A New Approach to Snow Detection in Australia using MODIS & Landsat TM

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Abstract – Seasonal snow cover has been identified as being particularly vulnerable to increasing air temperatures in a warming climate. Marginal snowfields such as those in Australia are likely to be among the most sensitive seasonal snow areas to these changes. Data scarcity in the Australian snowfields has limited attempts to characterise snow trends and restricted snow model evaluation in hydrologic and climate impact studies. Remote sensing has been widely adopted by our Northern Hemisphere counterparts to increase snow cover data. Global snow products have limitations when used in Australia's marginal snowfields. This study presents preliminary evaluation of a regional snow cover dataset based on MODIS retrievals that has been customised for snow detection in Australia for the period 2000-2010.

Keywords: Snow, Australia, MODIS

1. INTRODUCTION

Seasonal snow cover has been identified as particularly vulnerable to increasing air temperatures in a warming climate. There have been several previous attempts in Australia to detect climate signals and other long-term trends using seasonal snow depth metrics. The results of such analyses often show negative trends with low statistical significance (Ruddell et al. 1990; Nicholls 2005) or declines based on snow data at single locations only (Hennessy et al. 2003; Green & Pickering 2009).

Australia does not have a formalised snow data network and we rely on in-situ measurements collected and maintained by hydro-schemes and ski-field operators. Consequently, this data is spatially biased towards south-east facing slopes or other areas that have greater snow persistence.

Data scarcity in snow and ice covered areas is not a new problem and remote sensing observations have been widely adopted in the past to overcome many of the issues that limit in-situ snow observation networks (Hall 1985).

MODIS retrievals are available daily with spatial resolutions achievable to 250m, 500m and 1km and consequently are an appropriate source of data for high-resolution mapping at spatial and temporal intervals suitable for capturing seasonal snow cover dynamics. Using MODIS satellite data and the Melt Area Detection Index (MADI) snow detection method (Chylek et al. 2007) optimised for Australian snow conditions, a snow cover observational dataset for the Australian alpine region for the period 2000-2010 has been created.

2. DATA

2.1 Satellite Data

MODIS Level 1B Swath Version 5 products namely the MOD02HKM Calibrated Radiances 5-Min L1B Swath 500m and the MOD03 Geolocation data have been used as a basis for dataset development. Reflectance retrievals from Bands 1-7 were obtained for the South-east Australian region for the extended winter season, May – October, for the period 2000-2010. The MODIS data was reprojected onto a 500m grid to allow direct comparison with the MODIS snow cover product.

High resolution Landsat TM 4-5 & Landsat 7 ETM+ 30m resolution data and the global product MODIS/Terra Snow Cover 5-Min L2 Swath 500m (MOD10_L2) Version 5 was obtained for the purposes of evaluation.

3. METHODS

3.1 Snow Detection Algorithm

The MADI was developed to detect melting snow areas in Greenland and is derived using a ratio of reflectance values within two spectral bands. The algorithm when using MODIS data is reproduced from (Chylek et al. 2007) below.

$$MADI = \frac{R_{0.67}}{R_{2.1}} = \frac{R_{Band\,1}}{R_{Band\,7}} \quad (1)$$

For the MODIS sensor, Band 1 refers to a bandwidth range of 620-670nm and Band 7 refers to a 2105-2155nm window. As the recorded bandwidths vary between sensors the MADI algorithm when using Landsat data requires Band 3 reflectance in lieu of Band 1.

The MADI snow detection method was tested in Greenland with promising results for detection of wet and dry snow (Chylek et al. 2007). The MADI snow observing methodolgy has also been used to monitor ice-sheet melting in western Greenland (McCabe et al. 2011). Due to the sensitivity of the MADI technique to liquid water the approach was considered a suitable choice for detecting snow in Australia where liquid water contents are relatively high (Radok 1956).

3.2 Landsat Snow Cover Estimation

Landsat satellites overpass the Australian snowfields approximately every 18 days. Evaluation of the MODIS-MADI 500m snow cover dataset using Landsat imagery was conducted for temporally consistent clear-sky days of which there were 7 in total. The MADI approach was applied to the Landsat data for each of these days.

On clear-sky days the snow cover is easily distinguishable in Landsat true colour image composites (RGB 321). An optimised density slice threshold of 0.22 for Landsat Band 3 was deemed to capture the spatial pattern of the snow covered areas observed in the true colour composite.

4. DATA EVALUATION & RESULTS

4.1 Spencers Creek Locality

For visual simplicity the evaluation process has been confined to a 328.3km^2 sub-region of the Australian snowfields centered about Spencers Creek snowcourse (-36.42, 148.35 at elevation 1747m. This locality was selected for evaluation purposes as it includes a range of terrain elevations and aspects, includes snow margins and has the benefit of the high-quality long-term snowcourse at Spencers Creek maintained by SnowyHydro.

Figure 1 compares estimated snow cover patterns within the Spencers Creek locality for a single day in 2000. The yellow outline present in panel a.) represents the Landsat true colour image Band 3 density slice extent. The white areas in the MADI images (panels b. and c.) represent snow and the pale blue represents potential snow cover areas where the MADI value was lower than the threshold but higher than typical snow-free ground. The MOD10_L2 snow cover product appears in panel d.) where white refers to snow and grey refers to cloud cover.

The snow cover areas for the Landsat density slice, Landsat MADI, MODIS-MADI approaches and the MOD10_L2 product are 193.4, 181.9. 214.3 and 50.75km^2 respectively. There is good agreement between the spatial patterns of snow cover between panels a, b and c and the resulting snow cover area estimates. There is a significant error apparent with the MOD10_L2 data where a snow area of 206.25 km^2 was misclassified as cloud highlighting the potential errors associated with the MOD10_L2 snow product in Australian conditions.

There are 7 Landsat overpasses that occur during clear-sky days. Figure 2 shows the comparison of snow cover area estimates between the MODIS-MADI dataset, the Landsat-MADI and Landsat true colour density slice methods. There is good agreement between the two snow cover area estimates using the MADI technique derived from both MODIS and Landsat data (blue circles) indicating that there is little influence of resolution on the resulting snow cover area estimates. There is reasonable agreement between the snow cover area estimates from the MODIS-MADI dataset and the Landsat true colour density slices (red triangles) however discrepancies increase when snow cover is low. Others have reported increasing snow detection errors over marginal and patchy snow cover areas (Hall & Riggs 2007).

From the 7 temporally consistent comparison days the Mean Absolute Error (MAE) between the MODIS-MADI dataset and the Landsat-MADI estimates is 20.2% and the Landsat true colour estimates is 29.8%. Due to the low number of temporally consistent Landsat overpasses and clear-sky days the MAE is significantly influenced by a single day in 2006 that occurred very early in the snow season where the snow was quite patchy. If this data point were removed then the MAE values reported above would be reduced to 16.3 and 18.4%.

The Landsat true colour density slice method chosen is less sensitive to small localised low-lying cloud patches, vegetation masking and patchy snow cover than the other methods and as such is expected to provide overestimations when the snow is marginal.

5. DISCUSSION

A 500m resolution snow cover dataset for Australia for the period 2000-2010 has been derived using MODIS retrievals and the MADI snow detection technique. The dataset is unique to Australia and can provide snow cover area estimates and spatial pattern information.

Comparison of the snow cover area estimates obtained from the MODIS-MADI dataset with both Landsat-MADI and Landsat true colour image estimates shows that the dataset is most effective at detecting snow cover and the major snow patterns when the cover is established, reasonably consistent and free from patches. The MODIS-MADI regional dataset provides an improvement in snow cover estimates from the global MOD10 snow cover product.

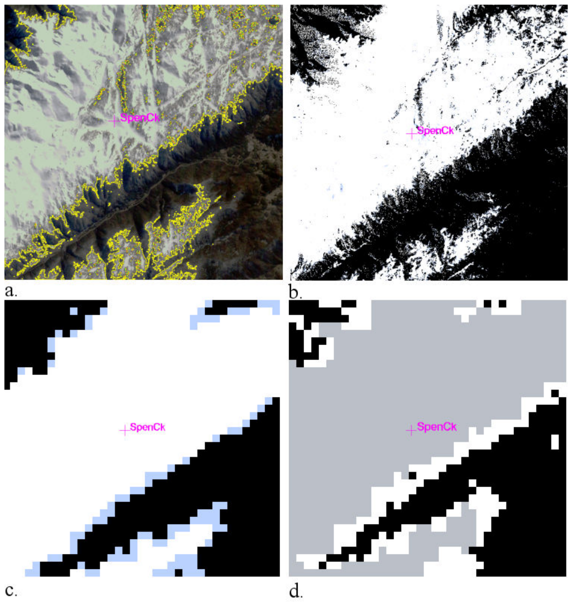

Figure 1. Spencers Creek locality (Station shown in magenta) estimated snow cover areas. Approx. 18.5km x 18.5 km viewing panes. a) Landsat TM true colour image and density slice extent, b) Landsat TM MADI, c) MODIS-MADI, d) MODIS MOD10L2

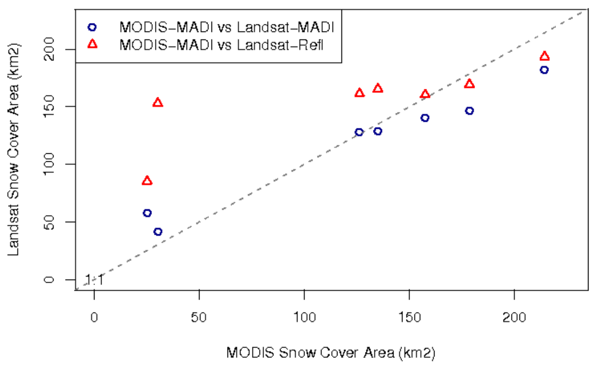

Figure 2: Spencers Creek locality snow cover comparison

6. CONCLUSIONS

This high resolution spatial and temporal dataset has the potential to provide a basis for snow cover characterisation and variability in the Australian snowfields as well as improve observational data available for snow model evaluation for a wide range of applications including snow-hydrology model evaluation and climate change studies.

7. REFERENCES

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