NOAA’s National Snow Analyses

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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)

<table>
<thead>
<tr>
<th>Economic Benefits of Snow</th>
<th>Economic Costs of Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter tourism</strong></td>
<td><strong>Snow removal</strong></td>
</tr>
<tr>
<td>Exceeds $8 billion / yr</td>
<td>Exceeds $2 billion / yr</td>
</tr>
<tr>
<td>New England and Rocky Mountains</td>
<td>U.S.</td>
</tr>
<tr>
<td><strong>Cold water fishing (snow is cold water source)</strong></td>
<td><strong>Road closures that cause lost retail trade, wages, and tax revenue</strong></td>
</tr>
<tr>
<td>Exceeds $2.3 billion / yr</td>
<td>Exceeds $10 billion / day</td>
</tr>
<tr>
<td>New England</td>
<td>Eastern U.S.</td>
</tr>
<tr>
<td><strong>Snowpack water storage</strong></td>
<td><strong>Flight delays</strong></td>
</tr>
<tr>
<td>Up to $348 billion / yr</td>
<td>$3.2 billion / yr</td>
</tr>
<tr>
<td>Western U.S.</td>
<td>U.S. carriers</td>
</tr>
<tr>
<td></td>
<td><strong>Damage to utilities</strong></td>
</tr>
<tr>
<td></td>
<td>Up to $2 billion / event</td>
</tr>
<tr>
<td></td>
<td><strong>Flooding from snowmelt</strong></td>
</tr>
<tr>
<td></td>
<td>$4.3 billion</td>
</tr>
<tr>
<td></td>
<td>1997 U.S. floods</td>
</tr>
</tbody>
</table>

“... 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.”

### Authors

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  U.S. Dept. of Commerce

NOAA’s National Snow Analyses  www.nohrsc.noaa.gov
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
- Ground
- Airborne
- Satellite

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

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

NOAA's National Snow Analyses  www.nohrsc.noaa.gov
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

Over 30,000 reporting stations

Snow Water Equivalent and Snow Depth

Federal, state, & private sources

BC Hydro SNOTEL

NRCS SNOTEL & Snow Course

CDWR SNOTEL

NWS COOP OBS
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

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

NOAA's National Snow Analyses  www.nohrsc.noaa.gov
Natural Terrestrial Gamma Radiation

- Background (no snow) spectrum
- Over snow spectrum
- $^{40}$K peak
- $^{208}$Tl peak

Counts/min vs. Energy (MeV)

- Background spectrum is one-time measurement
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

NOAA's National Snow Analyses  www.nohrsc.noaa.gov
National Snow Analyses (NSA)

Multi-sensor Snow Observations

Ground

Airborne

Satellite

Alaska Flight Line Network

191 Flight Lines
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)

## Multi-sensor Snow Observations
- **Ground**
- **Airborne**
- **Satellite**

## Advanced Very High Resolution Radiometer (AVHRR)

### Fractional Snow Cover

<table>
<thead>
<tr>
<th>100%</th>
<th>80%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>50%</td>
<td>20%</td>
</tr>
<tr>
<td>50%</td>
<td>20%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Percent Snow Cover

1 km 1 km 1 km 1 km
National Snow Analyses (NSA)

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

NOAA's National Snow Analyses

www.nohrsc.noaa.gov
# National Snow Analyses (NSA)

<table>
<thead>
<tr>
<th>Features</th>
<th>Major Products</th>
<th>Product Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy-and-mass-balance snow model</td>
<td>Snow water equivalent</td>
<td>National and regional map animations</td>
</tr>
<tr>
<td>Implemented for CONUS only</td>
<td>Snow depth</td>
<td>Interactive map: user selects time and place</td>
</tr>
<tr>
<td>Run at hourly time steps</td>
<td>Average snowpack temperature</td>
<td>Alphanumeric text: spatial averages</td>
</tr>
<tr>
<td>1 km² spatial resolution</td>
<td>Snowmelt</td>
<td>Time-series: modeled and observed</td>
</tr>
<tr>
<td>Incorporates all available data</td>
<td>Snowpack sublimation and condensation</td>
<td>Gridded: GIS and spatial applications</td>
</tr>
<tr>
<td>Generates hourly and daily snow products</td>
<td>24-hour change products</td>
<td>Text discussions on snowpack conditions</td>
</tr>
</tbody>
</table>
National Snow Analyses (NSA)

Snow Modeling and Data Assimilation

- **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

\[(K_{\downarrow} - K_{\uparrow}) + (L_{\downarrow} - L_{\uparrow}) + Q_e + Q_h + Q_g + Q_p = \Delta Q\]

**Atmosphere**

- **radiative energy exchanges**
  - solar
  - incident/emitted longwave
  - reflected solar
  - albedo

**Precipitation**

- snow
- rain

**Snow Layers (3)**

- melting
- refreezing

**Snow Pack Temperature Profile**

**Thermally Active Soil Layers (2)**

- melt flow
- conduction

**Canopy Wind Reduction**

**Blowing Snow (Sublimation Losses)**

**Sensible and Latent Heat Sublimation/Condensation**

**Turbulent Energy Exchanges**

**Canopy Shortwave Reduction**

**Temperature**

**Humidity**

**Vapor**
NOHRSC Operations

Ground-based Snow Data
- METAR, SNOTEL, CADWR, HADS, NWS Coop, etc.

Airborne Snow Water Equivalent

Satellite Snow Cover Data
- GOES, AVHRR, SSM/I, MODIS

NEXRAD Radar Data

Numerical Weather Model Data
- Eta, RUC2, MAPS

NOHRSC Database Management System
- Data ingest, quality control, pre-processing

Data and Product Archive

NOHRSC Snow Data Assimilation System
- Energy-and-mass-balance snow modeling and observed snow data assimilation

Product Generation and Distribution

Elements:
- Daily National Snow Analyses:
  - (water equivalent, snow depth, temperature, sublimation, condensation, snow melt)

Formats:
- Interactive map, time-series plots, text discussions, alphanumeric and gridded products

Distribution:
- NOHRSC Web Site, AWIPS, direct FTP, NSIDC, NCDC
Snow Modeling Framework

1. Hourly Input Gridded Data (1 km)
   - Temperature
   - Relative Humidity
   - Wind Speed
   - Solar Radiation
   - Atmos. Radiation
   - Precipitation
   - Precipitation Type

2. Data Assimilation
   - Snow Energy and Mass Balance Model
   - Blowing Snow Model
   - Radiative Transfer Model
  
3. NSA Product Generation
   - Snow Observations
     - Snow Water Equivalent
     - Snow Depth
     - Snow Cover
   - Interactive Maps
   - Digital Data
   - Discussions

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

Snow Modeling Framework

Hourly Input Gridded Data (1 km)
- Temperature
- Relative Humidity
- Wind Speed
- Solar Radiation
- Atmos. Radiation
- Precipitation
- Precipitation Type

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

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

Data Assimilation

Snow Observations
- Snow Water Equivalent
- Snow Depth
- Snow Cover

Interactive Maps
Digital Data
Discussions

NOAA's National Snow Analyses  www.nohrsc.noaa.gov
Over 30,000 Reporting Stations
National Snow Analyses (NSA)

Multi-sensor Snow Observations
- Ground
- Airborne
- Satellite

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

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

NOAA's National Snow Analyses
www.nohrsc.noaa.gov
National Snow Analyses (NSA)

Snow Information Products

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

- Snow Water Equivalent
- Snow Depth
- Snow Density
- Snow Sfc. Temperature
- Snow Avg. Temperature
- Snow Melt
- Sublimation
- Snow Wetness

Local Information (1 km²)

Continental U.S. Information

- 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

6,500 NWS forecast basins
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**

**Original Snow-17 SWE**

- Observed Stage
- Underestimated Forecast Stage

**NWSRFS updated with NOHRSC NSA data**

**Increased Snow-17 SWE**

- Corrected Forecast Stage

**Example:** Two river discharge peaks were observed but underestimated by NWSRFS
NOAA's Source for Snow Information

The National Operational Hydrologic Remote Sensing Center provides comprehensive snow observations, analyses, datasets 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.

Over 12 million hits per month
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 4900 stations nationwide using the query tool.
Interactive Snow Information System

Snow Water Equivalent

NOAA’s National Snow Analyses  www.nohrsc.noaa.gov
Interactive Snow Information System

Snow Water Equivalent

Inches of snow water equivalent

Elevation in feet (Not Estimated)

39 to 118 30 to 39 20 to 30 9.8 to 20 5.9 to 9.8 3.9 to 5.9 2.0 to 3.9

0.98 to 2.0 0.93 to 0.98 0.20 to 0.39 0.04 to 0.20 0.00 to 0.04 0.00 to 0.00 Not Estimated

> 13124 11484 to 13124 8293 to 11484 4922 to 8293 1641 to 4922 3 to 1641 < 3
Interactive Snow Information System

Snow Water Equivalent

NOAA’s National Snow Analyses  www.nohrsc.noaa.gov
Physical Element Map Options

Select Physical Element:
- Snow Water Equivalent

Hourly Snow Analyses:
- Snow Depth
- Shallow SWE
- Shallow Snow Depth
- Snowpack Temperature
- Snowpack Density

Hourly Driving Data:
- Snow Precipitation
- Non-Snow Precipitation
- Surface Air Temperature
- Solar Radiation
- Relative Humidity
- Surface Wind

Daily Snow Analyses:
- Snow Depth - Normal
- SWE Change
- Snow Depth Change
- Snow Melt
- Blowing Snow Sublim.
- Surface Sublim./Cond.
- Ave. Snow Temperature

Daily Satellite Obs.:
- Snow Cover (Percent)
- Snow Cover (Binary)
- Snow Cover (Alaska)

Climate Data:
- Freezing Degree Days
- Thawing Degree Days
- Monthly Depth Normal
- Latest Observations
  - Snow Depth (24 hrs)
  - Snow Depth (48 hrs)
  - Snow Depth (72 hrs)
  - SWE (24 hrs)
  - SWE (48 hrs)
  - SWE (72 hrs)
  - Total Snowfall (24 hrs)
  - Total Snowfall (48 hrs)
  - Total Snowfall (72 hrs)
  - Int. Total SF (24 hrs)
  - Int. Total SF (48 hrs)
  - Int. Total SF (72 hrs)
  - Raw S. Depth (24 hrs)
  - Raw SWE (24 hrs)
  - Raw Snowfall (24 hrs)
Interactive Snow Information System

24 Hour Change
Snow Water Equivalent
Interactive Snow Information System

Mean Snowpack Temperature

NOAA's National Snow Analyses  www.nohrsc.noaa.gov
Interactive Snow Information System

Station Time Series
Interactive Snow Information System

NOAA's National Snow Analyses       www.nohrsc.noaa.gov

www.nohrsc.noaa.gov
Interactive Snow Information System

Modeled

SWE

Density

Depth

Observed
Interactive Snow Information System

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

- Station: CHCU1 - CHALK CREEK
- Latitude: 40.850000 N
- Longitude: 111.06670 W
- Elevation: 9099 Feet
- Start Date: 041028-15
- Stop Date: 041103-14
- Forest Density: 75 %
- Land Use: Cool Conifer Forest

Modeled precip.
Observed precip.
Interactive Snow Information System

Snow Pack Temperature

Snowpack Density
Interactive Snow Information System
Interactive Snow Information System

Snow Melt, Sublimation, and Weather Forcing
Modeled and Observed

Station: CHCU1 - CHALK CREEK
Latitude: 40.850000 N
Longitude: 111.06870 W
Elevation: 9099 Feet
Start Date: 041028-15
Stop Date: 041103-14
Forest Density: 75%
Land Use: Cool Conifer Forest

Sublimation from Snow Surface
Sublimation from Blowing Snow
Observed Blowing Snow
Snow Melt Rate
Relative Humidity, 6-ft
Wind Speed, 33-ft (Observed)
Wind Speed, 33-ft (Modeled)
Interpolated Snowfall – last 72 hours
Interpolated Snowfall – last 72 hours
New Climate Diagnostic Tools

Daily Deviation from Monthly Normal Snow Depth
November (1961-1990)
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 Cover Extent
Snowfall
Snow Depth
Snow Water Equivalent
Snow Temperature
Snowmelt

Snow Water Equivalent

National Snow Headlines
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
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:

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