



# **NOHRSC**

## **Snow Information System**

### **Tools for Climate Variability**

**Tom Carroll**

**National Operational Hydrologic Remote Sensing Center**

*Office of Climate, Water, and Weather Services*

**National Weather Service, NOAA**

**U.S. Department of Commerce**



# Outline

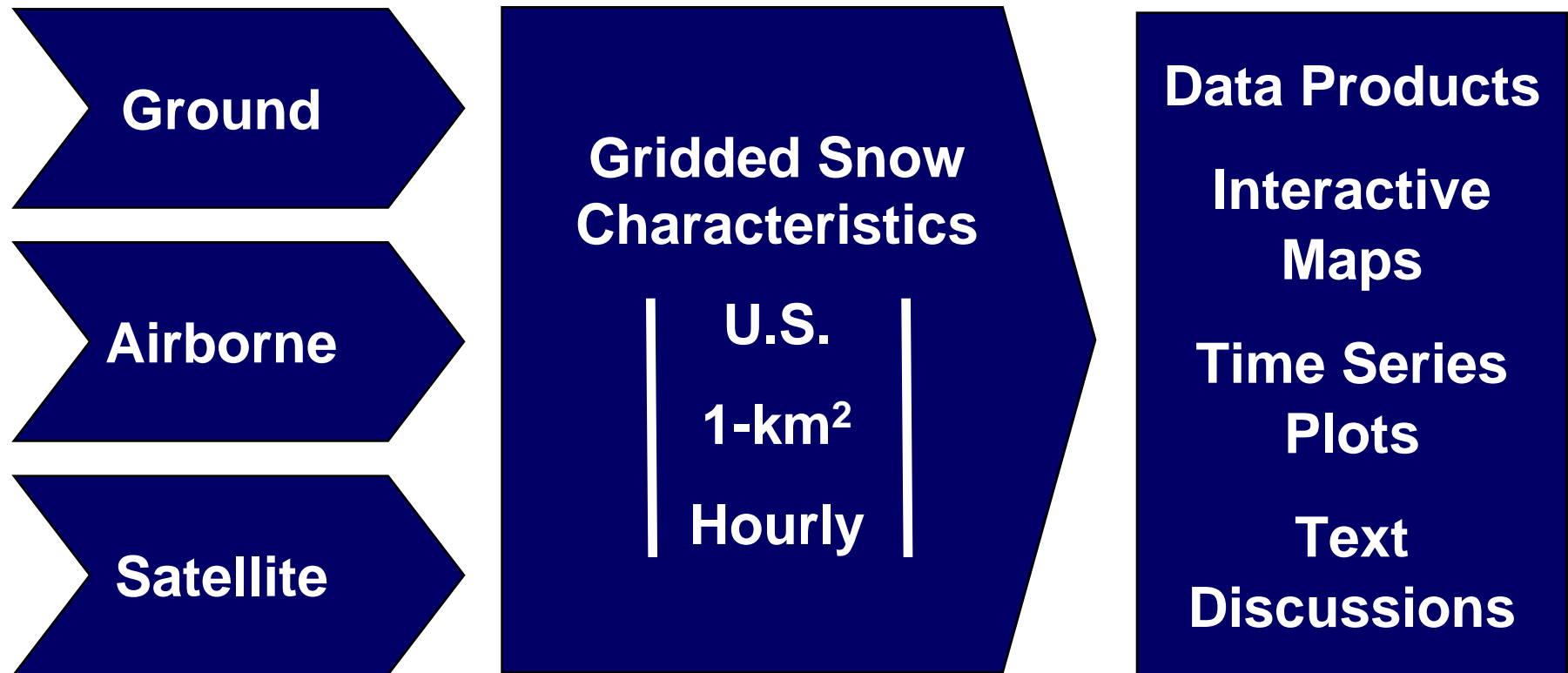
- **National Snow Analyses (NSA)**
  - Snow modeling and data assimilation system for U.S.
    - Overview of the data, modeling framework and products
- **Interactive Snow Information System (Snow-Info)**
  - Web-based mapping and data querying system for NSA information
    - Overview of functions and capability
- **New Climate Diagnostic Tools in Snow-Info**
  - Monthly normal snow-depth maps for U.S.
  - Daily departure-from-normal snow-depth maps for U.S.
  - Snow-depth climatology and NSA time-series for 4000 stations

# National Snow Analyses (NSA)

**Multi-sensor  
Snow Observations**

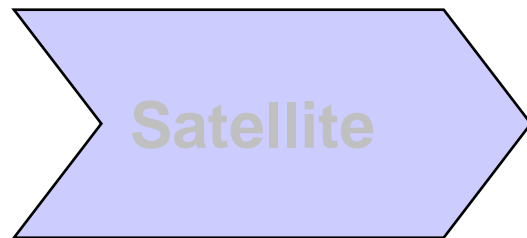
**Snow Modeling and  
Data Assimilation**

**Snow Information  
Products**



# National Snow Analyses (NSA)

## Multi-sensor Snow Observations

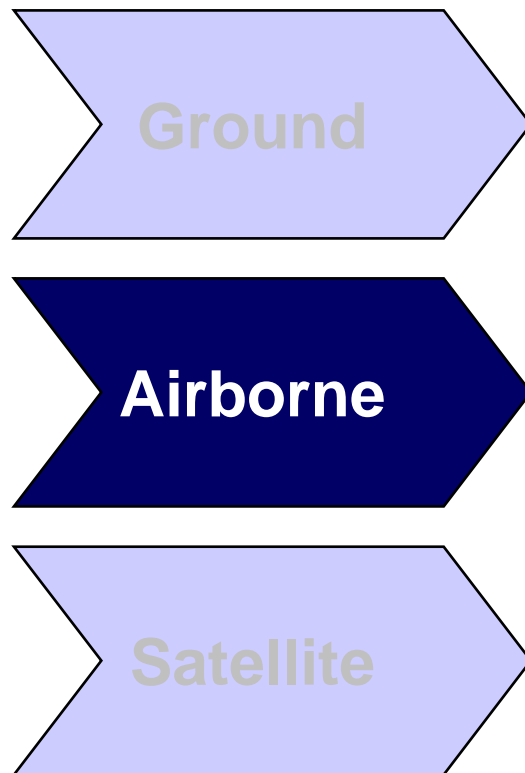


- **National Weather Service**
  - First-order Stations
  - Cooperatives
- **Federal and State Agencies**
  - NRCS SNOTEL and Snow Courses
  - USACE New England District Snow Surveys
  - Federal Aviation Administration
  - California Dept. of Water Resources
- **Regional Mesonets**
  - Maine Cooperative 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**  
**25,000+ actively reporting stations**  
**10,000+ unique stations reporting snow observations**

# National Snow Analyses (NSA)

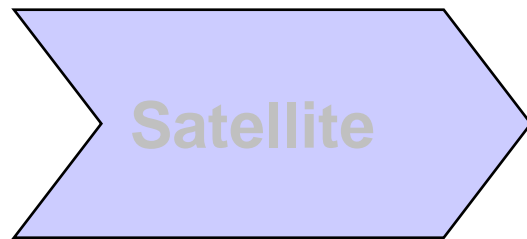
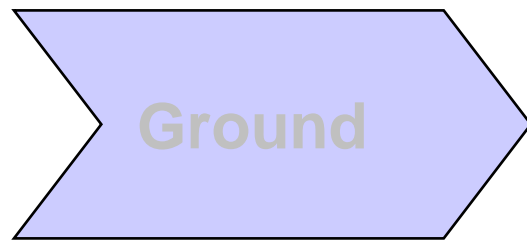
## Multi-sensor Snow Observations



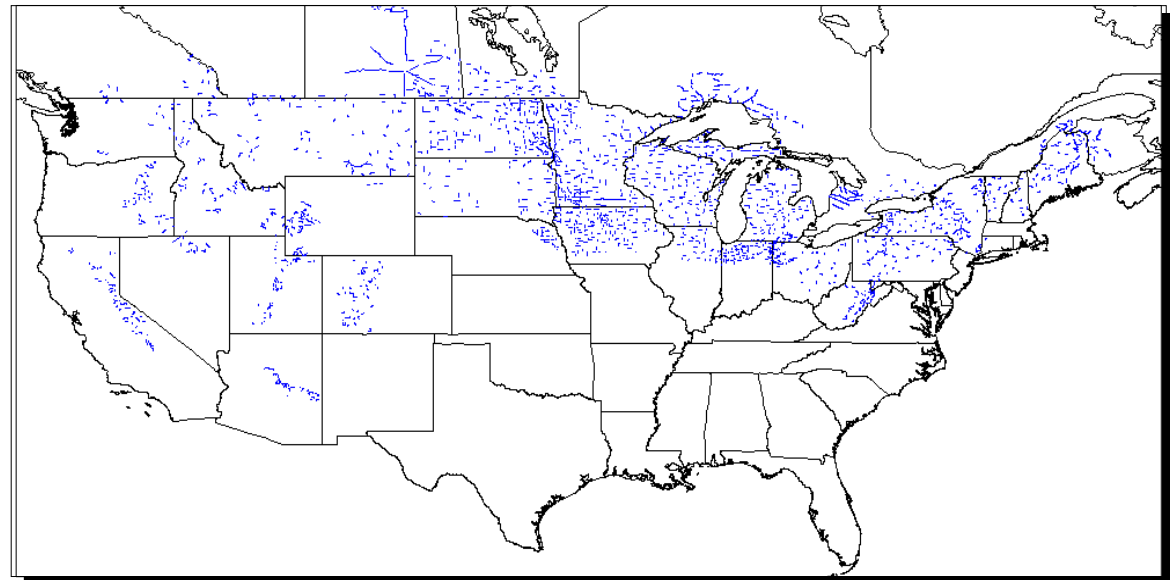
- **Snow Water Equivalent Measurement**
  - Attenuation of natural terrestrial gamma radiation by water in snow

# National Snow Analyses (NSA)

## Multi-sensor Snow Observations



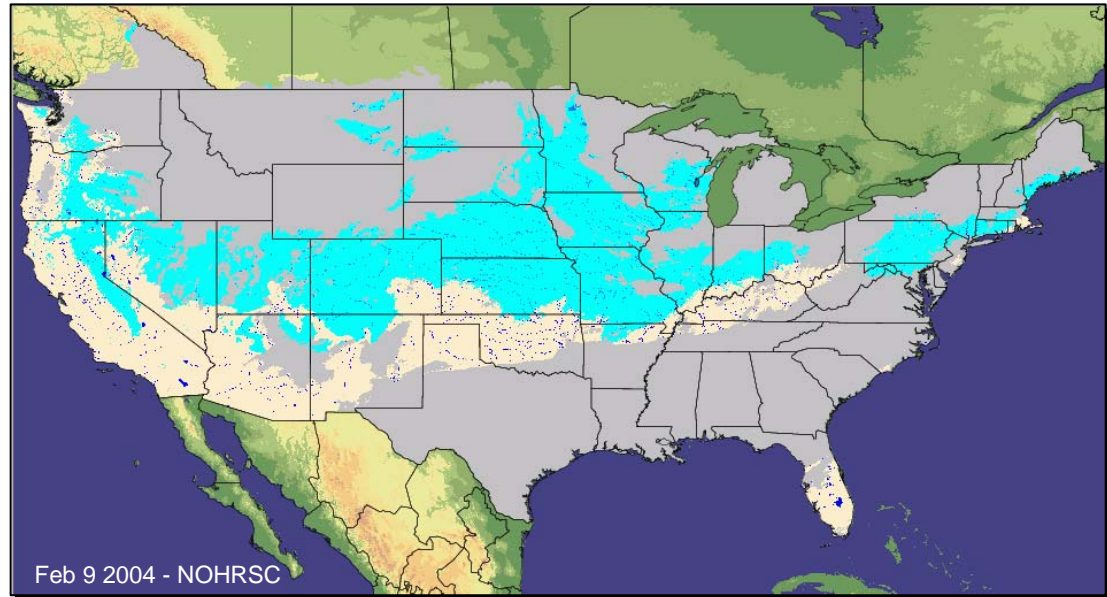
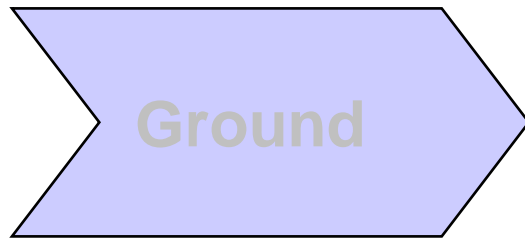
Airborne Snow Survey Program Flight Line Network



**2,187 Flight Lines**  
**31 States, 8 Provinces**

# National Snow Analyses (NSA)

## Multi-sensor Snow Observations



- 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)

## Snow Modeling and Data Assimilation

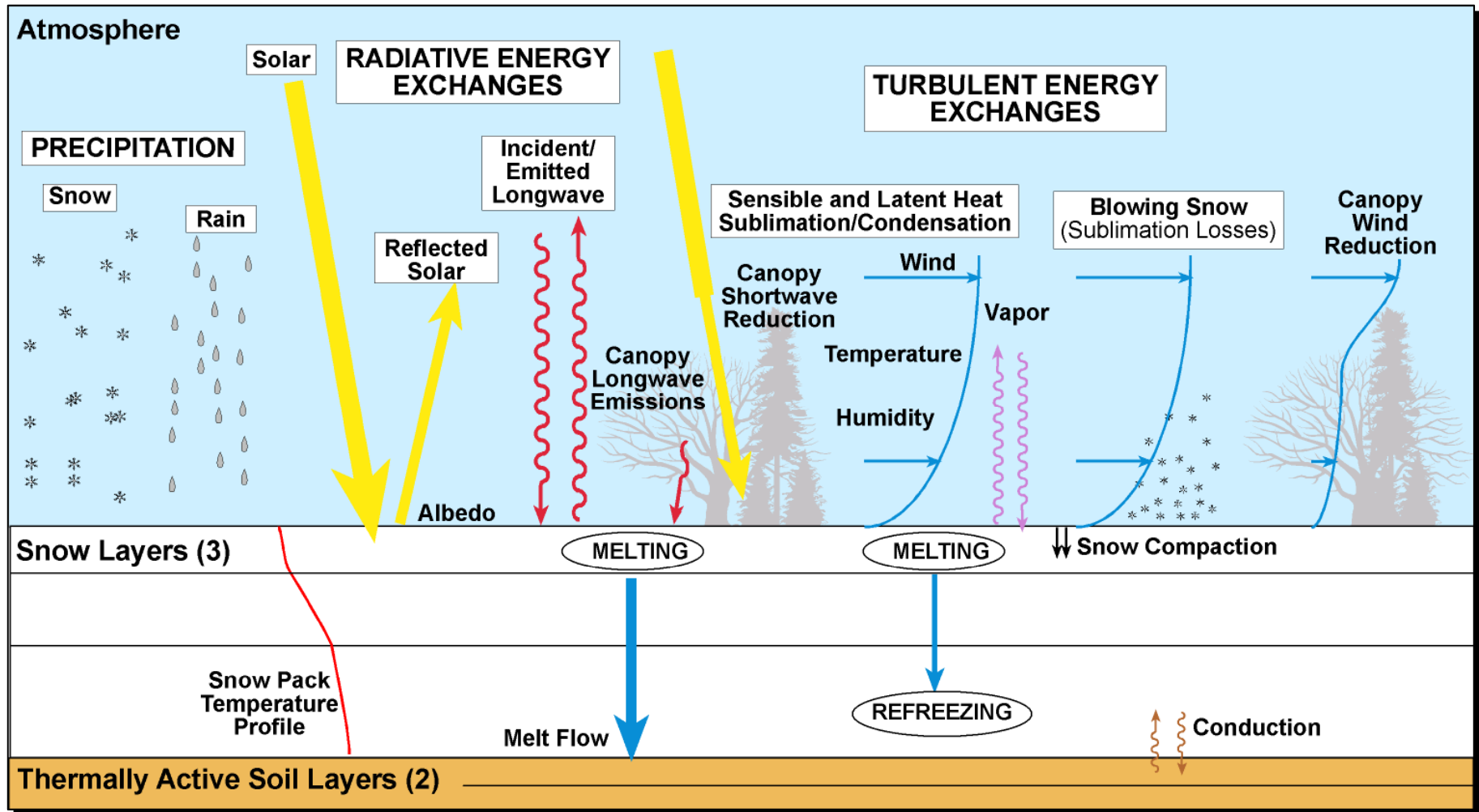
### Gridded Snow Characteristics

U.S.  
1-km<sup>2</sup>  
Hourly

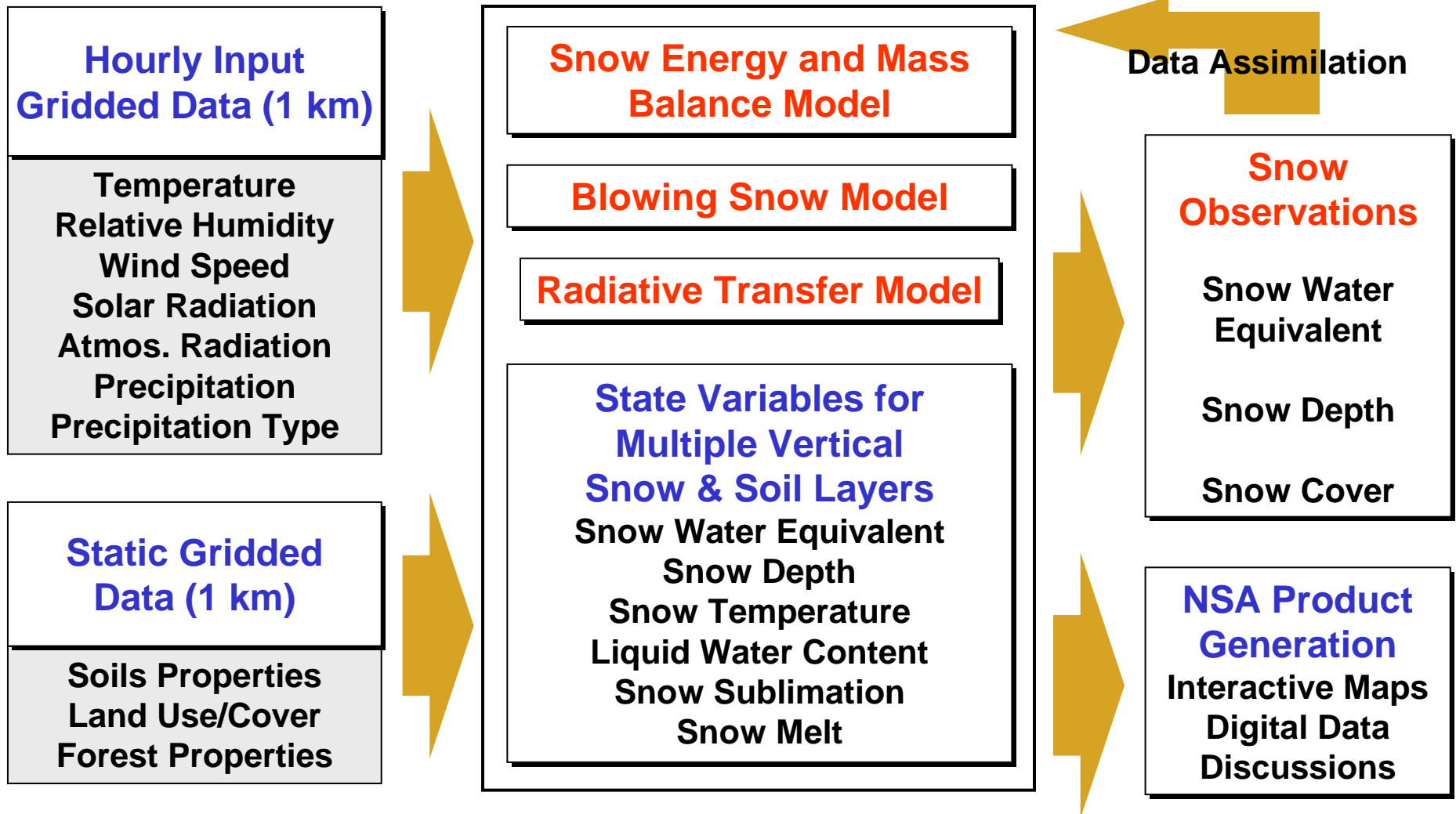
- **Land Surface Model for Snow and Soil**
  - Domain: Continental U.S.
  - Resolution: 1km<sup>2</sup>, Hourly
  - Physics: 5-Layer Energy and Mass Balance
    - Spatial implementation of modified 1-D SNTHERM model developed by ERDC/CRREL (*Jordan*)
    - Spatial implementation of Prairie Blowing Snow Model (*Pomeroy et al.*)
  - Forcing: Mesoscale Weather Analyses
    - RUC2, Eta physically downscaled to 1 km<sup>2</sup>
  - 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 Model Physics



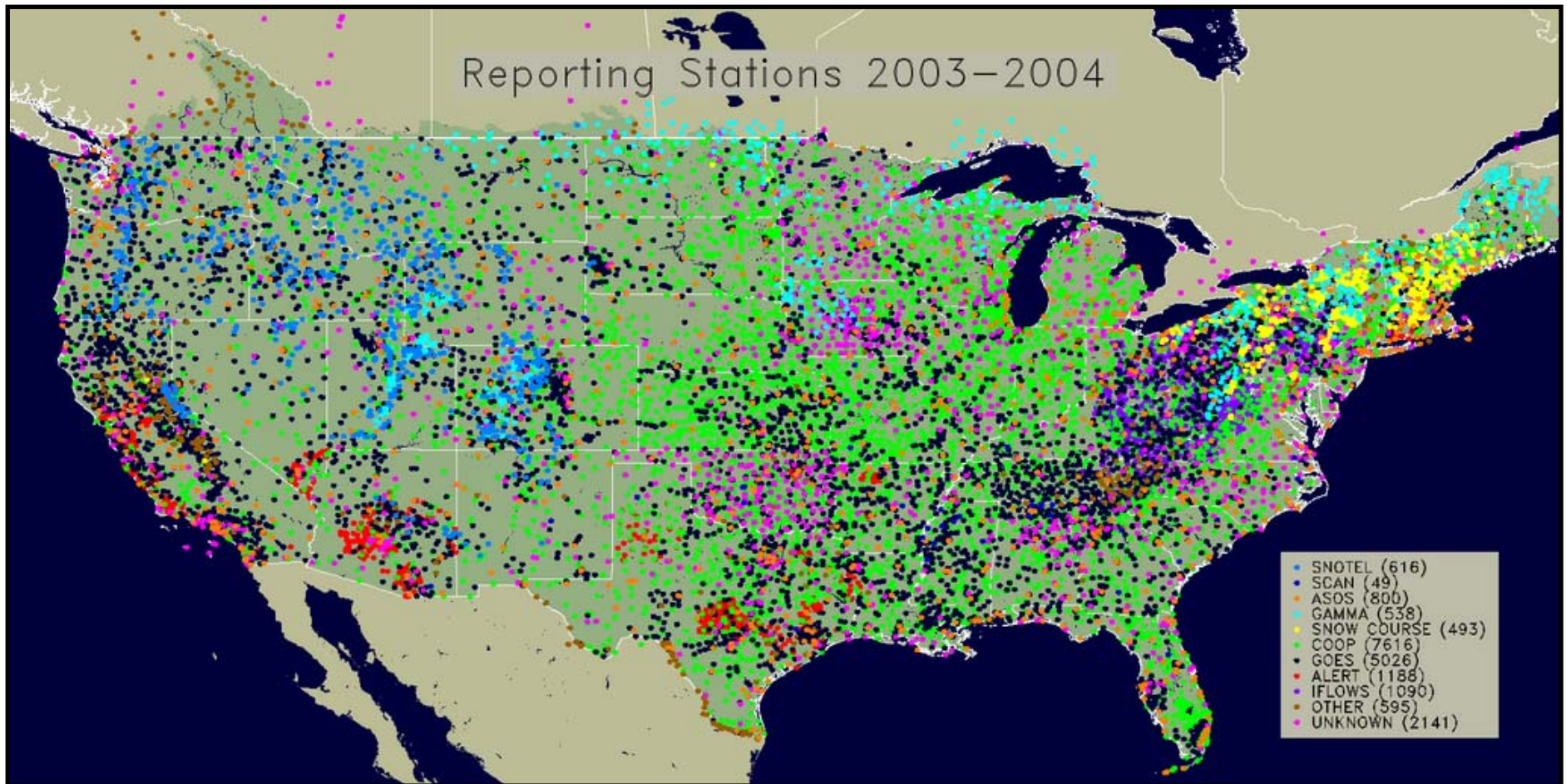
# Snow Modeling Framework



# Assimilation of Observed Snow Data into SNODAS Snow Model State Variables

## And Associated Problems

# Over 25,000 Reporting Stations



# Stations Without Metadata

- **1950 stations** sent observations across NOAAPort with unknown metadata from January 1, 2004 to August 1, 2004.
- **2,451,864 observations were lost** for the unknown 1950 stations.

# Importance of Data in SHEF

- If data is not sent across NOAAPort in SHEF it falls on floor.
- Many reports are lost in Public Information Statements and Local Storm Reports.
- Some offices send PNS or LSR products as RR products as well.
- Use stranger-station format to send data from infrequent reports.

NOUS45 KSLC 121745  
PNSSLC

PUBLIC INFORMATION STATEMENT...PRECIP TOTALS  
NATIONAL WEATHER SERVICE SALT LAKE CITY UT  
1030 AM MST FRI NOV 12 2004

...PRELIMINARY STORM TOTALS...

ANOTHER UPPER LEVEL LOW PRODUCED A MOIST EASTERLY FLOW  
BROUGHT PRECIPITATION TO MOST THE REGION.

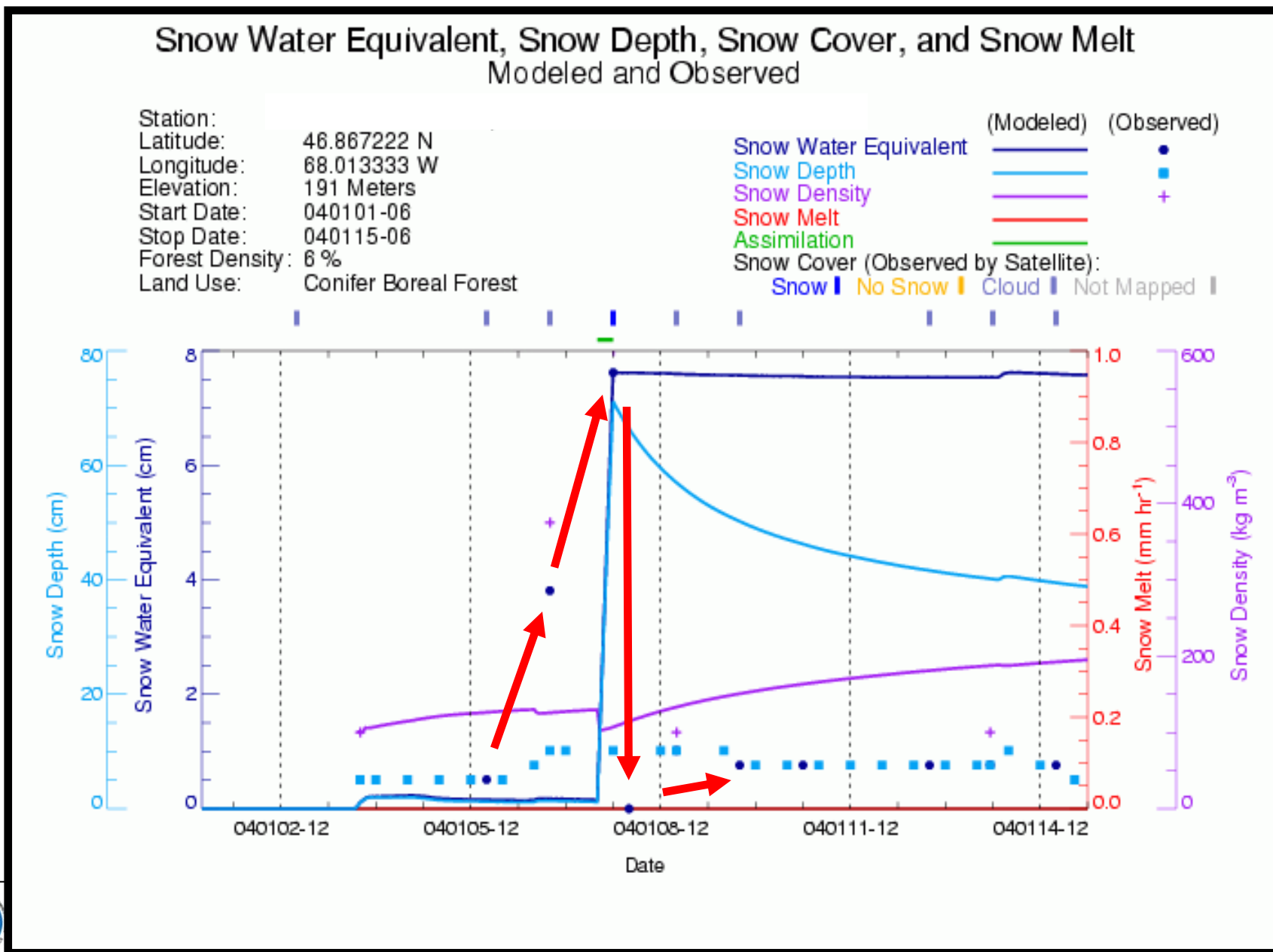
HERE IS A LIST OF TOTALS SINCE WEDNESDAY NIGHT.

LOCATION	PRECIPITATION (INCHES)	SNOWFALL (INCHES)
----------	---------------------------	----------------------

...WASATCH MOUNTAINS AND PLATEAU...

SNOWBASIN MID BOWL	0.54	6
FARMINGTON (8000 FT)	0.40	5
ROCKY BASIN (OQUIRRHS)	0.40	4
BEN LOMOND PEAK (8000 FT)	0.40	4
INDIAN CANYON (9100 FT)	0.40	4
WHITE RIVER (8500 FT)	0.40	4
SUNDANCE (7500 FT)	0.36	3
RED PINE RIDGE (9200 FT)	0.30	4
CLEAR CREEK (9200 FT)	0.30	4
TIMPANOGOS DIVIDE (8199 FT)	0.30	3
CASCADE MOUNTAIN (7800 FT)	0.30	2
HORSE RIDGE (8500 FT)	0.32	3
TONY GROVE	0.30	3
ALTA COLLINS	0.20	3

# Importance of Accurate Measurements

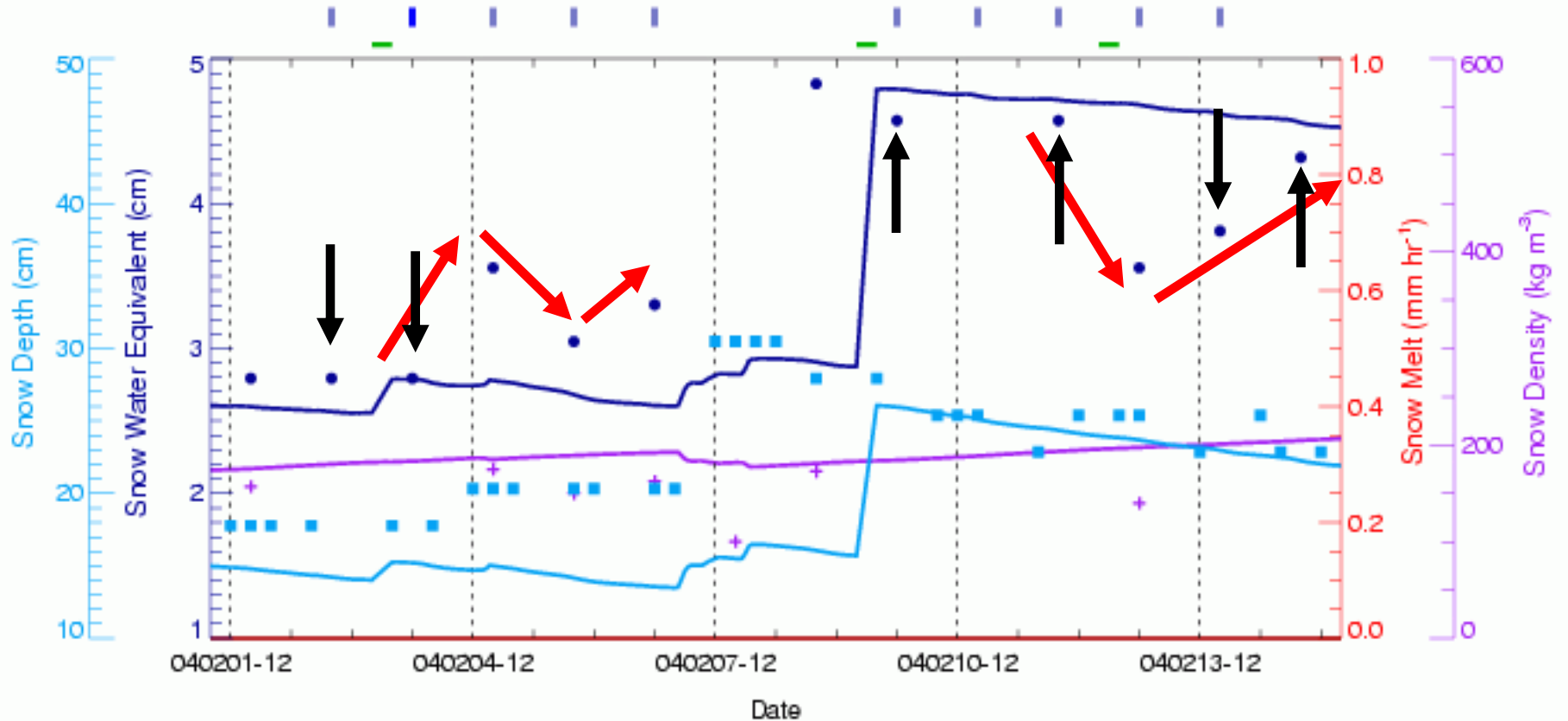


# Snow Water Equivalent, Snow Depth, Snow Cover, and Snow Melt

## Modeled and Observed

Station:  
 Latitude: 46.867222 N  
 Longitude: 68.013333 W  
 Elevation: 191 Meters  
 Start Date: 040201-08  
 Stop Date: 040215-08  
 Forest Density: 6 %  
 Land Use: Conifer Boreal Forest

	(Modeled)	(Observed)
Snow Water Equivalent	— (Blue)	• (Blue)
Snow Depth	— (Light Blue)	■ (Light Blue)
Snow Density	— (Purple)	+ (Purple)
Snow Melt	— (Red)	
Assimilation	— (Green)	
Snow Cover (Observed by Satellite):		
Snow	(Blue)	
No Snow	(Yellow)	
Cloud	(Grey)	
Not Mapped	(Dark Blue)	



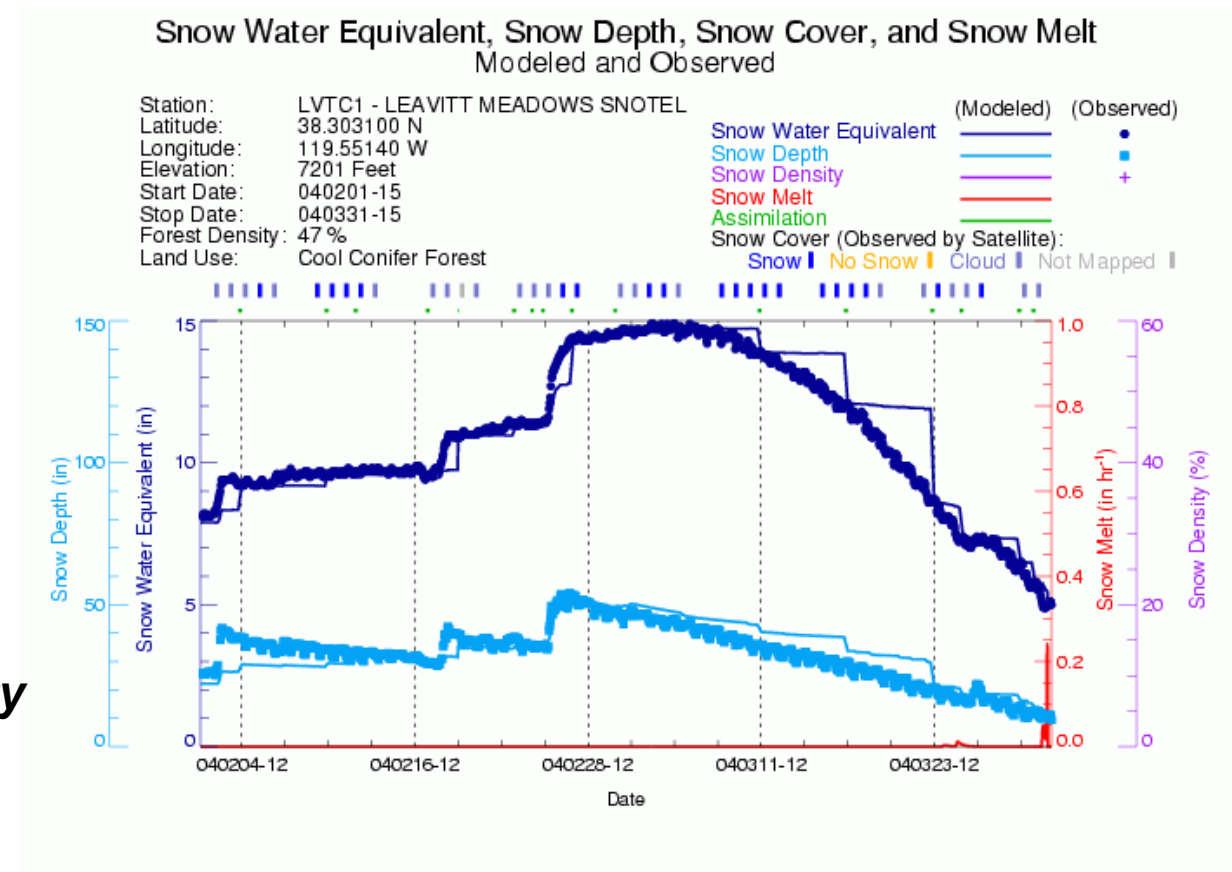


# Spatial Representativeness: Point-in-Pixel Problem

## Leavitt Meadows SNOTEL - Sierra Nevada, California



**Model:**  
**47% Forest Canopy Density**  
**Cool Conifer Forest**



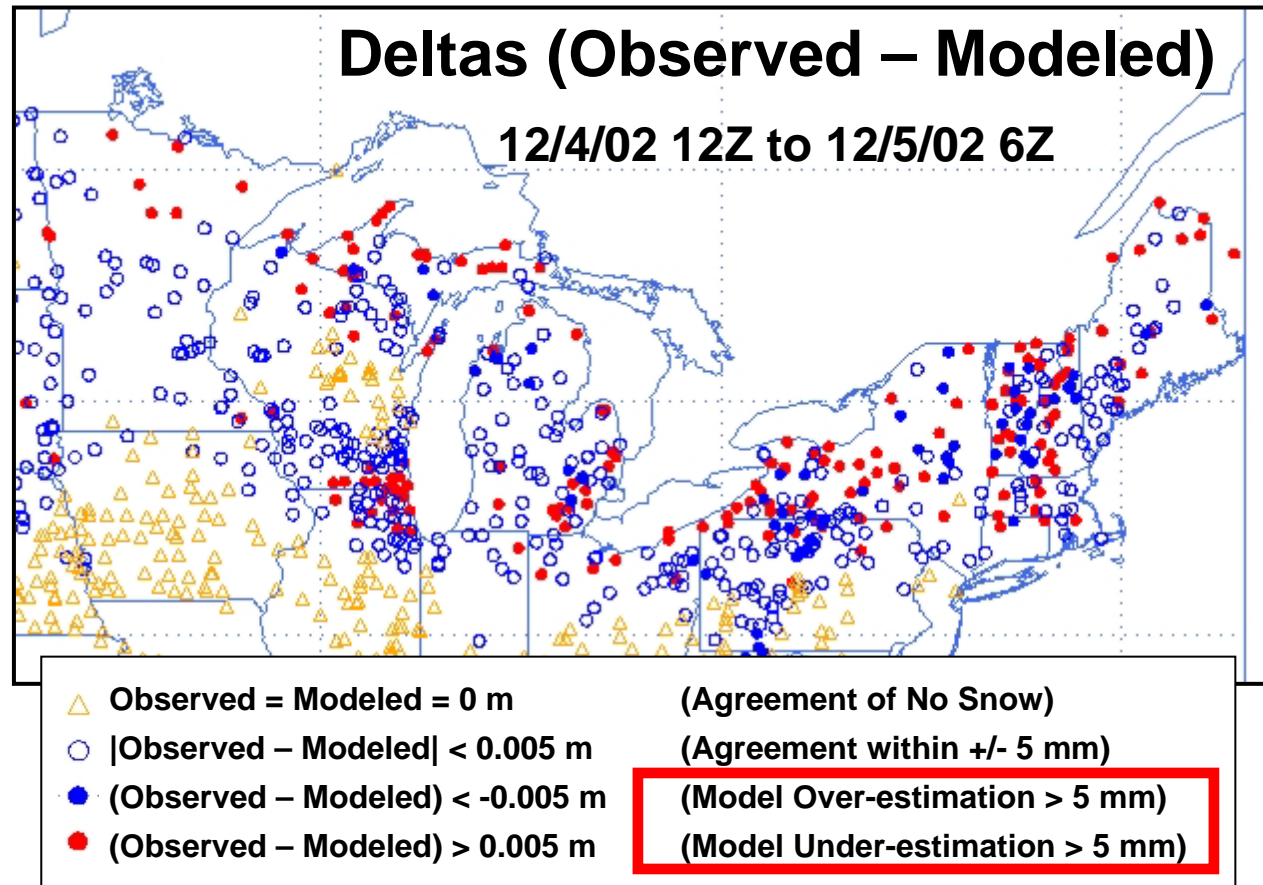
# Partial List of Recommendations

1. Make sure that station metadata in **NWSLI** are current and correct
2. **NEVER** infer snow water equivalent from tables or by dividing depth by 10
3. Code data in **SHEF** and send to AWIPS
4. Make and report snow depth with **ALL** snow water equivalent measurements

# Snow Observation Assimilation

*Daily SWE and Snow Depth Observations are used to update the model*

- Deltas between observed and modeled states are examined
  - *Coherent spatial pattern is required to warrant update*
    - Subgrid variability
- If pattern is explainable, update field is generated and used to nudge the model toward observed states



# National Snow Analyses (NSA)

## Snow Information Products

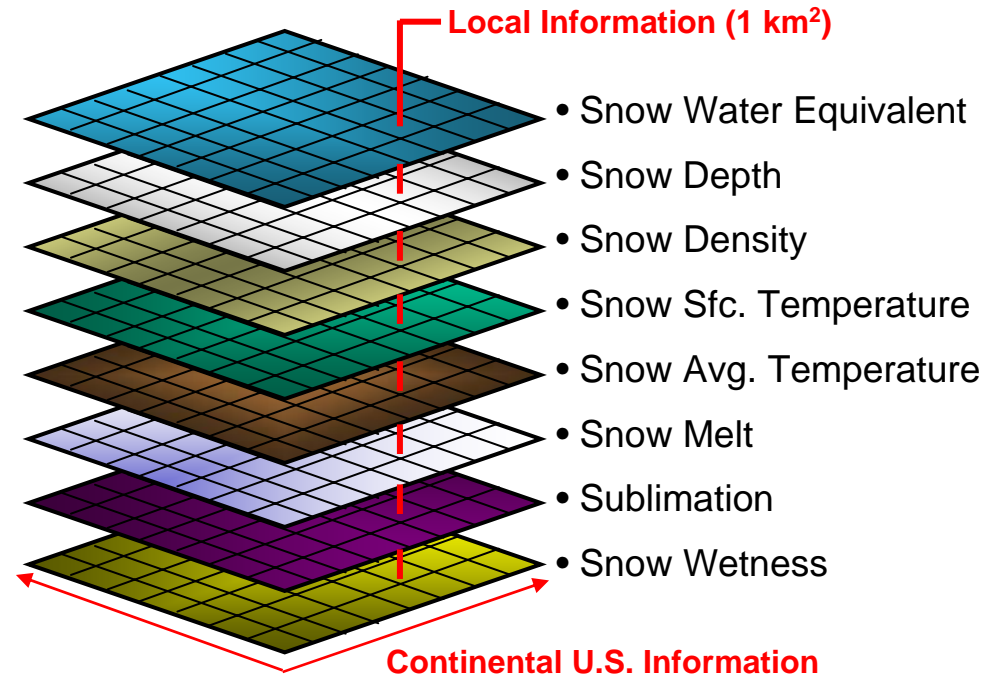
Data Products

Interactive  
Maps

Time Series  
Plots

Text  
Discussions

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



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

# National Snow Analyses (NSA)

Integrated Modeled / Observed Snowpack State Variables


Daily Basin-by-Basin SHEF Products Shipped to AWIPS

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*




# National Snow Analyses (NSA)



**National Weather Service**  
National Operational Hydrologic  
Remote Sensing Center

weather.gov



Site Map
News
Organization
NWS Search

Home

NOAA's Cryosphere Initiative

NOHRSC Overview

Snow Analyses

Interactive Products

Airborne Snow Survey Program

GIS Data Sets

SHEF Archive

Technology

Staff

Links

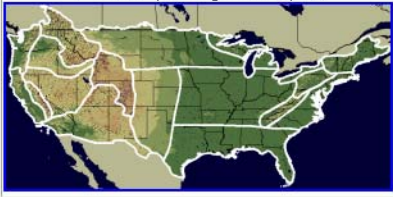
Site Help

Please Send Us Comments!

## Snow Analyses

National Snow Analyses

Click On Map for Regional Analyses



**Automated Model Discussion:**  
**November 3, 2004**

Area Covered By Snow: 8.7%

Area Covered Last Month: 0.2%

**Snow Depth**

Average: 0.9 cm

Minimum: 0.0 cm

Maximum: 899.2 cm

Std. Dev.: 4.9 cm

**Snow Water Equivalent**

Average: 0.2 cm

Minimum: 0.0 cm

Maximum: 476.1 cm

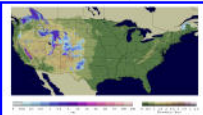
Std. Dev.: 1.3 cm

more...

Click on Image Below for Enlarged

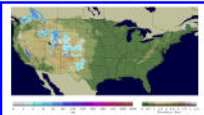
National  2004  November  3

Snow Water Equivalent



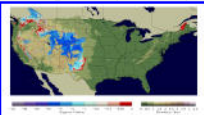
Animate: Season --- Two weeks --- One Day

Snow Depth



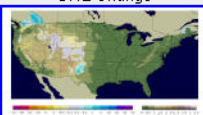
Animate: Season --- Two weeks --- One Day

Average Snowpack Temp



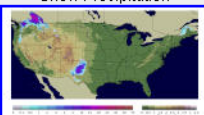
Animate: Season --- Two weeks --- One Day

SWE Change



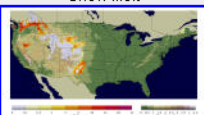
Animate: Season --- Two weeks --- One Day

Snow Precipitation



Animate: Season --- Two weeks --- One Day

Snow Melt



Animate: Season --- Two weeks --- One Day

Blowing Snow Sublimation
Surface Sublimation
Non-Snow Precipitation

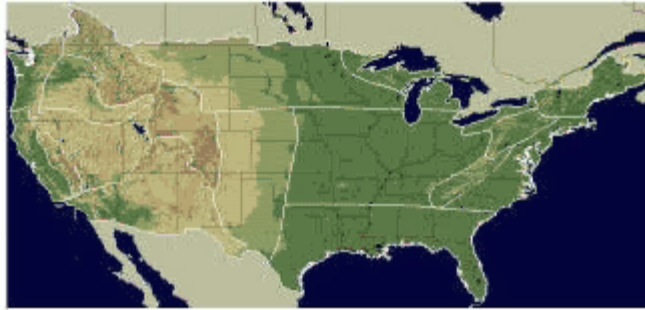
## Snow Water Equivalent (hourly)

2003 Oct 1 – 2004 May 23

OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

2003-2004  
Experimental

Snow Water Equivalent  
2003-10-01 to



0 0.01 0.1 0.5 1 2.5 5 10 15 20 50 75 100 150

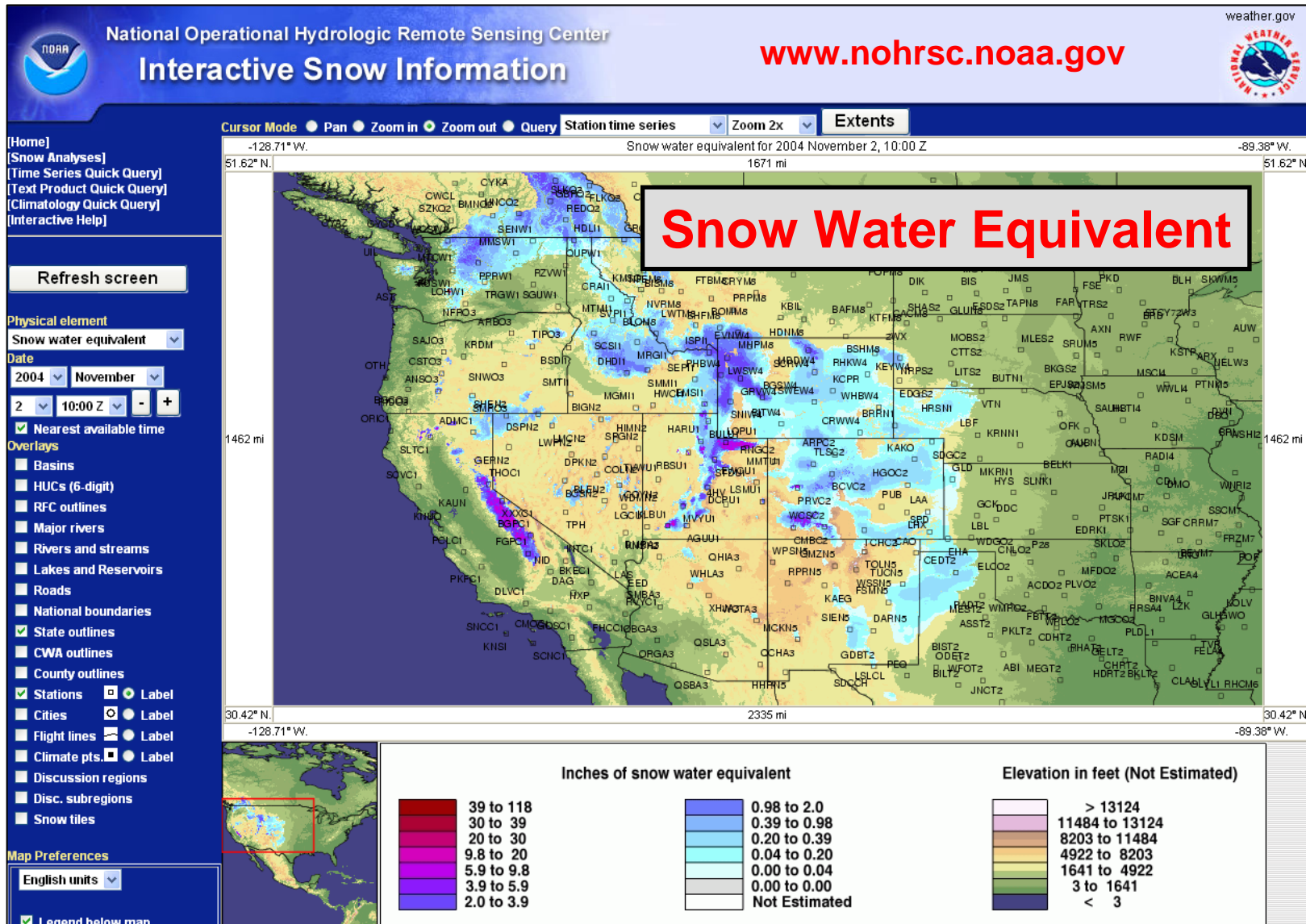
mm

0 0.0 1.0 2.0 3.0 4.0

Centimeters (Inch)

5,638 Frames
94 Frames / Second

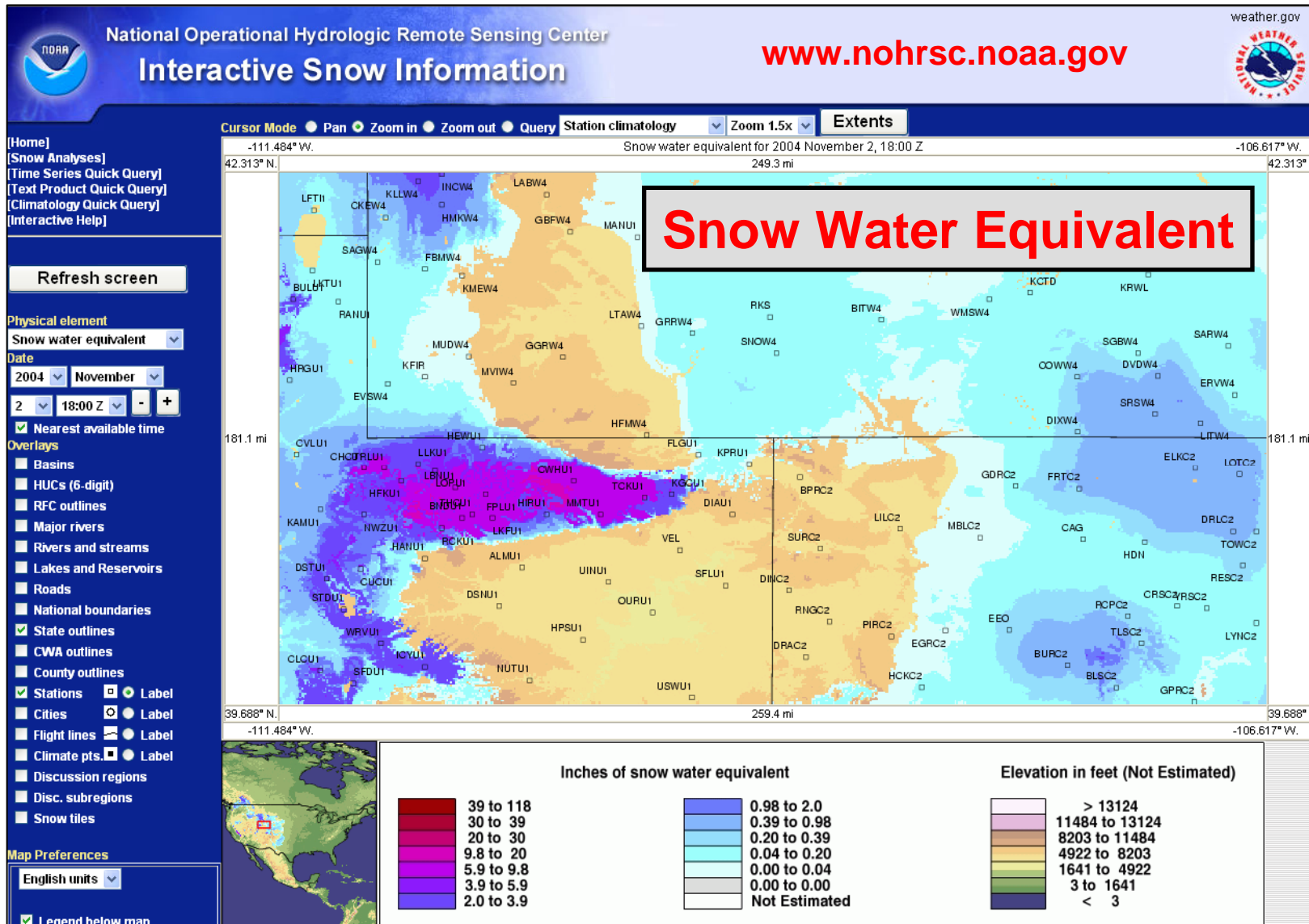
# Interactive Snow Information System



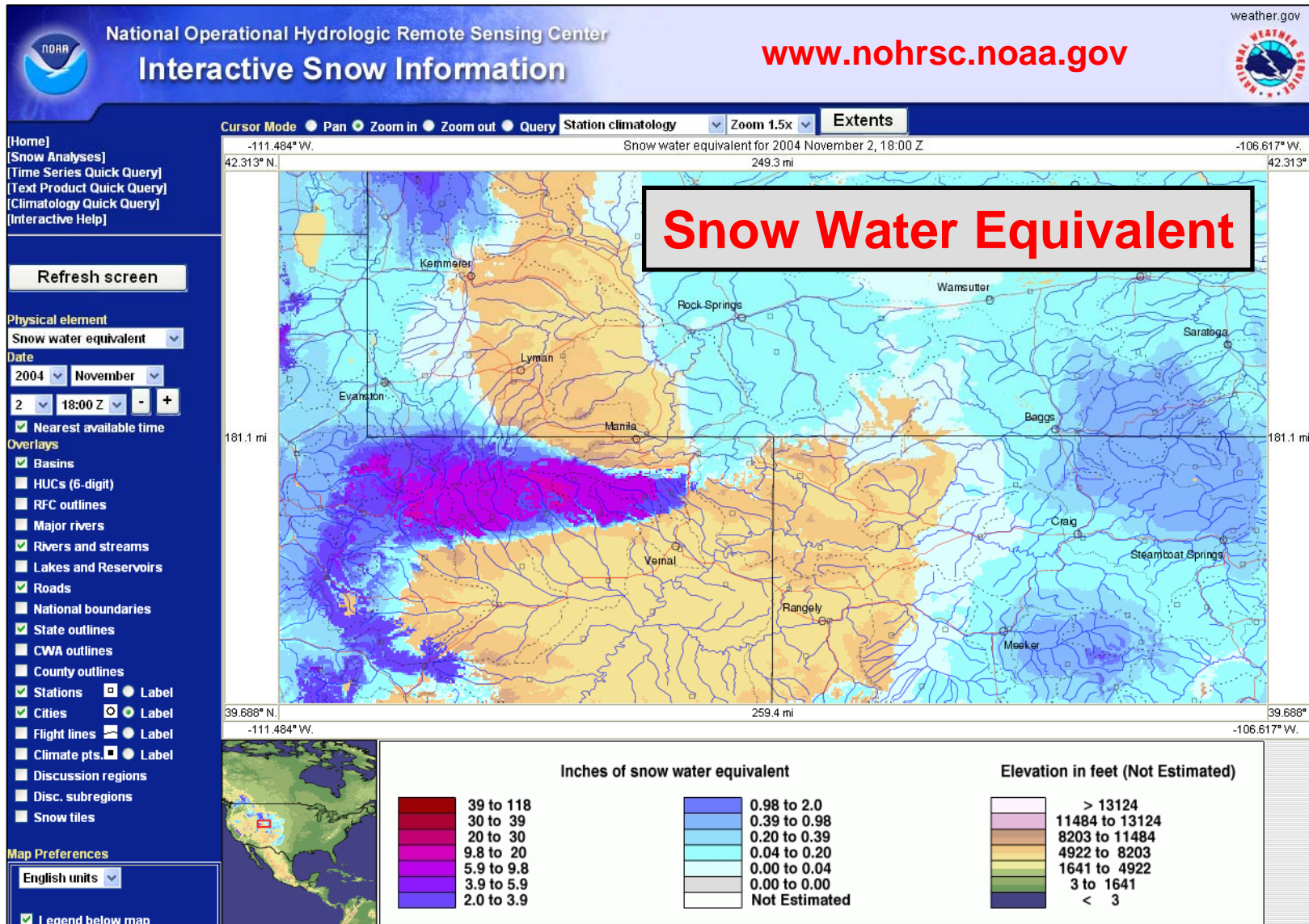




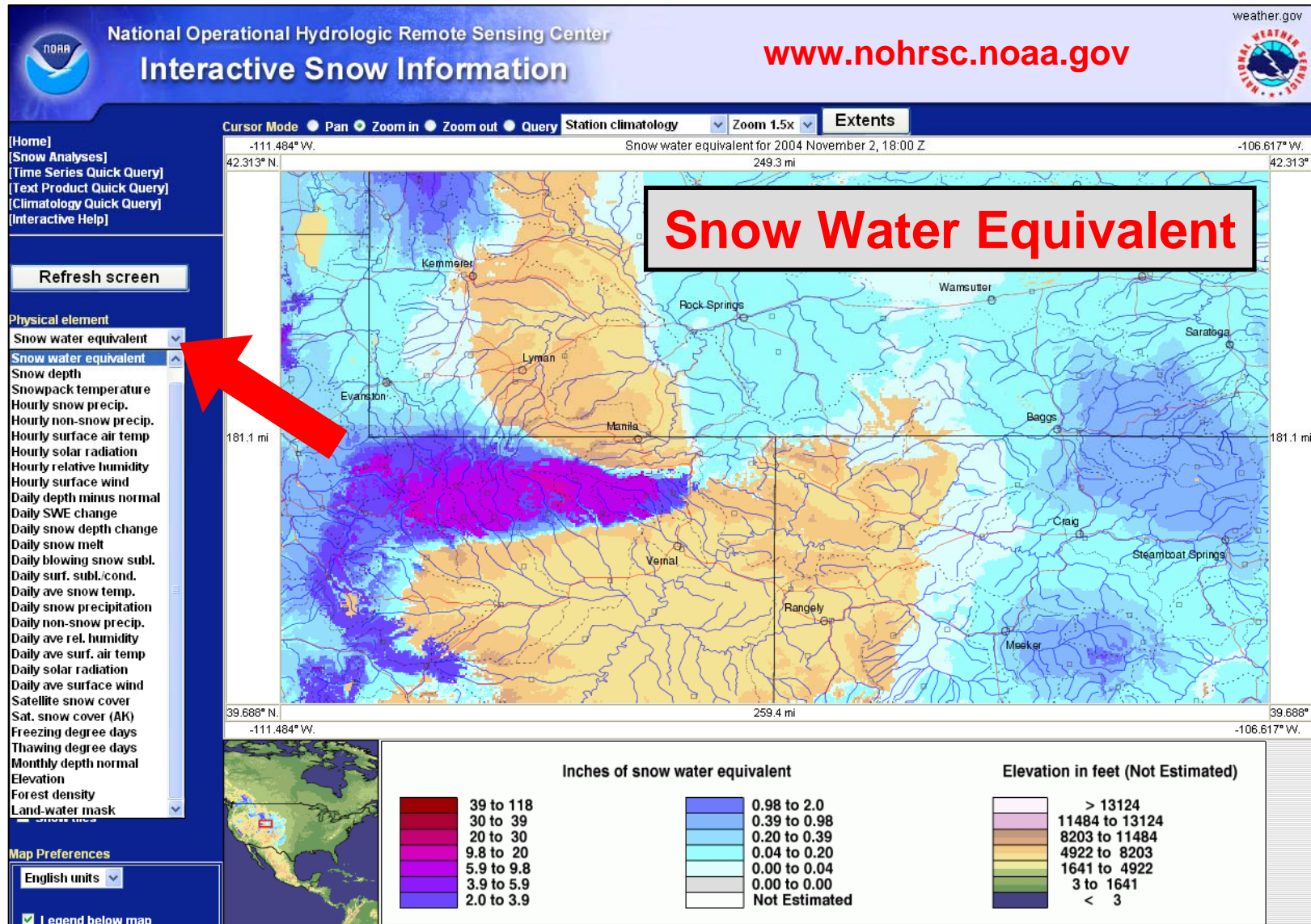
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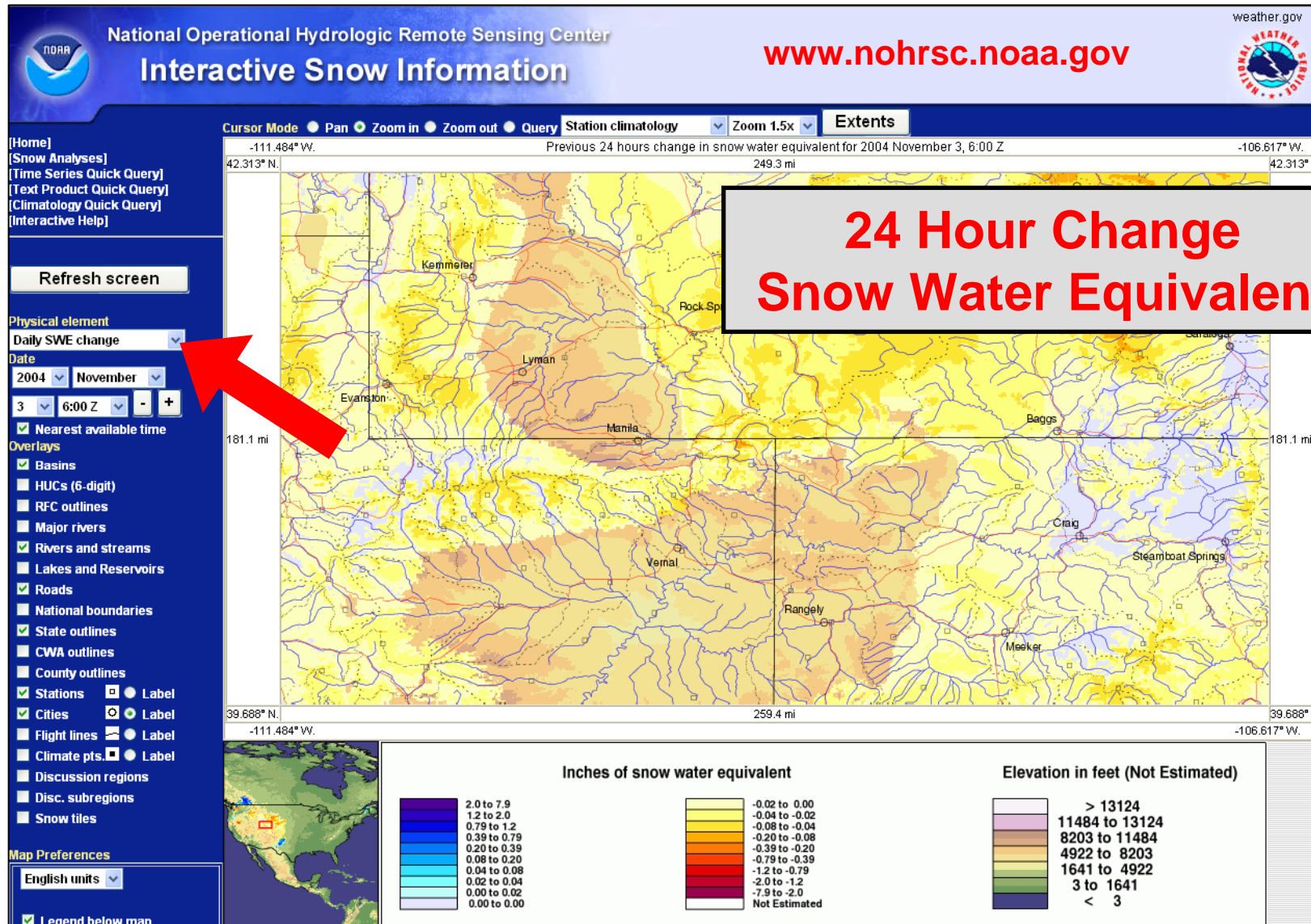
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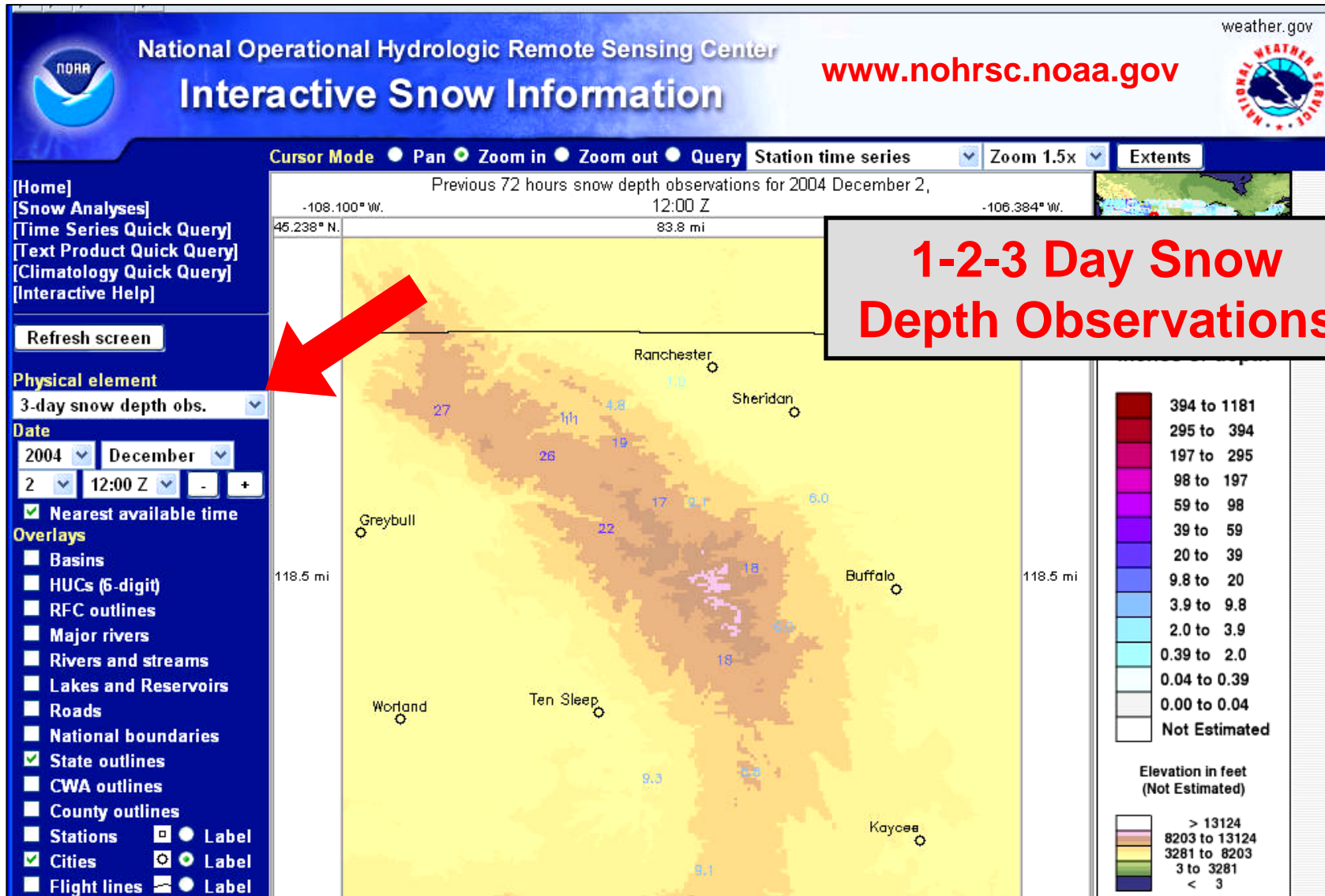
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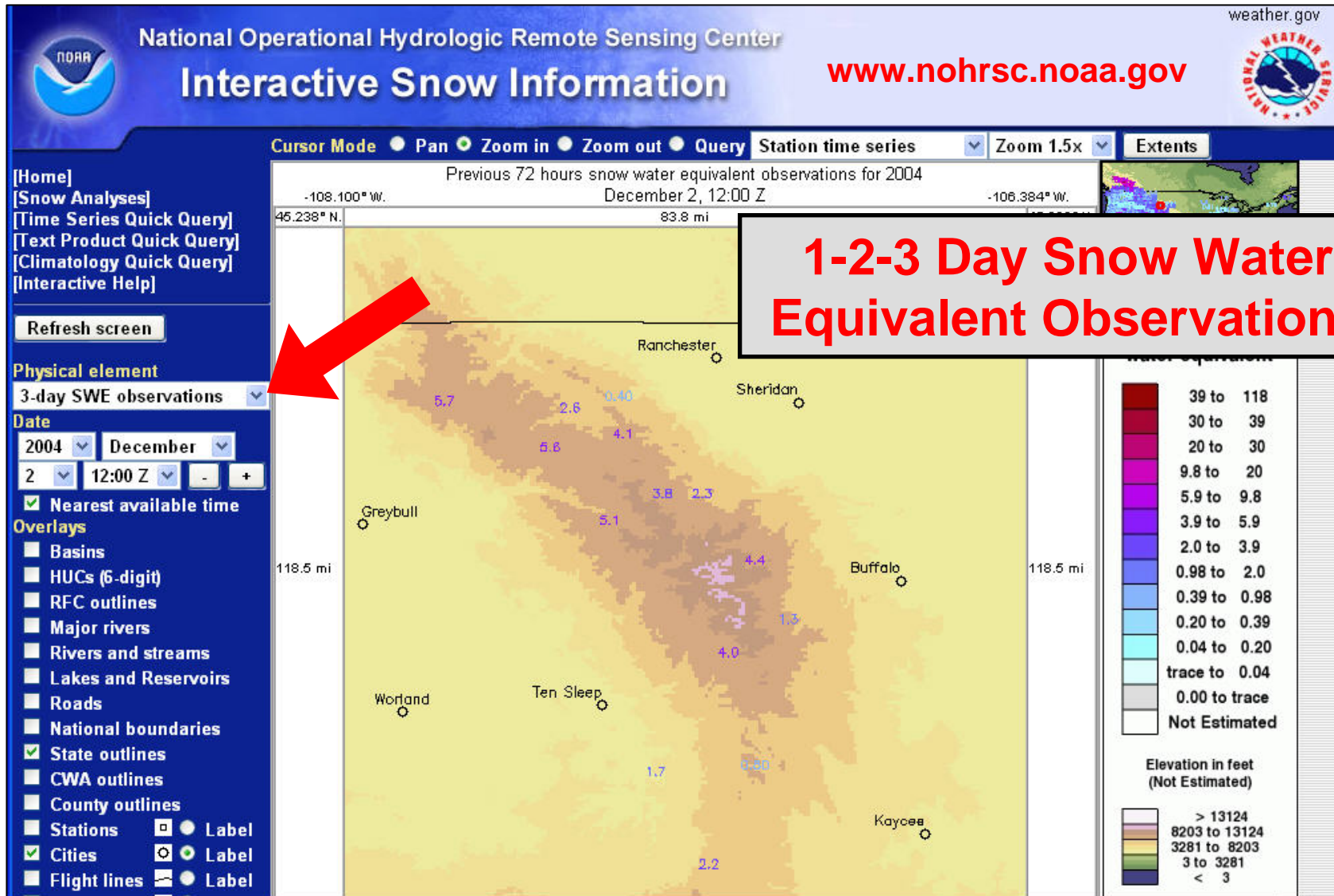
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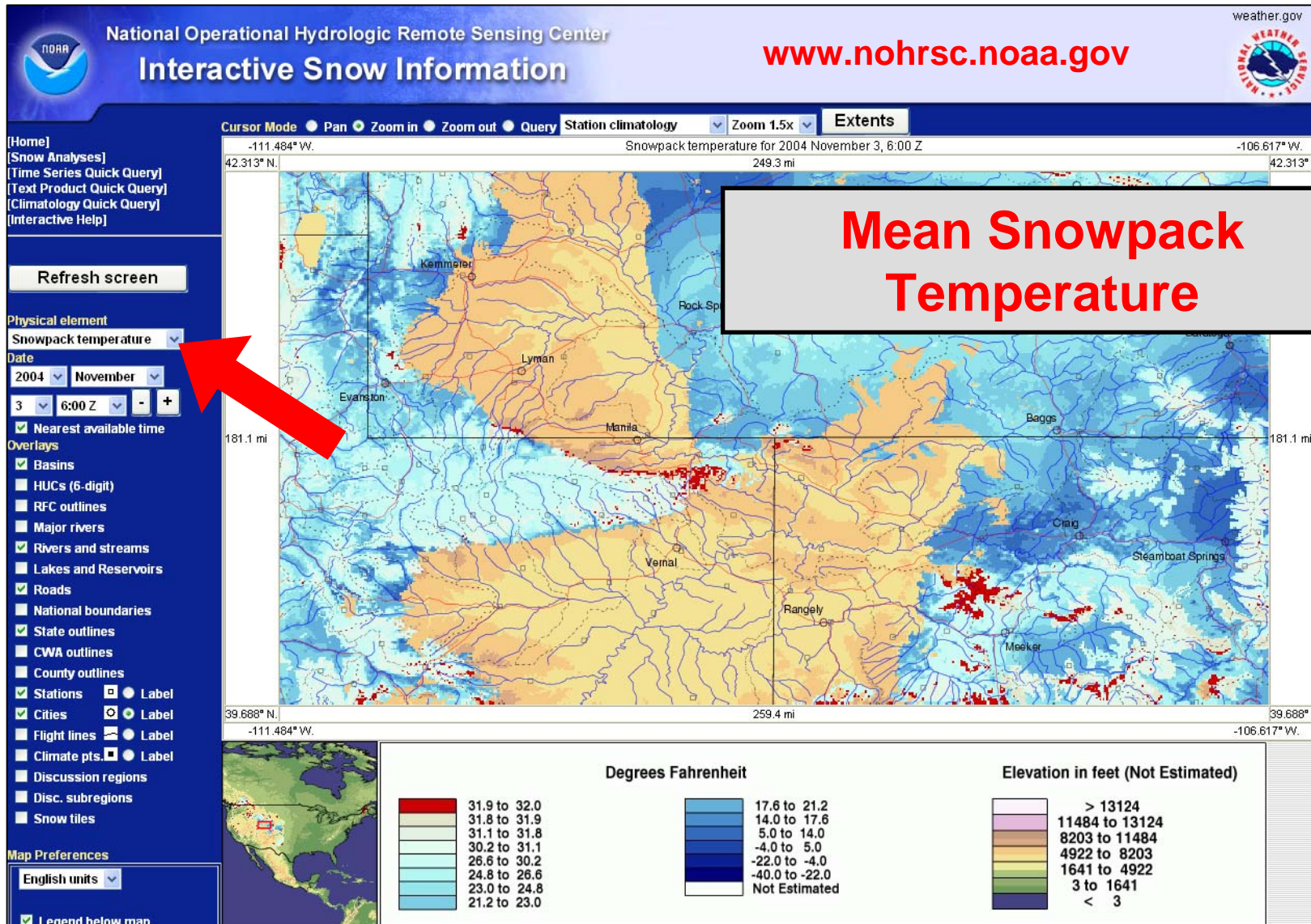
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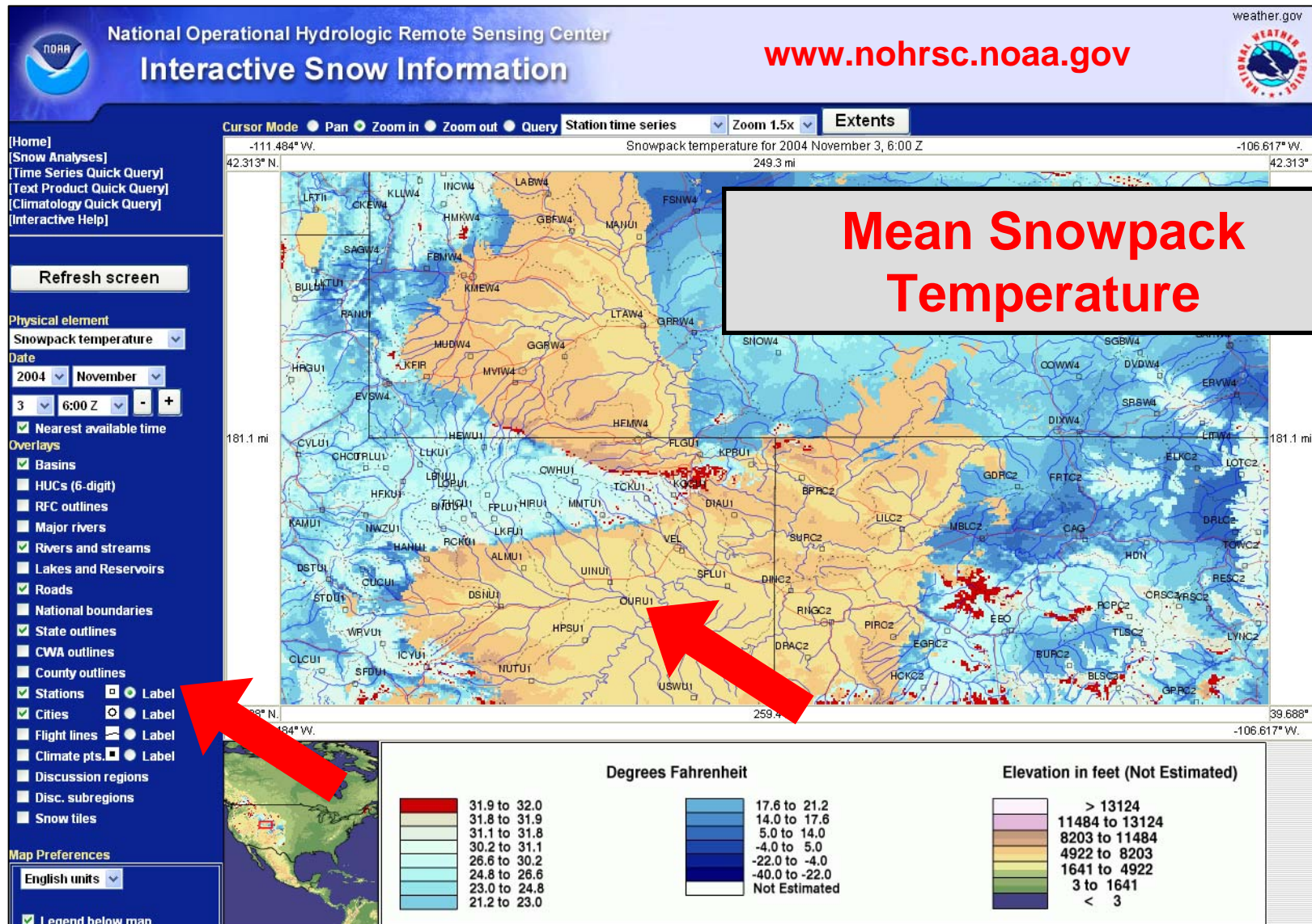
# Interactive Snow Information System



# Interactive Snow Information System



# Interactive Snow Information System





# Interactive Snow Information System

weather.gov  
www.nohrsc.noaa.gov

Station time series  
Station time series  
Flight line time series  
Station climatology  
Disc. region time series  
Subregion time series  
State time series  
Basin time series  
Basins by RFC  
Basins by HUC (6-digit)  
Basins by State  
Basins by CWA  
Basins by County

**Station Time Series**

Refresh screen

Physical element  
Snowpack temperature

Date  
2004 November 3 6:00 Z

Nearest available time

Overlays  
 Basins  
 HUCs (6-digit)  
 RFC outlines  
 Major rivers  
 Rivers and streams  
 Lakes and Reservoirs  
 Roads  
 National boundaries  
 State outlines  
 CWA outlines  
 County outlines  
 Stations  Label  
 Cities  Label  
 Flight lines  Label  
 Climate pts.  Label  
 Discussion regions  
 Disc. subregions  
 Snow tiles

Map Preferences  
English units

Legend below map

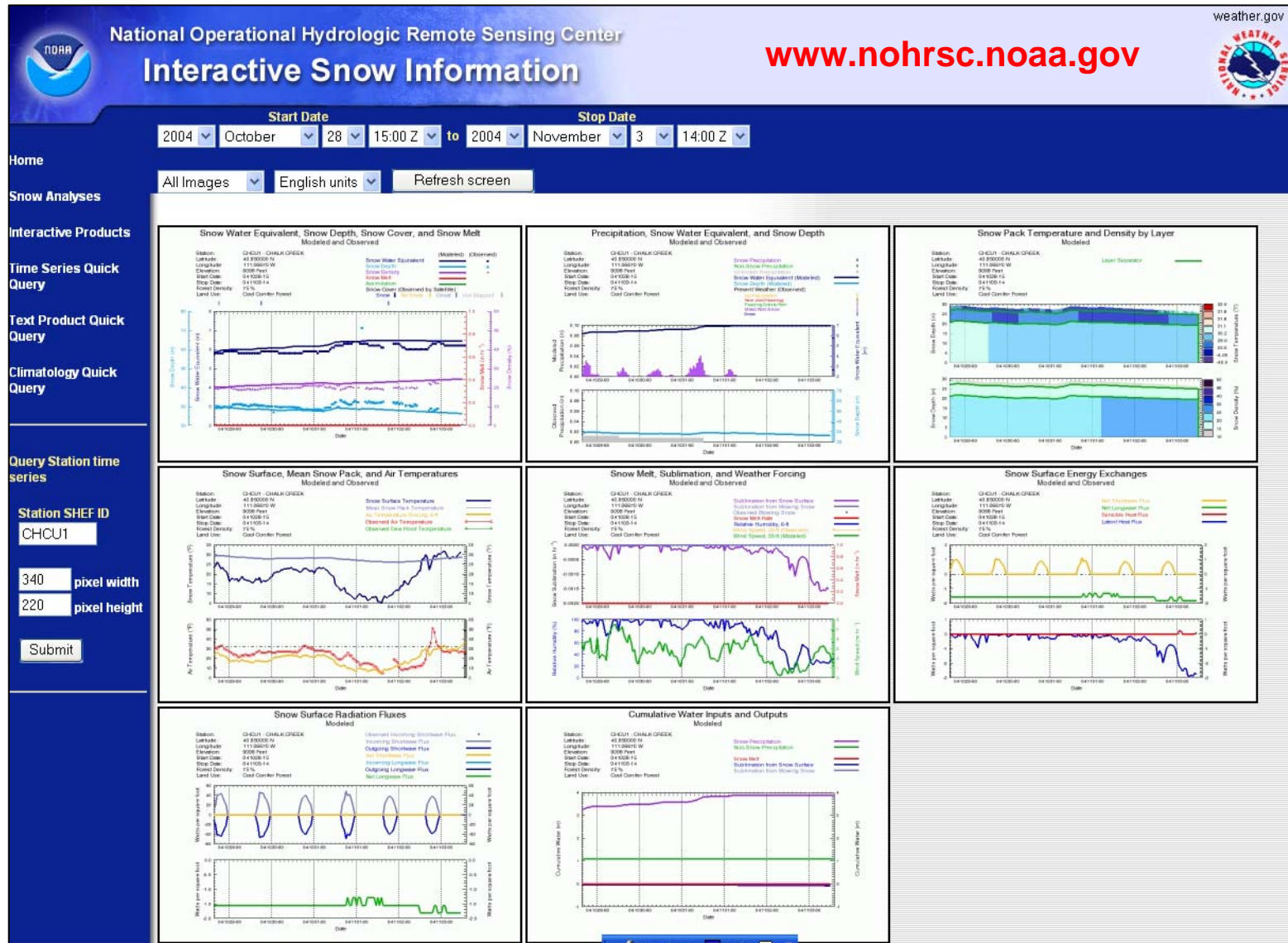
Degrees Fahrenheit

31.9 to 32.0
31.8 to 31.9
31.1 to 31.8
30.2 to 31.1
26.6 to 30.2
24.8 to 26.6
23.0 to 24.8
21.2 to 23.0

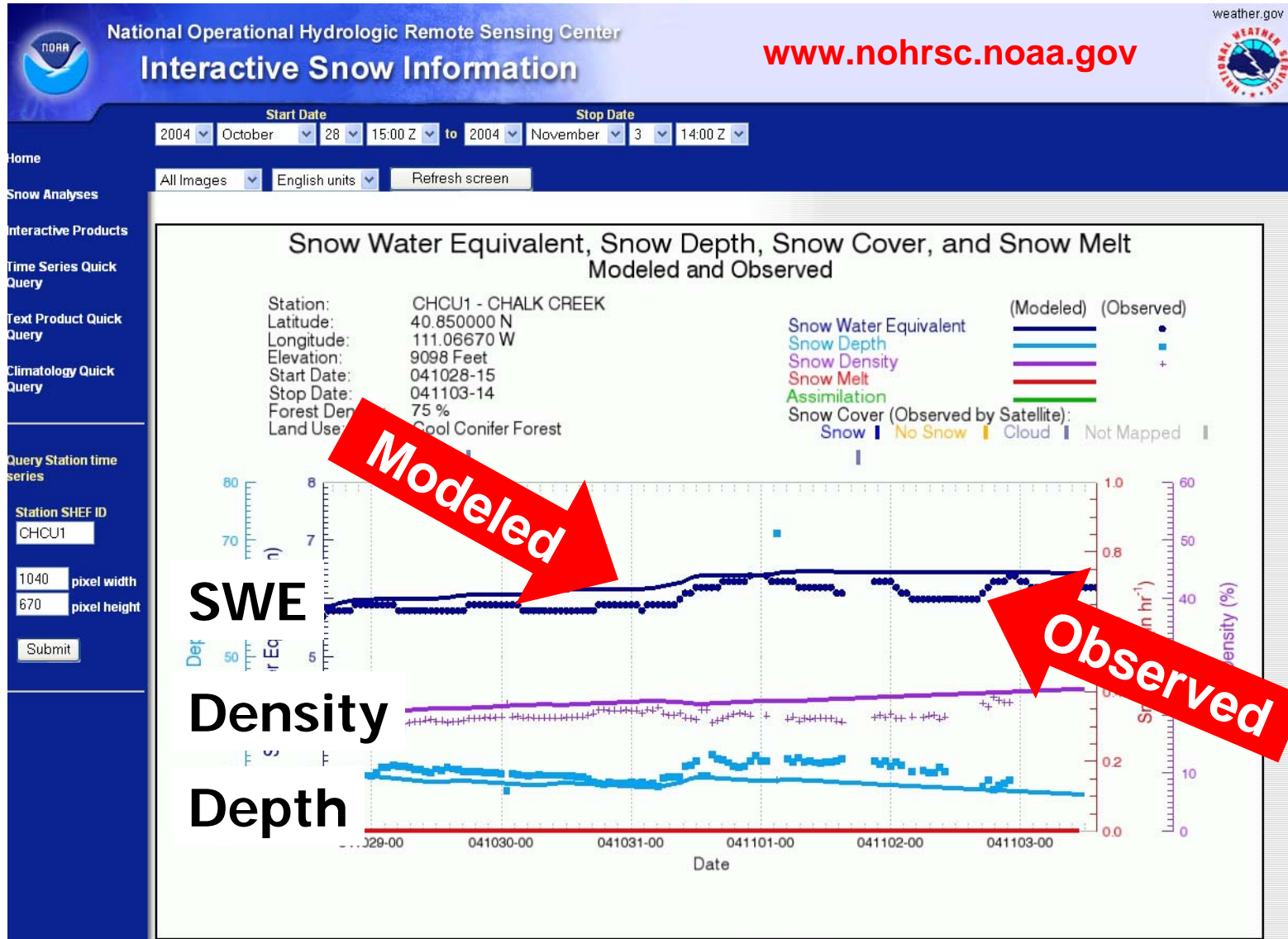
Elevation in feet (Not Estimated)

> 13124
11484 to 13124
8203 to 11484
4922 to 8203
1641 to 4922
3 to 1641
< 3

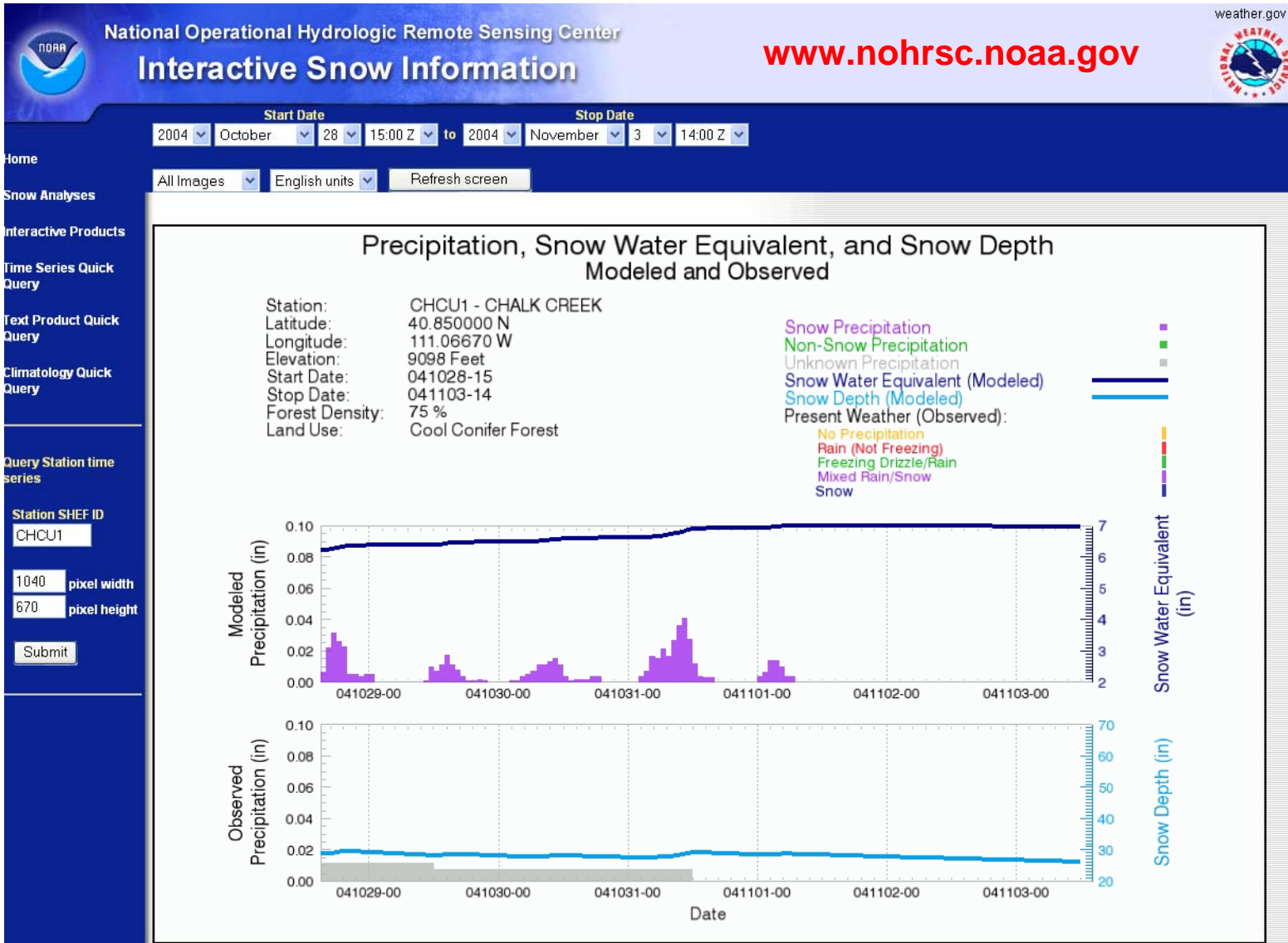
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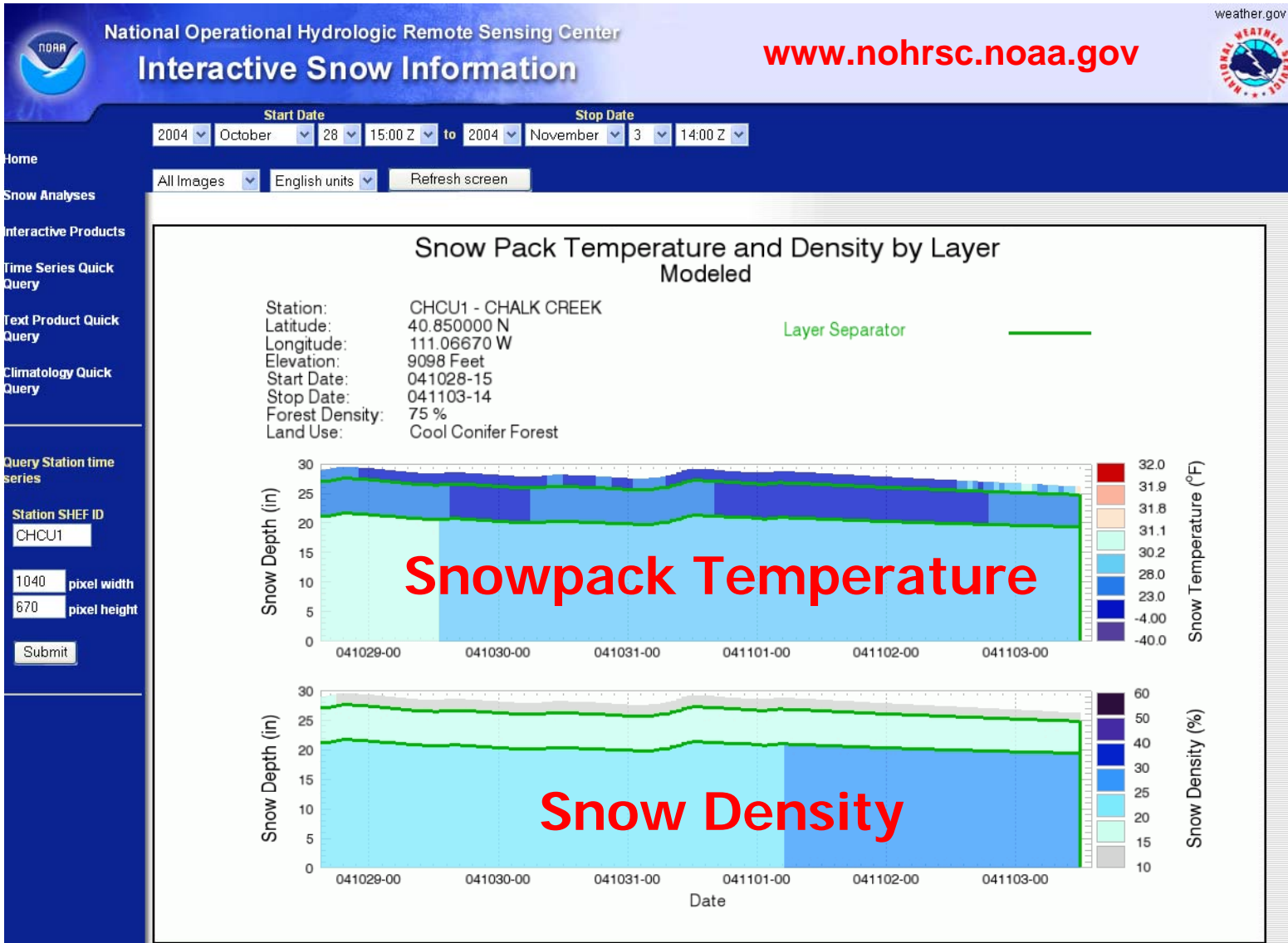
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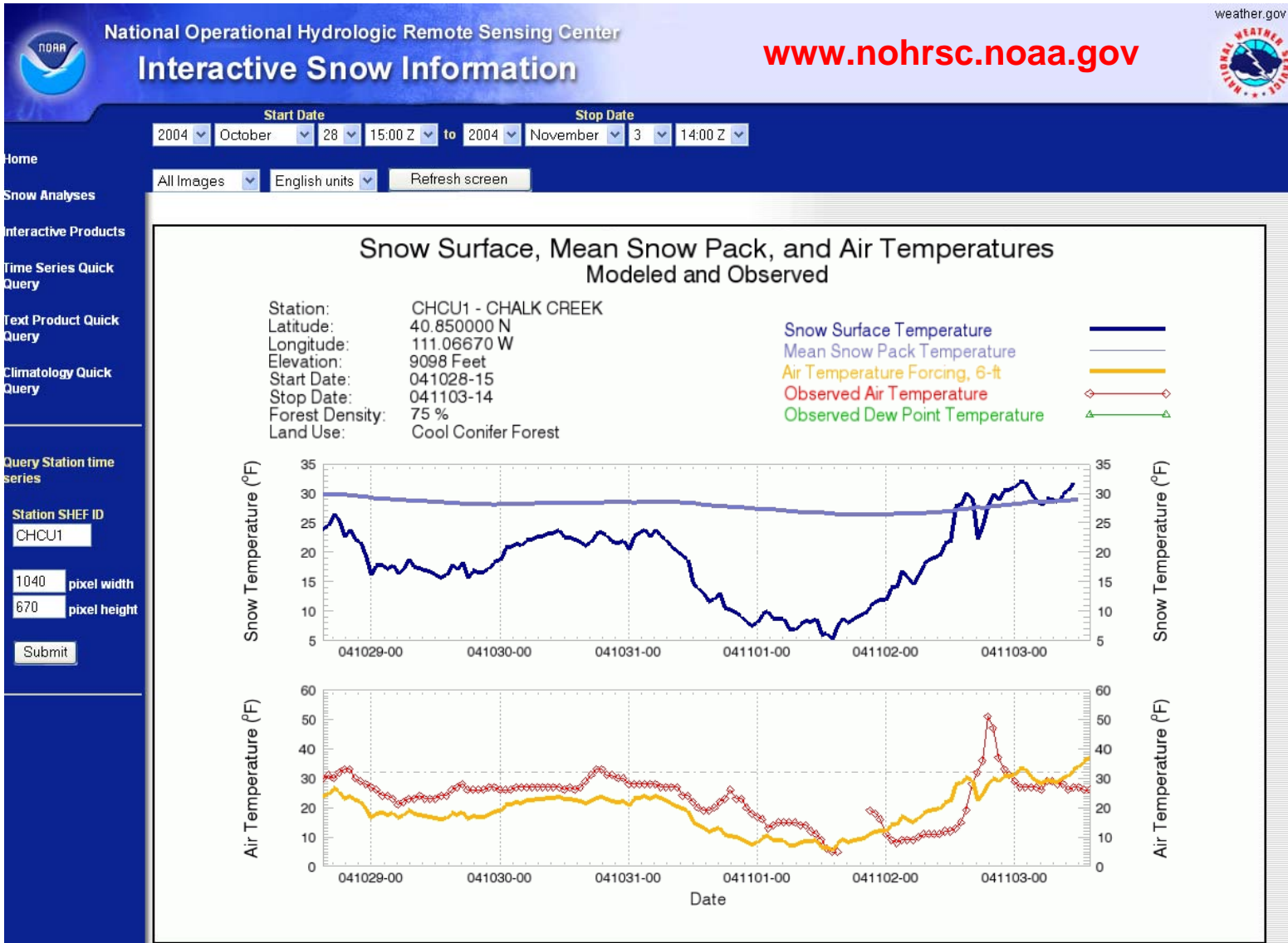
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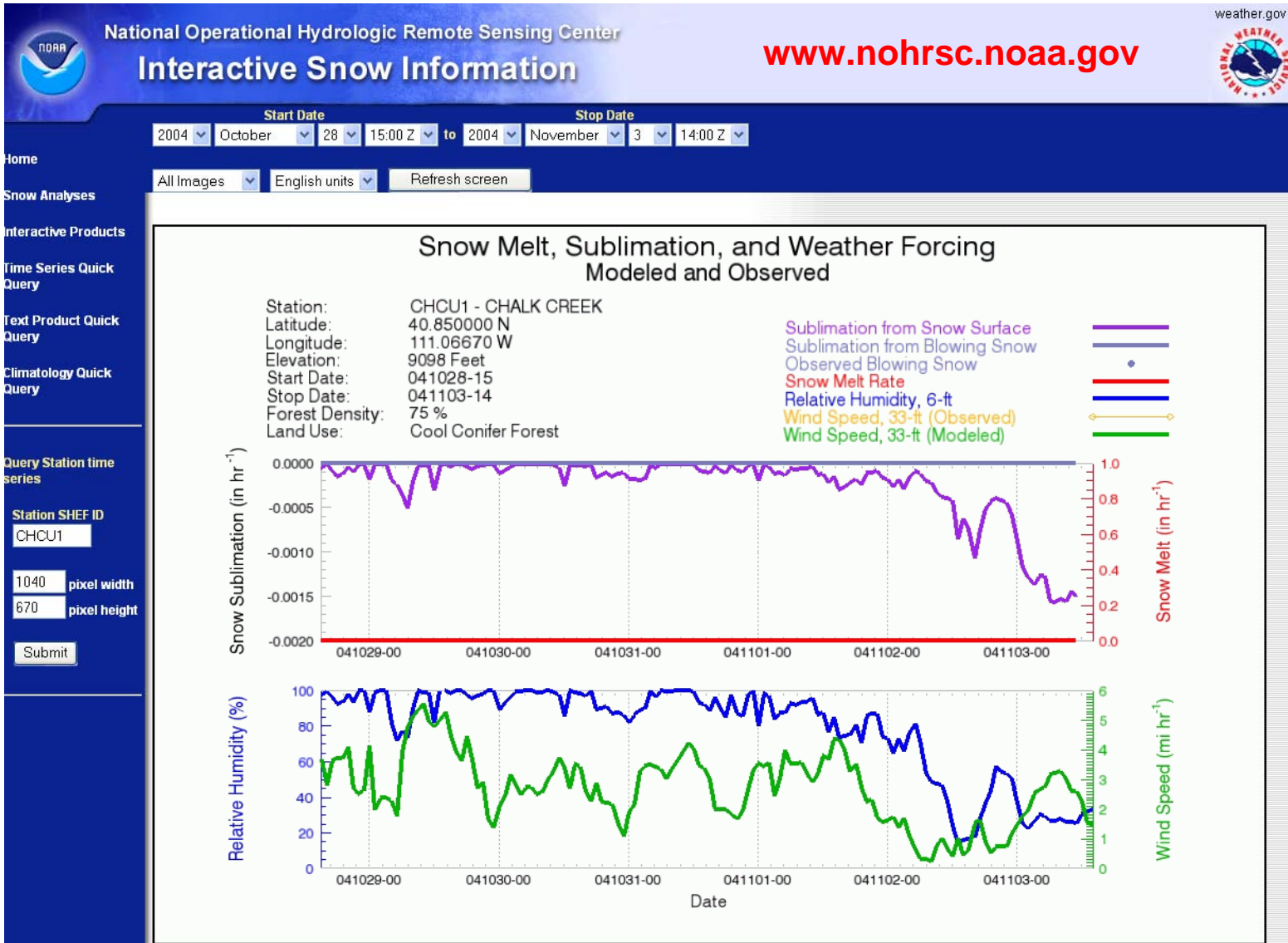
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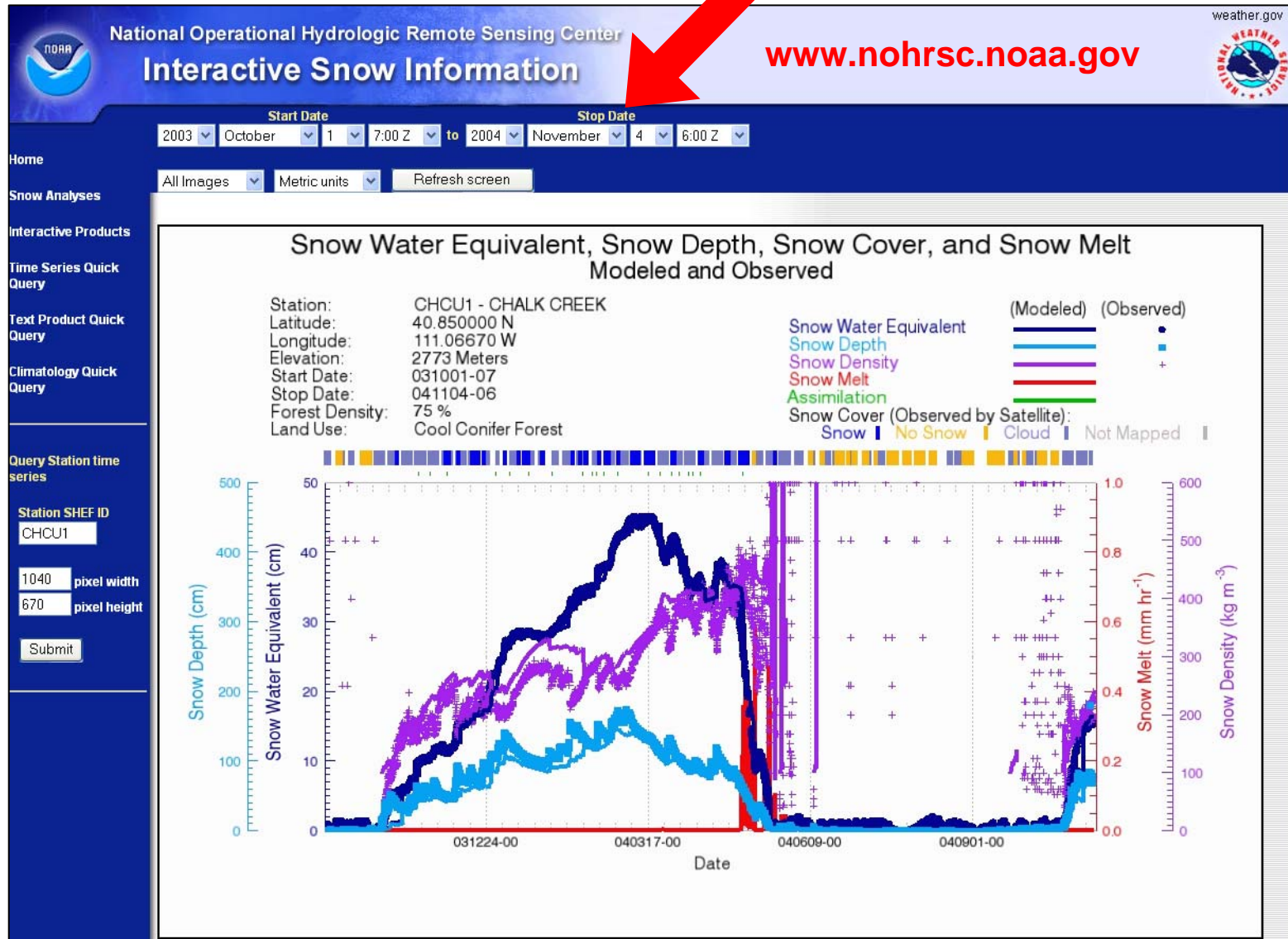
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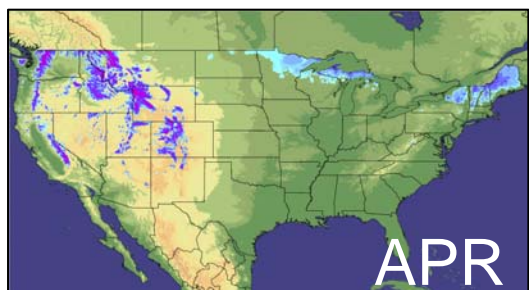
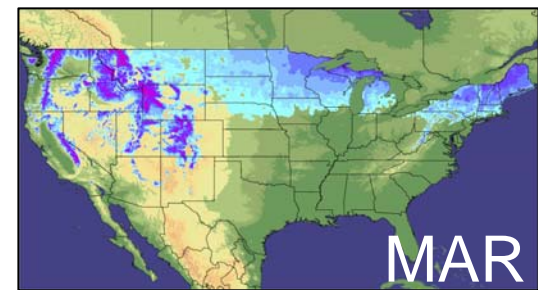
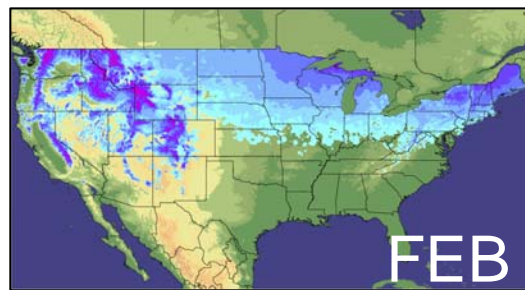
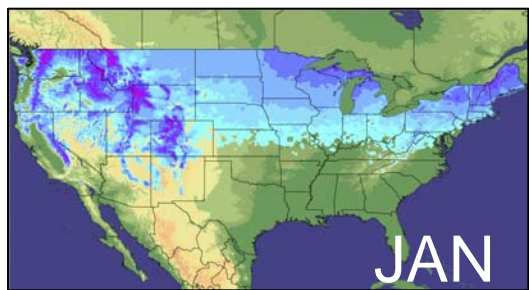
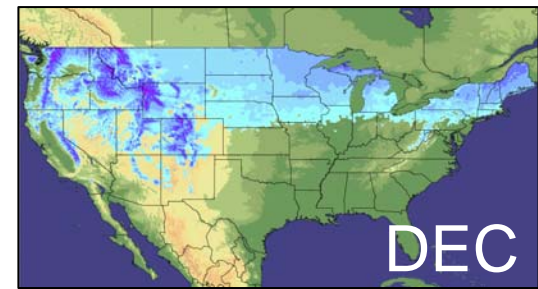
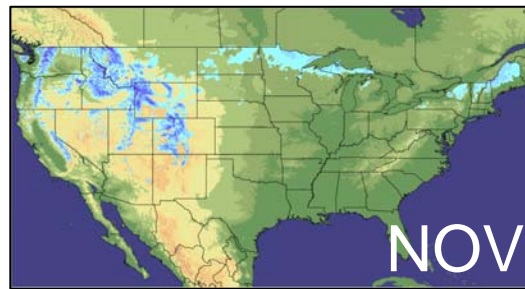
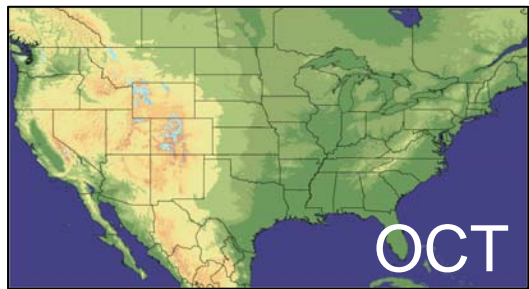


# New Climate Diagnostic Tools

- **Interactive climatological information in SNOW-Info**
  - New capability added this year
- **Two types of information**
  - **Maps: Monthly Normal Snow Depth**
    - NCDC 1961-1990 Climate Atlas for U.S.
      - October through April
      - 4 km resolution
      - Based on 5525 stations used in the NCDC U.S. Snow Climatology (TD-9641M)
        - » Note: Completed through 1996; when complete to 2000 normals maps for 1971-2000 can be produced
    - **Stations: Daily Snow Depth Climatologies**
      - NCDC TD3200 Cooperative Summary of the Day
        - 4000 first-order and cooperative observer stations
        - SNOW-Info database currently extends to 1970, eventually to 1948

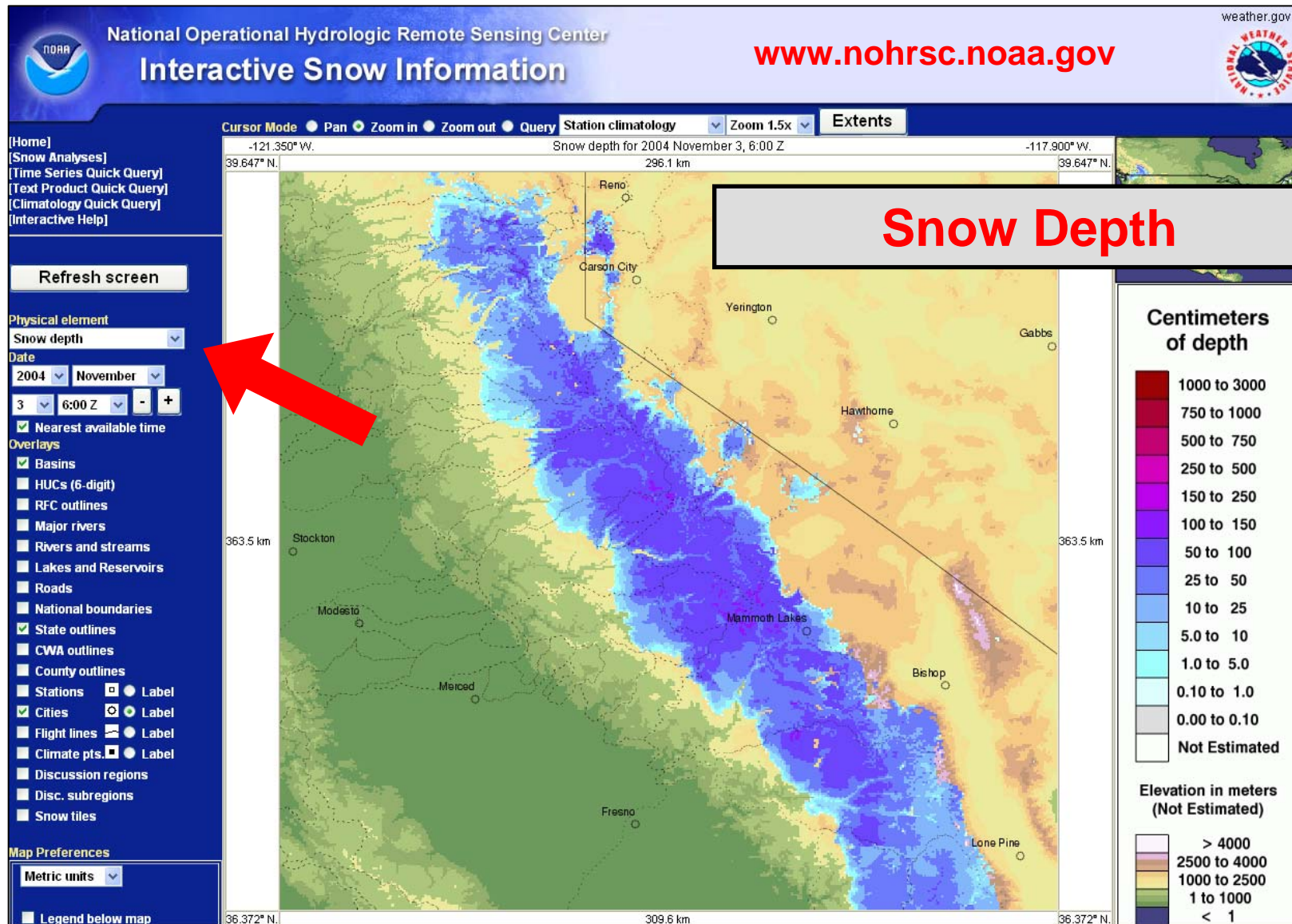
# New Climate Diagnostic Tools

## Monthly Normal Snow Depth 1961-1990

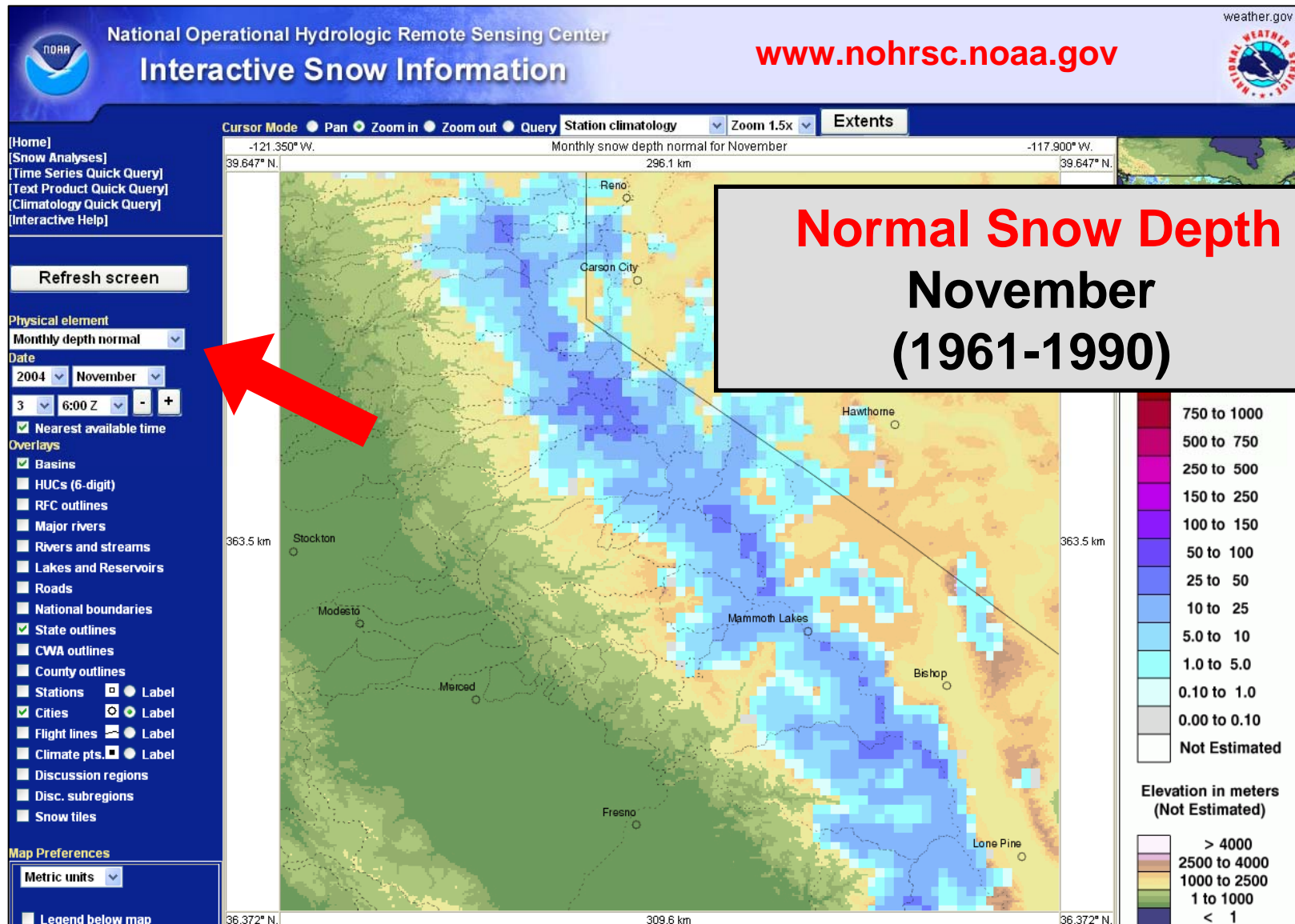


- SNOW-Info includes
  - monthly normals maps
  - daily NSA departure-from-normal maps

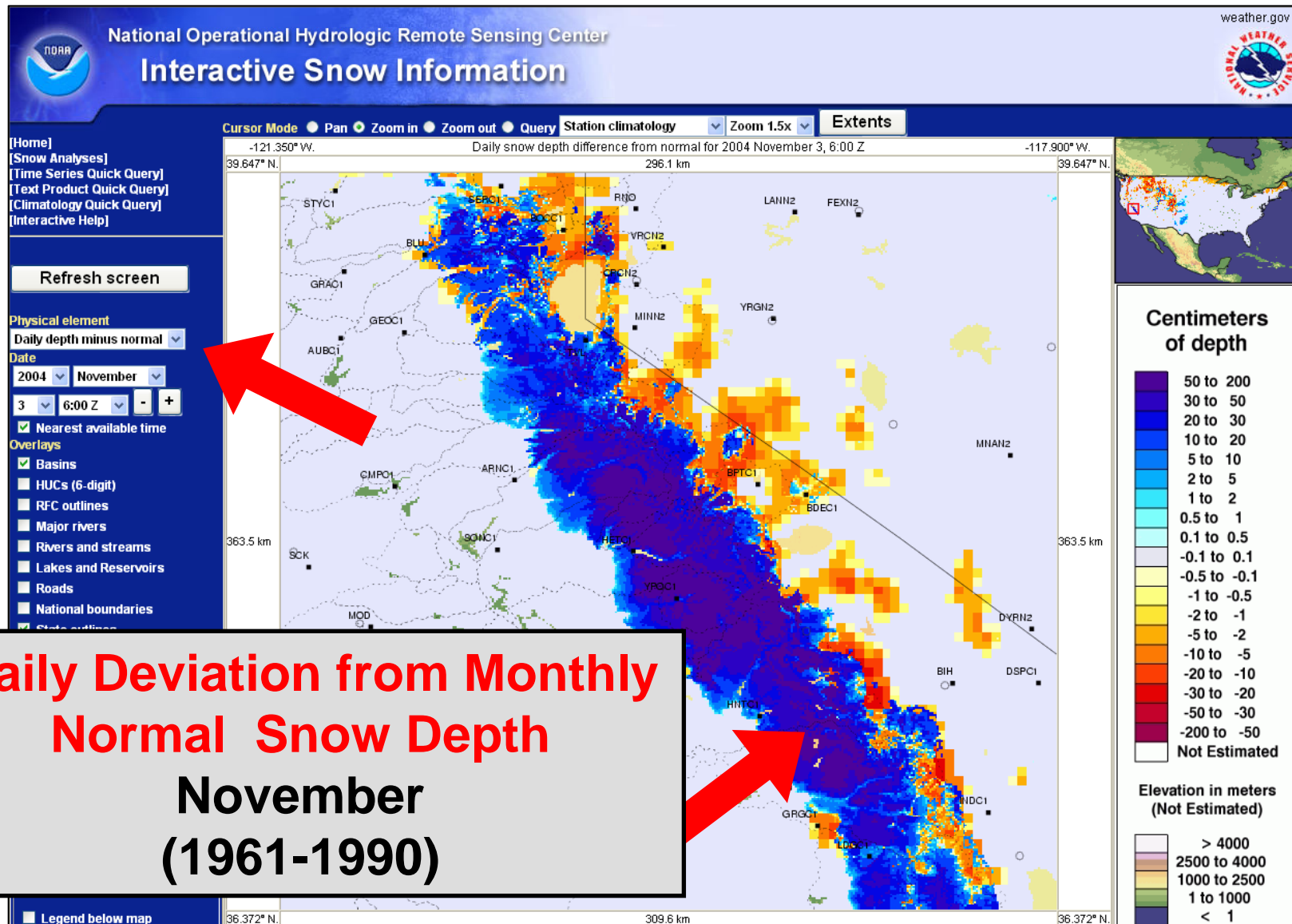
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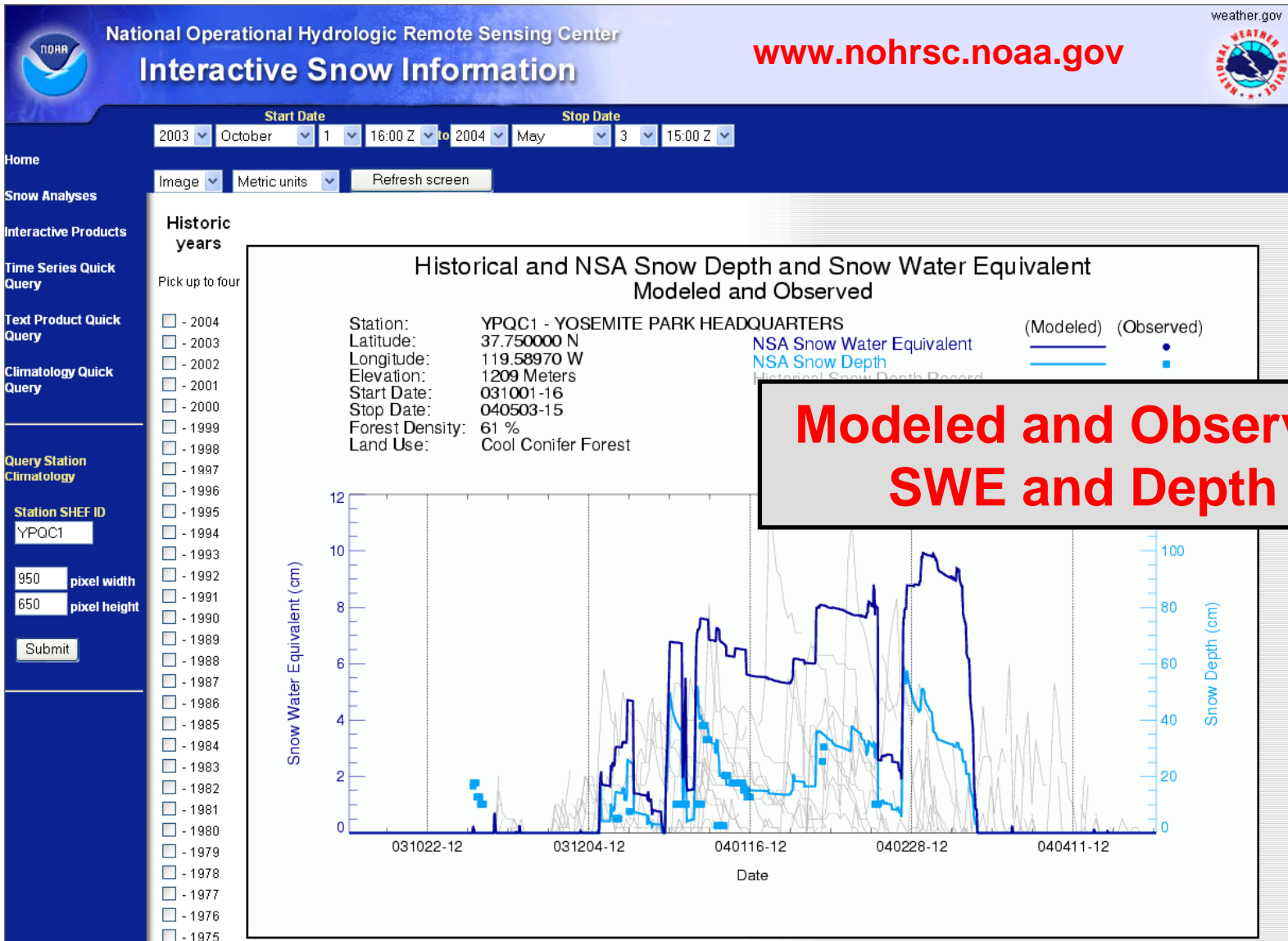
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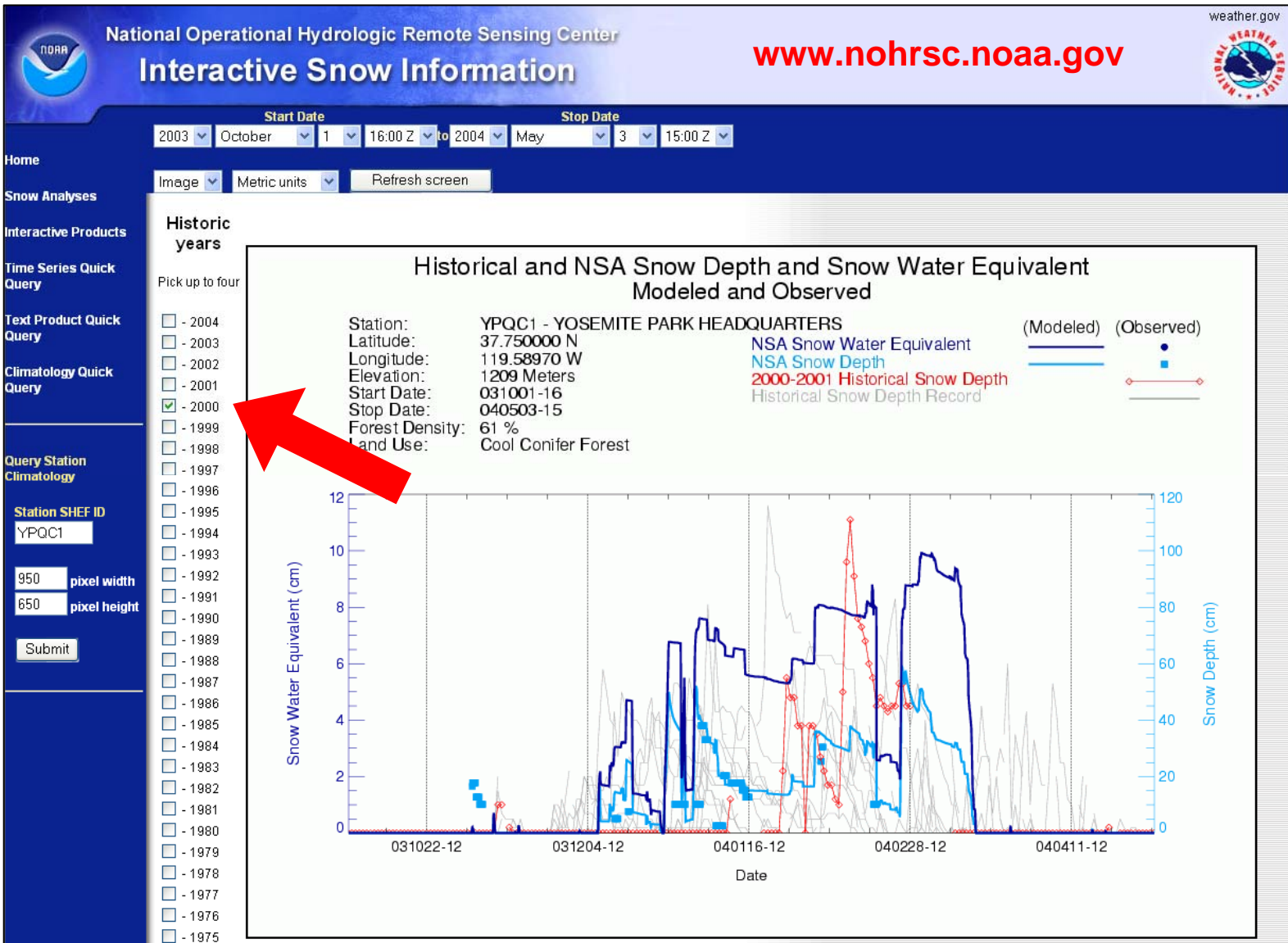
# New Climate Diagnostic Tools



# New Climate Diagnostic Tools



# New Climate Diagnostic Tools



# Summary

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  - Snow modeling and data assimilation system for U.S.
    - Overview of the data, modeling framework and products
  - New Snowpack SHEF Products
- **Interactive Snow Information System (Snow-Info)**
  - Web-based mapping and data querying system for NSA information
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- **New Climate Diagnostic Tools in Snow-Info**
  - Monthly normal snow-depth maps for U.S.
  - Daily departure-from-normal snow-depth maps for U.S.
  - Snow-depth climatology and NSA time-series for 4000 stations



***Thank You !***

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