NOHRSC – National Operational Hydrologic Remote Sensing Center

NOHRSC Overview

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Operations Manager & Chief Snow Survey
NOHRSC Mission

To support the National Weather Service’s mission by producing the best estimate of snow water equivalent using all available data including satellite, airborne, and in-situ observations to protect life and property and the enhancement of the national economy.
• In excess of 70% of Western States runoff originates in the snowpack
• The economic value of snowmelt is estimated at $350B/Yr
• Winter Tourism is $8 Billion / Yr industry

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

Snow Removal Exceeds $2 billion/ Yr

Road closures that cause lost retail trade, wages, and tax revenue exceeds $10 billion / day

Snowmelt Flooding – $4.3 Billion Red River of the North Flood 1997

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

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

“... investments that make only modest improvements in snow information will have substantial economic payoffs.”
# Who uses our information?

<table>
<thead>
<tr>
<th>National Weather Service</th>
<th>Federal and State Agencies</th>
<th>Private Sector</th>
<th>Canadian</th>
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<td>- 13 River Forecast Centers</td>
<td>- U.S. Army Corps of Engineers</td>
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<td>- New York Department of Environmental Protection</td>
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</tbody>
</table>
• PRODUCTS
  • Hourly and Daily
  • 1 km² Resolution

• INTERNET
  • Interactive Maps
  • 3D Visualization
    • e.g. Google Earth
  • Time-series loops
  • National/Regional Discussions
  • Text summaries by watershed
  • Point Queries

• DIRECT FEED
  • Push or Pull
  • Gridded Data
  • Flat Binary or GIS-ready
National Snow Analysis

Multi-sensor Snow Observations
- Ground
- Airborne
- Satellite

Snow Modeling and Data Assimilation
- Numerical Weather Prediction Model
- Gridded Snow Characteristics
  - U.S.
  - 1-km²
  - Hourly

Snow Information Products
- Data Products
- Interactive Maps
- Time Series Plots
- Text Discussions

NOHRSC
National Snow Analysis

Multi-sensor Snow Observations

Ground

Airborne

Satellite

• 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 and Surveys
  – State Mesonets
  – CoCoRAHS
  – MesoWest (150 smaller mesonets)

• International Agencies
  – St. John River Basin
  – Environment Canada
  – BC Hydro

Over 58,000 Current Reporting Stations / over 145,000 in NOHRSC database
National Snow Analysis

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
NOHRSC Airborne Mission

• Collect airborne gamma snow water equivalent and soil moisture data
  – Where no other data are available
  – To augment existing low density ground observation networks
• Critical to the NWS water program
  – Spring snowmelt-driven flood forecasts and water supply outlooks
  – Assimilated into NOHRSC snow model
  – Used qualitatively and quantitatively by River Forecast Center flood forecast models
  – USACE, New York City Department of Environmental Protection, and other Federal, State, and Local river forecasting and water resource decision support systems are dependent upon these data
• Supports NOAA and NWS Strategic Plan water resources objectives
Airborne Data Fills Data Voids

Red River Basin of the North Snow Water Equivalent Observations
Snow Season 2012-2013
Real Time Soil Moisture Observations

Limited Soil Moisture Information
National Snow Analysis

Multi-sensor Snow Observations

Ground

Airborne

Satellite

Airborne Snow Survey Program Flight Line Network

2,568 Flight Lines
37 States, 9 Provinces

- Typical year request 1300 hours
- Allocation of ~ 900 hours
- Fly ~ 1500 flight lines.
- Regions flown are based on risk of loss of life and property.

295 Flight Lines
## Survey Aircraft

### N45RF Jet Prop Commander
- **Type:** 1985 Jet Prop Commander AC-695A (#96089)
- **Engines:** Garrett TPE-331-10 (turboprop) 800 HP each
- **Crew:** 2 pilots, co-pilot acts as snow system operator
- **Ceiling:** 35,000 ft (pressurized)
- **Rate of Climb:** 2,800 fpm
- **Operational Speeds:** 120-250 kts (138-288 mph)
- **Max Gross Weight:** 11,250 lbs
- **Dimensions:** Wing span (52’), length (43’), tail (14’ 11”)
- **Fuel Load/Type:** 482 gallons / Jet-A

### N46RF and N48RF DeHavilland Twin Otter (DHC-6)
- **Type:** De Havilland DHC-6 Twin Otter, Series 300
- **Engines:** United Aircraft of Canada Limited PT6A-27 (turboprop)
- **Crew:** 2 pilots, co-pilot acts as snow system operator
- **Ceiling:** 12,500 ft (w/o supplemental O₂) 25,000 ft (with O₂)
- **Rate of Climb:** 1600 fpm
- **Operational Speeds:** 80-160 kts (104-170 mph)
- **Max Gross Weight:** 12,500 lbs
- **Dimensions:** Wing span (65’), length (52”), tail (19’ 6”)
- **Fuel Load/Type:** 2500 gallons / Jet A
Natural Terrestrial Gamma Radiation

- Atmospheric Radon
- Cosmic Radiation
- Potassium, Uranium, and Thorium
- no snow
Potassium, Uranium, and Thorium

Pure, uncollided gamma radiation

Radiation absorbed by water mass in snow pack

Natural Terrestrial Gamma Radiation

snow cover conditions
Typical Flight Line

10 miles long by 1,000 feet wide
(2 square mile area)
Airborne measurements integrate shallow and deep snow packs.
Airborne measurements integrate soil moisture over varying soil conditions.
Ground ice 2 to 4 inches thick also acts like snow water equivalent.
National Snow Analysis
Soil Moisture Fall 2015

444 Line Flown
248 Hours Flown
Record flooding occurred in Lower Michigan during the month of April 2014

The Muskegon River at Evart, Michigan reached record crest

The Muskegon River at Croton, Michigan reached second highest crest feet

The flooding along the Muskegon River impacted over 410 properties and caused over 1 million dollars in flood damages.

No fatalities and only 5 injuries were reported for this event. Over 280 households had to be evacuated and over 100 roads closed due to flooding.
Summary: This proposal identifies critical investments in soil moisture and snowpack monitoring in the Upper Missouri River Basin and plains, in order to reduce flood risk and improve river and water resource management in the Basin. This enhanced monitoring network will require a $6.25 million capital investment and approximately $1.5 million in annual operations. Decision makers will take the next step by determining funding sources and implementation priorities for the enhanced monitoring network.

Background: In the spring and summer of 2011, unprecedented flooding in the Upper Missouri River Basin caused over $2 billion in direct damages and led to FEMA disaster declarations in all states along the river. The events of 2011 continued a pattern of significant flooding that has emerged over the past two decades, including The Great Flood of 1993 and another significant plains snow flood events in 1995 and 1997. In addition, the basin endured an 8-year drought ending in 2007 and is currently in the midst of another drought.

In September 2011, the Corps commissioned an independent expert review panel to examine the causes and response to the flooding. As one of its six primary recommendations, the panel identified the need for better monitoring information across the Great Plains, particularly regarding snow water equivalent (SWE) and soil moisture.

Technical Review: Pursuant to the independent review, from September to December of 2012, a team of monitoring experts from across the region developed a technical report titled Snow Sampling and Instrumentation Recommendations.1 The report is built around three components:

1) Inventory: The team conducted an inventory of existing federal, state, and volunteer networks to measure weather, snowpack and soil moisture (Figure 1);

2) Gap Assessment: The team identified gaps in monitoring, including gaps in geographic coverage and monitoring capabilities for key parameters; and

3) Monitoring Recommendations: The team sought to identify what will be needed to meet forecasting and monitoring goals for the Upper Missouri River Basin. They considered how to maximize the use of existing resources to develop the pragmatic solution described here.

Monitoring Proposal: The proposal endorses three approaches to enhance data collection: 1) automated measurements; 2) manual snow sampling; and 3) aerial snow surveys. The proposed network would consist of both new and retrofitted weather stations managed by a combination of state and federal entities.

• Automated Measurements: Existing automated monitoring networks include the NRCS Soil Climate Analysis Network (SCAN), the NRCS Snowpack Telemetry (SNOTEL) Network, and the states’ Automated Weather Data Network (AWDN) sites. The proposal includes upgrades to 92 existing network sites as well as the addition of 29 new AWDN sites across South Dakota, Montana, and Wyoming. (See Figure 1.)

• Aerial Water Resource Surveys: The National Weather Service runs the Airborne Snow Survey Program, which can cover large regions and sample remote areas. Currently, the program runs just over 60 flight lines in the Upper Missouri Basin.

Photo: Missouri River Flood, 2011, Bismarck-Mandan.

1 Released February 1, 2013. The full proposal, including descriptions of the various existing and proposed monitoring platforms as well as detailed budgets, is available for review.

38 new flight lines added summer 2014
Yesterday, NOAA pilots detailed to the National Operational Hydrologic Remote Sensing Center performed an airborne survey of the snow over western New York. They measured up to 6 inches of water contained within the snow. They also provided the photos below.

The US National Weather Service Buffalo NY has issued flood statements for the possible melting of some of this snow pack in the next couple of days.

We are grateful for NOHRSC’s support this weekend as they typically do not fly snow surveys this early in the season.

Info on NOHRSC Snow Surveys can be found at http://www.nohrsc.noaa.gov/snowsurvey/

Information on flood statements can be found at http://www.weather.gov/nerfc/flood

Latest forecasts are available at http://water.weather.gov/ (4 photos)
Buffalo, NY Lake Effect Snow Event Nov. 2014
National Snow Analysis

Multi-sensor Snow Observations

Ground

Airborne

Satellite

EOS Terra MODIS
Sierra Nevada, Mar 7 2004

Fractional Snow Cover

SCA_{frac} = 0.5

MODSCAG Algorithm, images courtesy of T. Painter, U. Utah
Observations alone are not enough!
National Snow Analysis

Multi-sensor Snow Observations

Snow Modeling and Data Assimilation

Snow Information Products

Ground

Airborne

Satellite

Numerical Weather Prediction Model Forcings

Gridded Snow Characteristics

U.S.

1-km²

Hourly

Data Products

Interactive Maps

Time Series Plots

Text Discussions

NOHRSC
NOHRSC Snow Model Physics

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

- **Atmosphere**
  - **Solar**
  - **Reflected Solar**
  - **Incident/Emitted Longwave**
- **Radiative Energy Exchanges**
- **Precipitation**
  - **Snow**
  - **Rain**
- **Snow Layers (3)**
  - **MELTING**
  - **Snow Compaction**
- **Snow Pack Temperature Profile**
- **Melt Flow**
- **Thermally Active Soil Layers (2)**
  - **MELTING**
  - **REFREEZING**
  - **Conduction**
- **Turbulent Energy Exchanges**
  - **Sensible and Latent Heat Sublimation/Condensation**
  - **Blowing Snow (Sublimation Losses)**
  - **Canopy Wind Reduction**
Snow Modeling Framework

1. Hourly Input
   - Numerical Weather Models (1 km)
     - Temperature
     - Relative Humidity
     - Wind Speed
     - Solar Radiation
     - Atmos. Radiation
     - Precipitation
     - Precipitation Type

   - GIS Data (1 km)
     - Soils Properties
     - Land Use/Cover
     - Forest Properties

2. Snow Energy and Mass Balance Model
   - Blowing Snow Model
     - Radiative Transfer Model
       - State Variables for
         - Multiple Vertical
         - Snow & Soil Layers
         - Snow Water Equivalent
           - Snow Depth
           - Snow Temperature
           - Liquid Water Content
           - Snow Sublimation
           - Snow Melt

3. Data Assimilation
   - Snow Observations
     - Snow Water Equivalent
     - Snow Depth
     - Snow Cover

   - NSA Product Generation
     - Interactive Maps
     - Digital Data
     - Discussions
Snow Observational Assimilation

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

If pattern of differences is explainable, an update field is generated and used to nudge the model toward observed states.

- Uncertainties in driving data
  - RUC2 precipitation under/over estimation
  - Typing issue; rain/ snow
  - Placement of storm track

- Uncertainties due to model physics
  - Melt problems due to temperature bias
  - Sublimation rates
Assimilation Example
Best Estimate of SWE
### Airborne Snow Water Equivalent

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<td>LEWIS EAST</td>
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</tr>
<tr>
<td>1630</td>
<td>LEWIS WEST</td>
<td>3.8</td>
</tr>
<tr>
<td>2601</td>
<td>PIPESTEM RES LWR</td>
<td>3.4</td>
</tr>
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<td>2605</td>
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<td>2606</td>
<td>LAMOURE</td>
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<td>2609</td>
<td>COLUMBIA</td>
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<td>2610</td>
<td>STRATFORD WEST</td>
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<tr>
<td>2611</td>
<td>STRATFORD EAST</td>
<td>4.4</td>
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Airborne Snow Water Equivalent

SRUS43 KMSR 231924

.SR SWE

.BR MSP 010223 DM022323/DC02231924 /SWIPZ

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ESTIMATED SNOW WATER EQUIVALENT (INCHES)

COMPOSITE ANALYSES 01021401 - 01022323

BASIN NAME

1604 ATLANTIC
1605 LEWIS EAST
1630 LEWIS WEST
2601 3.4 PIPESTEM RES LWR
2605 3.1 PIPESTEM RES UPR
2606 3.3 LAMOURE
2607 3.9 WESTPORT
2609 3.0 COLUMBIA
2610 4.6 STRATFORD WEST
2611 4.4 STRATFORD EAST

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RFC NWSRFS Snow Model

Imported
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

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

Multi-sensor Snow Observations

- Ground
- Airborne
- Satellite

Snow Modeling and Data Assimilation

- Gridded Snow Characteristics
- Numerical Weather Prediction Model
- U.S. 1-km² Hourly

Snow Information Products

- Data Products
- Interactive Maps
- Time Series Plots
- Text Discussions
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.
Modeled Snow Water Equivalent for 2014 November 11, 12:00 UTC

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 on the map 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.

Vector GIS Datasets used by this page
Raster GIS Datasets used by this page
Physical Element Map Options
Questions?

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NOHRSC

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Chanhassen, MN

952-368-2503

www.nohrsc.noaa.gov
Mission Statement

The National Operational Hydrologic Remote Sensing Center (NOHRSC) produces modeled hydrology products for the enhancement of the national economy, environment, and safety. NOHRSC airborne, satellite, and ground-based remote sensing data are used along with estimates and observations to generate operational, daily NOHRSC snowpack analyses and forecasts. NOHRSC snowpack products allow water managers, emergency managers, and other end-users to make informed decisions that save lives and property.

Overview

The National Operational Hydrologic Remote Sensing Center (NOHRSC) produces snowpack products for the enhancement of the national economy, environment, and safety. NOHRSC airborne, satellite, and ground-based remote sensing data are used along with estimates and observations to generate operational, daily NOHRSC snowpack analyses and forecasts. NOHRSC snowpack products allow water managers, emergency managers, and other end-users to make informed decisions that save lives and property.

A look at the importance of snow information

Under the umbrella of the NWS, the National Snow Analysis (NSA) provides valuable snow accumulation information.

Water from melting seasonal snowpacks is a critical water resource in many mid-latitude regions of the world. In western USA, snowmelt from mountain basins has historically provided 70-90% of the annual runoff, and the winter snowpack acts as a reservoir to store water for spring and summer delivery to soils and streams. Studies have estimated the economic impact of snow in the USA at several hundred billion dollars per year. The value of water from spring snowmelt can exceed US$348 billion per year. The value of snow-related tourism in the USA exceeds US$7.9 billion per year, and snow removal from streets and highways in the USA exceeds US$2 billion annually.

Given the significant impact that snow can have on our lives and communities, there is an obvious need to monitor the snowpack accurately and consistently to meet a broad range of user interests and requirements. The National Weather Service (NWS), which issues river and flood forecasts, and provides hydrometeorological data and products to support the nation’s water resource managers, established the National Operational Hydrologic Remote Sensing Center (NOHRSC) in Chanhassen, Minnesota, as its center of expertise in satellite and airborne remote sensing and geospatial data analysis.
Interactive Snow Information

Change in Modeled Snow Water Equivalent during 24h preceding 2014 November 11, 6:00 UTC

Directions:
- Select a physical element to view, select a date, select overlays, and click "Redraw Map."
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Vector GIS Datasets used by this page
Raster GIS Datasets used by this page
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Vector GIS Datasets used by this page
Raster GIS Datasets used by this page
24 hour Total Melt
Forecasted Snow Precipitation

Total Modeled Snow Precipitation forecasted for 24h preceding 2014 November 13, 6:00 UTC
Latest Snow Depth Observed during 24h preceding 2014 November 11, 12:00 UTC

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.
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Vector GIS Datasets used by this page
Raster GIS Datasets used by this page
Integrated Modeled / Observed Snowpack State Variables

Daily Basin-by-Basin NSA Products Shipped to Web

6,500 NWS forecast basins
# BASIN-BY-BASIN SNOW SUMMARY FOR MBRFC

**SNOW WATER EQUIVALENT ANALYSIS (MODEL + OBSERVATIONS)**

February 9, 2010 02 Z

**NATIONAL OPERATIONAL HYDROLOGIC REMOTE SENSING CENTER**
Office of Climate, Water, and Weather Services
NATIONAL WEATHER SERVICE, NOAA
CHANHASSEN, MN 55317

URL: www.nohrsc.noaa.gov  Phone: 952-361-6610  Fax: 952-361-6634

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Done
Model Adjustments:

A data assimilation as done across the upper Rio Grande through the Plains to Tennessee River basin on December 9. Our model over-produced snowfall from the most recent storm in this region, and there was some mis-tying of precipitation. Three-quarters to 1 1/4 inches of water was removed from the modeled snowpack in Kansas through western Missouri. One-half to 3/4 inch of water was also removed from the Llano Estacado and Caprock. Up to an inch of water was removed from Arkansas through western Tennessee.
Basin Snow Cover Analysis

Modelled

SHEF ID: 821 - ROCK RIVER NR LUVERNE MN
RFC Name: MBRFC
Start Date: 2010-02-04 06
Stop Date: 2010-03-11 06
Basin Area: 420 sq. mi
(420 sq. mi modeled)

Average Modeled SWE
Min/Max Modeled SWE
Average Modeled Snow Depth
Min/Max Modeled Snow Depth
Modeled Percent Snow Cover
(Overlapping SWE and Snow Depth)

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Snow Analysis Highlights

Wednesday, November 12, 2014

Snow Model Status: The model analysis is out to Wednesday, 2014-11-12 1800 UTC. The daily model forecast is out to Saturday, 2014-11-15 0600 UTC.

more ...

Website News

We have recently enabled native support for CoCoRaHS station identifiers. If you are looking for observations for a CoCoRaHS station, it will be listed and be accessible by its CoCoRaHS identifier, and no longer by its MADIS ID (i.e. #######_MADIS).
50.4 % of CONUS snow covered on November 17, 2014.
move toward the Middle Atlantic coast. Four to 8 inches of snow are likely in the southern Great Lakes region, with up to a foot possible in northern Virginia through central Maryland. Light freezing rain is possible on the southern side of this snowband, roughly from western North Carolina through eastern Maryland.

Rapid deepening of the combined low will continue as the low moves offshore by Thursday. A foot of snowfall is likely over a small area of the East Coast, roughly from northern Virginia through eastern Massachusetts. At least 4 inches of snowfall is likely from Lake Erie through southern New Hampshire, south to eastern Virginia and in West Virginia. The system will be far enough to see that little precipitation is expected on Thursday.

A weak surface low will move into the Southwest from the Pacific today and bring up to a half-foot of snowfall to the southern Sierra Nevada. Widespread light precipitation is expected across the Southwest tomorrow. By Thursday, the low and its associated upper trough will move into the southern Plains, and a surface low is expected to spin up in the northwestern Gulf Coast. Sufficiently-cold air will be in place over the southern Plains to cause up to 1/2 foot of snowfall along the lower Red River on Thursday, with 1/2 to 1 inch of rainfall possible farther south from eastern Texas through Mississippi. This system will move eastward across the northern Gulf during the rest of the week and is expected to hook northeastward to the East Coast by the weekend.

### Snow Reports

#### Top Ten:

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Name</th>
<th>Elevation (feet)</th>
<th>Snowfall (in)</th>
<th>Duration (hours)</th>
<th>Report Date / Time (UTC)</th>
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<tbody>
<tr>
<td>LCVP1</td>
<td>LAUREL CAVERNS</td>
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<td>AGRF5</td>
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Note: these data are unofficial and provisional. Zip codes (where available) of observations will be included in text files after October 7, 2008.

Station Snowfall Reports
Station Snow Water Equivalent Reports
Station Snowdepth Reports

### Model Assimilation

A data assimilation as done across the upper Rio Grande through the Plains to Tennessee River basin on December 9. Our model over-produced snowfall from the most recent storm in this region, and there was some mis-typing of precipitation. Three-quarters to 1 1/4 inches of water was removed from the modeled snowpack in Kansas through western Missouri. One-half to 3/4 inch of water was also removed from the Llano Estacado and Caprock. Up to an inch of water was removed from Arkansas through western Tennessee.

### NOHRSC Airborne Snow Survey Program

The Airborne program has no scheduled flights in this region for the week of February 08, 2010.
Observations Near Chanhassen, MN

Nearest observations to Chanhassen, MN
44.86°N, 93.53°W (Elevation: 974 ft)

Raw Snowfall Observations

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<thead>
<tr>
<th>Station ID</th>
<th>Name</th>
<th>Elev. (ft)</th>
<th>Raw Snowfall (in)</th>
<th>Duration (hours)</th>
<th>Date (UTC)</th>
<th>Distance</th>
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<tbody>
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<td>MN-CV-14</td>
<td>CHANHASSEN 1.0 ESE, MN</td>
<td>915</td>
<td>1.10</td>
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<td>2014-11-13</td>
<td>1.3 mi SW</td>
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<tr>
<td>MPXM5</td>
<td>CHANHASSEN WSFO</td>
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<td>24</td>
<td>2014-11-12</td>
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<td>MN-HN-86</td>
<td>EDEN PRAIRIE 3.1 ESE, MN</td>
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<td>6.7 mi ESE</td>
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<td>MN-CV-1</td>
<td>CARVER 0.7 W, MN</td>
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Snow Depth Observations

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<th>Distance</th>
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<td>MN-HN-19</td>
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Snow Water Equivalent Observations

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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
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NOHRSC Snow Model Snapshot
2011-01-12

- Snow Water Equivalent
- Scaled Snow Precipitation
- Scaled Non-Snow Precipitation
- Average Snowpack Temperature
- Snow Melt
- Snow Cover
- Snow Depth
- Snow Density
- Snow Water Equivalent
- Surface Sublimation / Condensation
- Blowing Snow Sublimation