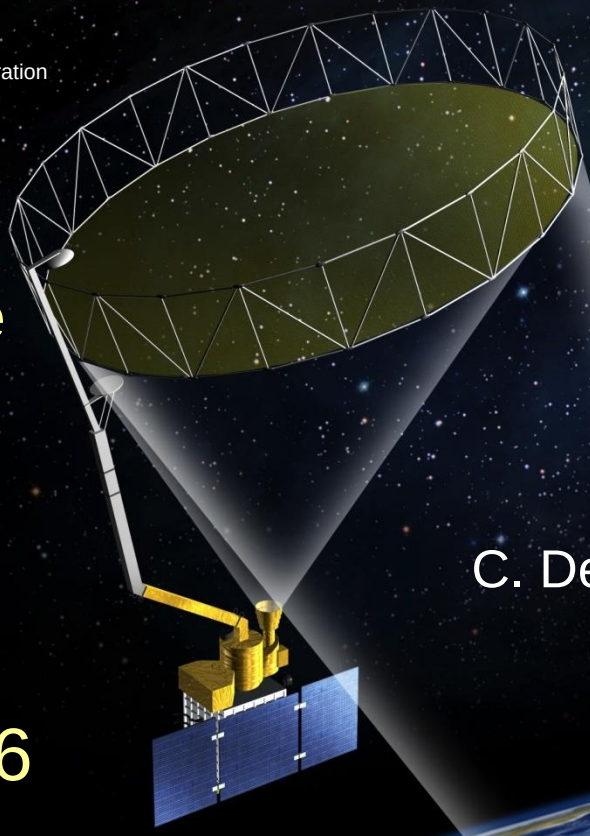
National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP

Cal/Val Workshop #6

Sept 1-3, 2015



L3 Freeze/Thaw: Product status and cal/val activities

X. Xu, S. Dunbar, A. Colliander, C. Derksen, K. McColl, J. Kimball, Y. Kim

Outline

1. L3_FT_A status and development (X. Xu)

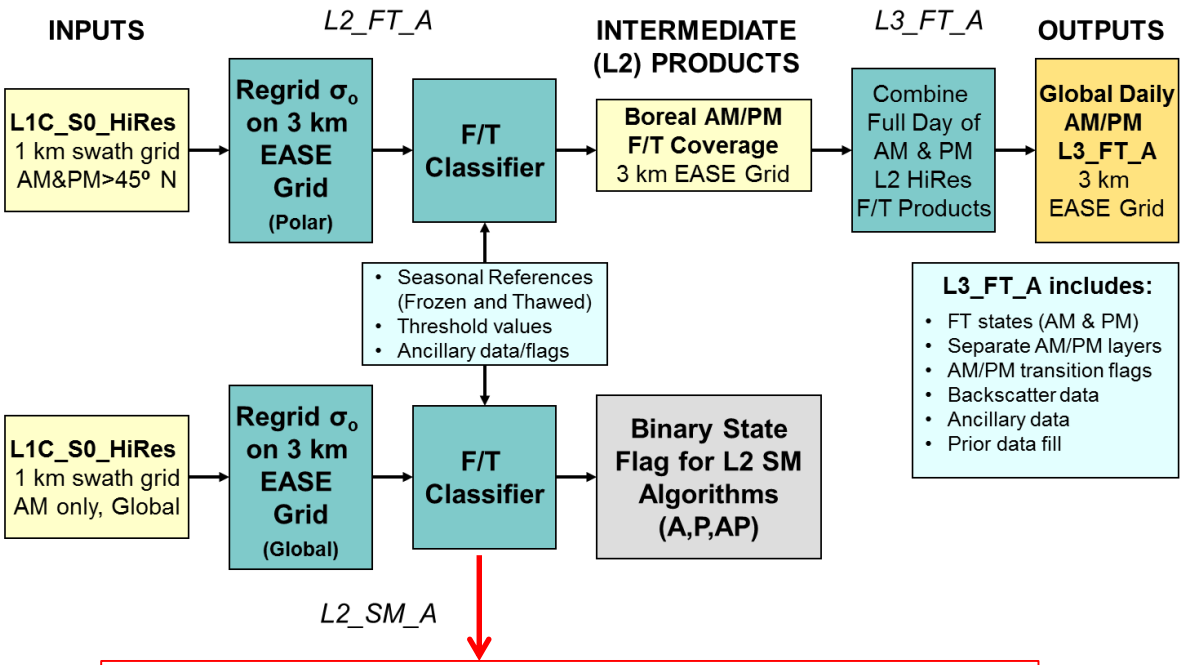
    - Algorithm overview
    - Oasis updated (waterbody)
    - Offline refinement: Artifact removal and reference analysis

2. Evaluation of L3_FT_A:
    - sparse networks (focus on SnoTel - Alaska) (X. Xu)
    - core sites (F to T transition limited to Saariselka; Imnavait; Cambridge Bay) (C. Derksen)

3. Categorical triple co-location (K. McColl)

SMAP L3_FT_A Baseline Algorithm

- Daily diurnal classification of freeze/thaw state for land areas north of 45°N
- Derived from SMAP high-resolution radar output to 3 km polar and global EASE grids
- Categorical classification: frozen, thawed, (inverse) transitional
- Monthly classification accuracy of 80% or above



$$D(t) = \frac{s(t) - s_{fr}}{s_{th} - s_{fr}}$$

$D(t) > T(=0.5), thaw$

$D(t) < T(=0.5), freeze$

Initial threshold = 0.5

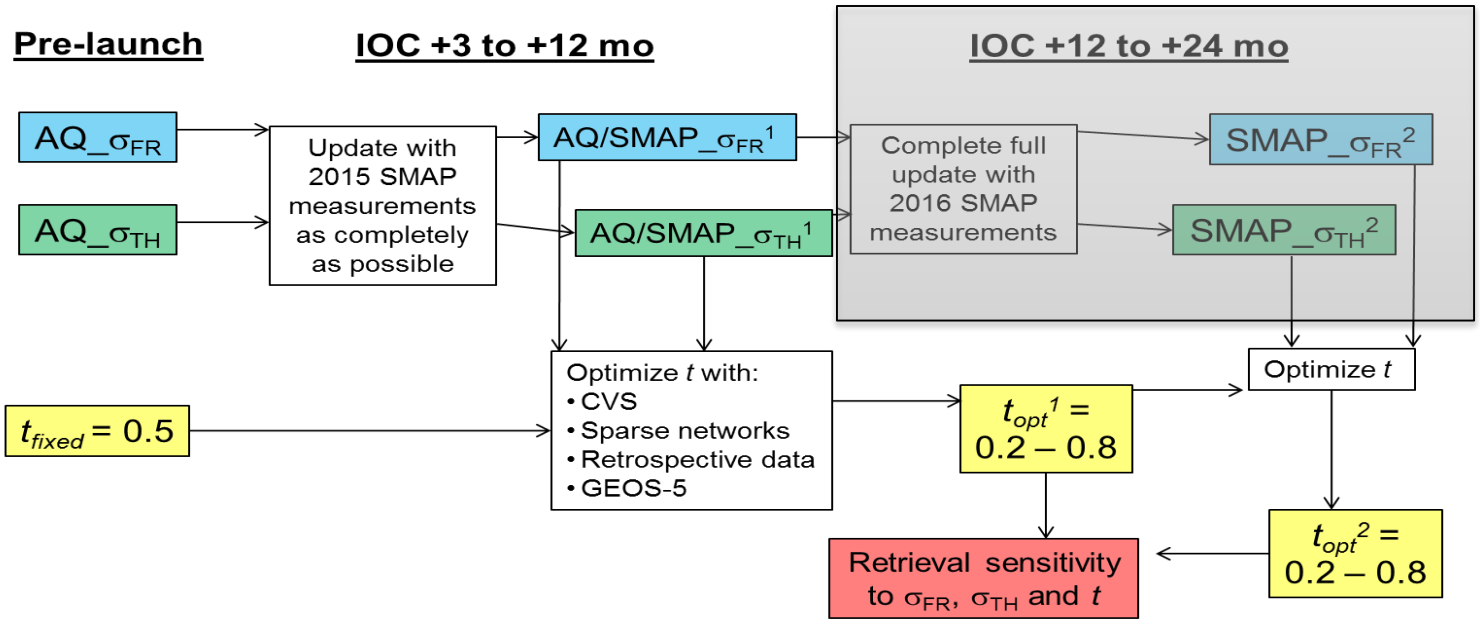
σ_{fr} = frozen season reference

σ_{th} = thawed season reference (vv+hh)

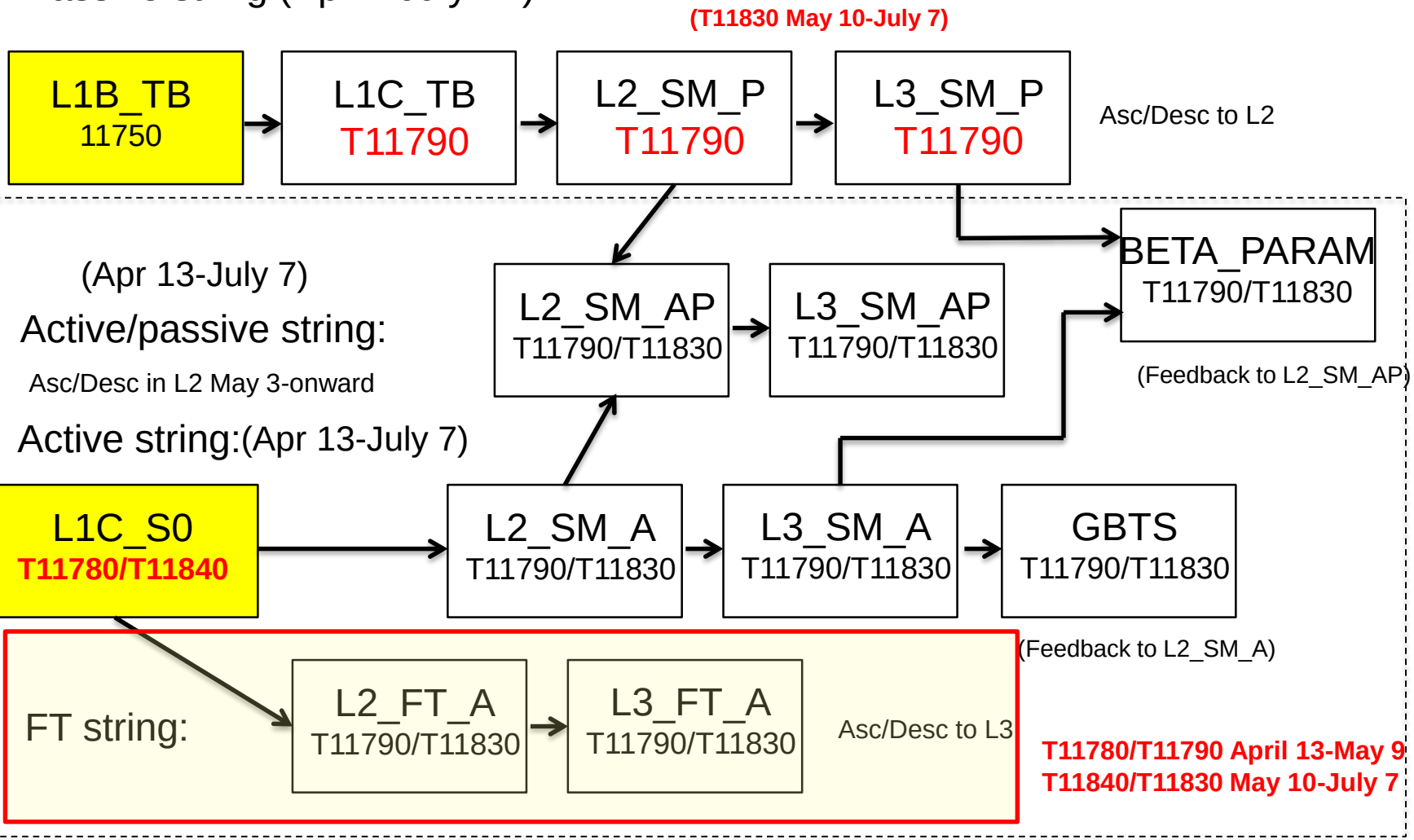
Schedule

	2015												2016											
Activity	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
F->T transition																								
T->F transition																								

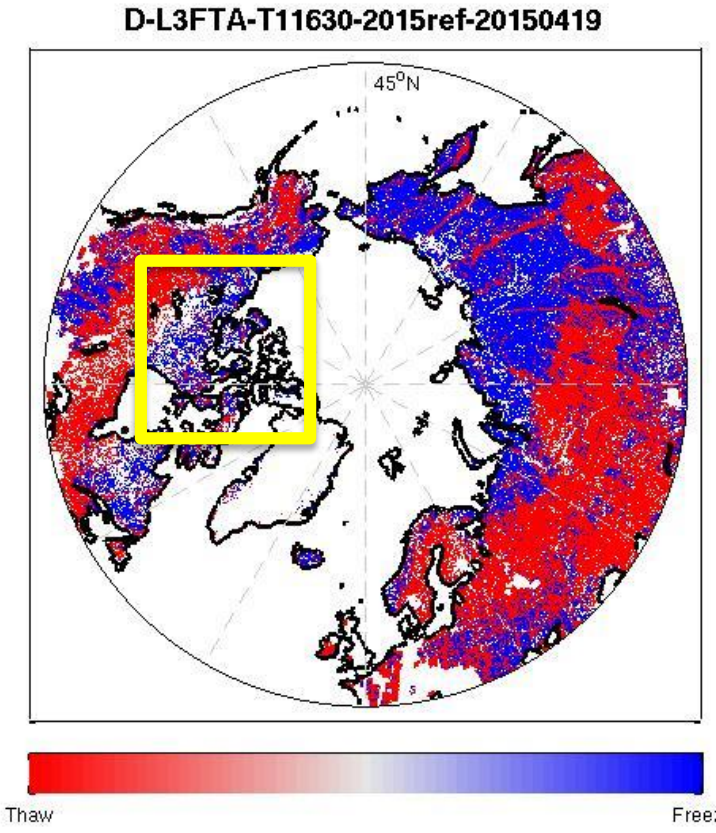
	2015												2016											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Milestones		L			L+3			L+6			L+9						L+15			L+18				
		IOC									SDS Reprocessing										SDS Reprocessing			
Freeze reference data																								
Freeze reference analysis																								
Thaw reference data																								
Thaw reference analysis																								
Threshold optimization																								
OASIS analysis																								
SDS checkout																								

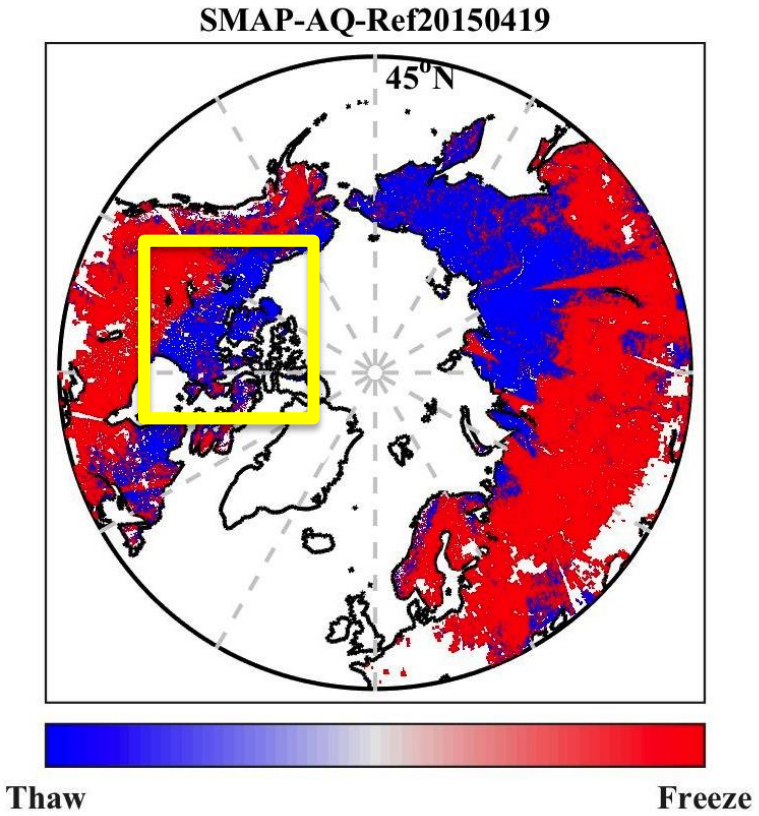


OASIS Reprocessing Map (T11750+updates)
Status as of 8/18/15



Water body threshold from 5% to 50%





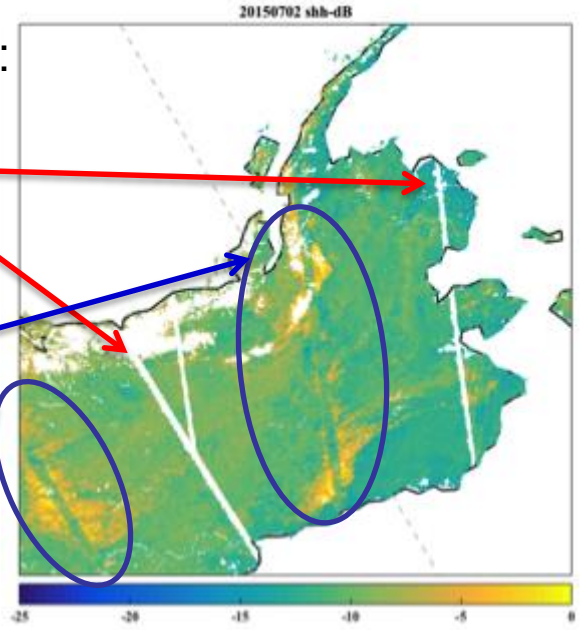
High water body tolerance in F/T algorithm.
Threshold (50%?) is under investigation.

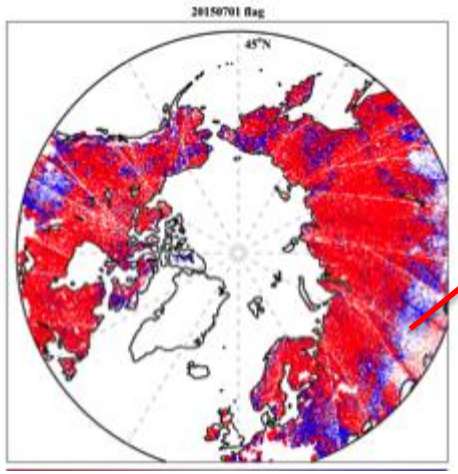
L3_FT_A Refinement

3 Issues with T11830:

- Edge effect (check filled value)

- Nadir artefacts (exclude nadir track for now)





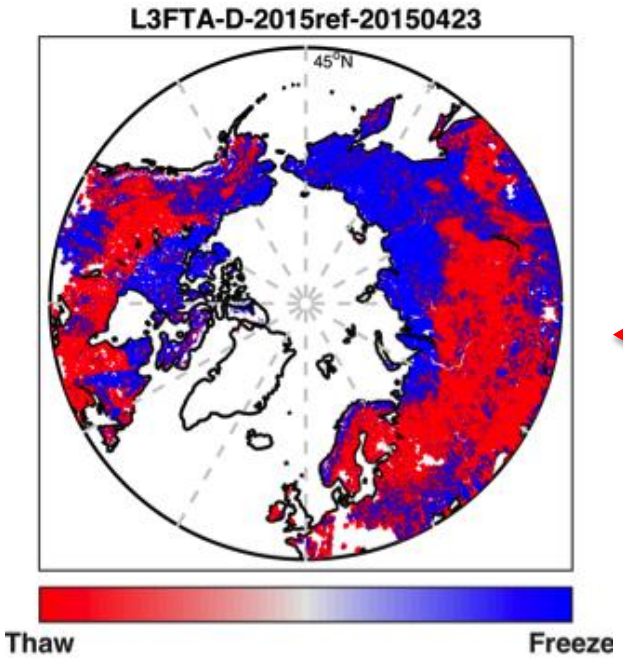
- Missing data (flag misread)

FT string *only* (April 13-July 7):

L1C_S0 R11850 → L2_FT_A D11650 → L3_FT_A D11650

Two test runs of complete data set:

- **Full-swath (including nadir)**
- **Nadir swath (300km) excluded**



SMAP Reference Update

- Thaw Reference
  - average over last ten days of SMAP data (06/27-07/06)

$$T_{ref} = \frac{1}{n} \sum_{i=1}^{n} (s_{vv} + s_{hh})$$

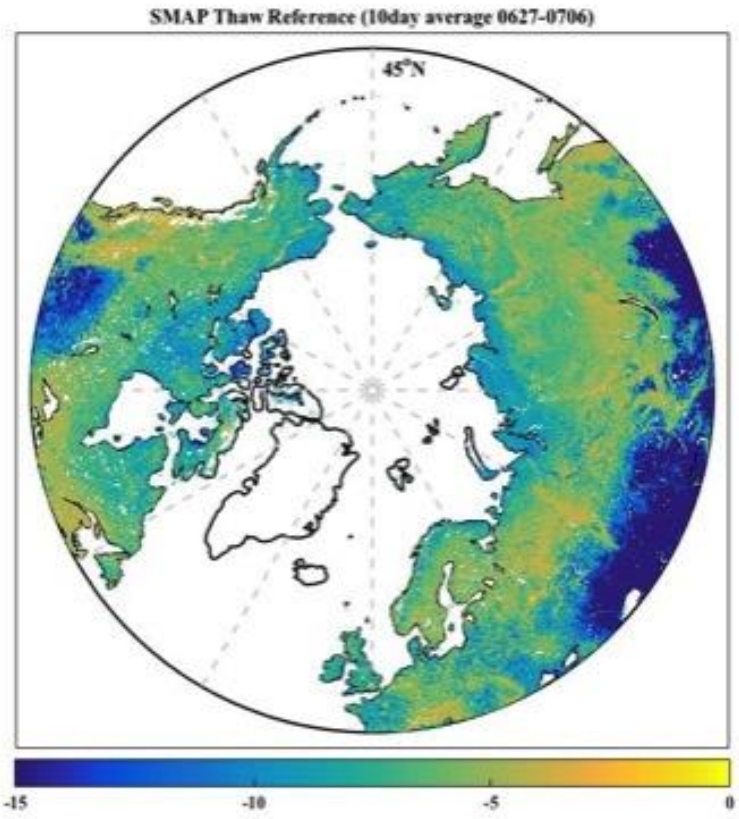
- Freeze Reference

- assume the reference difference is the same, only correct bias)

$$F_{ref} = T_{ref} - (T_{AQref} - F_{AQref})$$

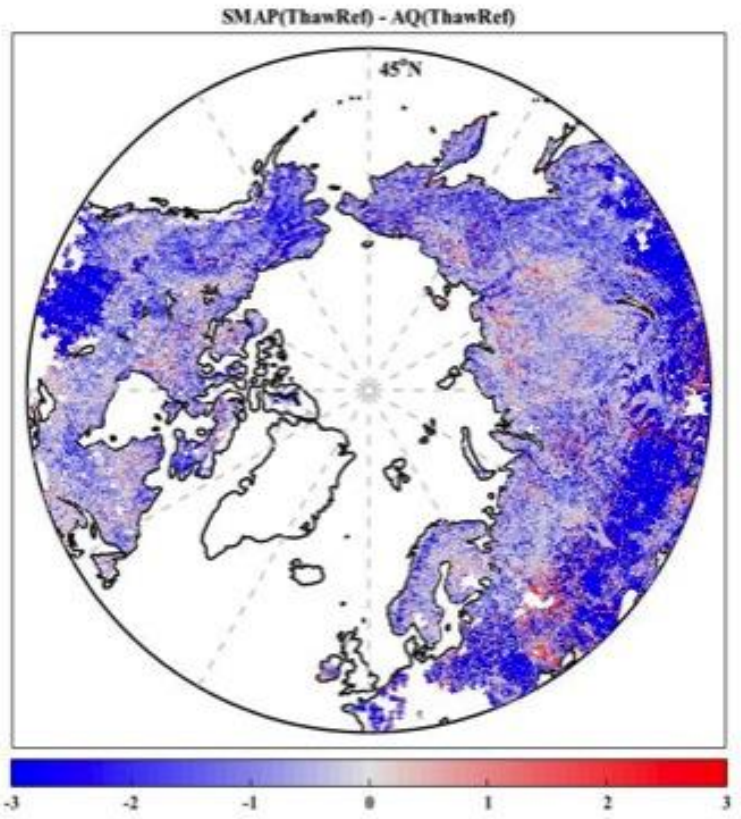
SMAP Reference Update

Thaw reference



Thaw reference comparison

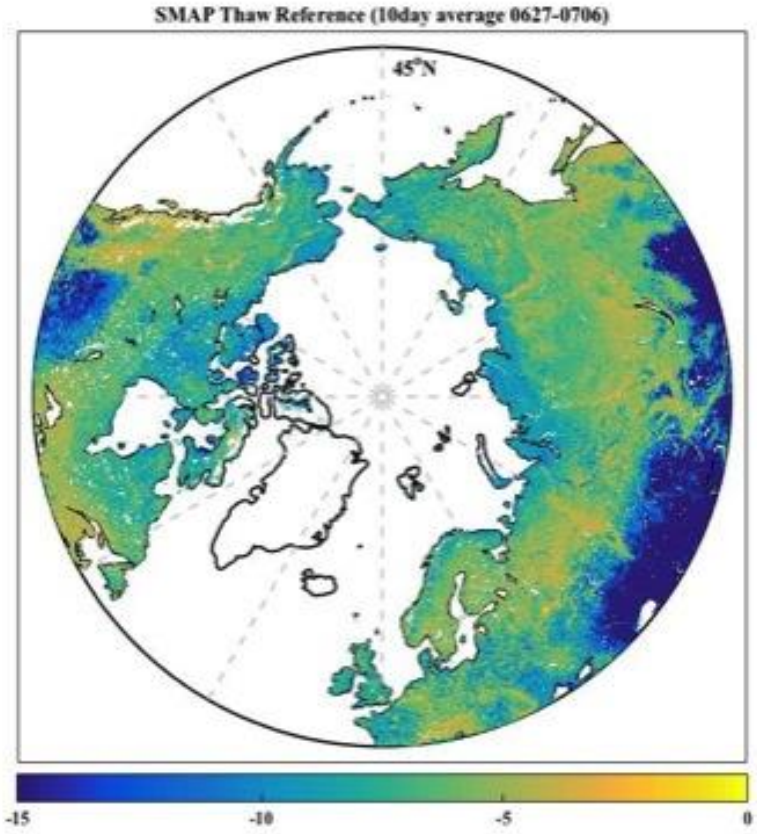
SMAP - AQ



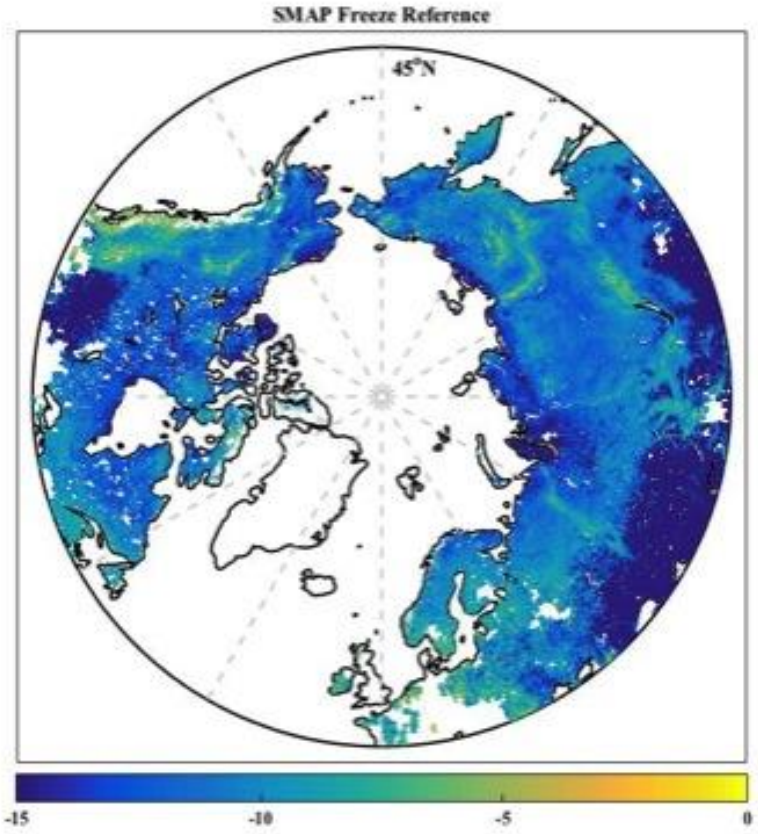
- Across the FT domain, the SMAP thaw references are lower than AQ especially in lower latitude/low vegetation areas

Bias Corrected Hybrid Reference

Thaw Reference



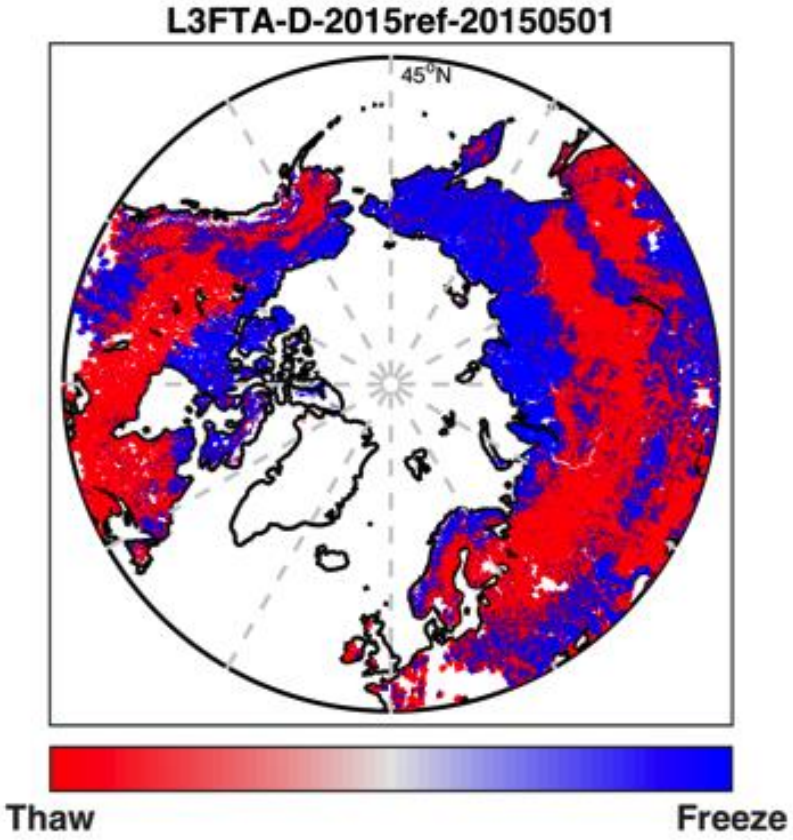
Freeze Reference



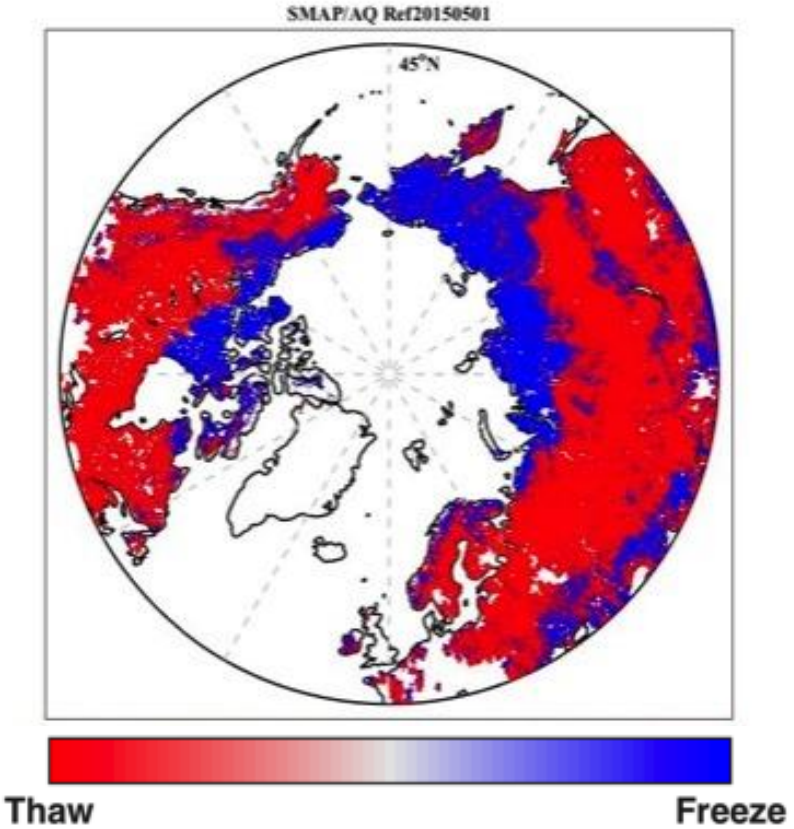
- AQ incidence angle artifacts are reduced

Snapshot Comparison (1 May 2015)

AQ Reference



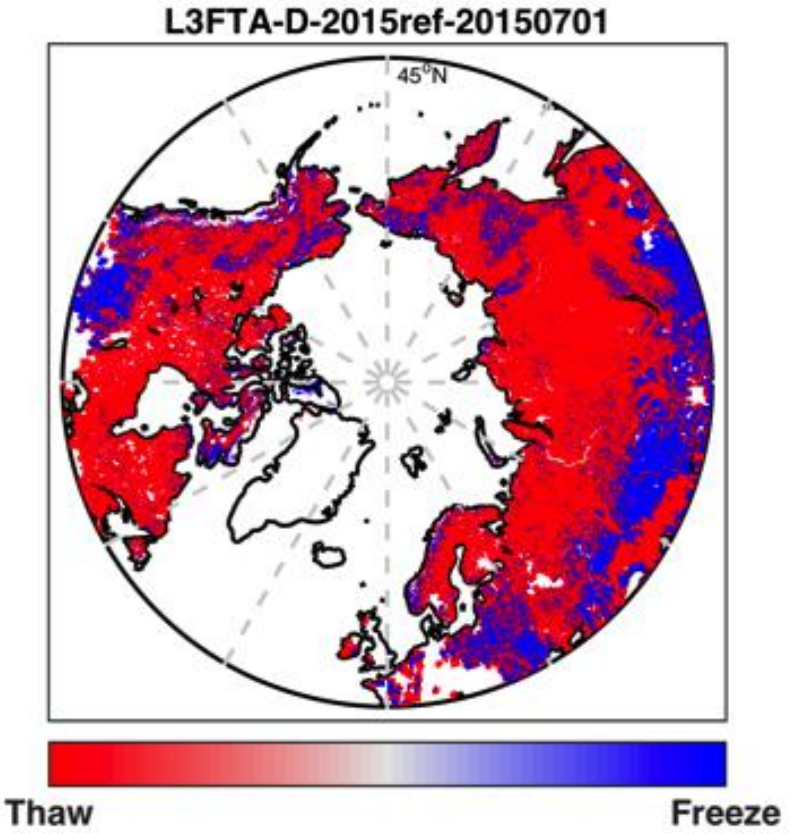
SMAP/AQ Reference



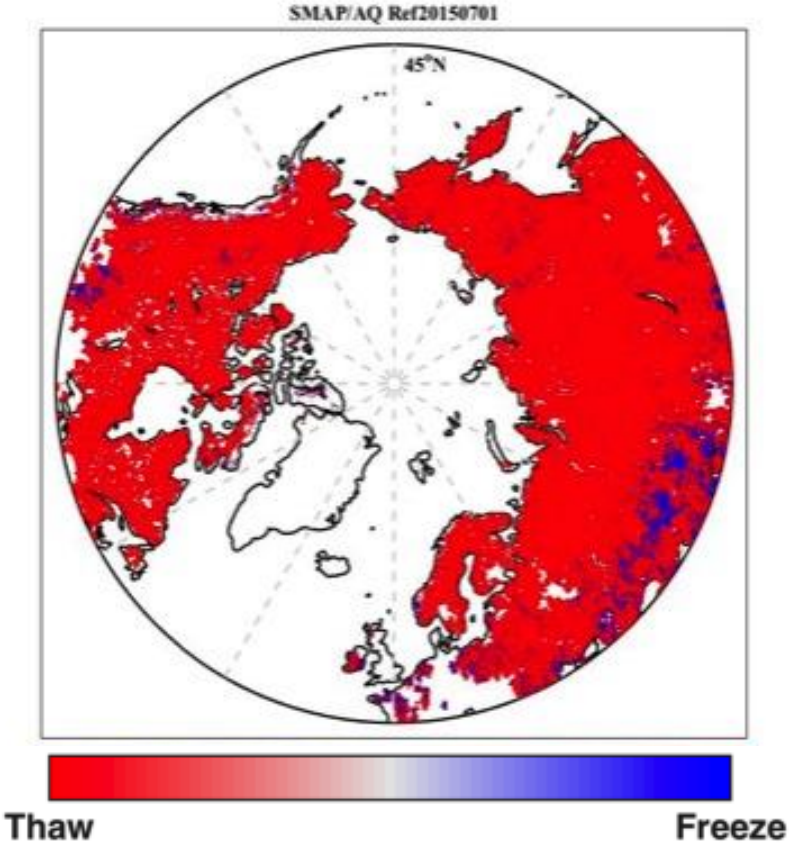
- The hybrid SMAP/AQ reference notably reduces false freeze flags

Snapshot Comparison (1 July 2015)

AQ Reference

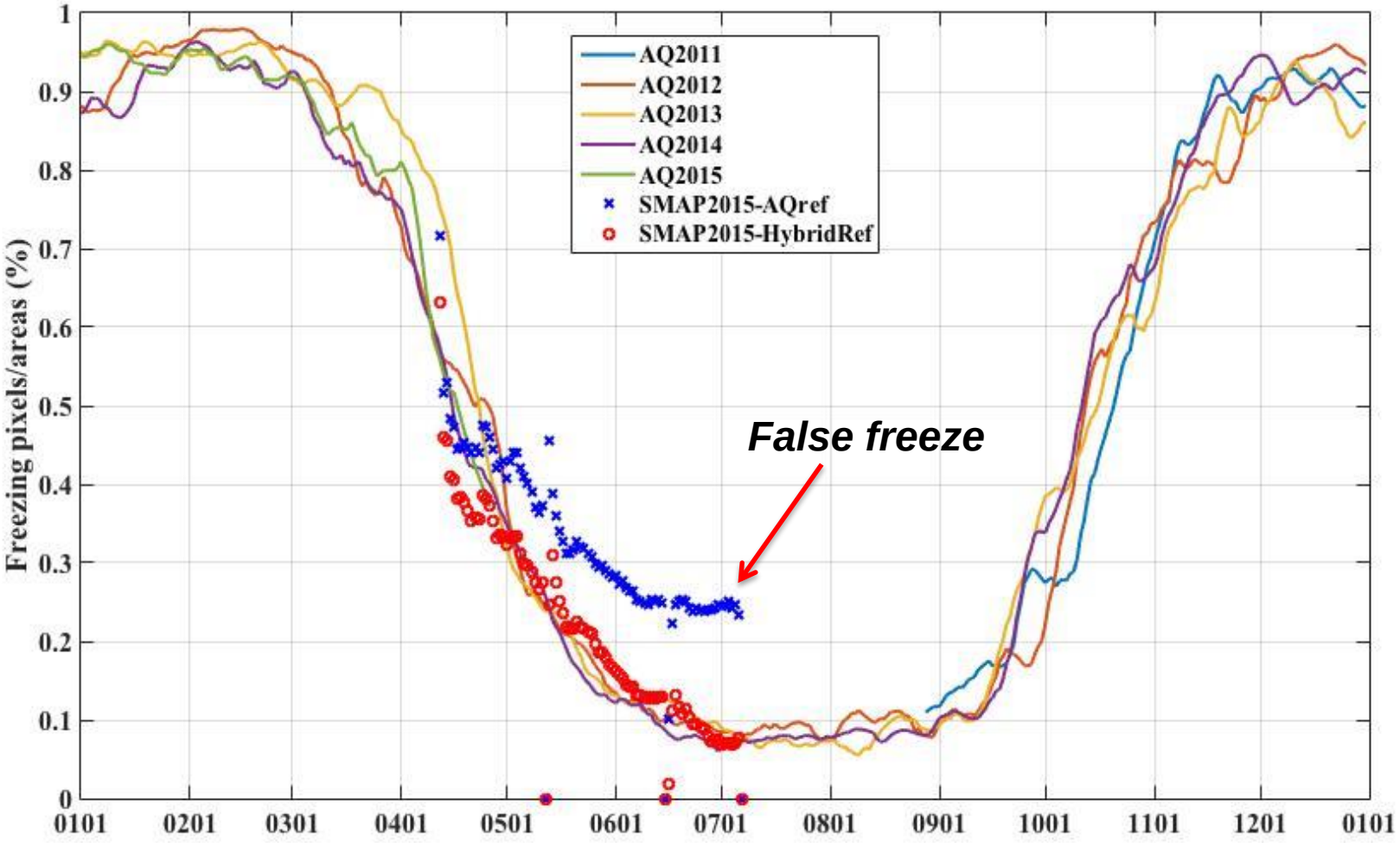


SMAP/AQ Reference

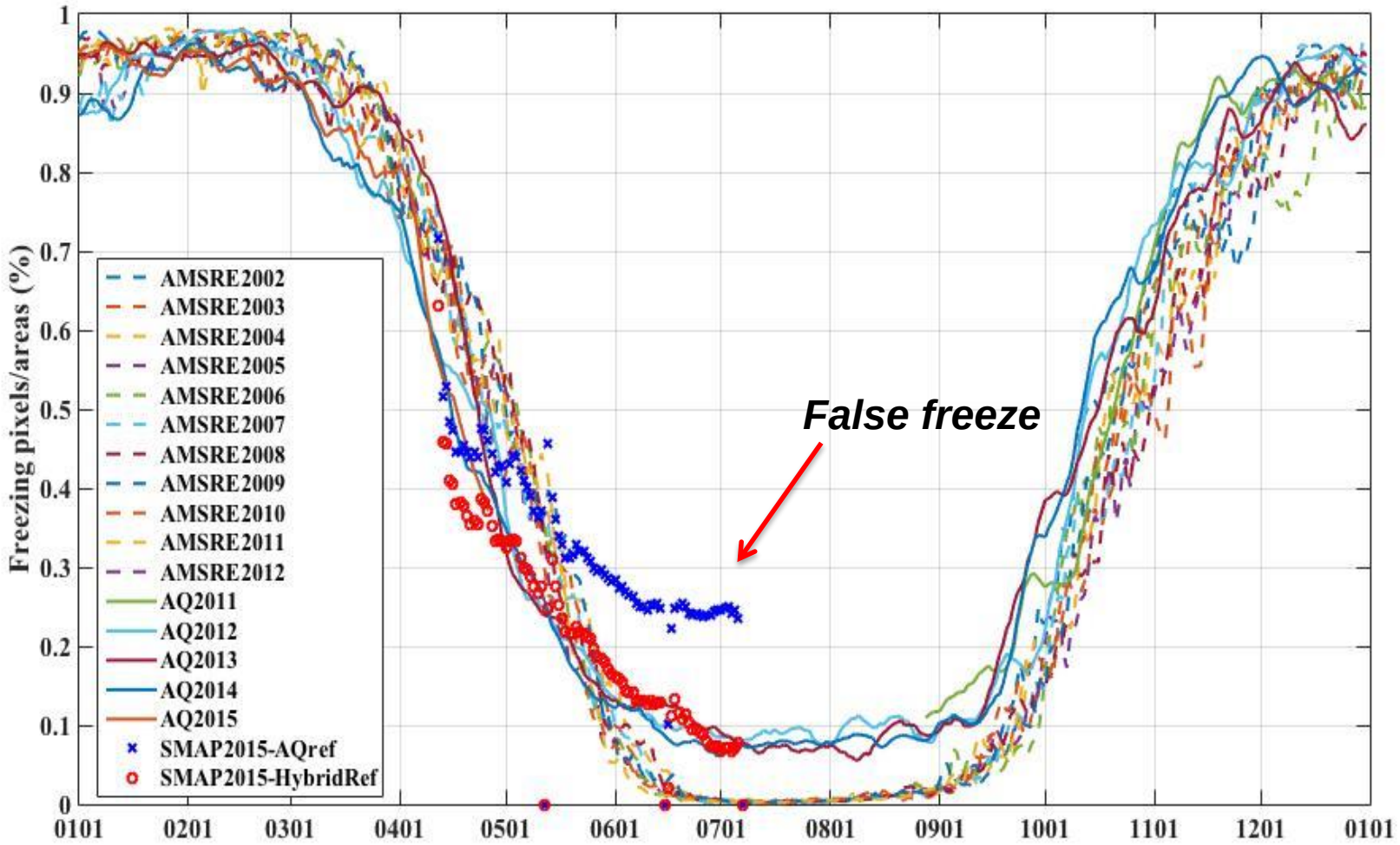


- The hybrid SMAP/AQ reference notably reduces false freeze flags

NH Freeze Area: SMAP versus 4 years of Aquarius

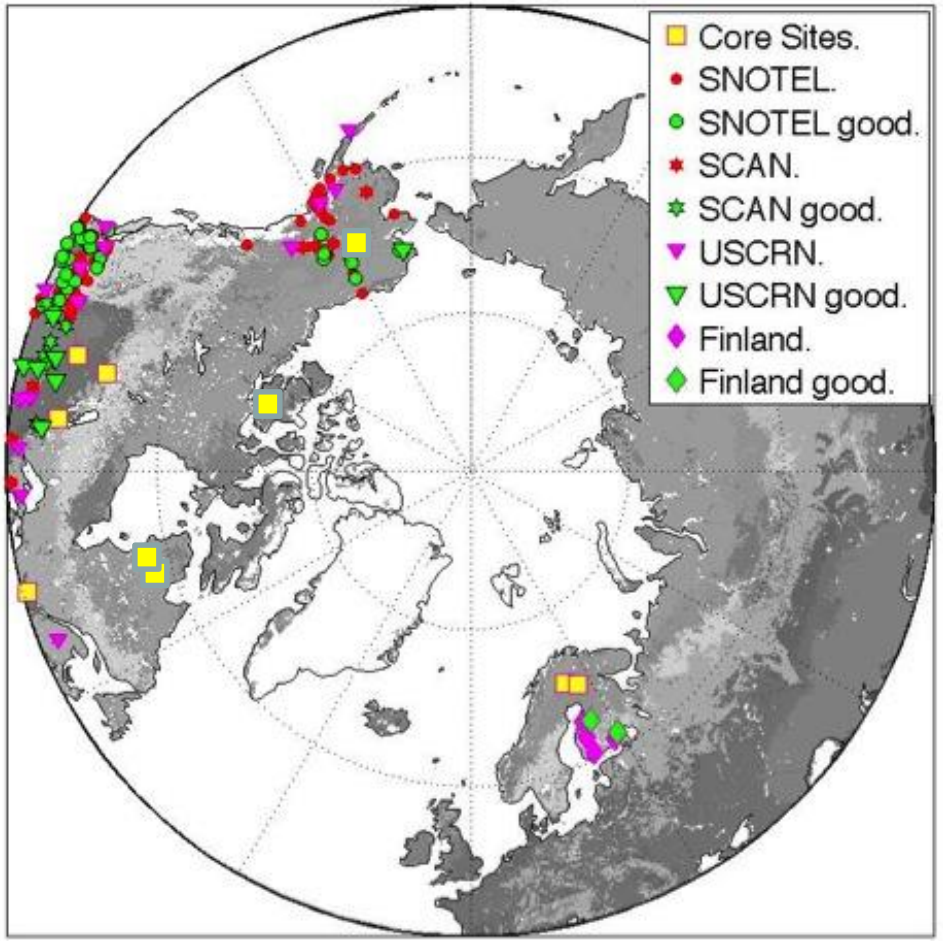


NH Freeze Area: adding 10 years of AMSR-E

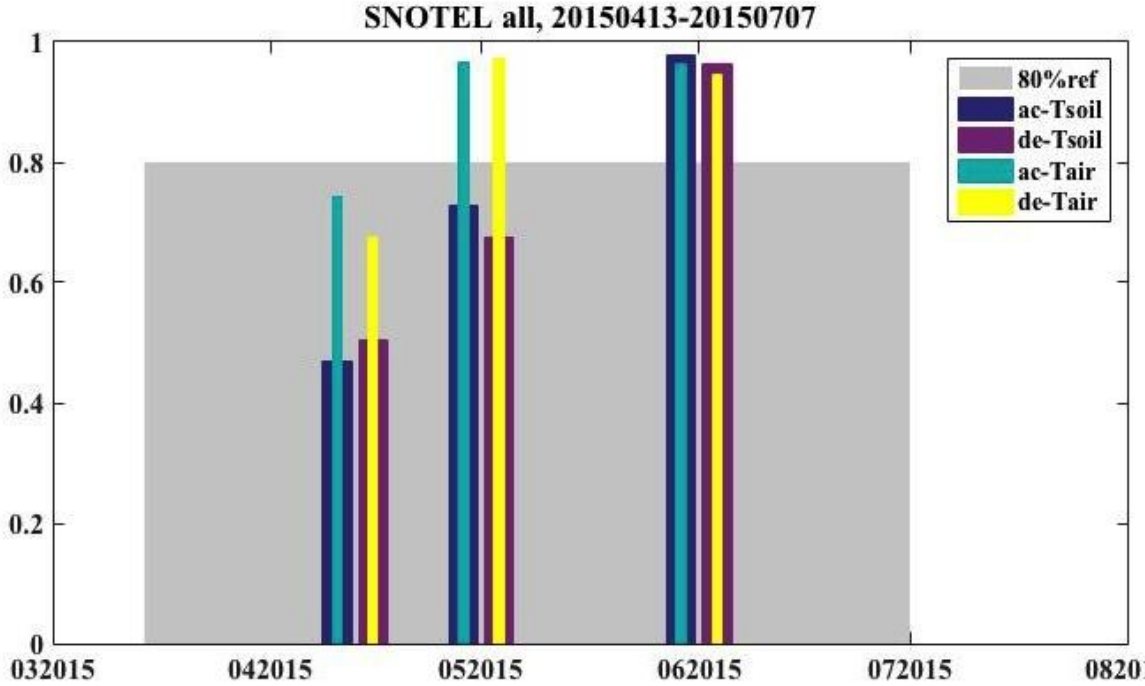


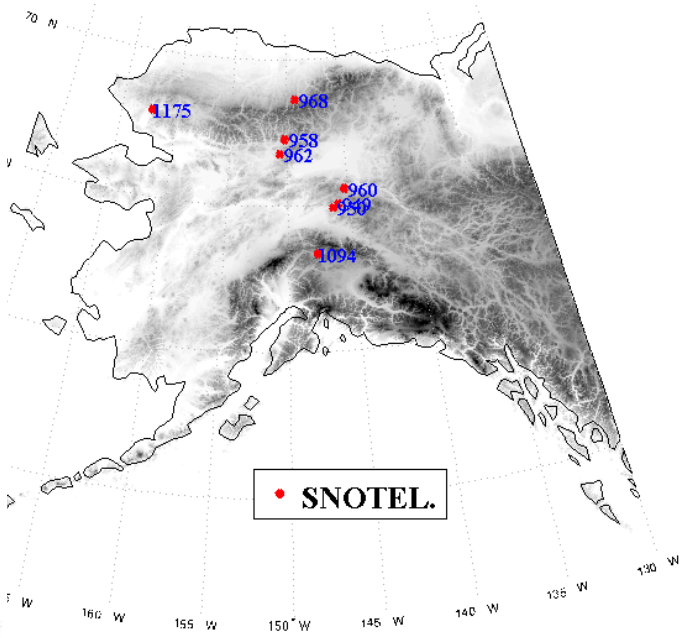
Sparse Networks

Network	Total FT Sites	2015 F→T Transition	Tier 1 FT Sites
SCAN	18	5	0
SnoTel	85	30	9
USCRN	22	4	1



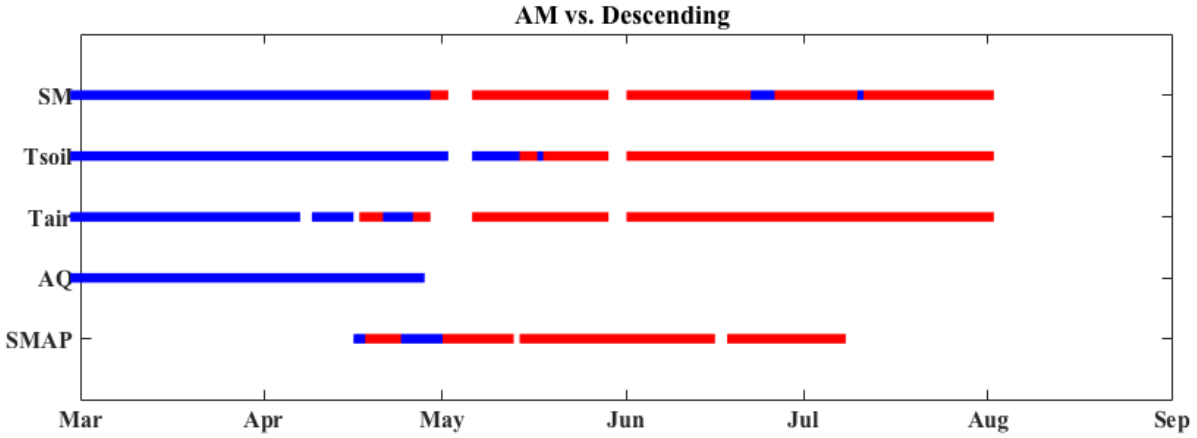
Updated Sparse Network: 1102- SNOTEL Stations

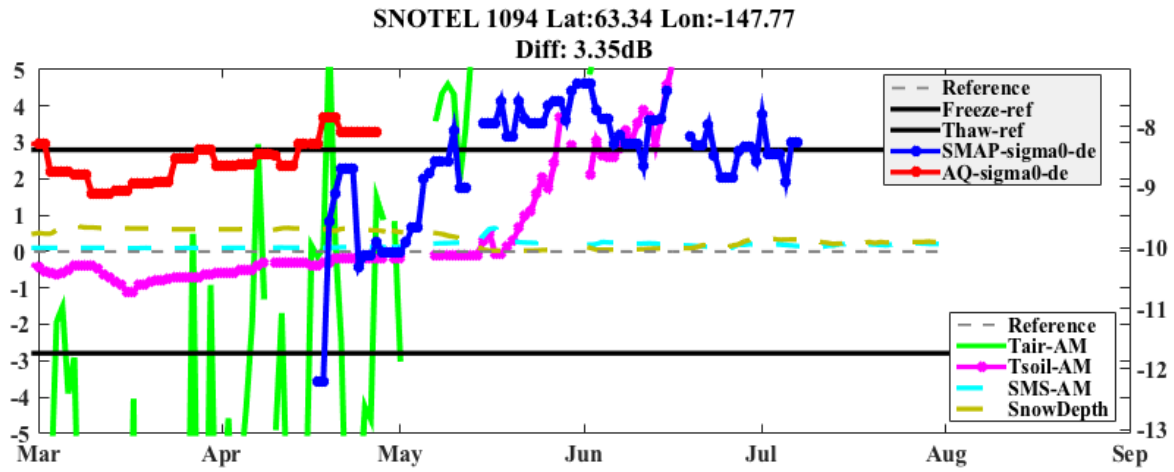


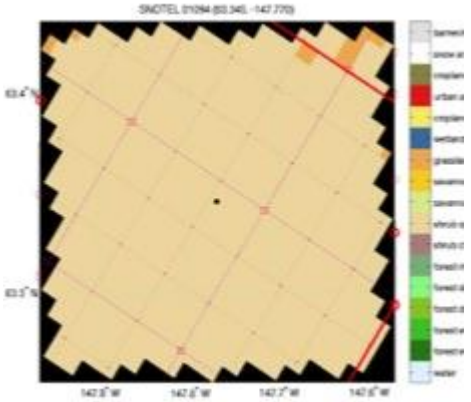


Time	TEMP _air	Agree	Error	SMAP-D/A-F obs-AMPM-F	SMAP-D/A-T obs-AMPM-T	SMAP-D/A-F obs-AMPM-T	SMAP-D/A-T obs-AMPM-F
2015.04	PM-A	0.74	0.26	0.20	0.55	0.15	0.11
2015.04	AM-D	0.67	0.33	0.33	0.34	0.11	0.22
2015.05	PM-A	0.97	0.03	0.00	0.97	0.02	0.01
2015.05	AM-D	0.97	0.03	0.02	0.96	0.01	0.02
2015.06	PM-A	0.96	0.04	0.00	0.96	0.01	0.03
2015.06	AM-D	0.94	0.06	0.00	0.94	0.01	0.04

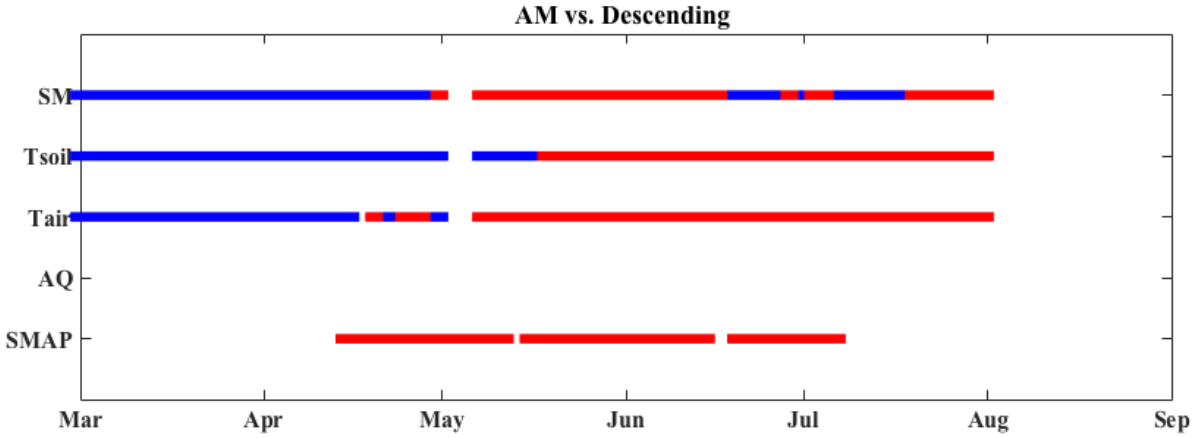
1094 AM – Open Shrub

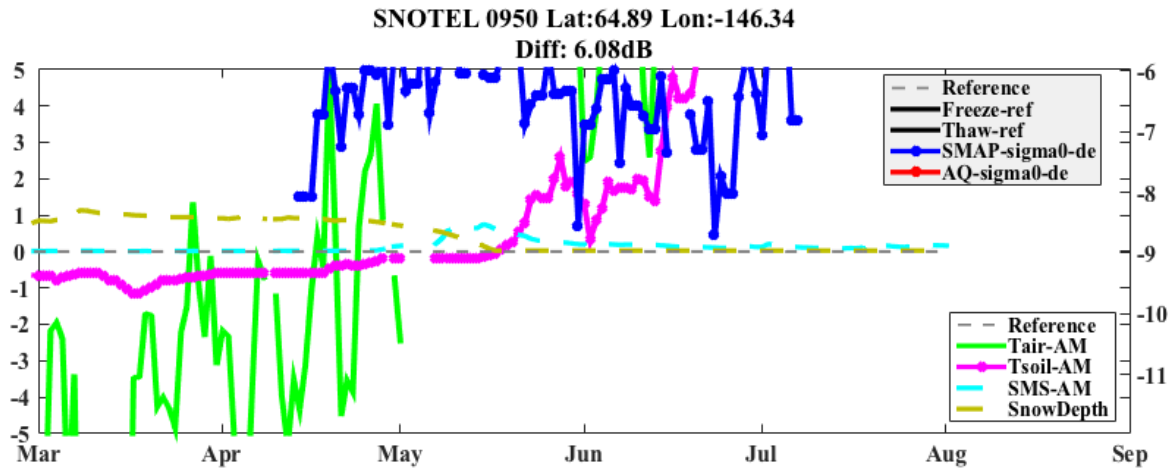


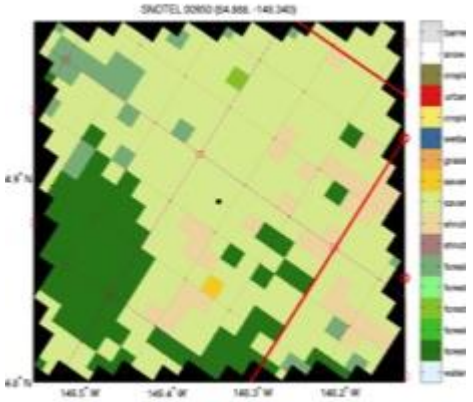




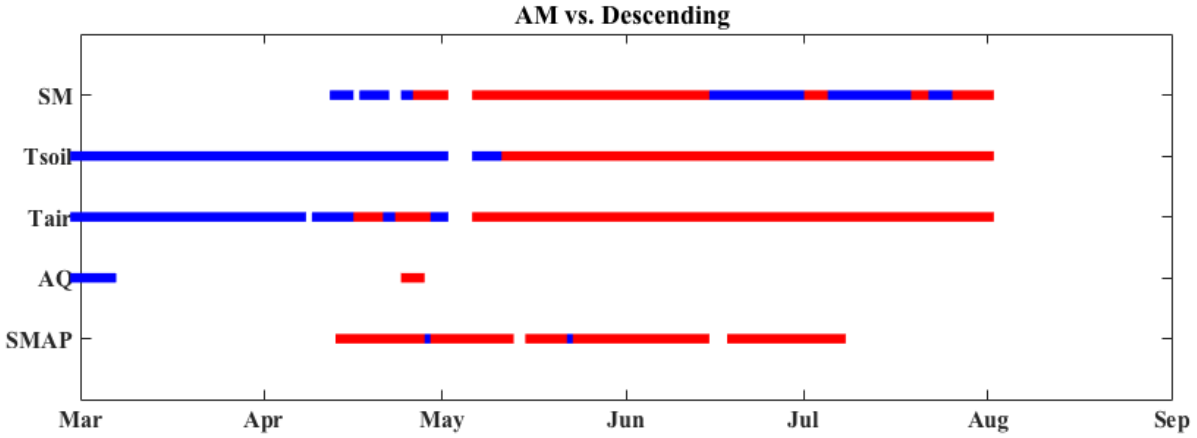
950 AM – Woody Savannah

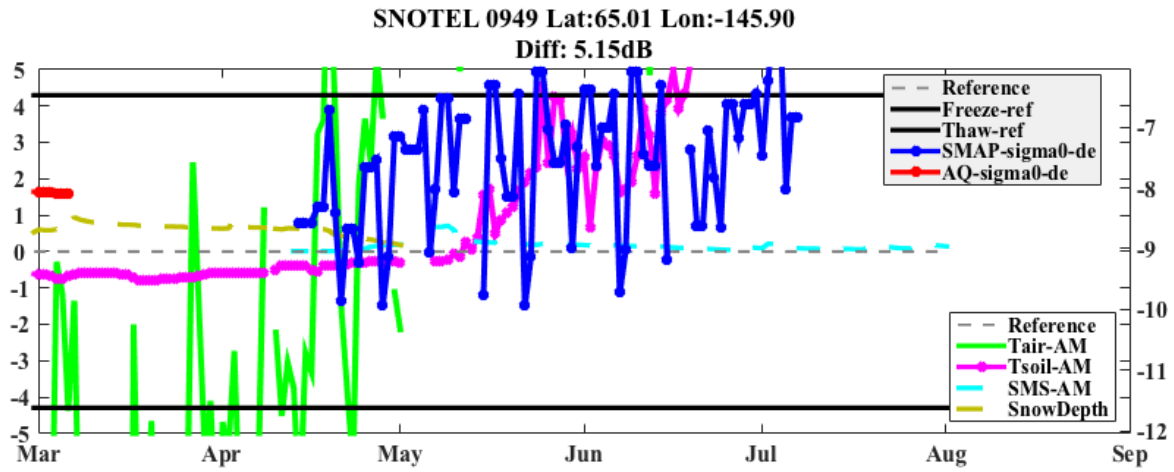


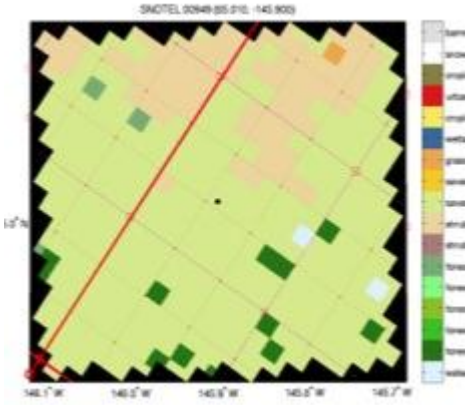




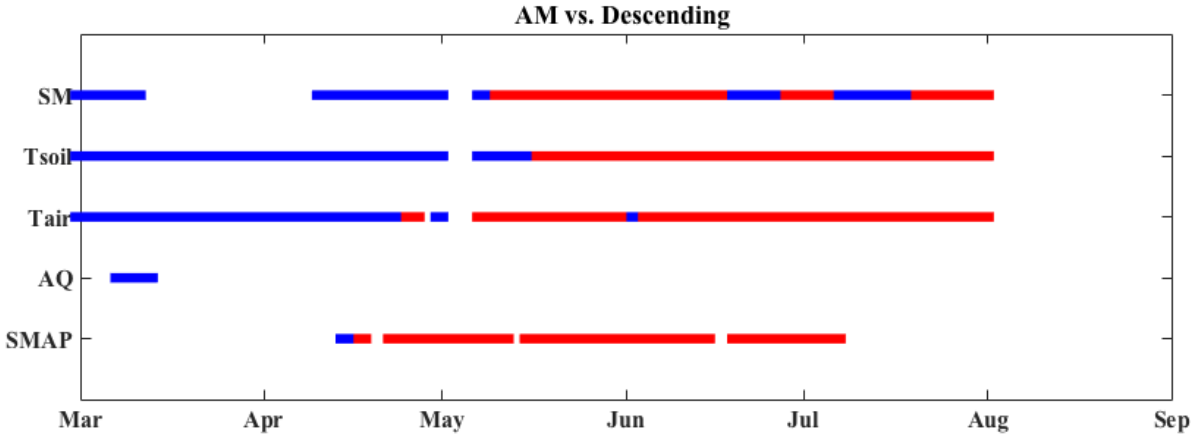
949 AM – Woody Savannah

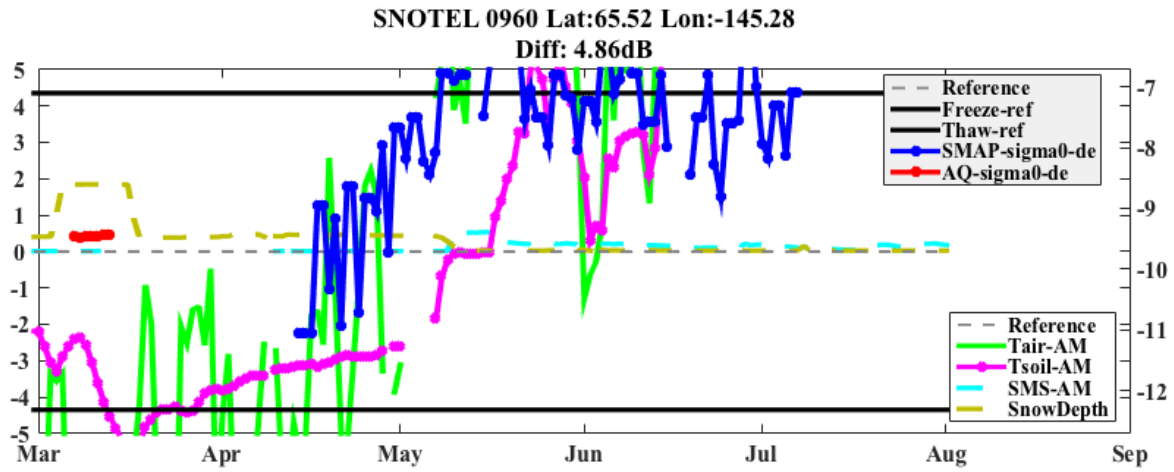


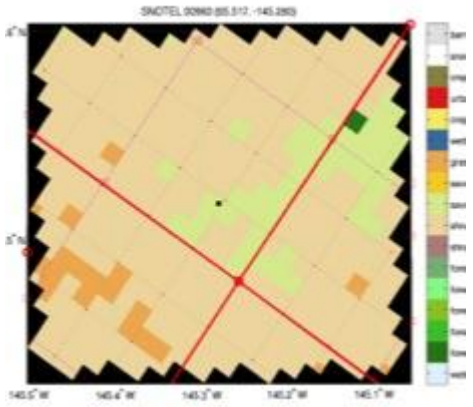




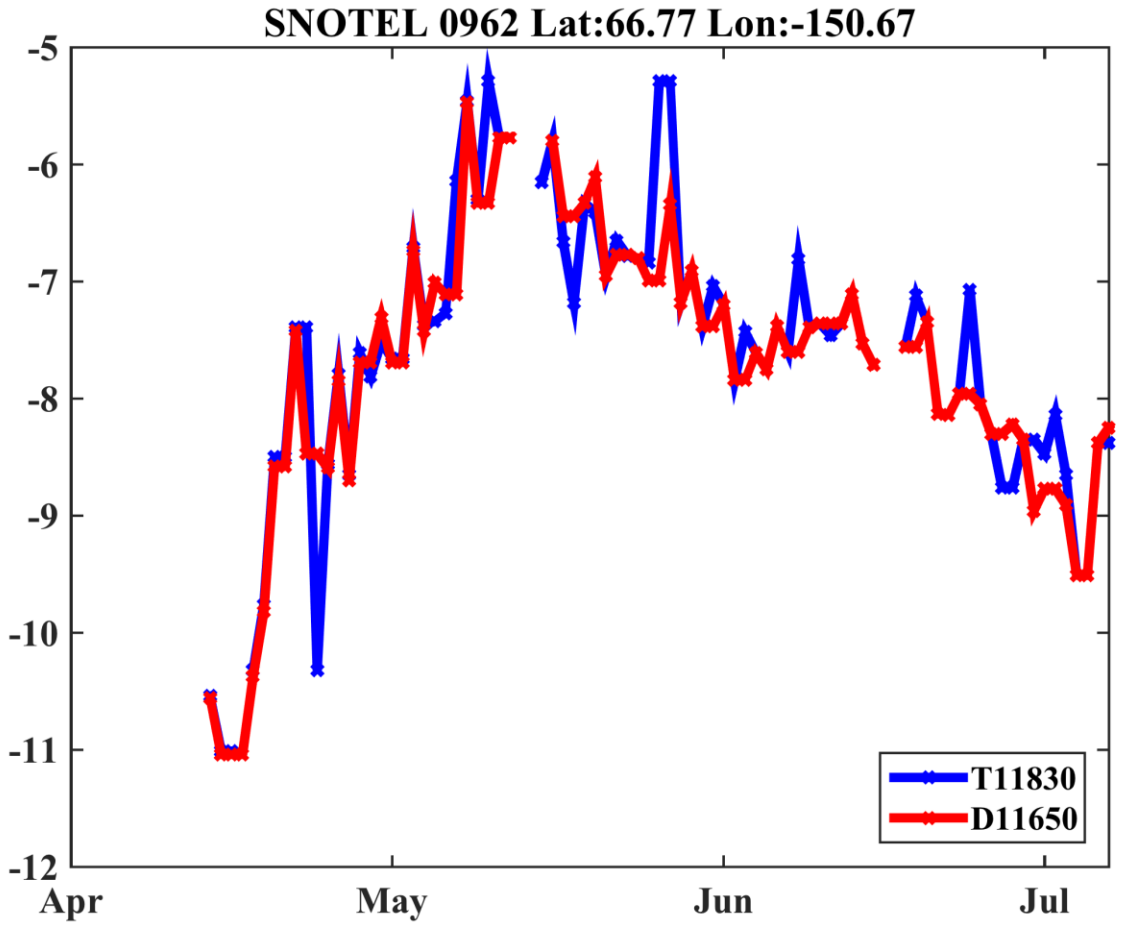
960 AM – Woody Savannah

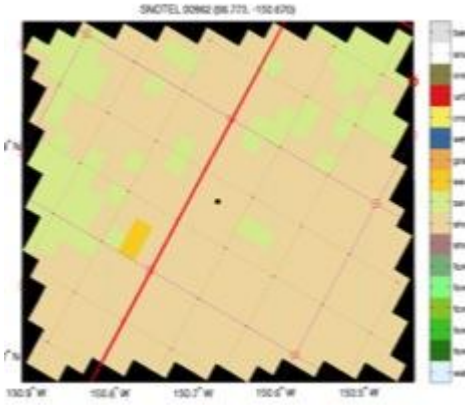




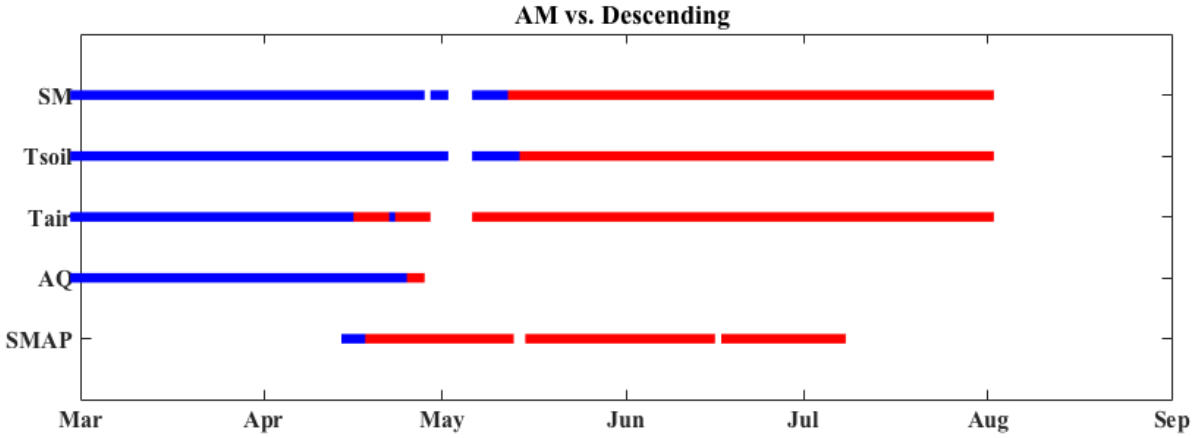


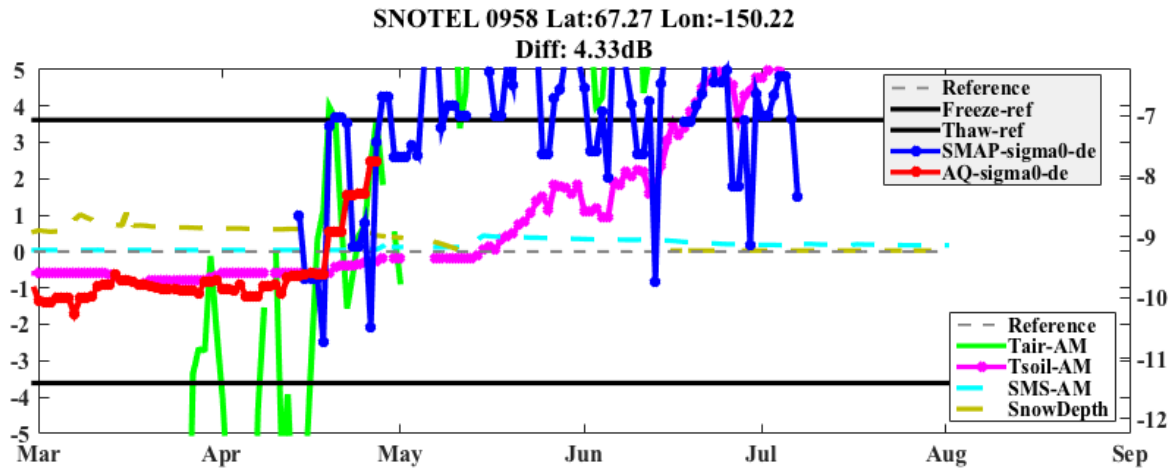
962 AM – Open Shrub

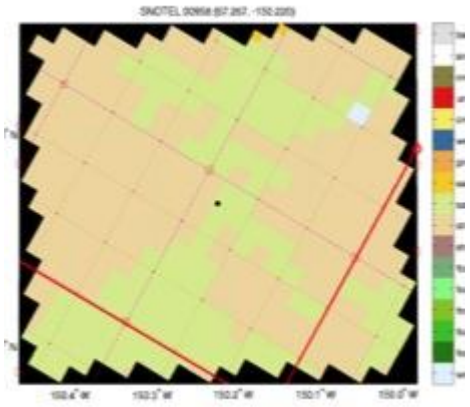




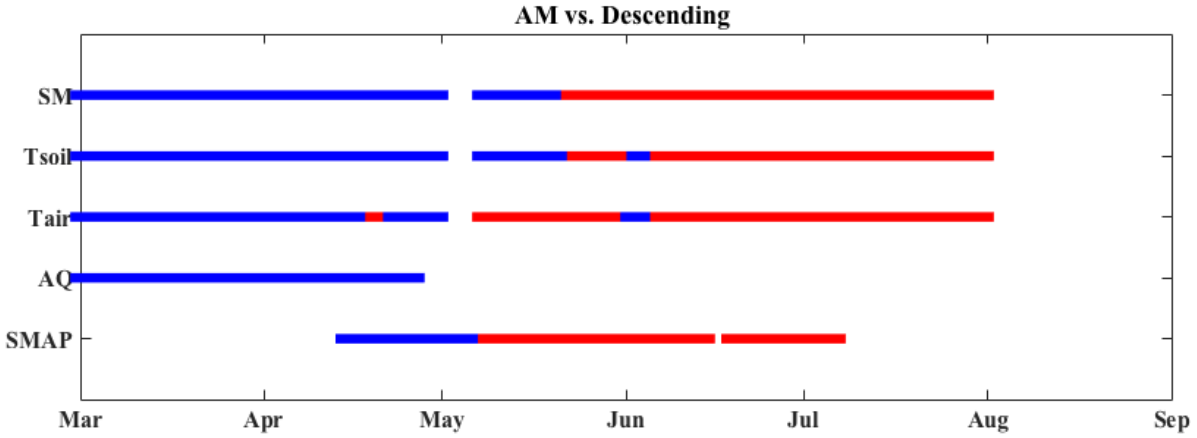
958 AM – Open Shrub

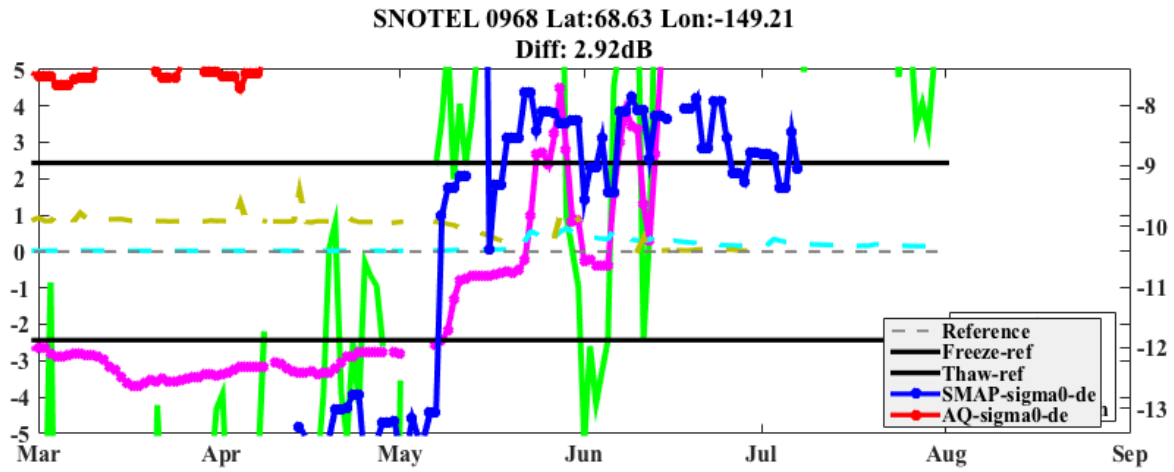


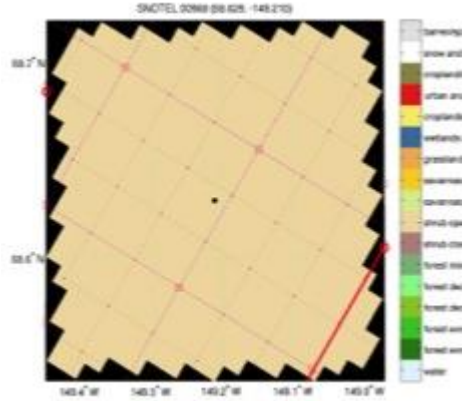




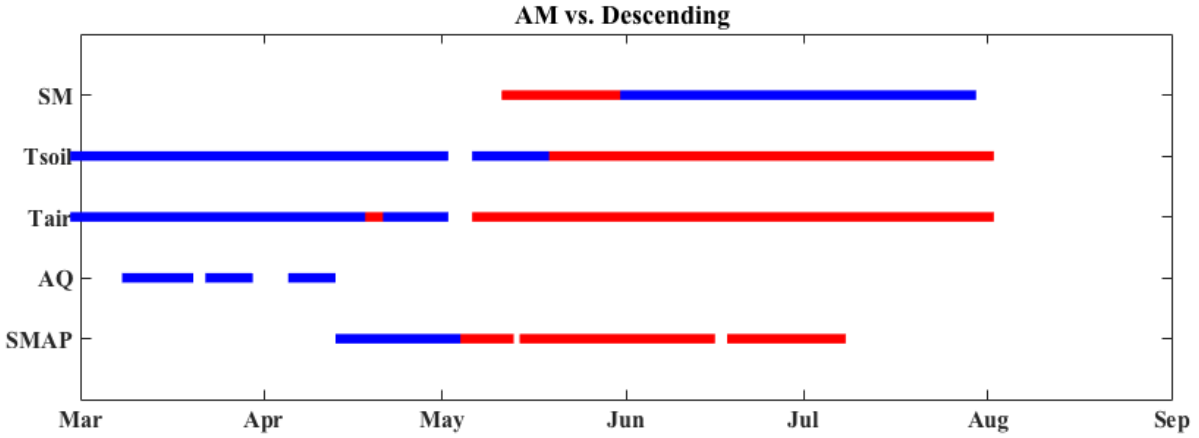
968 AM – Open Shrub

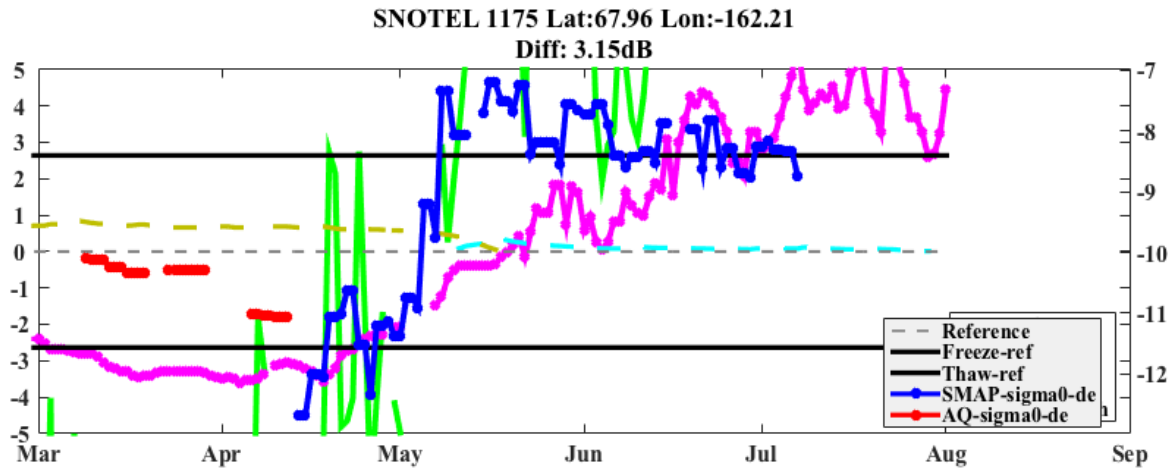


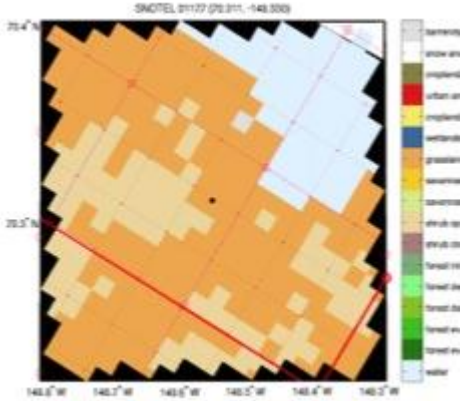




1175 AM - Grassland

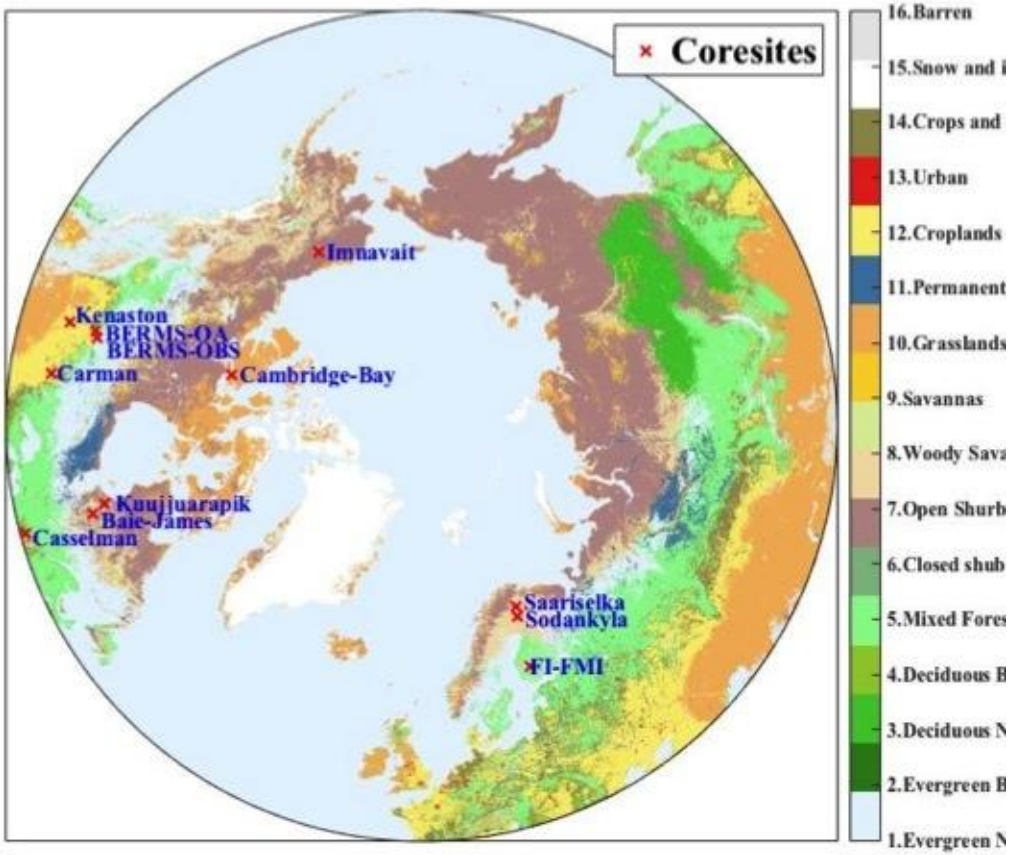




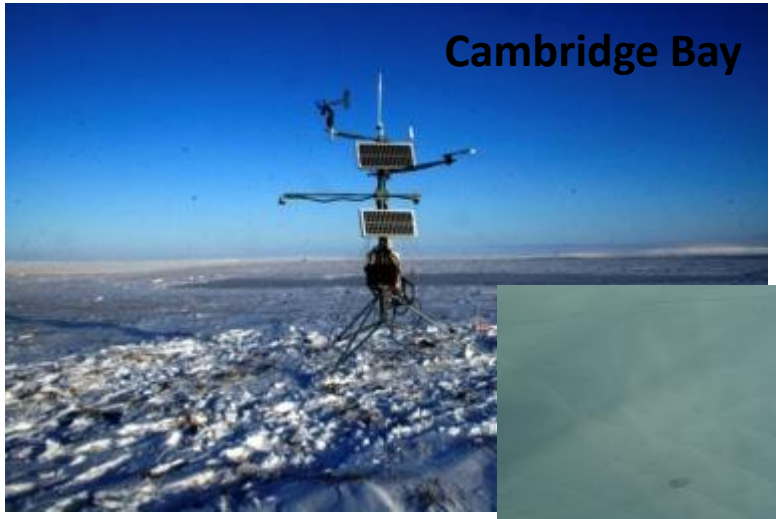


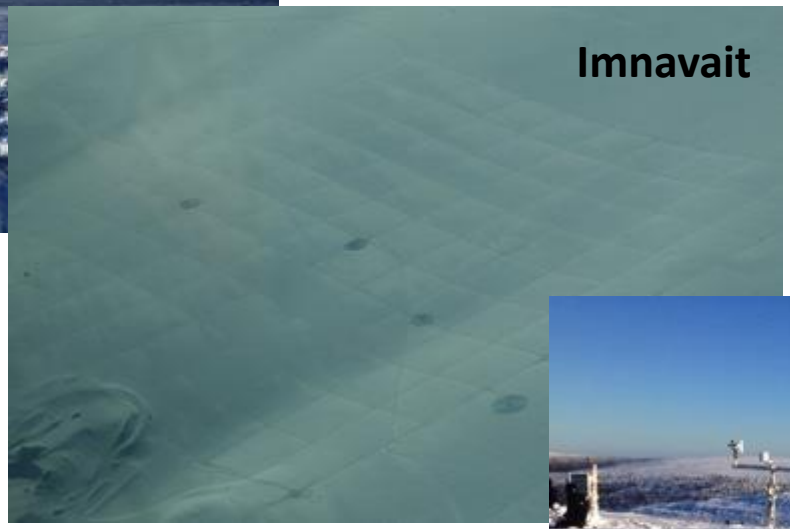
Core Sites

Site	2015 F→T transition	Tair	Tsoil	SM
Cambridge Bay	Late May	√	√	
Imnavait	Early May	√	√	
Baie-James	Early April			
Kuujjuaripik	Early April			
Sodankyla	Early April			
Saariselka	Mid April	√	√	√
BERMS	March			
Kenaston	March			
Carman	March			
Casselman	March			



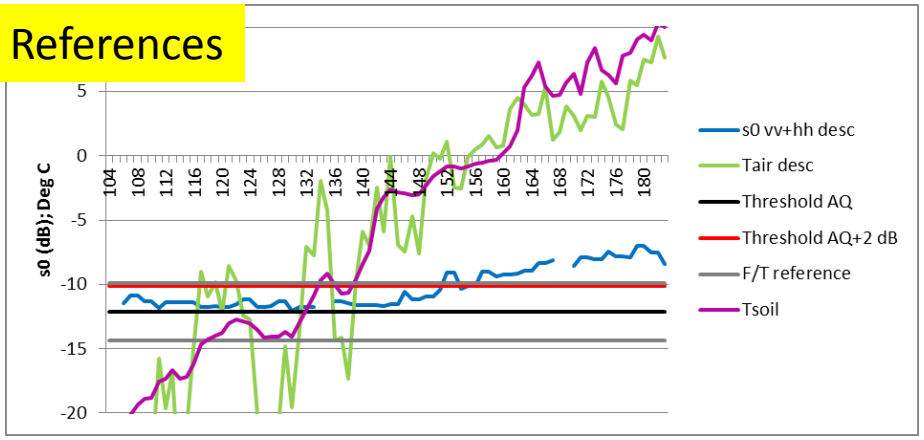
Core Sites

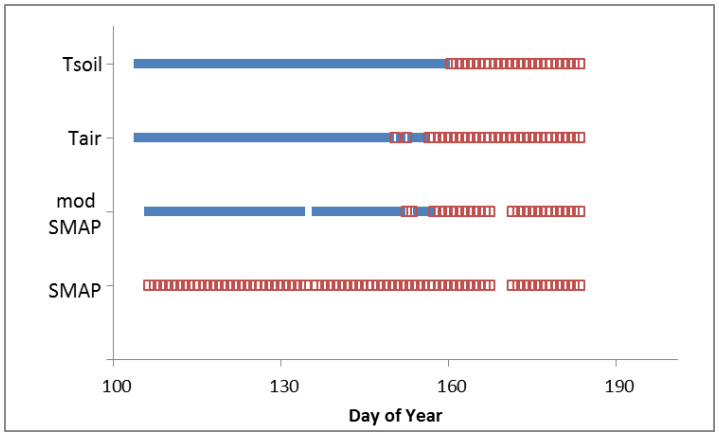




D11650 – Cambridge Bay - Descending

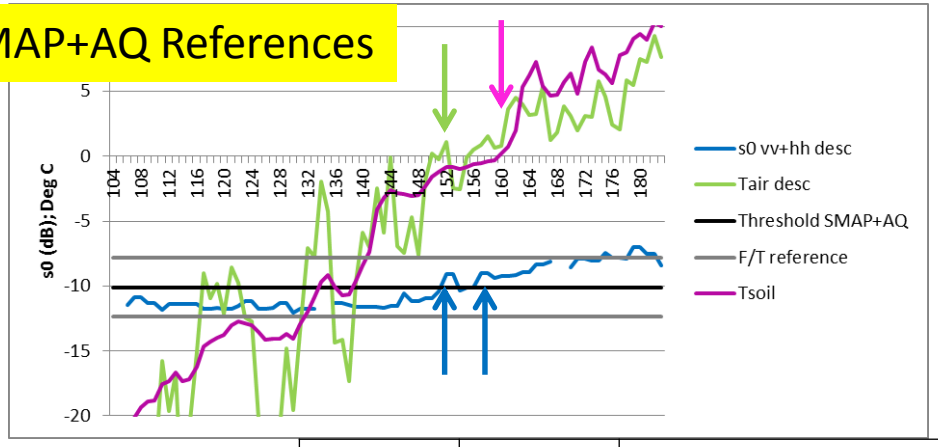
AQ References

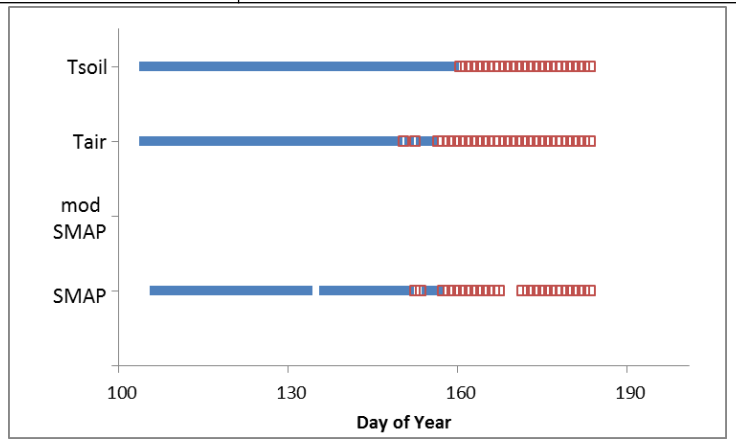




	Cases	% Agreement SMAP Tair	% Agreement mod SMAP Tair	% Agreement mod SMAP Tsoil
Des	73	0.37	0.96	0.93
Asc	77	0.51	0.95	0.84

SMAP+AQ References

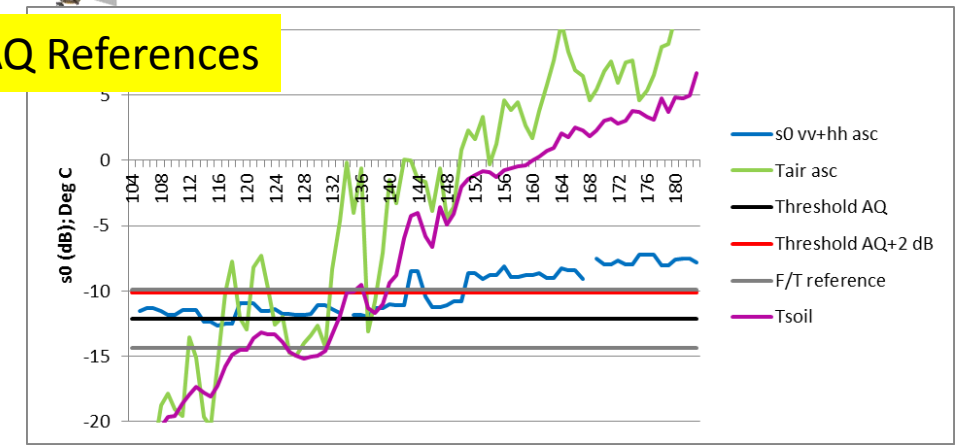


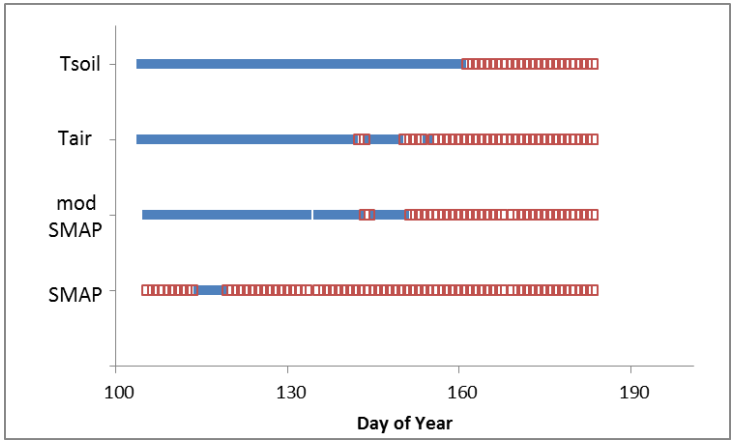


	Cases	% Agreement SMAP Tair	% Agreement SMAP Tsoil
Des	77	0.91	0.88
Asc	74	0.99	0.88

D11650 – Cambridge Bay - Ascending

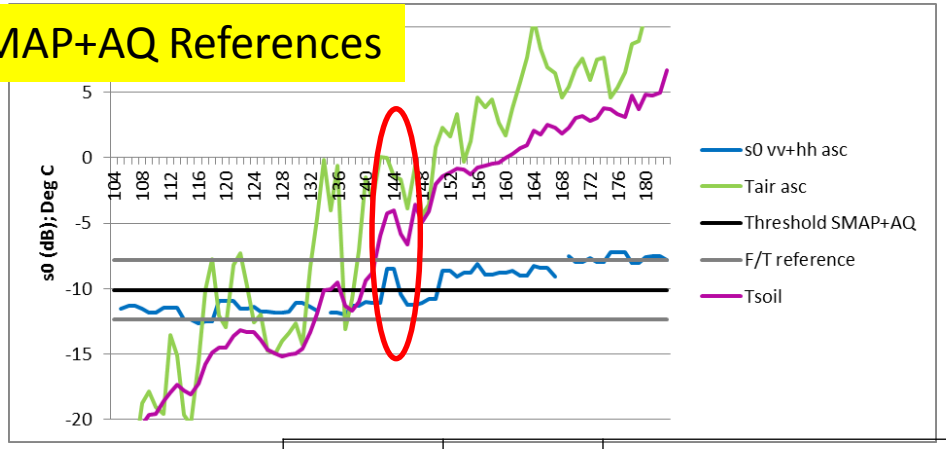
AQ References

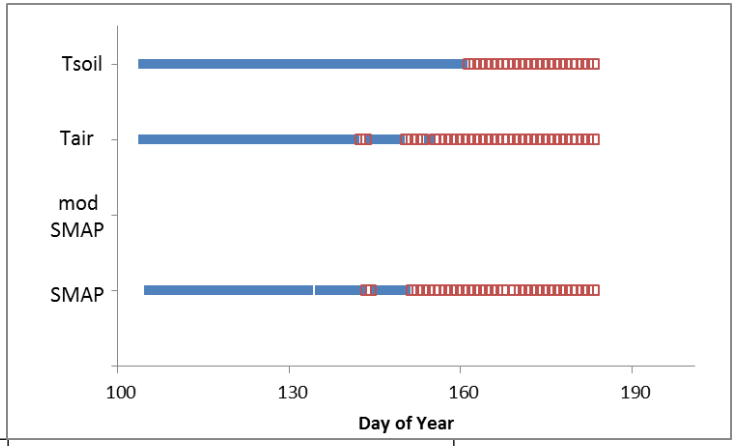




	Cases	% Agreement SMAP Tair	% Agreement mod SMAP Tair	% Agreement mod SMAP Tsoil
Des	73	0.37	0.96	0.93
Asc	77	0.51	0.95	0.84

SMAP+AQ References





	Cases	% Agreement SMAP Tair	% Agreement SMAP Tsoil
Des	77	0.91	0.88
Asc	74	0.99	0.88

D11650 – Cambridge Bay

AQ References

Tair

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
SMAP-Asc-F	5	0		
SMAP-Asc-T	39	34		
SMAP-Des-F			0	0
SMAP-Des-T			46	28

Tair

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
mod SMAP-Asc-F	41	2		
mod SMAP-Asc-T	3	32		
mod SMAP-Des-F			45	2
mod SMAP-Des-T			1	26

Tsoil

	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
mod SMAP-Asc-F	43	0		
mod SMAP-Asc-T	13	22		
mod SMAP-Des-F			47	0
mod SMAP-Des-T			5	22

SMAP+AQ References

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
SMAP-Asc-F	41	2		
SMAP-Asc-T	2	32		
SMAP-Des-F			45	2
SMAP-Des-T			1	25

Tair

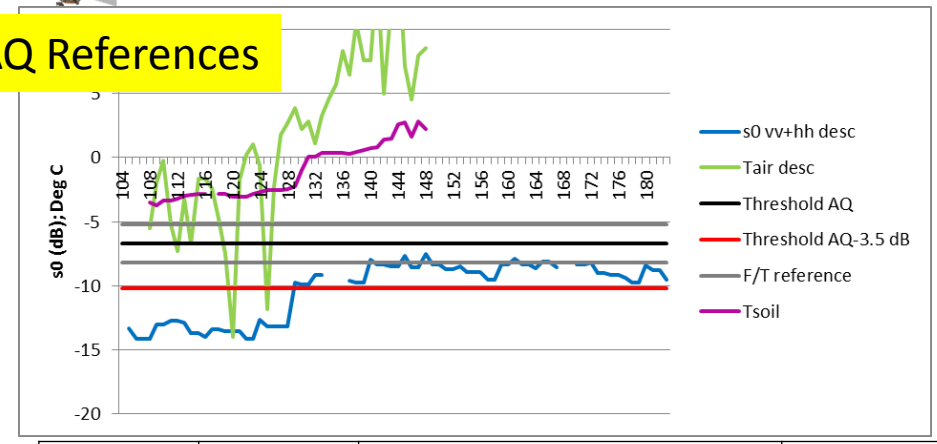
	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
SMAP-Asc-F	43	0		
SMAP-Asc-T	12	22		
SMAP-Des-F			47	0
SMAP-Des-T			5	21

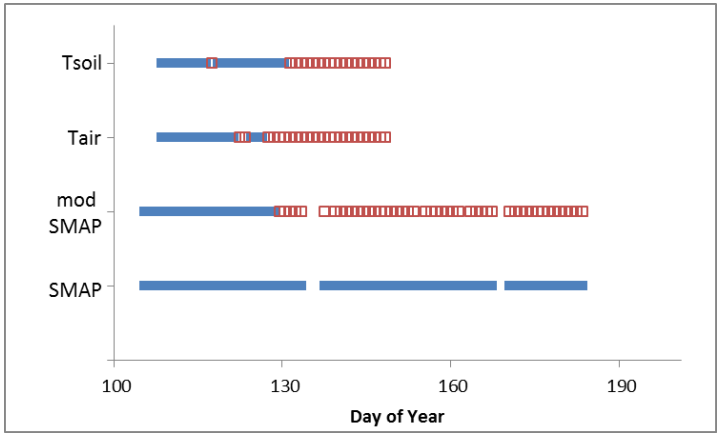
Tsoil

- Hybrid references produce excellent FT agreement with in situ Tair and Tsoil flags
- Asc radar signal responds to transient early FT events

D11650 – Imnavait - Descending

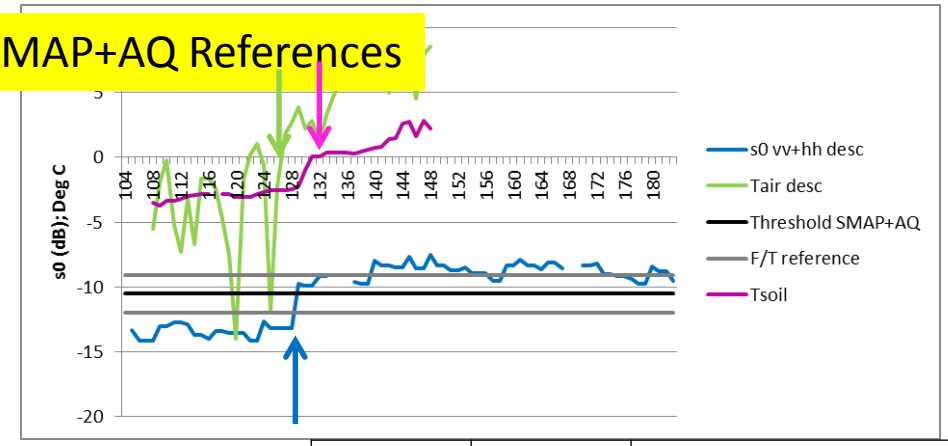
AQ References

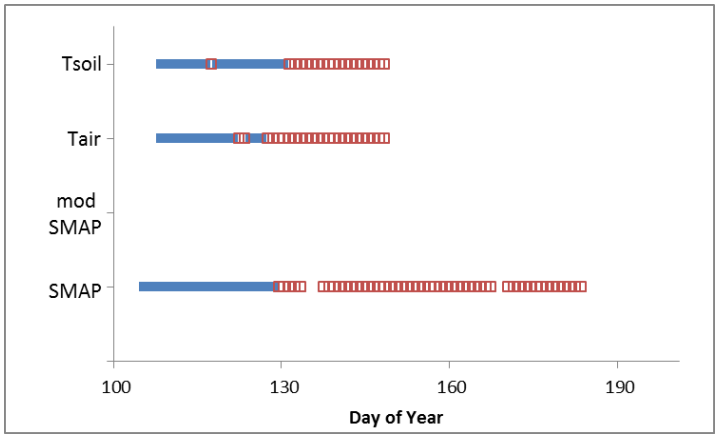




	Cases	% Agreement SMAP Tair	Agreement mod SMAP Tair	% Agreement mod SMAP Tsoil
Desc	37	0.43	0.89	0.92
Asc	37	0.35	0.81	0.92

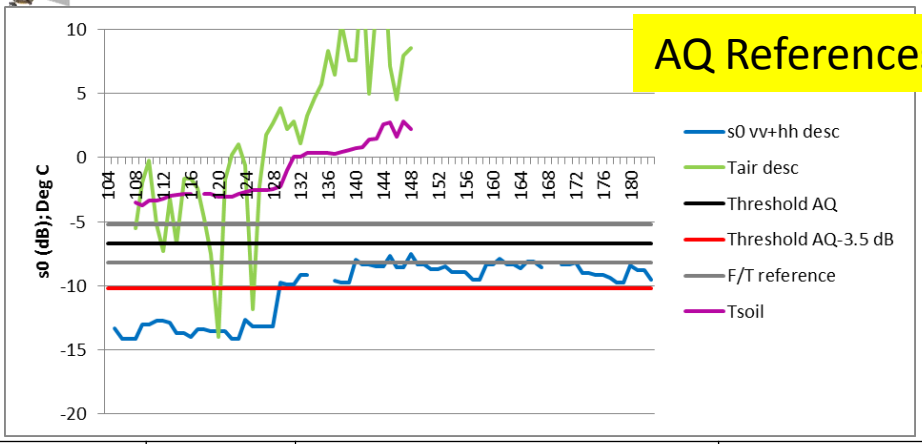
SMAP+AQ References

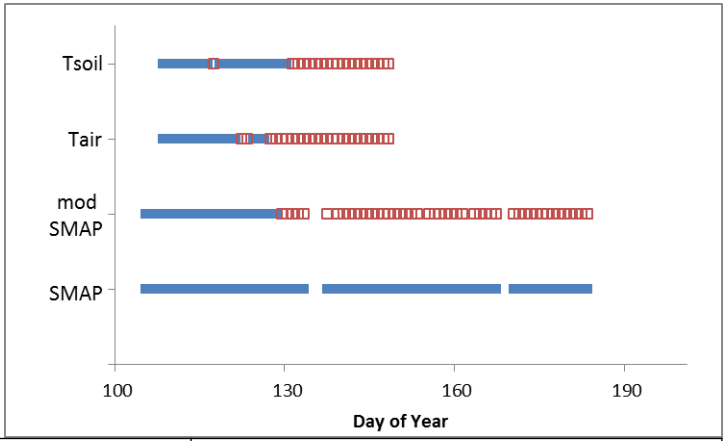




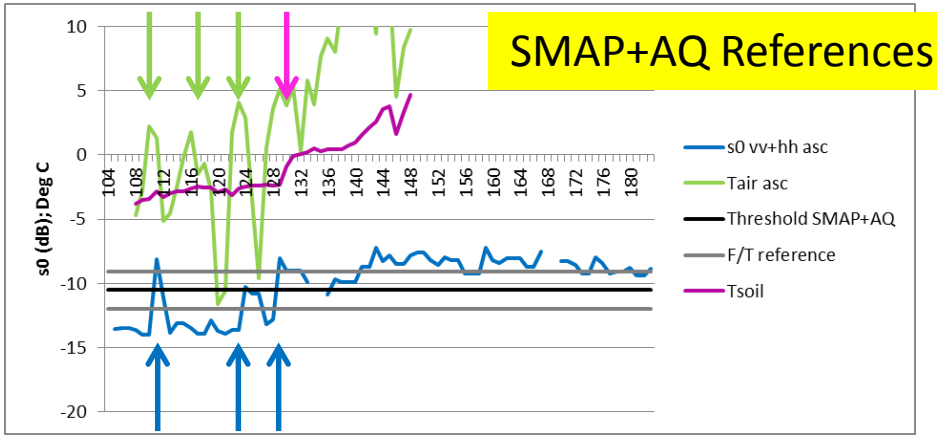
	Cases	% Agreement SMAP Tair	% Agreement SMAP Tsoil
Desc	38	0.92	0.92
Asc	39	0.85	0.87

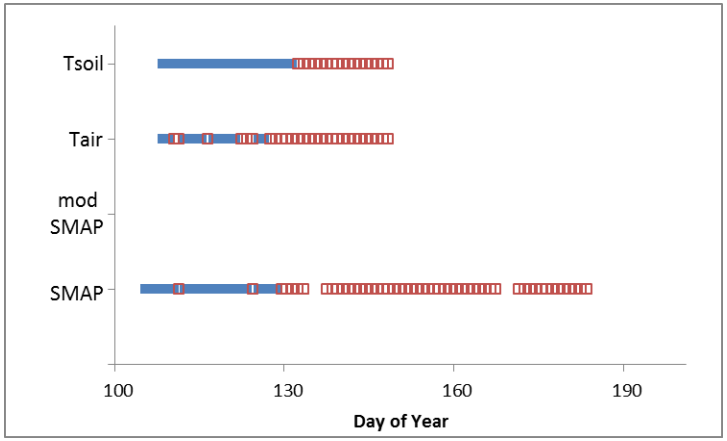
D11650 – Imnavait - Ascending





	Cases	% Agreement SMAP Tair	Agreement mod SMAP Tair	% Agreement mod SMAP Tsoil
Desc	37	0.43	0.89	0.92
Asc	37	0.35	0.81	0.92





	Cases	% Agreement SMAP Tair	% Agreement SMAP Tsoil
Desc	38	0.92	0.92
Asc	39	0.85	0.87

D11650 - Imnavait

AQ References

Tair

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
SMAP-Asc-F	13	25		
SMAP-Asc-T	0	1		
SMAP-Des-F			16	21
SMAP-Des-T			0	0

Tair

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
mod SMAP-Asc-F	13	7		
mod SMAP-Asc-T	0	19		
mod SMAP-Des-F			16	4
mod SMAP-Des-T			0	17

Tsoil

	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
mod SMAP-Asc-F	20	0		
mod SMAP-Asc-T	4	15		
mod SMAP-Des-F			19	1
mod SMAP-Des-T			2	15

SMAP+AQ References

	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
SMAP-Asc-F	13	6		
SMAP-Asc-T	0	20		
SMAP-Des-F			17	4
SMAP-Des-T			0	17

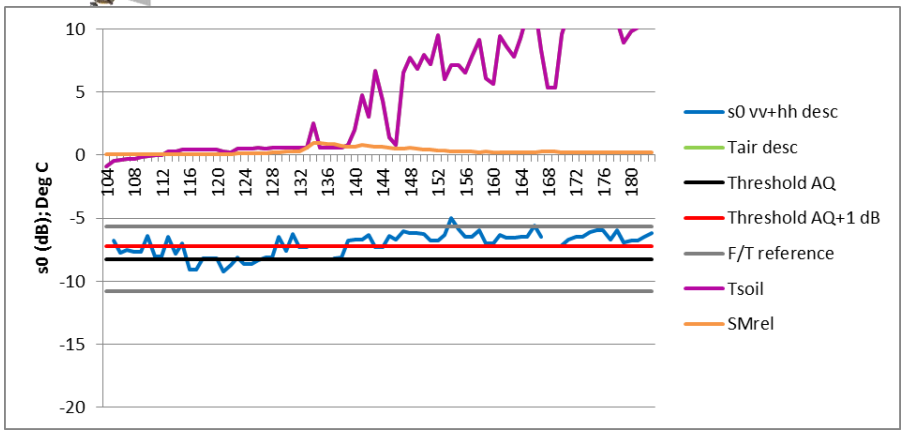
Tair

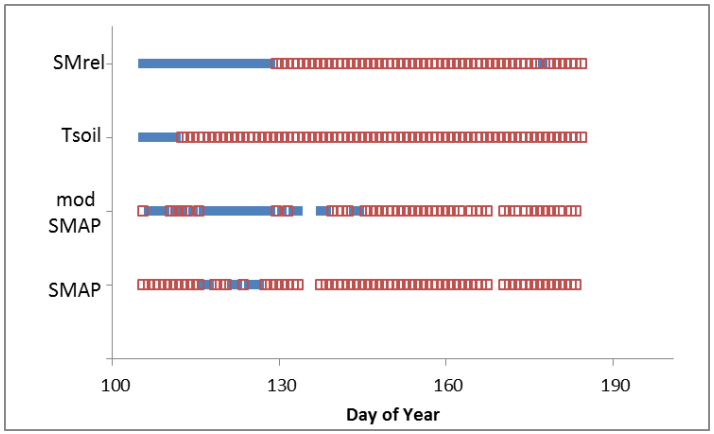
	Tair-PM-F	Tair-PM-T	Tair-AM-F	Tair-AM-T
mod SMAP-Asc-F	19	0		
mod SMAP-Asc-T	5	15		
mod SMAP-Des-F			20	1
mod SMAP-Des-T			2	15

Tsoil

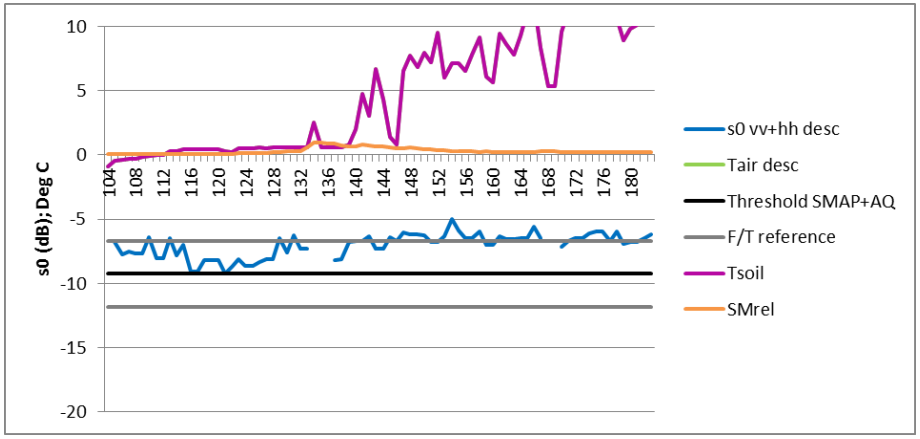
- Very clean radar response to primary FT transition (Tsoil)
- Asc radar signal responds to transient early FT events

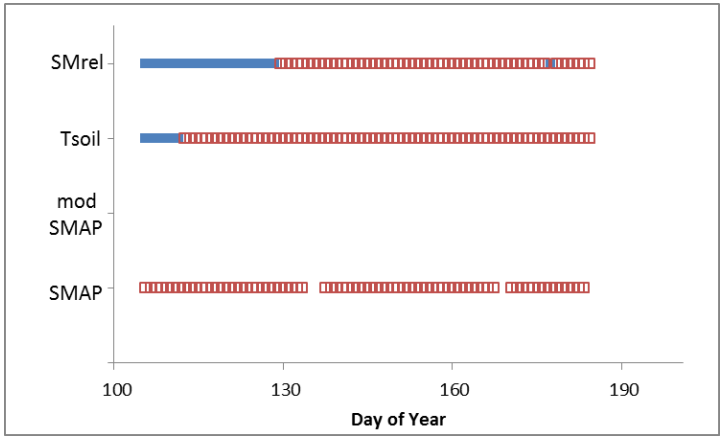
D11650 – Saariselka - Descending





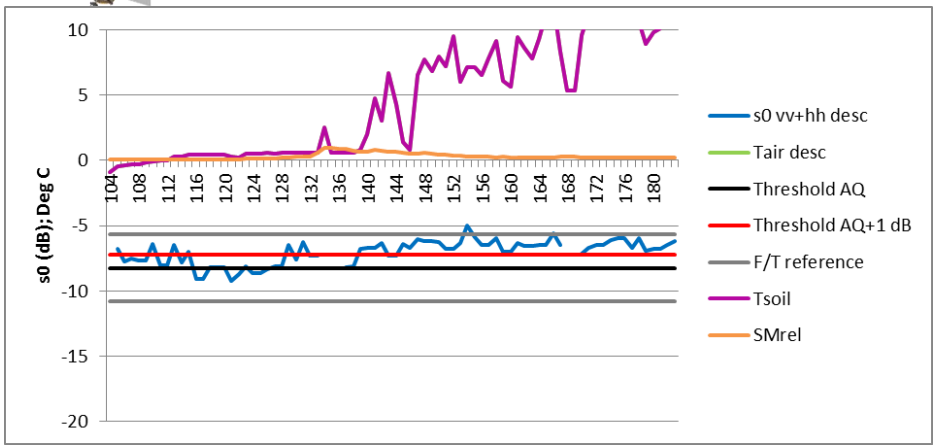
	Cases	% Agreement SMAP Tair	% Agreement mod SMAP Tsoil	% Agreement mod SMAP SMrel
Des	74	0.82	0.66	0.84
Asc	74	0.92	0.78	0.82

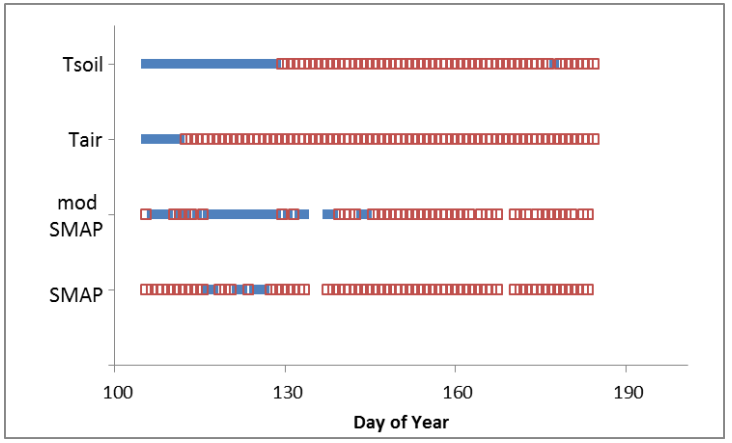




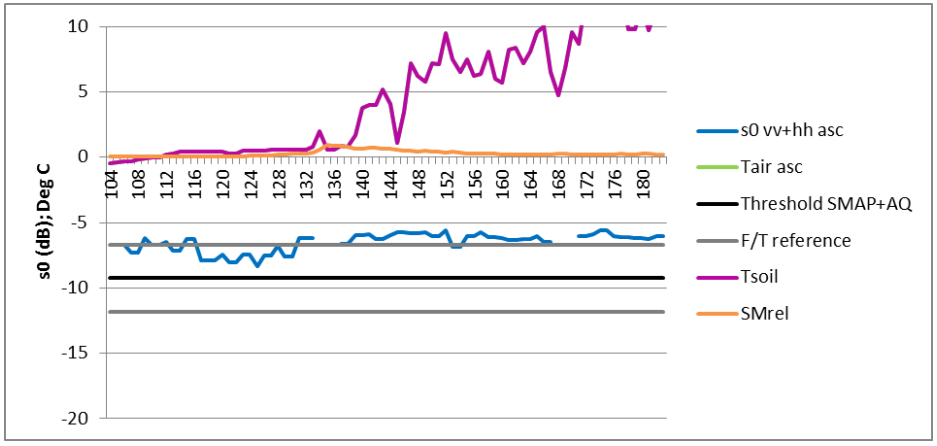
	Cases	% Agreement SMAP Tair	% Agreement SMAP SMrel
Des	73	0.92	0.67
Asc	73	0.93	0.68

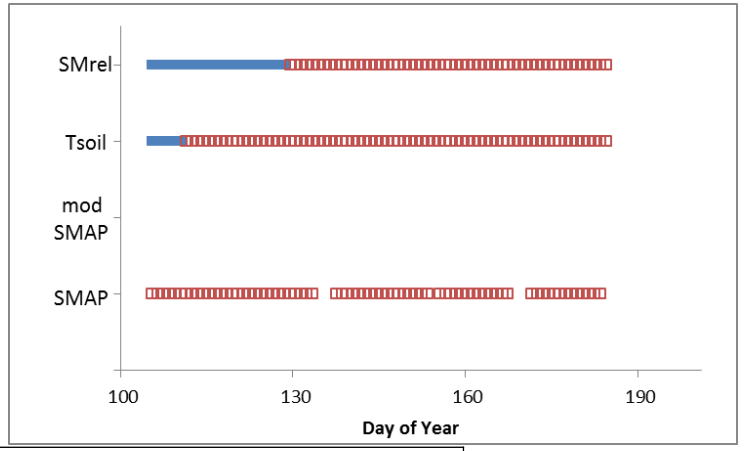
D11650 – Saariselka - Ascending





	Cases	% Agreement SMAP Tsoil	% Agreement mod SMAP Tsoil	% Agreement mod SMAP SMrel
Des	74	0.82	0.66	0.84
Asc	74	0.92	0.78	0.82





	Cases	% Agreement SMAP Tsoil	% Agreement SMAP SMrel
Des	73	0.92	0.67
Asc	73	0.93	0.68

D11650 - Saariselka

AQ References

Tair

	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
SMAP-Asc-F	0	1		
SMAP-Asc-T	5	67		
SMAP-Des-F			0	7
SMAP-Des-T			6	61

Tair

	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
mod SMAP-Asc-F	2	13		
mod SMAP-Asc-T	3	55		
mod SMAP-Des-F			4	23
mod SMAP-Des-T			2	45

Tsoil

	SMrel-PM-F	SMrel-PM-T	SMrel-AM-F	SMrel-AM-T
mod SMAP-Asc-F	13	2		
mod SMAP-Asc-T	10	48		
mod SMAP-Des-F			19	8
mod SMAP-Des-T			5	42

SMAP+AQ References

	Tsoil-PM-F	Tsoil-PM-T	Tsoil-AM-F	Tsoil-AM-T
SMAP-Asc-F	0	0		
SMAP-Asc-T	5	68		
SMAP-Des-F			0	0
SMAP-Des-T			6	68

Tair

	SMrel-PM-F	SMrel-PM-T	SMrel-AM-F	SMrel-AM-T
SMAP-Asc-F	0	0		
SMAP-Asc-T	23	50		
SMAP-Des-F			0	0
SMAP-Des-T			24	50

Tsoil

- SMrel in situ flag lags Tsoil by approx. 2 weeks
- FT retrievals indicate thaw for the entire period – consistent with likely wet snow in April

Triple collocation for categorical variables: application to validating landscape freeze/thaw retrievals

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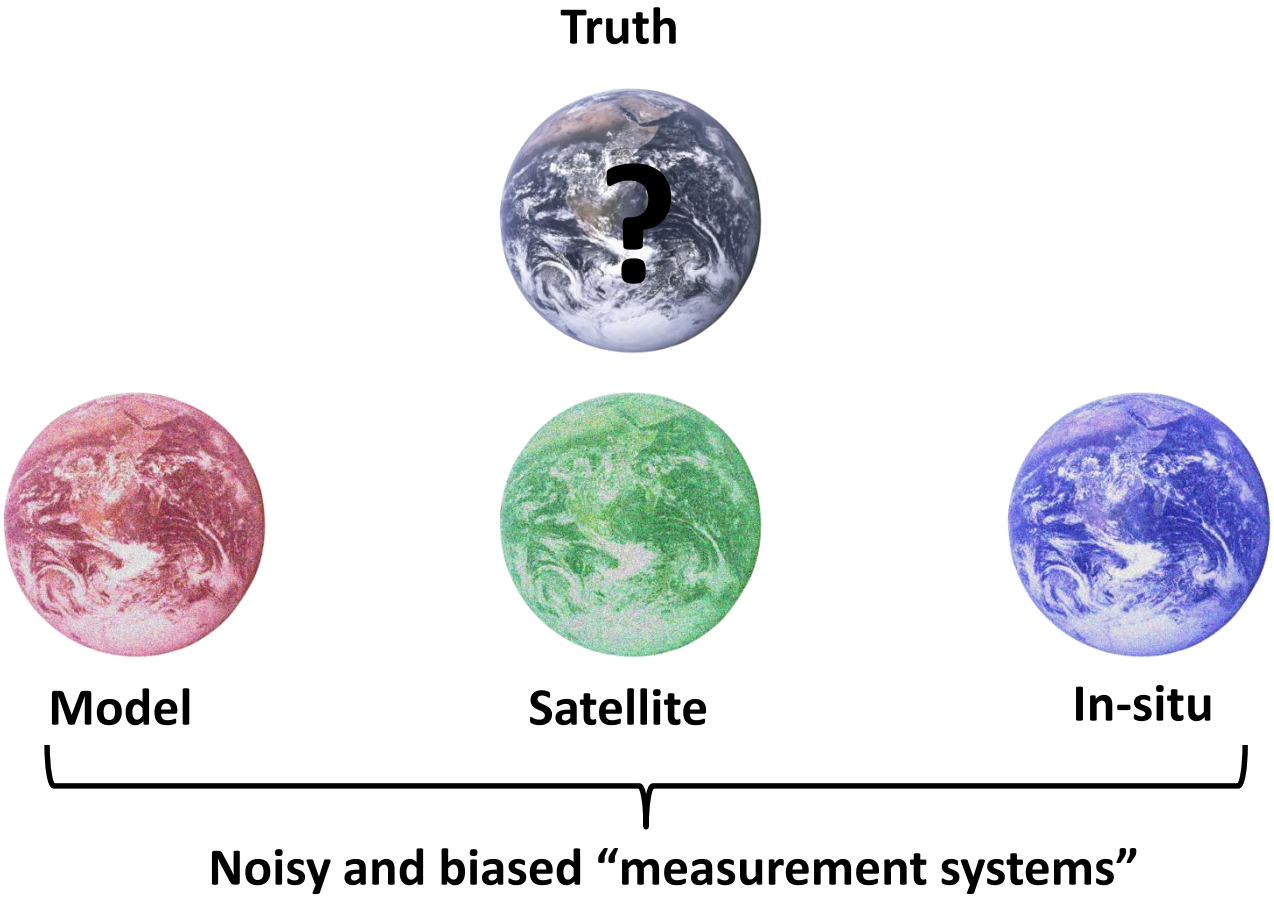
Alexandre Roy (Sherbrooke)
Chris Derksen (Environment Canada)
Alexandra G. Konings (MIT)
Seyed Hamed Alemohammad (MIT)
Dara Entekhabi (MIT)



Given we don’t know the truth, how can we

i) characterize errors of each system?

ii) calibrate each system with respect to a reference system?

Triple collocation (TC)

- A class of methods for error characterization and (relative) calibration in the absence of a "truth" dataset.
- Requires at least three (noisy, biased) measurement systems, with known correlation structure between errors (most simply, uncorrelated).
- Based on covariance matrix decomposition of observations from the measurement systems.

Overview

- Triple collocation (TC)
  - Classical TC (Stoffelen, 1998)
  - Categorical TC (McColl et al., submitted)
    - Application: validating freeze/thaw measurements

Overview

- Triple collocation (TC)
  - Classical TC (Stoffelen, 1998)
  - Categorical TC (McColl et al., submitted)
    - Application: validating freeze/thaw measurements

Classical TC: Assumptions

- Data model
  - $X_i = \alpha_i + \beta_i T + \varepsilon_i$ for $i = 1,2,3$
    - X_i are observations from *i*th measurement system
    - T is the true value
      - $\mathrm{Var}(T)$ is constant
    - α_i, β_i are calibration parameters
    - ε_i are random errors
- Error model
  - $\mathrm{E}(\varepsilon_i) = 0$
  - $\mathrm{Var}(\varepsilon_i)$ is constant
  - Not necessarily Gaussian
  - **$\mathbf{Cov}(\boldsymbol{\varepsilon_i}, \boldsymbol{\varepsilon_j}) = \mathbf{0}$ for $\boldsymbol{i \neq j}$**
  - **$\mathbf{Cov}(\boldsymbol{\varepsilon_i}, \boldsymbol{T}) = \mathbf{0}$ for all $\boldsymbol{i}$**

(Yilmaz & Crow, 2014)

Classical TC: Outputs

- Absolute MSEs
  - $\mathrm{Var}(\boldsymbol{\varepsilon}) = \begin{bmatrix} Q_{11} - \frac{Q_{12}Q_{13}}{Q_{23}} \\ Q_{22} - \frac{Q_{12}Q_{23}}{Q_{13}} \\ Q_{33} - \frac{Q_{13}Q_{23}}{Q_{12}} \end{bmatrix}$,

where $Q_{ij} = \mathrm{Cov}(X_i, X_j)$

- Relative calibration parameters
  - Set $\alpha_1 = 0, \beta_1 = 1$
  - $\beta_2 = \frac{Q_{23}}{Q_{13}}, \beta_3 = \frac{Q_{23}}{Q_{12}}$
  - $\alpha_2 = \overline{X_2} - \beta_2\overline{X_1}, \alpha_3 = \overline{X_3} - \beta_3\overline{X_1}$

- Absolute correlation coefficients (McColl et al., 2014)
  - $\boldsymbol{\rho_{T,X}}^2 = \begin{bmatrix} \frac{Q_{12}Q_{13}}{Q_{11}Q_{23}} \\ \frac{Q_{12}Q_{23}}{Q_{22}Q_{13}} \\ \frac{Q_{13}Q_{23}}{Q_{33}Q_{12}} \end{bmatrix}$

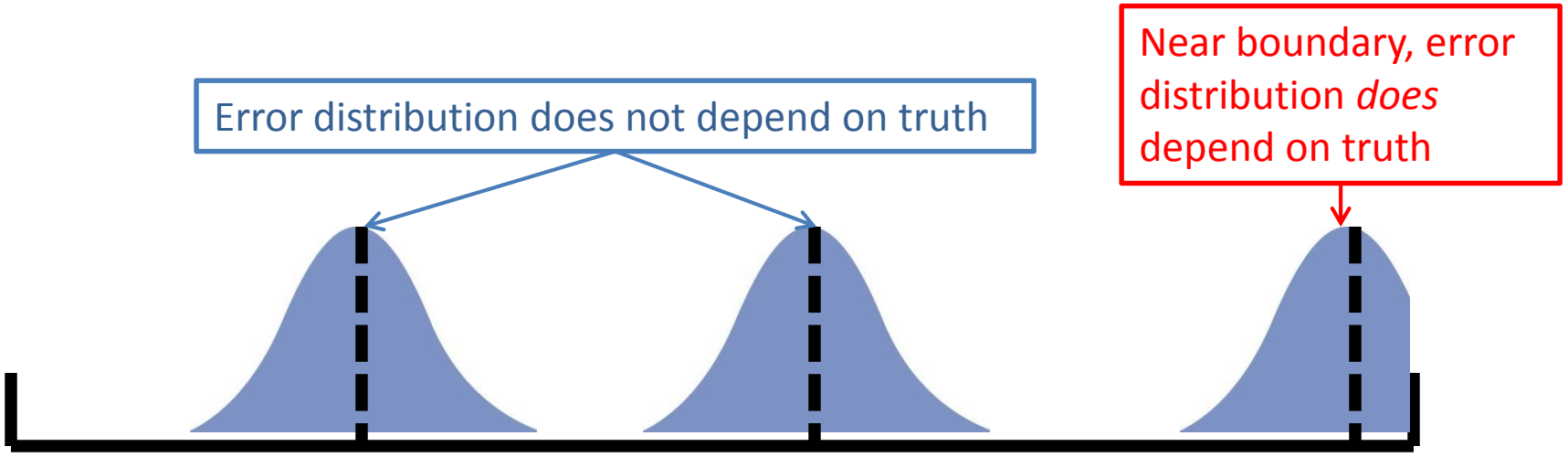
McColl, K.A., J. Vogelzang, A.G. Konings, D. Entekhabi, M. Piles, A. Stoffelen (2014). Extended Triple Collocation: Estimating errors and correlation coefficients with respect to an unknown target. *Geophysical Research Letters* 41:6229-6236

Overview

- Triple collocation (TC)
  - Classical TC (Stoffelen, 1998)
  - Categorical TC (McColl et al., submitted)
    - Application: validating freeze/thaw measurements

Categorical TC: motivation

- Classical TC fails when applied to categorical variables.
- Automatic violation of key assumptions due to boundedness.



- Need an alternative that relaxes this assumption.

Classical TC: Assumptions

- Data model
  - $X_i = \alpha_i + \beta_i T + \varepsilon_i$ for $i = 1,2,3$
    - X_i are observations from *i*th measurement system
    - *T* is the true value
      - $\mathrm{Var}(T)$ is constant
    - α_i, β_i are calibration parameters
    - ε_i are random errors
- Error model
  - $\mathrm{E}(\varepsilon_i) = 0$
  - $\mathrm{Var}(\varepsilon_i)$ is constant
  - Not necessarily Gaussian
  - $\mathrm{Cov}(\varepsilon_i, \varepsilon_j) = 0$ for $i \neq j$
  - $\mathrm{Cov}(\varepsilon_i, T) = 0$ for all i

Categorical TC: Assumptions

- Data model
  - $X_i = T + \varepsilon_i$ for $i = 1,2,3$
    - $X_i \in \{-1,1\}$ are observations from *i*th measurement system
    - $T \in \{-1,1\}$ is the true value
      - $\mathrm{Var}(T)$ is a function of $\mathrm{E}(T)$, which may vary in time
    - No calibration parameters
    - $\varepsilon_i \in \{-2,0,2\}$ are random errors, conditional on T
- Error model
  - $\Pr(\varepsilon_i, \varepsilon_j | T) = \Pr(\varepsilon_i | T) \Pr(\varepsilon_j | T)$
    - Weaker assumption compared to those in classical TC

Categorical TC: Outputs

Can obtain performance *rankings* of the three measurement systems with respect to their balanced accuracies

$$\pi_i = \frac{1}{2}(\psi_i + \eta_i)$$

(where $\psi_i = \Pr(X_i = T|T = 1)$ is the sensitivity and $\eta_i = \Pr(X_i = T|T = -1)$ is the specificity of measurement system *i*) by sorting in descending order

$$\boldsymbol{v} = \left[\sqrt{\frac{Q_{12}Q_{13}}{Q_{23}}}, \sqrt{\frac{Q_{12}Q_{23}}{Q_{13}}}, \sqrt{\frac{Q_{23}Q_{13}}{Q_{12}}}\right]$$

where $Q_{ij} = \mathrm{Cov}(X_i, X_j)$.

Full derivation in:

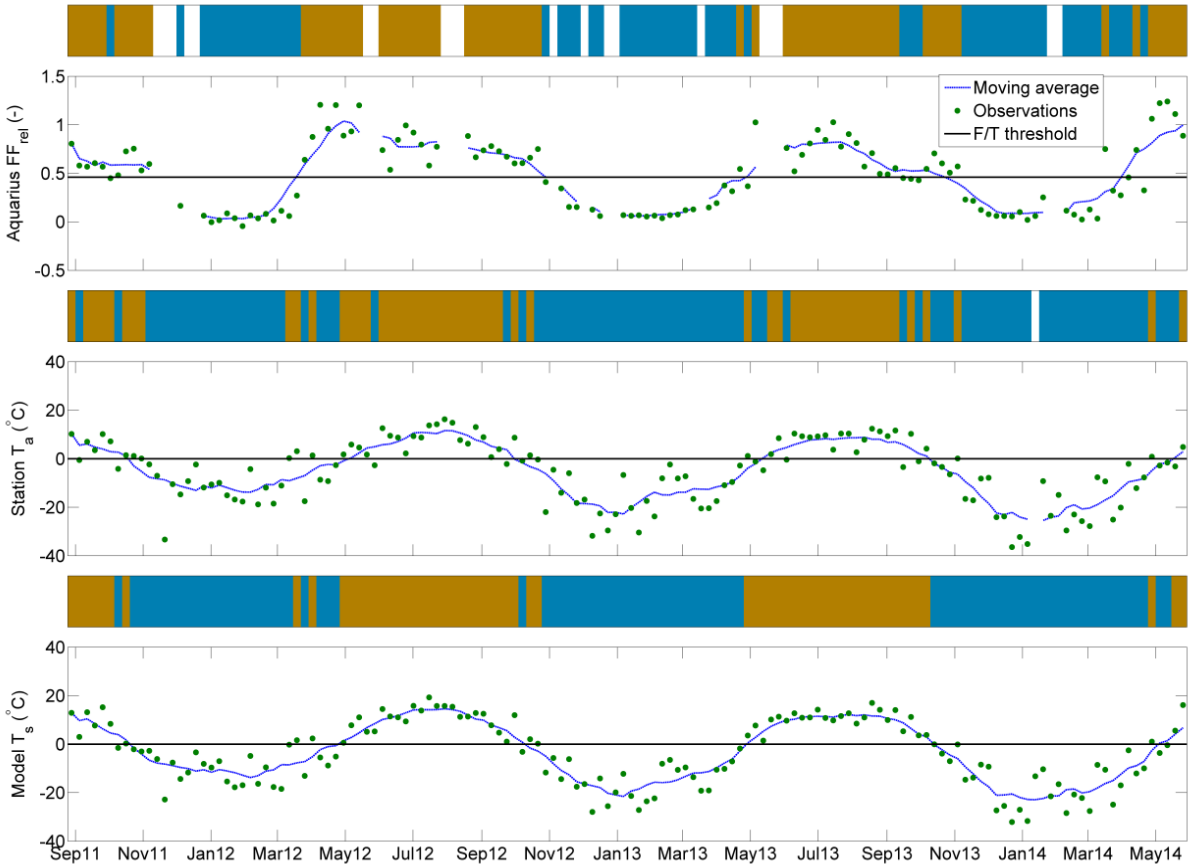
McColl, K.A., Roy, A., Derksen, C., Konings, A.G., Alemohammad, S.H., Entekhabi, D. Triple collocation for binary and categorical variables: application to validating landscape freeze/thaw retrievals. Submitted.

Application: freeze/thaw state

1. Aquarius L-band passive polarization ratio

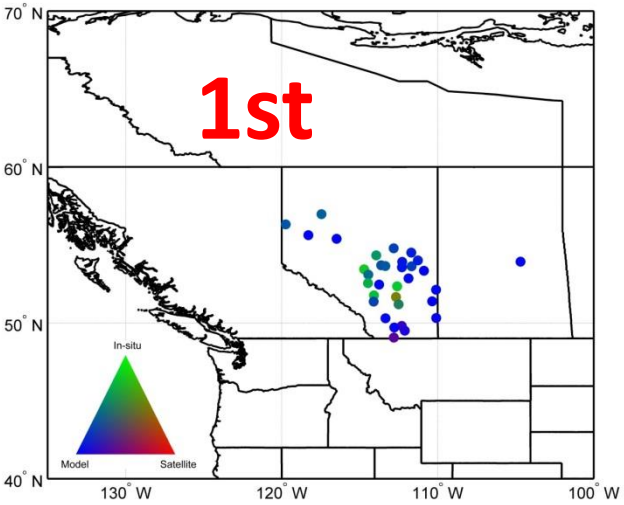
2. Station air temperatures

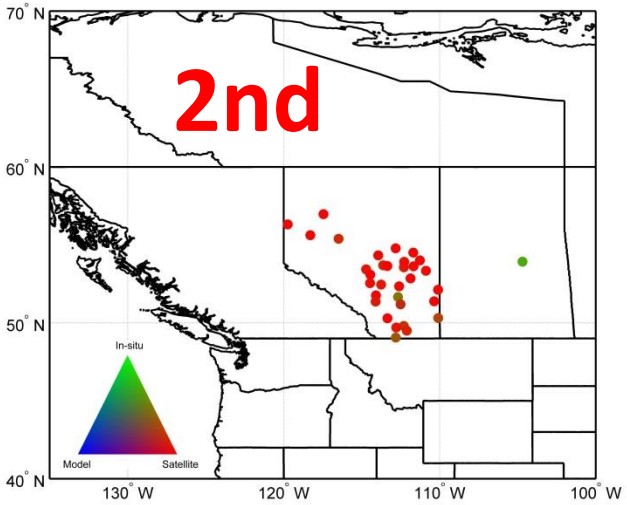
3. Canadian Meteorological Centre surface analysis soil temperatures

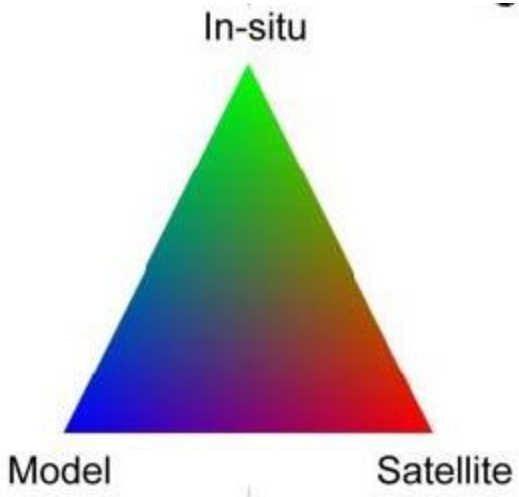


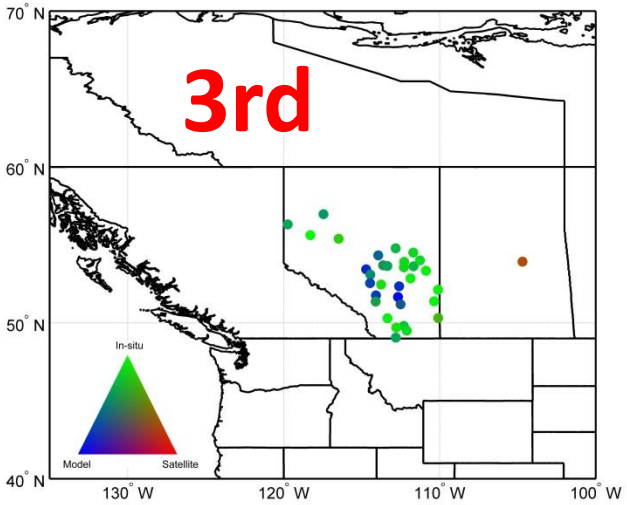
Example time series of freeze/thaw products at a single site.
Looked at 33 sites across Saskatchewan and Alberta, Canada.

Results: Rankings









- In-situ data often ranked last!
- Demonstrates importance of not assuming any measurement system is error-free.

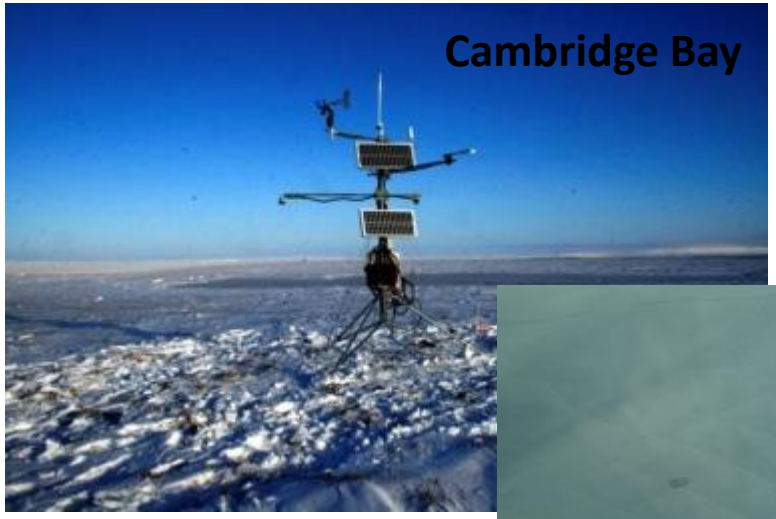
Summary

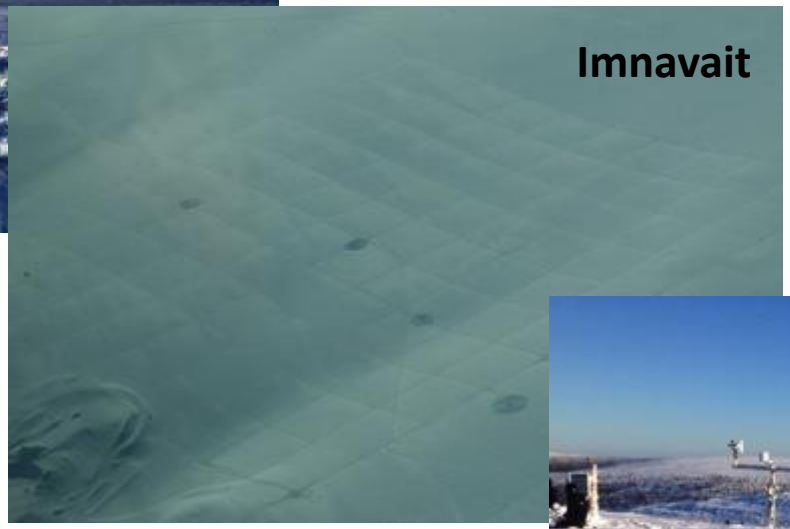
- Classical TC fails when applied to categorical variables because they are strongly bounded.
- We introduce CTC, designed for categorical variables and robust to boundedness.
- We apply CTC to F/T validation. *At large scales*, the in-situ product frequently shows the poorest performance over our study domain.
- Future work: apply CTC spatially (no longer require long time-series).

Summary

- Removal of swath edge and nadir effects in L1C_s0 (T11840) produces clean L3_FT_A retrievals
- Hybrid SMAP+AQ references remove need for major threshold adjustments which were required with SMAP inputs combined with AQ references
- Analysis at sparse and core sites indicates 80% flag agreement requirement is met during the 2015 spring transition (tundra sites reduce ambiguity between Tair and Tsoil)
- No major road blocks ahead of beta release in October
- Triple colocation adapted for categorical data, and applied to FT validation
- Recent analysis of SMOS and Aquarius measurements illustrates the potential for L-band radiometer retrievals of landscape freeze/thaw using a retrieval method conceptually similar to the SMAP radar retrieval
- Expected impacts on retrieval performance compared to L3_FT_A are related to change in sensitivity from the active to passive case, and increased spatial classification error due to coarser resolution (36 vs 3 km)

Thanks to our cal/val partners





Université de Sherbrooke; University of Alaska-Fairbanks; Finnish Meteorological Institute; University of Guelph; University of Saskatchewan; Agriculture and Agri-Food Canada; Alfred Wegener Institute; Natural Resources Conservation Service

Back-up

L1C_TB Derived (Passive) FT: Algorithm

- Recent analysis of SMOS and Aquarius measurements illustrates the potential for L-band radiometer retrievals of landscape freeze/thaw using a retrieval method conceptually similar to the SMAP radar retrieval

- Previous work (Rautiainen et al., 2014; Roy et al., in press) utilizes a radiometer derived freezing factor (*FF*), utilized in combination with frozen and thawed reference information

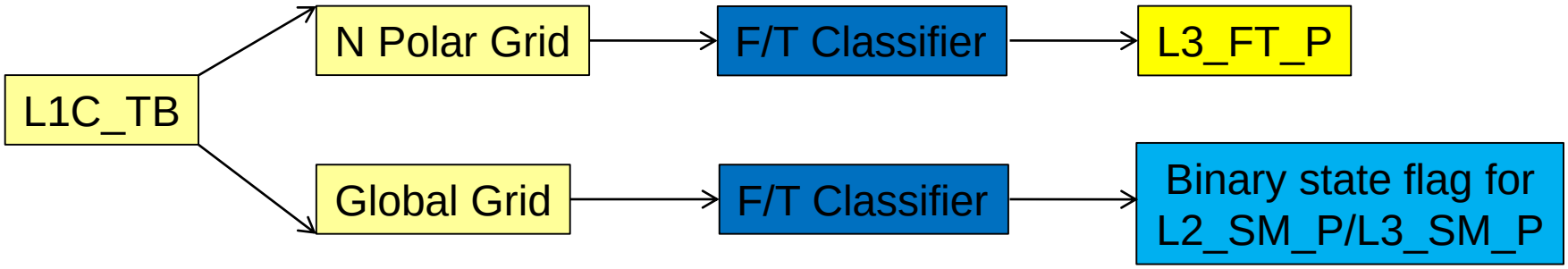
- The FF(t) term can be derived using various forms of the polarization ratio:

$$FF_{PR} = \frac{TB_H}{TB_V}$$

- Expected impacts on retrieval performance compared to L3_FT_A are related to change in sensitivity from the active to passive case, and increased spatial classification error due coarser resolution (36 vs 3 km)

Passive FT: Processing Flow

- L1C_TB product has global, north, and south polar grids
- Simple retrieval code required to extract the polar Tb's and output a daily AM/PM L3_FT_P product
- Same extraction could be applied for the global grid, or the global grid Tb's can propagate through an integrated FT algorithm in L2_SM_P and into an augmented AM/PM L3_SM_P product, including AM/PM transition flags.



Passive FT: Tasks

- Algorithm Development
  - Algorithm prototyping: code algorithm options, investigate performance of 2 polarization ratio approaches (Generate both options routinely for initial investigations)
  - Develop reference states/thresholds from Aquarius and compare to SMAP/SMOS; investigate magnitude of reference differences across north polar and global grids)
  - Code retrieval algorithm module (Fortran) for incorporation in L2/L3_SM_P, L3_FT_P
- Integrated passive FT in L2/L3_SM_P (global grid)
  - Update L2_SM_P code & interfaces to add FT parameter input, FT retrieval module
    - Modify SPDM interfaces for L2_SM_P (generate run config)
  - Augment L3_SM_P product to add PM (ascending) data layer, FT transition flags
    - Modify SPDM interface to input both AM & PM L2_SM_P data
  - L4_C change to assimilate L3_SM_P for global FT inputs (Kimball)
- L3_FT_P product (polar grid)
  - Product design (inherit features of L3_FT_A)
    - Product content, metadata
    - Product specification document, user guide inputs
    - Develop PAIS spec (needed for SPS Framework generation)
  - Processor design
    - Data flow (input/composite L1C_TB, retrieval algorithm, prior-day data fill, daily output)
    - Add L3_FT_P to SPS code generator software
    - SPDM interfaces: ancillary file inputs, runtime rules; everything needed for whole new product

Passive FT: Timeline

Assumptions:

- Algorithm development can continue throughout the Cal/Val period, delivering updates to reference state and threshold table as needed (pre-beta test, beta, validated); other software development in parallel
- Preliminary retrieval algorithm module can be developed immediately; use same code for both global (L2/L3_SM_P) and polar (L3_FT_P) products
- ADT supplies code development & ancillary data, documentation (SPDM interfaces, PSD, UG)
- SDS support for PAIS (product & metadata spec), code generation, and SPDM interfaces

Algorithm Development:

- Write retrieval code module (~<1 week)
- Prototype retrieval (Matlab/IDL), start development of reference states, thresholds, performance evaluations using SMAP/AQ/SMOS data (Aug 1)
  - Deliver preliminary FT parameter table by end of August
  - Update FT parameter table by October 10 (for SDS I&T for L2/L3 Beta release)
  - Validated SMAP-only FT parameters, retrieval algorithm updates by April 1, 2016 (for validated L2 release)

Integrated passive FT in L2/L3_SM_P

- L2_SM_P code & spec update to add FT retrieval module & FT parameter input (~2 weeks?)
- Test with preliminary FT table (end August/early September)
- Augment L3_SM_P spec for PM output layers, FT transition flags (~2 weeks?)
- SPDM interface changes for L2_SM_P, L3_SM_P (C. Wong, TBD)

Passive FT: Timeline (2)

L3_FT_P Product Development

- Product design
  - Product content (~1 week)
  - PAIS spec development, metadata (~2-3 weeks, need O. Kwoun)
  - Product spec and user guide documentation, needed for NSIDC by mid-October
- Processor design
  - Adaptation from L3_FT_A code, add in FT retrieval code module (~2 weeks)
  - SPS code generation from PAIS spec (~2 weeks?, need A. Niessner)
  - Define/implement SPDM interfaces (TBD?, need C. Wong)
  - Testing (2-3 weeks, run & analyze using existing SMAP L1C_TB data inputs)
  - Ready for SDS integration by early October?
- External interfaces
  - Documentation, test data to NSIDC
  - How much time does NSIDC need to be ready for new product?