Soil Moisture
Active Passive
Mission
SMAP

Cal/Val Workshop #4
Nov 5-7, 2013

The Level 4 Carbon (L4_C) Algorithms

John Kimball, Yonghong Yi, Joe Glassy, Lucas Jones (UMT), Rolf Reichle, Joe Ardizonne (GSFC)
**SMAP science objectives addressed:**
- Quantify net ecosystem CO₂ exchange (NEE) in boreal landscapes;
- Improve understanding of processes linking terrestrial water, carbon & energy cycles;

**Product requirements:**
- Determine NEE daily, seasonal & annual variability & heterogeneity;
- Link NEE with component C fluxes (GPP, $R_{eco}$) & primary moisture & thermal constraints to GPP & $R_{eco}$;

**Product success criteria:**
- Emphasis on northern (≥45°N) land areas;
- NEE accuracy (RMSE) commensurate with tower based C-fluxes (RMSE ≤30 g C m⁻² yr⁻¹).

---

1Estimated Error Budget (RMSE) for NEE

[Map showing NEE RMSE across the globe with error bars and data points for different regions]

1Derived from MODIS, FT-ESDR & MERRA inputs
Net Ecosystem CO$_2$ Exchange (NEE)

- **Approach**: Apply LUE & soil Decomp. Algs. driven by SMAP & other ancillary inputs;
- **Dynamic Inputs**: FT (L3_SM_A); SM, $T_s$ (L4_SM); $R_{sw}$, VPD, $T_{mn}$ (GMAO); FPAR (MODIS);
- **Outputs**: NEE (validated); GPP, $R_h$, SOC, EC & QA metrics (research);
- **Domain**: Global vegetated areas;
- **Resolution**: 9 km (1 km processing);
- **Temporal fidelity**: Daily;
- **Accuracy**: Emphasis on northern land areas; NEE RMSE $\leq 30$ g C m$^{-2}$ yr$^{-1}$ relative to tower C-flux Obs.
Pre-launch L4_C Cal/Val Activities

Model initialization:

• Site, region & global L4_C simulations using tower (FLUXNET), satellite (MODIS, AMSR) & reanalysis (MERRA) drivers;

Model calibration and evaluation:

• Model calibration (BPLUT) and options assessment using FLUXNET & global C products (MOD17, MTE, SOC inventories, model intercomparisons);

Ancillary data assembly:

• SOC, FPAR climatology, etc.

2Yi et al., 2013. *JGR - Biogeosci*. 118.
Rehearsal 1 Objectives for L4_C Product

**Primary:**
- Test delivery & reliability of near real-time tower data from participating core tower site partners;
  - ~weekly latency; daily fidelity; well characterized uncertainty
- Test JPL matchup tools & data transfer logistics;
- Test UMT software tools & resources for evaluating matchups.

**Secondary:**
- Test primary L4_C validation activities.

**Constraints:**
- Match-ups not temporally consistent;
- Limited number of core sites;
- Prototype L4_C software with coarse (0.5°) model outputs & Met. drivers (MERRA).
Phenology Representation (US-PFa\textsuperscript{1}, Mixed Forest)

\textsuperscript{1}Site PI: Arlyn Andrews
Water Stress Characterization (US-SRM², Woody Savanna)

GPP: 39010901 | US-SRM (Santa Rita AZ)

- GPP tower
- GPP L4_C

NEE: 39010901 | US-SRM (Santa Rita AZ)

- NEE tower
- NEE L4_C

---

Carbon flux (gC/m²/d)

- Tower_GPP
- L4_C_GPP
- Tower_SM
- Tower_NEE
- L4_C_NEE

Soil moisture (m³/m²)

- 2005
- 2006

Site PI: Russell Scott
Soil Moisture Constraints in Boreal/Arctic C Cycle

Important role of soil moisture in boreal/arctic C cycle:
• Decoupling of soil moisture & temperature in boreal/arctic area;
• Potentially different responses of GPP and $R_{eco}$ to soil moisture.

Summer (JJA) NEE response to air temperature

- Carbon loss
- Carbon gain

Summer (JJA) NEE response to soil moisture

- Carbon loss
- Carbon gain
More tower sites for validation:
- Involve all (~17) core tower sites, emphasizing northern biomes;
- Secondary sites (~80), global representation.

Mature L4_C software for comparisons:
- Co-located in space & time (core sites);
- Tower footprint vs. 1-9 km outputs;
- Model sensitivity runs to distinguish relative error sources (L4_C simulator)

Synergistic land C products:
- L4_C simulator outputs
- MODIS (MOD/MYD17) GPP
- Soil Carbon (SOC) inventories [static]
- Upscaled, Obs. based C products (MTE)
- Field campaigns (AirMOSS, SMAPVEX)
L4_C Product Example: NEE, July 20

NEE 9 km Grand Average

NEE 9 km by PFT Average Sub-Layers

- Broadleaf Crops (BCRP)
- Cereal Crops (CCRP)
- Grassland (GRS)
- Shrubland (SHR)
- Deciduous Broadleaf Forest (DBF)
- Deciduous Needleleaf Forest (DNF)
- Evergreen Needleleaf Forest (ENF)
- Evergreen Broadleaf Forest (EBF)
L4_C Biome Property Look-up Table (BPLUT)

- Defines PFT biophysical response characteristics for each 1-km grid cell
- Calibrated using global tower network observations (FLUXNET)
- Flexible design for global operational processing

### MODIS (MCD12Q1) Land Cover Classification

- PFT classes: Evergreen needleleaf forest (ENF), evergreen broadleaf forest (EBF), deciduous needleleaf forest (DNF), deciduous broadleaf forest (DBF), grassland (GRS), shrubland (SRB), cereal crop (CCRP), broadleaf crop (BCRP)
- Masked areas: Barren (BAR), Urban (URB), permanent ice/snow (ICE), open water (WAT)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>ENF</th>
<th>EBF</th>
<th>DNF</th>
<th>DBF</th>
<th>GRS</th>
<th>SRB</th>
<th>CCRP</th>
<th>BCRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{max}$</td>
<td>(g C MJ$^{-1}$)</td>
<td>1.10</td>
<td>1.20</td>
<td>1.10</td>
<td>1.20</td>
<td>0.85</td>
<td>0.85</td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td>$M_{min}$</td>
<td>($^\circ$ C)</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
<td>-8.0</td>
</tr>
<tr>
<td>$M_{max}$</td>
<td>($^\circ$ C)</td>
<td>8.3</td>
<td>9.1</td>
<td>10.4</td>
<td>9.9</td>
<td>12.0</td>
<td>8.8</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>MinPFD</td>
<td>(Pa)</td>
<td>500</td>
<td>1800</td>
<td>500</td>
<td>500</td>
<td>752</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>MaxPFD</td>
<td>(Pa)</td>
<td>4000</td>
<td>4000</td>
<td>4160</td>
<td>4160</td>
<td>5500</td>
<td>4455</td>
<td>5071</td>
<td>5071</td>
</tr>
<tr>
<td>MinSLM</td>
<td>(% Sat.)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>MaxSLM</td>
<td>(% Sat.)</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>$F_{FT}$</td>
<td>(DIM)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>$N_{FT}$</td>
<td>(DIM)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$C_{flag}$</td>
<td>(DIM)</td>
<td>0.49</td>
<td>0.71</td>
<td>0.67</td>
<td>0.67</td>
<td>0.76</td>
<td>0.62</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>CUE</td>
<td>(DIM)</td>
<td>0.55</td>
<td>0.45</td>
<td>0.55</td>
<td>0.55</td>
<td>0.6</td>
<td>0.6</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>$R_{lag}$</td>
<td>(DIM)</td>
<td>0.45</td>
<td>0.55</td>
<td>0.45</td>
<td>0.45</td>
<td>0.4</td>
<td>0.4</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>$K_{max}$</td>
<td>($d^{-1}$)</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
<td>0.0301</td>
</tr>
<tr>
<td>$K_{lag}:K_{max}$</td>
<td>(%)</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>$K_{lag}:K_{net}$</td>
<td>(%)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$T_{lag}$</td>
<td>($^\circ$ C)</td>
<td>20.0</td>
<td>25.0</td>
<td>20.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>$S_{lag}$</td>
<td>(% Sat.)</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>$c$</td>
<td>(DIM)</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>