NOMENCLATURE FOR MAPPING SEA ICE FROM HIGH RESOLUTION SATELLITE IMAGERY

By

W. J. Stringer
S. A. Barrett
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Sea ice nomenclature has reflected both man's interaction with the ice and his means of observation. The present World Meteorological Organization Nomenclature represents the cumulation of observations and interactions ranging from those of the early polar explorers and whaling ships to recent routine ice reconnaissance aircraft flights..

We are presently completing a large program of mapping nearshore ice conditions as part of the NOAA/BLM Outer Continental Shelf Environmental Assessment. The area of coverage included the Beaufort, Chukchi and Bering Sea regions of the Alaskan Coast. As part of this work, line drawing maps of sea ice conditions were made from Landsat images enlarged to 1:500,000 scale. In all, 469 images were mapped.

Over the course of this. project, a nomenclature developed as the need arose to identify various ice conditions and types. Where applicable, the WMO nomenclature was used. However, Landsat imagery allows a regional view of the ice not available before and in many cases, terms describing regional conditions needed to be invented.

The newly invented terms not only reflect this expanded simultaneous field of view but, of course, also reflect the viewing limitations of Landsat imagery. The obvious limitation of Landsat imagery is its ability

to allow detection of narrow linear features such as leads and ridges. Often, the size of the Landsat picture element (approximately 80 m) is taken to represent the "resolution" of Landsat. Actually, this number represents the absolute minimum separation between two point sources which will allow resolution between-the two and depends on the accidental arrangement of the picture element boundaries such that one picture element falls exactly between the two sources. Operationally, Landsat requires a. separatism of approximately 350 m to absolutely guarantee resolution of two point sources and an rms separation value of approximately 200 m to yield separation in 50% of *all cases.*

Although this result can appear to be disturbing we should remind ourselves that on the greatest Landsat enlargement normally available (the 1:250,000 scale 36 x 36 inch print), 350 m is 1.4 mm.

For small features "detectability" is more important than resolution. A small lead, because of its great contrast with the surrounding ice, can greatly modify the reflectance values of picture elements containing it. These picture elements then appear grey against the surrounding picture elements containing only *ice.* A lead 20 m in width represents 1/4 the area of an 80 m square picture element and would modify the reflectance value of a picture element to 75% the reflectance value of surrounding picture elements. There should be little doubt that a lead this wide would be detected. However, since the lead-would appear as grey instead of black, it would generally not be possible to determine whether the lead was wide-- and had partly frozen over or was narrow and entirely open. Obviously, sequential data could yield more information and' multi-spectral techniques making use of more than one of Landsat's spectral viewing bands might help remove uncertainties.

While detectability of leads is a rather simple problem to contemplate, the detectability of ridge systems is somewhat more complicated. Generally ridges are more detectable early in the year when low sun angles create long shadows and much later when the well-drained high-relief ridges appear white in contrast to other ice. Obviously the detectability of ridges is somewhat aspect sensitive as well. The irregularity of ridges tends to create a texture which, when added to the linearity of ridges makes large ridges and ridge systems identifiable.

- Unfortunately, at the early stages af the mapping program symbols were rapidly applied to identify various ice conditions as they were discovered and maps were produced. After-some time, it became difficult to 'expand the nomenclature in an entirely consistent manner. On the other hand, we did not wish to make previous maps obsolete by changing nomenclature. Hence a rather inconsistent nomenclature was tolerated.

With this experience behind us now, a more consistent nomenclature has been developed and is presented here. This presentation is not made with a view toward adoption. Rather, it is made with the hope of communicating the following general ideas:

1. This represents the range and type of conditions which can be expected to be identified from a high resolution satellite.
2. It also represents some of the limitations which are imposed on satellite ice mapping by the size of the image picture cell size (in this case some 80 m).
3. Lest we need be reminded, this list of terms reminds us again of the increase in information content of products from observational systems such as Landsat, and our need to be able to identify that information which is of value and discard or ignore that which is not.

α	New Ice	Symbol used to denote ice characterized by a dark shade of grey, usually with smooth texture. Thickness is on the order of 1-10 cm.
β	Young Ice	Symbol used to denote ice characterized by a light shade of grey on Landsat imagery, usually with smooth texture. Thickness is on the order of 10-30 cm...
γ	First Year Ice	Ice cover of age and thickness beyond "young" stage. This symbol is used principally to denote large expanses of ice in either fast or non-fast ice category. May be composed of single sheet, many pans frozen together (with their boundaries perhaps denoted by lines marked "k"). Thickness on the order of 30-70 cm.
A	River Overflow	Usually a springtime phenomenon, coastal rivers can often flood vast expanses of sea ice. These waters seldom freeze onto the ice and actually accelerate the melting of the flooded area. These floods appear black an Landsat imagery.
E	Broken Ice	Broken ice is, in general, a continuous sheet which has been fractured into individual pieces of various sizes. However, in contrast to an assembly of floes, broken ice has the appearance that the major pieces could be re-assembled to form the original ice sheet.

By	Broken First Year Ice	Broken ice originating from a sheet of first year ice.
Bα	Broken New Ice	Broken ice originating from a sheet of new ice.
Bβ	Broken Young Ice	Broken ice originating from a sheet of young ice.
Bpa	Broken Pans and New Ice	Broken ice originating from a sheet of ice of various ages - the most recent of which had progressed to the new ice stage. Often, several cycles of freezing and breaking are evident. See Pα. Bpα would result from the breaking of Pα.
Bpβ	Broken Pans and Young Ice	Broken ice originating from a sheet af ice af various ages - the most recent of which had progressed to the young ice stage. Often, several cycles of freezing and breaking are evident. See Pβ. Bpβ would result from the breaking of Pβ.
C	Fast Ice	Ice stationary and" continuous from shore without apparent fractures. The symbol is placed within large expanses of such ice and along the landward side of the seaward edge of the ice. Fast ice is not necessarily bounded on the seaward side by grounded ice and can therefore extend seaward considerable distances.
C_f	'Fractured Fast Ice	Fast ice, which although not apparently separated from shore by an open lead, is fractured by leads - often oriented at oblique angles to the edges of the fast ice.

D	Decayed Ice	Decaying or rotting ice. This ice is characterized by a dark mottled effect indicating voids and puddling.
F	Floe	Separately identifiable ice floe. The symbol is used to denote individual floes distinctly visible against their background - even when completely frozen into the surrounding ice.
$F_p \frac{x}{8}$	Floe Pack	Symbol used to denote assembly of floes. Concentration can be given in oktas. In contrast to broken ice, the individual flaes in a floe pack could not be reassembled to yield an original ice sheet. The summertime ice pack is the major example of this ice condition.
G	Grounded	This symbol used to denote ice which is clearly grounded.
H"	Hummock Field	Large expanses of piled ice. Usually denoted by dark grey appearance and rough texture.
K	Boundary	Denotes a boundary between what appear to be two different ice types or conditions. It is sometimes used even though the two ice conditions are not differentiated by defined ice types. It can also be used to denote what-appears to be a boundary between expanses of similar ice of perhaps different ages. Boundaries are usually distinct features on Landsat imagery and often appear as changes in texture or tone. Often one might suspect ridging along some boundaries.

L	Lead	A lead, usually identified as open by identification of two distinguishable edges in the ice containing black water between them. Or a single line, which by its observed age must necessarily contain open water. Narrow leads of indeterminant age observed , on Landsat imagery can not. generally be-differentiated . into open leads and leads frozen to new or young stage.
La β γ	Lead Frozen to New, Young or First Year Stage	Symbol used to denote a lead – necessarily one . sufficiently wide that both sides can be distinguished - that has frozen to the new, young or first year stage respectively.
L_P	Partly Frozen Lead	Symbol used to denote a lead - necessarily one sufficiently wide that both sides can be distinguished - that has partly frozen. The ice age within the lead is not uniform and may vary from new to late stages of young ice. .
Pa β	Pans in Matrix of New (Young) Ice	This symbol used to denote a condition wherein a sheet of ice has been broken tits pans followed by the voids freezing to the new (young) ice stage. [The breaking up of Pa (Pβ) would yield Bpα (Bpα)]
R	Ridge	Denotes "shear" or 'pressure" ridge or system of ridges. Ridges are identified on Landsat images by means of linearity and rough texture.

S	Smooth Ice	This symbol used to denote featureless ice of uncertain age - usually in very protected areas and covered with snow.
T	Tidal or Tension Cracks	Cracks in near shore ice opened by either tidal action or thermal tension. Identification may be indirect (snow drifts, drainage pattern, etc.).
W	Water	Denotes open water. Used in region where boundaries are drawn around ice - excluding water.
Y	Polynya	More specific than W. Used to "denote specific area of open water i.e., boundary drawn around area of water (as opposed to "W").
Z	Zone of Shear Induced Strati.	Symbol used to denote area where lead pattern indicates that strain has resulted from shear. Lead pattern usually in form of more or less regularly spaced leads running at oblique angle with respect to ice edge.