March 2003 EOS Aqua AMSR-E Arctic Sea Ice Field Campaign

Donald J. Cavalieri, *Member, IEEE*, Thorsten Markus, *Member, IEEE*, James A. Maslanik, Matthew Sturm, and Elena Lobl

***Abstract*—An overview of the March 2003 coordinated sea ice field campaign in the Alaskan Arctic is presented with reference to the papers in this special section. This campaign is part of the program to validate the Aqua Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) sea ice products. Standard AMSR-E sea ice products include sea ice concentration, sea ice temperature, and snow depth on sea ice. The validation program consists of three elements, namely: 1) satellite data comparisons; 2) coordinated satellite/aircraft/surface measurements; and 3) modeling and sensitivity analyses. Landsat-7 and RADARSAT observations were used in comparative studies with the retrieved AMSR-E sea ice concentrations. The aircraft sensors provided high-resolution microwave imagery of the surface, atmospheric profiles of temperature and humidity, and digital records of sea ice conditions. When combined with *in situ* measurements, aircraft data were used to validate the AMSR-E sea ice temperature and snow-depth products. The modeling studies helped interpret the field-data comparisons, provided insight on the limitations of the AMSR-E sea ice algorithms, and suggested potential improvements to the AMSR-E retrieval algorithms.**

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

I. Introduction

As PART of the overall Aqua Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) validation program, a field campaign was undertaken in the Alaskan Arctic in March 2003 to validate standard AMSR-E sea ice products, which include sea ice concentration, snow depth on sea ice, and sea ice temperature [1]. All of these products are available on polar stereographic grids at spatial resolutions of 12.5 and 25.0 km for sea ice concentration, 12.5 km for snow depth on sea ice, and 25.0 km for sea ice temperature at the National Snow and Ice Data Center (http://nsidc.org/data/amsre/). The scientific usefulness of these products depends on their level of accuracy, which will be determined through the implementation of a sea ice product validation program. The main objective of the sea ice validation program is to establish statistical relationships between the sea ice parameters derived from the AMSR-E sea ice algorithms and those same parameters derived from other data sets that were obtained from satellite-, aircraft-, and surface-based measurements covering as many different sea ice conditions as possible to provide a comprehensive measure of accuracy for each product. Other objectives are to understand the limitations of each of the AMSR-E sea ice algorithms including the reasons for their particular level of performance under different conditions and to suggest improvements to each of the algorithms based on the results of the validation studies.

The AMSR-E sea ice validation program consists of three elements, namely: 1) satellite data comparisons; 2) coordinated satellite/aircraft/surface measurements; and 3) modeling and sensitivity analyses. The first of two satellite/aircraft/surface Alaskan Arctic campaigns was completed in March 2003. The second campaign was completed in March 2006. The approach that was used for the validation of each of the AMSR-E sea ice products was necessarily product specific. For example, the validation of the sea ice-concentration product consisted of comparisons with ice concentrations derived from high-resolution Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and RADARSAT imagery for areas of the Bering and Chukchi Seas, which are two regions that provided a wide range of sea ice types and concentrations. For validation of the snow-depth and sea ice-temperature products, comparisons were made between the products derived from radiances obtained with the National Oceanic And Atmospheric Administration (NOAA) Environmental Technology Laboratory (ETL) Polarimetric Scanning Radiometers (PSR) on National Aeronautics and Space Administration (NASA) aircraft and coordinated surface-based measurements because no aircraft or spacecraft sensor was available to measure these products directly. The physical ice temperature measured by a satellite microwave radiometer is not a surface temperature but rather corresponds to the snow–ice interface temperature for snow-covered first-year ice and to a weighted-mean temperature of the freeboard portion of multiyear ice.

The postcampaign modeling studies provided insight on the reasons for the validation results and suggested potential sea ice-algorithm improvements. The models utilized in these studies include the MicroWaveMODel (MWMOD) model [2], a surface emission and atmospheric model that was designed to be used with a layered sea ice column with snow cover, and the Microwave Emission Model of Layered Snowpacks (MEMLS) model [3], which was used to study the sensitivity of snow parameters on the AMSR-E algorithm. These models provided a quantitative understanding of the effects of various snow parameters (e.g., grain size and density) and ice properties (e.g., first-year and multiyear ice types) on algorithm performance.

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D. J. Cavalieri and T. Markus are with the Hydrospheric and Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA (e-mail: donald.j.cavalieri@nasa.gov).

J. A. Maslanik is with the Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO 80309 USA.

M. Sturm is with the U.S. Army Cold Regions Research and Engineering Laboratory-Alaska, Fort Wainwright, AK 99703 USA.

E. Lobl is with the Earth System Science Center, University of Alabama, Huntsville, AL 35899 USA.

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This paper provides an overview of the March 2003 campaign including brief descriptions of the collected validation data sets, objectives of each aircraft flight, examples of coordination among satellite-, aircraft-, and surface-based measurements, and some insights gained from the modeling studies.

II. Validation Data Sets

A. Satellite Data

The two satellite sensors that were used in this campaign to obtain sea ice-concentration validation data sets were the Landsat-7 ETM+ and RADARSAT. Both instruments provide high-resolution imagery of sea ice, allowing both qualitative and quantitative comparisons.

The ETM+ measures radiation in the visible and near infrared (bands 1–4) and the shortwave infrared (bands 5 and 7) at a spatial resolution of 30 m. There is also a 60-m resolution thermal infrared band (band 6) and a 15-m resolution panchromatic band (band 8). Radiances that were obtained from the panchromatic band were converted to sea ice concentrations for comparisons with AMSR-E ice concentrations. Details of the methods that were employed to derive ice concentrations from Landsat as well as the statistical results are provided by Cavalieri *et al.* [4].

A total of 163 RADARSAT scan synthetic aperture radar (SAR) wide-beam quick-look images were obtained from the Alaskan SAR Facility. The RADARSAT images with a spatial resolution of 100 m permitted detailed comparisons with the 25-km AMSR-E sea ice-concentration grids using a geographic information system overlay technique. A discussion of this technique that is used to compare data sets of vastly different spatial resolutions and the results of the intercomparisons are provided by Heinrichs *et al.* [5].

B. Aircraft Measurements

A NASA P-3B aircraft made a total of seven flights from Fairbanks International Airport, Fairbanks, AK. The regions that were overflown included the Bering, Beaufort, and Chukchi Seas as well as two special study sites over the Elson Lagoon and the adjacent ocean near Barrow, AK, and at a Navy Ice Camp in the Beaufort Sea (Fig. 1). Two of the seven flights were coordinated with scientists making surface measurements of snow and ice properties including sea ice temperature and snow depth on sea ice at the Elson Lagoon study area and at the Navy Ice Camp. Two additional flights were dedicated to making heat and moisture flux measurements over the St. Lawrence Island polynya to support ongoing air–sea–ice processes studies of Arctic coastal polynyas. The remaining flights covered portions of the Bering Sea ice edge, the Chukchi Sea, and Norton Sound to assess the sea ice-concentration product. Each of the seven flights is summarized in Section III including a brief description of the flight objective, sea ice characteristics, and coordination with satellite and/or surface-based measurements.

The NASA P-3B aircraft was equipped with NOAA ETL Polarimetric Scanning Radiometers (PSR-A and PSR-CX) that cover the AMSR-E range of frequencies (6.9-GHz) at both vertical and horizontal polarizations. Boresighted with each PSR scanhead was an infrared scanning radiometer operating

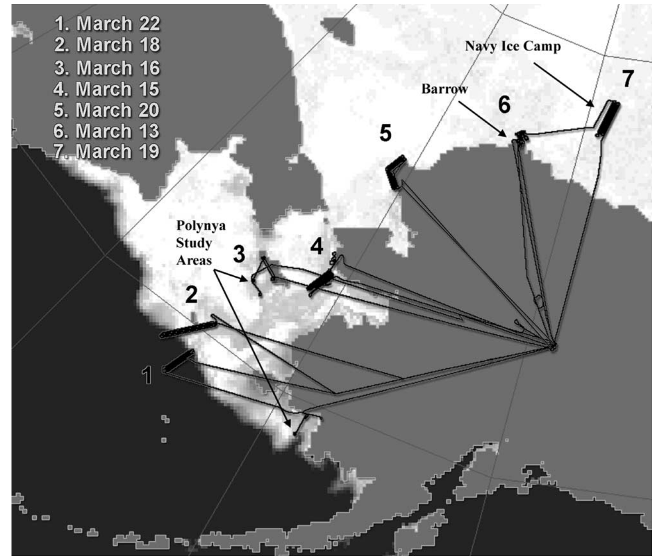

Fig. 1. Location of the seven NASA P-3B flights completed during the March 2003 AMSR-E Alaskan Arctic sea ice campaign. Light shades of gray are sea ice-covered areas; ice-free ocean areas are black (courtesy of A. Ivanoff).

at 9.6–11 μm. A system description of the PSR on the P-3B aircraft is provided on the PSR website: http://www.etl.noaa.gov/technology/psr.

The aircraft also carried the NASA Langley Research Center Turbulent Air Motion Measurement System (TAMMS) for measuring surface heat and moisture fluxes over coastal polynyas as well as the NASA Wallops Airborne Topographic Mapper (ATM) for measuring ice-surface topography. Detailed information on the TAMMS and on the ATM may be found at http://www-gte.larc.nasa.gov/trace/TP_Tamms.htm and http://atm.wff.nasa.gov, respectively. A system of dual aerial digital cameras documented the sea ice conditions continuously during each flight.

V. Summary

The successful completion of the AMSR-E Arctic sea ice field campaign in March 2003 has provided some of the spatially and temporally coincident data sets needed to begin the validation of the AMSR-E sea ice products. While the papers in this special section describe the sea ice conditions during this particular campaign and present results of the analyses, which serve as the initial validation of the AMSR-E sea ice products, much remains to be done. The March 2006 campaign had as its focus the validation of snow depth on sea ice and utilized a newly developed airborne snow radar [13] to provide the spatial coverage needed for truly validating snow depth over much larger areas of the Arctic.

As with any new geophysical algorithm, its validation must cover a variety of conditions. The continued validation of the AMSR-E sea ice products in other areas such as the Southern Hemisphere and for other seasons is essential if we are to fully document the accuracy and limitations associated with each of the sea ice products. Ultimately, these comparisons are also expected to lead to new and improved sea ice algorithms for current and future satellite multichannel microwave sensors.