Application of Satellite Microwave and Optical-IR Remote Sensing to Characterize Global Soil Moisture Constraints to Soil Respiration

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Abstract

Ecosystem respiration ($R_{ec}$) is a key component of terrestrial net ecosystem CO2 exchange (NEE) and difficult to estimate globally. We developed an algorithm for determining daily NEE using synergistic measurements from satellite optical/spectral and microwave remote sensing. The algorithm uses soil moisture and temperature information from the AMSR-E microwave radiometer, and gross primary productivity (GPP) inputs from MODIS. AMSR-E soil moisture retrievals are verified using antecedent data precipitation from the Tropical Rainfall Monitoring Mission (TRMM). We then explore the functional response of $R_{ec}$ to soil moisture by comparing model results to in situ tower based CO2 flux measurements and soil inventory data using a model-data analysis approach, in preparation for a more detailed Bayesian analysis. The assumed soil moisture response is roughly parabolic, though we find that relative to flux tower observations, the inferred moisture response does not constrain respiration in dry soil. This result is likely because the available flux tower data used in this analysis is not representative of water areas. We find that the seasonality of soil respiration and the global distribution of soil depth ($>10$ cm) soil organic carbon (SOC) are reasonably captured by the model. Areas of high disturbance frequency have lower SOC relative to steady-state values. This study represents an important step in monitoring terrestrial NEE from space borne observations and is informing development of future operational carbon products such as NASA Soil Moisture Active Passive (SMAP) Demand Survey mission. This work was conducted as part of the University of Montana and Jet Propulsion Laboratory, California Institute of Technology under contract to NASA.

Hypotheses and Objectives

- AMSR-E soil moisture retrievals are sensitive to daily surface ($>10$ cm depth) soil wetting and drying cycles where vegetation biomass water content levels are less than $<1.5$ kg m$^{-2}$.
- Satellite microwave and optical-IR remote sensing information from MODIS and AMSR-E provide sufficient information on primary climatic and ecological processes for broad-scale mapping and monitoring of NEE and SOC pools from atmospheric CO2 flux and GPP.
- The functional relationship between satellite indices can be inferred by process model-data analysis with flux tower observations.

Models and Methods

**Terrestrial Carbon Flux (TCF) Model**

We use a simple Terrestrial Carbon Flux (TCF) process model approach described in [1]. The model predicts ecosystem respiration ($R_{ec}$), net ecosystem CO2 exchange (NEE), and surface SOC content using soil temperature and moisture inputs from AMSR-E and GPP (MOD17) from MODIS. The basic model equation is given below:

$$N_{EE} = \text{Temp} \times \text{ResCh} \times \text{SWI} \times (1 - \text{LAI})$$

**Surface Wetness Index**

$$\text{NEE} = \text{ResCh} \times \text{Temp} \times (1 - \text{LAI})$$

**Constraints**

The dimensionless surface temperature multiplier ($T_{mult}$; 0-1) is an exponential function of mean daily soil temperature from AMSR-E [13]. The soil moisture multiplier ($SWI_{mult}$; 0-1) is an exponential function of mean daily soil moisture from AMSR-E [13]. Both the soil moisture and temperature multipliers were derived from the combination of AMSR-E and SWI algorithms.

**Soil C Storage in Relation to Satellite Climate Constraints**

**Ecosystem Respiration Responds to Soil Wetness**

**Conclusions**

- Satellite based soil moisture and temperature from AMSR-E and GPP from MODIS, combined within a simple TCF model framework, capture global SOC storage patterns relative to soil inventory data, and $R_{ec}$ temporal dynamics at $>33$ flux tower locations.
- AMSR-E surface wetness correlates significantly with surface wetness calculated from TRMM precipitation for the majority of the study domains. Significant correspondence decreases where vegetation optical depths $>0.8$ (Fig. 1-2).
- The TCF algorithm produces realistic steady state SOC pools using AMSR-E-derived indices of surface freeze-thaw status, soil moisture and temperature, and MODIS GPP (Fig. 3).
- Effective SOC pools can be inferred from tower observations and TCF model dynamics that correspond well with the available flux tower data and precipitation data alone (Fig. 5).

**References**


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