Validation of AMSR2 Soil Moisture and Snow Data Products Using Co-Located GPS and in situ Observations

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Outline

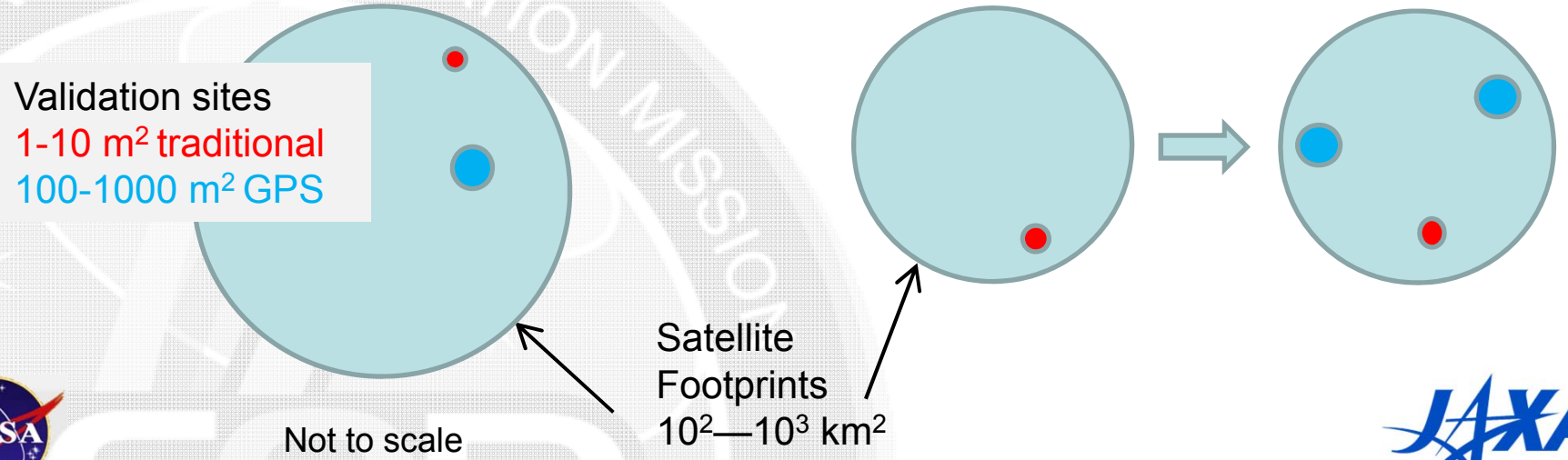
- Background and Motivation (review)
- GPS technique (review)
- Project objectives & approach
- Evaluation examples
- Project status
- Summary

Background and Motivation

Issues common to validation of soil moisture and snow:

scale difference between satellite footprint and available sources of validation data (i.e., ground stations)

spatial density of validation points in order to address sub-pixel heterogeneity



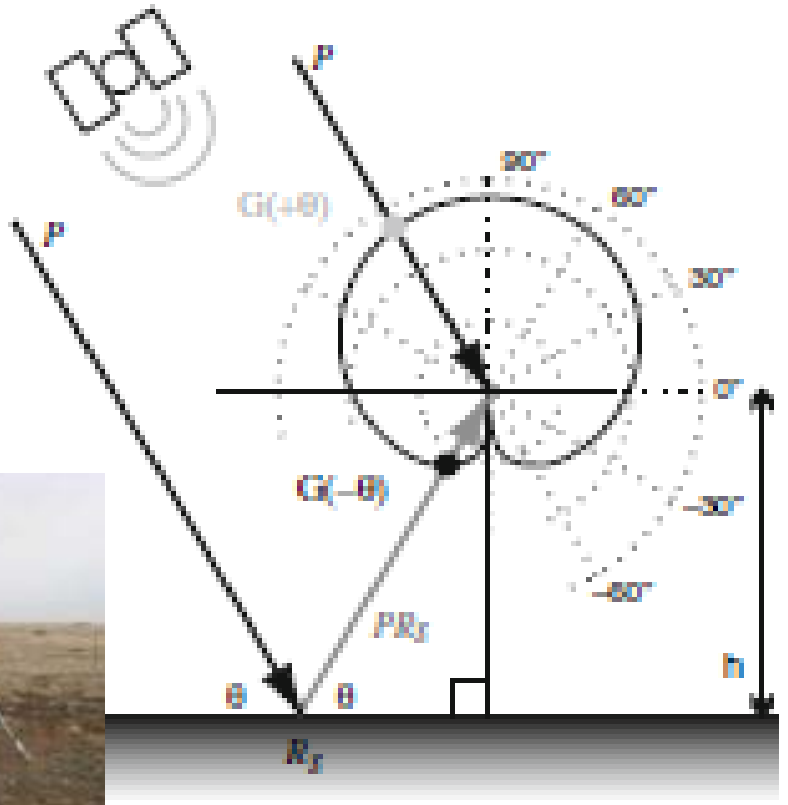
GPS-IR technique description

- Regular upward-facing antenna
- Uses interference of direct & reflected signals

= **GPS**-Interference **R**eflectometry

- Reflected signal depends on surface dielectric conditions—e.g. snow depth, soil moisture
- Receiver only needs fast temporal output.

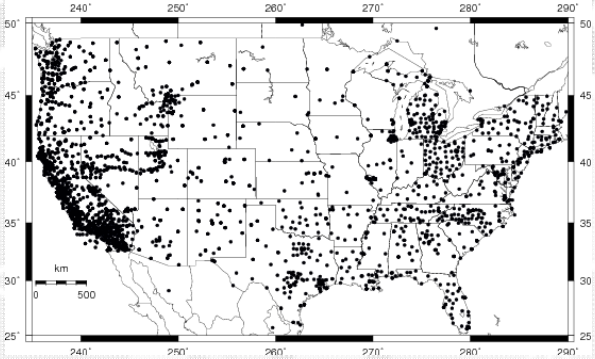
Side view



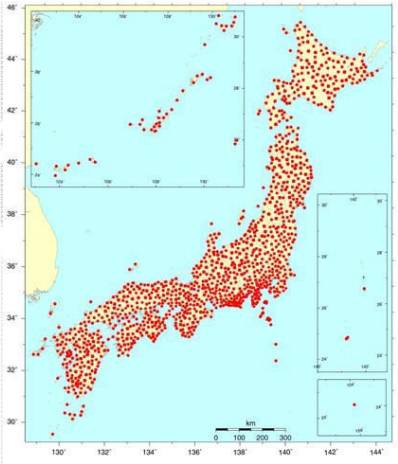
Larson et al, GRL 2009

GPS-IR technique potential

- GPS receiver must be geodetic quality & have certain hardware/software
- There are thousands of such geodetic GPS receivers worldwide. Potential new network for validation.
- Not all sites are suitable! Need to evaluate retrievals.



PBO
1100 sites



GEONET
~1000 sites

EPN
245 sites

Project Objectives & Approach

Objectives: Evaluate a new type of GPS measurement vs. AMSR2 & AMSR-E soil moisture & snow products; identify suitable GPS validation stations.

Approach: comparison among 4 types of measurements

a. AMSR-E/AMSR2 soil moisture/snow depth,
b. GPS soil moisture/snow depth, and
c. ground truth soil moisture/snow depth
d. SNOTEL snow depth

"c" is most limited, so mainly comparing "a" and "b"
NEW: added comparisons with "d" for snow

Snow Depth

Data compared:

- AMSR-E/2: Kelly algorithm SD
- GPS-IR: SD product
- SNOTEL: ultrasonic SD product

Map of GPS Stations in US with Non-Ephemeral Snow

- Non-Ephemeral snow: 84 sites

Not shown: Ephemeral snow: 34 sites

Not shown: Soil moisture: 59 sites

Map of SNOTEL Stations in US

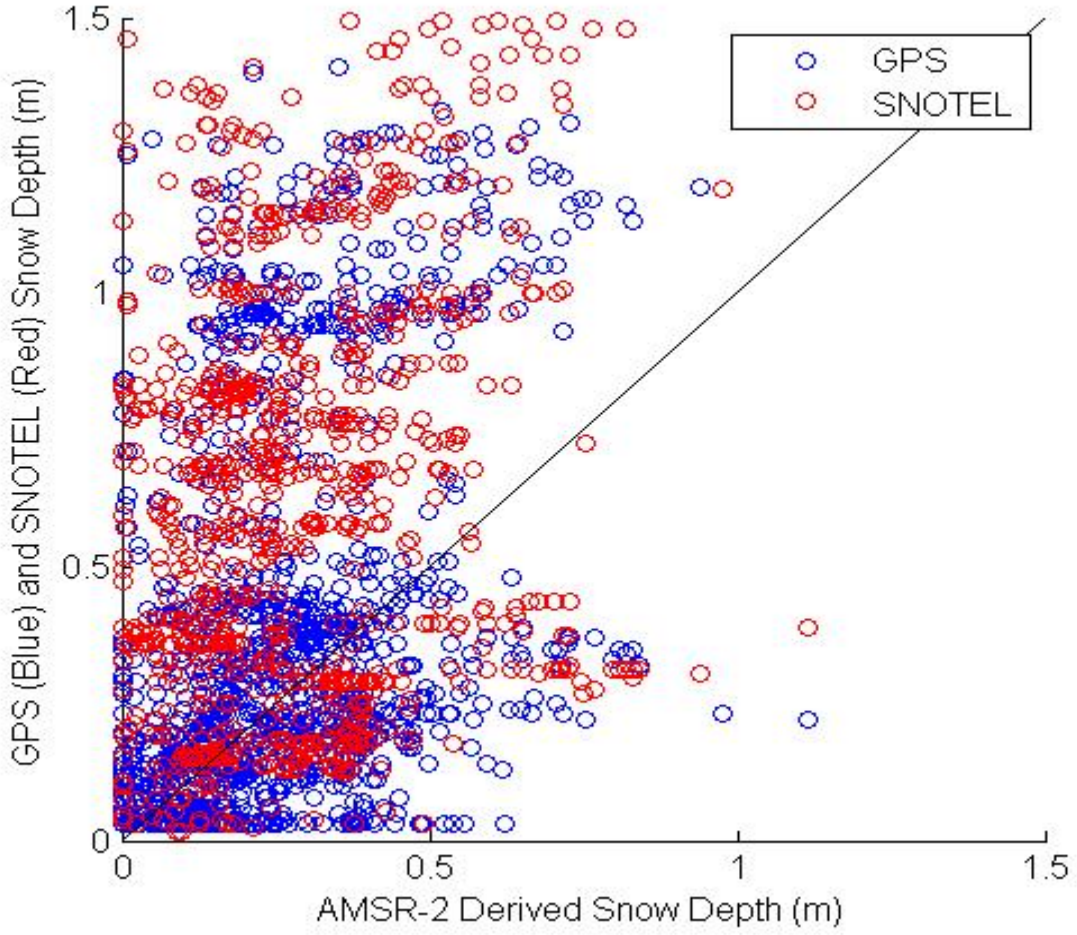
858 automatic stations
In western US states

Measurements include
snow depth and
snow water equivalent
at a point

Widely used as
Validation dataset
for snow remote sensing
(because there aren't
many alternatives)

Intentionally mainly in
mountainous areas,
many in forested areas.
Forest SNOTEL sites
are actually in clearings.

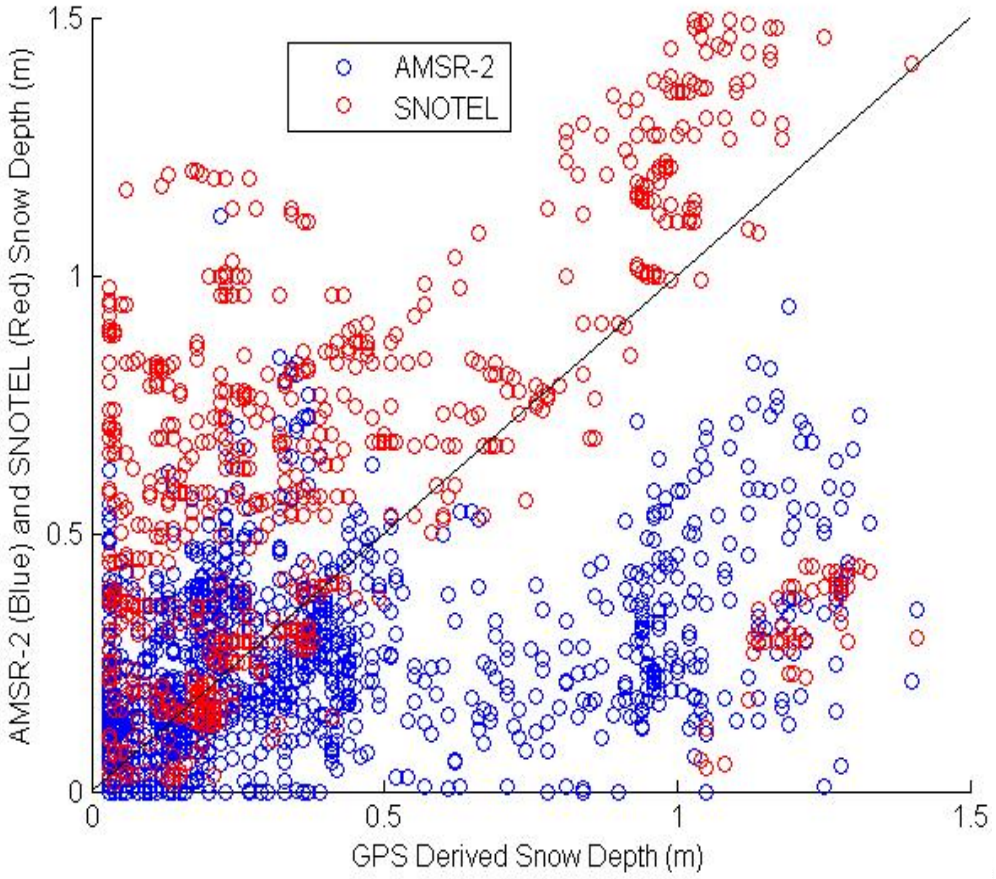
GPS and SNOTEL Snow Depth vs AMSR-2 Snow Depth



AMSR-2 derived snow depth is generally smaller in value (most data lies to left of ~0.5m on x-axis). This is likely to be well-known saturation of channels/algorithm at ~0.5m.

Otherwise, GPS and SNOTEL have similar ranges of snow depth (good).

AMSR-2 and SNOTEL Snow Depth vs GPS Snow Depth



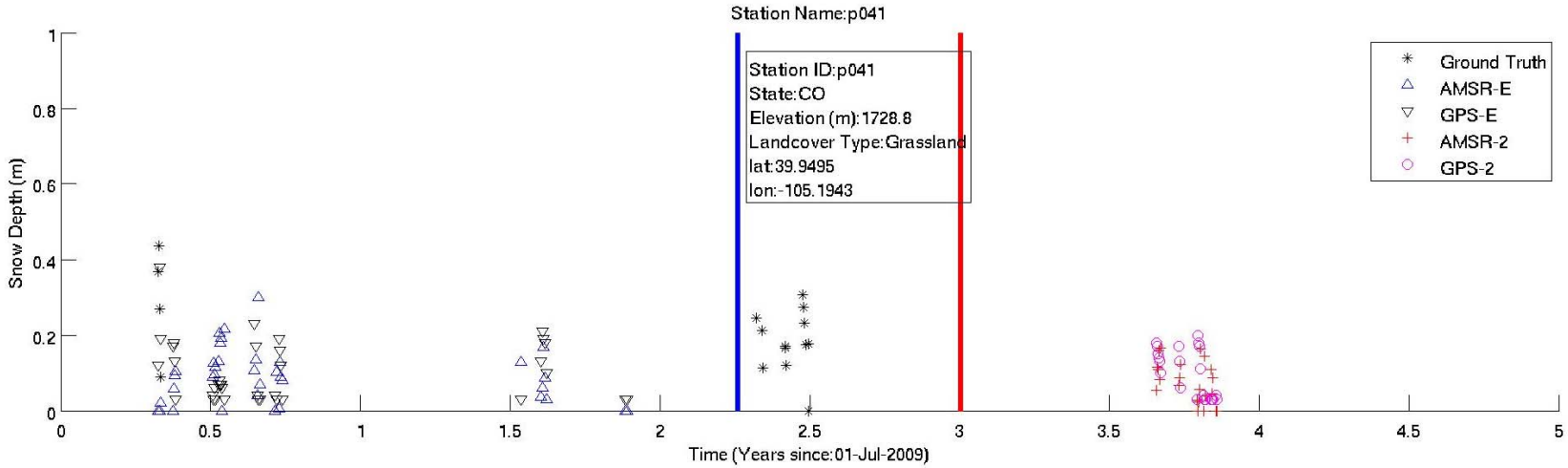
Again, we see AMSR-2 derived snow depth is generally smaller in value (most data lies below ~0.5m on y-axis).

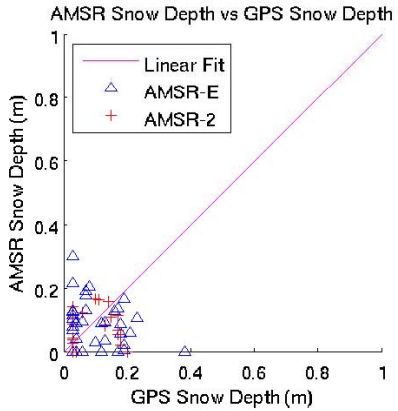
SNOTEL generally measures larger values of snow depth than GPS (data points above the 1:1 line), possibly because GPS sites require a larger clear space. A comparison study has just started to examine this.

There is a possible linear trend between SNOTEL and GPS (with a bias).

Snow Depth at GPS station p041

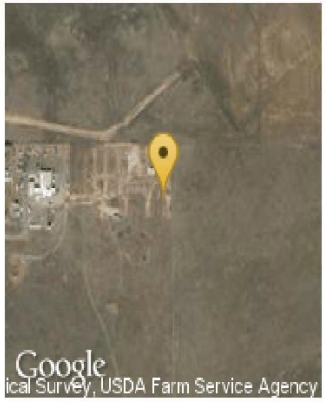
Station with ground truth data



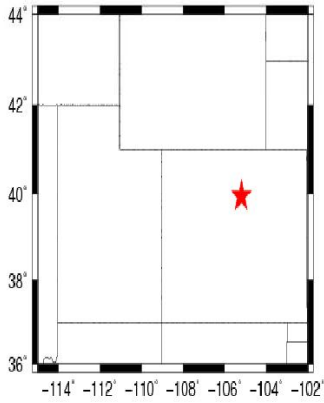


Site Picture

Aerial Image

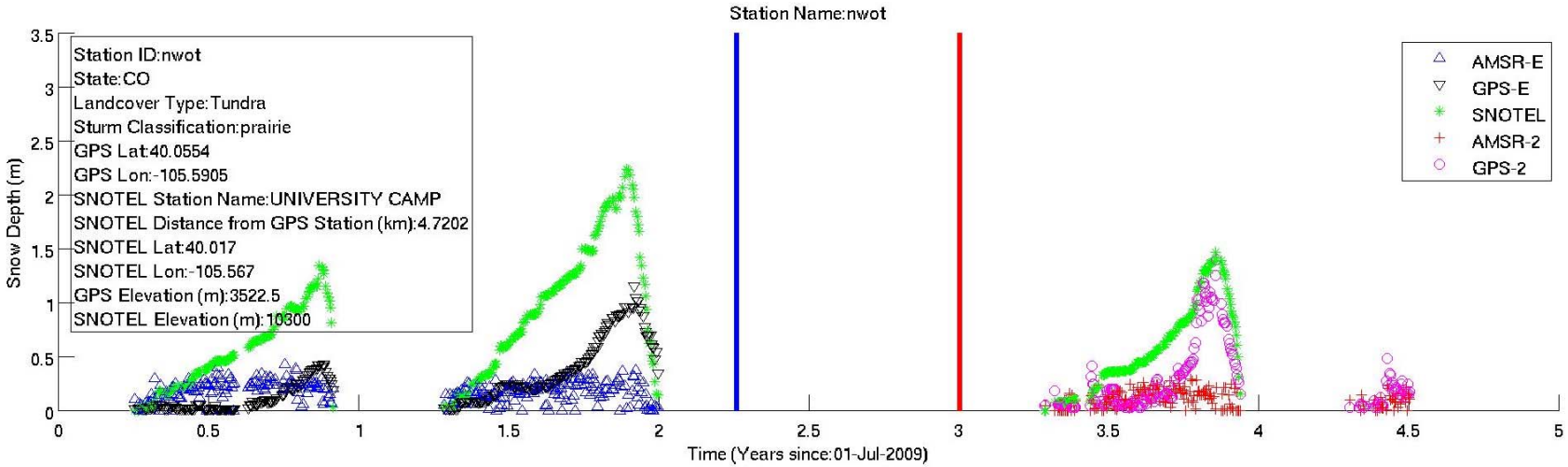


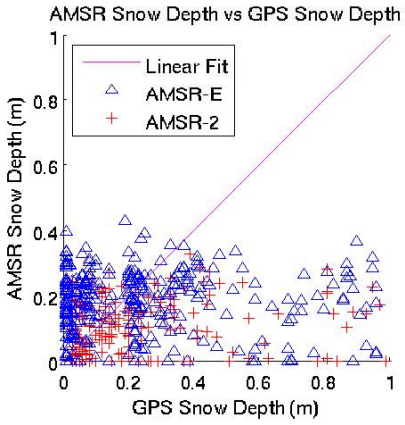
US Location

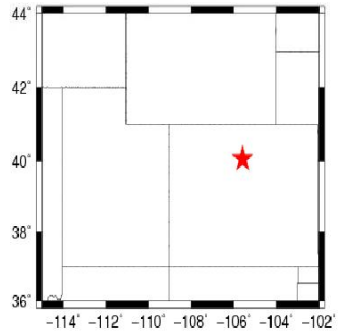


Snow Depth at GPS station nwot & SNOTEL 4.7 km away

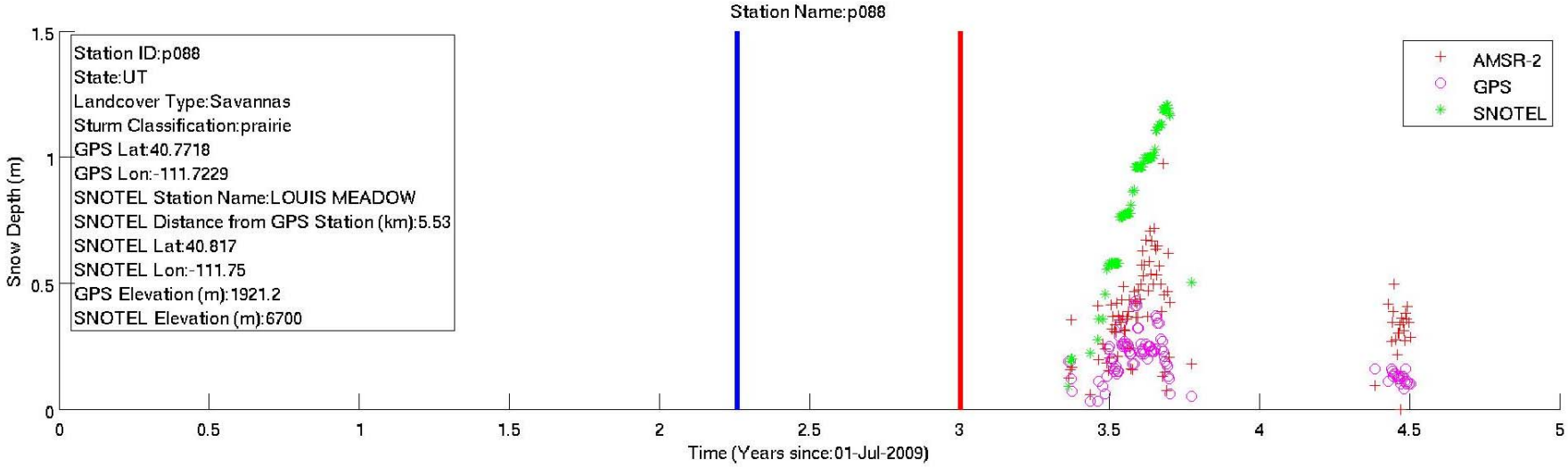
Mountainous GPS Station with the Most Snow

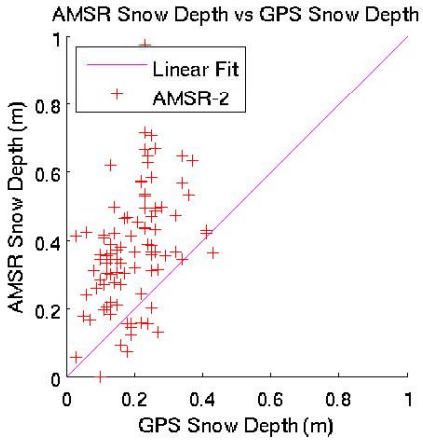






Snow Depth at GPS station p088 & SNOTEL 5.5 km away

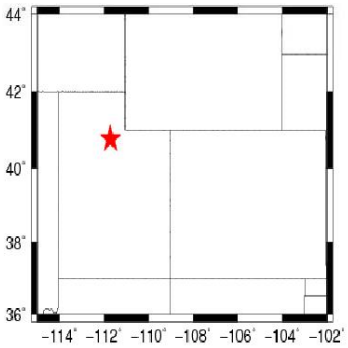




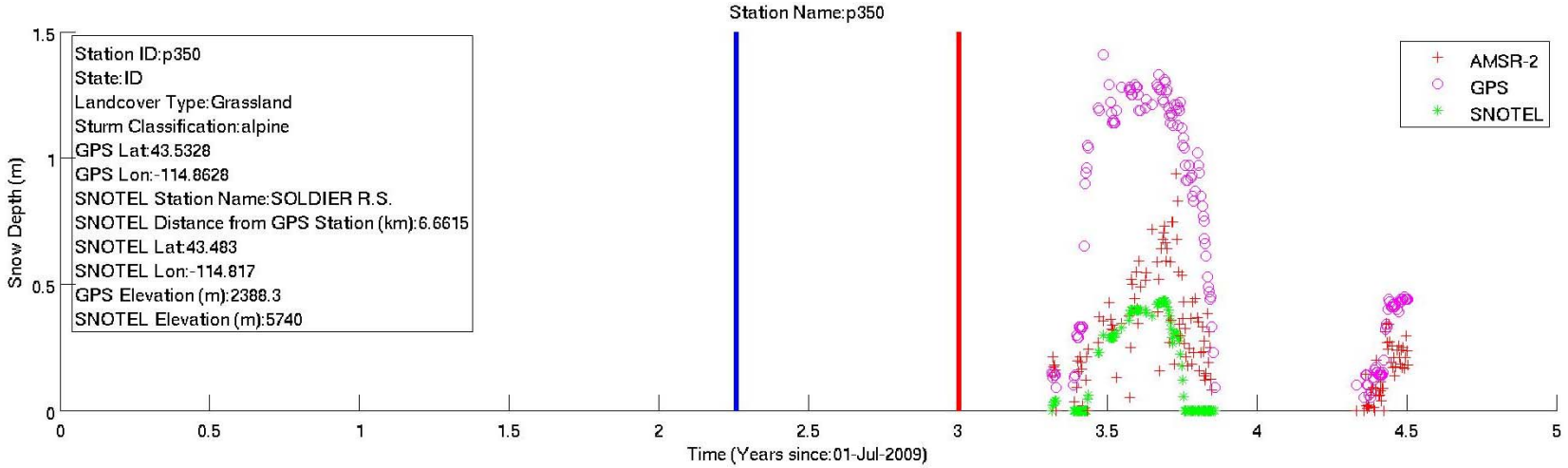
Site Picture

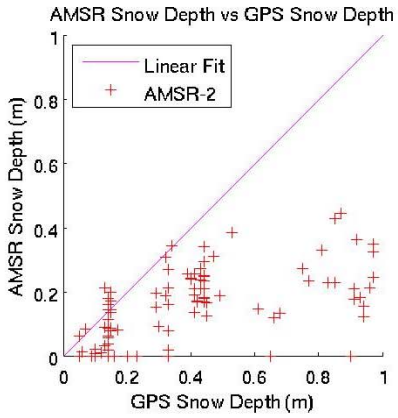
Aerial Image

US Location



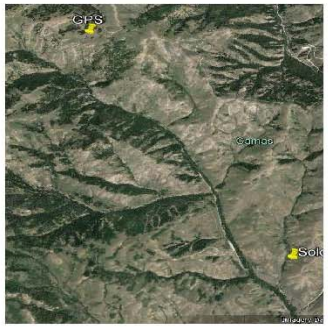
Snow Depth at GPS station p350 & SNOTEL 6.7 km away



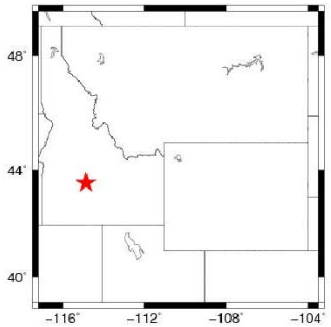


Site Picture

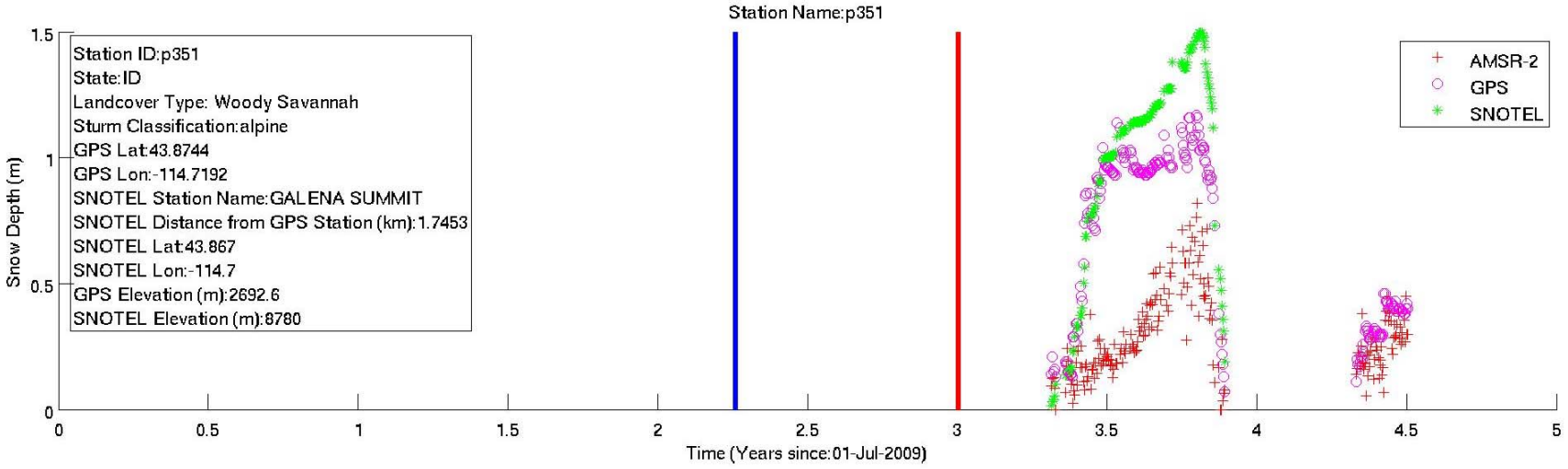
Aerial Image

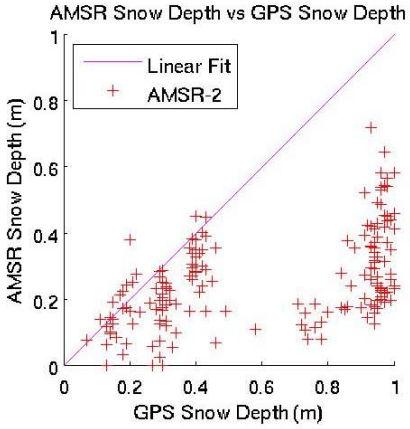


US Location



Snow Depth at GPS station p351 & SNOTEL 1.7 km away

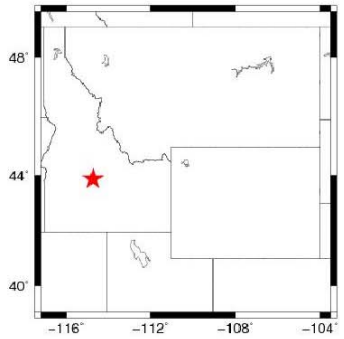




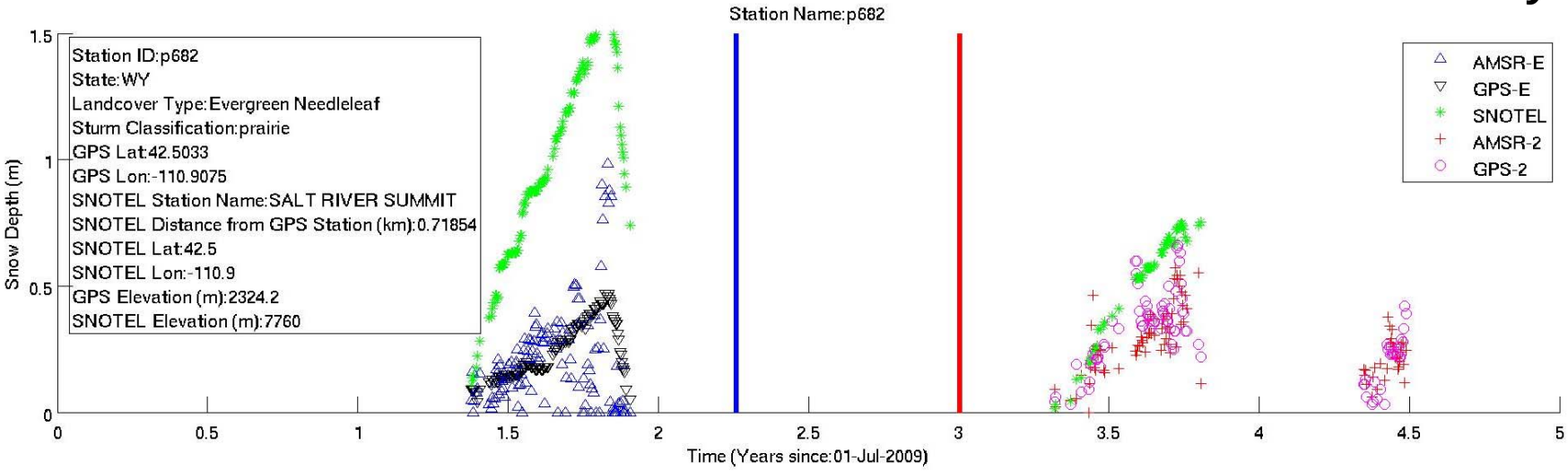
Site Picture

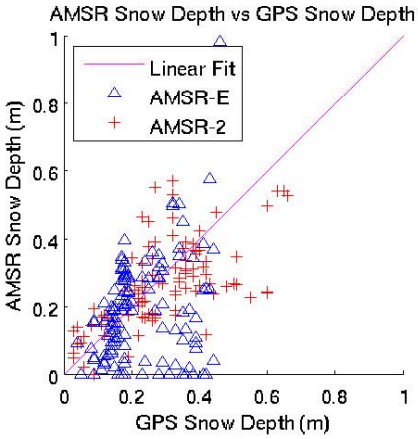
Aerial Image

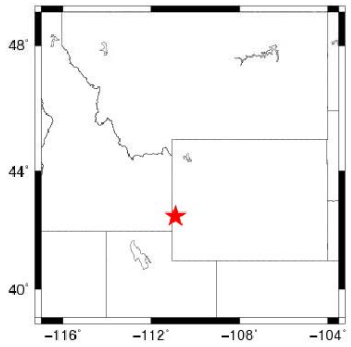
US Location



Snow Depth at GPS station p682 & SNOTEL 719m away

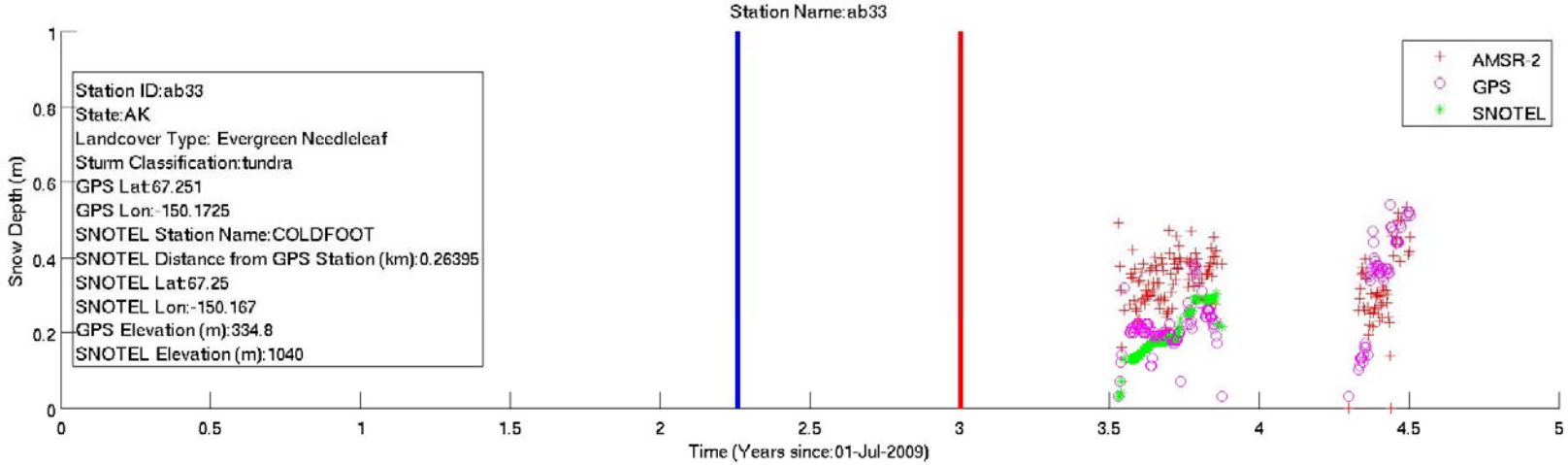


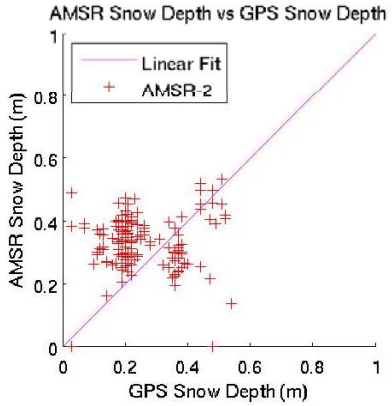




Snow Depth at GPS station ab33 & SNOTEL 264m away

Representative station in Alaska with no GPS snow depth data prior to AMSR-E stoppage

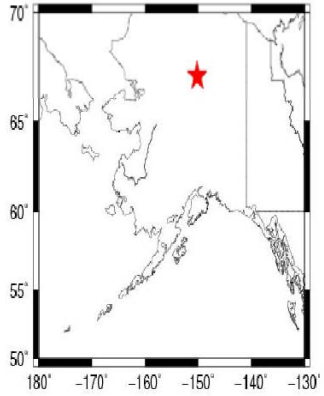




Site Picture

Aerial Image

US Location



Statistics for GPS, AMSR-2, and SNOTEL Snow Depth

Statistics for all GPS Stations with nearby SNOTEL and AMSR data	SNOTEL Sites	Mean of GPS SD	STD of GPS SD	Mean of AMSR2 SD	STD of AMSR2 SD	Mean of SNOTEL SD	STD of SNOTEL SD
10 km	9	0.35	0.30	0.30	0.17	0.64	0.38
Ephm	5	0.18	0.12	0.31	0.15	0.54	0.33
Non-ephm	4	0.50	0.33	0.29	0.18	0.73	0.40

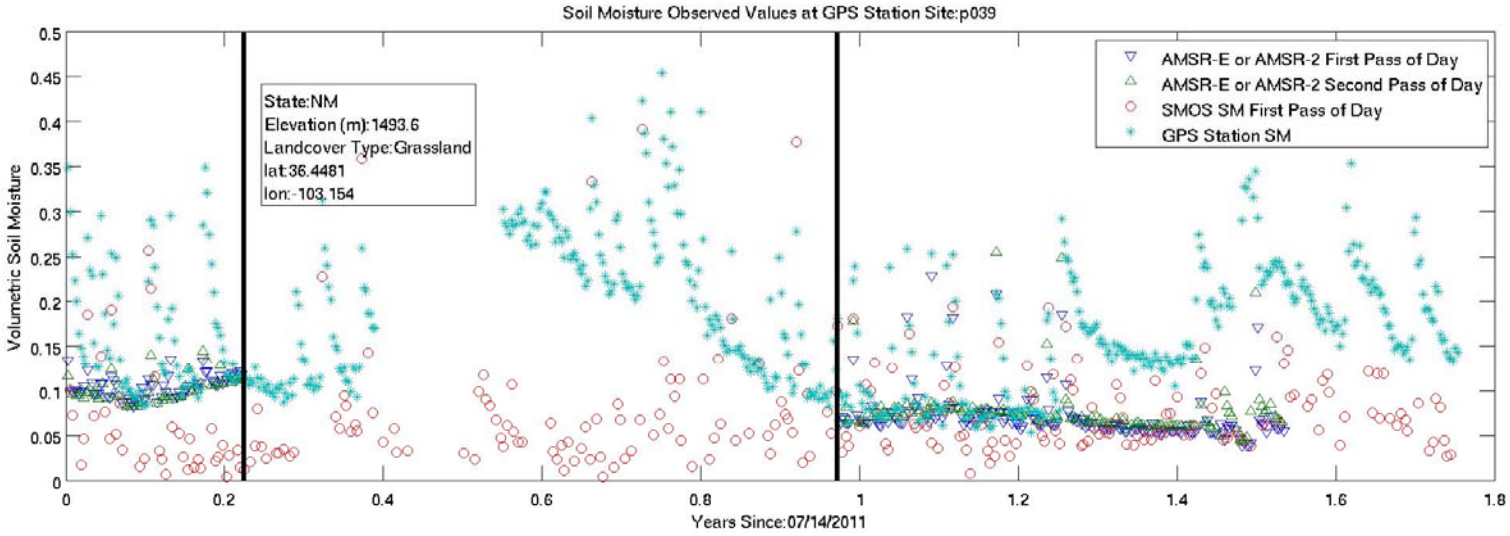
Statistics Broken Down by Sturm Classification	SNOTEL Sites	Mean of GPS SD	STD of GPS SD	Mean of AMSR2 SD	STD of AMSR2 SD	Mean of SNOTEL SD	STD of SNOTEL SD
water	0						
tundra	1	0.25	0.11	0.34	0.07	0.20	0.06
taiga	0						
maritime	2	0.34	0.22	0.28	0.24	0.51	0.25
ephemeral	0						
prairie	5	0.18	0.14	0.29	0.16	0.66	0.26
alpine	1	0.69	0.34	0.30	0.17	0.97	0.42
ice	0						

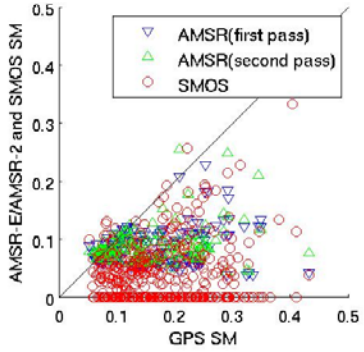
Soil Moisture

Data compared:

- AMSR-E/2: standard SM product
- SMOS: standard SM product
- GPS-IR: SM product

Soil Moisture at GPS station p039 vs. AMSR-E/AMSR2 & SMOS

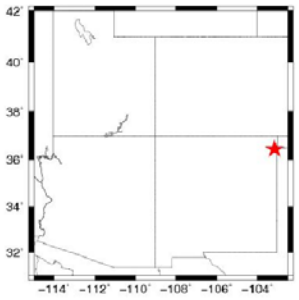




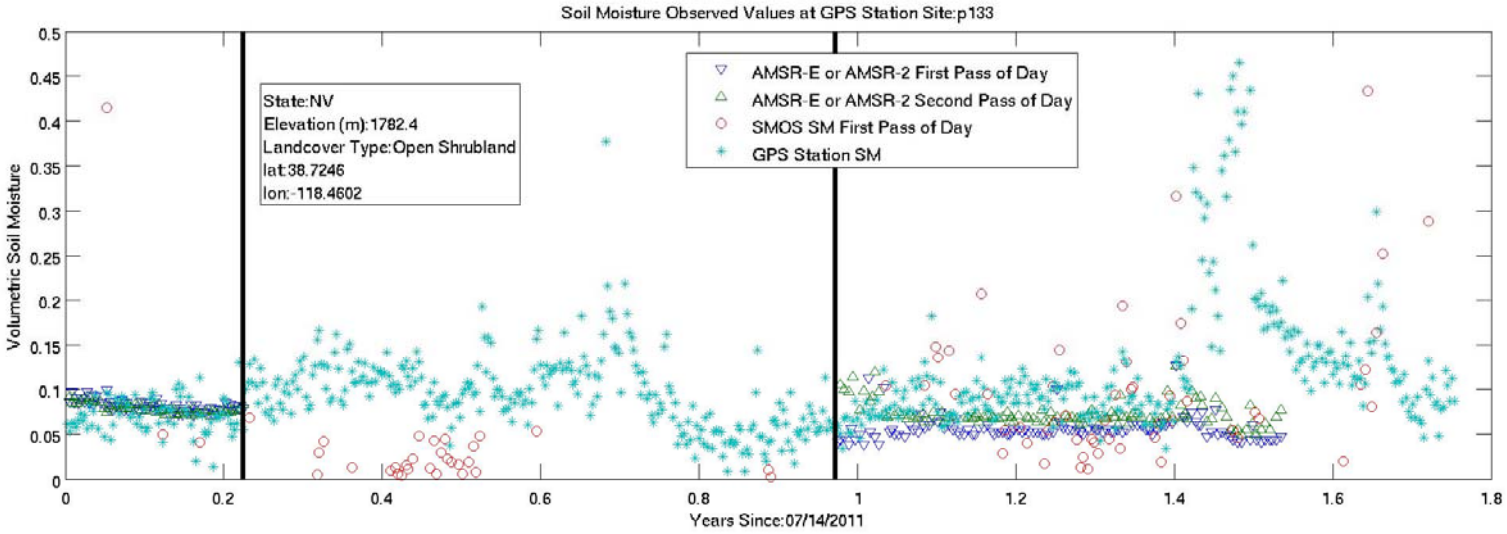
Site Picture

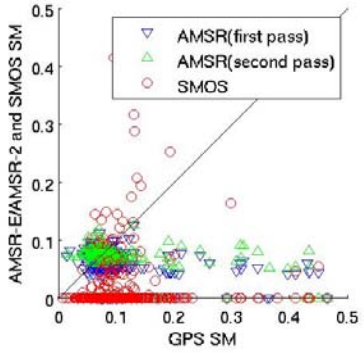
Aerial Image

US Location



Soil Moisture at GPS station p133 vs. AMSR-E/AMSR2 & SMOS

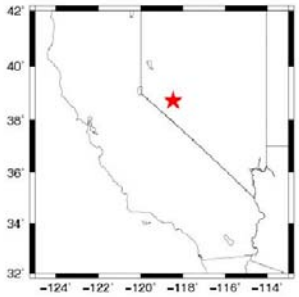




Site Picture

Aerial Image

US Location



Summary/Conclusions for years 1—3

- Evaluated 118 snow, 59 soil moisture GPS sites
- Generally, SNOTEL > GPS > AMSRE/2 for snow depth
- Generally, GPS> AMSRE/2 > SMOS for soil moisutre
- But different cases often seen
- No simple rules found to explain differences for snow
- Still evaluating soil moisture cases
- Project objectives to increase Total number & Spatial density of validation stations for snow and soil moisture have been achieved…
- But explanations of differences still elusive => future work
- Quantification of variations & differences will improve with each additional year of data => future work

Validation of AMSR2 Soil Moisture and Snow Data Products Using Co-Located GPS and in situ Observations

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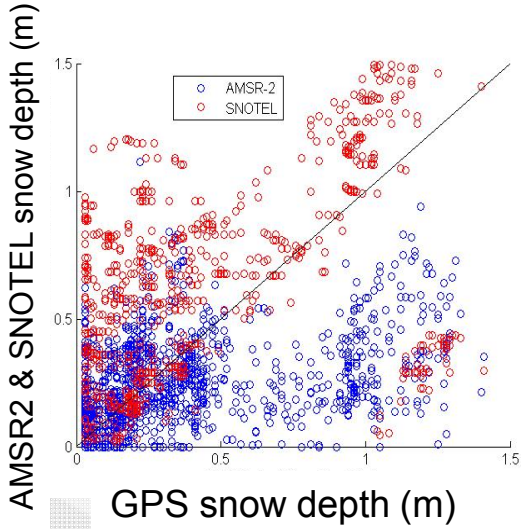
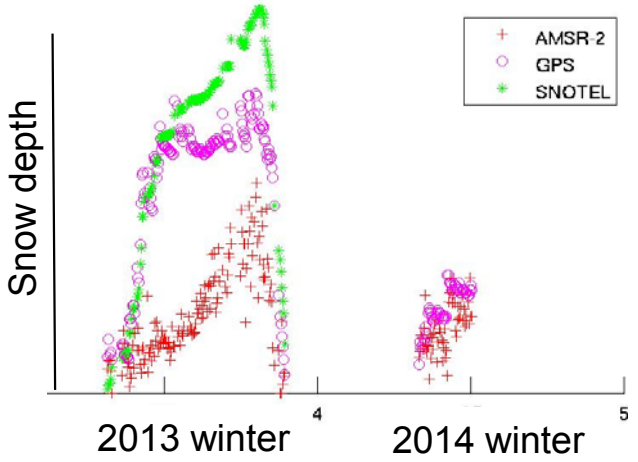
UCAR[2], Univ. of Colorado[3]

Project Outline

Compared Snow Depth from
- AMSR2/AMSR-E
- GPS
- SNOTEL

Compared Soil Moisture from
- AMSR2/AMSR-E
- SMOS
- GPS





Conclusions

- Evaluated 118 snow, 59 soil moisture GPS sites
- Generally, SNOTEL > GPS > AMSRE/2 for snow depth
- Generally, GPS> AMSRE/2 > SMOS for soil moisutre
- But different cases often seen
- No simple rules found; still evaluating
- Total number & Spatial density of validation stations increased for snow and soil moisture

BACKUP

Kelly, et al Snow Depth Algorithm

≈AMSR-E/AMSR2 algorithm for snow

For moderate to deep snow, either of the following two conditions must be satisfied:

$$TbV10 - TbV36 > 0$$
$$TbH10 - TbH36 > 0$$

Then snow depth is

$$SD = ff\left(\frac{A(TbV18-TbV36)}{1-b*fd}\right) + (1-ff)\,[A(TbV10 - TbV36)+B(TbV10 - TbV18)] \text{ cm}$$

SD = snow depth

ff = forest fraction (MODIS IGBP classification)

fd = forest density fraction (UMD MODIS VCF)

A = 1/log(36V-36H)

B = 1/log(18V-18H)