Assessment of EOS Aqua AMSR-E Arctic Sea Ice Concentrations Using Landsat-7 and Airborne Microwave Imagery

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***Abstract*—An assessment of Advanced Microwave Scanning Radiometer Earth Observing System (AMSR-E) sea ice concentrations under winter conditions using ice concentrations derived from Landsat-7 Enhanced Thematic Mapper Plus (ETM+) imagery obtained during the March 2003 Arctic sea ice validation field campaign is presented. The National Oceanic and Atmospheric Administration Environmental Technology Laboratory's Airborne Polarimetric Scanning Radiometer Measurements, which were made from the National Aeronautics and Space Administration P 3B aircraft during the campaign, were used primarily as a diagnostic tool to understand the comparative results and to suggest improvements to the AMSR-E ice concentration algorithm. Based on the AMSR-E/ETM+ comparisons, a good overall agreement with little bias (∼1%) for areas of first year and young sea ice was found. Areas of new ice production result in a negative bias of about 5% in the AMSR-E ice concentration retrievals, with a root mean square error of 8%. Some areas of deep snow also resulted in an underestimate of the ice concentration (∼10%). For all ice types combined and for the full range of ice concentrations, the bias ranged from 0% to 3%, and the rms errors ranged from 1% to 7%, depending on the region. The new-ice and deep-snow biases are expected to be reduced through an adjustment of the new-ice and ice-type C algorithm tie points.**

***Index Terms*—Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), Arctic, sea ice concentration, validation.**

I. Introduction

OUR knowledge of the global sea ice cover, including its seasonal and regional variability, its long-term trends on decadal time scales, and its interaction with other components of the climate system, stems largely from sea ice data records derived from satellite passive microwave observations. The first satellite radiometer to provide global sea ice observations was the single-channel Nimbus-5 Electrically Scanning Microwave Radiometer, which was launched in 1972. Since then, there has been an almost continuous satellite microwave coverage from more advanced multichannel radiometers, including the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR), which was launched in 1978, and the first Defense Meteorological Satellite Program Special Sensor Microwave/Imager (SSM/I), which was launched in 1987. More recently, the Advanced Microwave Scanning Radiometer Earth Observing System (EOS) (AMSR-E), which was designed and built by the Japanese Space Agency National Space Development Agency (NASDA) (now part of the Japan Aerospace Exploration Agency) for the EOS Aqua spacecraft, was launched in May 2002 [1]. The AMSR-E has a long heritage, and with its higher spatial resolution and wider range of frequencies, it promises to provide a more accurate measure of the Earth's sea ice cover than any of its predecessors.

The AMSR-E measures radiances at six frequencies, including 6.9, 10.7, 18.7, 23.8, 36.5, and 89.0 GHz at both horizontal and vertical polarizations. The spatial resolution is frequency dependent and varies from about 5-km at 89 GHz to about 50-km at 6.9 GHz. The frequency range spans that of the SMMR and SSM/I, and more importantly, the AMSR-E has about twice the spatial resolution of the older radiometers. The standard AMSR-E sea ice products include sea ice concentration, sea ice temperature, and snow depth on sea ice [2]. The standard sea ice concentration products are produced using the enhanced National Aeronautics and Space Administration (NASA) Team (NT2) algorithm [3]. Sea ice concentration difference maps derived using the NT2 and Bootstrap sea ice algorithms are also produced [2]. The ice concentration products are provided on polar stereographic grids at both 12.5- and 25.0-km resolutions (http://nsidc.org/data/amsre/). The 25.0-km resolution provides continuity with the existing SMMR and SSM/I sea ice concentration datasets. All of the AMSR-E sea ice products are archived at the National Snow and Ice Data Center (NSIDC) in Boulder, CO (http://nsidc.org/data/amsre/).

Previous studies have compared ice concentration retrievals using the SSM/I version of the NT2 algorithm with those derived from higher resolution visible and infrared (IR) satellite sensors [3]–[5]. The goal of this paper is to assess the accuracy of the AMSR-E version of the NT2 algorithm under clear sky winter conditions. This is accomplished using aircraft and satellite datasets collected during an Arctic field campaign in March 2003. These intercomparisons provide not only a quantitative

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measure of the AMSR-E ice concentration-retrieval accuracy relative to the validation dataset but also suggest ways to improve the AMSR-E retrieval algorithm.

The March 2003 Arctic field campaign consisted of seven aircraft flights using the NASA P 3B over the Bering, Beaufort, and Chukchi Seas [6]. Each of the seven flights had a specific objective. The Bering Sea flights were particularly useful for providing a wide range of sea ice concentrations and ice types. The flights made near Barrow, AK, and over the Beaufort Sea were coordinated with surface based measurements [7], and the data from these flights were used primarily for the validation of the sea ice temperature and snow depth on the sea ice products [8]. In addition to the aircraft datasets, high-resolution Landsat-7 Enhanced Thematic Mapper Plus (ETM+), EOS Moderate Resolution Imaging Spectroradiometer (MODIS), and RADARSAT imagery [9] were acquired.

The evaluation of the AMSR-E sea ice concentrations consists of intercomparisons with the other datasets derived from sources that provide ice concentrations at a higher spatial resolution than those available from AMSR-E. We present sea ice concentration comparisons for the 12.5-km product, provide an explanation of the observed differences between the AMSR-E retrievals and the validation datasets, and suggest potential improvements to the AMSR-E algorithm. Clearly, a single set of comparisons for one Arctic region and season is not sufficient to provide a full validation of a retrieved parameter. This paper is only the first in a series of studies that will be carried out to provide a comprehensive understanding of the accuracy of the AMSR-E ice concentration product for different regions and seasons.

V. Summary and Conclusion

Landsat ETM+ imagery was used to generate high resolution sea ice concentration datasets with which to assess AMSR-E ice concentration retrievals for four days in March 2003, under clear sky conditions during the EOS Aqua AMSR-E Arctic sea ice field campaign. The Landsat imagery covered a full range of ice concentrations, a variety of sea-ice-types, including new, young, and FY sea ice, and snow depths ranging from 0 cm, over new ice, to 40 cm, over FY ice.

March 13, 15, and 20, which were the days in which we had good temporal coincidence (within 36 min), provided a total of 1128 coincident AMSR-E/Landsat-7 12.5-km grid cells, covering the areas of the Bering and Chukchi seas. For March 13, which is the day we had a full range of ice concentrations, we find relatively little bias (-1.5%), overall, relative to Landsat with an rms difference of 6.6%. In contrast to young and FY ice, high concentrations of new ice resulted in negative biases ($\sim -5\%$) in the AMSR-E ice concentration retrievals relative to Landsat with an rms difference of about 8%. For all the ice types combined at concentrations greater than 99%, the bias relative to Landsat for all three days ranged from 0% to -4%, and the rms errors ranged from 1% to 6%, depending on the region.

In contrast to the days when we had good temporal coincidence, the results for March 22 showed a large bias overall. One likely reason for this large bias is that, during the 2-h difference between the Landsat and AMSR-E observations, the large fraction of OW and new ice in this diffuse marginal ice zone may have changed substantially. There is another more fundamental reason and that is the difference in the spatial resolution between the ETM+ and the AMSR-E sensors. Meier [5], in a comparison of the SSM/I sea ice concentration retrievals using several different algorithms with advanced very high resolution radiometer (AVHRR)-derived concentrations, found that the SSM/I retrievals tend to underestimate the ice concentrations relative to the AVHRR and that the major cause is likely the low spatial resolution of the microwave sensor rather than the specific SSM/I algorithm, because of the inability of the sensor to resolve the specific surface types.

From the analysis of the results for March 13, we discovered that the areas of new ice production still result in significant negative AMSR-E ice concentration biases relative to Landsat. The distribution of AMSR-E pixels in PR–GR space suggests that at least some of this bias may be reduced through an adjustment of the new-ice tie point. An analysis of the distribution of the snow depth on sea ice, which is derived from the AMSR-E snow depth retrieval algorithm [16] using the March 15 aircraft PSR radiances as input, revealed that a deep snow cover (~30–40 cm) still leads to a negative bias in the AMSR-E ice concentration retrievals. The location of the point in AMSR-E PR19/delta GR space corresponding to the deep snow area south of Nome, AK, is between the ice type C and OW tie points, explaining why the algorithm calculates a relatively low ice concentration. Physically, the high delta GR value of this point implies that there is even more surface scattering at the horizontal polarization than at the vertical polarization, which is currently allowed for in the ice type C tie point. This result suggests that we may be able to reduce the low ice concentration bias through an adjustment of the ice type C tie point.

The continued validation of the AMSR-E sea ice concentrations in other areas such as the Southern Hemisphere, in other seasons, and under cloudy conditions is essential if we are to fully document the capability and errors associated with the AMSR-E sea ice concentration algorithm. Ultimately, these comparisons are expected to lead to new and improved sea ice algorithms for current and future satellite multichannel microwave radiometers.