# NOAA's National Snow Analyses


**Tom Carroll**

**National Operational Hydrologic Remote Sensing Center**

***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. |

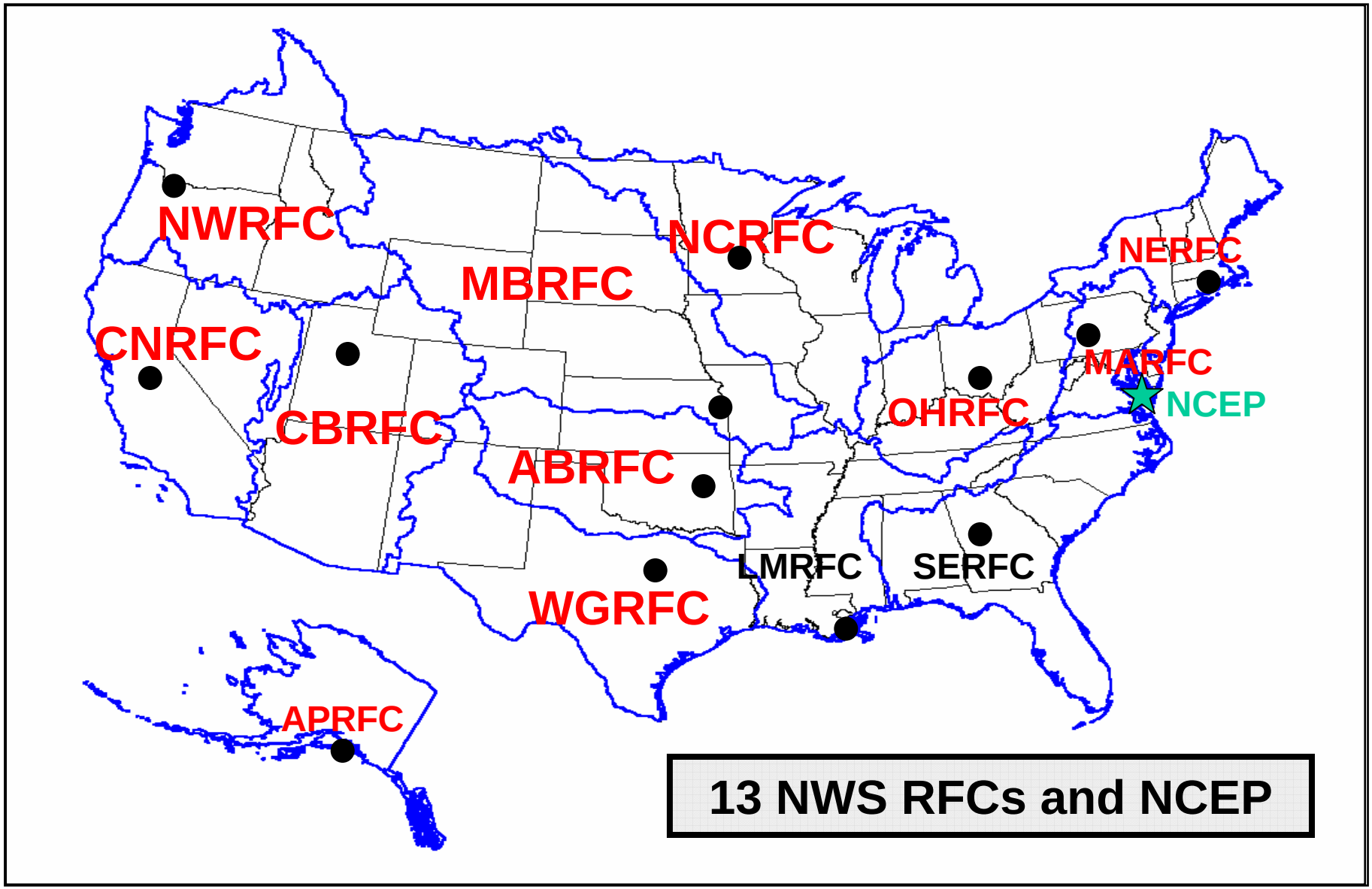
**"… improved snow information and services have potential benefits greater than $1.3 billion annually."**

### Economic Costs of Snow

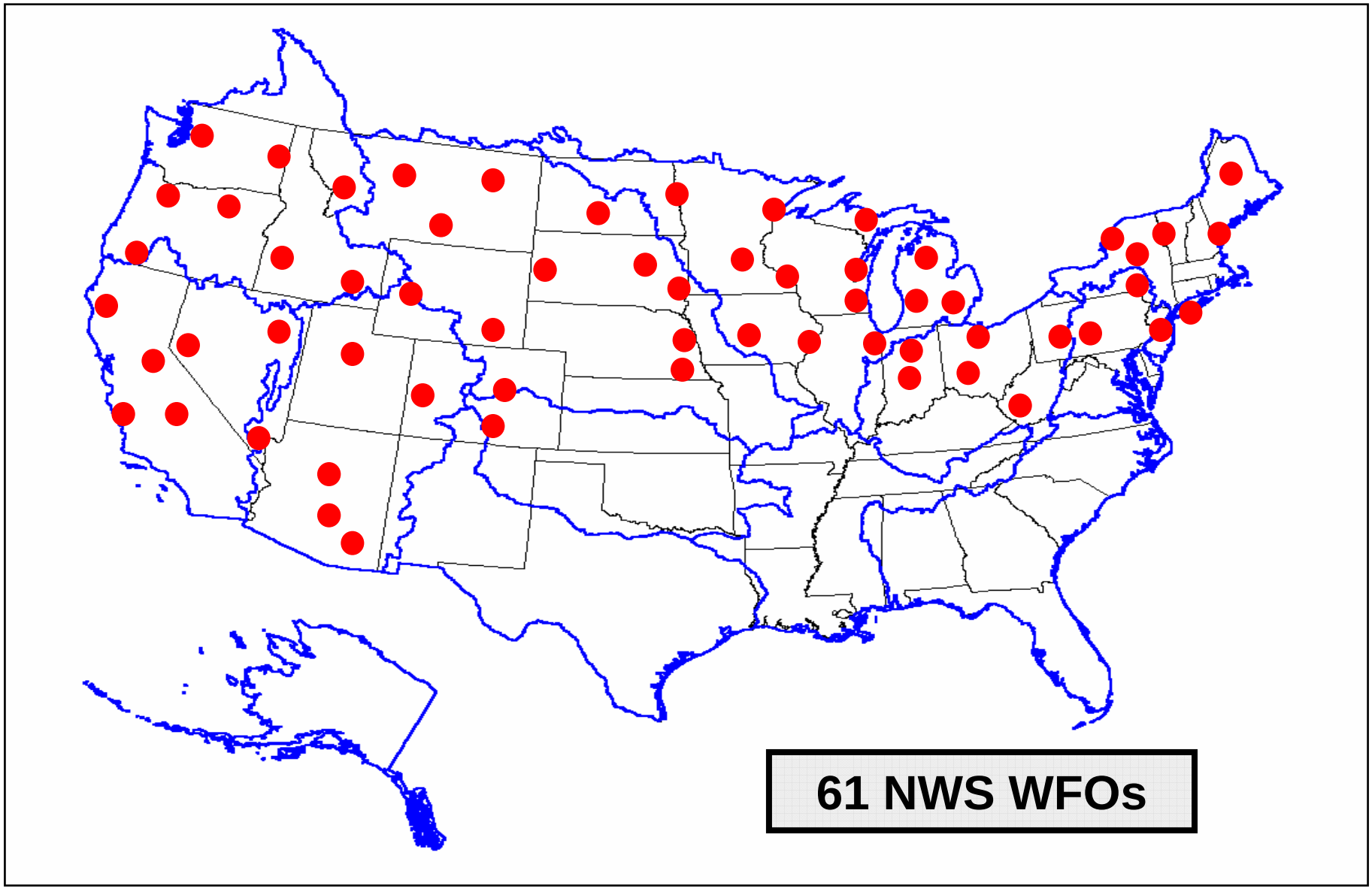
| | | |
|---|---|---|
| Snow removal | Exceeds $2 billion / yr | U.S. |
| Road closures that cause lost retail trade, wages, and tax revenue | Exceeds $10 billion / day | Eastern U.S. |
| Flight delays | $3.2 billion / yr | U.S. carriers |
| Damage to utilities | Up to $2 billion / event | |
| Flooding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

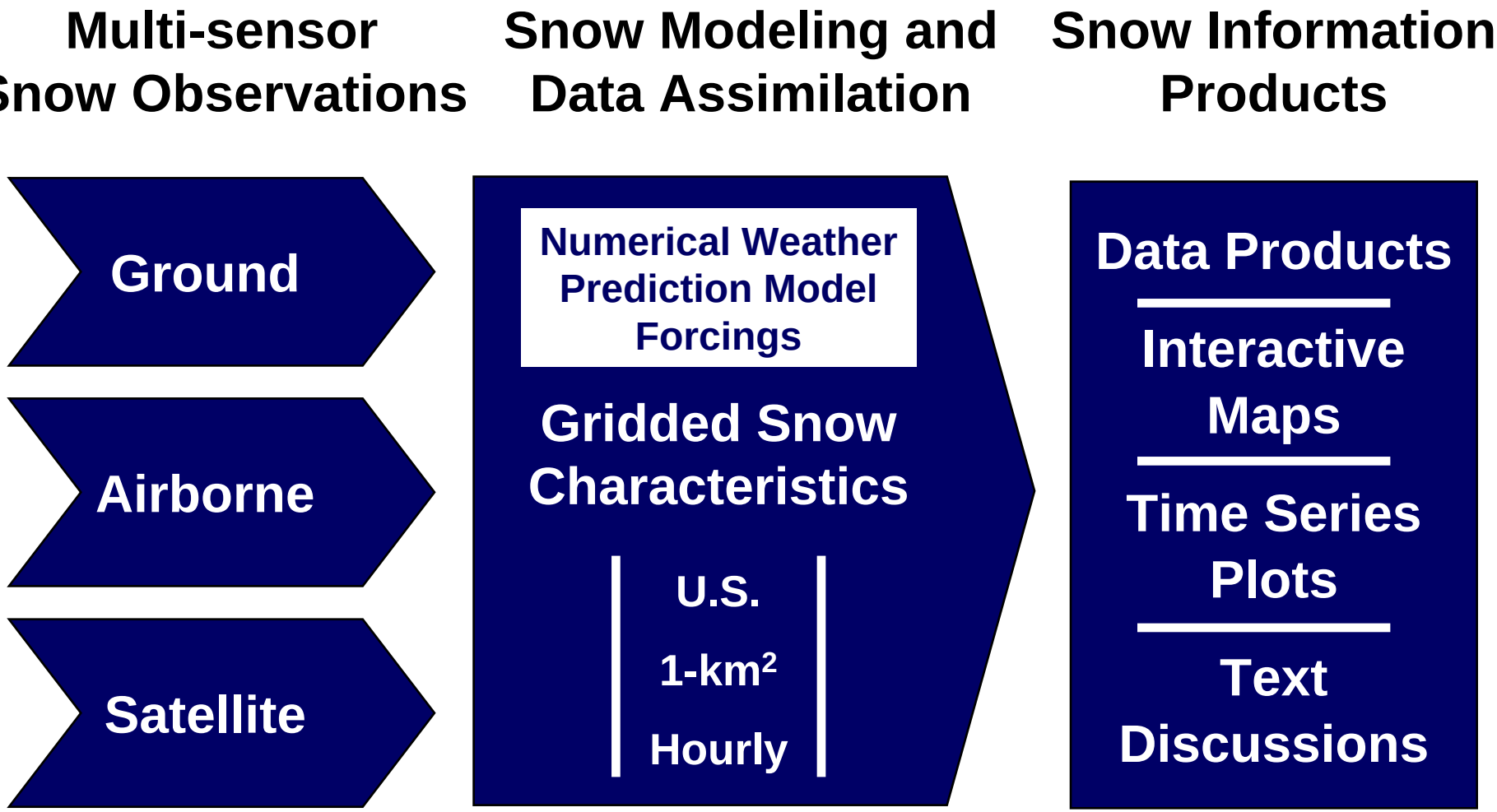


# NOHRSC External Stakeholders

***(selected)***

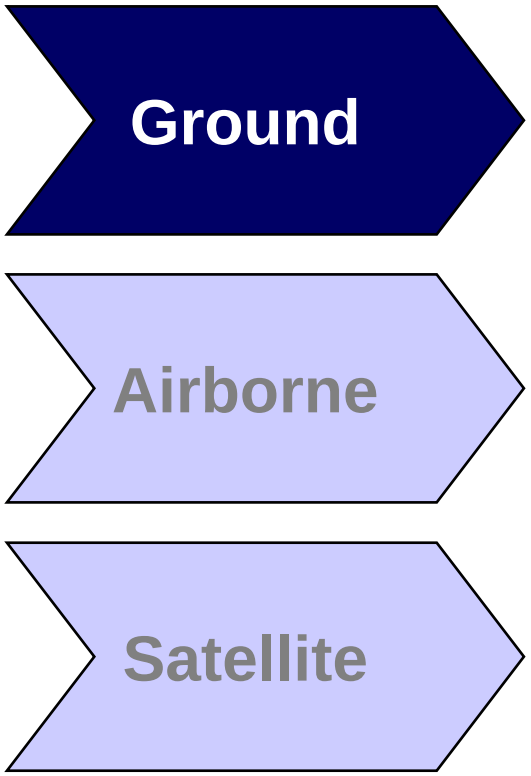
- United States
  - U.S. Army Corps of Engineers
  - Bureau of Reclamation
  - Natural Resources Conservation Service
  - Montana Department of Emergency Services
  - San Francisco Public Utilities Commission
  - University of Albany ASRC/CESTM
  - University of Wisconsin Sea Grant Institute
  - National 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)



# National Snow Analyses (NSA)

**Multi-sensor Snow Observations**



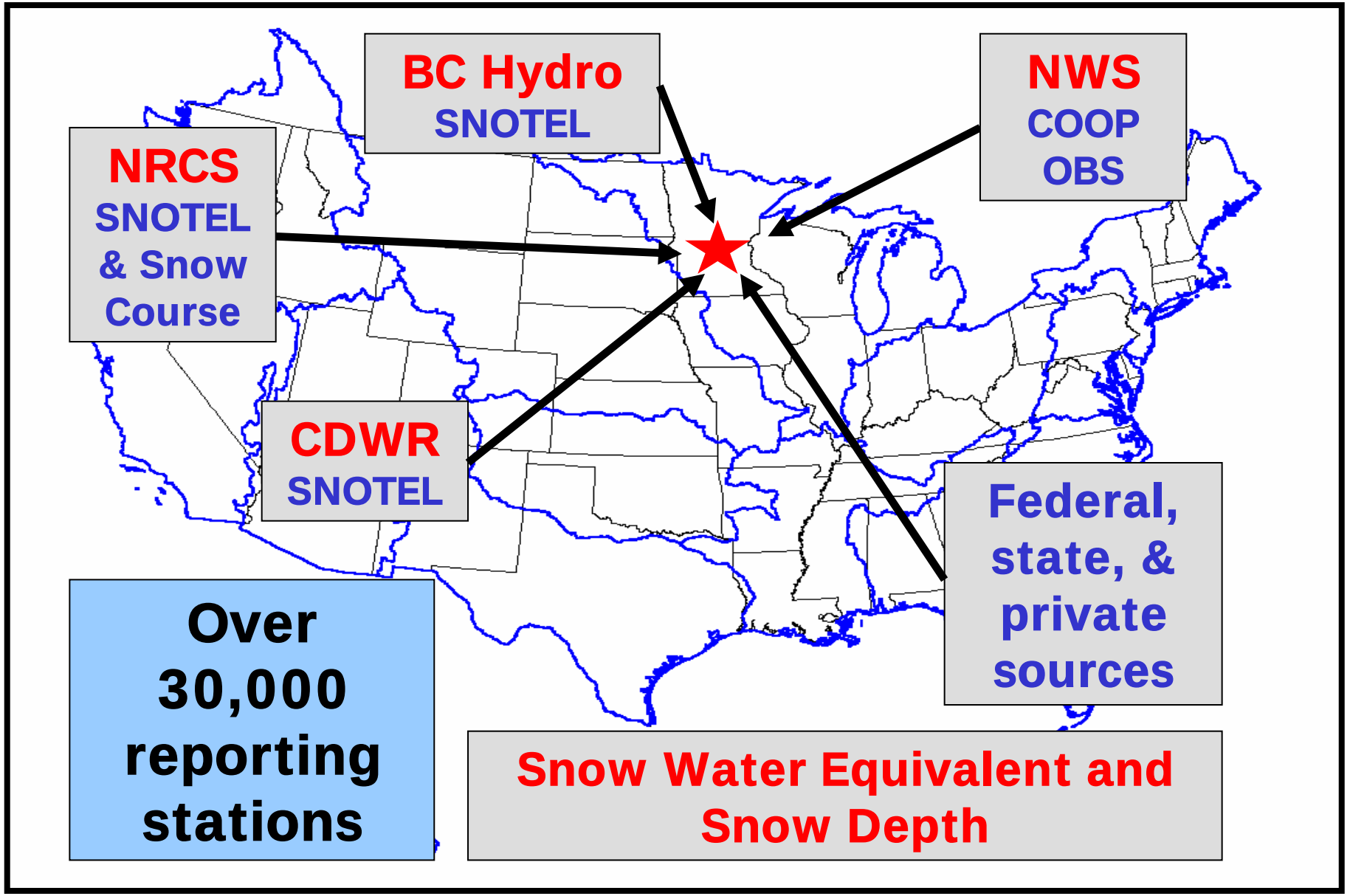

- **National Weather Service**
  - First-order Stations
  - Cooperatives
- **Federal and State Agencies**
  - NRCS SNOTEL and Snow Courses
  - USACE New England District Snow Surveys
  - Federal Aviation Administration
  - California Dept. of Water Resources
- **Regional Mesonets**
  - Maine Cooperative 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**

- Ground
- **Airborne**
- Satellite

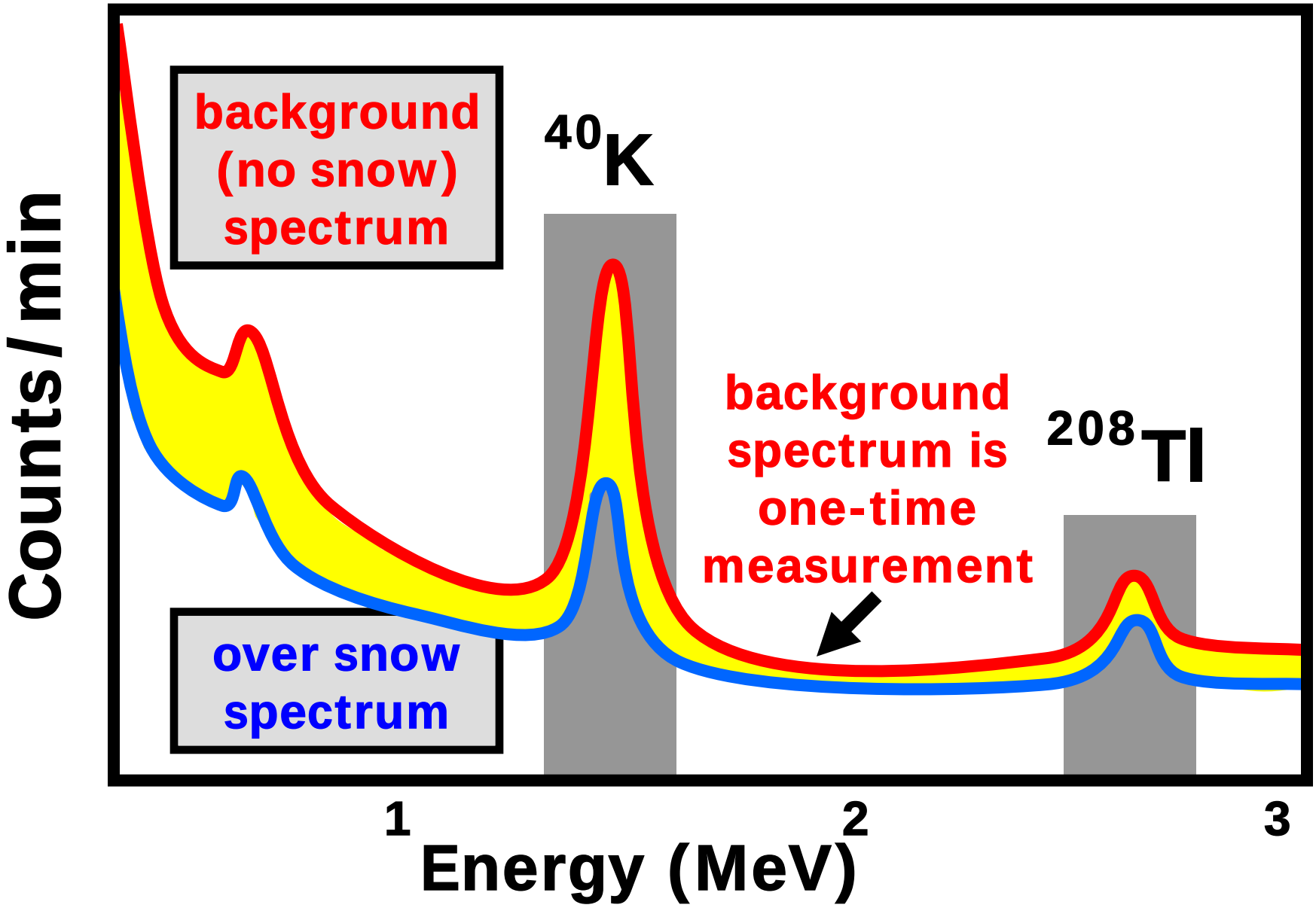
**NWS Airborne Snow Survey Program**


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

# Airborne Snow Survey Program

# Airborne Snow Survey Program

# Natural Terrestrial Gamma Radiation

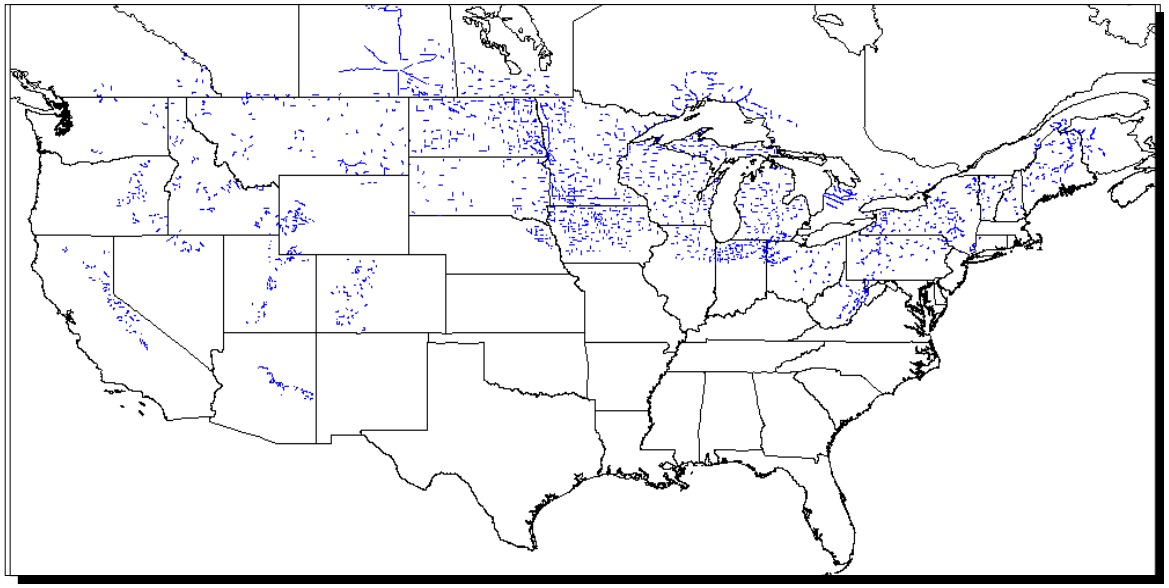


# National Snow Analyses (NSA)

**Multi-sensor Snow Observations**

- Ground
- **Airborne**
- Satellite

**Airborne Snow Survey Program Flight Line Network**



**2,187 Flight Lines**

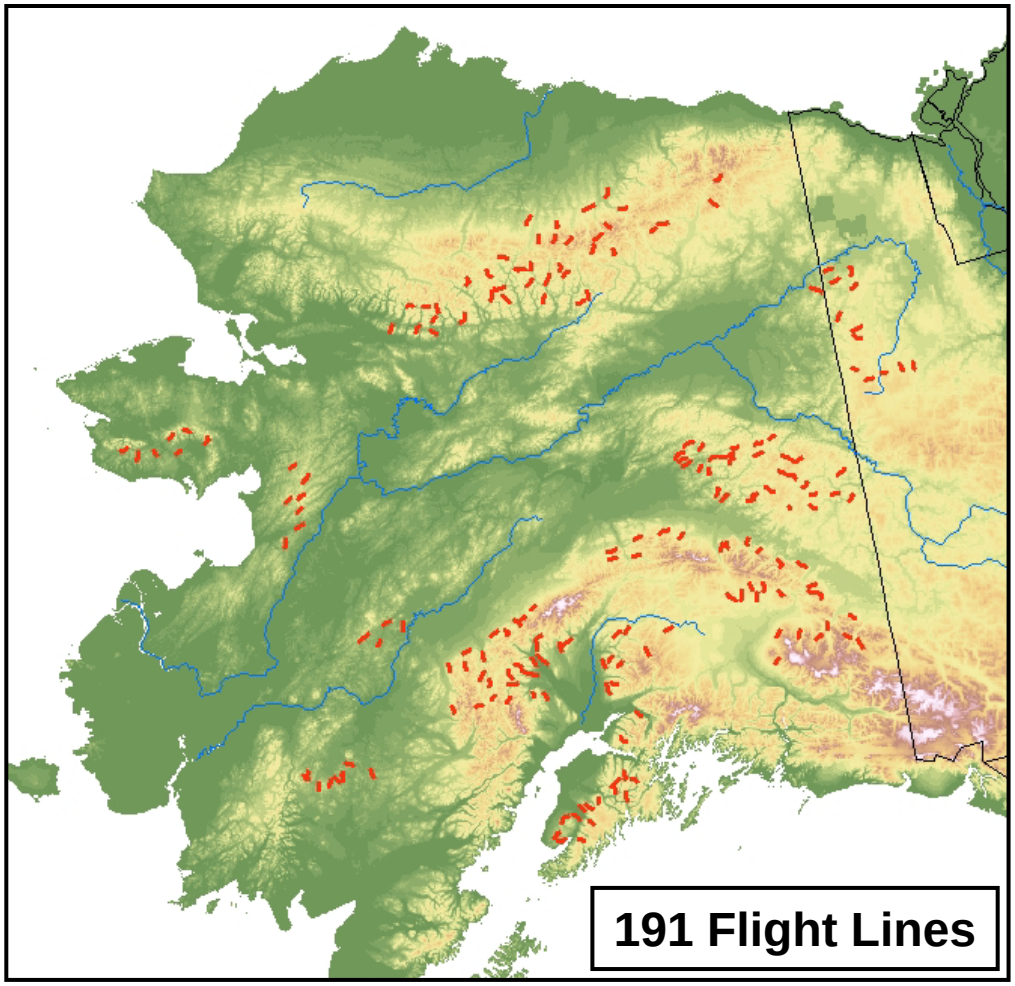
**31 States, 8 Provinces**

# National Snow Analyses (NSA)

**Multi-sensor Snow Observations**

- Ground
- **Airborne**
- Satellite

**Alaska Flight Line Network**

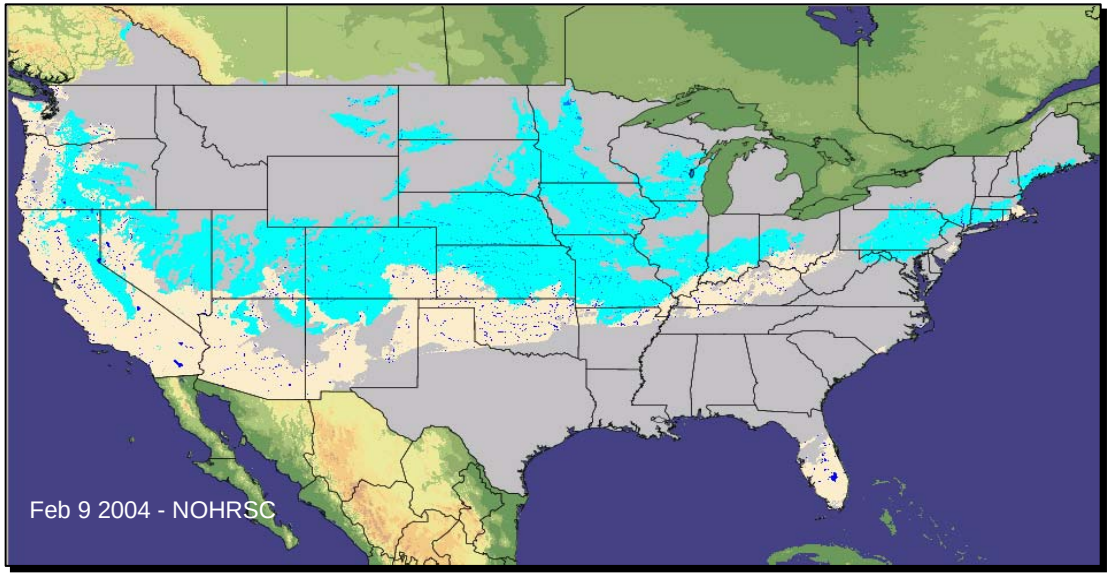


# National Snow Analyses (NSA)

## Multi-sensor Snow Observations

- Ground
- Airborne
- **Satellite**

## 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.

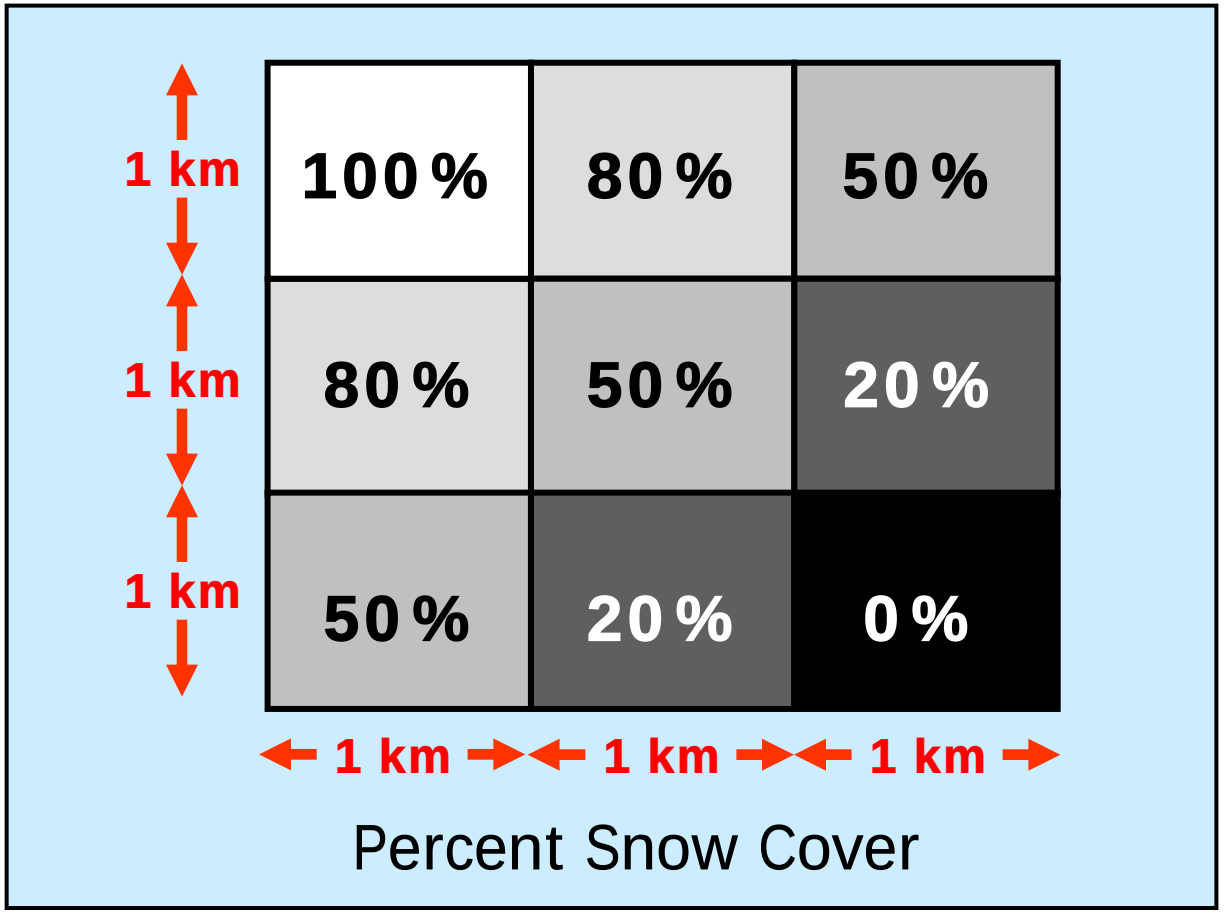
# National Snow Analyses (NSA)

**Multi-sensor Snow Observations**

- Ground
- Airborne
- Satellite

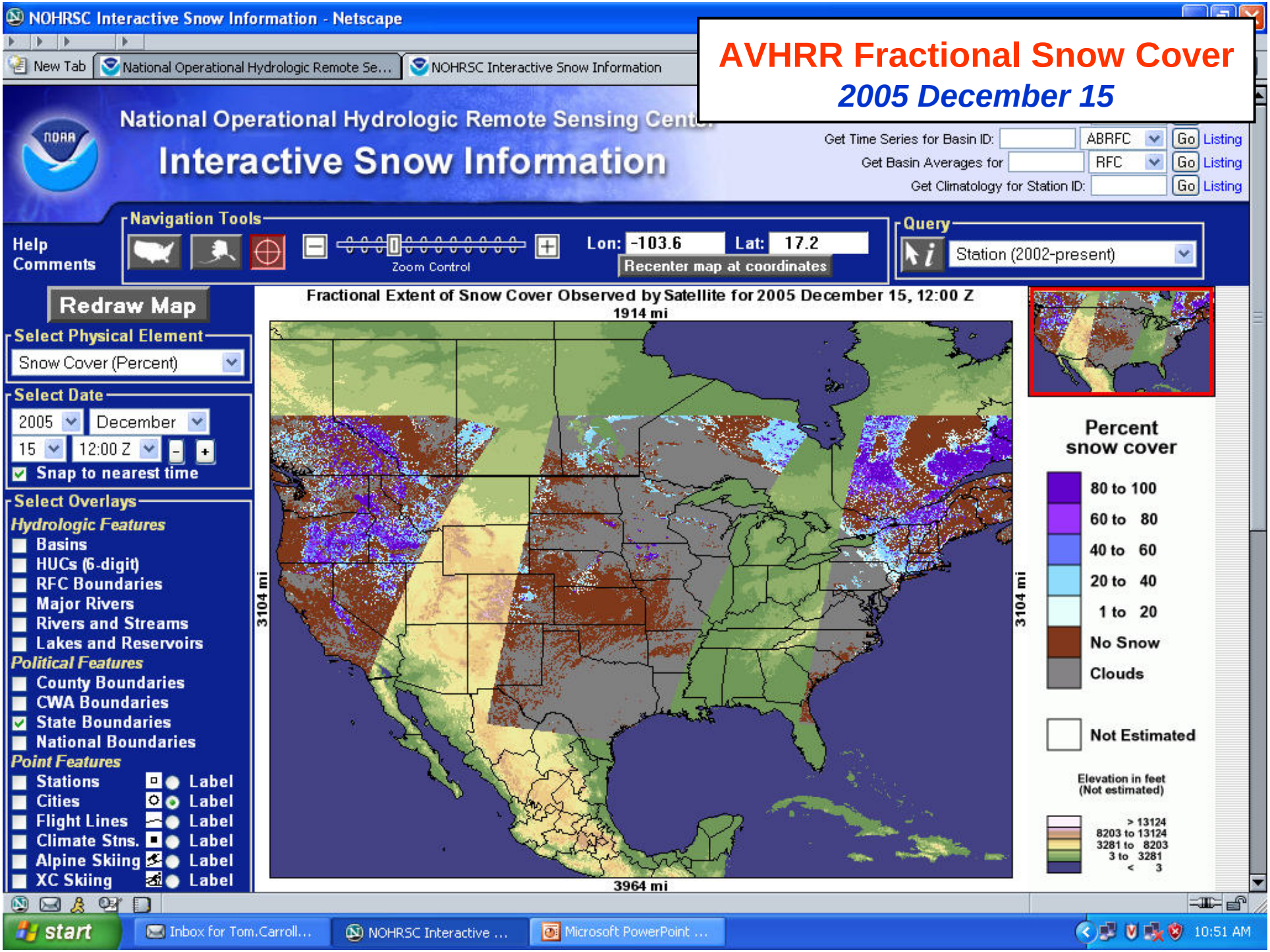
**Advanced Very High Resolution Radiometer (AVHRR)**

***Fractional Snow Cover***

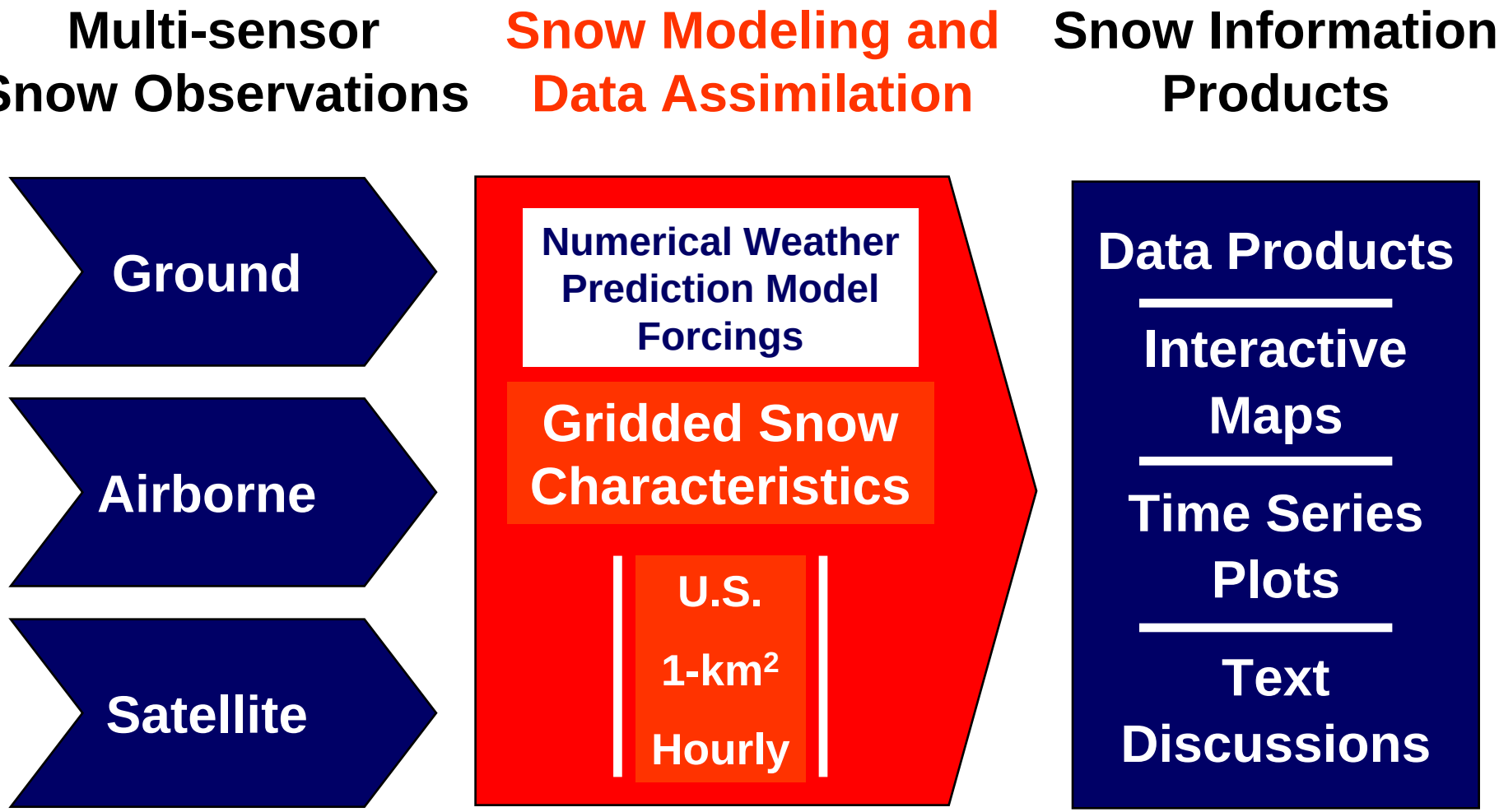


# AVHRR Fractional Snow Cover

## *2005 December 15*



# National Snow Analyses (NSA)



# 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.**

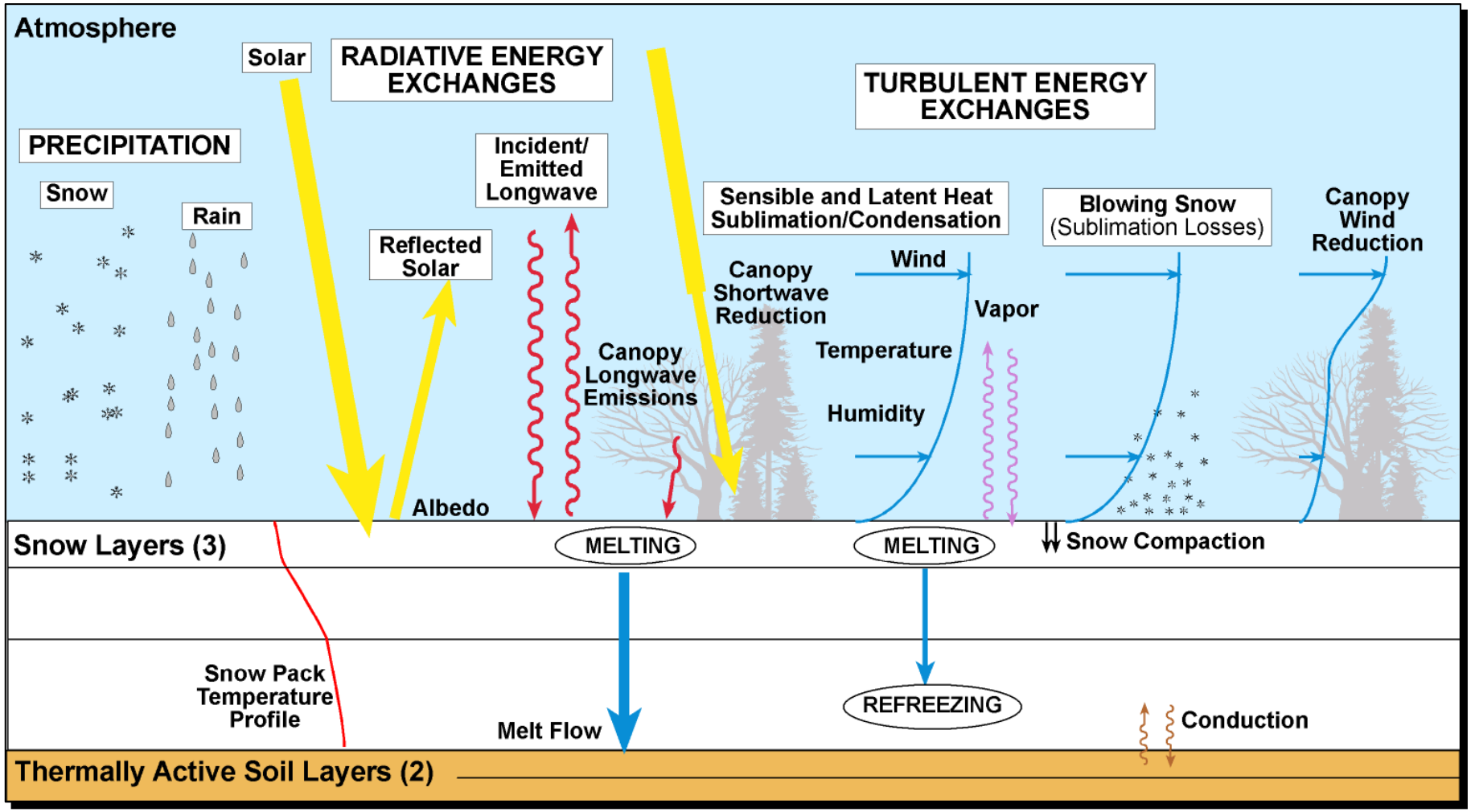
**1-km²**

**Hourly**

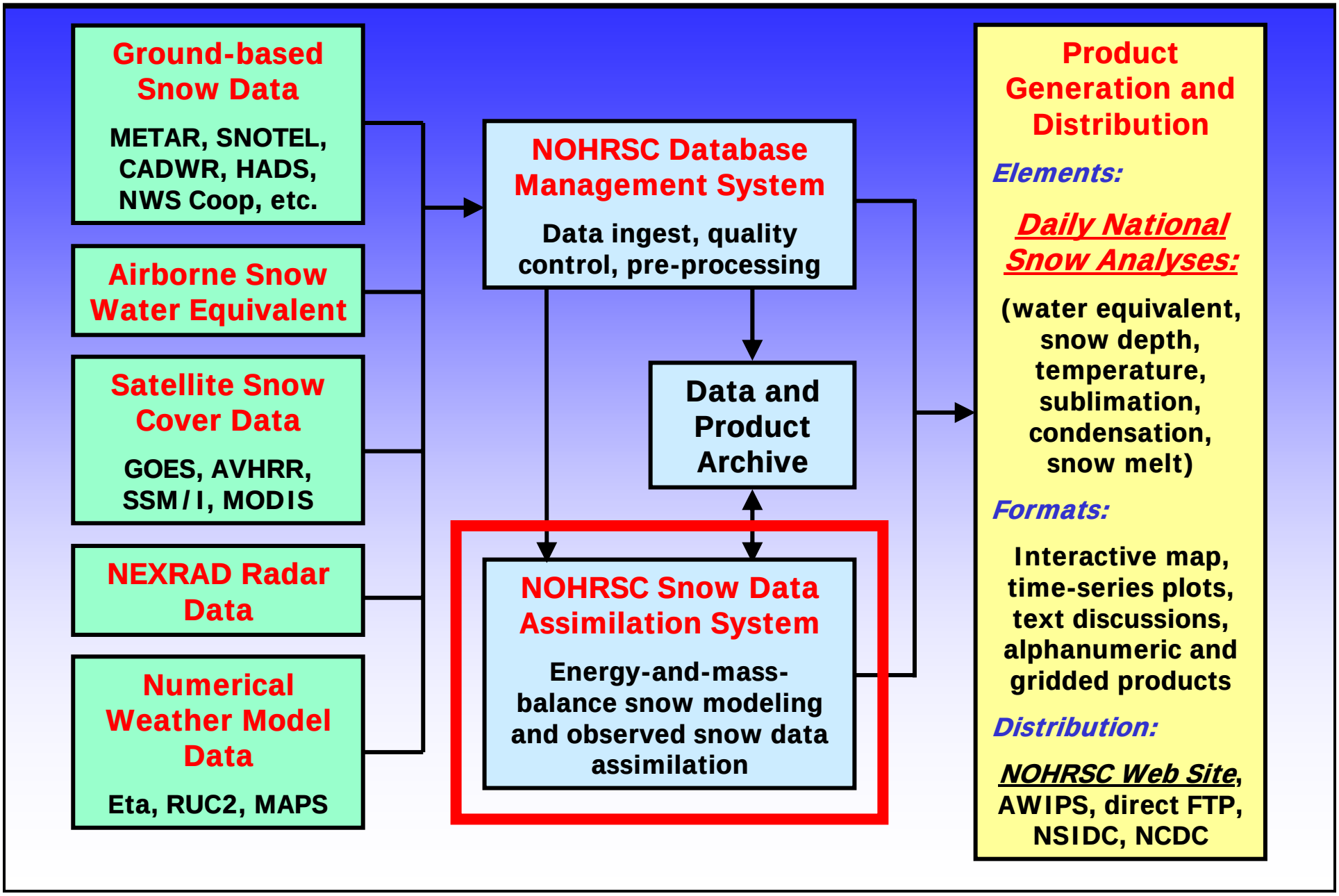
- **Land Surface Model for Snow and Soil**
  - Domain: Continental U.S.
  - Resolution: 1km², Hourly
  - Physics: 5-Layer Energy and Mass Balance
    - Spatial implementation of modified 1-D SNTHERM model developed by ERDC/CRREL *(Anderson/Jordan)*
    - Spatial implementation of Prairie Blowing Snow 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

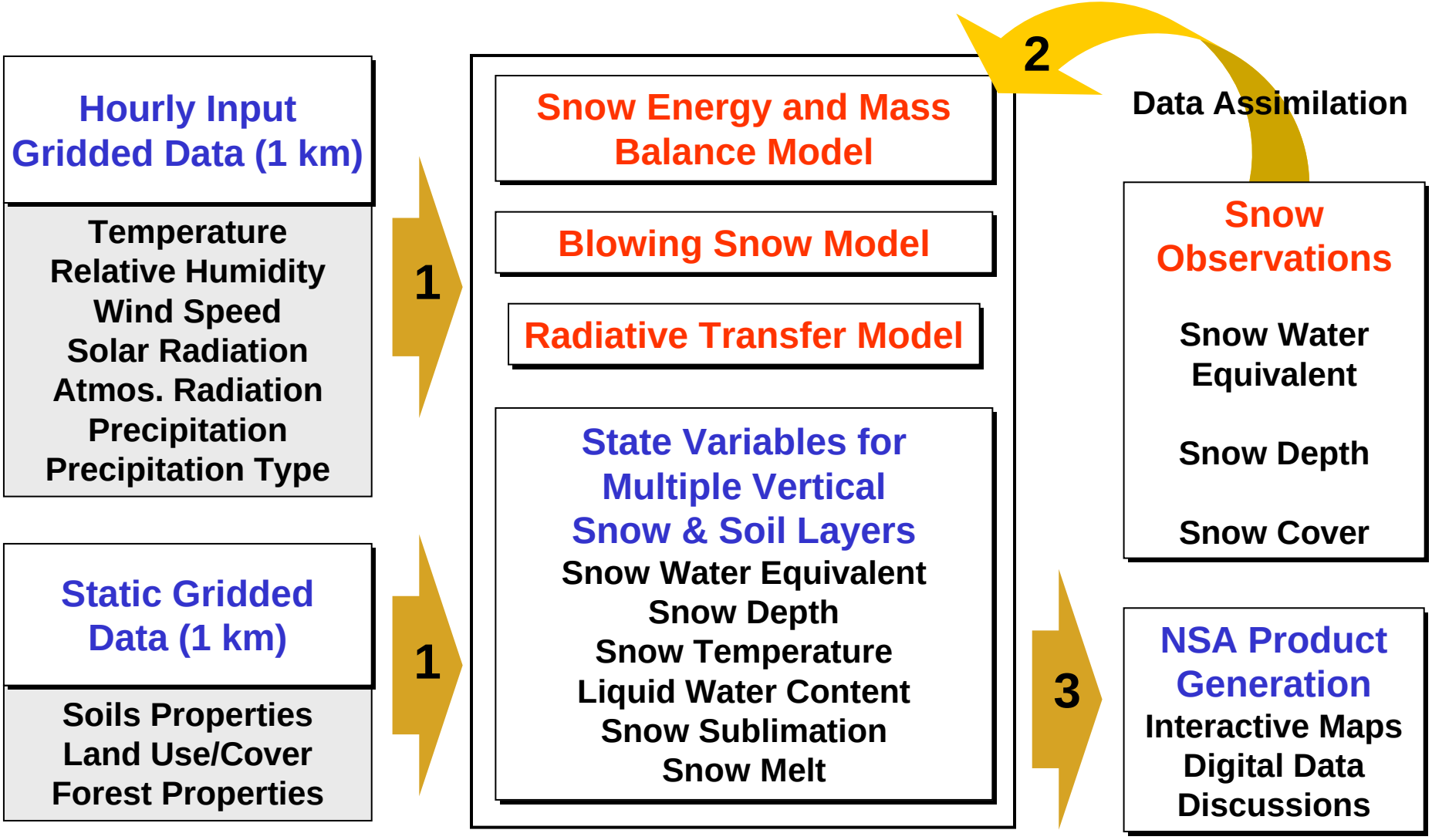
$$(K\downarrow - K\uparrow) + (L\downarrow - L\uparrow) + Q_e + Q_h + Q_g + Q_p = \Delta Q$$



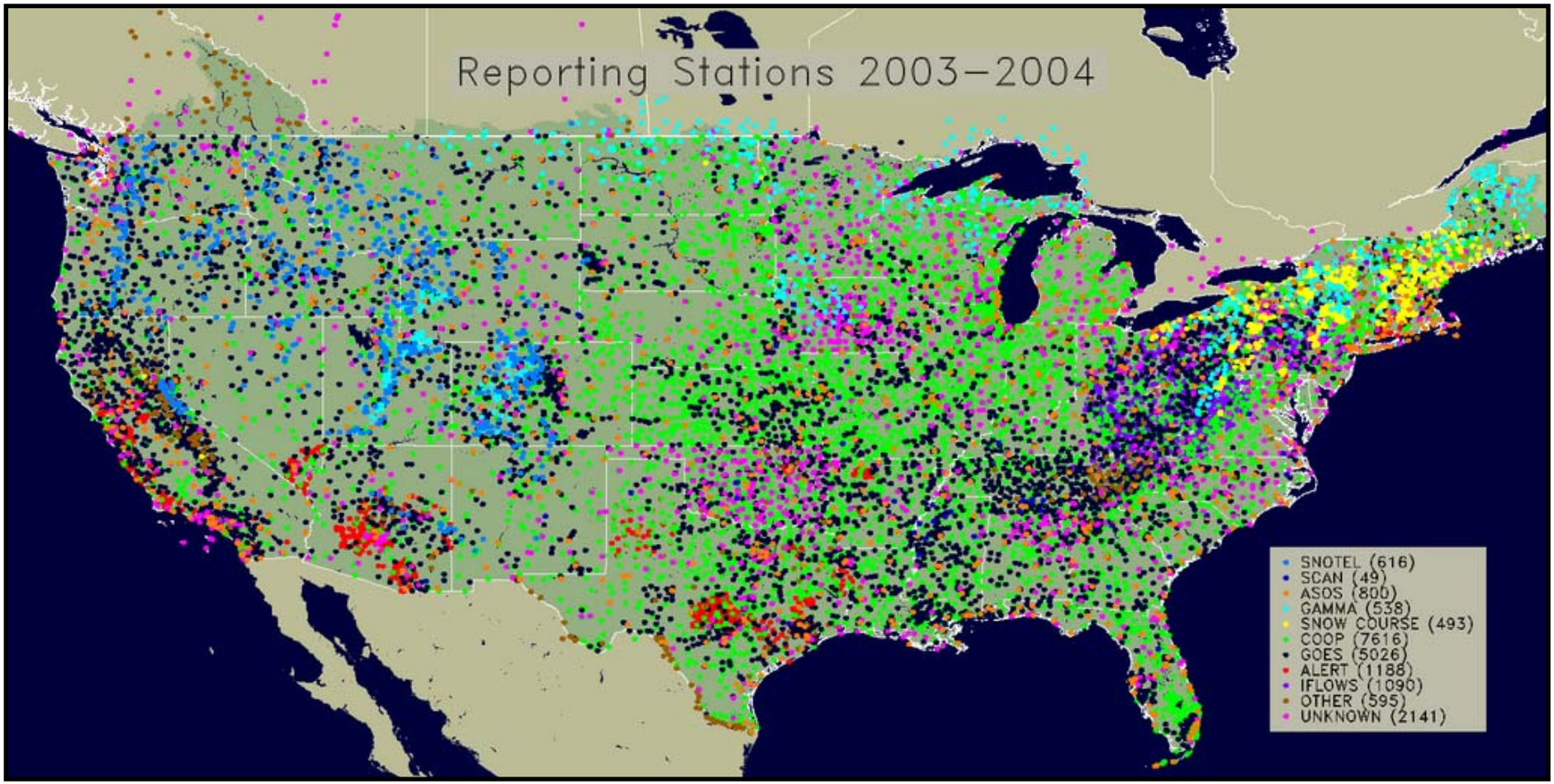
# NOHRSC Operations



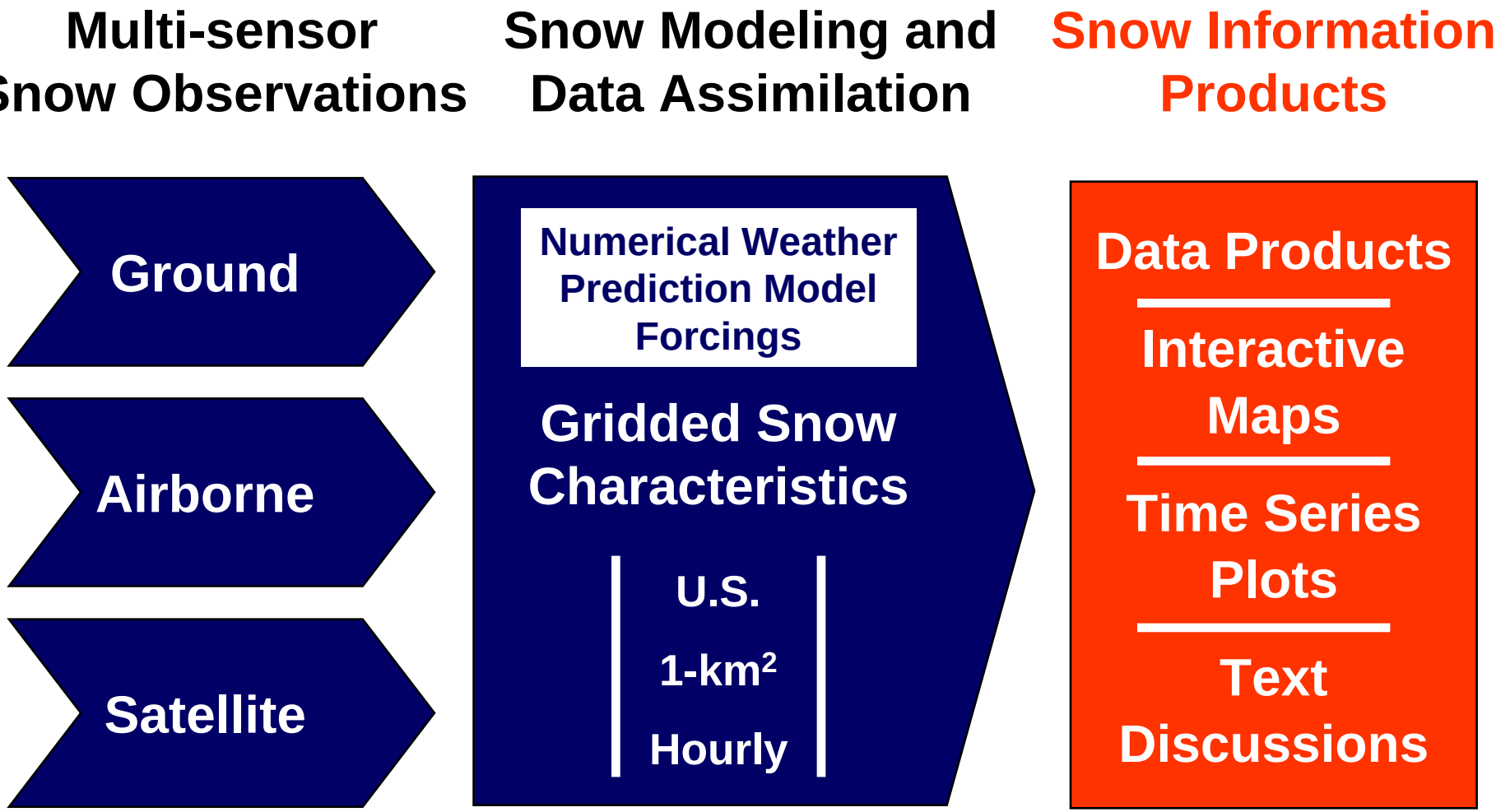
# Snow Modeling Framework



# Over 30,000 Reporting Stations



# National Snow Analyses (NSA)



# National Snow Analyses (NSA)

## Snow Information Products

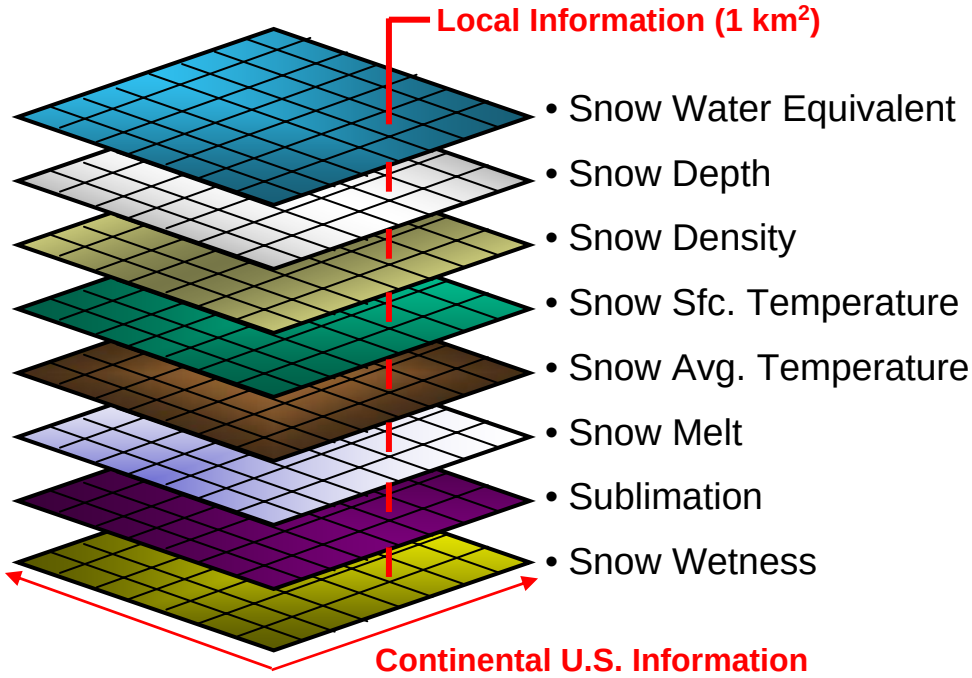
**Data Products**

**Interactive Maps**

**Time Series Plots**

**Text Discussions**

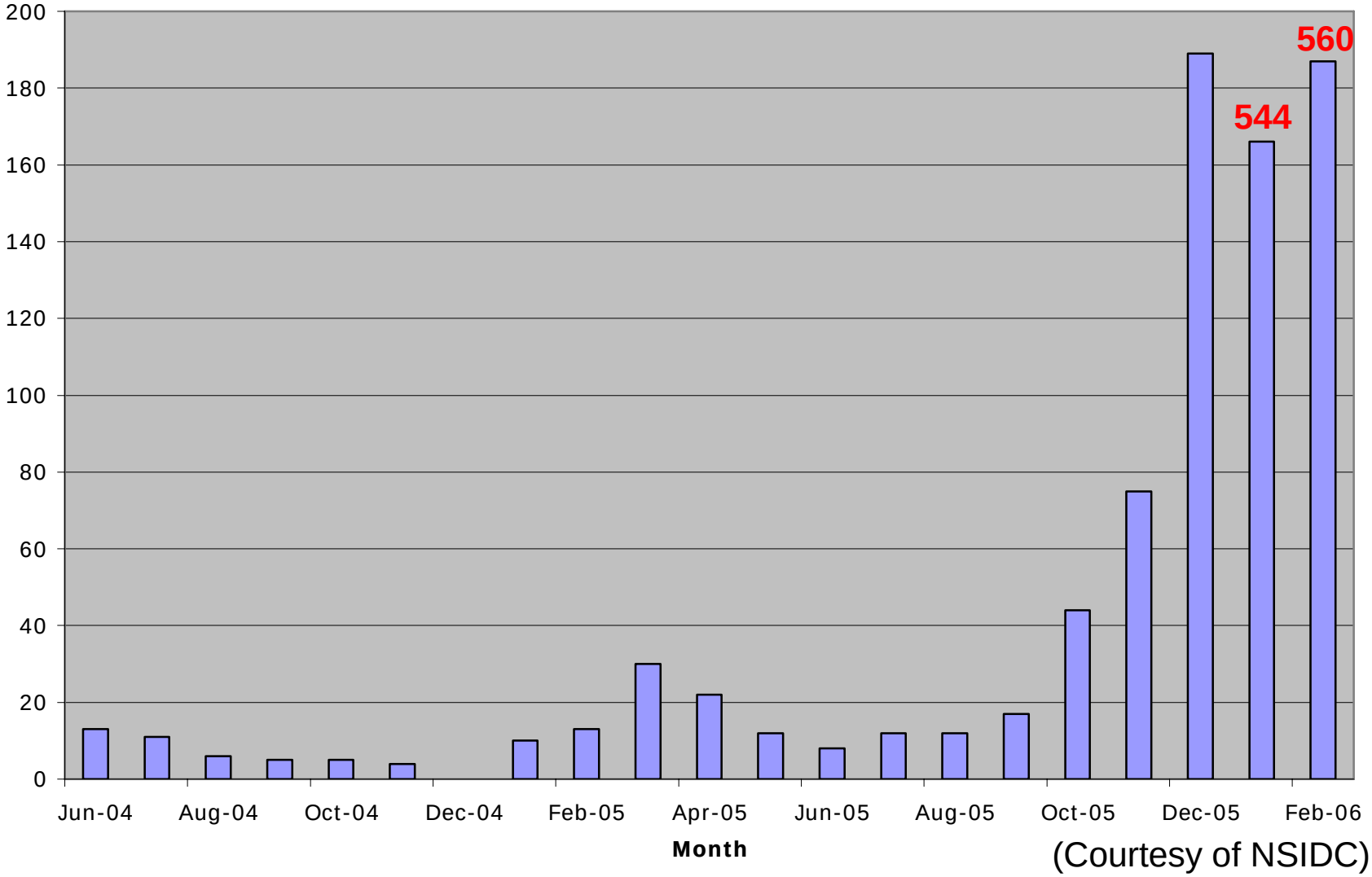
## High-resolution *Daily and Hourly* Gridded Snow Data Sets of Fused Model and Observations




- **Archived at NCDC, NSIDC, and NDFD (soon)**

# Unique Users per Month

## *SNODAS Data from NSIDC Archive*

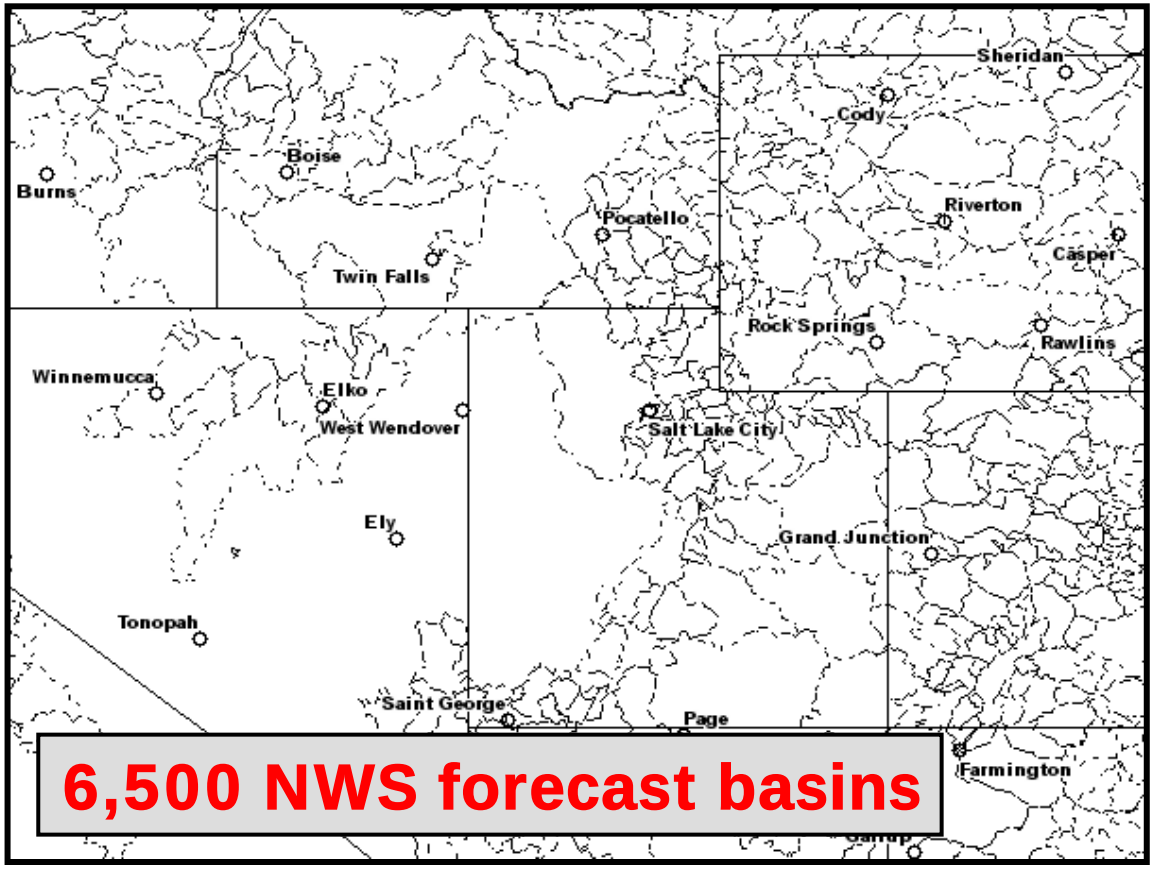



(Courtesy of NSIDC)

# 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*

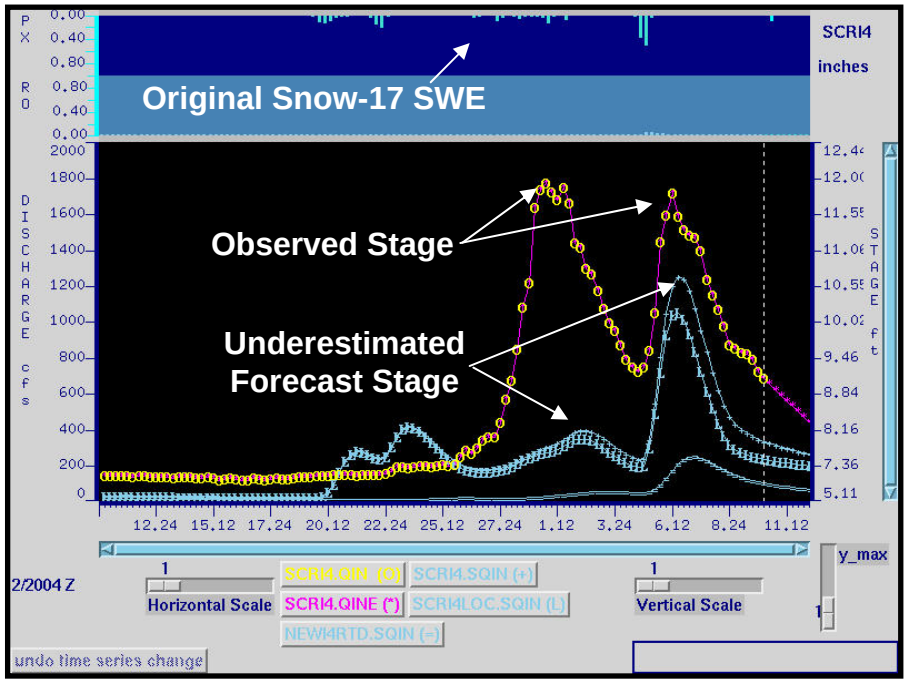
# Benefits of NSA Products

## *Use of NSA Information Products at NCRFC*

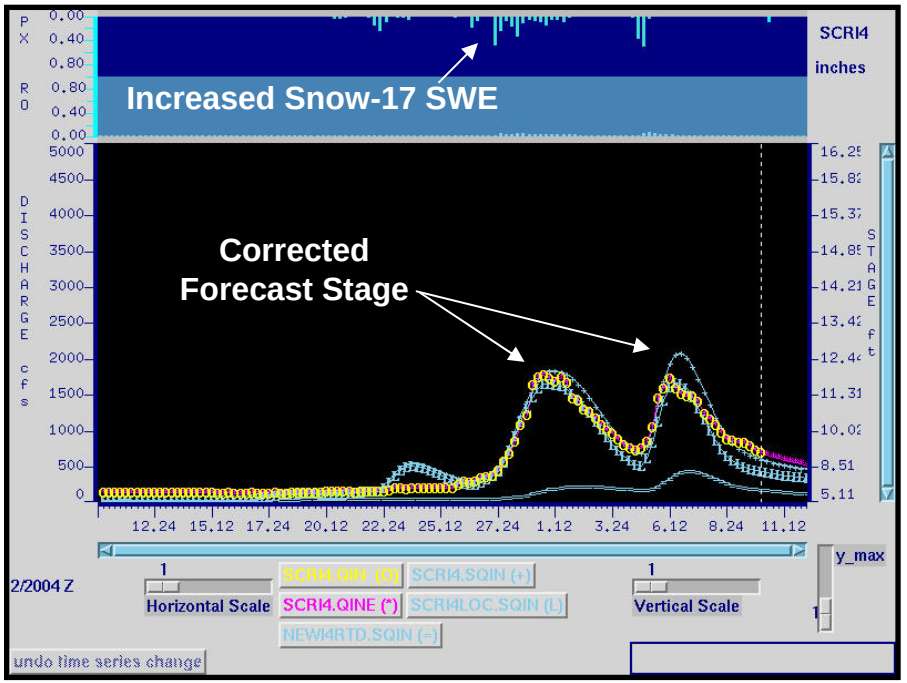
**NWS River Forecast System**

**N. Raccoon River, Des Moines River Basin** **2004 February 12 - March 11**

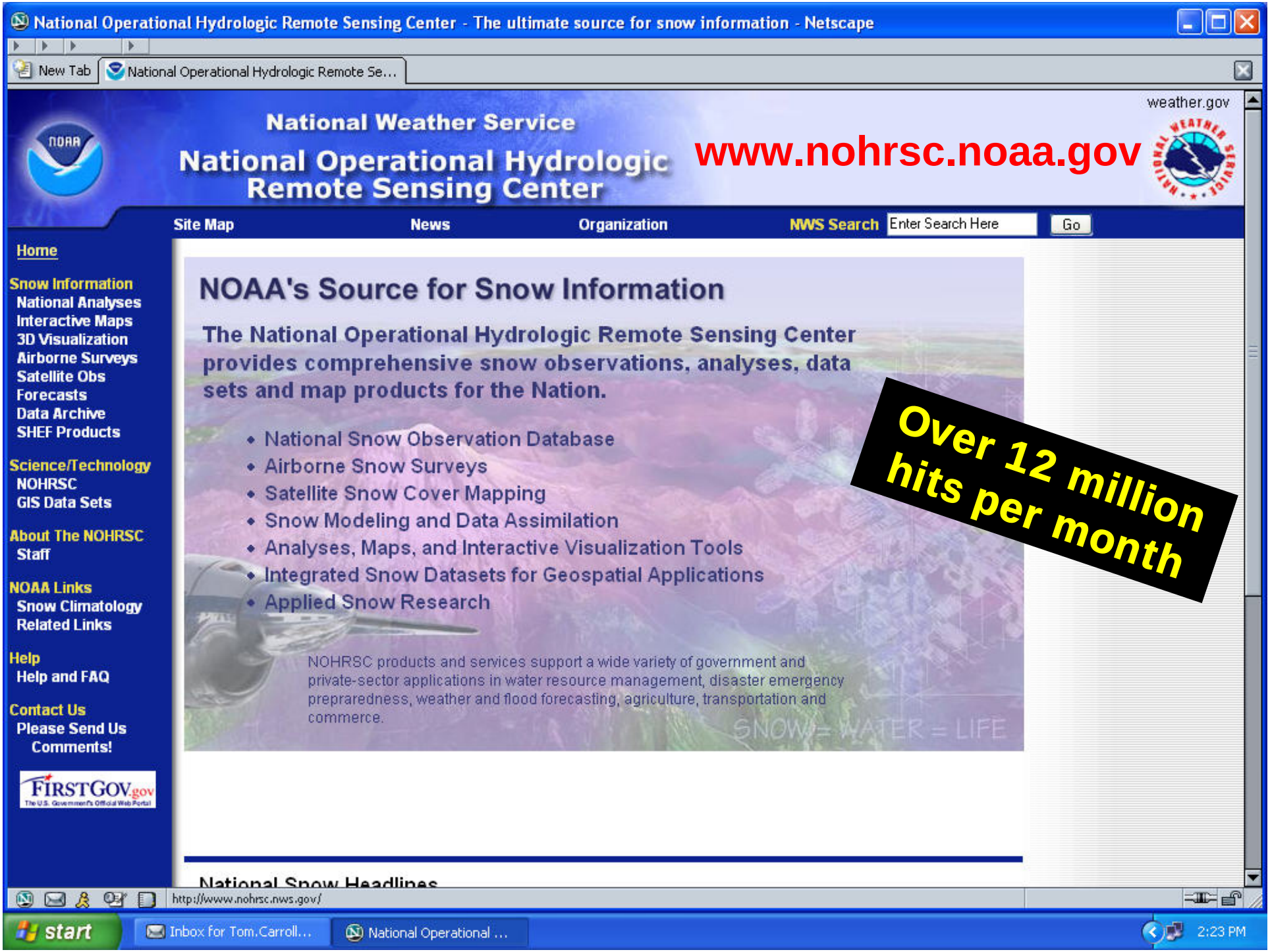
**NWSRFS without NOHRSC NSA data**




**NWSRFS updated with NOHRSC NSA data**




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


National Operational Hydrologic Remote Sensing Center - The ultimate source for snow information - Netscape
New Tab
National Operational Hydrologic Remote Se...
weather.gov
National Weather Service
National Operational Hydrologic Remote Sensing Center
www.nohrsc.noaa.gov
Site Map
News
Organization
NWS Search
Enter Search Here
Go
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!
FIRSTGOV.gov
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 prepraredness, weather and flood forecasting, agriculture, transportation and commerce.
SNOW = WATER = LIFE
Over 12 million hits per month
National Snow Headlines
http://www.nohrsc.nws.gov/
start
Inbox for Tom.Carroll...
National Operational ...
2:23 PM

National Operational Hydrologic Remote Sensing Center - The ultimate source for snow information - Netscape

New Tab | National Operational Hydrologic Remote Se...

weather.gov

National Weather Service

# National Operational Hydrologic Remote Sensing Center

Site Map | News | Organization | NWS Search | Enter Search Here | Go

- 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!

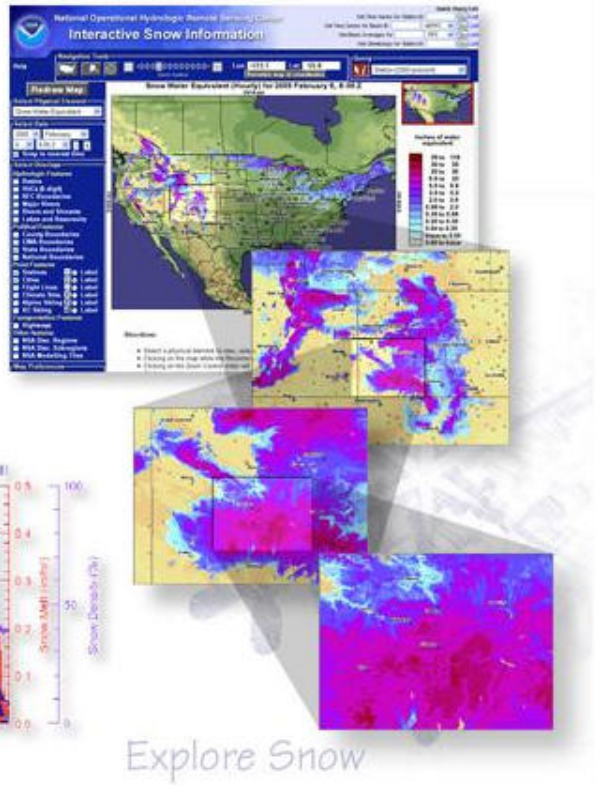
FIRSTGOV.gov The U.S. Government's Official Web Portal

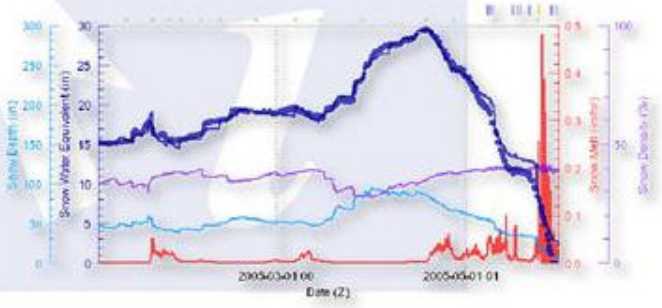
## INTERACTIVE SNOW MAPS

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.

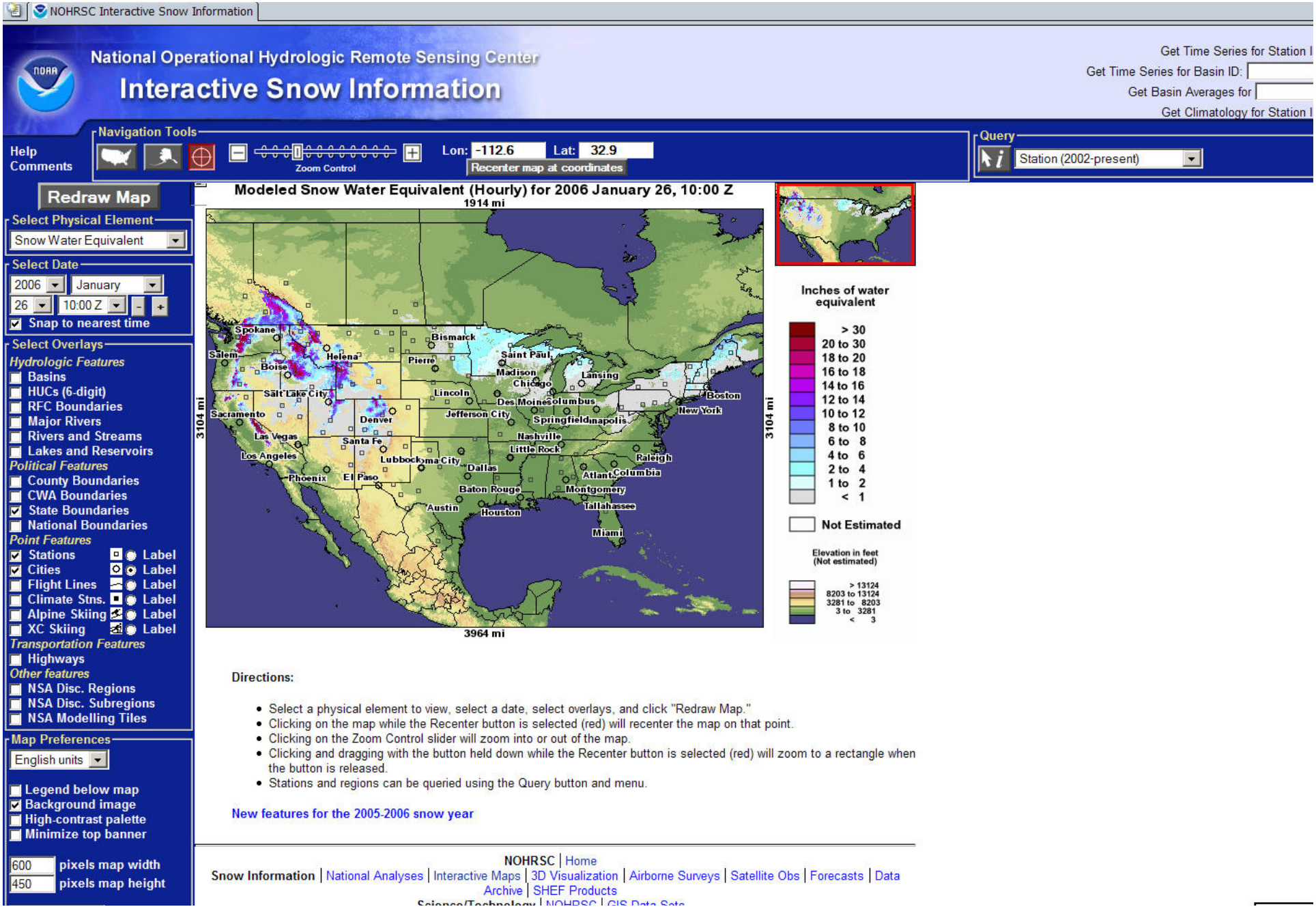


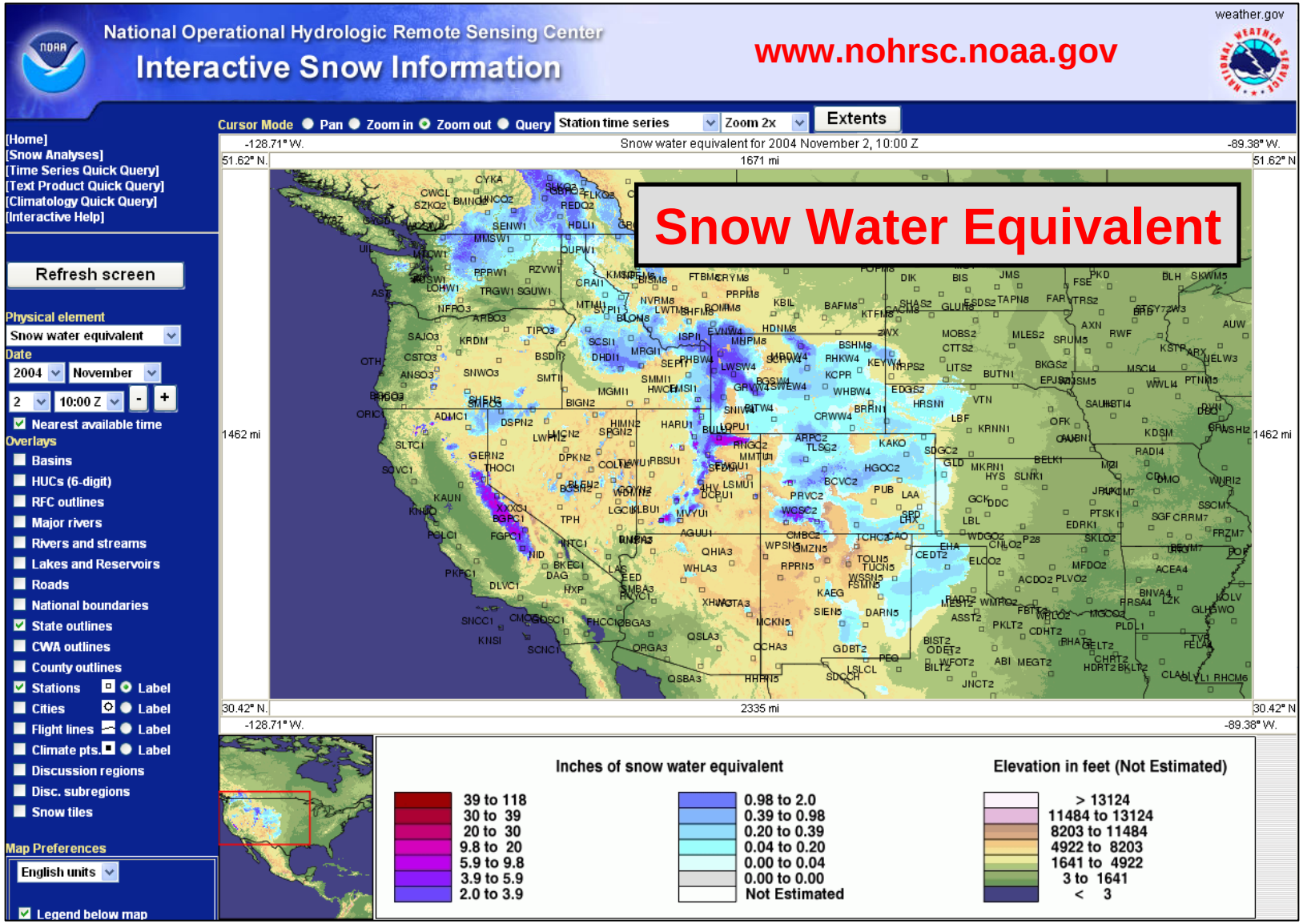
## National Snow Headlines

http://www.nohrsc.nws.gov/interactive/html/map.html

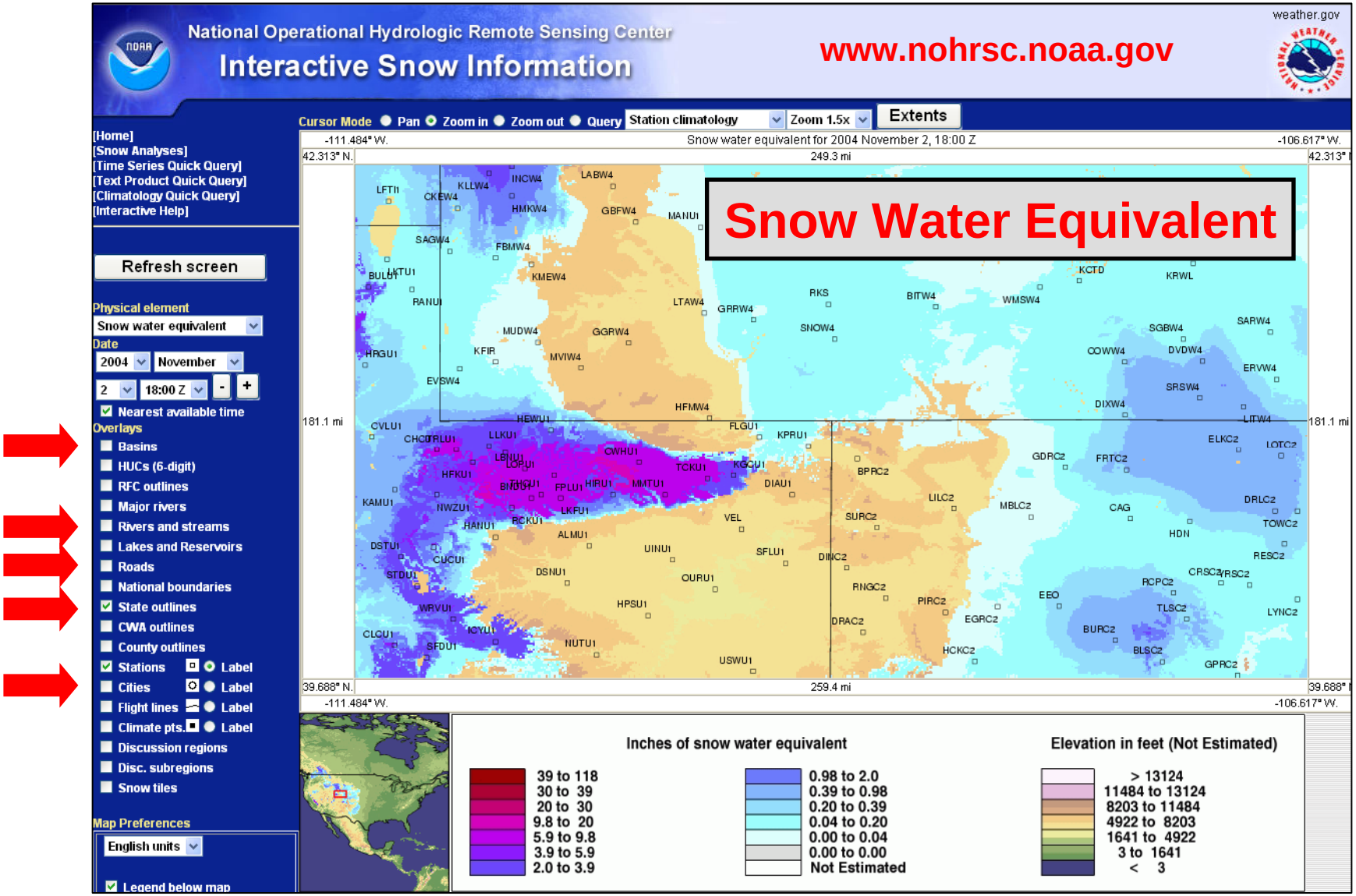
start | Inbox for Tom.Carroll... | National Operational ... | 2:23 PM


NOHRSC Interactive Snow Information
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
Help
Comments
Navigation Tools
Zoom Control
Lon: -112.6
Lat: 32.9
Recenter map at coordinates
Query
Station (2002-present)
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
Cities
Flight Lines
Climate Stns.
Alpine Skiing
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
3104 mi
3964 mi
Spokane
Salem
Boise
Helena
Bismarck
Pierre
Saint Paul
Madison
Chicago
Lansing
Salt Lake City
Lincoln
Boston
Sacramento
Denver
Des Moines
Columbus
New York
Jefferson City
Springfield
Indianapolis
Las Vegas
Santa Fe
Nashville
Little Rock
Los Angeles
Lubbock
Oklahoma City
Dallas
Raleigh
Phoenix
El Paso
Atlanta
Columbia
Baton Rouge
Montgomery
Austin
Houston
Tallahassee
Miami
Inches of water equivalent
> 30
20 to 30
18 to 20
16 to 18
14 to 16
12 to 14
10 to 12
8 to 10
6 to 8
4 to 6
2 to 4
1 to 2
< 1
Not Estimated
Elevation in feet (Not estimated)
> 13124
8203 to 13124
3281 to 8203
3 to 3281
< 3
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
NOHRSC | Home
Snow Information | National Analyses | Interactive Maps | 3D Visualization | Airborne Surveys | Satellite Obs | Forecasts | Data Archive | SHEF Products

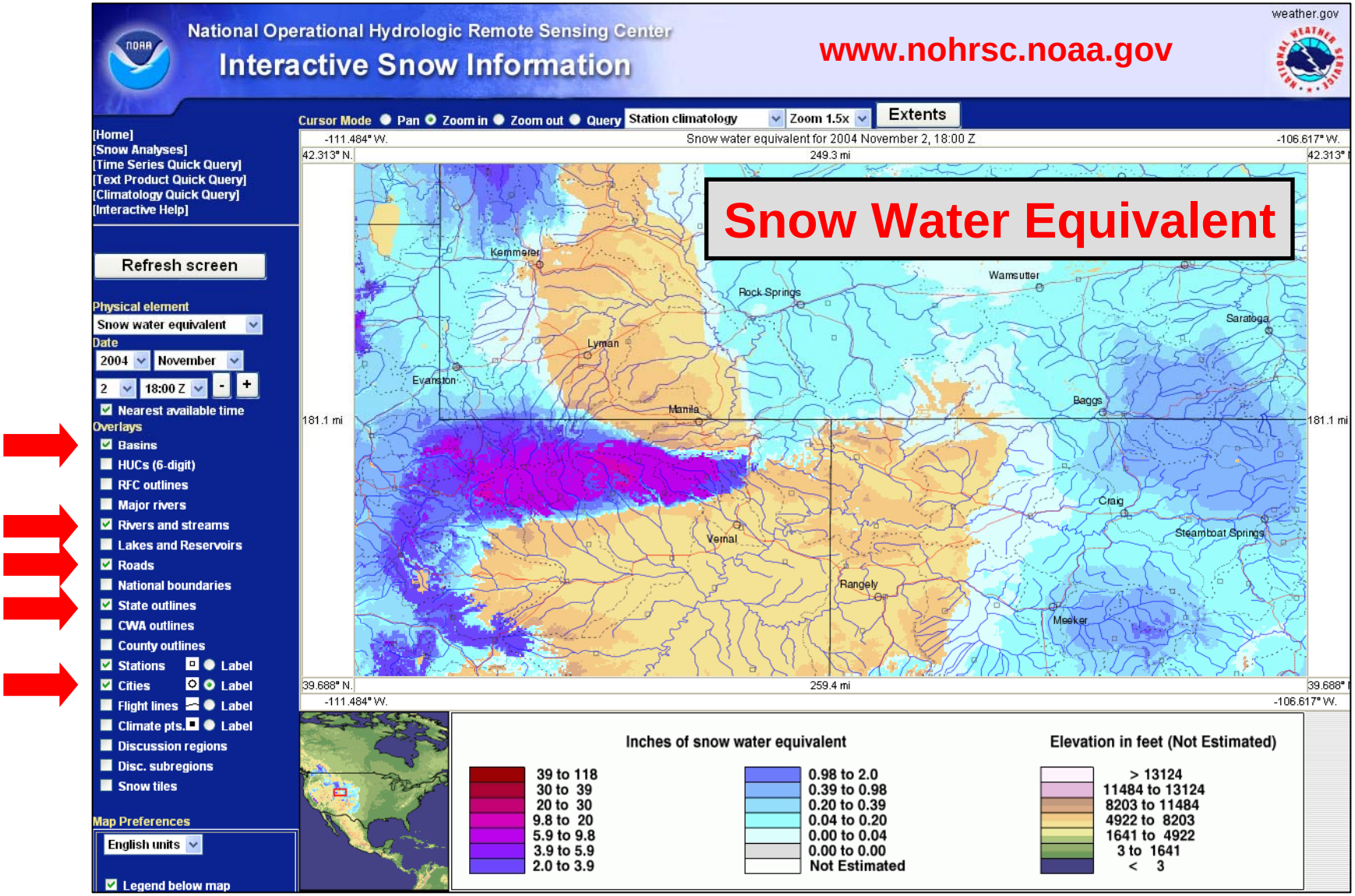
# Interactive Snow Information System



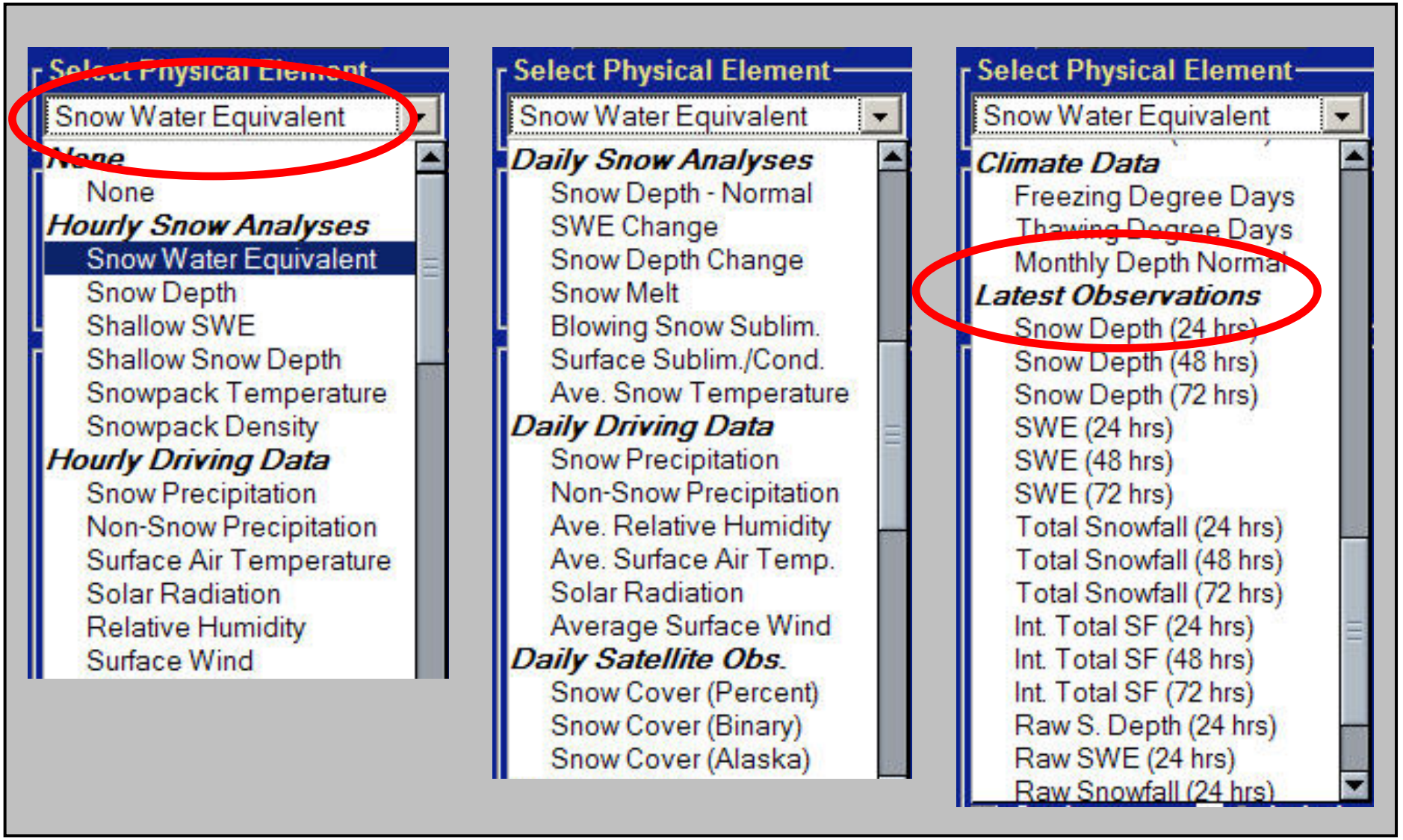
# Interactive Snow Information System



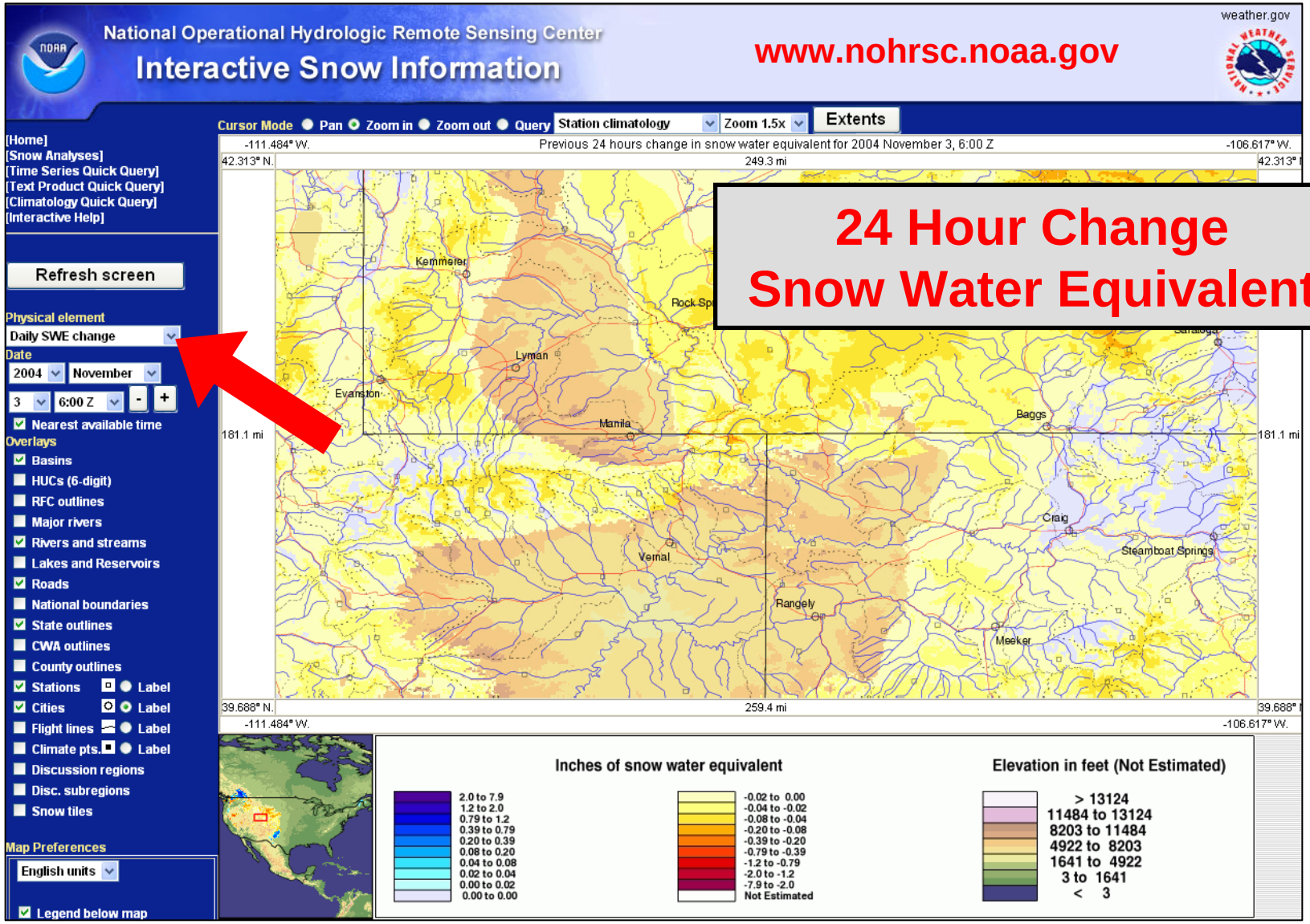
# Interactive Snow Information System



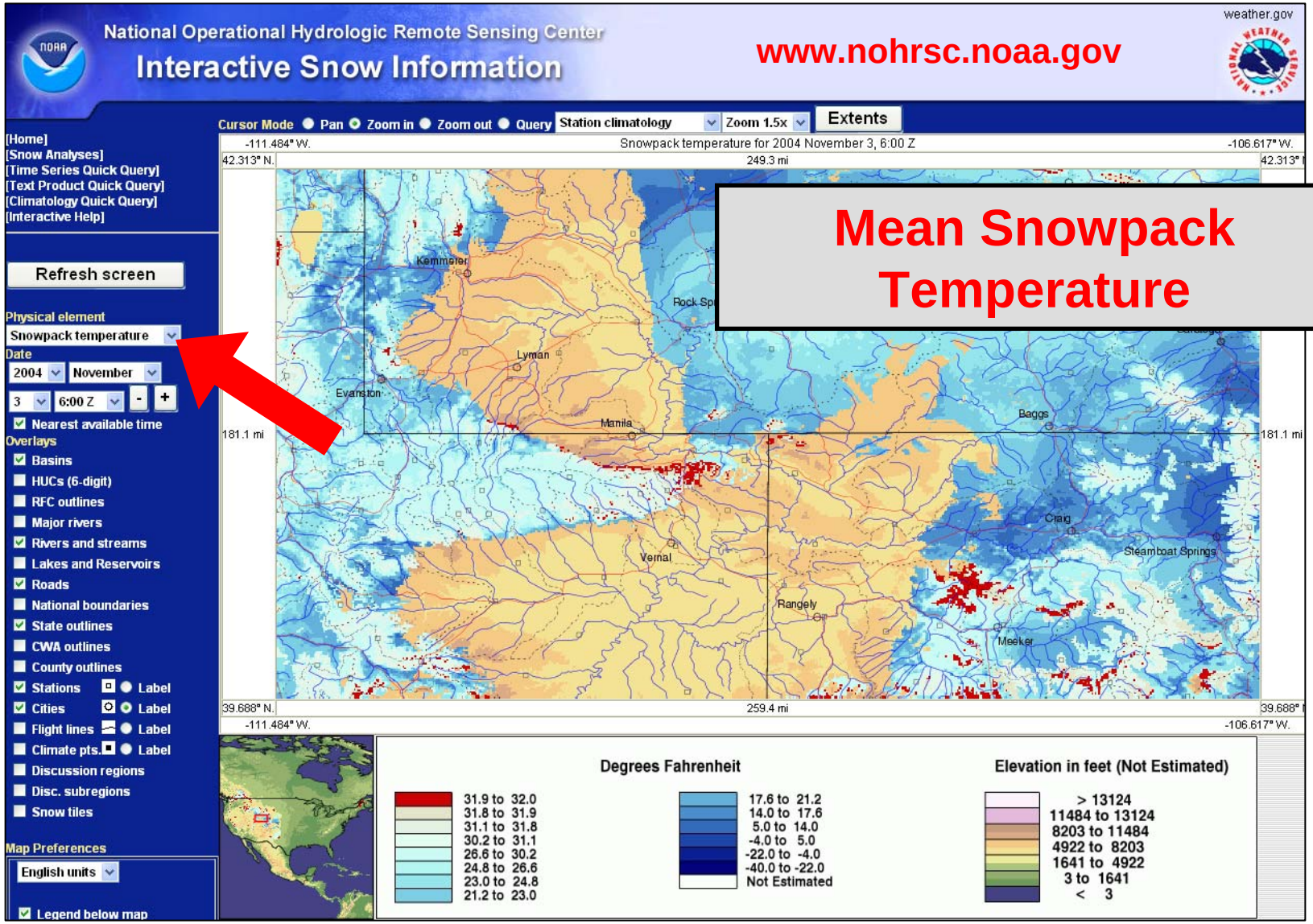
# Physical Element Map Options



# Interactive Snow Information System

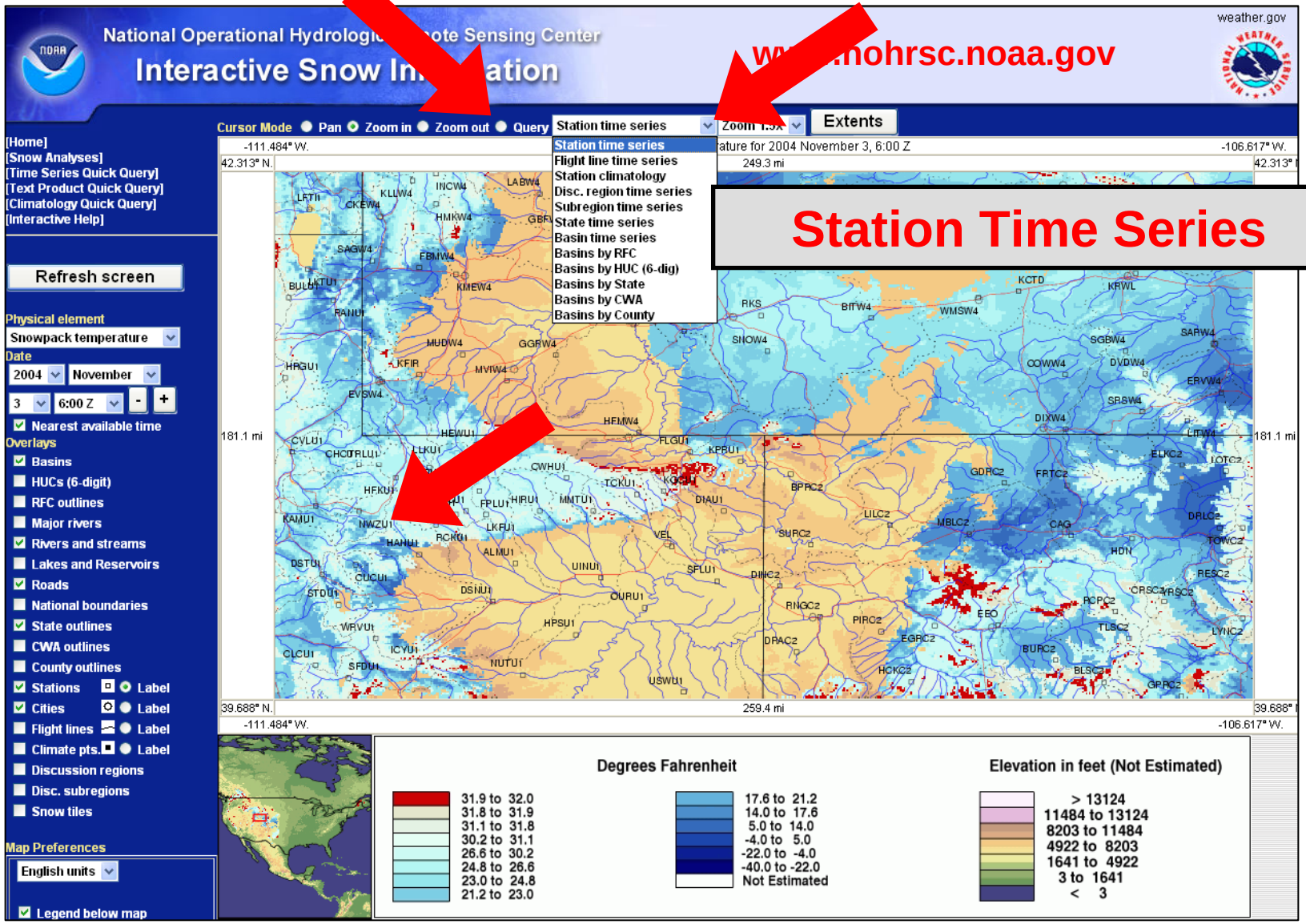


# Interactive Snow Information System

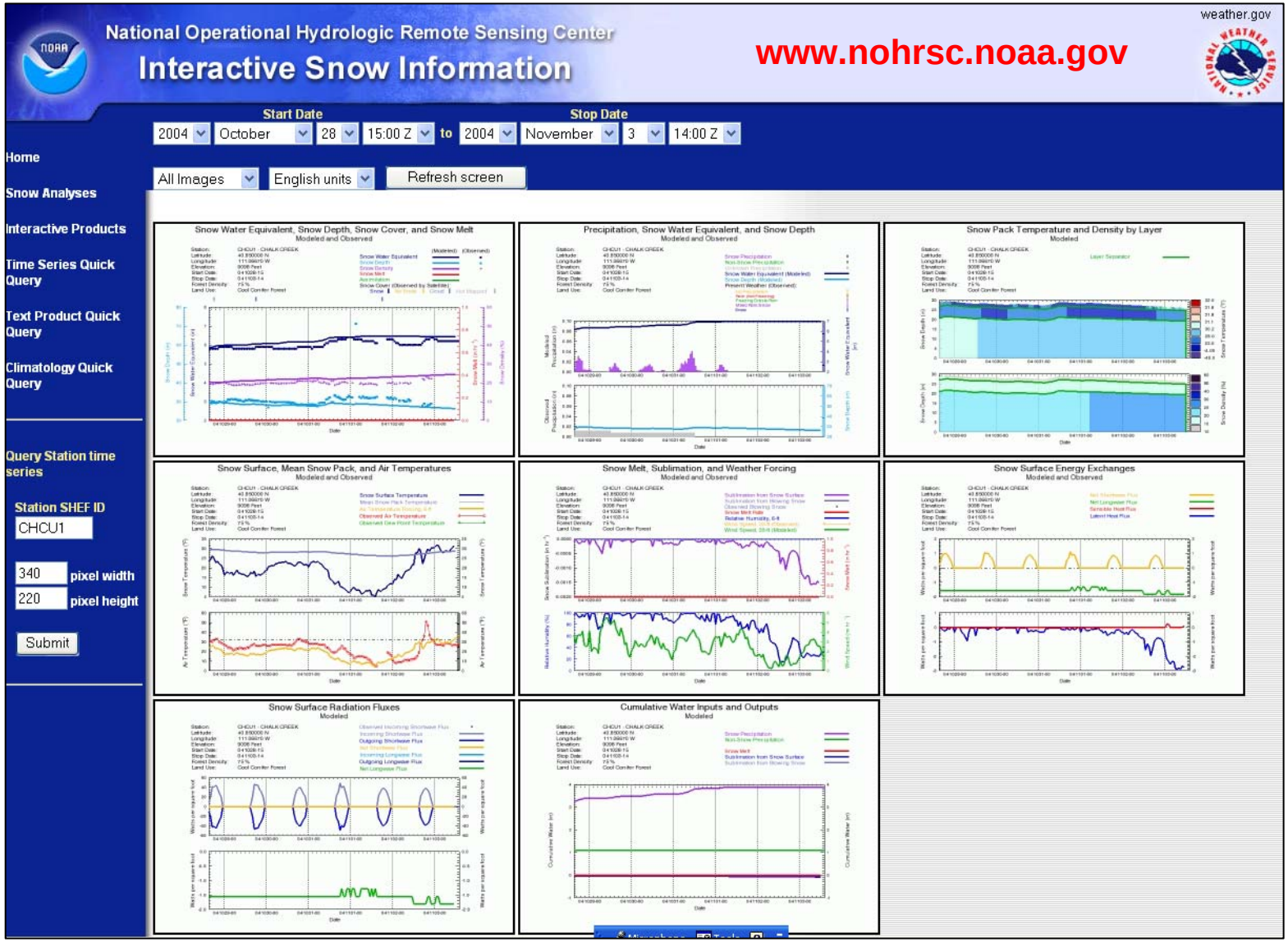



**Mean Snowpack Temperature**

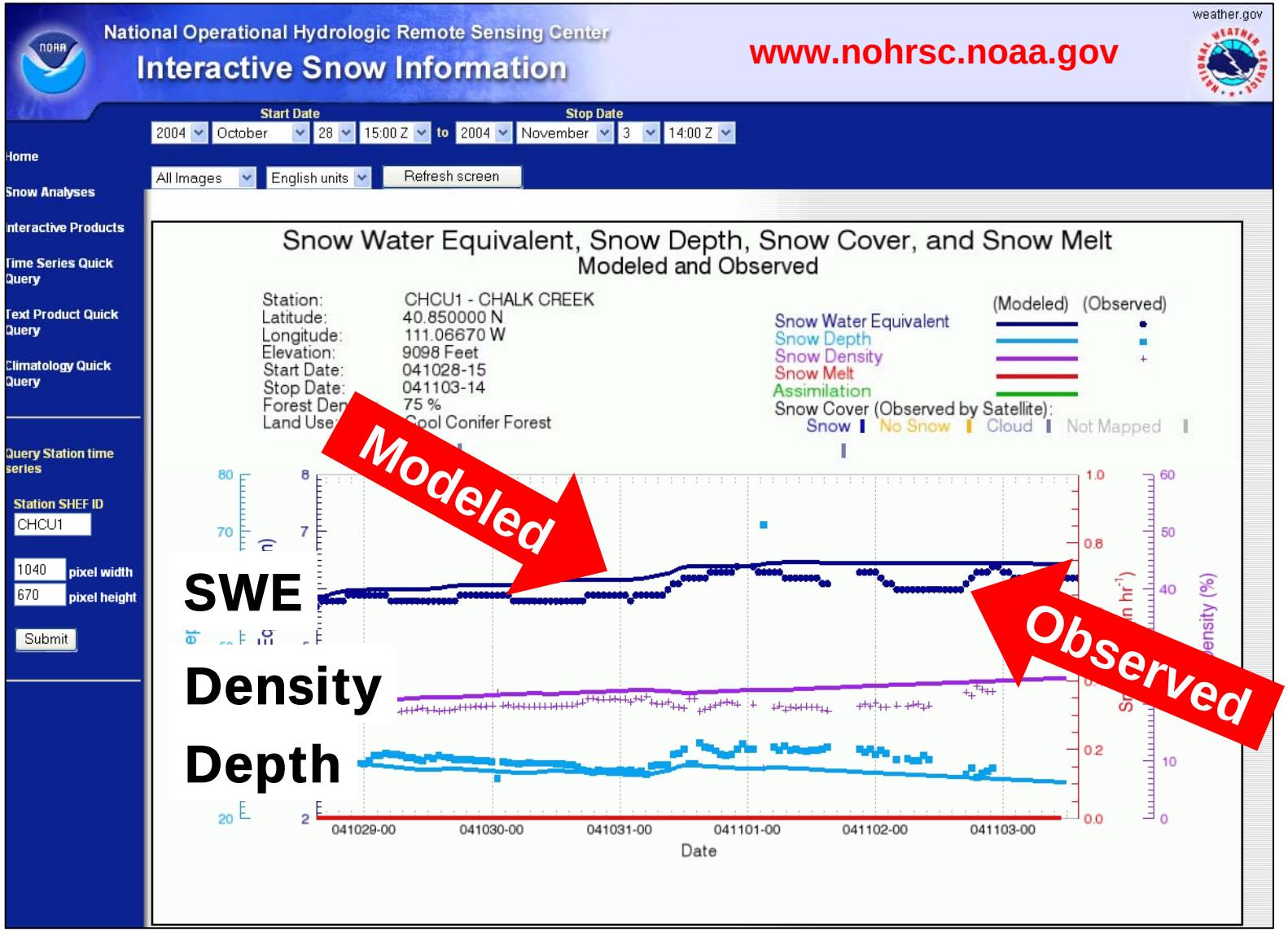
# Interactive Snow Information System



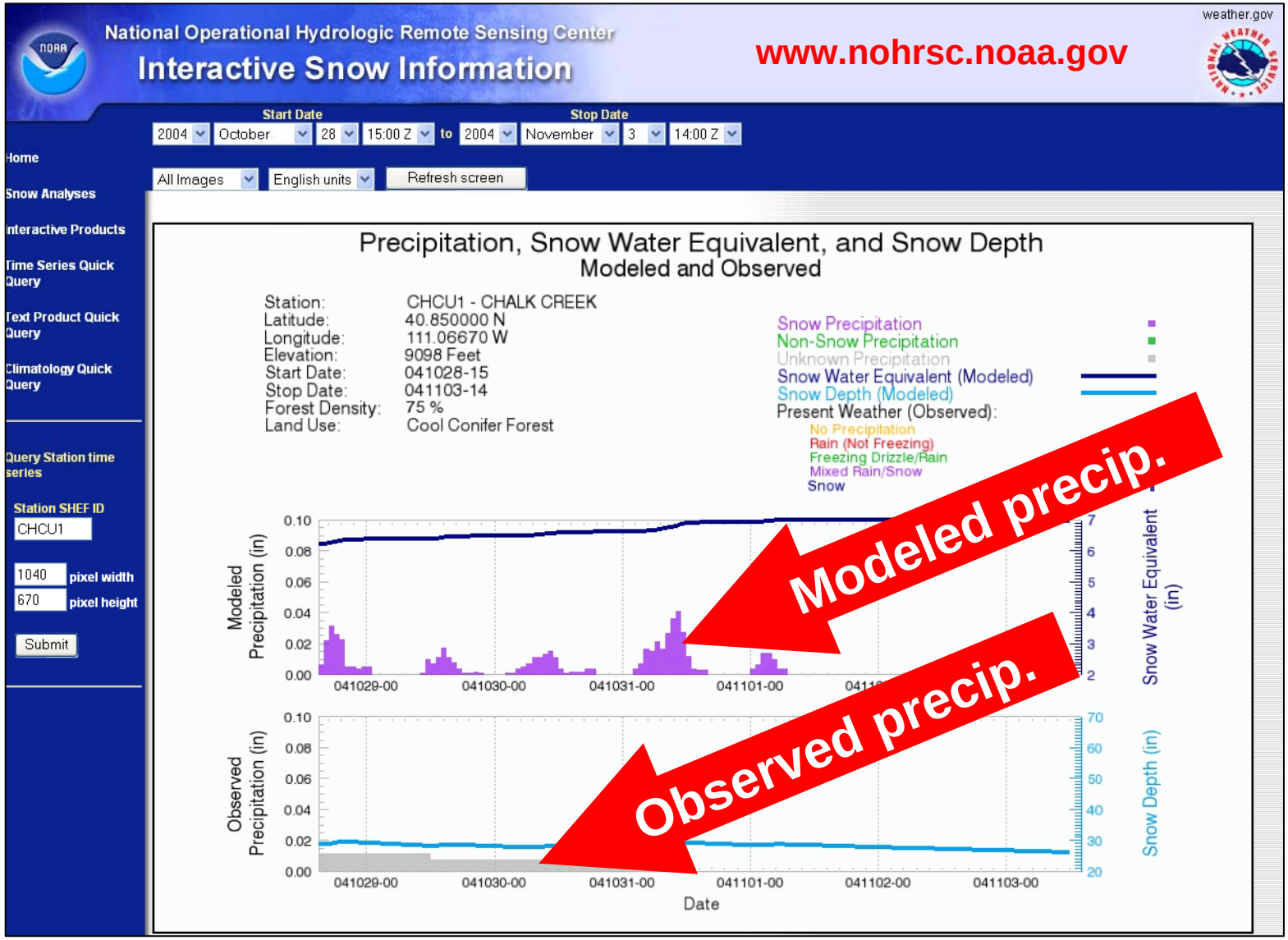
# Interactive Snow Information System



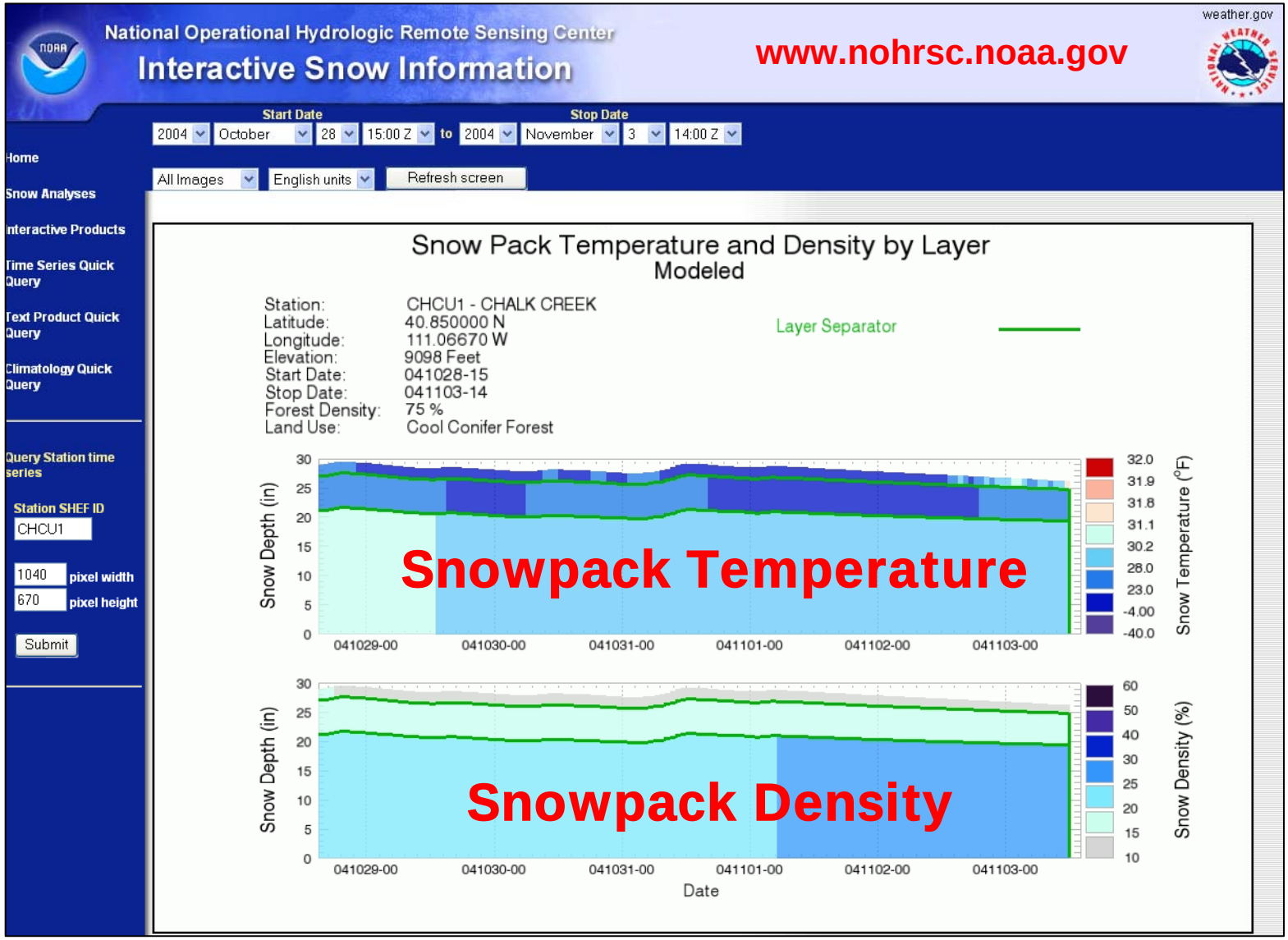
# Interactive Snow Information System



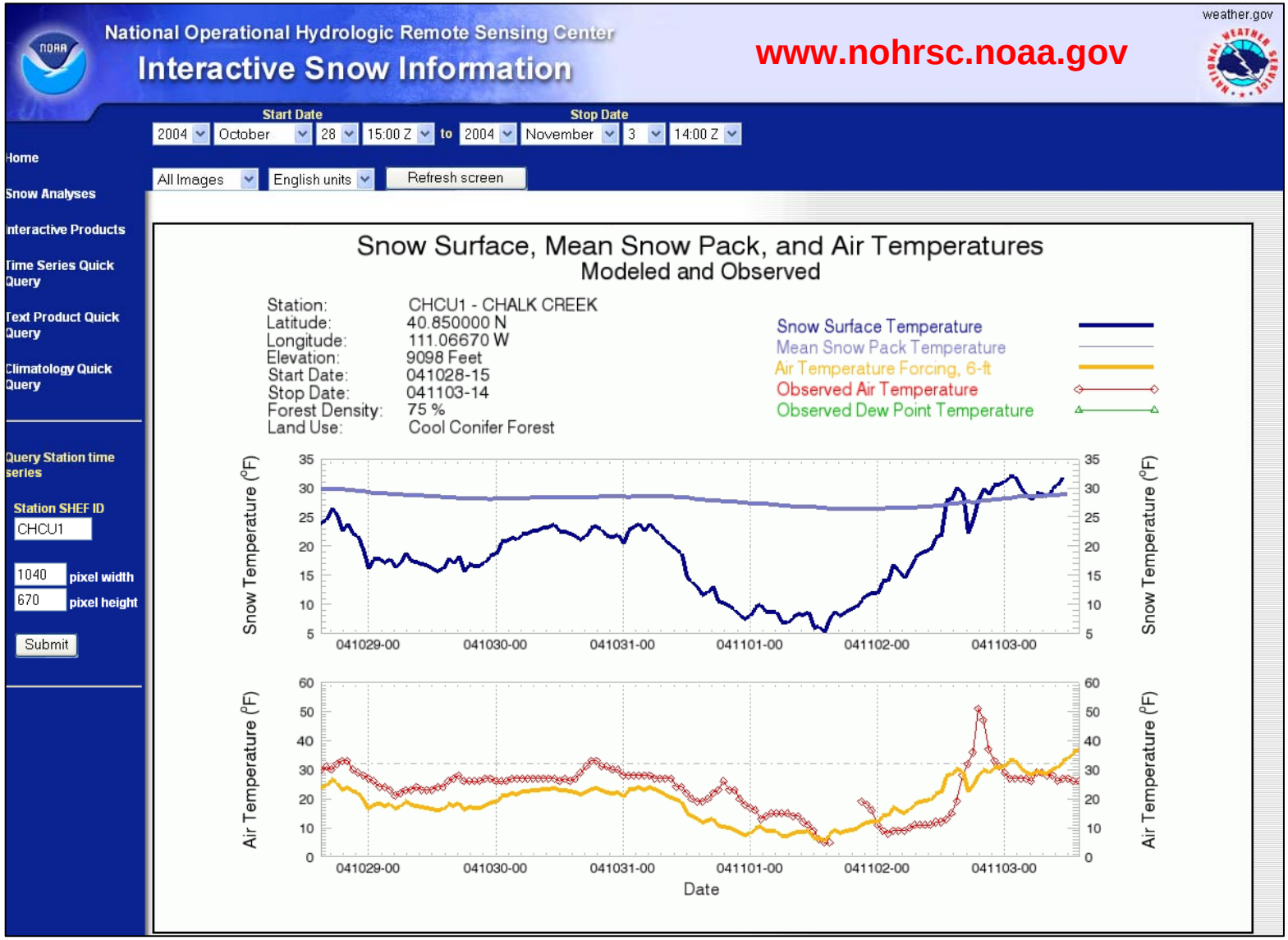
# Interactive Snow Information System



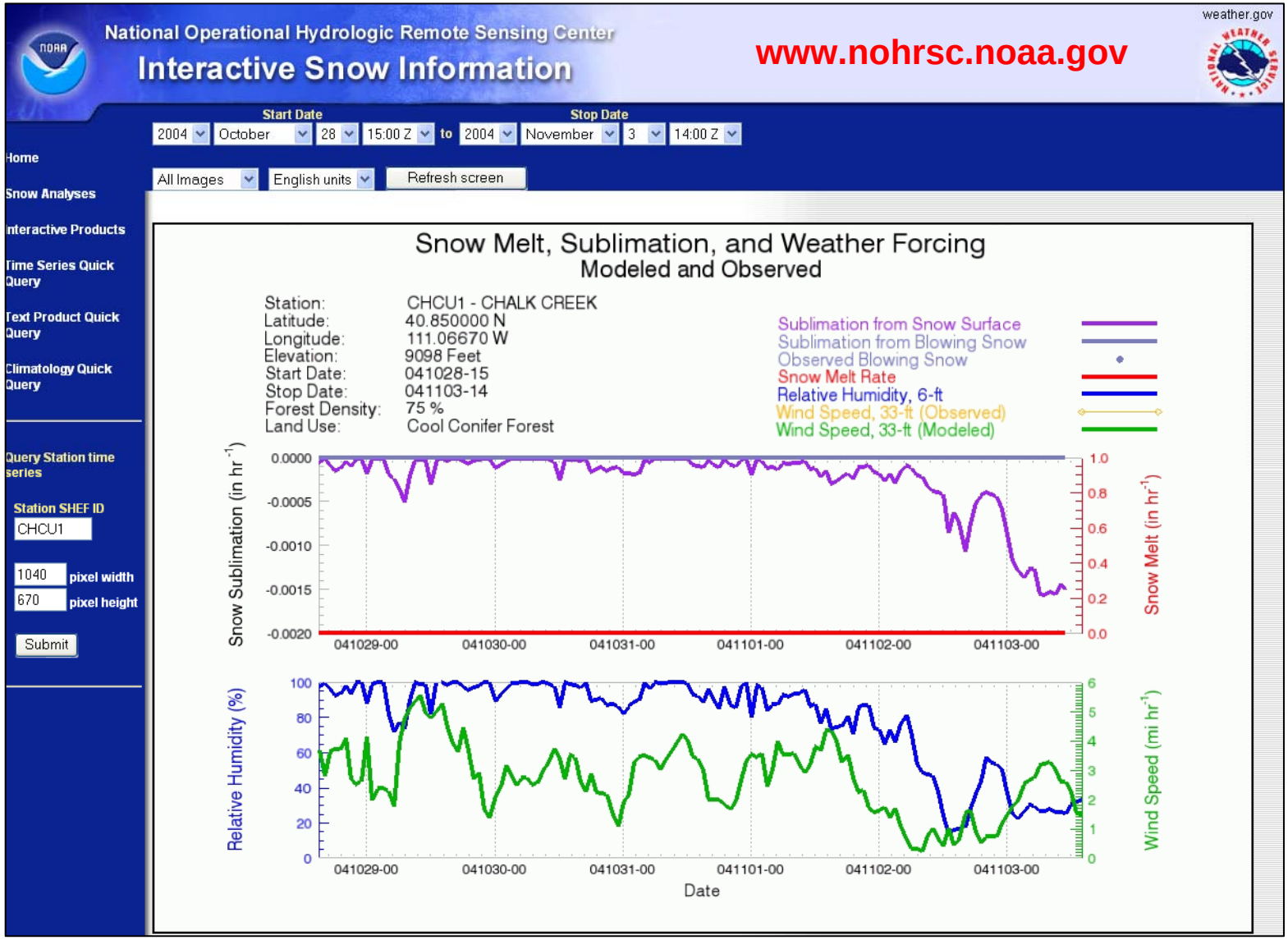
# Interactive Snow Information System

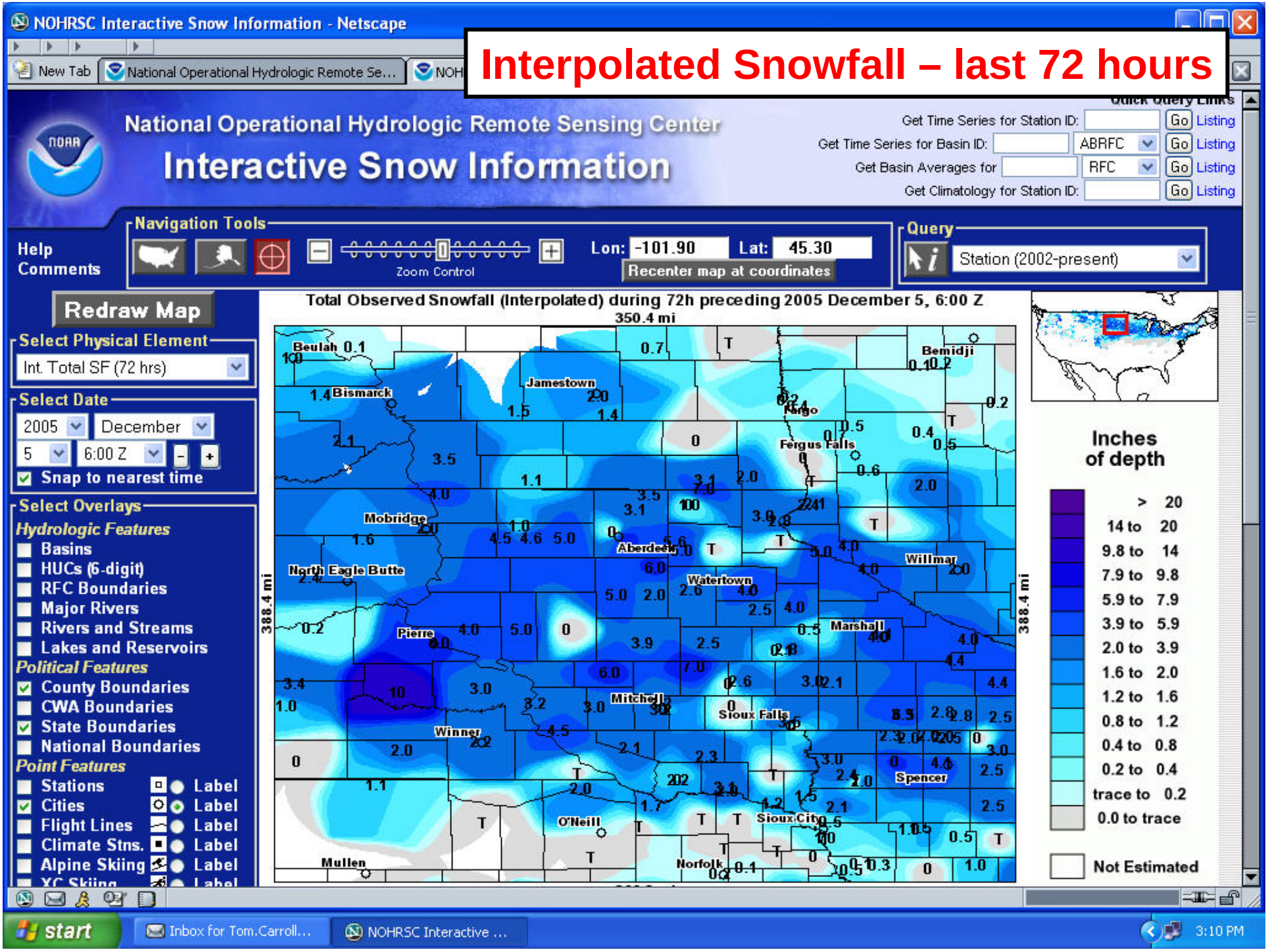


# Interactive Snow Information System

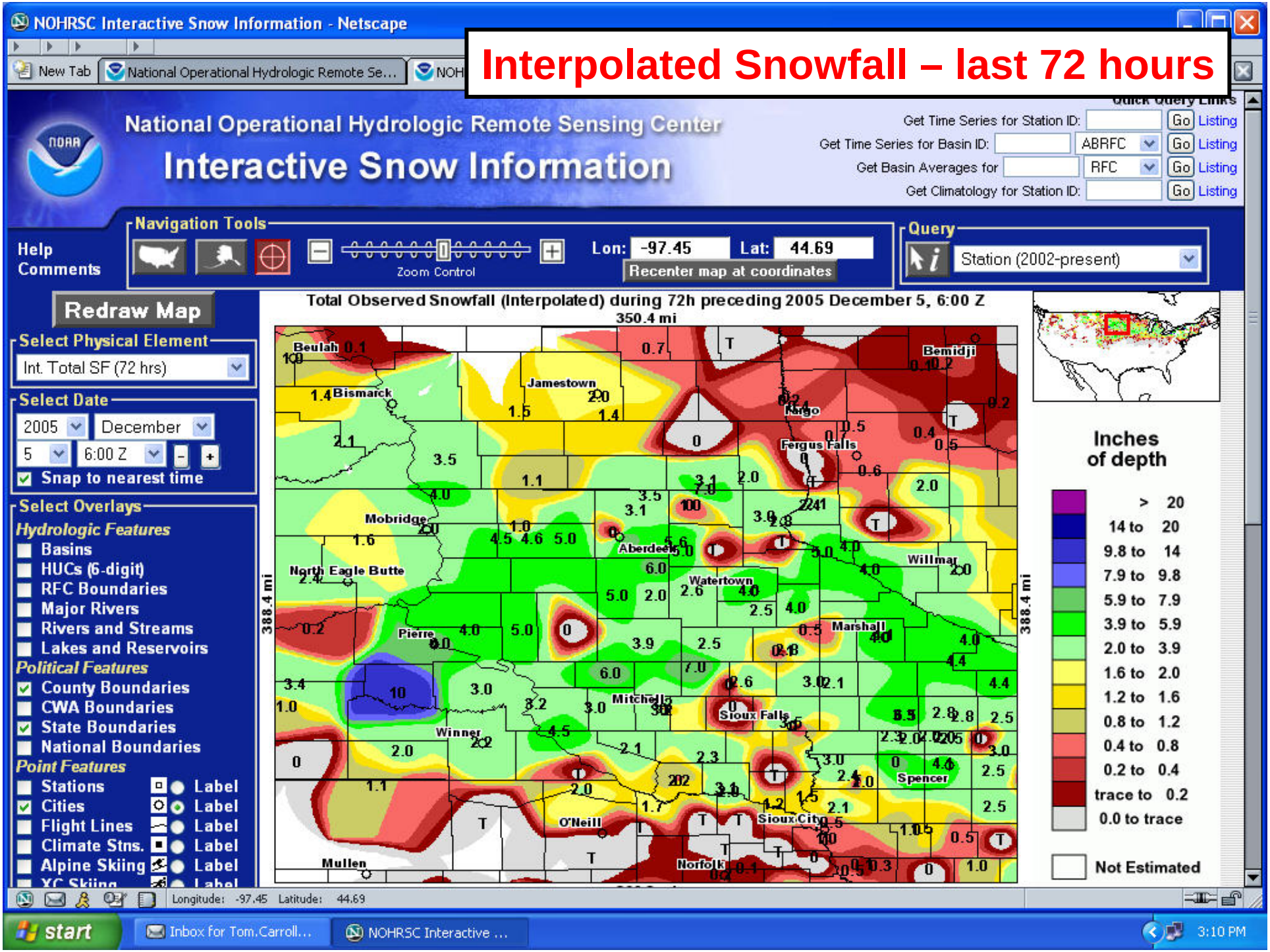


# Interactive Snow Information System

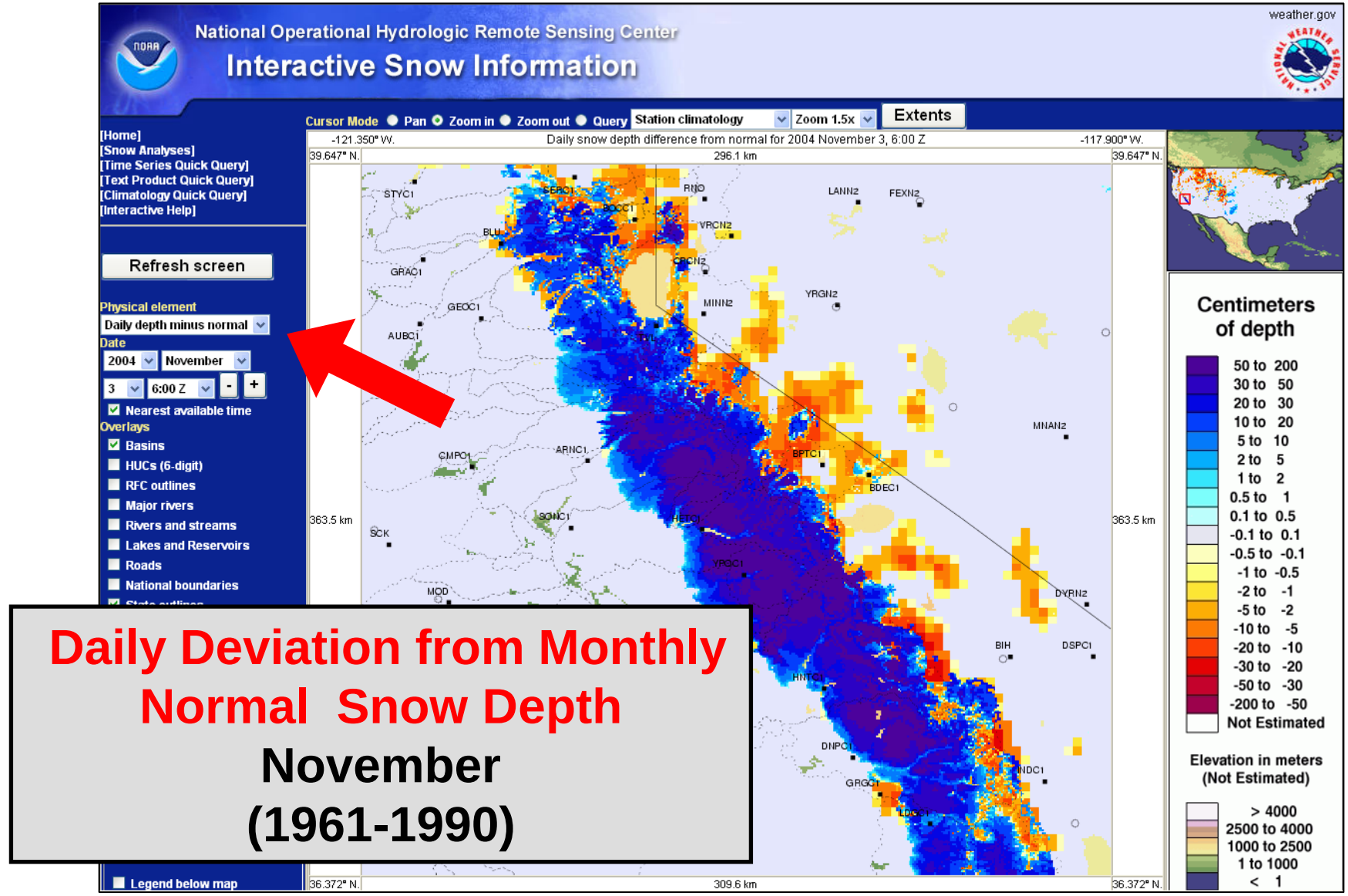



NOHRSC Interactive Snow Information - Netscape
Interpolated Snowfall – last 72 hours
National Operational Hydrologic Remote Sensing Center
Interactive Snow Information
Get Time Series for Station ID:
Get Time Series for Basin ID:
Get Basin Averages for
Get Climatology for Station ID:
Go
Listing
ABRFC
RFC
Help
Comments
Navigation Tools
Zoom Control
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
Label
Total Observed Snowfall (Interpolated) during 72h preceding 2005 December 5, 6:00 Z
350.4 mi
388.4 mi
Beulah
Bismarck
Jamestown
Bemidji
Fargo
Fergus Falls
Mobridge
Aberdeen
Willmar
North Eagle Butte
Watertown
Pierre
Marshall
Mitchell
Sioux Falls
Winner
Spencer
O'Neill
Sioux City
Norfolk
Mullen
Inches of depth
> 20
14 to 20
9.8 to 14
7.9 to 9.8
5.9 to 7.9
3.9 to 5.9
2.0 to 3.9
1.6 to 2.0
1.2 to 1.6
0.8 to 1.2
0.4 to 0.8
0.2 to 0.4
trace to 0.2
0.0 to trace
Not Estimated
start
Inbox for Tom.Carroll...
NOHRSC Interactive ...
3:10 PM

# Interpolated Snowfall – last 72 hours



# New Climate Diagnostic Tools




**Daily Deviation from Monthly Normal Snow Depth**

**November**

**(1961-1990)**

National Operational Hydrologic Remote Sensing Center - The ultimate source for snow information - Netscape

New Tab | National Operational Hydrologic Remote Se...

weather.gov

National Weather Service

# National Operational Hydrologic Remote Sensing Center

Site Map | News | Organization | NWS Search | Enter Search Here | Go

- 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!

FIRSTGOV.gov The U.S. Government's Official Web Portal

## NATIONAL SNOW ANALYSES

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

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



Snow Reports

| Station ID | Name | (in) | Snowfall | (in) | Time(UTC) |
|---|---|---|---|---|---|
| ASFW1 | RAINIER PARADISE RANGER STN | 1654 | 8.89 cm | 24 | 2005-11-01 16 |
| SELM8 | SEELEY LAKE RS | 1249 | 1.27 cm | 24 | 2005-11-02 00 |
| AGRC2 | APISHAPA RVR | 2697 | 1.27 cm | 24 | 2005-11-01 12 |
| OLNM8 | OLNEY | 964 | 0.25 cm | 24 | 2005-11-01 15 |
| POTM8 | POTOMAC | 1103 | 0.25 cm | 24 | 2005-11-01 15 |

Know Snow

National Snow Headlines

http://www.nohrsc.nws.gov/nsa

start | Inbox for Tom.Carroll... | National Operational ... | 2:23 PM

National Operational Hydrologic Remote Sensing Center - The ultimate source for snow information - Netscape

New Tab | National Operational Hydrologic Remote Se...

weather.gov

National Weather Service

# National Operational Hydrologic Remote Sensing Center

Site Map | News | Organization | NWS Search | Enter Search Here | Go

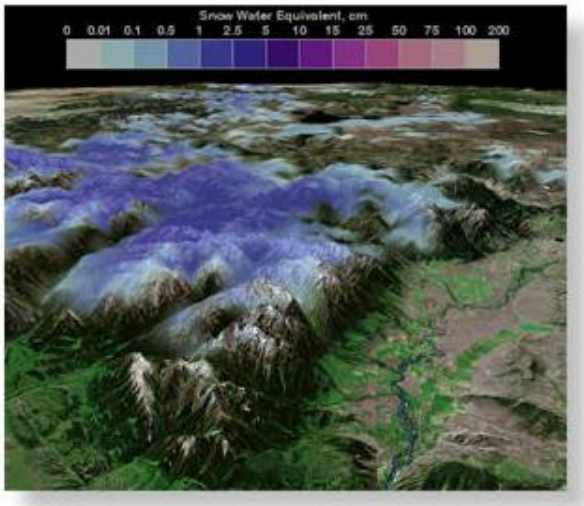
- Home
- **Snow Information**
  - National Analyses
  - Interactive Maps
  - 3D Visualization
  - Airborne Surveys
  - Satellite Obs
  - Forecasts
  - Data Archive
  - SHEF Products
- **Science/Technology**
  - NOHRSC
  - GIS Data Sets
- **About The NOHRSC**
  - Staff
- **NOAA Links**
  - Snow Climatology
  - Related Links
- **Help**
  - Help and FAQ
- **Contact Us**
  - Please Send Us Comments!

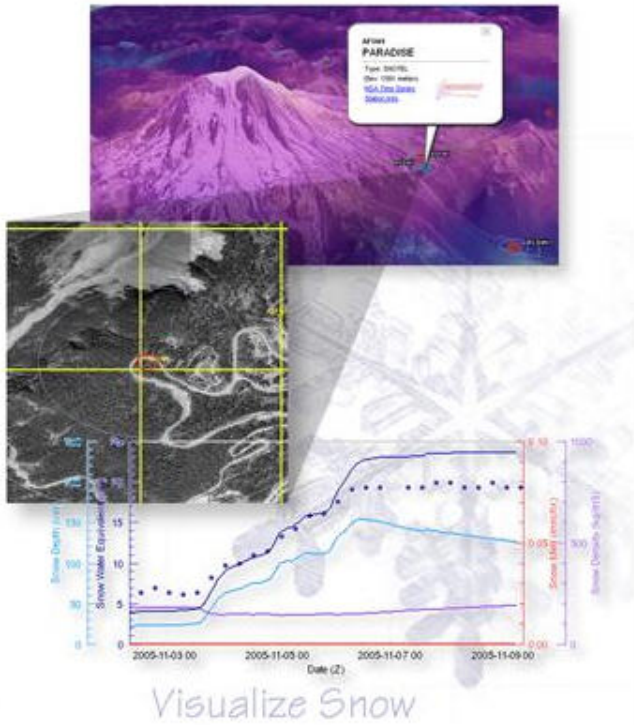
FIRSTGOV.gov The U.S. Government's Official Web Portal

## 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



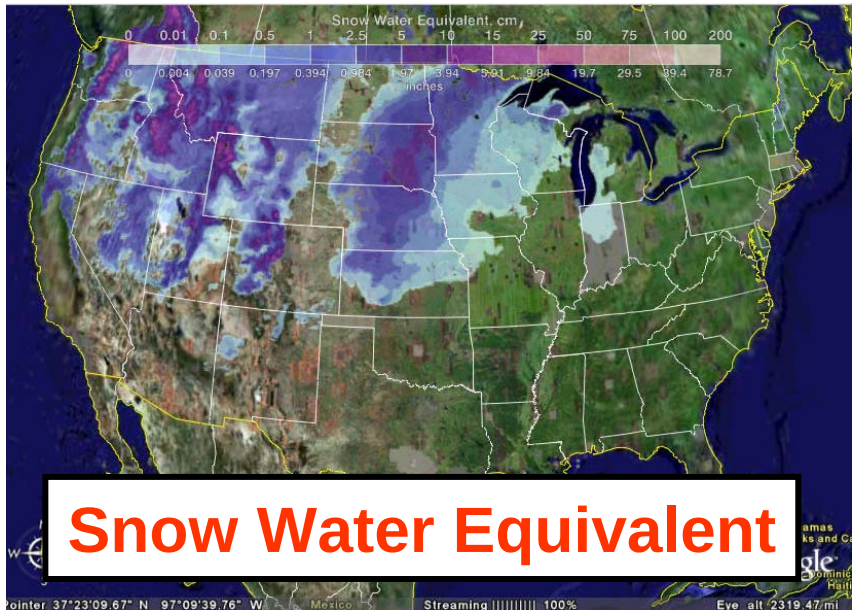



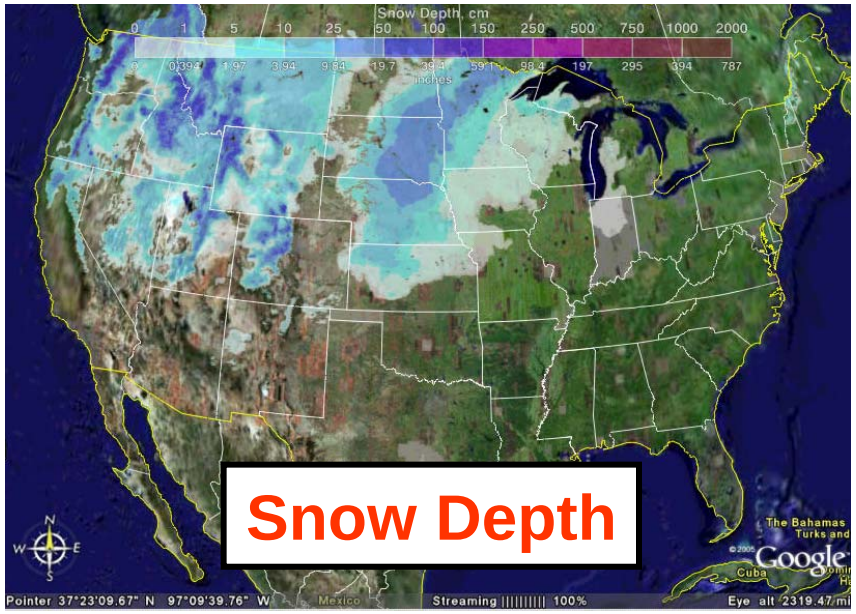

Visualize Snow

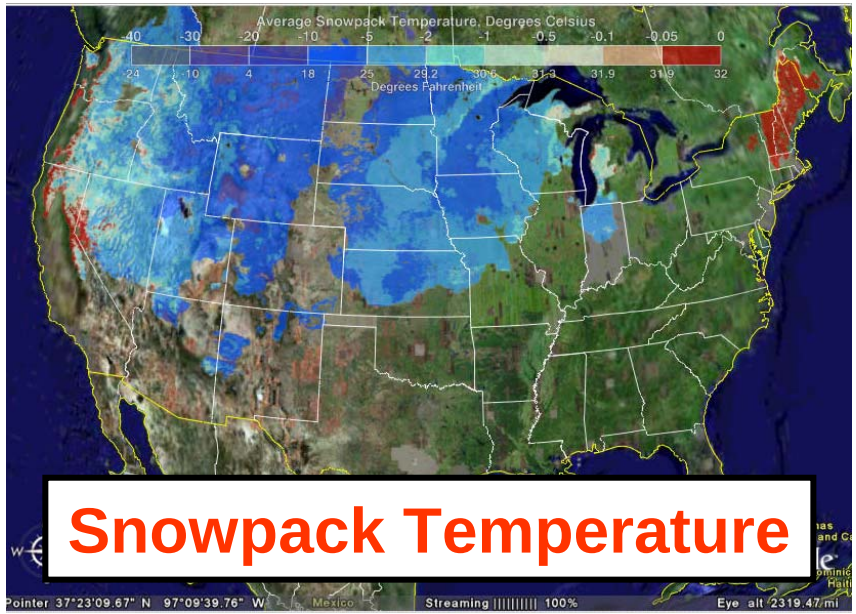
## National Snow Headlines

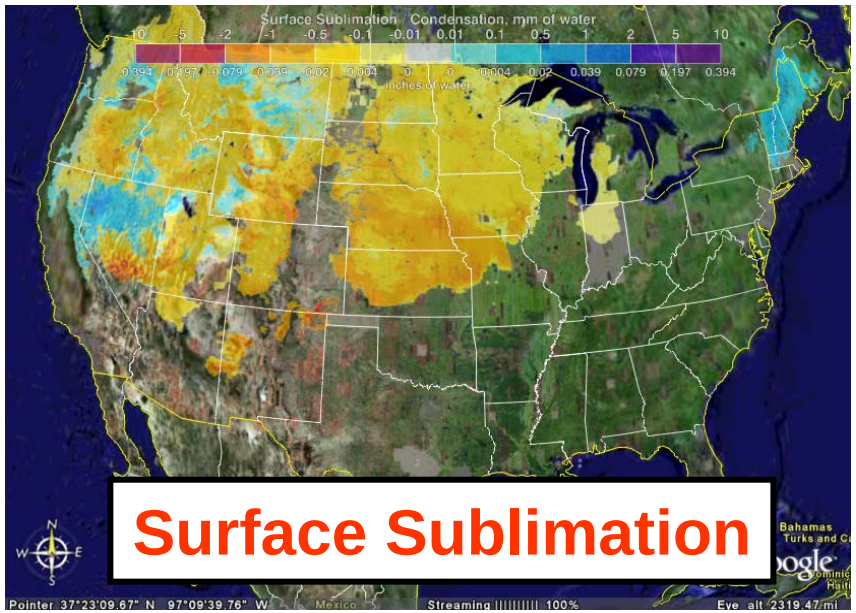
http://www.nohrsc.nws.gov/earth

start | Inbox for Tom.Carroll... | National Operational ... | 2:23 PM

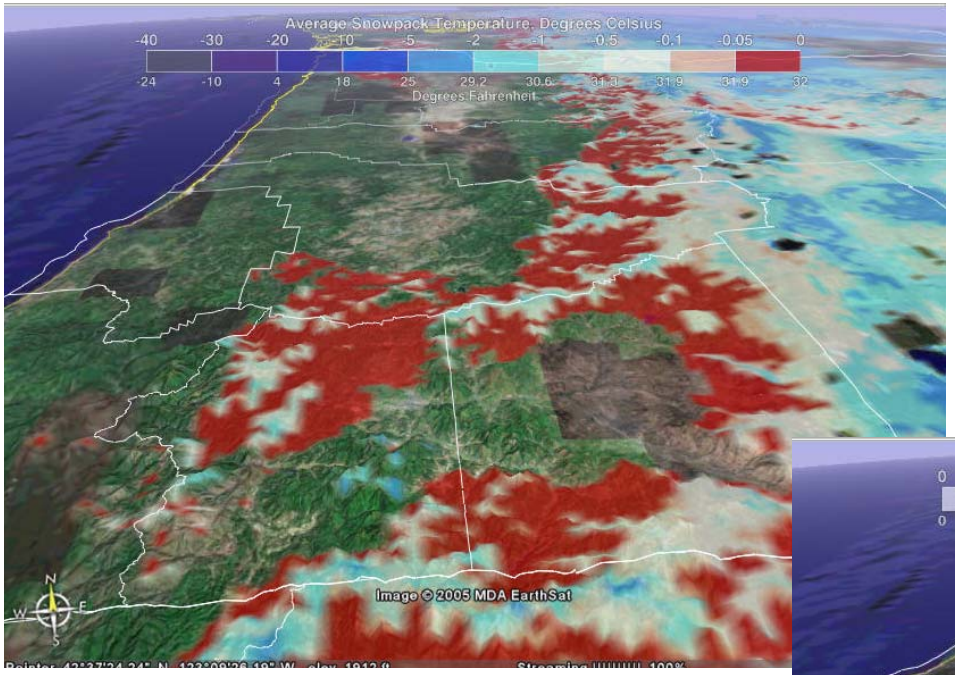

Snow Water Equivalent, cm
Snow Water Equivalent


Snow Depth, cm
Snow Depth

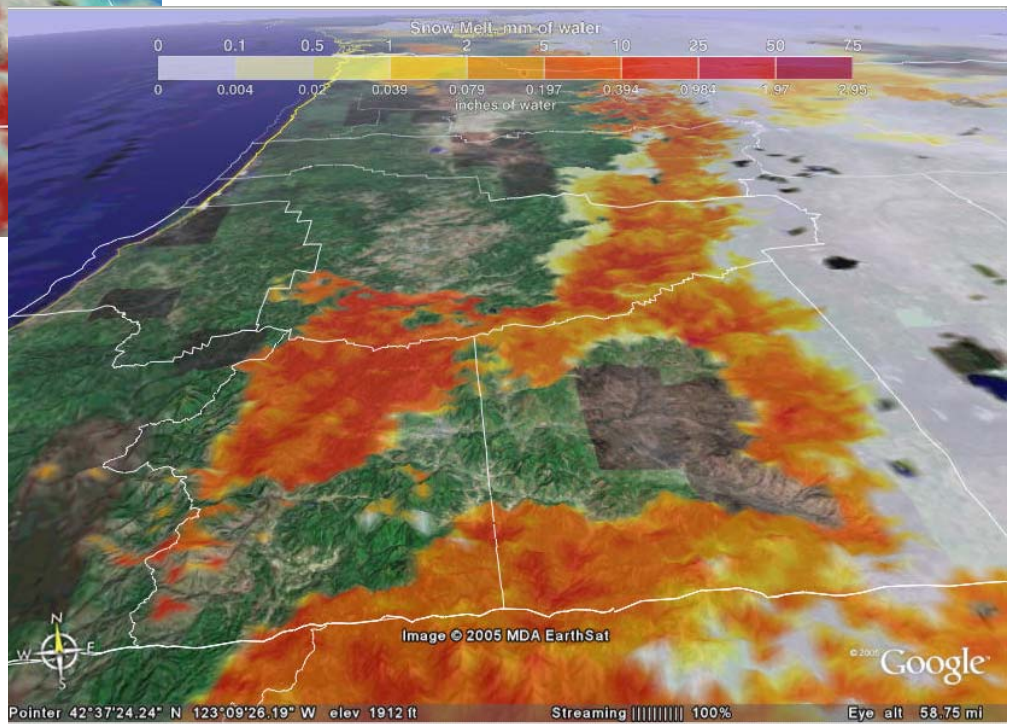

Average Snowpack Temperature, Degrees Celsius
Degrees Fahrenheit
Snowpack Temperature


Surface Sublimation / Condensation, mm of water
Surface Sublimation

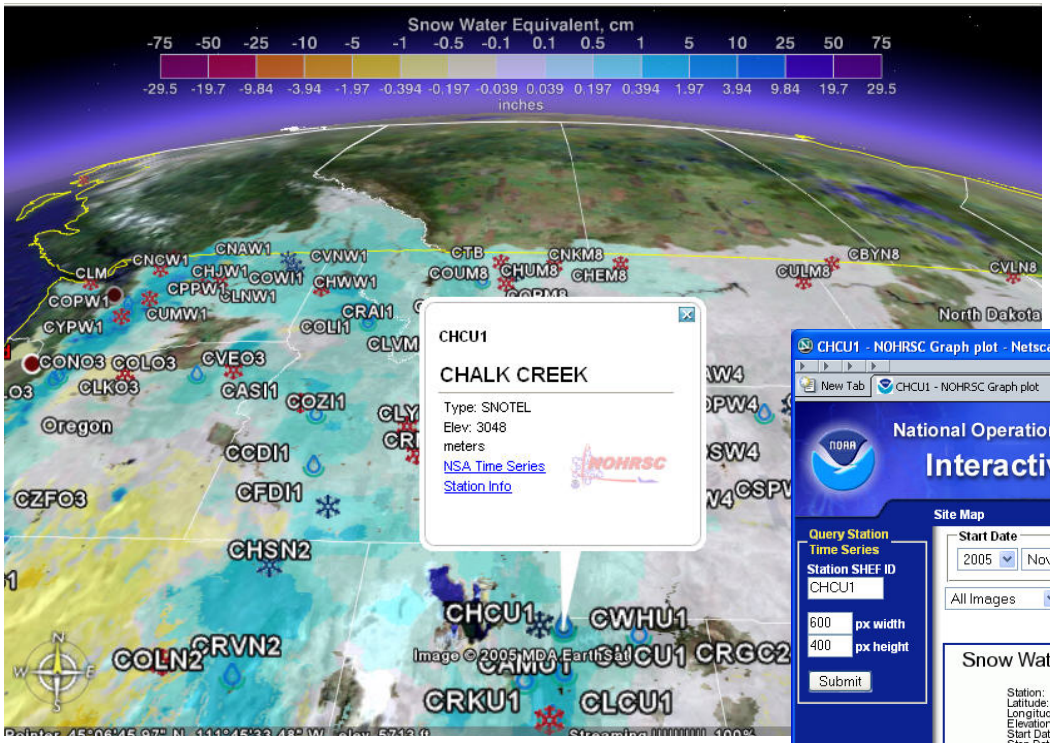
# Snowpack Temperature



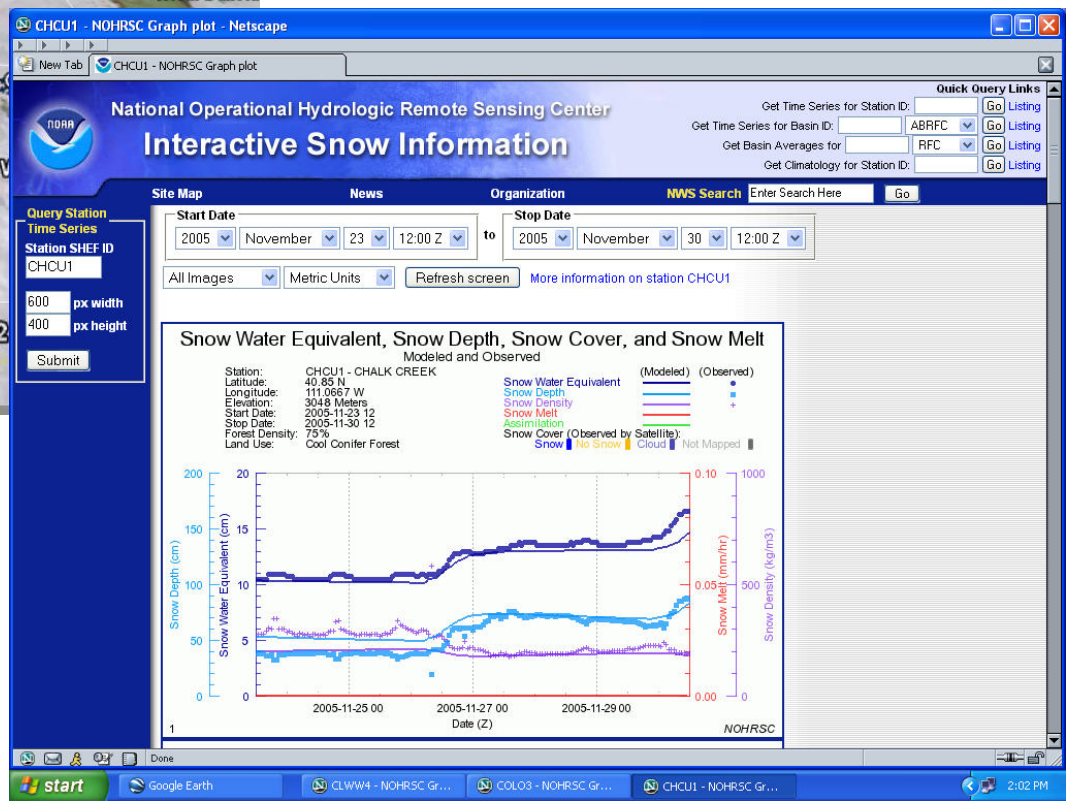

# Snowmelt



# 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**