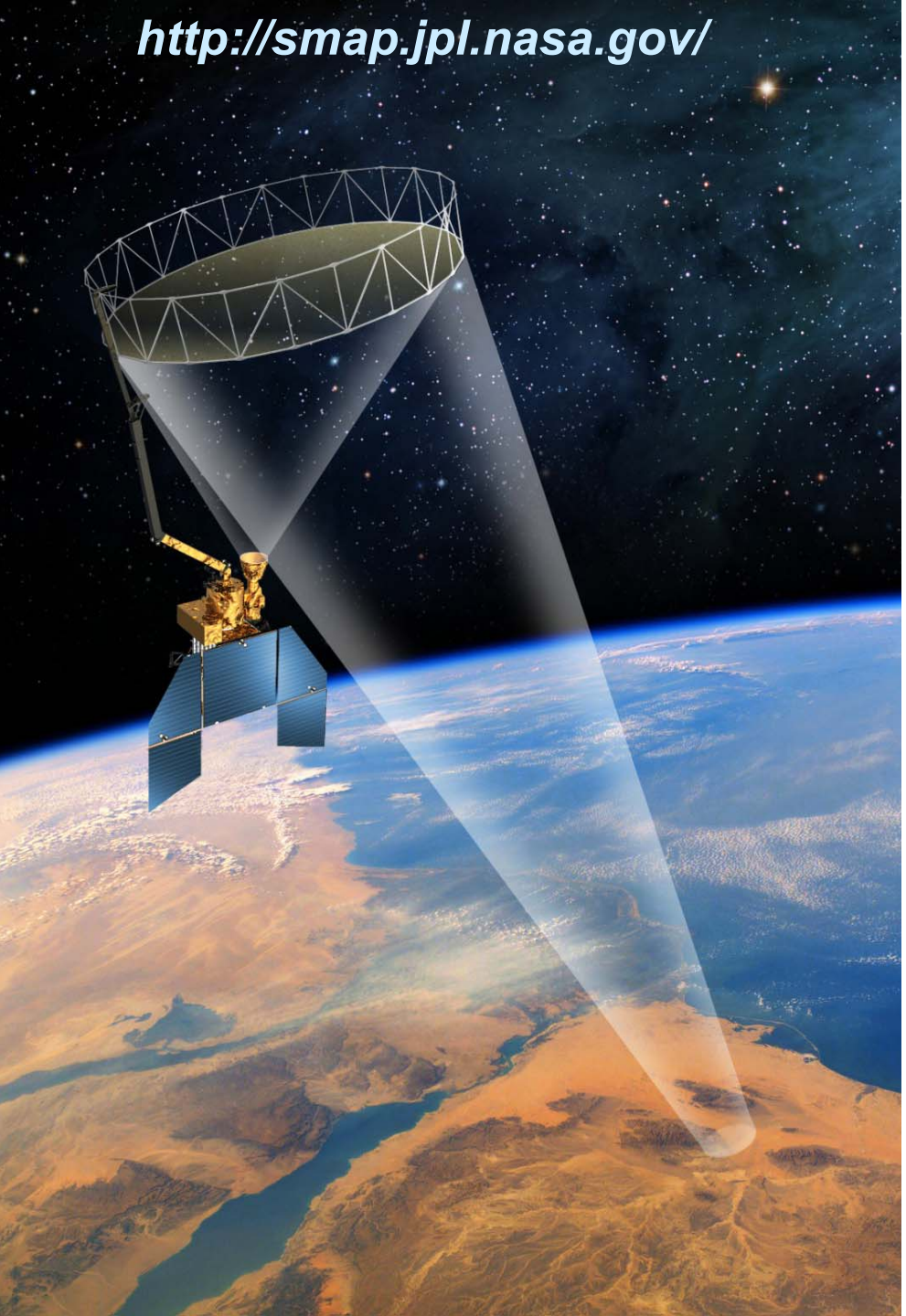

SMAP
L3_F/T Cal-Val

Kyle McDonald
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City University of New York

John Kimball
The University of Montana

2nd SMAP Cal /Val Workshop
Oxnard, CA
May 3-5, 2011

This work has been undertaken in part within the framework of the JAXA ALOS Kyoto & Carbon Initiative. PALSAR data were provided by JAXA EORC.

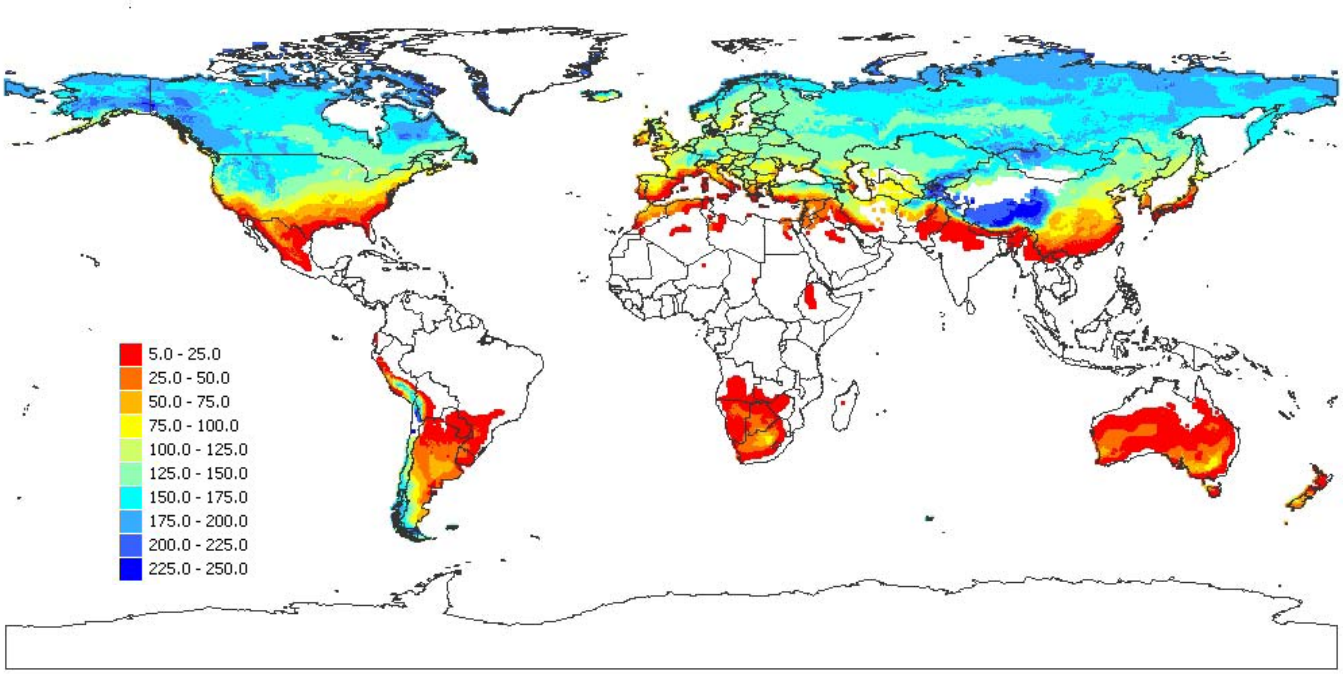
Baseline L3_F/T Product Summary

Land Surface Freeze/Thaw State

- **Motivation/Objectives**: Obtain measurements of binary F/T state in boreal (≥45N) zones with ≥80% spatial classification accuracy (baseline). Capture F/T constraints on boreal C fluxes consistent with tower flux measurements.
- **Approach**: Apply time series L1 radar backscatter to derive surface freeze-thaw state
- **Inputs**: Level 1 high res radar backscatter
- **Outputs**: Surface freeze-thaw state expressed as a binary value (frozen/thawed)
- Baseline **Domain**: Vegetated areas encompassing boreal/arctic latitudes (≥45°N)
- **Resolution**: 3 km (baseline)
- **Temporal fidelity**: 2 days (daily composite)

Define F/T Affected Regions

FT Affected Regions Defined by Cold Temperature Constraints Index & long-term reanalysis (GMAO) data



FT domain: Vegetated areas where CCI ≥ 5 d yr^{-1}

L3_FT_A: Algorithm Selection

Baseline Algorithm:

- **Seasonal threshold**

Approach: Classify the landscape freeze/thaw state based on time series radar backscatter relative to seasonal reference frozen and unfrozen states. AM and PM observations are classified separately. The AM and PM states are combined to provide the combined state as (1) frozen (frozen AM, frozen PM), (2) thawed (thawed AM, thawed PM), (3) transitional (frozen AM, thawed PM) and (4) inverse transitional (thawed AM, frozen PM) states.

Inputs: Time series radar backscatter (L1C_S0_HiRes), both AM and PM

Outputs: Landscape freeze/thaw state for AM, PM, and combined.3x3 km resolution, daily product.

Domain: Vegetated areas encompassing (1) boreal/arctic latitudes (≥45°N) and (2) global regions where temperature is a significant constraint to vegetation productivity.

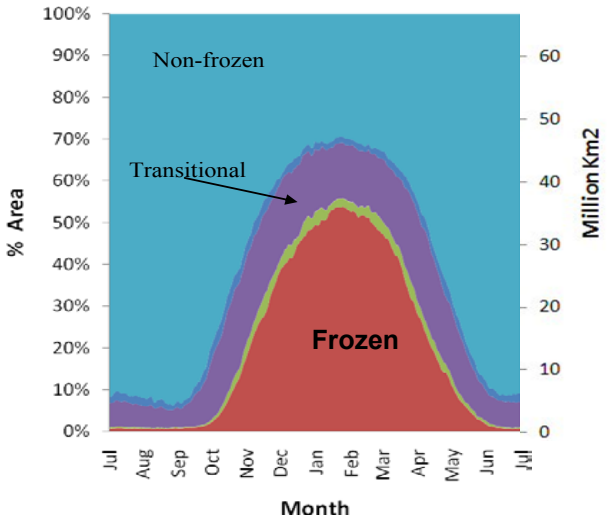
Optional Algorithms:

- **Moving window (Option 1)**
  Does not depend on pre-selection of seasonal reference states
- **Temporal edge detection (Option 2)**
  Not appropriate for a daily product

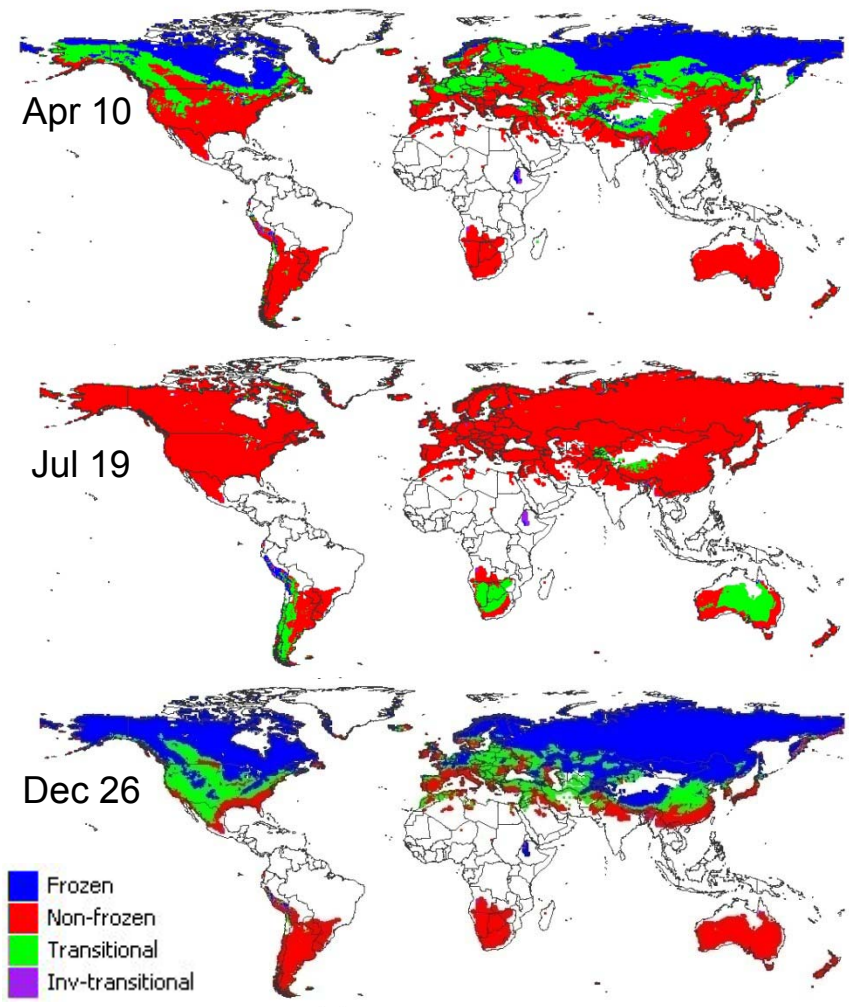
L3_FT_A AM-PM Combined Product Prototype

- **Daily F/T state maps:**
  - -Frozen (AM & PM),
  - -Thawed (AM & PM),
  - -Transitional (AM frozen, PM thaw),
  - -Inverse-Transitional (AM thaw, PM frozen)
- **Global domain - F/T affected areas:**
  - 66 million km^2 or 52% of global vegetated area);

Mean Seasonal F-T Progression
SSM/I 1988-2007



Daily Freeze-Thaw Status
SSM/I (37GHz, 25km Res.) 2004



Source: http://freezethaw.ntsg.umt.edu

L3_FT

Issues

Baseline Algorithm:

$\Delta(t) = [\sigma^0(t) - \sigma^0_{fr}] / [\sigma^0_{th} - \sigma^0_{fr}]$

σ^0_{fr} = frozen reference

σ^0_{th} = thawed reference

T = threshold

$\Delta(t) > T$ (Thawed)

$\Delta(t) \leq T$ (Frozen)

Algorithm Parameterizations:

- Seasonal frozen and thawed reference states
  - Varies with topography and landcover
- Threshold reference (T)
  - Selected based on difference in seasonal

Approach for Assignment of Parameters:

- Seasonal frozen and thawed reference states may be initially assigned using prototype SAR datasets and radar backscatter modeling over representative test sites.

- Ancillary landcover and topography information may be used to interpolate reference states across the product domain.

- The threshold reference (T) depends on landcover and topography.

frozen and thawed states

Setting initial algorithm parameters is a key application of the algorithm testbed.

- Final parameterization will be performed using the SMAP L2 radar data as part of reprocessing.

L3_FT_A Error Allocation

Baseline Algorithm:

$\Delta(t) = [\sigma^0(t) - \sigma^0_{fr}] / [\sigma^0_{th} - \sigma^0_{fr}]$

σ^0_{fr} = frozen reference

σ^0_{th} = thawed reference

T = threshold

$\Delta(t) > T$ (Thawed)

$\Delta(t) \leq T$ (Frozen)

- **Uncertainty in radar (radiometric) measurements**
  -varies with resolution and azimuth

- **Reference state and threshold parameters**
  - Variability of reference states within-season
  - Landcover, spatial heterogeneity
  - Topography
    - slope aspect
    - sensor viewing geometry (azimuth)
  - Differences in radiometric response on land cover components
    - open water vs vegetation

- Small differences (Δ) in frozen and non-frozen seasonal reference states

Priorities for L3_F/T Cal/Val

Pre-launch:

- Define domain & conditions where products meet accuracy requirements;
- Define candidate sites, tradeoffs for product validation;
- Final selection, justification of baseline algorithms;
- Define L-band dB reference states & temporal stability over product domain for L3_F/T algorithm implementation;

Post-launch:

- Product validation relative to accuracy requirements;
- Re-calibrate & define model parameters & reference states using SMAP inputs;

SMAP Radar Prototyping Activities

L3_F/T Prototype datasets:

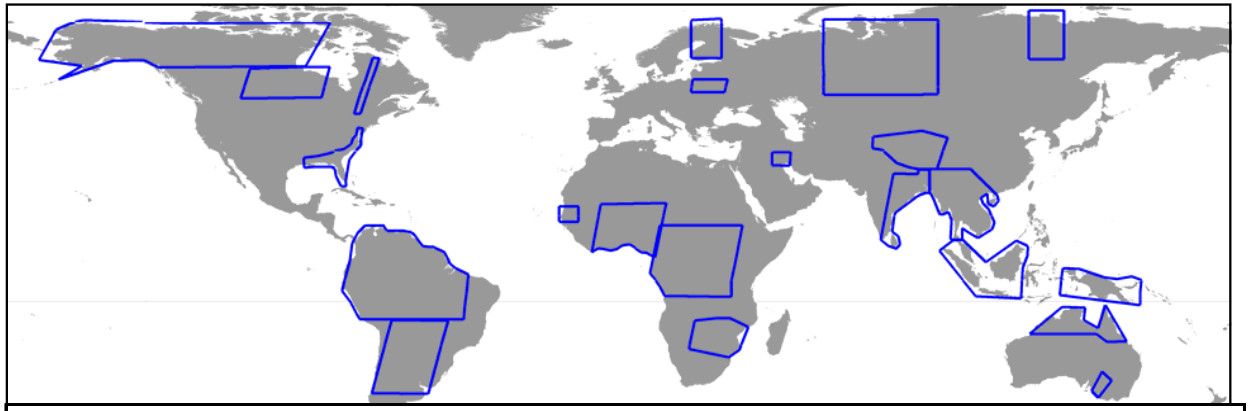
- ALOS PALSAR (L-band)
  - HH- and HV Pol Fine Beam Data
  - HH-pol ScanSAR
  - Global-scale, systematic obervations
- JERS-1 SAR (L-band)
  - HH-pol dual season boreal data
- SSM/I, AMSR-E, QuikSCAT

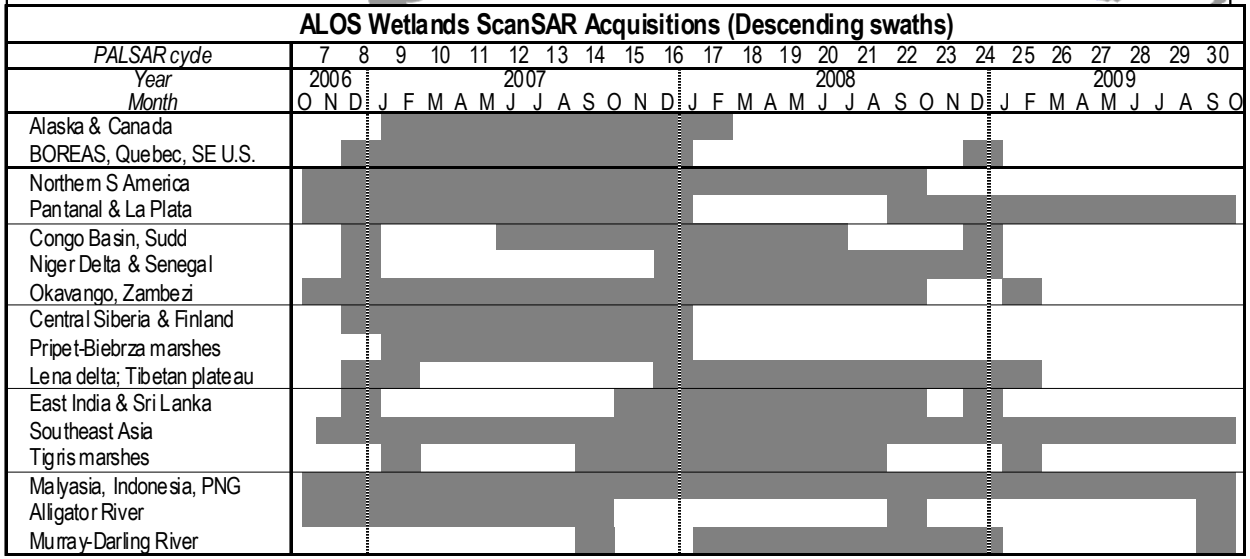
JAXA ALOS Kyoto and Carbon Initiative

- ALOS launched on January 24, 2006 and operated through April 2011
- Instruments:
  - PALSAR (L-band SAR)
  - AVNIR-2 (side-looking visible and near IR)
  - PRISM (Stereo high-resolution nadir panchromatic for mapping topography)
- Systematic Global Observation Strategy
- International science team to produce products
- Seasonal coverage of high priority areas
- 3 Science Themes:
  - Forests
  - Wetlands
  - Desert and Water

PALSAR Regional Coverage: ScanSAR regions

- Multi-temporal ScanSAR HH-pol data collected for key ecoregions, targeting wetlands.
- Systematic acquisition plan developed by K&C Science Team
- Global Fine-Beam dual pol (HH & HV) data collected.
- Database developing at JPL now includes more than 20,000 scenes.
- Processing at ASF supports expanding time series data in Boreal North Ameica.
- K&C Team is working to continue and expand acquisitions under ALOS II





Planned L3_F/T Cal/Val activities

Pre-launch:

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

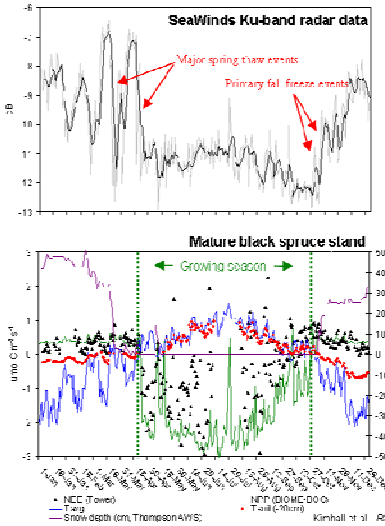
- Focused campaigns using available airborne (UAVSAR) and satellite L-band radar data spanning F/T transitions over regional gradients (climate, land cover, terrain);

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

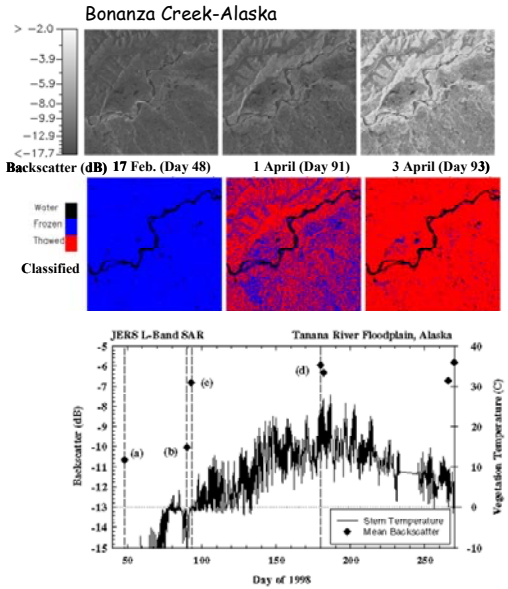
Post-launch:

- 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).



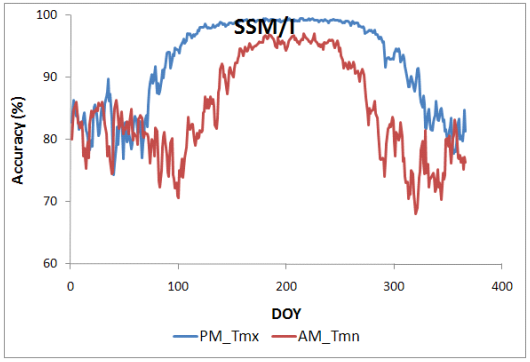
JERS-1 L-band Freeze-Thaw Classification



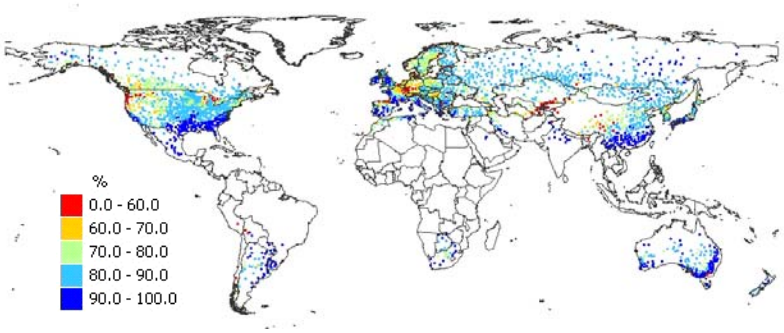
L3_FT_A Validation and Error Assessment

Global Comparisons with WMO Daily Air Temperature Observations

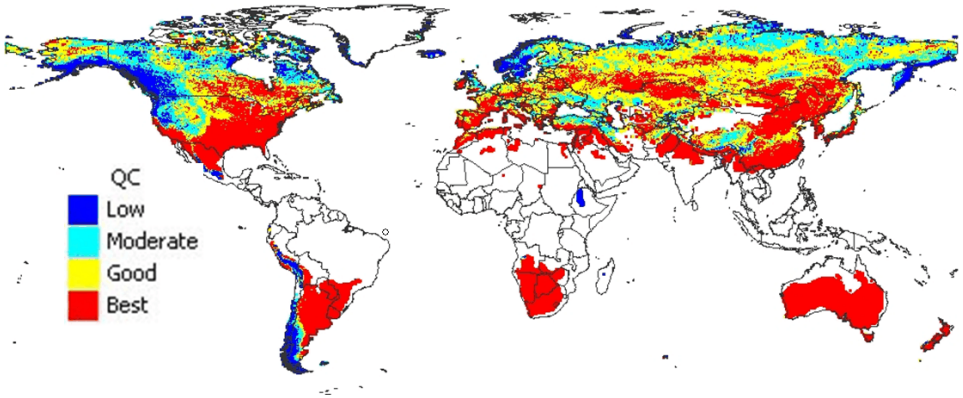
Mean Daily Accuracy



Mean Annual Accuracy



Spatially Explicit Quality Assessment



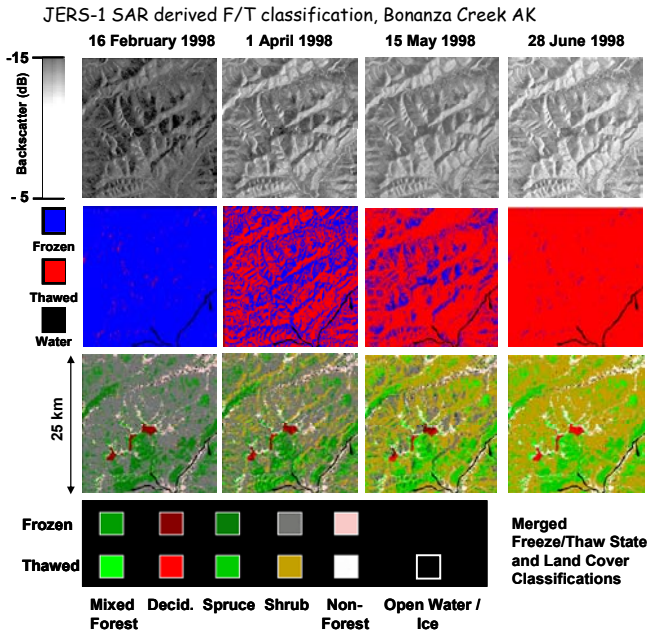
Retrieved

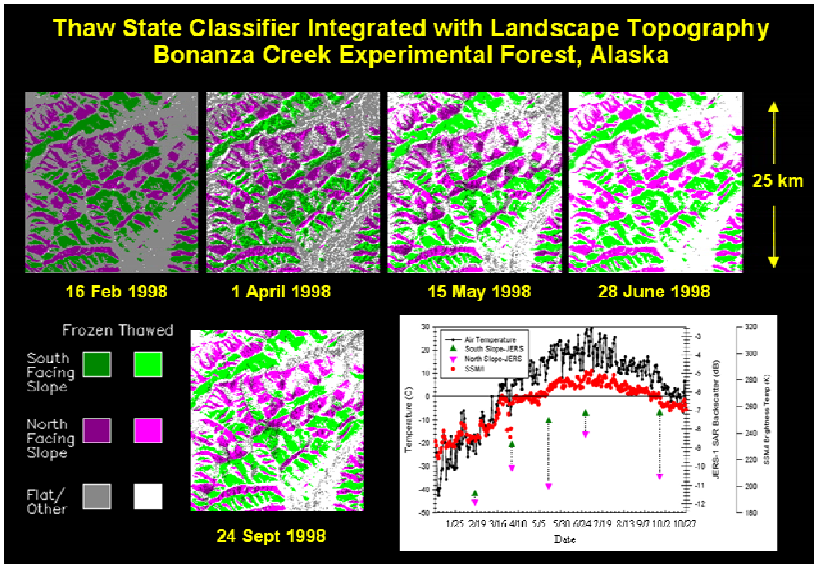
Truth	Thawed	Frozen
Thawed	Correct Thawed	False Frozen Detections
Frozen	Missed Frozen Detections	Correct Frozen

% classification accuracy = Σ(correct (T+F))*100/(total retrievals)

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.





L3_F/T_A validation site design

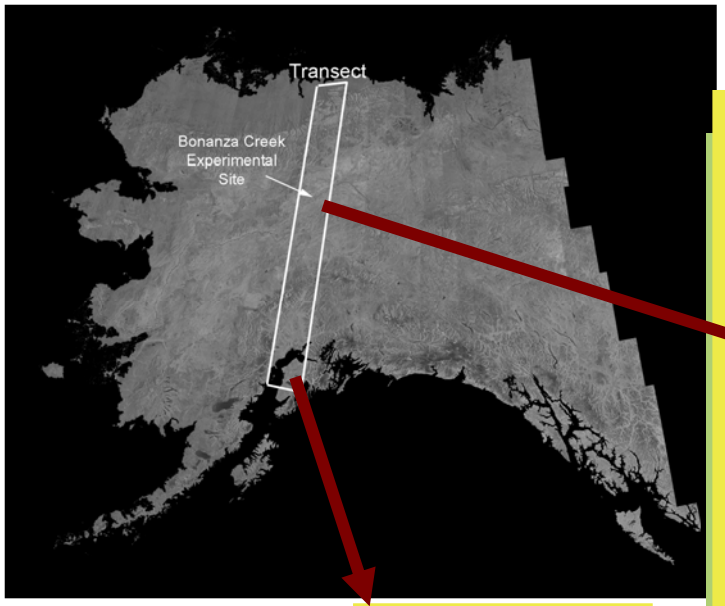
- **Represent major land cover and climate regimes**
  - Boreal evergreen needle-leaf forest, tundra, grassland
  - Disturbance and stand succession impacts

- **Capture microclimate heterogeneity within 1-3 km sensor FOV**
  - Select sites with relatively homogeneous land cover, terrain conditions.
  - Distributed measurements to capture sub-grid scale temperature variability
  - Continuous measurements to characterize diurnal and daily variability

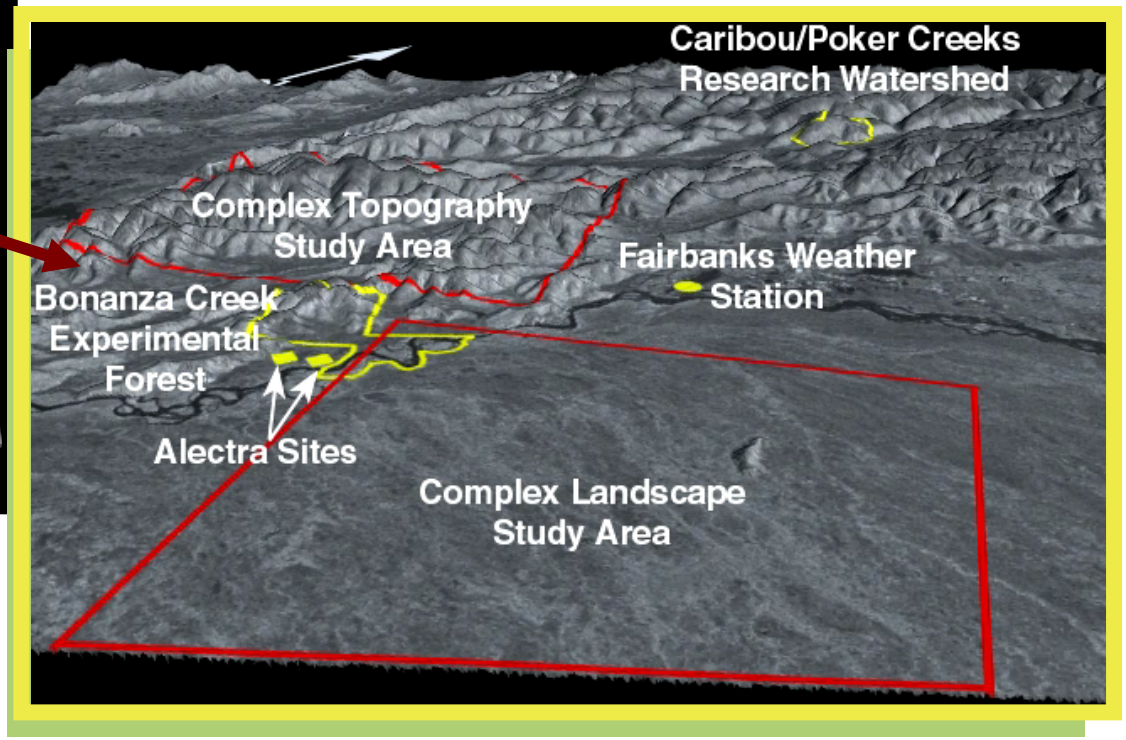
- **Represent F/T transitions of major landscape elements**
  - Snow, vegetation and surface soil layer

- **Coincident measurements of surface meteorology & H_20, CO_2 fluxes**
  - Enable freeze-thaw & water, energy & carbon cycle linkages

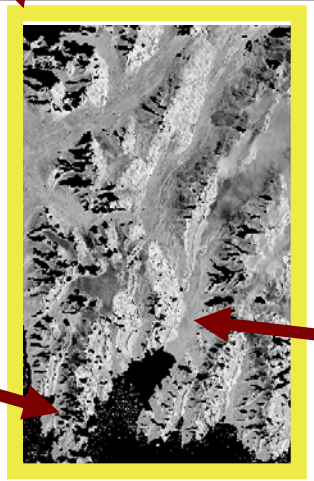
Freeze/Thaw Monitoring: Alaska



Interior Alaska



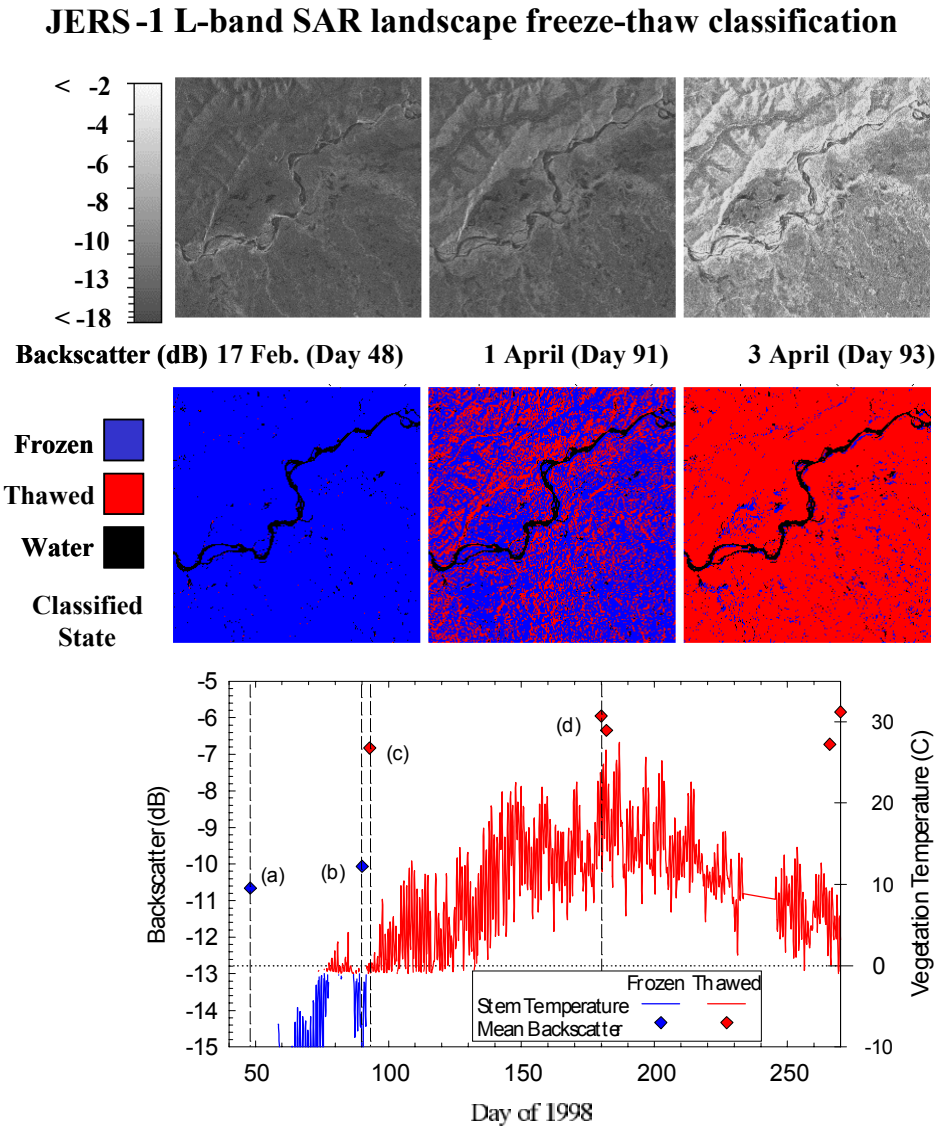
Kenai Peninsula



Resurrection Peninsula

Ellsworth Glacier

Bonanza Creek Experimental Forest, Alaska



Seasonal Threshold Algorithm

$$\Delta(t) = [\sigma^0(t) - \sigma^0_{fr}] / [\sigma^0_{th} - \sigma^0_{fr}]$$

σ^0_{fr} = frozen reference

σ^0_{th} = thawed reference

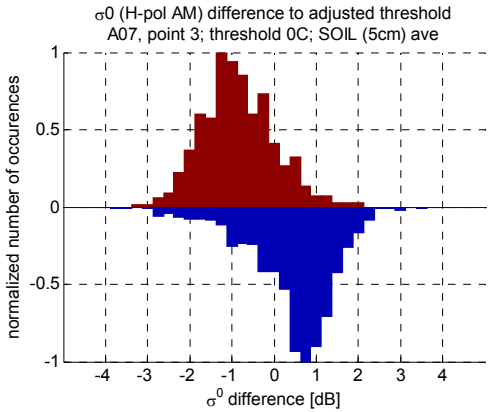
T = threshold

$\Delta(t) > T$ (Thawed)

$\Delta(t) \leq T$ (Frozen)

Comparison with in situ data

L3_FT_A: ALECTRA and QuikSCAT

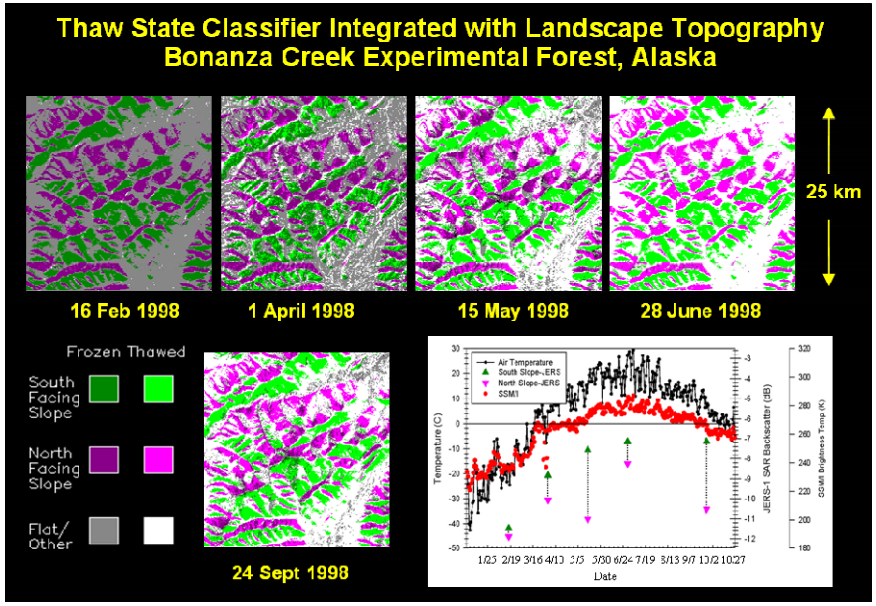


- QuikSCAT backscatter analyzed vs. ALECTRA biophysical network
- Sophisticated ALECTRA data valuable for the planning efforts
- Study indicates the most significant landscape components for explaining QuikSCAT backscatter changes
- Results vary with terrain and land cover conditions which may have implications on validation planning

ST.	SUB	AIR	STEM	BRANCH	SOIL-5	SOIL-10	Type
A01	1	0.23	0.22	0.24	-	0.30	White Spruce
	2	0.25	0.24	-	-	0.31	Black Spruce
	3	-	0.24	-	-	0.24	Poplar
	4	0.29	0.26	0.25	-	0.23	Alder Shrub
A04	1	0.18	0.17	0.16	-	0.25	Sitka Spruce/Poplar
	2	0.17	0.14	0.16	0.21	-	Alder
A05	1	0.26	0.24	-	-	0.37	Open Shrub (Willow)
	2	0.23	0.24	0.25	-	0.23	White Spruce
A06	1	0.29	0.29	0.29	-	0.34	White Spruce/Balsam Poplar
A07	1	0.25	0.24	0.29	0.24	-	Black Spruce bog
	2	0.24	0.25	0.22	0.23	-	Black Spruce, north slope
	3	0.24	0.25	0.22	0.21	-	White Spruce, south slope
	4	0.26	0.25	0.23	0.30	-	Open Shrub/Bog (Willow)
A08	1	0.26	0.26	0.27	0.23	-	White Spruce
	2	0.26	0.29	0.25	0.23	-	Open Shrub (Willow)
	3	0.29	0.26	0.28	0.24	-	Open Shrub, sloped (Willow)
	4	0.26	0.27	0.23	0.29	-	Open Shrub, Sandy soil
A09	1	0.26	0.23	-	-	0.20	Birch, south slope
	2	0.22	0.23	-	-	0.27	Black Spruce/Larch bog
	3	0.22	0.23	-	-	0.21	White Spruce, hill base

L3_FT_A Validation and Error Assessment

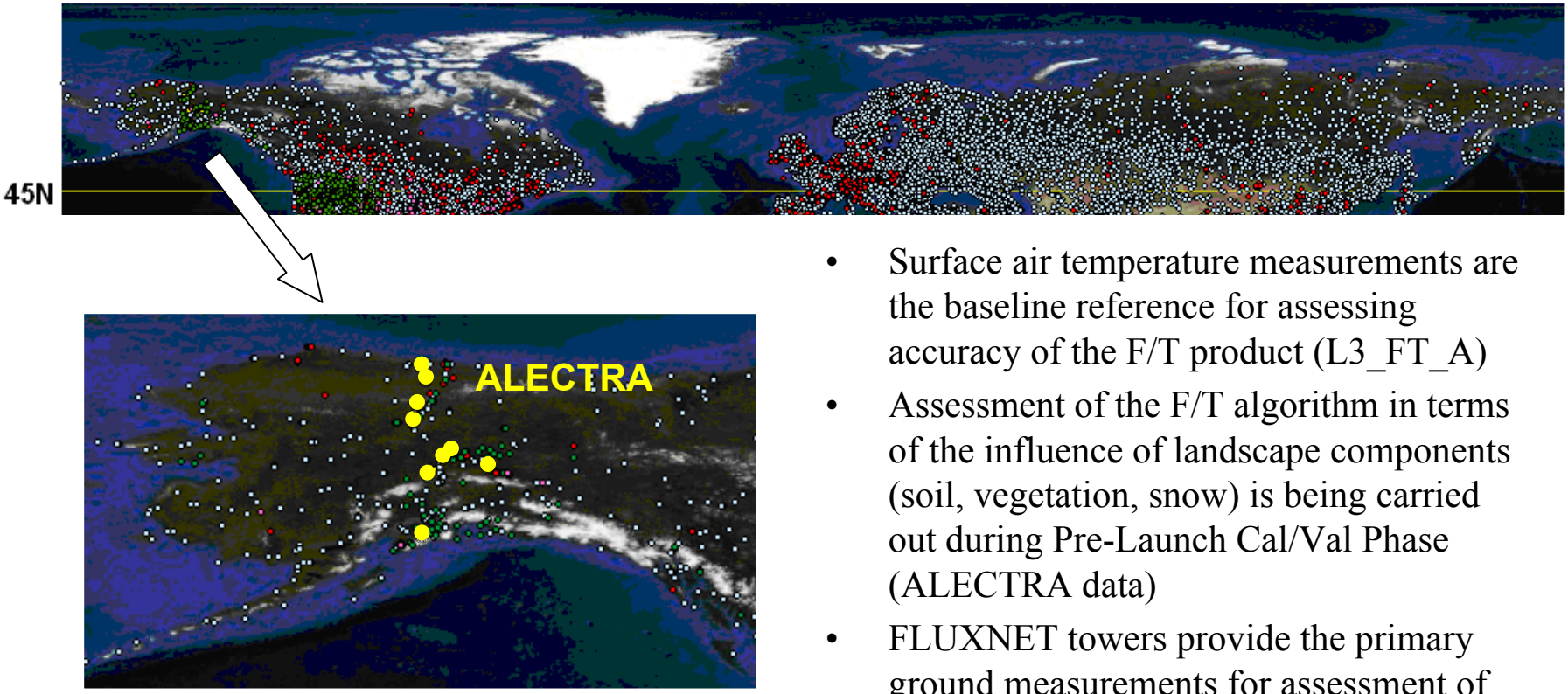
- **Focused studies over intensive sub-regions:**
  - Sub-grid scale terrain & land cover heterogeneity effects;
  - F/T sensitivity to individual landscape elements (snow, soil, vegetation);
  - Leverage planned NASA field campaigns involving synergistic measurements (CARVE, SMAP).
- **Comparisons with other synergistic datasets:**
  - Atm. CO_2 anomalies, Satellite based snow cover extent, GPP/NPP, NDVI & LST.



FT-ESDR Spring Thaw & [1]Snow Cover Extent Anomalies over Northern (>50ºN) Domain

[1]Source: D.A. Robinson (http://climate.rutgers.edu/snowcover)

In Situ Freeze-Thaw and NEE Resources



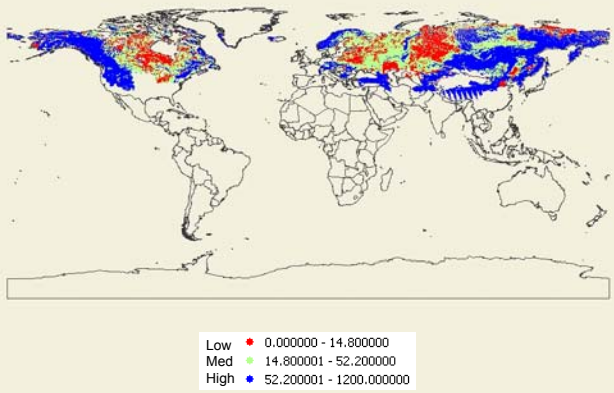
- Surface air temperature measurements are the baseline reference for assessing accuracy of the F/T product (L3_FT_A)
- Assessment of the F/T algorithm in terms of the influence of landscape components (soil, vegetation, snow) is being carried out during Pre-Launch Cal/Val Phase (ALECTRA data)
- FLUXNET towers provide the primary ground measurements for assessment of the NEE product (L4_C)

World Meteorological Organization's (WMO) global meteorological observation station network (the white dots) with ALECTRA, USDA-SCAN, NRCS-SNOTEL, FLUXNET networks.

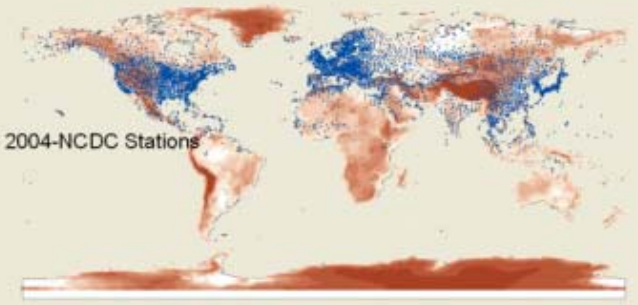
Post-launch: L3_F/T Validation using WMO Global Station Networks

- **Assumes T_a is effective surrogate for F/T & land cover & terrain primarily influence microclimate variability within grid cell;**
- **Numerous (>3700) sample sites; standardized global data collection/formatting; widely available, low cost & low latency;**
- **Limited array of measurement variables.**

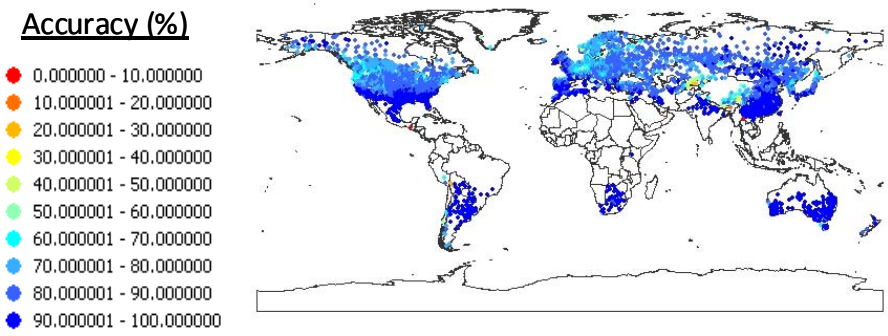
Terrain Heterogeneity within 25km grid cell



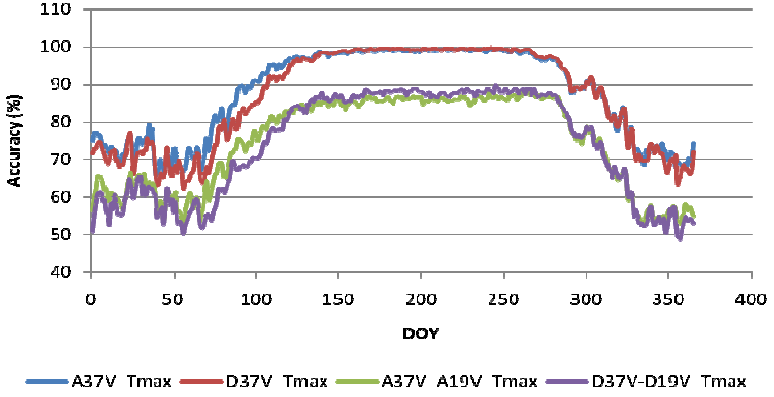
Global WMO Station Network



2004 SSM/I A37V and Tavg; NCDC=3,733 sites

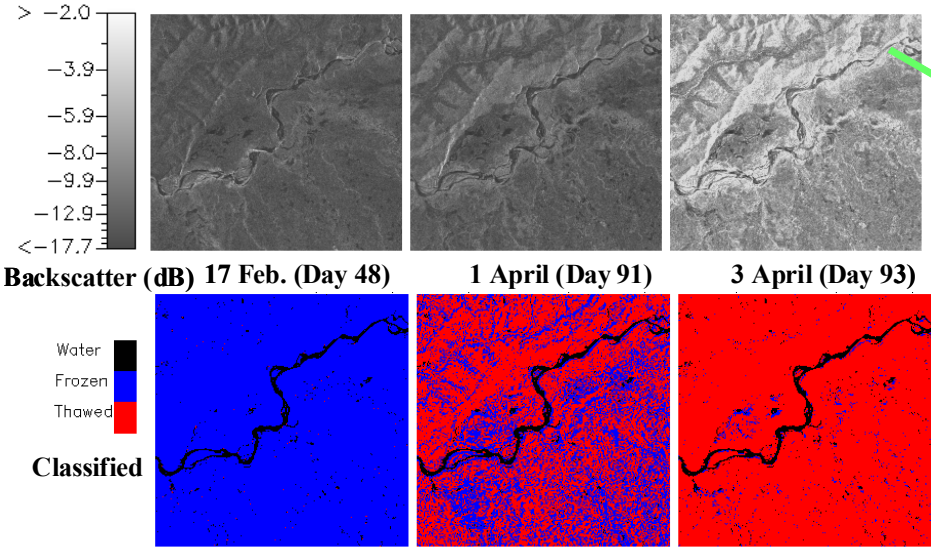


Mean daily F/T classification accuracy (2004 SSM/I, STA) relative to Tmax from 3,733 WMO stations

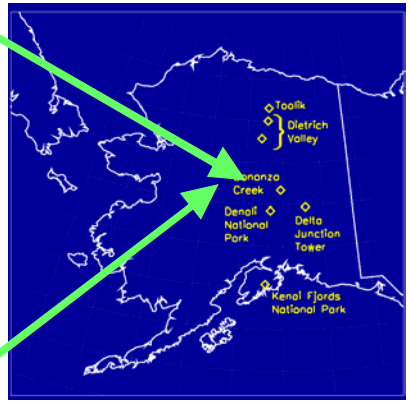


Post-launch: L3_F/T validation using other biophysical station networks

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

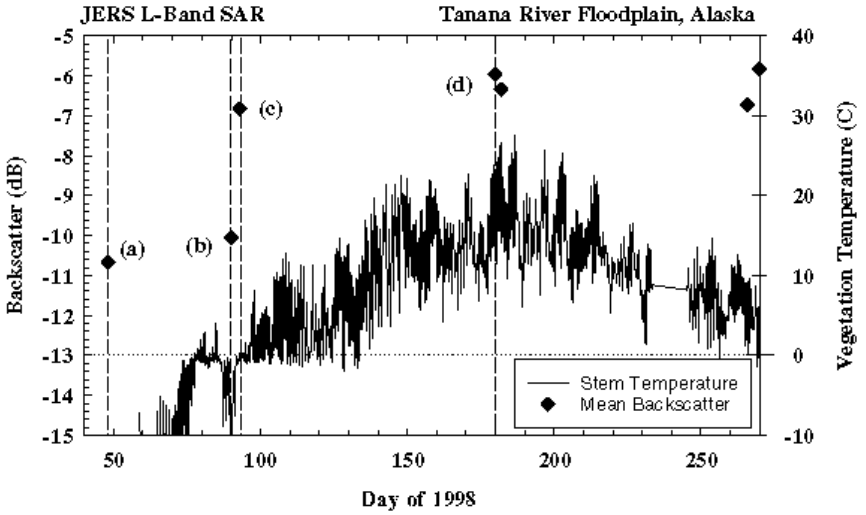


Bonanza Creek-Alaska



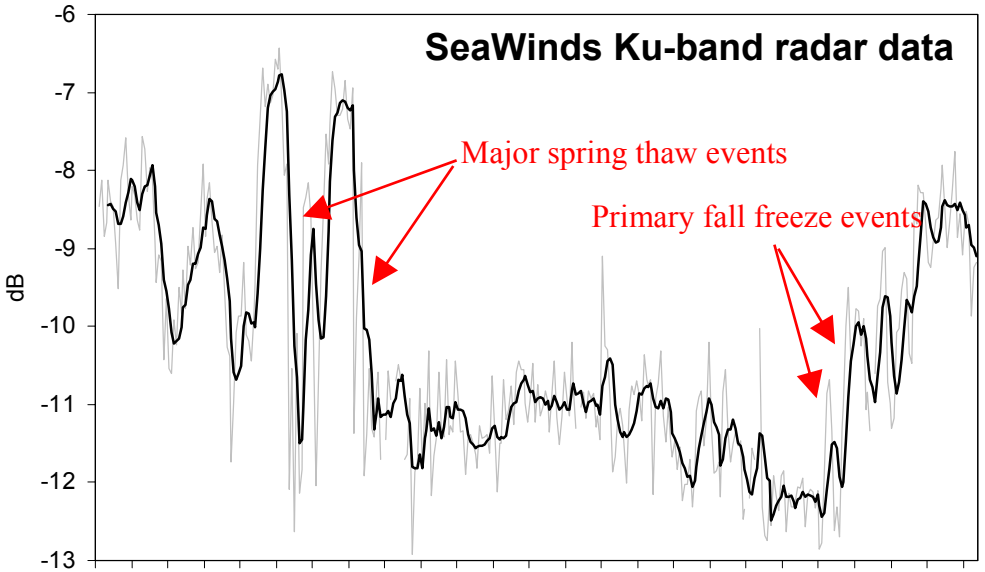
Validation with *in situ* Biophysical Measurements

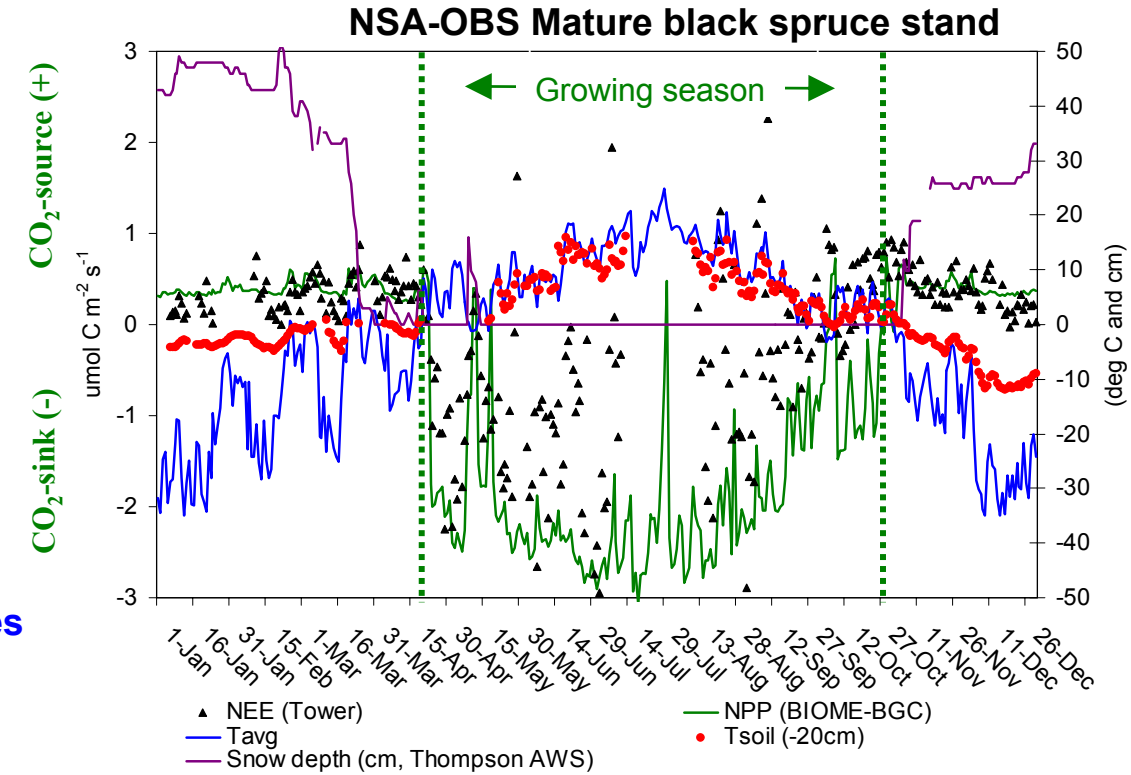
L-band backscatter increases with thaw



Post-launch: L3_F/T validation using FLUXNET

Verify F/T accuracy and Carbon linkages





L3_FT_A: Currently Ongoing

- Continue L3_FT algorithm global implementation and testing using available microwave RS inputs (AMSR-E, SeaWinds);

- Continue transition to algorithm testing using L-band radar inputs from PALSAR and SDS Testbed.

- Global calibration/optimization of L3_FT parameters (L-band dB reference states, dB dynamic ranges);

- Develop L3_FT mask for areas where accuracy requirements can be met;

- Continue to mature the L3_F/T ATBD

- Upcoming Canada field campaigns (FT scaling properties; landscape heterogeneity, open water and vegetation biomass impacts)

- Coordination with CARVE mission.