



National Aeronautics and  
Space Administration



# ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

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## Overview of NASA Snow Products

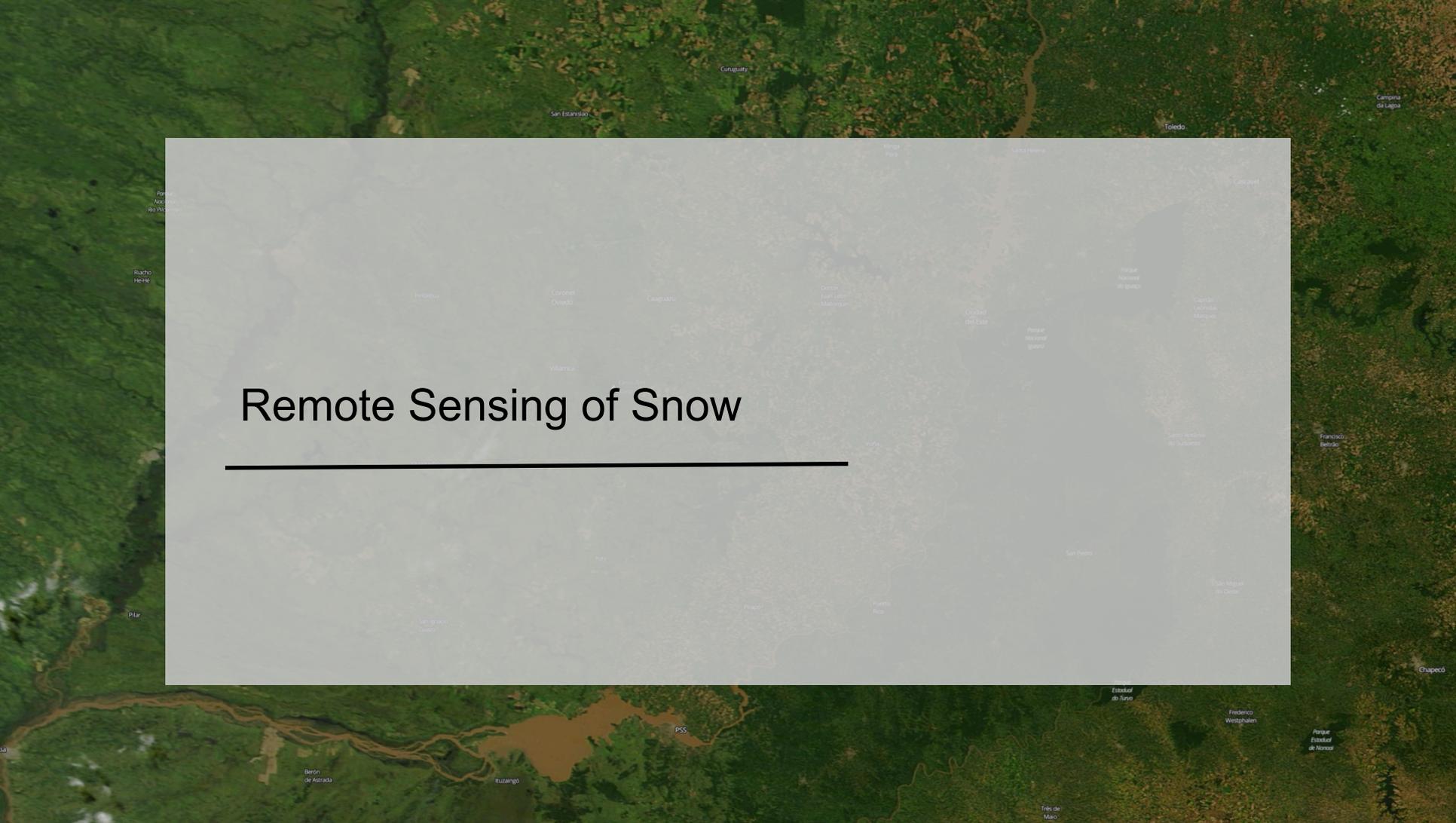
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## Objective

To be able to access NASA snow cover and snow water equivalence (SWE) data useful for climate monitoring and for water resources management, e.g. snow-fed river management.

# Outline

- Remote Sensing of Snow
- NASA Snow Products from Satellites and Earth Systems Models
- MODIS Snow Data Products and Access



# Remote Sensing of Snow

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# Definitions

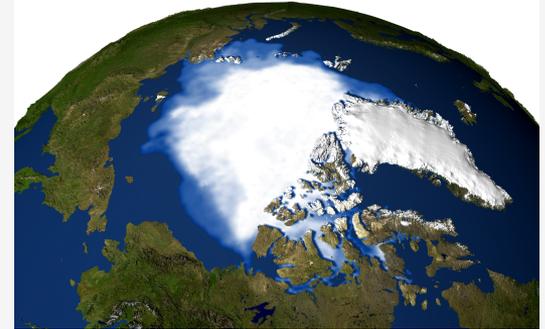
## What is ice?

- When a mass, layer, or surface of water freezes into a solid at cool temperatures

## What is snow?

- Deposition: when water vapor freezes directly into ice crystals
- Snowflakes are the aggregation of many ice crystals
- Snowfall is when snowflakes precipitate out of clouds

Sea Ice



Snow on Mountains



# Need for Snow Measurements

Snow covered areas are important for:

- Starting of and remaining snow coverage
- Reduction in snow cover
- Rate of snowmelt

Snow Dominated Regions of the World

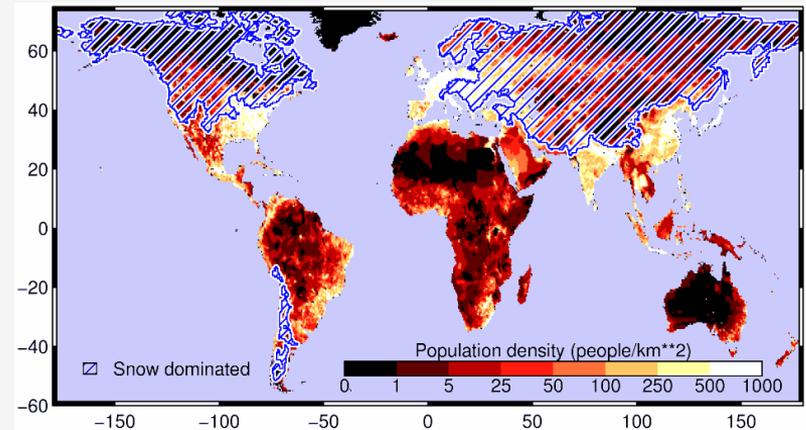
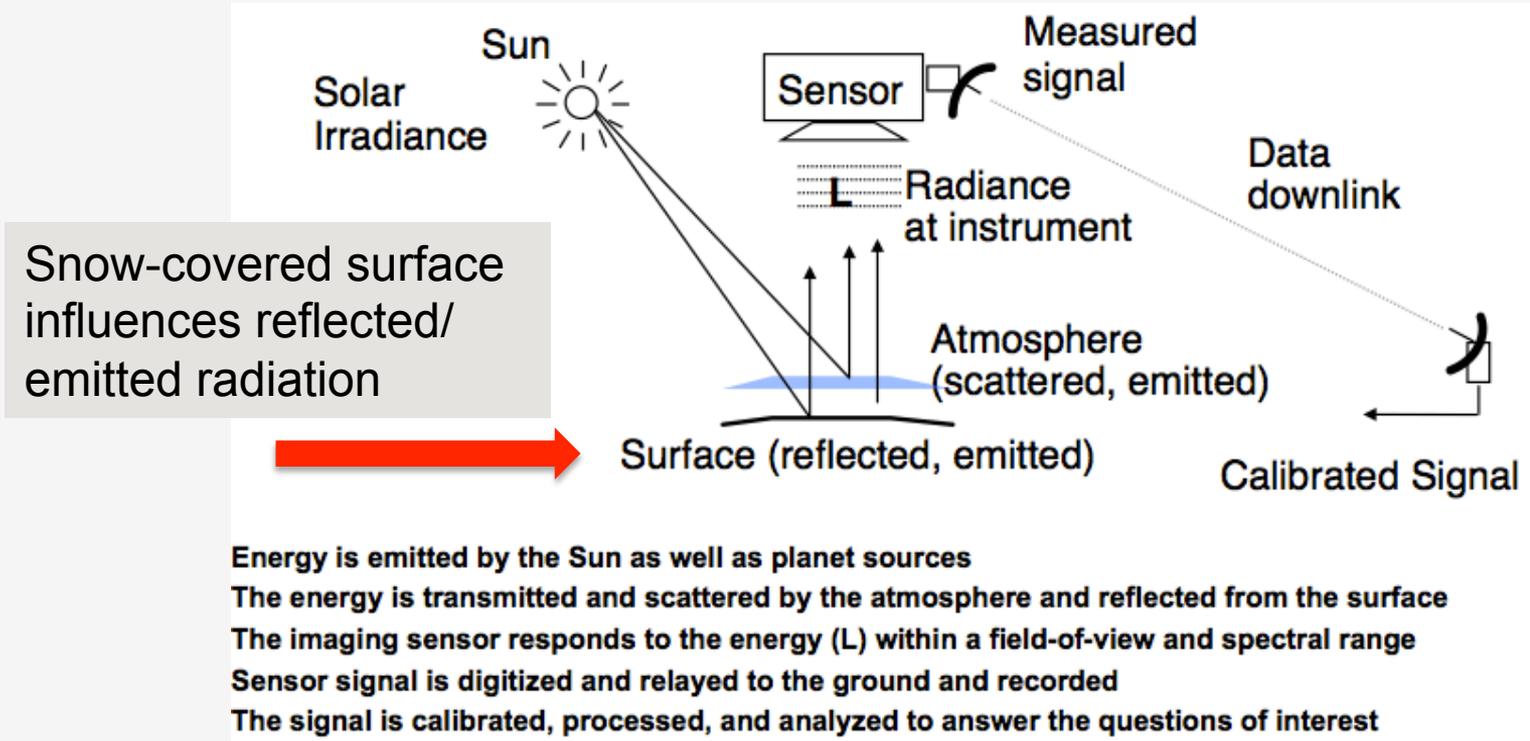


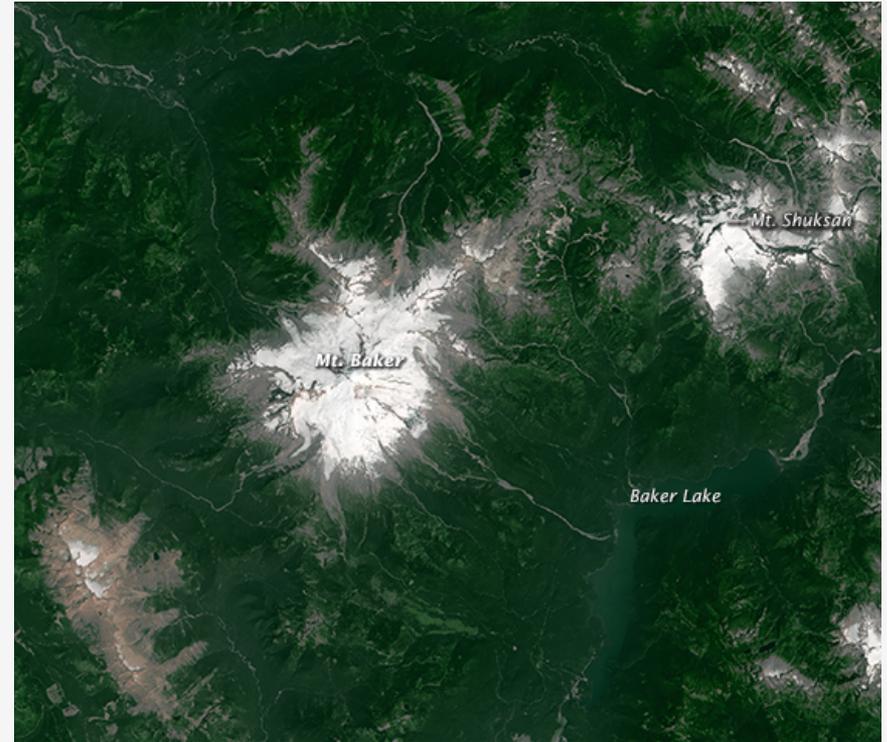
Figure courtesy Tim Barnett (Scripps Inst. Ocean)

# Remote Sensing Approach

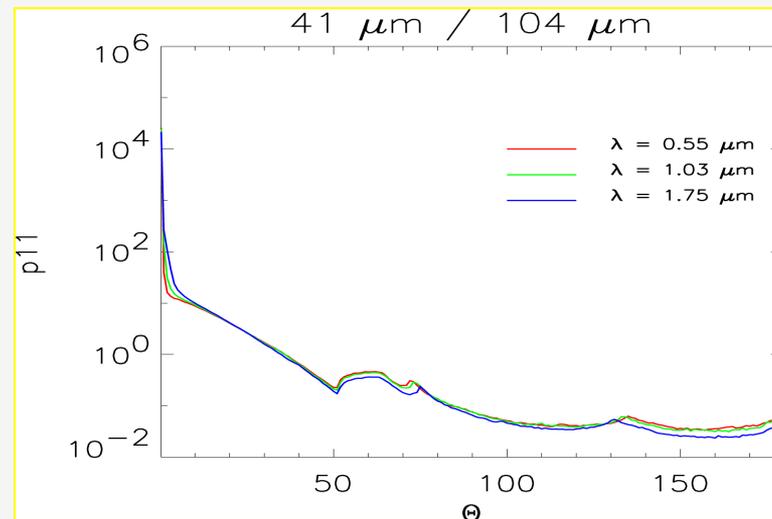
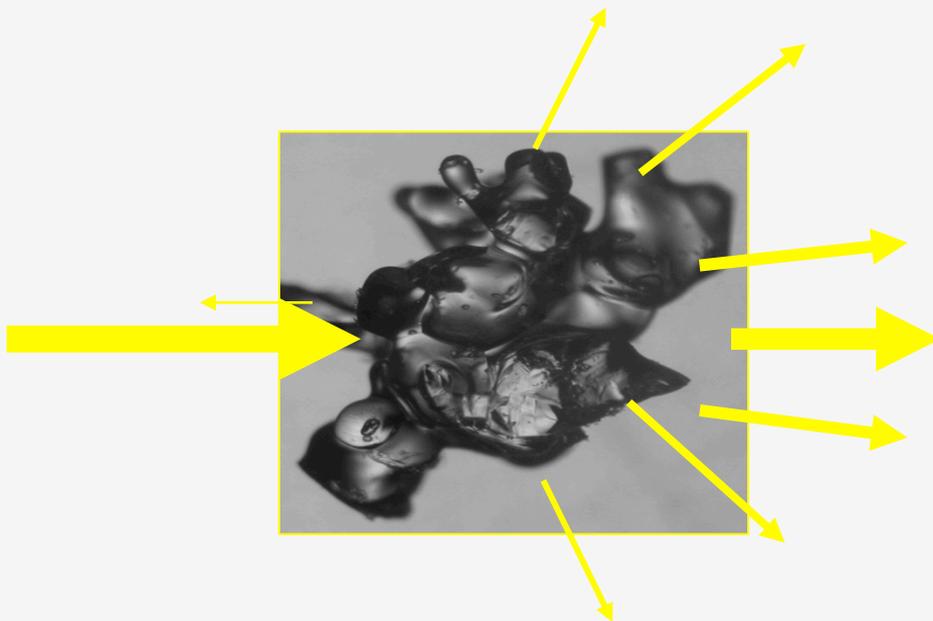


# Snow Properties

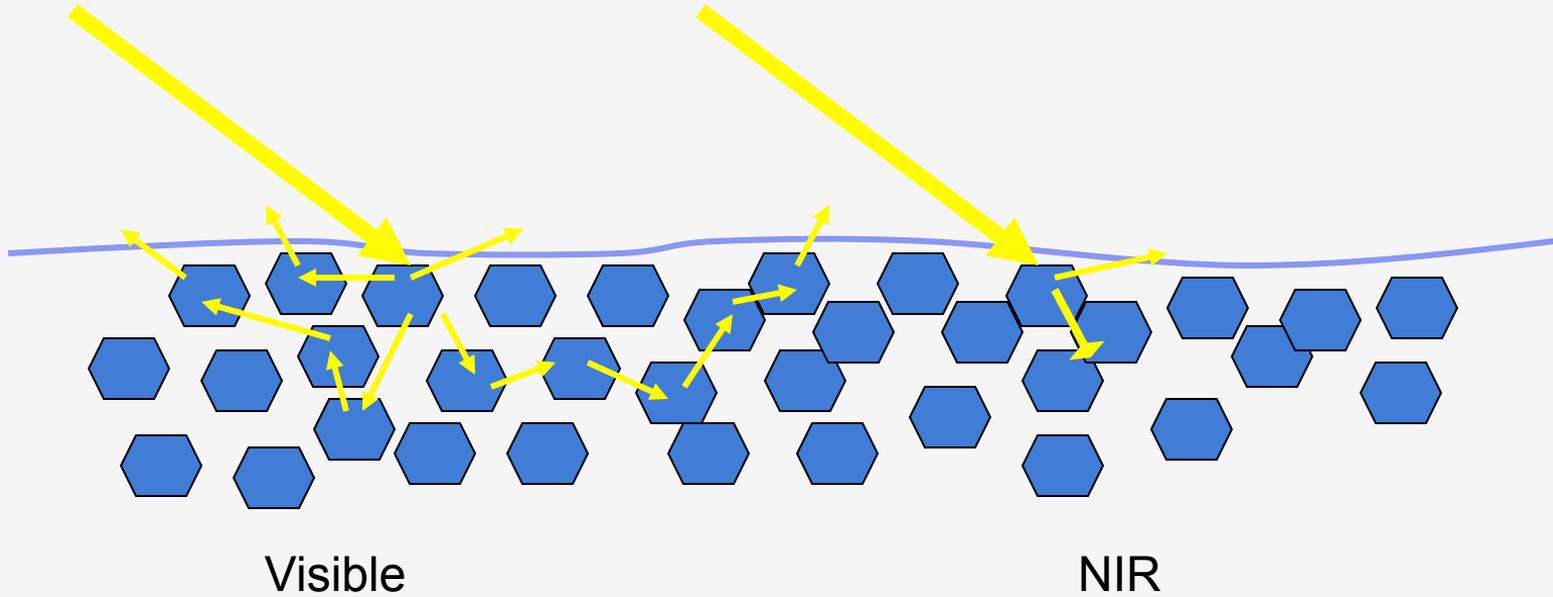
- Snow covered surfaces affect **albedo** – fraction of solar radiation reflected back into space
- Size of snow particles influences albedo
- Snow cover can highly vary in space-time



# Single Scattering by Snow Particles



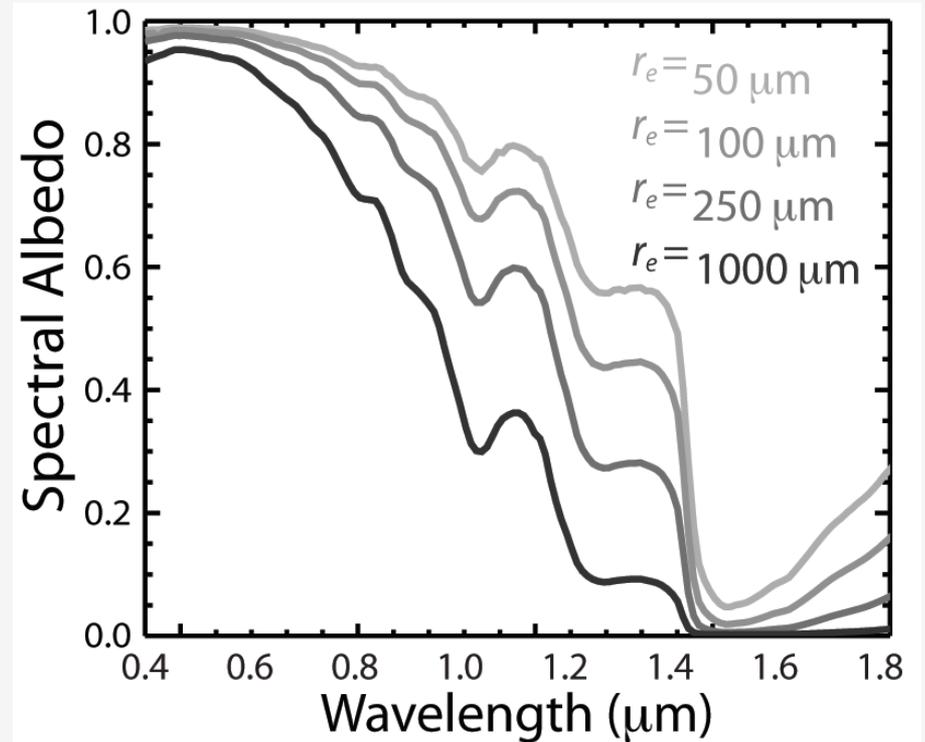
# Multiple Scattering by Snow Particles



# Snow Reflectance

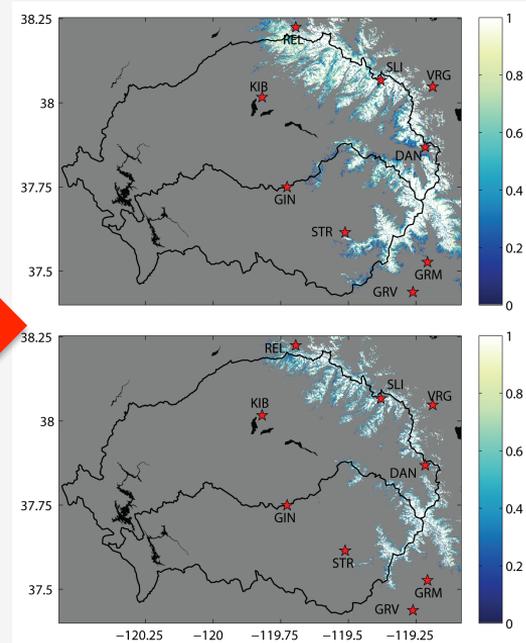
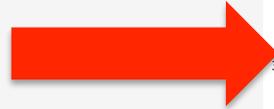
Satellite sensors measure solar radiation scattered by snow

Credit: Tom Painter (NASA- JPL)



# Benefits of Remote Sensing Measurements of Snow Cover

- Surface-based snow sensors collect point measurements and fail to provide accurate spatial distribution of snow cover
- Snow sensors do not cover the highest mountain elevations
- Remote sensing provides continuous spatial coverage and provides observations in hard to reach areas



Fractional snow cover from Landsat TM on July 2 and 18, 2011

Credit: Karl Rittger (University of California-Santa Barbara)



# NASA Snow Products from Satellites and Earth System Models

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# NASA Snow Products Available from Satellites

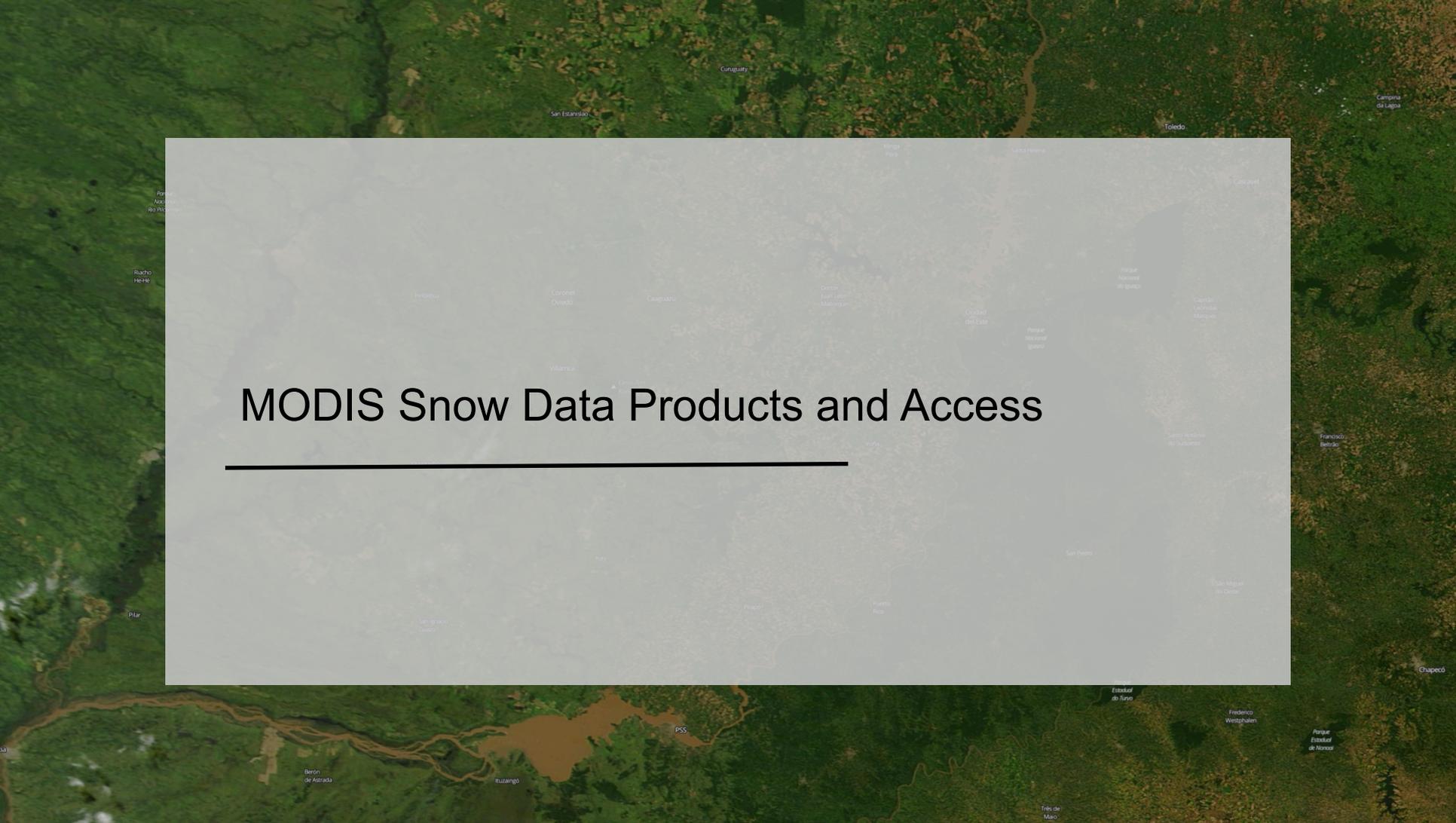
Satellite	Sensors	Quantities
Terra	<ul style="list-style-type: none"> <li>• MODerate Resolution Imaging Spectroradiometer (MODIS)</li> <li>• 500m spatial resolution</li> <li>• ~daily temporal resolution</li> </ul>	<ul style="list-style-type: none"> <li>• Snow covered area</li> <li>• Snow albedo</li> <li>• Snow grain size</li> <li>• Dust/BC radiative forcing</li> </ul>
Aqua		
NPOESS Preparatory Project (NPP) - Suomi	<ul style="list-style-type: none"> <li>• Visible Infrared Imaging Radiometer Suite (VIIRS)</li> <li>• 750m spatial resolution</li> <li>• ~daily temporal resolution</li> </ul>	
Landsat Data Continuity Mission (LDCM) (launch Feb 2013)	<ul style="list-style-type: none"> <li>• Operational Land Imager (OLI)</li> <li>• 30m spatial resolution</li> <li>• 16 day temporal resolution</li> </ul>	

# NASA Snow Products: Models

Snow Product	Source	Spatial Temporal
Snow Fall (kg/m <sup>2</sup> /second) Snow Depth Snow Mass	MERRA*  GLDAS-NOAH	<ul style="list-style-type: none"><li>• 0.5°x0.625°, monthly (1980-02/2016)</li><li>• 0.125°x0.125° and 1°x1°, 3-hourly (1948-05/2016)</li></ul>
Snow Water Equivalent* (kg/m <sup>2</sup> or m)	GLDAS-NOAH	<ul style="list-style-type: none"><li>• 0.125°x0.125° and 1°x1°, 3-hourly (1948-05/2016)</li></ul>

\*MERRA: Modern-era Retrospective Analysis for Research and Applications

\*Snow Water Equivalent is the depth of water to which a snowpack melts down

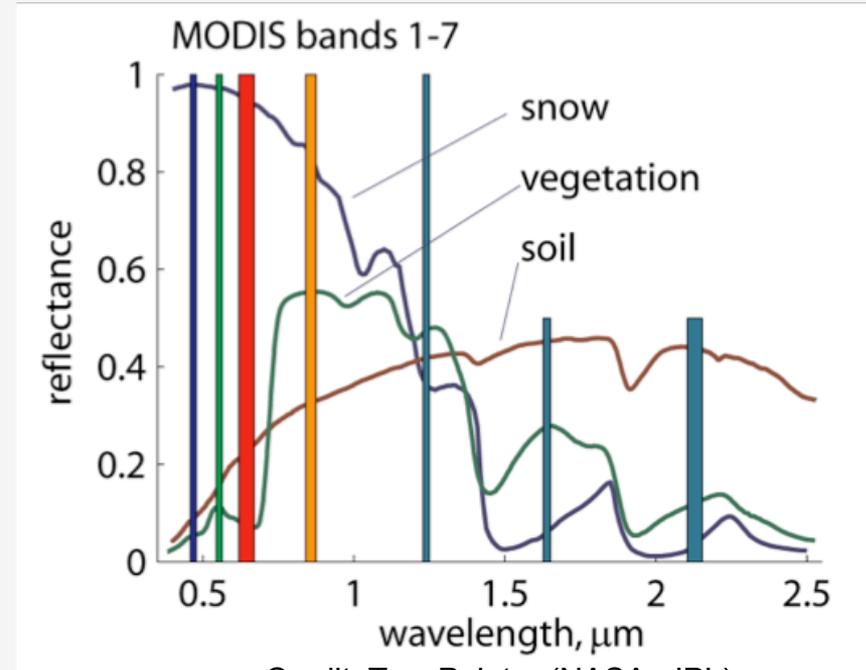


# MODIS Snow Data Products and Access

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# MODIS Snow Cover Data Products

- High resolution, daily coverage
- 1999 – present
- Available at 500m and 0.05°
- There are two snow cover products based on MODIS Spectral Reflectance:
  - Standard MODIS Product Fractional Snow Cover
  - MODSCAG (MODIS Snow Covered Area and Grain-size) Product
    - Fractional snow cover, grain size, snow water equivalent (SWE)



Credit: Tom Painter (NASA- JPL)

# MODIS Standard Products

[http://nsidc.org/data/modis/data\\_summaries#snow](http://nsidc.org/data/modis/data_summaries#snow)

MOD products are from Terra and MYD are from Aqua

## Snow Cover

Version 6 | Version 5

The following Version 6 snow cover data sets are currently available at NSIDC. This table will be updated as new data sets are released. NSIDC will continue to distribute Version 5 until Version 6 reprocessing is complete.

ID	Version	Title	Spatial Resolution	Temporal Resolution	Parameters
MYD10_L2	6	MODIS/Aqua Snow Cover 5-Min L2 Swath 500m, Version 6	500 m	5 minute	Snow Cover
MOD10_L2	6	MODIS/Terra Snow Cover 5-Min L2 Swath 500m, Version 6	500 m	5 minute	Snow Cover
MYD10A1	6	MODIS/Aqua Snow Cover Daily L3 Global 500m Grid, Version 6	500 m	1 day	Albedo, Snow Cover
MOD10A1	6	MODIS/Terra Snow Cover Daily L3 Global 500m Grid, Version 6	500 m	1 day	Albedo, Snow Cover
MYD10C1	6	MODIS/Aqua Snow Cover Daily L3 Global 0.05Deg CMG, Version 6	0.05 Deg	1 day	Snow Cover
MOD10C1	6	MODIS/Terra Snow Cover Daily L3 Global 0.05Deg CMG, Version 6	0.05 Deg	1 day	Snow Cover
MYD10A2	6	MODIS/Aqua Snow Cover 8-Day L3 Global 500m Grid, Version 6	500 m	8 day	Snow Extent
MOD10A2	6	MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid, Version 6	500 m	8 day	Snow Extent

# MODIS Standard Products: Access

Available to Download from National Snow and Ice Data Center

<http://nsidc.org/>

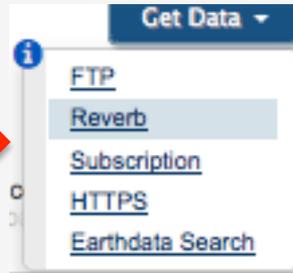
**Near-Real-Time SSMI-SSMIS EASE-Grid Daily Global Ice Concentration and Snow Extent**  
Temporal Coverage: 1995-05-04 to continuous  
Parameter: Ice Extent | Sea Ice Concentration | Snow Cover  
Data Format: HDF-EOS  
Summary: Notice (04/21/2016): On 04/05/2016 a change in the solar panel position to shade the nitrogen tank on board the Defense Meteorological Satellite Program (DMSP) F-17 satellite...More Detail

**MODIS/Terra Snow Cover 5-Min L2 Swath 500m**  
Temporal Coverage: 2000-02-24 to continuous  
Parameter: Snow Cover  
Data Format: HDF-EOS  
Summary: This data set reports the location of snow cover based on the Normalized Difference Snow Index (NDSI) and a series of screens designed to alleviate errors and flag uncertainties...More Detail

**MODIS/Aqua Snow Cover Daily L3 Global 500m Grid**  
Temporal Coverage: 2002-07-04 to continuous  
Parameter: Albedo | Snow Cover  
Data Format: HDF-EOS  
Summary: This data set contains daily, gridded snow cover and albedo derived from radiance data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board...More Detail

**MODIS/Terra Snow Cover Daily L3 Global 500m Grid**  
Temporal Coverage: 2000-02-24 to continuous  
Parameter: Albedo | Snow Cover  
Data Format: HDF-EOS  
Summary: This data set contains daily, gridded snow cover and albedo derived from radiance data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board...More Detail

**MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid**  
Temporal Coverage: 2000-02-26 to continuous  
Parameter: Snow Extent  
Data Format: HDF-EOS  
Summary: This data set reports the maximum snow cover extent during an eight-day period in 1200 km x 1200 km tiles. Tiles are generated by compositing 500 m observations from the...More Detail



- Data are in HDF format
- FTP jpg images of Level-2 and Level-3 snow cover
- Download by using Reverb or Earth Data Search (user registration required)

# MODIS Standard Products Access from Reverb

<http://reverb.echo.nasa.gov/reverb/>

Swath, Daily, and Monthly products are available

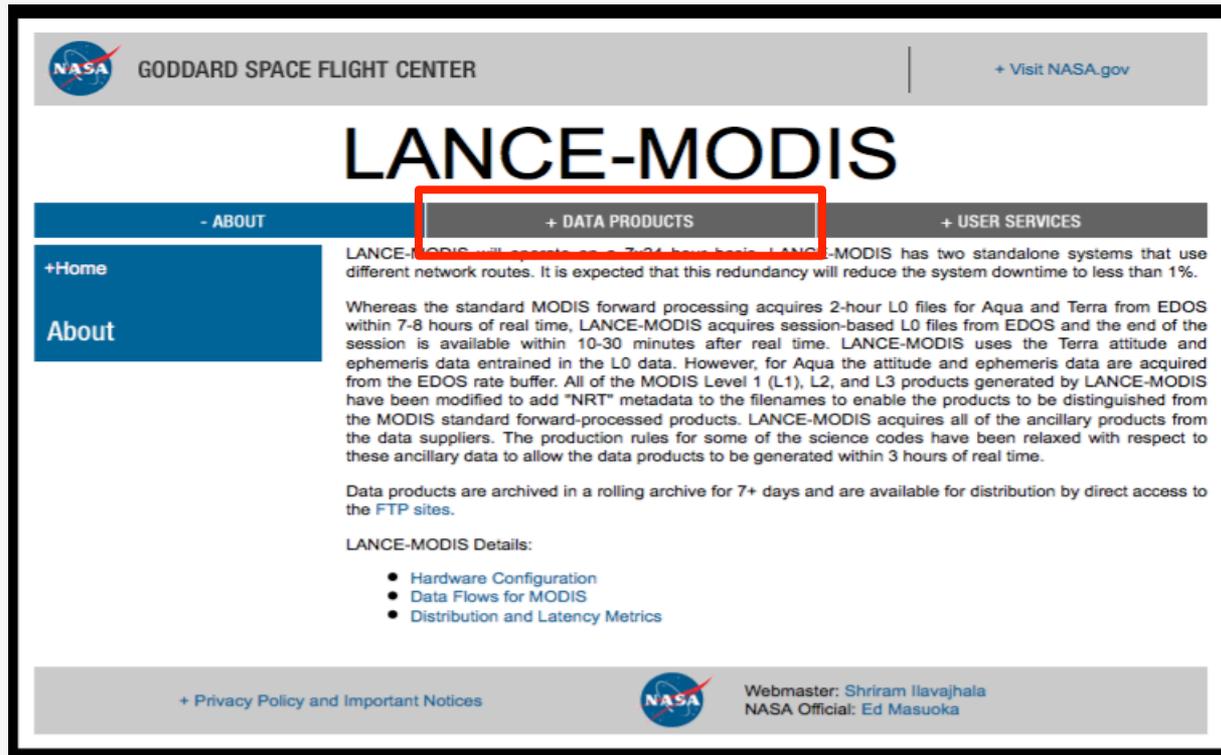
The screenshot displays the Reverb ECHO web interface. At the top, the NASA logo and 'National Aeronautics and Space Administration' are visible, along with 'EOSDIS NASA's Earth Observing System Data and Information System'. The 'Reverb | ECHO' logo is prominently displayed, with the tagline 'The Next Generation Earth Science Discovery Tool'. Navigation links include 'EOSDIS Home', 'Reverb Home', 'About', 'Tutorial', 'Shopping Cart (0)', 'Order Status', 'Service Request Status', and 'Sign In'.

The main content area is titled 'Step 1: Select Search Criteria'. It features a 'Spatial Search' section with a 'Bounding Box' input field containing the coordinates '-50.736, 163.477, -11.144, 105.680 (S,E,N,W)' and a 'Satellite' dropdown menu set to 'Satellite'. Below this is a map of the world with a bounding box overlaid on the North Atlantic region. To the right, the 'Search Terms' section has an input field with 'e.g. MODIS Fire AST\_L1A' and a 'Try out this query in Earthdata Search' button. The 'Temporal Search' section includes 'START' and 'END' date pickers, both set to 'YYYY-MM-DD HH:MM:SS', and a note that 'all times must be specified in CMT'. There are also 'Date Range' and 'Annual Repeating Dates' options.

The bottom section is titled 'Step 2: Select Datasets'. It shows a list of datasets, with one entry circled in red: 'MODIS/Aqua Snow Cover Monthly L3 Global 0.05Deg CMG V005'. Below this entry, the following details are listed: 'Archive Center: NSIDC', 'Short Name: MYD10CM', and 'Version: 5'. The interface also shows 'Found 1 dataset. Total Query Time: 0.15s' and several control buttons.

# Near Real-Time MODIS Snow Cover

<http://lance-modis.eosdis.nasa.gov/>



The screenshot shows the LANCE-MODIS website interface. At the top left is the NASA logo and 'GODDARD SPACE FLIGHT CENTER'. At the top right is a link '+ Visit NASA.gov'. The main heading is 'LANC-MODIS'. Below it is a navigation bar with three items: '- ABOUT', '+ DATA PRODUCTS' (highlighted with a red box), and '+ USER SERVICES'. On the left side, there is a vertical menu with '+Home' and 'About'. The main content area contains the following text:

LANC-MODIS will operate on a 7x24 hour basis. LANC-MODIS has two standalone systems that use different network routes. It is expected that this redundancy will reduce the system downtime to less than 1%.

Whereas the standard MODIS forward processing acquires 2-hour L0 files for Aqua and Terra from EDOS within 7-8 hours of real time, LANCE-MODIS acquires session-based L0 files from EDOS and the end of the session is available within 10-30 minutes after real time. LANCE-MODIS uses the Terra attitude and ephemeris data entrained in the L0 data. However, for Aqua the attitude and ephemeris data are acquired from the EDOS rate buffer. All of the MODIS Level 1 (L1), L2, and L3 products generated by LANCE-MODIS have been modified to add "NRT" metadata to the filenames to enable the products to be distinguished from the MODIS standard forward-processed products. LANCE-MODIS acquires all of the ancillary products from the data suppliers. The production rules for some of the science codes have been relaxed with respect to these ancillary data to allow the data products to be generated within 3 hours of real time.

Data products are archived in a rolling archive for 7+ days and are available for distribution by direct access to the [FTP sites](#).

LANCE-MODIS Details:

- Hardware Configuration
- Data Flows for MODIS
- Distribution and Latency Metrics

At the bottom, there is a footer with '+ Privacy Policy and Important Notices', the NASA logo, and contact information: 'Webmaster: Shriram Ilavajhala' and 'NASA Official: Ed Masuoka'.

# Near-real Time MODIS Snow Cover

<http://lance-modis.eosdis.nasa.gov/>

## Level-2 Swath Data 500m and 5km Resolution Snow Cover

### Terra

L2 Snow Cover, 5-Min Swath 500m	<a href="#">MOD10_L2</a>	0.26	<a href="#">L2 Snow Cover Browse</a>	N/A	07	0:46	1:32 (8)	3:14
L2 Coarse Snow Cover, 5-Min Swath 5km	<a href="#">MOD10L2C</a>	0.17				0:46	1:32 (8)	3:14

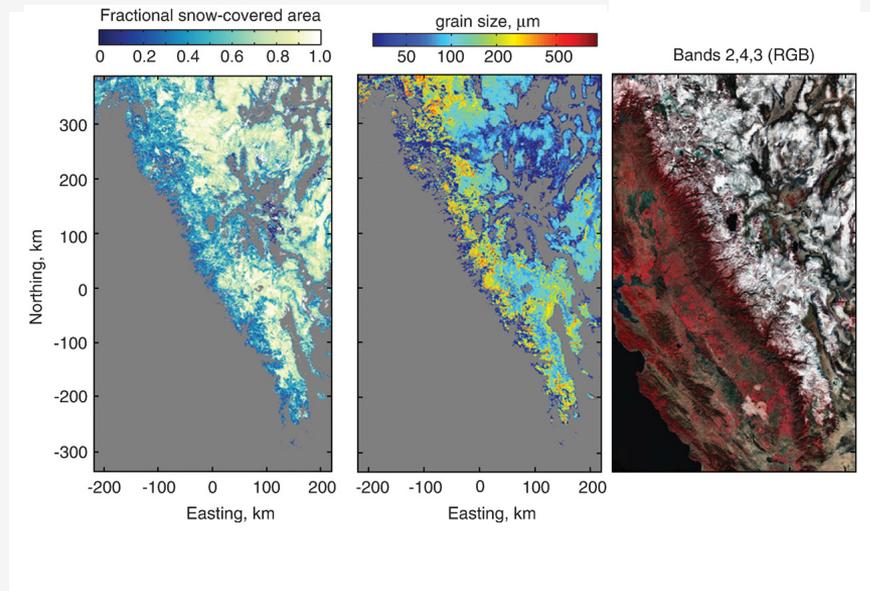
### Aqua

L2 Snow Cover, 5-Min Swath 500m	<a href="#">MYD10_L2</a>	0.26	<a href="#">L2 Snow Cover Browse</a>	N/A	07	1:00	1:47 (25)	3:30
L2 Coarse Snow Cover, 5-Min Swath 5km	<a href="#">MYD10L2C</a>	0.17				1:00	1:47 (25)	3:30

# MODSCAG Snow Products

- Uses the MODIS surface reflectance bands
- Matrix inversion to retrieve fraction of snow cover in each pixel
- Also determines the grain size and albedo of that fractional snow cover (giving what modelers want, not the composite)
- More accurate than the standard MODIS snow cover

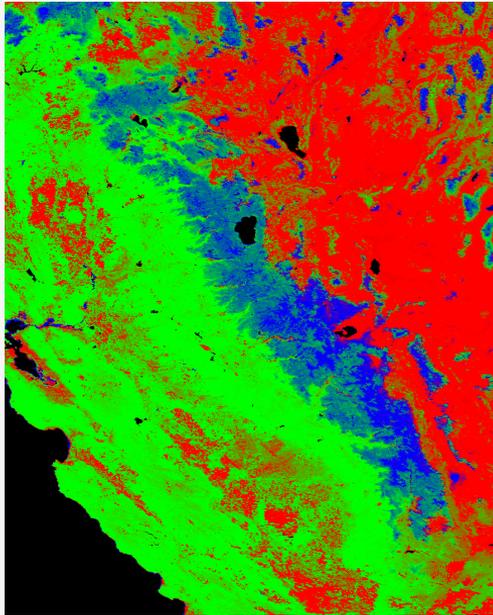
## MODSCAG Products



Credit: Tom Painter (NASA- JPL)

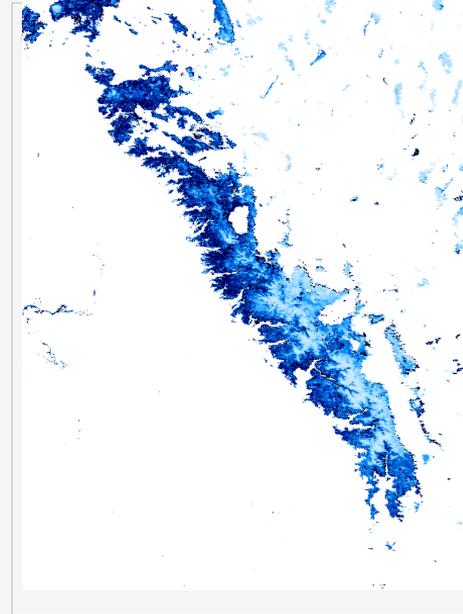
# MODSCAG Snow Data Products Examples

MODSCAG retrievals, Sierra Nevada, April 1, 20015



-  100% Snow Cover
-  100% Vegetation Cover
-  100% Rock Cover

Snow Grain Size



# MODSCAG Data Access

<http://snow.jpl.nasa.gov/portal/>

Available from JPL Snow Data Server

Home **Data** Publications Media People Links

## SNOW DATA SYSTEM

### Welcome to the Snow Data System

**About This Site....**

Welcome to the JPL Snow Data System. The Snow Data System serves cutting edge snow-related satellite and airborne remote sensing data, energy balance data for the Western US, and snow services targeting the snow, ice, climate, and water management communities.

For information about the project or comments, please contact:

Thomas Painter (thomas.painter@jpl.nasa.gov)  
Chris Mattmann (chris.a.mattmann@nasa.gov).

**Latest News**

28 November 2012 JPL Snow Products Training for SERVIR-Himalaya/ICMOD in Kathmandu, Nepal  
<https://servirglobal.net/Global/Articles/tabid/98/Article/1184/servir-himalaya-hosts-training-on-assessing-water-availability-and-flooding-pot.aspx>

24 Sept 2012  
[Avalanche on Manaslu, Nepal](#)

15 Feb 2012

**Latest Images**

**WATER RESOURCES RESEARCH**

Volume 48 | Number 7 | July 2012  
Articles published online 1 July - 31 July 2012

NASA Jet Propulsion Laboratory  
California Institute of Technology

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Snow Data System: Home → Data

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## Data

This page provides information about how to access snow data products and how to use them.

### Data Access

Thank you for your interest in data dissemination from the JPL Snow Server. We have several forms of data access, the most reliable of which is WebDAV-based dissemination, in which you download our products in GeoTIFF format.

To gain WebDAV-based access, please email [snowds-dev@jpl.nasa.gov](mailto:snowds-dev@jpl.nasa.gov) with the subject line "[DATA ACCESS REQUEST]" and a brief description of your area of work and the products you would like to access. We will process a new account for you in a timely fashion. Thank you!

### Documentation

Please see the [MODSCAG](#) and [MODRRFS](#) help pages for detailed information about these products.

### Snow Map (Experimental)

This experimental map overlays data from multiple remote sensing and in situ sources to provide a comprehensive picture of snow and ice properties.

### Western Energy Balance of Snow (WEBS) Data

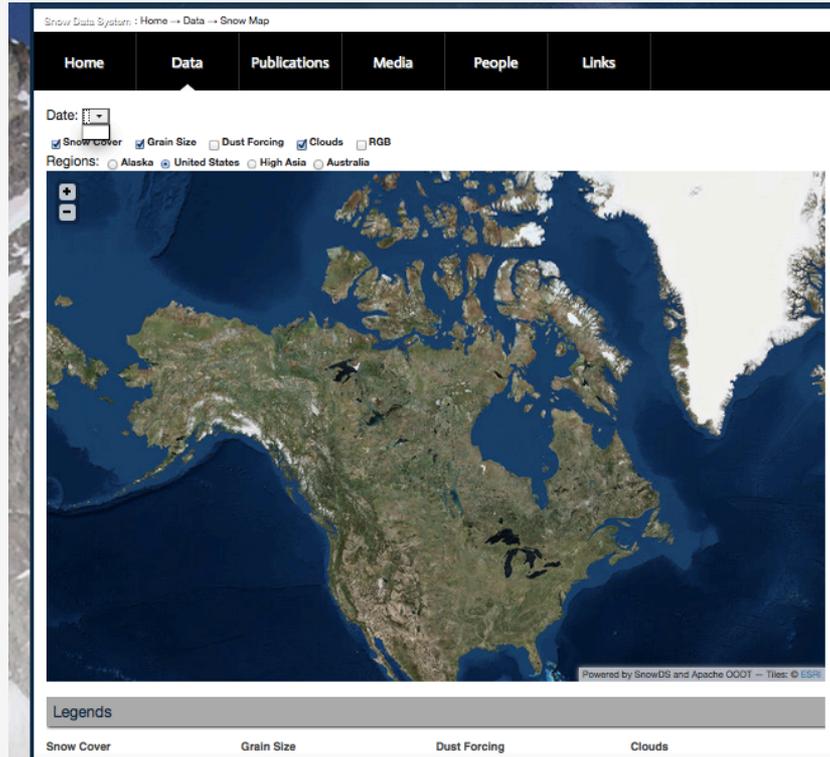
View [Western Energy Balance of Snow data](#) plotted by station and parameter.

Snow Data System Portal  
NASA Jet Propulsion Laboratory  
Built On Apache OODT  
[Privacy Usage Policy](#)

NASA Site Contact: Dr. Chris Mattmann & Dr. Tom Painter

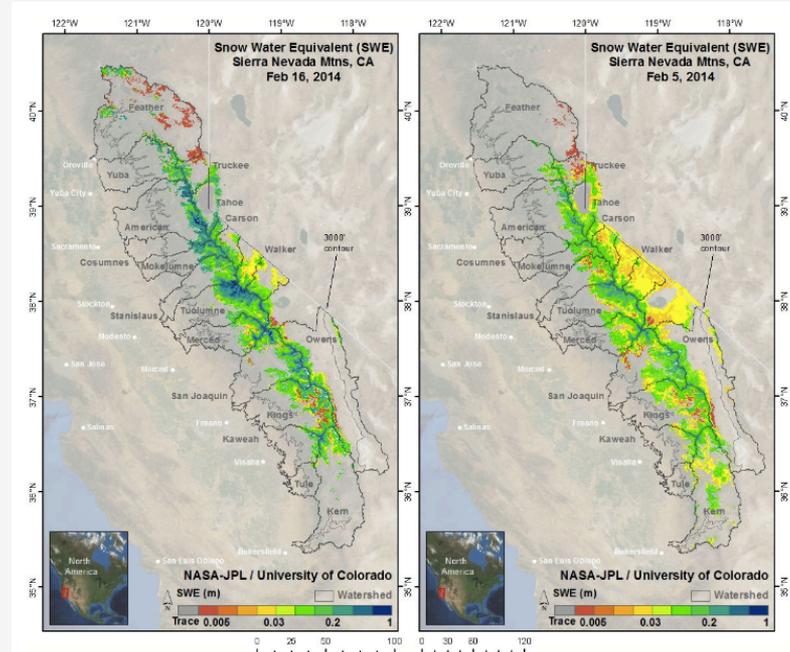
# MODSCAG Data Access

<http://snow.jpl.nasa.gov/portal/data/map/>



# MODSCAG-Derived Snow Water Equivalence

- Derived from snow cover, grain size, and albedo



[https://instaar.colorado.edu/uploads/research/labs-groups/mountain-hydrology-group/20140216\\_real\\_time\\_swe\\_report.pdf](https://instaar.colorado.edu/uploads/research/labs-groups/mountain-hydrology-group/20140216_real_time_swe_report.pdf)

# MODSCAG Application

**Water Resources**



**Integration of Precision NASA Snow Products with the Operations of the Colorado Basin River Forecast Center (CBRFC) to Improve Decision Making Under Drought Conditions**

Principle Investigator: Thomas Painter, Jet Propulsion Laboratory

**Abstract**  
The Colorado Basin River Forecast Center (CBRFC) is responsible for the entire Colorado Basin (CRB) and the eastern Great Basin (GB). From a water management perspective, the commitment of water to various users most often occurs in the spring, and is almost entirely based on estimates of the western USA snowpack. Improving seasonal drought predictions requires use of models that provide physically realistic simulations of fundamental hydrologic processes. Among these, for the western USA, representation of snow is perhaps most critical.

As drought frequency increases in the CRB and GB, it is critical that the CBRFC and the dependent water managers have more comprehensive real-time knowledge of the snow cover and its properties for more precise runoff forecasting and stakeholder decision support. The primary objective of this proposal is to integrate real-time high precision MODIS Snow Covered Area and Grain size (MODSCAG) fractional snow covered area (SCA) into CBRFC modeling and analysis systems and into stakeholder oriented data products, drastically reducing SCA uncertainties that have hampered forecasting operations for decades. A secondary objective is to ingest and study MODIS Dust Radiative Forcing in Snow (MODDRFS) radiative forcing imagery, to better understand its value as an input to modeling and forecasting approaches.

This collaboration directly addresses drought prediction, assessment, adaptation, and mitigation in support of energy security/efficiency; natural resource conservation; and household, municipal, industrial, and in-stream demands for water. It will also improve access and availability of actionable water monitoring, hence drought information. The Snow Cover and Dust Forcing products will be generated and distributed in near real-time by the JPL Snow Server for access by CBRFC. CBRFC will offer a direct connection to stakeholders (End Users) and together with other linked NWS operational centers provides an institutional home to maintain the advances of this effort beyond the project's end.

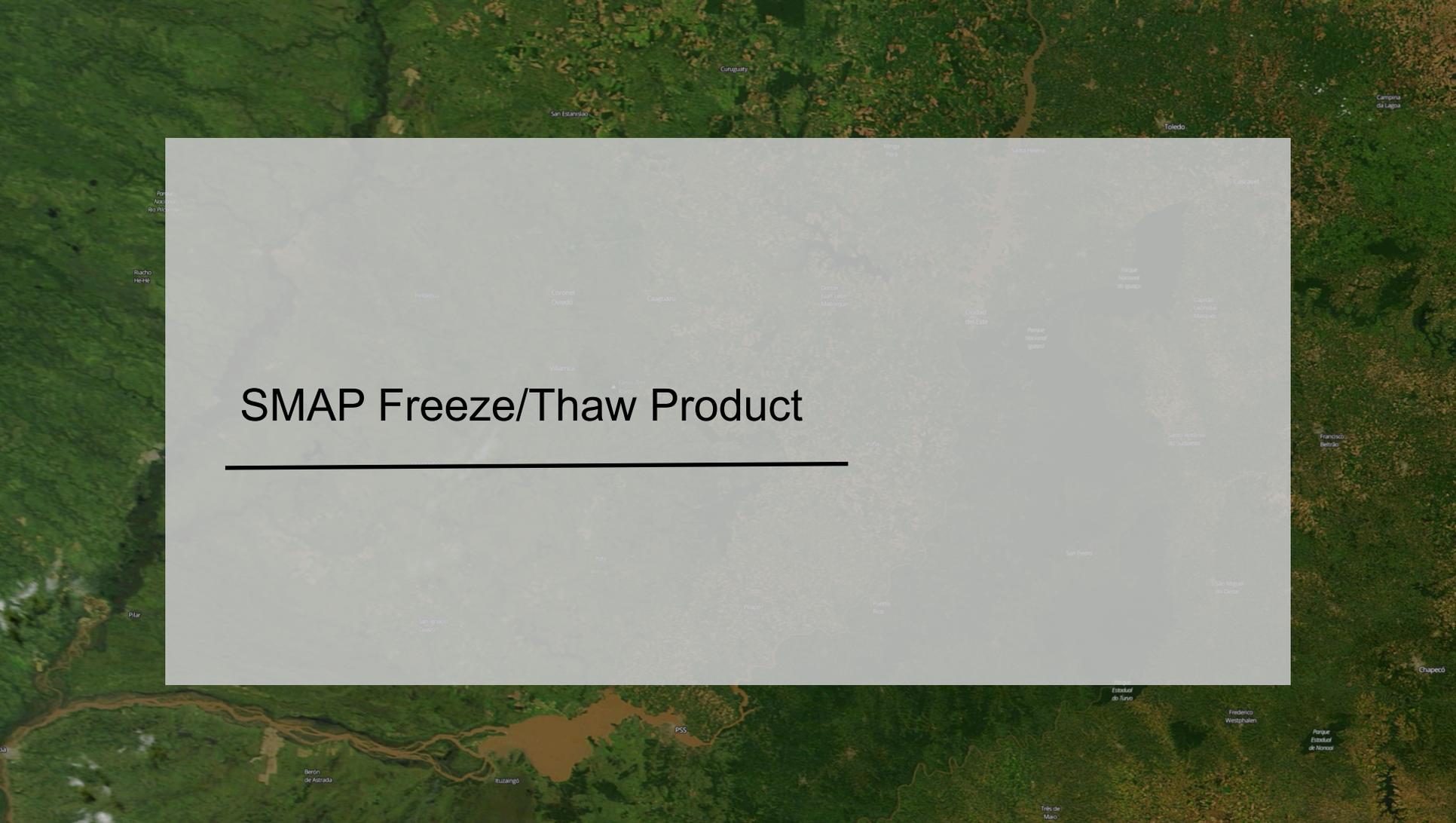
top

- Decision Making for River Basin Management
  - MODSCAG
  - Snow and Dust Radiative Forcing Information
  - Colorado Basin River Forecast Center (CBRFC)

Credit: Tom Painter (NASA- JPL)

## Limitations of MODIS Snow Data

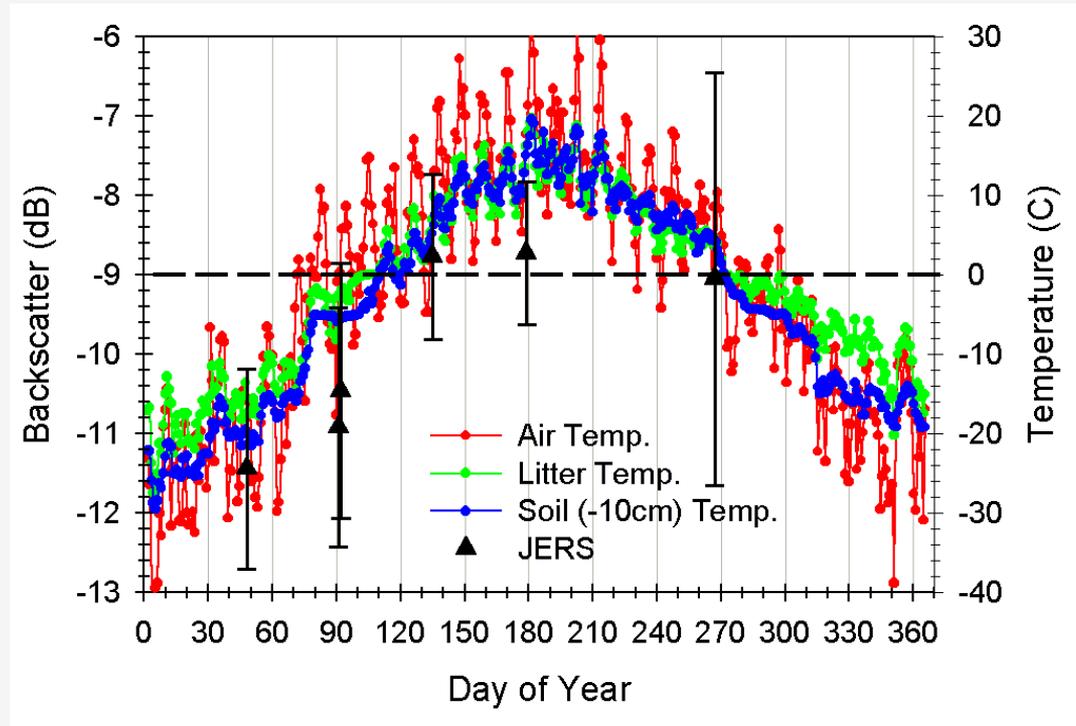
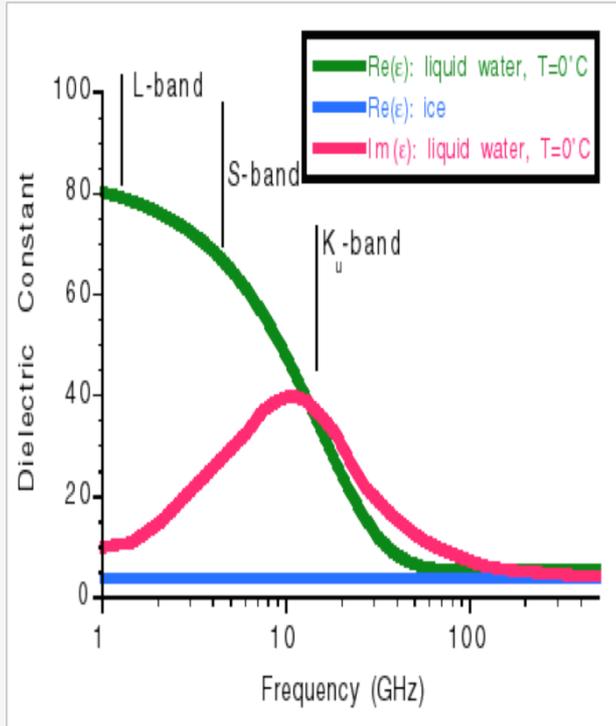
- No mapping under cloud cover
- Geometric considerations
- Noise considerations



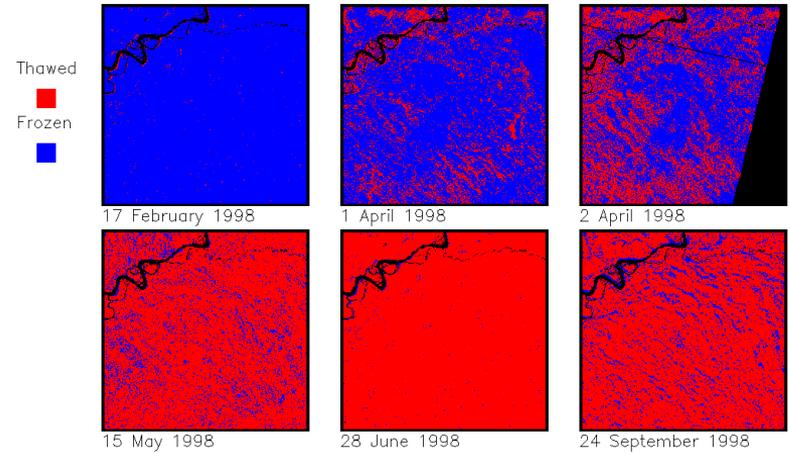
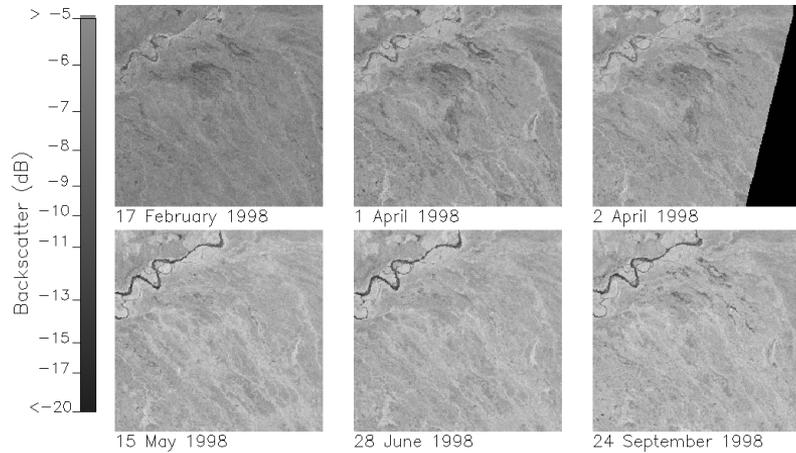
# SMAP Freeze/Thaw Product

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# Detecting Freeze/Thaw State with Microwave Remote Sensing

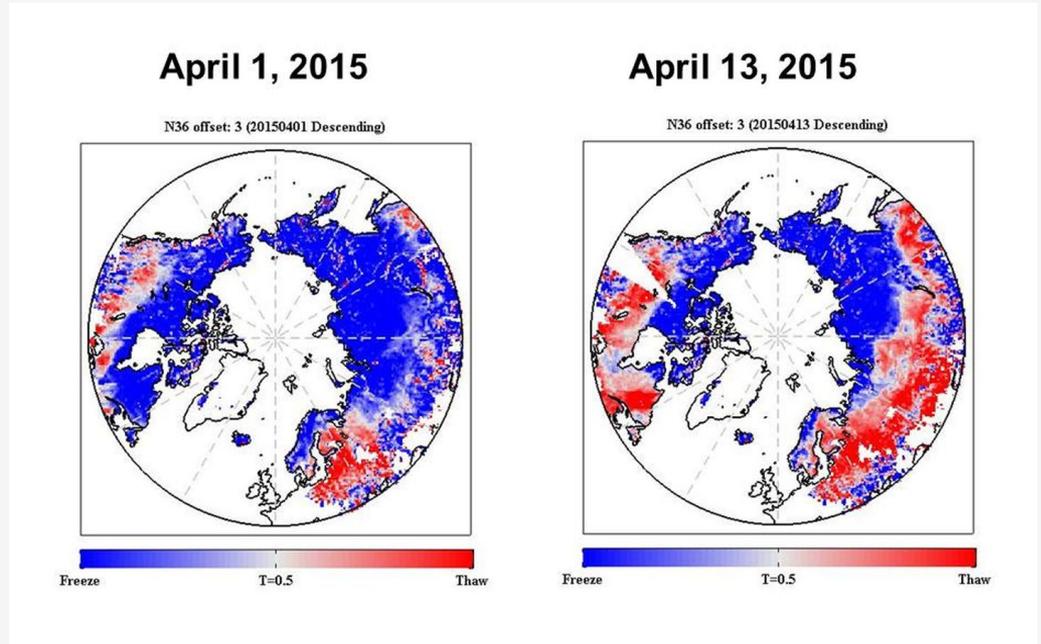


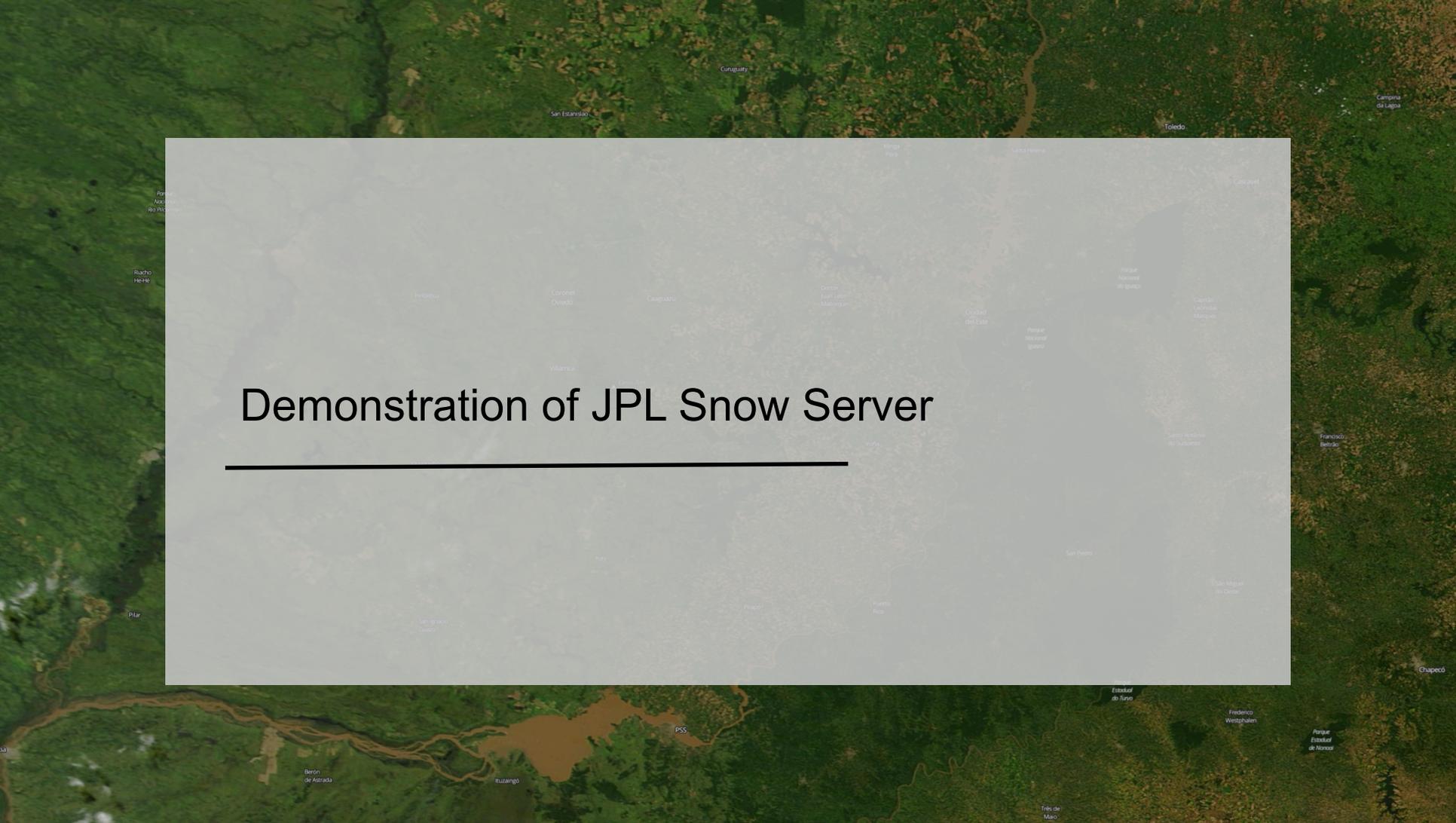
# Detecting Freeze/Thaw State with Microwave Remote Sensing



# SMAP Freeze/Thaw

- Indicates whether the land surface is frozen or thawed (includes snow melt)
- Characteristics
  - 36km resolution
  - Spatial repeat every 3 days
  - Binary measurement indicating frozen or thawed





# Demonstration of JPL Snow Server

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