Improving the Performance of an Eco-Hydrological Model to Estimate Soil Moisture and Vegetation Dynamics by Assimilating Microwave Signal

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1. Introduction
A microwave land data assimilation system that can address the interactions between subsurface soil moisture and vegetation dynamics has yet to be established.
1.2. Application of Passive Microwave Remote Sensing

Radiative Transfer in microwave region

- Radiation from soil → depends on Surface Soil Moisture
- Attenuation by canopy
  - → depend on Vegetation water content
- Radiation from canopy

- Microwave brightness temperature is influenced by surface soil moisture, vegetation water content, and temperature [e.g., Paloscia and Pampaloni, 1988]

→ By assimilating this data, we can improve the skill of eco-hydrological model to simultaneously calculate soil moisture and vegetation dynamics.
1.3. GOAL

- Estimating both hydrological and ecological unknown parameters in eco-hydrological model that can simulate both soil moisture and vegetation dynamics.

- Obtaining initial conditions of soil moisture vertical profile and biomass for prediction by assimilating microwave brightness temperatures.
1.4. Coupled Land and Vegetation Data Assimilation System (CLVDAS)

**Core-Model**

EcoHydro-SiB
[Sawada et al., 2014 WRR]
[Sawada and Koike, 2014 JGR-A]

Soil moisture
Vegetation (LAI)
Temperature

Forward-RTM

Estimated TB

Pass 0:
Parameter Selection

Parameter ensemble

Core-Model

TB TB TB TB

Sensitivity analysis
of each parameter

Pass 1:
Parameter Optimization

Parameter

Core-Model

~ 1 year

Estimated TB

Satellite observed TB

Schuffled Complex Evolution

Pass 2:
Data Assimilation

Soil Moisture, LAI ensemble

Core-Model

~ 5 days

Estimated TB

Satellite observed TB

Genetic Particle Filter

COST

COST
2. Parameter Selection Strategy

- **Pass 0:** Parameter Selection
  - Core-Model
  - Sensitivity analysis of each parameter

- **Pass 1:** Parameter Optimization
  - Parameter
  - Core-Model
  - Schuffled Complex Evolution
  - Estimated TB

- **Pass 2:** Data Assimilation
  - Soil Moisture, LAI ensemble
  - Genetic Particle Filter
  - Estimated TB

- **Core-Model**
- **Soil moisture**
- **Vegetation (LAI)**
- **Temperature**

- **EcoHydro-SiB**
- **Forward-RTM**
- **Estimated TB**
2.1. Global Sensitivity Analysis (GSA) [Saltelli et al., 2010]

\[ V_Y = \sum_i V_i + \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} + \ldots \ldots + V_{12\ldots n} \]

→ Total variance of the model’s output is decomposed to the variance that come from each parameter uncertainty.
2.2. Study area & Experiment design

- CLVDAS is applied to three in-situ sites that have different hydroclimatic conditions.
- All land use are grassland.
- Model is driven by in-situ meteorological forcings.
2.3. Results

Parameter Sensitivity to TBs (18.7GHz Horizontal)

Blue: West Africa (Hot and dry)
Orange: Mongolia (cold and dry)
Gray: California (US) (temperate)

→ In dry area, we can improve the performance by tuning only hydrological parameters
→ We can reduce the number of the calibrated parameters by using GSA.

[Sawada and Koike, 2014 JGR-A]
3. Parameter Optimization
3.1. Pass 1: Parameter Optimization

CLVDAS optimizes parameters by minimizing the difference between modeled and observed brightness temperature.
3.2 Results @ West Africa
Green: Optimized, Black: Default, Red: Observed, Yellow: Observed (Microwave VOD (NASA LPRM))

- Optimization improves the skill of estimating surface soil moisture and vegetation dynamics at the same time.
4. Data Assimilation
4.1 Pass 2: Data Assimilation by using Genetic Particle Filter (GPF)

Vertical distribution of soil moisture & LAI

According to the ‘distance’ from satellite observed TB, calculated particles are resampled to obtain good initial conditions for next time steps.
4.2. Study area & Experiment design

Yanco JAXA flux tower site is for validation of AMSR2 soil moisture product. We use AMSR2 brightness temperature and meteorological forcings to run the model.
4.3 Results @ Yanco, AUS

- **Black**: Open loop
- **Orange**: Open loop with parameter optimization
- **Grey**: Assimilation (particles)
- **Green**: assimilation (Ensemble mean)
- **Red**: observation

→ Data assimilation improves the skill of simulating LAI.

→ In growing season, we can effectively confine subsurface soil moisture by particle filtering because subsurface water and vegetation growth are explicitly connected in the model.
5. Discussion and Conclusion

- Microwave satellite data assimilation has the potential to simultaneously estimate the optimal parameters of both hydrological and ecosystem models.

- Data assimilation contributes to improve the performance to estimate sub-surface soil moisture profile as well as land surface conditions.

- Multi-frequency observation of AMSR series makes it possible.

- To further improve the skills, we should consider to assimilate other satellite data (e.g., GRACE, MODIS, SMOS, SMAP,...) to be assimilated.