Outlook for satellite-derived snow products

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Outline

(a journey through all 3 phases of water)

- Foreward on SMAP

- Snow products & satellite sensor outlook
- Sensing technique options & implications for future snow mission concepts
- How modeling & assimilation fit in
- Near term needs
- The snow mission outlook
- Summary
- Int'l snow remote sensing working group

- Afterward on ATMS sounder

SMAP launches very soon!

Mid-Dec or late-Jan

Rocket at launch pad

Satellite is ready

Satellite in orbit

What snow products do we care about?

- Presence or absence of snow
- Areal extent
- Depth
- SWE
- Melt status
- Albedo

- Global coverage; 1-2 day refresh

Confounding effects

Factors that complicate remote sensing of snow

- Clouds (VIS/IR)
- Lack of solar illumination at night & polar winter (VIS/IR)
- Forest cover (all techniques)
- Mountainous topography (all techniques)
- Snow metamorphism (all techniques)
- Variety of snow types (all techniques)

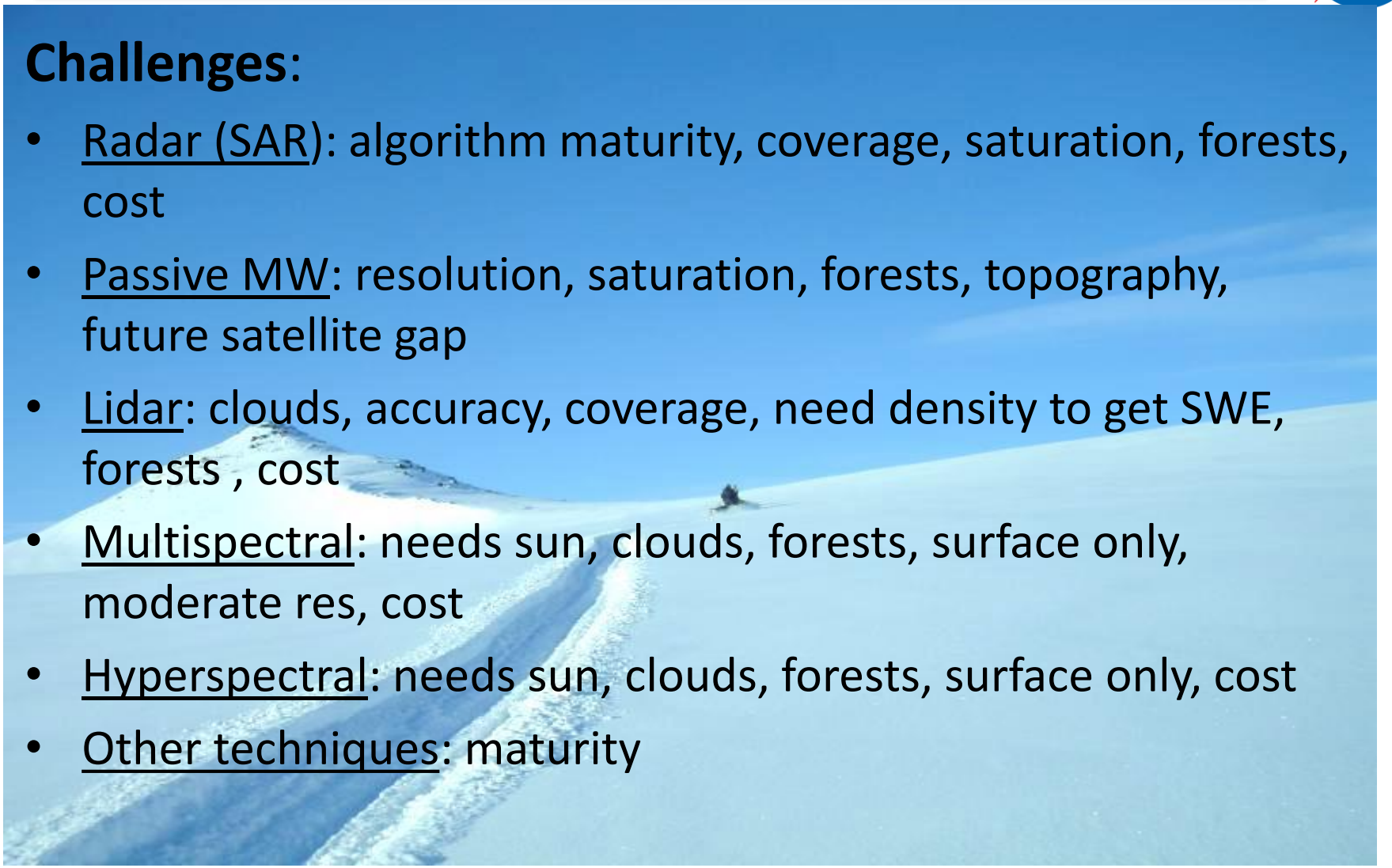
=> No single sensing technique works for all snow types, everywhere, all the time, under all conditions

Rem. Sensing techniques for global snow

Advantages/Strengths:

- Radar (SAR): senses SWE & melt, high res, topography OK, clouds OK, no sun needed
- Passive MW: senses SWE & melt, global daily coverage exists, clouds OK, no sun needed, very long record
- Lidar: snow depth, accuracy OK for deeper snow, SWE (need density), very high res, forests ~OK, topography OK
- Multispectral: MODIS/VIIRS exist, fSCA, albedo, grain size, moderate spatial res
- Hyperspectral: fSCA, albedo, surf grain size, mod/high spatial res
- Other techniques: a few in development

Rem. Sensing techniques for global snow



Challenges:

- Radar (SAR): algorithm maturity, coverage, saturation, forests, cost
- Passive MW: resolution, saturation, forests, topography, future satellite gap
- Lidar: clouds, accuracy, coverage, need density to get SWE, forests , cost
- Multispectral: needs sun, clouds, forests, surface only, moderate res, cost
- Hyperspectral: needs sun, clouds, forests, surface only, cost
- Other techniques: maturity

What's the solution?

- A multi-sensor approach, with sufficiently clever integration
- But how to design a multi-sensor mission concept that doesn't kill itself due to cost?

a) Keep the scope reasonable: don't need to retrieve snow products everywhere, all the time, under all conditions

b) Reduce the total cost by leveraging existing & future sensors. Don't expect one source to pay for all of it! € + $ + ¥ + RMB = enough?

What we know so far

- We know we need a mix of observations since snow is a complex target; we know the sensor types
- We know we can't afford to directly retrieve snow parameters everywhere all the time
- In theory, modeling can integrate the diverse obs & fill in the gaps, but how many successful examples of this do we have for snow?
- *exactly* what should we observe vs. depend (only) on models for?

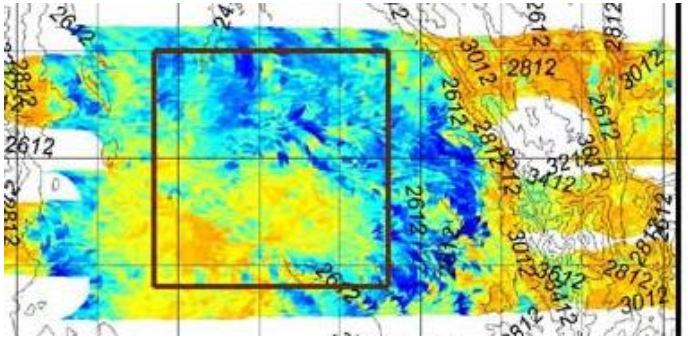
Before you say "OSSE," consider that:

- We don't know the error bars associated with each sensor type
- Especially as a function of different snow types & under different confounding factors (forests, topography, etc)
- A useful OSSE would need to be carefully designed to avoid GIGO

Not sure if we're ready for a full OSSE yet, but
we do know how to fix the error bar issue

Airborne campaigns

- Community consensus that multisensor snow campaigns with ground truth are needed to move forward
- Last highly multi-sensor snow campaign was 2002-2003 CLPX
  - Major step forward
  - Enabled a decade of snow remote sensing advances
- Dedicated snow campaigns are few
  - Partial 2013 support for ESA SnowSAR in Canada & Alaska
  - Partial ASO support, but addressing *global multisensor* snow requires new steps
  - Multisensor snow IIP campaigns 2015-16; radar, lidar, PM; but limited spatial scope



Airborne Multisensor Snow RS Activities

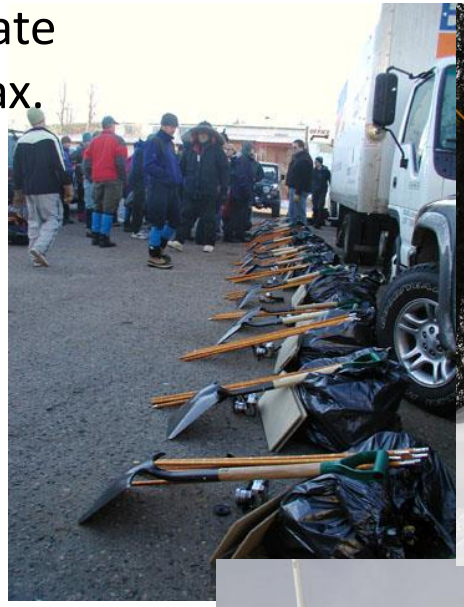
- Some examples of multisensor snow observations projects in North America.
- Not a complete list. Not all sensors flown simultaneously.
- "SnowBridge" is a notional activity modeled on IceBridge.

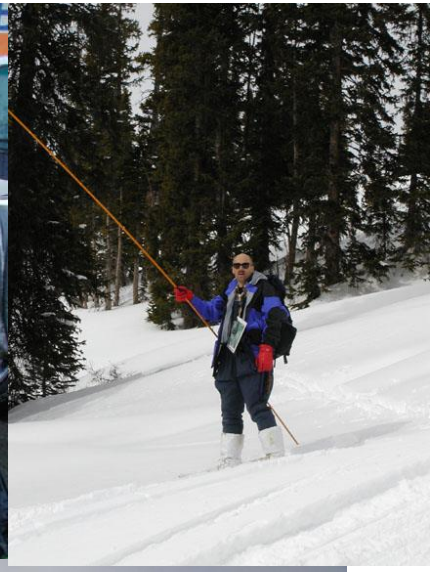
	CLPX-1	CLPX-2	Envir. Canada	ASO	Snow Net	Snow IIP	Ice Bridge	Snow Bridge
years	2002-2003	2007-2008	1990s? --now	2012 --	2008-2014?	2015-2016	1990s-2017	???
Radar	X	X	X		X	X	X	X
Passive MW	X		X			X		X
Lidar	X	X	X	X	X	X	X	X
Hyper spectral	X			X				X
VIS/IR					X	X	X	X
other	X						X	X

Field measurements

Field measurements are a key need

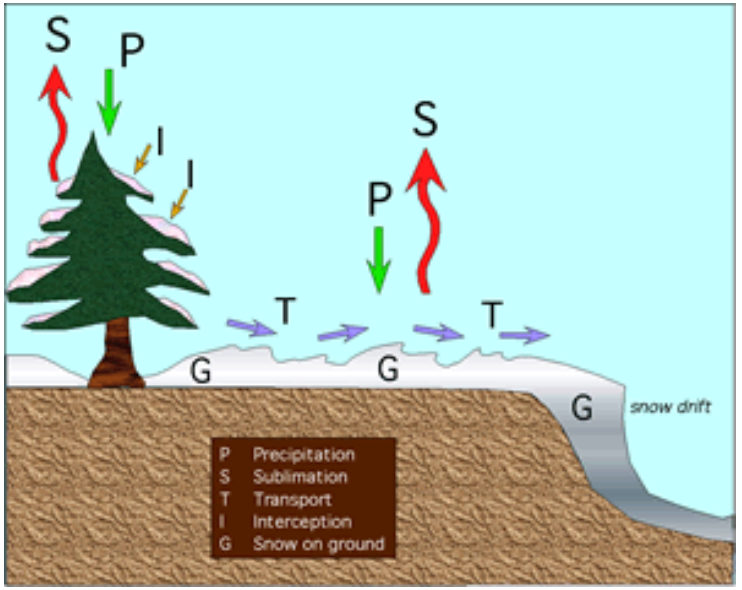
- At point/local scale to improve/validate remote sensing techniques under max. controlled conditions
- At watershed scale (multiple satellite footprints) for testing retrieval algorithms at useful scales
- In areas with confounding characteristics (forests, topography), field measurements at sub-footprint scale are the best way to address scaling-related uncertainty
- Large campaigns are of very limited use without good ground truth. Ground truth over large areas is rarely collected.





Land modeling, data assimilation

- Strong interest from global modeling community for more accurate SWE info
- Both NWP & seasonal forecast communities are making progress with respect to snow predictions
- Both need global snow observations
- Attempts to assimilate existing global SWE products like AMSR-E do not tend to yield significant improvement, but GlobSnow might have found a way…
- Validation of model output a key challenge; better validation data sources would be a significant improvement, & allow for a more rigorous answer

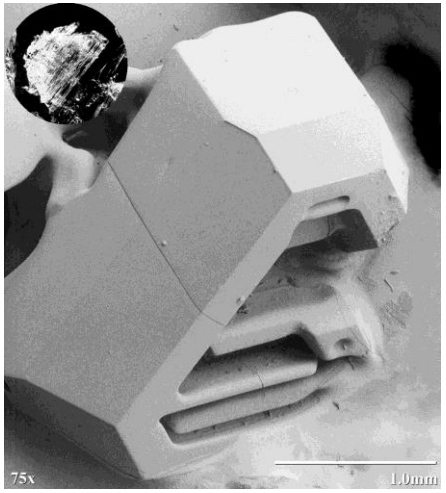


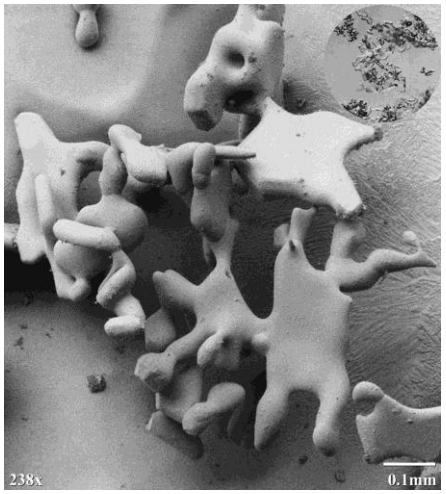
What is needed from models & assimilation?

- 2 key paradigm shifts are needed
  - Users need to participate in sensor requirements derivation. In a risk-adverse, cost-constrained world, "we'll use whatever you give us" is only an acceptable paradigm for the status quo. Don't let data assimilation lull you into false comfort.
  - Models need to get absolute parameter values (e.g., snow depth, SWE) right, not just be satisfied with high anomaly correlations, or compensating for an underprediction in X with an overprediction in Y so that X+Y looks good. The physics implications in nonlinear systems are scary.
- *Careful* validation of "improved" snow products is really important. Using validation data properly takes effort. Anyone can generate a scatter plot and a linear fit of any data. Is that really science?
- A lot of the best validation data is at the point scale. So some real advances are needed wrt scaling. How do we make them, & should we expect those from sensors, models, or both?
- More accurate microwave radiative transfer modeling, especially for radiance-based data assimilation. Microwave sensing is a key part of the multi-sensor approach, and the skill of forward models is a limiting factor. Field measurements are part of the answer.

Microwave radiative transfer modeling of snow

- **Gets to heart of the 30-year snow microwave remote sensing challenge**
- **Much advancement of models in past 10 yrs**
  - All leading models now include multiple layers
  - Grain size/correlation length treatment focus lately
  - Many new field & lab measurement tools
  - Dense medium effects can be explicitly treated
  - Passive & active cases
  - Most models now publicly available
- **Remaining challenges**
  - Validation in the real world
  - Spatial scaling
  - Saturation effects (well known for passive, now radar, too?)
  - Forests





The Snow Mission Outlook

(Your concept goes here)

One definition of insanity

- One definition of insanity is to try the same thing over and over again, while expecting a different outcome.
- Their have been 2 recent snow satellite mission attempts
  - NASA CLPP/SCLP
  - ESA CoReH2O
- Both were SAR-centric.
- Both were unsuccessful. Radar retrieval immaturity was a factor in both cases.
- Multi-sensor retrievals are even less mature.
- What are the next steps?
  - Work on multi-sensor retrievals; build their maturity (need multi-sensor obs w/ground truth)
  - Don't repeat the radar outcome…..again; avoid insanity
  - Explore upcoming leveraging options (next slide)

Future NASA Snow Mission Opportunities

- Decadal Survey 2
  - Exercise is starting; complete in a few years
  - Snow is getting attention lately
  - Tempered by DS1 ratio of 2:17 funded
- Global Ecosystem Dynamics Investigation (GEDI)
  - Lidar to fly on Int'l Space Station
  - Opportunity to try spaceborne lidar
  - Latitude limit of ISS
- Venture Class suborbital missions
  - EVS-2 selections expected November 2014
  - 2 known snow proposals
- Operational Missions
  - Microwave sounders (ATMS)
  - VIS/IR imager (VIIRS)
- Non-NASA missions in US
  - DMSP has one polar orbiter left
  - WindSat can die any day
  - GPM not ideal: has GMI, radar, but non-sun-sync & lat limit

Other Future Snow Mission Opportunities

- ESA: Earth Explorer 9
  - Need to start soon, but what to propose?
- EUMETSAT: MicroWave Imager (MWI)
  - 18-183 GHz more like a conical scan sounder; missing some key freqs for snow
- China: Water Cycle mission
  - Multiple freqs, SAR, & passive mw, but how real and when?
- Japan: GCOM
  - AMSR2 for now; don't expect an AMSR3

Issues to consider:

- Relative mission timeframes to get overlap
- different orbits => different local obs times
- Combining similar obs => intercalibration needed
- Latency needs for operational products

The next steps must consider

- Snow community consensus that a multisensor approach is needed
- Leveraging existing/future sensors & missions, but beware of which are real & which are likely to go away soon
- Integration of these diverse observations how?
- Direct retrieval (of depth or SWE) not required to work everywhere, all the time, for all snow conditions
- Required SWE or depth accuracies for different applications
- Estimate SWE directly from sensor obs or indirectly from depth; and how well do we need to know density to do the latter?
- Validation of “improved” products how?
- How to deal with scale mismatch between forecast model grid cell size and point-scale validation
- Required spatial and temporal resolutions for different applications

Thoughts on snow mission concepts

(My own view, not necessarily NASA's or working group's)

- Must address *Global* snow (this one is also a NASA view)
- Therefore must include multi sensors (community consensus)
  - Active & passive mw, lidar, multi-spectral VIS/IR
- Need mature technology & algorithms
  - SCLP & CoReH2O both suffered on radar algorithms
- Satellite mission must avoid high cost
  - Leverage existing assets (satellite PM & multispectral)
  - But some satellite assets might go away (PM?)
- International partnering is the key to
  - Leveraging technology & algorithm development investments
  - Spreading costs
- Some sensors can/should have suborbital components
  - E.g., Lidar on aircraft and other sensors on satellites
- Societal benefits & science return already strong

Summary

- Lots of progress in the last 1.5 years.
- International snow remote sensing working group (iSWGR) & SCLP/CoReH2O outcomes have generated consensus:
  - A multi-sensor approach is needed
  - Limiting scope of a future snow mission is smart & necessary
  - Affordability requires leveraging & an international approach
- Airborne *multisensor* snow studies are strongly needed over all snow types & confounding factors, with good ground truth. We are observation limited.
- Modeling & assimilation have a role as integrators. In near term, not quite ready for a full OSSE until sensor uncertainties are known, but careful limited-scope questions might benefit from limited experiments.
- Better validation datasets are sorely needed (SNOWPEX?).
- Spatial scaling is a recurring issue; real progress badly needed.
- User community/operational centers need a paradigm shift to fully contribute.
- Some *operational* snow products depend on satellites that will be going away; what will operational centers do?

Int'l snow remote sensing working group

- **What**: a group to foster snow community knowledge & activities related to snow RS; advocacy group for snow RS opportunities
- **Who**: anyone interested in snow remote sensing; international
- **How to join**: email chair,

  Matthew.Sturm@gi.alaska.edu
- **When**: reincarnated 2013
- **URL:** http://nasasnowremotesensing.gi.alaska.edu/

Int'l Snow Remote Sensing Working Group

Recent activities

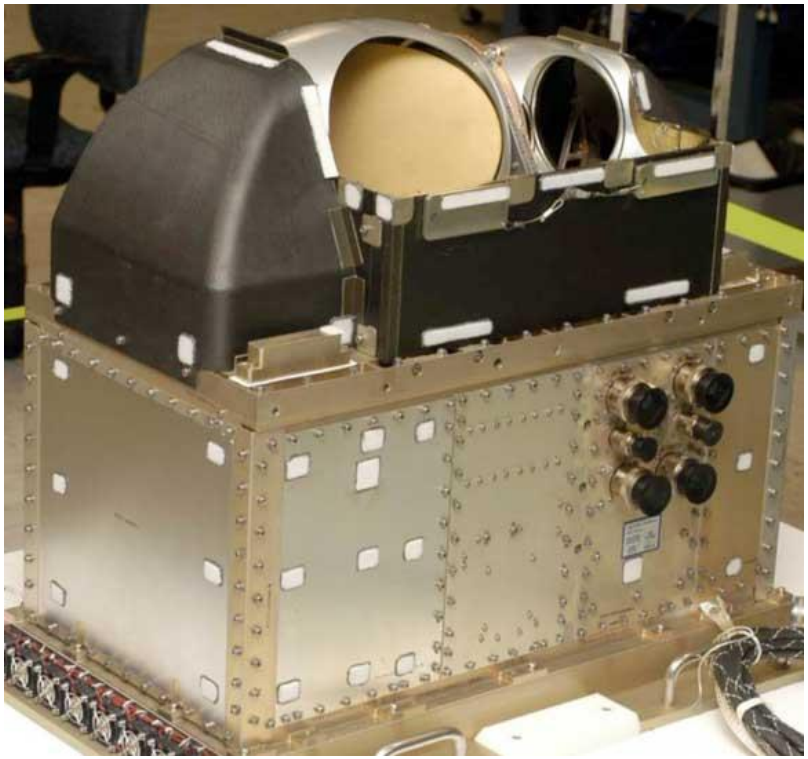
- Town hall meeting: AGU 2012
- Open workshops: Aug 2013, Jan 2014
- Strong international participation
- Field measurement school: Jan 2014 (Colorado USA)
- Modeling school: summer 2014
- Website

Upcoming activities

- 'Town hall' meeting: AGU 2014
- 2 Field measurement schools: early 2015
  - Sherbrooke, Canada
  - Sodankylä, Finland
- Decadal survey 2: white paper in progress
- Repeat modeling school?
- Add remote sensing school?

ATMS microwave sounder status

- ATMS on S-NPP celebrated 3-year mark last week, & is performing well
- ATMS for JPSS-1 is being assembled; known issues are being fixed!
- JPSS-1 launch early 2017
- JPSS-2 launch 2021
- Discussions underway **now** on improvements to J2+; what is on your wishlist? Speak now or you'll get nothing new until 2030 !



http://npp.gsfc.nasa.gov/atms.html