



Soil Moisture
Active Passive
Mission
SMAP

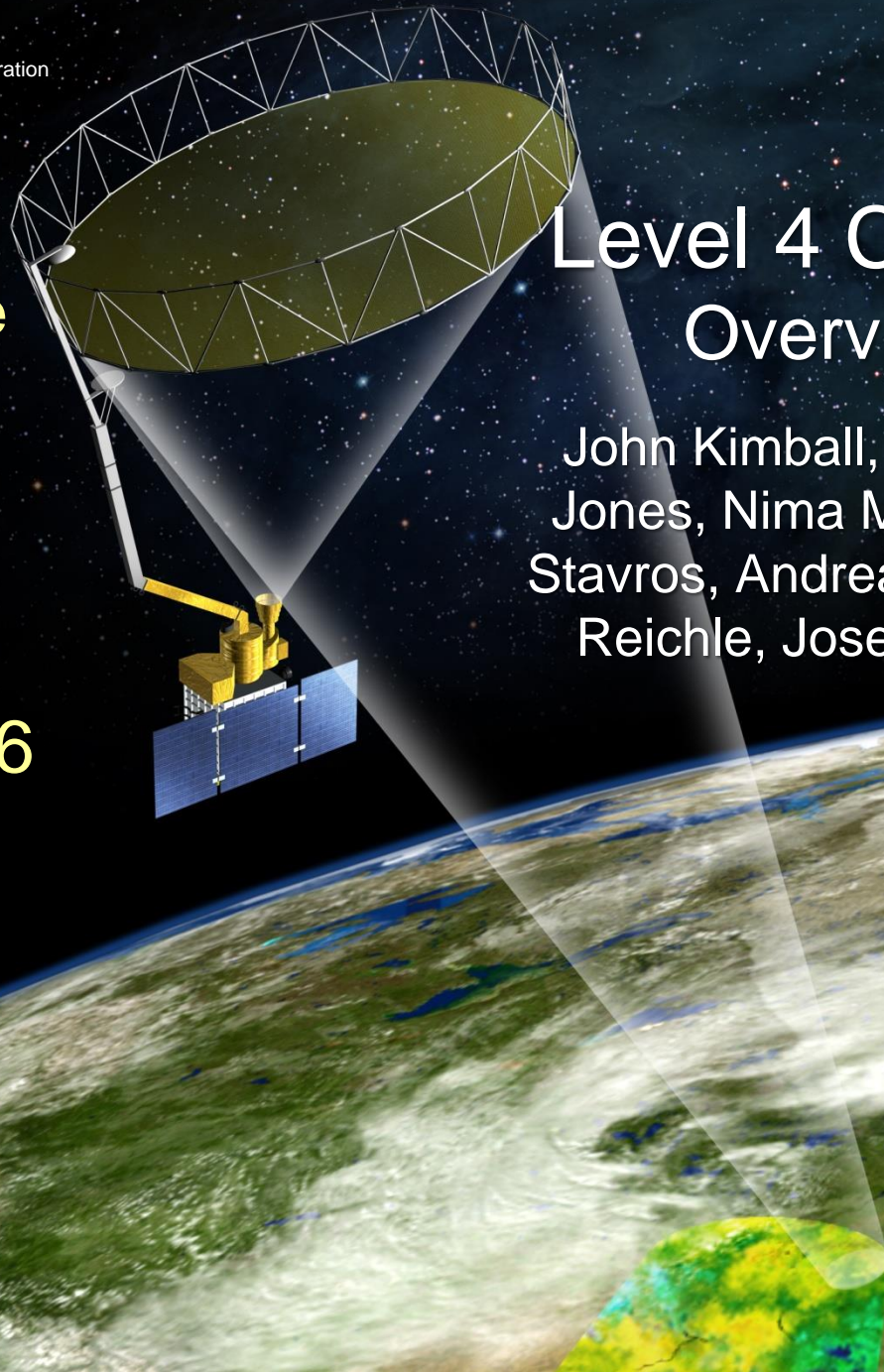
Cal/Val
Workshop #6

Sep 1-3, 2015

Columbia, MD

Level 4 Carbon (L4_C): Overview & Status

John Kimball, Joseph Glassy, Lucas Jones, Nima Madani (UMT), Natasha Stavros, Andreas Colliander (JPL), Rolf Reichle, Joseph Ardizzone (GSFC)





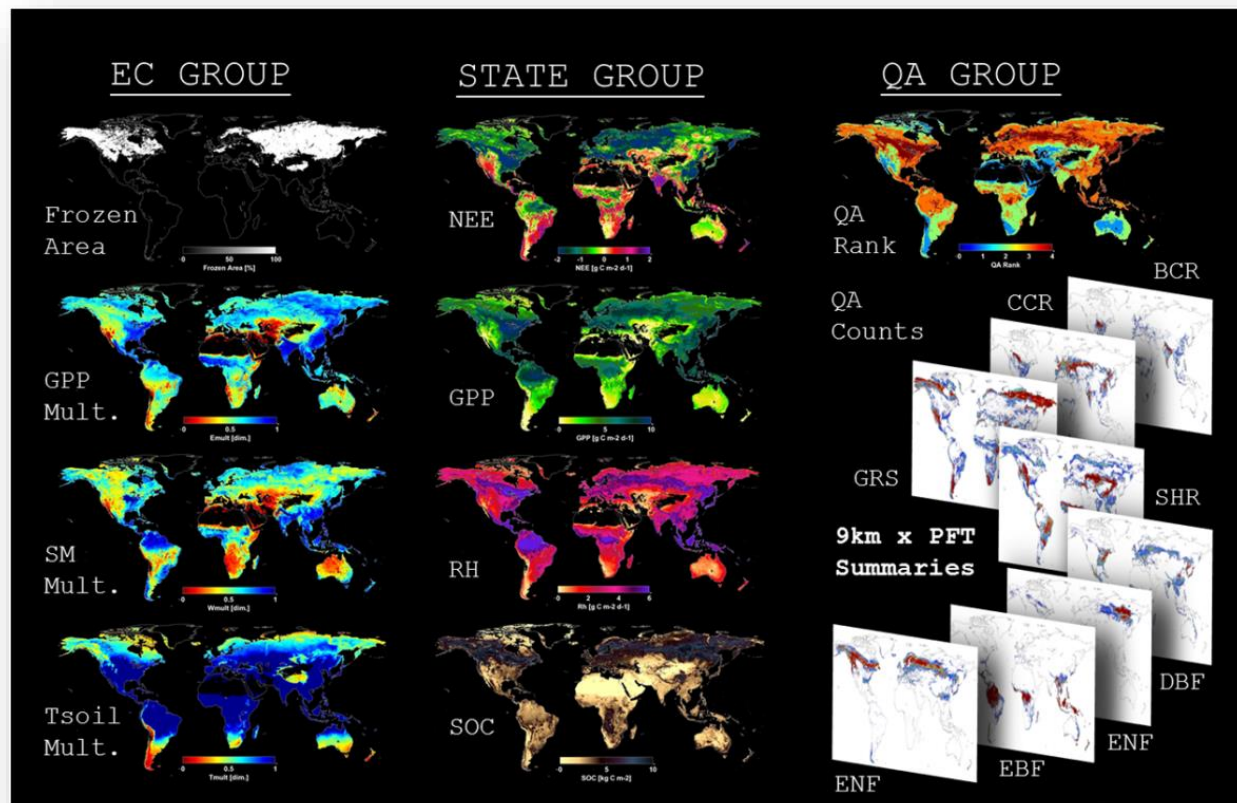
L4_C Product Summary



Carbon model enhanced estimation of daily carbon fluxes & underlying environmental constraints

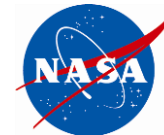
L4_C Daily Product Example

- Global 9-km grid, preserving sub-grid PFT means from 1-km processing
- SMAP FT (L3_SM_A) & SM (L4_SM) inputs used to constrain model GPP & ecosystem respiration calculations
- Multiple daily outputs: NEE (primary validated), GPP, R, SOC; EC metrics (T, SM, FT, LUE), & NEE quality assurance (QA)





L4_C Product Status & Availability



- L4_C product versions
 - At-launch Va1000 (Apr 13 – May 30)
 - Reprocessing update (Va1001, Apr 13 – *Jul 30)
 - Pending update (Va1002, Apr 13 – present)
 - Updates incorporate calibration improvements, software & product refinements effectively replacing earlier product versions.
- Online production status: <http://gmao.gsfc.nasa.gov/operations/status.php>
- Mean production latency within *14-day target
- Pre-beta data under limited distribution from JPL & NSIDC to support SMAP Cal/Val activities, partners & early adopters.
- Active global L4_C performance & validation assessments underway
- Beta product (Vb1002) release & public distribution through NSIDC planned for early Nov 2015 following mid-Oct product review.

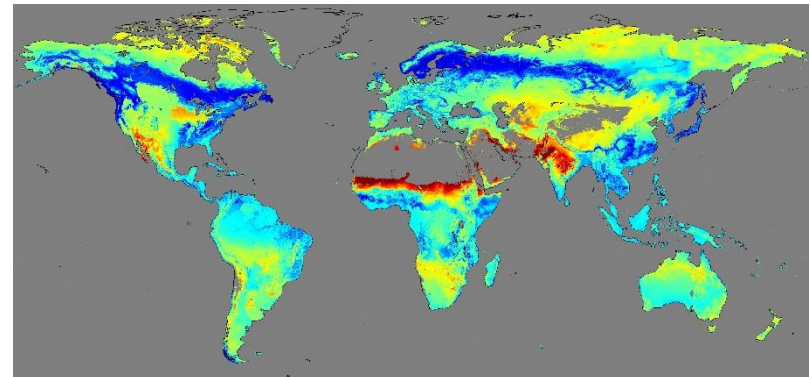
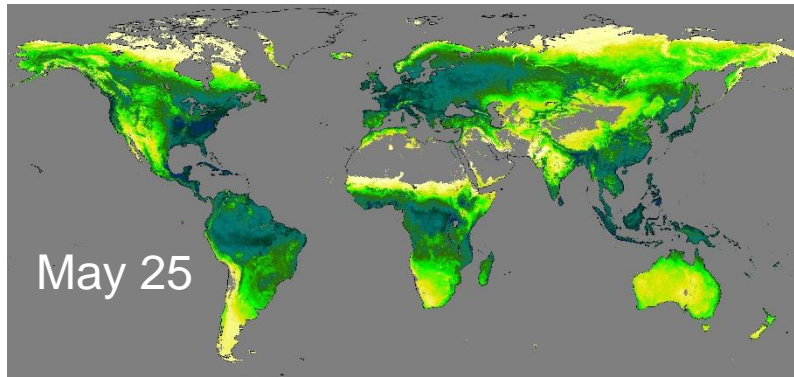
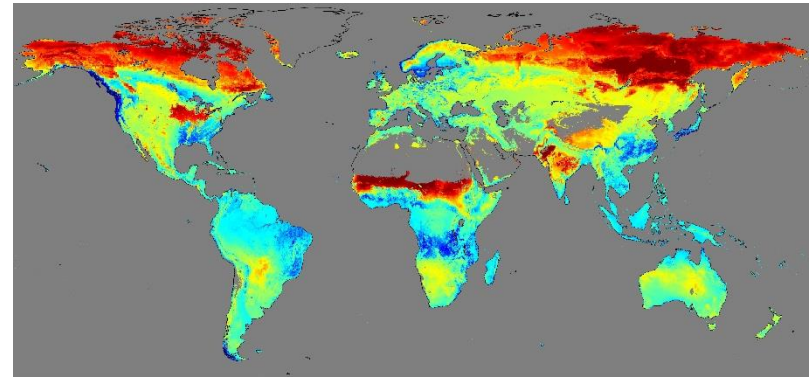
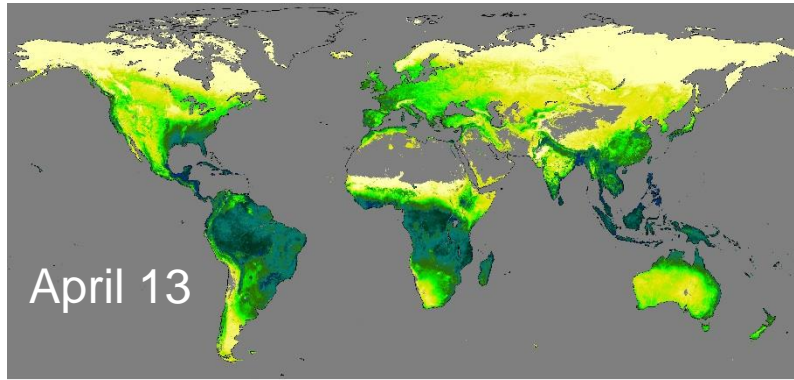
*Va1001 production epoch ended Jul 30 2015 with end of L3_SM_A product stream inputs to L4 processor

L4_C Product Example: Estimated Plant Growth (GPP) & Underlying Environmental Controls (EC)



GPP [$\text{g C m}^{-2} \text{d}^{-1}$]

% of potential LUE
Range: Low (100) - Full (0) constraint



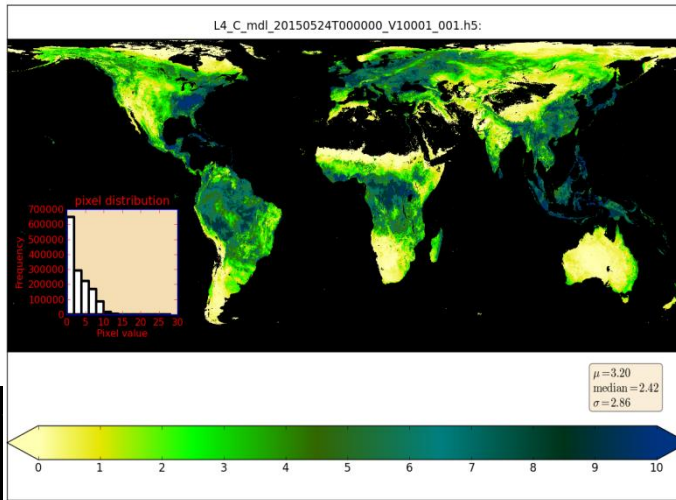
- GPP & EC dynamics captured, Incl. N. Hemisphere spring greening; drought stress over India, Sahel & SW USA.
- LUE reductions driven by combined impacts from SM_{RZ} , FT status, VPD & T_{min}.

L4_C Example: Sub-grid PFT (8) means for GPP

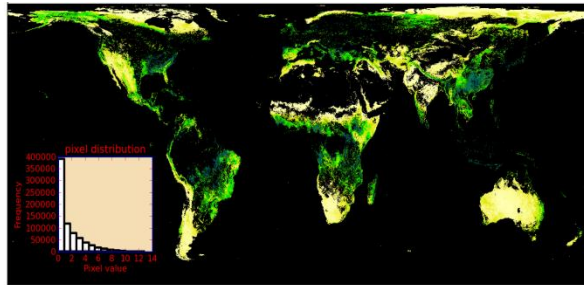
(May 24, 2015)



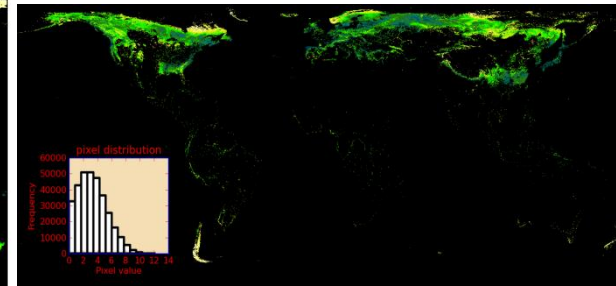
GPP Mean



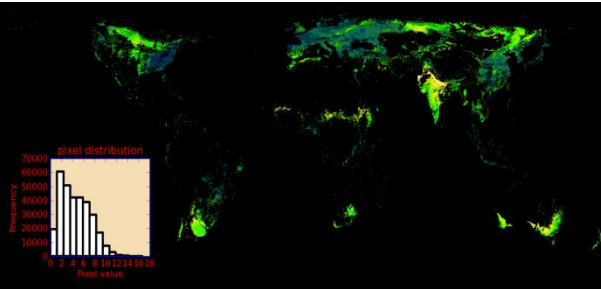
Grassland (6)



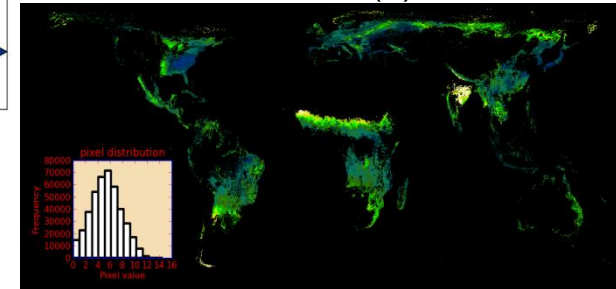
ENLF (1)



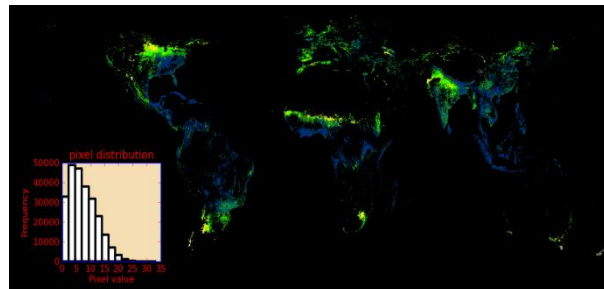
C3 Cropland (7)



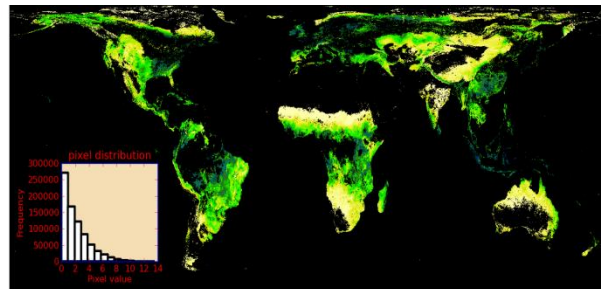
DBLF (4)



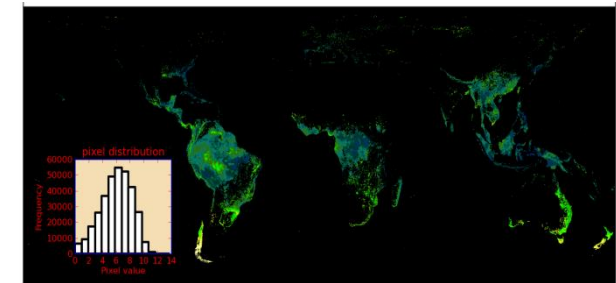
C4 Cropland (8)



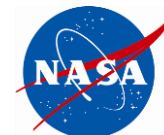
Shrubland (5)



EBLF (2)



L4_C Example: Soil Respiration (Rh) & Underlying Environmental Controls (EC)

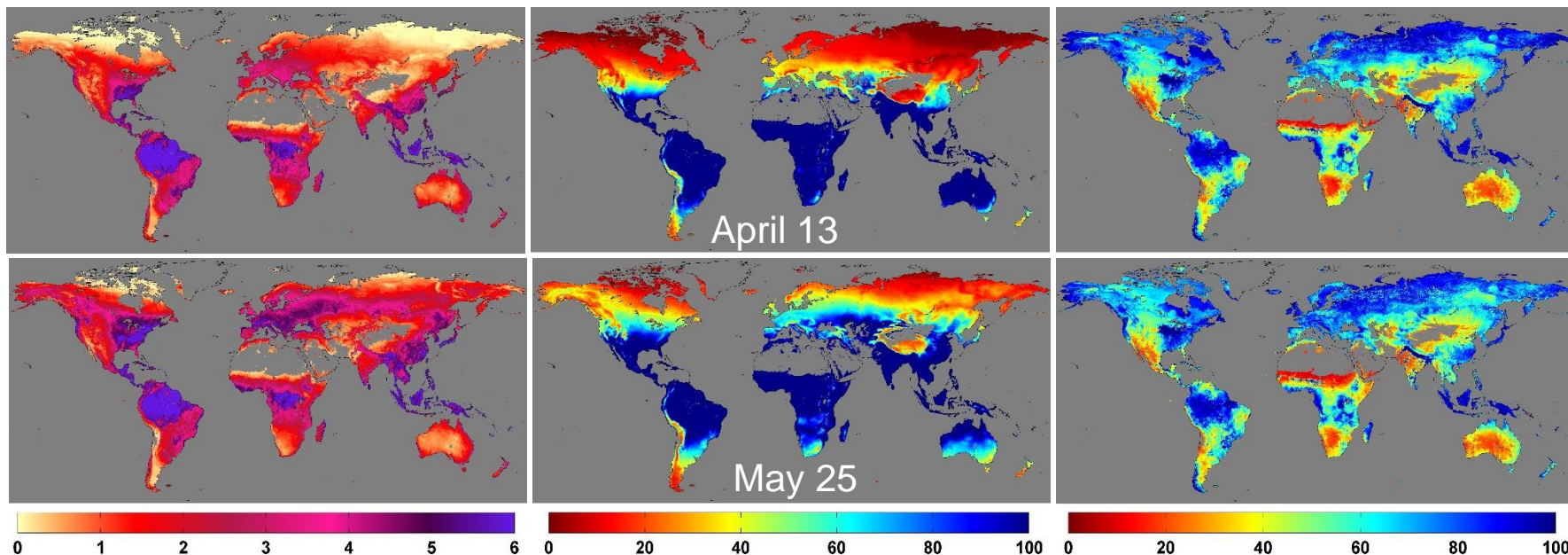


EC [%] Range: **Low (100)** to **Full (0)** constraint

Rh [$\text{g C m}^{-2} \text{d}^{-1}$]

Tmult [%]

Wmult [%]



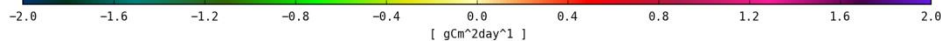
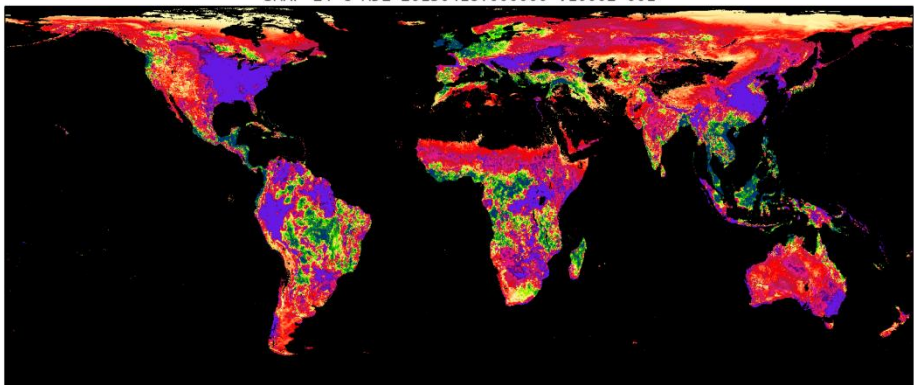
- Rh cold temperature (Tmult) constraint relaxes with spring onset (N. hemisphere); Rh increase offset by surface SM drying.



L4_C Example: NEE Seasonal Progression

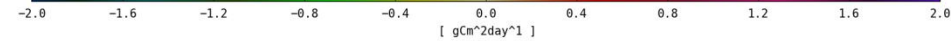
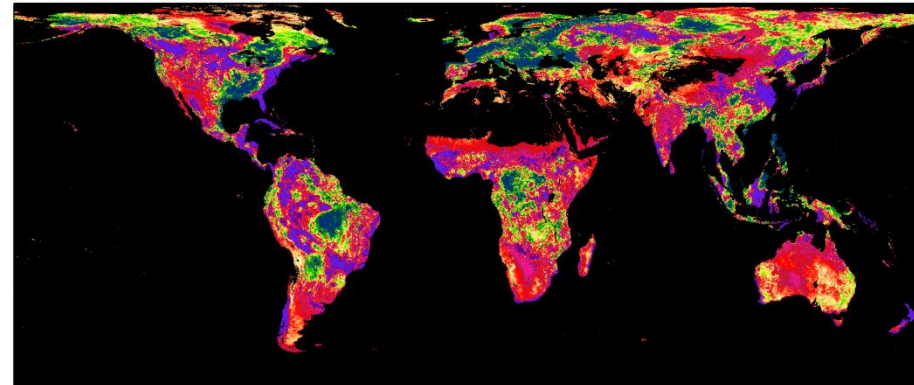
April 18

nee mean
SMAP L4 C MDL 20150418T000000 V10002 001



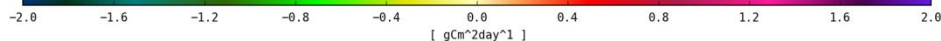
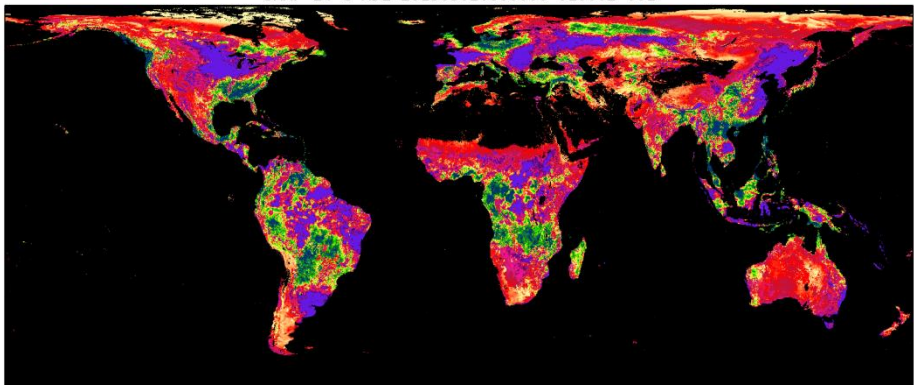
June 2

nee mean
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May 2

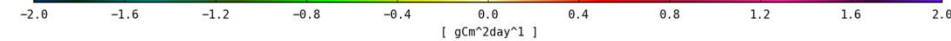
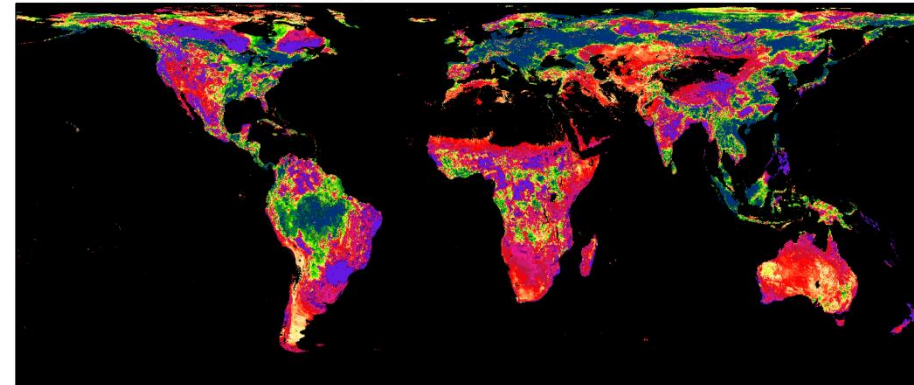
nee mean
SMAP L4 C MDL 20150502T000000 V10002 001



C source (+); C sink (-)

July 2

nee mean
SMAP L4 C MDL 20150702T000000 V10002 001





L4_C Cal/Val Framework



Demonstrate L4_C performance relative to SMAP science objectives & accuracy requirements

- Primary:
 - C-flux comparisons at core tower sites, emphasizing NEE & northern ecosystems; comparisons consistent in space & time.
 - C-flux comparisons against global historic FLUXNET site records; comparisons consistent spatially, but not temporally.
 - Global model sensitivity & performance assessments
- Secondary:
 - Consistency checks against other global C products: soil inventory; GPP (MODIS, MTE); SIF (OCO-2, GOME-2); Carbon model inversions (CT, CMS)
 - Comparisons, sensitivity studies using field experiment data (SMAPVEX, AirMOSS, CARVE, ABoVE)

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



L4_C Cal/Val Resources



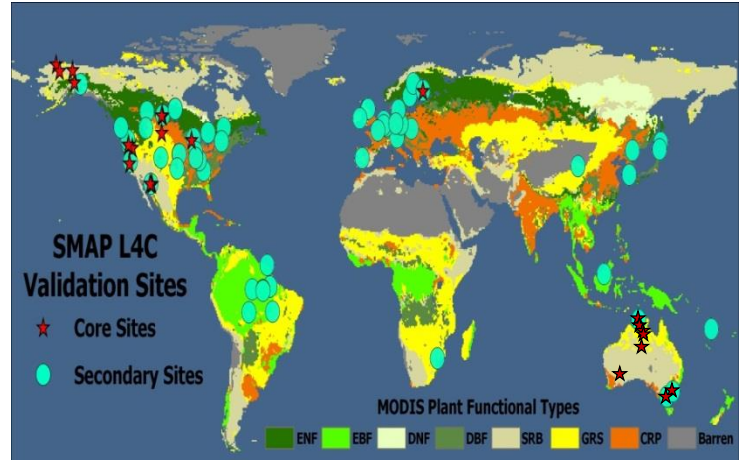
- ✓ **Core tower sites (30) providing daily C-fluxes & supporting data**
 - 12 sites emphasizing northern biomes
 - 18 sites representing other global biomes
 - Active tower Cal/Val partners provide near real-time data access

- ✓ **Additional tower site records from global FLUXNET archives**

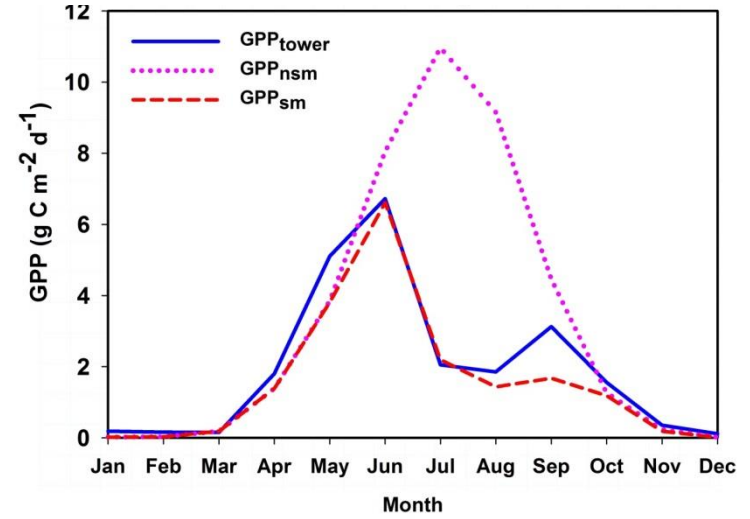
- >200 sites, global representation
- Multi-year data records, consistent methods, well characterized uncertainty, but not real-time

- ✓ **Synergistic global land products**

- L4_C model simulator
- Satellite data: GPP (MODIS); SIF (OCO-2/GOME-2)
- Soil Carbon (SOC) inventories [static]
- Upscaled, Obs. based C products (MTE)



GPP sensitivity to soil moisture control (L4_C simulator; US-Bkg, GRS tower site)



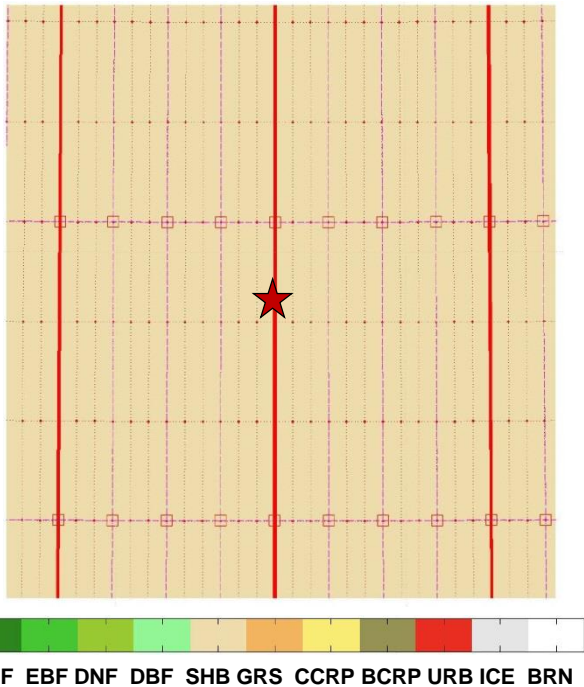


L4_C Pre-Beta Core Tower Site Comparisons



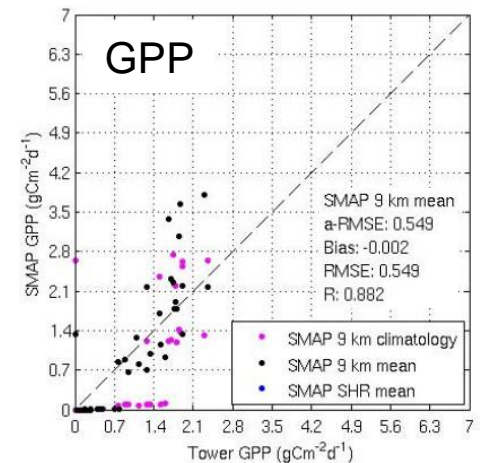
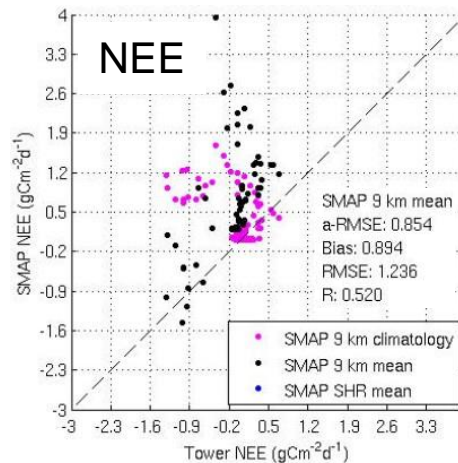
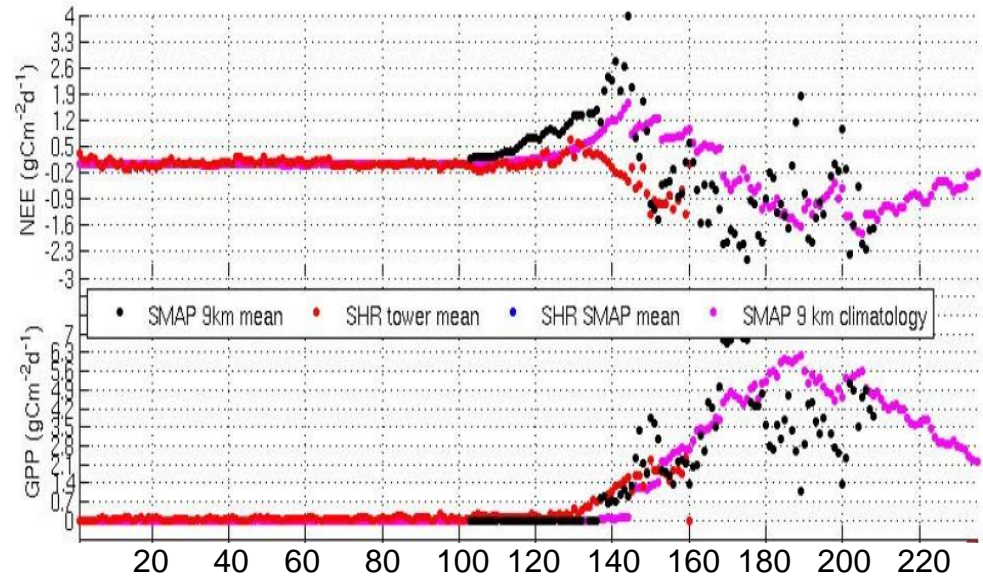
- ~30 core tower sites providing near real-time tower data for SMAP validation
- Comparisons consistent in space & time.

US-Ivo Land Cover (PFT)



US-Ivo data courtesy: Walt Oechel, SDSU

Ivotuk, Alaska (US-Ivo, tundra)

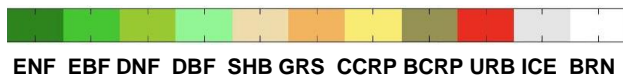
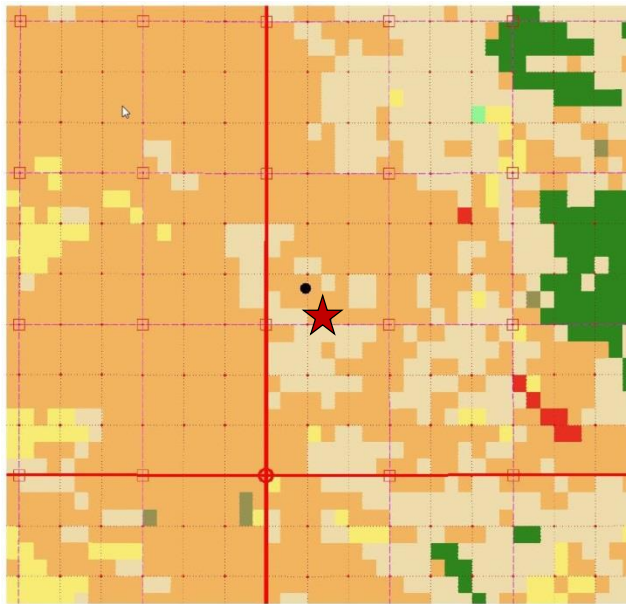


Pre-Beta Core Tower Site Comparisons Cont.



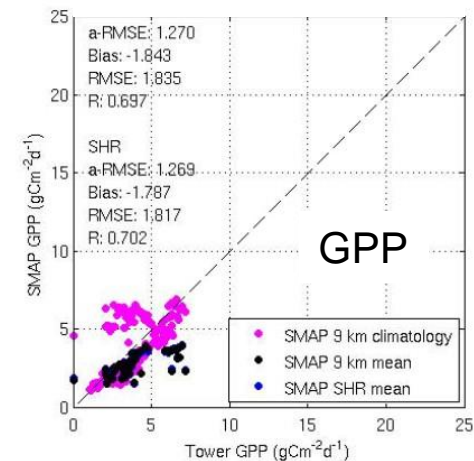
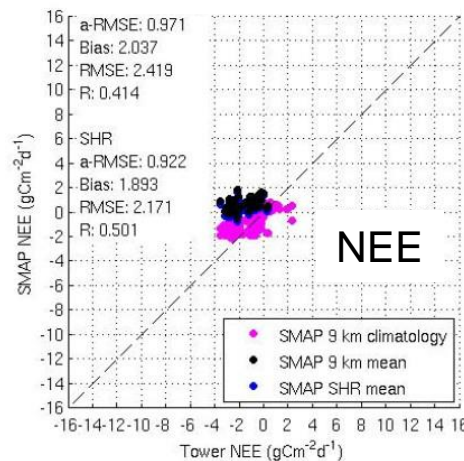
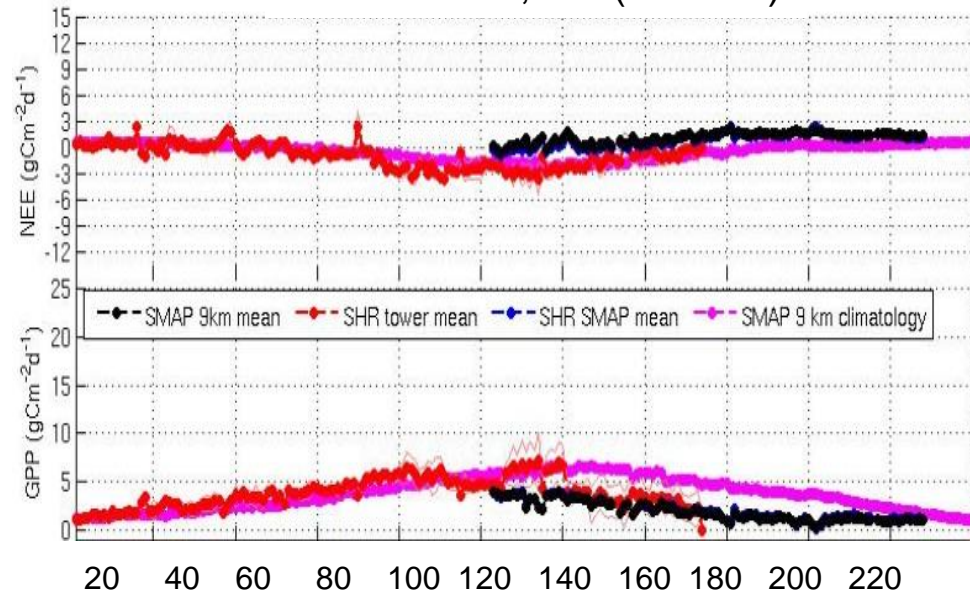
- Daily C-flux comparisons (GPP, NEE) for both individual towers & multiple sites.
- Frequent updates & local knowledge assessments enabled through active tower PI involvement

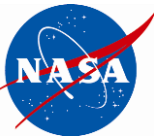
US-Ton Land Cover (PFT)



US-Ton data courtesy: Dennis Baldocchi, UCB

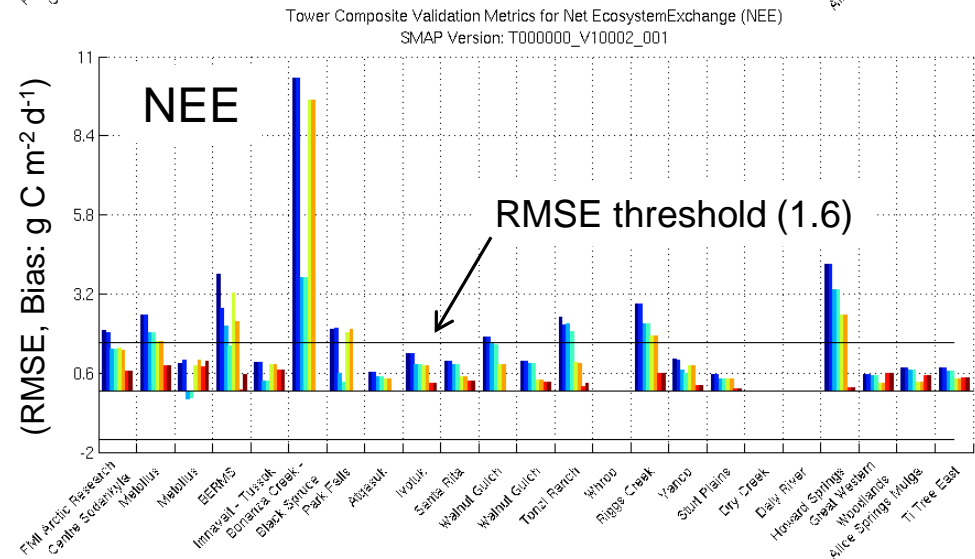
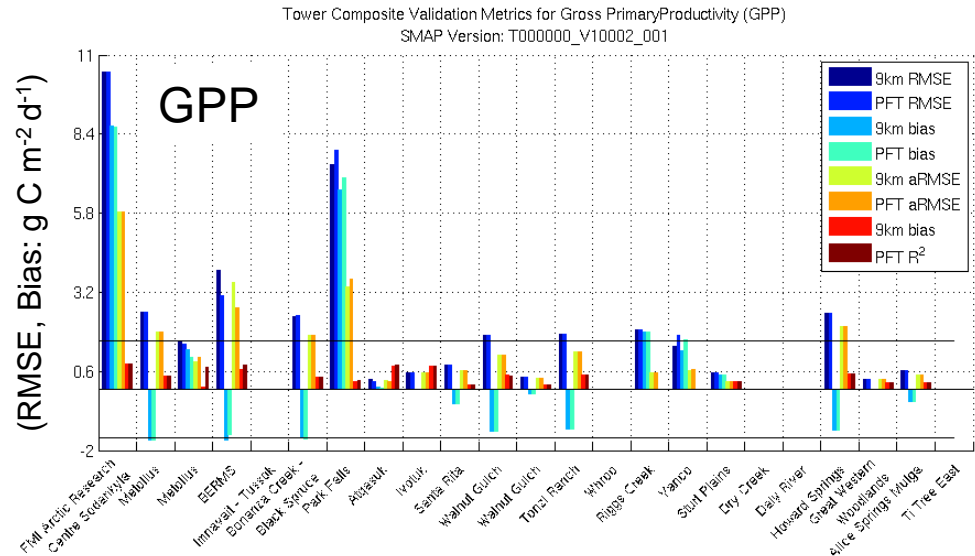
Tonzi Ranch, CA (US-Ton)





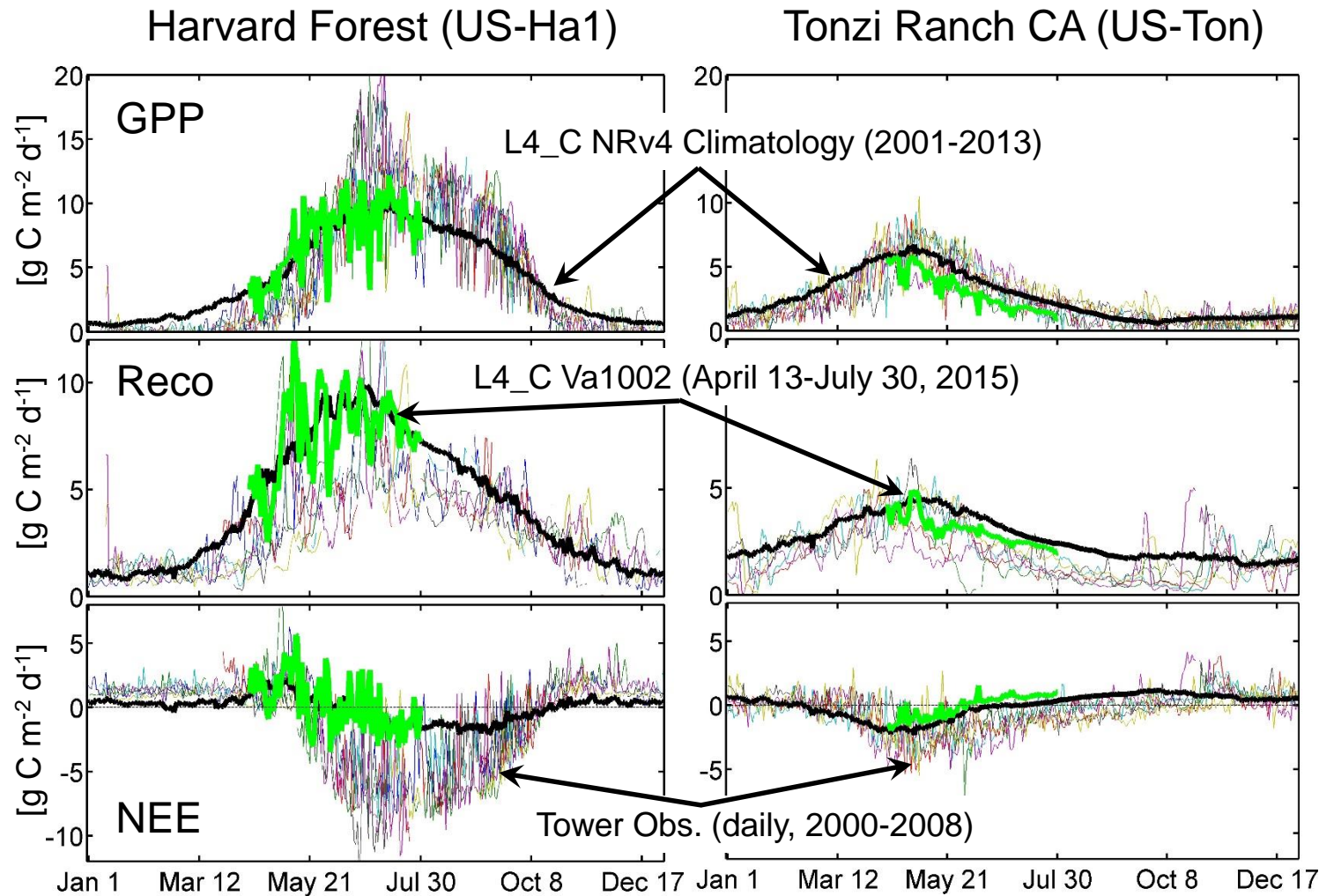
Pre-Beta Core Tower Site Validation Summary

- Pre-Beta L4_C (Va1001) performance generally within NEE target accuracy based on core tower site comparisons (Apr 15 – Jul 31 2015)
- Outliers mainly traced to artifacts from tower/data processing (e.g. FI-Sod, US-Pfa)
- Other outliers reflect PFT differences between local tower footprint & coarser model grid (e.g. CA-Oas)
- Further refinements expected from L4_C reprocessing, longer data records, & matchup software updates

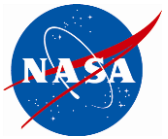




L4_C Performance Checks using Historical Tower Records

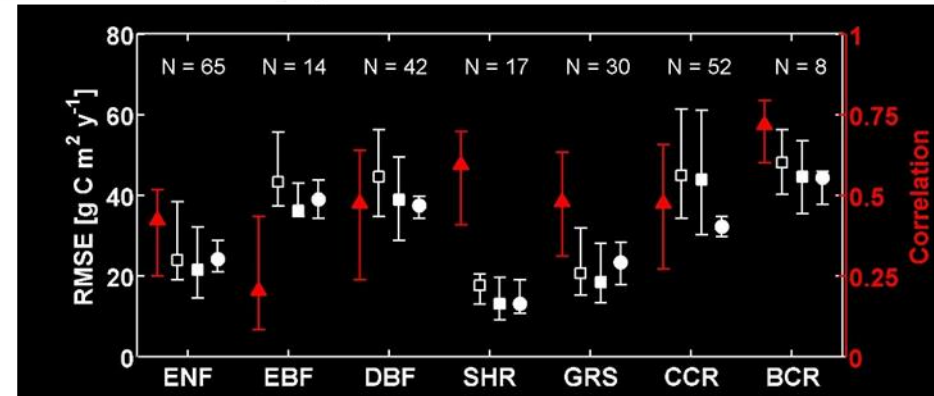
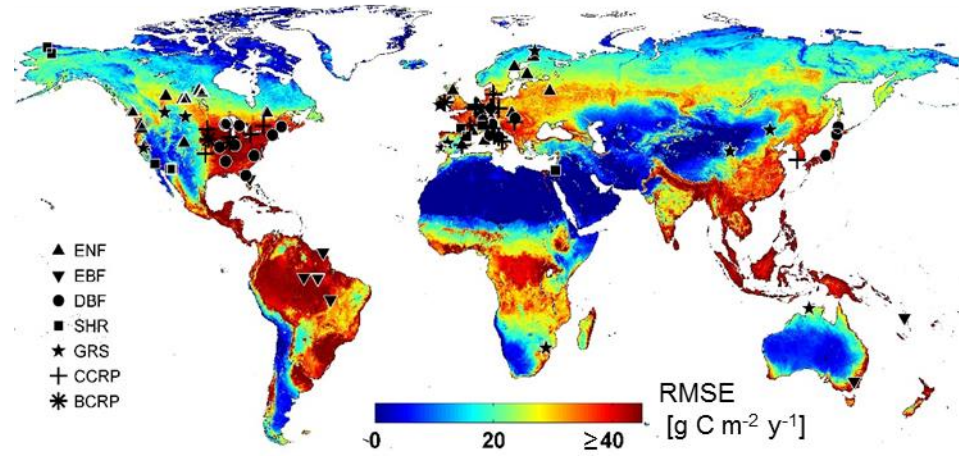


L4_C Pre-Beta Global Performance Summary



- NEE target accuracy: $RMSE \leq 30 \text{ g C m}^{-2} \text{ yr}^{-1}$ or $1.6 \text{ g C m}^{-2} \text{ d}^{-1}$; emphasis on northern ($\geq 45^\circ\text{N}$) land areas
- Historical data records from 228 global tower (FLUXNET) sites used for L4_C performance assessment
- Current performance consistent with product design & observed NEE variability
 - NEE RMSE proportional to productivity level
 - Target accuracy currently met over ~66% & 83% of global & northern domains
 - Expected improvements from continuing L4 processing refinements

L4_C NEE (Va1002) Global Performance



- Correlation vs. Tower
- RMSE vs. Tower
- Mean RMSE by global PFT class
- RMSE (Unbiased)
- I ±25 & 75 percentiles

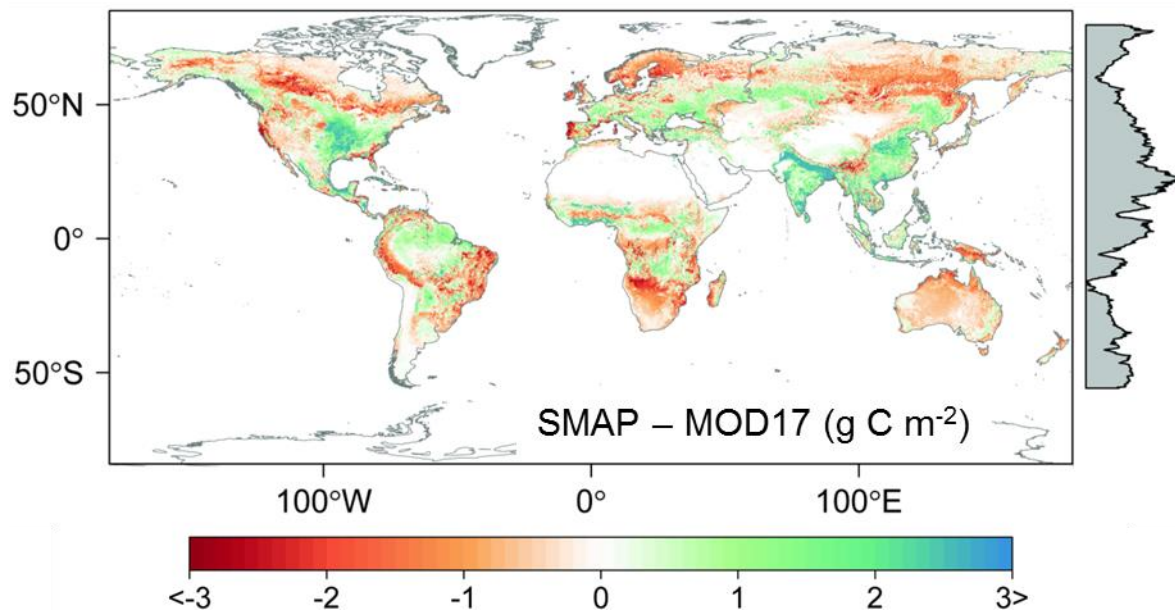
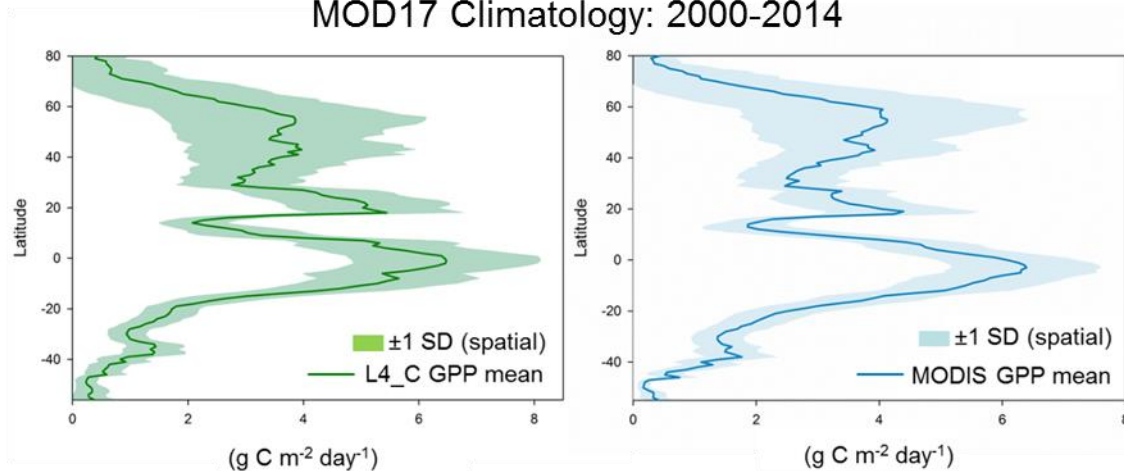
Global GPP Assessment: L4_C vs MOD17



Similar mean global productivity distribution but with regional differences:

- Widespread lower L4_C GPP in water limited areas due to SMAP-derived soil moisture constraints
- Higher L4_C GPP in the temperate zone due to better representation of C3 & C4 croplands
- 2015 climate anomalies relative to long-term MODIS GPP climatology:
 - CA & SW-USA drought
 - Early spring in NA boreal/Arctic

L4_C V10002: Apr 13 – Jul 21, 2015 record
MOD17 Climatology: 2000-2014

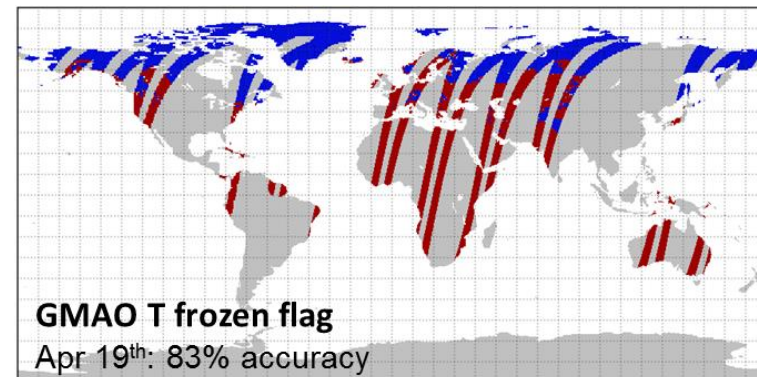
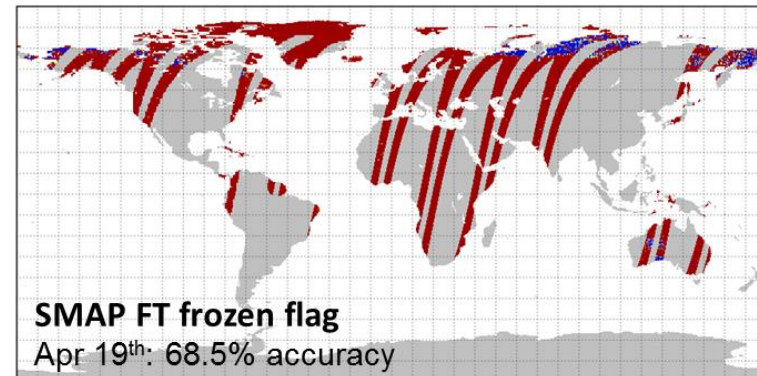
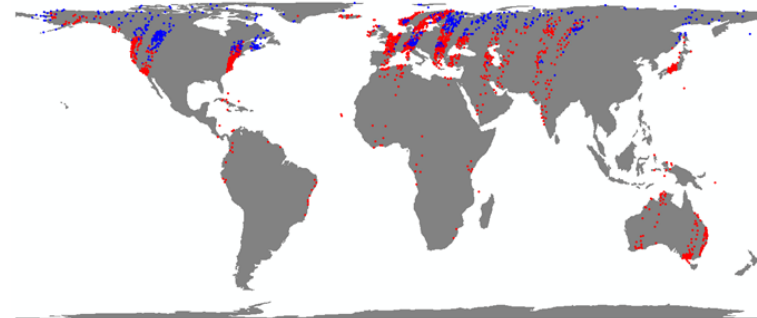




L4_C Issues (known)

- MODIS global 8 class PFT characterization vs local land cover heterogeneity
- Inconsistent climatology between GMAO NRv4 record used for L4_C initialization/calibration & GMAO FP surface meteorology used for L4_C operations
 - Decreasing impacts expected with longer SMAP record & reprocessing refinements
- Frozen soil constraint to L4_C productivity calculations defined from GMAO daily surface temperatures rather than SMAP FT retrievals
 - Switch to SMAP FT derived frozen flag planned for later (post-Beta release) L4_C product versions
 - Implementation schedule depends on FT global performance, either from radar or radiometer

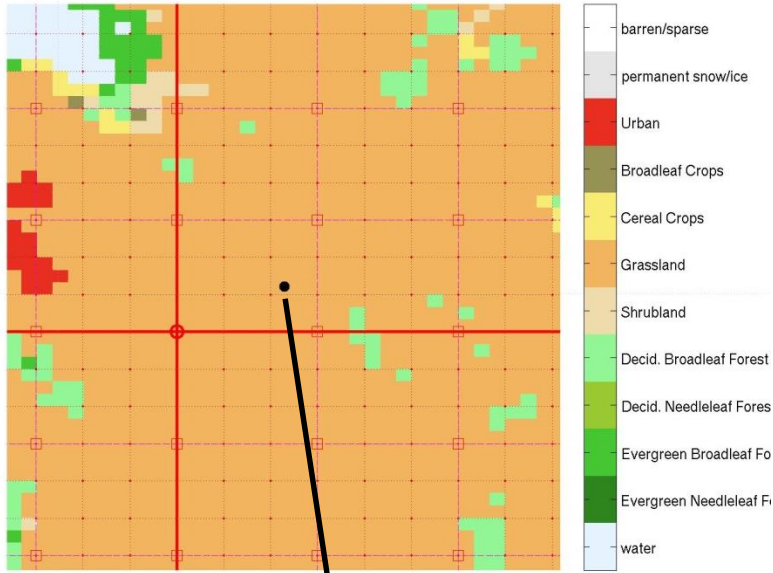
FT from 2,261 weather stations



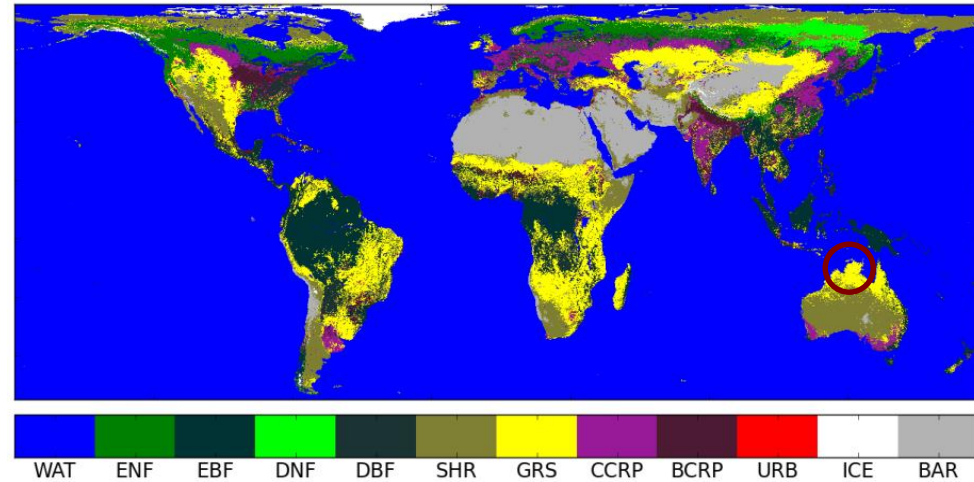
Land Cover Mismatch between L4_C PFT & local Conditions



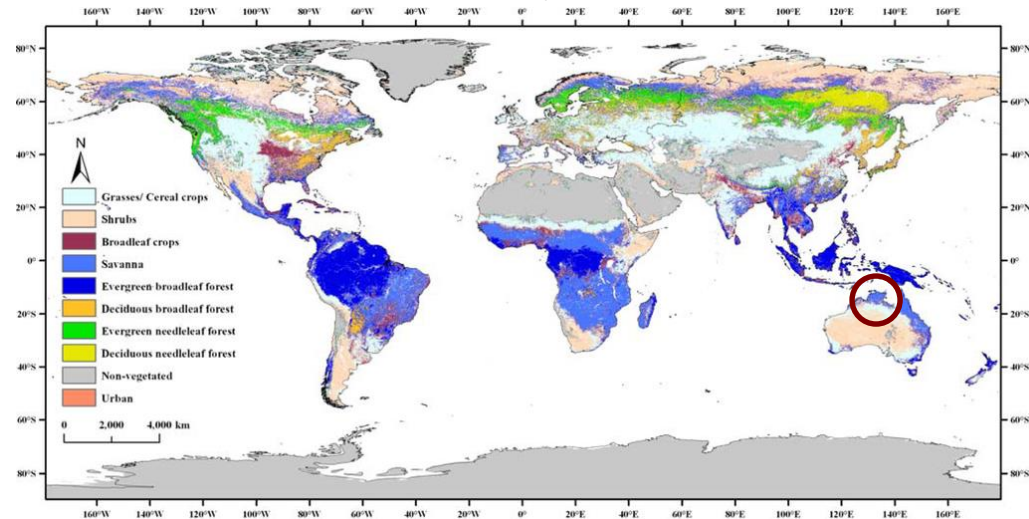
Tower Cal/Val Window (AU-HWS)



L4_C PFT Map (MCD12Q1 Type 5)



MCD12Q1 Type 3 PFT Map

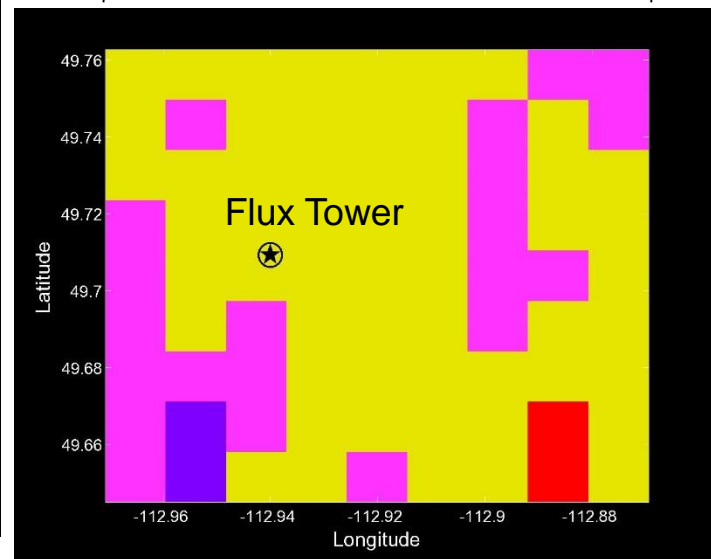
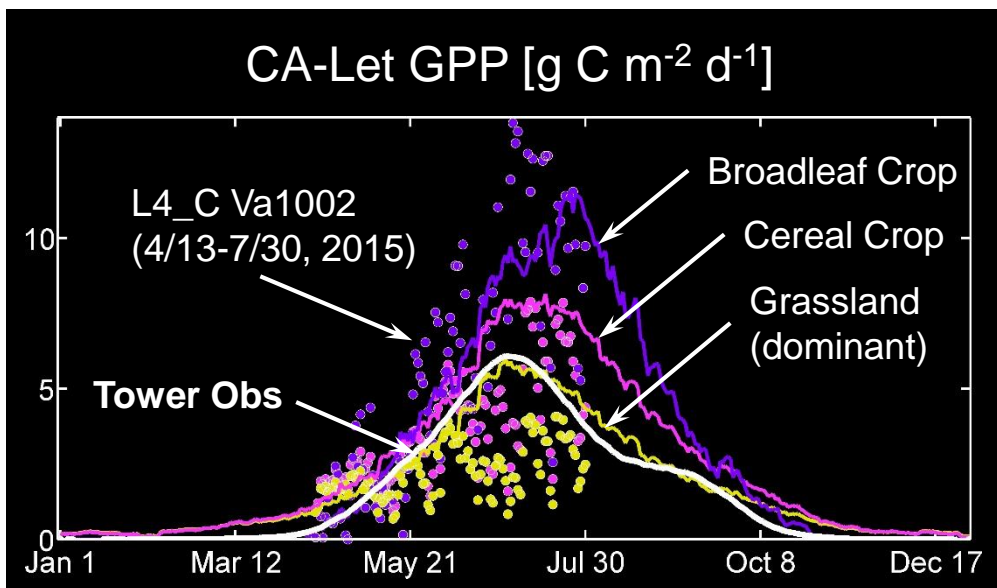
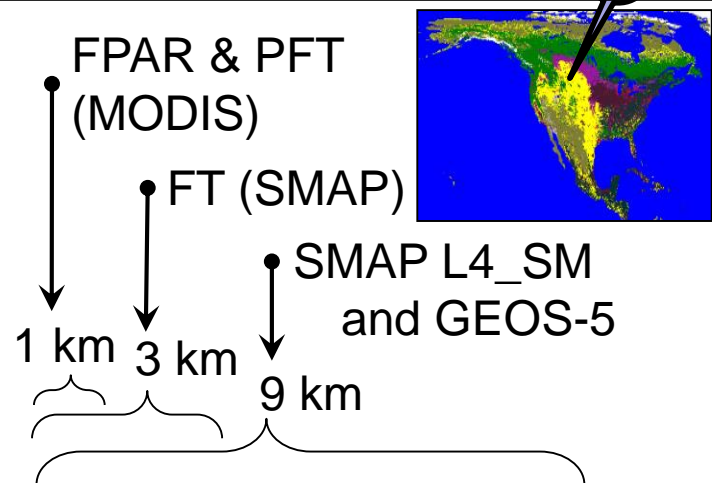




L4_C Representation of Heterogeneous PFT Grid Cells

- Sub-grid PFT means preserved from 1-km processing for each 9-km cell
- Preserves PFT heterogeneity: e.g. CA-Let grassland drought response vs adjacent irrigated cropland (below)
- Partial Cal/Val mitigation of local model-tower PFT mismatch

Lethbridge, AB Canada (CA-Let)



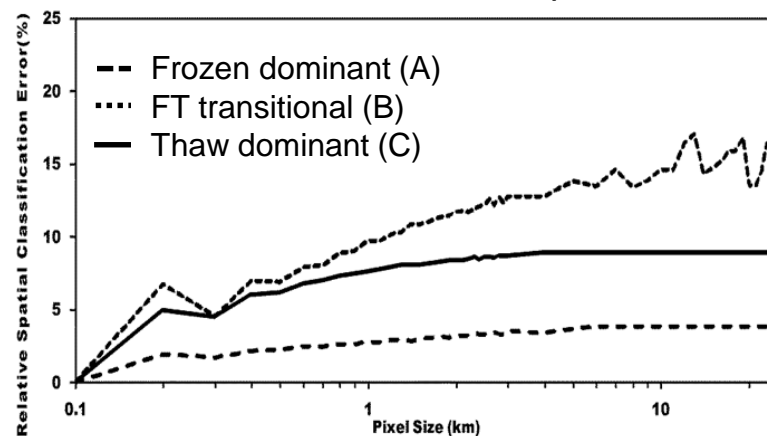


SMAP Radar Loss Impacts & Mitigation

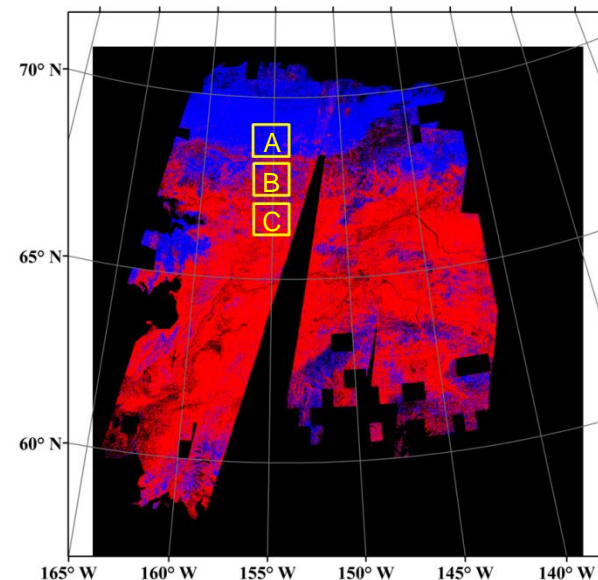


- Radar anomaly resulting in lost 3-km Res. freeze-thaw (FT) inputs to L4_C algorithms
- FT inputs define frozen soil constraints to ecosystem production (GPP, NPP)
- Mitigation options:
 - Frozen flag defined from GMAO T_{surf} (L3_SM_A) currently used in L4_C production
 - Frozen flag derived from SMAP radiometer FT classification
- Anticipated impact from mitigation:
 - Loss of FT spatial fidelity (3km vs 36km) may degrade L4_C accuracy, particularly during seasonal FT transitions
 - Potential global delineation of diurnal (AM, PM) FT impacts may enhance L4_C utility

¹FT classification error vs pixel size



AK FT map (PALSAR, 100m Res.)



¹Source: Du, J. et al., 2014. *TGARS* 53, 1, 542-556.



L4_C Milestones

- ✓ Initial at-launch (Va1000) data release to JPL for Cal/Val tools refinement (May 2015)
 - ✓ L4 reprocessing (Va1001):
 - Export to JPL for DAART/ST Cal/Val (Jun 2015); released to NSIDC for restricted distribution to Cal/Val partners & Early Adopters (Jun 2015)
 - L4_C recalibration & re-initialization using SMAP data; software fix to FPAR screening
 - Production ended Jul 30 2015 with end of L3_SM_A product stream
 - L4_C reprocessing update (Va1002) & export to JPL, NSIDC (Sep 2015)
 - Eliminated dependency on L3_SM_A frozen flag inputs to allow continuing L4_C operations; recalibration refinements & minor software fixes.
 - Additional reprocessing updates anticipated, incorporating continuing L4 calibration & algorithm refinements, including use of radiometer based FT inputs
 - L4 Beta release to NSIDC (Oct/Nov 2015)
 - L4 Validated release to NSIDC (Jul 2016)
-



Summary

- L4_C Cal/Val intensive assessments underway
 - Includes both primary & secondary Cal/Val activities (CEOS Stage 1-3)
 - Continuing Cal/Val tools refinement
 - Regular updates & interactions with Cal/Val partners & early adopters via scheduled telecons
 - Current performance assessments indicate L4_C targeted accuracy met for ~66% and 83% of global & northern domains (i.e. NEE RMSE $\leq 30 \text{ g C m}^{-2} \text{ yr}^{-1}$ or $1.6 \text{ g C m}^{-2} \text{ d}^{-1}$).
 - On schedule for L4 public Beta data release through NSIDC (Oct/Nov)
 - Including updates to L4_C product documents & support tools
 - L4_C impact assessment from SMAP radar anomaly initiated, while mitigation plans include use of alternative radiometer based FT retrievals.
 - Further reprocessing events planned, incorporating L4 algorithm updates, use of SMAP FT retrievals & continuing calibration refinements.
-