# Preliminary Comparison of Total Volume of Snow Water Equivalent for the Helmand Watershed upstream of Kajakai Reservoir between SSM/I satellite imagery and the USGS FEWS Snow Model

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## Results

The preliminary comparison has been made of the total snow water equivalent for the Helmand River Watershed upstream of Kajakai Reservoir between SSM/I satellite imagery and the USGS FEWS snow model. (Figure 1).The distributed FEWS SWE results were provided to ERDC-CRREL (J. Verdin, personal communication). GIS analysis of the FEWS results was used to determine the totals for the Kajakai Reservoir watershed. A brief description of the SSM/I analysis follows.

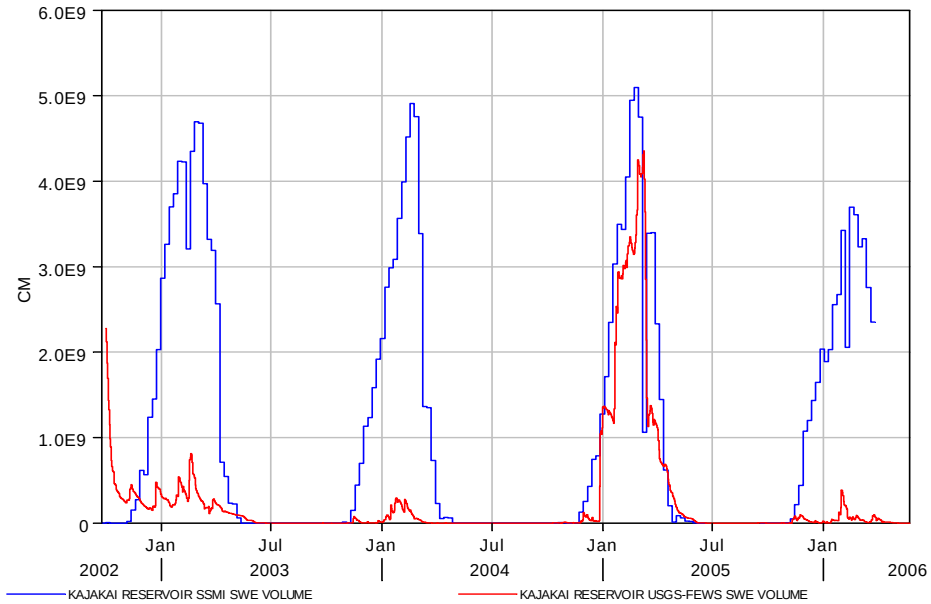


Figure 1. Comparison of the SSM/I Estimate of total snow water equivalent (blue line) and USGS FEWS snow model (red line).

## REMOTE SNOW MEASUREMENTS BY SATELLITE

Satellite imagery can provide information on the snow covered area (SCA), snow water equivalent (SWE), and snow depth. In this study we concentrated on SWE, the snow parameter of most interest for water resource management. Satellite measurements from which SWE can be derived are available from the Special Sensor Microwave/Imagers (SSM/I) (Armstrong et al 2005). The satellite data are processed and available in 25 km equal-area grids. The satellite measurements represents the mean SWE for each grid cell which covers a total area of 625 square km. Measurements made during the coldest time of day are used to estimate the snow properties. The measurements are processed to account for the presence of vegetation, remove false measurements, account for variations in the satellite swath coverage, and remove noise in the SWE signal caused by temporary atmospheric phenomena (e.g. warm, precipitating weather fronts).

The SWE measurements can be affected by a number of factors that can apply to the Helmand watershed (NSIDC 2006). Mountainous areas with large topographic variability can return low SWE values. Samples from these areas contain a mixed signal from a large footprint that may include deep snow on north-facing slopes, snow-free south-facing slopes, wind-scoured Alpine areas, etc. Areas containing melting snow or wet snow packs typical of maritime snow conditions return low or no SWE values, because the microwave emission from liquid water overwhelms scattering from the snow pack. Shallow or intermittent snow during fall and early winter typically does not result in sufficient microwave scattering to reliably detect SWE. It is not clear how much the SWE estimates for the Helmand River watershed have been impacted by these factors.

## GIS ANALYSIS

*SMM/I Data*. The SSM/I data was provided by NSIDC in the Equal-Area Scalable Earth Grid (EASE-Grid). The data in each grid cell corresponded to the SWE in each cell in millimeters. The EASE-GRID projection parameters are listed in Table 1. Each data file consisted of an array of binary, 16-bit signed, little endian integers (least significant byte of the data field was stored at the lowest memory address). The majority of the data, acquired from 8/3/1987 to 3/21/05, was provided as a weekly product that had undergone

quality control at NSIDC. Each weekly product spanned 7 days, from a Monday to a Sunday. Each cell in the weekly product represented the maximum SWE that had been detected in that cell over the 7 day period. A second group of data, acquired from 3/28/2005 to 3/27/2006, was provided as a daily product that had not undergone quality control by NSIDC.

| | |
|---|---|
| Projection: | lambert_azimuthal |
| Units: | meters |
| radius of the sphere of reference: | 6371228 |
| longitude of center of projection: | 0 0 0 |
| latitude of center of projection: | 90 0 0 |
| false easting (meters): | 0 |
| false northing (meters): | 0 |

**Table 1. EASE Grid projection parameters**

The SSM/I files were imported to Arc Grid format using the Workstation ArcInfo *imagegrid* command. A header file, listed in Table 2, was created for each SSM/I file prior to the conversion to be used by the *imagegrid* command. The *projectdefine* command was run to assign the EASE Grid projection parameters (Table 1) to the imported grid.

| | |
|---|---|
| nrows: | 721 |
| ncols: | 721 |
| nbands: | 1 |
| nbits: | 16 |
| byteorder: | I |
| layout: | bsq |
| ulxmap: | -9024309 |
| ulymap: | 9024309 |
| xdim: | 25067.525 |
| ydim: | 25067.525 |

**Table 2. ArcInfo Header File Information**

The Grid *con* function was used to remove values in the imported grids that were greater than or equal to 65000. These data represent negative numbers in the original SSM/I SWE data and are incorrectly converted due to limitation in the ArcInfo *imagegrid* function. These values were not needed for analysis and were removed from the grid.

The daily SSM/I files (acquired from 3/28/2005 to 3/27/2006) were processed into a weekly product using the Grid *max* function on each group of 7 daily grids that spanned from a Monday to a Sunday. The *max* function determined the maximum value on a cell-by-cell basis for each group of 7 input grids. This was consistent with the process that NSIDC used to create the weekly product covering the time frame of 8/3/1987 to 3/21/05. Occasionally, seven days of data were not available for the weekly product, in which case the 5 or 6 days available were used.

Once the SSM/I data had been converted to ArcInfo grids and was all in a consistent weekly format the data was then processed to determine the total SWE volume of the Kajakai Reservoir watershed as well as the entire Helmand Watershed. First, the weekly SSM/I grids were converted to a map projection suitable for watershed analysis in Afghanistan using the *project* command. The projection parameters used are listed in Table 3.

| | |
|---|---|
| projection: | albers equal area |
| units: | meters |
| parameters: | |
| 1st standard parallel: | 31 0 0.000 |
| 2nd standard parallel: | 37 0 0.000 |
| central meridian: | 67 0 0.000 |
| latitude of origin: | 23 0 0.000 |
| false easting (meters): | 0.00000 |
| false northing (meters): | 0.00000 |

**Table 3. Projection Parameters**

The grids were re-sampled to a 1km resolution using the Grid *resampl*e function. This was done to allow accurate "clipping" of the SSM/I SWE data to the watersheds. The total snow water volume contained in each watershed was calculated using the Grid *zonalstats* command on the 1km SSM/I SWE grids with the *sum* option and a grid of each watershed (also at a 1km resolution) as the zone grid. This sum of snow water height was then multiplied by the area of a grid cell ($1 \times 10^6$ sq. meters) and then converted to cubic meters.

**REFERENCES**

Armstrong, R.L., M.J. Brodzik, K. Knowles, and M. Savoie (2005), *Global monthly EASE-Grid snow water equivalent climatology*. Boulder, CO: National Snow and Ice Data Center. Digital media.

National Snow and Ice Data Center (2006)
http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology.gd.html