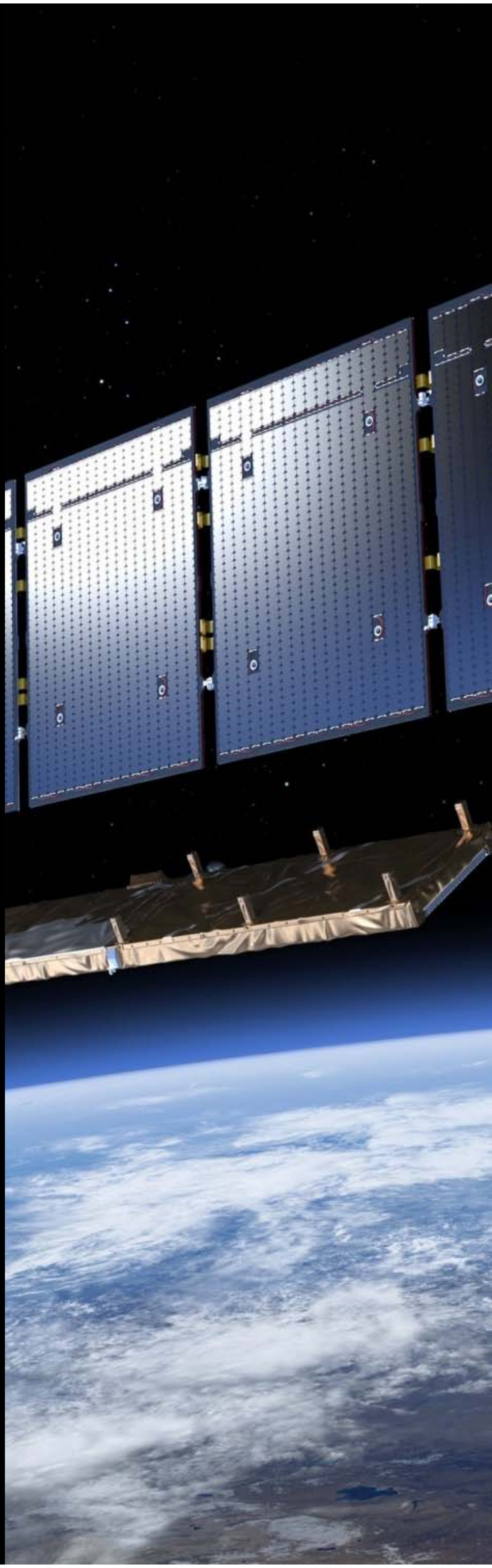
Snow Cover Monitoring

Dr. Tarendra Lakhankar



In this lecture:

- Information on the snow cover : Why do we need it
- History of snow remote sensing
- Interactive snow cover mapping
- Physical principles of automated snow detection
    - Visible and infrared
    - Microwave
- Available snow products
- Application of snow data

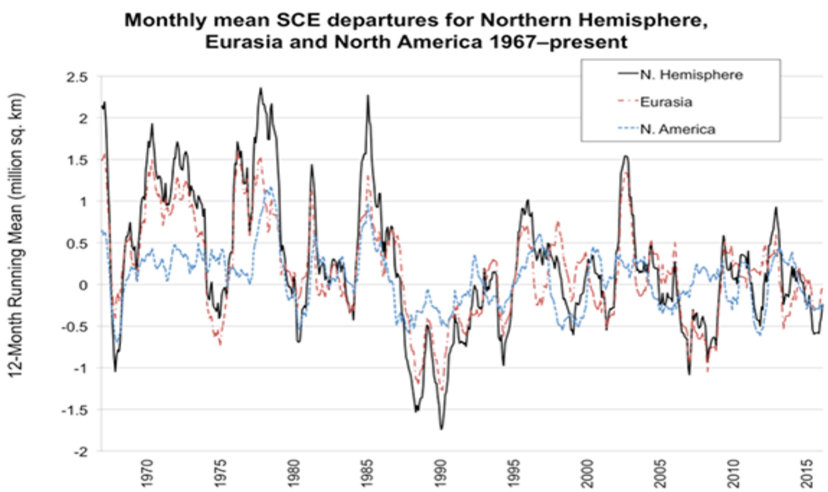
Snow cover: Facts

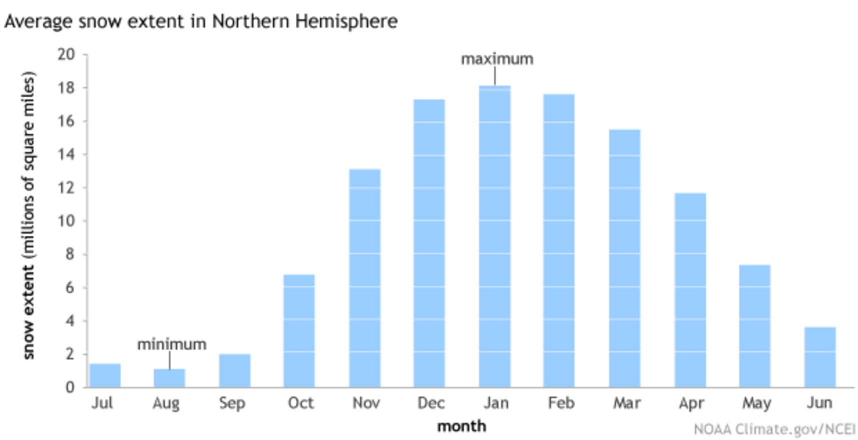
- About 77% of Earth's freshwater is frozen
- Snow cover (seasonal and perennial)
  - Affects about 30% of land area
    Northern Hemisphere ~ 40 million km^2
    Southern Hemisphere ~ 6.5 million km^2
- Glaciers and Ice Sheets
  - About 10% of land area
- Snow cover controls
  - Albedo, surface temperature
  - Heat fluxes
  - Water balance

Snow melt in Greenland

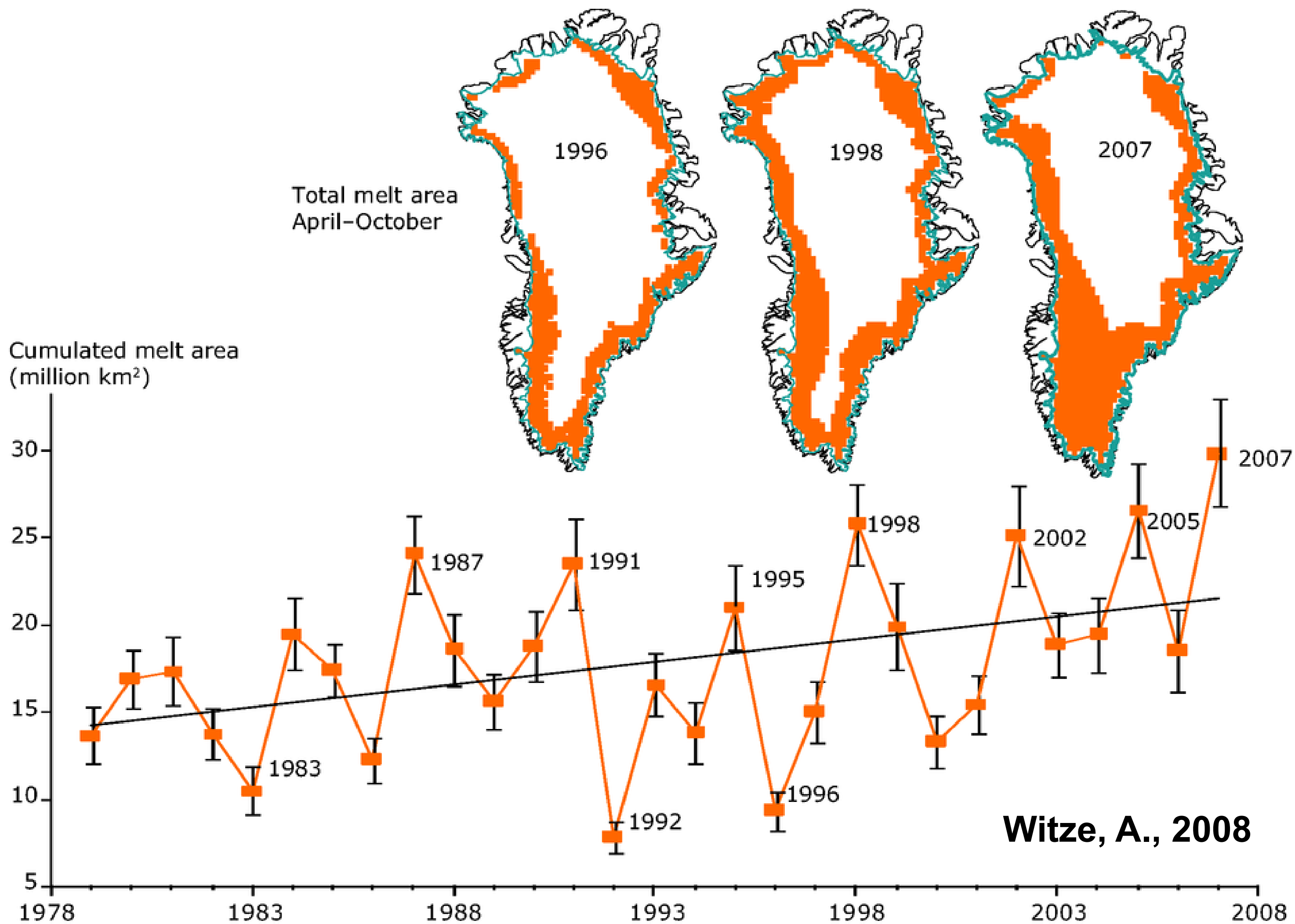
Snow cover variations and trends

- **Snow cover varies at different temporal scales**
- Short-term (daily) variations:
  - Daily changes of the snow extent may amount to thousands km^2
  - Snow cover boundary can change its position by hundreds km a day
- Seasonal variations
  - Northern Hemisphere: Winter snow extent decreases by ~ 95% in summer
- Long-term trends
  - Snow melt occurs earlier in the year
  - Seasonal snow cover duration decreases (~ 2 days per decade average)
  - Most glaciers demonstrate retreat in the last 30 years





Greenland Ice Melt



Ice melt in Greenland has been gradually increasing in the last 30+ years

Study and monitor snow cover: Why ?

Snow is an important factor for

- Transportation
- Hydro-power generation
- Agriculture
- Wildlife
- Recreation
- Public water supply

NOAA needs information on snow to

- Predict weather
- Monitor climate change
- Make hydrological forecasts, issue flood warnings

Uses for Snow Cover Data

Time scale	Applications	Users

Days	Daily weather forecasting, hydrology, transportation:
	• Forecasting:
	  • High and low temperatures
	  • Low clouds and fog development
	  • Storm snowfall, road icing, blowing snow potential
	• Trends in snowpack conditions
	• Avalanche risk assessment
	• Runoff, rapid snow melt, and flooding potential
	• Recreation
		• Meteorologists in snow affected areas
		• Numerical weather and hydrologic prediction
		• Hydrologists
		• Transportation and commerce
		• Emergency managers
		• Search and rescue
		• Power industry
		• Recreation

Weeks	Forecasting, monitoring, managing: • Trends in snowpack conditions • Estimating spring runoff and water resources • Watershed management • Surface water for vegetation, crops, and humans • Potential hazards including floods, droughts, and fires • Large-scale runoff • Hydroelectric power generation • Recreation	• Hydrologists and climatologists • Numerical weather, climate and hydrologic prediction • General circulation modeling • Forest managers • Agriculture • Power industry • Recreation
Years	Monitoring global snow coverage for: • Global and regional climate trends • Long-term climate monitoring and prediction • Global energy distribution • Water resource management	• Climate modeling, prediction and research • General circulation modeling • Transportation and commerce

Snow Cover: What Parameters We Need

For weather and climate analysis

- Snow extent and snow depth/snow water equivalent
- Daily updates, spatial continuity (no gaps in coverage)
- Continental or global scale coverage
- 1-4 km resolution

For water management / hydrological studies

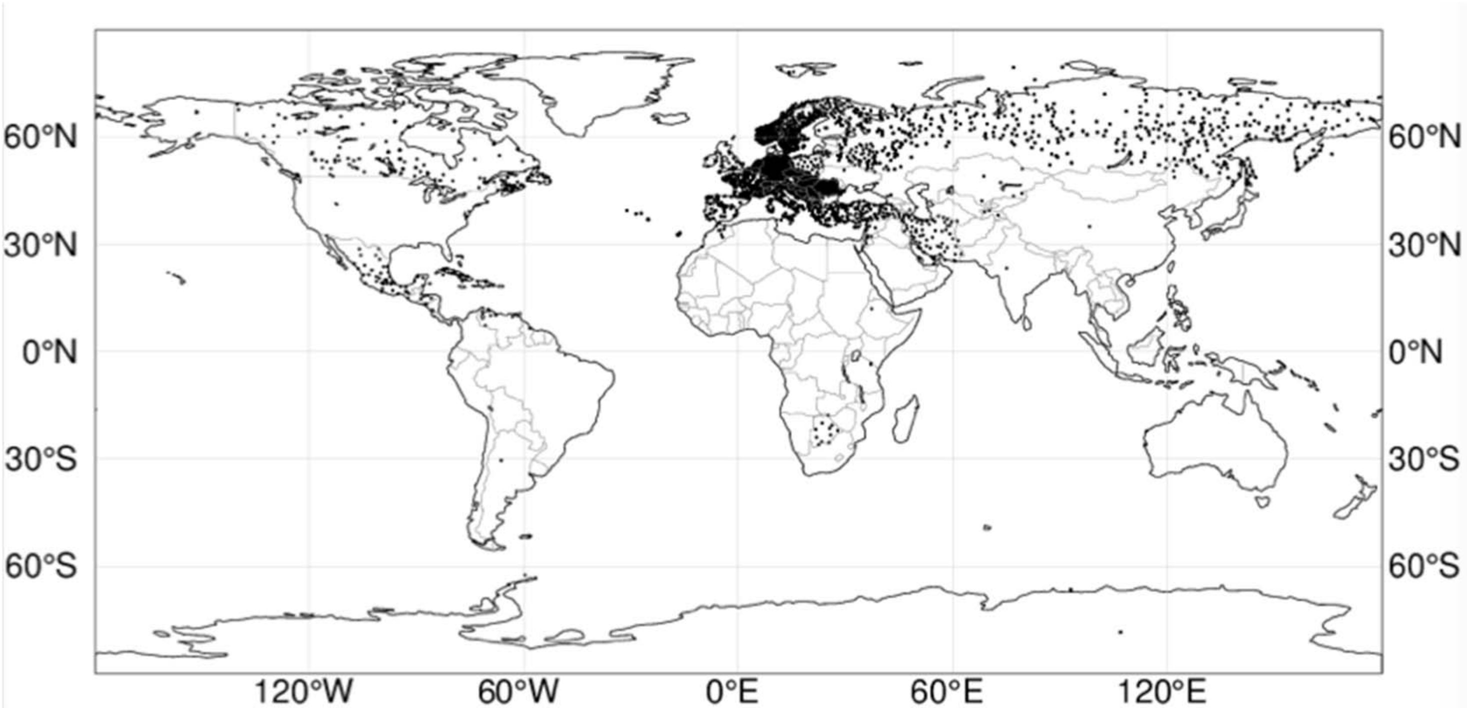
- Maximum snow accumulation prior to snowmelt begins
- Updates everyone to several days during snowmelt period
- < 1 km spatial resolution, watershed coverage

For glacier studies

- Minimum yearly snow extent
- 10-20 m spatial resolution
- Yearly updates

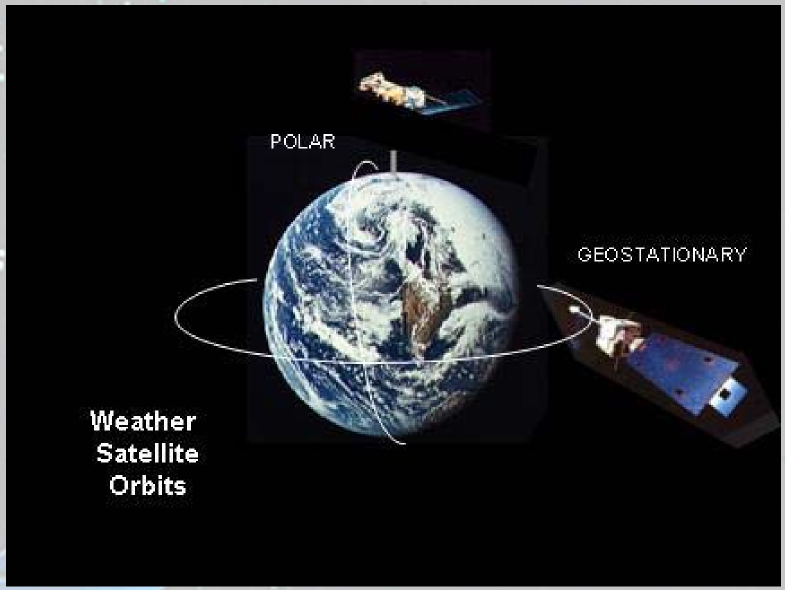
Weather satellites can not be used due to coarse spatial resolution

Snow reports from ground stations



- Snow depth is routinely observed at ground-based synoptic stations
- Observation data are delivered to national weather centers
- However the ground station network is sparse in many regions
- Some countries (e.g., China) do not release information on the snow depth at all
- There very few reports coming from South America

Why use satellites to study snow cover ?



Weather satellites provide

- Global observations
  - Help to monitor snow in remote areas

+

- Frequent revisits
  - Timely capture changes in the snow cover distribution

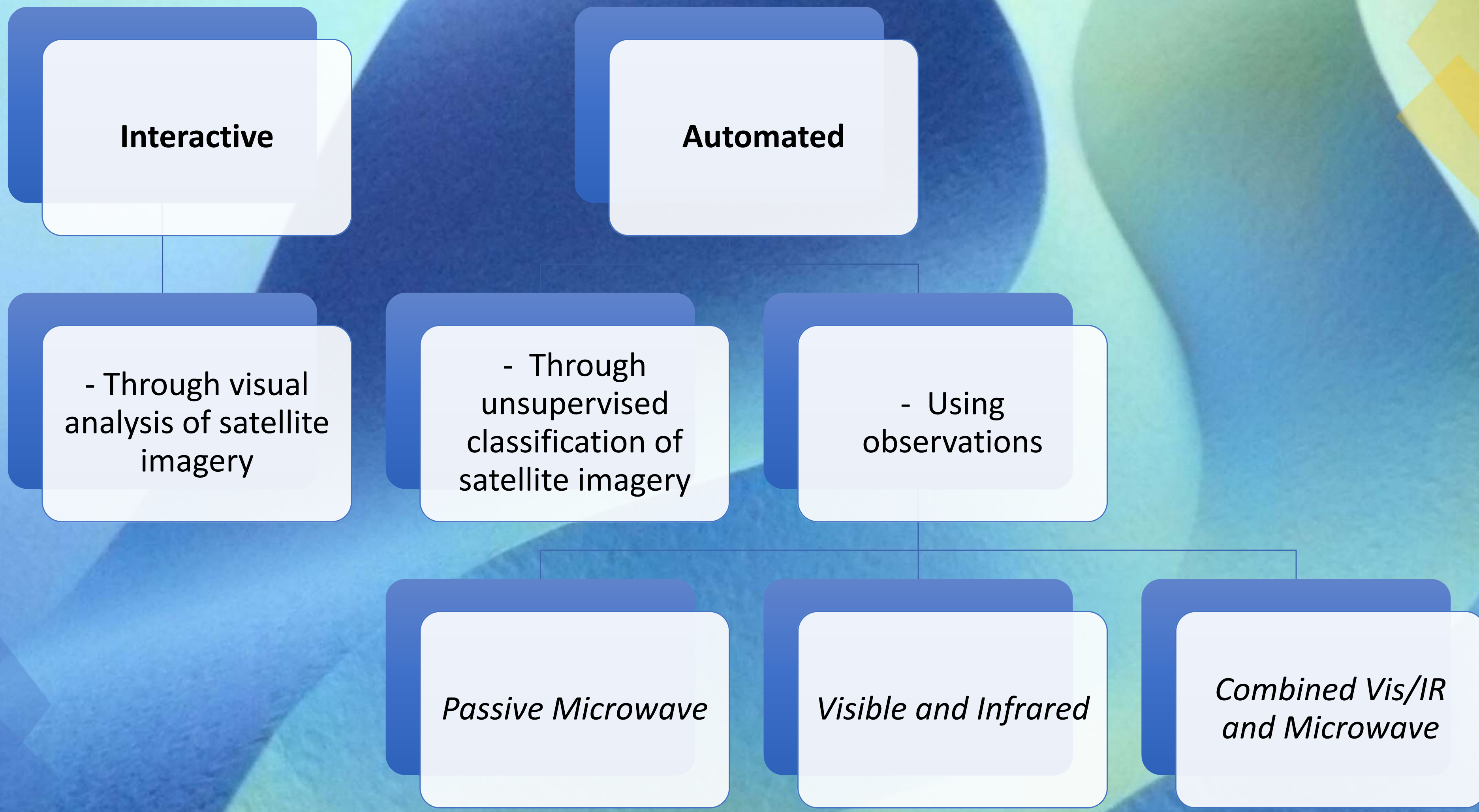
+

- High and uniform spatial resolution
  - Provide spatially detailed characterization of the snow cover

` **+**

- Over 30 years worth of data
  - Can be used to study climate change

Two approaches to extract information on snow from satellite data



Interactive mapping of snow cover

One of NOAA's signature products

The oldest quantitative satellite product:

- First charts produced at NOAA in 1966
- Routine mapping since 1972
- Product generation is ongoing

Snow cover charting 1972 - 1997

1972-1997

Product characterizes snow extent in the Northern Hemisphere

Snow charts were produced manually by analysts, who would

- Examine satellite imagery (photo copies)

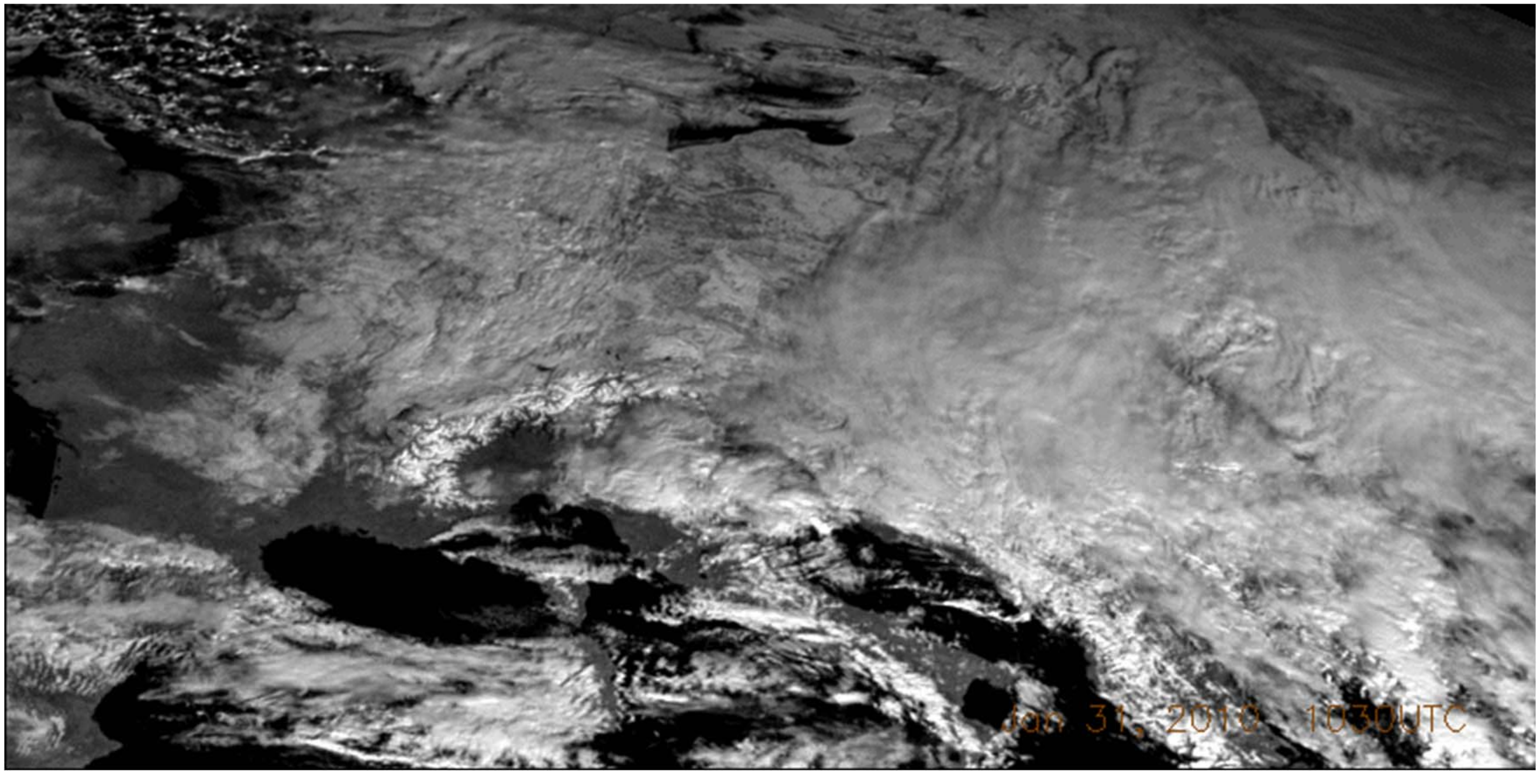
- Draw maps of snow and ice cover by hand on paper

- Digitize the charts over a 89x89 pixel grid

Snow charts were produced weekly
Spatial resolution was about 200 km

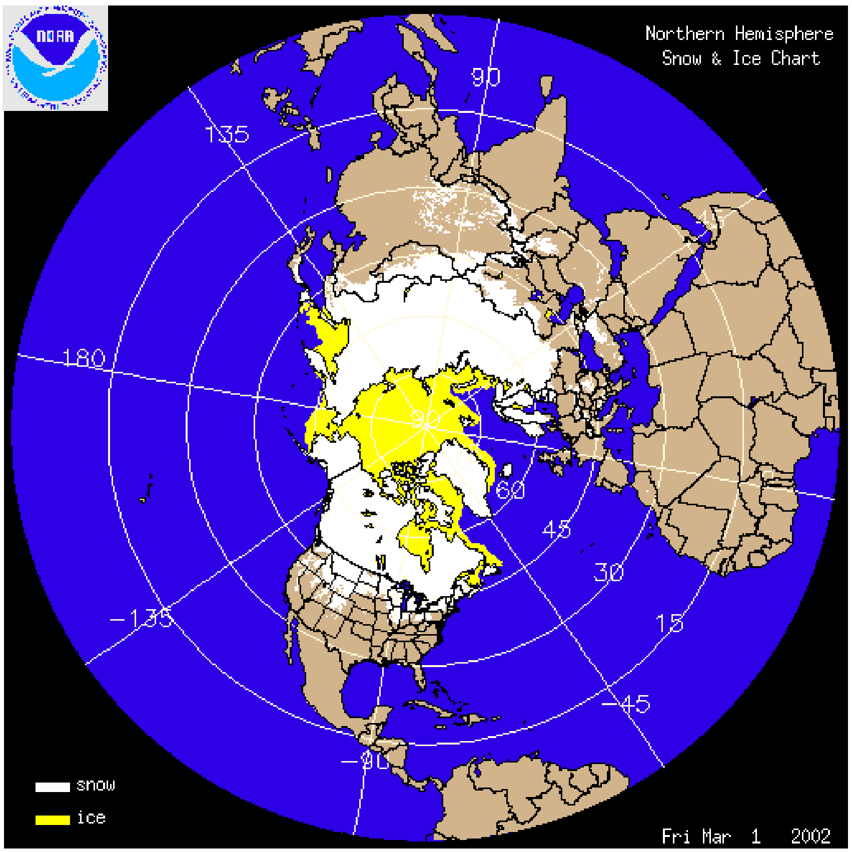
On the Web: http://www.natice.noaa.gov/ims/

Animation: Easier to Identify Snow



Animations with imagery from geostationary satellites started to be used for interactive snow mapping in mid-1990s.

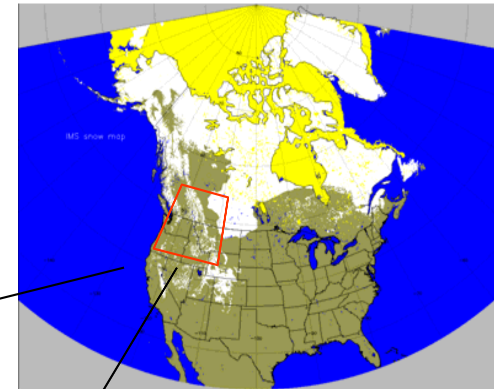
Since 1997: Interactive Multisensor Snow and Ice Mapping System (IMS)



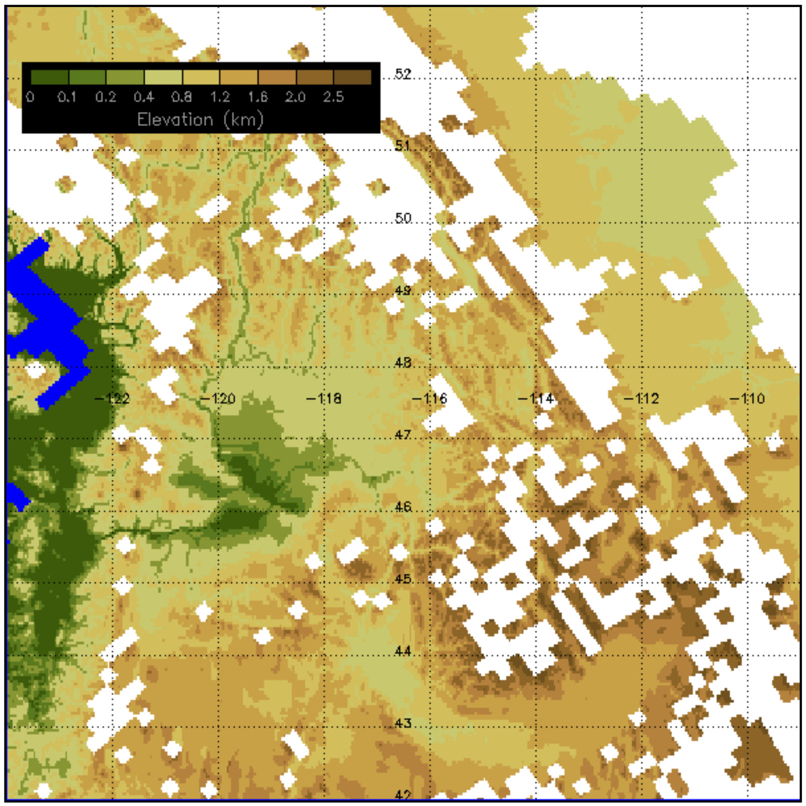
On the Web: http://www.natice.noaa.gov/ims/

- Computer-based image analysis and product generation system for interactive snow and ice mapping was introduced in 1997
- Spatial resolution gradually improved
  - 24 km in 1997
  - 4 km in 2004
  - 1 km in 2015
- Analysts have access to
  - Satellite Images
  - Automated satellite products
  - Model output
  - Ground-based observations
  - Live web cameras

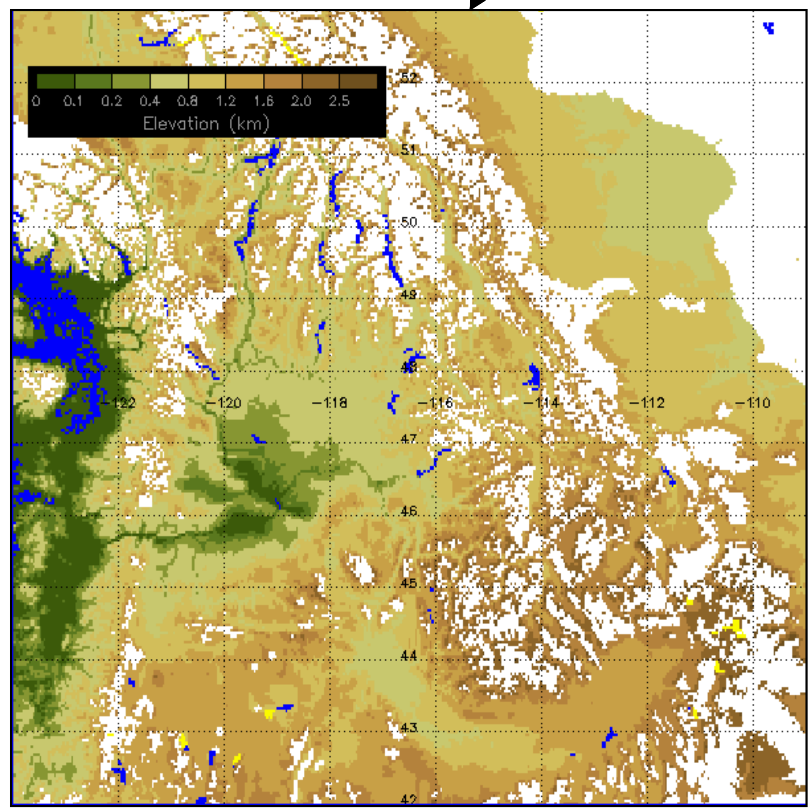
IMS Snow Map: 4 km since 2004



Higher spatial resolution of snow maps is needed to better reproduce snow cover in the mountains



24 km resolution (1998-2004)



4 km resolution (2004-2015)

Remote Sens. **2012**, *4*, 1134-1145; doi:10.3390/rs4051134

OPEN ACCESS

Remote Sensing

ISSN 2072-4292

www.mdpi.com/journal/remotesensing

Article

Validation of NOAA-Interactive Multisensor Snow and Ice Mapping System (IMS) by Comparison with Ground-Based Measurements over Continental United States

Christine Chen [1,2], Tarendra Lakhankar [1,*], Peter Romanov [1], Sean Helfrich [3], Al Powell [4] and Reza Khanbilvardi [1]

[1] NOAA-Cooperative Remote Sensing and Technology Center (NOAA-CREST), New York, NY 10031, USA; E-Mails: cchen18@ccny.cuny.edu (C.C.); peter.romanov@noaa.gov (P.R.); khanbilvardi@ccny.cuny.edu (R.K.)

[2] Byrd Polar Research Center, The Ohio State University, Columbus, OH 43210, USA

[3] National Ice Center, NOAA, Washington, DC 20395, USA; E-Mail: Sean.Helfrich@noaa.gov

[4] Center for Satellite Application and Research, NOAA, Washington, DC 20395, USA; E-Mail: Al.Powell@noaa.gov

* Author to whom correspondence should be addressed; E-Mail: tlakhankar@ccny.cuny.edu; Tel.: +1-212-650-5815; Fax: +1-212-650-8097.

Received: 3 March 2012; in revised form: 17 April 2012 / Accepted: 17 April 2012 / Published: 25 April 2012

Abstract: In this study, daily maps of snow cover distribution and sea ice extent produced by NOAA's interactive multisensor snow and ice mapping system (IMS) were validated using *in situ* snow depth data from observing stations obtained from NOAA's National Climatic Data Center (NCDC) for calendar years 2006 to 2010. IMS provides daily maps of snow and sea ice extent within the Northern Hemisphere using data from combination of geostationary and polar orbiting satellites in visible, infrared and microwave spectrums. Statistical correspondence between the IMS and *in situ* point measurements has been evaluated assuming that ground measurements are discrete and continuously distributed over a 4 km IMS snow cover maps. Advanced Very High Resolution Radiometer (AVHRR) land and snow classification data are supplemental datasets used in the further

Hindawi

Journals | Publish with us | Publishing partnerships | About us | Blog

Advances in Meteorology

Journal overview | For authors | For reviewers | For editors | Table of Contents | Special Issues

Advances in Meteorology / 2020 / **Article**

On this page

Research Article | Open Access
Volume 2020 | Article ID 4532478 | 10 pages | https://doi.org/10.1155/2020/4532478

Intercomparison and Validation of MIRS, MSPPS, and IMS Snow Cover Products

Jessica Chiu,[1] Stephany Paredes-Mesa,[1,2] **Tarendra Lakhankar**,[1] Peter Romanov,[1,3] Nir Krakauer,[1] Reza Khanbilvardi,[1] and Ralph Ferraro[3]
Show more

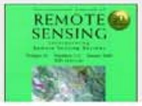
Academic Editor: Hiroyuki Hashiguchi

Received	Revised	Accepted	Published
16 Oct 2019	03 Feb 2020	11 Feb 2020	23 Mar 2020

PDF
Download Citation
Download other formats
Order printed copies

Abstract

We evaluate the agreement between automated snow products generated from satellite observations in the microwave bands within NESDIS Microwave Integrated Retrieval System (MIRS) and Microwave Surface and Precipitation Products System (MSPPS), on the one hand, and snow cover maps produced with manual input by the NOAA's Interactive Multisensor Snow and Ice Mapping System (IMS), on the other. MIRS uses physically based retrievals of atmospheric and surface state parameters to provide daily global maps of snow cover and snow water equivalent at 50 km resolution. The older MSPPS delivers daily global maps at the spatial resolution of 45 km and utilizes mostly simple empirical algorithms to retrieve information. IMS daily maps of snow and sea ice cover for the Northern Hemisphere are produced interactively through the analysis of satellite imagery in the visible, infrared, and microwave spectral bands. We compare the performances of these products across the Northern Hemisphere for 2014–2017, using IMS as the standard. In this intercomparison, the daily overall agreement of the automated snow products with IMS ranges between 88% and 99% for MIRS and 87% and 99% for MSPPS. However, daily snow sensitivity is lower, ranging between 36% and 90% for MIRS and 26% and 91% for MSPPS. We analyze this disagreement rate as a function of terrain and land cover type, finding that, relative to IMS, MIRS shows fewer false positives but more false negatives than MSPPS over high elevation and grassland



Journal
International Journal of Remote Sensing ›
Volume 38, 2017 - Issue 16

Articles

Evaluation of MODIS land surface temperature with *in-situ* snow surface temperature from CREST-SAFE

Carlos L. Pérez-Díaz, Tarendra Lakhankar, Peter Romanov, Jonathan Muñoz, Reza Khanbilvardi & Yunyue Yu

Pages 4722-4740 | Received 11 Dec 2015, Accepted 10 May 2017, Published online: 23 May 2017

Download citation https://doi.org/10.1080/01431161.2017.1331055 Check for updates

ABSTRACT

This article presents the procedure and results of a temperature-based validation approach for the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (LST) product provided by the National Aeronautics and Space Administration Terra and Aqua Earth Observing System satellites using *in-situ* LST observations recorded at the Cooperative Remote Sensing Science and Technology Center – Snow Analysis and Field Experiment (CREST-SAFE) during the years of 2013 (January–April) and 2014 (February–April). A total of 314 day-and-night clear-sky thermal images, acquired by the Terra and Aqua satellites, were processed and compared to ground-truth data from CREST-SAFE with a frequency of one measurement every 3 min. CREST-SAFE is a synoptic ground station, located in the cold county of Caribou in Maine, USA, with a distinct advantage over most meteorological stations because it provides automated and continuous LST observations via an Apogee Model SI-111 Infrared Radiometer. This article also attempts to answer the question of whether a single pixel (1 km^2) or several spatially averaged pixels should be used for satellite LST validation by increasing the MODIS window size to 5 × 5, 9 × 9, and 25 × 25 windows.

Advantages and weaknesses of interactive snow mapping

- Straight-forward: easy to train analysts
- Robust, maps are quality-controlled
- Easy to implement, many sensors available

BUT

- Labor intensive
- Subjective factors may affect the accuracy
  - Analyst experience, attentiveness
- Does not (can not) use full potential of satellite data

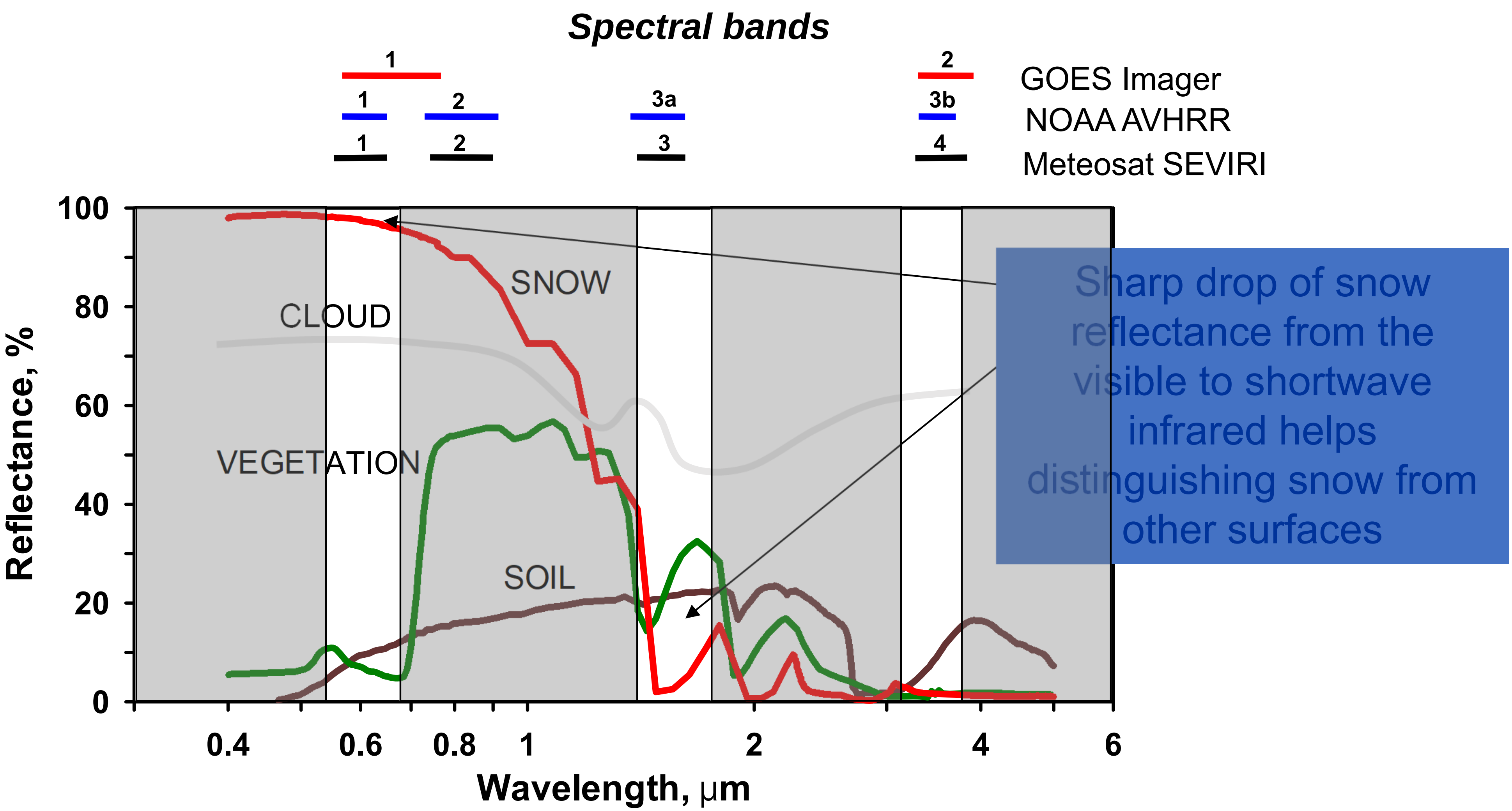
Automated snow mapping techniques

- **Advantages:**
- Less labor demanding/more cost effective
- Can more efficiently utilize instrument capabilities

  - Multiple spectral bands, high spatial resolution, frequent updates.
- Other characteristics of snow can be derived
- Allow for consistent reprocessing of historical data

Snow identification in the visible and infrared

Spectral reflectance: Snow vs Clouds, etc.



Minimal set of spectral measurements for automated mapping snow cover includes visible (0.6 µm), shortwave or middle infrared (within 1.6 µm to 3.7 µm) and thermal infrared (11 µm). Most current satellite sensors do have these bands.

Snow spectral reflectance indices

Normalized difference snow index:

$$NDSI = (R_{vis} - R_{swir}) / (R_{vis} + R_{swir})$$

Snow index:

$$SI = R_{vis} / R_{swir}$$

where R_{vis} is observed reflectance in the visible band (0.6 µm)

R_{swir} is observed reflectance in the shortwave infrared band (1.6µm)

- Large NDSI and/or SI is indicative of snow
- NDSI and SI can also be used for ice detection since spectral features of ice are similar to the ones of snow
- Information on the surface temperature in thermal infrared is used for more reliable snow identification

VIS/IR: Basic snow detection algorithm

Very simplified since:

-Reflectance depends on geometry of observations

- Surface reflectance changes with surface type

- Snow reflectance depends on snow physical properties (e.g. grain size, impurities)

- Vegetation tends to mask snow

- Threshold values are instrument specific

IF

$NDSI > NDSI^T$

$SI > SI^T$

$R_{0.6} > R_{0.6}^T$; visible test

$R_{1.6} < R_{1.6}^T$; shortwave IR test

$T_{11} < T_{11}^T$; IR test

→ **SNOW**

^{T} threshold value

ELSE → **CLOUD or LAND**

NASA Algorithm:

Cloud masking sometimes performed before snow detection

NDSI threshold depends on NDVI

$NDVI=(R_{0.9}-R_{0.6})/(R_{0.9}+R_{0.6})$ normalized difference vegetation index

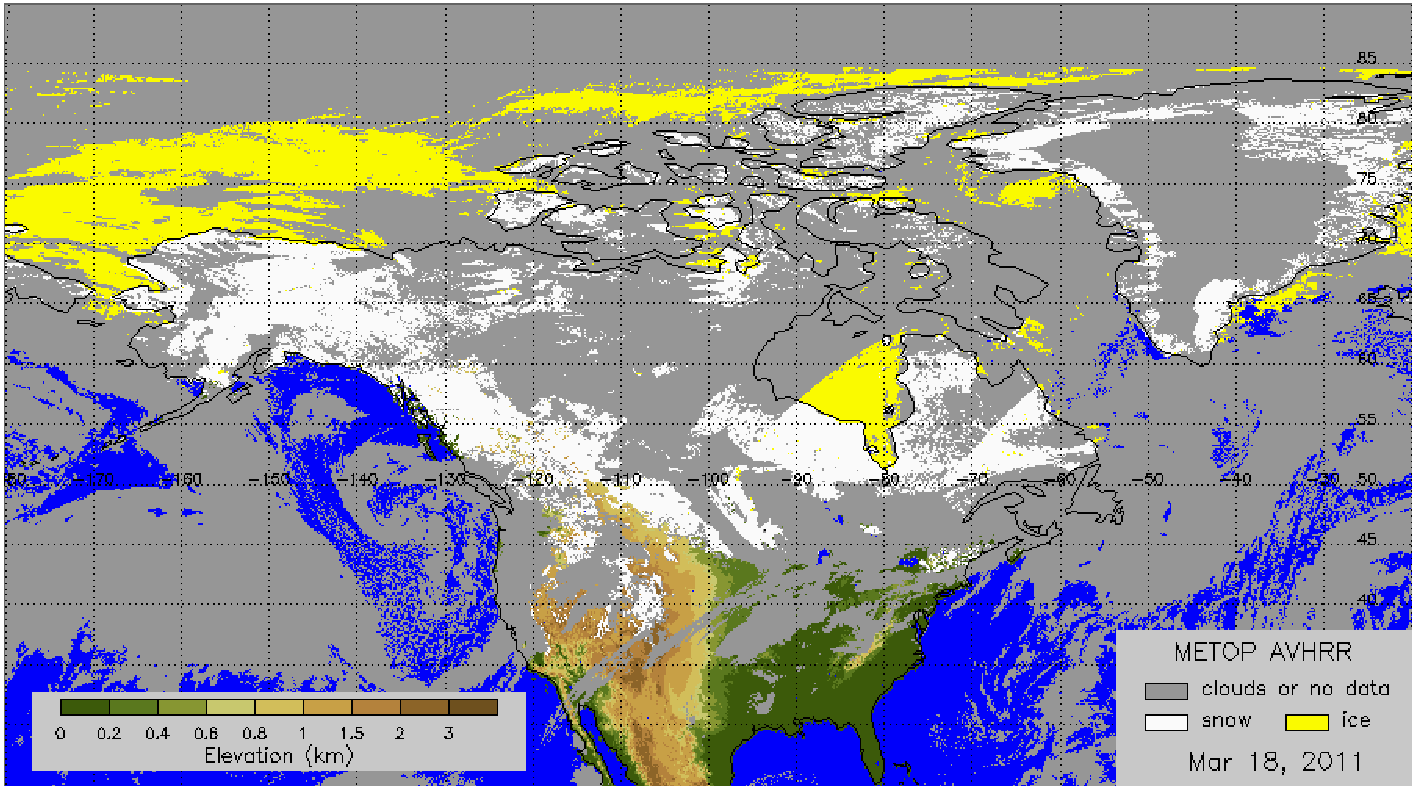
Features of snow and ice maps derived from visible and infrared imagery

High spatial resolution (0.5 – 1 km)

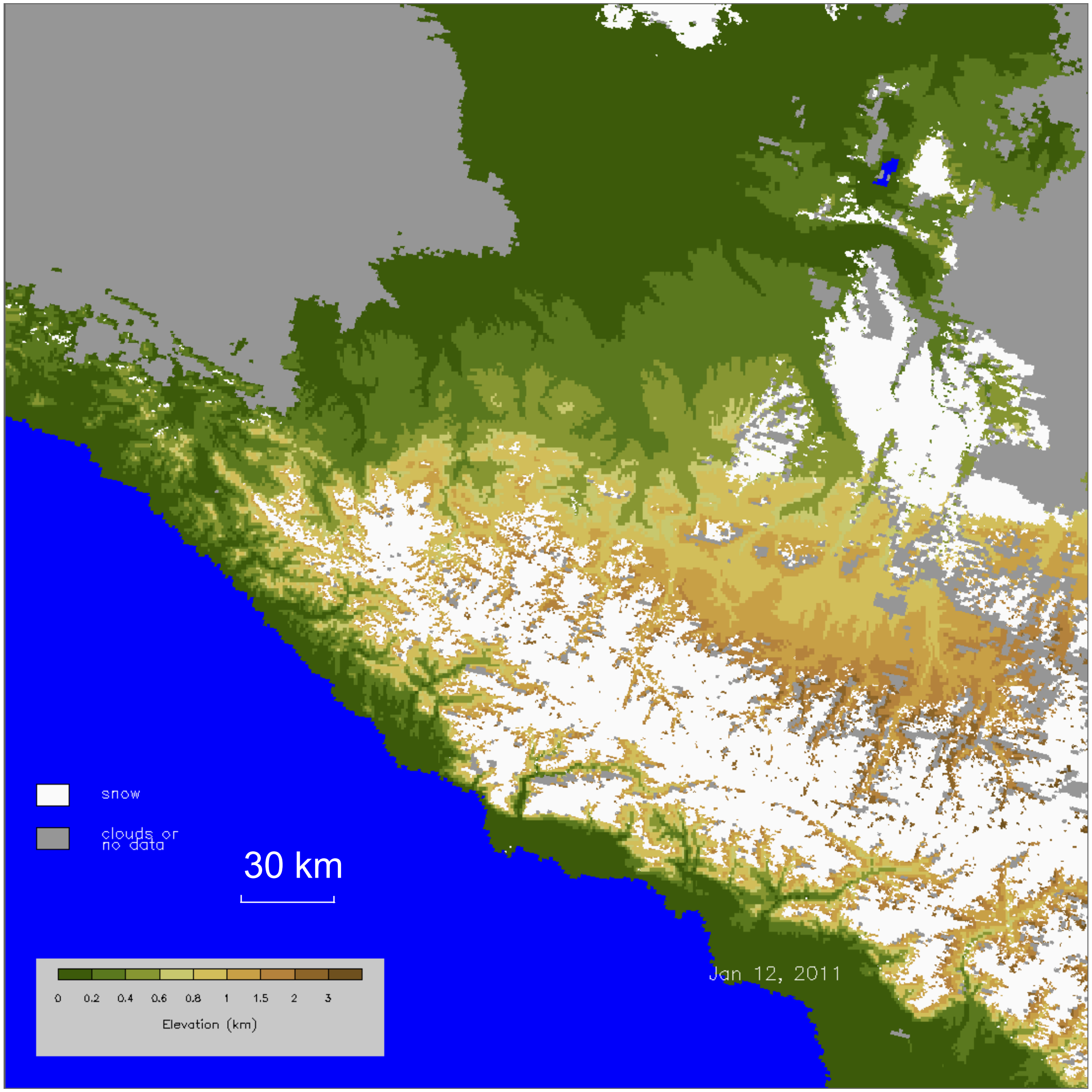
High accuracy: 95-97% of snow is mapped correctly

Clouds typically affect 50-60% of the land area

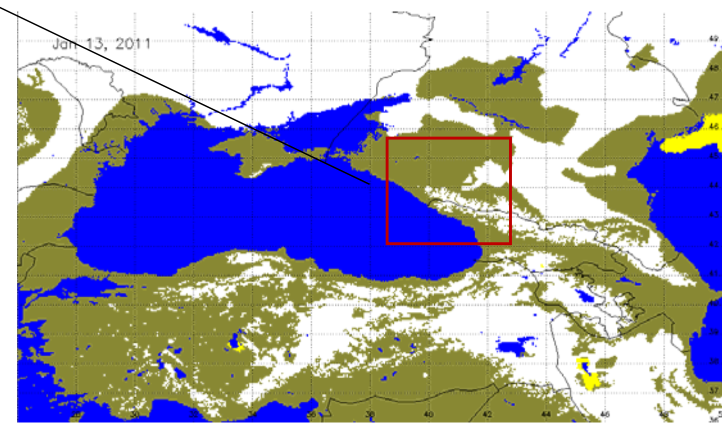
Because of gaps these products are hard to use in models



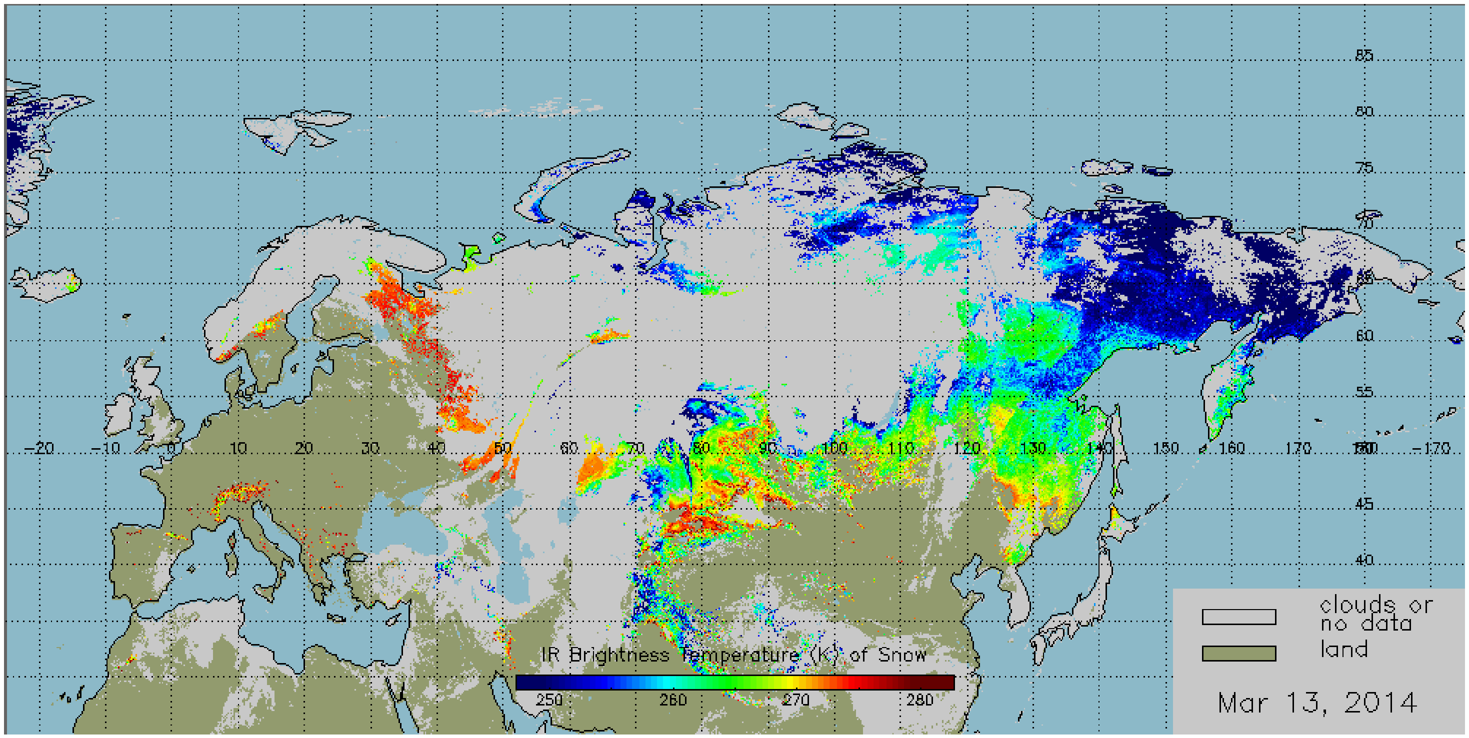
MODIS snow maps



- Global coverage
- 2 times per day (Terra and Aqua satellites)
- 500 m resolution
- Affected by clouds (gray)
- Similar maps are generated from VIIRS NPP since 2012



Snow Temperature

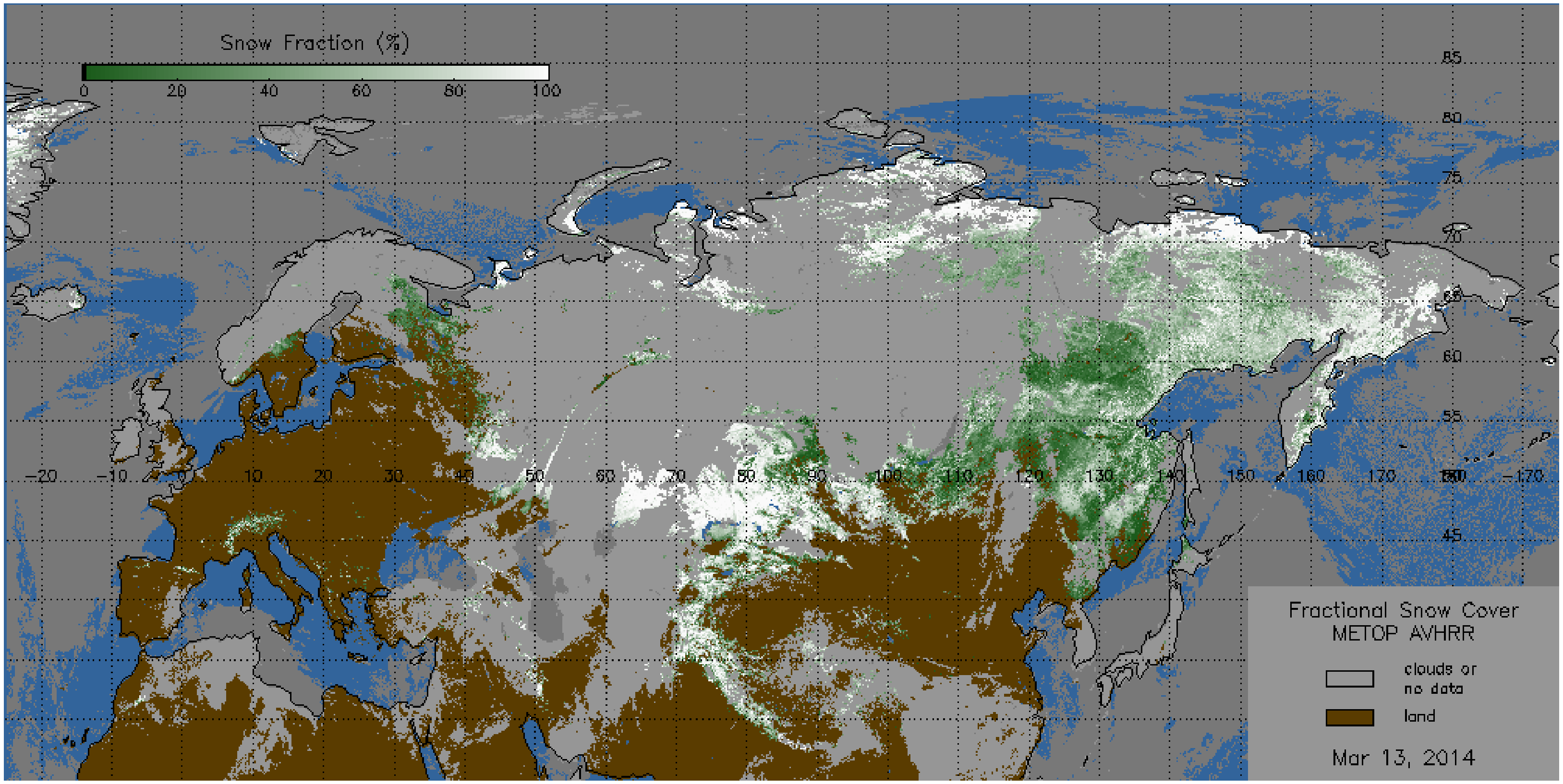


Surface temperature data combined with the snow map help to identify areas of snowmelt.

Snow cover at T>273 indicates snowmelt. Most snowmelt occurs at the snow cover boundary

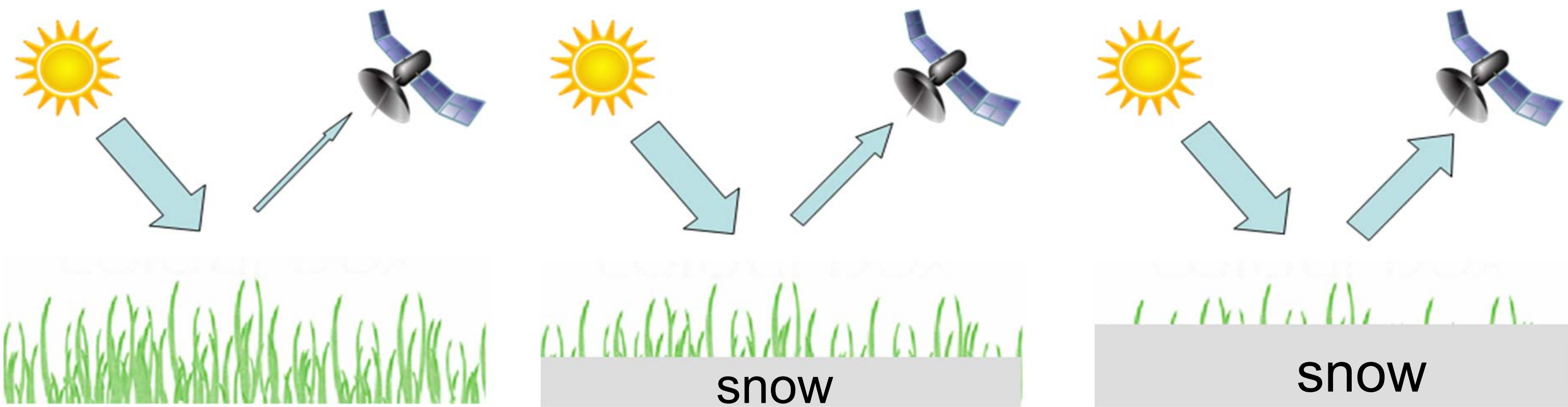
In the map snow melt areas are shown in red

Snow Fraction



High sensitivity of observed reflectance to the presence of the snow cover allows for estimating **what fraction of satellite pixel is covered with snow**. Information on the snow cover fraction is needed to properly determine the land surface albedo for numerical weather prediction models.

Snow Depth from Observed Reflectance

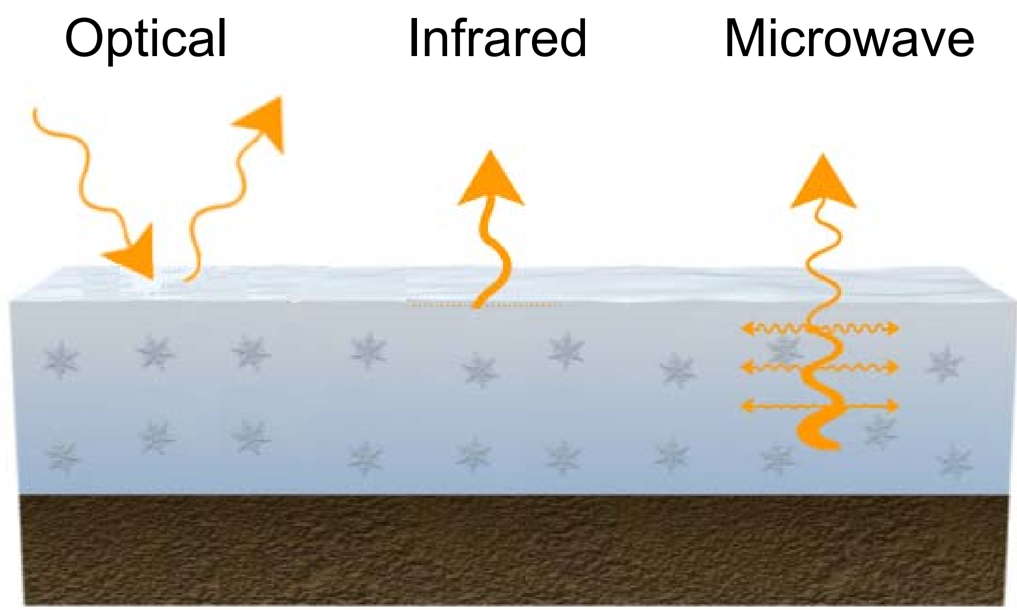


<u>There are some potentials to infer snow depth from visible reflectance</u>

- Deeper snow packs mask more of land surface features (e.g., grass)
- This increases land surface reflectance in the visible band
- Particular relationship between the snow depth and reflectance is established empirically
- This approach is not applicable over forested areas

Snow remote sensing in the microwave

Microwave: The way to "look" inside the snowpack



Formation of upwelling radiation in the optical (visible, near infrared), infrared and microwave spectral range

Optical and infrared radiation from the snow pack is determined by physical properties of the very top layer (0.5-1 cm) of the snow pack

Upwelling microwave radiation is emitted by the sub-snow surface and scattered by the snow pack.

Therefore it carries information on the physical properties of the whole snow pack.

Microwave: Spectral bands for snow remote sensing

Spectral range from 10 to 100 GHz is (3 cm to 0.3 cm) is most efficient for snow remote sensing.

Most sensors have spectral bands centered at 10, 19, 22, 37 and 85 GHz

SSMI spectral bands

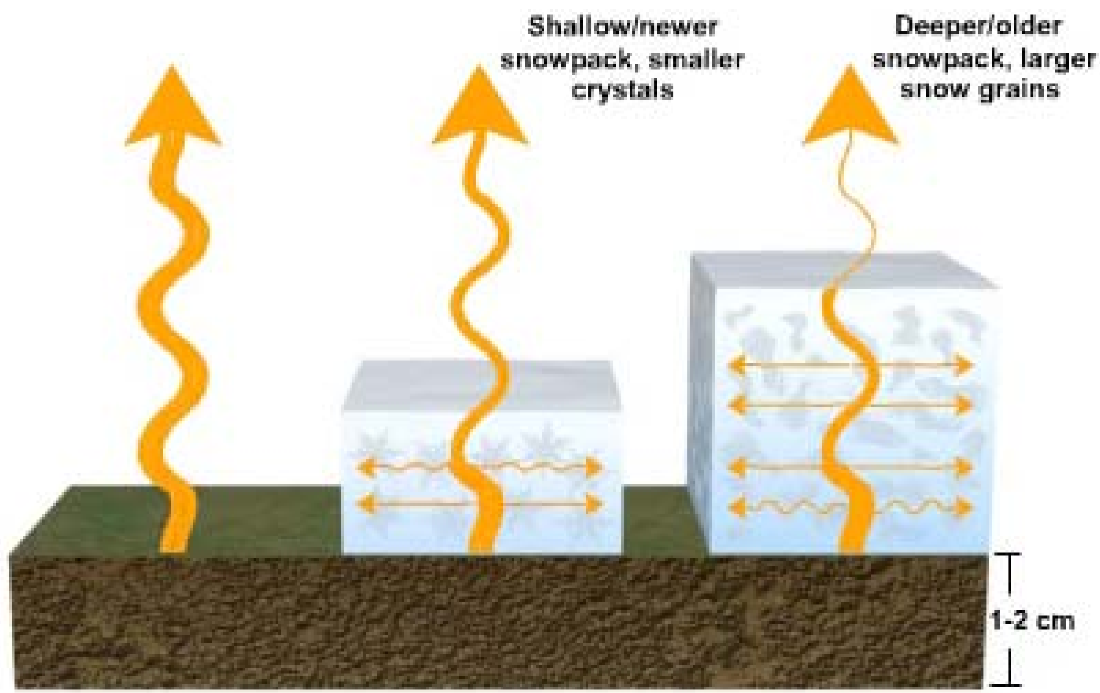
Band	Frequency (μm)	Polarization	Pixel size (km)
1	19.35	Horizontal	69 x 43
2	19.35	Vertical	69 x 43
3	22.35	Vertical	50 x 40
4	37.0	Horizontal	37 x 28
5	37.0	Vertical	37 x 28
6	85.5	Horizontal	15 x 13
7	85.5	Vertical	15 x 13

Microwave radiation is emitted by the top 1-2 cm layer of soil

Dry snow only scatters microwave radiation

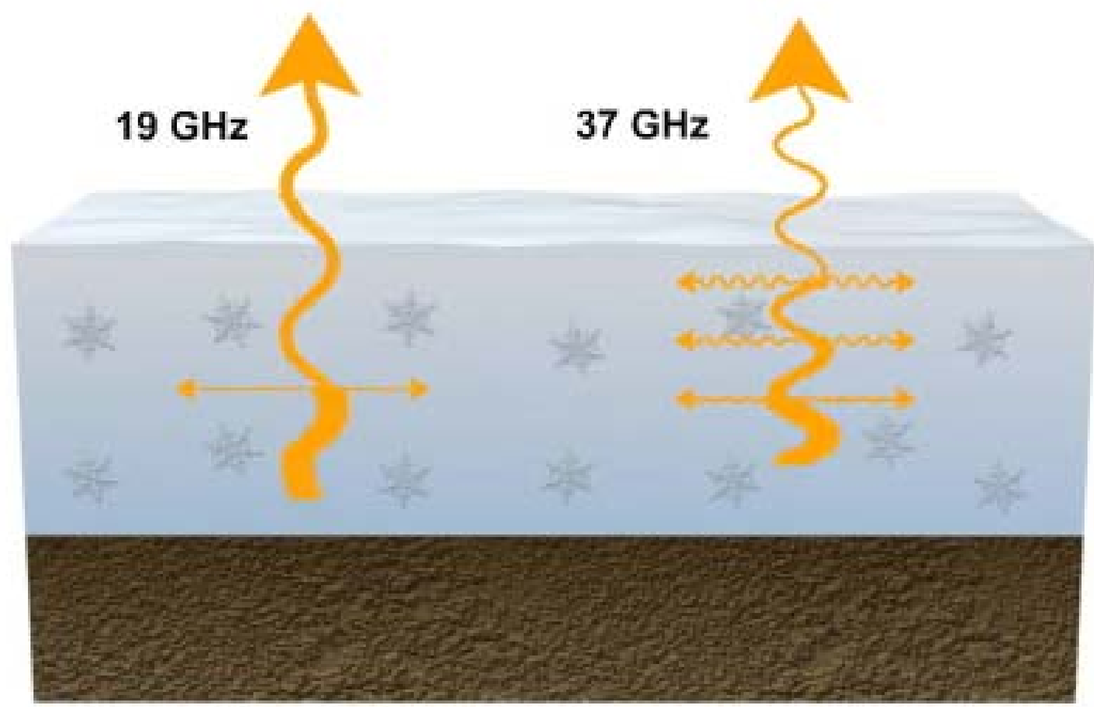
Scattering by snow increases with snow depth and/or snow grain size.

This feature makes possible estimating snow depth or snow water equivalent from satellite observations in the microwave.



At larger frequencies scattering of radiation in snow increases and brightness temperature decreases.

Negative gradient of the brightness temperature is primary indicator of snow on the ground.



CREST-SAFE: Snow Experiment Site

CREST-Snow Analysis and Field Experiment (CREST-SAFE) is located on the premises of National Weather Service office at Caribou, ME provides manual and automated snow measurements.

2015

Weather sensor (precipitation, visibility)

2014

Snow Wetness profiler
GMON3 SWE Sensor

19 and 10.65 GHz Radiometers
CIMEL Sun Photometer (BRDF)

2013

Infrared Thermometer
(Skin Temperature)
Snow Depth Sensor
Radiation Sensors
Wind Speed/Direction, Humidity/ air temperature

2012

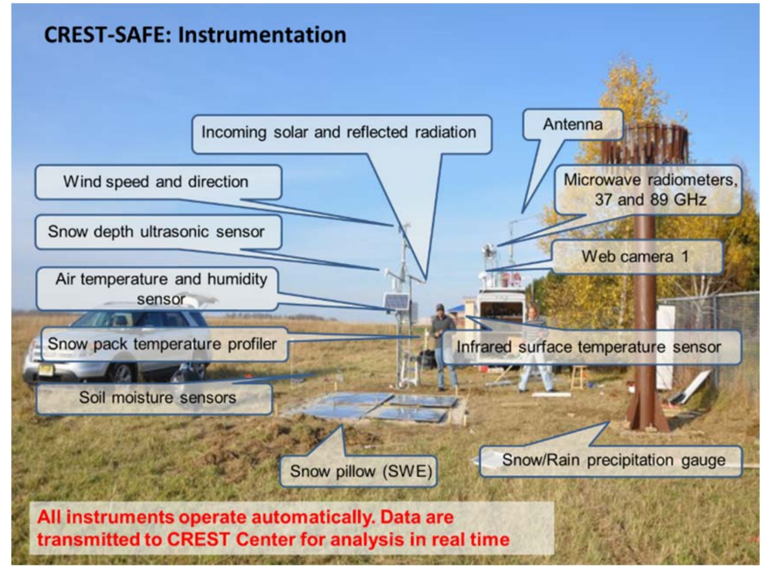
Snow Pillow (SWE)
Rain/Snow Gauge
Soil Moisture (2.5, 5, 10cm)
Soil Temp (2.5, 5, 10cm)
Manual Snow Pit measurements
Network Cameras (2)

2011

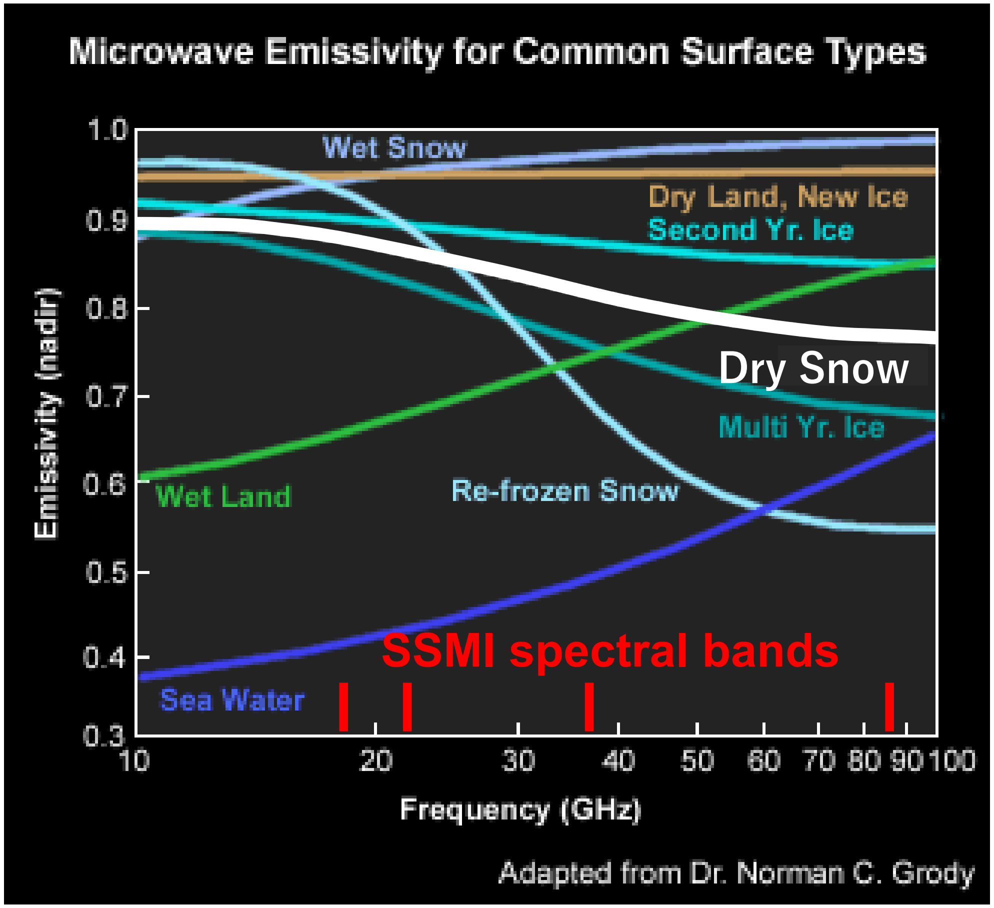
Snow Temperature Profiler

2010

37 GHz Radiometer
89 GHz Radiometer



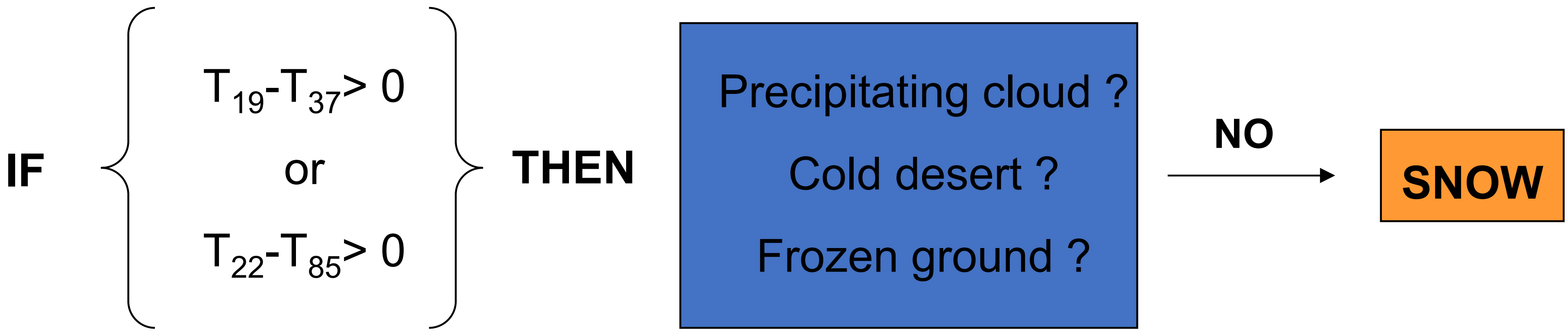
Emissivity of different surfaces



SSMI: Special Sensor Microwave Imager on DMSP satellites

- Emissivity of frozen surfaces hence their brightness temperature decreases with increasing frequency
- Emissivity of thawed surfaces or liquid water and hence their brightness temperature increases with increasing frequency
- Wet snow looks spectrally similar to the snow-free land surface and therefore can not be identified
- Frequencies typically used for snow identification: 17, 22, 37, 89 GHz

Generic algorithm to detect snow in microwave



T_{19}, T_{22}, T_{37}, T_{85} : Brightness temperature at 19, 22, 37, 85 GHz

Snow depth/SWE algorithms

Brightness temperature spectral gradient between 19 GHz and 37 GHz bands is typically used to derive the snow depth or the snow water equivalent (SWE)

$SD=a(T_{19}-T_{37})+b$ (Chang, 1987 algorithm)

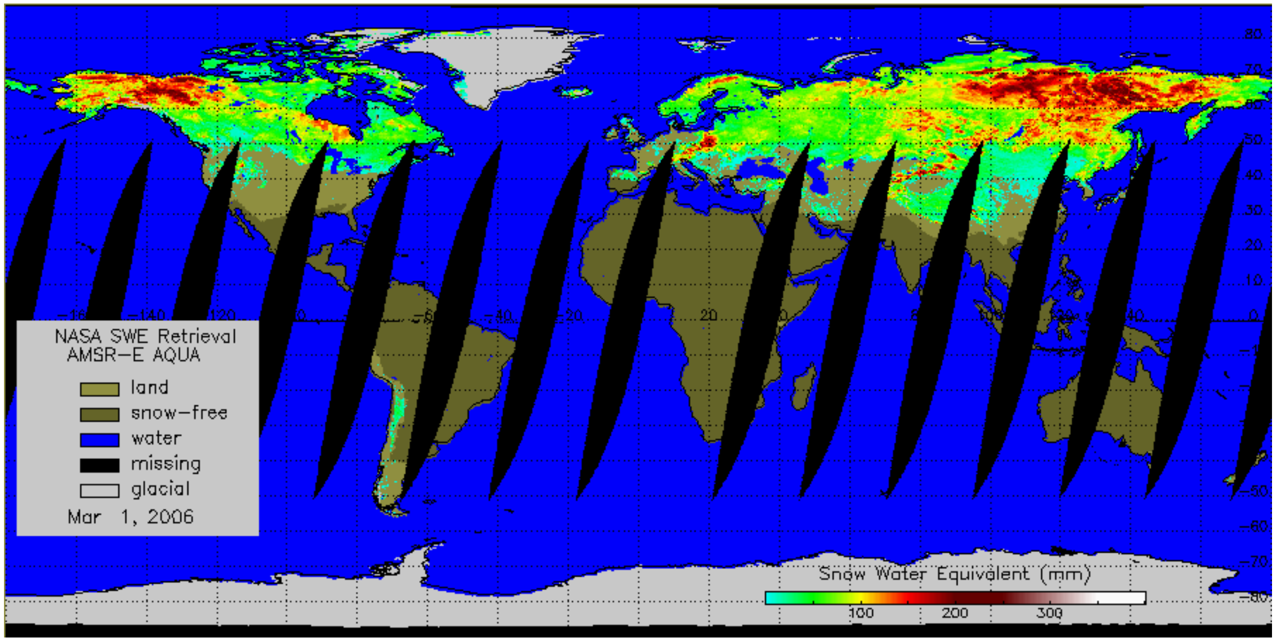
$SD=a(T_{19}-T_{37})/(1-c*ff)$ (Kelly, 2003),

"ff" is forest fraction

However retrieval errors are large ~ 50-100%

Observations lose sensitivity to snow depth when snow pack is over ~1 m thick.

Microwave daily snow products



AMSR-E Aqua
Snow water equivalent
Daily, 25 km resolution

Similar products are available from other microwave sensor data (SSMI, AMSU)

Derived maps are spatially continuous: Most clouds are transparent

The spatial resolution is coarse, 20-50 km: Due to coarse resolution of sensors

Snow is underestimated in spring and fall due to melting snow conditions

Snow extent is overestimated in the mountains: Cold rocks look the same as snow

Snow mapping accuracy is 80-90%, less reliable than visible/infrared snow maps

Combining snow retrievals in Vis/IR and Microwave

Motivation:

Generate continuous (with no gaps) snow map on a daily basis at highest possible spatial resolution and accuracy

Basic Approach:

Vis/IR retrievals over cloud clear areas

+

MW: Only reliable snow identifications for cloudy areas

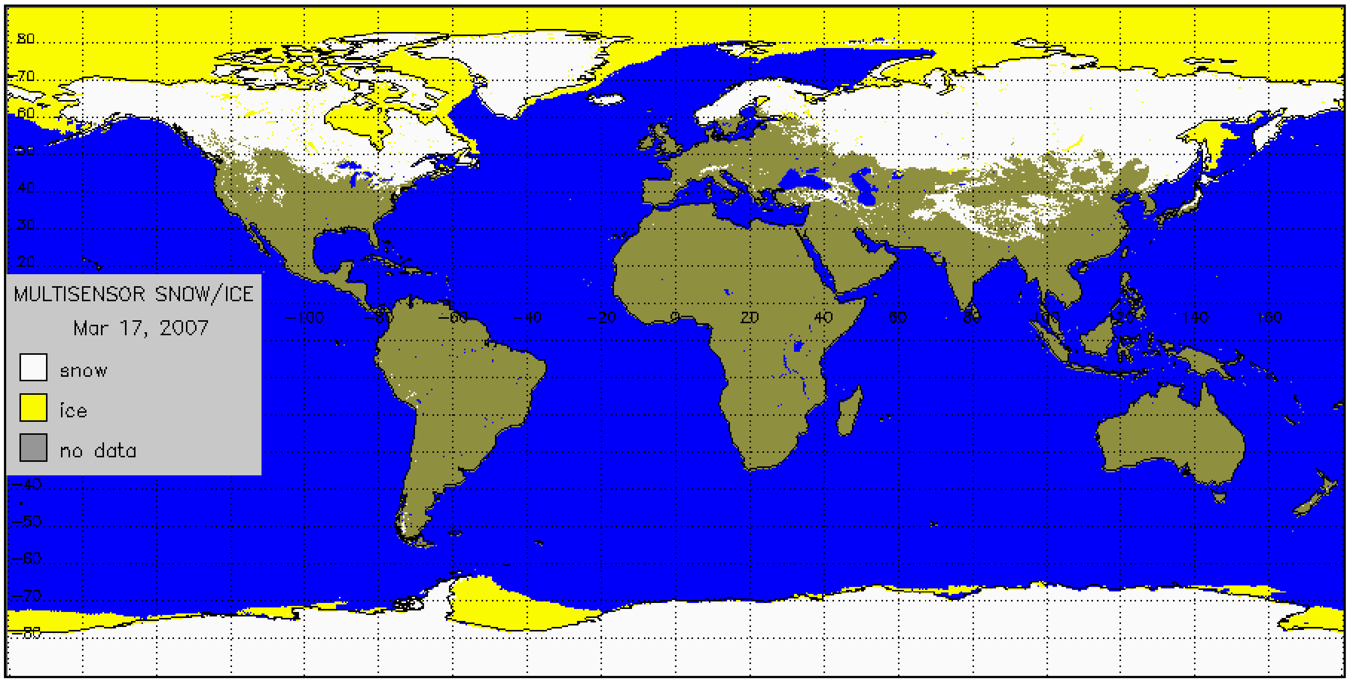
+

First guess map Previous day snow map to fill in remaining gaps

→

Daily continuous snow cover map

NOAA Multisensor Automated Snow and Ice Mapping System



Satellite data used:

Imager/GOES-10 and -12
SEVIRI/MSG
AVHRR/METOP
SSMI(S)/DMSP-15,16,17

Map features:

- Daily, global
- 4 km resolution
- Continuous coverage (no gaps)
- Operational since 2006

On the Web: http://www.orbit.nesdis.noaa.gov/smcd/emb/snow/HTML/multisensor_global_snow_ice.html

Problems of automated algorithms/products

- Delayed identification of snow onset
  - None of algorithms works over precipitating clouds
- Spurious variations in mapped snow cover
  - Different spatial resolution of vis/IR and MW sensors
- Snow on forest floor in late spring
  - None of algorithms sees snow through vegetation

Available satellite-based snow products: IMS

NOAA IMS Interactive Snow and Ice Cover Maps
http://www.natice.noaa.gov/ims/

Daily snow and ice cover maps at 1,4 and 24 km
Daily maps provide continuous coverage of the Northern Hemisphere
Polar projection
ASCII, GeoTiff, GRIB formats
Maps are generated operationally

Historical data (since 1972) are available at coarser spatial and temporal resolution

This is the best option for climate studies and for model applications. The effect of the change in the spatial resolution on the consistency of time series should be examined.

Available satellite-based snow products: GMASI

NOAA Global Multisensor Automated Snow and Ice Mapping System
http://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow.htm

Daily global snow and ice cover maps at 4 km spatial resolution
Use combined observations from different satellites
Fully automated algorithm
Continuous coverage (no gaps)
Latitude-longitude projection
Binary format
Maps are generated operationally
Time series since 2006

This is a good option for model applications and for studies of snow cover change in the last 10 years. The time series are consistent throughout the whole time period.

Available satellite-based snow products: MODIS

NASA MODIS Snow Maps
http://nsidc.org/data/modis/index.html

Daily snow cover maps at 0.5 km to 5 km spatial resolution
Provided in 5 minutes granules or tiles in the sinusoidal projection
Fully automated algorithm
Map have gaps due to clouds
HDF format
Maps are not operational
Time series since 1999

This is an interesting option for studies where high spatial resolution is needed but daily updates are not critical, e.g., for snow hydrology studies in the mountains and associated river runoff. May be used for validation of snow accumulation and snow-melt models. Should not be used in operational applications.

Available satellite-based snow products: VIIRS

NOAA VIIRS Snow Maps
http://www.class.ncdc.noaa.gov/saa/products/search?datatype_family=VIIRS_EDR

Snow product is similar to MODIS snow product
Daily snow cover maps at 375 m spatial resolution
Fully automated algorithm
Provided in 1.5 minute granules
Map have gaps due to clouds
HDF format
Maps are operational
Time series since 2012

Another option for snow-related studies where high spatial resolution is needed but daily updates are not critical. May be used for validation of snow accumulation and snow-melt models. The product needs to be gridded. Can be used in operational applications.

Available satellite-based snow products: AMSR2 GCOM-W1

JAXA (Japan) Snow Water Equivalent Maps
https://gcom-w1.jaxa.jp/auth.html

Snow Water Equivalent (SWE) retrievals from microwave data
Daily SWE maps at 10 km spatial resolution
Continuous coverage (no gaps)
Fully automated algorithm
Provided in swath projection
HDF format
Maps are operational
Time series since 2015

Provides SWE retrievals at relatively fine spatial resolution (10 km). The accuracy of retrievals needs to be carefully evaluated. Expect larger errors in the mountainous areas and over melting snow.

Summary

- Information on the global snow cover properties is derived both interactively and with automated satellite data processing techniques

- Automated snow products are available from a number of different satellite sensors operating in the visible/infrared and in the microwave spectral bands

- Products derived from visible and infrared imagery have high spatial resolution (0.5-1 km) and high accuracy, but are not available in cloudy conditions. Limited information on the snow depth can be derived.

- Microwave observations are independent of the weather and can provide information on the snow depth and snow water equivalent but are less accurate and have coarser spatial resolution of 20-50 km

- Most promising are techniques involving combined satellite observations in both visible/infrared and in the microwave.

Data Links

- NOAA IMS Interactive Snow and Ice Cover Maps
- http://www.natice.noaa.gov/ims/

- NESDIS Automated Snow and Ice Maps
- http://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow.htm

- MODIS snow cover products
- http://nsidc.org/data/modis/index.html

- VIIRS products (including snow)
- http://www.class.ncdc.noaa.gov/saa/products/search?datatype_family=VIIRS_EDR

- GCOM-W1 AMSR2 microwave data (including snow water equivalent):
- https://gcom-w1.jaxa.jp/auth.html

NOAA Collaboration Meetings, Workshop and other highlights

The CCNY delegation included President Vincent Boudreau; Dee Dee Mozeleski (Executive Director, Combined Foundations for City College); Reza Khanbilvardi, Shakila Merchant, Jonathan Munoz; Tarendra Lakhankar and students visited to Snow Analysis and Field Experiment (CREST-SAFE), site in Caribou, ME on April 3rd and 4th 2019. Activities includes research, education outreach and collaboration with local university (University of Maine at Presque Isle), Micmac Tribal Community, Local High School in Caribou and National Weather Service office at Caribou ME.