Use of Snow Data from Remote Sensing in Operational Streamflow Prediction

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CBRFC

Colorado Basin River Forecast Center (CBRFC)

Full staff: 3 mgmt, 9 hydrologists, 1 admin, 1 IT

Vacancies: 1 mgmt, 1 hydro

Operational streamflow forecasts across the Colorado River basin and eastern Great Basin

Operational forecast types:
- daily streamflow
- seasonal peak flow
- seasonal water supply volume

www.cbrfc.noaa.gov
Colorado Basin River Forecast Center (CBRFC)

Hydrologic regimes:
- snow-dominated to flash flood hydrology
- natural to regulated

500+ streamflow forecast points

~1150 modeling units (snow and soil moisture model run on each)
Importance of Snow

Annual streamflow:
→ primarily snowmelt-driven in CBRFC area of responsibility

Streamflow forecast users then, in turn, depend on snow:
• NWS Weather Forecast Offices
• US Bureau of Reclamation
• water conservation districts
• municipalities
• recreational community
• others
Operational CBRFC Models

Operational Snow Model: SNOW17 (temperature-index model)

Operational Soil Moisture Model: Sac-SMA
Operational CBRFC Models

Operational Snow Model: SNOW17

• minimum inputs: precip and temperature
• minimal computational power needed
• decades of NWS experience
• calibrated to streamflow using the 1981-2010 historical period (manual process at CBRFC)
• temperature-index model
  → “melt factor” to relate snowmelt to air temp.
• forecasts snowmelt pretty well under near-normal conditions of the calibration period
• doesn’t do so hot when conditions deviate from near-normal – manual adjustments needed
Snow and the CBRFC Operational Forecasting Process

CBRFC Operational Hydrologic Forecasting Process:
Ultimately driven by CBRFC forecast users, who have decision deadlines and who need forecasts consistently and reliably

CBRFC Hydrologist / Forecaster (the “human component”)
Given information about hydrologic conditions, the forecaster may modify the forecast that initially comes directly from the model (including manual adjustment of snow and/or soil model states)

Input Datasets:
Must be reliably available in a timely manner

CBRFC Hydrologic Model
Computing = local Linux boxes (no supercomputer available)

where snow improvements may potentially lead to streamflow prediction improvements

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Official CBRFC Streamflow Forecasts

CBRFC Forecast Users and Stakeholders:
NWS Weather Forecast Offices, Bureau of Reclamation, Water Conservation Districts, Recreational River Community, others

CBRFC

The R2O Gap
Project Goals and Motivation
MODSCAG & DRFS Datasets
Uses of NASA/JPL Data at CBRFC
Future Directions
Emphasizing the Importance of Collaboration
Summary
Bridging the R2O Gap

Collaborative partnerships among operational and research-oriented groups
→ intended to accelerate the improvement of snowmelt-driven streamflow predictions at CBRFC

Productive research and academic communities ≠
automatic and easy transfer of research to operations (R2O)
Some reasons for the notoriously difficult-to-bridge R20 gap:

**Cultural** - both sides need to understand their counterparts
→ researchers – usually have a specialty
→ NWS operational hydrologists - jacks/jills of many trades

**Differences in hydrologic science and models used**

**Operational time constraints**
• forecasting agency needs input datasets available in NRT
• forecast users need info quickly and reliably → decisions

**Scale of datasets** (space and time)
• field experiments vs. datasets with long period of record
• dedicated experimental basins vs. results across a large area

**IT Issues**
• computing power (no supercomputer for NWS hydro)
Expanding info available to the CBRFC forecaster:

Snowpack observations \(\rightarrow\) crucial to improving CBRFC streamflow prediction

Point networks (SNOTEL) = the backbone and remain crucial to CBRFC ops.

Remote sensing (RS) data can fill in gaps between point stations, especially at high elevations, in mountainous terrain.

Past (pre-2013):

Point networks **only**

Present and future:

Point networks + Remote sensing (MODIS, VIIRS) = More robust set of snowpack observations
Establish a multi-year CBRFC/JPL collaboration:
Actually get across the R2O gap!

More efficiently integrate RS snow datasets into CBRFC forecasting

Improve overall understanding and communication between operational and research groups

Develop beneficial relationships specifically among snow and remote sensing science researchers and operational hydrologic forecasters
Exploit differences in spectral characteristics of snow in the VIS and NIR to derive snow cover and dust information

- MODSCAG provides per-pixel (500 m) fractional snow cover (%)
- MODDRFS provides per-pixel (500 m) radiative forcing by dust in snow (W m$^{-2}$)

Both gridded datasets are available from JPL server in near-real time and over the MODIS period of record (2000-present)

REFERENCES:


Limitations of MODIS-derived Snow Data

1. No direct SWE information
2. Limited seasons of usefulness (fSCA values bounded by 0 to 100%)
3. Impacts of vegetation
4. Clouds, especially during stormy periods

MODSCAG fSCA
April 11, 2014

MODSCAG fSCA
April 12, 2014
(clouds = gray)
2012: initial exploratory phase
• CBRFC set up NRT processing of data from JPL
• both groups began learning what they had gotten themselves into

2013:
• semi-quantitative use of MODSCAG fSCA at CBRFC → binary indicator of snow presence (or lack of)
→ add/subtract small amount of SWE
• historical analysis of patterns in streamflow prediction errors and MODDRFS dust-on-snow data (Annie Bryant PhD work)
• 3 week visit to CBRFC during melt season by JPL’s Annie Bryant

2014:
• added another version of MODSCAG fSCA to toolbox
• automated alerts of model vs. MODSCAG “fSCA differences”
• more extensive use of MODDRFS dust data in 2014 than 2013
• began refining semi-quantitative method of treating of fSCA and dust info in CBRFC forecasting and modeling
May 16, 2013 CBRFC forecast modifications due to MODSCAG (snow cover)

Coal Creek, near Cedar City, UT, NWS ID: COAU1/USGS ID: 10242000

**Before** small SWE adjustment:

**After** small SWE addition:

Recent Obs Q
Model Sim Q
Official Fcst Q

MODSCAG & DRFS Datasets

Uses of NASA/JPL Data at CBRFC

Future Directions

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Summary
Dust in the snowpack primarily impacts timing of snowmelt (and timing of subsequent snowmelt-driven streamflow peaks)

Analysis shows that a dustier than average snowpack results in center of mass that is observed earlier than predicted (esp. SW CO)

Very dusty years coincide with larger streamflow prediction errors

REFERENCE:
Multiple MODSCAG fSCA Products

“Viewable” MODSCAG fSCA
• what the MODIS instrument “sees”
  ➔ if trees are snow-free but a snowpack exists under them, MODIS will not observe that snowpack
• more accurate in a remote sensing aspect
• MODSCAG fSCA product used by CBRFC during 2013 melt

“Canopy-adjusted” MODSCAG fSCA – new for 2014 melt
• In a nutshell: if MODSCAG algorithm detects snow and green vegetation in the same pixel, the fSCA value is reset to 100%
• higher fSCA value than “viewable” MODSCAG fSCA
• less accurate in a remote sensing sense but more hydrologically useful
• closer to SNOW17 values of snow cover extent
Multiple MODSCAG fSCA Products

MODSCAG (a) “viewable” and (b) “canopy-adjusted” fSCA over southwestern Colorado, April 9, 2014, as viewed by CBRFC forecasters.
Example: April 2014 Storm
CODOS, April 4: “… dust layer D4 may emerge in the coming week, absorbing solar radiation and accelerating the warming of the underlying snowcover at higher elevations, or enhancing snowmelt rates at lower elevations where the snowcover was already isothermal.”
Near Real-time Dust Impacts on Q Forecasts

**Uses of NASA/JPL Data at CBRFC**
- Future Directions
- Emphasizing the Importance of Collaboration

**Summary**
- Recent Obs Q
- Model Sim Q
- Official Fcst Q

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Before

"cranking up the melt factor" – sim Q is too low

After

"cranking up the melt factor" – sim Q matches much better
Near Real-time Dust Impacts on Q Forecasts

CBRFC

The R2O Gap

Project Goals and Motivation

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Summary

Forecasts issued late in the week and over the weekend were better.

Forecasts issued early to middle of last week were too low.
Near Future Directions

**For melt season 2015 (and beyond):**

* Continue to use information provided by NASA/JPL at CBRFC
  - manual SWE adjustments from MODSCAG fSCA info
  - “melt factor” (MF) adjustments from MODDRFS dust info
  - Fine-tune the range of allowable SWE and MF adjustments

* Connect patterns in JPL MODIS snow data to patterns in snow model parameters, including calibrated SNOW17 areal depletion curves

* Adjustments to MODIS NASA/JPL datasets – estimates for cloudy pixels, vegetation adjustments (filling in gaps in the time series of data)

* Continue to explore pieces of the snowmelt forecasting puzzle – e.g., energy balance snow modeling

* Improve communication between CBRFC and users of CBRFC forecasts on snow remote sensing data at CBRFC and conditions as melt progresses.

* JPL continues to develop the Airborne Snow Observatory to map spatial distribution of SWE
CBRFC/NASA/JPL Collaboration

Collaboration and open exchange of information → very beneficial to both CBRFC and NASA/JPL

CBRFC gains detailed knowledge of:
- NASA/JPL snow cover and dust-on-snow data and remote sensing in general
- How to overcome limitations in datasets (e.g., vegetation, clouds)

NASA/JPL gains awareness of:
- CBRFC operational forecasting and modeling process (including the “human component”)
- Operational requirements for data availability and timeliness

People involved → KEY to the project’s success.
CBRFC is using JPL’s snow remote sensing data!

- MODSCAG fSCA for SWE adjustments
- MODDRFS dust info for “melt factor corrections”

Potential future uses of snow remote sensing data:

- Further analysis of historical MODIS datasets
- Improvements in JPL remote sensing datasets (estimating conditions on cloud days, further vegetation corrections, ASO)

People make the collaborative R2O wheels go round.

- Operational hydrologists
- Remote sensing science experts

Take Home Messages

Operational forecasting agencies CAN use snow remote sensing data.

Best, most robust way to use data in operational hydrology is still TBD.

Successful R2O collaborations are driven by dedicated people on the operations side AND the research side.

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