2.2 SYNTHETIC APERTURE RADAR SATELLITE (SARSat) IMAGERY AND THE SEA ICE DESK AT WFO ANCHORAGE

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INTRODUCTION

The sea ice/sea surface temperature desk at the Anchorage, Alaska Weather Forecast Office (WFO) provides sea ice analyses, and sea ice forecasts for the Beaufort Sea west of 125W, the Chukchi Sea east of 175E, the Bering Sea east of 171E and Cook Inlet. The most effective tool the forecaster has for analyzing sea ice is Synthetic Aperture Radar Satellite (SARSat) imagery. SARSat is an active microwave instrument (radar frequency) whose data consists of high-resolution (10M) reflected returns from the Earth's surface, based on a polar orbiting satellite.

Unlike the more common optical channels used by meteorologists (e.g., visible, infrared, and water vapor) SARSat passes through the atmosphere relatively unaffected by clouds, precipitation or sun-angle to scan surface features. The energy returned to the satellite is a function of the physical characteristics of the surface features. This attribute makes SARSat ideal for analyzing sea surface features over the stormy northern latitudes. However, there are a limited number SARSat passes on any given day. There are 2 images/day at 70N in the Beaufort Sea. However, at 60N in the Bering an image is received once every 2 to 2 1/2 days. Microwave imagery from the more abundant SSM/I and QuikSCAT imagers are used to fill in the data gaps. Though coarser in resolution and more limited in capability, imagery from these satellites provide consistent, daily background information of sea ice for the entire ocean basin.In addition, imagery is also received from POES, DMSP and MODIS which is only useful on cloudless days.
Because the sea ice edge can be covered by clouds for up to three weeks at a time, microwave imagery is the tool of choice for sea ice analysis.

What makes these tools vitally important to the mission of the NWS in Alaska is that the imagery is used daily to improve ice analysis and forecasts for some of the most dangerous industry/occupations in the United States: the crab fishery in the Bering Sea. Prior to1995 the average yearly death/vessel loss rate for the preceding ten years was 5 men dead/2 vessels lost per crabbing season. During the crabbing seasons of 1998 through 2003, the industry experienced the loss of life or vessels during only one year. Feedback from customers indicate that at least a small portion of the success can be attributed to information derived from SARSat, SSM/I and QuikSCAT.

DISCUSSION

Synthetic Aperature Radar (SAR) imagery allows for the best indirect estimate of the age (thickness) of the sea ice, and also allows for an indirect estimate of the probability of how far the ocean water adjacent to the ice edge will freeze in the near future. Direct sea ice observations are limited and few. Most ship marine reports (mareps) and buoy reports occur east of the Alaskan Peninsula and south of 55N in the Bering Sea. Sea Ice observations are taken in Cook Inlet by the Anchorage WFO sea ice forecaster, oil platforms and Cook Inlet Spill Prevention and Response, Inc. (CISPRI). The Weather Service Offices (WSO) of Barrow, Kotzebue, Nome, St. Paul, Cold Bay and Kodiak provide routine sea ice observations. Marine freight, fishing vessels, Alaska Fish and Game managers, the U.S. Coast Guard and the whalers of the North Slope Borough provide limited sea ice observations usually when the sea ice forecast is wrong and life or/and property is endangered.

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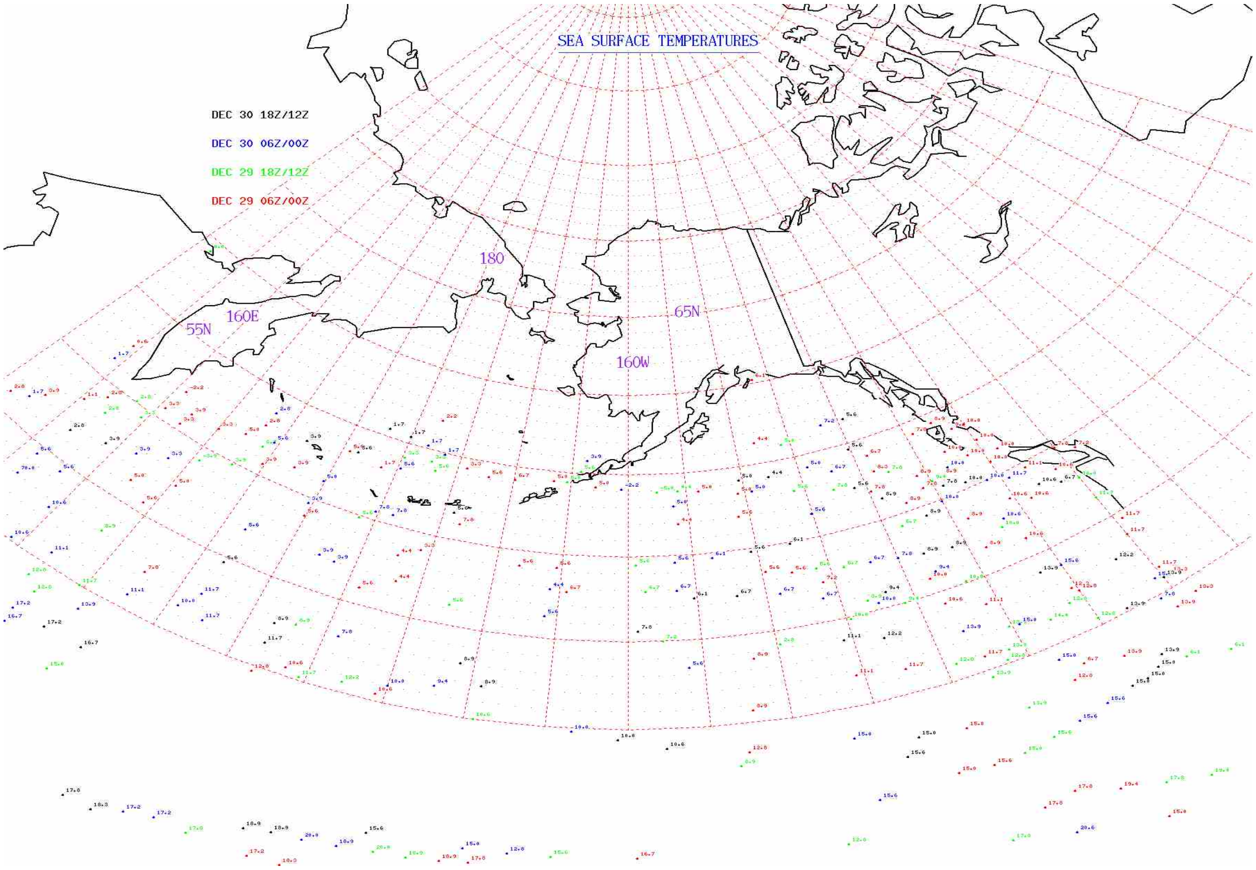

Figure 1. Locations of ship and buoy SST observations over a 48 hour period.

Figure 1 shows the locations of all synoptic ship and buoy sea surface temperature (SST) observations collected over a 48 hour period. Note how few are in ocean basins that have sea ice. When one considers that one ship may report as many as 8 synoptic observations during two days, one is impressed by the scarcity of surface data in the Alaskan waters. This pattern of surface observations is common throughout the year.

There are several factors needed to make a successful sea ice forecast. The two essential requirements are an exact delineation of the initial ice edge in conjunction with an exact delineation of sea water temperatures colder that -0.5C (31.1F) and it distance from the existing ice edge. These two factors are so important that it is impossible to create a accurate ice edge forecast without them even if one has a perfect model forecast of the other critical components: a. good wind and air temperature forecast. Figures 2a and 2b show that, east of 171W in the Bering Sea, the critical sea water isotherm of -0.5C extended from 50NM to 90 NM south of the ice edge providing the zone of vulnerability for sea water freezing in place.

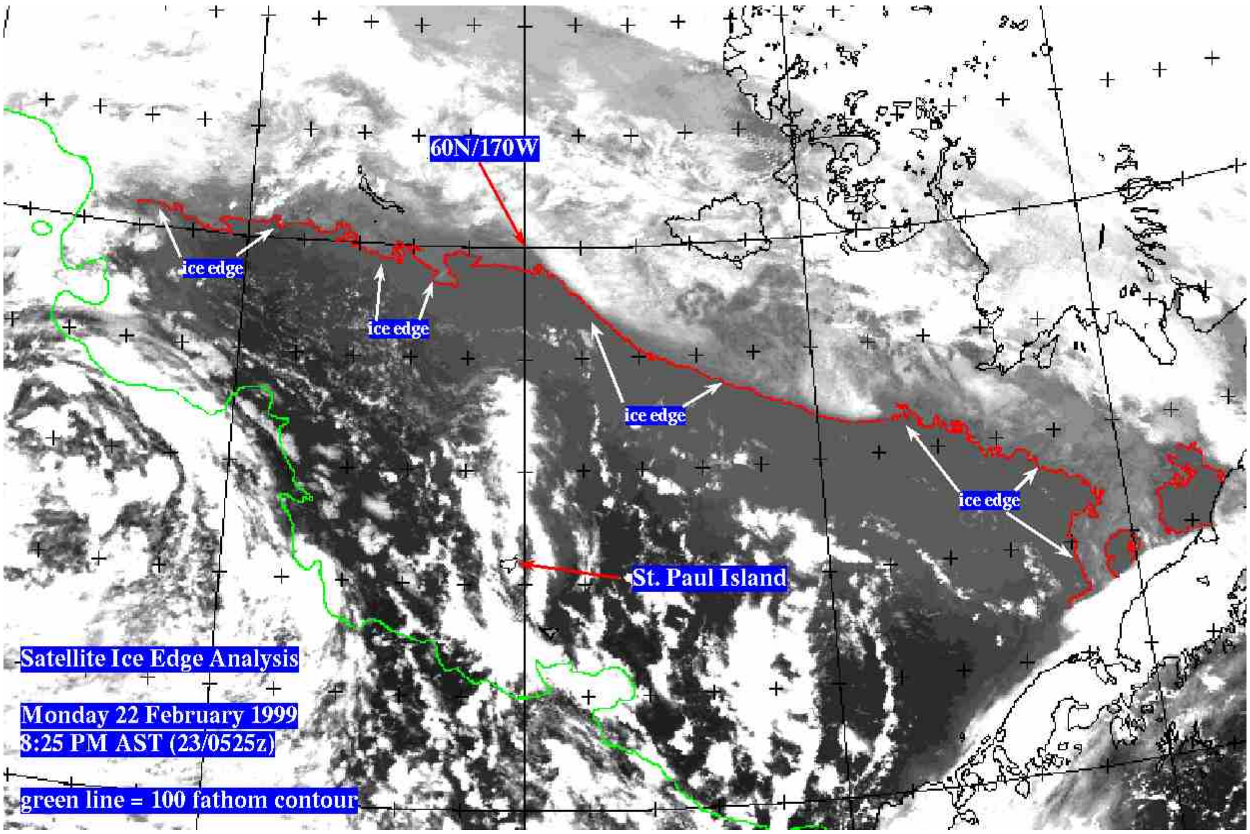

Figure 2a. POES IR imagery of the ice edge.

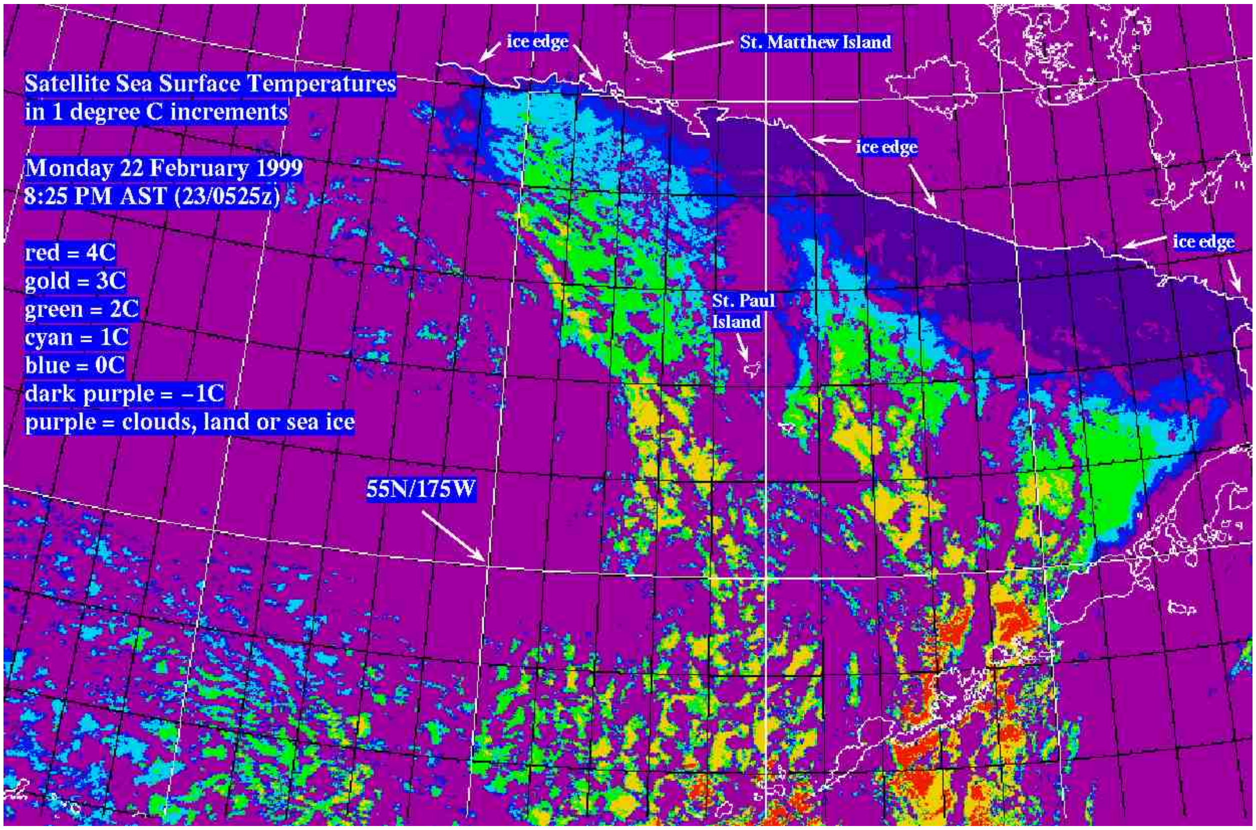

Figure 2b: POES IR imagery of the ice edge and SST in 1C increments.

However, this technique has several weaknesses. First, there is the requirement for a clear sky over the ice edge. Second, an estimate ocean surface roughness and the amount of any upwelling taking place is needed. When there is vertical mixing in a water column, warm subsurface waters replace the colder surface water as the entire water column cools. This action can postpone the freezing of the surface water for several weeks. Since mareps are scarce, the forecaster depends upon the isobaric analysis of the surface chart to guess the wind speed and direction over a given surface of ocean and from that indirectly compute an estimated wave height or roughness of the ocean.

Without low light capabilities, satellite visible imagery cannot discern the ice edge in Alaskan waters from the last week in November until the first week in February. There is also a requirement the ice be at least two inches thick before it can be detected in the visible imagery.
In weak wind regimes, IR imagery has difficulty discerning the ice edge from fog or thin stratus which can form near the ice edge. For this reason, visible imagery is preferred over IR imagery when there is no threat of ocean water freezing and the forming new ice.

Because fine ice needles form in a column of ocean water before surface ice forms, they increase the viscosity of the ocean water. This increased viscosity causes the ocean waves to be smaller and smoother for a given wind speed over a given fetch. Mariners describe this ocean surface as being “leaden.” As the water becomes colder and the ocean surface becomes smoother, ice will form at the surface. The waves will initially fracture the thin new ice and cause it to raft and ridge upon itself. This “plate tectonics” of new ice on the ocean’s surface produces a very rough feature the can be recognized in SAR imagery as a “feathery white” feature. The SAR image of Cook Inlet (Figure 3) was taken on 29 December 1998. Anchorage reported overcast skies with ceiling ranging from 9,000 to 130,000 ft. SAR imagery can detect roughness. The smoother a surface is, the blacker the object is. The rougher a surface is, the whiter an object is. Clouds and weather are not shown on this image. A large body of sea ice labeled A extends from upper east side of Cook Inlet around the East Foreland toward Kalgin Island. Dark stretches of smooth water labeled B lie on the east coast of Cook Inlet south of Kenai, on the south coast of Kalgin Island and on the west coast of Cook Inlet in Trading and Redoubt Bays.

Feathery white stripes of new ice labeled C are forming near Kalgin Island and in Trading and Redoubt Bays.

The highest waves in the Inlet are the whitish grey areas labeled D. The orderly arranged dots north of the forelands are oil platforms. One can easily discern the sea ice from the ocean water surface in the image. One cannot tell from the image alone if the dark surfaces indicating smooth surface water is caused by ice needles floating in the water column or simply a lack of wind. By comparing wind and SST observations and/or pressure gradients from surface analysis charts, the forecaster to make a logical guess. Black areas that have SST below -0.5C near areas of new ice formations are probably areas that have ice needles in the water column and will probably be the next areas to freeze if cold air remains over the area. Black areas with light winds nearby and SST above 0C will probably not freeze quickly.

Figure 3. SAR image of Cook Inlet. Copyright Canadian Space Agency

The last two Figures show how much information a SAR image can give a marine forecaster. The Lin-J sank 8 NM northwest of St. Paul Island at 2200UTC (1 PM AST) on 18 March 1999 in seas around 25 ft. The closest SAR image (Figure 5)of the area was taken at 0437 UTC (7:37 PM AST March 18) on 19 March 1999 The closest POES IR imagery (Figure 4) to the SAR image was taken at 04:55 UTC on 19 March 1999 (7:55 PM AST, 18 March 1999.). It is almost impossible to discern the ice edge north of St. Paul Island with the POES IR imagery alone.

Figure 4 . POES IR imagery of St Paul waters taken at 2200 UTC, 18 March , 1999

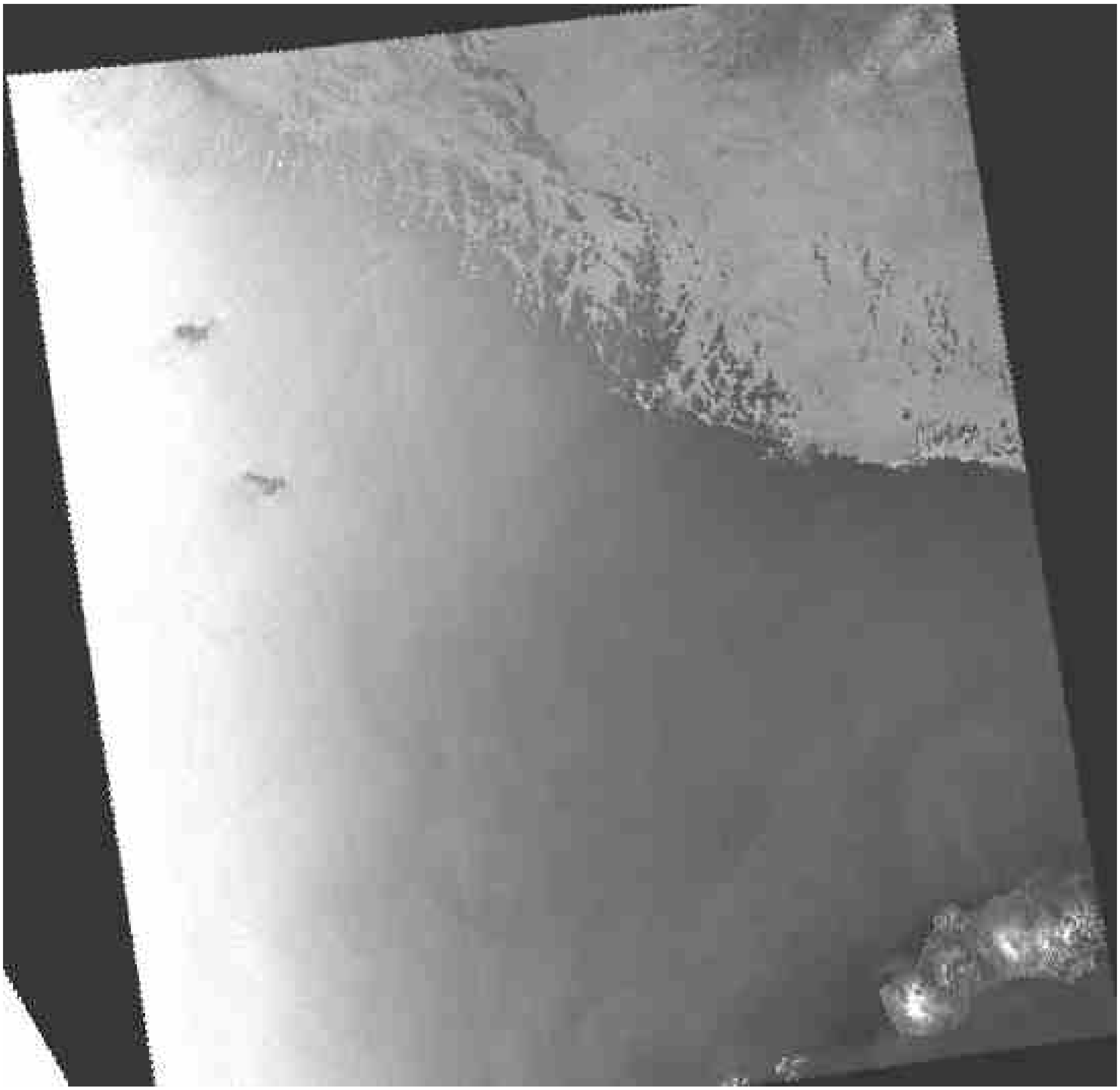

Figure 5. SAR imagery of St Paul waters at 0437 UTC, 19 March 1999. Copyright Canadian Space Agency.

The whitish areas of ocean water had waves around 25 ft. A ship about 70 NM east southeast of St. George Island reported seas of 4 ft. (The distance between St. Paul and St. George Islands is about 35 NM..) The SAR gives the marine forecaster an indication of how tight gradient of wave heights is over a relative short distance. What surprises new users of SAR images is that is easy to discern the narrow strips of sea ice even in very rough seas.

BRIEF HISTORY OF MICROWAVE IMAGERY AT ANCHORAGE WFO

1. Began receiving Dr. Robert Grumbine's SSM/I sea ice concentrations images in 1998.

2. Began receiving first limited SAR imagery in the fall 1998 with routine delivery beginning in January 1999.

3. A computer virus corrupted the software at the SAR facility in Fairbanks, AK during the late fall of 1999. Received first QuikSCAT microwave imagery in January 2000 from Paul Chang of NESDIS via the Internet.

The commercial opilio crab fishery in the Bering Sea begins on January 15 and lasts from 2 weeks to 21/2 months with an average season of one month. The average yearly death and vessel lost rate for the ten years prior to the 1995 season was 5 men dead and 2 vessels lost per season. There were seasons when no one died or season when no vessels sank but never a season that had both zero deaths and zero vessel lost.

The first commercial opilio crab fishery with both zero deaths **and** zero vessel loss was in1998 followed by 2000, 2001, 2002 and 2003.

This safety record is attributed to the following:
1. Increased efforts during safety inspections by the USCG of vessels prior to the fishing season.
2. A building of trust between the NWS and the fishing fleet so that the ice forecaster could obtain real time sea ice and marine observations from the fleet.
3. Availability of improved satellite technology to the sea ice forecaster in conjunction with the availability of improved models from the NWS, the Navy and the European Community.
4. The availability of most of the satellite imagery and model data in conjunction with the latest forecasts to the fleet via the Internet through satellite communications.

Annotated and non-annotated Microwave, visible and IR satellite imagery plus looping of visible and IR imagery are available at the Anchorage WFO's ice desk website at the url: http://pafc.arh.noaa.gov/ice.php .