INTRODUCTION

Global climate studies have shown that sea ice is a critical component in the global climate system through its effect on the ocean and atmosphere, and on the earth's radiation balance. Polar energy studies have further shown that the distribution of thin ice and open water largely controls the distribution of surface heat exchange between the ocean and atmosphere within the winter Arctic ice pack. The thickness of the ice, the depth of snow on the ice, and the temperature profile of the snow/ice composite are all important parameters in calculating surface heat fluxes. In recent years, researchers have used various combinations of DMSP SSMI channels to independently estimate the thin ice type (which is related to ice thickness), the thin ice temperature, and the depth of snow on the ice. In each case validation efforts provided encouraging results, but taken individually each algorithm gives only one piece of the information necessary to compute the energy fluxes through the ice and snow. In this paper we present a comparison of the results from each of these algorithms to provide a more comprehensive picture of the seasonal ice zone using passive microwave observations.

THE ALGORITHMS

The three algorithms used in this study were developed to operate on the brightness temperatures available from the DMSP SSMI sensor. In addition, we make use of surface temperature estimates generated by Massom and Comiso from AVHRR radiances [1].

The thin ice algorithm [2] uses the 19.4 GHz vertical and horizontal, and the 37.0 GHz vertical channels of the SSMI to obtain an improved measure of ice concentration and to determine the distribution of new, young, and first-year ice types in seasonal sea ice zones. This algorithm was validated by high resolution AVHRR imagery and aircraft observations. The ice temperature algorithm [3], makes use of the radiances at 19.4 GHz vertical polarization as well as the ice type and corrected concentration output from the thin ice algorithm to determine the physical temperature of the ice. The temperature algorithm was validated with surface temperature estimates from AVHRR and air temperature observations from Point Barrow and Gambell Stations. The snow thickness algorithm uses the ice concentration information and the 37 and 19.4 GHz horizontal polarization radiance data to estimate snow depth [4]. The validation for this algorithm was provided by in situ observations over similar ice in the sea ice around Antarctica.

COMPARISON OF ALGORITHM PRODUCTS

The initial comparison of products was made for April 4, 1988 in the Bering Sea. Ice type retrievals for the area of interest are shown in Figure 1.

To focus our comparisons in this initial study, we limited ourselves to a small area around St. Lawrence Island. Ice type, ice temperature, and snow depth are shown in Figures 2, 3, and 4 respectively.
Figure 1. Ice type, in the Bering Sea, on a linear gray scale. The brighter areas contain thicker first year ice while darker areas contain thinner ice. Black areas are open water, and solid gray areas indicate either land or missing data. The gray area at the bottom left in the image is western Alaska. The white area in the bottom right is the thick first year ice in the Chukchi Sea. A large refrozen polynya is visible to the west and south of St. Lawrence Island.

Figure 2. Ice type for the study area in the immediate vicinity of St. Lawrence Island, shown in black. The gray scale is the same as the scale in Figure 1.

Figure 3. Ice temperature derived from the SSNI radiances for the study region. The scale ranges from 240K (black) to 275K (white), where the darkest gray in the image corresponds to 260K. Again, St. Lawrence Island is masked in black.

Figure 4. Snow depth derived from the SSNI radiances. The scale ranges from 0 (black) to 7 cm (white). To differentiate it from regions with no snow, St. Lawrence Island is shown in solid gray, at the same position as in the previous two figures.

DISCUSSION

The data presented in image format in the figures above are represented in scatter plot form below. Figure 5 reveals that there is relationship between the snow depth and the ice type, as expected. The thicker first year ice, which has been transported through the Bering Strait from the Chukchi Sea, has significantly thicker snow cover than the thinner first year ice types grown in the Bering Sea.
Figure 5. Snow Depth versus Ice type for the focus region around St. Lawrence Island.

The relationship between snow thickness and SSMI retrieved temperature is shown in Figure 6. For thin to thick first-year ice types, corresponding to ice types between 60 and 100, there is an inverse relationship between snow depth and temperature. Because the greater snow depth occurs on the thicker ice, we expect that the retrieved temperature should be colder where the thicker snow exists.

Figure 6. SSMI derived temperature vs. SSMI derived snow depth.

A similar plot for the AVHRR derived skin temperature is shown in Figure 7. We note that although the cluster shape is similar to Figure 6, the dynamic range of temperatures is larger for the SSMI than for the AVHRR. This is consistent with our expectation that the AVHRR retrieved temperature should be very close to the air temperature for snow covered ice.

Again, in these scatter plots we consider only the thin to thick first year ice, corresponding to ice types between 60 and 100. We do this because the AVHRR derived temperatures appear to be quite a bit colder than expected over the new ice reasons. This may be due to vapor plumes rising from these areas that have gone undetected. Accordingly, we have deferred discussion of the thinner ice regions until we have a better understanding of the potential errors in both the microwave and infrared derived temperatures.

Figure 7. AVHRR derived temperature vs. SSMI derived snow depth.

CONCLUSION

The authors have initiated an effort to examine the relationship between the parameters derived from the SSMI radiances. At the present time, the algorithms examined appear to generate products that are consistent with physical expectations. In the absence of additional ground truth observations, this is an important error check.


