JAXA GCOM-W1AMSR2 snow product science development .

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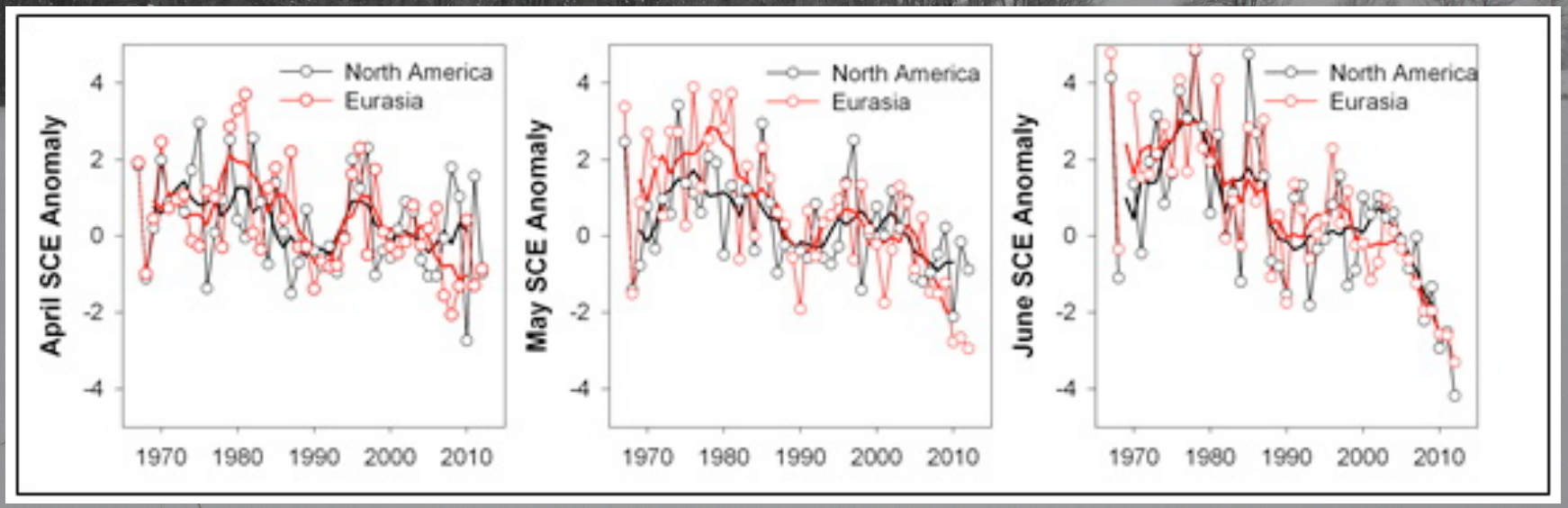
JAXA



Arctic snow cover extent anomalies for April, May and June (1970-2012) with respect to 1988-2007 mean (Derksen & Brown, 2012).

Snow depth (JAXA)

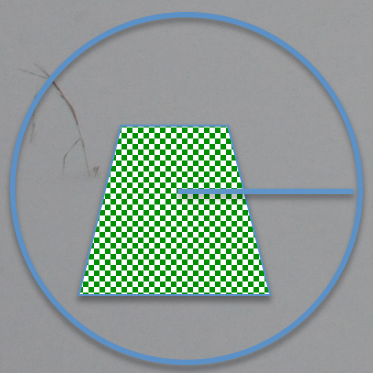
Mixing model approach (observation-based)

$SD = ff(SD_f) + (1-ff)*(Sd_o)$ [cm] $SWE = SD*\rho_{clim}$ [mm]

where

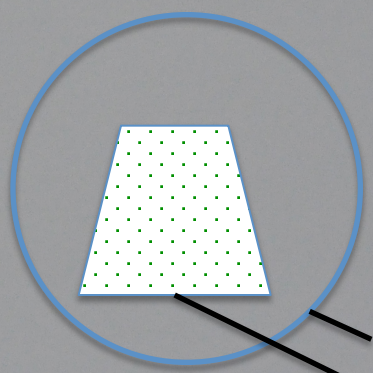
$SD_f = 1/\log_{10}(pol_{36}) * (Tb_{18V}-Tb_{36V})/(1-fd * 0.6)$ [cm]

$SD_o = [1/\log_{10}(pol_{36}) * (Tb_{10V}-Tb_{36V})]+[1/\log_{10}(pol_{18}) * (Tb_{10V}-Tb_{18V})]$ [cm]



fd=50%
ff=40%

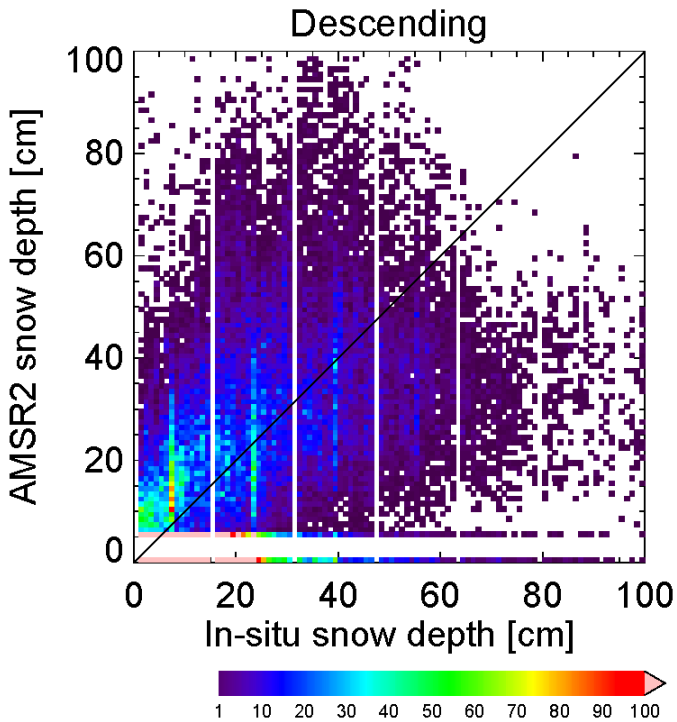
r=12.5km



fd=10%
ff=40%

IFOV radius=12.5 km
Forest stand

AMSR2-SND-statistic-20121001-20130228



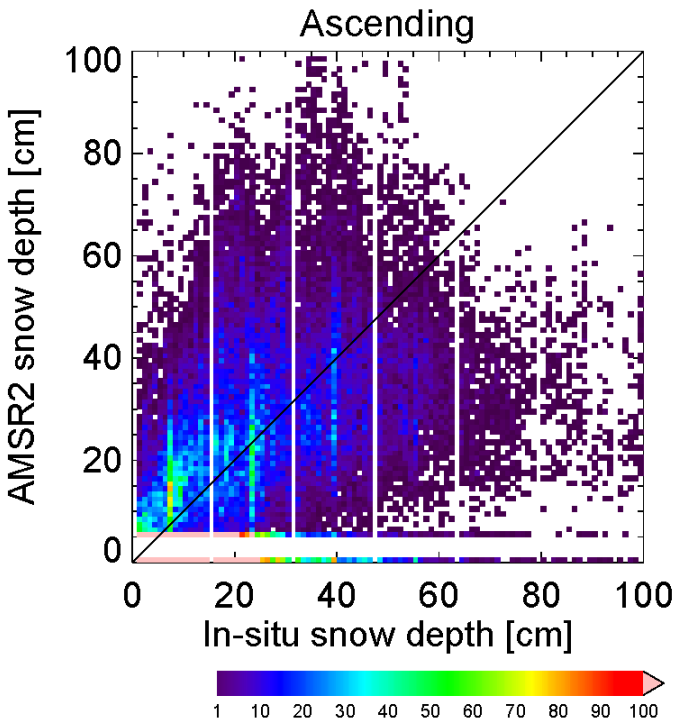
Num. = 49144

R = 0.426

RMSE = 20.144

Bias = 0.343

MAE = 14.762



Num. = 50957

R = 0.450

RMSE = 19.412

Bias = -1.066

MAE = 14.279

....not bad for 6 months development and delivery...

[Kelly, 2009]

‘new’ approach

2 essential variables for estimation:

- #1 Snow detection (snow/no snow)
  - Presence / absence builds history of snow cover that is used for variables in #2
- #2 SWE/snow depth (DMRT-ML)
  - DMRT-ML needs to know #1, Tphys, grain size, density, Tbs (Kelly *et al.* 2003)

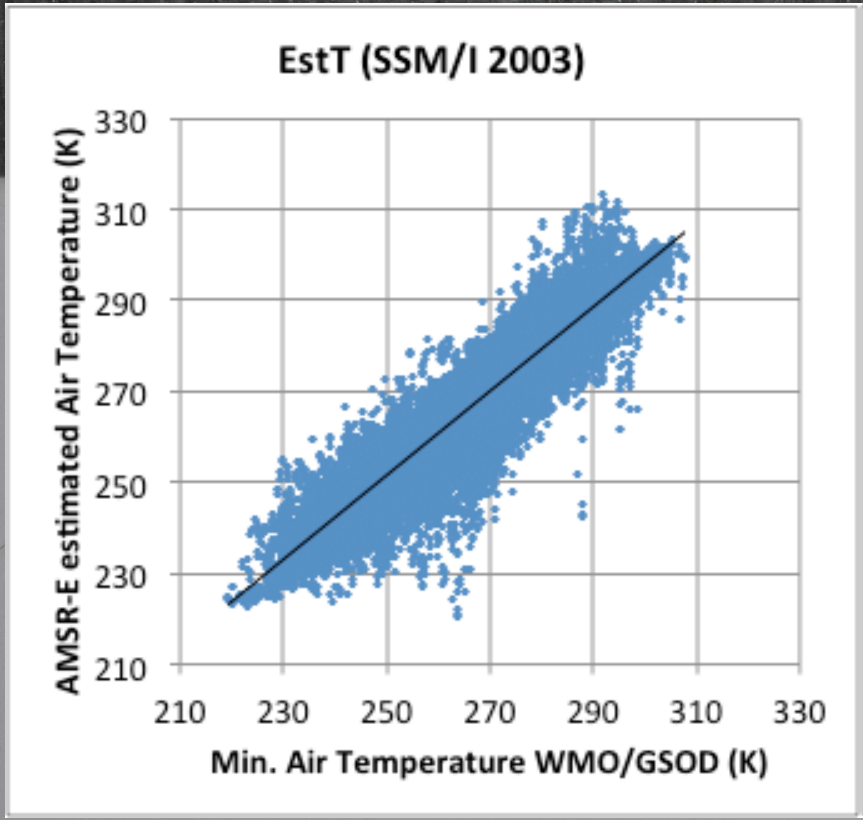
<u>Essential Variable #1:</u> *snow detection*

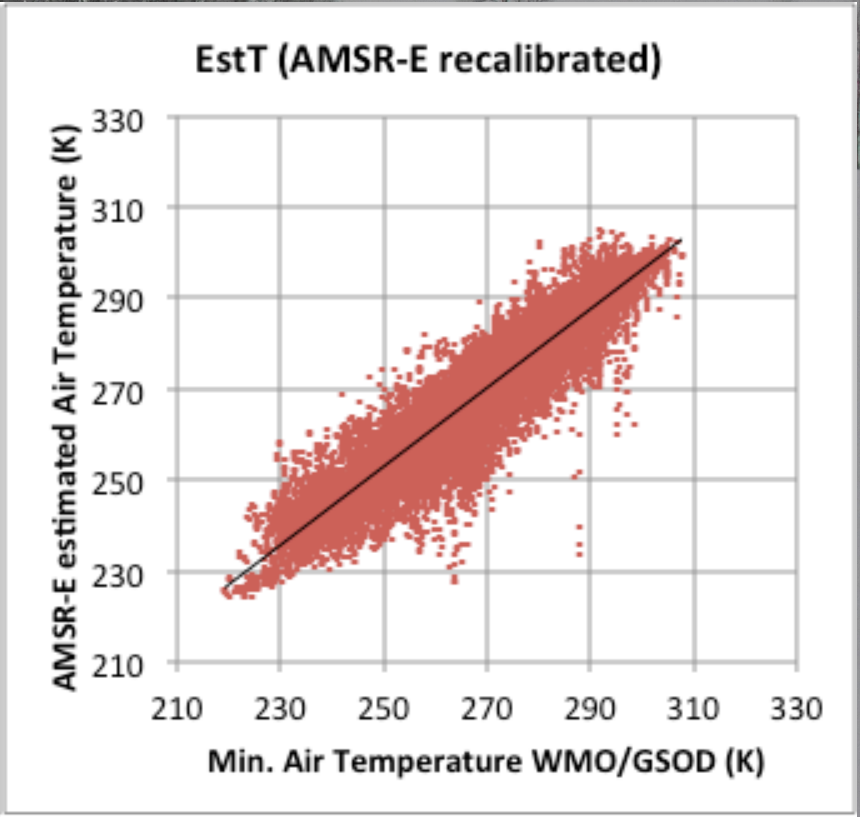
Required to obtain snow onset date

- System screens: bad data, sat. attitude & RFI (10 GHz)
- Geophysical screening
  - Water fraction (>40%)
  - Water state (frozen / unforozen)
  - Non-snow scattering (high elevation deserts etc)
- Tb19V/H-Tb36V/H should identify snow if Tbs are cold:
  - Mean emissivity of fresh snow at 36 GHz→ 0.94 (*V*), 0.91 (*H*) (Mätzler, 1994)
  - Assuming dry snow, a reasonable upper Tb limit for moderate snow accumulation is:
    - 273*0.94=256K (Tb36V)
    - 273*0.91=248K (Tb36H)
- Use Tb gradients (H and V) to determine shallow snow along with 89GHz and surface temperature estimator:

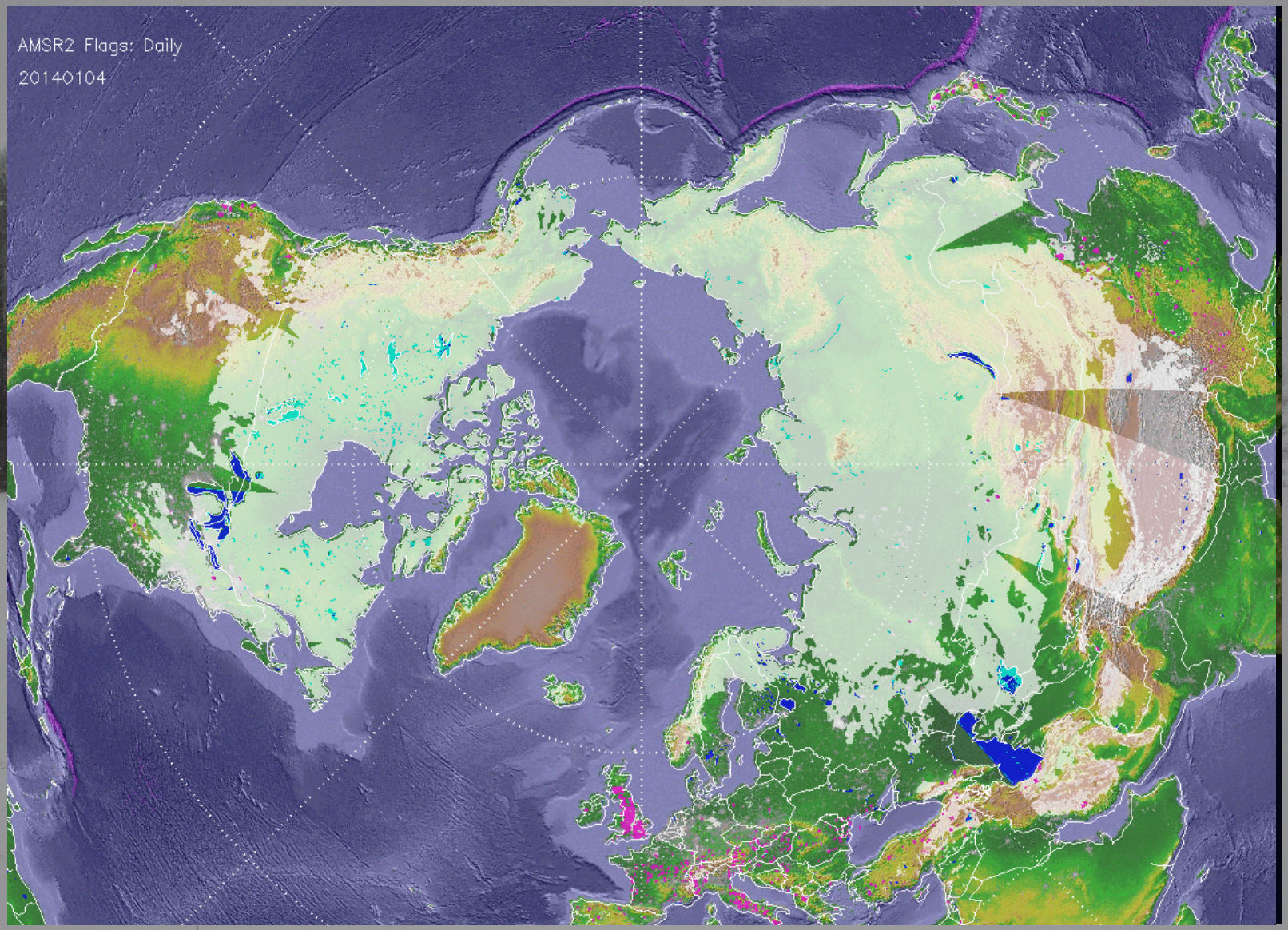
Recalibrated temperature estimation of above snow surface (Kelly *et al.* 2003). Matched AMSRE 2005 data reveal small change from SSMI version.

- $T_{phys} = 62.4 - 0.05Tb18V + 0.84Tb23V - 0.40Tb36H + 0.41Tb89V$



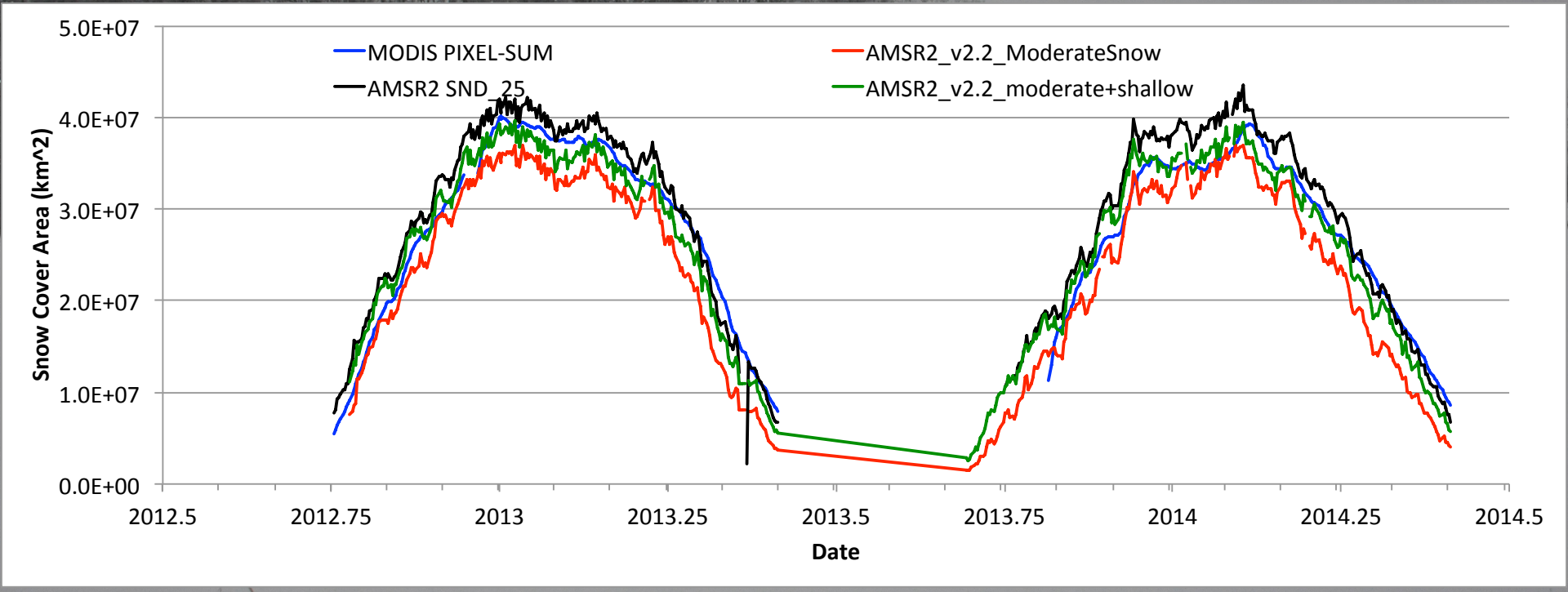


Standard error (y):	6.9K	5.7K
R^2 CoD	80%	85%



Estimated snow cover extent on 4 January 2014: AMSR2 and MODIS

Detection record 2012-14

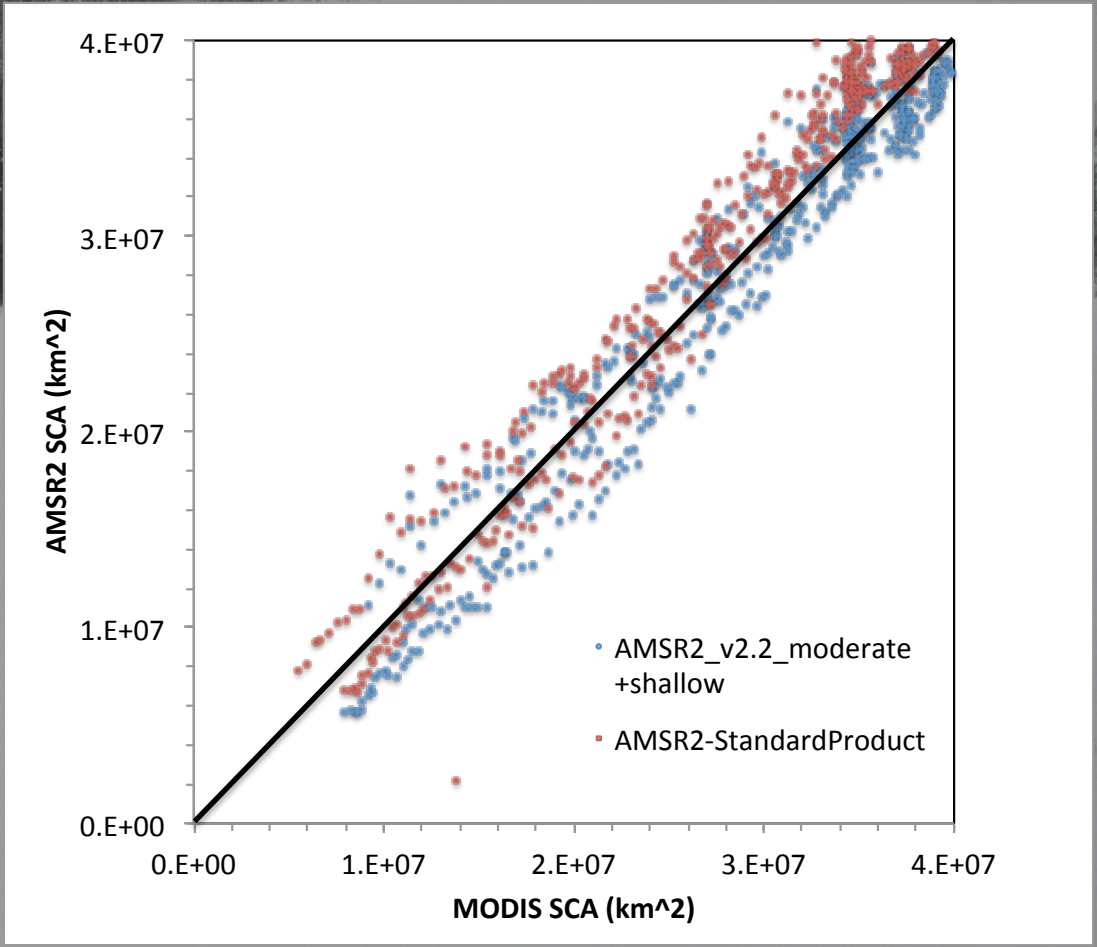


Northern hemisphere snow.

Shallow snow detector is off (on for SND_25).
Forest correction is off (on for SND_25)

Metrics of fit with MODIS SCA

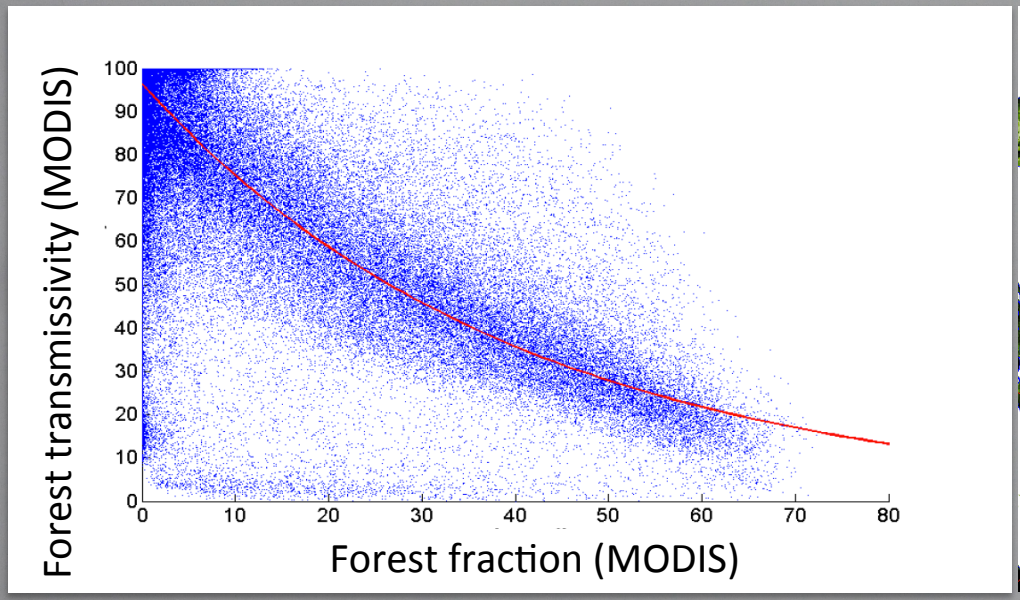
	RMSE $x10^6$ km^2	Bias $x10^6$ km^2
AMSR2 v2	5.632	0.916
AMSR2 standard	6.025	2.902

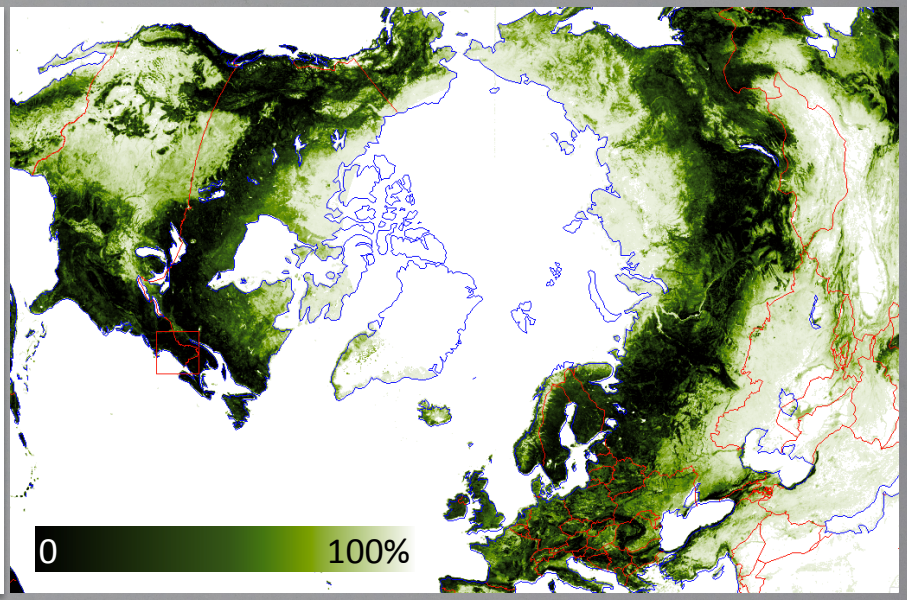


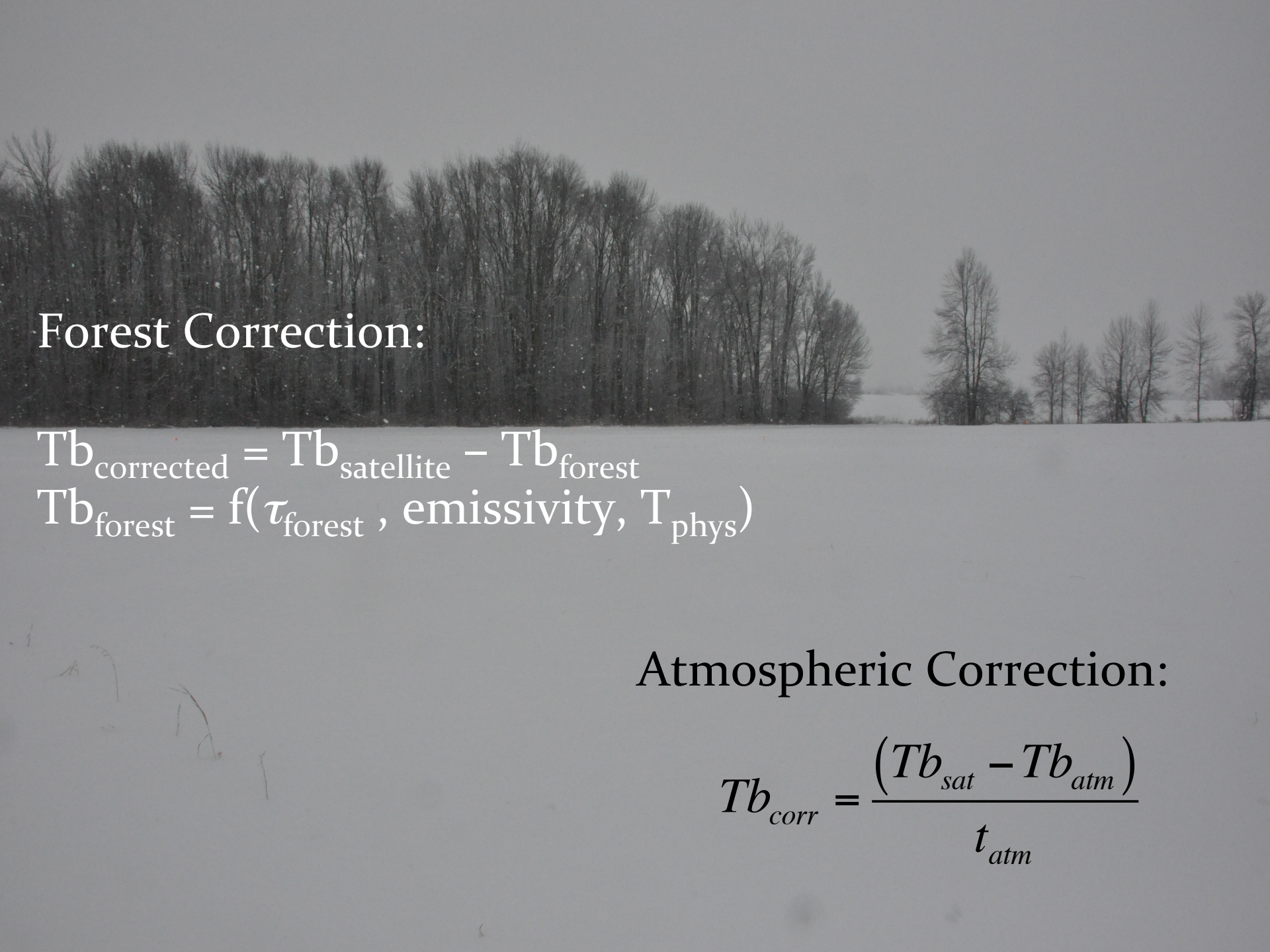
- Further corrections:
  - Forest canopy attenuation
  - Atmospheric attenuation

Forest transmissivity

- Example from Finland (Metsämäki et *al.* 2005)
- Based on Landsat TM analysis applied to MODIS
- Transmissivity is a function of canopy structure.
- Although not the same as forest fraction or NDVI we can predict it to marginal snow regions based on a derived linear forest spatial cover relationship.







Forest Correction:

$Tb_{corrected} = Tb_{satellite} - Tb_{forest}$

$Tb_{forest} = f(\tau_{forest}, \text{emissivity}, T_{phys})$

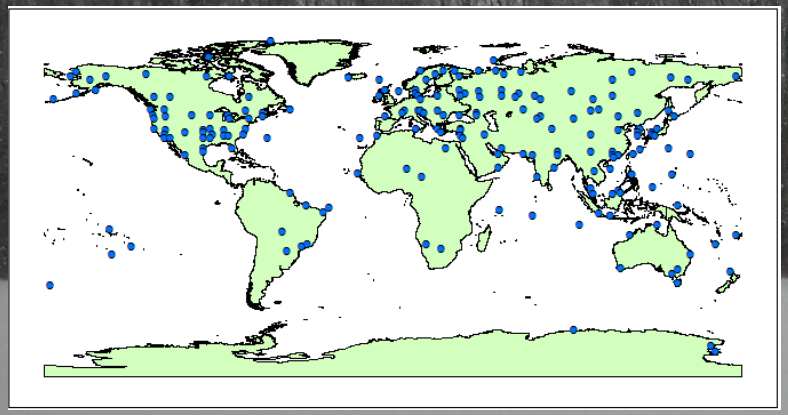
Atmospheric Correction:

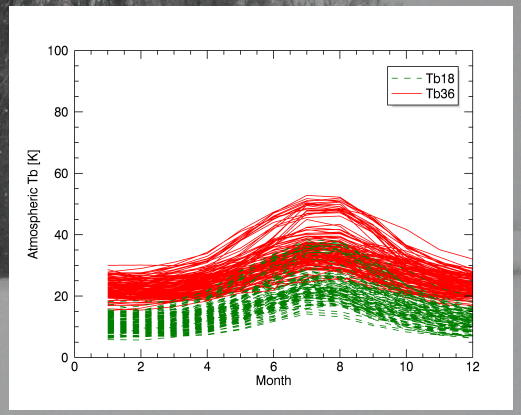
$$Tb_{corr} = \frac{\left(Tb_{sat} - Tb_{atm}\right)}{t_{atm}}$$

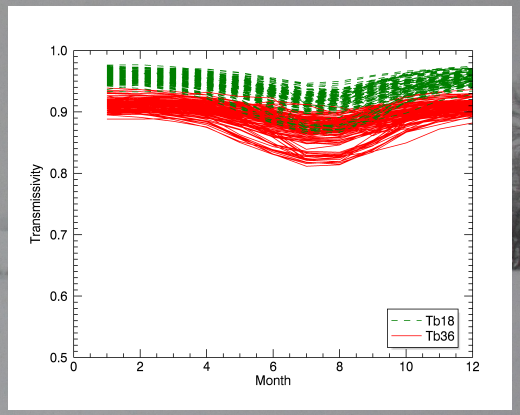
Atmospheric attenuation

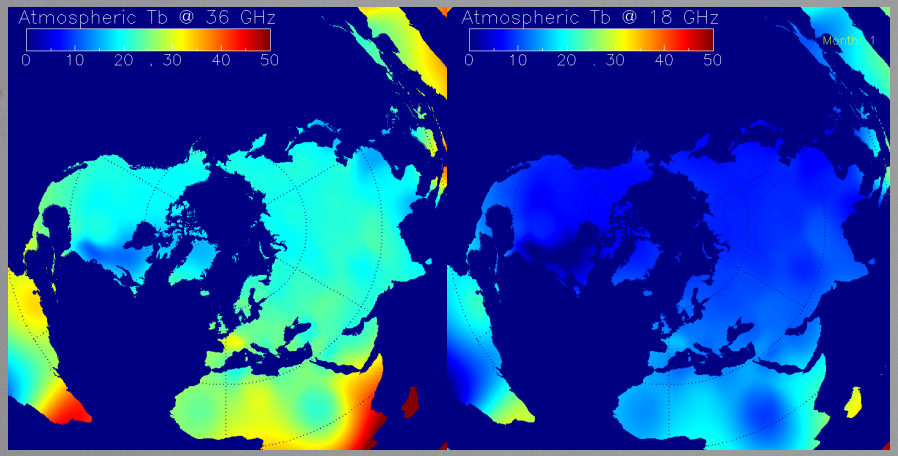
thx G. Luo for RT code, after "the other Rosenkrantz (1995)"

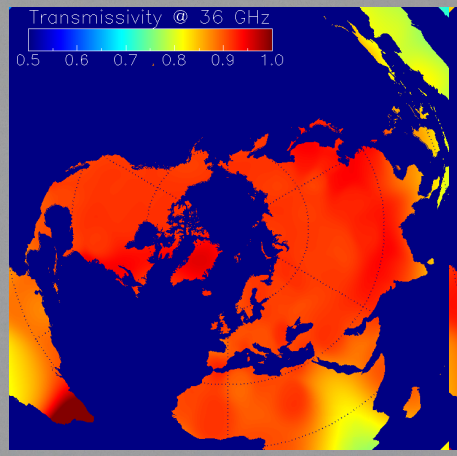
Monthly average radiosonde data 2001-2011

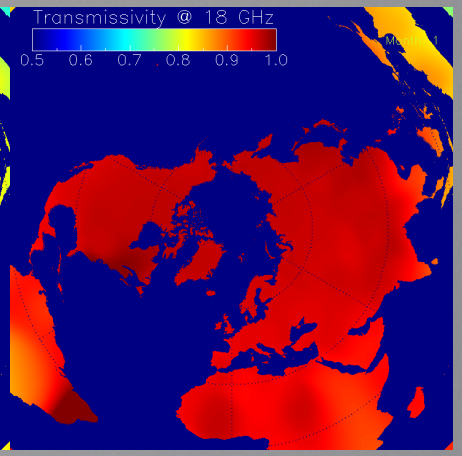








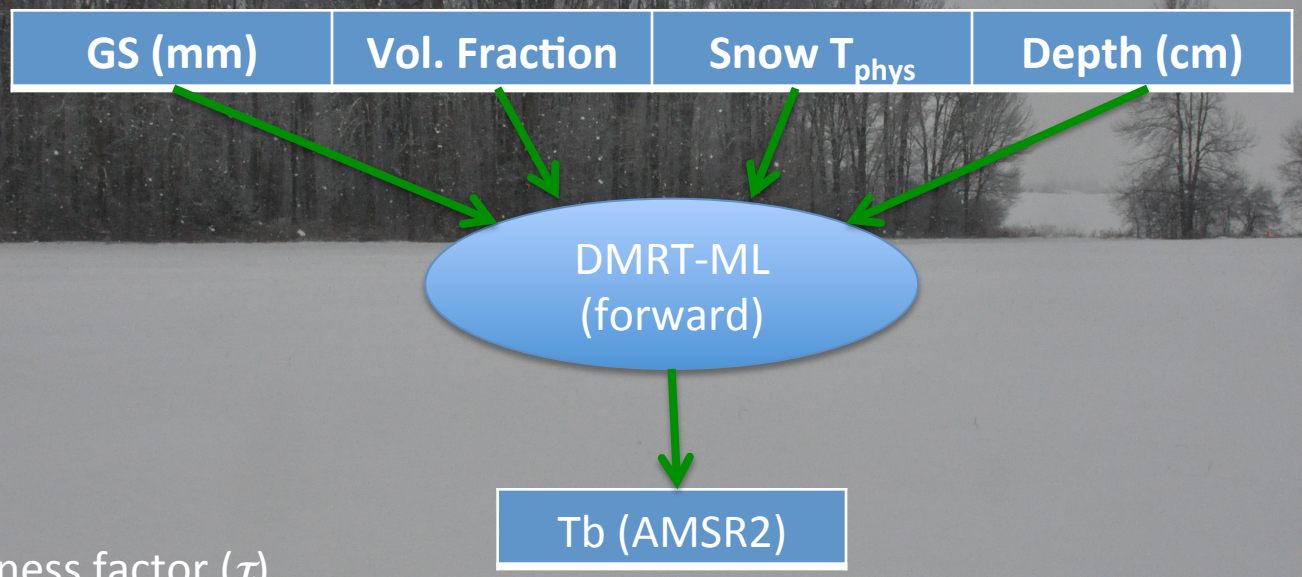




January gridded monthly averages of Tb and transmissivity

Essential Variable #2: *SWE/Snow depth*

DMRT-ML: how well does it match AMSR2?



- Stickiness factor (τ)
- Number of Layers (n)
- Frequency of interest (e.g. AMSR2) and incidence angle
- Soil substrate choice (significant?)
- Snow Tphys is calculated from AMSR2
- Snow depth is obtained from CMC/WMO data
- Gs and density (VF) constant are estimated from Sturm et al approaches (1997 and 2010 respectively)

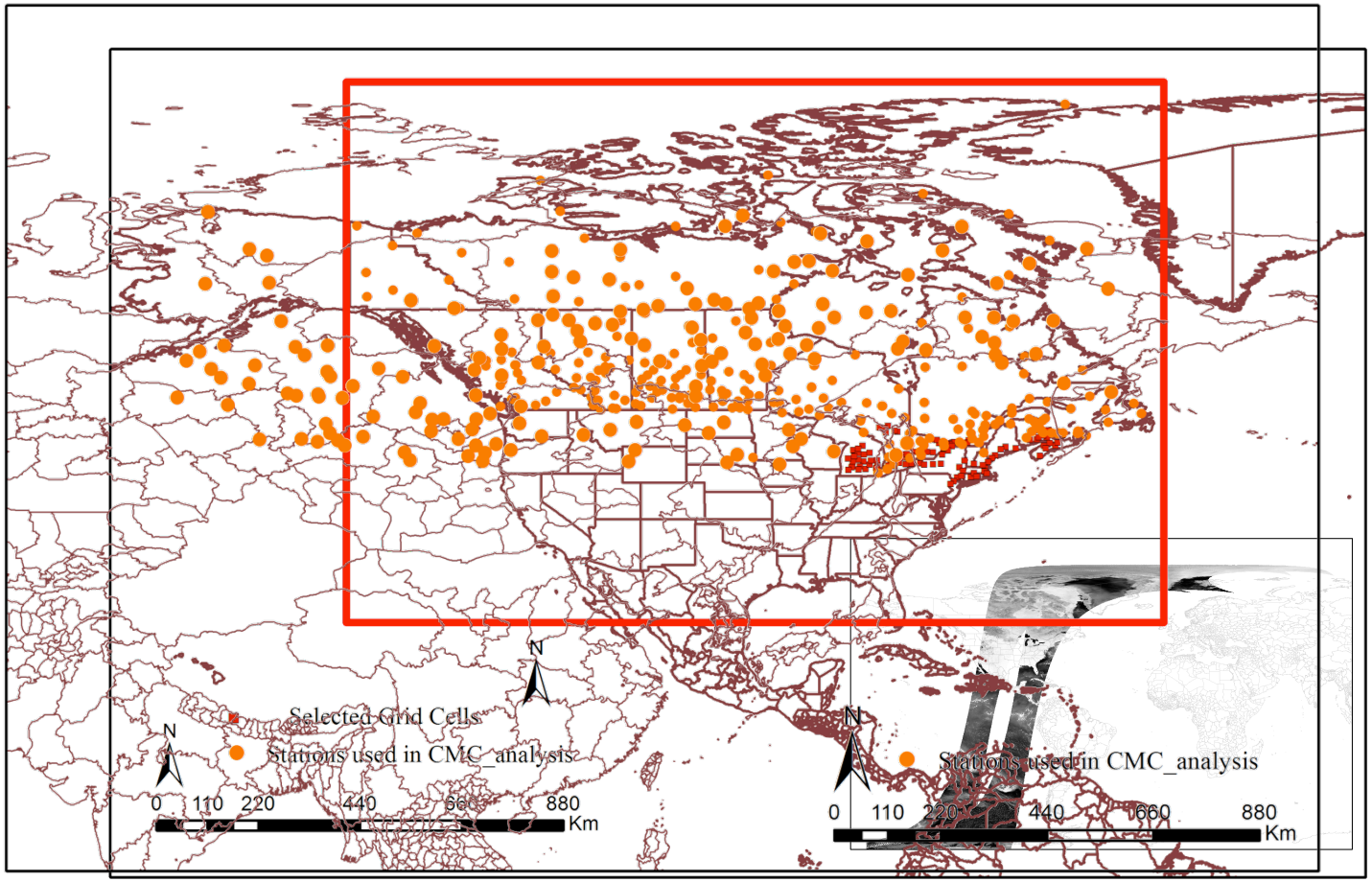
DMRT-ML Evaluation For SWE Retrieval

DMRT-ML: how well does it match AMSR2?

Case 1 Feb. 2013
S. Ontario to N.E. USA
SD from CMC Analysis
20 days, 100 grid cells,
(n=2000)

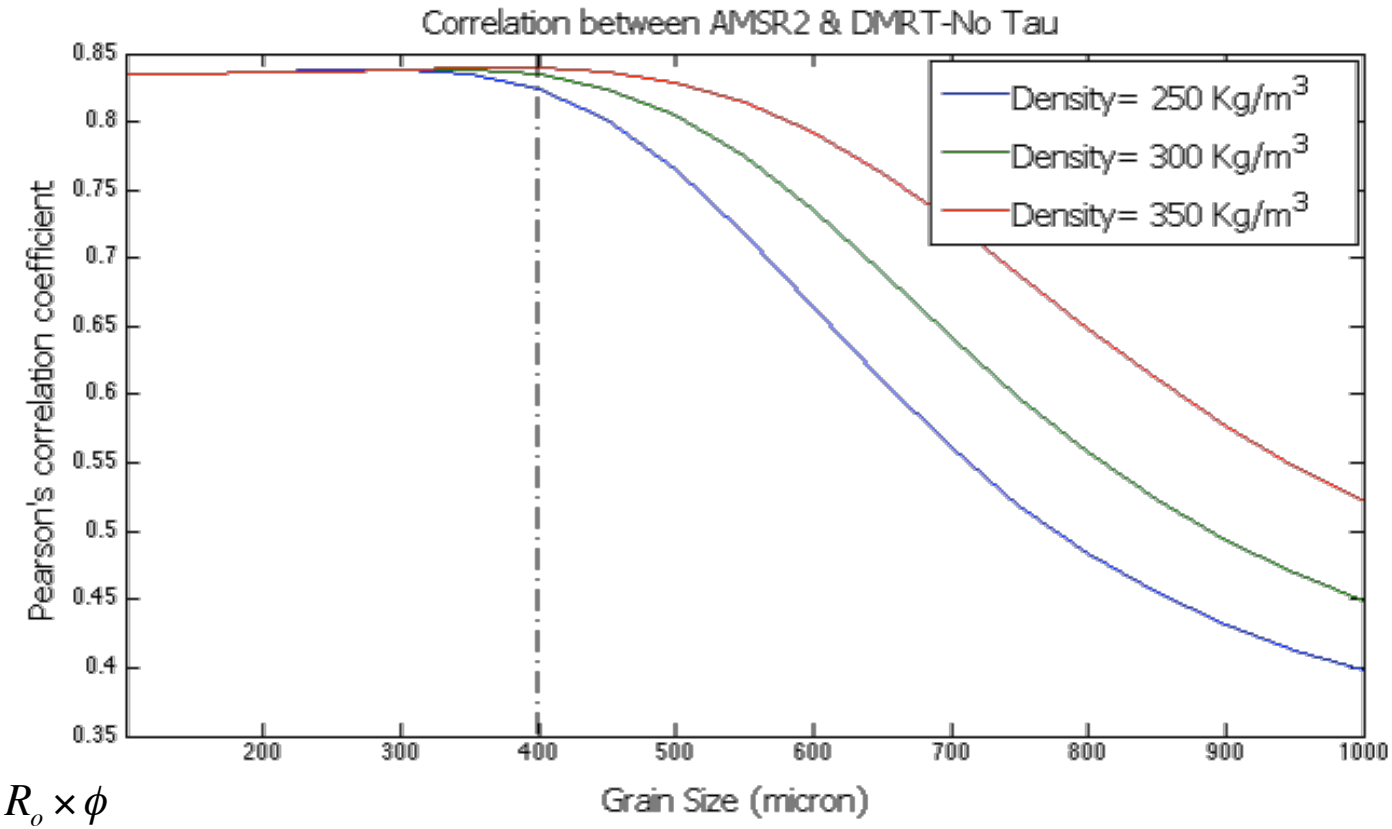
Case 2 Dec 2013 - Jan 2014
N. America
SD from CMC stations
60 days, 242 CMC station
(n=10144)

Case 3 Dec 2013 - Jan 2014
Siberia
SD from CMC stations
60 days, 162 CMC stations
(n=9720)



Data QC:
Shallow snow, snow Depth<5cm
Stations in neighborhood of water-bodies (15 km buffer)

Case1: Optimum optical grain size for DMRT-ML simulation to fit AMSR2 best



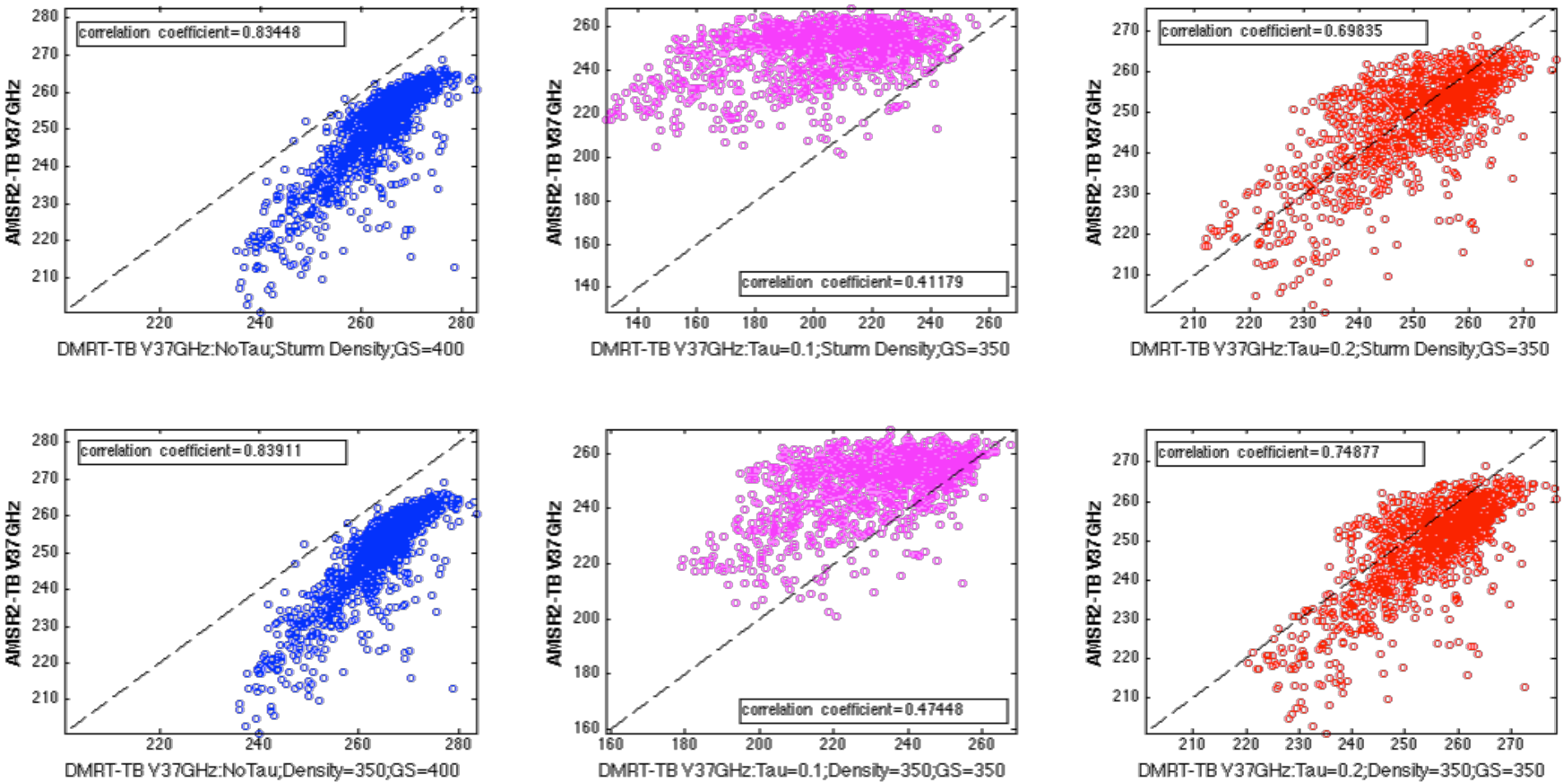
$$R_{eff} = R_o \times \phi$$

$$\phi = 3.3$$

(Roy *et. al* 2012)

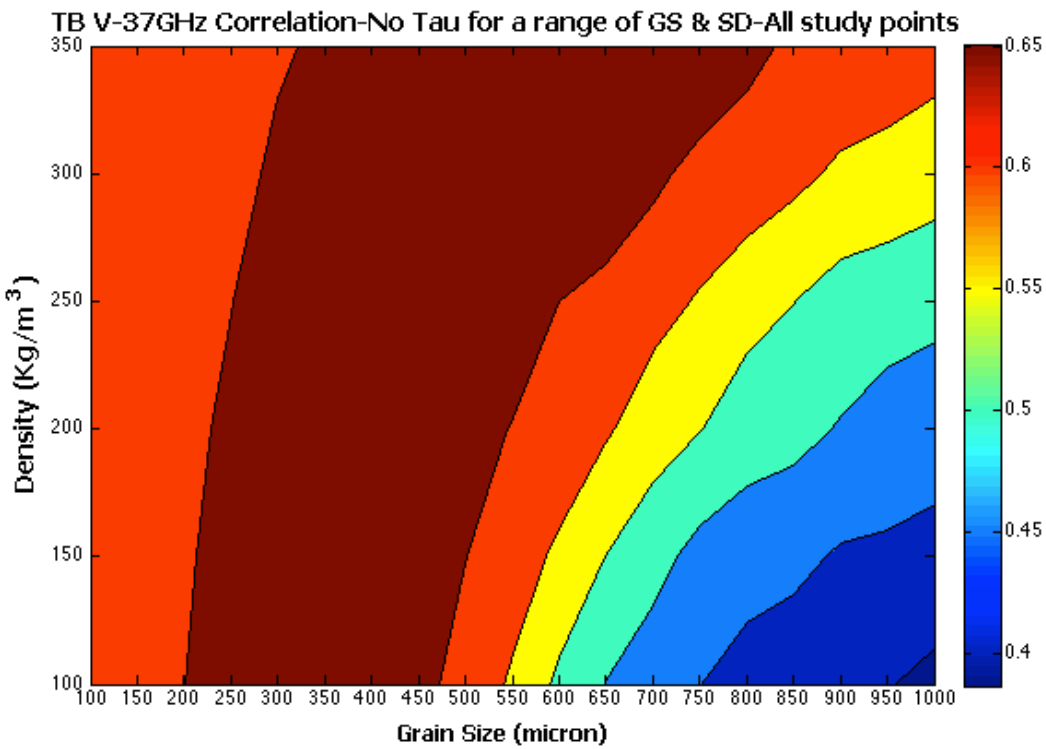
20 days, 100 Grid cell, 2000 sample

Case 1: Correlation between AMSR2 & DMRT For different stickiness and density assumptions



Sturm snow class density: $\rho_{h_i,DOY_i} = (\rho_{\max} - \rho_0)[1 - \exp(-k_1 \times h_i - k_2 \times DOY_i) + \rho_0$

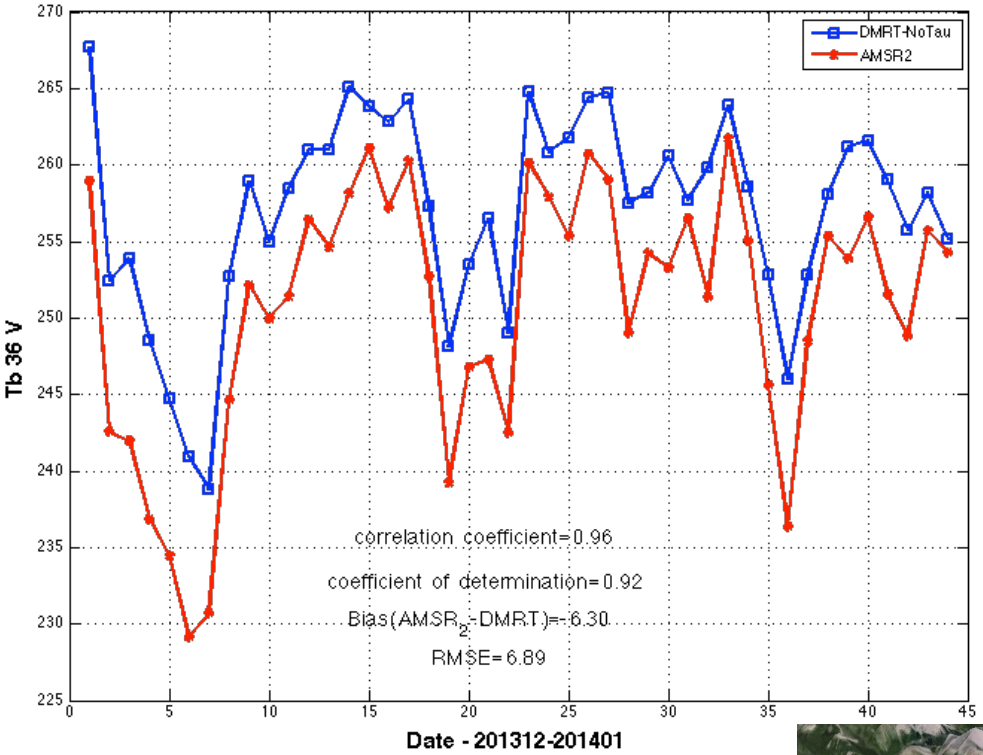
Case 2:
Comparing Simulated T_B From DMRT-ML With AMSR2 observations

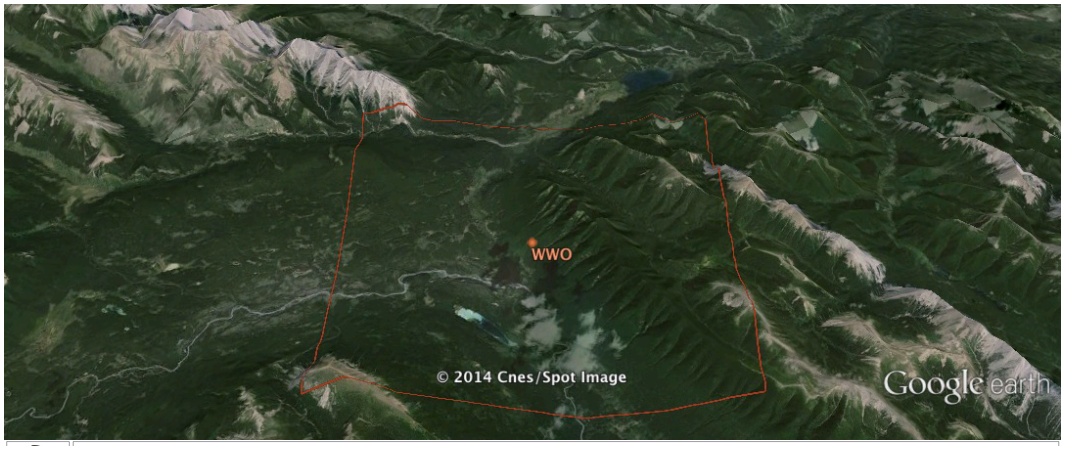


- **Median value of correlation for each station point**
- **No substratum- semi-infinite assumption**
- **No stickiness**
- **Snow depth=*in situ* (met station)**
- **Physical temperature= AMSR2 *TB* in**

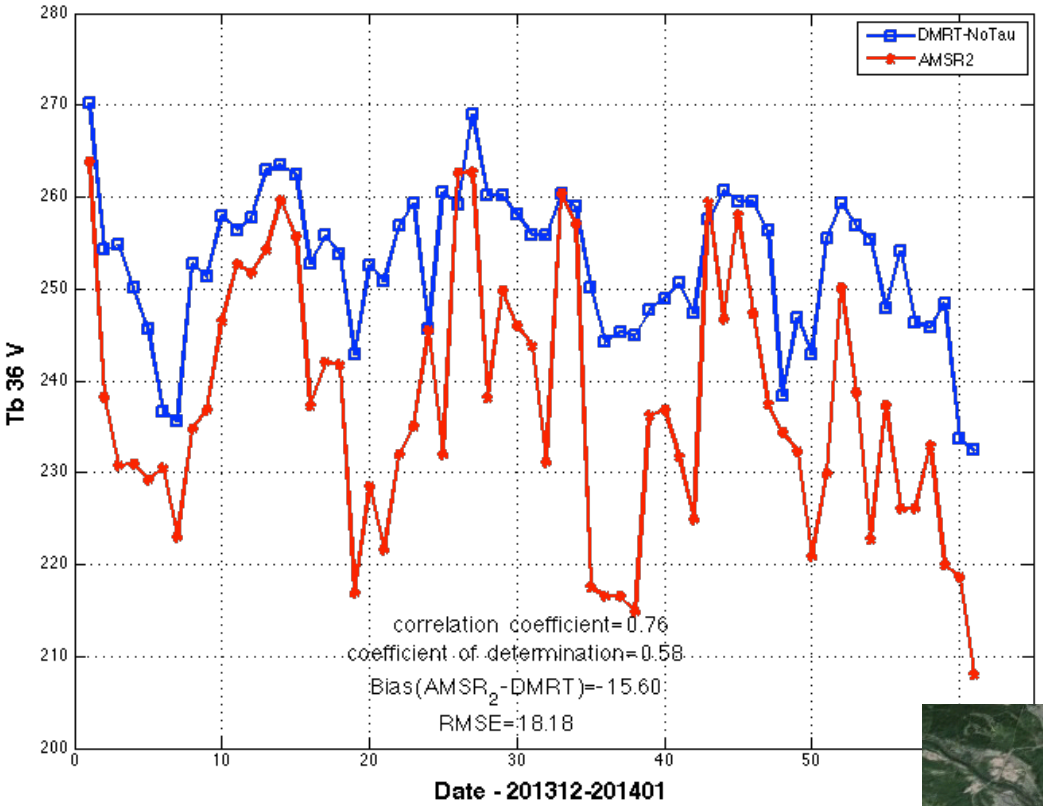
60 days, 242 CMC station; 10144 samples

Case 2: Comparing Simulated T_B From DMRT-ML and AMSR2 Observations

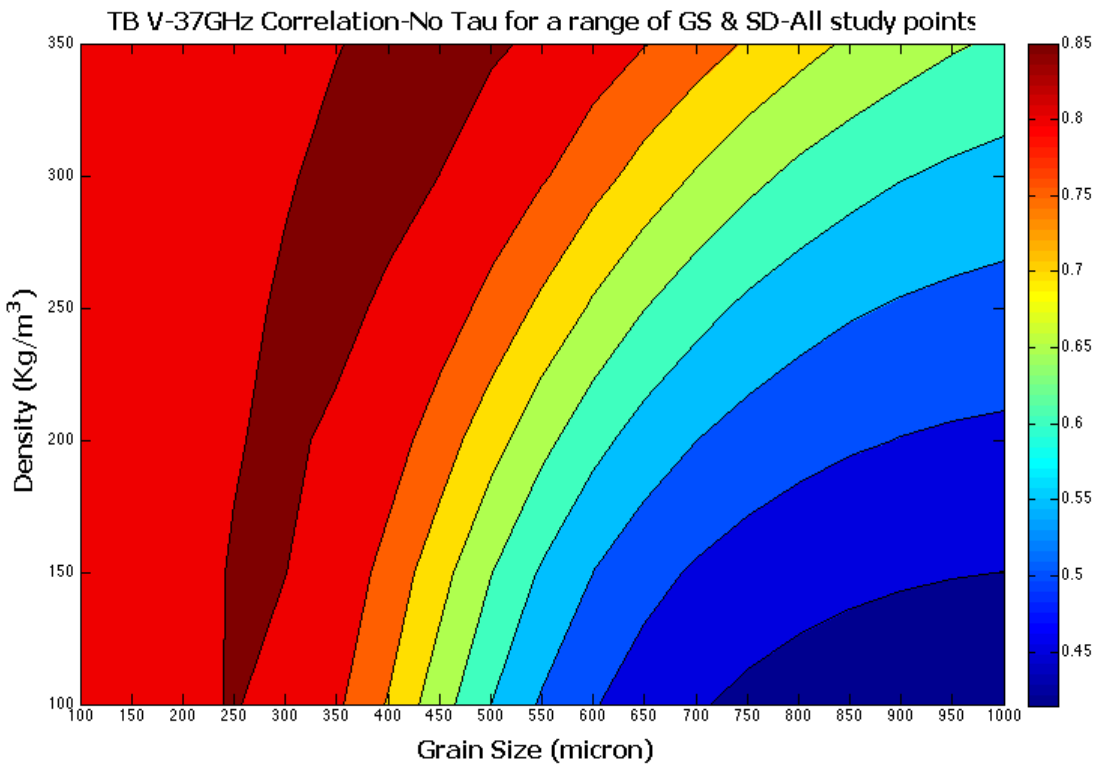




Case 2: Comparing Simulated T_B From DMRT-ML and AMSR2 Observations



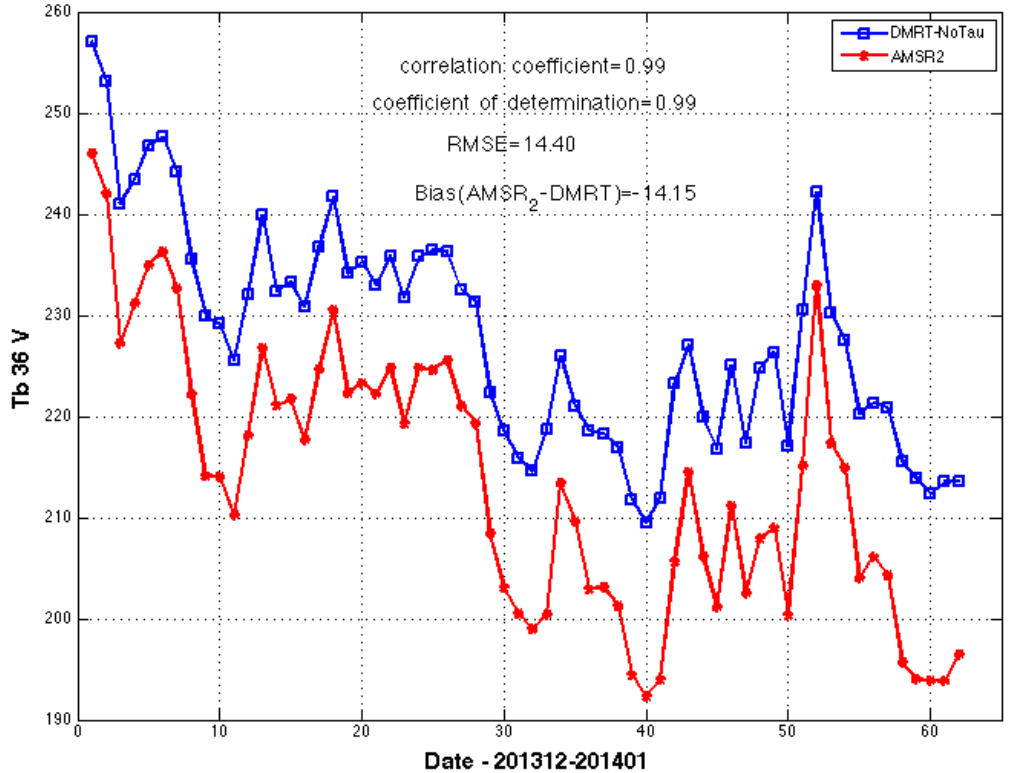
Case 3:
Comparing Simulated T_B From DMRT-ML and AMSR2 Observations

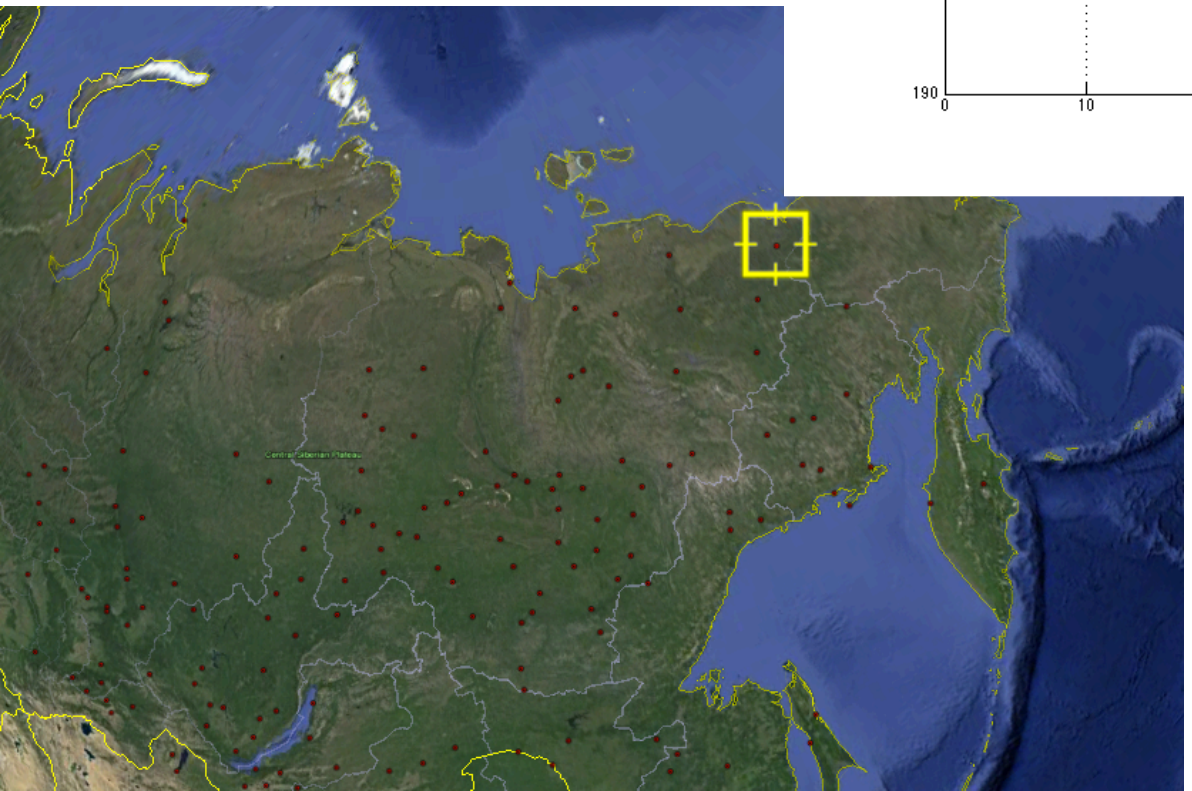


- **Median value of correlation for each station point**
- **No substratum- semi-infinite assumption**
- **No stickiness**
- **Snow depth=*in situ* (met station)**
- **Physical temperature= AMSR2 *TB* in**

60 days, 162 CMC station; 9720 samples

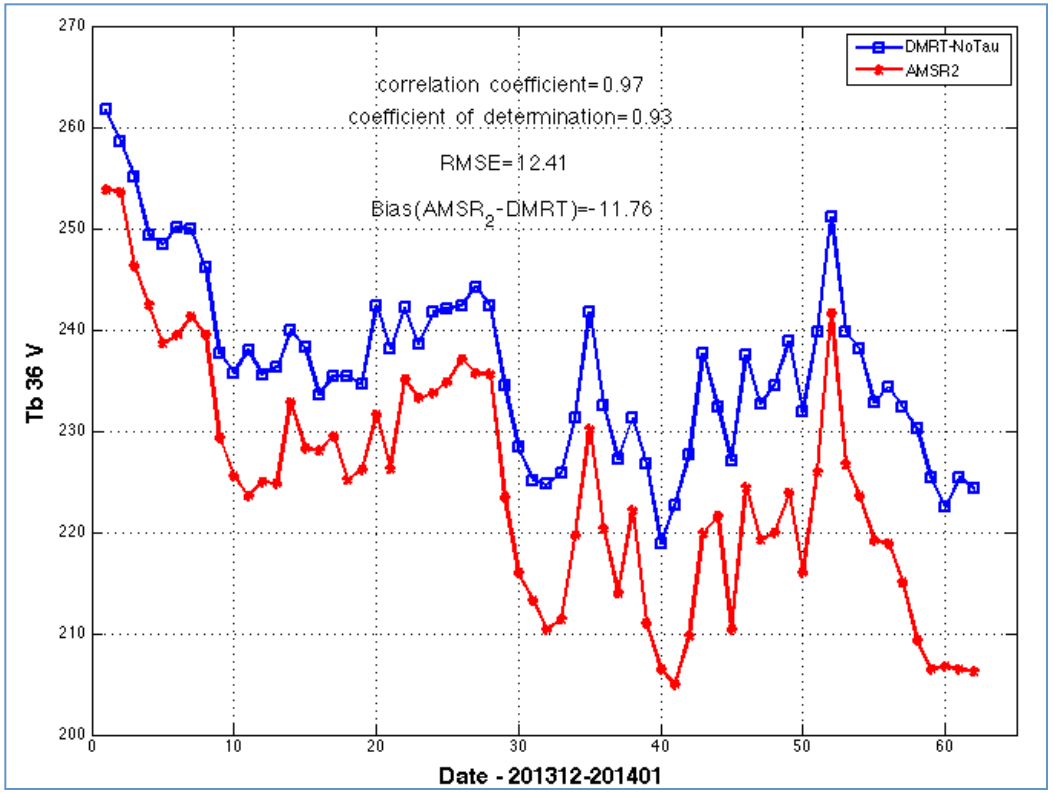
Case 3:
Some Examples

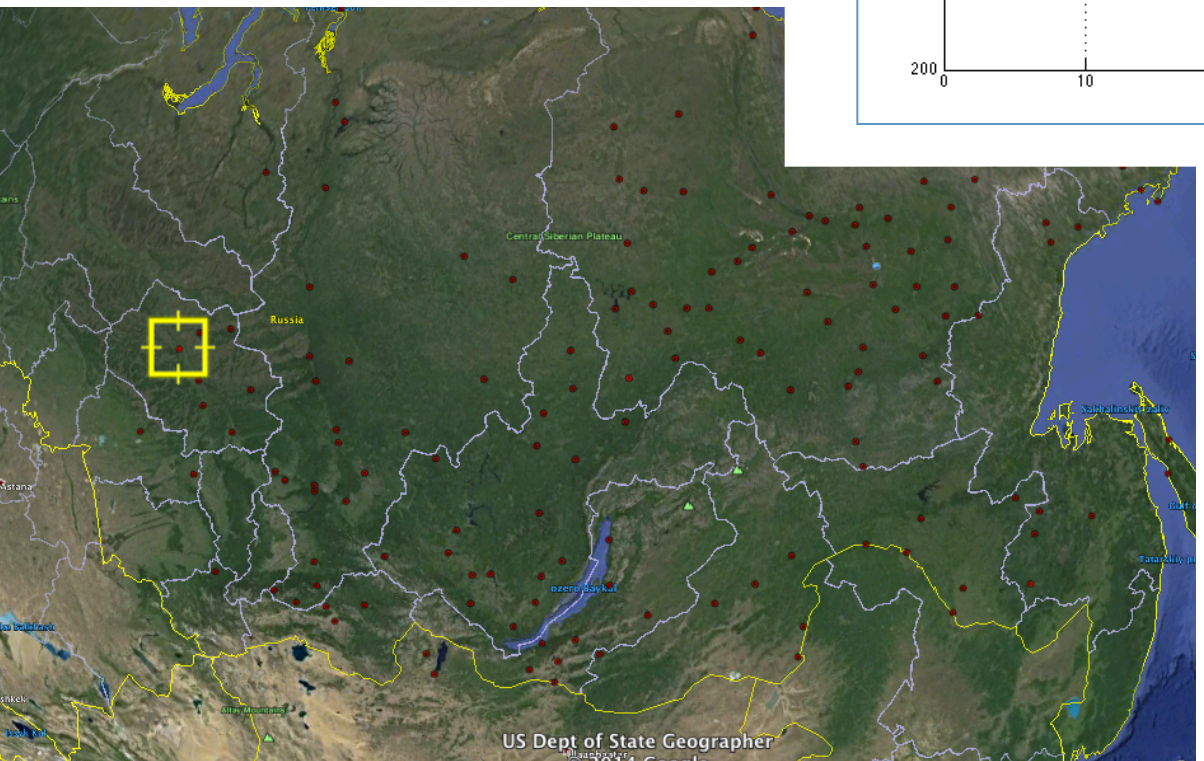




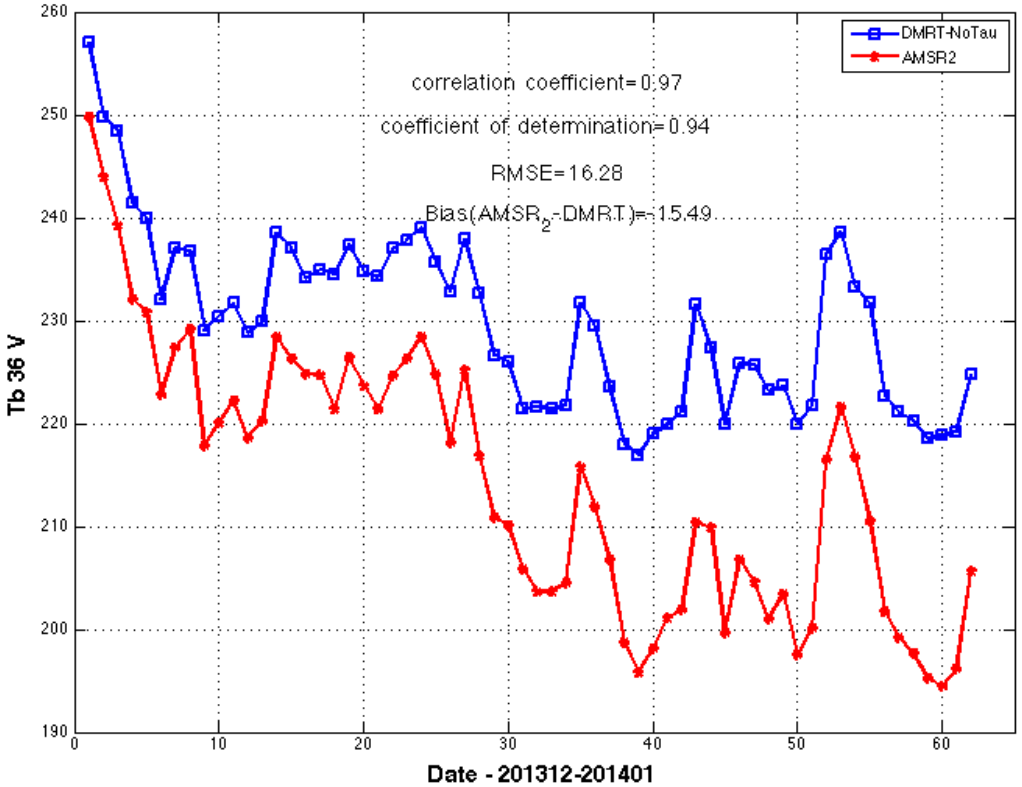
- No substratum- semi-infinite assumption
- No stickiness
- Snow depth=*in situ* (met station)
- Physical temperature= AMSR2 *TB* in
- Grain size = 400 μ
- Density = 250kg/m^3

Case 3:
Some Examples



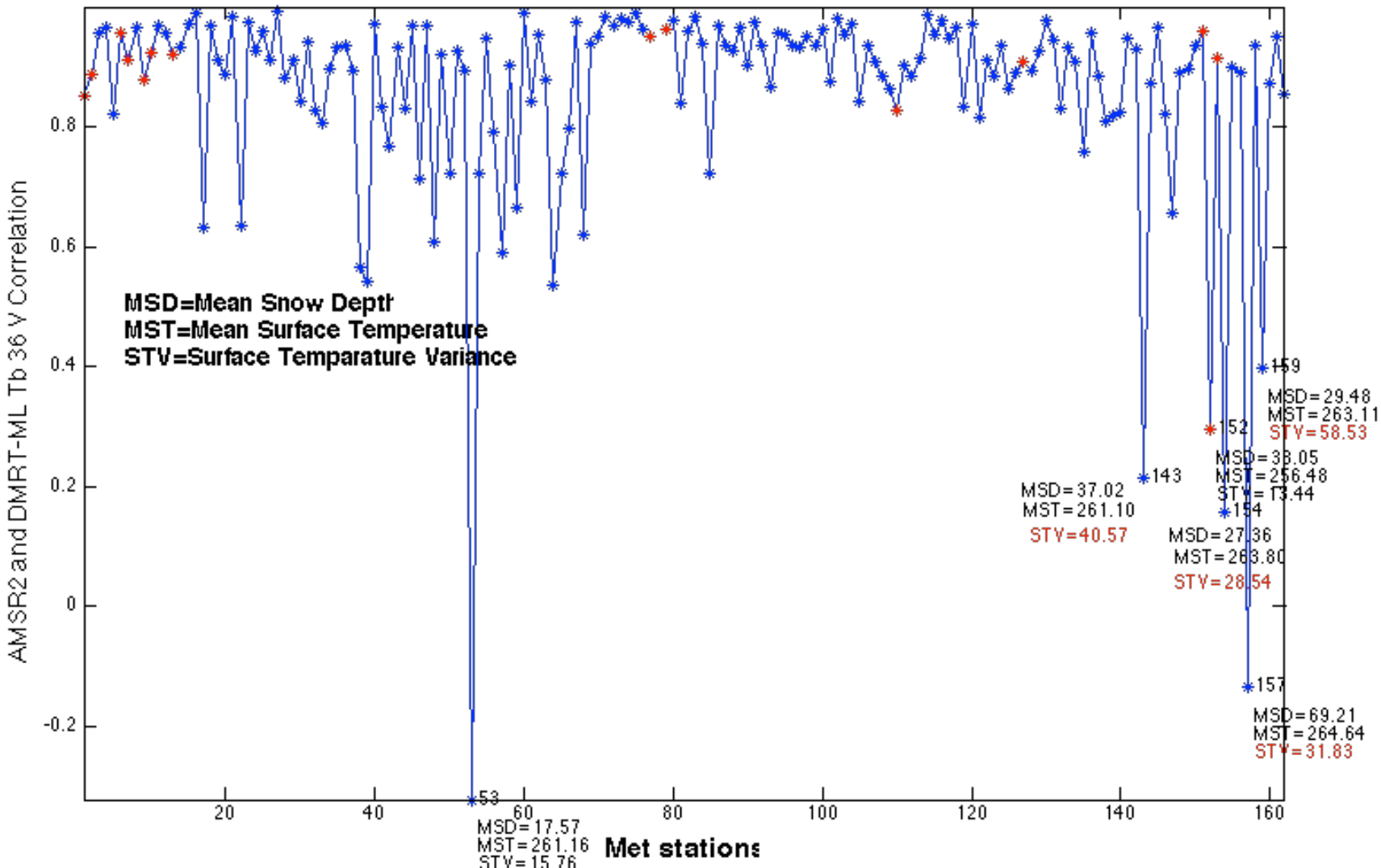


Case 3:
Some Examples



Mean correlation during study period in each met station(36 V)

GS=250 / Density=250/ Water bodies adjacent (*)



Summary

- Space-based only estimates of SWE are challenging. JAXA needs AMSR2 SWE/ snow depth that is robust (risk-free) and straightforward to implement
- Semi-empirical retrieval approach offers advantages from both physics-based and empirical approaches.

- We are putting together the pieces now and testing.
  - Snowcover mapping – simple and robust
    - Forest attenuation correction – transmissivity estimates
    - Atmospheric attenuation correction – based on 11 year period
  - DMRT-ML (grain size and density from simple empirical model) shows good sensitivity and needs now to have reasonably consistent gs and density estimate.
  - Inversion – simple single frequency approach, with inclusion of snow history to estimate grain size.
- Evaluation is based on multiple sources.

Acknowledgements: Ghislain Picard