



# **SATELLITE-BASED MONITORING OF SNOW COVER: APPLICATION TO MOUNTAIN REGIONS OF EURASIA**

***Peter Romanov***

Cooperative Institute for Climate Studies, University of Maryland  
Center for Satellite Applications and Research, NOAA/NESDIS

---

# Overview

---

- Snow remote sensing techniques
- Satellite snow products for studies in Northern Eurasia
  - NOAA and NASA
- Problems of snow mapping in mountains

Focus on large-scale monitoring of seasonal snow cover

# Extent of seasonal snow cover

---

- Northern Hemisphere
  - over 40 mln km<sup>2</sup>
  - 70% of the total land area
  - 100% of NEESPI study area

# Snow cover: Applications

---

**Information on snow cover is needed for or used in**

- Numerical weather prediction
- Hydrology
- Climate studies
- Agriculture, Fire control
- Transportation, Recreation
- Hydropower Generation
- Civil Engineering
- Other environmental applications



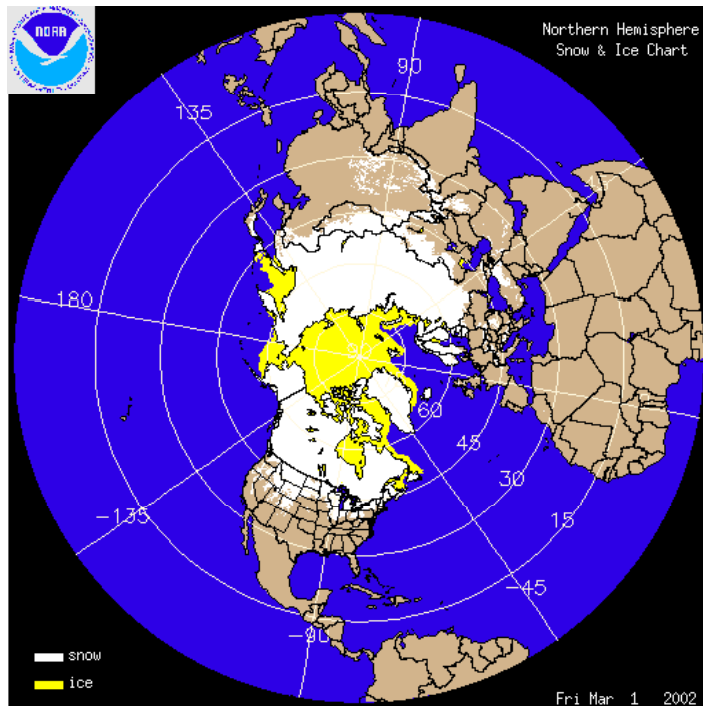
# Satellite snow mapping techniques

---

- **Interactive**
  - *Visible imagery*
- **Automated**
  - *Visible/middle-infrared/infrared*
  - *Microwave*
  - *Combined Vis/IR and Microwave*

# NOAA Interactive Multisensor Snow and Ice Mapping System (IMS)

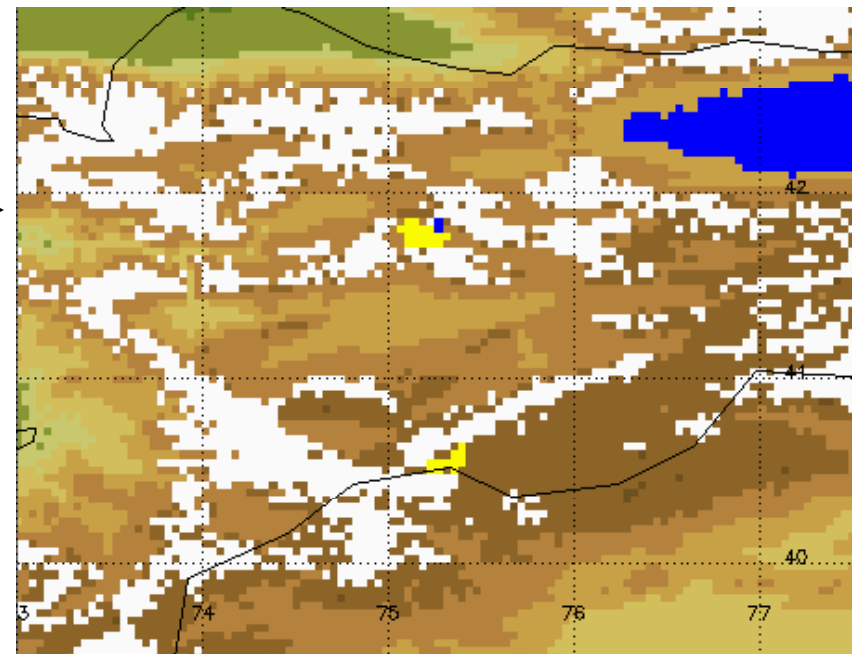
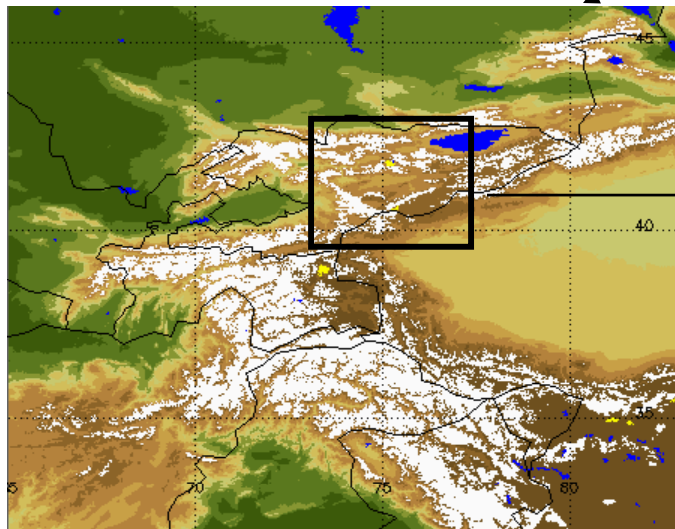
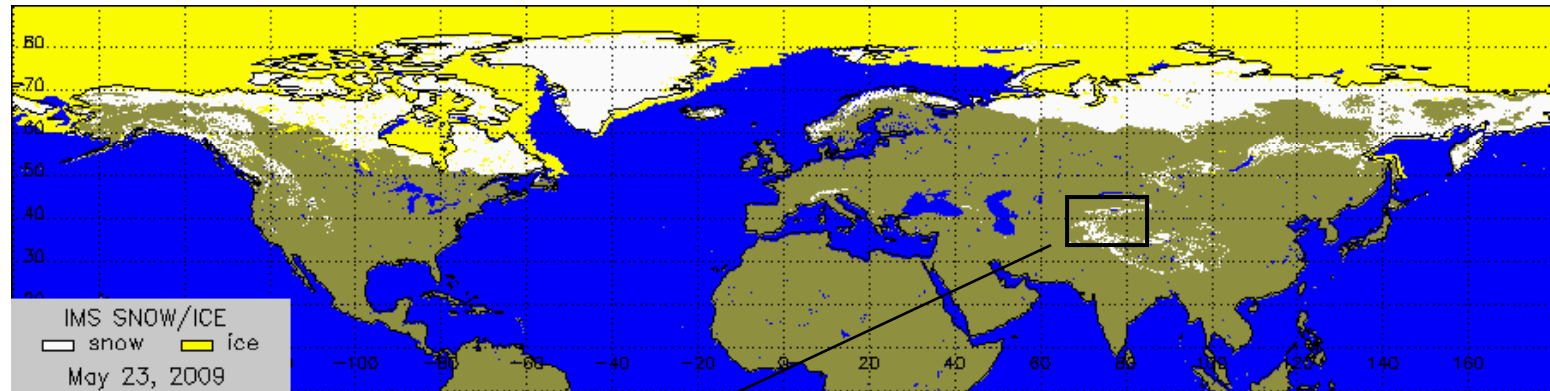
35+ years of hand-drawn snow and ice maps for Northern Hemisphere



- Interactive analysis
- Visible imagery from satellites
- Gradual improvement of temporal and spatial resolution:
  - 1972-1998: weekly at 180 km
  - 1998-2004: daily at 24 km
  - 2004-current: daily at 4 km

*On the web:: <http://www.natice.noaa.gov/ims/>*

# IMS: Daily snow at 4 km resolution



# IMS: Important issue

---

- **Changes in spatial and temporal resolution**

**Therefore**

- **Consistent climatology is available only**
  - **At 180 km resolution**
  - **For 1972-1998**

# Automated snow detection in VIS/IR

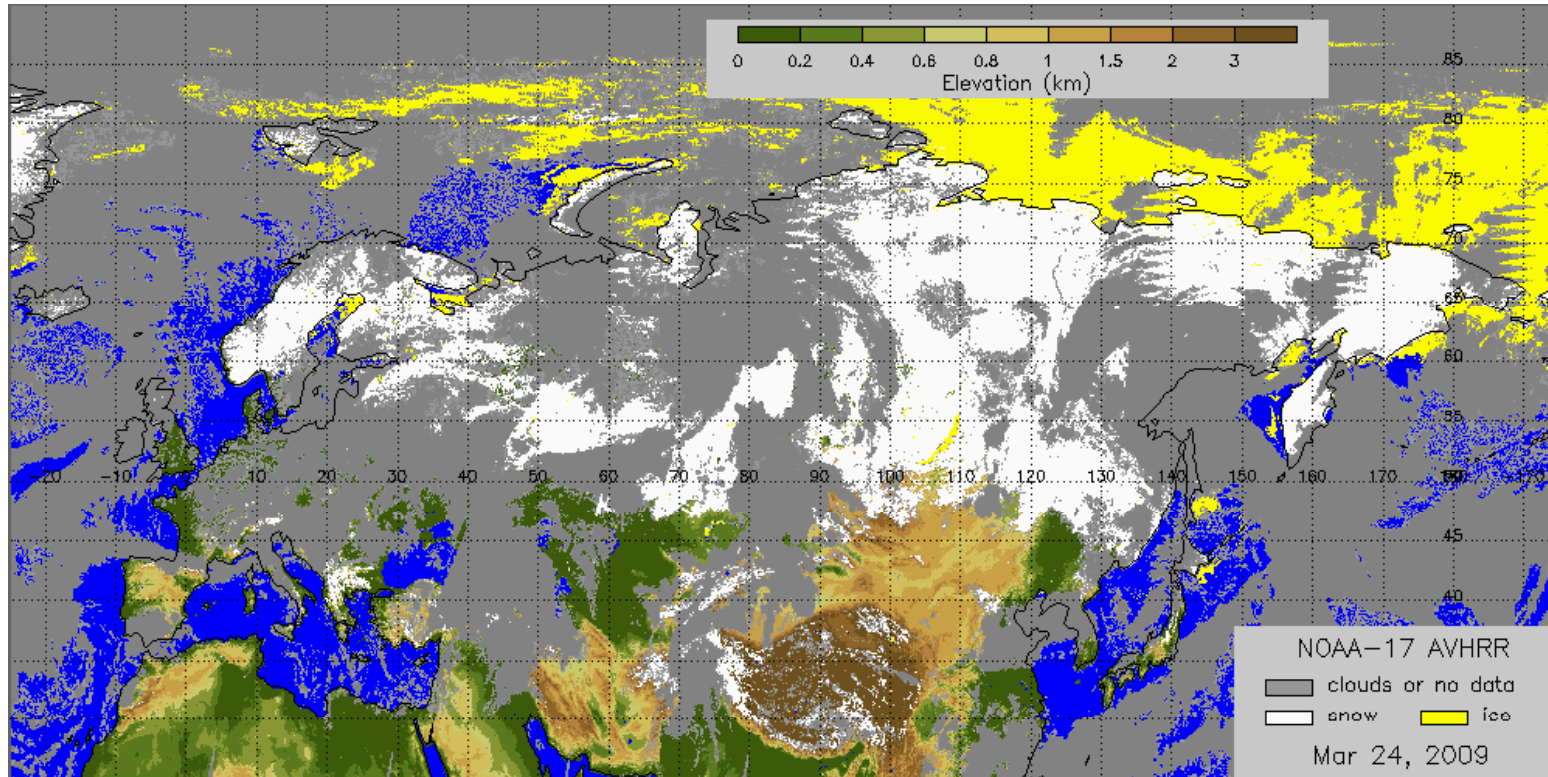
---

- Uses specific spectral signature of snow reflectance (high  $R_{vis}$ , low  $R_{sir}$ )
- Requires daylight
- Maps have gaps due to clouds
- Spatial resolution 0.5 km to 5 km
- Probability of correct snow identification ~92%-97%
  
- Daily snow maps are available from
  - NOAA AVHRR (NOAA)
  - MODIS Terra & Aqua (NASA)
  - GOES-East, West (NOAA)
  - Meteosat SEVIRI (NOAA, EUMETSAT)

# AVHRR/NOAA snow/ice map (NESDIS)

---

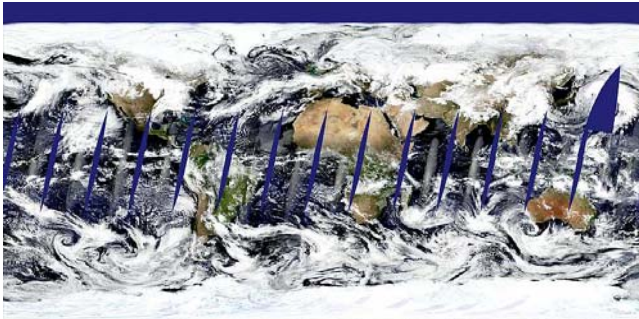
- Daily, global, 4 km resolution
- Available since 2006
- Clouds cover about 40% of the land area



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

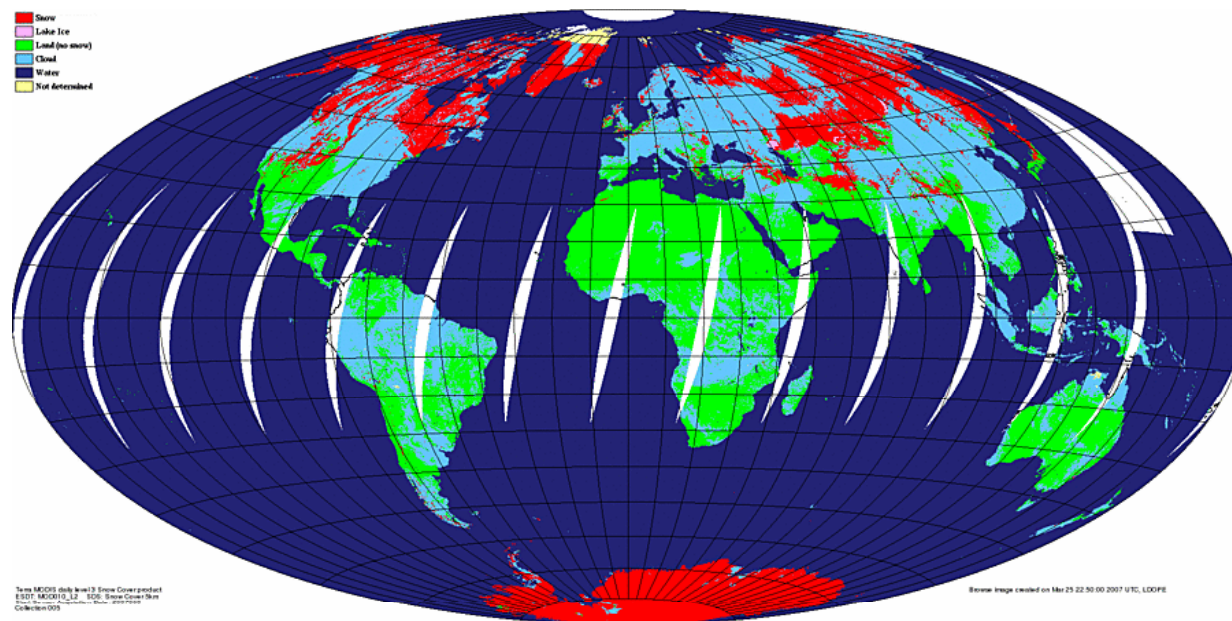
# MODIS snow map (NASA)

---



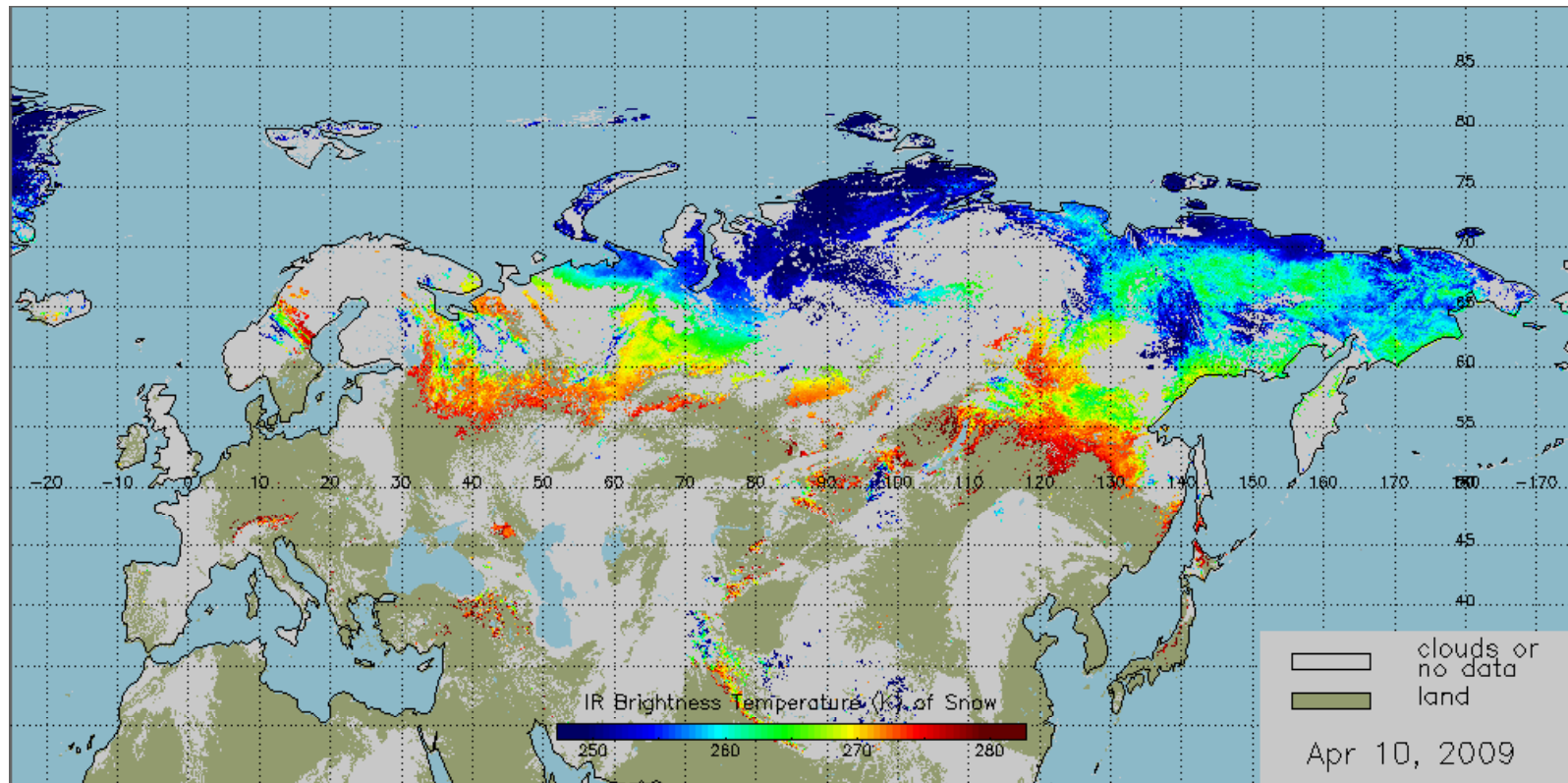
## Map features:

- Global, daily
- 0.5 km and 5 km resolution
- Available since 2000
- Terra, Aqua



On the Web: <http://modland.nascom.nasa.gov/cgi-bin/browse/browse.cgi>

# Snow surface temperature, NOAA/AVHRR

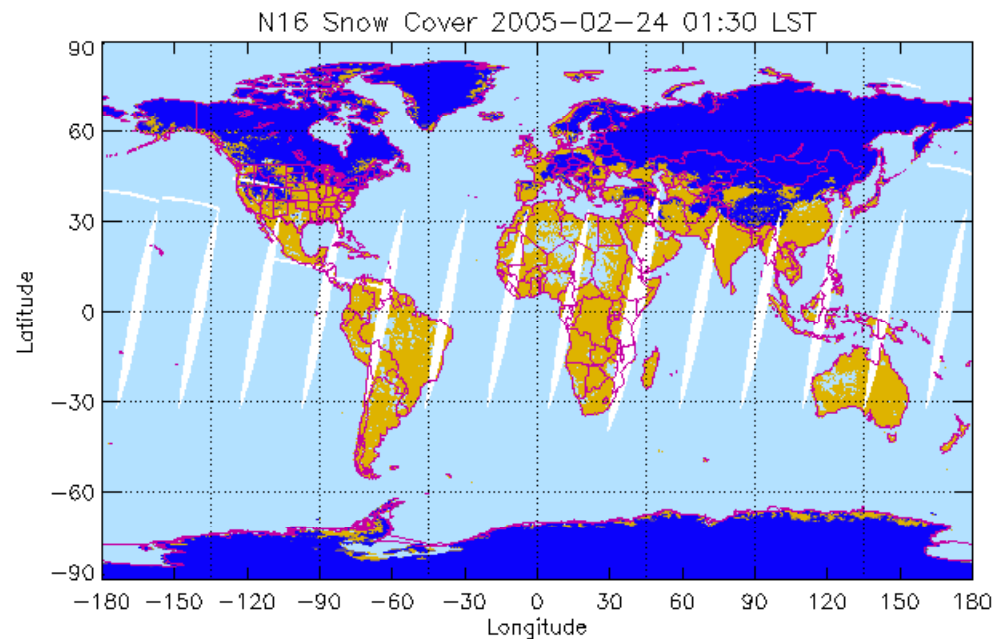


Red color: Melting snow

# Automated snow detection in the microwave

- Identified by decreasing brightness temperature within 10GHz – 100GHz
- All-weather capability
- Spatial resolution 25 km - 50 km
- Snow detection accuracy: ~ 80%
- Problems: melting snow, shallow snow, frozen ground
- Daily maps available from

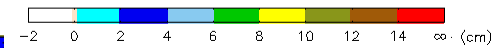
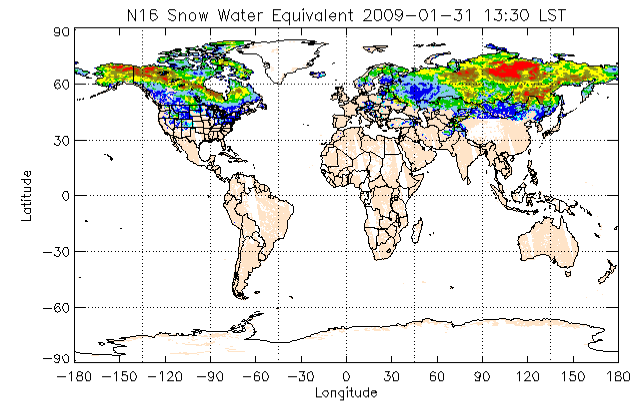
AMSU NOAA (NOAA)  
SSMI DMSP (NOAA)  
AMSR-E Aqua (NASA)



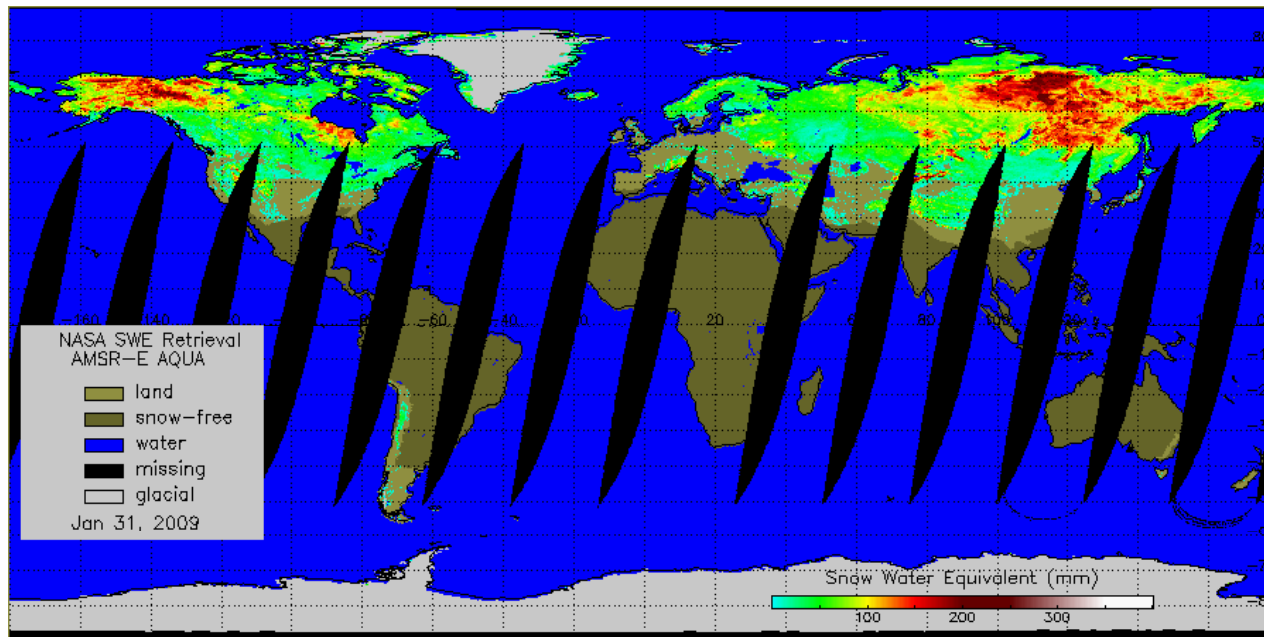
Blue is snow, yellow is land without snow, light blue is undetermined (rain, desert, water, etc.)

# Snow depth & snow water equivalent

- Typical approach:  $SWE = a (T_{19} - T_{37}) + b$
- a and b determined empirically
- 50%-100% retrieval accuracy



SWE  
AMSU NOAA



SWE  
AMSR-E Aqua

# Synergy of VIS/IR and microwave (data fusion)

---

## **Objective:**

Generate continuous snow map on a daily basis  
at highest possible spatial resolution

## **Approach:**

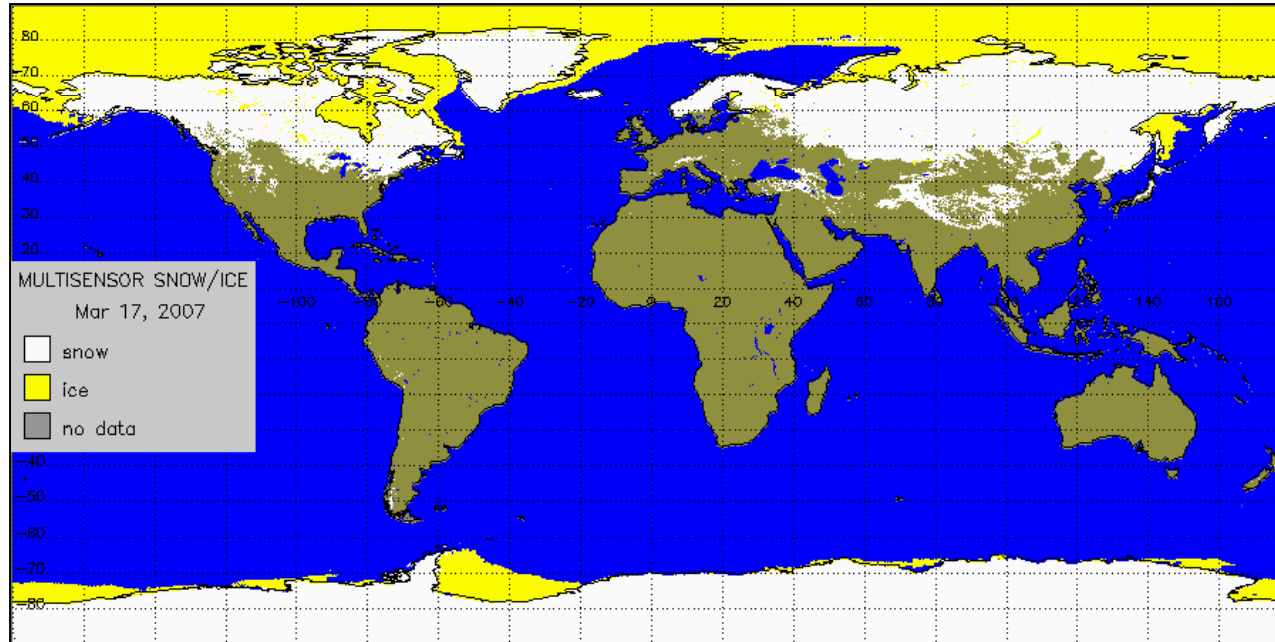
Use VIS/IR snow data if available  
Add snow from microwave if cloudy or dark

## **Daily products available:**

MODIS + AMSR-E, at 5 km resolution  
AVHRR + SSM/I + GOES + METEOSAT at 4 km resolution

# NESDIS Multisensor Automated Snow/Ice Map

---



4 km nominal resolution; ~90%-95% accuracy; Operational since 2006

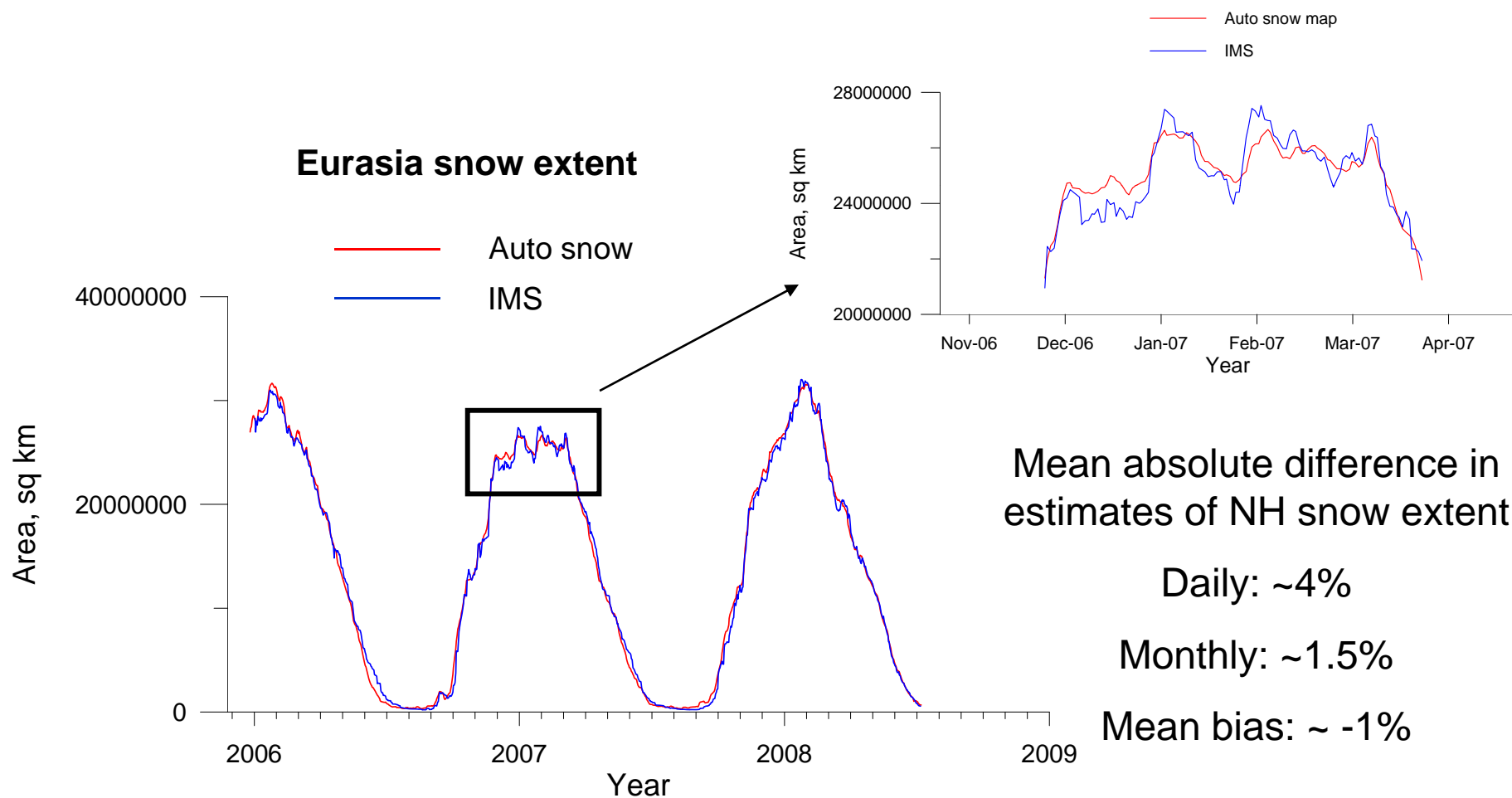
## System processes data from the following satellite instruments

Imager/GOES-10 and -12 (geo)  
SEVIRI/MSG (geo)

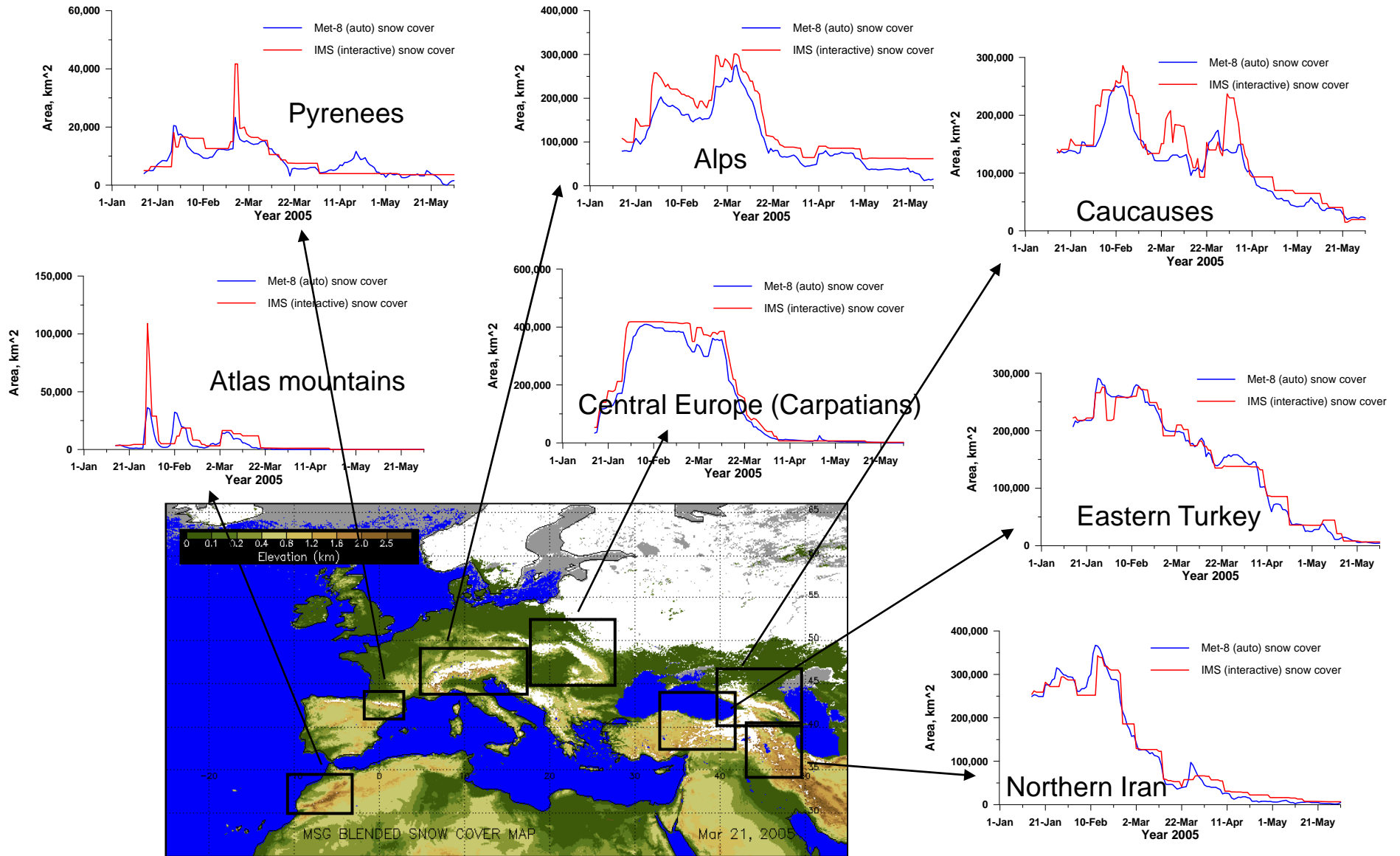
SSM/I/DMSP-15,16,17 (polar, microwave)  
AVHRR/NOAA-17, 18 (polar, vis/IR)

# Snow extent

Snow extent from NESDIS automated snow maps vs interactive (IMS)



# Snow Extent: Auto vs IMS



# Problems in snow mapping in mountains

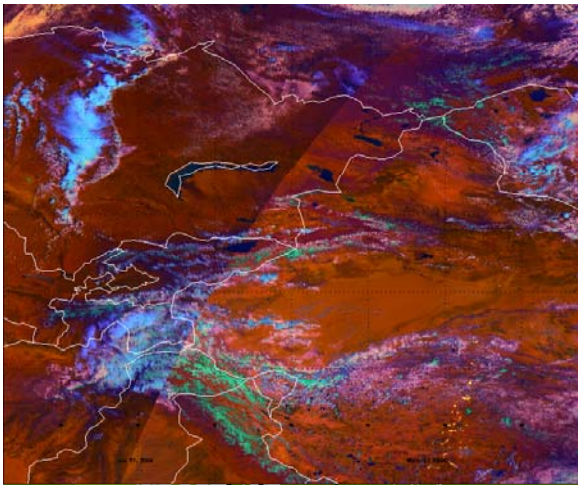
---

- Highly inhomogenous snow distribution
- Shadows
- Lack of ground truth data
- Accuracy of VIS/IR maps may decrease
- Microwave-based products are not valid

## **Potential applications of snow products in the mountains:**

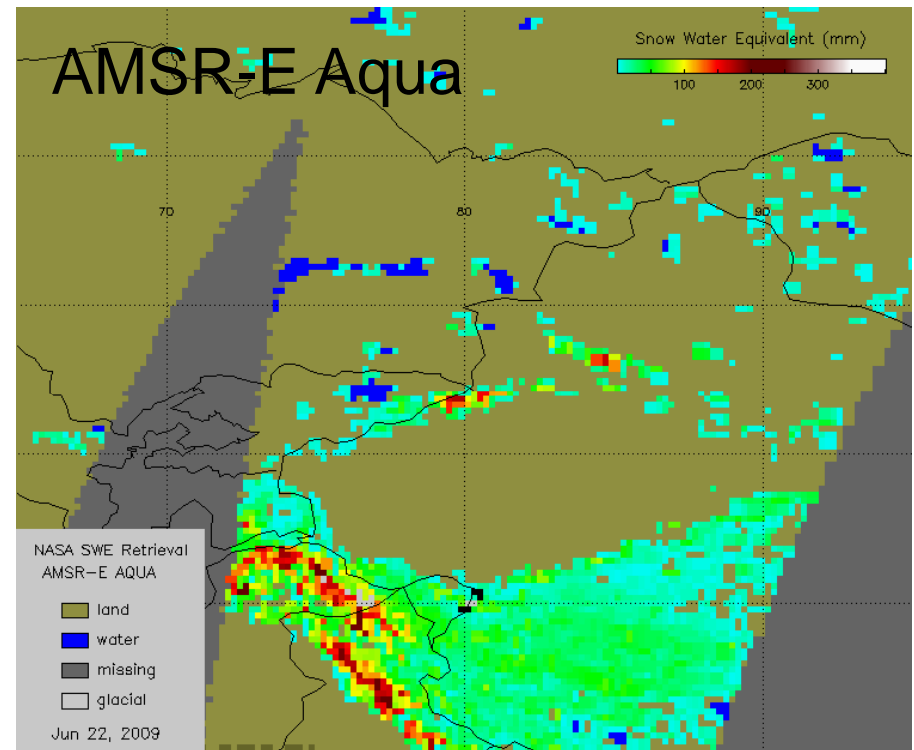
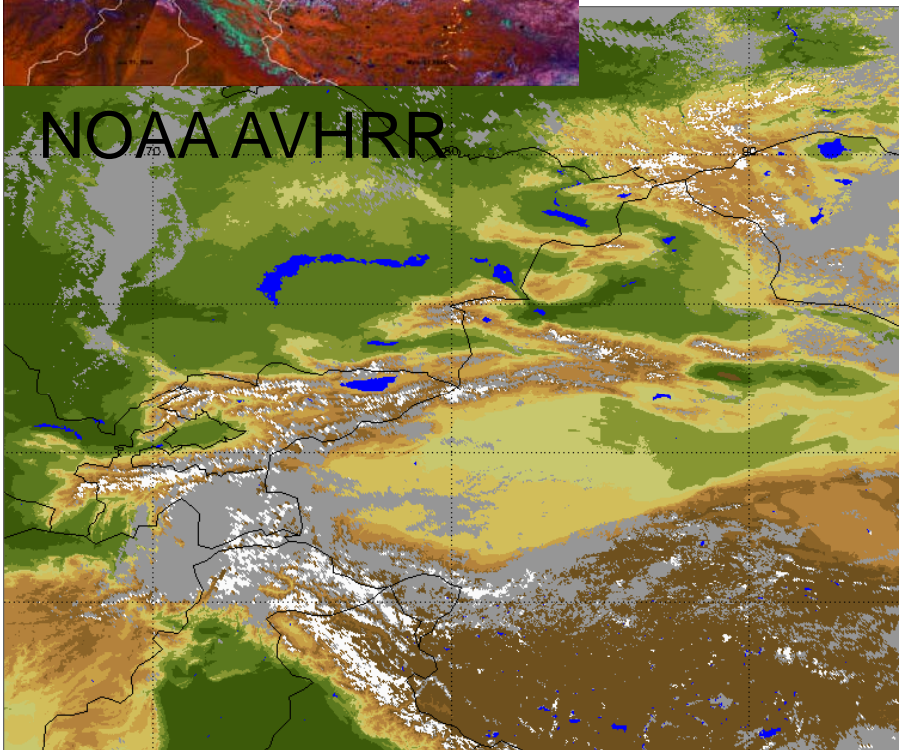
- Studies involving seasonal snow cover
- Large scale (over ~10-100 sq km) snow extent
- Spatial resolution of snow maps is too coarse for glaciology

# Overestimate of snow in the microwave



Spectral response of cold rocks in the microwave is similar to snow

Mixed land/water surfaces are often confused with snow



# Scaling issues

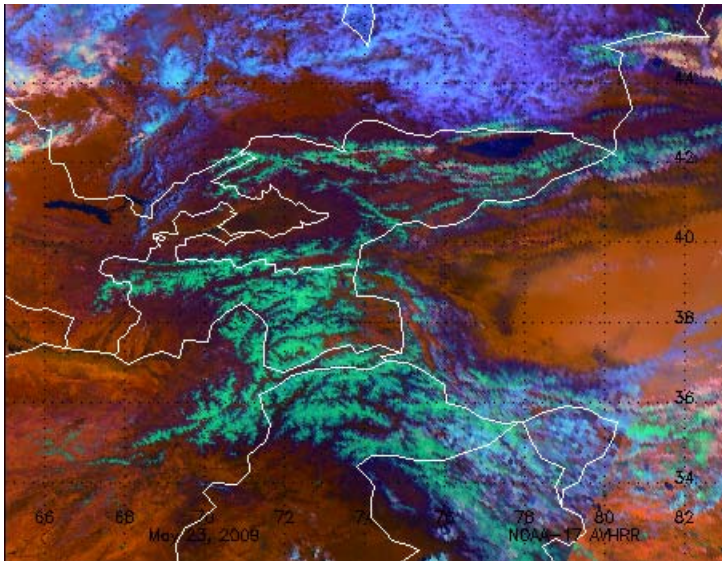
---

- Algorithms and analysts tend to overestimate subresolution snow
- Absolute overestimation of snow extent is larger for larger pixels

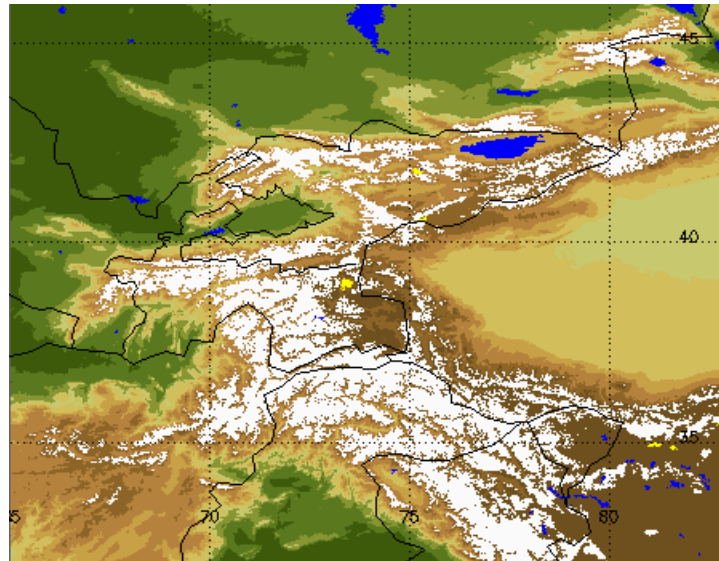
## **As a result:**

- Upscaled products typically show less snow extent than corresponding products derived from coarse resolution data

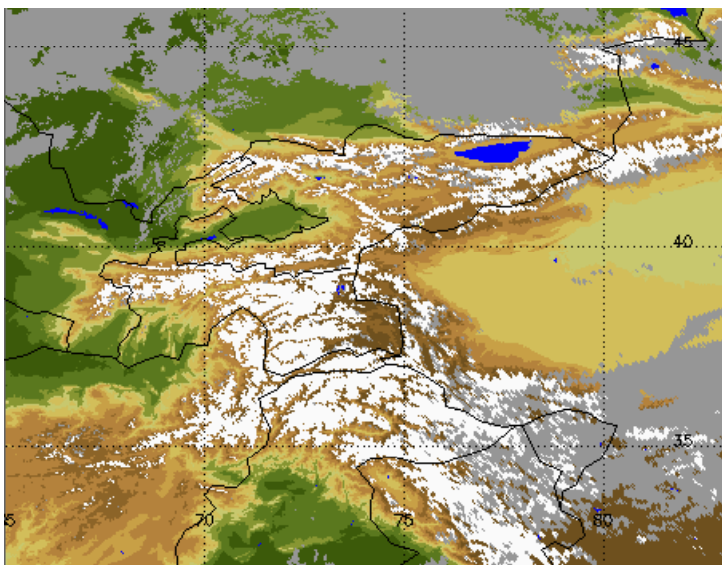
**May 23, 2009**



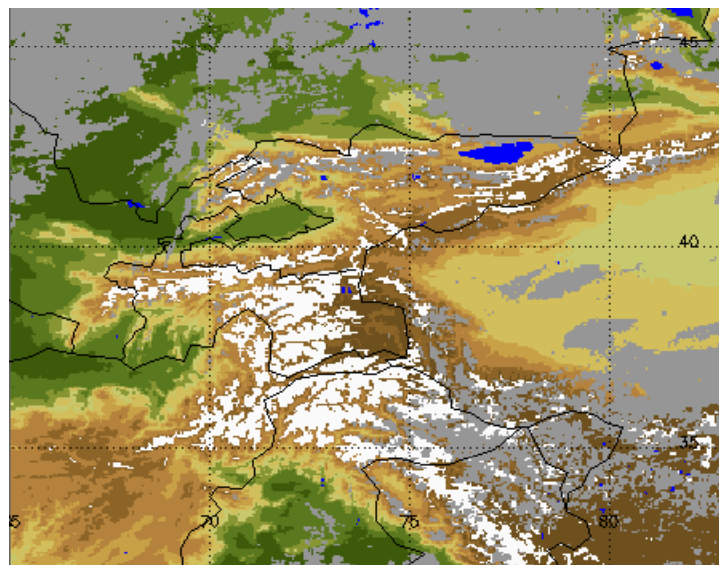
AVHRR, RGB false color composite



IMS (Interactive), 4 km

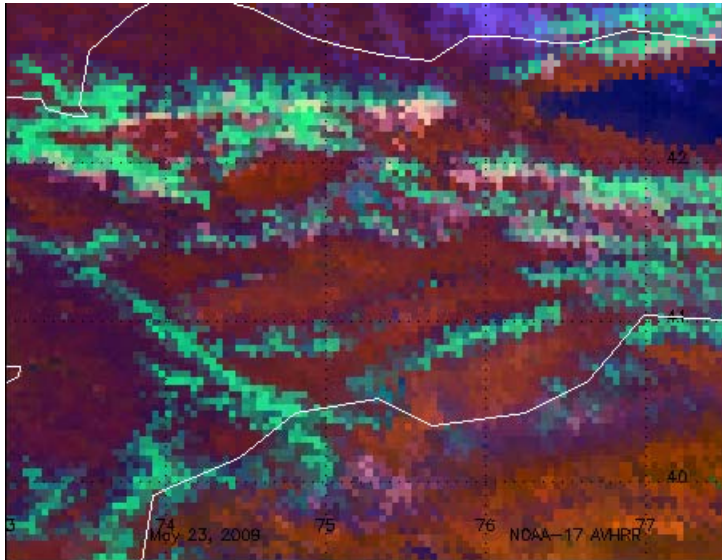
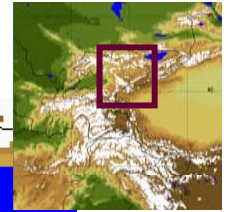


AVHRR, 4 km

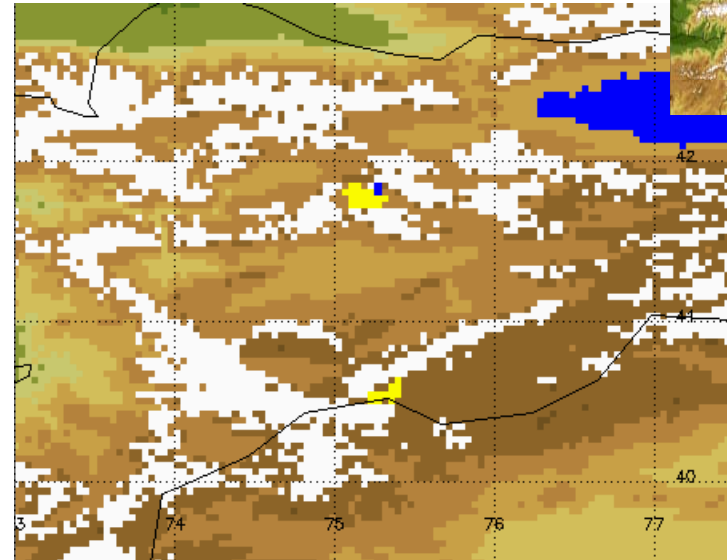


MODIS 5 km (derived from 0.5 km map)

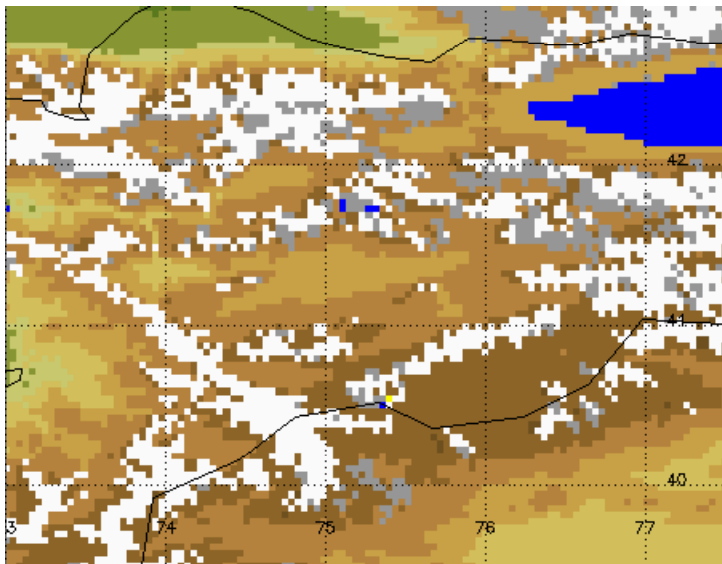
May 23, 2009



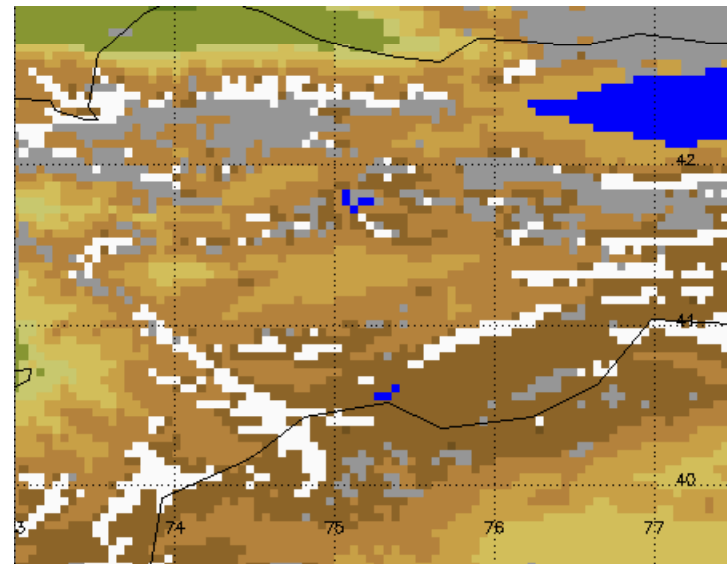
AVHRR, RGB false color composite



IMS (Interactive), 4 km



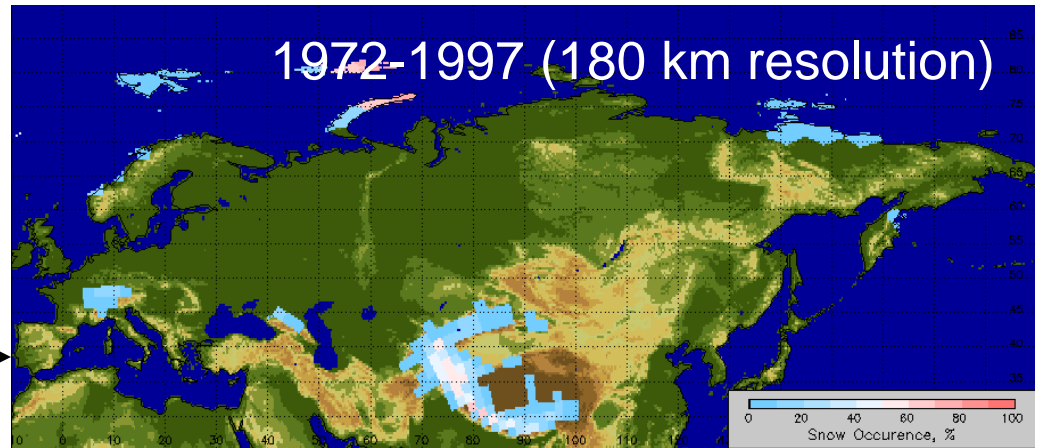
AVHRR, 4 km



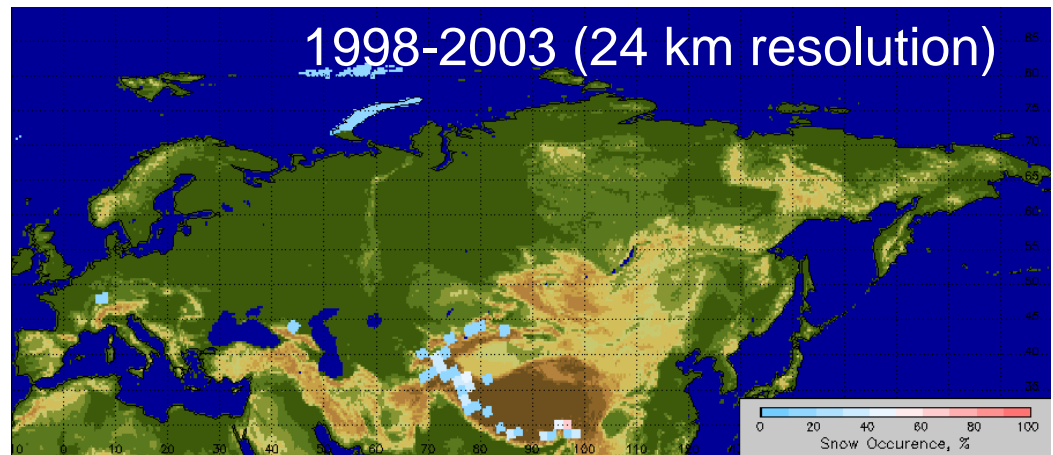
MODIS 5 km (upscaled from 0.5 km map)

# Snow frequency of occurrence from interactive maps

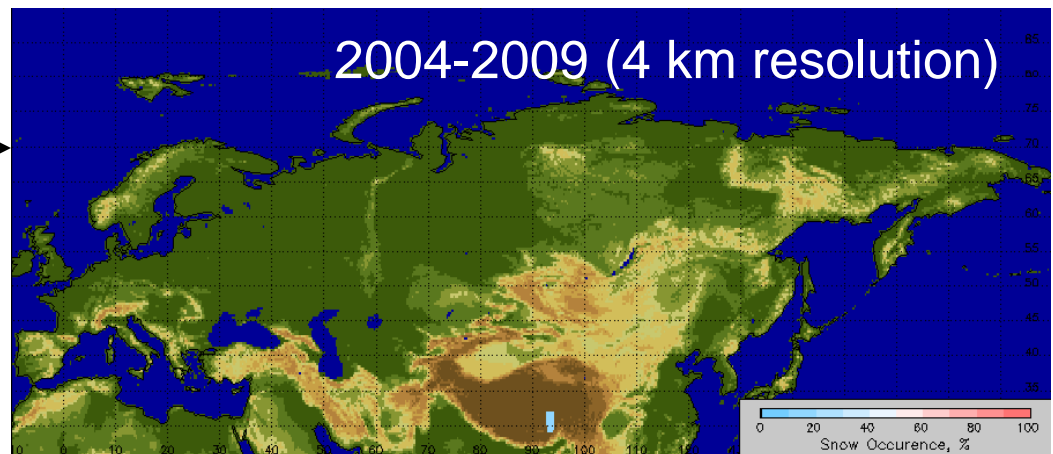
Derived from 180 km resolution data



Upscaled from 24 km to 180 km resolution



Upscaled from 4 km to 180 km resolution



Snow frequency of occurrence, week 33 (Aug 13-19)

# Problems and solutions

---

- No perfect technique for snow mapping
  - Use data fusion
- Consistent snow cover climatology: coarse resolution, 1972-1999
  - Reprocessing historical AVHRR data may help
- Limited potentials to estimate snow depth/SWE
  - Potential solution: satellite retrievals blended with surface obs
- All algorithms/products are global or continental
  - For smaller areas try using locally-tuned algorithms

# Links

---

NESDIS Automated snow remote sensing page:

<http://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow.htm>

NOAA Interactive snow charts:

<http://www.natice.noaa.gov/ims/>

NESDIS Microwave remote sensing page:

<http://www.star.nesdis.noaa.gov/corp/scsb/mspps/>

Peter Romanov

[peter.romanov@noaa.gov](mailto:peter.romanov@noaa.gov)

**THANK YOU**

