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Microwave radiometry of vegetated land

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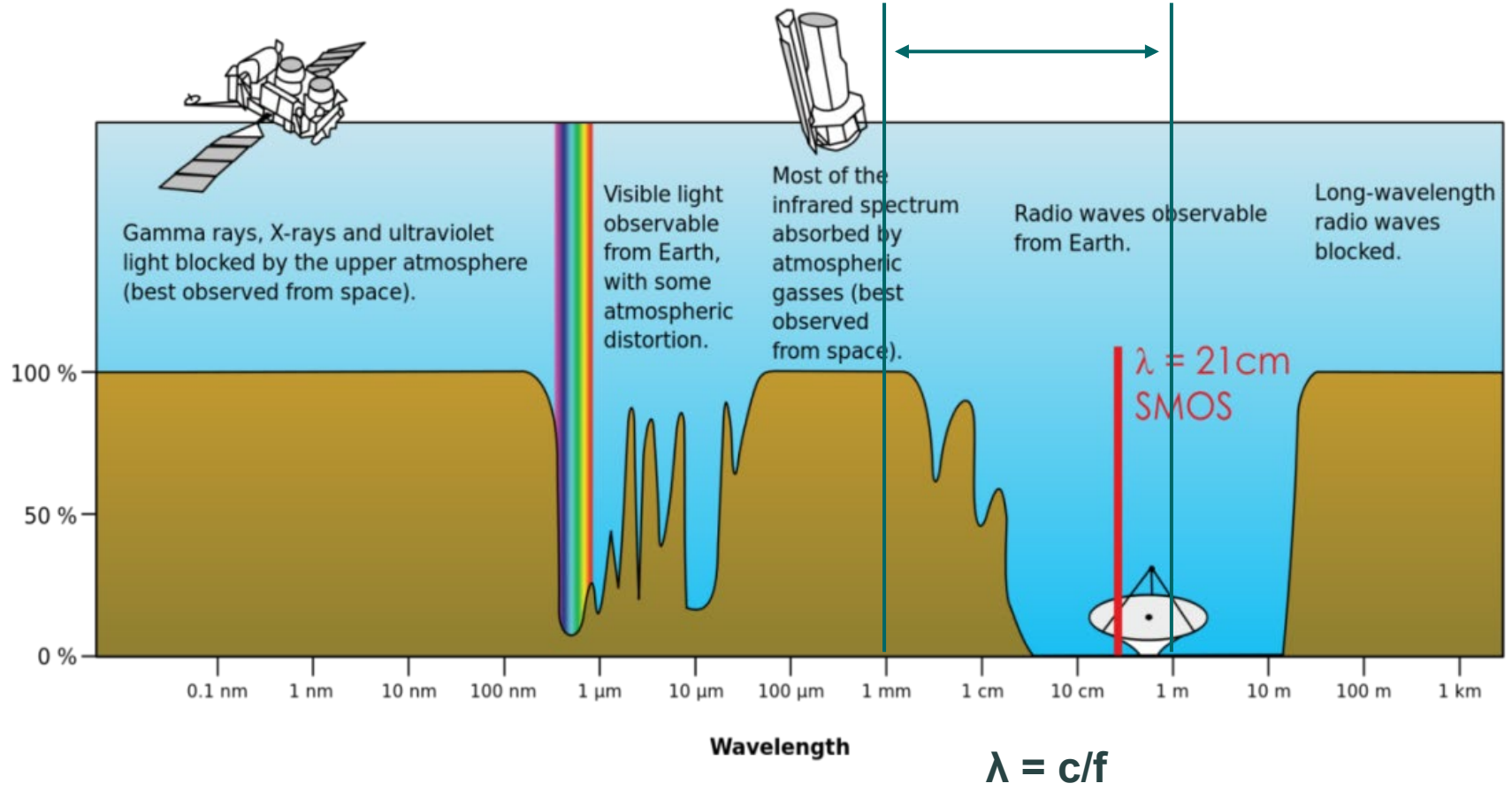
Outline

- Introduction of microwave radiometry
- Microwave satellites
- Microwave Emission Model and Implementation in Retrieval
- Summary and future vision

Microwave

Electromagnetic waves with wavelength from around 1 mm to 1 m



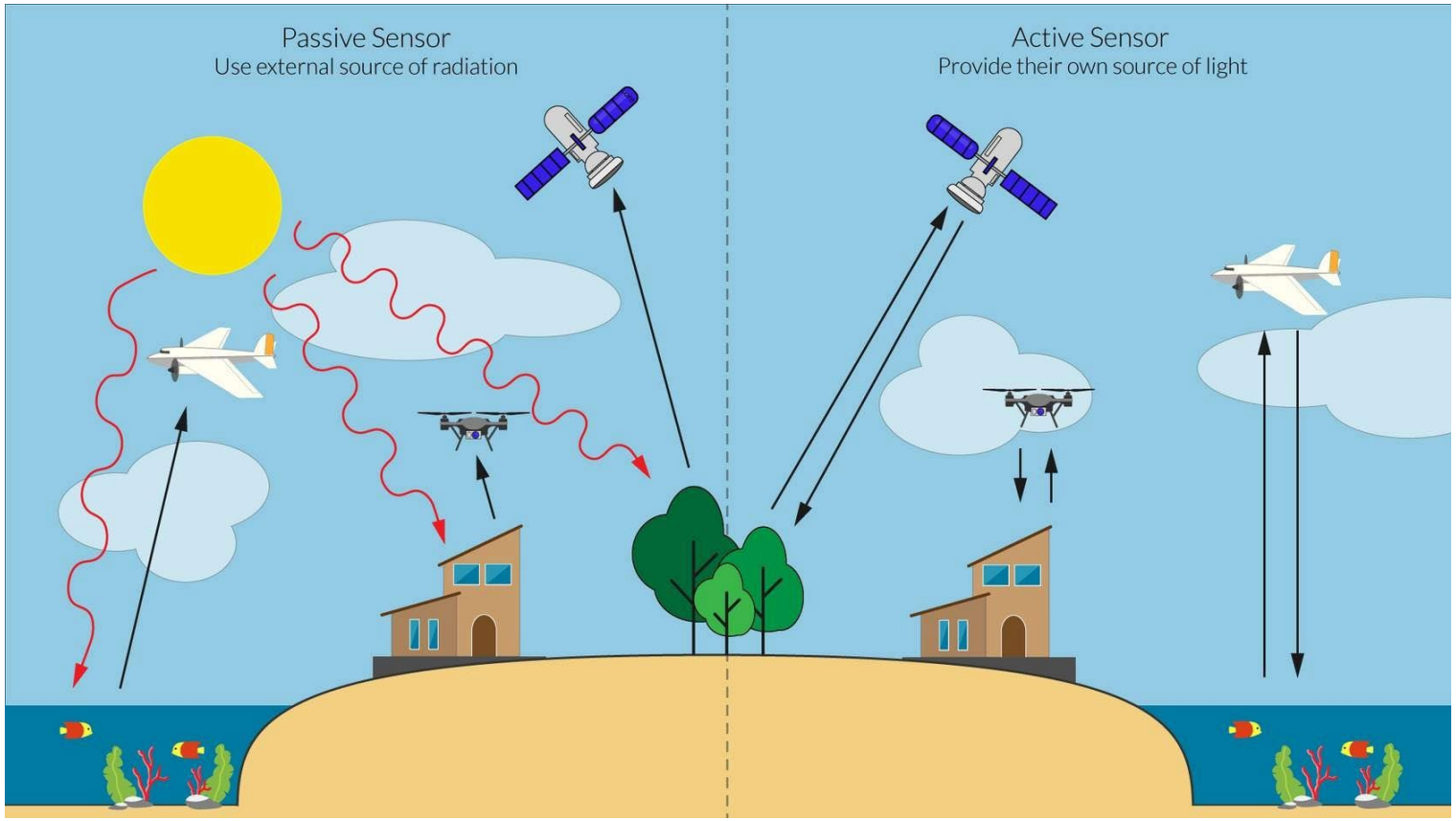
$\lambda = c/f$

Low frequency: High penetration& Low resolution

High frequency: Low penetration& High resolution

X-band (λ: 2.4–3.8 cm, f:8-12 GHz)
C-band (λ: 3.8–7.5 cm, f:4-8 GHz)
S-band (λ: 7.5–15 cm, f:2-4 GHz)
L-band (λ: 15–30 cm, f:1-2 GHz)
P-band (λ: 30–100 cm, f:0.3-1 GHz)

Active vs. passive remote sensing



Active Sensor (RADAR):

- **RADAR** = **RA**dio **D**etection **A**nd **R**anging
- Act as their own energy source
- Detect backscattered signature (energy / phase / polarization)

Passive Sensor (radiometer):

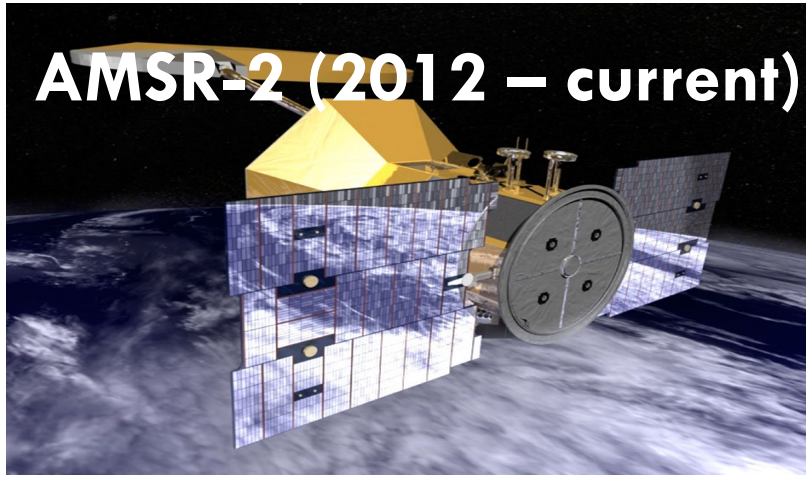
- Rely on thermal emission of the target
  Detect only naturally occurring EM radiance (Brightness Temperatures)
- More sensitive to permittivity change, less sensitive to surface roughness

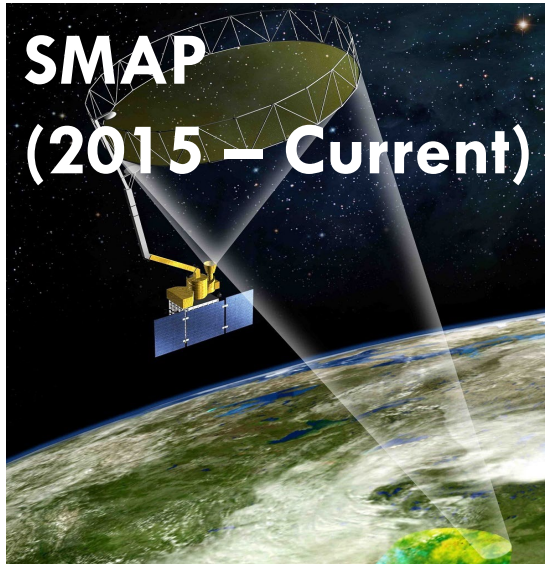
Both can penetrate clouds/vegetation to acquire sub-surface information
Short repeat time (high temporal resolution)!

Microwave satellite missions

SMOS (Soil Moisture and Ocean Salinity) (2009 – current, L-band mission)

Launch: 02/11/2009
Spatial resolution: 35 km
Radiometric resolution: 0.8 - 2.2K
Temporal resolution: 3 days

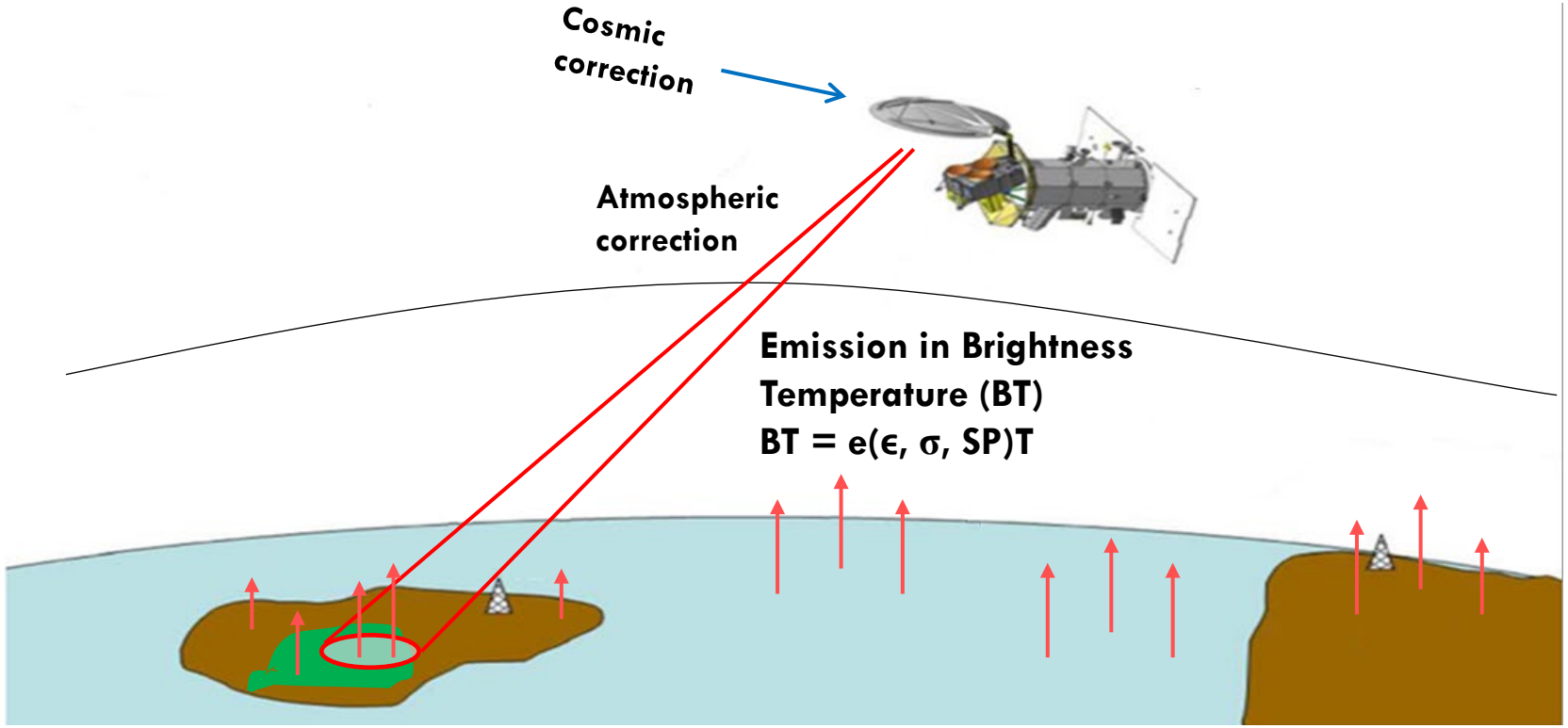




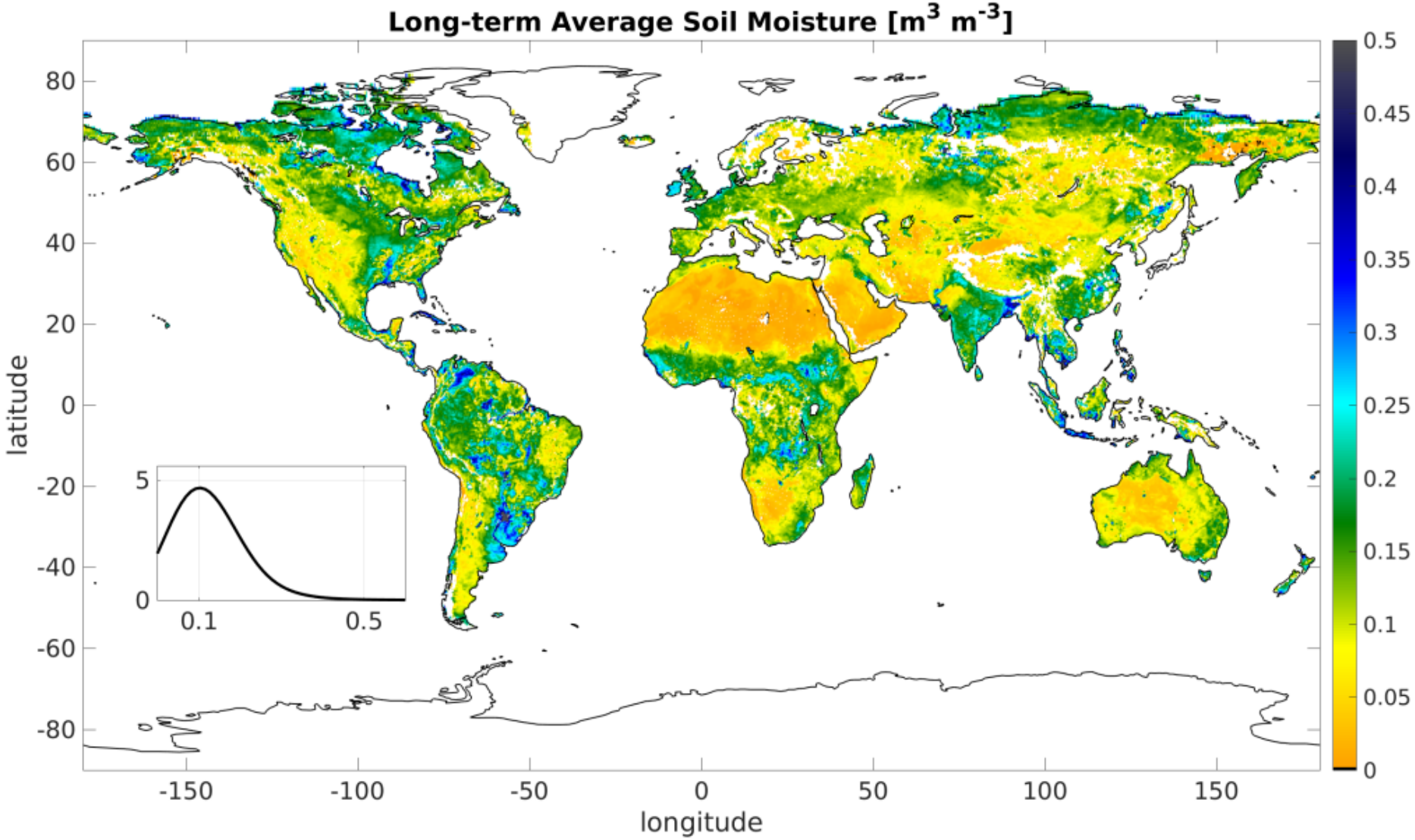
Interpretation of Satellite Measurements

Remote sensing is an indirect method of measurement.

⇒ Correlations between state-parameters of interest (e.g. soil moisture, vegetation / snow properties) and remotely sensed brightness temperatures (BTs).



Examples of SMOS Application *Soil Moisture & Vegetation dynamics*



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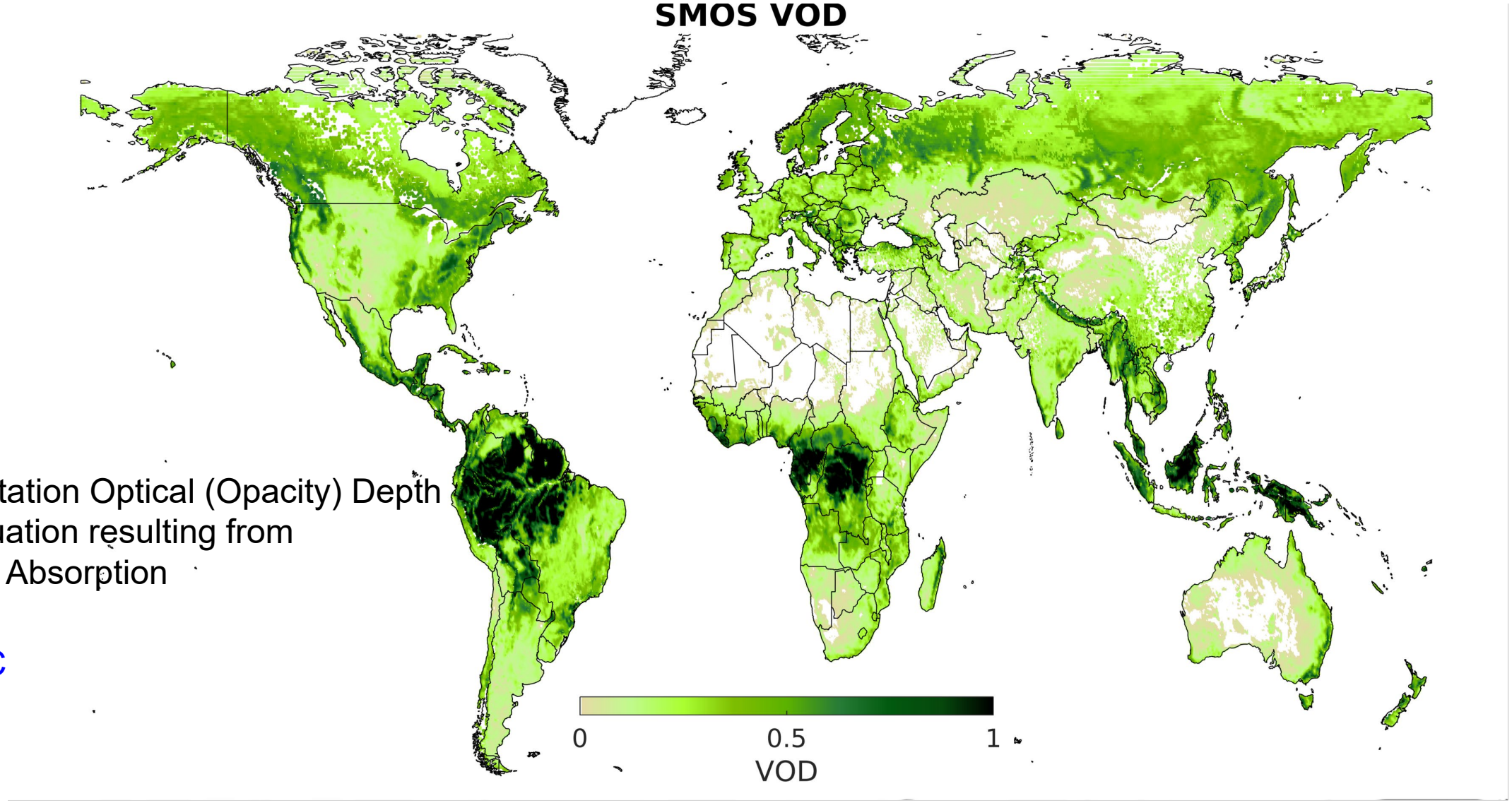


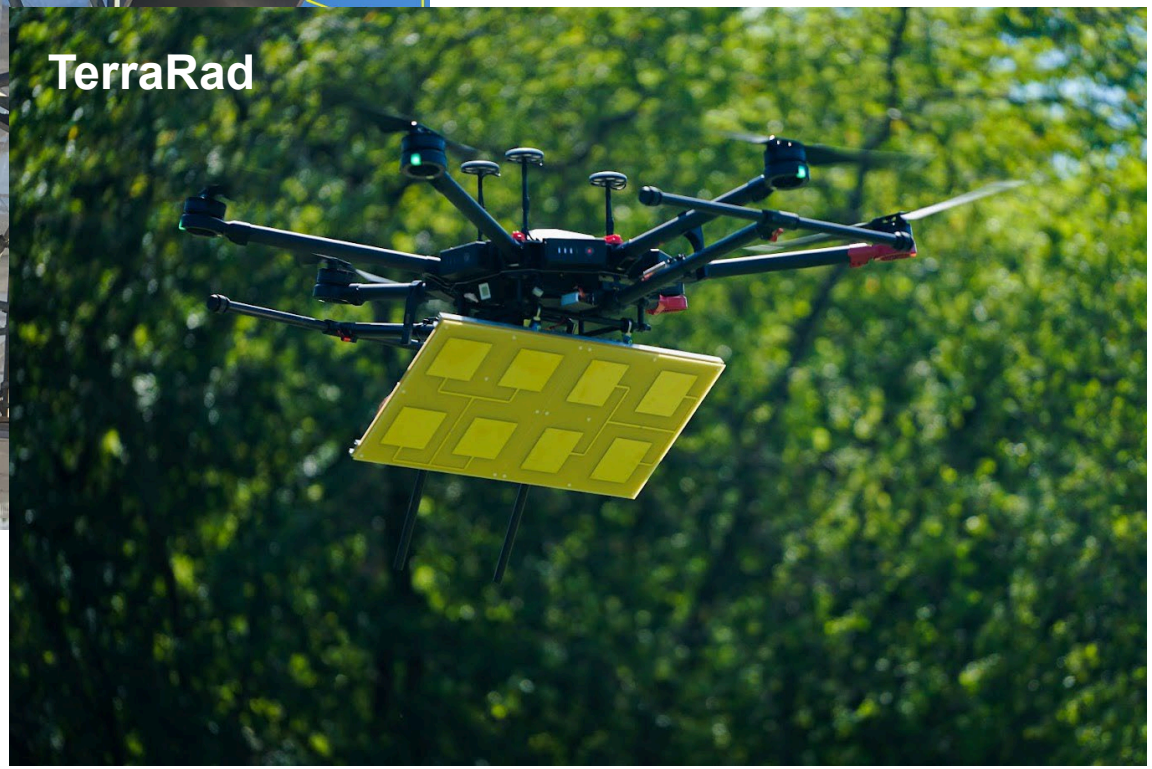
VOD - Vegetation Optical (Opacity) Depth
Wave attenuation resulting from
Scattering + Absorption

VOD – VWC
VOD – AGB

From the space to the ground

Ground based Measurements

- *calibration*
- *validation*
- *signature studies*
- *model development*



Projects

- **ESA funded project – “10 Years of SMOS – Passive Microwave Vegetation Opacity Study(PM-VO-S)” (Vegetation)**

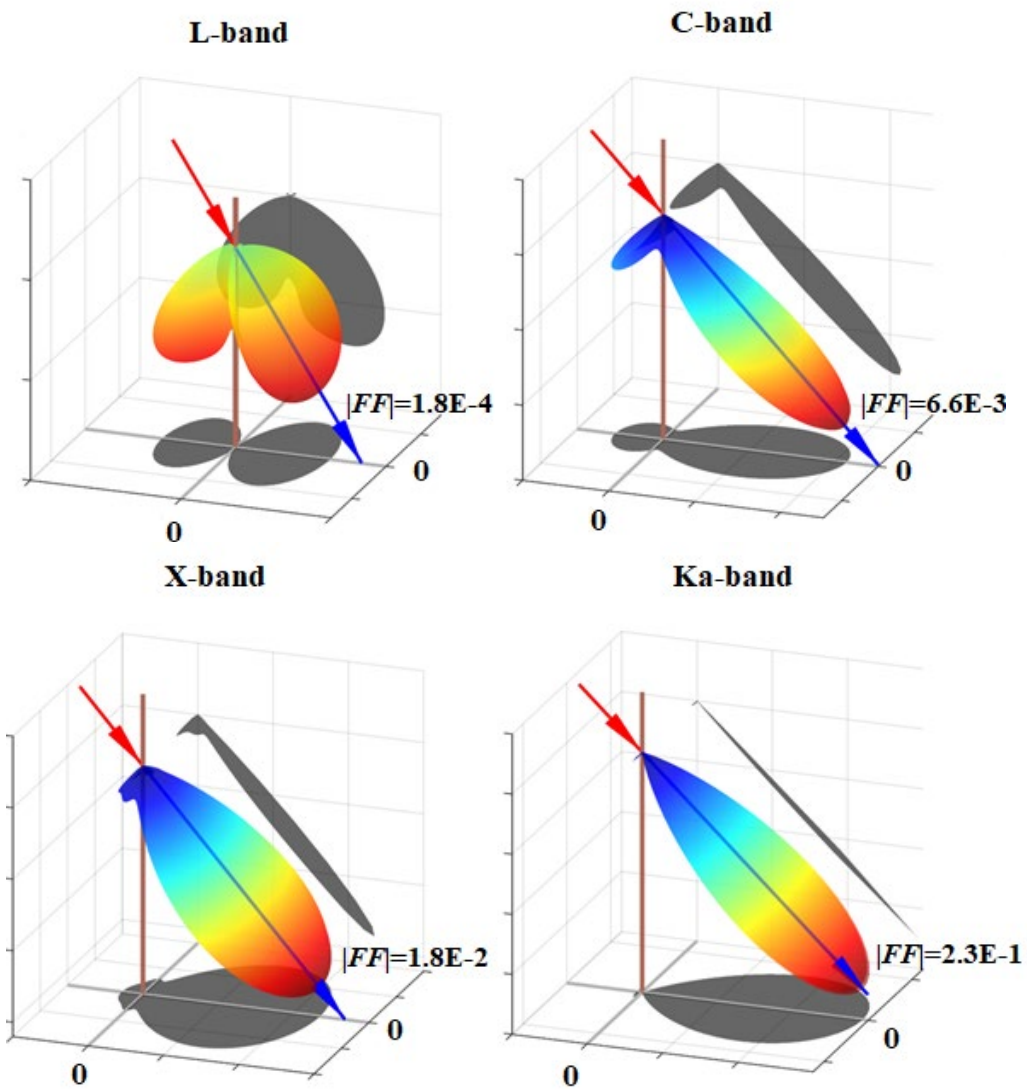
  Develop a universal physics-based model – Microwave Emission Model for Layered Vegetation (MEMLV) to simulate the scattering and absorption of vegetation canopy over 400 MHz - 37 GHz. This will allow for using multi-frequency satellite data to retrieve vegetation opacity depth (VOD).

- **InnoSwiss funded project – “Miniaturized Passive Microwave Sensor for Agricultural Sustainability” (Vegetation + Soil)**

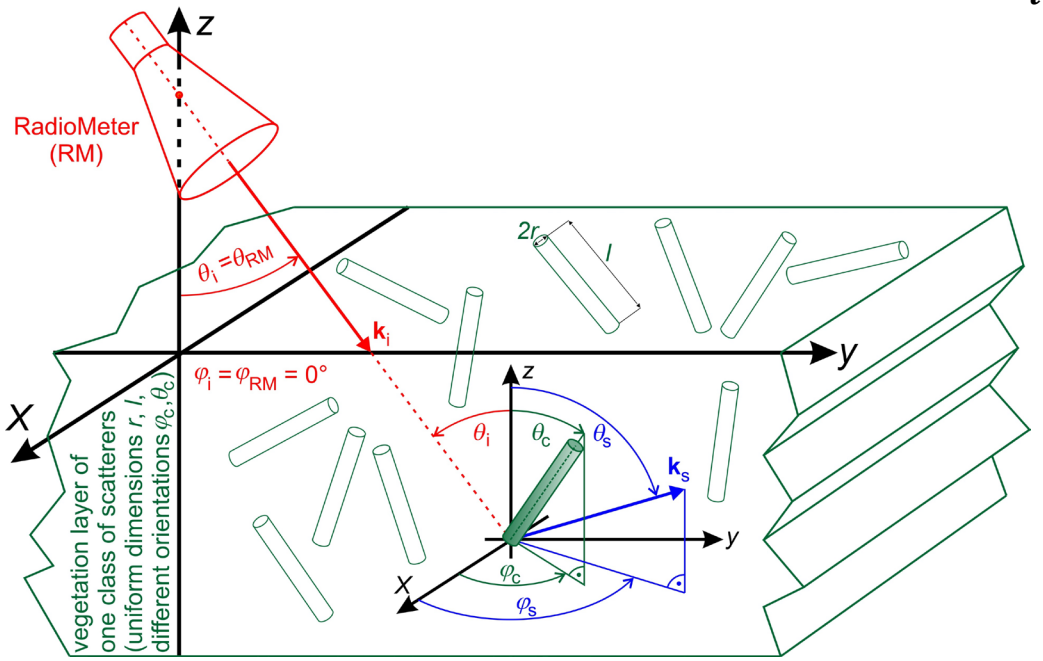
- **ESA funded project – “Temperature Effects on L-VOD of a Boreal Forest” (Vegetation)**

- **Collaboration with FMI for Cryosphere radiometry (Snow)**

Single-Layer Discrete Scatter Model



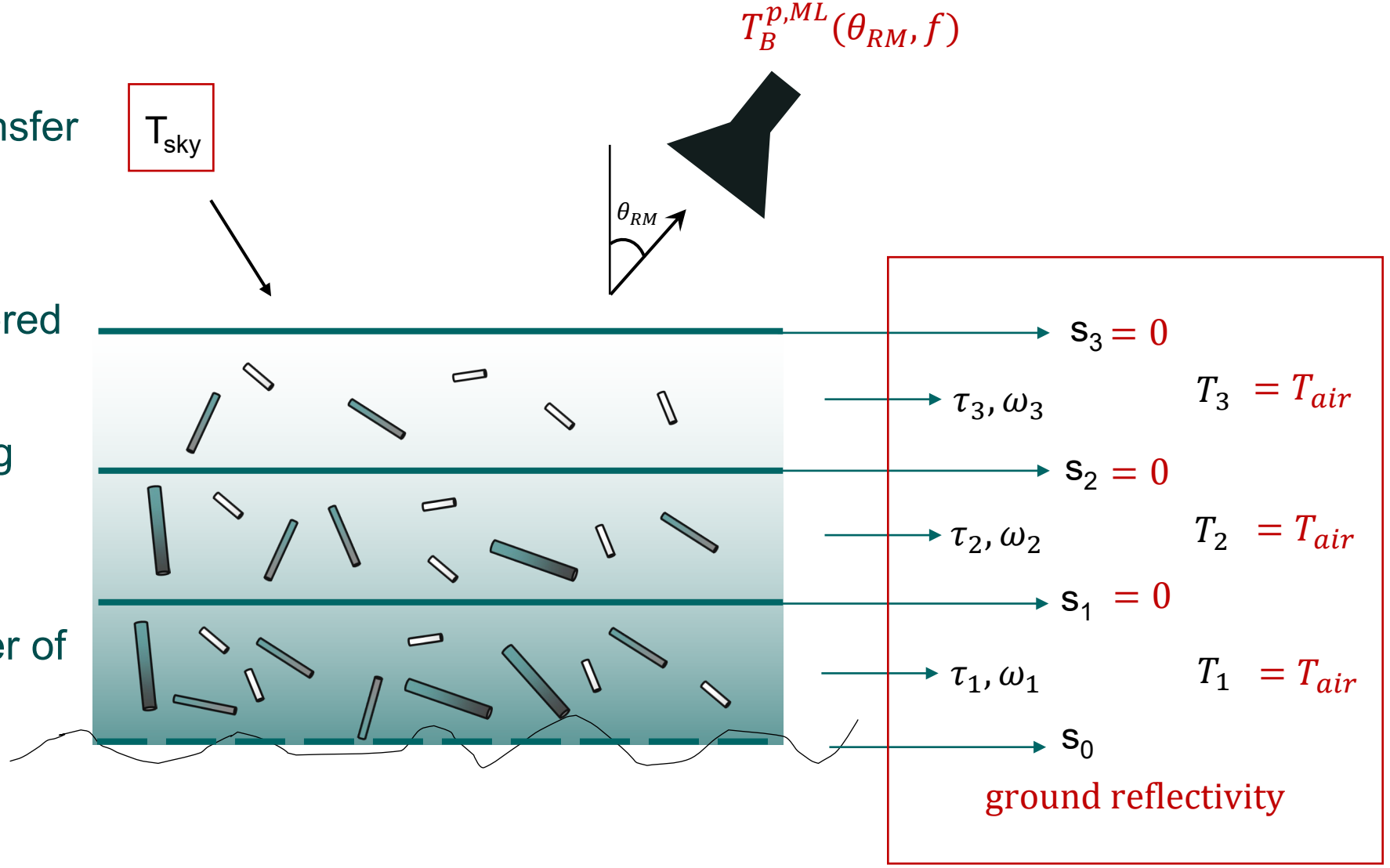
Scatt. & Extinc Coefficients: $\kappa_s^p = \sum_{i=1}^{M} \rho_i \cdot \hat{\kappa}_{s,i}^p$ $\kappa_e^p = \sum_{i=1}^{M} \rho_i \cdot \hat{\kappa}_{e,i}^p$



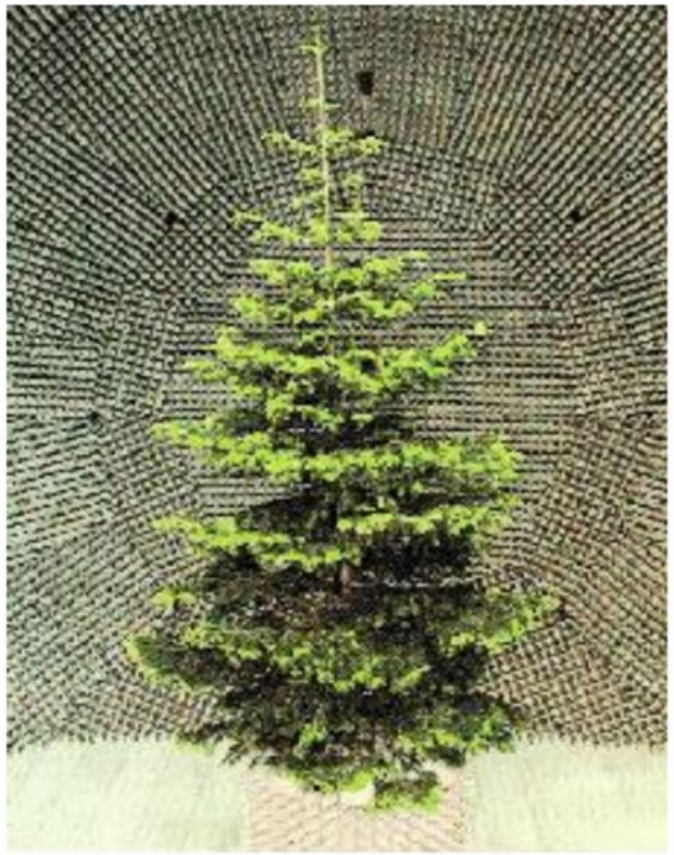
$\tau^p = \kappa_e^p \cdot h$ $\omega^p = \kappa_s^p / \kappa_e^p$

2-Stream Microwave Emission Model

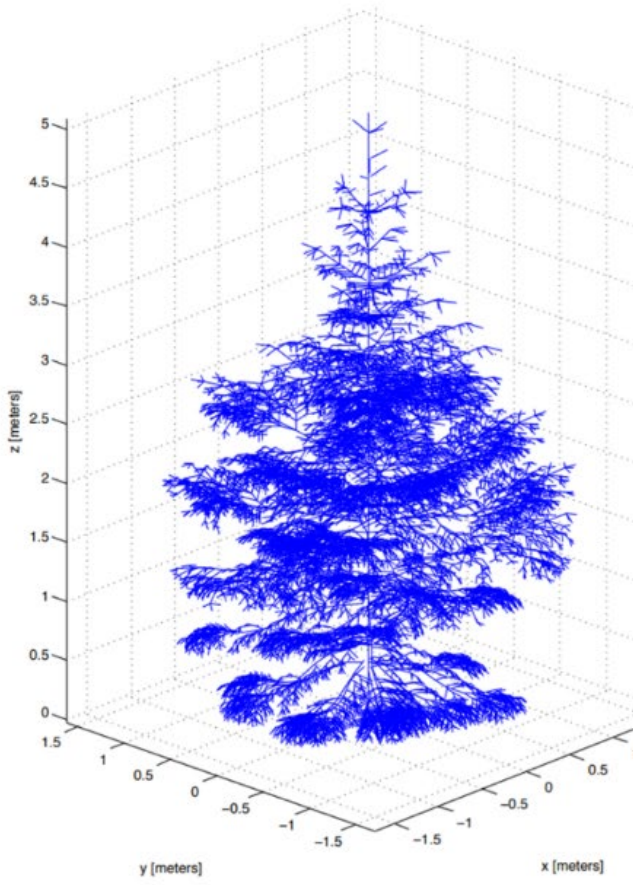
- Formulate the radiative transfer as up- and down- welling fluxes of radiative energy
- Originally designed for layered snowpacks (MEMLS)
- Consider multiple scattering and reflections
- Closed-form expression suitable for arbitrary number of layers



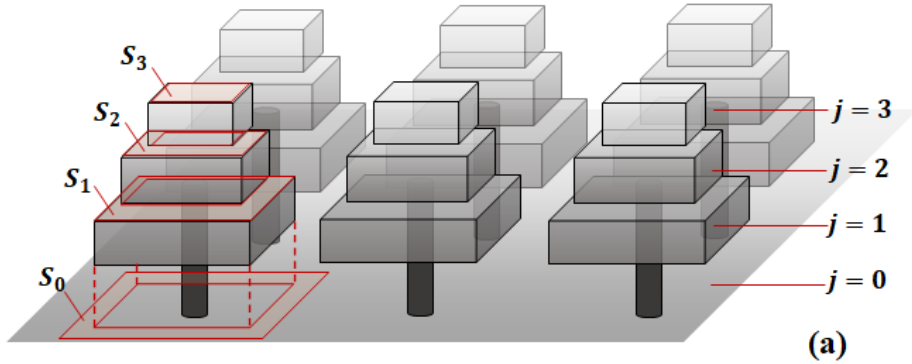
Tree Structure Model



(a)



(b)



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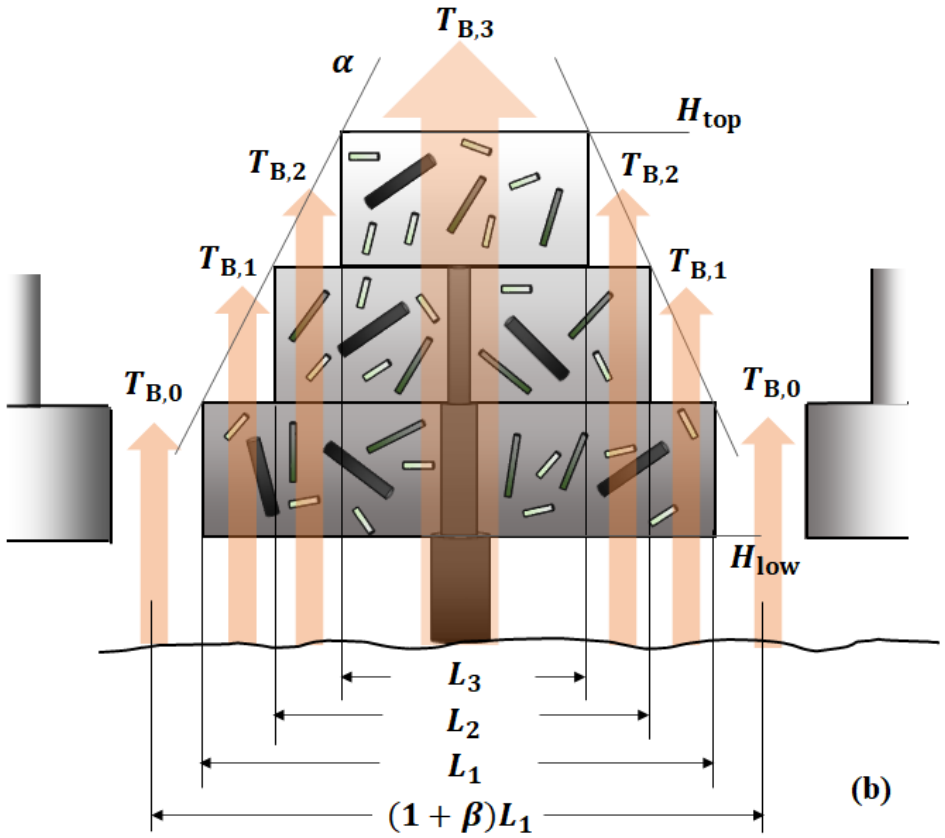
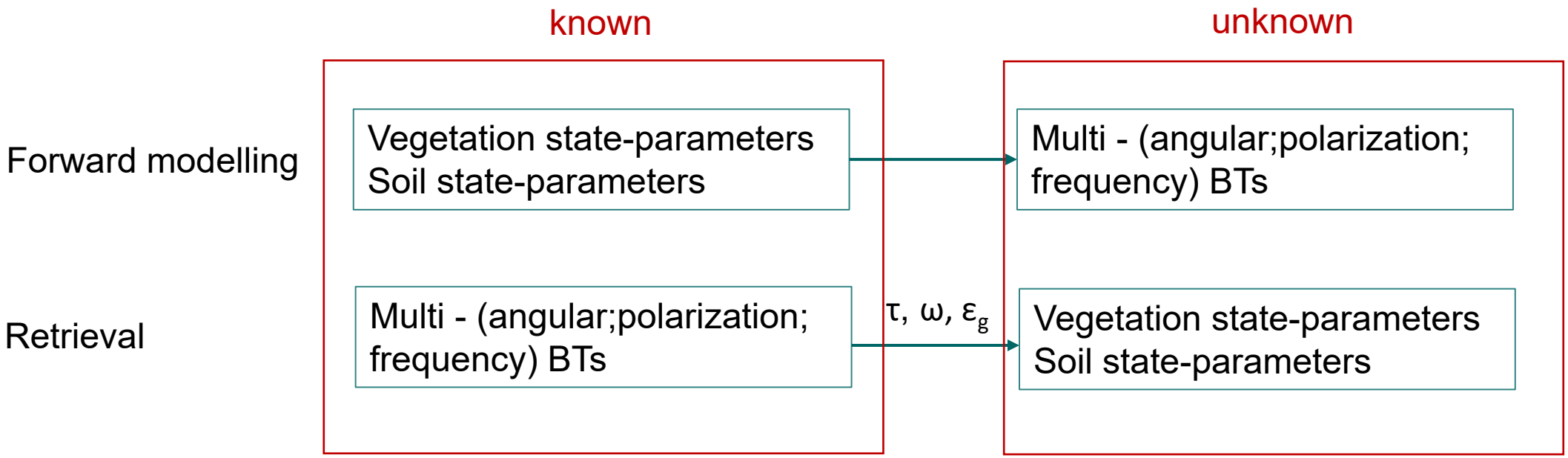


(b)

Forward modelling and Retrieval



$$CF(\tau_{\mathrm{eff}}, \omega_{\mathrm{eff}}) = \sum_{p,\theta_{\mathrm{RM}}} \left[T_{\mathrm{B}}^{p,\mathrm{ML}}(\theta_{\mathrm{RM}}, f) - T_{\mathrm{B}}^{p,1\mathrm{L}}(\tau_{\mathrm{eff}}, \omega_{\mathrm{eff}}, \theta_{\mathrm{RM}}, f) \right]^2$$

BTs from forward modelling

Equivalent single-layer medium with effective τ, ω

The application of MEMLV

- understand the spectrum of τ and ω

- evaluate the impact from tree height, moisture content and contribution from different constituents

- Implementation in satellite retrieval

Summary

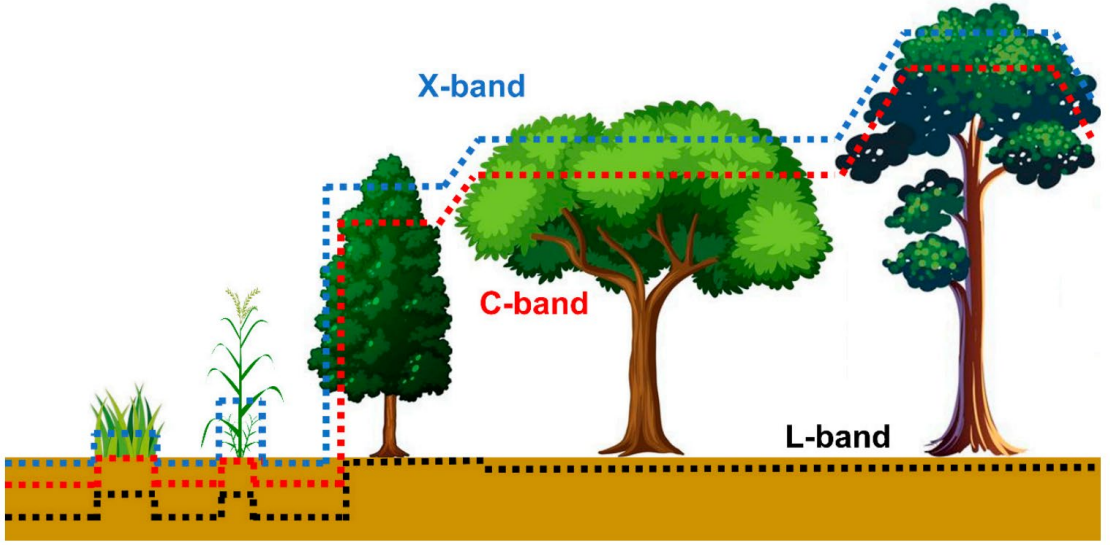
- Microwave radiometry has unique advantages in remote sensing of vegetation and soil.
- Ground-based microwave radiometry is key to support to satellite retrieval and understanding physics behind the measurements and vegetation/soil conditions.
- Physics-based modelling is important for understanding the impact from different parameters and guide the retrieval algorithm.

Future Vision

- Relying on multi-frequency microwave radiometer measurements and developed modelling tool (MEMLV) to reconstruct vegetation water status profile.

- Using the vegetation water status profile for plant physiology study, enabling the possibility of large-scale ecosystem evaluation.

- Pfynwald may be an ideal site for close-range radiometer measurements.



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Vielen Dank!

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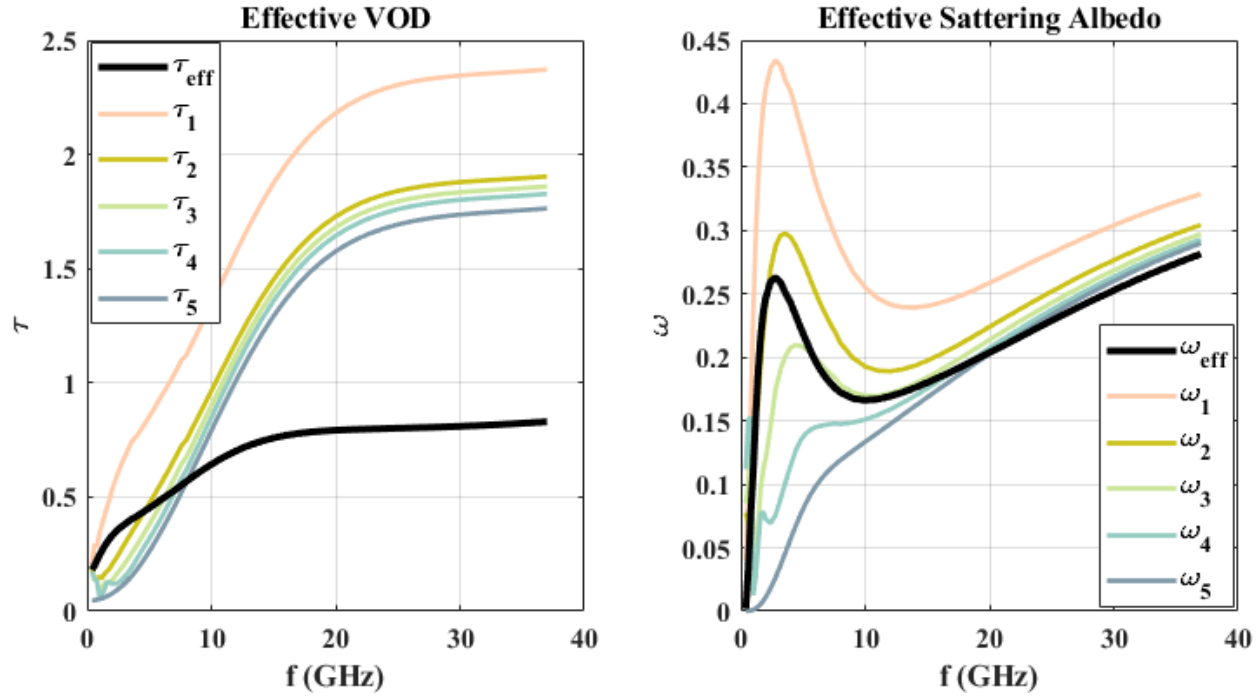
Backup slides

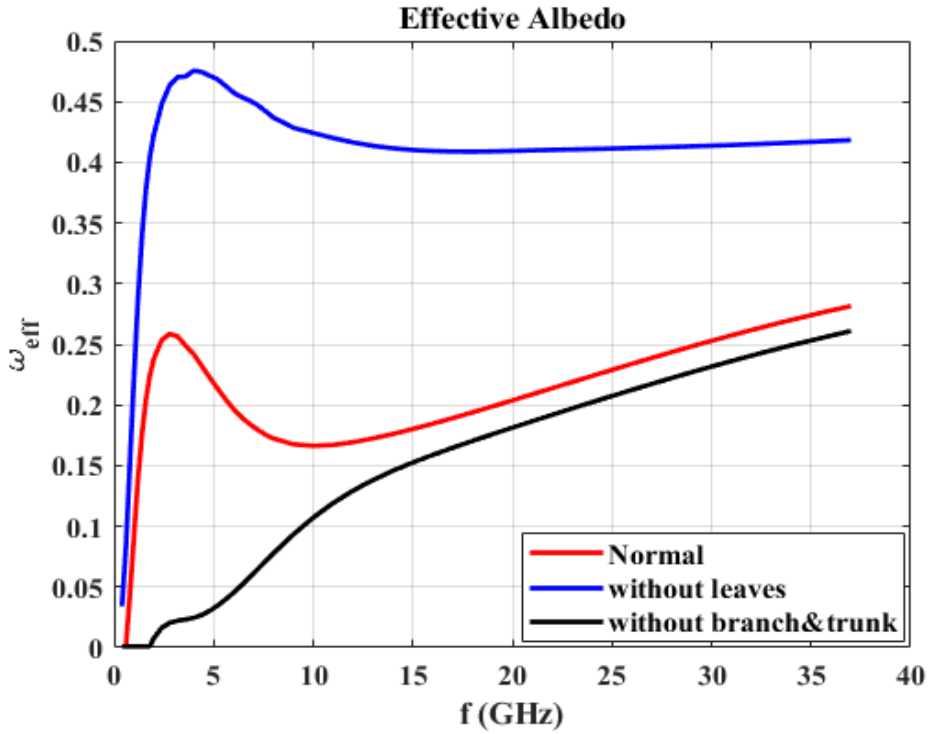
The application of MEMLV

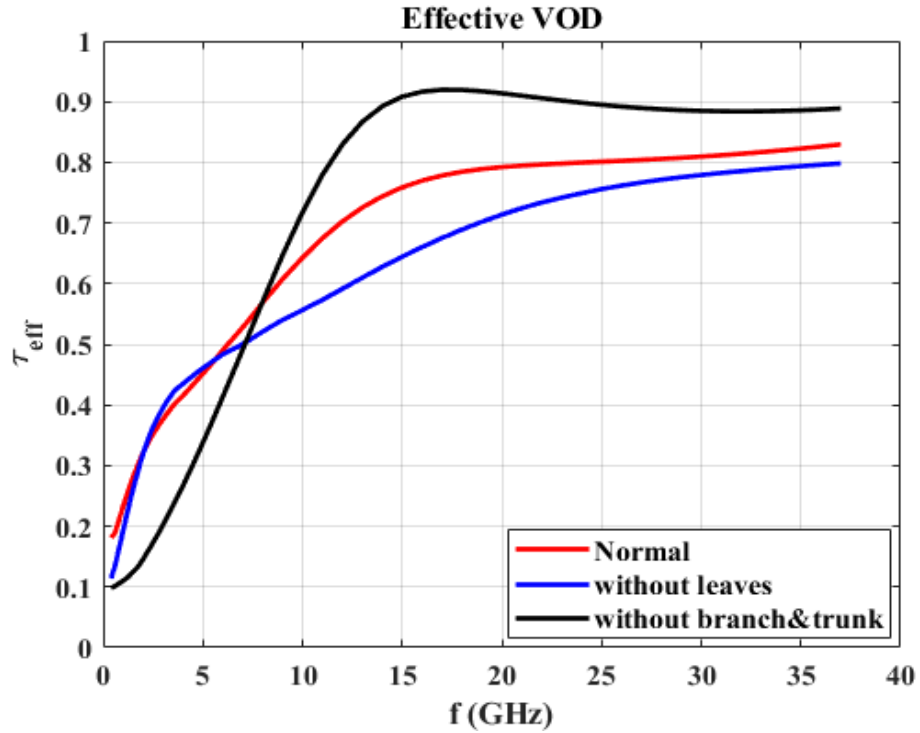
- understand the spectrum of τ and ω



The application of MEMLV

- evaluate the impact from tree height, moisture content and contribution from different constituents, e.g.:





The application of MEMLV
- Implementation in satellite retrieval