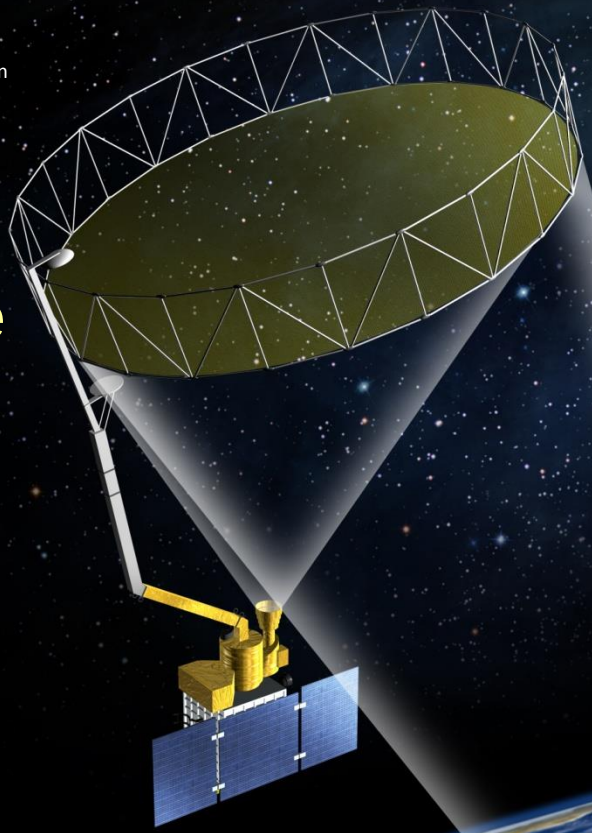
National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP



Level 4 Carbon (L4C): Results & Status

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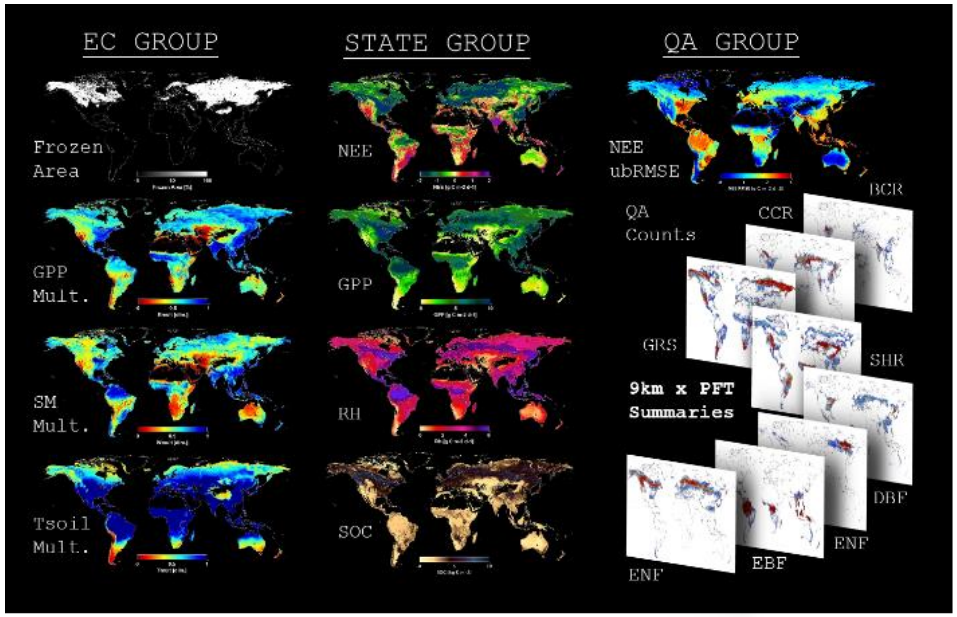
Cal/Val Workshop #8
June 20-22, 2017
Amherst, MA

L4C Product Status

- Available at NASA NSIDC DAAC: http://nsidc.org/data/SPL4CMDL
- ~27 month daily data record (3/31/15 to present)
- ~11-day product latency
- Product versions: **Vv2040** (3/31/15 – 3/29/17); **Vv2043** (3/30/17-present);
    - Vv2043 uses MODIS C6 FPAR inputs, rather than C5 FPAR (Vv2040) which is no longer in production
- CEOS Stage 3 validation level based on comprehensive global assessments using in situ sparse tower site measurements, other observation benchmarks & model sensitivity studies.
- Product performance consistent with design and target accuracy: NEE *ubRMSE* ≤ 1.6 g C m^{-2} d^{-1} or 30 g C m^{-2} yr^{-1} for northern (≥45°N) land areas.

L4C Daily Product Set



Jones, L.A., J.S. Kimball, R.H. Reichle, N. Madani, et al. 2017. The SMAP Level 4 Carbon product for monitoring ecosystem land-atmosphere CO2 exchange. *IEEE TGARS*.

L4C Cal/Val Framework

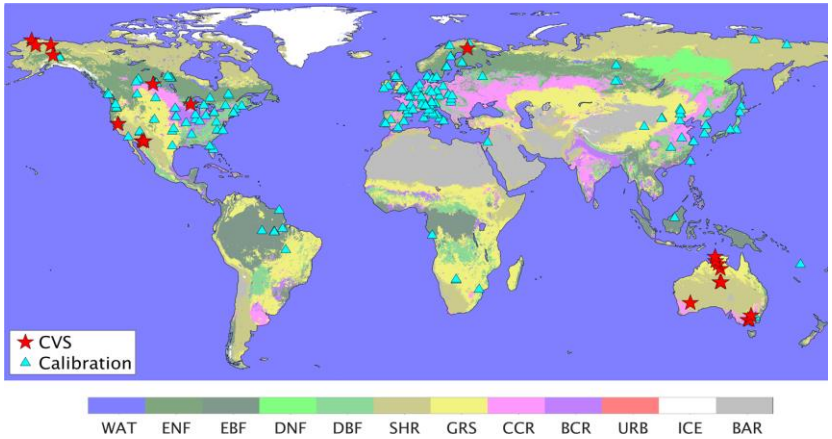
Document L4C performance relative to SMAP science objectives & accuracy requirements

- ✓ C-flux comparisons at core tower sites (CVS); comparisons consistent in space & time.
- ✓ Comparisons against historical FLUXNET site records; spatially but not temporally consistent
- ✓ Global model sensitivity & performance assessments
- ✓ Consistency checks against other global C products, Incl. GPP (MODIS, MTE), SIF (OCO-2, GOME-2), & Carbon model inversions (CT)
- ✓ Comparisons, sensitivity studies using field experiment data (ABoVE, SMAPVEX)

SMAP L4_C Validation Approach

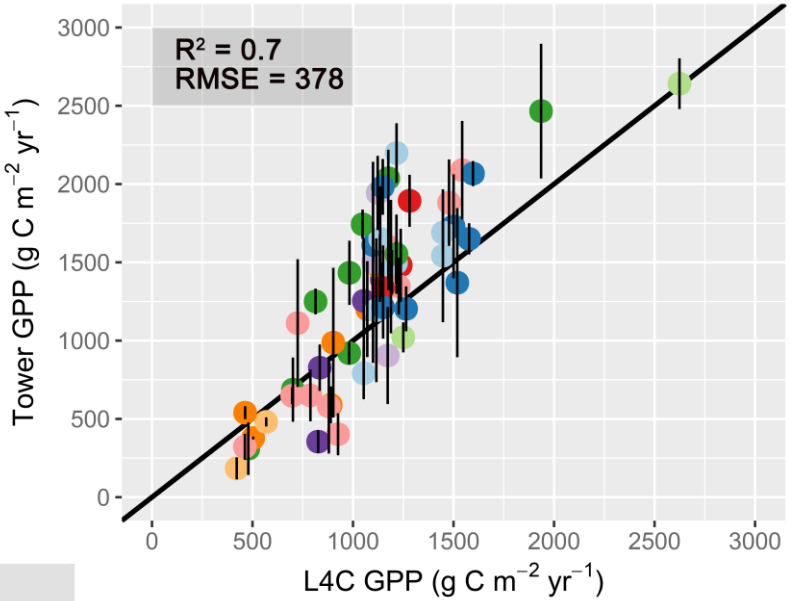
Methodology	Data	Importance	Metric
Core Sites	Observed grid cell average values (time-continuous)	Primary	Correlation, RMSE, bias
Sparse Networks	Observed values (time-continuous)	Primary	Correlation, RMSE, bias
Satellite Products	Grid cell match-ups (MODIS, OCO-2, GOME-2)	Secondary	Anomaly correlation, RMSE, bias
Model Products	Site & Global modeling systems, model inversions	Primary	Sensitivity diagnostics, correlation, RMSE, bias
Field Experiments	Detailed estimates for a very limited set of conditions	Secondary	Correlation, RMSE, bias

L4C Tower Cal/Val Sites

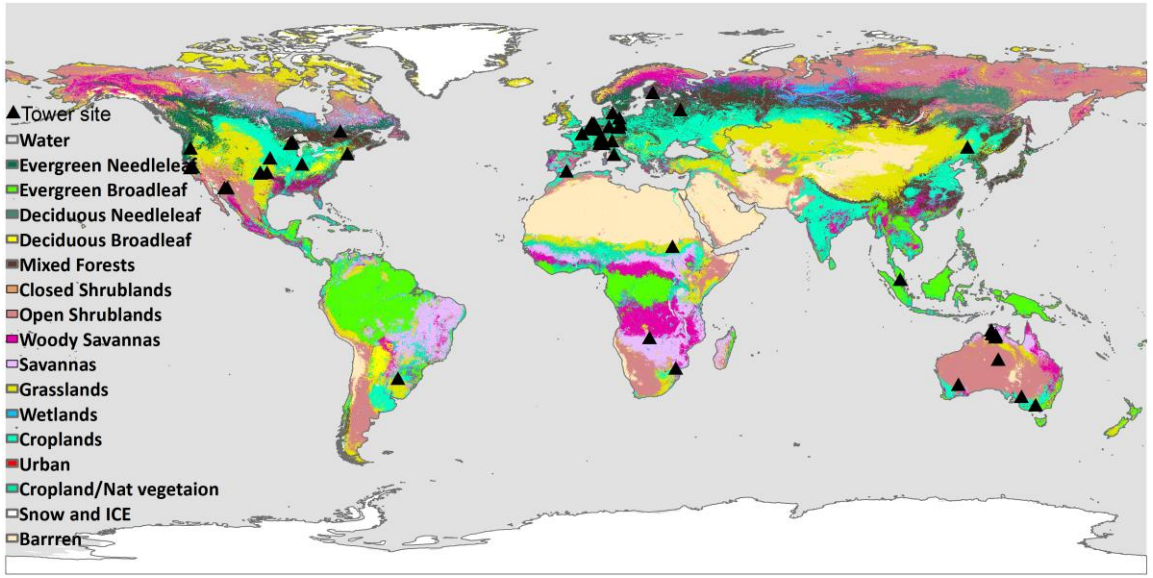


L4C Cal/Val using latest FLUXNET Synthesis

- L4C (Apr 2015- Mar 2017) vs FLUXNET-2015 (2007-2014) mean annual GPP.
- Error bars show inter-annual variability (SD) in flux tower GPP estimates.
- New sites (~60) & longer data records provide enhanced validation relative to prior FLUXNET (LaThuile) data used for L4C Cal/Val.



FLUXNET-2015 Tower Sites

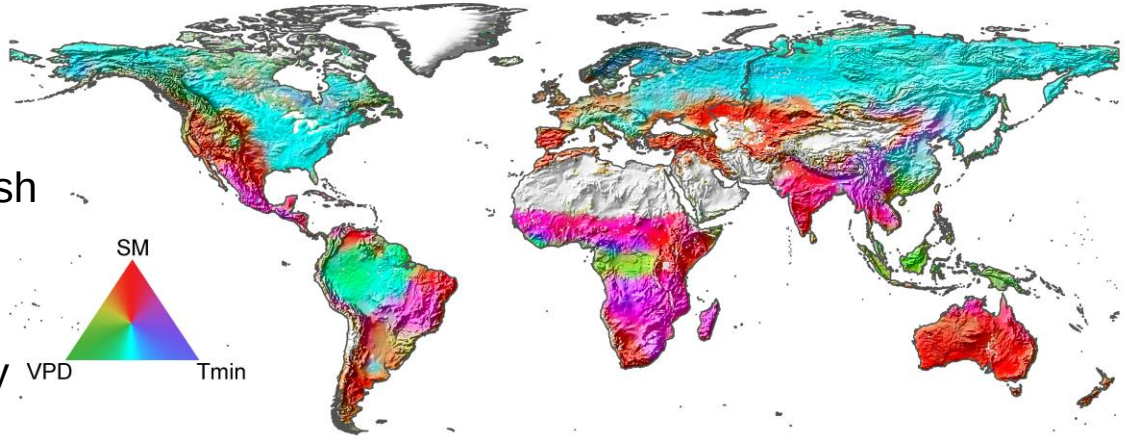


- Data capture significant recent climate extremes, including anomalous drought and rainfall events.
- Favorable L4C and tower agreement despite differences in temporal coverage.

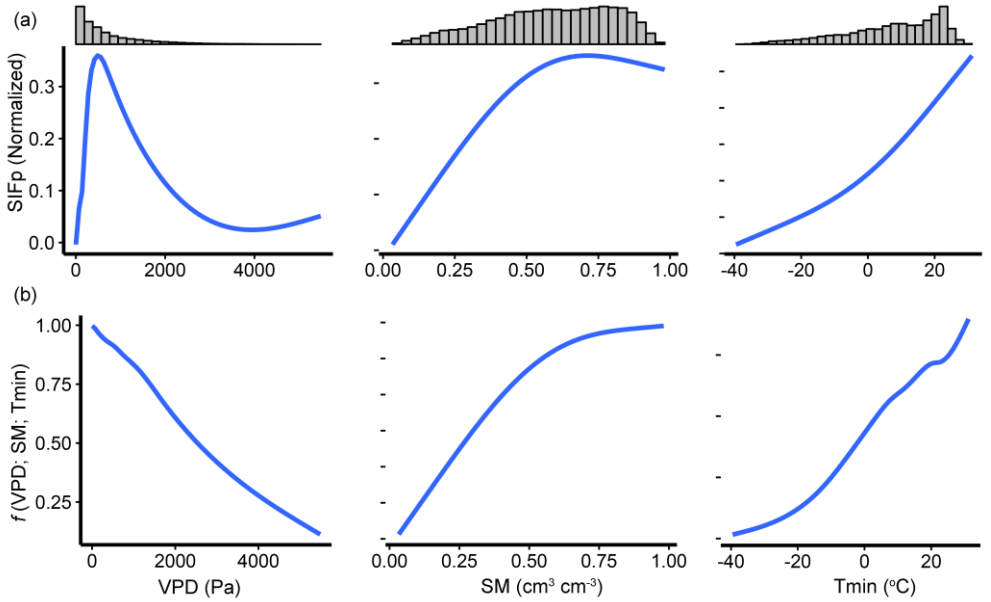
Evaluating Global Climate Controls on Productivity
(L4C GPP vs GOME-2 SIF)

- Satellite SIF (Solar-Induced Fluorescence) from GOME-2 (2007-2014) used as a GPP proxy.
- SIF normalized using PAR to distinguish climate sensitivity from canopy phenology.
- Correlations mapped between monthly SIF & selected MERRA-2 climate parameters.
- Global SIF and L4C response curves compared.
- SM in ~35% of the global land area explains SIF's seasonal variability.
- Similar SIF and L4C climate sensitivity and response characteristics verify model calibration and performance.

Relative Climate Impacts on SIF Observations



SIF and L4C Global Productivity Response Curves

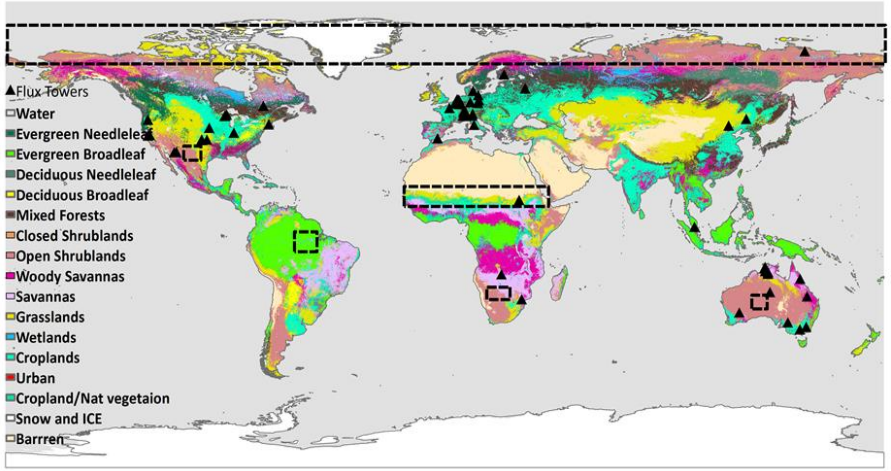


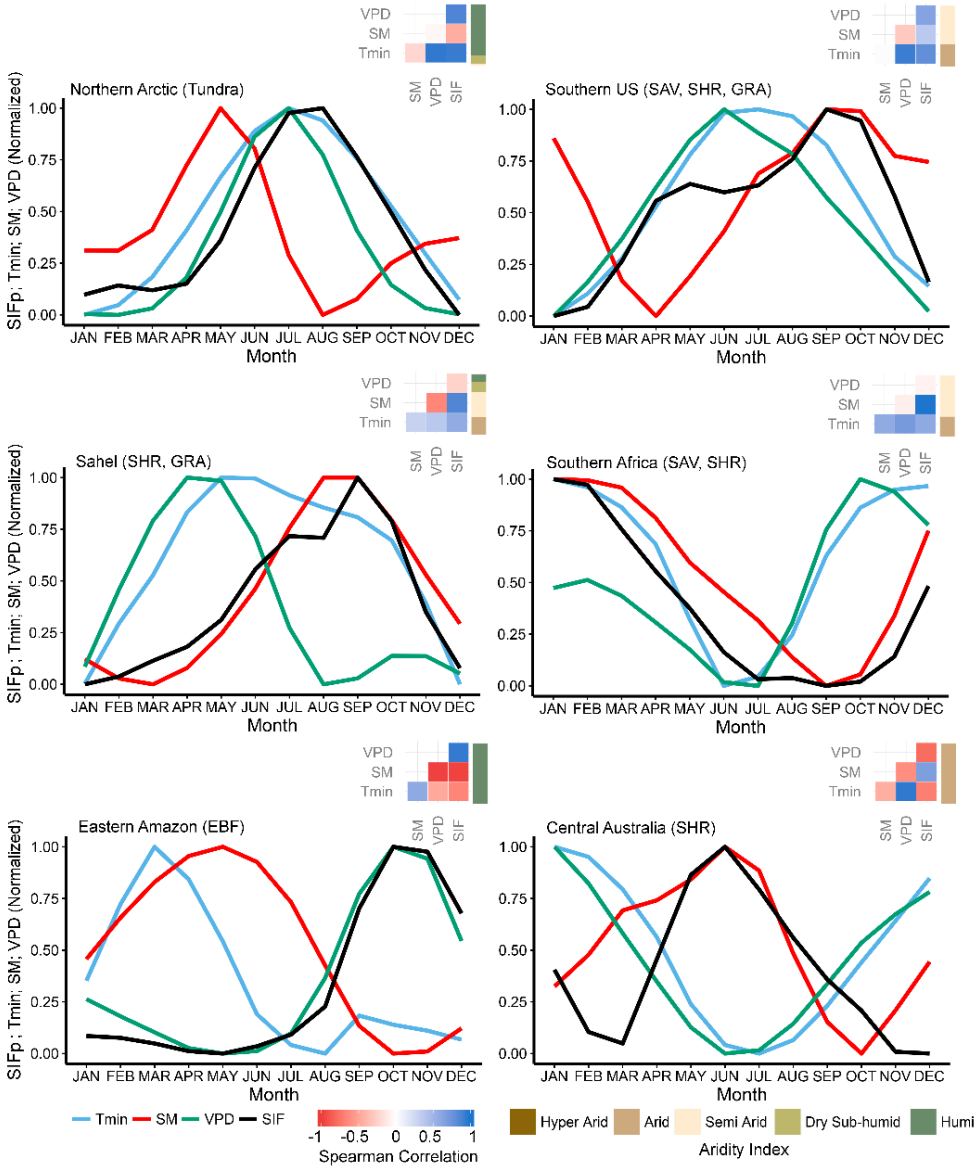
Source: Madani et al. 2017. *Remote Sensing* 9, 530.

Verifying Bioclimatic Controls on Seasonal Productivity (GOME-2 SIF vs SMAP L4C)

- Seasonality of GOME-2 SIF and apparent climate controls on productivity vary for different biomes.
- Strength and sign of SIF and soil moisture correlation varies according to climate aridity.
- Potential L4C calibration enhancement using SIF rather than sparse tower sites.
- Caveat: Coarse SIF footprint.

Selected Biome Sub-regions

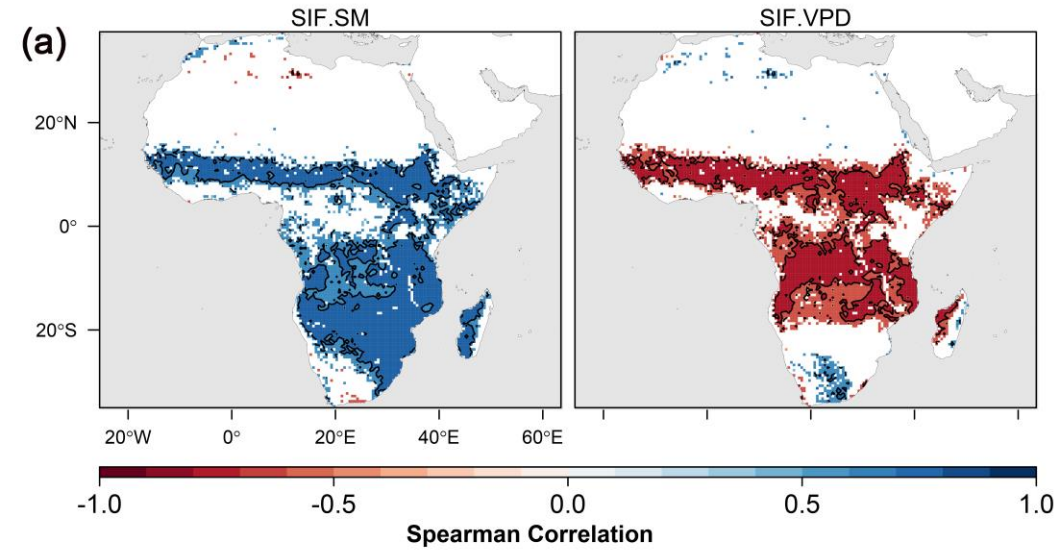


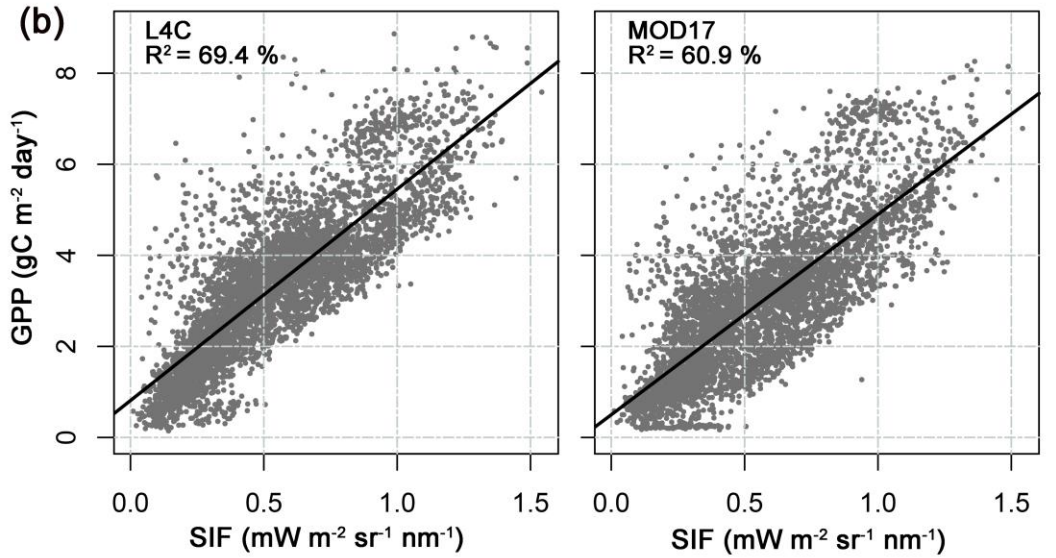


Source: Madani et al. 2017. *Remote Sensing 9, 530.*

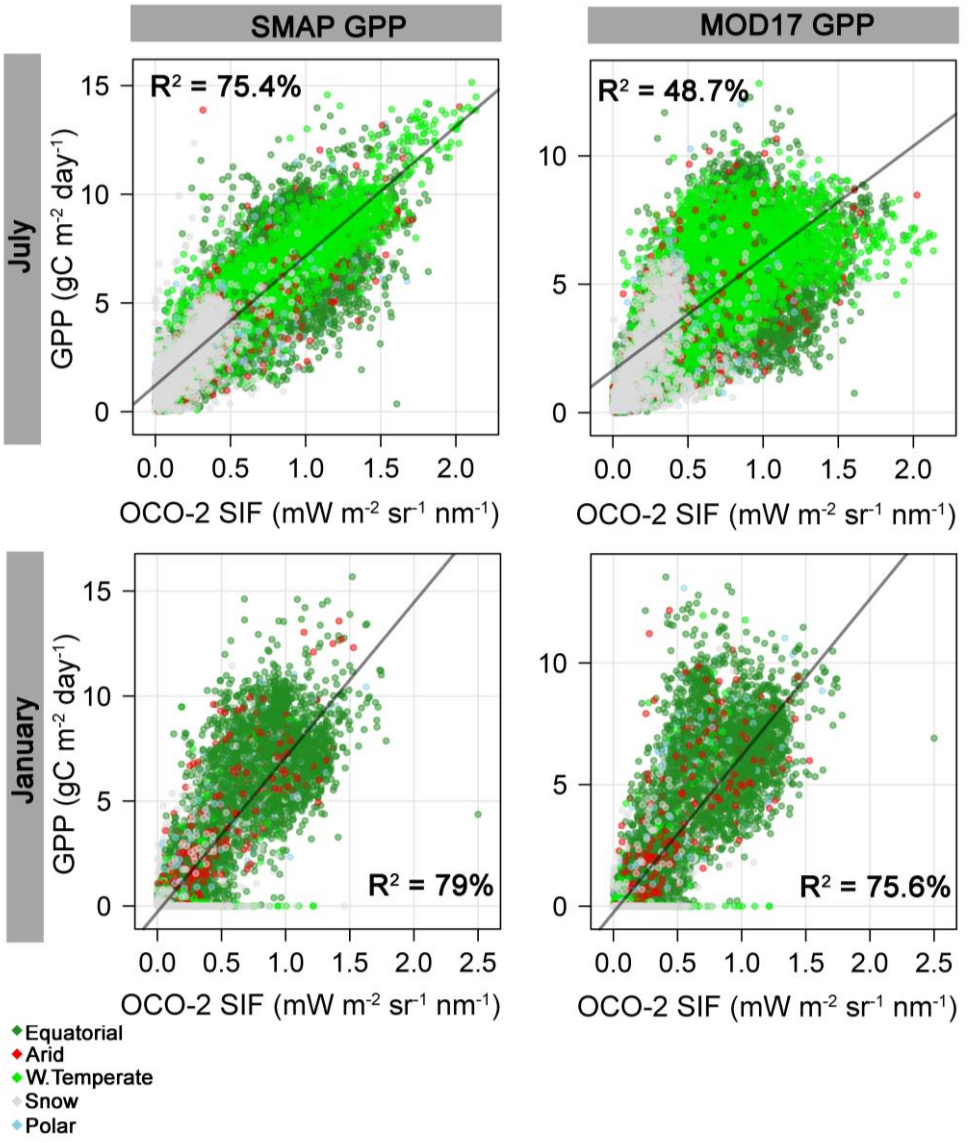
Water Constraint Factors Affecting SMAP L4C GPP and GOME2 SIF over Africa (Apr-Dec 2015)

- Significant correlation (p<0.05) between Apr-Dec mean SIF and SM and VPD across Africa indicate strong regional moisture constraints to productivity.
- Significant SIF-SM correlated areas cover 16% more area than SIF-VPD correlated areas.
- SMAP-L4C GPP, which accounts for soil moisture constraints, shows higher correspondence with SIF than MODIS-MOD17 GPP, which only uses VPD to represent water constraints.



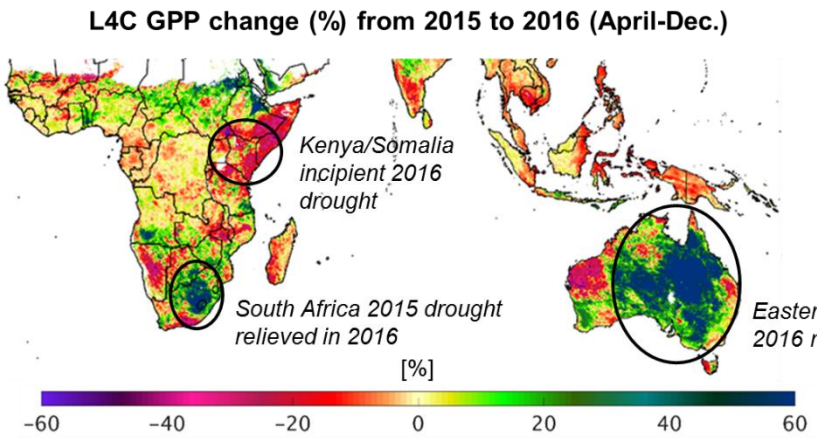


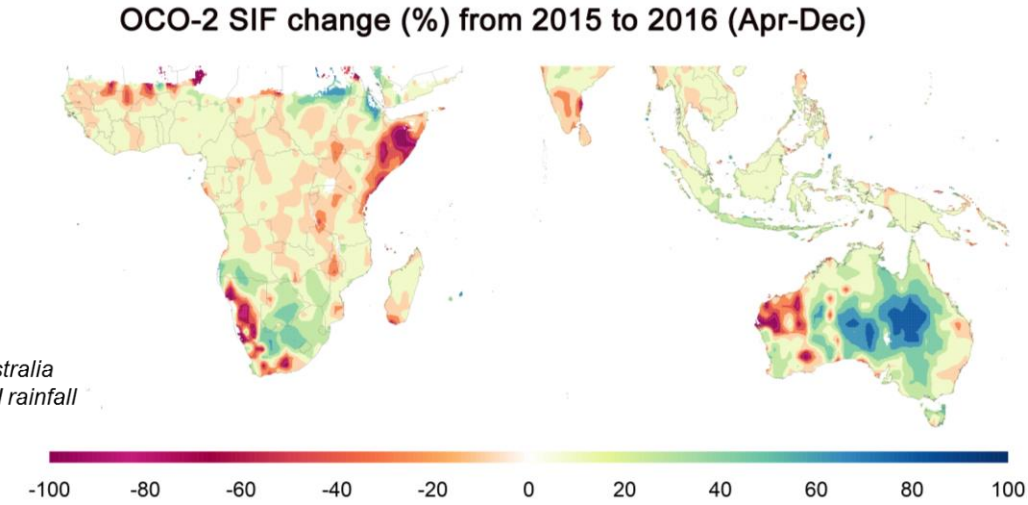
OCO-2 SIF vs SMAP L4C and MODIS MOD17 GPP (Global Assessment; 2015-2016)

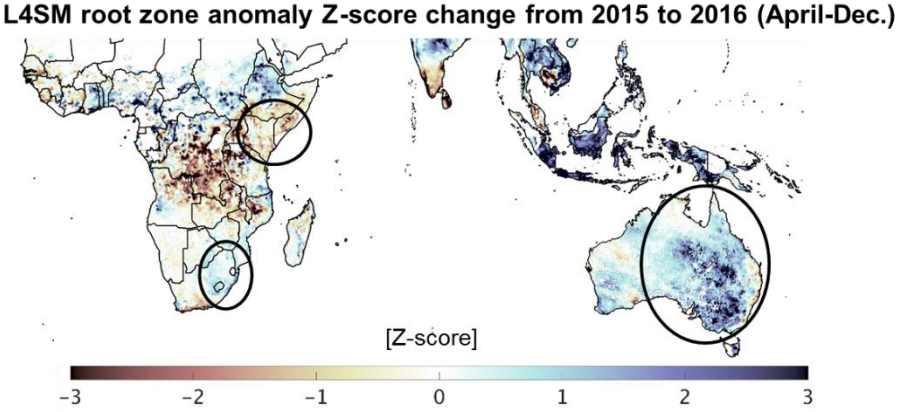


- L4C GPP shows higher correlation with OCO-2 SIF than MOD17.
- Both GPP products show good correlation with SIF when Temperate forests are at dormancy.
- L4C GPP shows stronger correlation with SIF than MOD17 during active growing season, esp. where SM constraints are more severe.
- All the global monthly averaged pixels at 9-km spatial resolution are analyzed; grid cells classified by Köppen climate categories.

SMAP L4C and OCO-2 SIF Capture Similar Productivity Response to Recent Climate Anomalies



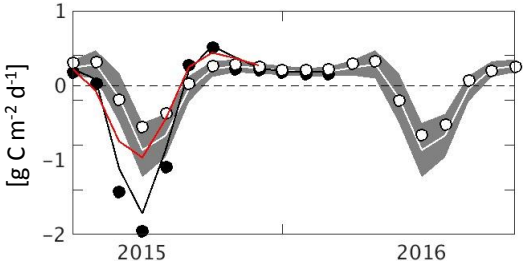




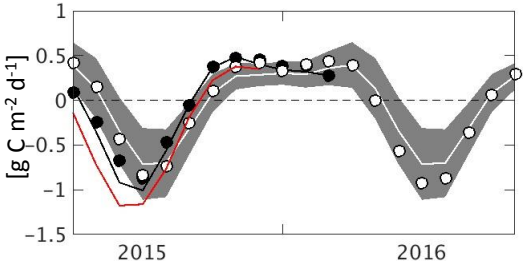
- SMAP L4C GPP and OCO-2 SIF show similar response patterns to recent climate anomalies.
- Strong productivity increase in central and eastern Australia from record 2016 rainfall.
- Large productivity decline in East Africa due to extreme drought and high temperatures in 2016.

SMAP L4C NEE vs Other Global Benchmarks (CarbonTracker; MPI-MTE)

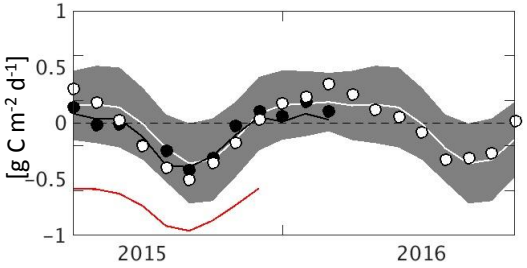
Boreal



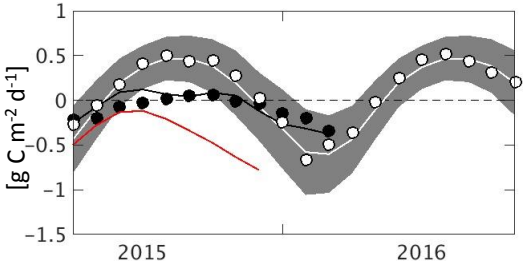
Northern Temperate

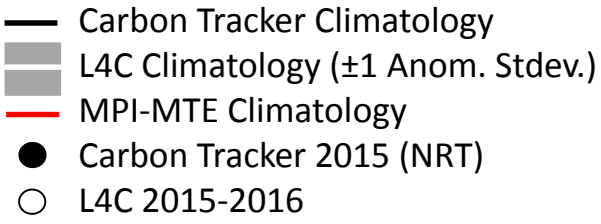


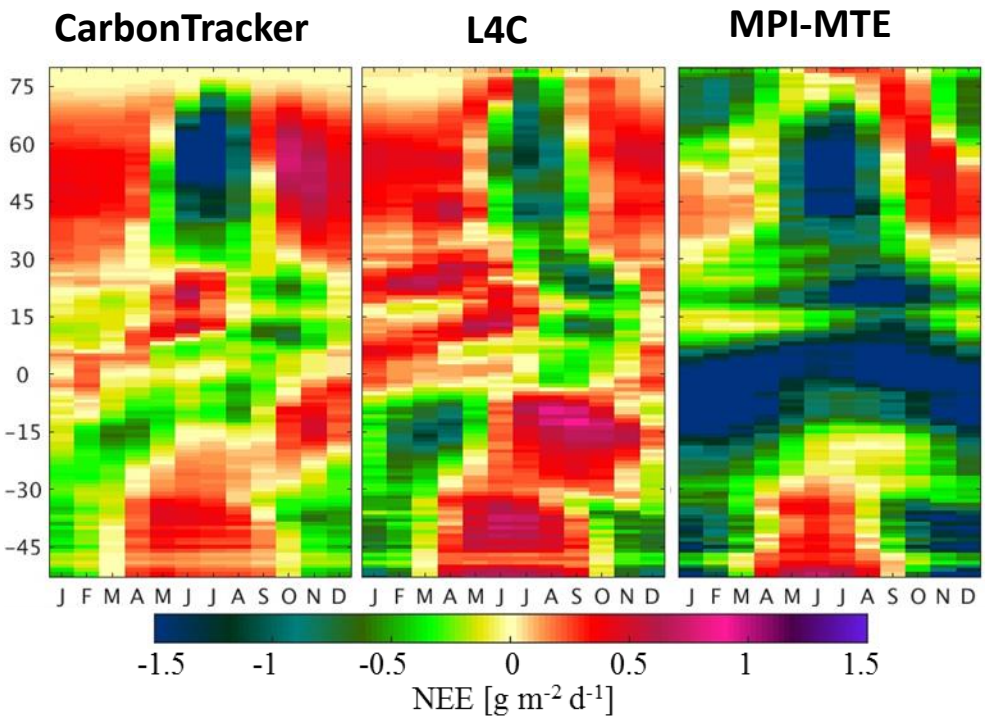
Tropical



Southern Temperate







Summary and Plans

- Current product performance consistent with design
  - Mean NEE ubRMSE ≤ 1.6 g C m^{-2} d^{-1} or 30 g C m^{-2} yr^{-1}
  - Favorable agreement with other global benchmarks
- New science investigations enabled, including northern C-cycle, drought sensitivity and disturbance recovery, and global climate controls
- Jun 2017: Full reprocessing (3/31/2015 – present) of L4C product stream scheduled
  - Incorporating: latest L4SM (Vv3030) and MODIS FPAR (C6) inputs; reinitialized SOC pools using updated GEOS-5 (NRv4.1) land model and carbon model recalibration
  - Latest L4C release (Vv3040) will replace earlier product versions (Vv2040, Vv2043) at NSIDC
- Continuing L4C assessments focusing on selected sub-regions and longer record
- SMAP application studies for science and Cal/Val enhancements
  - Multi-sensor assessments: SMAP, MODIS, GRACE, AMSR, GOME-2, OCO-2
  - Exploiting data from new field campaigns (ABoVE, SMAPVEX)

Recent Publications

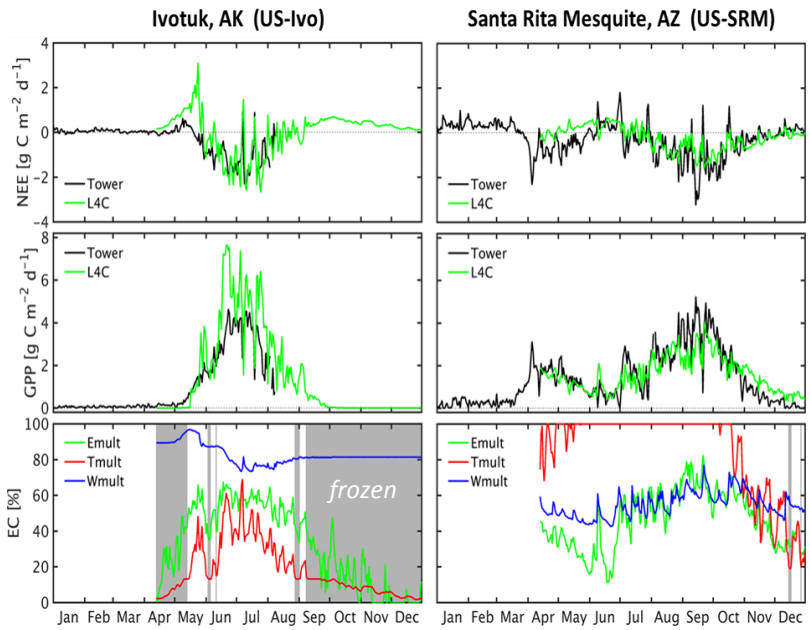
- Madani, N., J.S. Kimball, L.A. Jones, N.C. Parazoo, and K. Guan, 2017. Global analysis of bioclimatic controls on ecosystem productivity using satellite observations of solar-induced chlorophyll fluorescence. *Remote Sensing* 9, 530.
- Jones, L.A., J.S. Kimball, R.H. Reichle, N. Madani, et al. 2017. The SMAP Level 4 Carbon product for monitoring ecosystem land-atmosphere CO2 exchange. *IEEE TGARS* (In press).
- Kimball, J.S**.**, L. A. Jones, J. Glassy, et al., 2016. Soil Moisture Active Passive Mission L4_C Data Product Assessment (Version 2 Validated Release). *GMAO Office Note No. 13 (Version 1.0)*.
- He, M., J.S. Kimball, S. Running, et al., 2016. Satellite detection of soil moisture related water stress impacts on ecosystem productivity using the MODIS-based photochemical reflectance index. *RSE* 186, 173-183.
- Hursh, A., A. Ballantyne, J. Kimball, et al., 2016. The sensitivity of soil respiration to soil temperature, moisture, and carbon supply at the global scale. *Global Change Biology* 23, 5, 2090-2103.

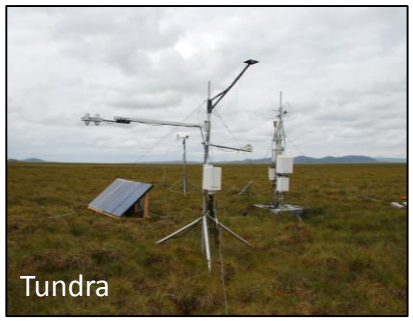
[EXTRA SLIDES]

SMAP L4C Core Site Validation Results

Overall Stats:

NEE [g C m^{-2} d^{-1}]				GPP [g C m^{-2} d^{-1}]				R_{eco} [g C m^{-2} d^{-1}]			
R	RMSE	ubRMSE	N	R	RMSE	ubRMSE	N	R	RMSE	ubRMSE	N
0.52	1.04	0.79	26	0.72	1.27	0.85	26	0.65	1.16	0.62	24





tundra, desert, grasslands → *savannah, forest*

increasing biomass and flux magnitude (abs(GPP+RECO))

Source: Jones et al. 2017. *IEEE TGARS*

L4C Transition from MODIS C5 to C6 FPAR Inputs

- MOD15A2 FPAR C5 to C6 Inputs:
  - FPAR C5 production ended Mar 31, 2017 and shifted to C6.
  - C6 has finer (500m) resolution and other differences.
- L4C Vv2040 uses FPAR C5 inputs, while Vv2043 uses FPAR C6.
- Different C5/6 FPAR inputs create inconsistency between L4C Vv2040 (Mar 31, 2015 – Mar 31-2017) and Vv2043 (Apr 1, 2017 – present) records.
- Both Vv2040 and Vv2043 performance still within product design.
- L4C Reprocessing planned (Jun-17) to produce consistent record using C6 FPAR inputs (Mar 31, 2015 – present).

2015 mean annual FPAR difference between MODIS (MOD15A2) C6 and C5 FPAR over CONUS