Norwegian Meteorological Institute
met.no

Norwegian Ice Service

Key Facts for the Season 2010/11

Nick Hughes

Leader of the Norwegian Ice Service

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Signe Alvarstein and Håvard Larsen

Introduction

- WMO Publication No. 574 "*Sea Ice Information Services of the World*"
- 2 Norwegian Ice Services
  - Norwegian Meteorological Institute ("met.no" after http://www.met.no/)
    - Represented at IAW-3 by Nick Hughes, Signe Alvarstein and Håvard Larsen
  - Norwegian Coastal Administration (Kystverket)
    - Handles ice information for southern Norway (Oslofjord and Skagerrak)
    - Customer of met.no

- Organisation
  - History
  - Employees
  - Ice Chart Production
- Data Acquisition
  - Radarsat-2
  - Envisat ASAR
  - AMSR-E
  - OSI SAF
  - AVHRR and MODIS
- Output Products
  - Ice Charts (Arctic and Antarctic)
  - METAREA-XIX Ice Edge
- Forecasts and Forecast Methods
- Publications
- Mailing and Internet Addresses

History

Isfjord Radio on Svalbard

- First organised sea ice reporting started in 1930, with reporting from Isfjord Radio on Svalbard, and continued until WW2
- Ice reporting from Bjørnøya and Isfjord Radio resumed in 1963 by Norwegian Polar Institute
- IR images started to be used from the winter of 1969/70 when met.no started to download analogue satellite images
- met.no took over the Ice Service (Istjenesten) in April 1970 with weekly ice chart production
- In June 1997 Ice Service moved to the Forecasting Division for Northern Norway (Vervarslinga for Nord-Norge) and production moved to a digital format with updating every weekday
- First SAR (Radarsat-1) images used in 2005
- Weekly Antarctic (Weddell Sea and Peninsula) chart production started in 2009/10 season

Forecasting Division for Northern Norway, Tromsø

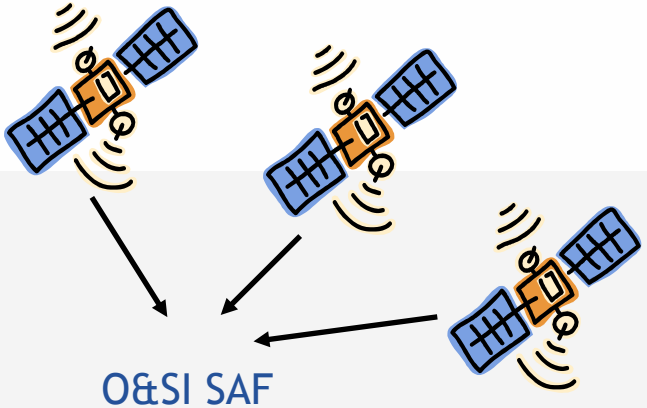
Employees

- Leader of the Ice Service
  - Nick Hughes

- Ice Analysts
  - Trond Robertson
  - Signe Alvarstein
  - Håvard Larsen
  - Odd Ivar Olsen
  - A.N. Other (starts July)

- Research Group
  - Frode Dinessen
  - Keguang Wang

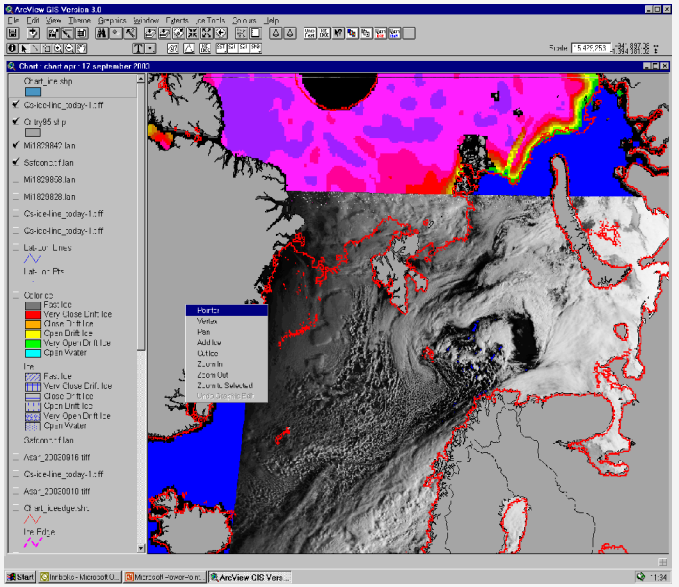
Ice Chart Production



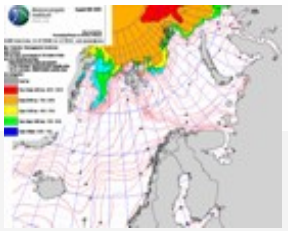
O&SI SAF
SSM/I, SSMIS and AMSR-E
AVHRR/MODIS
SeaWinds
Envisat ASAR
Radarsat-1/2 SAR

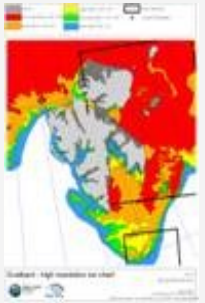
Ice forecast
Weather forecast
Other observations

ArcView (GIS)



Ice Charts

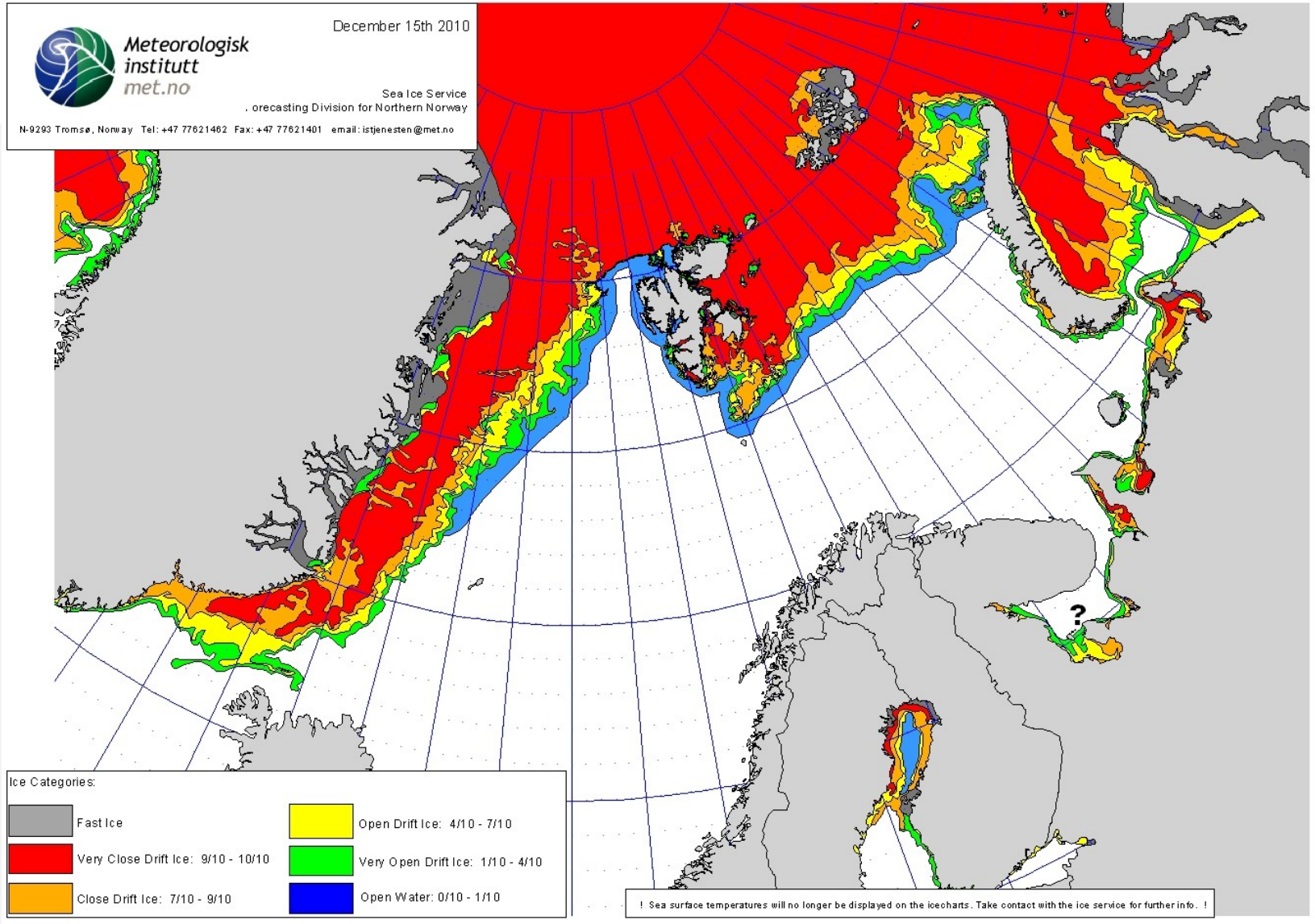




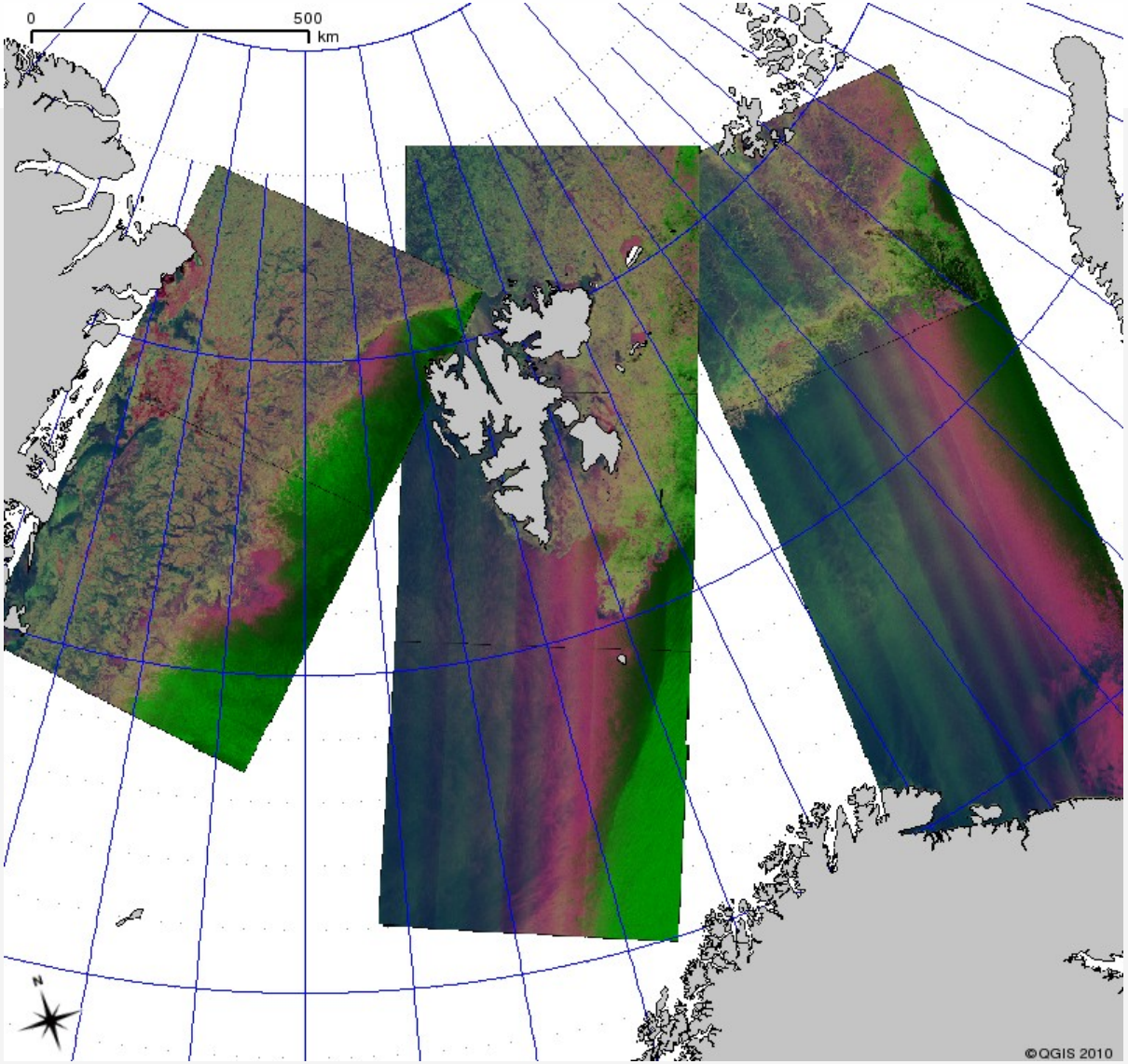
Internet, Fax, Radio,
E-mail, Post, Satellite

Weather model
Fishing boats
Cruise ships
Research vessels
Yachts
Coastguard
Skidoo drivers
Rescue missions
Insurance companies
Researchers
Oil/Gas
Explorers

Typical Ice Chart

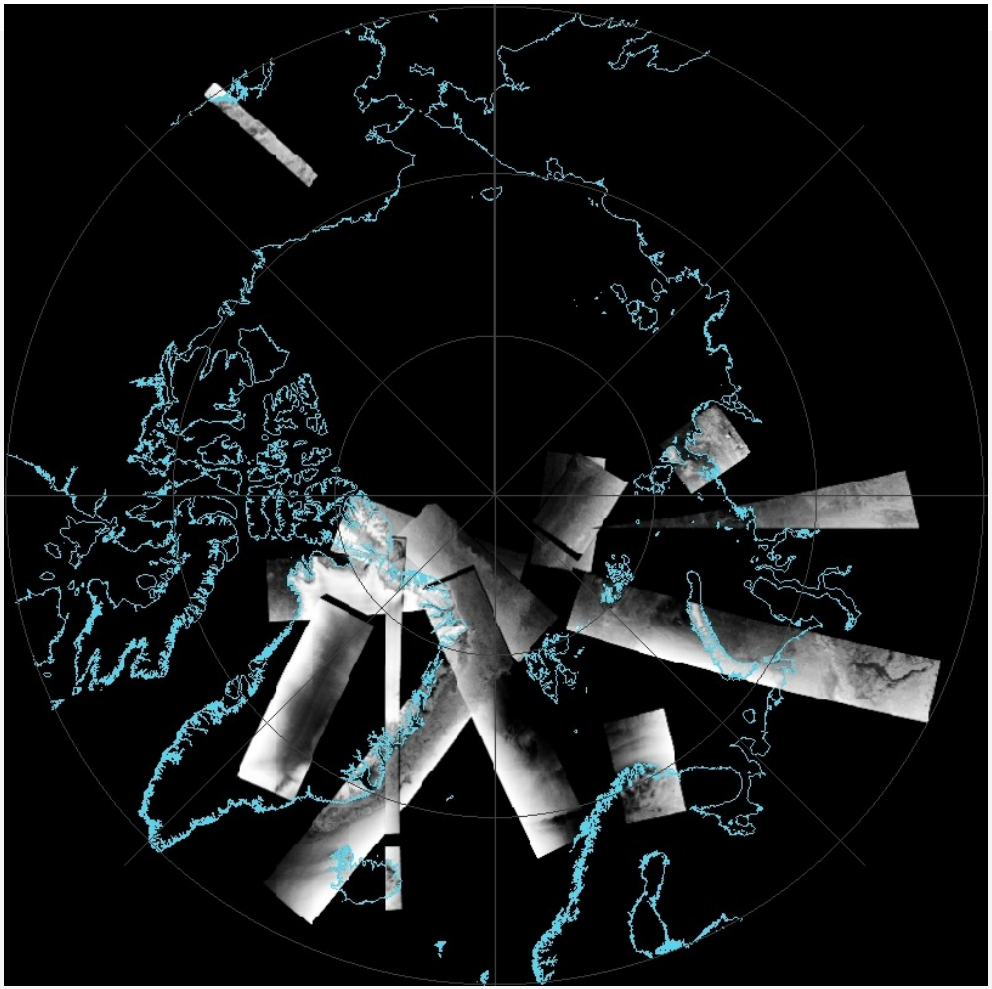


Radarsat-2 Images



- Radarsat-2 dual-polarisation images for 15 December 2010
- RGB composite
  - Red = HH
  - Green = HV
  - Blue = HH – HV
- Use of RS2 for ice charting started in September 2008
  - HV provides better open water detection
- Image archive
  - > 1,500 images
  - Coverage mostly in the region shown
    - Also datasets for Northern Sea Route, North West Passage, and Antarctica

Envisat ASAR

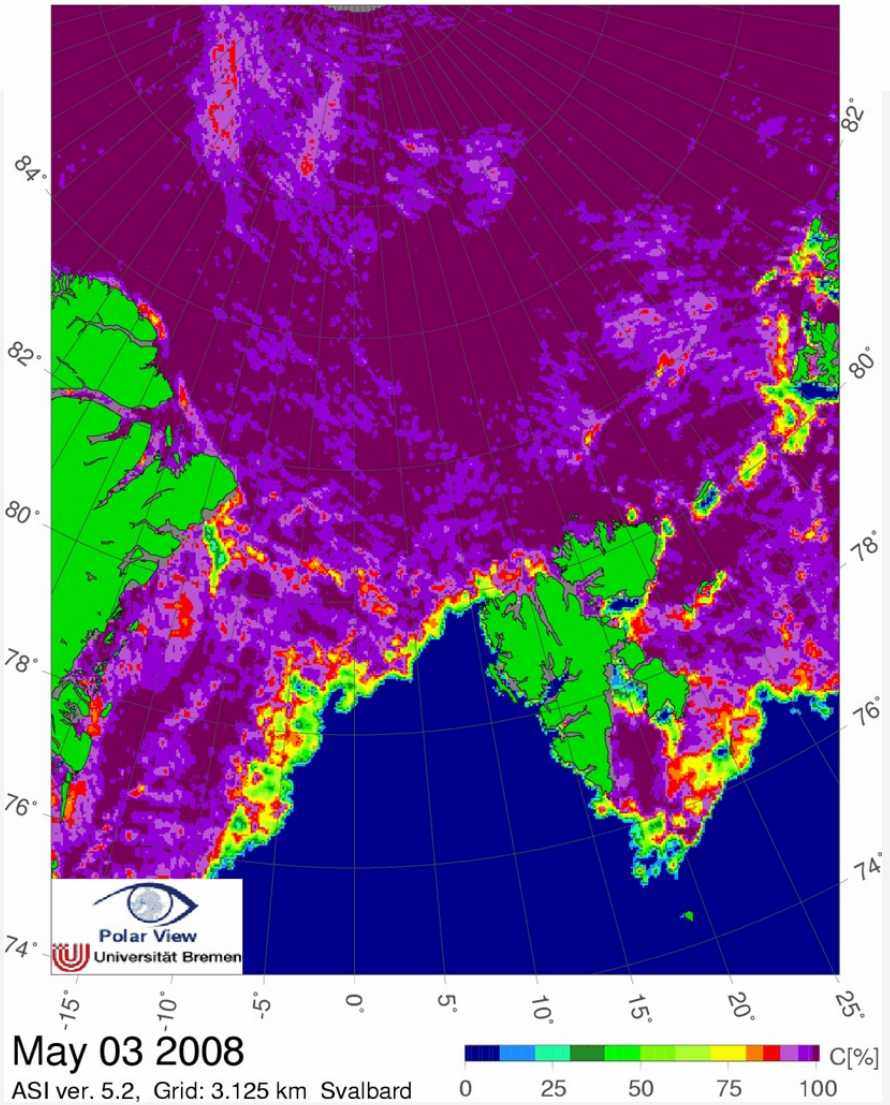


- Specifications
  - Active radar in C-band 5.331 GHz
  - Resolution depends on operating mode
    - 1km Global Monitoring
    - 125m Wide Swath
    - 25m Alternating Polarisation
    - 12.5m Imaging
  - Single polarisation (HH or VV) or alternating (HH+HV, VV+VH)
- Data can be utilized for a wide range of uses, and in Tromsø there are research institutions working on
  - Ship detection
  - Wave and wind detection
  - Ice analysis

AMSR-E

(Advanced Microwave Scanning Radiometer – EOS)

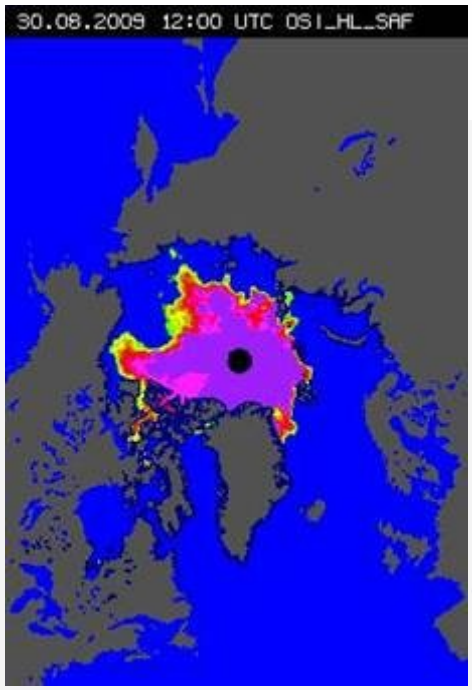
- Instrument onboard NASA's Aqua EOS satellite
  - 12 channels
    - 6 frequencies ranging from 6.9 to 89.0 GHz, H and V polarized
  - Approximately double the resolution of SSM/I
    - 6.25 km for 89.0 GHz channels
  - Precursor to future advanced passive microwave sensors
- University of Bremen produces ice concentration data that the ice service uses for ice charting



OSI SAF

The EUMETSAT Network of Satellite Application Facilities

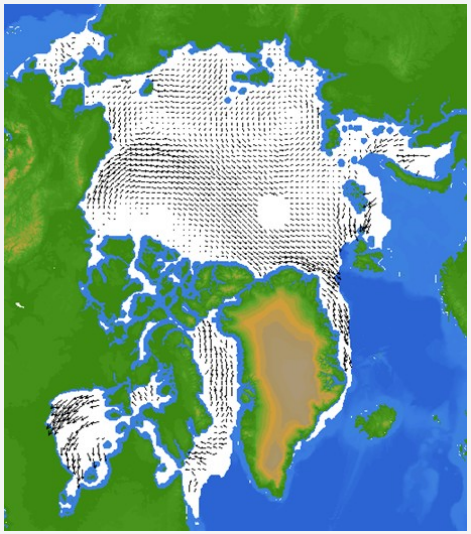
OSI SAF
Ocean and Sea Ice



Ice Concentration

Ice Type

Ice Edge


Ice Drift

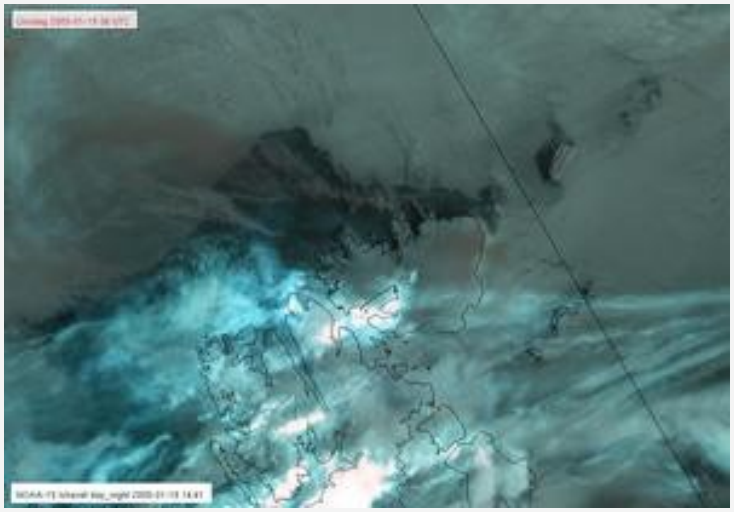
- Coordinated by EUMETSAT
- High Latitude Processing Centre
  - met.no Oslo (http://saf.met.no/)
  - Generates sea ice concentration, type and edge products

- Generated automatically daily
- Based on satellite data from SSM/I and ASCAT data
- Resolution 10 km

AVHRR

(Advanced Very High Resolution Radiometer)

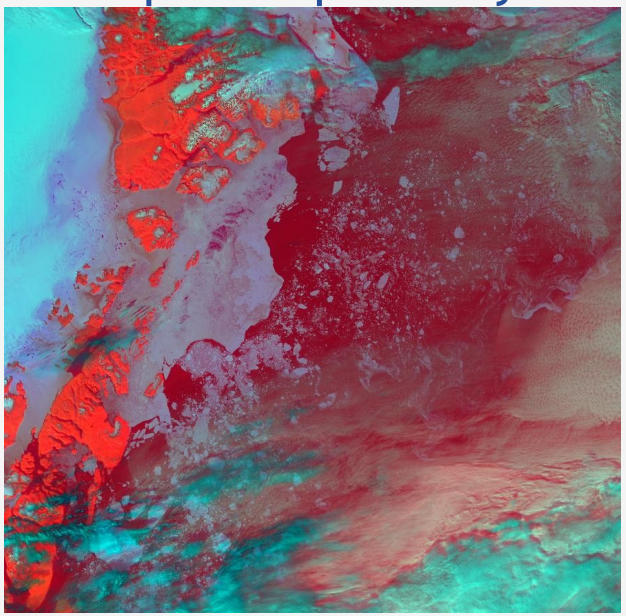
- Standard sensor on NOAA meteorological satellites
  - Latest version is 6 channels covering visual and infrared
  - 1km resolution



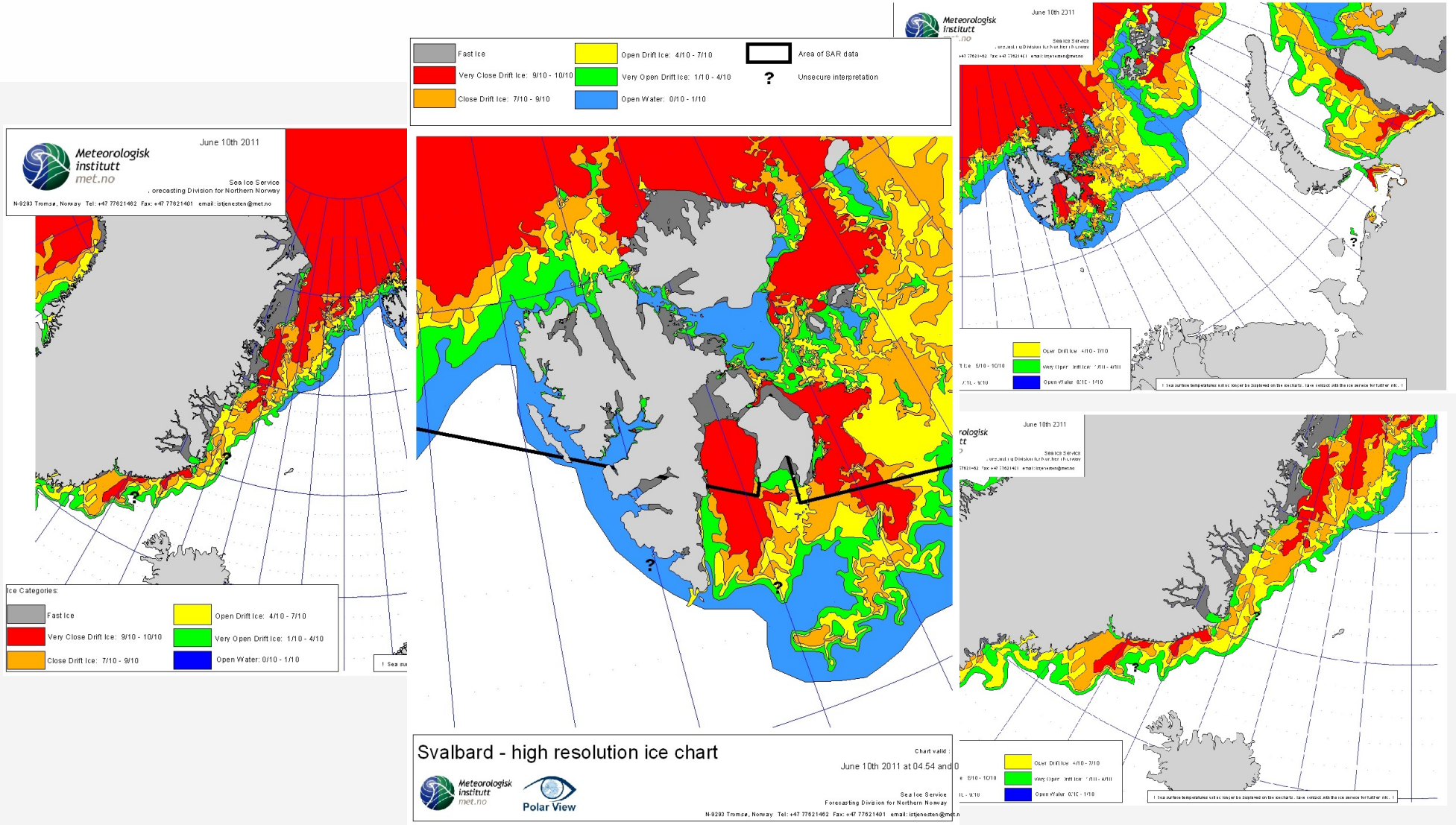
MODIS

(Moderate Resolution Imaging Spectroradiometer)

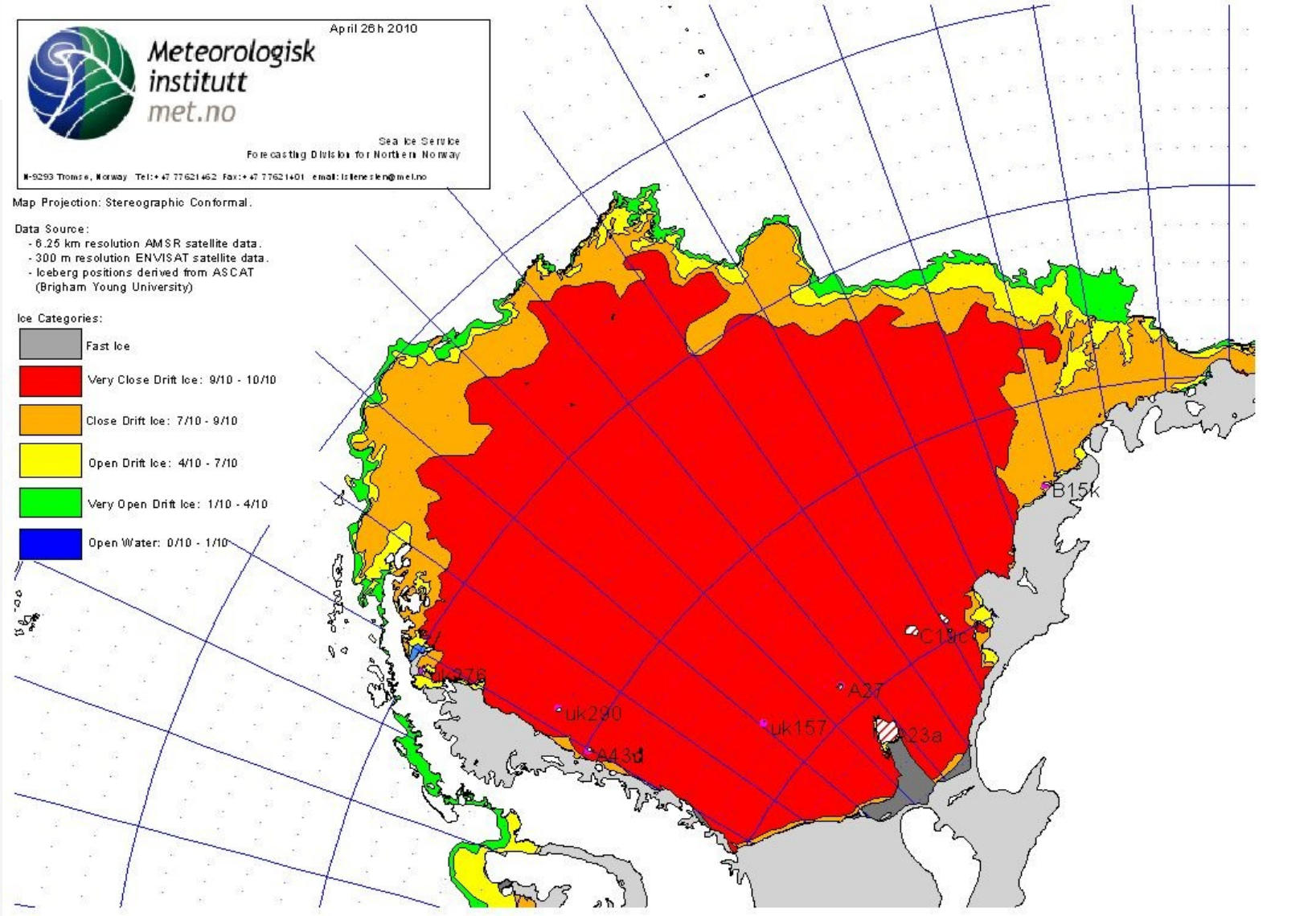
- Sensors on NASA EOS Aqua and Terra satellites
  - 36 spectral bands covering visual and infrared
  - 1km, 500m and 250m resolution
- Ice service uses data from the Rapid Response System



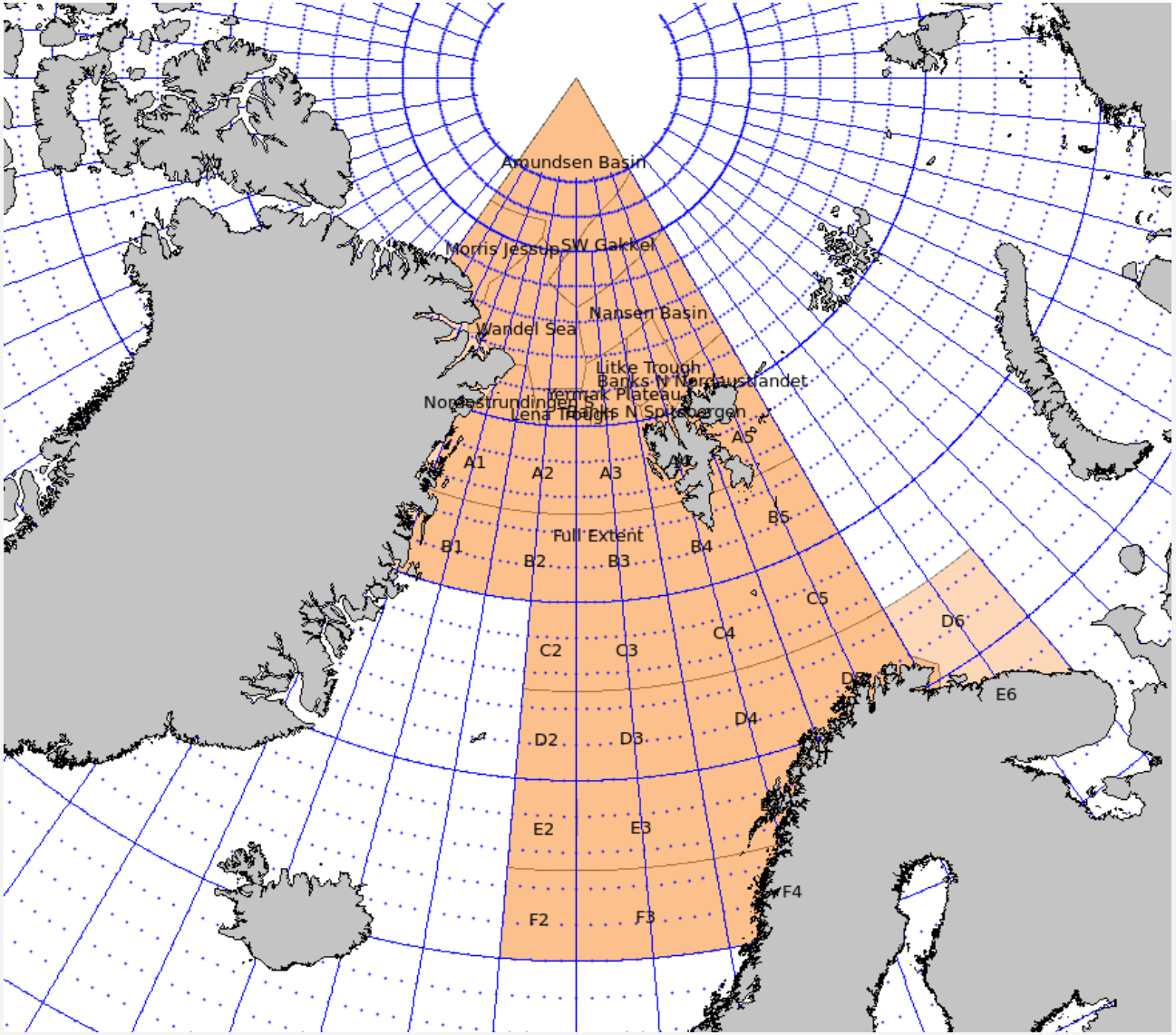
Output Products - Ice Charts



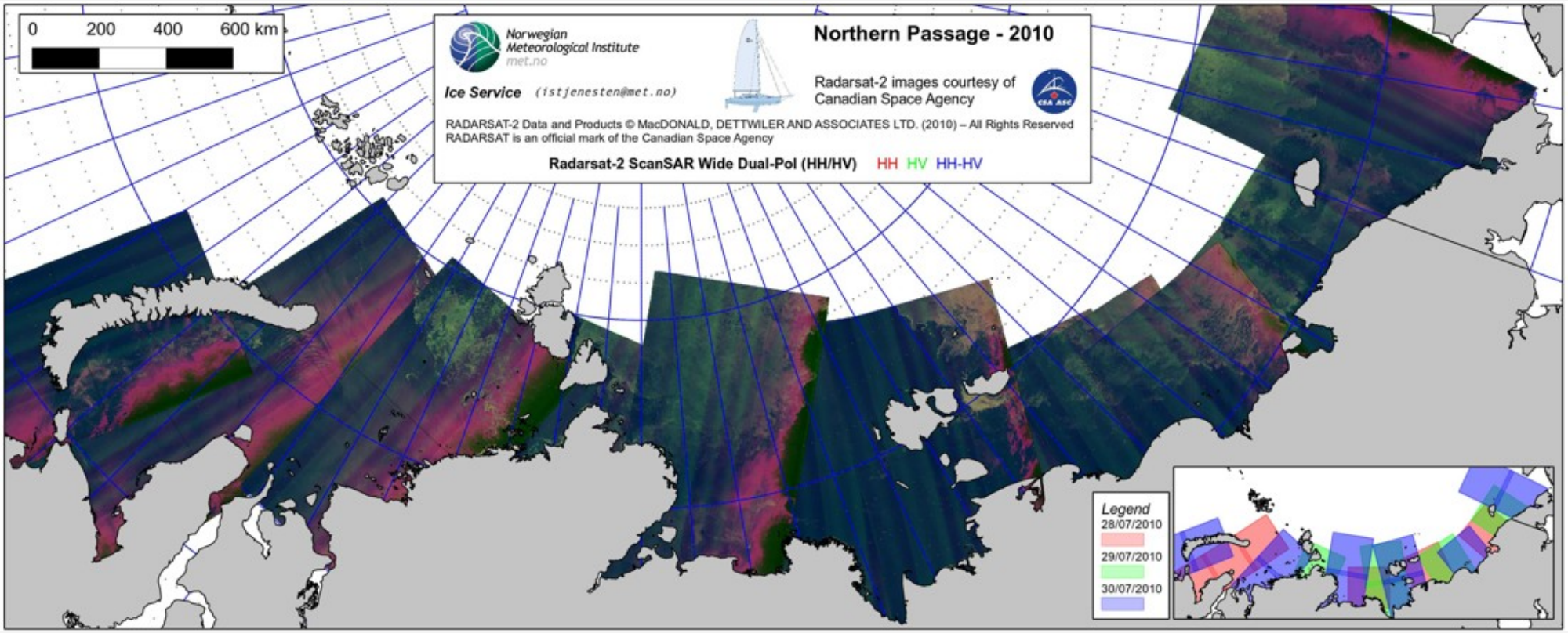
Antarctic Ice Charts



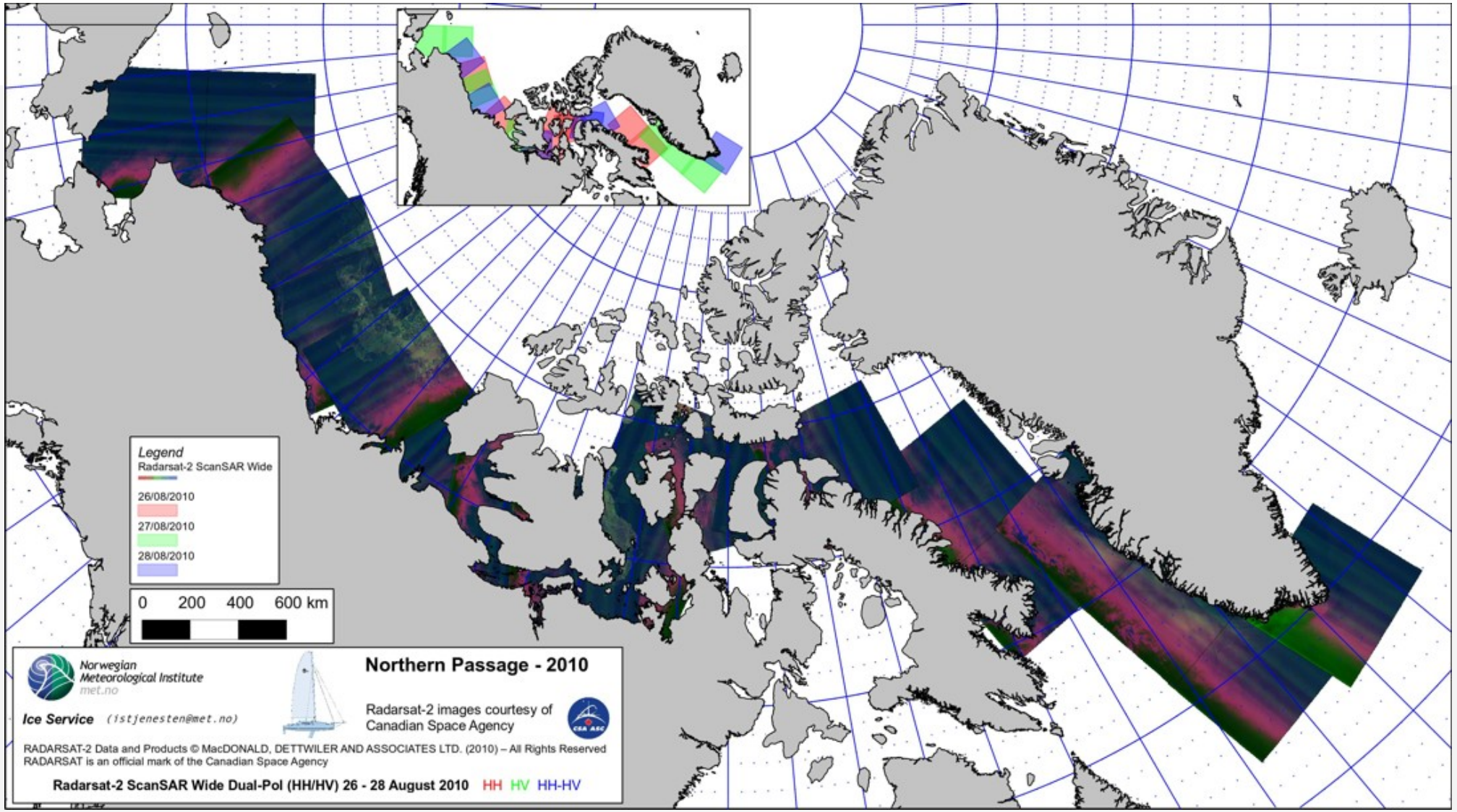
METAREA-XIX


Amundsen Basin
Morris Jessup
SW Gakkel
Nansen Basin
Wandel Sea
Litke Trough
Banks N Nordaustandet
Yermak Plateau
Lena Trough
Banks N Spitsbergen
A1
A2
A3
A4
A5
B1
B2
B3
B4
B5
Full Extent
C2
C3
C4
C5
D2
D3
D4
D6
E2
E3
E6
F2
F3
F4

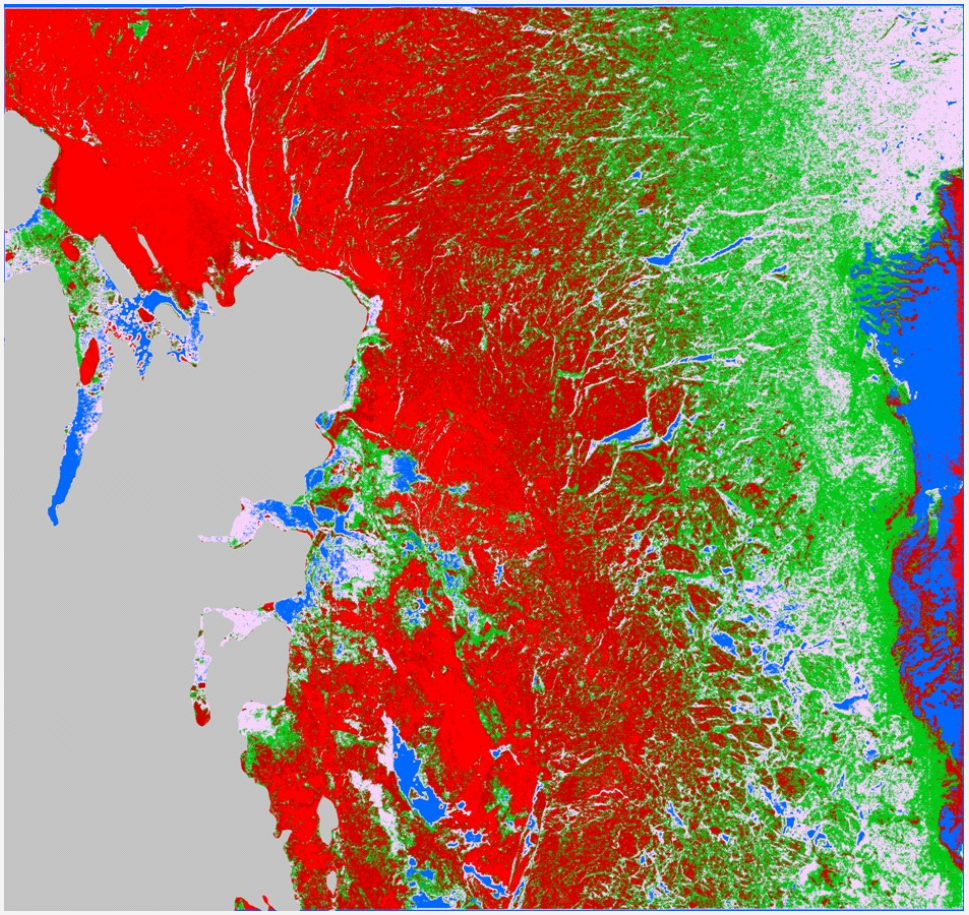
Customer Products - Northern Sea Route



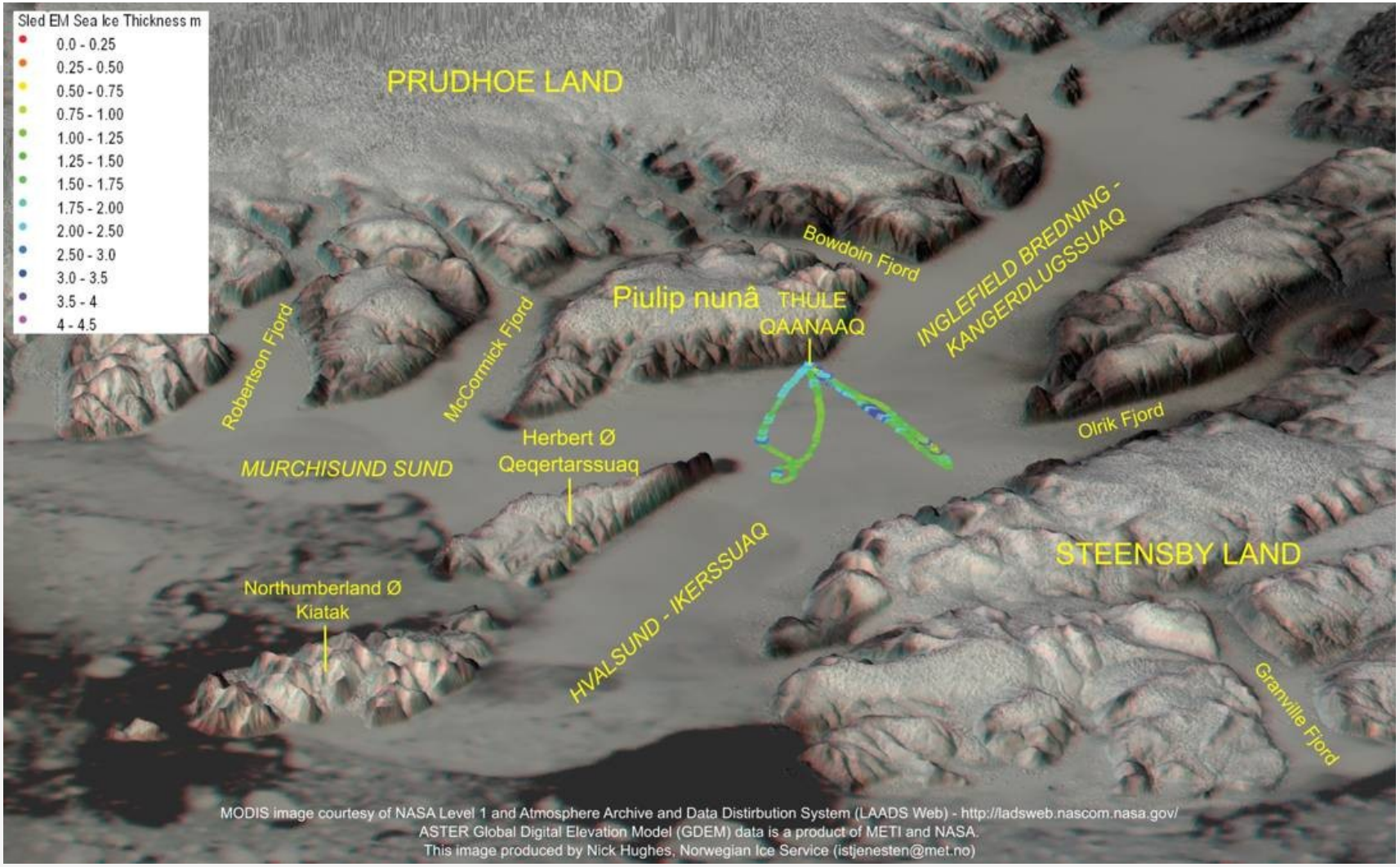
Customer Products - North West Passage



Customer Products – Multi Year Ice Mapping



Fusion and Presentation of Different Sea Ice Information Sources



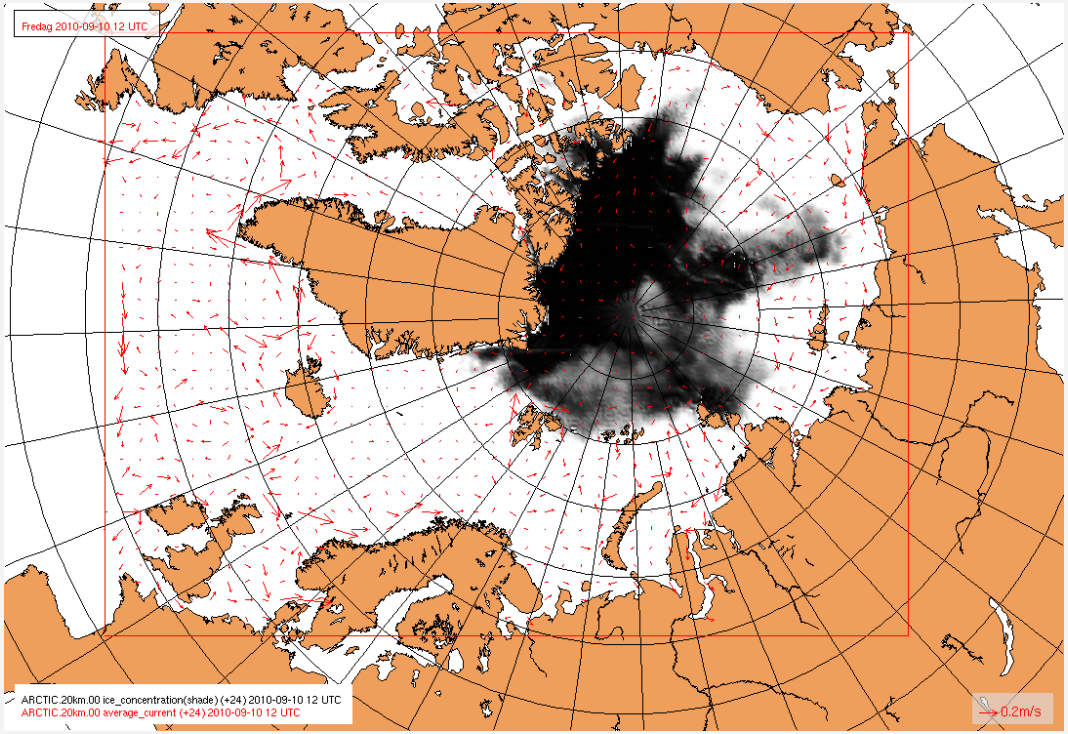
Forecasts and Forecast Methods

- MI-IM (Røed and Debernard, 2004) (RegClim; Damocles; SatHav-is)
  - EVP dynamics
  - 1 ice layer with prognostic internal energy + insulating snow cover
  - Coupled to MIPOM, and to MICOM as part of the ORCM
  - Nudging of ice concentration in MI-IM
- CICE, v4.0 and 4.1 (Hunke and Lipscomb, 2010) (NorClim; iAOOS; ACCESS)
  - EVP dynamics
  - 5 thickness cathegories, 4 levels, 1 snow layer
  - Part of the NorESM, iAOOS: coupling to ROMS
- ROMS-ice (Budgell, 2005) (RegClim; NorClim; iAOOS; myOcean)
  - Based on 2003 version of MI-IM, somewhat simpler thermodynamics, but more advanced coupling to ocean (incl. double diffusive effects when ice melts)
  - No assimilation
- TOPAZ (MyOcean)
  - EVP (CICE solver on a B-grid)
  - Based on Drange and Simonsen (1996), Semtner 0-layer thermodynamics
  - Advanced assimilation based on EnKF
- FRAMPS (Istjenesten)
  - Nested fine resolution model developed by Keguang Wang
  - http://polarview.met.no/regs/f24.png

MI-IM

"Meteorological Institute's (met.no's) Ice Model"

- Full description
  - Røed and Debernard, 2004
- Used in the RegClim, Damocles and SatHav-Is projects
- Elastic-viscous-plastic (EVP) dynamics
- 1 ice layer with prognostic internal energy + insulating snow cover
- Coupled to
  - MIPOM
    - Meteorological Institute's Princeton Ocean Model
  - MICOM (as part of the ORCM)
    - Miami Isopycnic Coordinate Ocean Model
    - Oslo Regional Climate Model
- Nudging of ice concentration in MI-IM

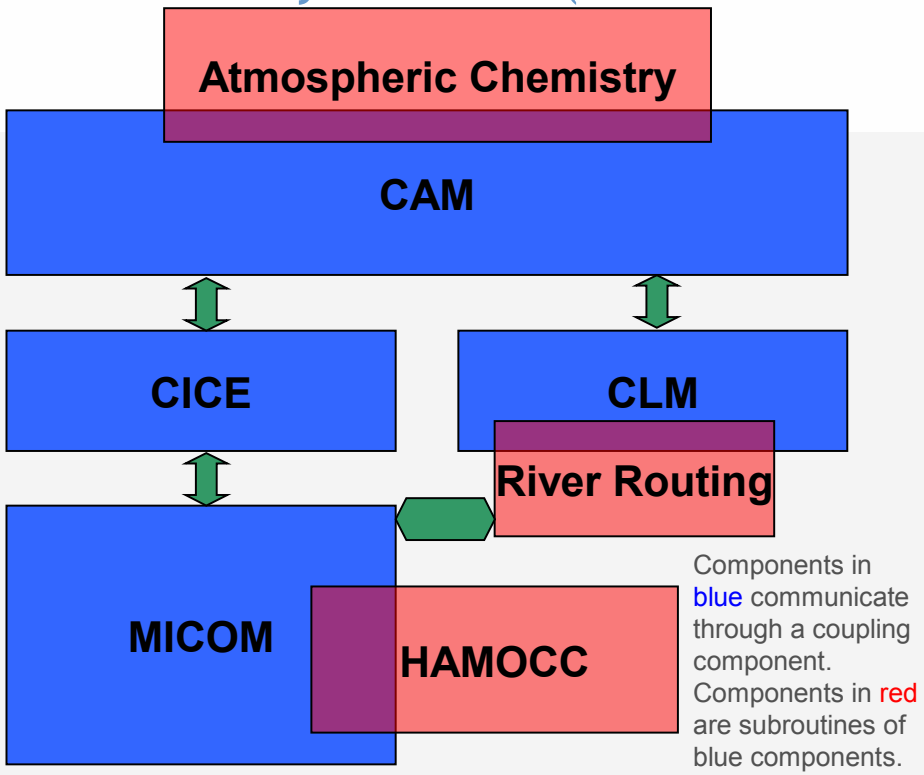


Arctic.20KM, 24 hour forecast sea ice concentration and surface current valid 1200 UTC, 9 September 2010.

Røed and Debernard, 2004 - http://www.met.no/filestore/MI-IM-Documentation.pdf

CICE

A Community Ice Code (Los Alamos Sea Ice Model)



NorESM framework and model components.

- Description of CICE v4.0 and 4.1
  - Hunke and Lipscomb, 2010
- Used in the NorClim, iAOOS and ACCESS projects
- Elastic-viscous-plastic (EVP) dynamics
- 5 thickness categories
  - 4 ice levels
  - 1 snow layer

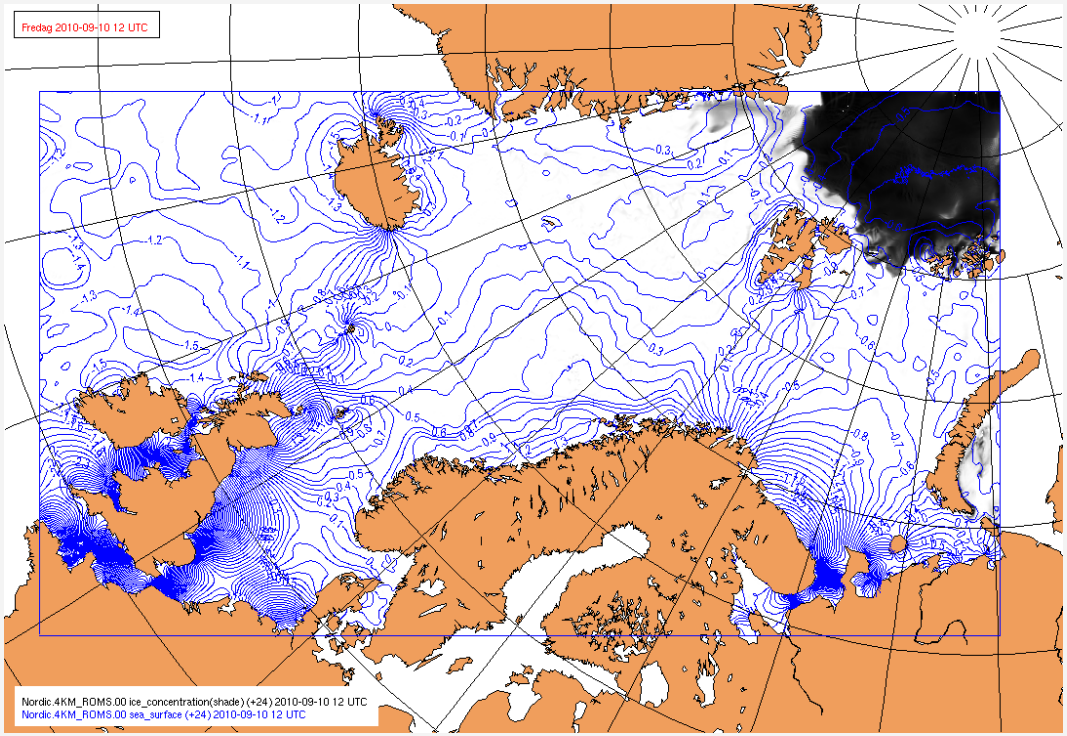
- Current work as part of the NorESM and iAOOS
  - Coupling to ROMS
  - Regional Ocean Modelling System

Hunke and Lipscombe, 2010 - http://oceans11.lanl.gov/trac/CICE/raw-attachment/wiki/WikiStart/cicedoc.pdf

ROMS-ice

Regional Ocean Modelling System - Ice

- Description in
  - Budgell, 2005
- Used in the RegClim, NorClim, iAOOS, and MyOcean projects
- Based on 2003 version of MI-IM
  - Somewhat simpler thermodynamics
  - More advanced coupling to ocean
    - Including double diffusive effects when ice melts
- No data assimilation

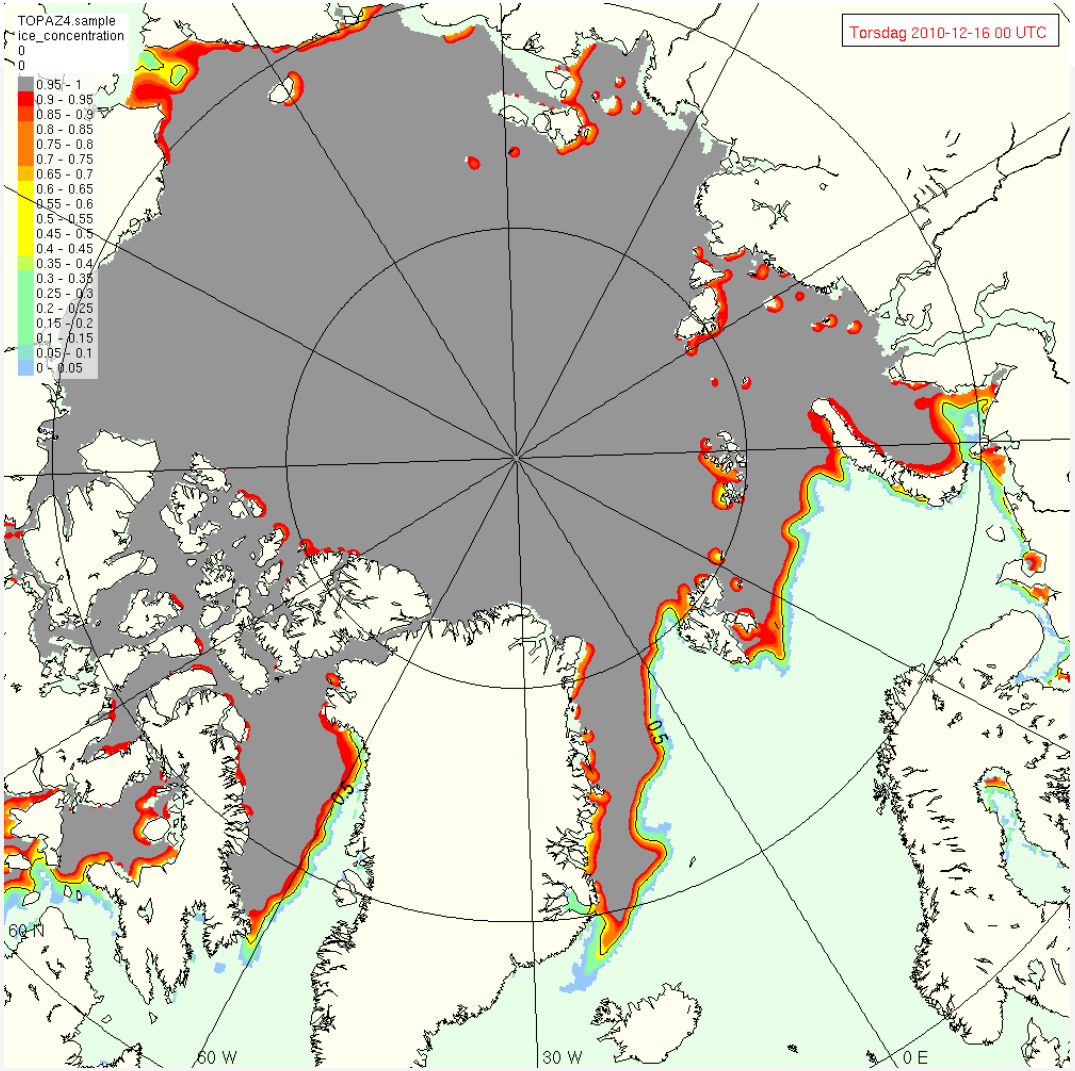


Nordic.4KM-ROMS, 24 hour forecast sea ice concentration and sea surface height valid 1200 UT, 9 September 2010.

Budgell, 2005 -
http://www.myroms.org/Papers/Budgell_od.pdf

TOPAZ

"(Towards) an Operational Prediction system for the North Atlantic European coastal Zones"



- Used in the MyOcean project
- Elastic-viscous-plastic (EVP)
  - CICE solver on a B-grid
    - Bentsen et al, 1999
- Semtner 0-layer thermodynamics
  - Drange and Simonsen, 1996
- Advanced data assimilation based on the Ensemble Kalman Filter (EnKF)
  - Lisæter et al, 2003

Bentsen et al, 1999 - http://journals.ametsoc.org/doi/abs/10.1175/1520-0493%281999%29127%3C2733%3ACTOASU%3E2.0.CO%3B2

Drange and Simonsen, 1996 -

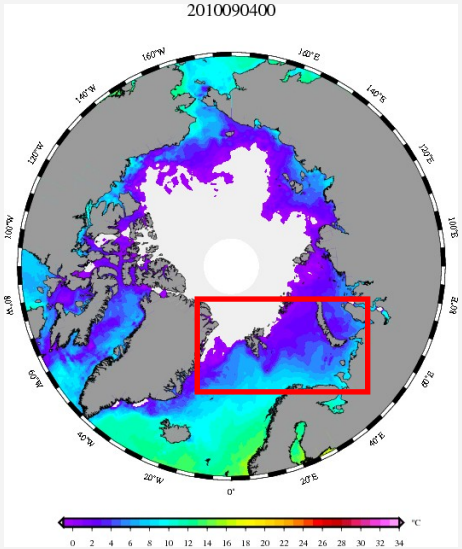
Drange, H. and K. Simonsen (1996): Formulation of air-sea fluxes in the ESOP2 version of MICOM, Technical Report, 125, Nansen Environmental and Remote Sensing Center, Bergen

Lisæter et al, 2003 - http://enkf.nersc.no/Publications/lis03a.pdf

FRAMPS

(Fine Resolution Arctic Modelling and Prediction System)

- Being developed by Keguang Wang at the Norwegian Ice Service
  - Experimental output charts now available!
  - http://polarview.met.no/regs/f24.png
- Using the existing TOPAZ or CICE met.no model runs for the pan-Arctic

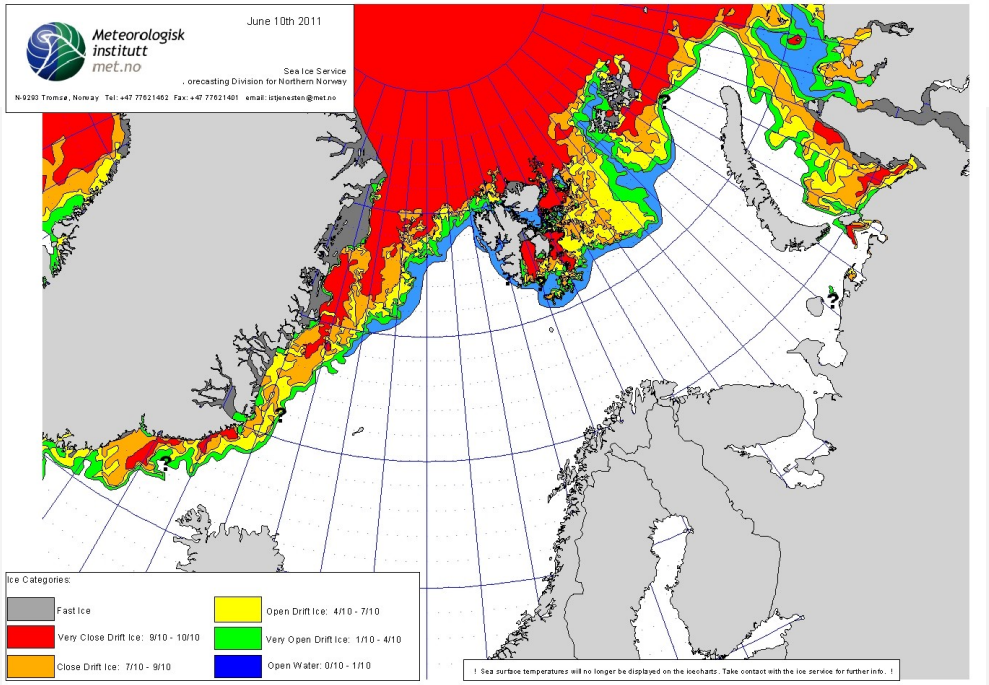


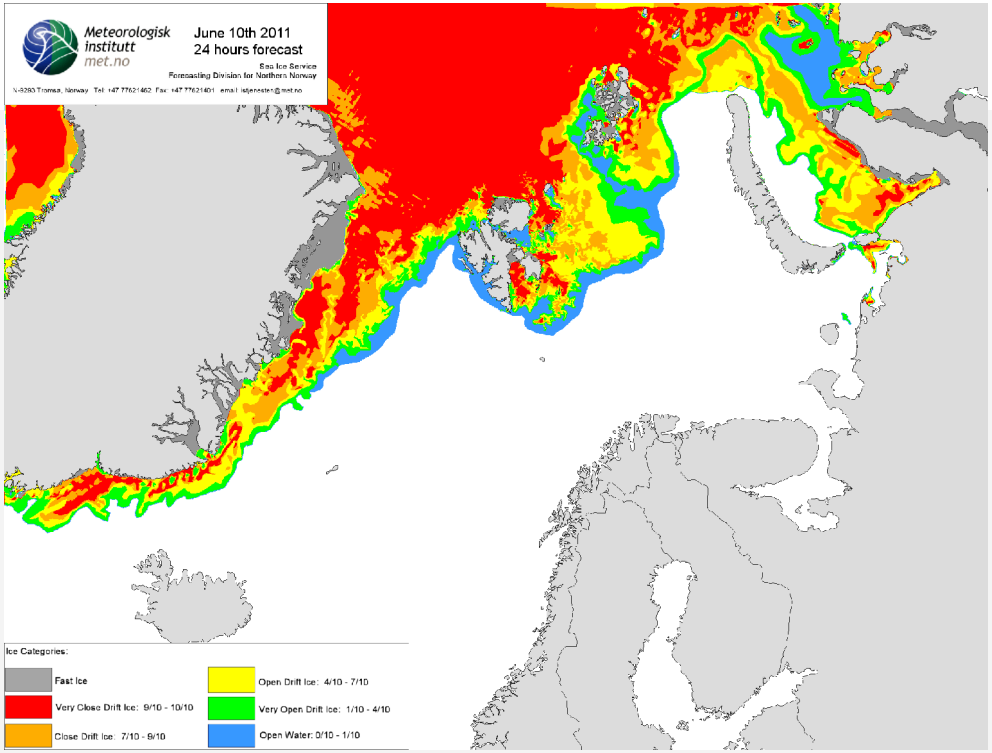
Model domain:
- Pan-Arctic domain (> 60°N): ~ 10 km resolution
- Fram Strait, Svalbard, Barents Sea: 2 km resolution

- Nested fine resolution model
  - Dynamic and thermodynamic sea ice model
    - Dynamic component (Wang and Wang, 2009)
    - Thermodynamic component, similar to Saloranta (1997) and Launiainen and Cheng (1998)
    - Transportation model: particle-in-cell
- Ice categories
  - Level ice
    - New ice: < 10 cm
    - Grey ice: 10 – 15 cm
    - Grey-white ice: 15 – 30 cm
    - Thin first-year ice: 30 – 70 cm
    - Thick first-year ice: > 70 cm
    - Multiyear ice
  - Deformed ice
    - Rafted ice
    - Ridged ice
  - Data assimilation

FRAMPS

(Fine Resolution Arctic Modelling and Prediction System)



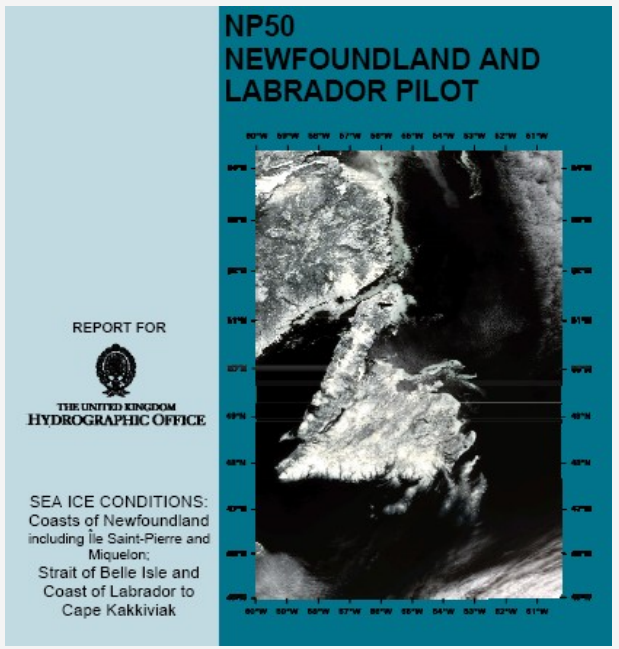


Publications

- No weekly or monthly summaries are prepared
- An annual summary is prepared for the IICWG
- Ice Service participates, in collaboration with the Norwegian Polar Institute, in SEARCH regional sea ice outlooks

Research and Consultancy

- Research
  - SIDARUS
  - ACCESS
  - ICEMAR
  - Polar View
  - OSI SAF
- Other
- Consultancy
- Number of different clients requesting data and analysis



Research – SIDARUS

(Sea Ice Downstream Services for Arctic and Antarctic Users and Stakeholders)

- Overall objective is to develop and implement a set of downstream services for
  - Climate research
  - Marine safety (offshore industry, shipping companies)
  - Environmental monitoring
- Will provide
  - New satellite-derived sea ice products
  - Ice forecasting from regional models
  - Validation of sea ice products using non-satellite data
- Services include
  - High-resolution sea ice and iceberg mapping using SAR
  - Sea ice albedo from optical satellite sensors
  - Sea ice thickness from radar altimeter and passive microwave data
  - ARGOS tracking of marine mammals combined with sea ice maps
  - Ice forecasting based on numerical models and satellite data

Research – SIDARUS

(Sea Ice Downstream Services for Arctic and Antarctic Users and Stakeholders)

- The project will analyse data from in situ, airborne and under-ice field campaigns
  - This is essential for validating satellite retrievals and quantifying the level of errors in products.
- User Group
  - Will participate in the design phase where the system requirements,, user requirements, and system architecture are defined.
  - Participants required!
  - A Service Level Agreement (SLA) will be made with members.
  - User workshops (including training) will be held annually
    - Reporting on development of products
    - Users to give their feedback

Research – ICEMAR

(The GMES Pilot Ice Service for Maritime Operational Use)

- Overall objective is to establish a pilot downstream GMES sea ice information service to improve access to existing and new ice information products to aid ships navigating near or within ice-infested waters in the European Arctic.
- Will include:
  - One-entry user and stakeholder access to sea ice information products
  - Assure the availability of relevant ice information that can be used for determining and predicting the development of climate change
  - Establish a technical end-to-end service chain enabling the capability to visualize the assembled and integrated ice information on-board a vessel
  - Document the usefulness of the service for selected users, and raise the awareness of the existence of the service among the users
  - Expand the service utilisation into new users and/or geographical areas
- User Group

Research – ACCESS

(Arctic Climate Change, Economy and Society)

- Overall objective is quantification of climate change impacts on economic sectors in the Arctic
- Project is a follow-on to DAMOCLES
- ACCESS will evaluate climate impacts (for the next 20 years) on
  - Marine transportation (including tourism)
  - Fisheries
  - Marine mammals
  - Extraction of hydrocarbons
- met.no work includes
  - Collating existing and new datasets
  - Producing the climate model scenarios (R&D, Oslo)
  - Evaluation of user requirements and needs for forecasting of ice conditions
    - Based on current conditions
    - Based on predicted conditions due to climate change
    - User participants required!
  - Development of modelling to aid oil-spill in/under ice response
  - Iceberg detection and tracking

Scientific Output

- Conferences
  - Arctic Frontiers, Tromsø, January 2010
    - Hughes, N.E., F. Dinessen, S. Eastwood, L.-A. Breivik, T. Lavergne. *Regional and Global Sea Ice Reanalysis*
  - International Glaciological Society Symposium on Sea Ice, Tromsø, May 2010
    - Hughes, N.E., J.P. Wilkinson, and P. Wadhams. *Multi-Satellite Sensor Analysis of Fast Ice Development in the Norske Øer Ice Barrier* (Paper in press, Annals of Glaciology, 57).
  - ESA Living Planet Symposium, Bergen, July 2010
    - Hughes, N.E., J. Rodrigues, and P. Wadhams. *Comparison of ENVISAT ASAR and Submarine Sea Ice Thickness Statistics* (Paper in press)
- Papers
    - Hughes, N.E. (2009). Sea ice type classification from multichannel passive microwave datasets, *IEEE International Geoscience and Remote Sensing Symposium 2009 (IGARSS'09)*, vol.3, no., pp.III-125-III-128, 12-17 July 2009. doi: 10.1109/IGARSS.2009.5418031
    - Wilkinson, J.P., et al. (2009), Ice Tank Experiments Highlight Changes in Sea Ice Types, *Eos Trans. AGU*, **90**(10). doi:10.1029/2009EO100002.

Mailing and Internet Addresses

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  Postboks 6314
  NO-9293 Tromsø
  Norway

- Telephone: +47 77 62 14 62
- Telefax: +47 77 62 13 15
- E-mail: istjenesten@met.no
- Internet:
  - http://www.met.no and http://www.yr.no
  - http://retro.met.no/kyst_og_hav/iskart.html (regular ice charts)
  - http://www.yr.no/satellitt/ (satellite imagery, mainly NOAA)
  - http://retro.met.no/radar/index.html (real-time radar imagery for the Baltic Sea and Norwegian coastal waters)
  - http://polarview.met.no (alternative web site for ice charts and experimental products including Antarctic and WMS)