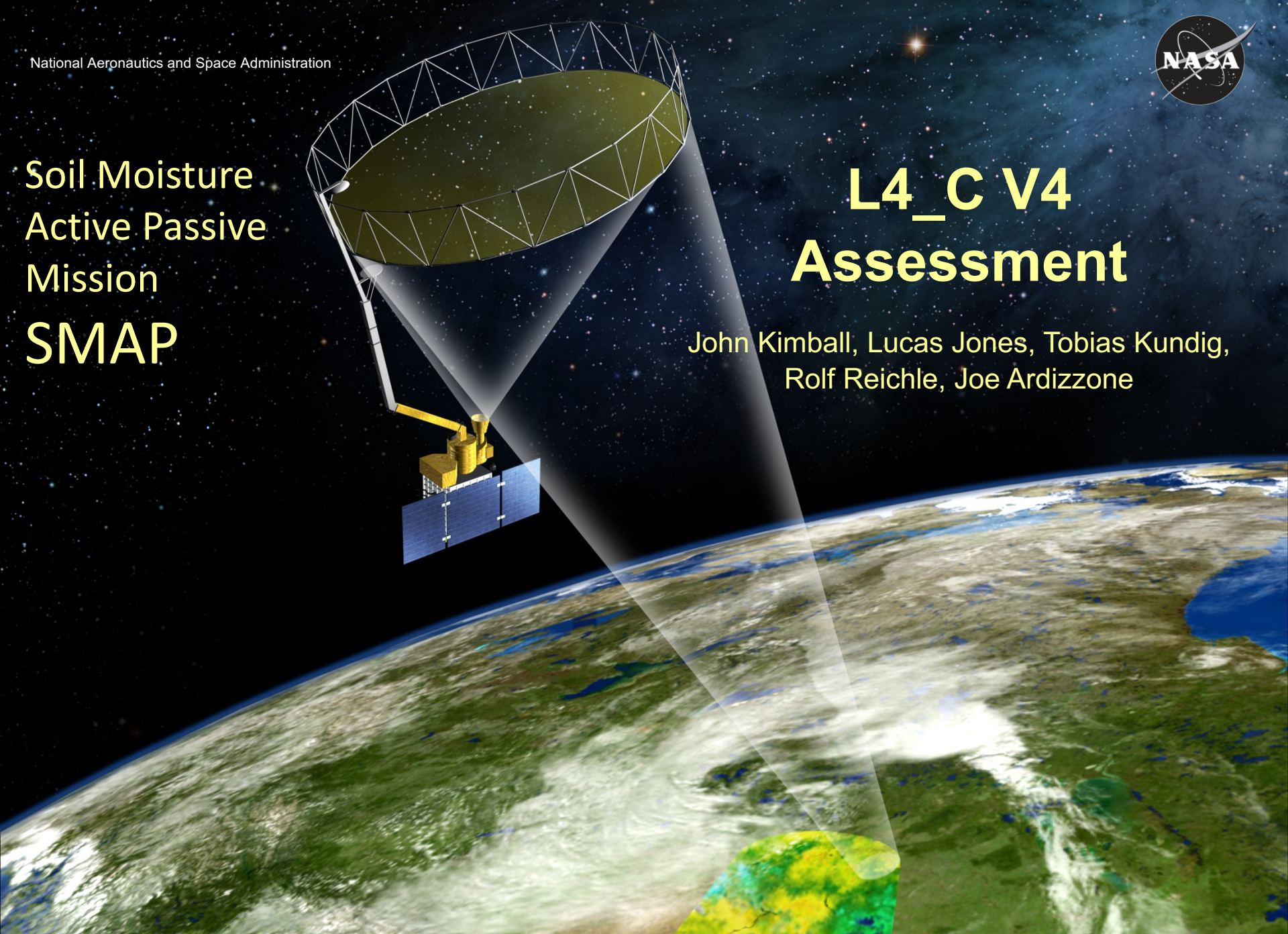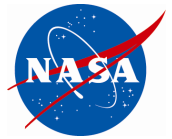Soil Moisture Active Passive Mission
SMAP

L4_C V4 Assessment

John Kimball, Lucas Jones, Tobias Kundig, Rolf Reichle, Joe Ardizzone

SMAP L4C Product Summary

- Satellite data-driven C-flux model

  - Inputs: SMAP L4SM, MODIS (LC, FPAR) and GMAO FP daily meteorology (VPD, Tmn, PAR)

  - Daily product set Incl. C-fluxes (GPP, RH, NEE), SOC, EC and QA metrics.

- Model calibrated using global tower C-flux records (FLUXNET)

- 1-km processing and 9-km posting of model outputs

- Target accuracy: Mean NEE ubRMSE≤1.6 g C m^{-2} d^{-1}, emphasizing northern (≥45°N) ecosystems

- Objective: Link estimated C-fluxes with underlying environmental controls including SM related constraints to C-sink activity.

L4C daily product set
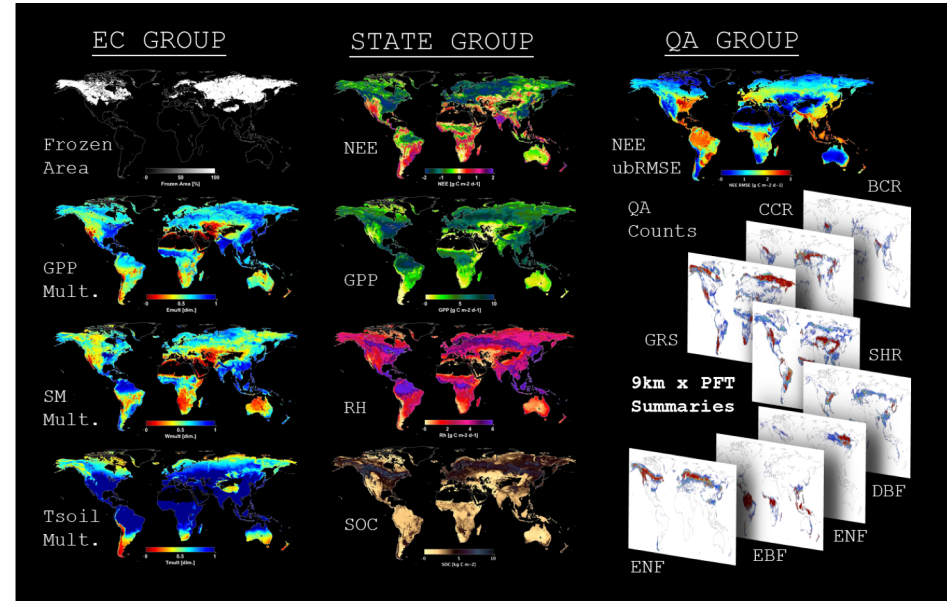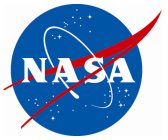
L4C Data streams

- **NRv4.1**:
  - ○ L4C V3 simulations using SMAP L4SM NRv4.1, MODIS, and MERRA2 (2000-2017) inputs
- **NRv7.2**:
  - ○ L4C V4 simulations using SMAP L4SM NRv7.2, MODIS, MERRA2 (2000-2017)
- **V3** (Vv3040):
  - ○ Current L4C Ops record using SMAP L4SM (V3), MODIS and GMAO FP
  - ○ Model parameterization, initialization using MERRA2 and SMAP NRv4.1
- **V4** (Vv4020):
  - ○ <u>Future</u> L4C Ops stream using SMAP L4SM (V4 Ops), MODIS and GMAO FP
  - ○ Parameterization, initialization using MERRA2 and SMAP NRv7.2
- **Tv4000**:
  - ○ L4C V4 <u>Test</u> stream using L4SM (Tv4), MODIS and GMAO FP
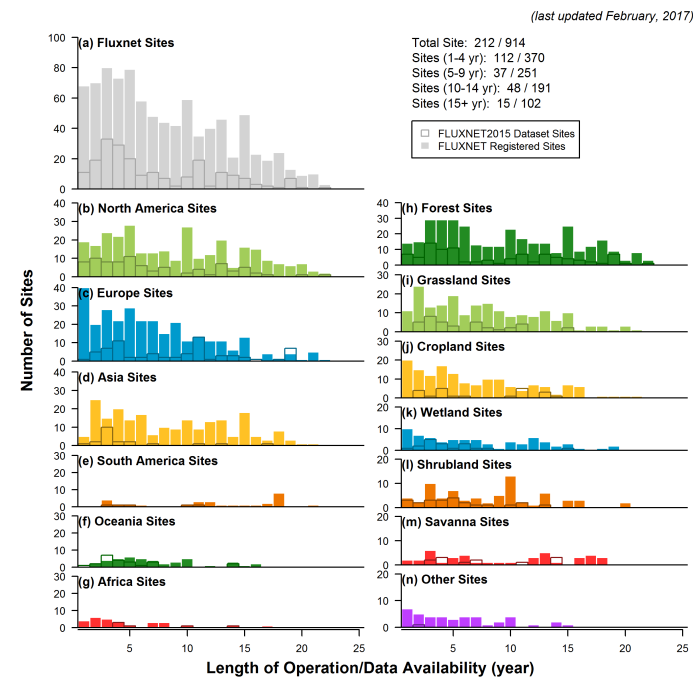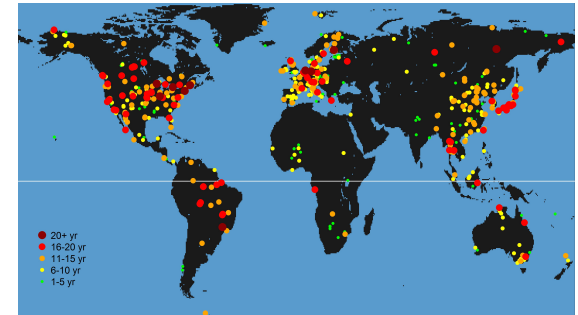 - ○ Parameterization, initialization using MERRA2 and SMAP NRv7.2
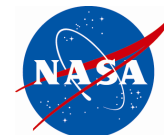
L4C V4 changes from V3

- L4SM (V4) daily SM and Tsoil inputs based on SMAP NRv7.2 modeling system (NRv4.1 for V3)

- Revised L4C calibration and SOC initialization using NRv7.2 and MERRA2 climatology

  - Augmented global tower record used for L4C BPLUT calibration and validation

    - Longer tower records, new sites and LC types represented (335 sites for V4 vs 228 sites for V3)

    - SOC map used for model SOC calibration for each PFT across tower locations.

  - Extended (2000-2015) MODIS C6 FPAR and NRv7.2 records used for L4C initialization

  - Other minor changes, incl. modified spatial weighting of multiple towers within a grid cell and reduced outlier influence on curve fitting.

- V4 changes only apply to ancillary BPLUT and initial SOC pools, with no internal code changes

FLUXNET 2015

(last updated February, 2017)

Total Site: 212 / 914
Sites (1-4 yr): 112 / 370
Sites (5-9 yr): 37 / 251
Sites (10-14 yr): 48 / 191
Sites (15+ yr): 15 / 102

SMAP L4C V4 CVS Assessment

- L4C V4 (Tv4000) assessment for SMAP Ops POR.

- V4 performance consistent or slightly better than V3 in RMSE terms; improvement generally larger for drier sites (e.g. SHB)

- V4 meets target performance (mean NEE ubRMSE ≤1.6 g C m^{-2} d^{-1})

L4C V4 (Tv4000) performance vs CVS site observations (29 global tower sites)

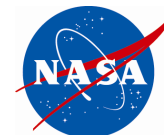|	NEE [g C m^{-2} d^{-1}]			GPP [g C m^{-2} d^{-1}]			RECO [g C m^{-2} d^{-1}]		
	R	RMSE	ubRMSE	R	RMSE	ubRMSE	R	RMSE	ubRMSE
V3	0.55	1.15	0.92	0.75	1.61	1.22	0.71	1.29	0.91
V4	0.55	1.07	0.87	0.73	1.45	1.12	0.71	1.21	0.85

Tower Cal/Val Sites
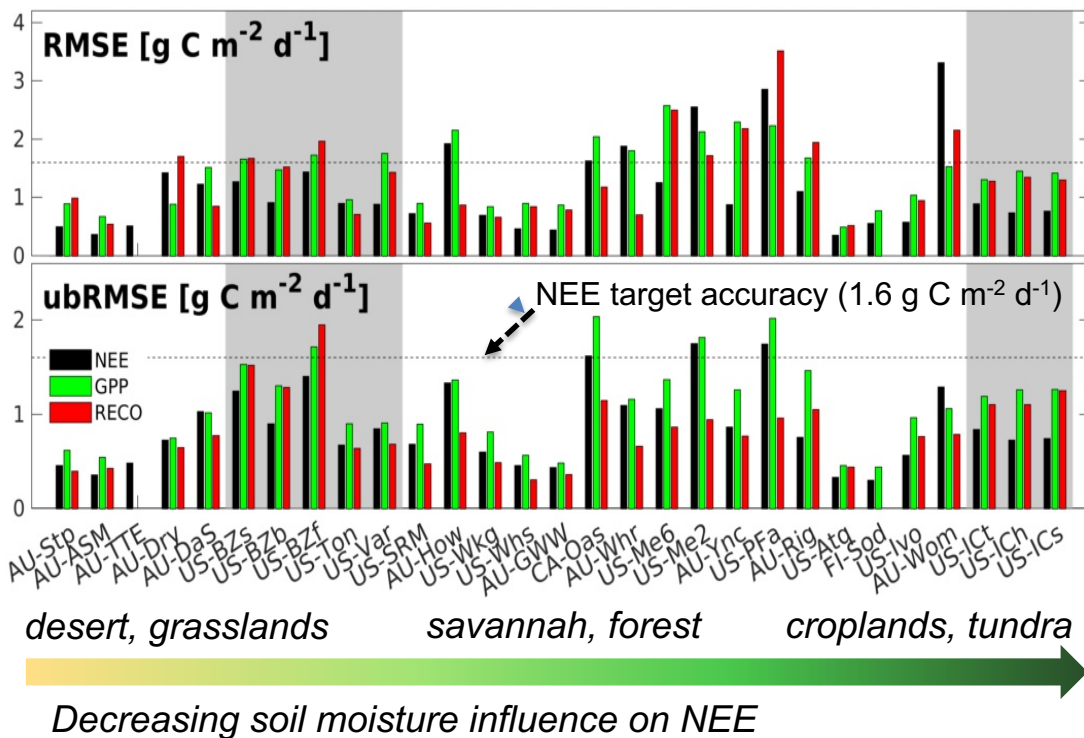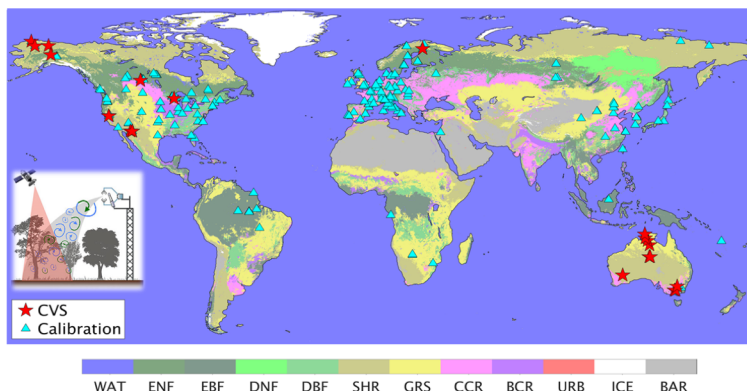
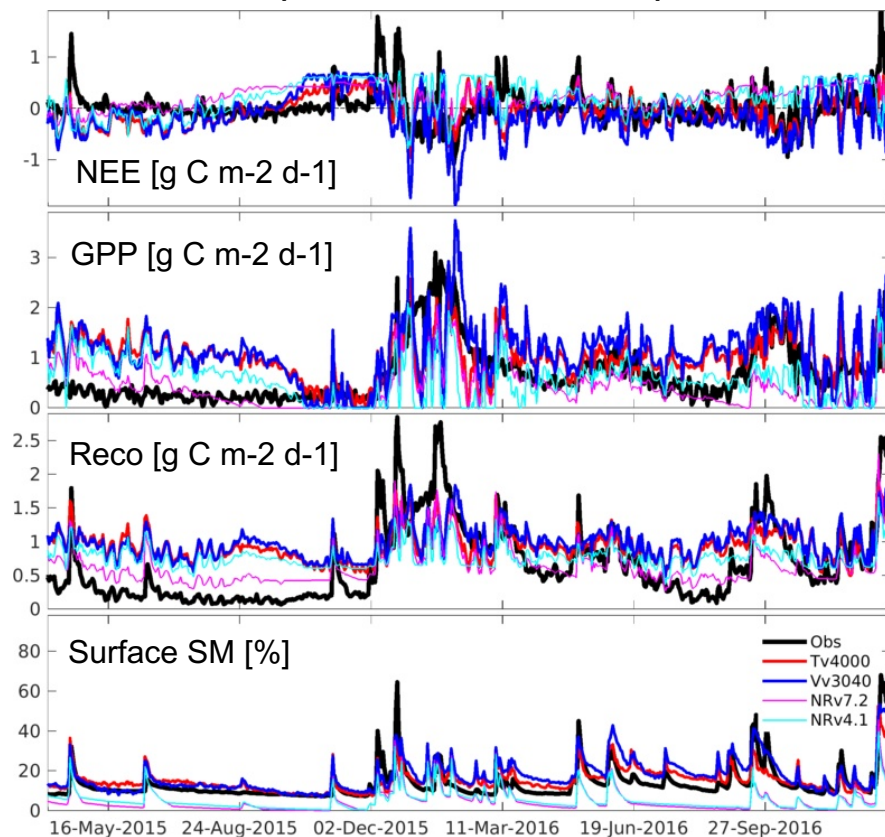**Grey shades denote towers sharing the same SMAP footprint
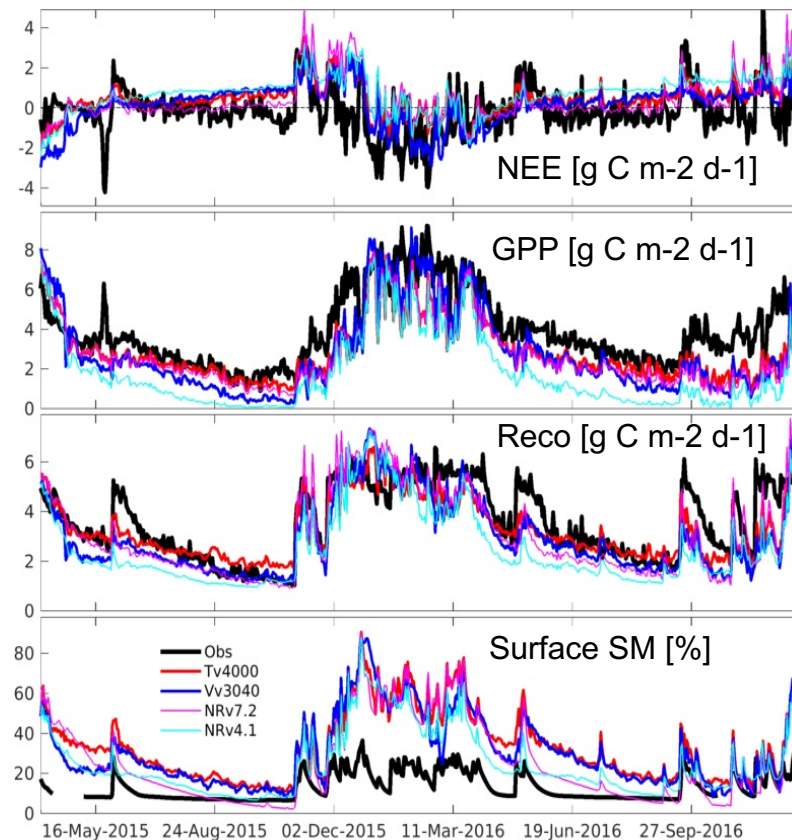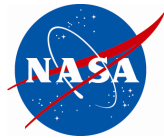
Example Time Series Across Climate Gradient

- Similar V3 (Vv3040) Ops and Tv4000 results
- L4C accuracy impacted by L4SM (Tv4, Vv3040) skill and offsets relative to NR (v7.2, v4.1); GPP and RECO bias may offset each other, reducing NEE bias.

**Alice Springs, Australia
(Lower-biomass, Arid)**

**Daly Savannah, Australia
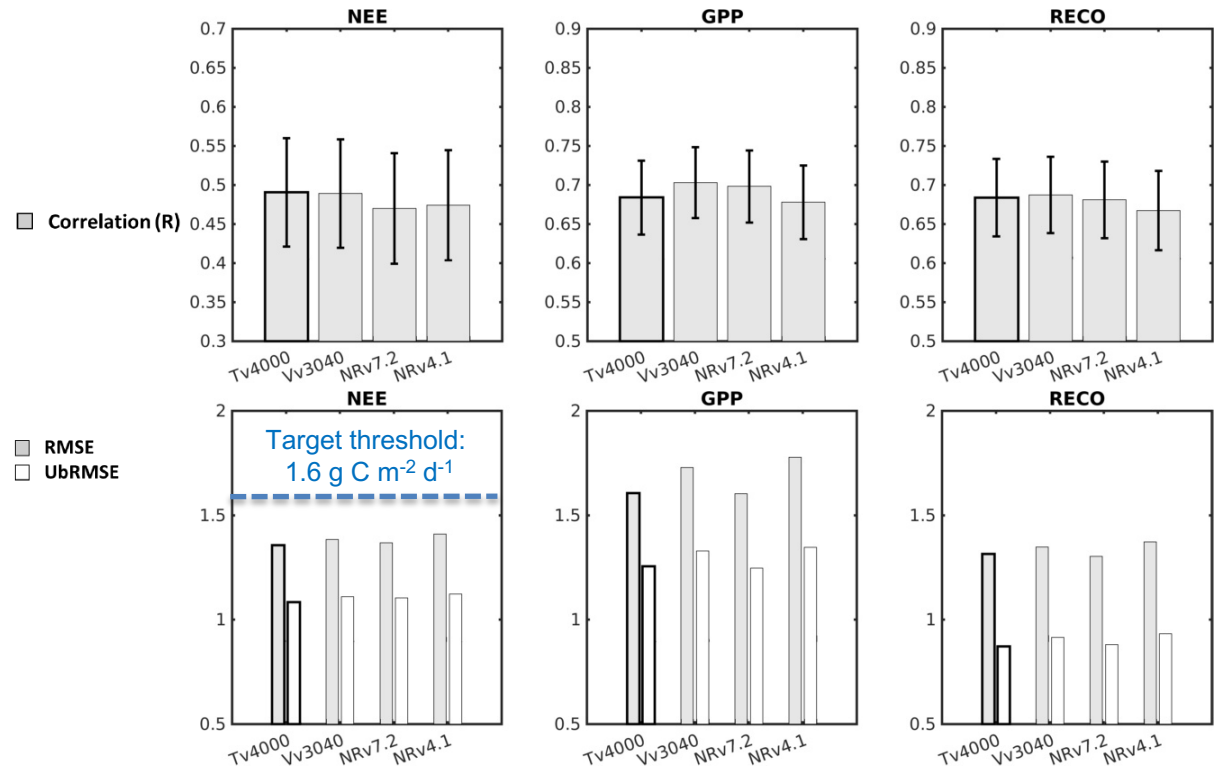(Higher-biomass, Seasonal)**

L4C performance for Ops POR

Ops:2015-2017
(40 global tower sites)

- Similar overall V4 performance as V3;

- Small V4 (Tv4000, NRv7.2) performance gain for NEE and Reco; mixed for GPP (lower R, but better RMSE)

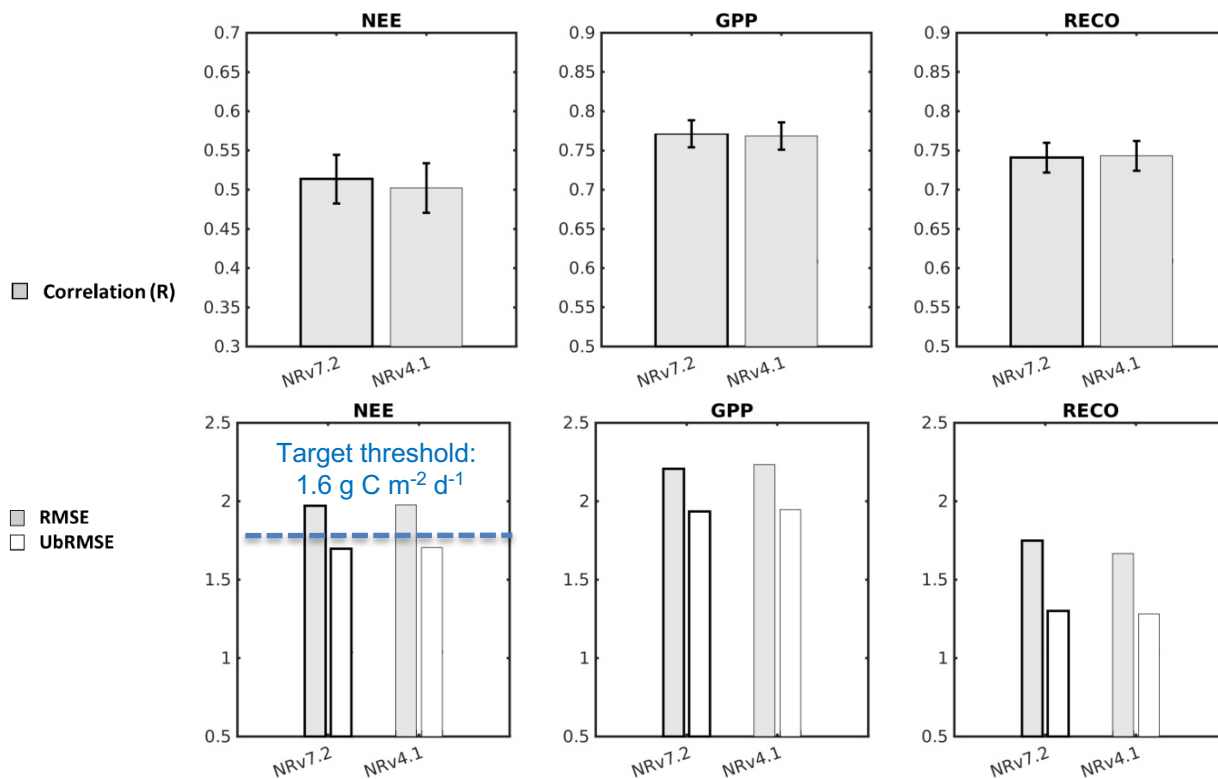- V4 (NRv7.2, Tv4000) well within performance target

Jan 1, 2000 – Dec 31, 2017
(335 global tower sites)

- Similar overall NRv7.2 performance as NRv4.1;

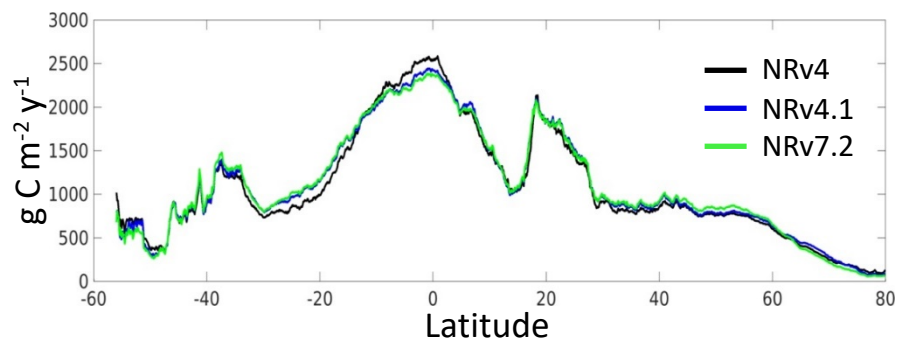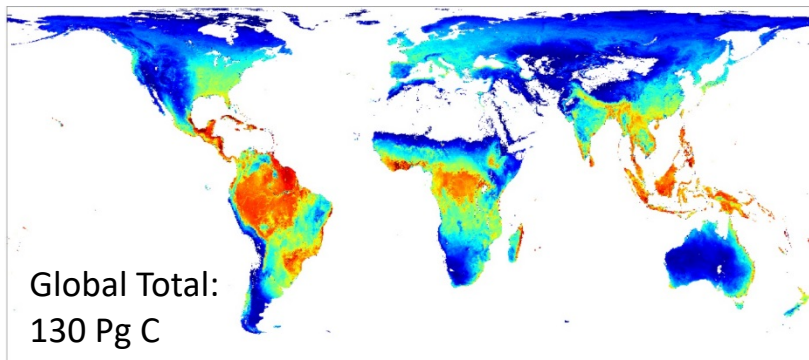- NRv7.2 performance gain for NEE, GPP; but not significant overall
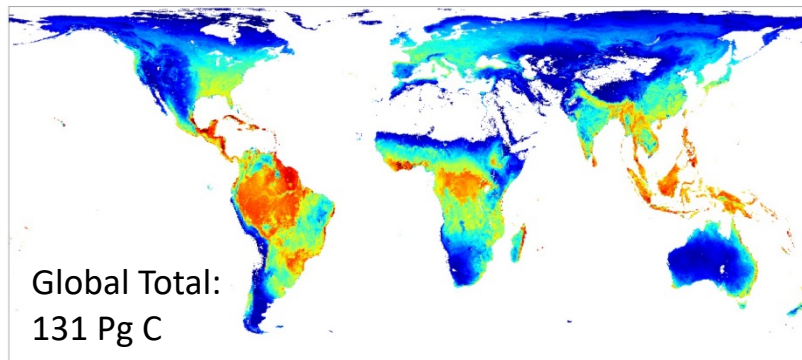
L4C NR Mean Annual GPP (2000-2017)

- L4C NR results similar to other global GPP estimates that range from 126-134 Pg C (Beer et al. 2010, Madani et al. 2017).

- NRv7.2 slightly higher than NRv4.1 overall, but lower in the tropics than earlier versions.
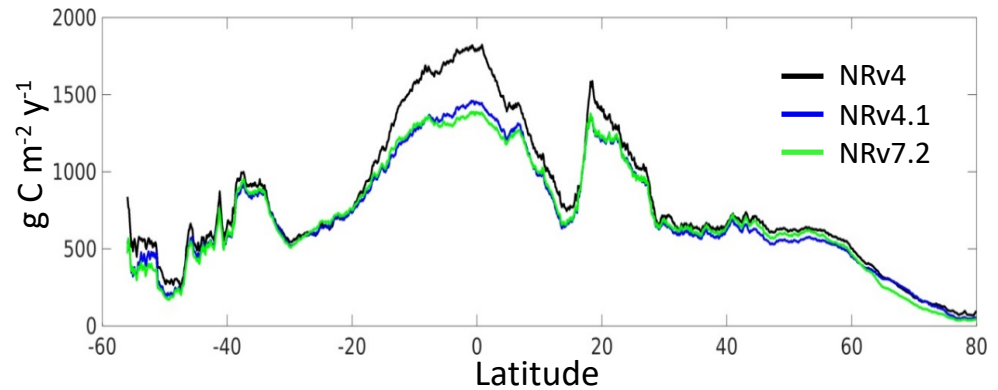

NRv4.1

Global Total: 130 Pg C

NRv7.2

Global Total: 131 Pg C

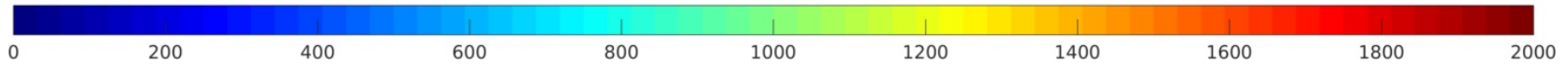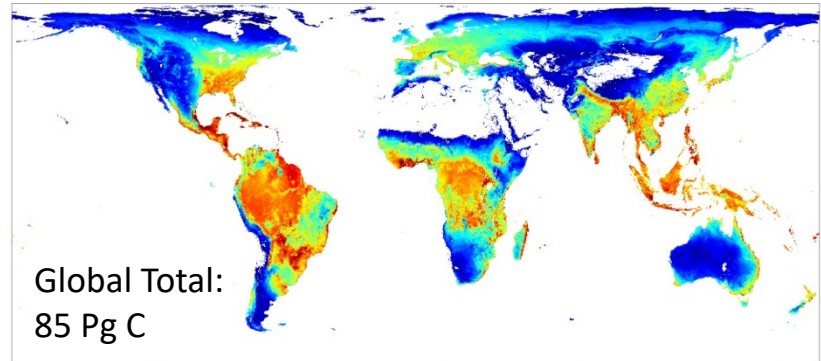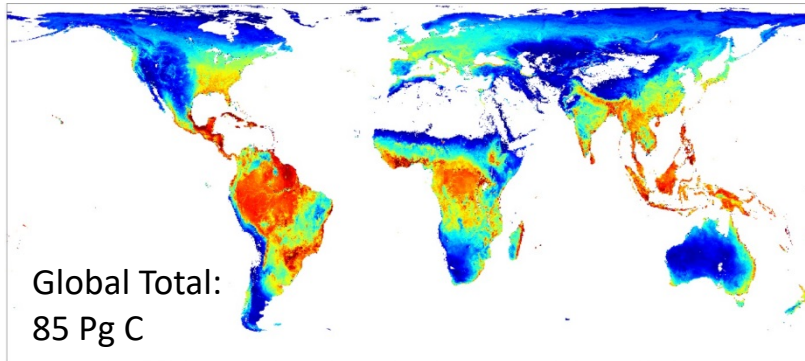Annual Average Gross Primary Productivity [g C m^{-2} y^{-1}]

- NRv7.2 results consistent with prior NRv4.1 version.

- Results within the 68-98 Pg C yr^{-1} range of other available global estimates (Hashimoto et al. 2015).
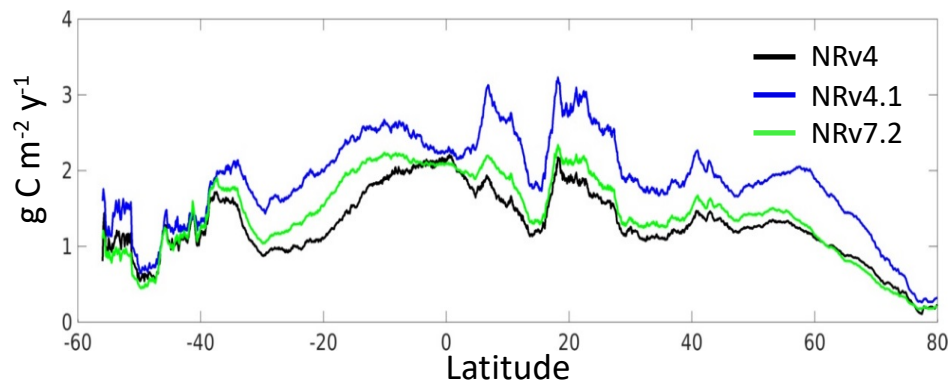

NRv4.1

NRv7.2

Global Total: 85 Pg C

Global Total: 85 Pg C

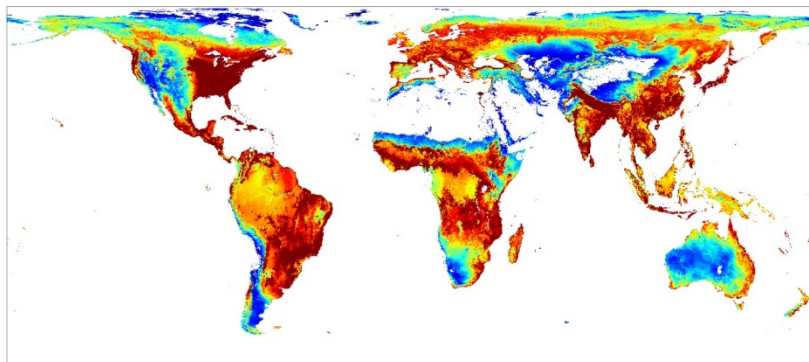Annual Average Heterotrophic Respiration [g C m^{-2} y^{-1}]
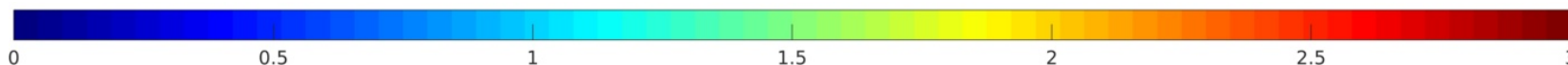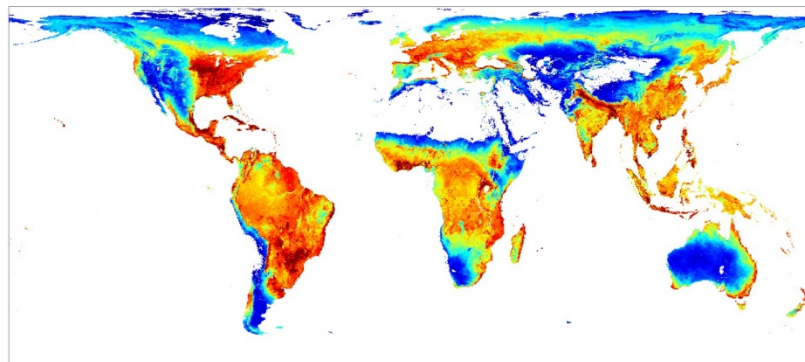
L4C NR Mean Annual NEE (2000-2017)

- L4C NRv7.2 generally intermediate between the two earlier versions.

- NEE patterns and seasonality consistent with tower observations and expectations.

- Lower estimated NEE ubRMSE in higher productivity zones
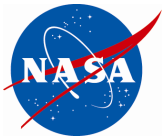

NRv4.1

NRv7.2

Daily Average NEE QA ubRMSE [g C m^{-2} d^{-1}]

L4C V4 Summary

- Latest L4C NR and Tv4000 results largely consistent with current V3 record.

- V4 performance is well within product design specs, with no apparent anomalies; reproduces characteristic global C-flux patterns and seasonality, and underlying controls.

  - Meets target accuracy threshold (Mean NEE ubRMSE < 1.6 g C m^{-2} d^{-1})

  - Similar or slightly improved V4 results relative to tower observations, but differences from V3 largely insignificant

  - V4 incorporates latest L4 refinements for SMAP product consistency

- Tv4000 updates and performance satisfy requirements for new product release.
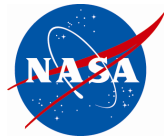
Future L4C Releases

- Capture significant updates and enhancements in model drivers: SMAP NR, L4SM; MODIS LC, FPAR

- Include geographic projection coordinates in HDF-5 metadata (requested by NSIDC to facilitate use of SMAP data with a broader range of applications software)

- Harmonize artifact differences between L4C pre- and post-launch records due to NR (MERRA2) vs Ops (GMAO FP) climate drivers

- Improve MODIS FPAR gap-filling and noise reduction (prototype tested, but significant code modification required)

- Further calibration refinements, including:

  o Add wetland SM constraint on RH calculation

  o Update model SOC calibration reference using latest 30m JRC Harmonized World Soil Database rather than older IGBP-DIS 2000 data