

Biomass - EAS's polarimetric P-band SAR mission

→ 4th ADVANCED COURSE ON RADAR POLARIMETRY

30 January – 2 February 2017 | ESA-ESRIN | Frascati (Rome), Italy



ESA UNCLASSIFIED - For Official Use

European Space Agency

٠

ESA's satellite programs





ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 2

= 88 🛏 == + 88 == 🔚 = 81 88 == 12 👬 🖬 🖬 = 12 💥 🙌

European Space Agency





- 1. ESA's 7th Earth Explorer Mission
- 2. An interferometric, polarimetric P-band SAR
- 3. To be deployed in Space in 2021

ESA UNCLASSIFIED - For Official Use



What is Biomass about



Forest biomass

Forest height

Disturbances



ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 4

_ II ⊾ :: ■ + II ■ ½ _ II II _ Z = :: II ₩ . [1]





8.3±0.4 GtC/yr



1.0±0.5 GtC/yr net flux



4.3±0.1 GtC/yr 2.6±0.9 GtC/yr Calculated as t residual of othe flux componen

2.5±0.5 GtC/yr



Global Carbon Project, 2012 Klaus Scipal | ESTEC | 30/01/2017 | Slide 5

ESA UNCLASSIFIED - For Official Use



esa

Beyond Carbon: Changes in forest affect the benefits we gain from forests

Changes in forest have major effects on the socio-economics, material, energy, protective, biodiversity & cultural benefits offered by forests







Klaus Scipal | ESTEC | 30/01/2017 | Slide 6

ESA UNCLASSIFIED - For Official Use

_ II ⊾ :: ■ + II ■ ½ _ II II _ Z = :: II ₩ . [] II _ II . []

Required measurement properties

esa

1. The **crucial information need** is in the tropics:

deforestation (~95% of the Land Use Change flux)

regrowth (~50% of the global biomass sink) Biomass measurements are needed where the changes occur and at the

effective scale of change: 4 hectares

- 3. A biomass accuracy of 20% at 4 hectares, **comparable to ground-based observations**
- 4. Forest height to provide a further constraint on biomass estimates
- 5. Detection of deforestation at 0.25 ha
- 6. Repeated measurements over multiple years to identify deforestation and growth





2.





How to measure biomass?







Tree allometry links biomass to 1. Diameter (D) 2. Height (H)

 $Biomass = \rho D^2 H$

ESA UNCLASSIFIED - For Official Use

Which system to meet our requirements





ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 9

SAR can deliver 3 independent types of information related to biomass





ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 10

P-band SAR measures biomass and quantifies landscape dynamics



P-band SAR image (HH, VV, HV)



ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 11

_ II ⊾ :: ■ + II ■ ½ _ II II _ _ II = ... X II ... X IV

Global consistency in the biomass – P-band backscatter relationship



The simplest inversion: Similar power-law relationships between backscatter and biomass are found for all forests where we have data

$$\log(AGB) = a + b \cdot \gamma^0_{HV}$$



ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 12

Moisture and topography affects "disturbe" the backscatter-biomass relationship



Moisture term

ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 13

Topography term

•



Biomass map, Remningstorp, Sweden





SAR can deliver 3 independent types of information related to biomass



Klaus Scipal | ESTEC | 30/01/2017 | Slide 15

+



European Space Agency

PolInSAR provides a second estimate of biomass using height ...



UNCLASSIFIED - For Official Use



European Space Agency



PolInSAR has mapped height over tropical and boreal sites





ESA UNCLASSIFIED - For Official Use



40

*

European Space Agency

UNCLASSIFIED - For Official Use





Seasonal variation: coherence is higher in the dry season, giving better height estimates

TropiScatt experiment:

- Tower-based P-band tomographic measurements.
- Measurements every 15 minutes.
- Started December 2011, still running.







SAR can deliver 3 independent types of information related to biomass





European Space Agency

SAR tomography, a new concept to explore 3D forest structure

esa

Generates images of different forest layers from multi-orbit SAR images



ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 20

SAR tomography provides basic information to improve Biomass retrieval





TomoSAR:

- 1. Provides a 3D reconstruction of forest backscatter.
- 2. Allows an interpretation of scattering processes
- 3. Gives guidance to the PoISAR and PoIInSAR retrieval algorithms.

ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 21

From observation concept to mission requirements



What do we need?

- 1. A P-band SAR
- 2. Multiple polarisations
- 3. Orbit that allows interferometry (i.e. small baseline and short repeat cycle)
- 4. A tomographic phase to gain understanding and reference information

ESA UNCLASSIFIED - For Official Use

European Space Agency

•

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

ESA UNCLASSIFIED - For Official Use

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



ESA UNCLASSIFIED - For Official Use

How to cover the earth when your swath is 60 km instead of the required 600 km





= 88 🛌 == += 88 💻 🚝 == 88 88 == 32 88 💻 🚳 88 == 88 88 88



Coverage



- 1. Acquisition mask restricted by US Space Objects Tracking Radar (SOTR)
- 2. Systematic Acquisitions for forested land (red area) in both ascending and descending passes.
- 3. Best effort acquisitions for non forested areas (yellow + ocean/sea ice ROIs)



(Red = Primary objective coverage mask, Yellow = Secondary objective coverage mask)

ESA UNCLASSIFIED - For Official Use

What information will we get from Biomass



Forest biomass Forest biomass State Aboye-ground biomass (tons/hectare)	Forest height Upper canopy height (meter)	<image/> <text></text>
 200 m resolution 1 map every 6 months global coverage of forested areas accuracy of 20%, or 10 t ha⁻¹ for biomass < 50 t ha⁻¹ 	 200 m resolution 1 map every 6 months global coverage of forested areas accuracy of 20-30% 	 50 m resolution 1 map every 6 months global coverage of forested areas 90% classification accuracy

ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 27

* ÷.

Biomass will allow DEM production under dense tropical canopies





ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 28

= II 🛏 ## #I 💻 #= !! = II II == == ## 🛶 🚺 II == ## ## !!

P-band enhances subsurface imaging in arid zones



P-band SAR



European Space Agency

What are the challenges we need to solve in the next years



- 1. How can we combine TomoSAR, PolInSAR and PolSAR information
- 2. How can we correct for environmental nuisance effects (moisture, freeze/thaw, topography ...) given the Biomass measurement space
- 3. Can we find common parameters in Lidar and TomoSAR/PolInSAR to learn about vertical and horizontal forest structure
- 4. Can we combine C-, L- and P-band for forest structure retrievals.
- 5. How useful is P-band for ice applications
- 6. For deserts what is the value of PolInSAR/TomoSAR
- 7. What do we know about the Ionosphere at P-band
- 8. Etc., etc., etc.

ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 30

•

To adress these questions: Biomass Test Bed



o Harmonized data (GeoTiff, ESRI)

- SLC SAR images
- Local incidence angle
- DEM
- ROI shapes

o Common tools

- Projector
- Matchup tool

o Orchestrator

• Data processing management



<u>Cloud computing platform (scalable)</u>

- Processing resources (2 CPUs)
- Storage (500 GB)
- Memory (16 GB)
- Pre-installed open source software (QGIS, PolSARpro, PolSARproSim, OTB)

o Campaign data available today

- BIOSAR-1 (7 GB)
- BIOSAR-2 (14 GB)
- TROPISAR (41 GB)
- BIOSAR-3 (15 GB)
- AfriSAR_ONERA (20 GB)

ESA UNCLASSIFIED - For Official Use

Summary – Biomass a true Earth Explorer



- 1. Biomass implementation started in Nov. 2013. We are currently in Phase-B2 (until Q1 2017, PDR Q2/17, CDR Q2/19). We will launch in mid 2021.
- 2. Biomass is the first P-band SAR and the first radar tomographic space mission; it is a true Earth Explorer with a lot of unknowns and exciting science.
- 3. The new unique vision of Earth from Biomass will extend beyond forests and into measurements of ice, sub-surface geomorphology, topography and the ionosphere.

ESA UNCLASSIFIED - For Official Use

Klaus Scipal | ESTEC | 30/01/2017 | Slide 32

•

European Space Agency