Variability in Sublimation in the Upper Colorado River Basin

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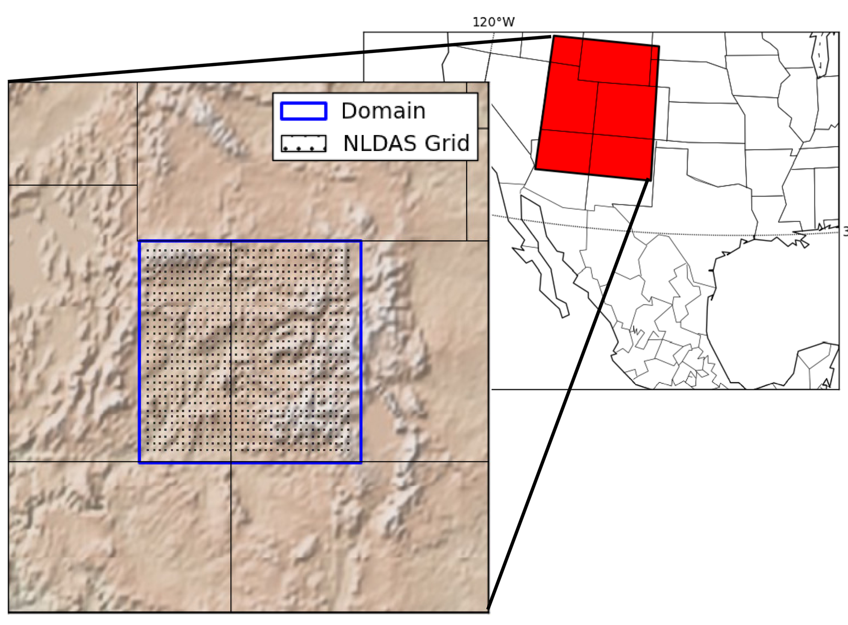
Introduction

Water reserves stored in the form of mountain snowpack in the Upper Colorado River Basin (UCRB) provides the primary source of water for much of the population and environment (Christensen et al., 2007). The wintertime ablation of the snowpack via sublimation is a process which removes water that would otherwise be realized as runoff later during the spring melt. This study sought to investigate the spatial and temporal patterns of snowpack sublimation through the use of a physically-based numerical model known as SnowModel.



Model Description

SnowModel – A spatially distributed snow evolution model consisting of four sub-models.

- MicroMet – Produces high resolution meteorological forcing distributions by assimilating and interpolating observations
- EnBal – Performs standard surface energy balance calculations
- SnowPack – Simulates snowpack depth and Snow Water Equivalent (SWE)
- SnowTran 3D – Snow re-distribution model capable of simulating three dimensional snow transport and blowing snow sublimation

Forcing Data

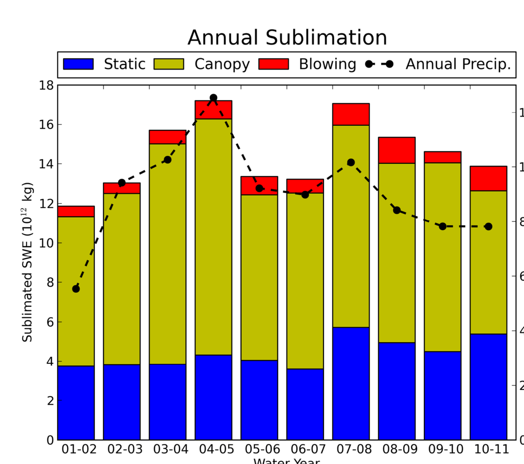
- Forced using gridded analysis from the North American Land Data Assimilation Systems (NLDAS)
- Non-precipitation fields are derived from the North American Regional Reanalysis (NARR) which are downscaled to the hourly NLDAS domain
- Precipitation fields are generated through a combination of daily gauge, NARR reanalysis and Stage 2 precipitation data that is temporally disaggregated to hourly time-steps using WSR-88D radar estimates

Results

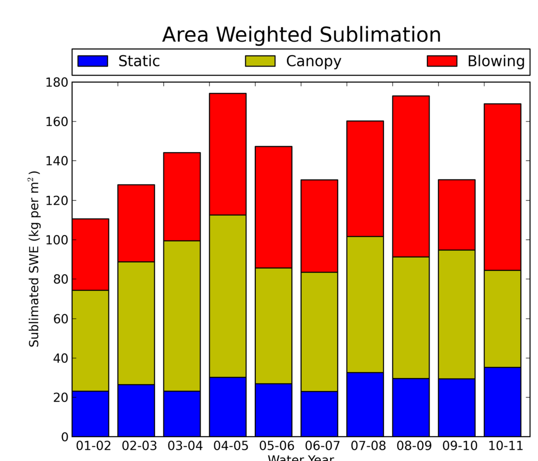
Temporal Variability

The model was used to simulate snow evolution for 10 water years from October 1, 2001 through September 30 2011.

- The magnitude of annual sublimation within the domain is primarily a function of the spatial extent and longevity of the snowpack
- Sublimation from the tree canopy accounts for the majority of the water loss via sublimation
- Blowing snow sublimation rivals canopy sublimation in terms of water loss per unit area, despite it occurring over a relatively small area



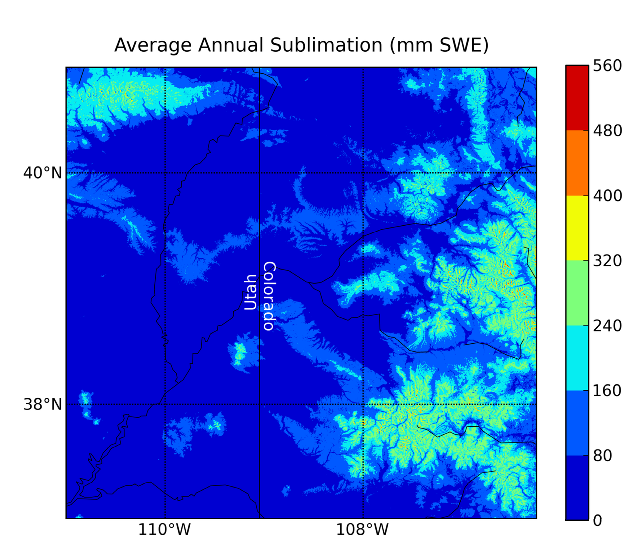
Domain total sublimation and precipitation



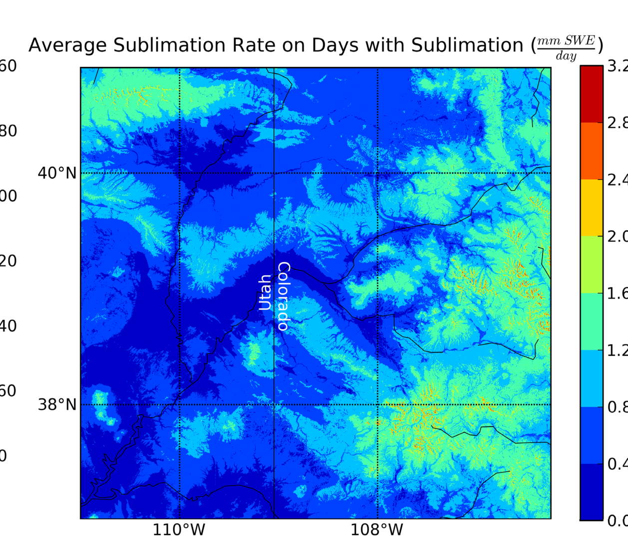
Domain total sublimation weighted by area of sublimation type

Spatial Variability

Results from the model simulations show a distinct elevational gradient, with high elevation areas experiencing the greatest sublimation rate. These extreme rates are likely due to a combination of increased ventilation and large vapor pressure deficits made possible at low atmospheric pressures.



Average annual sublimation from October 1, 2001 through September 30, 2011



Average daily sublimation rate from October 1, 2001 through September 30, 2011 during days when sublimation occurred

Discussion

Verification

Various sources were used to verify the model output. Most of these sublimation results are consistent with previous work (Beaty, C. B., 1975, Schimidt, et al., 1992). While every effort has been made to assemble the most accurate representation of the real world into the simulations, any numerical model is constrained by incomplete access to real world phenomenon.

- Initial verification indicates that modeled SWE values are smaller than observations and gridded snow analysis
- Modeled canopy sublimation values of 6.37×10^7 kg/km^2 are slightly higher than the 4.47×10^7 kg/km^2 found by Schmidt et al., 1992.

Sensitivity Analysis

Additional model runs will be carried out for specific years to investigate the sensitivity of the model to changes in two parameters

- Canopy sublimation sensitivity will be investigated by altering the Leaf Area Index of coniferous species, in line with the ongoing reduction in evergreen stands associated with the Rocky Mountain Pine Beetle
- Model under-estimates of SWE will be investigated by running SnowModel in assimilation mode, where real world observations will be used to adjust the modeled SWE

Conclusions

Results from the model simulations show that not only does sublimation occur preferentially in high elevations, but the overall magnitude of sublimation varies greatly from year to year.

- Absolute magnitude of sublimation is approximately proportional to the area of exposed snow, and therefore the spatial extent and longevity of the seasonal snowpack
- Canopy sublimation accounts for the majority of mass loss via sublimation
- Sublimation from blowing snow rivals canopy sublimation in terms of mass loss per area
- Verification and sensitivity analysis is ongoing

Acknowledgements

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