CCI sea ice project

Science leader: Stein Sandven,

Nansen Environmental and Remote Sensing Center

Consortium Members

Over-arching science challenges

- Observe global sea ice variability and change on seasonal, interannual and longer time scales
- Understand and quantify the role of sea ice in the climate system
- Develop modelling and prediction capabilities for sea ice on various time scales

GCOS definition of sea ice ECV

Product O.1: Sea-ice concentration

- Sea-ice variability is a key indicator of climate change variability and change, and there are a number of parameters characterizing it.
- Sea ice extent and concentration play a major role in ice albedo feedback, energy and moisture fluxes between ocean and atmosphere, and the temperature and salinity of high-latitude oceans.
- Ice volume is an important component of high-latitude heat and is needed to characterise the seasonal to inter-annual variability in freshwater export (in the form of sea ice) from the polar oceans.
- Ice volume estimates require estimates of ice thickness in combination with ice concentrations.

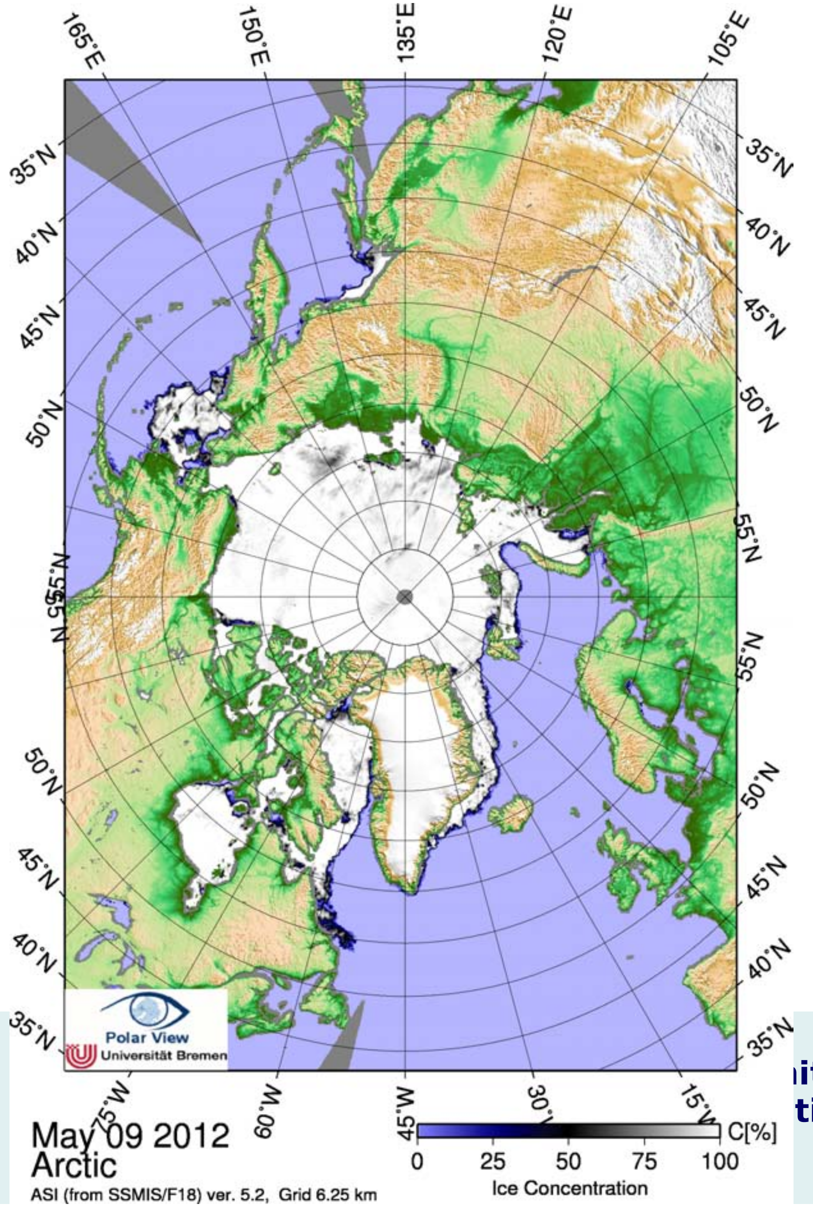
GCOS requirements for ice concentration measurements

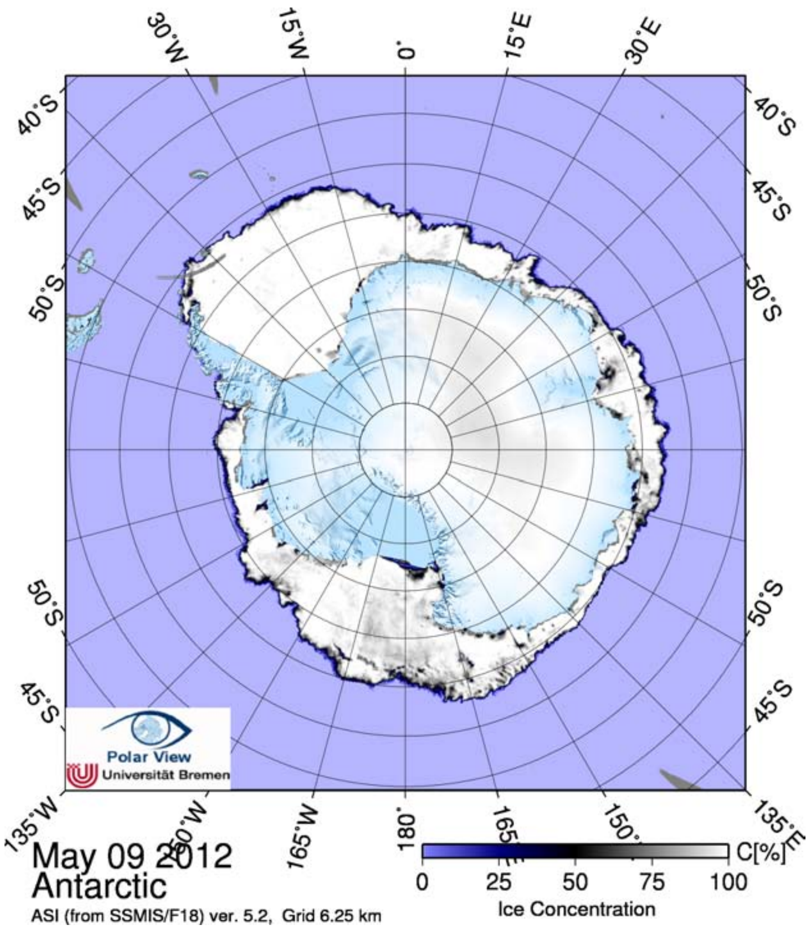
Sea ice concentration	GCOS requirements	Current capability
Accuracy	5%	5 -20 %
Spatial resolution	12 km	5 – 25 km
Temporal resolution	daily	daily
Stability	5 % per decade	not determined

Observing sea ice parameters by satellite sensors

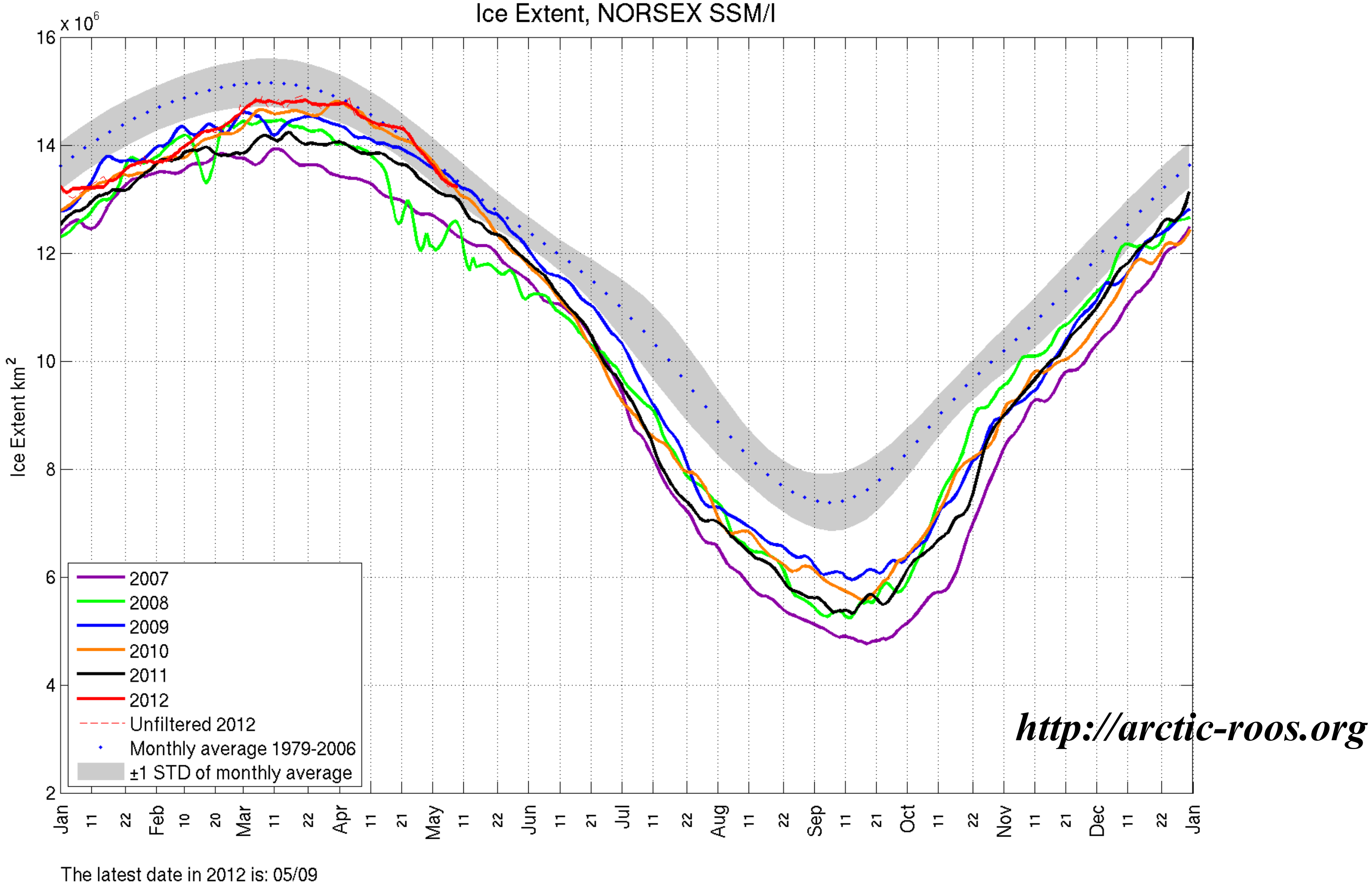
Ice variable	Remote sensing data	Research and operational status
Area, extent and concentration	Passive microwave data Scatterometer data Visual/IR data	Global products are available daily from SSMI, AMSR-E, and scatterometer data Operational ice charts are produced with support form visual and IR data
Ice thickness	Radar altimeter / Laser altimeter	Large-scale maps for the Arctic have been demonstrated by ERS data. Expected products from CRYOSAT from 2010
	L-band passive microwave data	SMOS data from 2010, thin ice thickness
	IR data using thermodynamic equation	AVHRR, MODIS, etc, during late winter, spring, thin ice thickness
Ice drift	Passive microwave data Scatterometer data SAR wideswath data	Operational products are available using scatterometer and passive microwave data SAR-based ice drift is available for selected regions and periods
Ice-snow albedo, melt ponds, surface temperature, etc.	Optical / IR images	Research activity, pathfinder data sets have been produced
Ice type classification / ice age	Scatterometer, SAR and passive microwave	Multi-year and first-year products are available, various levels of young and first-year ice can be produced from SAR
Ice roughness	Radar and laser altimeter	Products expected from Icesat and CryoSat
Icebergs in the Arctic and Antarctic	High resolution optical and SAR images	Research activity

Regular observation of Arctic and Antarctic sea ice by passive microwave data since 1978

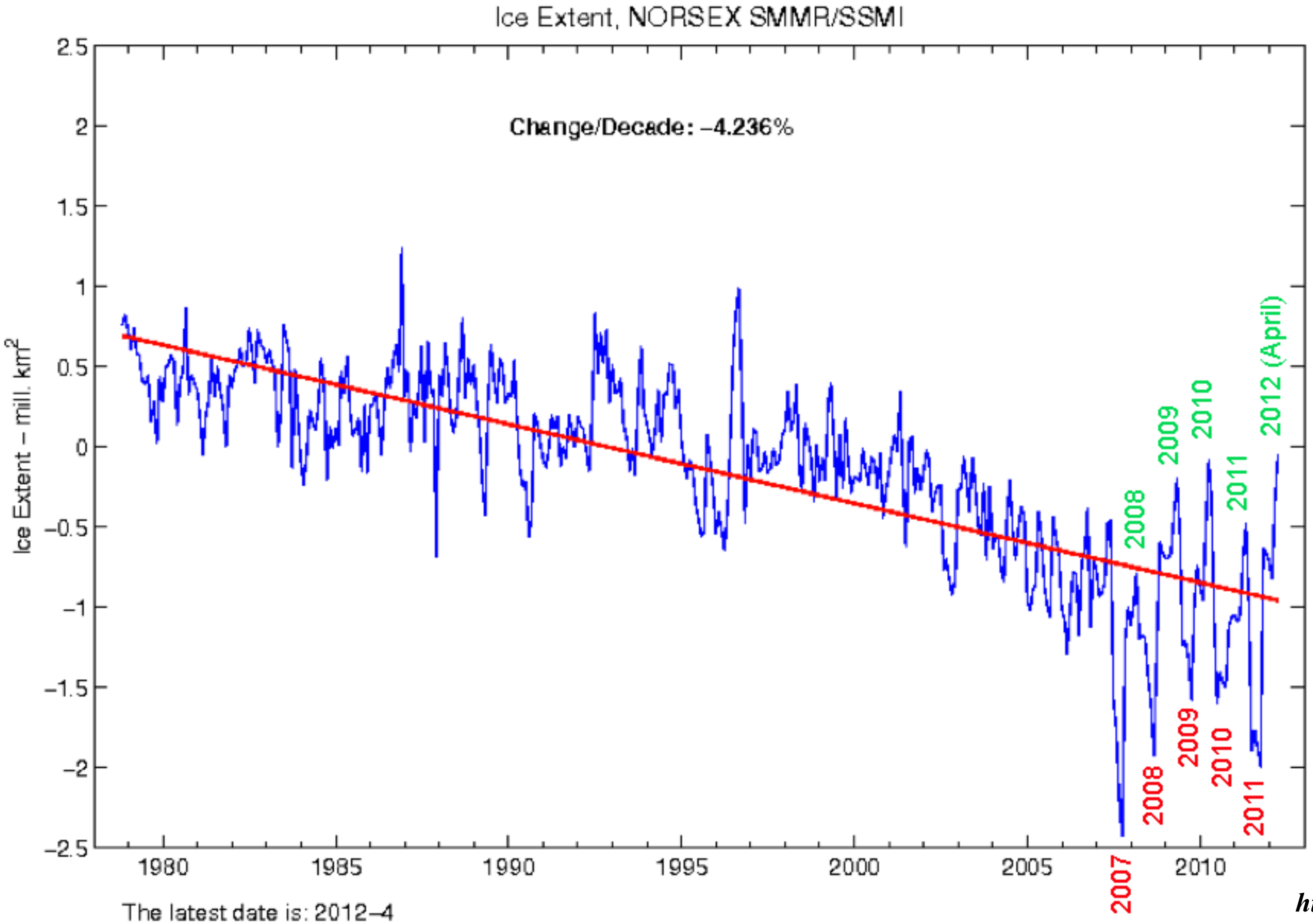




Seasonal sea ice area from passive microwave (SSMI) data

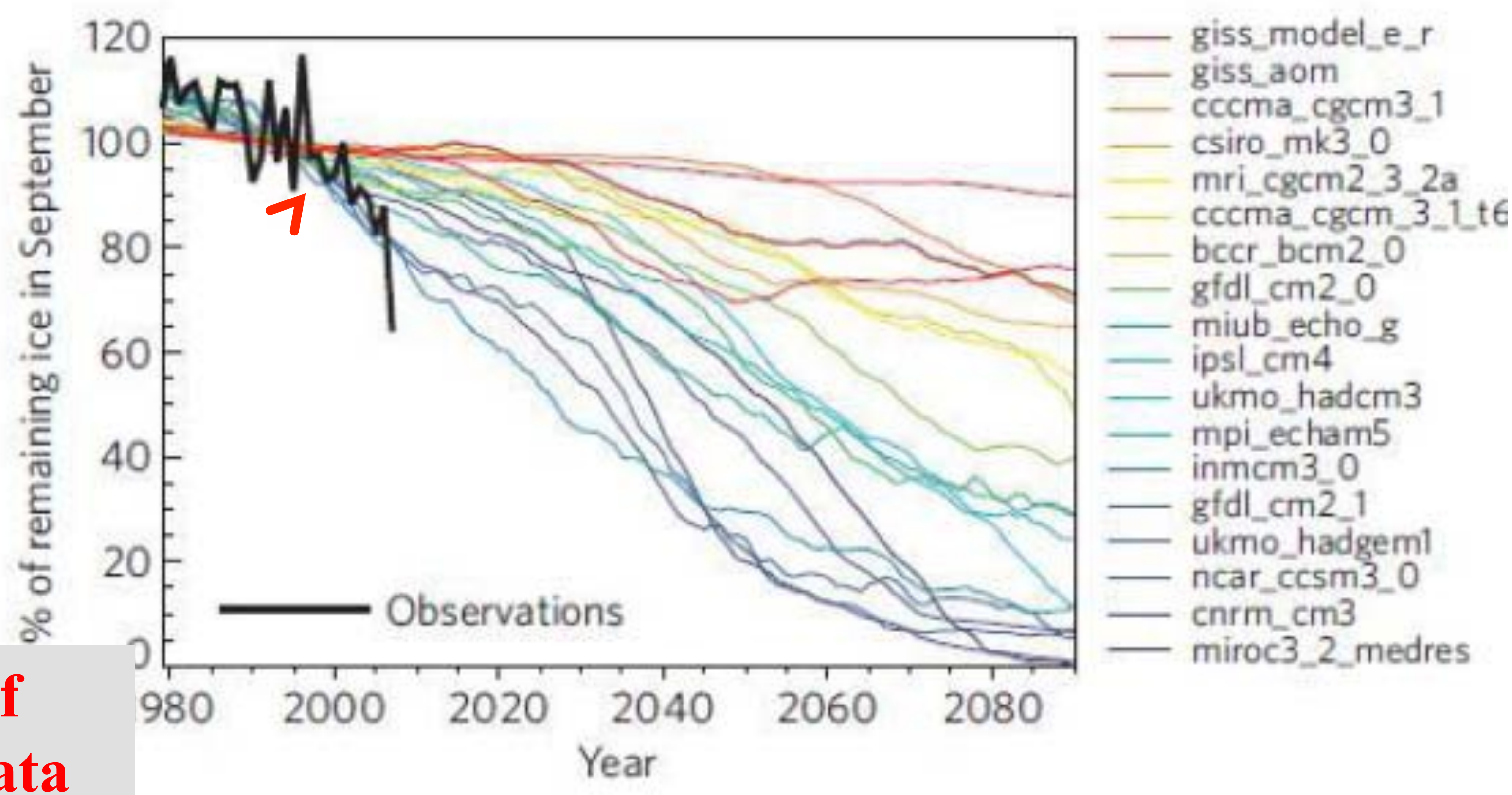


Arctic sea ice extent anomalies 1979 - 2012



http://arctic-roos.org

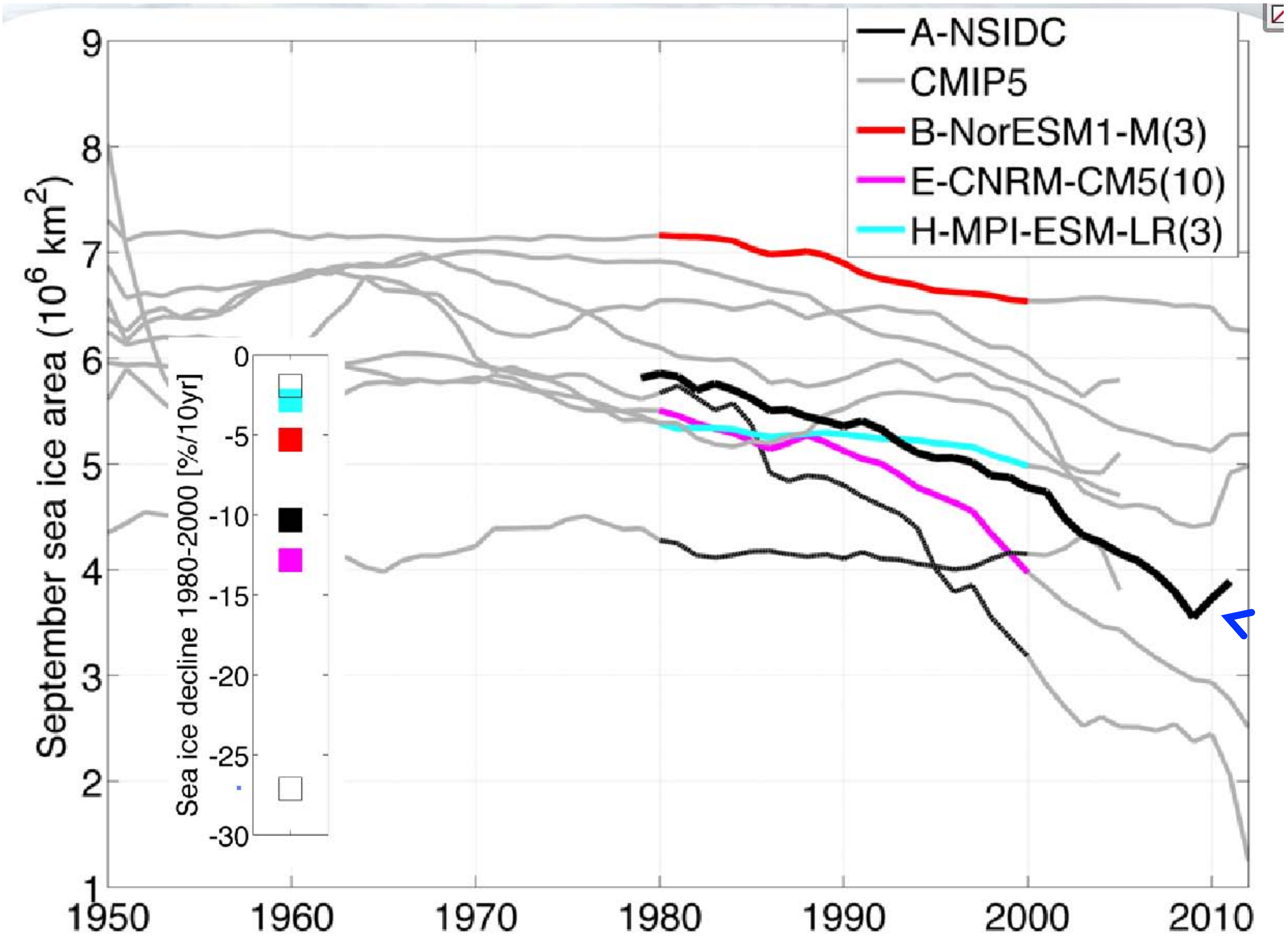
Predicted Arctic sea ice area in September from CMIP3



30 years of satellite data

Comparison of output from 18 different CMIP3 GCM's. Reference sea ice extent is mean the sea ice extent from 1979-2007 ("Satellite Era"). Forcing is the SRES A1B emissions scenario "medium forcing" ie CO2 concentrations of 700 ppm by 2100 (from [Boe et al., 2009]).

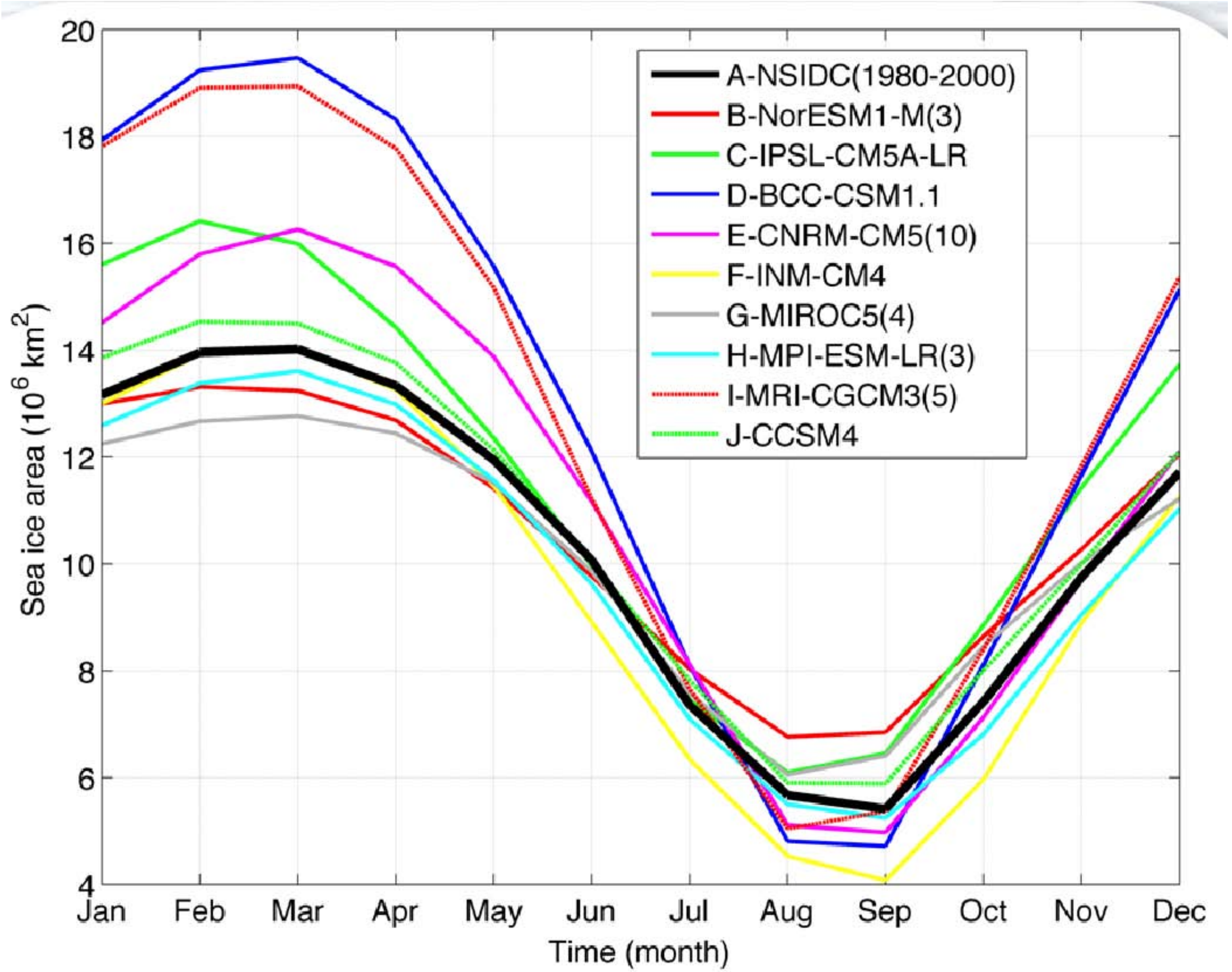
CMIP5 models of Arctic sea ice area in September



Satellite observations

Ref. Geyer et al., 2012

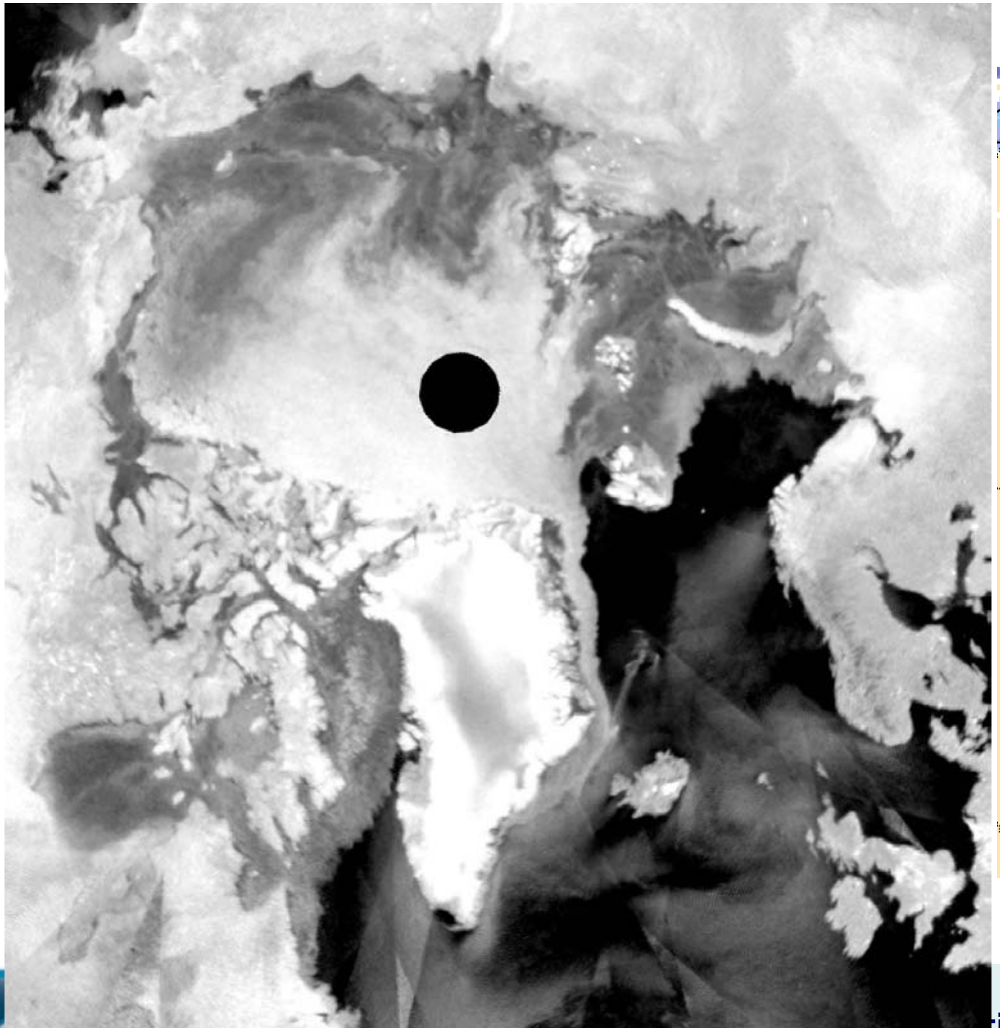
Seasonal cycle of Arctic sea ice area from CMIP5



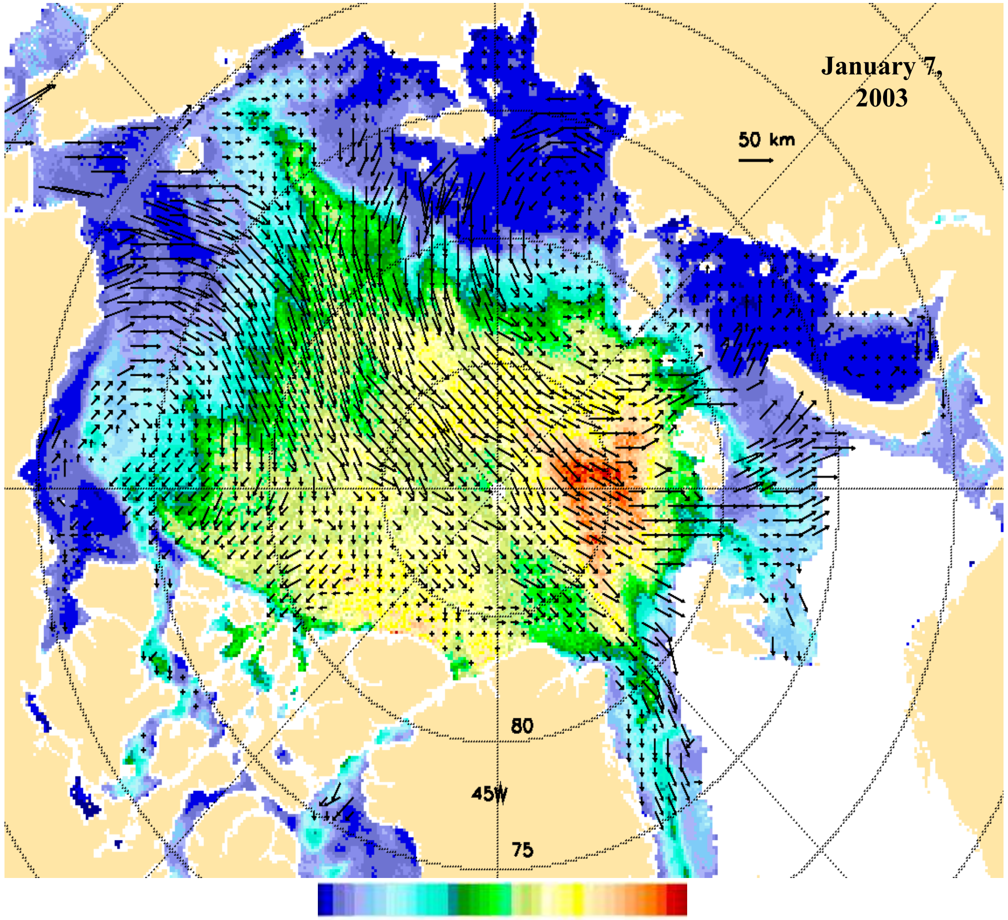
Black line: Satellite observations

Sea ice drift and multiyear ice from scatterometer and passive microwave data

Quikscat backscatter image

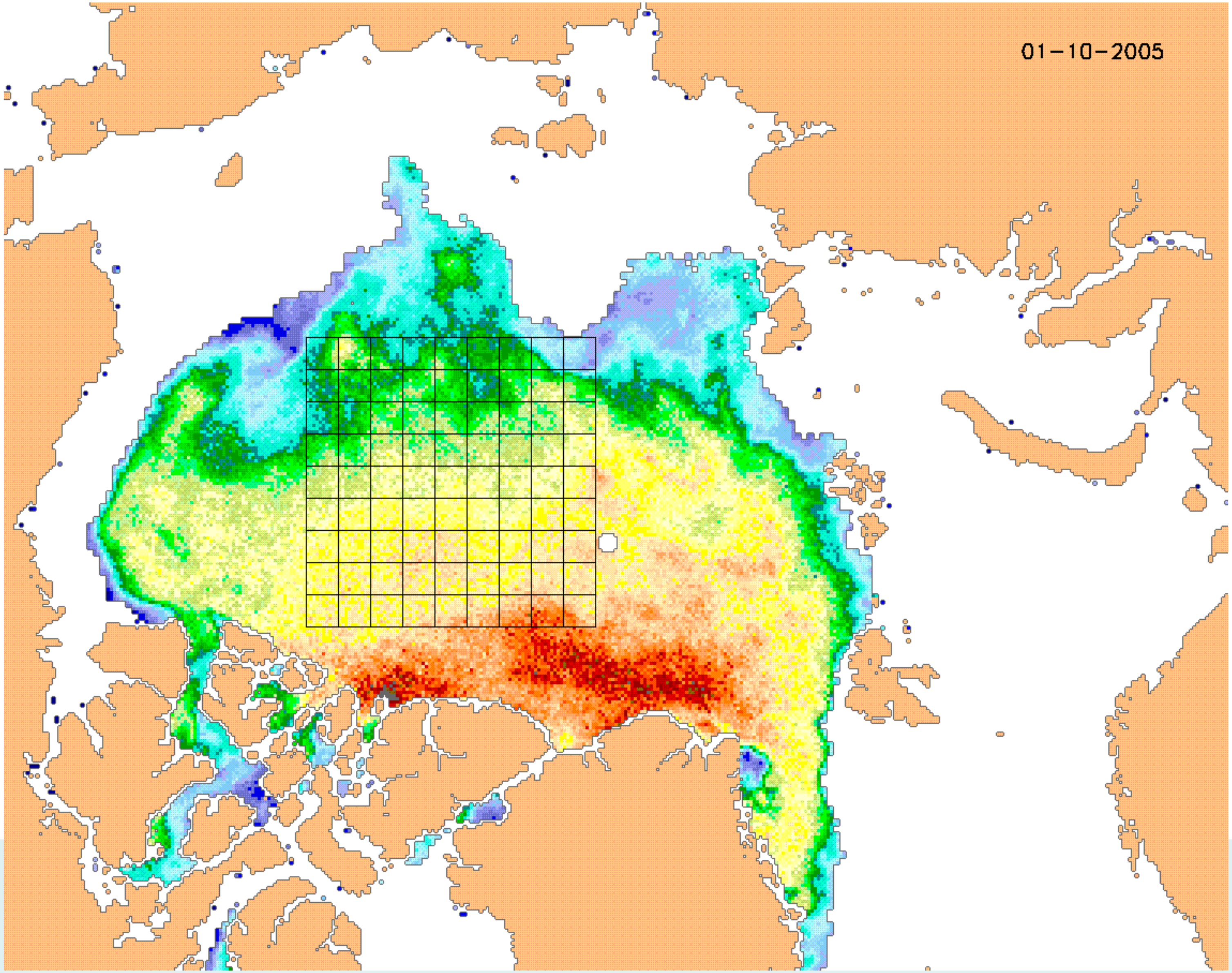


Ice types and ice drift



Courtesey: R. Ezraty, IFREMER

Sea ice motion and ice type change during a winter season



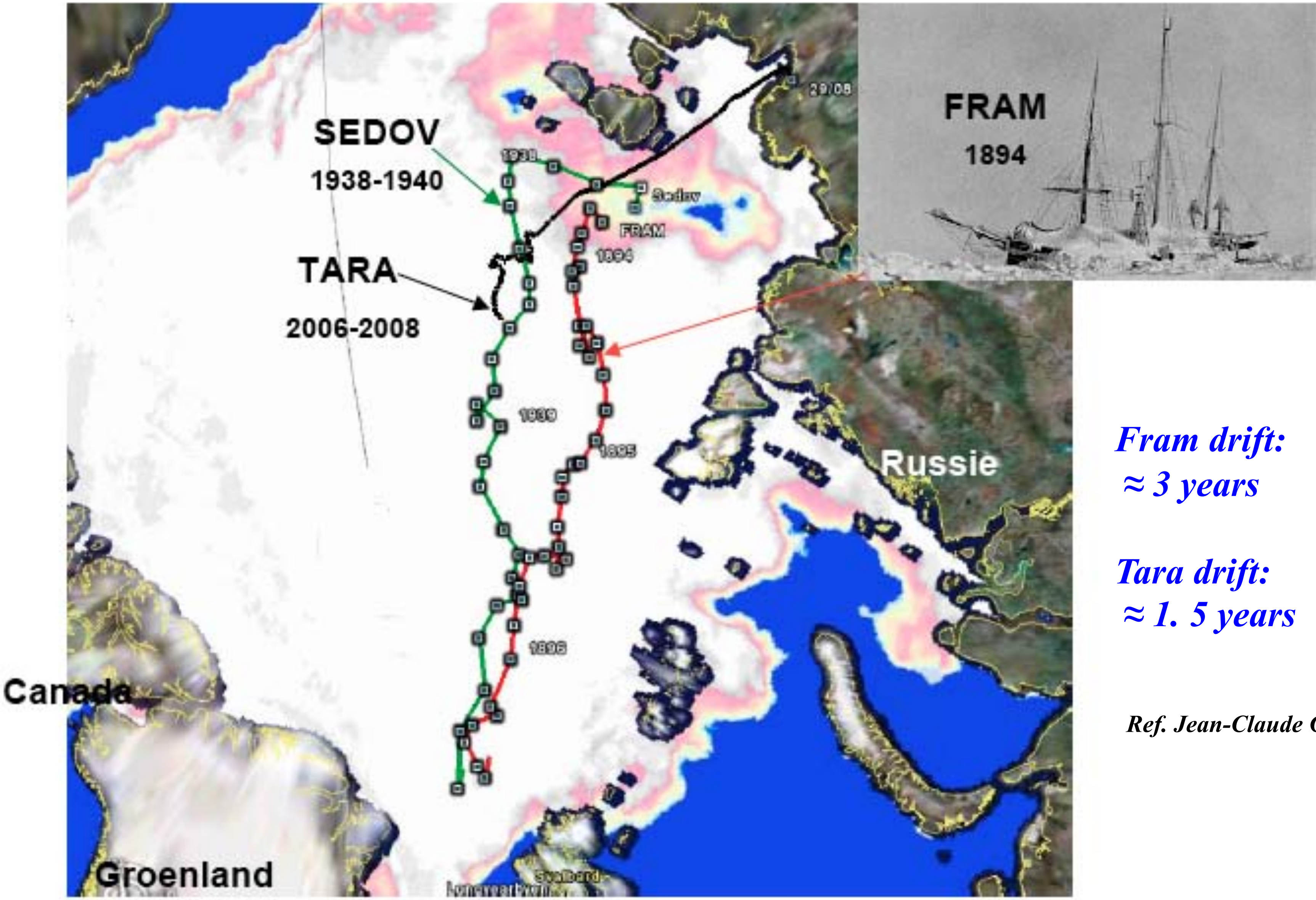
From 01 October 2005 to 30 April 2006 at 3 day interval.

Colour: ice types from scatterometer data
Motion: drift vectors from passive microwave data

Courtesy: Ifremer

NERSC

Transpolar ice drift: 1894 – 1938 – 2006

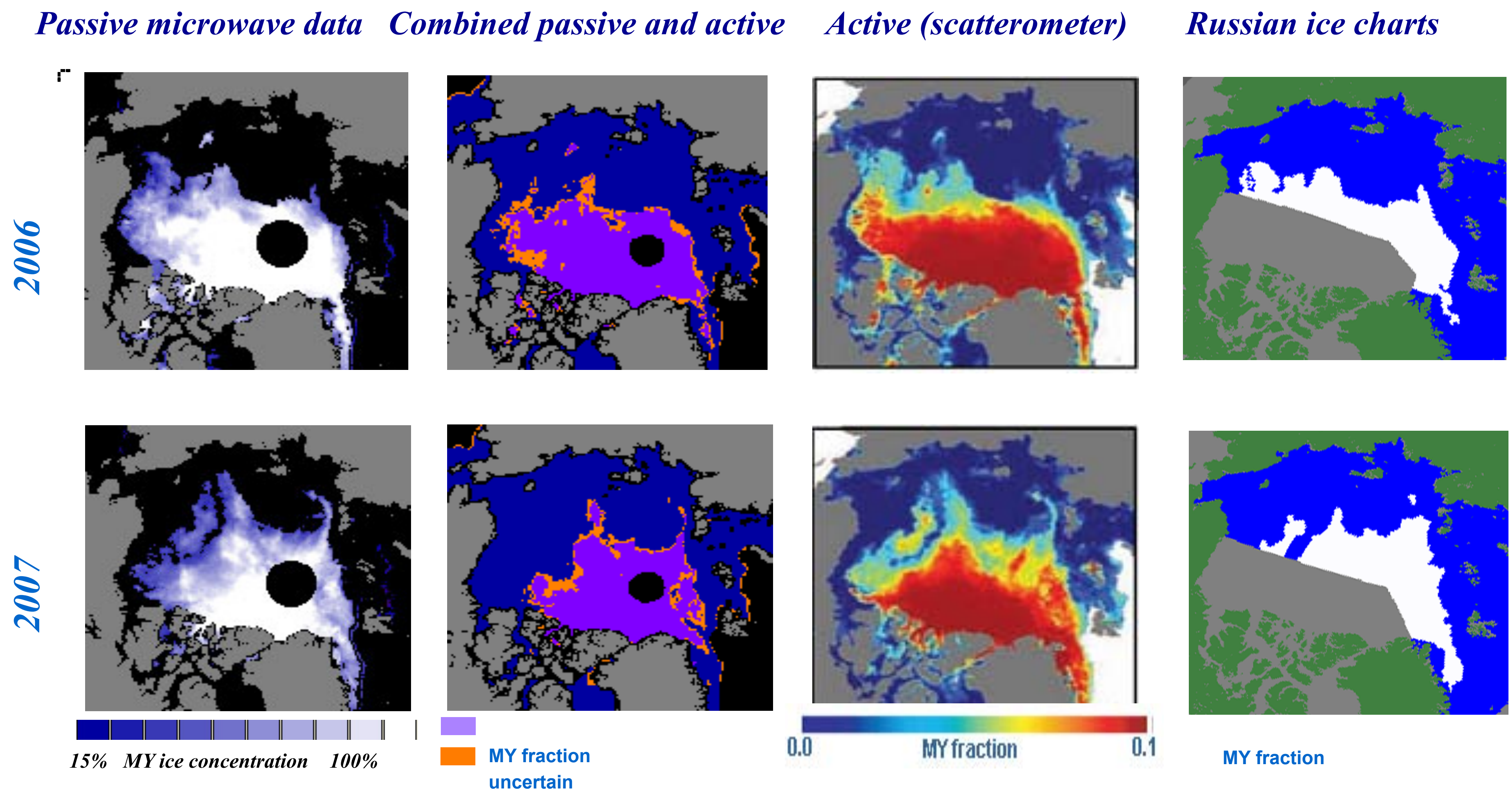


Fram drift:
≈ 3 years

Tara drift:
≈ 1. 5 years

Ref. Jean-Claude Gascard

Comparison of different MY ice products



NIERSC MY ice concentration maps

OSI SAF MY ice maps ftp://saf.met.no/archive/ice/type/

Kwok et al, 2009

AARI sea ice charts

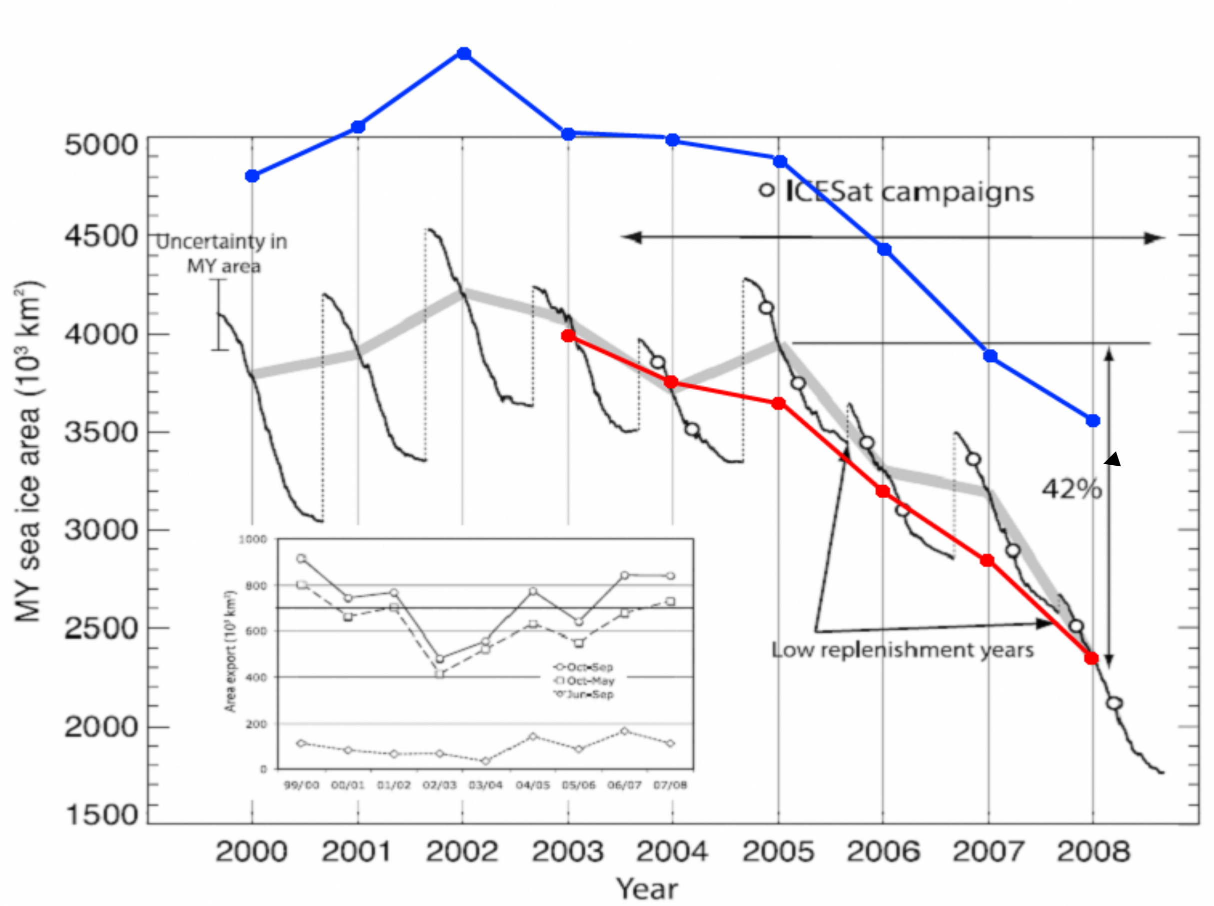
ftp://sidads.colorado.edu/pub/DATASETS/NOAA/G02176

MY ice area estimation from 2000 to 2008

Black - MY ice from QuikSCAT data and Fram Strait ice export (Kwok et al, 2009)
Grey - MY ice in January (Kwok et al, 2009)

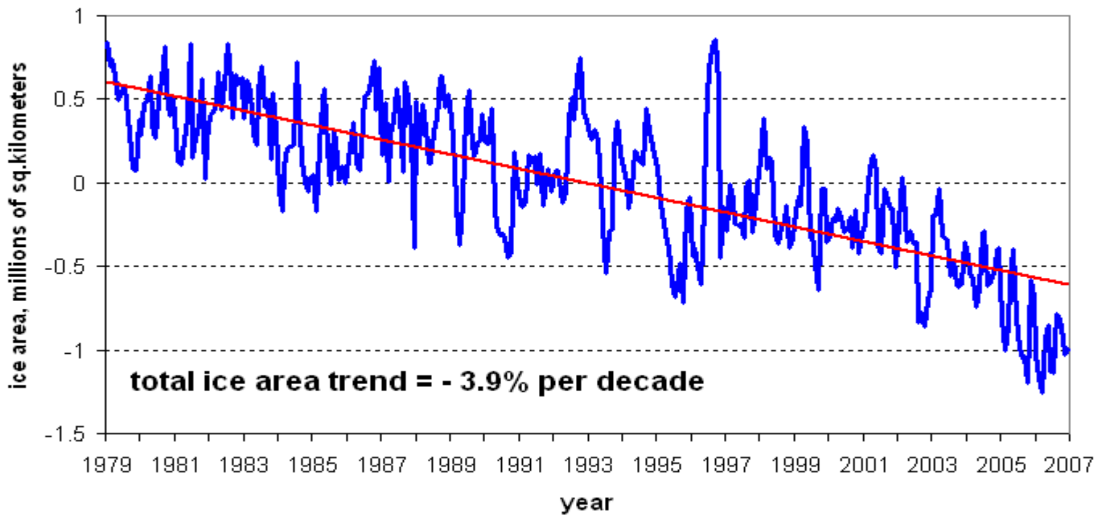
Blue - MY ice in January from SSM/I (NORSEX)

Red - MY ice in January from SSM/I and QuikSCAT (Shalina, 2009)



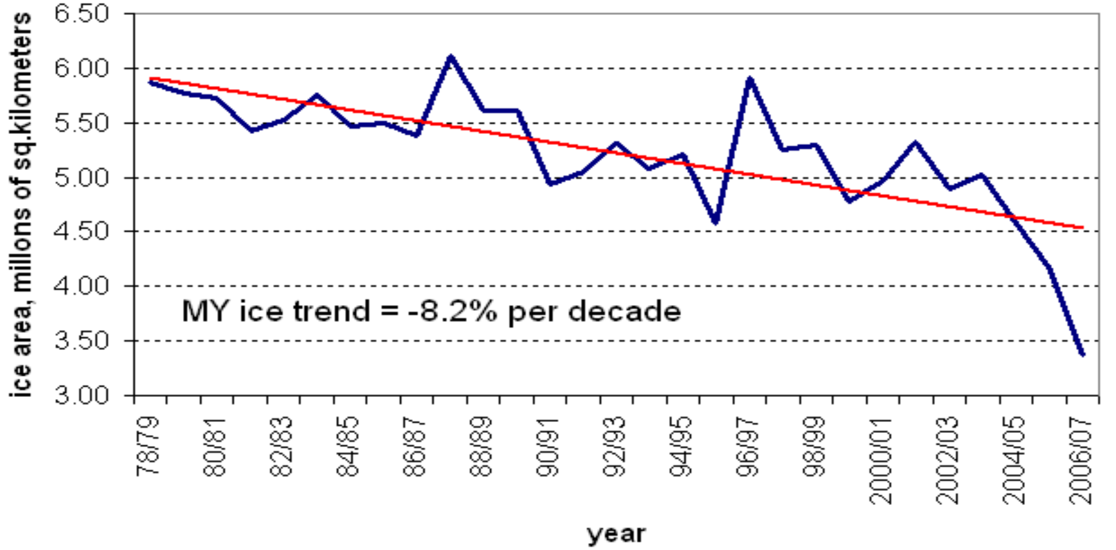
1 540 x 10^3 km^2 loss

Monthly ice area from SSMI data 1979 -2007



Total ice area:

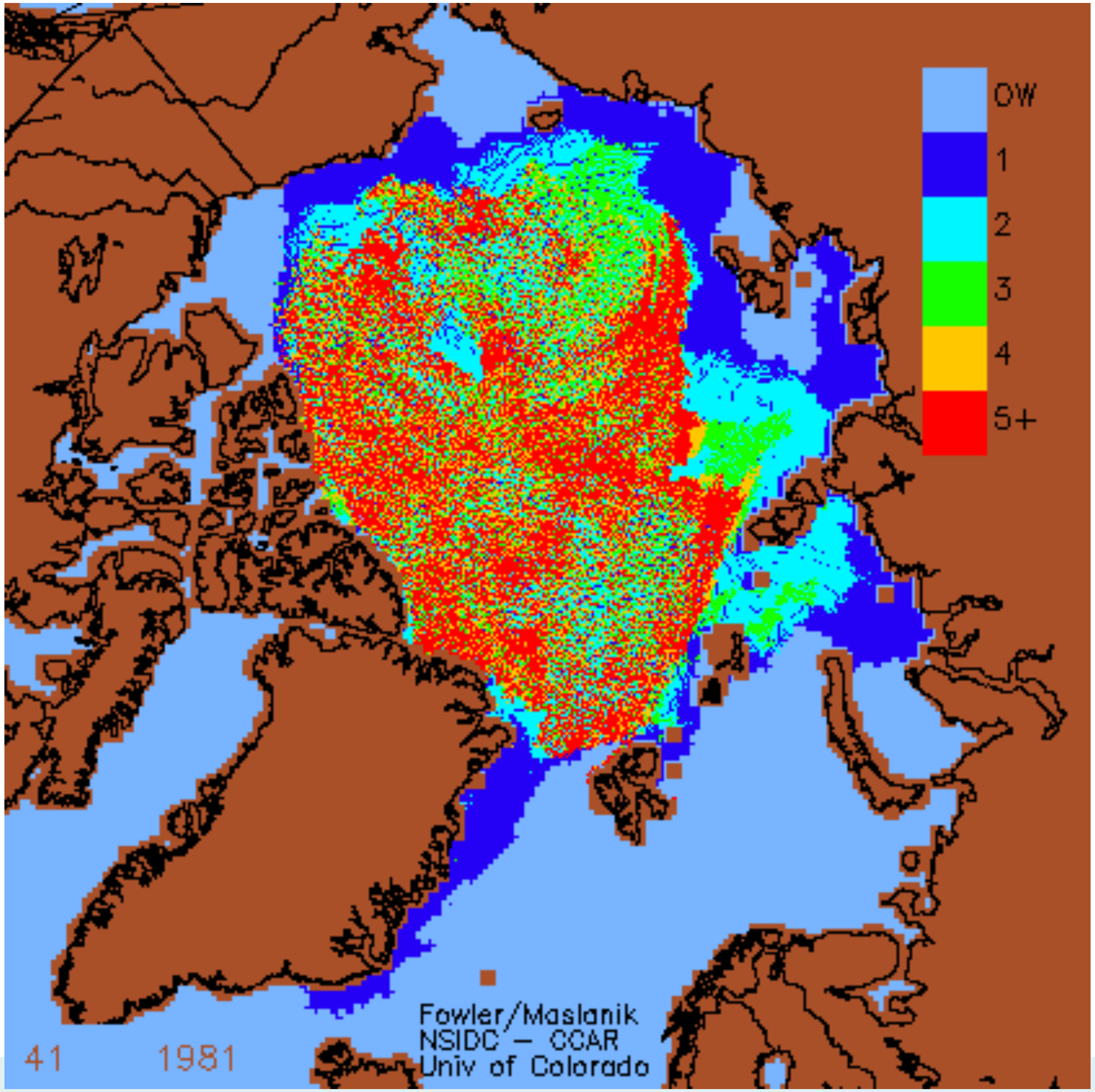
10 % reduction



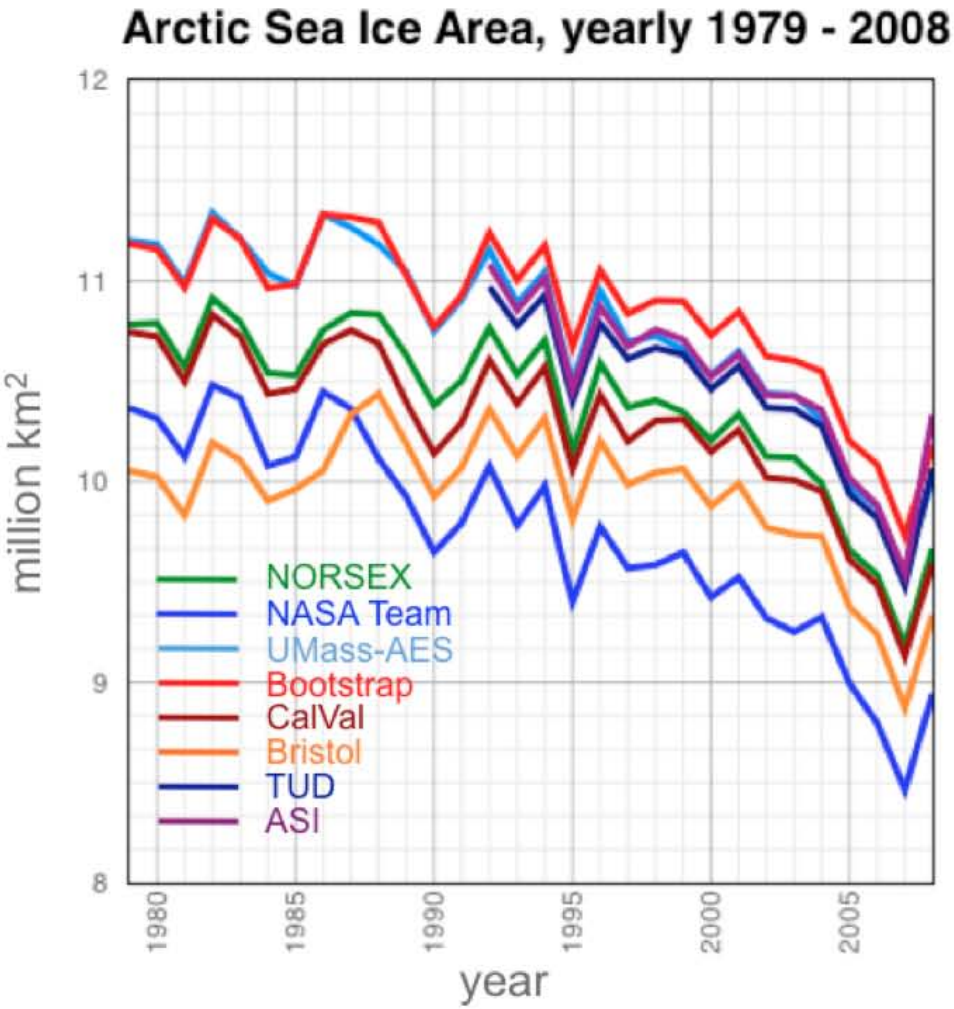
Multiyear ice area:

24 % reduction

Changes in old sea ice from 1981 to 2007



Comparison of algorithms

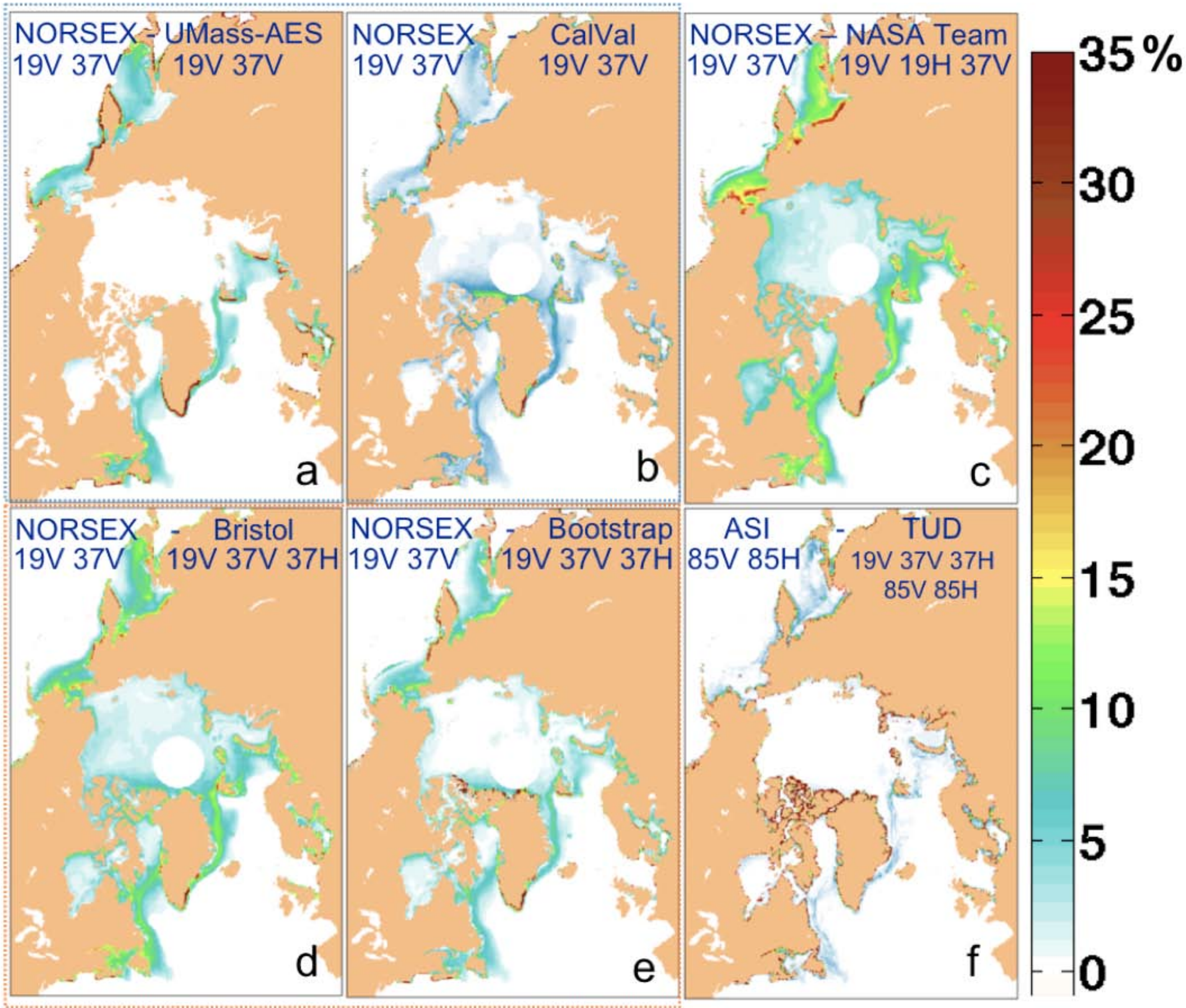


Sea ice area linear trends

Algorithm	Yearly minimum	Yearly mean	Yearly maximum
NORSEX	10.4	3.7	1.9
NASA Team	11.5	4.6	2.4
UMass-AES	10.6	4.0	2.3
Bootstrap	10.2	3.7	1.9
Cal Val	10.7	3.6	2.0
Bristol	9.8	2.4	0.4
TUD	18.4	6.0	3.0
ASI	18.8	5.8	3.1

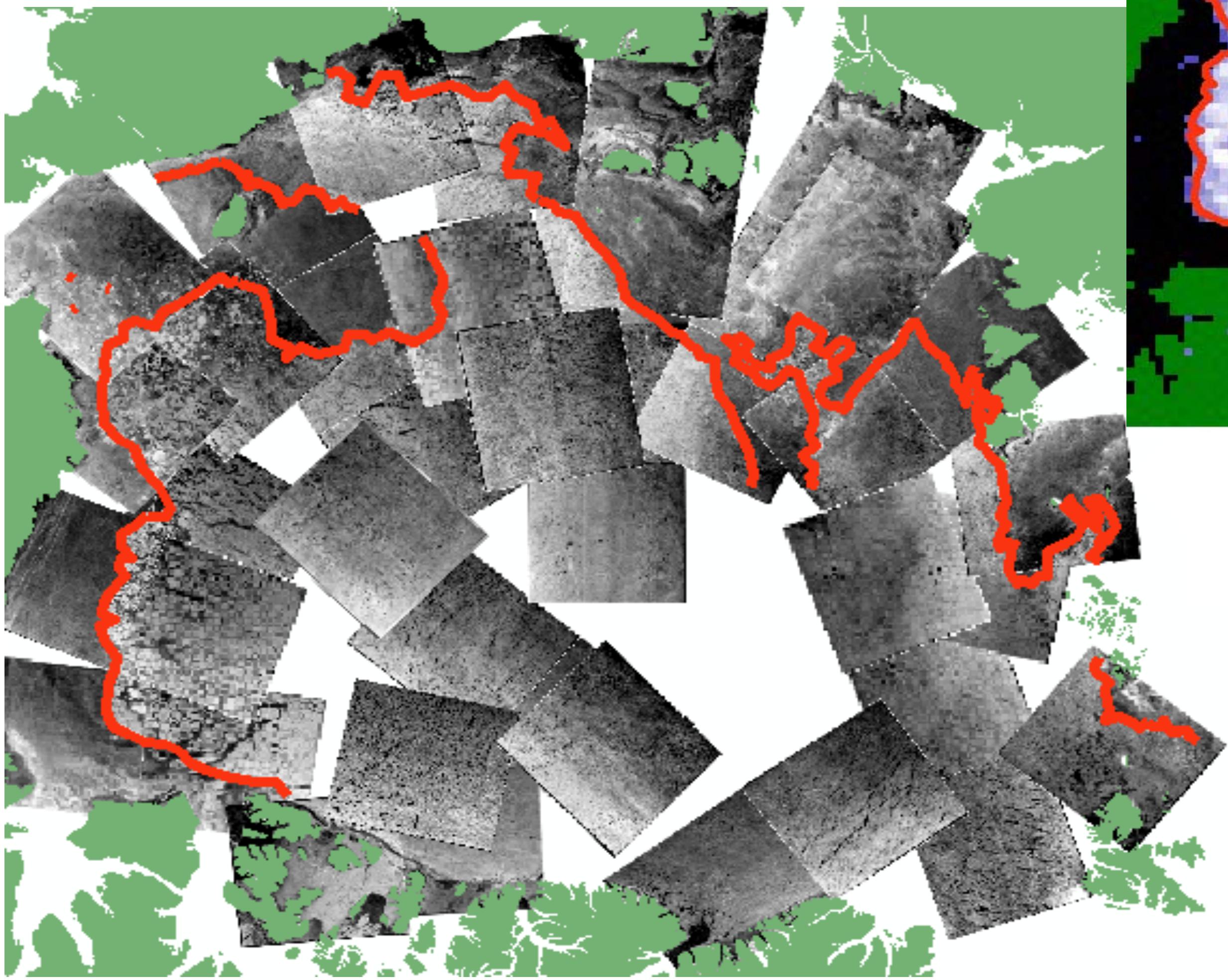
Arctic sea ice area change from 1979 to 2008 in % of 1979 value, per decade. For TUD and ASI algorithms it is change from 1992 to 2008 in % of 1992 value, per decade. September is taken as yearly minimum and March as yearly maximum.

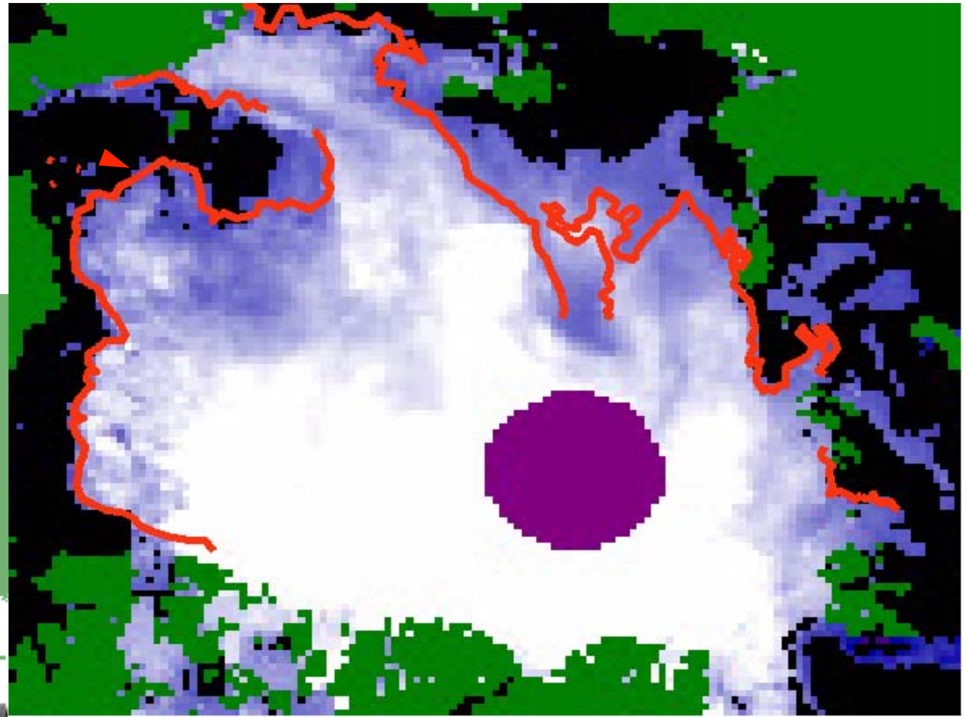
Differences are mainly in the Marginal Ice Zone and during the melt season



SAR mosaic for validation of MY ice map

SAR mosaic with
MY ice boundary

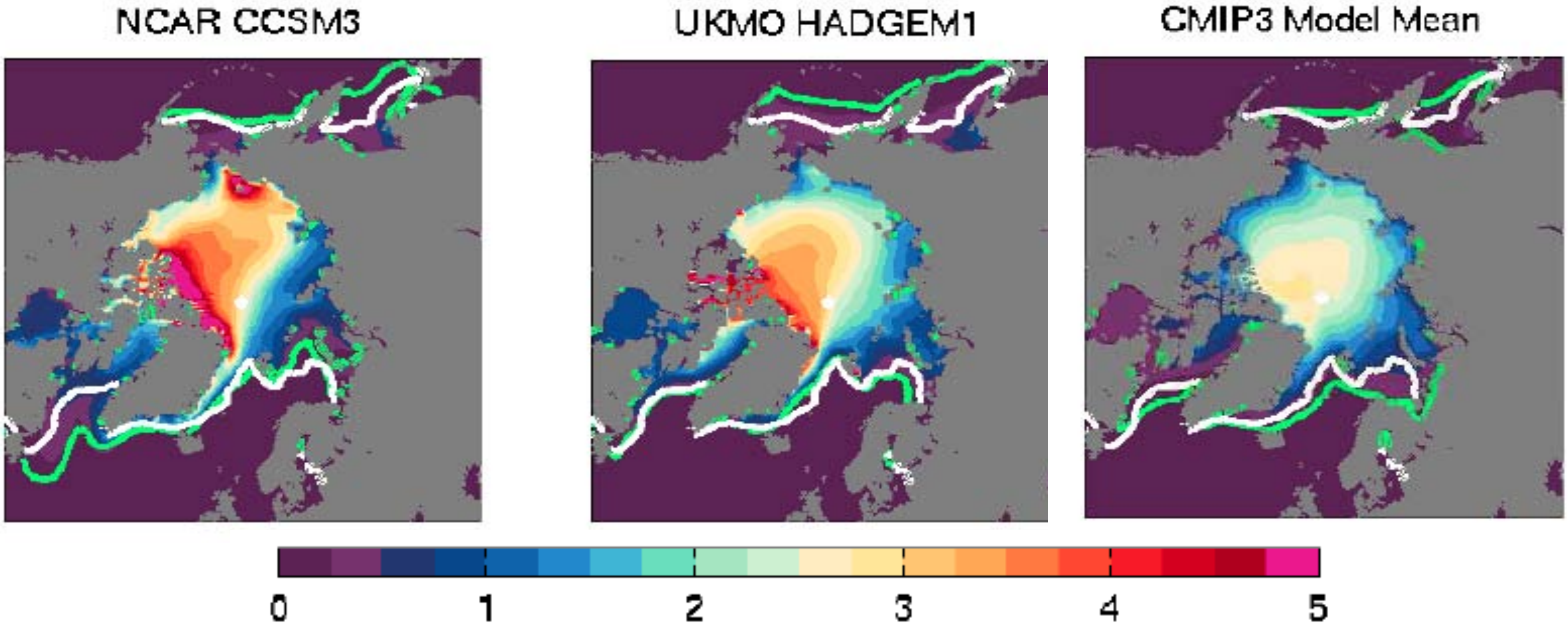




MY ice map January 2006

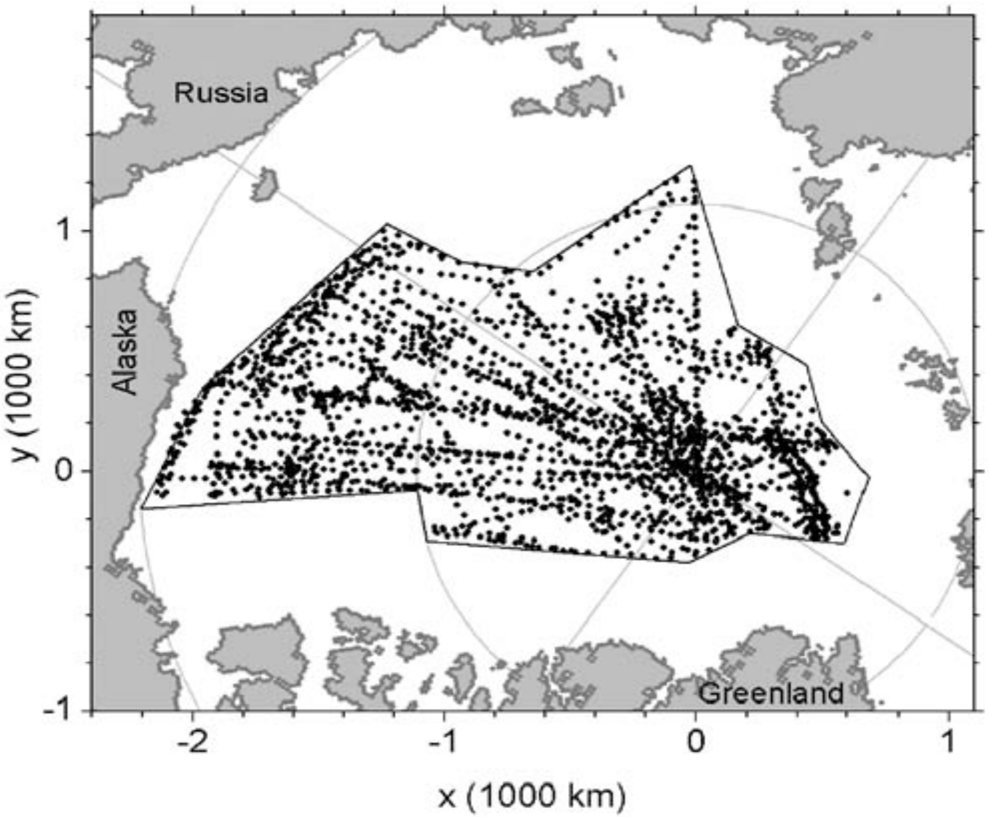
MY ice boundary is drawn
on the SAR mosaic from ENVISAT
basing on visual interpretation
and then it is placed on the
NORSEX MY ice map

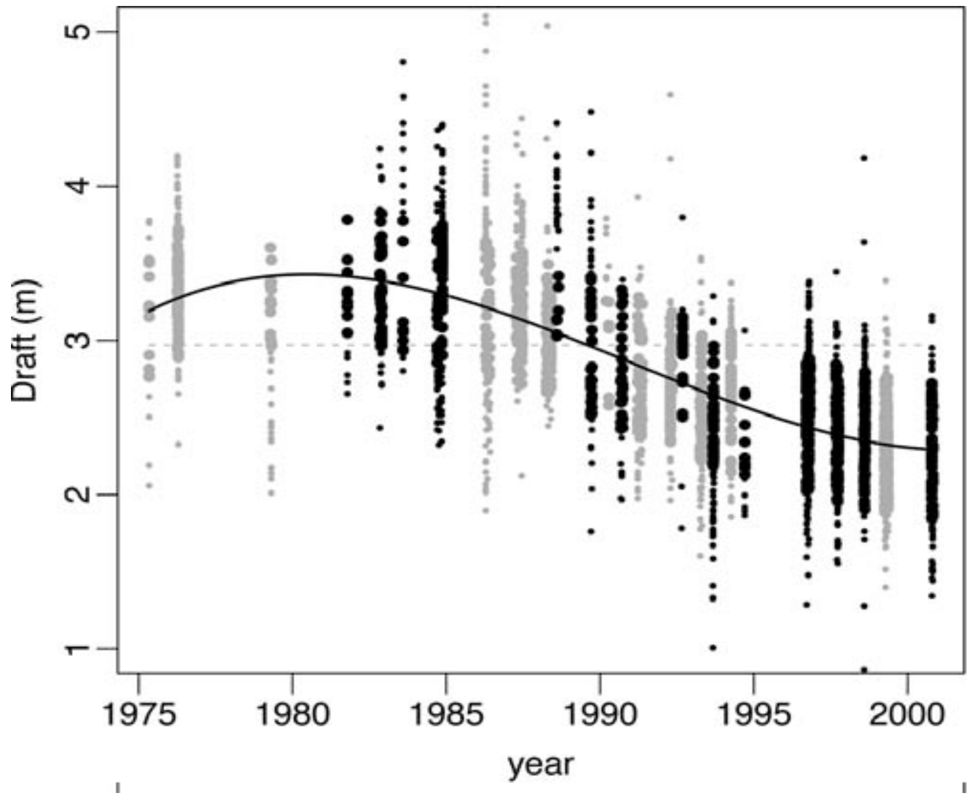
Ice thickness from climate models



1980-1999 mean sea ice thickness (in m) from two climate models and the mean from CMIP3 models and annual mean ice extent from the models (green line) with observed ice extent (white line) (Ref. Bitz et al., 2010).

Observed thickness reduction from submarine data 1975 -2000

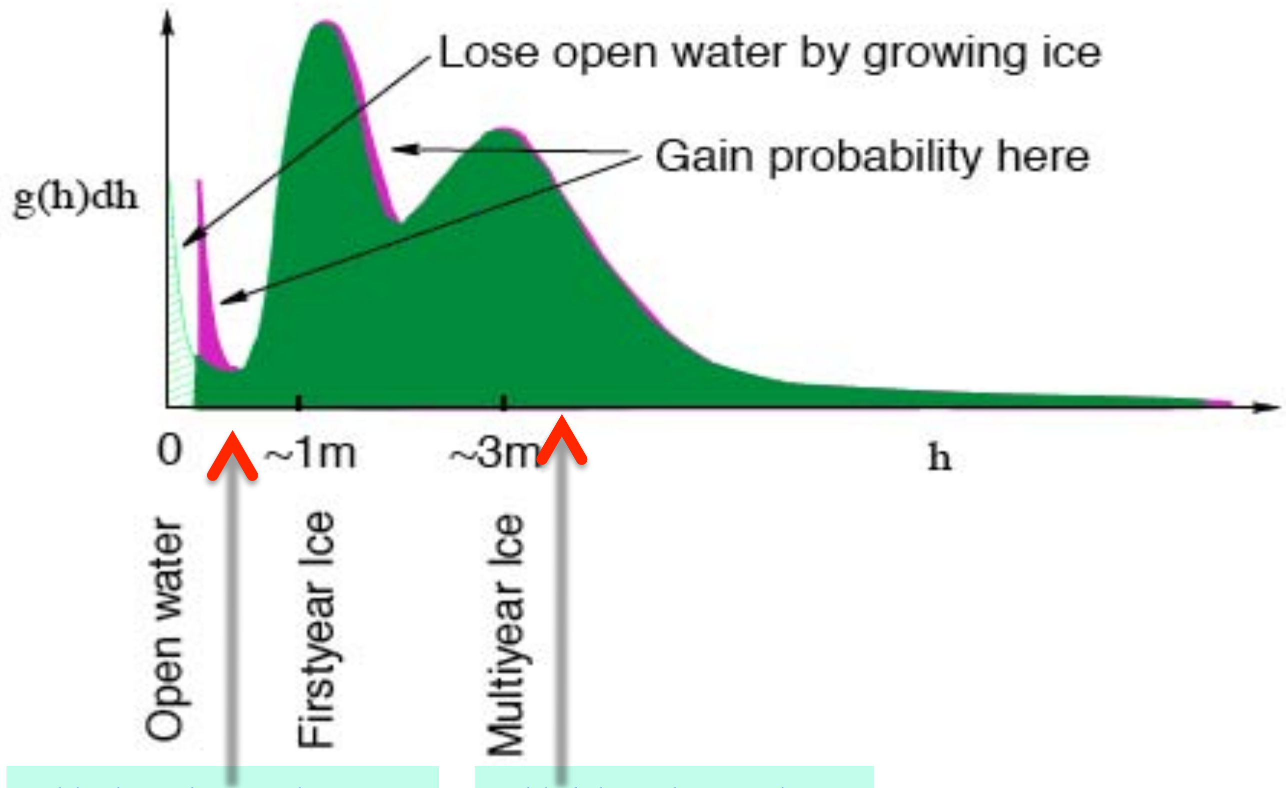




1980: 3.42 m, 2000: 2.29 m (mean value) Rothrock et al., 2008

Ice thickness distribution

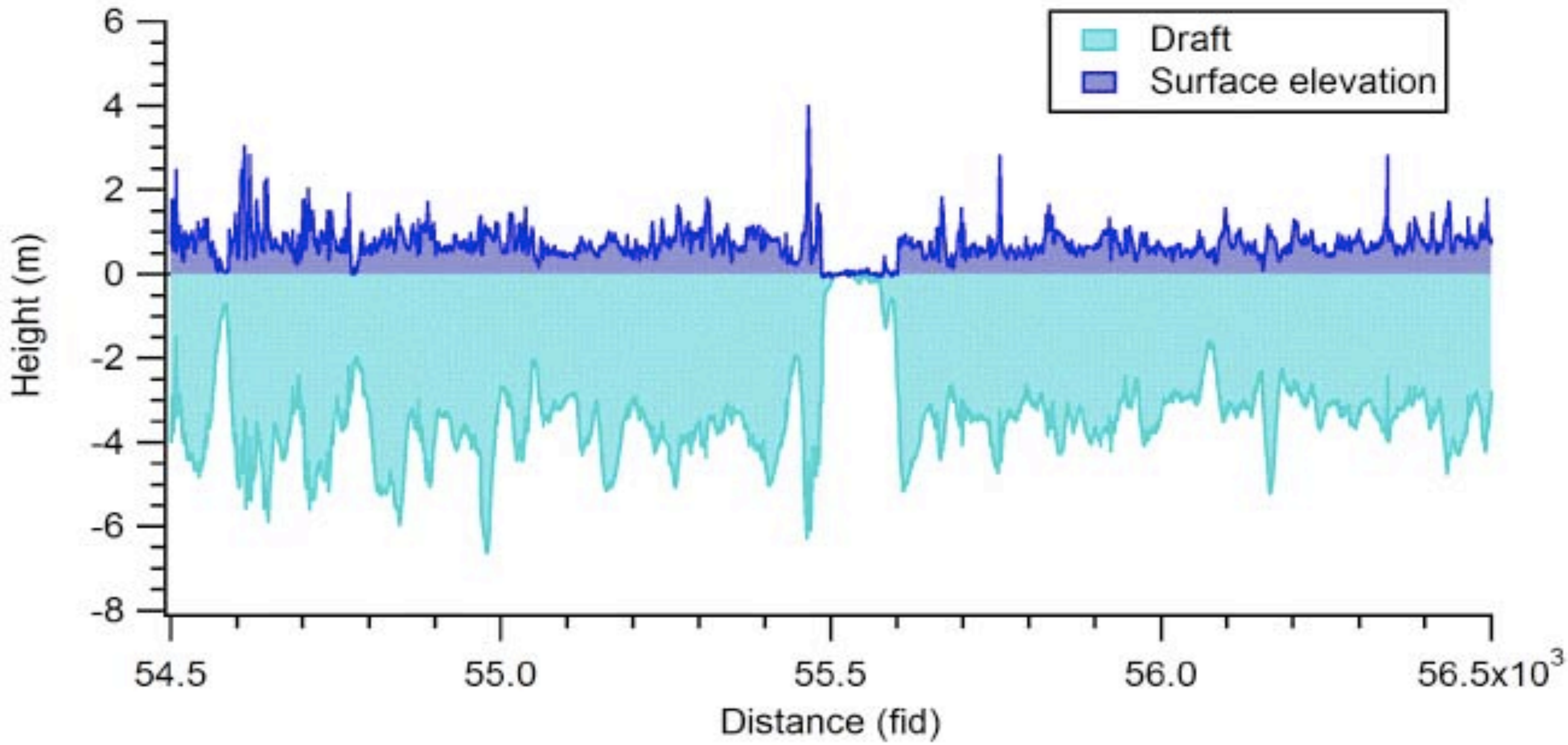
(probability density function – pdf)



Thin ice observations (SMOS, IR)

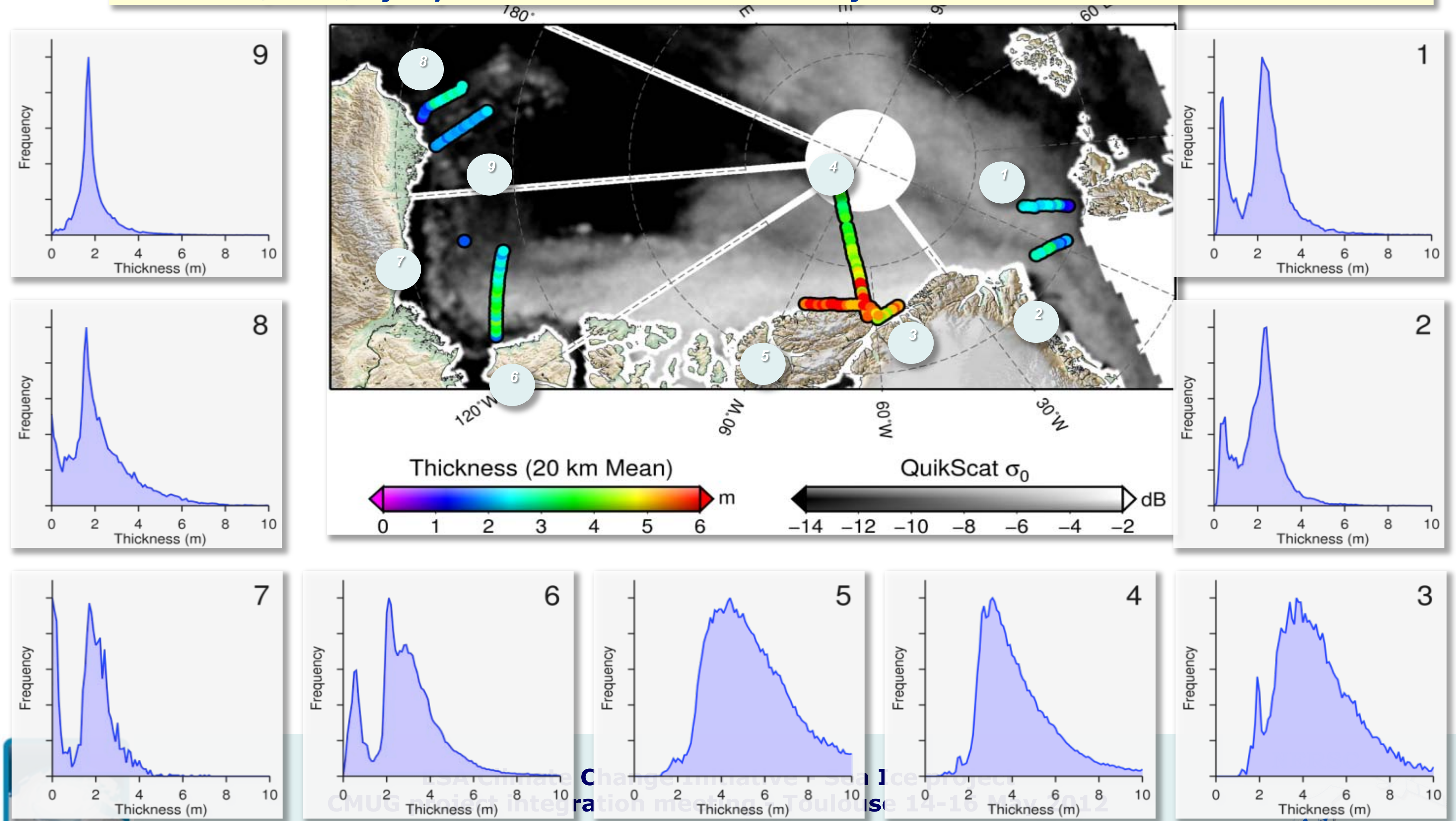
Thick ice observations (CryoSat, IceSat)

Sea ice freeboard and draft from airborne EM surveys

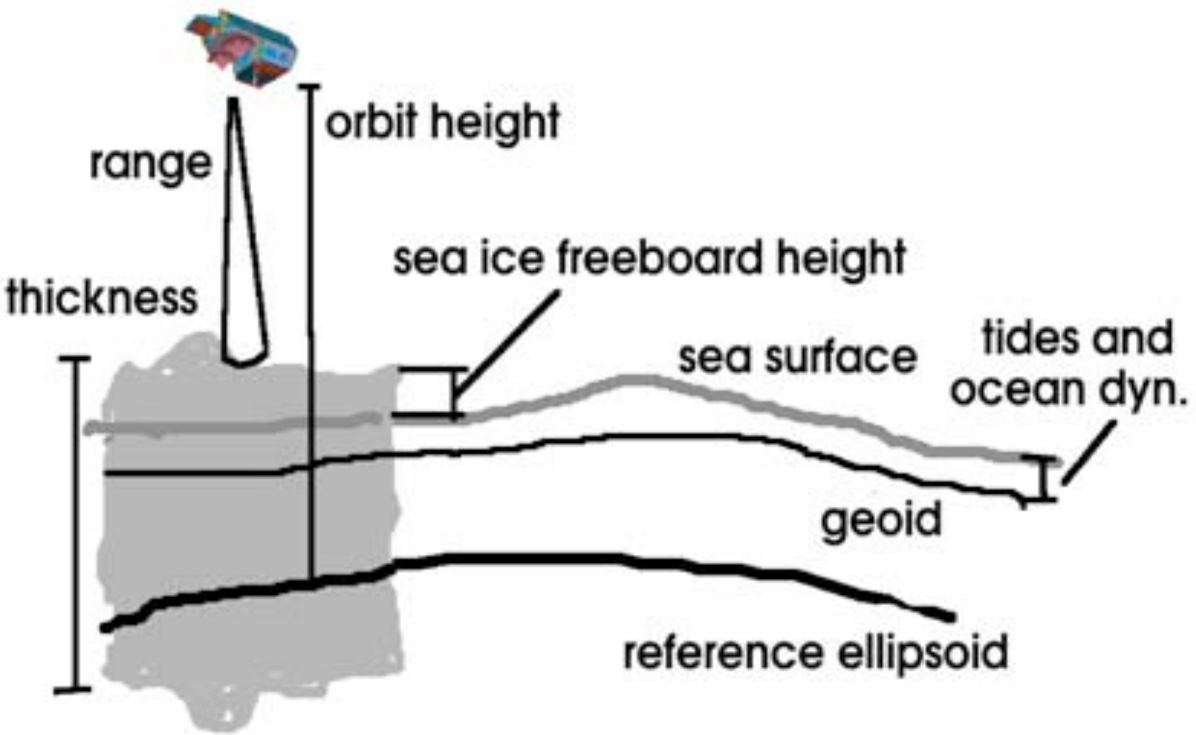


Ice thickness data from aircraft EM surveys 2009

Haas et al., 2010, Synoptic airborne thickness surveys reveal state of Arctic sea ice cover



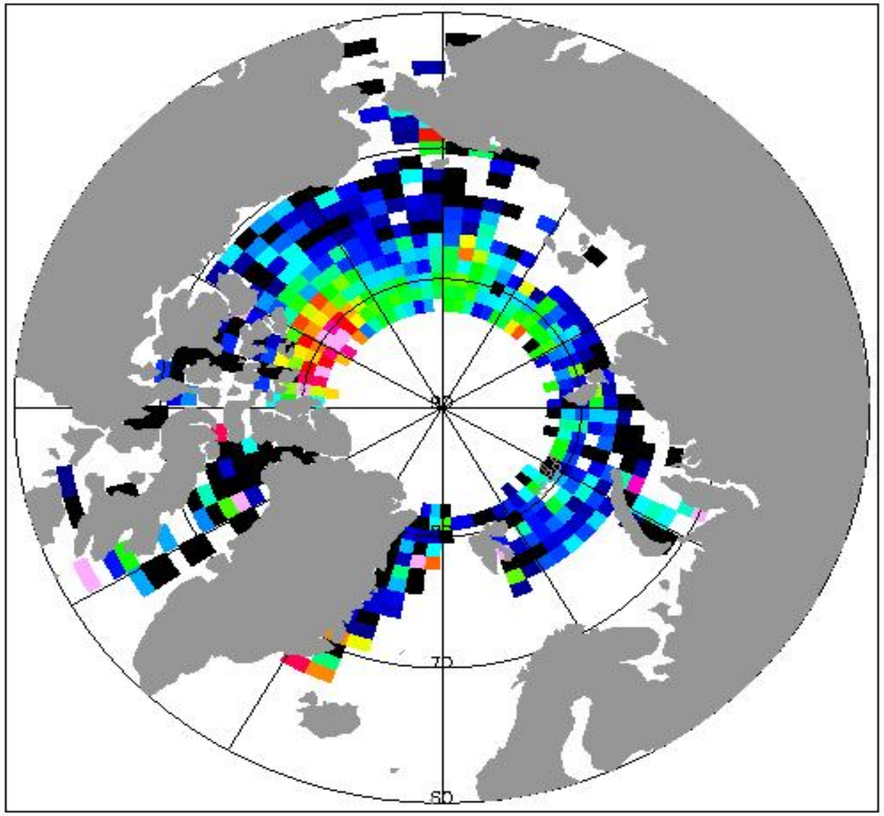
Observing sea ice freeboard height by satellite altimetry



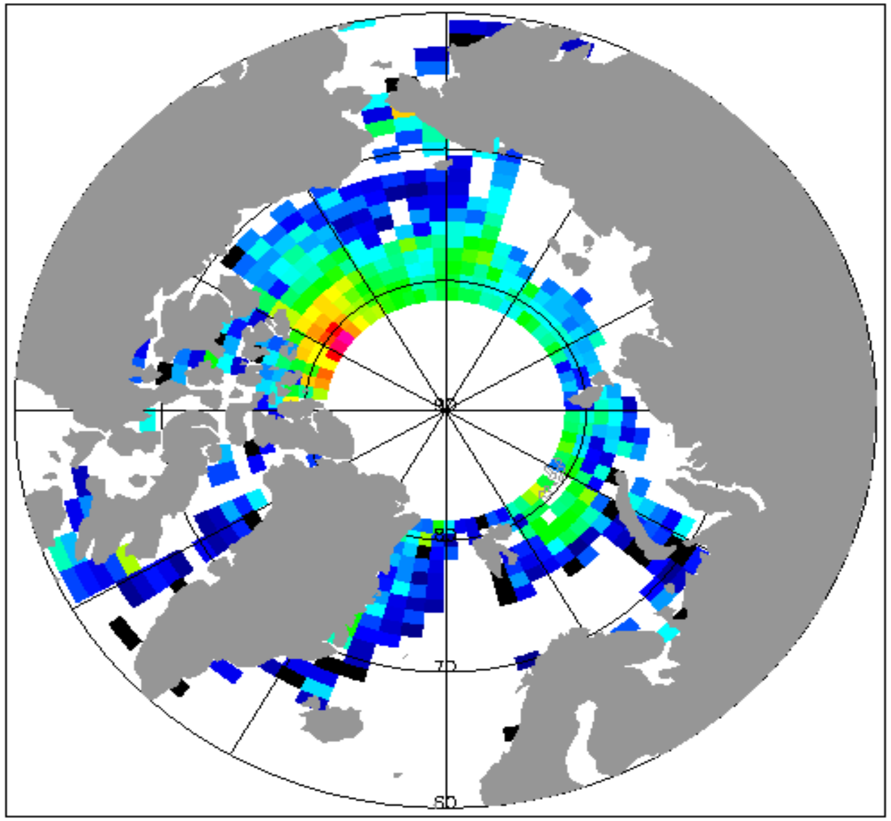
Sea ice freeboard measurements

Overlapping data: 9 Dec 02 -> 13 Jan 03

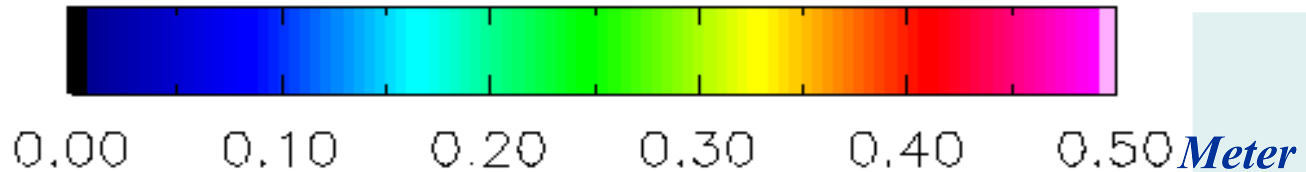
Envisat (from 2002)



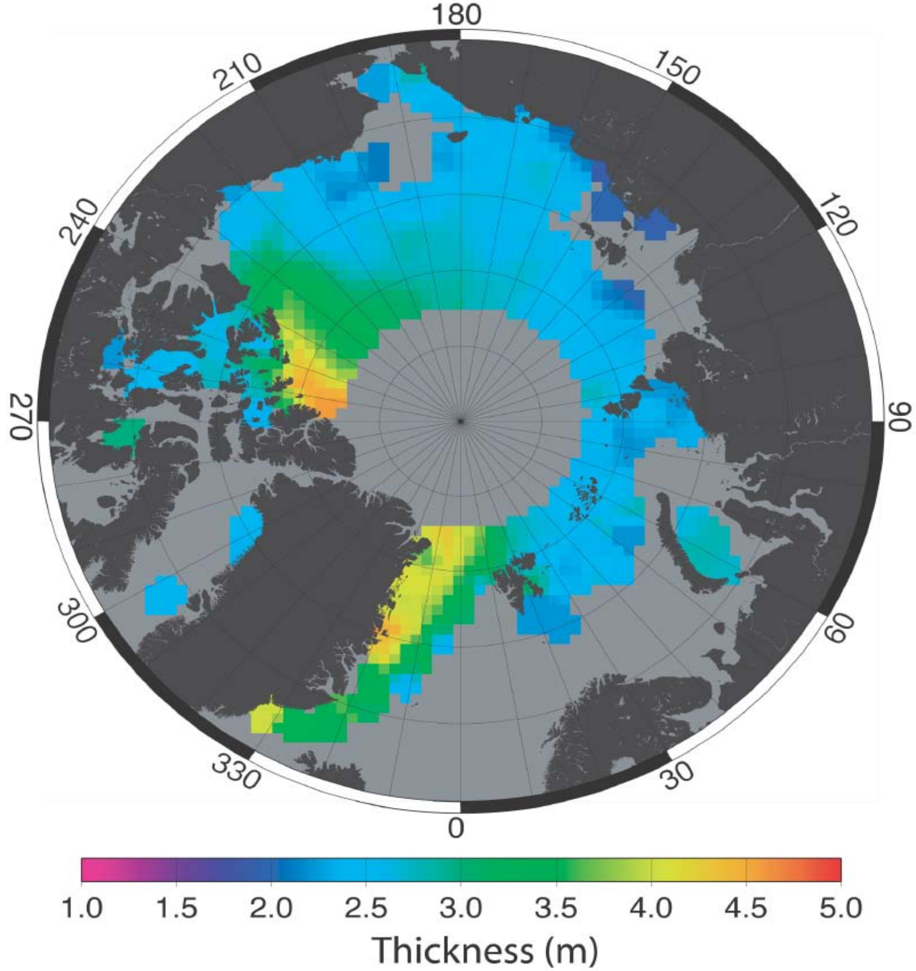
ERS-1 and 2_from 1993



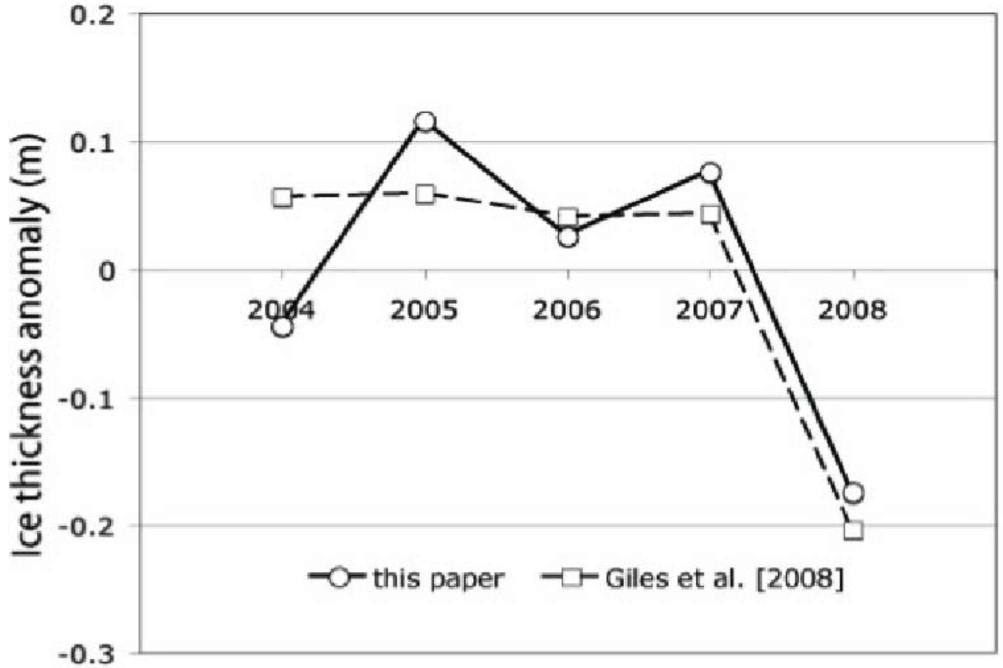
Courtsey: A. Ridout, UCL



Thickness from radar altimeters 1993 - 2008

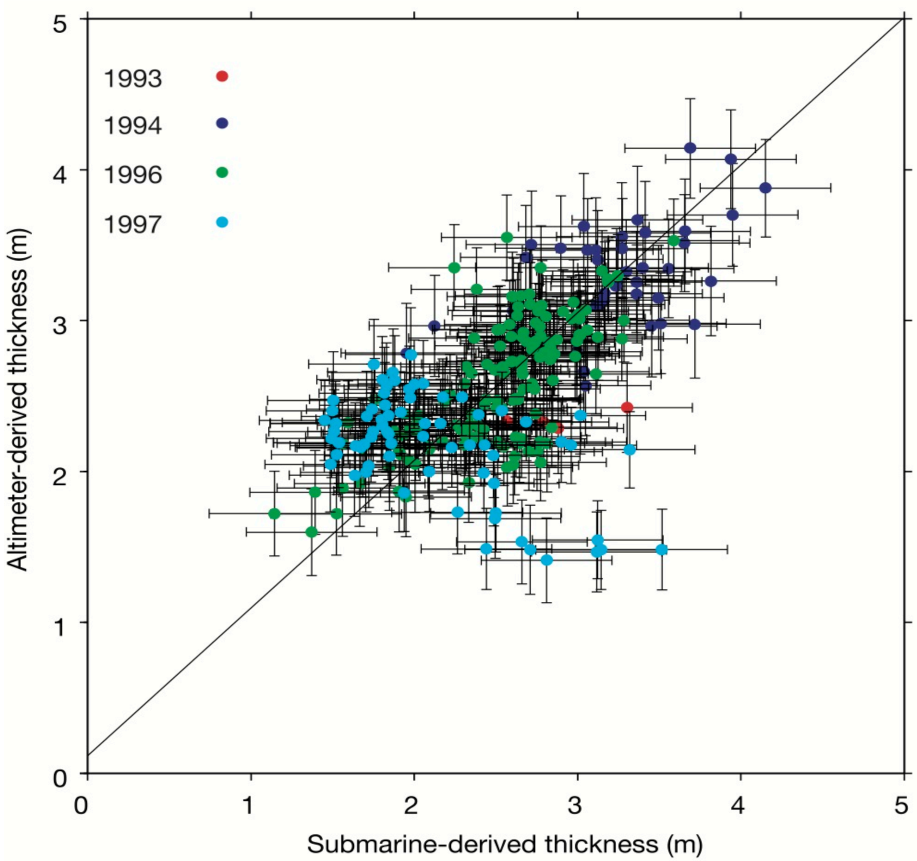


Average winter (October to March) Arctic sea ice thickness from October 1993 to March 2001 from ERS satellite altimeter measurements of ice freeboard (Laxon, et al., 2003)



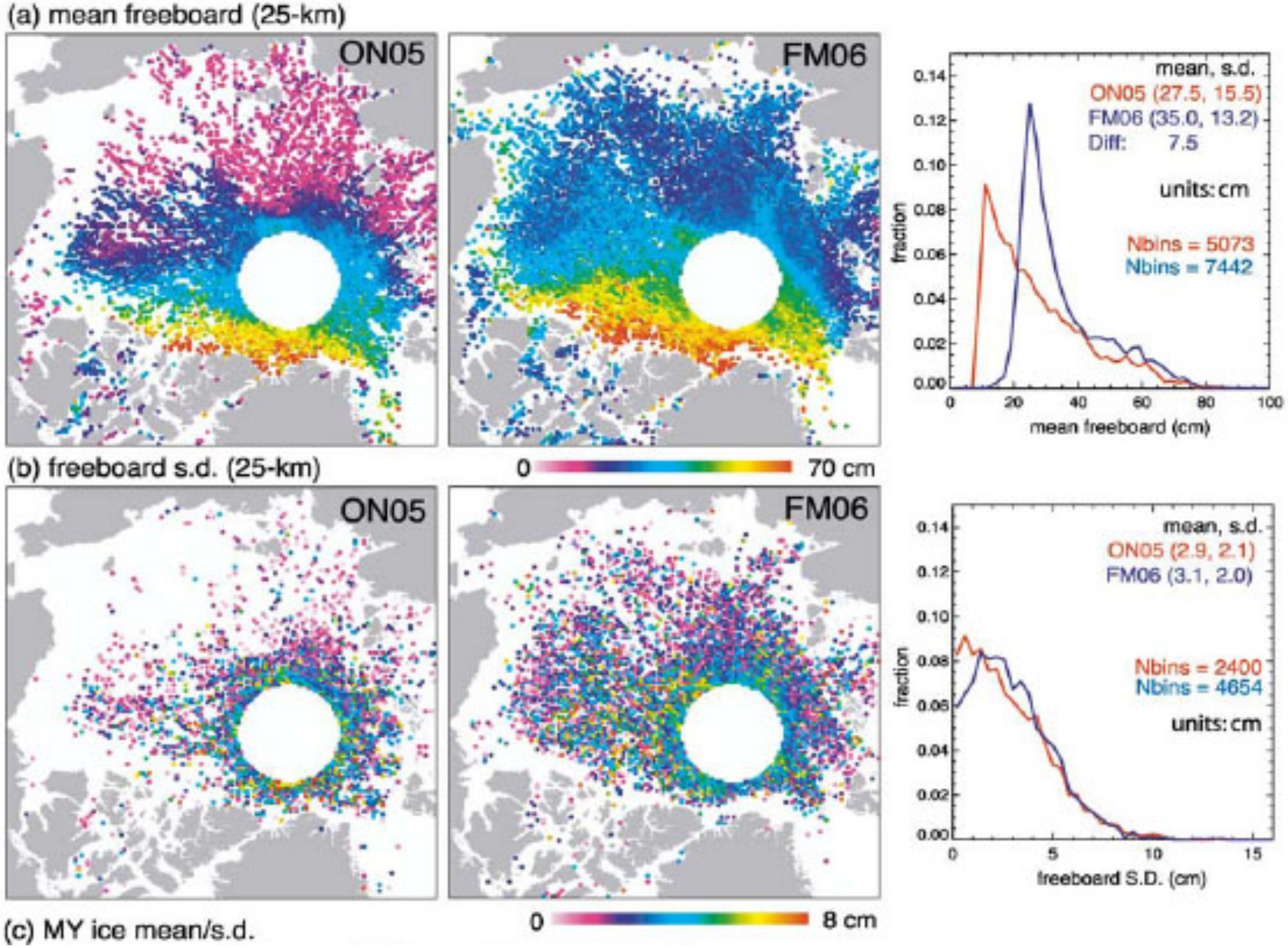
Comparison of ice thickness anomalies between IceSat and Envisat in areas of mission overlap (from [Kwok et al., 2009], citation Giles et al. (2008)

Validation of radar altimeter thickness using submarine data



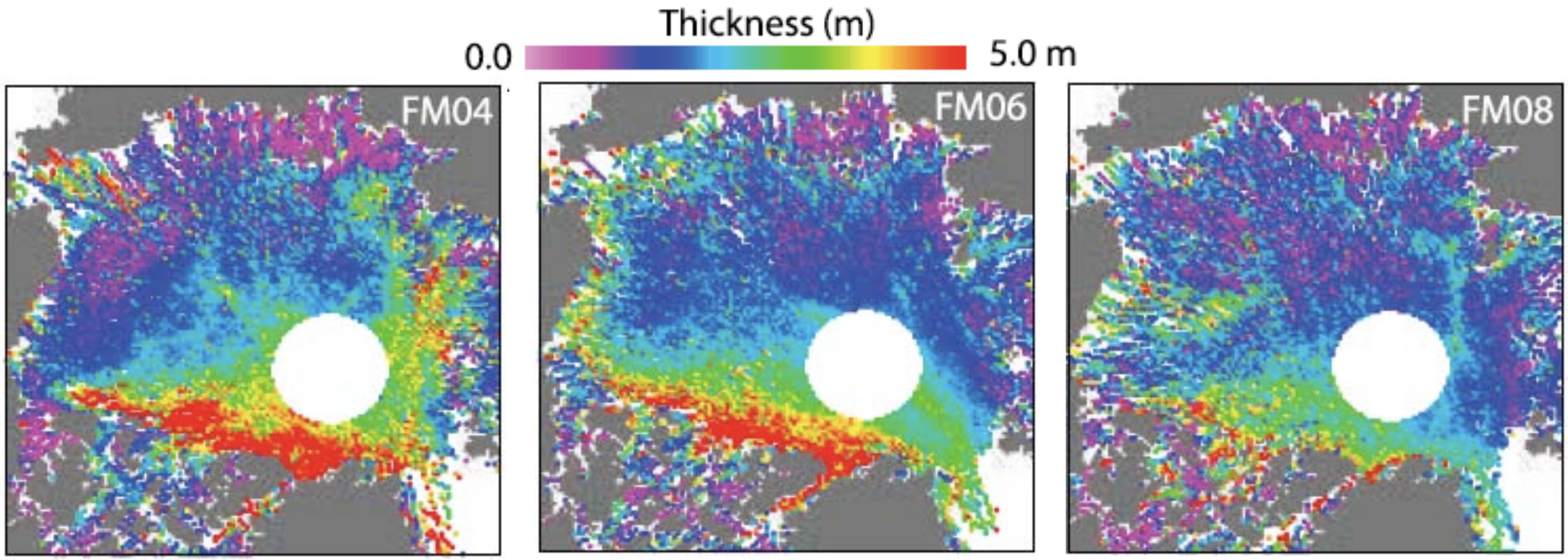
Comparison between ERS satellite altimeter and submarine derived ice thickness in the Beaufort Sea during the 1990s. Submarine thicknesses are shown for each of the 50 km segments gathered during the four missions during the 1990s. Altimeter thickness estimates are generated from observations within 15 days and 100 km of the submarine draft sections [Laxon et al., 2003].

Sea ice + snow freeboard from laser altimeter on IceSat



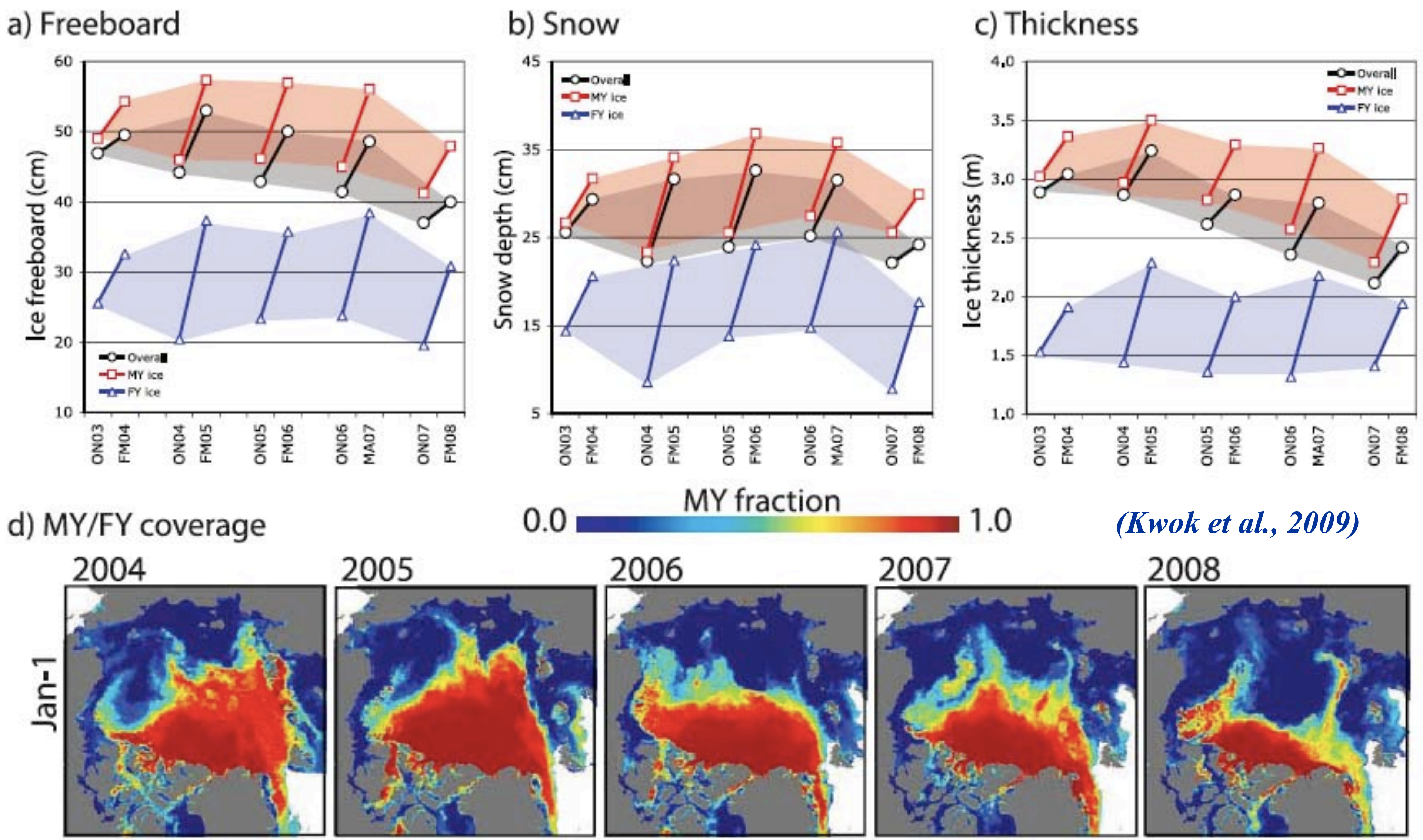
Maps of retrieved freeboards (25 km bins) from the ON05 and FM06 ICESat data set.Upper panel: Mean freeboard. Lower panel: Standard deviation (Ref. Ron Kwok).

Ice thickness retrieval from IceSat data: 2004, 2006, 2008



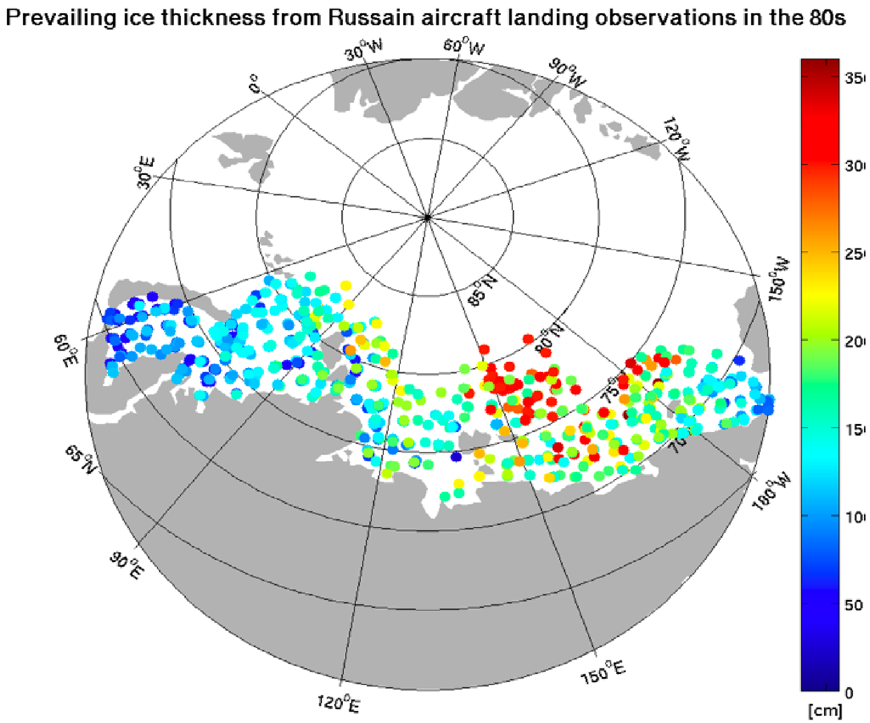
(Kwok et al., 2009)

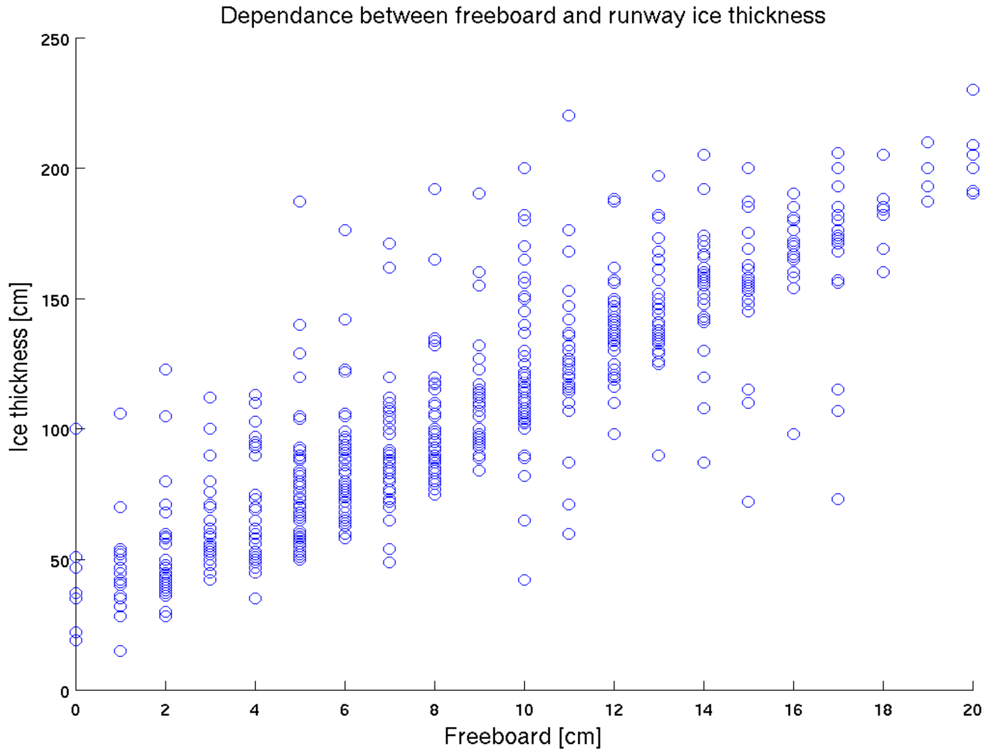
Example of ice freeboard and thickness retrieval from IceSat data (2003 - 2008)



(Kwok et al., 2009)

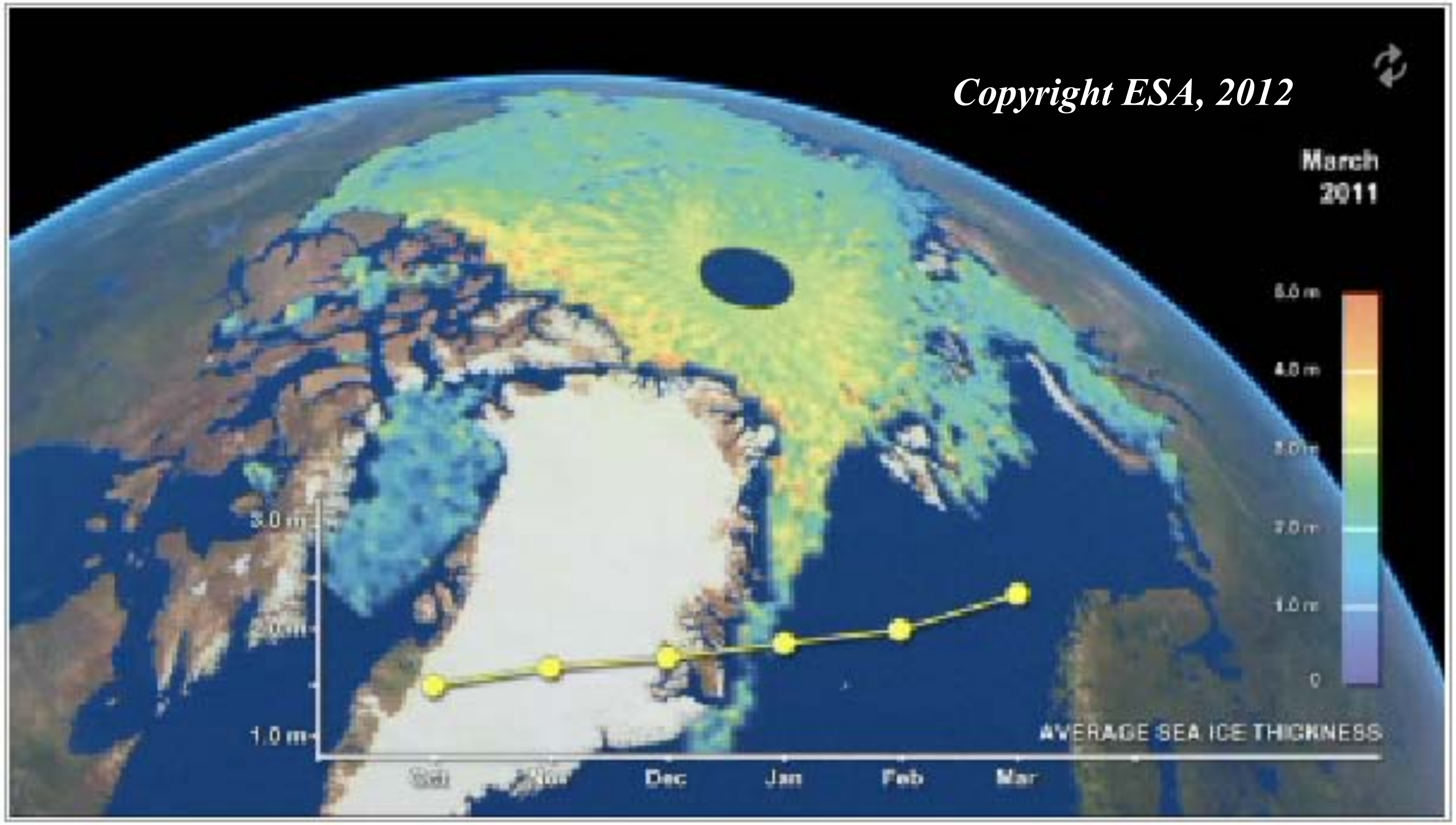
Validation of the thickness-freeboard relation





Analysis of coincident ice thickness and freeboard measurements from Russian aircraft landings in the 1980s (Alexandrov e al., 2010)

CryoSat-2: first results of ice thickness retrieval Oct 2010- March 2011



Status and plans for the CCI Sea ice project