Jet Propulsion Laboratory
California Institute of Technology

Soil Moisture
Active Passive
SMAP
Mission

SMAP Mission Status

Simon Yueh, Project Scientist
April 4, 2016

4th SMAP Application Workshop

Jet Propulsion Laboratory,
California Institute of Technology

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Topics

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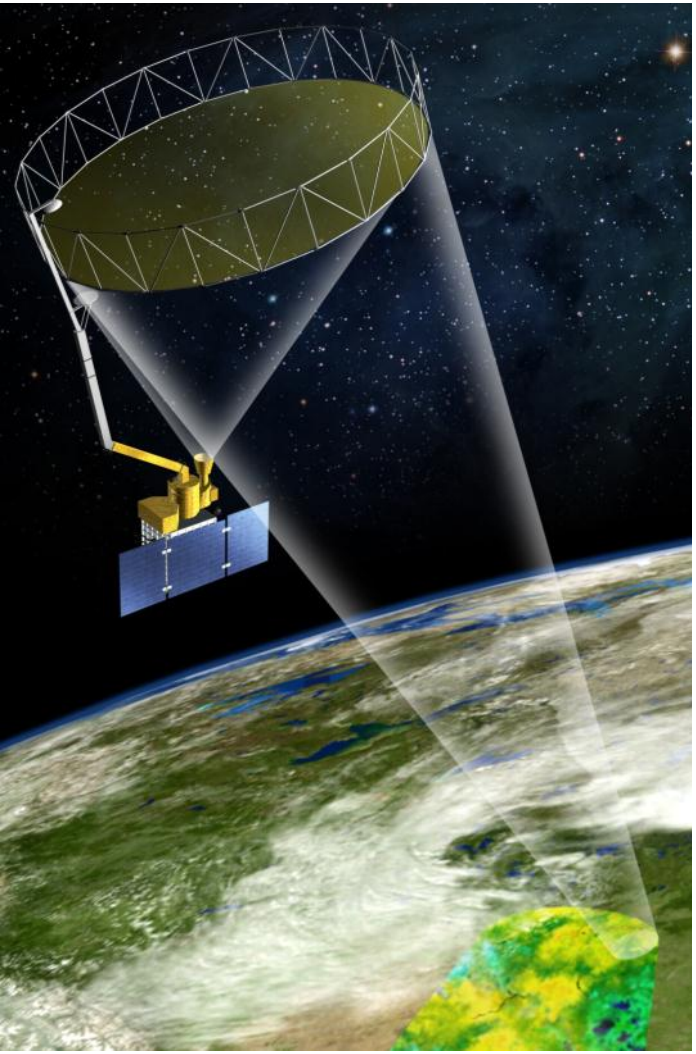
- Mission Status
- Current Baseline Radiometer Science Performance
- Overall Science Recovery Scope
- Enhanced Resolution Passive product development
- Radiometer-Derived F-T Product
- SMAP Radiometer and Sentinel Radar Active-Passive Product
- Summary

Background: Project Overview



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

Primary Science Objectives

- Global, high-resolution mapping of soil moisture and its freeze/thaw state to
  - Link terrestrial water, energy, and carbon-cycle processes
  - Estimate global water and energy fluxes at the land surface
  - Quantify net carbon flux in boreal landscapes
  - Extend weather and climate forecast skill
  - Develop improved flood and drought prediction capability

Mission Implementation

Partners	• JPL (project & payload management, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Risk	• 7120.5E Category 2; 8705.4 Payload Risk Class C
Launch	• January 31, 2015 on Delta 7320-10C Launch System
Orbit	• Polar Sun-synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band (non-imaging) synthetic aperture radar (JPL) • L-band radiometer (GSFC) • Shared 6-m rotating (13 to 14.6 rpm) antenna (JPL)

NRC Earth Science Decadal Survey (2007) recommended SMAP as a Tier 1 mission

Background

- SMAP launched successfully January 31, 2015, Antenna deployment & spin-up complete Mar 26, and conducted successful PLAR on May 6.
- Data release of passive-only and beta active-passive products by Nov 1.
- Mission was operating successfully and appeared likely to meet all requirements when radar stopped operating 7 July 2015 (4 months into prime mission).
  - Radiometer, antenna and other spacecraft systems continue to function nominally
- Attempts to recover radar were unsuccessful in August 2015.
- Science recovery activities ongoing to enhance radiometer product resolution and active-passive disaggregation using Sentinel-1/SMAP data

SMAP Passive Soil Moisture Has Been Distributed through NSIDC since Sept 2015

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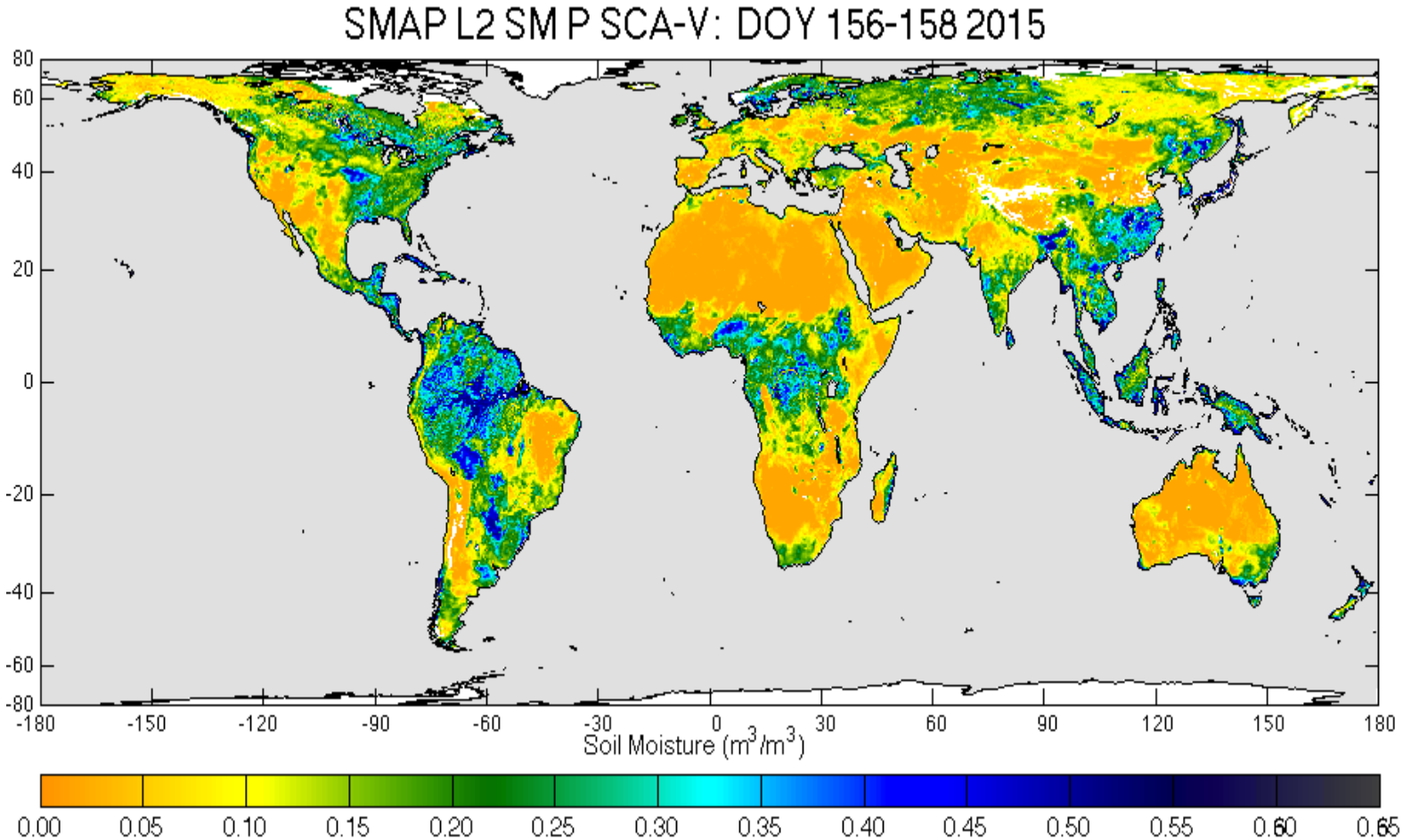
- Single channel vertical (SCA-V) polarization algorithm is the current baseline.

June 5-7, 2015



SMAP Radiometer Soil Moisture Performance at Core Validation Sites

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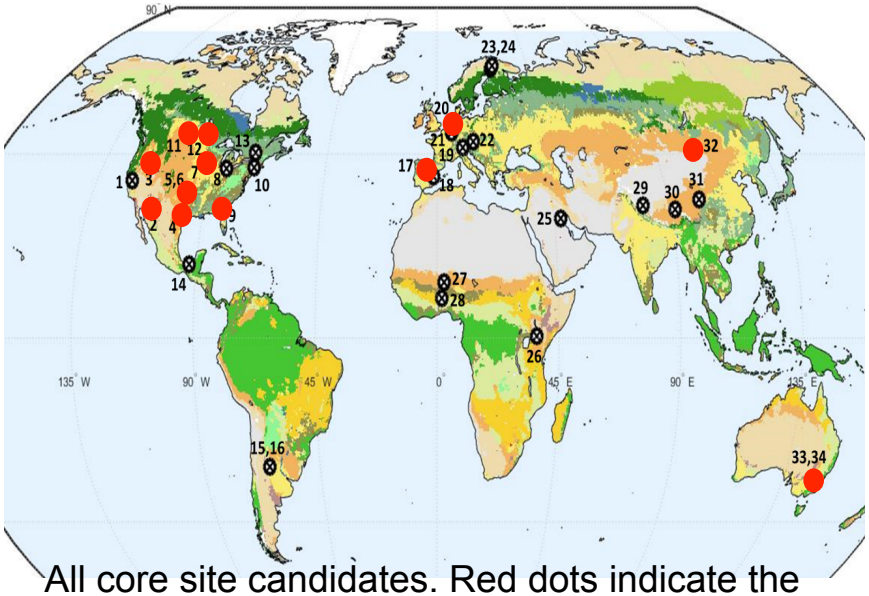
Performance Metrics

	SMAP L2_SM_P Soil Moisture			
Site name	**RMSE [m³/m³]**	**ubRMSE [m³/m³]**	**Bias [m³/m³]**	**R**
Reynolds Creek	0.051	0.041	-0.030	0.670
Walnut Gulch	0.028	0.028	-0.006	0.686
TxSON	0.031	0.029	-0.012	0.944
Fort Cobb	0.049	0.029	-0.040	0.883
Little Washita	0.028	0.021	-0.018	0.940
South Fork	0.083	0.053	-0.064	0.515
Little River	0.098	0.028	0.094	0.920
Kenaston	0.043	0.026	-0.035	0.775
Carman	0.103	0.058	-0.085	0.620
REMEDHUS	0.041	0.039	-0.013	0.896
Twente	0.037	0.036	-0.006	0.754
MAHASRI	0.037	0.037	-0.008	0.765
Yanco	0.041	0.038	0.016	0.935
TOTAL	**0.051**	**0.037***	**-0.015**	**0.798**

*This performance meets the SMAP requirement of 0.04

SMAP Core Validation Site Program

- Core Site Definition:
  - Multiple in situ sensors within satellite footprint
  - Well-calibrated in situ sensors
  - Spatial up-scaling to footprint scale established
  - Frequent access to the data



All core site candidates. Red dots indicate the sites that meet the criteria above. These sites are used for the metrics computation on the left.

Effect of RFI: Localized Analysis

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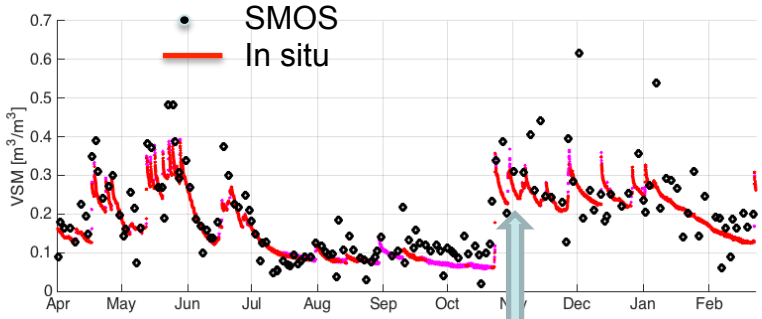
Effect of an RFI source in Texas: SMOS

- A new source of illegal RFI was detected* in the vicinity of the TxSON core site in Texas at the end of October 2015
- SMOS soil moisture measurements are sometimes irrecoverable as a consequence (SMOS measurements are noisier which can be seen in the plot below in the pre-RFI period

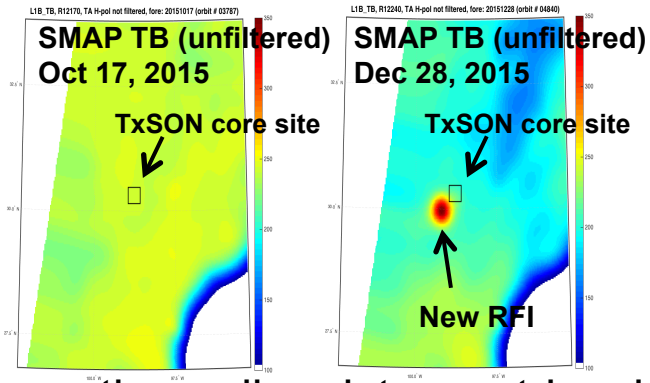


SMOS and TxSON soil moisture time-series

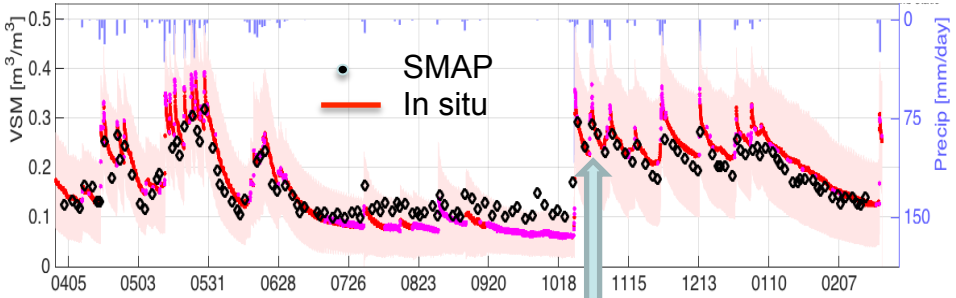
RFI source emerges

Effect of an RFI source in Texas: SMAP

Emergence of the RFI source detected:



Not impacting soil moisture retrieval because of the filtering:



RFI source emerges

SMAP and TxSON soil moisture time-series

(*The SMAP measurements were relatively unaffected by the emergence of the RFI source in Texas. It was the SMOS team that alerted the SMAP team about the source since it corrupted the SMOS retrievals and made them unreliable.)

Preliminary Results from CaLDAS Assessment of SMAP Data

Stephane Belair, EC, March 4, 2016

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- Environment and Climate Canada (EC) has produced evaluation scores for soil moisture produced by CaLDAS-SMAP vs the current operational assimilation system (OI).
  - The evaluation was done with observations from Soil Climate Analysis Network (SCAN), US climate reference network (USCRN), and the Alberta Ag Drought Monitor (AGDM).
  - Wg and W2 stands for near-surface (0-10cm) and root-zone soil moisture.
- Assimilation of SMAP data has resulted in significant improvement in correlation and moderate reduction in standard deviation with in situ observations

Soil Moisture Verification Scores: July – August 2015

Soil Moisture Network	Correlation		STDE (m^3 m^{-3})	
	W_g	W_2	W_g	W_2
SCAN(121)	0.30; 0.50	0.26; 0.43	0.051; 0.042	0.024; 0.022
USCRN (73)	0.28; 0.52	0.21; 0.48	0.055; 0.043	0.027; 0.023
AGDM (27)	0.32; 0.59	0.13; 0.51	0.059; 0.045	0.022; 0.019

- OI-Operational
- CaLDAS-SMAP

Radiometer Resolution Enhancement Results Using the Backus-Gilbert (BG) Algorithm

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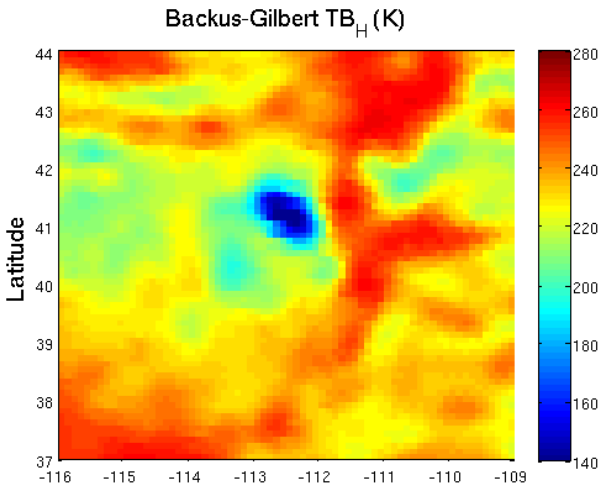
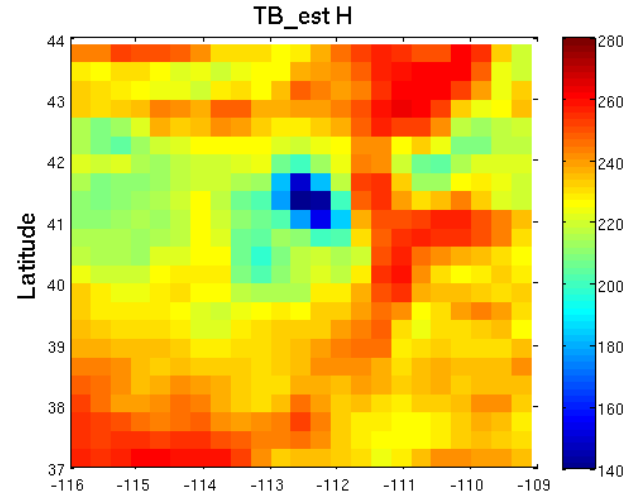
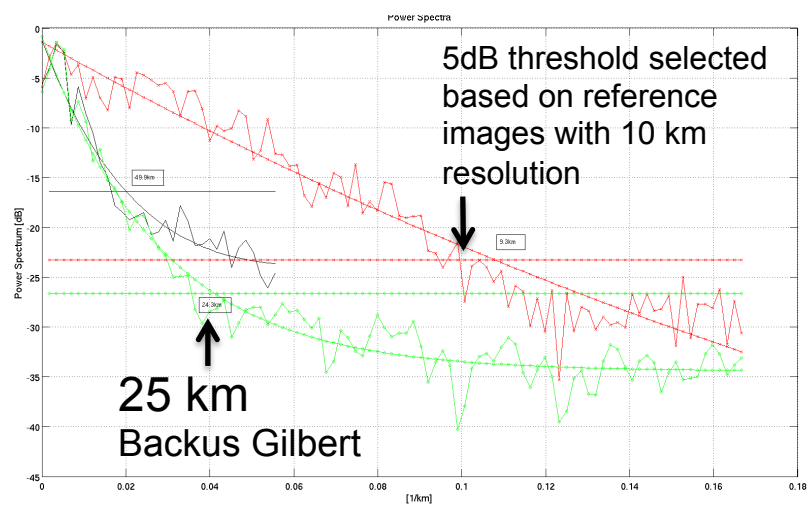
Backus Gilbert Optimum Interpolation 0.1x0.1 deg



Simulated SMAP data binned on 0.3x0.3 deg grid
Similar to nominal SMAP grid



- Use high-fidelity SMAP radiometer simulator to provide test- and evaluation-data
- Apply the BG algorithm to optimally interpolate the data on 3 km swath grid
- Spectral analysis of the BG indicates a spatial resolution of **25 km** (5 dB threshold above noise floor)



Backus-Gilbert Resolution Enhancement Reduces Land Surface Heterogeneity Error (Case 2)

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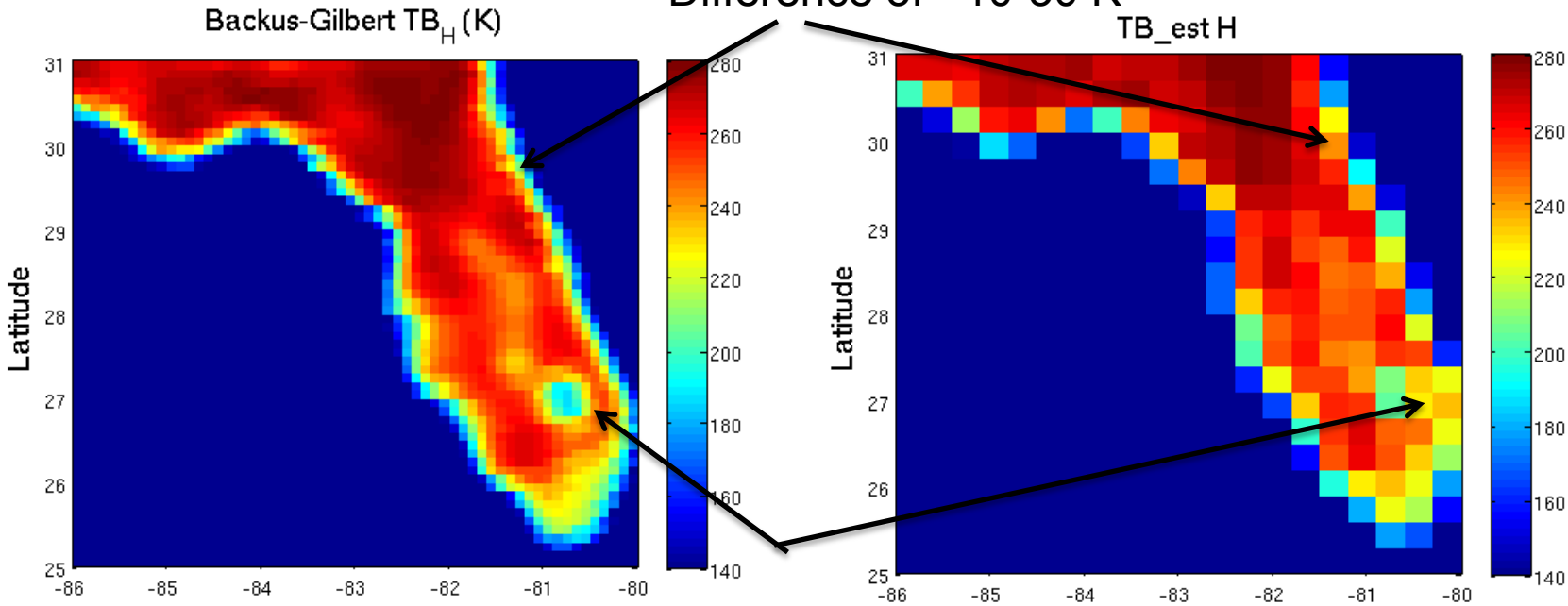
Backus Gilbert Optimum Interpolation 0.1x0.1 deg

Simulated SMAP data binned on 0.3x0.3 deg grid
Similar to nominal SMAP grid

Difference of ~10-30 K



Difference of ~20-30 K

- Backus-Gilbert provides better resolution of features with sharp boundaries than the SMAP 0.3 deg gridded product.
- BG reduces the spatially averaging errors due to water/land brightness temperature contrasts

Backus-Gilbert Resolution Enhancement Reduces Land Surface Heterogeneity Error (Case 3)

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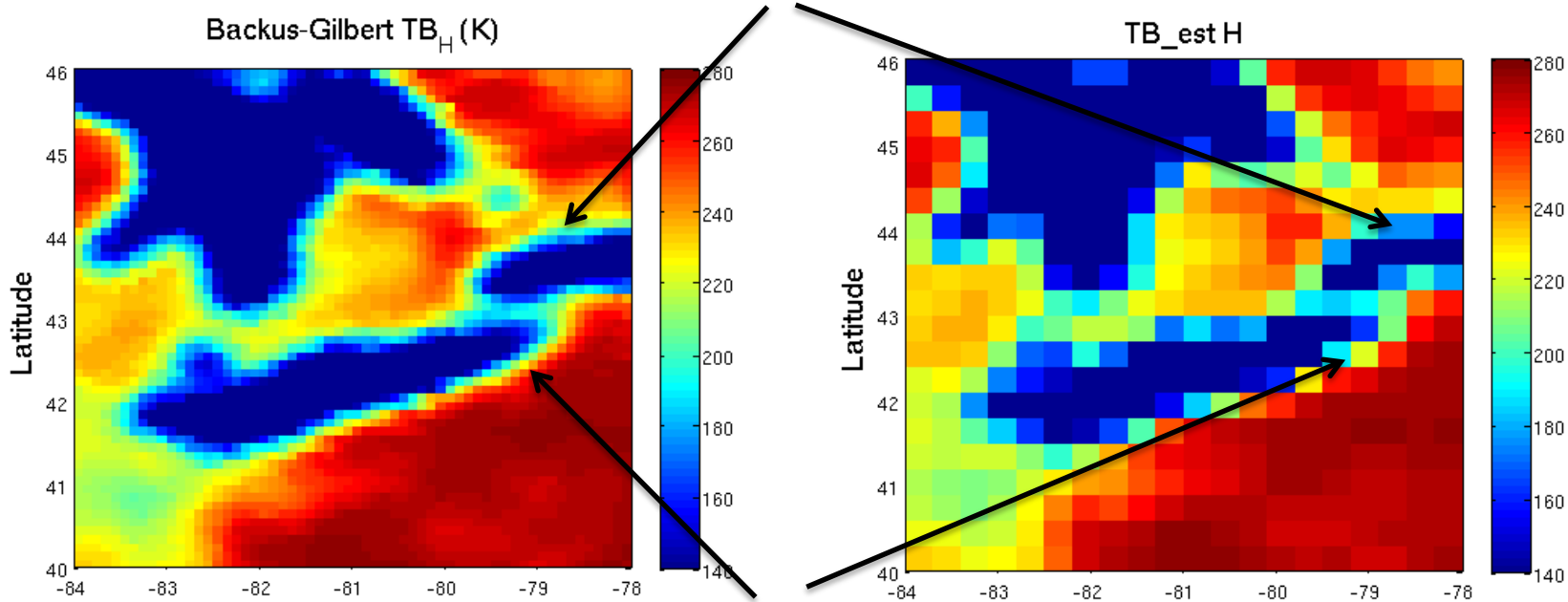
Backus Gilbert Optimum Interpolation 0.1x0.1 deg

Simulated SMAP data binned on 0.3x0.3 deg grid
Similar to nominal SMAP grid

Difference of ~10-30 K



Difference of ~20-30 K

- Backus-Gilbert provides better resolution of features with sharp boundaries than the SMAP 0.3 deg gridded product.
- BG reduces the spatially averaging errors due to inland water body brightness temperature contrasts

Passive FT for SMAP

With the loss of the radar, there are three primary capabilities that can be recovered by using the radiometer data for FT retrieval:

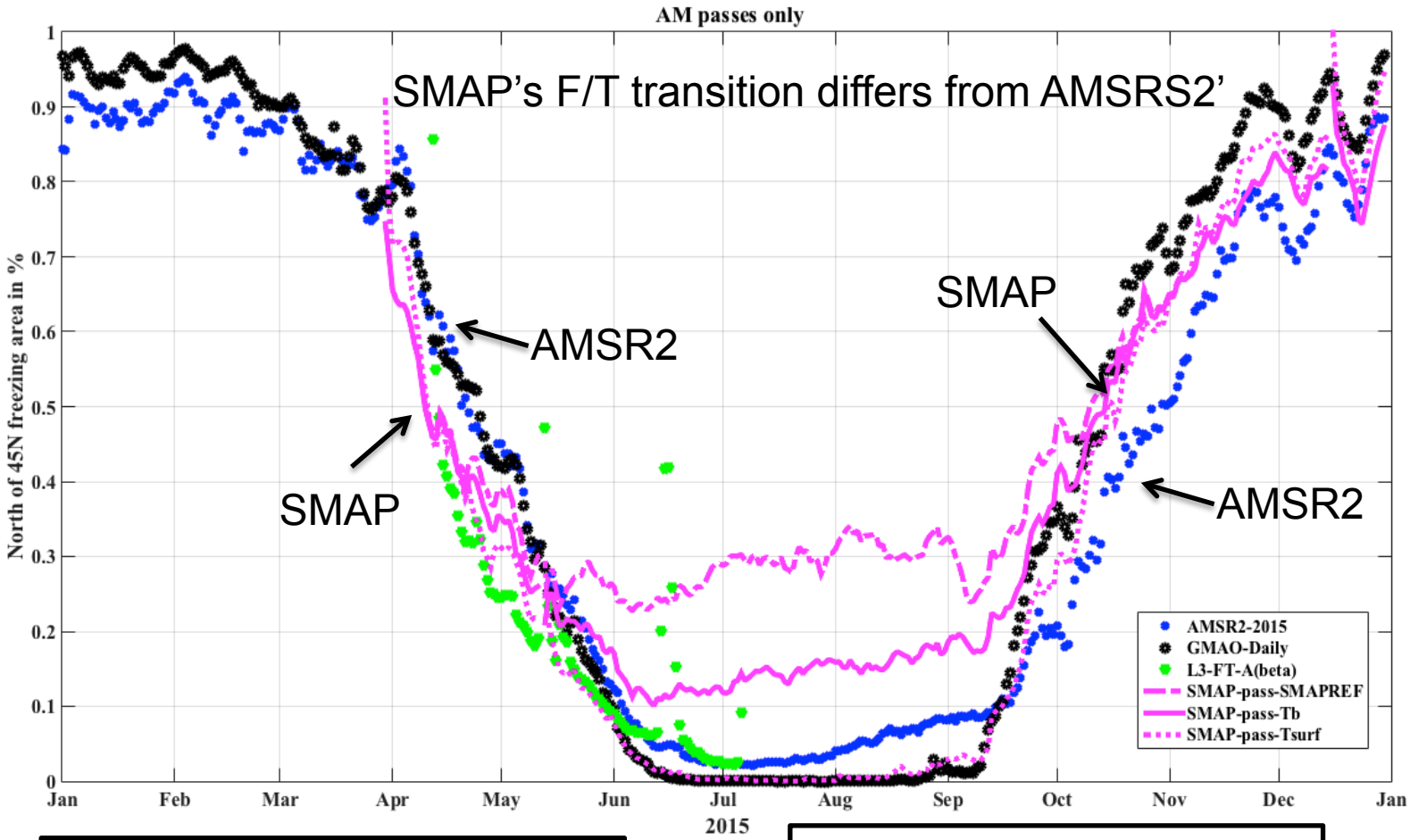
- ***SMAP Passive FT products complement existing AMSR-2 FT products***

- ***Autonomous SMAP-derived FT flag for passive soil moisture retrievals in L2_SM_P***
  - Passive FT flag replaces radar FT flag in L2_SM_P product

- ***Global FT state input to L4_C, via the FT flags in L3_SM_P***
  - Augment L3_SM_P with PM orbits to provide transition states

Any future resolution enhancements of the radiometer data (L1C_TB*) can also be incorporated in this plan.

Cross-Product Comparison (GMAO, AMSR2, L3-FT-A, L3-FT-P)



SMAP-pass-TB:
TBv/TBh > 273K, thaw

SMAP-pass-Tsurf:
if Tsurf > 5C, thaw
if Tsurf < - 5C, freeze

SMAP vs AMSR-2 View of Freeze/Thaw Transition Cambridge Bay

Derksen and Kimball

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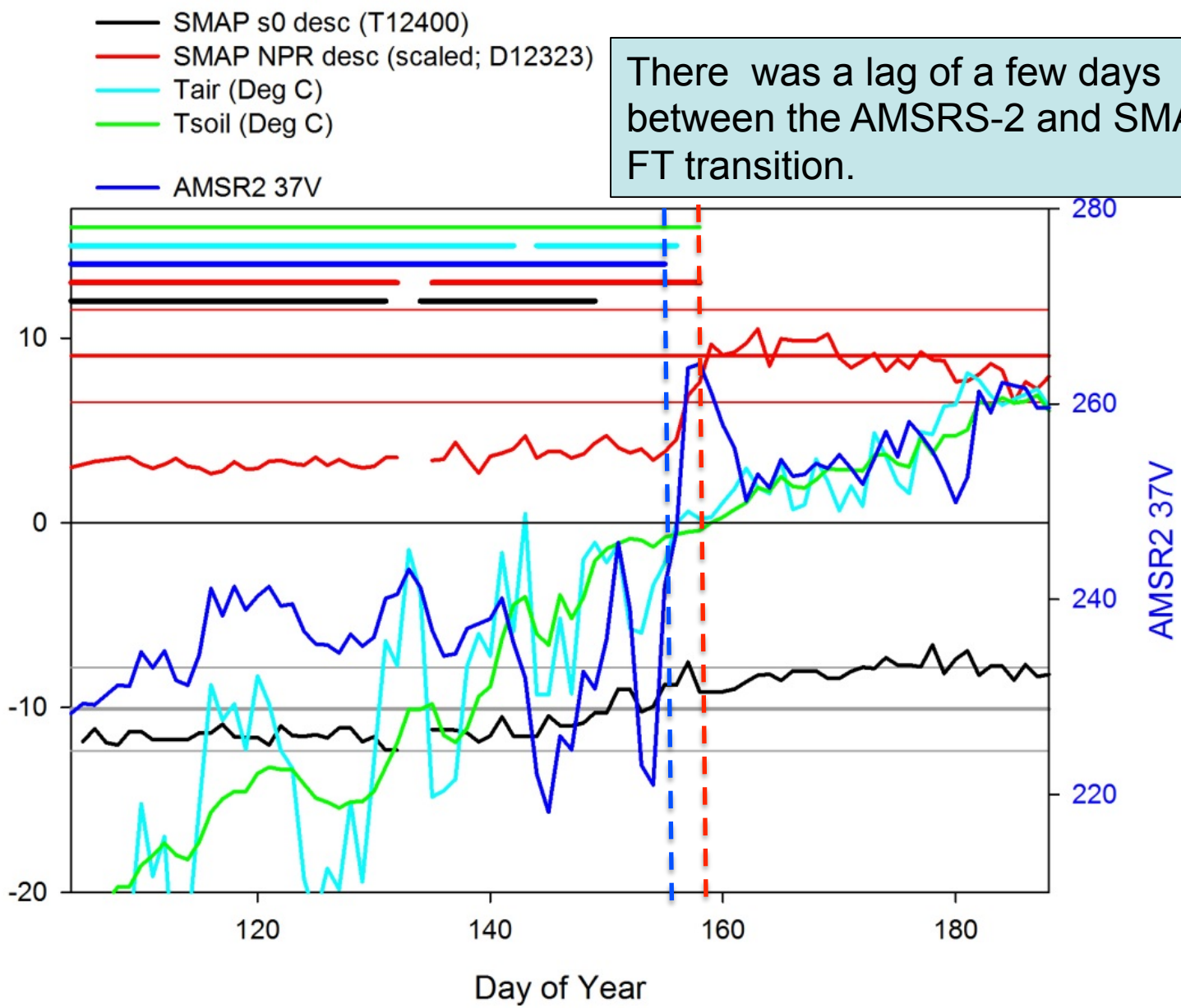
There was a lag of a few days between the AMSRS-2 and SMAP FT transition.



Summary of Freeze/Thaw Performance Assessment

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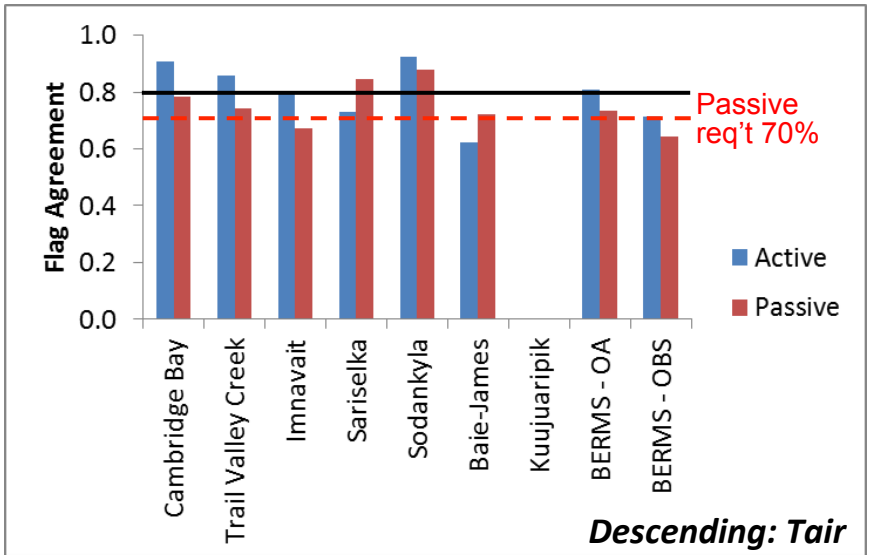
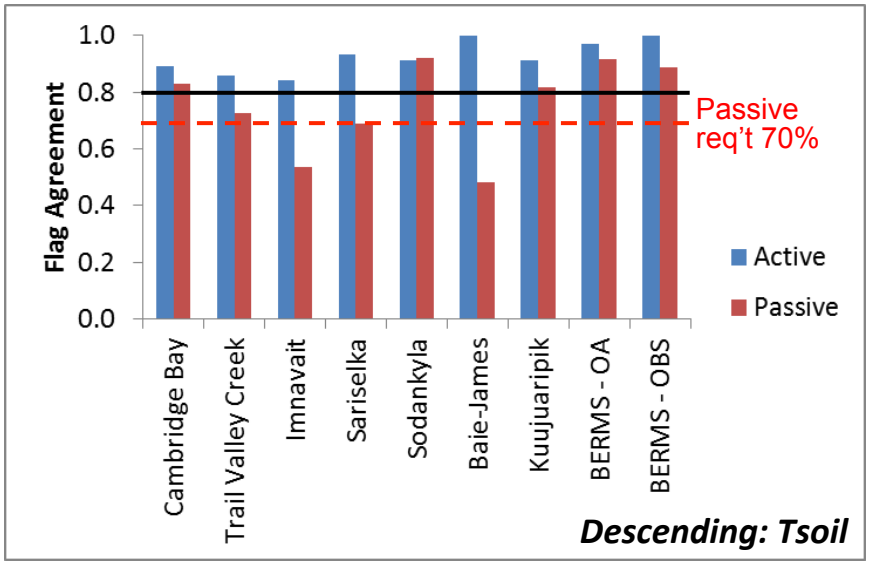
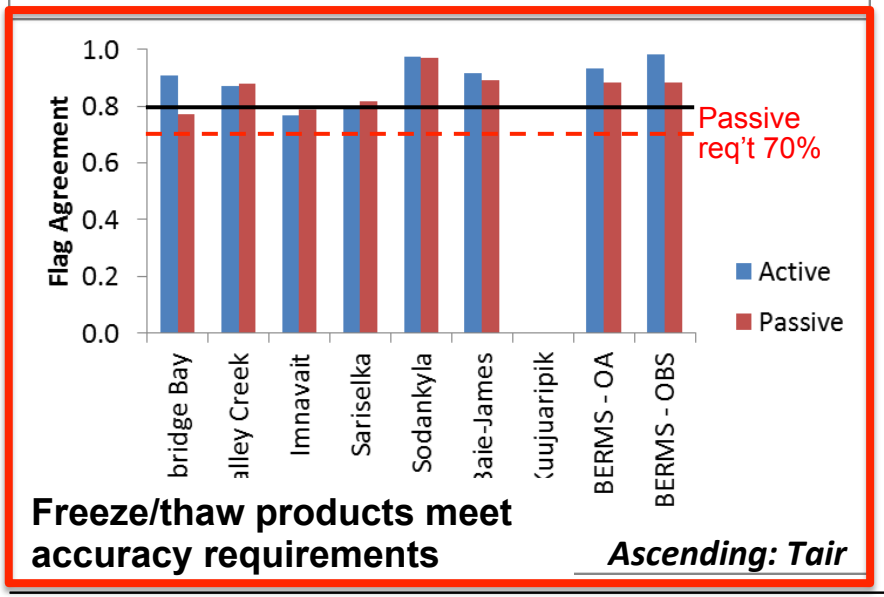
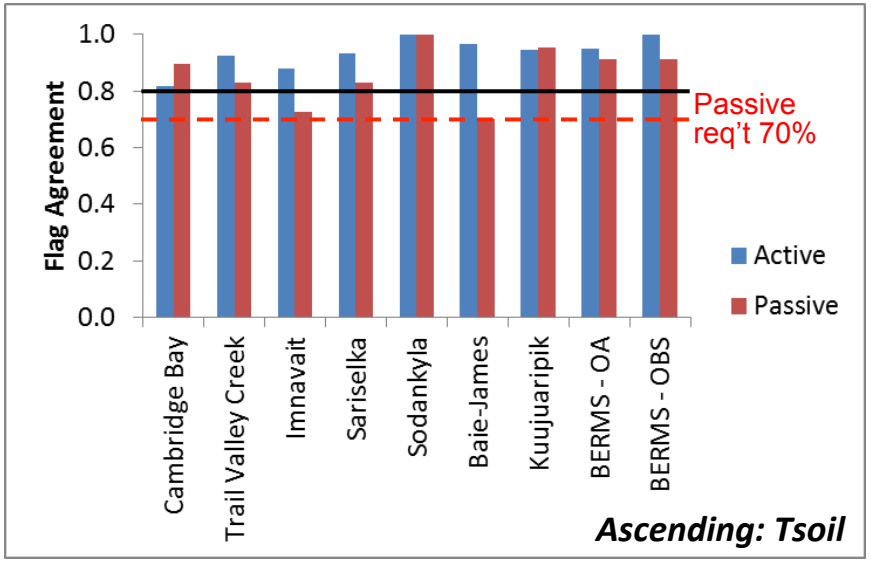






Freeze/thaw products meet accuracy requirements



Sentinel-1 IW Dual Pol# of Acquisitions April 24-July 7, 2015

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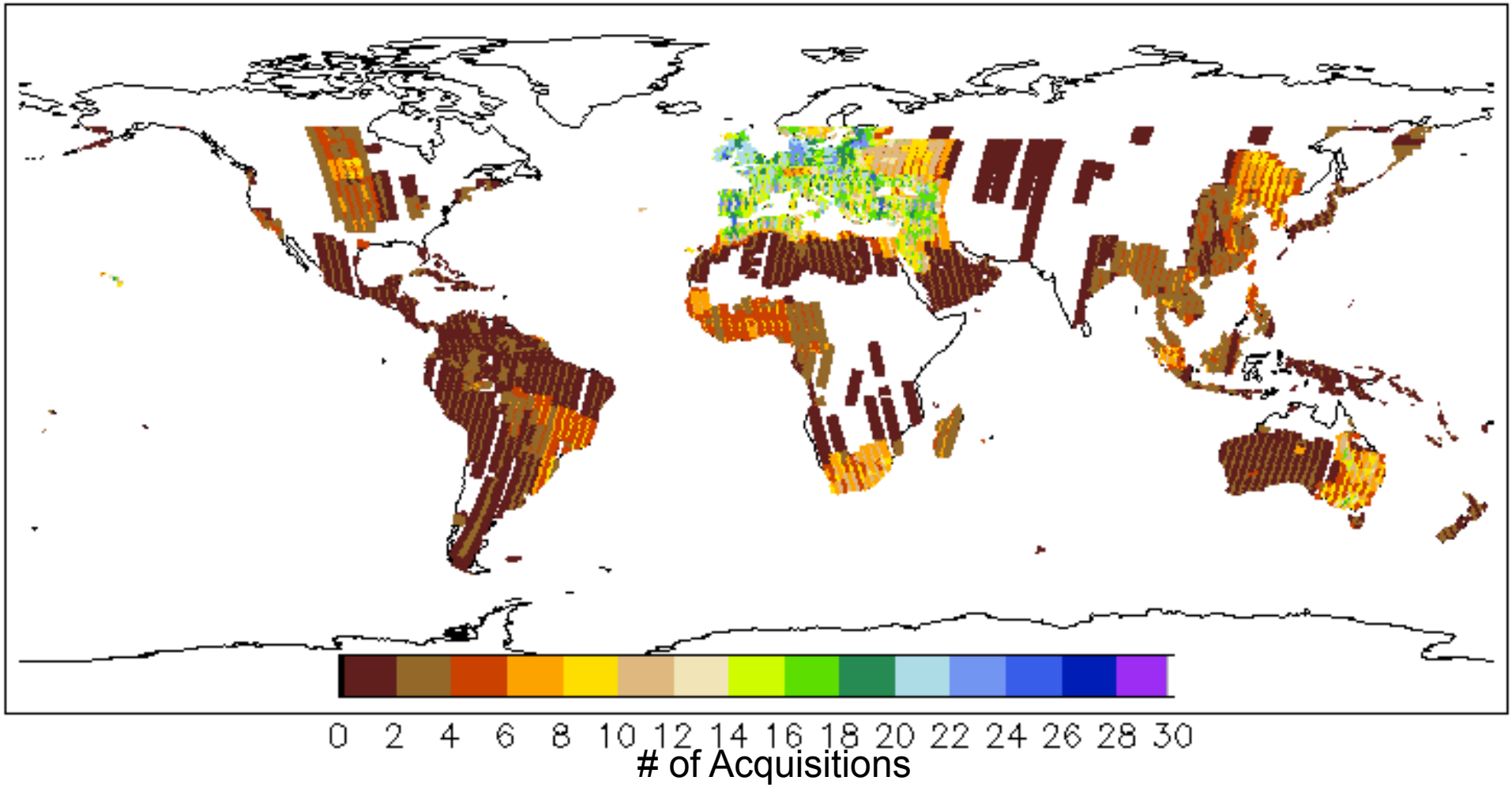
- Dual pol (VV+VH) IW only



Sentinel-1 data for preliminary SMAP/Sentnel-1 Active Passive algorithm analysis

Preliminary SMAP Sentinel-1 AP Results

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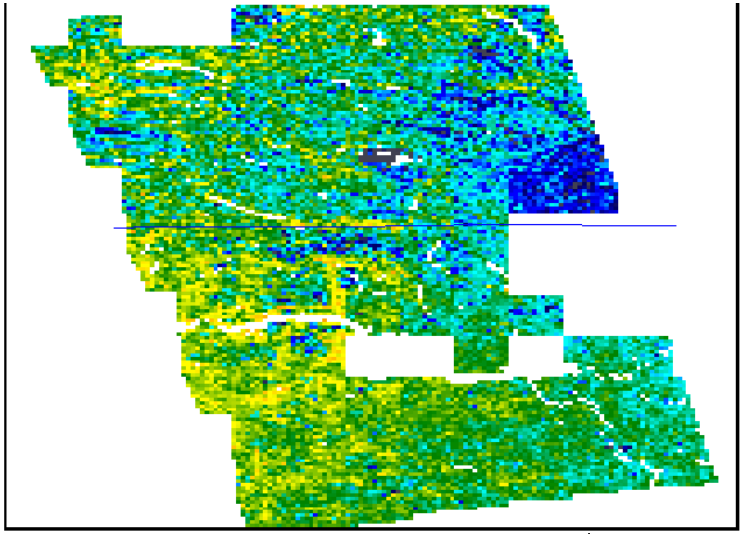
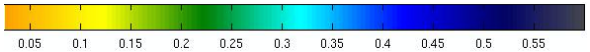
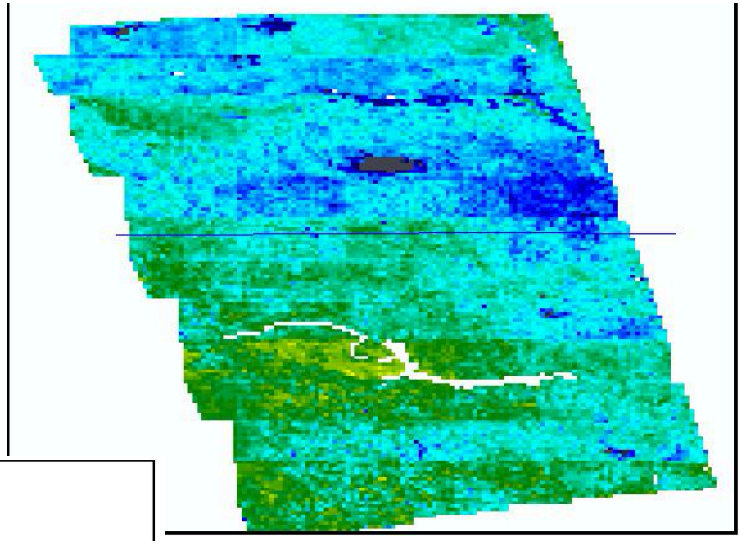
3 [km] SMAP Radar+Radiometer



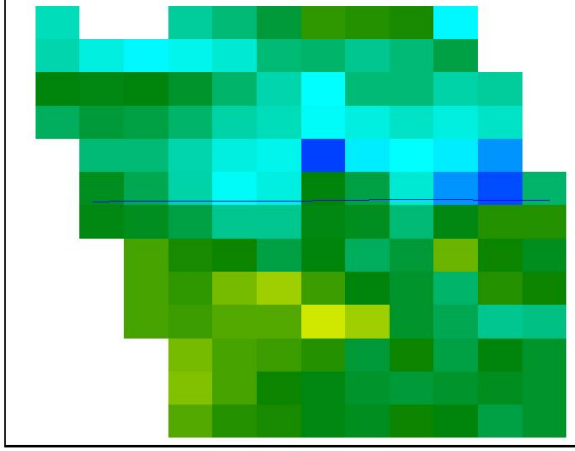


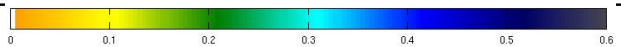
Soil Moisture [$cm^3\ cm^{-3}$]

3 [km] SMAP Radiometer+Sentinel Radar



36 [km] SMAP Radiometer





- Based on SMAP AP algorithm
- Parameters tuned from L-band to C-band using May-June data and theoretical model
- Some wet bias with respect to the SMAP AP product

Southern Canada

(Example from period with SMAP radar and radiometer data acquisition)

Source: N. Das (JPL)

SMAP-Sentinel Joint Retrievals Validation

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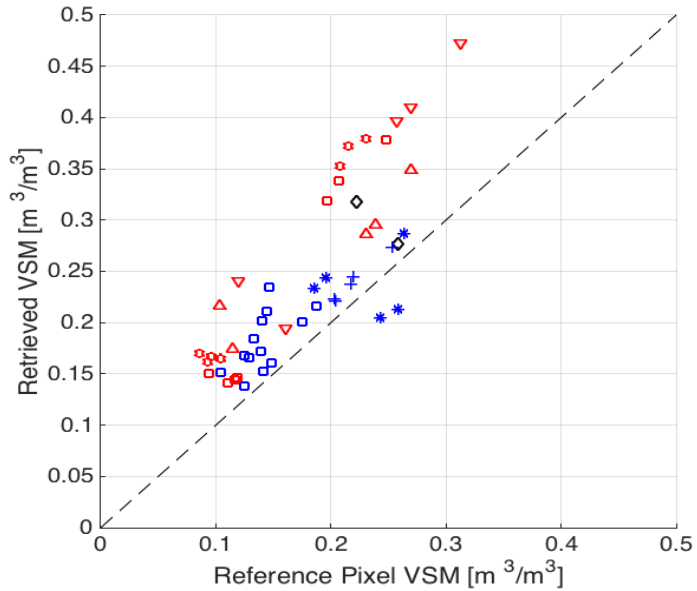
L2_SM_SP3km-BL (-)

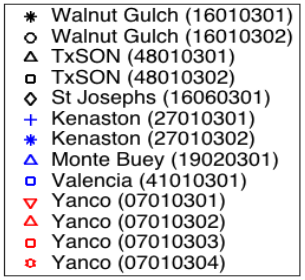
2015/04/13 - 2015/07/08

Performance Metrics

Ref Pixel	ubRMSE	Bias	RMSE	R
Walnut Gulch (1601-03-01)	NaN	NaN	NaN	NaN
Walnut Gulch (1601-03-02)	NaN	NaN	NaN	NaN
TxSON (4801-03-01)	NaN	NaN	NaN	NaN
TxSON (4801-03-02)	NaN	NaN	NaN	NaN
St Josephs (1606-03-01)	0.038	0.057	0.069	-1.000
Kenaston (2701-03-01)	0.003	0.021	0.021	0.989
Kenaston (2701-03-02)	0.041	0.008	0.042	0.098
Monte Buey (1902-03-01)	NaN	NaN	NaN	NaN
Valencia (4101-03-01)	0.022	0.040	0.046	0.621
Yanco (0701-03-01)	0.044	0.119	0.127	0.950
Yanco (0701-03-02)	0.022	0.073	0.076	0.949
Yanco (0701-03-03)	0.047	0.075	0.088	0.983
Yanco (0701-03-04)	0.040	0.105	0.112	0.994
MEAN:	**0.032**	**0.062**	**0.073**	**0.573**
SMAP AP Soil Moisture REQUIREMENT:	**<0.04**			



- Preliminary SMAP/Sentinel-1 soil moisture meets the SMAP AP ubRMSE requirement
- Wet bias to be reduced



Source: A. Colliander

Request for Sentinel-1 Data at the SMAP Cal/Val Sites Being Evaluated by ESA

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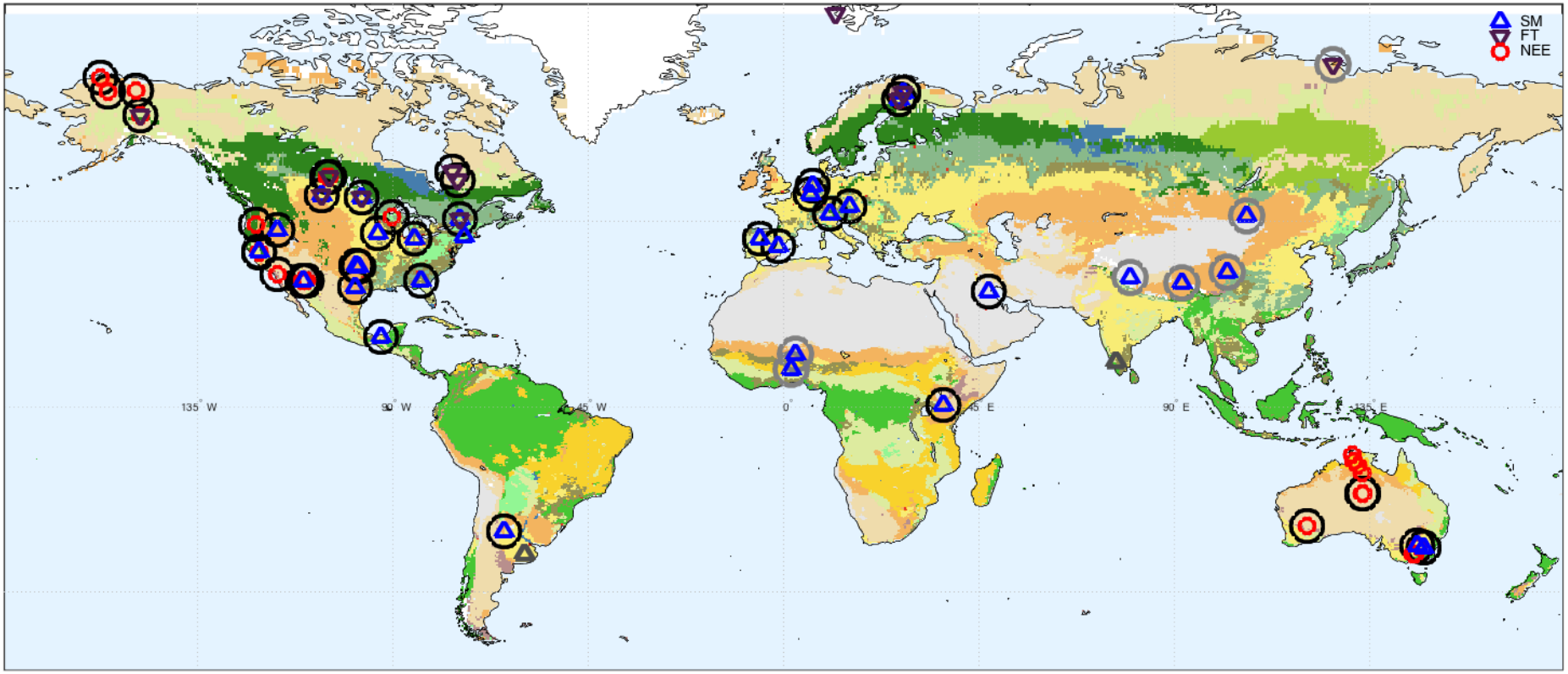

Black circles: Near real-time data access established
No circle: Near real-time data access being established
Grey circles: No near real-time data access available (data available at the end of Cal/Val Phase)
Grey triangles: installations on-going, but expected to provide useful data at some point during the Cal/Val Phase

The Sentinel-1 data over SMAP's core cal/val sites will

- Be beneficial for the calibration/validation of Sentinel-1 sigma0 and soil moisture
- Be used to cal/val SMAP/Sentinel-1 soil moisture products

Request for Expanded Coverage of Sentinel-1 Data Agreement with EU required

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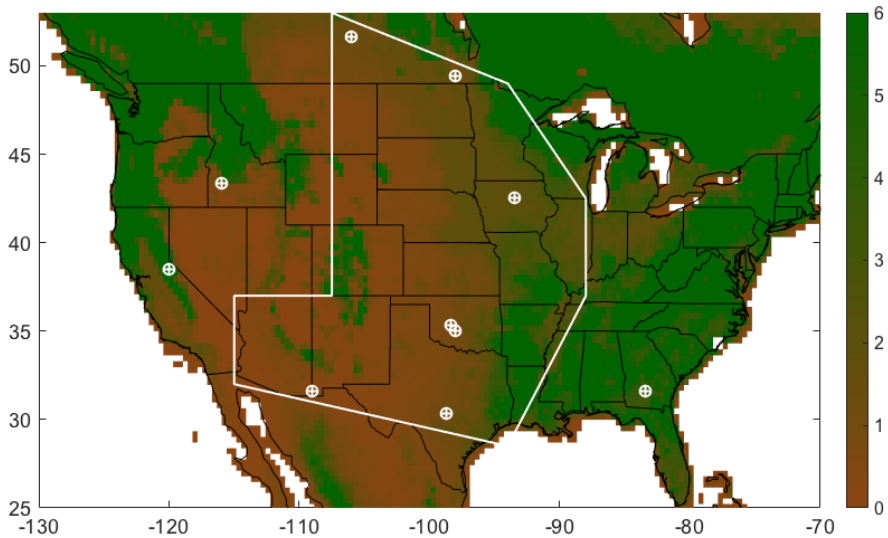
- Expanded coverage includes Illinois agriculture, goes along Mississippi (excludes East of River which is high VWC), includes Texas, New Mexico and Arizona and avoids the Rockies. It goes to include the two Canadian cal/val sites.
- What it encloses are the priority/relevant core cal/val sites, US croplands and relevant Midwest areas of land-atmosphere coupling.
- The box size/shape can be revised based on detailed data acquisition analysis
- Regular repeat sampling required.



The box is defined by the lat/lon pairs:

```
bx=[42.5  -88.0;...
    37.0  -88.0;...
    28.5  -94.0;...
    32.0 -115.0;...
    37.0 -115.0;...
    37.0 -107.5;...
    53.0 -107.5;...
    49.0  -94.0;...
    42.5  -88.0];
```

Planned Science Product Update Schedule

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Data Product		4/16 V2	12/16 V1_E	3/17 V3, V1_E	3/18 V4, V2_E
L1B_TB	Baseline products with annual updates	✓		✓	✓
L1C_TB		✓		✓	✓
L2/3_SM_P		✓		✓	✓
L4_SM		✓		✓	✓
L4_C		✓		✓	✓
L1B_S0_LoRes	SMAP radar products with final delivery in April 2016	✓			
L1C_S0_HiRes		✓			
L2/3_SM_A		✓			
L2/3_SM_AP		✓			
L3_FT_A		✓			
L1B_TB_E (Enhanced resolution)	Science recovery products		✓		✓
L1C_TB_E (Enhanced resolution)			✓		✓
L2/3_SM_E (Enhanced resolution)			✓		✓
L3_FT_P (Enhanced resolution)			✓		✓
L3_SM_SP (SMAP/Sentinel-Passive)				✓	✓

Summary

- SMAP radiometer has been performing exceptionally well
- Radiometer soil moisture products to be released at the end of April will meet 0.04 ubRMSE requirements
- On track to deliver the next version data release at the end of April
- Operational processing codes for radiometer resolution enhancement algorithm (Backus Gilbert) being developed
  - Will be applied to both soil moisture and freeze/thaw detection
- Preliminary soil moisture retrievals from 2+ months of SMAP/Sentinel-1 data are very encouraging – need to mature algorithms using a longer time series
  - Operational processing codes are being developed.

Backus-Gilbert Resolution Enhancement Reduces Land Surface Heterogeneity Error (Case 1)

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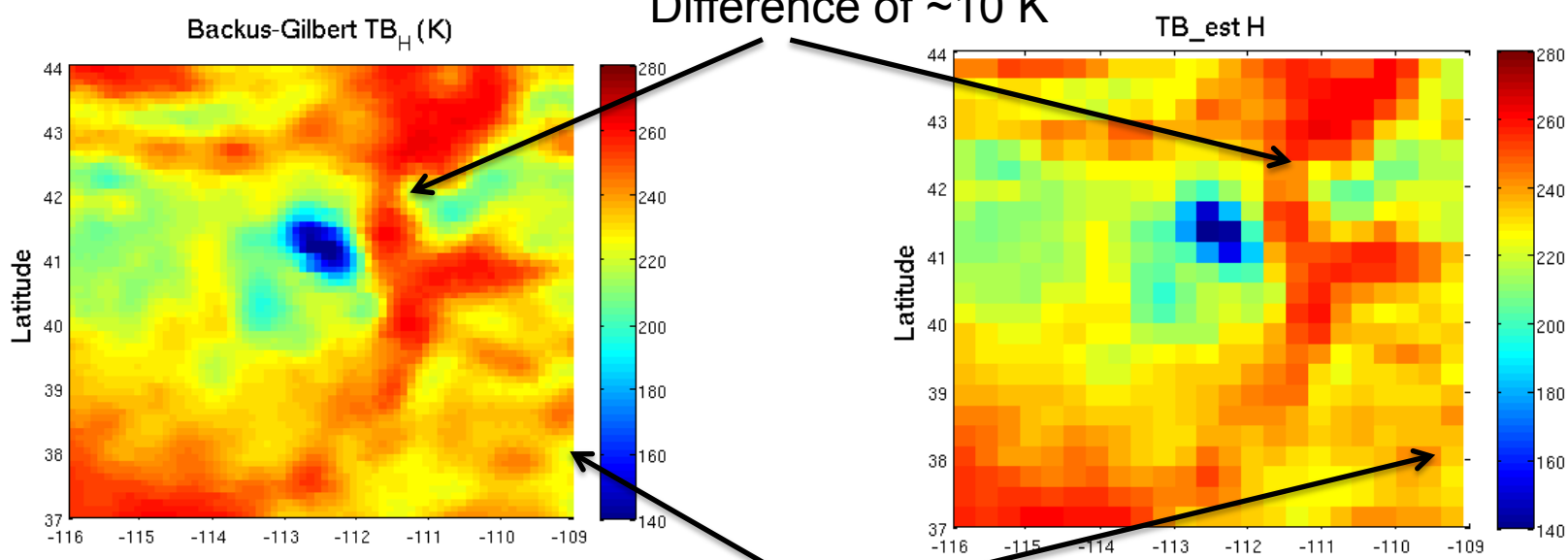
Backus Gilbert Optimum Interpolation 0.1x0.1 deg

Simulated SMAP data binned on 0.3x0.3 deg grid
Similar to nominal SMAP grid

Difference of ~10 K



Difference of ~5 to 10 K

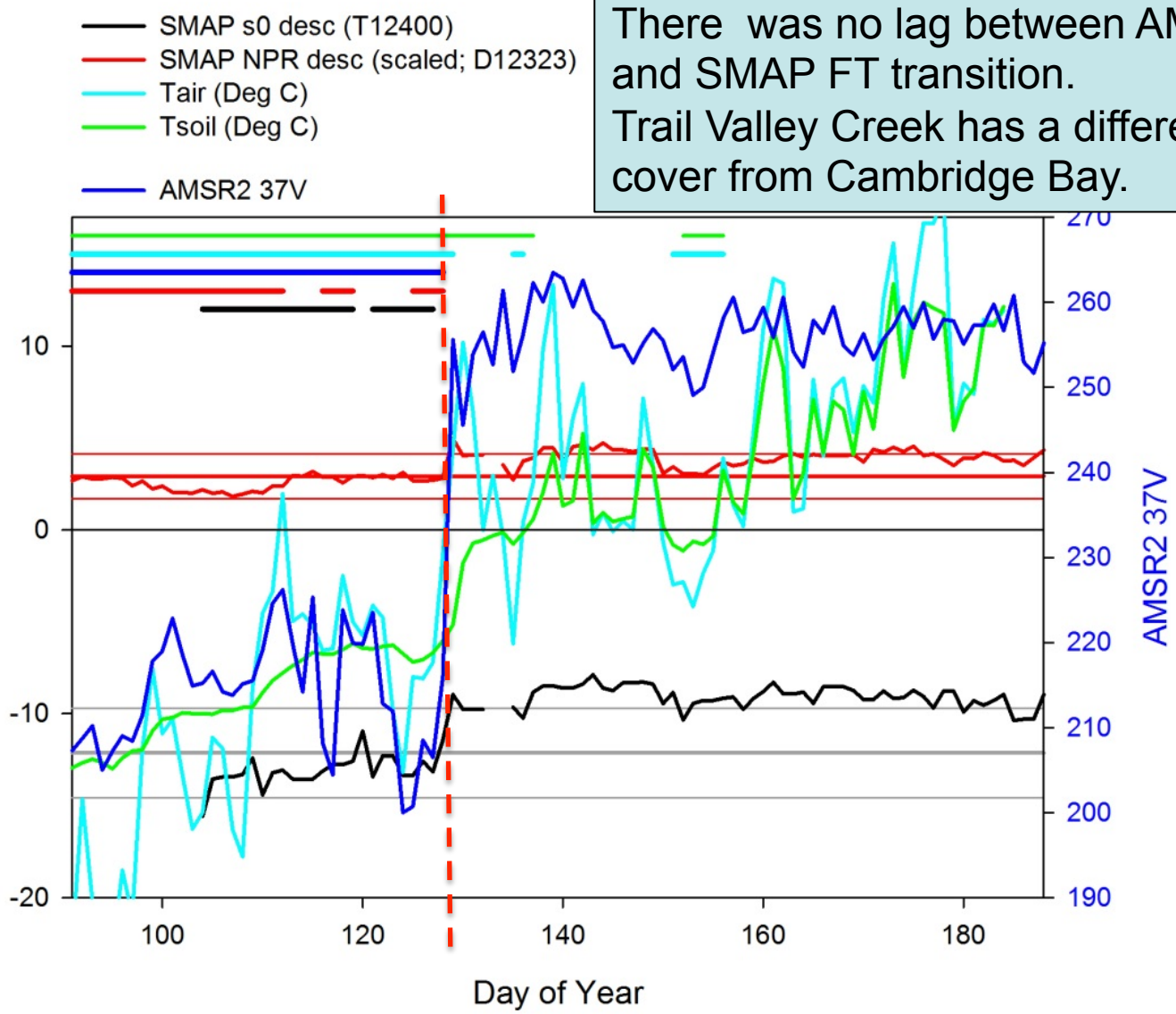
- Backus-Gilbert provides better resolution of features with sharp boundaries than the SMAP 0.3 deg gridded product.
- BG reduces the spatially averaging errors due to land surface heterogeneity

SMAP vs AMSR-2 View of FT Transition
Trail Valley Creek

Derksen and Kimball

Jet Propulsion Laboratory
California Institute of Technology

There was no lag between AMSRS-2 and SMAP FT transition.
Trail Valley Creek has a different land cover from Cambridge Bay.



Science Utilization of SMAP Passive Freeze/ Thaw Product

- From an ecosystem perspective, the SMAP passive FT product should provide enhanced L-band detection of deeper vegetation canopy and surface soil conditions relative to available higher frequency (e.g. AMSR2 37 GHz) FT products that really just see the very top surface skin layer properties. Thus, the L-band data should show a slower spring thaw and fall freeze response closer to the timing of soil FT cycles influencing vegetation access to soil moisture, and soil decomposition and respiration processes.
- Environment and Climate Canada (EC) will utilize the radiometer freeze/ thaw estimates at 36 km* for:
  - evaluation of new land surface analyses produced from the Canadian Land Data Assimilation System. These analyses include soil freeze/thaw state, and the SMAP FT product provides an excellent means for evaluation.
  - evaluation of spring season terrestrial melt dynamics across the Arctic which EC contributes to various climate assessments, such as the NOAA Arctic Report Card

*The SMAP passive FT algorithm will be applied to Backus-Gilbert 25 km resolution brightness temperature product posted on 9 km grid