



NOAA's National Snow Analyses

Tom Carroll

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Office of Climate, Water, and Weather Services

National Weather Service, NOAA

U.S. Department of Commerce

Minneapolis, Minnesota



Outline

- NOHRSC National Snow Analyses (NSA)
 - NOHRSC Clients and Stakeholders
 - Snow Observations
 - Ground-based, Airborne, and Satellite
 - Snow Modeling and Data Assimilation
 - Snow Data Assimilation System (SNODAS)
 - Snow Information Products
 - RFC Benefits of NSA Products
 - NOHRSC NSA Web-based Products
 - Modeled Snow Products
 - Observed Snow Products
 - Climate Snow Products
 - 3-D Visualization Products

Snow Economics

“The Value of Snow and Snow Information Services” (2004)

Dr. Richard Adams
Professor, Agricultural and
Resource Economics
Oregon State University

Dr. Laurie Houston
Research Assistant
Oregon State University

Dr. Rodney Weiher
Chief Economist
National Oceanic and
Atmospheric Administration
U.S. Dept. of Commerce

Economic Benefits of Snow

Winter tourism	Exceeds \$8 billion / yr	New England and Rocky Mountains
Cold water fishing (snow is cold water source)	Exceeds \$2.3 billion / yr	New England
Snowpack water storage	Up to \$348 billion / yr	Western U.S.

“... improved snow information and services have potential benefits greater than \$1.3 billion annually.”

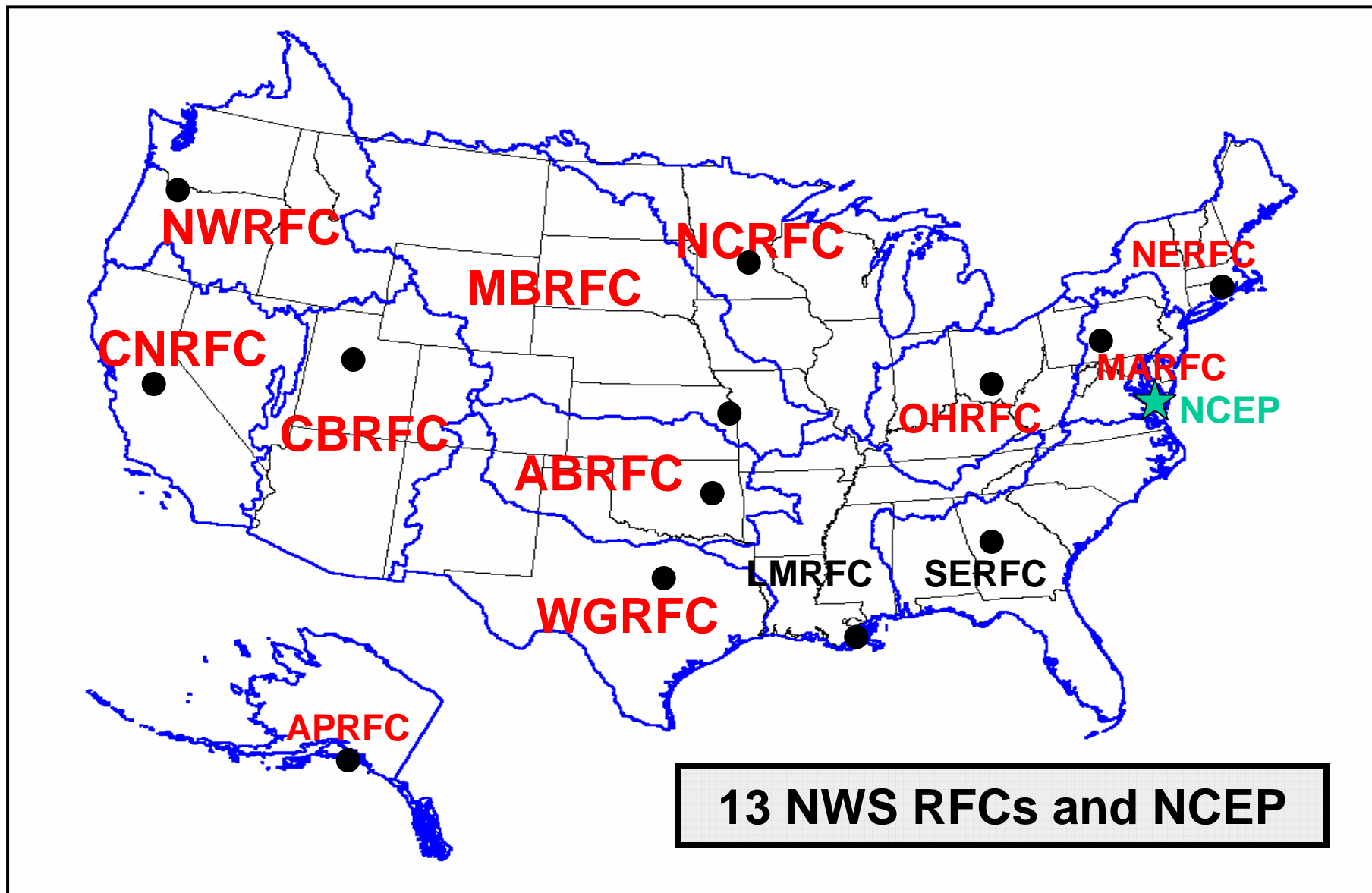
Economic Costs of Snow

Snow removal	Exceeds \$2 billion / yr	U.S.
Road closures that cause lost retail trade, wages, and tax revenue	Exceeds \$10 billion / day	Eastern U.S.
Flight delays	\$3.2 billion / yr	U.S. carriers
Damage to utilities	Up to \$2 billion / event	
Flooding from snowmelt	\$4.3 billion	1997 U.S. floods

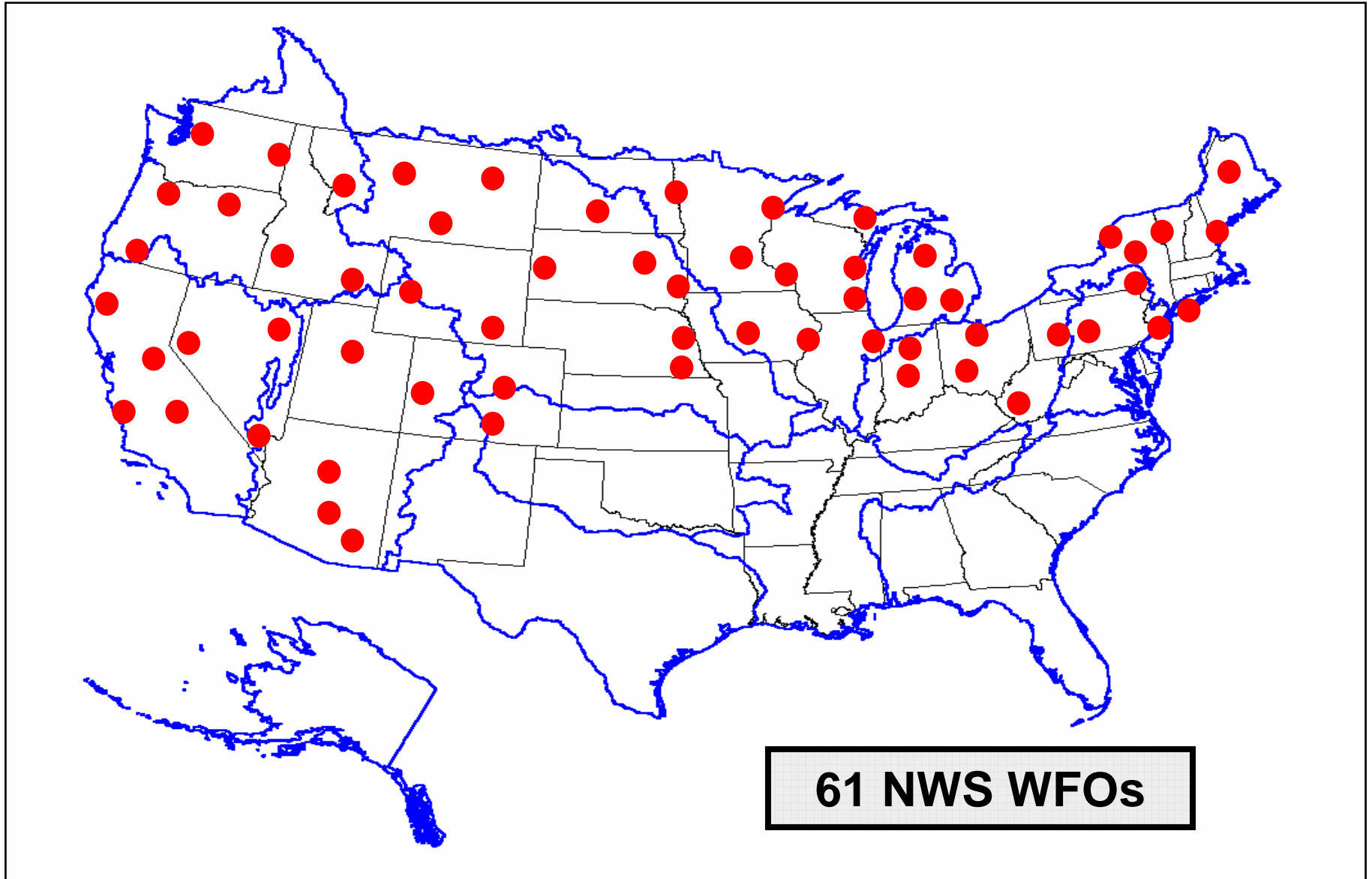
“... investments that make only modest improvements in snow information will have substantial economic payoffs.”



NOHRSC NWS Clients



NOHRSC NWS Clients



NOHRSC External Stakeholders

(selected)

- United States
 - U.S. Army Corps of Engineers
 - Bureau of Reclamation
 - Natural Resources Conservation Service
 - Montana Department of Emergency Services
 - San Francisco Public Utilities Commission
 - University of Albany ASRC/CESTM
 - University of Wisconsin Sea Grant Institute
 - National Snow and Ice Data Center
 - Baron Advanced Meteorological Systems, LLC
 - Meteorlogix, Inc.
 - Weather Decision Technologies, Inc.
 - General Public
- Canada
 - Manitoba Department of Natural Resources
 - New Brunswick Department of Natural Resources

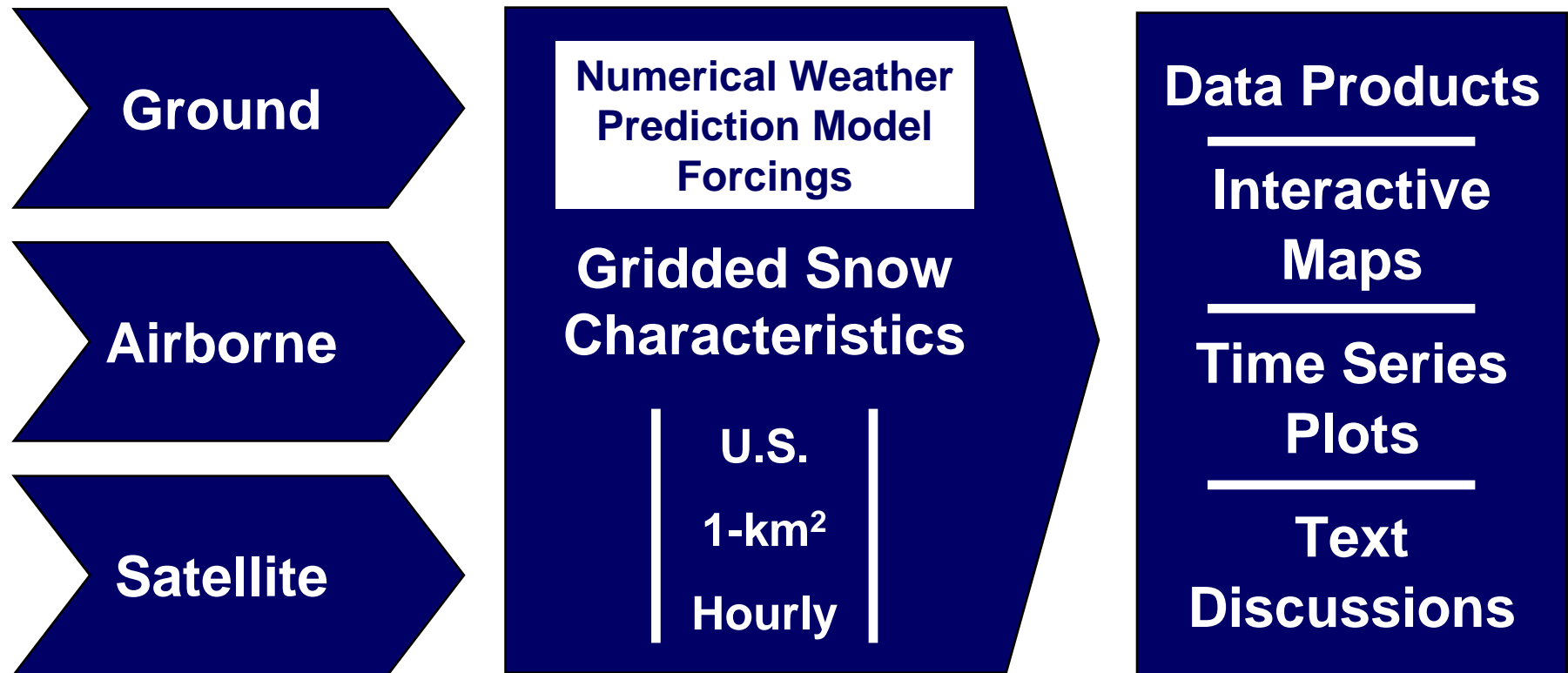


National Snow Analyses (NSA)

Multi-sensor
Snow Observations

Snow Modeling and
Data Assimilation

Snow Information
Products



National Snow Analyses (NSA)

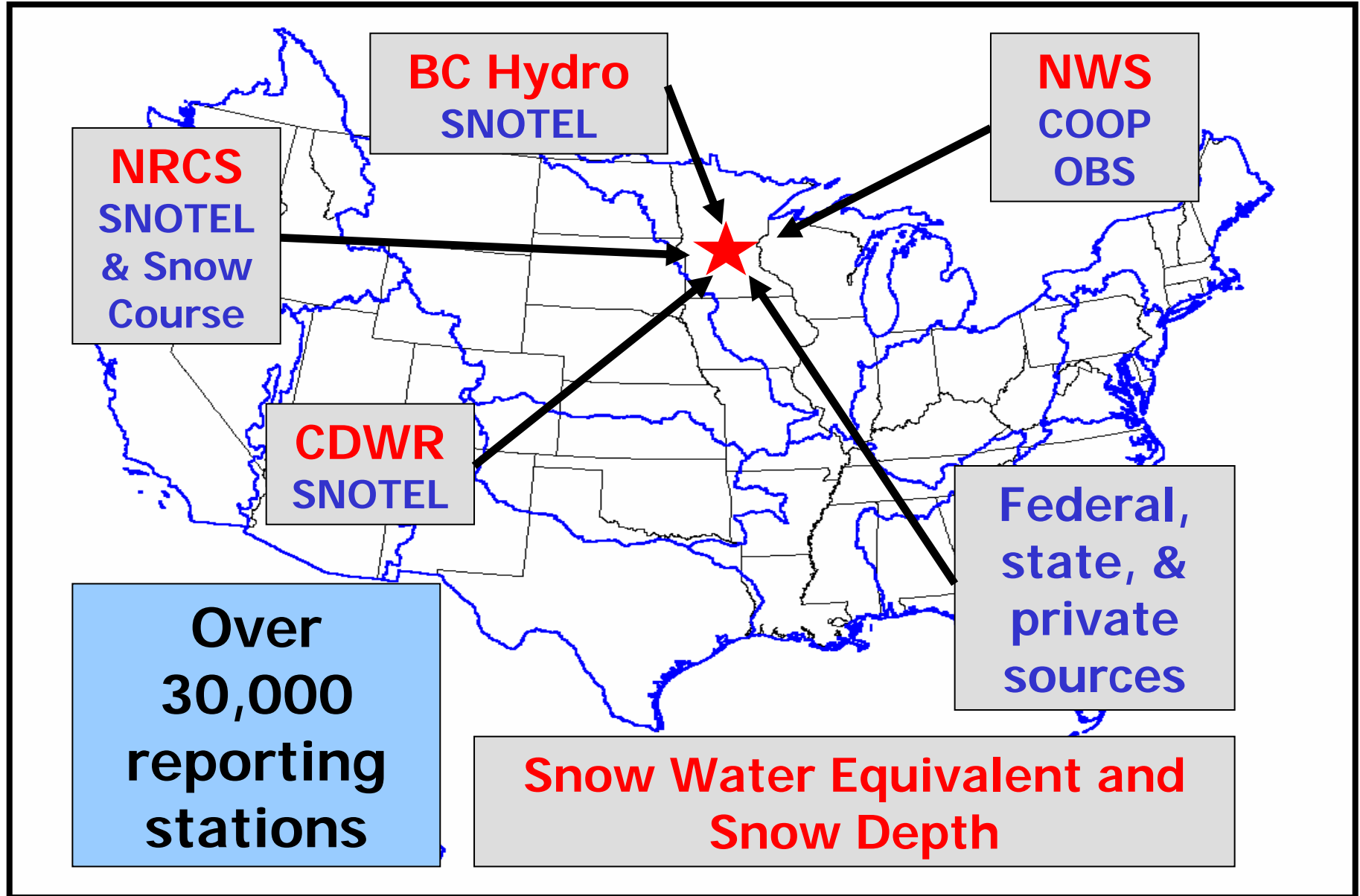
Multi-sensor Snow Observations



- **National Weather Service**
 - First-order Stations
 - Cooperatives
- **Federal and State Agencies**
 - NRCS SNOTEL and Snow Courses
 - USACE New England District Snow Surveys
 - Federal Aviation Administration
 - California Dept. of Water Resources
- **Regional Mesonets**
 - Maine Cooperative Snow Survey
 - PA, OK, IA, ND, NC State Mesonets
 - MESOWEST (150 smaller mesonets)
- **International Agencies**
 - St. John River Basin
 - Environment Canada
 - BC Hydro

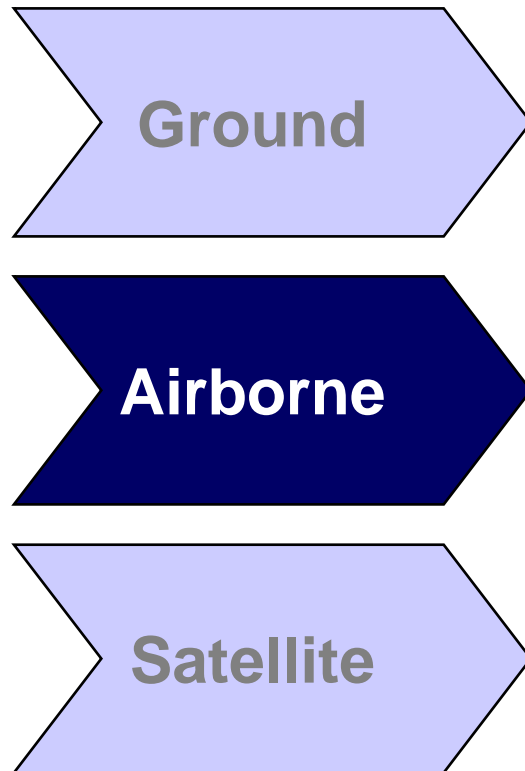
50,000+ stations in database
30,000+ actively reporting stations
10,000+ unique stations reporting snow observations

Ground-Based Snow Observations



National Snow Analyses (NSA)

Multi-sensor Snow Observations



NWS Airborne Snow Survey Program



- **Snow Water Equivalent Measurement**
 - Attenuation of natural terrestrial gamma radiation by water in snow

Airborne Snow Survey Program

Aero Commander



Survey aircraft fly at 500 feet agl.

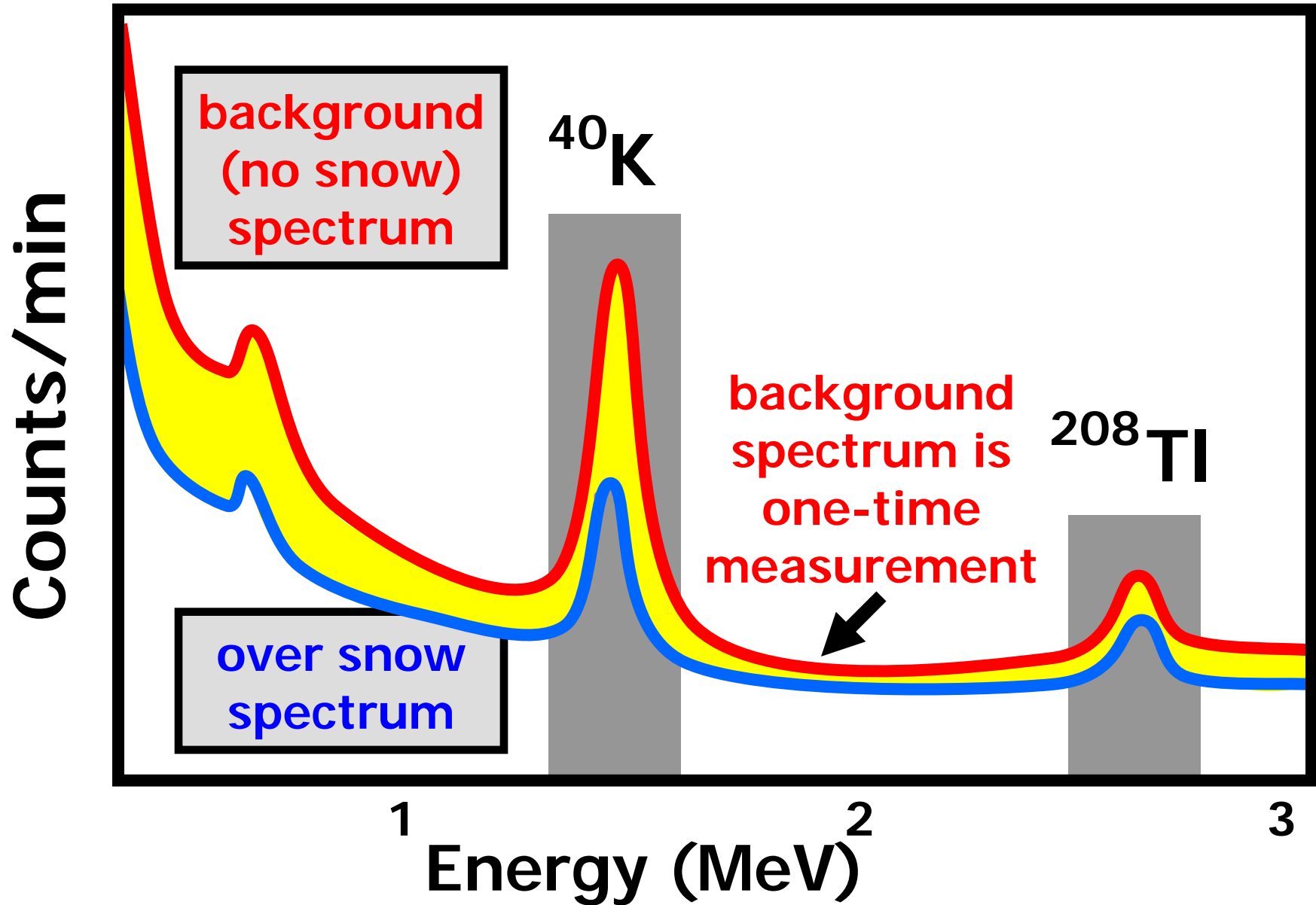
Airborne Snow Survey Program

Turbo Commander used in the West and in Alaska



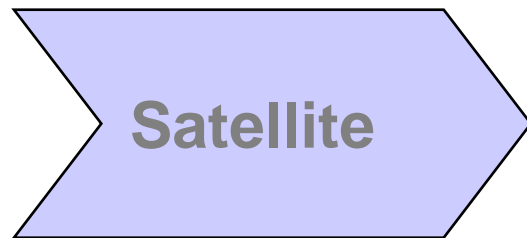
1984 Turbo Commander

Natural Terrestrial Gamma Radiation

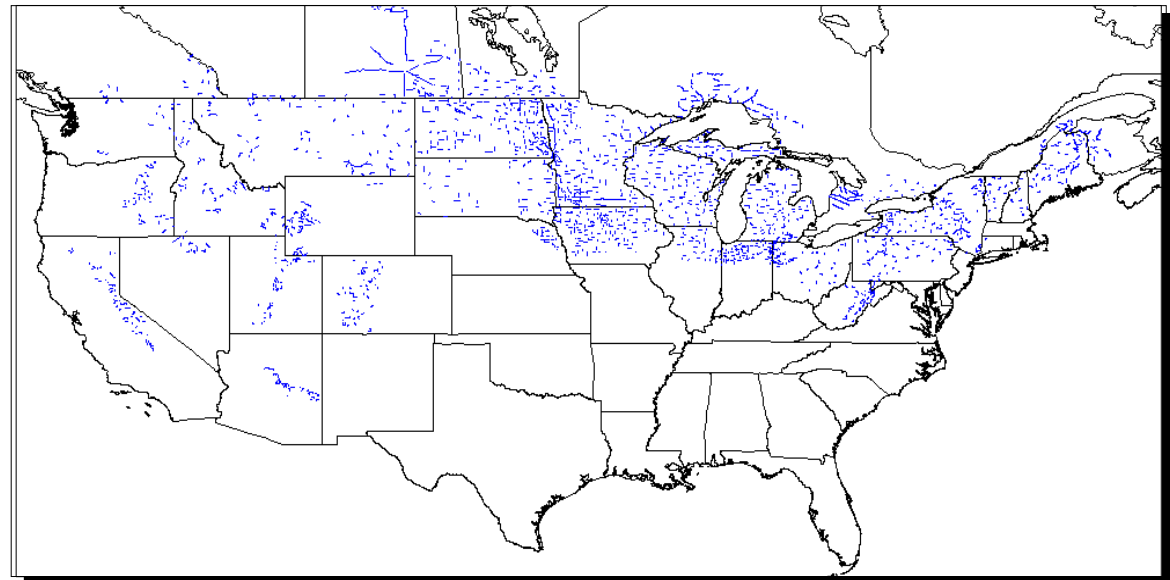


National Snow Analyses (NSA)

Multi-sensor Snow Observations



Airborne Snow Survey Program Flight Line Network

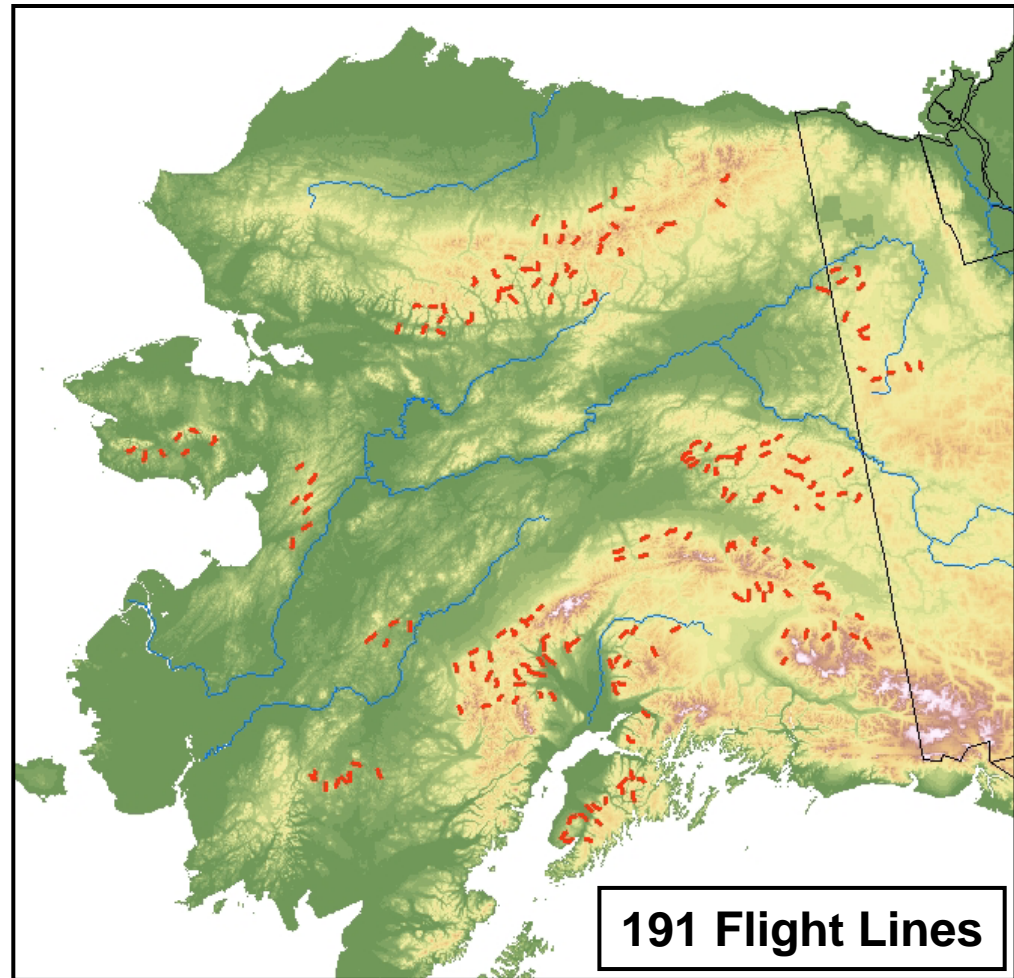


2,187 Flight Lines
31 States, 8 Provinces

National Snow Analyses (NSA)

Alaska Flight Line Network

Multi-sensor Snow Observations

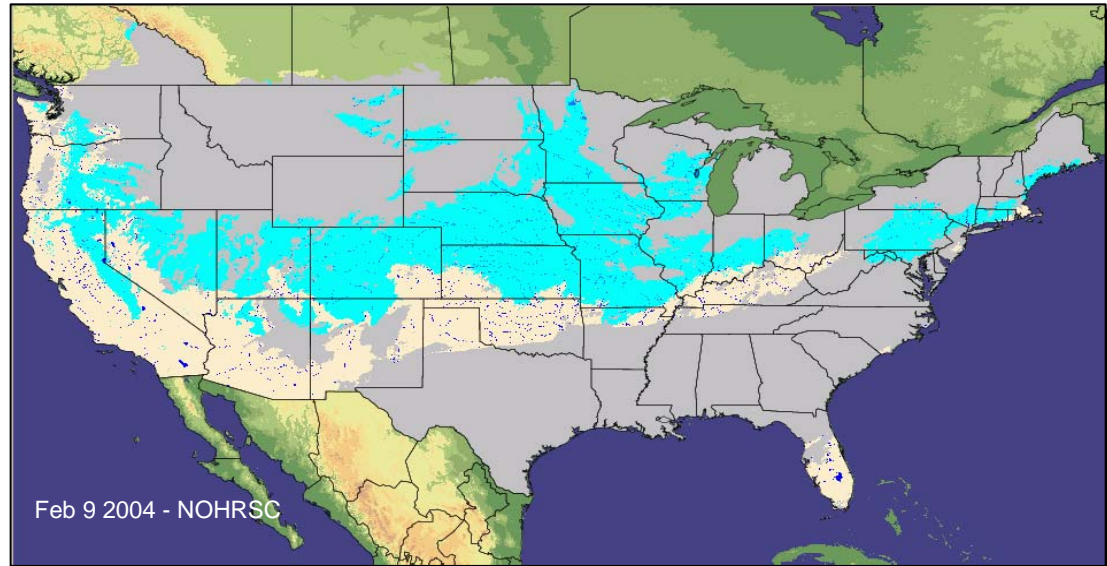


National Snow Analyses (NSA)

Multi-sensor Snow Observations



Satellite Areal Extent of Snow Cover

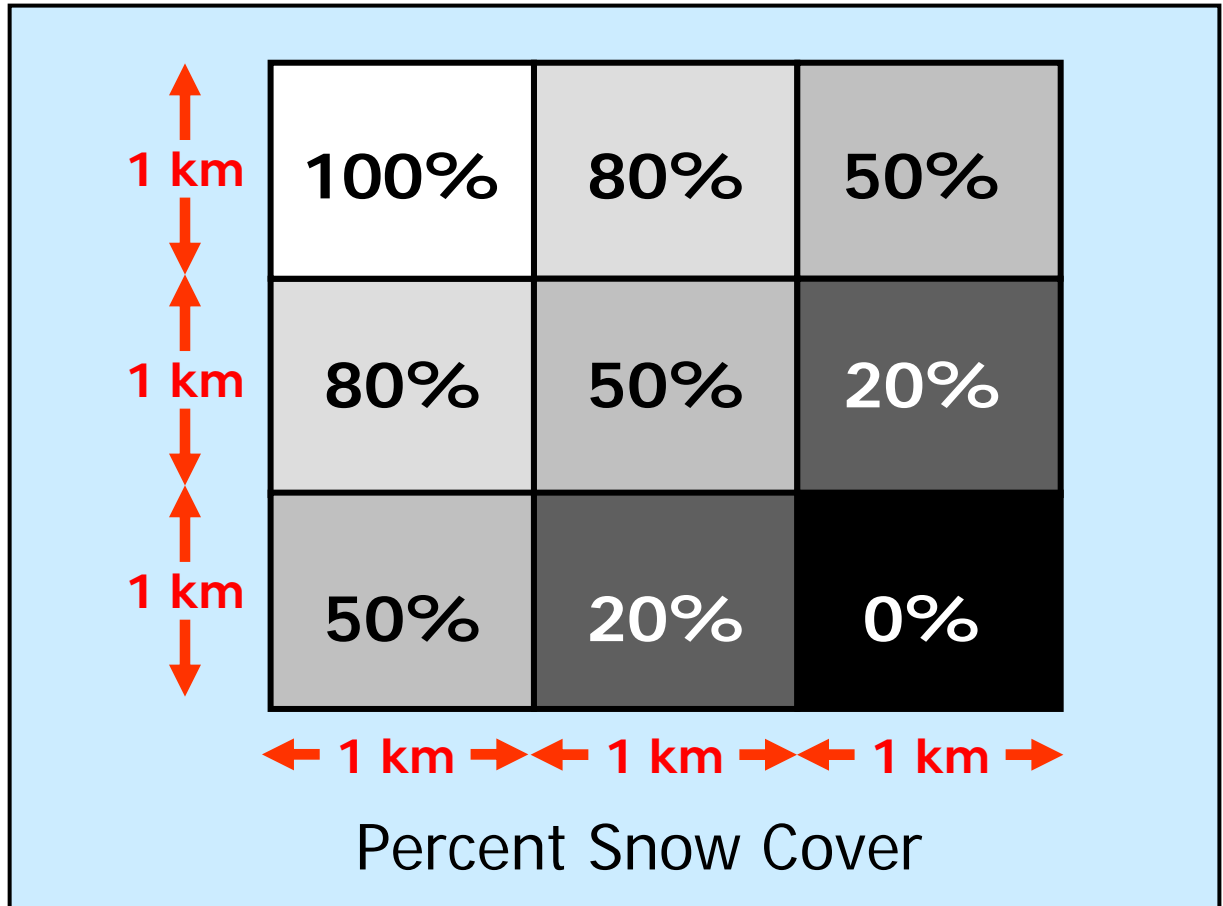


- Areal extent of snow cover is mapped using optical remote sensing data from geostationary and polar-orbiting satellites.
- Cloud cover obscures surface – significant problem.
- Sub-pixel percentage of snow cover (FSCA) developed by ERDC/CRREL is in second year of testing in NWS/NOHRSC operations.

National Snow Analyses (NSA)

Advanced Very High Resolution Radiometer (AVHRR)
Fractional Snow Cover

Multi-sensor
Snow Observations



AVHRR Fractional Snow Cover 2005 December 15



National Operational Hydrologic Remote Sensing Center Interactive Snow Information

Get Time Series for Basin ID: ABRFC [Listing](#)

Get Basin Averages for RFC [Listing](#)

Get Climatology for Station ID: [Listing](#)

Navigation Tools

Help
Comments



Lon: Lat:

Query

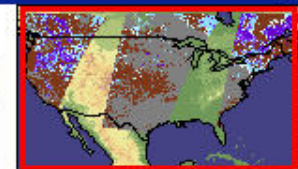
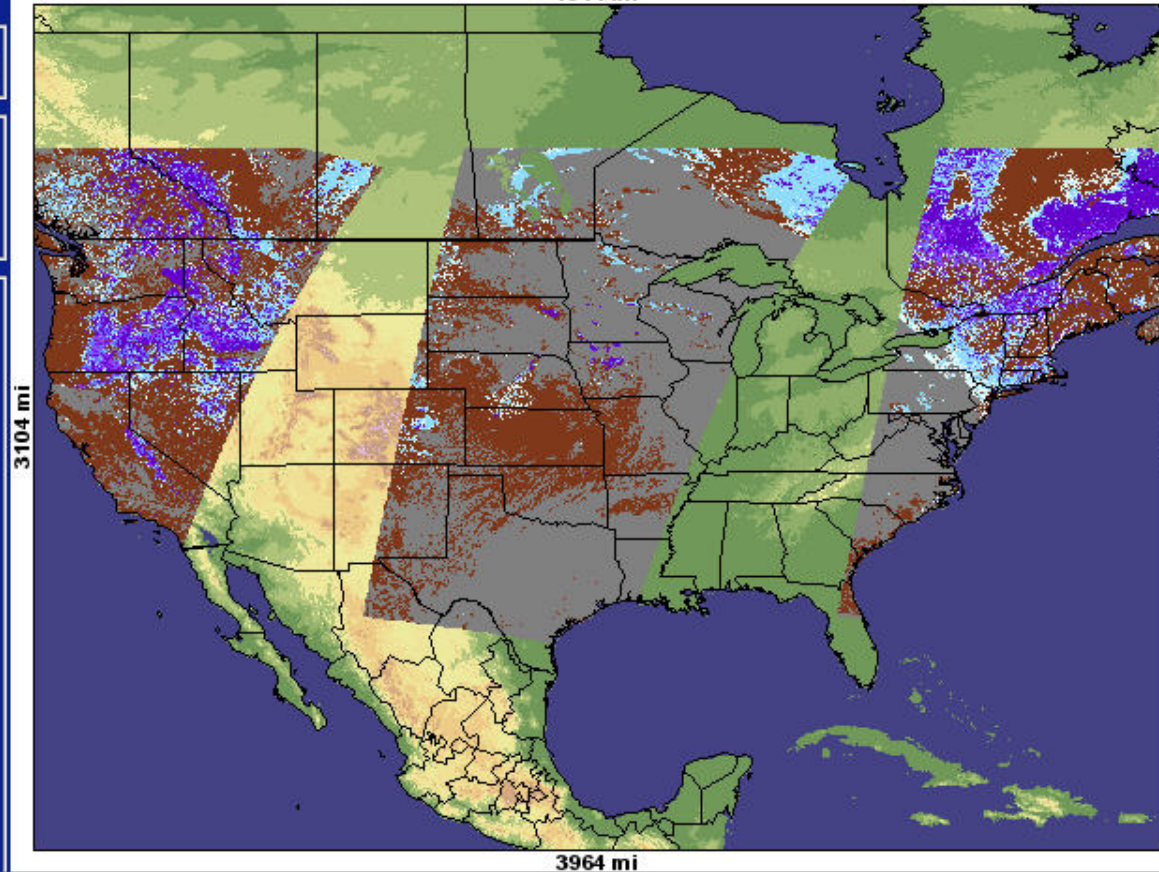
Redraw Map

Select Physical Element

Select Date
 2005 December 15 12:00 Z
 Snap to nearest time

- Select Overlays
- Hydrologic Features**
- Basins
 - HUCs (6-digit)
 - RFC Boundaries
 - Major Rivers
 - Rivers and Streams
 - Lakes and Reservoirs
- Political Features**
- County Boundaries
 - CWA Boundaries
 - State Boundaries
 - National Boundaries
- Point Features**
- Stations Label
 - Cities Label
 - Flight Lines Label
 - Climate Stns. Label
 - Alpine Skiing Label
 - XC Skiing Label

Fractional Extent of Snow Cover Observed by Satellite for 2005 December 15, 12:00 Z
1914 mi



Percent snow cover

- 80 to 100
- 60 to 80
- 40 to 60
- 20 to 40
- 1 to 20
- No Snow
- Clouds
- Not Estimated

Elevation in feet (Not estimated)

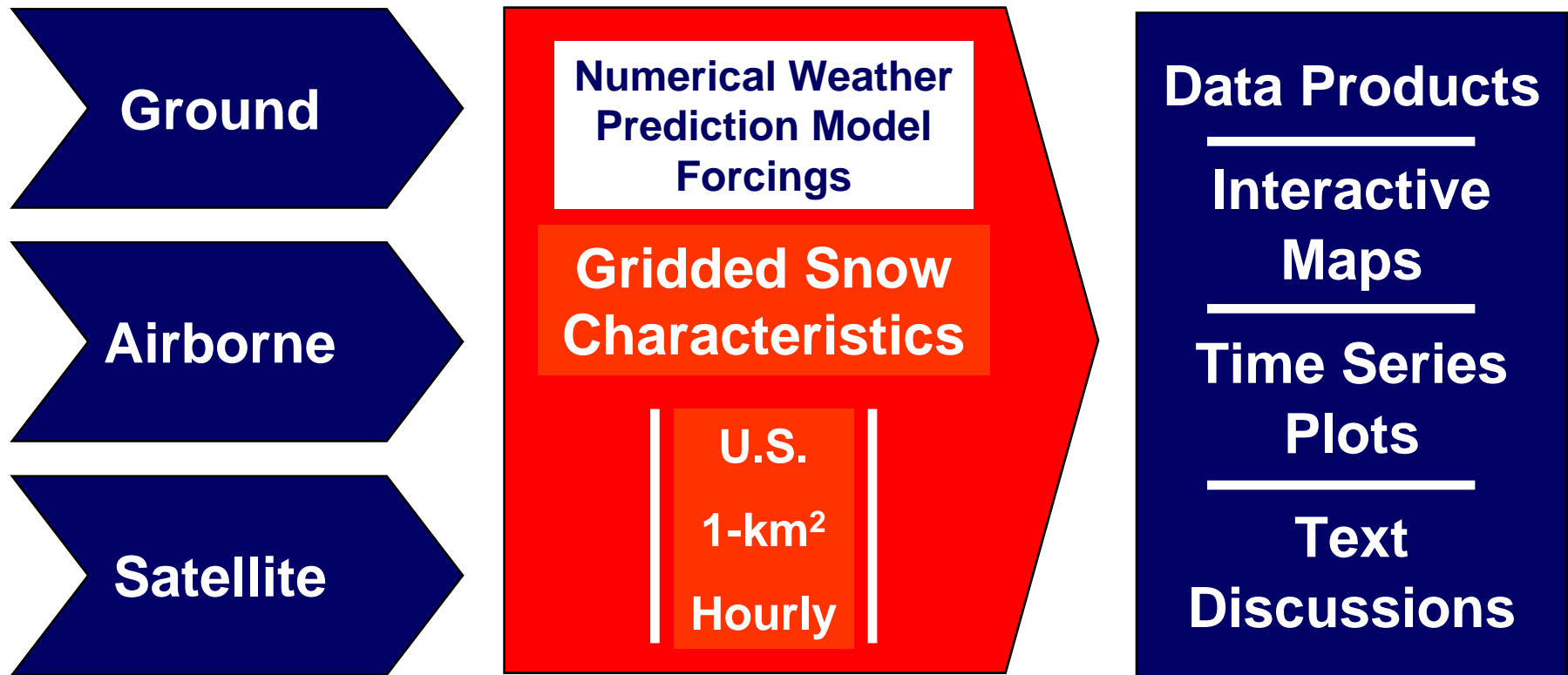
- > 13124
- 8203 to 13124
- 3281 to 8203
- 3 to 3281
- < 3

National Snow Analyses (NSA)

Multi-sensor
Snow Observations

Snow Modeling and
Data Assimilation

Snow Information
Products



National Snow Analyses (NSA)

Features	Major Products	Product Formats
Energy-and-mass-balance snow model	Snow water equivalent	National and regional map animations
Implemented for CONUS only	Snow depth	Interactive map: user selects time and place
Run at hourly time steps	Average snowpack temperature	Alphanumeric text: spatial averages
1 km ² spatial resolution	Snowmelt	Time-series: modeled and observed
Incorporates all available data	Snowpack sublimation and condensation	Gridded: GIS and spatial applications
Generates hourly and daily snow products	24-hour change products	Text discussions on snowpack conditions

National Snow Analyses (NSA)

Snow Modeling and Data Assimilation

Numerical Weather
Prediction Model
Forcings

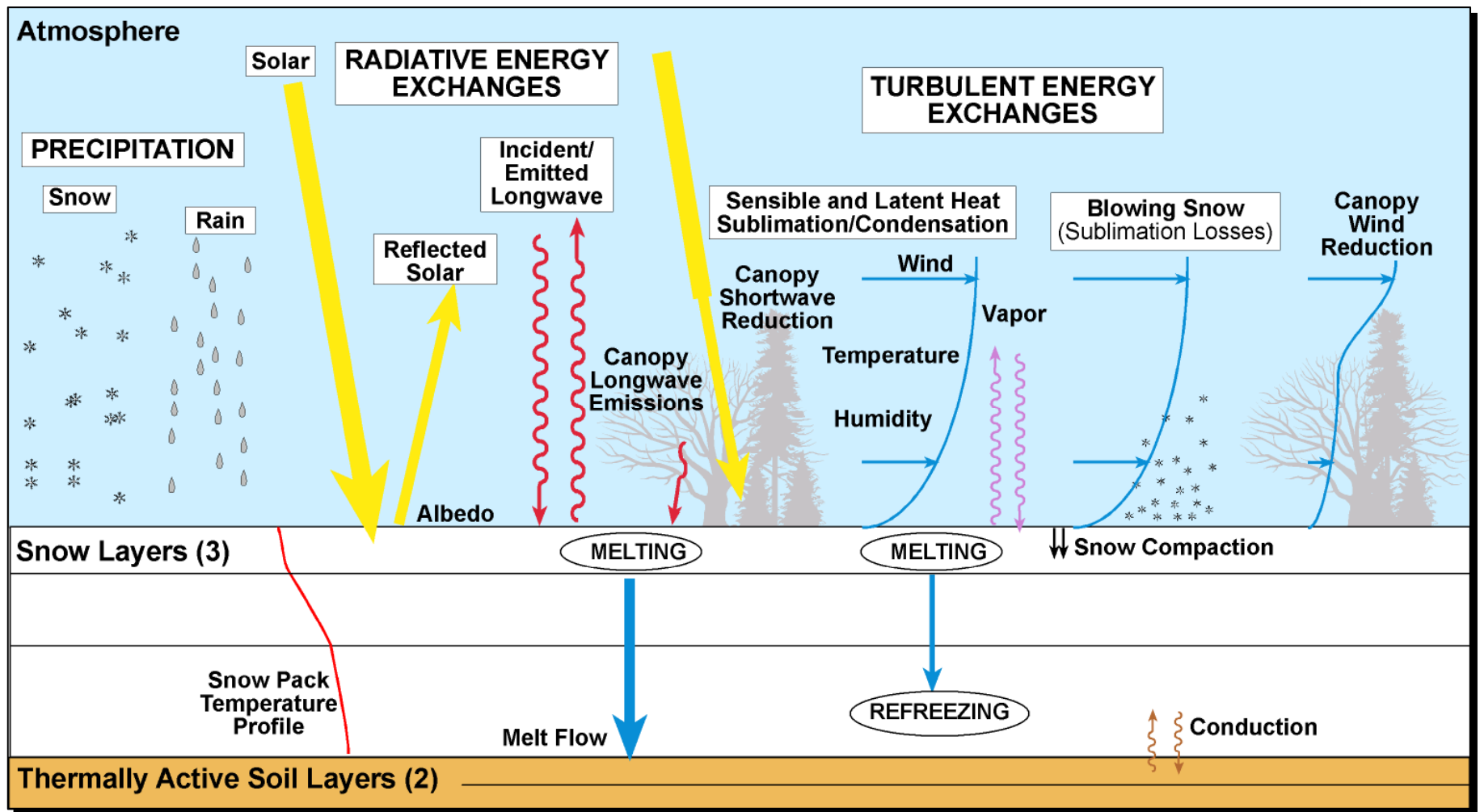
Gridded Snow
Characteristics

U.S.
1-km²
Hourly

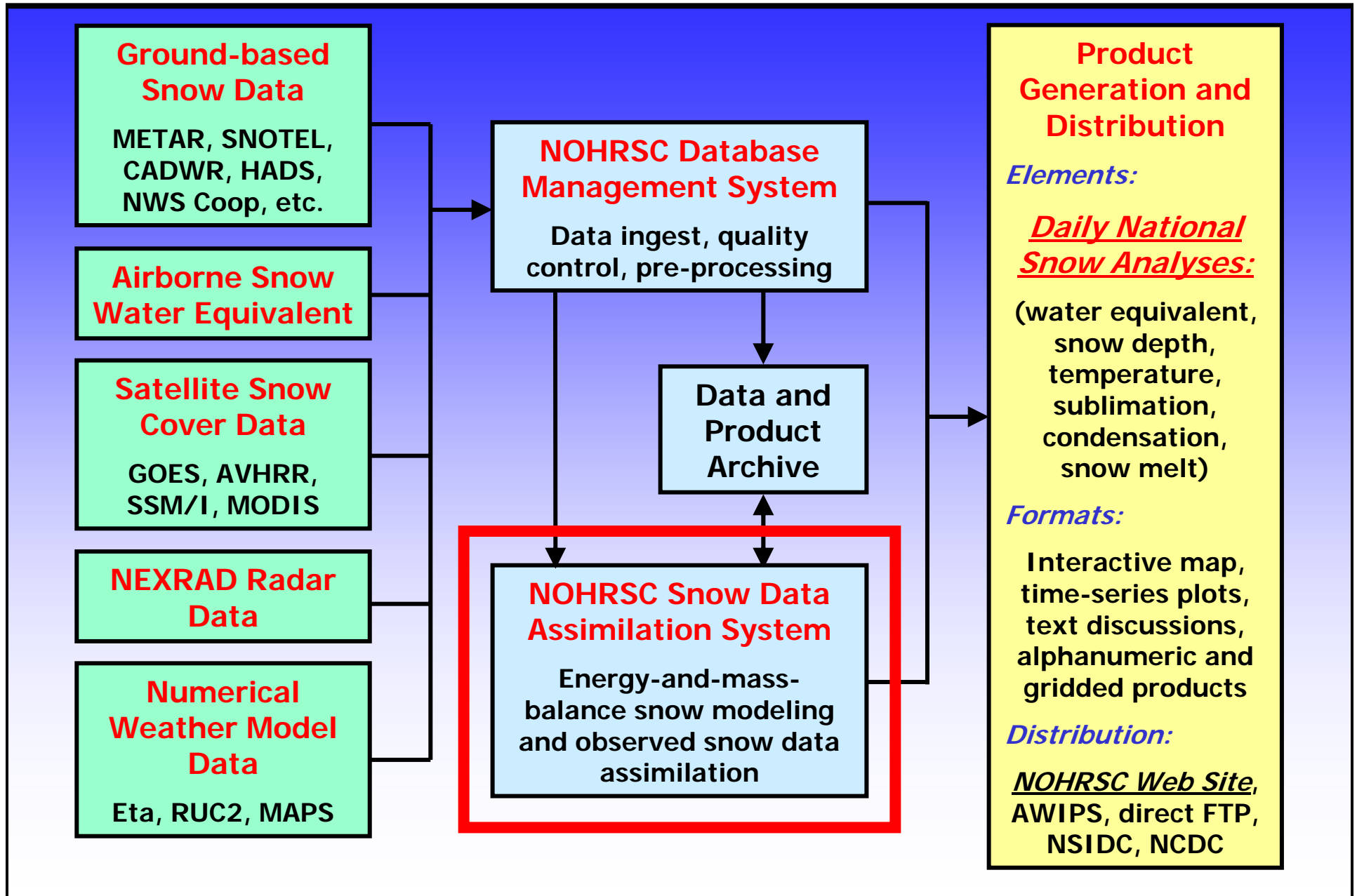
- **Land Surface Model for Snow and Soil**
 - Domain: Continental U.S.
 - Resolution: 1km², Hourly
 - Physics: 5-Layer Energy and Mass Balance
 - Spatial implementation of modified 1-D SNTherm model developed by ERDC/CRREL (*Anderson/Jordan*)
 - Spatial implementation of Prairie Blowing Snow Model (*Pomeroy et al.*)
 - Forcing: Mesoscale Weather Analyses
 - RUC2, Eta physically downscaled to 1 km²
 - Snow State Variables:
 - Water Equivalent (SWE)
 - Total Depth
 - Surface Temperature
 - Average Temperature
 - Liquid Water Content (Snow Wetness)
 - Snow Melt
- **Snow Data Assimilation System**
 - Multi-sensor data fusion to update snow states in model (SWE, snow depth)

NOHRSC Snow Model Physics

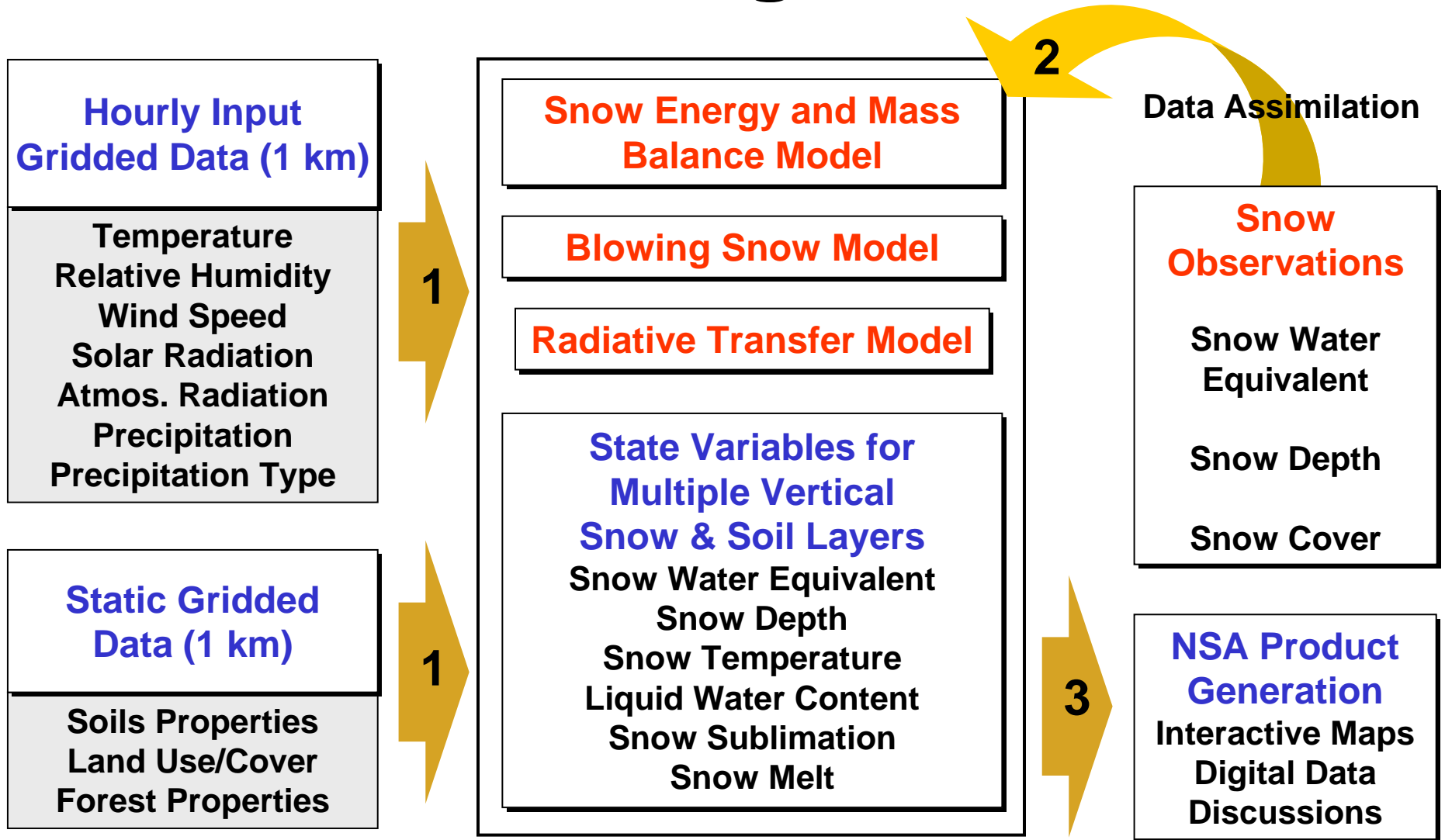
$$(K\downarrow - K\uparrow) + (L\downarrow - L\uparrow) + Q_e + Q_h + Q_g + Q_p = \Delta Q$$



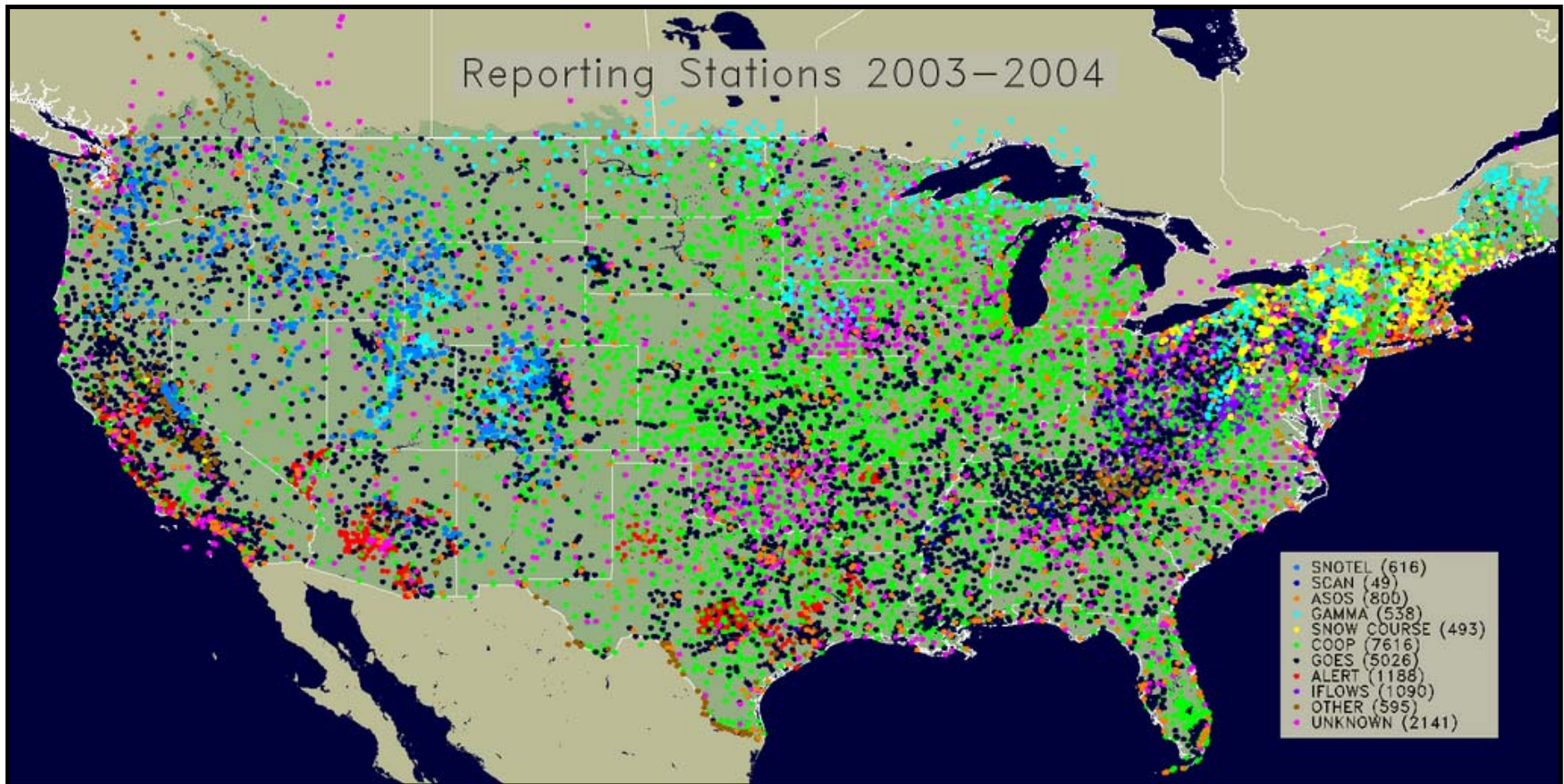
NOHRSC Operations



Snow Modeling Framework



Over 30,000 Reporting Stations

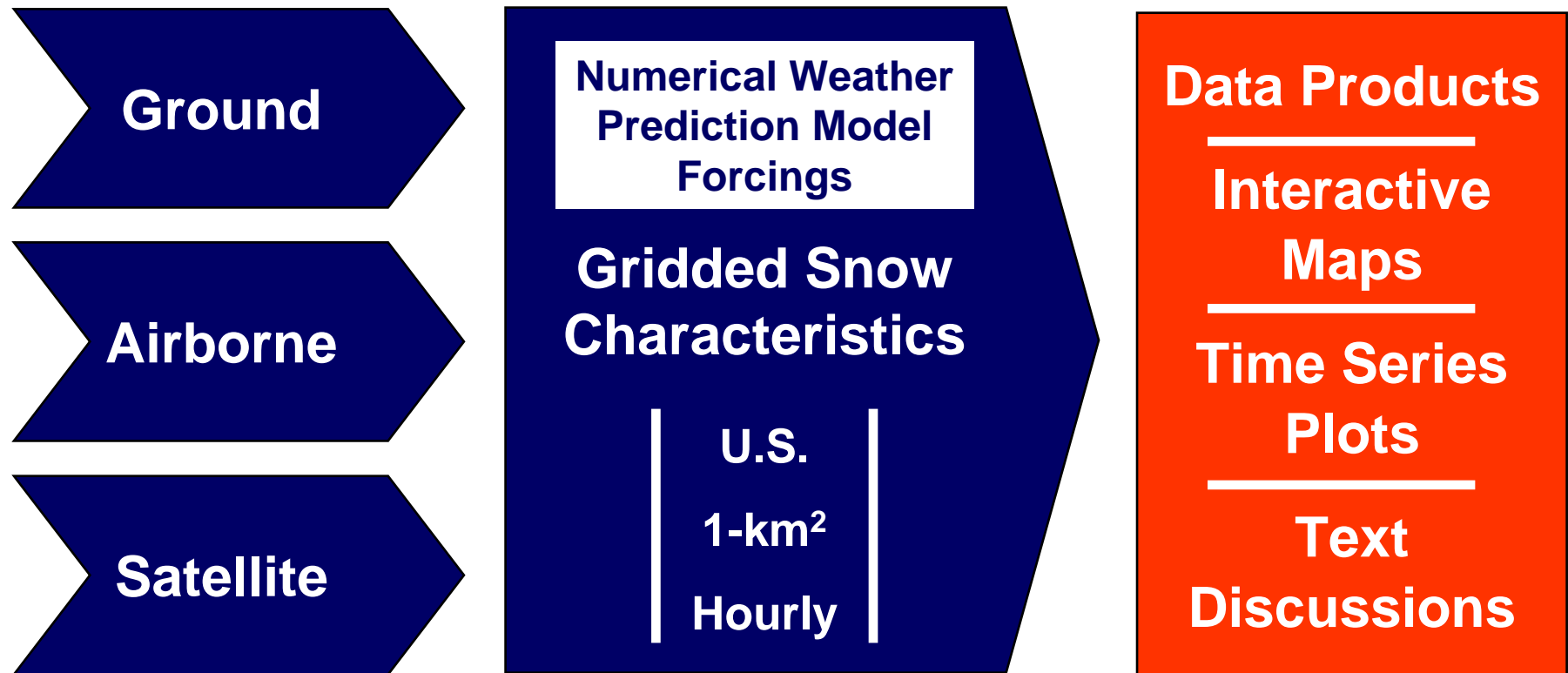


National Snow Analyses (NSA)

Multi-sensor
Snow Observations

Snow Modeling and
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Snow Information
Products



National Snow Analyses (NSA)

Snow Information Products

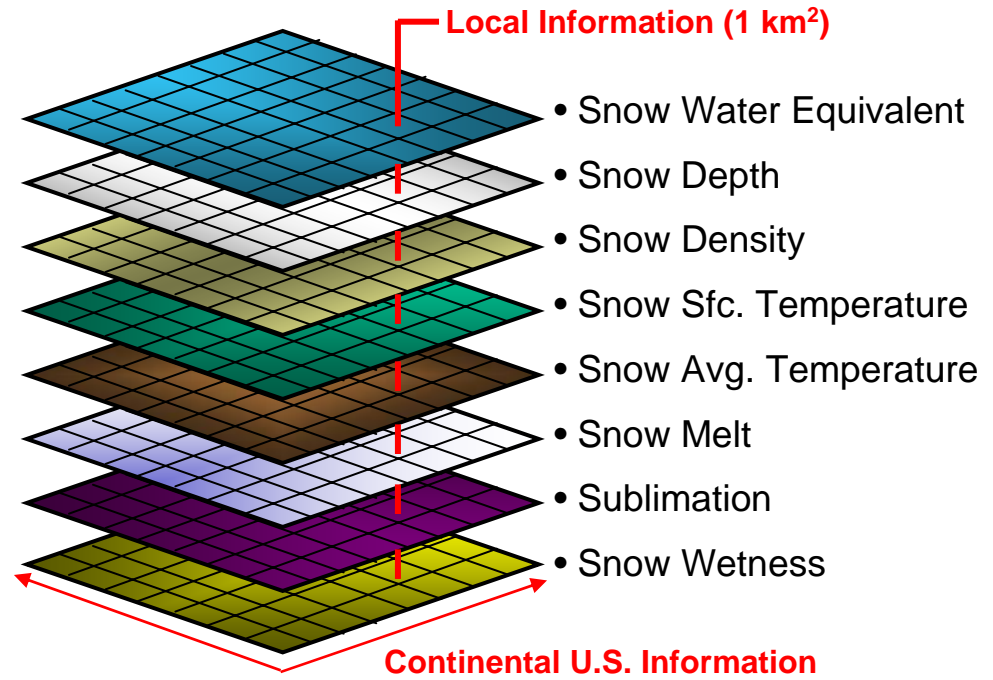
Data Products

Interactive Maps

Time Series Plots

Text Discussions

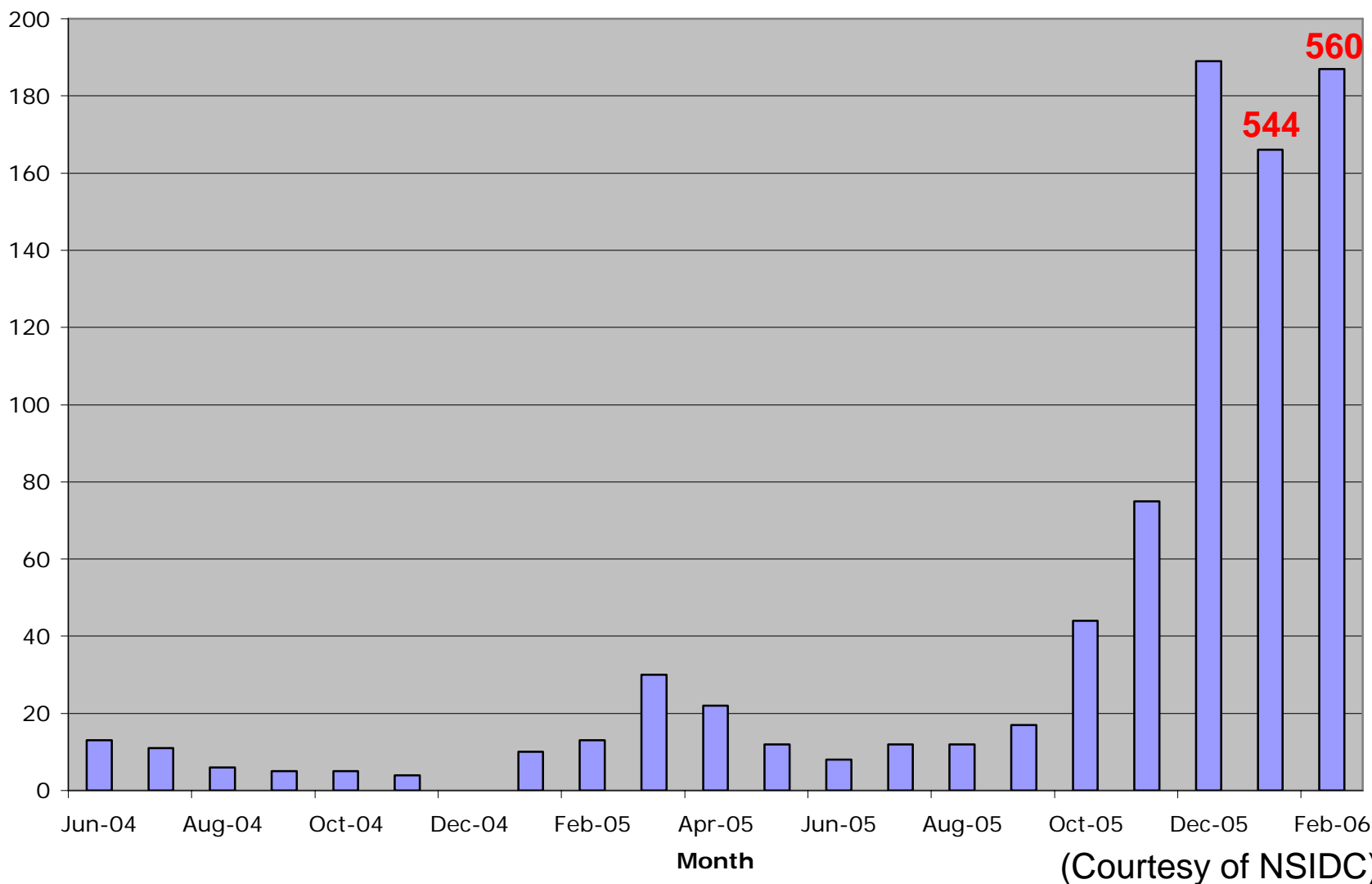
High-resolution *Daily and Hourly* Gridded Snow Data Sets of Fused Model and Observations



• Archived at NCDC, NSIDC, and NDFD (soon)

Unique Users per Month

SNODAS Data from NSIDC Archive



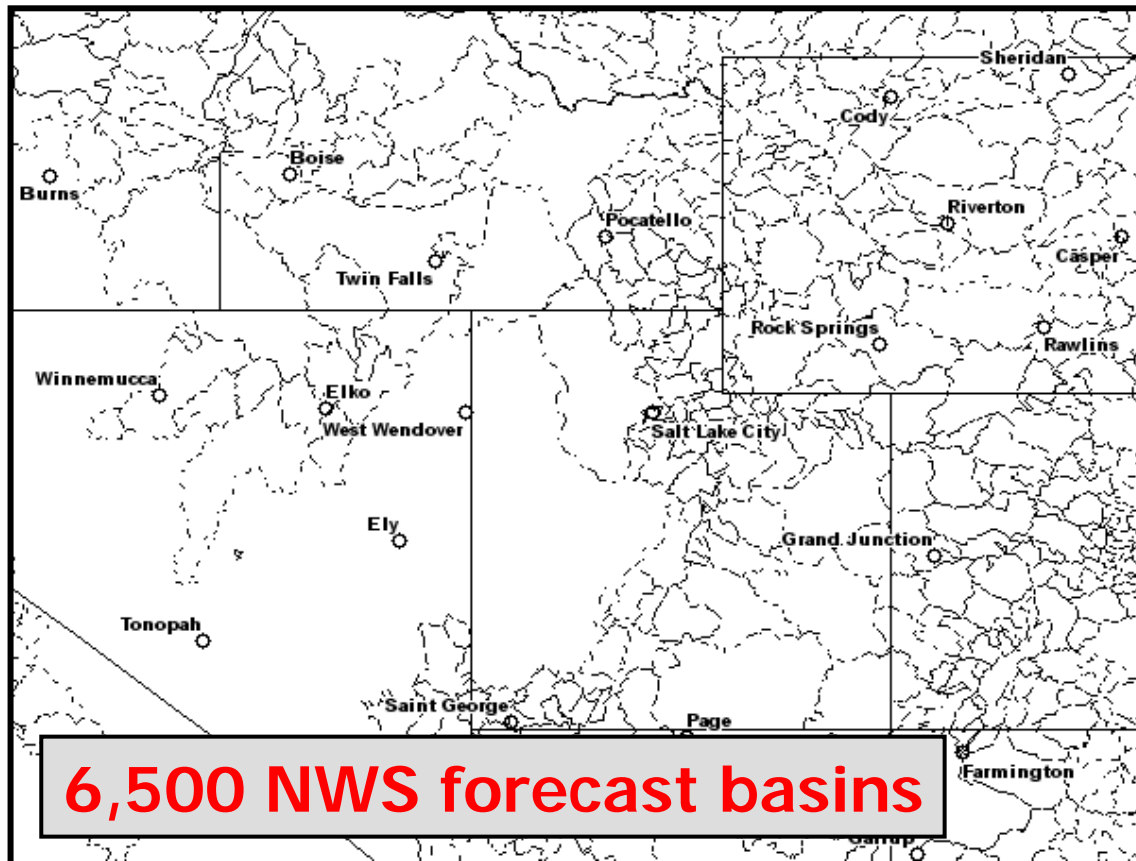
(Courtesy of NSIDC)



National Snow Analyses (NSA)

Integrated Modeled / Observed Snowpack State Variables

Daily Basin-by-Basin NSA Products Shipped to Web



National Snow Analyses (NSA)

Integrated Modeled / Observed Snowpack State Variables

Daily Basin-by-Basin NSA Products Shipped to Web

1. Snow Water Equivalent *
2. Snow Depth *
3. Areal Extent of Snow Cover *
4. Blowing Snow Sublimation
5. Surface Sublimation
6. Snowmelt
7. Average Snowpack Temperature
8. Rain plus Melt

** Includes assimilated snow observations*

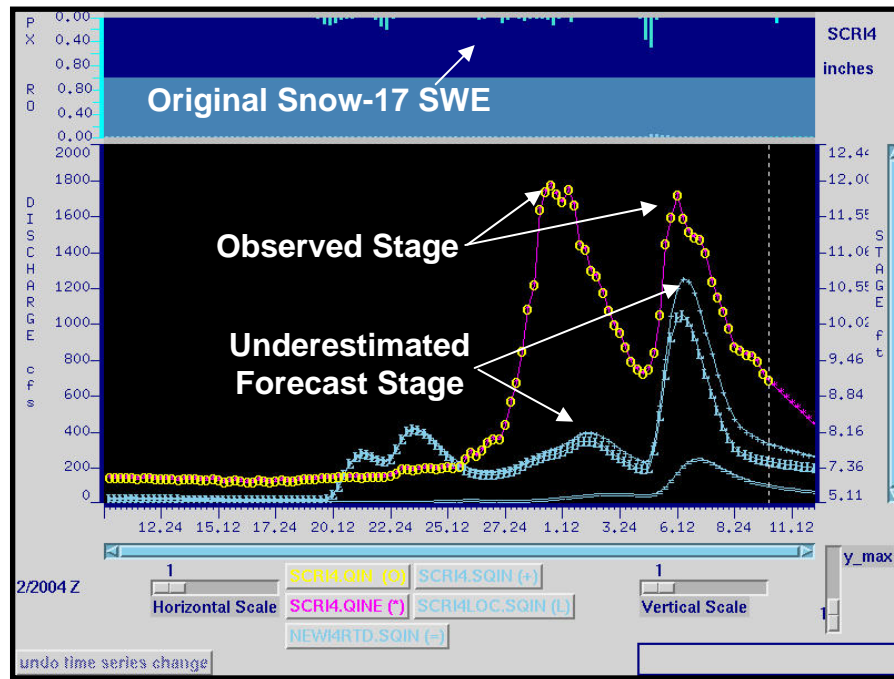


Benefits of NSA Products

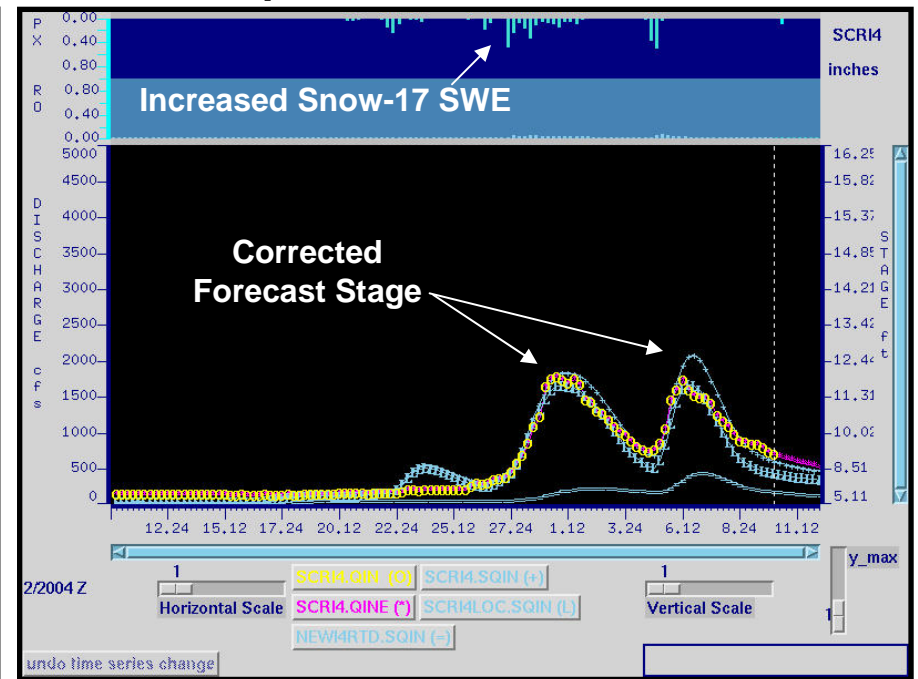
Use of NSA Information Products at NCRFC

NWS River Forecast System
N. Raccoon River, Des Moines River Basin 2004 February 12 - March 11

NWSRFS **without** NOHRSC NSA data



NWSRFS updated **with** NOHRSC NSA data



Example: Two river discharge peaks were observed but underestimated by NWSRFS



National Weather Service National Operational Hydrologic Remote Sensing Center

www.nohrsc.noaa.gov



weather.gov

[Home](#)

Snow Information

- National Analyses
- Interactive Maps
- 3D Visualization
- Airborne Surveys
- Satellite Obs
- Forecasts
- Data Archive
- SHEF Products

Science/Technology

- NOHRSC
- GIS Data Sets

About The NOHRSC

Staff

NOAA Links

- Snow Climatology
- Related Links

Help

Help and FAQ

Contact Us

Please Send Us
Comments!



NOAA's Source for Snow Information

The National Operational Hydrologic Remote Sensing Center provides comprehensive snow observations, analyses, data sets and map products for the Nation.

- ◆ National Snow Observation Database
- ◆ Airborne Snow Surveys
- ◆ Satellite Snow Cover Mapping
- ◆ Snow Modeling and Data Assimilation
- ◆ Analyses, Maps, and Interactive Visualization Tools
- ◆ Integrated Snow Datasets for Geospatial Applications
- ◆ Applied Snow Research

NOHRSC products and services support a wide variety of government and private-sector applications in water resource management, disaster emergency preparedness, weather and flood forecasting, agriculture, transportation and commerce.

SNOW = WATER = LIFE

Over 12 million hits per month

National Snow Headlines



National Weather Service National Operational Hydrologic Remote Sensing Center



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Enter Search Here

Go

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- Snow Information
- National Analyses
- Interactive Maps**
- 3D Visualization
- Airborne Surveys
- Satellite Obs
- Forecasts
- Data Archive
- SHEF Products

- Science/Technology
- NOHRSC
- GIS Data Sets

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- Help and FAQ

- Contact Us
- Please Send Us Comments!

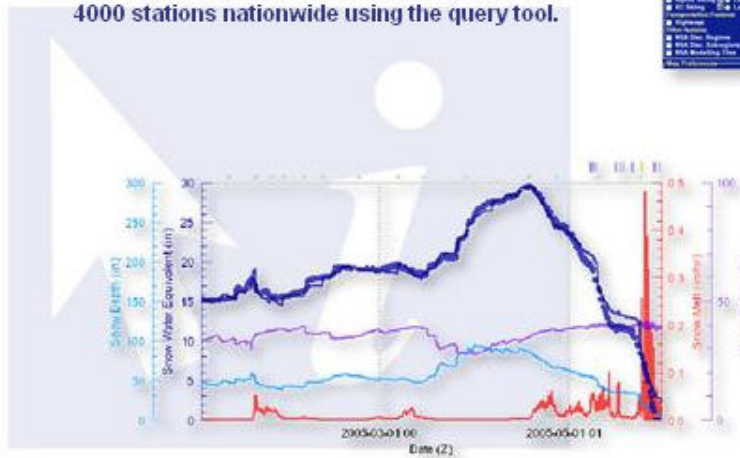
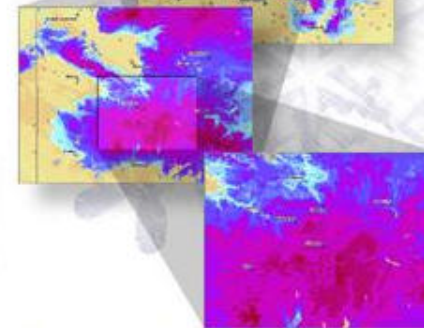


INTERACTIVE SNOW MAPS

Explore our online GIS for comprehensive snow information.

- Build custom maps for your region of interest
- Choose from over 40 snow themes
- Overlay roads, cities, rivers, etc.
- Query detailed conditions at over 20,000 locations

Get detailed snowpack conditions at over 4000 stations nationwide using the query tool.



Explore Snow

National Snow Headlines



National Operational Hydrologic Remote Sensing Center Interactive Snow Information

Get Time Series for Station I
 Get Time Series for Basin ID:
 Get Basin Averages for
 Get Climatology for Station I

Navigation Tools

Help
Comments



Lon: Lat:
 Recenter map at coordinates

Query

Redraw Map

Select Physical Element

Snow Water Equivalent

Select Date

2006 January 26 10:00 Z

Snap to nearest time

Select Overlays

Hydrologic Features

- Basins
- HUCs (6-digit)
- RFC Boundaries
- Major Rivers
- Rivers and Streams
- Lakes and Reservoirs

Political Features

- County Boundaries
- CWA Boundaries
- State Boundaries
- National Boundaries

Point Features

- Stations Label
- Cities Label
- Flight Lines Label
- Climate Stns. Label
- Alpine Skiing Label
- XC Skiing Label

Transportation Features

- Highways

Other features

- NSA Disc. Regions
- NSA Disc. Subregions
- NSA Modelling Tiles

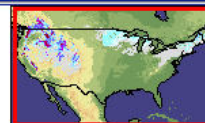
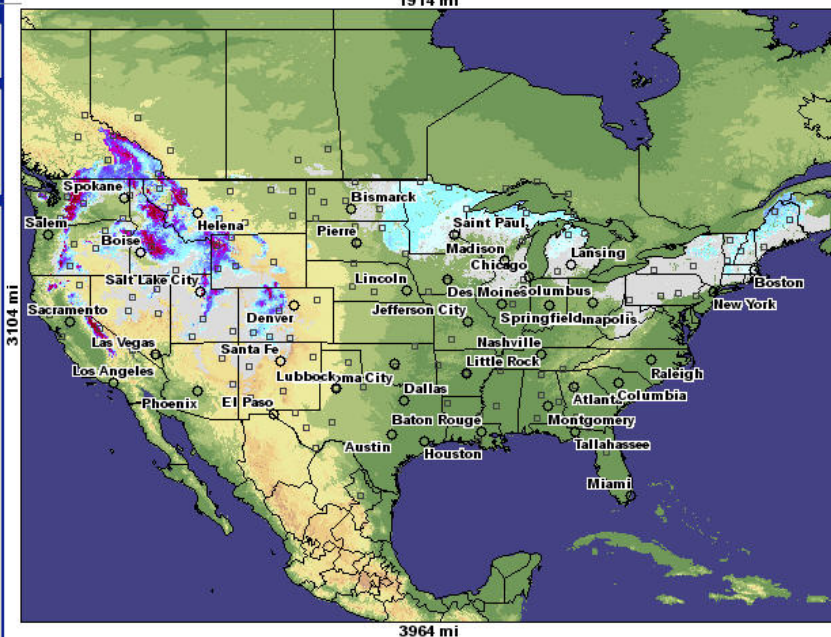
Map Preferences

English units

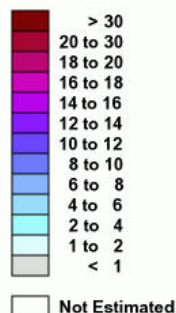
- Legend below map
- Background image
- High-contrast palette
- Minimize top banner

600 pixels map width
450 pixels map height

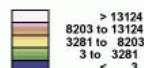
Modeled Snow Water Equivalent (Hourly) for 2006 January 26, 10:00 Z
1914 mi



Inches of water equivalent



Elevation in feet (Not estimated)



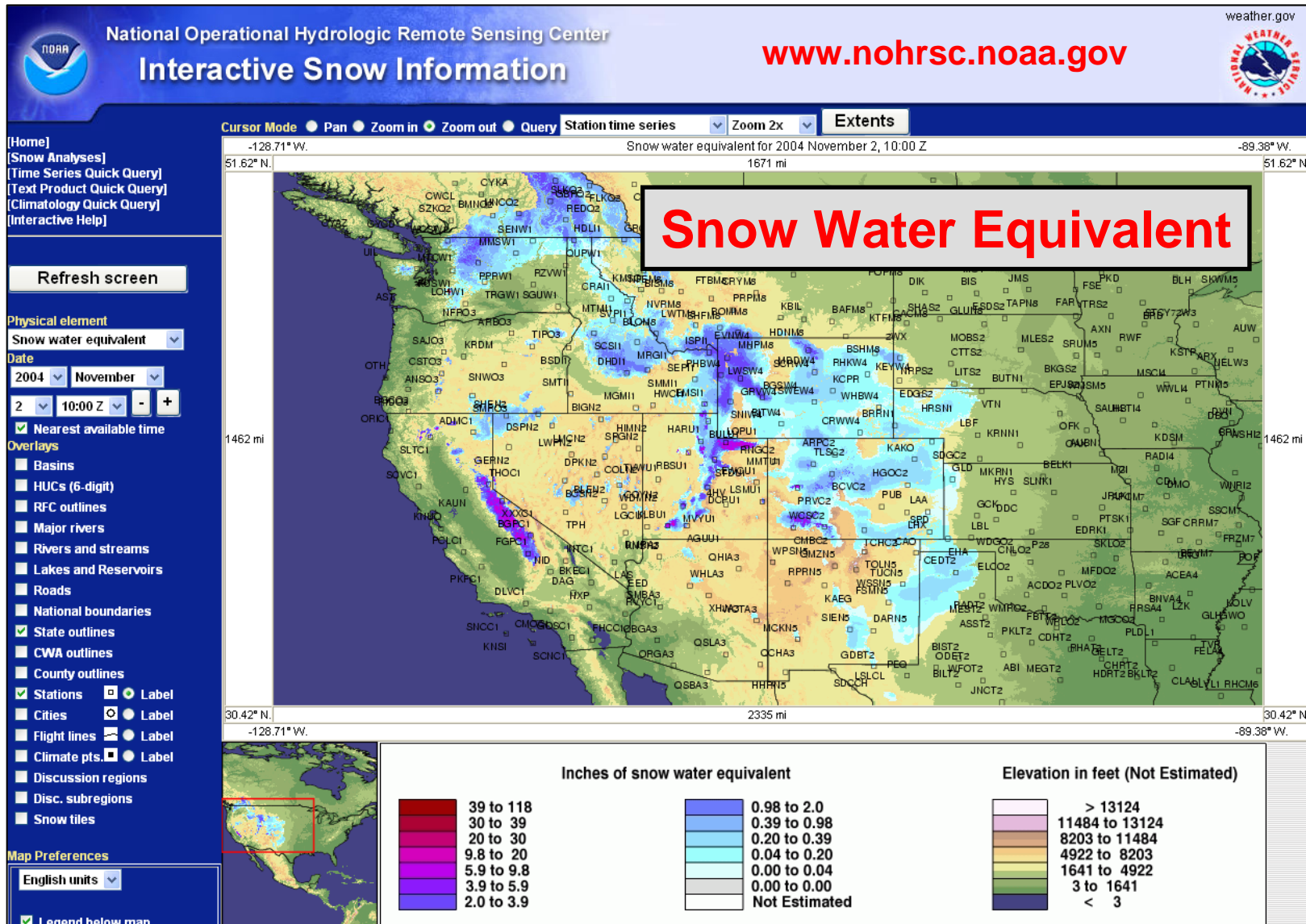
Directions:

- Select a physical element to view, select a date, select overlays, and click "Redraw Map."
- Clicking on the map while the Recenter button is selected (red) will recenter the map on that point.
- Clicking on the Zoom Control slider will zoom into or out of the map.
- Clicking and dragging with the button held down while the Recenter button is selected (red) will zoom to a rectangle when the button is released.
- Stations and regions can be queried using the Query button and menu.

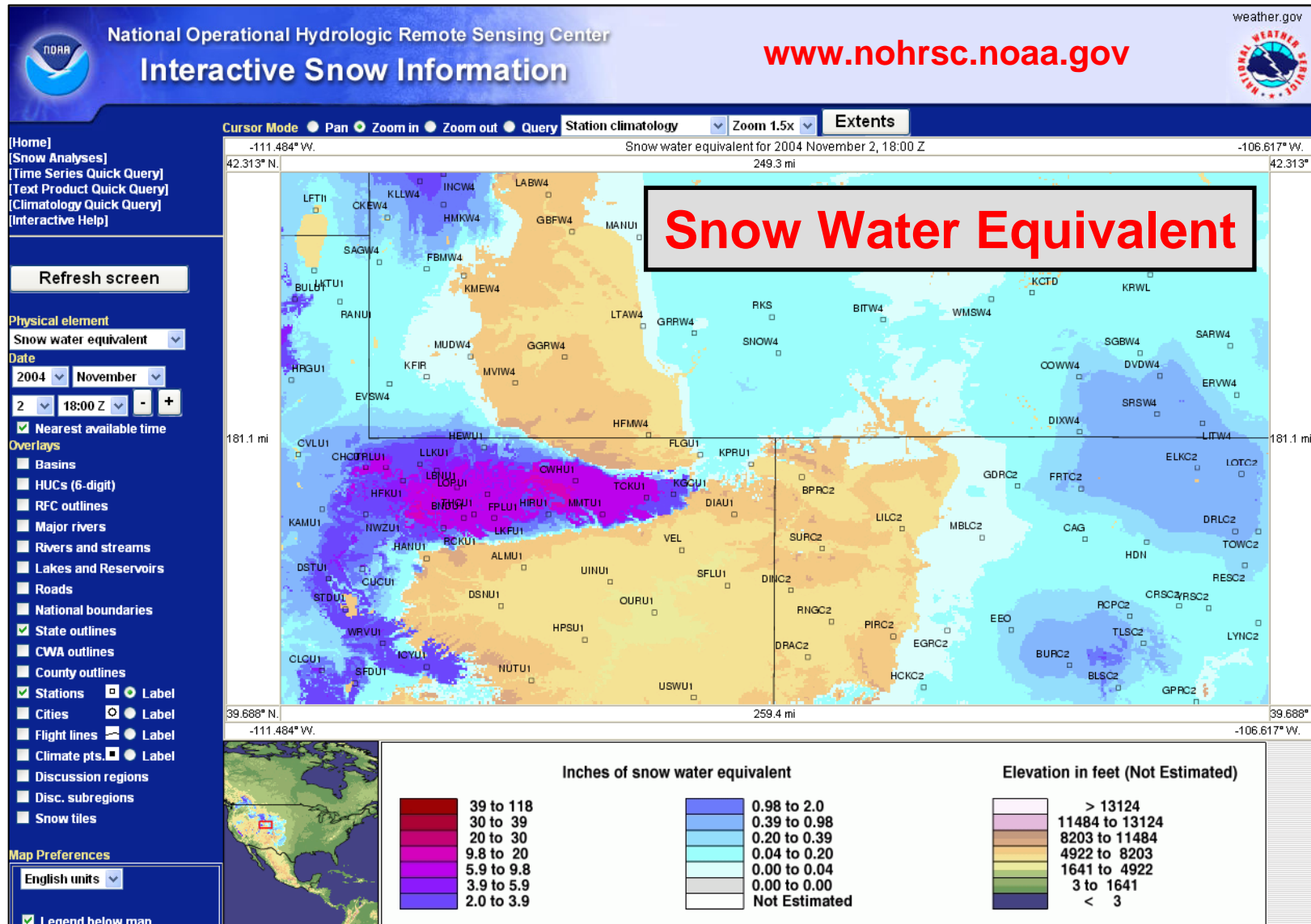
New features for the 2005-2006 snow year



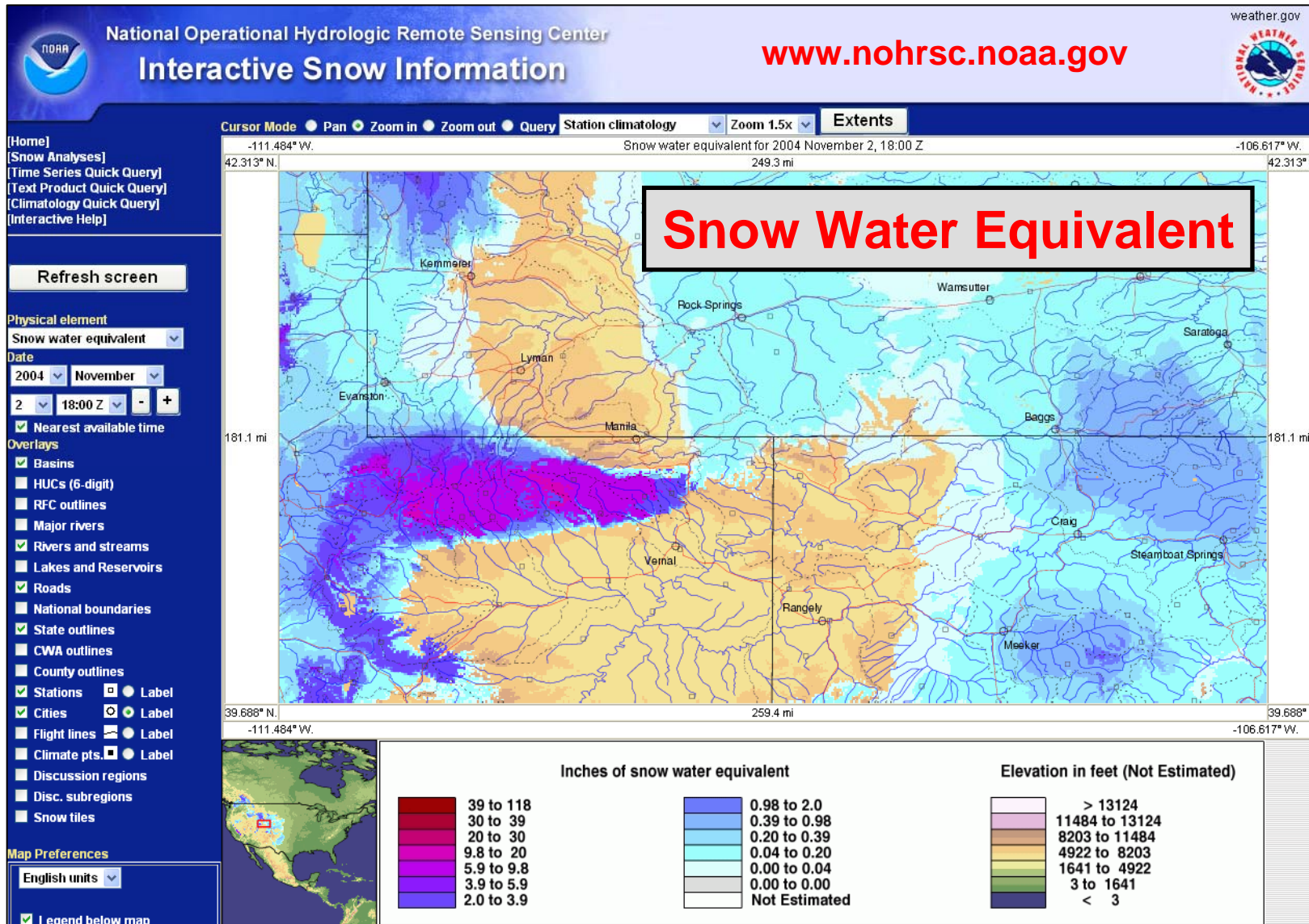
Interactive Snow Information System



Interactive Snow Information System



Interactive Snow Information System

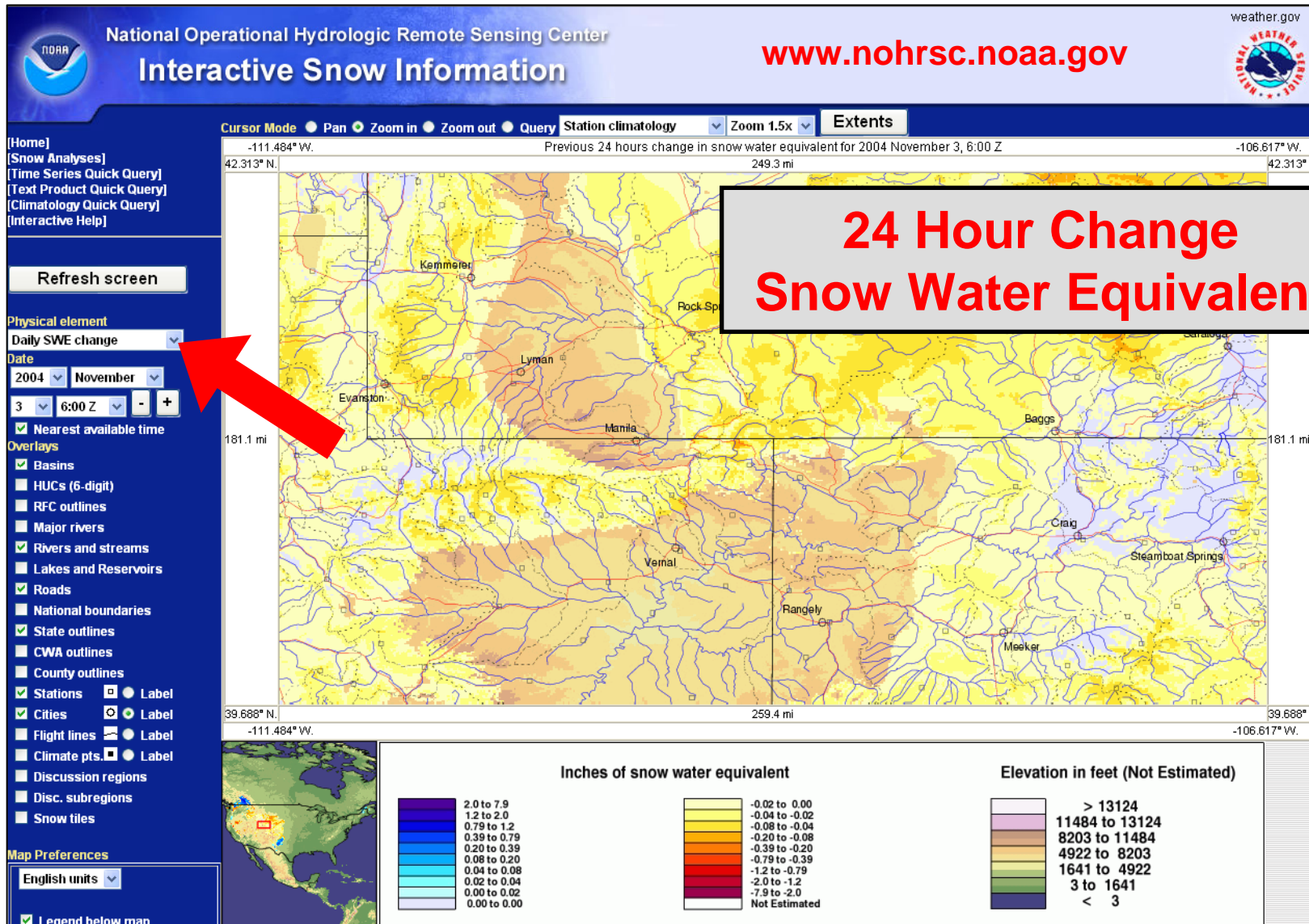


Physical Element Map Options

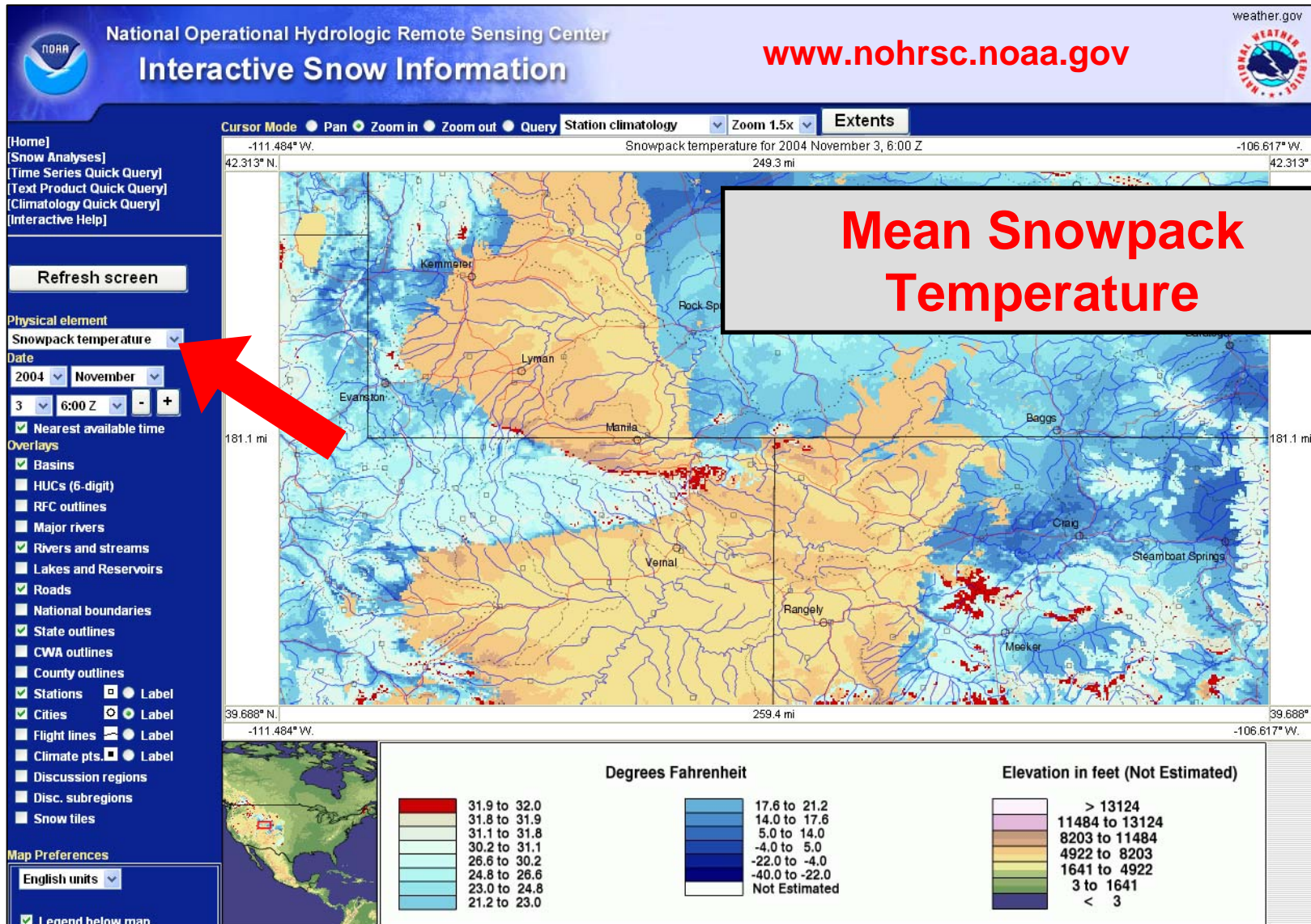
The image displays three screenshots of the 'Select Physical Element' dropdown menu, illustrating different categories of physical elements available for mapping. Each screenshot shows a list of options with 'Snow Water Equivalent' selected in the dropdown.

- Left Screenshot:** Shows the 'Hourly Snow Analyses' category. The 'Snow Water Equivalent' option is circled in red.
- Middle Screenshot:** Shows the 'Daily Snow Analyses' category. The 'Snow Water Equivalent' option is selected in the dropdown.
- Right Screenshot:** Shows the 'Latest Observations' category. The 'Snow Depth (24 hrs)' option is circled in red.

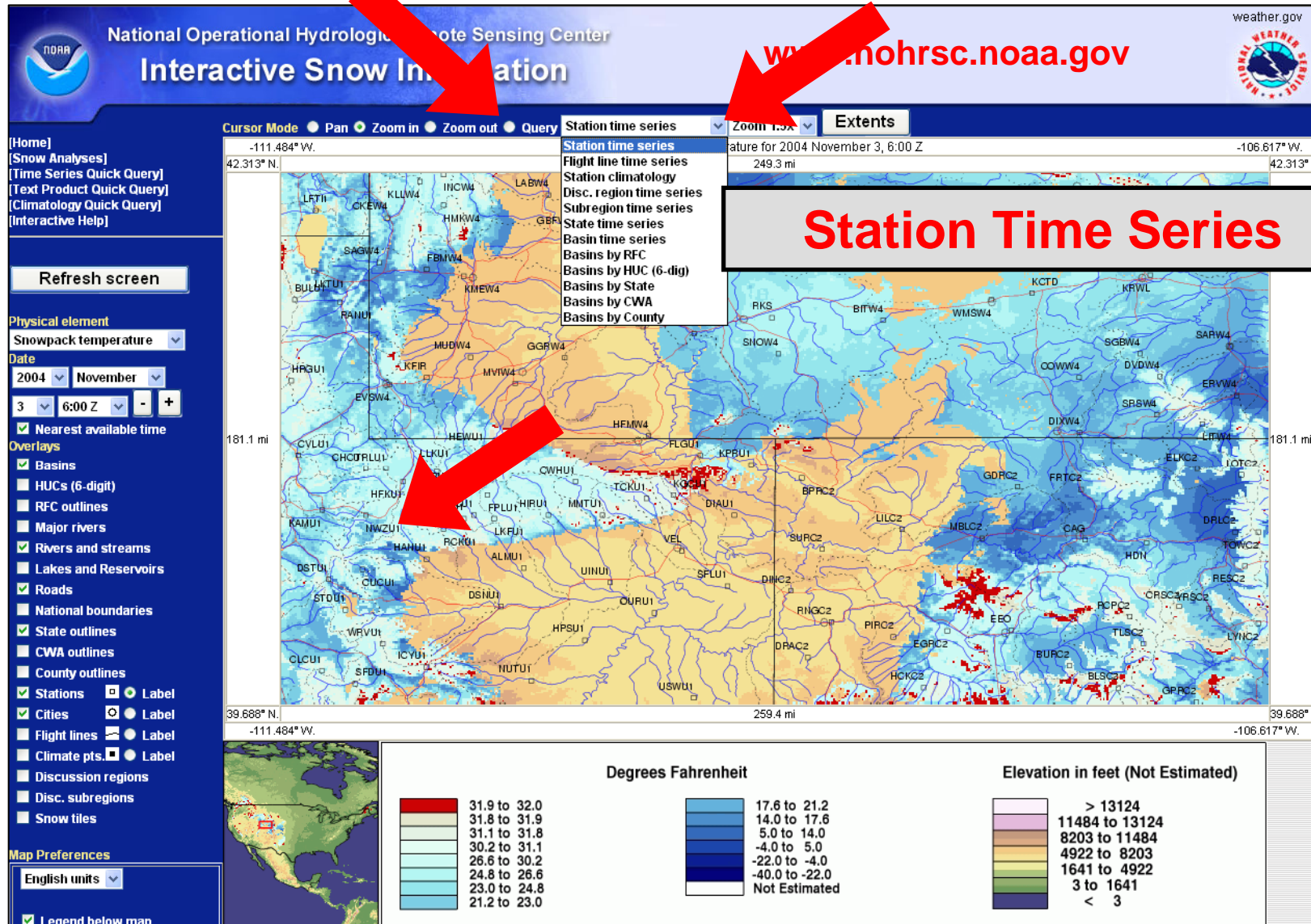
Interactive Snow Information System




Interactive Snow Information System



Interactive Snow Information System




Interactive Snow Information System



National Operational Hydrologic Remote Sensing Center
Interactive Snow Information

weather.gov
www.nohrsc.noaa.gov



Start Date: 2004 October 28 15:00 Z to Stop Date: 2004 November 3 14:00 Z

Home | All Images | English units | Refresh screen

Snow Analyses

Interactive Products

Time Series Quick Query

Text Product Quick Query

Climatology Quick Query

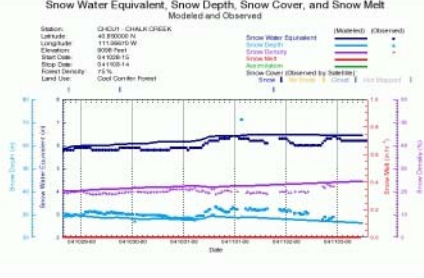
Query Station time series

Station SHEF ID
CHCU1

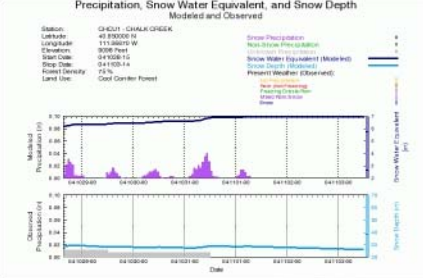
340 pixel width
220 pixel height

Submit

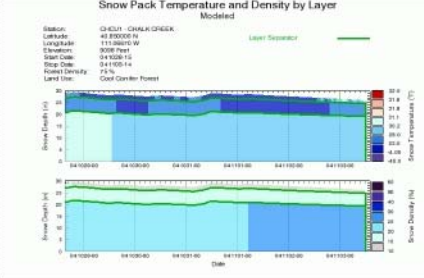
Snow Water Equivalent, Snow Depth, Snow Cover, and Snow Melt
Modeled and Observed



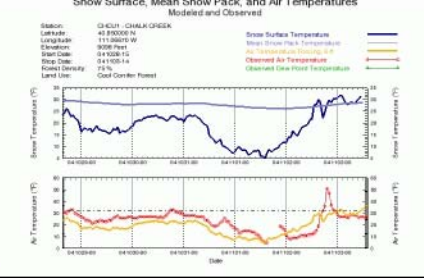
Precipitation, Snow Water Equivalent, and Snow Depth
Modeled and Observed




Snow Pack Temperature and Density by Layer
Modeled



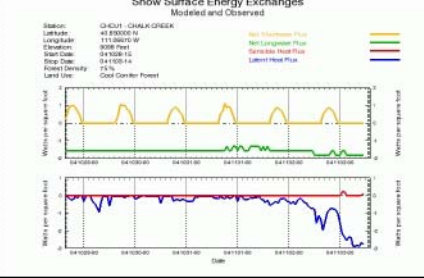
Snow Surface, Mean Snow Pack, and Air Temperatures
Modeled and Observed



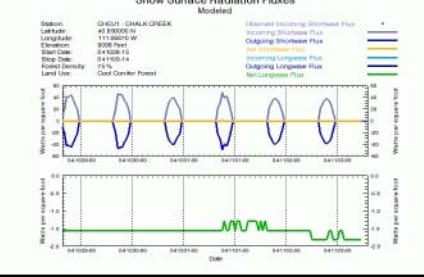
Snow Melt, Sublimation, and Weather Forcing
Modeled and Observed




Snow Surface Energy Exchanges
Modeled and Observed




Snow Surface Radiation Fluxes
Modeled



Cumulative Water Inputs and Outputs
Modeled



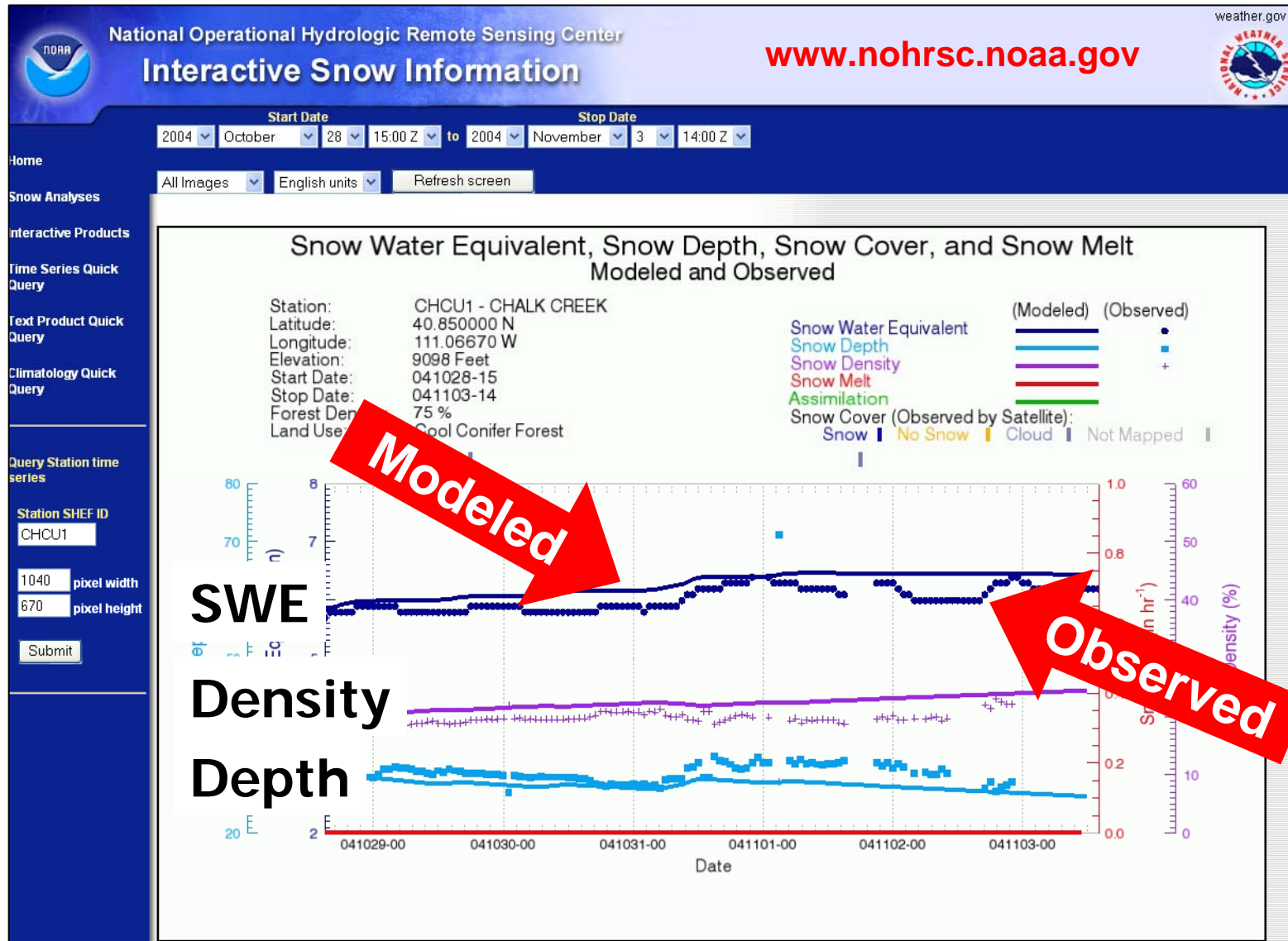


NOAA's National Snow Analyses

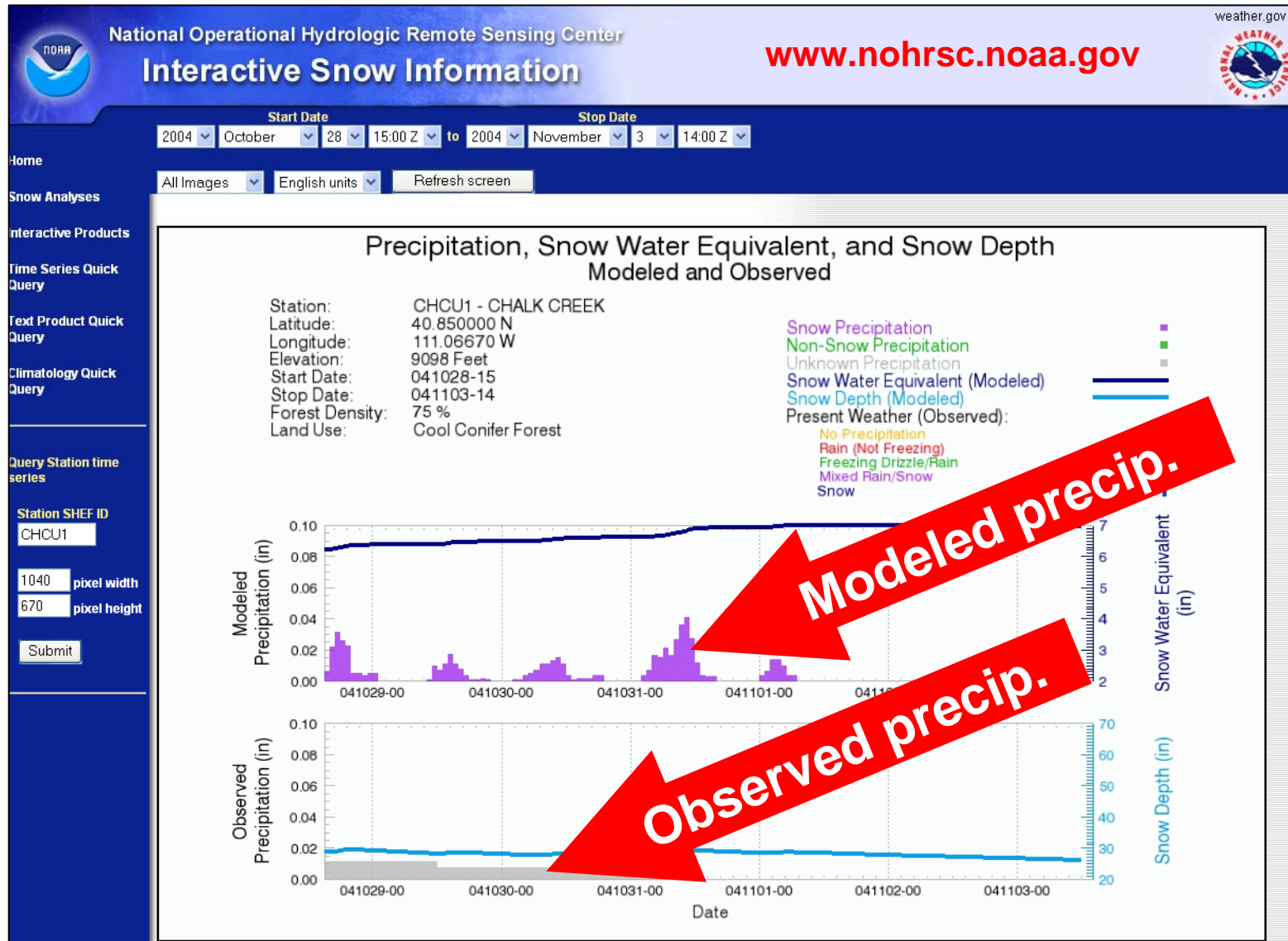
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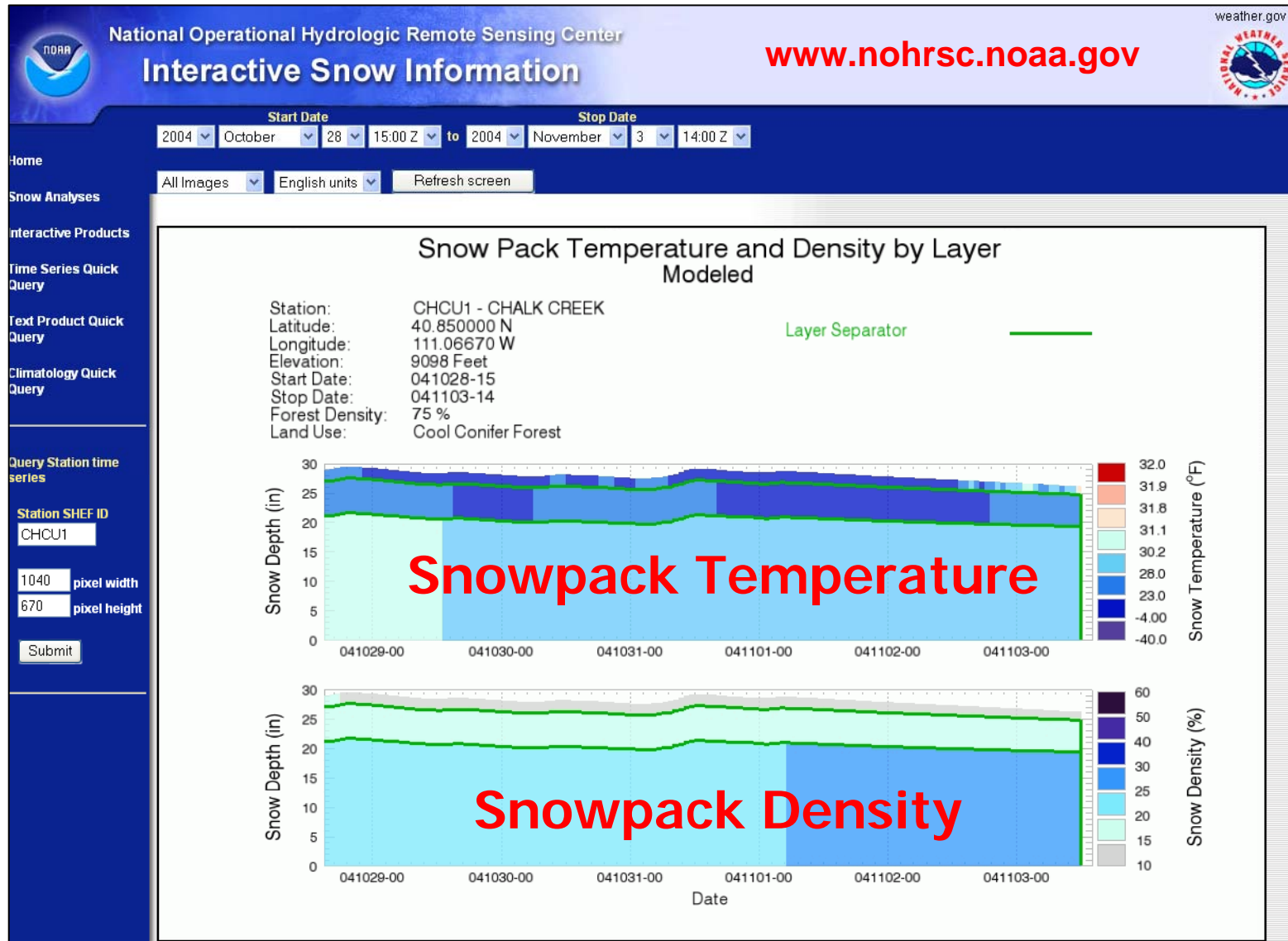
Interactive Snow Information System



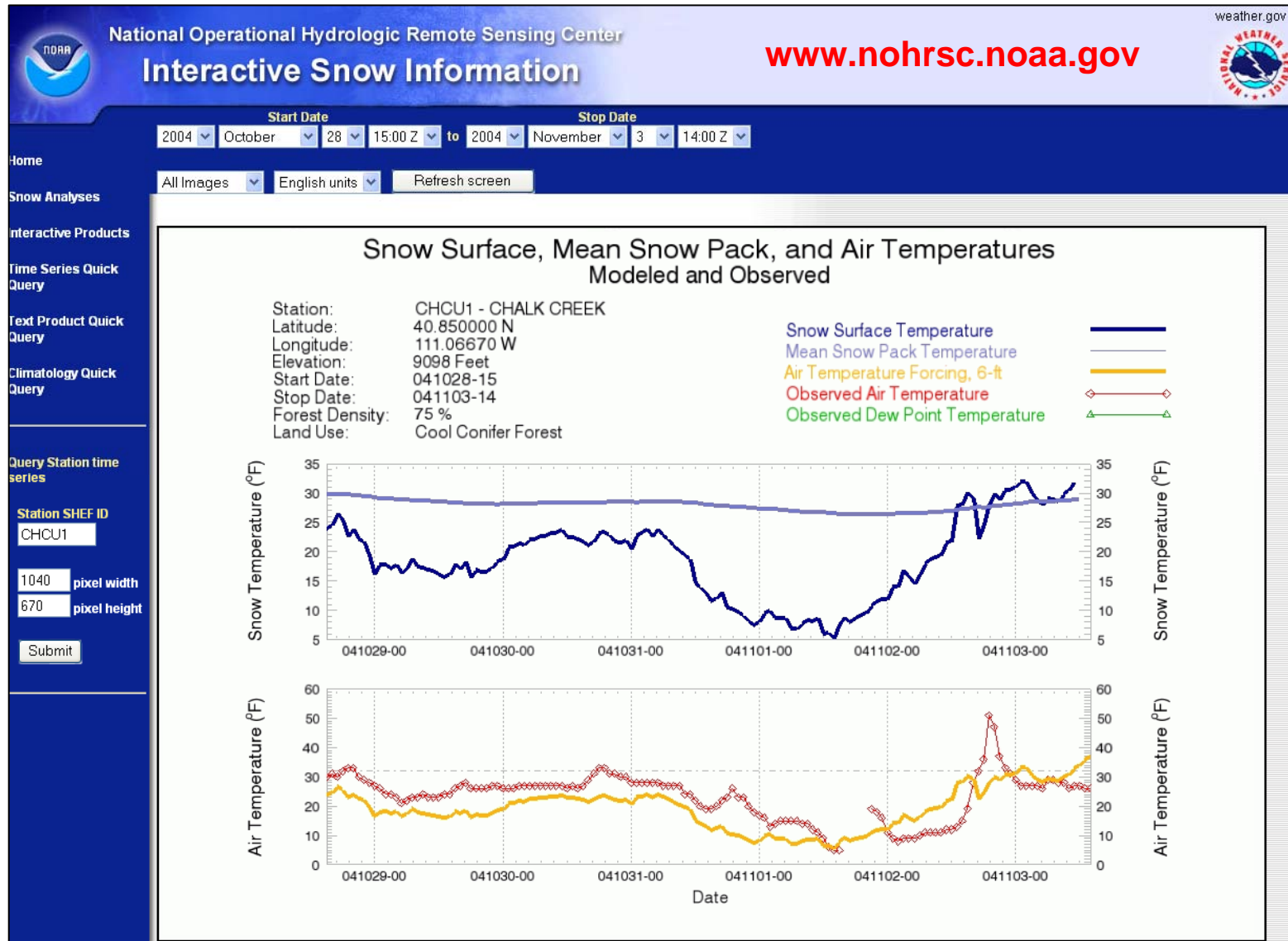
Interactive Snow Information System



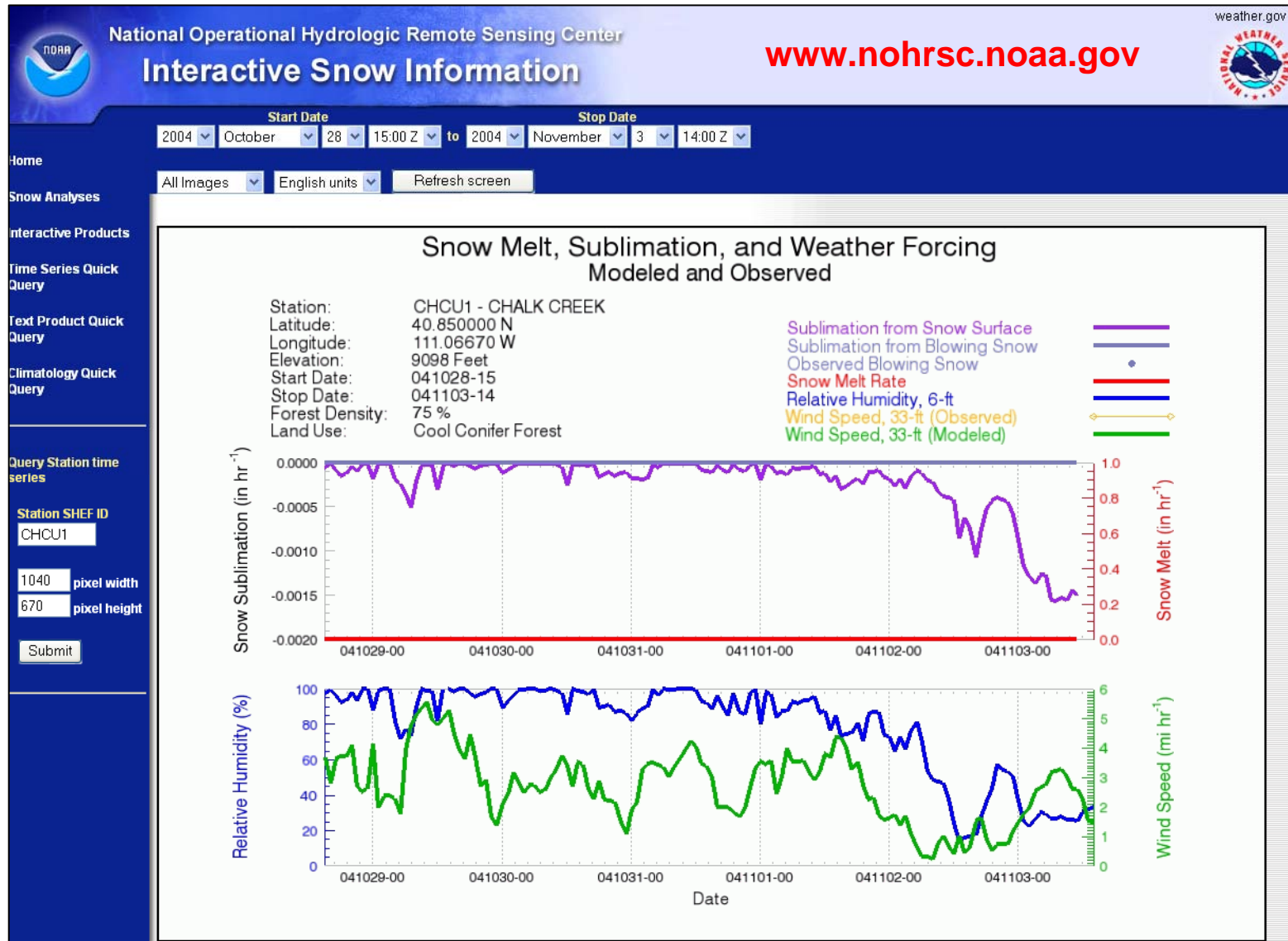
Interactive Snow Information System



Interactive Snow Information System



Interactive Snow Information System



Interpolated Snowfall - last 72 hours



National Operational Hydrologic Remote Sensing Center Interactive Snow Information

Quick Query Links

Get Time Series for Station ID: [Go](#) [Listing](#)

Get Time Series for Basin ID: ABRFC [Go](#) [Listing](#)

Get Basin Averages for RFC [Go](#) [Listing](#)

Get Climatology for Station ID: [Go](#) [Listing](#)

Navigation Tools

Help
Comments



Lon: -101.90 Lat: 45.30

Recenter map at coordinates

Query

Station (2002-present)

Redraw Map

Select Physical Element

Int. Total SF (72 hrs)

Select Date

2005 December

5 6:00 Z

Snap to nearest time

Select Overlays

Hydrologic Features

- Basins
- HUCs (6-digit)
- RFC Boundaries
- Major Rivers
- Rivers and Streams
- Lakes and Reservoirs

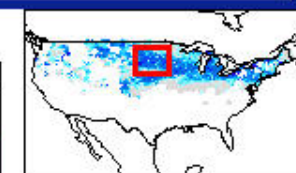
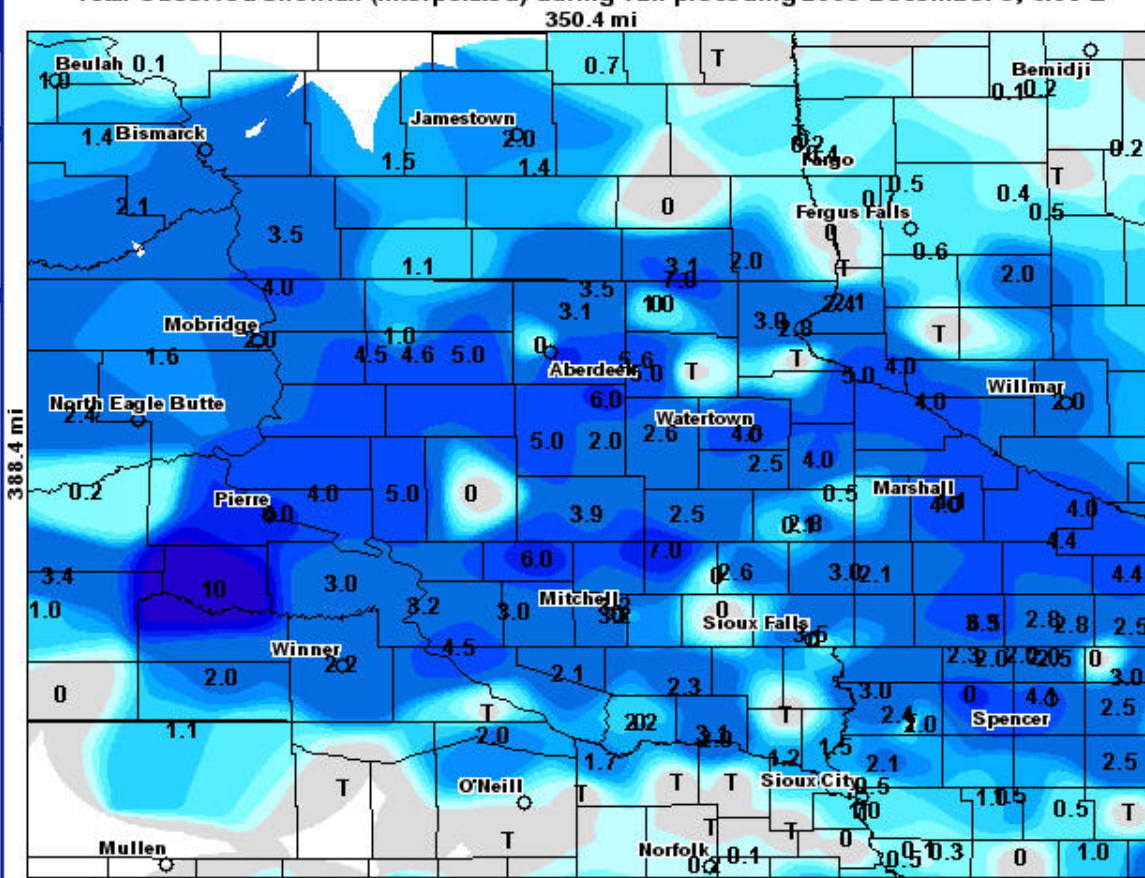
Political Features

- County Boundaries
- CWA Boundaries
- State Boundaries
- National Boundaries

Point Features

- Stations
- Cities
- Flight Lines
- Climate Stns.
- Alpine Skiing
- XC Skiing

Total Observed Snowfall (Interpolated) during 72h preceding 2005 December 5, 6:00 Z



Interpolated Snowfall – last 72 hours



National Operational Hydrologic Remote Sensing Center Interactive Snow Information

Quick Query Links

Get Time Series for Station ID: Listing

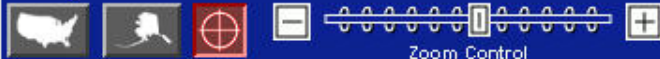
Get Time Series for Basin ID: ABRFC Listing

Get Basin Averages for RFC Listing

Get Climatology for Station ID: Listing

Navigation Tools

Help
Comments



Lon: -97.45 Lat: 44.69

Query

Station (2002-present)

Redraw Map

Select Physical Element

Int. Total SF (72 hrs)

Select Date

2005 December

5 6:00 Z

Snap to nearest time

Select Overlays

Hydrologic Features

- Basins
- HUCs (6-digit)
- RFC Boundaries
- Major Rivers
- Rivers and Streams
- Lakes and Reservoirs

Political Features

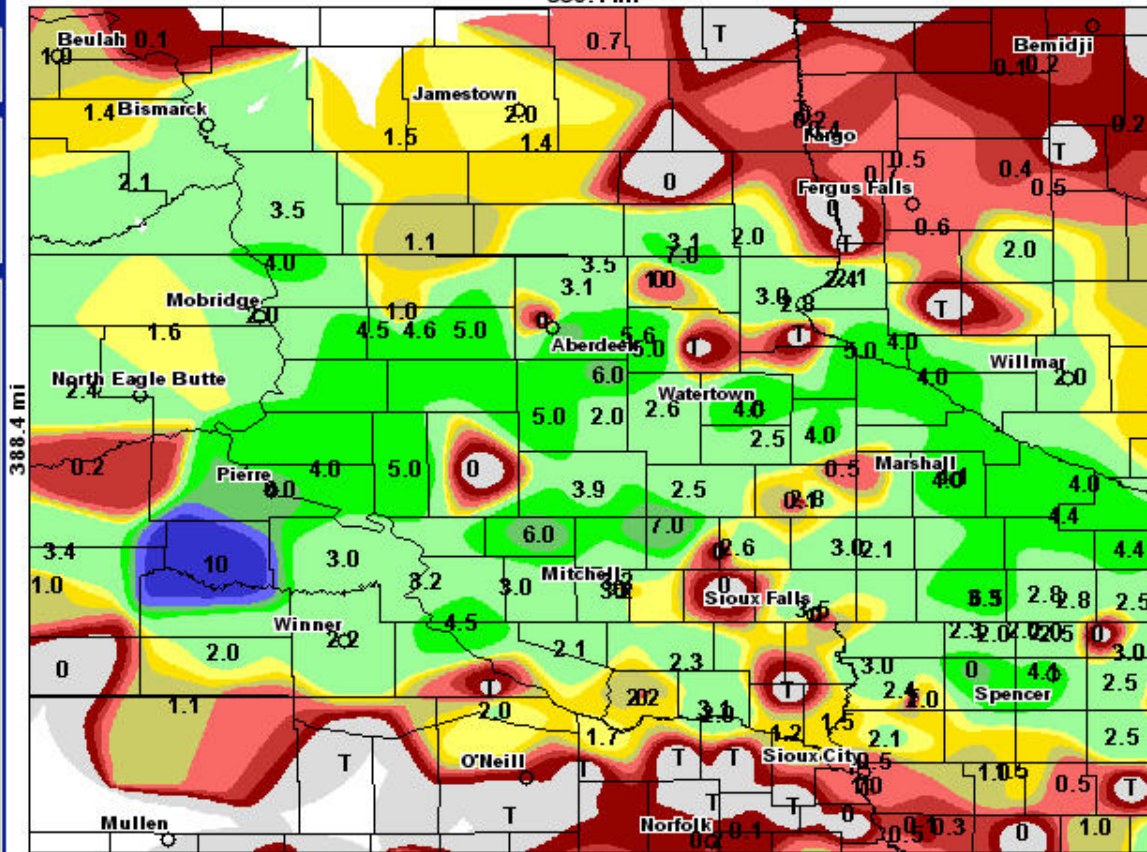
- County Boundaries
- CWA Boundaries
- State Boundaries
- National Boundaries

Point Features

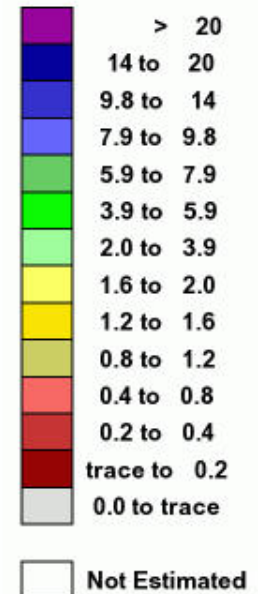
- Stations Label
- Cities Label
- Flight Lines Label
- Climate Stns. Label
- Alpine Skiing Label
- XC Skiing Label

Total Observed Snowfall (Interpolated) during 72h preceding 2005 December 5, 6:00 Z

350.4 mi



Inches of depth



Longitude: -97.45 Latitude: 44.69

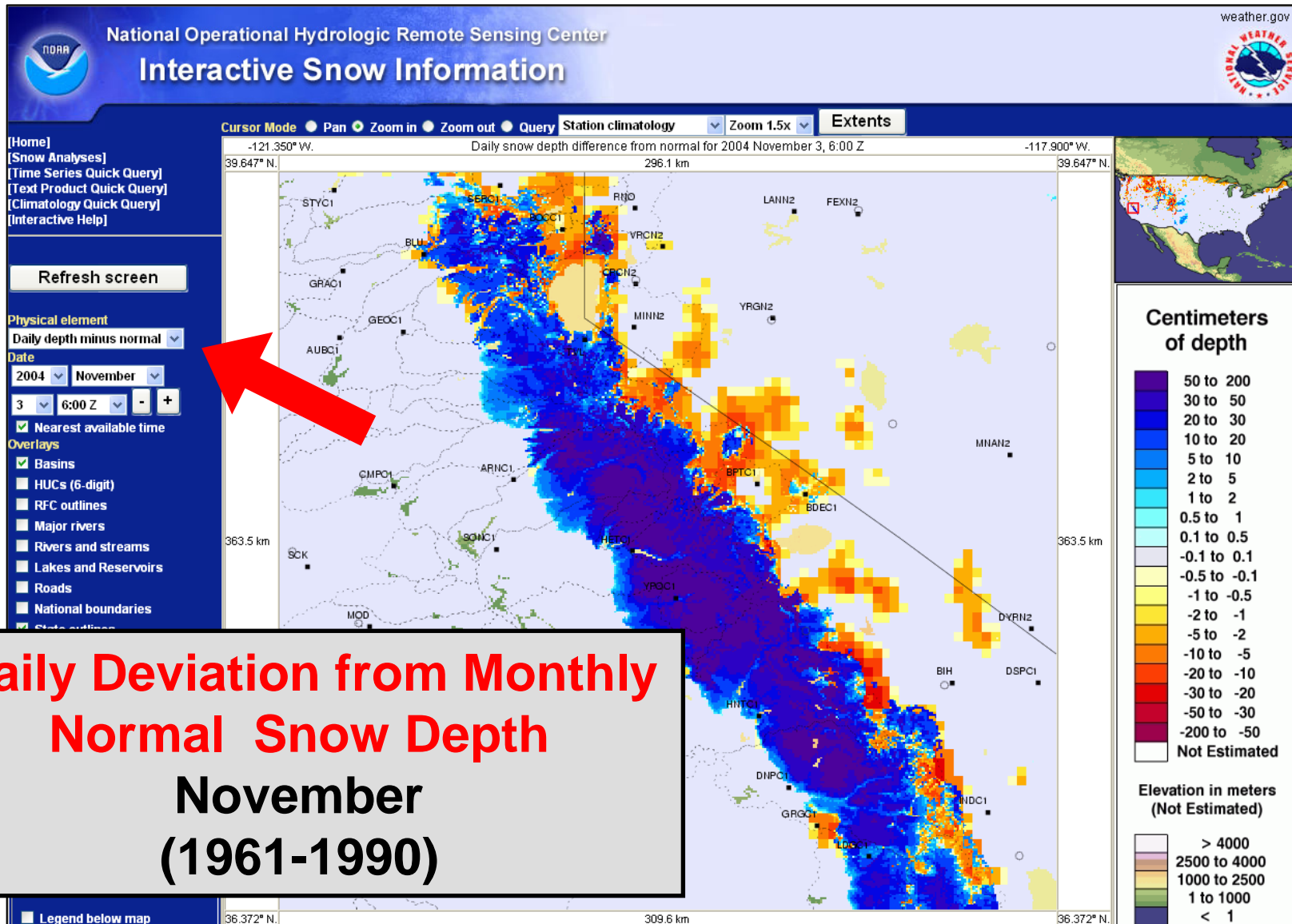


Inbox for Tom, Carroll...

NOHRSC Interactive ...

3:10 PM

New Climate Diagnostic Tools





National Weather Service National Operational Hydrologic Remote Sensing Center



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 - Help and FAQ
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NATIONAL SNOW ANALYSES

Get the latest in-depth analyses of national and regional snow conditions.

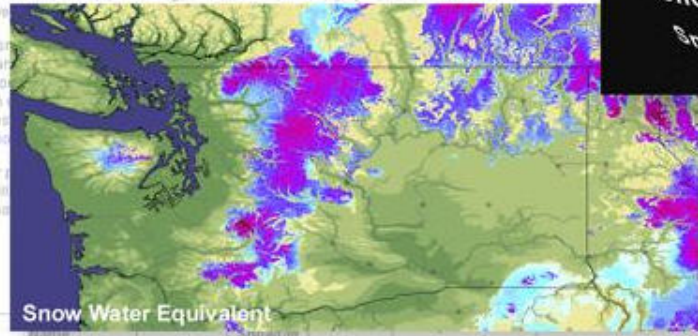
- Maps and **movies**
- Commentary and analysis
- Observations and statistics



A cold front with strong onshore flow and rapid flow aloft passed through the region yesterday and brought 2 to 4 inches of snow to the higher elevations in the Olympics and northern Cascades. At low...

Up to 1/2 inch of additional snow at locally higher elevations. Warm air and rain occurred over most of the region. Some blowing snow...

An active weather system with an upper-level low will bring snow to the region. Pressure will bring...



Snow Reports

Station ID	Location	(in)	Snowmelt (in)	Time(UTC)
ASFW1	RAINIER PARADISE RANGER STN	1654	0.09 cm	24 2005-11-01 16
SELM0	SEELEY LAKE RS	1249	1.27 cm	24 2005-11-02 00
AGRC2	APISHAPA RVR	2697	1.27 cm	24 2005-11-01 12
OLNMB	OLNEY	864	0.25 cm	24 2005-11-01 15
POTMB	POTOMAC	1103	0.25 cm	24 2005-11-01 15
ATF5M1	ATF 255014	101	0.17 cm	24 2005-11-01 11



National Snow Headlines



National Weather Service National Operational Hydrologic Remote Sensing Center

weather.gov



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 - Staff

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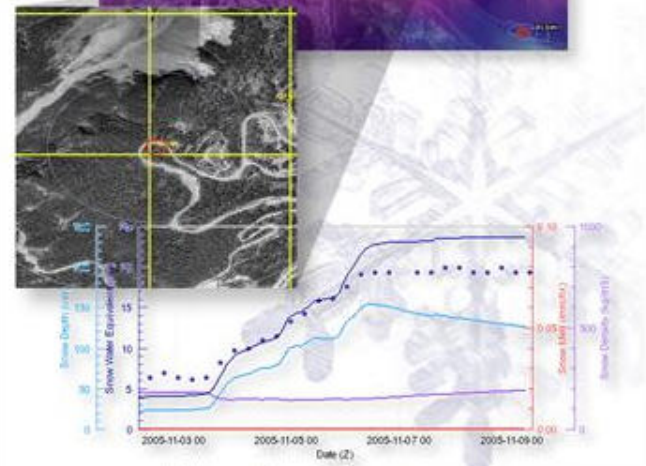
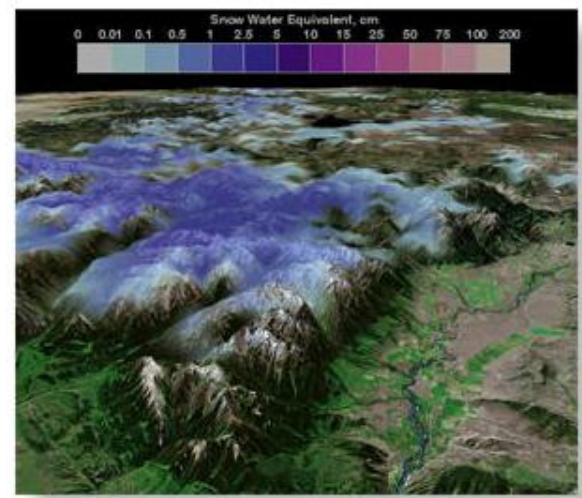
- Contact Us
 - Please Send Us Comments!



NATIONAL SNOW ANALYSES IN 3D

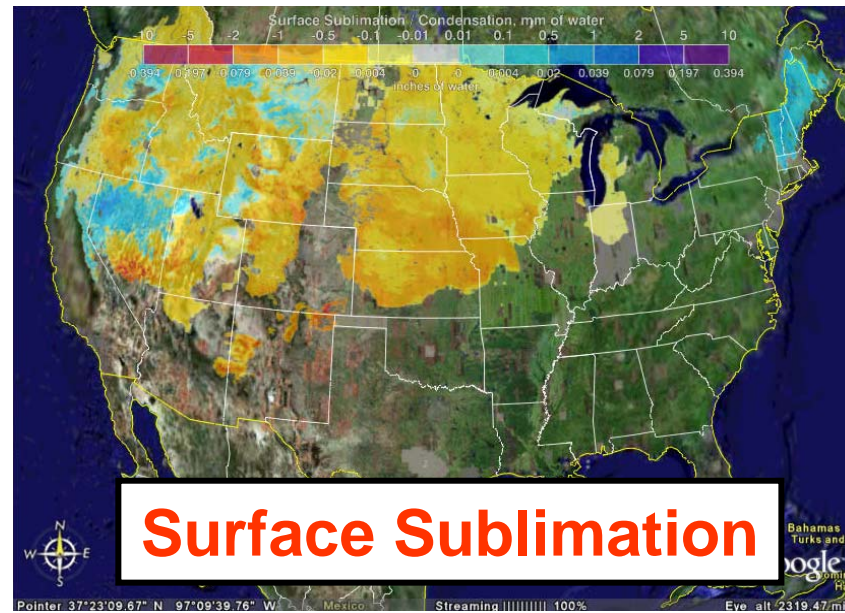
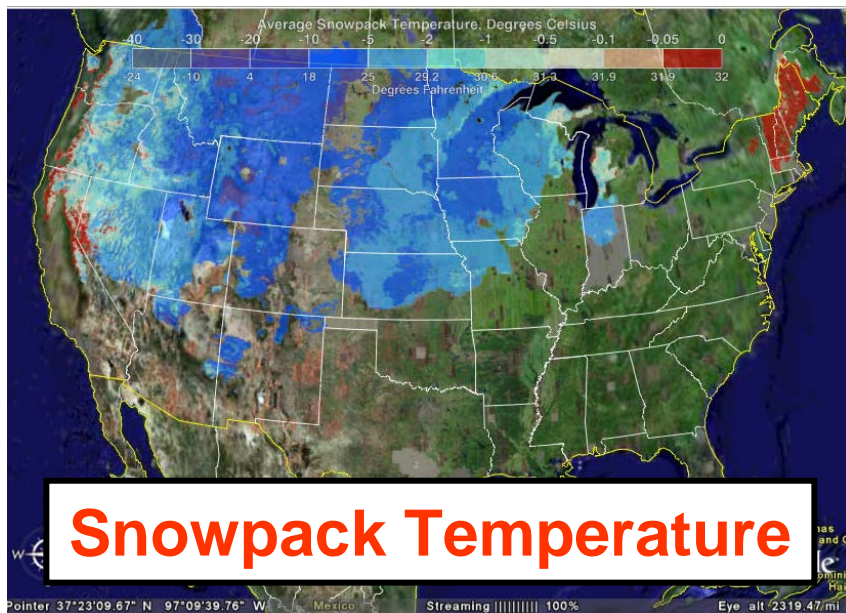
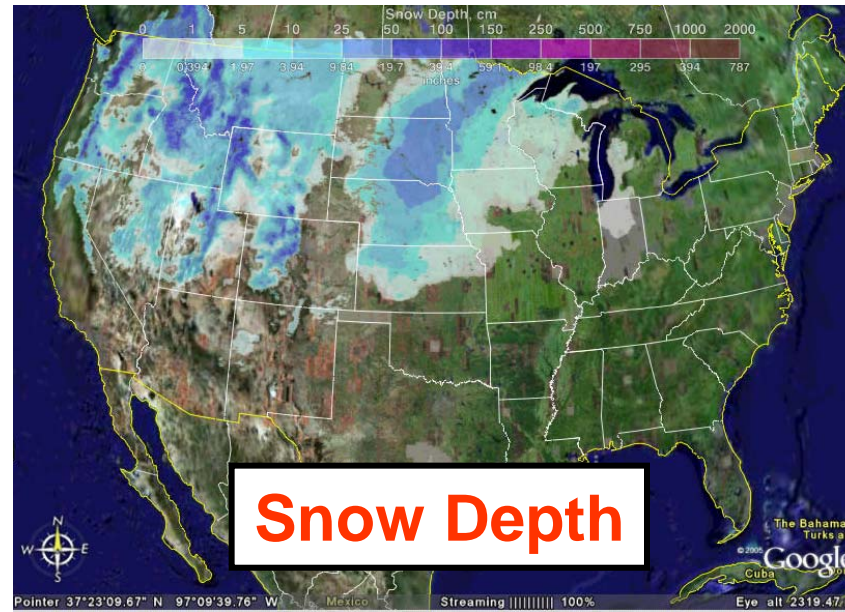
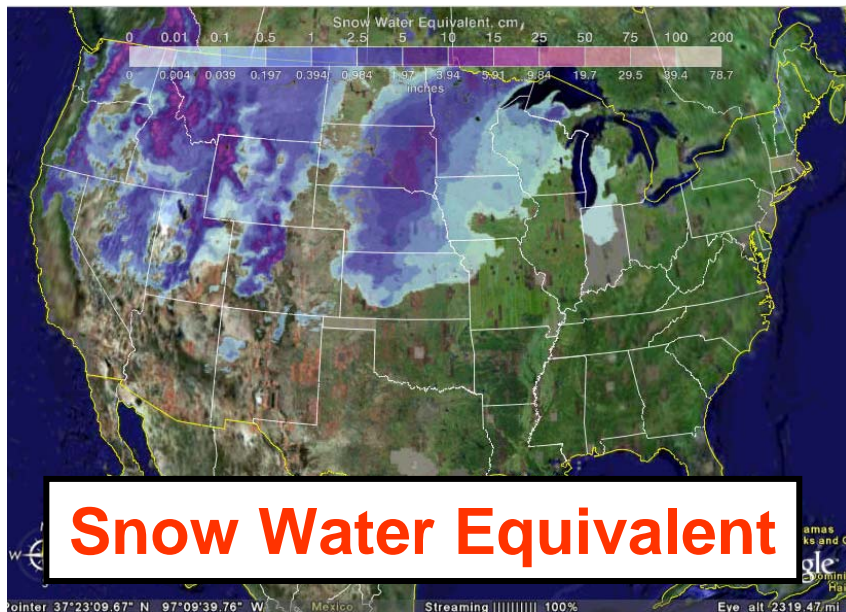
3D visualization - it's a key to understanding the National Snow Analyses.

- Fly over terrain
- Explore snow reporting stations
- Get the latest snow observations

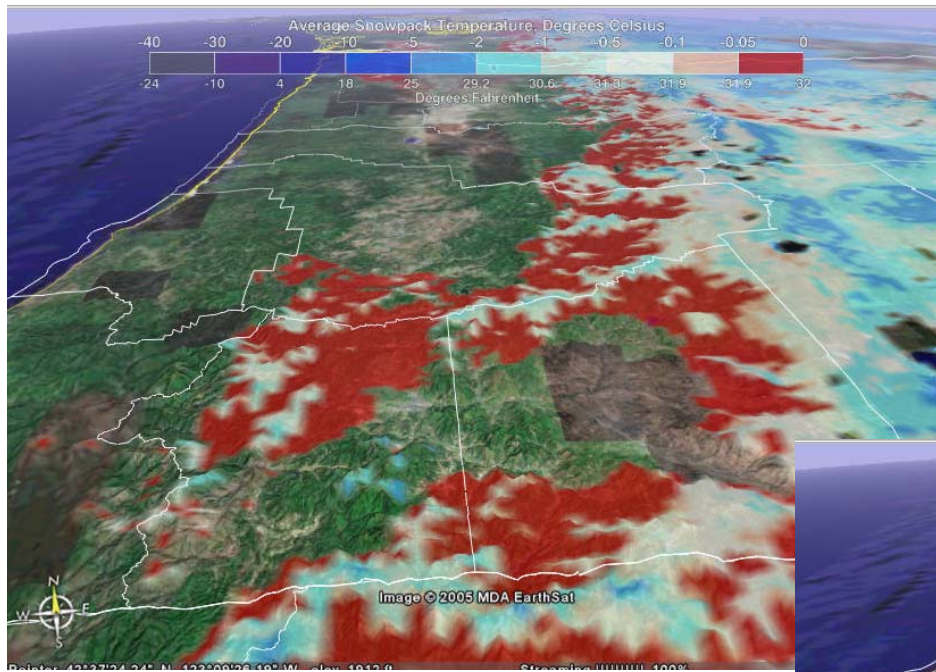


Visualize Snow

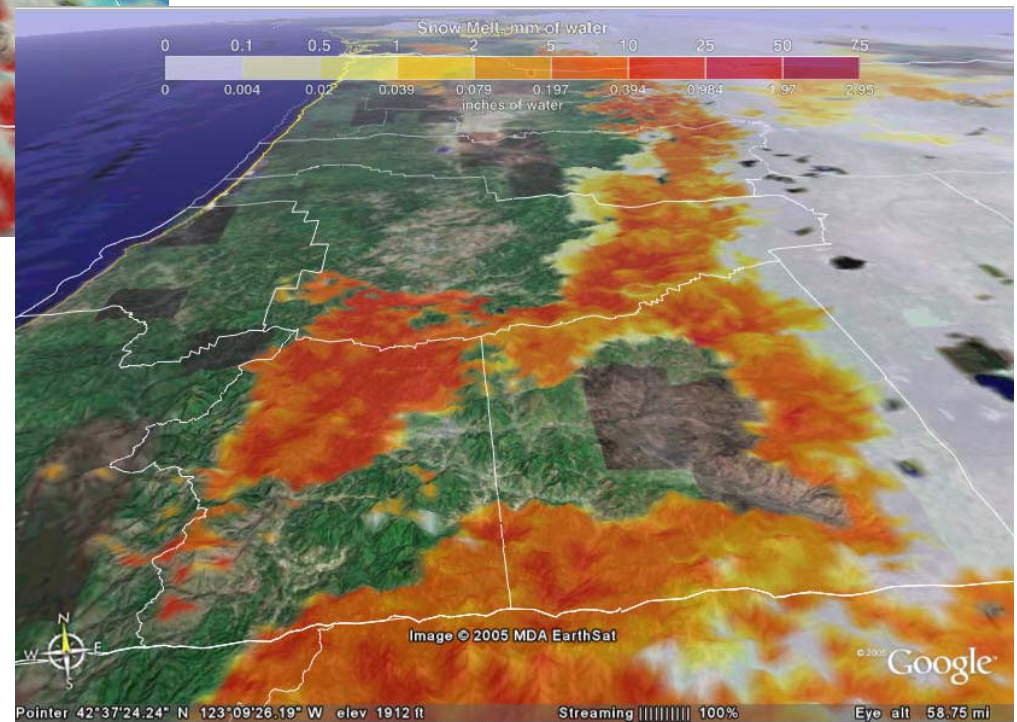
National Snow Headlines



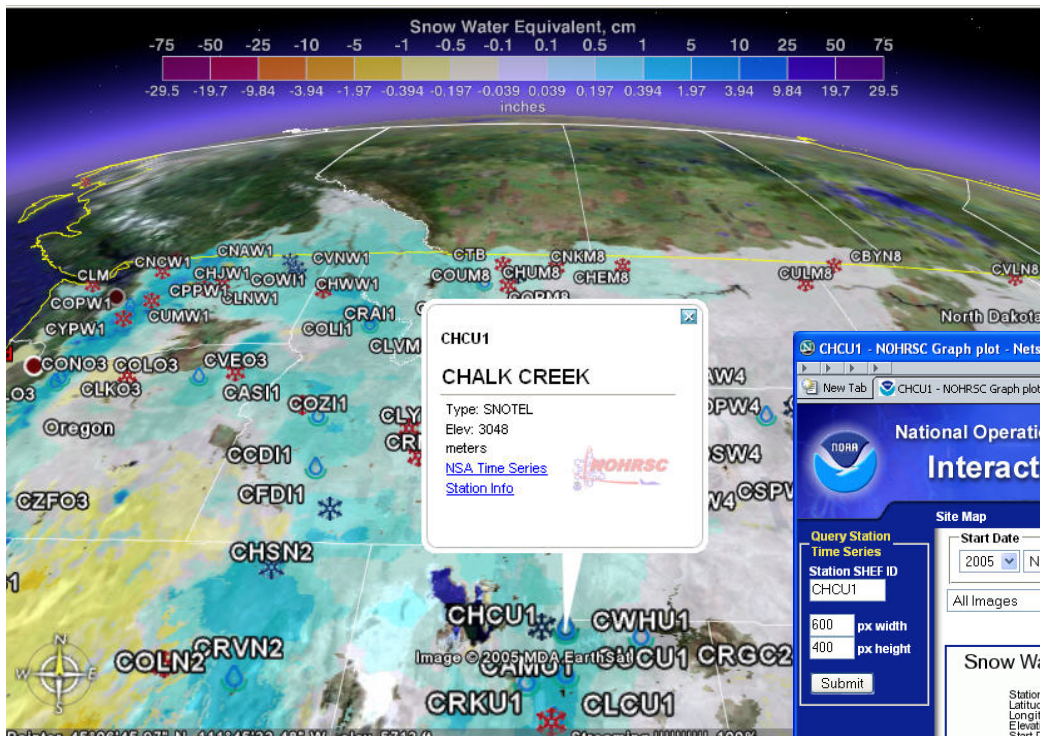
Snowpack Temperature



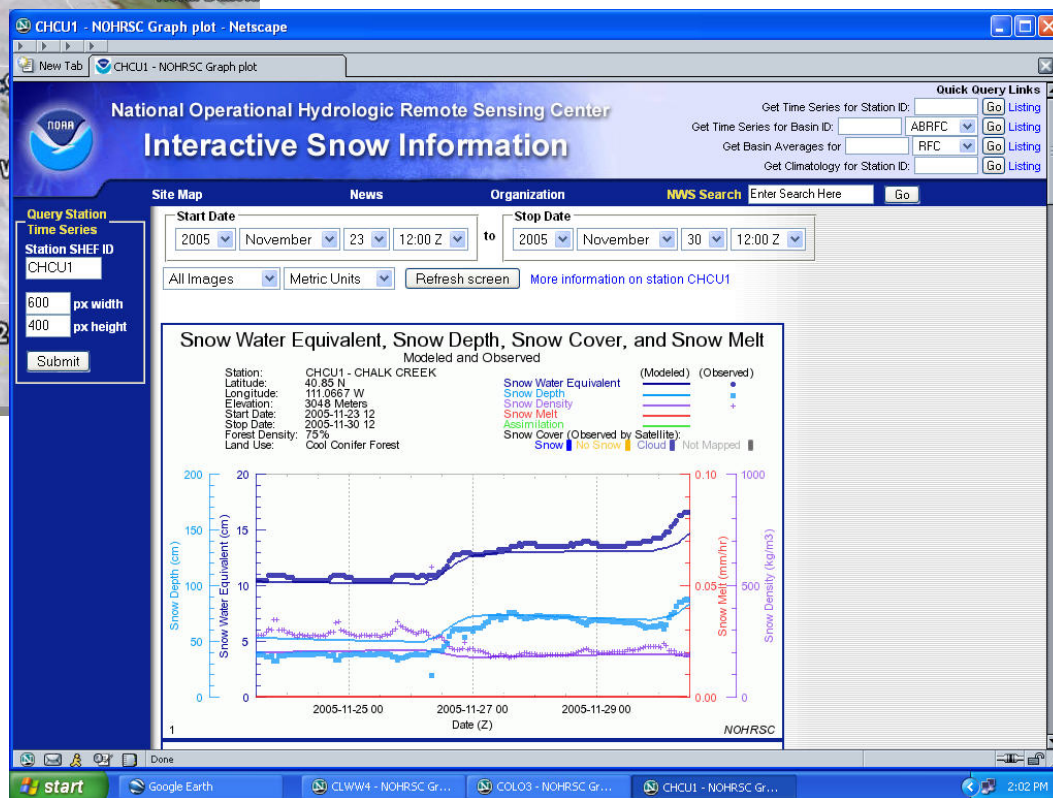
Snowmelt



10,000 Snow Reporting Stations



NOHRSC NSA Time Series





Thank You !

For more information on
NOAA's National Snow Analyses
and the ***NOHRSC***, contact:

Tom Carroll

Tom.Carroll@noaa.gov

(952) 361-6610 ex 225

