

Current state of sea ice analysis for operational use US Alaska and Arctic waters.

June 30th, 2016
DRAFT VERSION 6/22/16

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Summary

In this report the UAF-GINA team identifies the current state of sea ice analysis for operational use. This report is based on UAF-GINA’s experience in the field of Arctic-specific satellite imagery, its professional relationships with sea ice researchers at the University of Alaska Fairbanks, and access to sea ice analysts at the National Weather Service (NWS). Findings of the report include recommended satellite feeds for sea ice analysis, recommended sea ice models for sea ice forecasting, and confirm the need of a trained human analyst for sea ice analysis; no automated process exists that improves on the analysis provided by human analysts. In conversations with these sea ice domain experts, the conclusion of this report is Recomendations for Sea Ice Products for Operational Users.

Operational Ice Data Products

The two primary sources for operational ice forecasting in Alaska and Arctic waters is the National Ice Center and the Alaska National Weather Service Sea Ice desk.

National Ice Center: The U.S. National Ice Center produces several ice-related products, which are updated daily and available on their website. These include:

- [NIC 1km Geotiff Products](#)
- [NIC Daily KML](#)
- [NIC Daily Ice Analysis Products](#)

The process for generating products such as the items listed above is well-documented; ice products are created by trained ice analysts using near real-time satellite data.

“NOAA/NESDIS prepares a daily snow and ice chart of the Northern Hemisphere (NH). Chart preparation is performed by a meteorologist through the inspection of visible imagery from sensors on-board geostationary satellites including the Geostationary Operational Environmental Satellite (GOES), the Meteorological Satellite (METEOSAT), and the Geostationary Meteorological Satellite (GMS), polar orbiting satellites including the Polar-orbiting Operational Environmental Satellite (POES), and imagery from the

Defense Meteorological Satellite Program's (DMSP) Special Sensor Microwave/Imager (SSM/I), as well as sea ice charts from the National Ice Center and ground weather observations."

- Bruce Ramsay, 2000 "Prospects for the Interactive Multisensor Snow and Ice Mapping System (IMS)"

The visible imagery sensors for sea ice analysis that Ramsay references above (and associated sea ice analysis practices and procedures) have since been updated. In recent years products such as Day Night Band (DNB) and long range infrared (LWIR) have gained importance as tools for winter months when visible spectrum sensor products lose their efficacy.

National Weather Service - The National Weather Service (NWS) Sea Ice Program also produces daily sea ice analysis maps which are available on their website:

- [NWS Daily Sea Ice Analysis Products](#)

Like the NIC, the NWS' sea ice maps are produced by a meteorologist from near real time (NRT) satellite data products, synthetic aperture radar (SAR) imagery, weather model data, and any other sources as they are available. To create these products NWS uses near real time satellite imagery from GINA, mainly from VIIRS sensor on Suomi NPP (SNPP) and MODIS sensor on the AQUA and TERRA satellites. SAR imagery is also used because it is not affected by cloud cover, although there are limits to accessing data and the resulting products are more difficult to interpret. The Global Forecast System (GFS) model is used to provide weather model data, as it is consistent for the areas with sea-ice.

Human vs. Automated Sea Ice Products

To date no effective automated sea ice products exist. While the National Ice Center has been working on automating sea ice products, it has not yet achieved this objective. While it may be possible to automate sea ice products for areas near the North Pole and in the high latitude Arctic, in the marginal ice zone where humans and property are at risk, human analysis of satellite imagery and weather models remain the most reliable and effective process for creating sea ice products.

"We do not have the technology to automate the ice analysis to a level that is safe for mariners that work in the marginal ice zone."

- Kathleen Cole, retired National Weather Service Sea Ice Desk

Components of National Sea Ice Products

The key components used to generate national operational sea ice products are focused on satellite imagery and operational model data.

Satellite Imagery used by Sea Ice Analysts:

- MODIS
 - Natural color
 - MODIS land cover, bands 7,2,1

- VIIRS
 - Day night band (DNB)
 - Natural color
 - False color, bands 3,2,1
- SAR - Synthetic Aperture Radar
 - Multiple satellite based SAR sensors are available. SAR imagery is not affected by cloud cover. Sea ice analyst has to be familiar with SAR imagery as it is different than visible spectrum imagery and requires different interpretation skills
 - Note: Currently access to SAR based datasets is not easily available for near realtime integration into Sea Ice analysis due to a variety of challenges:
 - Restrictive licensing and ownership of SAR datasets
 - Limited automated delivery into operational environments for use by ice analysts.
- Additional sensors:
 - Need to use sensors like SNPP VIIRS Day-night-band (DNB) and longwave infrared (LWIR) during winter months (LWIR) during winter months due to visible sensor limitations in middle of winter.
 - DMSP OLS sensor similar to DNB but at coarser resolution and not currently available for operational sea ice monitoring
 - Potential: microwave sounders
 - Coarser resolution visible spectrum sensors on Metop-B and POES (AVHRR)

Operational Models used by Sea Ice forecasters at NWS and NIC:

- GFS model
- NAM model
 - Doesn't cover the high Arctic or the Bering Sea

The “natural color” imagery is used as it is easy for the user interpret the data, as it is what the user would expect to see from space, if viewed using the human eye. The “false color” imagery is used, as the presentation makes it easy to differentiate between clouds and ice or snow. VIIRS day night band is used as it provides a view of the sea ice during periods of darkness when the visible bands are not present. SAR has the advantage of being unaffected by cloud cover, but is more challenging to interpret.

Recommendations for Creating Effective Sea Ice Products for Maritime Operational Users

The Geographic Information Network of Alaska (GINA) believes in creating products that effectively address user needs. This requires products to be delivered consistently, in the area of interest, at the resolution required, and at the smallest possible rate of refresh given the technologies available.

To this end, GINA has consulted with NWS satellite liaison Eric Stevens, sea ice expert Kathleen Cole, NWS Sea Ice Desk, NOAA leads Eugene M Petrescu and premier sea ice researchers Andrew Mahoney and Hajo Eicken recommends the following framework for creating sea ice products to fit maritime operational user needs:

- Product is clearly and easily presented for ease of decision-making, emphasizing use of visual representation

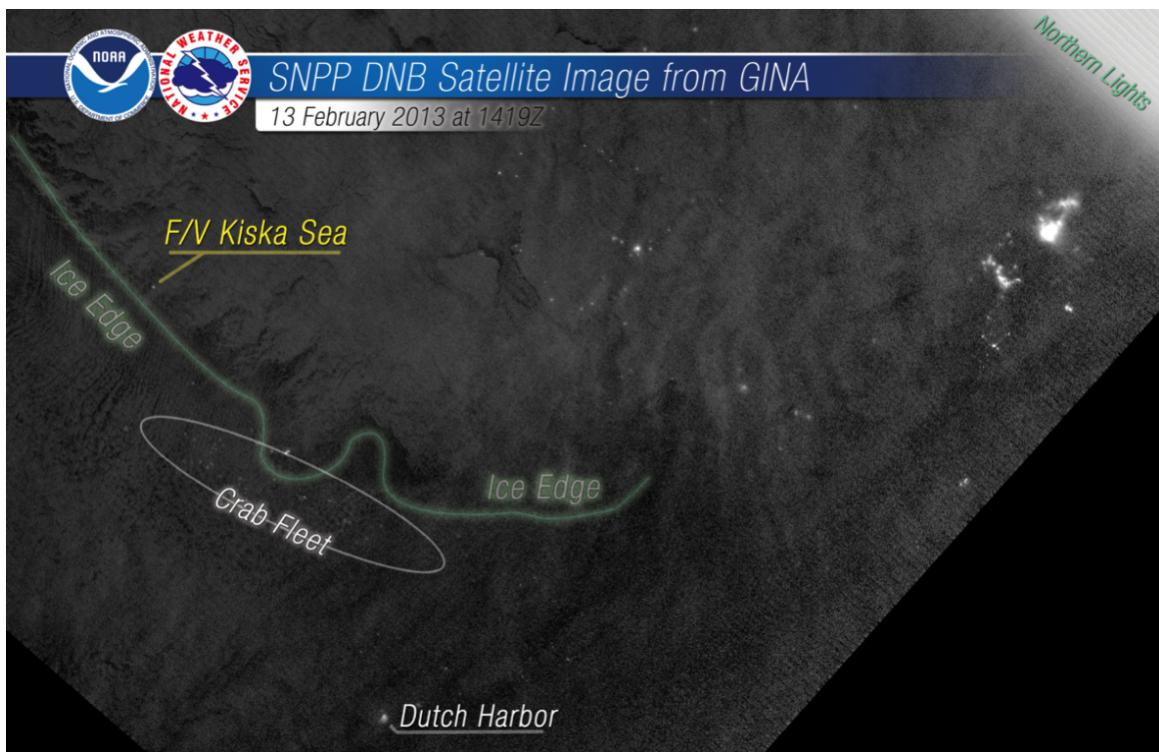
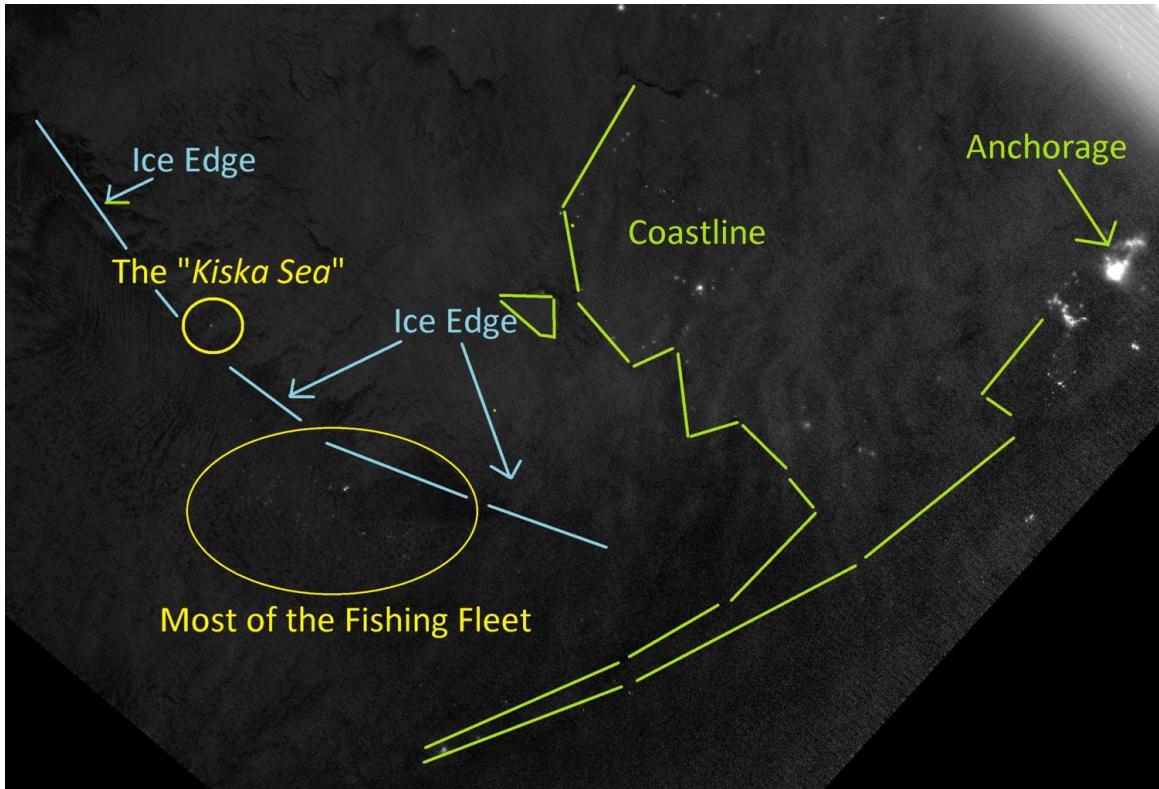
- Information used to make sea ice product is best available, using near real time satellite imagery and operational weather / ocean models
- Product does not require decision-makers to be sea-ice specialists
- Product limits use of jargon, measurement units, classifications or scientific terminology that is not commonly used by maritime operator
- As much as possible, the product presents the maritime operator with the information they need to know, where they can safely operate their ship. No Ice, Ice you can drive through, Ice you cannot drive though. (Product emphasizes ship and personnel safety)
- Product focus on the area people are actually operating in, the marginal ice zone.

Given the requirements listed above, GINA recommends a sea ice product specifically tailored to maritime operator needs that is comprised of a consistently updated, most-recent satellite image focusing on the area in question with annotation by an experienced sea-ice analyst to indicate key concerns for operators and decision-makers: thickness of nearby sea ice and direction of ice movement over time.

Imagery Examples

SNPP Day Night Band (DNB) for Operational Use

NWS Sea Ice desk map using the SNPP VIIRS DNB (Day Night Band) to identify fishing fleet and a lost boat via the lights on the boat.

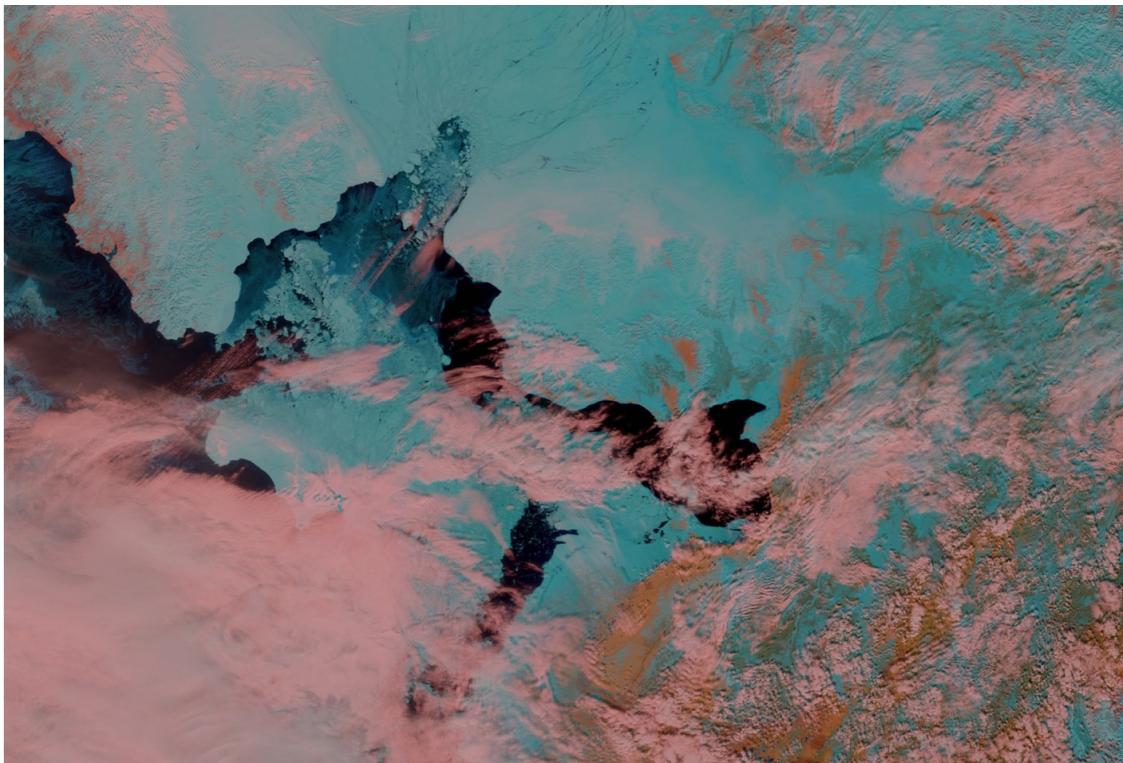


SNPP VIIRS imagery from GINA

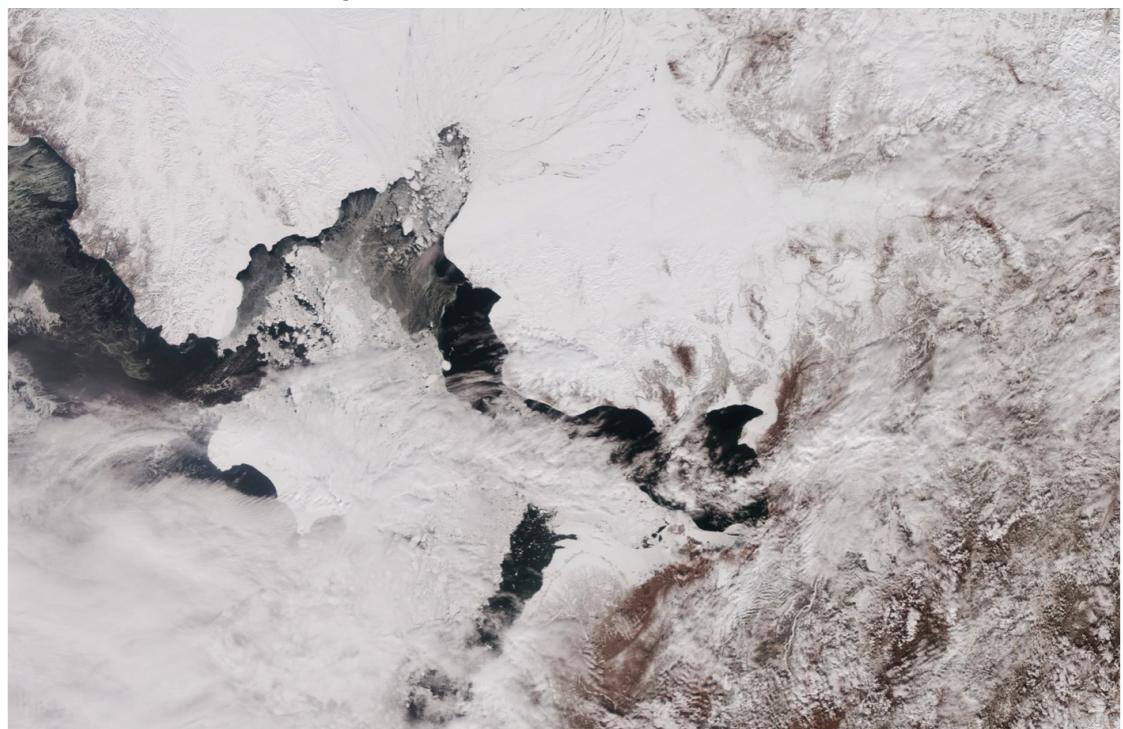
“Landcover” (bands 3,2,1) is differentiates between ice/snow (blue) and cloud (pink)

Example: Suomi NPP VIIRS “Natural Color” RGB product.

A custom RGB band combination that causes snow and ice to appear blue and clouds pink. A key product used by Alaska NWS Sea Ice desk.

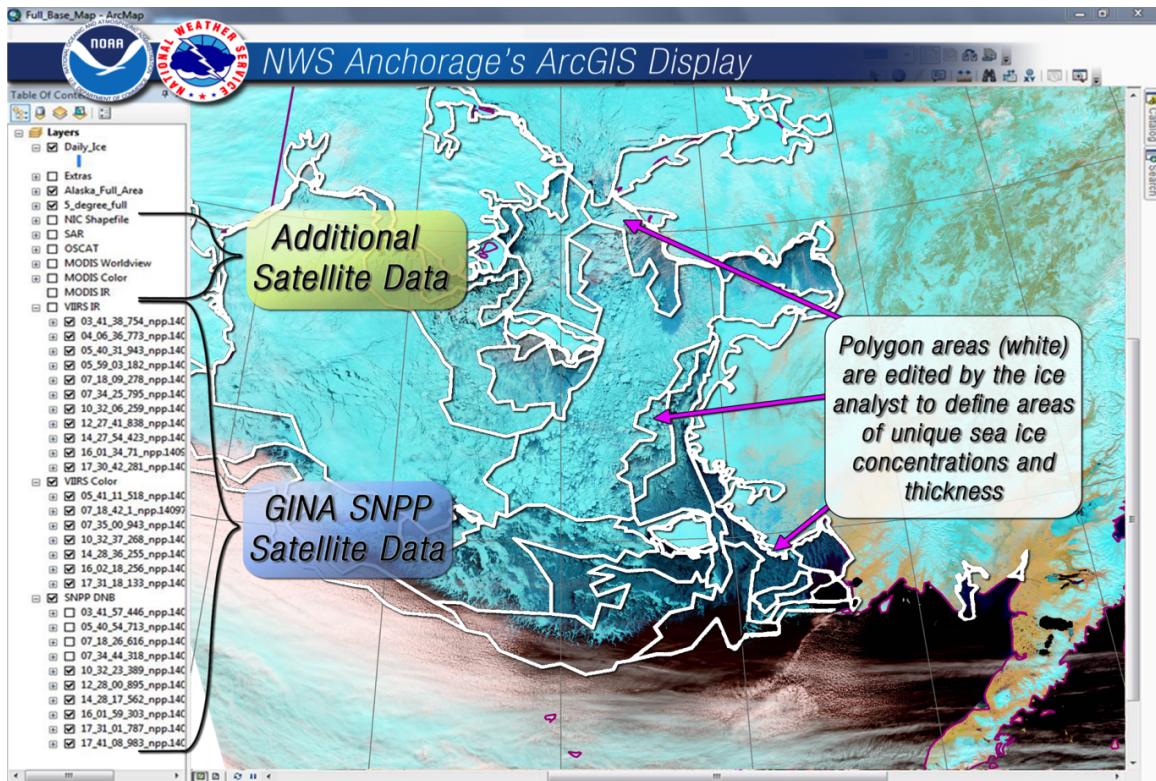


Same SNPP VIIRS scene using standard visible spectrum bands for RGB:



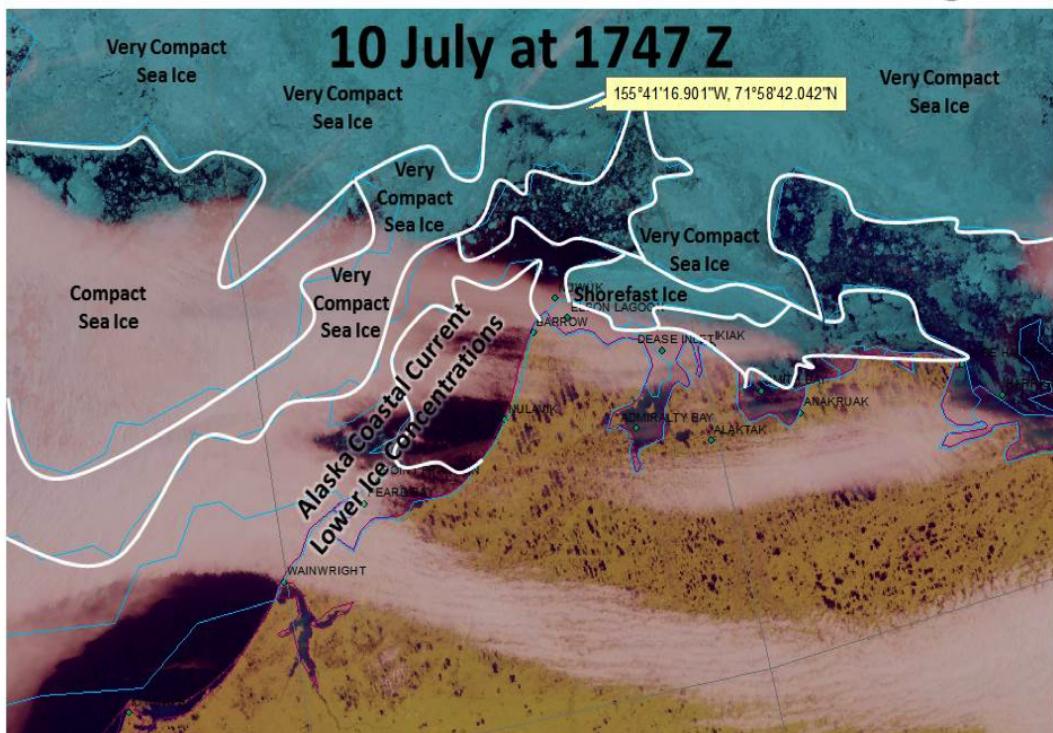
Examples: Alaska NWS usage of GINA near real time VIIRS products

Screenshot of Alaska NWS ArcGIS ice analysis screen showing their environment with GINA satellite imagery and current sea ice concentrations.

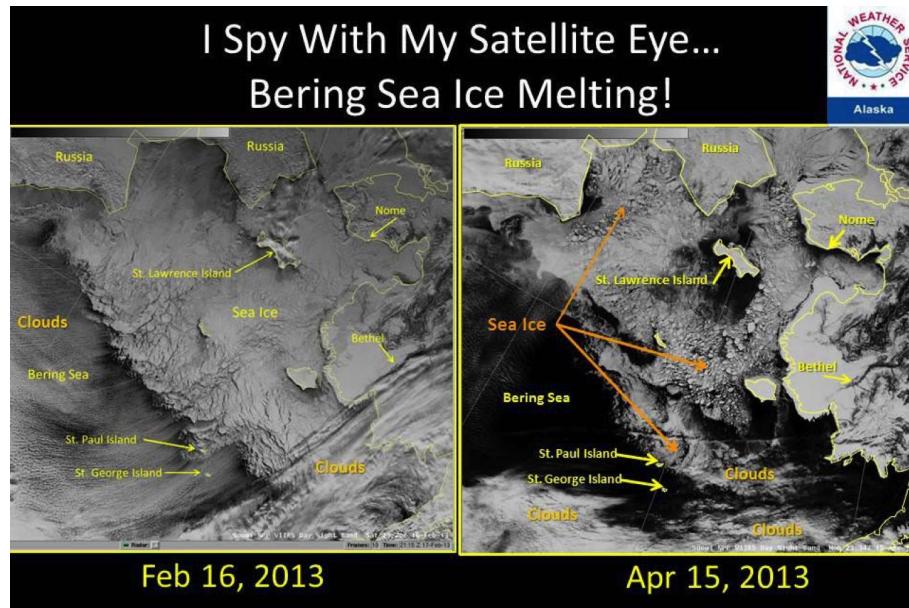


Sea ice analysis report by Alaska NWS for July 2015

Suomi NPP False Color Satellite Image



Alaska National Weather Service public education material by Sea Ice desk explaining the use of satellite imagery to show 2013 sea ice breakup.



Daily Sea Ice Concentration Analysis map.

