Observations of Physical Properties and Microwave Emission of Snow at CREST Station in Caribou, ME

Peter Romanov[1,2], Tarendra Lakhankar[1], Carlos Perez Diaz[1], Reza Khanbilvardi[1]

[1]NOAA-CREST, City University of New York, New York, NY
[2]Center for Satellite Applications and Research, NESDIS/ NOAA

Why and What For ?

Motivation

Lack of synchronous observations of snow MW emission and physical properties

- Hampers development of satellite snow retrieval algorithms

Objectives

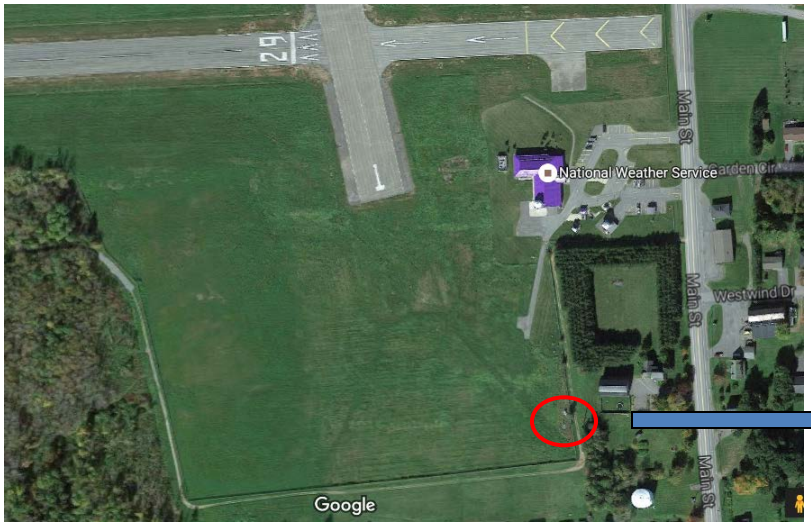
- Continuous monitoring of physical and radiative properties of snow
  - Snow pack physical and microwave emission modeling
  - Satellite products/algorithms cal/val
- Field work training for students
- Testing new instrumentation for snow research

CREST-SAFE Snow Field Research Station: Location

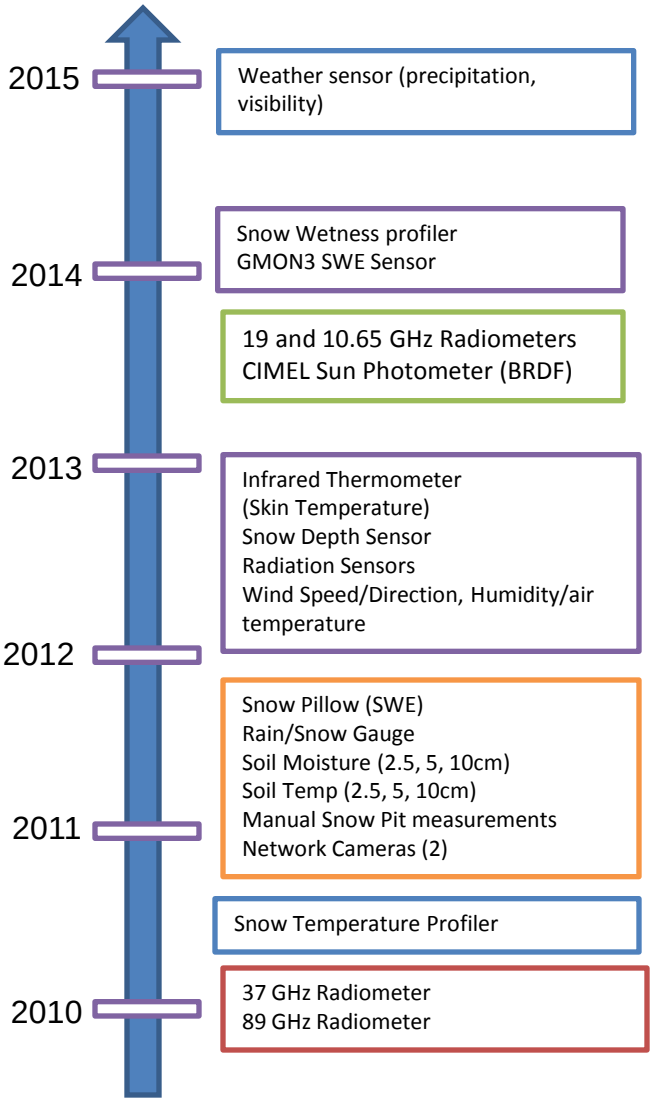
CREST Station

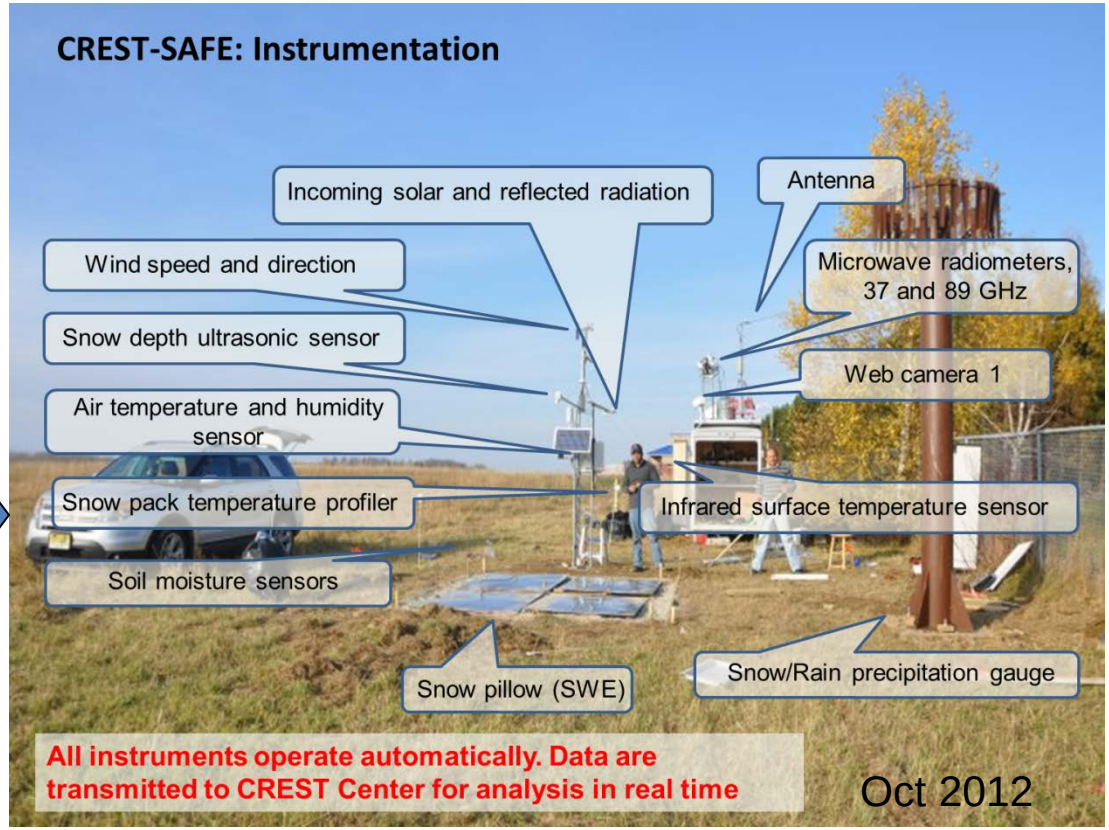
- Established in 2010
- Located in Caribou, ME
- Premises of regional airport
- Next to NWS RFC

Mean seasonal snowfall: 2.8 m
Seasonal max snow depth: 60-70 cm
Snow cover duration: 4 months



CREST Snow Station: Growing Each Year





Currently: over 15 sensors operating 24/7

Snow pit measurements 2-3 time a week

Data from most sensors is available online

Funding: NOAA, CCNY, DoD

Where we are now…

- Over 15 instruments running 24/7
- Instrumental observations are automated
- Snow pit measurements 2-3 times a week
- Web cameras

Provide

- Snow pack physical properties
    - Depth, SWE, temperature, density, grain size, profiles
- Snow pack radiative properties (MW, IR, VIS)
- Soil moisture/temperature
- Standard meteorology & radiation
- Site Imagery (weather, clouds)

Most data are transmitted to CREST, processed and posted online within 1-2h

CREST Microwave Radiometers

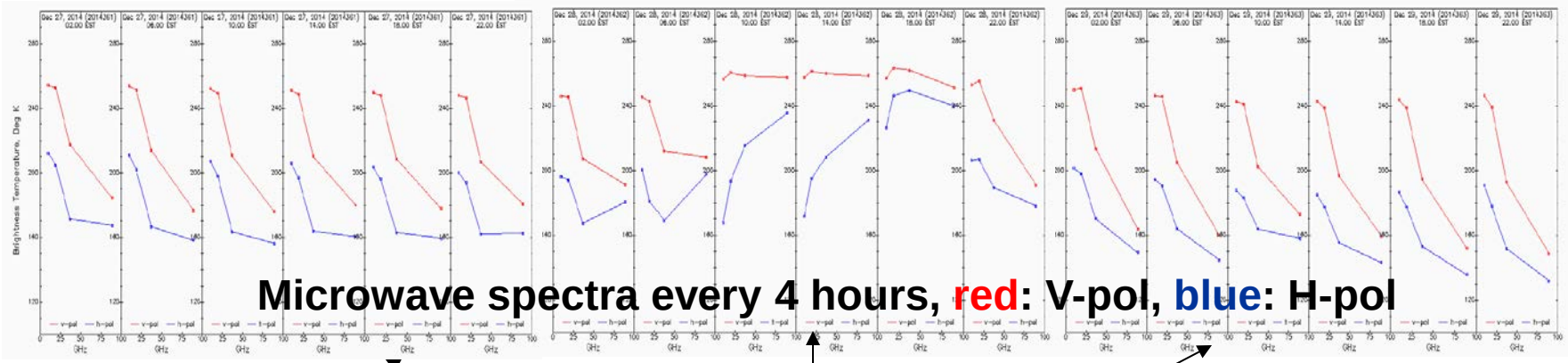
CREST-SAFE	SSMI	AMSR-E/2	TMI	WindSAT	GMI (GPM)
		6.93 VH		6.8 VH	
10.65 VH		10.65 VH	10.7 VH	10.7 VH	10.65 VH
19 VH	19 VH	18.7 VH	19.4 VH	18.7 VH	18.7 VH
	22 V	23.8 VH	21.3 V	23.8 VH	23.8 V
37 VH	37 VH	36.7 VH	37 VH	37.0 VH	36.5 VH
89 VH	87 VH	89 VH	85.5 VH		89.0 VH

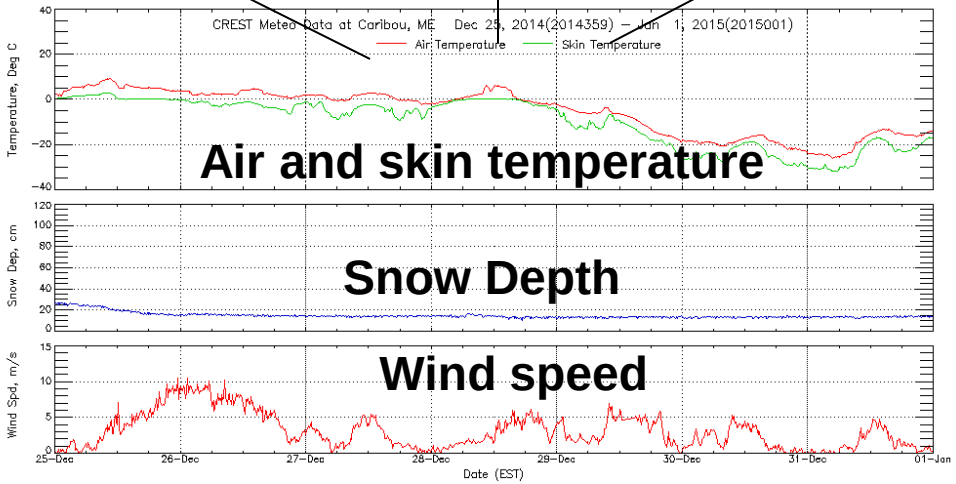
CREST Microwave Observations

- Spectral bands same as at satellites
- Polarized (V,H)
- Collected at 30 sec interval 24/7
- Resampled to 5 min interval
- Calibration 3-4 times a year
- Less than 3% data loss in the last two winter seasons

Microwave spectra: Snow melt and refreeze

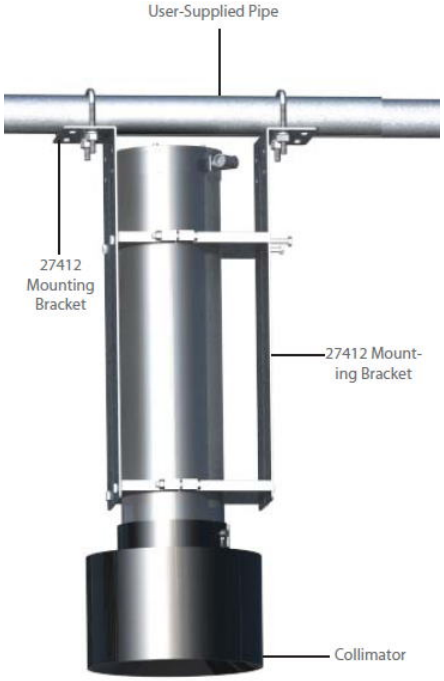
Dec 27, 2015 Dec 28, 2015 Dec 29, 2015

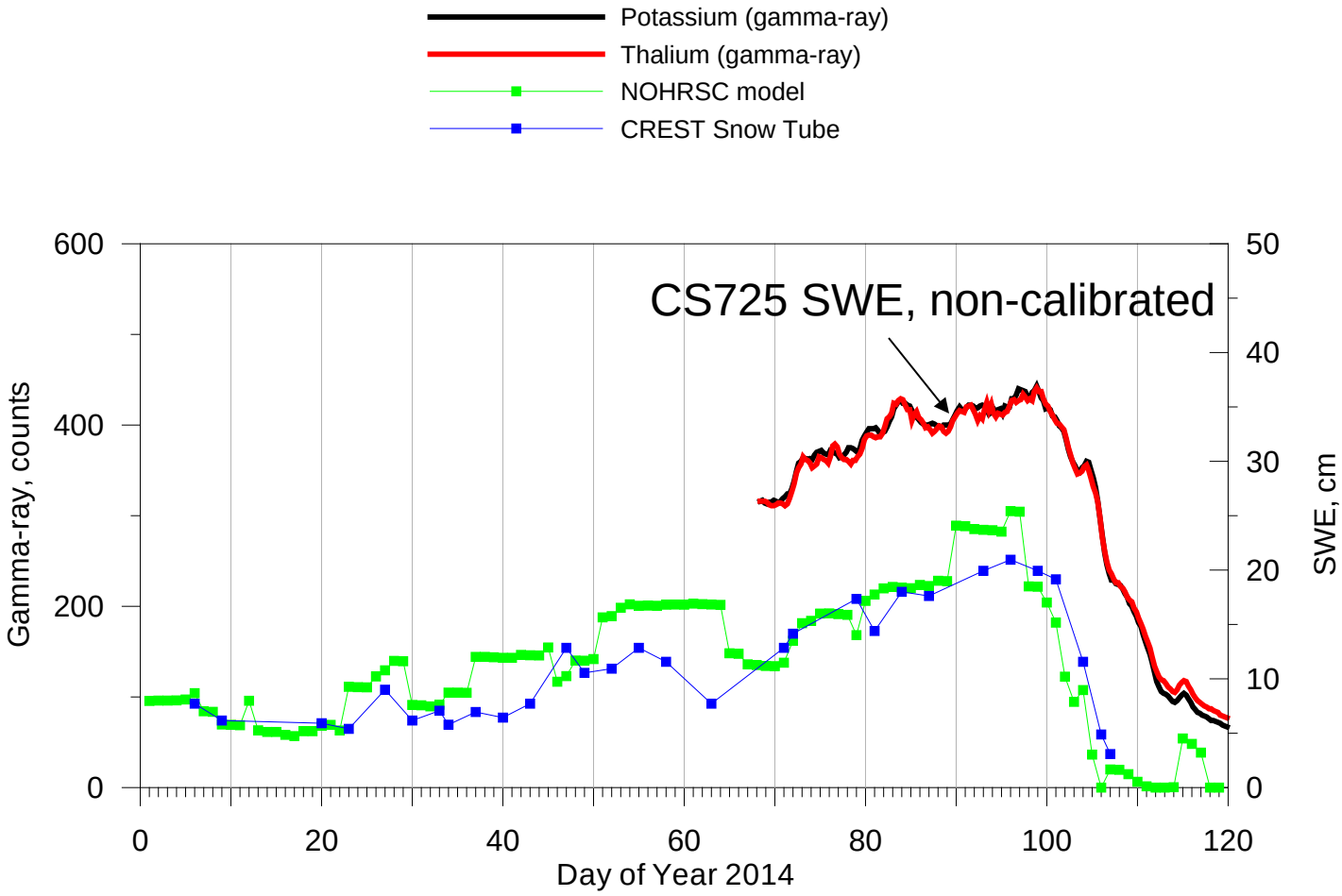




Gamma-Ray Snow Water Equivalent Sensor

- CS725 (GMON3) Sensor: SWE estimates using observed gamma-ray emission
- Installed in spring 2014
- Data have yet to be calibrated

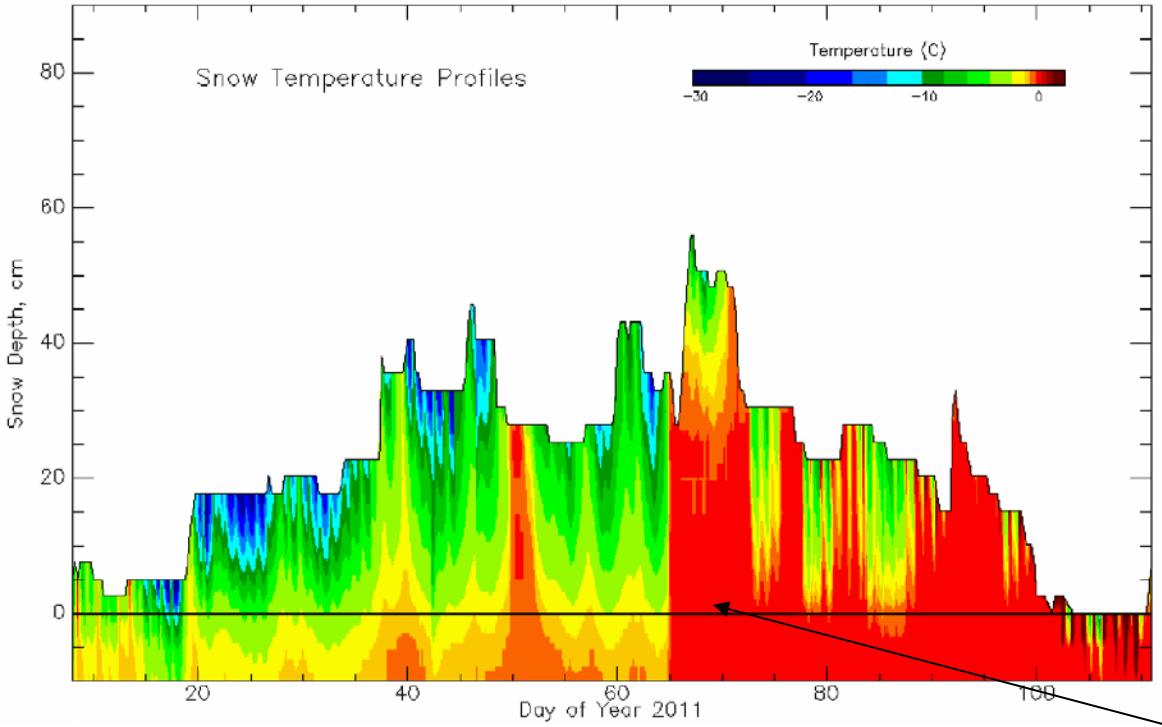




Snowpack Temperature Profiler

Snow pack and soil temperature profile

- Temperature at 16 levels
- Down to 10 cm into the soil
- Up to 90 cm in the snow pack
- Reported every 5 min



Observed snow depth and snow temperature profiles in January to March 2011

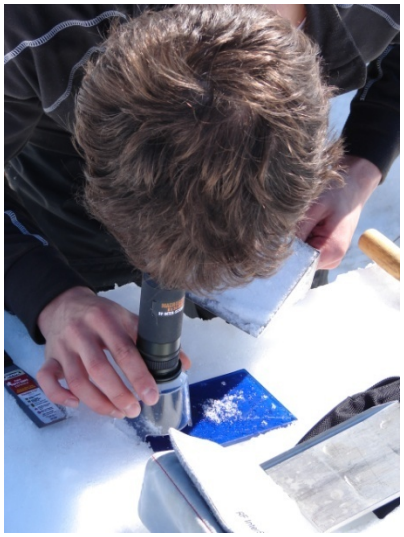
Red color indicates temperature of 0^0 C and over

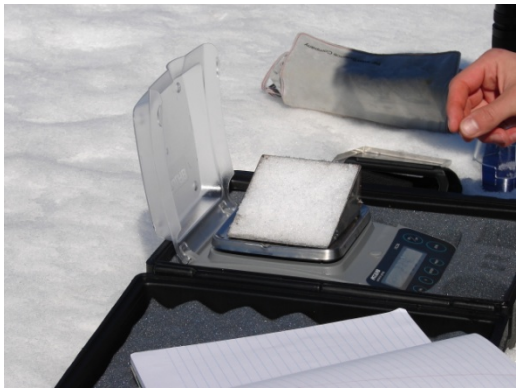
Manual Observations of Snow Pack

Started in December 2011

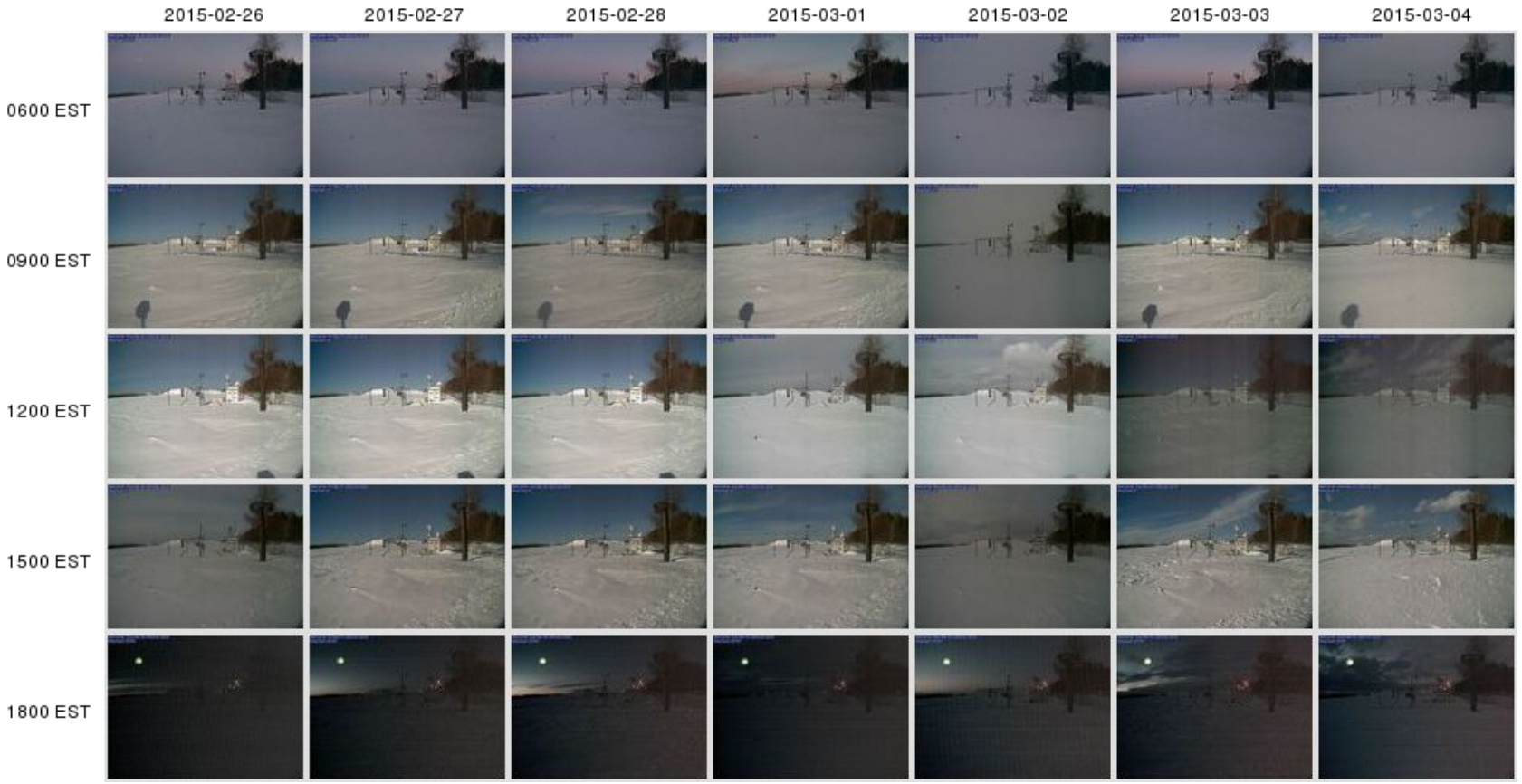
Include:

- Snow pit measurements, every 2-3- days
  - Vertical profiles of snow density, grain size, hardness, temperature
  - Snow depth, SWE
  - Performed by local students, trained by CREST personnel





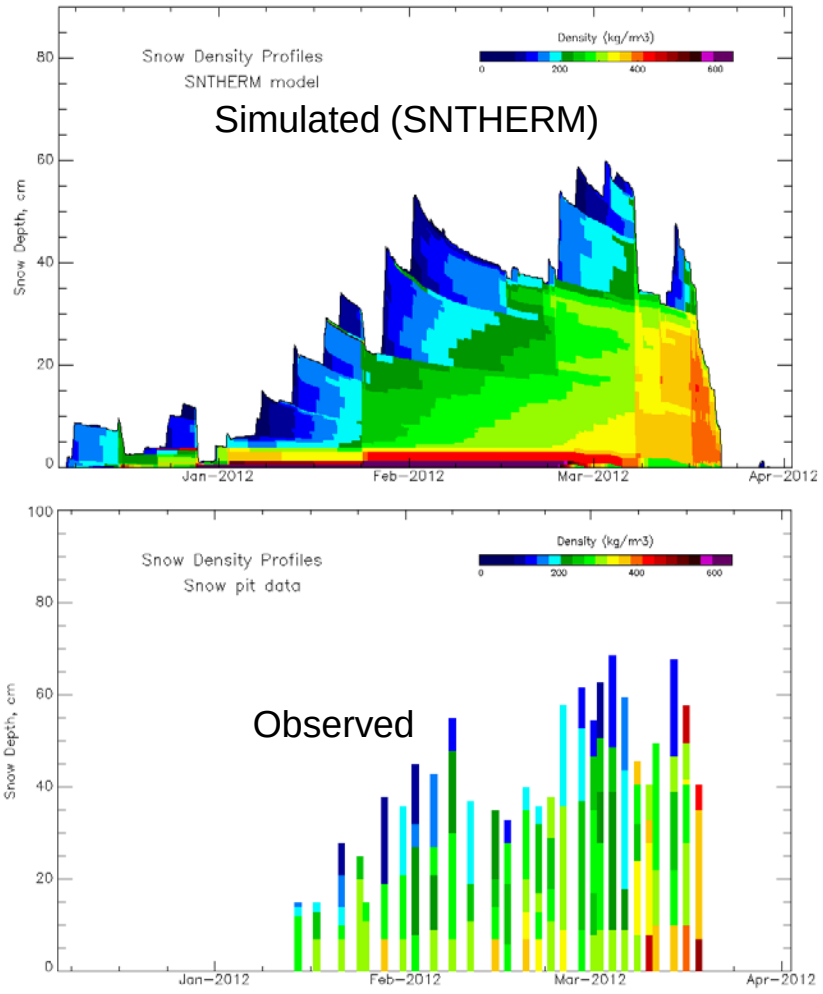
Webcam Imagery



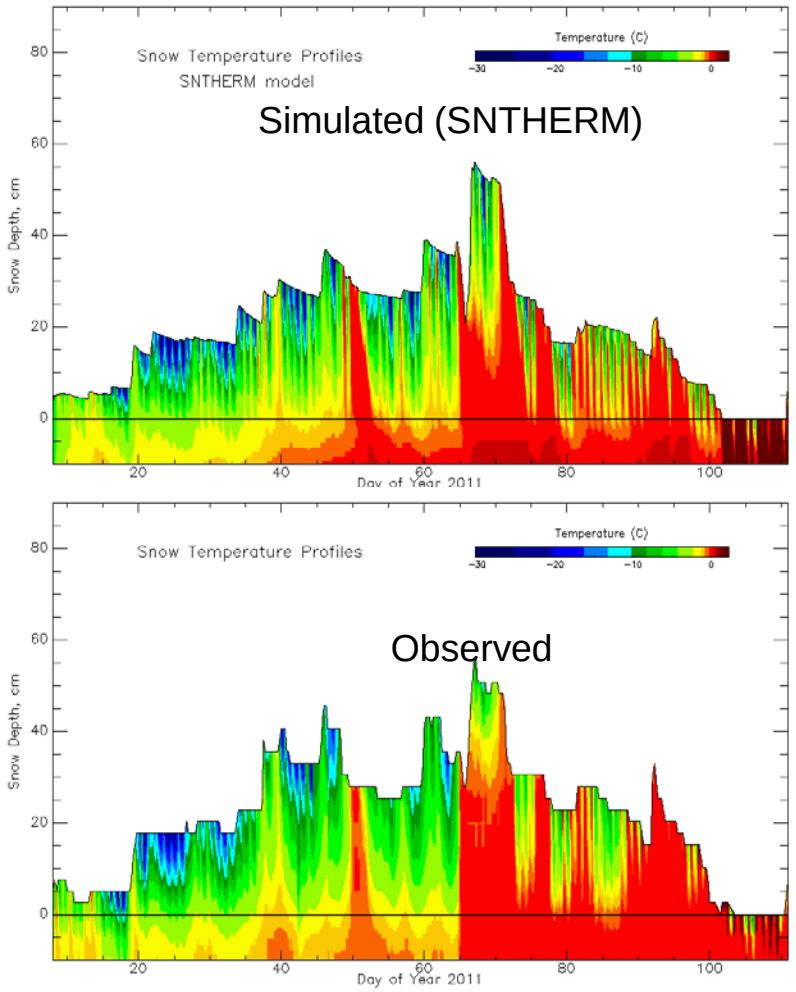
Helps to better characterize the weather type and to identify clear and cloudy periods of the day

Snowpack Phyisical Modeling (SNTHERM)

Snow Density (2011-2012)

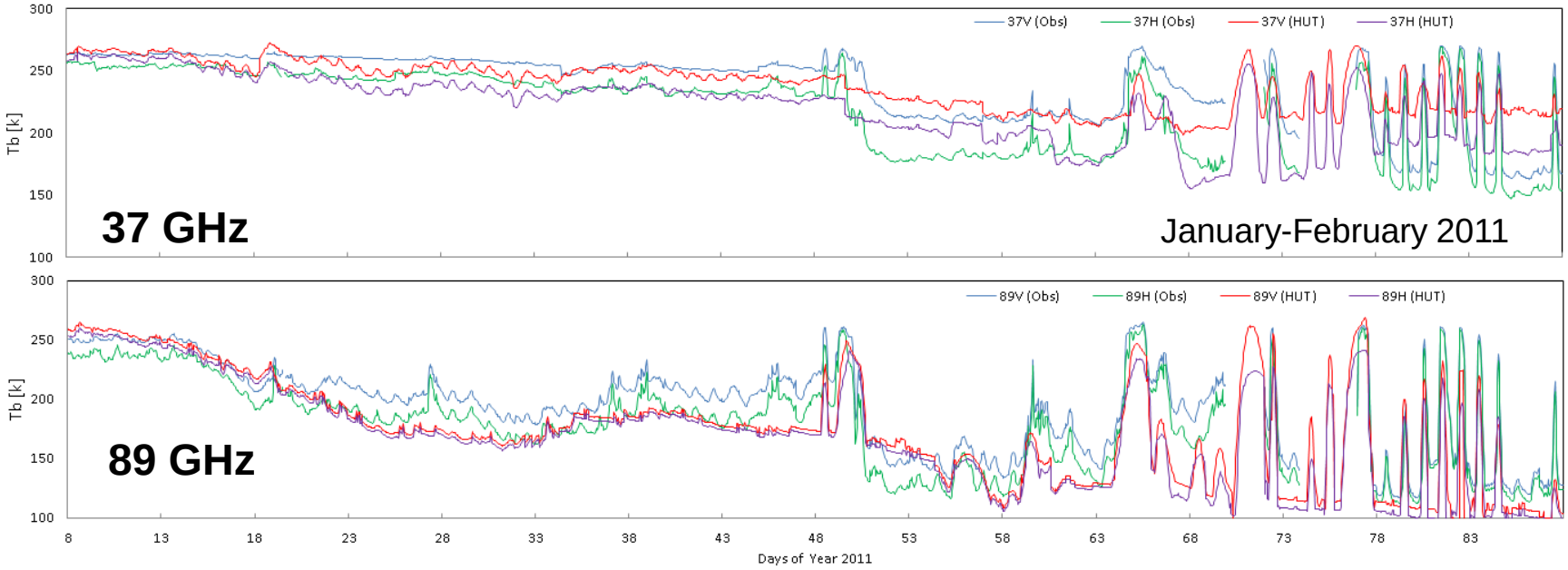


Snow Temperature (2010-2011)



Model vs in situ: good agreement on the temperature profile, not so good on the snow density and grain size.

Microwave Emission: Observed vs Simulated (HUT)



HUT with input from SNTHERM, single snow layer : red (V) and purple (H)
Observed BTs: blue (V) and green (H)

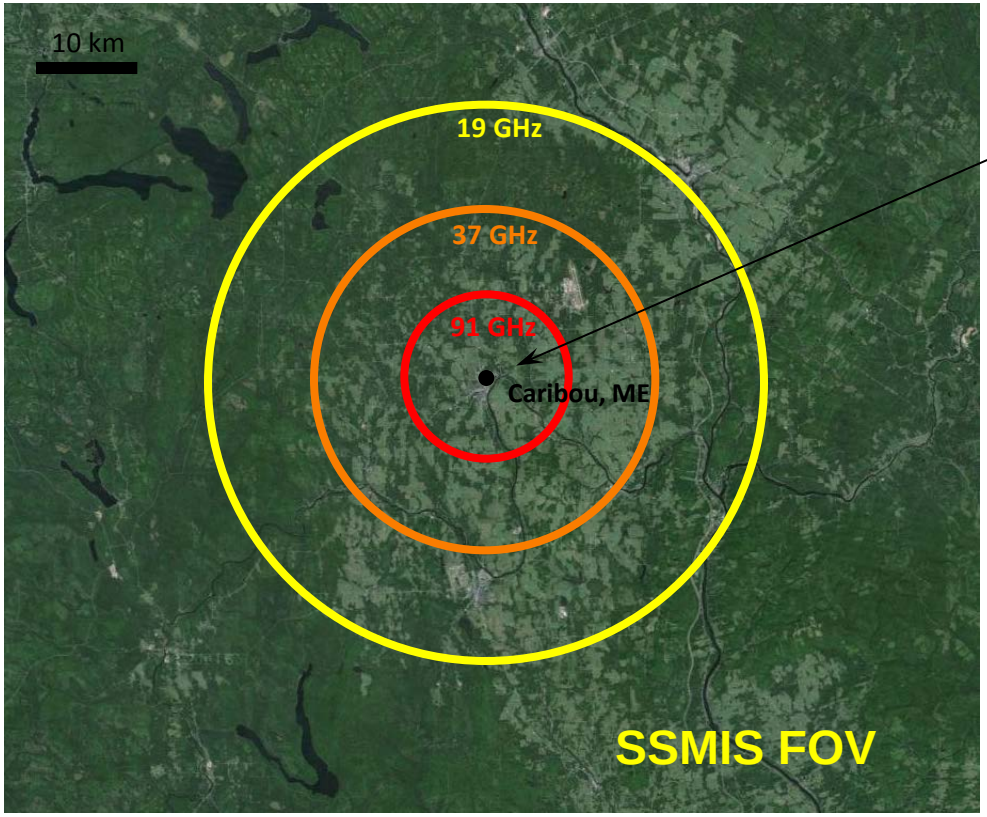
Model vs observed

Differences up to 20K-30K, larger disagreement after the first snowmelt (Day 50)

Model underestimates polarization difference at 89 GHz

Small improvement with MEMLS and DMRT

Comparing Satellite and in Situ: Consider Forest Cover



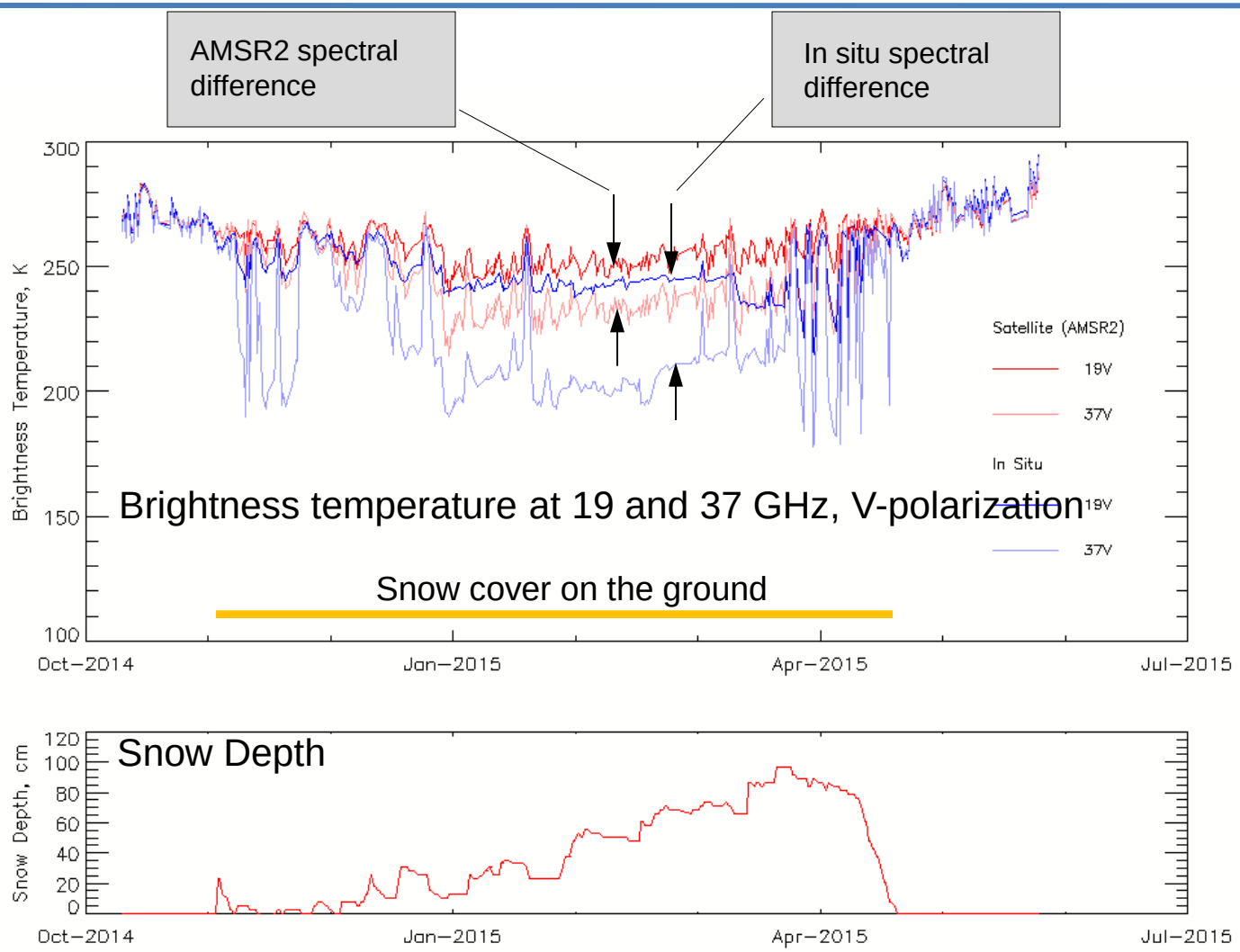
Each SSMIS and AMSR2 pixel is ~ 20-50% covered by forest

Range of forest cover fraction (%) within sensor FOV

	10 GHz	19 GHz	37 GHz	89/91 GHz
SSMIS	-	44-51	27-47	18-46
AMSR2	26-46	19-45	16-44	3-50

Range of forest cover fraction was calculated assuming 5 km maximum displacement of the center of the satellite sensor FOV from the station location

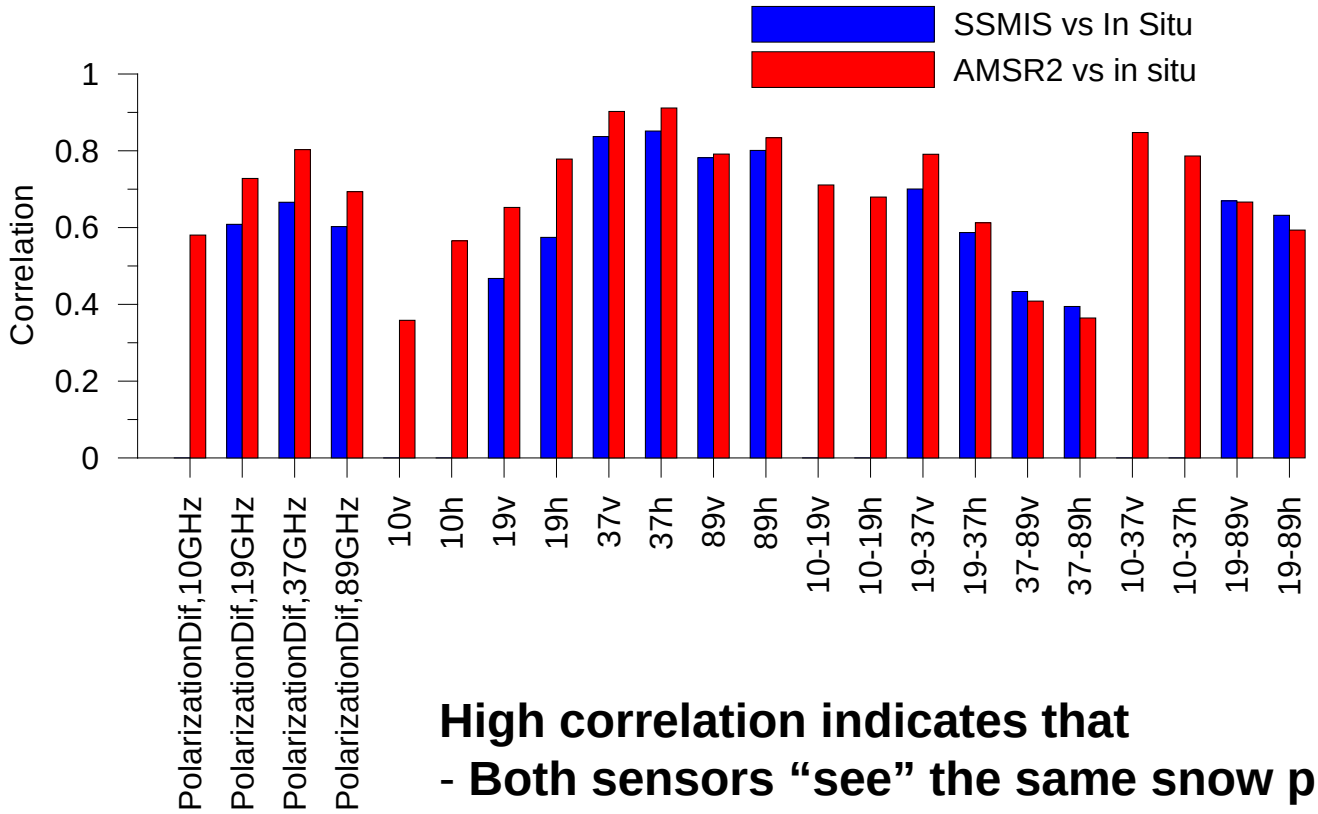
Microwave emission at 19 and 37 GHz: In situ vs AMSR2



- **Larger satellite BTs and smaller spectral gradient are due to forest cover**
- **Largest differences in the beginning and in the end of snow season**
- **Close similarity over snow free land**

Correlation of Satellite (AMSR2, SSMIS) and in Situ Observations

January 1 to April 20, Fully snow-covered land surface



High correlation indicates that

- Both sensors “see” the same snow processes

- Station obs. are representative for wider area

What's next

NASA SnowEx experiment, Feb 2017, Grand Mesa, Colorado

- Surface + airborne measurements

Proposal pending at DoD to acquire

- Microwave radiometer 1.4 GHz
  - Soil moisture, state of soil surface
- Microwave radiometer 150 GHz
  - Snow emission, atmospheric remote sensing
- Scanning lidar
  - Evaluate terrestrial laser scanning (TLS) technique for areal snow studies

Info/Data Access

Project web site: crest.ccny.cuny.edu/snow/data.html
Data:
www.star.nesdis.noaa.gov/smcd/emb/snow/caribou/caribou_microwave.html

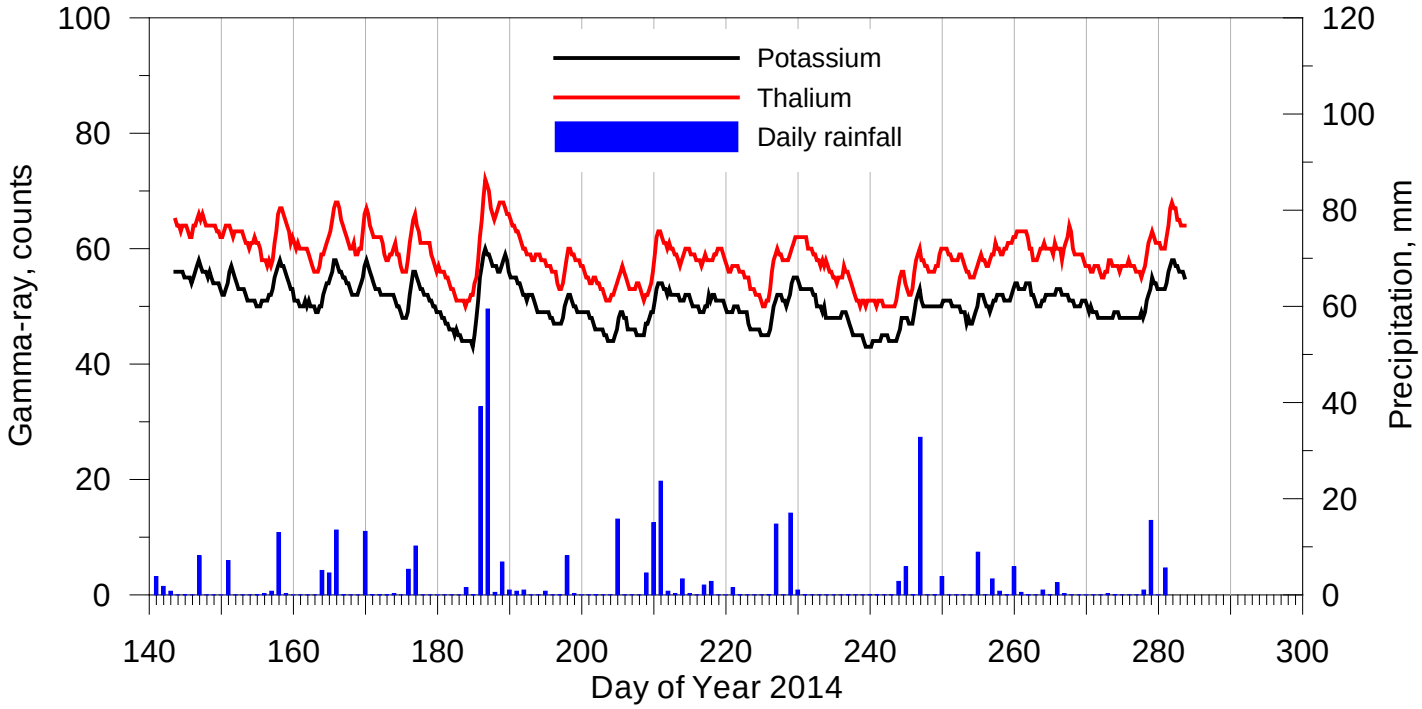
Questions, comment to: peter.romanov@noaa.gov, tlakhankar@ccny.cuny.edu

We are open for collaboration

- Will provide data for analysis, model development, joint projects
- Other instrumentation ? We have some space at the station.
- Specific experiments with available instrumentation ?

Thank you !

Gamma-ray: can be also used in soil moisture studies



- Gamma ray sensor data are strongly correlated with rainfall
- Sensitive to monitor soil moisture.

Snow Wetness Profiler

Instrument consists of 16 CS625 water content reflectometers

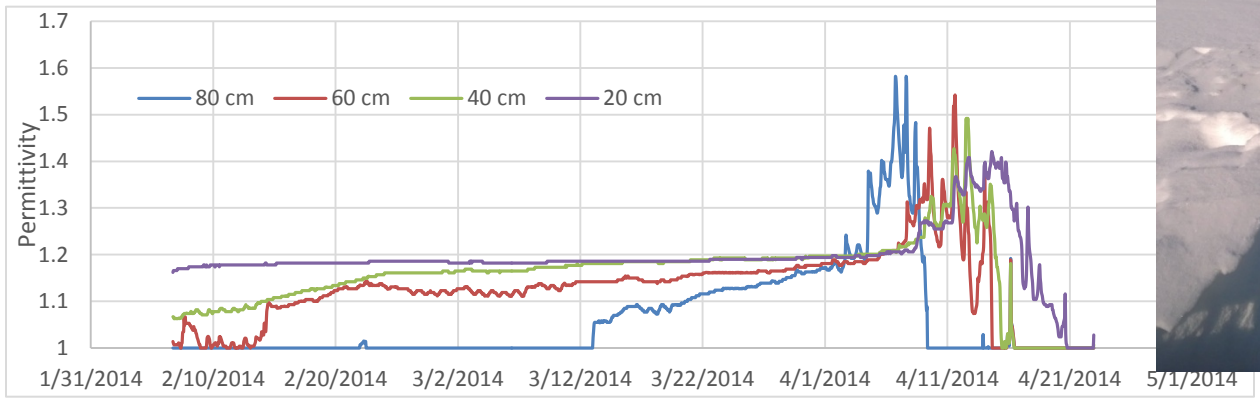
Liquid water content can derived from measured permittivity

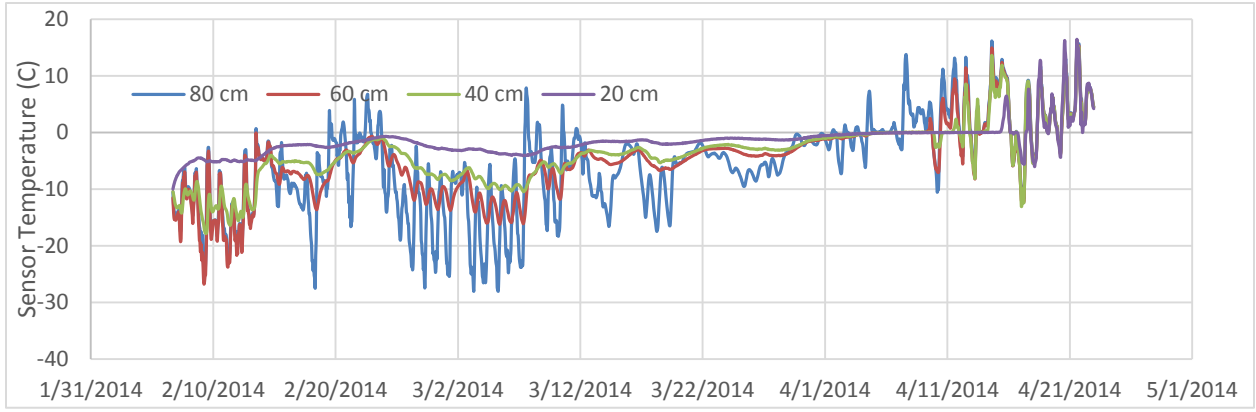
Relationship between snow permittivity and liquid water content has yet to be established.

CS650
Water Content
Reflectometer

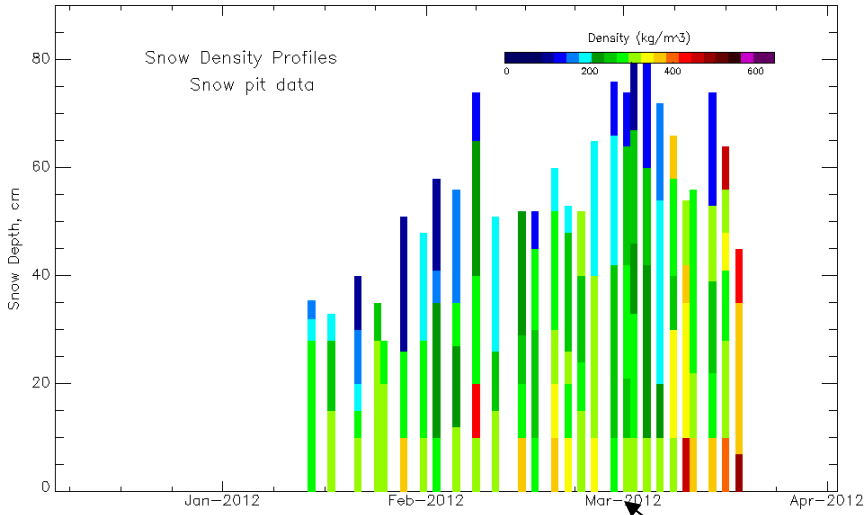
Dielectric Permittivity

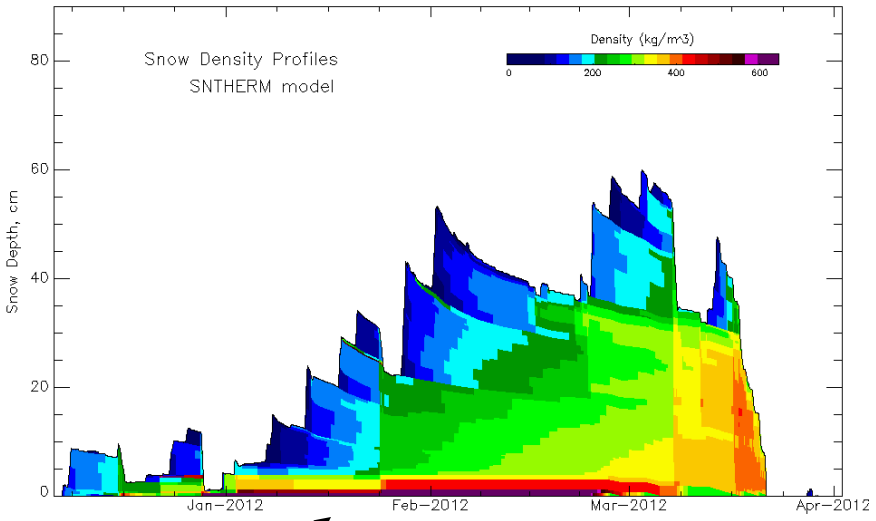
Vertical Snow Wetness Profile





Applications: Snowpack modeling





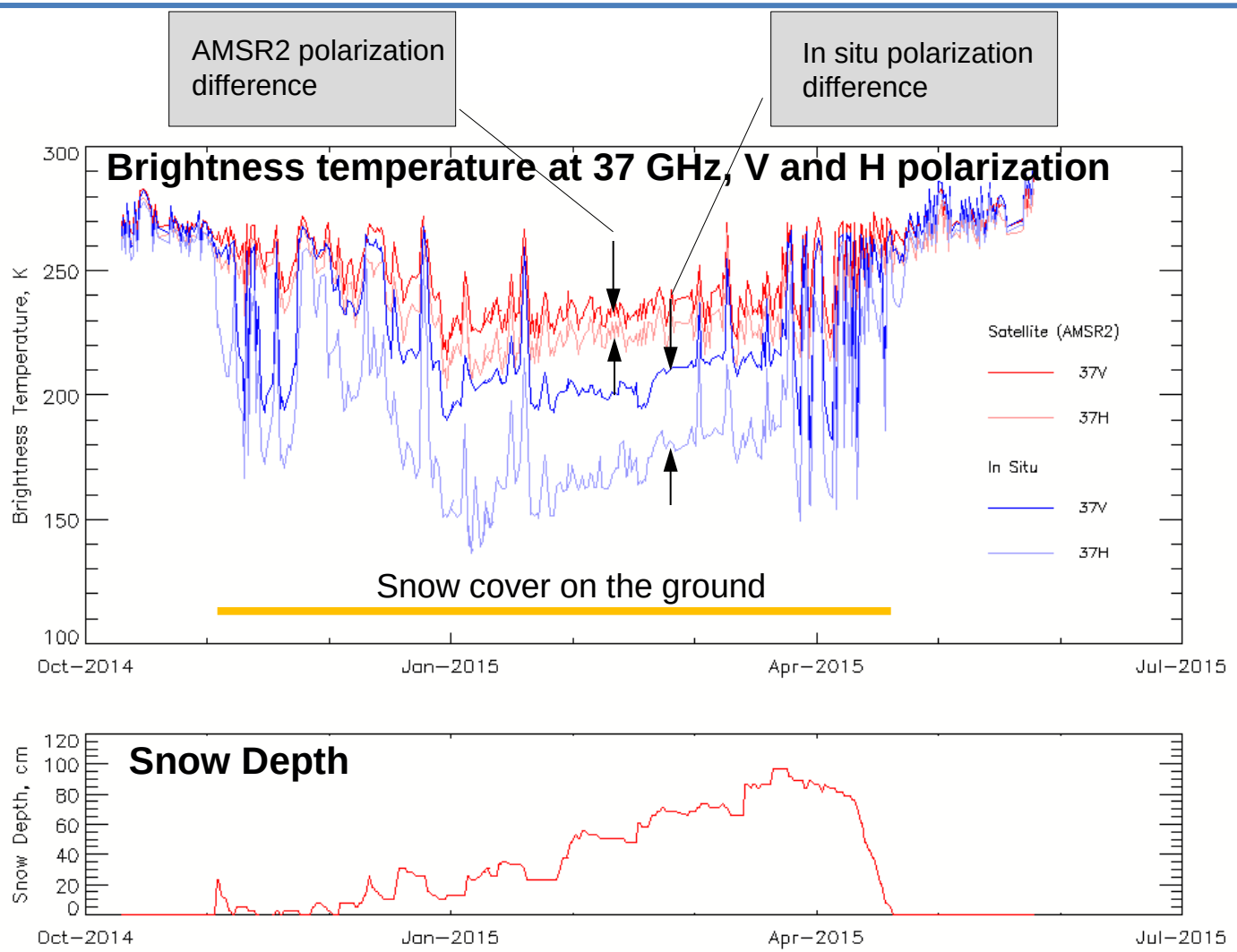
Observed

Simulated (SNTHERM)

Ice layer at the bottom of the snow pack is not reported

Reporting protocol should be improved to allow for detailed characterization of ice layers

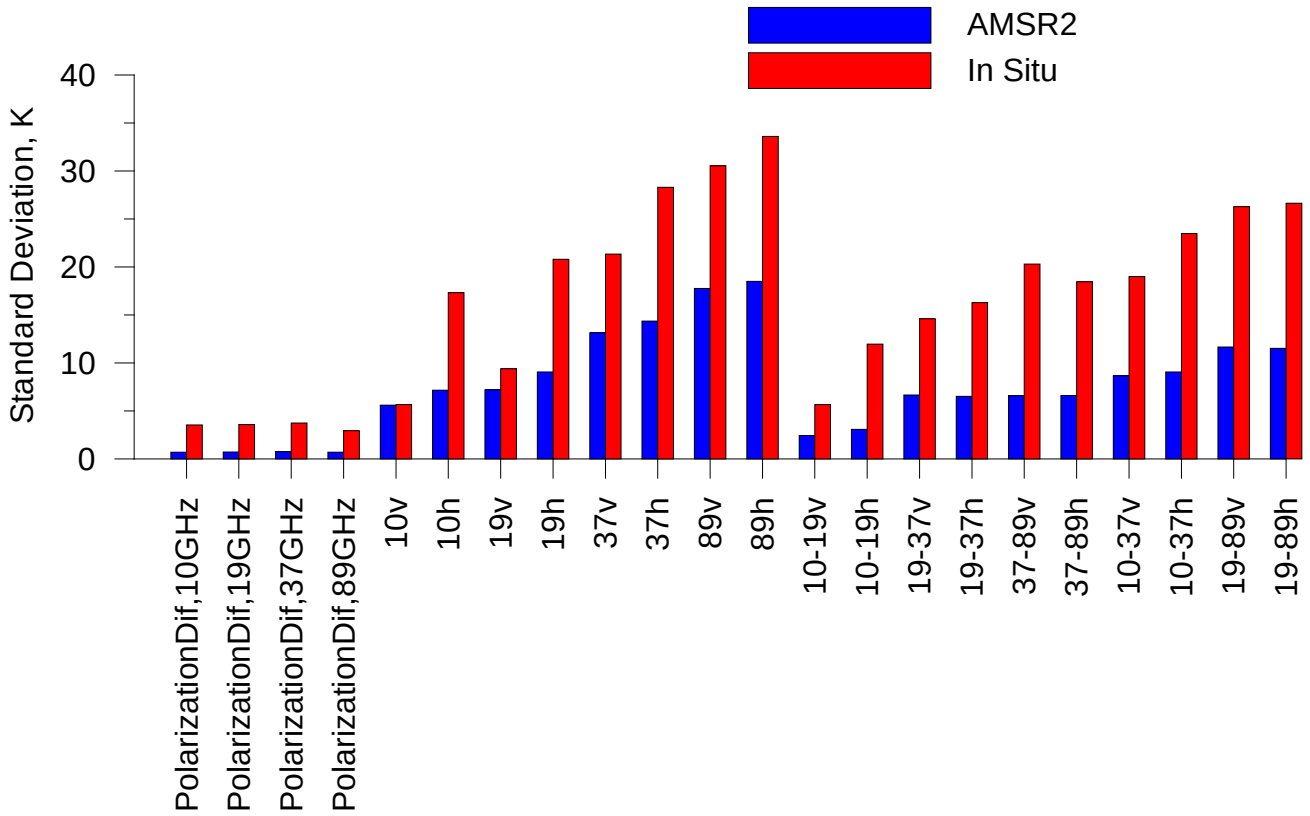
Microwave emission at 37 GHz, V&H: In situ vs AMSR2



Satellite: Much smaller polarization difference over snow-covered land

Standard Deviation, AMSR2 and in Situ

Jan 1 – April 20, 2015, Fully snow-covered land surface

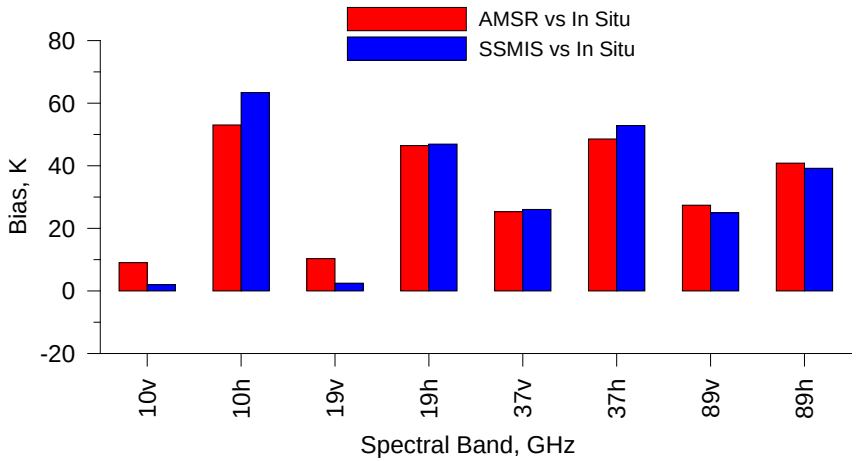


-Much larger variability of in situ temperatures

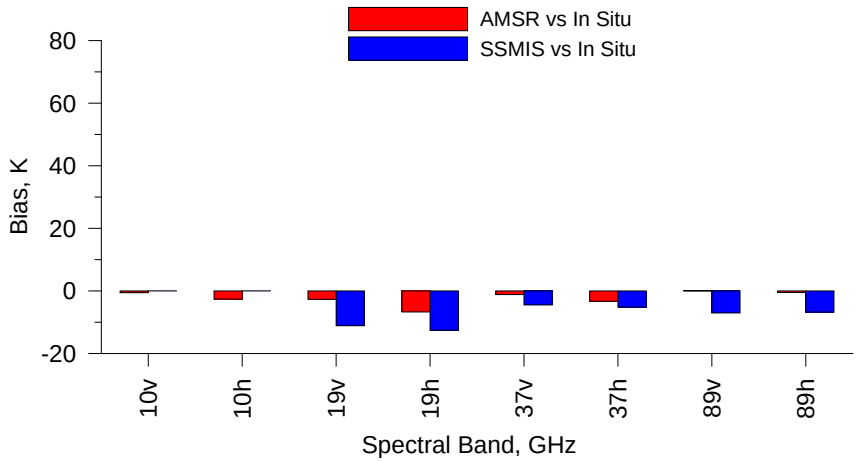
- Variability of satellite temperatures may be dampened by forest cover

Mean Bias, Satellite vs In Situ

Snow on the ground (Jan 1 – April 20)



No snow on the ground (May 1 – May 31)



- Larger in situ-satellite differences in winter
- Larger differences in H-pol
- Close agreement to AMSR2 with no snow on the ground
- Better in situ agreement to AMSR2 than to SSMIS