Snow Data Issues and NSA Model Assimilation

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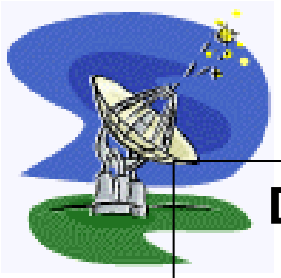
National Weather Service, NOAA

U.S. Department of Commerce

Outline

- **Snow Observations**
  - Importance of snow observations to NSA assimilation.
    - Data collection, metadata issues, and quality control of snow observations.
- **National Snow Analyses (NSA)**
  - Snow modeling and data assimilation system for U.S.
    - Overview of the data assimilation process.

Where do snow observations come from?



Data Feeds

- NoaaPort
- MADIS

Regional Surveys

- Maine Cooperative Snow Survey
- USACE New England District
- Saint Johns River Basin
- Milk River Basin, MT

February 6, 2004

11623 snow depth reports from 4198 unique stations

9201 snow water equivalent reports from 968 unique stations

March 1, 2004

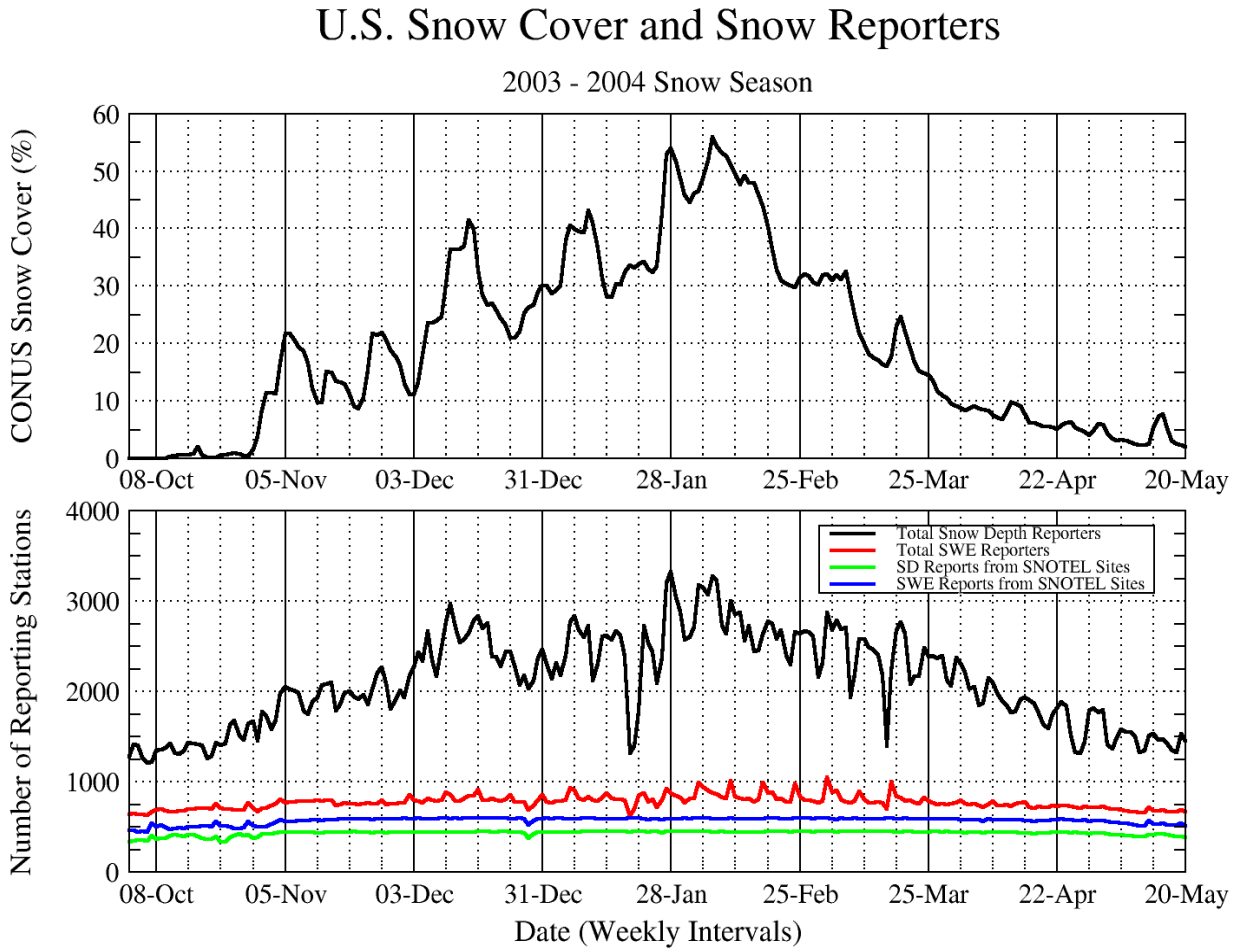
10939 snow depth reports from 3979 unique stations

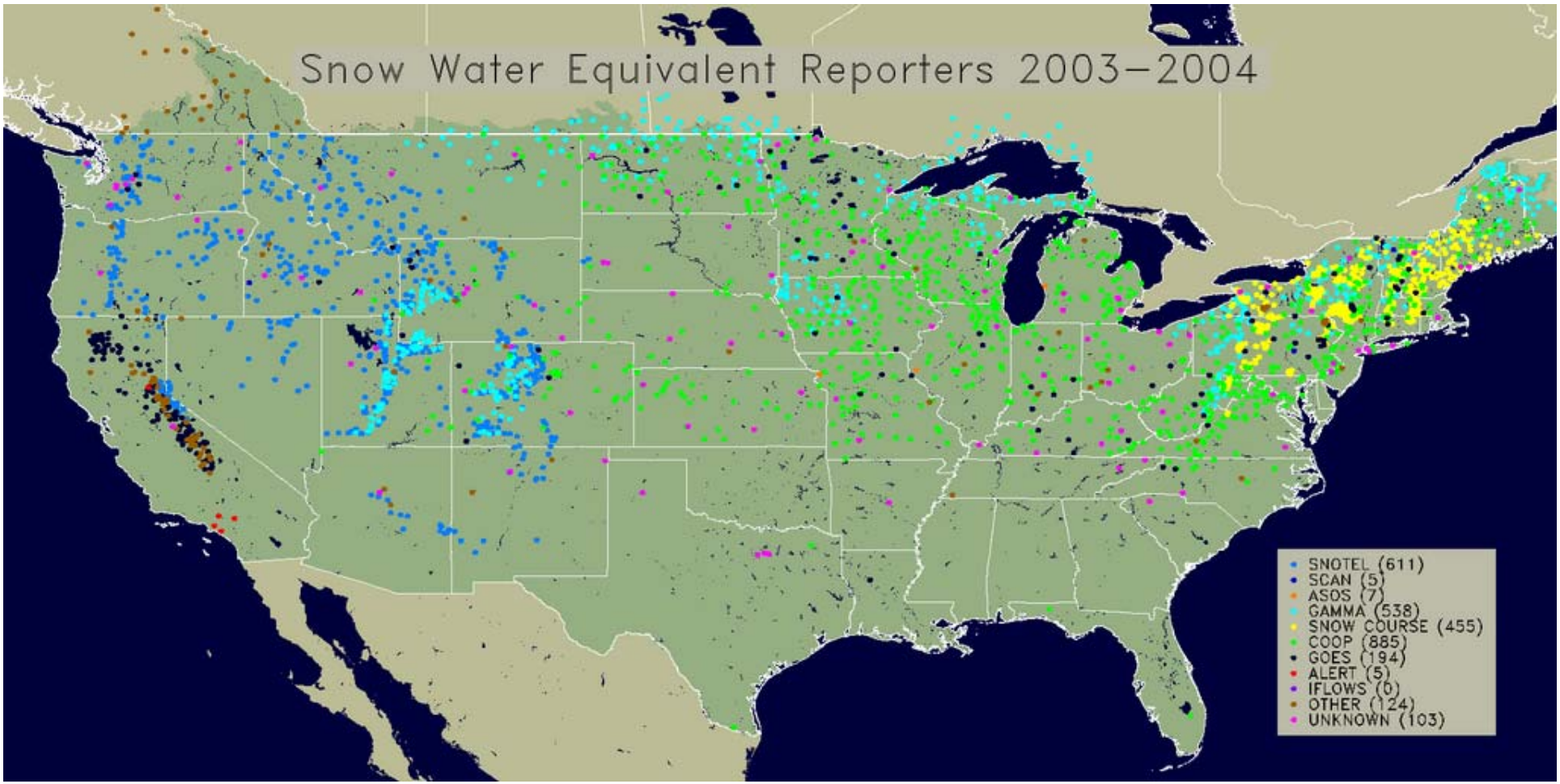
9285 snow water equivalent reports from 1302 unique stations

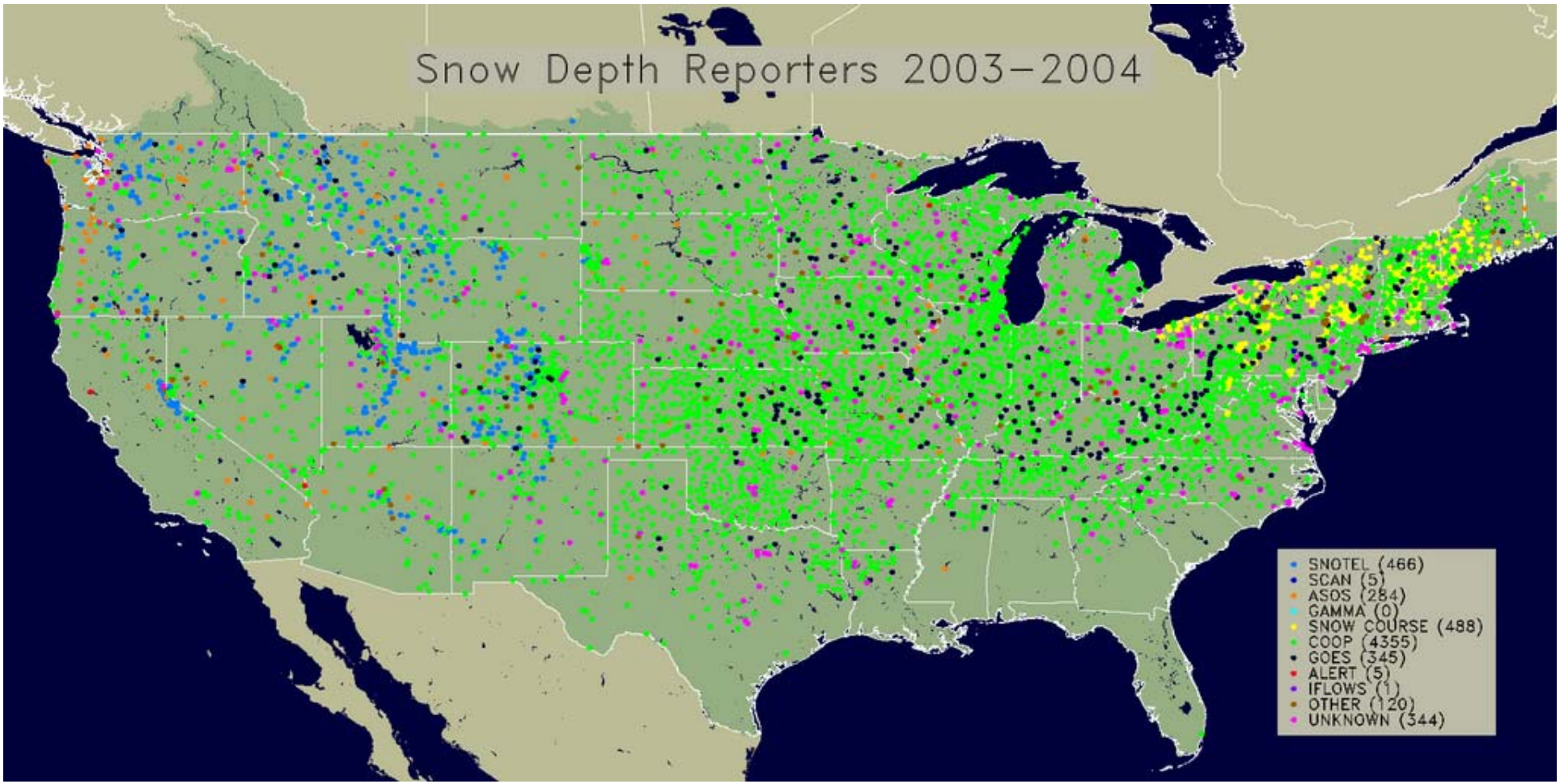
Average day ~ 20,000 stations report any physical element

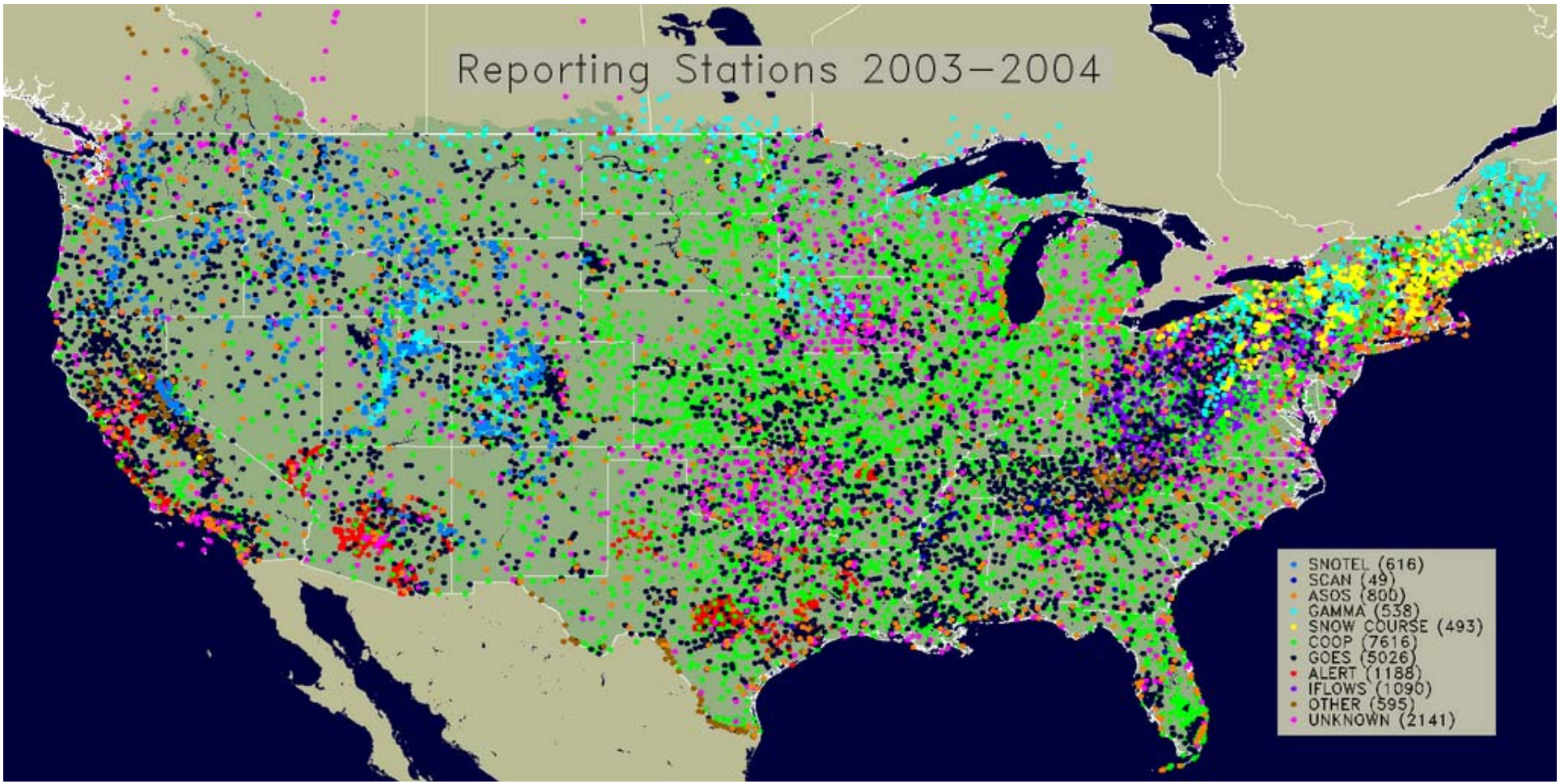
- Past season
  ~ 4000 stations reported SWE.
- Average day
  ~ 750 stations report SWE
- Of these 750
  ~ 500 are SNOTEL

- The remaining 250 observations come from a set of ~ 3000 stations.




Snow Water Equivalent Reporters 2003–2004
SNOTEL (611)
SCAN (5)
ASOS (7)
GAMMA (538)
SNOW COURSE (455)
COOP (885)
GOES (194)
ALERT (5)
IFLOWS (0)
OTHER (124)
UNKNOWN (103)


Snow Depth Reporters 2003–2004
SNOTEL (466)
SCAN (5)
ASOS (284)
GAMMA (0)
SNOW COURSE (488)
COOP (4355)
GOES (345)
ALERT (5)
IFLOWS (1)
OTHER (120)
UNKNOWN (344)


Reporting Stations 2003–2004
SNOTEL (616)
SCAN (49)
ASOS (800)
GAMMA (538)
SNOW COURSE (493)
COOP (7616)
GOES (5026)
ALERT (1188)
IFLOWS (1090)
OTHER (595)
UNKNOWN (2141)

Metadata Sources at NOHRSC

Over 40 different sources used for station Metadata

National Weather Services Database

NWSLI
CSSA (B44's)
Meteorological Station Location Information
NWS-ICAO
NWS-METAR
MADIS-FSL
Hydromet. Automated Data System
NCDC

Federal and State Agencies

NRCS SNOTEL and Snow Courses
USACE New England District Snow Surveys
Federal Aviation Administration
California Department of Water Resources
Maine Cooperative Snow Survey
MesoWest (150 + smaller mesonets)
Numerous State Mesonets

Weather Forecast Offices, River Forecast Centers and Regional Offices

Over 50,000 Stations in NOHRSC's Database

NEED ONE-STOP SHOPPING FOR STATION METADATA

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 unknown1950 stations.

Importance of Accurate Metadata

- Numerous databases leads to uncertainties in the station metadata
  - Example : Cole Canyon, station CLCW4
    - Latitude and Longitude from NWLSI places this station in Canada, it should be in Wyoming
    - Snotel Metadata
      - 44.80000
      - -104.0667
      - Elevation 5910 meters
    - NWSLI Metadata
      - 49.4889
      - -104.4161
      - Elevation 5910 meters

Importance of Data in SHEF

- If data is not sent across NOAAPort in SHEF format 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...

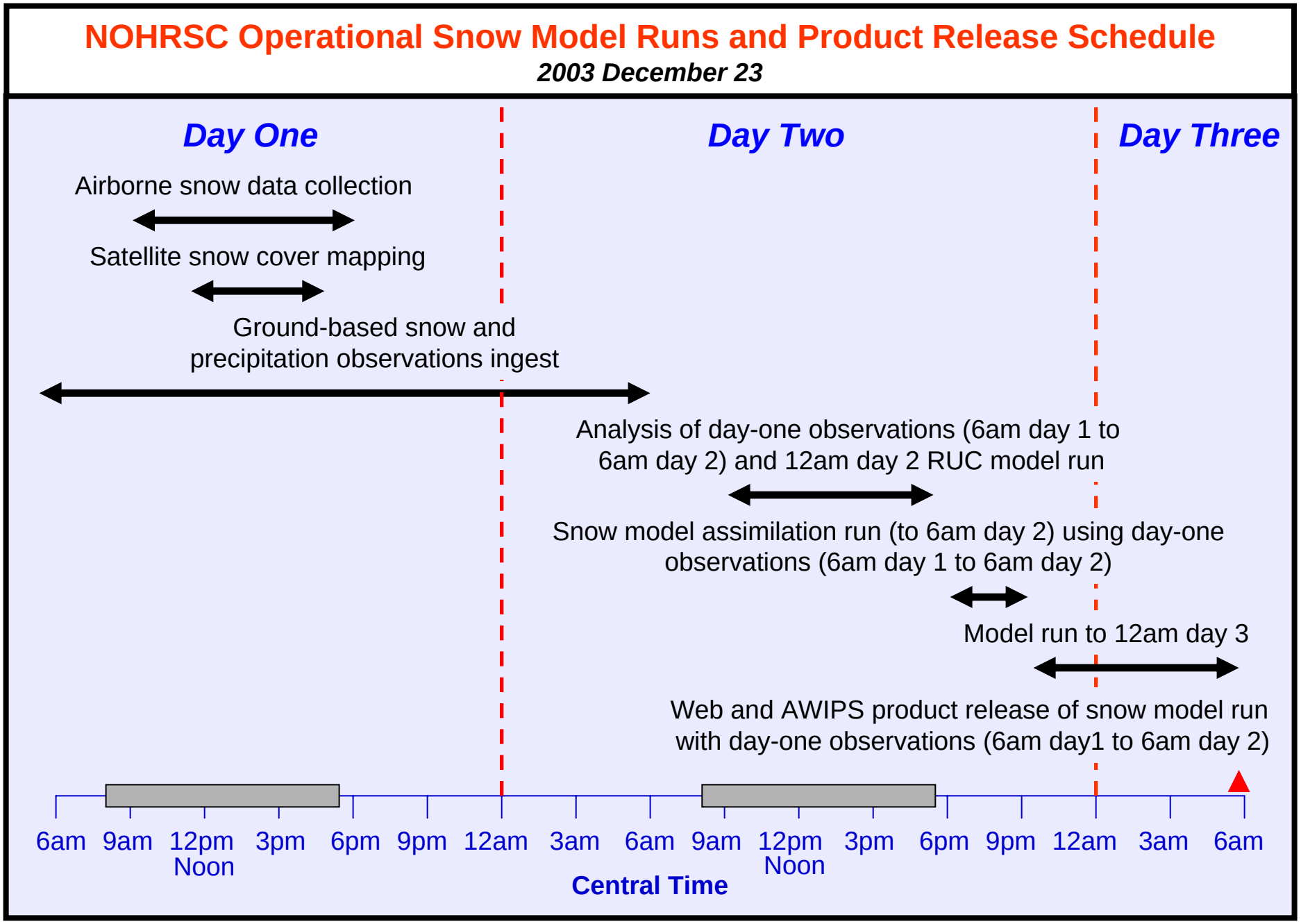
ANOTHER UPPER LEVEL LOW PRODUCED A MOIST EASTERLY FLOW BROUGHT PRECIPITATION TO MOST THE REGION.

HERE IS A LIST OF TOTALS SINCE WEDNESDAY NIGHT.

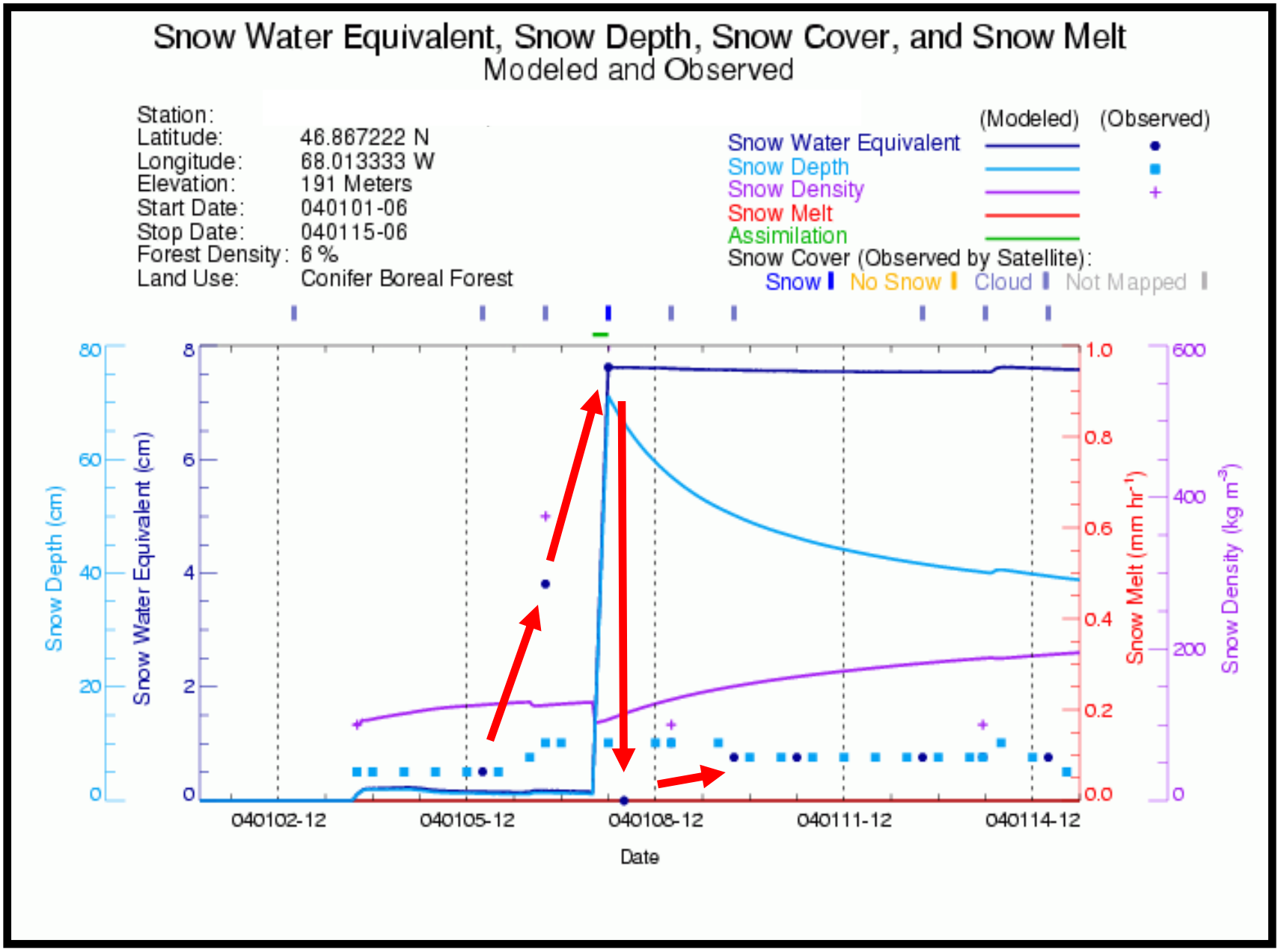
LOCATION	PRECIPITATION (INCHES)	SNOWFALL (INCHES)
...WASATCH MOUNTAINS AND PLATEAU...		
SNOWBASIN MID BOWL	0.54	6
FARMINGTON (8000 FT)	0.40	5
ROCKY BASIN (OQUIRRHS)	0.40	4
BEN LOMOND PEAK (8000 FT)	0.40	4
INDIAN CANYON (9100 FT	0.40	4
WHITE RIVER (8500 FT)	0.40	4
SUNDANCE (7500 FT)	0.36	3
RED PINE RIDGE (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

NOHRSC Operational Snow Model Runs and Product Release Schedule

2003 December 23



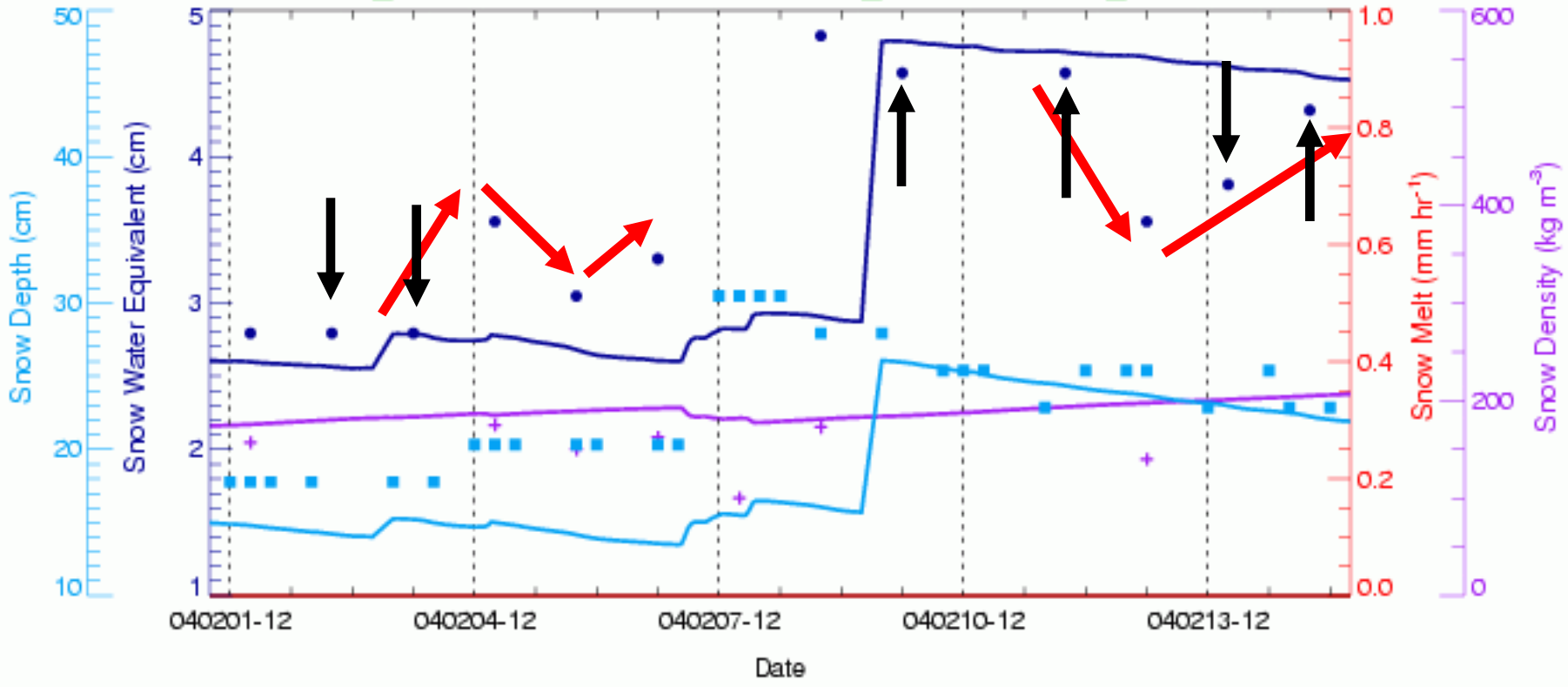
Importance of Accurate Measurements



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: 040201-06
Stop Date: 040215-06
Forest Density: 6 %
Land Use: Conifer Boreal Forest

(Modeled) (Observed)
Snow Water Equivalent
Snow Depth
Snow Density
Snow Melt
Assimilation
Snow Cover (Observed by Satellite):
Snow | No Snow | Cloud | Not Mapped



Meteorological Handbook No. 1, Surface Weather Observations and Reports (FCM-H1-1995).

Paragraph 12.7.2, a. Precipitation, (d) Snow Depth on Ground (4/sss). At designated stations, the total snow depth on the ground group shall be coded in the 0000 and 1200 UTC observation whenever there is more than a trace of snow on the ground. It shall be coded in the 0600 and 1800 UTC observation if there is more than a trace of snow on the ground and more than a trace of precipitation (water equivalent) has occurred within the past 6 hours. The remark shall be coded in the format, 4/sss, where 4/ is the group indicator and sss is the snow depth in whole inches using three digits. For example, a snow depth of 21 inches shall be coded as "4/021".

The NWS requests the above paragraph be changed to:

At designated stations, the total depth of snow on the ground shall be coded in the 0000, 0600, 1200, and 1800 UTC observation whenever there is more than a trace of snow on the ground. The remark shall be coded in the format, 4/sss, where 4/ is the group indicator and sss is the snow depth in whole inches using three digits. For example, a snow depth of 21 inches shall be coded as "4/021".

National Weather Service Observing Handbook No.7, Part IV, Supplementary Observations

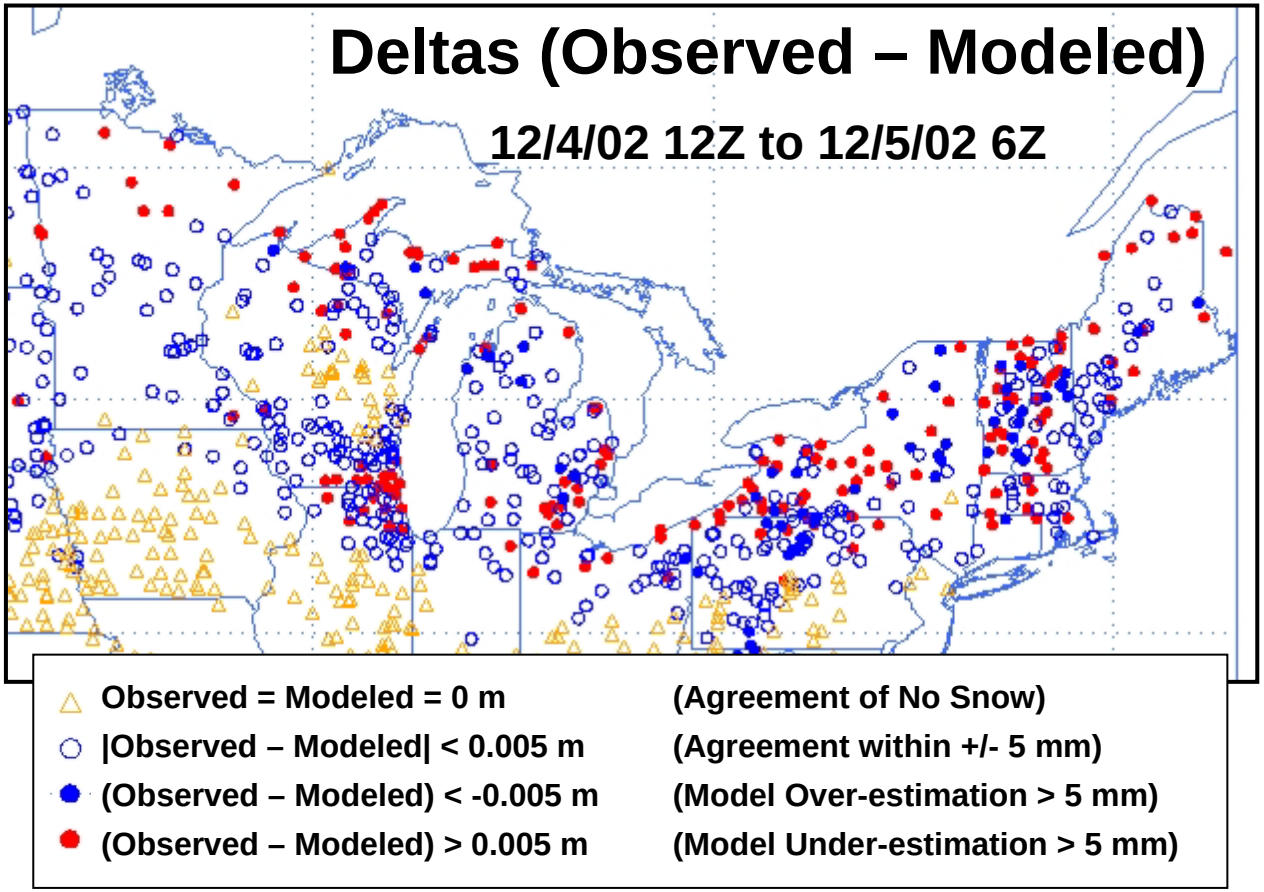
- **Estimating snow water equivalent using 10 to 1 ratios or lookup tables is *NOT NWS* policy**.
  (Data is more than worthless)
- Revisions have been made this past summer.
- The new manual is NWSM 10-1311, Supplementary Observations
- http://www.nws.noaa.gov/directives/010/pd01013011a.pdf

- **Importance of Snow Observations to the National Snow Analyses (NSA)**
  - Snow modeling and data assimilation system for U.S.

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**

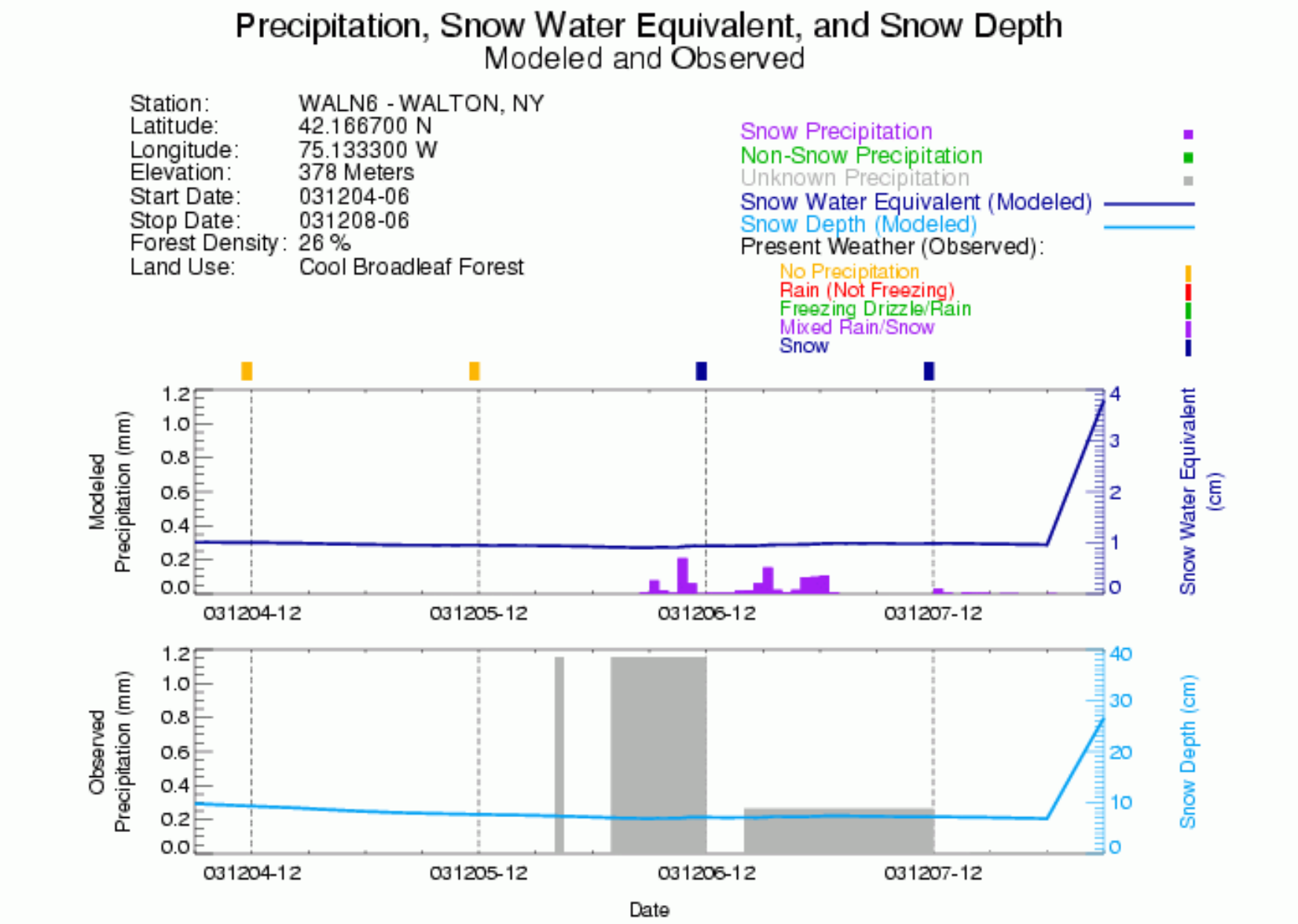


Why Assimilate?

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

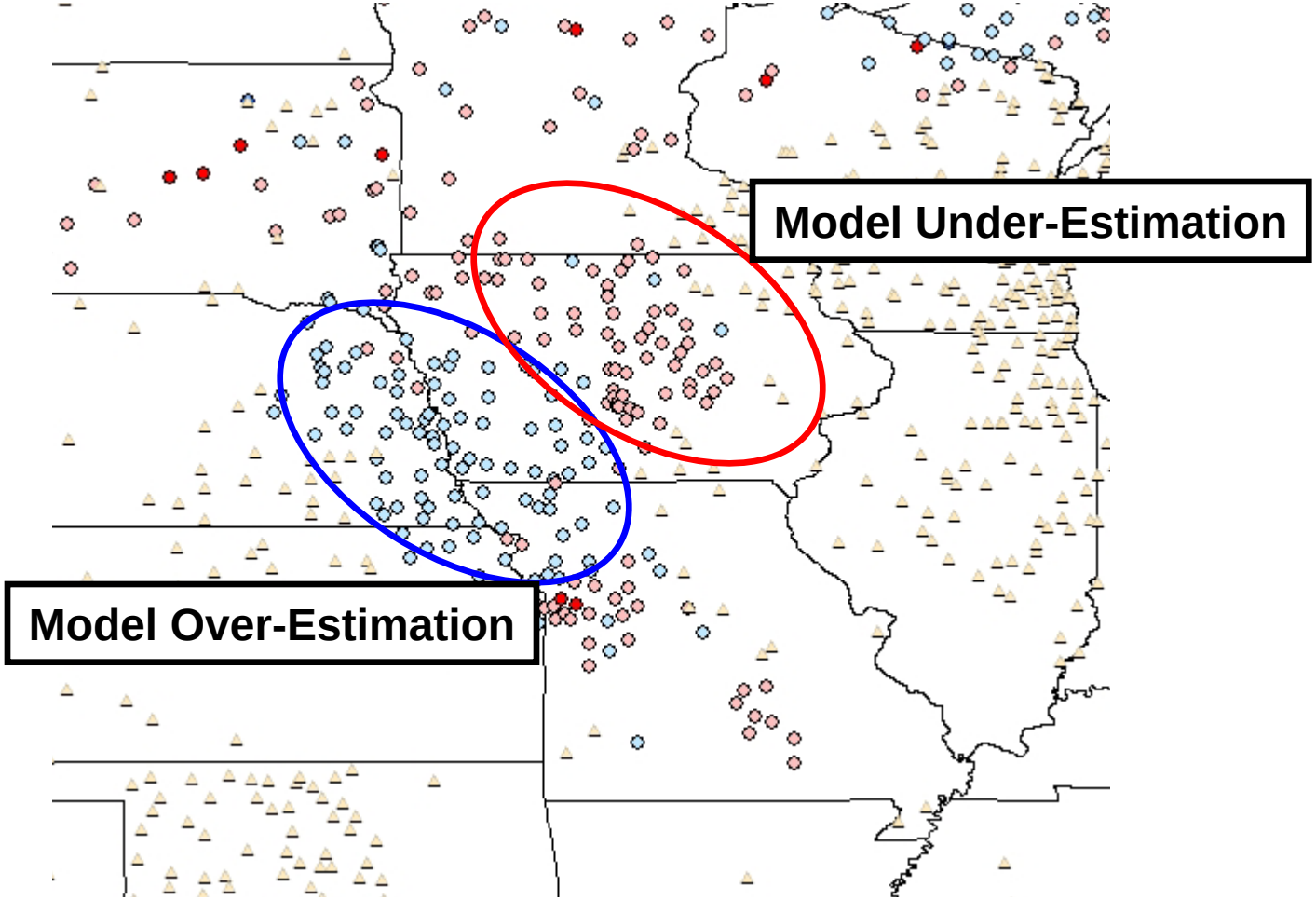
- Uncertainties due model physics
  - Melt problems due to temperature bias
  - Sublimation rates

RUC2 Underestimated Precipitation



Placement of Storm Track

- **The model propagated the system through the region too slowly.**

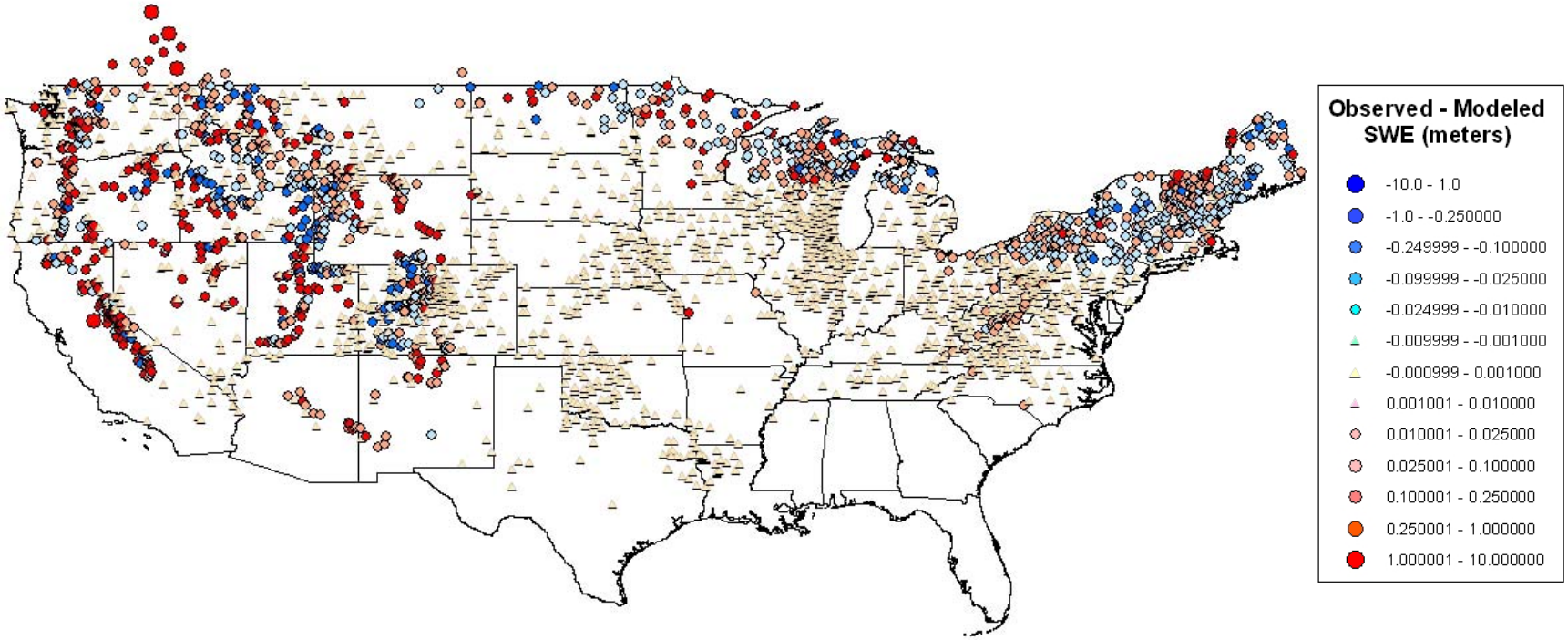


Data Sources Used to Determine Assimilation Region

- Use Current Observations
  - Ground Based Snow Depth
  - Ground Based Water Equivalent
  - Ground Based Snow Density
  - Airborne Gamma Data
- Satellite Snow Cover
  - 1km NOHRSC Snow Map
  - 5km NESDIS Snow Map
- Snow Model Snow Cover
- Present Weather
  - Temperature
  - Precipitation
- Model Bias
  - Typing of precipitation
  - Temperature bias

(Observed – Modeled) Snow States

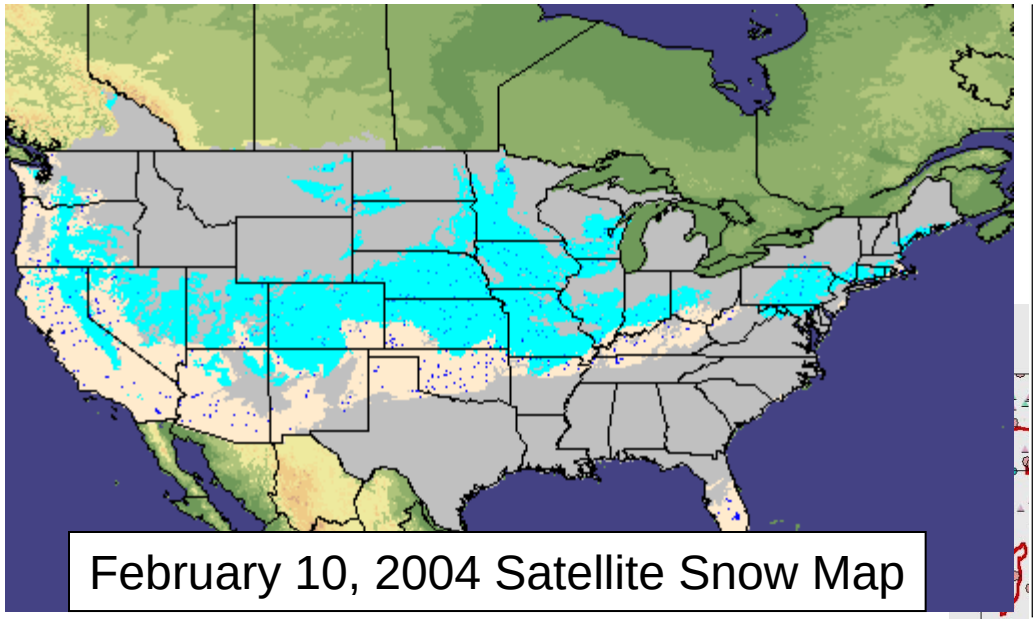
Observations collected from previous 24 hours ending at 12Z of current day



2000 to 3000 Snow Depth or Water Equivalent Ground Observations

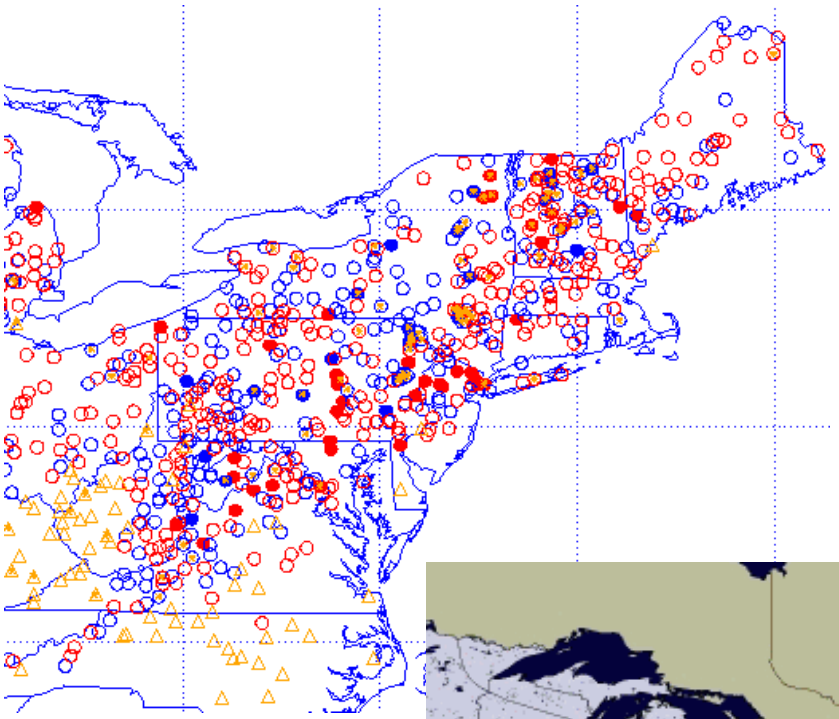
Determination of Assimilation Region

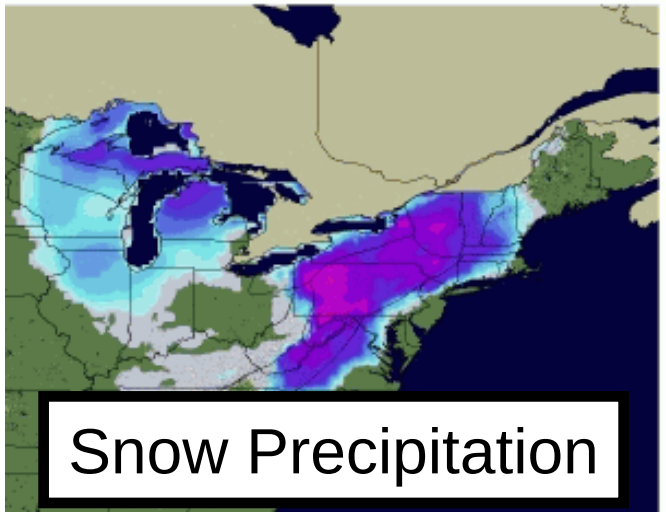
Satellite Snow Cover

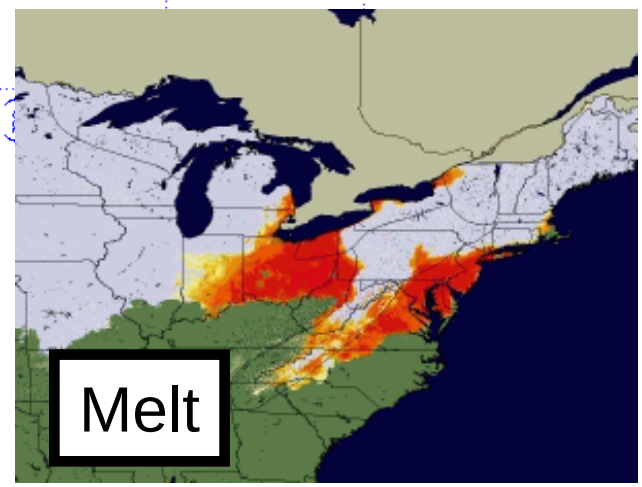


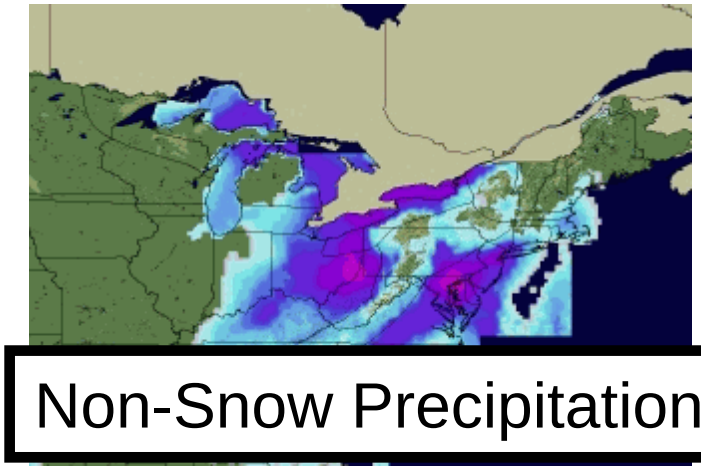
February 10, 2004 Satellite Snow Map

Determination of Assimilation Region
Present Weather







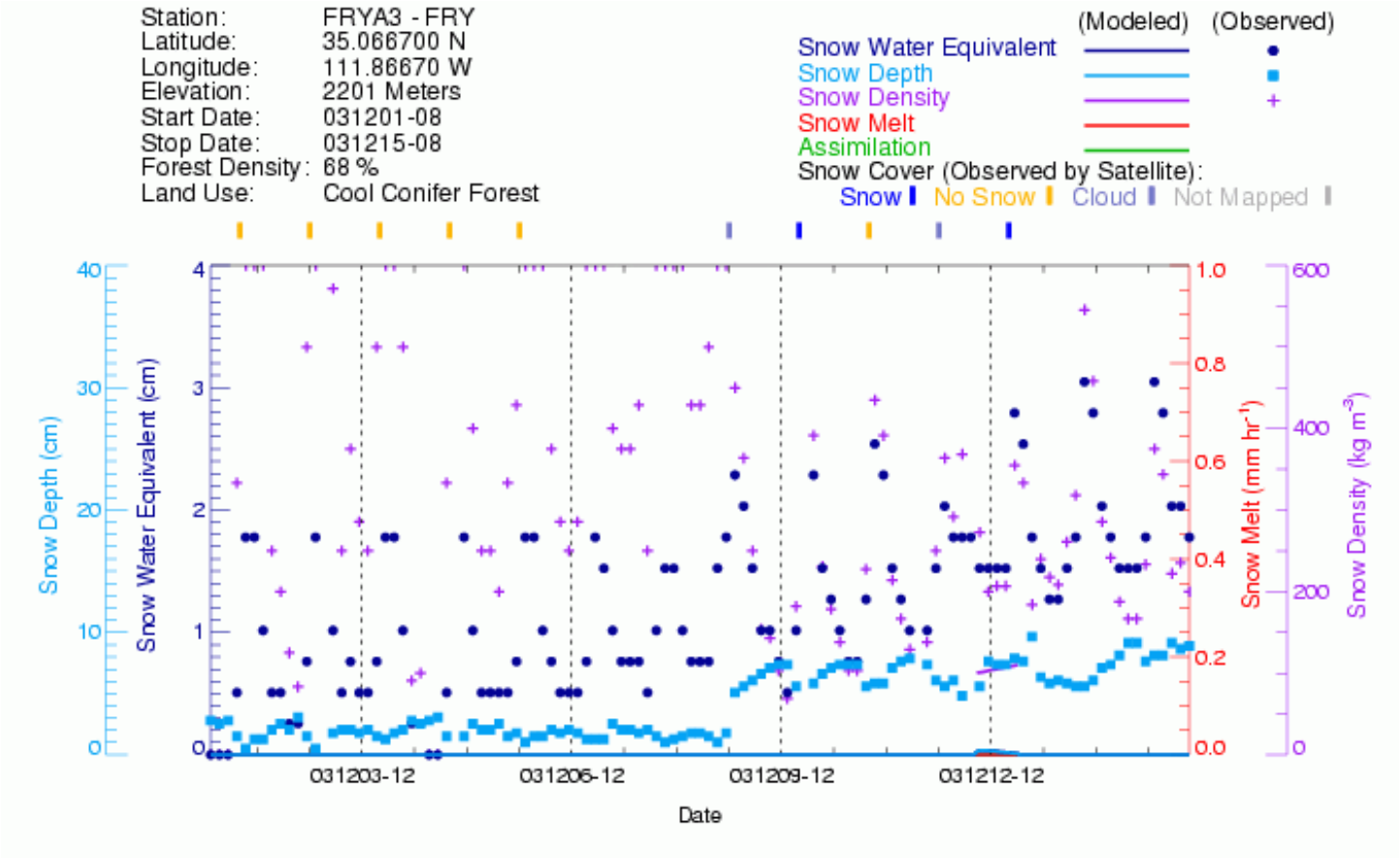


Quality Control of Data

- All observations go through automated quality control
- Outlier observations are manually quality control
- Snow data quality control issues
  - Station instability
  - Spatial representativeness of observation; point-in-pixel consistency
  - Fundamental measurement errors

Manual Quality Control

Temporal Consistency

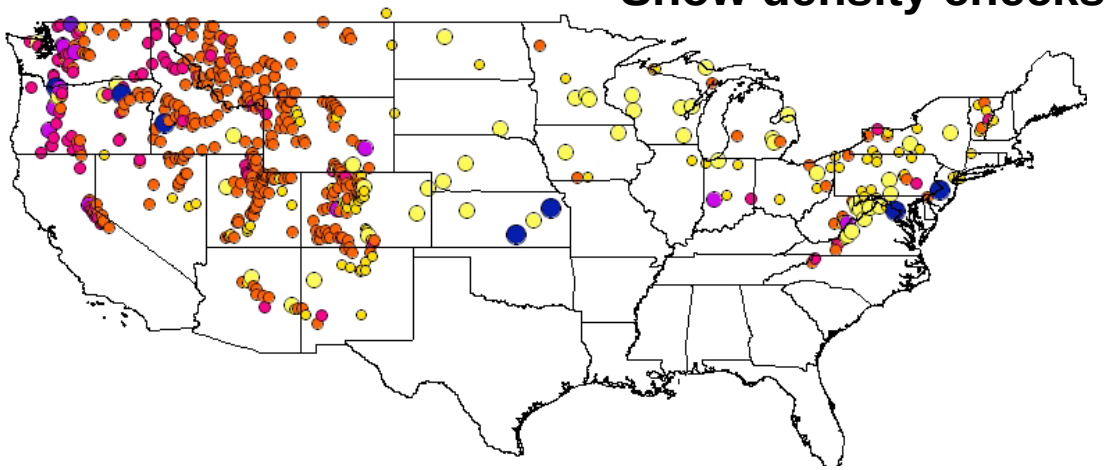


Unstable snow pillow observations in early and late season when SWE is less than 2 inches water.

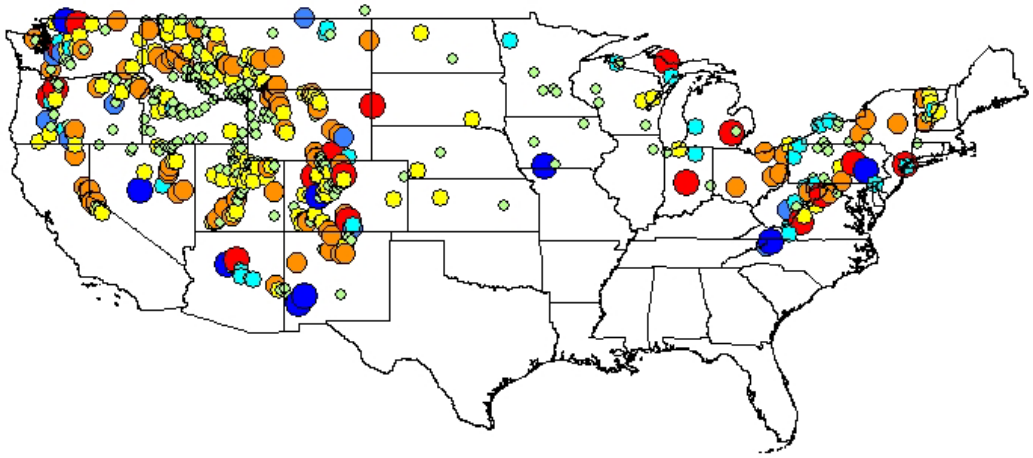
Manual Quality Control

Internal Consistency

Snow density checks



DENSITY_OB
- 0.000000
- 0.000001 - 100
- 100 - 200
- 200 - 300
- 300- 400
- 400 - 500
- 500 - 600
- 600 - 10500



Modeled - Observed Density
- -309.480988 - -200.000000
- -199.999999 - -100.000000
- -99.999999 - -75.000000
- -74.999999 - 0.000000
- 0.000001 - 75.000000
- 75.000001 - 100.000000
- 100.000001 - 200.000000

Spatial Representativeness: Point-in-Pixel Problem

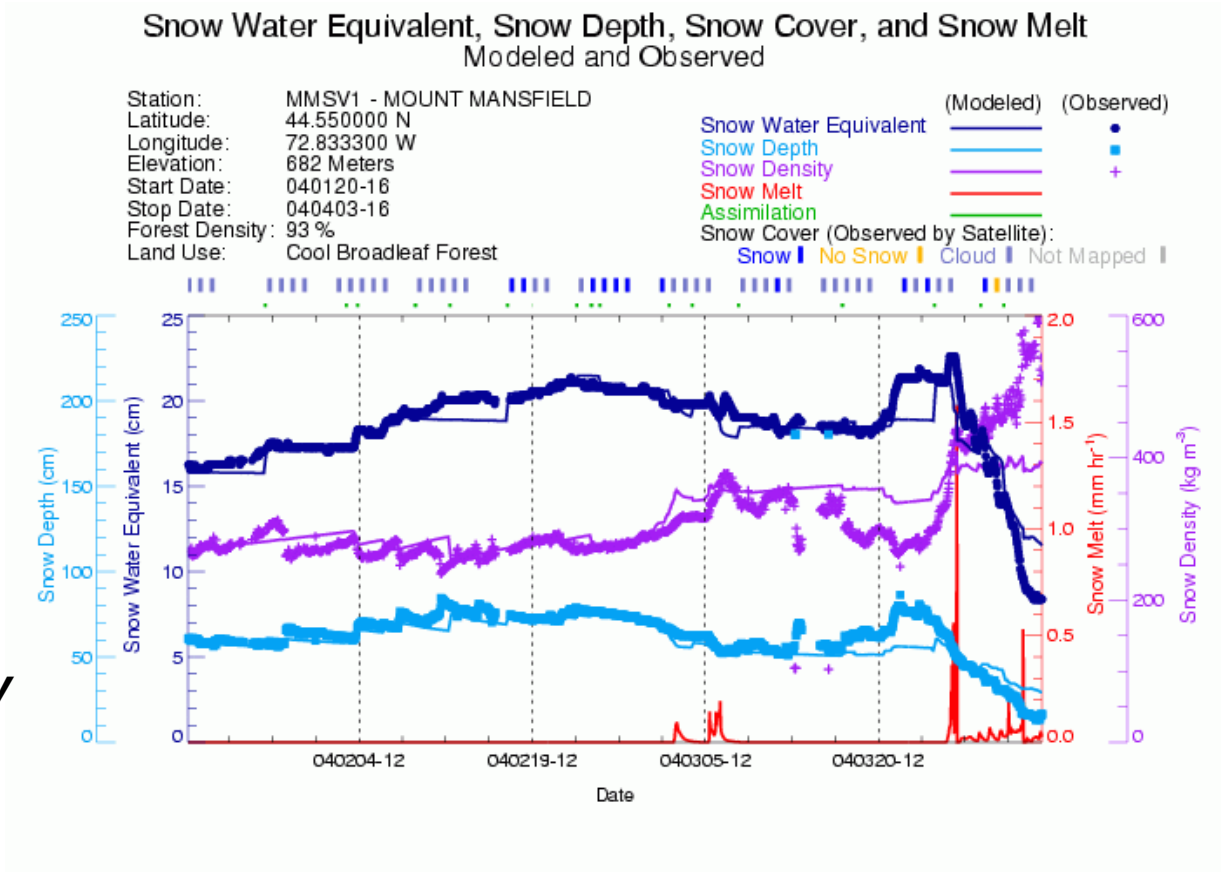
Mt. Mansfield SCAN Site

- Vermont

Model:

93% Forest Canopy Density

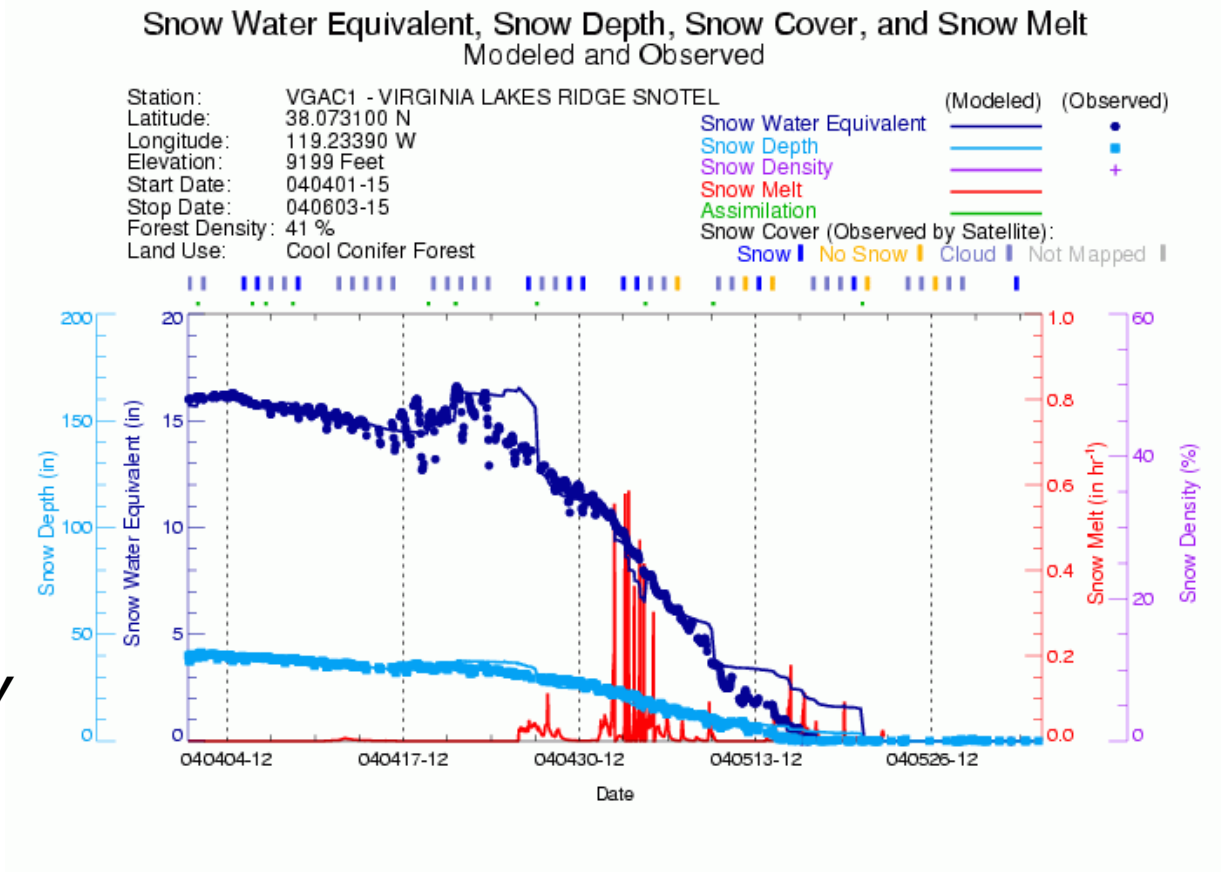
Cool Broadleaf Forest



Spatial Representativeness: Point-in-Pixel Problem

Virginia Lakes Ridge SNOTEL

- Sierra Nevada, California



Model:

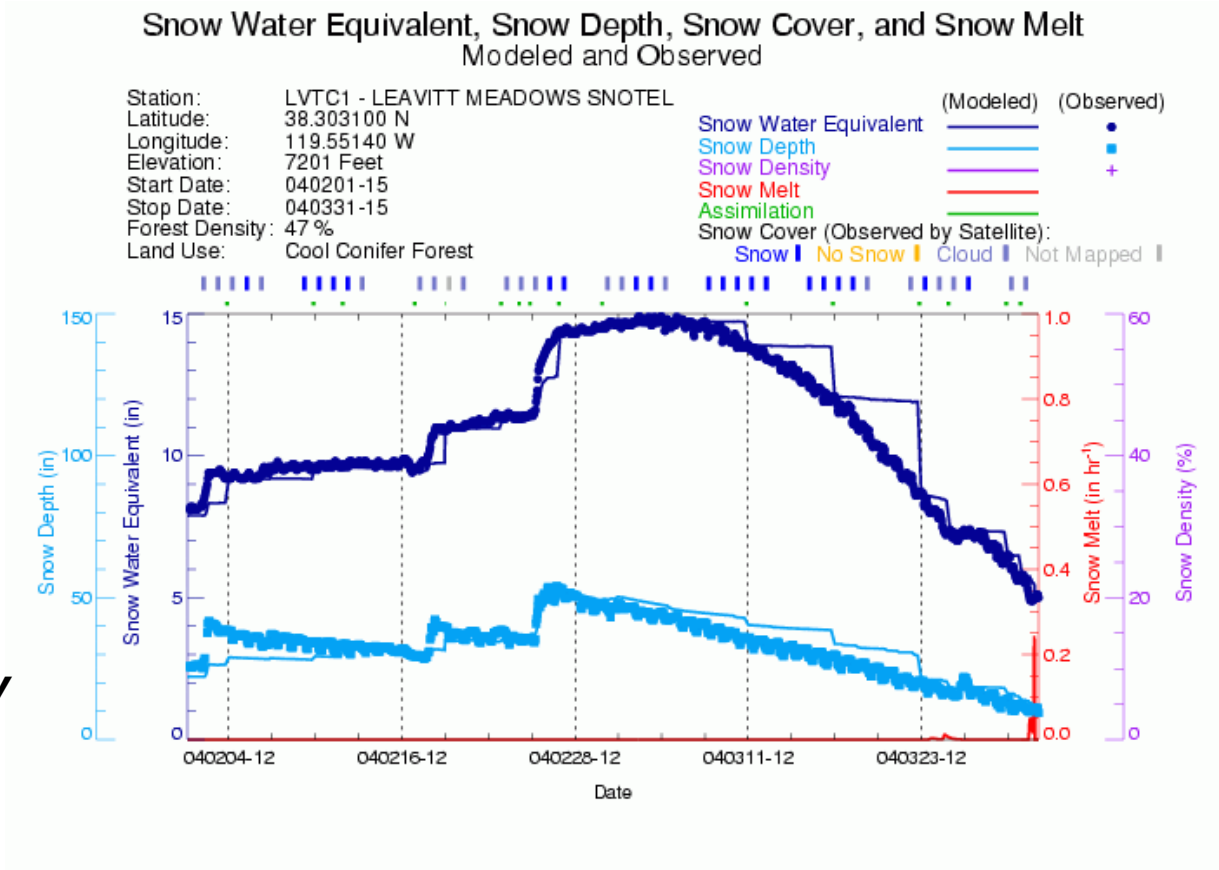
41% Forest Canopy Density

Cool Conifer Forest

Spatial Representativeness: Point-in-Pixel Problem

Leavitt Meadows SNOTEL

- Sierra Nevada, California



Model:

47% Forest Canopy Density

Cool Conifer Forest

Spatial Representativeness: Point-in-Pixel Problem

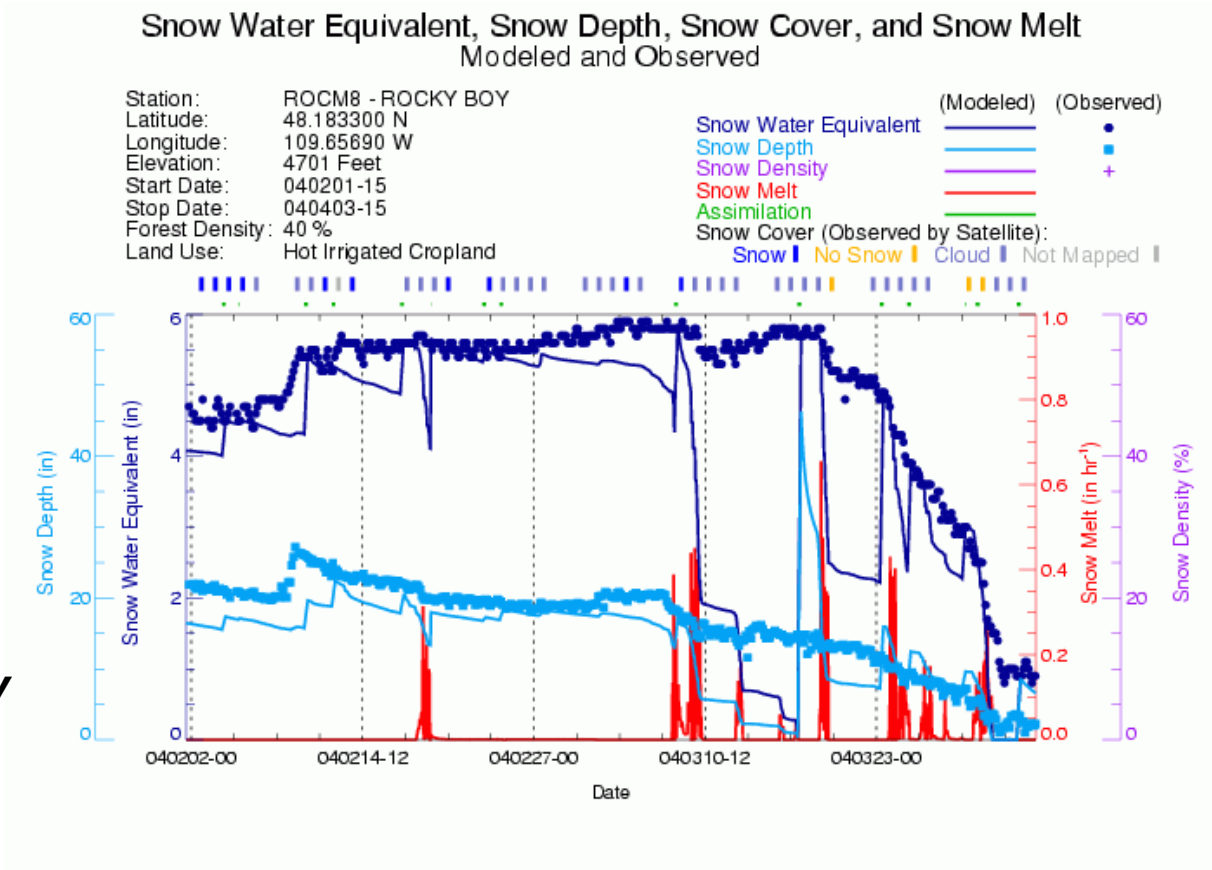
Rocky Boy SNOTEL

- Central Montana

Model:

40% Forest Canopy Density

Hot Irrigated Cropland



Spatial Representativeness: Point-in-Pixel Problem

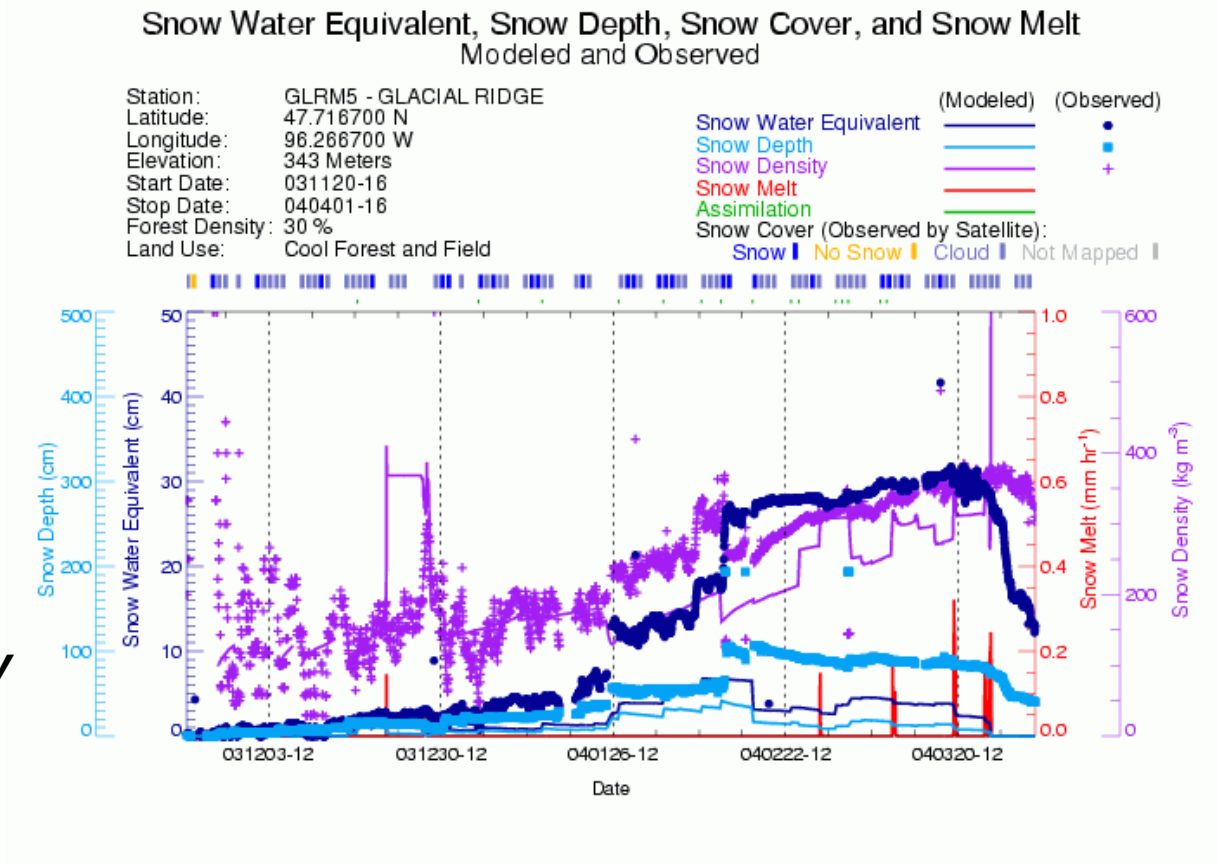
Glacial Ridge SCAN Site

- Central Minnesota

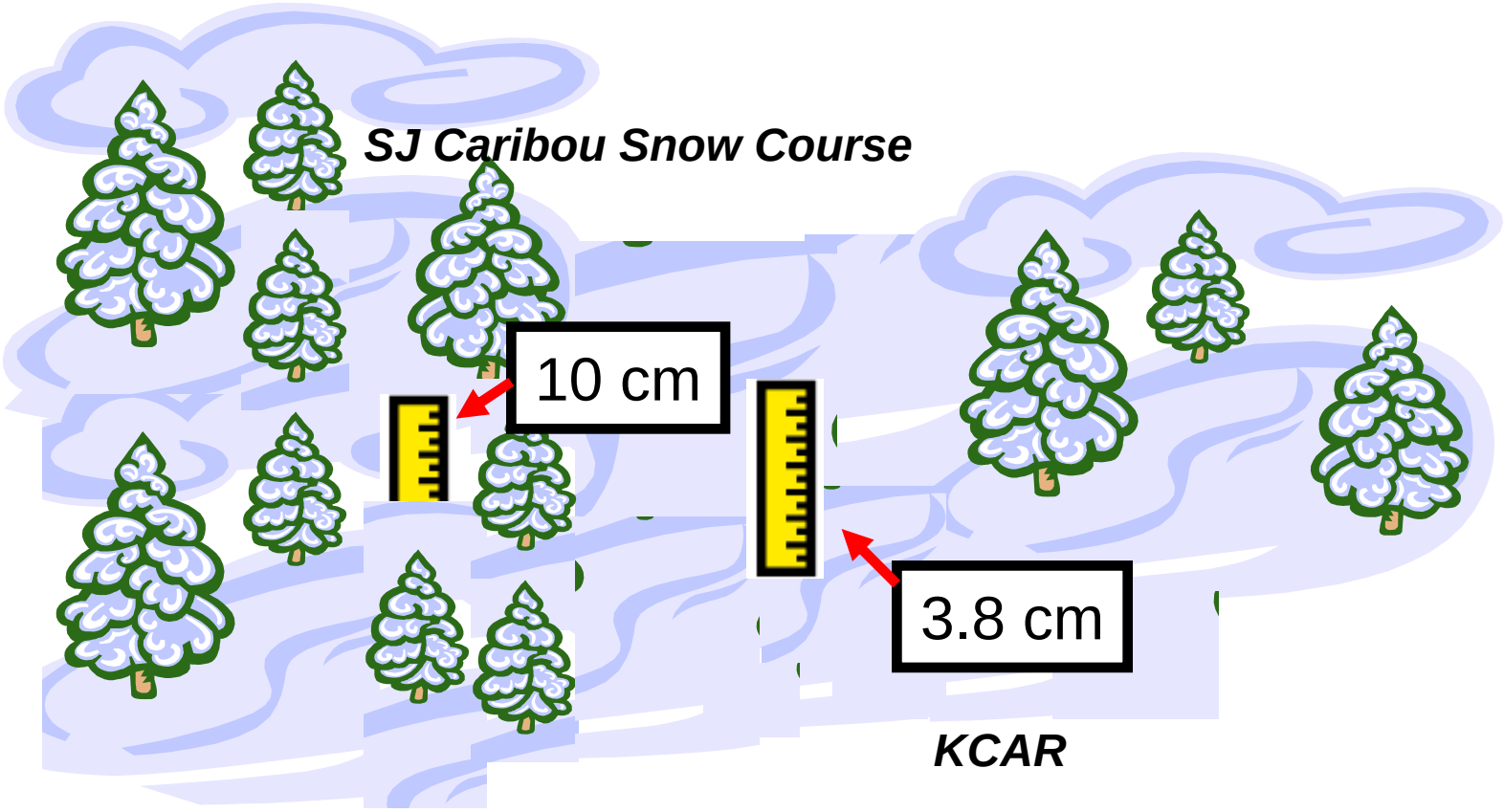
Model:

30% Forest Canopy Density

Cool Forest and Field



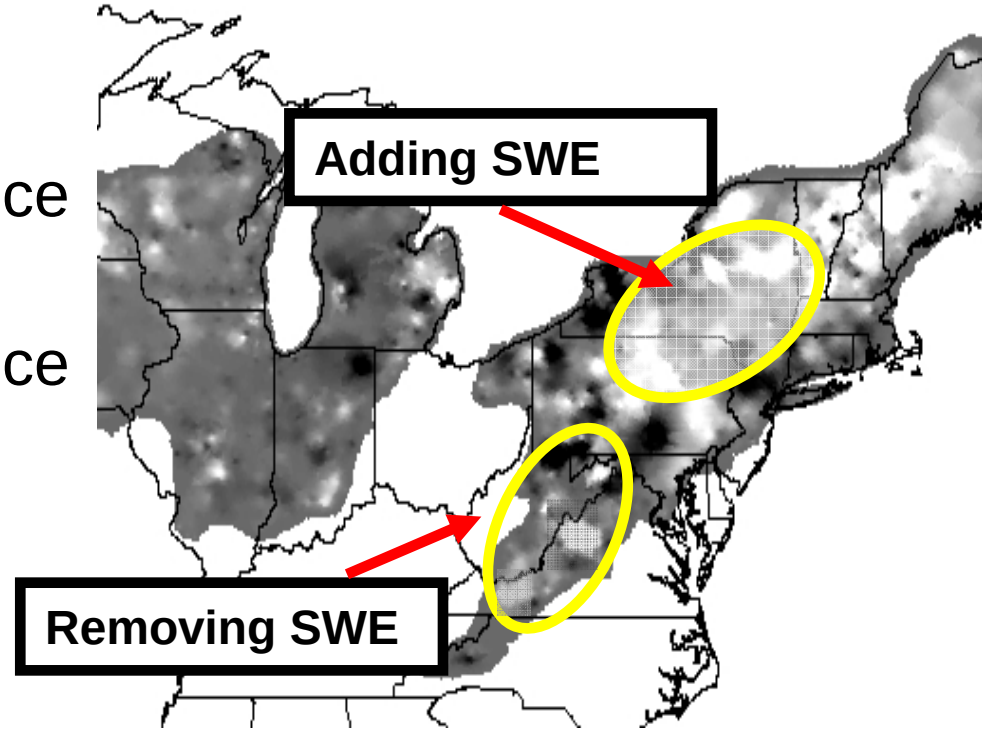
Spatial Representativeness



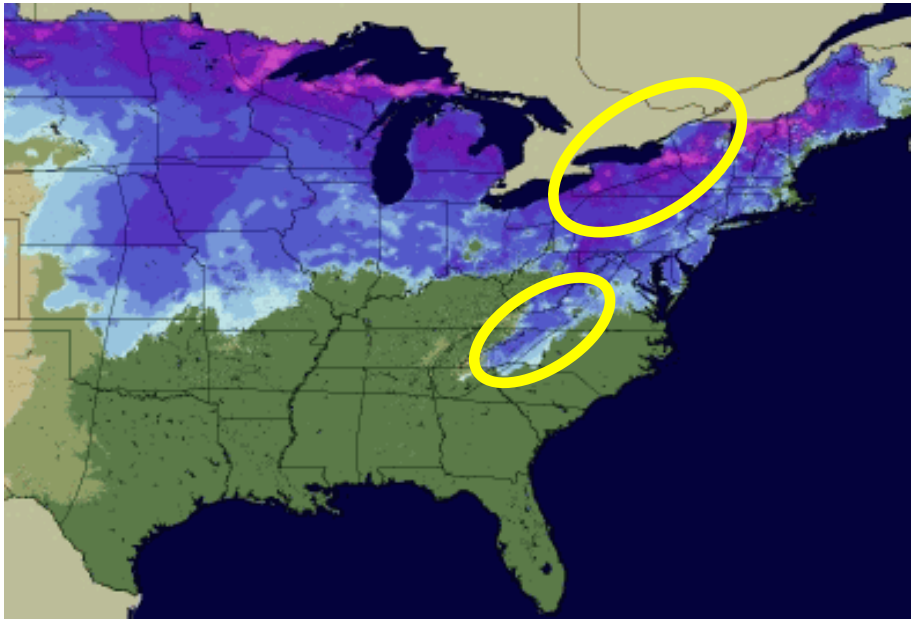
2 stations at the same latitude and longitude

Generate Nudging Layer

- Methods
  - Vertical and Horizontal Distance Weighted
  - Horizontal Distance Weighted

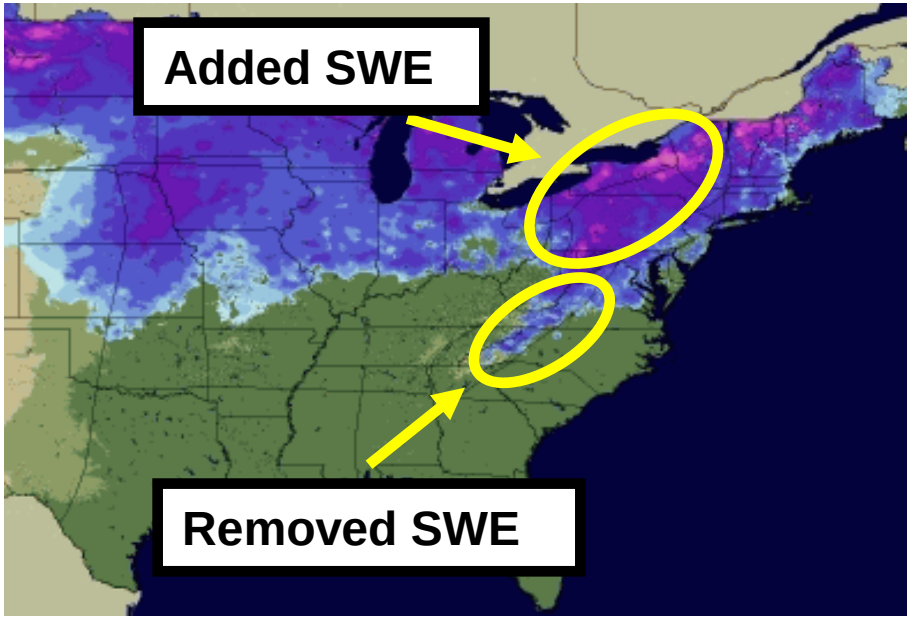


Results



February 4, 2004

Before Assimilation



February 5, 2004

After Assimilation

Recommendations

1. Make accurate, representative snow measurements.
2. Report snow depth with all snow water equivalent measurements.
3. Do not divide snow depth by 10 to infer snow water equivalent; it's worse than useless.
4. Code all snow data from all U.S. and Canadian reporting stations in SHEF and send to AWIPS.
5. Report time of snow observations; otherwise, 1200 UTC is the system default.
6. Ensure that the correct units are reported in SHEF for each observation; otherwise, English units are the system default.

Recommendations

7. Send snow data (in SHEF) to AWIPS as soon as possible, ideally within 24 hours after observation.
8. Use appropriate AWIPS headers for all SHEF snow data.
9. Check NWSLI to ensure that all reporting stations are in NWSLI.
10. Check NWSLI to ensure that all lat/long metadata in NWSLI are correct and reported to 4 decimal points for all snow reporting stations.
11. If available, provide digital photographs of each snow course location, estimate of percent forest cover, forest type, and canopy closure.

Questions ?

www.nohrsc.noaa.gov