12.9 EVALUATION OF PASSIVE MICROWAVE ICE CONCENTRATIONS USING DIGITIZED OPERATIONAL ICE CHARTS

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1. INTRODUCTION

Passive microwave sea-ice concentrations estimates have been compared with other types of airborne and satellite sea-ice observing systems (Comiso et al. 1997; Emery et al., 1994; Steffen et al, 1991). This paper compares sea ice concentration estimates using the NASA Team algorithm (NT) with independent operational digitized sea-ice charts which contain detailed information on sea ice concentration by ice type. The purpose of this study is to compare sea ice covered area estimates over a much longer period of time than previous studies using the weekly Canadian regional and US hemispheric ice charts over a long period of overlapping data (1979-96). The Canadian ice charts cover four regions of Canada: East Arctic, West Arctic, East Coast and Hudson Bay. A total of over 1380 regional Canadian weekly ice charts for four Canadian regions and 839 hemispheric United States weekly sea ice charts are compared with passive microwave sea ice concentration estimates using the NASA Team algorithm.

The National Ice Center (NIC) northern hemisphere ice chart data were obtained from the National Snow and Ice Data Center (Arctic Climatology Project, Environmental Working Group Joint Ice Atlas, 2000). A description and initial evaluation of the data can be found in Debrick et al. (2001). Both ice chart series are in Geographic Information System (GIS) format. The Canadian Ice Service (CIS) weekly digital ice charts represents sea-ice conditions for different regions of Canada for the day specified on each weekly chart. Experienced ice analysts who synthesize all available ice information produce the charts. Each chart represents the best estimate of sea ice conditions on that day.

The NASA Team estimates of sea-ice concentration were obtained from National Snow and Ice Data Center (NSIDC). The NASA Team algorithm, developed at the Goddard Space Flight Center Administration), was selected for comparison because it has been used to investigate sea ice trends over the Northern Hemisphere including Canadian marine areas (Parkinson et al., 1999) and has been carefully quality controlled for that purpose. Cavalieri et al., 1999). The average pixel resolution of the data is about 25 km by 25 km.

2. METHODOLOGY

The daily passive microwave sea ice concentration data was extracted for the valid day of each weekly ice chart and then imported into ArcView along with the corresponding ice chart. Sea-ice area for each ice chart was calculated by adding up the sea-ice area of each polygon in the ice chart. Passive microwave sea-ice area was determined by adding up the ice area of each pixel. Only polygons and/or pixels with a 20% or greater ice concentration were used to calculate total sea ice area. When small amounts of sea-ice are present, differences in NT and CIS charts can produce very large percent differences. For this reason, only ice charts with more than 25,000 km^2 of sea-ice cover were compared.

The main error in estimating sea ice extent from the ice charts is the positional error in the location of the ice edge. A positional error of +/- 20 km in the ice edge of length 600 km and ice extent of 6×10^{5} km^{2}, typical for the east coast charts, results in an error of 4 % in the sea ice extent. If we assume that the error in estimating sea ice concentration on the charts is one tenth of a sea ice concentration or 10% and that the errors are additive with the ice edge error, then the error in estimating sea ice area is about 11%.

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3. RESULTS

3.1 Hudson Bay Charts

The top panel of Fig. 1 shows sea ice area for the NT data, the ice charts and the area difference (as green dots). A consistent maximum in underestimation of the NT total ice area compared to the CIS ice charts occurs during sea ice growth in the late fall and sea ice melt in late spring each year.

The first three rows of Table 1 summarize the overall differences found for sea-ice area for Hudson Bay over the 1979 to 1996 period. The winter season covers the months of January, February, and March with the other seasons following in sequence. Mean differences as a percent of the sea-ice area from the ice charts are shown. Although winter comparisons are good, mean differences of –43.5% and –33.5% for summer and fall indicate large underestimation (negative means underestimation) by the NT data. Standard deviations (SD) are large indicating considerable scatter and lack of a consistent pattern in the differences. Underestimation at these times can be as much as 50% of the sea-ice area estimated from the ice chart.

Examination of individual weeks (not shown), indicate that the NASA Team algorithm misses thin and young ice types during the freeze-up (growth) periods. This results in underestimation each year. During melt, the passive microwave sensors cannot distinguish between melt ponds and open ocean. This results in the NT data again underestimating sea-ice concentrations and total ice area.

3.2 East Coast Charts

For the East Coast charts, the second panel of Fig. 1 shows the passive microwave ice-covered area has the largest underestimation near maximum sea ice extent in February and March of each year. At this time the underestimates are again as large as 50% of the sea-ice area based on the ice charts. These underestimations occur near the end of the ice growth period when there is the largest amount of new and young ice types present. Table 1 shows underestimation of -29.2%, -21.9%, and -15.6% in winter, spring and fall respectively.

3.3 East and West Arctic Charts

For the Arctic charts, Table 1 indicates consolidation periods in winter perform very well but the NT underestimates sea ice area during summer melt and fall freeze-up by –32.6% and –21.5 % respectively. SD is low indicating consistency of these underestimates. The best results are for the West Arctic charts where underestimation of sea ice area by the PM data is –20.4% with a SD of 7.1% in summer and –7.6% with a SD of 7.0% in fall. The relatively good performance for this region may reflect the fact that a large portion of the West Arctic region is not in the marginal sea ice zone compared to the other regions.

4.4 Hemispheric Charts

Figure 2 shows the sea ice area for the NIC ice charts, the NT data and the difference for the period 1979 to 1994. Largest underestimation occurs each summer (July, August and September). Table 2 shows mean area differences in km^2 and as a percent of the sea-ice area by season for the entire period. The overall average is good with a slight under estimation of 7.8% and standard deviation of 7.8%. The breakdown by season shows that summer has the largest underestimation of 18.6% underestimation. Within this season the month of July and August underestimating the most with 22.5% and 19.6% (not shown). This is related to the time of maximum ponding on the ice that occurs in July/August rather than at minimum ice extent in September when there is more opportunity for melt pond refreezing. The comparisons at other seasons are good.

These results are better than the results using the Canadian ice charts although it should be kept in mind that passive microwave data is used to some degree in producing the northern hemispheric charts so the comparison is not completely independent. Canadian ice chart analysts do not use passive microwave in preparing the Canadian ice charts. Also, the NT data uses global calibration tie points to tune the algorithm to perform best over the hemisphere. Another consideration is that the NIC charts represent ice conditions over a 72 hours period around the time of the chart while the NT data was for a specific day. This would tend to increase random differences.

4. CONCLUSIONS

Basic limitations of the passive microwave sensor and the NASA Team algorithm during periods of sea ice growth and sea ice melt are known. This study shows how this translates into differences in estimates of ice-covered area and how systematically this error occurs every spring melt and fall freeze-up. During these times each year, low sea ice concentration and errors in location of the ice edge by the NASA Team algorithm can produce large differences in ice area estimates for Hudson Bay and the East Coast of 50% or more.

Comparisons with the hemispheric charts are better because: 1) regional charts cover the MIZ where a large percentage of the time melt or growth conditions exist, 2) in preparing the hemispheric charts, use is made of the passive microwave data, 3) the tie points used to calibrate the NT algorithm are tuned to perform best over the hemisphere not for individual regions. The NT algorithm performs the worst for Eastern Canada where a large percent of the ice cover is composed of new and young ice

These results suggest caution should be used in applying the NT data to sea ice studies and sea-ice trend analysis in the marginal sea-ice zone where melt and freeze-up conditions are a major component of the sea ice regime.

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Region	Ice Season	Ice Area Difference	No. of charts
Hudson Bay	Summer – ice growth	-43.5% (27.9)	149
	Winter – ice consolidation	-1.5% (3.9)	38
	Fall – ice melt	-33.5% (28.1)	119
East Coast	Winter – ice growth	-29.2% (9.7)	169
	Spring – ice melt	-21.9% (27.6)	168
	Fall – ice growth	-15.6% (32.4)	33
East Arctic	Summer – ice melt	-32.6% (10.2)	138
	Fall – ice growth	-21.5% (11.6)	178
	Winter – ice consolidation	-0.1% (4.6)	38
West Arctic	Summer – ice melt	-20.4% (7.1)	184
	Fall – ice growth	-7.6% (7.0)	139
	Winter – ice consolidation	-0.2% (2.9)	38

Table 1. Sea-ice area differences as a percent of the ice chart (standard deviation in brackets).

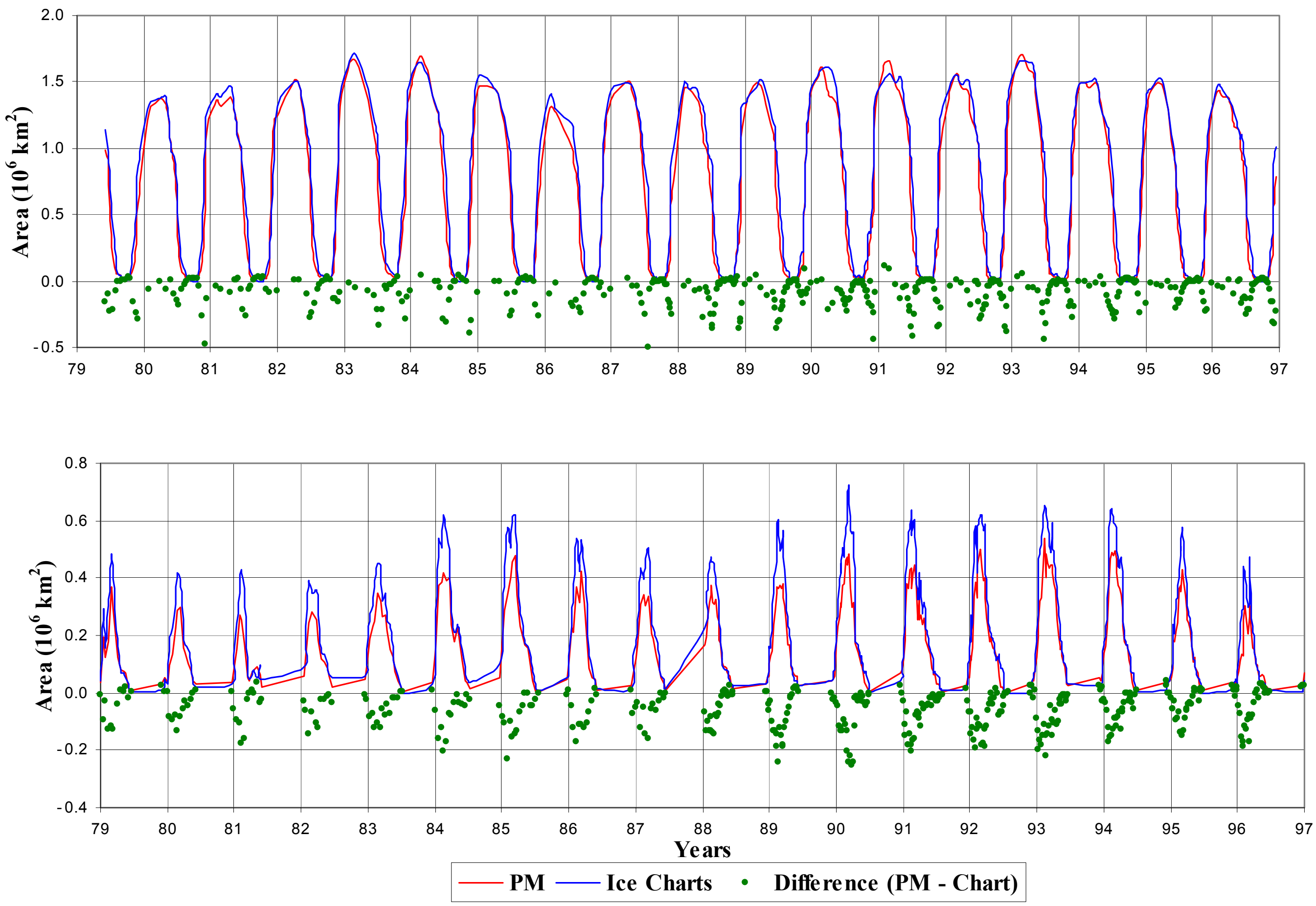

Fig. 1. Passive microwave and Ice Chart estimates of total sea-ice area for: Hudson Bay (top) and East Coast (bottom).

Season	Charts	Statistic	Area Differences	
			Area (km^2)	Fraction
Annual	839	Mean	-642,948	-7.8%
		SD	494,010	7.8%
Winter	206	Mean	-474,703	-3.5%
		SD	321,917	2.4%
Spring	206	Mean	-494,969	-4.5%
		SD	380,719	4.0%
Summer	211	Mean	-1,183,507	-18.6%
		SD	496,327	7.1%
Fall	215	Mean	-416,123	-4.6%
		SD	294,772	3.5%

Table 2. Summary of Northern Hemisphere ice area differences in km^2 and as a percent of ice chart area.

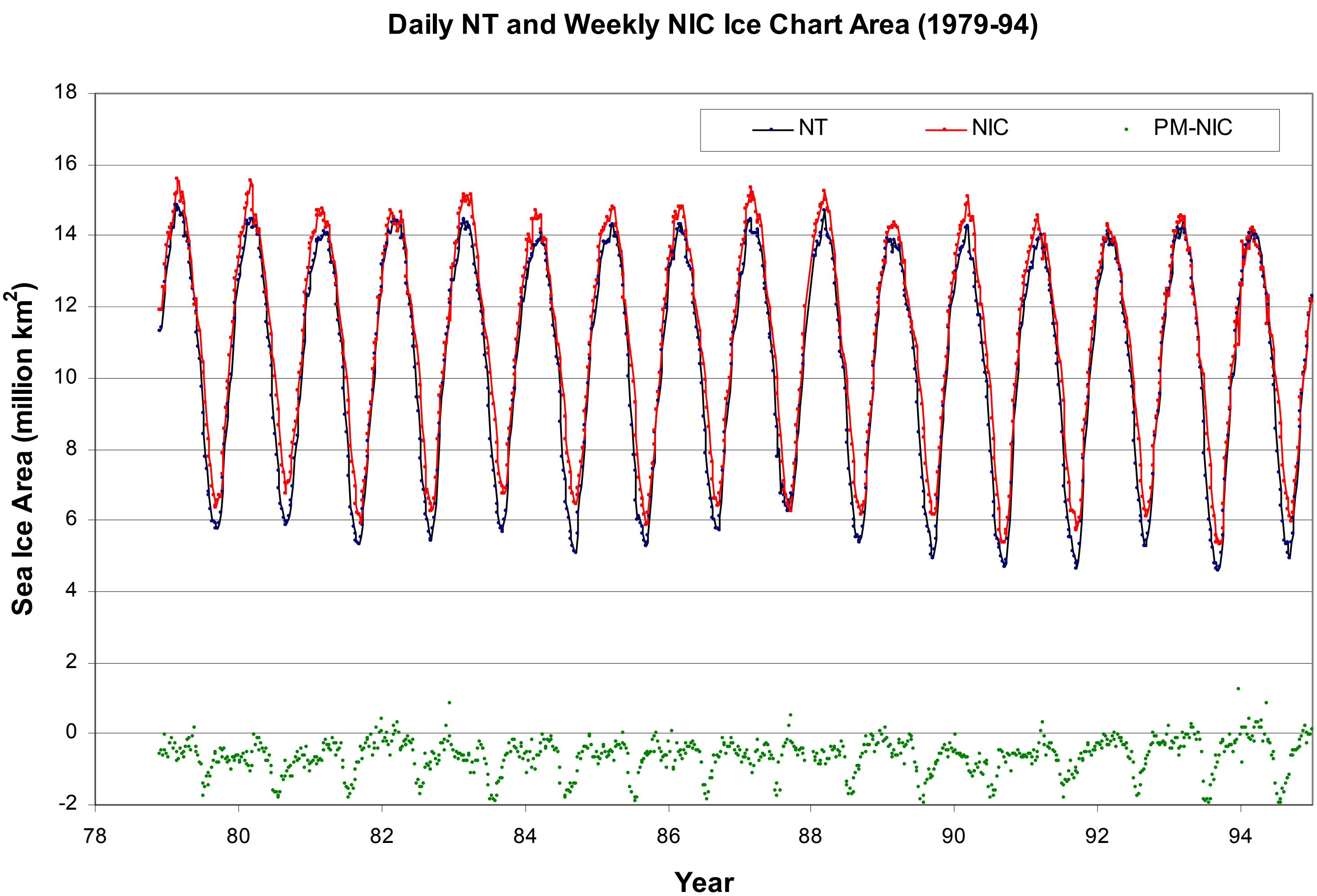

Figure 2. Northern Hemisphere sea ice area from the weekly National Ice Center charts (NIC), the NASA team algorithm (NT) and the difference.