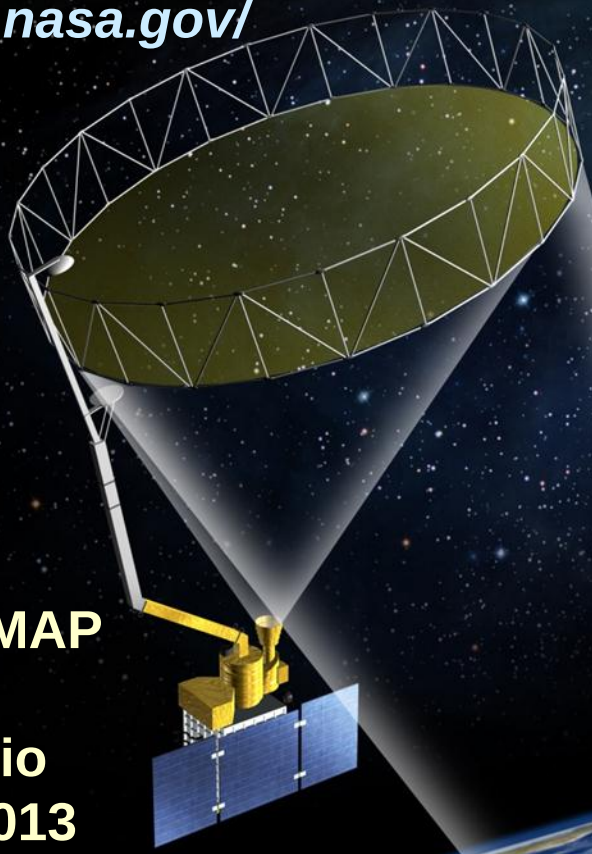
http://smap.jpl.nasa.gov/

Soil Moisture Active Passive Mission



SMAP Freeze-Thaw Cal/Val

Kyle McDonald

CUNY Environmental Crossroads Initiative and CREST Institute
The City College of the City University of New York

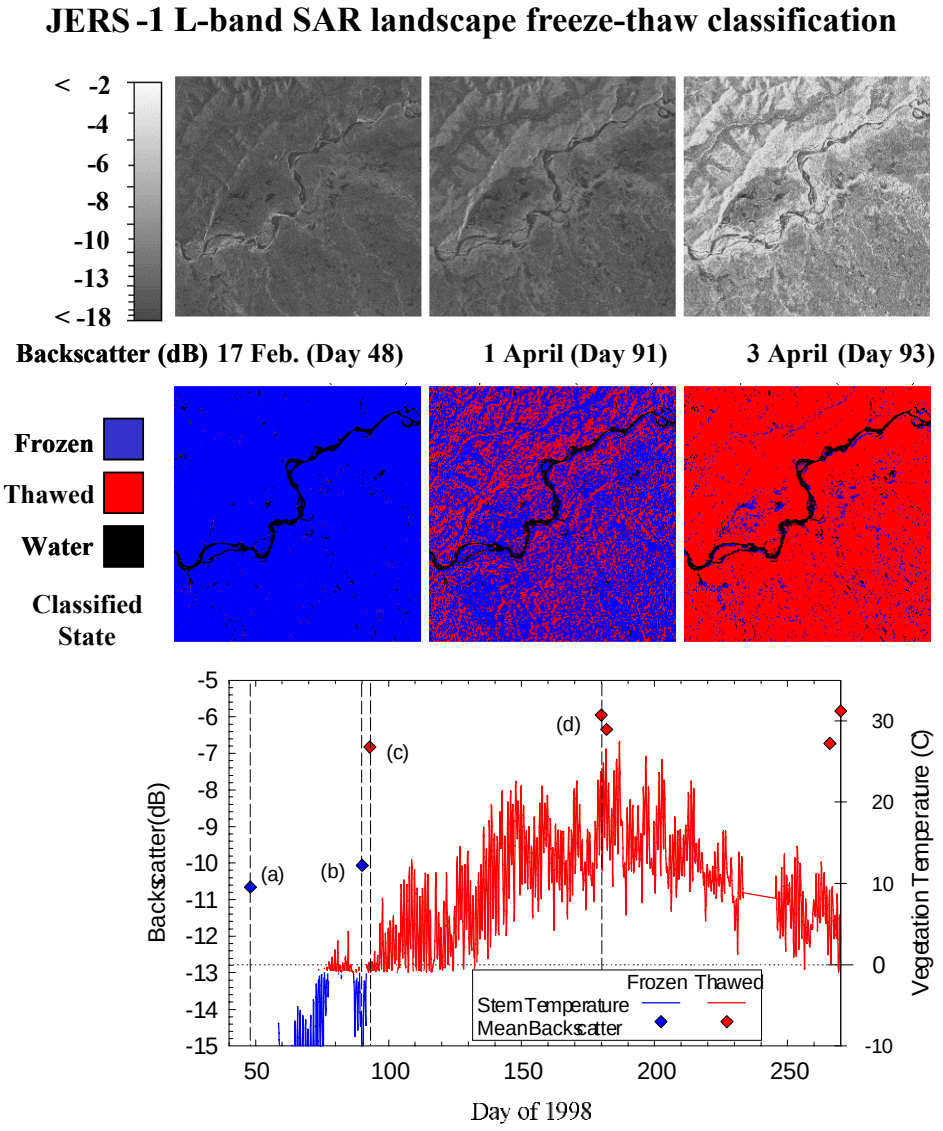
3rd Canadian SMAP Workshop
Ottawa, Ontario
March 20-21, 2013

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)

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

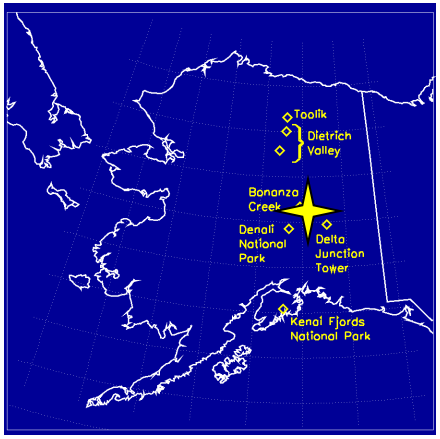
σ^0_{th} = thawed reference

T = threshold

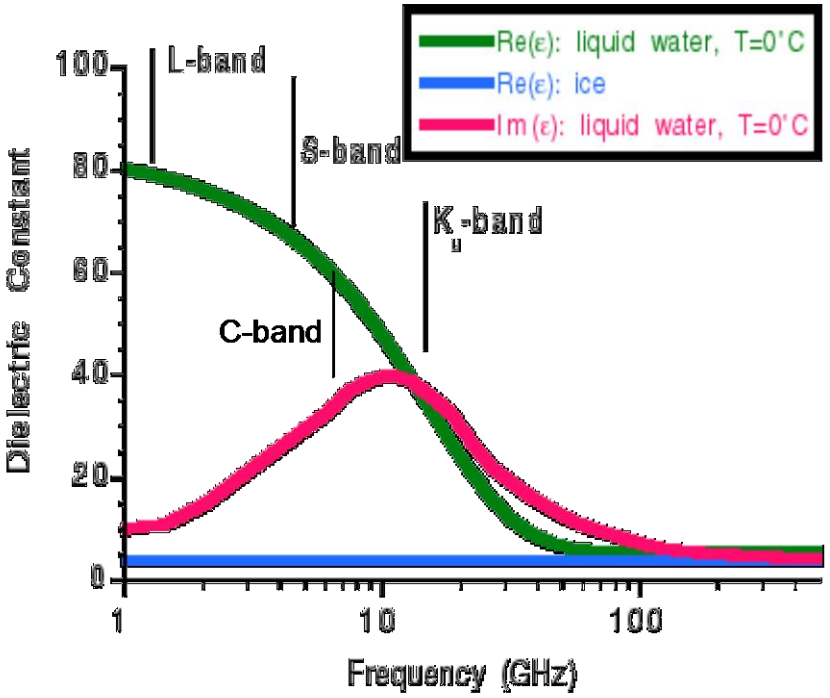
$\Delta(t) > T$ (Thawed)

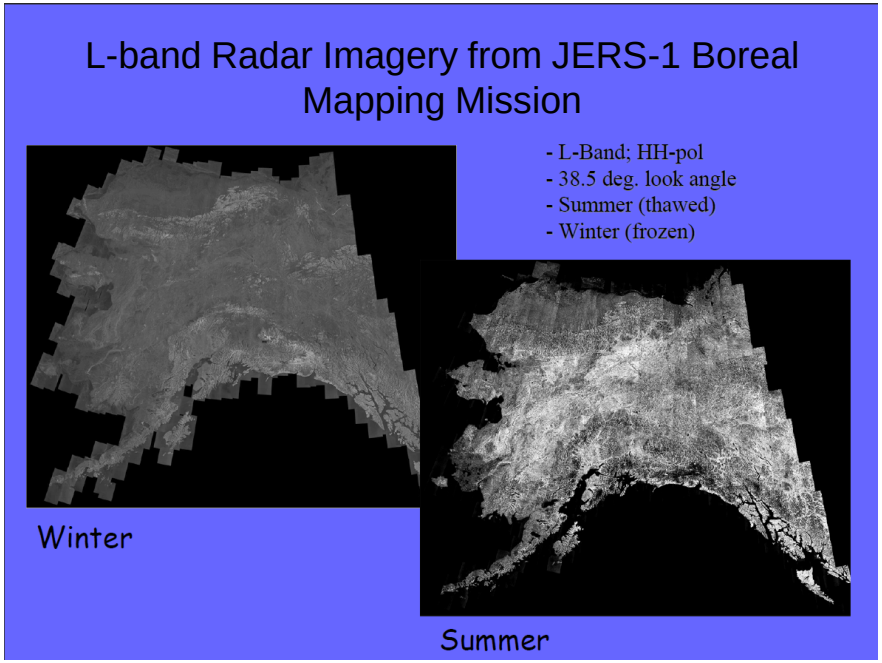
$\Delta(t) \leq T$ (Frozen)

Comparison with in situ data



Microwave-Based Freeze/Thaw Classifications

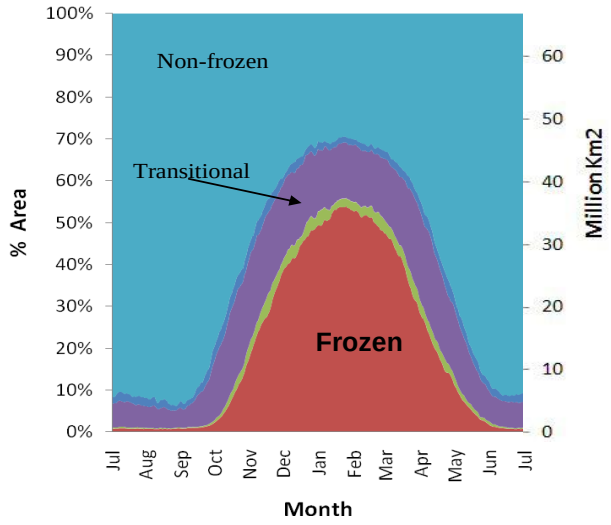




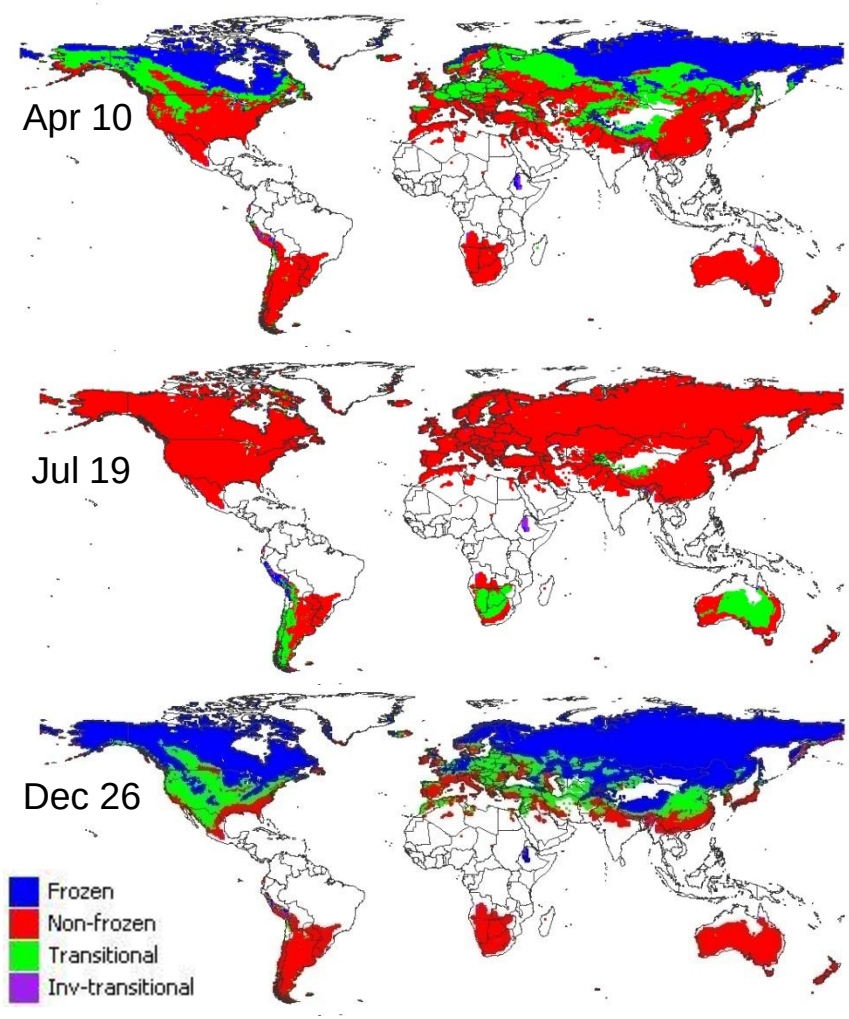
L3_FT_A Combined AM+PM Product Prototype

- **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

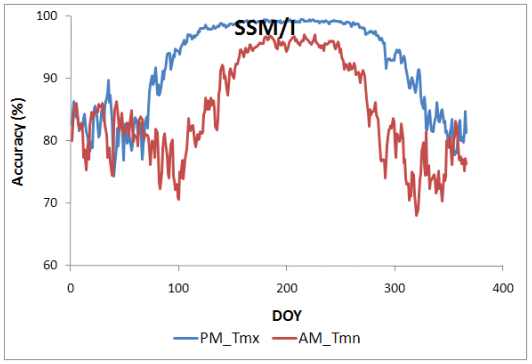


Source: http://freezethaw.ntsg.umt.edu

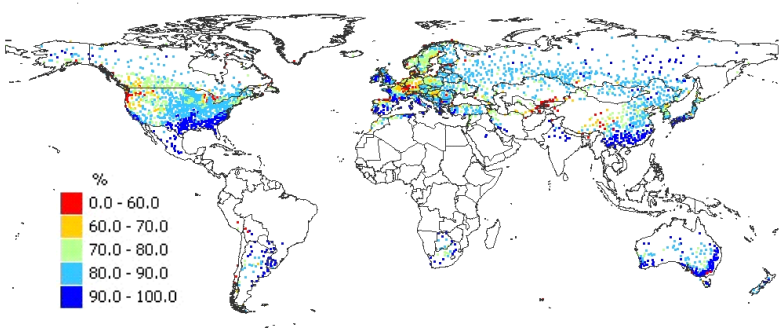
L3_FT_A Validation and Error Assessment

Global Comparisons with WMO Daily Air Temperature Observations

Mean Daily Accuracy

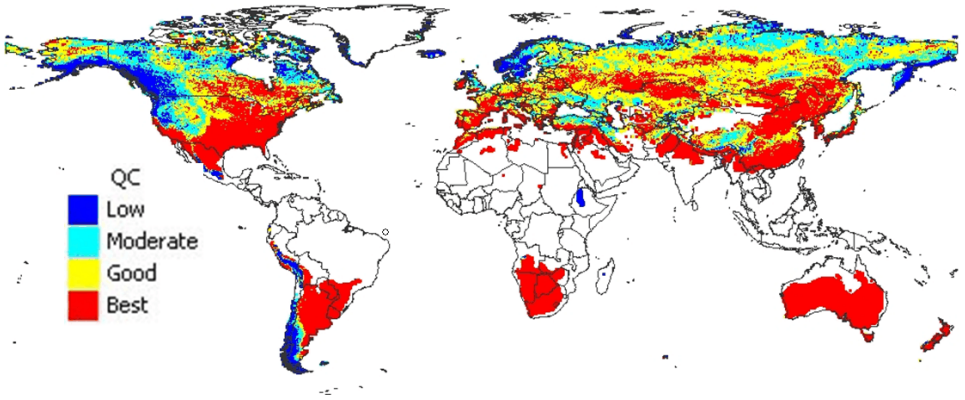


Mean Annual Accuracy



Source: Kim et al. 2010. *TGARS*

Spatially Explicit Quality Assessment



Truth \ Retrieved	Thawed	Frozen
Thawed	Correct Thawed	False Frozen Detections
Frozen	Missed Frozen Detections	Correct Frozen

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

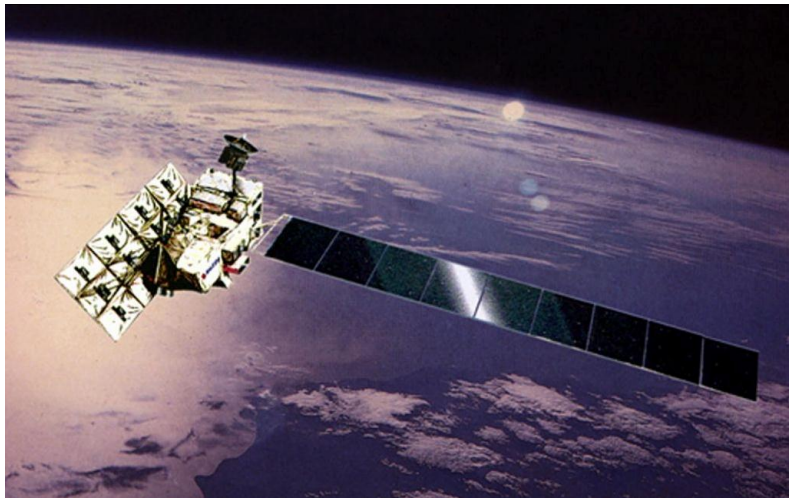
SMAP Radar Prototyping Activities

L3_F/T Prototype datasets:

- **ALOS PALSAR (L-band)**
  - **HH- and HV Pol Fine Beam Data**
  - **HH-pol ScanSAR**
  - **Global-scale, systematic obervations**
- **SSM/I, AMSR-E, QuikSCAT**
- **Aquarius, SMOS (L-band)**

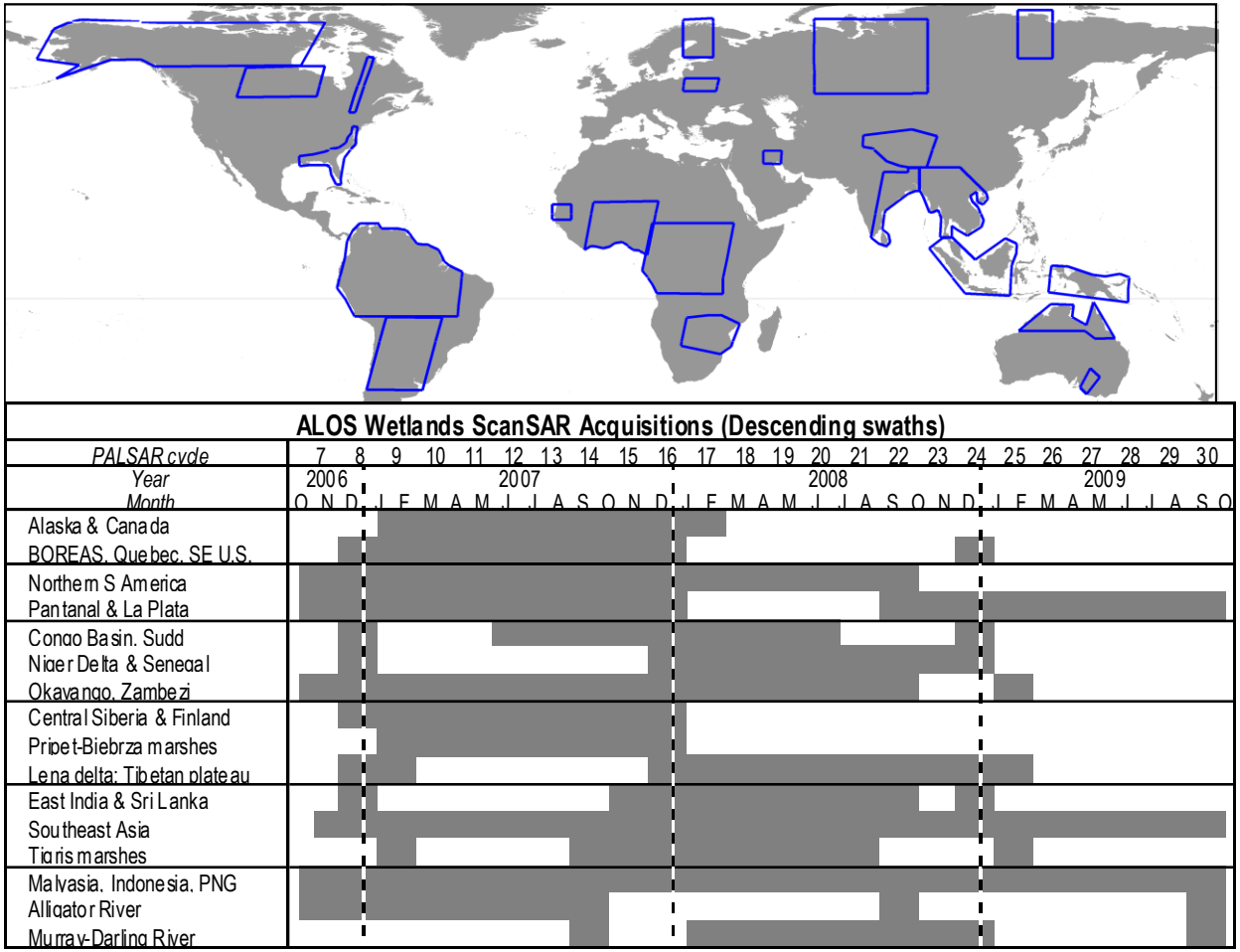
JAXA ALOS Kyoto and Carbon Initiative

- 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

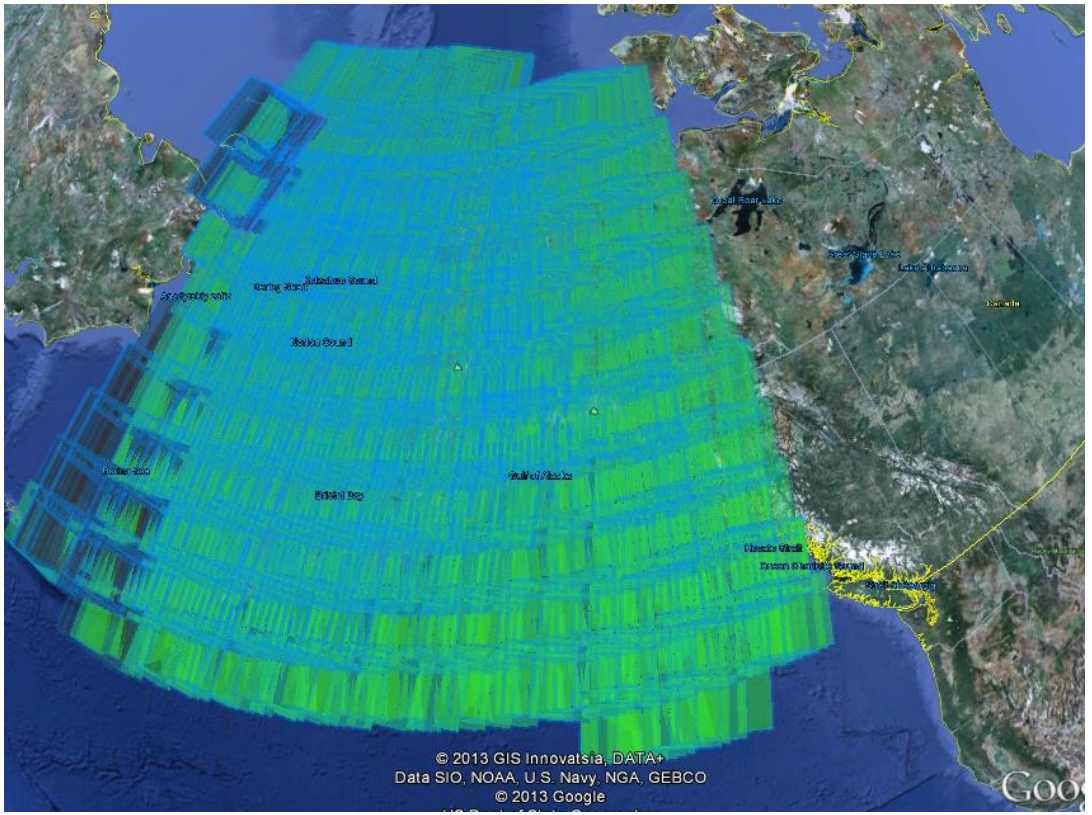
- Multi-temporal ScanSAR HH-pol data collected for key ecoregions, targeting wetlands.
- Systematic acquisition plan developed by K&C Science Team
- Global Fine-Beam dual pol (HH & HV) data collected.
- Processing at ASF supports expanding time series data in Boreal North Ameica.



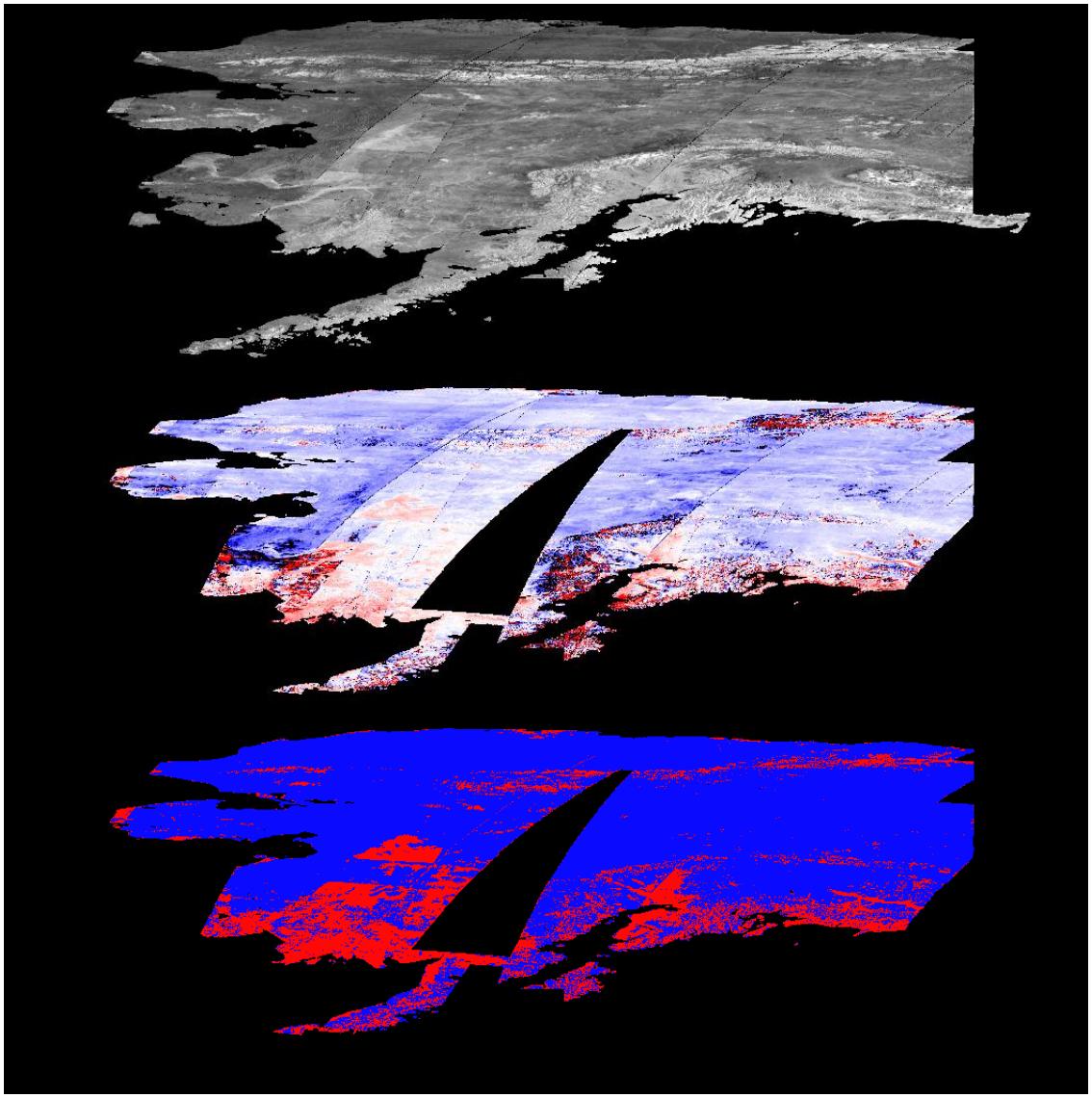
PALSAR ScanSAR data coverage over Alaska

About 4400 scenes from 2006/10 to 2011/04.

Each ScanSAR image is about 400km x 380 km and has a wide range of incidence angle variation (18 ° to 42°).



PALSAR Freeze-Thaw Retrieval



ALOS PALSAR Oct 2010
w/40° incidence angle correction

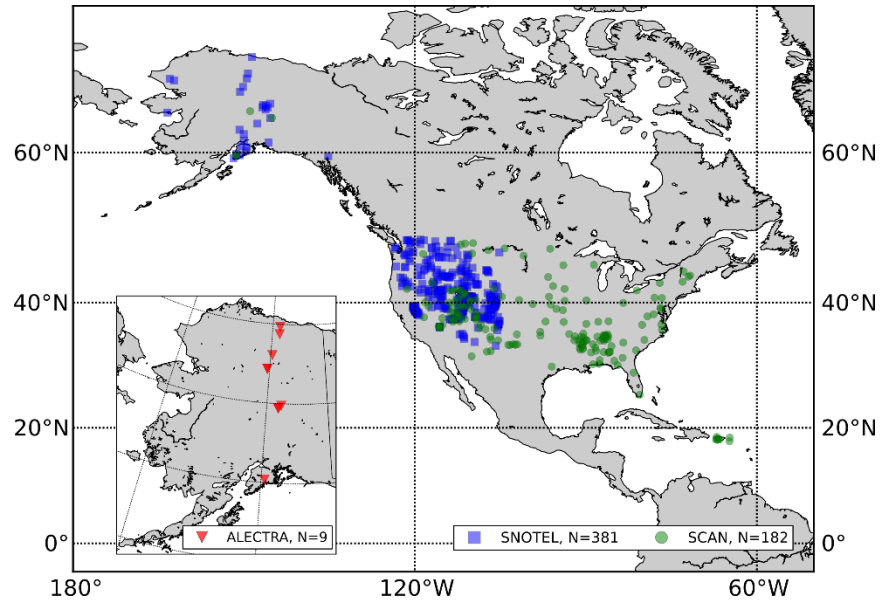
HH sigma0 @ 3km grid

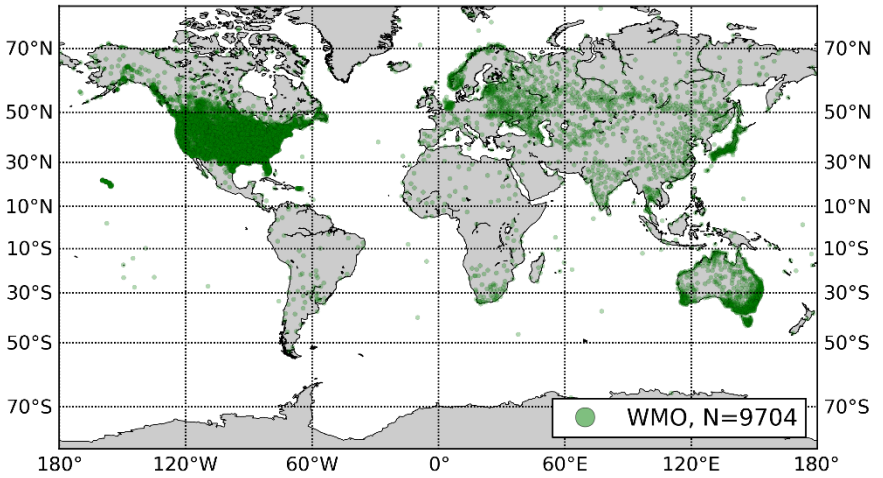
Change-detection parameter

$$\Delta(t) = \frac{\sigma(t) - \sigma_{fr}}{\sigma_{th} - \sigma_{fr}}$$

Freeze-thaw retrieval using threshold of $\Delta = 0.5$

F/T Ground Validation Sites



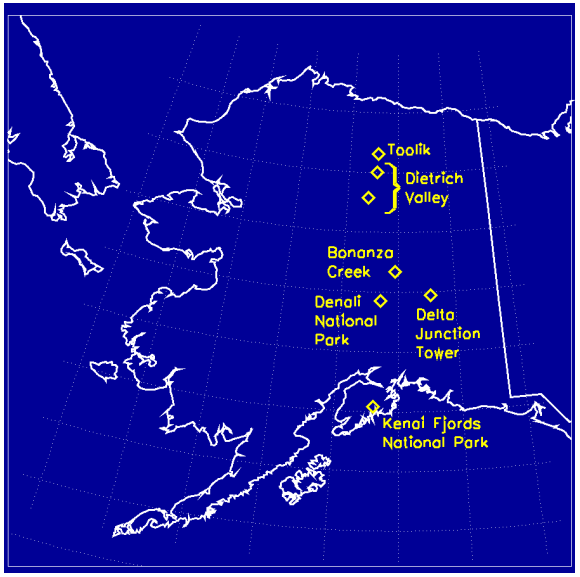


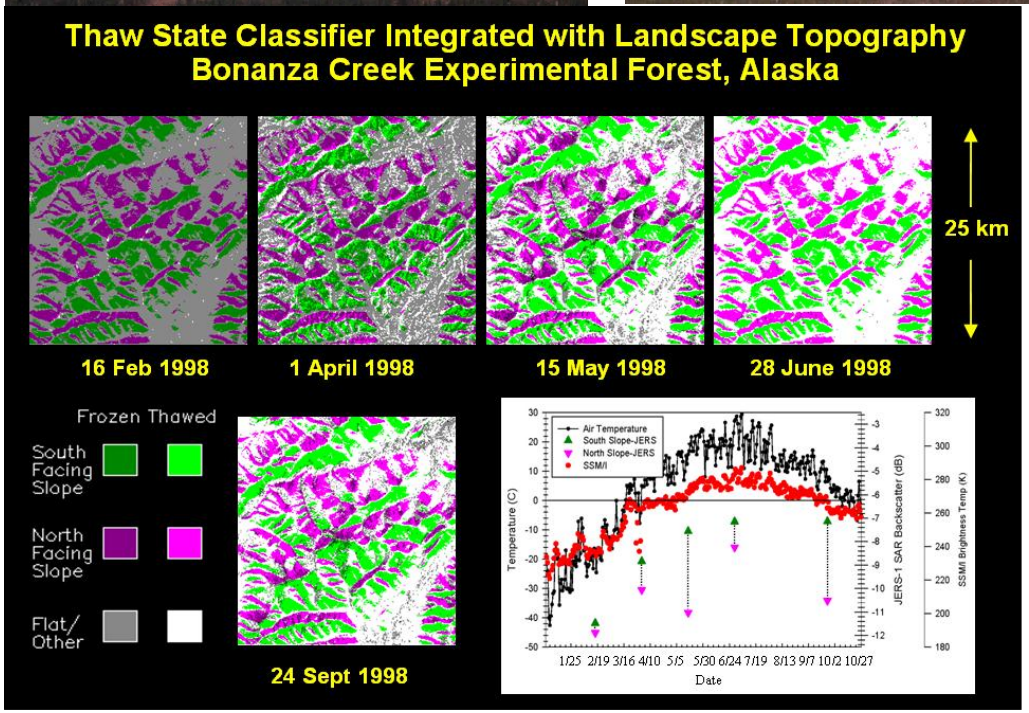
Planned Freeze/Thaw Ground Validation Sites

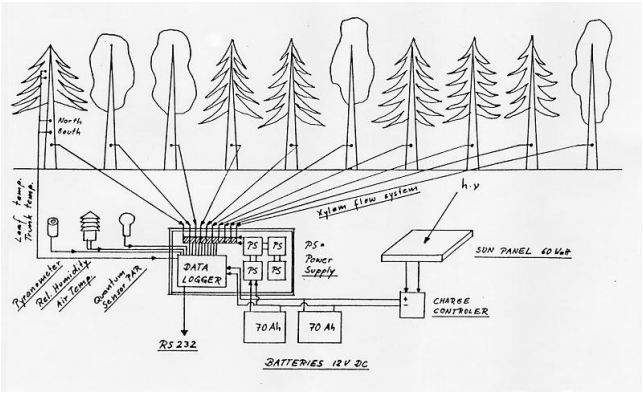
- Stations Networks with Air ***and*** Soil Temperature Measurements
  - SNOTEL/SCAN
  - ALECTRA
- Station Networks with ***only*** Air Temperature
  - WMO

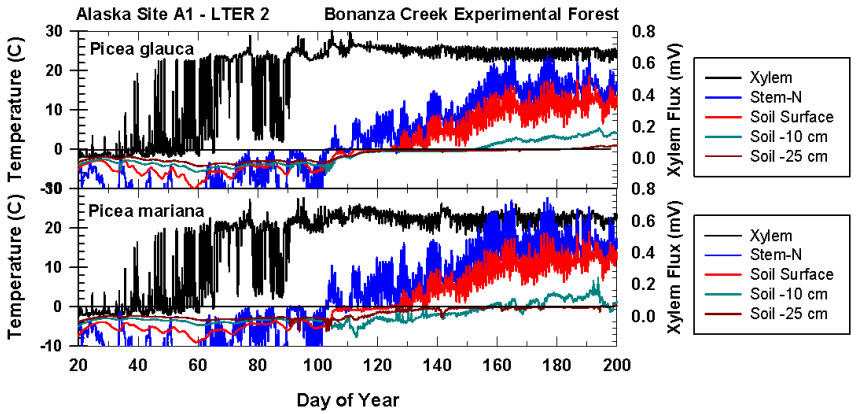
Alaska Ecological Transect (ALECTRA)

Similar Stations are in place or planned in Colorado, California, Europe, Africa









Biophysical Monitoring Stations (ALECTRA)

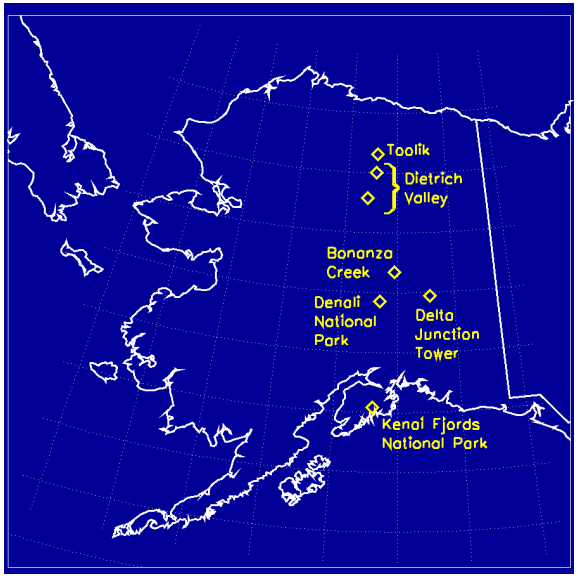
Bonanza Creek Experimental Forest
- Floodplain session forest
- Black spruce bog

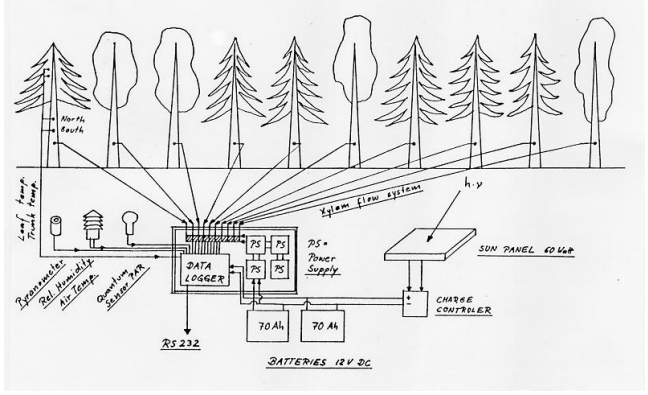
Caribou Poker Creek Experimental Watershed
- Tree line
- South Slope mixed boreal forest

Dietrich Valley
- Northern tree line/tundra transition
- Black spruce bog & north facing slope

North Slope
- Frankilin Bluff (Wet tundra)
- Sagwon (dry tundra)

Kenai
- Cool coastal mixed spruce forest





Biophysical Monitoring Stations

Colorado:

Fraser Experimental Forest, upper montaine mixed conifer forest

San Bernardino, CA:

Montaine Mediterranean mixed conifer forest

Germany:

Au Am Rhein floodplain, mature old growth oak-ash floodplain forest

Northern Black Forest

mixed conifer

young poplar

Bayreuth – young floodplan forest (5 species)

Turkey:

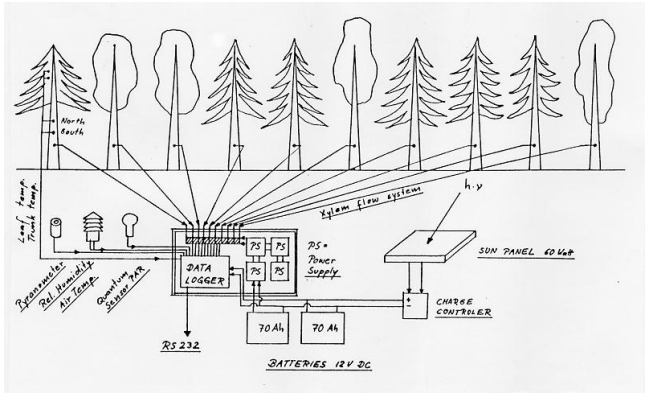
Southwest Anatolia, Mature mountainous forest with Lebanon Cedar

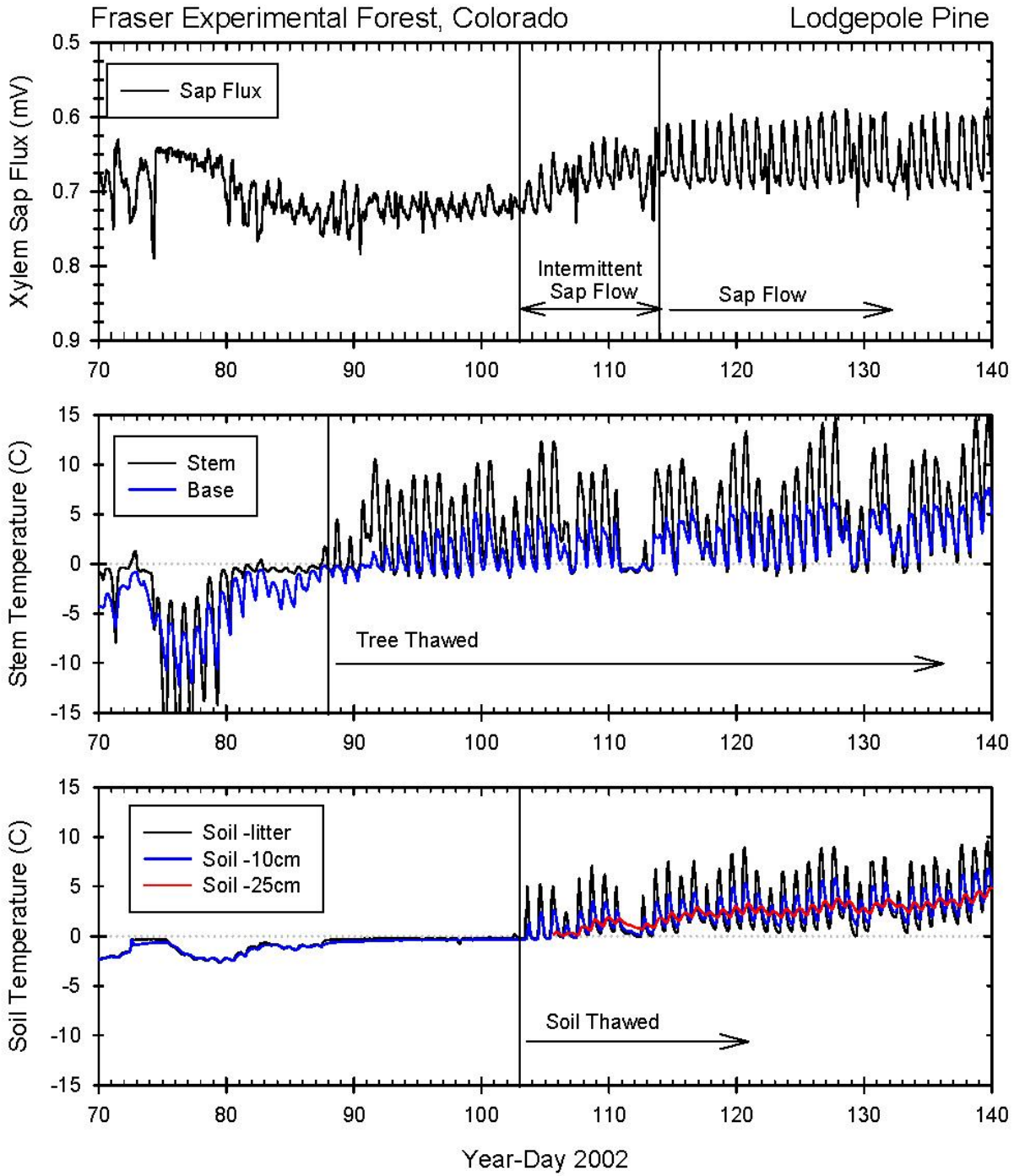
Africa (planned February 2013):

Tanzania: Tree line forest

Peru:

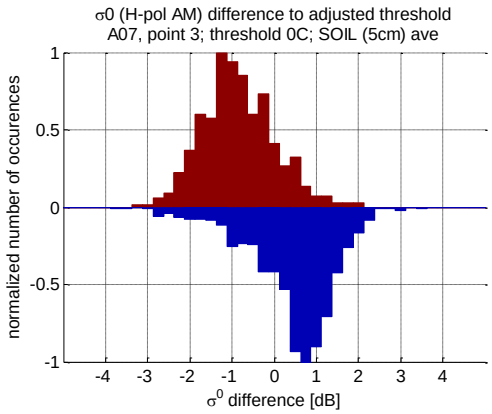
Central Andes Mountains: Balla Auraura, upper montaine forest (3600 meters)



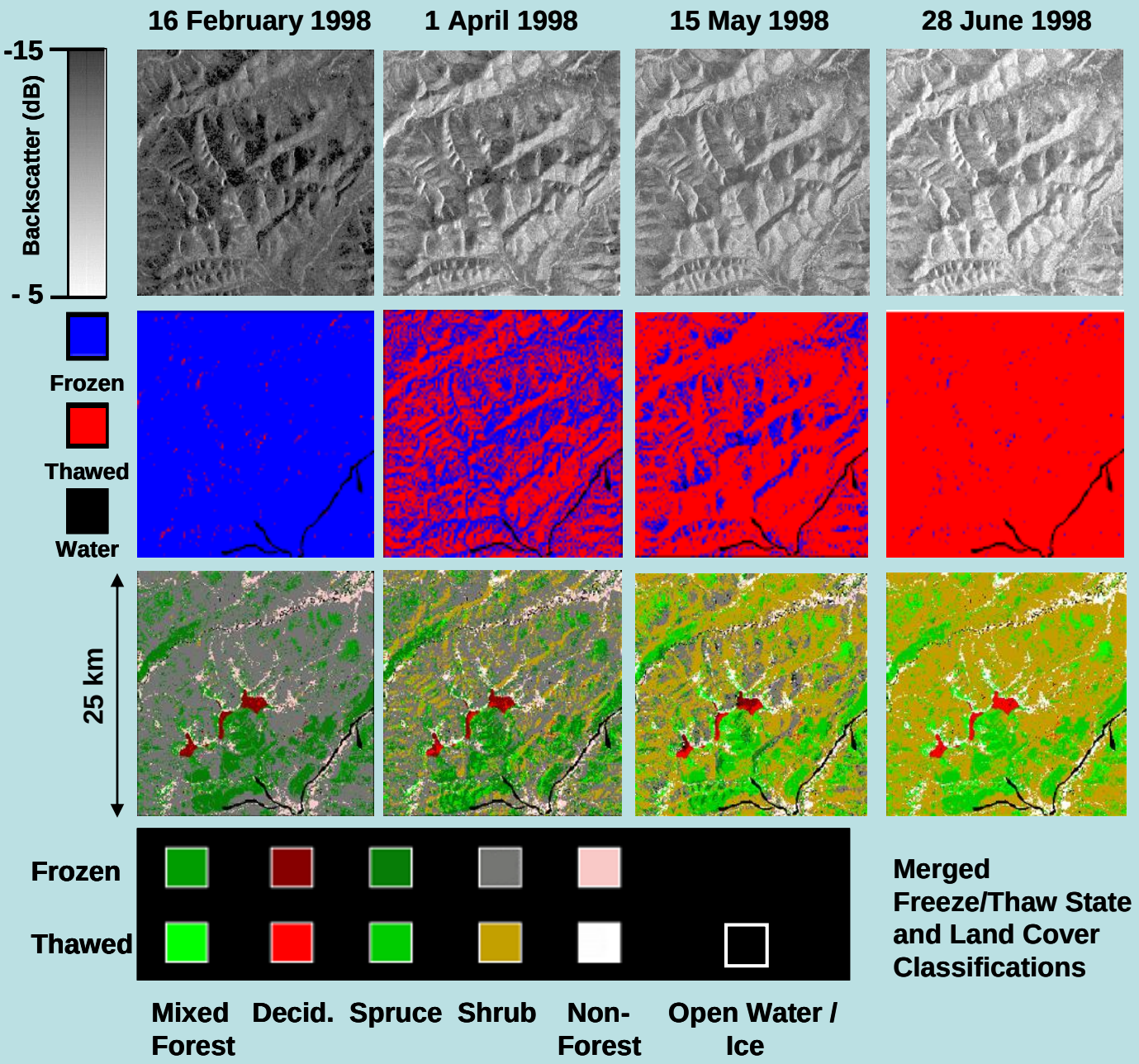

Fraser Experimental Forest, Colorado
Lodgepole Pine
Xylem Sap Flux (mV)
Sap Flux
Intermittent Sap Flow
Sap Flow
Stem Temperature (C)
Stem
Base
Tree Thawed
Soil Temperature (C)
Soil -litter
Soil -10cm
Soil -25cm
Soil Thawed
Year-Day 2002

L3_FT_A: ALECTRA and QuikSCAT

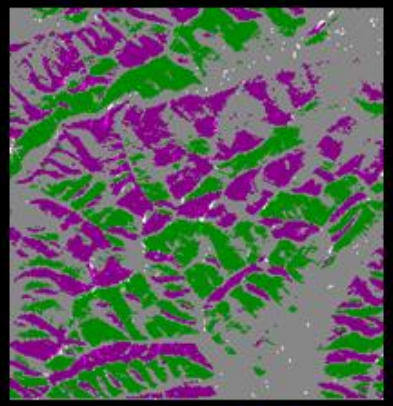
- QuikSCAT backscatter analyzed vs. ALECTRA biophysical network
- Sophisticated ALECTRA data valuable for the planning efforts
- Study indicates the most significant landscape components for explaining QuikSCAT backscatter changes
- Results vary with terrain and land cover conditions which may have implications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



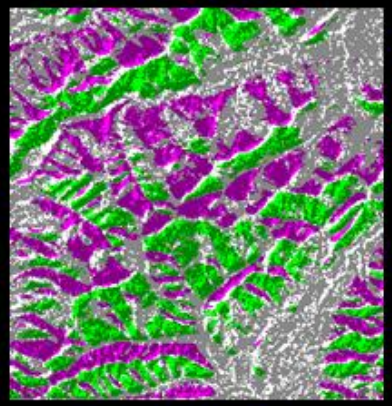
ST.	SUB	AIR	STEM	BRANCH	SOIL-5	SOIL-10	Type
A01	1	0.23	0.22	0.24	-	0.30	White Spruce
	2	0.25	0.24	-	-	0.31	Black Spruce
	3	-	0.24	-	-	0.24	Poplar
	4	0.29	0.26	0.25	-	0.23	Alder Shrub
A04	1	0.18	0.17	0.16	-	0.25	Sitka Spruce/Poplar
	2	0.17	0.14	0.16	0.21	-	Alder
A05	1	0.26	0.24	-	-	0.37	Open Shrub (Willow)
	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


JERS-1 SAR derived F/T classification, Bonanza Creek AK
16 February 1998
1 April 1998
15 May 1998
28 June 1998
-15
Backscatter (dB)
- 5
Frozen
Thawed
Water
25 km
Frozen
Thawed
Mixed Forest
Decid.
Spruce
Shrub
Non-Forest
Open Water / Ice
Merged Freeze/Thaw State and Land Cover Classifications

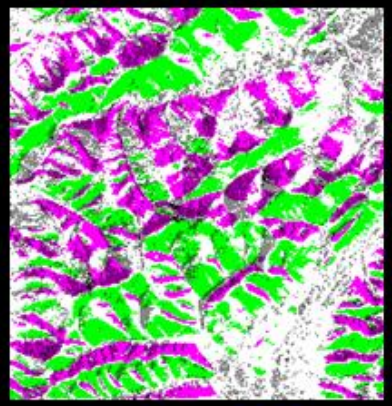
Thaw State Classifier Integrated with Landscape Topography
Bonanza Creek Experimental Forest, Alaska



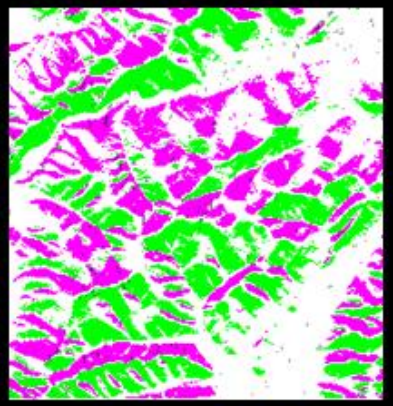
16 Feb 1998



1 April 1998



15 May 1998



28 June 1998

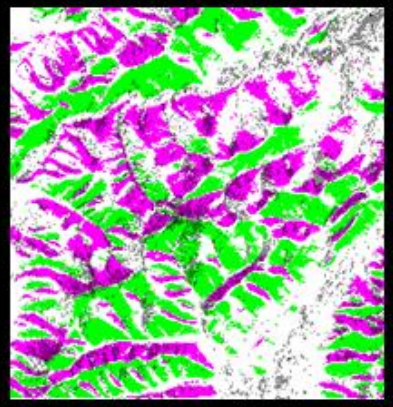
25 km

Frozen Thawed

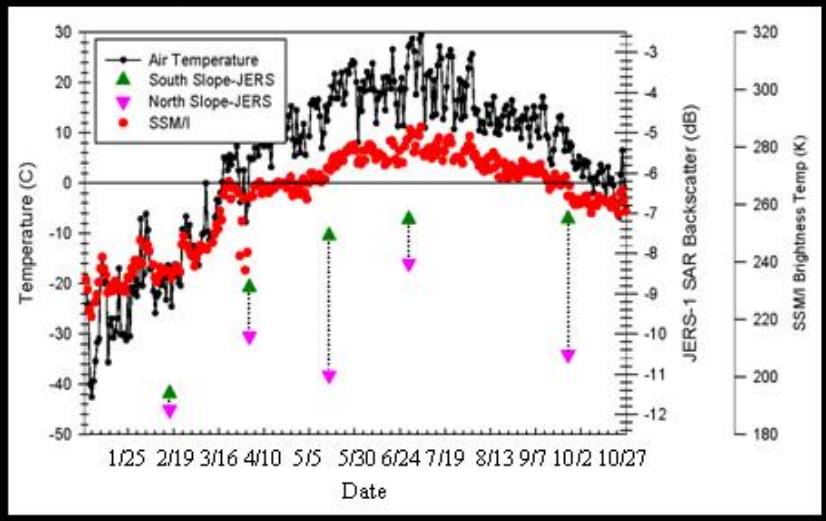
South Facing Slope

North Facing Slope

Flat/ Other

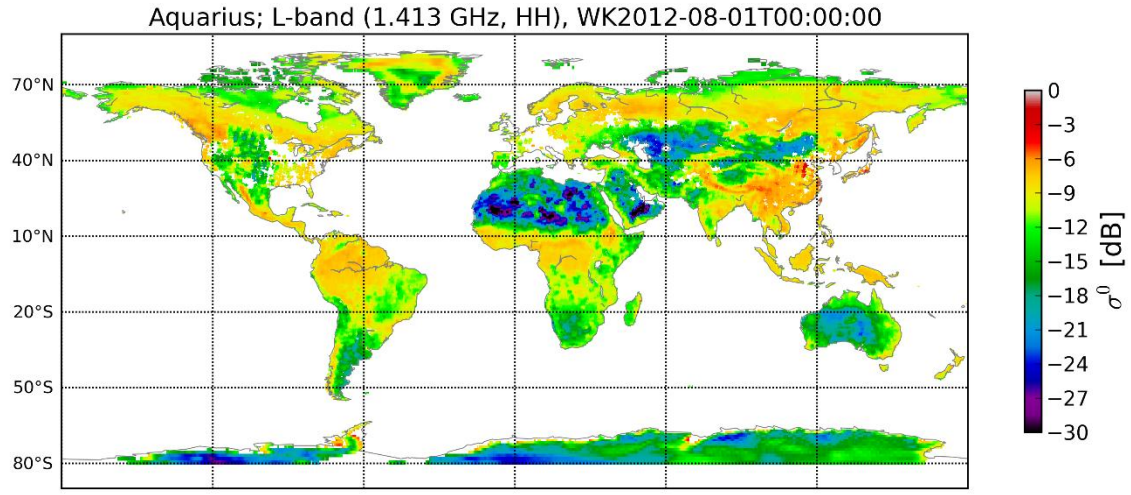


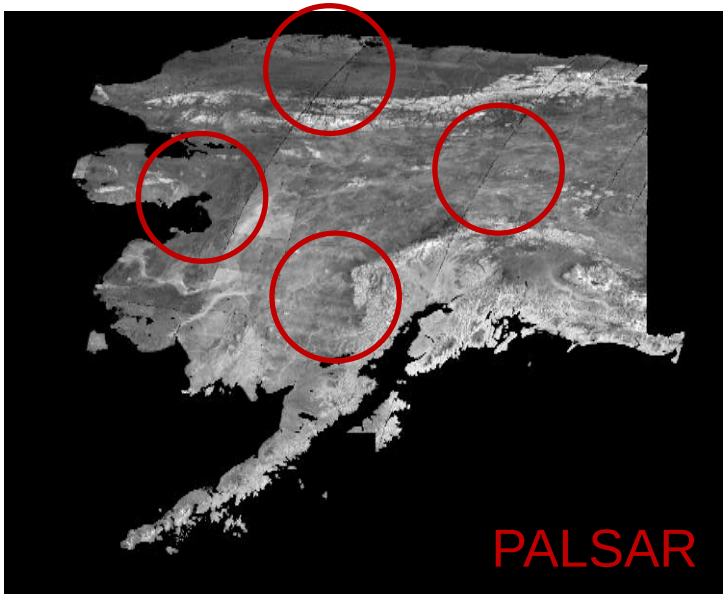
24 Sept 1998



Aquarius and PALSAR

Seasonal variation of L-band backscatter for different land cover types in four regions of Alaska

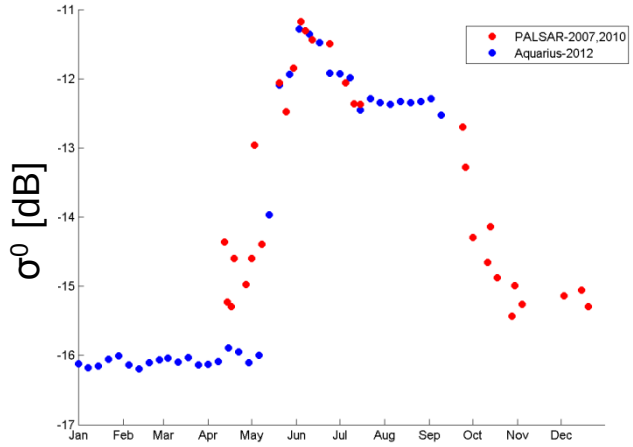




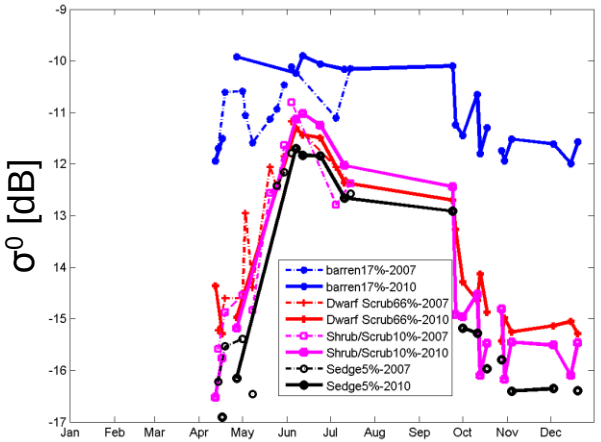
Aquarius and PALSAR

Site I: North Slope

PALSAR and Aquarius

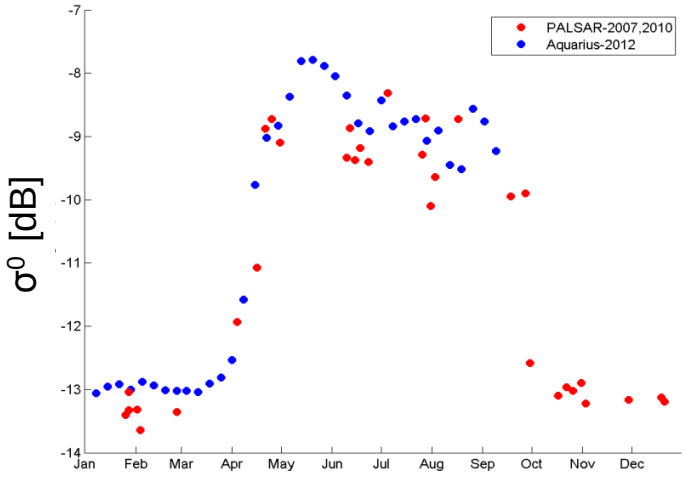


PALSAR – Dominant Landcover Types

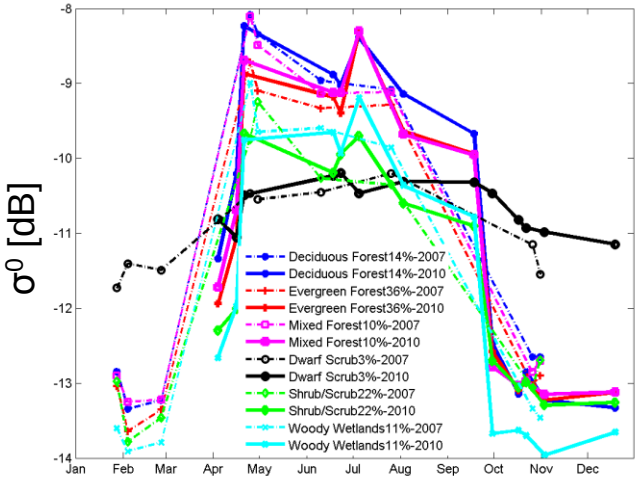


Site II: Interior Alaska

PALSAR and Aquarius



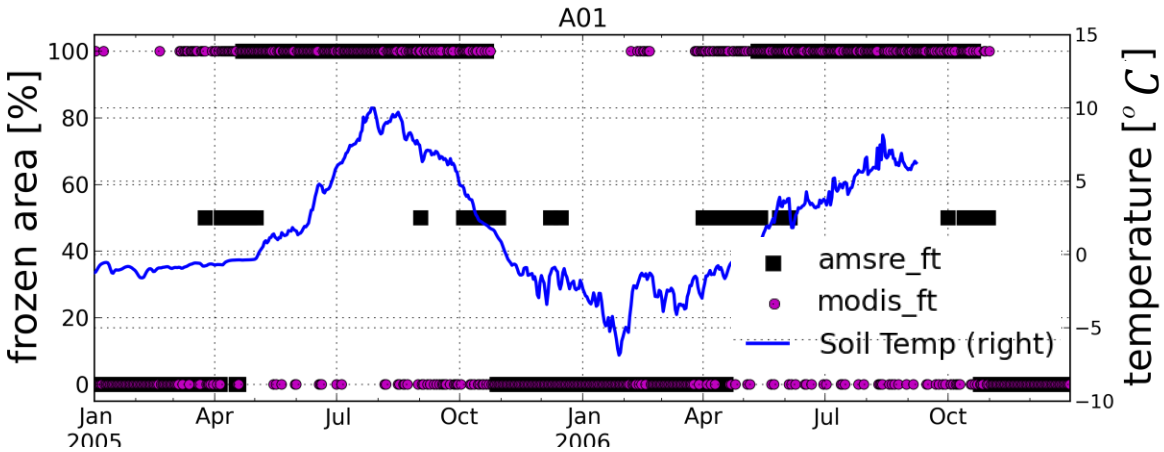
PALSAR – Dominant Landcover Types

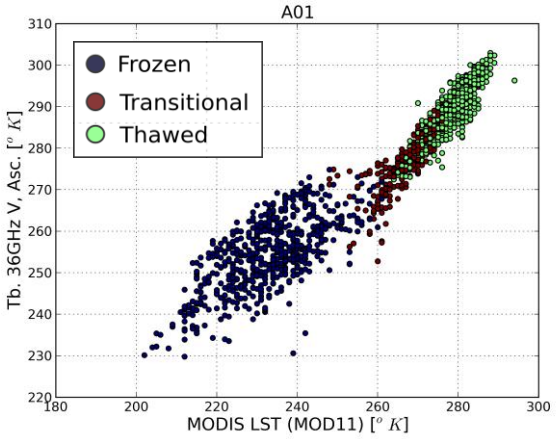


MODIS LST and AMSR-e F/T

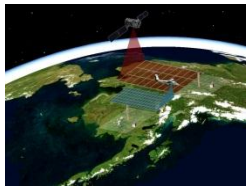
Jet Propulsion Laboratory
California Institute of Technology

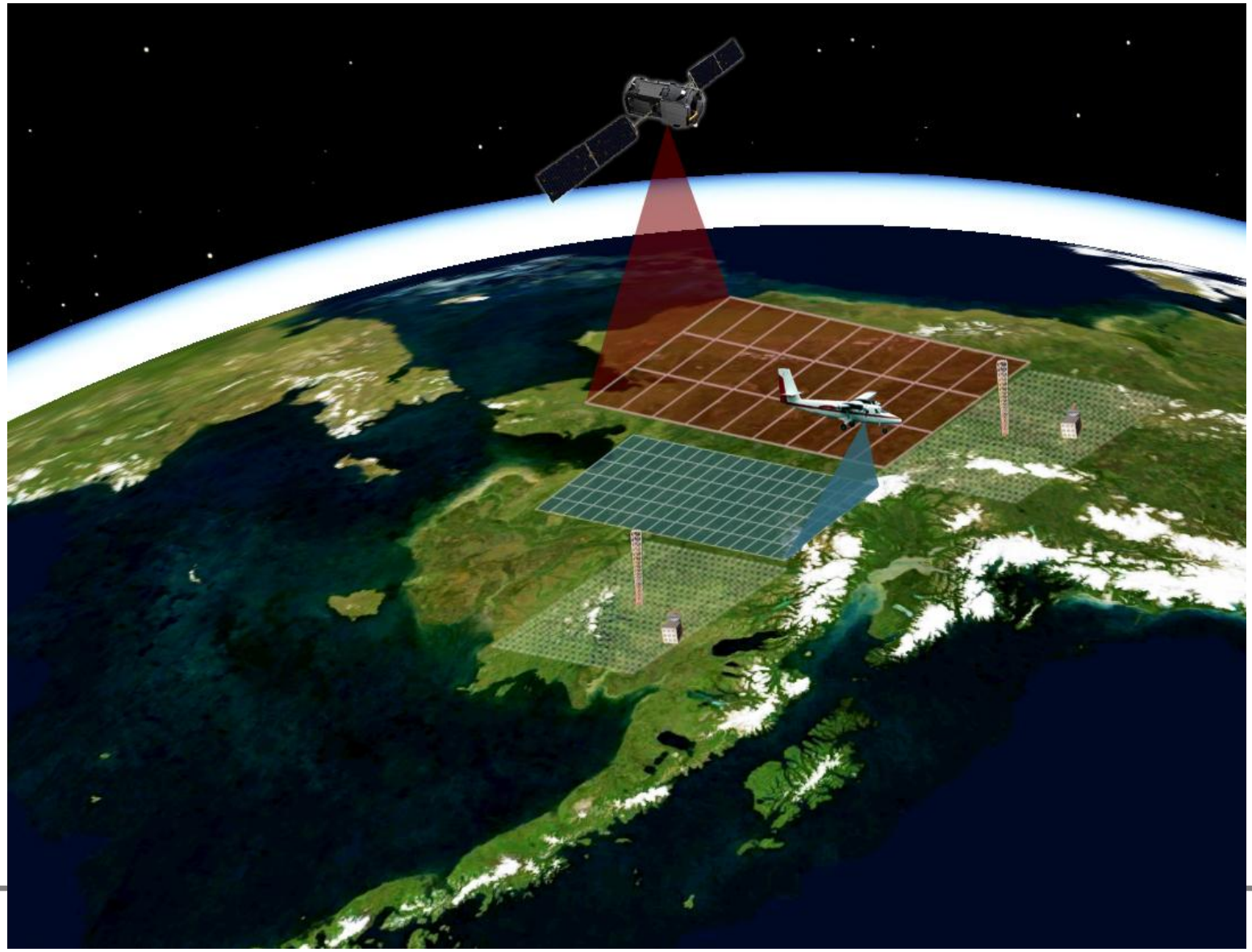
	AMSR-e F/T and MODIS LST			InSitu Soil F/T and MODIS LST		
Station	Agreement [%]	N	MODIS Threshold [deg.K]	Agreement [%]	N	MODIS Threshold [deg.K]
Toolik	91.31%	2419	265	91.82%	3168	278
Sagwon	92.48%	2275	263	86.47%	2751	275
Coldfoot (958)	92.77%	1952	266	85.47%	1977	270
Bonanza Creek (A01)	96.08%	1481	270	86.52%	1893	276



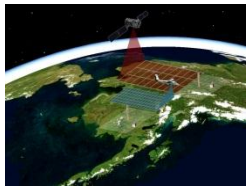


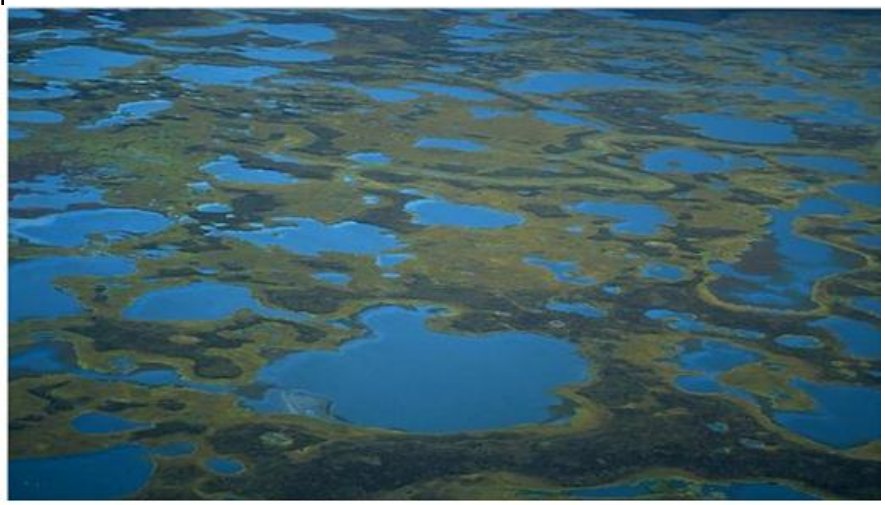
CARVE: Carbon In Arctic Reservoirs Vulnerability Experiment

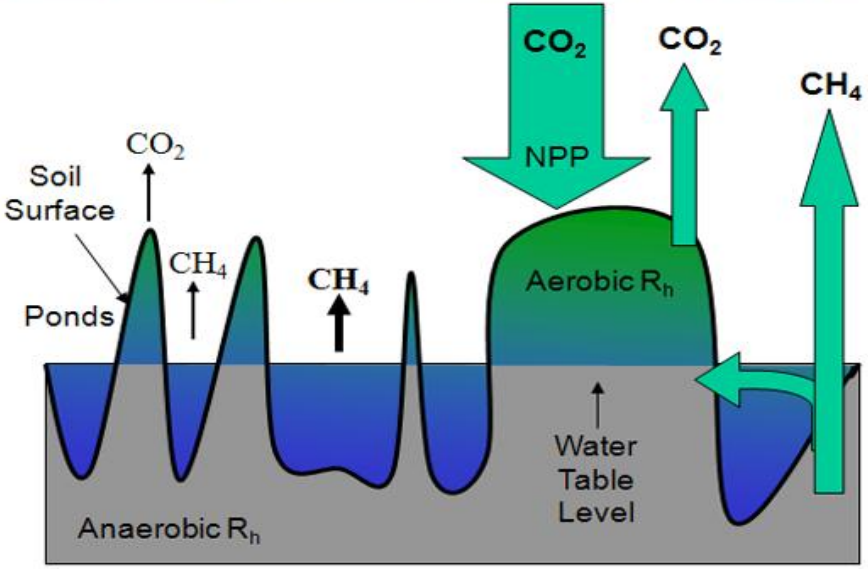


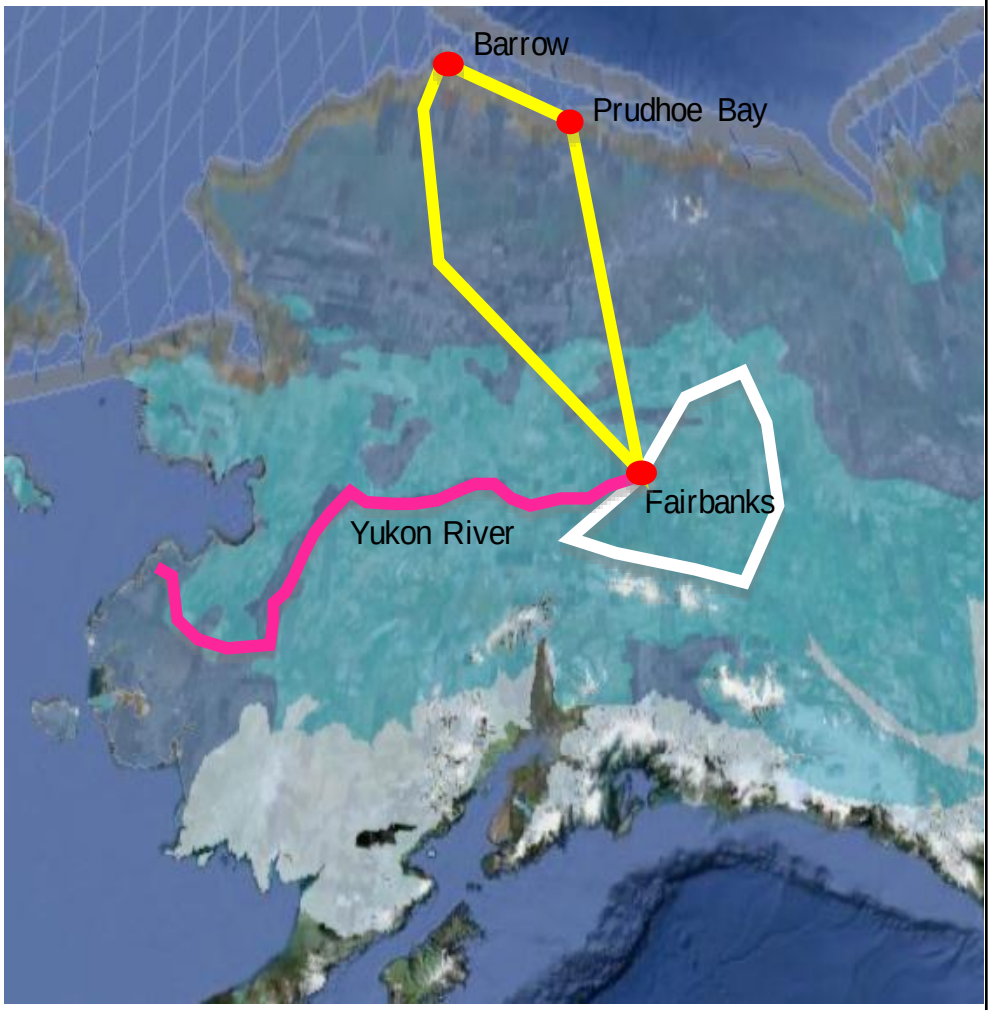


The CARVE Science Investigation



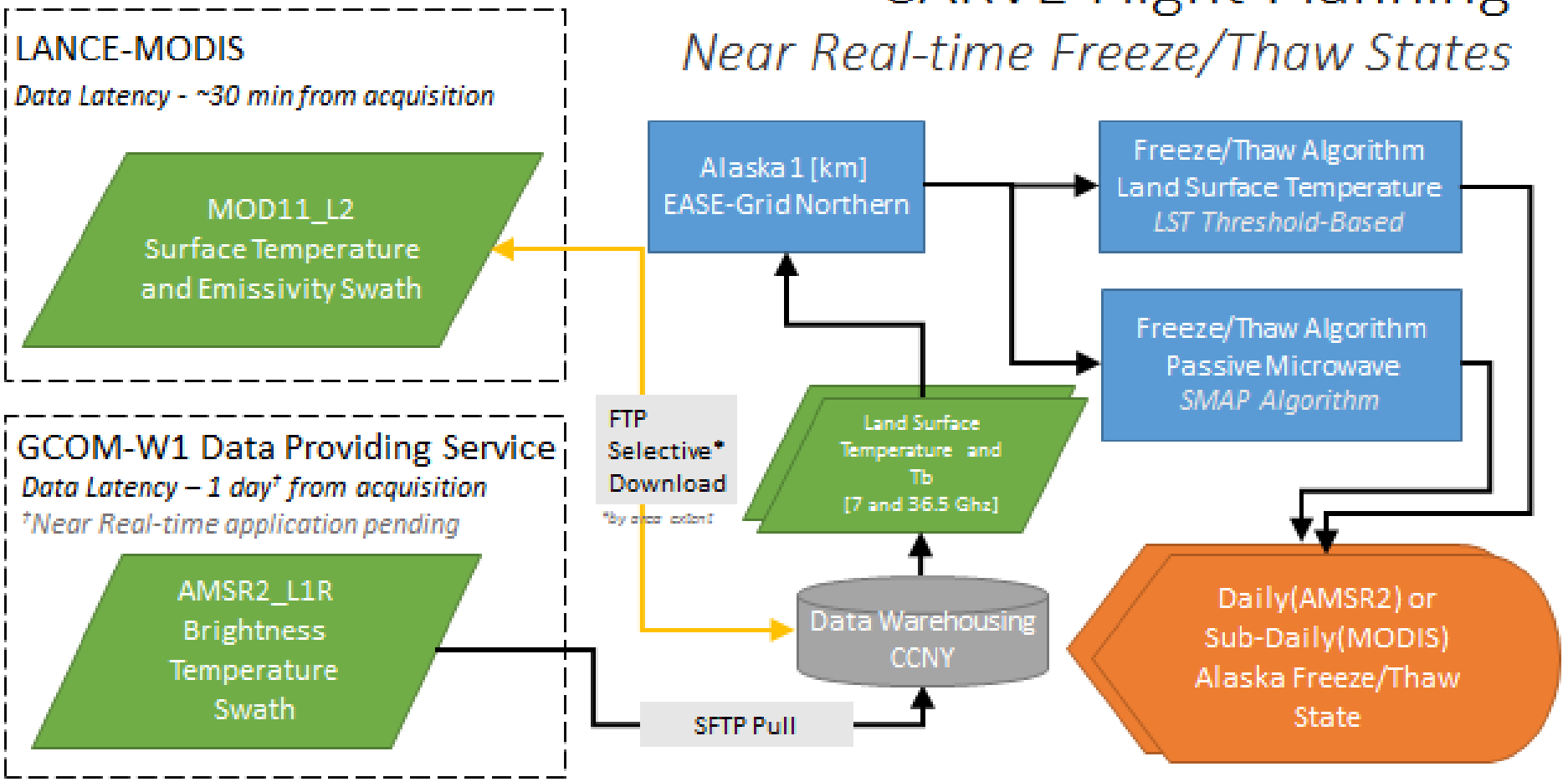






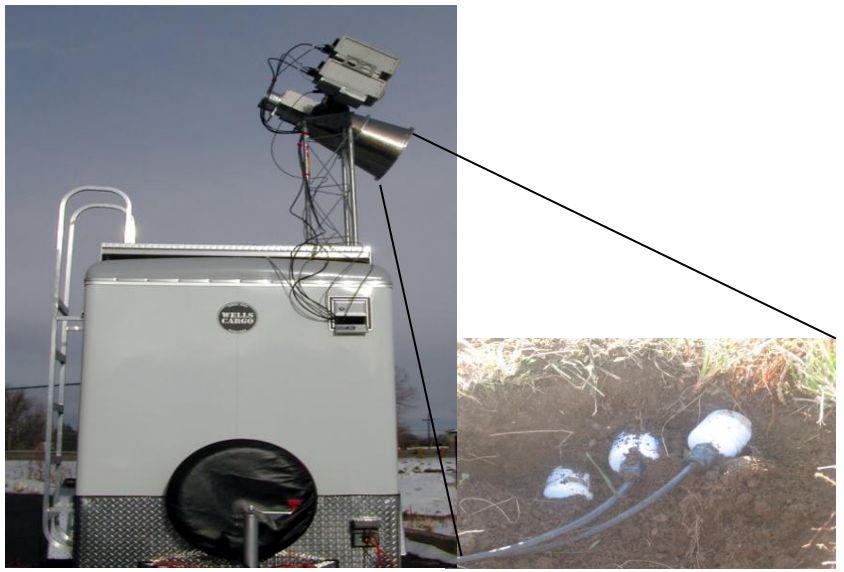
CARVE Flight Planning

Near Real-time Freeze/Thaw States



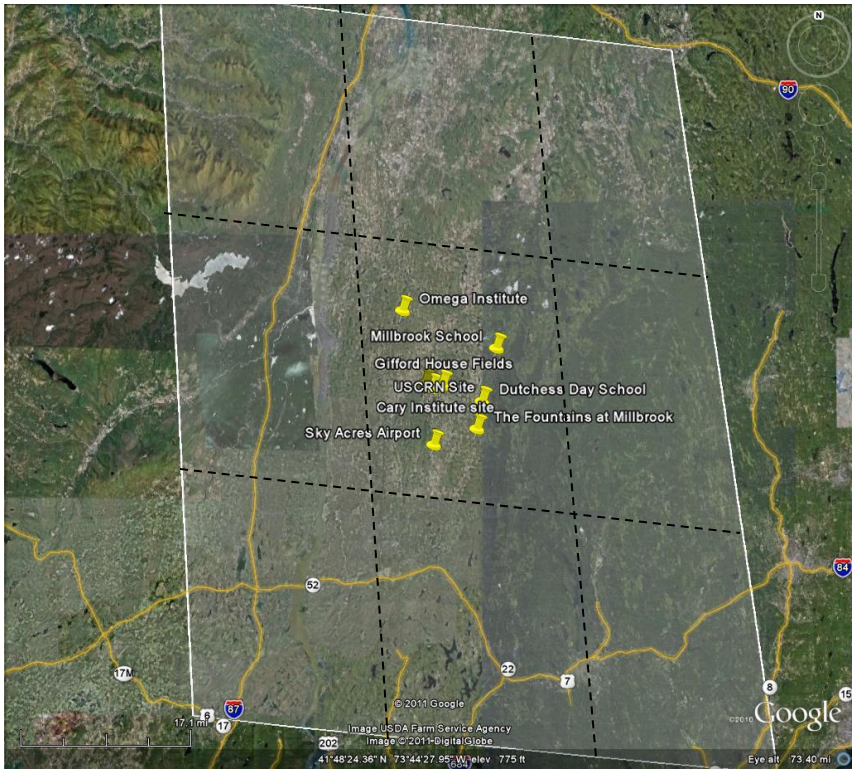
Site Description

- Type of site
  - Single point evolving to core site level (minimum of 7 points; 6 probes per point)
- Measurements provided
  - L band brightness temperature (as well as 37 and 89 GHz readings)
  - Soil moisture at 2.5, 5 and 10 cm; Sensors used: Stevens Digital Hydra Probe II
  - Freeze/Thaw
  - NDVI
  - Precipitation
  - Air temperature
  - Streamflow
  - Gravimetric soil moisture



Network spatial distribution

	Site	Location	Description	Soil moisture observation	Freeze/thaw observations
Operational	Cary Institute	Lat:41 deg 47 min, long: -73 deg 44 min, elevation: 128 m	- Electric power - UPS unit - solar panel - wireless internet connection.	X	X
	NOAA NWS Caribou ME	Lat: 46°52'2.14"N Long: 68° 0'48.47"W Elevation: 135 m	- Electric power unit. - 37 and 89 GHz radiometers - Infrared Thermometer - Snow Temperature Profiler - wireless internet connection.	X	X
	USCRN/NY Millbrook 3 W site	Lat:41 deg 47 min, long: -73 deg 44 min, elevation: 128 m	- Temperature - Precipitation -Wind / Solar Radiation - Surface Temperature	X	X
To be deployed in spring 2011	Gifford House Fields	Lat:41 deg 47 min long: -73 deg 43 min, elevation 122 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	
	Greenhouse Fields	Lat:41 deg 47 min long: -73 deg 45 min, elevation 124 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	
	Dutchess Day School	Lat:41 deg 46 min long: -73 deg 39 min, elevation 208 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	
	Sky Acres Airport	Lat:41 deg 42 min long: -73 deg 44 min, elevation 210 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	
	Millbrook School	Lat:41 deg 51 min long: -73 deg 37 min, elevation 243 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	
	The Fountains at Millbrook	Lat:41 deg 43 min long: -73 deg 39 min, elevation 310 m	- Solar panel - Data Logger - Six - Soil moisture probes	X	

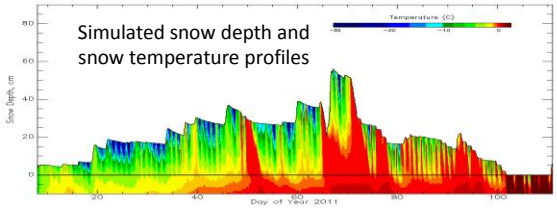


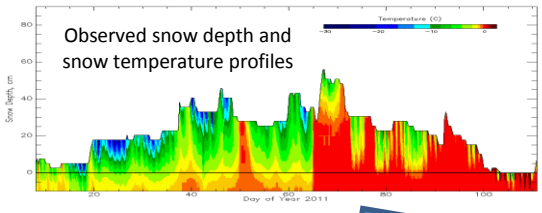
Scale: 17.1 mi

CREST-SAFE - Snow Analysis and Field Experiment

- The CREST-**S**now **A**nalysis and **F**ield **E**xperiment (CREST-SAFE) is setup in the backyard of the National Weather Service office at Caribou, ME using high frequency (37 and 89 GHz), dual polarized microwave radiometers to develop, improve and validate the snow retrieval algorithms.
- The field experiment site equipped with Snow Pillows, ultrasonic snow depth sensor, Infrared Thermometer, Radiation Sensors, Humidity, Temperature, snow temperature profiler, snow grain size, density, and network camera for real time remote monitoring of the site.

Real time Web-cam monitoring of site (23 Feb 2012)

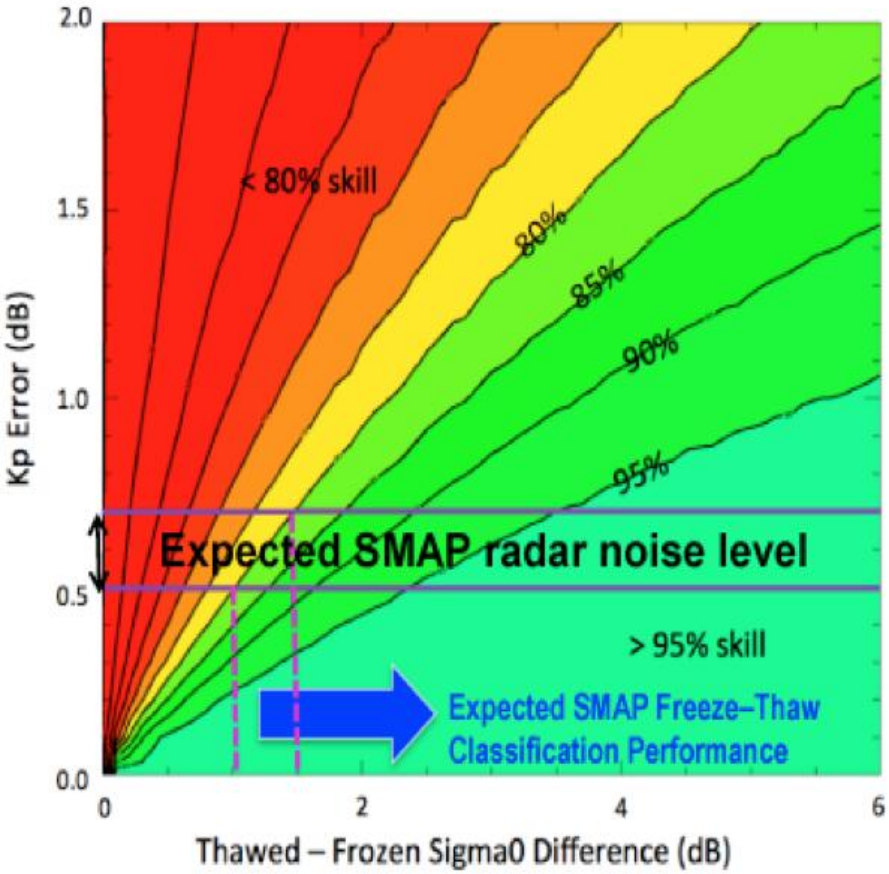




Extra Charts

Error Budget

- Expected components
  - Monte Carlo (“toy”) model of classification accuracy sensitivity to σ_o noise (Kp) and reference state differences
  - Landcover & terrain (topographic height and variance) variability
- Test with Palsar and Aquarius data



L3_FT_A: Algorithm

Algorithm:

- **Seasonal threshold**

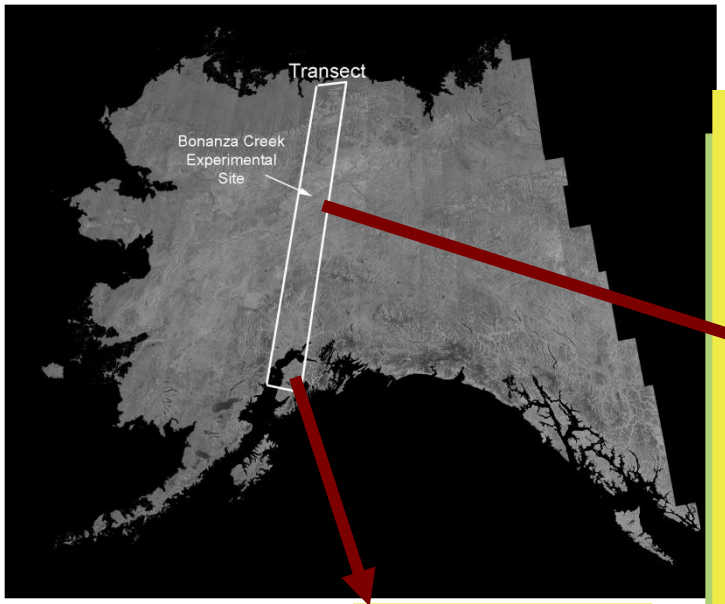
Approach: Classify the landscape freeze/thaw state based on time series radar backscatter relative to seasonal reference frozen and unfrozen states. AM and PM observations are classified separately. The AM and PM states are combined to provide the combined state as (1) frozen (frozen AM, frozen PM),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

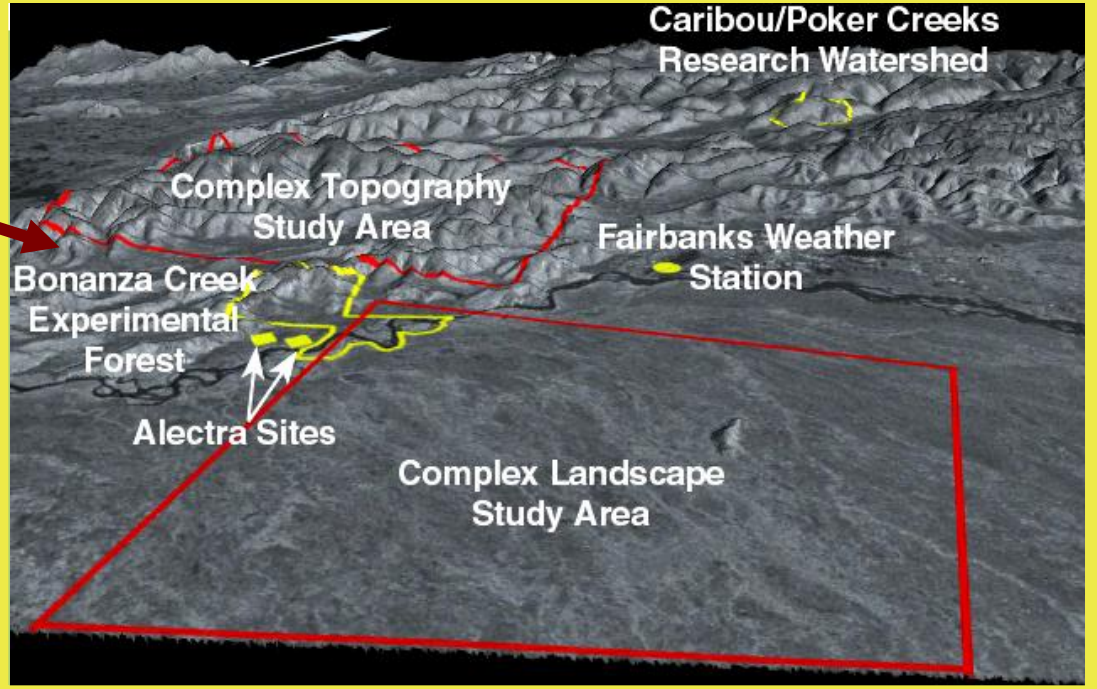
Outputs: Landscape freeze/thaw state for AM, PM, and combined.3x3 km resolution, daily product.

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

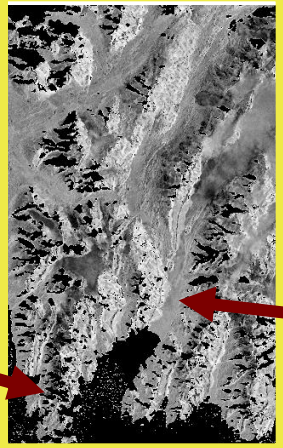
Freeze/Thaw Monitoring: Alaska



Interior Alaska



Kenai Peninsula



Resurrection Peninsula

Ellsworth Glacier