K&C Phase 4 – Final report

Coupling radar-based estimates of forest information with biosphere models for improved carbon flux estimation

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Project outline and objectives

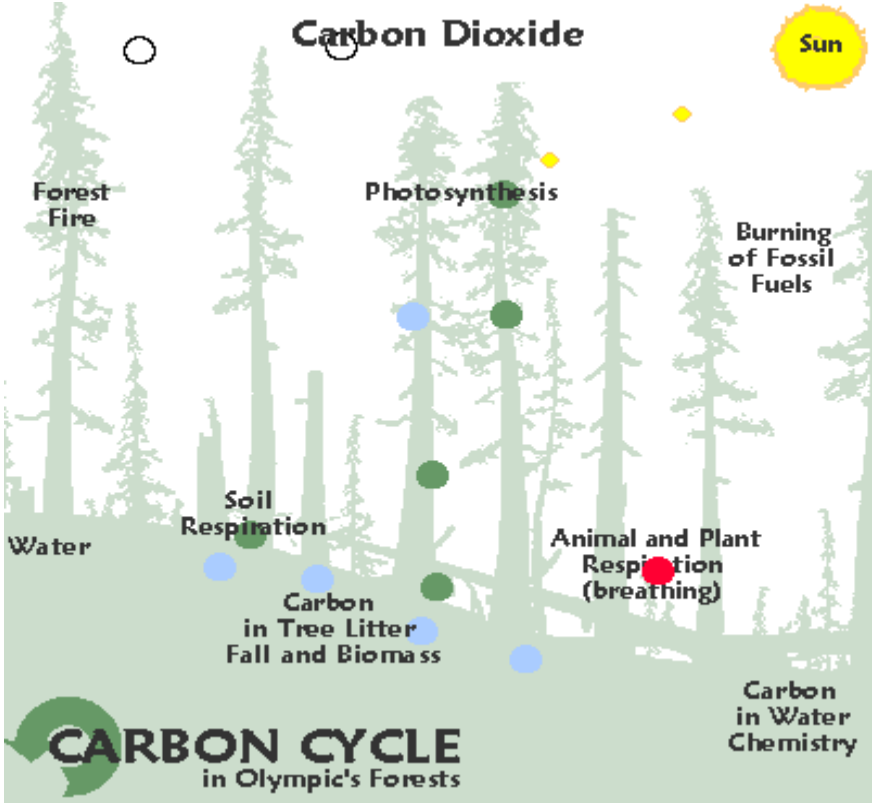
Objective: estimate biomass from ALOS PALSAR data to

- Parameterize biosphere models with a high resolution data stream in different regions located in the boreal, temperate and tropical zones (“static” component of project)

- Constrain carbon (flux) models to improve their estimation (“dynamic” component of project). Site: Europe.
  - PALSAR-2, PALSAR-1 as well as JERS-1 acquired over Europe are used to derive **time series of biomass** estimates (1992-1998; 2007-2010; 2014-onwards)

Relating EO data to ecosystem models

Ecosystem C-cycle modeling



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

Quantifying carbon turnover times, τ

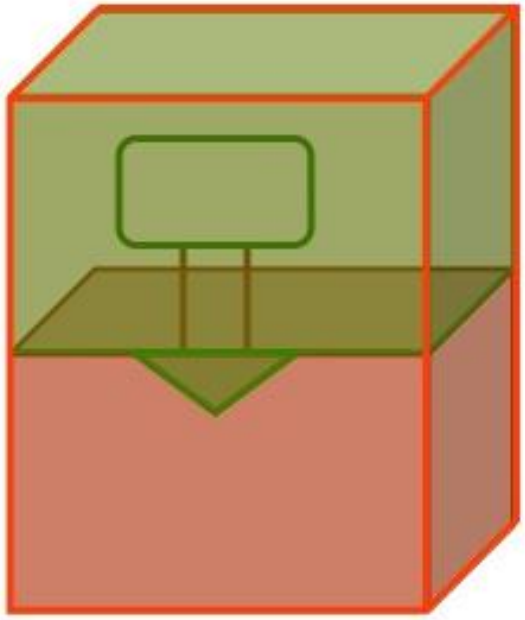
Turnover time: time it takes for a carbon atom fixed in a plant by photosynthesis to return into the atmosphere as carbon dioxide

$$\frac{\partial C}{\partial t} = F_{in} - C/\tau \Leftrightarrow \tau = \frac{C}{F_{out}} \approx \frac{C}{F_{in}}$$ (in steady state)

$$\tau_{AGB} = \frac{AGB}{NPP}$$

$$\tau_{veg} = \frac{C_{veg}}{NPP}$$

$$\tau_{soil} = \frac{C_{soil}}{R_h}$$



Total carbon

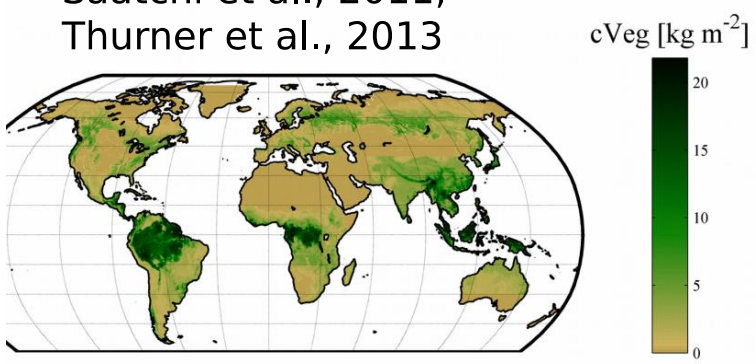
$$\tau = \frac{C_{total}}{GPP}$$

Carbon fixed with photosynthesis (flux)

$$\tau = \frac{C_{total}}{R_{eco}}$$

Carbon turnover from EO

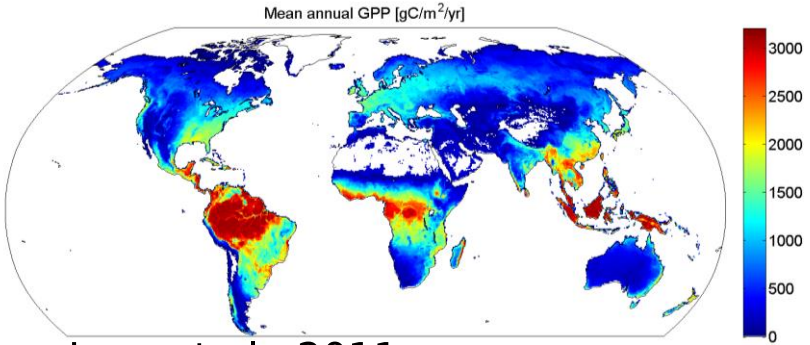
Saatchi et al., 2011;
Thurner et al., 2013



Carvalhais et al., 2014

From soil carbon databases

ASAR, ICESAT, MODIS

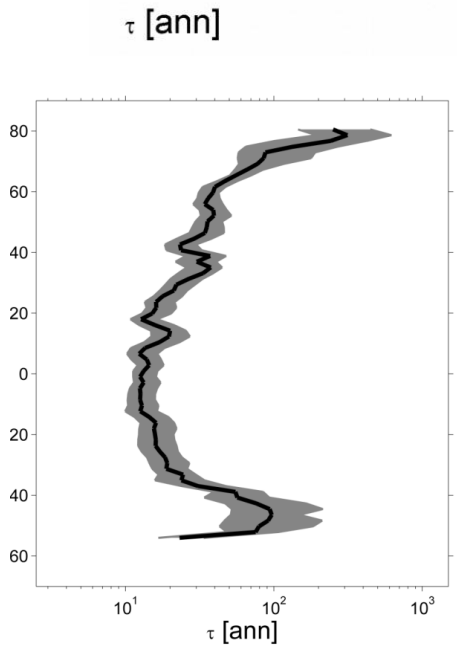


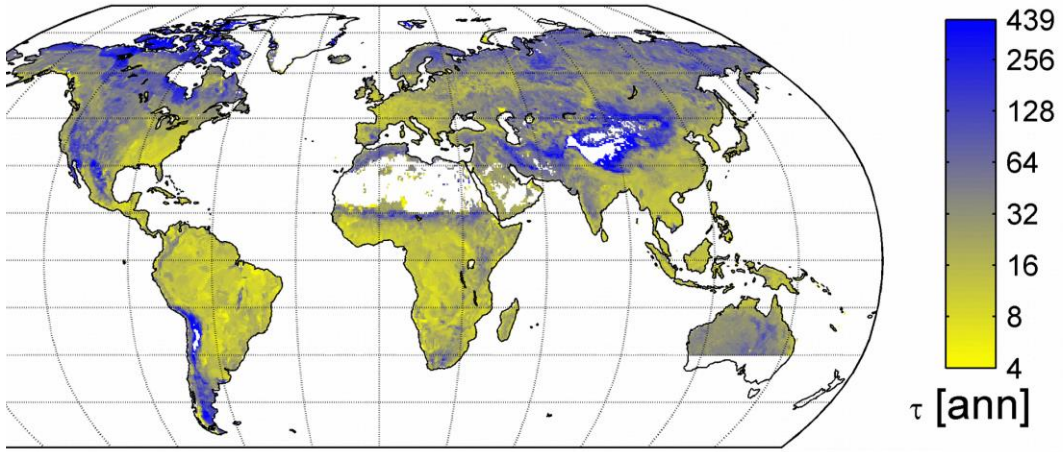
Jung et al., 2011

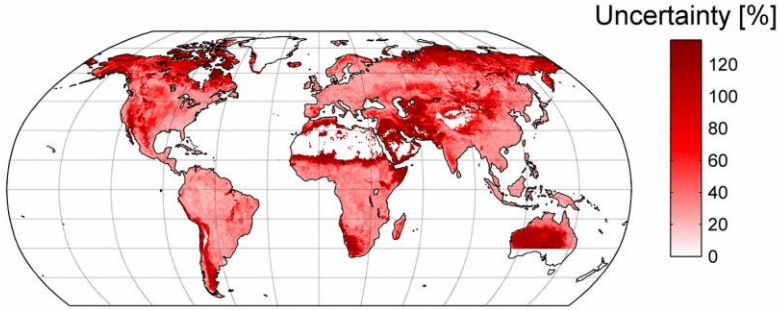
MODIS

$$\frac{C_{veg} + C_{soil}}{GPP} = \tau$$

Data ensemble: $\frac{C_{total}}{GPP} = 23^{+7}_{-4}\,yr$

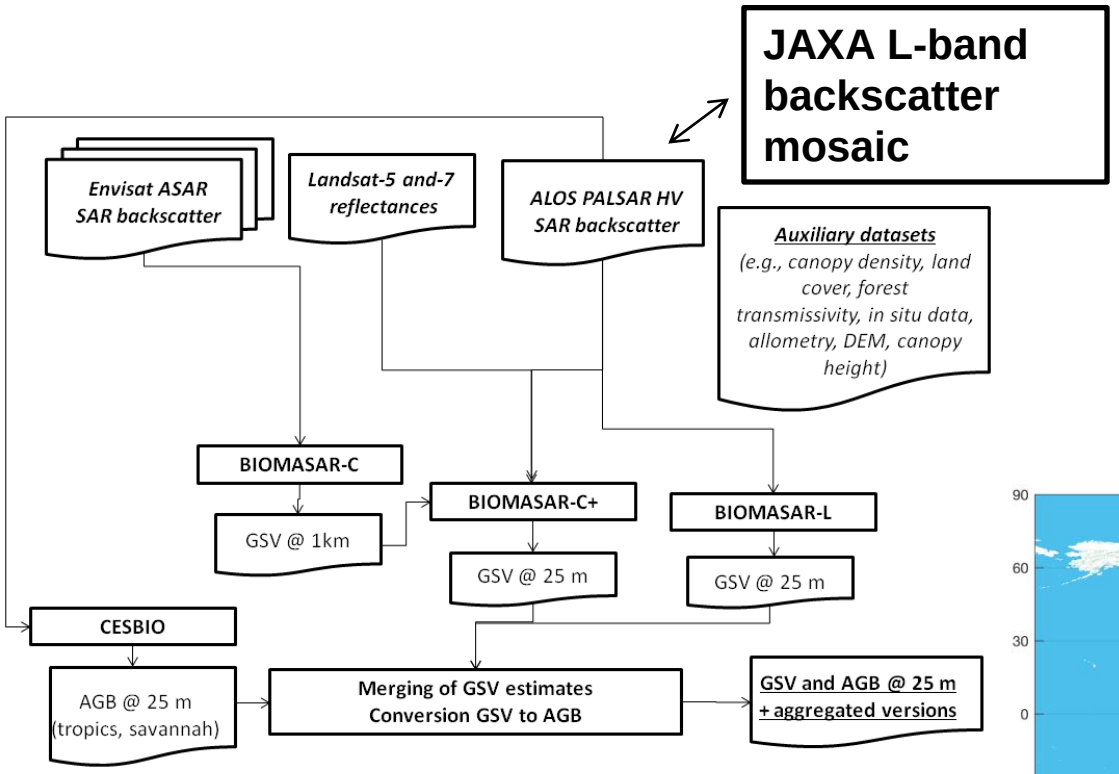


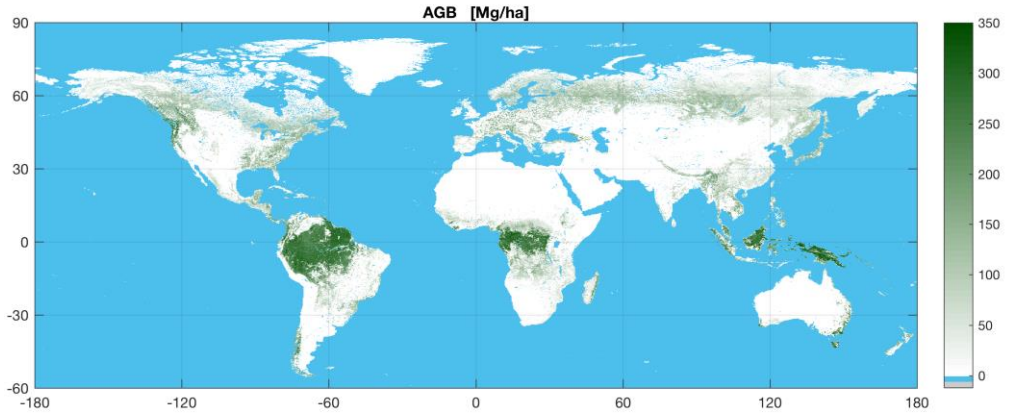




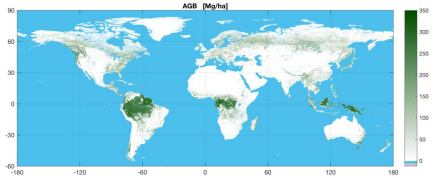
Carvalhais et al., 2014

The GlobBiomass approach
Estimating biomass from multiple EO sources

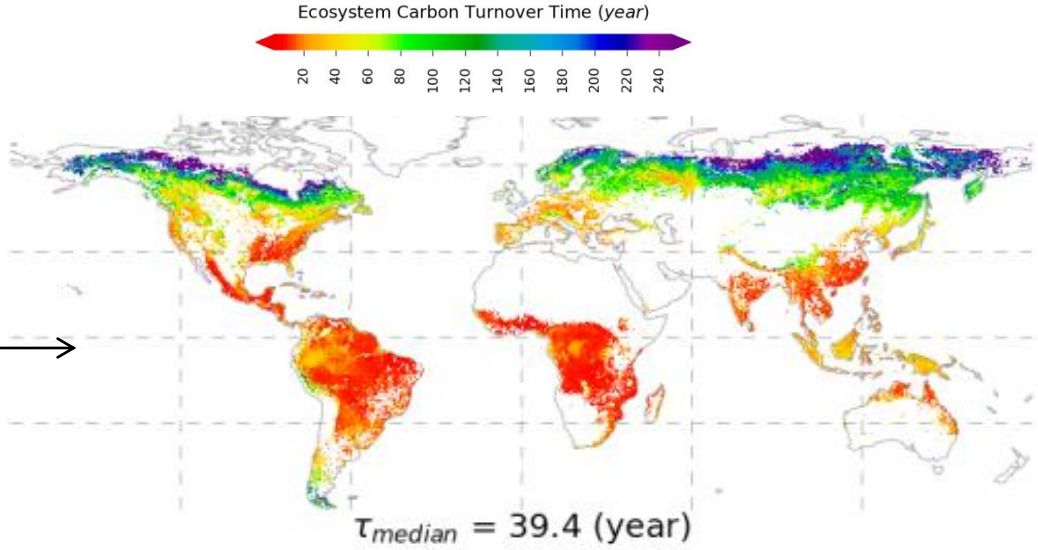




Quantifying carbon turnover with the GlobBiomass dataset



$$\frac{C_{veg} + C_{soil}}{GPP}$$



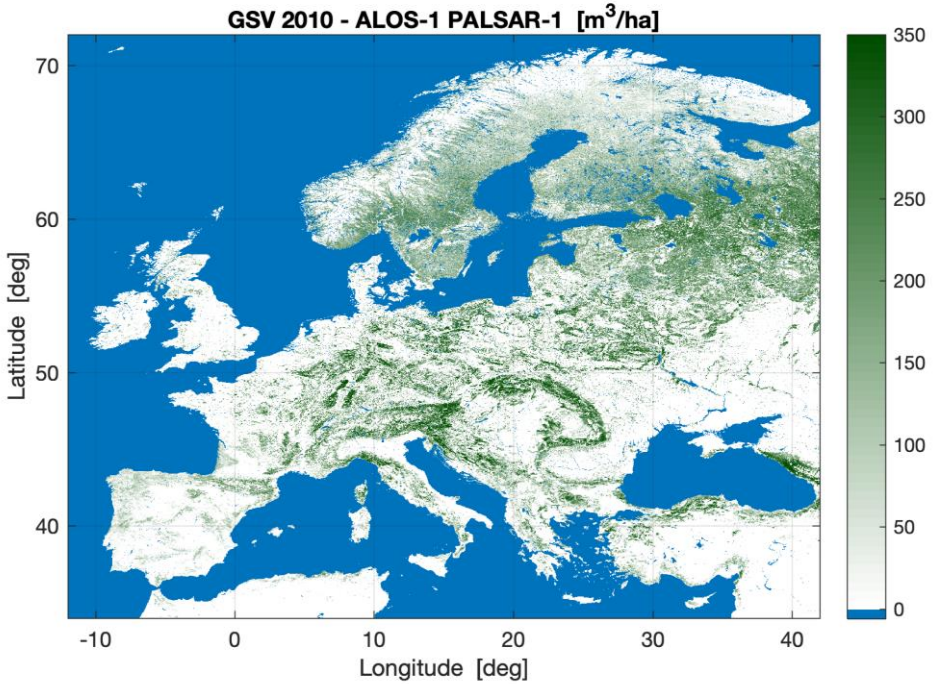
- Consistent with previous estimates of turnover based on coarse resolution satellite data
- Small overall difference with respect to turnover computed from other global maps of biomass although these present different regional patterns
- Intriguing small-scale patterns seen in GlobBiomass, not visible elsewhere

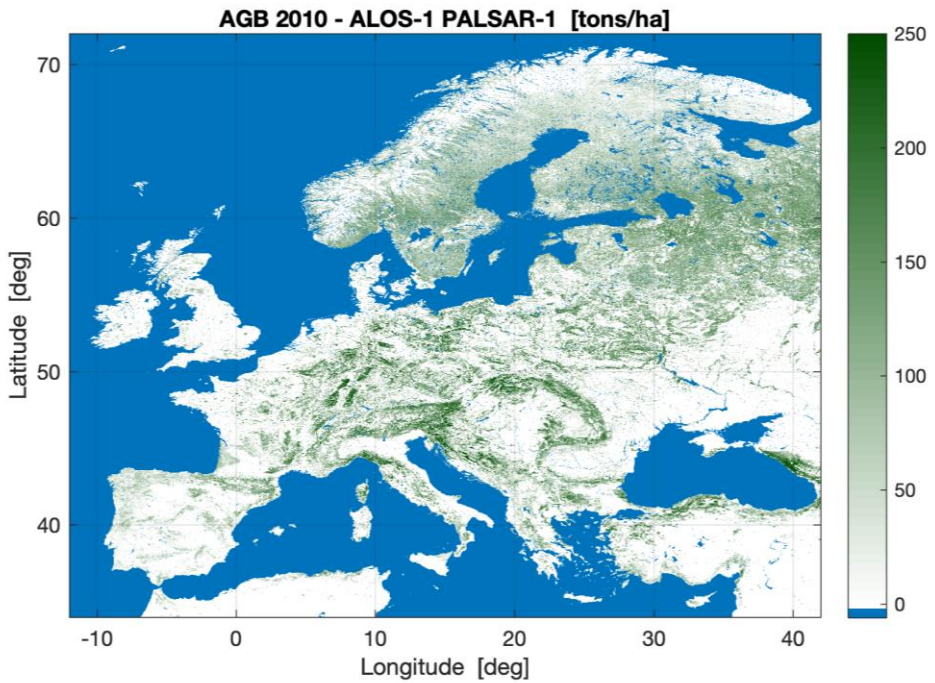
Biomass dynamics in Europe from L-band

L-band JAXA mosaics – pre-processing

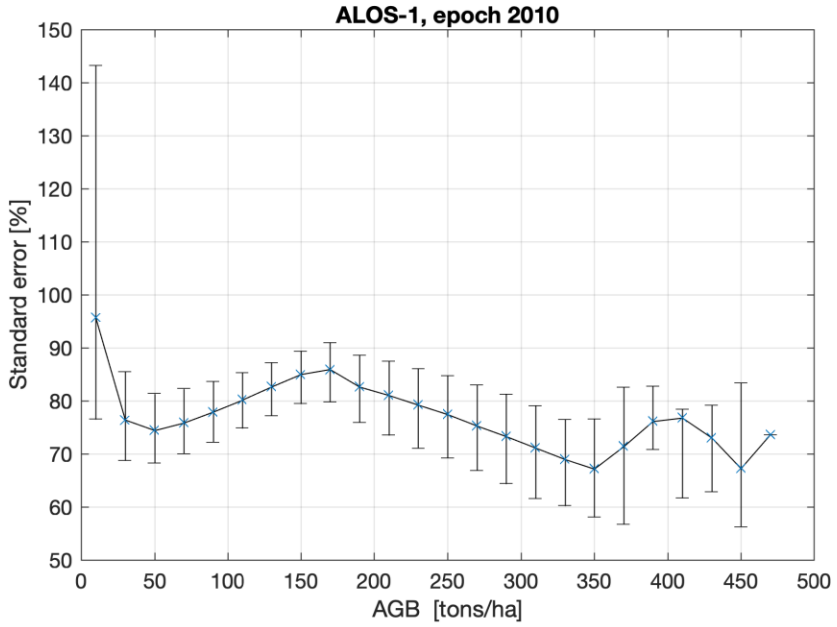
- JERS: single multi-year dataset (epoch 1996), HH-pol,
  - Dataset has been co-registered to ALOS-1 mosaic (see presentation of KC22 meeting)
- ALOS-1 PALSAR-1: 4 yearly datasets (2007-2010), HH- and HV-pol.
  - Base: year 2010. Individual strips presenting clear environmental effects (e.g., acquired at freeze events) have been replaced with other years (2009 and 2008)
- ALOS-2 PALSAR-2: 3 yearly datasets (2015-2017), HH- and HV-pol.
  - Base: year 2017. Quality of 2017 mosaic superior to 2015 and 2016 (see this presentation)

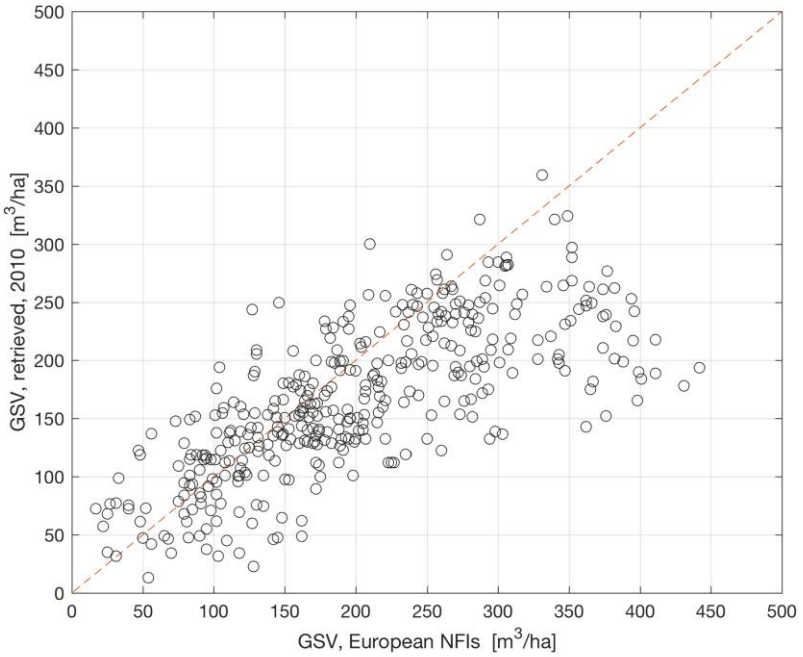
ALOS-1 PALSAR-1 biomass dataset of Europe, epoch 2010





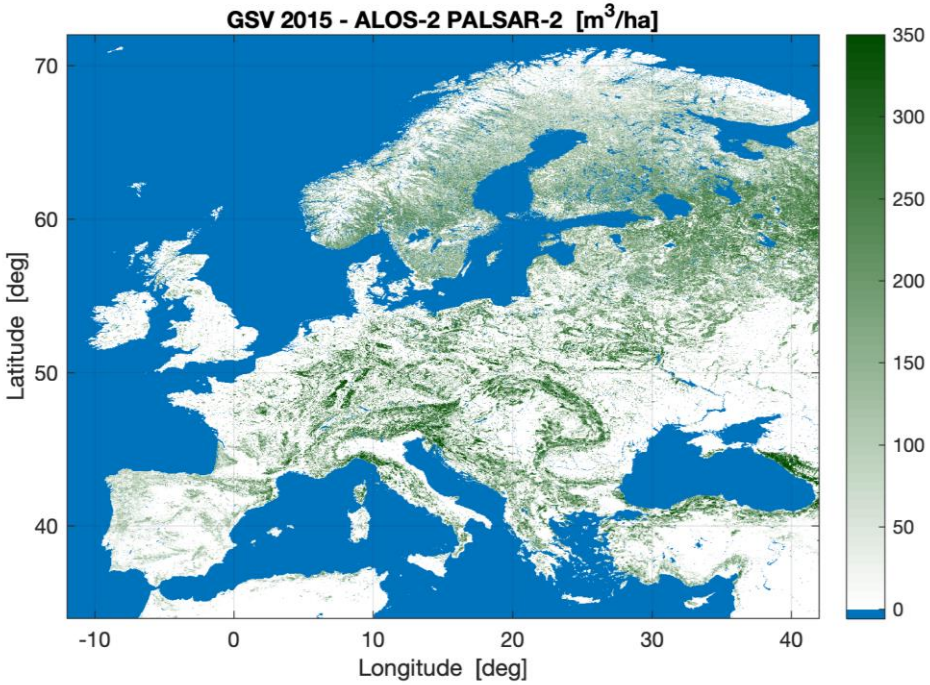
Assessment of 2010 biomass dataset

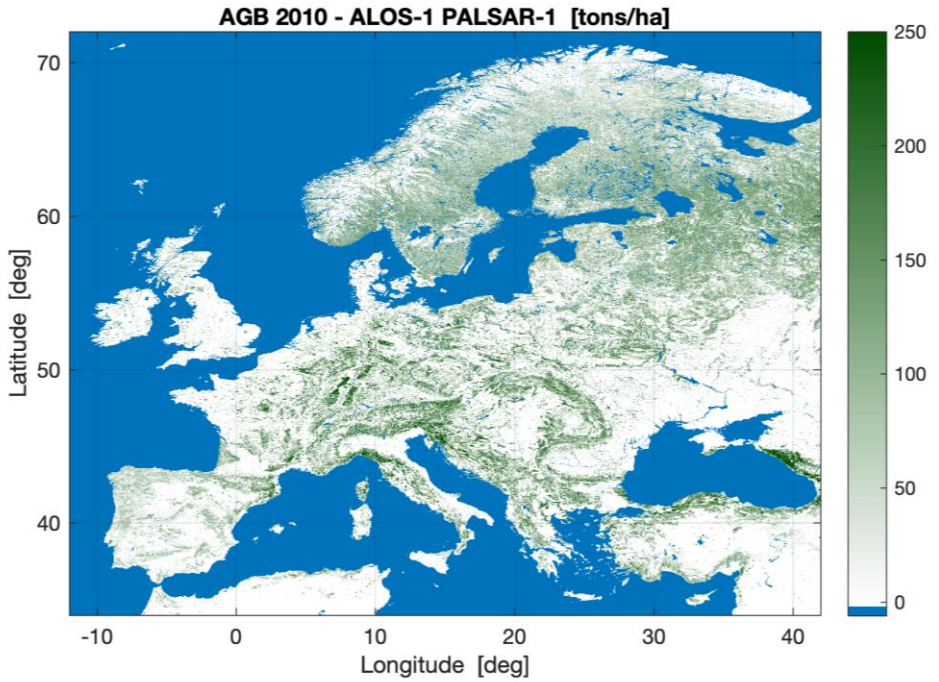




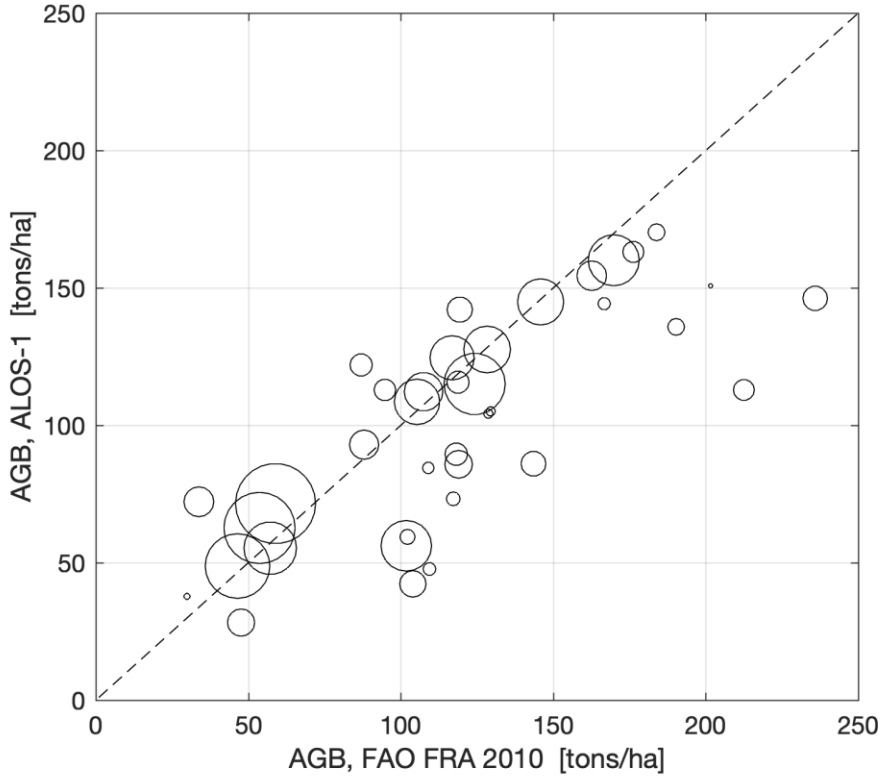
- Biomass levels captured but, with a single L-band observation, we observe
  - Underestimation in high biomass regions
  - Very large uncertainty (70-80%) at pixel level

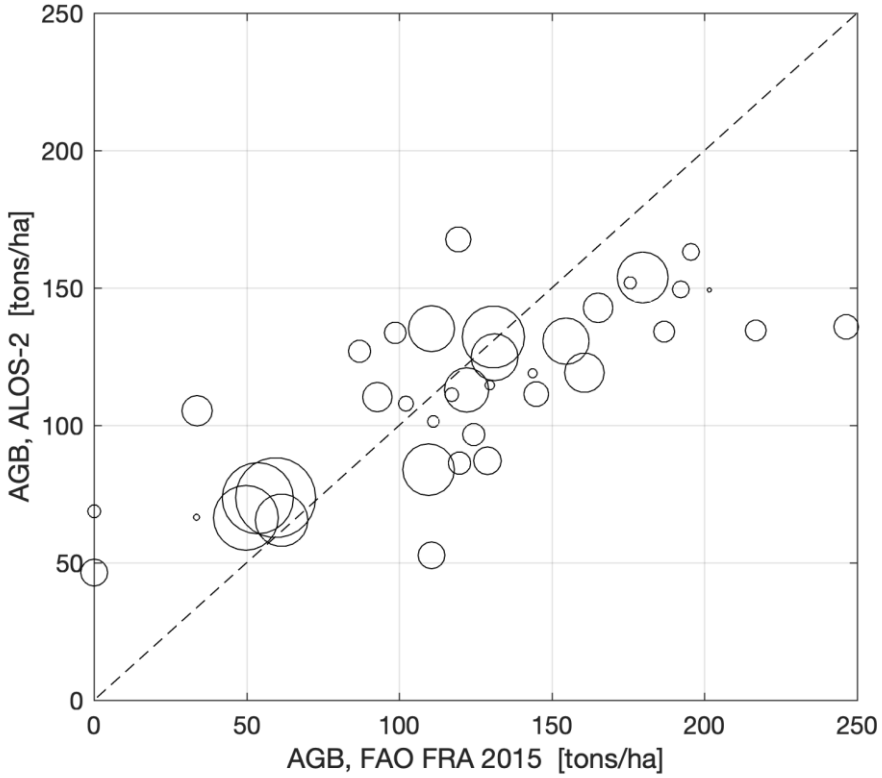
ALOS-2 PALSAR-2 biomass dataset of Europe, epoch 2015 (based on JAXA mosaic of 2017)





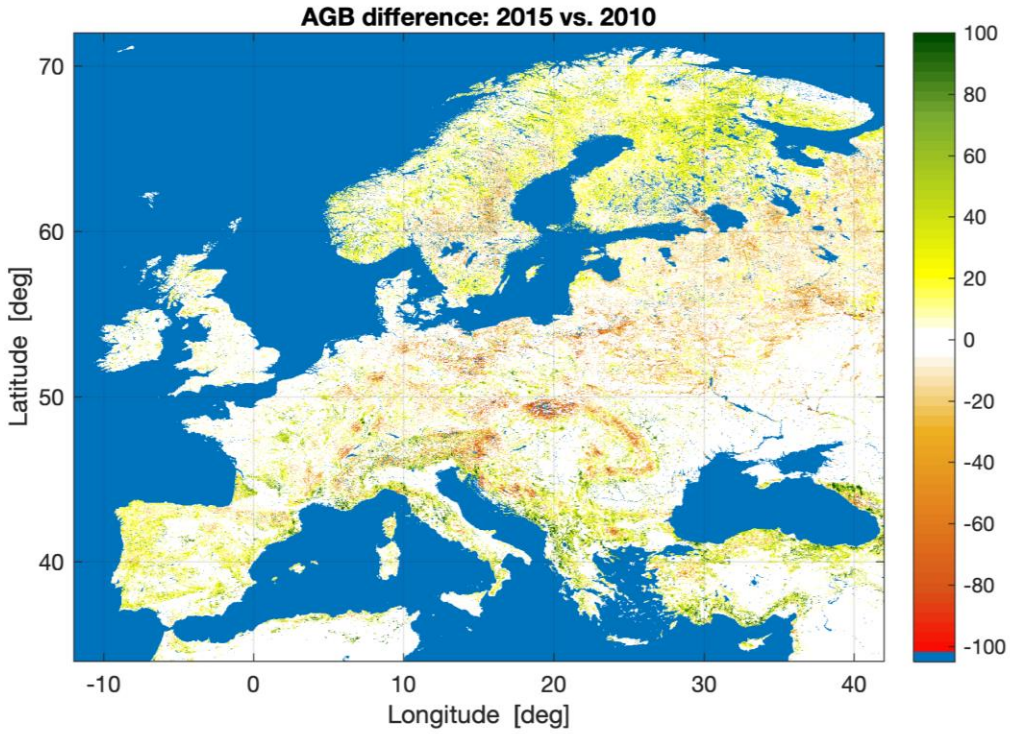
Plausibility of AGB estimates

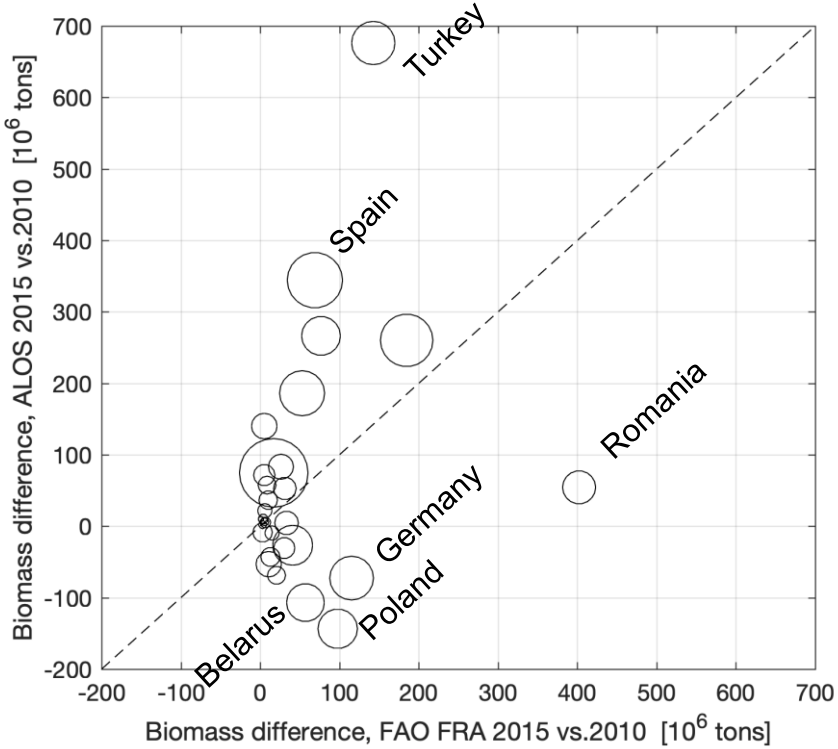




- Size of circles proportional to the forest area in a country
- Stronger agreement with FAO FRA country statistics for the 2010 dataset

AGB difference: epoch 2015 vs. epoch 2010





- Scandinavian and Mediterranean regions: we estimate biomass increase
- Central and Eastern European countries: we estimate biomass decrease
- Biomass dynamics from L-band data are often contrasting with data published by FAO → quality of mosaics? Quality of FAO FRA?

Conclusions

1) L-band mosaics of SAR backscatter provided by JAXA are currently the main predictor to estimate wall-to-wall forest biomass using remote sensing data
2) EO data fed to data-driven approaches to model carbon and ecosystem functioning reveal spatial patterns that were not visible with “traditional” measurements (e.g., climate variables, sparse in situ information)
3) Quality of the estimates scales with number of observations → Accurate estimation of biomass cannot be based on data from a single sensor. Even less on a single observations from a single sensor.
4) The quality of the ALOS-2 mosaics was unfortunately inferior compared to the ALOS-1 mosaics
5) Dissimilarities of the mosaic products did not allow for tracking biomass dynamics at high resolution and so to verify their impact on ecosystem models at small scales → multi-sensor approach required

Deliverables

- A forest biomass map of Europe produced with ALOS-1 data for 2010 epoch
- A forest biomass map of Europe produced with ALOS-2 data for 2015 epoch
- A forest biomass map of Europe produced with JERS-1 data for the 1995 epoch attempted

- Report on model-data integration
- Yearly feed-back to JAXA on quality of their data products.
- Ground-truth data has been delivered during the KC24 meeting

Deliverables, datasets

- The biomass maps based on a single L-band observation (i.e., a mosaic) are improved when combining with data acquired with other sensors (e.g., C-band, LiDAR, optical)
- The forest biomass map of epoch 2010 is part of ESA's GlobBiomass global datasets of AGB and GSV (free to download):

  http://globbiomass.org/products/global-mapping/
- The forest biomass map of epoch 2015 will be part of ESA's CCI Biomass global datasets of AGB

  http://cci.esa.int/biomass
- The JERS dataset of epoch 1996 (see presentation of KC 24) will be considered for a prototype map of biomass for the 1990's with ERS data in CCI Biomass.

Pubblications

- Santoro, M. (2018): GlobBiomass – global datasets of forest biomass. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.894711
- Santoro M. et al., Forest aboveground biomass pool of 2010 estimated from high-resolution spaceborne remote sensing observations, to be submitted
- Several presentations of the GlobBiomass map at conferences and workshops.
- Note: the impact of this K&C project on ecosystem studies is yet to come

PALSAR/PALSAR-2 data access

Please list the PALSAR/PALSAR-2 data you have

(1) requested and (2) obtained.

JERS mosaic of SAR backscatter, epoch 1995 – obtained

ALOS-1 PALSAR-1 mosaics of SAR backscatter 2007-2010 – obtained

ALOS-2 PALSAR-2 mosaics of SAR backscatter 2015-2017 – obtained

Do you have sufficient data to complete your research (according to your K&C agreement)?

Yes but results are of limited usefulness because based on a single observations of the radar backscatter per epoch.

This project strongly encourages the release of per-cycle mosaics (without replacements) to allow for reducing biomass retrieval errors (similarly to ScanSAR mosaics).