CBRFC Snow Data Research and Development

Andy Wood
Stacie Bender
NOAA / NWS
Colorado Basin River Forecast Center

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CBRFC Snow-related R&D Efforts

Motivations

- Snow (water equivalent, covered area) is a primary predictor for streamflow
- Snowpack in recent years has exhibited extremes in both directions (high, low)
- A number of geospatial datasets for monitoring snowpack have existed for the last decade (the ‘EOS Era’). These datasets have potential to improve model estimates of the snowpack at the RFC.

- **Datasets to be evaluated:**
  - MODIS-based 500-m snow cover grids – 2000-present, twice daily overpass by **satellites**
    - > two different algorithms for deriving fractional snow covered area (FSCA) from MODIS
  - NWS NOHRSC **SNODAS** – modeled 1 km snow cover and SWE grids
    ~2000 to present, 3 times daily

- **Note** – despite potential for use, snow data impacts on RFC streamflow predictions need to be evaluated in a research/experimental mode at the RFC to explore this potential
Opportunities related to Snow Data

- CWCB sponsored a 2011 RTi effort to QC and process MOD10A fSCA and SNODAS grids for western US RFCs (CB, MB, WG) – yielding timeseries (for RFC model areas) and grids
- JPL+CBRFC awarded NASA grant in 2012 to bring MODSCAG grids and timeseries into CBRFC
- NCAR/CU/CBRFC NOAA grant 2011-2014 for alternative snow modeling approaches
- NWS CHPS modeling system allows for incorporation of external snow data
- New RFC Snow Modeling and Data Assimilation (SMADA) testbed helps RFC partner with external groups to evaluate snow modeling and use of data (NCAR, GSFC, JPL, OHD, etc.)
General Plans for the Snow Datasets

- **Qualitative:**
  - Develop familiarity and understanding of dataset characteristics, especially in periods of interest
  - Compare the MODIS-based (both versions – Hall and JPL/Painter) and the SNODAS-based snow datasets to RFC model estimates
  - Use the data as a way to “sanity check” the model estimates when the estimates differ substantially

- **Quantitative:**
  - Diagnose significant differences in the snow analyses and evaluate in context of flow simulation errors
  - Where warranted, use the MODIS-based and SNODAS-based datasets in assimilation experiments in the snow models
  - Generate operational snow imagery products for watersheds of interest
Current Specific Goals

In 2012:
- set up real time datafeeds and ingest MODIS-based (Hall and Painter/MODSCAG versions) for in-house RFC experimentation; SNODAS ingest is done.
- obtain historical data as available for the Painter/MODSCAG version and for the SNODAS-based datasets
- evaluate MODIS- and SNODAS-based snow datasets for potential use in an operational environment
- compare datasets to MODIS-RFC snow model estimates of snowpack (qualitatively and quantitatively)

Future
- investigate other sources of snow observations
- explore possibilities for data assimilation
MOD10A (one version of MODIS-based snow cover data)

- Data availability:
  - Grids are available from NASA and NSIDC in real time
    - RFC working on operational ingest
  - Historical data for the period of 2/2000-6/2011 were processed in 2011 by RTi for the Upper Colorado R. and the Great Basin
    - RTi provided grids and FSCA estimates for RFC basins
    - RFC has these in house already and is starting analysis

- FSCA is determined using the Hall/GSFC algorithm (based on linear regressions)
Datasets: MOD10A FSCA Time Series

- Sample FSCA time series from RTI (MOD10A)
  - Red = MODIS-based estimate of FSCA
  - Blue = RFC model estimate of FSCA
  - Green = SNODAS-based estimate of FSCA

Often, the MODIS estimates of snow covered area are lower than the model or SNODAS estimates.
Datasets: MOD10A FSCA Time Series

OBSERVED (from MODIS) & SIMULATED SNOW COVER EXTENT FOR WEBER @ OAKLEY (OAWU1) for WY10

• = FSCA estimates for OAWU1 middle and upper zones, derived from MODIS-based grids of snow cover

* = Simulated snow cover for OAWU1 middle and upper zones

Blue = high elevations of OAWU1 basin
Green = middle elevations of OAWU1 basin

Qualitative Notes:
1. Drastic differences during accum. season
2. MODIS-based FSCA is lower than model in mid-winter.
3. Obs show slightly faster melt than the model did.
Datasets: MOD10A FSCA Time Series

**Purple** = Simulated snow cover extent

**White** = Observed snow cover extent from MODIS (Hall alg.), when it non-missing (clouds sometimes block the view).

**Upper** Elevations of OAWU1 →

**Middle** Elevations of OAWU1 →
Datasets: MOD10A FSCA Grids

May 5, 2011
→ MODIS FSCA Grid from RTi
→ MODIS Visible image from USFS (http://activefiremaps.fs.fed.us/imagery.php?op=fire&passID=130779)

June 22, 2011
→ MODIS FSCA Grid from RTi
→ MODIS Visible image from USFS (http://activefiremaps.fs.fed.us/imagery.php?op=fire&passID=136716)
Datasets: MODSCAG FSCA

MODSCAG (another version of MODIS-based snow cover data)

- Data availability:
  - Current grids are available from NASA/JPL in real time (per Tom Painter on 3/26)
    - RFC is currently working on getting these in-house
  - RFC (or NOHRSC) will process grids into FSCA estimates for individual basins (not available yet)
  - Historical grids:
    - will be available in a few weeks per Painter, as JPL group is reprocessing w/ improved cloud masking and de-striping.

- MODSCAG algorithm determines FSCA in a different way than the Hall/GSFC algorithm
  - Hall/GSFC based on regressions
  - MODSCAG based on spectral mixture models
JPL ready to start serving operational grids to CBRFC

Sample imagery in Utah, April 2010

Datasets: MODSCAG FSCA
Sample imagery for upper Colorado Basin April 2010
RFC SNODAS investigation
SNOW17 SWE
Substantial Differences
Comparison at watershed level
• Snow Modeling and Data Assimilation (SMADA) Testbed
  • ~10 watersheds
  • relatively unimpaired
  • good SWE and flow observations
SMADA

- Collectively, the datasets help define state of current RFC practice
- The staging of models & data facilitates/focuses research in an RFC-relevant context

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<thead>
<tr>
<th>NWSRFS Calibration Deck (as of March 22, 2011)</th>
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<tbody>
<tr>
<td>MAT, MAP forcings from most recent calibration (1980-2010)</td>
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<tr>
<td>• Upper Tier MAT</td>
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<tr>
<td>• Lower Tier MAT</td>
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<tr>
<td>• Upper Tier MAP</td>
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<td>• Lower Tier MAP</td>
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Daily SWE obs from nearby SNOTELs

<table>
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<tr>
<th>Current SWE plots for nearby SNOTEL stations:</th>
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<tr>
<td>• Dry Lake (DRLC2)</td>
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<td>• Tower (TOWC2)</td>
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Current Flow Plot for FISC2

USGS web page for FISC2

Map in English Units

- Obs. Mean Daily Q in cfs (all obs CBRFC has)
- Sim. Mean Daily Q in cms/d (1980-2010)

The whole nine yards (all datasets in one tarball)
Next Steps

Snow Data Grid & Timeseries Evaluation
- Visualizing SNODAS and MODIS products side-by-side with RFC simulations in CHPS
- Event-focused assessment for particular basins (eg 2010, 2011 melt periods)
  - Can information from these ‘new’ datasets increase the accuracy of RFC modeling?

Research Partnerships (using SMADA)
- Alternative snow modeling approaches (with Martyn Clark, Drew Slater, Pedro Restrepo, Andy Wood)
- MODSCAG applications in RFCs (with Tom Painter, Andy Wood, Stacie Bender, Kevin Werner)
- Data assimilation projects (with DOE PNNL, NASA GSFC – still being scoped)

Snow Product Development
- providing watershed or basin-focused spatial imagery from various sources
  - current states
  - trends – eg, changes in last few days, week

Feedback from Water Users
- guidance for product development