COMBINING AMSR-E AND 1UIKSCAT TO RETRIEVE SEA ICE TYPES AND CONCENTRATIONS IN THE ARCTIC

Mohammed Shokr and Thomas A. Agnew
Science and Technology Branch, Environment Canada
4905 Dufferin St., Toronto, Ont. Canada, M3H 5T4

ABSTRACT

A new sea ice algorithm, Environment Canada's Ice Concentration Extractor (ECICE), combines several different satellite sensors to extract ice types and concentrations. Results are presented for the Arctic region during the ice growth season of 2007/08. Three ice types are specified: young, first year and multi year. The algorithm was applied using AMSR-E (36.5 GHz channel) combined with backscatter from QuikSCAT scatterometer. Total ice concentration is in agreement with estimates from other algorithms under winter ice conditions. The two-sensor combination can also identify multi year ice better than single sensor algorithms. Case studies are presented as well as the spatial distribution of ice types over the Arctic Ocean. Young ice exists for short periods (average of few days) except for polynyas where it persists for more than 25 days. First year ice grows rapidly to cover most of the Arctic region with fastest rate of growth observed during the first half of November. Multi year ice continued to be pushed against the Queen Elizabeth Islands and be drifted southward during fall/winter seasons along the coast of Greenland and Ellesmere Island. Variation of multi-year ice concentration distributions with time (on weekly basis) is also shown. Most of the ice in the channels within the Canadian Arctic Archipelago is locally-grown first year, but multi-year ice is imported from the central Arctic Ocean. Anomalous conditions of melt-refreeze, which are common during seasonal transition periods, cause errors in estimating first year ice and multi year ice concentrations.

II. DATA SETS

In addition to QuikSCAT and AMSR-E data, two other data sources were used to support interpretation of the ice concentration results: the operational ice charts from the Canadian Ice Service (CIS) and the U.S. National Ice Center (NIC); and meteorological parameters output from the operation weather model, the Canadian Global Environmental Multiscale (GEM) model.

III. ALGORITHM DESCRIPTION

ECICE can be used to resolve any number of ice types using any combination of remote sensing observations provided that the number of observations is at least equal to the number of ice types [1]. The approach uses a radiometric mixing model, similar to that used in previous studies (e.g. in NT, NT2 and ASI) but improves on this by solving the radiometric equations using a constrained optimization technique (with inequality constraints) and by considering the tie points for each ice type as a distribution of possible values rather than a single value. The added information from the multi-sensor combination input to ECICE makes it possible to extend the number and type of sea ice surfaces that can be reliably estimated. A short description of the algorithm is provided here but more details can be found in [2].

IV. PROBABILITY DISTRIBUTIONS OF RADIOMETRIC PARAMETERS

The CIS ice charts and sea ice history leading up to the particular day were used to identify area of uniform distribution of each surface in the Arctic Basin. Each input parameter was then sampled from each area. Anomalies such as surface melt due to warm air advection were avoided. Young ice samples were obtained from areas along the pack ice edge during its expansion in the fall. Hence, YI data in this study includes all possible forms of newly-formed ice; namely grease ice, nilas, slush, and pancake ice, along with the thicker Gray and Gray White ice.

V. RESULTS AND DISCUSSIONS

A. Comparison with other algorithms

Total ice concentration from ECICE, using only AMSR-E data and then using both AMSR-E and QuickSCAT, was compared to results from the NT2 and ASI algorithms. For winter ice, all algorithms produce essentially the expected near 100% total ice concentration with insignificant difference between them. In contrast, more significant differences are noticed during the early freezing season. It was reported [3] that NT2 underestimates total ice concentration by 20% during summer melt.

B. Complementing AMSR-E with QuikSCAT Data

The first example is the identification of MYI in Baffin Bay. Almost all sea ice cover disappears from the bay each summer and then reforms during winter freeze-up so that the sea ice cover comprises mostly FYI. However, some MYI from the Arctic Ocean is exported into northern Baffin Bay through Nares Strait between northern Greenland and Ellesmere Island. This often results in a stream of relatively high concentration MYI extending down the western side of Baffin Bay. Figure 1 shows MYI concentration from ECICE in Baffin Bay for January 14, 2009 using AMSR-E only and AMSR-E combined with scatterometer observations. Only when AMSR-E and scatterometer observations are combined is the MYI stream identified. The existence of the MYI is verified in the CIS ice weekly chart for January 14, 2007. The DD and FF areas (in brown) show regions with +9 tenths ice cover of which 5 to 7 tenths MYI is imbedded. The successful identification of MYI when scatterometer data are included is due to the wide separation of backscatter distribution of MYI from the distributions of the other surfaces. The failure of AMSR-E data in identifying MYI can also be realized by comparing in the top images (a) and (c) in the figure. The confidence level at which the MYI estimates were produced is also shown. Calculation of this parameter is explained in [2]. The confidence level at locations where AMSR-E fails to identify MYI is relatively low (in other words the algorithm assigns FYI (not shown) to the MYI stream area but with low confidence level). The confidence level is also low from using AMSR-E and QuikSCAT combination at the same locations but in this case it is due to the coexistence of the two ice types (FYI and MYI) with approximately same concentration.

C. ECICE During Anomalous Melt-refreeze Conditions

Two situations of anomalous radiometric signature of sea ice due to melt/refreezing conditions are observed. The first occurs during the early ice formation season. It causes misclassification of MYI as FYI. The correct classification, however, is restored shortly after refreezing prevails. The second occurs during spring and causes FYI to be classified as MYI. This was always observed in areas south of 75°N latitude. The duration of this misclassification lasts longer (up to two weeks) even after the disappearance of the warm atmospheric temperature stimulus. The difference between these two anomalies is perhaps related to difference between the responses of the saline snow (on top of FYI) and the saline-free snow (on top of MYI) to warm atmospheric temperature.

D. Sea Ice Growth over the Arctic Basin

The ability of ECICE to combine AMSR-E and QuickScat data to identify YI, FYI, MYI and open water is used to examine the ice growth (age and extent) over the Arctic basin during ice expansion from September 1st 2007 through the winter to May 31st 2008. During late summer, maximum melt ponding on the ice surface occurs in early August [4]. By mid-to-late September minimum ice extent occurs. Refreeze begins first within various parts of the pack ice with refreezing of the melt ponds while other parts of the pack are still changing back and forth between melt and refreeze determined to a large extent by synoptic weather conditions. By October, all the melt ponds have refrozen, all remaining FYI is reclassified as second year and the ice cover expansion along the ice edge begins. At this point, how the sea ice cover expands and develops over the Arctic basin can be seen from the distribution of YI, FYI and MYI concentrations estimated by the ECICE algorithm.

REFERENCES:

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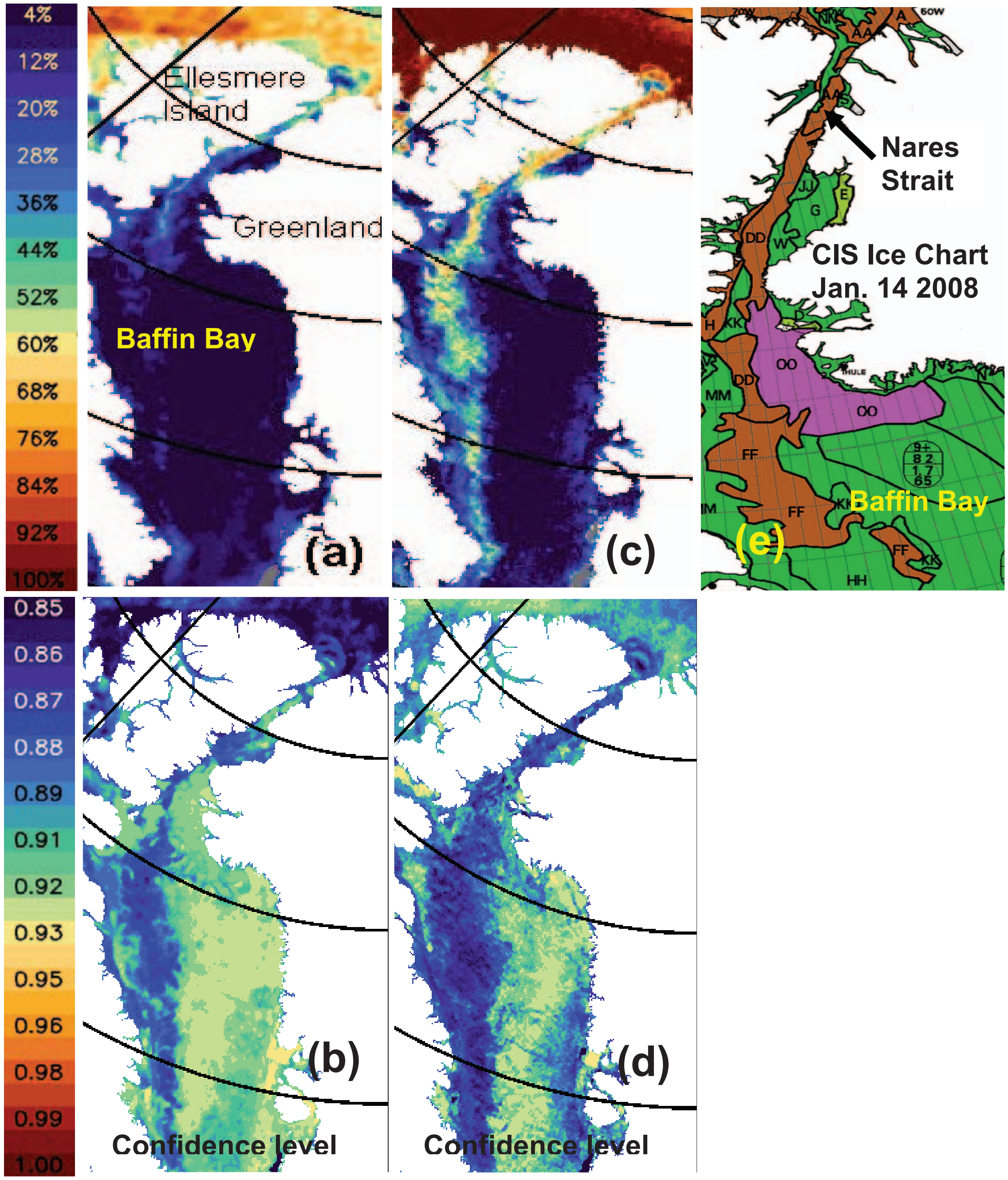

Fig. 1 Estimate of multi-year ice concentration and its confidence level from using AMSR-E observations only (a) and (b); respectively, and using AMSR-E combined with scatterometer (c) and (d). The weekly CIS ice chart is also shown (c).