Ocean currents in ice infested waters

Leif Toudal Pedersen, Gorm Dybkjær, Jun She
Danish Meteorological Institute

DMI experiences in ice infested waters

- 50years experience of ice service in Greenland, now 21 staff member for ice service
- Remote sensing group working on OSISAF, PolarView, ESA ECVs (SST, Sea Ice), MYO/MYO2, Aquamar, Marcoast etc
-
- Polar modelling group working on coupled HIRHAM-HYCOM-CICE model, provide operational forecasting service, public and commercial service

Requirements for currents in ice infested waters

- Increasing demands of predictions of currents, sea ice drift, iceberg drift and oil drift for oil/gas/mineral exploration operations, ship routine service at higher latutudes

- National as well as International strategies calls for increased focus on safety and security of such operations

Product 1: Ocean eddies from small scale ice drift

- **Problem:**
  - Detailed modelling of ocean currents and the drift of sea ice and icebergs are needed for improving safety of off shore oil/gas activities
- **Suggestion(s):**
  - Identify small scale ocean surface features /eddies for validation and assimilation using sea ice as a tracer
  - High temporal resolution satellite data allows observations during cloud free periods (frequent in some areas during Summer)

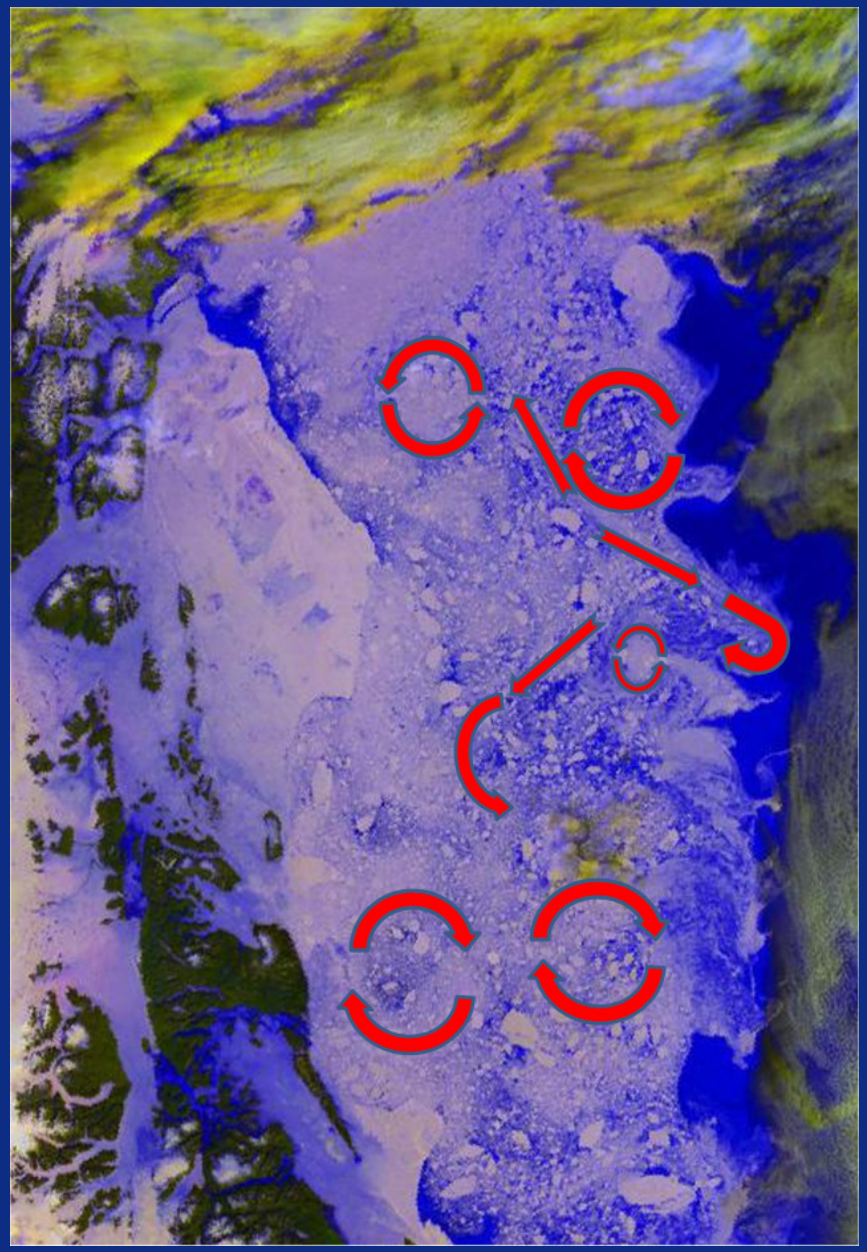
DMI
Center for Ocean and Ice

Animation of selected AVHRR images
METOP and NOAA
July 23-27, 2011
74 images in animation

DMI
Center for Ocean and Ice

Detection of ocean eddies by high temporal observations of ice drift during calm periods.

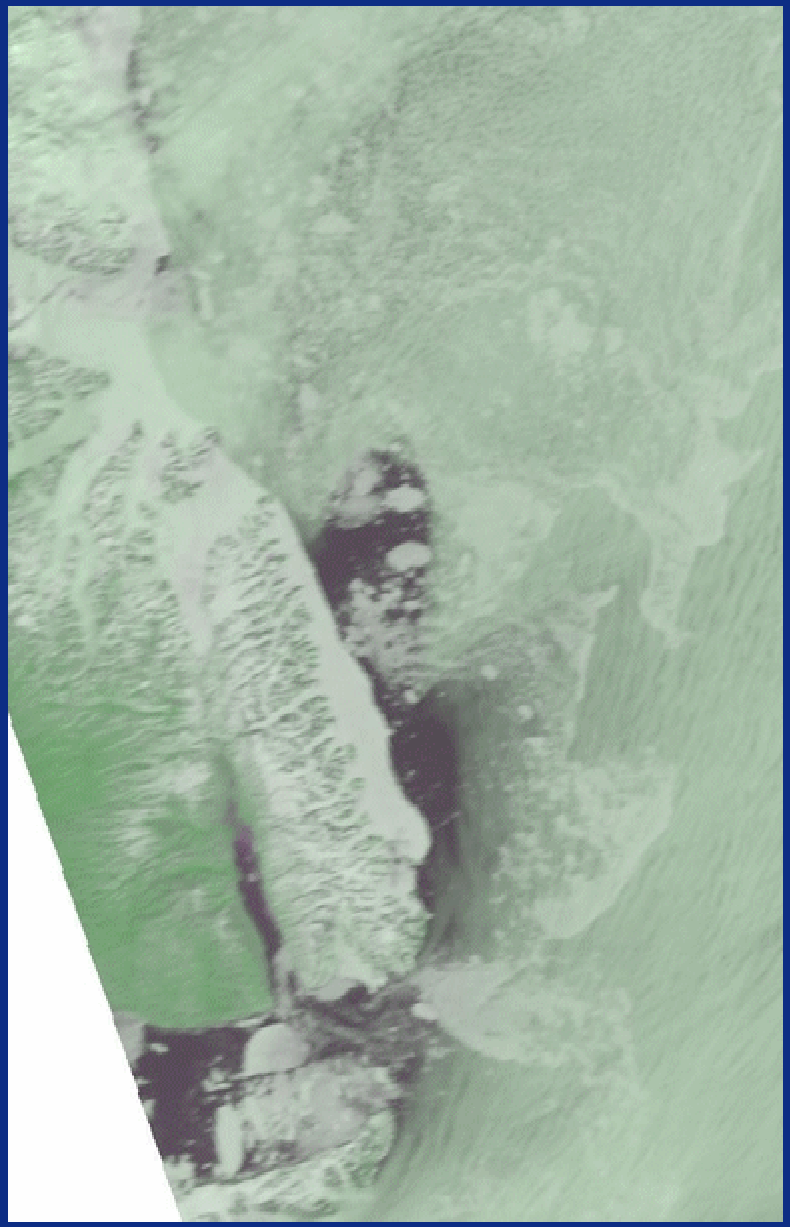
Typically 15-25 AVHRR images per 24h from NOAA and METOP



Ca. 400x500 km)

DMI
Center for Ocean and Ice

MODIS
(possible supplement, but only daytime)



3-4 MODIS images per day (TERRA+AQUA)

From Dundee satellite station

Products / users

- **Product:**
- Quantified maps of eddies in the East Greenland Current and Baffin Bay areas. (Location, diameter, timing etc).

- **Users:**
- Oil companies operating in ice infested areas off East and West Greenland are requesting improved predictions of sea ice and iceberg drift. Current model capabilities do not capture the eddy field, and neither do current observation techniques.

Product 2: Average surface ocean currents from existing ice drift datasets

- **Problem:**
  - Validation of model ocean currents in ice infested waters is needed
- **Suggestion(s):**
  - Use large observational datasets of sea ice drift
  - Colocate ice drift data and wind from ECMWF
  - Calculate wind component of ice drift
  - Subtract wind generated ice drift (the largest component)
  - Average the residual to obtain average ocean currents

Distributed surface current under sea ice

Methodology

The Sea ice drift (*U, V*) relates to wind (*u,v*) via the speed reduction factor (*F*) and wind-ice turning angle (*θ*). The time average residual from this relation is assumed to be the average surface current (*cu, cv*).

$$\begin{bmatrix} U \\ V \end{bmatrix} = F \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} + \begin{bmatrix} c_u \\ c_v \end{bmatrix}$$

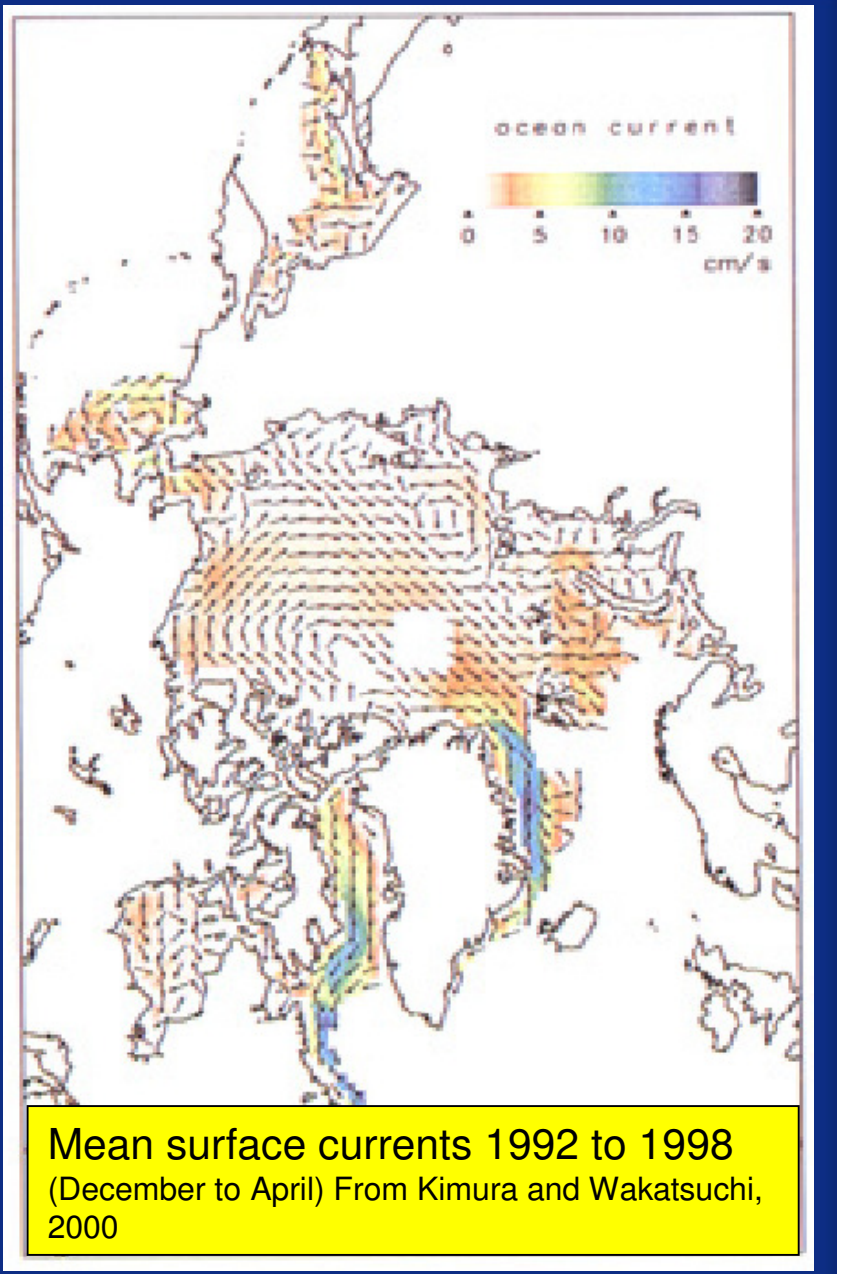
F, θ and c_u, c_v are assumed constant during the period of interest.

DMI
Center for Ocean and Ice

Distributed surface current under sea ice

Data 1 – large scale

- **Global surface currents estimated from SSMI by Kimura and Wakatsuchi. We will apply the method – but use higher precision ice drift data and consequently produce annual surface current cycles for the Polar oceans.**
- **Data:**
  - 9 year reanalysis of low resolution and high precision AMSR ice drift (OSISAF)
  - 3 years of medium resolution and very high precision AVHRR ice drift and (OSISAF)
  - 4 years of high resolution and very high precision SAR ice drift (DTU-space)



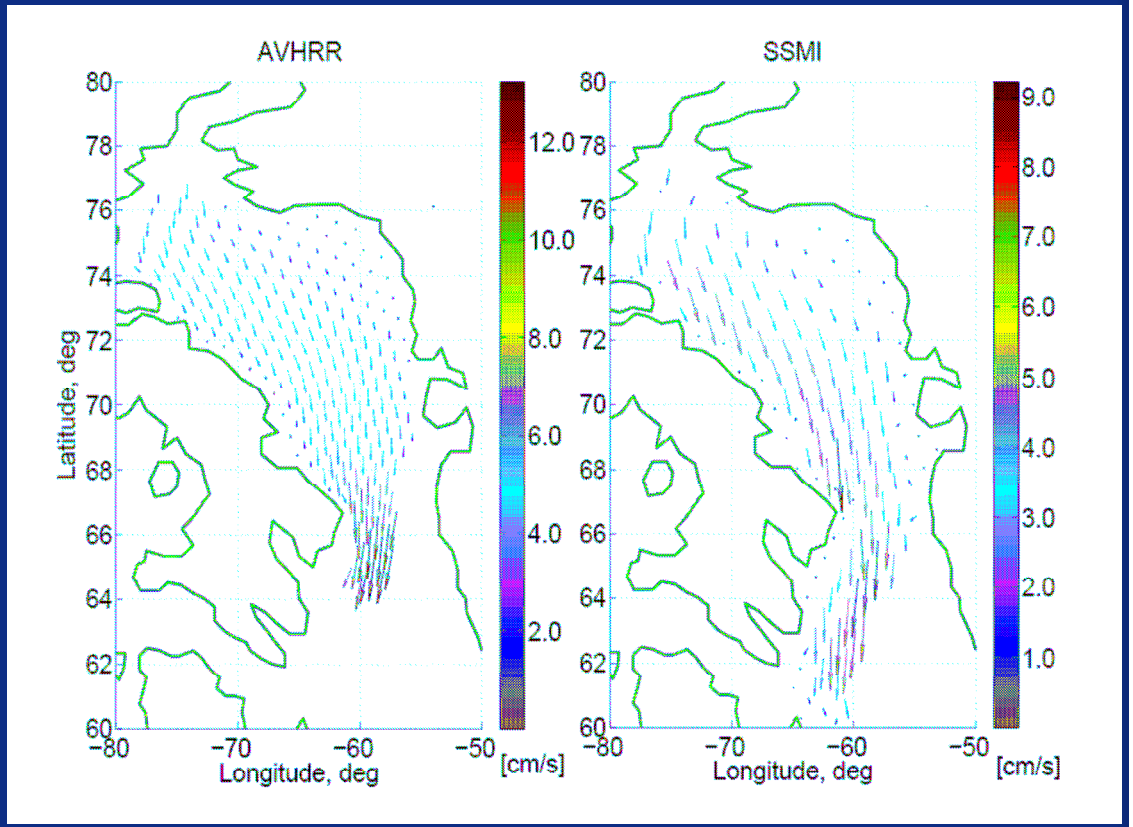
Mean surface currents 1992 to 1998
(December to April) From Kimura and Wakatsuchi, 2000

DMI
Center for Ocean and Ice

Distributed surface current under sea ice

Data 2 - fine resolution

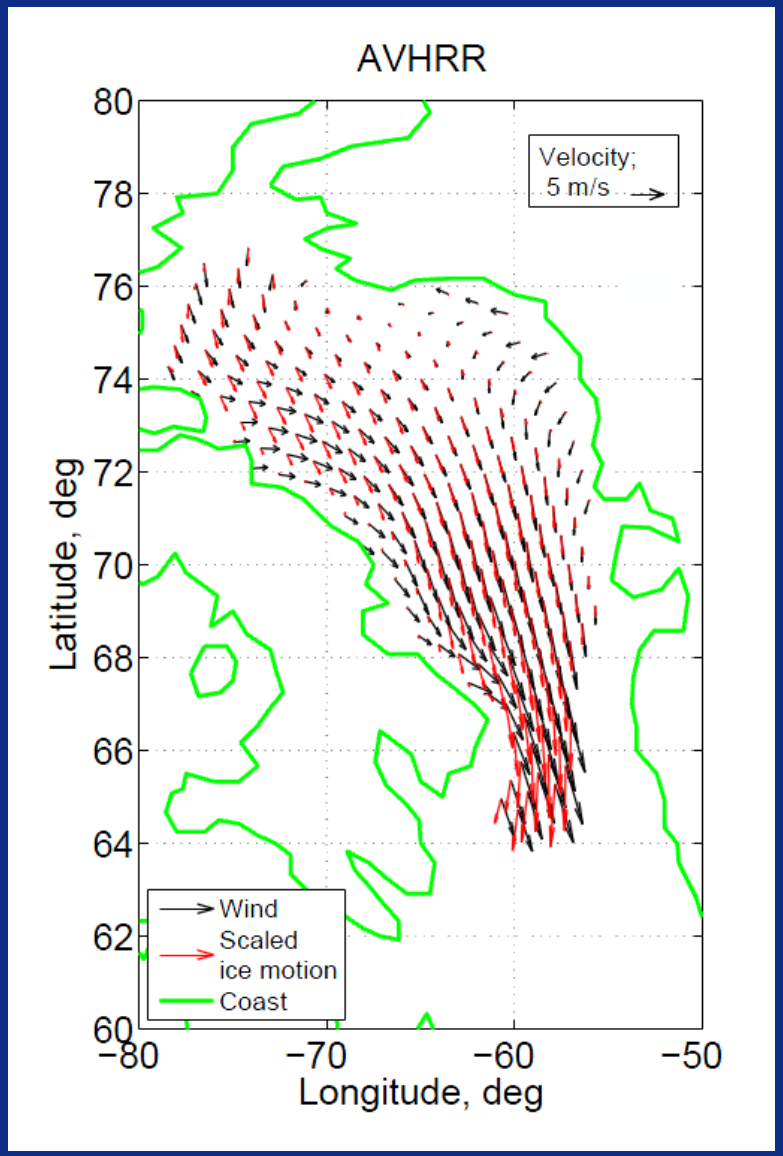
- Baffin Bay Ocean current
  - AVHRR (fine res., left)
  - SSMI (coarse res., right)
- High resolution AVHRR and SAR ice drift can be applied for higher resolution ocean current analysis and low resolution ice drift, from AMSR, SSMI and SSMIS, can fill gaps and represent large scale surface current.



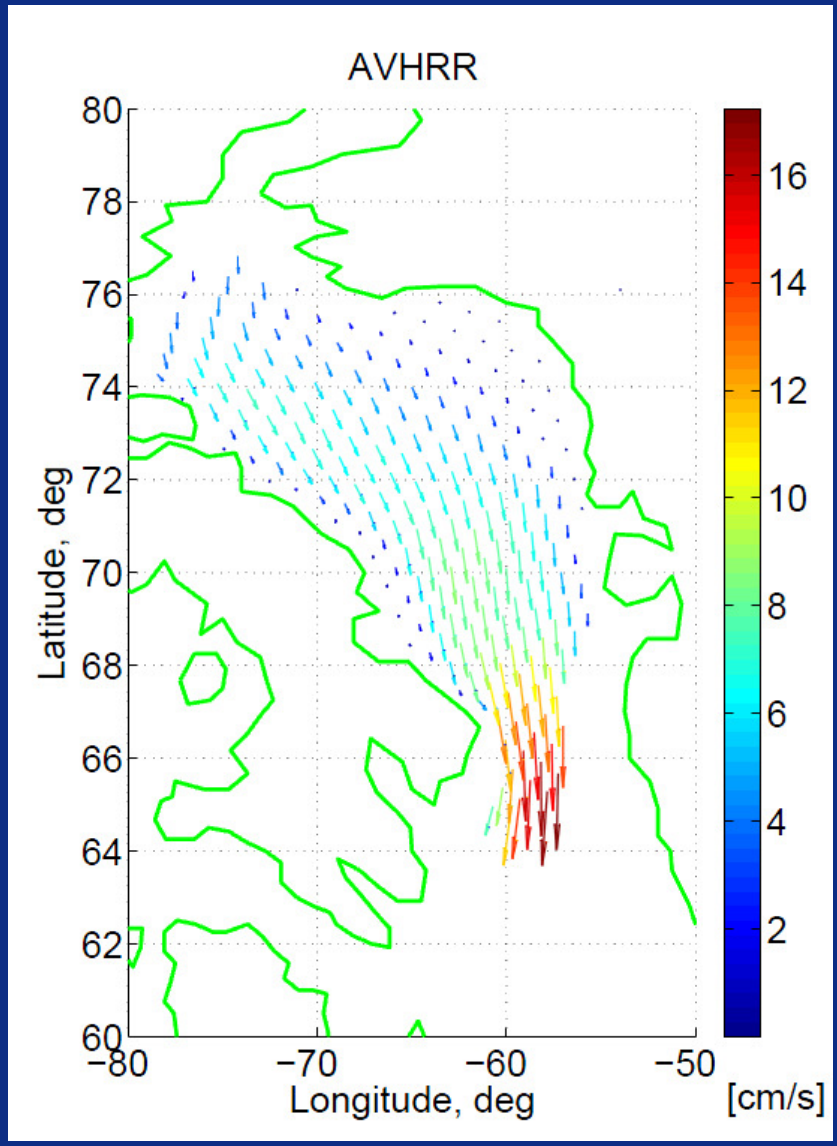
Winter mean ocean current in Baffin Bay (December to April) 1992 to 1998. (Note different scales)
From Lise Lotte Christoffersen, DMI.

DMI
Center for Ocean and Ice

Average wind and ice drift



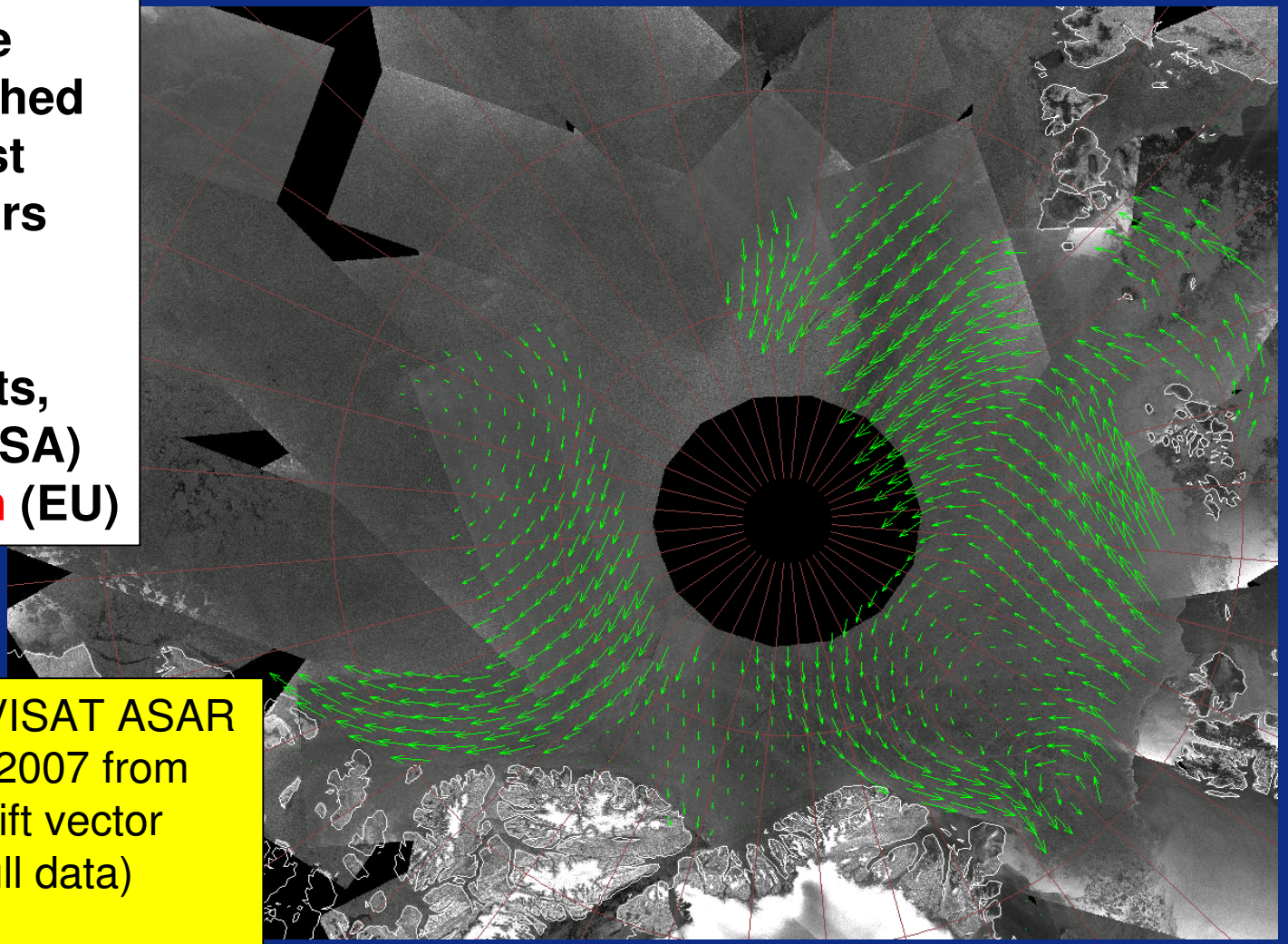
Resulting average Ocean Currents



DMI
Center for Ocean and Ice

Excellent higher resolution ice drift datasets have been established during the last couple of years thanks to EUMETSAT OSISAF efforts, PolarView (ESA) and MyOcean (EU)

20070701



Ice drift from ENVISAT ASAR Daily since June 2007 from MyOcean. (Ice drift vector every 10 Km in full data) Arctic + Antarctic

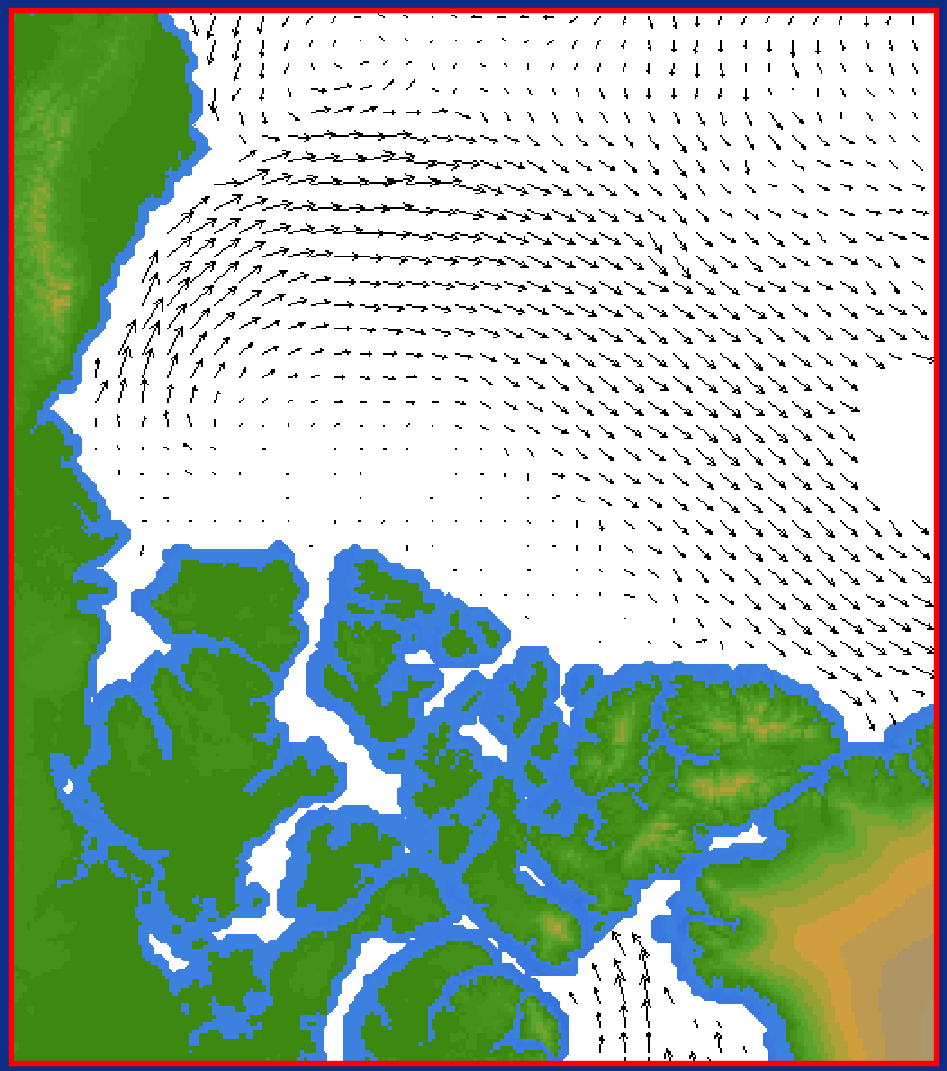
DMI
Center for Ocean and Ice

AMSR-E 48h ice drift
from 2008/01/29 to 2008/01/31
CMCC

OSISAF ice drift dataset
from AMSR-E, ASCAT and
SSMIS
48 hour drift
Available 2001-

Ice drift vector every 62 Km

Arctic and Antarctic



Product/users

- **Products:**
- **Maps of monthly mean ocean currents under ice in the Arctic and Antarctic oceans. Also monthly climatology of ocean surface currents in the Arctic Ocean can be calculated from the scheduled icedrift reanalysis of the entire ssmr-ssmi-ssmis-amsr data sets.**

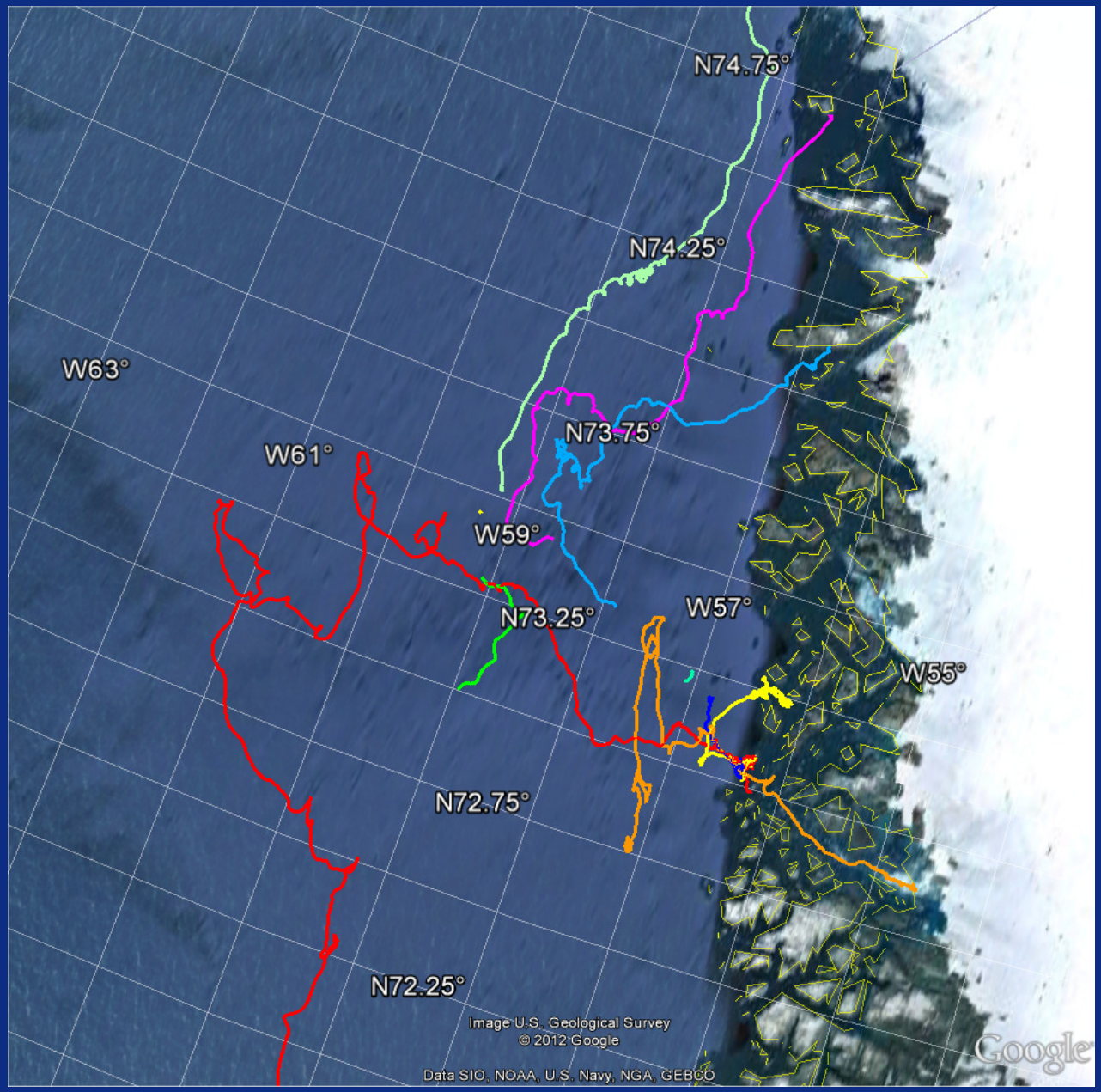
- **Users:**
- **Ocean model communities – climate and forecast for model validation**

Product 3: Using iceberg drift tracks to infer 3D ocean currents

- **Problem:**
  - Remote observations of ocean currents at depth are not directly possible from satellite
  - We need improved iceberg drift modelling capabilities
- **Suggestion(s):**
  - Use observational datasets of iceberg drift
  - Colocate iceberg drift data and wind from ECMWF
  - Subtract wind generated iceberg drift
  - Merge HYCOM model analysis and short term predictions with observed iceberg tracks to estimate drift at different depths (optimal estimation constrained by observations)

DMI
Center for Ocean and Ice

Iceberg drift

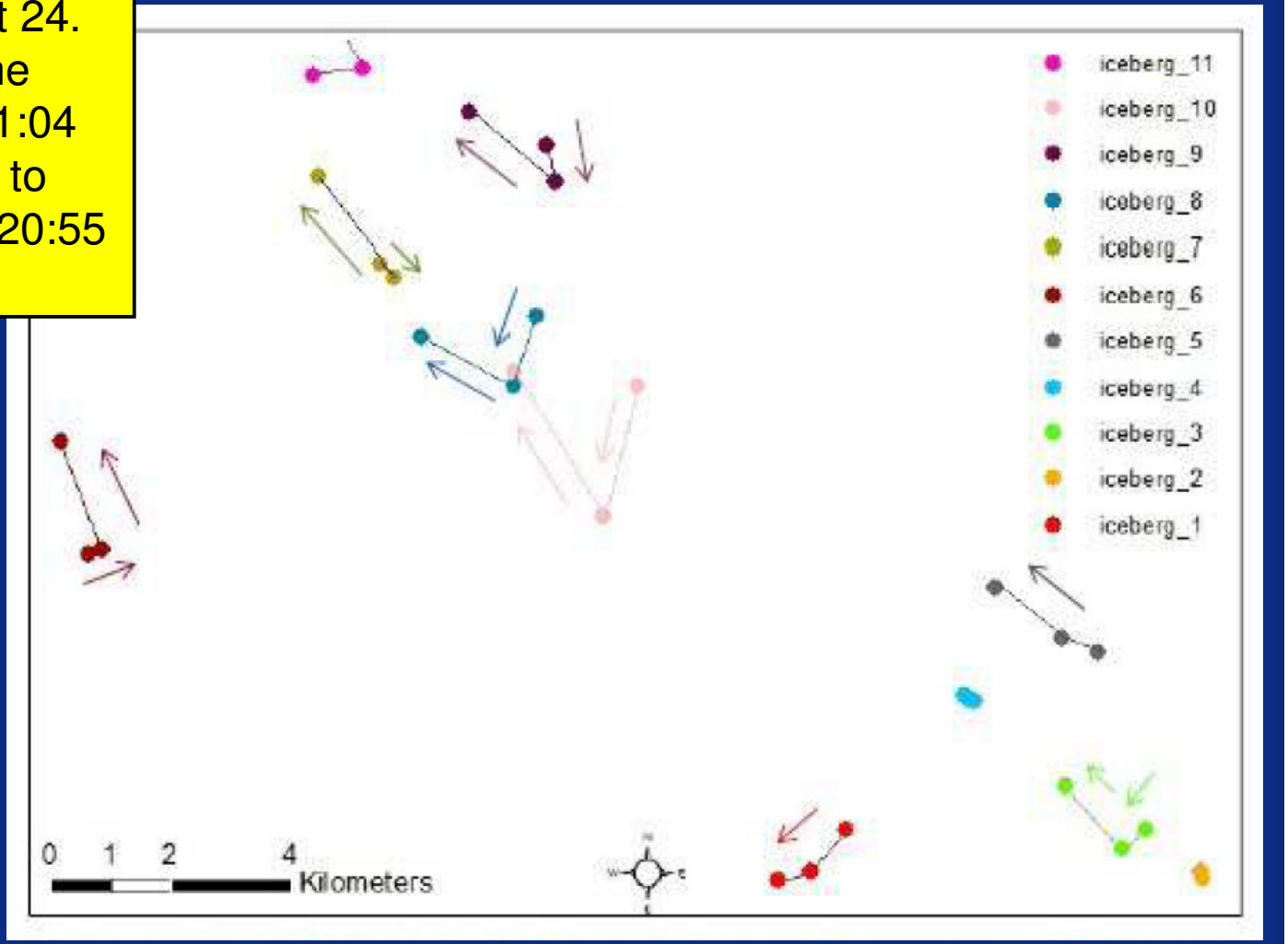


Iceberg drift tracks detected with GPS beacons off the West Coast of Greenland

DMI
Center for Ocean and Ice

Satellite detection of iceberg tracks

Iceberg drift August 24. The arrows mark the movements from 11:04 UTC (TerraSAR-X) to 16:06 (Landsat) to 20:55 (RADARSAT-1)



Iceberg tracking from satellite

I. Detection of larger icebergs is relatively easy

II. However in the Northern Hemisphere even larger icebergs are typically only a few pixels in general purpose SAR images

III. It can therefore be difficult to recognise unambigously the same iceberg

IV. This calls for higher temporal resolution in satellite coverage. Typically using a combination of SAR satellite systems (ENVISAT, RADARSAT-1+2, Cosmo Skymed, TerraSAR-X, Sentinel-1.....) in combination with occasional high resolution visible images (1-2 images per day is typically necessary in Greenland Waters)

Products / Users

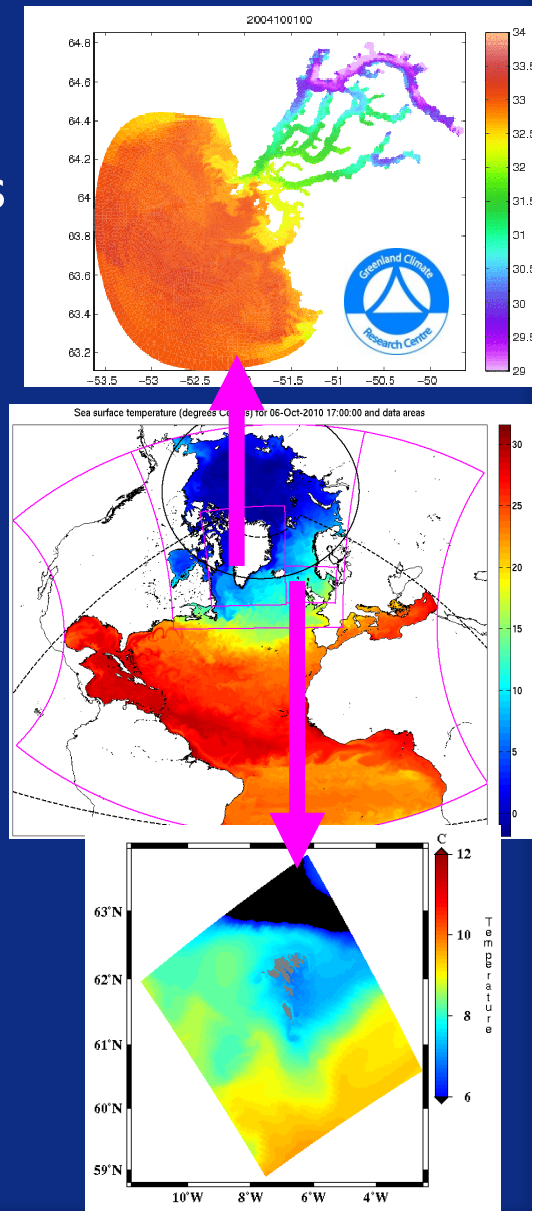
- **Product:**
- Quantification of the ocean drag on icebergs and subsequently using this knowledge to infer vertical profile of ocean currents from observed iceberg trajectories at the location of icebergs.

- **Users:**
- Prediction of iceberg drift trajectories is high on the list of any off-shore operator in iceberg infested waters. Especially operators that need to follow a given track or even have to stay fixed over the same location needs this information for iceberg managing (which icebergs to try to move, and which they need to avoid). A limiting factor in iceberg trajectory modelling is validation of modelled ocean currents in the relevant ocean areas. This relatively inexpensive method will provide validation and tuning data.

Projects

DMI applications

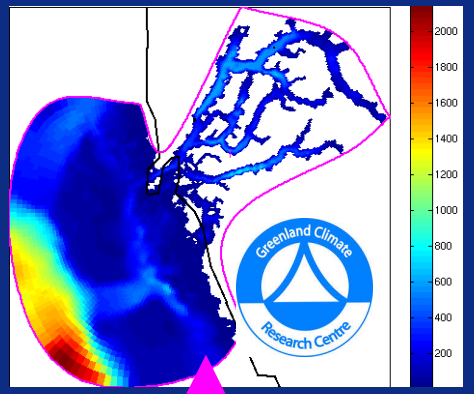
- HYCOM/CICE for opr. forecast
  - ~10 km horizontal reso., 29 hybrid layers
  - HIRLAM / ECMWF forcing
  - Assimilation from satellite data
  - Nesting for finer scale areas
  - Dynamic sea-ice
- Godthaabsfjord: fine scale application
- Faroe shelf exchanges

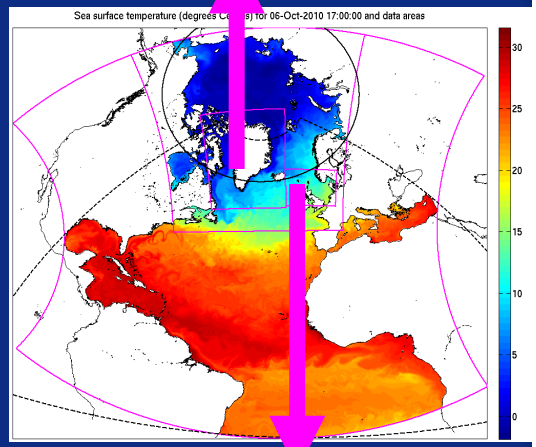


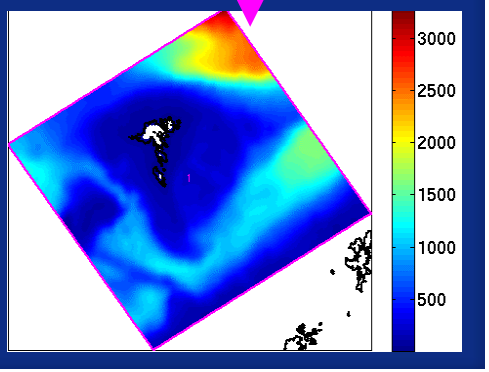
Projects

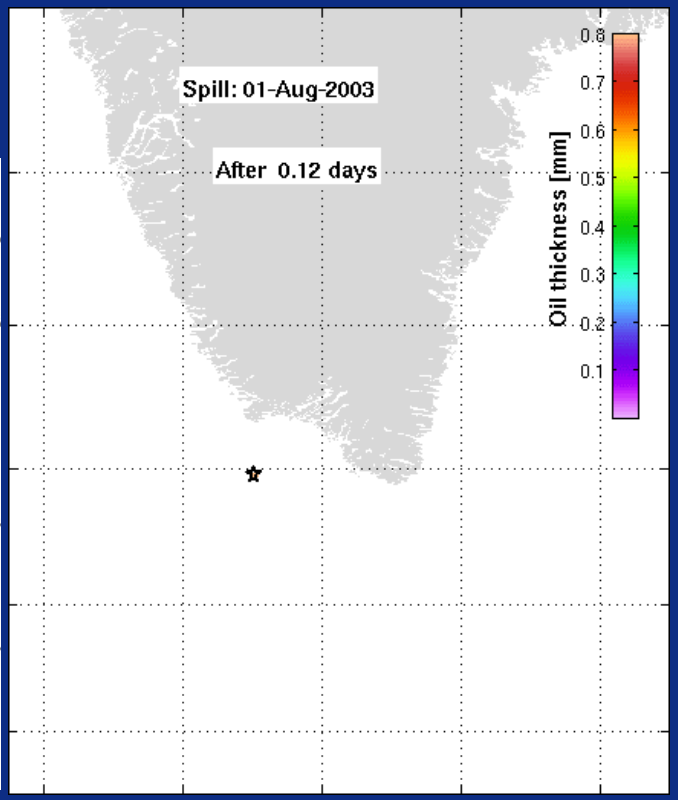
DMI applications

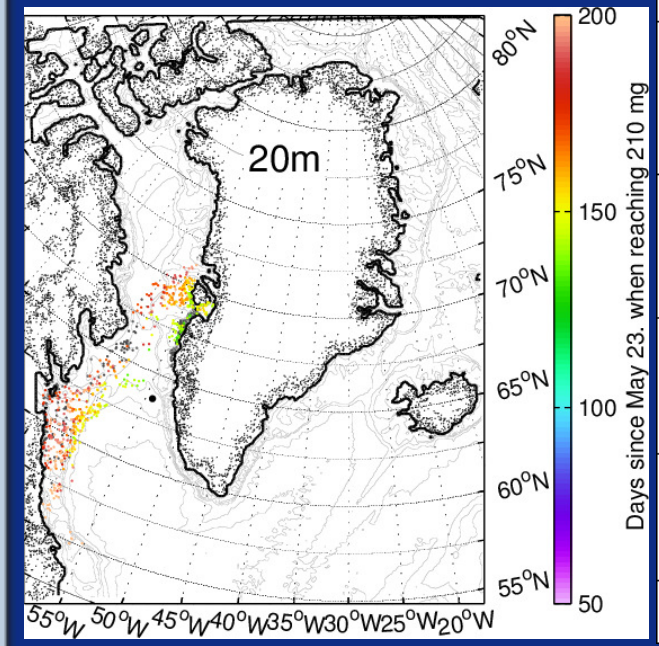
- HYCOM
- Godthaabsfjord: fine scale applications
- Faroe shelf exchanges
- Oil spill modeling in Greenland Waters
- Drift of eggs/larvae











Modelling

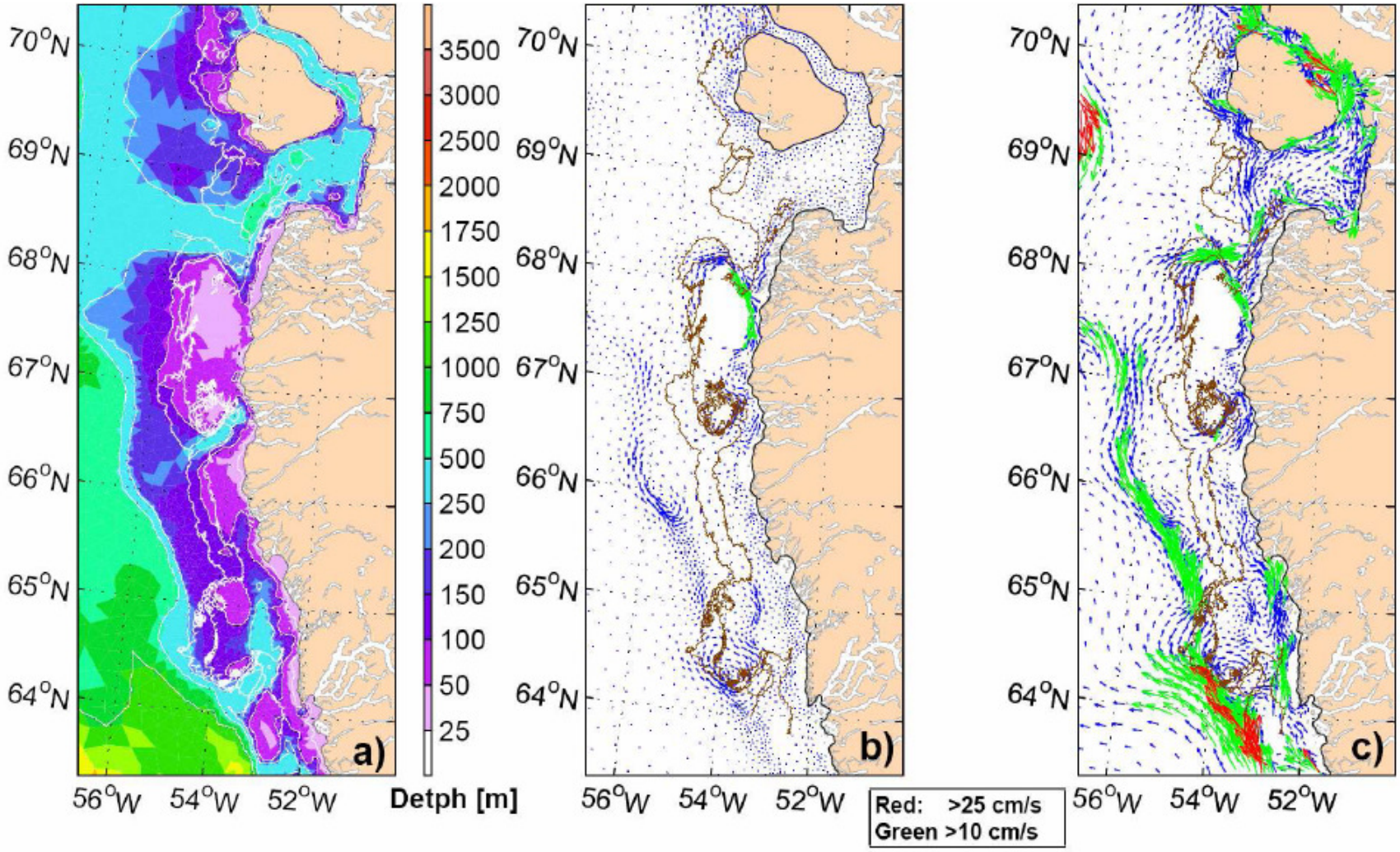
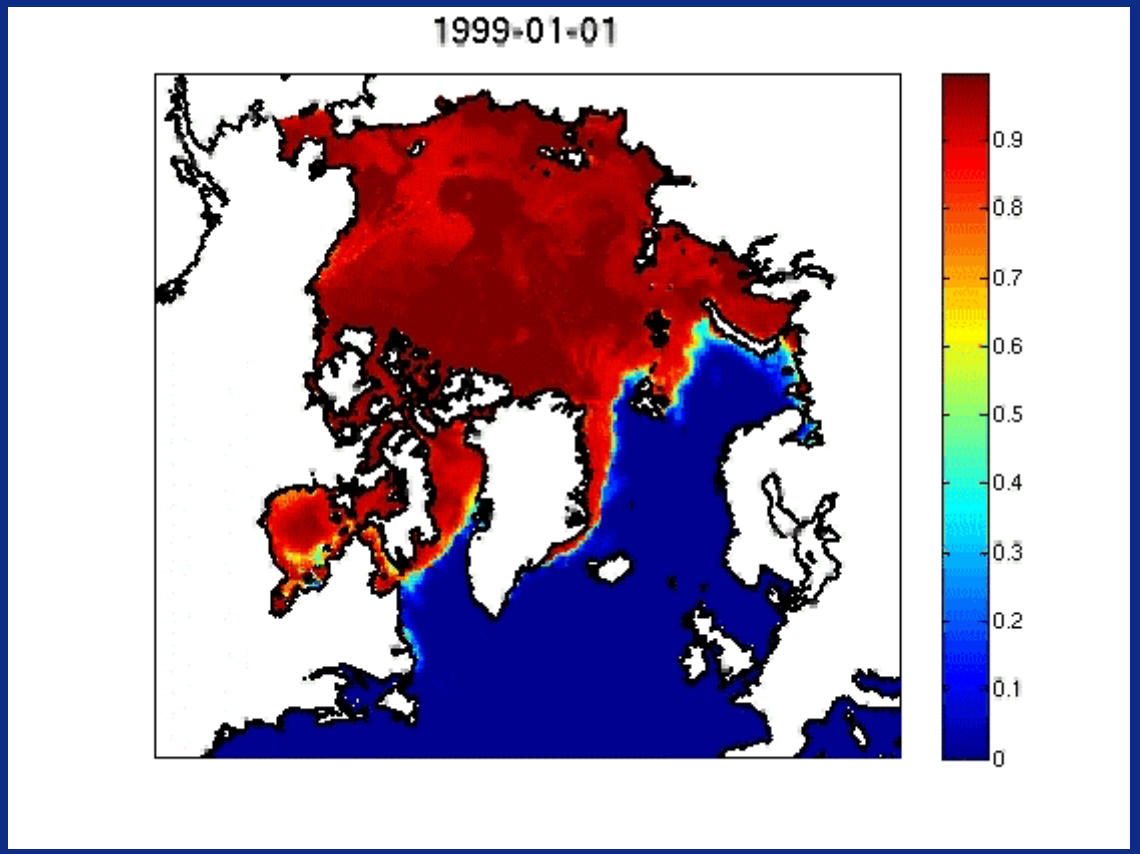


Figure 7. (a) Bathymetry, (b) Modelled barotropic mean currents (April to November) at West Greenland in 2000 and (c) the sum of the barotropic and baroclinic currents all at 50 m depth. Overlayed on the panels are trajectories of 2 WOCE-SVP drifters drogued at 30 m. From Ribergaard et al. (2004).

Sea ice coverage



Conclusions

- A number of suggestions to derive ocean current information using satellite data have been presented.

- The currents derived from satellite data would be very helpful to improve ice/ocean/iceberg forecasting skills and services in ice infested waters