THE SEPARATION OF SEA-ICE TYPES IN RADAR IMAGERY

(Abstract)

by

Benjamin Holt and F.D. Carsey

(Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, U.S.A.)

ABSTRACT

The ability to distinquish the several major types of sea ice with active radar instruments has been well studied in recent years. The separation of sea-ice types by radar results principally from variations in radar back-scatter due to characteristic differences of these ice types in surface morphology and brine content. When sea ice is viewed with an active radar at angles greater than about 20° from nadir, undeformed ice reflects radar waves and results in a low return, while ridges, hummocks, and small-scale surface features scatter the radar waves and produce a high return. The presence of salt increases the dielectric constant of ice; penetration by radar into the ice is then negligible, and the return is essentially determined by surface morphology. The absence of salt reduces the dielectric properties of ice; radar waves can then penetrate the ice to some depth and are scattered by air bubbles and brine-drainage channels (called volume scattering), thereby enhancing the return even for roughened surfaces. All these properties vary significantly with radar frequency and polarization as well as seasonally. For example, higher radar frequencies respond to smaller-scale surface features, while lower radar frequencies penetrate further into the ice with resulting volume scattering.

The high-resolution imagery from synthetic aperture radars (SAR), mounted on aircraft, shuttle, or satellite platforms, is very effective for many sea-ice studies, including the separation of ice types. An aircraft-mounted X-band (9 GHz) SAR, for example, can discriminate smooth first-year ice, rough first-year ice, multi-year ice, and open water by the intensity (tone) of the radar returns and floe geometry. The preferred SARs to date for satellites and shuttle platforms have been L-band (1–2 GHz) systems. SAR imagery of sea ice was extensively acquired by Seasat in 1978 over the Beaufort Sea, with limited quantities obtained by the Shuttle Imaging Radar (SIR-B) over the Weddell Sea in 1984. While L-band SAR can discriminate rough and smooth ice along with roughened open water based on image intensity and floe geometry, the returns from thick first-year ice and multi-year ice are not clearly distinguishable. The fact that there is volume scattering from multi-year ice suggests that there may be textural or spatial frequency variations that could be used to separate these two major ice types in radar imagery. In order to investigate the separation of sea-ice types in the large amount of L-band SAR imagery available, image-analysis techniques including filtering and classification programs have been utilized, pointing towards an automatic classification algorithm for use in future SAR sea-ice data sets, especially from space.

An important characteristic of all SAR imagery is the presence of image speckle, a coherent form of noise caused by the random variability of scatterers across even a uniform surface. Most SAR processors reduce this effect by averaging multiple independent samples but this is done at the cost of reducing resolution. Speckle reduction can also be accomplished by filtering. Several filters have been tested including median, box, and adaptive edge filters. Each filter has different characteristics in terms of smoothing speckle and in the response to sharp gradients or edges, such as ridge or lead openings, as well as computational requirements. Optimization of each filter's parameters has been determined by the quality of classification of each ice type.

The classification programs that have been tested are based on tone and texture image characteristics. The programs are supervised; that is, a small training area for each class is pre-selected for statistical analysis. From these statistics, the remainder of the imagery is subjected to the particular classification algorithm. The tone program separates classes based on the mean, standard deviation, and number of standard deviations of each class, and includes a Bayesian maximum-likelihood classifier for ambiguous elements. The texture program determines the statistical homogeneity of each class and the optimal segmentation of each small area into the various classes.

CARTOGRAPHIC REMOTE-SENSING MONITORING OF GLACIOLOGICAL SYSTEMS (EXAMPLE, MOUNT EL'BRUS, U.S.S.R.)

(Abstract)

by

Yu. F. Knizhnikov, V.I. Kravtsova and I.A. Labutina

(U.S.S.R.)

ABSTRACT

Remote-sensing methods in monitoring the glacierization of Mount El'brus are used to produce base and dynamic maps, and to obtain quantitative information (dynamic indices) about the rate, intensity, and variations of the process. The monitoring system is divided, according to scope and territory covered, into small-scale for total glacierization and the periglacial zone, medium-scale for separate glaciers, and large-scale (detailed) for part of the glaciers or sectors of the adjoining slopes. The approximate relationship of even scales is 1 : 4.

Small-scale monitoring remote-sensing systems are important for making maps showing the complex characteristics of the glaciological system. A series of maps was produced including geographical, those of high-altitude zones, slope and exposure angles, geological, glaciomorphological, climatic (temperature, precipitation, and winds), distribution of direct solar radiation, hydrological (source of streams), seats of avalanches, and landslides. All these data serve as a cartographical basis in monitoring the glacierization of Mount El'brus. They are compiled from remotely sensed and Earth-based data.

Current monitoring on a small scale includes observations of the conditions which determine the existence of the glacial system – this includes data on winter snowfall and