Toolkit for snow cover area calculation and display of Interactive Multisensor Snow and Ice Mapping System over the Tibetan Plateau

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INTRODUCTION

Snow-Man is a toolkit for snow-cover area calculation and display based on the Interactive Multisensor Snow and Ice Mapping System (IMS)[NIC, 2008]. The Tibetan Plateau region as an example to describe the toolkit's method, and results

The National Snow and Ice Data Center (NSIDC) provides to the public IMS, a well-used system for monitoring the snow and ice cover. A stereographic projection arranges the daily snow and ice coverage data into a grid. IMS provides latitude and longitude coordinates for each grid point; Unfortunately, they don't include the surface areas that each grid point represents.

Snow-Man provides the areas of snow and ice coverage provided by IMS. Furthermore, Snow-Man can display IMS data with maps, and time series, and hence enrich the IMS's capability. Thus, our toolkit can be a useful tool for further studies of snow cover, snow depth-snow water equivalence, climate forecast, and hydrological engineering planning and management.

AREA CALCULATION METHOD

Grid cell areas are modeled as quadrangles, whose corners are the centroids of the surrounding four points. Snow-Man calculates these points and converts them from degrees to meters using the Lambert azimuthal equal area (LAEA) projection.[Snyder, 1984] Then the area of each quadrangle is determined using the shoelace formula.[Braden, 1986]

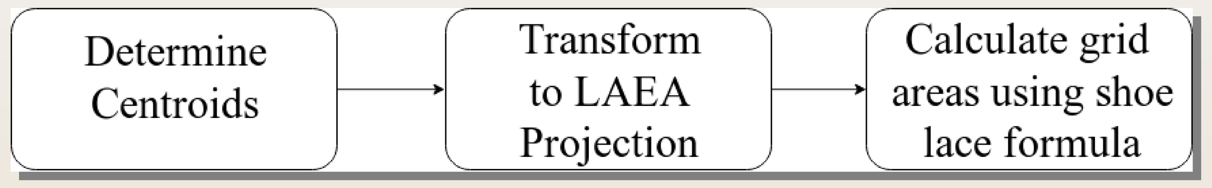

Figure 1. Flow chart describing area calculation process.

$$x = Rk' cos\phi_1 sin(\lambda - \lambda_0) \quad (1)$$

$$y = Rk'[cos\phi_1 sin\phi - sin\phi_1 cos\phi cos(\lambda - \lambda_0)] \quad (2)$$

$$k' = \sqrt{\frac{2}{1 + sin\phi_1 sin\phi + cos\phi_1 cos\phi cos(\lambda - \lambda_0}} \quad (3)$$

$$A_{ij} = \frac{1}{2} \sum_{k=1}^{3} x_k y_{i+1} + x_n y_1 - \sum_{k=1}^{3} x_{k+1} y_k - x_1 y_n \quad (4)$$

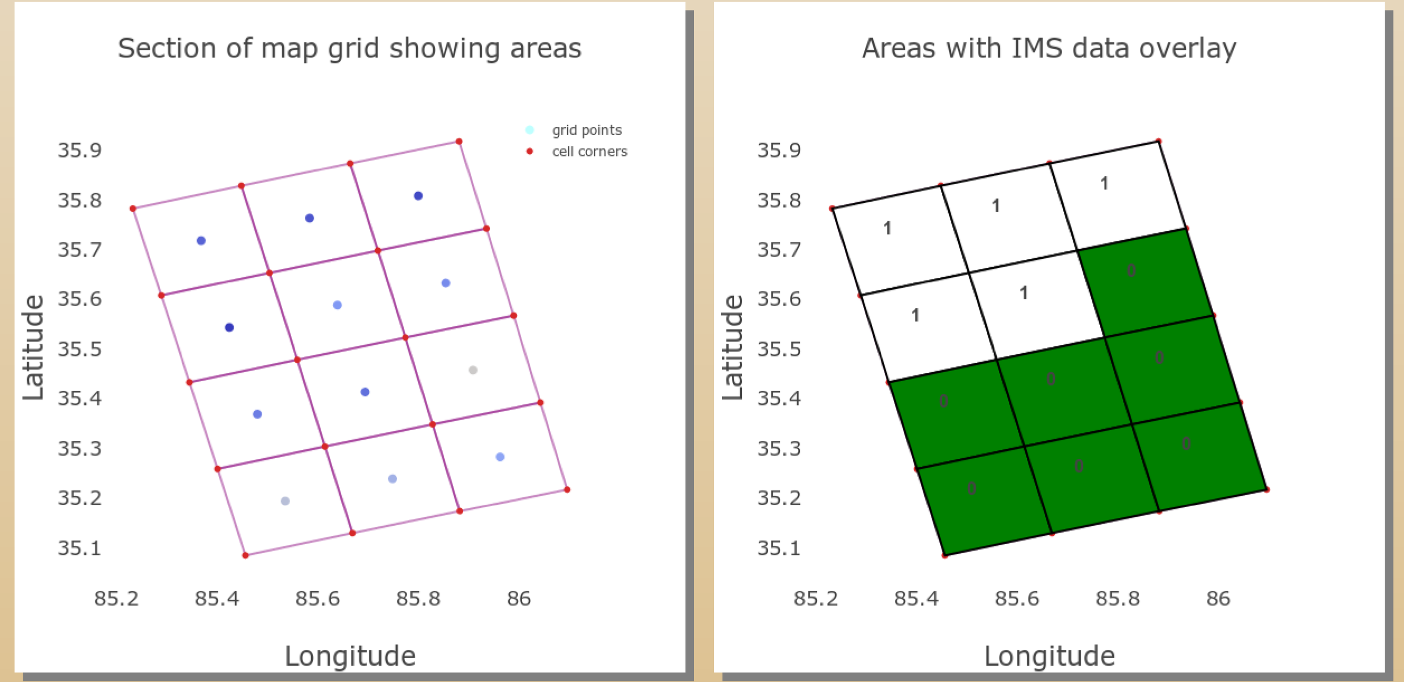

Figure 2. Section of grid showing lat-long points with surrounding centroids. Sub figure on the right shows overlay of IMS data. Areas covered in snow are indicated by '1', otherwise '0'.

TIME SERIES GENERATION METHOD

The Snow-Man routine flattens a map consisting of given snow and ice data into a vector of booleans representing snow and ice coverage. Each item of the vector has an associated area, stored in a separate vector. The dot product between these two vectors yields the total area of snow and ice coverage.

RESULTS

Areas calculated using shoelace formula (4) of the Tibetian region were compared with l'Hullier formula and were found to have a distance of 0.0466 % and 0.0329 % difference for 24x24 and 4x4 km resolutions respectively.

Uniform grid assumption and shoe lace methods are plotted side by side, shown in Figure 4. The errors in assuming a uniform grid can be as large as 54.79% and as small as 32.22% over the history of the IMS product.

Shown in figure 5, Differences in resolution for regions as large as the Tibetian Plateau are as large as 48.42% during summer months. The coarse resolution isn't able to see smaller ice fields and glaciers.

Differences in resolution vary seasonally. With more snow reported by the 4x4 km data set in the warmer months. Small glaciers and ice fields are too small to be seen by the 24x24 set. The coarser 24x24 also reports more snow during snowy months, suggesting a slight positive bias.

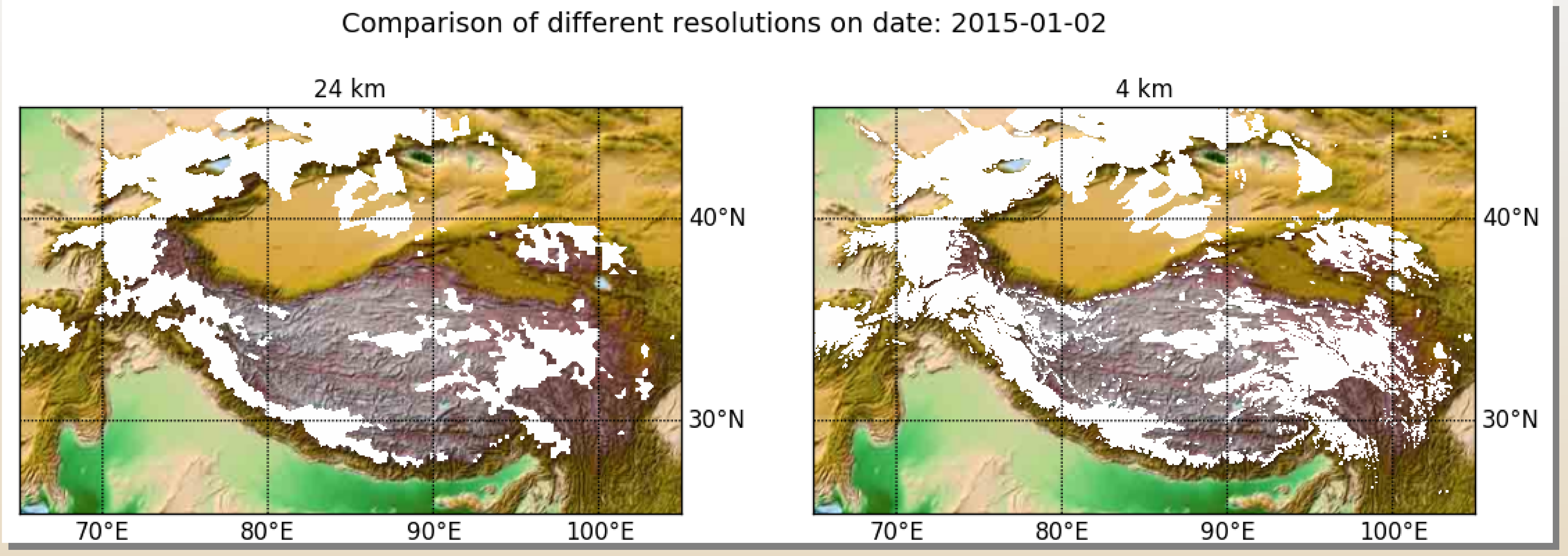

Figure 3. Comparison between 24x24 and 4x4 km resolution. Although there appears to be greater coverage on the right, The difference in calcualted coverage is minimal.

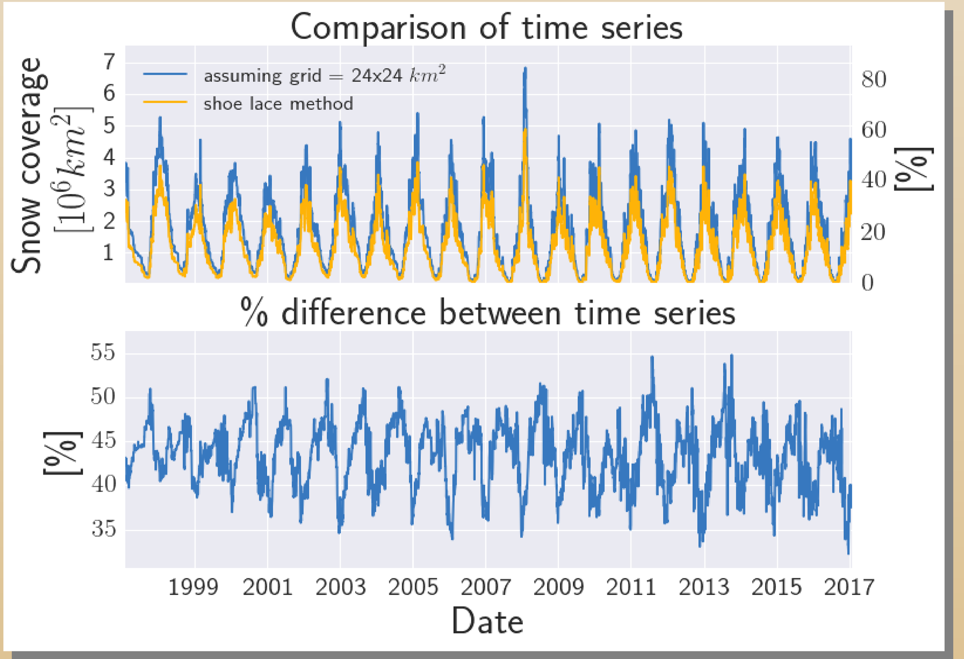

Figure 4. Comparison between 24x24 uniform grid assumption and shoe lace method.

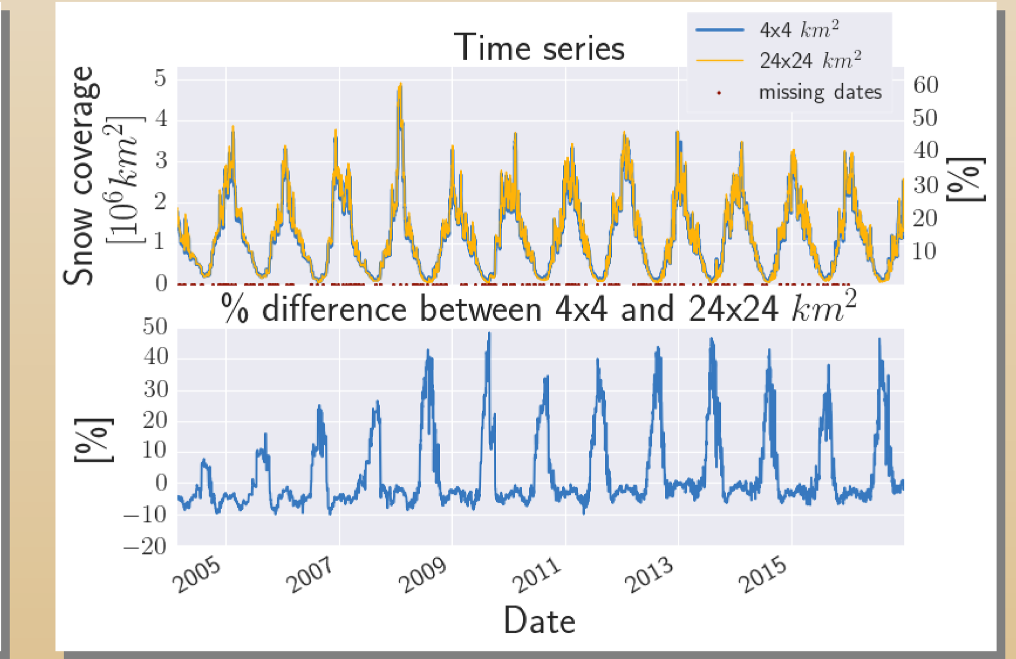

Figure 5. Comparison between 24x24 km and 4x4 km resolutions.

Table 1 shows that climate anomalies have a tendency to be negative on average. A positive skew indicates that positive outliers balance out the mean. Negative slope on trendlines (figure 6) suggests a slight overall decrease in snow coverage.

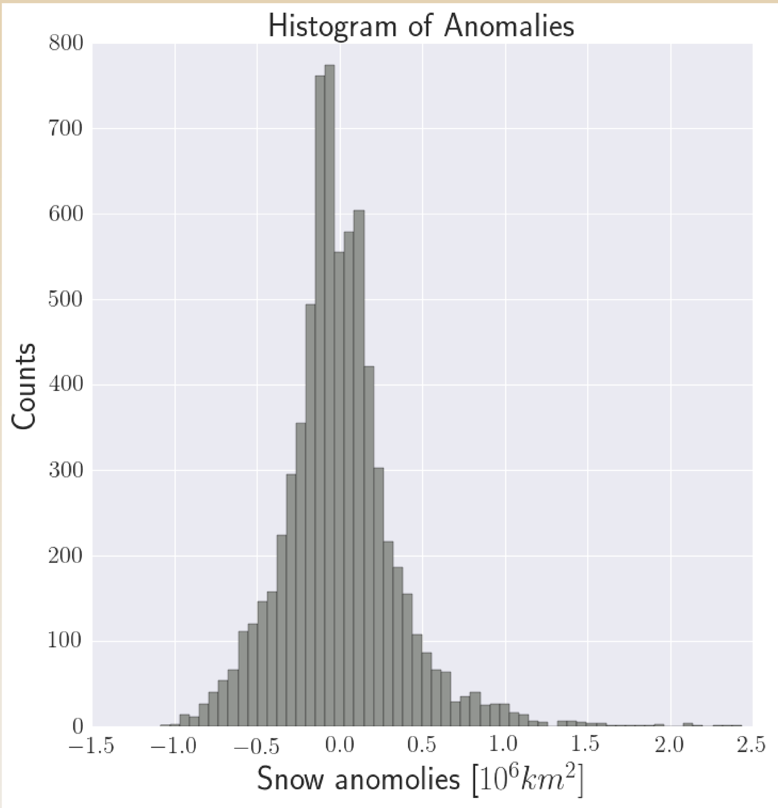

Figure 6. Histogram of anomalies.

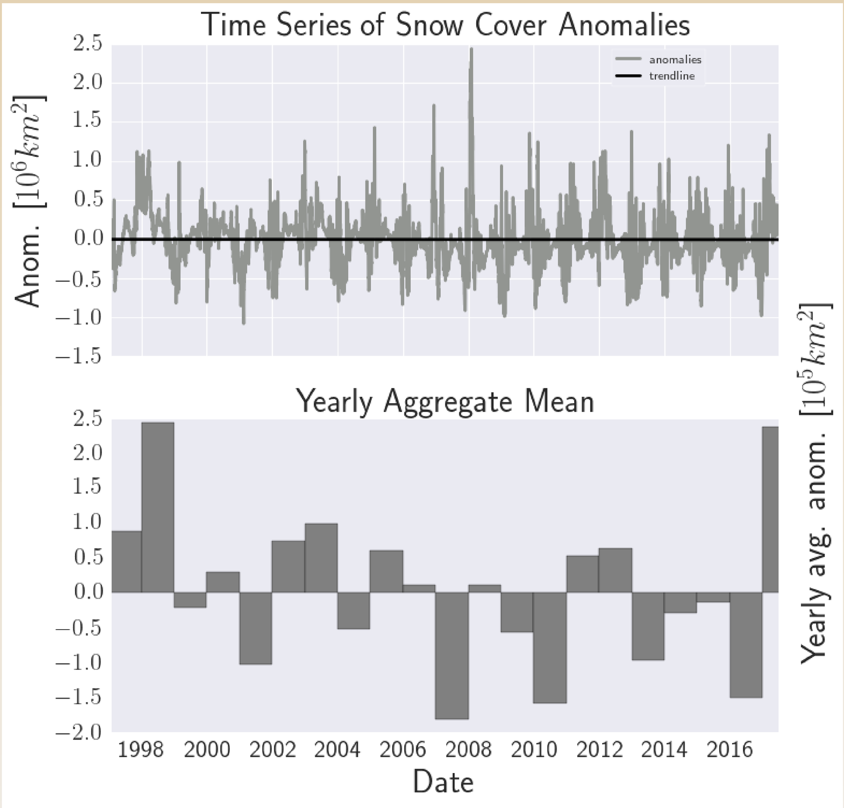

Figure 7. Top: Time series of anomalies, shown . Bottom:Yearly aggregated means

Distribution Statistics	Value
Mean (km^2)	-252.8
Standard deviation	3.443x10^5
Skew	0.984
Kurtosis	4.144
Regression Parameters	**Value**
Slope [km^2/day]	-1.951x10^-13
Intercept [km^2]	0.2289

Table 1. Distribution statistics and regression parameters

CONCLUSIONS AND FUTURE WORK

The Snow-Man project has shown potential to be a powerful tool for analyzing and displaying IMS data. Finer data sets provide greater accuracy than the coarser but require 'big data' solutions to handle such large files. Current work using database designed project is underway to handle the 1x1 km data set.

The project is limited to those who can program in Python. The best method for expanding the user base for Snow-Man is to develop it into a website. A browser based interface to a continually maintained database is undergoing development.

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