NASA Operational Approaches and Exploratory Activities for Improving SWE Estimates And Snowmelt Detection From Passive Microwave Observations

M. Tedesco[1,2]

With historical contributions by
R. Kelly, A. Chang, J. Foster, and many others

1. *The City College of New York*
2. *Temporarily serving as Program Director at NSF*

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OUTLINE

- Distributed AMSR-E SWE operational product
- SWE Research prototype algorithm
- AMSR2 SWE product (US Team)
- Enhanced AMSR-E SWE product investigation

DISTRIBUTED AMSR-E SWE OPERATIONAL PRODUCT

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Product Specifications

Product Name	NASA AMSR-E/AMSR2 SWE
Sensor and applied spectral bands	AMSR-E/AMSR2 (X, Ku, K)
Temporal Characteristics	
Period (Start – End)	2002 – to date
Temporal resolution (1 day, 1 week, ..)	Daily, 5 days, monthly
Spatial Characteristics	
Spatial resolution / Pixel size	25 km
Spatial Coverage	Global
Map Projection / Datum	EASE Grid
If applicable: Cloud screening	
Algorithm	
If applicable: Valid / non-valid areas	
Invalid/masked areas	Snow classification (~ 1980s)
Product Format	HDF
Products accessible at	*http://*nsidc.org
Contact Person Name email	Marco Tedesco mtedesco@ccny.cuny.edu

Examples of file names:
AMSR_E_L3_DailySnow_X##_yyyymmdd.hdf
AMSR_E_L3_5DaySnow_X##_yyyymmdd.hdf
AMSR_E_L3_MonthlySnow_X##_yyyymm.hdf

X = Product Maturity Code
= file version number
yyyy = four digit year,
mm = two-digit month
dd = two-digit day

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Ancillary and input files (current algorithm)

Data set	***Source***	***Temporal Static/Dynamic***
Global forest fraction	Boston University IGBP data (*MOD12Q1IGBP*) (*Hansen et al., 2003*)	S
Global forest 'density'	UMD/VCF (based on *MOD09A1*	S
Land, Ocean Coasts & Ice mask	derived from MODIS *MOD12Q1 IGBP* land cover data (collection V004).	S
AMSR-E/Aqua L2A Tb	http://arcss.colorado.edu/data/ae_l2a.html	D
Snow possibility/impossibility	Snow climatology data set (*Dewey and Heim, 1984*)	S
Snow density	Seasonal snow classification map *Liston and Sturm (1998)*	S

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Quality assessment (automatic)

- 1. File is correctly named and sized
- 2 File contains all expected elements
- 3 File is in the expected format
- 4 Required EOS fields of time, latitude, and longitude are present and populated
- 5 Structural metadata is correct and complete
- 6 The file is not a duplicate
- 7 The HDF-EOS version number is provided in the global attributes
- 8 The correct number of input files were available and processed

Quality assessment (cont'd)

- If less than 50 percent of a granule's data is good, the science QA flag is marked "suspect" when the granule is delivered to NSIDC
- the science QA includes checking the maximum and minimum variable values, and percent of missing data and out-of-bounds data per variable value.
- At the Science Computing Facility (SCF), also at GHCC, science QA involves reviewing the operational QA files, generating browse images, detection of errors in geolocation, verification of calibration data, trends in calibration data
- Geolocation errors are corrected during Level-2A processing to prevent processing

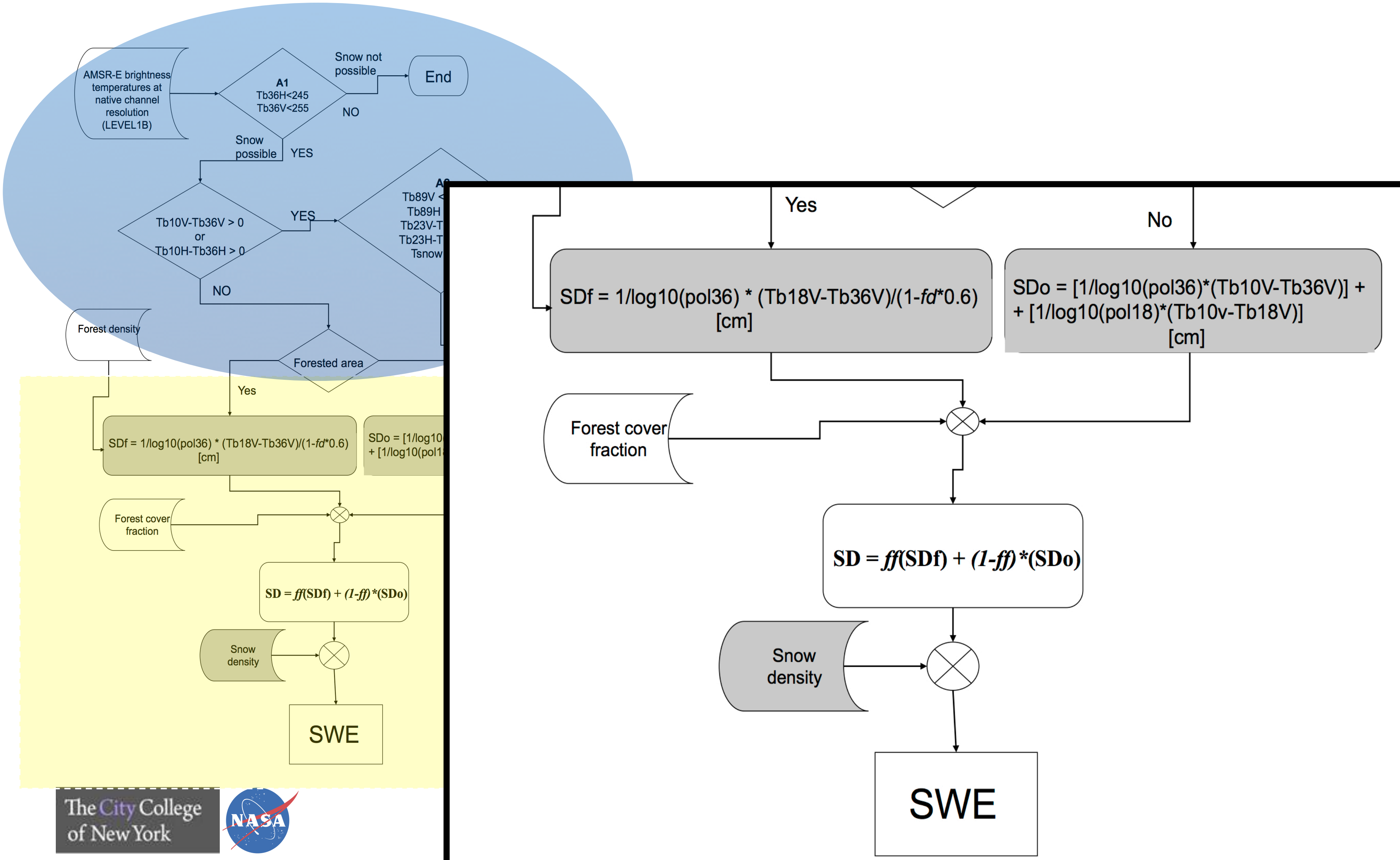
Flag values

- Distributed SWE values are in a stored **data range of 0-240 mm**. Users must **multiply the SWE values in the file by a factor of 2** to scale the data up to the correct range of 0-480 mm.

- Values for the remaining SWE fields are:

Value	Description
247	incorrect spacecraft attitude
248	off-earth
252	land or snow impossible
253	ice sheet
254	water
255	missing
241	non-validated

Workflow algorithm



Error sources and validation

ERROR SOURCES

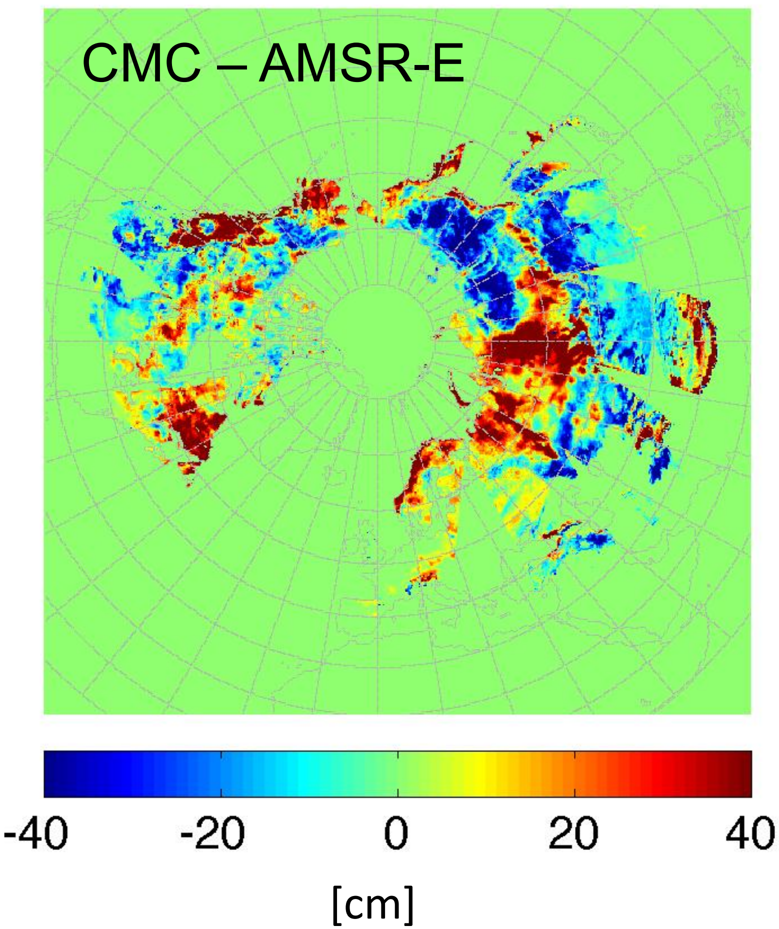
- Wet snow
- Sensitivity to SD (vs. grain size or density)
- Water bodies
- Obscuration by forest
- Mixed pixel
- Atmospheric effects
- Grain size variability

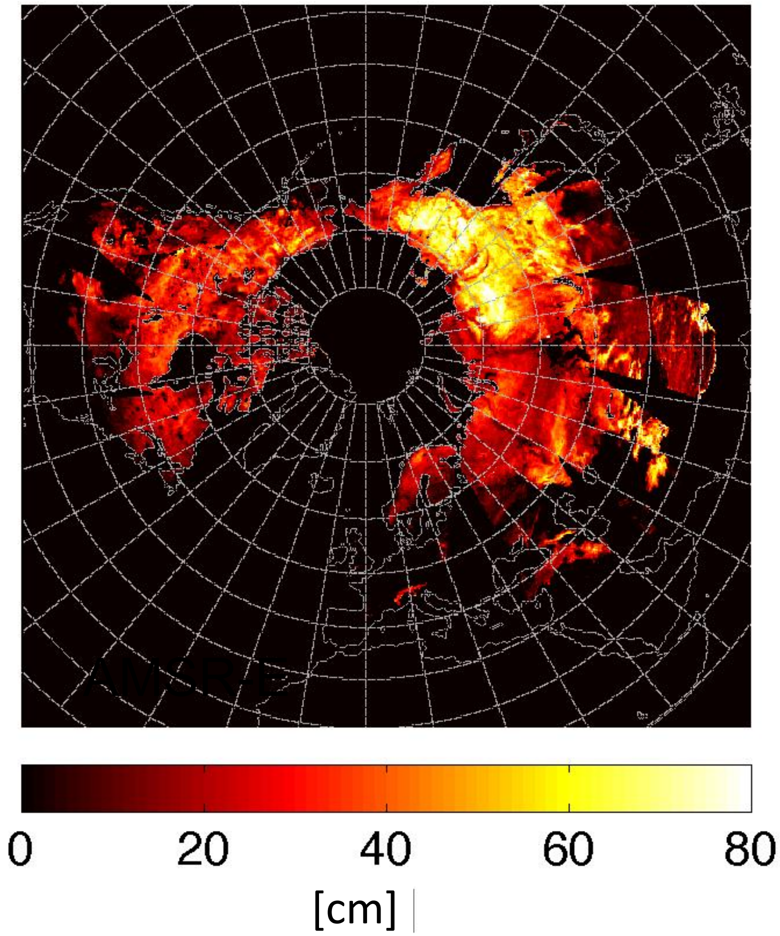
VALIDATION

- Kelly et al., 2009
- Tedesco and Narvekar, 2010
- Vuyovich et al., 2014
- Many others … no systematic collection of validation efforts

RESEARCH PROTOTYPE ALGORITHM

Example of comparison between AMSR-E SWE and CMC (snow depth)



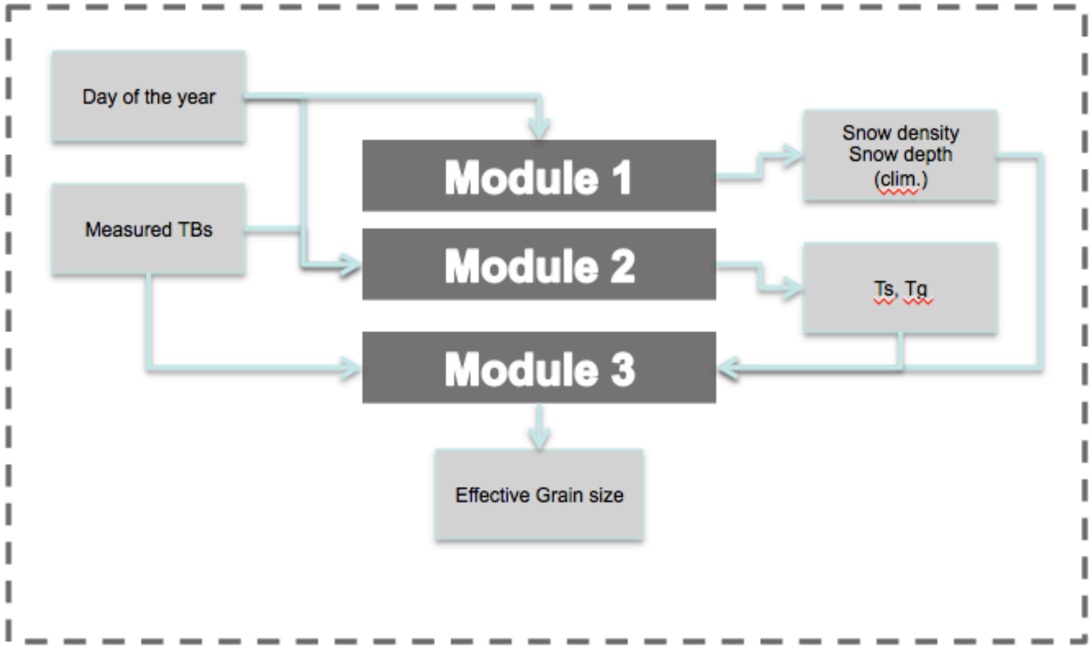


e.g., January 2004

SWE research prototype algorithm

- Use of neural networks and electromagnetic model to derive quantities related used in retrieval coefficients (e.g., effective grain size)
- Formula for retrieval coefficients (e.g., those relating the snow depth to Tbs)
- Density used to convert snow depth to SWE
- New formula for surface temperature estimate

Module 4



$$SD = ff^{*}\ (newfact_{36}{}^{*}(18V-36V)) + (1-ff)^{*}\ [\ (newfact_{36}{}^{*}(10V-36V)) + (newfact_{18}{}^{*}(10V-18V)$$

$$newfact_{freq} = \frac{pfrost_{fact}}{\exp\left(gr_{freq} - gr_0\right)}$$

$$pfrost_{clim\_temp} = \frac{V_{10GHz\_clim}}{0.95}$$

$$pfrost_{fact} = \frac{pfrost_{clim\_temp}}{240}$$

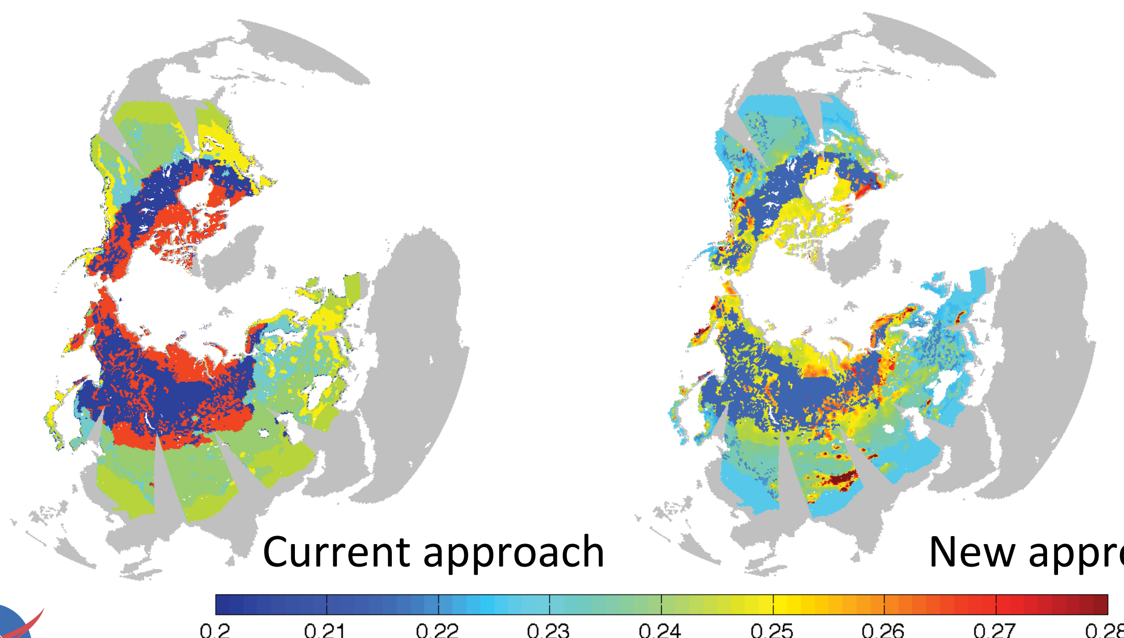
$gr_0 = 0.9$ mm

Density spatio/temporal evolution

- **ρ(**DOY, SD, SC) = **(ρ** max - **ρ** 0)(1-exp(-k1*SD-k2*DOY))+ **ρ** 0

Snow Class	ρ_{max}	ρ_0	k_1	k_2
Alpine	0.5975	0.2237	0.0012	0.0038
Maritime	0.5979	0.2578	0.0010	0.0038
Prairie	0.5940	0.2332	0.0016	0.0031
Tundra	0.3630	0.2425	0.0029	0.0049
Taiga	0.2170	0.2170	0.0000	0.0000

DOY = Day of the year
SD = snow depth
SC = snow class



Using Sturm et al., 2011

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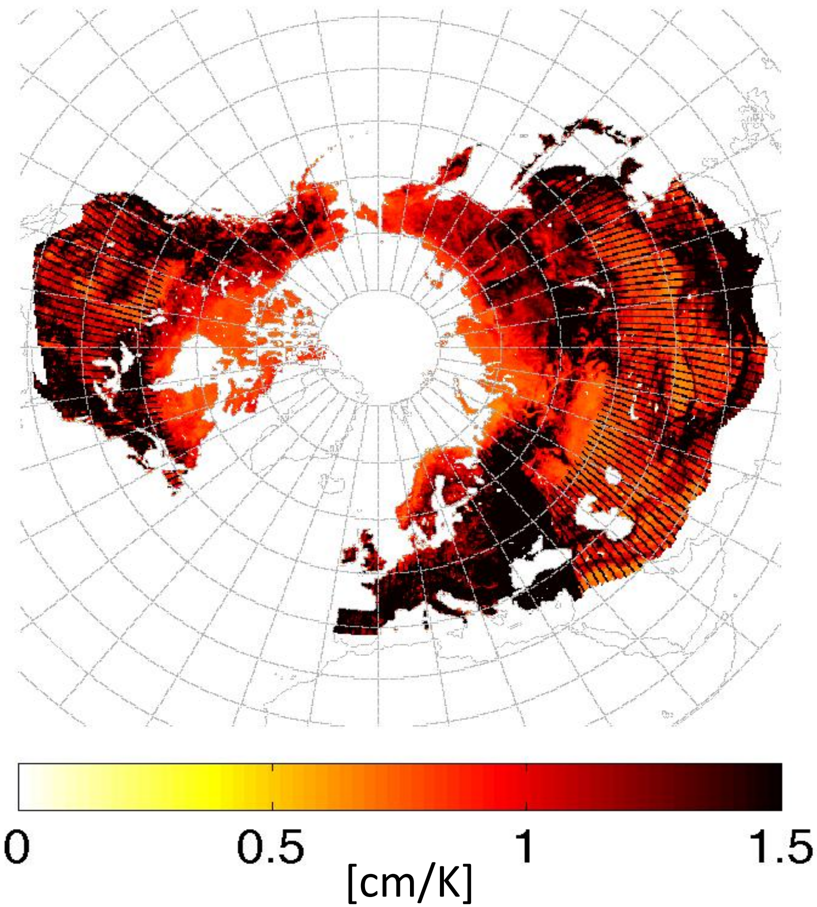
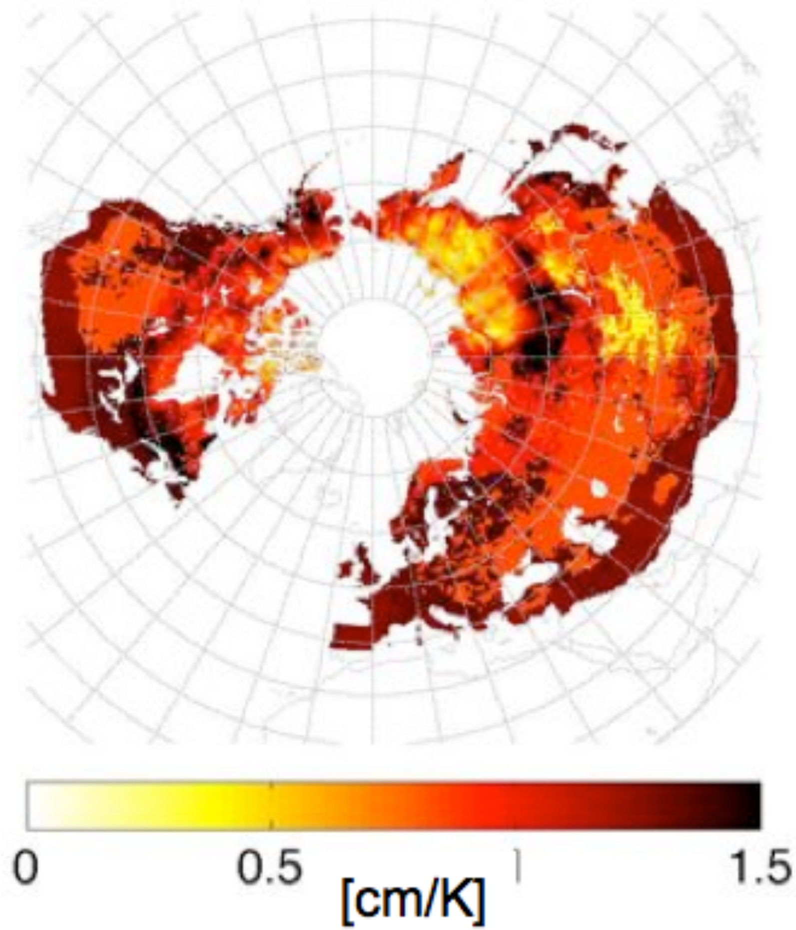
Current operational vs. new coefficients



Current dynamic coefficient
map at 37 GHz



New dynamic coefficient
map at 37 GHz

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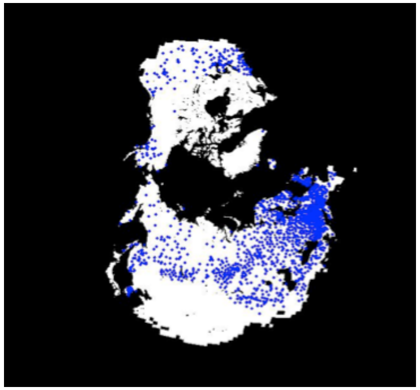
Preliminary assessment of the research prototype algorithm

AMSR-E vs. CMC

	Correlation		RMSE		Bias	
	Orig.	*Mod.*	*Orig.*	*Mod.*	*Orig.*	*Mod.*
November	0.114±0.070	0.185±0.063	14.774±1.211	13.171±1.169	14.636±1.396	11.239±1.167
December	0.182±0.063	0.309±0.068	18.769±1.471	15.760±1.438	17.384±1.922	12.393±1.216
January	0.180 ± 0.075	0.346±0.056	23.105±1.421	18.445±1.319	22.648±2.719	16.267±1.551
February	0.129±0.070	0.276±0.047	26.360±1.125	21.765±1.156	28.843±2.775	22.323±1.897
March	-0.007±0.086	0.120±0.054	29.065±1.386	25.838±1.404	36.358±3.560	28.862±2.423
April	-0.119±0.0782	0.177±0.070	31.307±1.872	24.037±1.176	41.094±3.367	27.675±2.197

AMSR-E vs. WMO SD

	Original		Modified	
	RMSE	Bias	RMSE	Bias
January	20.661	29.187	17.931	20.571
February	22.775	37.884	19.173	27.537
March	27.336	45.62	24.703	37.289
April	32.123	44.678	27.897	30.303
October	11.4344	11.234	10.3453	10.235
November	13.6451	13.8224	13.156	11.0168
December	17.1517	18.207	16.1324	13.5751



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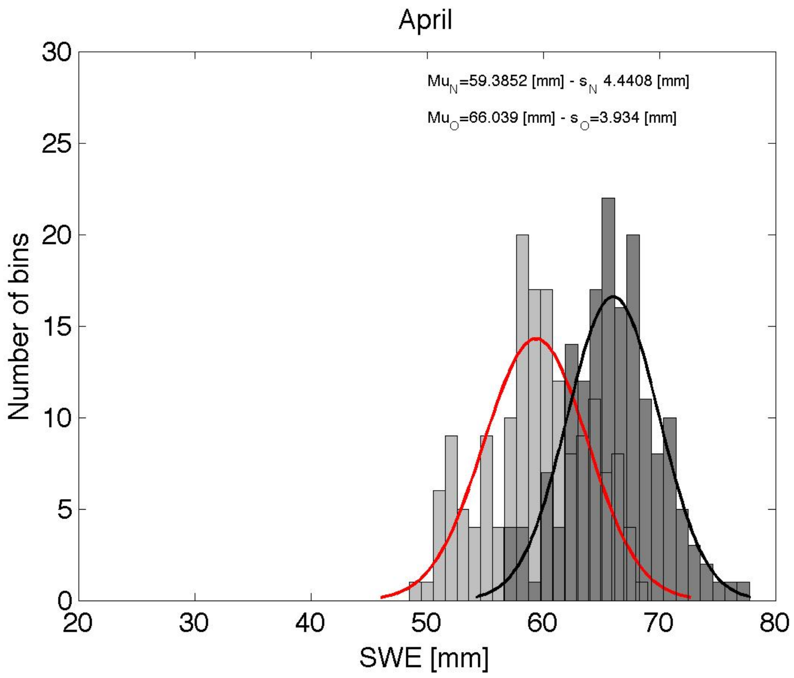
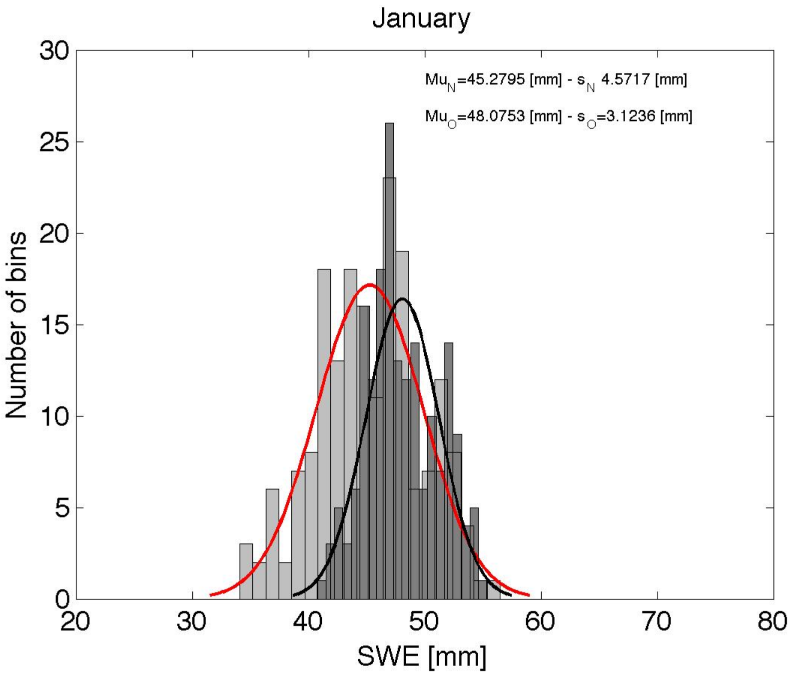
Assessment: NEW vs. OLD algorithm GlobSNOW (SWE)

As in the case of CMC and WMO data, the new algorithm provides better results than the original one for all months





AMSR2 SWE PRODUCT (US TEAM)

AMSR2 Science Team related activities

- Modifying the current operational AMSR-E code for AMSR2 and testing
- Level 2A originally used for AMSR-E are being replaced with JAXA L1R Tbs
- Cross-calibration of AMSR-E and AMSR2 Tbs (through SSMI/S) for climate data record purposes
- Unifying ancillary data sets for all AMSR2 science products (e.g., masks, flags, land types, etc.)

ENHANCED AMSR-E SWE PRODUCT INVESTIGATION

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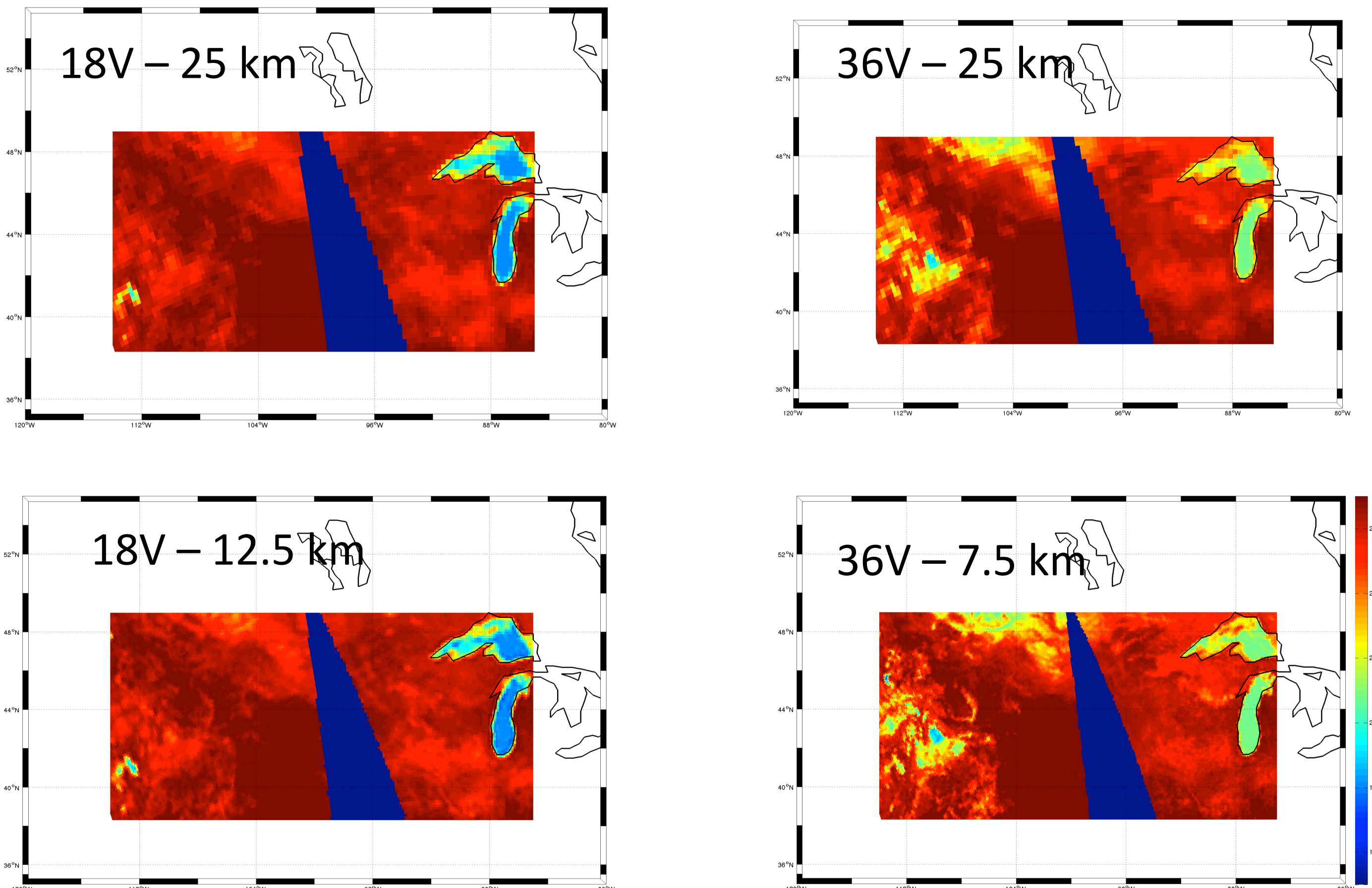
Examples of enhanced spatial resolution maps



Enhanced product generated by D. Long, BYU

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AMSR-E enhanced spatial resolution

Brightness temperatures are produced at 12.5 km (18.7 GHz) and 7.5 km (36.5 GHz) by D. Long at BYU using for the AMSR-E and SSM/I data sets

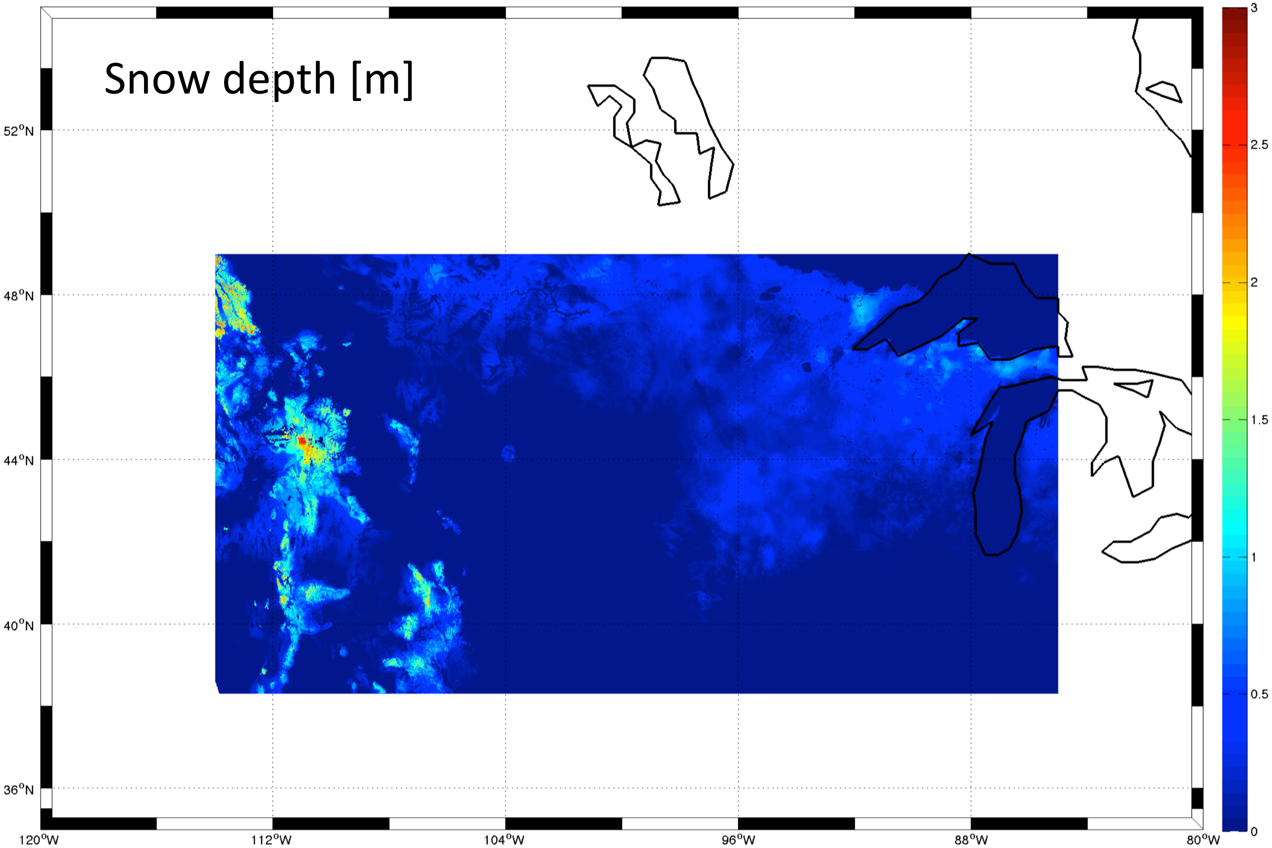
PROS:

- **SWE and melt enhanced spatial maps**
- **Potential application over mountain areas**
- **Improved understanding of mixed pixel effect (e.g., forest cover, water bodies, etc.)**

CONS:

- **18 and 37 GHz are produced at different resolutions (7.5 and 12.5 km)**
- **Temporal resolution (decreases with latitude)**
- **Enhancing resolution introduces noise**

SNODAS co-registered datasets



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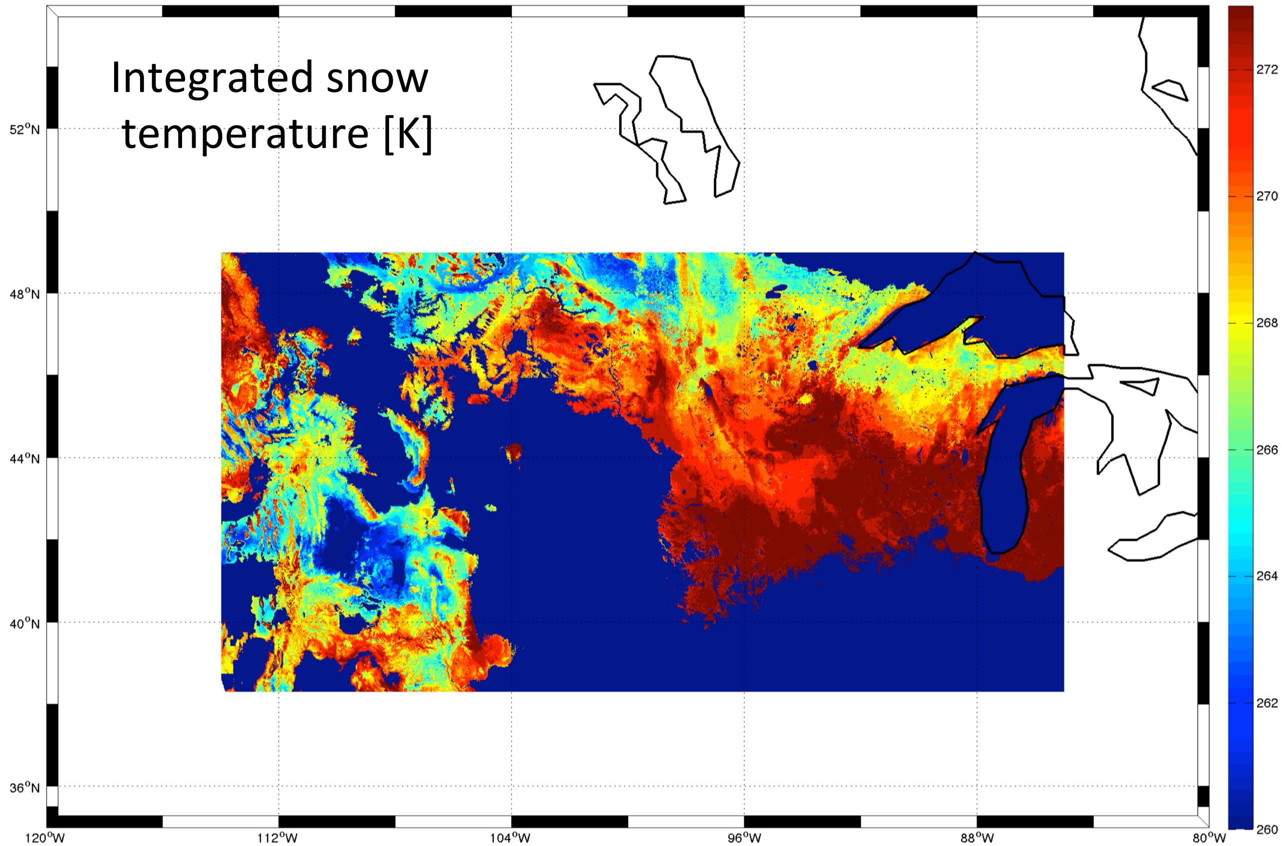
SNODAS co-registered datasets



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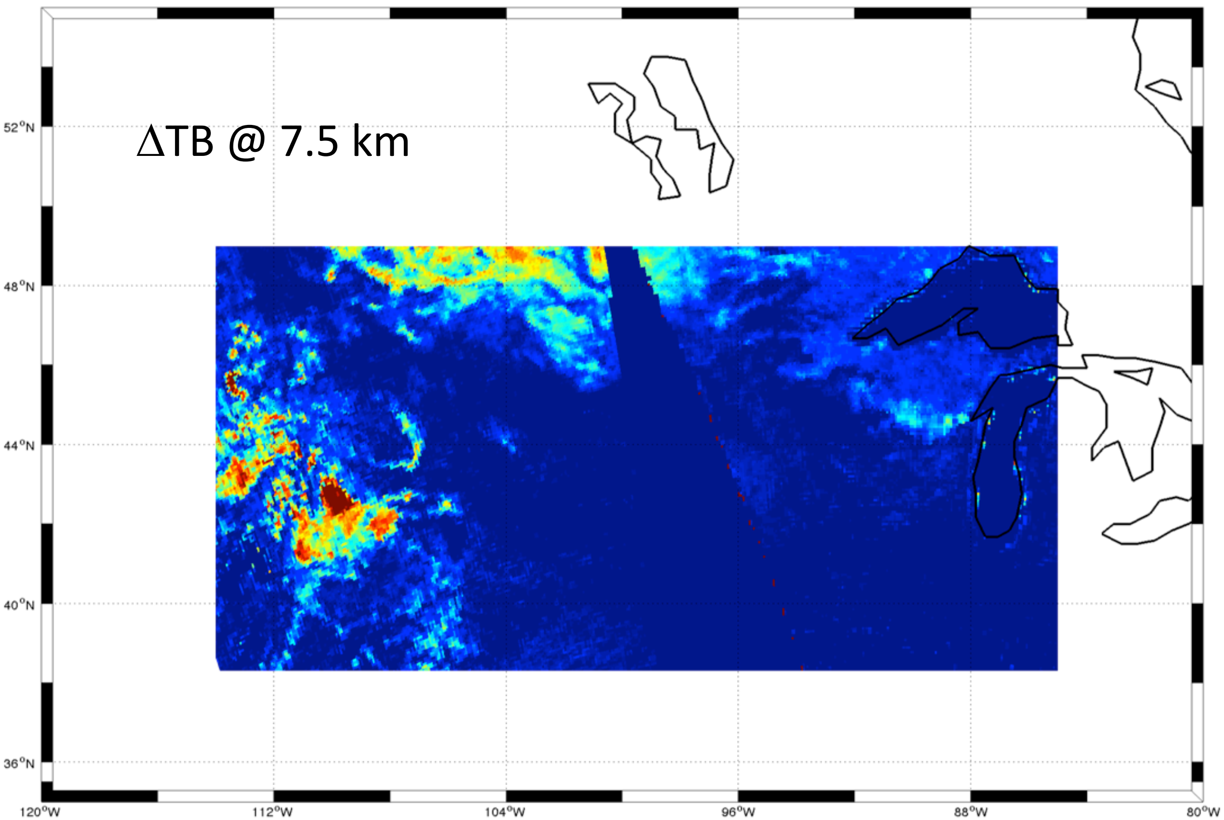
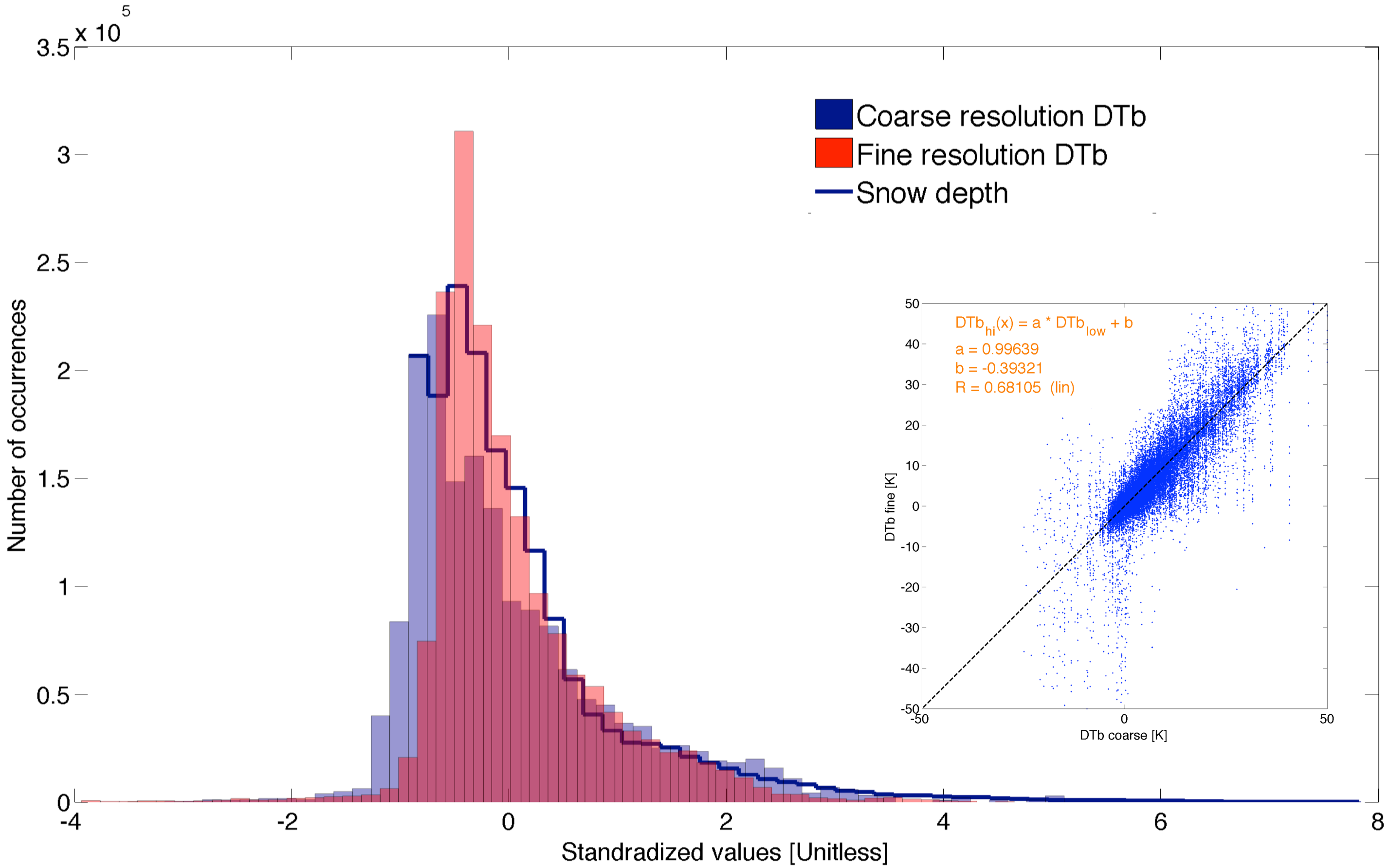
18V minus 36 V



Distribution of ΔTb and snow depth



Finalized and ongoing activities

- Spatial and temporal co-registration of enhanced Tbs with SNODAS and WMO data for the whole AMSR-E time series
- Assessment of impact of noise introduced by enhancement on algorithm performance (both SWE and melting maps)
- Statistical analysis of Tbs and snow parameters at different spatial scales
- Fusion with other sensors and models outputs at high-spatial resolution (e.g., MODIS SCA)