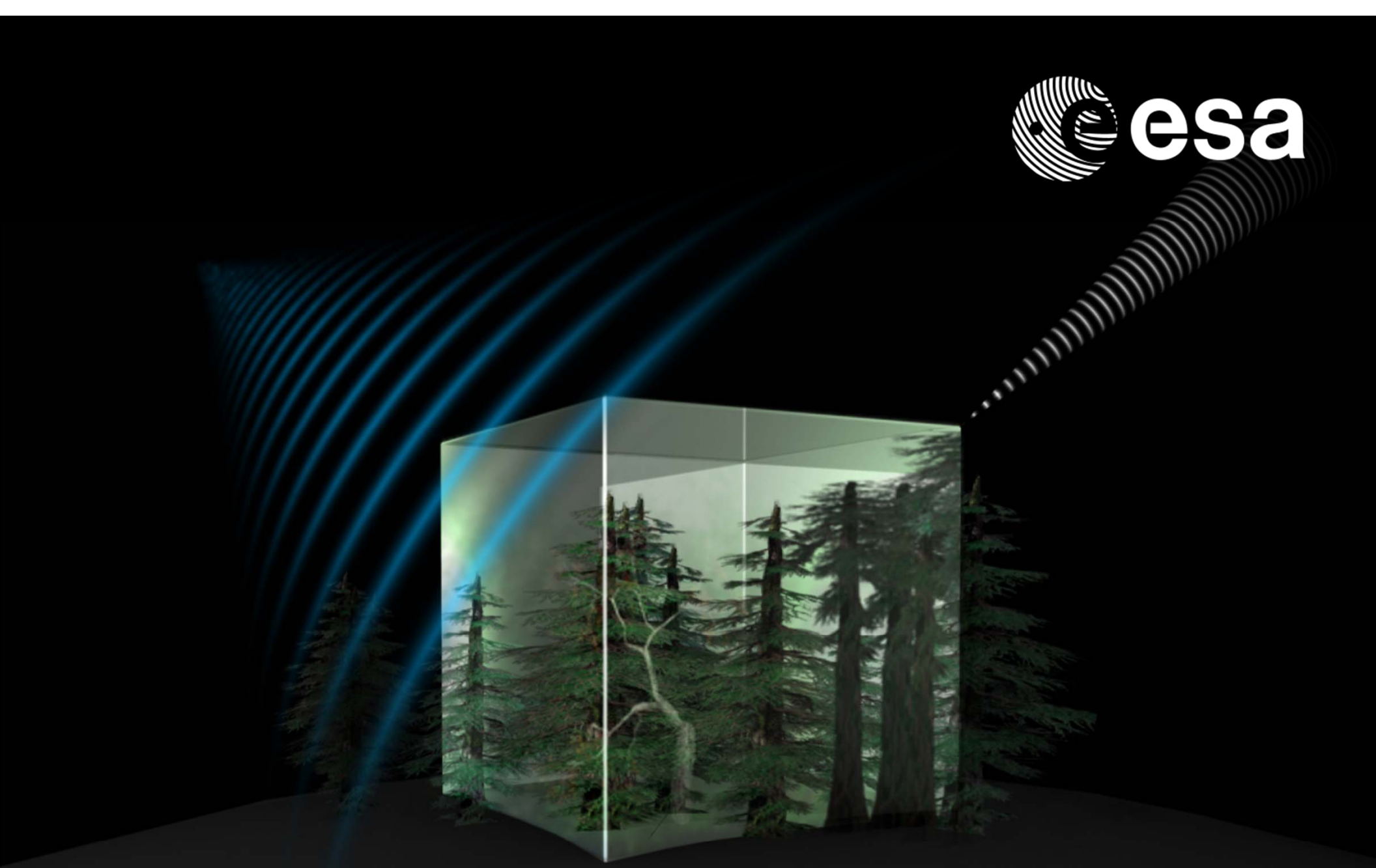


ESA's Biomass mission candidate: system and payload overview

K. Scipal, M. Arcioni, F. Fois, C. Lin

PolInSAR 2013 Workshop, ESA-ESRIN

Primary mission objectives

1. Reducing the major uncertainties in carbon fluxes linked to Land Use Change, forest degradation and regrowth
2. Providing support for International Agreements (UNFCCC and REDD+)
3. Inferring landscape carbon dynamics and supporting predictions
4. Initialising and testing the land component of Earth System models
5. Providing key information on forest resources, ecosystem services, biodiversity and conservation

Secondary objectives

1. Sub-surface geology in deserts;
2. DTMs under dense vegetation;
3. Glacier and ice sheet velocities

Biomass product requirements

Above-ground biomass (tons/hectare)

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

Upper canopy height (meter)

- 200 m resolution
- 1 map every 6 months
- global coverage of forested areas
- accuracy of 20-30%

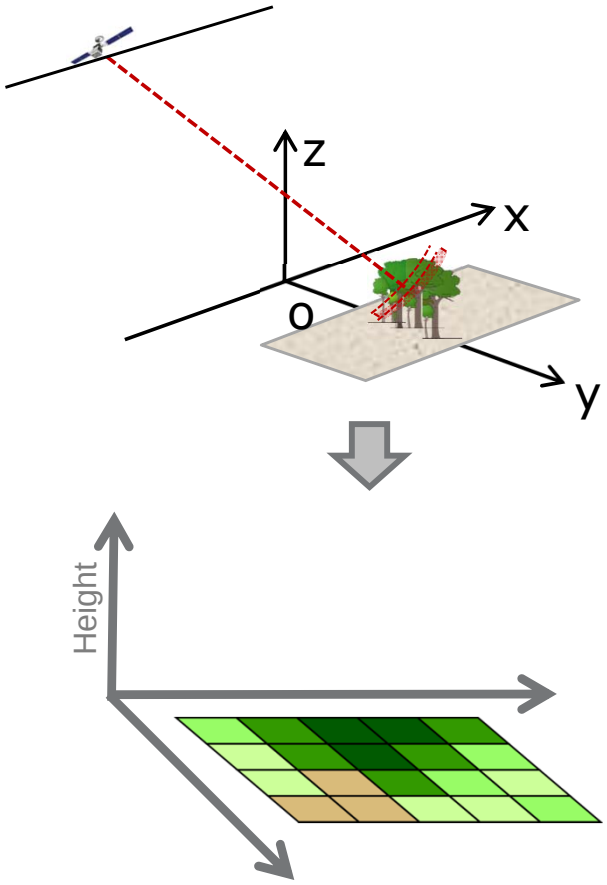
Areas of forest clearing (hectare)

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

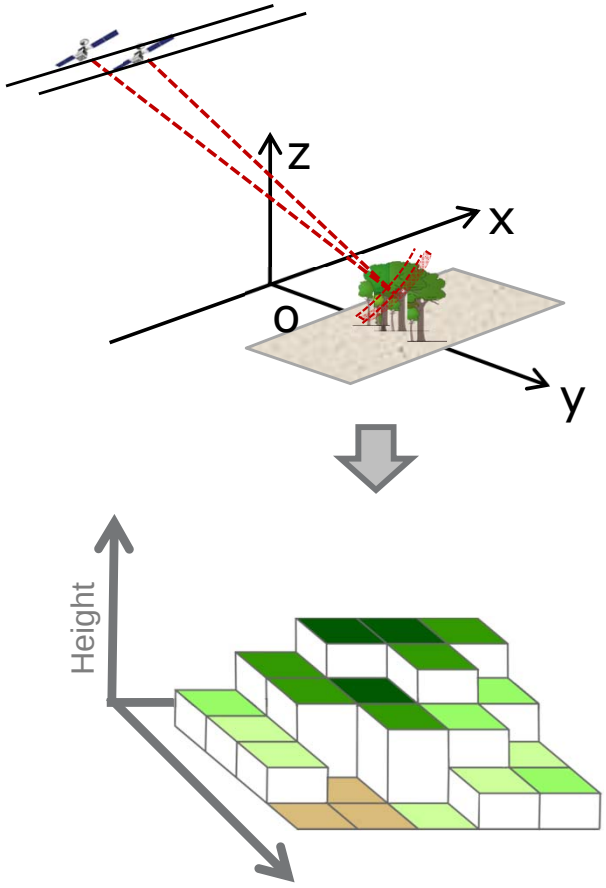
Biomass will be implemented as SAR

Nominal Phase

Polarimetry

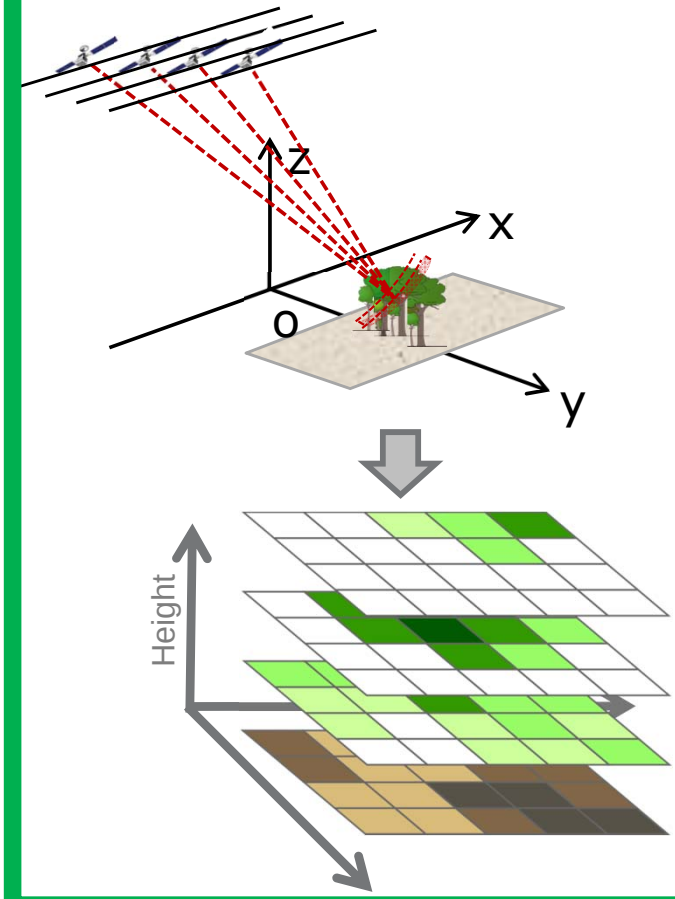


Polarimetric SAR Interferometry

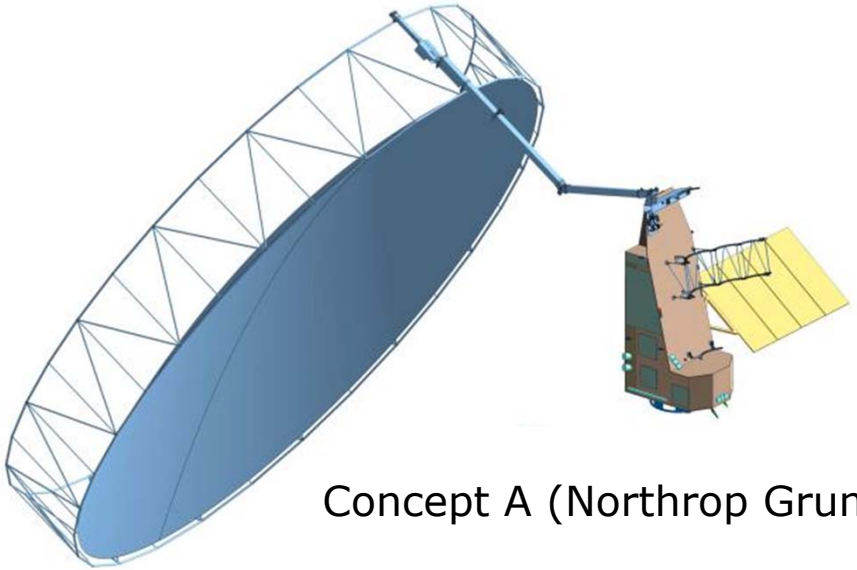


Tomographic Phase

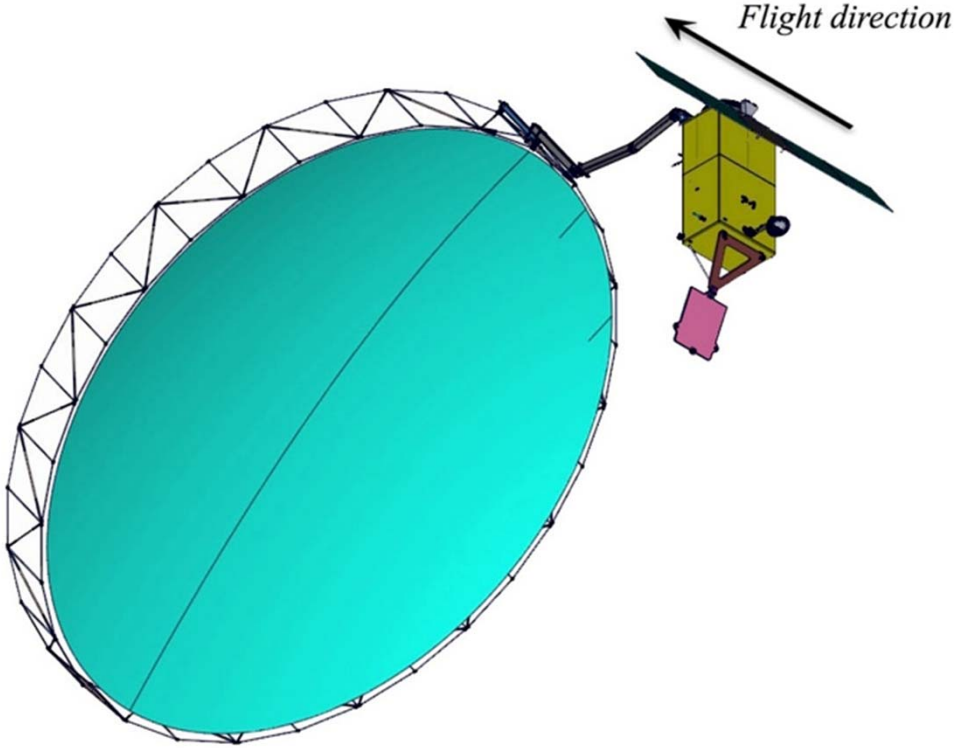
SAR Tomography



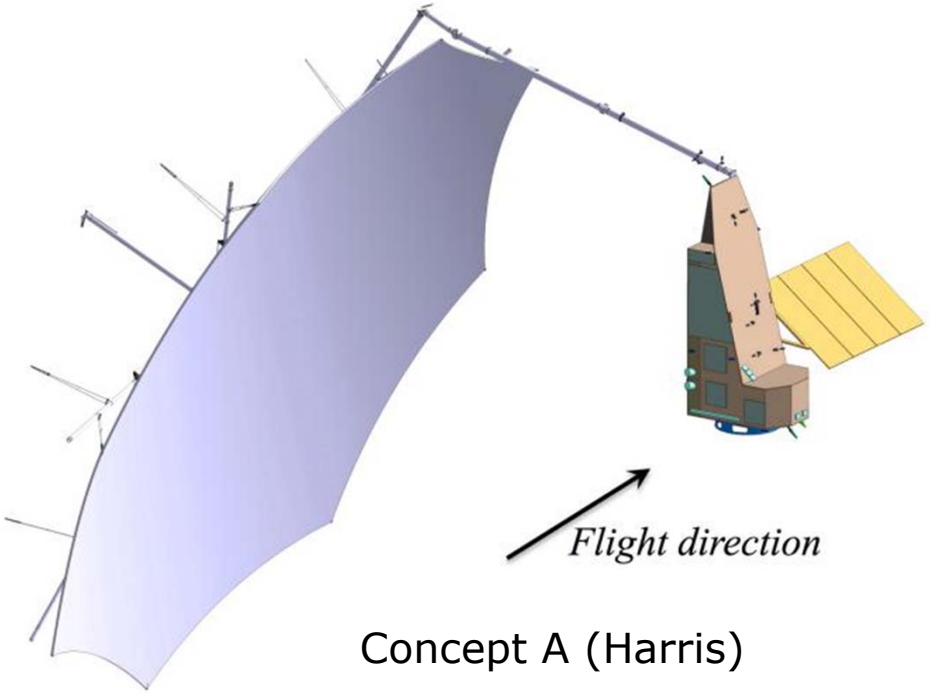
Satellite configuration and key drivers



Concept A (Northrop Grumman)



Concept B (Northrop Grumman)



Concept A (Harris)

Satellite design drivers

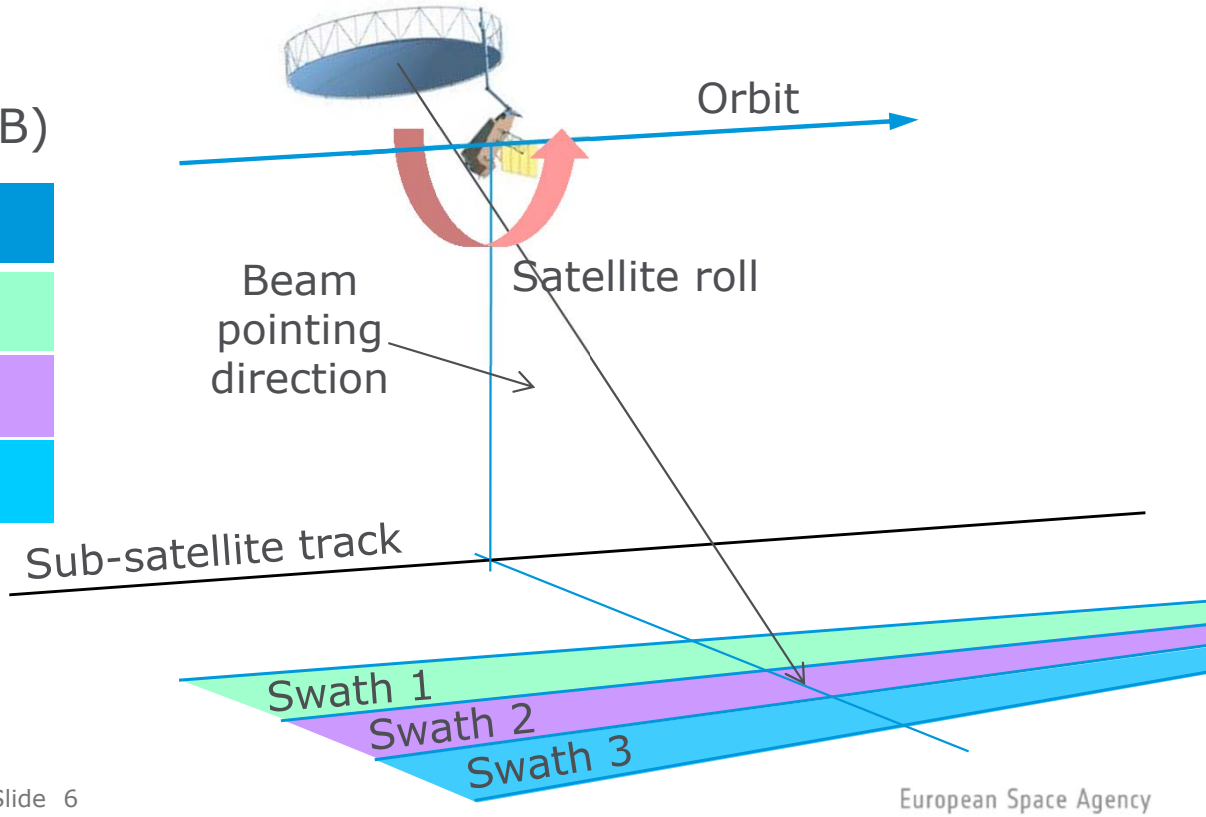
- Large deployable antenna of 12 m diameter
- Vega launcher compatibility

Payload overview

- The **P-band** (435 MHz, ~69 cm wavelength) Synthetic Aperture Radar (SAR) has **full polarimetric** and **multi-pass interferometric** capabilities
- The signal bandwidth is 6 MHz, a maximum allowed by the frequency spectrum allocation (ITU)
- The SAR has a single antenna beam and operates in a **simple stripmap mode** with successive switching after each orbit cycle over to three swath positions through satellite-roll

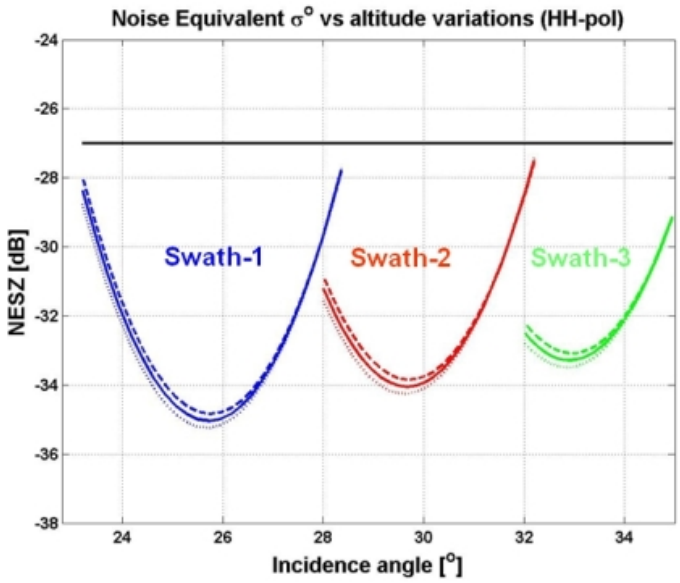
Incidence and roll angles (Concept B)

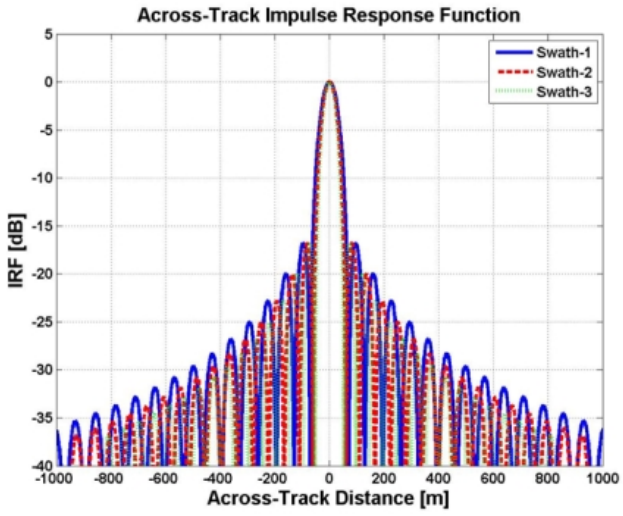
	Inc. mid-swath	Roll
Swath 1	25.9°	0°
Swath 2	30.2°	2.81°
Swath 3	33.4°	3.86°

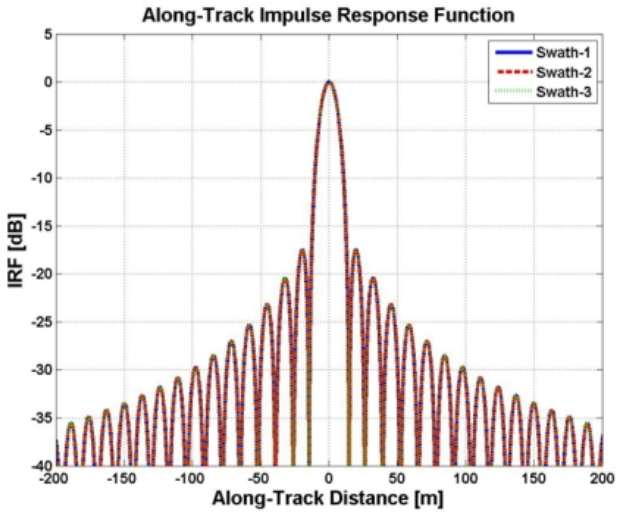


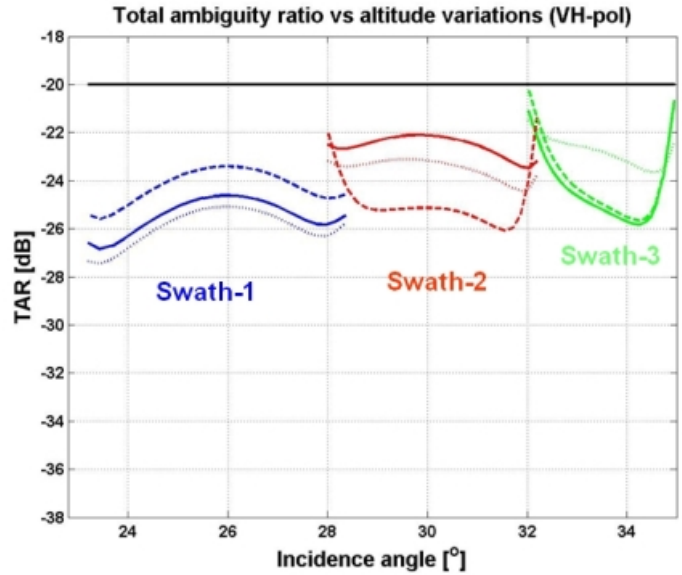
System performance at Level 1B

Key Parameters	Requirement	Concepts A and B
Sensitivity (NESZ)	≤ -27 dB	≤ -27 dB ✔
Total Ambiguity Ratio (TAR)	≤ -20 dB	≤ -20 dB ✔
Geometric Resolution	≤ 50 m x 50 m	≤ 50 m x 50 m ✔
Effective Number of Looks	≥ 4	≥ 4 ✔
Radiometric Stability	≤ 0.5 dB	0.35 dB ✔
Absolute Radiometric Bias	≤ 1.0 dB	0.45 dB ✔









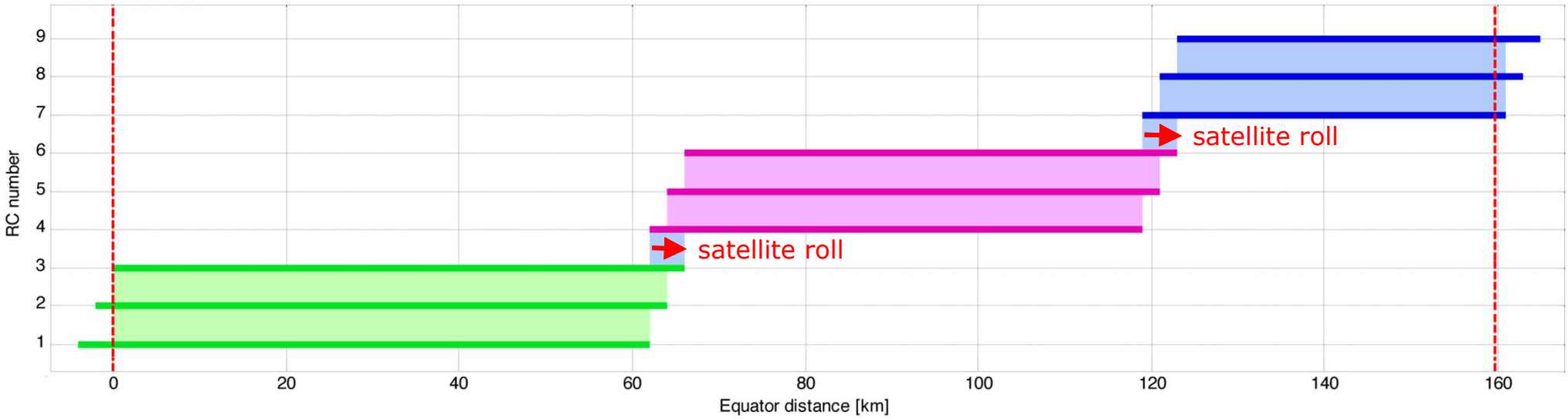
Orbit and observation geometry

Determining factors

- 25 days revisit or less
- Forest coverage in 6-7 months
- SAR swath width & radiometric performance
- Minimise ionospheric disturbance
- Avoid excessive air drag
- Drift for interferometric baseline

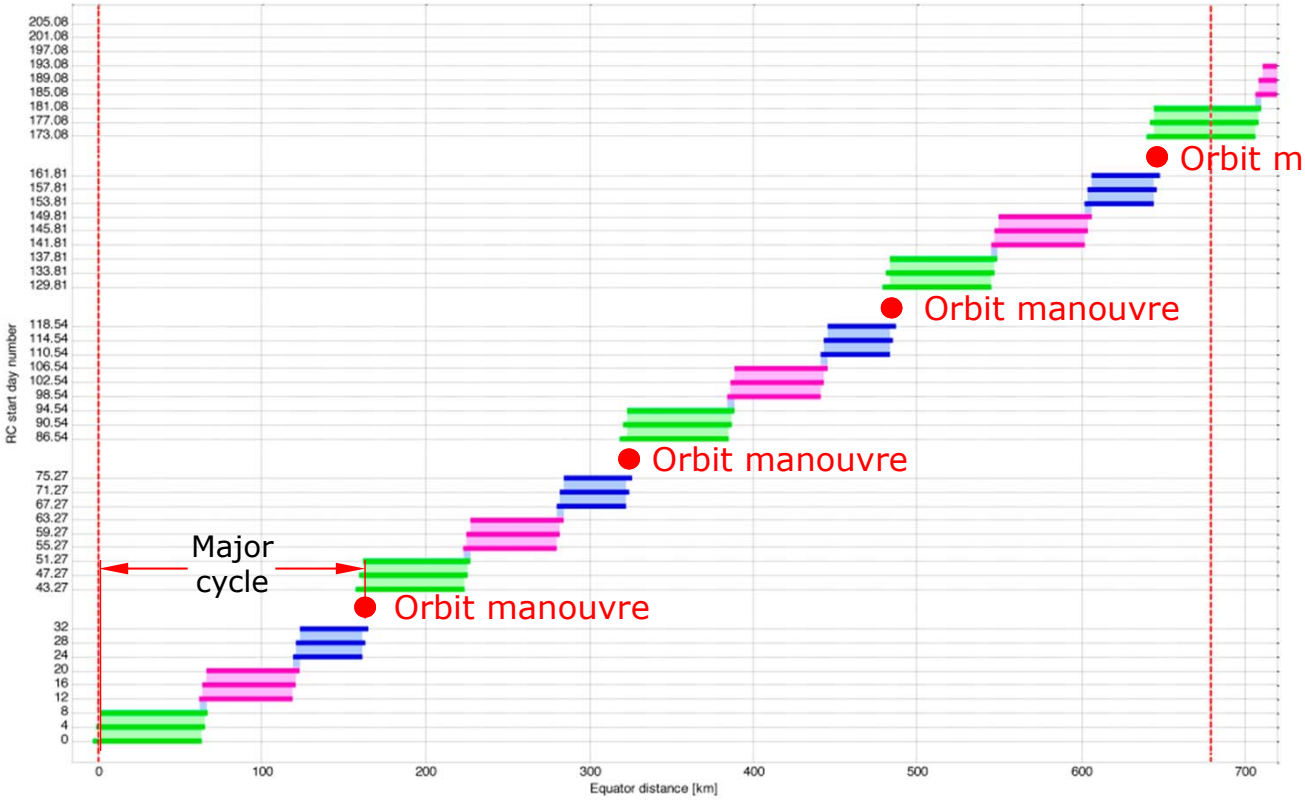
Baseline orbit

- Sun-synchronous drifting
- Local time 06:00
- Repeat cycle (RC): 17 days
- Altitude: 672 km
- Ascending & Descending Acquisitions
- Beam re-pointing after every 3 cycles by satellite roll manoeuvre
- Swaths: ~60 km, ~50 km, ~40 km

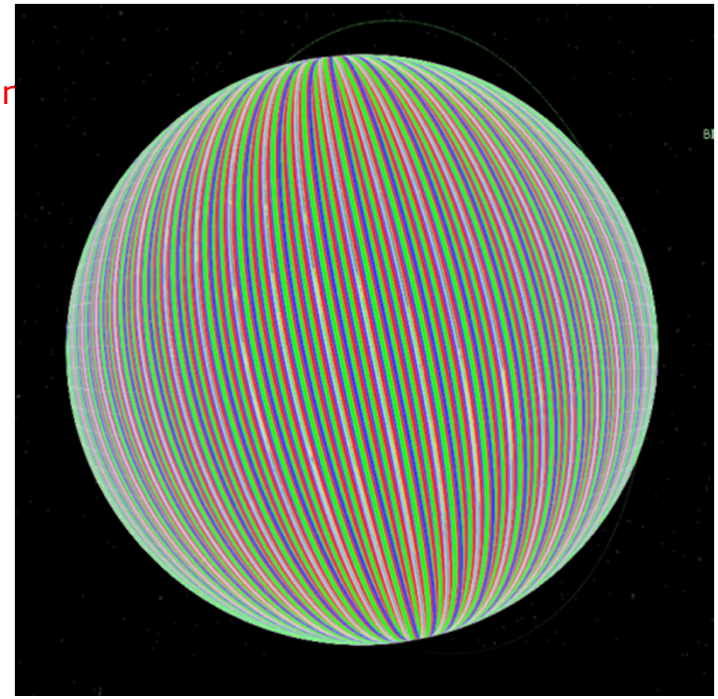


Orbit and observation geometry (Option)

- In order to minimise the temporal decorrelation, a new observation concept with a repeat cycle as low as 3 or 4 days has been studied and is proposed as an option
- This optional concept uses orbit manoeuvres lasting 11-7 days after every nine repeat cycles (defined as a major cycle) to introduce a ground track shift
- In such a way, global coverage is achieved in 6-7 months by a sequence of major cycles, each followed by an orbit manoeuvre

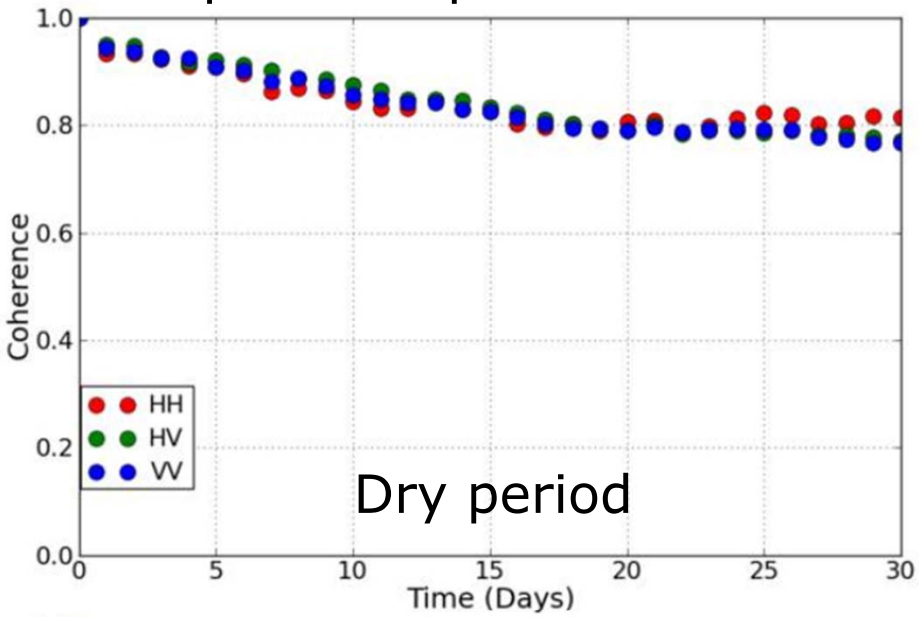


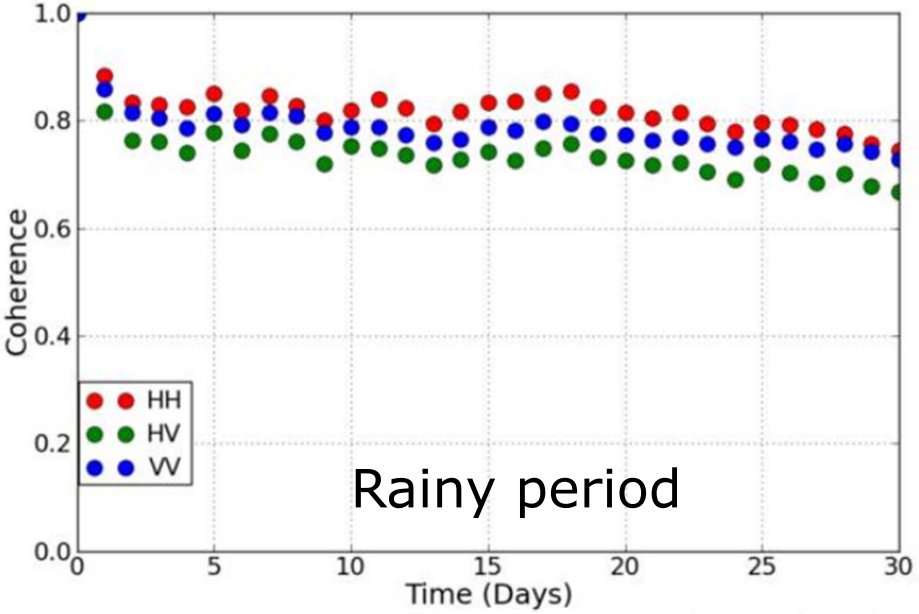
Coverage build-up



At P band, coherence remains high (> 0.7) in airborne and ground based data

TropiScat experimental data





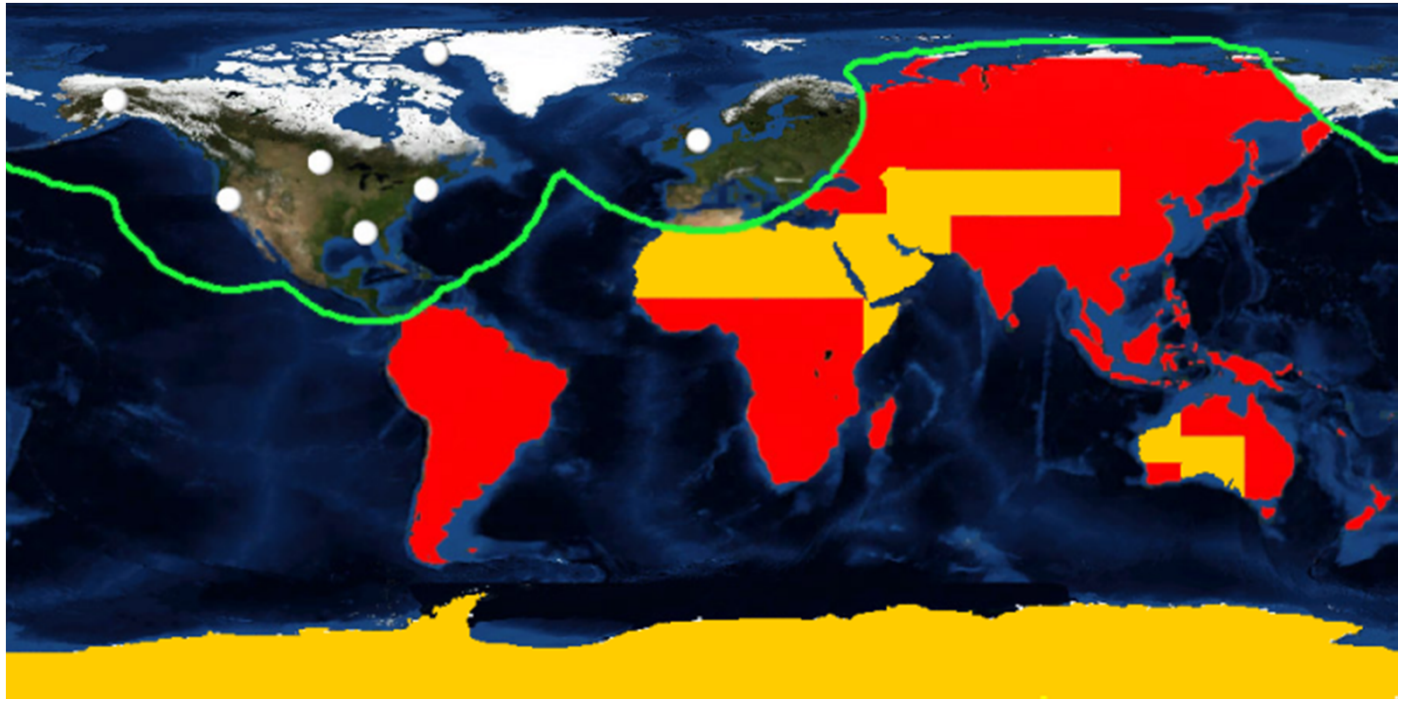
Operations concept

	Baseline	Option
Launch & Early Orbit Phase	1 week	
Commissioning	5 months	
Tomographic Phase		
Repeat Cycle	4 days	4 days
Duration	3 months	1 year
Coverage	Partial	Global
Nominal Phase		
Repeat Cycle	17 days	4 days
Duration	4.7 years	4 years
Coverage	Global	Global
Disposal	9 days	

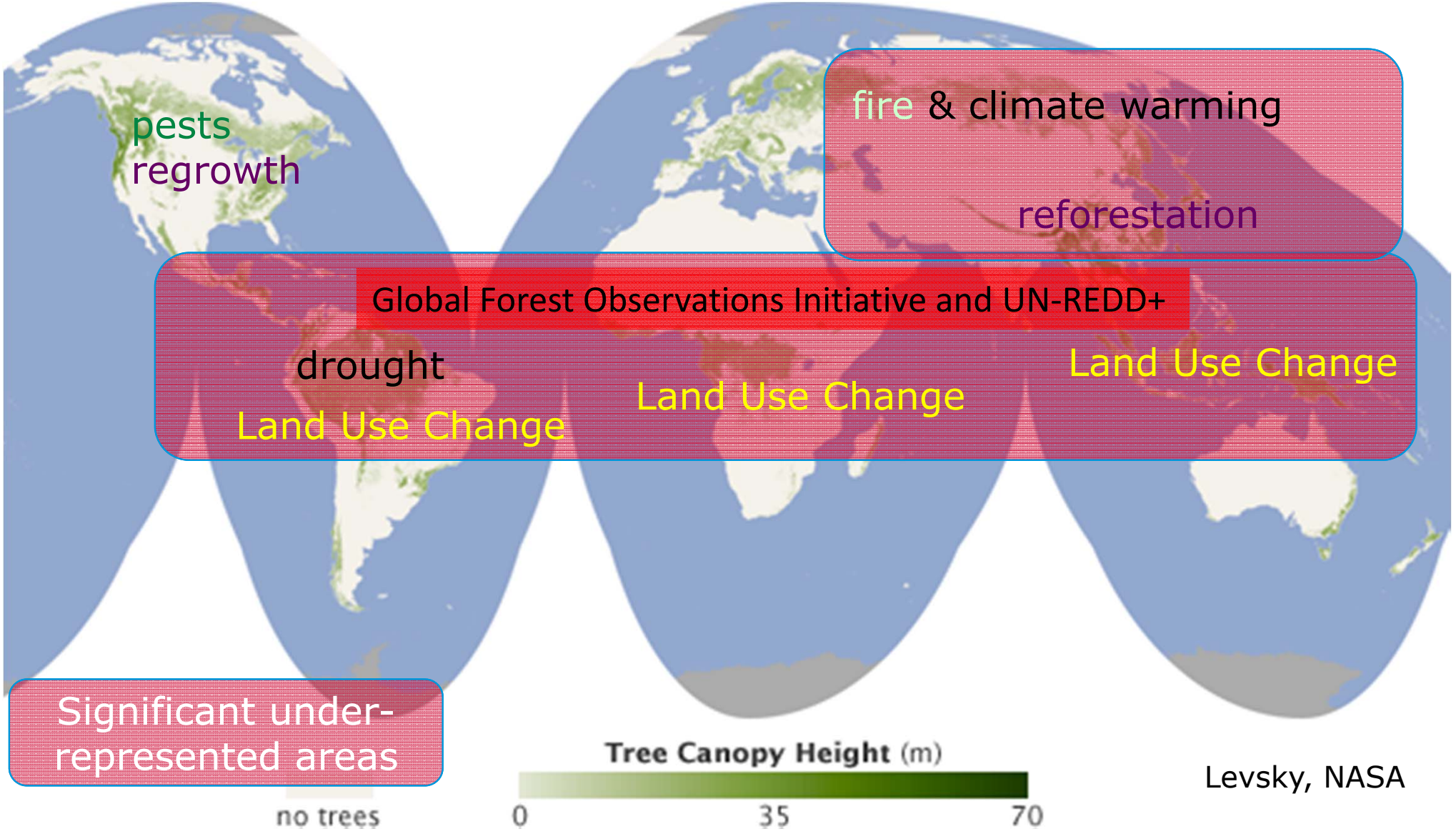
Option

Critical areas - SOTR

- Operation of Space Objects Tracking Radar (SOTR) systems restricts the imaging opportunities for Biomass because of the potential impact on the SOTR performance from the Biomass SAR signal.
- Discussions have taken place between ESA and the USA Department of Defense (DoD).
- Preliminary analysis performed by DoD concluded that ESA do no operate Biomass when in sight of SOTR stations.



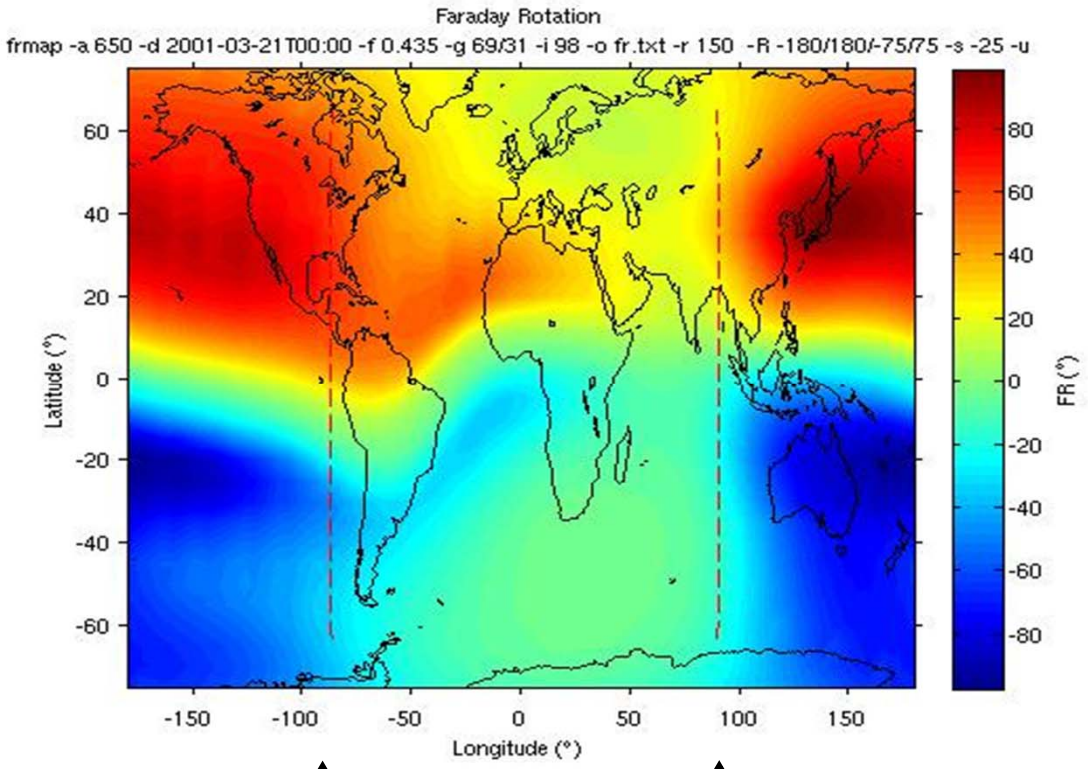
Where are the unobserved areas and the critical zones of forest change?



Levsky, NASA

The ionosphere has little effect on Biomass primary objectives: Faraday rotation

Faraday Rotation

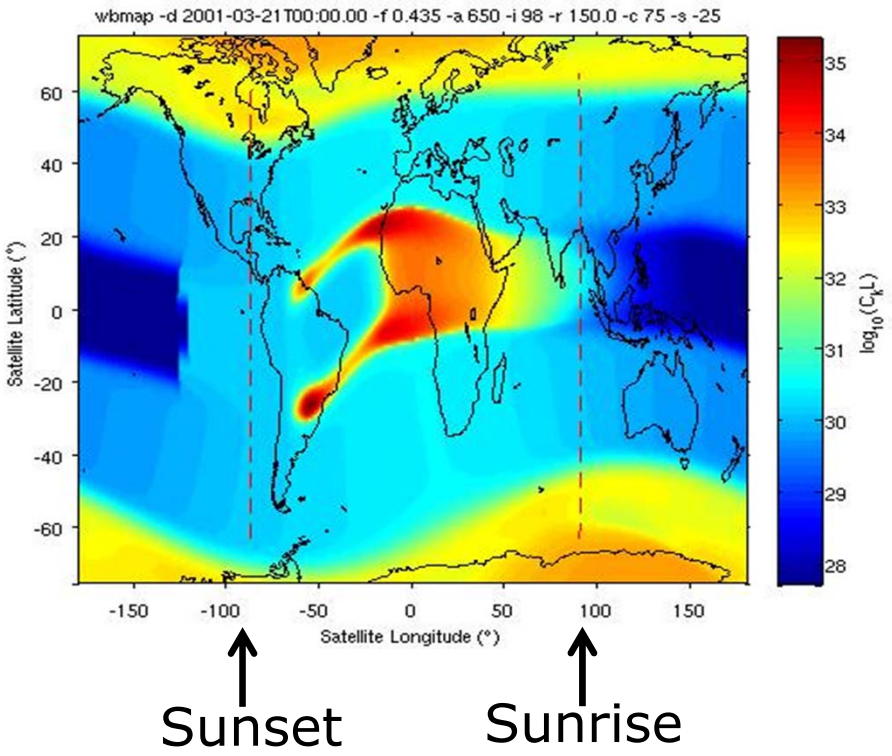


Faraday rotation can be corrected to better than 1º using polarimetric data, which gives negligible effect on PolSAR and PolInSAR.

In the process, Total Electron Content is measured, making Biomass an excellent tool for measuring ionospheric structure.

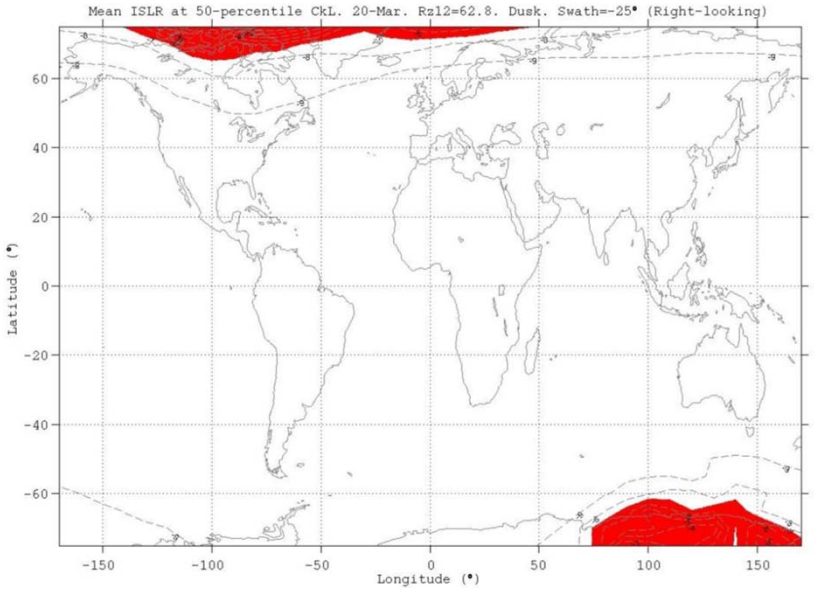
The ionosphere has little effect on Biomass primary objectives: scintillations

Scintillation



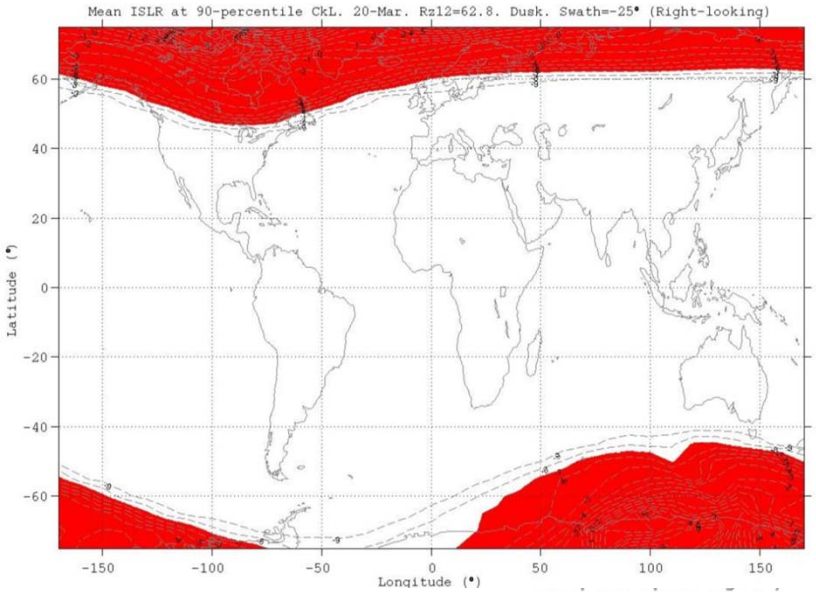
Scintillations cause loss of image contrast. A dawn-dusk orbit avoids the severe equatorial conditions, but cannot avoid auroral scintillations.

Probability = 50%

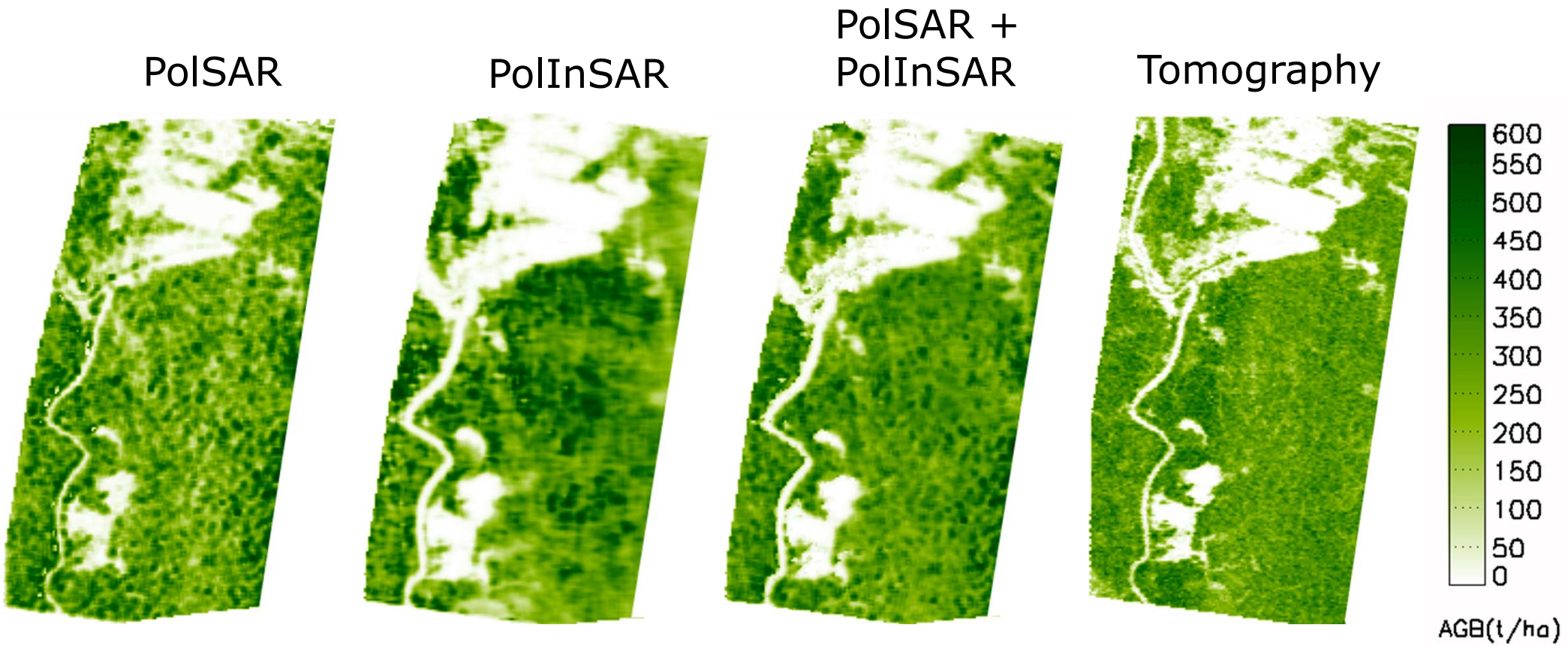


Degradation region, median solar conditions

Probability = 10%



Biomass estimators: tropical forest



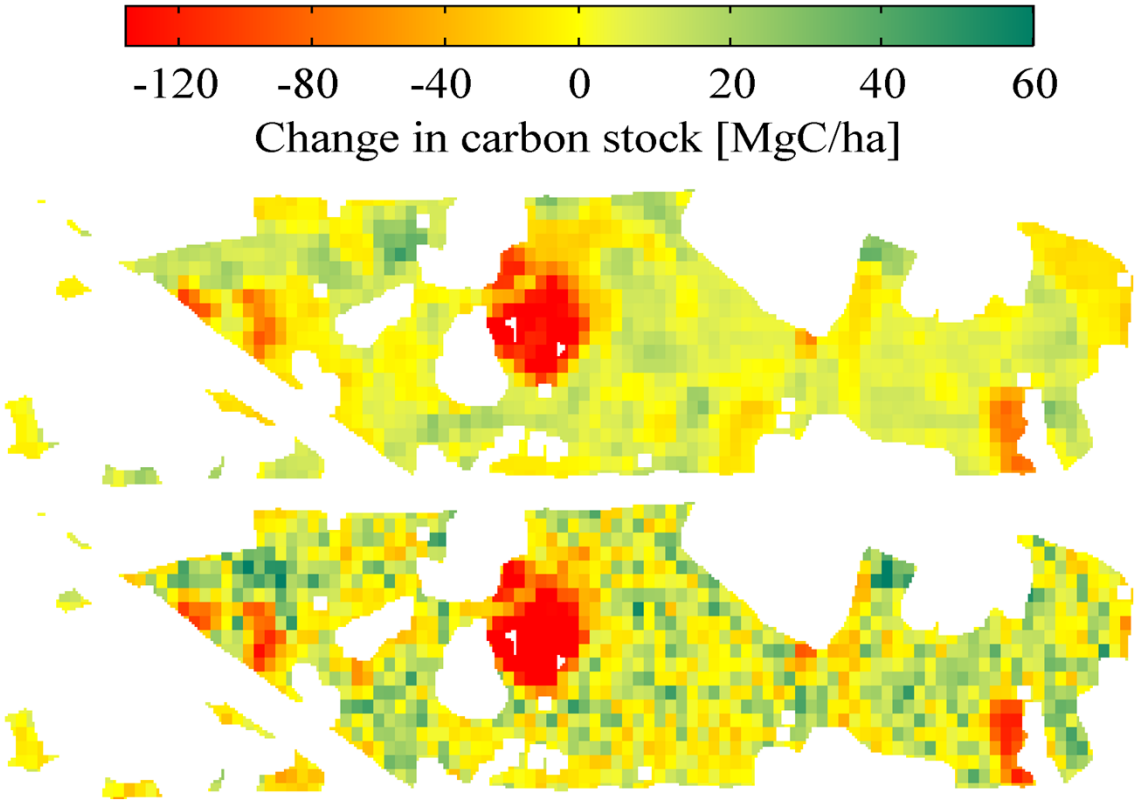
22 % **18 %** **19 %** **13 %**

$$\frac{\text{RMS biomass error (estimated} - \text{in situ)}}{\text{mean biomass}}$$

Paracou, French Guiana, 6 MHz data, in situ biomass:260-430 ton/hectare

Changes in carbon stock

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



Lidar data

P-band PolSAR data

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

Conclusion

1. Biomass is a true Earth Explorer
   a) First P-band SAR in Space.
   b) First mission in space allowing systematic tomographic acquisitions.
2. Biomass meets all its performance requirements
   a) Inversion results over tropical and boreal forests indicate an accuracy of ~20% for biomass and ~30% for forest height.
   b) Change maps over a 4 year period achieve a performance better than 20%.
   c) The potential of SAR tomography has been demonstrated.
3. Biomass is technically feasible
   a) At platform level no critical elements have been identified.
   b) At payload level, some development risks are associated (specifically in the feed system, the power amplifier and the instrument calibration).

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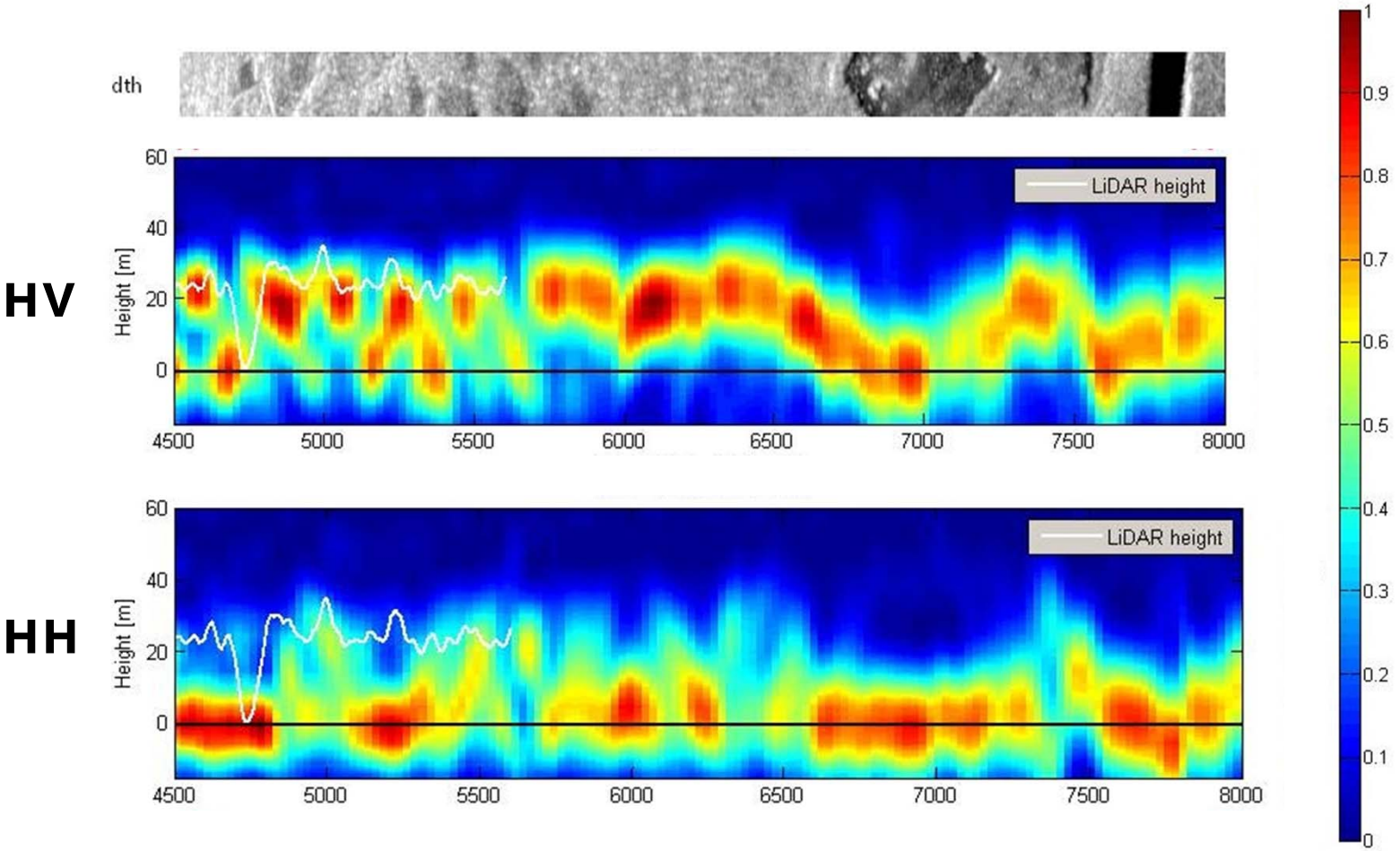
Mission Selection on the 6-7th March in Graz, Austria

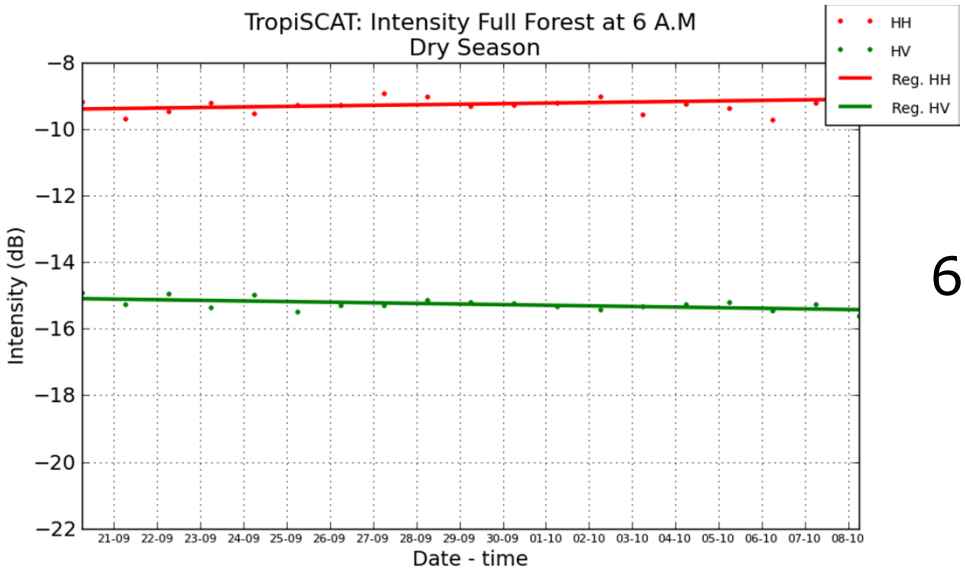
Thank You!

SAR tomography provides information for PolSAR & Pol InSAR

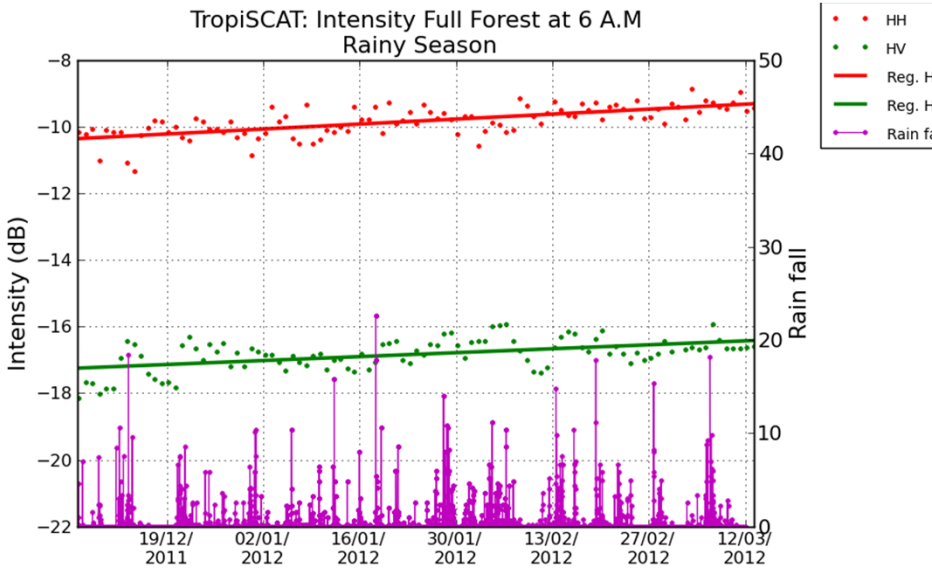


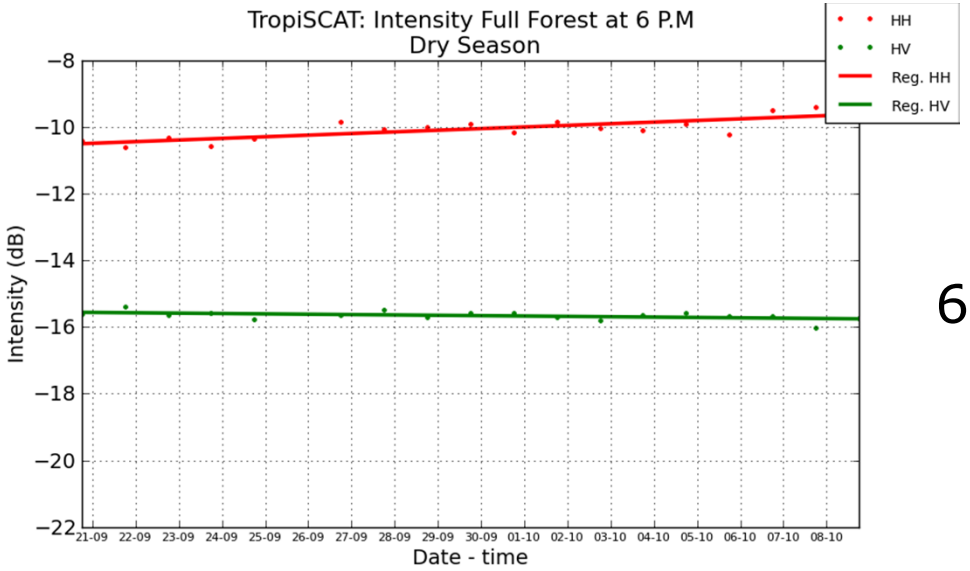
- Vertical reflectivity for Pol InSAR
- Structure information for PolSAR
- Biomass and height maps for PolSAR & Pol InSAR calibration

Temporal effects in tropical forests

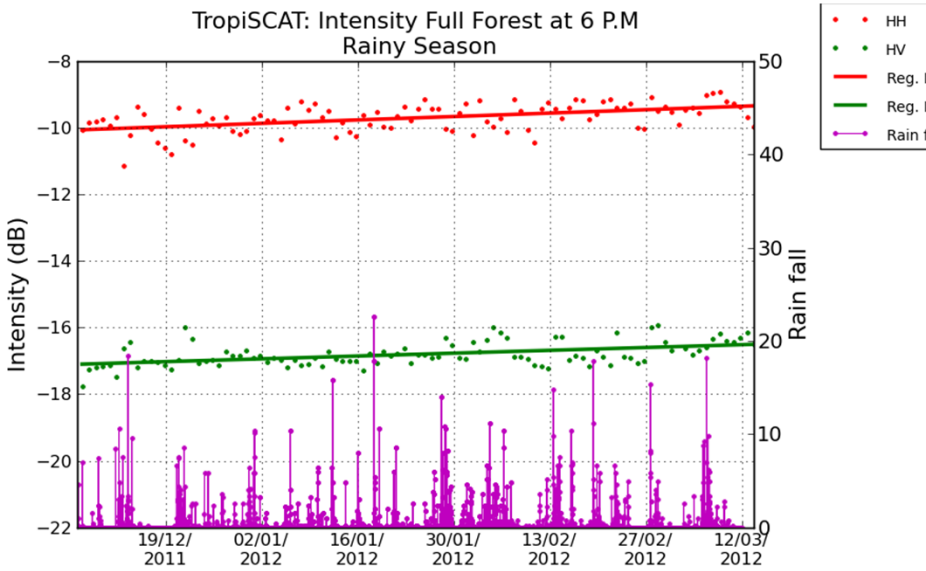


6 A.M.





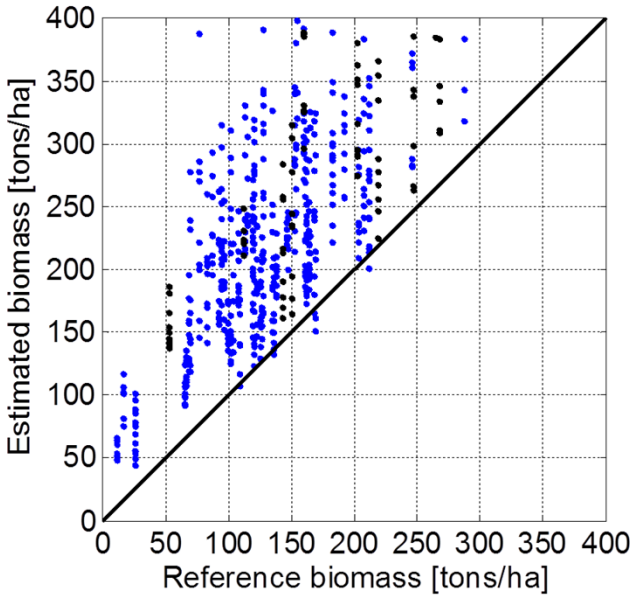
6 P.M.



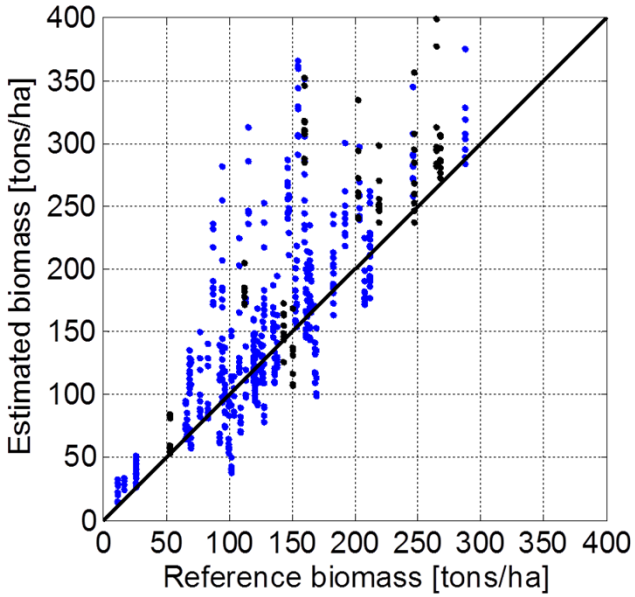
Using polarisation & slope information radically improves measurement accuracy

Remningstorp 70 MHz data: varying environmental conditions in 3 months

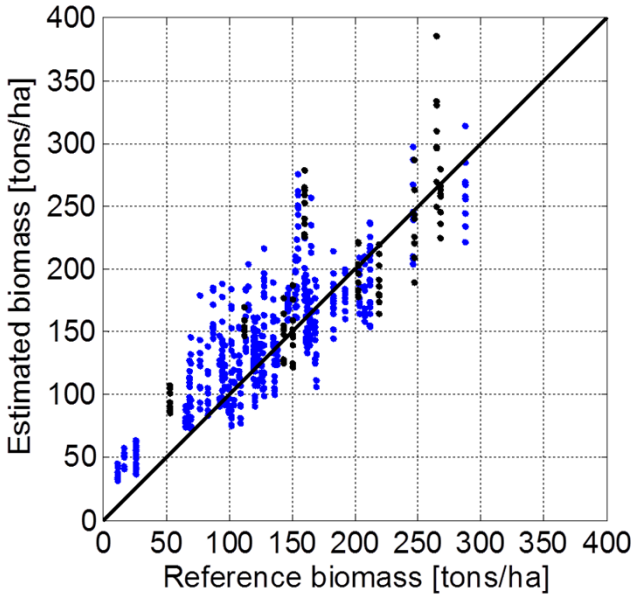
HV only



HV, HH & VV



HV, HH, VV & DEM



Training on stratified subset of Krycklan (northern site) data

Reference data in Remningstorp (southern site):

Blue - from lidar map, std. error = 25 ton/ha

Black - from 80 m x 80 m *in situ* plots, std. error = few %