The trials and tribulations of an ESA mission PI

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- Getting into the game
- Winning the game
- The consequences – reality bites

The University Of Sheffield.

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Getting into the game: ESA Call for Ideas

ESA ask for the community's views on what missions will provide the highest scientific return and the best response to key scientific and social challenges (cf. the ESA EO Strategy documents) within the EO Envelope Programme.

- Must address an important scientific issue.
- Candidate missions will be selected on the basis of innovation and scientific excellence (but cost < €400M for EE-10)
- Technically feasible
- The mission context must be clear

Note: EE-9 AO had to be reissued because none of the initial missions met the criteria (cost?)

Getting into the game: who decides?

The Advisory Committee for Earth Observation (previously the Earth Science Advisory Committee), supported by advisory panels, recommends missions to go forward.

Stephen Hobbs EE-10 PI; G-Class.

Nearly winning is important: if ACEO recommends further study on a mission concept this allows ESA to spend money on such studies.

“Although not selected in the ESA EE8 call, TRUTHS received a strong recommendation of support and encouragement that an early implementation should be explored as part of a wider international collaborative effort.”

Nigel Fox PI: TRUTHS (will be proposed as an operational Earth Watch mission at the November Ministerial meeting)

BIOMASS addresses important science and societal issues

Fate of anthropogenic CO_2 emissions (2008–2017)

Sources = **Sinks**

34.4 ±1.8 $GtCO_2$/yr 87%

5.3 ± 2.6 $GtCO_2$/yr 13%

17.3 ±0.4 $GtCO_2$/yr (44%)

11.6 ± 2.9 $GtCO_2$/yr (29%)

8.9 ± 1.8 $GtCO_2$/yr (22%)

BIOMASS mission objectives

Primary objective: determine the worldwide distribution of forest above-ground biomass (AGB) in order to reduce the major uncertainties in carbon stocks and fluxes associated with the terrestrial biosphere, including carbon fluxes associated with Land Use Change, forest degradation and forest regrowth.

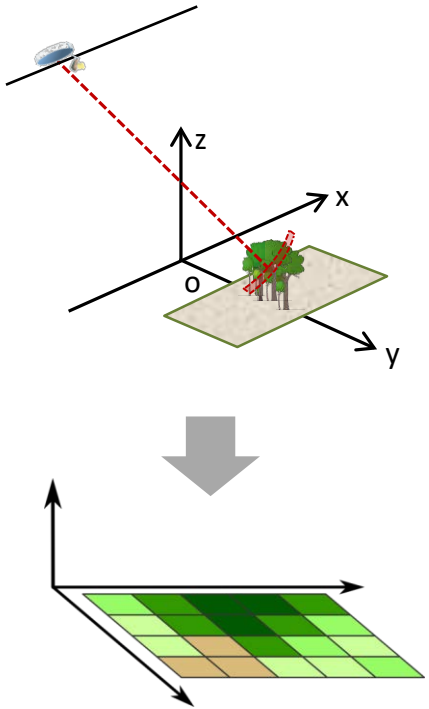
Secondary Objectives:

- sub-surface mapping in arid zones
- icesheet motion
- bare earth DTM
- ionospheric structure

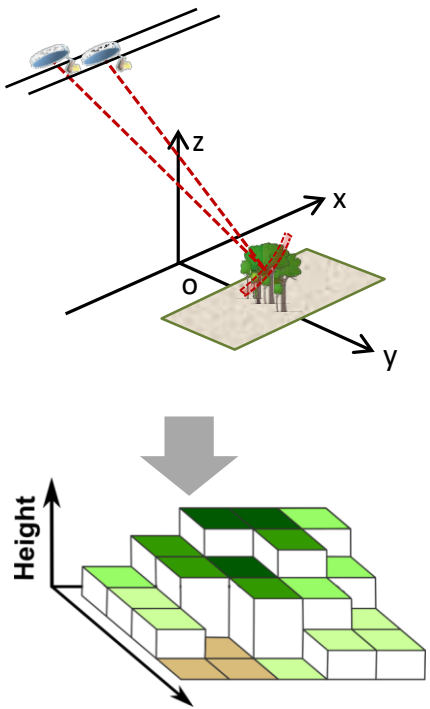
BIOMASS mission: 1st measurement concept

P-band SAR with 2 modes:

Polarimetric



Polarimetric Interferometry



Proposal submitted to ESA in July 2005 following 2004 approval of the P-band frequency as a secondary allocation for EO.

Highly innovative:

- 1st P-band radar in space
- 1st systematic use of Pol-InSAR to measure forest height from space

Winning the game: Phases 0 and A, the Report for Selection & the User Consultation Meeting (UCM)

- Phase 0: assessment studies elaborating the mission concept, typically carried out by the Mission Advisory Group
- Phase A: technical feasibility studies by industry & ESA

  New development: the UNFCCC initiative on Reduction of Emissions from Deforestation and Forest Degradation
- Output: the Report for Selection
- The UCM: trial by ordeal

BIOMASS: Reports for Assessment & Selection + 2 UCMs

New development: the UNFCCC initiative on Reduction of Emissions from Deforestation and Forest Degradation

UCM 1 (January 2009): Report for Assessment; 6 missions culled to 3

New developments:

- SAR tomography
- Tropical and boreal campaigns
- Better inversion algorithms

UCM 2 (March 2013): Report for Selection; 3 highly developed missions, 1 winner.

May 2013: BIOMASS is selected

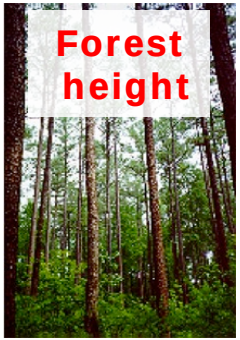
November 2014: review of risks by Programme Board for EO gives green light

April 2016: Airbus UK sign contract to build the instrument

Biomass product requirements

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}



Upper canopy height (meter)

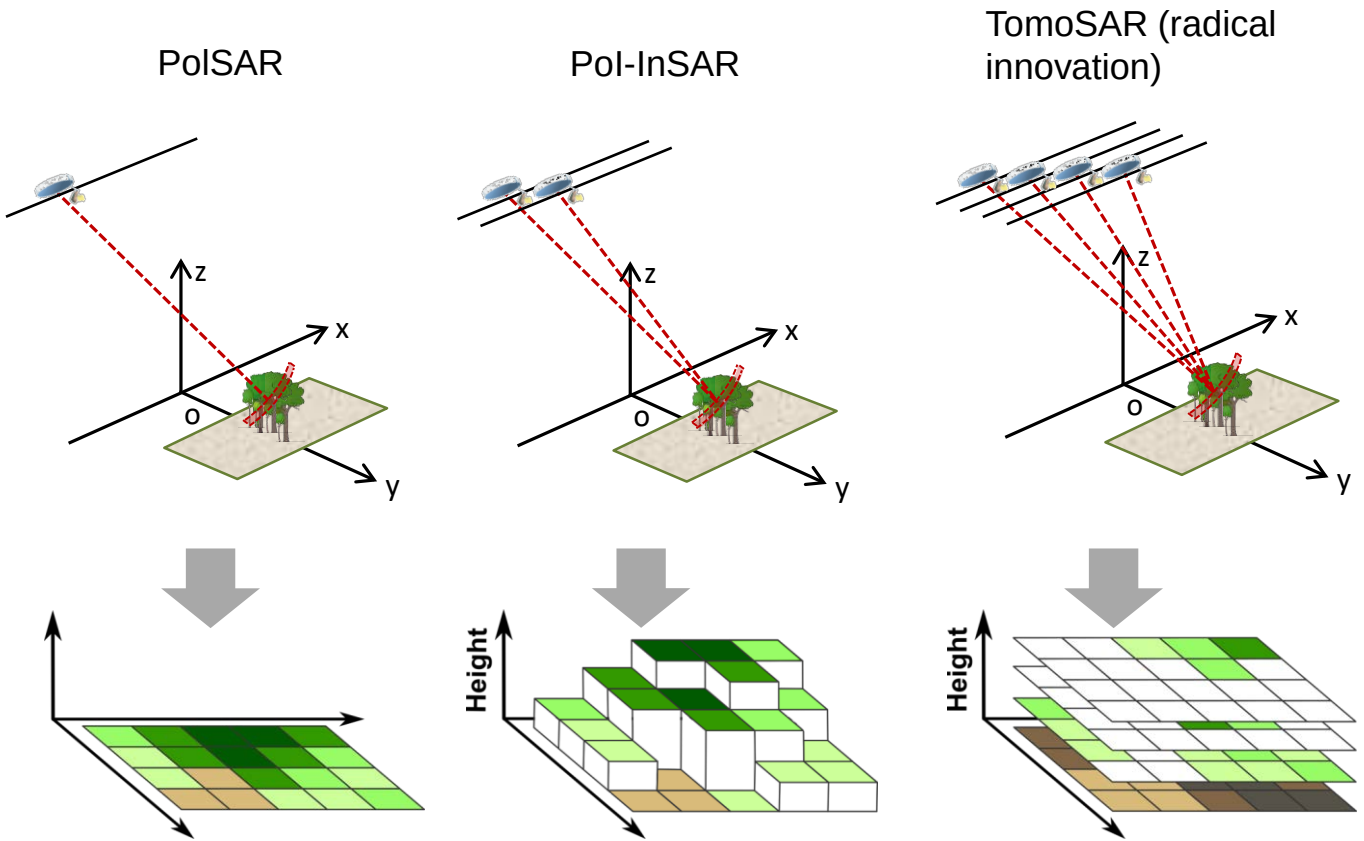
- 4 hectare resolution
- 1 map every 6 months for 4 years
- global coverage of forested areas
- accuracy of 20-30%

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

Urgently required for IPCC, UNFCCC, REDD, national forest planning

BIOMASS mission: 2nd measurement concept



What happens next: reality kicks in

New Mission Advisory Group is formed with one purpose - **to ensure that the mission delivers on its science objectives** (psychological readjustment).

- Refinement of the Science and Mission Requirements Documents
- Recommending science studies & campaigns
- Advising on issues of compliance by industry, i.e. suppose industry cannot meet the requirements in the MRD, what then?
- Advising on mission planning

Three protagonists: ESA, industry and the MAG.

Key people: Project manager, ESA mission scientist, Chairman of the MAG and, increasingly towards launch, ground segment at ESRIN.

Mission budget

Total budget = €470M

Industrial return = €220M; this must satisfy geo-return

Science budget = €10M

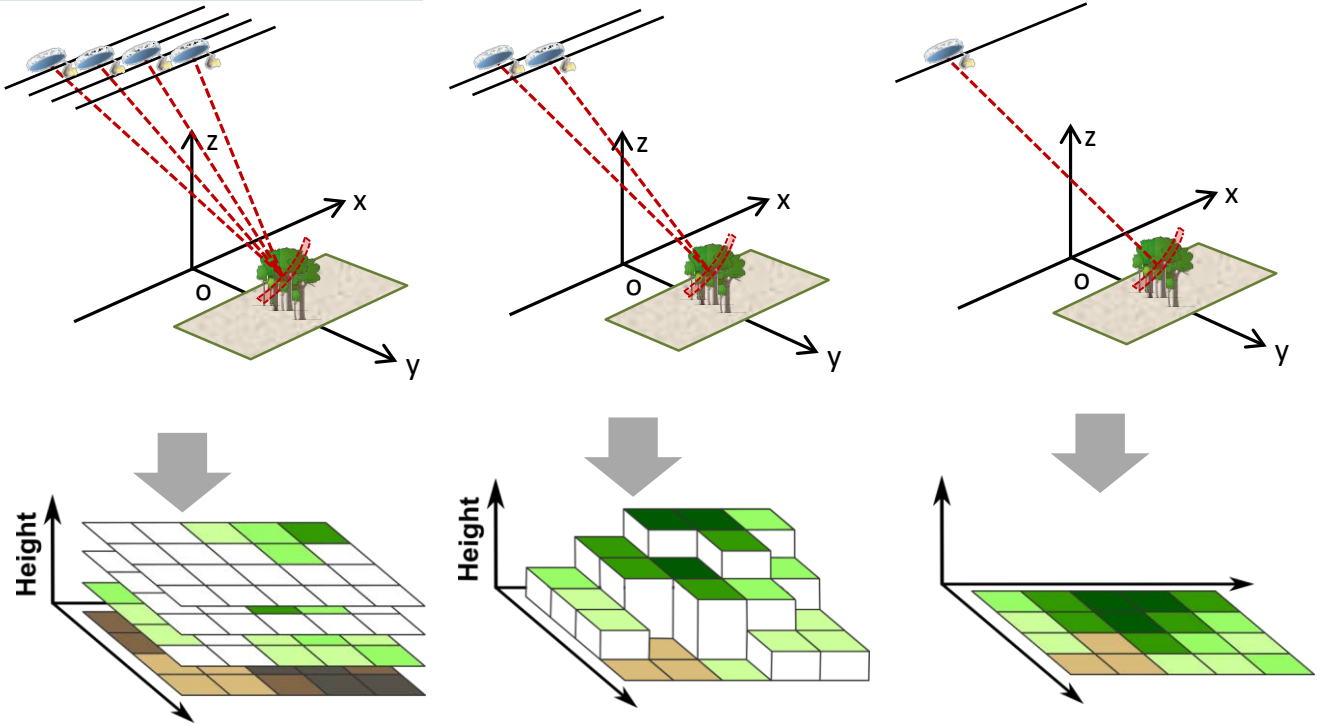
BIOMASS measurement modes: the mission

Tomographic Phase:
7 x 3-day repeat
14 months for global coverage

Interferometric Phase:
3 x 3-day repeat; 7 months for global coverage

PoI-InSAR

PolSAR



Major post-selection activities

Industry: Set up all the sub-contracts required to build the instrument; pass ESA's risk assessments, and build the instrument.

Science (competitive studies):

1. Define the external calibration and ionospheric correction strategy (to be implemented by industry)
2. Finalise the algorithms to be used to measure forest biomass, height and disturbance and provide them to ESRIN for implementation

Implications of the BIOMASS orbit: natural targets are essential for routine calibration

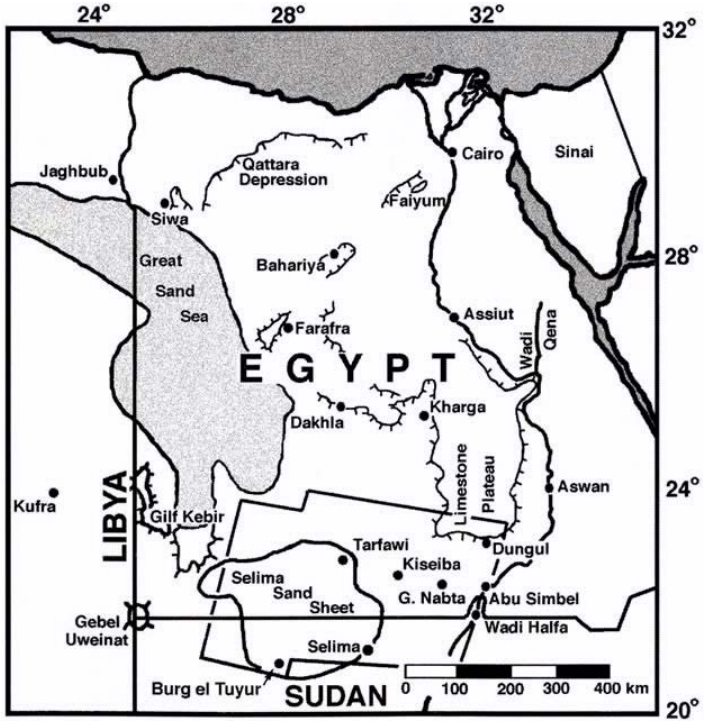
A calibration transponder would only be seen:

- 21 times over 3 months in the commissioning phase to characterise the antenna pattern and estimate system errors
- once in 14 months in the Tomographic phase
- once every 7 months in the Interferometric phase.

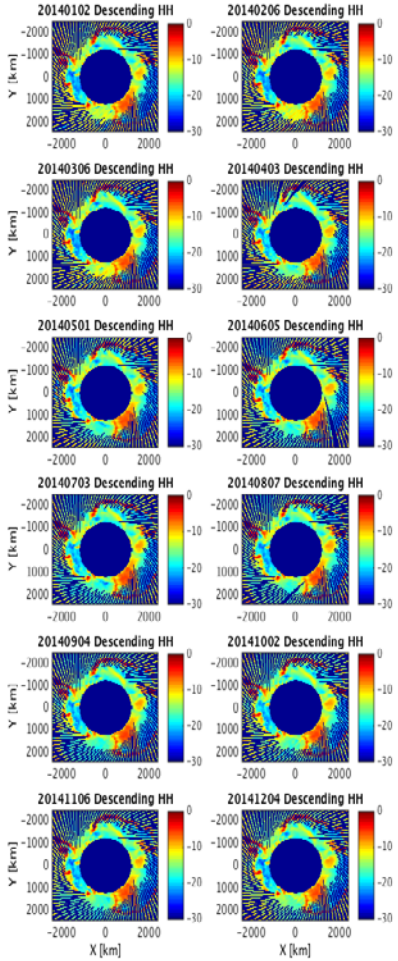
Hence **natural targets of opportunity have to be used** for routine calibration between visits to the transponder.

NB: Estimating system errors from the transponder measurements is difficult. We developed the algorithms to do this & also the necessary ionospheric correction methods.

Deserts as calibrators



Selima Sand Sheet in Eastern Sahara



Icesheets as calibrators

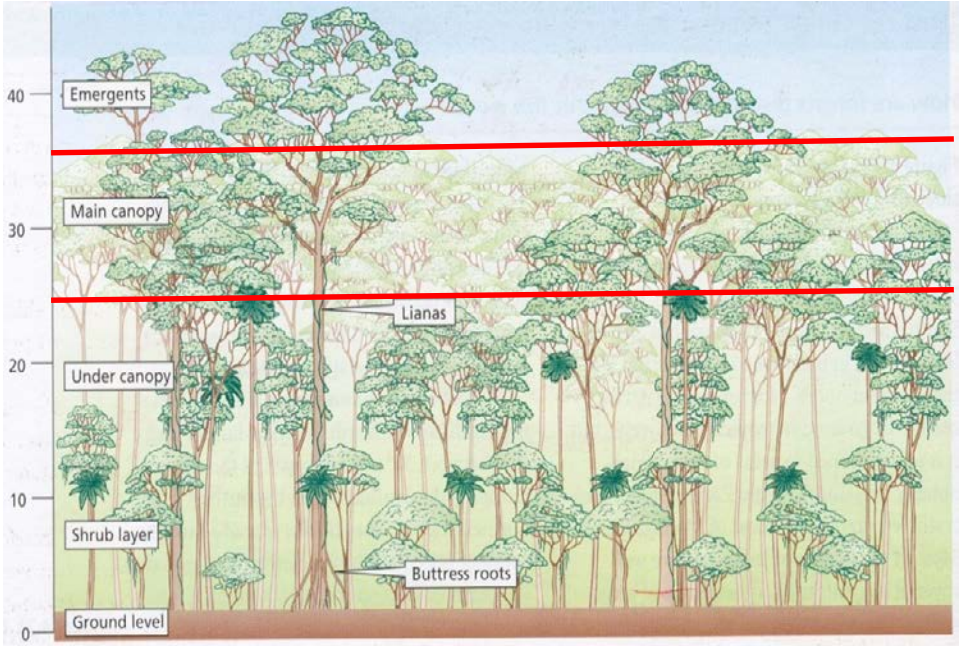
Space Object Tracking Radar restrictions mean that we cannot use the Arctic, and must use the Antarctic.

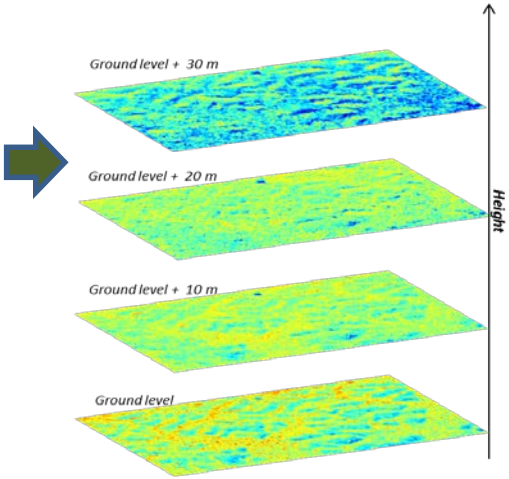
Aquarius L-band scatterometer measurements were used to assess radar brightness, stability and homogeneity.

Dome C is bright and stable at L-band, and expected also to be at P-band.

Ionospheric scintillation may affect radiometry but current calculations indicate this is not a significant problem.

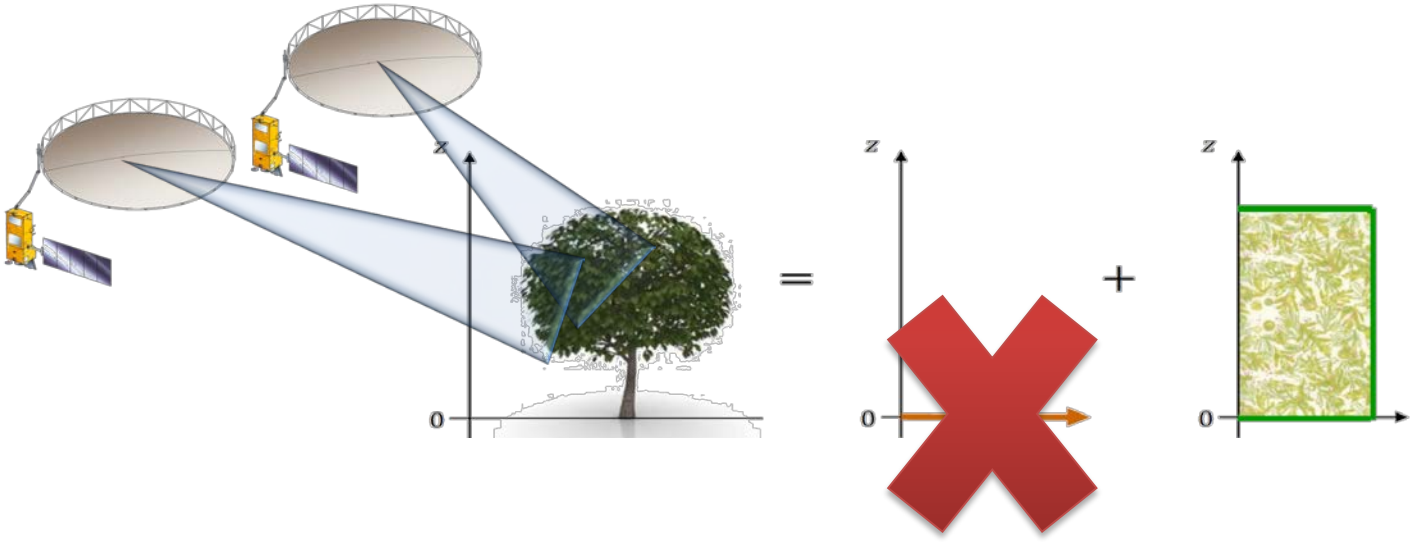
The importance of tomography





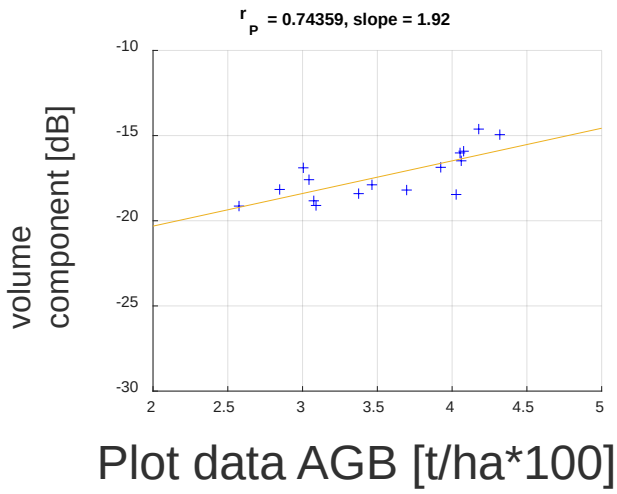
Pol-InSAR &TomoSAR allow ground cancellation

Crucial point: for biomass inversion to perform well, data must be processed to retain only the volume component of the forest canopy

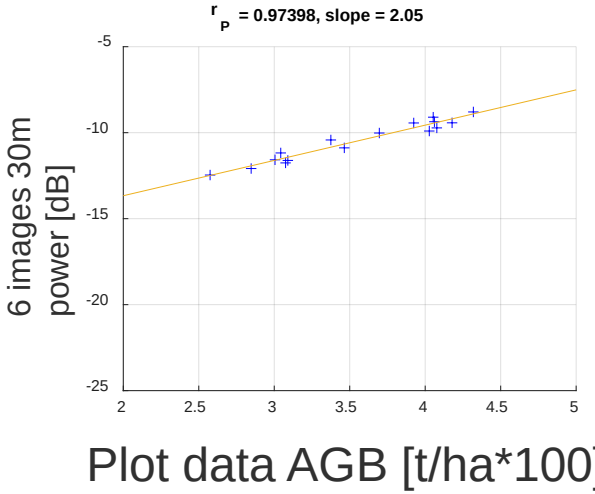


Biomass from tomography and ground cancellation

Ground-cancelled TomoSAR:
volume only



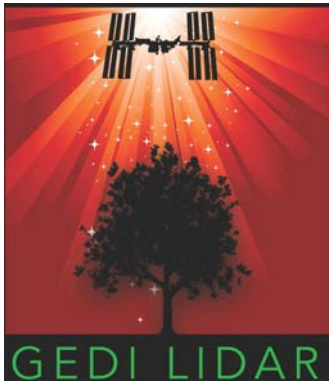
TomoSAR @ 30 m



Ground cancellation is possible with TomoSAR & Pol-InSAR. It yields much better correlation and sensitivity to Above-Ground Biomass (AGB) than backscattered power, which contains ground contributions.

New context: new space missions measuring biomass

Forest biomass & height (2022-2027)

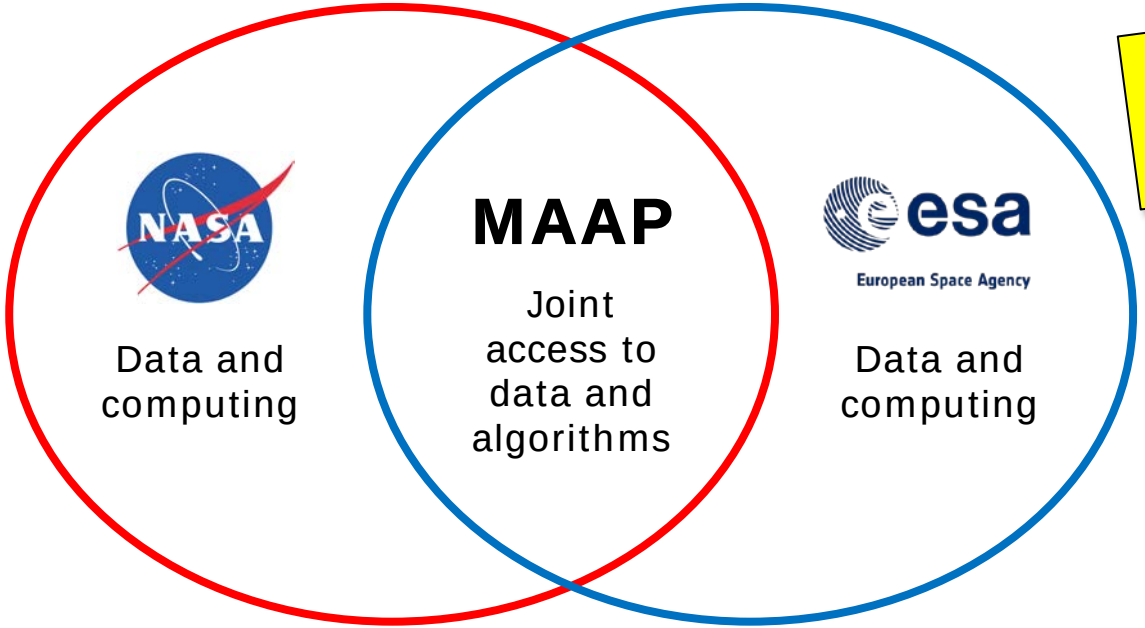


Forest structure
& biomass (2018-2020)

Forest structure & above-ground biomass < 100 t/ha (2022-32)

The "4th mission": in situ networks

Unified user access to the functions of a joint ESA/NASA Joint Mission Algorithm and Analysis Platform model



Approved during bilateral ESA-NASA meeting!

Up to date data and algorithms + Collaborative community

Developing the user community

- Establishing strong links with the carbon cycle and climate modelling community (aided by the ESA CCI-Biomass project).

- Developing links with national and international policy activities (e.g. national emissions reporting to IPCC, REDD, forest resources, etc.)

Qualities of a good PI

1. Stamina:
- Biomass proposed 2005, launch 2022
- Earthcare proposed 2003, launch 2021
2. Authority:
- Focus on what's important and how that evolves
- Willing to make judgements outside one's own expertise
- Enlightened management of a team of prima donnas
3. Remembering the objective: the mission, not just the instrument and algorithms.
4. Luck