"OPERATIONALLY BLENDED"

SATELLITE DATA CAN IMPROVE SEA ICE FORECASTS

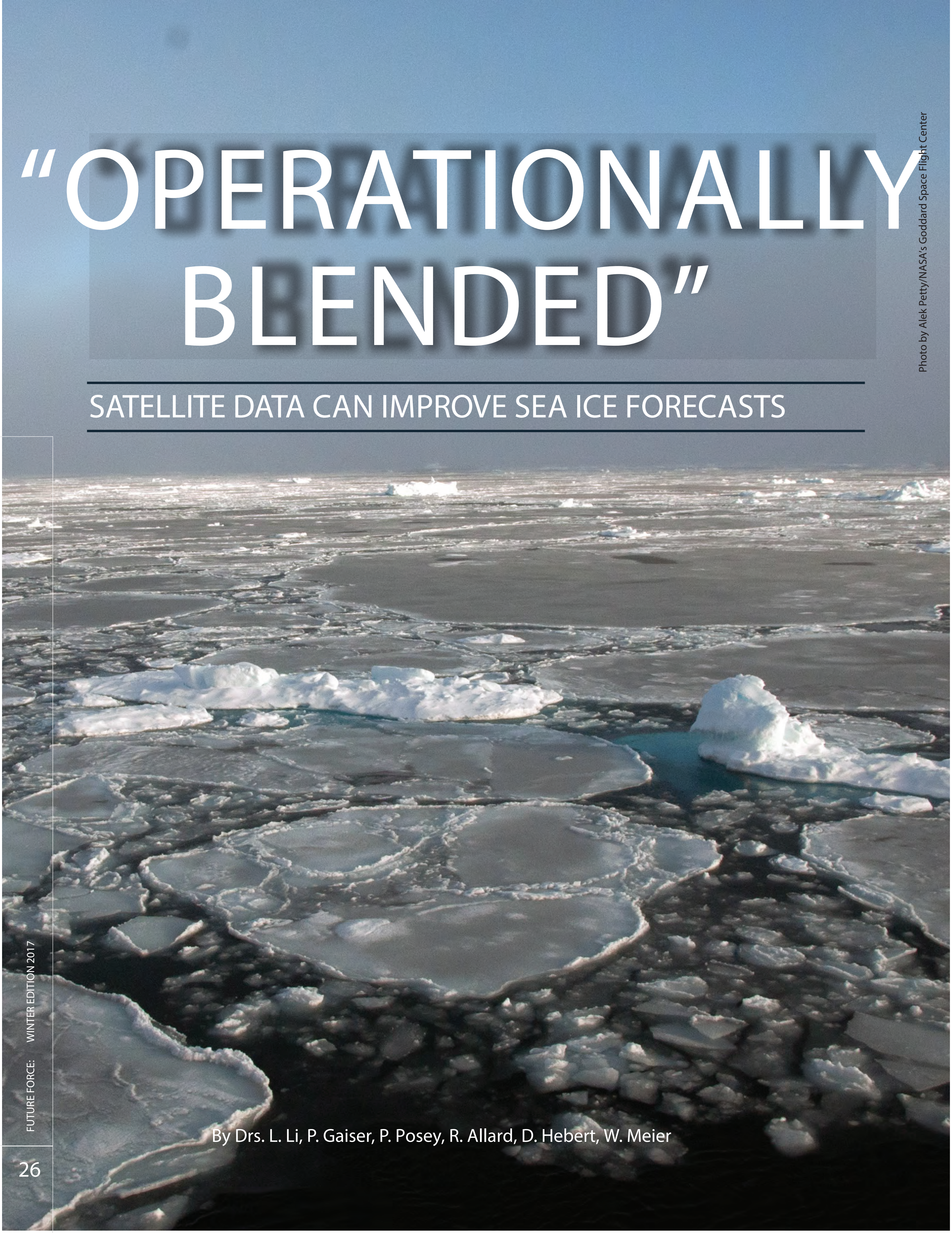


Photo by Alek Petty/NASA's Goddard Space Flight Center

By Drs. L. Li, P. Gaiser, P. Posey, R. Allard, D. Hebert, W. Meier

WITH LESS AND LESS ICE EVERY SUMMER IN THE ARCTIC, THE NAVAL RESEARCH LABORATORY AND NASA ARE COLLABORATING ON A SYSTEM THAT COMBINES DATA FROM DIFFERENT SATELLITE SYSTEMS TO HELP IMPROVE ICE FORECASTING.

The Arctic climate system is experiencing dramatic changes. One particularly important and very visible change is the reduction in the summertime sea ice cover. The Intergovernmental Panel on Climate Change models predict a further decrease in sea ice cover with a potentially ice-free summertime Arctic before 2100. The projections vary widely, however, with some models predicting an ice-free Arctic as early as 2040. Given the observed and forecast reduction in sea ice cover, Arctic shipping and commercial activities are expected to increase in the future. Warfighters must adapt to the fast changing Arctic, and it is vital for them to have access to accurate and timely information on sea ice conditions and forecasts at relatively small scales. This demands higher accuracy in sea ice observations and forecasts than is available today.

The Navy's current operational Arctic sea ice forecasting system is the Arctic Cap Nowcast/Forecast System (ACNFS), which has a grid resolution of approximately 3.5 kilometers (2.2 miles) at the North Pole. The ice concentration fields from ACNFS are updated daily with satellite-derived ice concentrations from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager and Sounder (SSMIS) at a resolution of approximately 25 kilometers (15.5 miles), and the Advanced Microwave Scanning Radiometer (AMSR2) at a resolution of approximately 10 kilometers (6 miles). Higher-resolution sea ice information from satellites is therefore critically needed to complement the ACNFS model resolution.

In response to this need for accurate ice forecasts by the Navy for its operations, the Naval Research Laboratory (NRL) and NASA's Goddard Space Flight Center developed a joint operational satellite data system to generate blended near-real-time, high-resolution sea ice products from microwave and visible/infrared satellite sensor platforms. The system's data products are currently being tested using the Navy's ACNFS for improved operational sea ice forecasts and safe navigation in the Arctic, especially in the marginal ice zone, the transitional point between the open sea and pack ice. Making such a satellite data system available to the Naval Oceanographic Office will provide the Navy with an in-house capability for producing near real time sea ice observations, ending the practice of using satellite ice concentration products from non-Navy sources. This work responds directly to the Navy Arctic Roadmap's call to "support efforts to research, develop, resource, and sustain an Arctic environmental observation system to support U.S. operations" and to improve "the Navy's ability to understand and predict the Arctic physical environment." In addition, the sea ice concentration data products provided by this project support development of a fully coupled air-sea-wave-ice interaction model.

Technical Approach

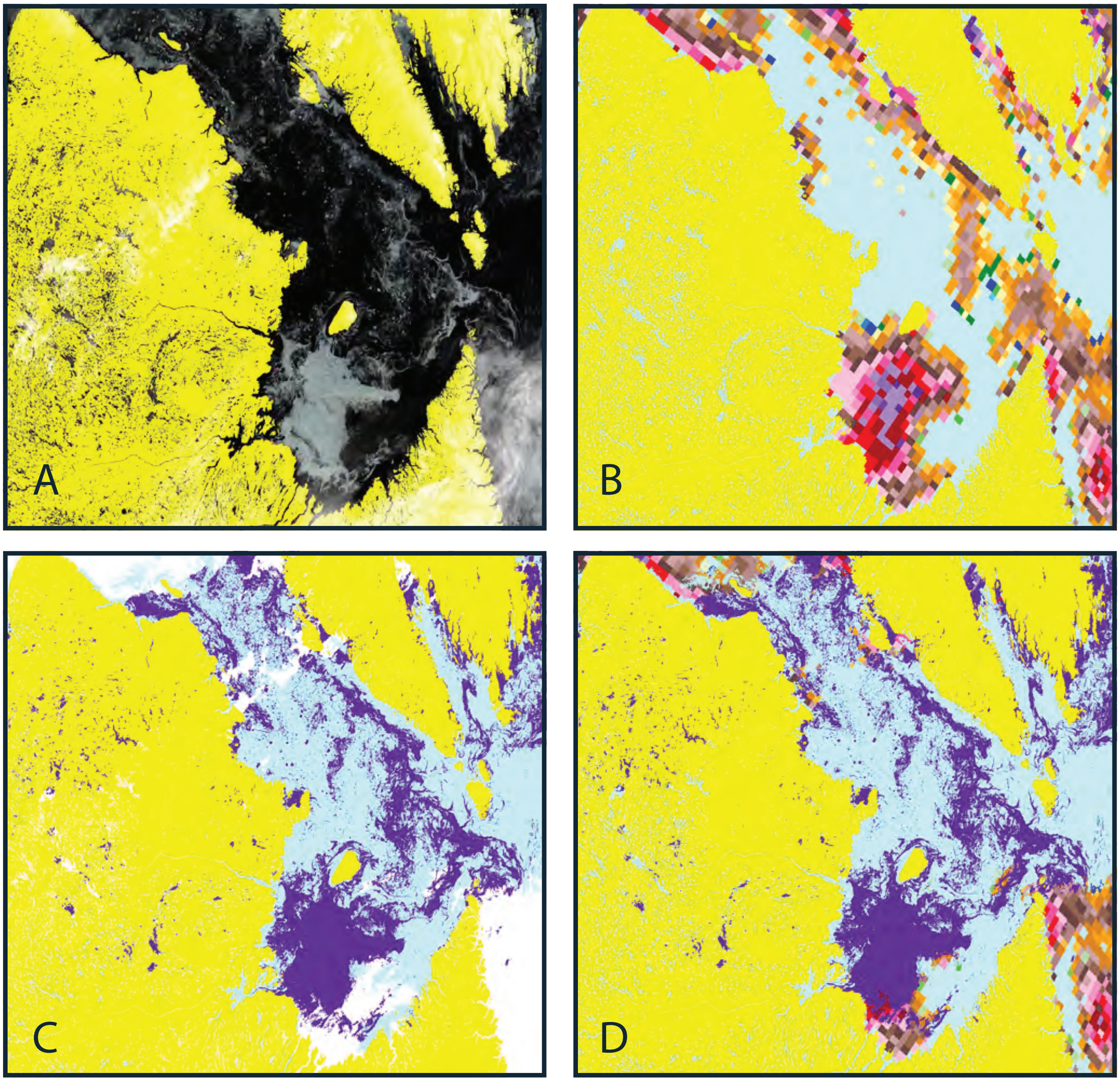
Sea ice concentration is a key parameter for the Arctic battlespace environment. Satellite passive microwave (PMW) and visible/infrared data provide complementary observations of sea ice, and are performance drivers of sea ice forecast models. Passive microwave data (such as SSMIS and AMSR2) have complete daily coverage in all sky conditions, but also have low spatial resolution and cannot detect low sea ice concentration.

On the other hand, visible/infrared data (such as NASA's Moderate-resolution Imaging Spectroradiometer [MODIS] and Visible Infrared Imager Radiometer Suite [VIIRS]) provide higher spatial resolution and the ability to detect thin or melting ice. However, clouds limit both visible and infrared imagery throughout the year. Working with the complementary nature of PMW and visible/infrared data, a blended algorithm can combine data from various satellites where users automatically receive the best and most consistent sea ice concentration data at the highest resolution available.

Implementation and Result

Working toward a blended data product, we first selected AMSR2 as the source for the passive microwave products because of its wide availability. In addition, the Naval Oceanographic Office also established a data link to receive AMSR2 raw data in near real time. AMSR2 PMW imagery provides complete daily coverage of sea ice concentration in all sky conditions. Sea ice concentration is derived from the satellite obtained brightness temperature data using empirically derived algorithms. The current SSMIS sea ice concentration product is available at 25-kilometer (15-mile) resolution, while AMSR2 provides standard products on a 10-kilometer (6-mile) grid, which is a considerable improvement.

MODIS and its follow-on mission VIIRS were selected as the source for the visible/infrared products because of their wide-availability, long history of use, and well-calibrated measurements. Their visible and near-infrared data have very distinct spectral signatures against the ocean background and cloud cover. Based on these signatures, we developed new sea ice algorithms for both VIIRS and MODIS instruments. The sea ice classification algorithm was based on the spectral analysis of the high-resolution data, 500 meters (1,640 feet) for MODIS



An example of combined concentration product in the Davis Strait region on 20 June 2014, with a), Visible Infrared Imager Radiometer Suite (VIIRS) true color image, b), Advanced Microwave Scanning Radiometer (AMSR2) sea ice concentration, c), VIIRS sea ice concentration (clouds are in white), and d), combined VIIRS/AMSR2 sea ice field.

and 750 meters (2,460 feet) for VIIRS. The algorithm uses combinations of visible and near-infrared bands to separate different surface types. For the purpose of calculating sea ice concentration, we grouped surface types into five classes: sea ice, snow on sea ice, cloud, water, and land. The land surface type is determined by the 250-meter resolution MODIS land mask data. The water surface is identified by its very low albedo in the visible spectrum. Ice/snow/cloud pixels are characterized and separated by their strong visible reflectance and strong short-wave infrared absorbing characteristics, represented by the Normalized Difference Snow Index. And additional screening of high and thin clouds is performed using the 1.38-micrometer channel. Using this 500-meter resolution sea ice classification data, sea ice concentrations were calculated at a degraded 4-kilometer resolution and projected onto a 4-kilometer grid to facilitate merging with the AMSR2 data.

After the 4-kilometer VIIRS and MODIS ice concentration data products are produced, we combine them with the AMSR2 10-kilometer ice concentration data, subsampled to the 4-kilometer common grid, to create the blended 4-kilometer AMSR2/VIIRS/MODIS dataset that integrates the spatial coverage with visible/infrared resolution. The optimal combination is achieved based on error statistics of standalone VIIRS/MODIS and AMSR2 ice concentration data. For example, in the marginal ice zone, the PMW data from AMSR2 data is underweighted because of larger errors in the microwave data in this region. As a result, errors in the blended data are smaller in the marginal ice zone than when using only the AMSR2 data.

Figure 1 shows an example result of blended VIIRS/AMSR2 sea ice concentration data in the Davis Strait region (located on the western side of Greenland) on 20 June 2014. The yellow background is the land mask. In general, the AMSR2 and VIIRS standalone data are clearly very consistent, except that some areas are masked out by cloud cover (white color) in the VIIRS data. The greater detail provided by VIIRS compared to AMSR2 in the clear sky regions is apparent. Also, the VIIRS concentrations are generally higher than AMSR2, which correct the well-known low bias in passive microwave concentrations during summer melt when water pools on the ice surface. Finally, the VIIRS ice edge extends farther than AMSR2, which is in agreement with visual inspection of the VIIRS reflectance image and is not surprising because passive microwave algorithms may not detect thin, melting ice near the edge. There is discontinuity between the VIIRS region (Figure 1c) and the AMSR2 region (Figure 1b) at the boundary of the VIIRS swath edge (Figure 1d). This could potentially be resolved or at least reduced by adjusting AMSR2 concentration or algorithm coefficients so that the passive microwave estimates are consistent with VIIRS. Nonetheless, the current product does provide improved fields in clear-sky regions.

Benefit to the Navy

The benefit of the blended visible/infrared/PMW sea ice concentration data can be tested in ACNFS to determine the improvement in the model forecast fields. Currently, the ACNFS assimilates near real-time sea ice concentration derived from SSMIS and AMSR2 by updating the initial ice concentration analysis fields along the ice edge. In the past year, NRL tested the 4-kilometer blended AMSR2/VIIRS ice concentration dataset as the initial condition to the ACNFS model run. Daily analysis of the ice edge location indicated the ACNFS initialized with the merged AMSR2/VIIRS dataset has substantially lower ice edge error (on average 30 km vs 50 km) than the ACNFS initialized using the coarser SSMIS data for a month-long study in 2008. The software for processing the blended sea ice products is currently undergoing system testing at the Naval Oceanographic Office at the Stennis Space Center as an operational satellite sea ice processing system. A successful transition of this new capability will result in an immediate leap in sea ice forecasting skills by the Navy, as well as a data system that integrates existing and future multisensor sea ice data in a physically consistent way.

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