NOAA's Airborne Snow and Soil Moisture Survey and The National Snow Analysis

Office of Water Prediction
Carrie Olheiser

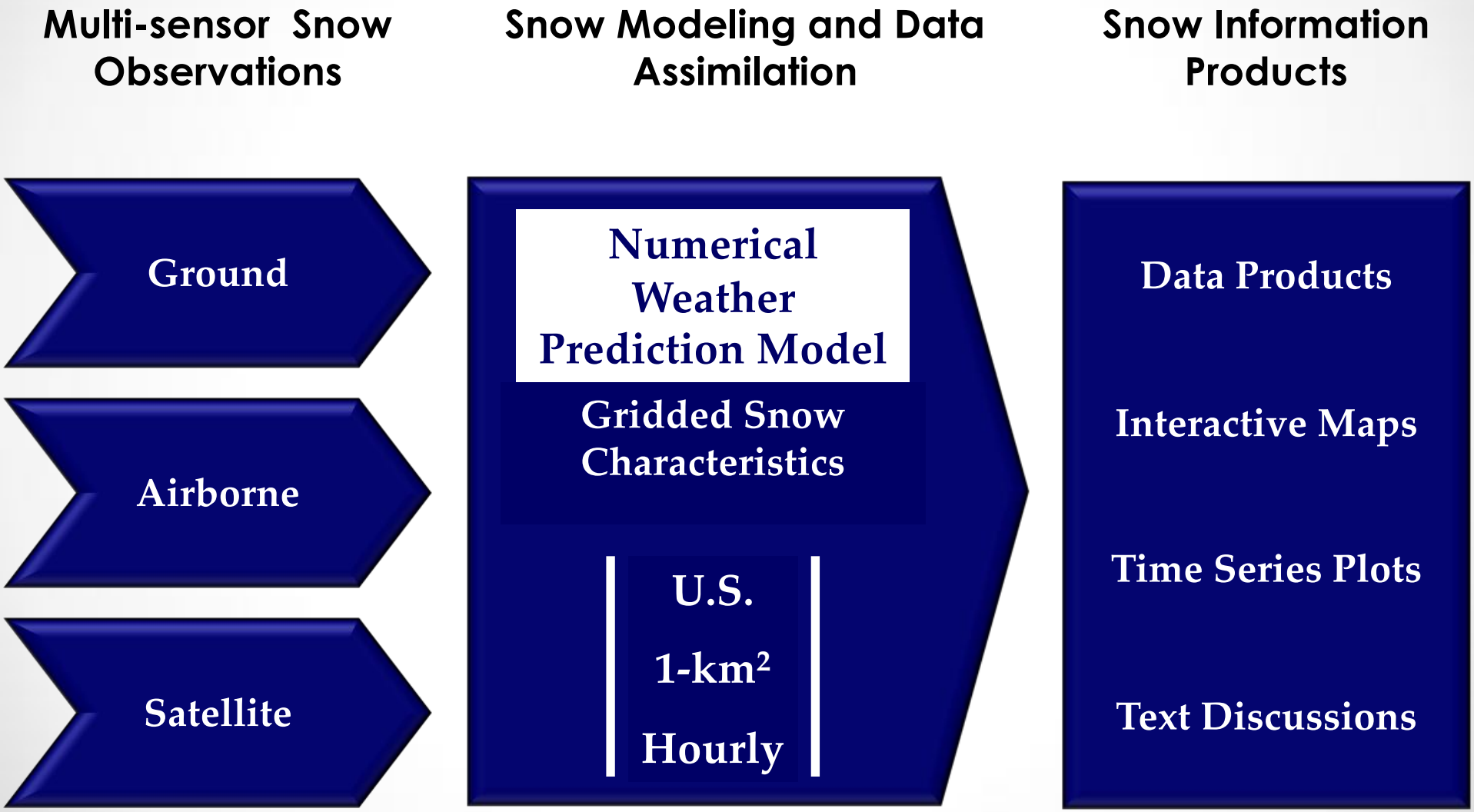
SnowEx September 18, 2019

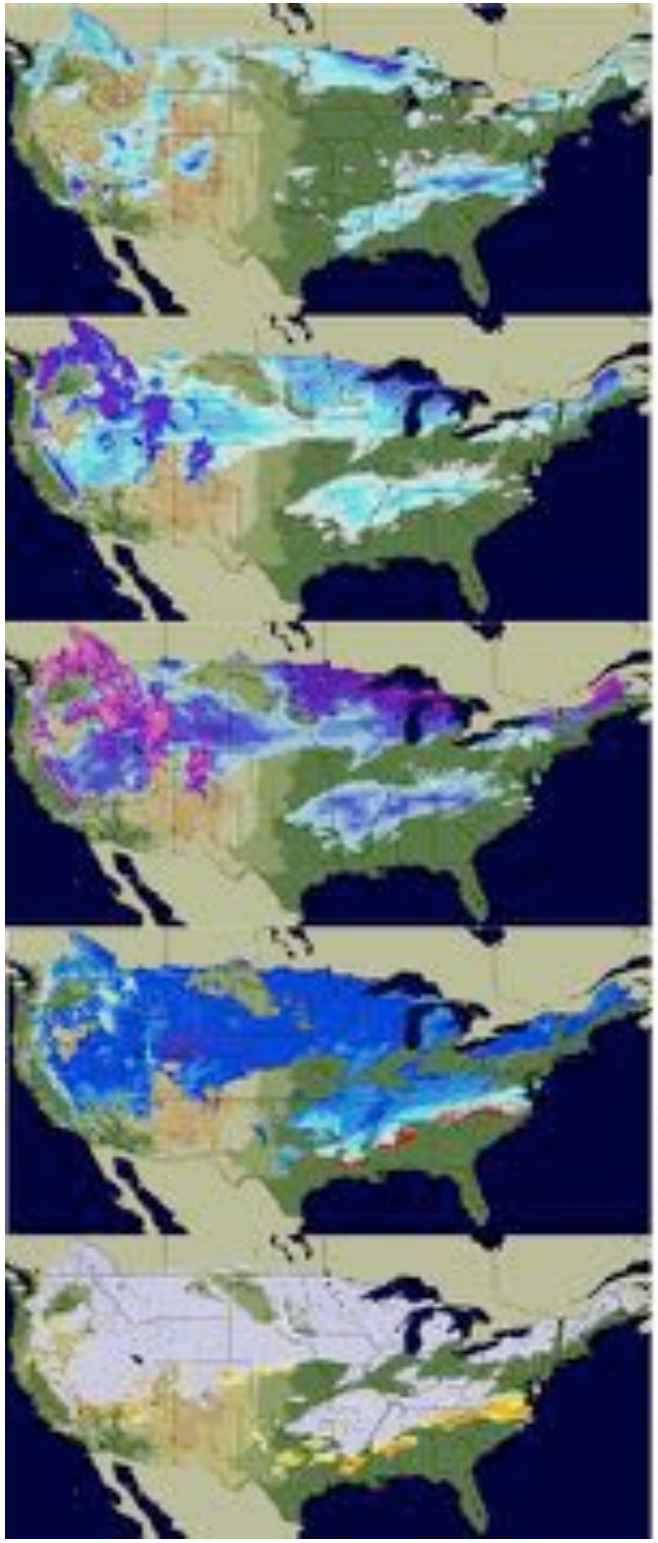
Mission

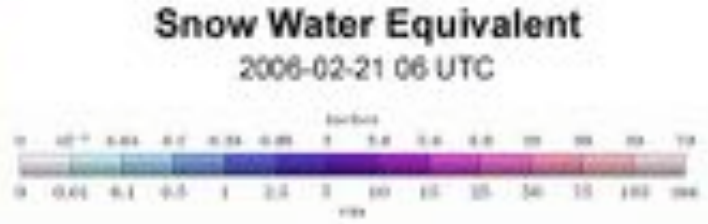
To support the National Weather Service's mission by producing the best estimate of snow water equivalent using all available data including satellite, airborne, and in-situ observations to protect life and property and the enhancement of the national economy.

Operational mission collecting SWE measurements since 1980.

National Snow Analysis

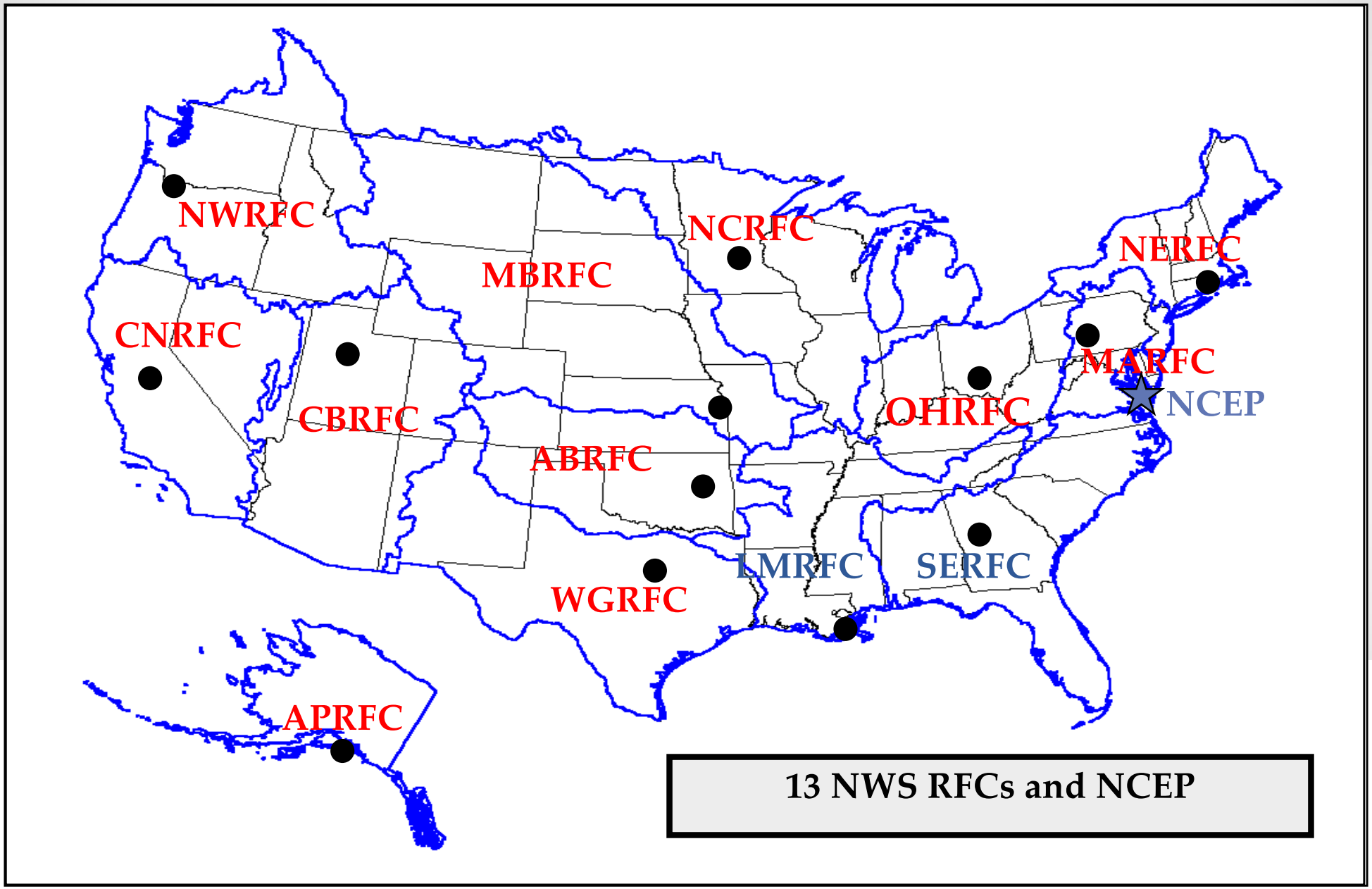






- **PRODUCTS**
  - Hourly and Daily
  - 1 km^2 Resolution
- **INTERNET**
  - Interactive Maps
  - 3D Visualization
    - e.g. Google Earth
  - Time-series loops
  - National/Regional Discussions
  - Text summaries by watershed
  - Point Queries
- **DIRECT FEED**
  - Push or Pull
  - Gridded Data
  - Flat Binary or GIS-ready

OWP NWS Clients



Who uses our information?

National Weather Service

- 13 River Forecast Centers
- Weather Forecast Offices

Federal and State Agencies

- U.S. Army Corps of Engineers
- Bureau of Reclamation
- New York Department of Environmental Protection
- Natural Resources Conservation Service
- Department of Transportation
- 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
- FEMA

Private Sector

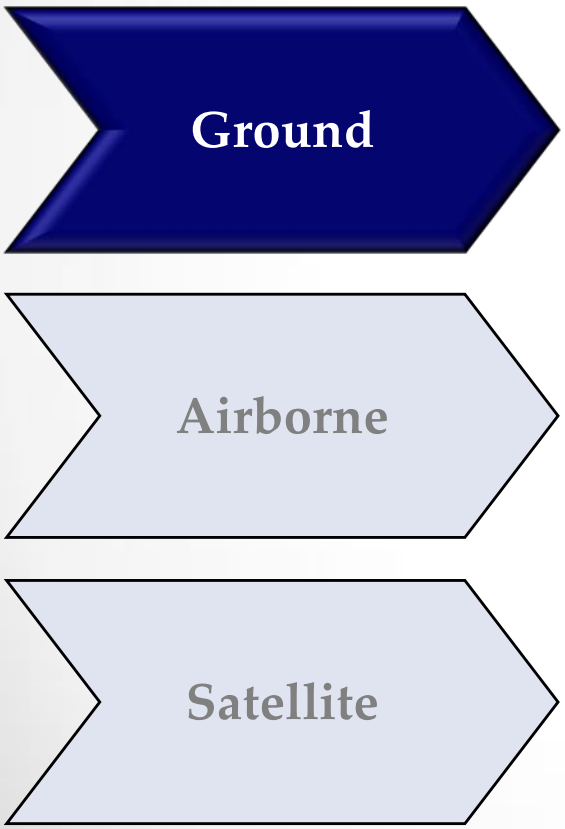
- Baron Advanced Meteorological Systems, LLC
- Weather Channel
- Meteorlogix, Inc.
- Merrril Lynch
- Weather Decision Technologies, Inc.
- SnowStreet
- AccuWeather
- Snow Plow Operators
- Oppenheimer
- Campbell Soup Company
- Snowmobile outfitters
- Mountaineers
- General Public

Canadian

- Manitoba Department of Natural Resources
- New Brunswick Department of Natural Resources
- Alberta Environment
- BC Hydro
- British Columbia Ministry of Environment
- Environment Canada
- Saint John River Basin Commission

National Snow Analysis

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 and Surveys**
  - State Mesonets
  - CoCoRAHS
  - MesoWest (150 smaller mesonets)
- **International Agencies**
  - St. John River Basin
  - Environment Canada
  - BC Hydro

Over 71,432Current Reporting Stations / over 199,718 in NOHRSC database

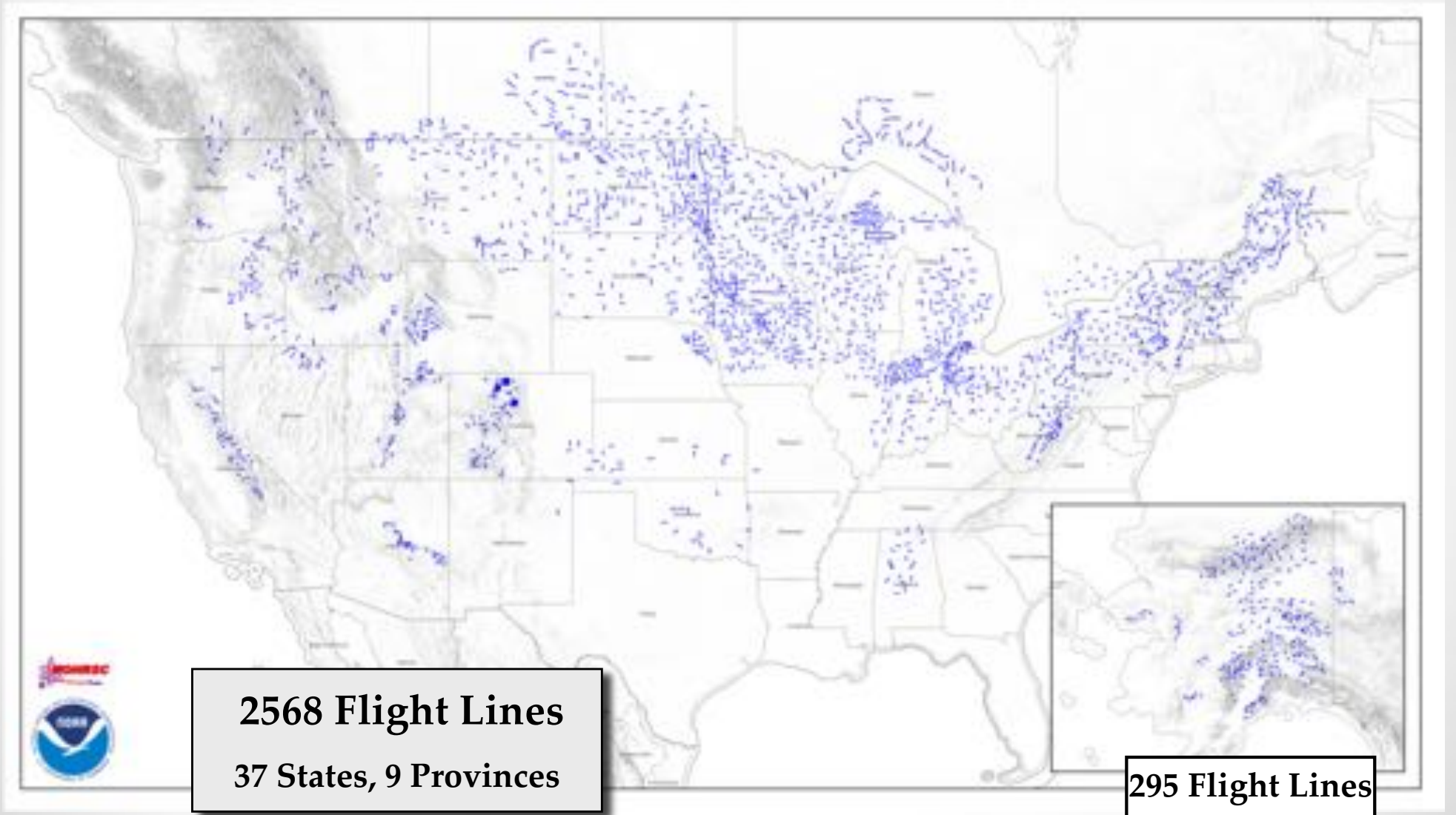
National Snow Analysis

Multi-sensor Snow Observations

- Ground
- **Airborne**
- Satellite

NWS Airborne Snow Survey Program

Airborne Snow Survey Network



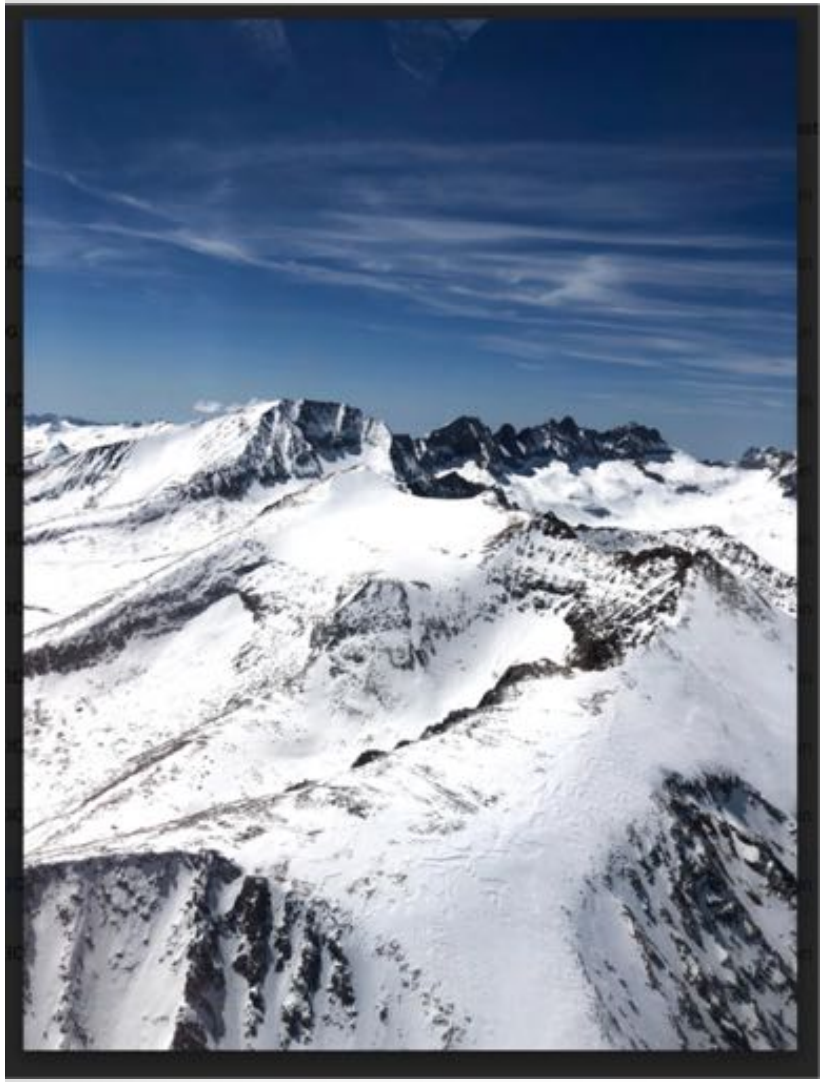
2568 Flight Lines

37 States, 9 Provinces

295 Flight Lines

in Alaska

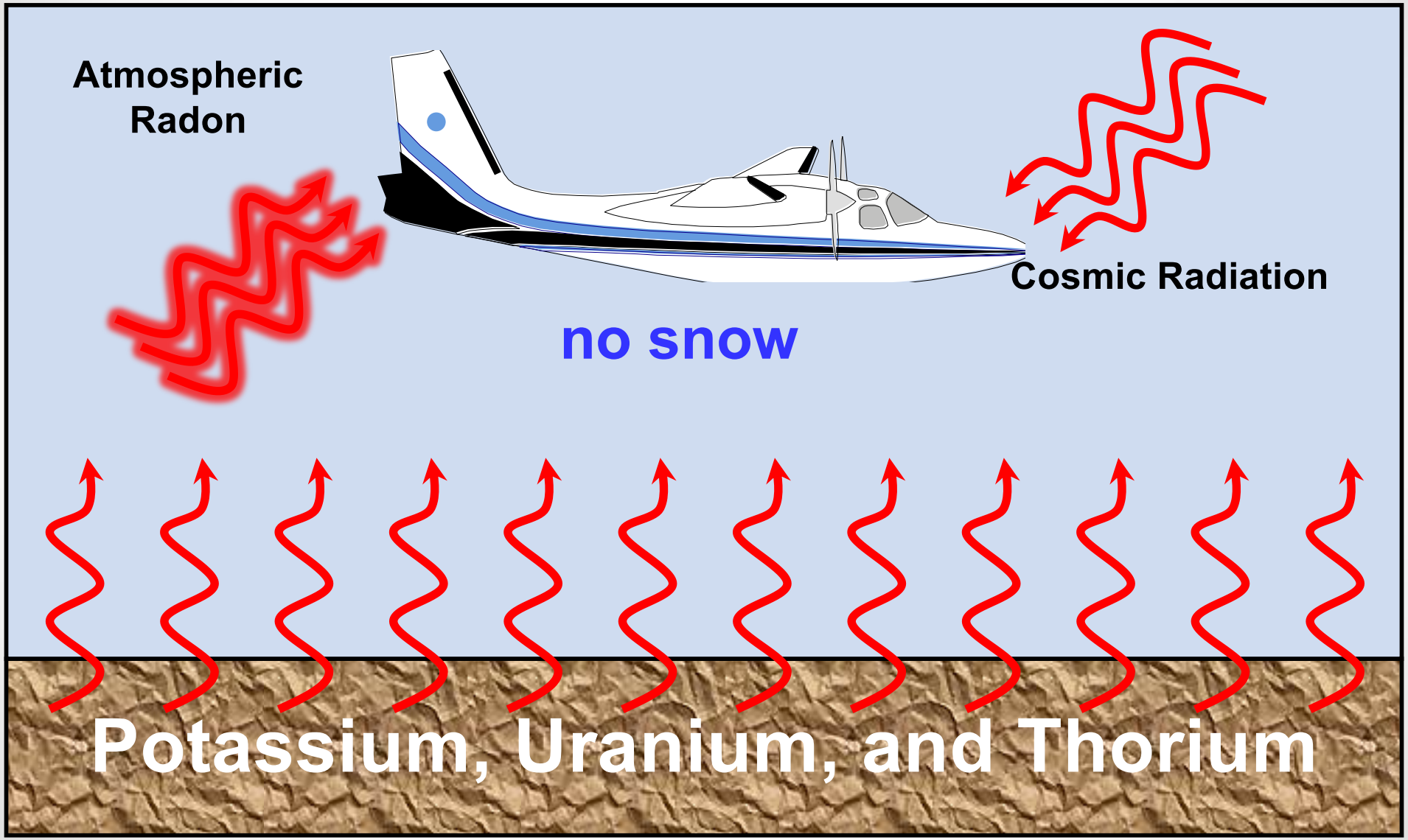
Airborne Platforms



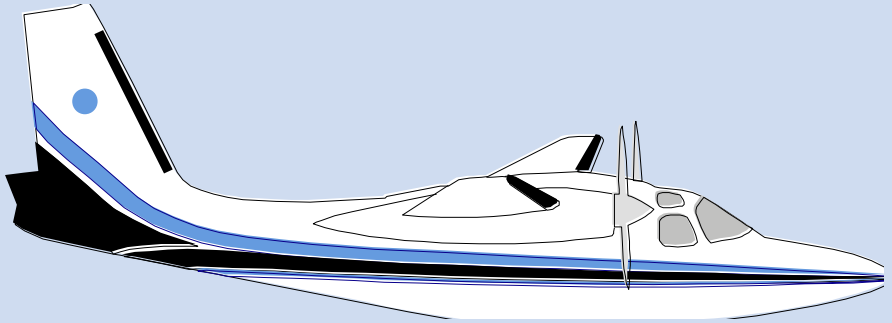
Gamma Detection System

Gamma Detection System Today

Natural Terrestrial Gamma Radiation



Natural Terrestrial Gamma Radiation



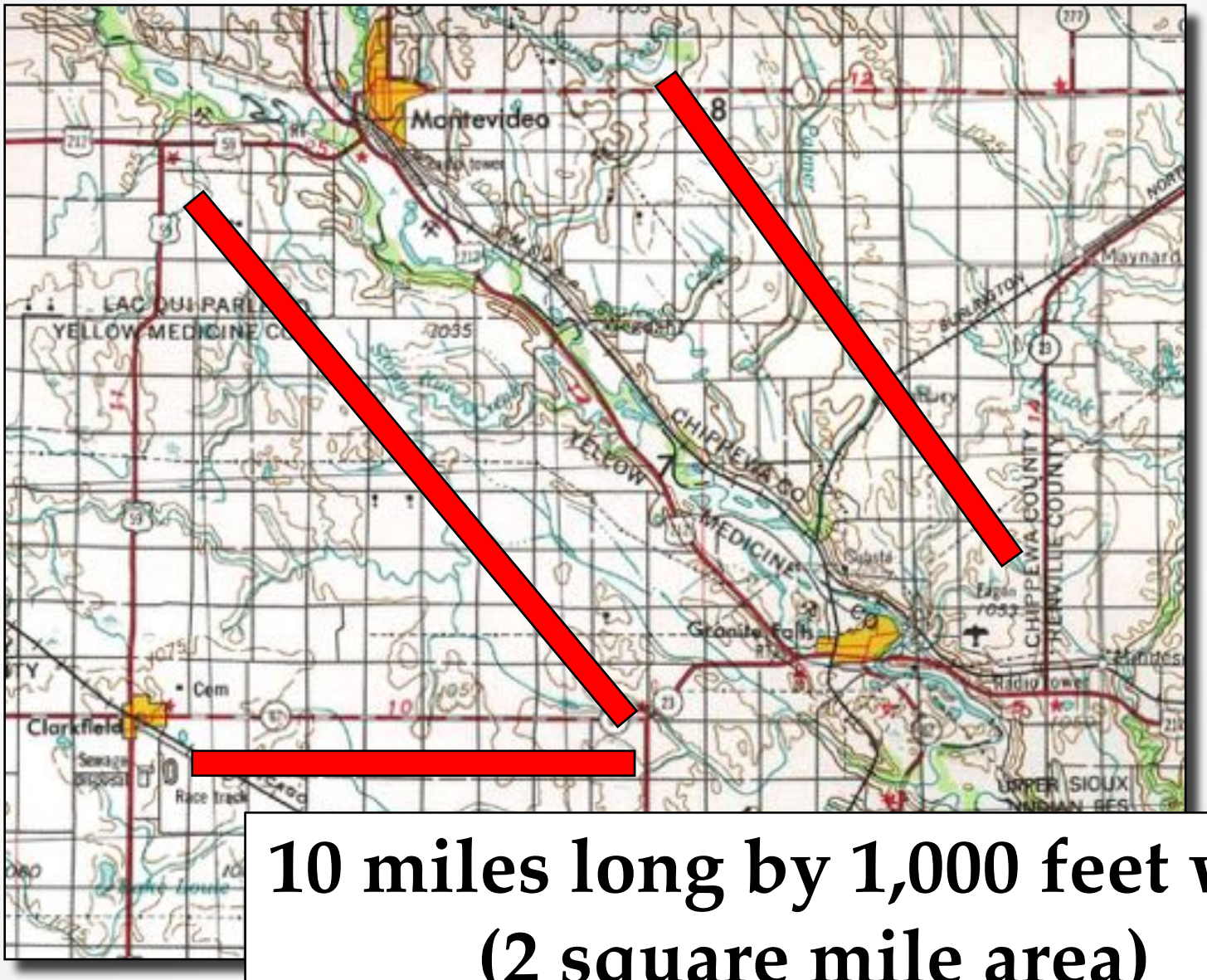
snow cover conditions

Pure, uncollided gamma radiation

Radiation absorbed by water mass in snow pack

Potassium, Uranium, and Thorium

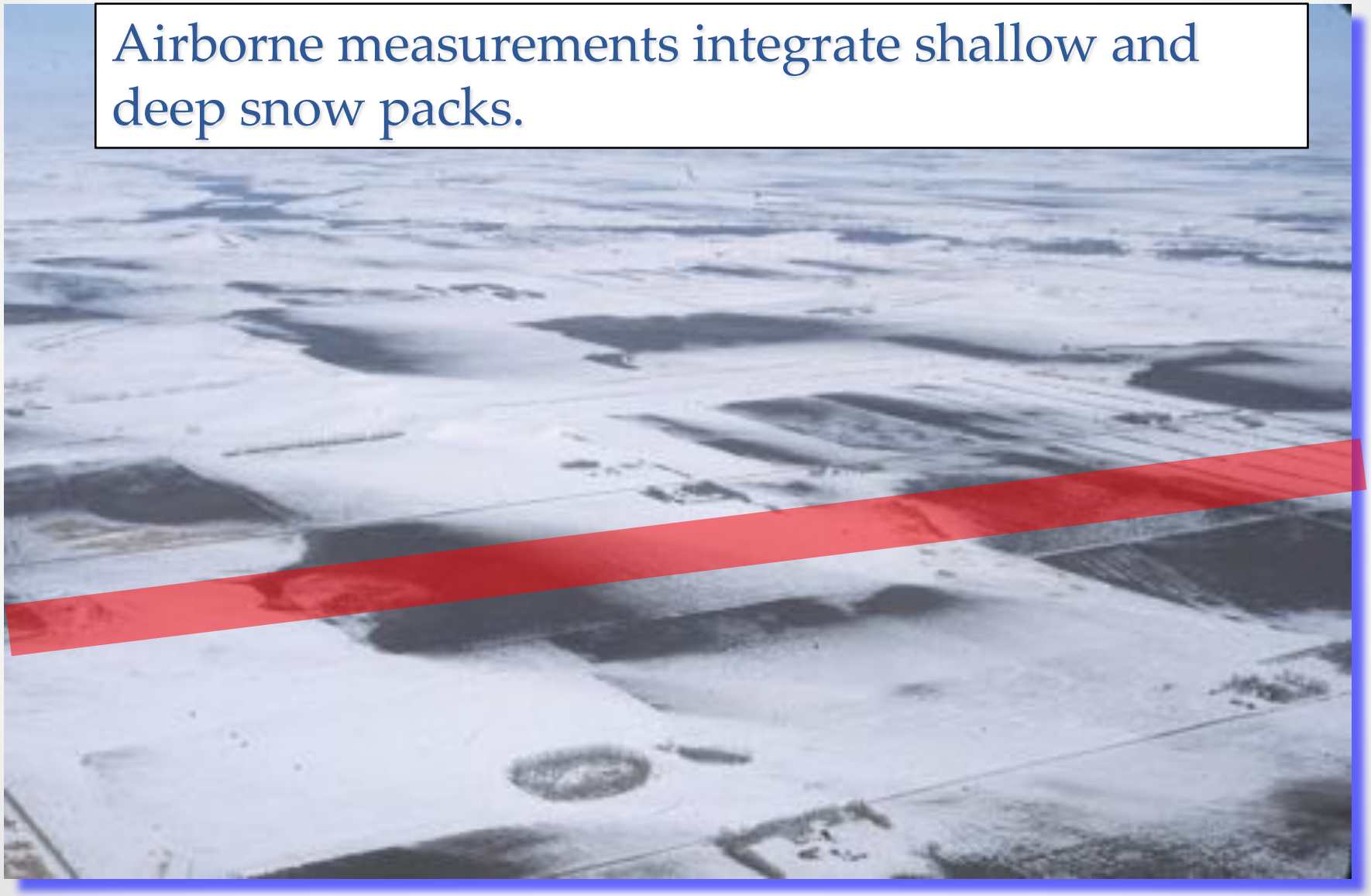
Typical Flight Line



10 miles long by 1,000 feet wide (2 square mile area)

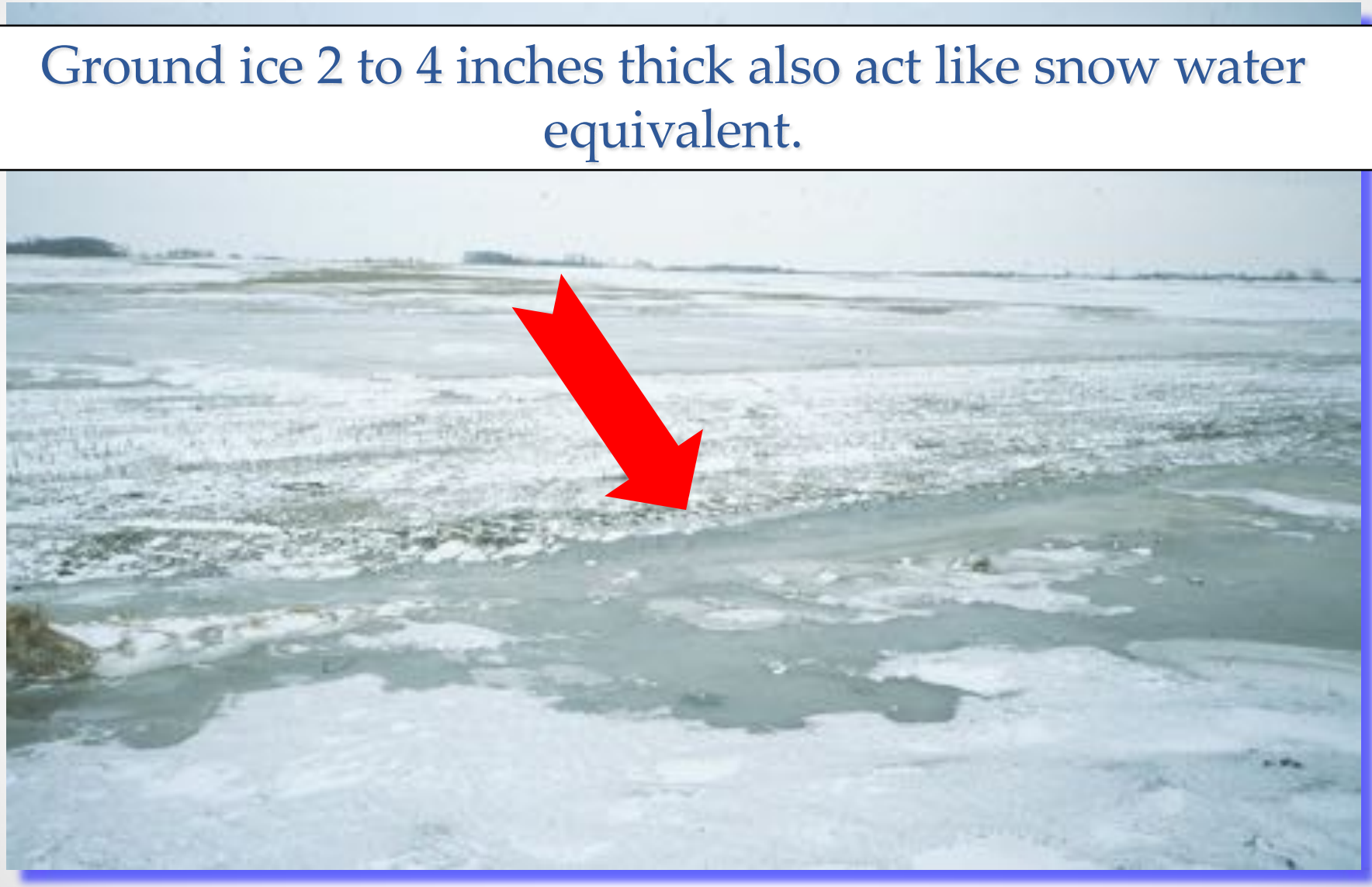
Typical Flight Line

Airborne measurements integrate shallow and deep snow packs.

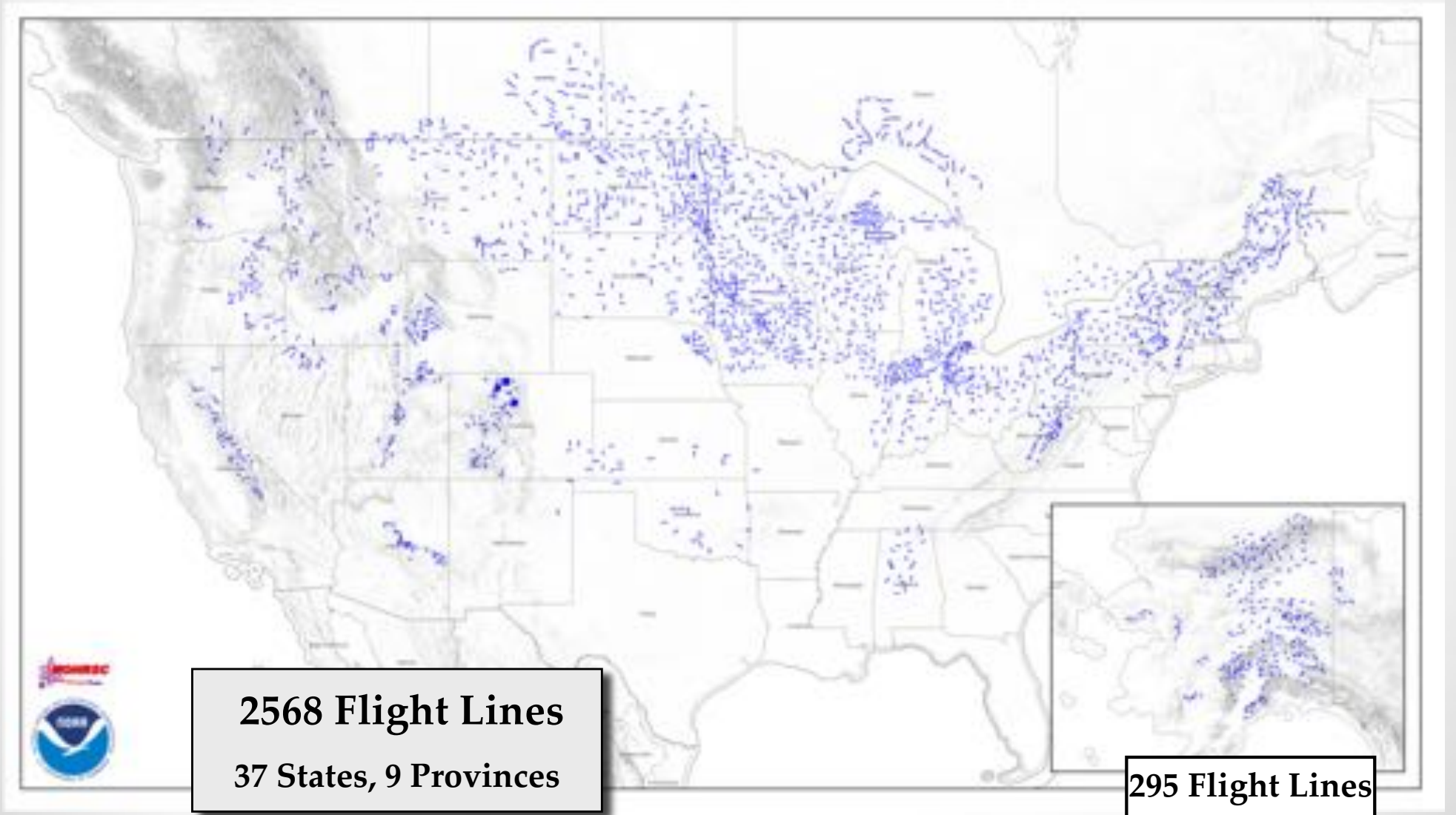


Typical Flight Line

Ground ice 2 to 4 inches thick also act like snow water equivalent.



Airborne Snow Survey Network



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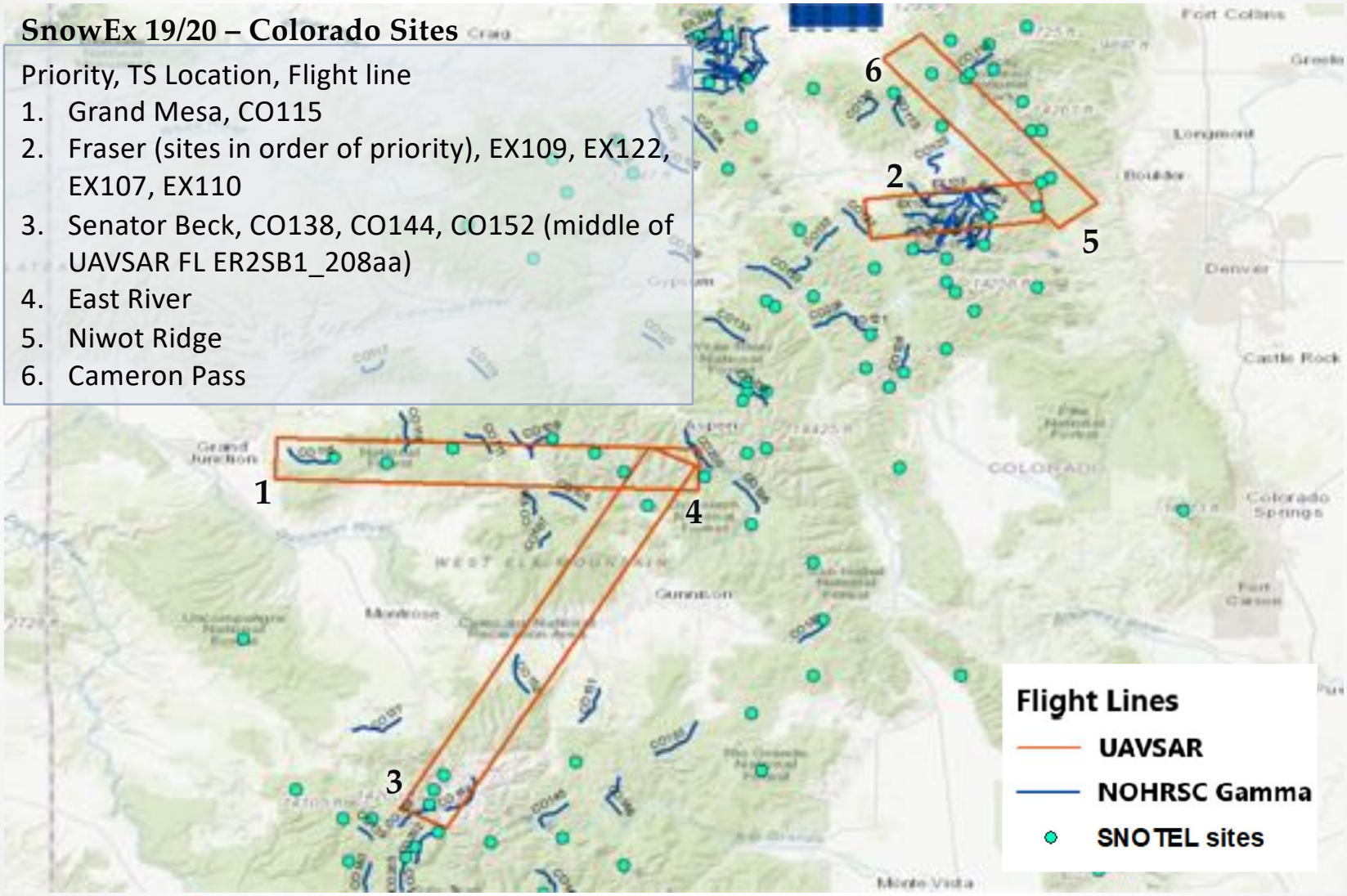
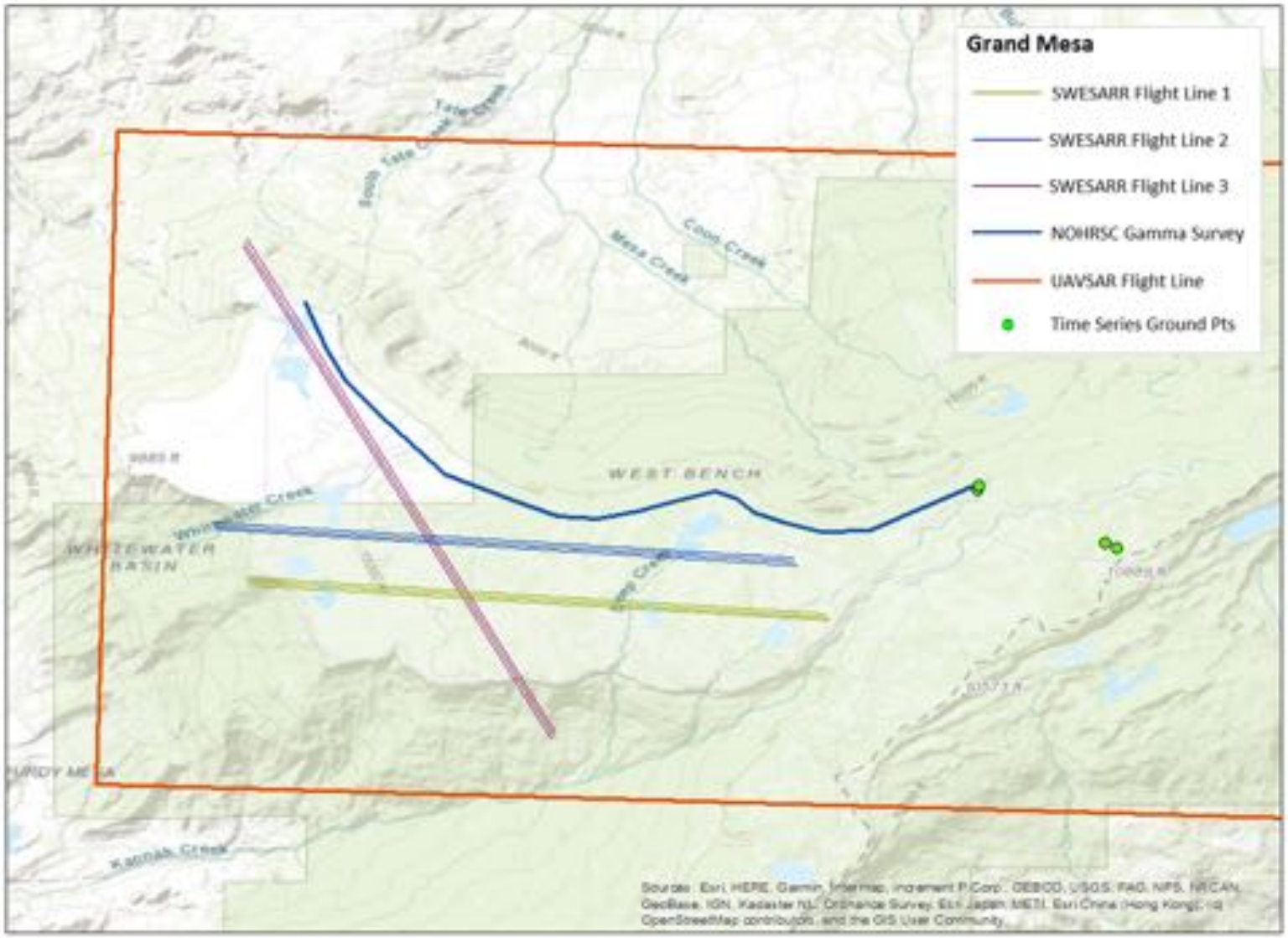
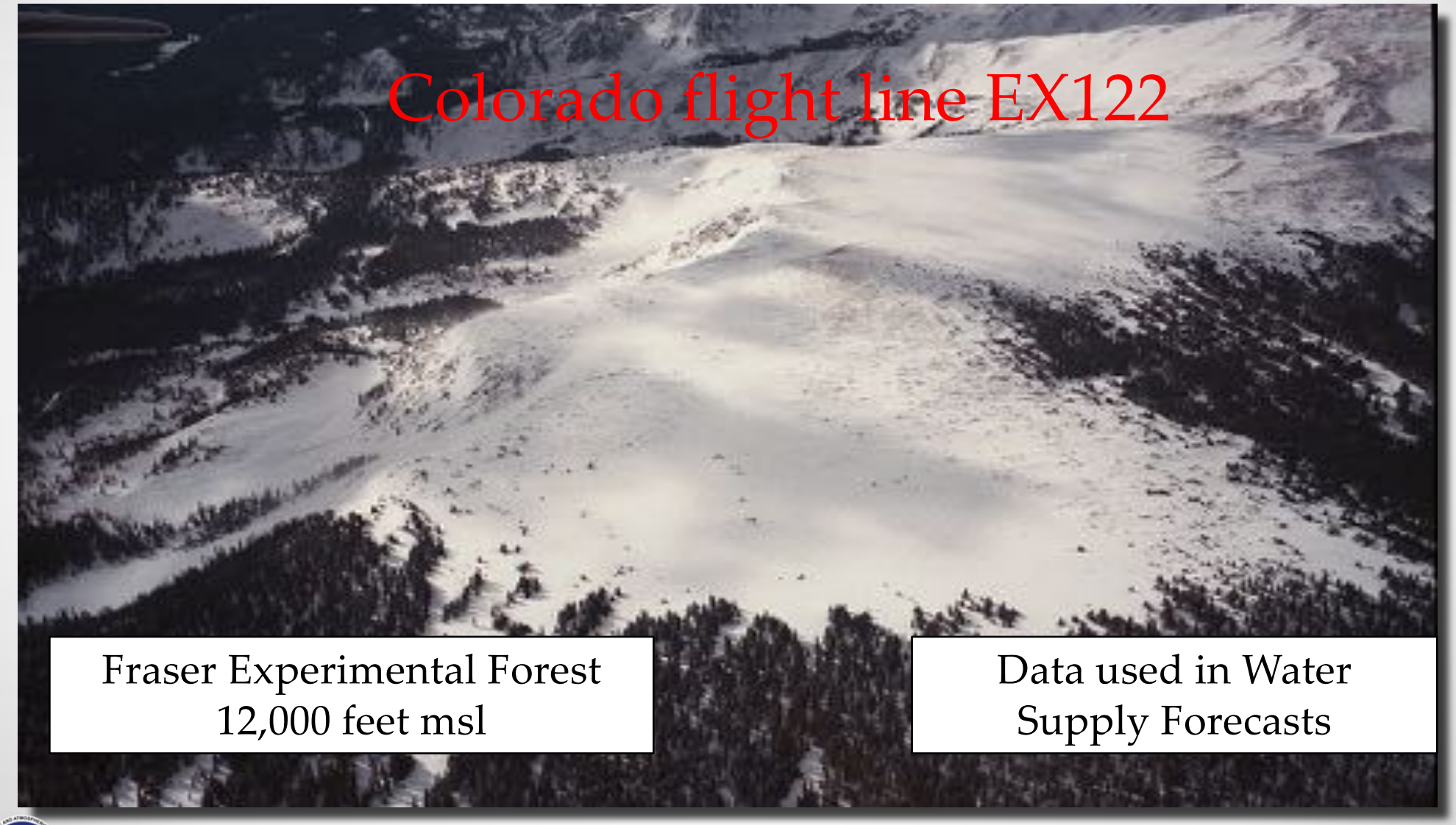
Colorado SnowEx 19/20



Colorado SnowEx 19/20



Airborne Snow Survey Network



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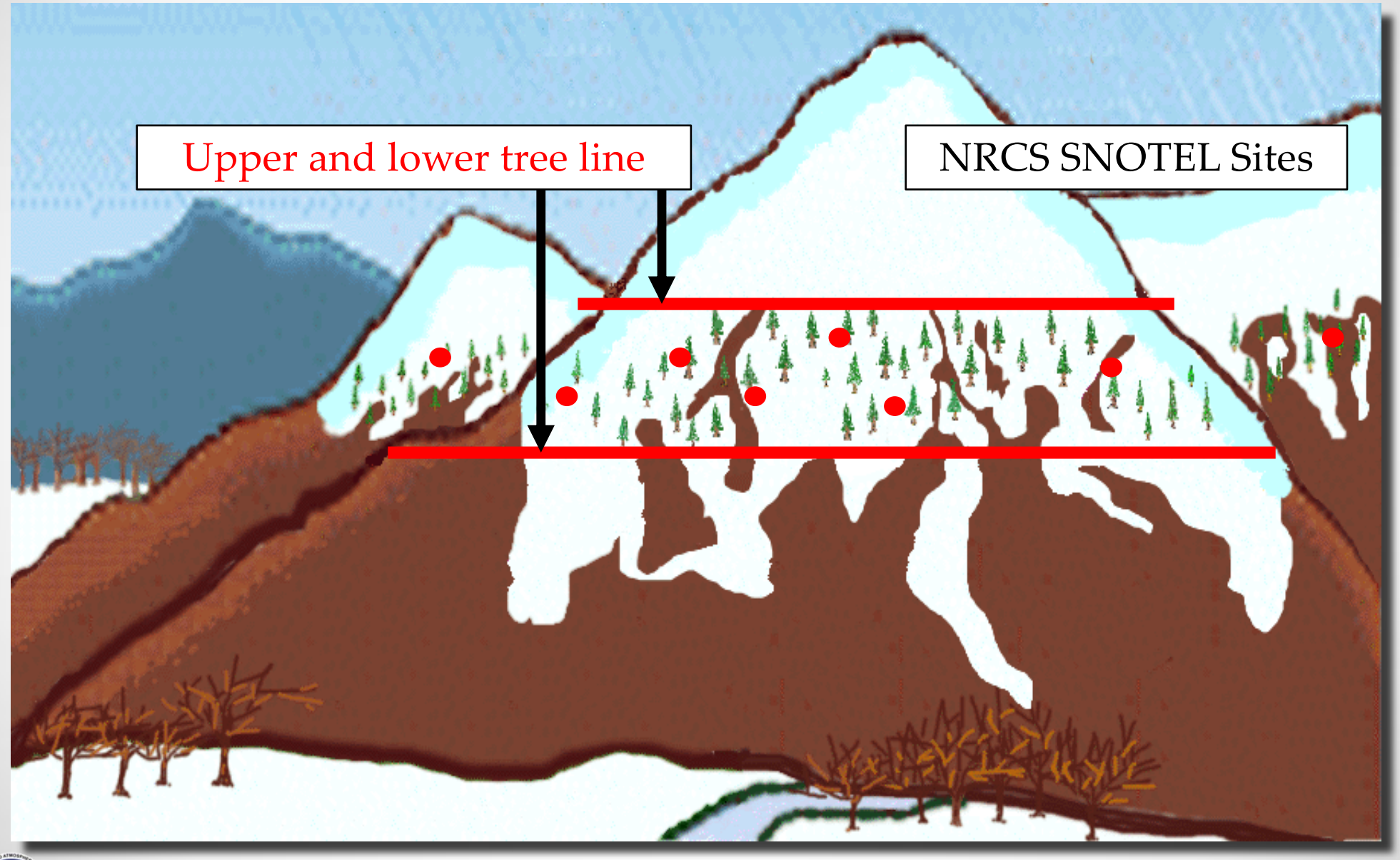
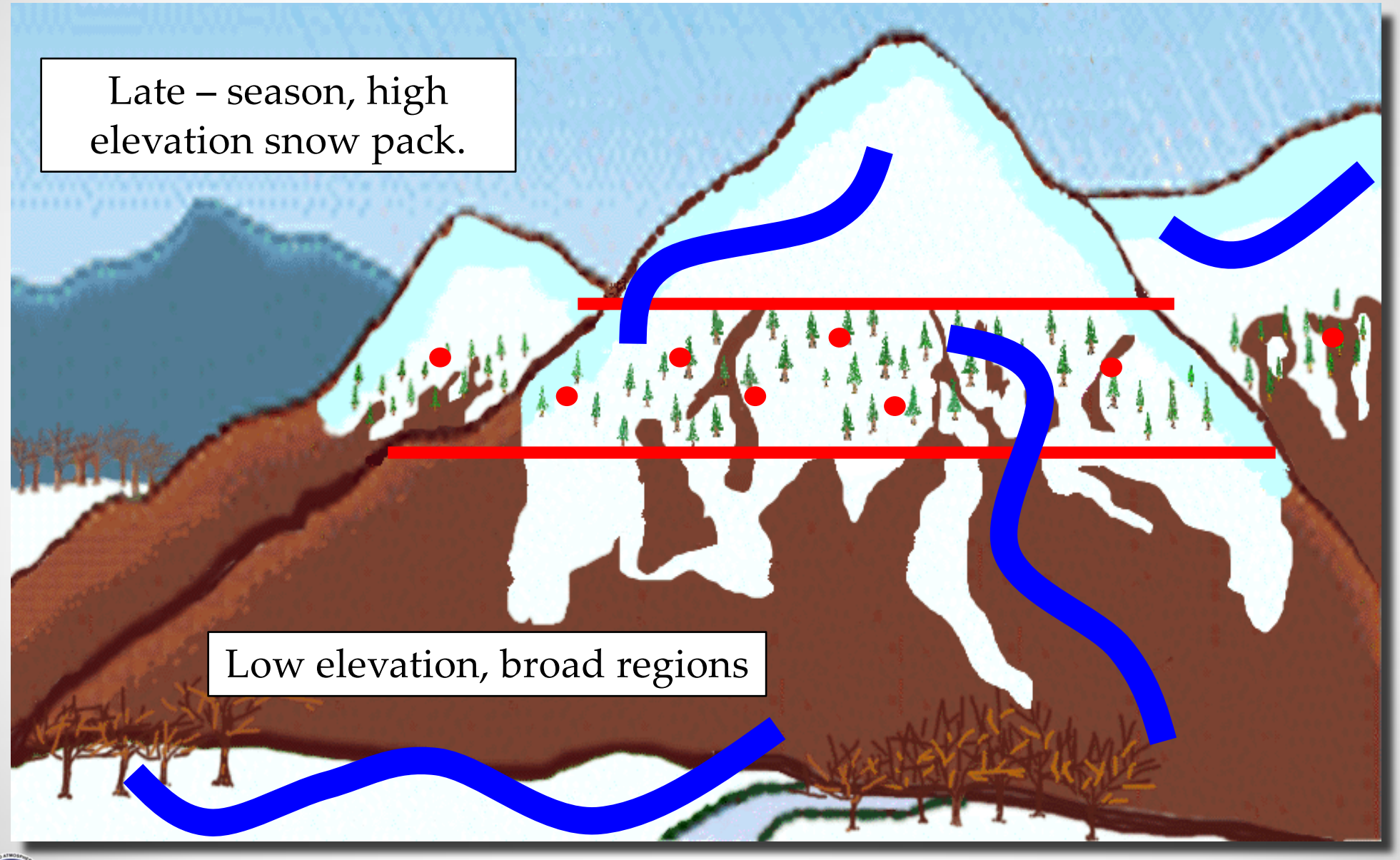
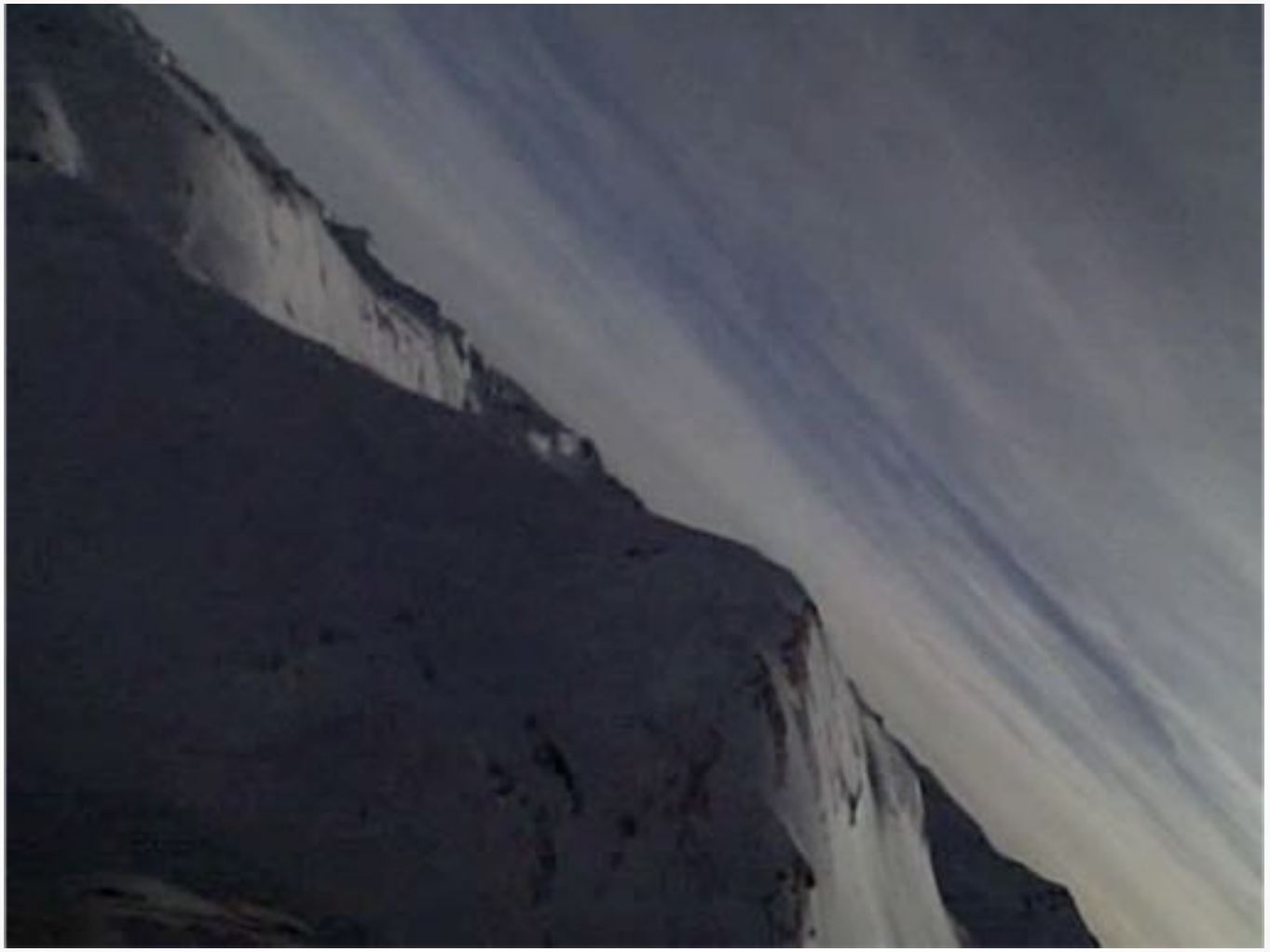


Airborne Snow Survey Network



Colorado Flight Line

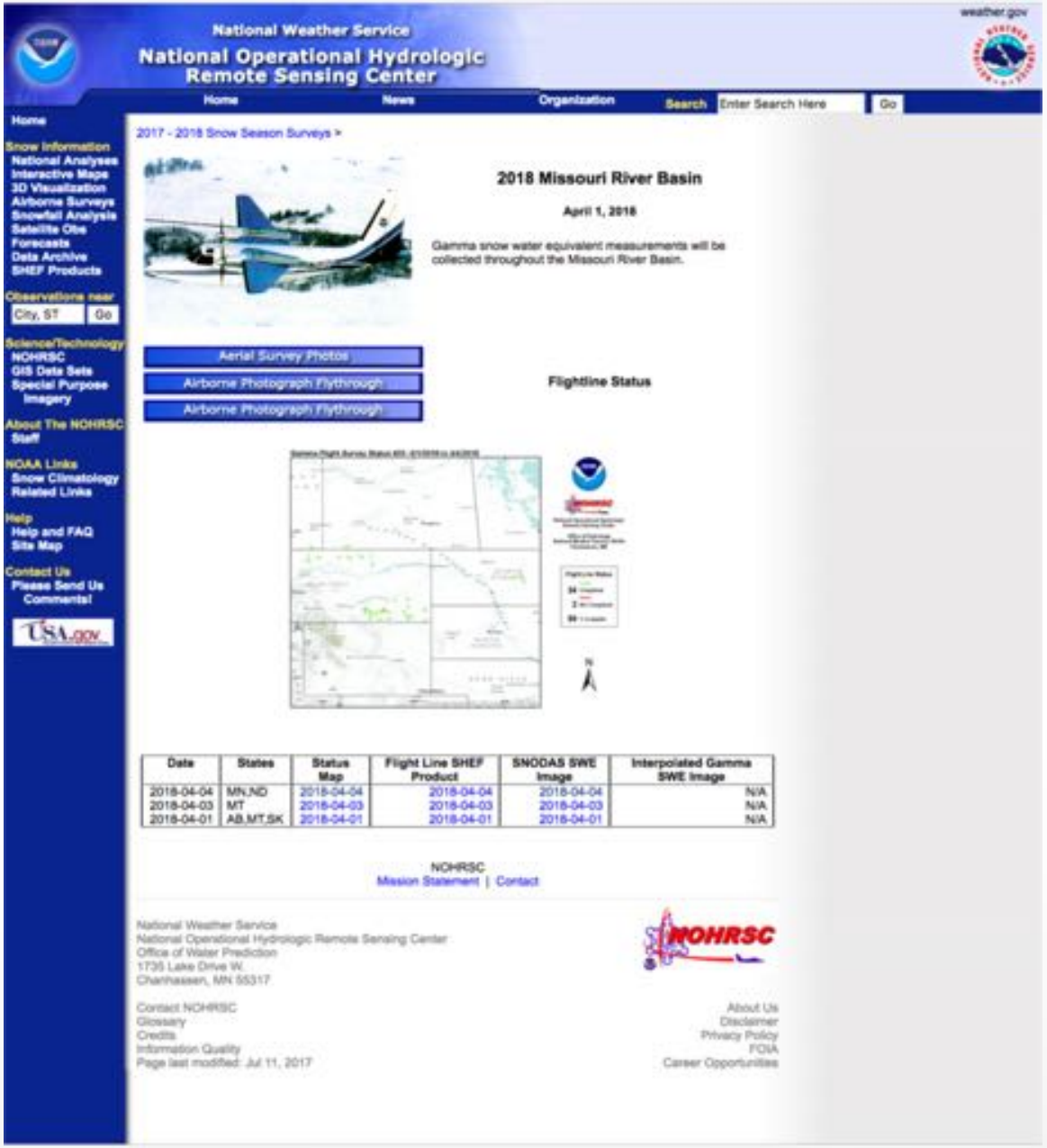


National Snow Analysis

Multi-sensor Snow Observations

- Ground
- **Airborne**
- Satellite

National Snow Analysis

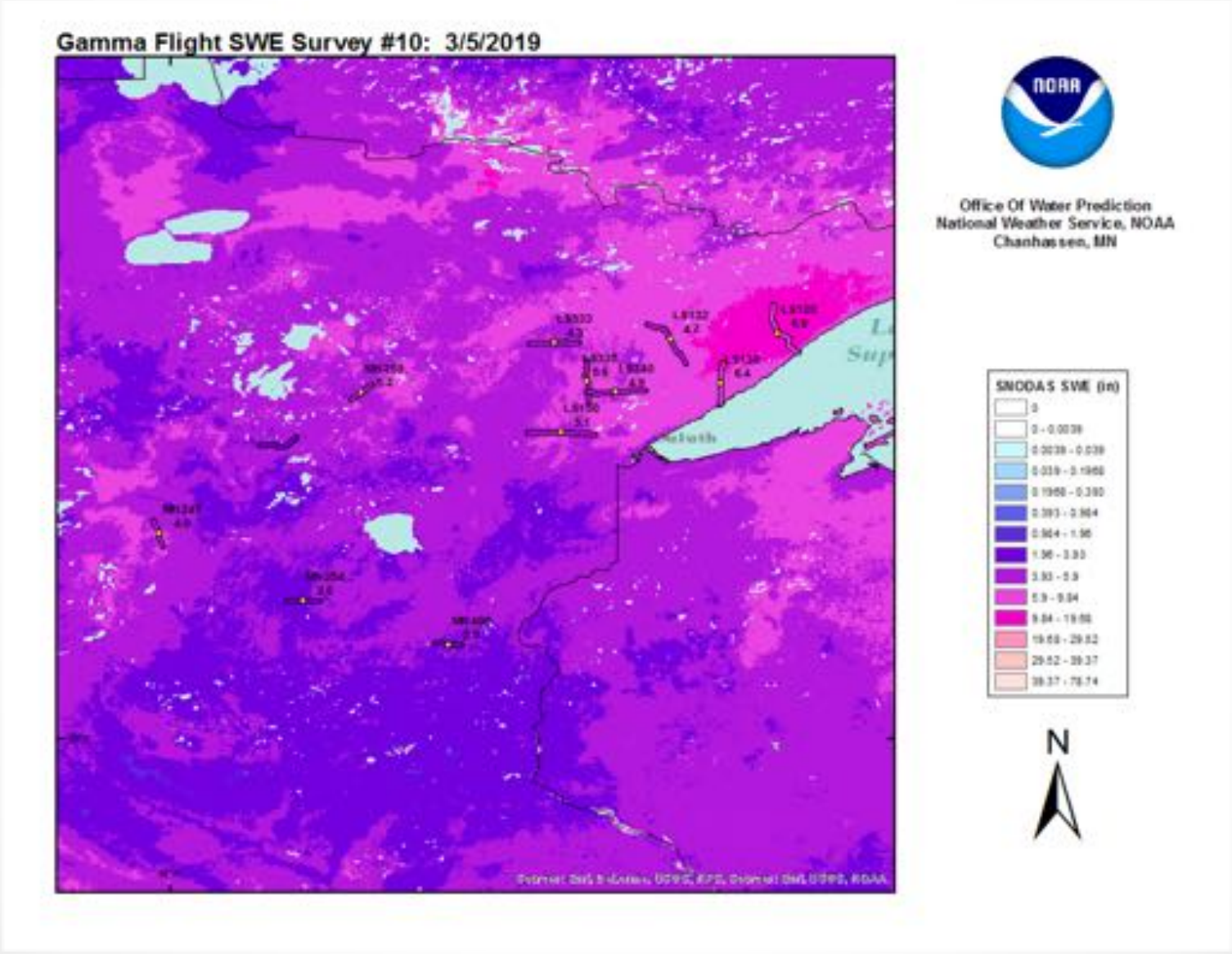


National Snow Analysis

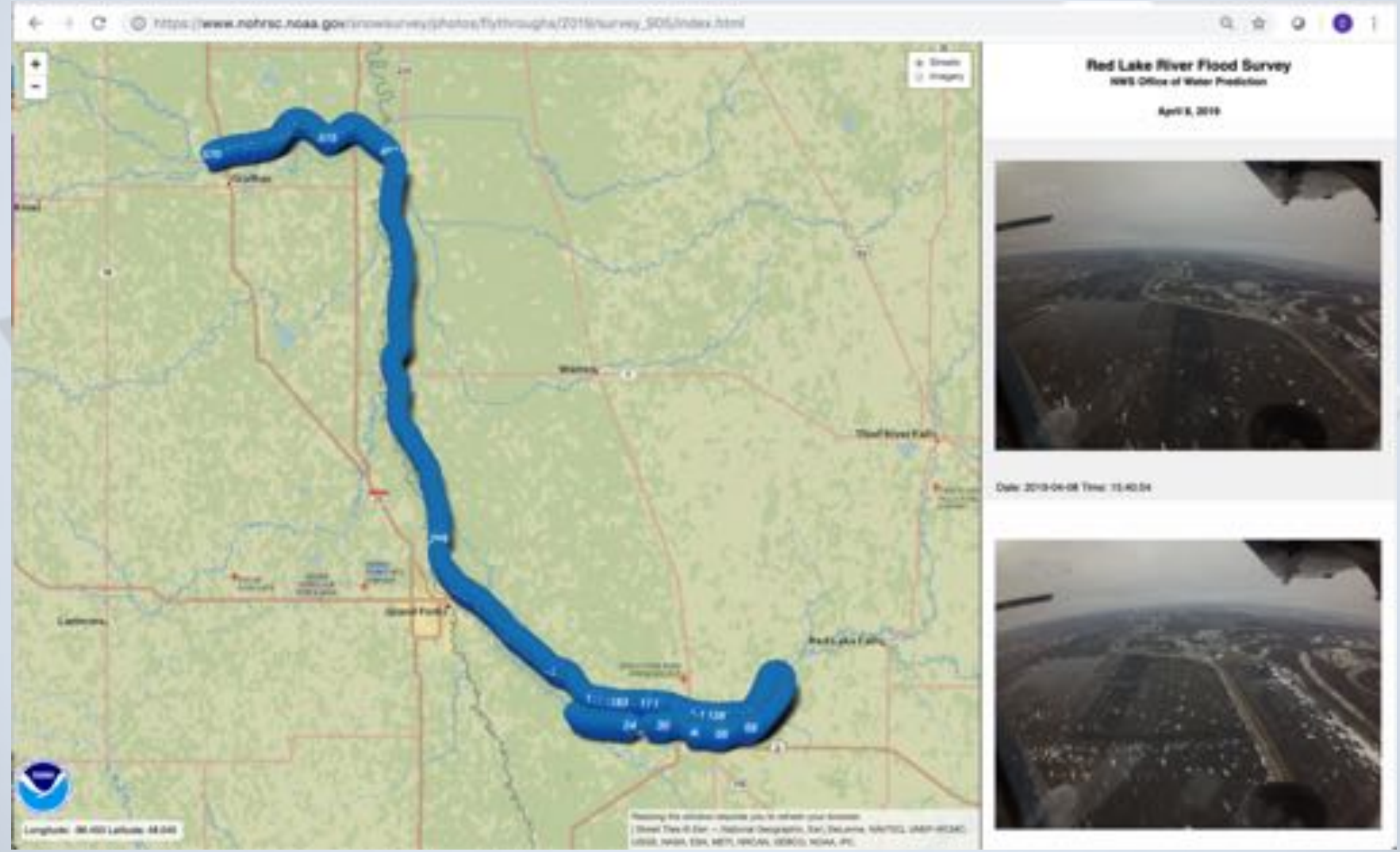
```
SRUS43 KMSR 041017
RRMASP

.BR GAMMA 180404 /SAIRF/SWIRF
:TO ------ Service Hydrologist (Please give HARDCOPY to SH)
:FROM ---- Carrie Olheiser, (952) 368-2503, Minneapolis, Minnesota
:Visit our web page at www.nohrsc.noaa.gov
:SUBJECT - AIRBORNE SNOW WATER EQUIVALENT DATA                    180404101712
:-------------------------------------------------------------------------------
: Total No. of flight lines sent = 21
:-------------------------------------------------------------------------------
:Line   Survey    %SC   SWE   SWE %SM Est Fall  %SM  Pilot
:No.    Date          (in) (35%) (M) Typ Date  (F)  Remarks
:===============================================================================
MT404  DY180404 /  95 / 1.9 : 1.2, 23 AI 170919 , 23
MT405  DY180404 /  95 / 2.0 : 1.5, 26 AI 170919 , 26 field stubble
MT406  DY180404 / 100 / 2.0 : 1.5, 26 AI 170919 , 26 field stubble
MT407  DY180403 / 100 / 2.1 : 1.8, 29 AI 170919 , 29
MT409  DY180403 / 100 / 2.5 : 2.1, 28 AI 170919 , 28
MT410  DY180404 / 100 / 1.8 : 1.3, 26 AI 170919 , 26 Little Bighorn River open
MT411  DY180404 / 100 / 2.7 : 2.2, 26 AI 170919 , 26
MT412  DY180404 / 100 / 3.7 : 3.0, 23 AM 170912 , 23 Rosebud Creek open
MT414  DY180404 / 100 / 3.3 : 2.5, 22 AI 170919 , 22 snow in trees
MT415  DY180403 / 100 / 1.3 : 1.4, 36 AM 170918 , 36
MT416  DY180403 / 100 / 0.6 : 0.6, 36 AI 170919 , 36
MT417  DY180403 / 100 / 0.6 : 0.7, 36 AI 170919 , 36
MT418  DY180403 / 100 / 3.5 : 2.5, 18 AM 151013 , 18 Little Missouri Rvr open
MT419  DY180403 / 100 / 1.8 : 2.0, 38 AI 170919 , 38 Boxelder Ck partial frzn
MT420  DY180403 / 100 / 1.9 : 1.6, 30 AI 170919 , 30 snow in trees
MT421  DY180403 / 100 / 2.3 : 1.6, 22 AI 170919 , 22
MT422  DY180403 / 100 / 2.1 : 1.7, 29 AI 170919 , 29
MT423  DY180403 / 100 / 1.5 : 1.6, 38 AM 170918 , 38
MT425  DY180403 / 100 / 1.7 : 1.4, 30 AI 170919 , 30
MT426  DY180403 / 100 / 1.8 : 1.7, 34 AI 170919 , 34
MT427  DY180403 / 100 / 1.9 : 1.3, 24 AM 170912 , 24
.END
Lines in SE Montana flown today. The Milk river is partially open up to
the town of Havre and then frozen with small patches of open areas
headed east. In the Glasgow area, the snow cover becomes lighter.
Beaver Creek is partially open. There are some flooded farm fields 4
miles south of Bowdoin. The Judith River appears open up to the
Missouri River with heavy new snow in the area. The Missouri River is
frozen from Fort Peck Lake but opens up where the Yellowstone River
meets the Missouri.
NNNN
```

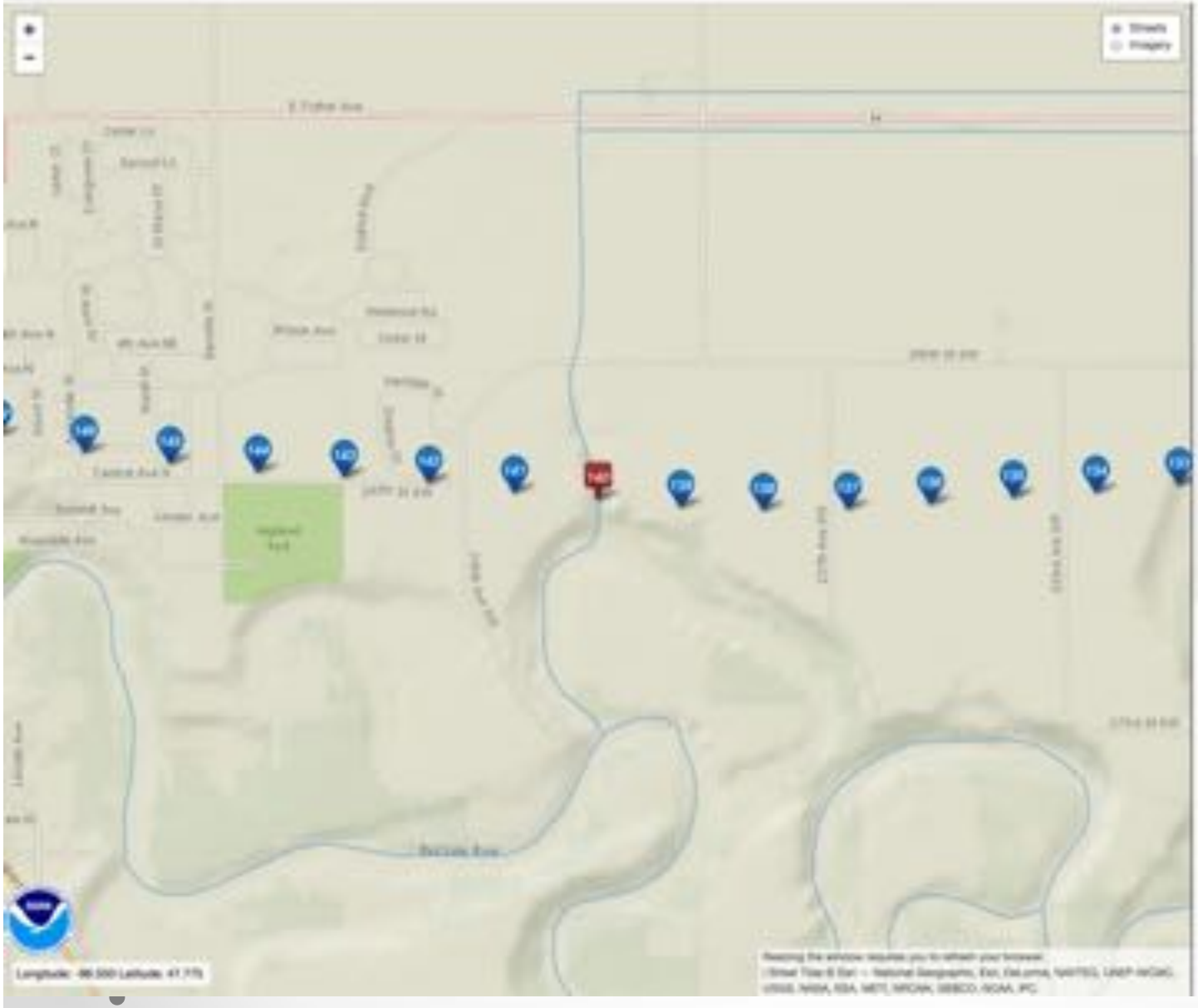
National Snow Analysis



Airborne Photos

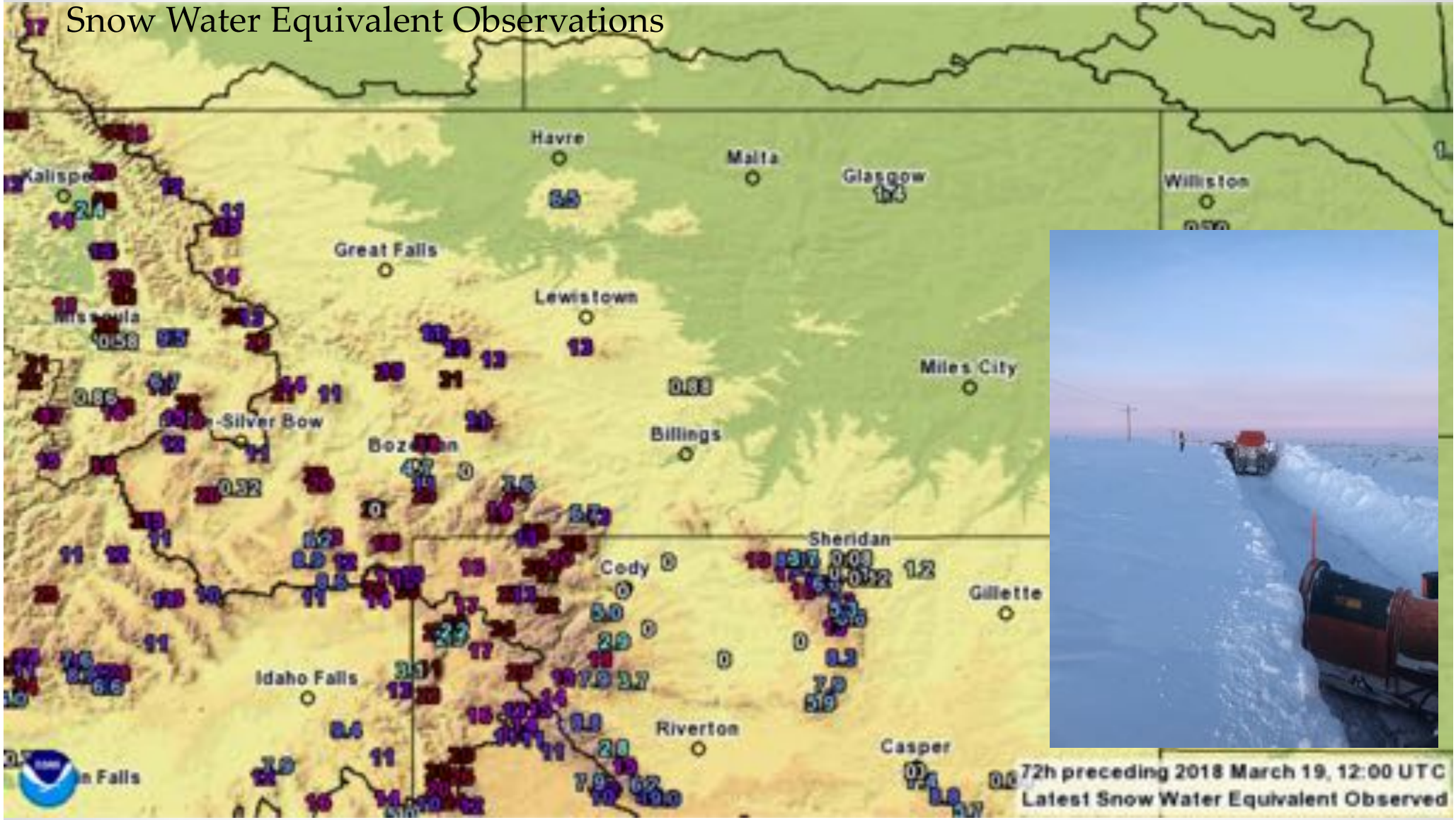


Airborne Photos

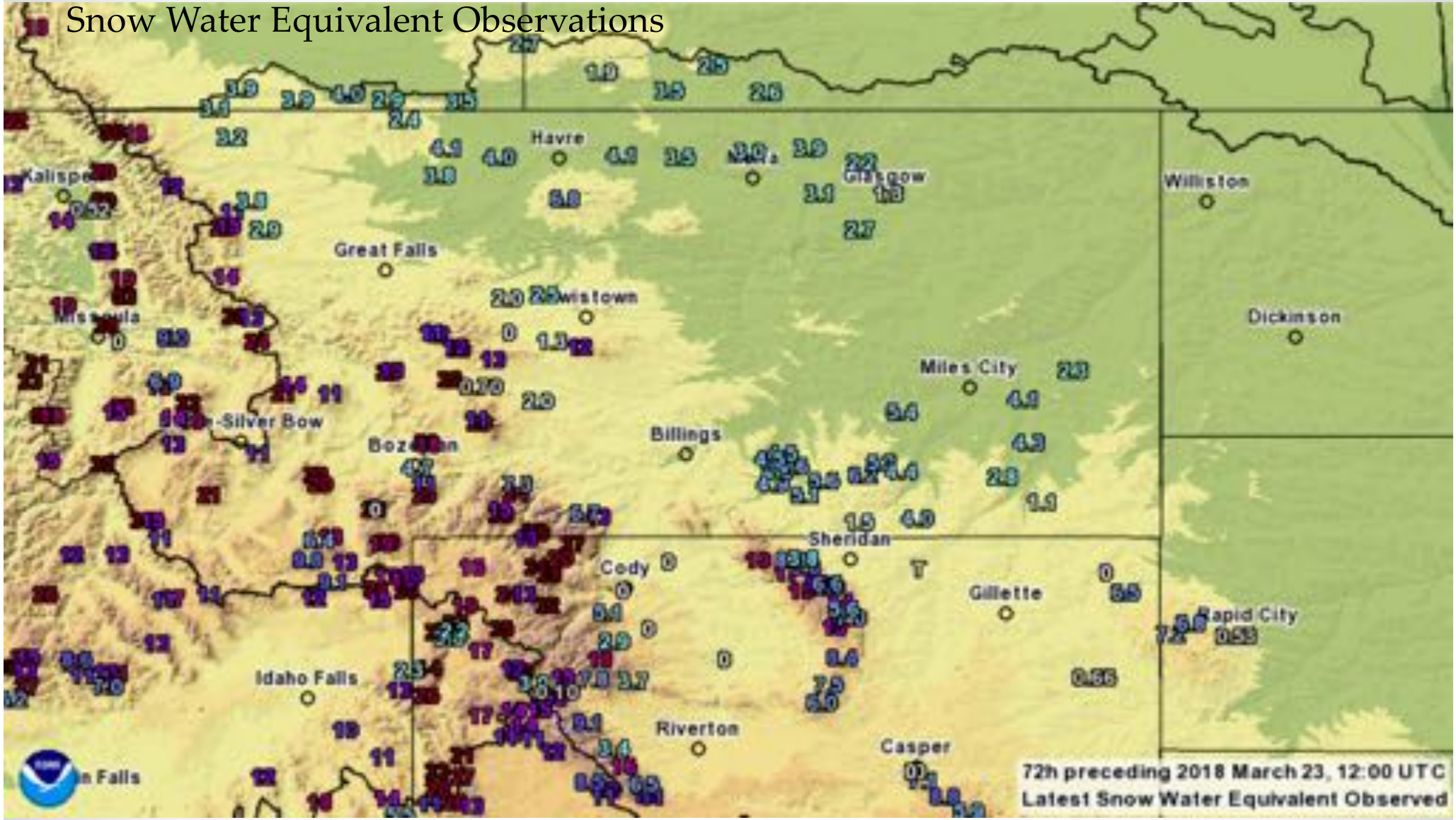


04/08/2019
03:53:02 PM

Missouri River Basin Flooding

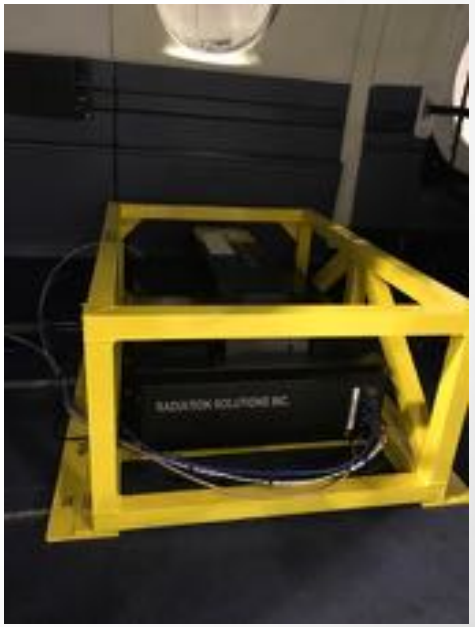


Missouri River Basin Flooding

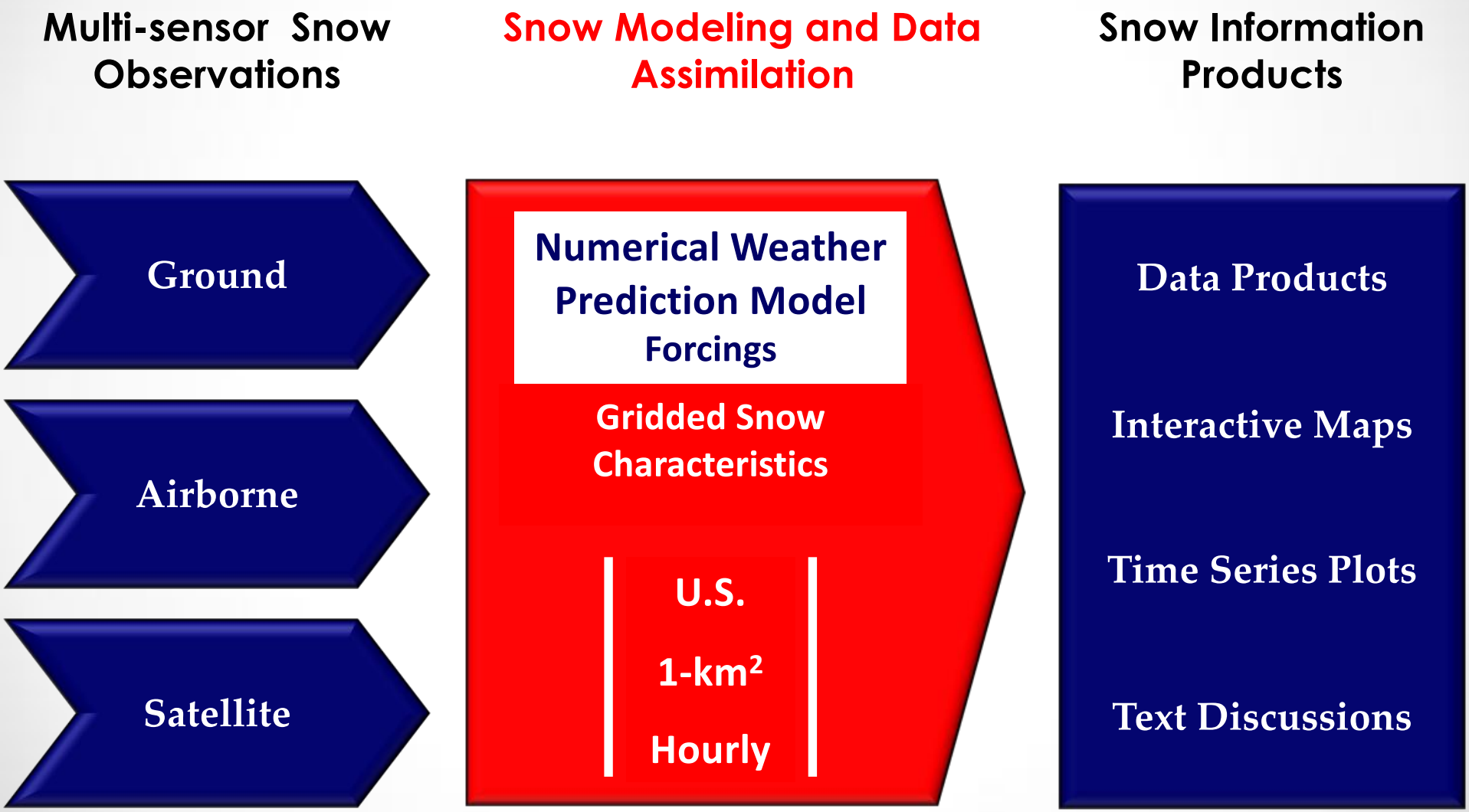


The Future - King Air

- JetProp Commander is an aging airframe – Built in 1984
- Per the OMAO Recapitalization Plan a new King Air will replace the JetProp in 2020.
- Feasibility Study of a King Air 350ER was completed Fall / early winter 2017-2018

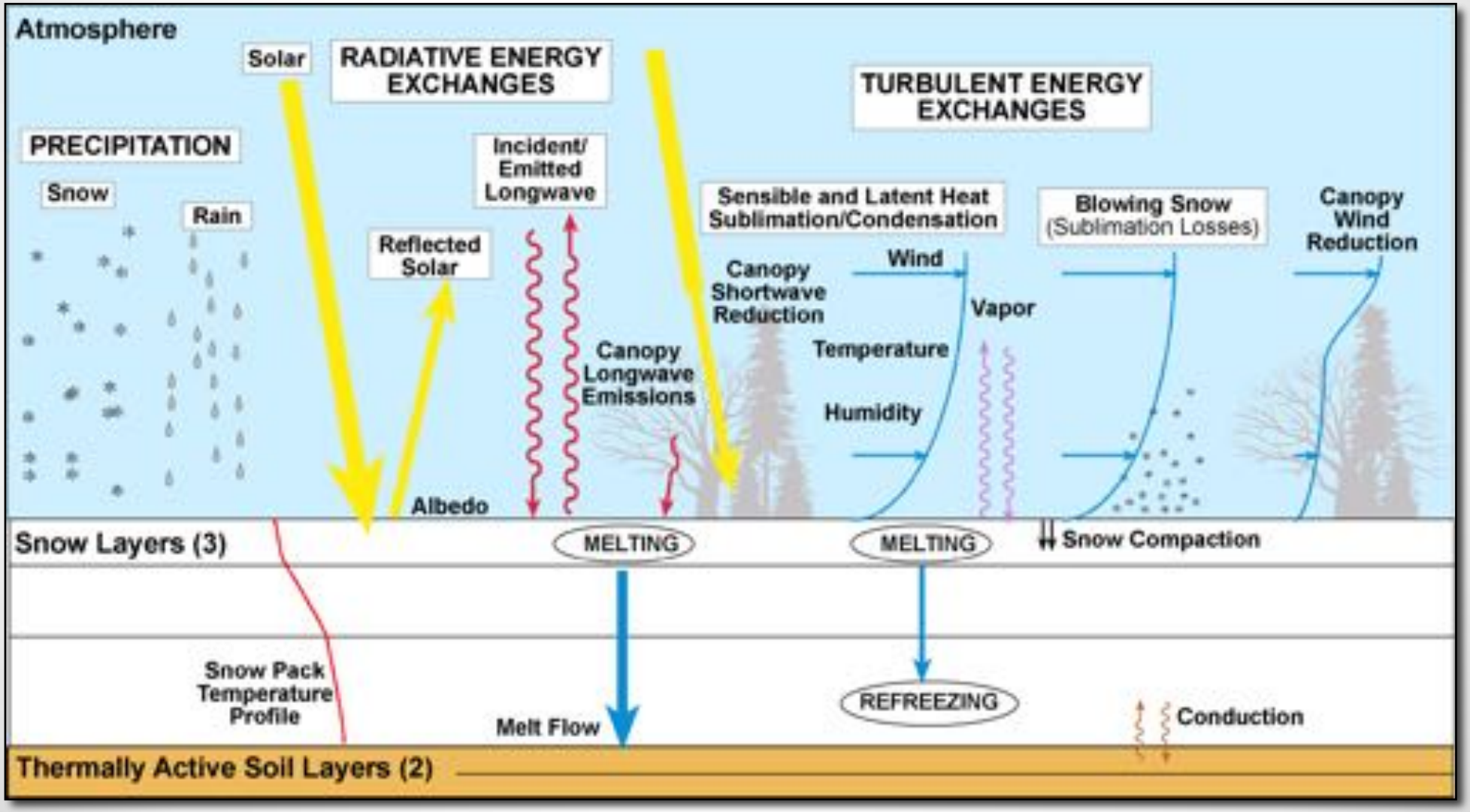


National Snow Analysis

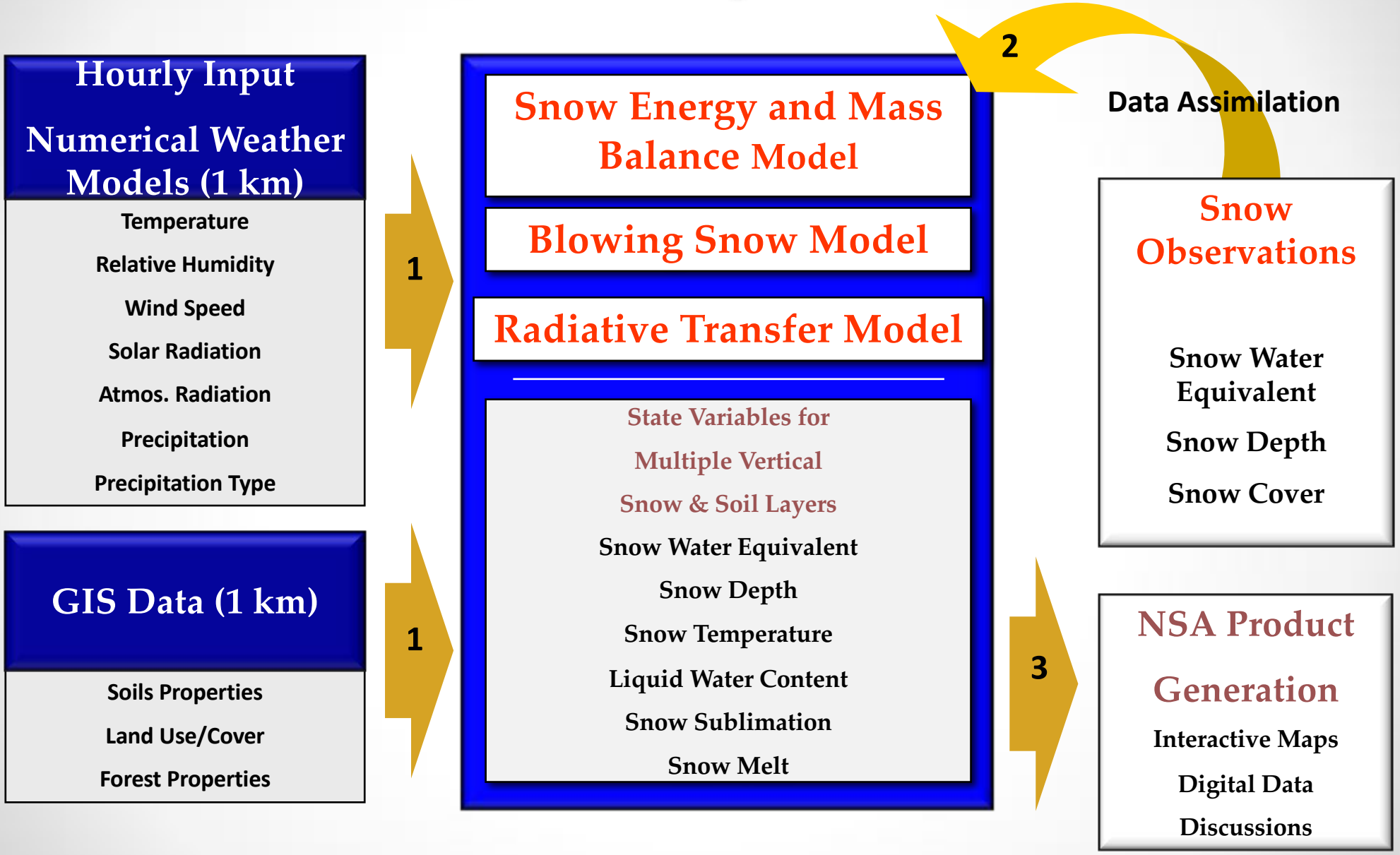


NOHRSC Snow Model Physics

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



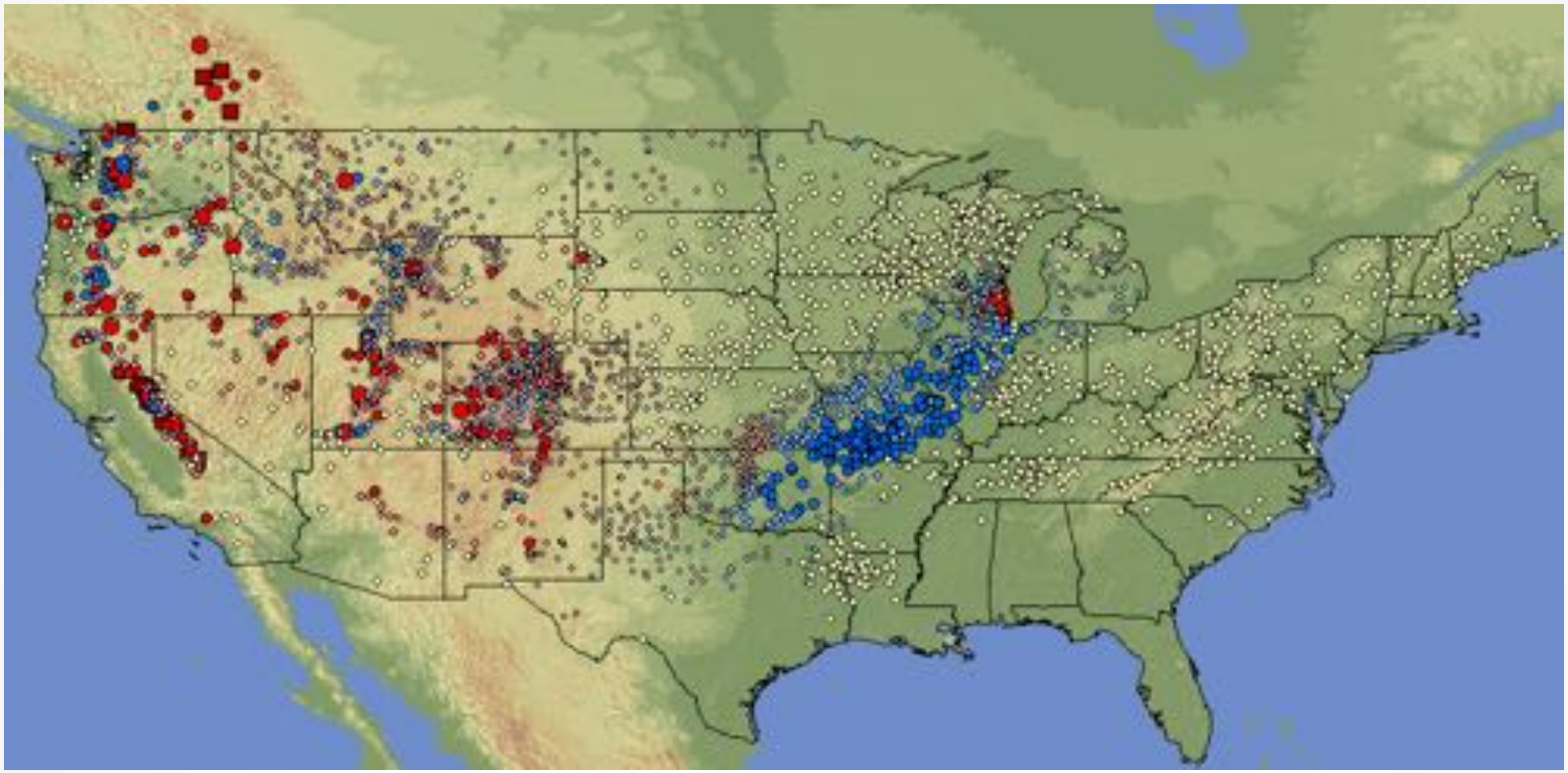
Snow Modeling Framework



Snow Observational Assimilation

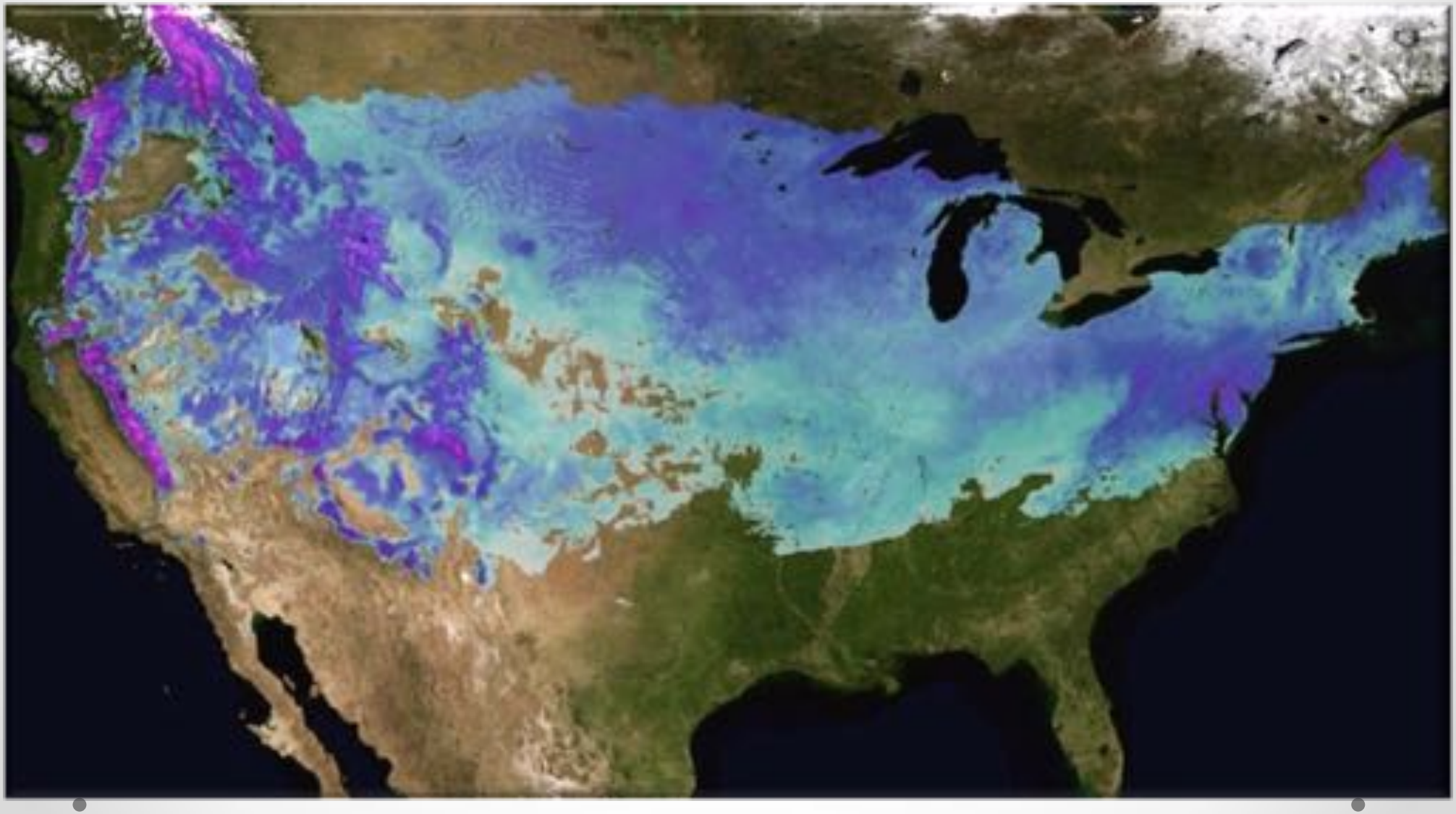
Daily SWE and Snow Depth Observations are used to update the model

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



- Uncertainties in driving data
  - 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

Best Estimate of SWE



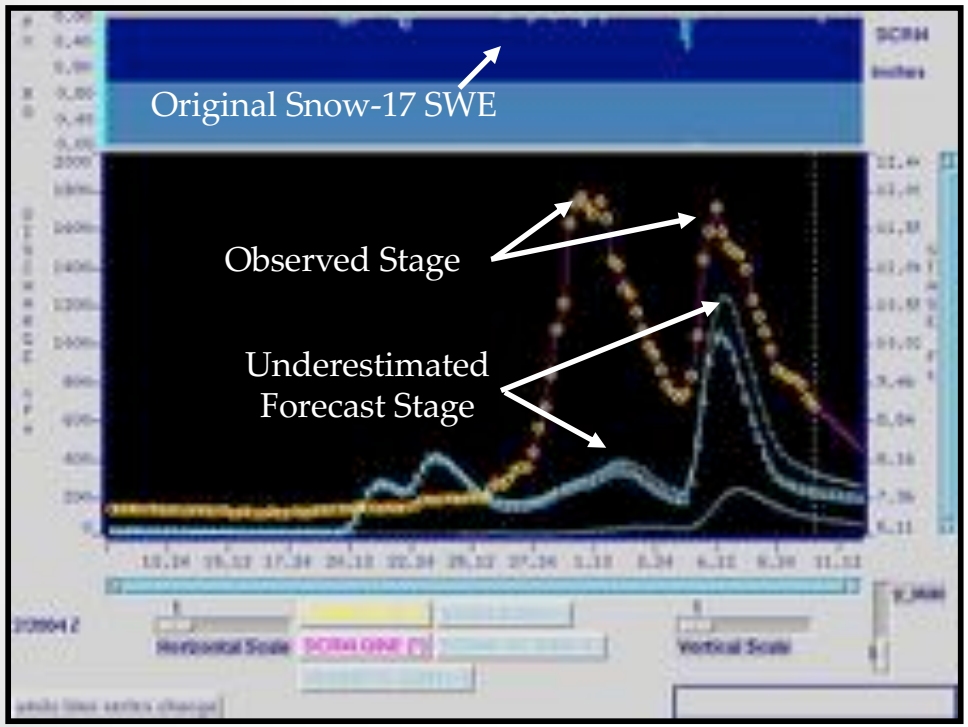
Benefits of NSA Products

Use of NSA Information Products at NCRFC

NWS River Forecast System

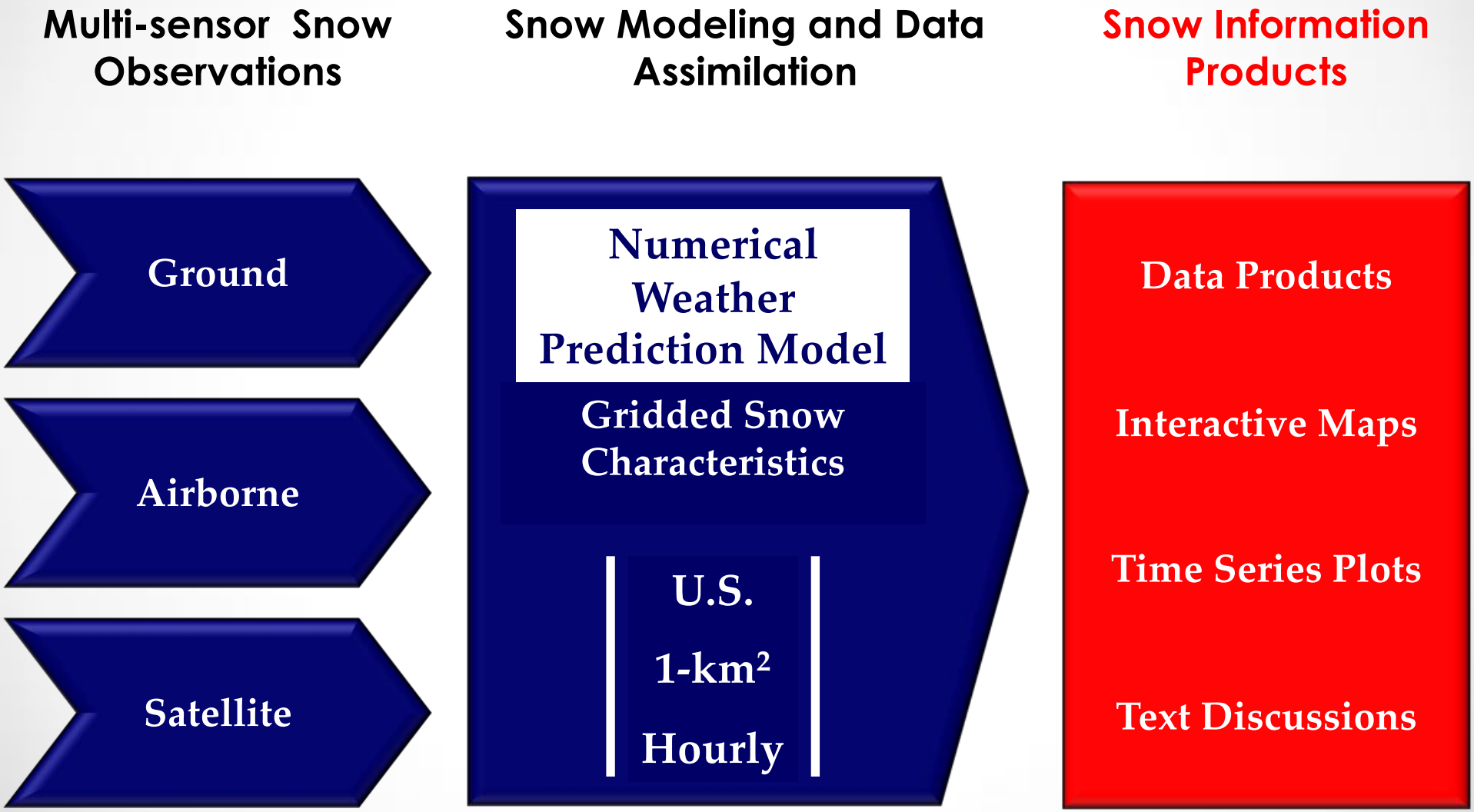
N. Raccoon River, Des Moines River Basin 2004 February 12 - March 11

NWSRFS without NSA data



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

National Snow Analysis



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

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop http://www.nohrsc.nws.gov/ Search

Home Bookmarks mozilla.org mozillaZine Web Mail National Operational... Login : Messenger E... f_loop.gif (GIF Imag...

National Operational Hydrologic Remote Se...

National Operational Hydrologic Remote Sensing Center

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Interactive Maps
3D Visualization
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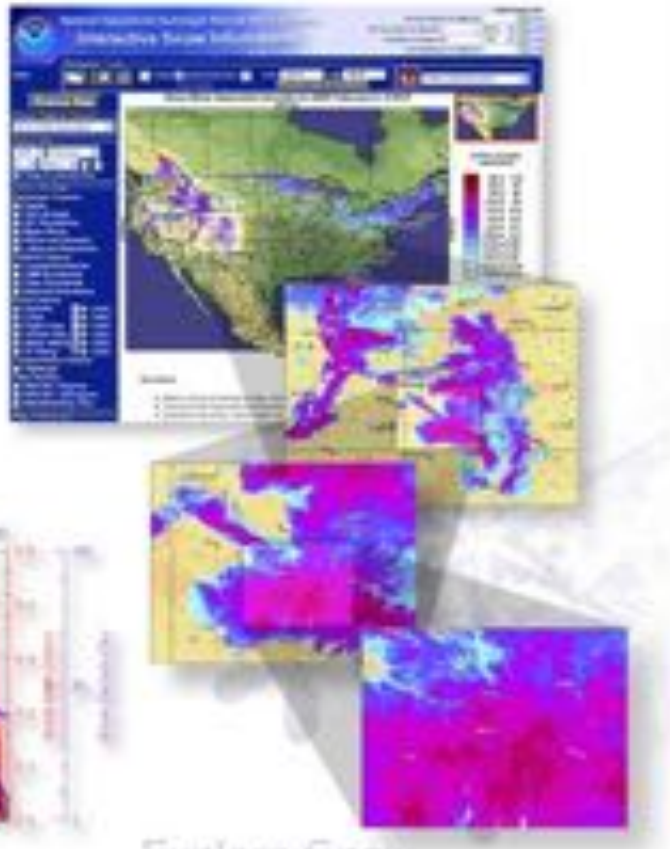
FirstGov.gov

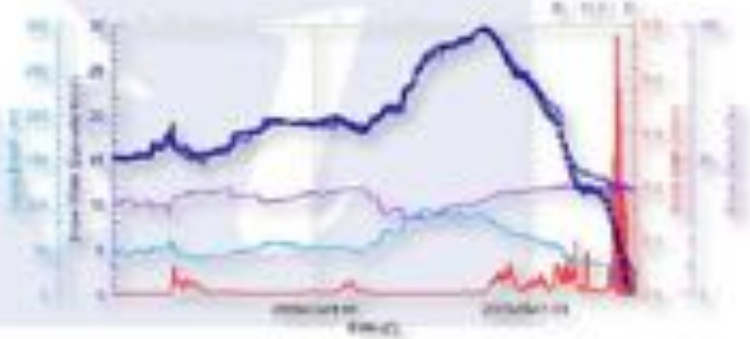
INTERACTIVE SNOW MAPS

Explore our online GIS for comprehensive snow information.

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

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





Explore Snow

National Operational Hydrologic Remote Sensing Center

Interactive Snow Information

Quick Query Links

Get Time Series for Station ID: Go Listing
Get Time Series for Basin ID: ABRFC Go Listing
Get Basin Averages for: RFC Go Listing
Get Climatology for Station ID: Go Listing

Navigation Tools

Home Help Comments

41.39 N, 91.29 W Zoom

Query: Station (2002-present)

Redraw Map

Select Physical Element: Snow Water Equivalent

Select Date: 2019 February 17 00:00 UTC

-- - + ++

Snap to nearest time

Select Overlays

Hydrologic Features
- RFC Basins Label
- Other Basins Label
- HUCs (6-digit)
- RFC Boundaries
- Rivers and Streams
- Lakes and Reservoirs

Political Features
- County Boundaries
- CWA Boundaries
- State Boundaries
- National Boundaries
- Fed. Indian Land Areas

Point Features
- Stations Label
- Cities Label
- Flight Lines Label
- Climate Stns Label
- Skiing Label

Transportation Features
- Roads and Highways

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

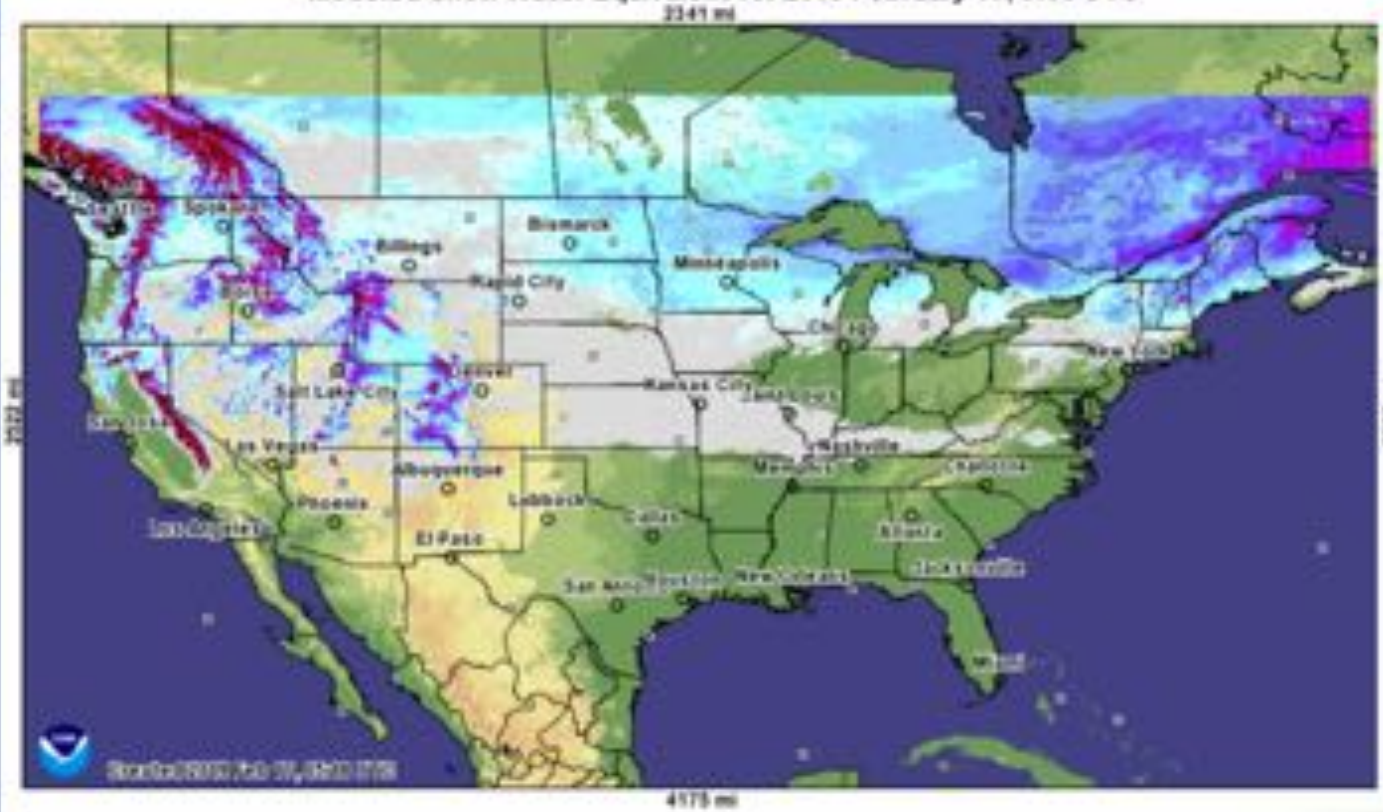
Map Preferences

English units

- Legend below map
- Background image
- Hill shading
- High-contrast palette
- Title on image

800 pixels map width
450 pixels map height

Modeled Snow Water Equivalent for 2019 February 17, 0:00 UTC



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
trace	to	1

Not Estimated

Elevation in feet

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

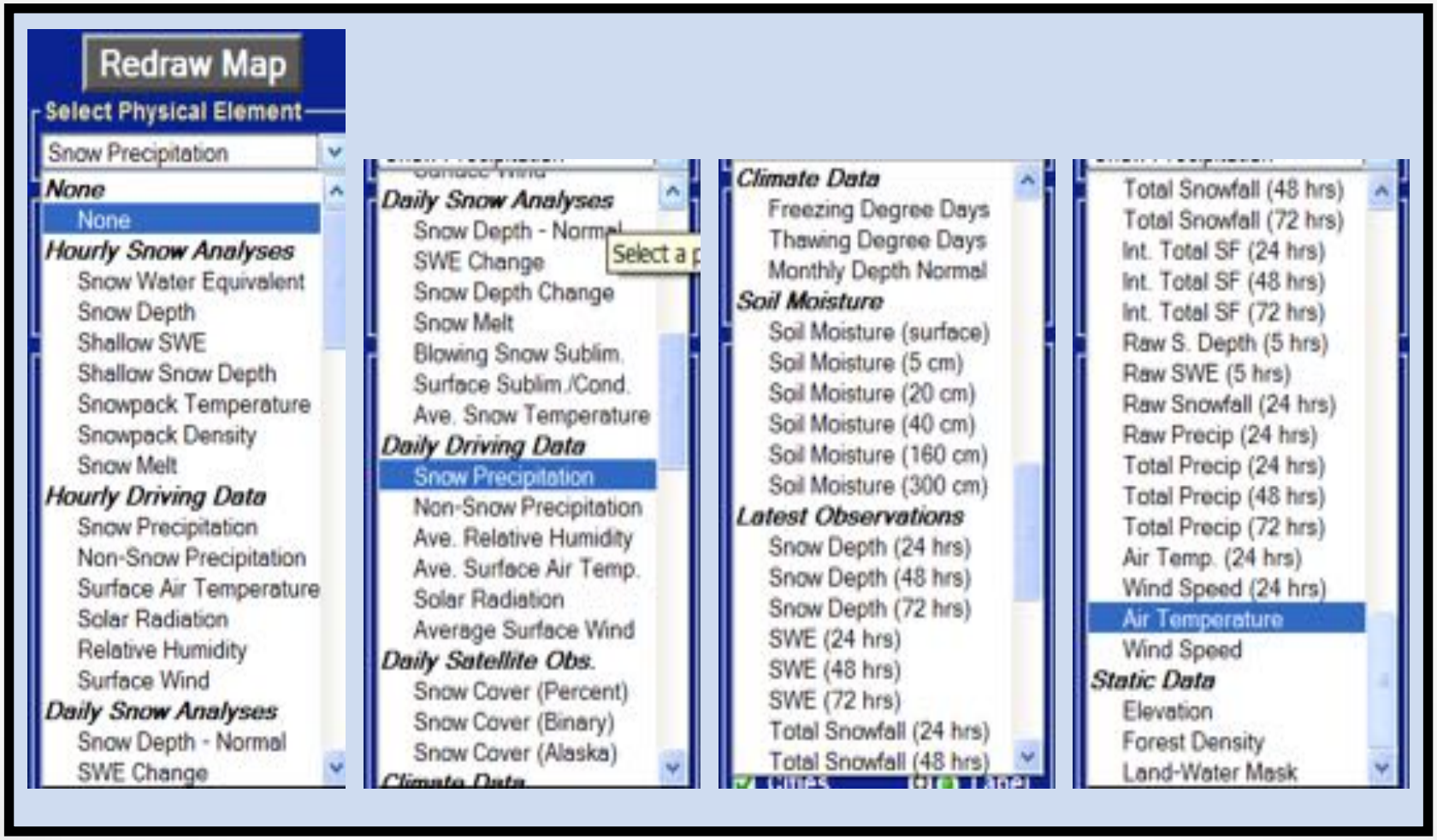
- Gridded observed snowfall images, seasonal totals, and data downloads in several formats can now be found on the National Snowfall Analysis page.

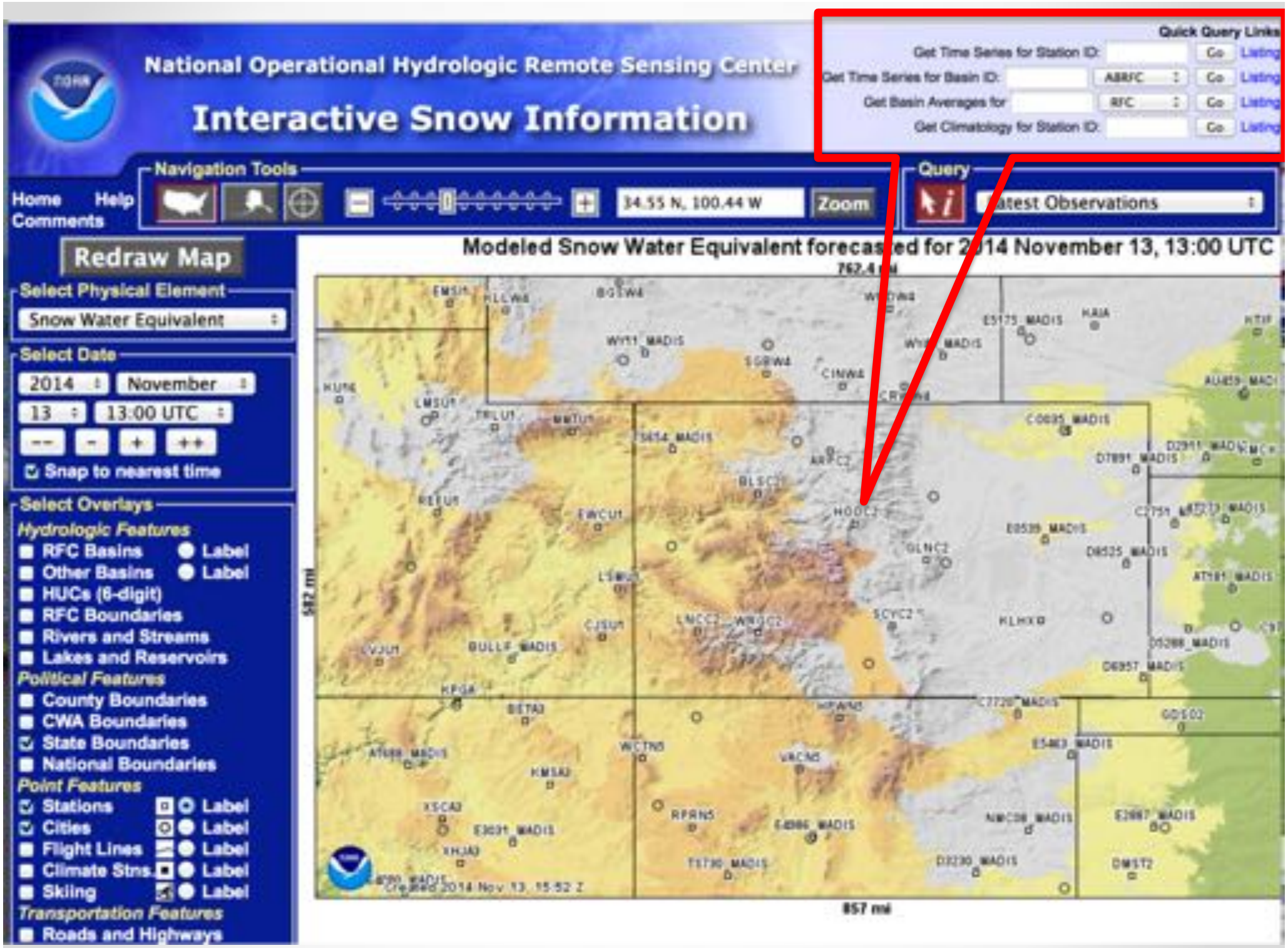
Directions:

- 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




National Operational Hydrologic Remote Sensing Center
Interactive Snow Information
Quick Query Links
Get Time Series for Station ID:
Get Time Series for Basin ID:
ABRFC
Get Basin Averages for:
RFC
Get Climatology for Station ID:
Go
Listing
Navigation Tools
Home
Help
Comments
34.55 N, 100.44 W
Zoom
Query
Latest Observations
Redraw Map
Select Physical Element
Snow Water Equivalent
Select Date
2014
November
13
13:00 UTC
Snap to nearest time
Select Overlays
Hydrologic Features
RFC Basins
Other Basins
HUCs (6-digit)
RFC Boundaries
Rivers and Streams
Lakes and Reservoirs
Political Features
County Boundaries
CWA Boundaries
State Boundaries
National Boundaries
Point Features
Stations
Cities
Flight Lines
Climate Stns
Skiing
Label
Transportation Features
Roads and Highways
Modeled Snow Water Equivalent forecast for 2014 November 13, 13:00 UTC
582 mi
857 mi
Created 2014 Nov 13, 15:52 Z

National Operational Hydrologic Remote Sensing Center

Interactive Snow Information

Quick Query Links

Get Time Series for Station ID: Go Listing

Get Time Series for Basin ID: ABRFC Go Listing

Get Basin Averages for RFC Go Listing

Get Climatology for Station ID: Go Listing

Home News Organization Search Enter Search Here Go

Query Station Time Series

Station SHEF ID MESC2

600 width

400 height

Submit

Reference Map

Links

Plot 1 image
Plot 2 image
Plot 3 image
Plot 4 image
Plot 5 image
Plot 6 image
Plot 7 image
Plot 8 image

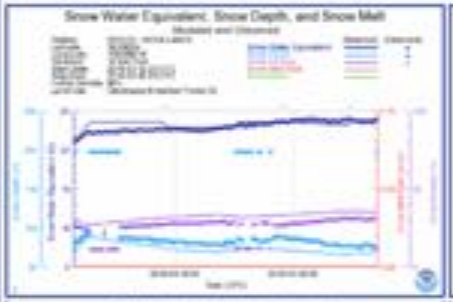
Latest page

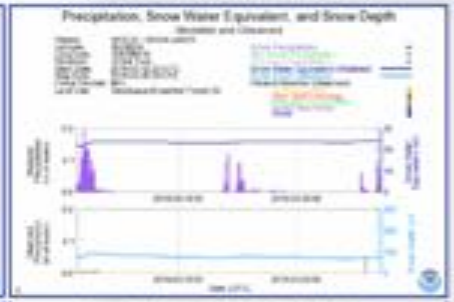
Preferences

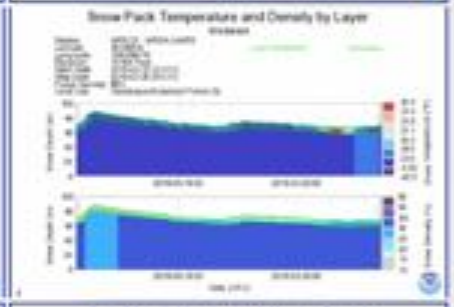
Cookies off

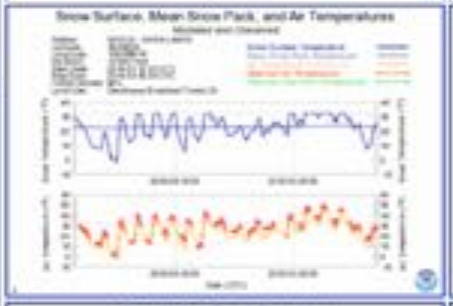
Start Date 2019 March 12 23:00 Z to Stop Date 2019 March 30 23:00 Z

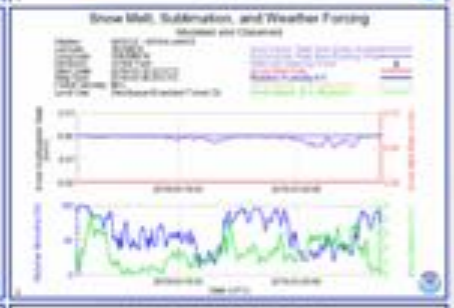
All Graphs English Units Refresh screen More information on station MESC2

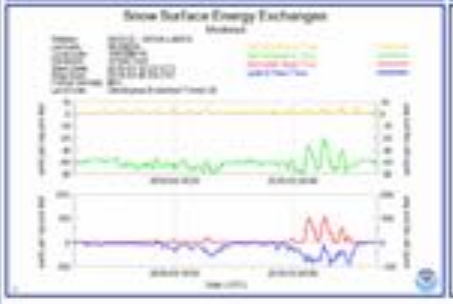


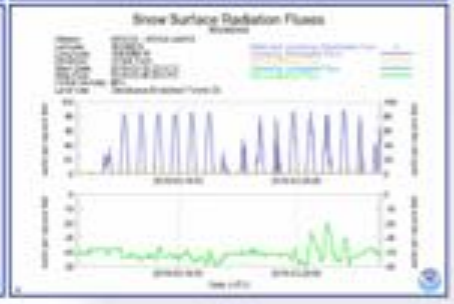












SnowEx

- *Synergies from research to operations.*
- *King Air Calibration and Validation*
- *Snow DA meeting - Improving Water Prediction by Assimilating Snow and Soil Observations.*

Questions?

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Office of Water Prediction
1735 Lake Drive West
Chanhassen, MN
952-368-2503

www.nohrsc.noaa.gov

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

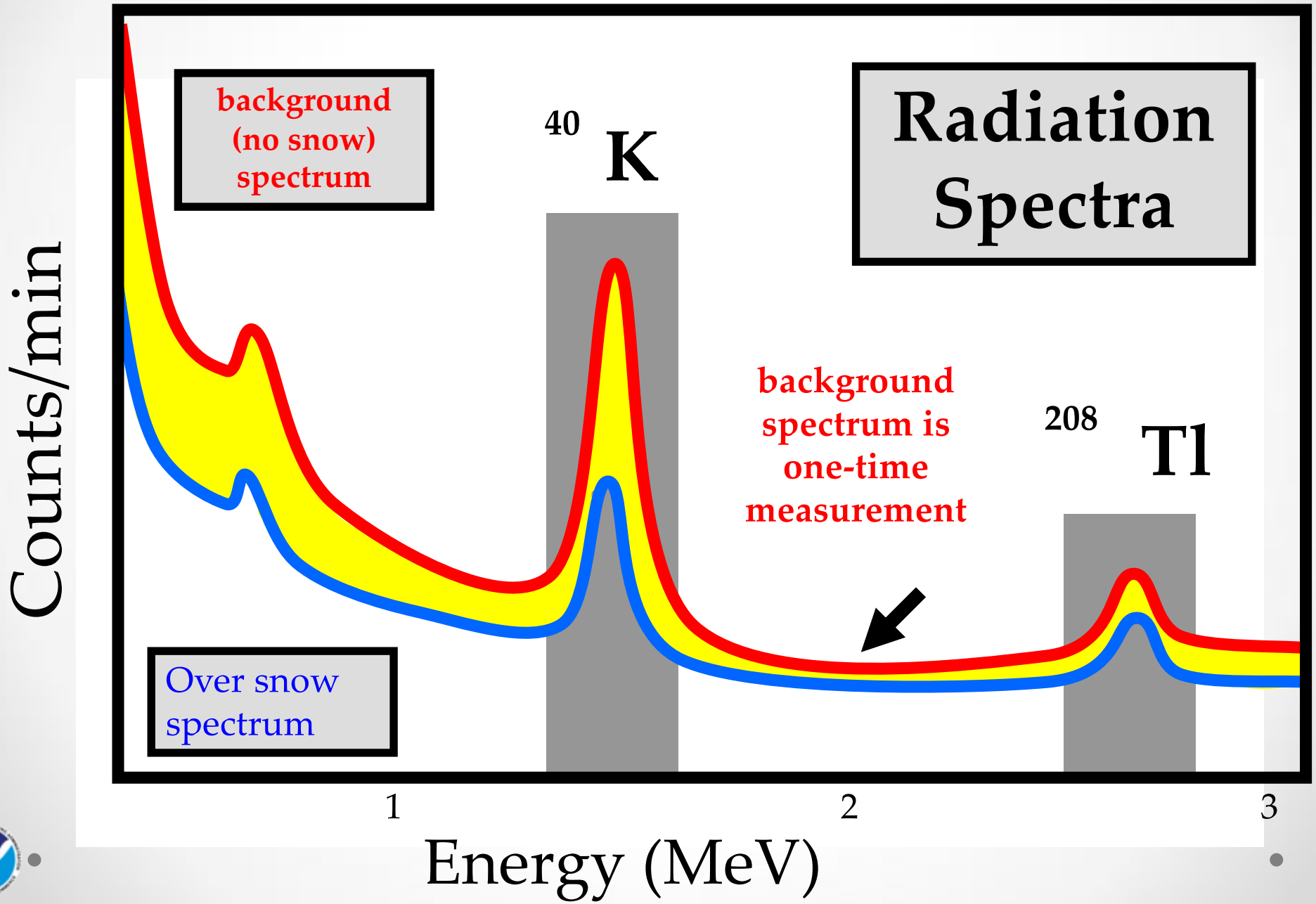
"… investments that make only modest improvements in snow information will have *substantial economic payoffs*."

Airborne Snow Water Equivalent

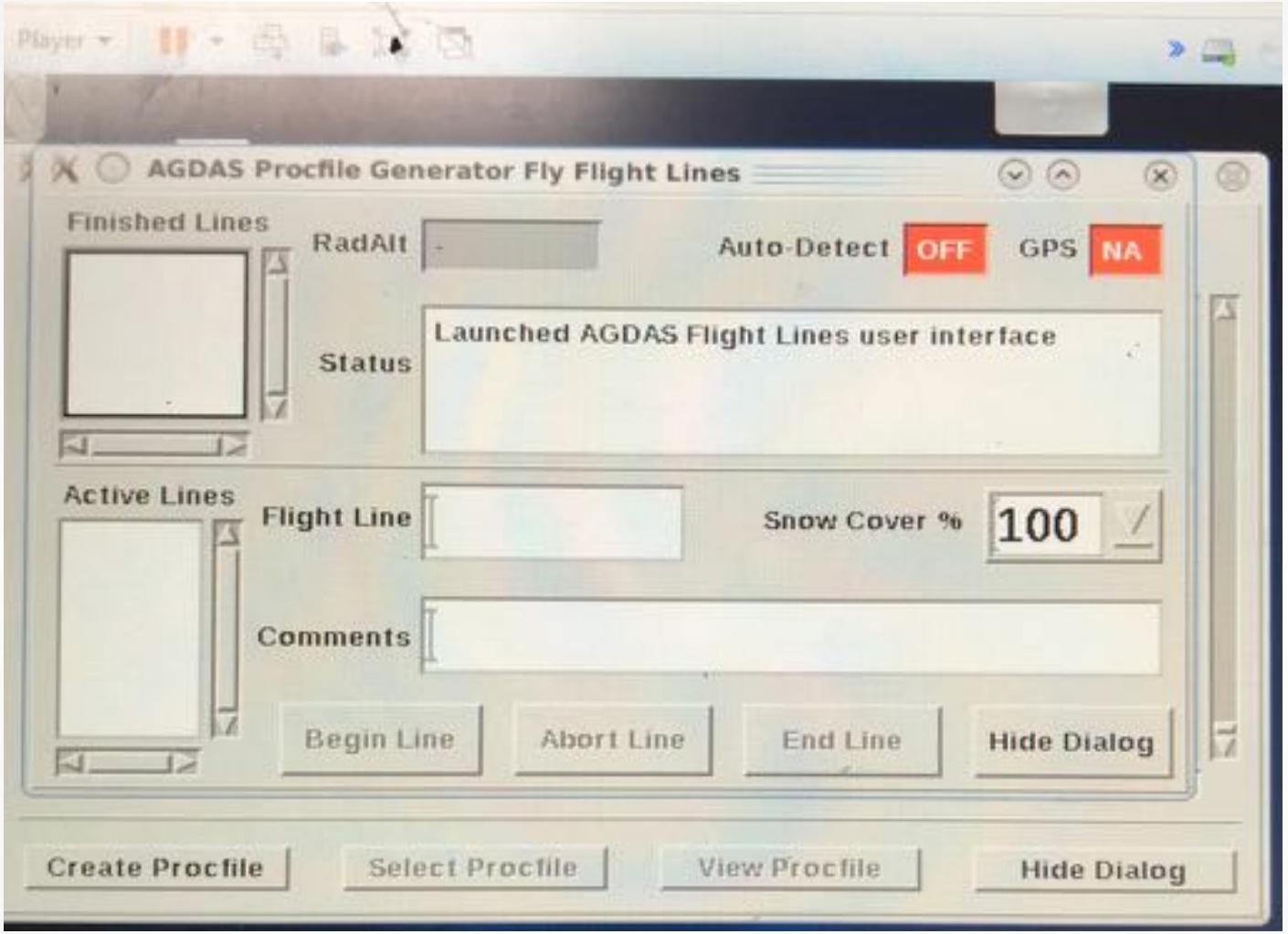
Measurement Error (cm)

	Agri.	Forest
Root Mean Square Error	0.81	2.31
Average Absolute Error	0.75	1.87
Average Bias	0.54	0.15
Percent Bias	12.10	1.28
N (flight lines)	23	70

Natural Terrestrial Gamma Radiation



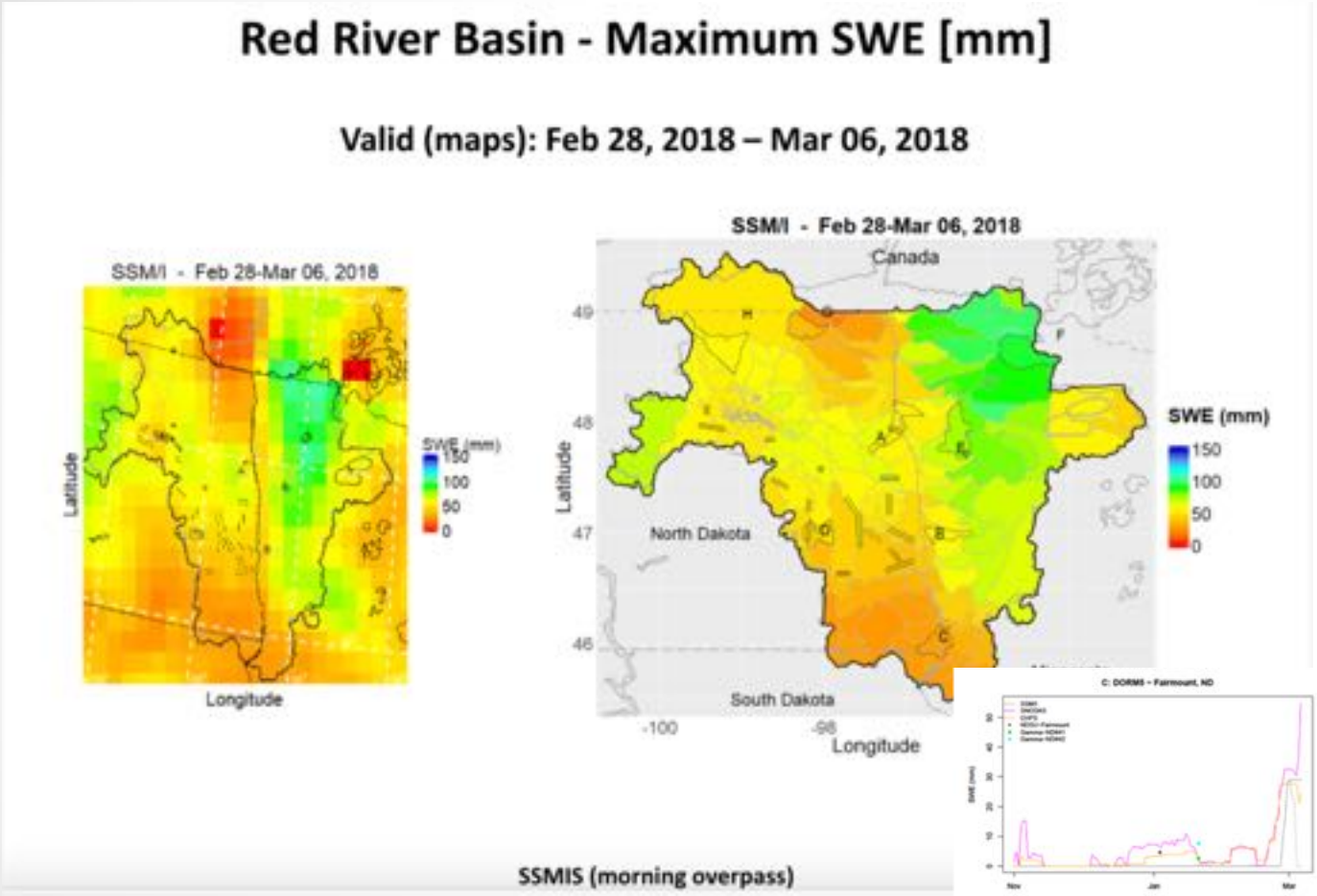
Data Collection

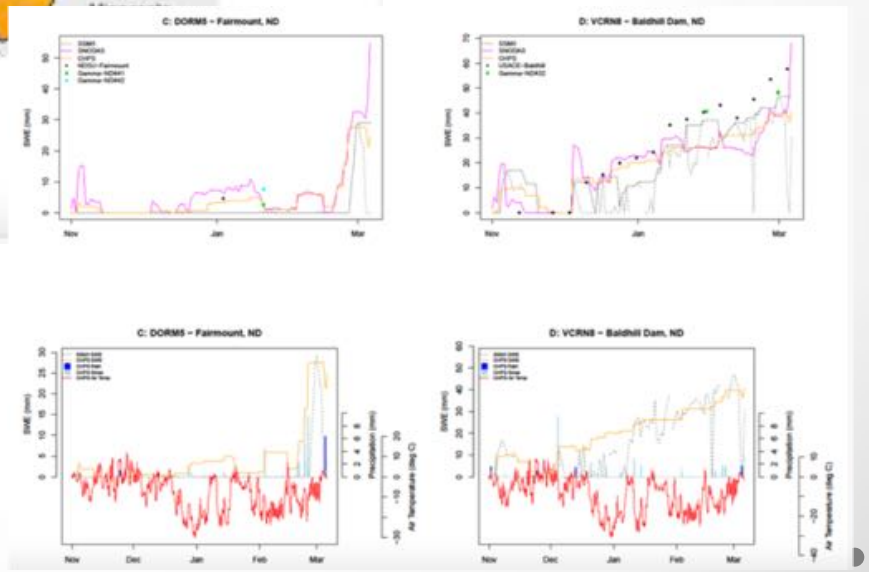


AGDAS

Airborne Gamma Data Acquisition Software

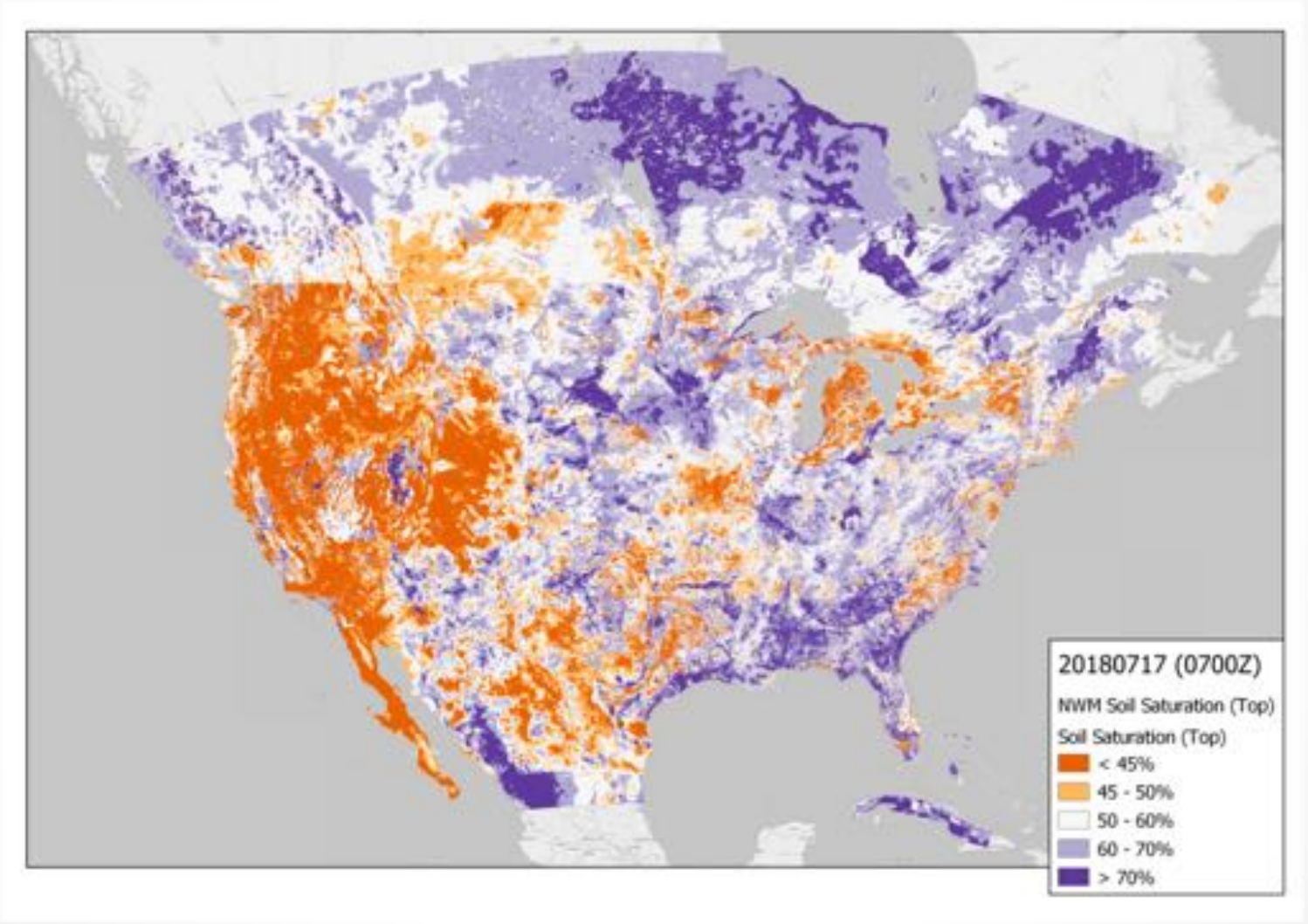
Red River Basin - UNH NCRFC

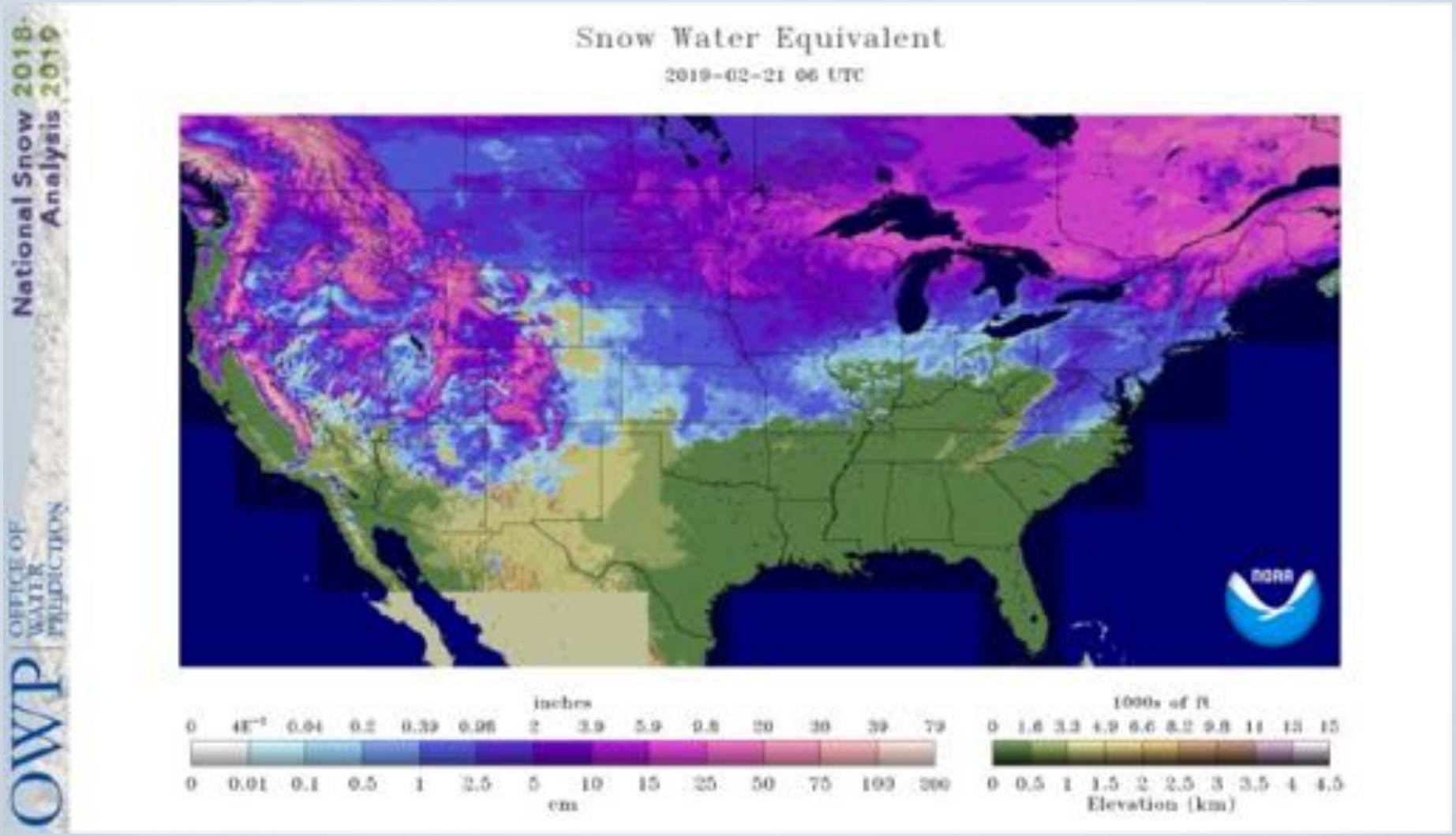




National Water Model

Soil Moisture



NOHRSC NSA

58.8 % of CONUS snow covered on February 21, 2019.