The AMSR2 snow depth and SWE retrieval product: development of V2 and evaluation

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IC3

JAXA

GCOM-W1 AMSR2

Contextual requirement: space-based retrieval

- Consistent and independent of ground data
- Wide range of frequencies (NB RFI 6/7 + 10 GHz)
- Daily (JAXA interested in Asc and Desc)
- AMSR2 launched in 2012
  - 6, 7, 10, 18, 23, 36, 89 GHz (V&H)
  - Calibration is relatively stable for our purposes.
- V1 available. V2 in development (delivery in 2014).

V1 Product (available)

- Predicated on the AMSR-E algorithm. Developed and implemented in 2003/4 (in response to deficiencies in static algorithm. Kelly (2009).
  - Grain size is dynamic *but not enough*
  - Forest correction is first order
  - No atmospheric correction
  - Lake ice not addressed

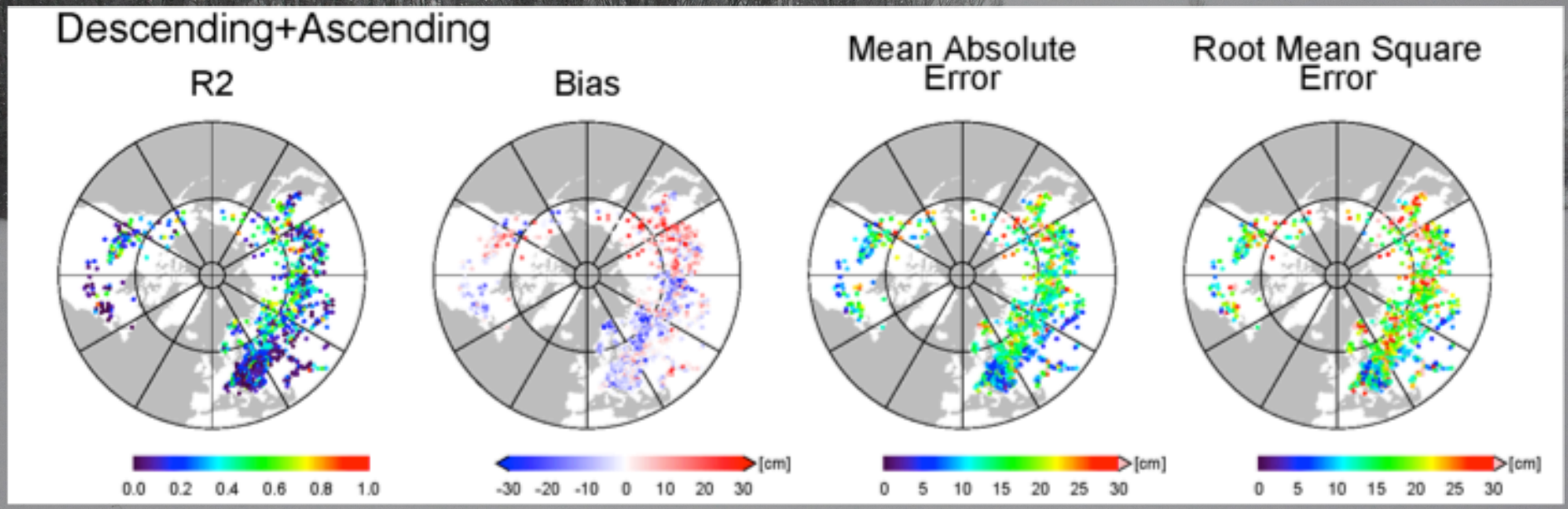
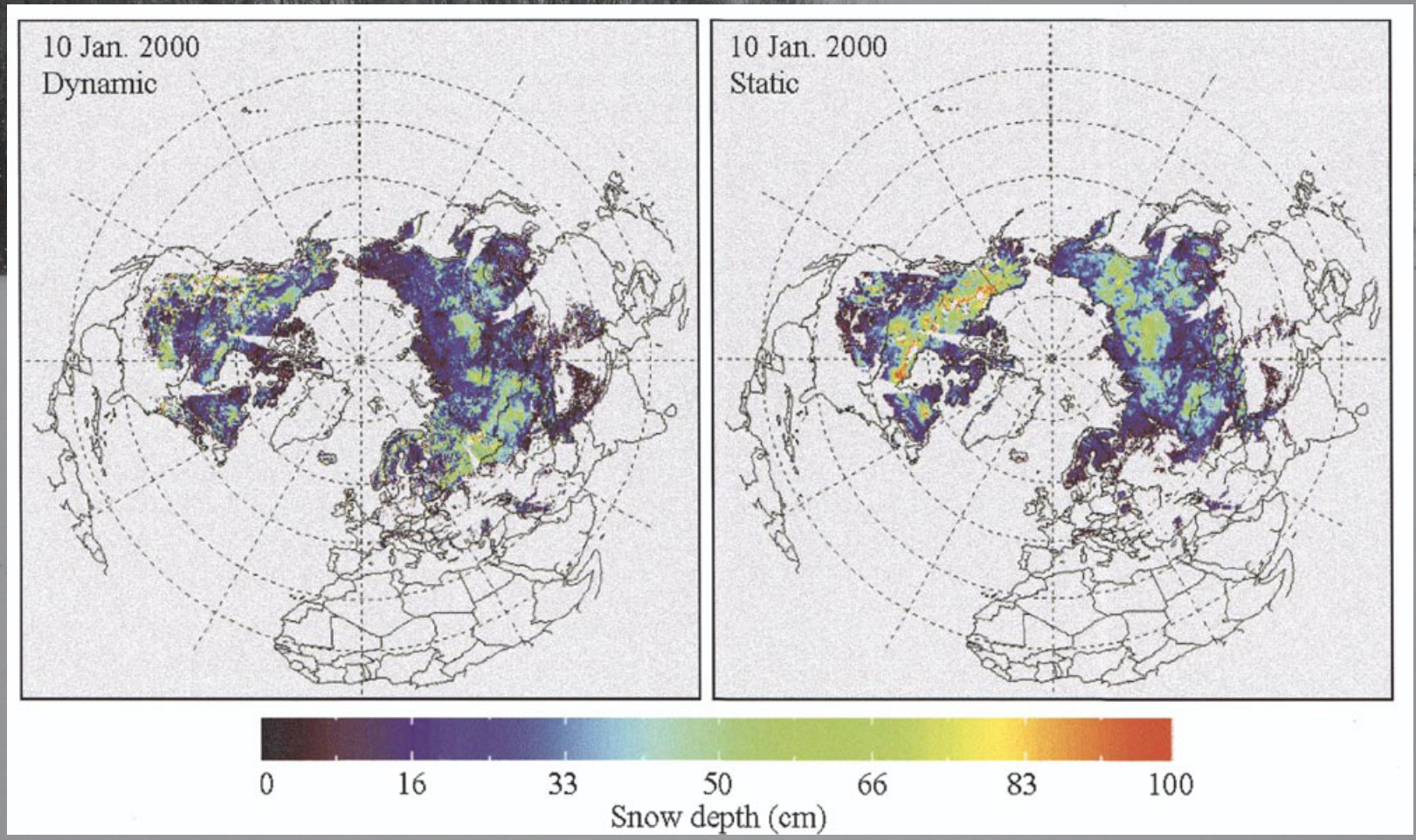


Figure 6. Error maps for snow depth based on 1007 stations between 1/10/2012 and 31/3/2013 (from EORC/JAXA), 2013, Status of AMSR2 Products)

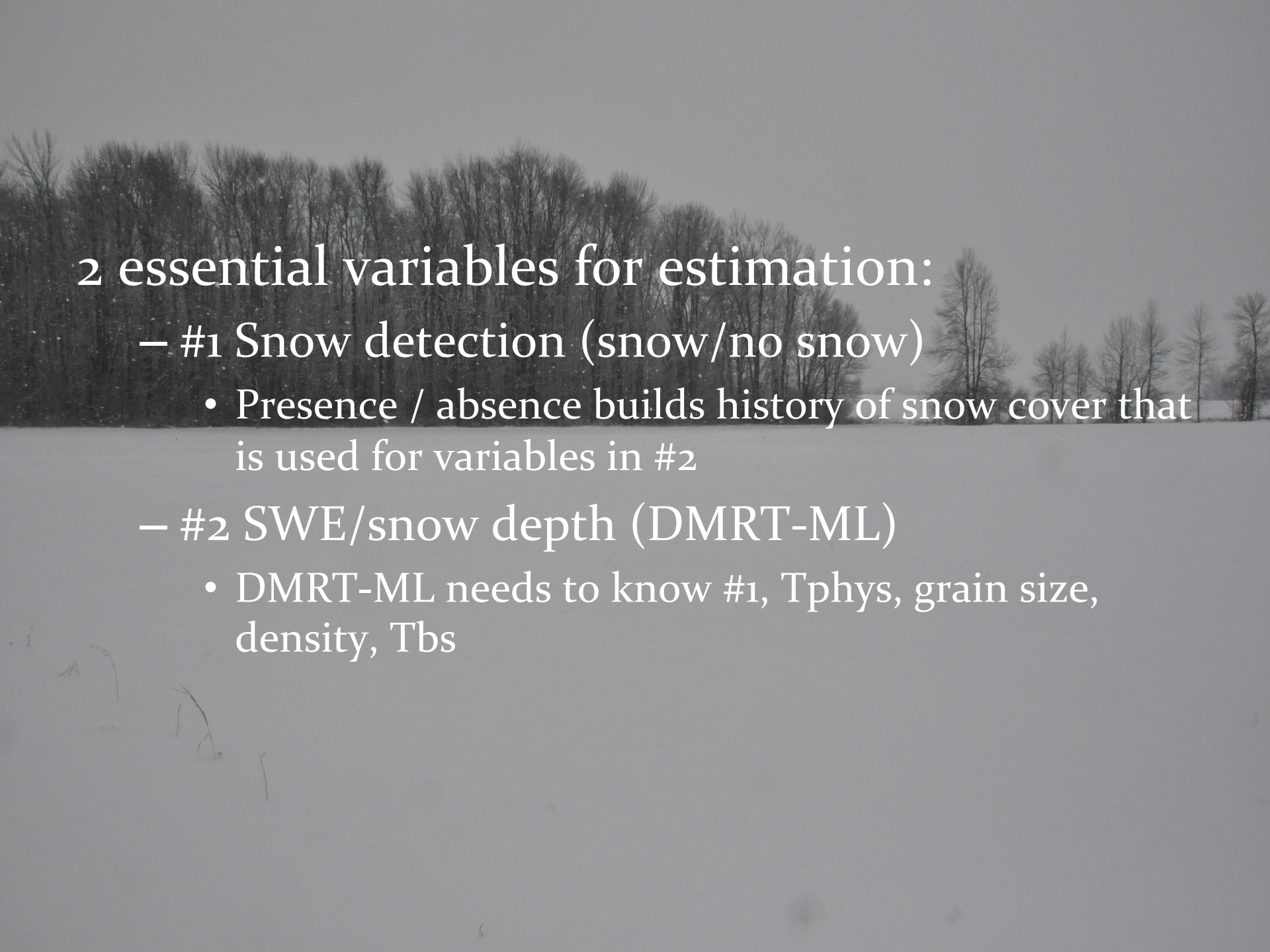
V2 Product (in development)

- V2 predicated on the *prototype* AMSR-E algorithm. Developed in 2003 but considered intractable for implementation. Kelly *et al.* (2003).
  - Grain size & density are estimated dynamically
  - Forest correction is model-based
  - Atmospheric correction
  - Lake ice addressed
  - RFI determination (10 Ghz)


10 Jan. 2000
Dynamic
10 Jan. 2000
Static
0
16
33
50
66
83
100
Snow depth (cm)

Version 2: AMSR2

- The Approach:
  DMRT model parameterized by a simple inversion using satellite-estimated:
  - Tphys
  - Grain size
  - Density
  - Tb (SSMI)



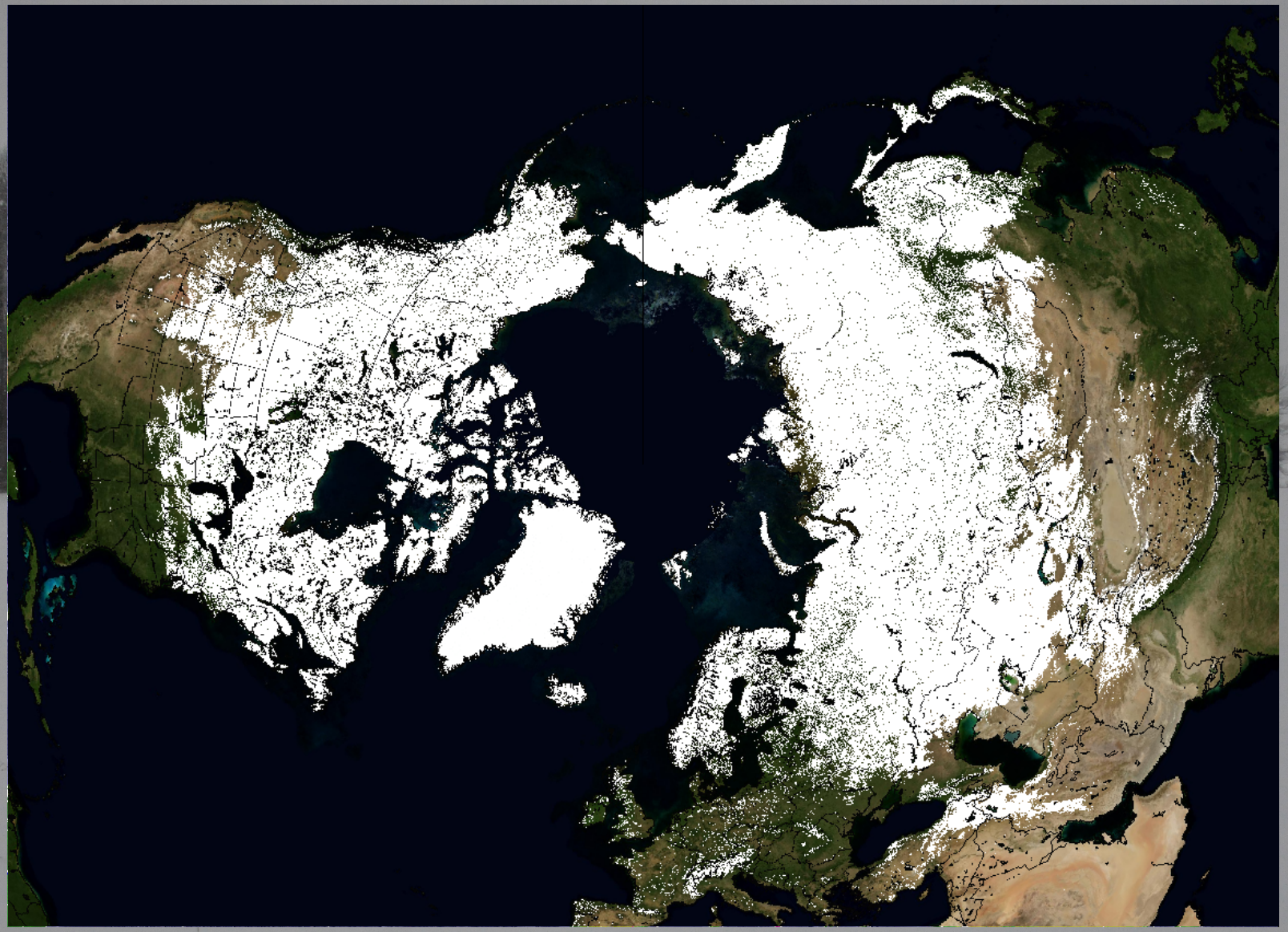
2 essential variables for estimation:

- #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

Essential Variable #1: *snow detection*

Required to obtain snow onset date

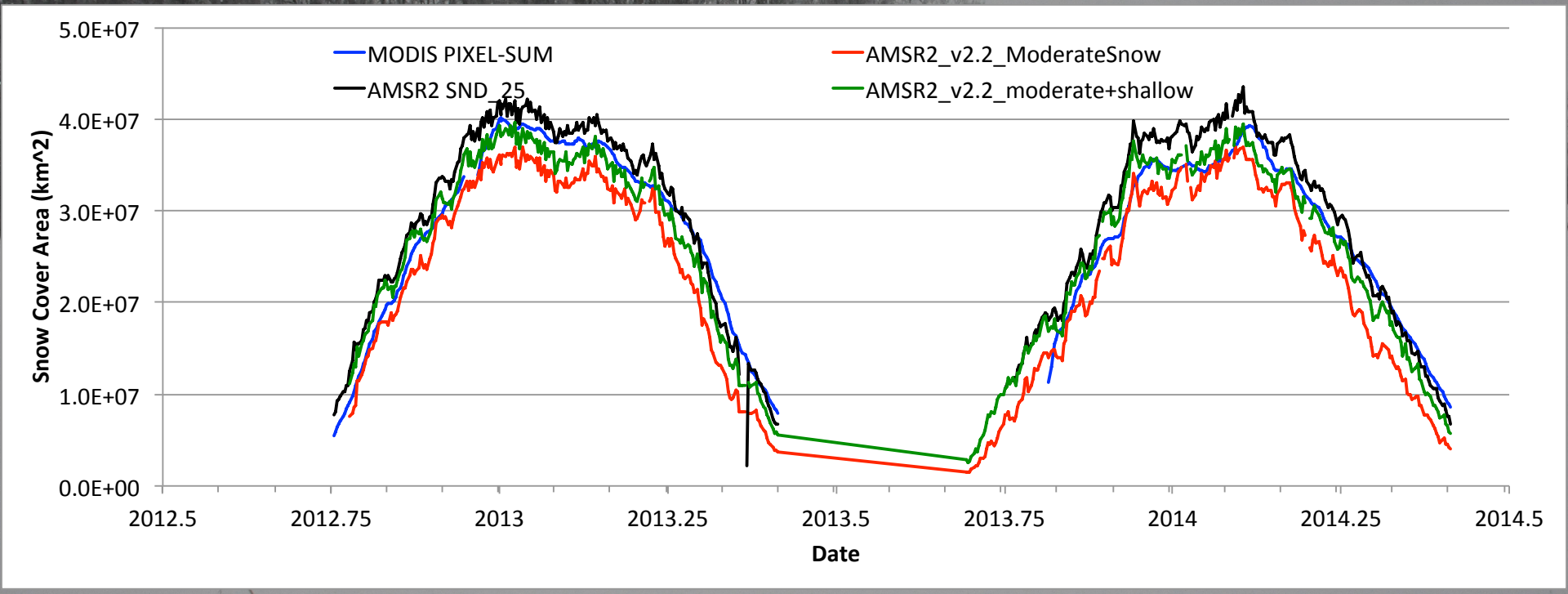
- System screens: bad data, sat. attitude & RFI (10 GHz)
- Geophysical screening
  - Water fraction (>40%)
  - Water state (frozen / unforozen)
  - Non-snow scattering (high elevation deserts etc)
  - Atmospheric correction
- Tb19V/H-Tb36V/H should identify snow if Tbs are cold:
  - Mean emissivity of 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:



Lake Frozen | RFI (10GHz) | Lake (unfroz) | Dry Snow | High Desert

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

Detection record 2012-14

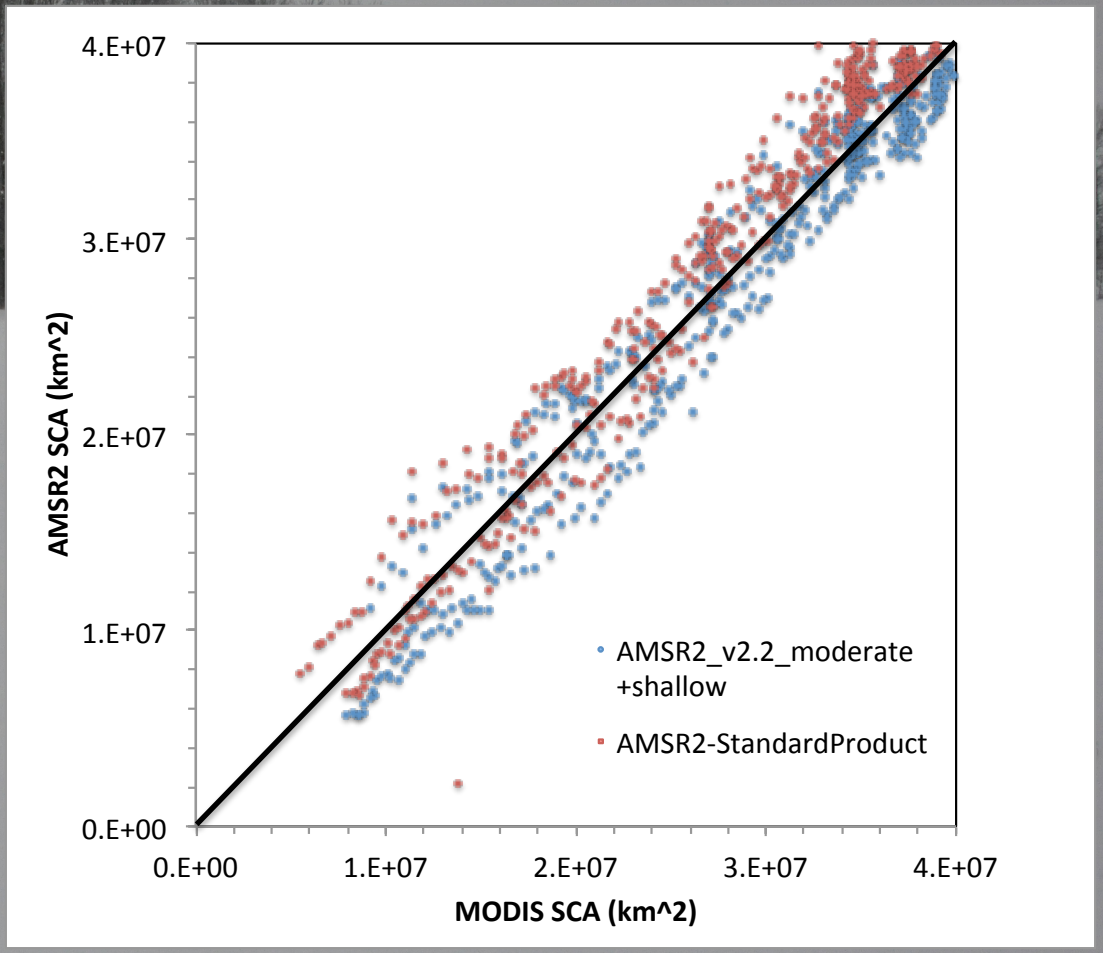


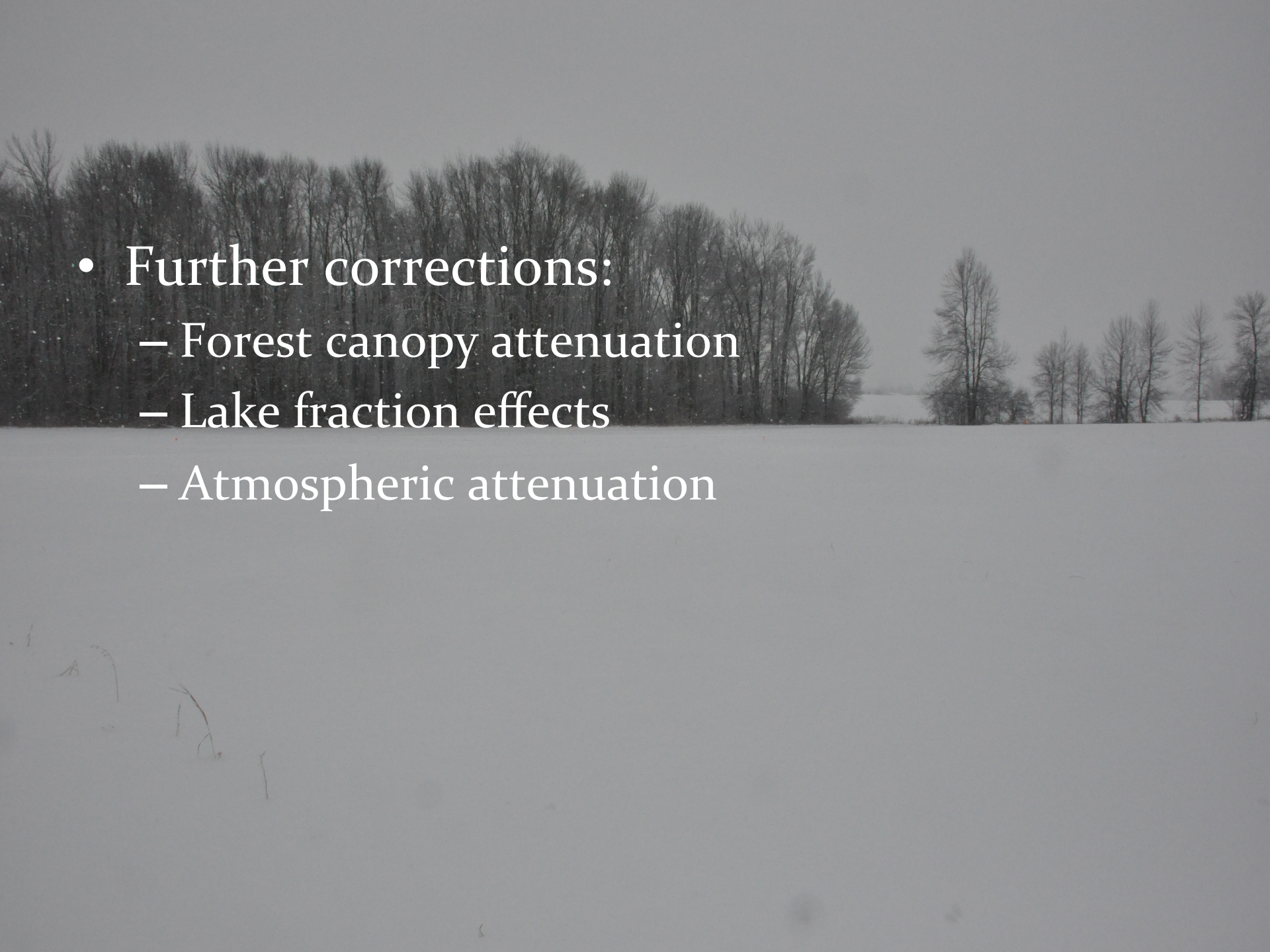
Northern hemisphere snow.

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

Metrics of fit with MODIS SCA

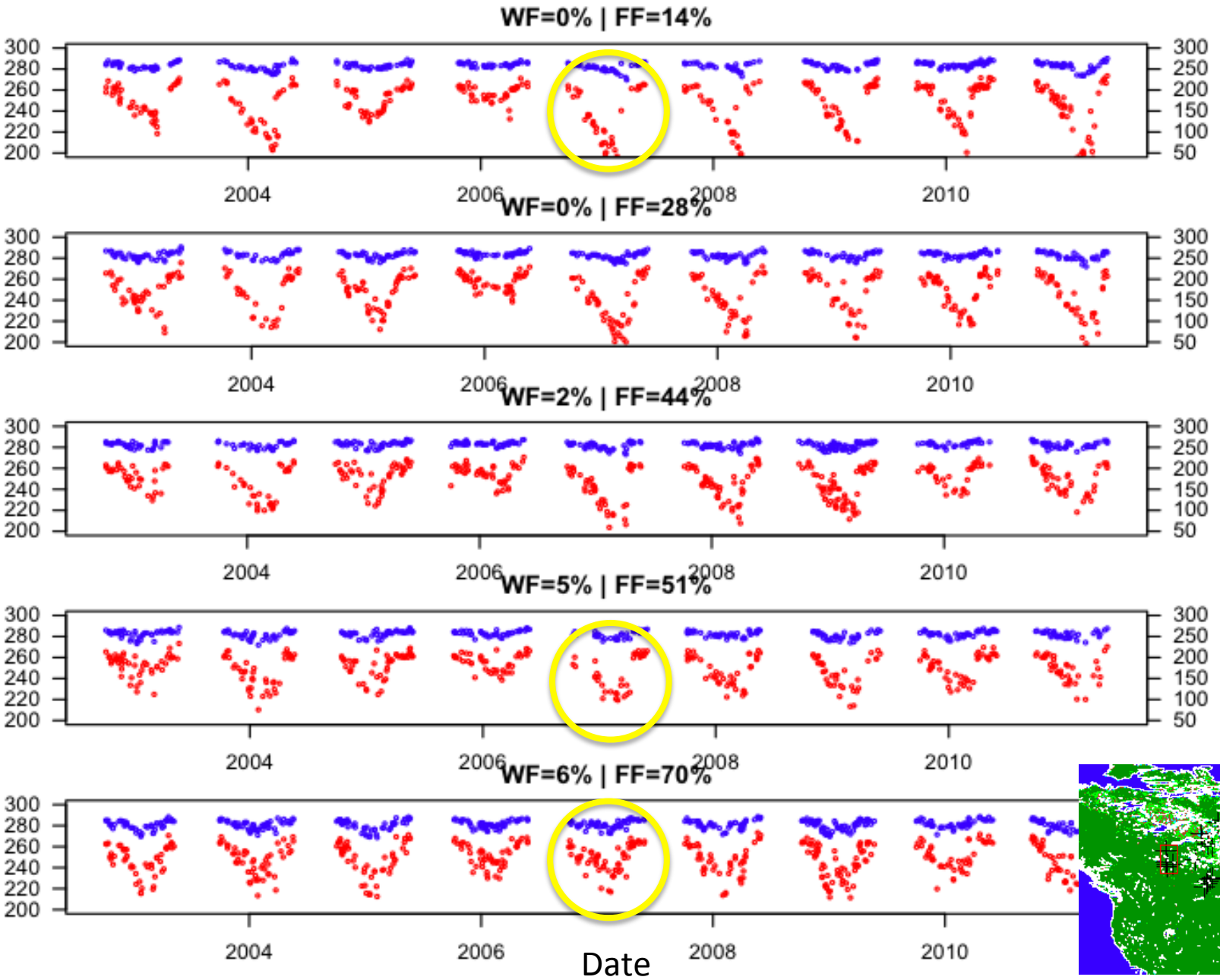
	RMSE $x10^6$ km^2	Bias $x10^6$ km^2
AMSR2 v2	5.632	0.916
AMSR2 standard	6.025	2.902





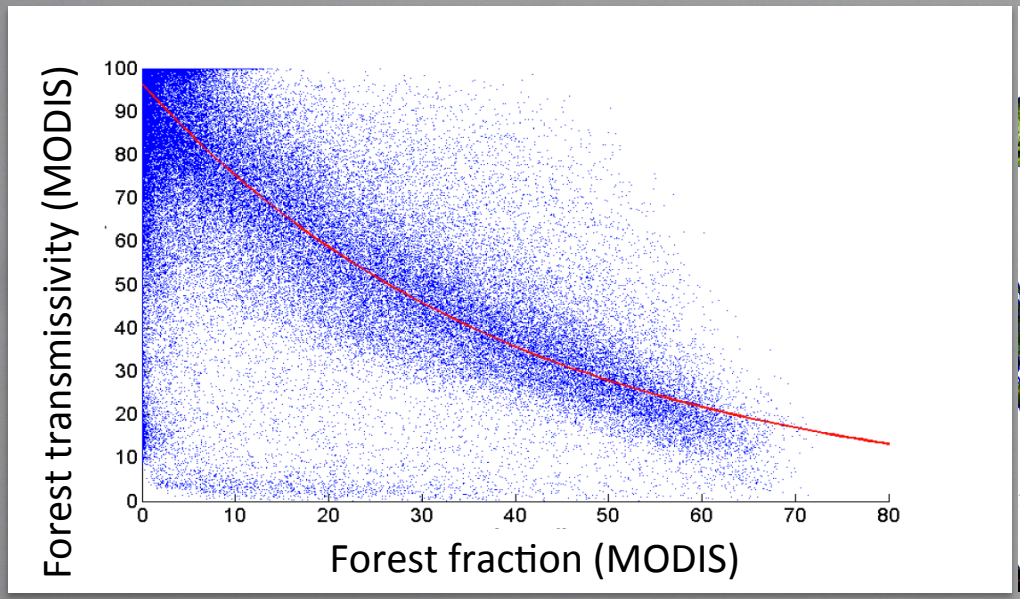
- Further corrections:
  - Forest canopy attenuation
  - Lake fraction effects
  - Atmospheric attenuation

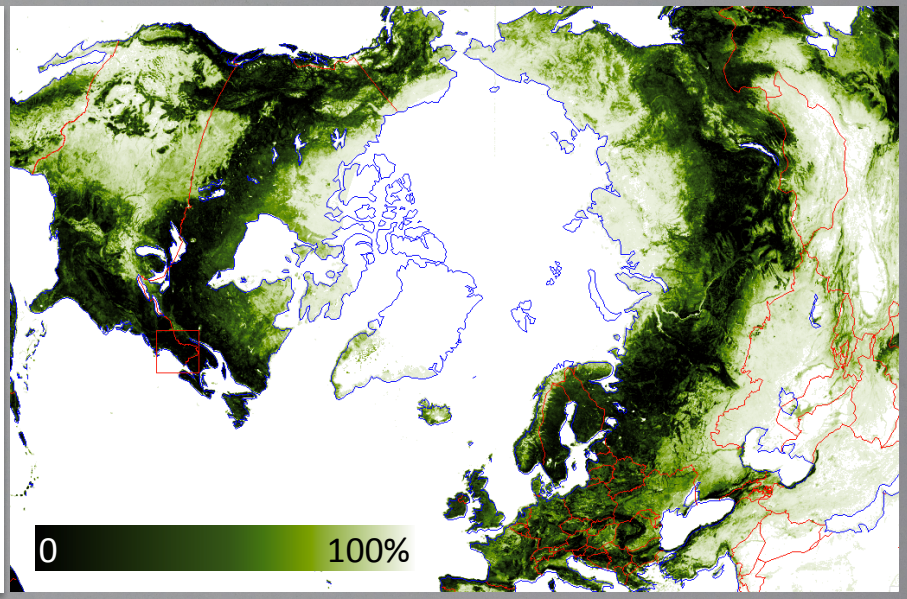
AMSR Tbs (36V & 18V): centre within 4 km of locations of interest

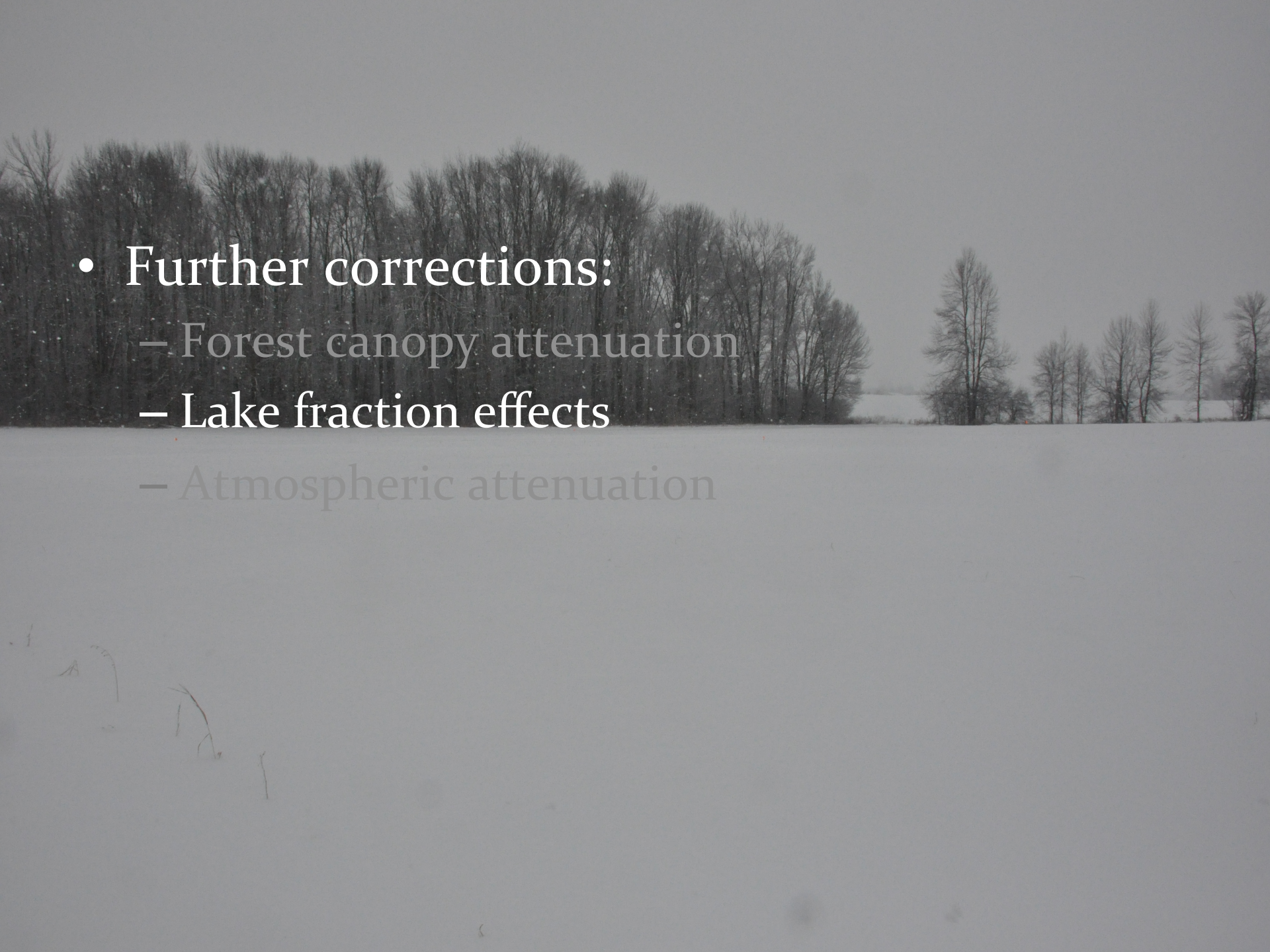


Forest transmissivity

- 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.







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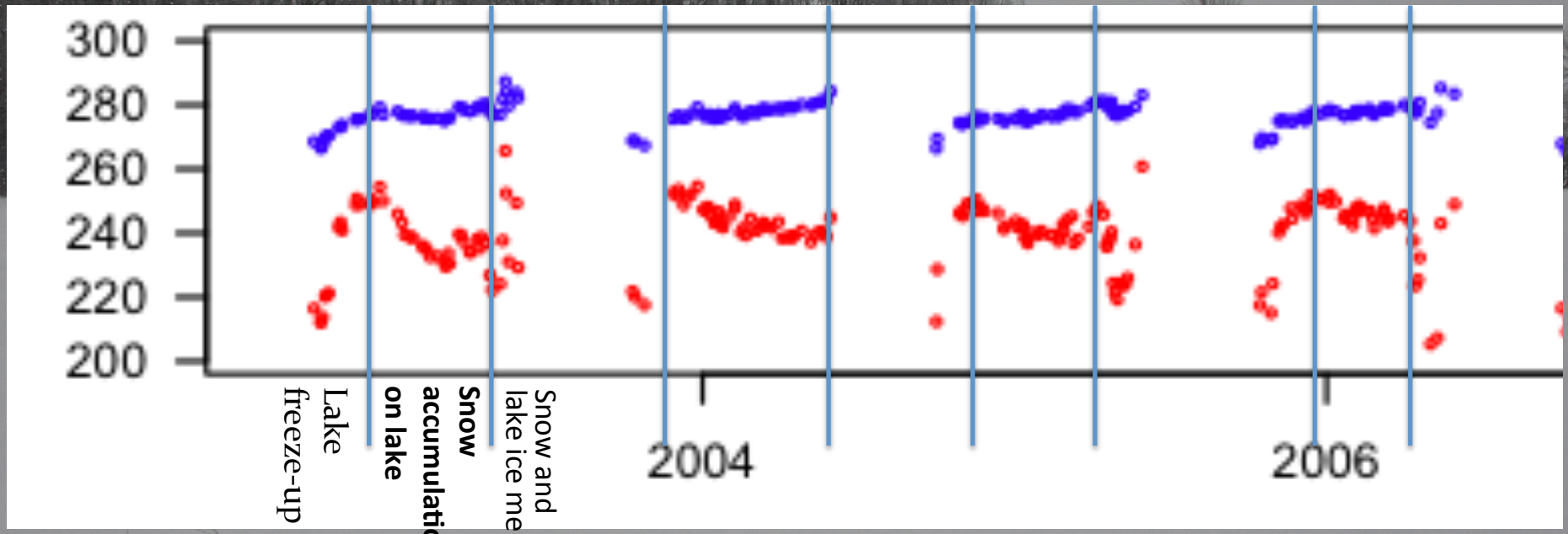
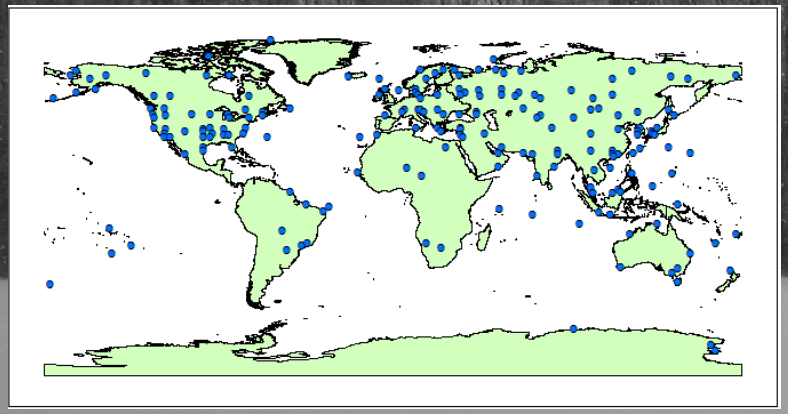
AMSR Tbs (36V & 18V)

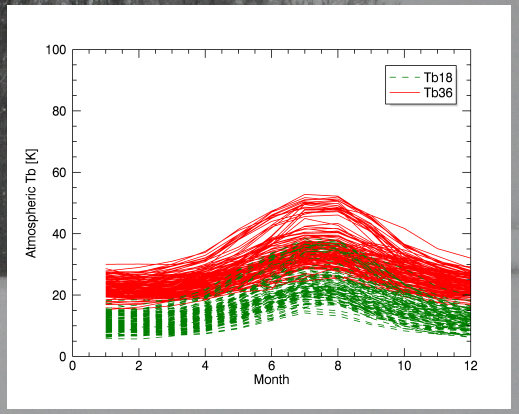


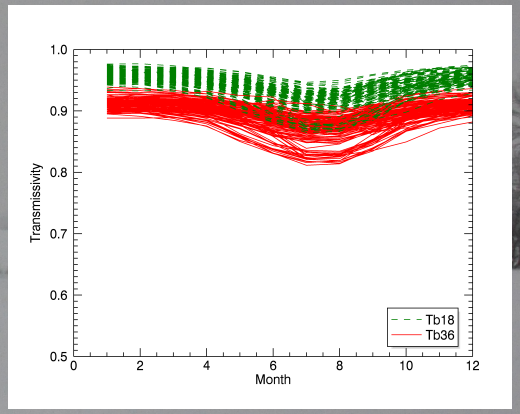
- Further corrections:
  - Forest canopy attenuation
  - Lake fraction effects
  - Atmospheric attenuation

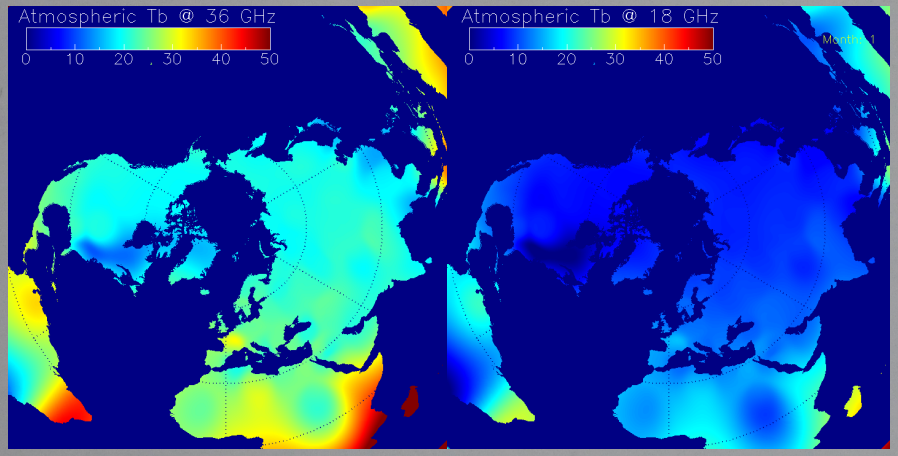
Atmospheric attenuation

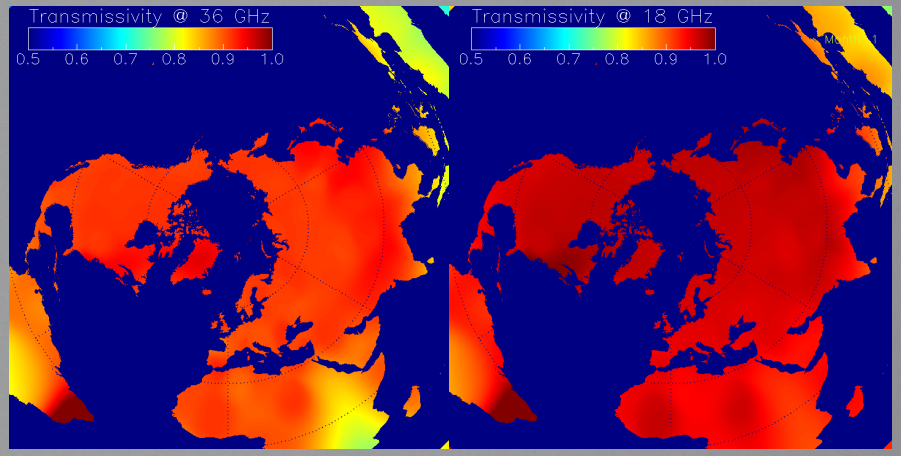
Radiosonde data 2001-2011 (incl.)







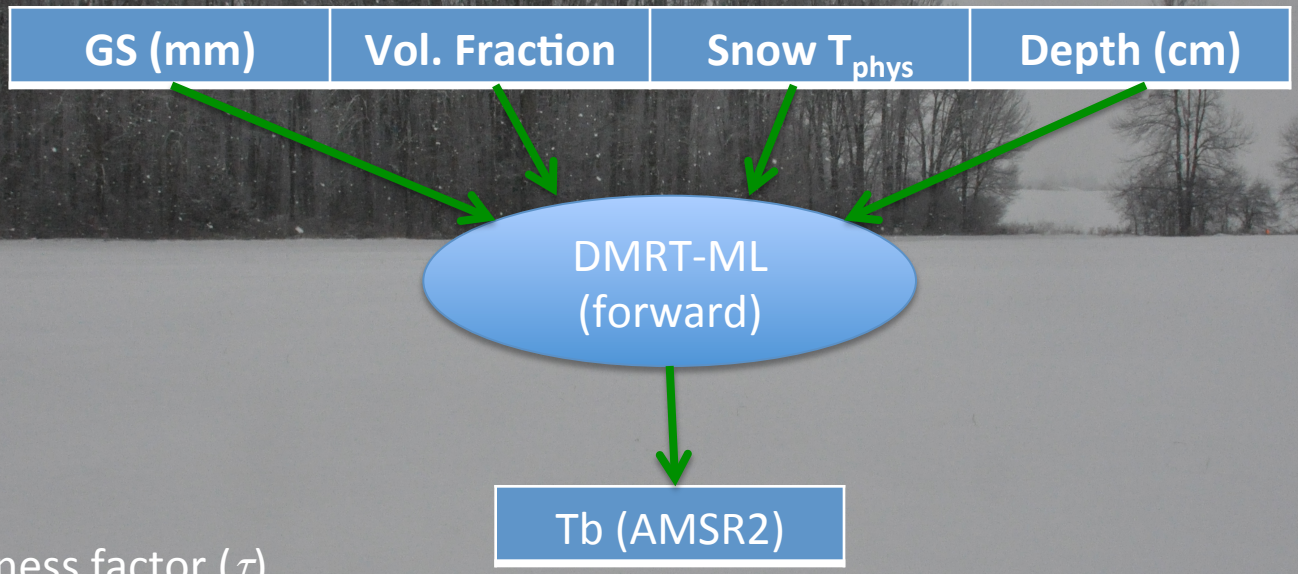




January gridded monthly averages of Tb and transmissivity

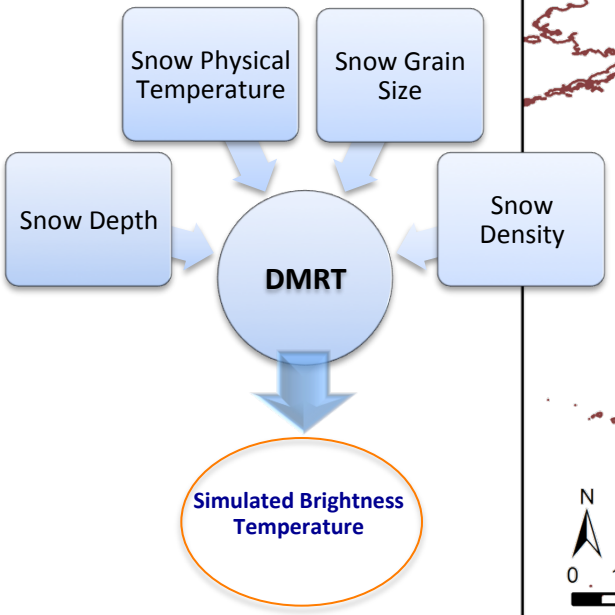
Essential Variable #2: *SWE/Snow depth*

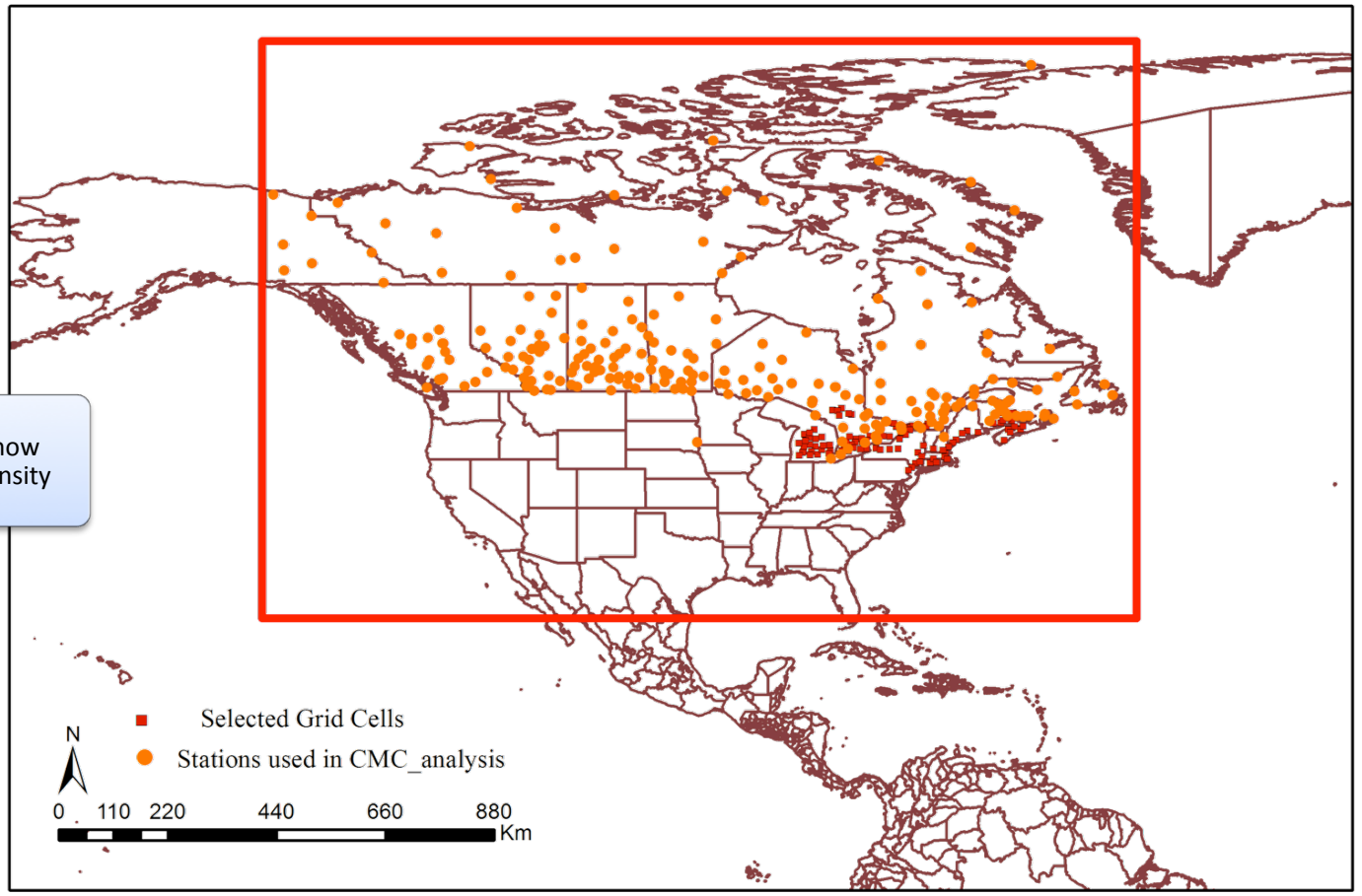
DMRT: how well does it match AMSR2?



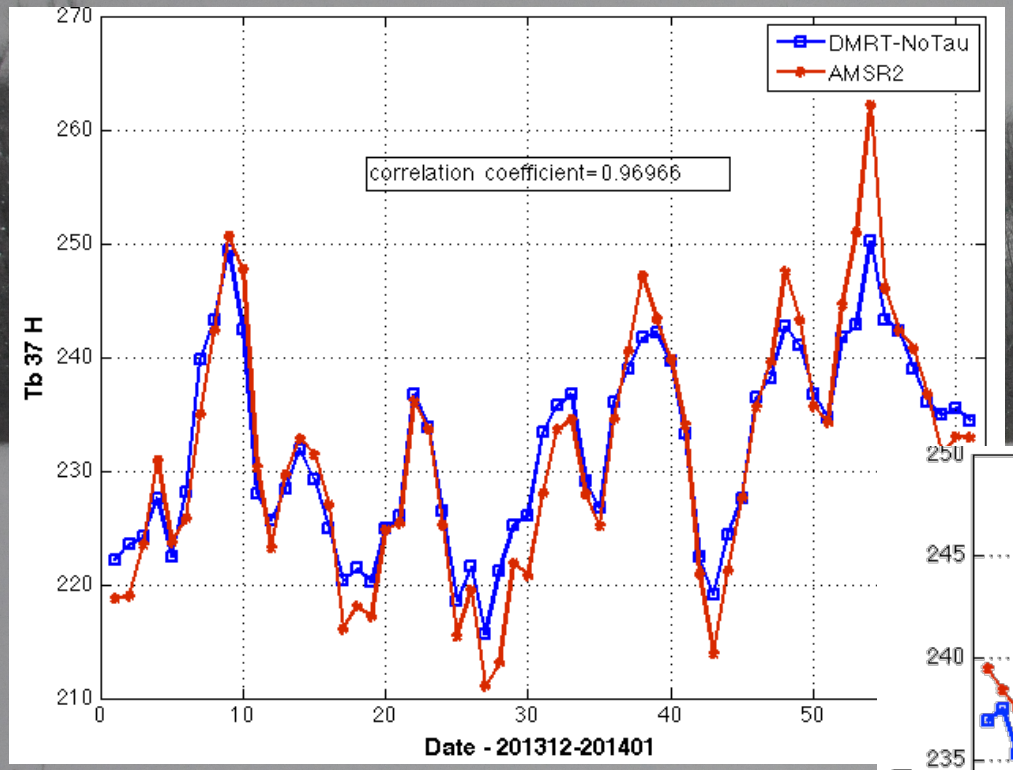
- Stickiness factor (τ)
- Number of Layers (n)
- Frequency of interest (e.g. AMSR2)
- Public open source (Picard, *et al*, 2012 after Tsang *et al.*, (2000))
- Snow Tphys is calculated from AMSR2
- Snow depth is obtained from CMC/WMO data
- Gs and density (VF) constant are estimated from Sturm et al approaches (1997 and 2010 respectively)

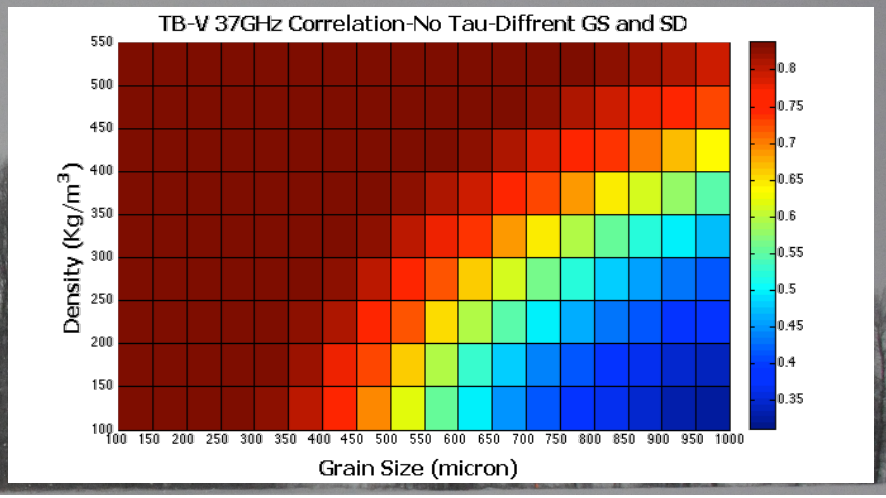
- Case study 1
- Case study 2



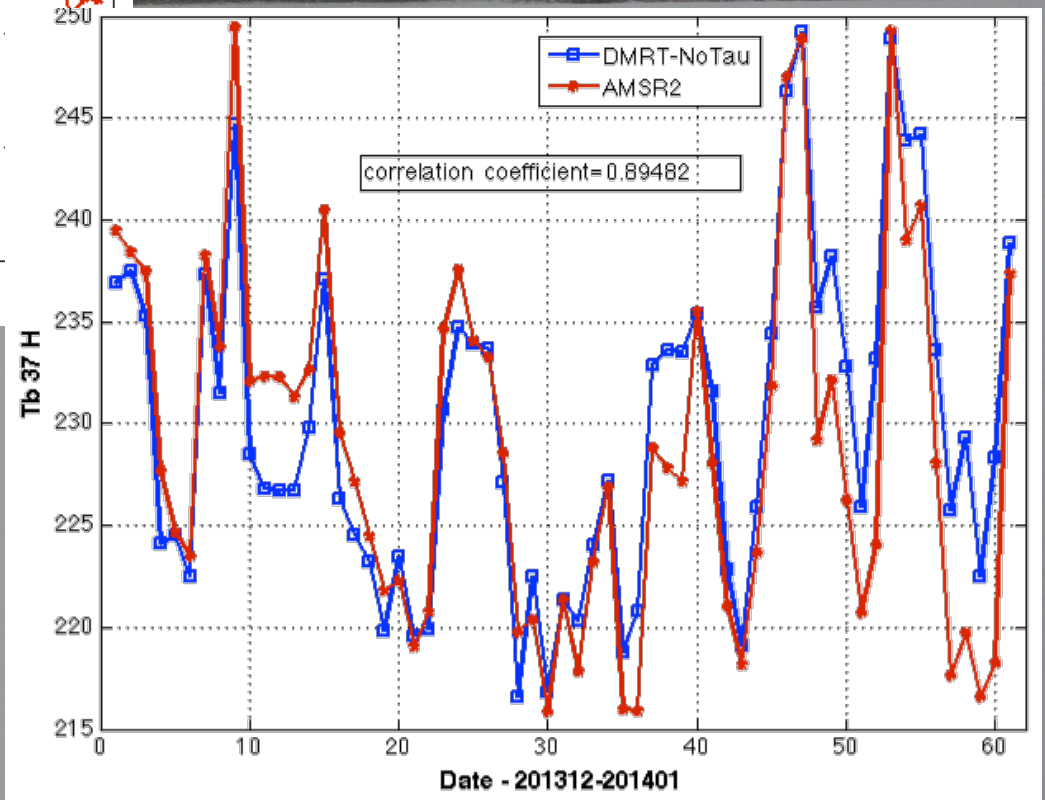


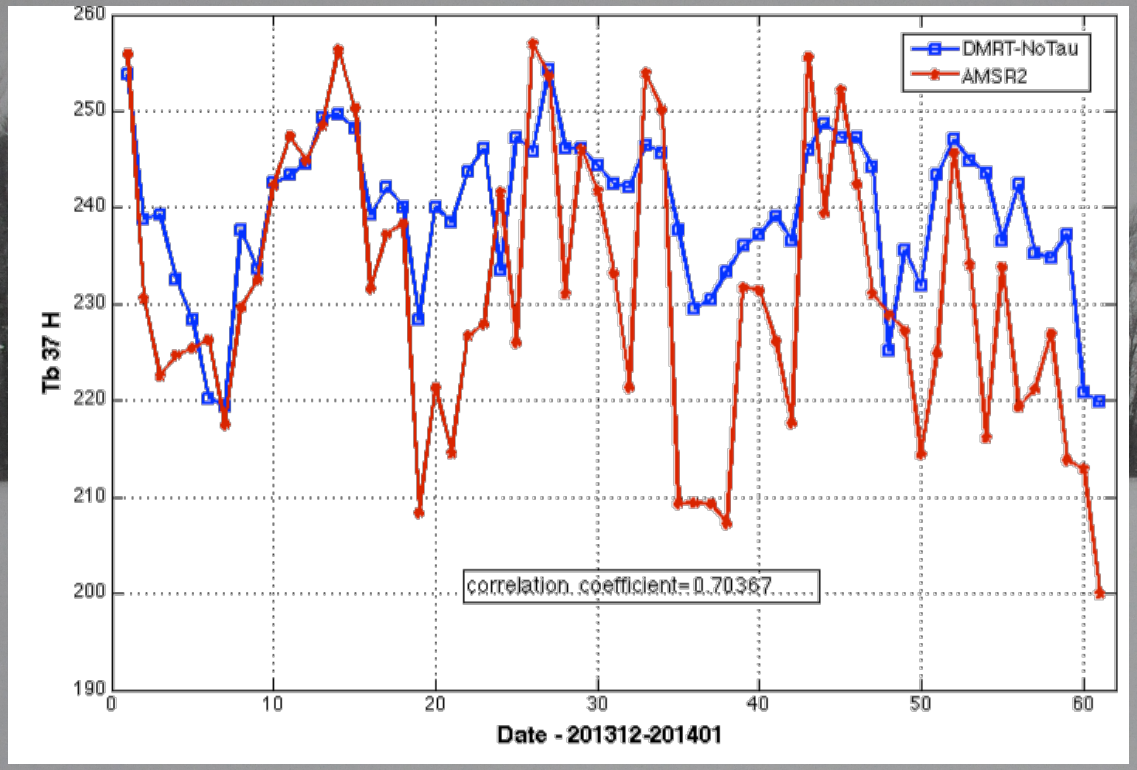
Comparing Simulated T_B From DMRT-ML With AMSR2 observations

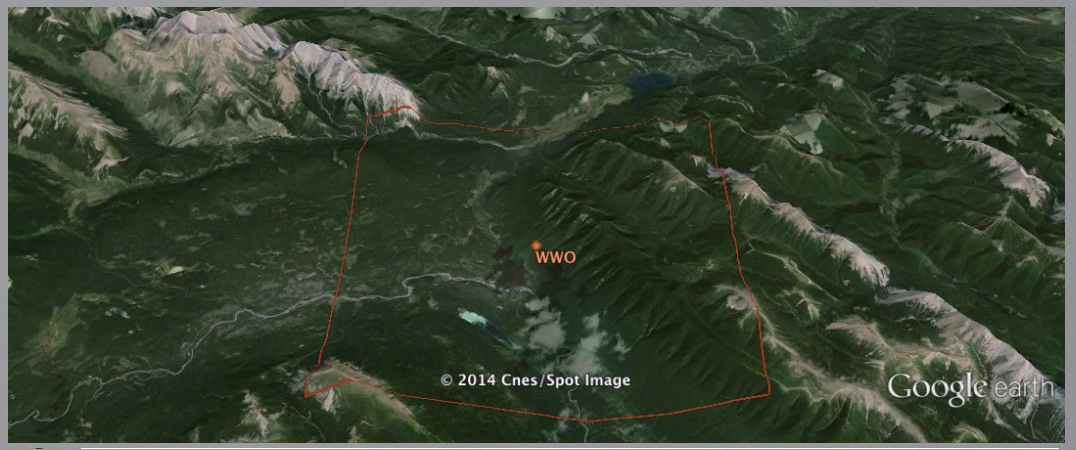




- No substratum
- No stickiness
- Snow depth=*in situ* (met station)
- Physical temperature= AMSR2 *TB* in
- Grain size = 400 μ
- Density = 350kg/m^3




DMRT-NoTau
AMSR2
correlation coefficient= 0.70367
Tb 37 H
Date - 201312-201401
260
250
240
230
220
210
200
190
0
10
20
30
40
50
60


WWO
© 2014 Cnes/Spot Image
Google earth

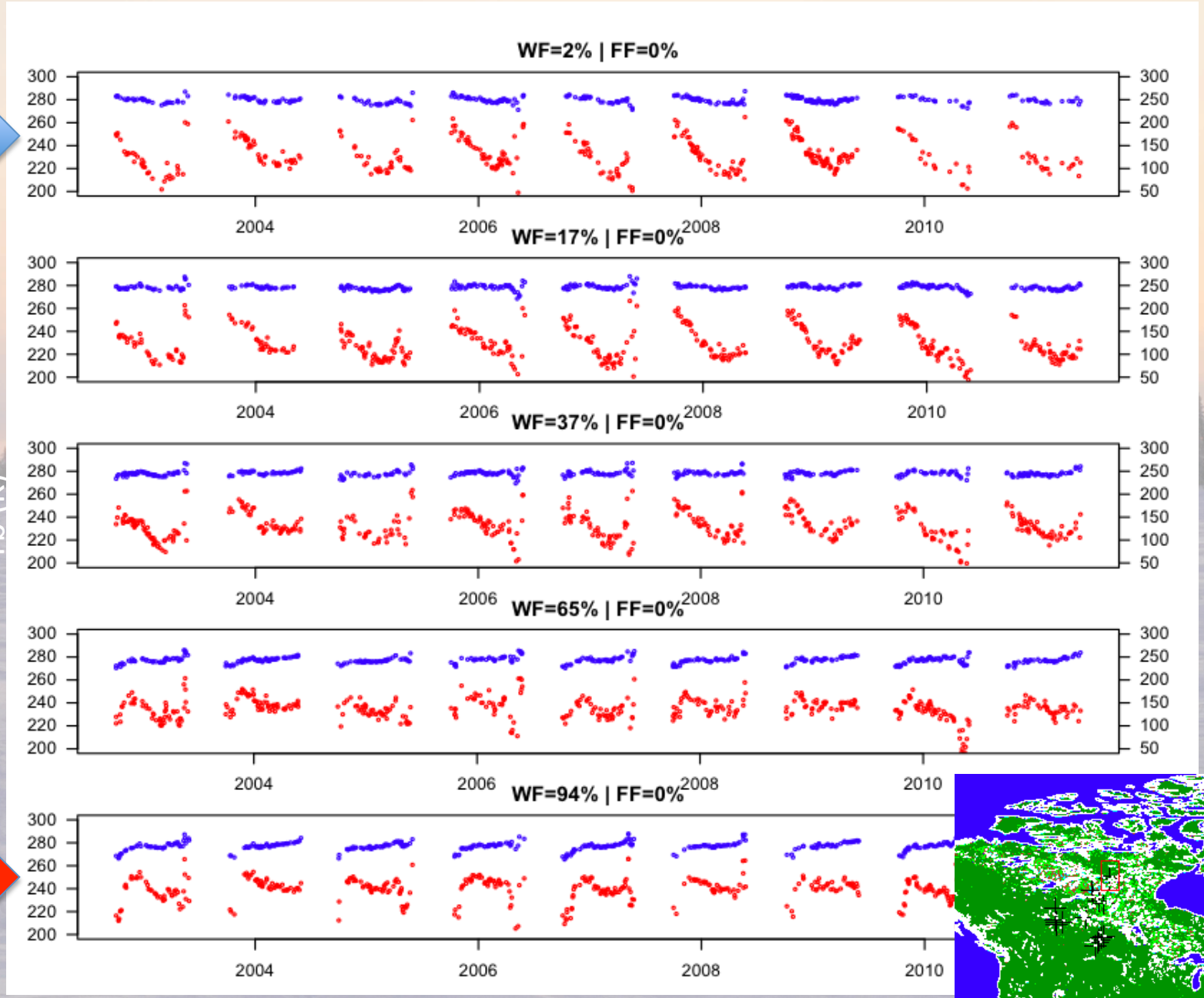
conclusion

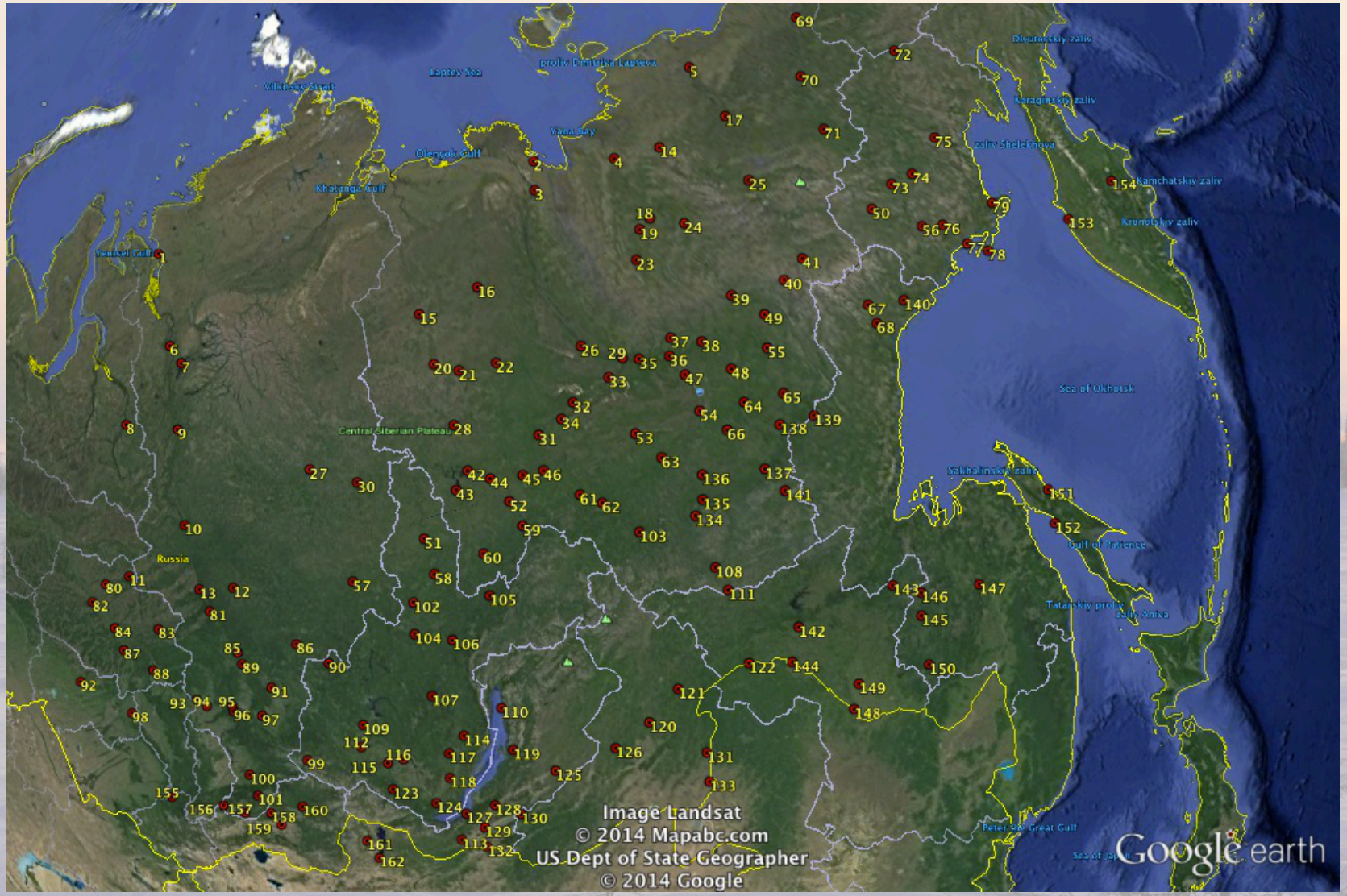
- Space-based only estimates of SWE are fraught with difficulty
- Semi-empirical approaches offer advantages over empirical and physics-based.
- JAXA needs AMSR2 SWE/snow depth that is robust (risk-free) and straightforward to implement
- We are putting together the pieces now and testing.
  - Snowcover mapping - good
  - Forest attenuation - improvement
  - Atmospheric correction – based on 11 year RAOB & RT model
  - DMRT-ML (grain size and density from simple empirical model) shows good sensitivity and needs now to have reasonably consistent gs and density estimates.
- Evaluation based on multiple sources.

Product Name	JAXA SD/SWE Product (v2)
Sensor & Applied Spectral Bands	AMSR2 (18, 36, 10, 23 GHz)
Temporal Characteristics	
Period	2012- present (+AMSR-E application)
Temporal Resolution	1 day
Spatial Characteristics	
Spatial Resolution / gridding	10 & 25 km, swath
Spatial coverage	Near-global per day
Map projection	Geographic, PSG
If applicable, cloud screening	
Algorithm	Rosenkrantz (1998) (11 year RAOB + RT)
If applicable, valid/non-valid areas	
Invalid mask area	Snow climate mask (Dewey and Heim, 1981/1983)
Product format	Hdf5
Product accessible at	http://gcom-w1.jaxa.jp (V1 product)
Contact person **Name** **Email**	 Richard Kelly rejkelly@uwaterloo.ca

Acknowledgements: Ghislain Picard

AMSR Tbs (36V & 18V): centre within 4 km of locations of interest





162 Met stations that have in-situ snow depth measurements during Dec2013 and Jan2014

DMRT-ML

Applied for all 162 met stations data-60 days (36 GHz)