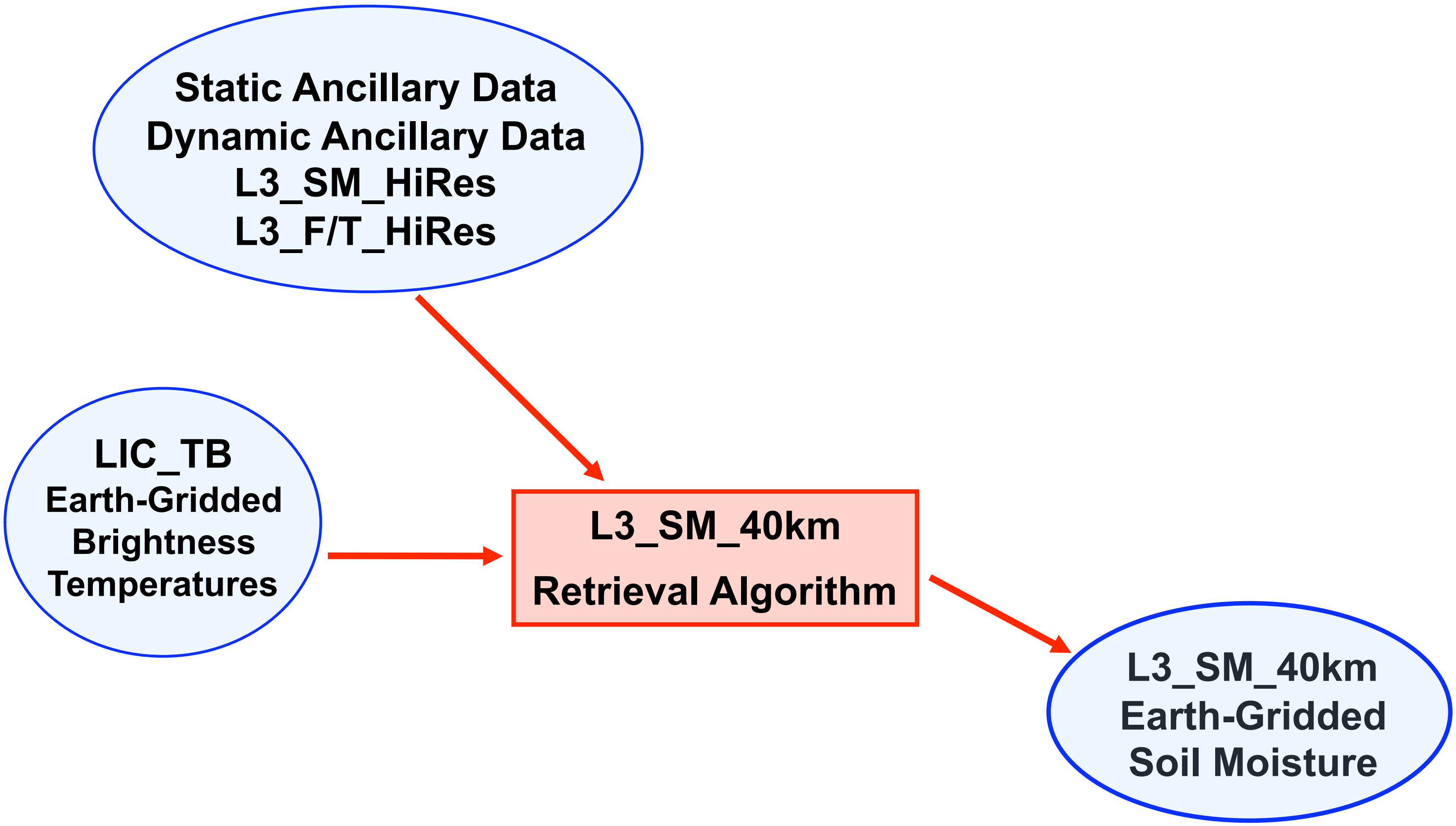
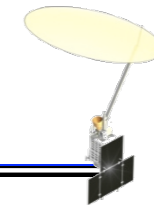
Level 3-4 Algorithm Cal/Val Requirements

- L3_SM_40km Cal/Val requirements (P. O'Neill)
- L3_SM_HiRes Cal/Val requirements (J.C. Shi)
- L3_SM_A/P Cal/Val requirements (N. Das)
- L3_F/T & L4_C Cal/Val requirements (J. Kimball)

Radiometer SM L3 Data Flow



L3_SM_40km Inputs / Outputs



<u>DATA INPUT</u>:
Grid cell location on fixed Earth grid (lat, lon)
Time tag (date and time of day)
Calibrated L1C_TB
Static ancillary data [permanent masks (land / water, urban, etc.), soil type, DEM info, % land cover types]
Dynamic ancillary data :
-- Soil temperature
-- Vegetation water content
-- Vegetation parameters (*b*, *τ*, *ω*)
% open water in pixel [from L3_SM_HiRes] -- temperature of open water from Ts at 6 am
Frozen ground flag [from L3_F/T_HiRes]
Precipitation flag (if set) [from ????]
Snow/ice flag (if set) [from ????]
RFI flag [from L1_TB]
Quality flag [from L1_TB]

<u>DATA OUTPUT</u>:
Grid cell location on fixed Earth grid (lat, lon)
Time tag (date and time of day)
Calibrated L1C_TB
Retrieved soil moisture for 6 am overpass
Dynamic ancillary data :
-- Soil temperature
-- Vegetation water content
-- Vegetation parameters (*b*, *τ*, *ω*)
% open water in pixel -- temperature of open water
Frozen ground flag
Precipitation flag (if set)
Snow/ice flag (if set)
RFI flag
Quality flag

L3_SM Single-Channel Error Budget Table

Error Source	Est. TB Error (K)
Atmospheric Gases & Clouds	**0.15**
Soil Temperature (2°C error)	**1.7**
Vegetation Water Content (10%)	**1.6**
Model Parameterization (h, ω, b, all at 5% error, classification, etc.)	**1.4**
Surface Heterogeneity	**0.9**
Total RSS of Geophysical Errors	**2.87**
Radiometer Precision & Calibration Stability	**1.3**
Total RSS Error	**3.15**

[Error budget to be confirmed]

[radiometer absolute calibration error not yet included]

L3_SM_40km Algorithm Priorities

Pre-Launch – leads to selection of baseline algorithm & expected SM retrieval accuracy performance

- **refine model parameterizations – VEGETATION is a priority**
  - -- need good b (or τ) and ω for main vegetation types
  - -- polarization & seasonal dependence?
  - -- determination of VWC
  - -- scaling for effective VWC
- **how good is radar information on % open water in pixel?**
- **develop & compare algorithm error budgets**
  - -- need to know error in ancillary data sets
- **evaluate algorithm performance using:**
  - -- algorithm testbed simulations
  - -- analysis of ground & A/C measurements
  - -- SMOS / Aquarius data

Twin Otter w/PALS and ComRAD microwave truck system, SMAPVEX08, October 13, 2008

Post-Launch Test & Evaluation

Post-Launch – are accuracy requirements met?

- comparison against long-term measurement networks which include surface soil moisture
- field measurements from intensive SMAP C/V field campaigns
- modeling / data assimilation & other satellites (GCOM-W?)

RADAR CAL/VAL DATA REQUIREMENTS

What is to be Tested	Optimum Platform/Scene	Spatial/Temporal Reqmnt
Range of Validity of Dubois model	Aircraft (UAVSAR/PALSAR) over areas with varying amounts and types of vegetation	50 km x 50 km Preferably few acquisitions with different moisture conditions
Effects of viewing geometry	Crossing flight lines over areas with topography and/or crops with row structure	Same
Scaling effects	Aircraft over heterogeneous areas	Same
Time Series Algorithm	Initially truck mounted scatterometer, later aircraft Data over different vegetation classes	Long time series preferably on daily basis

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

CAL/VAL for L3_SM_A/P product

Dara Entekhabi (MIT) and **Narendra Das** (JPL/CalTech)

SMAP Algorithms and Calibration/Validation Workshop
June 9-11, 2009
Oxnard, CA

Prelaunch Cal/Val Activities for L3_SM_A/P product

Focus Should be on Algorithm Development Efforts

- Requires longer Time-Series Airborne Radiometer and Radar Data
  - *To test the time series algorithms approach rigorously*
  - *To cover full dynamic range of soil moisture evolution*
  - *To investigate affects of changing VWC on time series parameters*
  - *Airborne L-band radiometer and radar at different azimuth viewing angle to investigate influence of azimuthal affects on time series algorithms*
- Ground truth required at compatible spatial scales
- Accommodate varied landuse/landcover to enhance applicability
- Develop spatial scaling methods to scale in situ data to evaluate the global soil moisture products

Post-launch Cal/Val Activities for L3_SM_A/P product

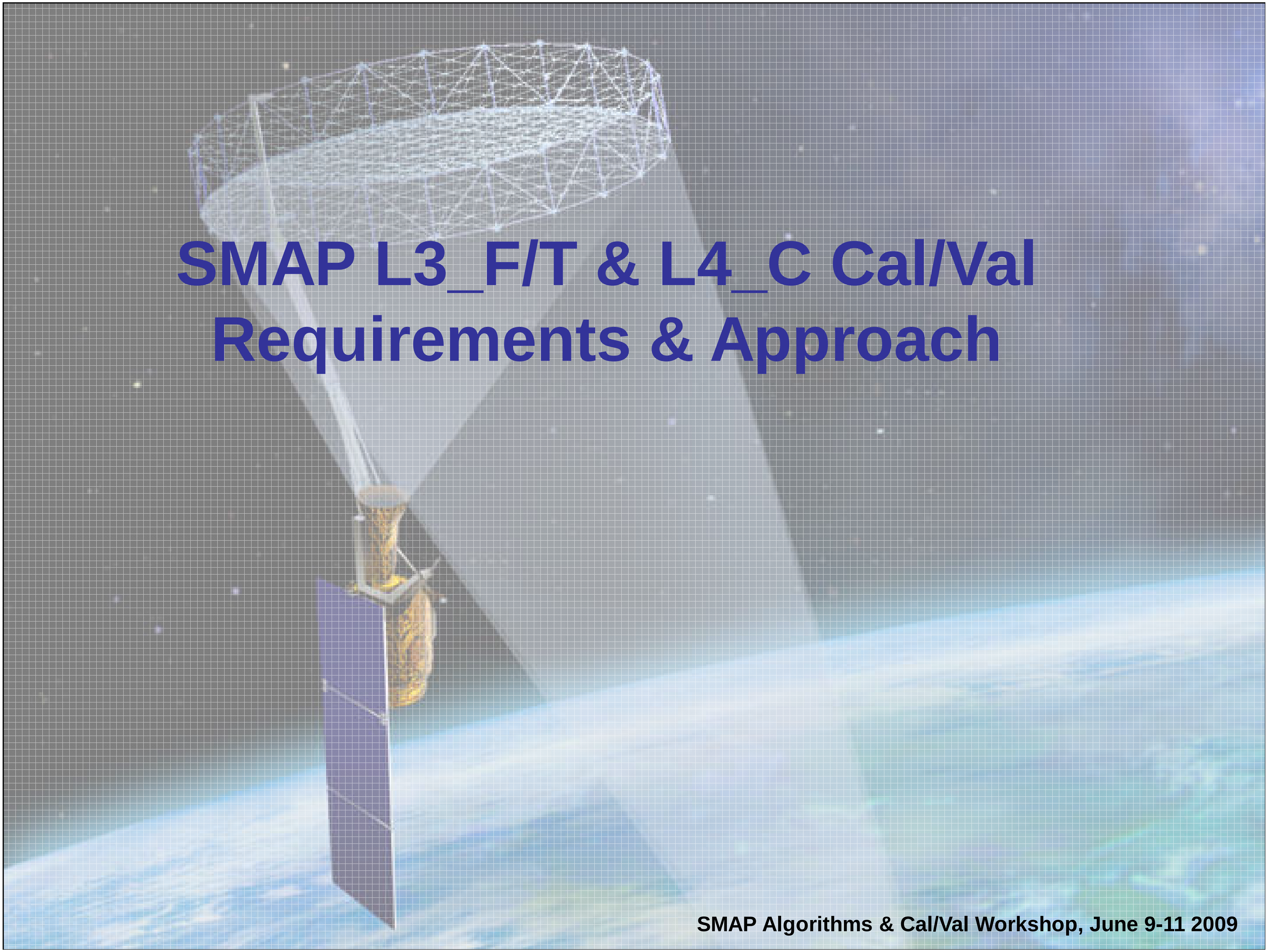
Focus on calibration and fine tuning of algorithm used for L3_SM_A/P product, and to estimate bias and errors in the product

- Highest priority: Soil moisture ground truth sites with scaling established (temporally stable) to 10 km land cover and soil moisture conditions as required for the product

- Use ancillary information (e.g., Precipitation and VWC) for validation

- Use independent hydrological models for validation

- Other compatible satellite data for validation


SMAP L3_F/T & L4_C Cal/Val
Requirements & Approach
SMAP Algorithms & Cal/Val Workshop, June 9-11 2009

Cal/Val activities address algorithm accuracy requirements

L3_F/T:

Obtain measurements of binary F/T transitions in boreal (≥45N) zones with ≥80% spatial classification accuracy (baseline); capture F/T constraints on boreal C fluxes consistent with tower flux measurements.

L4_Carbon:

Obtain estimates of land-atmosphere CO_2 exchange (NEE) at accuracy level commensurate with tower based CO_2 Obs. (RMSE ≤ 30 g C m^{-2} yr^{-1}).

Planned L3_F/T Cal/Val activities

Pre-launch:

- Algorithm definition, testing, refinement using SMAP SDS test-bed simulations & available satellite L-band radar (PALSAR, SAOCOM) data;

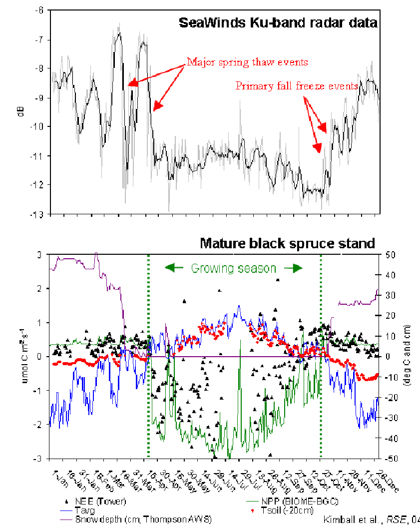
- Focused campaigns using available airborne (UAVSAR) and satellite L-band radar data spanning F/T transitions over regional gradients (climate, land cover, terrain);

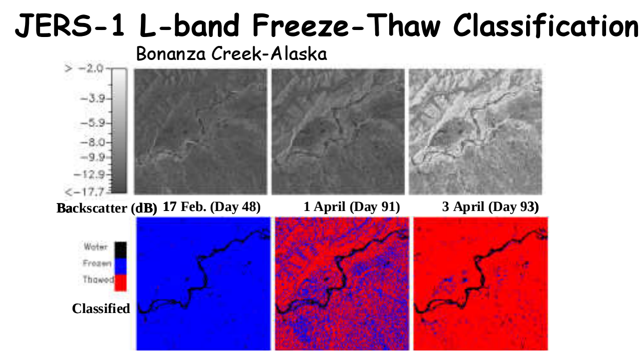
- Initialization of algorithm parameters (e.g. F/T reference states) over L3_F/T domain;

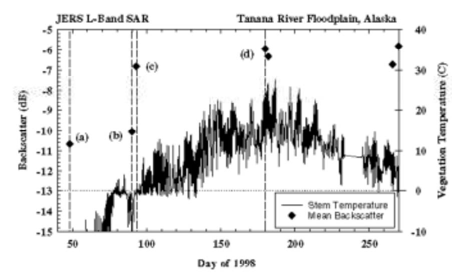
Post-launch:

- L3_F/T comparisons over northern biophysical monitoring sites (e.g. FLUXNET, WMO, ALECTRA);

- Intensive validation Field campaigns (airborne & tower based L-band Obs. with in situ measurements).







Planned L4_C Cal/Val activities

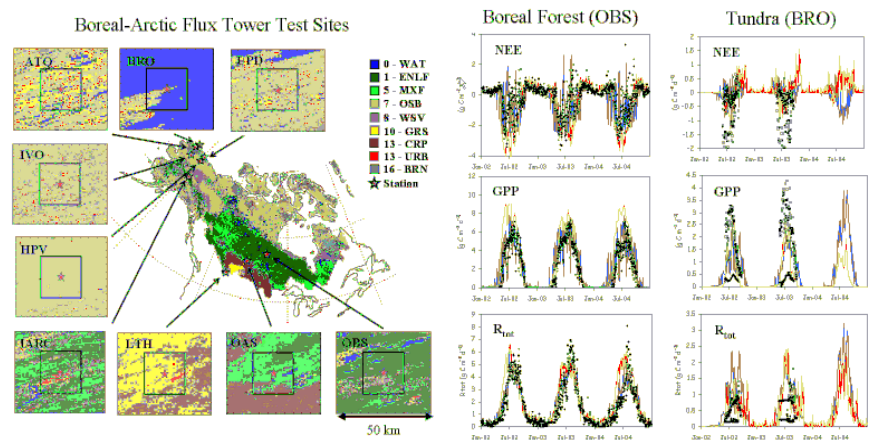
Pre-launch:

- Assess accuracy of L4_C inputs (L4_SM; GPP) over northern (≥ 45°N) domain;

- Algorithm development, testing, refinement using available inputs (e.g. MODIS GPP, SMOS, GMAO SM & T;

- Initialization/calibration/optimization of L4_C algorithm parameters (e.g. BPLUT, SOC pools);

L4_C Test using MODIS & AMSR-E Inputs



Kimball et al. *TGARS* 2009

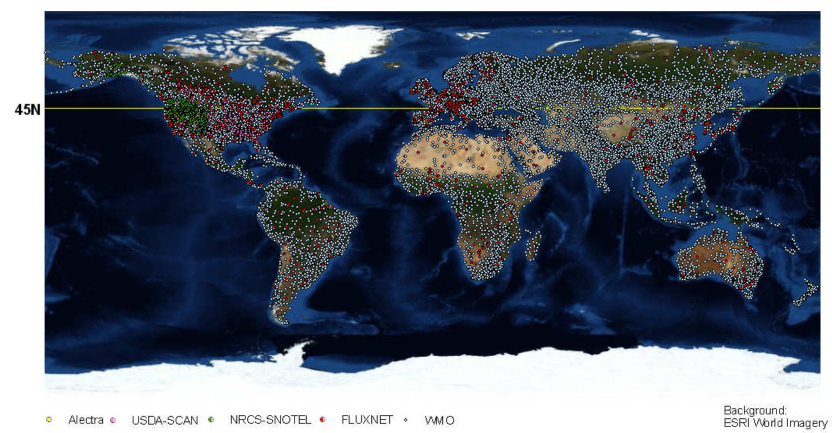
Post-launch:

- Verify L4_C accuracy using CO_2 data from northern monitoring sites (e.g. FLUXNET);

- Re-initialization of algorithm parameters using SMAP and L4_SM inputs;

- Carbon model assimilation of L4_C products (e.g. NASA-TOPS, NOAA-CarbonTracker);

Global Biophysical Station Networks



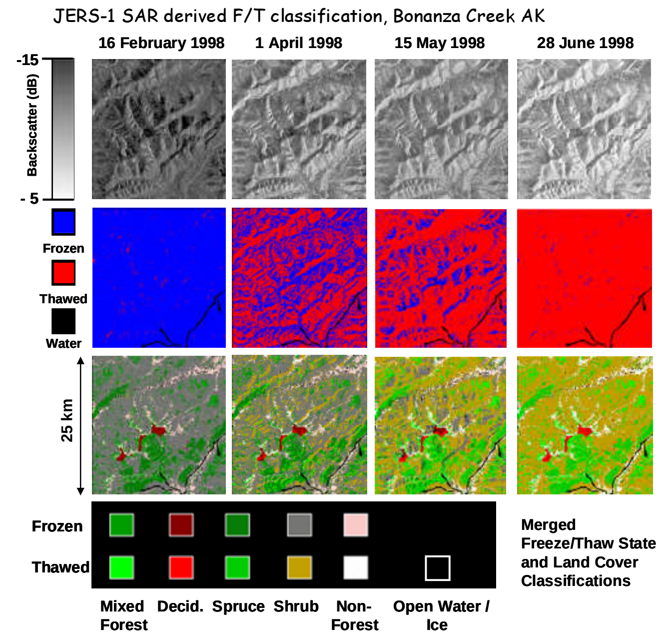
Pre-launch: Verify L3_F/T accuracy requirements

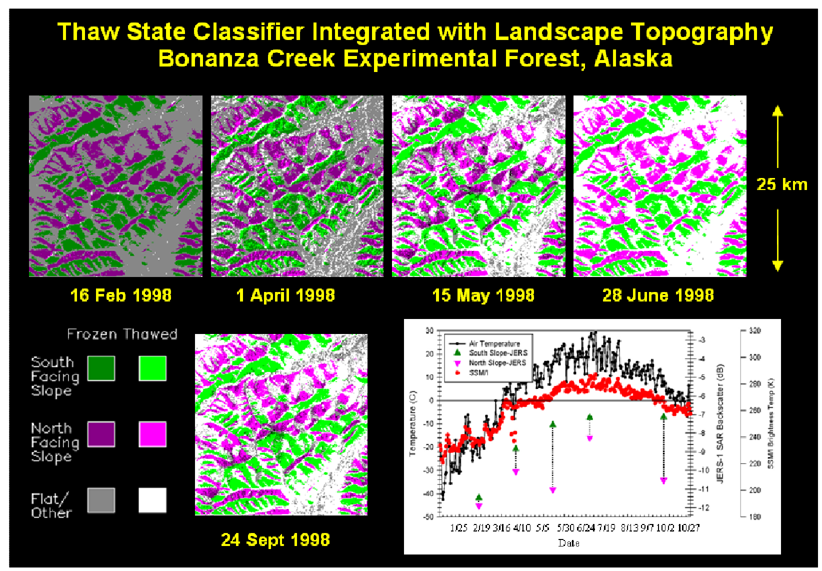
• Define domain & conditions where SMAP can meet L3_F/T requirements.

• Classification error increases rapidly as spatial resolution approaches scale of landscape F/T spatial heterogeneity.

• F/T spatial heterogeneity varies by region and on a seasonal basis; heterogeneity is maximized during spring/fall transitions, in complex land cover and terrain, and along lower elevations and latitudinal boundaries.

• Classification accuracy drops off rapidly with decreasing spatial resolution during F/T transitions when landscape heterogeneity is maximized.



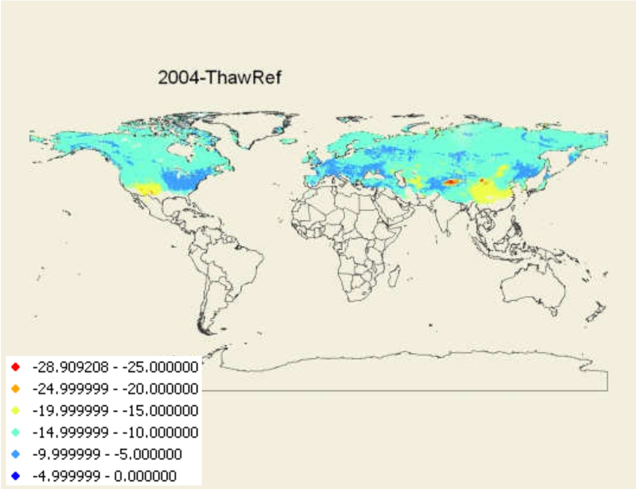


Pre-launch: Establish L-band reference states for L3_F/T Algorithms

- Utilize SMAP SDS algorithm test-bed with available satellite L-band radar data (PALSAR, SAOCOM) to assess expected dynamic range of L-band backscatter variability over northern domain;

- Define L3_F/T frozen & non-frozen reference conditions

SeaWinds (2004) Ku-band frozen (mean dB, Jan) and non-frozen (mean dB, July) reference states

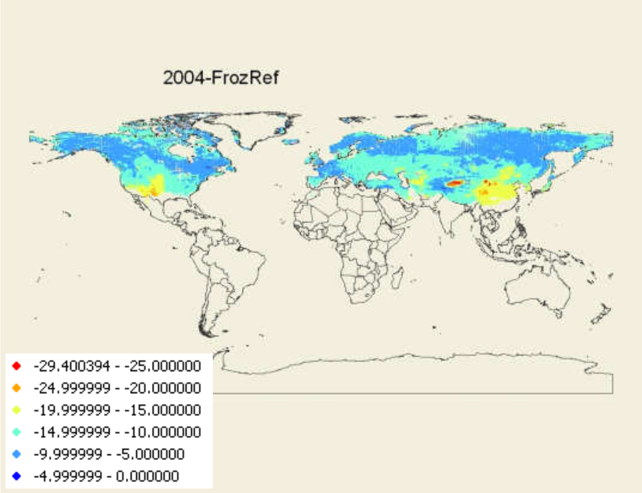


L3_F/T seasonal threshold Algorithm:

$$\Delta(t) = \sigma(t) - \left\{\sigma_{fr} + \left(\sigma_{th} - \sigma_{fr}\right)T\right\}$$

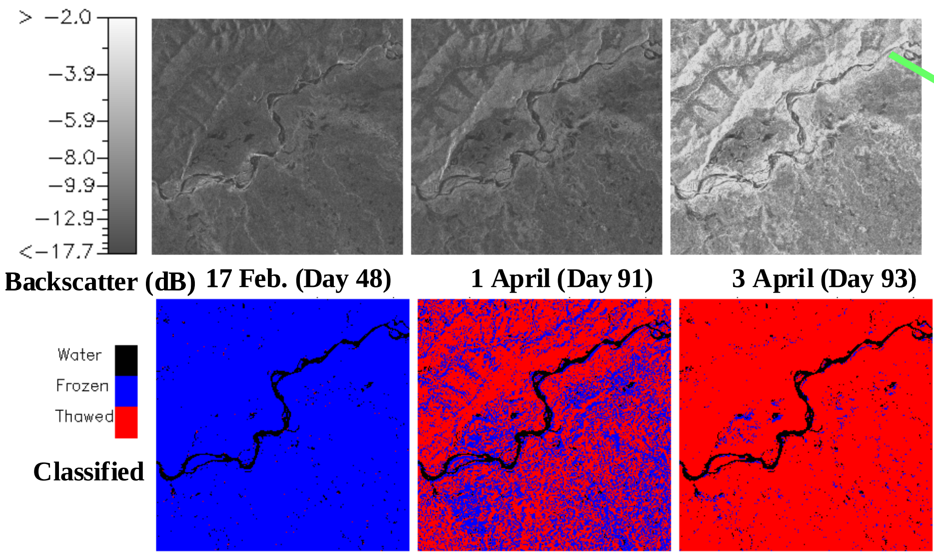
$\Delta(t) > 0$ Thawed

$\Delta(t) \leq 0$ Frozen

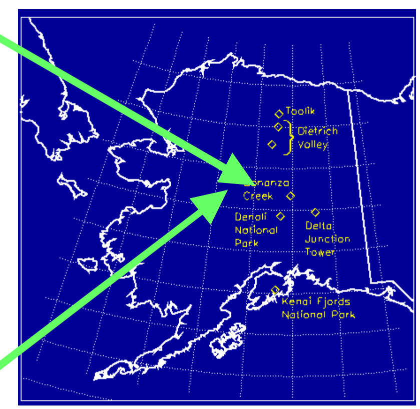


Post-launch: L3_F/T validation using in situ station networks

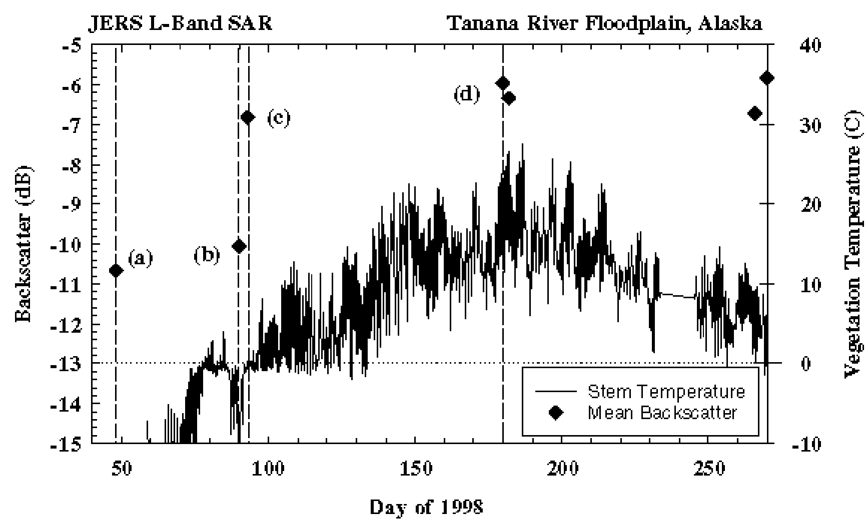
JERS-1 L-band Freeze-Thaw classification assessment using in situ temperature data



Bonanza Creek-Alaska

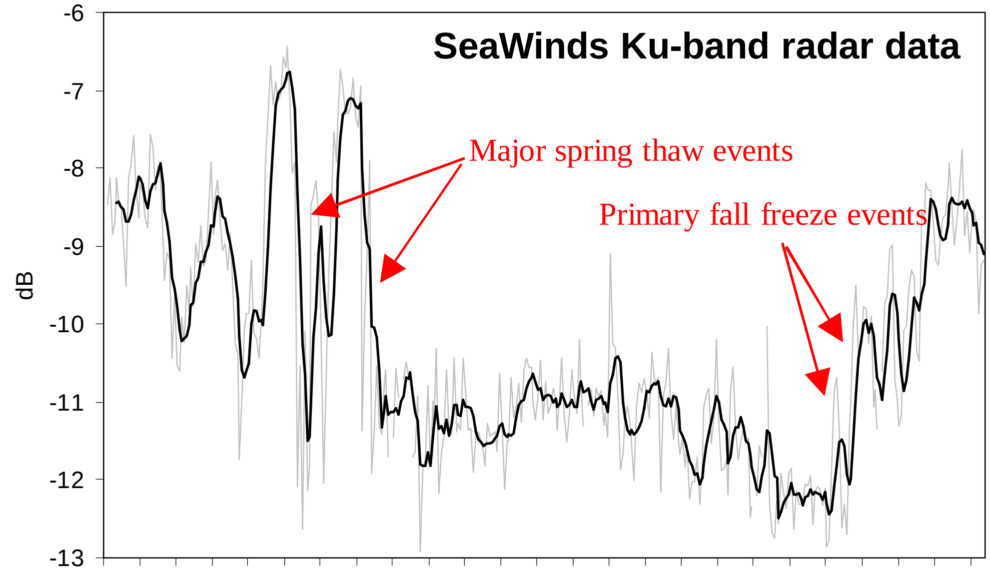


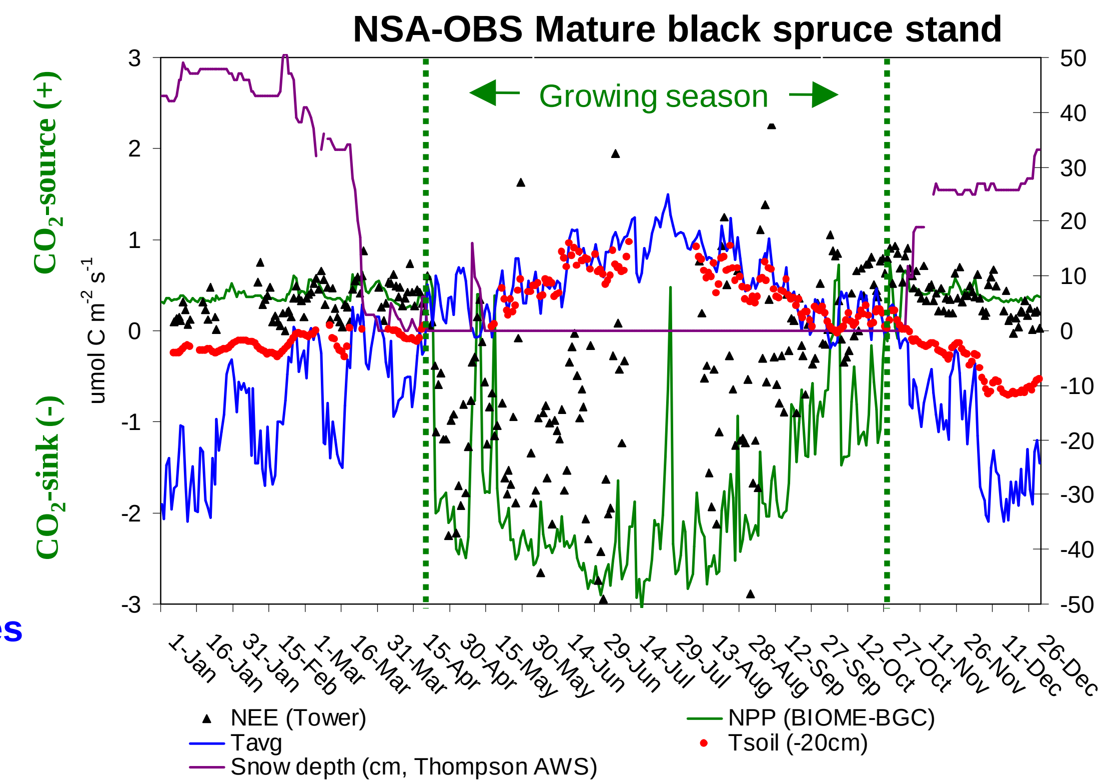
Validation with *in situ* Biophysical Measurements



L-band backscatter increases with thaw

Post-launch: L3_F/T validation using FLUXNET





Verify F/T accuracy and Carbon linkages

Source: Kimball et al., *Rem. Sens. Environ.*, 90.

Pre-Launch: Calibration of L4_C parameters using FLUXNET

- Baseline L4_C algorithm parameterized for general biomes and assumptions of dynamic equilibrium between GPP and R under average climate conditions, *but succession and disturbance can push ecosystem from steady-state;*

- Parameterization error contributes ~30% of total L4_C uncertainty;

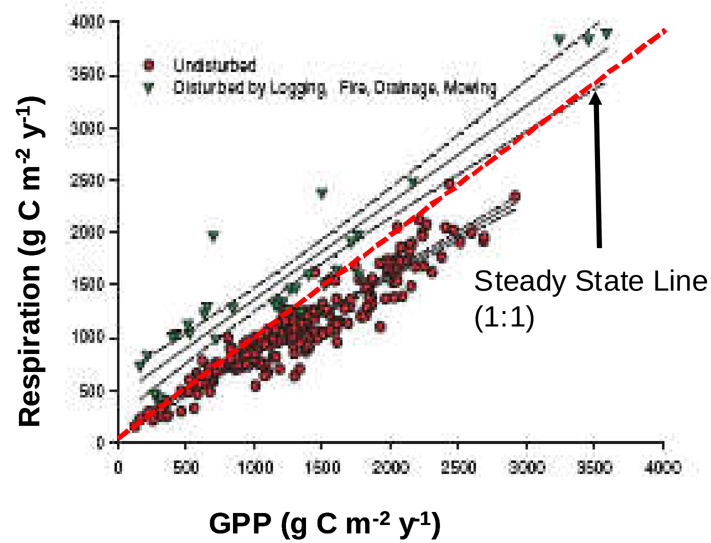
- *CO_2 measurements from global observation networks (FLUXNET) can be used for model calibration and to account for non steady-state conditions;*

Table 2. General Biome Properties Look-up Table (BPLUT) describing ecophysiological parameters for L4_C model calculations.

[A]Land cover	[B]C_{fract} (DIM)	[C]CUE (DIM)	[C]R_a:GPP (DIM)
Tundra (OSB)	0.72	0.54	0.46
Evergreen forest	0.49	0.54	0.46
Mixed Forest	0.59	0.54	0.46
Grassland	0.76	0.6	0.6

[A] MODIS IGBP global land cover classification (Friedl et al. 2002) for dominant boreal/tundra vegetation classes: Tundra or open shrubland (OSB); Grassland; Evergreen needleleaf coniferous forest; Mixed broadleaf deciduous and evergreen needleleaf coniferous forest types;
[B] Proportional NPP allocation to metabolic and structural (1-C_{fract}) SOC pools from Potter et al. (1993) and Ise and Moorcroft (2006);
[C] Carbon Use Efficiencies (NPP:GPP) and corresponding R_a:GPP ratios for representative boreal and grassland ecosystems from Gifford et al. (2003).

[1]Succession/Disturbance Effects on Tower CO_2 Fluxes

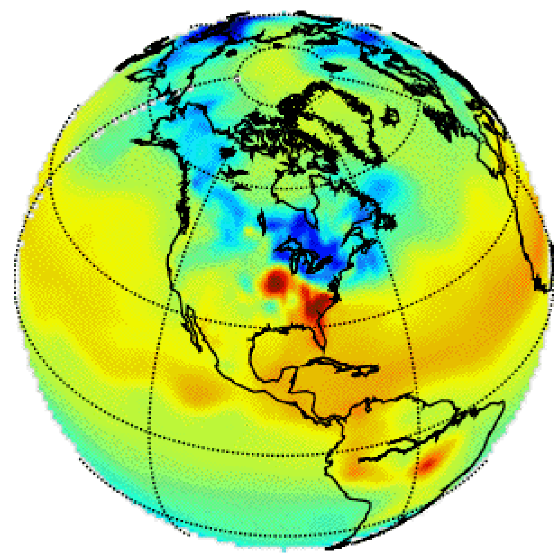


[1] Baldocchi, 2008. *Australian J. Bot*.

Post-launch: L4_C model assimilation to quantify boreal C source-sink activity

NOAA CarbonTracker:

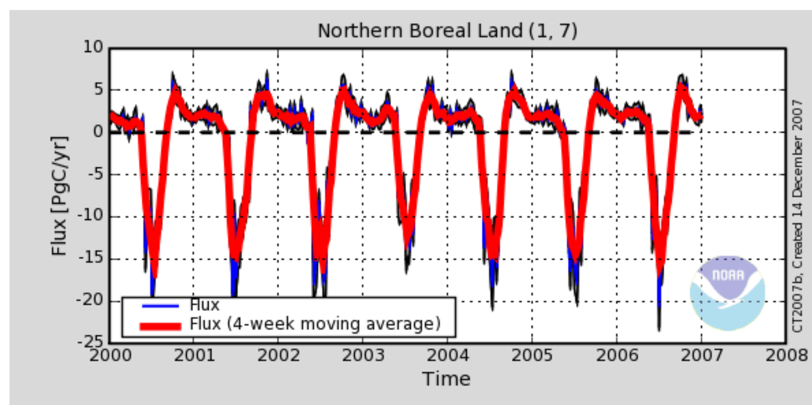
- Carbon data assimilation system for tracking global CO_2 exchange and net C source/sink activity;
- Atmospheric perspective based on atmospheric transport model (TM3) constrained by satellite remote sensing and sparse surface observations;
- Accounts for fossil-fuel and fire related CO_2 emissions;
- Currently uses 1-degree CASA land model to define land-atmosphere C exchange (NEE);
- Provides means to quantify boreal Carbon source/sink activity (SMAP Decadal Survey objective);



Annual C balance

Results Summary (all units PgC/yr)

Year	First Guess	Estimate	Fire Emission	Fossil Emission	Total Flux
2000	-0.30 ± 1.67	-1.37 ± 1.35	0.15	0.11	-1.11 ± 1.35
2001	-0.25 ± 1.67	-1.18 ± 1.33	0.11	0.11	-0.96 ± 1.33
2002	-0.24 ± 1.80	-1.25 ± 1.38	0.25	0.11	-0.89 ± 1.38
2003	0.02 ± 1.61	-0.86 ± 1.25	0.38	0.11	-0.37 ± 1.25
2004	0.01 ± 1.69	-1.07 ± 1.32	0.15	0.12	-0.80 ± 1.32
2005	-0.03 ± 1.57	-1.12 ± 1.25	0.11	0.12	-0.89 ± 1.25
2006	-0.16 ± 1.72	-0.98 ± 1.21	0.14	0.12	-0.71 ± 1.21



http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/index.html