Arctic Marine Research:

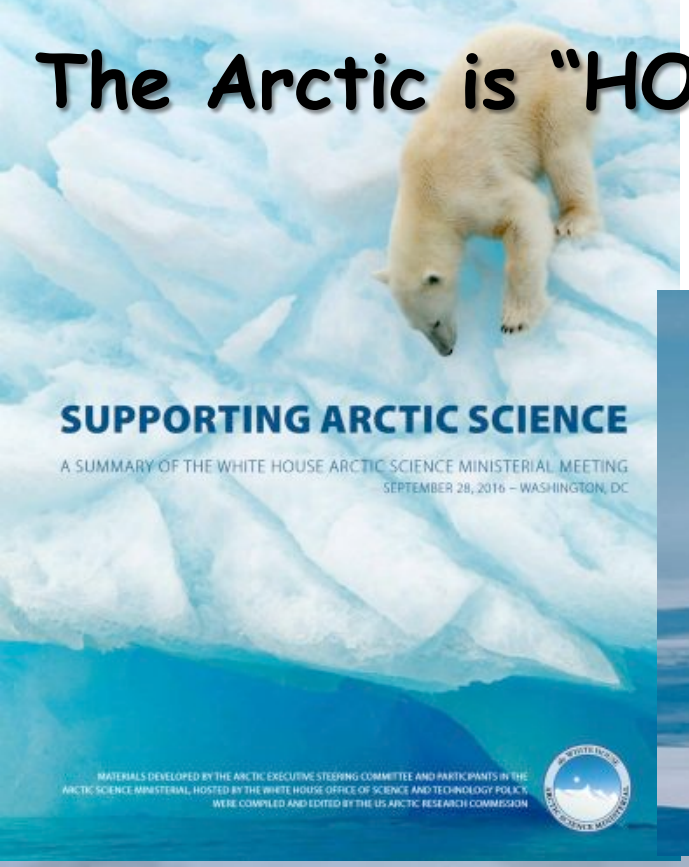
A Practitioner's Perspective

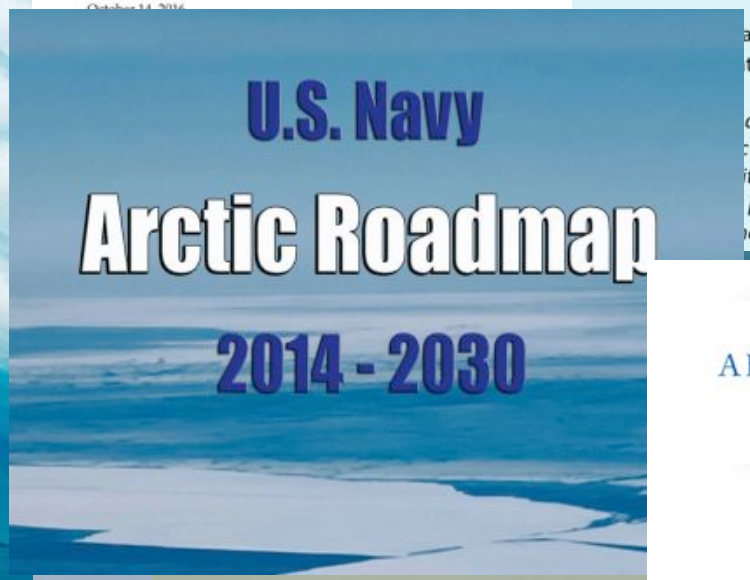
Larry Mayer
Professor and Director
Center for Coastal and Ocean Mapping
University of New Hampshire, USA

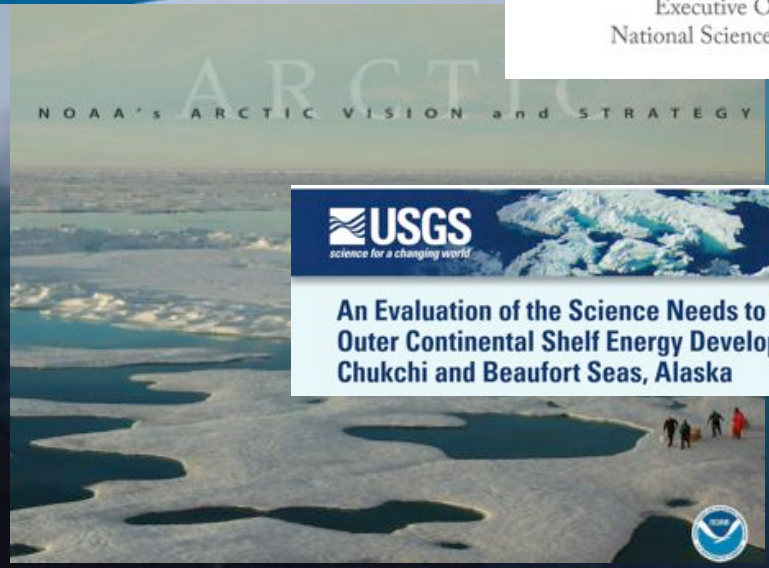
UNOLS Annual Meeting

Arlington, VA 30 November 2016

The Arctic is "HOT"







U.S. invests approximately $400M→$1B per year in Arctic research through at least 15 agencies

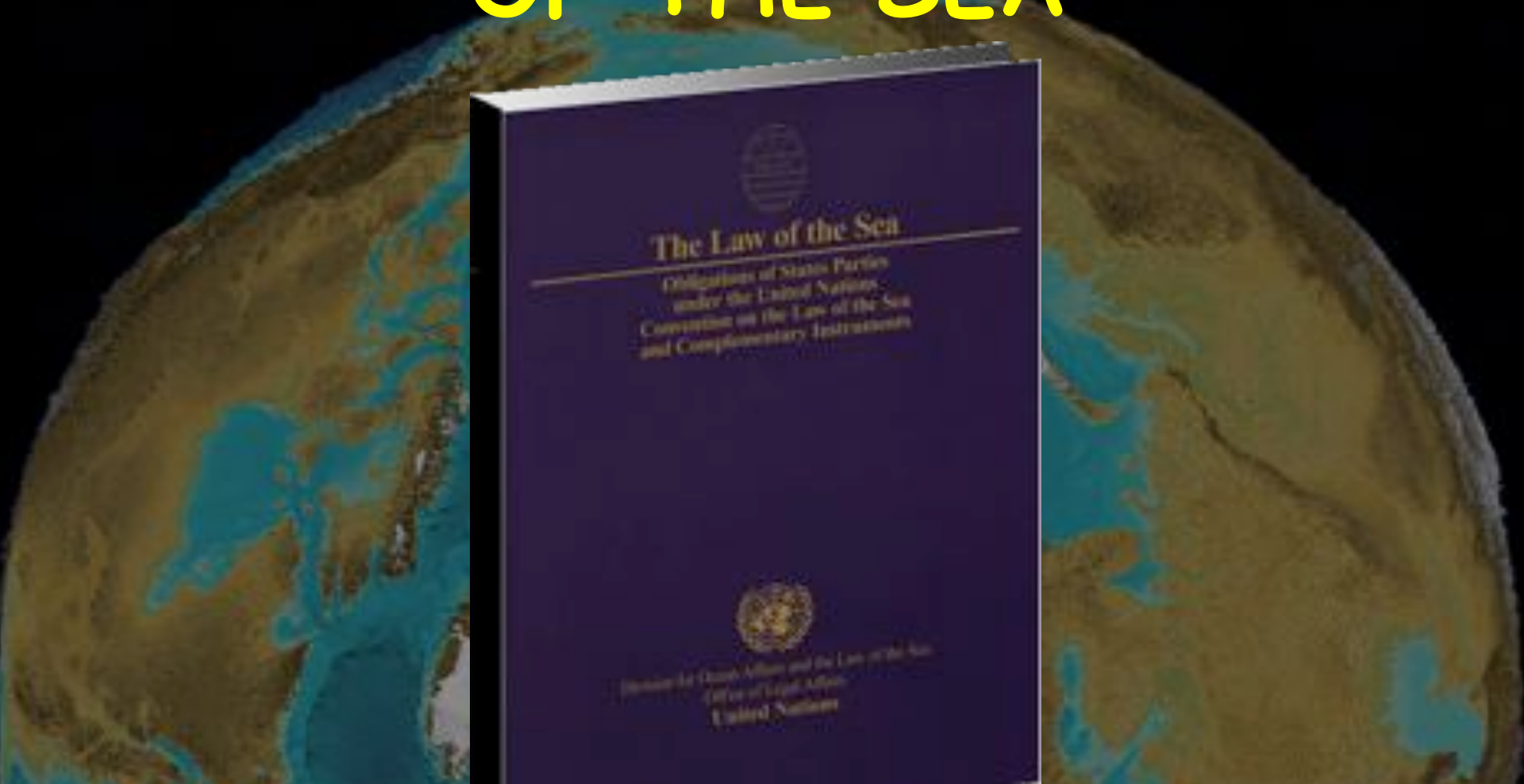
US ARMY CORPS
OF ENGINEERS

MANY AREAS OF FOCUS - ONE IS EXTENSION OF "CONTNENTAL SHELF" THROUGH CONVENTION ON THE LAW OF SEA

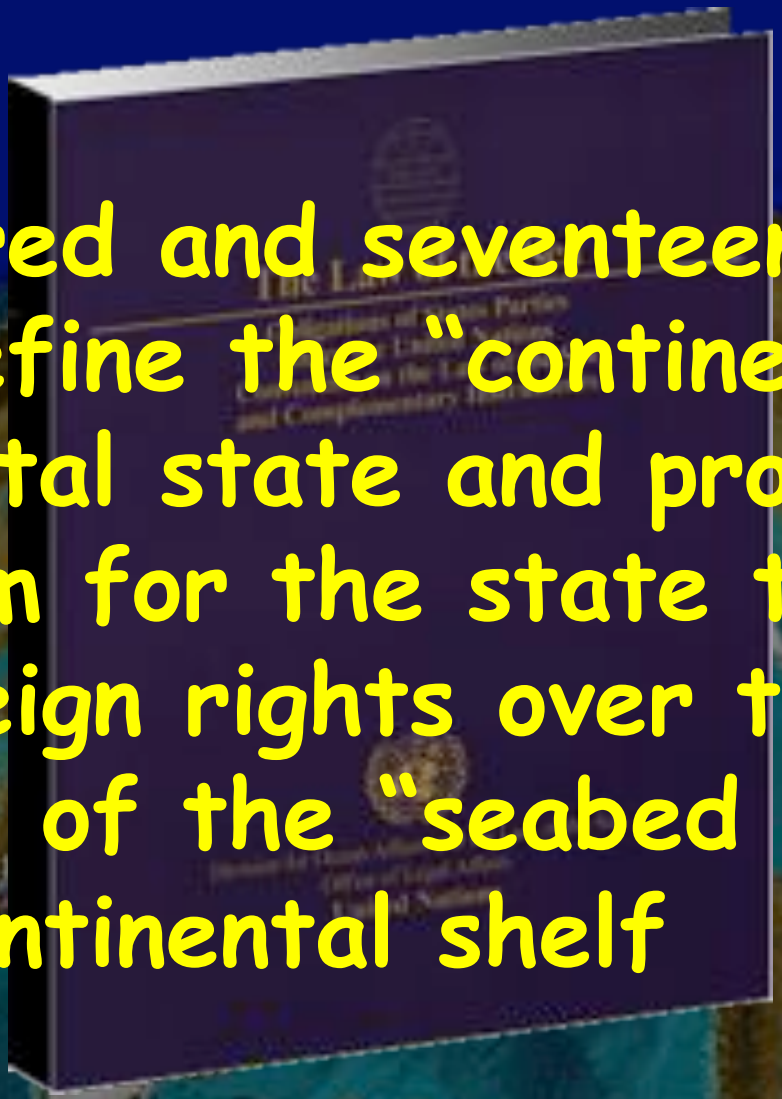
US ARMY CORPS OF ENGINEERS

US Arctic Research Commission

THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA



ARTICLE 76 of UNCLOS



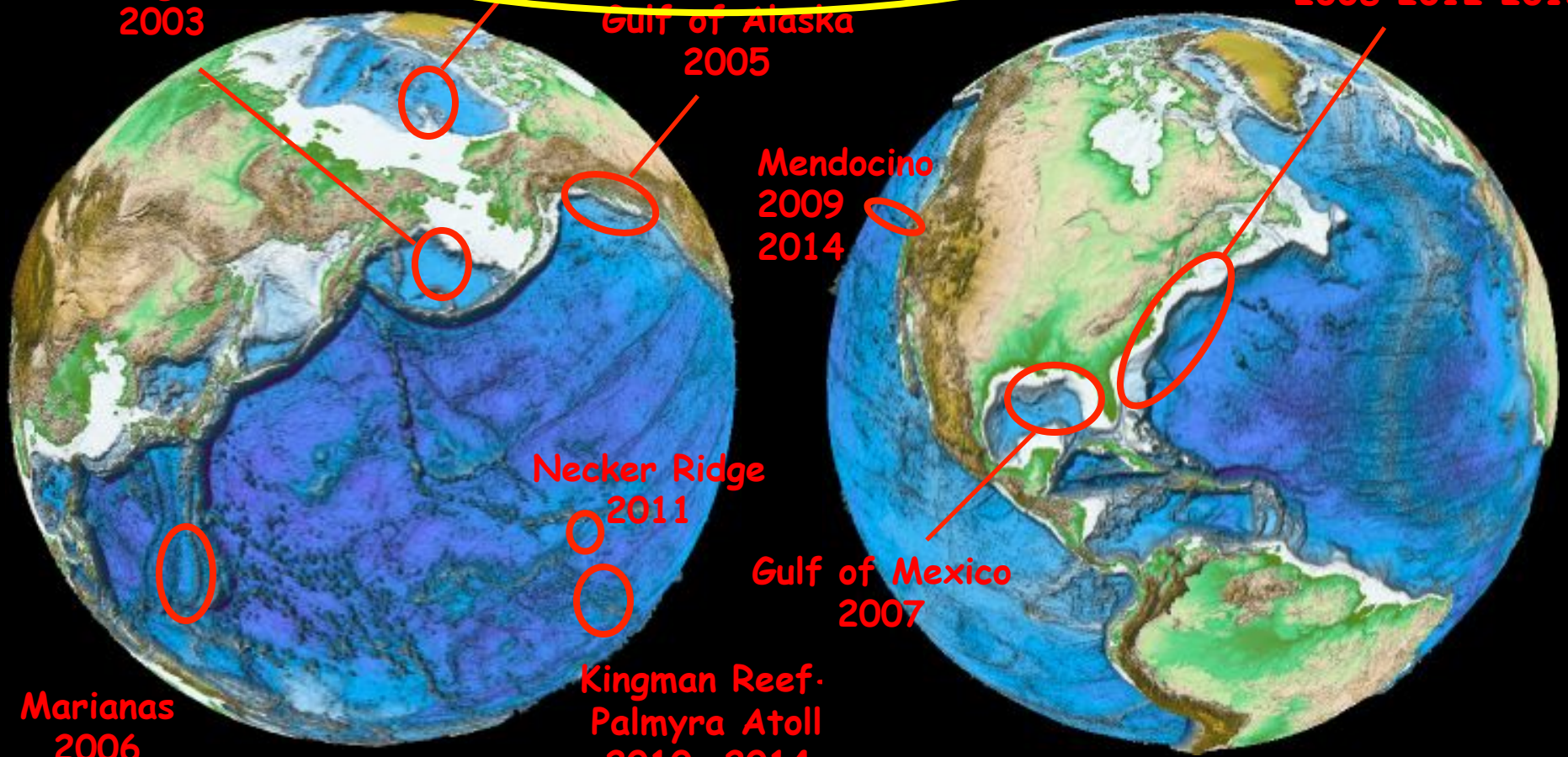
Six hundred and seventeen words that redefine the "continental shelf" of a coastal state and provide a mechanism for the state to extend its sovereign rights over the resources of the "seabed and subsoil" of the continental shelf

Article 76 Data Required

- To establish an extended continental shelf a coastal state must demonstrate that region is "natural prolongation" of continental landmass (*creative ambiguity*) – limits are then determined by
  - depth and shape of the seafloor (FOS and 2500m contour)
  - the thickness of the underlying sediments (1% line)
  - distances from the territorial sea baselines (350 nm line)

Need to map the seafloor

UNH CCOM-JHC U.S. Law-of-the-Sea Bathymetric Mapping to Date



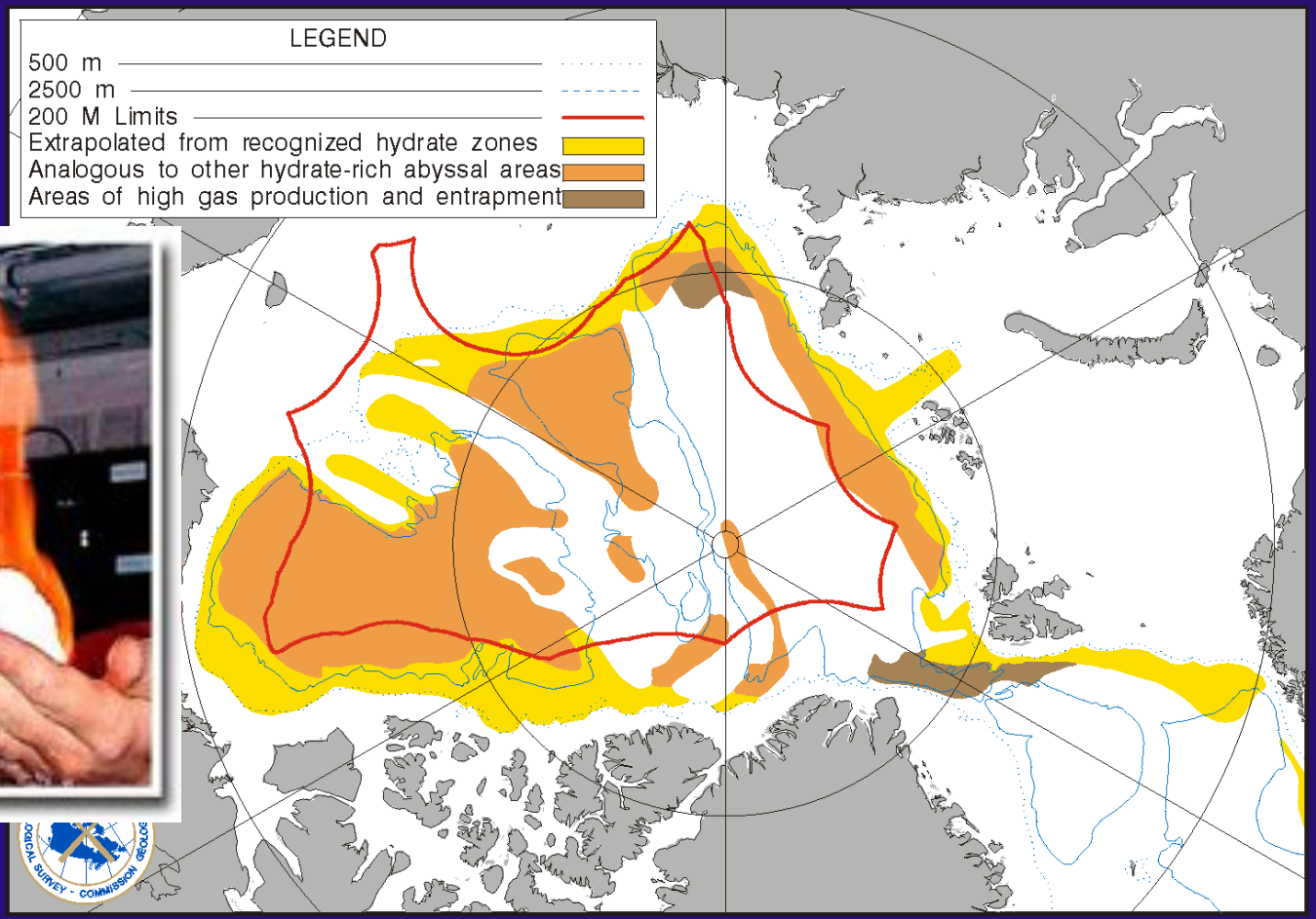
> 2,665,000 km²

Arctic is unique as an ocean basin in that >52% is made up of shelf (geologic)

Potential for Oil and Gas in the Arctic

USGS (2009) 13% of world's undiscovered oil, 30% undiscovered gas, 20% undiscovered natural gas liquids

HYDRATE LIKELIHOOD AREAS IN THE ARCTIC



Adapted from Max and Lowrie, 1990

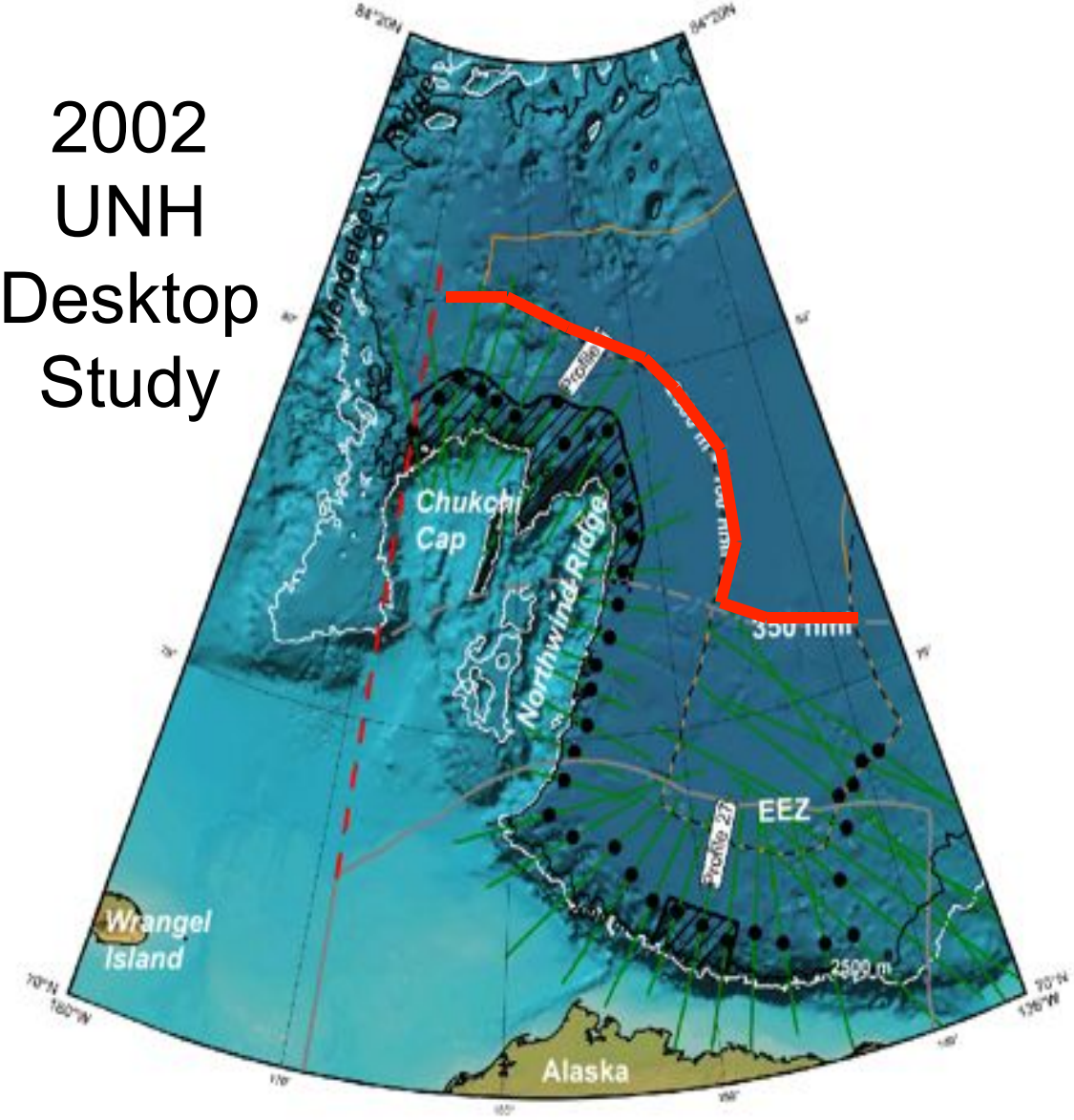
DV, RM & GC GSC Atlantic June 1997 (Revised)

Slide courtesy Ron Macnab

Five nations having potential extended shelves

From Ron MacNab

2002 UNH Desktop Study



5.10B. Bathymetry from IBCAO in detailed area ARC, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.11. Note that the orange line, which represents the 2500 m + 100 nm, makes use of the 2500 m contour of the Alpha-Mendeleev Ridge as well as the Canadian shelf.

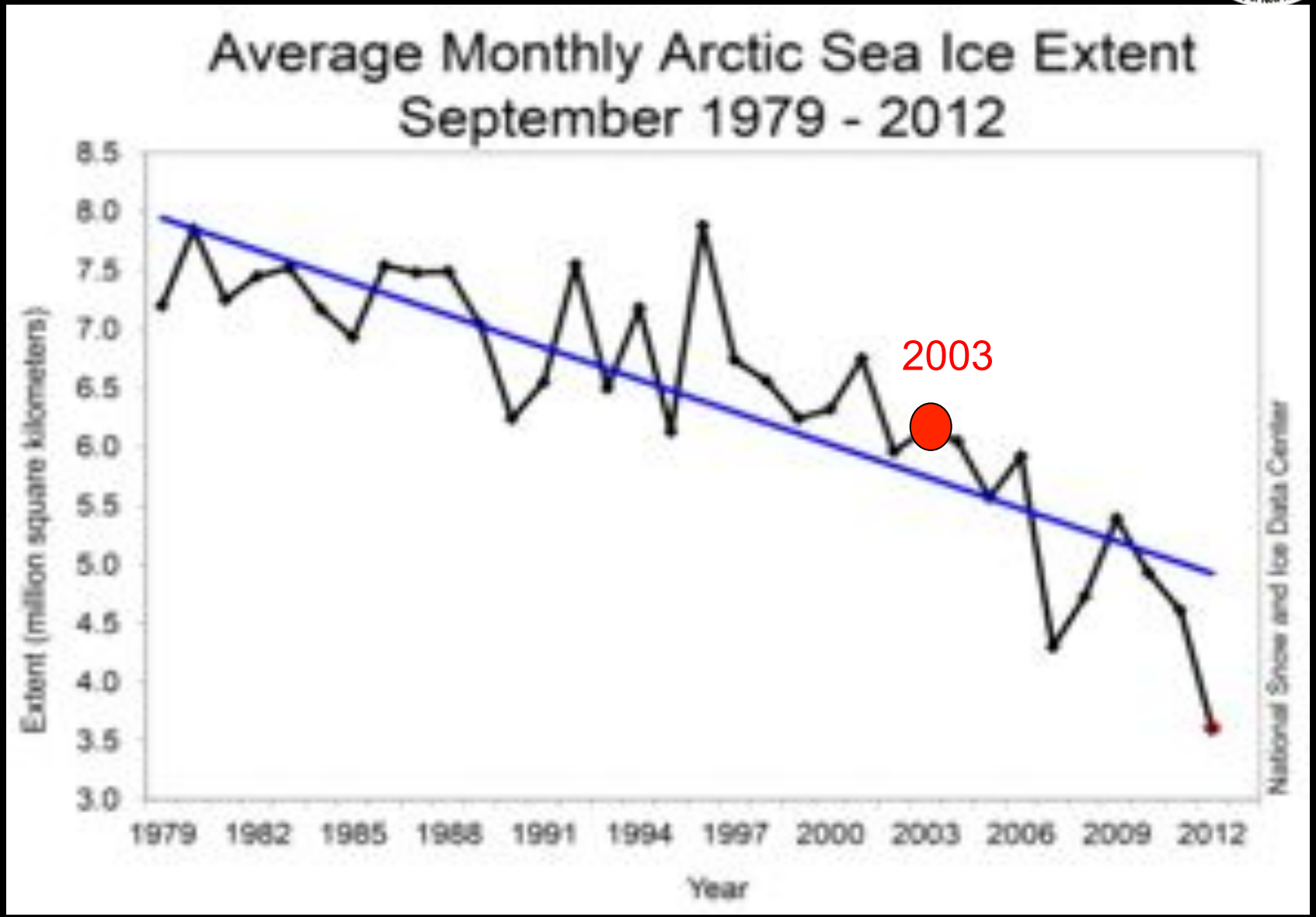
How do we map in this?


MBES 2003 - 2009 - Seabeam 2112 2x2 deg 12 kHz
Now - Kongsberg EM122 - 1x1 deg 12 kHz MBES
Hi-Res Subbottom - Knudsen 350B Chirp Sonar
Dredging

Multibeam mapping

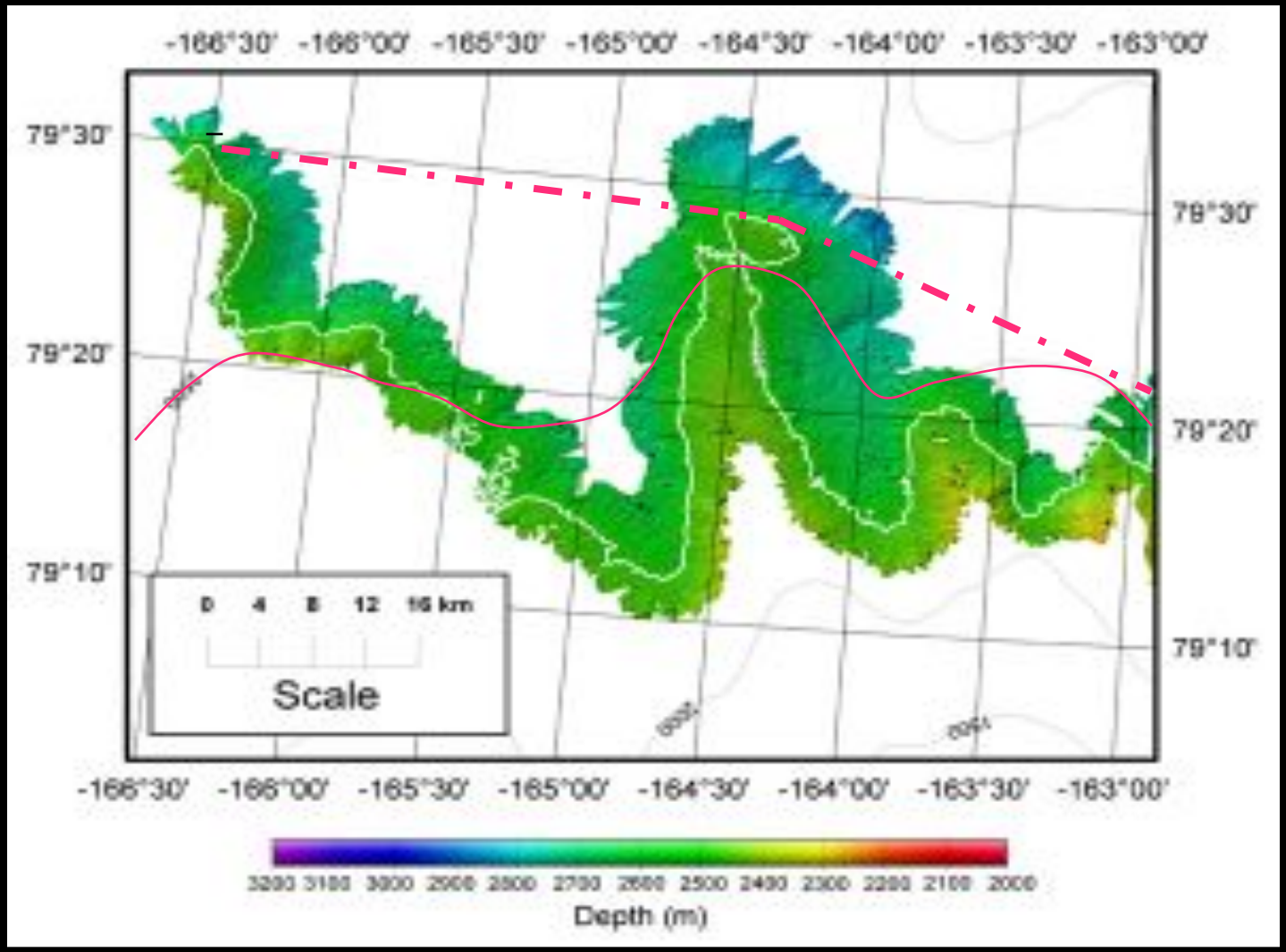
BUT NONE WOULD HAVE BEEN ABLE TO EASILY COLLECT USEFUL DATA 15-20 YEARS AGO

Minimum Ice Extent




typical ice conditions
2003
8/10 “cheesy” ice

Redefinition of the 2500 m contour

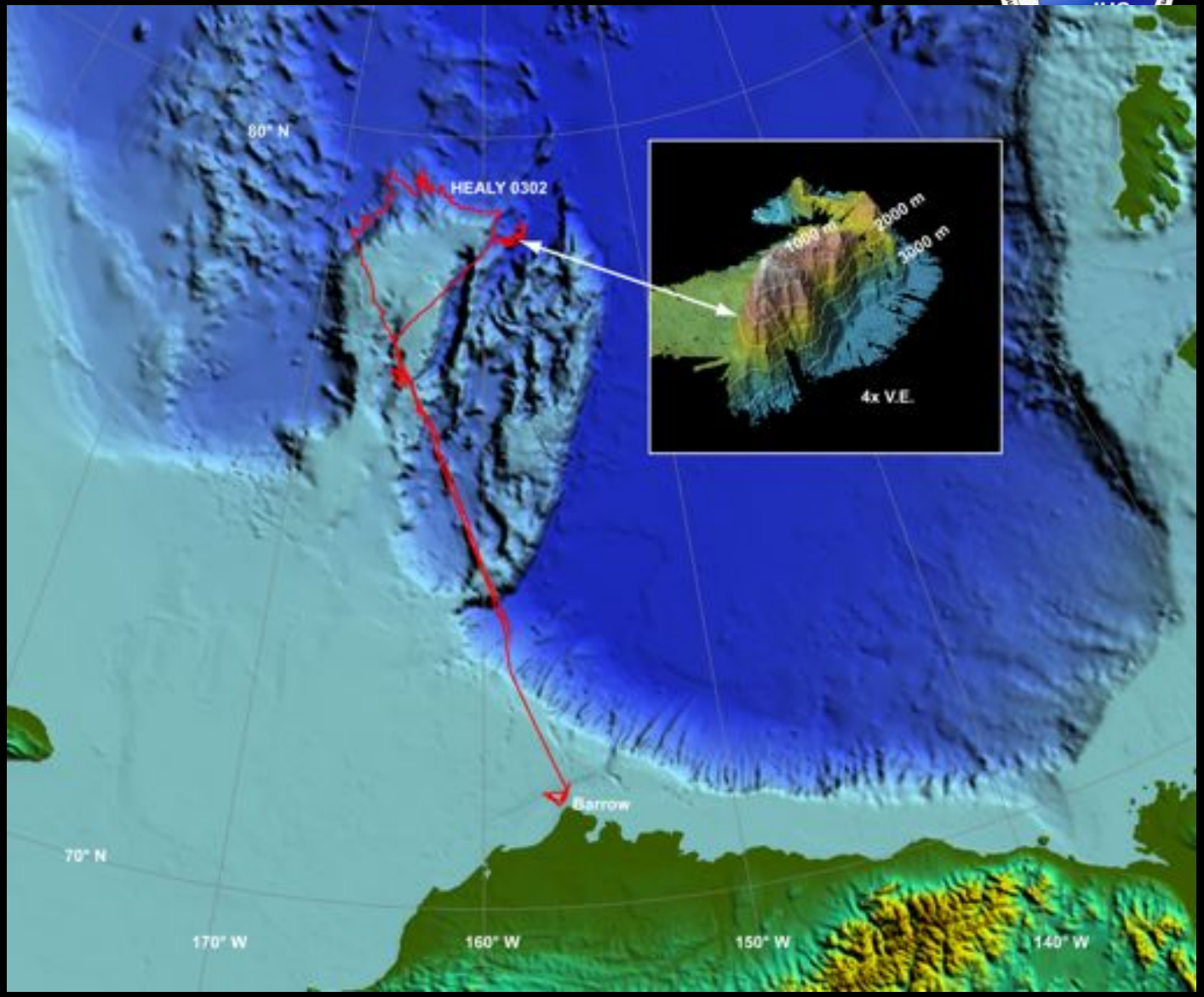


Healy 03-02

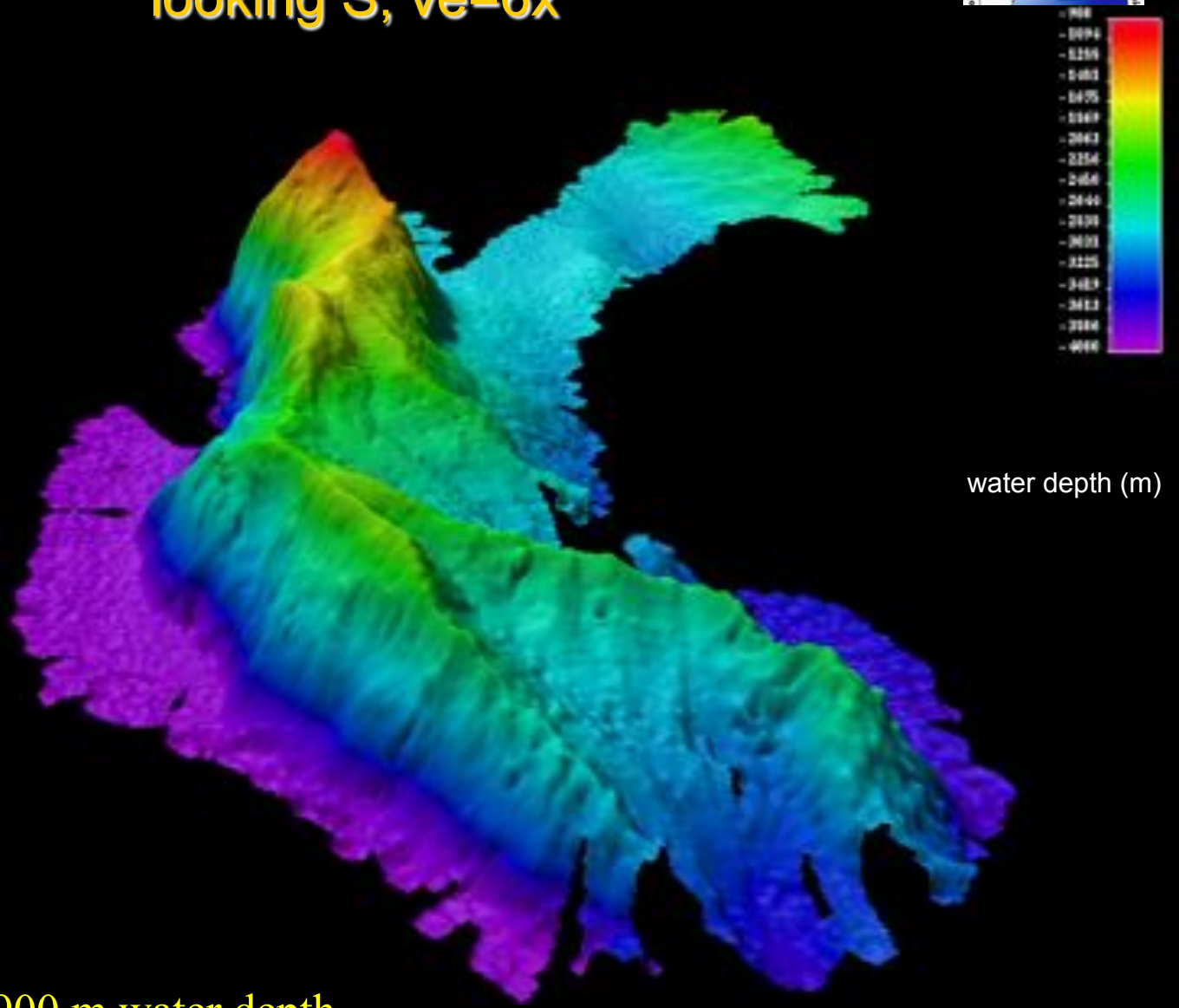
~3000 km of multibeam sonar bathymetry

1-11 Sept 03

8/10 ice



Healy Seamount
looking S, ve=6x

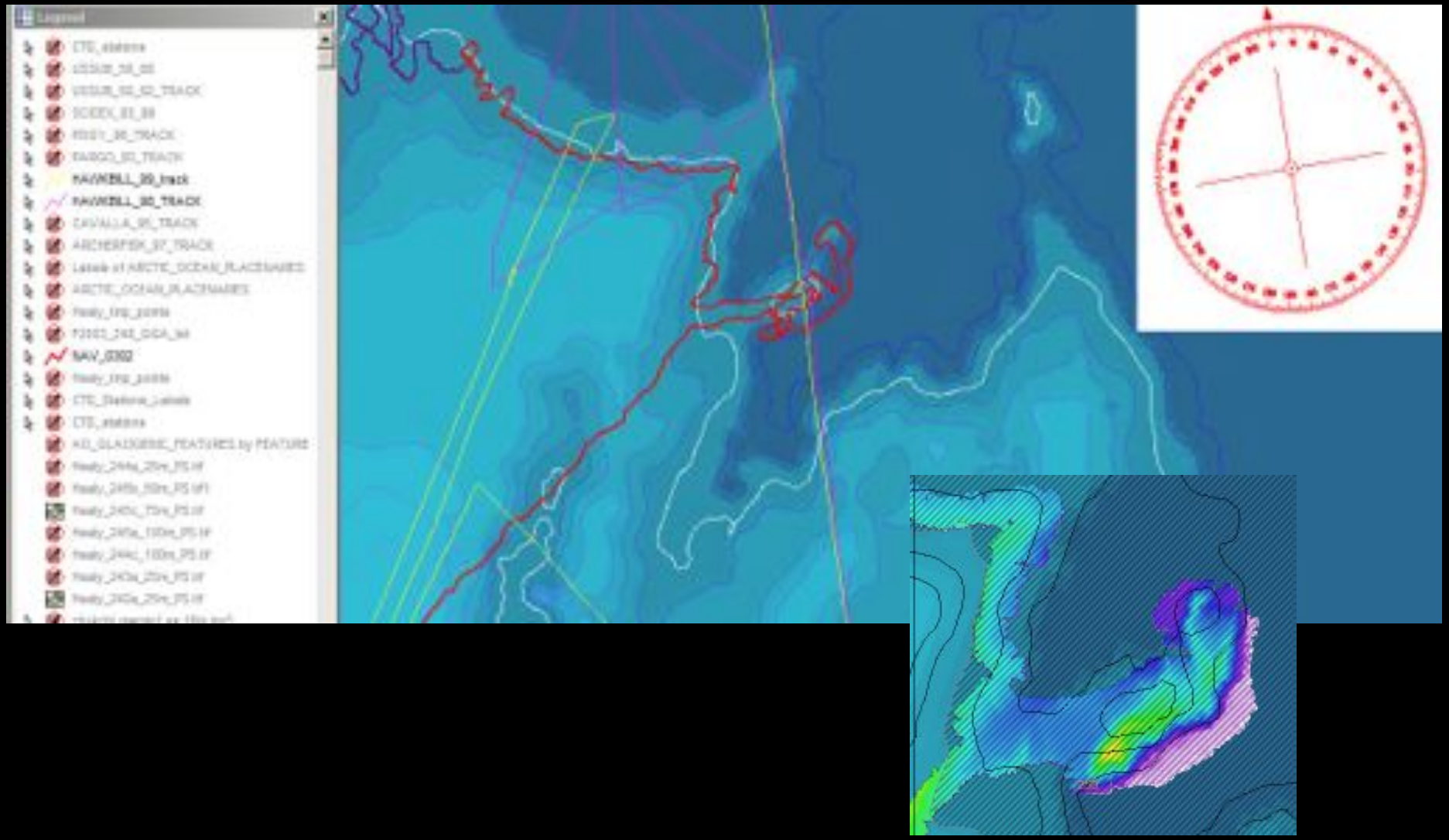


water depth (m)

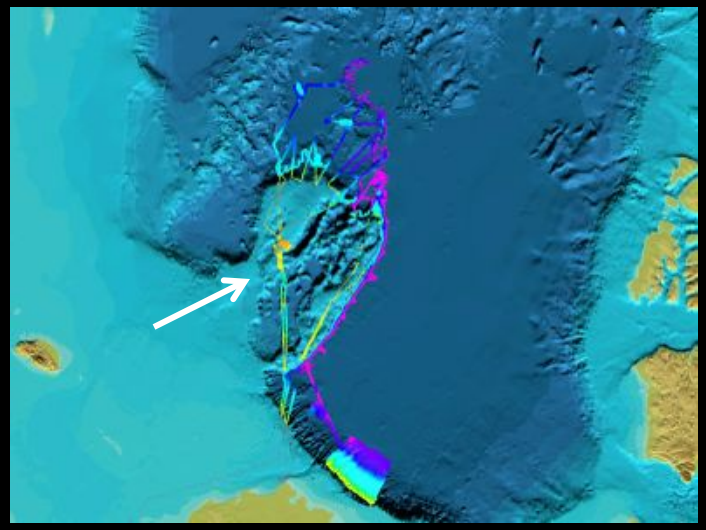
3100 m high, summit at 900 m water depth

45 km long x 15 km wide

Healy Seamount Survey



Central Chukchi Plateau pockmarks



200-m diameter
20-m deep

VE = 10x
looking SW

3 to 5 m deep

ice grooves

-470 m

0 5 km

central Chukchi Plateau

-380 m

nature COMMUNICATIONS

Jakobsson et al, 2016

Altmetric: 25 Views: 3,185 Citations: 1 More detail »

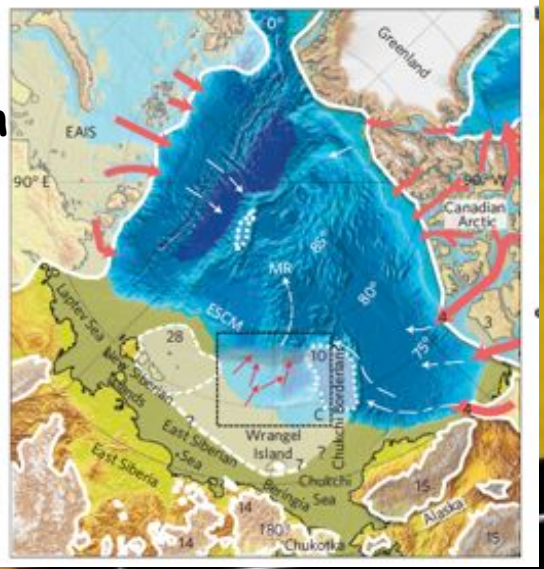
Article | OPEN

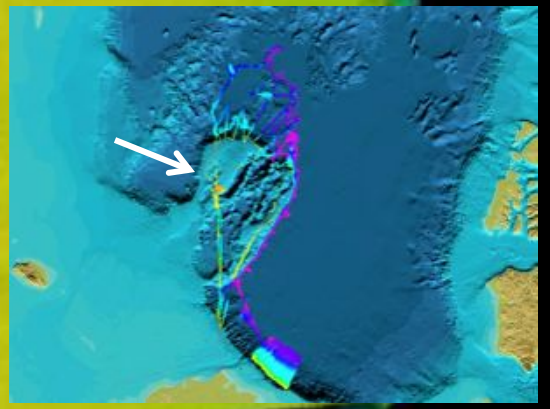
Evidence for an ice shelf covering the central Arctic Ocean during the penultimate glaciation

Martin Jakobsson, Johan Nilsson, Leif Anderson, Jan Backman, Göran Björk, Thomas M. Cronin, Nina Kirchner, Andrey Koshurnikov, Larry Mayer, Riko Noormets, Matthew O'Regan, Christian Stranne, Roman Ananiev, Natalia Barrientos Macho, Denis Cherniykh, Helen Coxall, Björn Eriksson, Tom Flodén, Laura Gemery, Örjan Gustafsson, Kevin Jerram, Carina Johansson, Alexey Khortov, Rezwan Mohammad & Igor Semiletov

NATURE GEOSCIENCE DOI: 10.1038/NGEO1904

Niessen et al, 2013

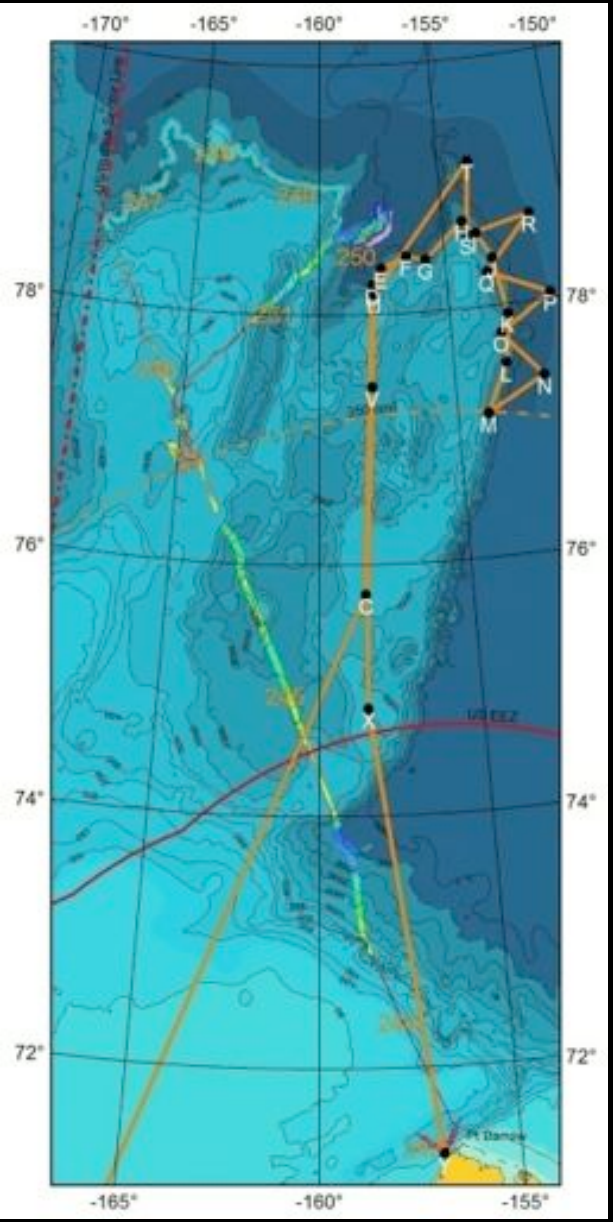




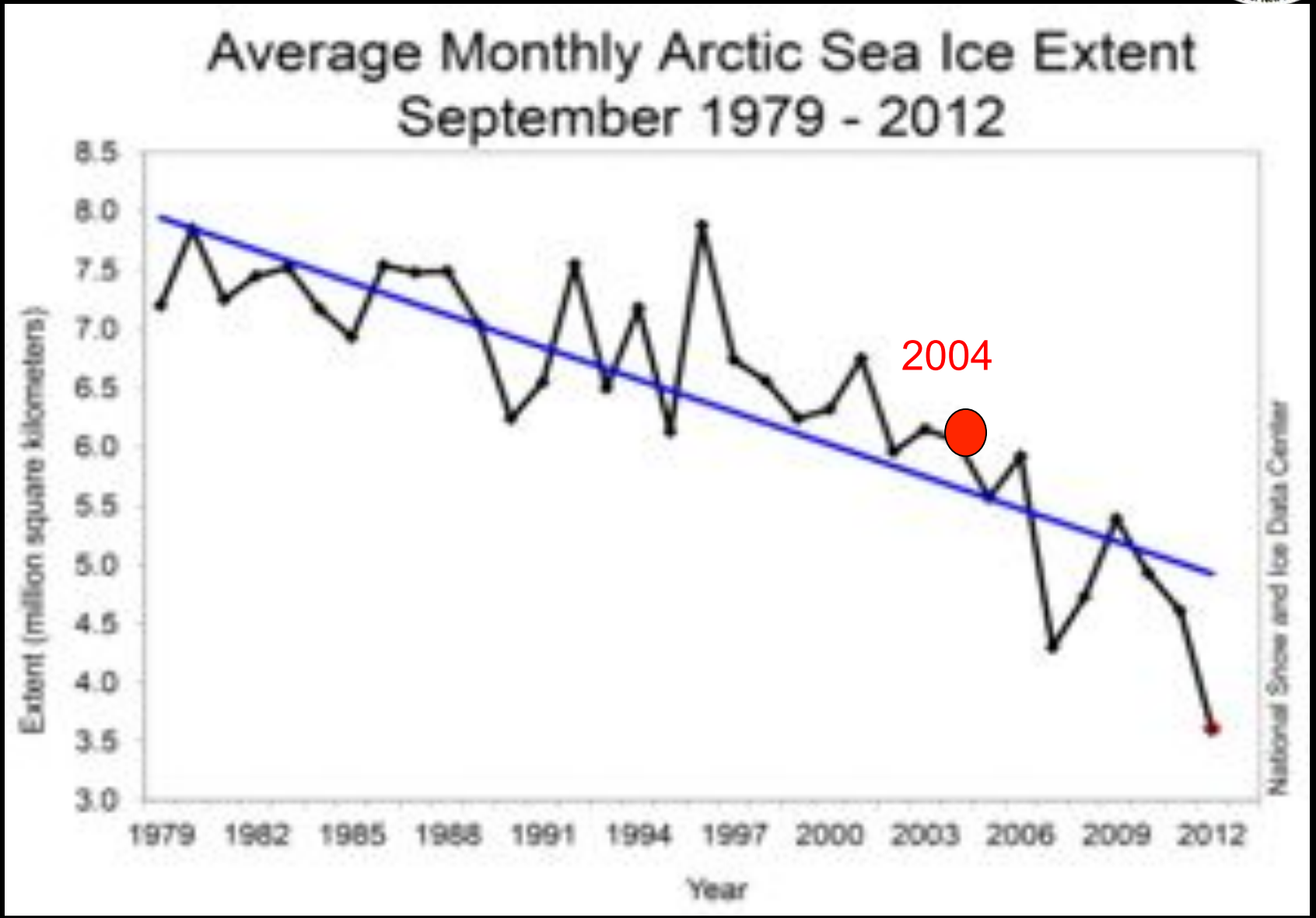
bedforms

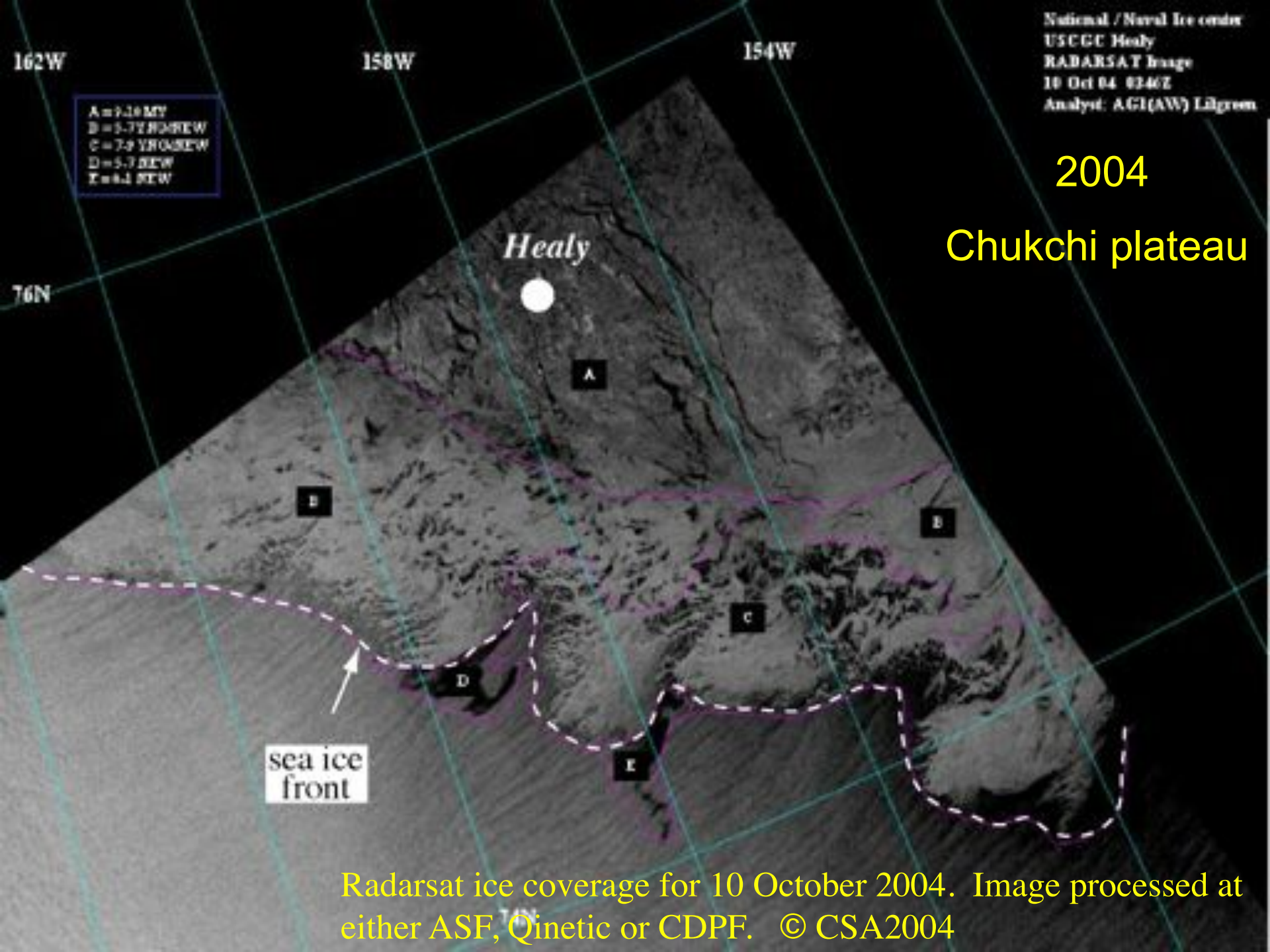
λ = ~2 km
H = ~10 m

HEALY 2004 - Plan



Minimum Ice Extent



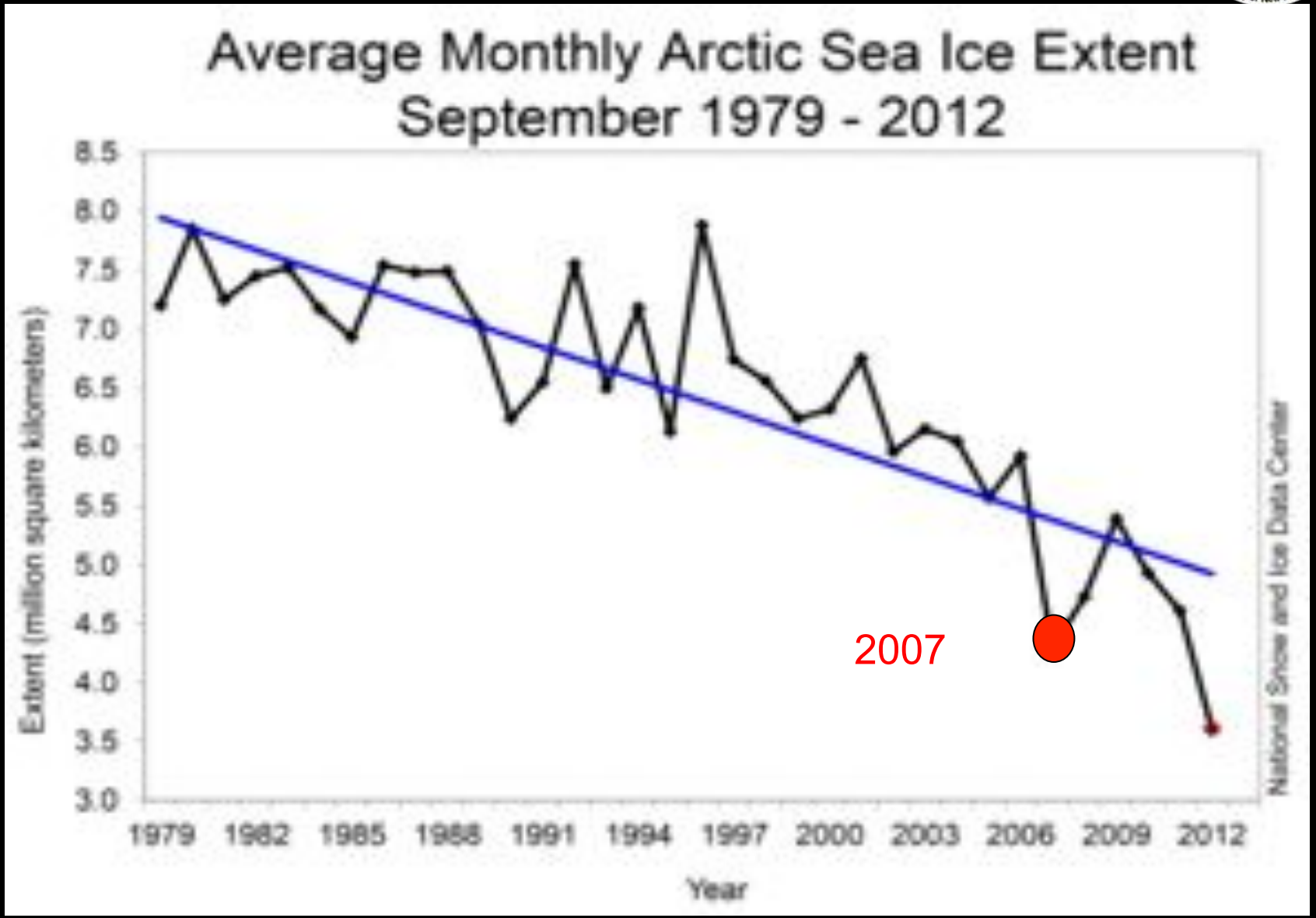


2004

Chukchi plateau

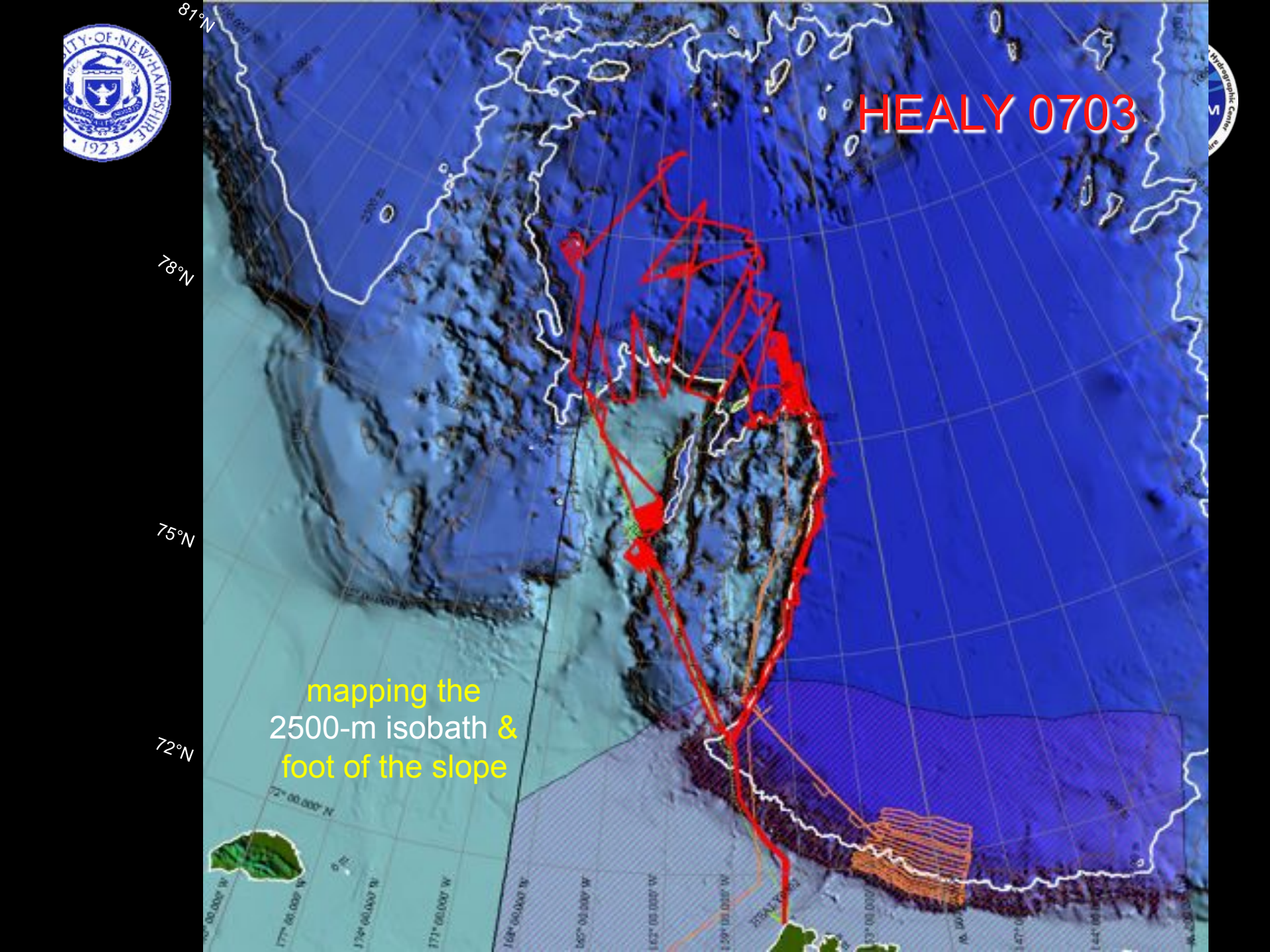
Radarsat ice coverage for 10 October 2004. Image processed at either ASF, Qinetic or CDPF. © CSA2004

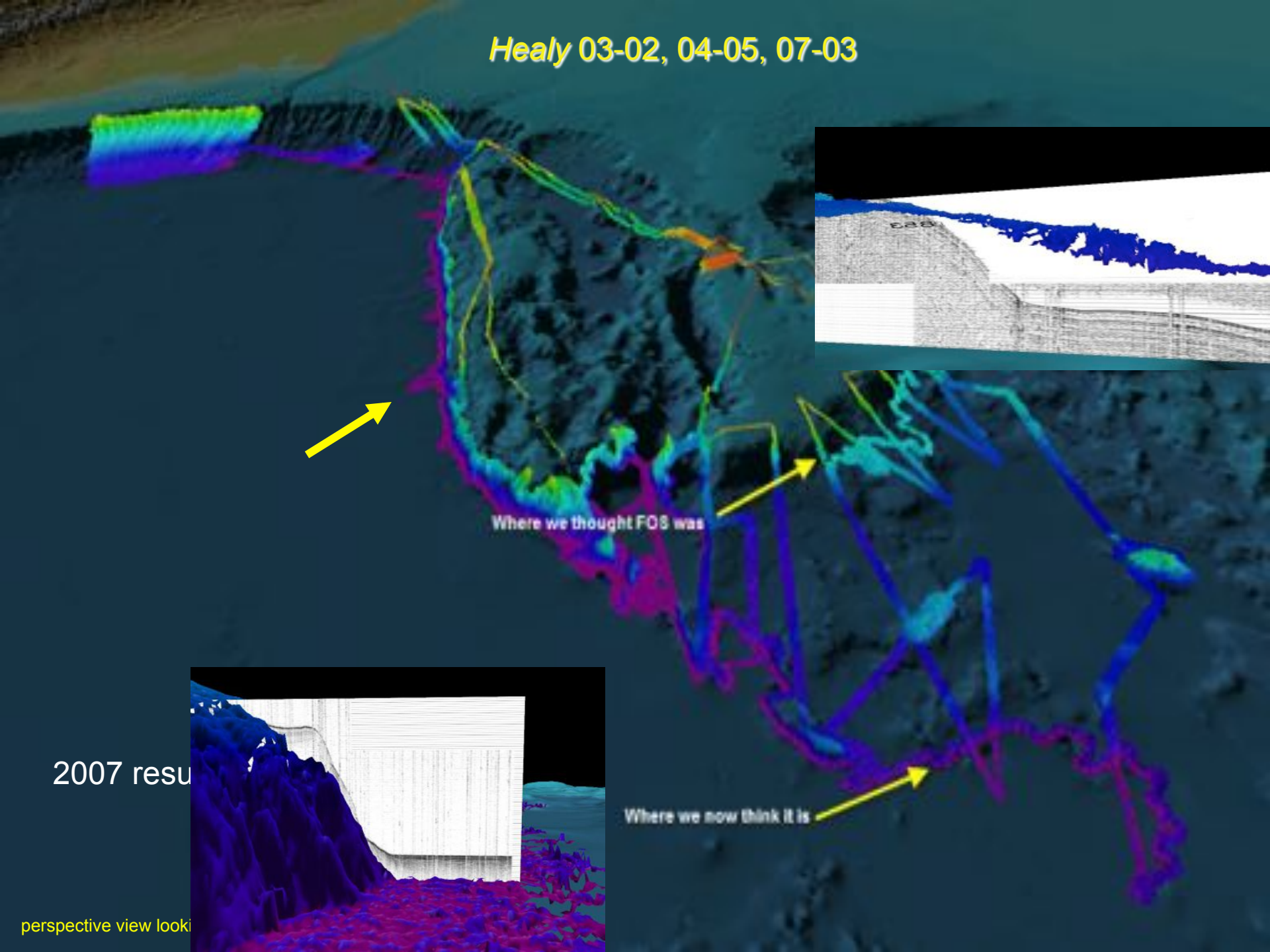
Minimum Ice Extent



TIME

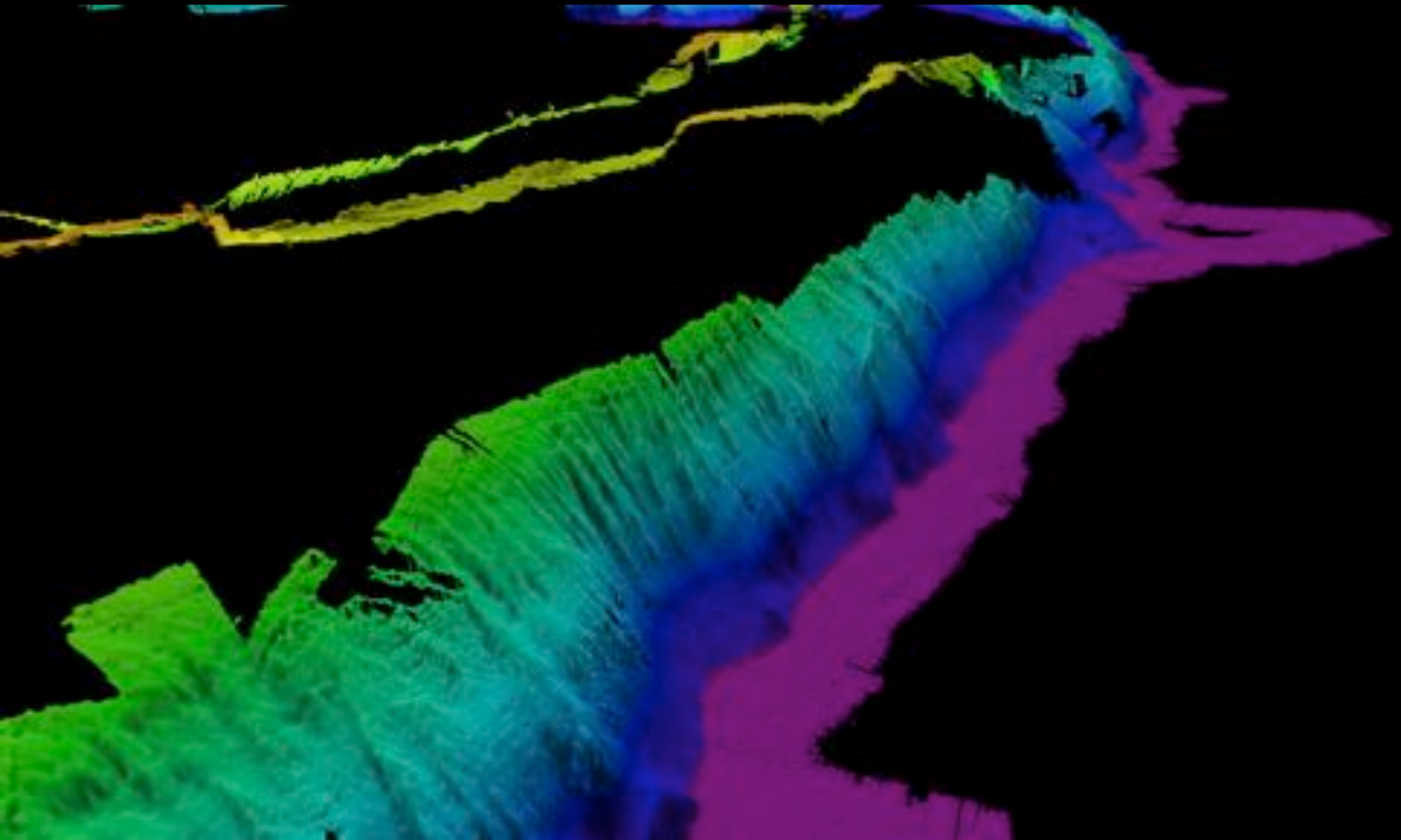
May 7, 2009: Smokin' Pole - The Fight for Arctic Riches


81°N
78°N
75°N
72°N
HEALY 0703
mapping the
2500-m isobath &
foot of the slope



2007 resu

perspective view looki



2008 DREDGING IN THE ICE

HEALY 0805 – SHIPTRACK AND DREDGE SITES

Volcaniclastic sedimentary rock – hyaloclastite . Vesiculatlion in glass and grading of pumice implies deposited soon after shallow water volcanic eruption.

Flood Basalts – 100-82 Ma

Metasediments - slate and coarse sandstones representing proximal continental arc sources – at least 420 Ma (zircon ages).

Also 112 Ma flood basalts.

WESTERN ARCTIC

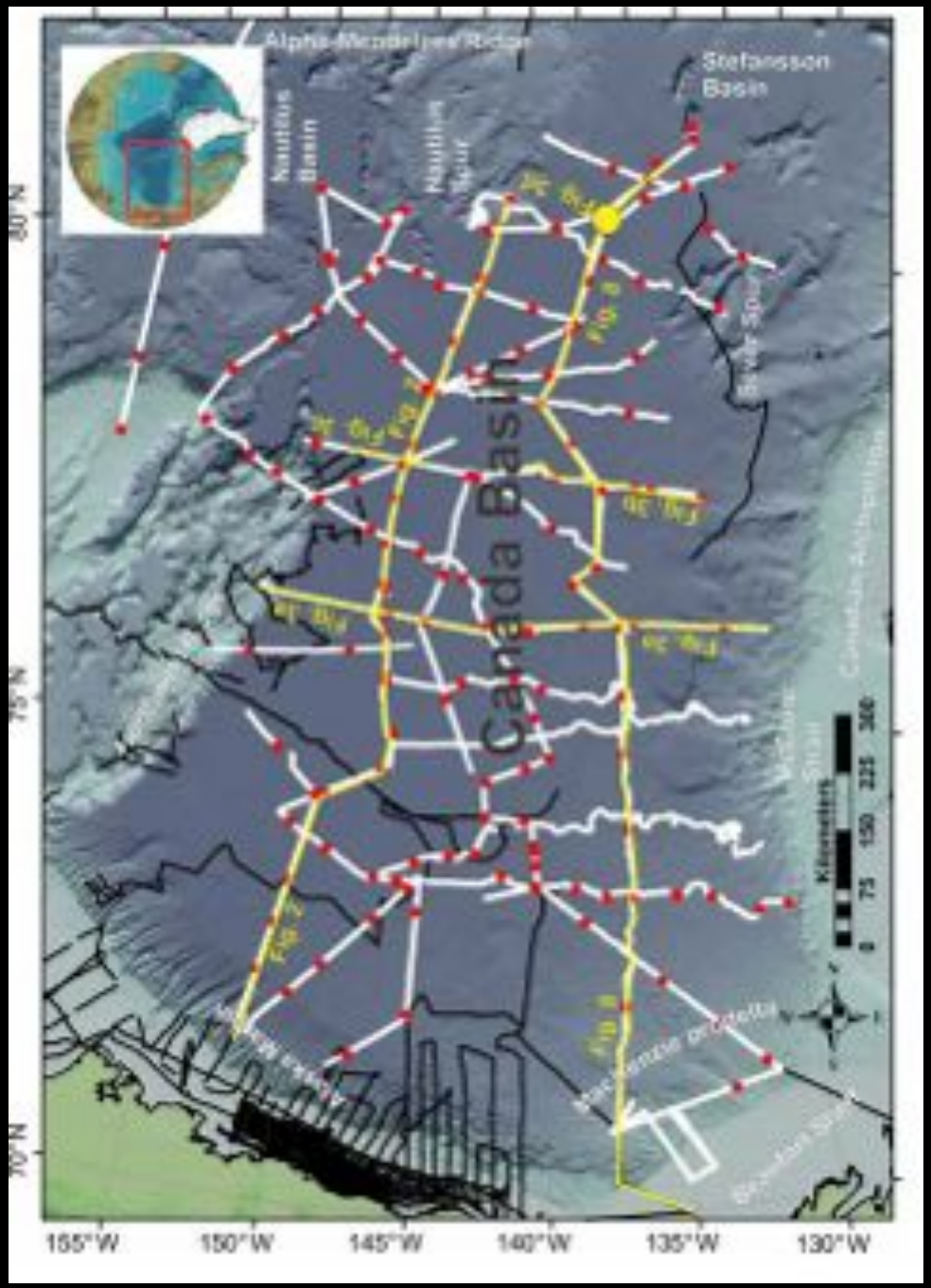
JOINT PROGRAMS CANADIAN AND US ICEBREAKERS

LOUIS S. St. LAURENT and *HEALY*

2008
2009
2010
2011

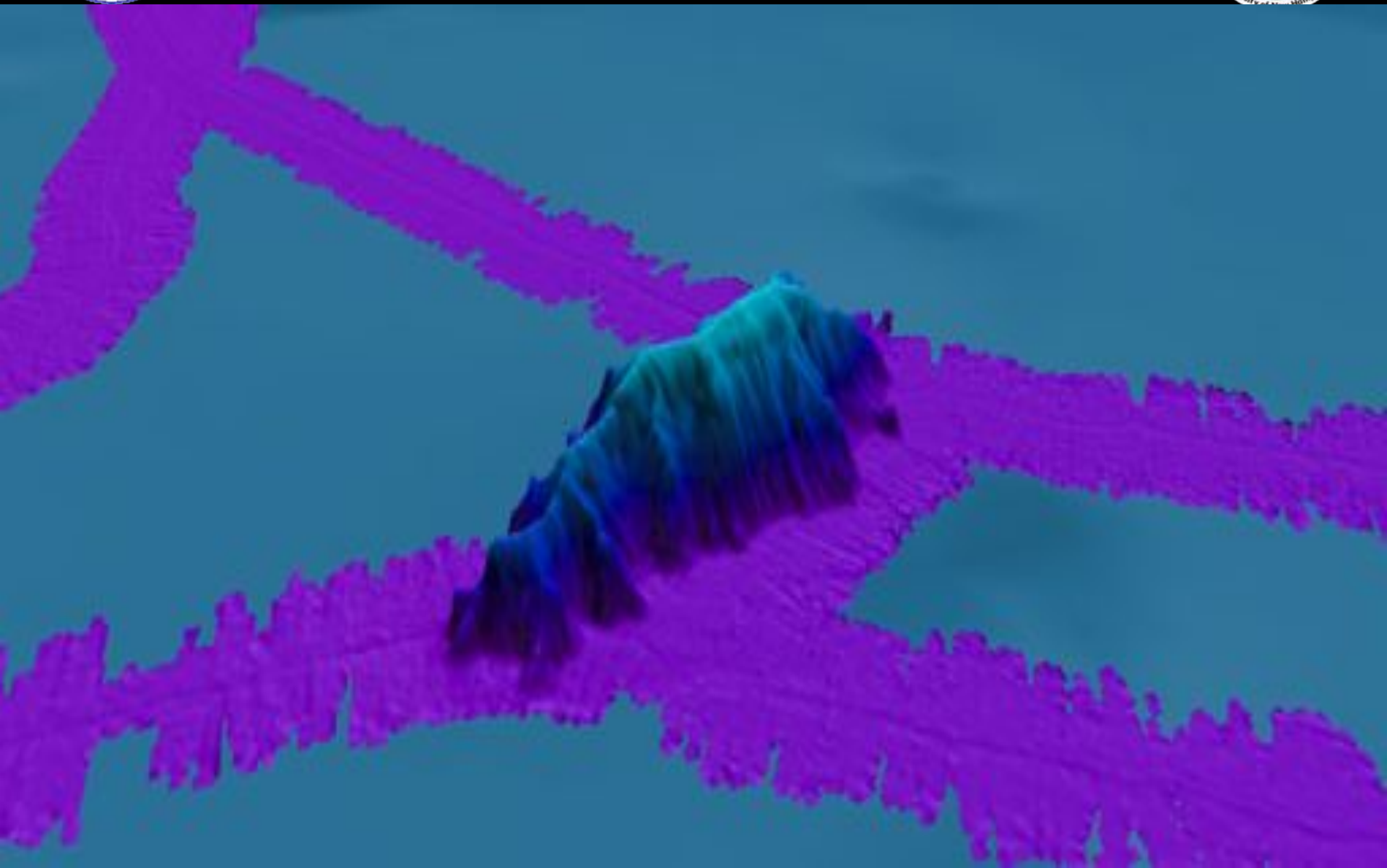
LSSL SEISMIC DATA

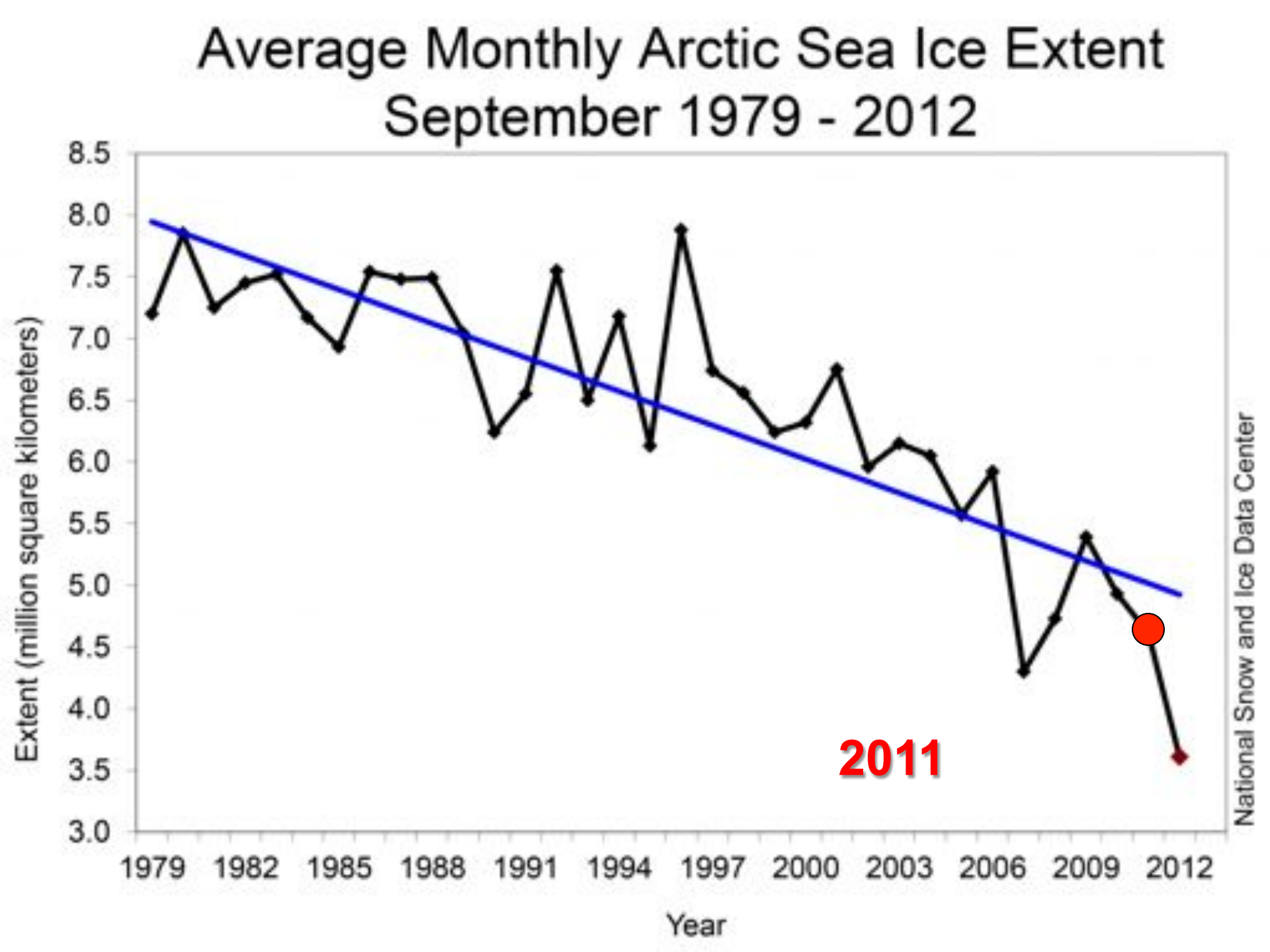
15,481 km

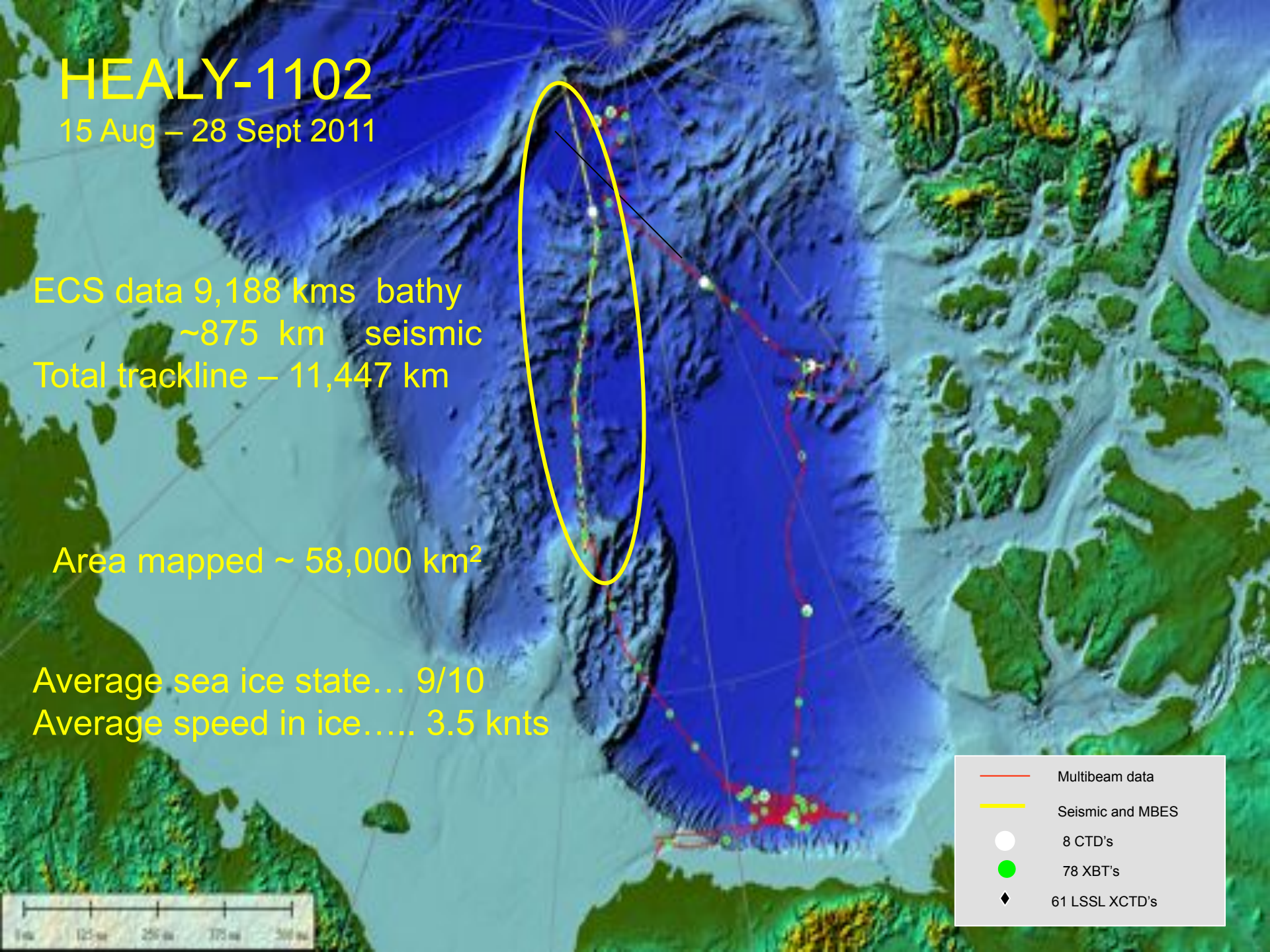


From David Mosher

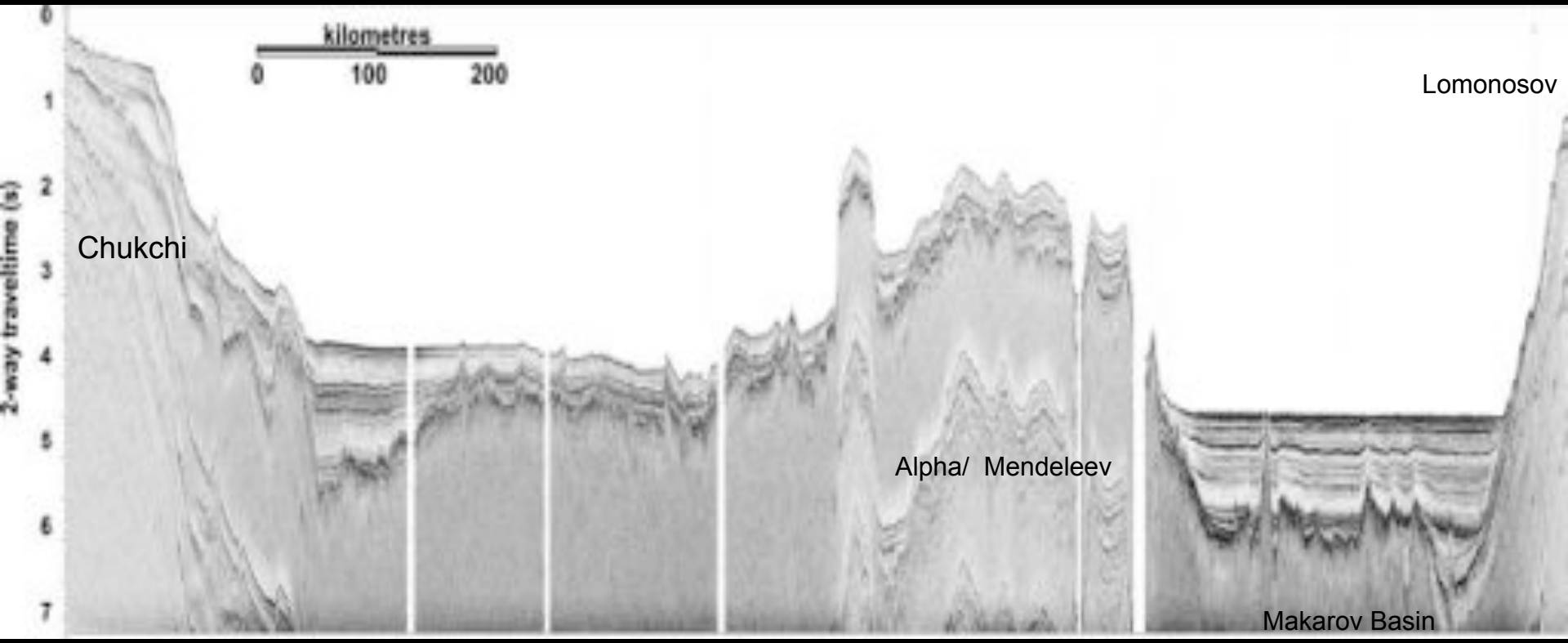
New Seamount: Savaqatigiit Seamount

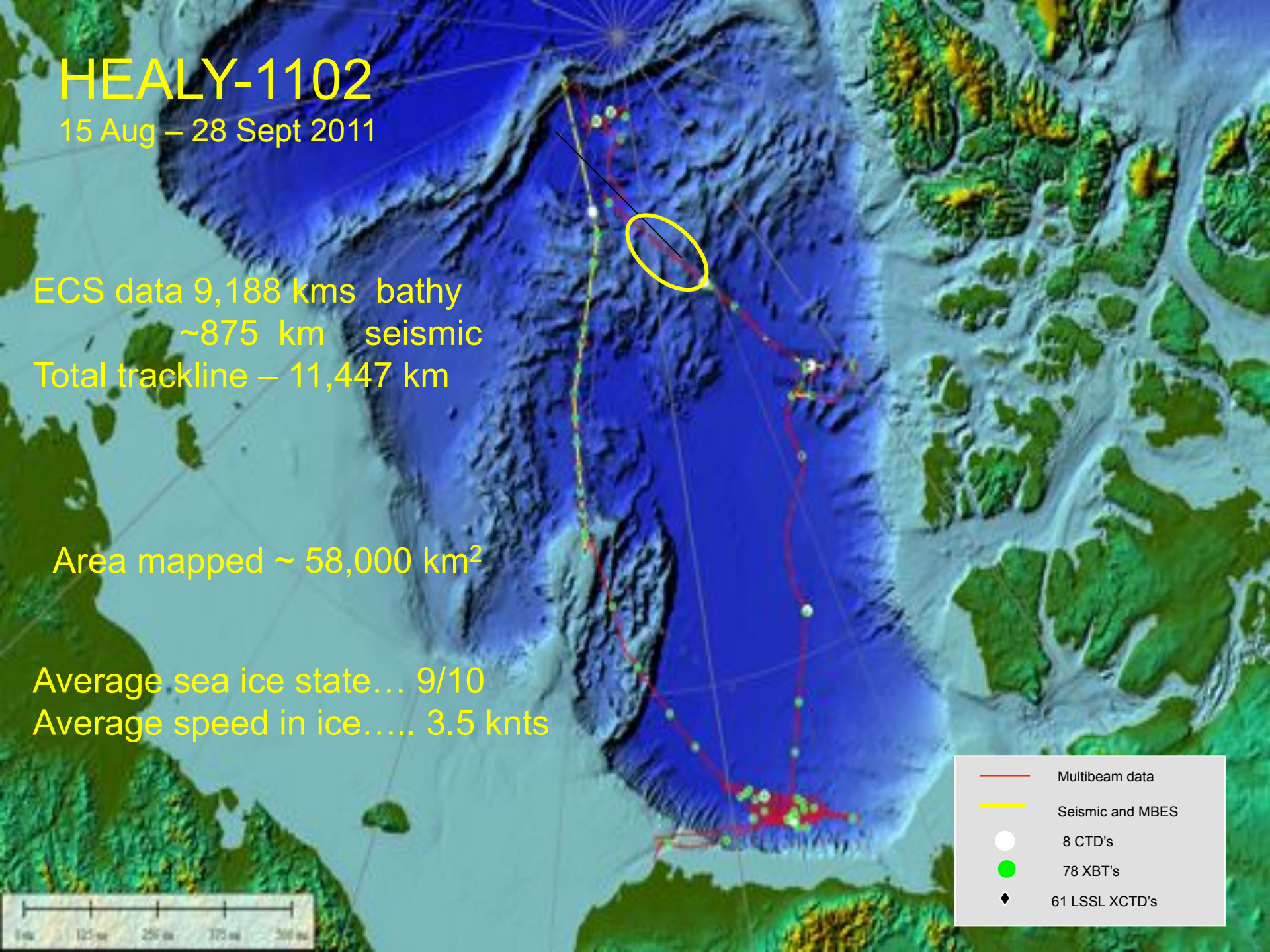



Average Monthly Arctic Sea Ice Extent
September 1979 - 2012
Extent (million square kilometers)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Year
2011
National Snow and Ice Data Center


HEALY-1102
15 Aug – 28 Sept 2011
ECS data 9,188 kms bathy
~875 km seismic
Total trackline – 11,447 km
Area mapped ~ 58,000 km²
Average sea ice state… 9/10
Average speed in ice….. 3.5 knts
Multibeam data
Seismic and MBES
8 CTD's
78 XBT's
61 LSSL XCTD's

LSSL Monitor Records

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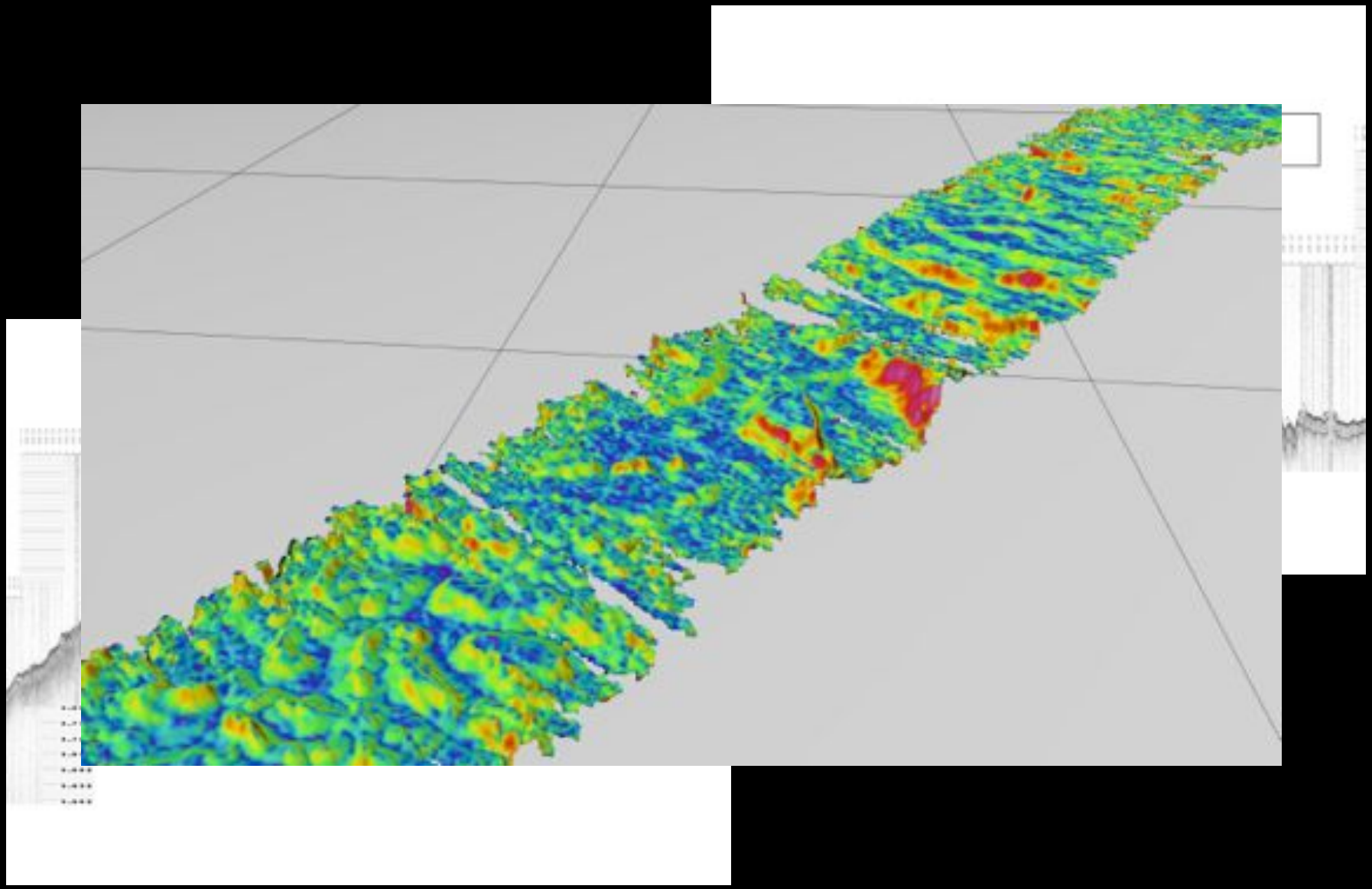
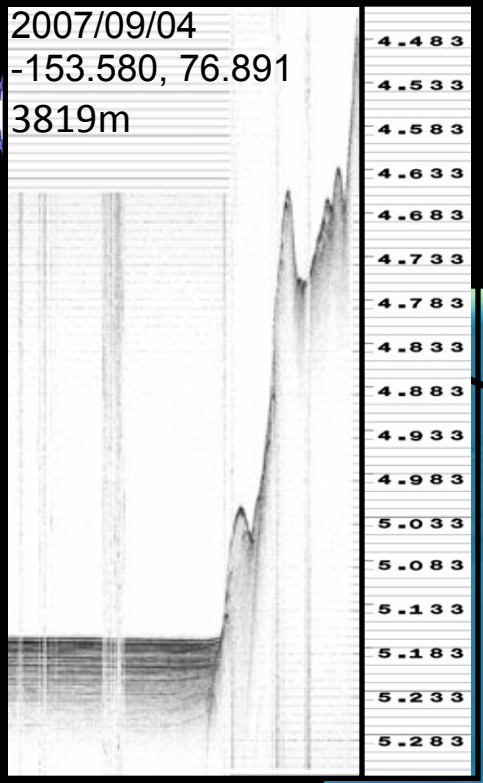
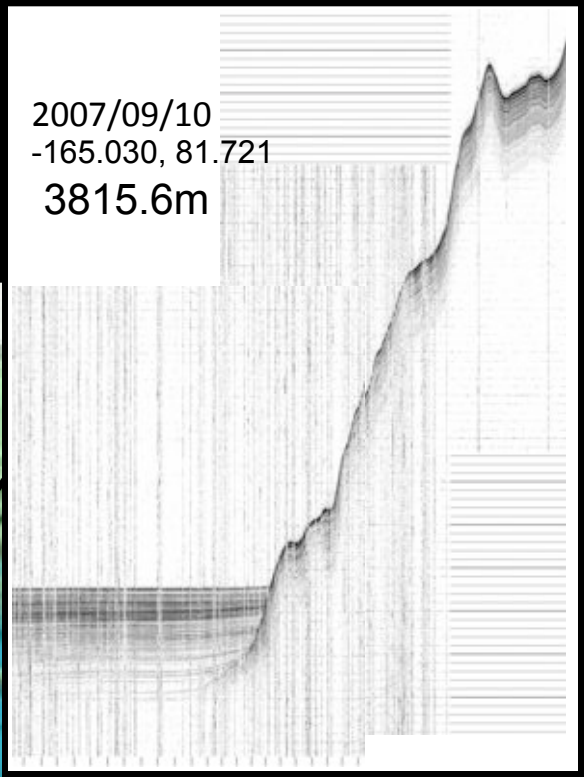
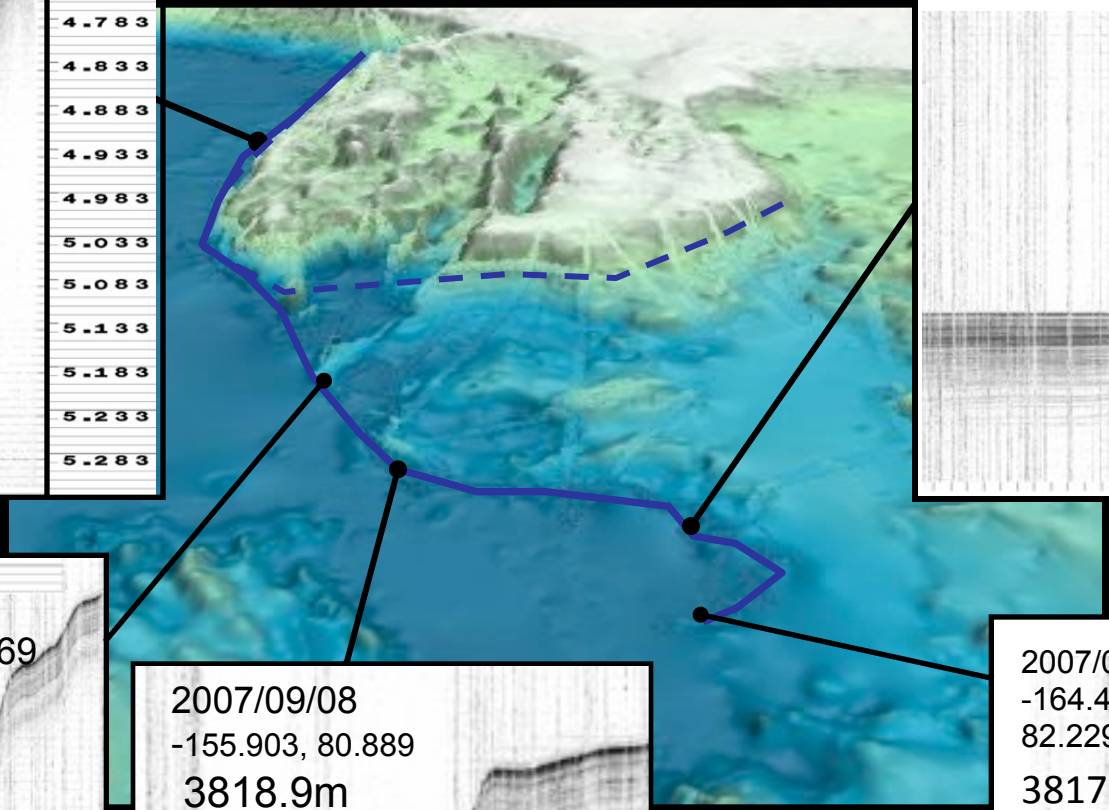
Hyperbolic Echoes on Alpha/Mendeleev Ridge

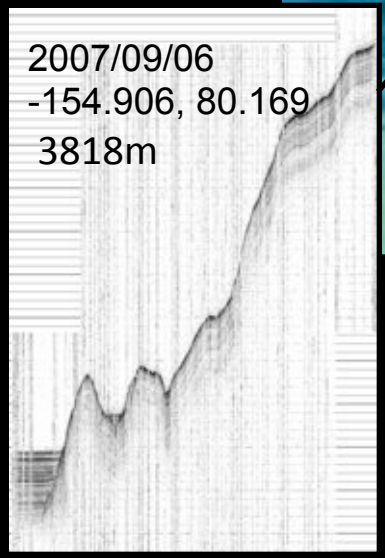


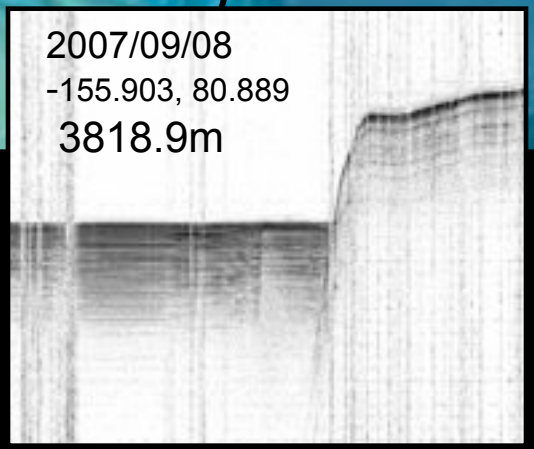
The “Foot of the Slope”

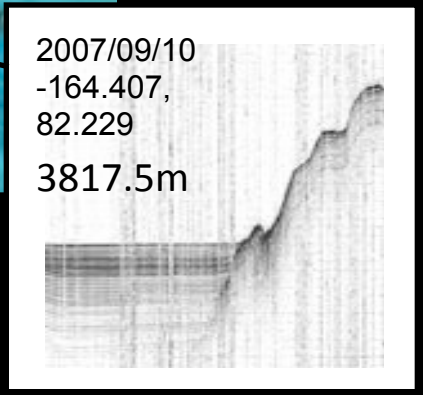






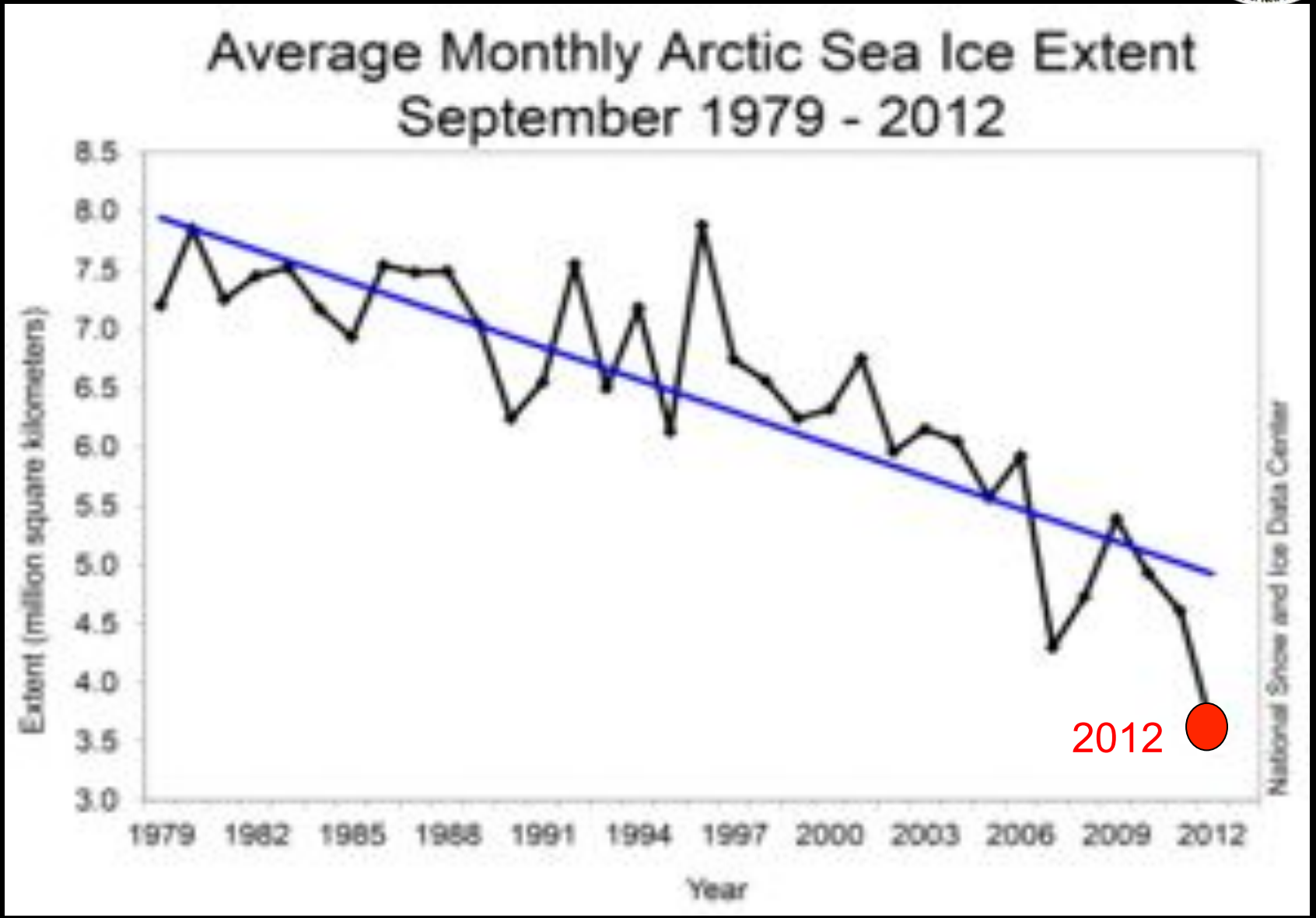


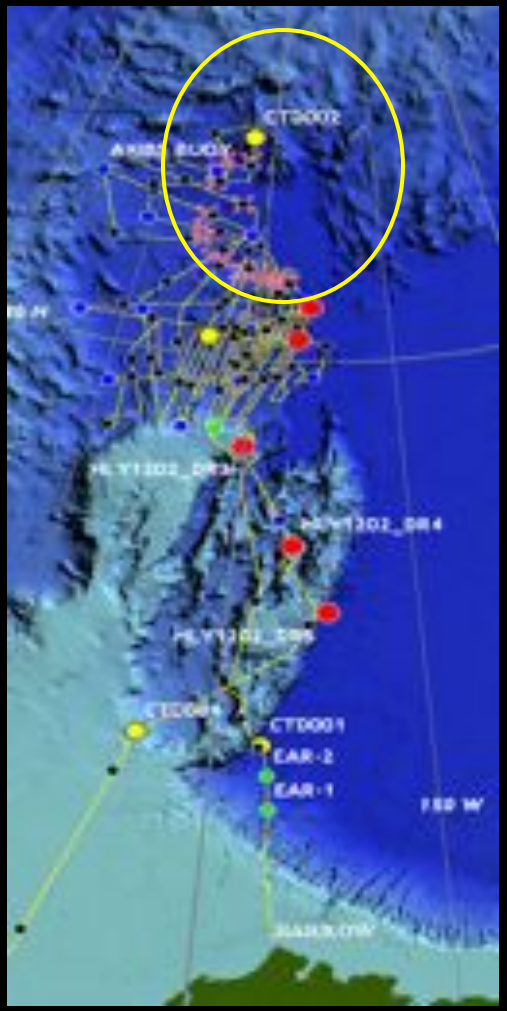


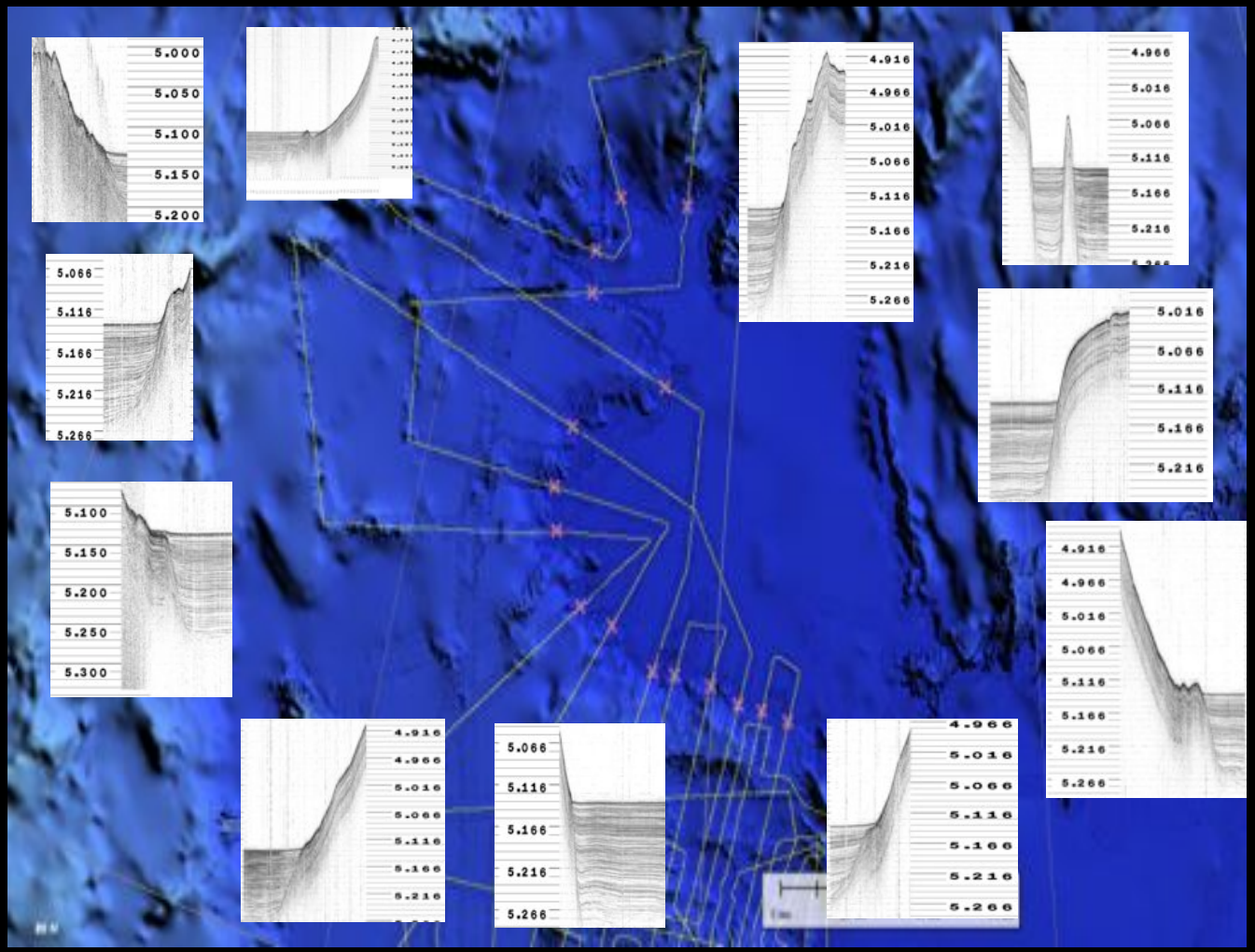


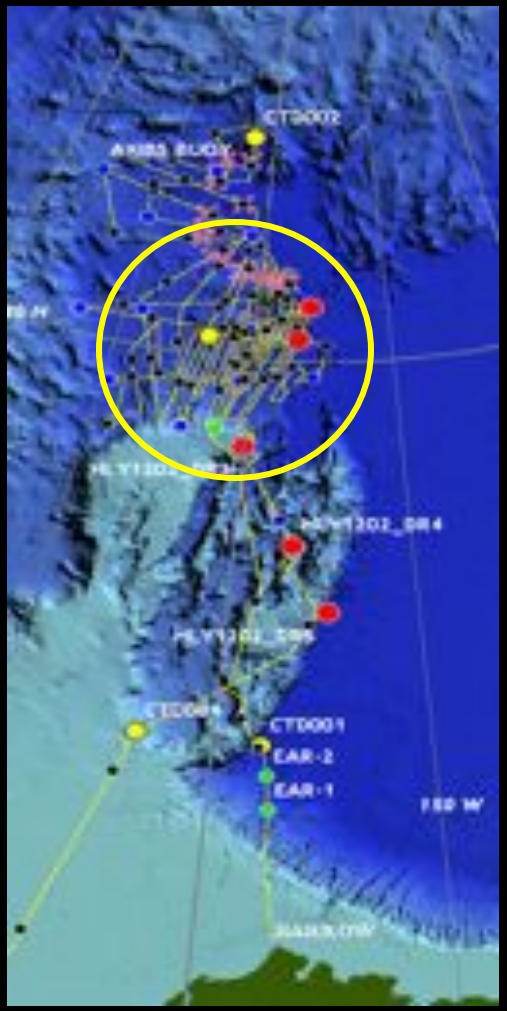
(From Brumley, 2009)

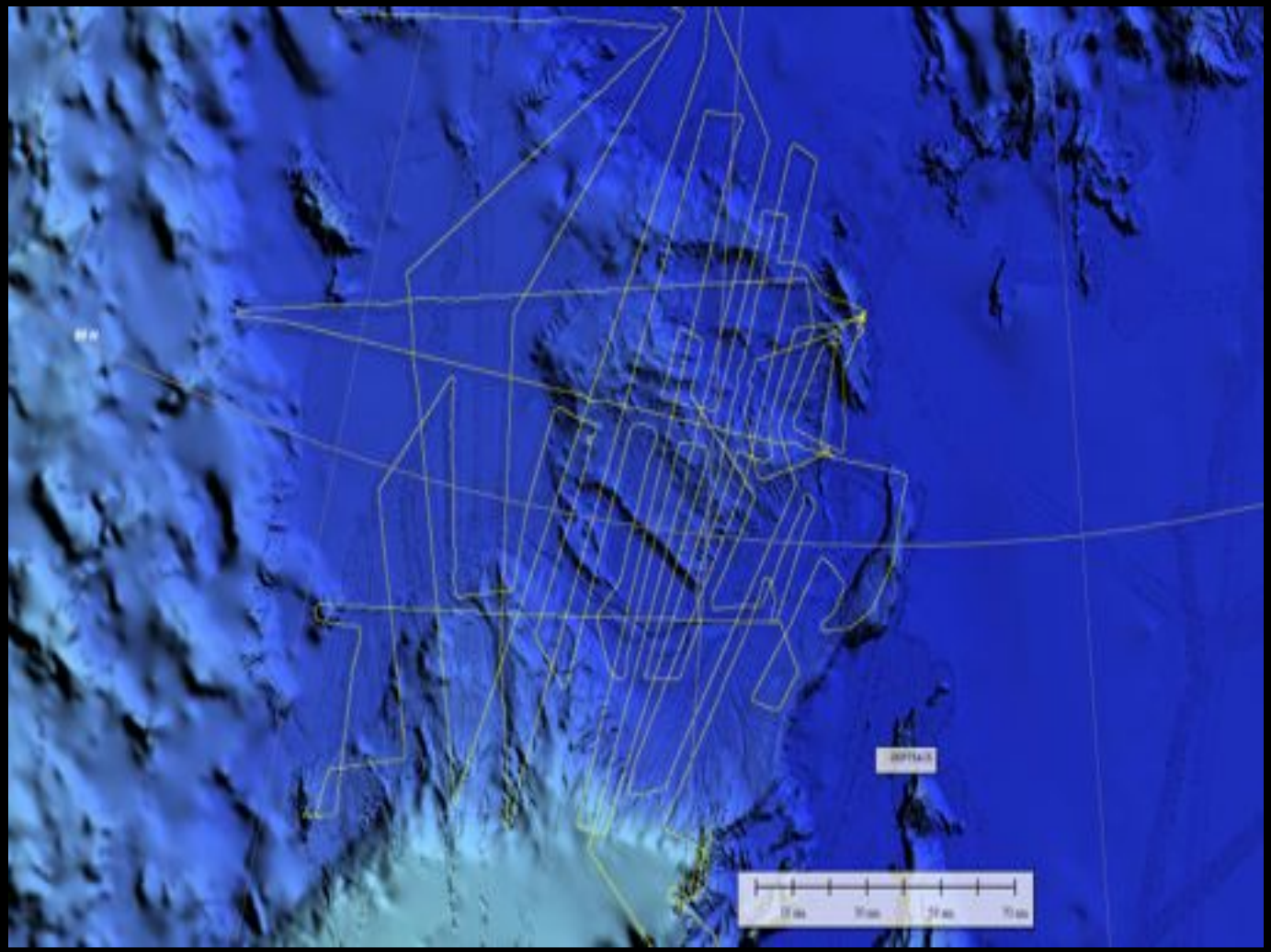
Minimum Ice Extent



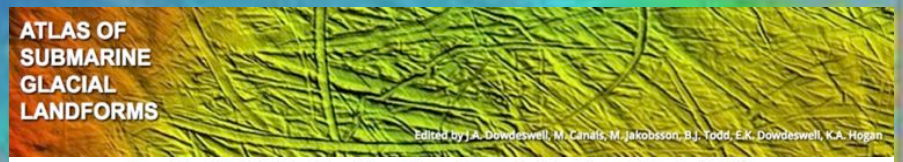

CT3002
CT3001
EAR-2
EAR-1


5.000
5.050
5.100
5.150
5.200
4.916
4.966
5.016
5.066
5.116
5.166
5.216
5.266
5.300


CT0002
CT0001
EAR-2
EAR-1



The Weather Channel



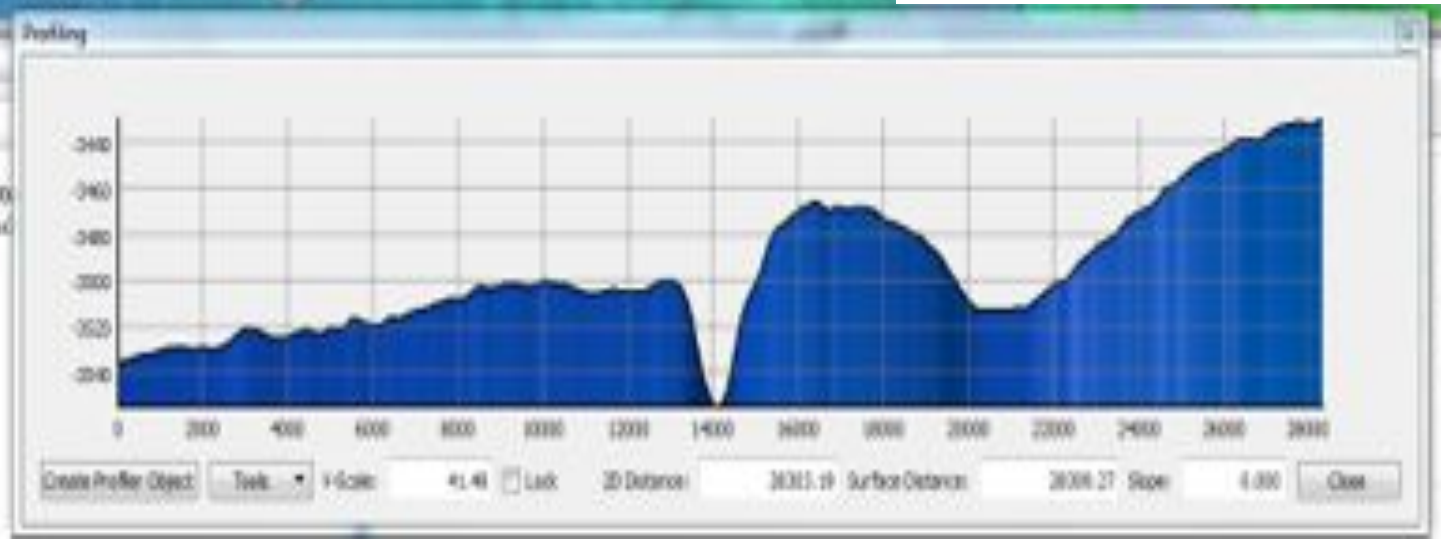
An ultrahigh-latitude submarine channel: Northern Chukchi Rise

L. A. MAYER[1]*, J. V. GARDNER[1] & A. A. ARMSTRONG[2]

[1]*Center for Coastal and Ocean Mapping, University of New Hampshire, Durham, New Hampshire 03824, USA*

[2]*Joint Hydrographic Center, University of New Hampshire, Durham, New Hampshire 03824, USA*

**Corresponding author (e-mail: larry@ccom.unh.edu)*



HEALY 1202 DREDGE SITES

HLY1202_DR1

HLY1202_DR2

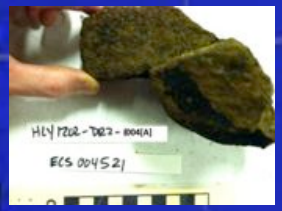
HLY1202_DR3

HLY1202_DR4

volcanoclastic

Fossil corals

Primona redaeformis?
43.5 BP



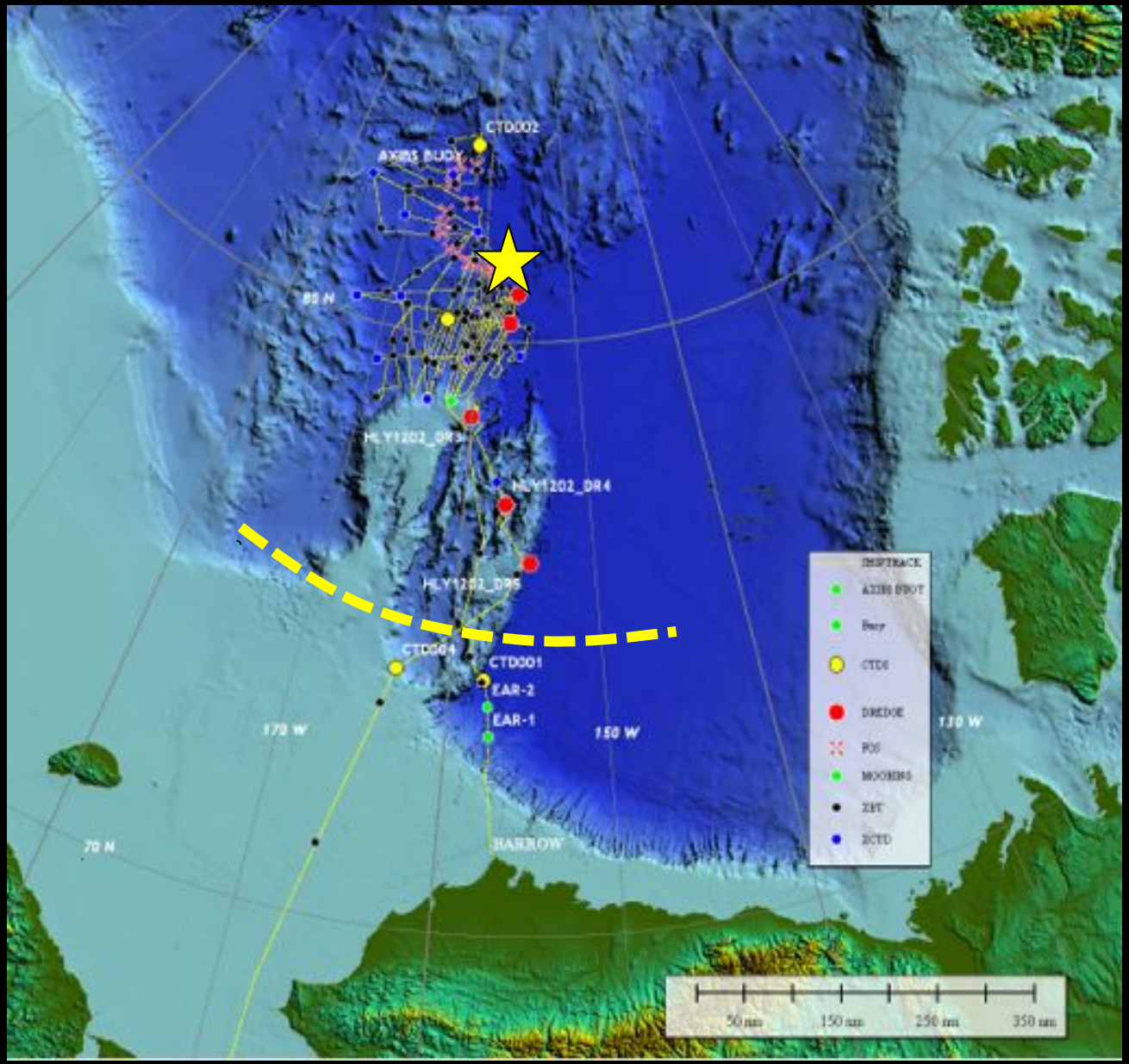
altered basalt

Metasediment/
carbonates

Foliated
calcareous
sandstones
and phyllites

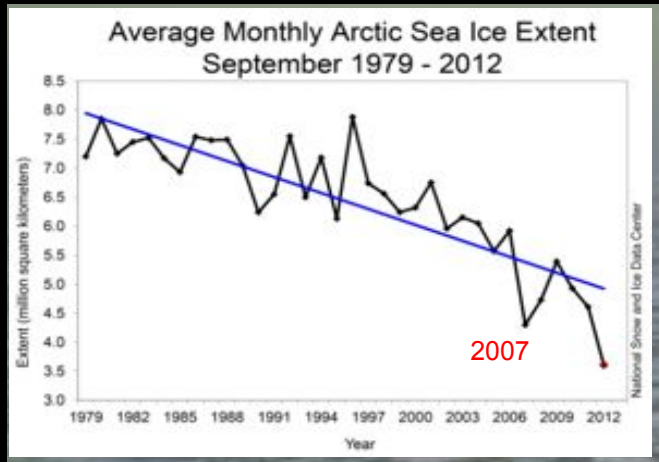
Metasediment /
greenschisht facies

Typical Sept Ice Margin

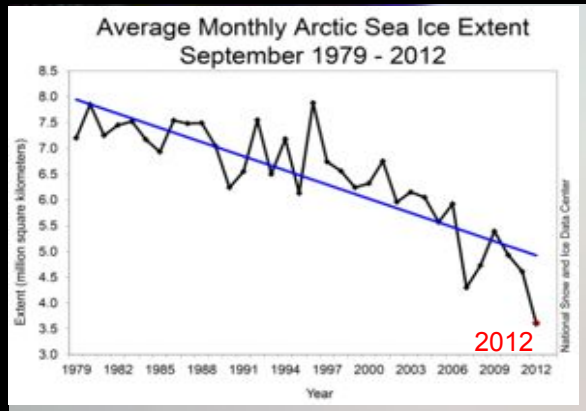


Long/Lat: -132 08.2 W, 80 01.7 N
2008 (9-13-2008)

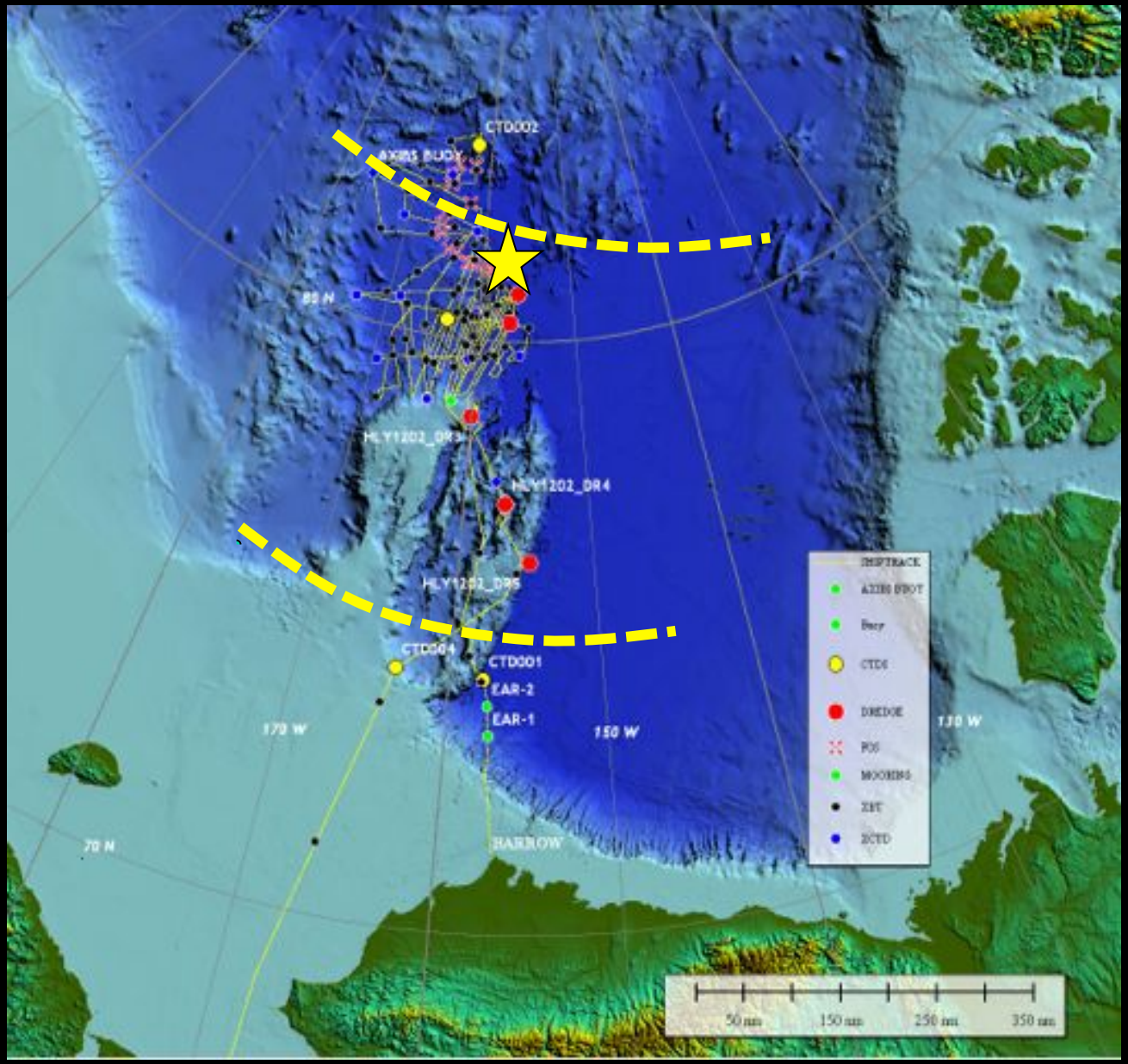
Long/Lat: -156.072055 W, 80.293353 N
2007 (9-6-2007)



Long/Lat: -156.072055 W, 80.293353 N
2012 (9-12-2012)



HEALY 1202 – Aug- Sept 2012

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Arctic sea ice up 60 percent in 2013


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Sunday, Apr 20th 2014 3PM 44°F 6PM 48°F 5-Day Forecast
Mail Online
News
And now it's
Arctic ice cap
• 533,000 more square
• BBC reported in 2007
summer by 2013
• Publication of UN clin
caused by humans pu
By DAVID ROSE
PUBLISHED: 18:37 EST, 7 September

The New American
THAT FREEDOM SHALL NOT PERISH
HOME
U.S. NEWS
WORLD NEWS
ECONOMY
SCI/TECH
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OP-ED/REVIEWS
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Al Gore Forecasted "Ice-Free" Arctic by 2013; Ice Cover Expands 50%
Written by Alex Newman
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font size
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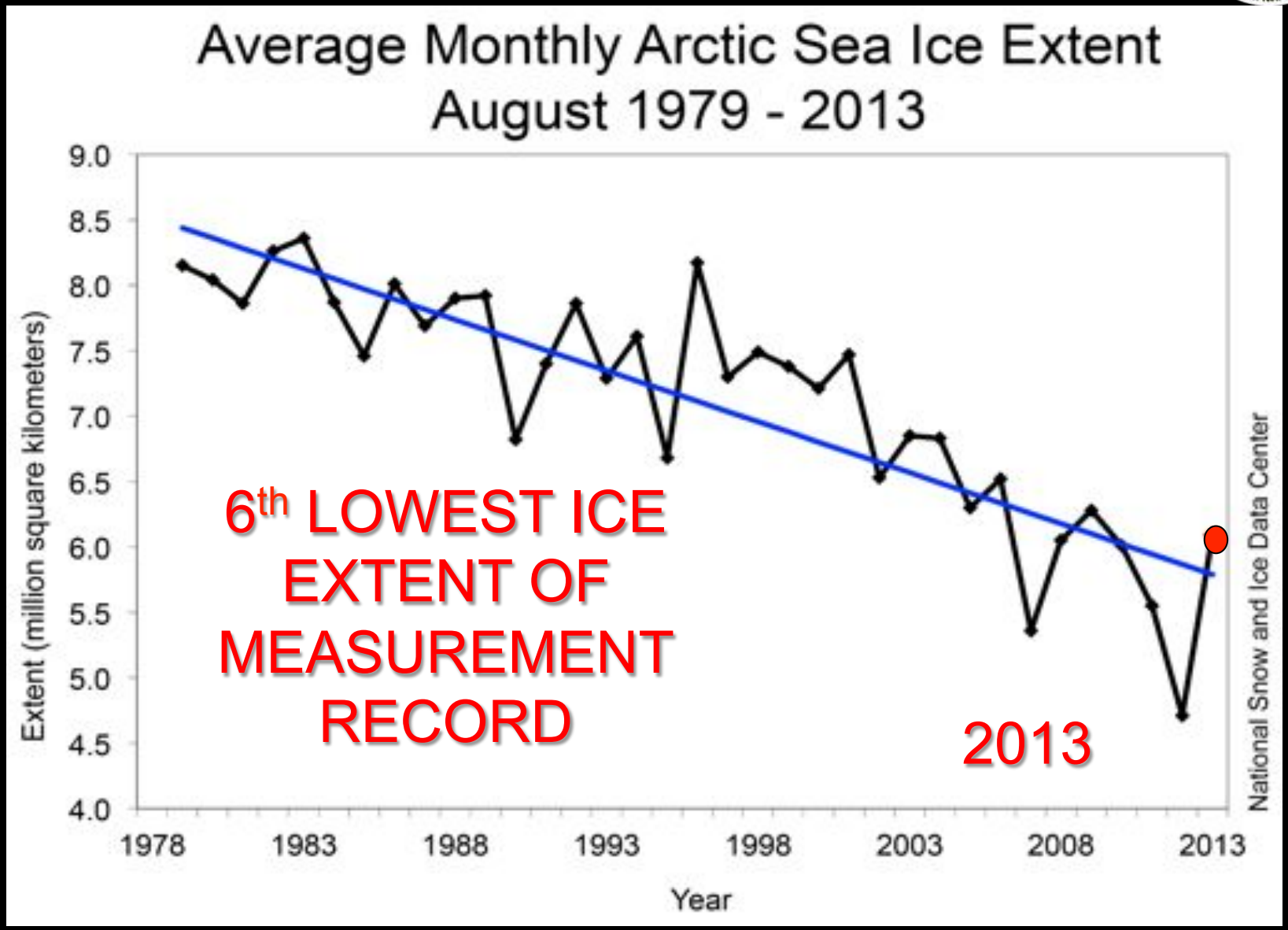
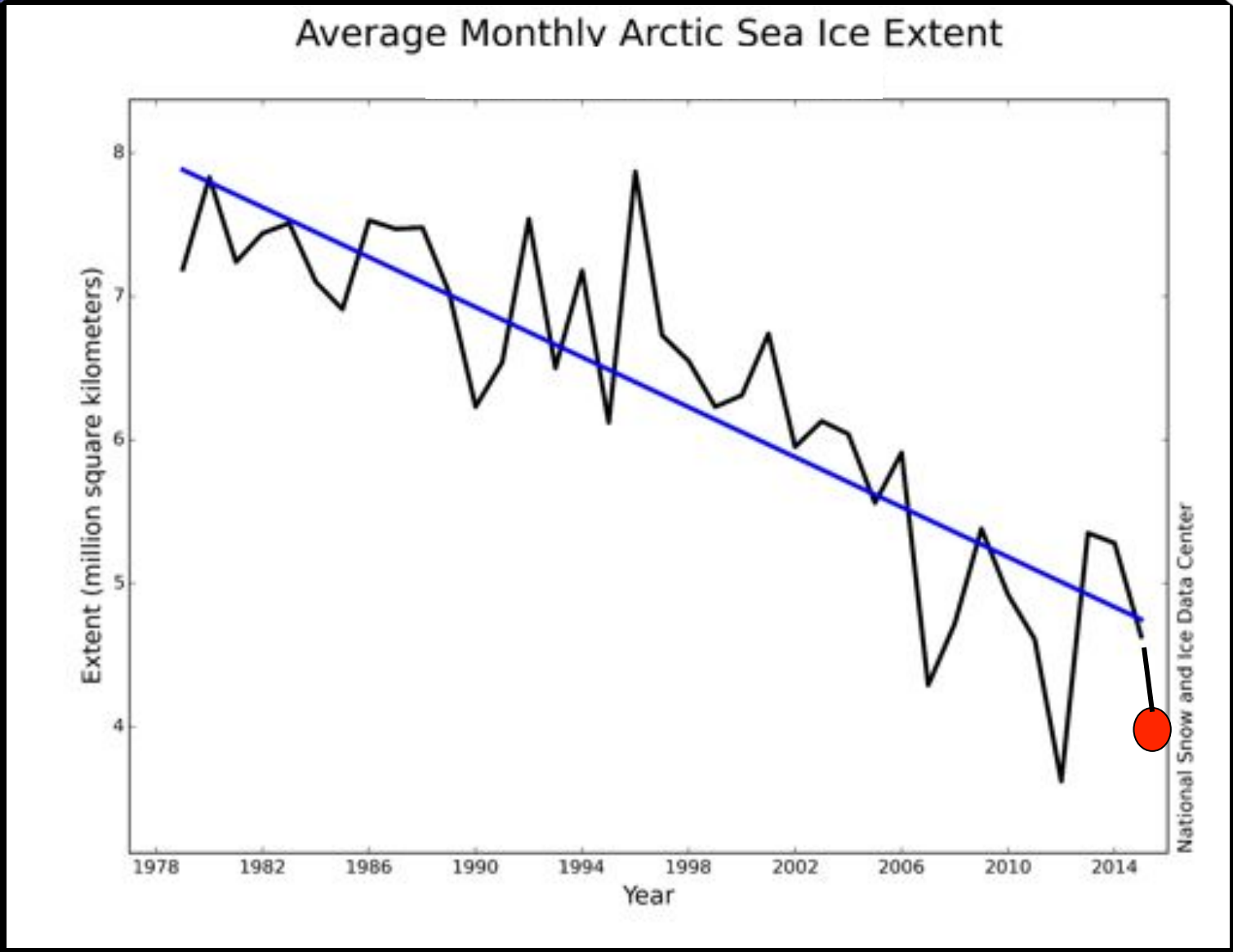
AND 2013??

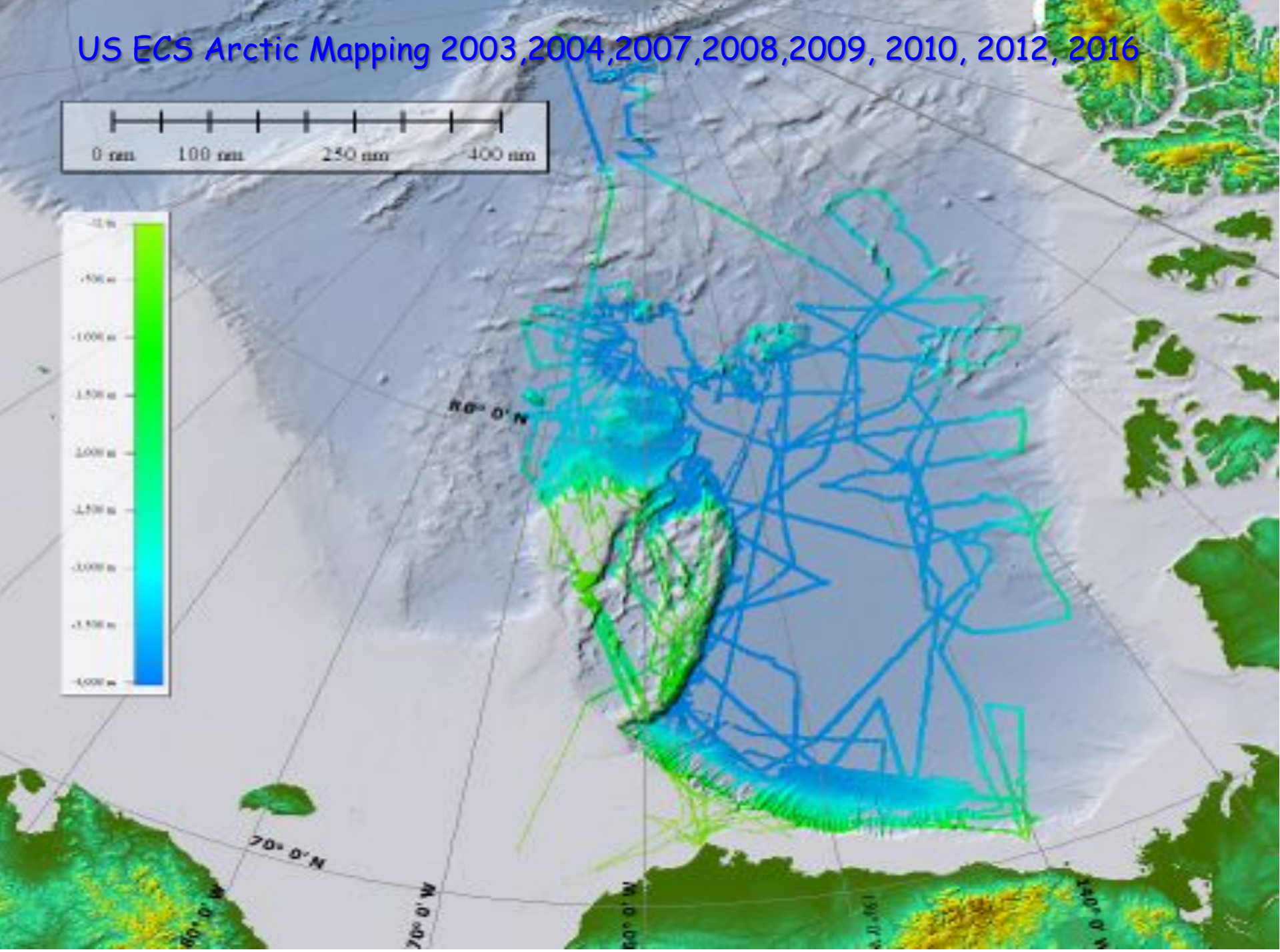

Average Monthly Arctic Sea Ice Extent
August 1979 - 2013
Extent (million square kilometers)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
1978
1983
1988
1993
1998
2003
2008
2013
Year
6th LOWEST ICE EXTENT OF MEASUREMENT RECORD
2013
National Snow and Ice Data Center

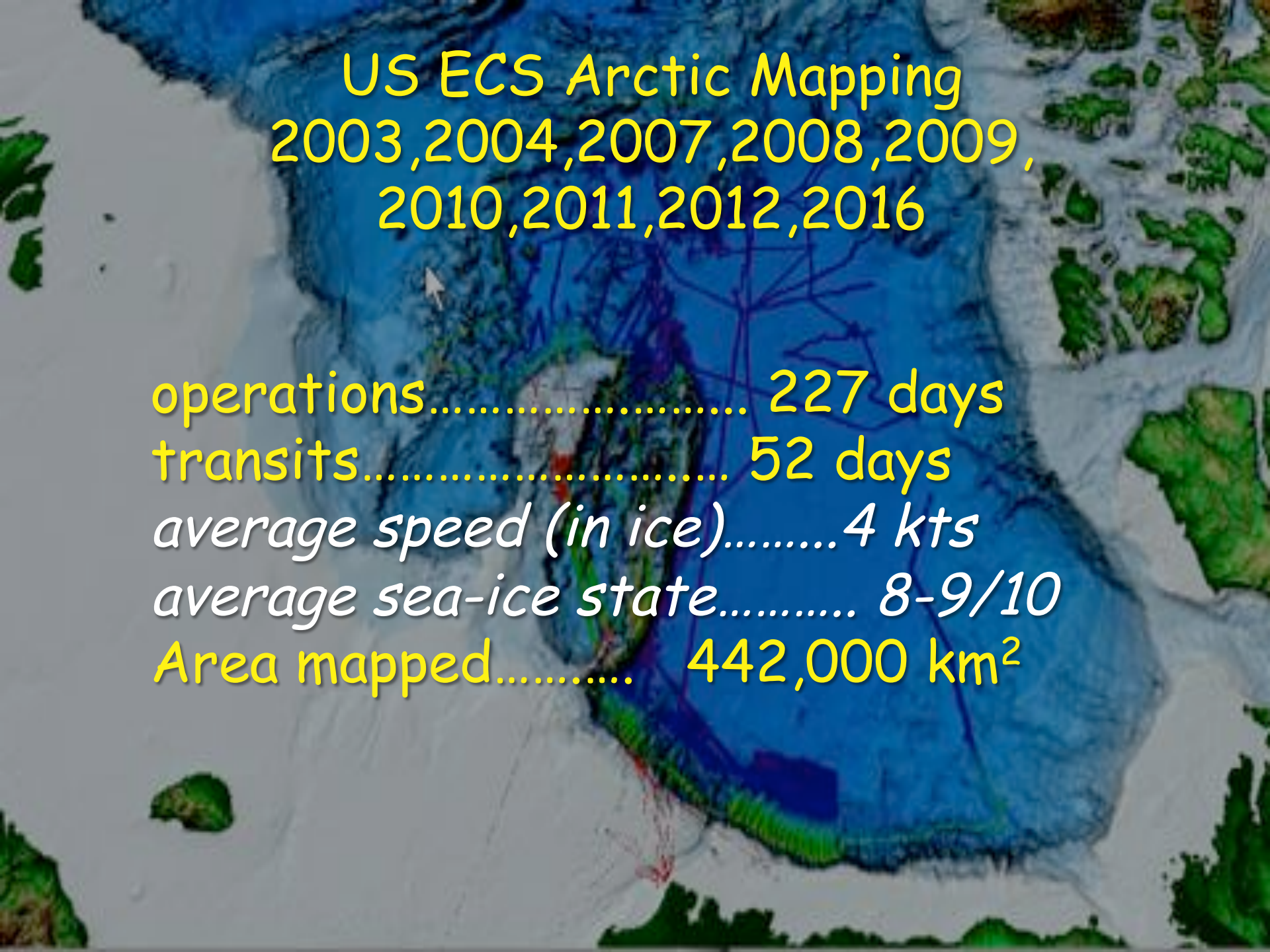
MINIMUM ICE EXTENT THROUGH 2016



HEALY 1603


Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Google Earth


US ECS Arctic Mapping 2003,2004,2007,2008,2009, 2010, 2012, 2016
0 nm
100 nm
250 nm
400 nm
80° 0' N
70° 0' N


US ECS Arctic Mapping
2003,2004,2007,2008,2009,
2010,2011,2012,2016
operations..... 227 days
transits..... 52 days
average speed (in ice).....4 kts
average sea-ice state..... 8-9/10
Area mapped..... 442,000 km²

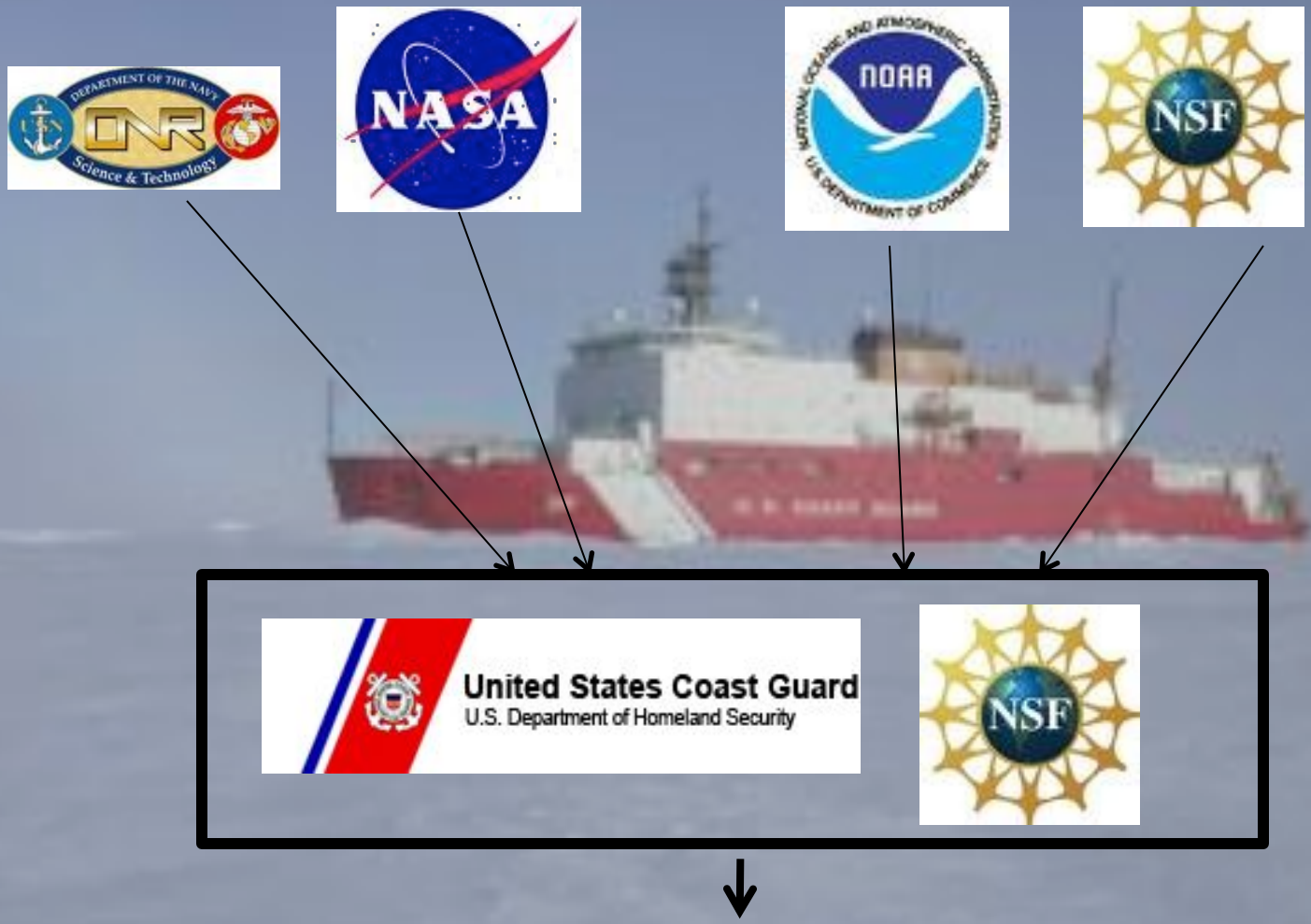
ALL BATHYMETRIC DATA MADE AVAILABLE WITHIN A FEW MONTHS OF COLLECTION

CHALLENGES

ACCESS!

ACCESS!

SCHEDULING:

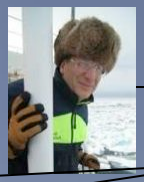


HEALY 1101	25 Jun/29 Jul	Dutch/ Kodiak	Ecosystems & Chemistry	NASA
HEALY 1102	11 Aug/28 Sep	Barrow/ Barrow	Law of Sea ECS	NOAA
HEALY 1103	05 Oct/27 Oct	Nome/Dutch	W. Arctic Currents	NSF

COORDINATION WITH THE LOCAL COMMUNITY and LOCAL LOGISTICS – PARTICULARLY FOR NON-NSF PIs

PERMITTING:

ENVIRONMENTAL COMPLIANCE



National Environmental Policy Act

Full title	National Environmental Policy Act of 1969
Acronym	NEPA
Enacted by the	91st United States Congress
Effective	January 1, 1970
Citations	
Public Law	P.L. 91-190
Stat.	83 Stat. 852 (1969)
Codification	
Title(s) amended	42 (Public Health and Welfare)
U.S.C. sections created	42 U.S.C. § 4321 *et seq.*

NOAA FISHERIES SERVICE

Office of Protected Resources and the Marine Mammal Protection Act

The Marine Mammal Protection Act of 1972 was enacted in response to increasing concerns among scientists and the public that significant declines in some species of marine mammals were caused by human activities. The Act established a national policy to prevent marine mammal species and population stocks from declining beyond the point where they ceased to be significant functioning elements of the ecosystems of which they are a part. Nowhere else in the world had a government made the conservation of healthy and stable ecosystems as important as the conservation of individual species.

The Department of Commerce through the National Marine Fisheries Service is charged with protecting whales, dolphins, porpoises, seals, and sea lions. Walrus, manatees, otters, and polar bears are protected by the Department of the Interior through the U.S. Fish and Wildlife Service. The Animal and Plant Health Inspection Service, a part of the Department of Agriculture, is responsible for regulations managing marine mammals in captivity.

Endangered Species Act

Full title	An Act to provide for the conservation of endangered and threatened species of fish, wildlife, and plants, and for other purposes
Acronym	ESA
Enacted by the	93rd United States Congress
Effective	December 28, 1973
Citations	
Public Law	P.L. 93–205
Stat.	87 Stat. 884 (1973)
Codification	
U.S.C. sections created	16 U.S.C. §1531

Magnuson-Stevens Fishery Conservation and Management Act

Public Law 94-265

As amended through October 11, 1996

AN ACT

To provide for the conservation and management of the fisheries, and for other purposes.

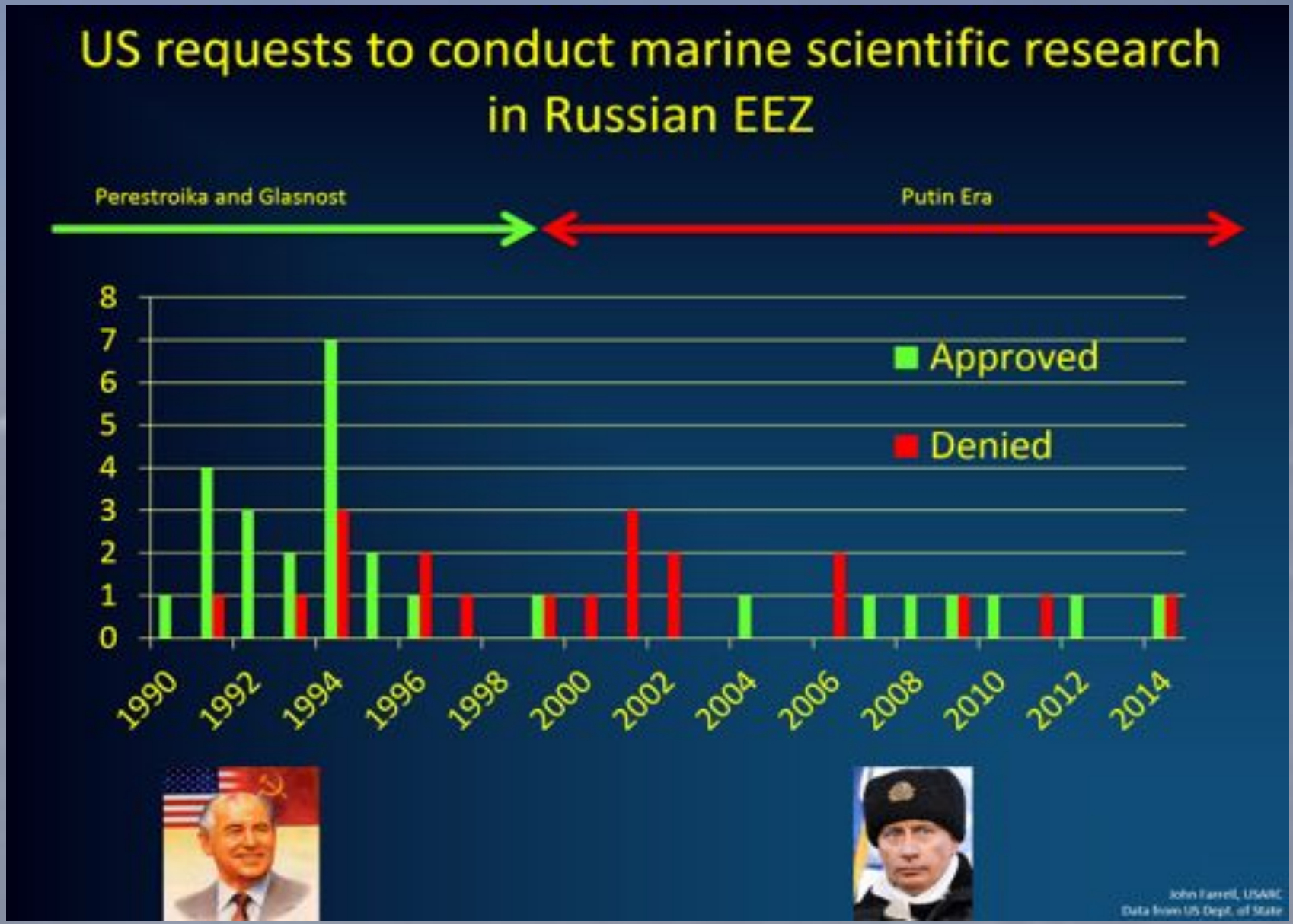
CATEGORICAL EXCLUSION – no significant impact

ENVIRONMENTAL IMPACT STATEMENT – open for public comment and other federal agencies

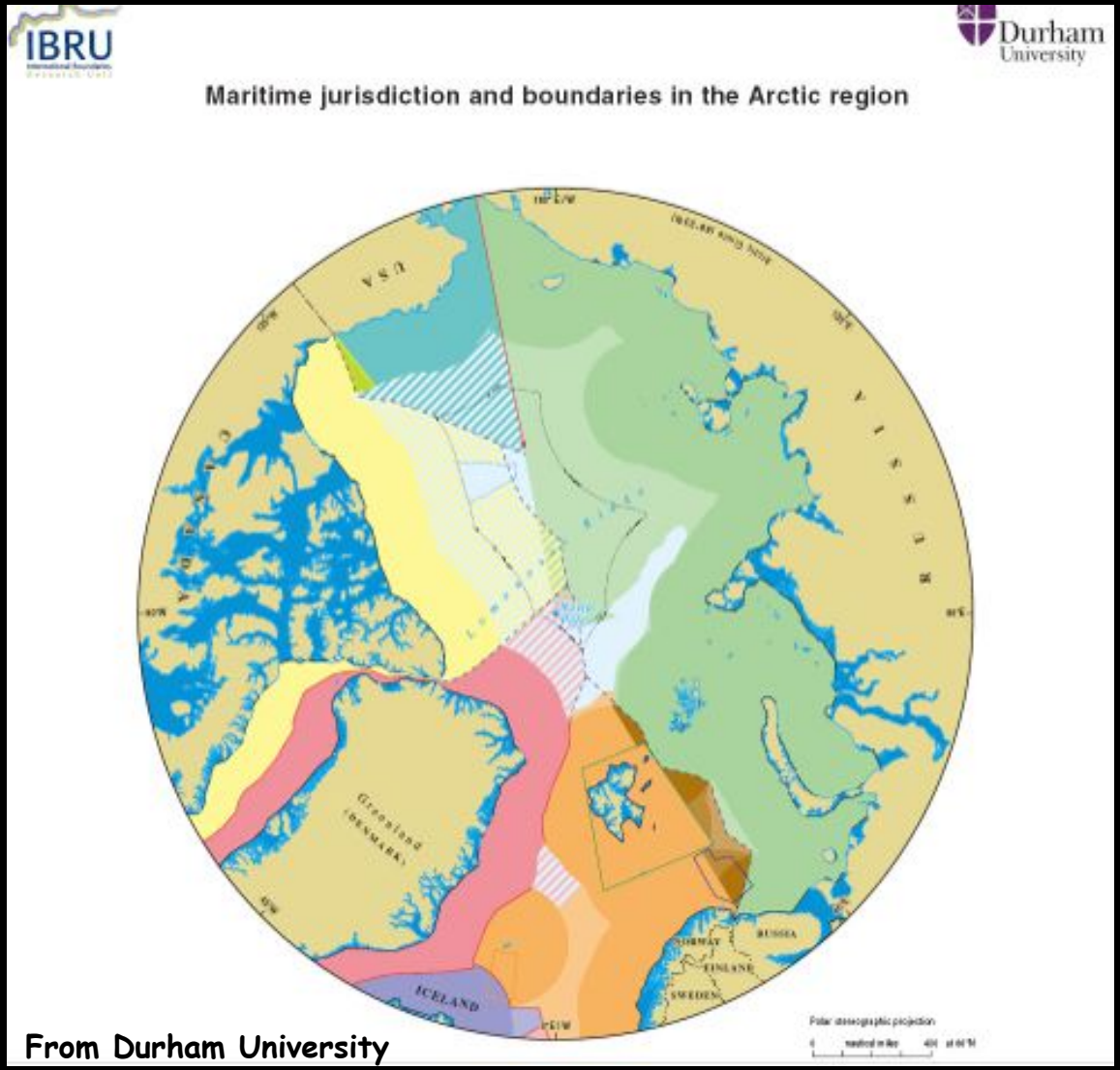
INCIDENTAL HARASSMENT AUTHORITY (IHA) mitigation procedures – Marine Mammal/ Protected Species Observers

PERMITTING:

AUTHORIZATIONS



ACCESS!



AUTHORIZATION

SWERUS C3

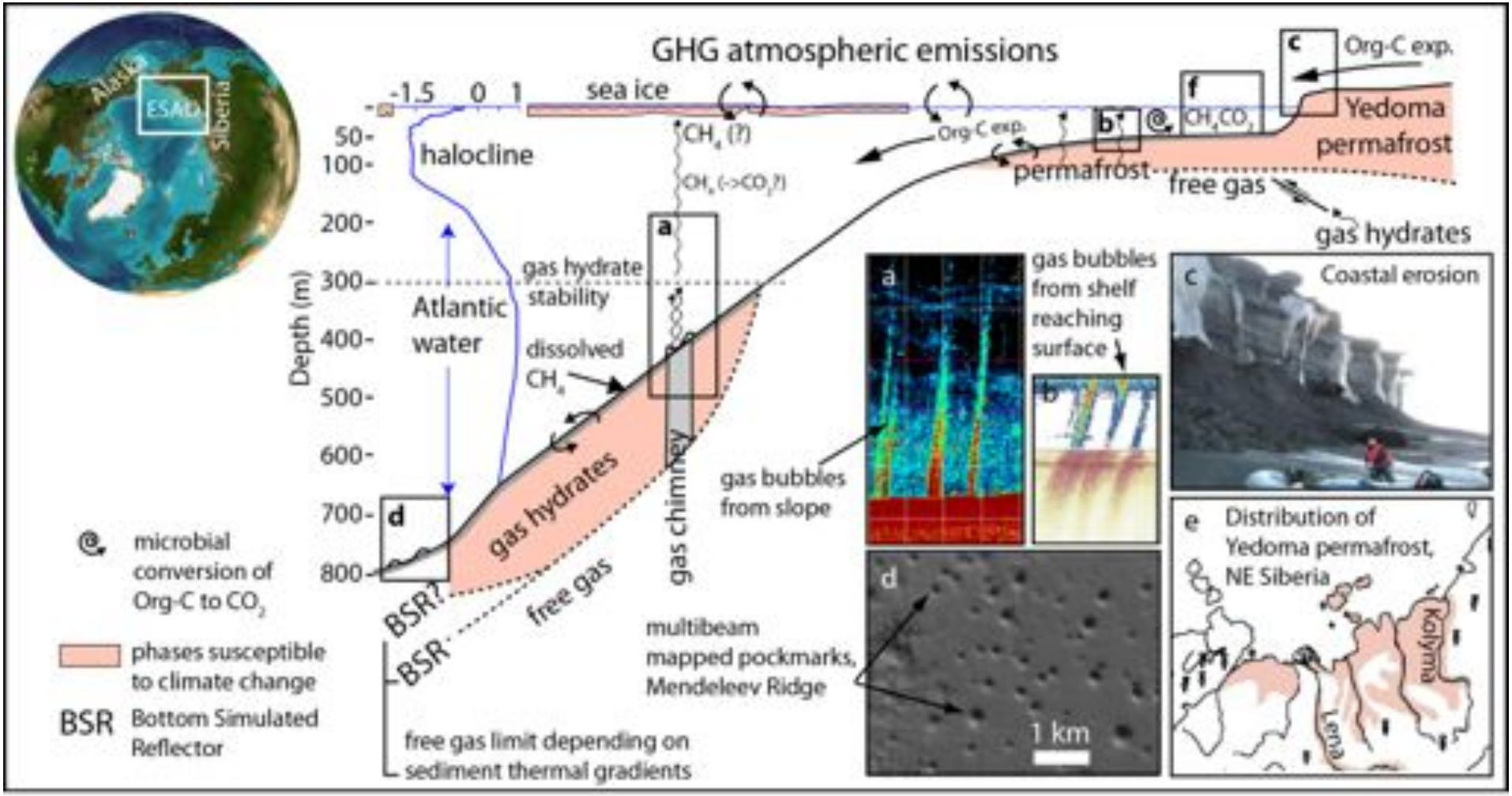
2014

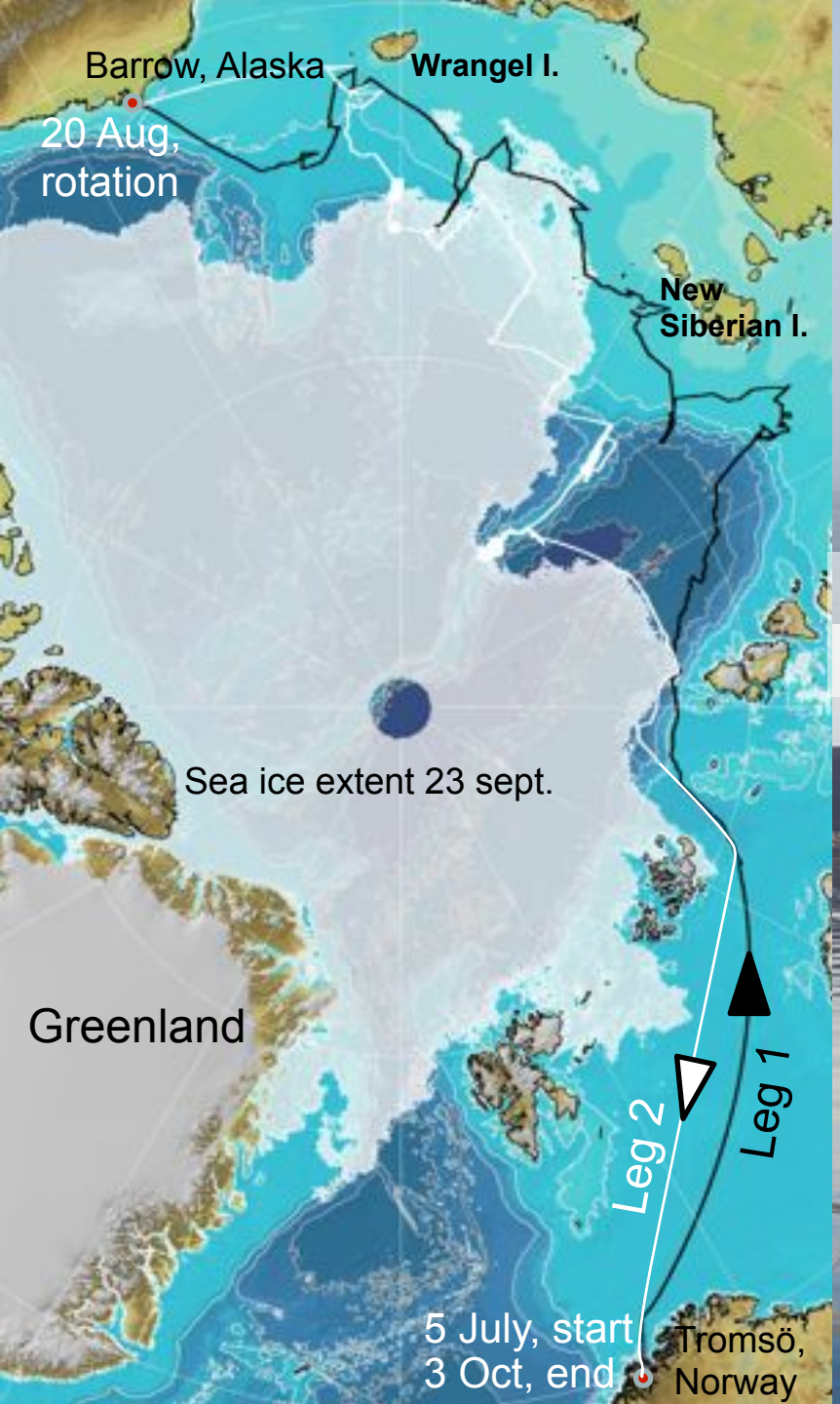
The Swedish-Russian-US-Arctic Ocean Investigation of Climate-Cryosphere-Carbon Interactions

C3 = Carbon-Cryosphere-Climate

SEA ICE, PERMAFROST, CARBON CYCLE, GASHYDRATES IN SEDIMENTS, RELEASE OF CH_4 FROM SHELF AND SLOPE, GLACIAL HISTORY, OCEAN CIRCULATION, CLOUD FORMATION

Stockholm University



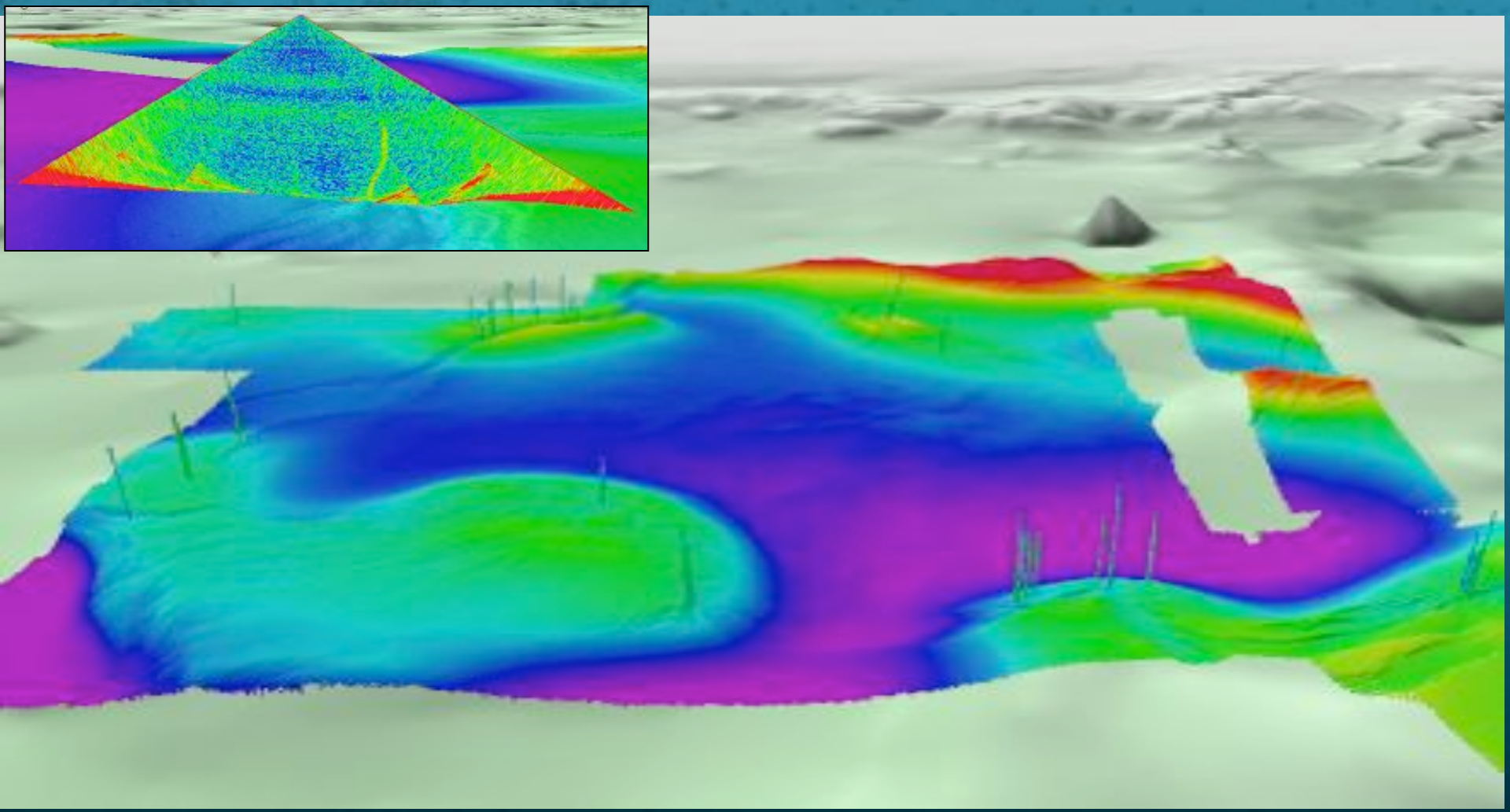


SWERUS 2014

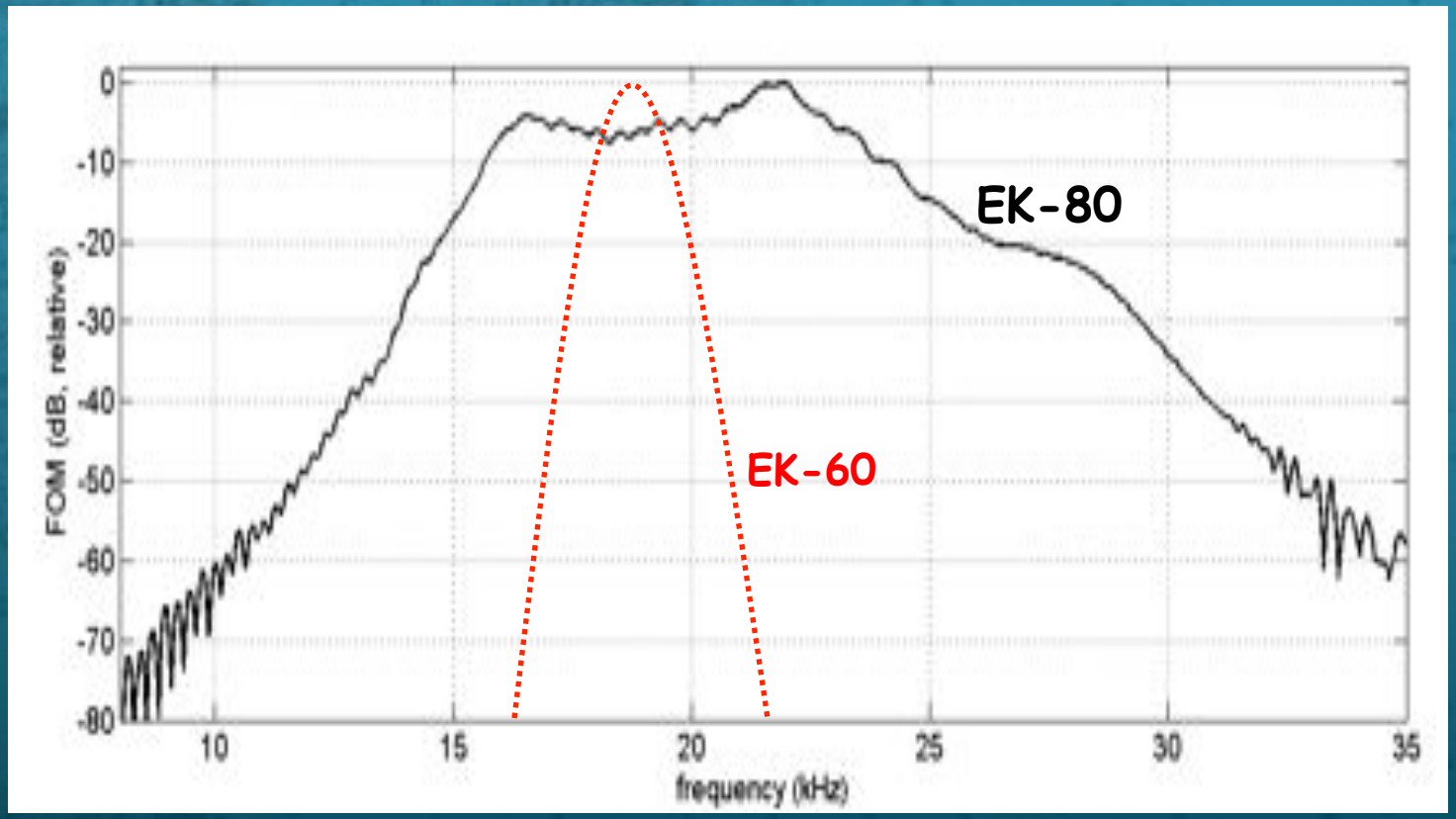
Tromsö-Barrow-Tromsö on 90 days

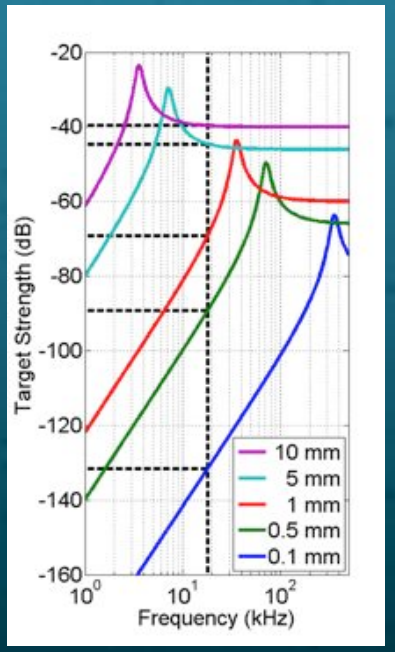
TASKS:

- Acoustically map the distribution of gas seeps
- Acoustically determine the flux (rate) of methane release?



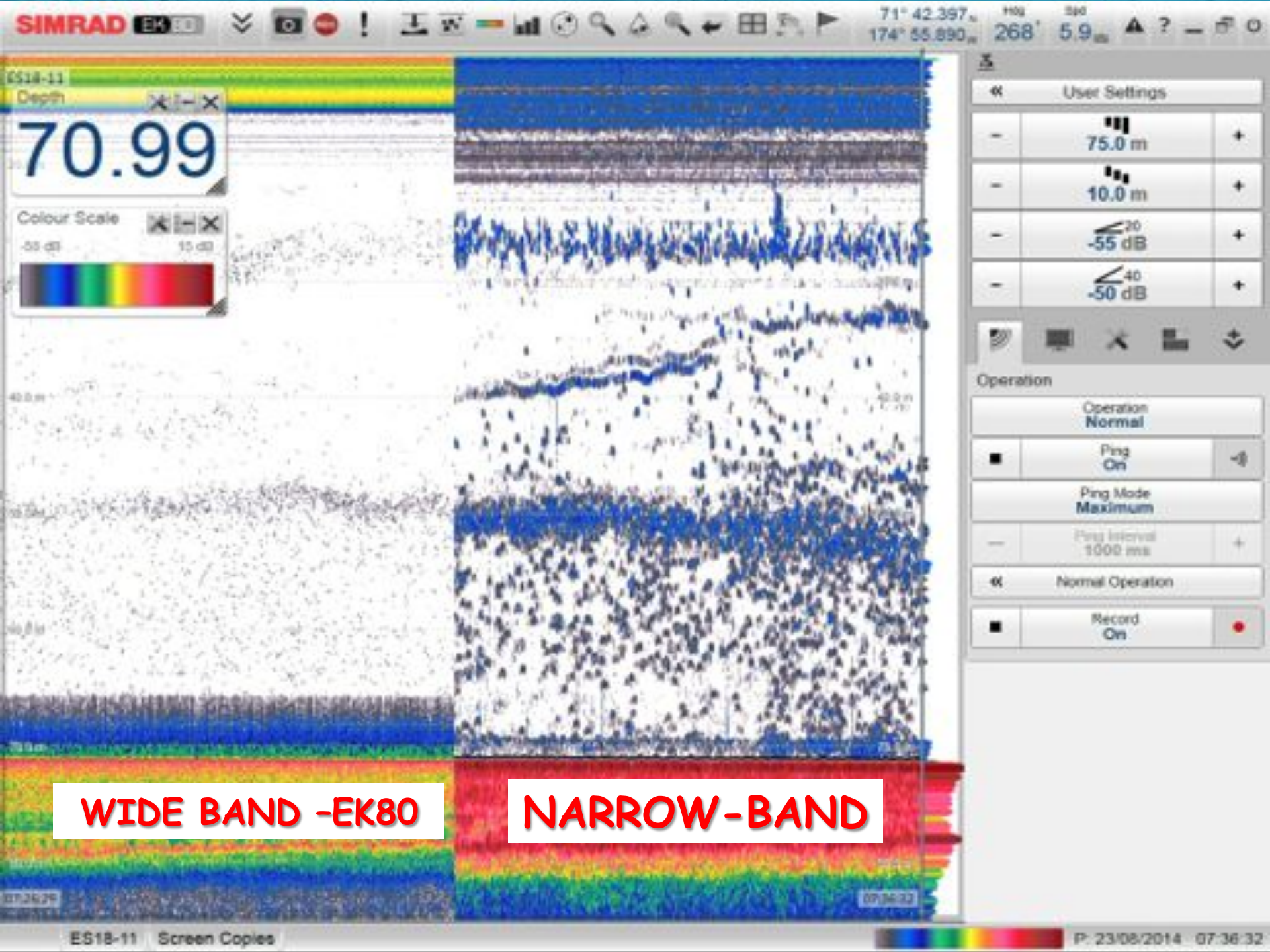
EK-80 on ODEN
Wide-Band Transceiver

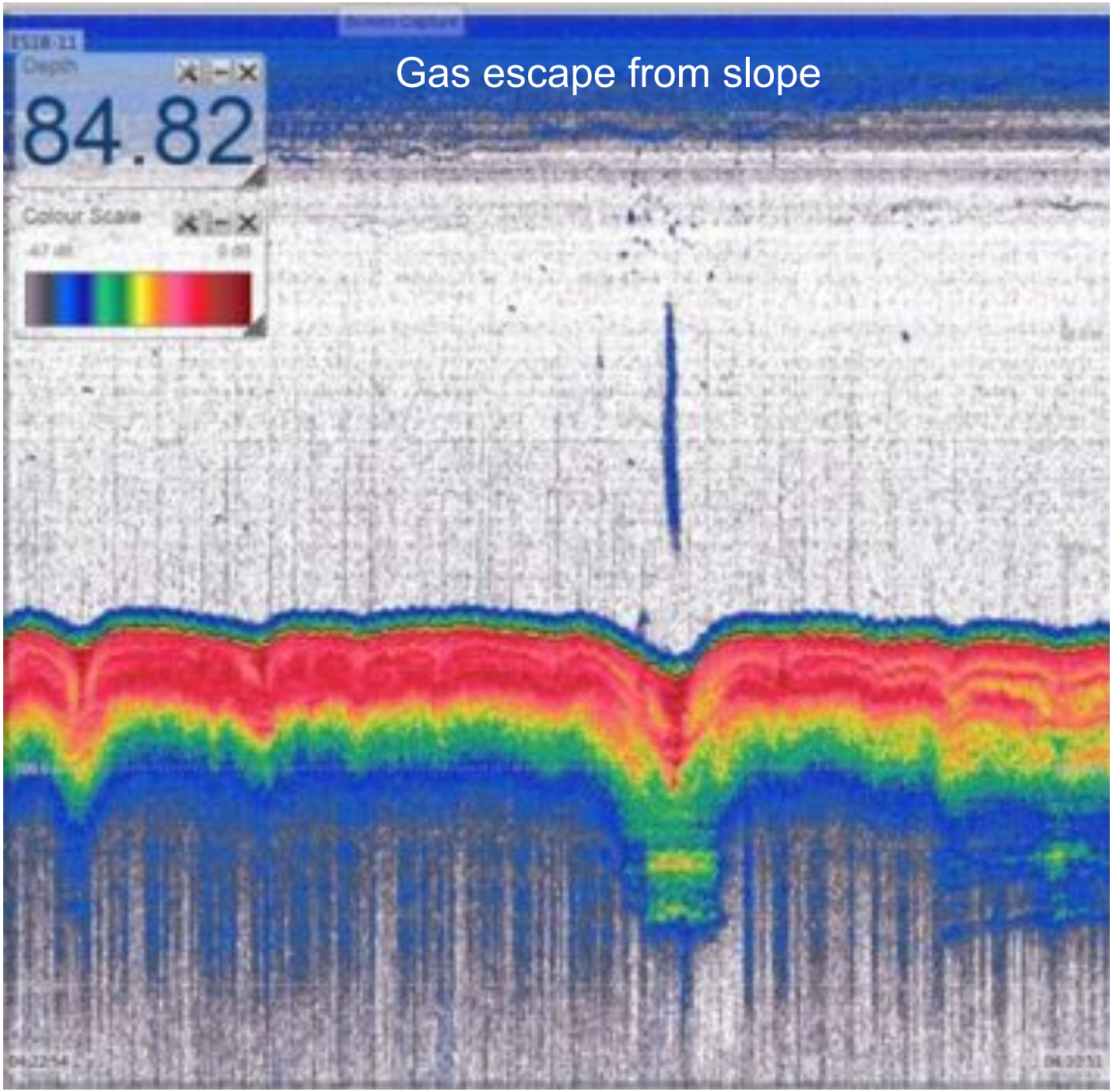




CCOM JHC

University of New Hampshire


SIMRAD
71° 42.397
174° 55.890
268
5.9
ES18-11
Depth
70.99
Colour Scale
User Settings
75.0 m
10.0 m
-55 dB
-50 dB
Operation
Operation
Normal
Ping
On
Ping Mode
Maximum
Normal Operation
Record
On
WIDE BAND -EK80
NARROW-BAND
ES18-11
Screen Copies
P: 23/08/2014 07:36:32


Gas escape from slope
84.82
Colour Scale

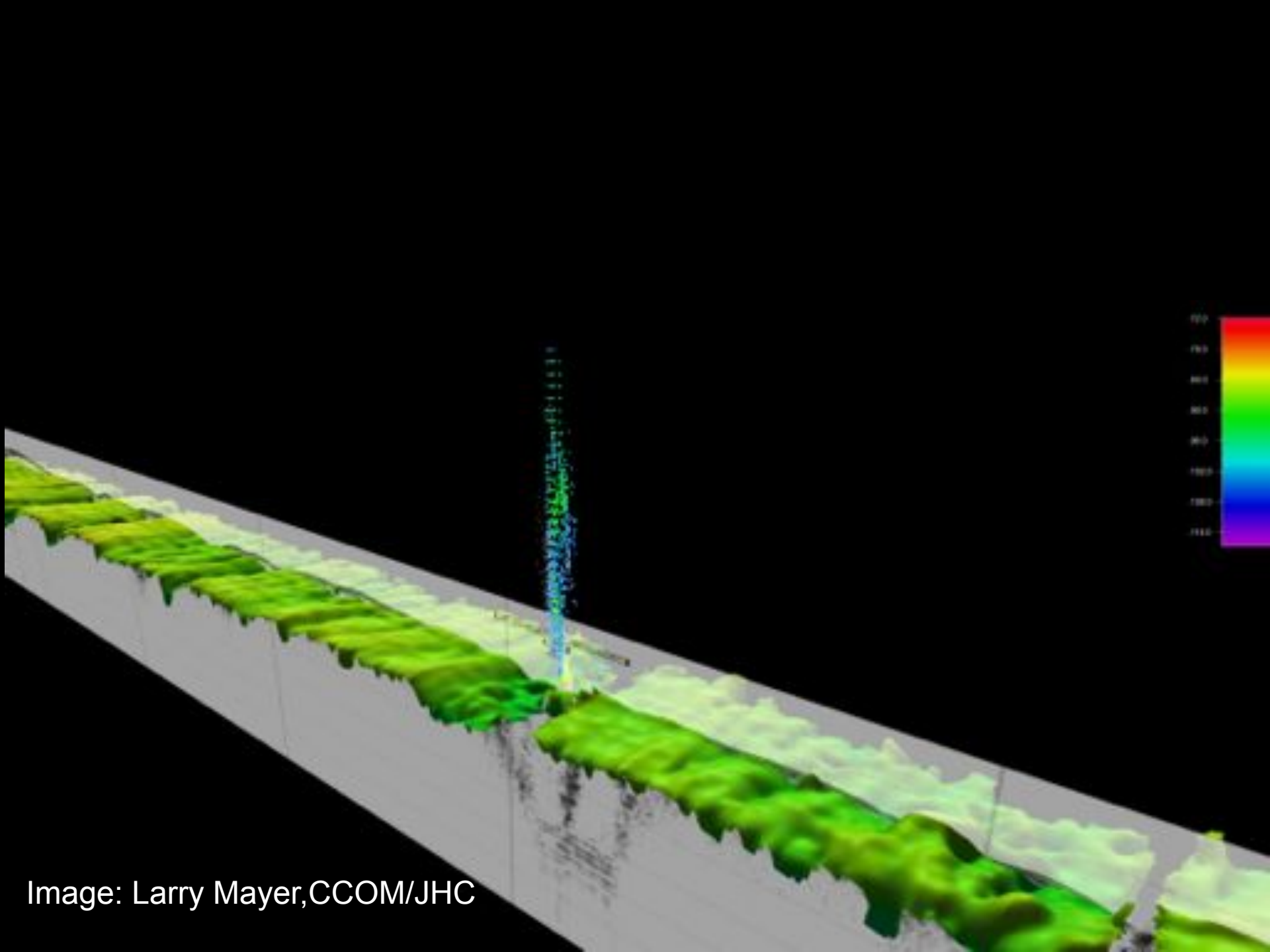
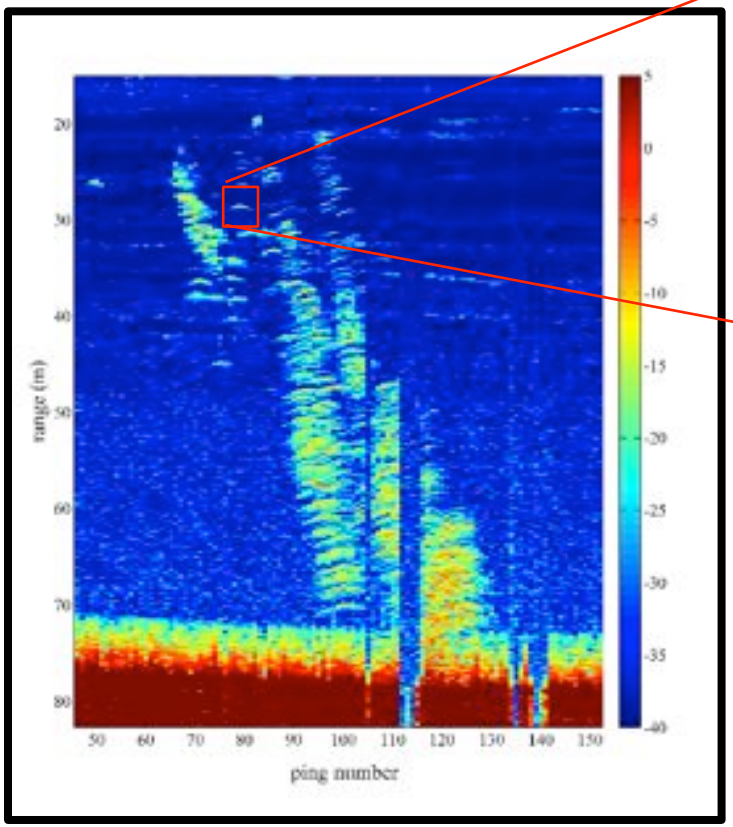
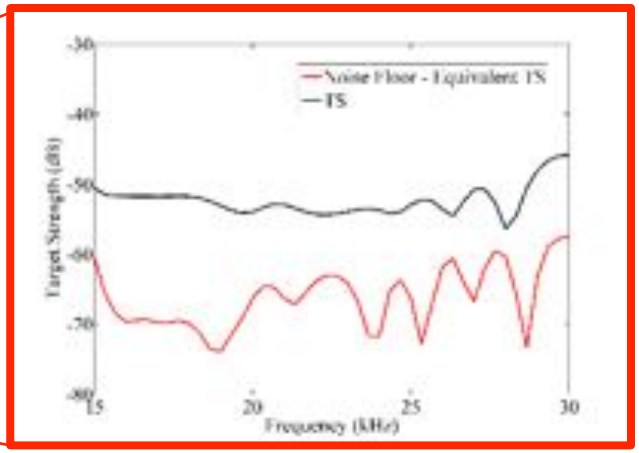
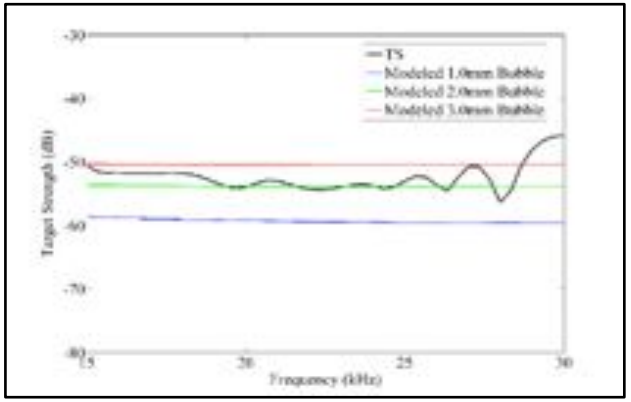


Image: Larry Mayer,CCOM/JHC

Acoustic Determination of Bubble Size → Estimation of Flux from Target Strength

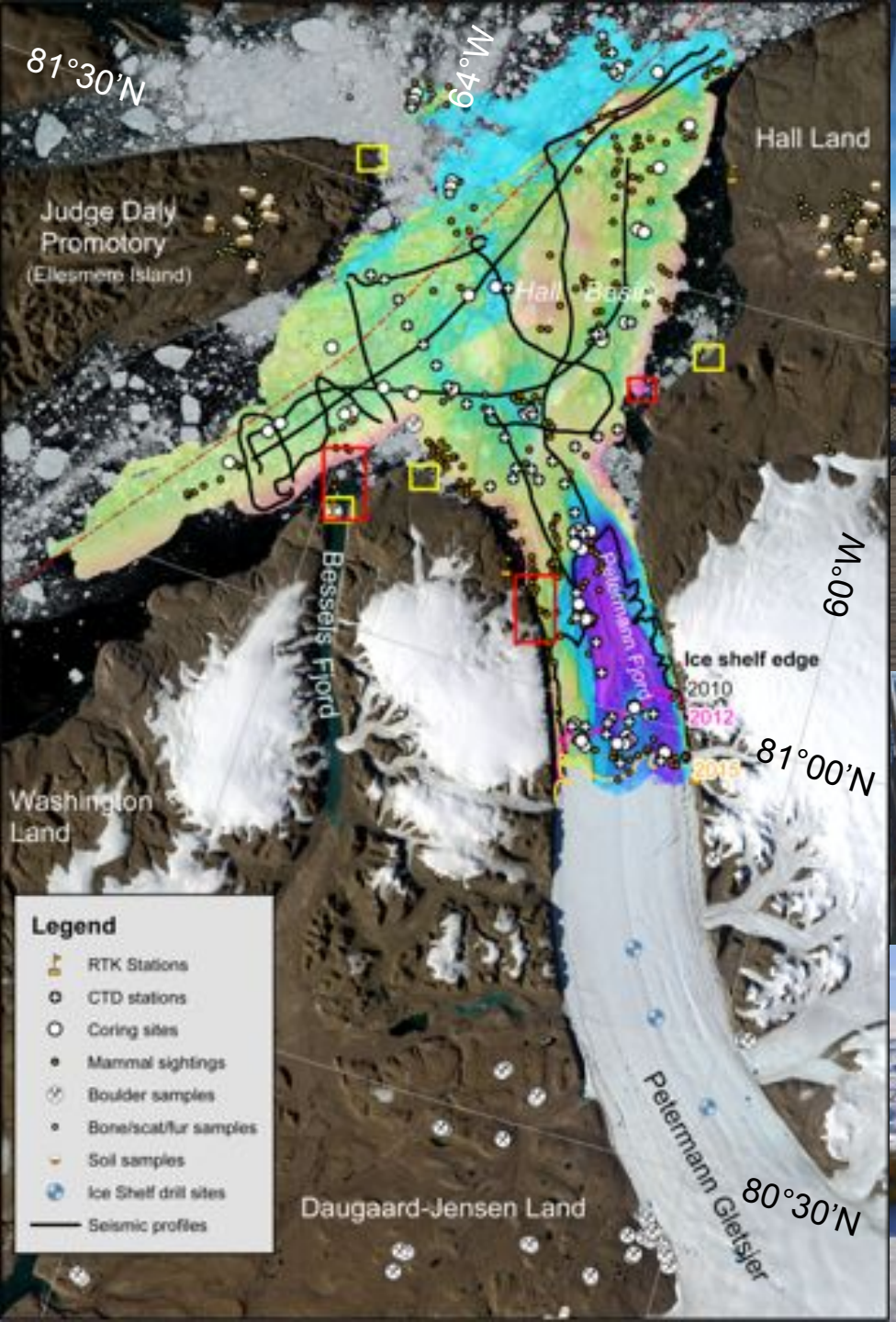


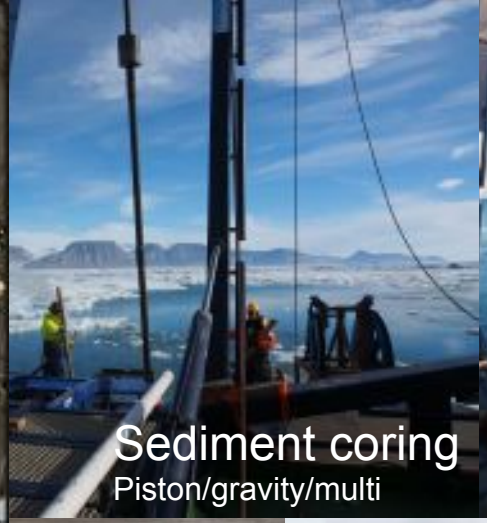




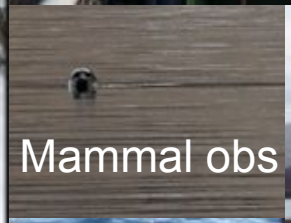
GREAT STEP FORWARD: Coordination between NSF and Swedish Polar Secretariat

Petermann 2015 Expedition with Icebreaker Oden

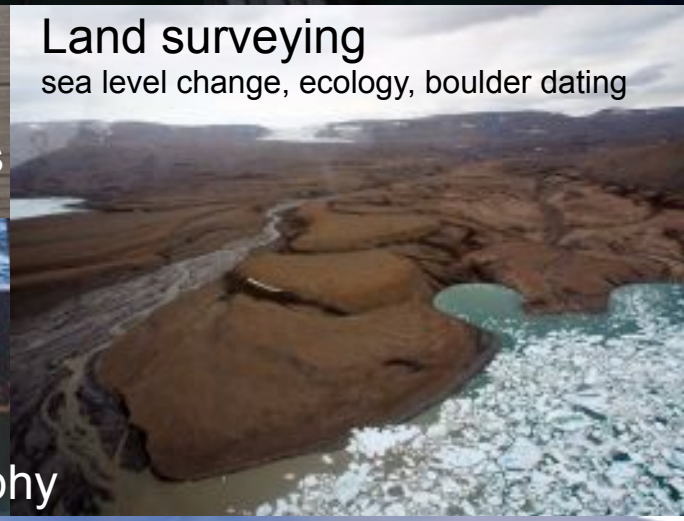

81°30'N
64°W
Hall Land
Judge Daly Promotory
(Ellesmere Island)
Hall Basin
Bessels Fjord
Petermann Fjord
60°W
Ice shelf edge
2010
2012
2015
81°00'N
Washington Land
Legend
RTK Stations
CTD stations
Coring sites
Mammal sightings
Boulder samples
Bone/scat/fur samples
Soil samples
Ice Shelf drill sites
Seismic profiles
Daugaard-Jensen Land
Petermann Gletsjer
80°30'N


Sediment coring
Piston/gravity/multi


Seismic profiling
GI gun, 210 cu, 48 chan/300 m


Mammal obs

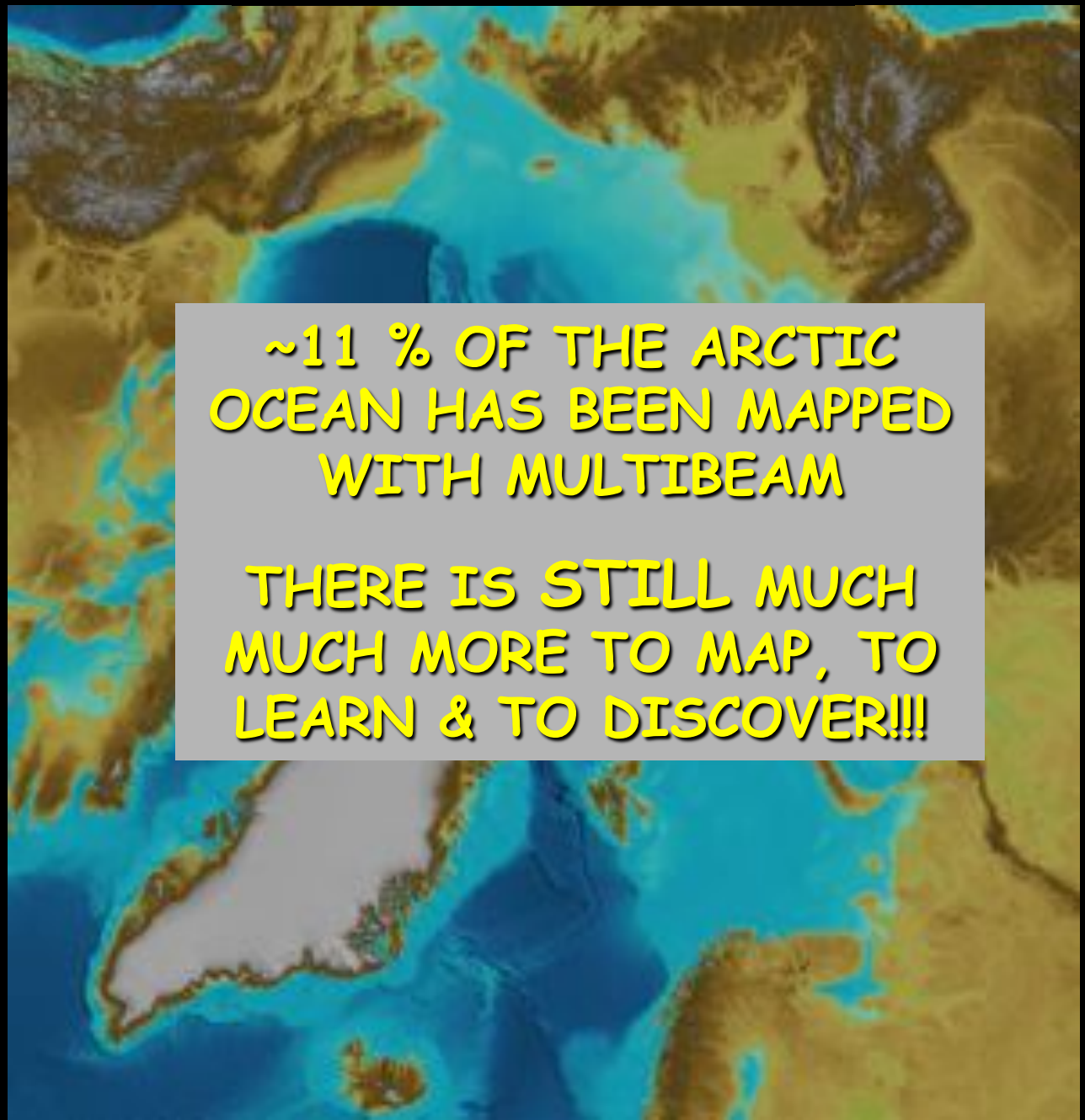

Oceanography


Land surveying
sea level change, ecology, boulder dating


Ice Shelf Drilling


CAN THIS SORT OF ARRANGEMENT BE EXTENDED TO OTHER ICEBREAKERS – OTHER NATIONS?

IBCAO VER 3.0 2013



~11 % OF THE ARCTIC OCEAN HAS BEEN MAPPED WITH MULTIBEAM

THERE IS STILL MUCH MUCH MORE TO MAP, TO LEARN & TO DISCOVER!!!