K&C Phase 4 – Status report

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

Maurizio Santoro & Oliver Cartus
GAMMA Remote Sensing

Nuno Carvalhais
Max Planck Institute for Biogeochemistry (MPI-BGC)

Science Team meeting #24
Hatoyama, Japan, January 29-31, 2018

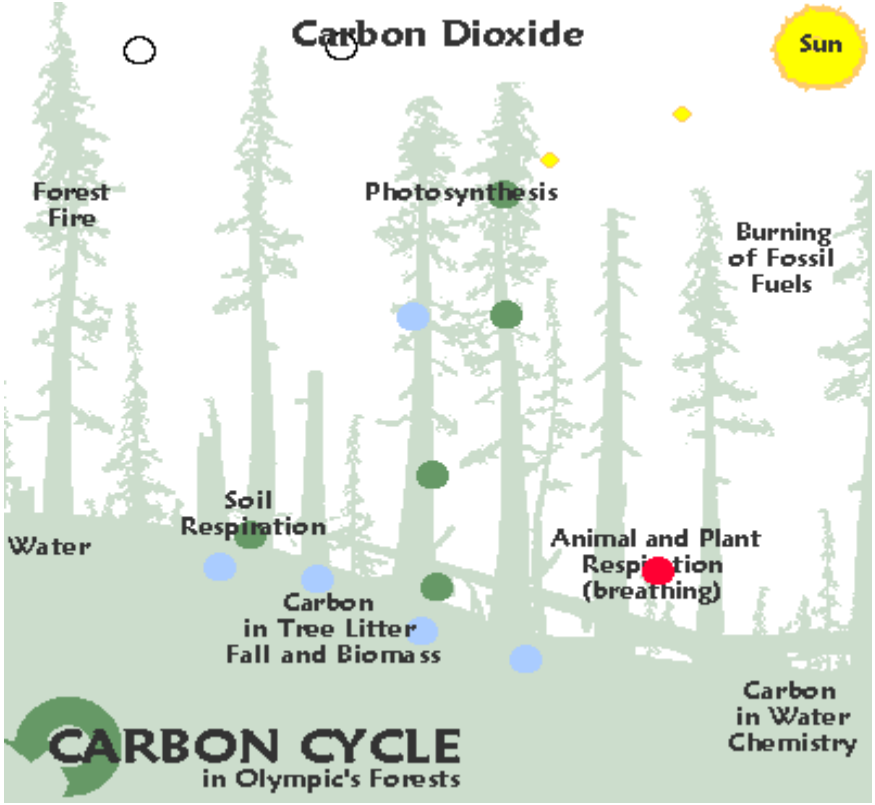
Project outline and objectives

Objective: estimate biomass regionally 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)
  - Demonstration with ALOS-1 multi-temporal data (see Phase 3)
  - Remote sensing part completed; link with biosphere models on hold.

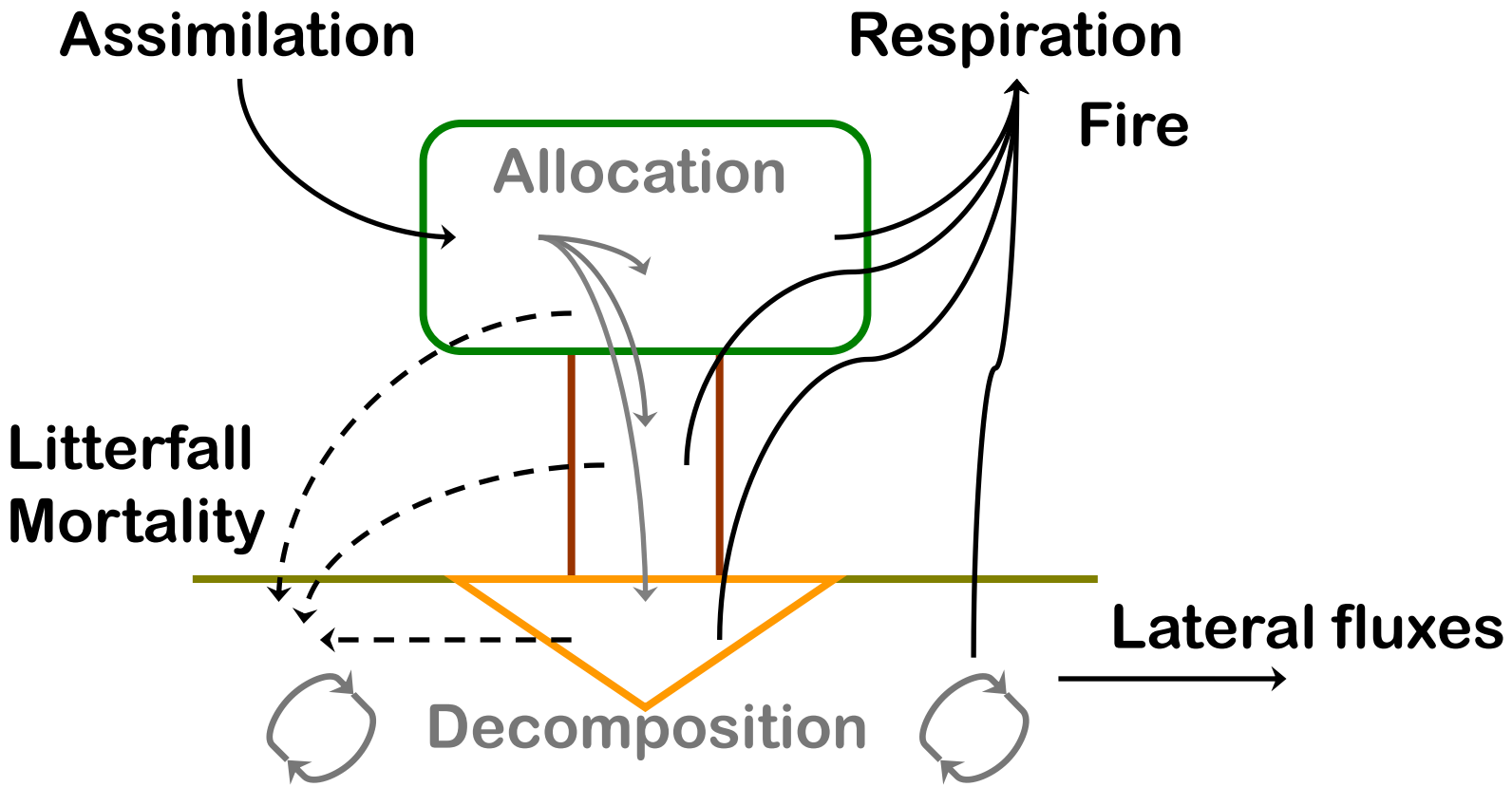
- Constrain carbon flux models to improve their estimation (“dynamic” component of project).
  - PALSAR-2, PALSAR-1 as well as JERS-1 acquired over Europe are used to derive **time series of biomass** estimates (1992-1998; 2007-2010; 2014-onwards).

Ecosystem C-cycle modeling



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

Ecosystem C cycling and fluxes



[Adapted from Lasslop 2010]

Data

- Meteorological measurements (model forcing)
  - Air temperature (Tair), precipitation (P), radiation (Rg), vapor pressure deficit (VPD), potential evapotranspiration (PET)
- Ecosystem fluxes (model constraints)
  - Net ecosystem exchange (NEE), evapotranspiration (ET), gross primary production (GPP) and ecosystem respiration (TER)

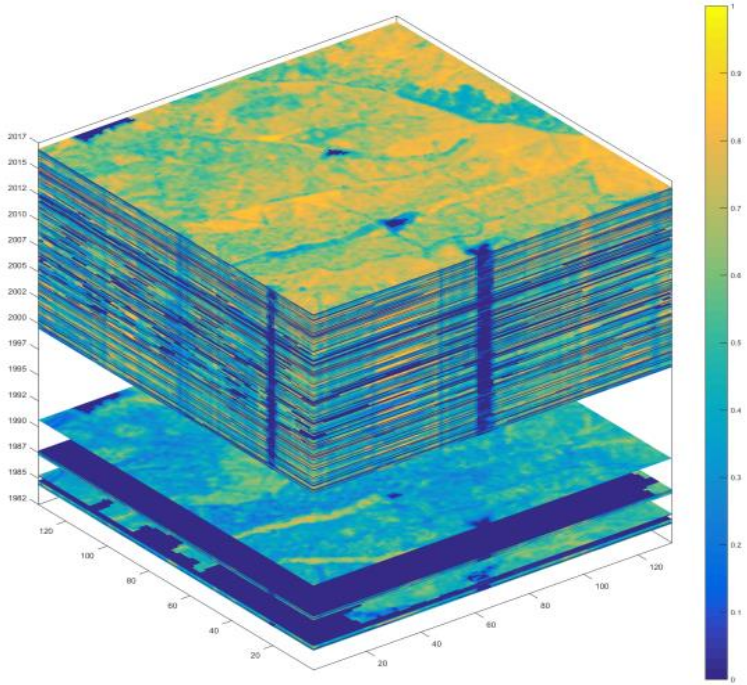
Experiment Site

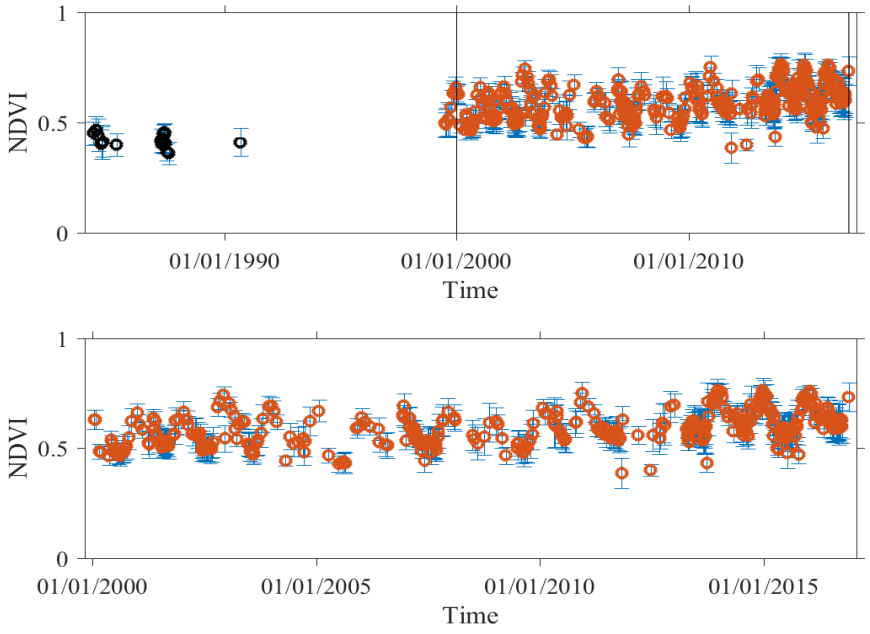
Mediterranean oak woodland are hetereogeneous ecosystem: trees, shrubs and grass

Herdade da Machoqueira do Grou , PT (39º08'N, 08º19'W)

Data

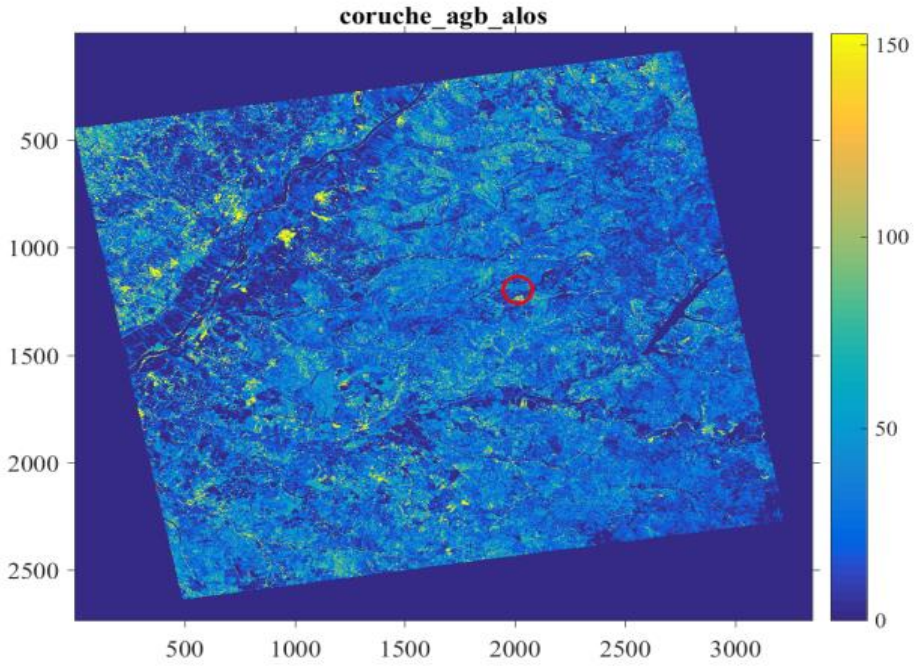
- Remotely sensed vegetation index (model constraint): Normalize Difference Vegetation Index (NDVI); Landsat-based

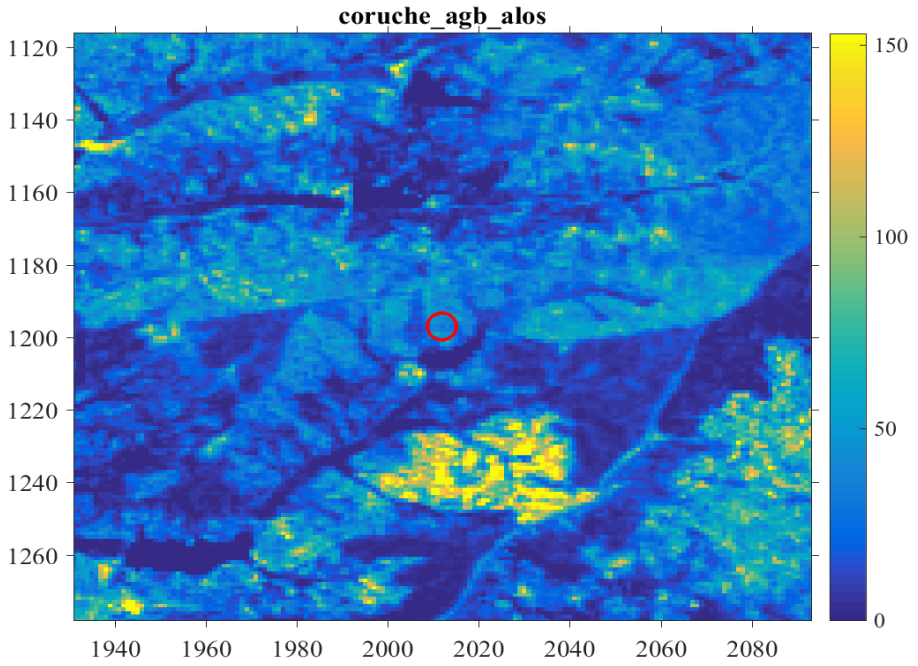




Data

- Aboveground biomass (AGB) from multi-temporal ALOS PALSAR (model constraint)





Model

- The ecosystem model used here is a prognostic version of the Carnegie Ames Stanford Approach (CASA) model [*Carvalhais et al.*, 2010; *Field et al.*, 1995; *Potter et al.*, 1993] where FAPAR (a linear function of NDVI) is dynamically estimated from the development of plant carbon pools

Experiments

Constraints for:

- cfID1: NEE; GPP; ET;
- cfID2: NEE; GPP; ET; NDVI
- cfID3: NEE; GPP; ET; AGB
- cfID4: NEE; GPP; ET; NDVI; AGB

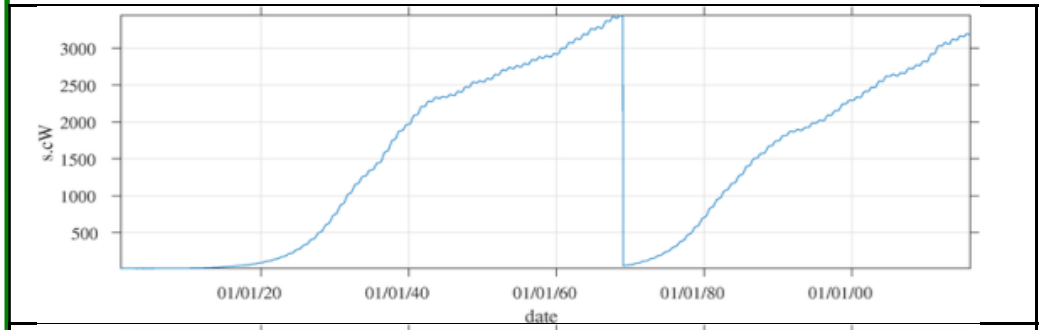
Results

		NSE				r	NRMSE
Exp#	**Constraints**	**NEE**	**GPP**	**ET**	**TER**	**fAPAR**	**cW**
cfID1	NEE,GPP,ET	0.32	0.33	0.20	0.14	-0.37	0.13
cfID2	NEE,GPP,ET,fAPAR	0.32	0.33	0.18	0.13	0.06	0.03
cfID3	NEE,GPP,ET,cW	0.33	0.32	0.19	0.10	-0.26	9E-06
cfID4	NEE,GPP,ET,fAPAR,cW	0.31	0.33	0.18	0.14	0.08	5E-07
ML		0.42	0.37	0.52	0.17		

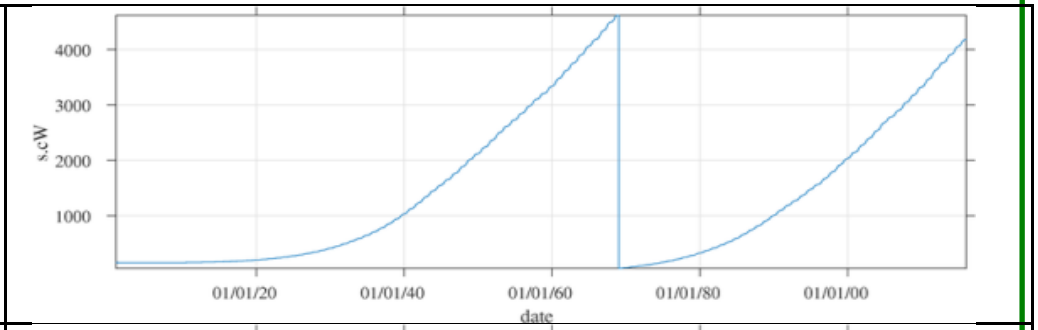
1) AGB improves substantially without significantly detrementing the performance on the other fluxes
2) The model is able to cope with AGB and NDVI (FAPAR) as constraints (cfID4) and provide a description of C and water fluxes similar to the standard constraints (cfID1)
3) The model is not perfect but the difference to a machine learning approach (ML) is small except in ET.

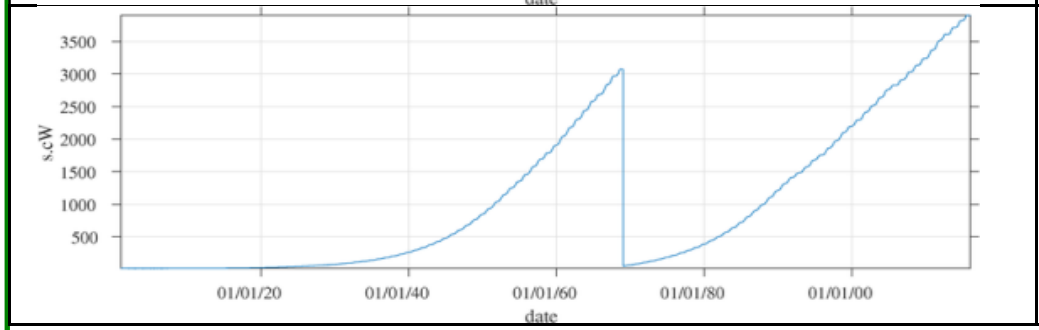
Results for the Coruche site

cfID1

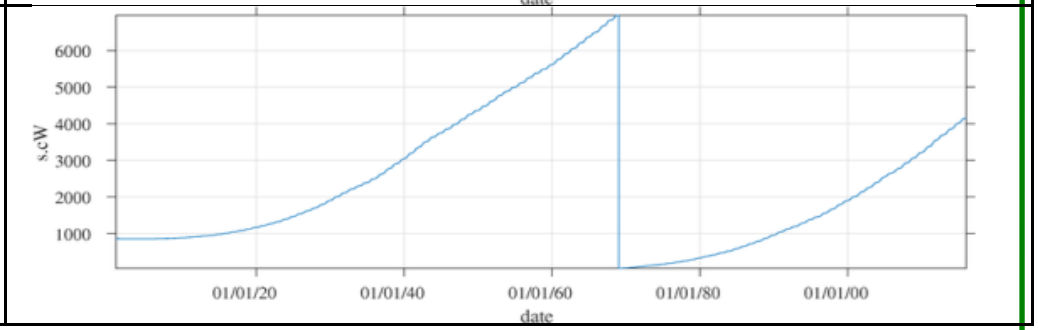


cfID2





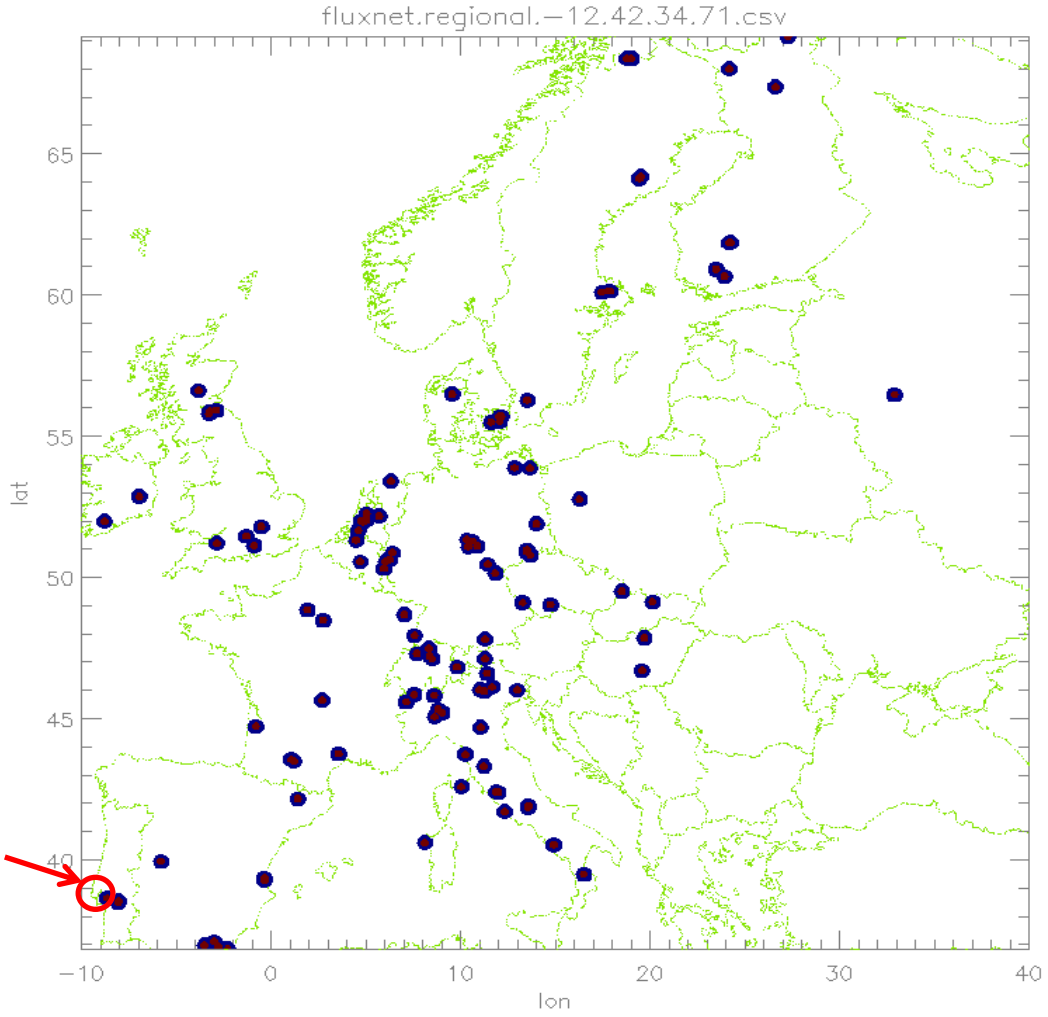
cfID3



cfID4

Both total AGB, as well as the trajectories before and after disturbances change between experiments, revealing the importance of multiple constraints on solving for equifinality, and the importance of repeated measurements

From site level to continental scale ….



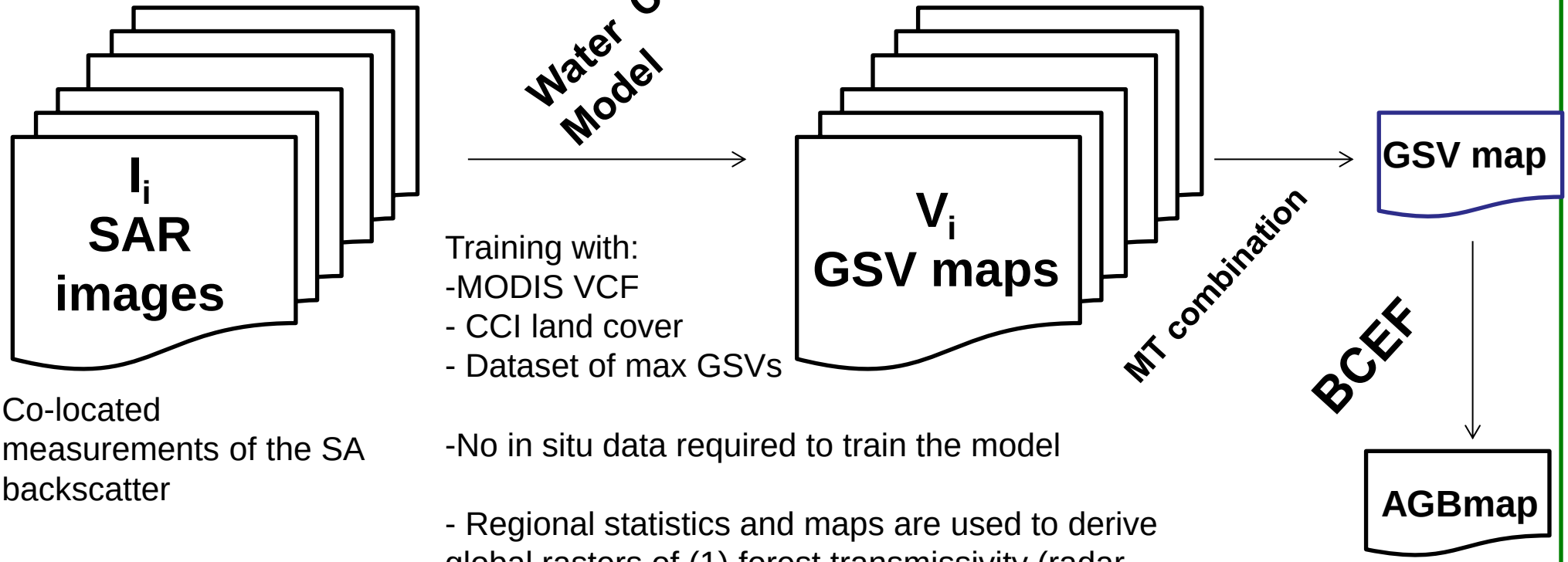
Coruche

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: 1 yearly dataset (2015) so far, HH- and HV-pol.
  - Mosaic obtained and ingested
- Multi-channel filter applied to improve ENL

The BIOMASAR approach

Retrieving forest growing stock volume from SAR backscatter



Co-located measurements of the SA backscatter

Training with:
-MODIS VCF
- CCI land cover
- Dataset of max GSVs

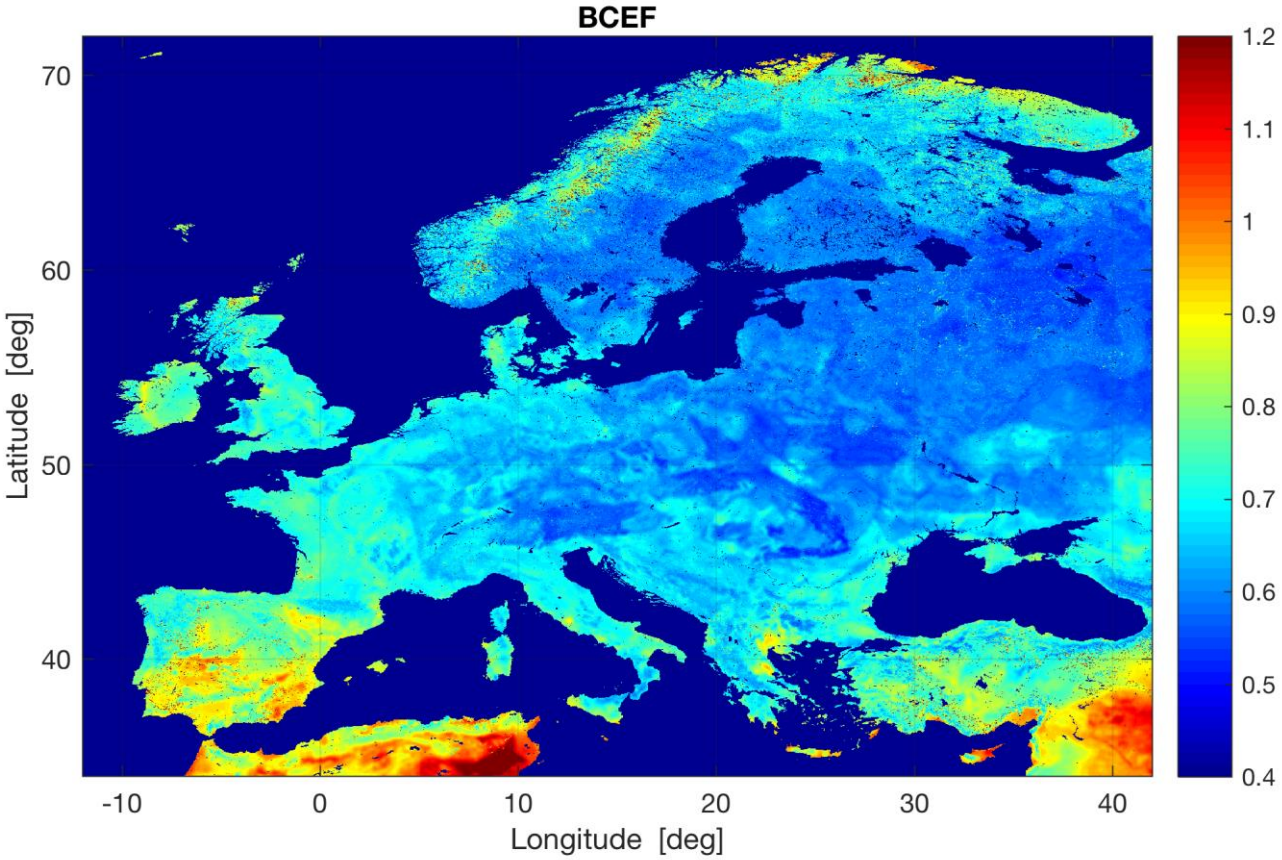
-No in situ data required to train the model

- Regional statistics and maps are used to derive global rasters of (1) forest transmissivity (radar parameter) and (2) max retrievable GSV

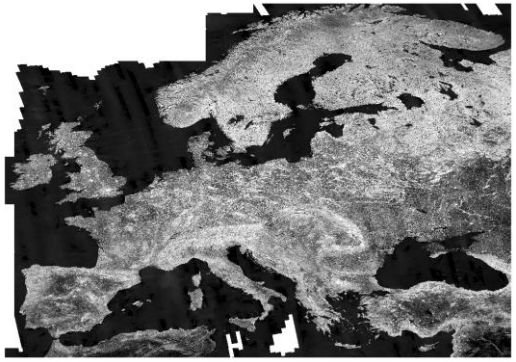
BCEF = Biomass Conversion and Expansion Factor =

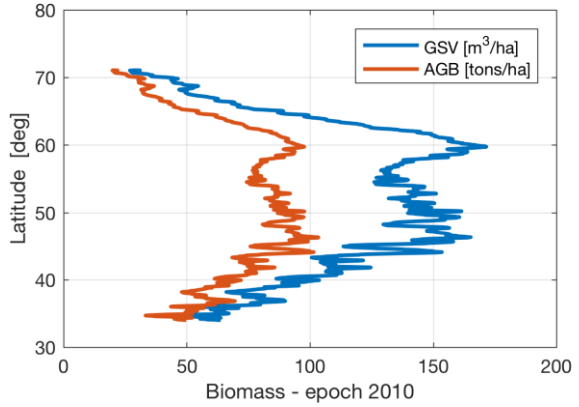
wood density * total-to-stem biomass ratio

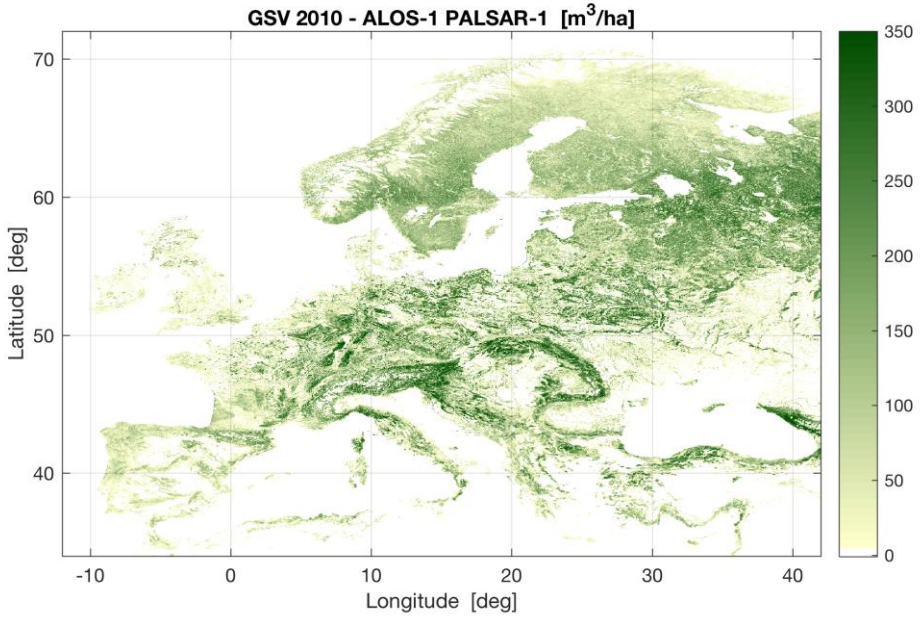
AGB = BCEF * GSV

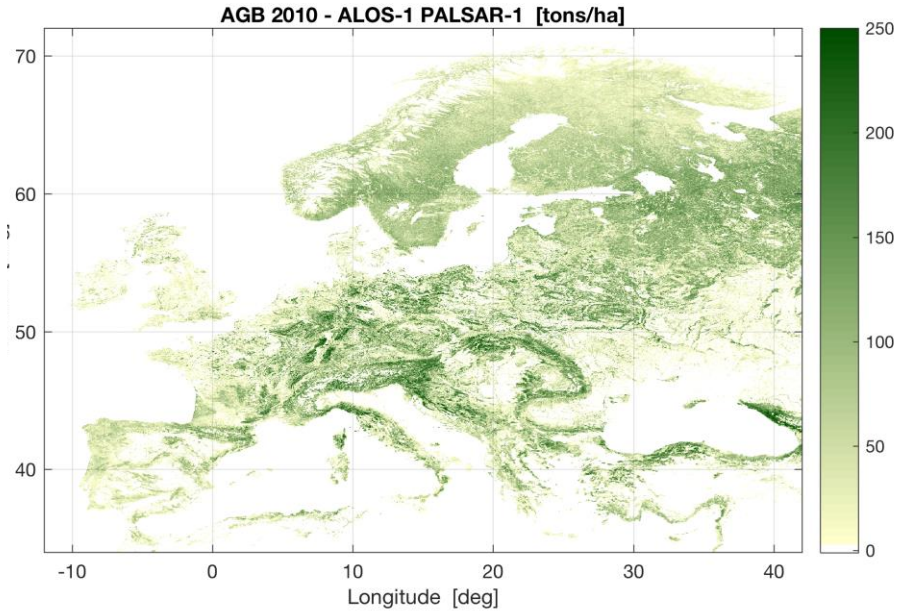


ALOS-1 PALSAR-1 biomass dataset of Europe, epoch 2010

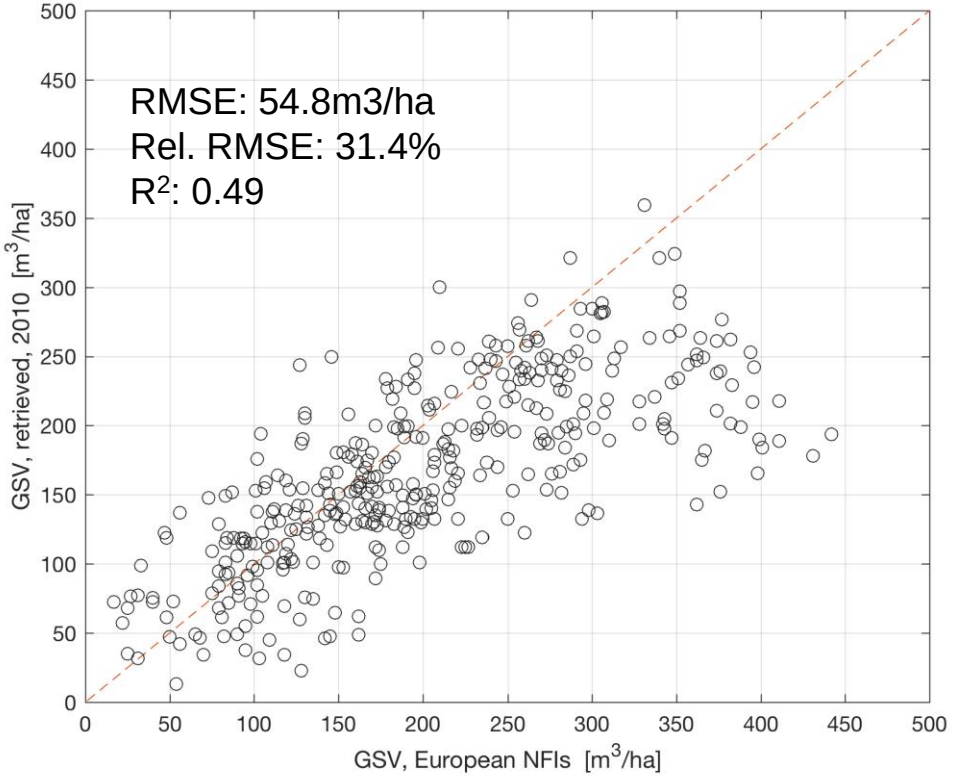






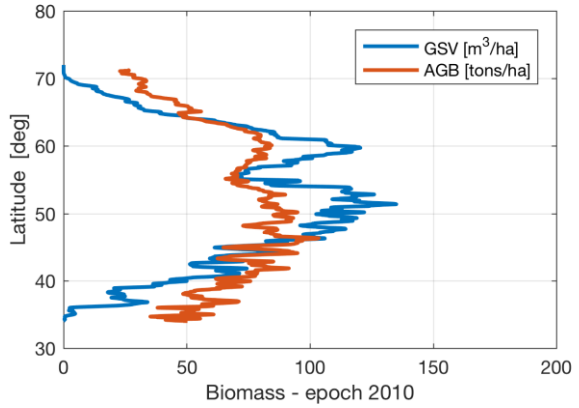


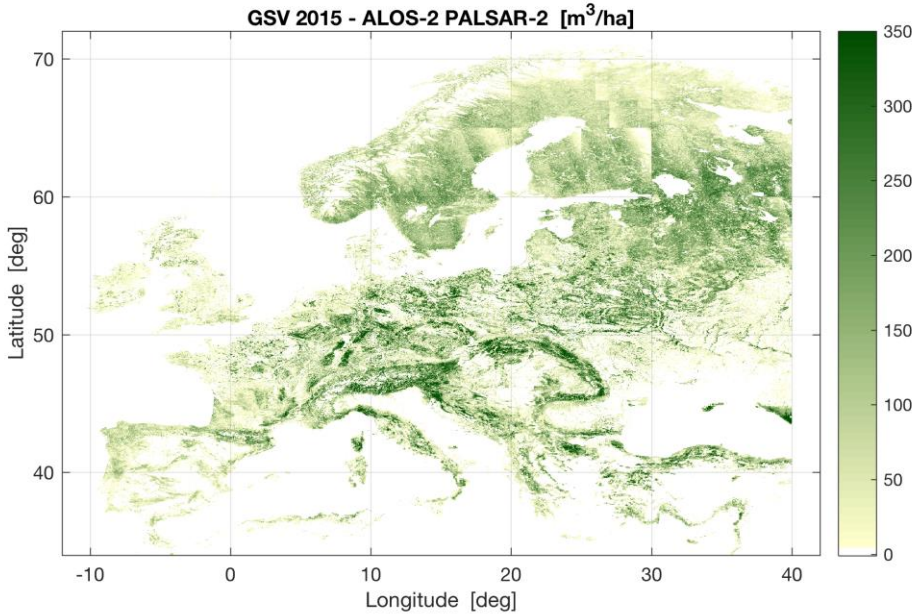
Validation

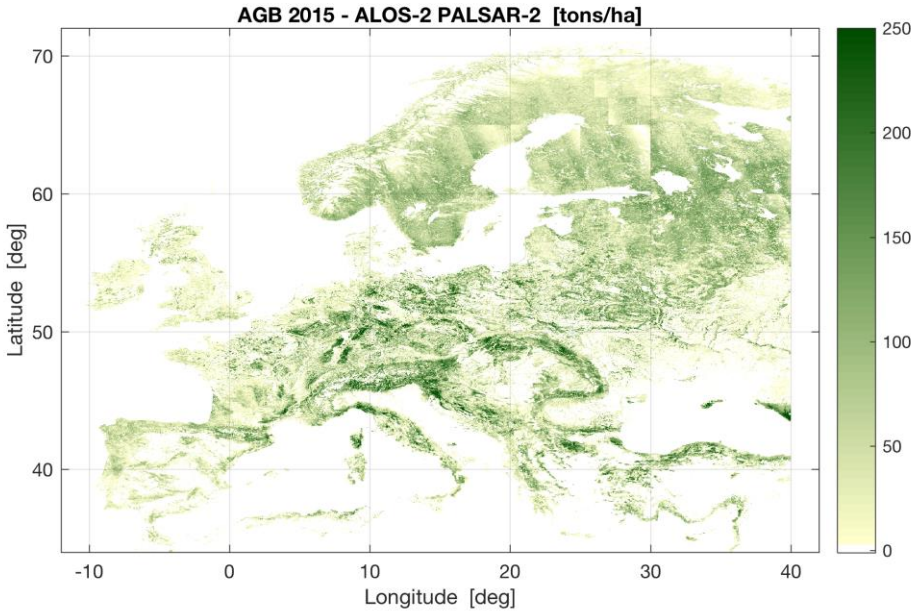


- Same results when comparing in terms of AGB
- Underestimation in high biomass regions due to L-band single observation, retrieval model or precision of NFI reference data currently being clarified

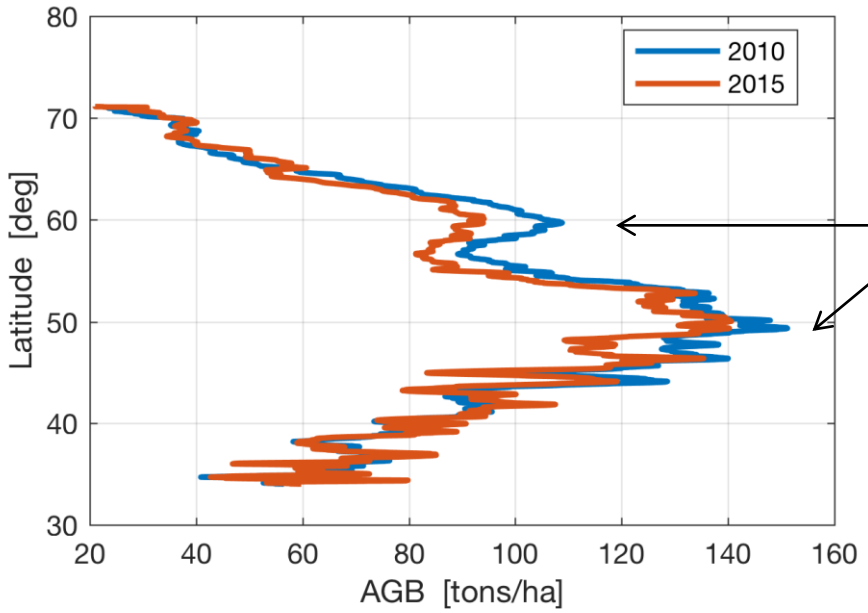
ALOS-2 PALSAR-2 biomass dataset of Europe, epoch 2015







Latitudinal profiles of AGB estimates



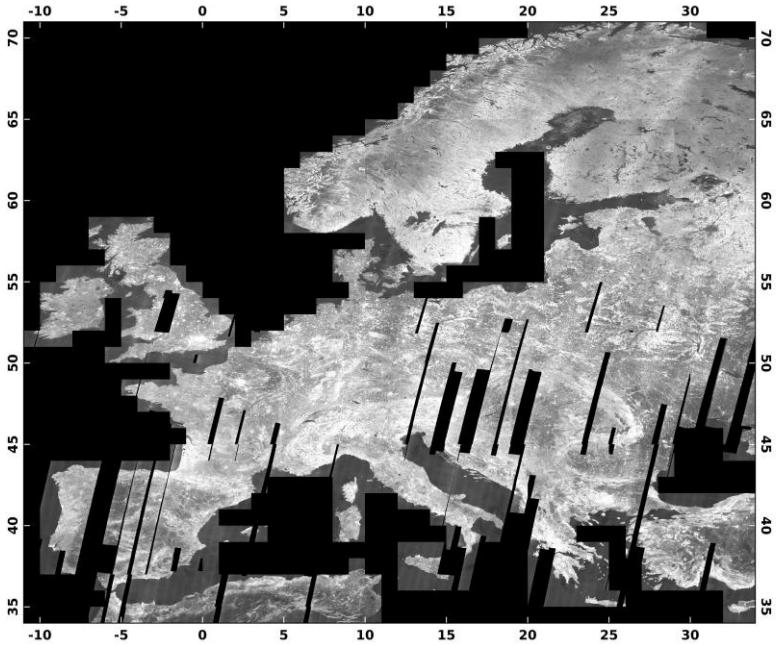
Due to artefacts in the 2015 mosaic

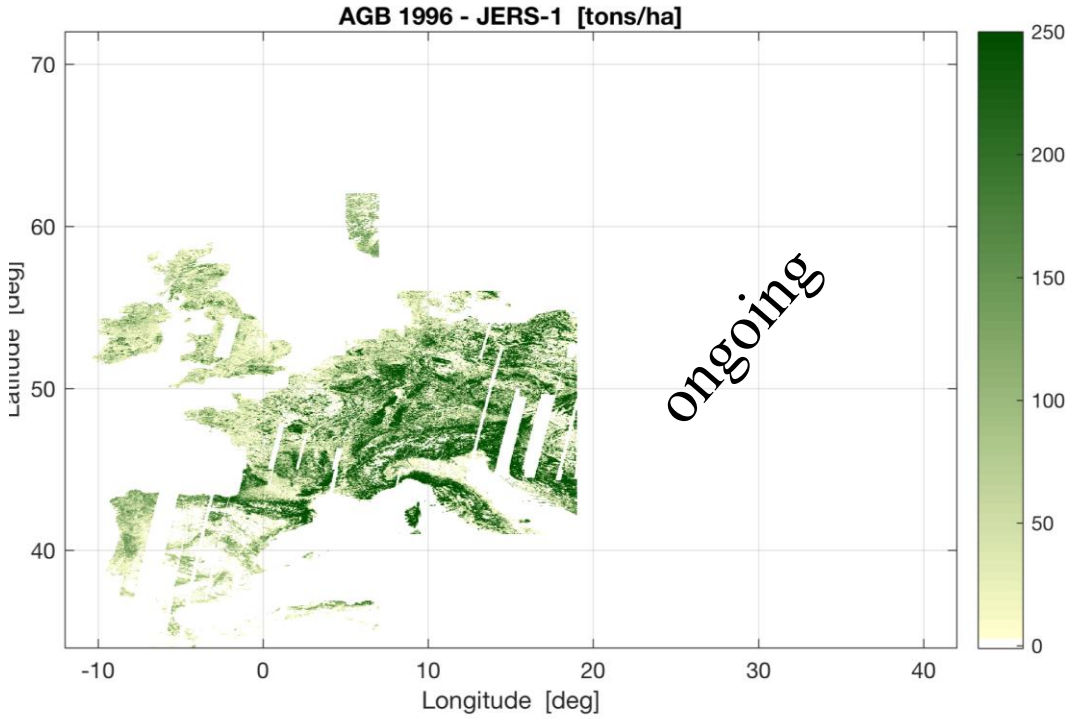
We would expect that the red profile (2015) is positively offset with respect to the blue profile (2010) because of the overall increase of biomass in Europe. Why isn‘t it?

1)Patchiness of the 2015 mosaic → need to implement multi-year ALOS-2 mosaics

2)Different model training approaches applied for 2010 and 2015 → need to run the same

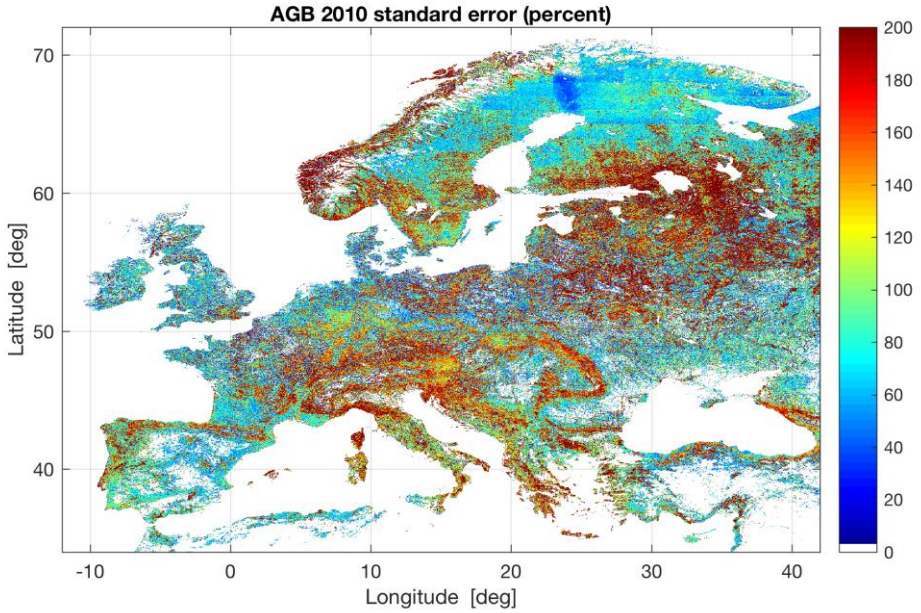
JERS-1 biomass dataset of Europe, epoch 1996

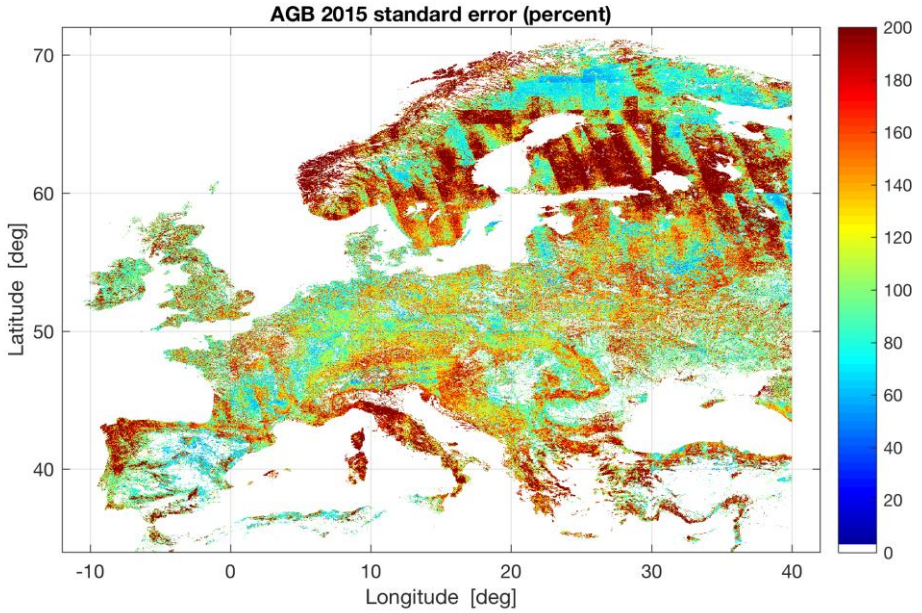




- Estimation of biomass attempted
- One channel (HH) captures mostly the extremes
- The coverage is not full

Standard error of AGB estimates





- Very large uncertainties due to having one single backscatter observation

Strengths and weaknesses

Strengths

- Spatial distribution of biomass reproduced
- High level of detail thanks to the 25 m spatial resolution of ALOS PALSAR mosaics
- Temporal consistency if data acquired under similar weather conditions and viewing geometry

Weaknesses

- Patchiness of yearly mosaics does not allow for time series → multiple years need to be compiled to obtain a homogeneous distribution of an epoch (i.e., 2008+2009+2010 for epoch 2010)
- Artefacts in EO data translated into biomass artefacts (seams, topography etc.)
- A biomass based on a single backscatter value carries the property of that observation (so possibly unrelated with forest and related with dielectrics)
- It seems that one L-band observation is not able to resolve the high biomasses
- Very large uncertainties

Project status-quo and way ahead

1) Biomass retrieval algorithm for ALOS data in place (BIOMASAR-L algorithm)
2) Retrieval with ALOS-1 mosaics is well understood and verified
3) Retrieval with ALOS-2 mosaics is less well understood and requires some additional algorithmic step to be implemented (extension, will be supported by ESA CCI Biomass project)
4) Retrieval with JERS-1 data needs further investigation (extension, will be supported by ESA CCI Biomass project)
5) Need to rely on multi-year mosaics to compile an epoch → difficult to support time series studies such as carbon flux modeling but will be attempted having available 3 epochs
6) Implementation of biomass estimates at flux towers in biosphere flux models currently being implemented (extension required)

Project milestones & Data sharing

- Final evaluation of biomass estimates from K&C Phase 3 data products
- Set up of database of JERS-1 and ALOS-1 mosaics
- Set up of database of ALOS-2 mosaic (2015: done, 2016: to be downloaded)
- Improvement of biomass maps from ALOS-1, ALOS-2 and JERS-1; possible complement with other sensors (see GlobBiomass data product for 2010 including ALOS-1 mosaic for epoch 2010)
- Yearly feedback to JAXA on quality of their data products.

In situ information collected in the Könizberg Wald, south of Bern, provided at this meeting

Green = completed, Red = to be undertaken in extension

Deliverables

- A forest biomass map of Europe produced with JERS-1 data for the 1995 epoch
- 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
- Report on model-data integration
- Yearly feed-back to JAXA on quality of their data products.

NOTE: the 3 maps will be delivered once all completed and cross-checked

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 2015 (old version), currently retrieving 2015 (newest) and 2016

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

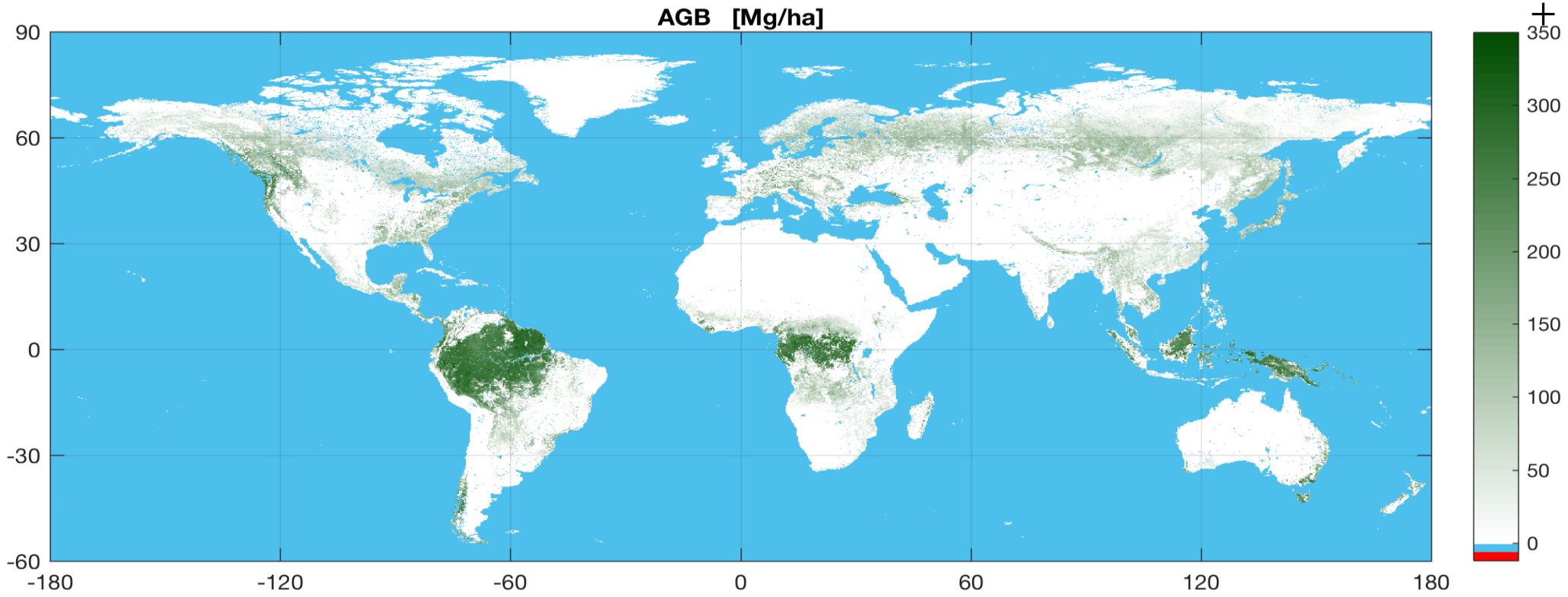
Yes

ALOS

K&C Initiative

An international science collaboration led by JAXA

GlobBiomass AGB



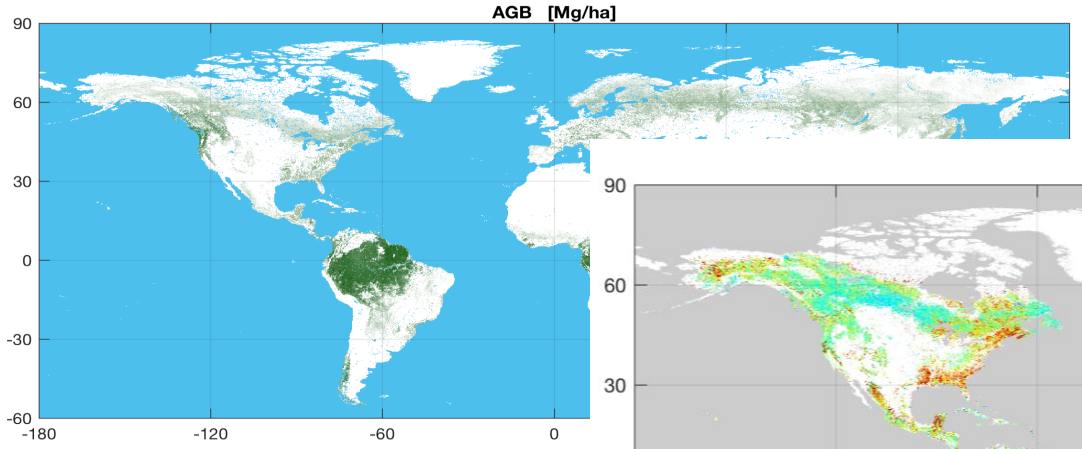
Based on ALOS-1 mosaic, Envisat ASAR, Landsat, ICESAT

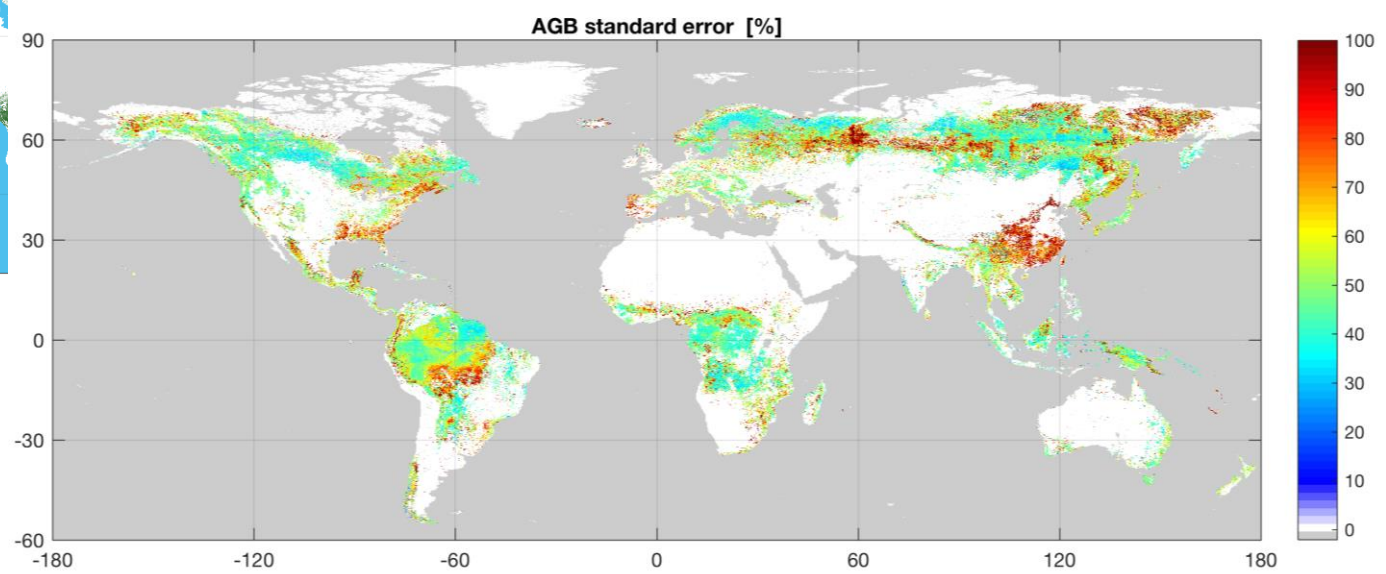
Epoch 2010, 30-40% relative RMSE at 100 m scale

☺Reliable estimates everywhere

☹ local flaws in areas of strong topography or flooded regions

GlobBiomass AGB





Available spring 2018, see http://www.globbiomass.org

For questions and feedback, contact santoro@gamma-rs.ch