Evaluation of gridded snow water equivalent & satellite snowcover products for mountain basins in a hydrologic model

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- Snowcover products
- Model performance
- Future directions
AVHRR SCA product

Fractional snow covered area (SCA)
Mapping of Colorado River & Rio Grande basins
1995-2002

% SCA
75-100
50-75
25-50
0-25
cloud

Mar 7, 1995
AVHRR SCA & study areas

Headwater study areas:
- Rio Grande
- Salt River (Black basin)

Feb 19, 1995
Snow cover mapping process

- Scene evaluation: cloud cover & coverage over study basins
- Build cloud masks using several spectral-based tests
- Execute atmospheric corrections, conversion to engineering units using AVREF
- AVHRR bands
- Build thermal mask
- Apply cloud, thermal & geographic masks to raw AVTREE output
- Georegister image using GEOREG script
- Snow map algorithm output: mixed clouds, high reflective bare ground, & sub-pixel snow cover
- Execute sub-pixel snow cover algorithm: AVTREE using bands 1,2,3 (reflectance) as input
- Composite cloud mask
- Geographic mask
- Masked fractional snow covered area map
- Interpolate using hypsometric method
- Combine sub-pixel SCA & ground-based interpolated SWE to produce total basin water maps
- Total snow water equivalent map
- Topography
- Ground measured snow water equivalent
- Snow cover mapping process: AVHRR (HRPT FORMAT) pre-processed at UCSB [NOAA-12,14,16]
Interpolated SWE based on SNOTEL

Feb 3, 1995

% SCA
- 75-100
- 50-75
- 25-50
- 0-25
- cloud
AVHRR SCA

- Rio Grande
- Black River

Feb 3, 1995

% SCA
- 75-100
- 50-75
- 25-50
- 0-25
- cloud
Blended AVHRR SCA & interpolated SWE

- Rio Grande
- Black River

Feb 3, 1995
AVHRR SCA – consistent product

Black River basin, 1995
## Number of AVHRR SCA scenes processed

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Test basins

R. Grande

- 3400 km²
- Elevation, m:
  - 0 - 2,500
  - 2,500 - 3,000
  - 3,000 - 3,500
  - 3,500 - 4,000
  - 4,000 - 4,500
- Forested:
- Non-forested:

Black R.

- 1440 km²
- Elevation, m:
  - 0 - 2,500
  - 2,500 - 3,000
  - 3,000 - 3,500
  - 3,500 - 4,000
  - 4,000 - 4,500
- Forested:
- Non-forested:
Precipitation-Runoff Modeling System (PRMS)

- Modular, deterministic, distributed-parameter modeling system developed to evaluate the impact of various combinations of precipitation, climate & land use on streamflow, sediment yields & basin hydrology

- Hydrologic Response Units: 1-km$^2$ grid to match AVHRR

- Forcing: max & min temperature & precipitation
  - XYZ distribution method: uses monthly multivariate regressions of the spatial relations between geographic (independent) & climate (dependent) variables
  - Modeled snowpack from temperature & precipitation compared to snowpack from experimental SCA & SWE data
Assimilation modeling scheme

- Data cube
  - t
  - y
  - x

- Climatology
- Vegetation
- Topography
- Soils

- SWE
- SCA
- Precipitation
- Temperature
- Air

Hydrologic model (PRMS)

- Basin potential runoff

- Pixel by pixel SWE & SCA

- Pixel by pixel runoff potential

- Time
Black River – WY 1995

Discharge, m$^3$ s$^{-1}$

- observed
- base
- assimilate
- updates
- rainfall

mix of snow & rain
mostly snowmelt in March

Jun 5

Jun 10

Jun 11

Jun 12
Initialize run: use SCA & SWE only to update conditions at the beginning of snowmelt, ~ April 1
AVHRR SCA – georegistration issue

Black River Basin, 1995
Canopy corrections

Canopy factor = \frac{100}{SCA_{\text{max}}}

Black

SCA, %

0
1 - 25
26 - 50
51 - 75
76 - 99

corrected SCA, %

0
1 - 25
26 - 50
51 - 75
76 - 99

canopy factor

1
2
3
4
5
9

Grande

Canopy factor = 100 / SCA_{\text{max}}
vegetation correction reduced the difference on the Grande but had little effect on the Black
Concluding thoughts & next steps

- Blended AVHRR-SCA & interpolated SWE product generally indicates less SCA & SWE than model
  - small improvement in water balance in Black
- MODIS provides improved SCA product – but cloud problem remains
- Follow-up in Rio Grande with both AVHRR & MODIS; extend to Sierra Nevada
- Mass balance deficit on Grande plus small measured SCA suggests either:
  - model shortcoming
  - SCA detection problem
  - SWE measurement problem
Next steps – model shortcoming

– unaccounted for lag between snowmelt & runoff
– snowmelt algorithms
– energy balance & albedo data
– water storage after snowmelt
Next steps – SCA detection problem

- MODIS vs. AVHRR: better classification & georegistration now available
- Clouds: improve & implement estimation of SCA under clouds
- Vegetation: canopy correction should improve detection problem
- View angle: empirical correction vs. physical model
Next steps – SWE measurement problem

- snow telemetry & snow course measurements provide limited information on spatial water balance
- testbeds for spatial snow measurements
- blending satellite & ground measurements

April SWE bias a 4 SW CO sites