The IMAPP MODIS Ice Cover and Concentration Products

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1 INTRODUCTION

This document describes the implementation of the MODIS ice cover and concentration code within the International MODIS AIRS Processing Package (IMAPP). The ice cover and concentration retrievals are done only over water surfaces under clear conditions.

In Sections 2 and 3, the methods for identifying the ice cover and determining the ice concentration are described. Algorithm output and an example are shown in Section 4. A brief summary is given in Section 5.

2 METHOD FOR IDENTIFYING ICE COVER

2.1 ICE SURFACE TEMPERATURE AND NORMALIZED DIEFFERENCE SNOW INDEX

Ice surface temperature under clear sky conditions is retrieved following the method in Key et al. (1997).

$$Ts = a + bT11 + cT12 + d\,[(T11\text{-}T12)(\sec\theta\text{-}1)]$$

where Ts is the estimated surface skin temperature (K), T11 and T12 are the brightness temperatures (K) at 11 μm and 12 μm bands, and θ is the sensor scan angle. Coefficients a, b, c, and d are derived for the following temperature ranges: T11 < 240K, 240K < T11 < 260K, T11 > 260K.

The Normalized Difference Snow Index (NDSI) is defined as

$$NDSI= (R_1- R_2)/(R_1+R_2)$$

Where R_1 is often the reflectance in visible channel, R_2 is the reflectance in short-wavelength infrared channel. In this algorithm, channel 2 (0.86 μm), and channel 6 (1.6 μm) are selected to calculate NDSI. One advantage of 0.865 μm over 0.55 μm to calculate NDSI is the lower misidentification rate of water surface as ice surface.

2.2 DAYTIME

Most of the snow and ice surfaces have high reflectance at visible but low values at short-wavelength channels longer than 1.4 μm, which can be used to identify ice cover from other surfaces. Clouds have high reflectance at both visible and near infrared channels. Water is dark at all wavelengths (Riggs et al. 1999). However, there is low contrast between some ice types, such as clear lake ice, grease ice, and open water.

Over water under clear conditions in daytime (solar zenith angle lower than 85 degree), a MODIS pixel is determined as possibly ice-covered if the Normalized Difference Snow Index (NDSI) value is larger than a set threshold (0.6), the reflectance at MODIS channel 2 (0.86 μm) higher than 0.08 (Hall et al. 2001, 2006), and retrieved surface temperature lower than set thresholds (273 K over fresh water, and 271.0 K over ocean).

2.3 NIGHTTIME

Ice cover is colder than open water. Water with higher salinity has a lower melting temperature. During the nighttime (solar zenith angle higher than or equal to 85 degree), a MODIS pixel is identified as possibly ice-covered if the surface temperature is lower than 273.0 K (271.0 K) over fresh water (ocean or salty water).

Pixels determined as ice in this step are reassigned to be water if the retrieved ice concentration is less 15%. After ice-covered pixels have been identified, ice concentration is retrieved as described in section 3.

3 METHOD FOR DETERMINING ICE CONCENTRATION

The ice concentration is the fraction of the surface covered by ice in each pixel. With the assumption that a single ice type appears in a limited area and pure ice and water reflectance or temperature is homogeneous, surface reflectance/temperature (daytime/nighttime) at the pixel level changes linearly with ice concentration (Lindsay and Rothrock, 1995).

Ice concentration for a pixel (F_p) inside the search window can be calculated by

$$F_p = (B_p - B_{water}) / (B_{ice} - B_{water})$$

where B_{water} is the reflectance/temperature of pure water pixels, B_{ice} is the reflectance/temperature of pure ice pixels; B_p is the observed reflectance/temperature of the pixel, of which ice concentration will be calculated. In this algorithm, the reflectance in MODIS channel 1 (0.64 μm) is used in daytime and for certain conditions such as melting ice, while ice surface temperature is used mainly in nighttime.

Pure ice and open water reflectance and temperature can be determined from a tie point method. In a search window with a size of 50 × 50 pixels, the ice reflectance/temperature probability density function (PDF) is determined using all the possible ice covered pixels detected as in Section 2. This PDF is presented as a histogram bins, with the minimum bin value 0 (230.0 K), bin width 0.02 (0.5 K), and total bin number 9 for reflectance (temperature). Then the histogram bins are smoothed by a running boxcar filter with the size of 5 bins, resulting in a new smoothed PDF. The ice reflectance/temperature tie point is determined as the reflectance/temperature with the maximum probability density in the smoothed PDF. In this algorithm, the tie point reflectance of open water is set as a function of solar zenith angle, with 0.05 for solar zenith angle less than 65 degree and 0.07 for solar zenith angle larger or equal to 65 degree. Tie point surface temperature of open water is a function of the water salinity: 273.0 K for fresh water and 271.0 K for salty water. The tie point algorithm described above is adapted from the similar algorithm by Appel and Kenneth (2002).

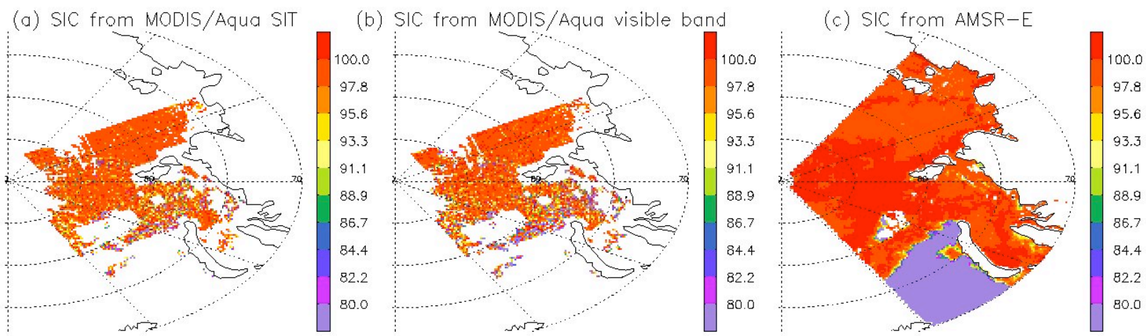
4 ALGORITHM OUTPUT

The outputs of this algorithm are ice cover and ice concentration, with spatial resolution as the lowest spatial resolution of all the input data.

Table1. Algorithm output

Definition	Description	Unit
Ice concentration	The fraction (percentage) of the sea or lake surface covered by ice	Unitless
Ice cover	A pixel is ice covered or not. Value 1: ice detected using daytime tests 2: ice detected using nighttime tests 3: unfrozen water 4: non-retrievable due to cloud cover	Unitless

Figure 1 shows an example of sea ice concentration (SIC) retrievals from MODIS on March 31st 2006 based on MODIS retrieved ice surface skin temperature, and MODIS visible band reflectance at 0.64 μm. Both retrievals show similar results, with high sea ice concentration near the North Pole and lower values near the ice edges. The comparison with SIC from Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) product show similar pattern and values.



5 CONCLUSIONS

This document provides a high level description of the technical approach for the ice cover and concentration determination over water surfaces under clear conditions using MODIS data in IMAPP. Group threshold methods are used to identify ice cover; a tie-point algorithm is used to determine the representative reflectance/temperature of 100% ice covered surface for the estimation of ice concentration. Limited validations show good agreement with products from passive microwave observations. This algorithm will continue to be refined.

6 REFERENCES

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