Use of Snow Observations at CBRFC

CBRFC Stakeholder Forum

July 31, 2012

Overview

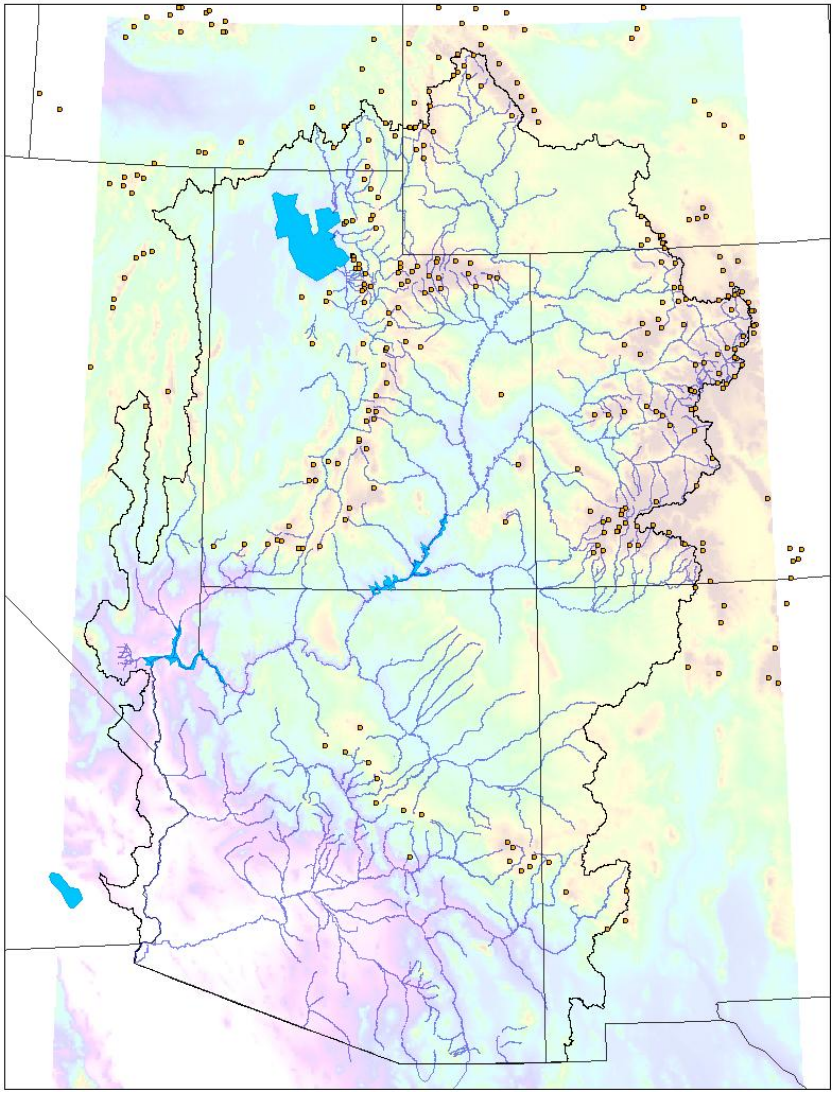
- Importance of snow observations in the RFC forecasting process
- Snow Datasets/Observing networks used in current operations
- Operational methods for updating snow model conditions
- New Snow Cover Datasets at CBRFC

Importance of Snow Obs

- Snow (water equivalent, covered area) is a primary predictor for streamflow in the Colorado River Basin

- Snowpack in recent years (even just in the last two years, 2011 and 2012) has exhibited extremes in both directions
  - Accurate observations are essential to the forecasting process, especially in abnormal years.

SNOTEL Obs in RFC Ops



NRCS SNOTEL Network

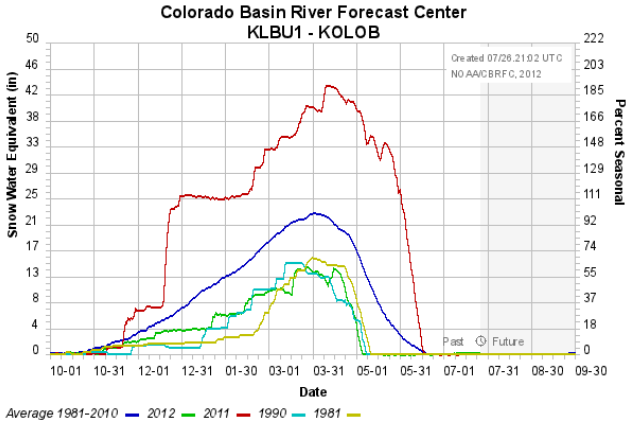
CBRFC uses snow water equivalent (SWE) and precipitation observations from stations across the Colorado River basin.

The SWE and precip are used in different aspects of forecasting at the RFC.

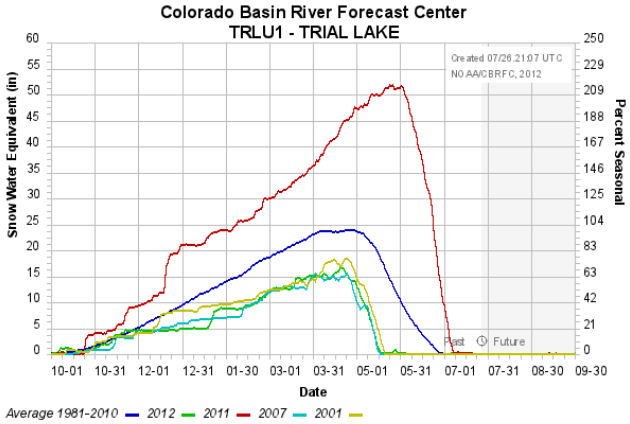
SNOTEL Obs in RFC Ops

SWE is used on the 1st of the month to make seasonal water supply forecasts

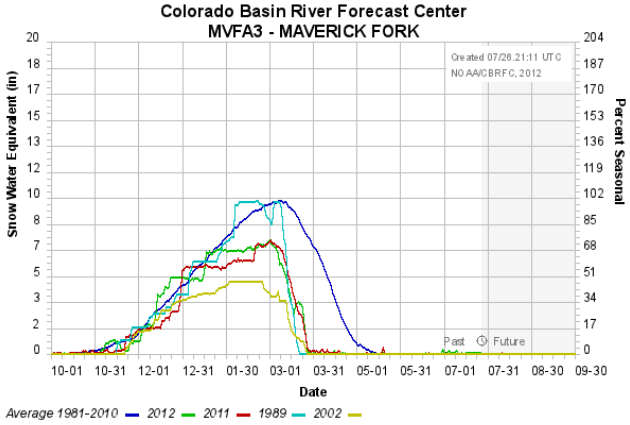
- quantitatively as a predictor variable in statistical regression models
- qualitatively to get an idea of general snow pack conditions while making seasonal water supply forecasts (above/below average, median, similar years, etc.)



Kolob, UT
Dark Blue = 81-10 Average
Green = 2012
Red = 2011
Light Blue = 1990
Yellow = 1981



Trial Lake, UT
Dark Blue = 81-10 Average
Green = 2012
Red = 2011
Light Blue = 1992
Yellow = 2002



Maverick Fork, AZ
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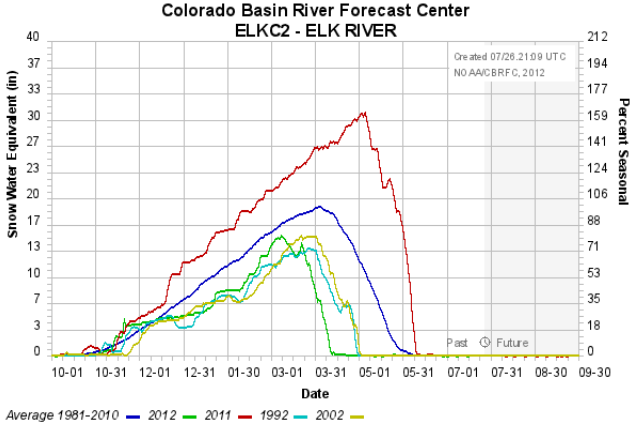
Green = 2012
Red = 2011
Light Blue = 1989
Yellow = 2002

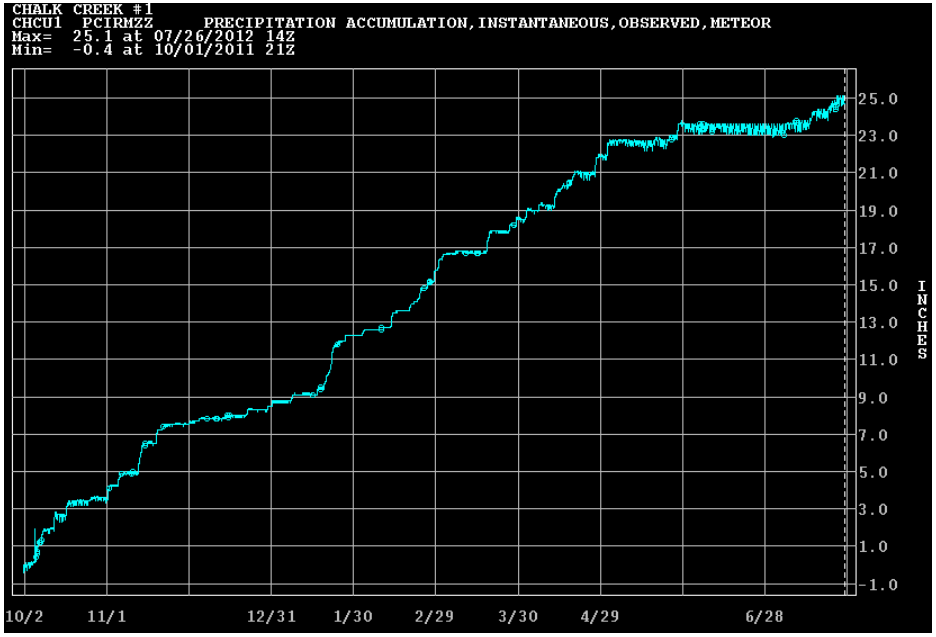


Elk River, CO
Dark Blue = 81-10 Average
Green = 2012
Red = 2011
Light Blue = 1992
Yellow = 2002

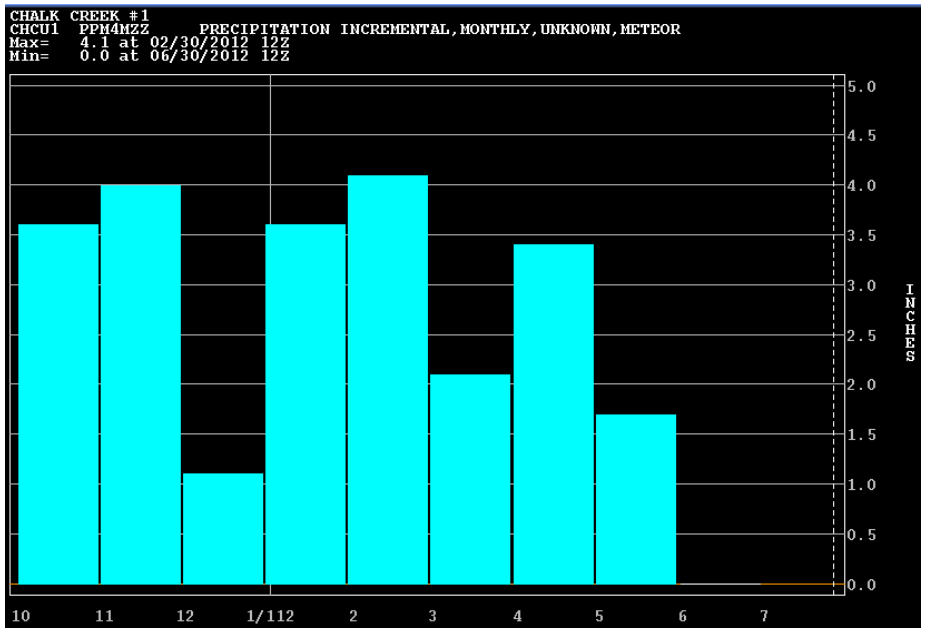
SNOTEL Obs in RFC Ops

Precip:

- Daily and 6-hourly increments are used to generate mean areal precipitation (MAP) in the deterministic model (year round)
- Accumulated values are used
  - to adjust model snow states between Dec and Apr
  - in statistical regression models run from Jan to June



Accumulated Precipitation Trace at Chalk Creek #1, UT for WY12



Monthly Precipitation Values at Chalk Creek #1, UT for WY12

Snow Updating

What is snow updating?

- An operational method to adjust model SWE using SNOTEL precipitation observations.

- Model SWE is updated, but not model snow cover.
  - snow cover = ~1.0 (100%) anyway in winter at high elevations

- Updates to model SWE
  - **When**: usually mid Nov to early Apr, at least twice a month (more often in abnormal years)
  - **Where**: model areas above ~8000 ft, where precip type is very likely to be snow between Nov and Apr

Snow Updating

Why bother doing updates to model snow as winter progresses?

- **Having the best possible estimate of real-world SWE is essential to successful long-lead streamflow forecasts in basins where flow is dominated by snowmelt.**

- Mid winter updates allow us to incorporate more thoroughly QC'd, monthly (vs. real time) SNOTEL observations into the forecasting process.

Snow Updating

Why do we use SNOTEL precip and not SNOTEL SWE obs to update model SWE?

⇛Boils down to being consistent with model calibration.

⇛Updating the model snowpack in a way consistent with how the model was designed and calibrated means one less source of uncertainty in the forecasting process.

RFC uses precip →

Building snowpack in the calibration process	Updating model SWE during the winter
SNOTEL precip (snow in the winter) → MAPs	SNOTEL precip (snow in the winter) → MAPs *SAME AS IN THE CALIBRATION PROCESS*
	

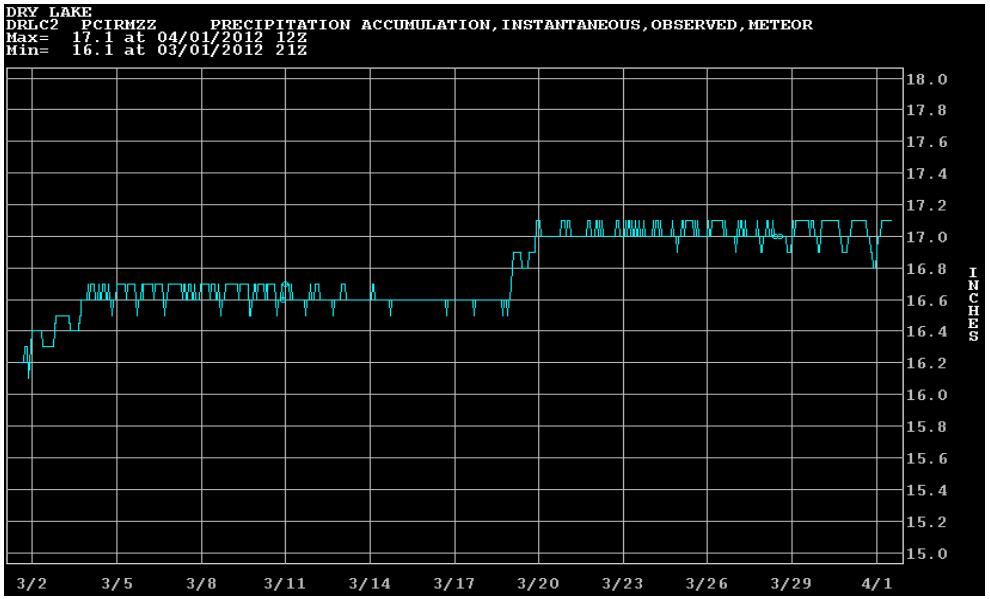
NOT SWE →

Building snowpack in the calibration process	Updating model SWE during the winter
SNOTEL precip (snow in the winter) → MAPs	SNOTEL SWE
	

Snow Updating

Why use monthly SNOTEL precip instead of real-time obs?

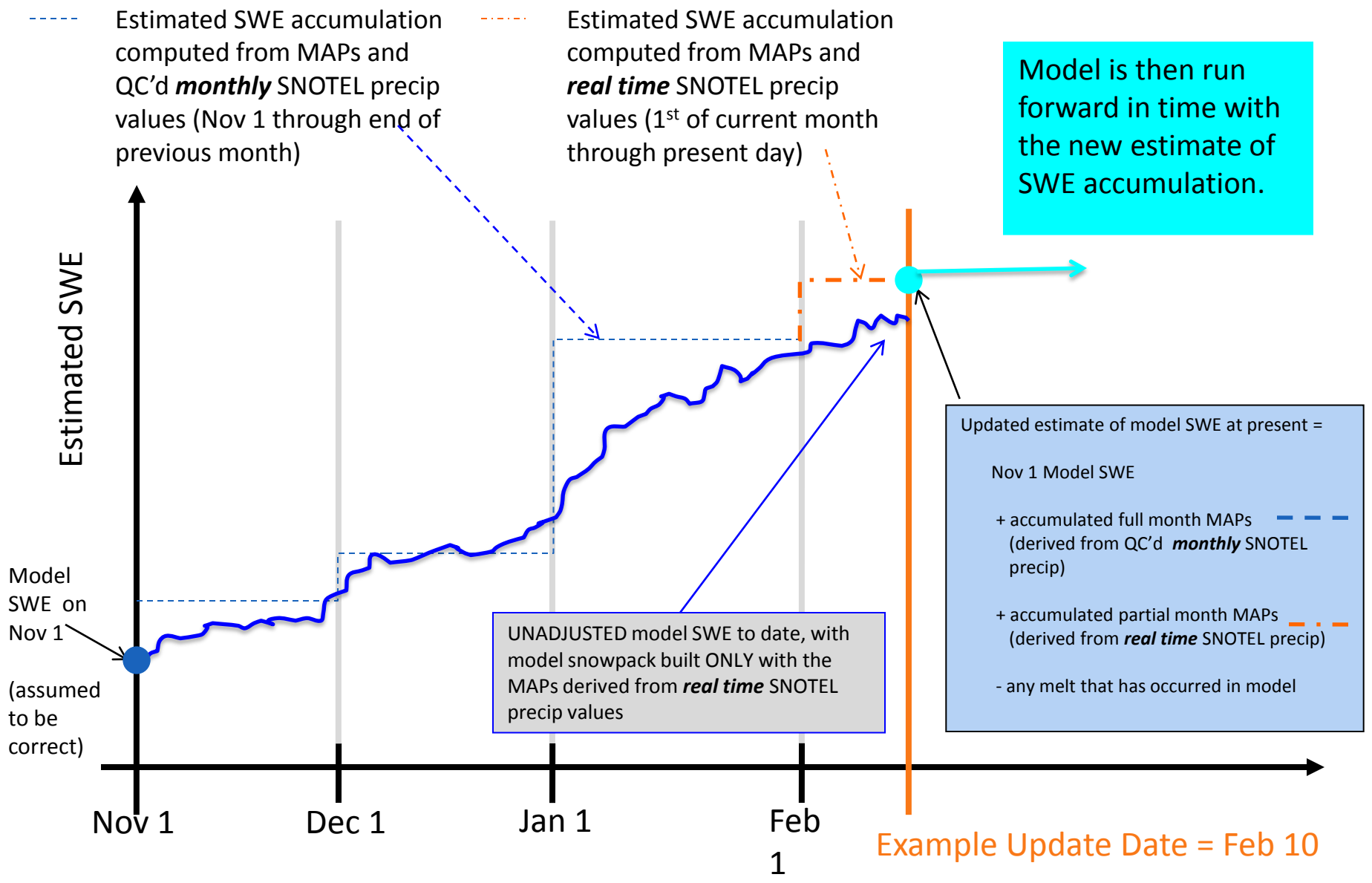
- Real time SNOTEL precip traces can be jumpy.



- These precip values
  - Are used to build the model snowpack via MAPs in the winter daily model runs.
  - Add some uncertainty to the model snow conditions since they can be jumpy.

- To reduce the uncertainty introduced by jumpy real time precip values:
  - "Update" the accumulated Nov 1-to-date MAP values to include those QC'd monthly precip values, which should be of better quality than the real time precip values.
  - Use the "updated" accumulated MAP to get a new, updated estimate of SWE for the model.

Snow Updating



New Snow Cover Datasets at CBRFC

Snow cover datasets to be evaluated:

MODIS-based 500-m snow cover grids – 2000-present, daily snow cover grids

- two different algorithms for deriving fractional snow covered area (FSCA) from MODIS

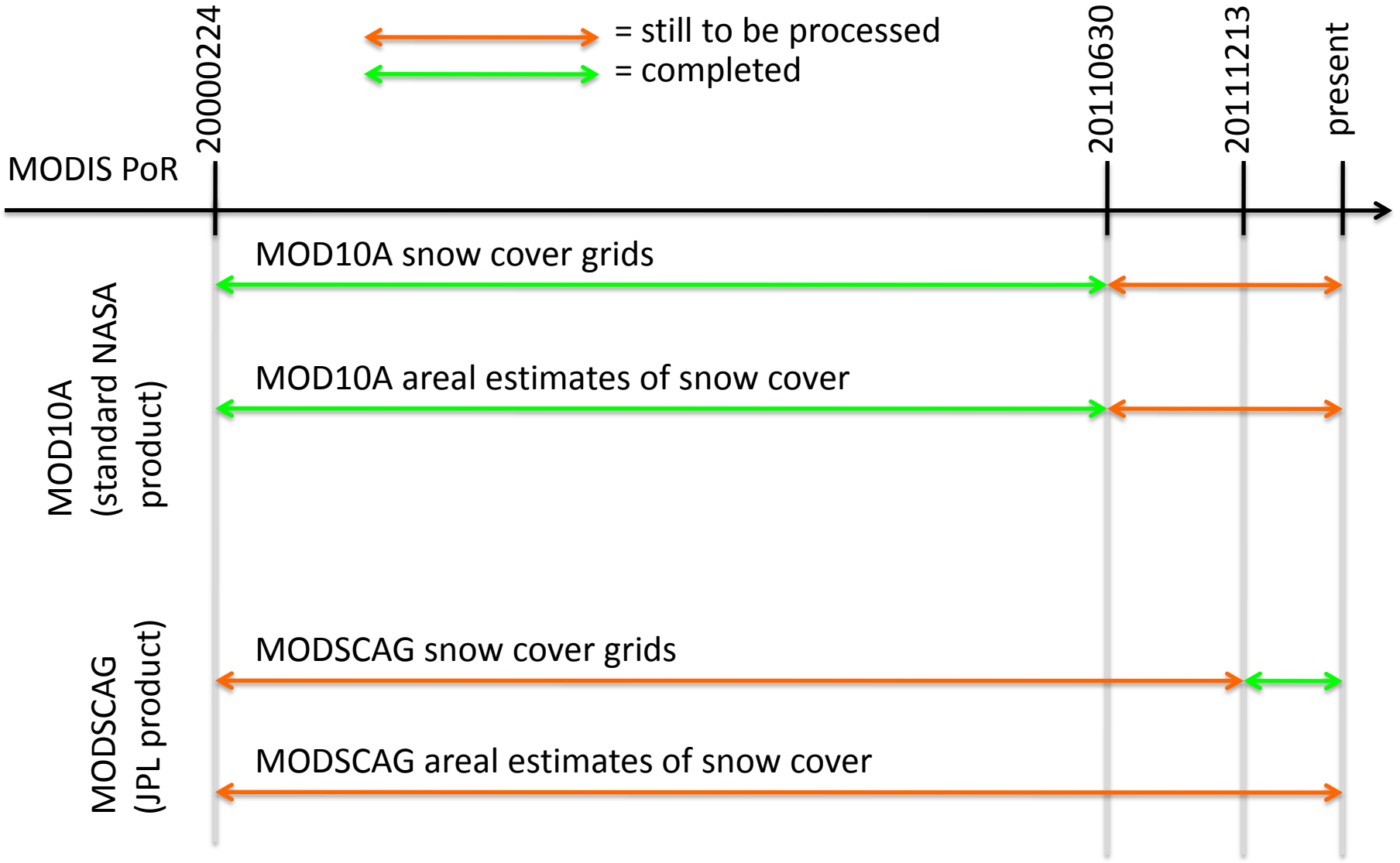
<u>MOD10A</u>

- standard NASA MODIS snow cover product
- uses linear regression relationships developed with Landsat snow cover to compute FSCA for each 500 m pixel
- Sometimes misses snow
- No corrections for vegetation

<u>MODSCAG</u>

- New snow cover product from NASA's JPL
- Uses spectral mixture models to estimate FSCA for each 500 m pixel
- MODSCAG id's snow more often where it exists.
- Corrects for vegetation by assuming that any snow "seen" through the canopy means that the ground is snow-covered under the trees.

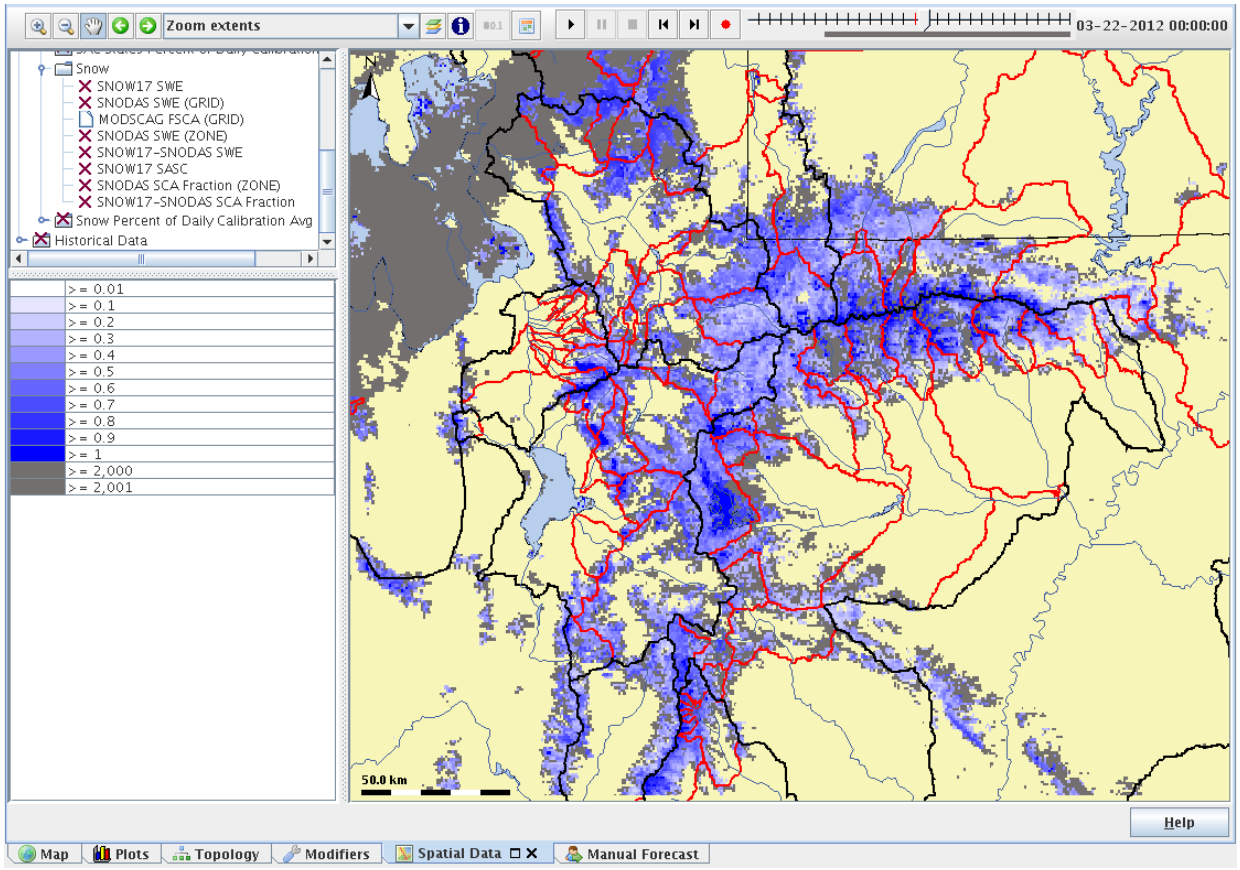
New Snow Cover Datasets at CBRFC



New Snow Cover Datasets at CBRFC

Qualitative use
- Visuals
- Spatial displays

Quantitative use via updating of model snow states



MODSCAG FSCA across northern Utah and the Uintas in CHPS display – March 22, 2012 (gray = cloud cover)

New Snow Cover Datasets at CBRFC

Cases where MODIS FSCA could be useful in terms of updating model snow conditions

1. Observed snow cover differs greatly from the model snow cover and a large correction is needed.

2. Rapid melt

   → Provided that clouds aren't persistent, daily acquisitions of MODIS snow cover grids can help determine how fast the snowpack is disappearing.

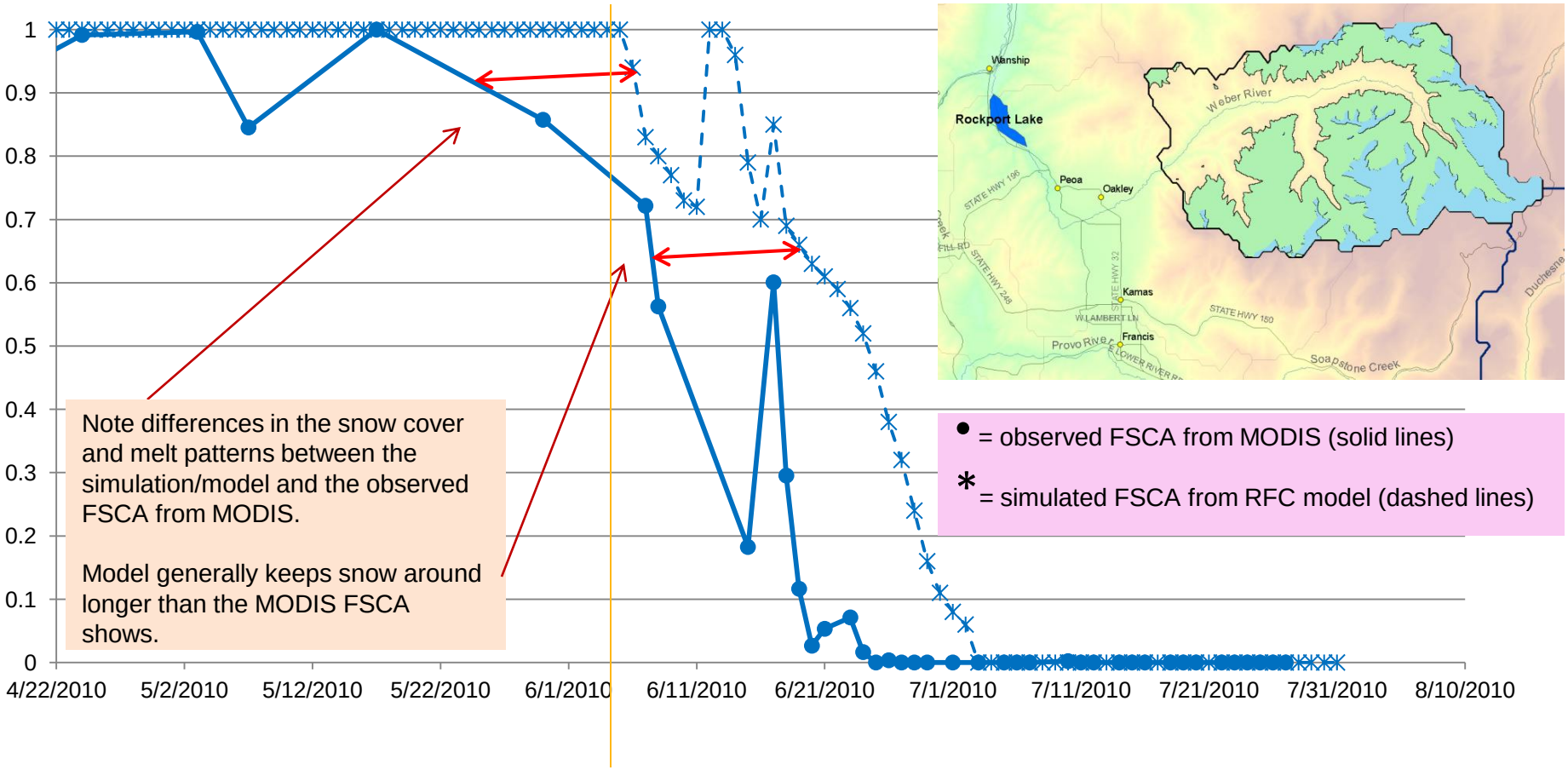
3. When snowpack persists in places where it should have melted out (south faces, lower elevations – example: June 2010)

   → MODIS FSCA can help determine the location of the snowpack.

MOD10A FSCA example

Example: June - July 2010, where observed snow cover differs greatly from the model snow cover and there was rapid melt

OBSERVED (from MODIS MOD10A product) & SIMULATED SNOW COVER EXTENT FOR UPPER ELEV ZONE - WEBER @ OAKLEY (OAWU1)



Note differences in the snow cover and melt patterns between the simulation/model and the observed FSCA from MODIS.

Model generally keeps snow around longer than the MODIS FSCA shows.

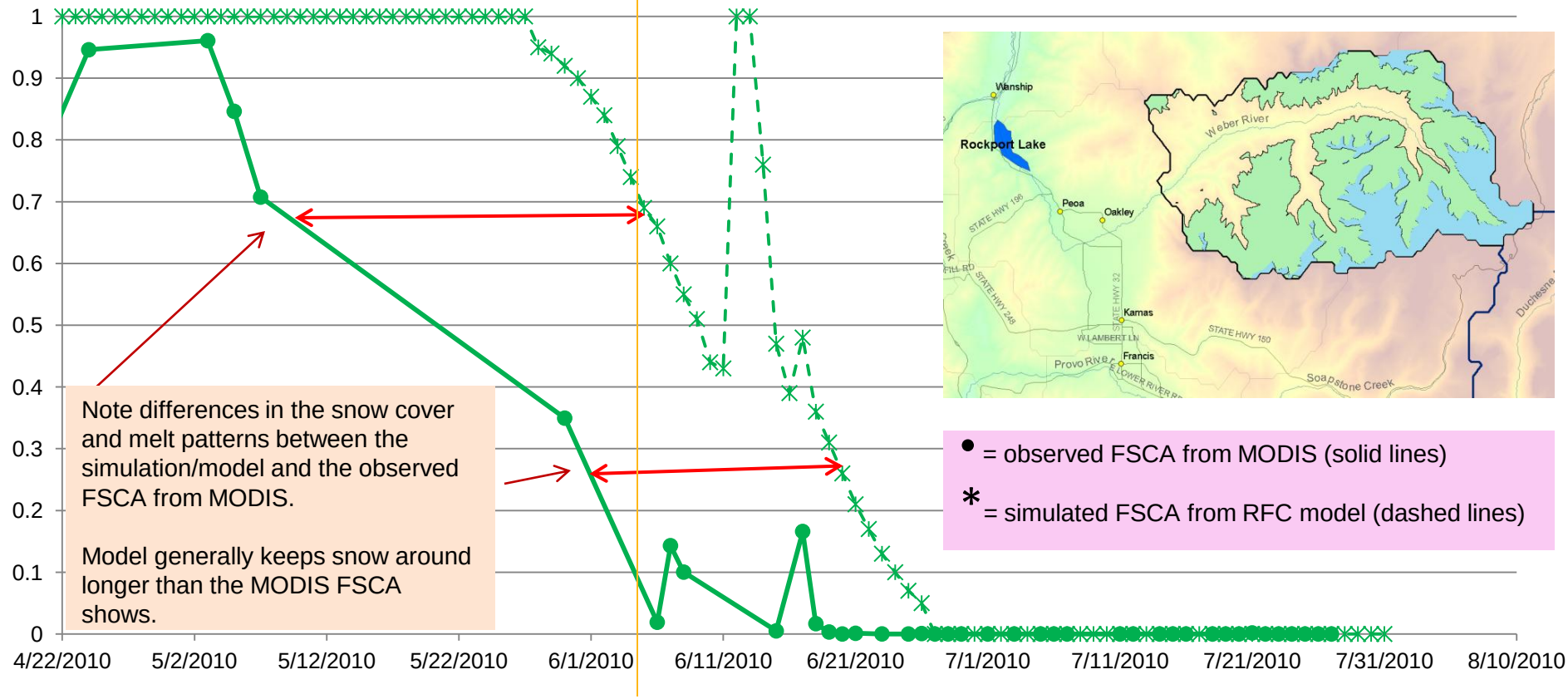
● = observed FSCA from MODIS (solid lines)

* = simulated FSCA from RFC model (dashed lines)

MOD10A FSCA example

Example: June - July 2010, where observed snow cover differs greatly from the model snow cover and there was rapid melt

OBSERVED (from MODIS MOD10A product) & SIMULATED SNOW COVER EXTENT FOR MID ELEV ZONE - WEBER @ OAKLEY (OAWU1)



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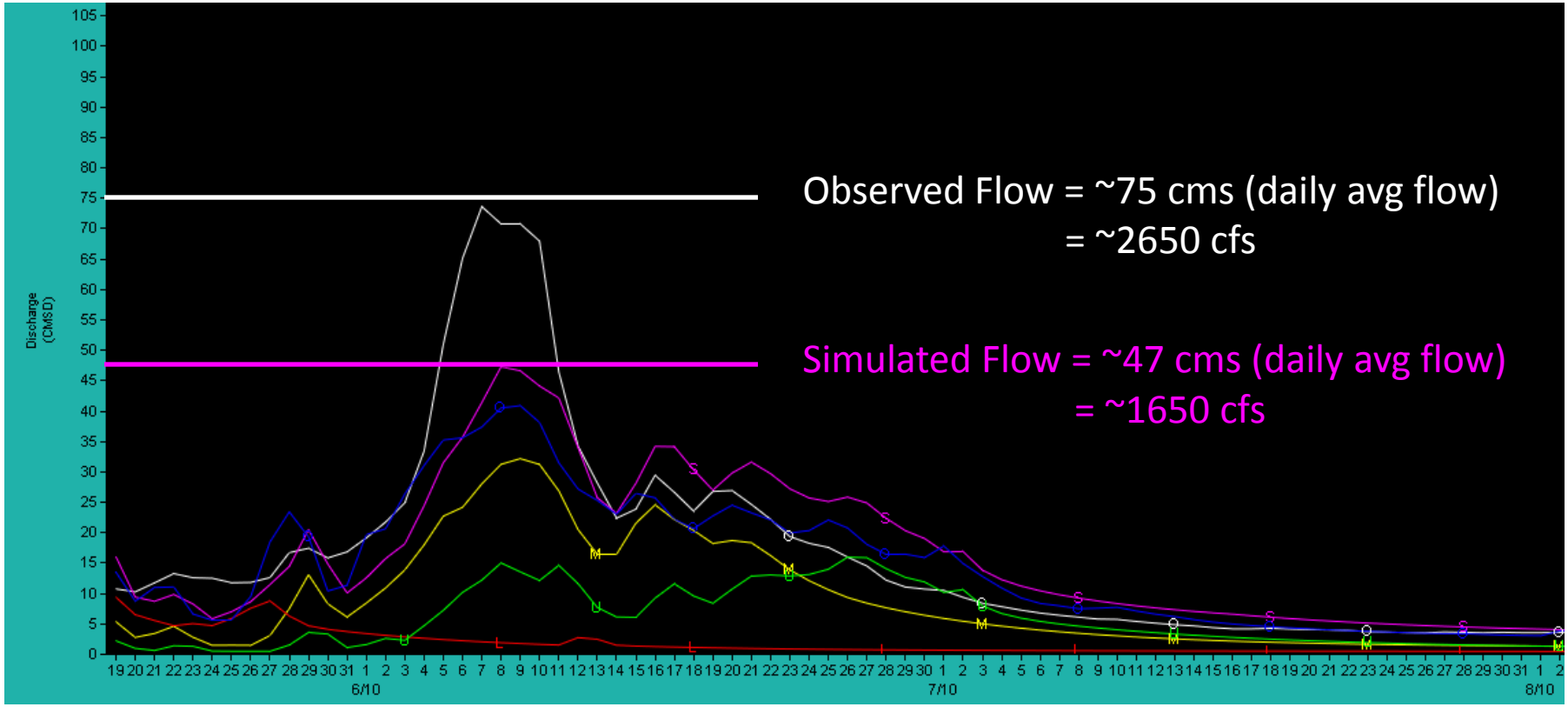

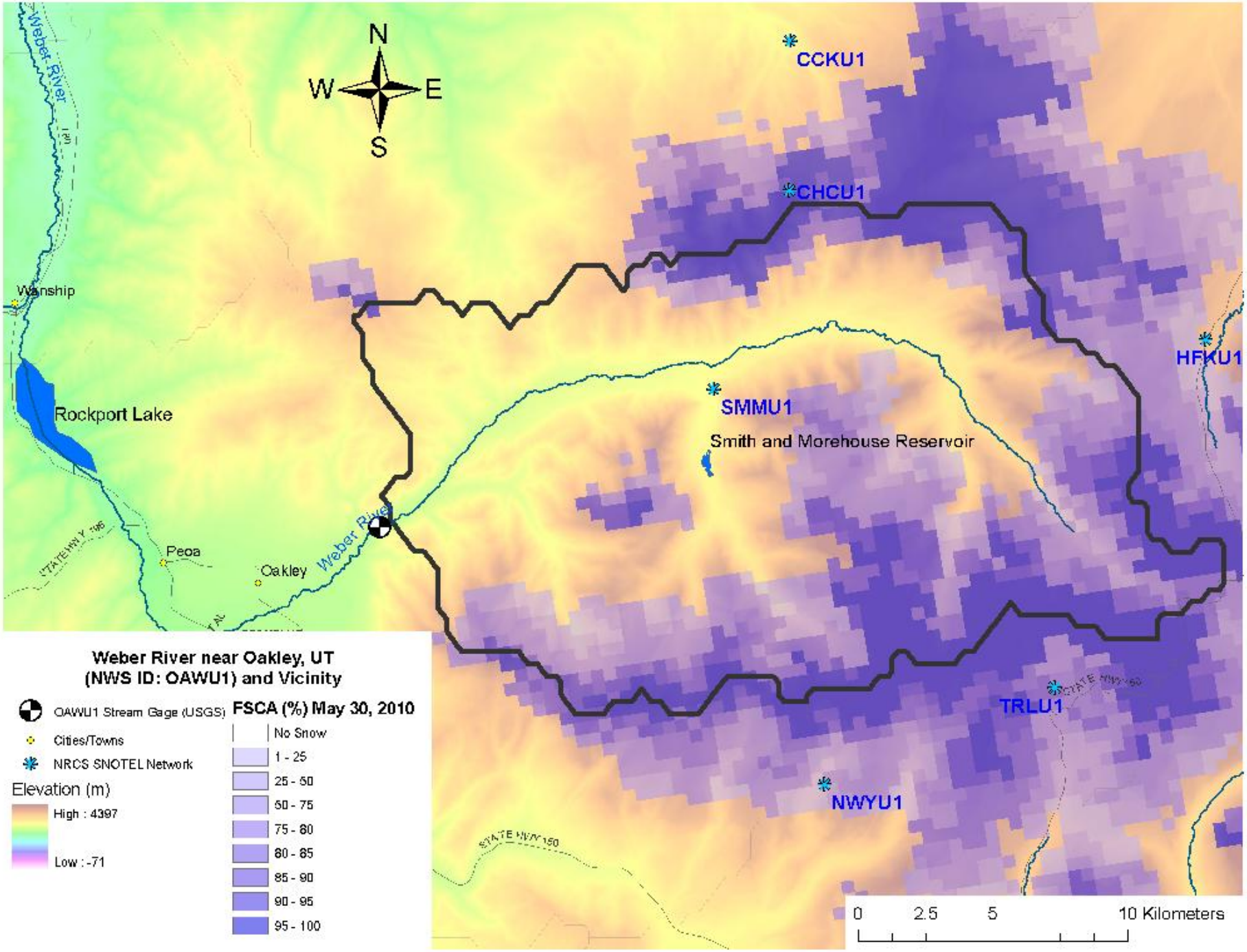
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CCKU1
CHCU1
HFKU1
SMMU1
Smith and Morehouse Reservoir
Rockport Lake
Weber River
Wanship
Peoa
Oakley
TRLU1
NWYU1
STATE HWY 150
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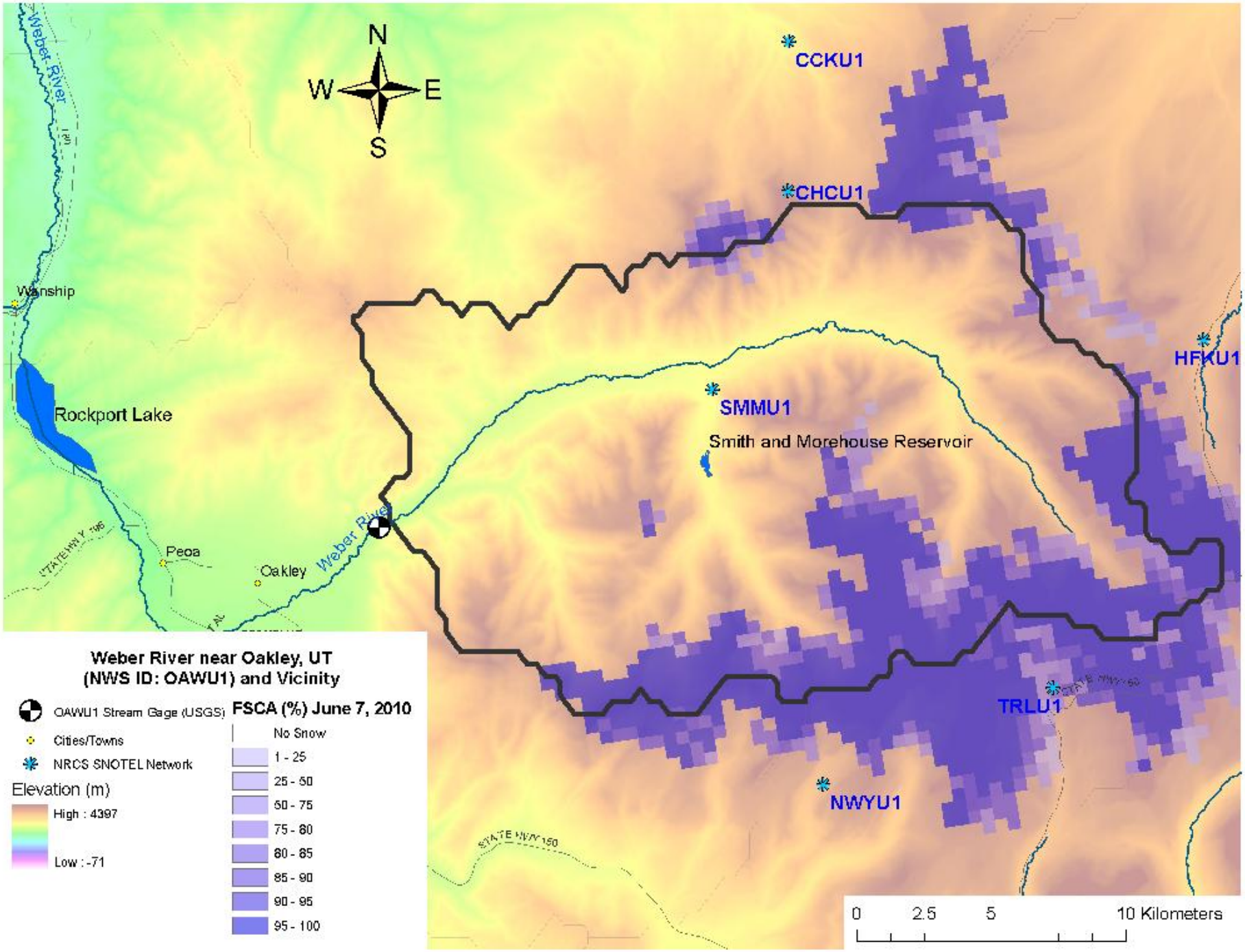
10 Kilometers
Weber River near Oakley, UT
(NWS ID: OAWU1) and Vicinity
OAWU1 Stream Gage (USGS)
Cities/Towns
NRCS SNOTEL Network
Elevation (m)
High : 4397
Low : -71
FSCA (%) May 30, 2010
No Snow
1 - 25
25 - 50
50 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100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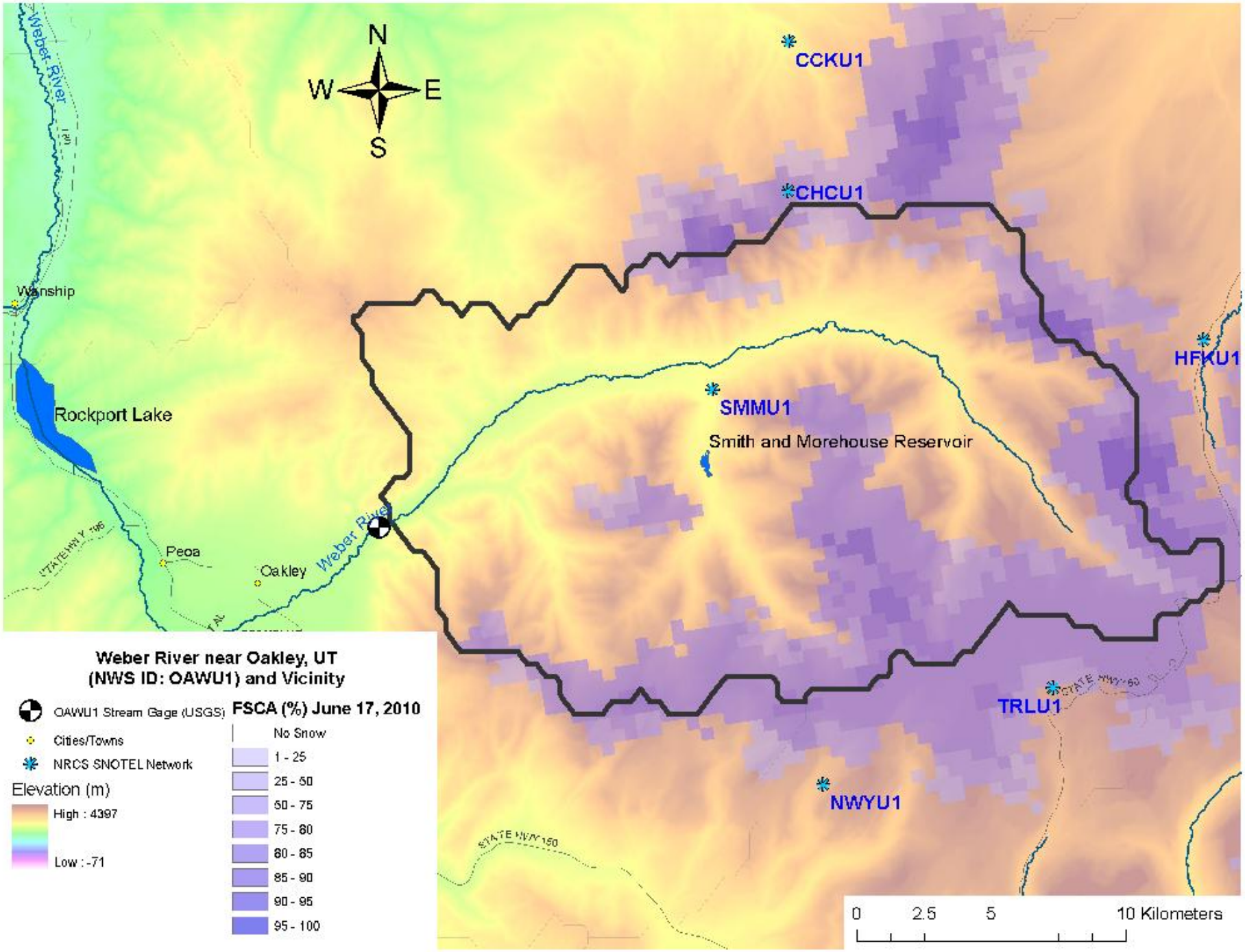
FSCA (%) June 7, 2010
No Snow
1 - 25
25 - 50
50 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100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FSCA (%) June 17, 2010
No Snow
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25 - 50
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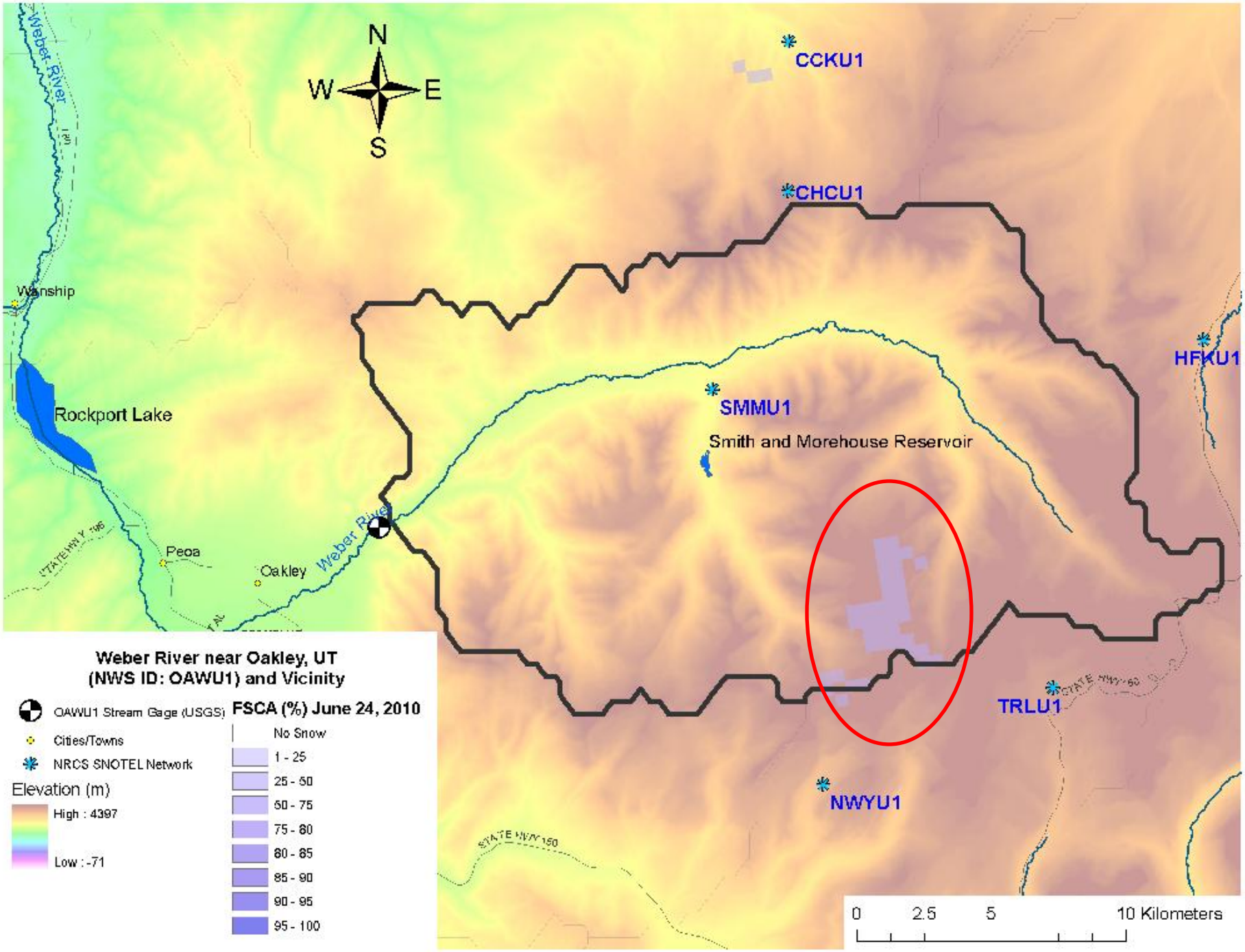
95 - 100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FSCA (%) June 24, 2010
No Snow
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95 - 100

Future Directions

Evaluation of snow observations/datasets:

- Compare impacts to streamflow forecasts of using the MOD10A and MODSCAG datasets in CBRFC forecasting (in research mode at first) and answer:
  - Does one result in more improvement to streamflow forecasts than the other? Are there negative impacts?
  - Do the impacts depend on how the FSCA datasets are used in the modeling process (for example, different types of formal data assimilation schemes)?

- Generate snow cover climatology with MOD10A and MODSCAG FSCA data

- Explore additional ways of using SNOTEL SWE obs in RFC forecasts, besides in regression-based seasonal water supply forecasts

Opportunities for stakeholder engagement:

- Identify cases where a better forecast from the RFC could have helped the organization make more informed decisions.
- Provide feedback regarding experimental forecasts when they are available.

Summary

Use of Snow Observations in CBRFC Operations:

- SNOTEL precip is used for multiple purposes:
  - daily/deterministic, seasonal water supply forecasts
  - model snow updates
- SNOTEL SWE is used:
  - Seasonal water supply forecasts

New/Experimental Snow Cover Datasets:

- Potential, future uses of MODIS FSCA :
  - Update snow states in model
  - Monitor location of snow pack
  - Monitor how quickly the snowpack decreases in areal coverage
  - Snow cover climatology studies

How Stakeholders Can Help:

- Identify cases for study
- Provide feedback on experimental forecasts

Take Home Messages
NRCS's SNOTEL network (especially long-term stations) is valuable to CBRFC.
CBRFC is pursuing new datasets that have potential to improve our snow modeling (and, in turn, our snowmelt-driven streamflow forecasts).
Stakeholder input will help focus our efforts to areas where specific improvement is needed.