Report on Work for SAF Project at DMI, 8 April – 4 May 2001

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Introduction

A collaborative project was undertaken between the U.S. National Ice Center (NIC) and the Danish Meteorological Institute (DMI) in Copenhagen, Denmark from 8 April through 4 May 2001. The project evaluated five SSM/I passive microwave ice concentration algorithms. The NASA Team and Bootstrap algorithm are existing algorithms that have been extensively evaluated and have been employed for long-term climate change detection of the sea ice. The Cal/Val algorithm is the operational standard at the NIC and is used to supplement higher resolution imagery from AVHRR, OLS, and Radarsat to produce weekly ice analyses over the entire Arctic and Antarctic regions. The SAF algorithm is a hybrid NASA Team/Bootstrap algorithm designed for better performance at the ice edge and over open water. The NASA Team 2 algorithm is a new algorithm that utilizes high frequency SSM/I 85 GHz channels. These channels have to date been underused because of higher atmospheric contamination, but under clear skies they are of value for resolving surface ambiguities in the passive microwave signal. This new algorithm employs a radiative transfer model to correct for the atmospheric effect. The NIC Hybrid is another new algorithm, a combination of the Cal/Val, the NASA Team, and a modified NASA Team with specialized tiepoints sensitive to thin ice (which the standard NASA Team tends to significantly underestimate).

These five algorithms were tested during the month of March 2001 in the Arctic. This midwinter time period is where SSM/I is generally most beneficial because of consistent surface features. In this study, the E. Greenland Sea region was chosen as a case study for several reasons: (1) It is a region of operational interest, particularly to DMI and the SAF, (2) DMI has a large archive of AVHRR imagery from the region, (3) the region is an area where large differences in the performance of the algorithms might be expected since there are a mixture of ice types (multiyear, first-year, thin ice, pancakes, small floes, large floes, etc.) in close proximity to each other, (4) the ice surface can change quickly providing a good test of the flexibility of the algorithms, and (5) such a quick change in the ice, an Odden event, occurred during the middle of the month during a field expedition where coincident Radarsat imagery was acquired, as well as clear-sky AVHRR images.

Results

The results of the study highlight the strengths and weaknesses of the various algorithms. First, the Cal/Val and NIC Hybrid employ only the 37 GHz channel at the ice edge, all the other algorithms additionally use at least one 19 GHz channel. Because the 37 GHz channels have a much smaller footprint (FOV) size (36 x 30 km) compared to the 19 GHz channels (70 x 40 km), the Cal/Val and NIC Hybrid can have a more precise ice edge, by as much as two pixels. Two pixels, or 50 km, can be of significant importance for operational activities.

A drawback of the Cal/Val is that, while being sensitive to thin ice (and hence of benefit operationally), it tends to quickly saturate to 100%, leading to the loss of variability within the pack ice. Such small variability at high concentrations within the ice pack is not crucial for operational analyses (which are most concerned with regions in the vicinity of the ice edge). The Cal/Val RMS error is generally lowest. This may be due in part to the fact that it is a region of close to 100% ice and the tendency to saturate is not adverse here.

The NASA Team underestimates ice at high concentrations and overestimate at low concentrations, yielding a net underestimate of ice. The overestimation at low concentration is in part due to the lower ice edge resolution from the use of the 19 GHz channel. The underestimation at higher concentration has been noted in other studies and is likely due to tiepoint errors, particularly in dealing with thin ice. Such errors in NASA Team can be important operationally.

The Bootstrap algorithm has a low bias overall and RMS error and performs comparable to Cal/Val in general, with a higher bias than Cal/Val, but a lower RMS error. The low bias in the Bootstrap however results, like the NASA Team, from an overestimation in low concentration regions, and an underestimation in high concentration regions.

The SAF algorithm yields results almost indistinguishable from the NASA Team. The SAF is designed primarily to overcome NASA Team weaknesses over open water and very small ice concentrations and only differs from NASA Team for concentrations less than 35%. In this study, the effects of the ice surface was emphasized, so there were not many water values. In addition, weather filters that were employed likely filtered out any erroneous ice retrievals from NASA Team. Also, there were very few low ice concentration pixels as the transition from ice to water happens over a very short distance in the East Greenland Sea.

The NIC Hybrid uses thin ice tiepoints in regions where thin ice is likely to exist and standard tiepoints otherwise, within the NASA Team framework. It also employs the Cal/Val field as an ice/no-ice binary mask to obtain the more precise ice edge resulting from the use of only the 37 GHz channels. This methodology appears to work quite well. The NIC Hybrid has the lowest RMS errors in regions of at least 15% ice cover. The bias is higher than Cal/Val, but substantially lower than NASA Team. Some errors may be due to the use of the thin ice tiepoints. In the East Greenland Sea, the ice in March is largely a mixture of multiyear, first-year, and thin ice. Since the algorithm assumes at most two ice types within a given pixel, this could lead to errors, particularly where the thin ice types are employed and only first-year and thin ice is assumed to exist. Here, however, the NIC Hybrid does not seem to be significantly affected by this assumption, although there are areas where discontinuities in the ice concentration field occur, due to the abrupt switching from the standard tiepoints to the thin ice tiepoints.

The NASA Team 2 algorithm also shows a lower bias than NASA Team and Bootstrap in areas with ice concentration above 15%. It also has a fairly low RMS error. Some errors in the NASA Team 2, particularly in lower concentration regions (nearer to open water), are possibly due to the use of the 85 GHz channels, which are

more susceptible to atmospheric contamination in regions where there is substantial open water area. While the NASA Team 2 does correct for the atmosphere, it does so by fitting the retrieved SSM/I brightness temperatures to corrected brightness temperatures based on one of 11 standard atmospheric models. The simplifications inherent with this approach can lead to errors in the correction. This is noticeable as noise in the NASA Team 2 concentrations resulting from switching between the standard atmospheric models from one pixel to the next. This can lead to a 'speckled' appearance of ice concentration images. Nonetheless, the NASA Team 2 algorithm is a new, promising algorithm, that may potentially be useful for the SAF project.

Summary

This study confirms that the use of the NASA Team and Bootstrap algorithms for the SAF Project is reasonable. The use of the other algorithms, particularly the NASA Team 2 and the NIC Hybrid, may also add some benefit. It should be noted that the above results and conclusions should not be overly generalized. There was a fairly small sample of clear sky AVHRR images with which to compare, so the statistics may not be applicable to the entire region (although clear sky transects were chosen to be as representative as possible). Also, results from the mid-winter time period may well not be indicative of the performance of the algorithms at other times of the year, particularly during the melt season. Finally, the E. Greenland Sea region is not necessarily indicative of other regions, particularly regions of operational interest where thin ice is predominant. While not evaluated in depth, this study indicates that regions in the Bering Sea and the Sea of Okhotsk, where there is primarily thin ice, are dramatically underestimated in the NASA Team concentrations; the other algorithms, particularly the Cal/Val and the NIC Hybrid, appear to perform much better in these regions.

The results from this collaboration between the NIC and DMI for the SAF Project will be presented at the AMS 6th Conference on Polar Oceanography and Meteorology in San Diego, California, on 14-18 May 2001. A journal paper is in preparation that will use these results as a starting point. For the paper, additional regions in the Barents Sea and Baffin Bay and comparisons will be extended into the summer melt season. This will yield a more complete picture of the performance of the six algorithms and assessment of which algorithms may be most appropriate for a given region and season.