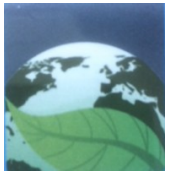


The relevance of JAXA´s SAR observations to quantify the world's forest biomass pools

M. Santoro, O. Cartus

GAMMA REMOTE SENSING

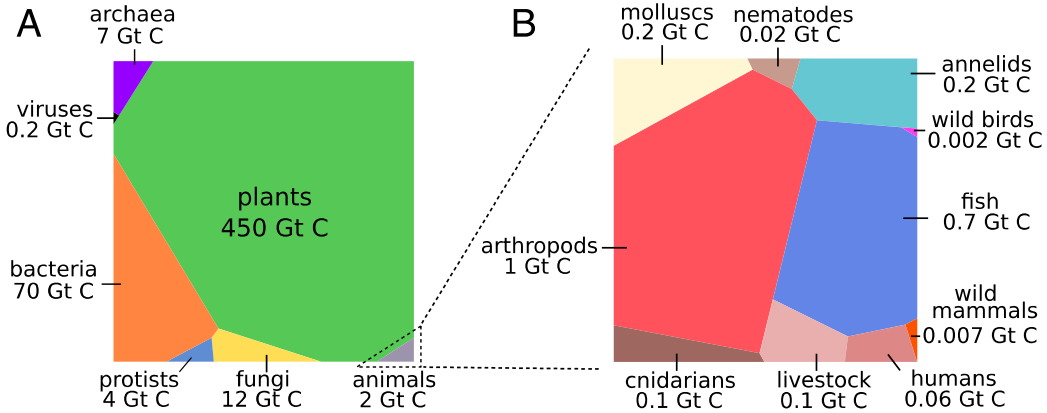
With the contribution and support by

***GlobBiomass** project team, **CCI BIOMASS** project team,*

***JAXA EORC,** A. Rosenqvist, J. Kellndorfer*

What is biomass?

Biomass represents the organic mass of the living world



(Bar-on et al., 2018)

Of the estimated 550 Gigatons of biomass carbon, 80% is stored in plants. The biomass of forests represent the largest pool of carbon stored in plants

Why is aboveground biomass relevant?

Aboveground biomass (AGB) is an Essential Climate Variable because vegetation can sequester / release CO2 from / to the atmosphere and, thus, impact climate.

Sources

E_{FF} = 34.1 ± 1.7 $GtCO_2$ yr^{-1} (91 %)

E_{LUC} = 3.5 ± 1.8 $GtCO_2$ yr^{-1} (9 %)

Partitioning

G_{ATM} = 16.4 ± 0.4 Gt CO_2 yr^{-1} (44 %)

S_{OCEAN} = 9.7 ± 1.8 Gt CO_2 yr^{-1} (26 %)

S_{LAND} = 11.5 ± 3.1 Gt CO_2 yr^{-1} (30 %)

$E_{FF} + E_{LUC} = G_{ATM} + S_{OCEAN} + S_{LAND}$

S_{LAND} - Not adequately measured

CO_2 sinks include response of land and ocean to elevated CO_2 & changes in climate and other environmental conditions

”Measuring” biomass

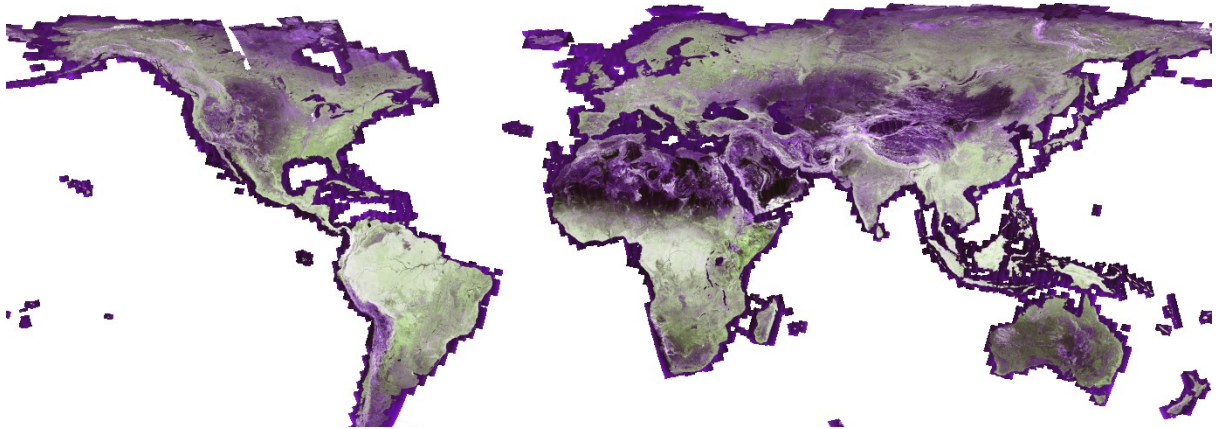
- Select trees
- Measure (and infer)
- Cut sample trees and weight

How do you “measure” this tree?

How can you actually “measure” 3 trillion trees??

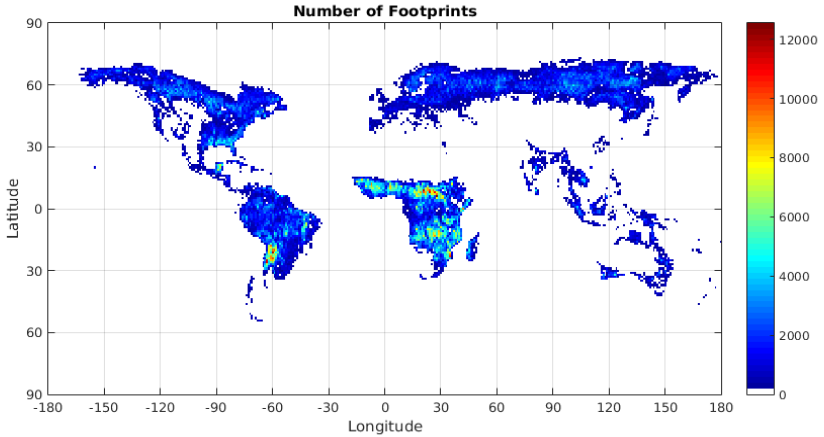
(Crowther et al., 2015)

Remote sensing in support of land surface studies



Sentinel-1 SAR
C-band, 2017

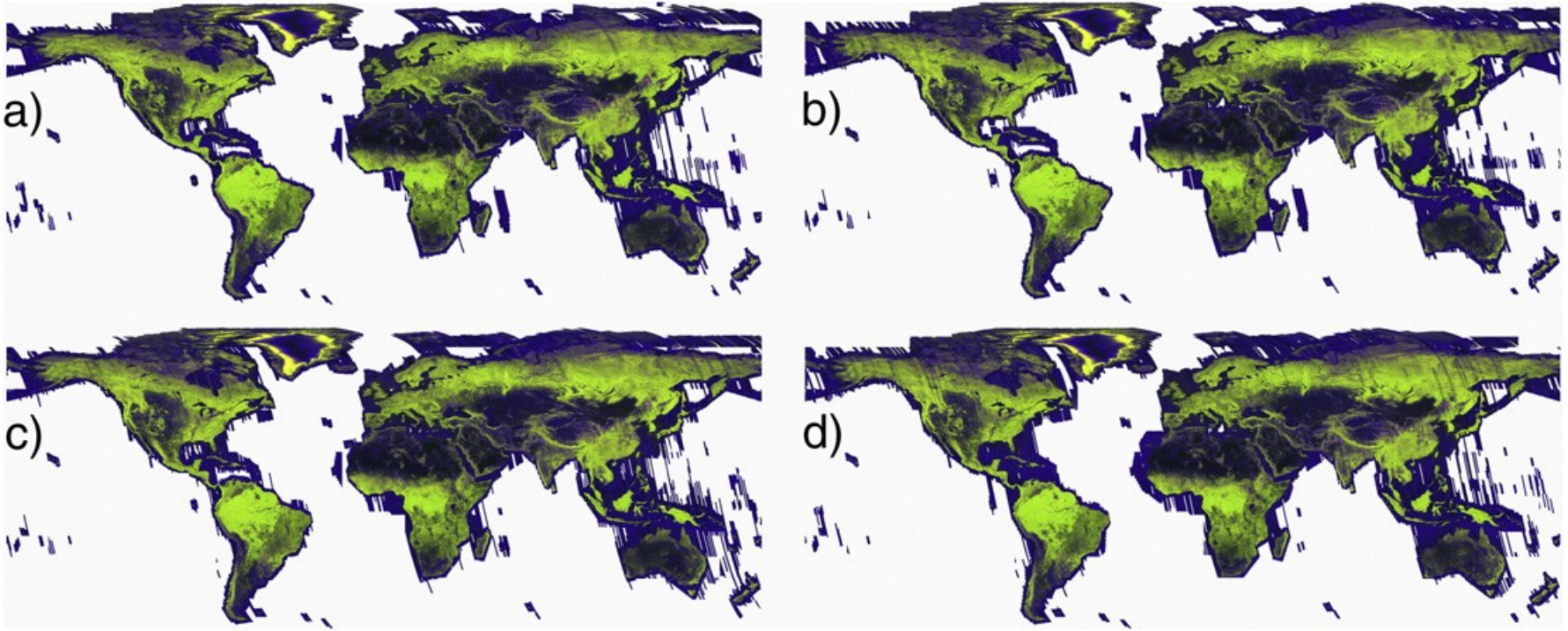
(Santoro et al., 2017,
processed by Earth Big Data)



ICESAT GLAS, LiDAR
waveforms, 2003-2009

(processed as part of the
GlobBiomass project)

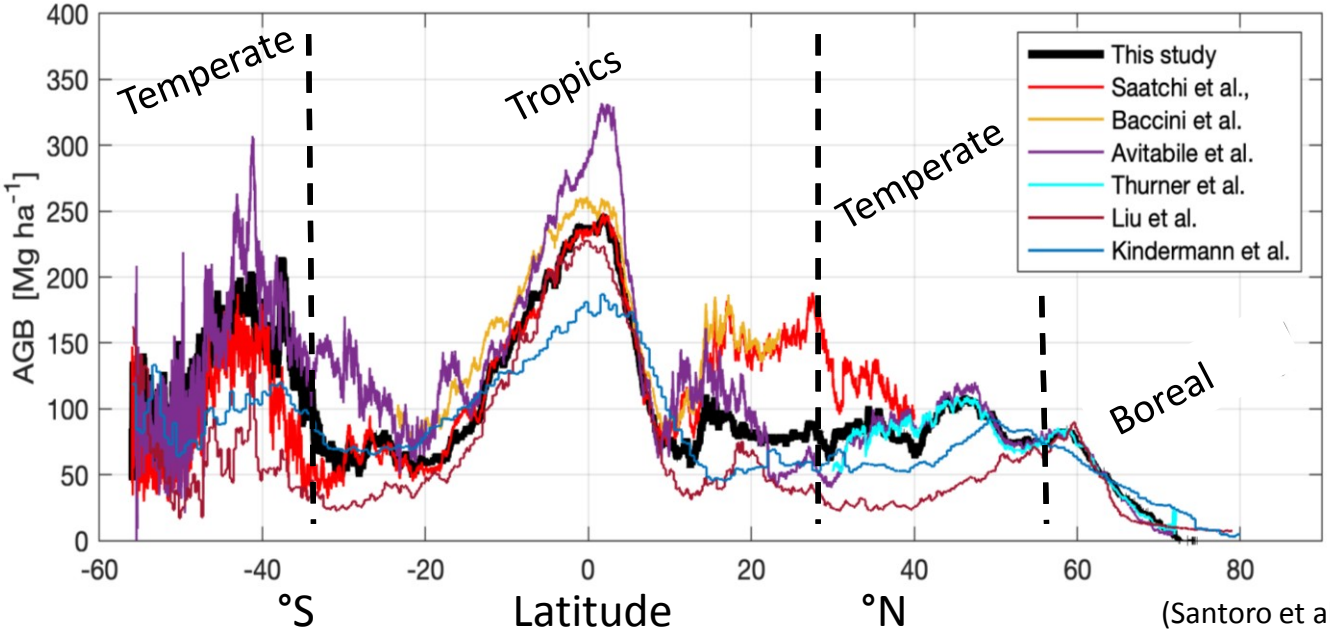
Remote sensing **time series** in support of land surface studies



ALOS PALSAR mosaics, L-band, 2007-2010 (Shimada et al., 2014)

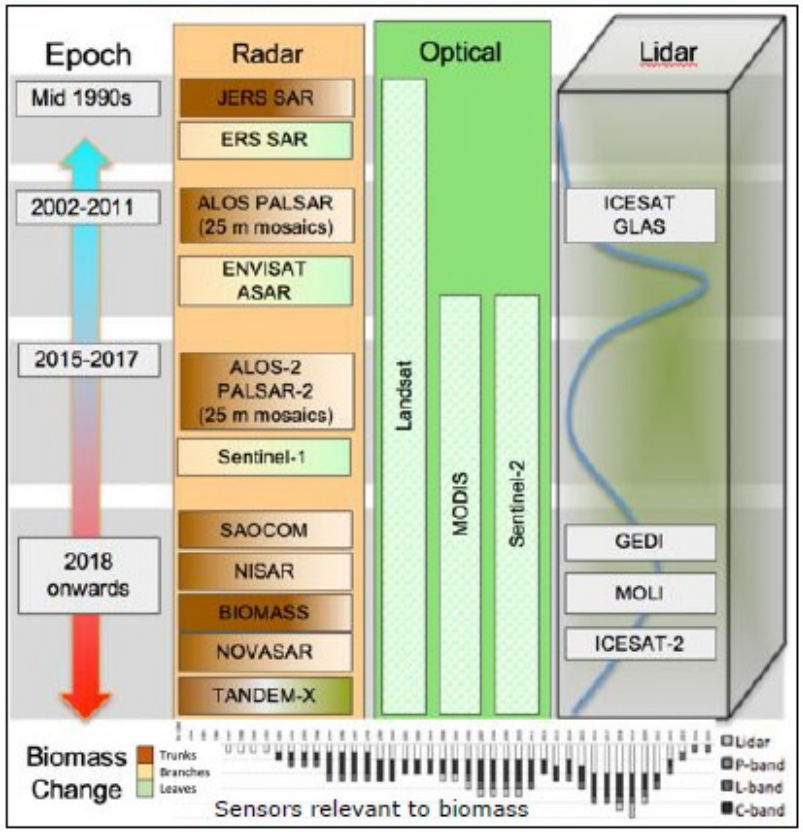
Remote sensing of forest AGB

- Earth Observation does NOT measure biomass
- Biomass is inferred from remote sensing observations using models
- As such, biomass estimates differ depending on EO data and models used



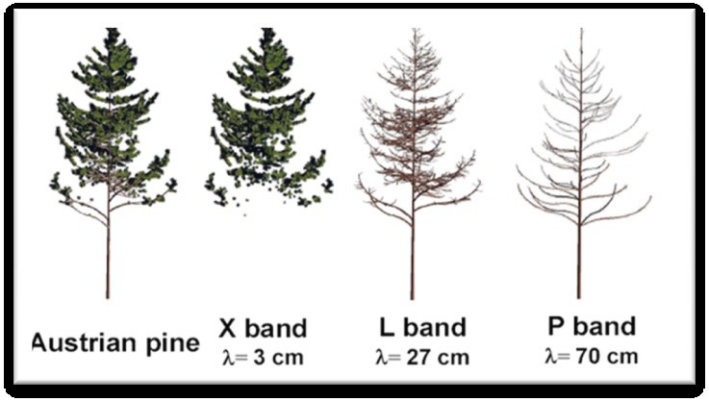
(Santoro et al., in prep.)

Spaceborne Earth Observation relevant to biomass



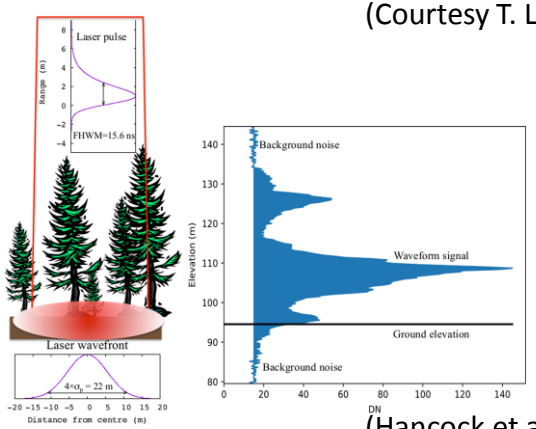
(Courtesy R. Lucas)

SAR



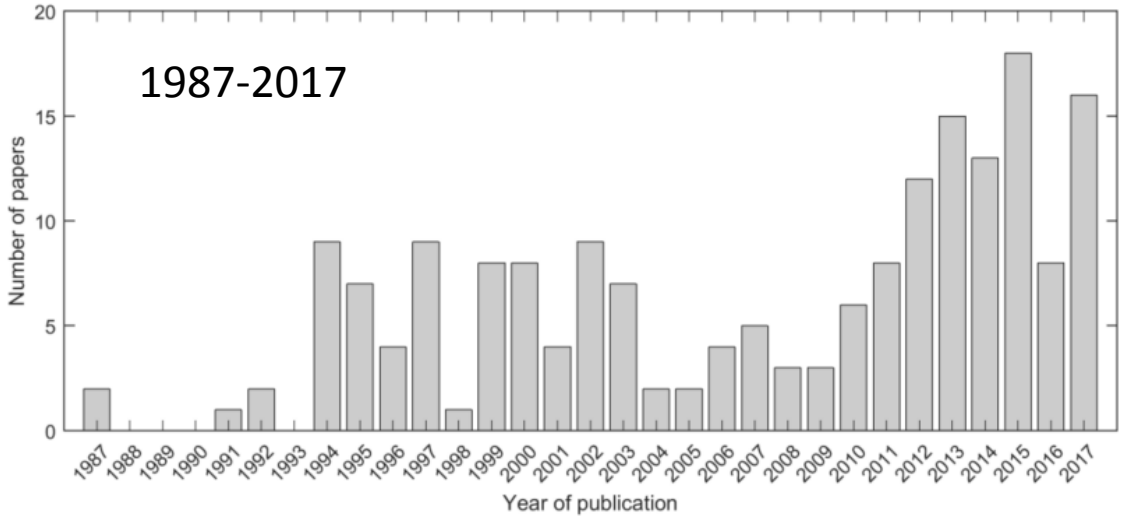
(Courtesy T. Le Toan)

LiDAR



(Hancock et al., 2019)

The importance of (JAXA's) L-band observations



(Santoro & Cartus, 2018)

- Among all observations from space, L-band are the most sensitive to biomass
- Surveyed 186 papers on biomass estimation with SAR backscatter and SAR interferometry
- 43% of papers used JERS-1, ALOS-1 or ALOS-2 data
- Peaks slightly after periods of operation of JAXA's SAR missions

ESA's Climate Change Initiative (CCI) BIOMASS activity

CCI aims at *realizing the full potential of the long-term global EO archives that ESA, together with its Member states, has established over the last thirty years..... as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change*

CCI BIOMASS *foresees the generation of three global AGB maps for 2010, 2017 and 2018 with a suite of EO data and assessment of AGB changes with an evaluation in climate and carbon models.*

Measurement domain	Essential Climate Variables
Atmospheric	Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning Composition: carbon dioxide (CO2), methane (CH4), other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone
Oceanic	Physics: temperature: sea surface and subsurface; salinity: sea surface and subsurface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat flux Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide (N_2O), ocean colour Biology/ecosystems: plankton, marine habitat properties
Terrestrial	Hydrology: river discharge, groundwater, lakes, soil moisture Cryosphere: snow, glaciers, Ice sheets and Ice shelves, permafrost Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature Human use of natural resources: water use, greenhouse gas fluxes

CCI BIOMASS follows up on the GlobBiomass activity where retrieval strategies were developed in first place

The CCI BIOMASS strategy to estimate AGB

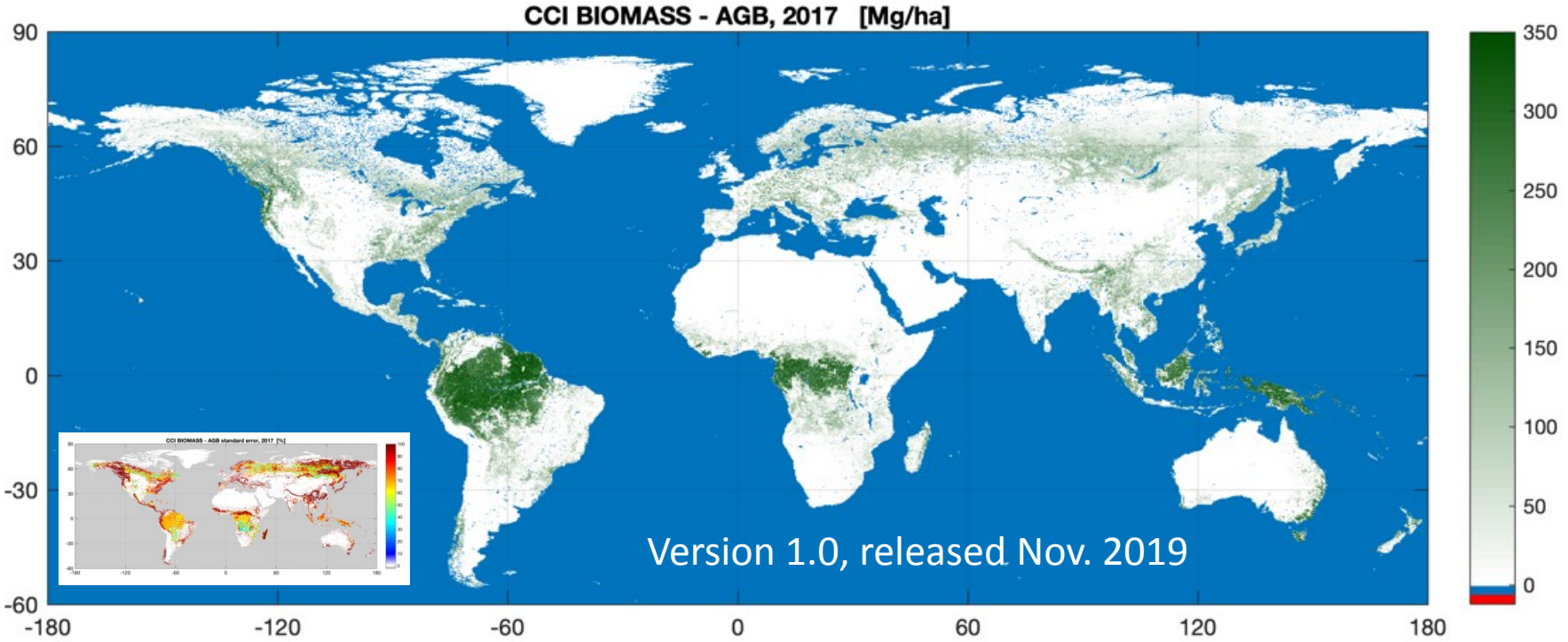
- Exploit as much as possible the information content on “biomass” in EO data
- (i) select established modelling frameworks, (ii) that allow tuning of the model parameters in space and time, and (iii) possibly do not require in situ data for training

Implementation

- **Data:** Multiple EO observations with global, repeated coverages and open to the public
  - *L-band SAR backscatter (ALOS PALSAR, ALOS-2 PALSAR-2)*
  - *C-band SAR backscatter (Envisat ASAR, Sentinel-1A/B)*
  - *ICESAT GLAS LiDAR waveform (ICESAT-2 and GEDI)*

- **Models**: Water Cloud Model, BIOMASAR algorithm, forest allometries
- **Auxiliary data**: canopy density maps, land cover maps, wood density, biomass factors

CCI BIOMASS data product for 2017



- Based on ALOS-2 PALSAR-2 and Sentinel-1, 100 m spatial resolution
- Available at https://catalogue.ceda.ac.uk/uuid/bedc59f37c9545c981a839eb552e4084

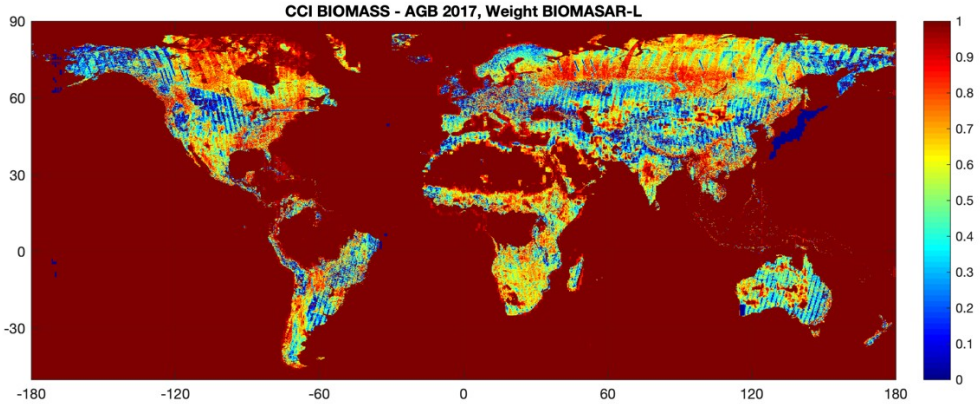
The contribution of ALOS-2 PALSAR-2 mosaics

TAr = Tropical rainforest
TAwa = Tropical moist dec. forest
TAwb = Tropical dry forest
TBSh = Tropical shrubland
TBWh = Tropical desert
TM = Tropical mountain

SCf = Subtropical humid
SCs = Subtropical dry
SBSh = Subtropical steppe
SBWh = Subtropical desert
SM = Subtropical mountain

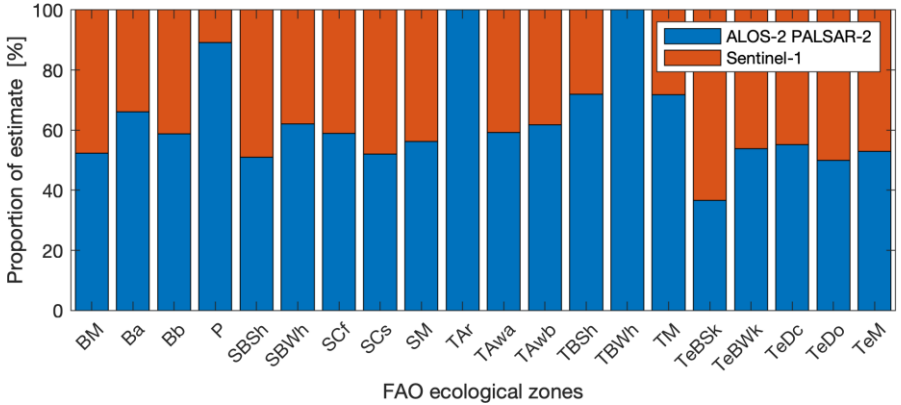
TeDo = Temperate oceanic
TeDc = Temperate continental
TeBSk = Temperate steppe
TeBWk = Temperate desert
TeM = Temperate mountain

Ba = Boreal coniferous
Bb = Boeal tundra woodland
BM= Boreal mountain
P = Polar



ALOS-2 PALSAR-2

Sentinel-1

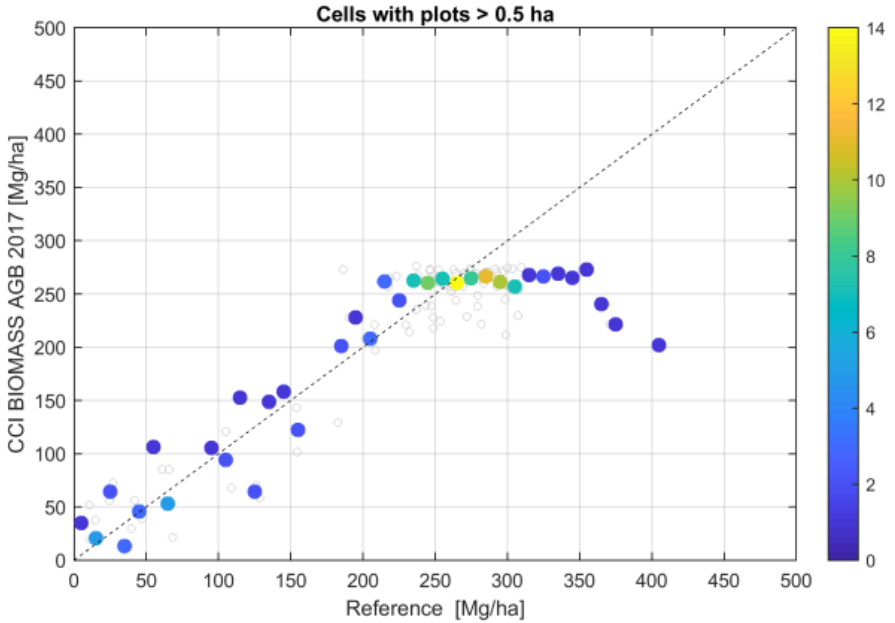


Global figures

ALOS-2, L-band: 67%

Sentinel-1, C-band: 33%

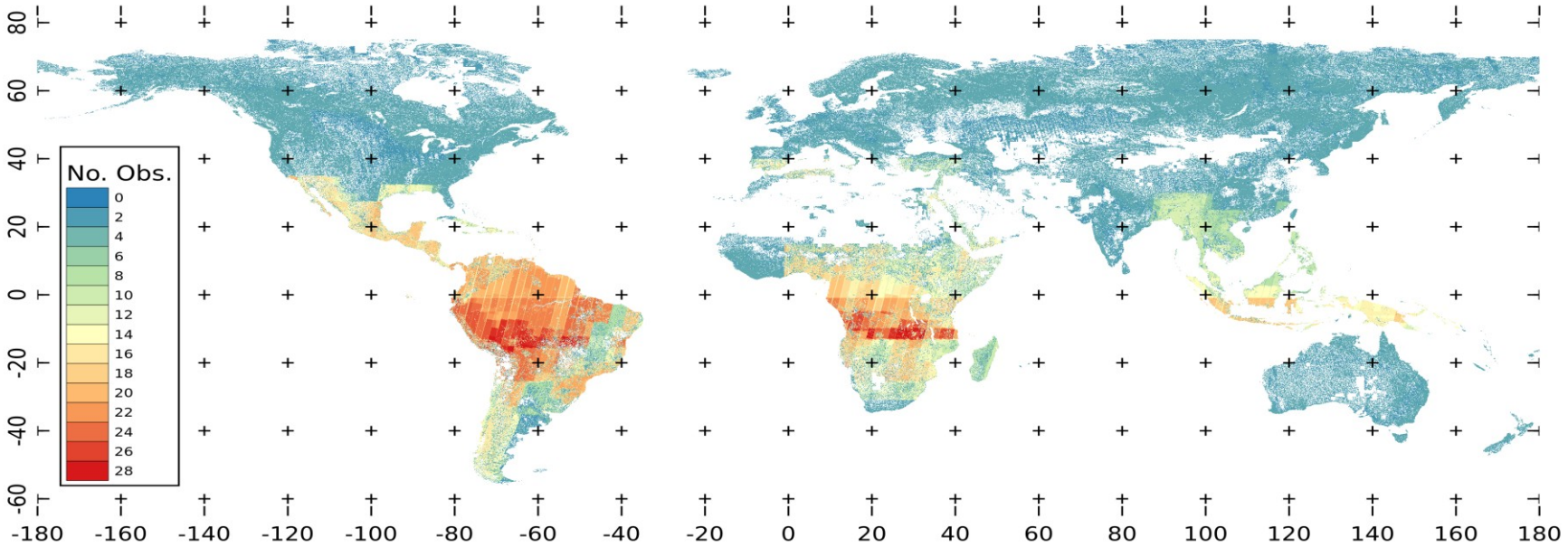
Assessing the spatial patterns of the CCI Biomass map



Number of inventory plots in a 0.1° grid cell

- Spatial patterns well reproduced but underestimation in high AGB forests
- Major reason: not having accounted for height in the retrieval models
- Version 2.0 will implement height-to-AGB allometries, currently being produced

Key element: multiple observations

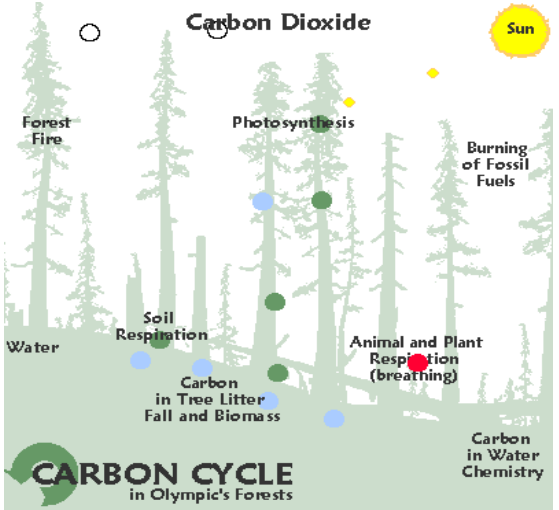


JAXA FBD annual mosaics and Kyoto & Carbon per-cycle ScanSAR mosaics

Impact of global AGB datasets on current science

With CCI and GlobBiomass datasets, the climate and carbon modelling communities derive for the first time detailed and global knowledge on

- Belowground biomass
- Total carbon stored in vegetation
- Carbon turnover time
- Plant water content and tree physiology
- How degradation impacts climate predictions



http://en.wikipedia.org/wiki/FluxNet

In addition, the AGB maps are evaluated as part of processes to

- Support to inventory in developing countries
- Calibration of algorithms for other sensors

AGB estimation in the 2020s

• Spaceborne remote sensing observations are mandatory to quantify the carbon cycle and understand in which direction our planet is going

• For the first time, several missions will fly with the target of observing forest ecosystems (BIOMASS, NiSAR, GEDI, MOLI)

• The wide range of observations will quantify AGB to an unprecedented level

• In addition, several observational datasets will be extended into the 2020-2030 epoch (ESA C-band series, ALOS series) complementing the vector of observations above and generating decadal consistent time series

AGB estimation in the 2020s

- From the perspective of a data producer, five aspects are fundamental
  - **Frequent observations** (not one image per year but per cycle!)
  - **Original observations** (SLC, GRDs, waveforms etc.) rather than mosaicked images
  - **Global datasets must have a free and open data policy**
  - **Rely on end-to-end cloud computing resources**
  - **Open communication between researchers and data**