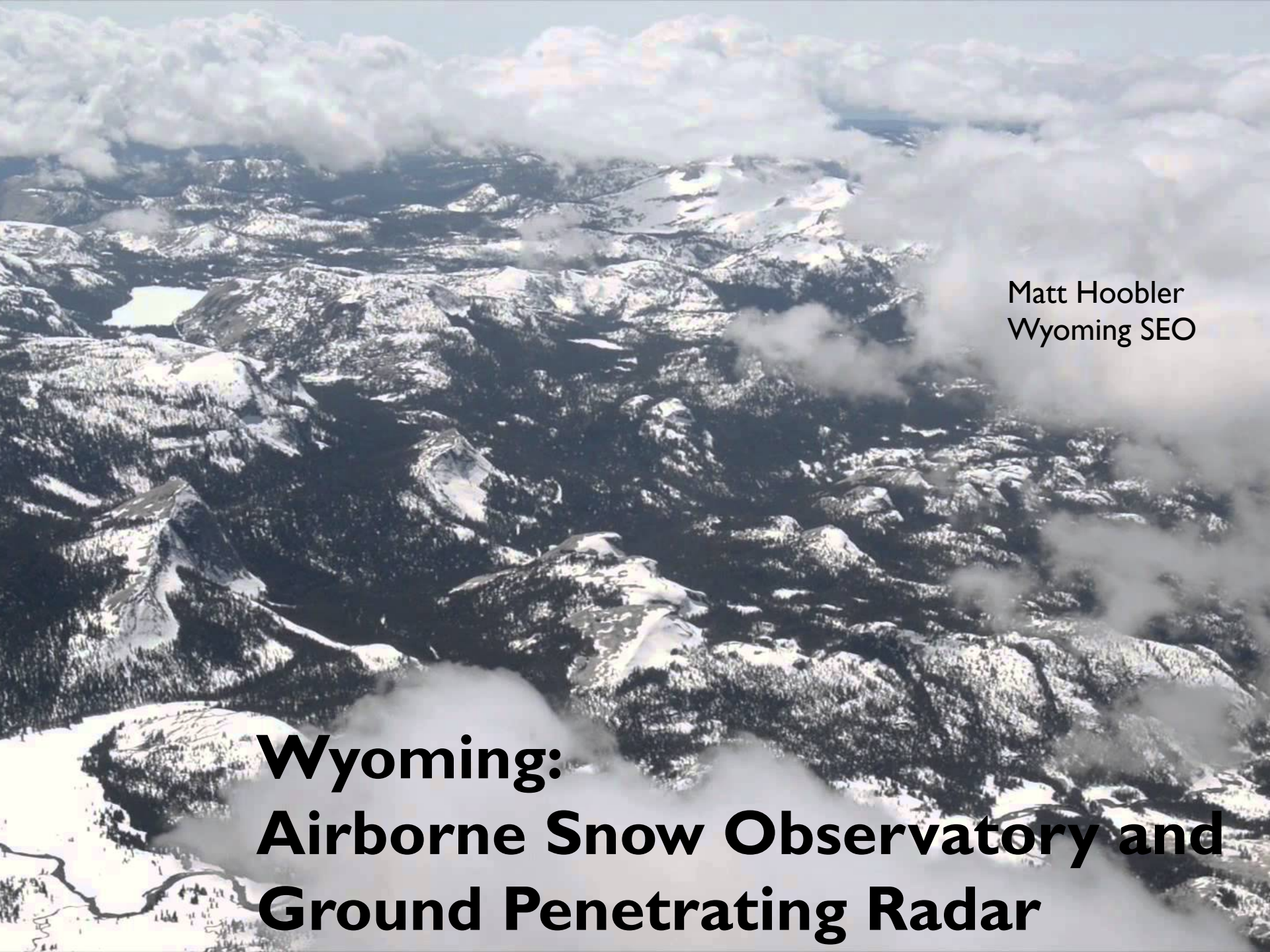
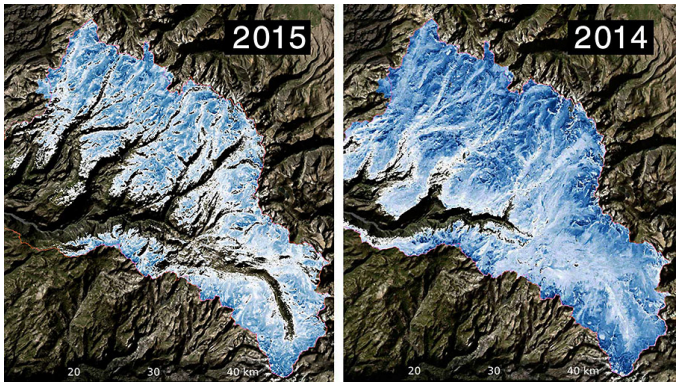


Matt Hoobler
Wyoming SEO

Wyoming: Airborne Snow Observatory and Ground Penetrating Radar

ASO in Wyoming

- SEO has established a draft agreement with NASA JPL
- Was the top priority of Initiative #1 (Credible Climate, Weather and Stream Flow Data) of the Governor's Water Strategy
- Wyoming Mountain Ranges
  - Wind River Range
  - Wyoming Range
  - Snowy Range
  - Sierra Madre Range

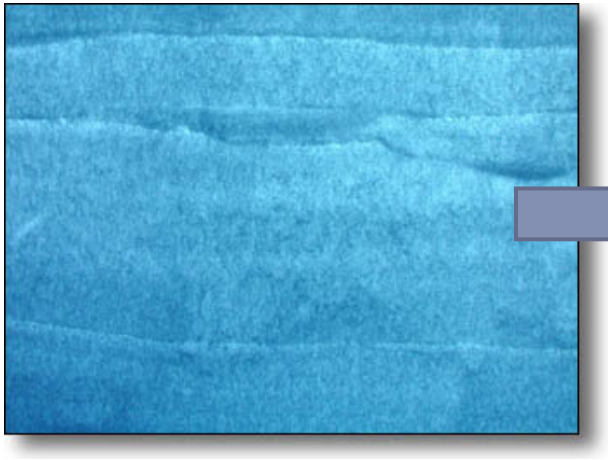


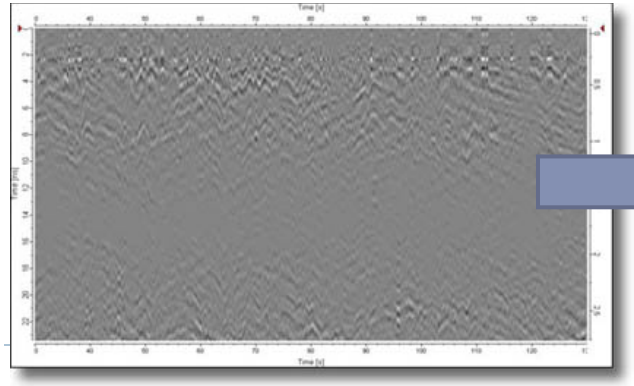
- $850K initial year includes one snow off and 4 snow on flights
- Complementary assessment tool for the Wyoming Weather Modification Project

Implementing National Aeronautics and Space Administration's (NASA) Airborne Snow Observatory (ASO) for Wyoming

- Because most of the water in Wyoming's streams and rivers originates as snow, improving the predictive modeling of atmospheric, land-surface, and snowpack-to-meltwater processes is pivotal in understanding and planning for water availability each spring. Management and regulation associated with water availability is a major component of Wyoming's water law and abiding by the State's nine distinct interstate compacts and court decrees. Developing a more robust and accurate water supply forecast model assists water managers in preparing and planning for the scarcity or abundance of runoff. NASA's Jet Propulsion Laboratory administers the ASO utilizing aircraft-based Light Detection and Ranging (LIDAR) to collect three-dimensional information about the shape of the Earth and its surface characteristics, including snow depths and snow water equivalent (SWE). Because snow LIDAR maps cover large expanses of mountainous terrain, it can provide more information about the entire range's snowpack in near real-time. This information then builds upon the individual snow telemetry station (SNOTEL) and manual snow survey site data to provide a more accurate understanding of future runoff and water supplies. LIDAR also provides a means to verify SNOTEL data which can often produce misleading data as a result of instrumentation problems. Processed data from ASO flights can aid in generating a more accurate snowpack run-off and thus an improved water-supply forecast, as well as a complementary assessment tool for the Wyoming Weather Modification Project.
- Contact: Matt Hoobler, Wyoming State Engineer's Office, Matt.Hoobler@wyo.gov

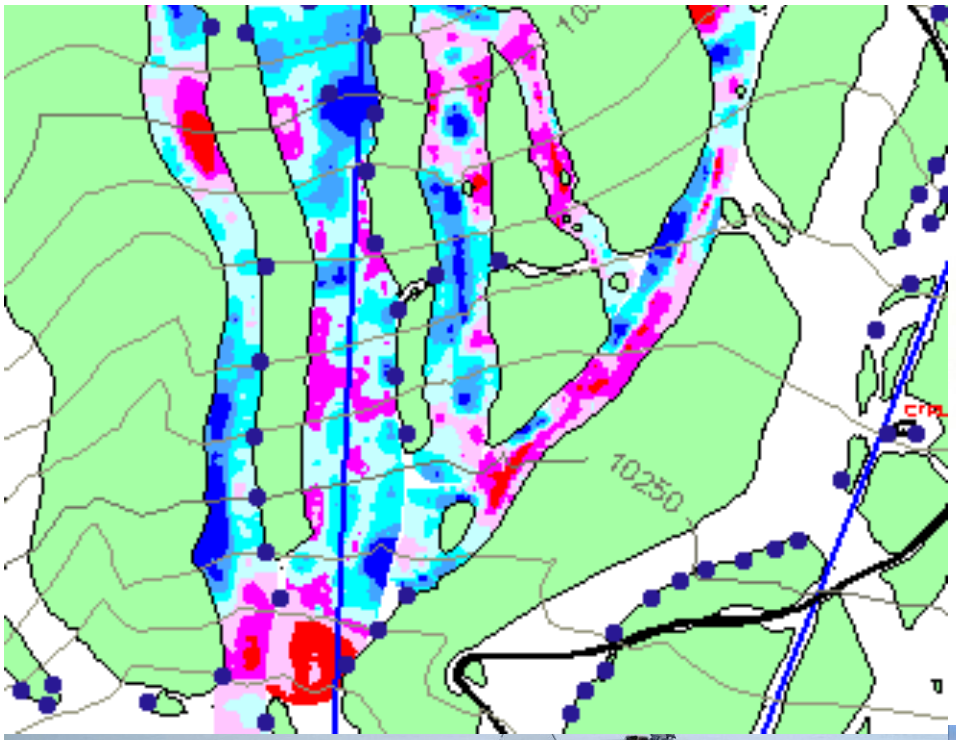
Ground Penetrating Radar in Wyo

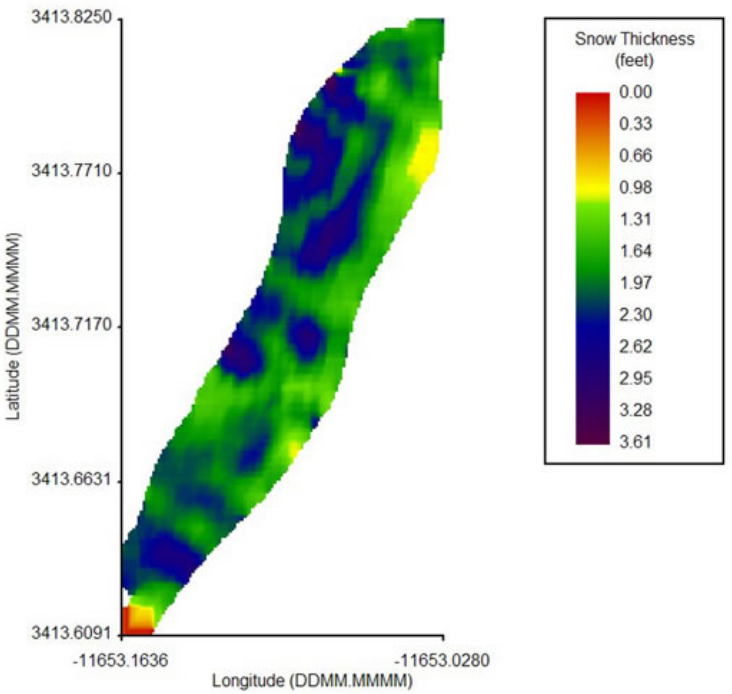




SWE

Ground Penetrating Radar in Wyo





Wyoming Partnership

- GPR readily maps snow thicknesses and use of the GPR wave velocity provides snow-to-water content conversion factors
- Build upon the existing snow surveys in Wyoming by collecting complementary data
- GPR available for use in Laramie

NRCS
Natural Resources Conservation Service

UW

Wyoming State Engineer's Office

Ground Penetrating Radar in Wyo

- Estimating snow-water equivalent (SWE) over long mountain transects with snowmobile-mounted GPR.
  - *Dr. W. Steven Holbrook, Matthew Provart, Dr. Scott Miller & Dr. Mine Dogan. Univ. of Wyoming*

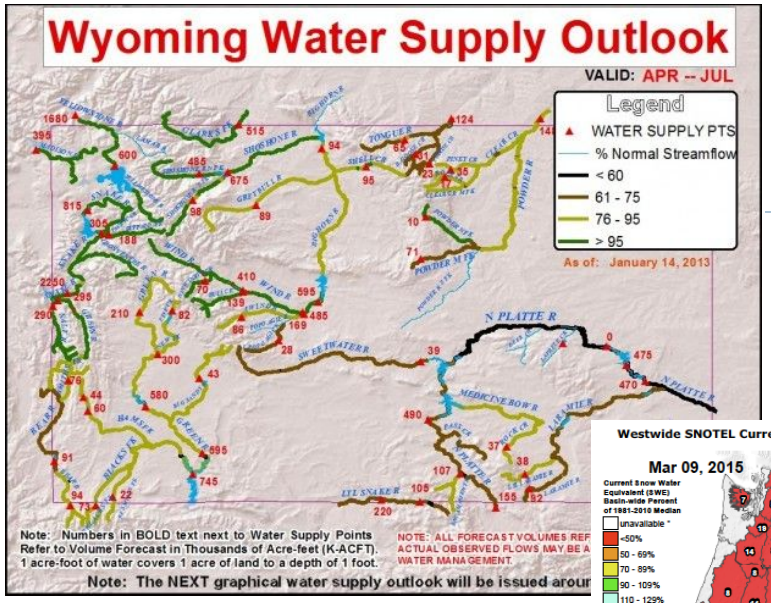
The hydrologic balance in most alpine watersheds is dominated by snowmelt, which provides peak spring runoff and recharges mountain aquifers, contributing to baseflow throughout the year. Measurement of snow-water equivalent (SWE) is necessary for accurate modeling of alpine hydrology but is challenging due to the variability in snow accumulation, ablation and redistribution at scales from microtopography to hillslopes to mountainsides. Here we present a method for imaging snow stratigraphy and estimating SWE over large distances from a ground-penetrating radar system mounted on a snowmobile. We mount commercial GPR systems (500 and 800 MHz) to the front of the snowmobile to provide maximum mobility and ensure that measurements are taken on pristine snow. High-quality images show detailed snow stratigraphy down to the ground surface over snow depths up to at least 8 m, enabling elucidation of snow accumulation and redistribution processes. We estimate snow density (and thus SWE, assuming no liquid water) by measuring radar velocity of the snowpack through migration focusing analysis. Results from the Medicine Bow Mountains, Wyoming, show that estimates of snow density from GPR (0.40±0.15 gm/cm3) are in good agreement with those from coincident snow cores (0.35±0.08 gm/cm3). Using this method, snow thickness, snow density, and therefore SWE can be measured over large areas solely from rapidly acquired common-offset GPR profiles, without the need for common-midpoint acquisition or snow cores.

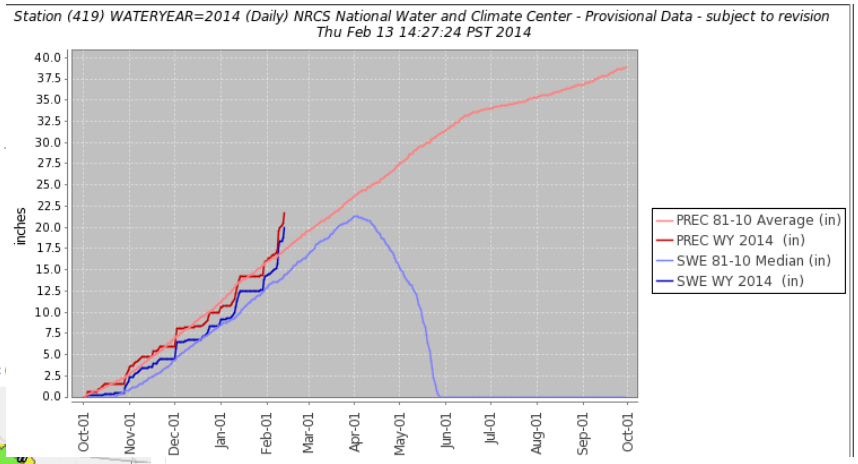
Modeling Seasonal Snowpack Evolution

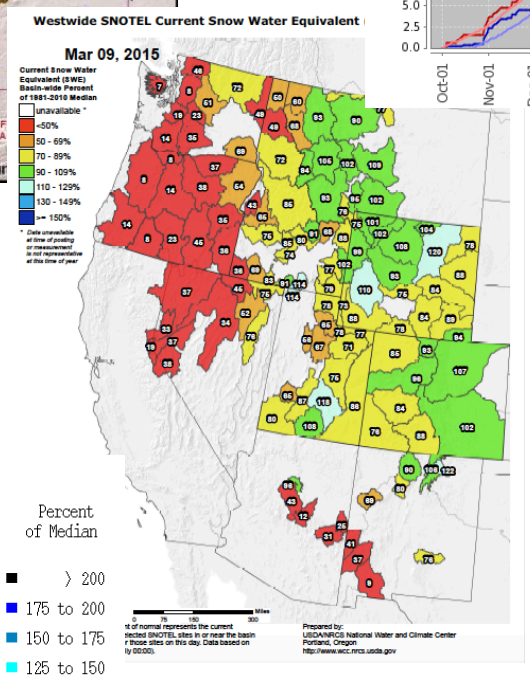
- National Center for Atmospheric Research (NCAR)
- Evaluation of six land surface models against SNOTEL data
- Perform same evaluation in Wyoming mountain ranges, hopefully utilizing additional ASO and GPR data
- Utilize NCAR Supercomputer in Cheyenne
- Establish a model accuracy value and identify data gaps

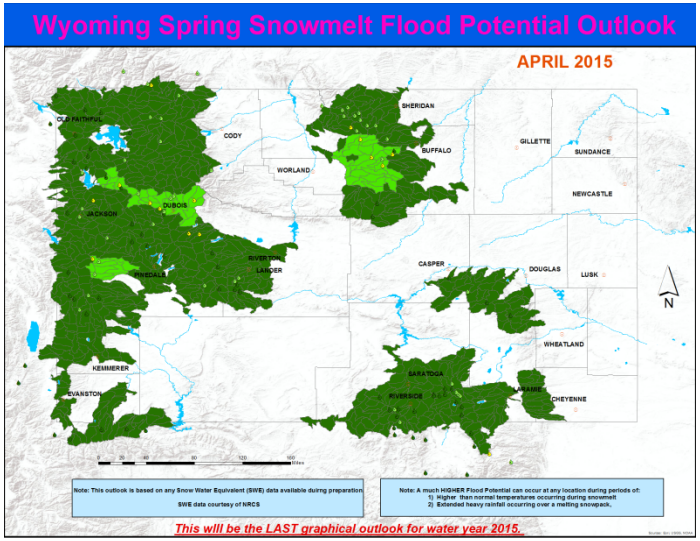
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

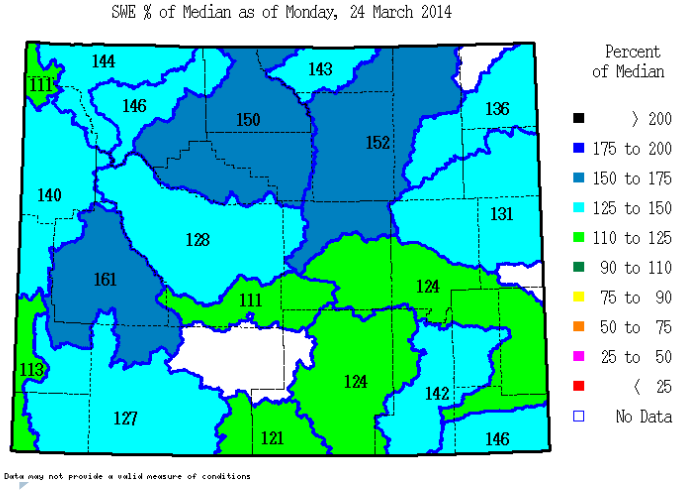
- Modeling seasonal snowpack evolution in the complex terrain and forested Colorado Headwaters region: A model intercomparison study
  - Chen, F., M.J. Barlage, M. Tewari, R.M. Rasmussen, J. Jin, D. Lettenmaier, B. Livneh, C. Lin, G. Miguez-Macho, G.-Y. Niu, L. Wen, and Z.-L. Yang, 2014: Modeling seasonal snowpack evolution in the complex terrain and forested Colorado Headwaters region: A model intercomparison study. *Journal of Geophysical Research-Atmospheres*, **119**, 13795-13819, DOI: 10.1002/2014JD022167
- Correctly modeling snow is critical for climate models and for hydrologic applications. Snowpack simulated by six land surface models (LSM: Noah, Variable Infiltration Capacity, snow-atmosphere-soil transfer, Land Ecosystem-Atmosphere Feedback, Noah with Multiparameterization, and Community Land Model) were evaluated against 1 year snow water equivalent (SWE) data at 112 Snow Telemetry (SNOTEL) sites in the Colorado River Headwaters region and 4 year flux tower data at two AmeriFlux sites. All models captured the main characteristics of the seasonal SWE evolution fairly well at 112 SNOTEL sites. No single model performed the best to capture the combined features of the peak SWE, the timing of peak SWE, and the length of snow season. Evaluating only simulated SWE is deceiving and does not reveal critical deficiencies in models, because the models could produce similar SWE for starkly different reasons. Sensitivity experiments revealed that the models responded differently to variations of forest coverage. The treatment of snow albedo and its cascading effects on surface energy deficit, surface temperature, stability correction, and turbulent fluxes was a major intermodel discrepancy. Six LSMs substantially overestimated (underestimated) radiative flux (heat flux), a crucial deficiency in representing winter land-atmosphere feedback in coupled weather and climate models. Results showed significant intermodel differences in snowmelt efficiency and sublimation efficiency, and models with high rate of snow accumulation and melt were able to reproduce the observed seasonal evolution of SWE. This study highlights that the parameterization of cascading effects of snow albedo and below-canopy turbulence and radiation transfer is critical not only for SWE simulation but also for correctly capturing the winter land-atmosphere interactions.


Wyoming Water Supply Outlook
VALID: APR -- JUL
Legend
WATER SUPPLY PTS
% Normal Streamflow
< 60
61 - 75
76 - 95
> 95
As of: January 14, 2013
Note: Numbers in BOLD text next to Water Supply Points Refer to Volume Forecast in Thousands of Acre-feet (K-ACFT). 1 acre-foot of water covers 1 acre of land to a depth of 1 foot.
NOTE: ALL FORECAST VOLUMES REF
ACTUAL OBSERVED FLOWS MAY BE A
WATER MANAGEMENT.
Note: The NEXT graphical water supply outlook will be issued arou


Station (419) WATERYEAR=2014 (Daily) NRCS National Water and Climate Center - Provisional Data - subject to revision
Thu Feb 13 14:27:24 PST 2014
inches
PREC 81-10 Average (in)
PREC WY 2014 (in)
SWE 81-10 Median (in)
SWE WY 2014 (in)
Oct-01
Nov-01
Dec-01
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01


Westwide SNOTEL Current Snow Water Equivalent
Mar 09, 2015
Current Snow Water Equivalent (SWE) Basin-wide Percent of 1981-2010 Median
unavailable *
<50%
50 - 69%
70 - 89%
90 - 109%
110 - 129%
130 - 149%
>= 150%
Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov


Wyoming Spring Snowmelt Flood Potential Outlook
APRIL 2015
Note: This outlook is based on any Snow Water Equivalent (SWE) data available during preparation.
SWE data courtesy of NRCS
Note: A much HIGHER Flood Potential can occur at any location during periods of:
1) Higher than normal temperatures occurring during snowmelt
2) Extended heavy rainfall occurring over a melting snowpack.
This will be the LAST graphical outlook for water year 2015.


SWE % of Median as of Monday, 24 March 2014
Percent of Median
〉 200
175 to 200
150 to 175
125 to 150
110 to 125
90 to 110
75 to 90
50 to 75
25 to 50
〈 25
No Data
* = Data may not provide a valid measure of conditions

Contact Information

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