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TAKING THE PULSE OF OUR PLANET FROM SPACE

# Biomass’ secondary objectives: an overview

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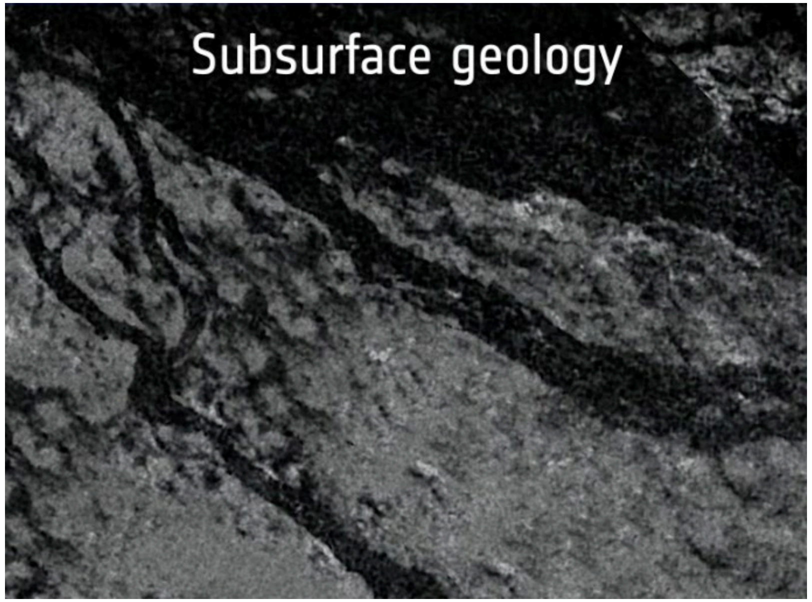
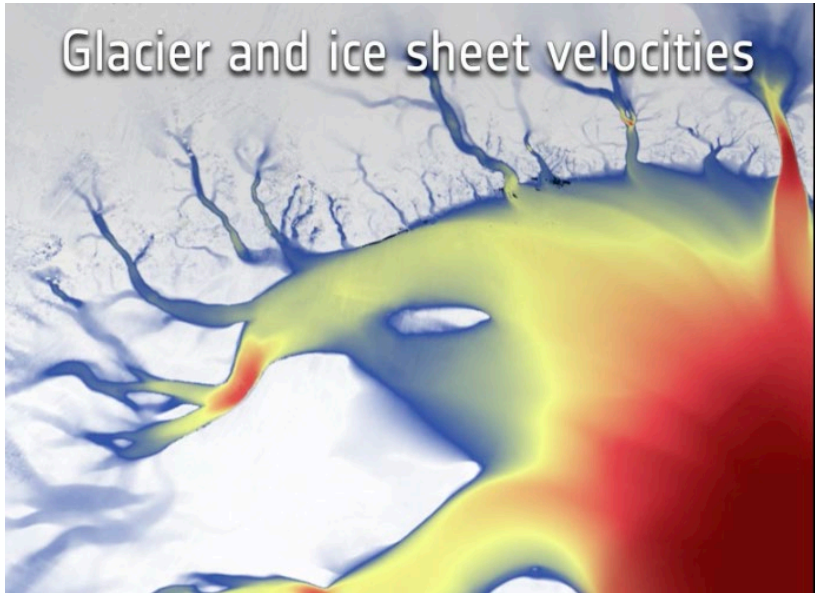
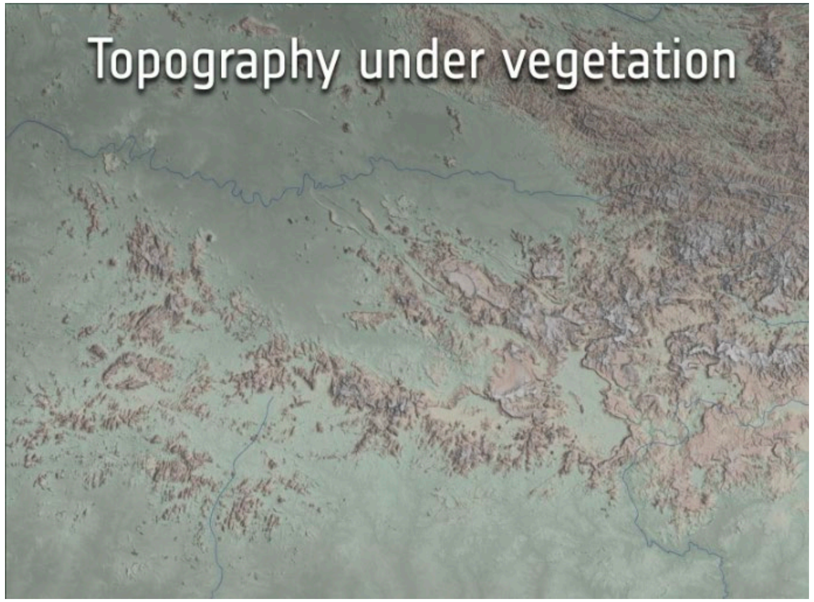
25/05/2022

# Overview

## Biomass' secondary mission objectives:



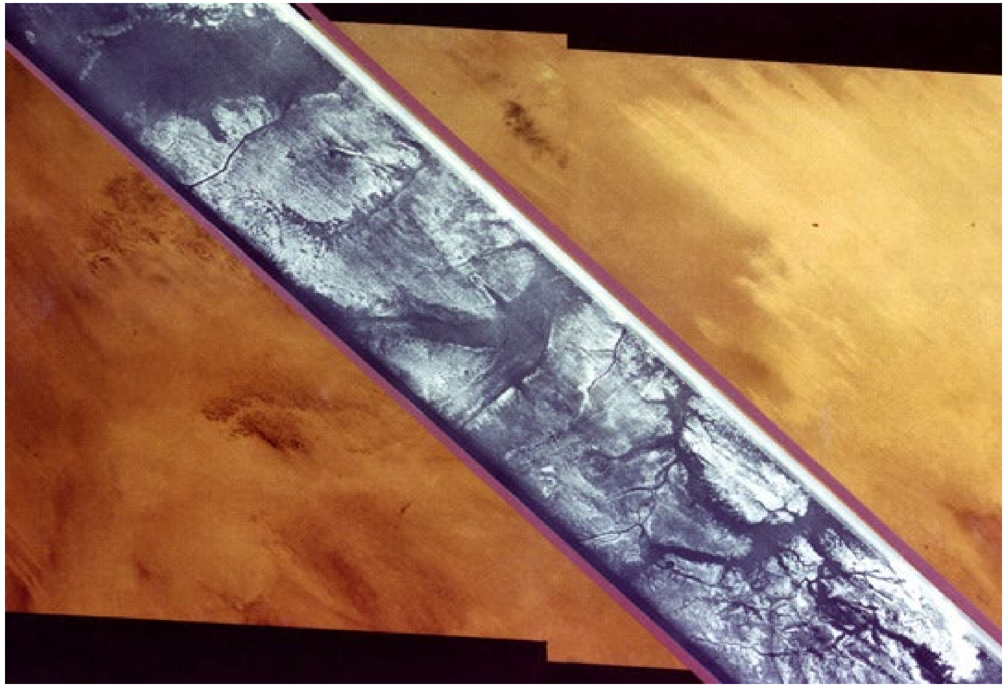



# Subsurface geology in arid regions

## Mapping sub-surface geology in deserts

→ palaeo-hydrological structures (rivers, lakes)
→ study past climate of desert areas
→ prospecting of fossil water resources

**P-band SAR provides a deeper penetration (up to 5 meters in dry sand)**

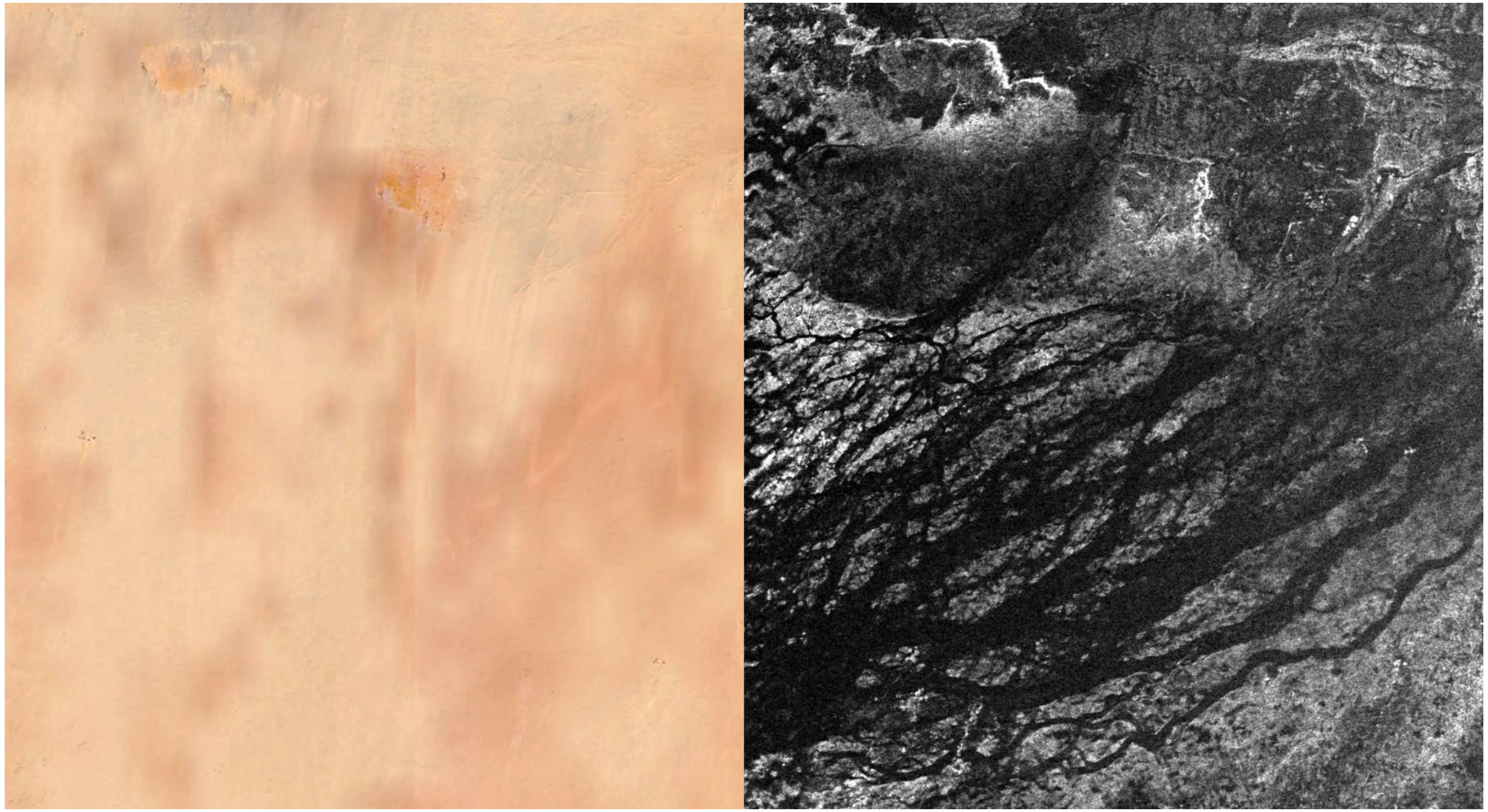


# Subsurface geology in arid regions

## Example #1

*Left*: SPOT Image of the Bir Safsaf desert region in southern Egypt, covering 30x30km and showing an homegeneous aeolian sand cover.

*Right*: ALOS (JAXA) L-band radar image revealing numerous buried paleo-channels under the superficial sand layer (penetration depth estimated to 1-2 meters).

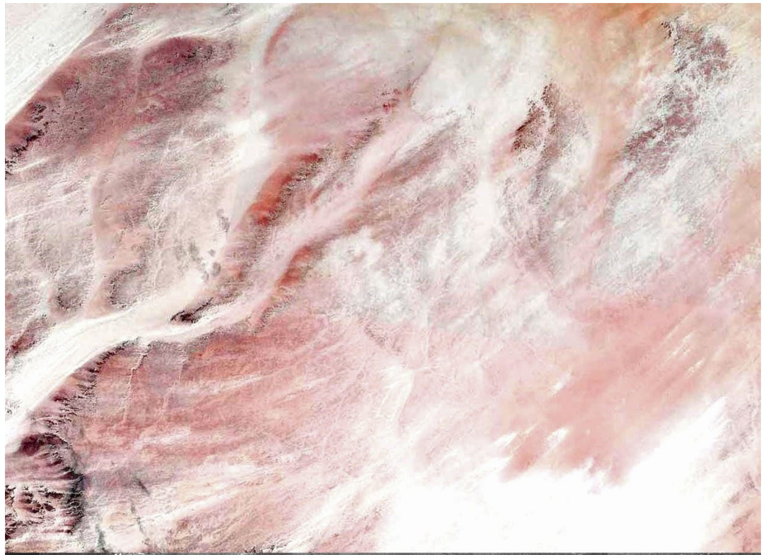


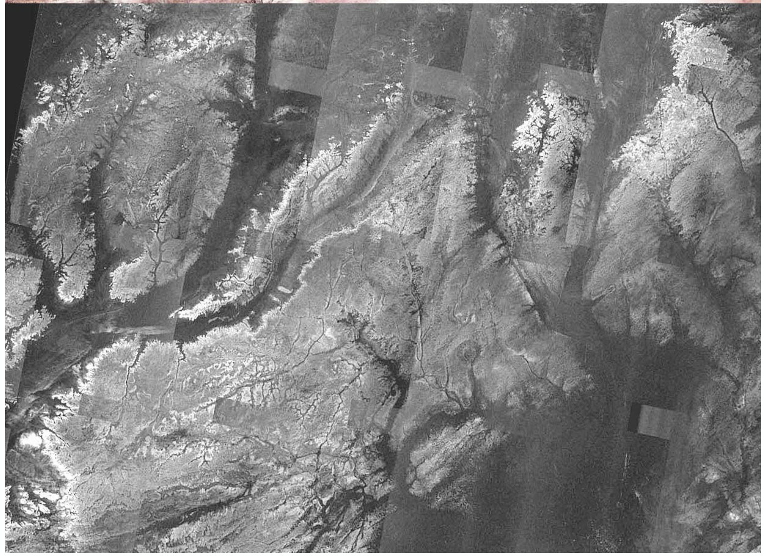
# Subsurface geology in arid regions

## Example #2

*Top*: Landsat-5 image of a desert region in northern Sudan, covering an area of about 200x150km.

*Bottom*: ALOS (JAXA) L-band radar image revealing a past drainage system partially covered under the sand deposits. The dark structure in the lower left part of the image is likely to be an ancient mega-lake.





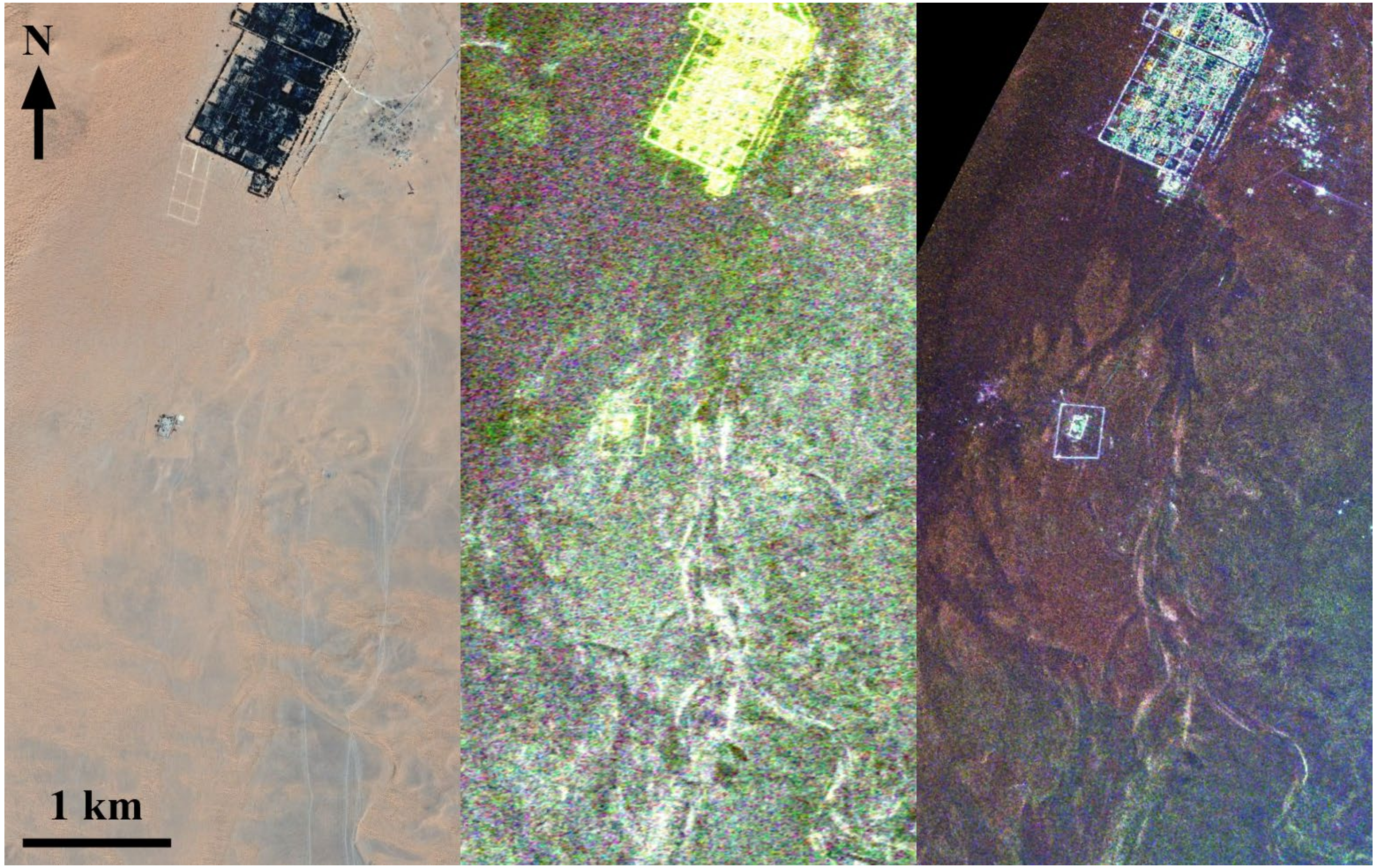
# Subsurface geology in arid regions

## Example #3

*Left*: SPOT image of the Ksar Ghilane oasis region in southern Tunisia, palaeo-channels are hidden by aeolian sand deposits.

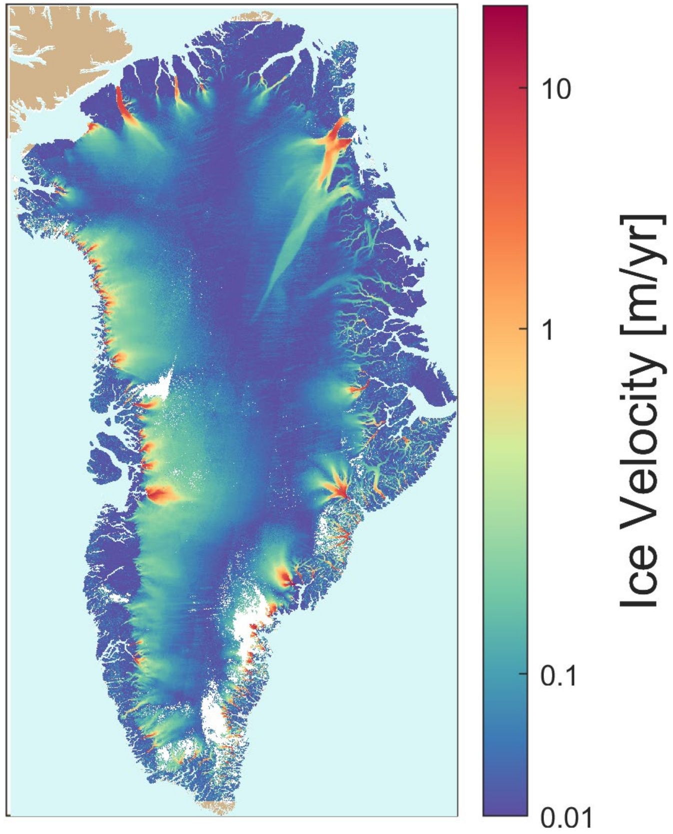
*Middle*: ALOS-2 L-band radar image, showing some subsurface features still blurred by the radar return of the superficial sand layer.

*Right*: SETHI P-band radar image, revealing sub-surface hydrological features in a very efficient way (ONERA/CNES).



# Ice sheet velocity mapping

- Ice sheet mass balance can be estimated from ice velocity and ice thickness (flux).
- Biomass has a potential in the Antarctic whereas ITU frequency allocations prevent Biomass from mapping Greenland, where ice velocities are mapped routinely with S1.
- Biomass has its smaller polar gap over the South Pole (unlike S1).
- Currently available Antarctica maps have an accuracy of 1–17 m/yr, while the histogram for the entire Antarctica peaks at 5 m/yr.
- Accuracy is favored by a large temporal baseline, but temporal decorrelation may be prohibitive.



Solgaard et al., 2021

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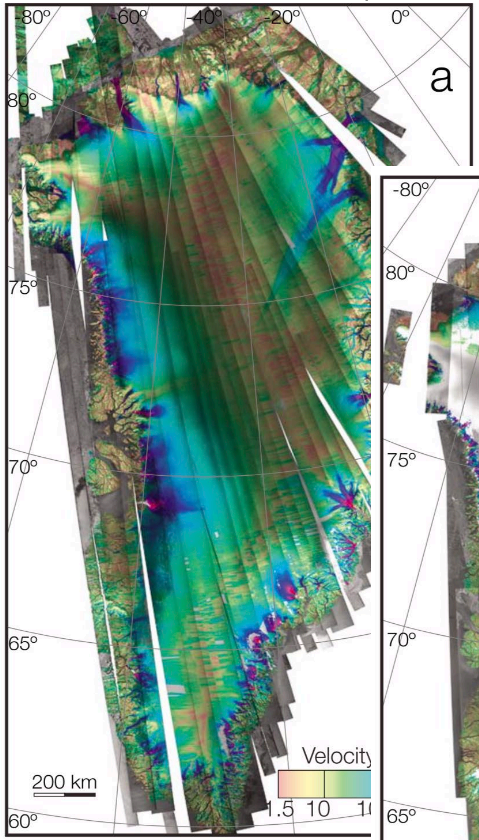
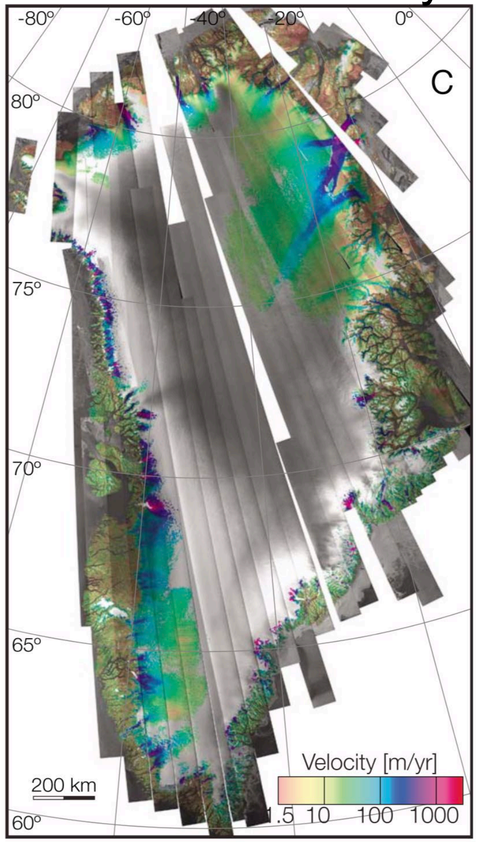
- Accuracy is favored by a large temporal baseline, but temporal decorrelation may be prohibitive.
- The decorrelation time increases with decreasing frequency due to (1) a deeper penetration to more stable scatterers and (2) a smaller phase shift resulting from a given spatial shift of scatterers.

L-band 46 days




C-band 35 days



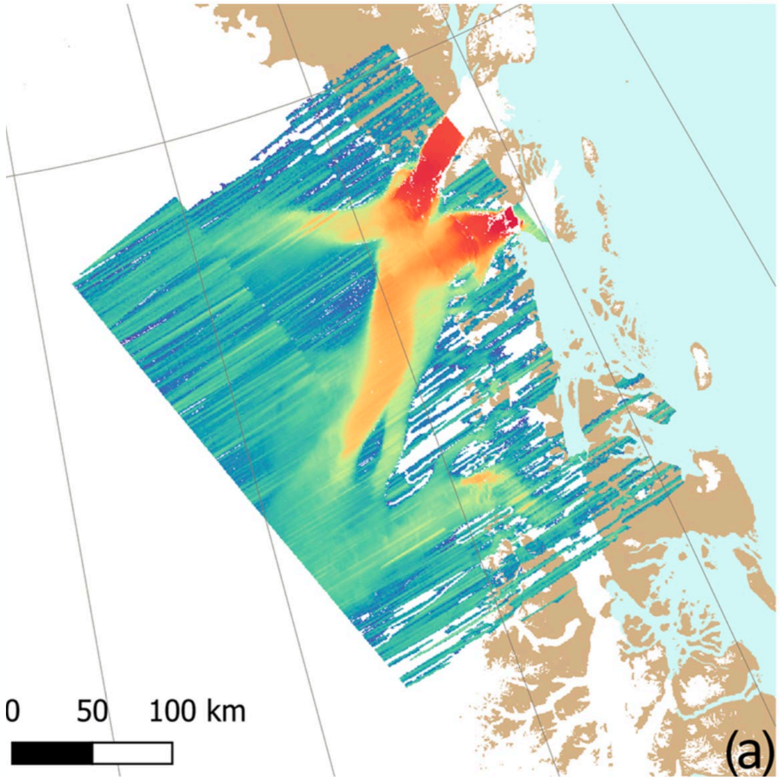

Rignot, 2012

# Differential interferometry

**Interferometry (applied to data acquired from both ascending and descending orbits) is preferred to offset tracking:**

- If applicable, interferometry offers a better velocity accuracy, as needed for most of the Antarctic ice sheet.
- Coarse range resolution => the range component of the velocity is estimated with a poor accuracy if using offset tracking.
- When using offset tracking, ionospheric scintillations in particular impact the azimuth component of the velocity.

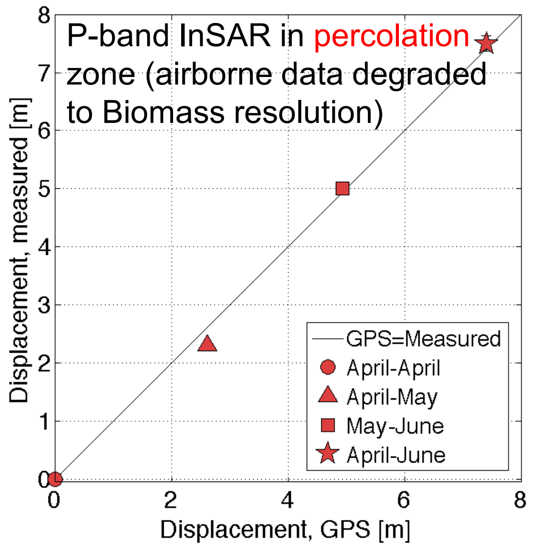
Ice velocity map in case of strong scintillations (S1, 6 day baseline)




Solgaard et al. 2021

# Temporal decorrelation at P-band

- Biomass's short temporal baselines (~3 days) do not offer a sufficient velocity accuracy in most of Antarctica.
- Biomass's temporal baseline corresponding to the global mapping cycle (~8 months) may allow the low ice velocities in the interior of Antarctica to be mapped, but …
- … the P-band correlation time is unknown, as no P-band data from the dry snow zone exist.
- In the dry snow zone, the P-band correlation time is likely to exceed 8 months …
- … as even in the percolation zone it is sufficient for interferometry with a temporal baseline of several months.

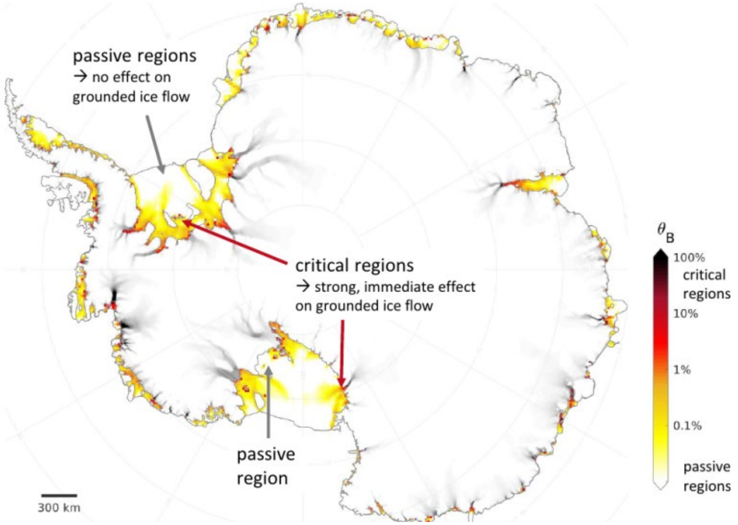


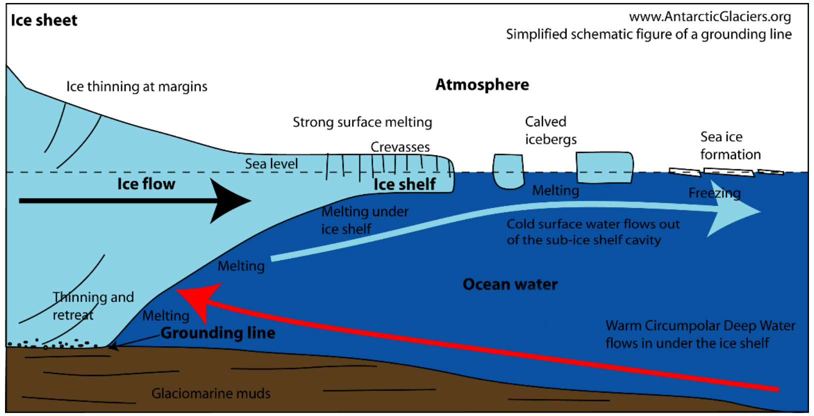


# Ice shelf basal topography: motivation

**Why are ice shelves important?**

- Ice shelves can buttress the grounded ice sheet, thereby stabilizing it.
- Ice rises and ice rumples contribute to the stabilization of the ice shelves.
- Ice shelf thinning can be caused by warm ocean water circulation.
- Mean ice shelf thickness can be measured with radar altimetry (surface elevation), but the basal topography is important, e.g. channels are common.



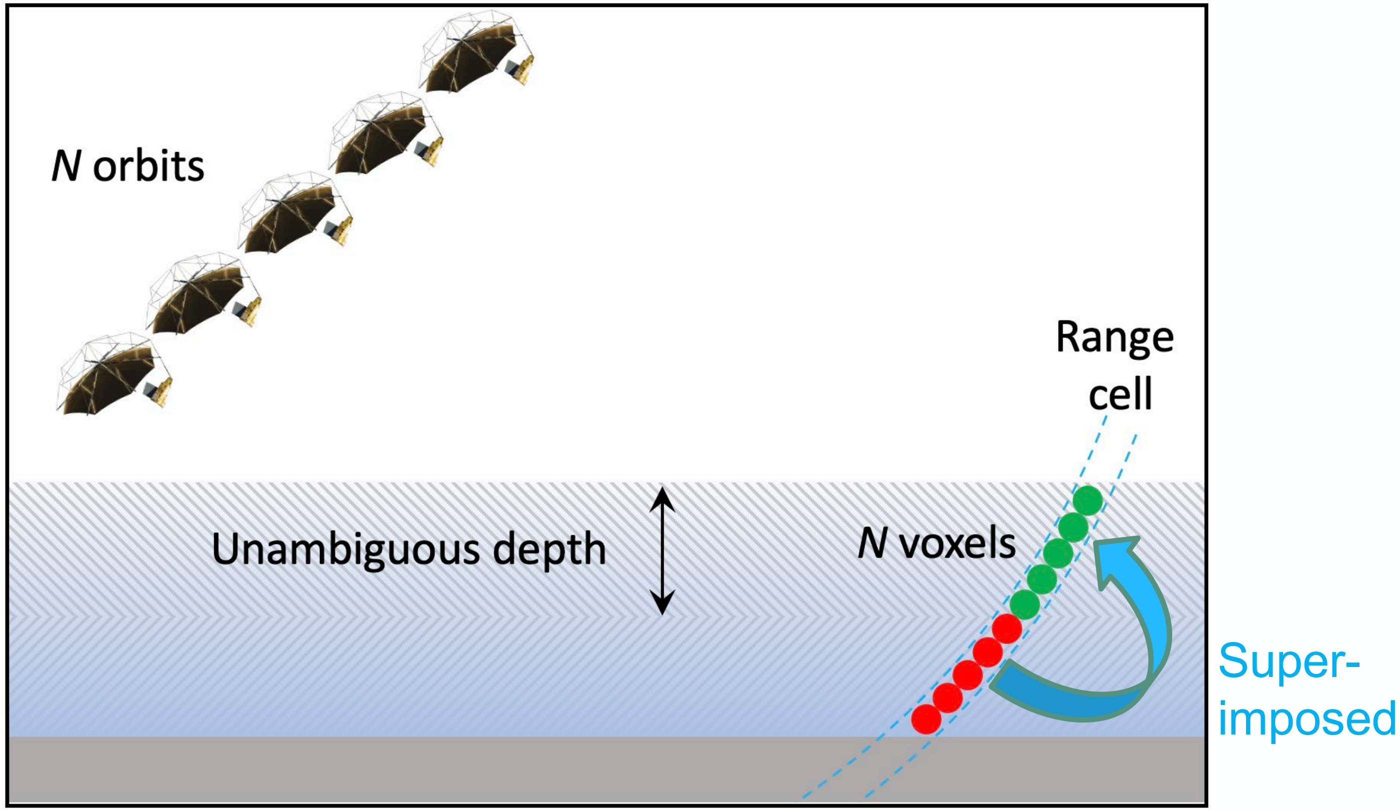




Reese 2018

# Ice shelf basal topography: feasibility

**TomoSAR** may be an applicable technique, even in presence of volume clutter, but …

- the unambiguous depth must exceed the ice shelf thickness.



# Ice shelf basal topography: feasibility

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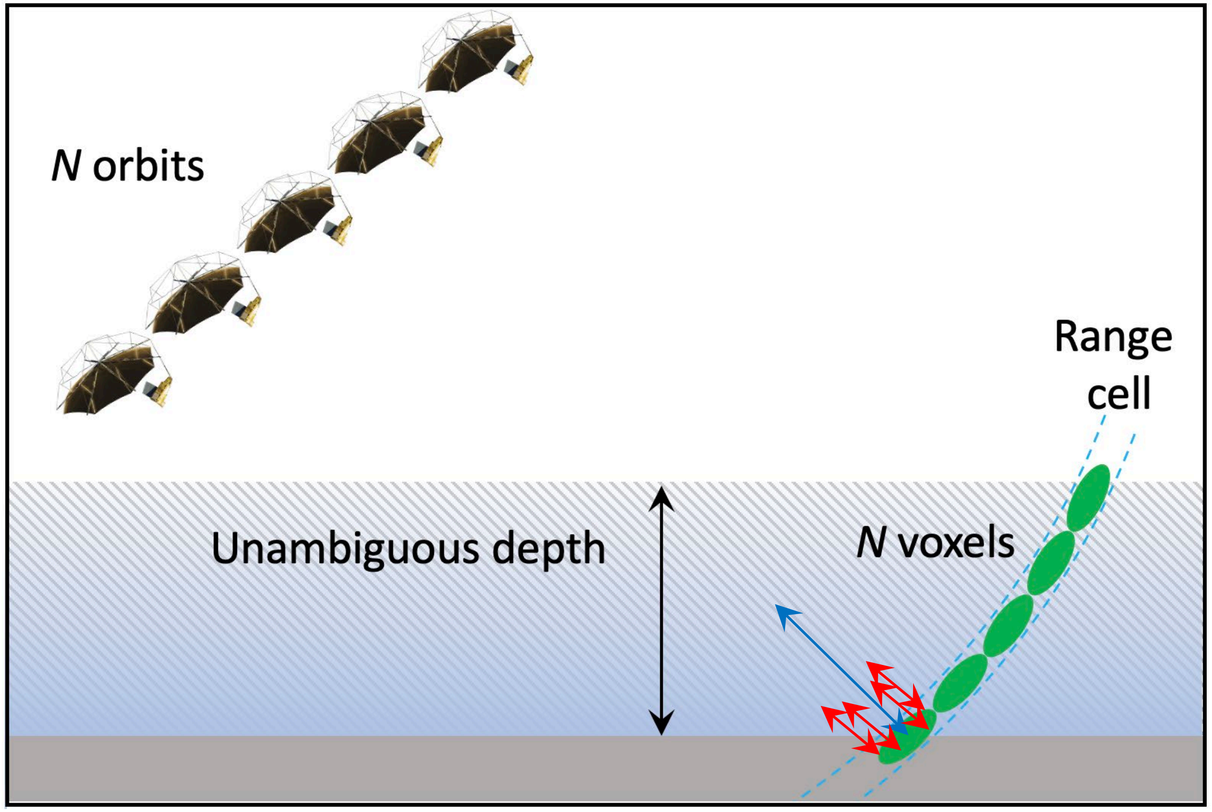
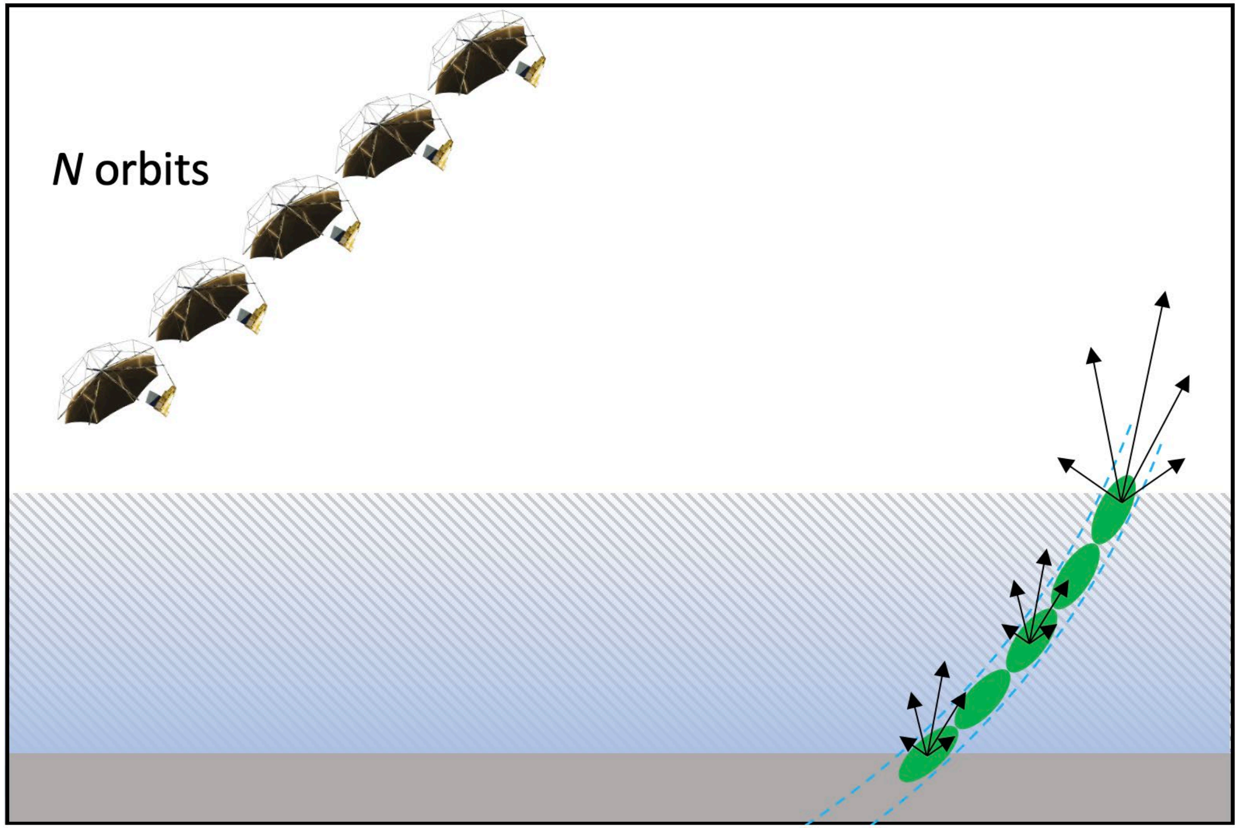
- the voxels must be so small that an adequate signal-to-volume-clutter ratio results.



# Ice shelf basal topography: feasibility

**Feasibility assessed with an electromagnetic model:**

- BIOMASS SAR parameters.
- TomoSAR geometry, e.g. $k_z$.
- Ice parameters, e.g. attenuation and scattering patterns for surface, volume, and base from airborne P-band radar.
- TomoSAR processing (direction of arrival (DOA) estimation, e.g. with MUSIC).
- Basal topography from DOA

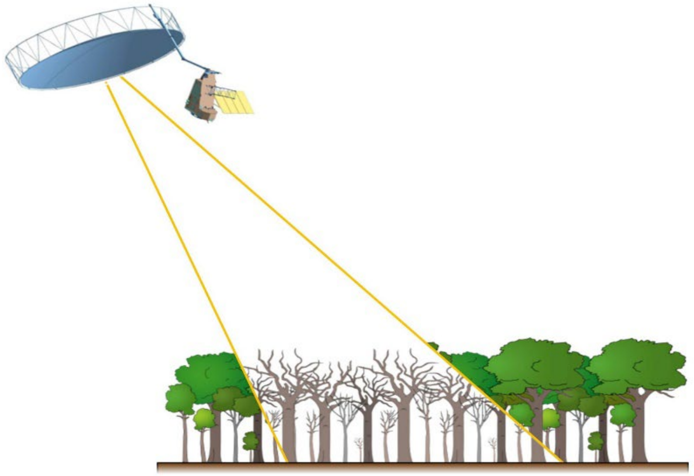



**No conclusions yet (work in progress)**

# BIOMASS DTM

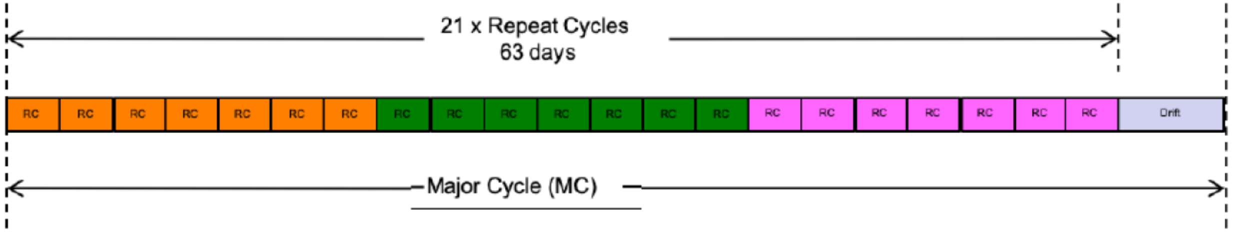
**P-band**

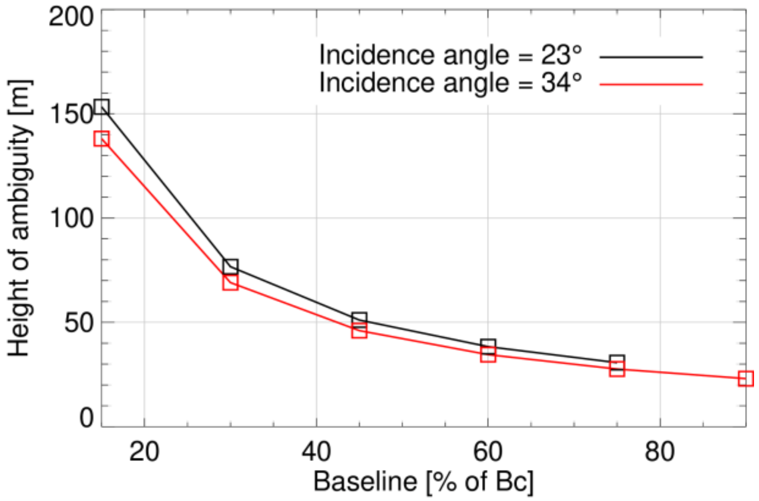
- Penetrates through forest
- Strong ground return



[1] http://www.esa.int/ESA_Multimedia/Images/2018/10/P-band_radar_piercing_through_forest_canopy

## BIOMASS TOM Phase




**Height of ambiguity diversity for BIOMASS TOM Stack**

# BIOMASS DTM

**P-band**
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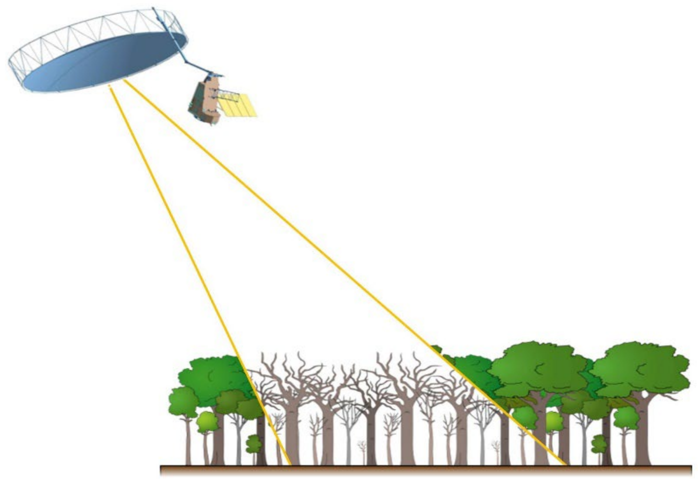

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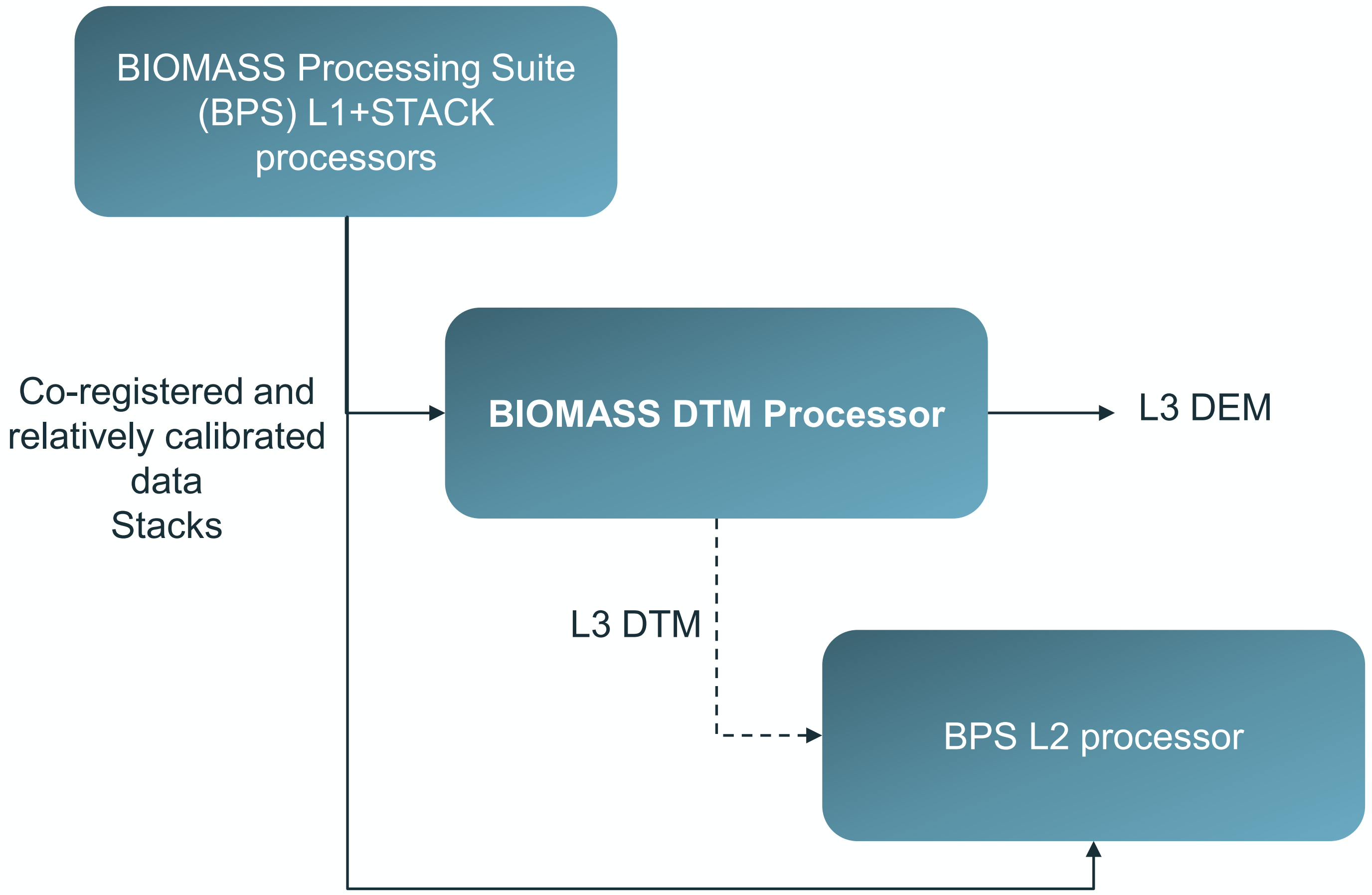
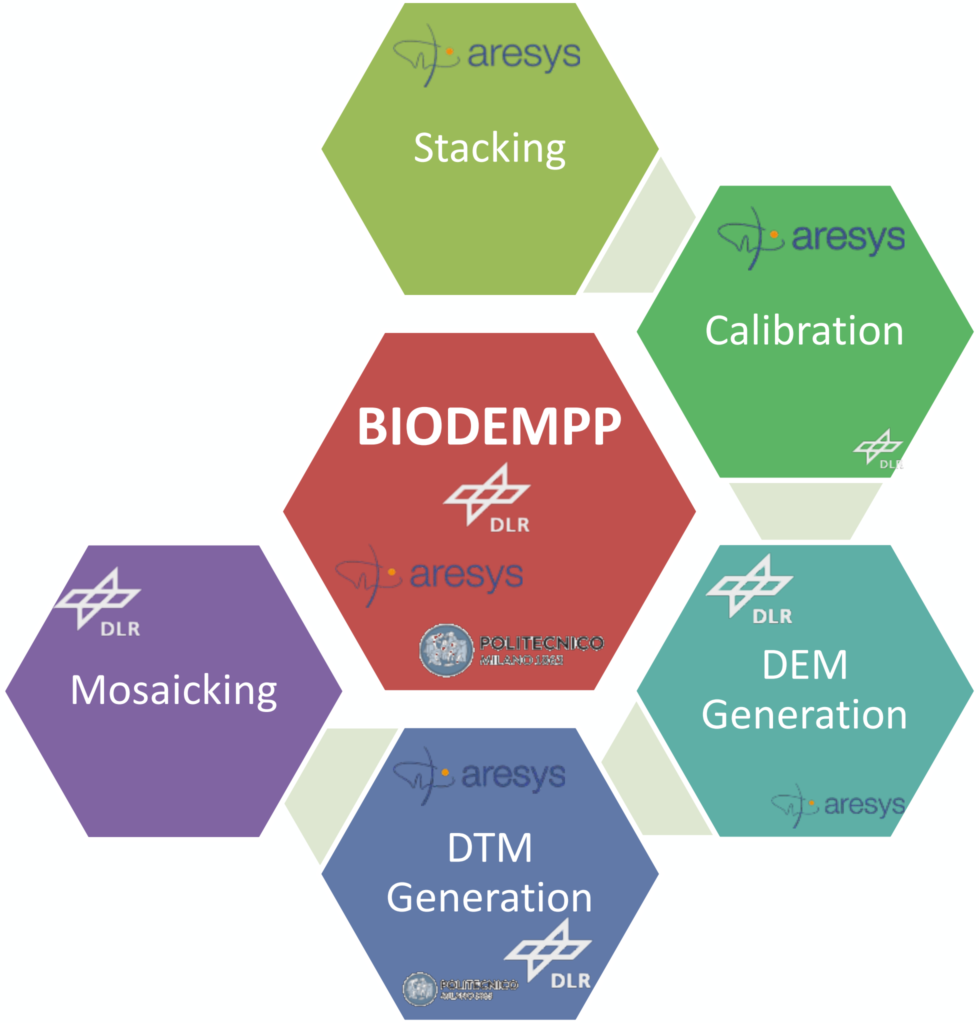


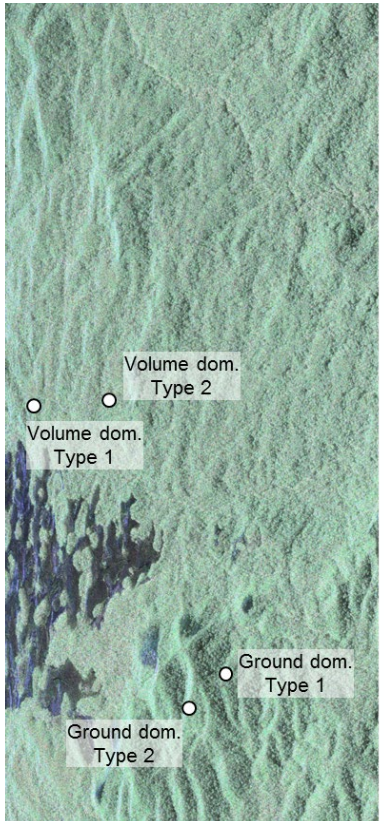
# BIOMASS DTM – The BIODEMPP

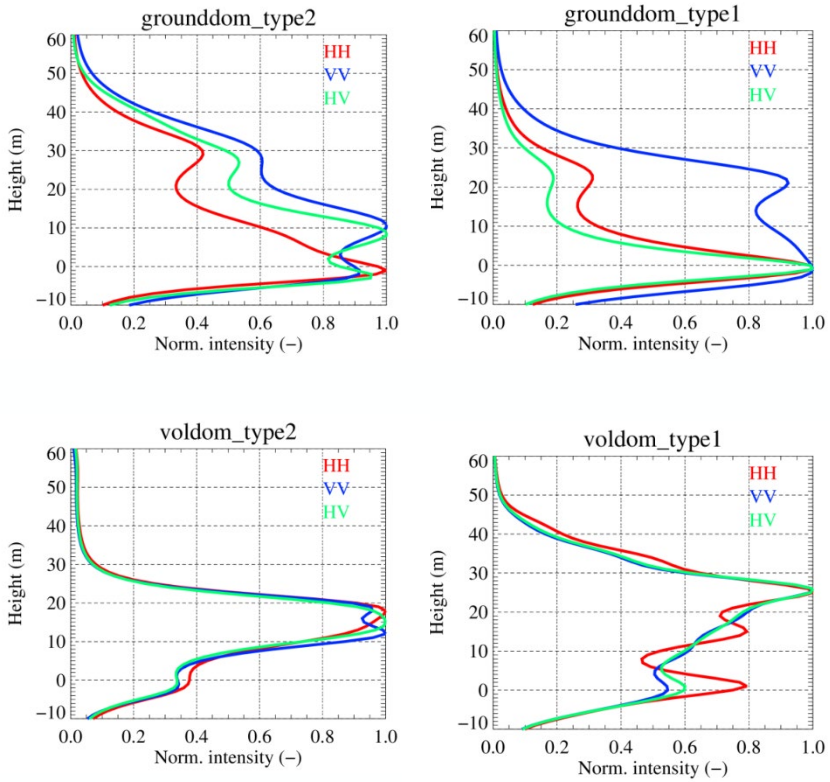
- Proof of concept and prototyping of the BIOMASS DTM processor were carried out in the BIODEMPP study
- The study included the prototyping of co-registration and calibration modules now included in the BPS STACK processor (operational processor)
- Moreover, dedicated modules for DEM (interferometry based) and DTM (interferometry + tomography based) were developed
- Study included verification and validation of methods and products with BIOMASS simulated data (both fully synthetic and from airborne acquisitions)



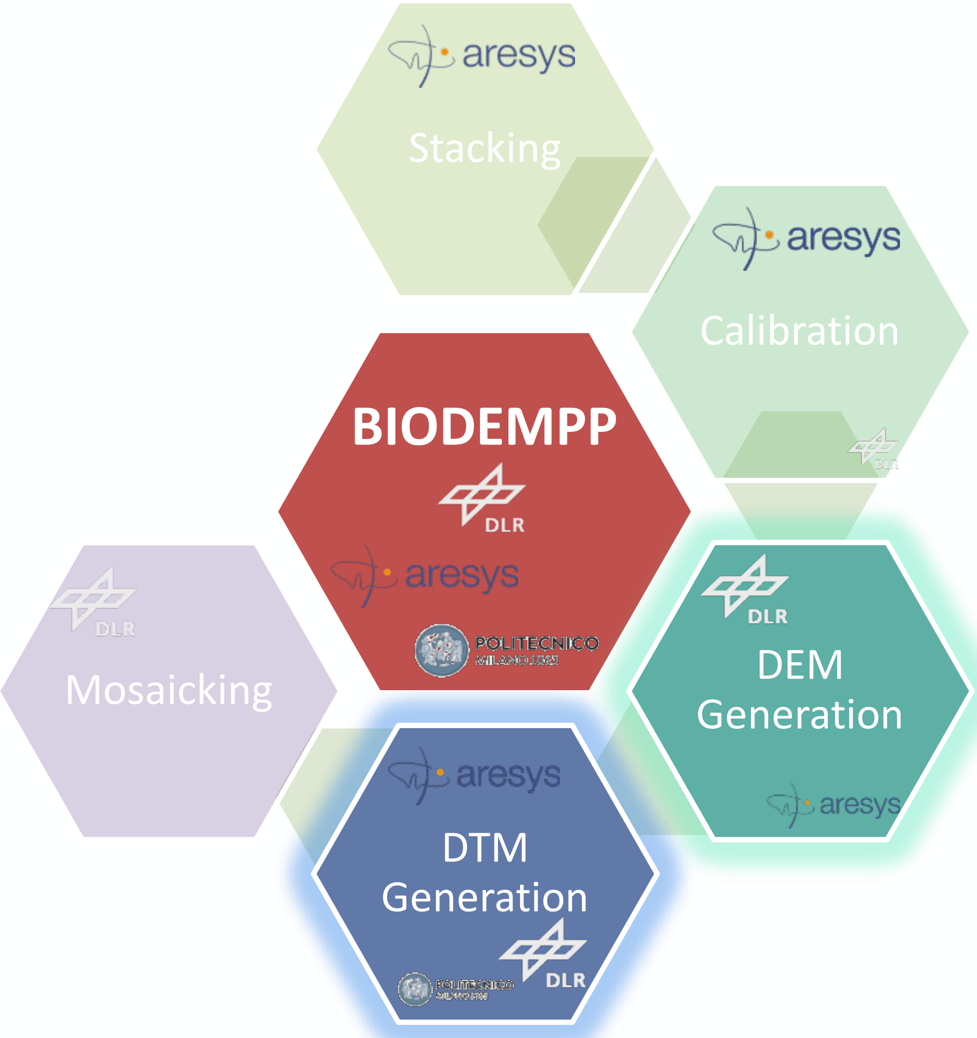
# BIOMASS DTM – Challenges

**Tomographic profiles for different volumetric targets (AfriSAR campaign)**




**Even for P-band, volume-dominant targets are present and require de-bias**



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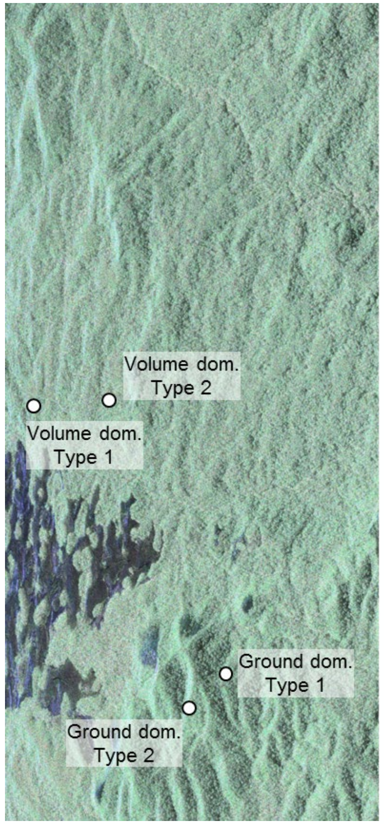
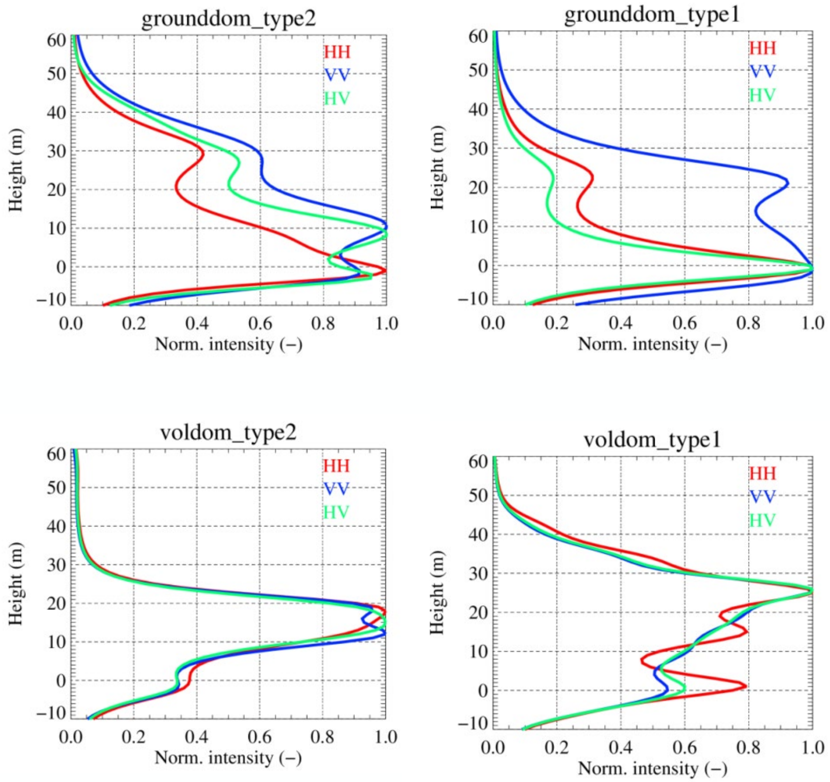



**Even for P-band, volume-dominant targets are present and require de-bias**

**The BIODEMPP solution**

**Phase center DEM estimation with multi-baseline interferometry**

↓

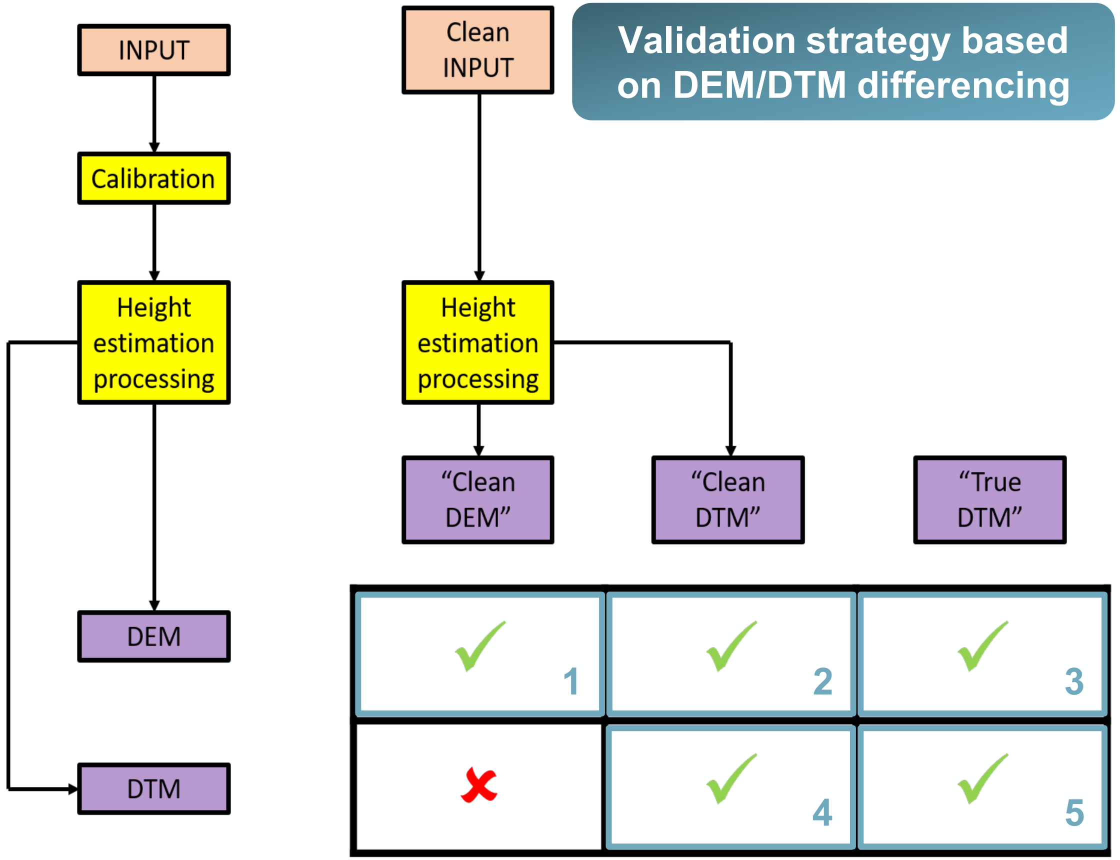
**Ground steered phase with Sum of Kronecker Products (SKP)**

↓

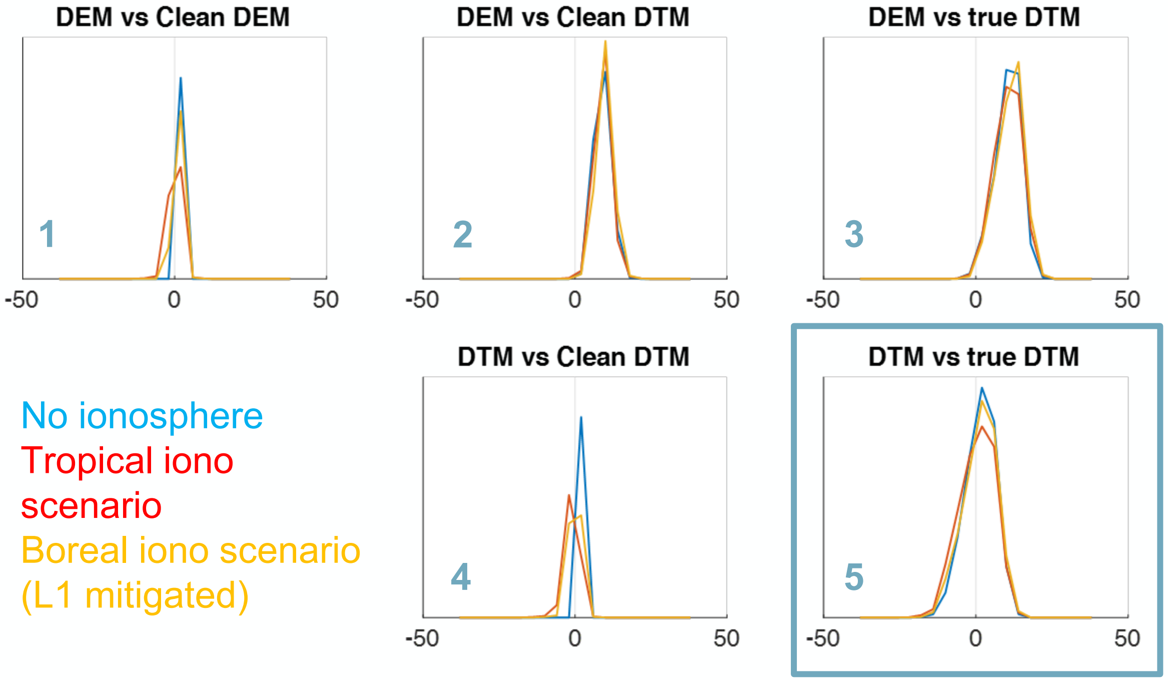
**Phase center DTM estimation with multi-baseline interferometry**

# BIOMASS DTM – Validation

## Validation strategy based on DEM/DTM differencing




## BIOMASS validation for tropical ionosphere scenario, tropical forest (BIOMASS simulation based on TropiSAR)




No ionosphere
Tropical iono scenario
Boreal iono scenario (L1 mitigated)

$\mu = 0.41$ $\sigma = 5.75$

$\mu = 1.35$ $\sigma = 5.36$