THE GLOBAL FOREST BIOMASS ESTIMATION ALGORITHM FOR ESA'S BIOMASS MISSION

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Global biomass estimation algorithm for BIOMASS

Outline:

1. P-band SAR for biomass estimation
2. The great breakthrough of ground cancellation
3. Modelling the biomass-backscatter relationship
4. Obtaining global coverage
5. Algorithm outline
6. Towards the launch of BIOMASS and beyond

Image credit: Thuy le Toan

P-band SAR for biomass estimation

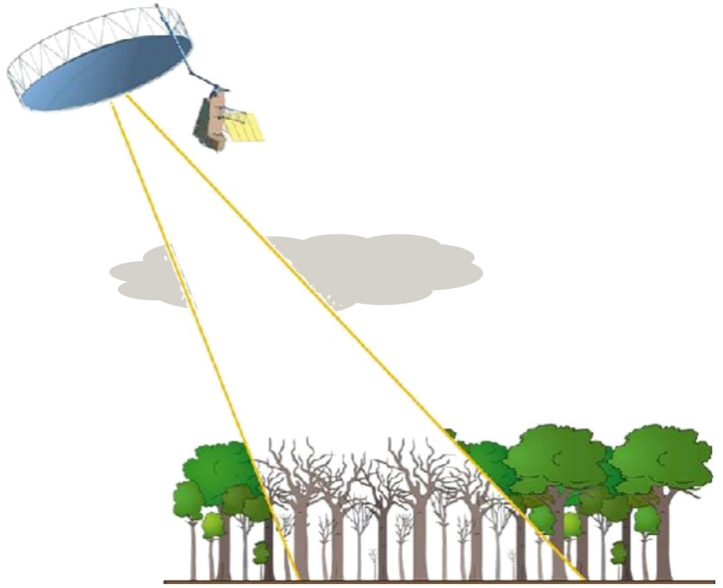
P-band SAR: long waves (~ 70 cm) → good canopy penetration:

- Strong scattering from tree trunks and large branches
- Good temporal coherence

... but also ...

- Strong scattering from the ground

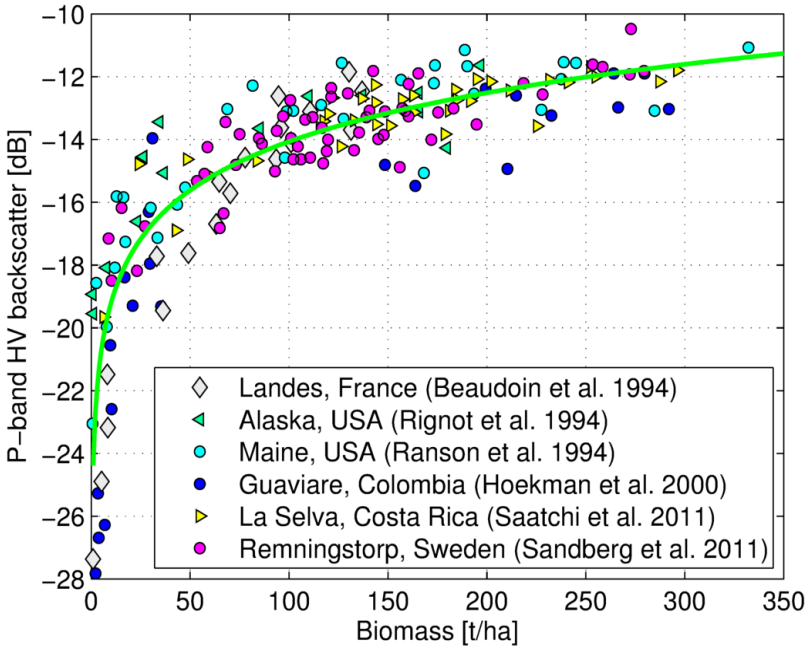
Good potential for biomass estimation, but with **some challenges**...



P-band SAR for biomass estimation

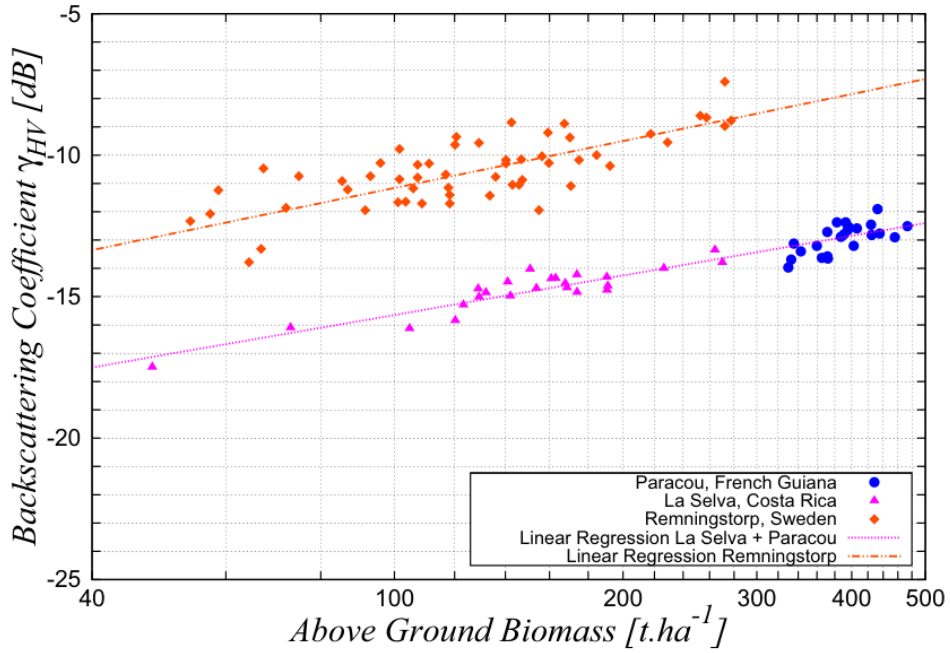
Challenge 1: variability across test sites/biomes...

Le Toan et al., 2011



... Initially attributed to calibration & manually removed

Quegan et al., 2019

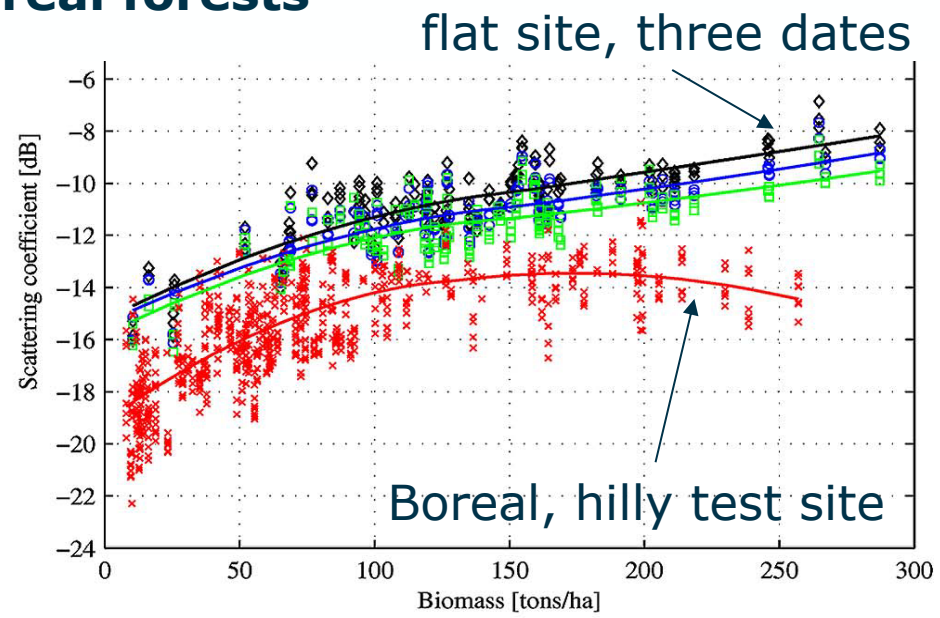


... but now considered to be dominated by **physical effects** that need to be retained

P-band SAR for biomass estimation

Challenge 2: topography and moisture

Boreal forests

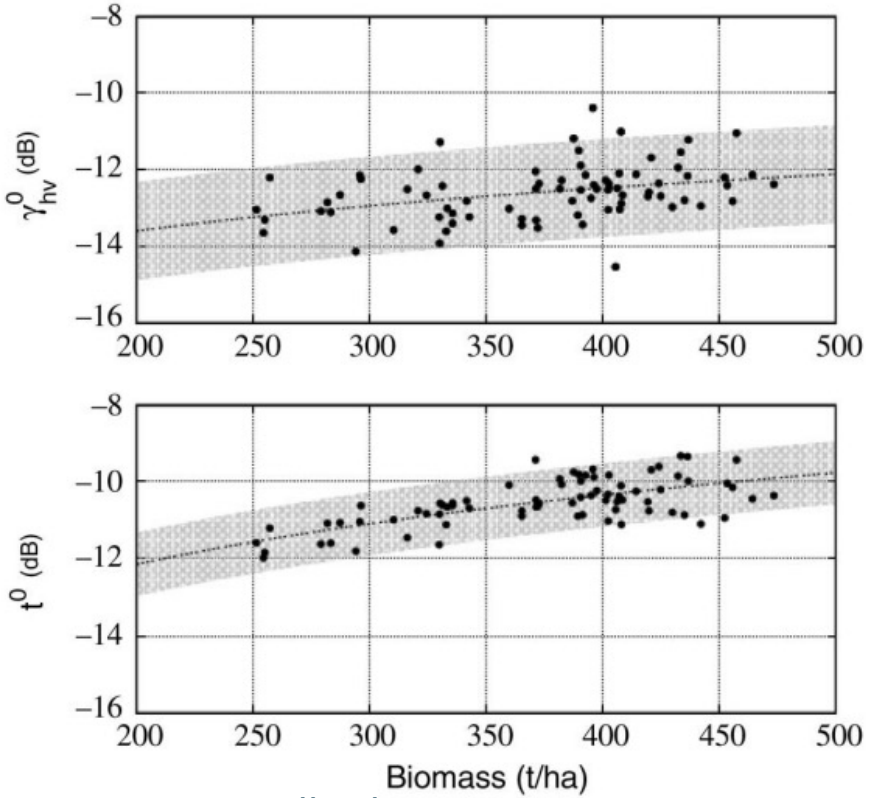


Soja et al., 2013

Topographic & moisture effects are still not well-understood or well-modelled

Tropical forest, hilly terrain

Topographic correction applied

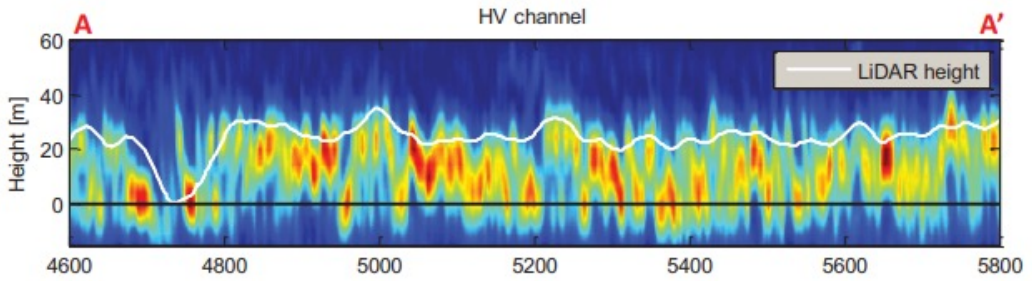


Villard & Le Toan, 2015

The great breakthrough of ground cancellation

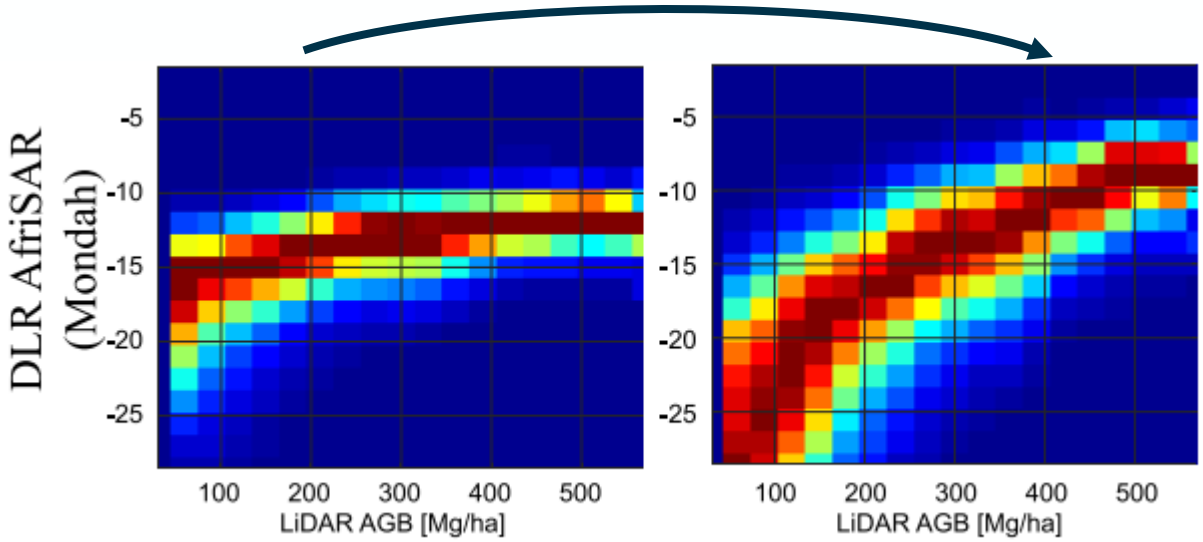
- **Remove ground backscatter using TomoSAR or InSAR data!**
- Possible methods that improve biomass estimation:
  - **TomoSAR** (e.g., backscatter @ 30m height); requires ~14 months of acquisition for BIOMASS
  - **Ground cancellation** suppresses ground-level backscatter & works with 3-pass InSAR data (~7 months of acquisition)

Tomographic profile



Minh et al., 2014

Ground cancellation applied



d'Alessandro et al., 2020

Modelling

- Selected **power law model** for canopy backscatter

$$\sigma_{pi}^{0} = L_{pi} W^{\alpha_{pk}} \cos^{n_p} \vartheta_i$$

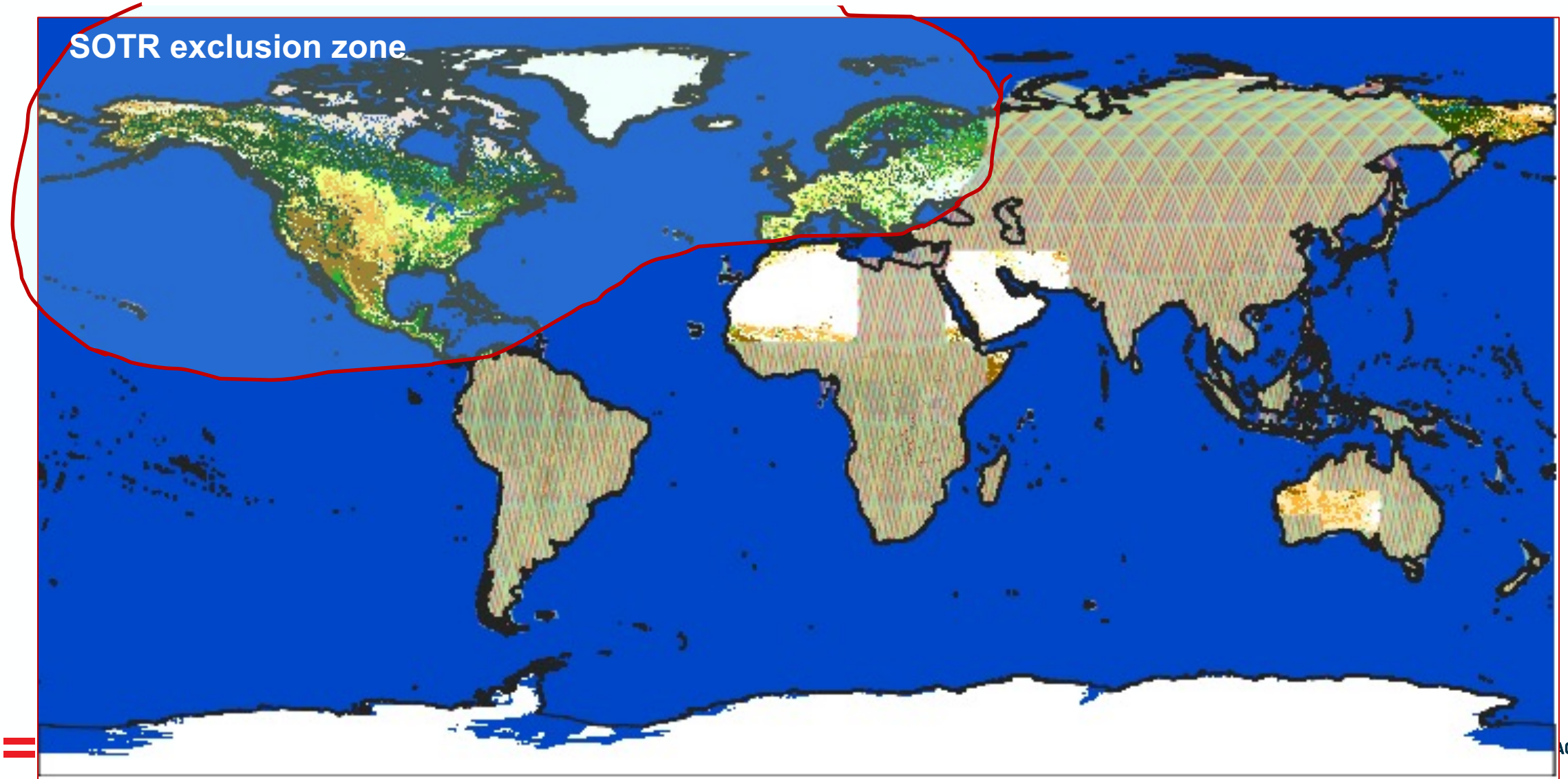
canopy backscatter — biomass — Local incidence angle

- All model parameters change with **polarisation** p; additionally:
  - L_{pi} changes with **acquisition** i, accounting for moisture variability
  - α_{pk} changes with **land cover class** k, thus accounting for structural variability
- Good performance across six tropical forest sites, consistent with other models in literature (e.g., power law for σ^0, γ^0), easy to linearise & fit, easy error modelling

Quegan et al., 2019; Soja et al., 2021

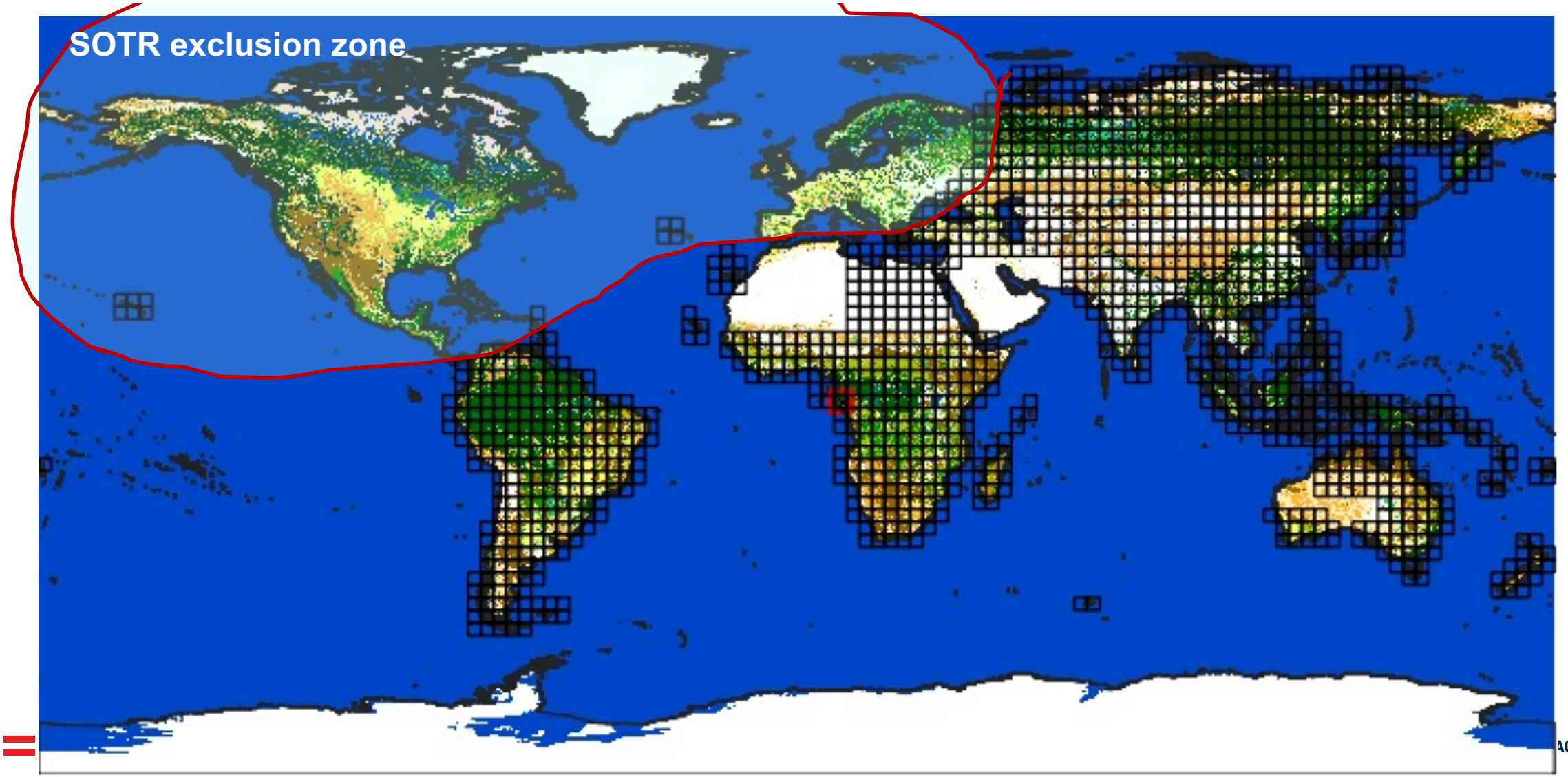
Obtaining global coverage

Simulated BIOMASS data coverage



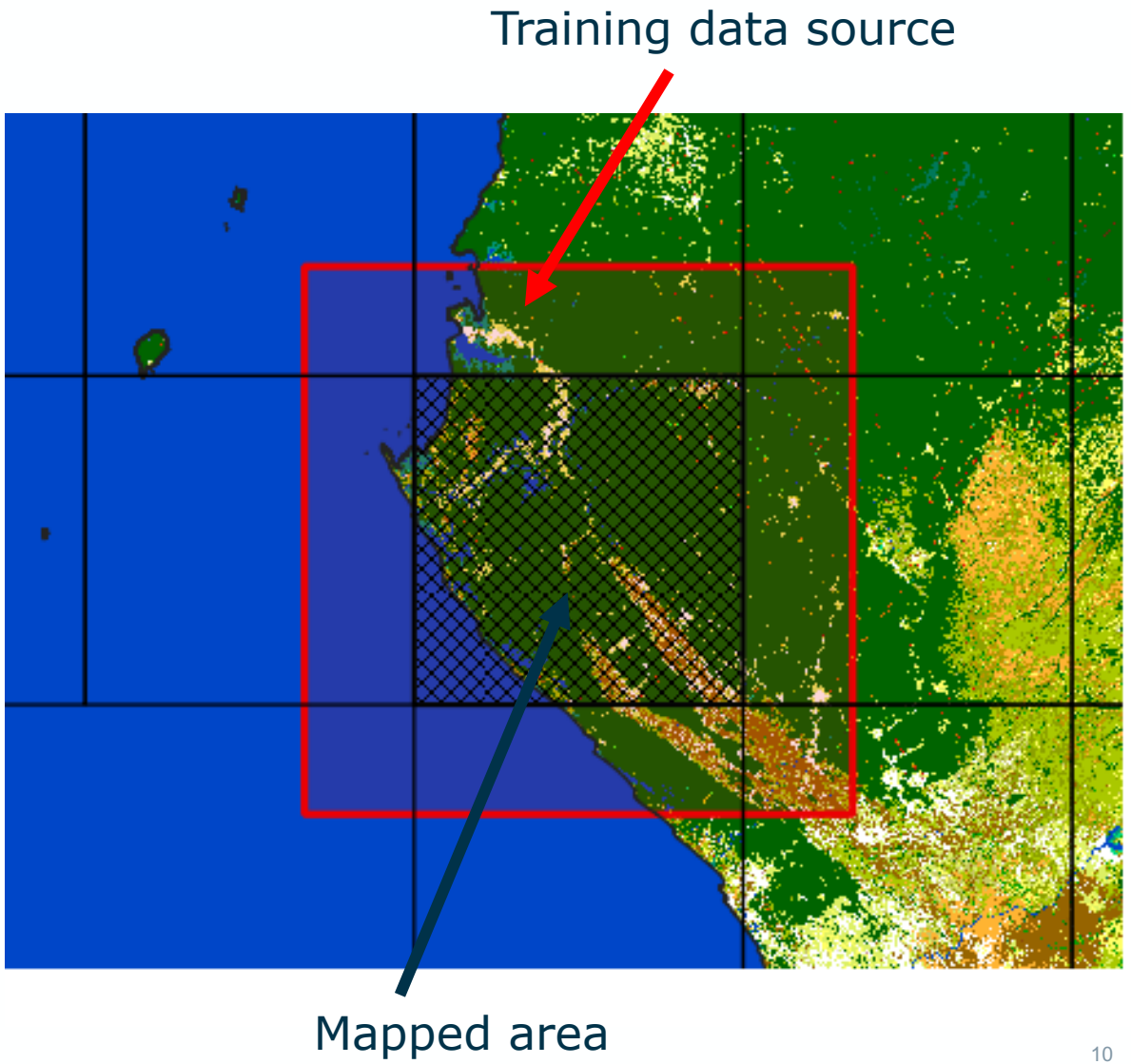
Obtaining global coverage

3°×3° processing blocks used as mapping units



Obtaining global coverage

- Mapping done using $3° \times 3°$ **processing blocks**
- Training data sampled within a $5° \times 5°$ **neighbourhood** to enforce some continuity across blocks
- Model parameters estimated with **linear regression** from reference biomass data.



Reference biomass data

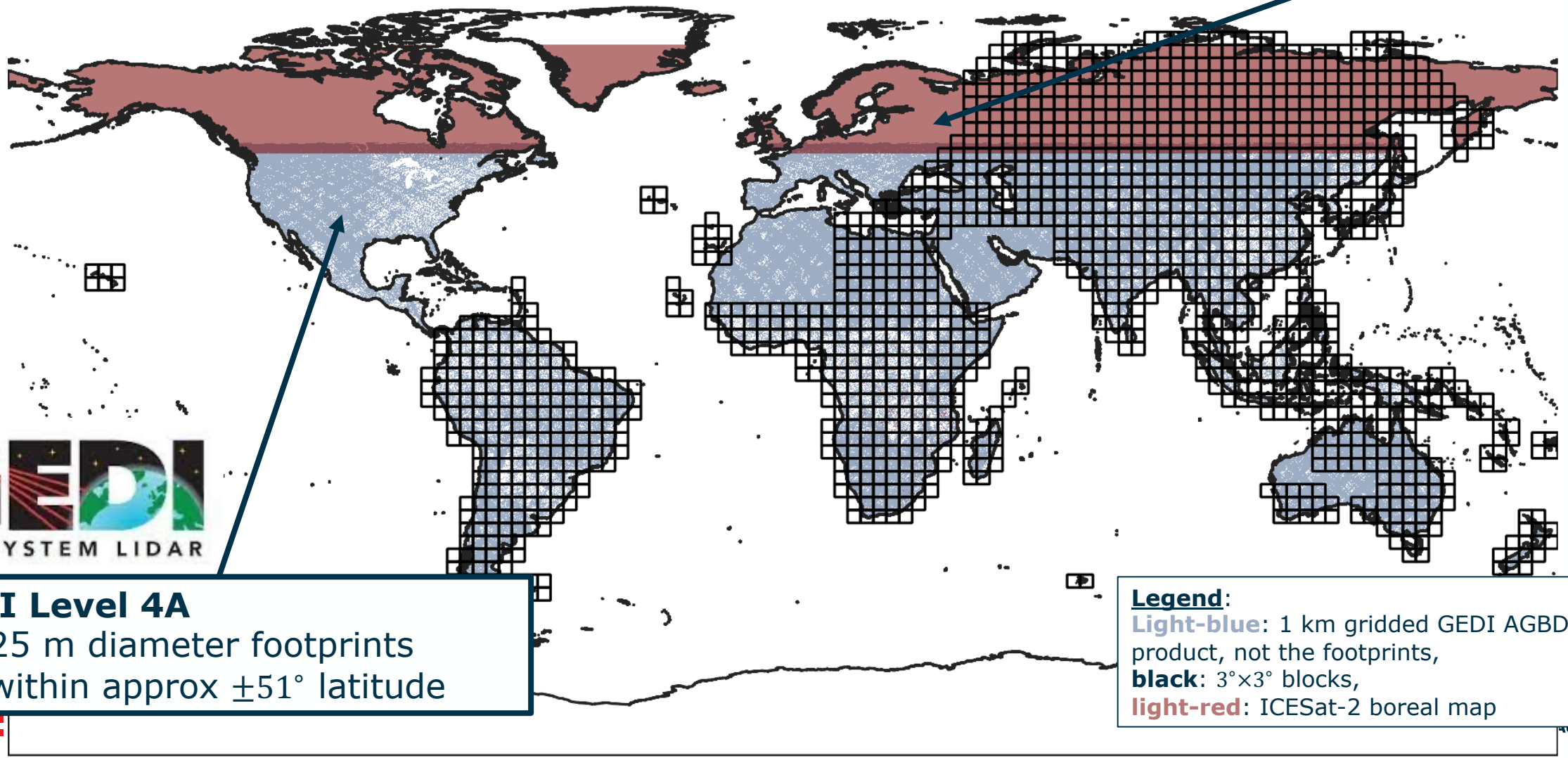
Reference data are essential for biomass estimation & mapping!

Requirements:

- **Global, spatially dense:** to account for the large expected spatiotemporal variability
- **Easily accessible and available now**: so that the global algorithm can be implemented and tested prior to launch
- **With good sensitivity to biomass** across the entire biomass range, and good potential for accurate estimates within the next few years.

Reference AGBD data sources

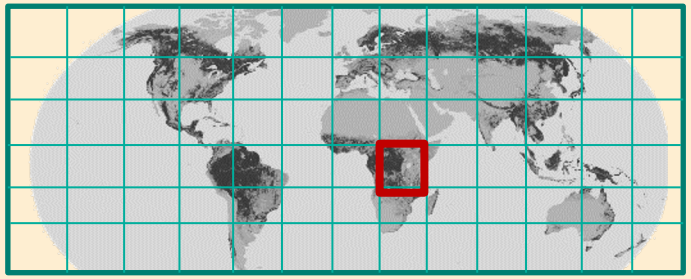
ICESat-2 boreal map
- 30 m resolution maps
- Between 50°N and 75°N

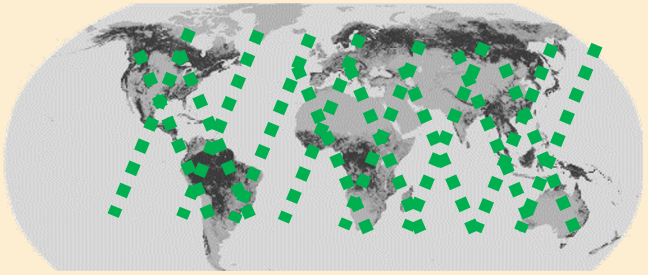


GEDI Level 4A
- 25 m diameter footprints
- within approx ±51° latitude

Legend:
Light-blue: 1 km gridded GEDI AGBD product, not the footprints,
black: 3°×3° blocks,
light-red: ICESat-2 boreal map

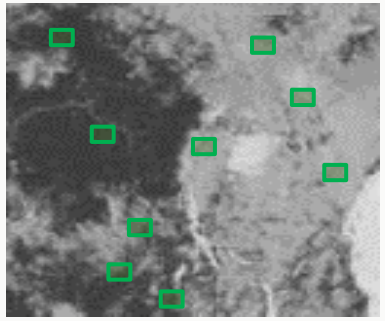
1: Create 3°×3° processing blocks and consolidate reference data





2: Map the blocks

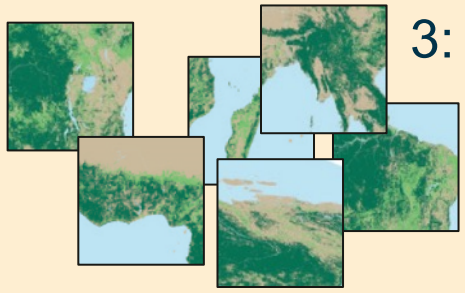
Fit the model

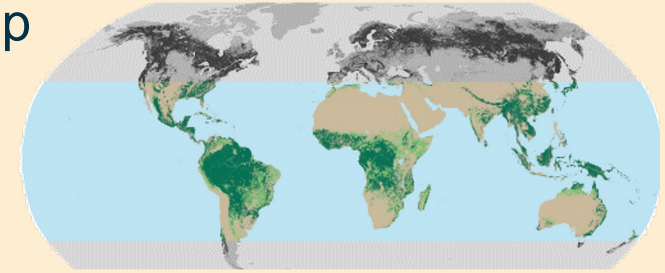


Model parameters

Estimate biomass

3: Create a global map





(4: iterate once to fill gaps)

Towards the launch and beyond

Status:

- ✓ Simple, fast, flexible algorithm proposed, to be implemented within the next year
- ✓ GEDI- & ICESat-2-based biomass estimates proposed as reference

Remaining work prior to launch:

- Reference data consolidation, quality assurance, investigation of alternative reference data sources,
- Fine-tuning of the parameter variability & estimation approach
- Revision of the topographic and incidence angle effects in the model
- Fine-tuning of the training approach for subsequent global acquisitions
- Further investigation of added-value of tomography & forest height

After launch:

- Investigation of parameter estimates and their global patterns
- Implementing the new knowledge from tomographic phase data
- ...

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