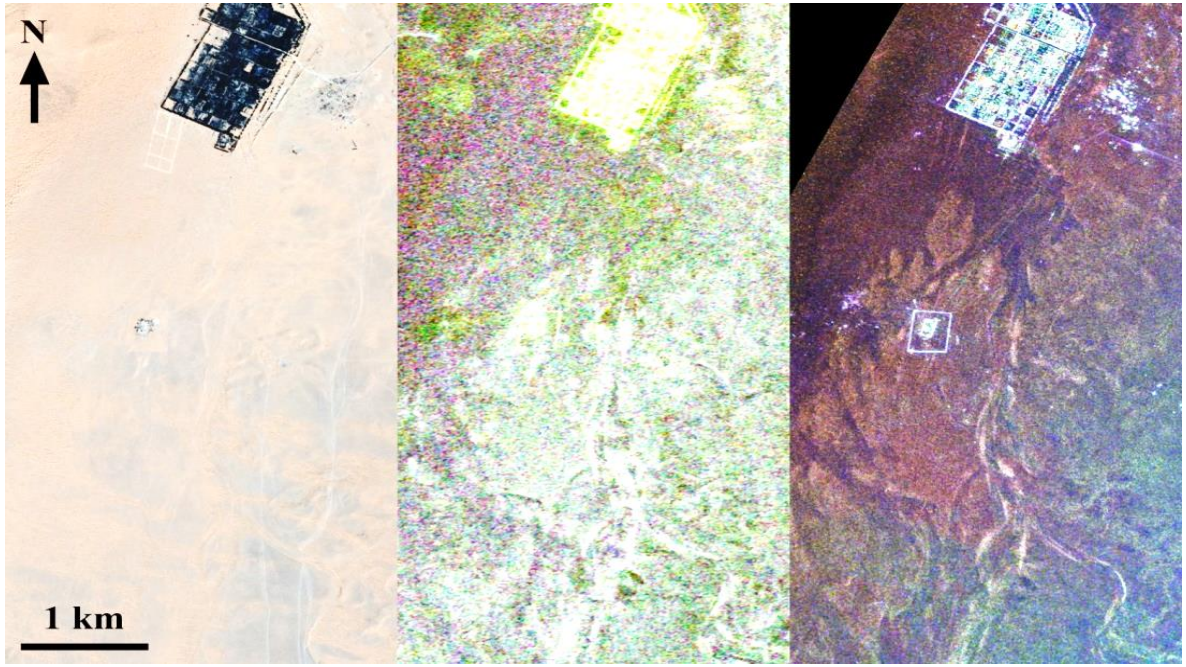


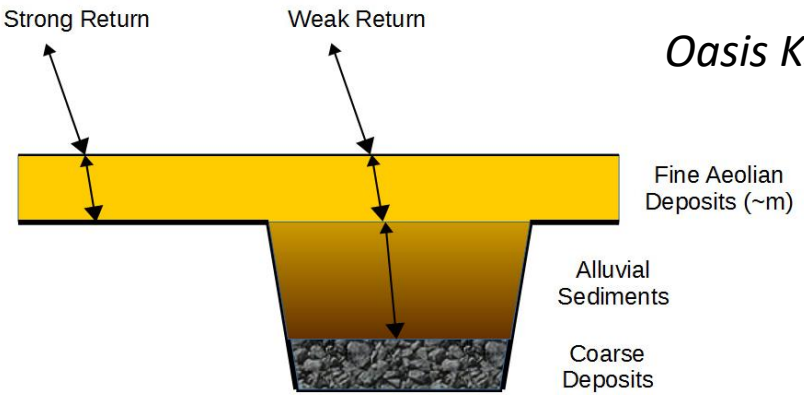


Secondary products

P-band enhances subsurface imaging in arid zones

SPOT ALOS-2 SETHI (P-band)





Oasis Ksar Ghilane (Tunisia)

Philippe Paillou

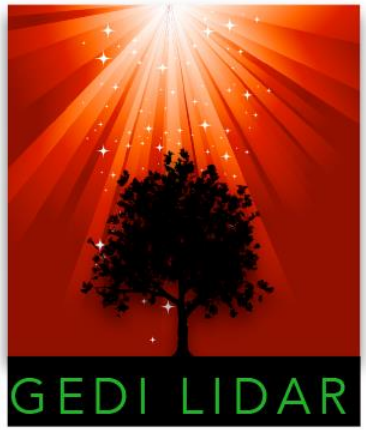
Summary – Biomass a true Earth Explorer

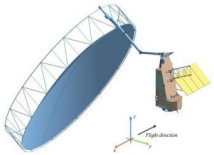
The Biomass implementation started in Nov. 2013. We are currently in Phase-C . We will launch in mid 2021.

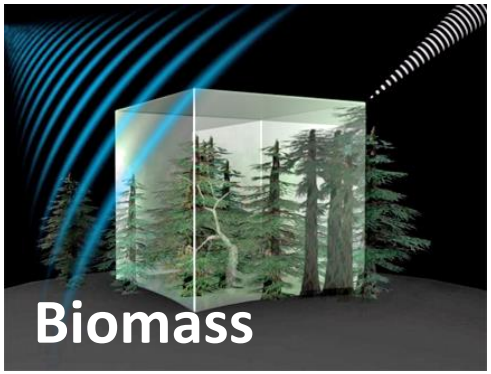
1. Biomass will **reduce uncertainties on the spatial distribution, the quantity and dynamics of forest carbon stocks, sources and sinks**

2. Biomass is the first P-band SAR and first radar tomographic space mission; it is a true Earth Explorer with unknowns and exciting sciences .e.g measurements of ice, sub-surface geomorphology in deserts, topography, the ionosphere, ocean.

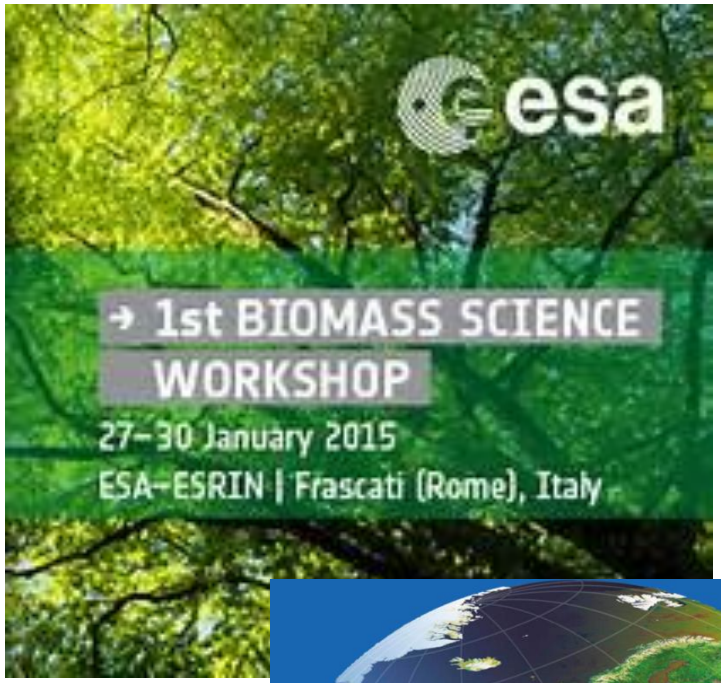
Within the next 5 years, spaceborne missions to monitor the Earth's forests



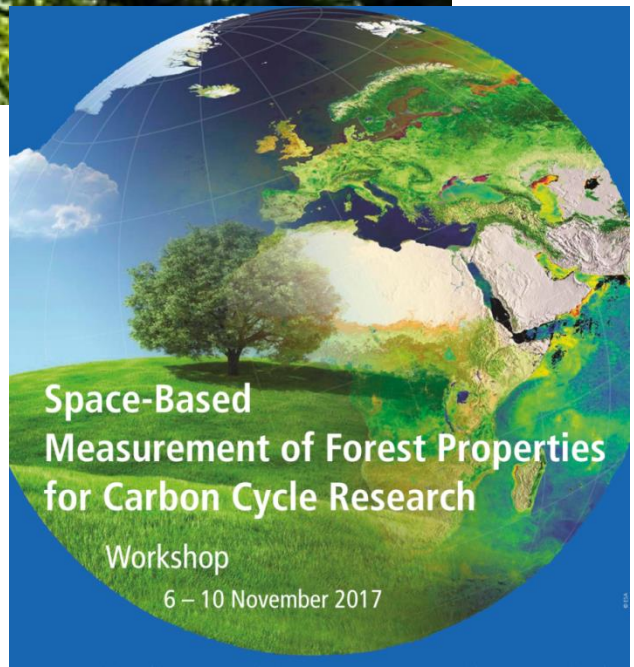




The selection of these missions brings together the ecological, modelling, policy and EO communities



NASA-ESA Smithsonian Biomass workshop
May 31-June 3, 2016



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