Improved Vegetation Parameterization for SMAP's Passive Retrieval Algorithms

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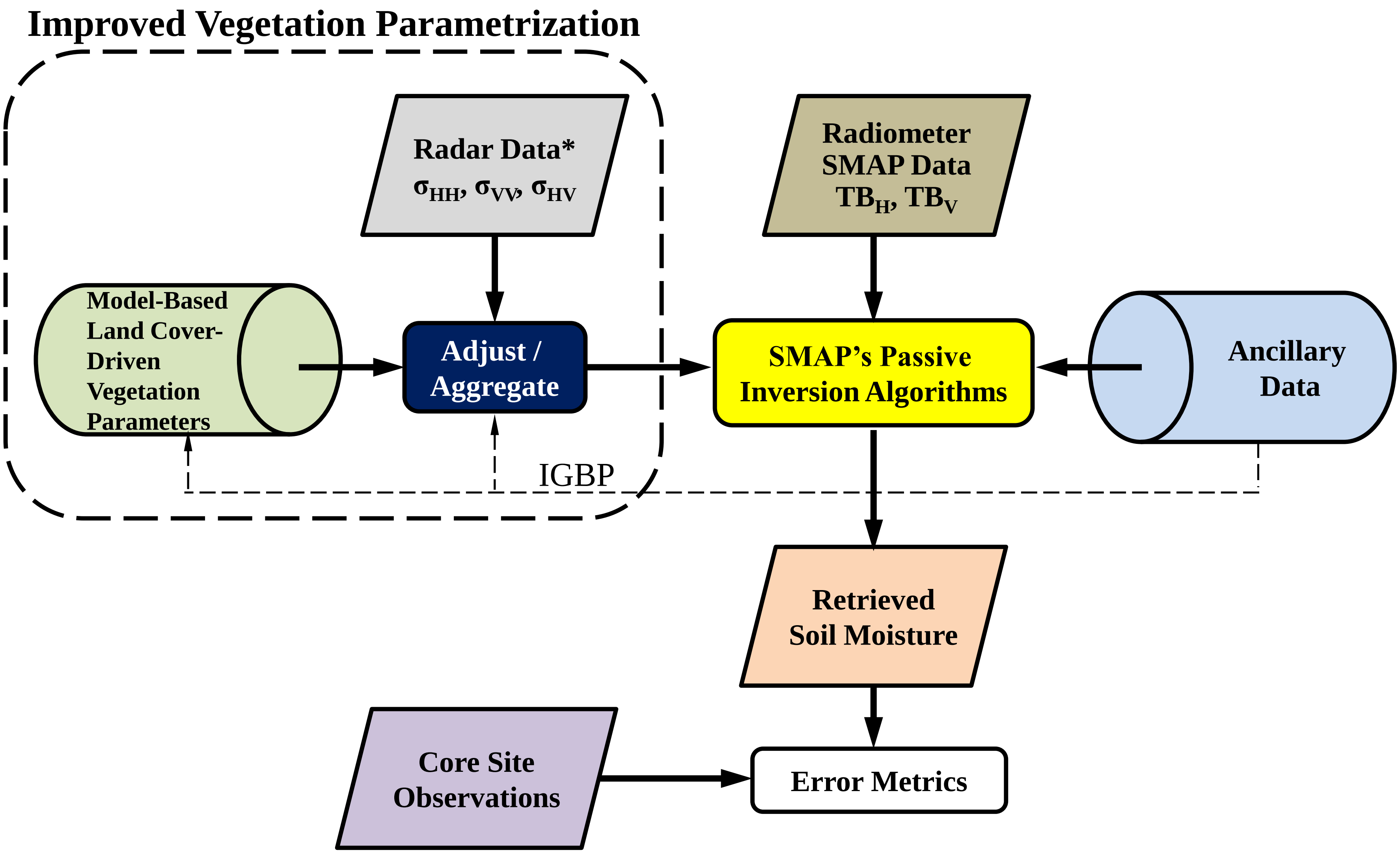
Motivation: Passive Soil Moisture retrievals

- **Current Approach:**
  - Land cover-driven look up table.
- **Given the complex vegetation structure:**
  - Empirical values.
  - Temporally static vegetation conditions.
  - Ancillary optical geophysical estimate.
- **Our aim:**
  - To reduce/eliminate SMAP's reliance on empirical indices from optical satellites for vegetation characterization.
- **Our approach:**
  - The modified tau-omega model*
  - High-resolution radar within the passive inversion process
  - Dynamic (i.e., temporally varying) vegetation parameterization.
- **Advantage of the approach:**
  - The complementary nature of active and passive remote sensing
  - Joint-Physics based modeling
  - Moderate (3-5 kg/m^2) to Dense Vegetation(>5 kg/m^2)

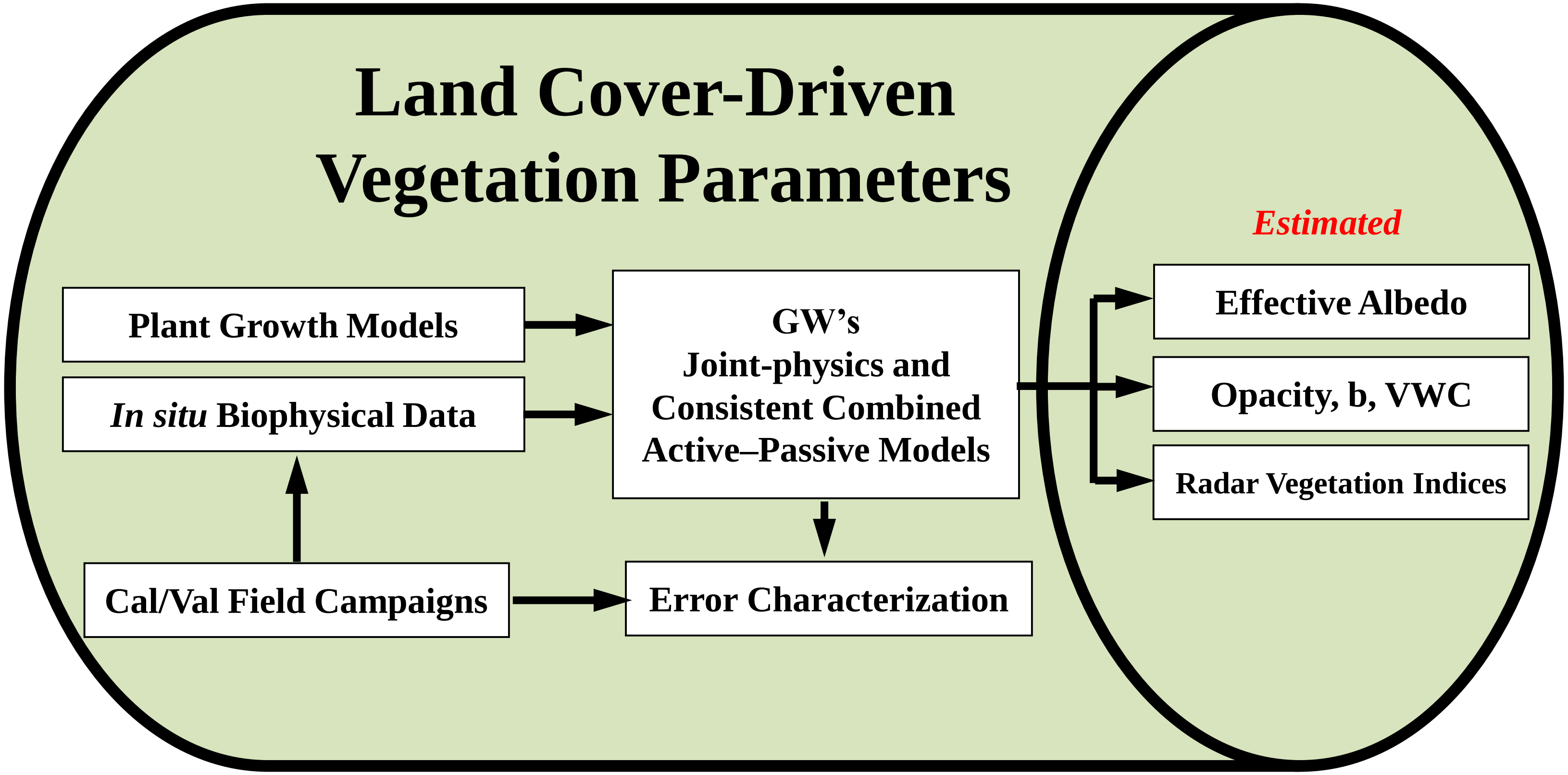
*M. Kurum, "Quantifying Scattering Albedo in Microwave Emission of Vegetated Terrain," Remote Sensing of Environment, vol. 129, pp. 66–74, Feb. 2013

Overall Retrieval Algorithm



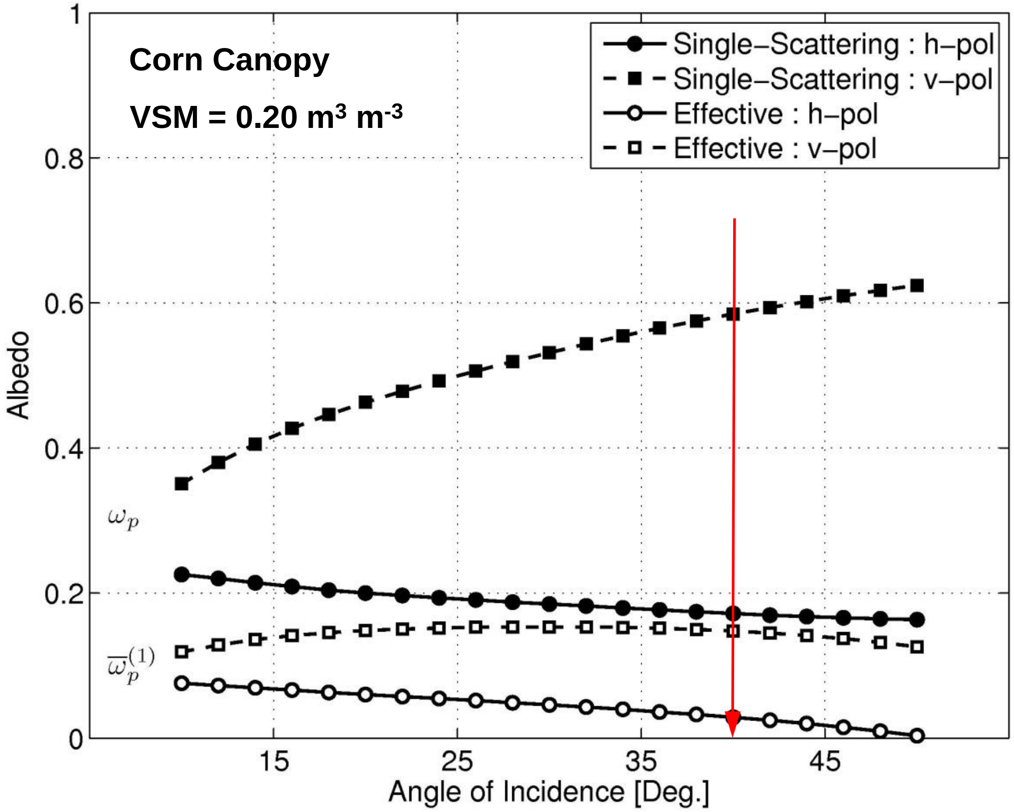
* Legacy SMAP radar data, ALOS-2, Sentinel-1, Radarsat-2

Physical-based Vegetation Parameterization



Single Scattering vs. Effective Albedo

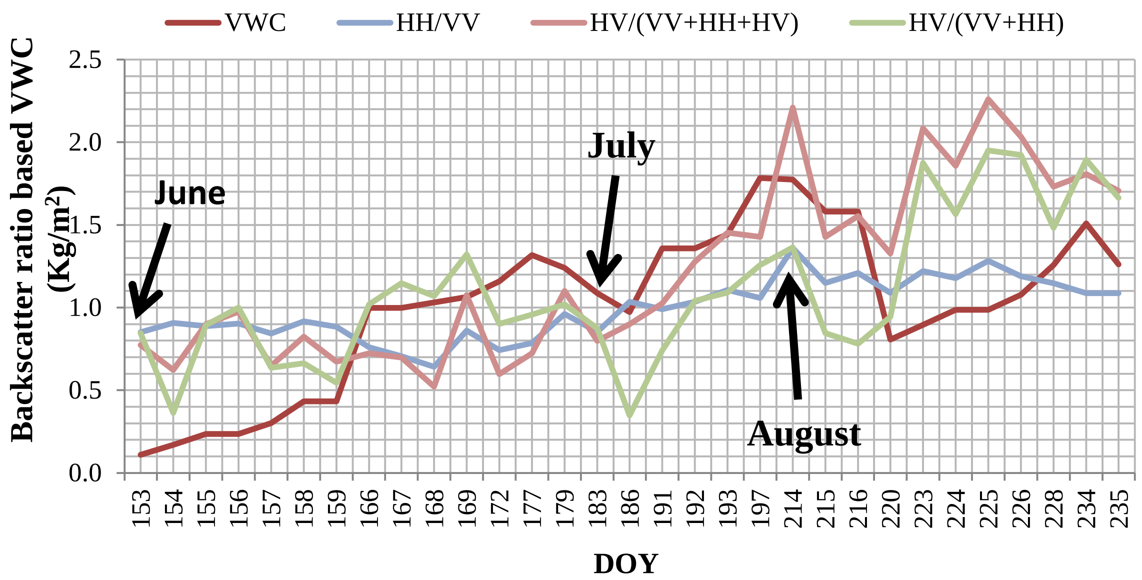
Kurum, RSE 2013



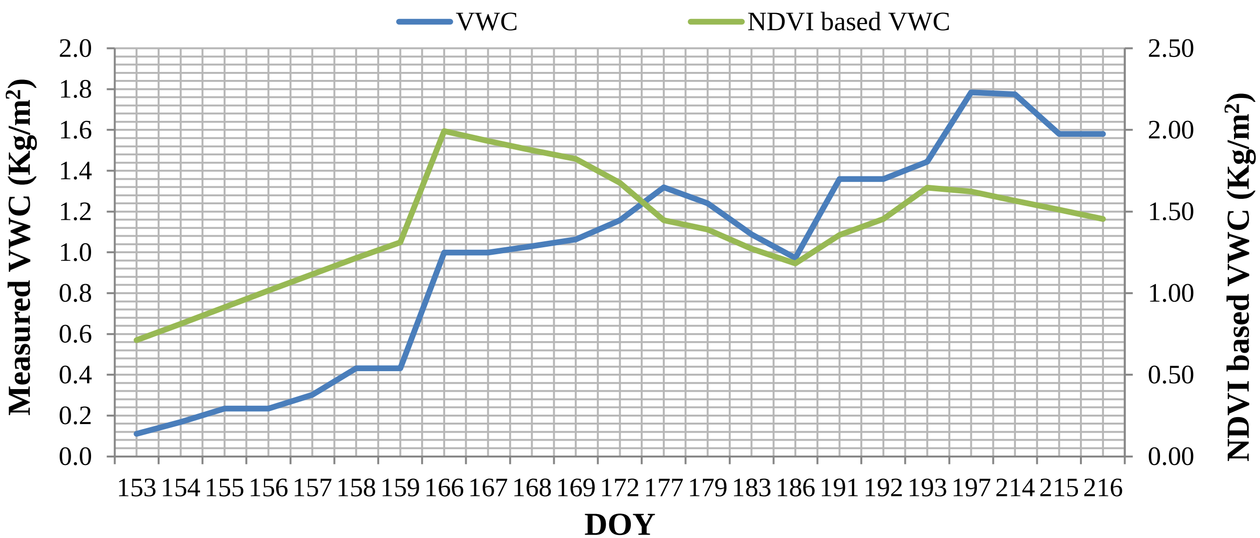
- Single-Scattering Albedo : $\omega_p(\theta) = \dfrac{\kappa_{sp}}{\kappa_{sp} + \kappa_{ap}}$

- First-Order Effective Albedo : $\overline{\omega}_p^{(1)}(\theta) = \omega_p(\theta) - \dfrac{\Omega_p^{(1)}(\theta)}{\left[1 + \gamma_p(\theta) R_{gp}(\theta)\right]\left[1 - \gamma_p(\theta)\right]}$

VWC Estimation with Radar Ratios



The temporal patterns revealed by HV ratios are close to the measured VWC.



VWC estimated from CropScan measurements match the general trend of the measured VWC.

O'Neill *et.al.*, IGARSS 2015

Summary

- **Our advantage:**
  - Extensive experience in vegetation modeling
  - Various joint-physics and consistent combined active–passive vegetation models,
  - Ability to determine physical-based tau and effective omega (the modified tau-omega model)

- **Dynamic parameterization:**
  - Varying vegetation attributes.
  - Analysis by our joint-physics formulation.
  - Plant growth models.
  - Existing/post-launch field data.

- **Core Site Validation:**
  - Evaluate the approach with real SMAP data over selected core sites

- **Extension to Large Scales:**
  - Temporal behaviors of vegetation.
  - Heterogeneity impacts for selected target areas on a global basis.

- **Improved SM retrievals:**
  - Quantitative assessments of vegetation effects for moderately to densely vegetated areas, leading to improved SMAP's SM retrievals.

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Thank you…

Back-Up

Formulation - Radiative Transfer Theory Approach

The first-order solution from vegetation (**Kurum *et. al.*, 2011**) leads to an expression given by

$$e_{sp}^{1} = 1 - \gamma_p^2 R_p - \omega_p \left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right) + \Omega_p$$

where Ω_p denotes the additional scattering contribution to the zero-order model.

This solution can be put into a form similar to the tau-omega model by factoring $\left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right)$ from the last two terms:

$$e_{sp}^{1} = 1 - \gamma_p^2 R_p - \bar{\omega}_{sp} \left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right)$$

where we define a new RT-based parameter called *effective albedo*

$$\bar{\omega}_{sp} = \omega_p - \frac{\Omega_p}{\left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right)}$$

Formulation - Wave Theory Approach

Using the Distorted Born Approximation (**Lang, 1981**) and Using Peake's principle (**Peake, 1959**) that relates active and passive problems, emissivity of the vegetation layer can be written as

$$e_{ap}^{1} = 1 - W_p^{spec} - W_p^{diff}$$

where

$$W_p^{spec} = \gamma_p^2 R_p \qquad W_p^{diff} = \frac{1}{4\pi\cos\theta}\int_{2\pi}\left[\sigma_{qq}^{0} + \sigma_{pq}^{0}\right]\cos\theta'\, d\Omega'$$

multiplying and dividing the last term (diffuse albedo term) by $(1+\gamma R)(1-\gamma)$, we obtain

$$e_{ap}^{1} = 1 - \gamma_p^2 R_p - \bar{\omega}_{ap}\left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right)$$

where we define a new active/passive parameter called *effective albedo*

$$\bar{\omega}_{ap} = \frac{W_p^{diff}}{\left(1 + \gamma_p R_p\right)\left(1 - \gamma_p\right)}$$