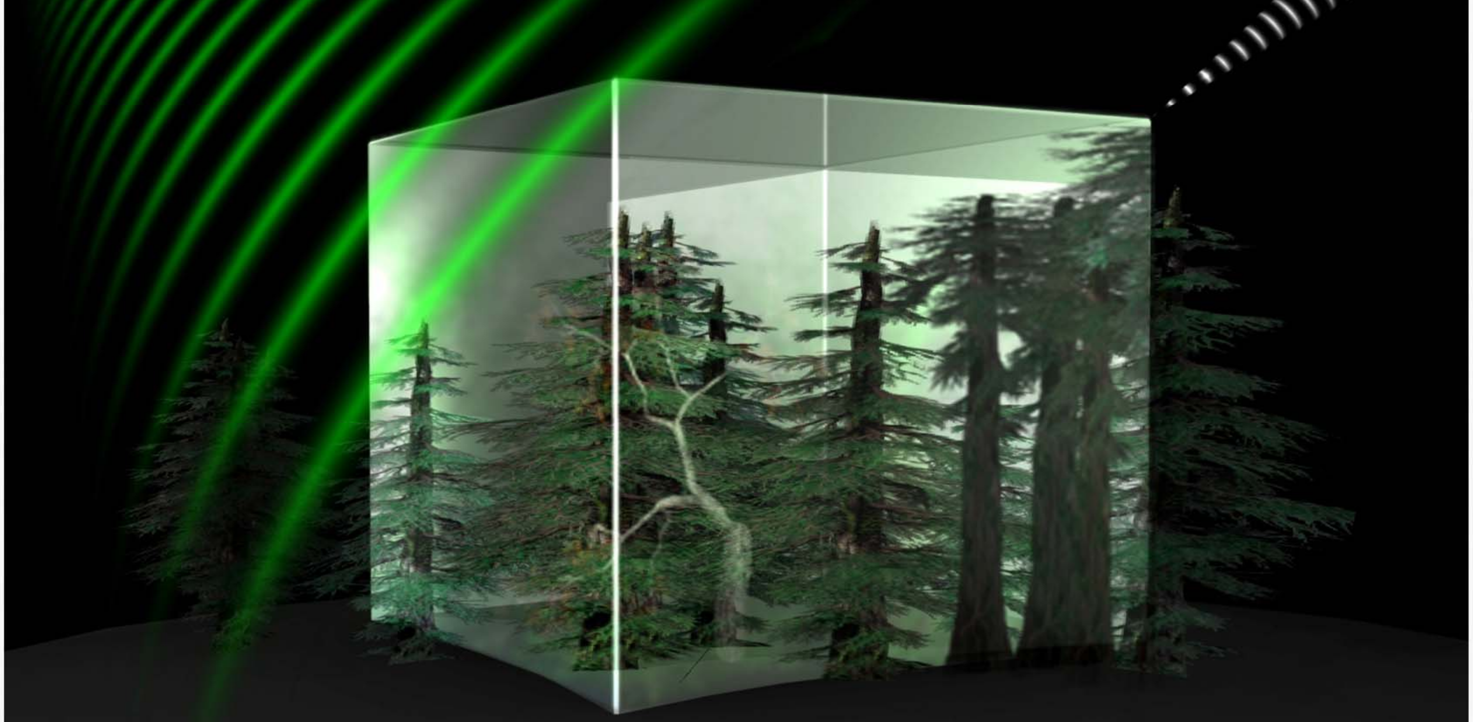
→ POLINSAR 2013

The 6th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry

Status of the retrieval algorithms of the Biomass mission



Thuy Le Toan, Lars Ulander, Kostas Papathanassiou, Fabio Rocca,
Sassan Saatchi, Shaun Quegan, Klaus Scipal
& the BIOMASS MAG

Biomass product requirements

Forest biomass

- 200 m resolution
- accuracy of 20%, or 10 t ha^{-1} for biomass < 50 t ha^{-1}
- 1 biomass map every 6 months
- global* coverage of forested areas

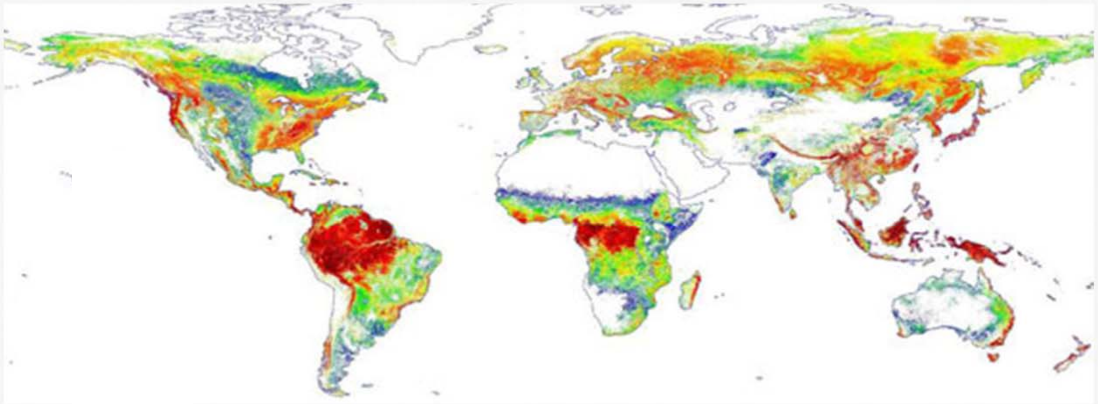
Forest height

- 200 m resolution
- biome dependent, ~20% for tree > 10 m
- 1 height map every 6 months
- global* coverage of forested areas

Disturbances

- 50 m resolution
- 90% classification accuracy
- 1 map every 6 month
- global* coverage of forested areas

* global subject to SOTR restrictions



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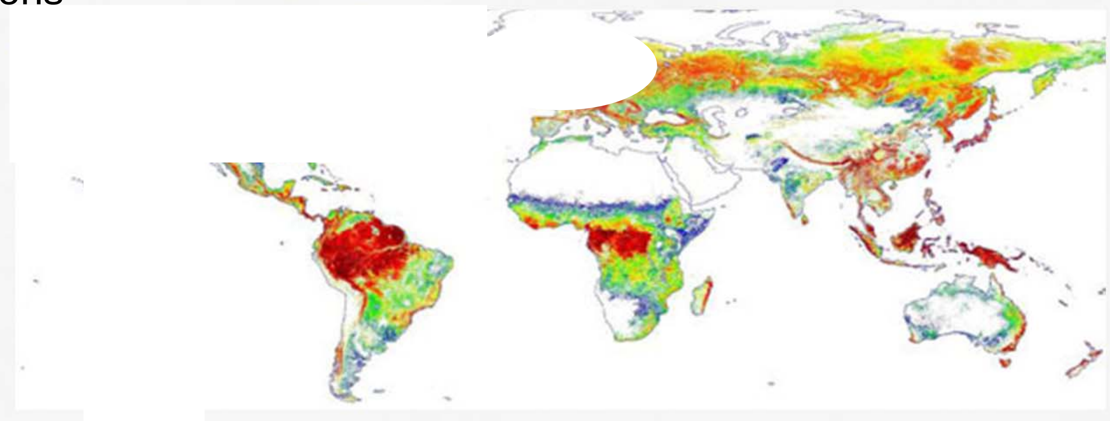


Forest biomass is a key component in the carbon cycle

1. Biomass is ~50% carbon
2. Forests hold 70–90% of Earth's above-ground biomass, with the majority of forest biomass located within the Tropics
3. Forest biomass is very poorly known and is a major source of uncertainty in carbon flux estimation.
4. Our objective is to measure biomass globally, and its change over time.

Biomass = dry weight of woody matter + leaves (tons/hectare)

Required measurement properties

1. The crucial information gap is in the tropics:
   - –deforestation (~98% of the Land Use Change flux)
   - –regrowth (~52% of the global biomass sink)
2. Biomass measurements are needed where the changes occur and at the scale of change: 1-4 hectares.
3. An accuracy of 20% at 4 hectares, comparable to ground-based observations.
4. Forest height to provide a further constraint on biomass estimates
5. Repeated measurements over multiple years to identify deforestation and growth

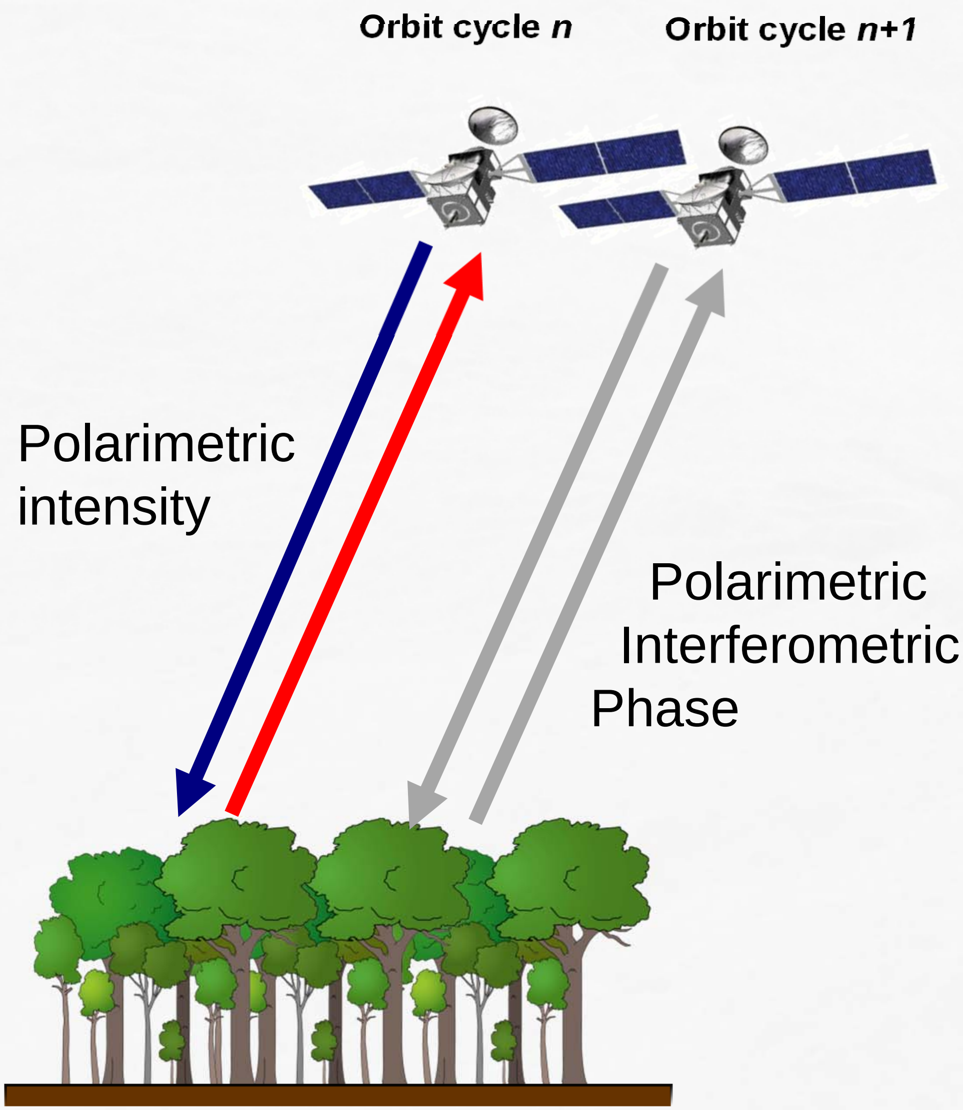
Why are tropical data most uncertain and so important?

Tropical biomass
= 360-680
billion tons

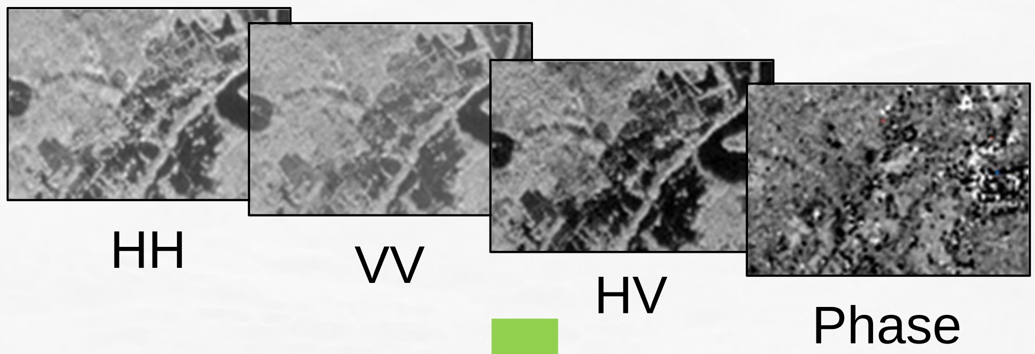
Uncertain due to
1. biodiversity
2. poorly coordinated/ sparse measurements

C sink/source	2000-2007 GtC/yr
Boreal	0.5±0.08
Temperate	0.72±0.08
Tropical Intact	**1.02±0.47**
Tropical regrowth	**1.72±0.54**
Tropical de-forestation	**-2.82±0.45**
Tropical land use change	**-1.10±0.70**

A single satellite providing continuous polarimetric interferometric P band SAR data over forested areas



Calibration, Ionospheric correction

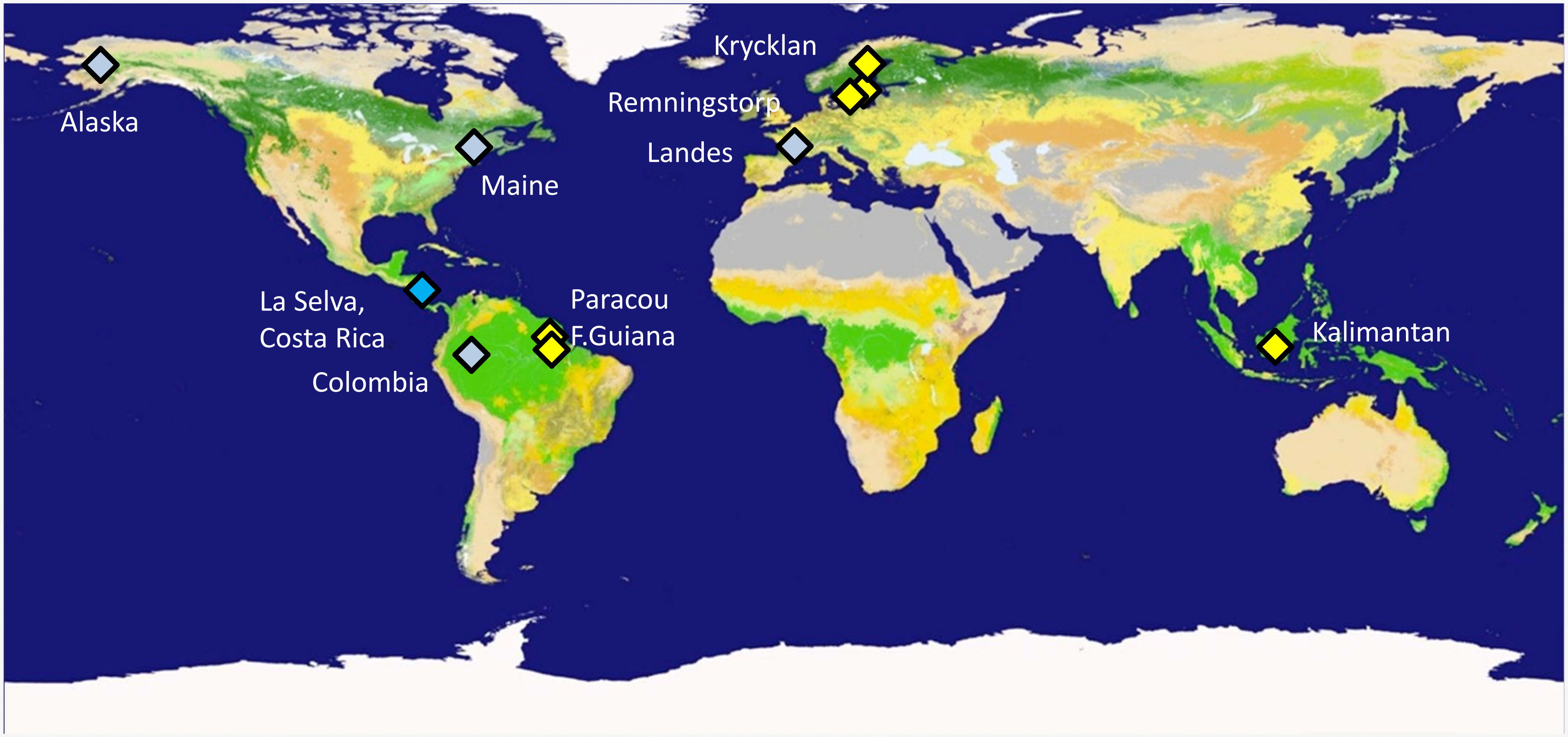


Retrieval algorithm

- Forest biomass
- Forest height
- Forest disturbance

Campaign data as material to develop methods

esa



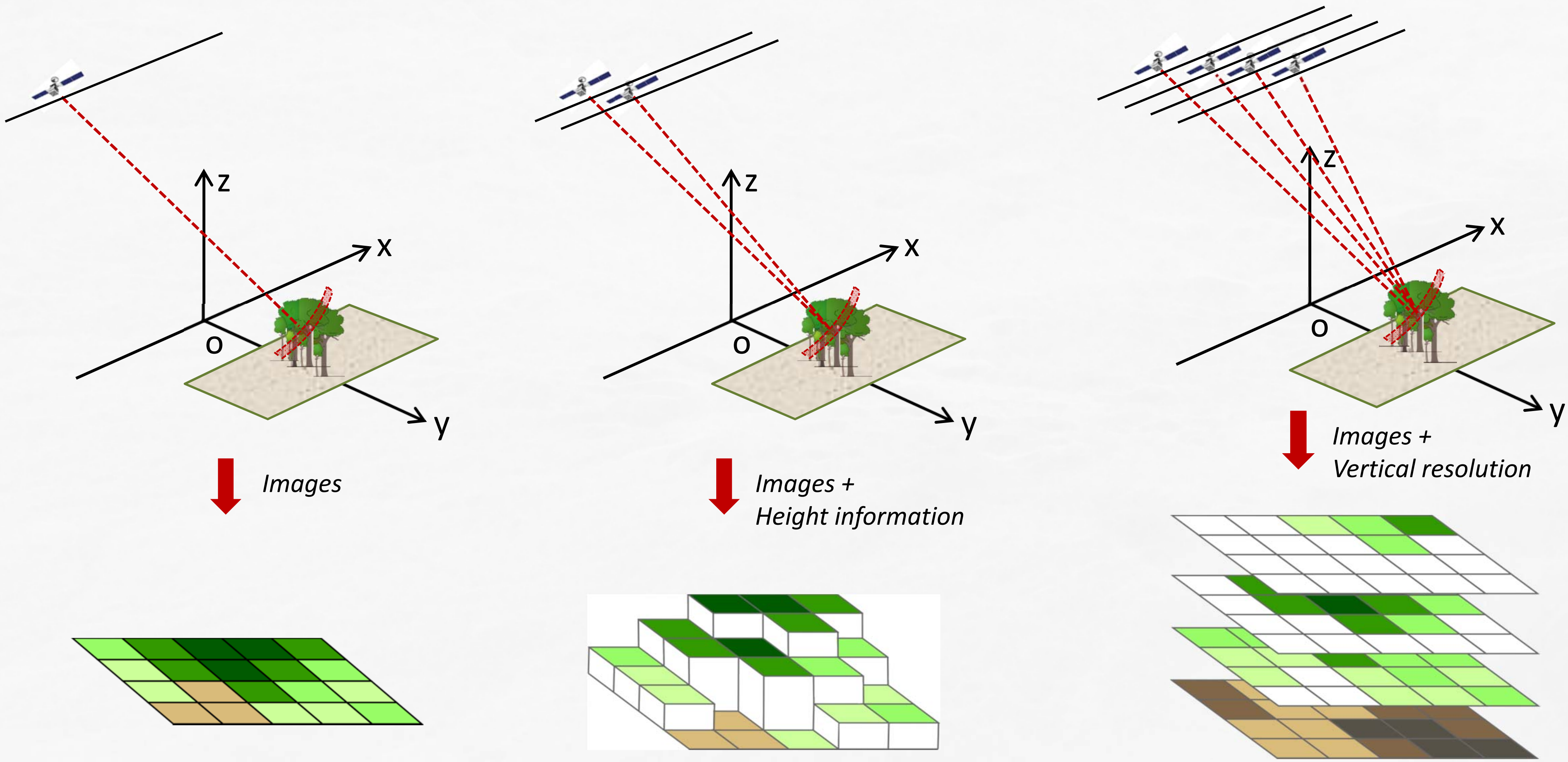
Major recent campaigns:

- Kalimantan 2004 (Indrex)
- Remningstorp 2007 (BioSAR 1), 2010 (BioSAR 3)
- Krycklan 2008 (BioSAR 2)
- F. Guiana 2009 (TropiSAR), 2011-13 (TropiScat)

Recent campaign datasets for method development

Campaign	Objectives	Test sites	Time	Forest conditions
INDREX-2 (Hajnsek et al., 2008)	Forest height retrieval in tropical forest and measurement of repeat-pass temporal decorrelation	Sungai-Wai & Mawas Borneo, Indonesia	Nov 2004	Tropical rain forest. Sungai-Wai: lowland with biomass up to 600 t ha^{-1}. Mawas: peat swamp with biomass up to 200 t ha^{-1}
TropiSAR (Dubois-Fernandez et al., 2012)	Biomass estimation in tropical forest, multiday decorrelation	Paracou & Nouragues French Guiana	Aug 2009	Tropical rain forest with biomass up to 500 t ha^{-1}, lowland and hilly terrain
Tropiscat (Albinet et al., 2012)	Ground-based high temporal resolution measurements to determine long-term temporal decorrelation	Paracou, French Guiana	Oct. 2011–Oct. 2012	Tropical rain forest with biomass up to 500 t ha^{-1}
BioSAR-1 (Hajnsek et al., 2008)	Biomass estimation in hemi-boreal forest and measurement of multimonth temporal decorrelation	Remningstorp, southern Sweden	Mar–May 2007	Hemi-boreal forest, low topography with biomass up to 300 t ha^{-1}
BioSAR-2 (Hajnsek et al., 2009)	Topographic influence on biomass estimation in hilly boreal forests	Krycklan, northern Sweden	Oct 2008	Boreal forest, hilly, with biomass up to 300 t ha^{-1}
BioSAR-3 (Ulander et al., 2011a)	Forest change and multiyear coherence relative to BioSAR-1	Remningstorp, southern Sweden	Sep 2010	Hemi-boreal forest, low topography with biomass up to 400 t ha^{-1} (includes additional high biomass stands compared to 2007 campaign)

A same sensor on a single satellite to deliver 3 independent information for biomass

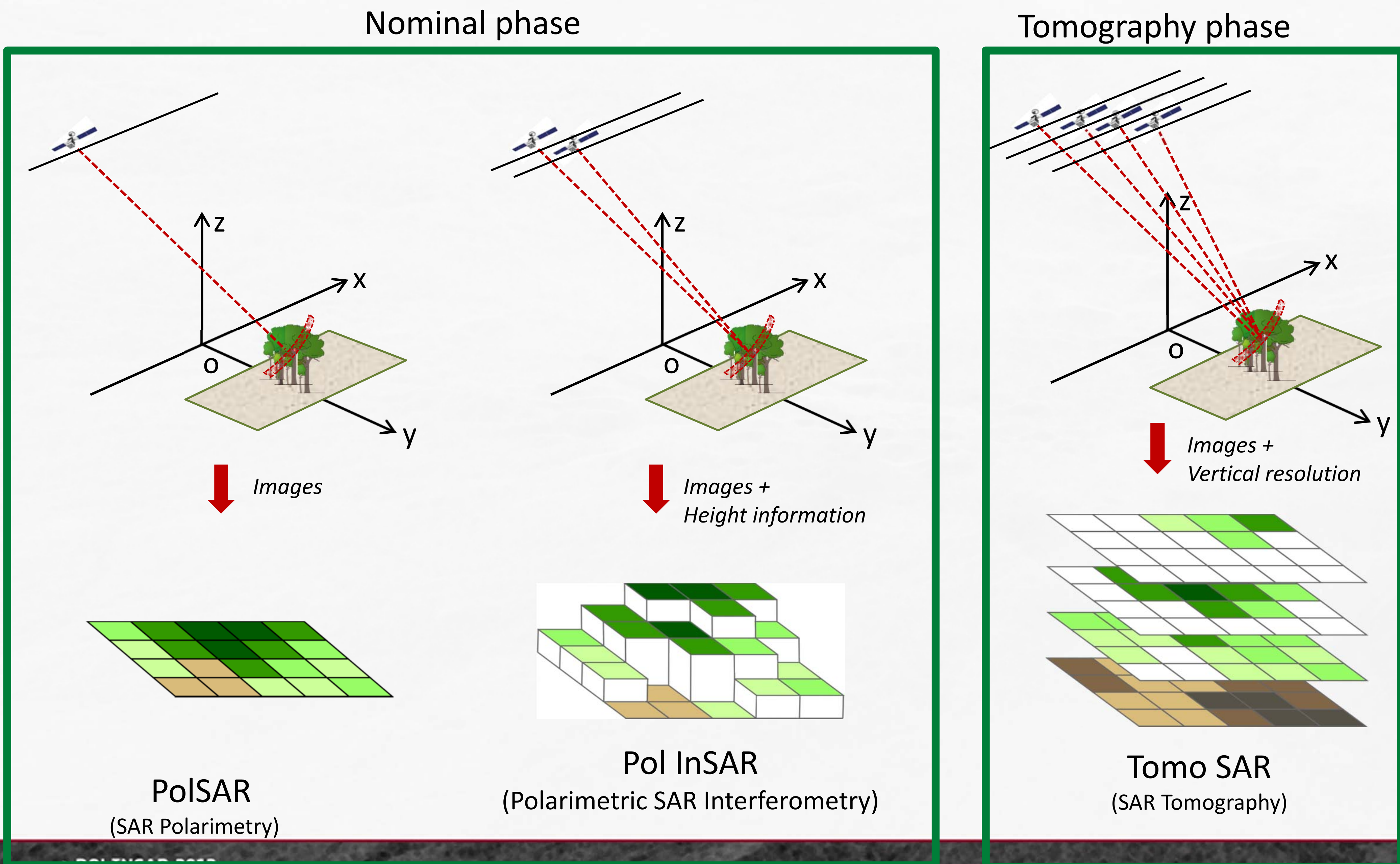


PolSAR
(SAR Polarimetry)

Pol InSAR
(Polarimetric SAR Interferometry)

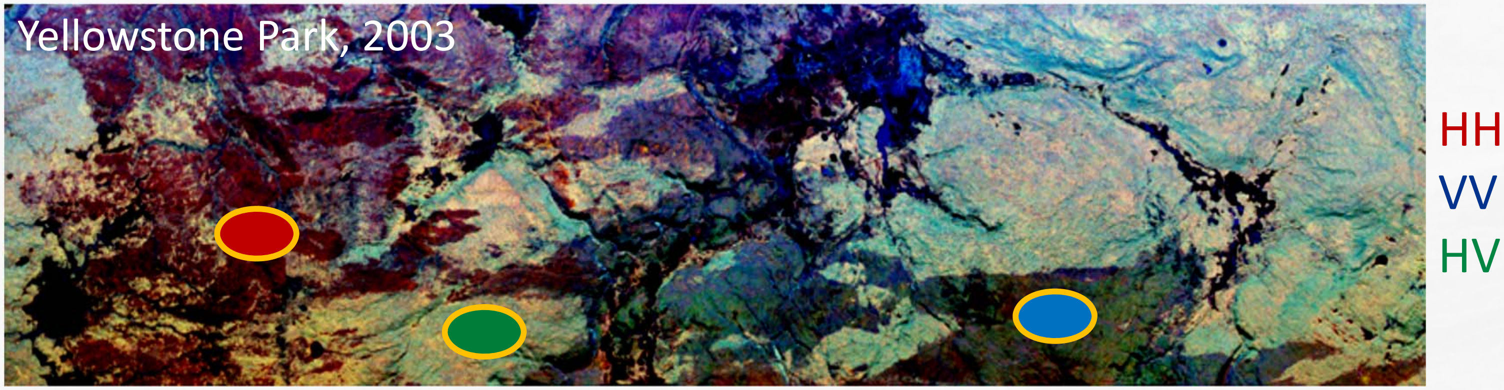
Tomo SAR
(SAR Tomography)

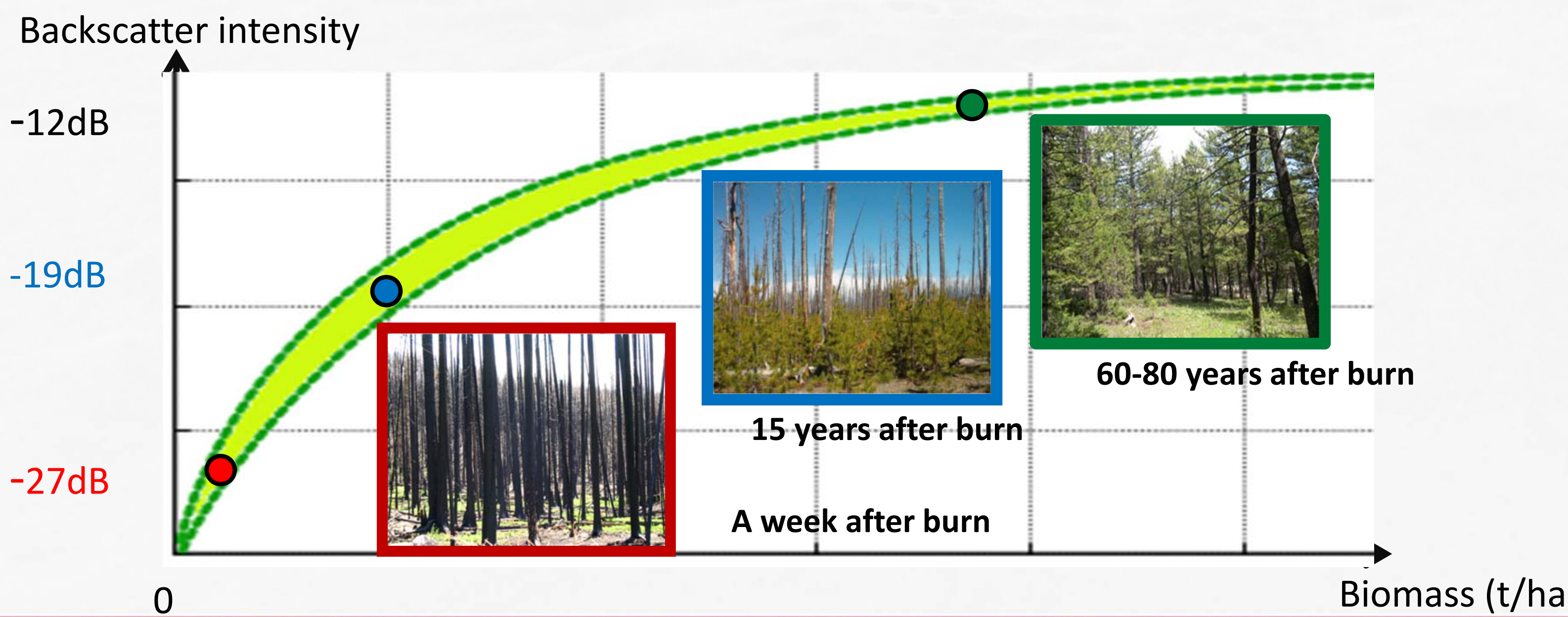
A same sensor on a single satellite to deliver 3 independent information for biomass



P-band SAR measures biomass and quantifies landscape dynamics

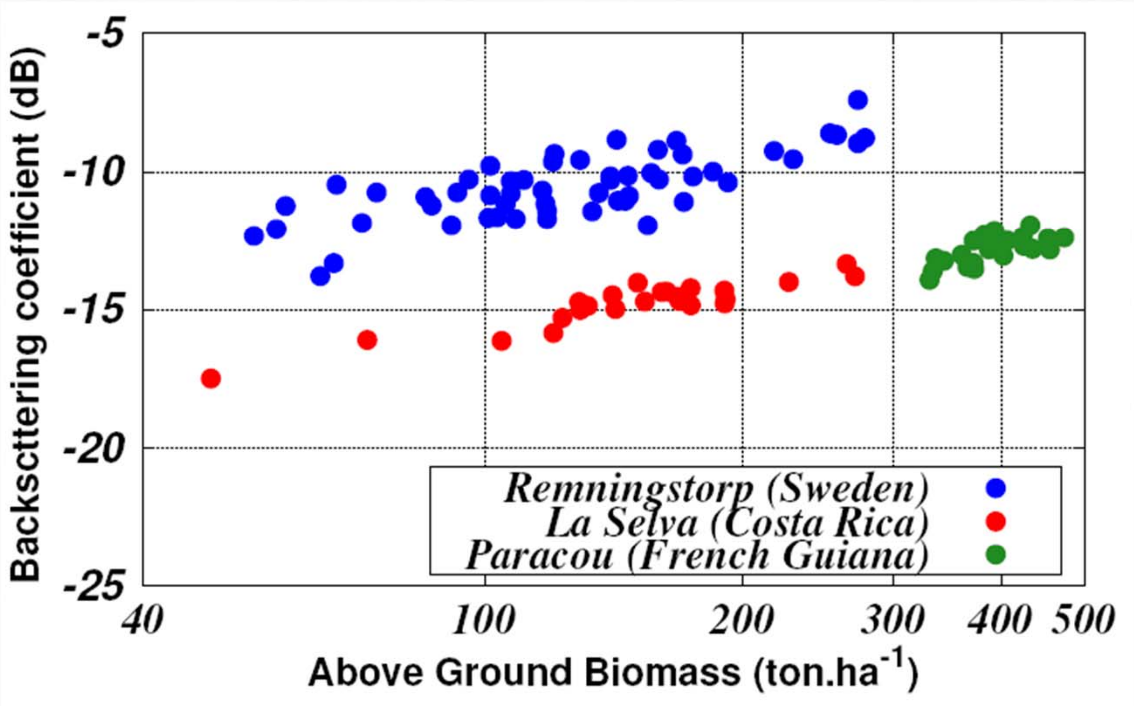
Large dynamic range as a function of biomass





Global consistency in the biomass-backscatter relationship

- Similar relationship is found for all forests where we have data
- Differences in forests implies the need to understand why this happens and to devise inversion techniques and stratification / training approach to deal with them



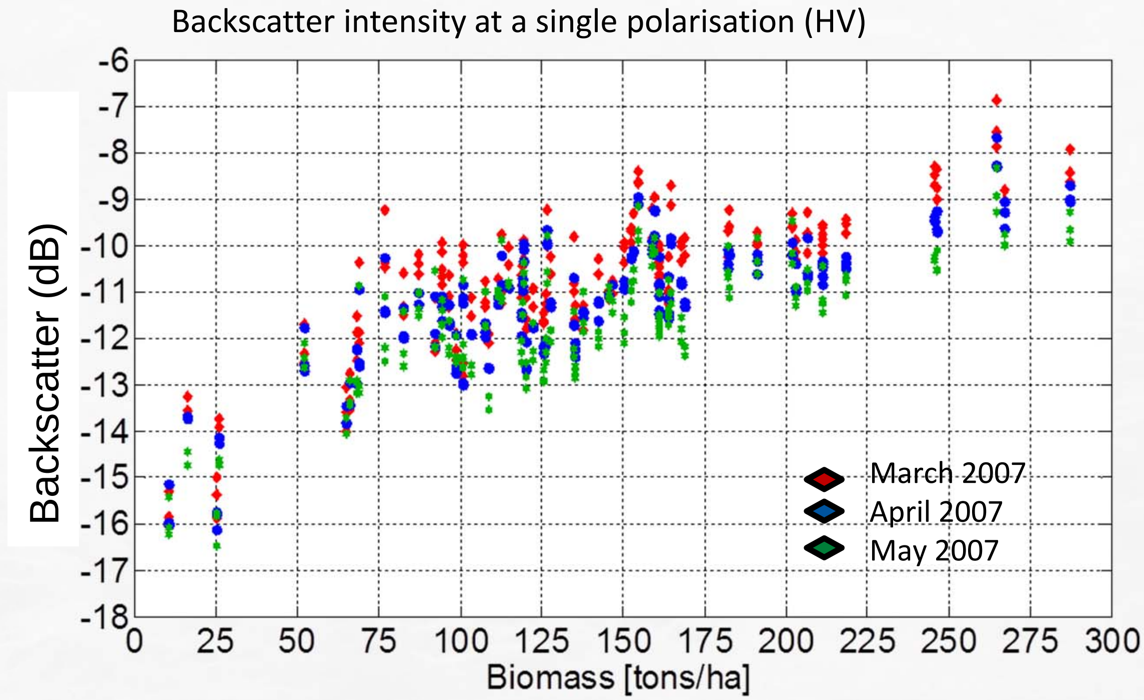
Soil moisture and topography change the backscatter intensity in boreal forest

Remningstorp forest (Sweden)

March 2007

April 2007

May 2007



All polarisations are used to reduce environment and topographic effects

$$\log B = a_0 + a_1 \log HV + a_2 . \log(HH/VV) + a_3 . slope . \log(HH/VV)$$

DEM

Accounting for soil moisture variation

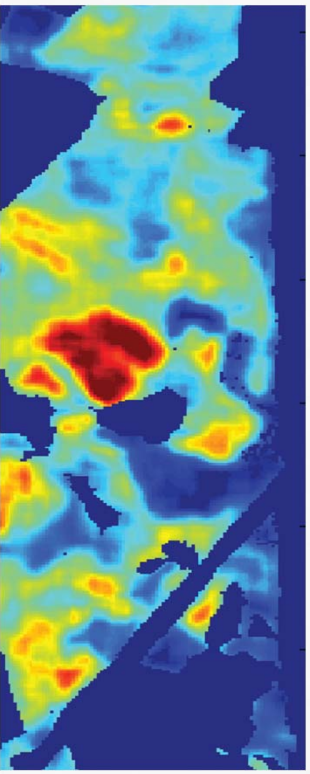
Accounting for topographic effect

Consistency of biomass estimates after correction of environment effects

Biomass map, Remningstorp, Sweden

Training at Krycklan

Inversion using
single polarisation (HV)



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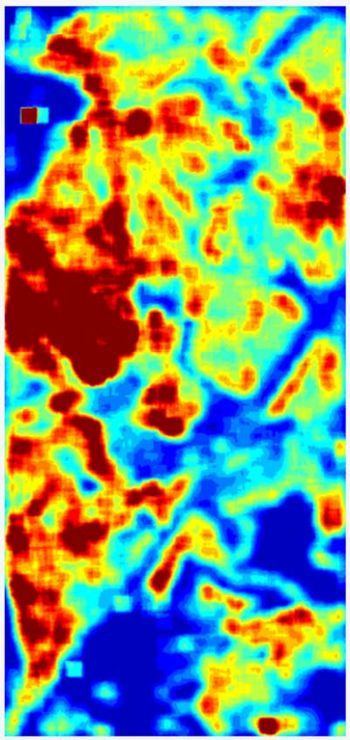
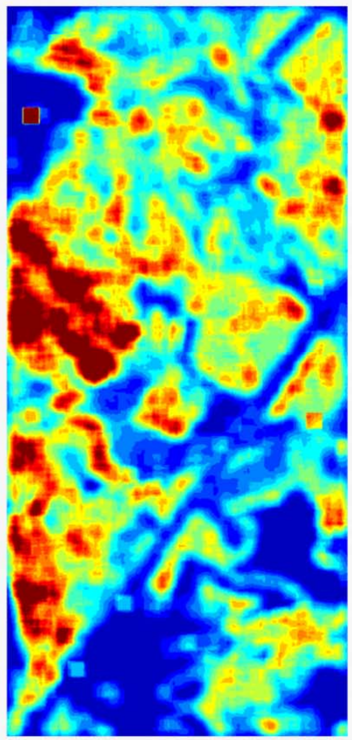
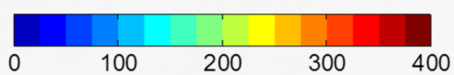


March



May

Biomass (ton/ha)



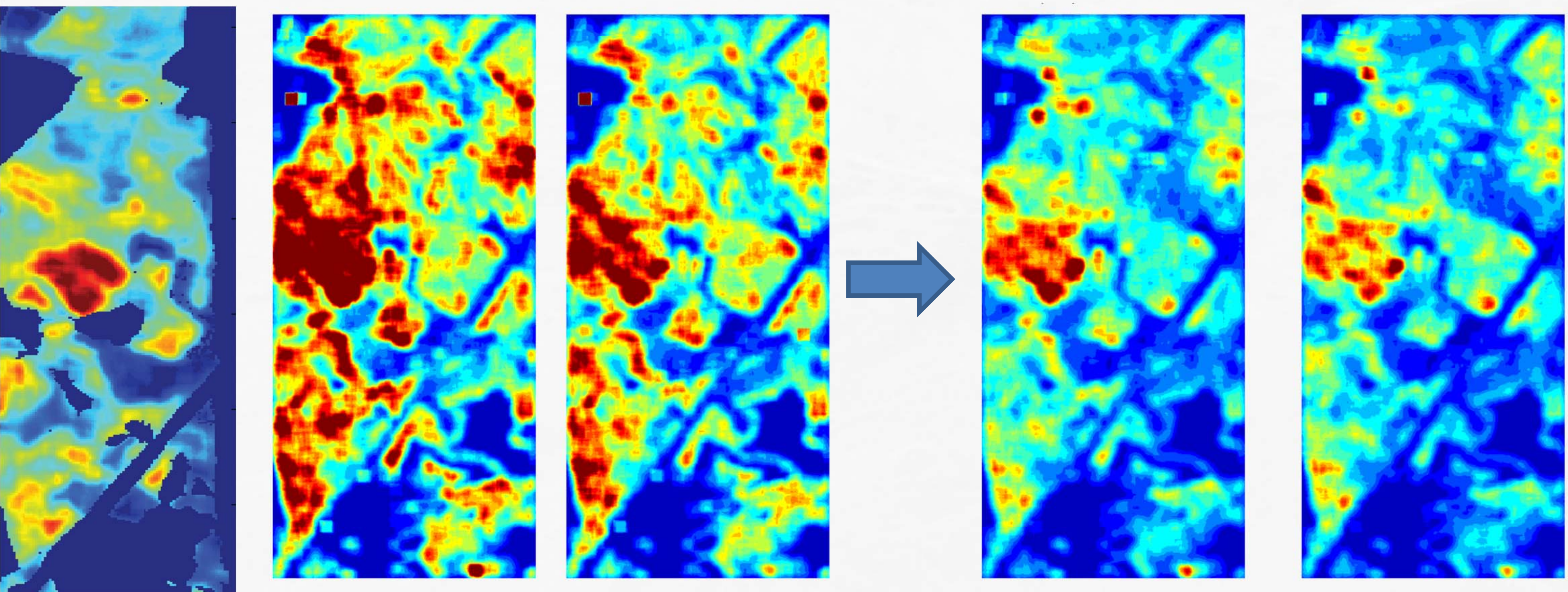
Consistency of biomass estimates after correction of environment effects

Biomass map, Remningstorp, Sweden

Training at Krycklan

Inversion using single polarisation (HV)

Inversion using multiple polarisation and DEM

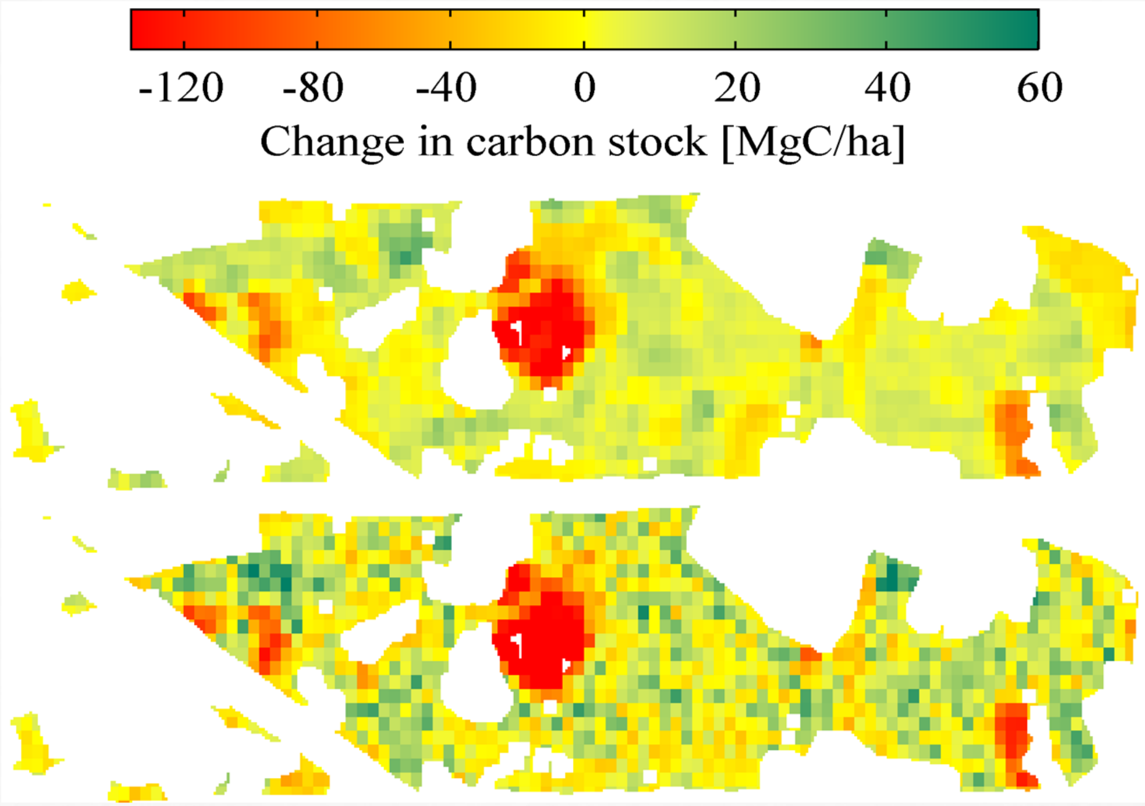


Reference | March | May | March | May

Biomass (ton/ha)

Changes in carbon stock in boreal forest

Maps of change in carbon stock from spring 2007 (ESAR) to autumn 2010 (SETHI) at Remningstorp; resolution = 200 m



Lidar data

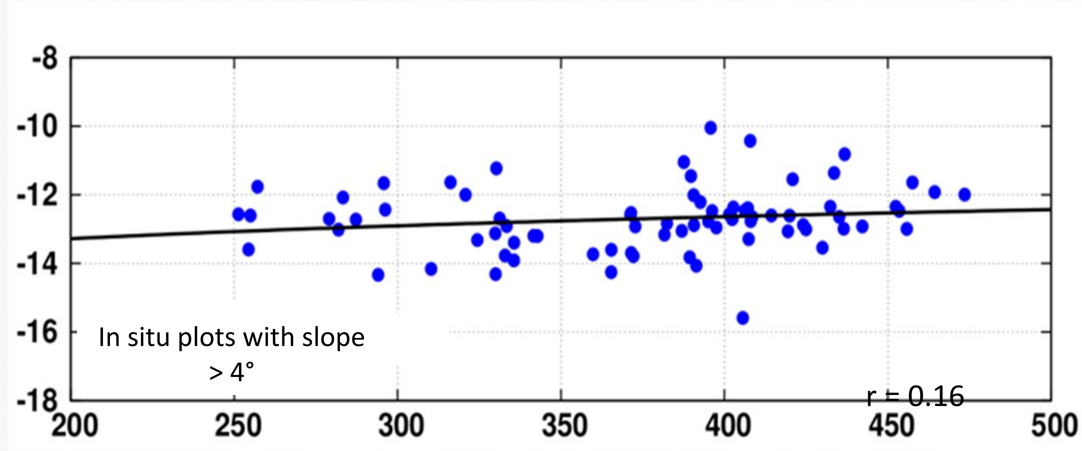
P-band PolSAR data

Biomass will be able to detect a 10MgC/ha change during a 4- year period

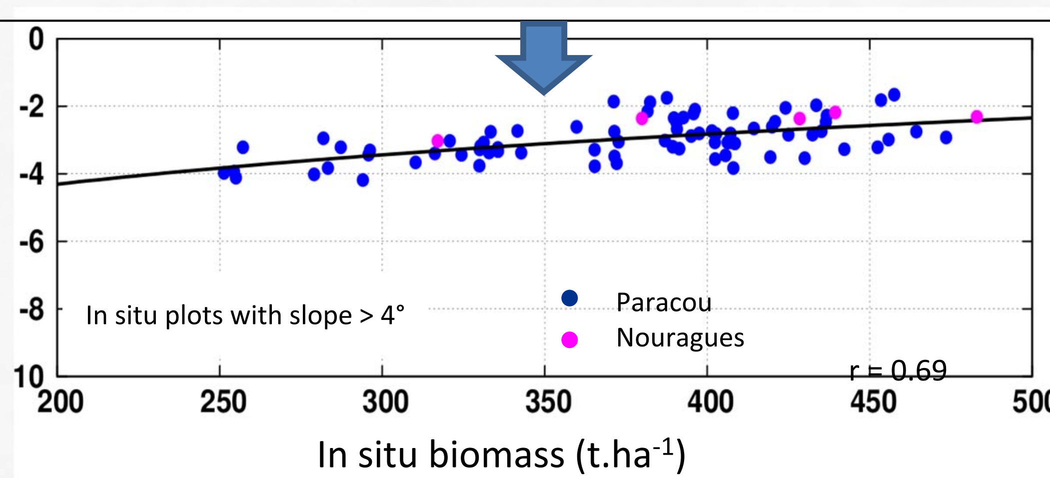
In high biomass tropical forest, topographic effect is the disturbing factor to be removed

Tropical forest
French Guiana

Backscatter at single polarisation (HV in dB)



Correction for effects on both geometry and scattering mechanisms caused by topography . Requires full polarimetric data

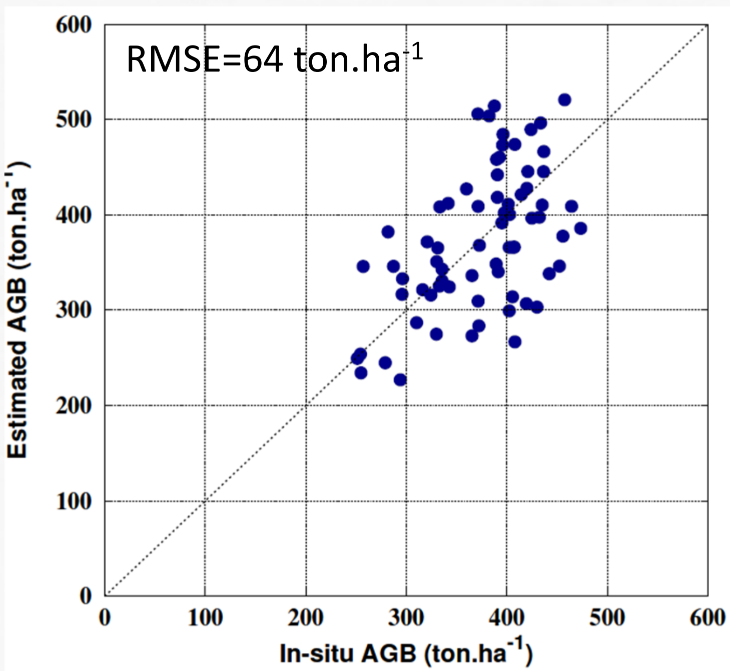


Backscatter after topographic correction using polarimetry (t0 in dB)

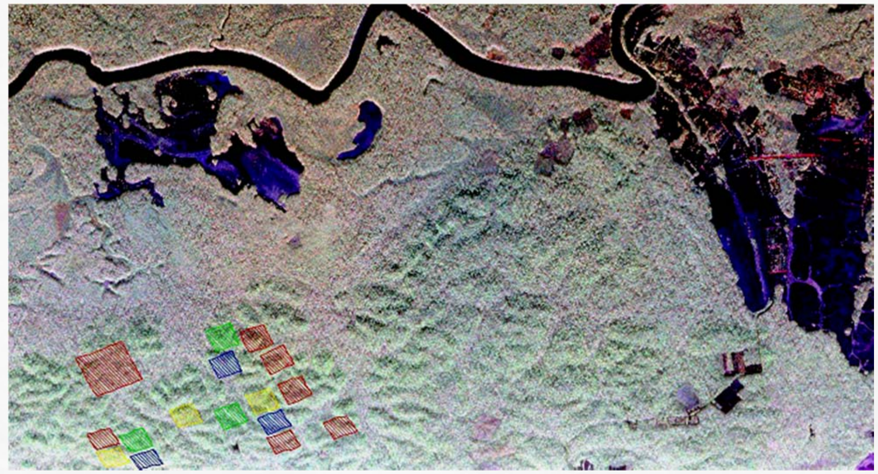
Tropical forest: biomass map from PolSAR

Tropical forest, French Guiana

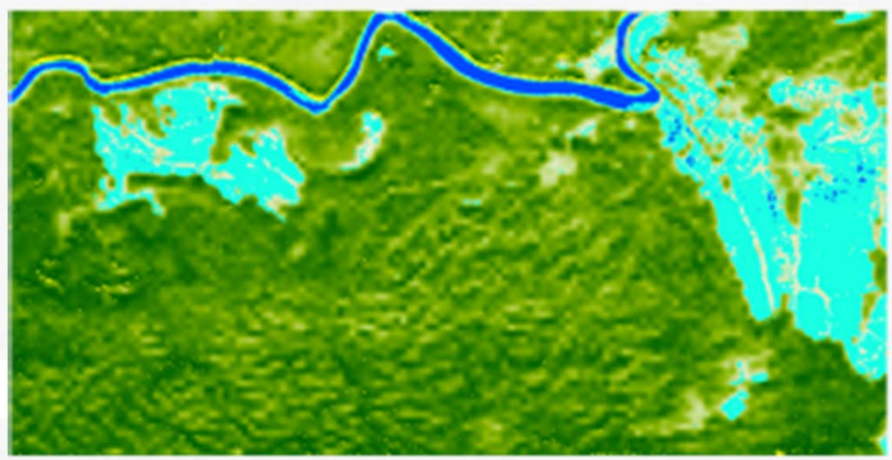
Training at Nouragues
Validated at Paracou

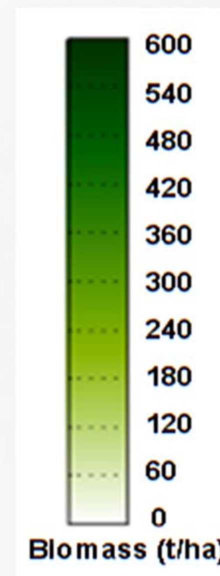


P-band SAR image (SETHI of ONERA)



Biomass map using P-band PolSAR

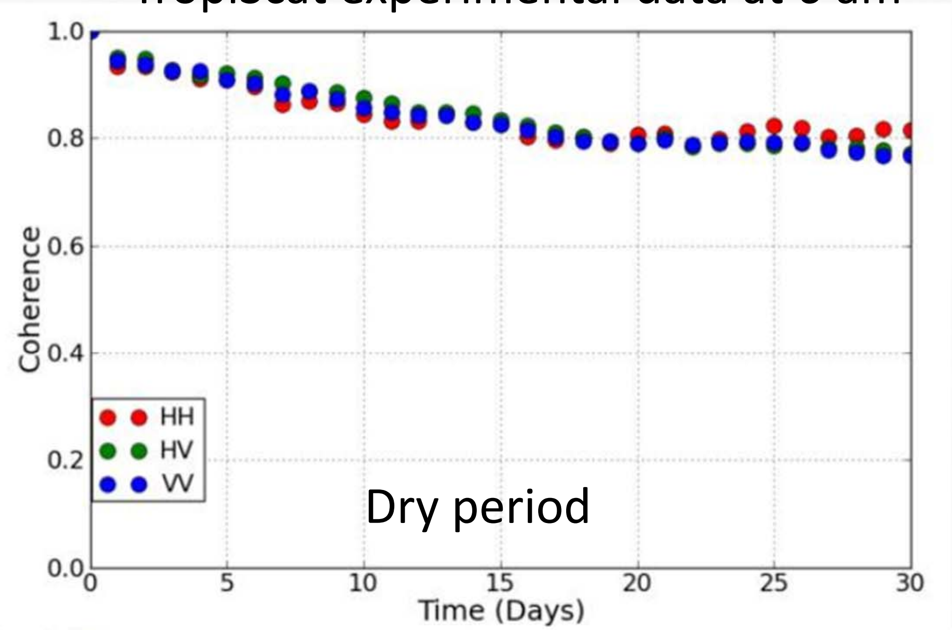


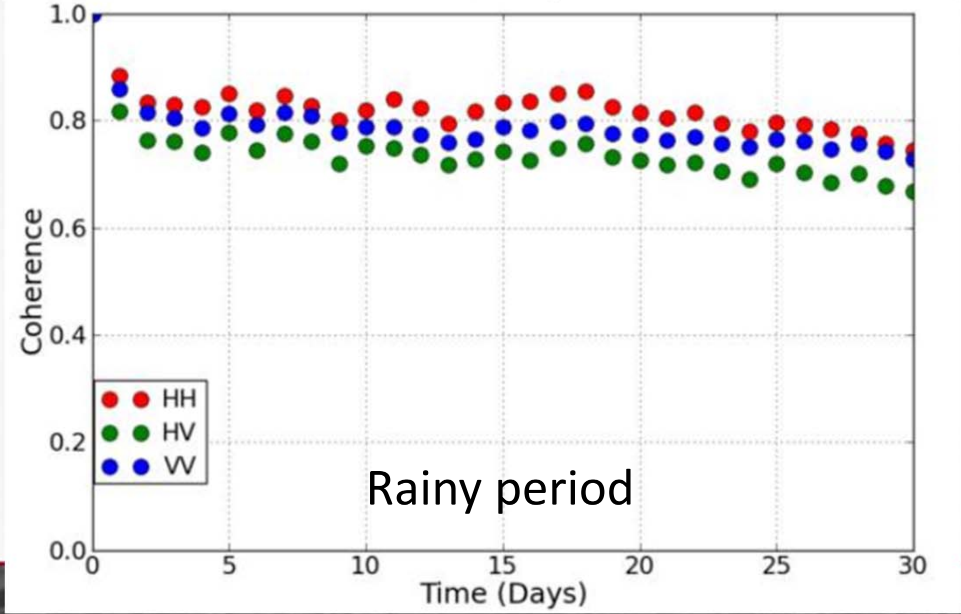


Importance for Pol INSAR : coherence remains high (> 0.7 after 1 month)

- Highest coherence with time interval < 15 days
- Decreases with rain event

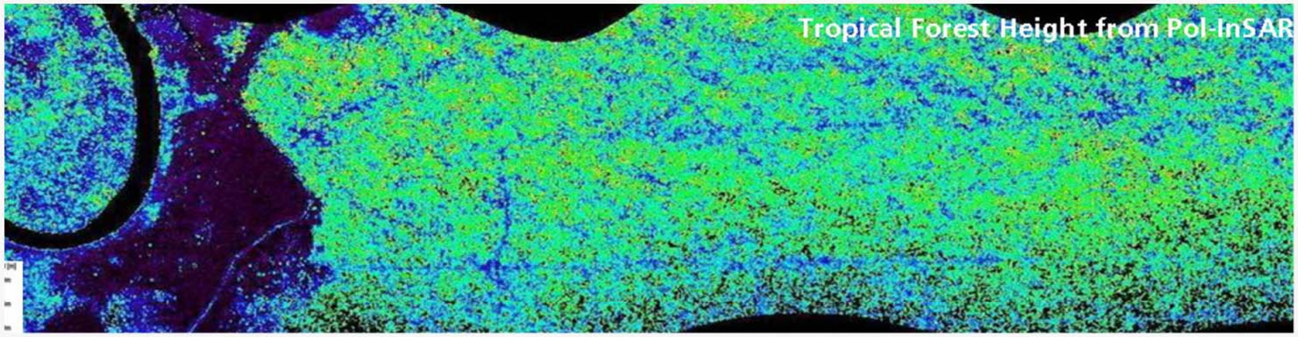
TropiScat experimental data at 6 am

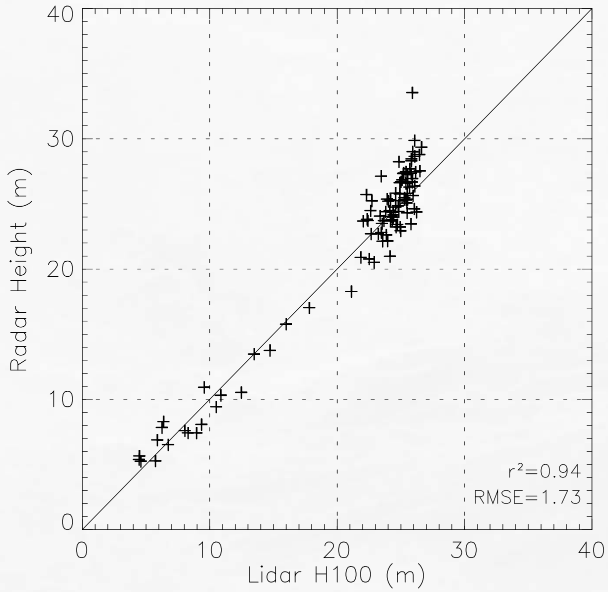




Height from Pol InSAR at tropical and boreal sites

Tropical forest, Kalimantan, Indonesia

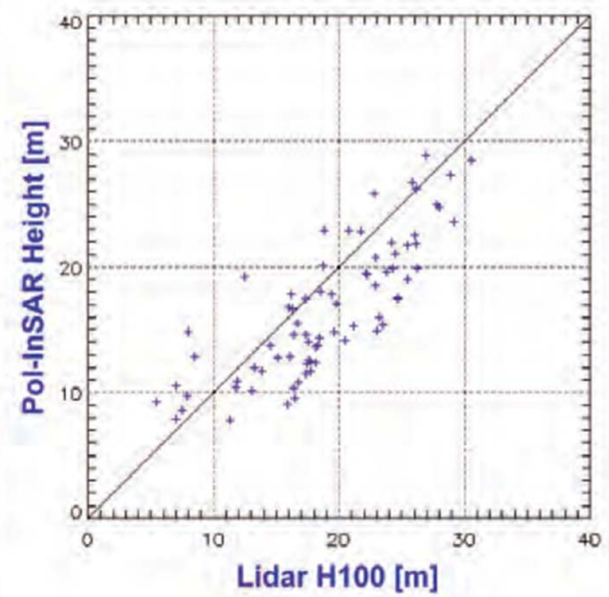




Boreal forest, Remningstorp, Sweden

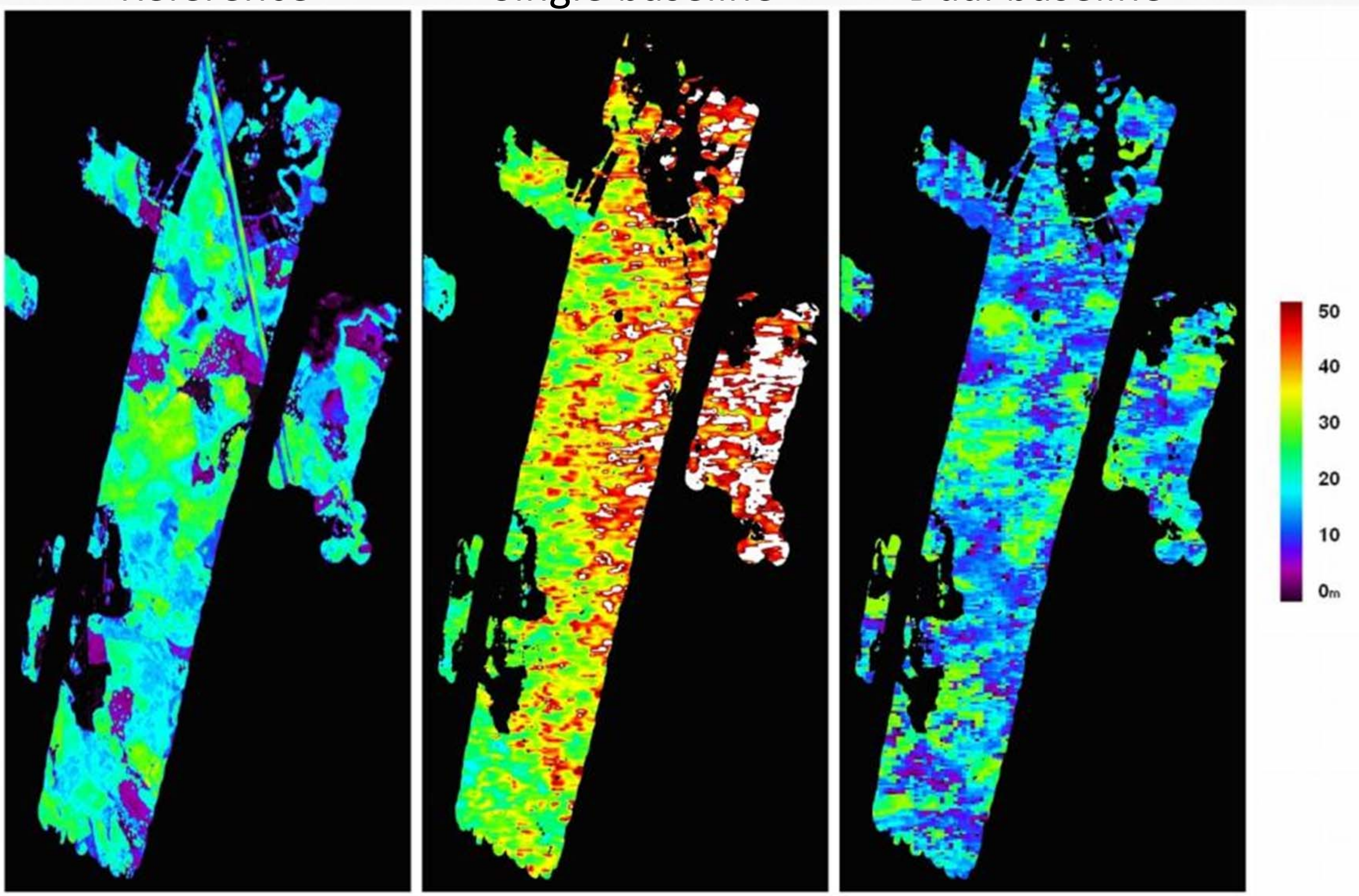
Height map from Pol InSAR

Height map from Lidar

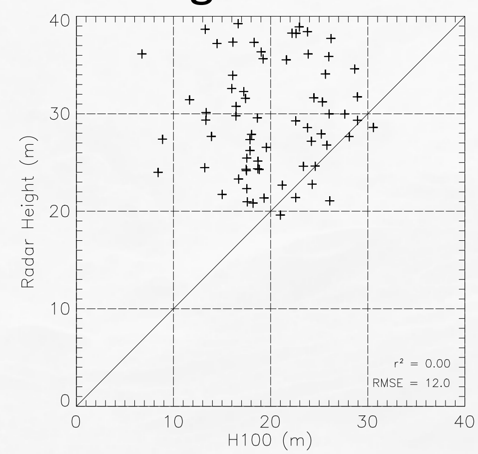


Using dual baseline PolInSAR gives accurate height maps in boreal forest

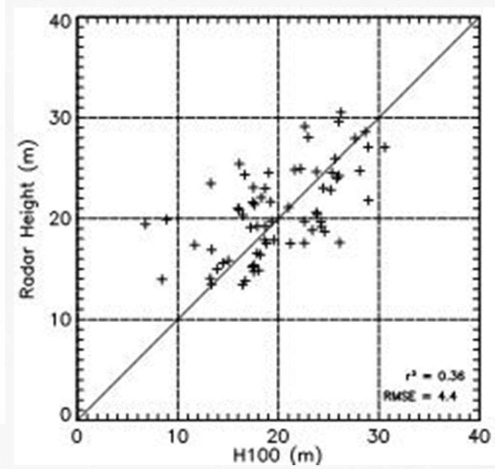
Reference | Single baseline | Dual baseline



Single baseline

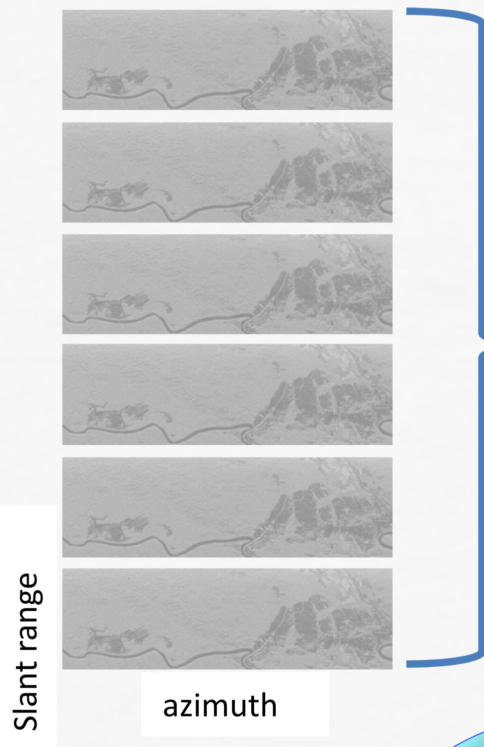


Dual baseline

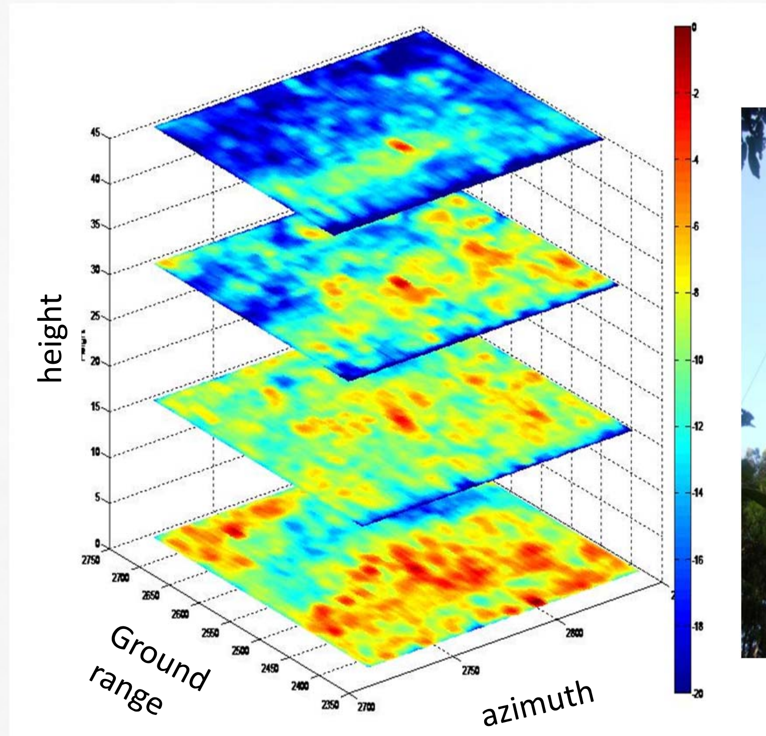


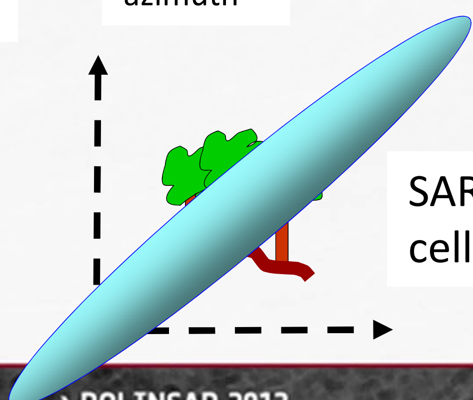
SAR tomography for sounding forest canopy

From ***multi baseline*** SAR images ⇨ generation of ***multi layer*** SAR images



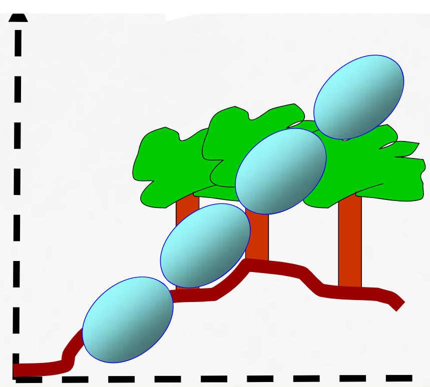
Tomographic Processor ⇨



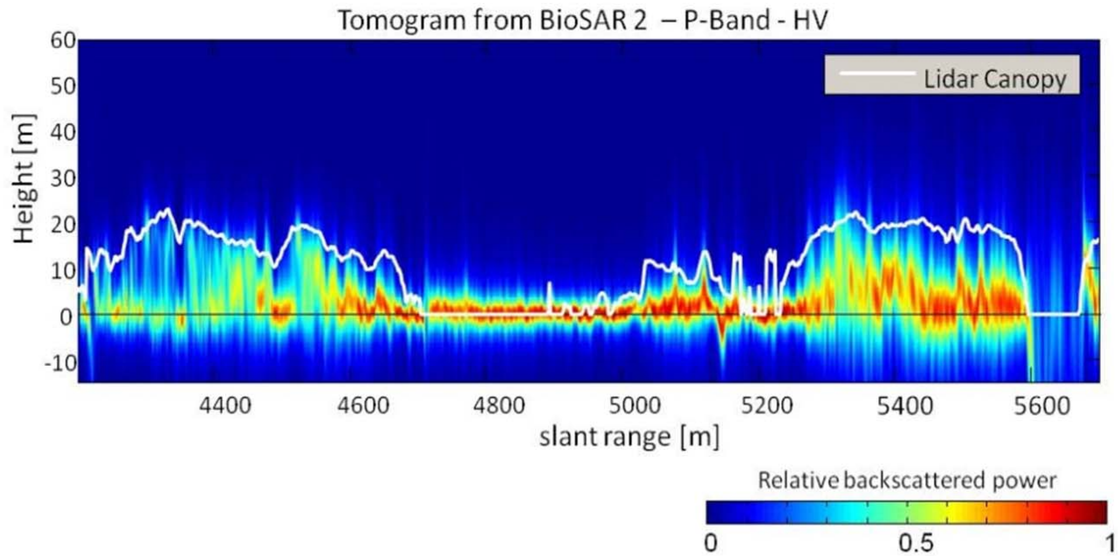


SAR resolution cell

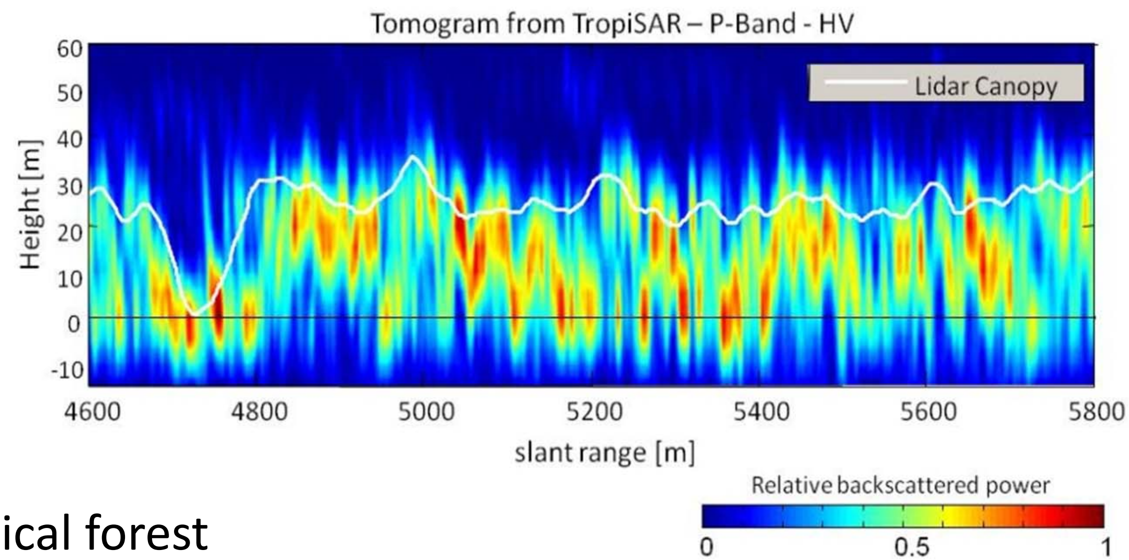
SAR Tomography resolution cell



Using tomography to understand the P-band SAR signal over forests



Boreal forest

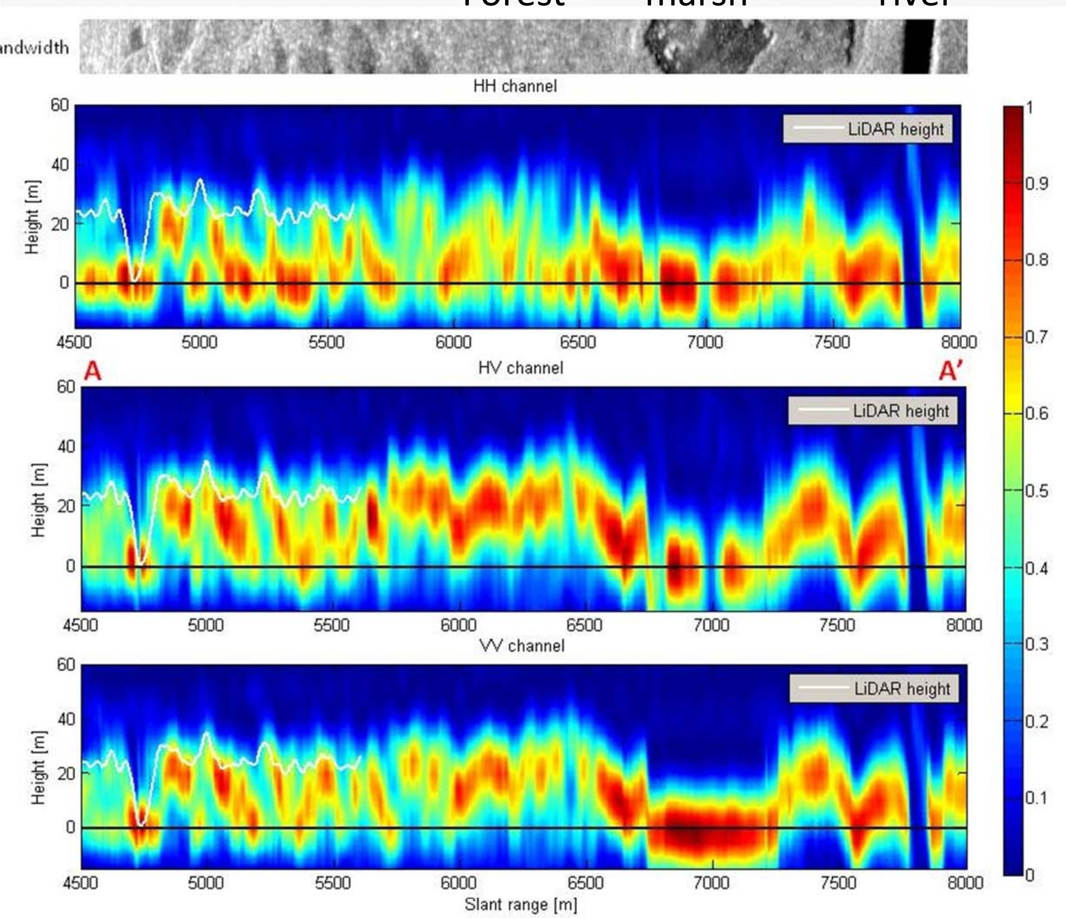


Tropical forest

Using tomography to understand the P-band SAR signal over forests

125 MHz

Forest marsh river



HH

HV

VV

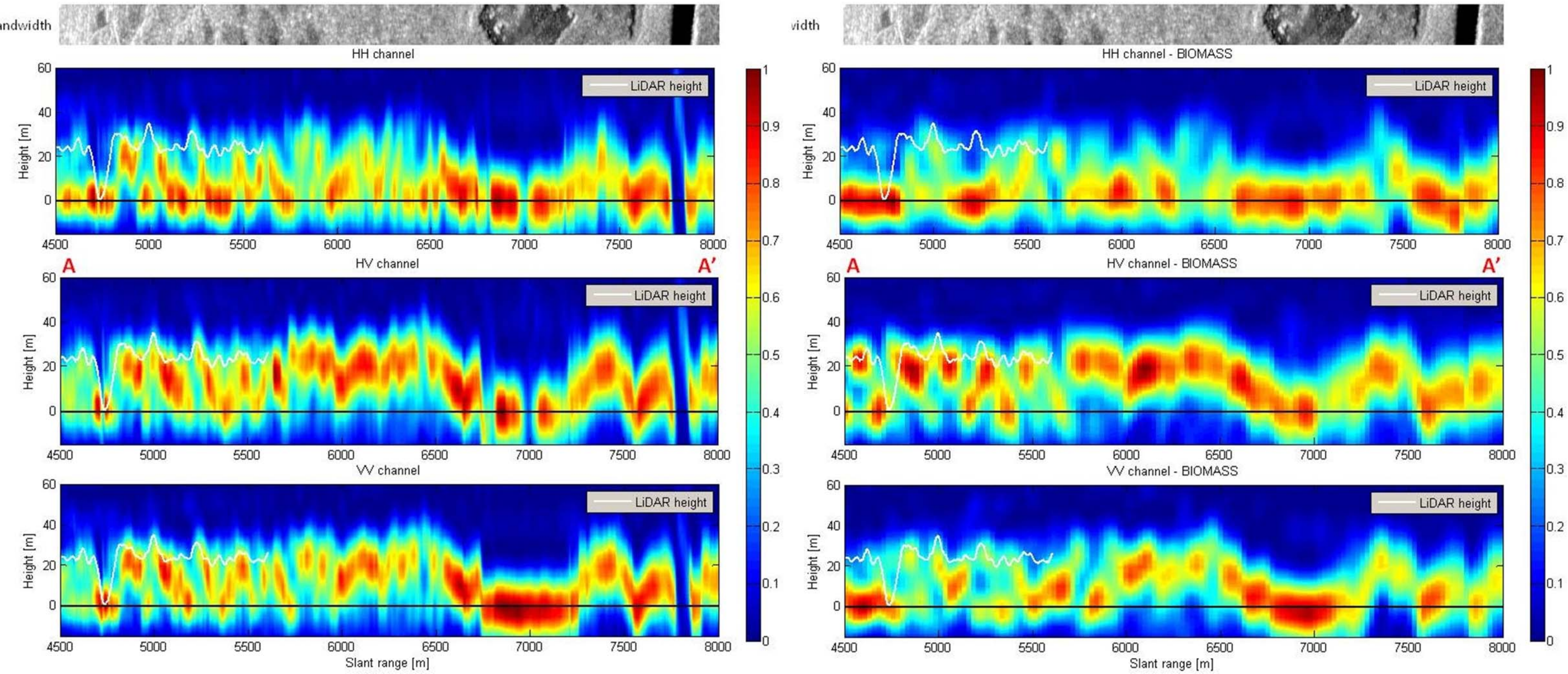
Paracou forest, French Guiana

Using tomography to understand the P-band SAR signal over forests

125 MHz

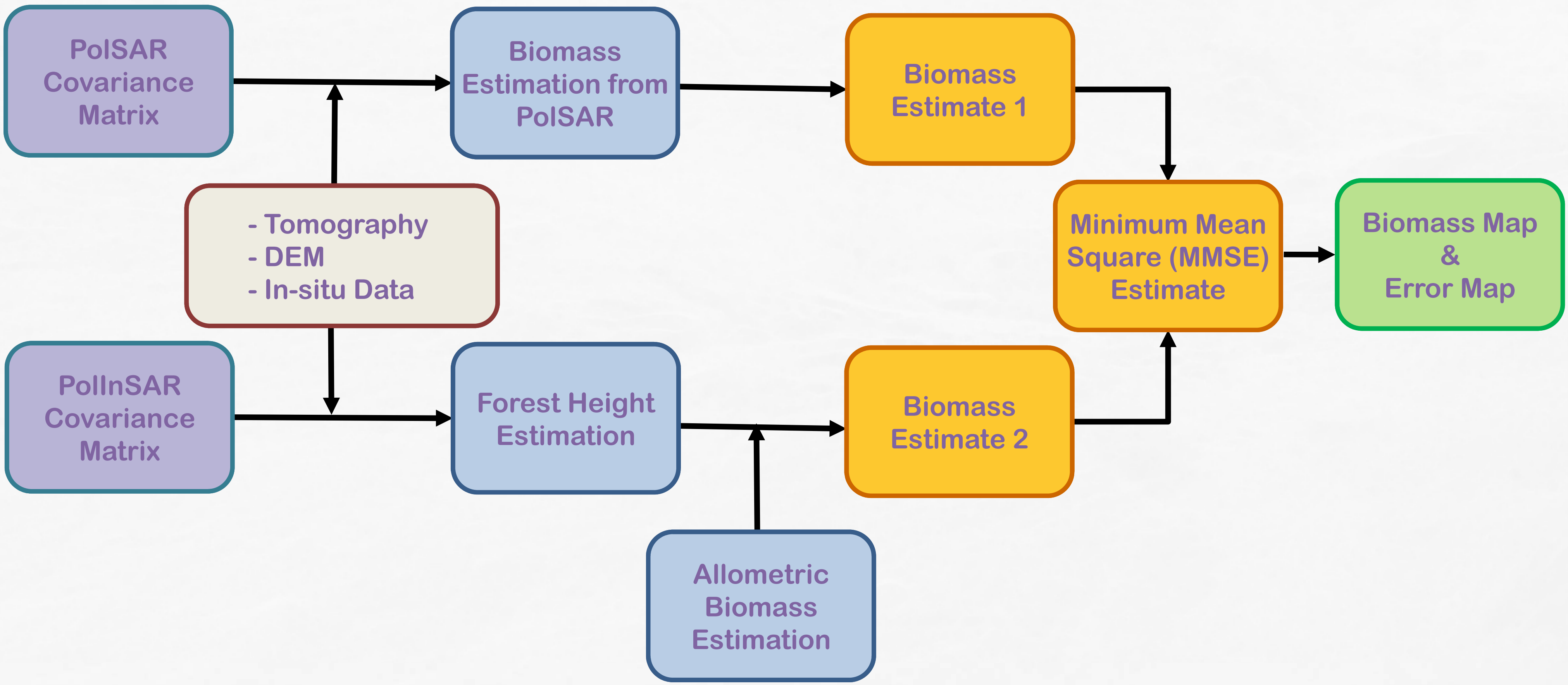
6 MHz

Forest marsh river

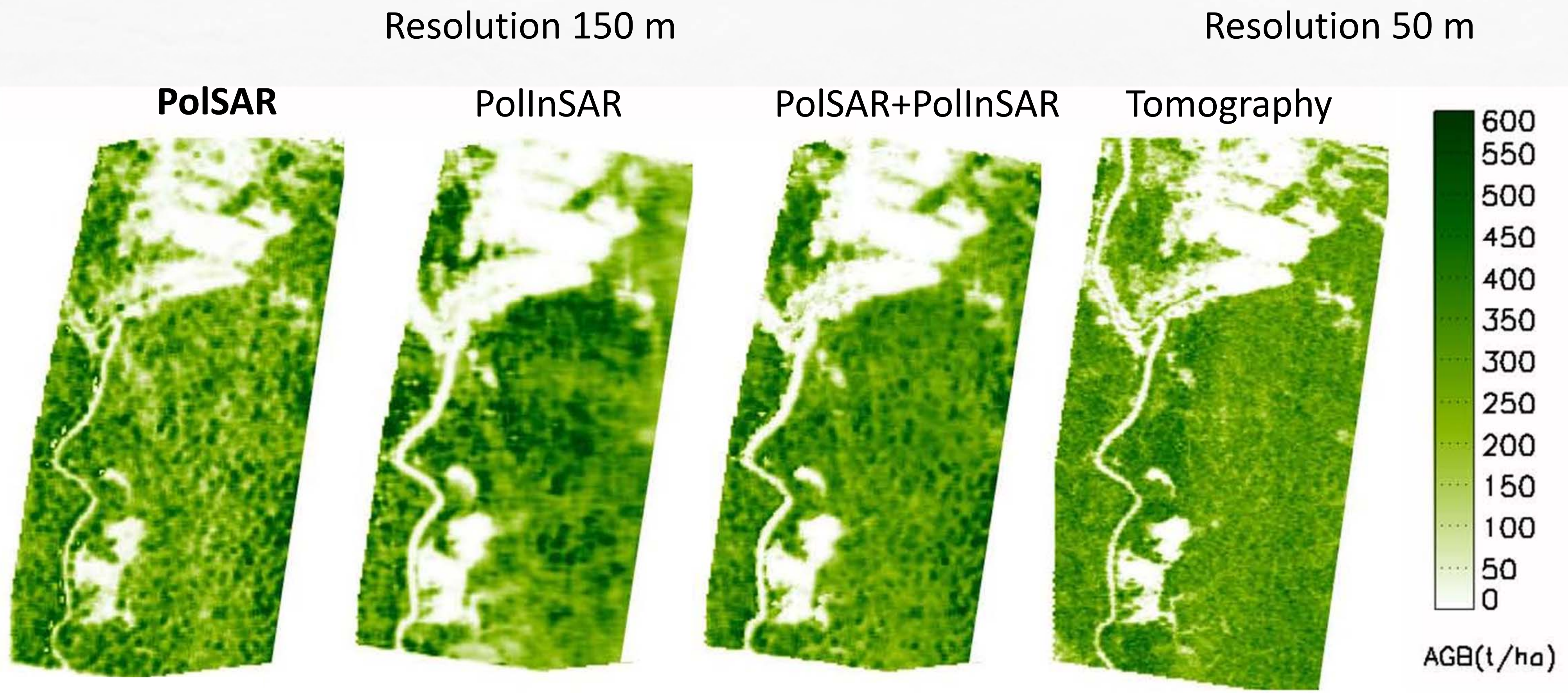


Paracou forest, French Guiana

Combined approaches for biomass estimation



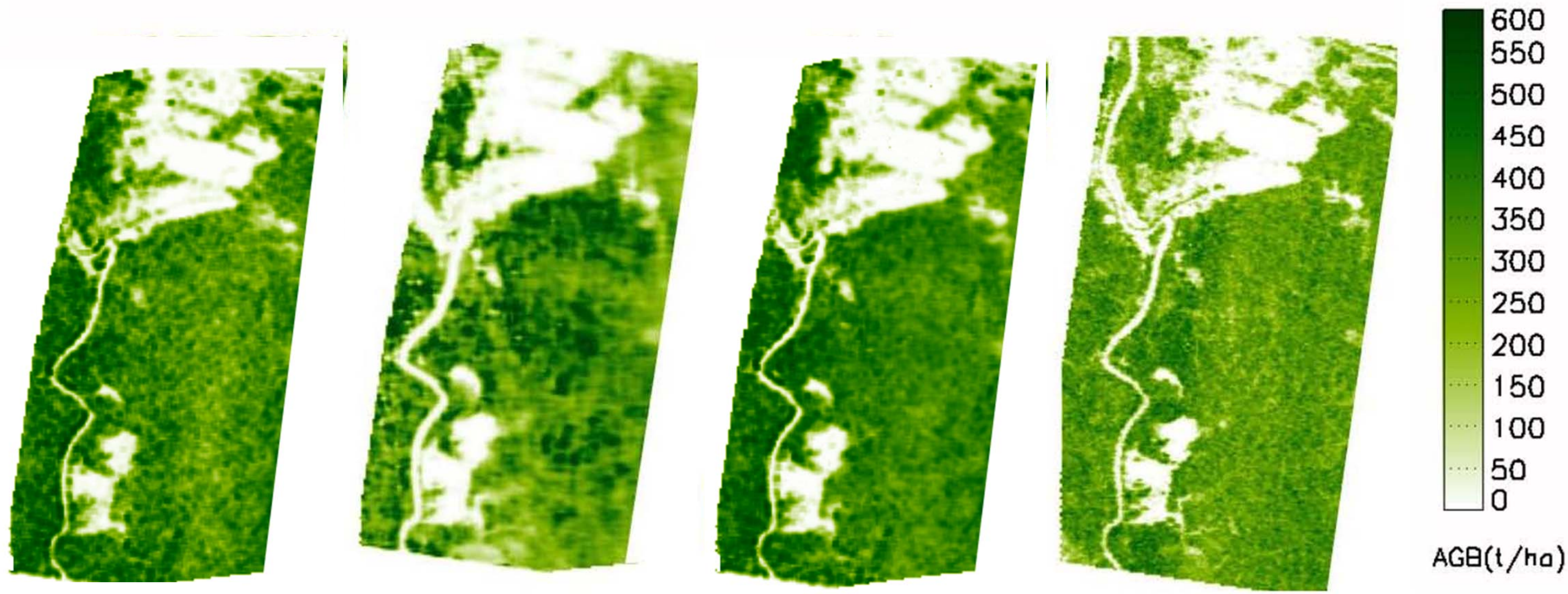
Combined approaches for tropical forests



Using interpolated DEM from SRTM

Combined approaches for tropical forests

PolSAR | PolInSAR | PolSAR + PolInSAR | Tomography



Using a 30 m DEM

RMSE < 20%

RMSE ~10%

(Root Mean Square Error RMSE using reference plots)

Summary

The BIOMASS measurement concept has been demonstrated at different forest ecosystems, including wet tropical forests

- Three approaches have been used to reach biomass estimates: PolSAR, Pol InSAR and TomoSAR. Combination of them to improve estimates has been shown.
- Biomass is technically mature and feasible to meet science requirements
- If selected in May 2013, it will open the field for more new and innovative ways to use SAR data by a large community

(PolInSAR 2015!)

To conclude:

Explore a new face of Earth and pioneer the first P-band radar in space: choose BIOMASS !