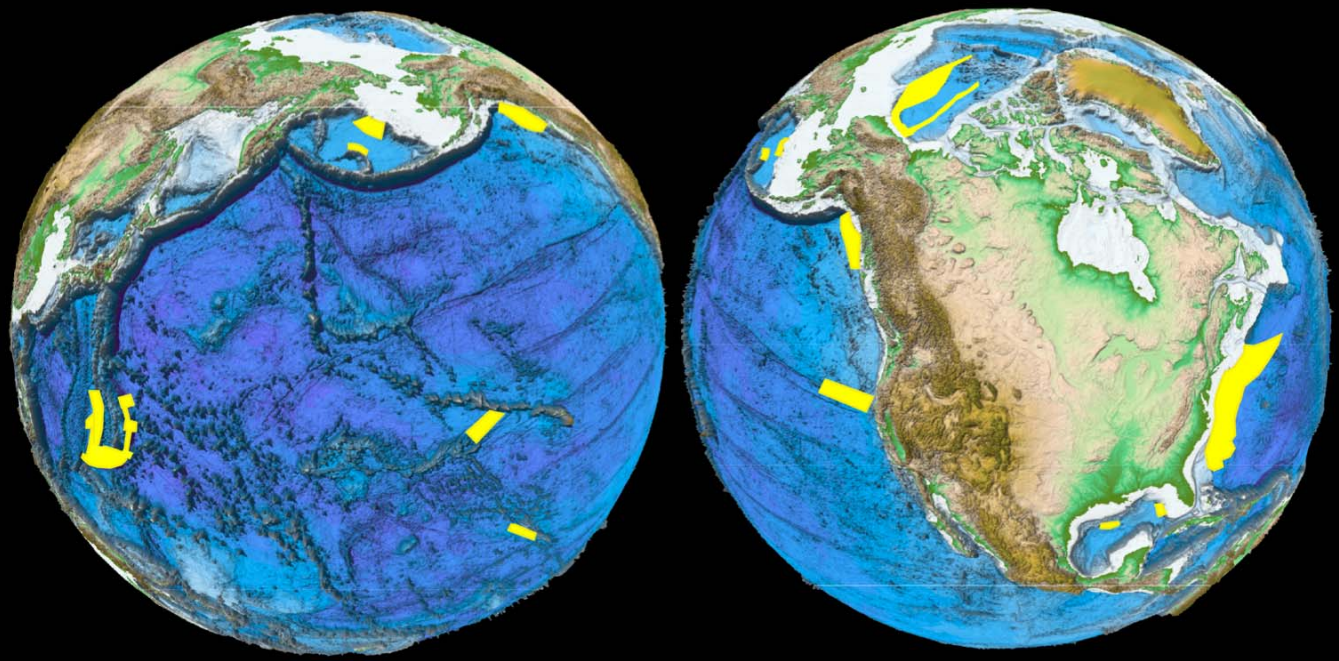
U.S. Extended Continental Shelf Mapping (2002-2015)

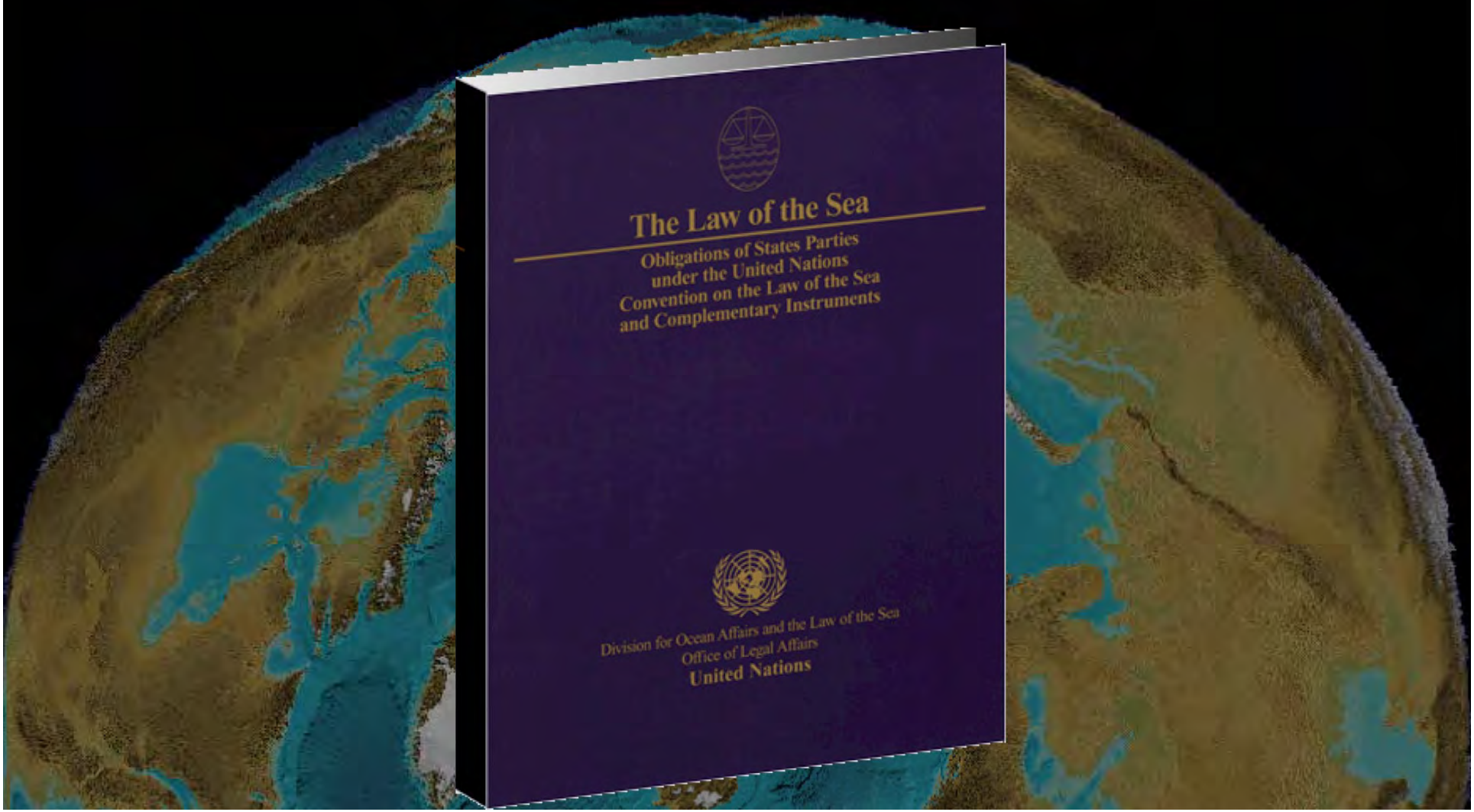
Larry Mayer, James V. Gardner, Andrew A. Armstrong & Brian R. Calder



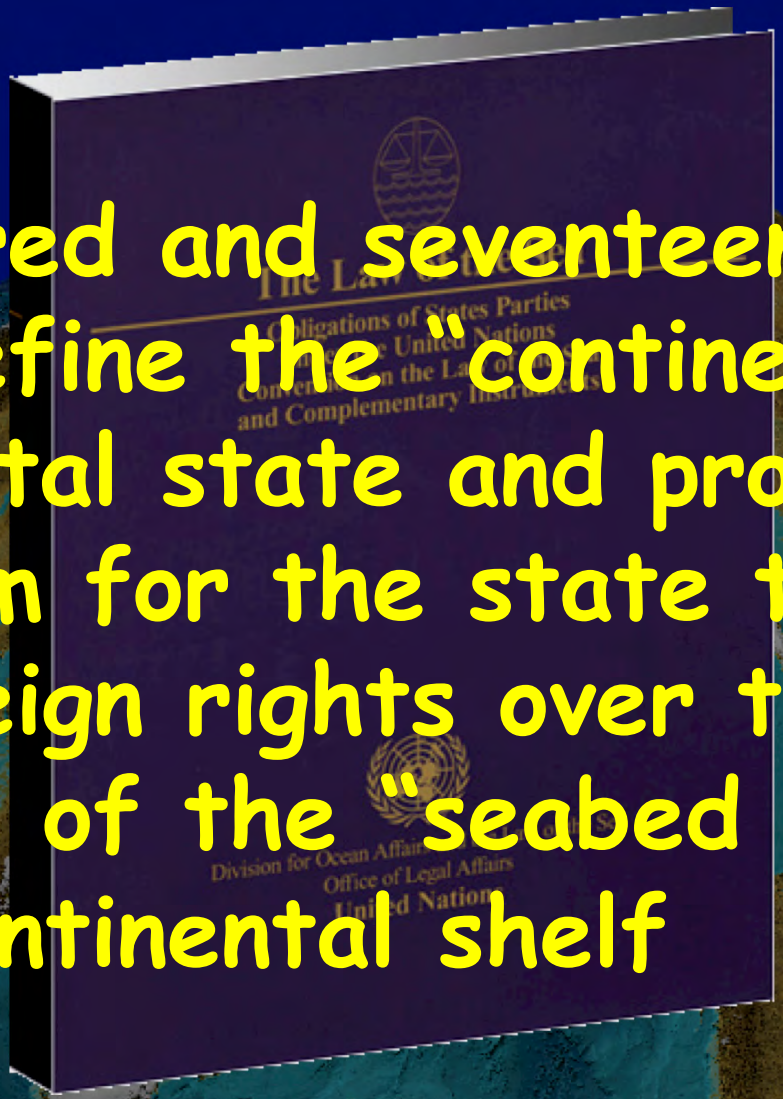
Ocean Exploration Advisory Board

1 Oct. 2015

THE CONVENTION ON THE LAW OF THE SEA

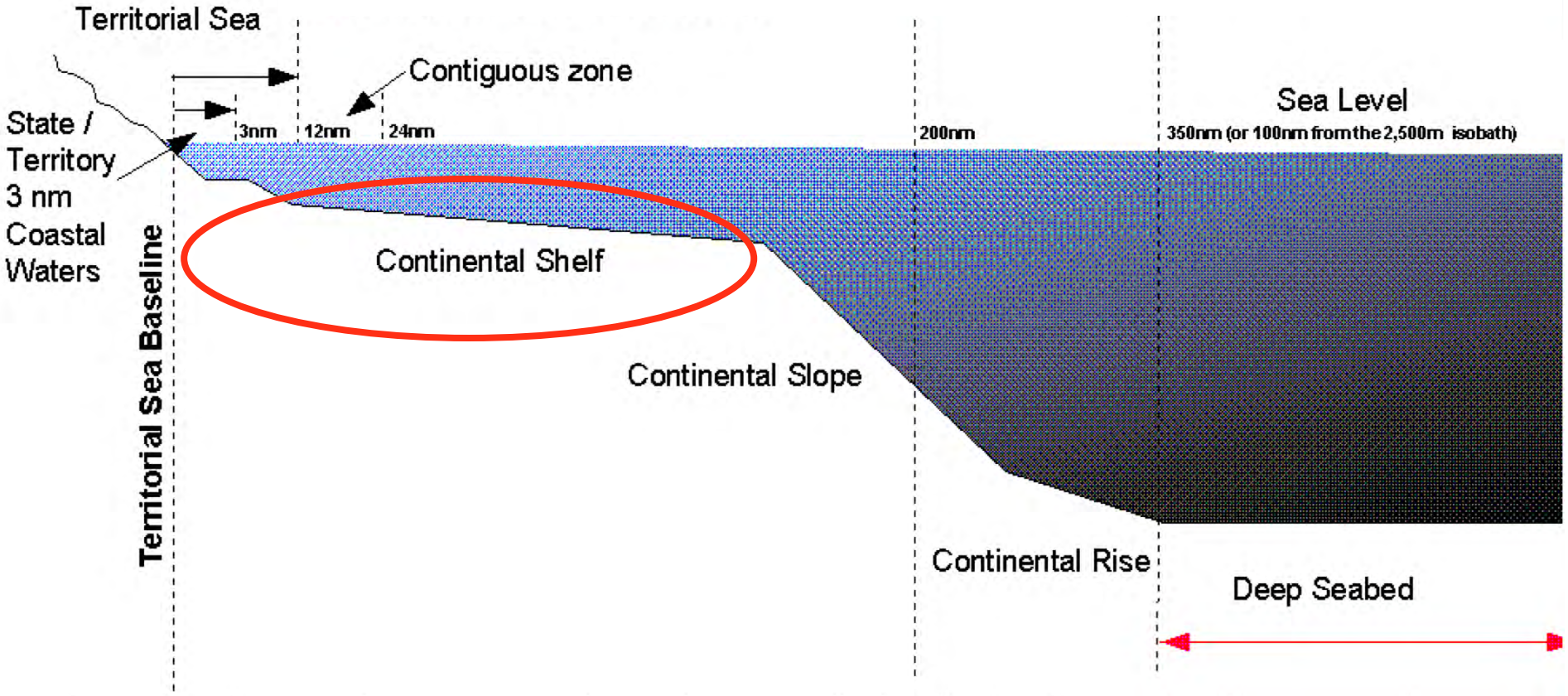


ARTICLE 76 of UNCLOS



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

MARITIME ZONES

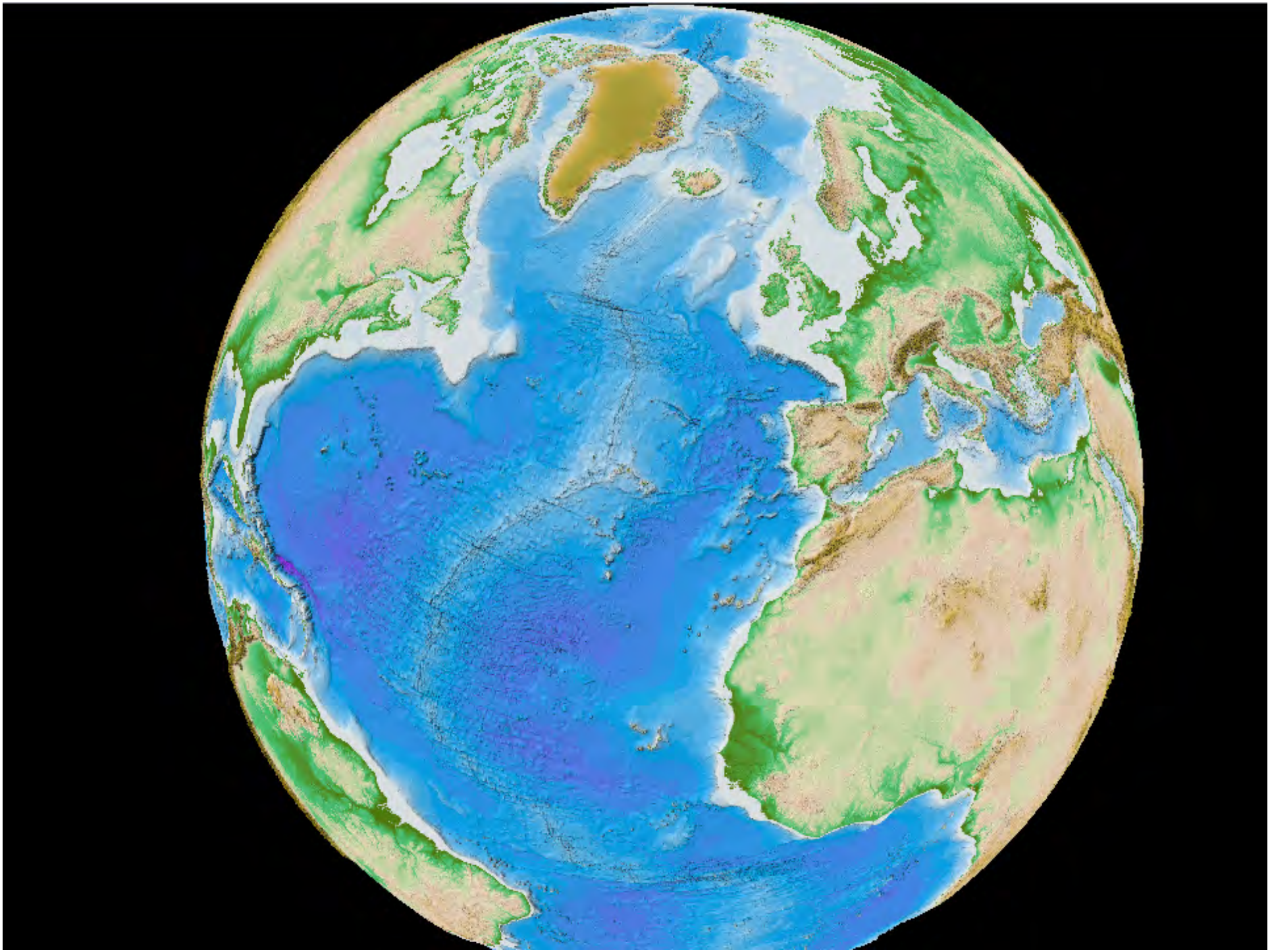


From http://www.environment.gov.au/coasts/oceans-policy/publications/images/maritime-zones.gif

RESOURCES OF THE SEABED AND SUBSOIL

- Non-living resources: gas and oil, gas hydrates, minerals
- Living resources (bottom dwelling):
  - Food stocks: sedentary species, e.g., scallops, clams

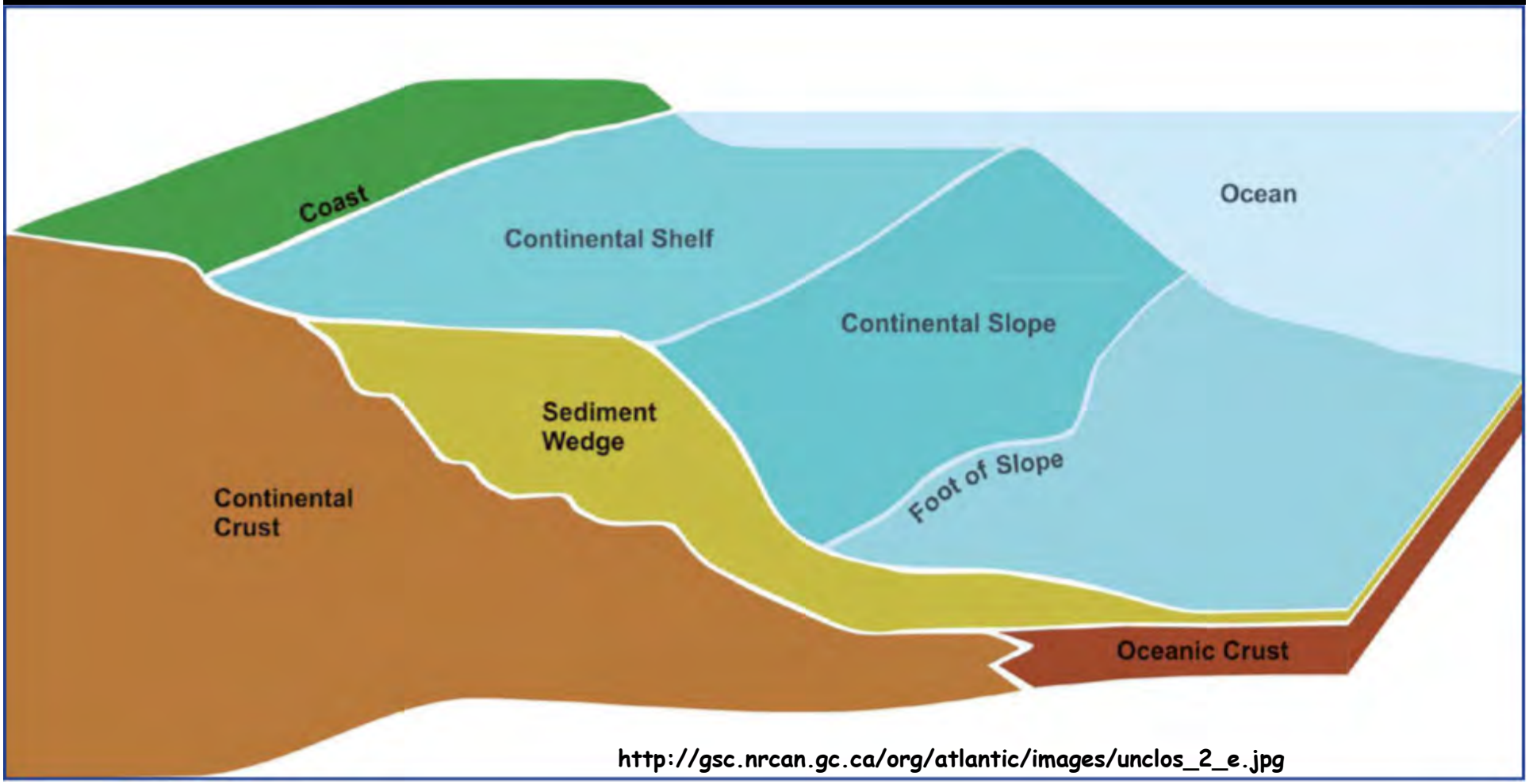
ALSO THE RESPONSIBILITY TO PROTECT AND MANAGE THESE RESOURCES



Data Required

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

Need to map the seafloor

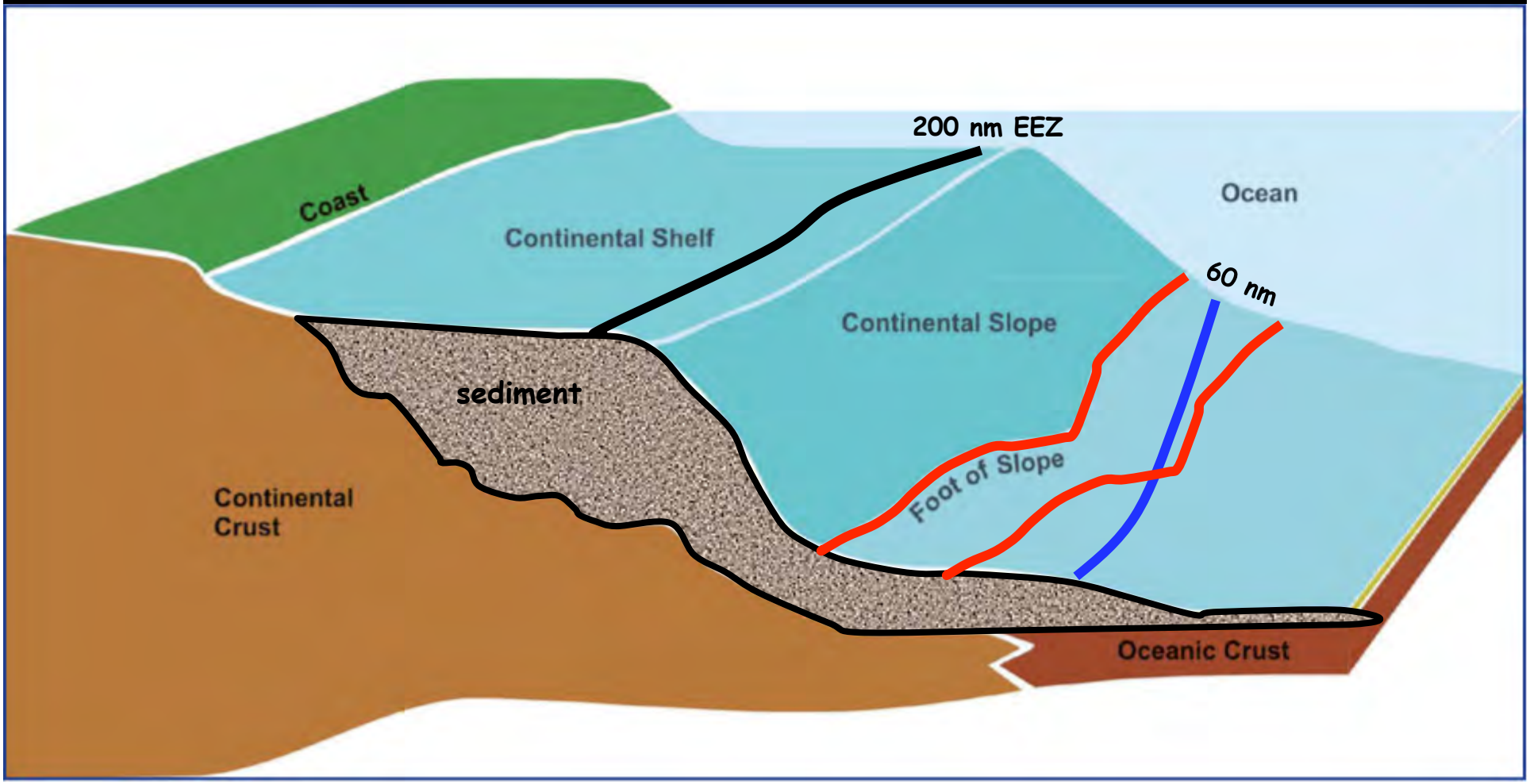


http://gsc.nrcan.gc.ca/org/atlantic/images/unclos_2_e.jpg

Formulae Lines:

Foot of Slope + 60 nmi - bathy

Gardiner line - sediment thickness less than 1% of distance back to FOS - seismic and bathy



Formulae Lines:

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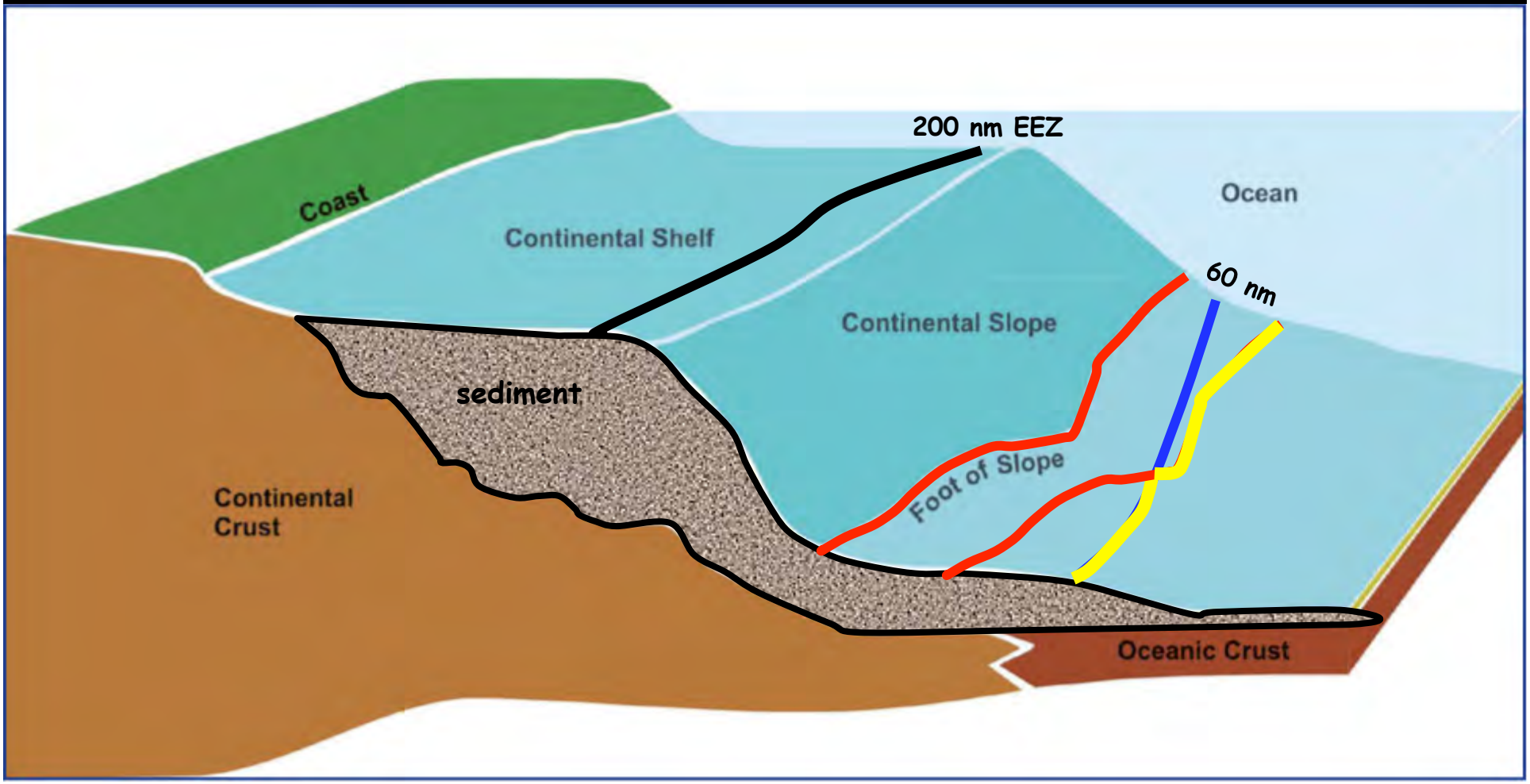
Gardiner line - **sediment thickness less than 1% of distance back to FOS** - seismic and bathy

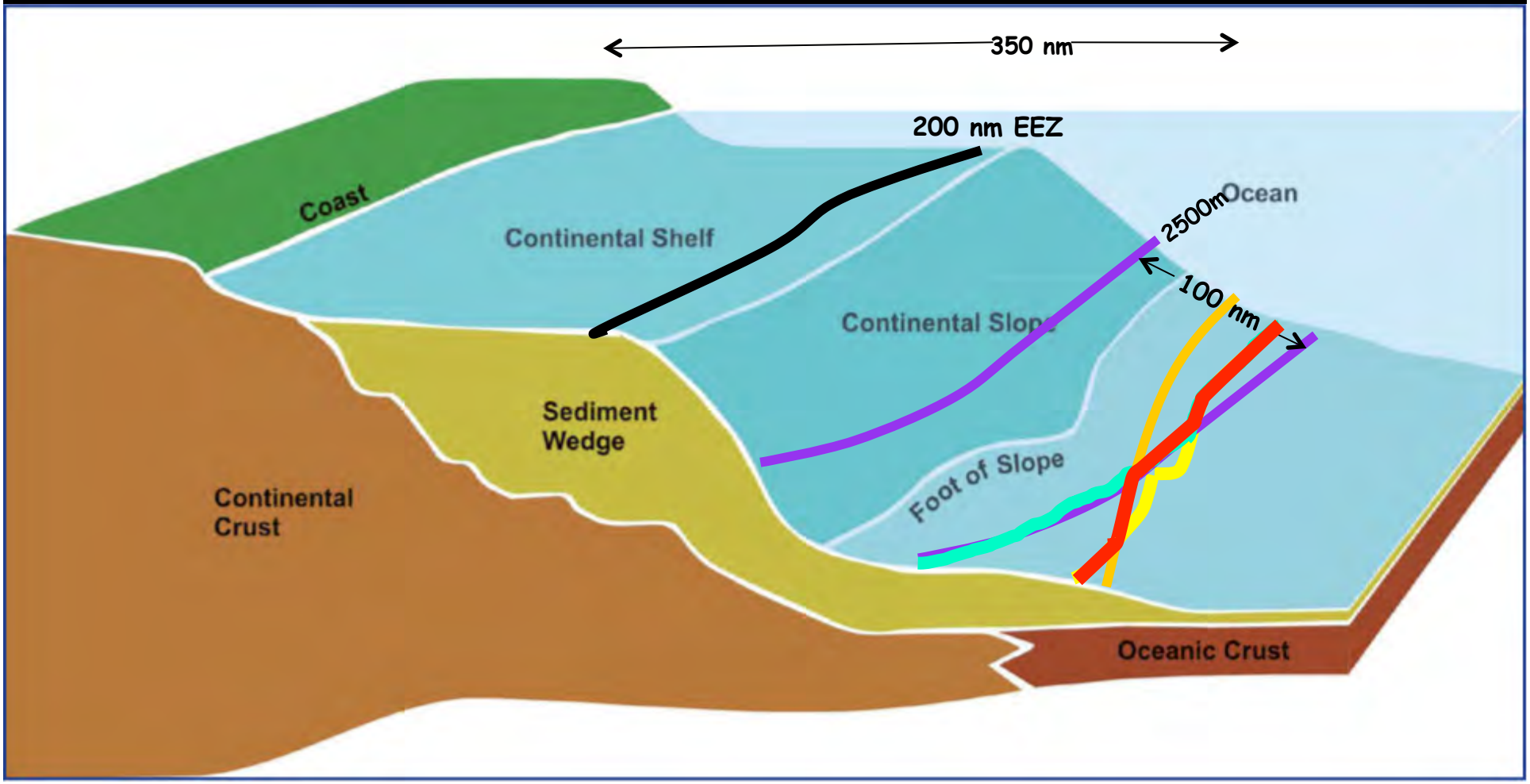


Limit Lines

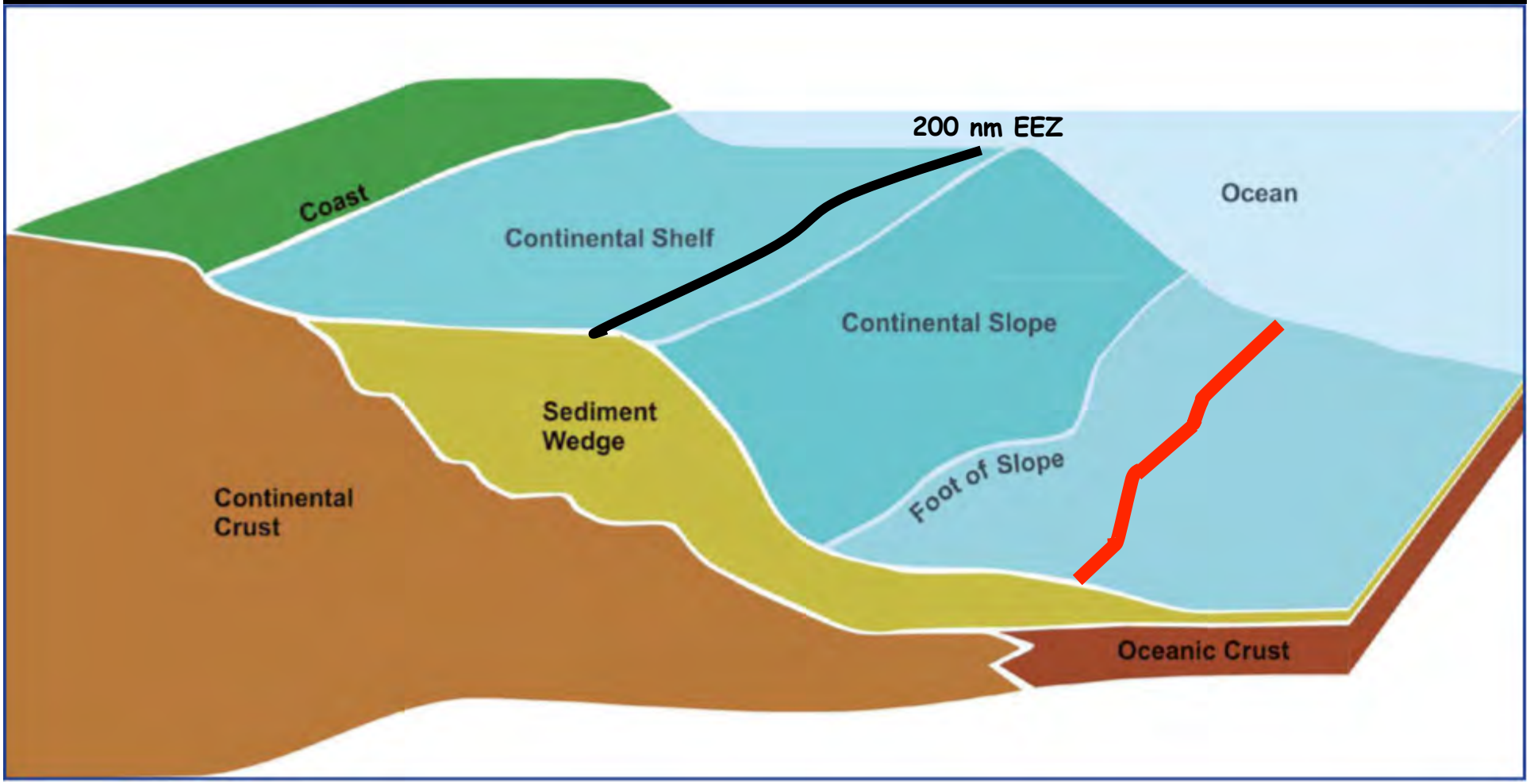
Continental Margin

2500 m contour + 100 nmi - bathy

350 nmi from baseline - distance

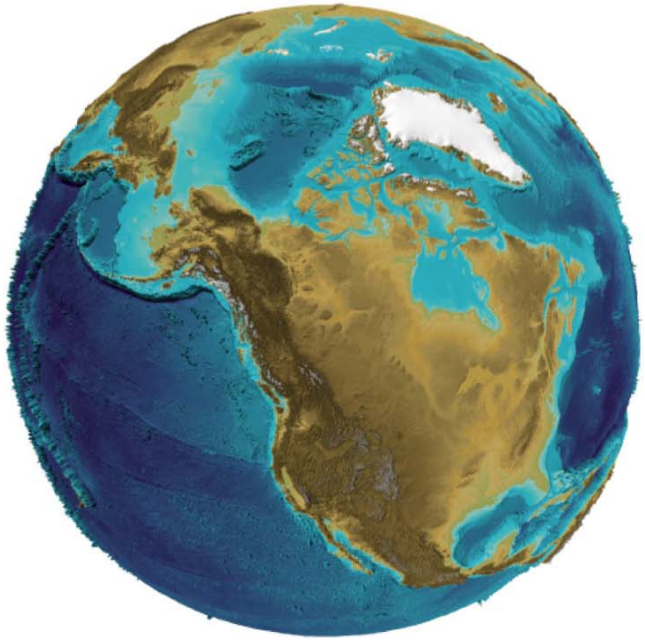


'EXTENDED' CONTINENTAL SHELF



2002
Desktop Study
...the beginning

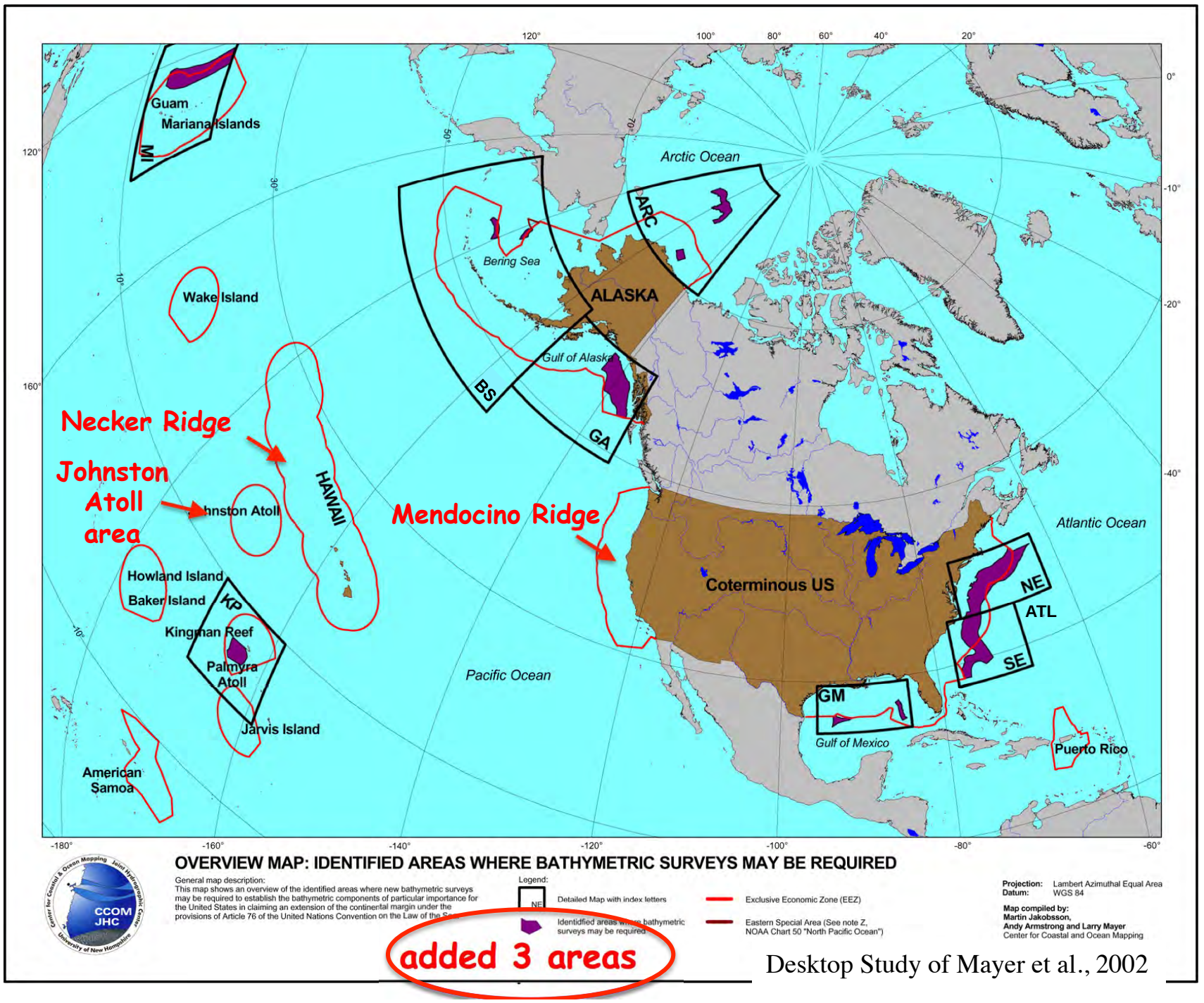
The Compilation and Analysis of Data Relevant to a U.S. Claim Under United Nations Law of the Sea Article 76: A Preliminary Report



Center for Coastal and Ocean Mapping/Joint Hydrographic Center
University of New Hampshire

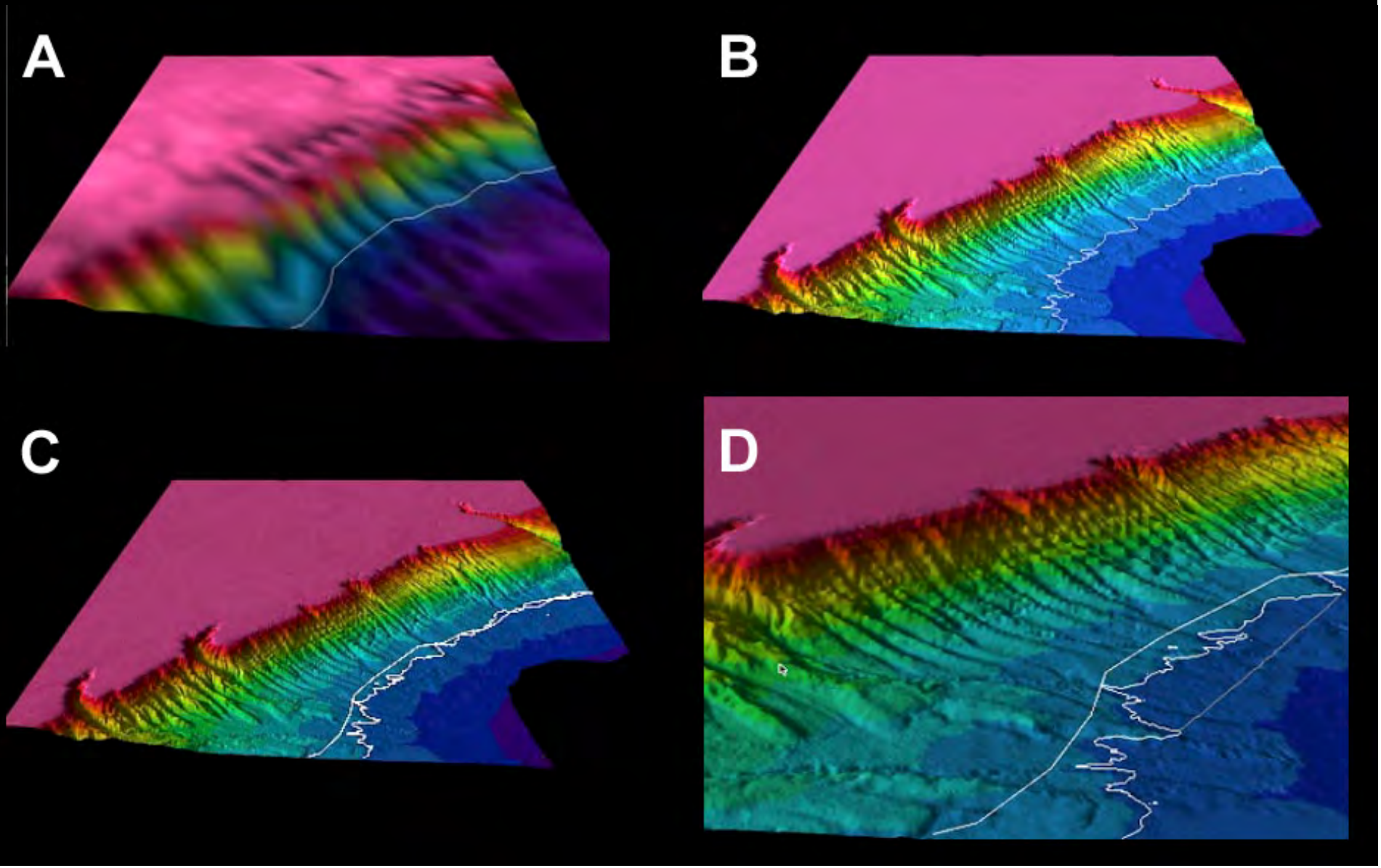
Durham, N.H.
May, 2002

Larry Mayer, Martin Jakobsson and Andrew Armstrong



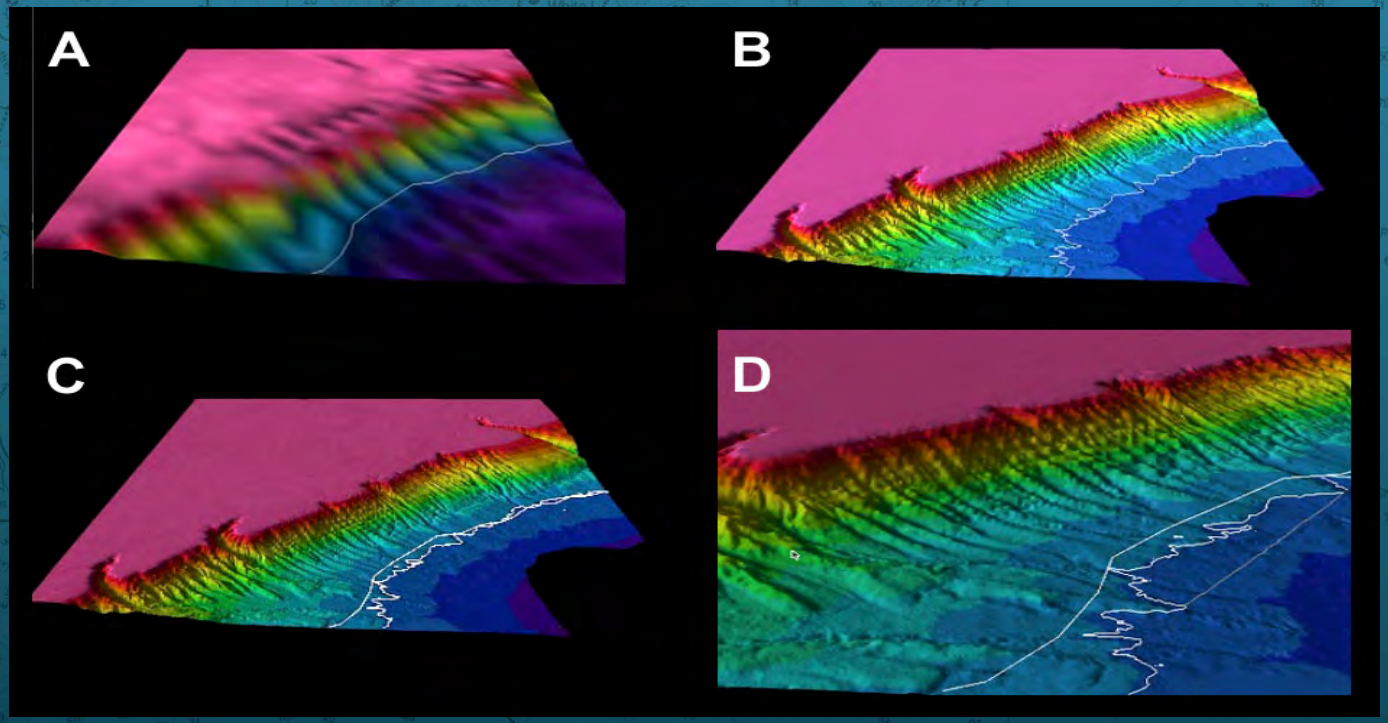
Desktop Study of Mayer et al., 2002

FOS defined by Multibeam



Approach

- FULL MULTIBEAM SONAR COVERAGE OF KEY AREAS
- LIMIT SURVEYS TO THOSE NEEDED TO ESTABLISH KEY LOS PARAMETERS
- INITIAL FOCUS ON MAPPING AT FULL SPEED



Mapping Objectives

- Provide the fundamental bathymetry data for U.S. submission to UNCLOS Commission

- Accurately map the entire 2500-m isobath (*requirement for a limit line*)

- Map entire lower slope and rise to determine UNCLOS Article 76 "foot of the slope" zone (*requirement for both formula lines*

ESTABLISH THE FUNDAMENTAL GEOSPATIAL CONTEXT FOR MILLIONS KMS OF UNEXPLORED SEAFLOOR UNDER POTENTIAL U.S. JURISDICTION - THE FIRST STEP IN EXPLORATION AND DISCOVERY

- Rapid and open dissemination of data for other uses

USCGC *Healy* (2003, 2004, 2007, 2008, 2009, 2011, 2012)

USNS *Bowditch* (2006 & 2007)

NOAA Ship *Ron Brown* (2012)

RV *Davidson* (2003)

RV *Northern Resolution 2007*

RV *Atlantis* (2014)

USNS *Henson* (2004)

NOAA Ship *Okeanos Explorer* (2009)

USNS *Pathfinder* (2005)

RV *Langseth* (2015)

RV *Kilo Moana* (2005, 2011 2014, 2015)

USNS *Sumner* (2010)

24 cruises on 12 different ships in 13 years

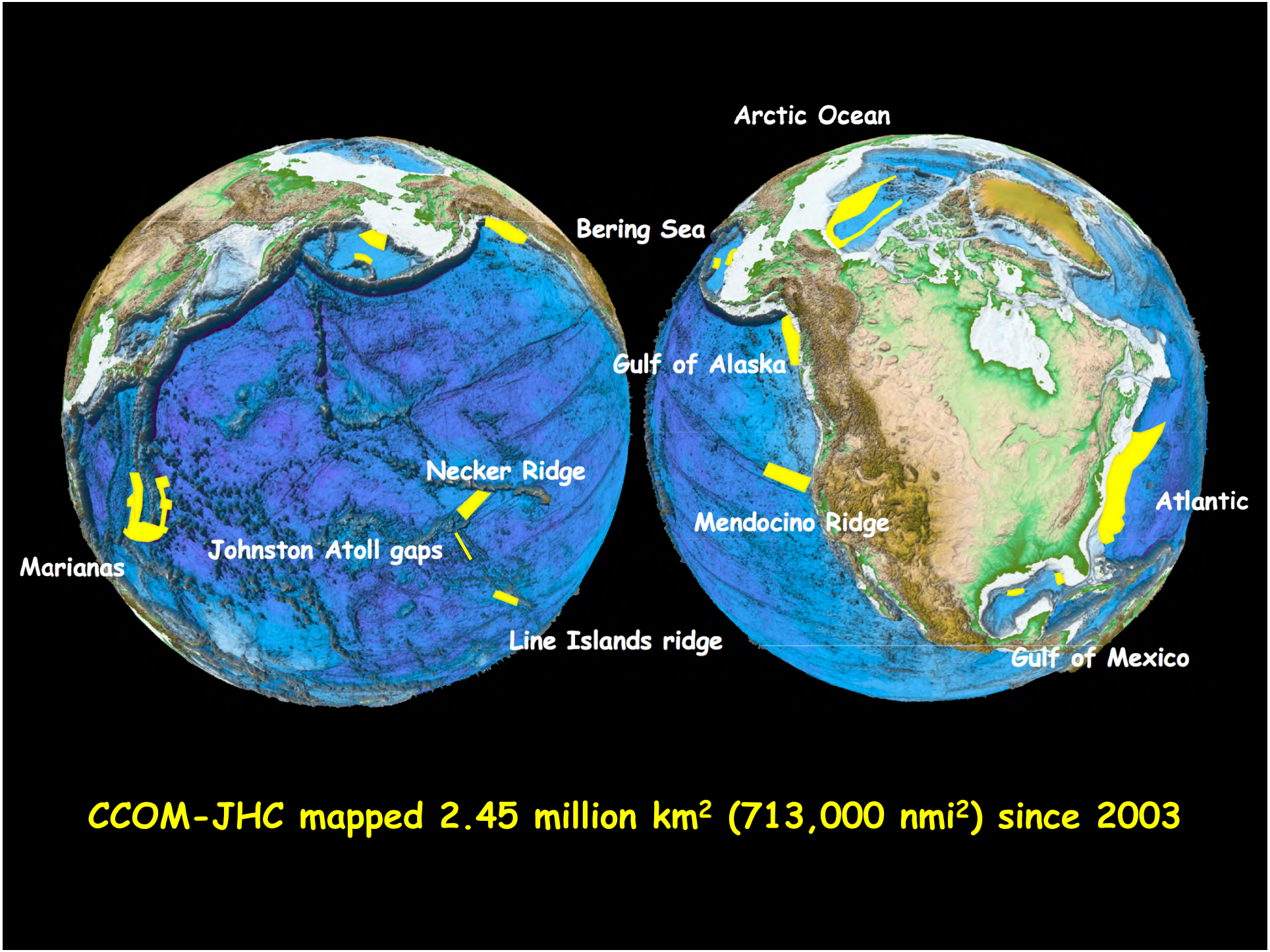
U.S. Extended Continental Shelf Project

The ECS Task Force was established in April 2007 by the Interagency Committee on Ocean Science and Resource Management Integration.

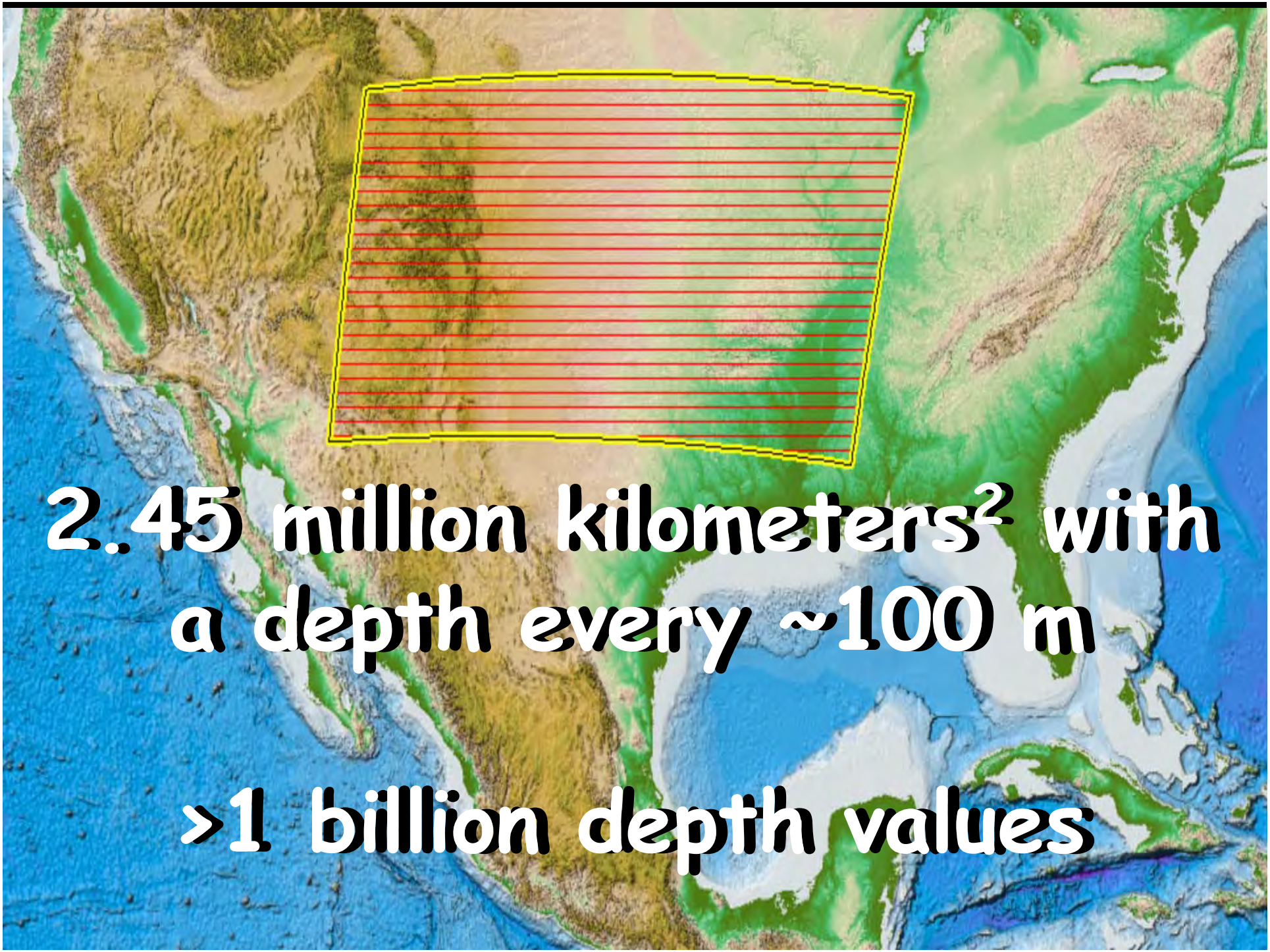
The Task Force is chaired by Department of State, with co-vice chairs from Department of the Interior and National Oceanic and Atmospheric Administration.

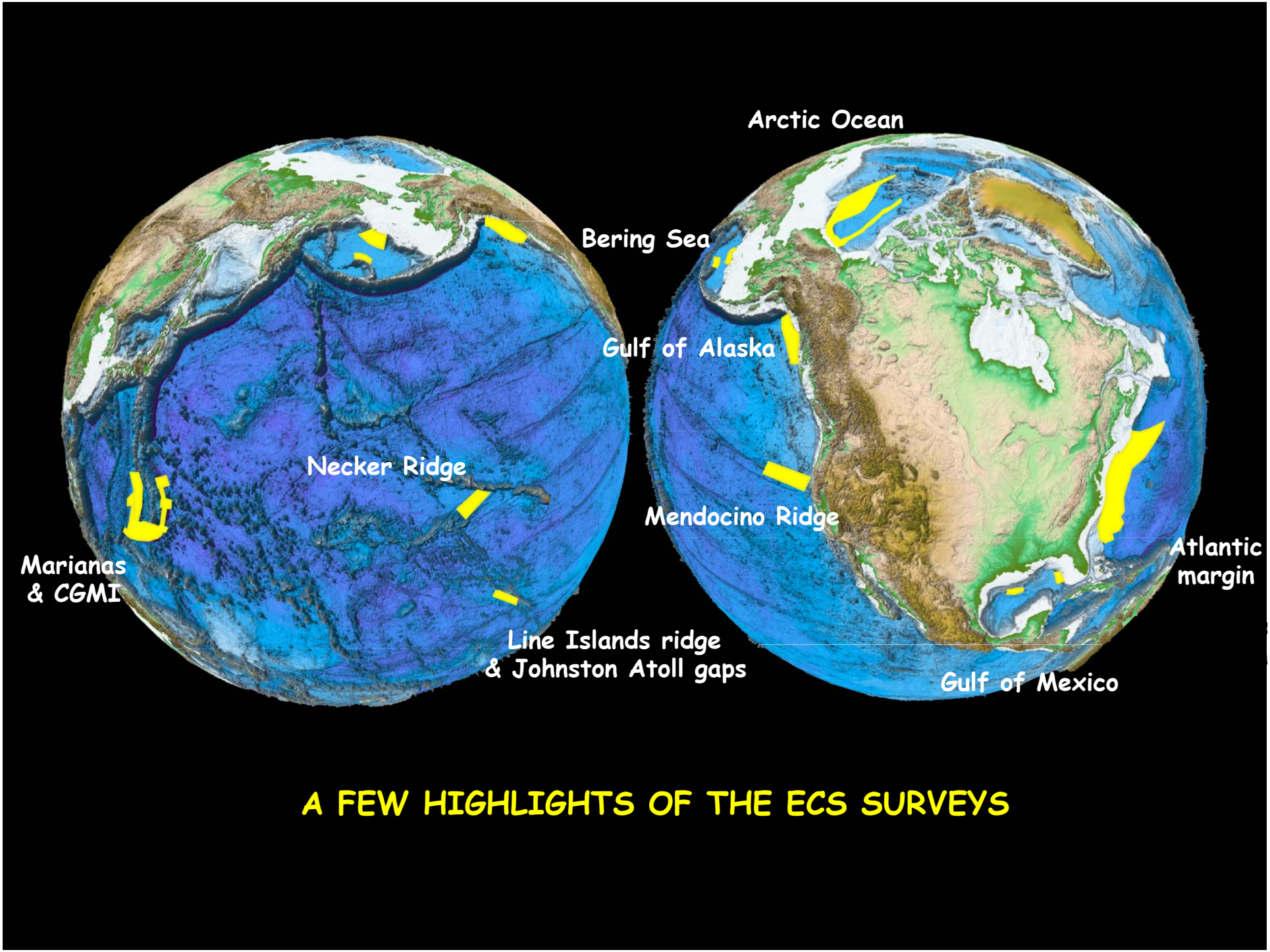
The Task Force now reports to the National Ocean Council (NOC) Steering Committee.

In 2008, funds were appropriated for NOAA to acquire the necessary data to define the US ECS and develop the data analysis and archive system



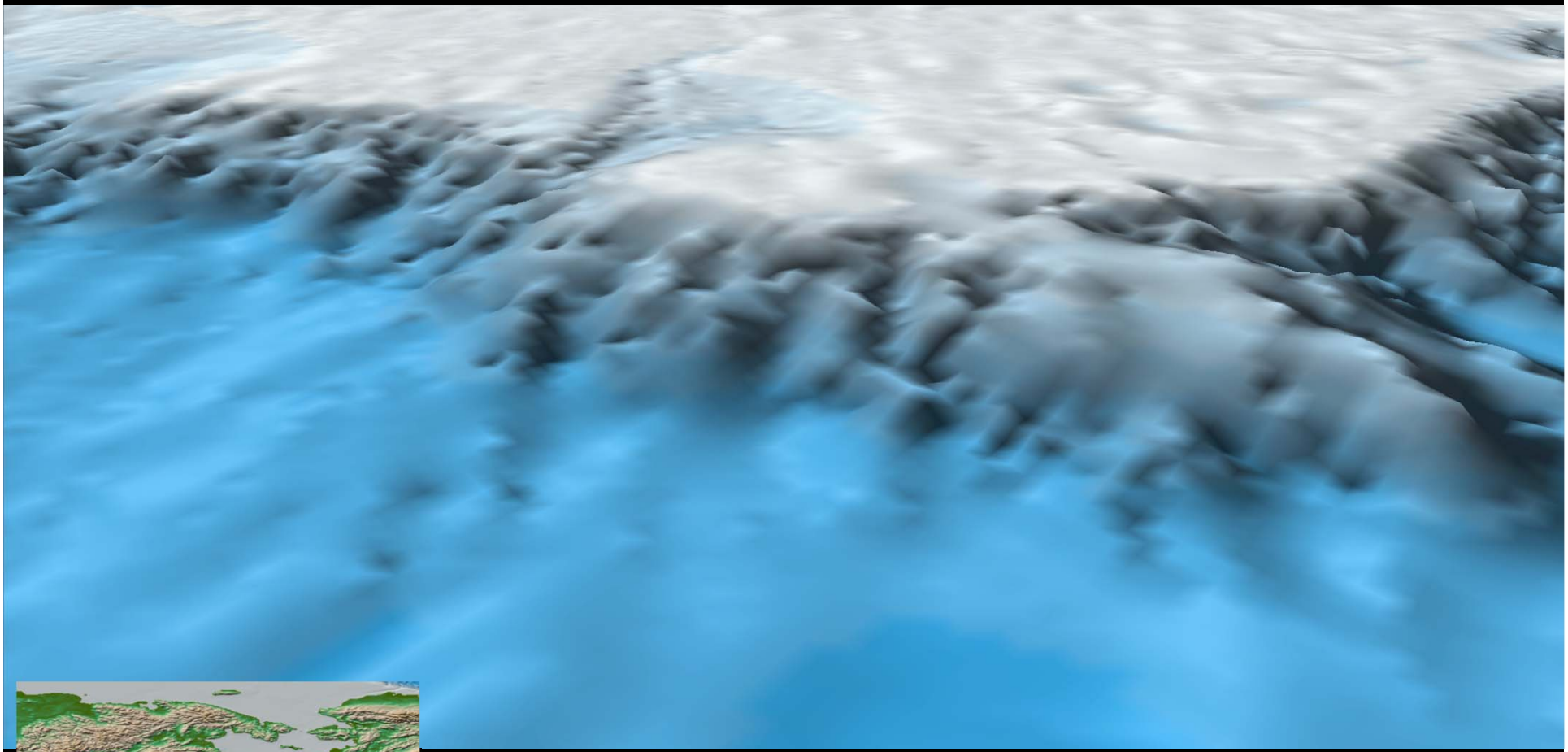
CCOM-JHC mapped 2.45 million km² (713,000 nmi²) since 2003

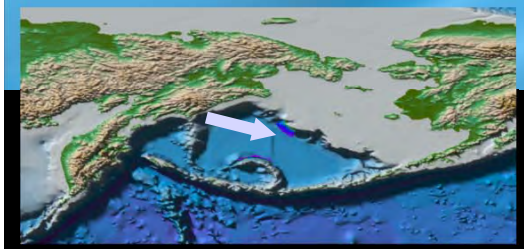

2.45 million kilometers^2 with
a depth every ~100 m
>1 billion depth values



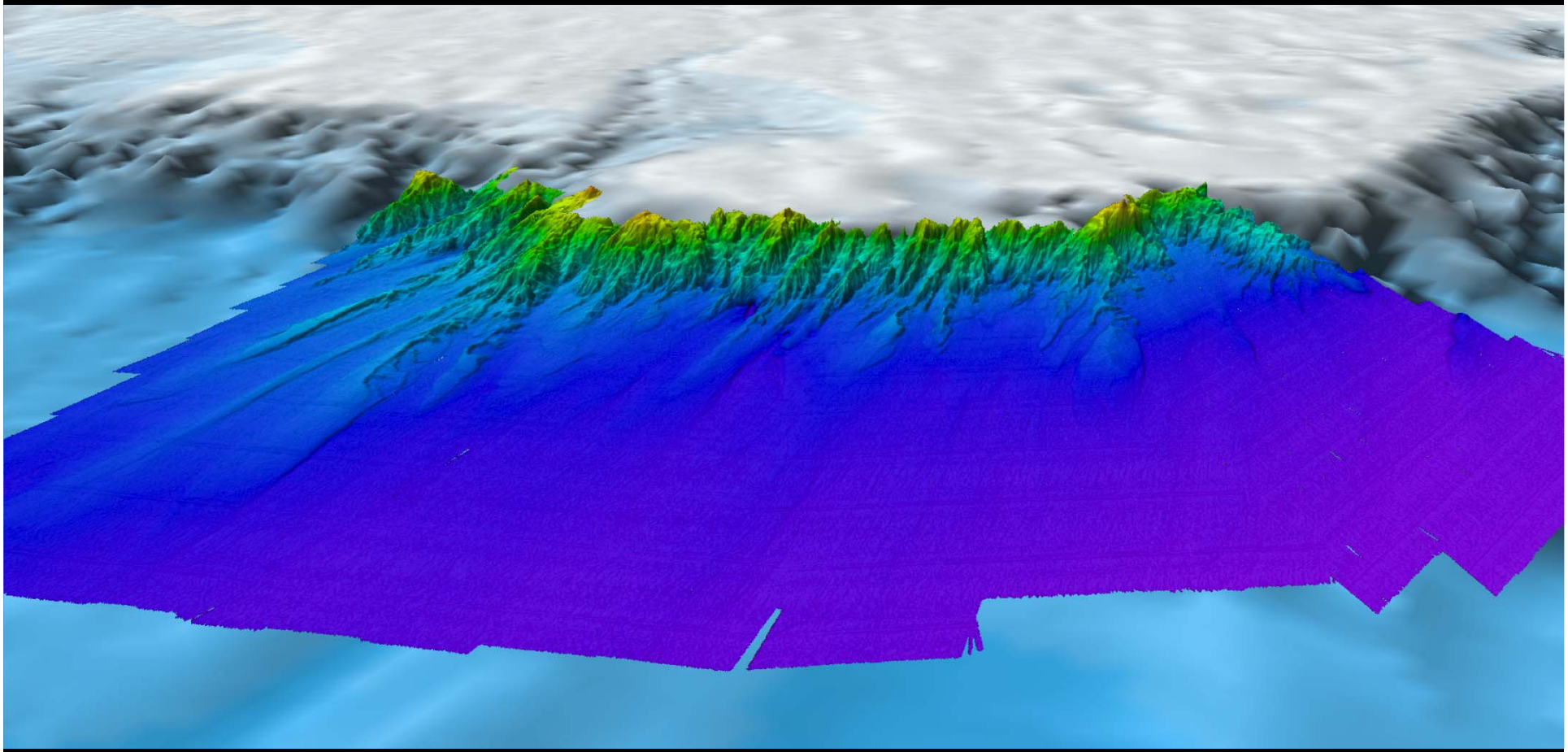
A FEW HIGHLIGHTS OF THE ECS SURVEYS

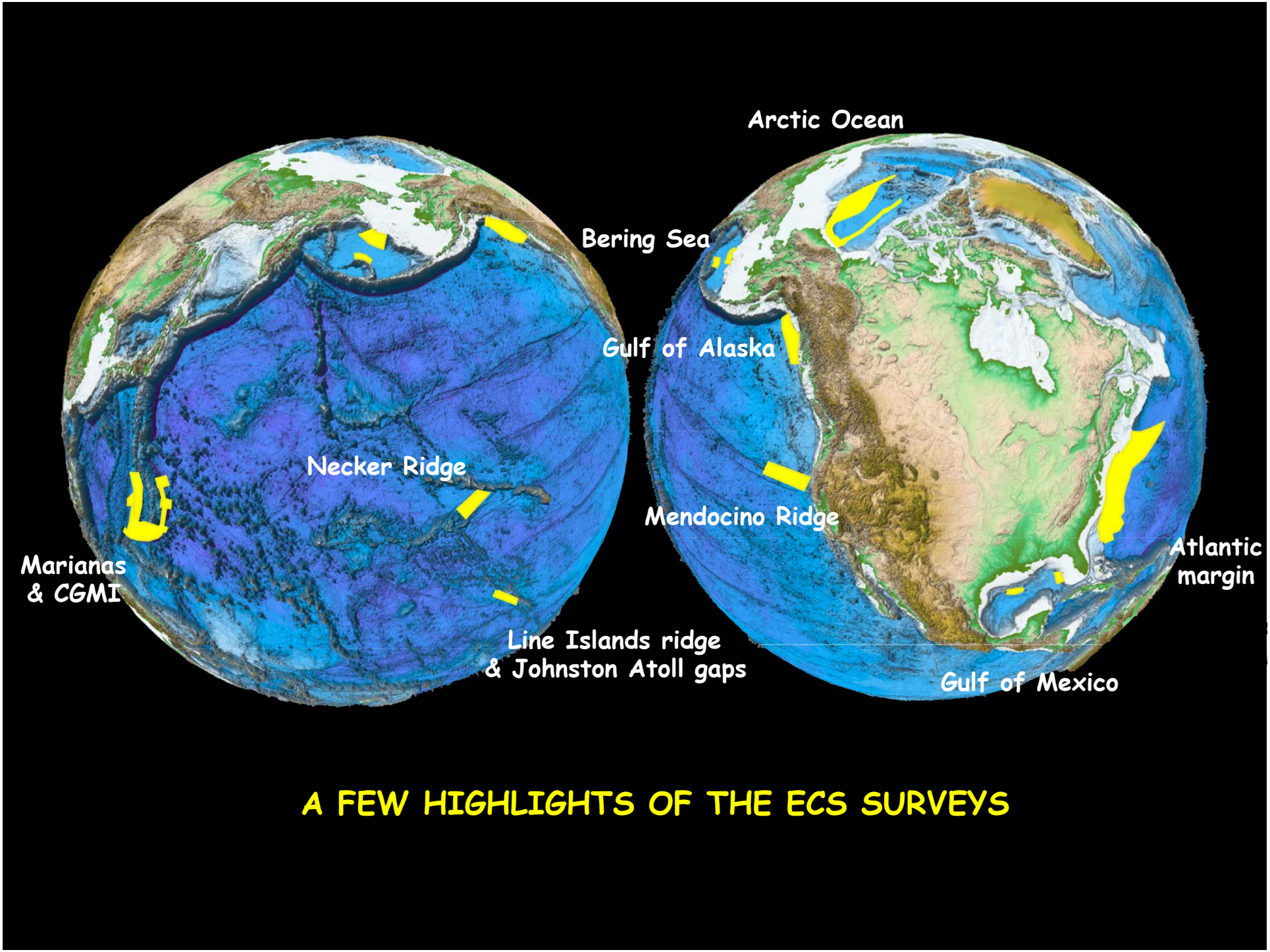
Beringian Margin





Beringian Margin

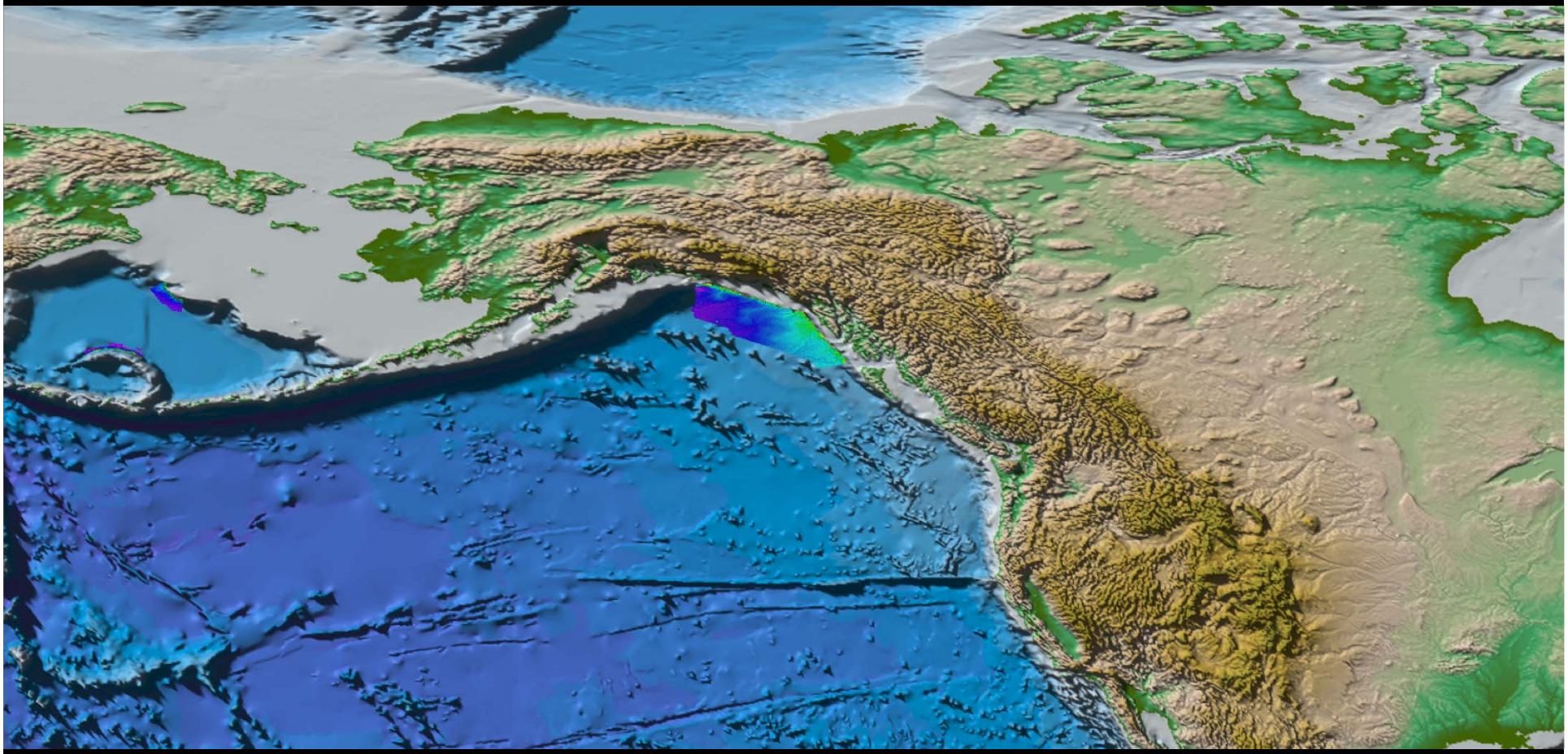




A FEW HIGHLIGHTS OF THE ECS SURVEYS

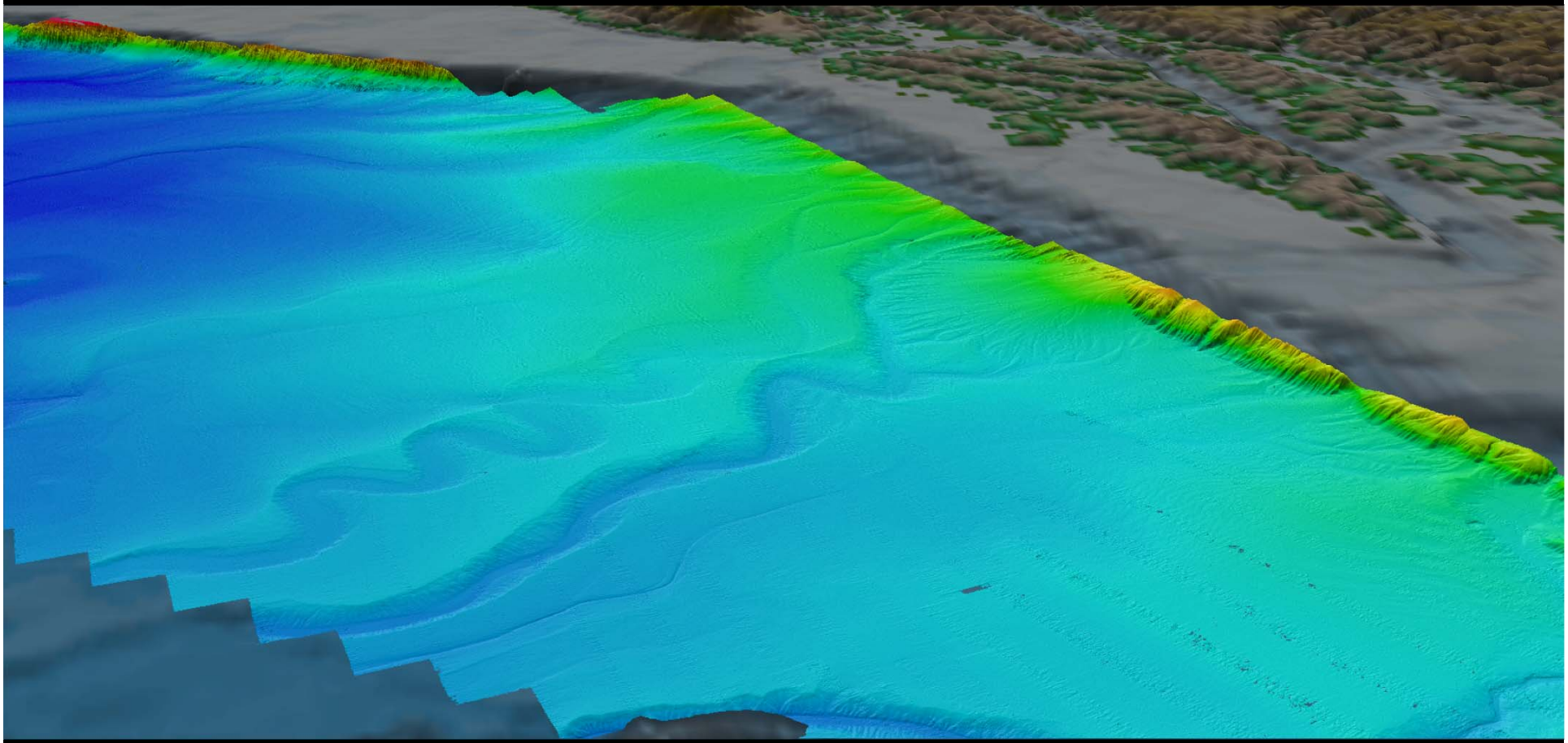
Gulf of Alaska

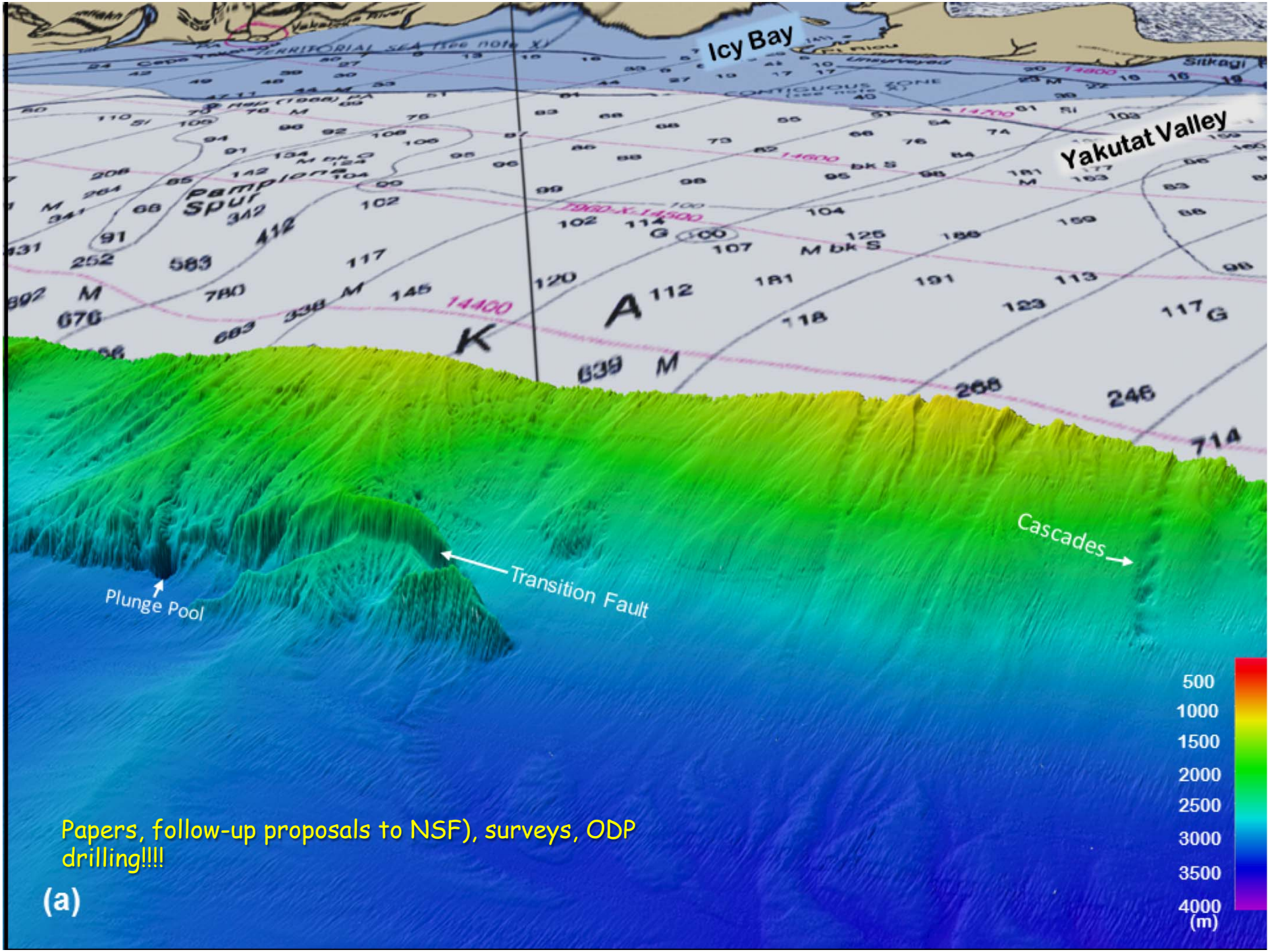
165,000 km^2 - *R/V Kilo Moana* 2005

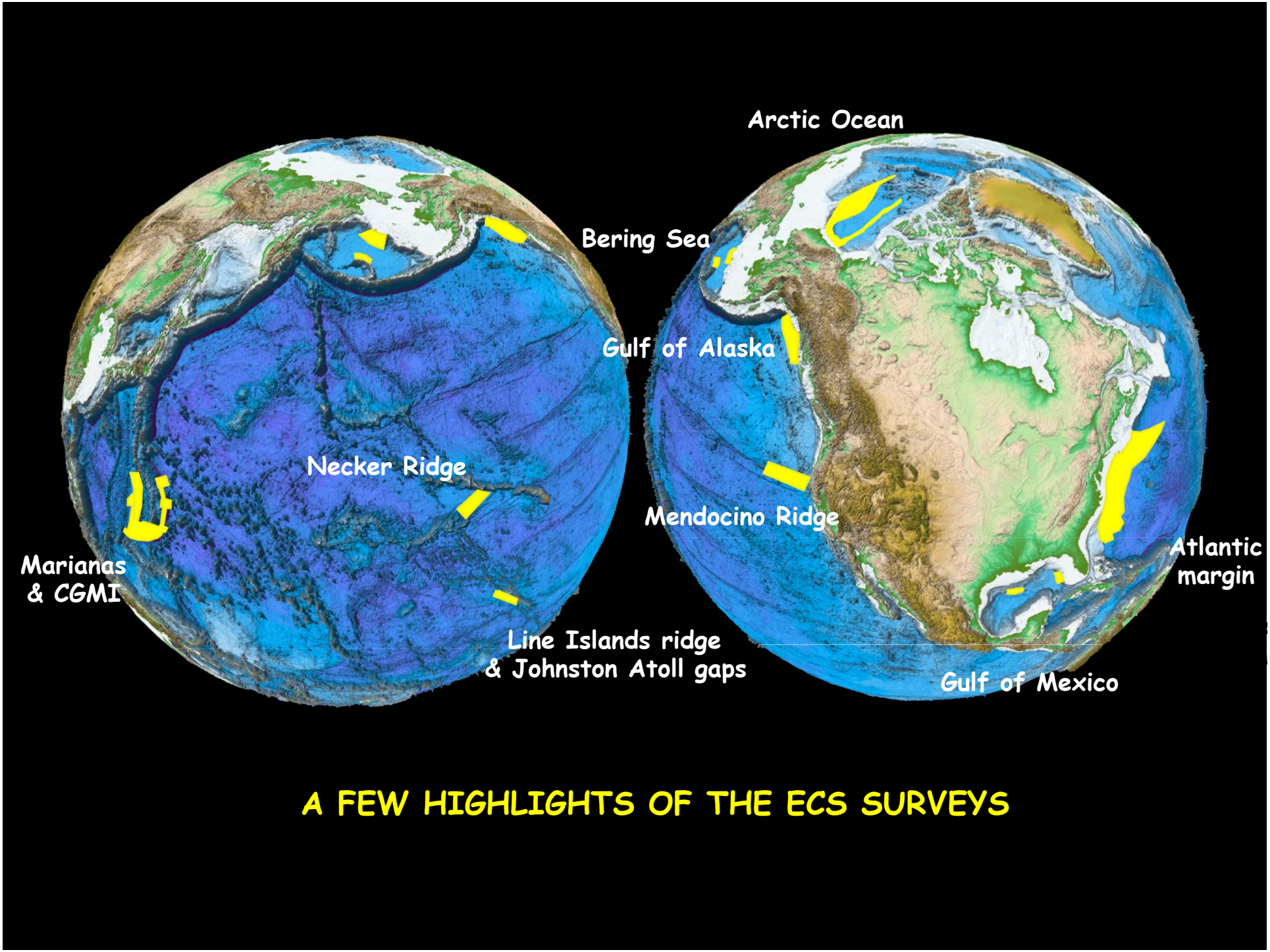


Gulf of Alaska

Gulf of Alaska




Icy Bay
Yakutat Valley
Pamplona Spur
Plunge Pool
Transition Fault
Cascades
500
1000
1500
2000
2500
3000
3500
4000
(m)
Papers, follow-up proposals to NSF), surveys, ODP drilling!!!!
(a)



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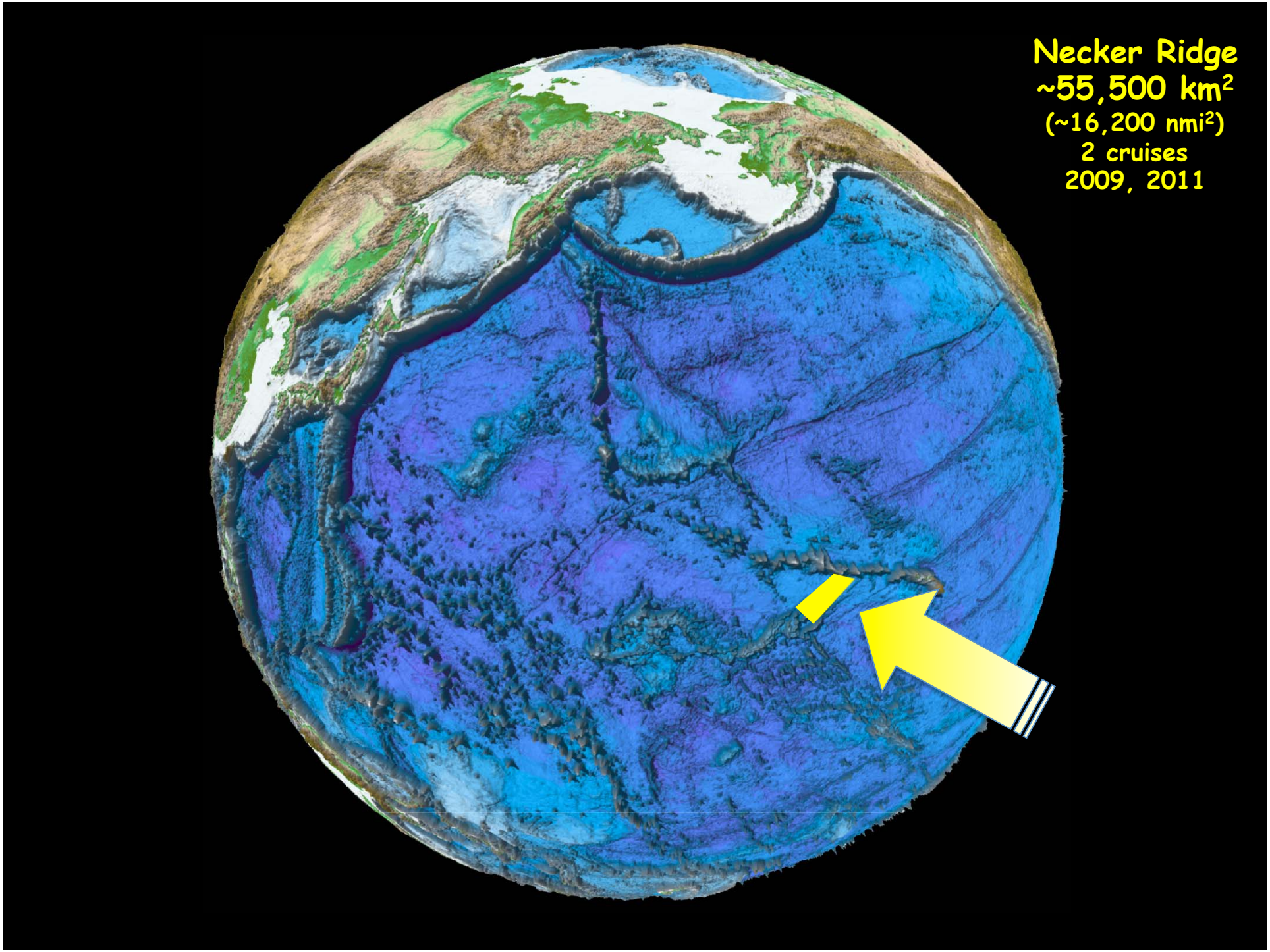
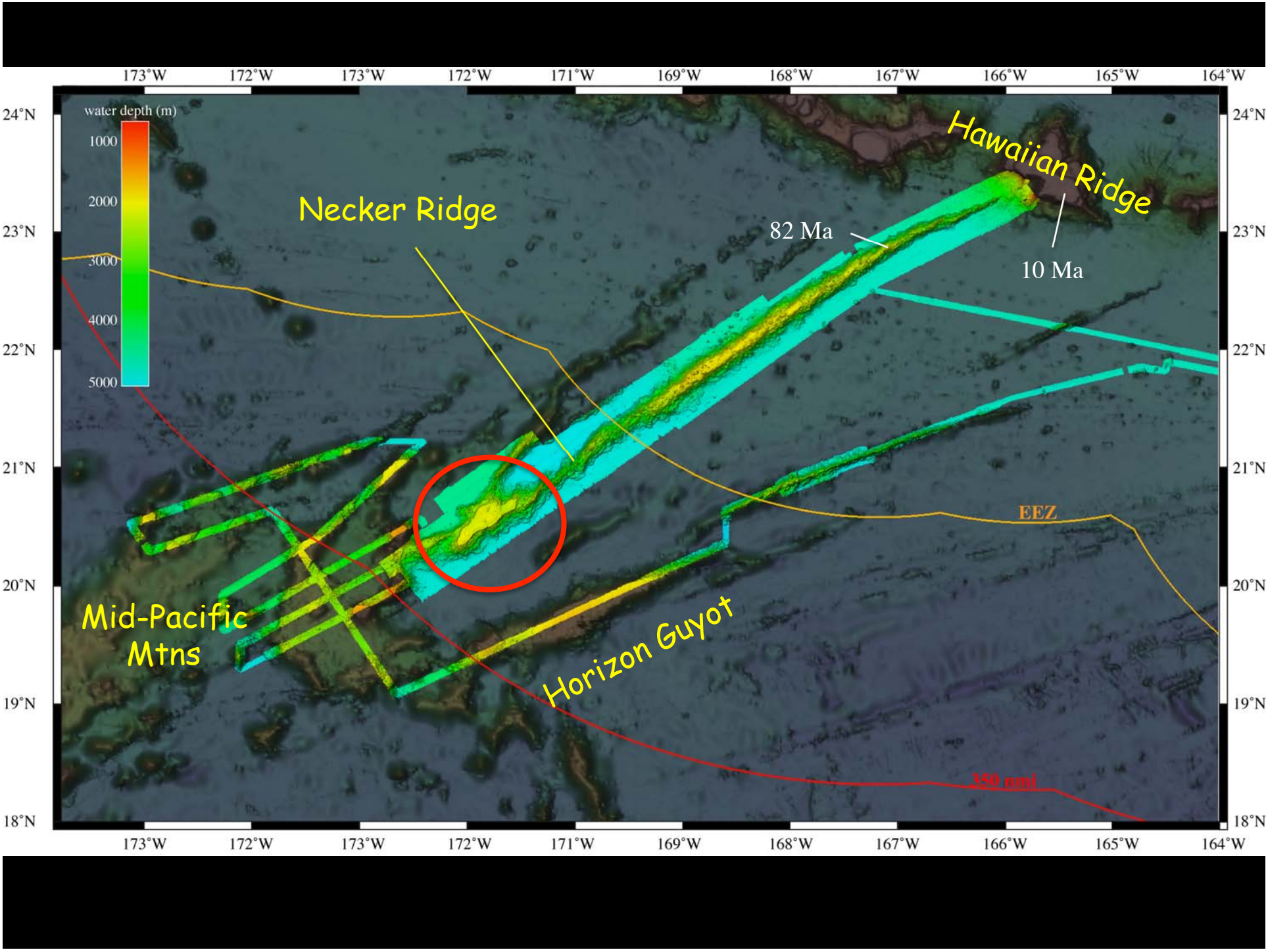
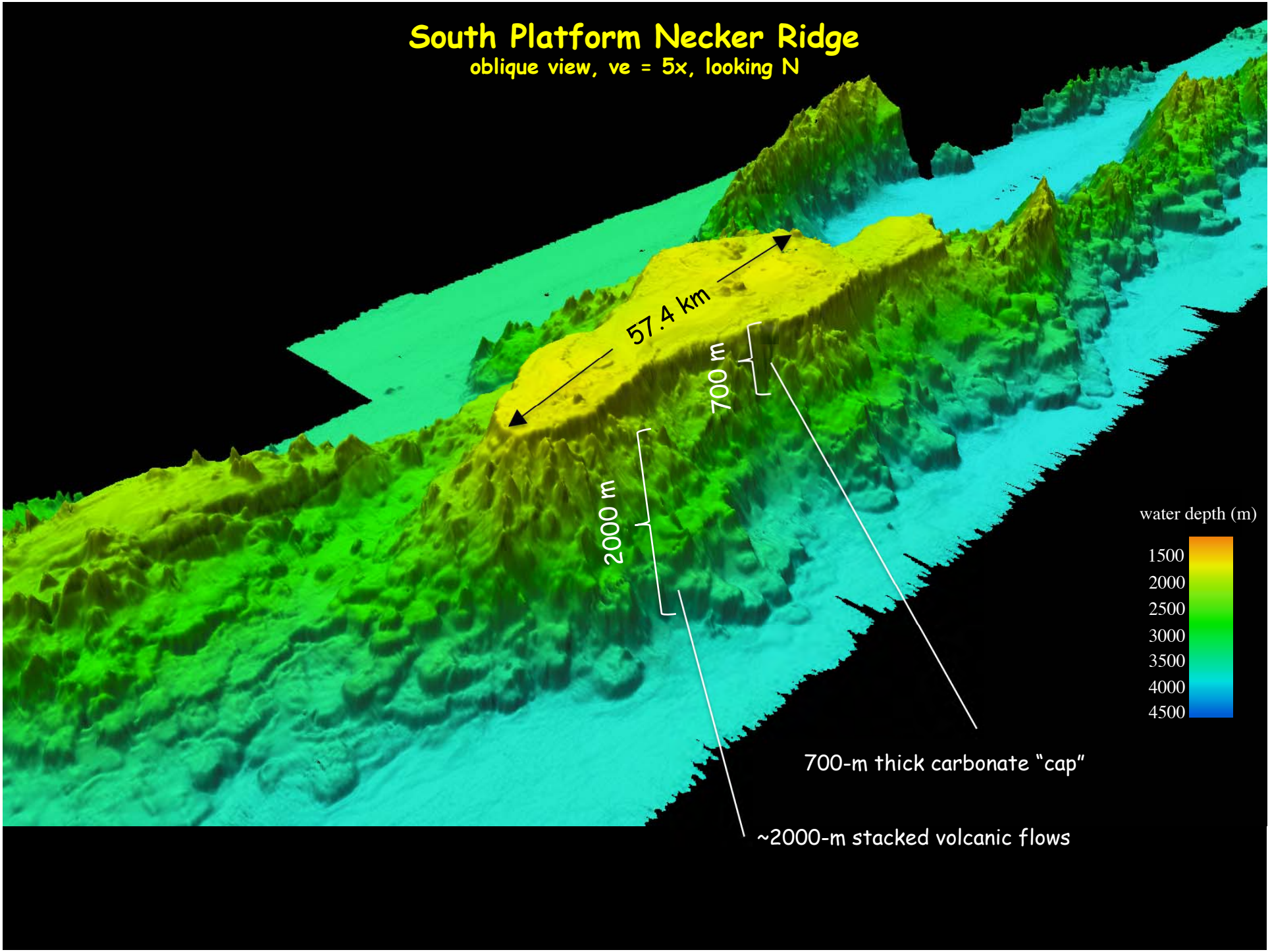
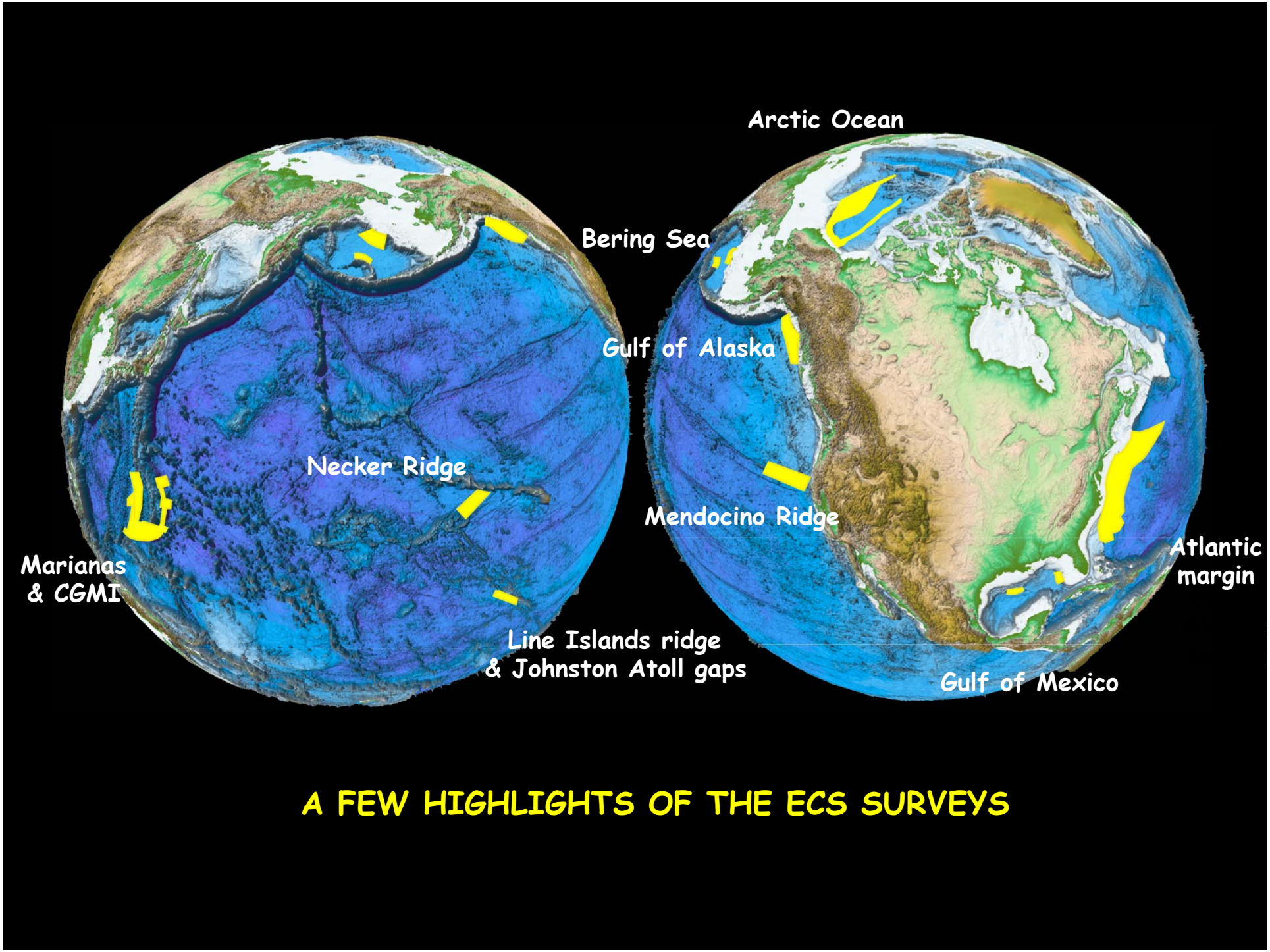
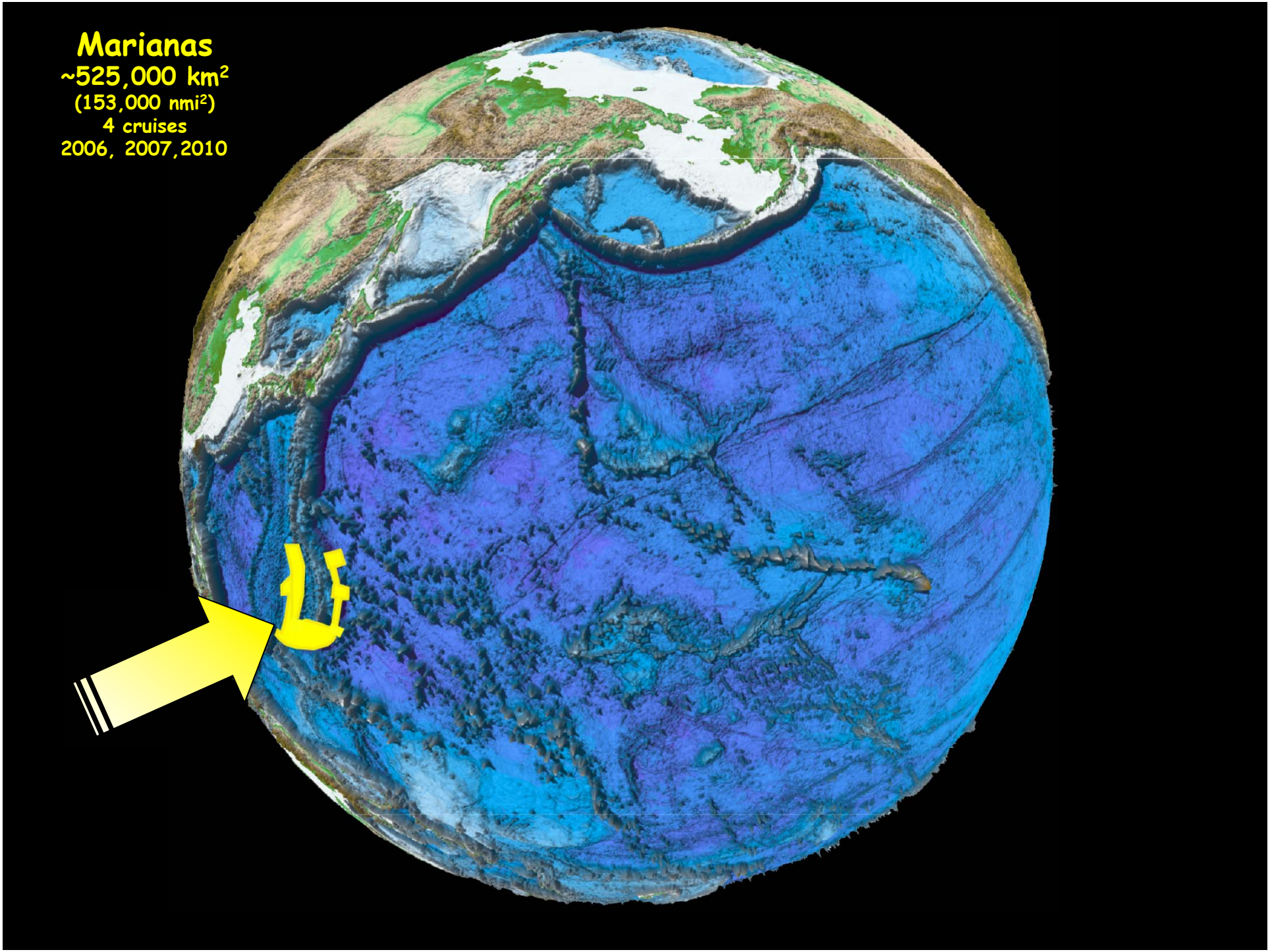

Necker Ridge
~55,500 km²
(~16,200 nmi²)
2 cruises
2009, 2011


water depth (m)
1000
2000
3000
4000
5000
Necker Ridge
Hawaiian Ridge
82 Ma
10 Ma
EEZ
Mid-Pacific
Mtns
Horizon Guyot
350 nmi
173°W
172°W
171°W
169°W
168°W
167°W
166°W
165°W
164°W
24°N
23°N
22°N
21°N
20°N
19°N
18°N

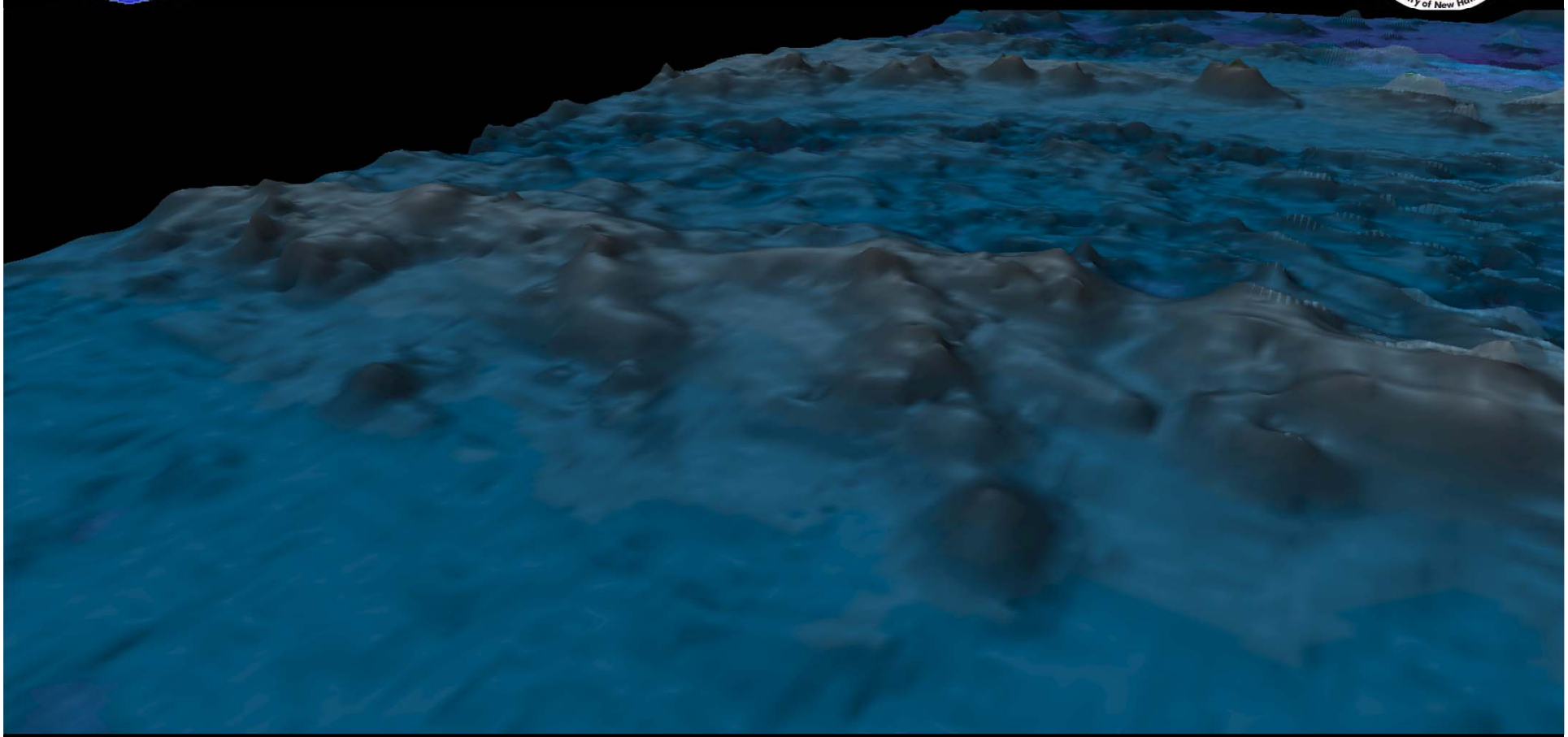

South Platform Necker Ridge
oblique view, ve = 5x, looking N
57.4 km
700 m
2000 m
water depth (m)
1500
2000
2500
3000
3500
4000
4500
700-m thick carbonate "cap"
~2000-m stacked volcanic flows



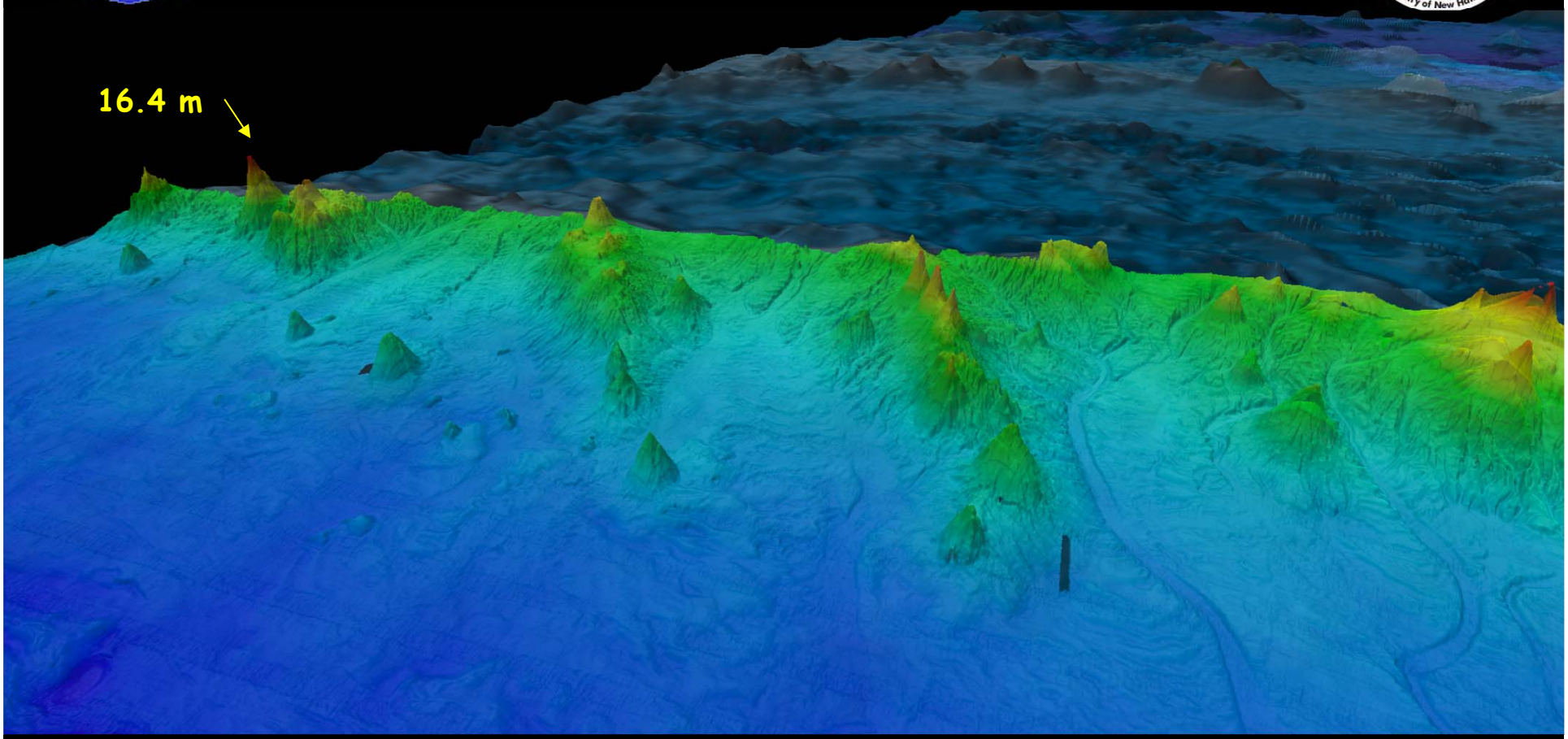
A FEW HIGHLIGHTS OF THE ECS SURVEYS


Marianas
~525,000 km²
(153,000 nmi²)
4 cruises
2006, 2007,2010

Marianas



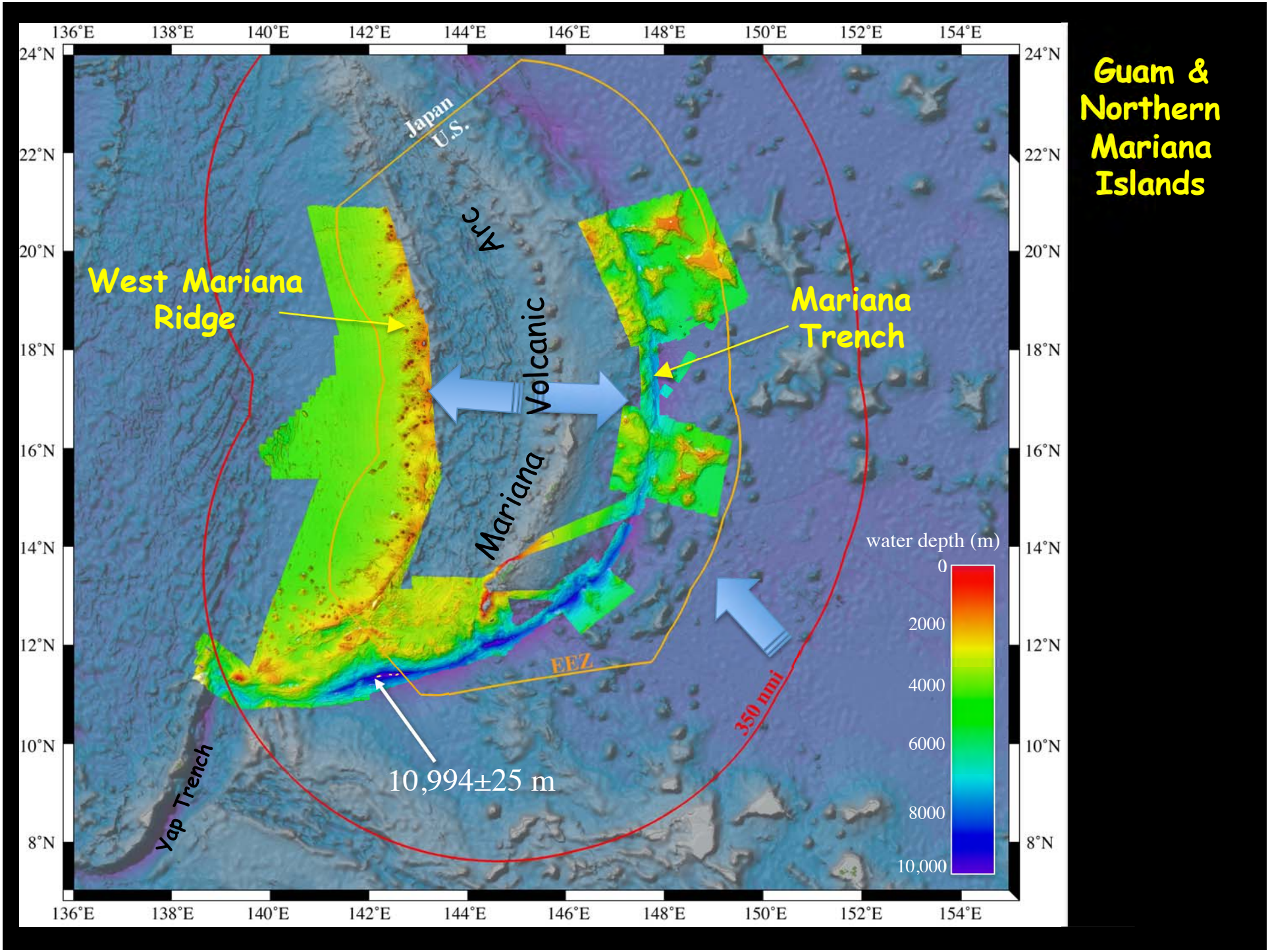
Marianas



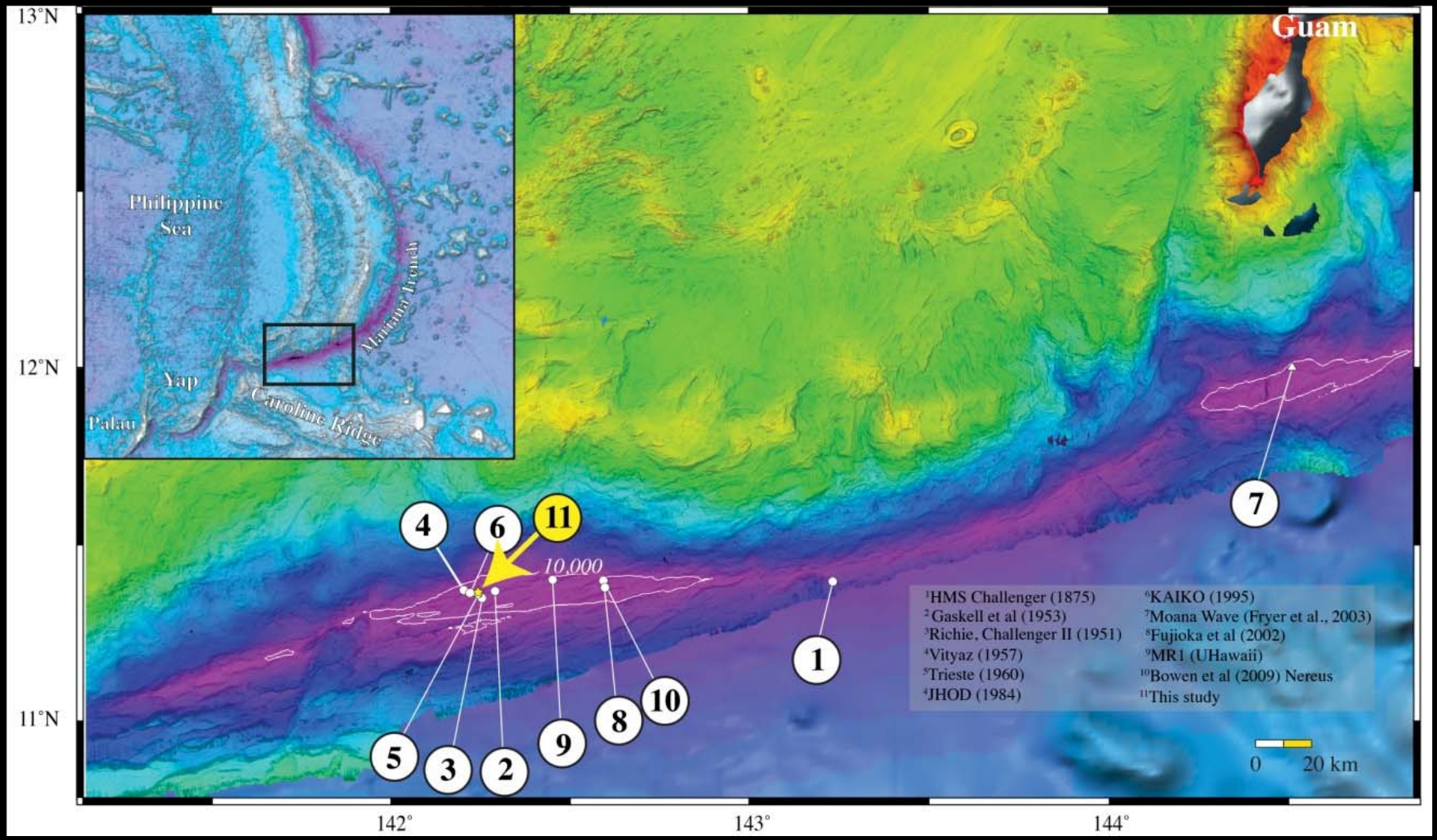
10 seamounts < 500 m

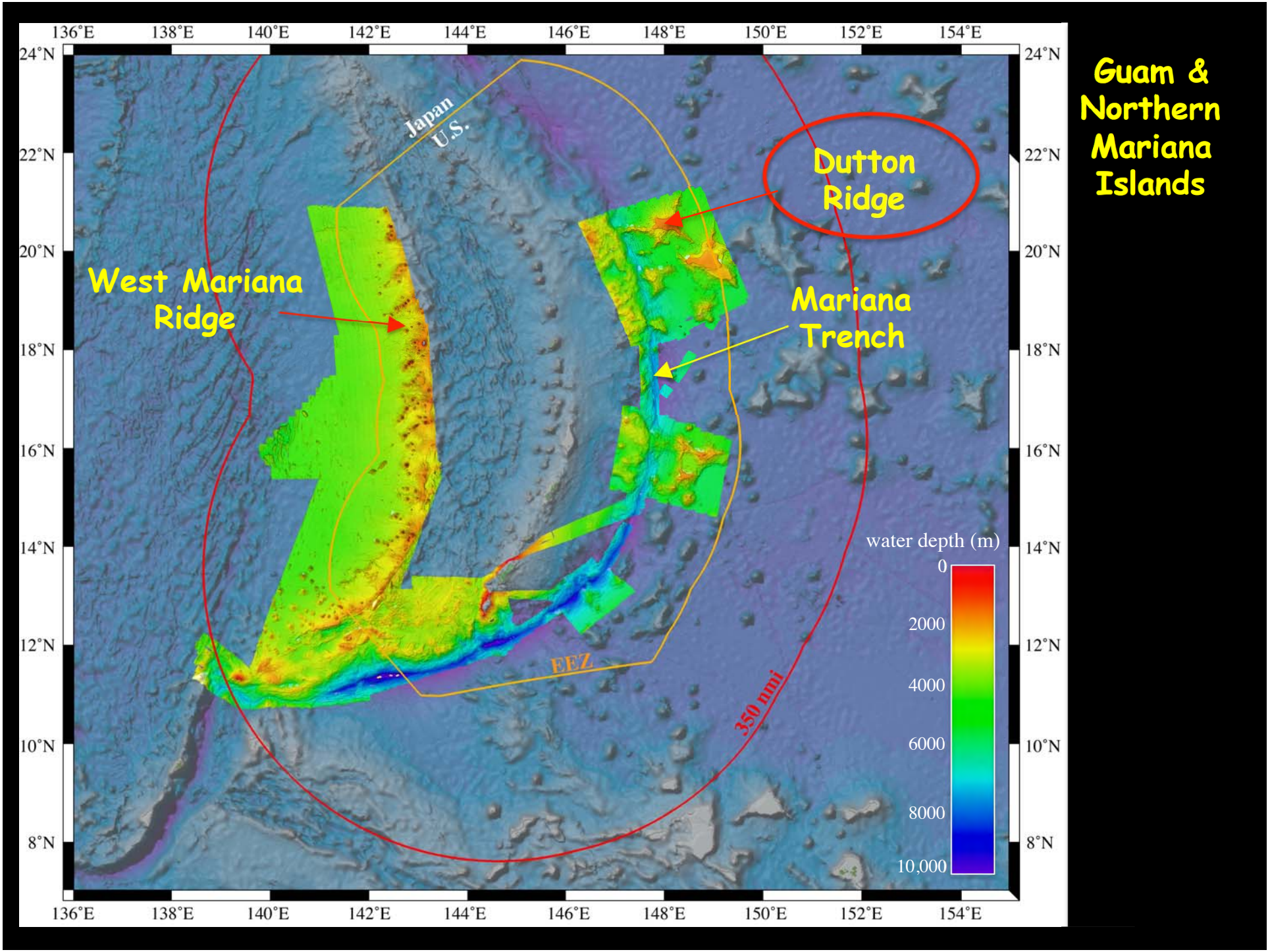
USS San Francisco (SSN 711) - in drydock after hitting uncharted seamount

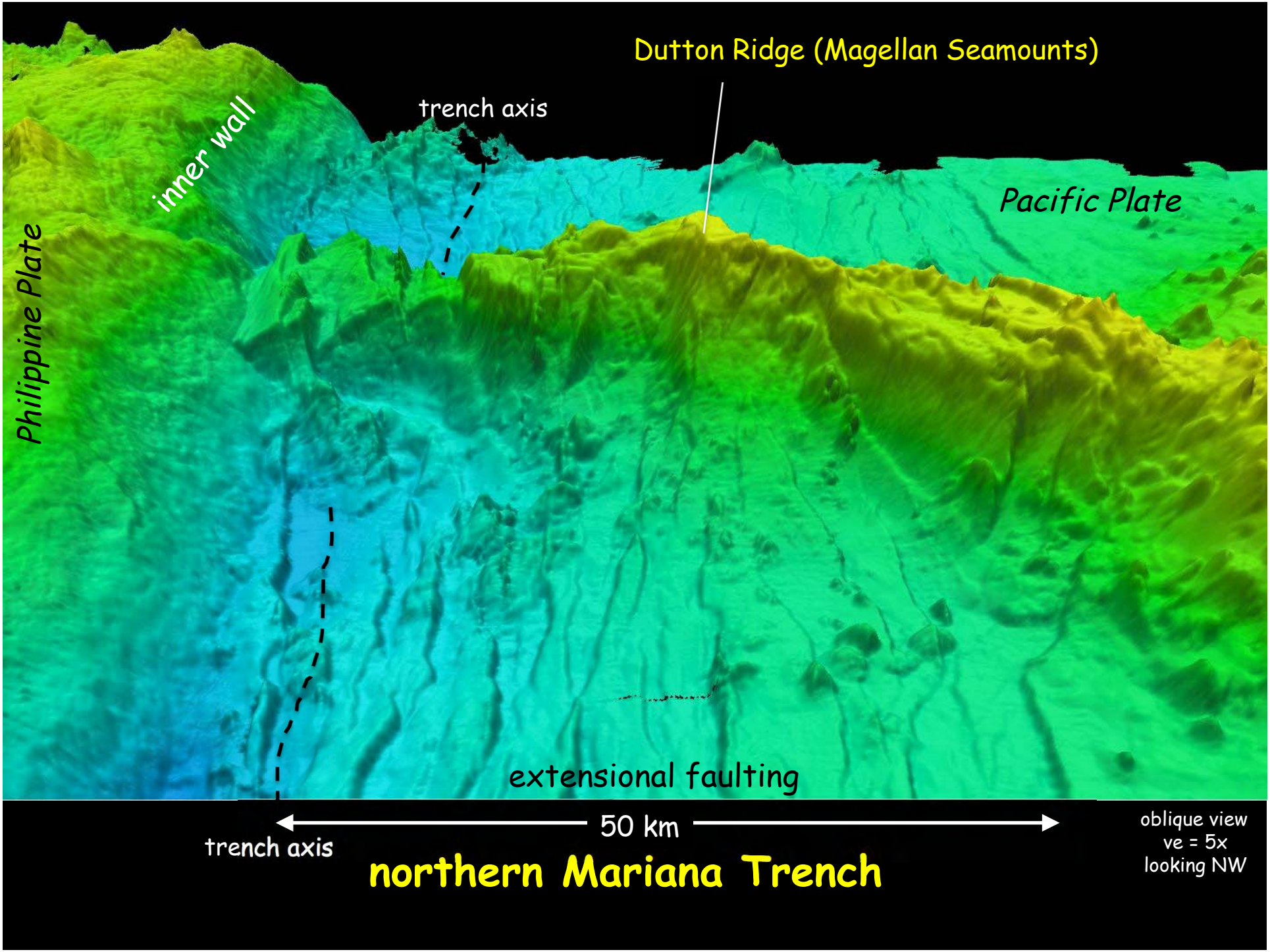
http://www.freerepublic.com/focus/f-news/1330034/posts?page=515

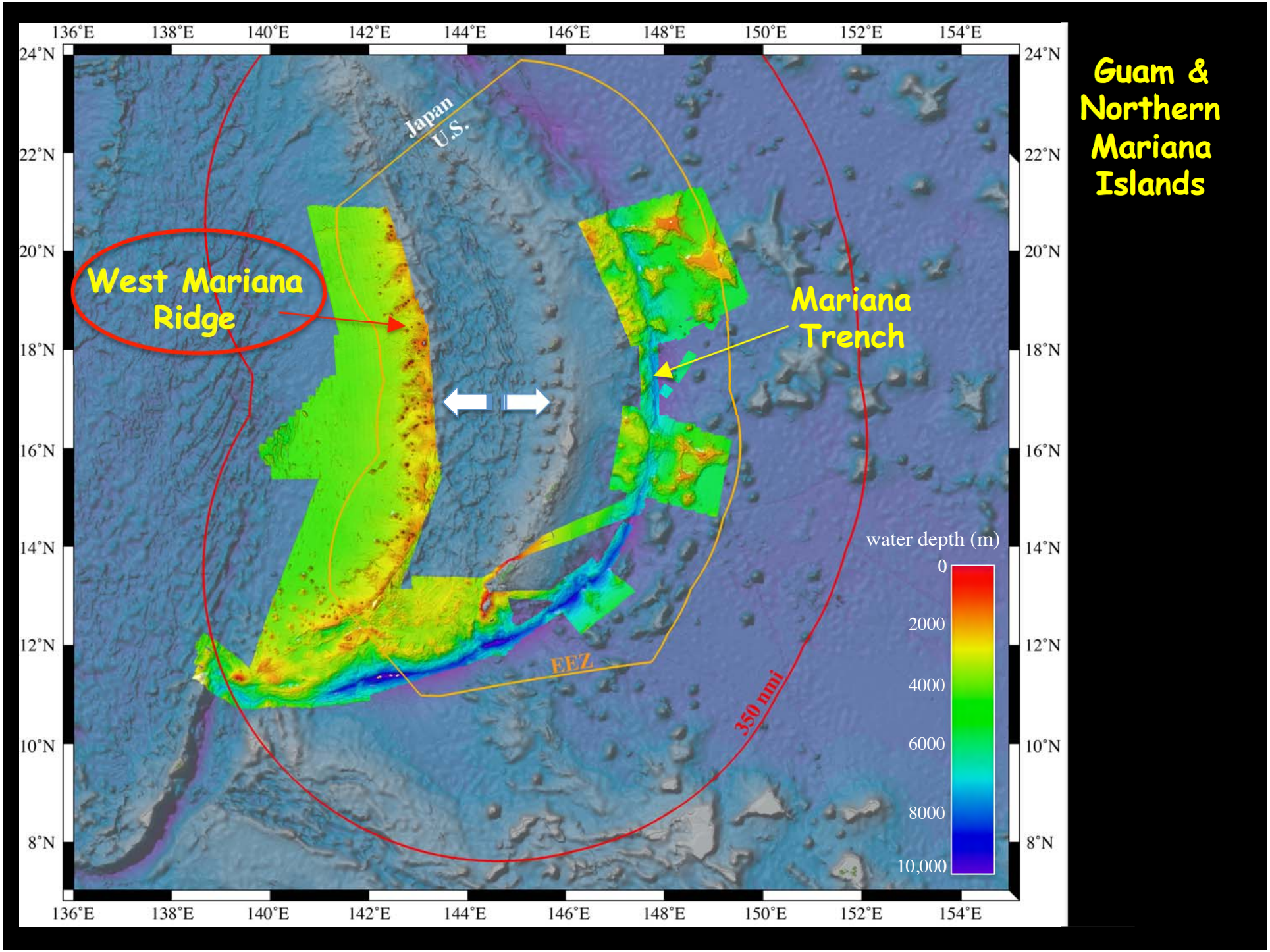

Guam & Northern Mariana Islands
West Mariana Ridge
Mariana Trench
Japan
U.S.
Arc
Volcanic
Mariana
EEZ
350 nmi
Yap Trench
10,994±25 m
water depth (m)
0
2000
4000
6000
8000
10,000
136°E
138°E
140°E
142°E
144°E
146°E
148°E
150°E
152°E
154°E
24°N
22°N
20°N
18°N
16°N
14°N
12°N
10°N
8°N

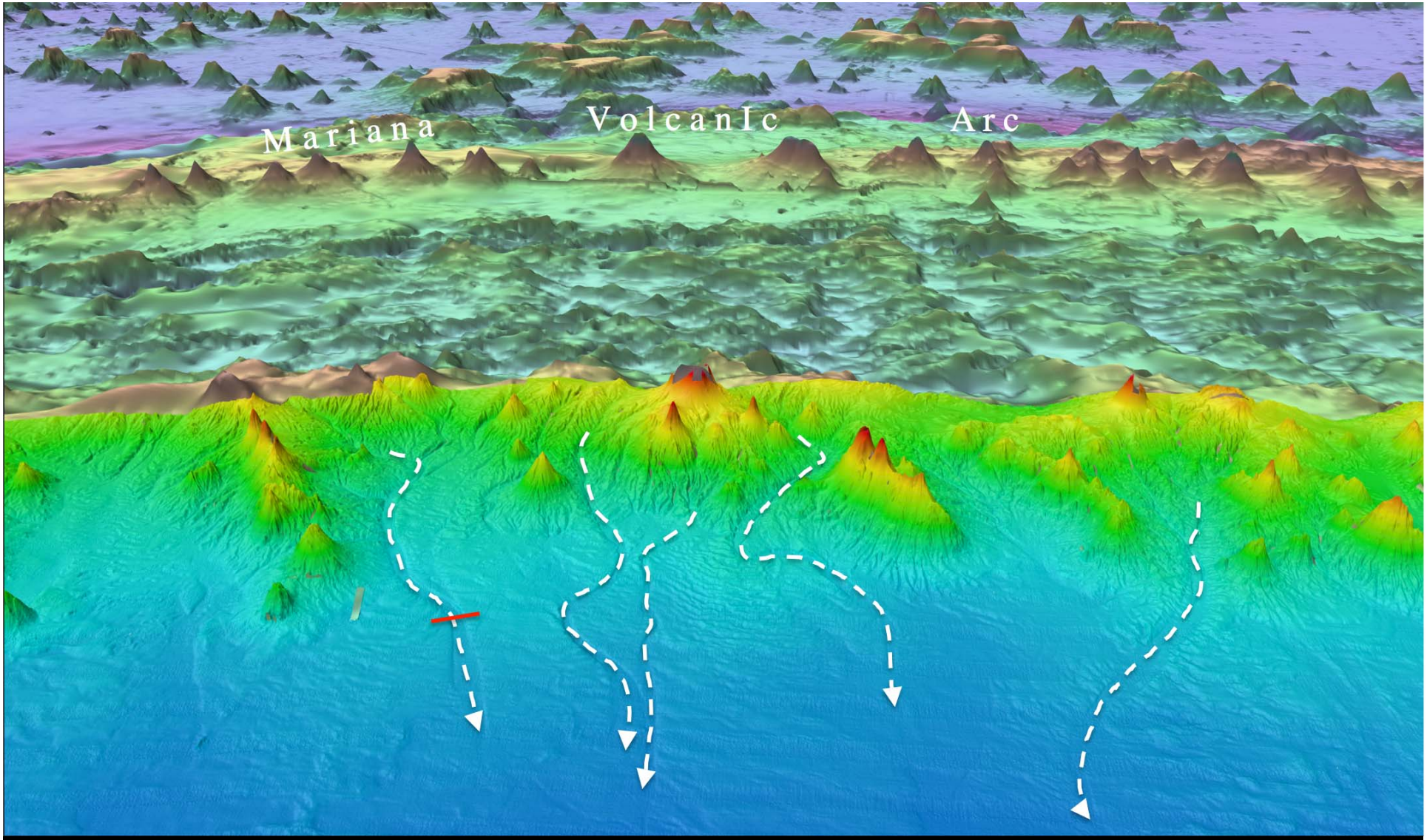
Determined with calculated uncertainty the deepest depth in the ocean -- 10,994m +/-25m




Guam & Northern Mariana Islands
Dutton Ridge
West Mariana Ridge
Mariana Trench
Japan
U.S.
EEZ
350 nmi
water depth (m)
0
2000
4000
6000
8000
10,000
136°E
138°E
140°E
142°E
144°E
146°E
148°E
150°E
152°E
154°E
24°N
22°N
20°N
18°N
16°N
14°N
12°N
10°N
8°N

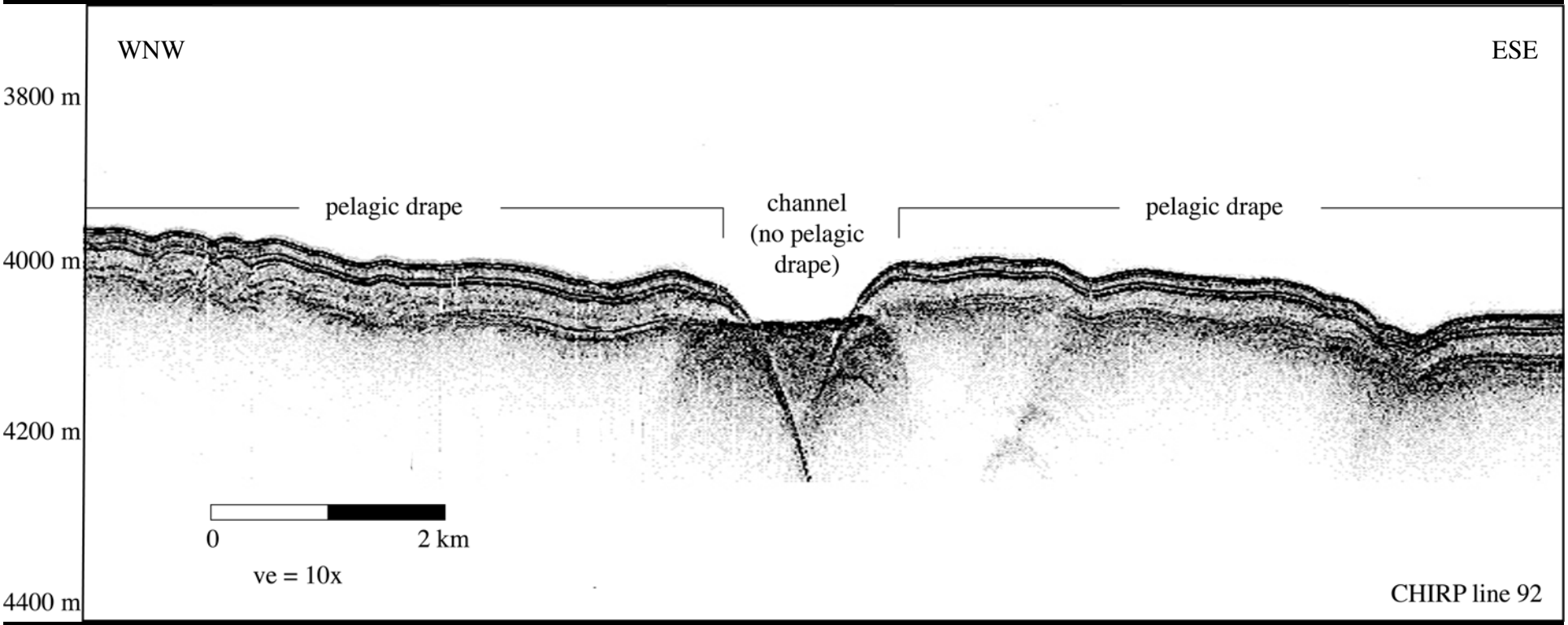

Dutton Ridge (Magellan Seamounts)
trench axis
inner wall
Philippine Plate
Pacific Plate
extensional faulting
trench axis
50 km
oblique view
ve = 5x
looking NW
northern Mariana Trench

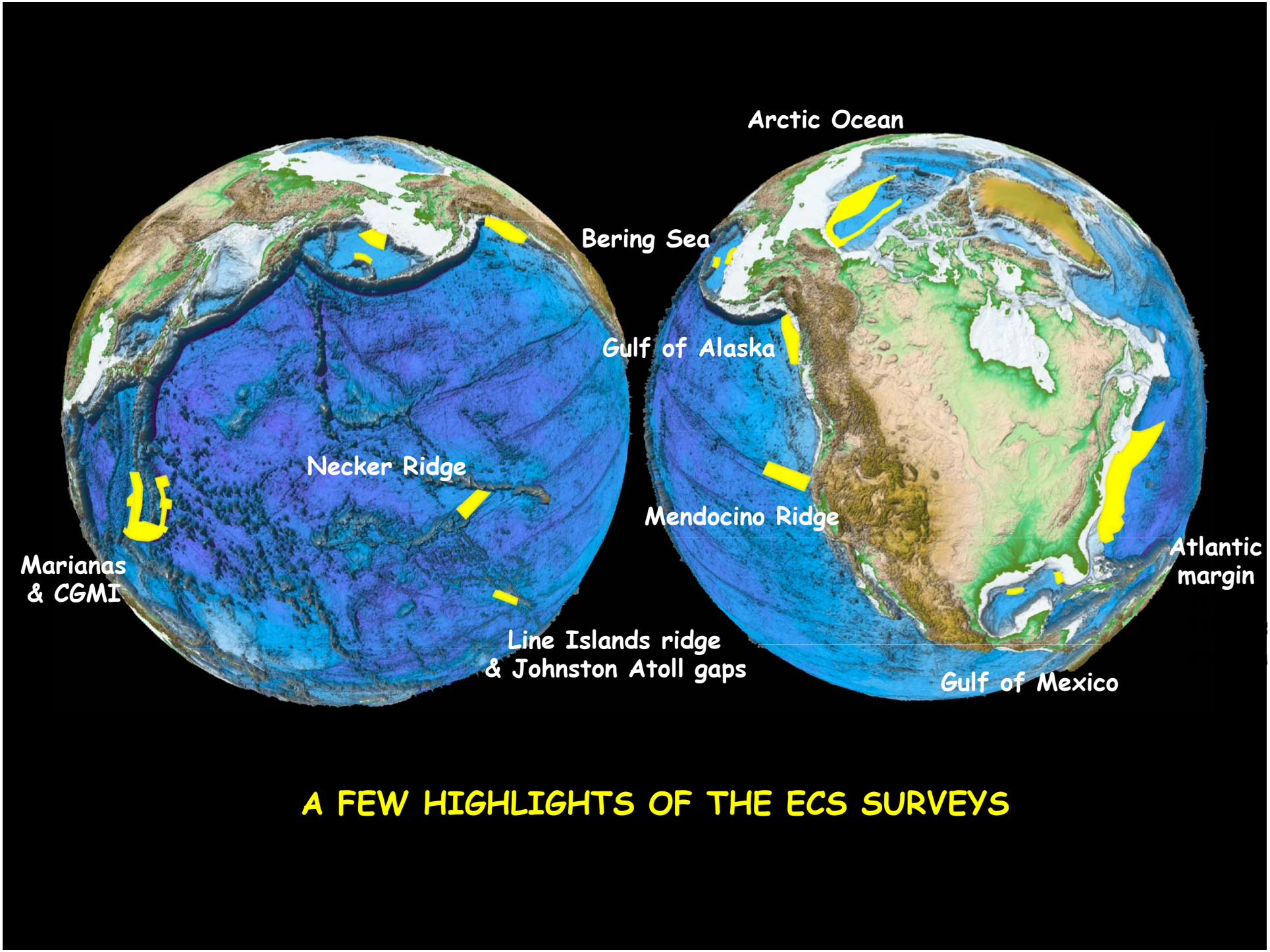

Guam & Northern Mariana Islands
West Mariana Ridge
Mariana Trench
Japan
U.S.
EEZ
350 nmi
water depth (m)
0
2000
4000
6000
8000
10,000
136°E
138°E
140°E
142°E
144°E
146°E
148°E
150°E
152°E
154°E
24°N
22°N
20°N
18°N
16°N
14°N
12°N
10°N
8°N



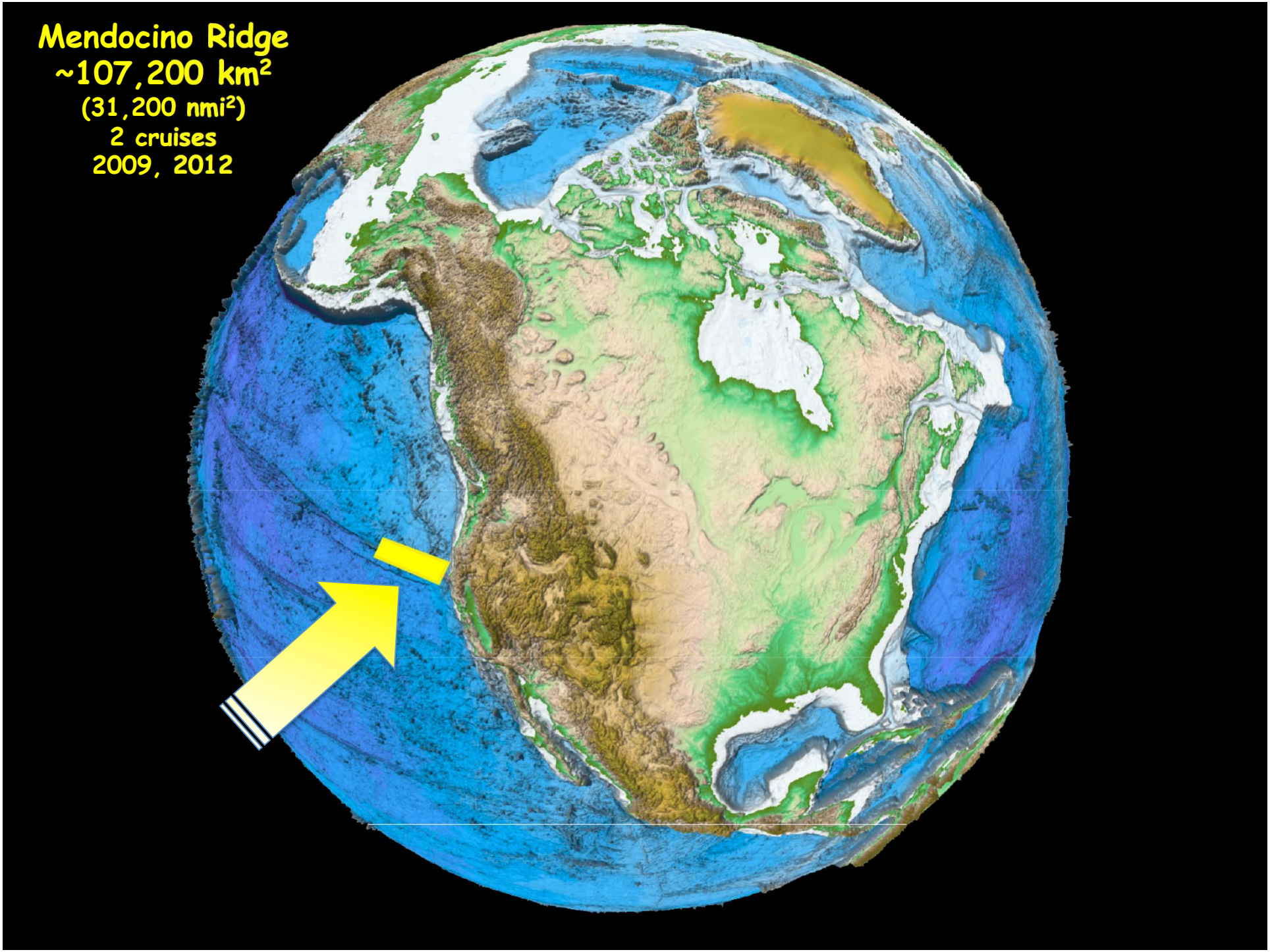
West Mariana Ridge (ve = 5x, looking E)

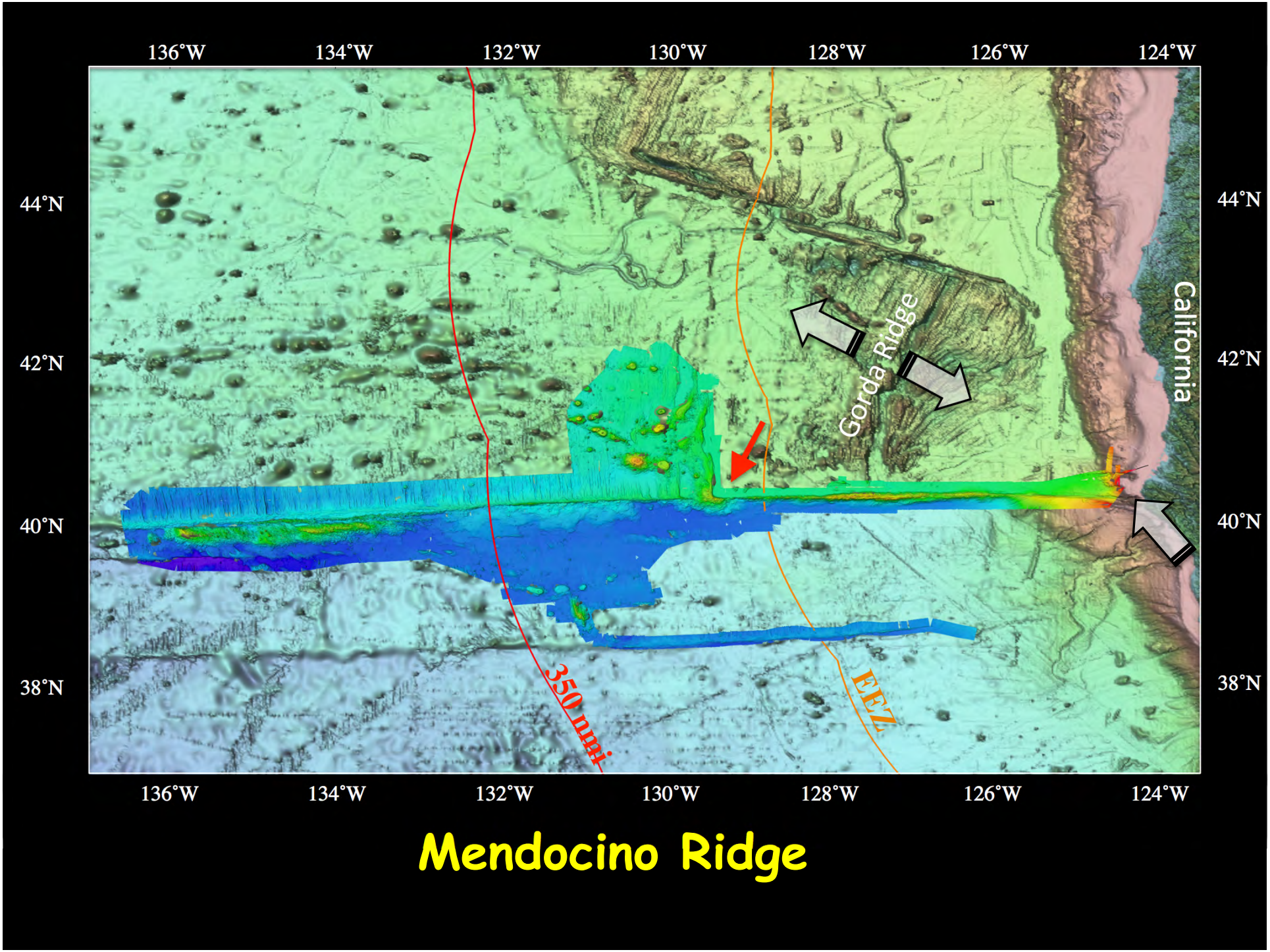
750 1500 2250 3000 3750 4500 5250
water depth (m)

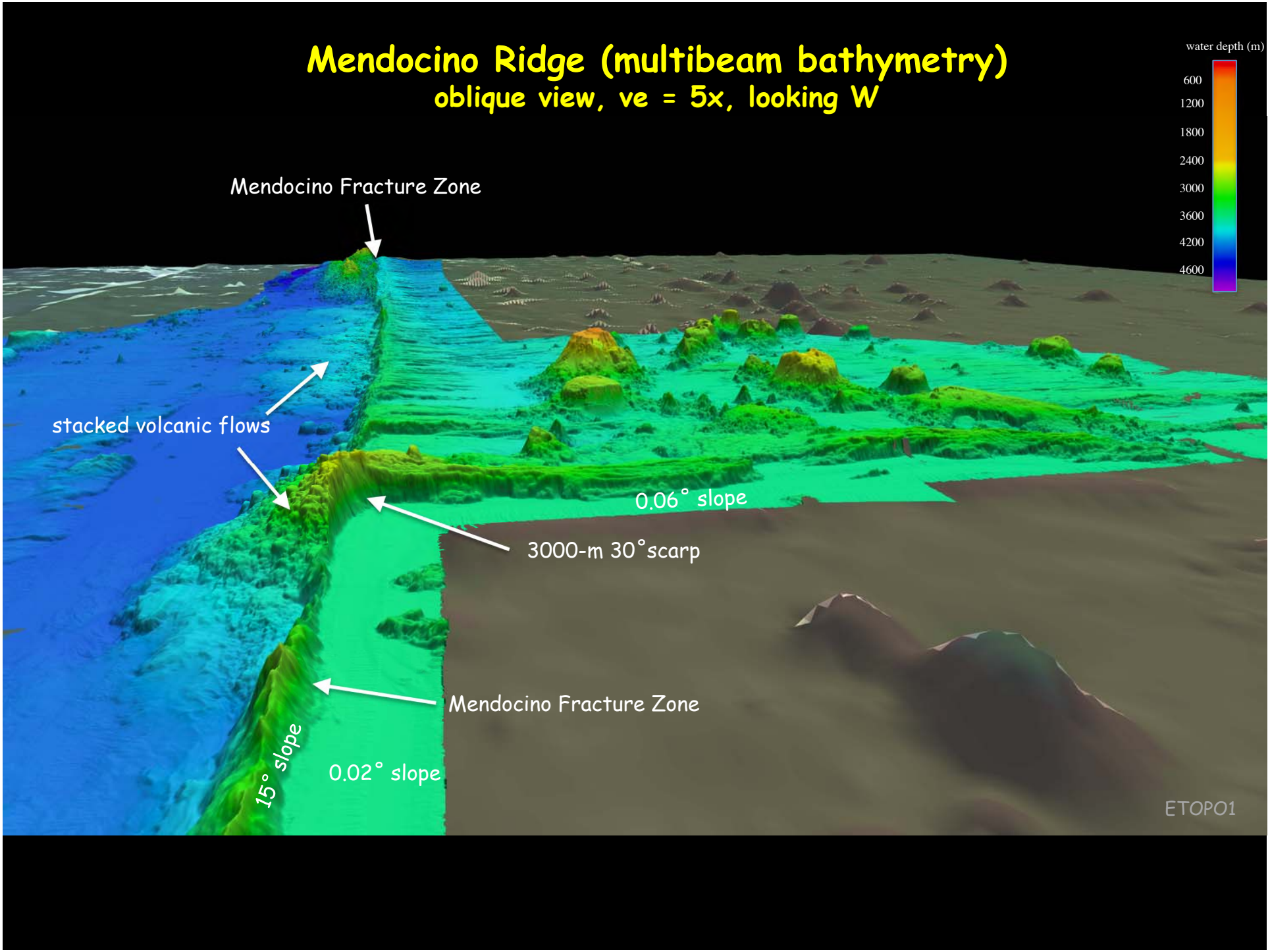

WNW
ESE
3800 m
4000 m
4200 m
4400 m
pelagic drape
channel
(no pelagic
drape)
pelagic drape
0
2 km
ve = 10x
CHIRP line 92

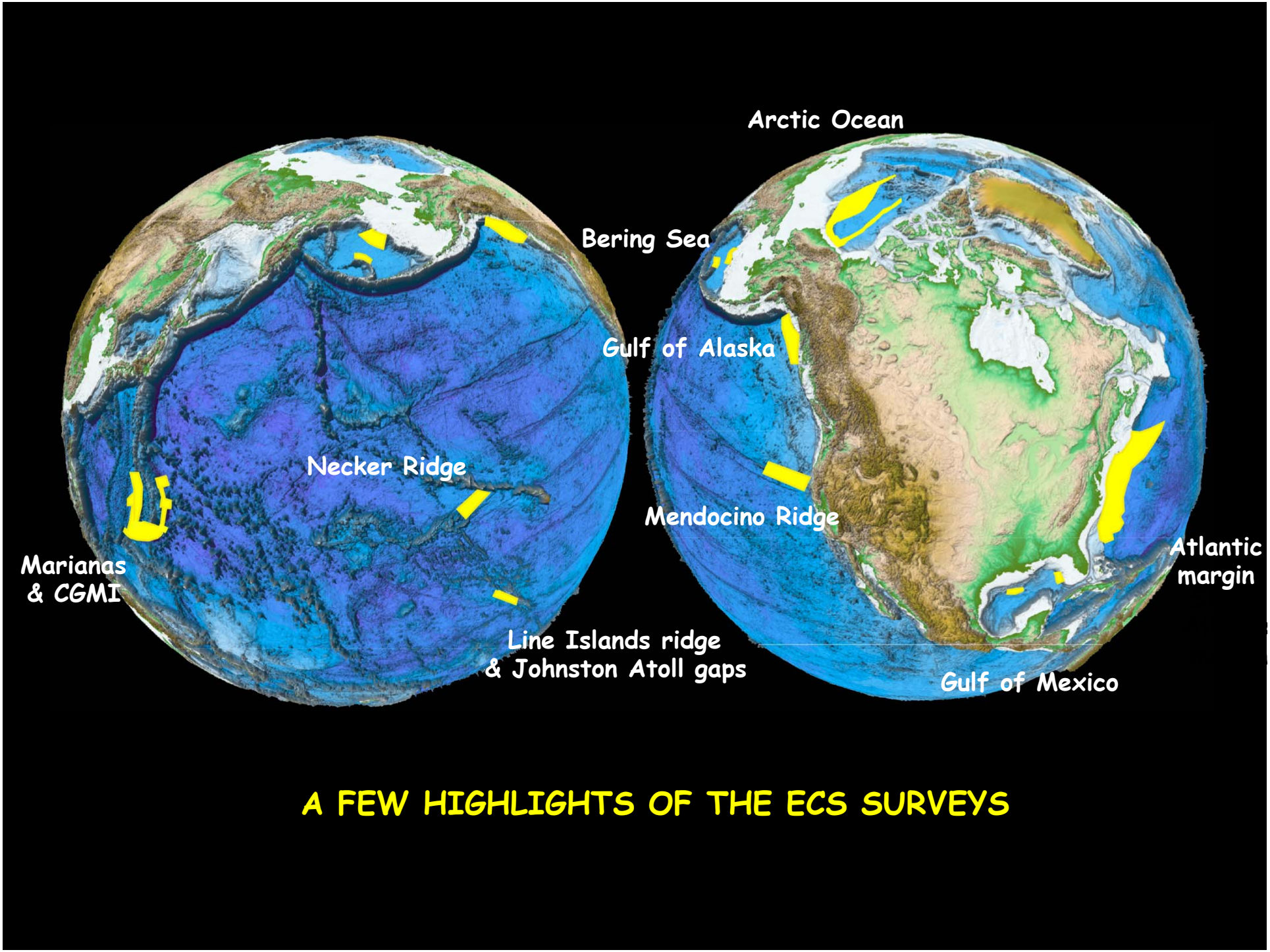


A FEW HIGHLIGHTS OF THE ECS SURVEYS

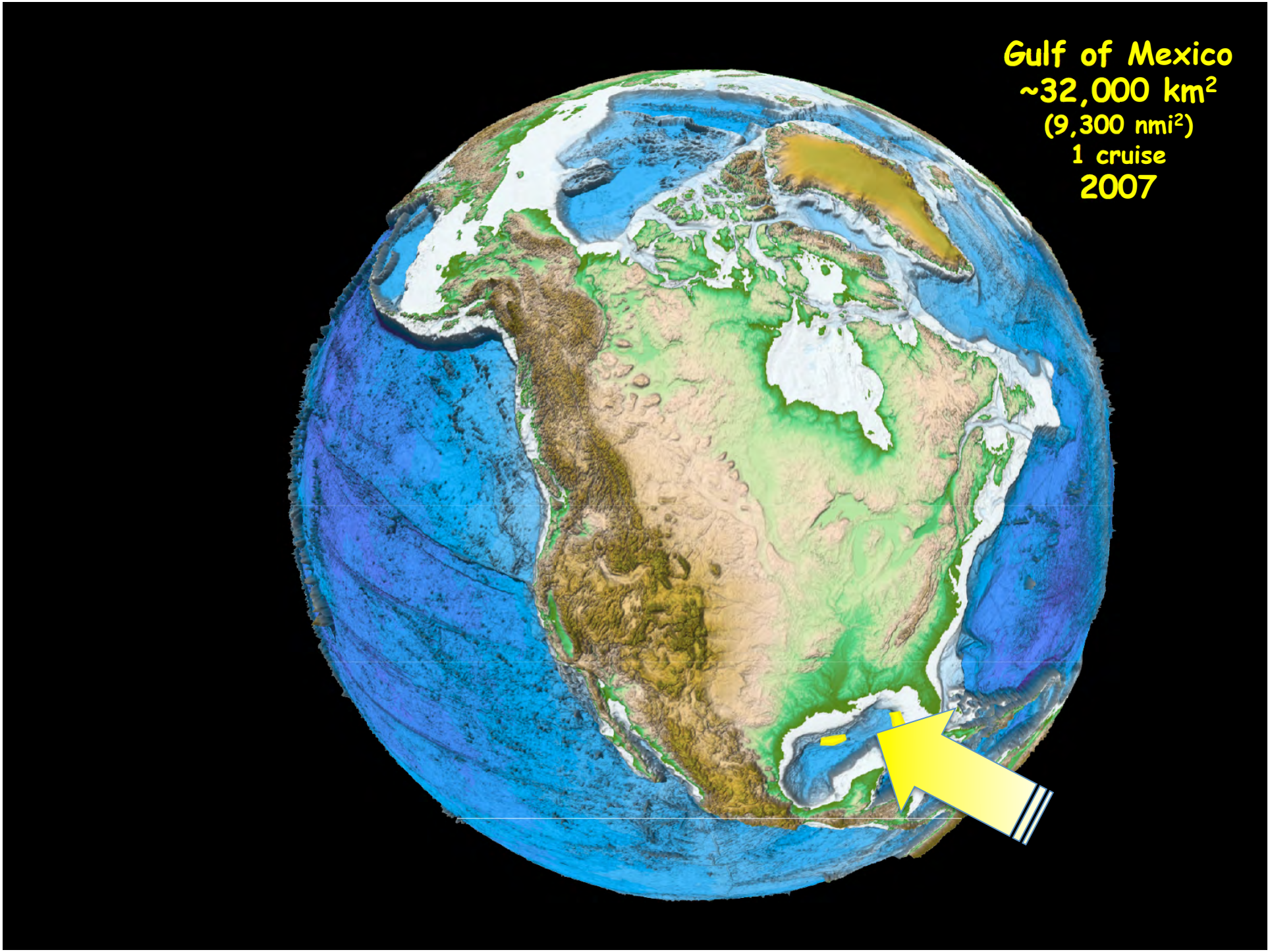

Mendocino Ridge
~107,200 km²
(31,200 nmi²)
2 cruises
2009, 2012

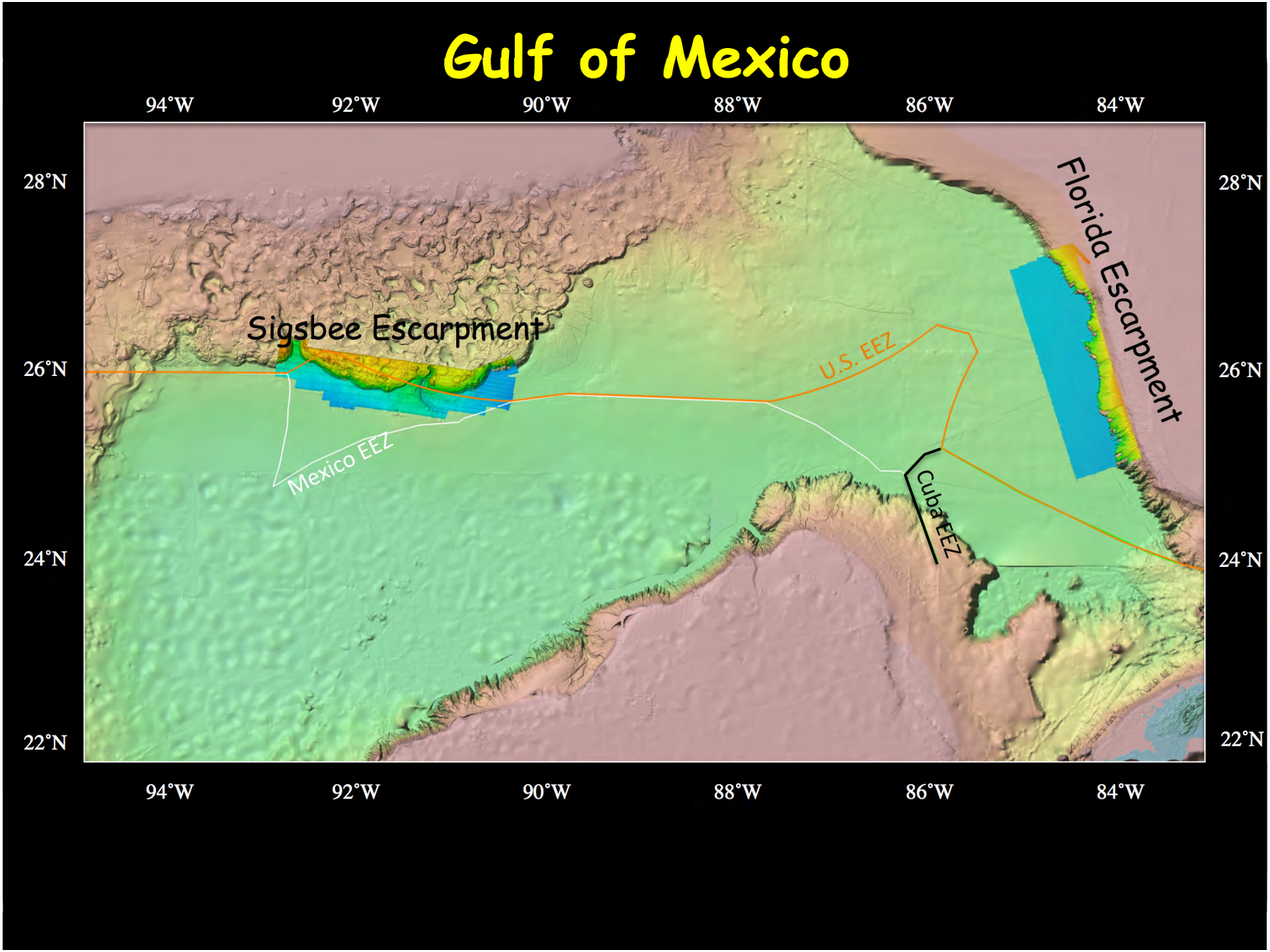

136°W
134°W
132°W
130°W
128°W
126°W
124°W
44°N
42°N
40°N
38°N
Gorda Ridge
California
350 nmi
EEZ
Mendocino Ridge


Mendocino Ridge (multibeam bathymetry)
oblique view, ve = 5x, looking W
water depth (m)
600
1200
1800
2400
3000
3600
4200
4600
Mendocino Fracture Zone
stacked volcanic flows
0.06° slope
3000-m 30°scarp
Mendocino Fracture Zone
15° slope
0.02° slope
ETOPO1



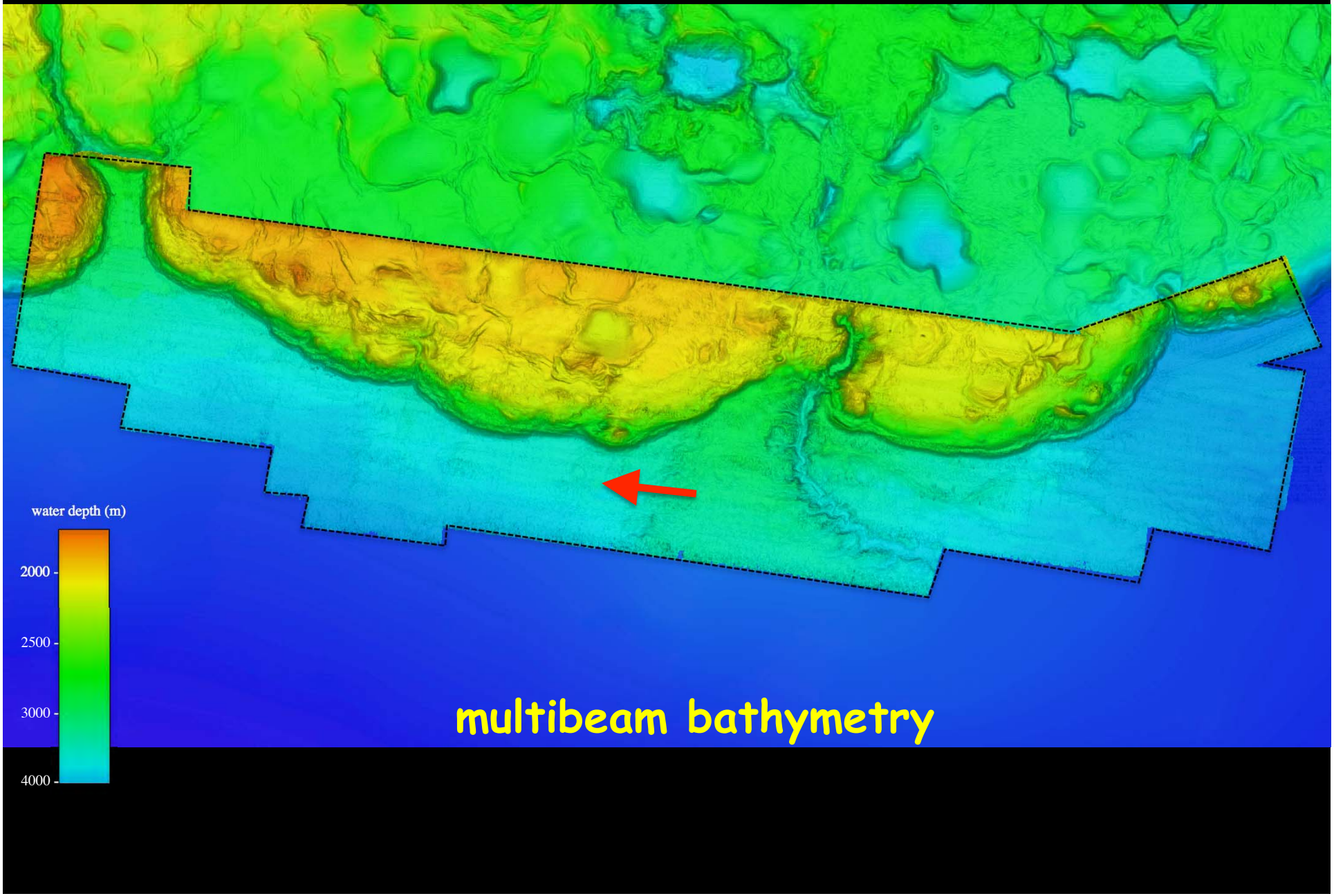
A FEW HIGHLIGHTS OF THE ECS SURVEYS


Gulf of Mexico
~32,000 km²
(9,300 nmi²)
1 cruise
2007


Gulf of Mexico
94°W
92°W
90°W
88°W
86°W
84°W
28°N
26°N
24°N
22°N
Sigsbee Escarpment
Florida Escarpment
U.S. EEZ
Mexico EEZ
Cuba EEZ


Gulf of Mexico
94°W
92°W
90°W
88°W
86°W
84°W
28°N
26°N
24°N
22°N
Sigsbee Escarpment
Florida Escarpment
U.S. EEZ
Mexico EEZ
Cuba EEZ

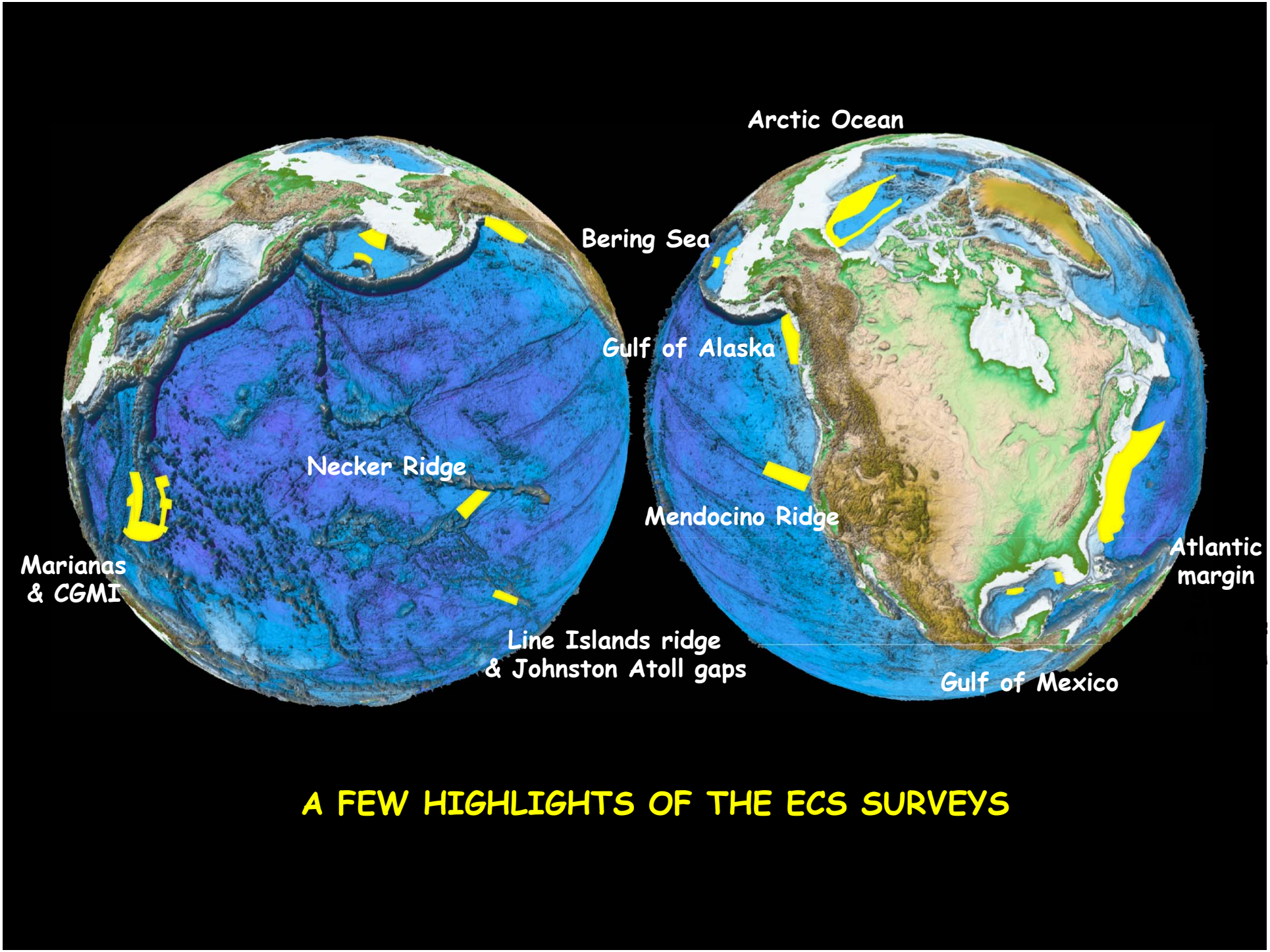
Sigsbee Escarpment – Gulf of Mexico



erosional furrows (λ ~150 m, height <1 m) **south of Sigsbee Escarpment, GOM**

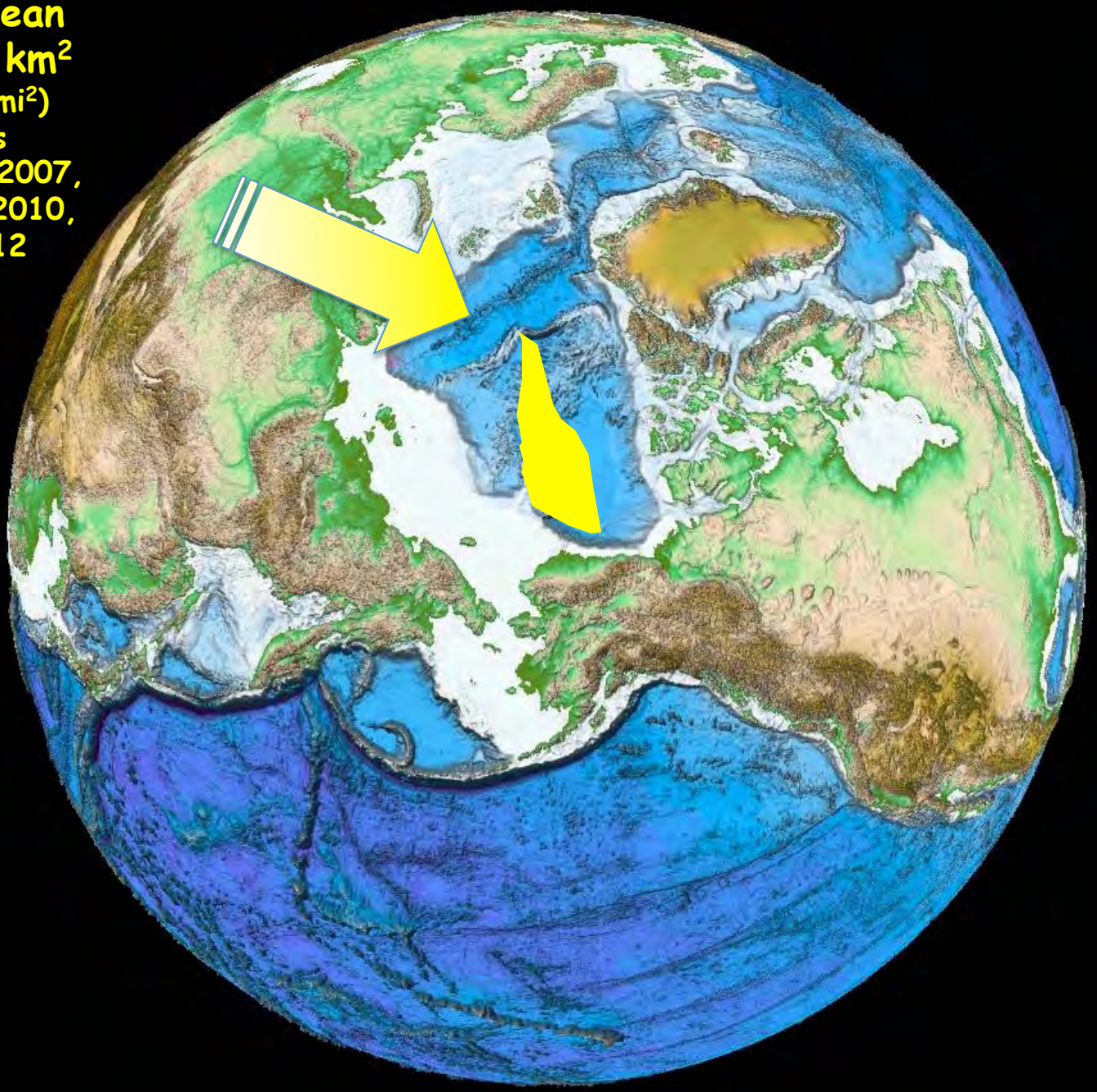
3150 to 3275 m water depths

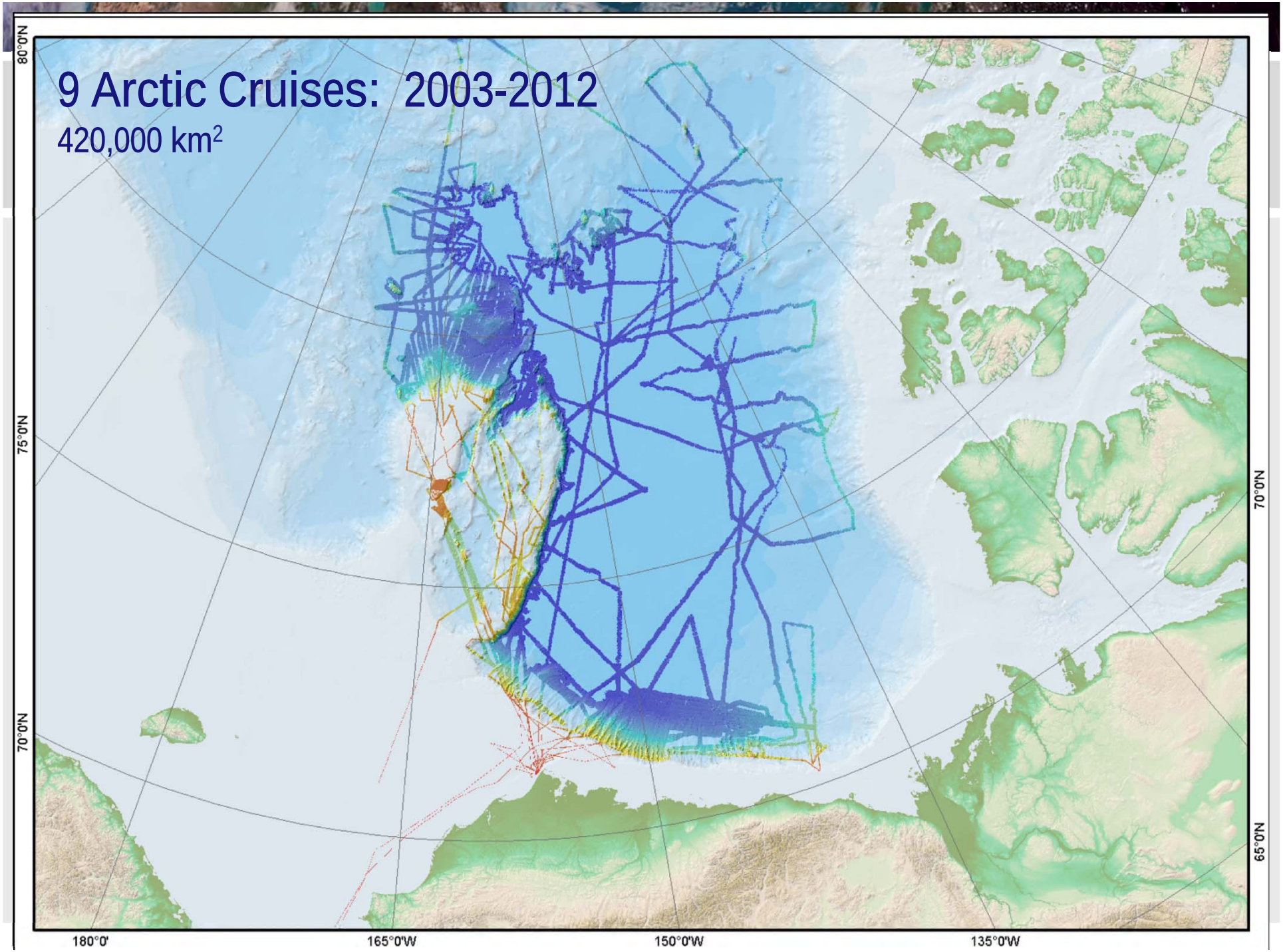
oblique view, ve = 5x, looking W



A FEW HIGHLIGHTS OF THE ECS SURVEYS

Arctic Ocean
~420,000 km^2
(122,300 nmi^2)
9 cruises
2003, 2004, 2007, 2008, 2009,2010, 2011, 2012



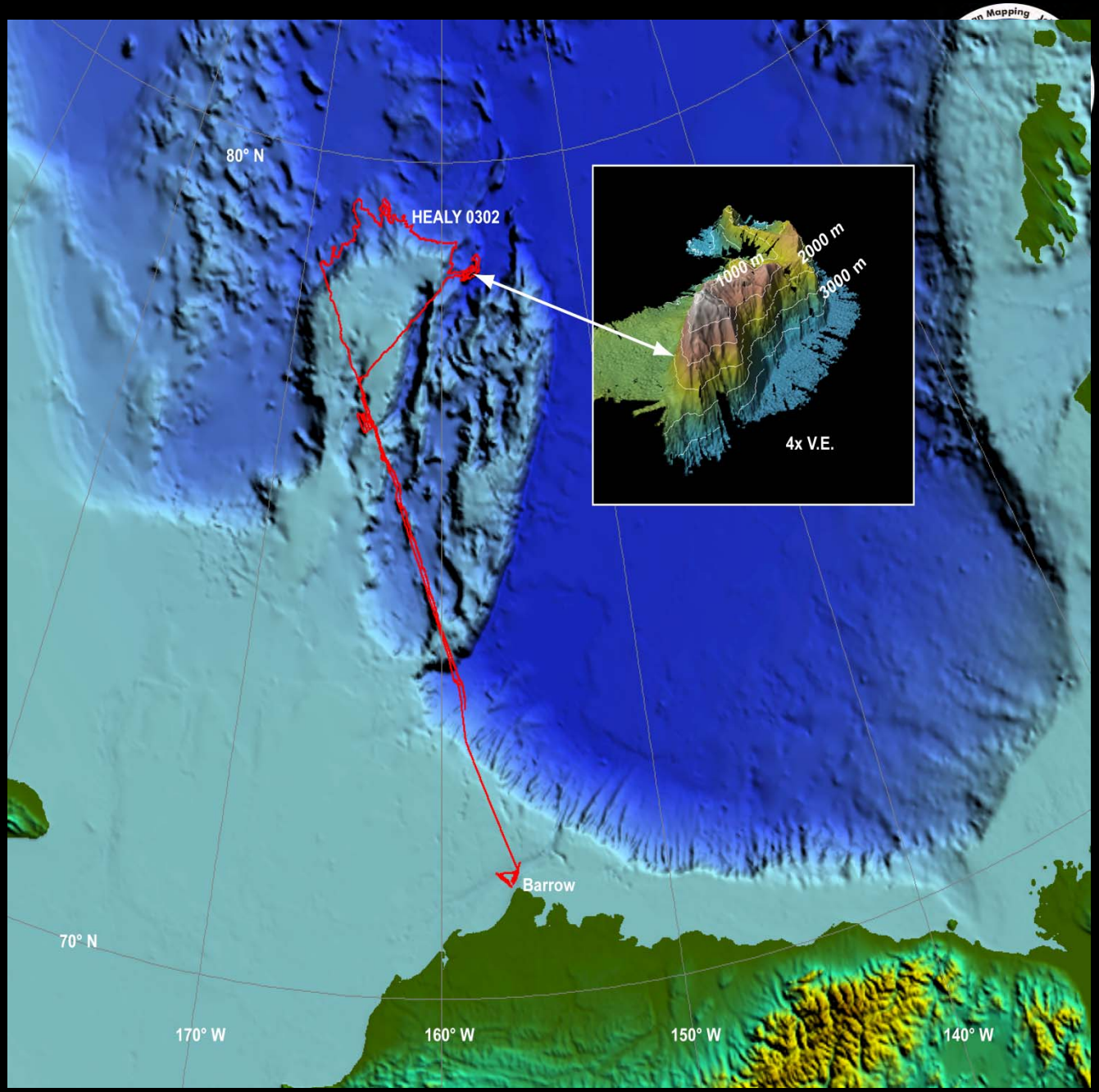

9 Arctic Cruises: 2003-2012
420,000 km2
80°0'N
75°0'N
70°0'N
70°0'N
65°0'N
180°0'
165°0'W
150°0'W
135°0'W

Healy 03-02

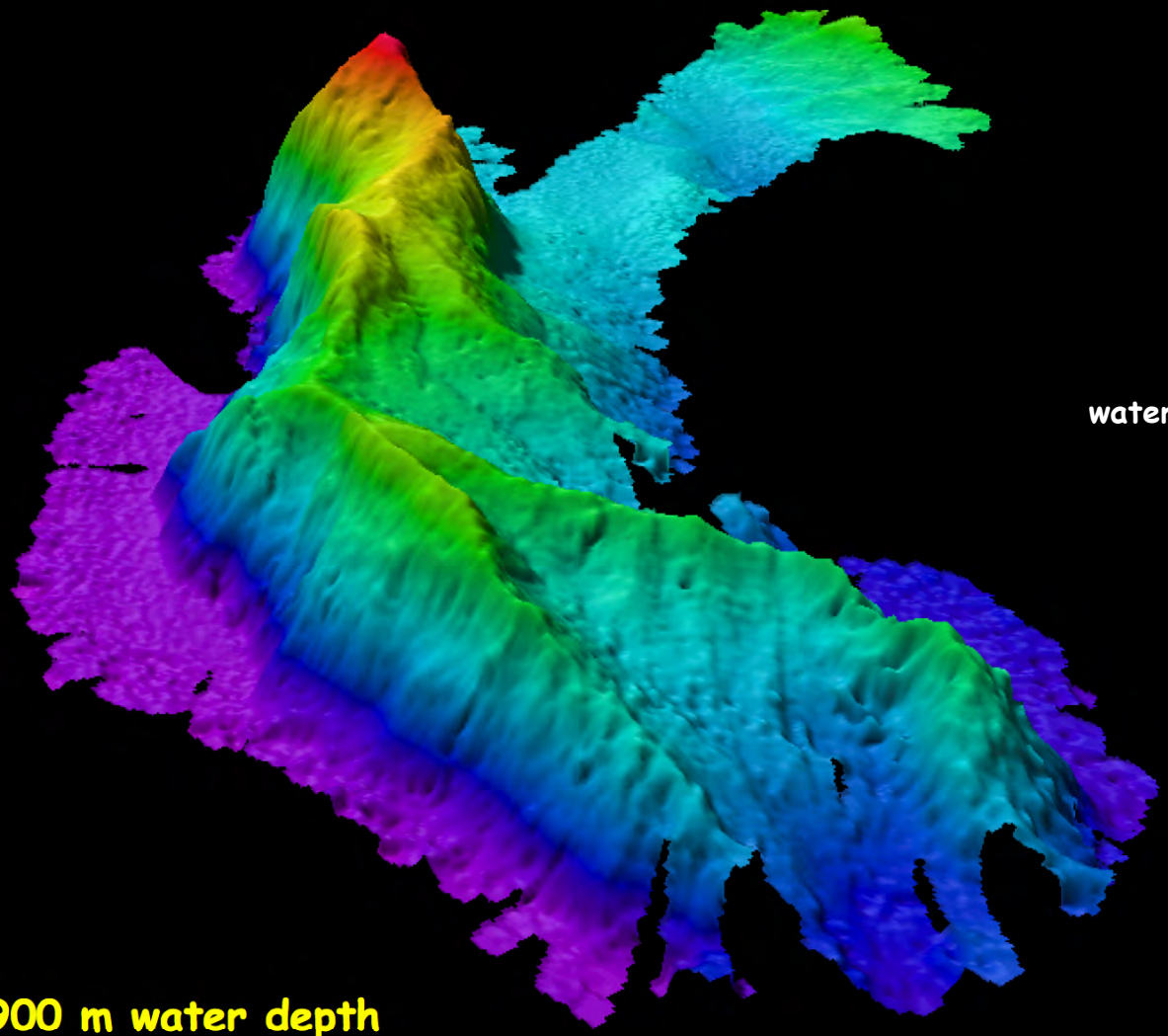
~3000 km of multibeam sonar bathymetry

1-11 Sept 03

8/10 ice



Healy Seamount
looking S, ve=6x



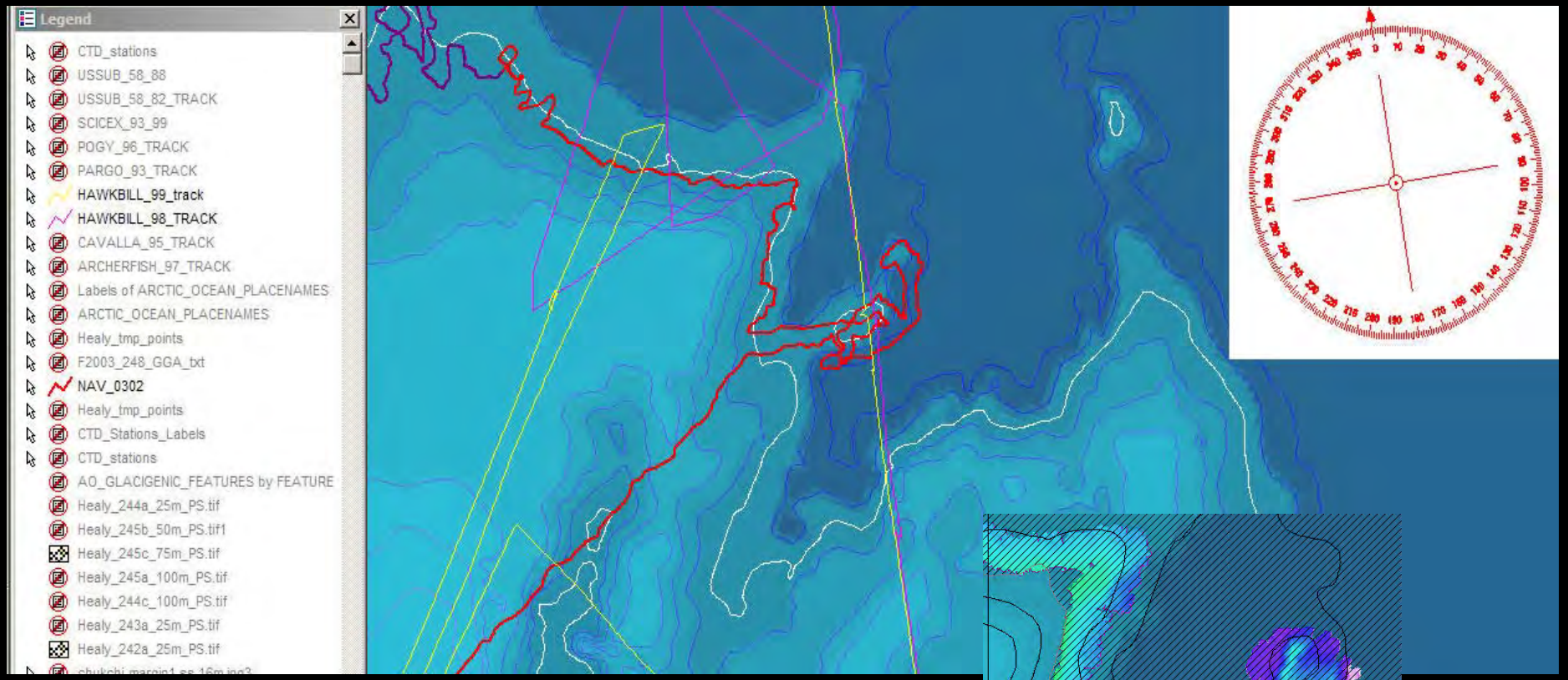
-900
-1094
-1288
-1481
-1675
-1869
-2063
-2256
-2450
-2644
-2838
-3031
-3225
-3419
-3613
-3806
-4000

water depth (m)

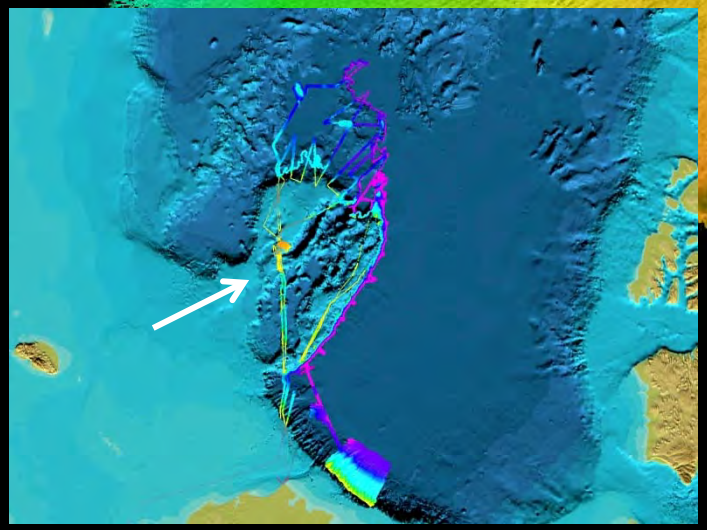
3100 m high, summit at 900 m water depth

45 km long x 15 km wide

Healy Seamount Survey



Central Chukchi Plateau pockmarks

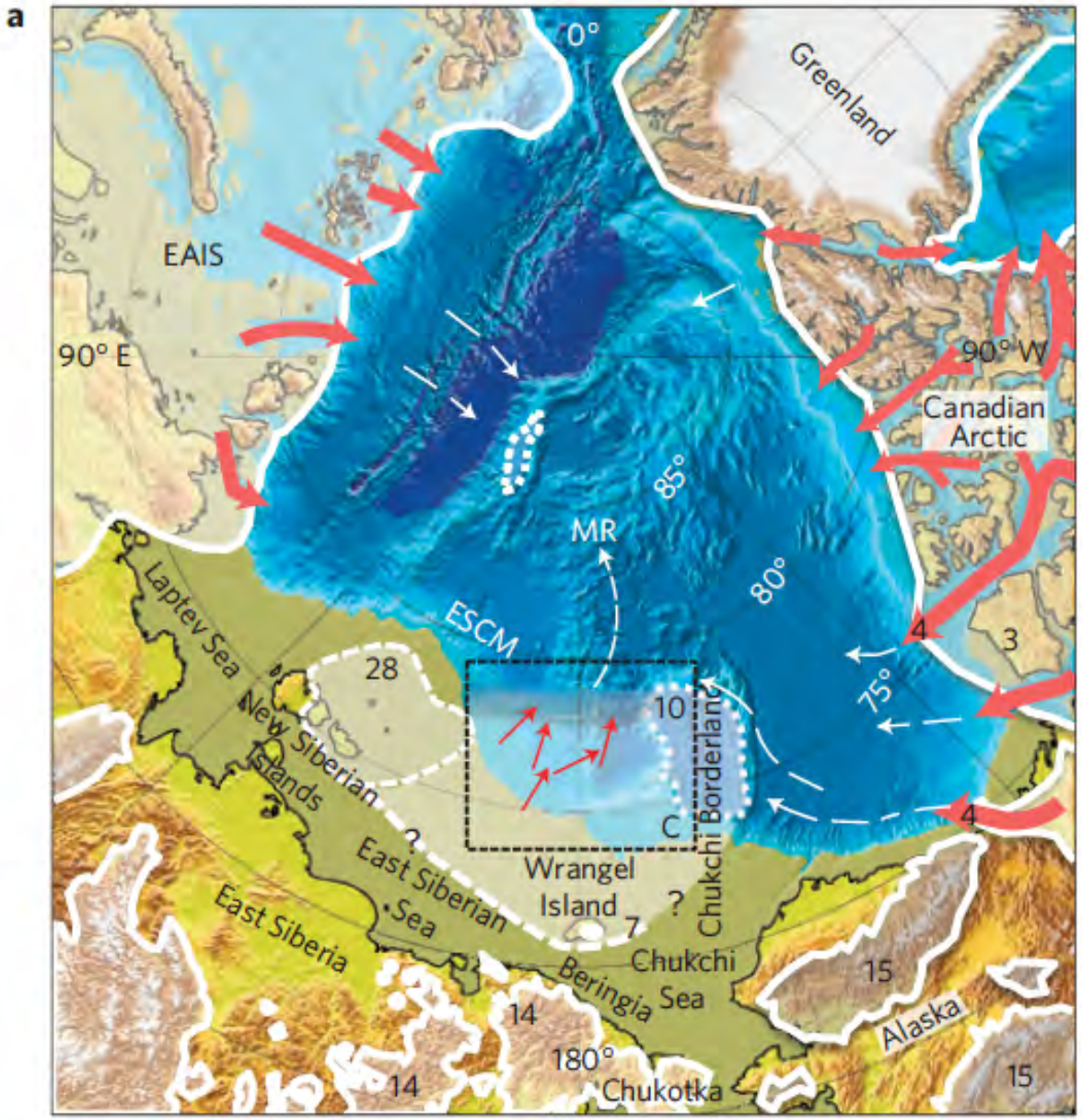


200-m diameter
20-m deep

VE = 10x
looking SW

NATURE GEOSCIENCE DOI: 10.1038/NGEO1904

Niessen et al, 2013



2008 DREDGING IN THE ICE

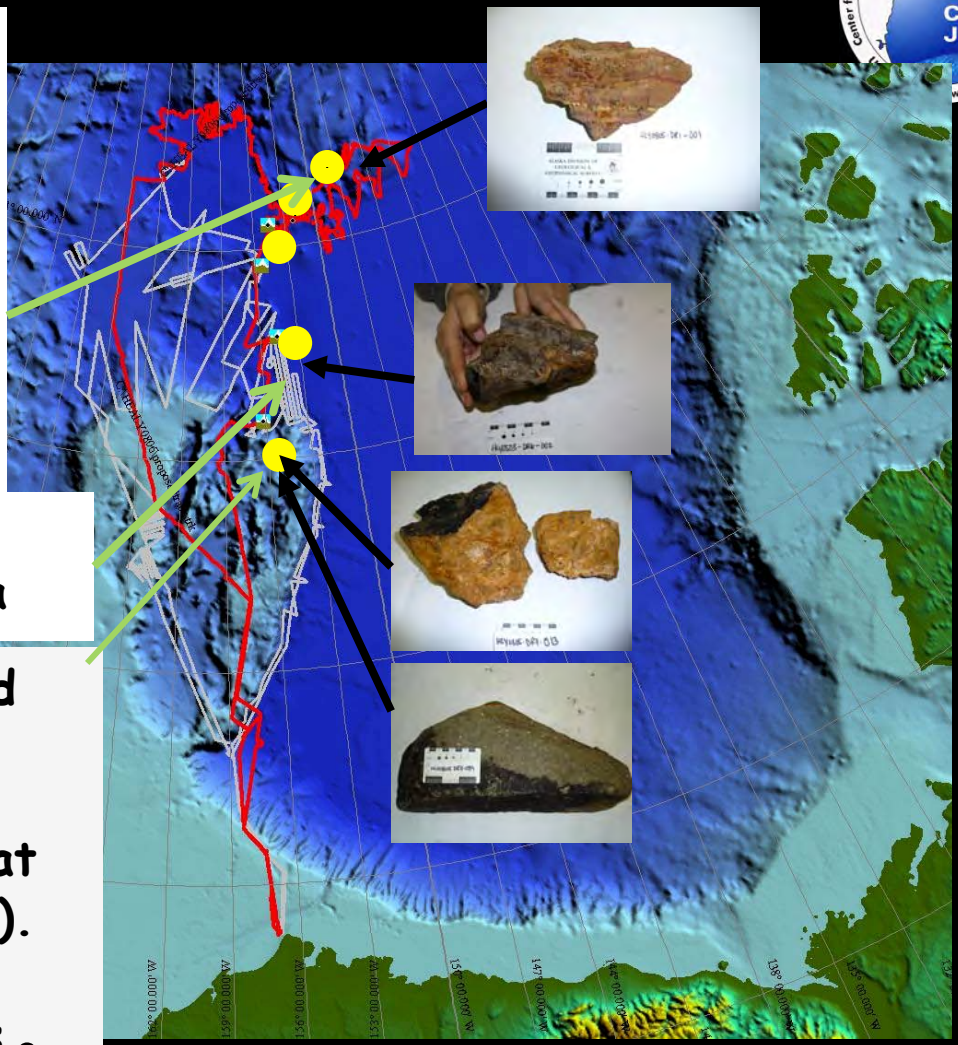
HEALY 0805 - SHIPTRACK AND DREDGE SITES

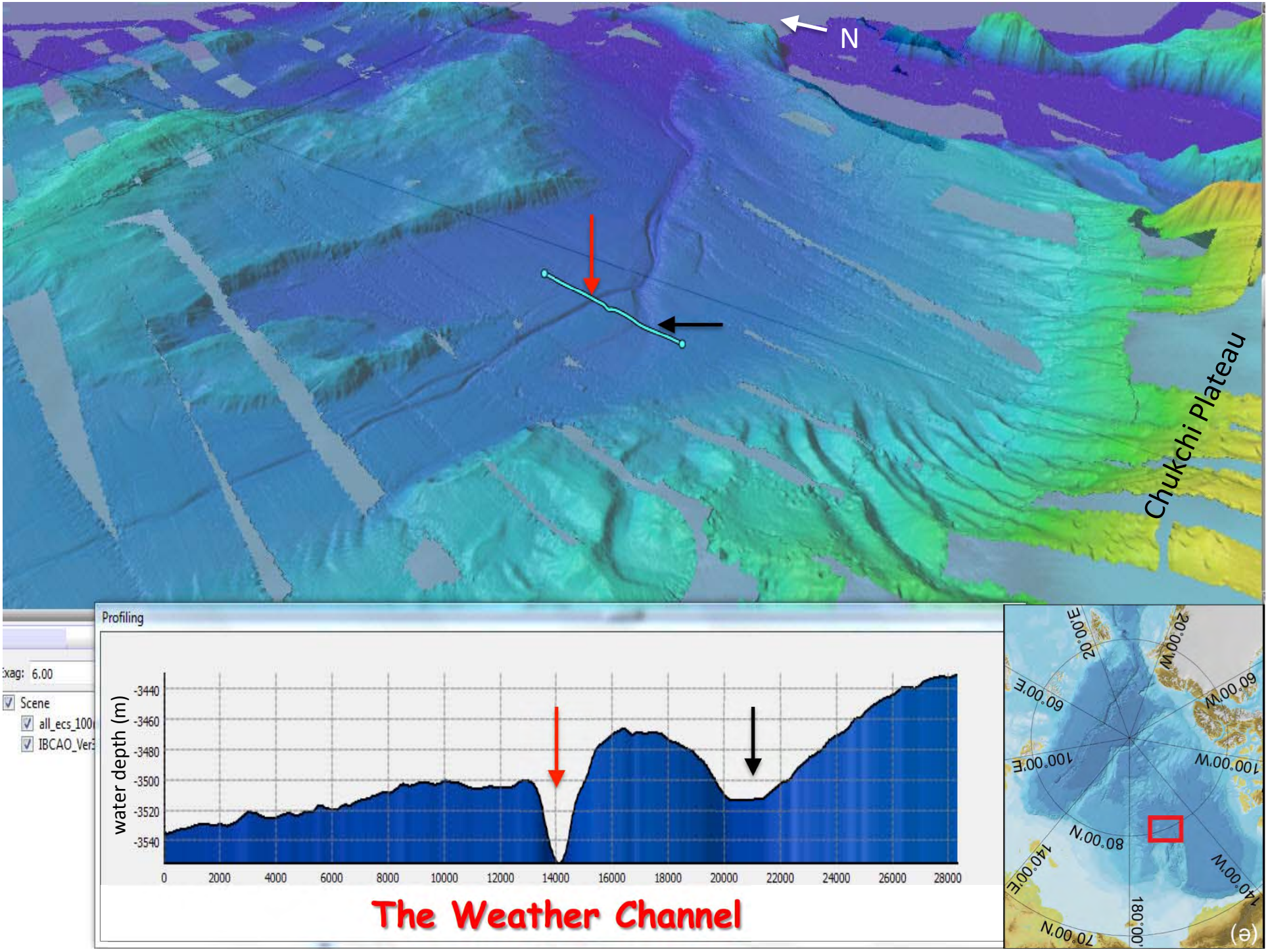
Volcaniclastic sedimentary rock – hyaloclastite . Vesiculatlion in glass and grading of pumice implies deposited soon after shallow water volcanic eruption.

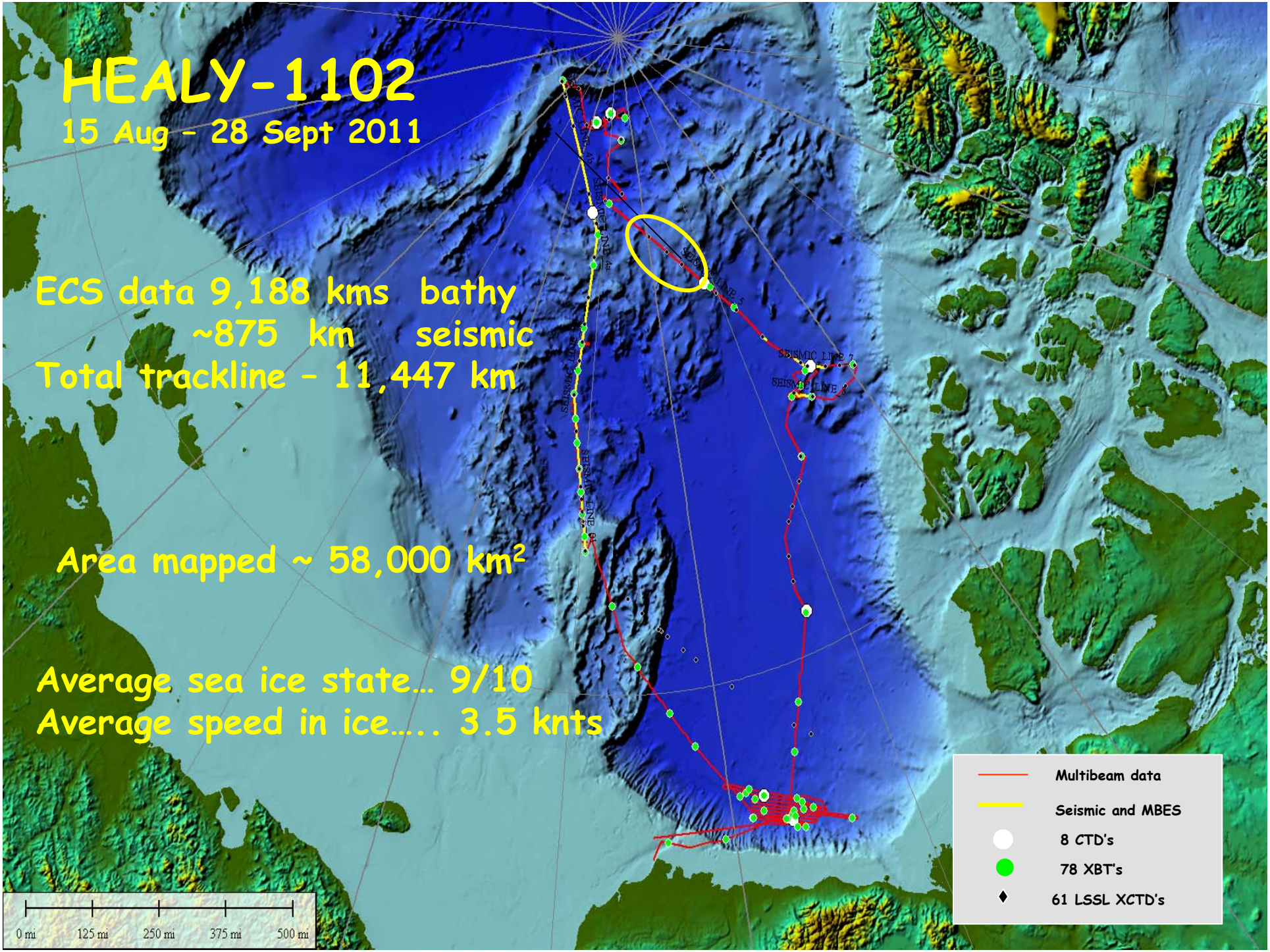
Flood Basalts – 100-82 Ma

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

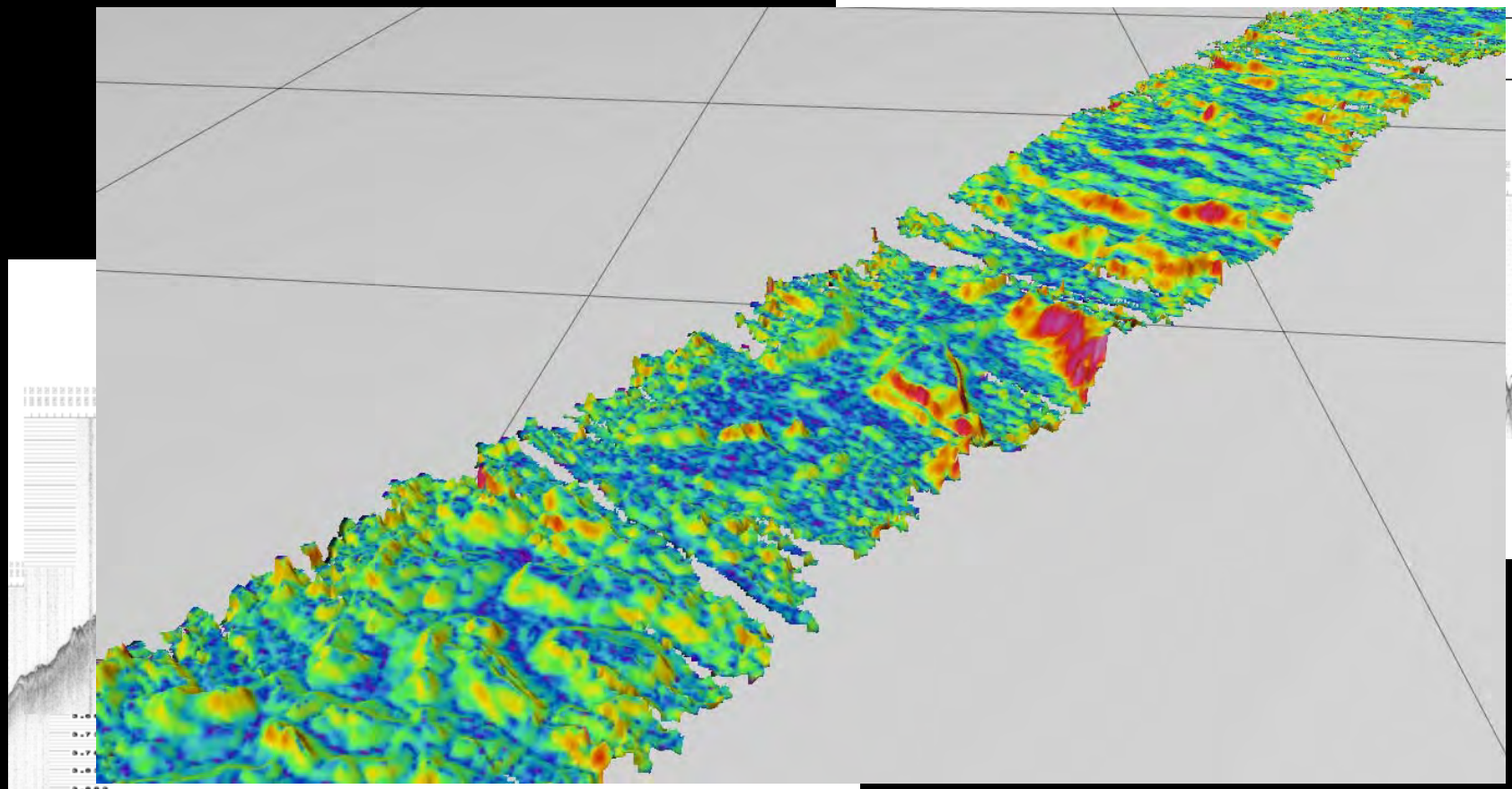
Also 112 Ma flood basalts.

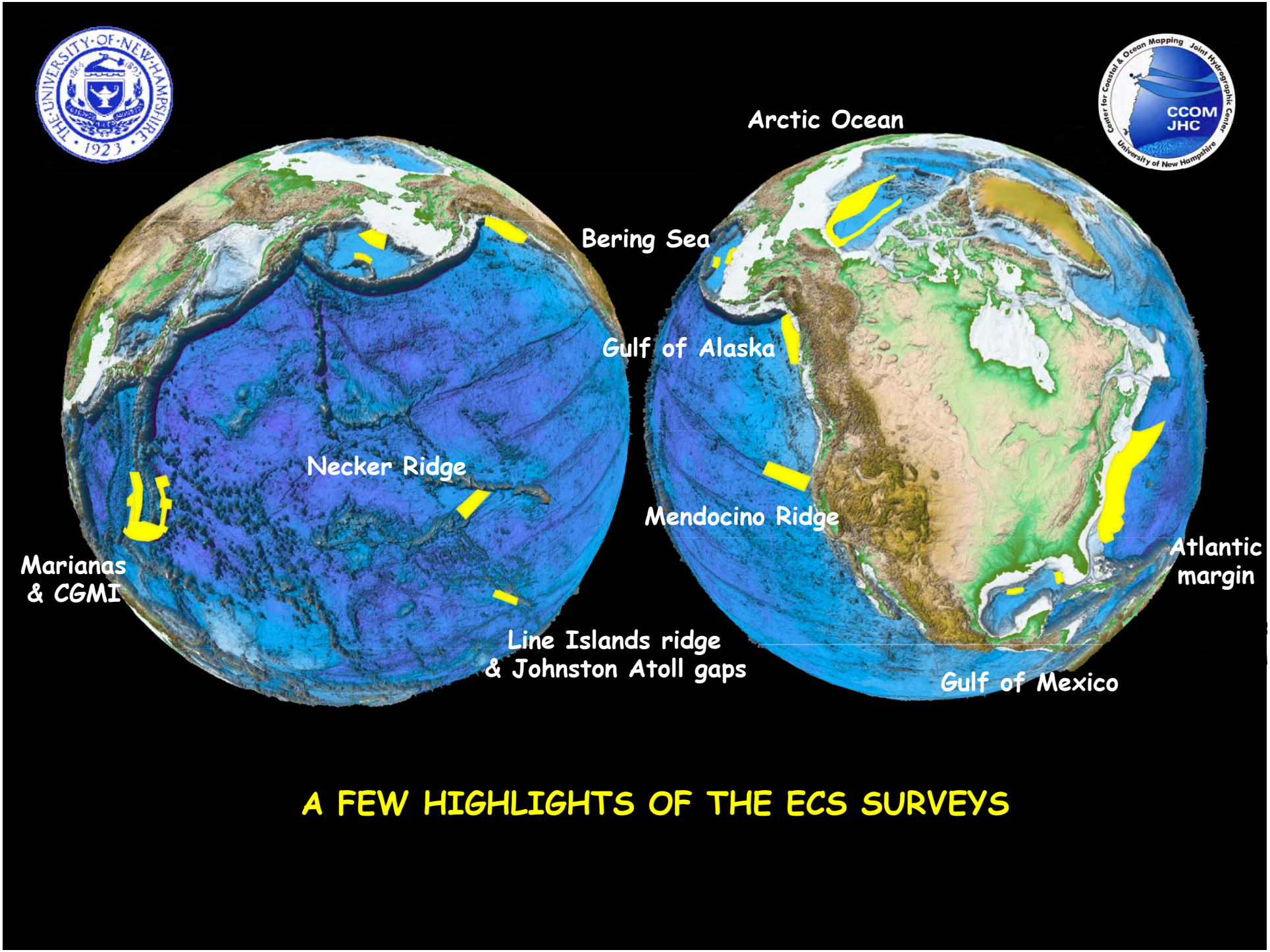



N
Chukchi Plateau
Profiling
water depth (m)
-3440
-3460
-3480
-3500
-3520
-3540
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
The Weather Channel
Scene
20°00'E
20°00'W
60°00'E
60°00'W
100°00'E
100°00'W
140°00'E
140°00'W
80°00'N
70°00'N
180°00'
(a)

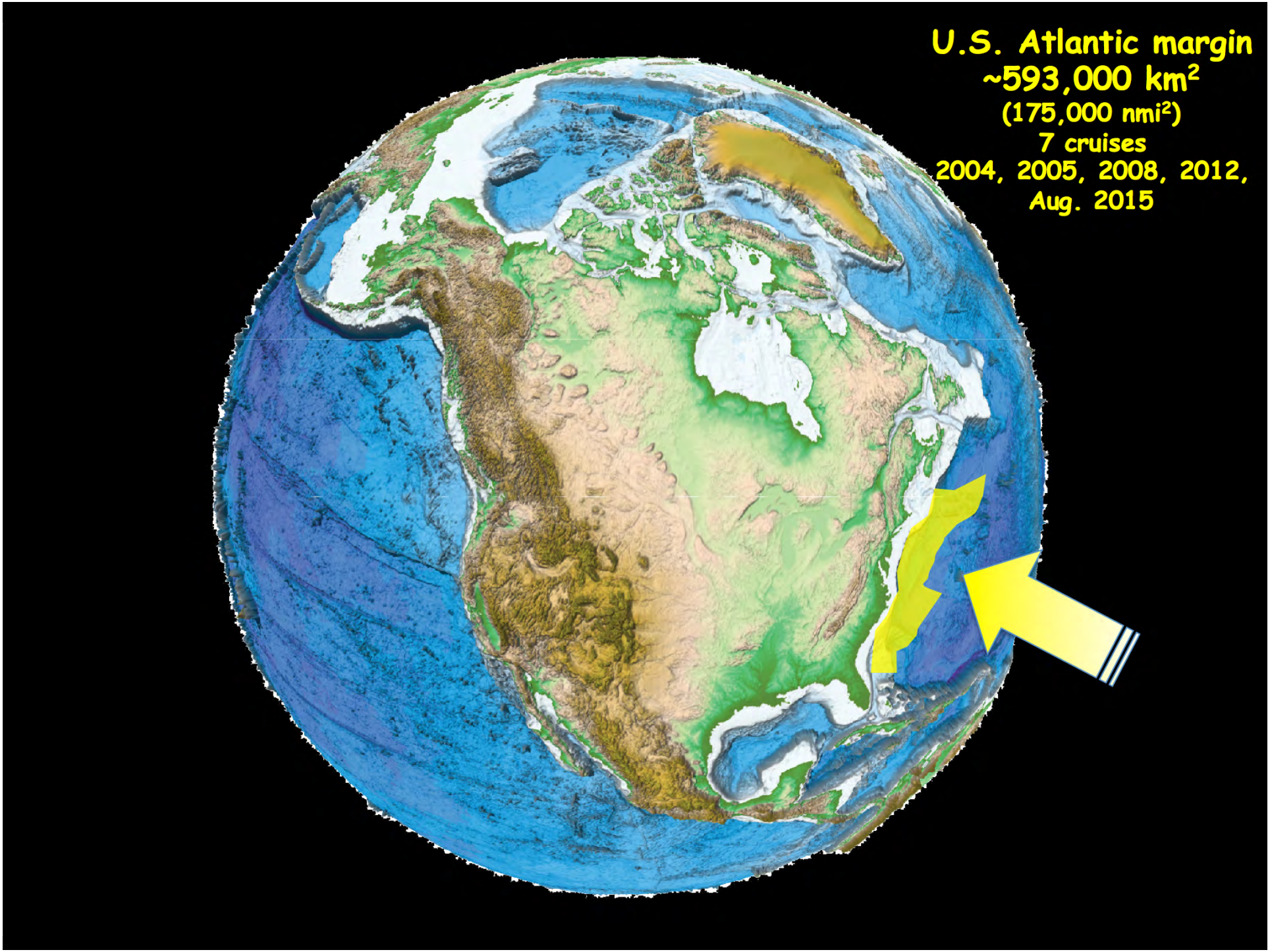

HEALY-1102
15 Aug – 28 Sept 2011
ECS data 9,188 kms bathy
~875 km seismic
Total trackline – 11,447 km
Area mapped ~ 58,000 km²
Average sea ice state… 9/10
Average speed in ice….. 3.5 knts
Multibeam data
Seismic and MBES
8 CTD's
78 XBT's
61 LSSL XCTD's
0 mi
125 mi
250 mi
375 mi
500 mi

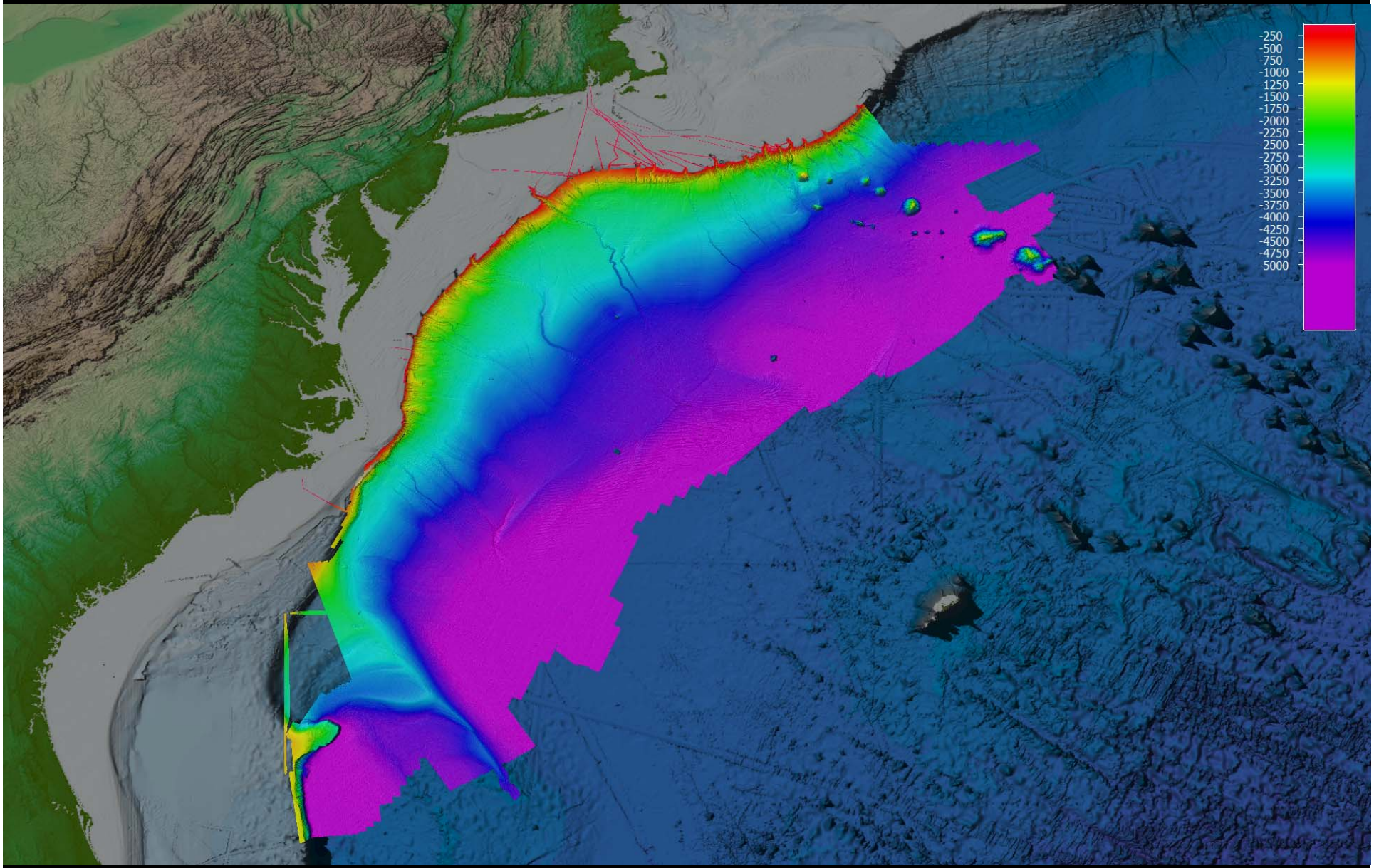
Hyperbolic Echoes on Alpha/Mendeleev Ridge





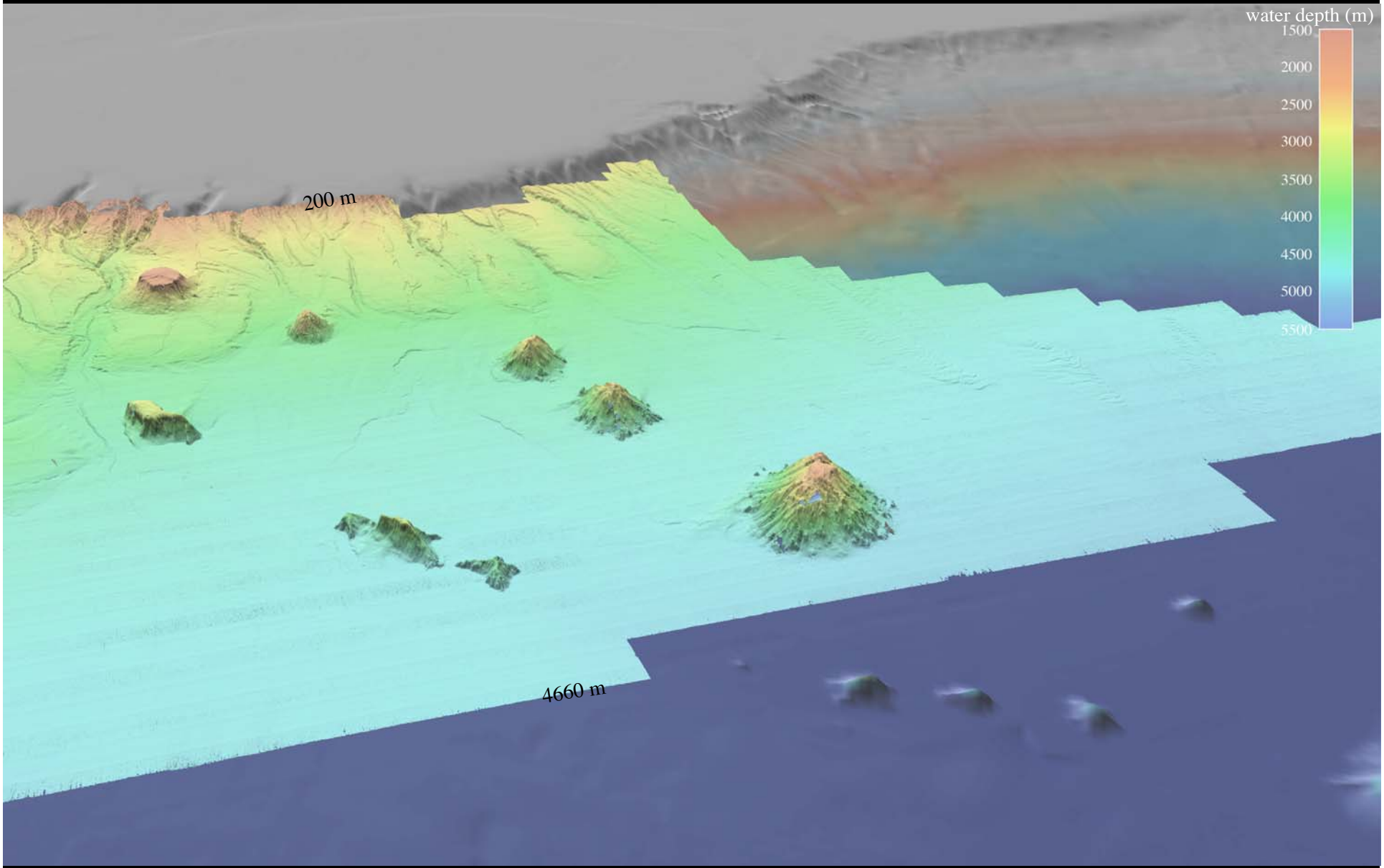
A FEW HIGHLIGHTS OF THE ECS SURVEYS


U.S. Atlantic margin
~593,000 km²
(175,000 nmi²)
7 cruises
2004, 2005, 2008, 2012,
Aug. 2015


-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
-3000
-3250
-3500
-3750
-4000
-4250
-4500
-4750
-5000

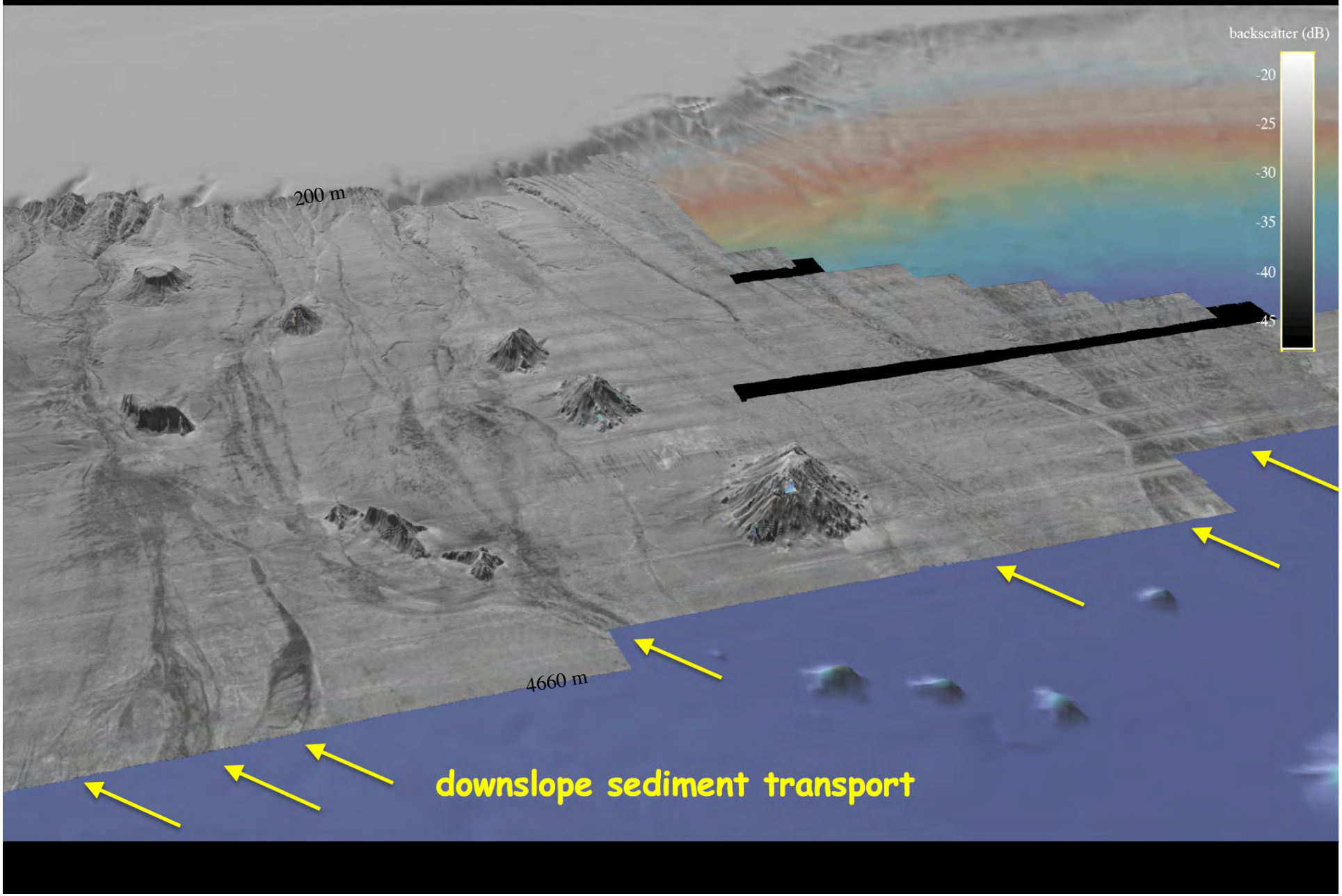
Perspective view, ve = 5x looking NW

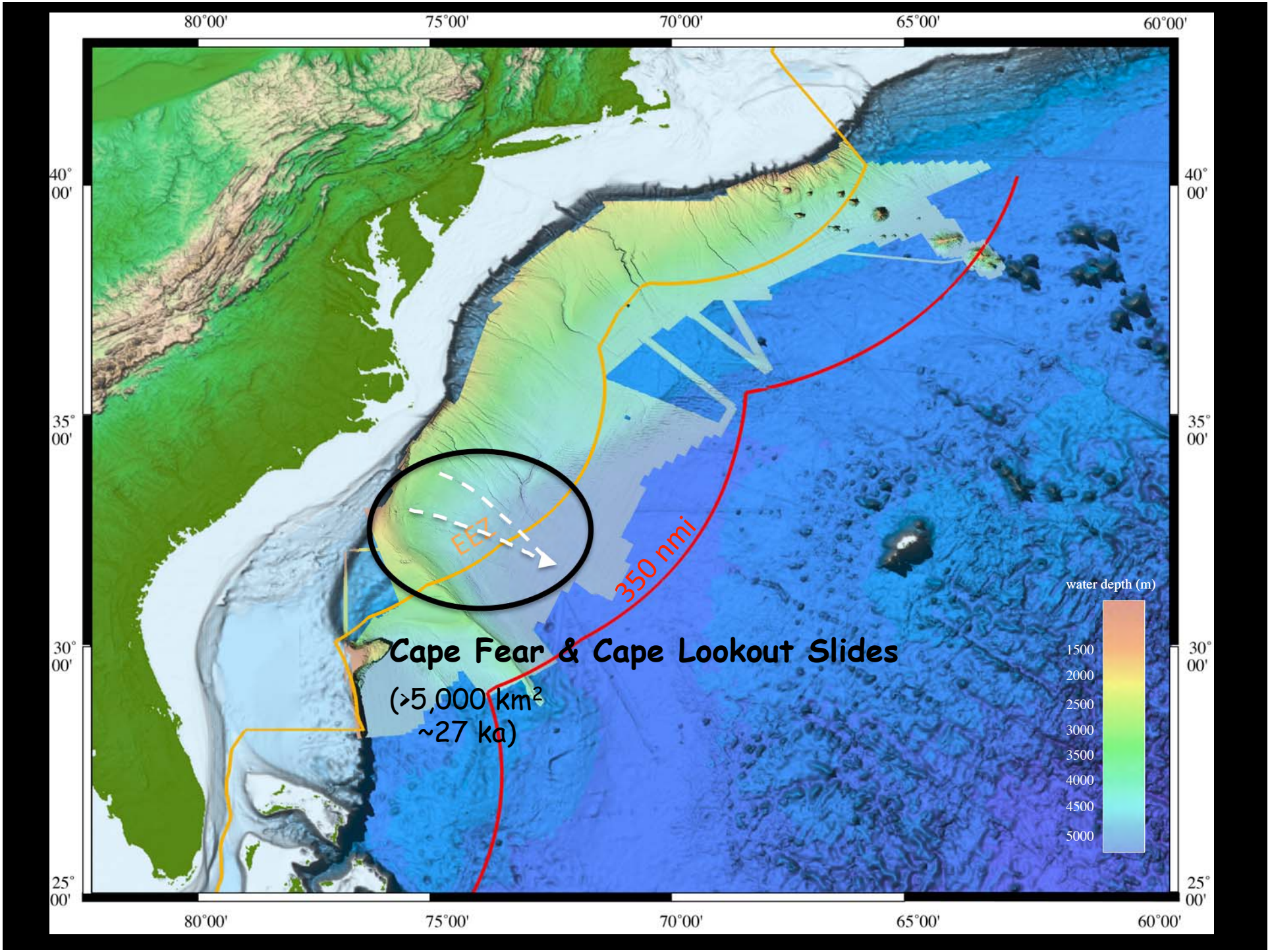
New England Seamounts (bathymetry)



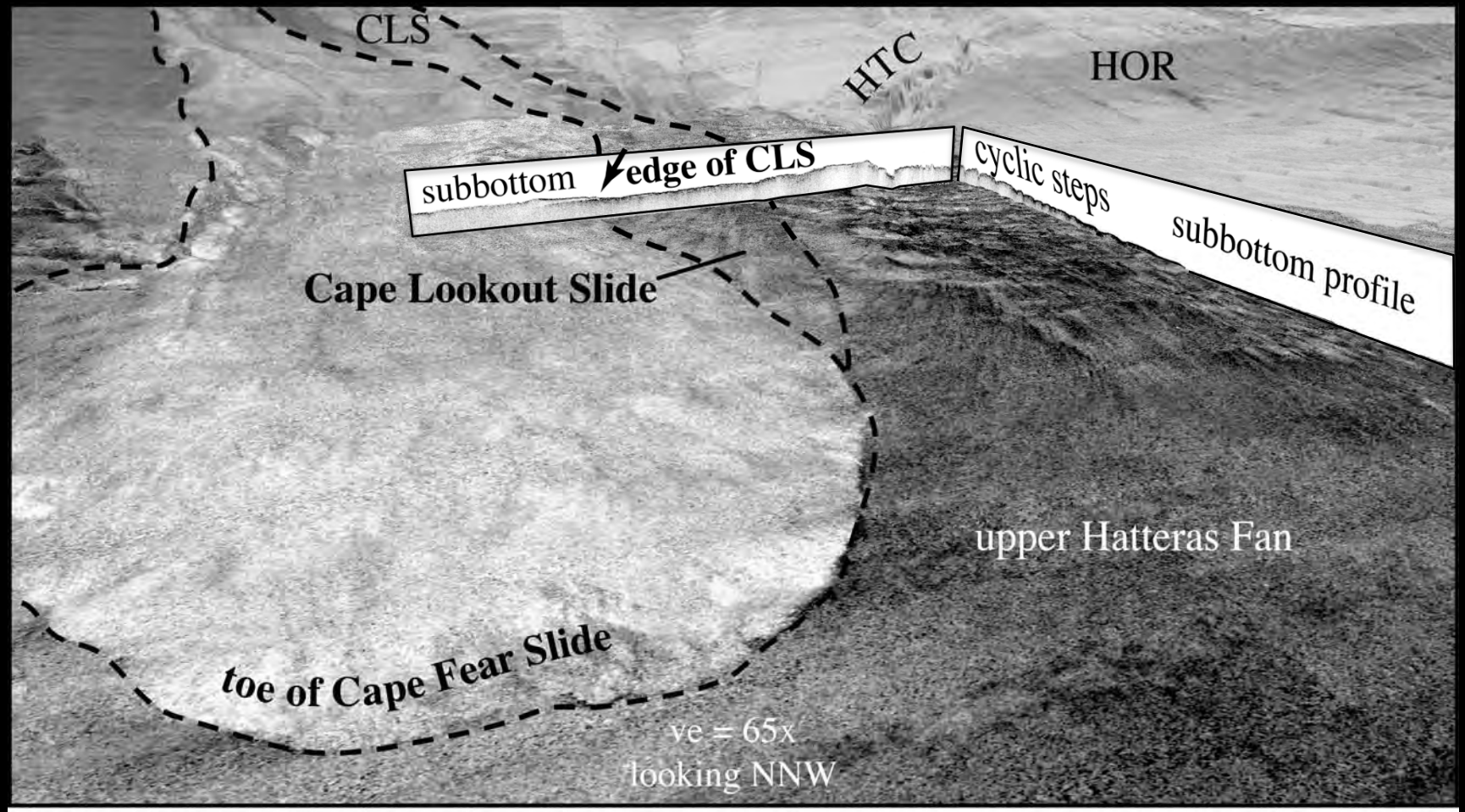
Perspective view, ve = 5x looking NW

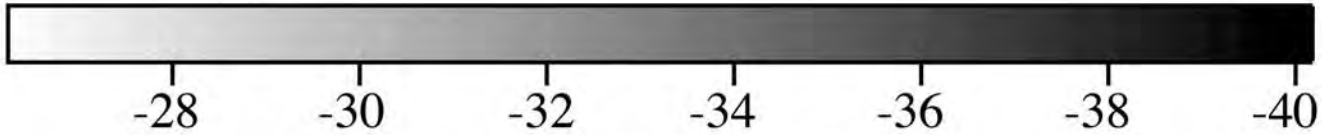
New England Seamounts (backscatter)



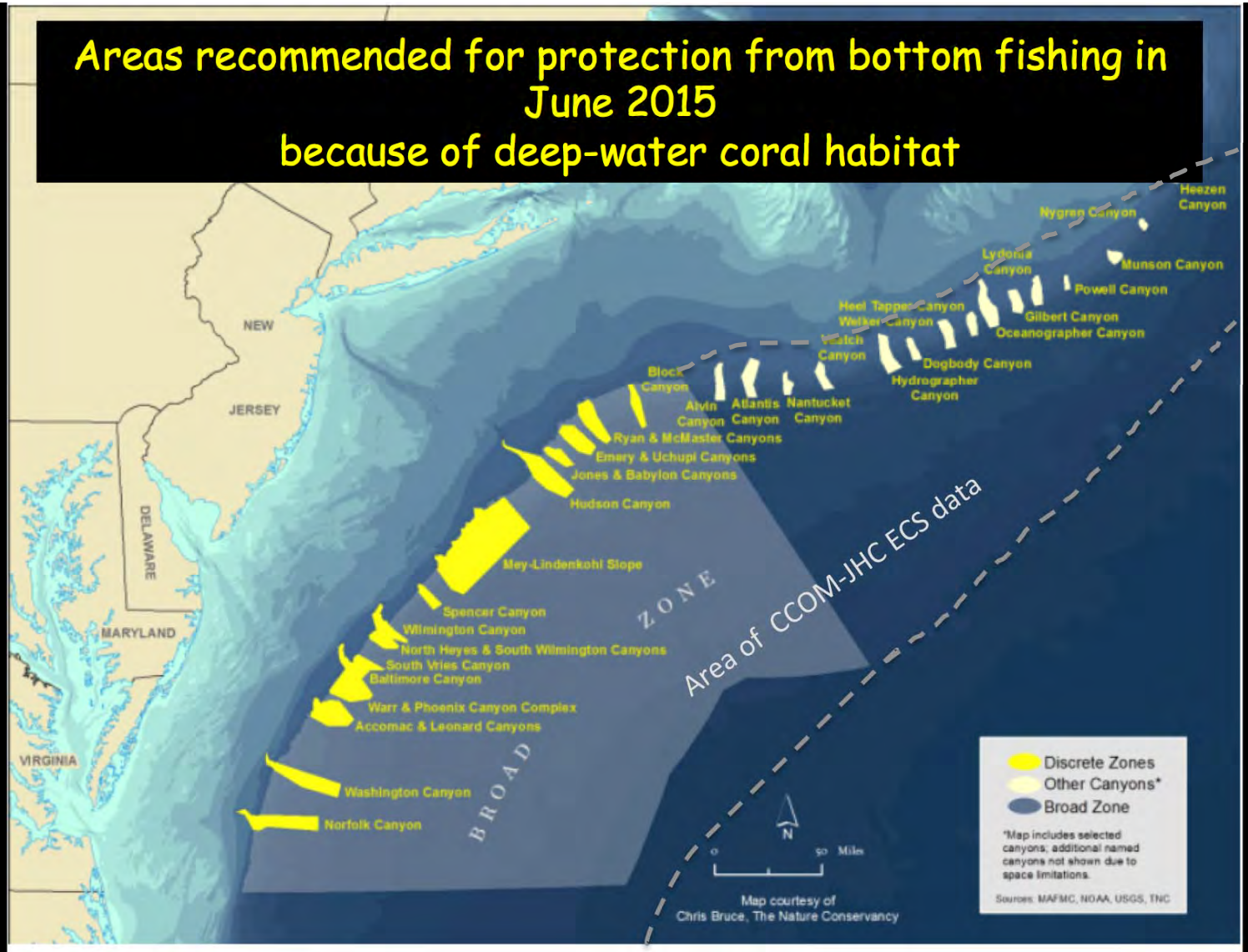

80°00'
75°00'
70°00'
65°00'
60°00'
40° 00'
35° 00'
30° 00'
25° 00'
EEZ
350 nmi
Cape Fear & Cape Lookout Slides
(>5,000 km²
~27 ka)
water depth (m)
1500
2000
2500
3000
3500
4000
4500
5000

perspective view of backscatter draped on bathymetry





Areas recommended for protection from bottom fishing in June 2015 because of deep-water coral habitat



A map depicting the 15 discrete protected zones (in yellow) and large broad protected zone, as agreed upon by the MAFMC. The total area of these proposed zones spans 38,000 square kilometers, roughly the size of Virginia. Credit: The Nature Conservancy

From NCCOS News and Features 25 June 2015

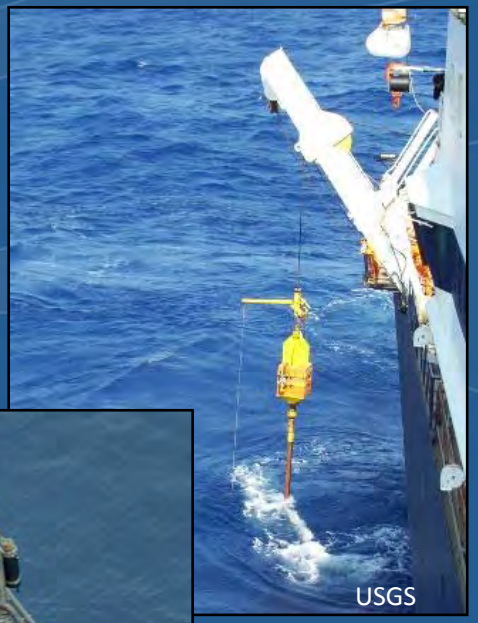
Derek Sowers (OER/CCOM) - Ph.D Thesis

Can ECS and other multibeam data from the Atlantic Margin, along with other existing ancillary datasets, to generate marine ecological classification maps and potential habitat prediction maps useful for supporting Ecosystem-Based Management?

1. Ground truth data

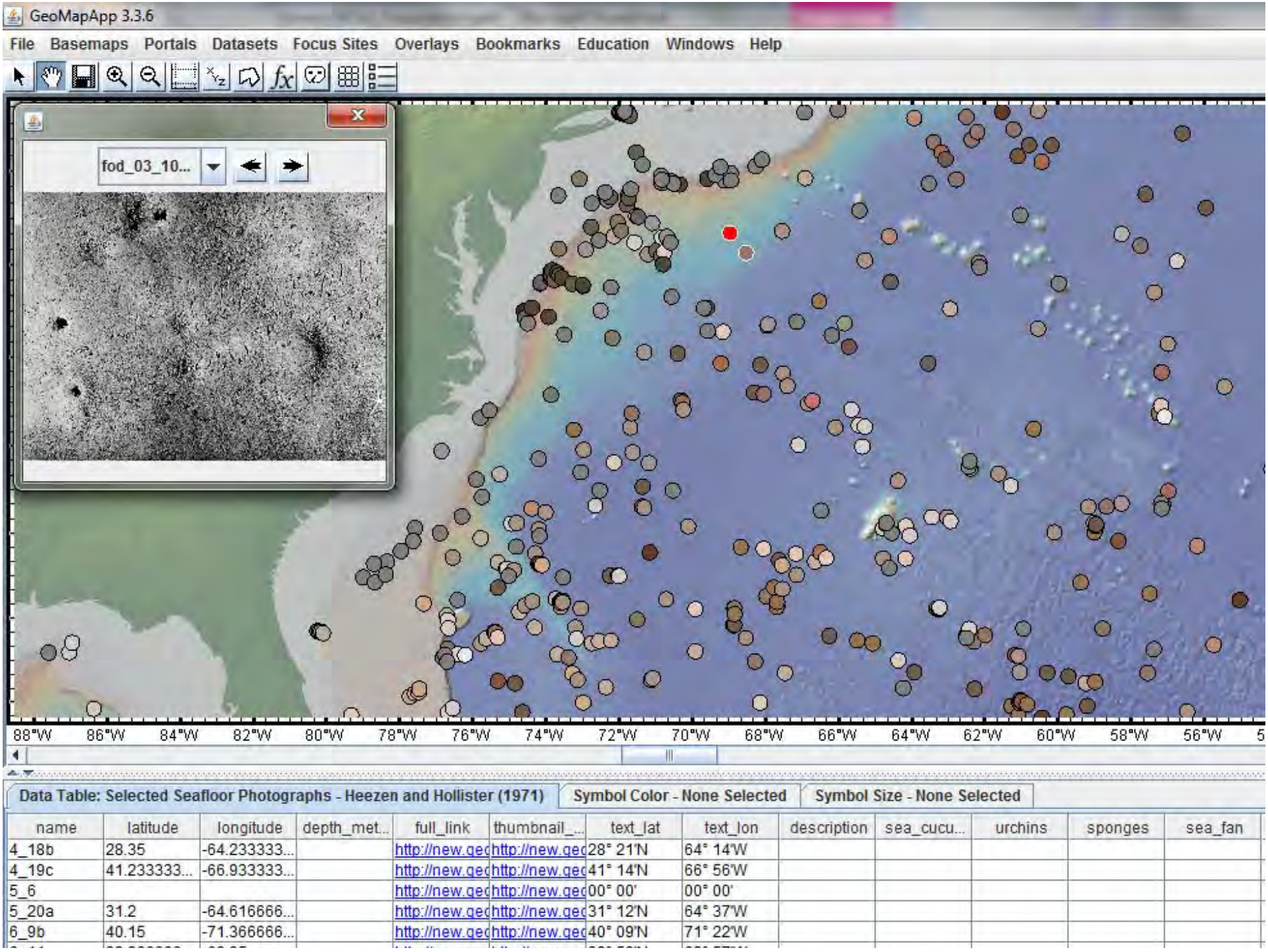
- Video
- Photos


Nizinski et al. NOAA/NMFS/NEFSC, WHOI 2012


USGS


NOAA Ocean Explorer

- Sediment Grabs/Cores
- Biological Samples

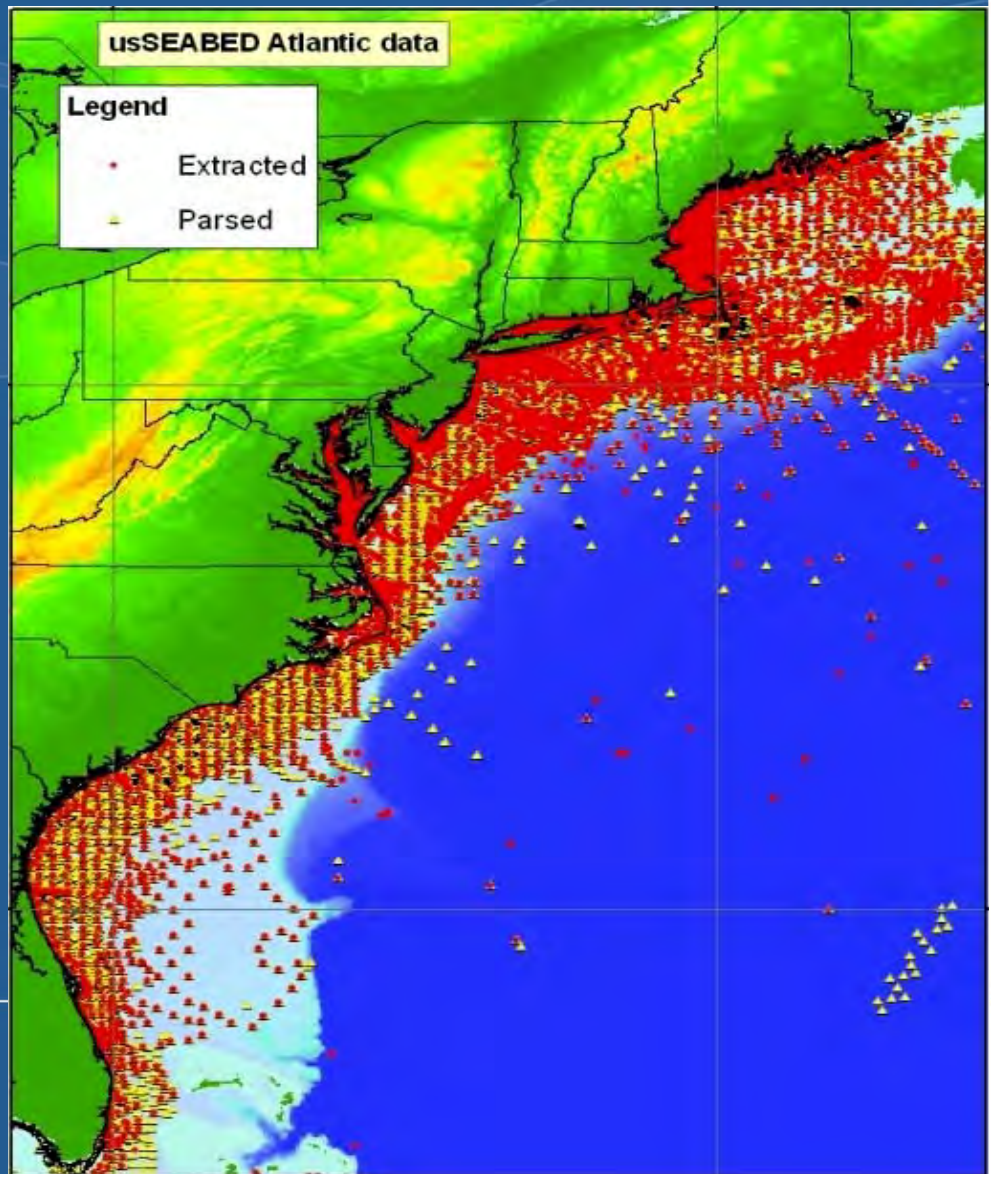


Data Table: Selected Seafloor Photographs - Heezen and Hollister (1971) | Symbol Color - None Selected | Symbol Size - None Selected

name	latitude	longitude	depth_met...	full_link	thumbnail_...	text_lat	text_lon	description	sea_cucu...	urchins	sponges	sea_fan
4_18b	28.35	-64.233333...		http://new.geo	http://new.geo	28° 21'N	64° 14'W					
4_19c	41.233333...	-66.933333...		http://new.geo	http://new.geo	41° 14'N	66° 56'W					
5_6				http://new.geo	http://new.geo	00° 00'	00° 00'					
5_20a	31.2	-64.616666...		http://new.geo	http://new.geo	31° 12'N	64° 37'W					
6_9b	40.15	-71.366666...		http://new.geo	http://new.geo	40° 09'N	71° 22'W					

Sediment Samples: usSEABED (USGS)

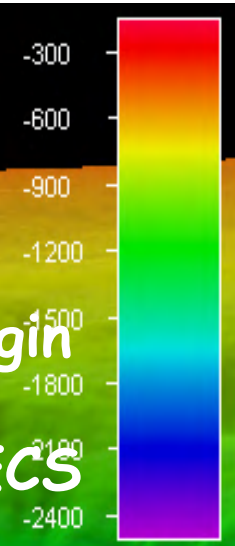
- 150 data sources
- 200,000 data points



http://pubs.usgs.gov/ds/2005/118/

http://www.csc.noaa.gov/digitalcoast/publications/cmecs

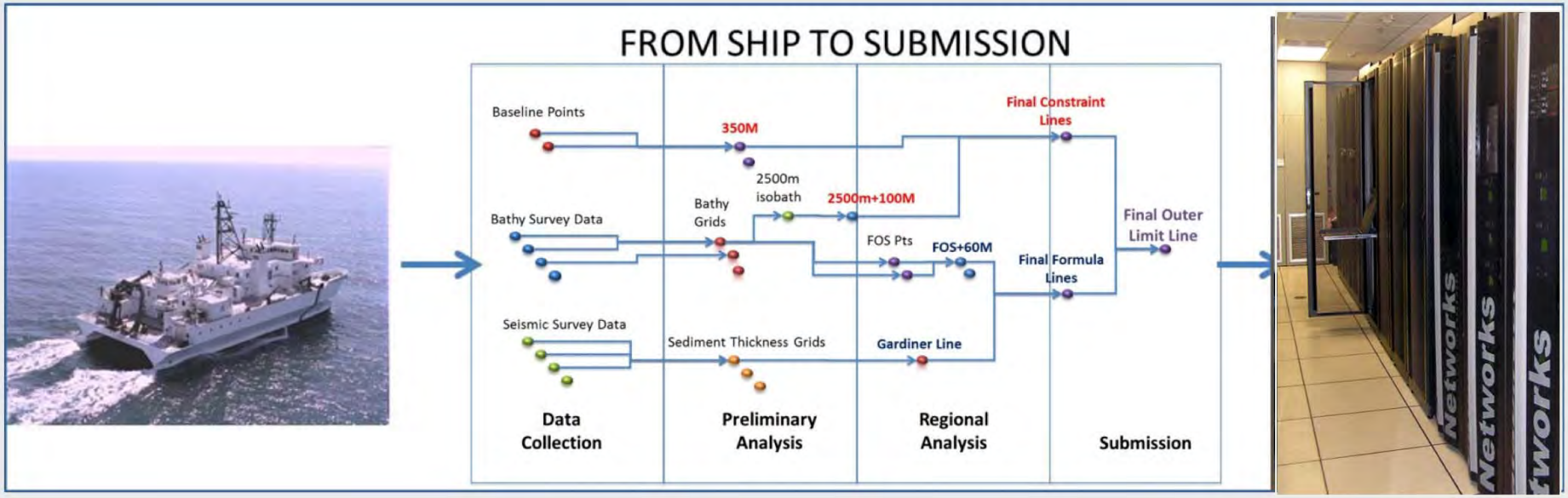
Anticipated Results:



1. CMECS habitat maps of ECS area of Atlantic Margin
2. Protocols on how to apply this approach to other ECS datasets
3. Recommendations on the type and location of future data gathering efforts that would substantially improve our ability to classify and map marine habitat in this region
4. Improved capability to utilize multibeam sonar data to identify potential Habitats of Particular Concern (with emphasis on deepwater corals)

ECS Data Management

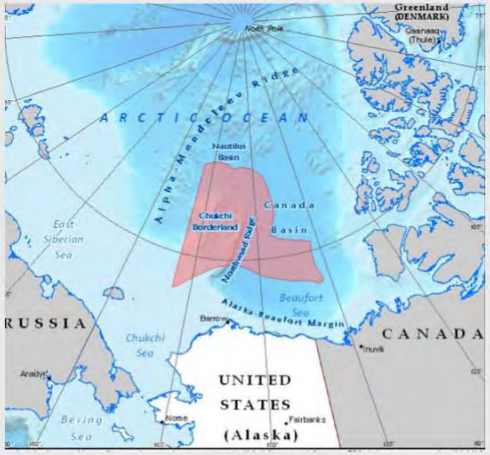
Leveraging NOAA's National Data Center infrastructure (**human, hardware, and software**) to manage and document data from collection through product generation and analysis, to final delineation of our maritime limits.

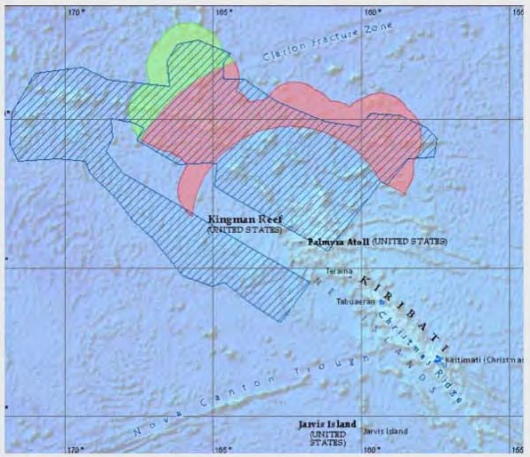


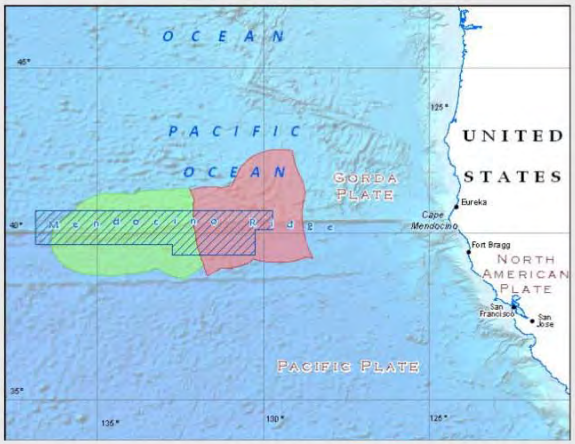
Proposed FY16-18 Activities

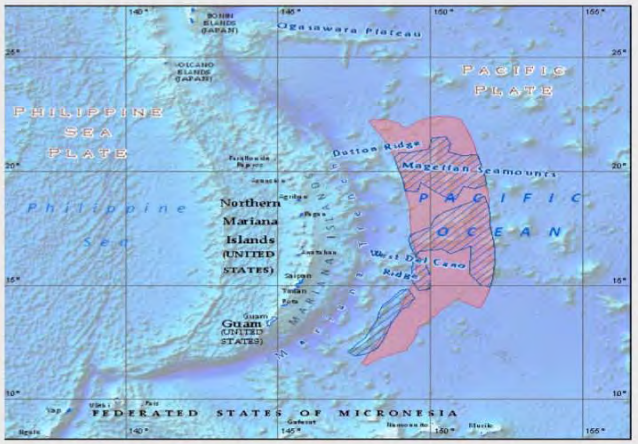
Bathymetric Surveys:

- Central Pacific
- Western Pacific
- Gulf of Alaska
- Arctic?
- Mendocino Ridge (samples?)

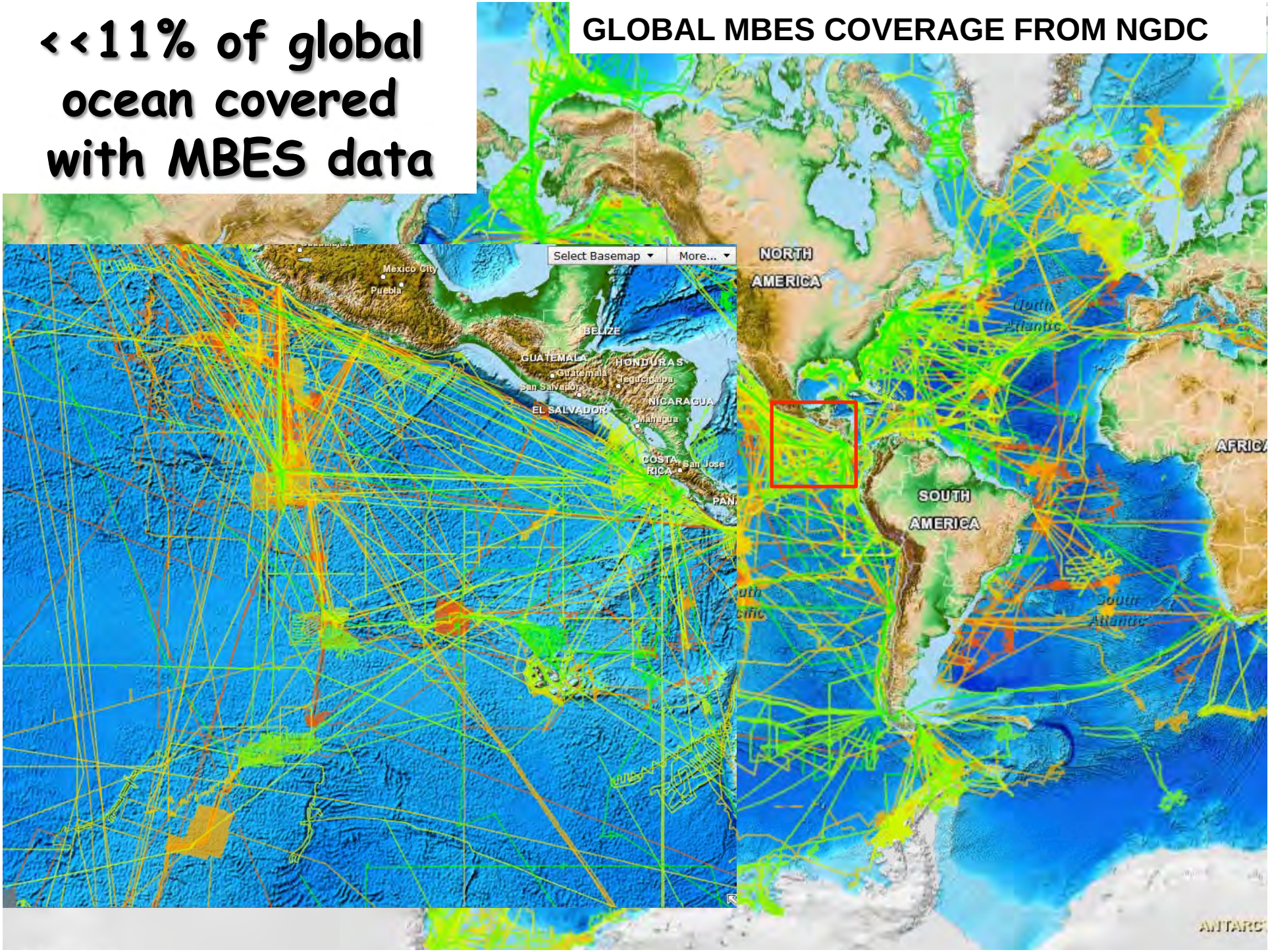


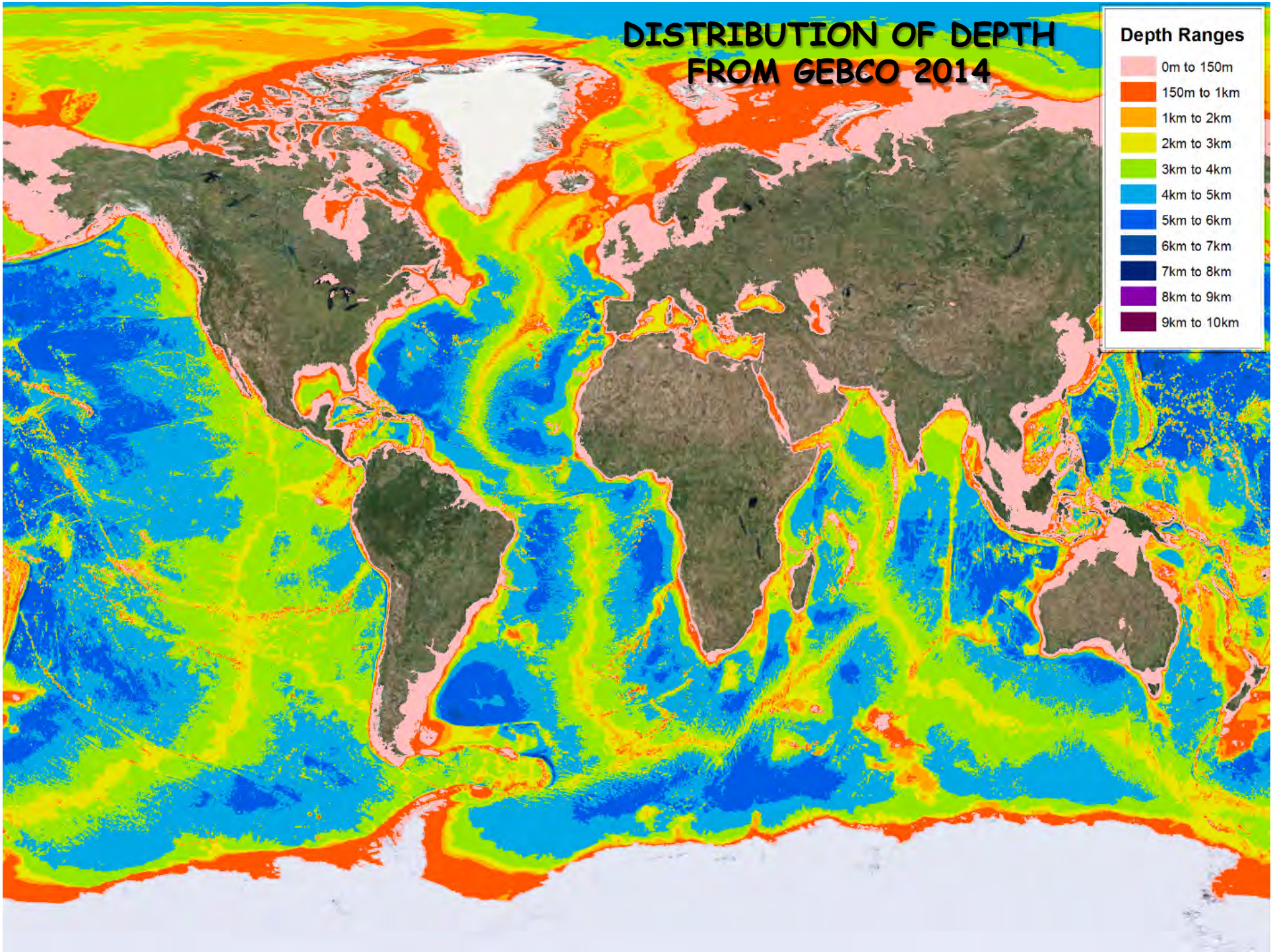




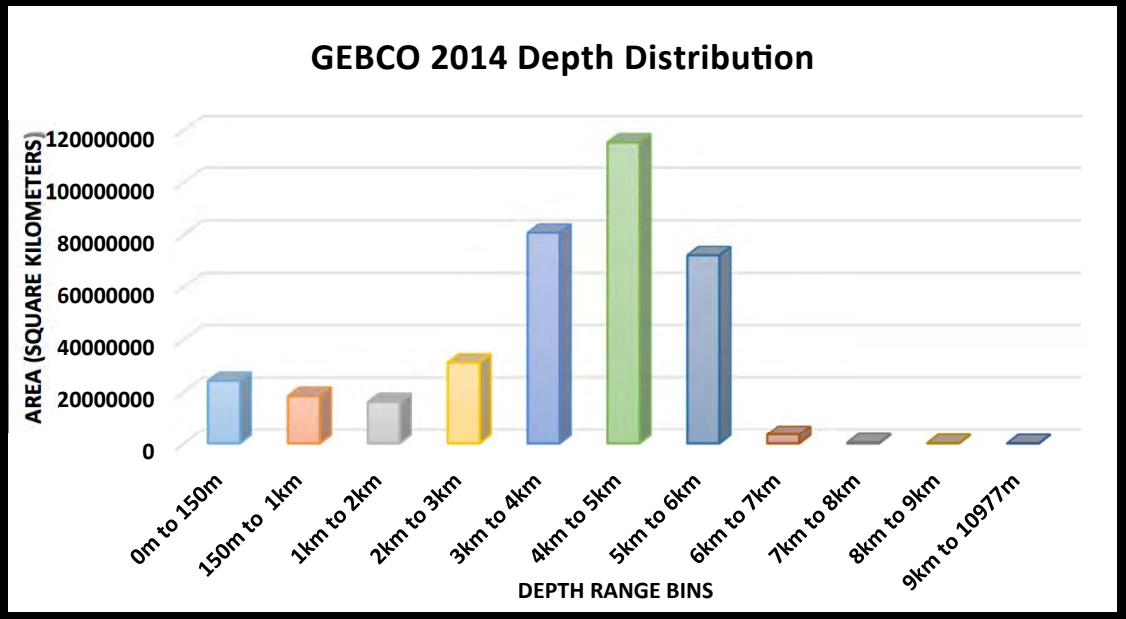


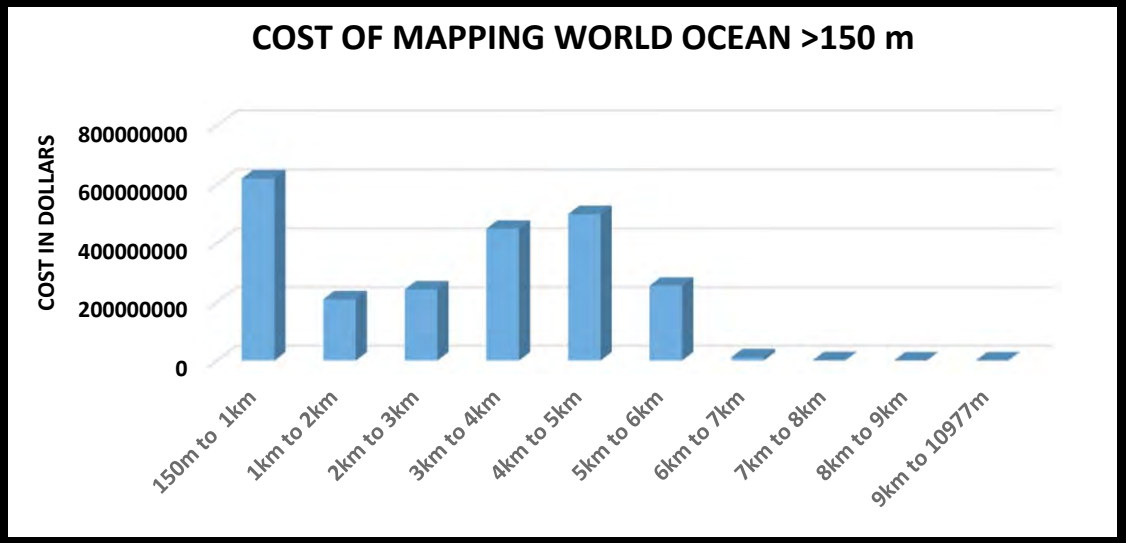
<<11% of global ocean covered with MBES data




DISTRIBUTION OF DEPTH
FROM GEBCO 2014
Depth Ranges
0m to 150m
150m to 1km
1km to 2km
2km to 3km
3km to 4km
4km to 5km
5km to 6km
6km to 7km
7km to 8km
8km to 9km
9km to 10km

MAPPING THE WORLD OCEAN WITH MBES





Assuming:
4x swath width
10 knots

Number of Days:
65,246

Ship Cost:
$35,000/day

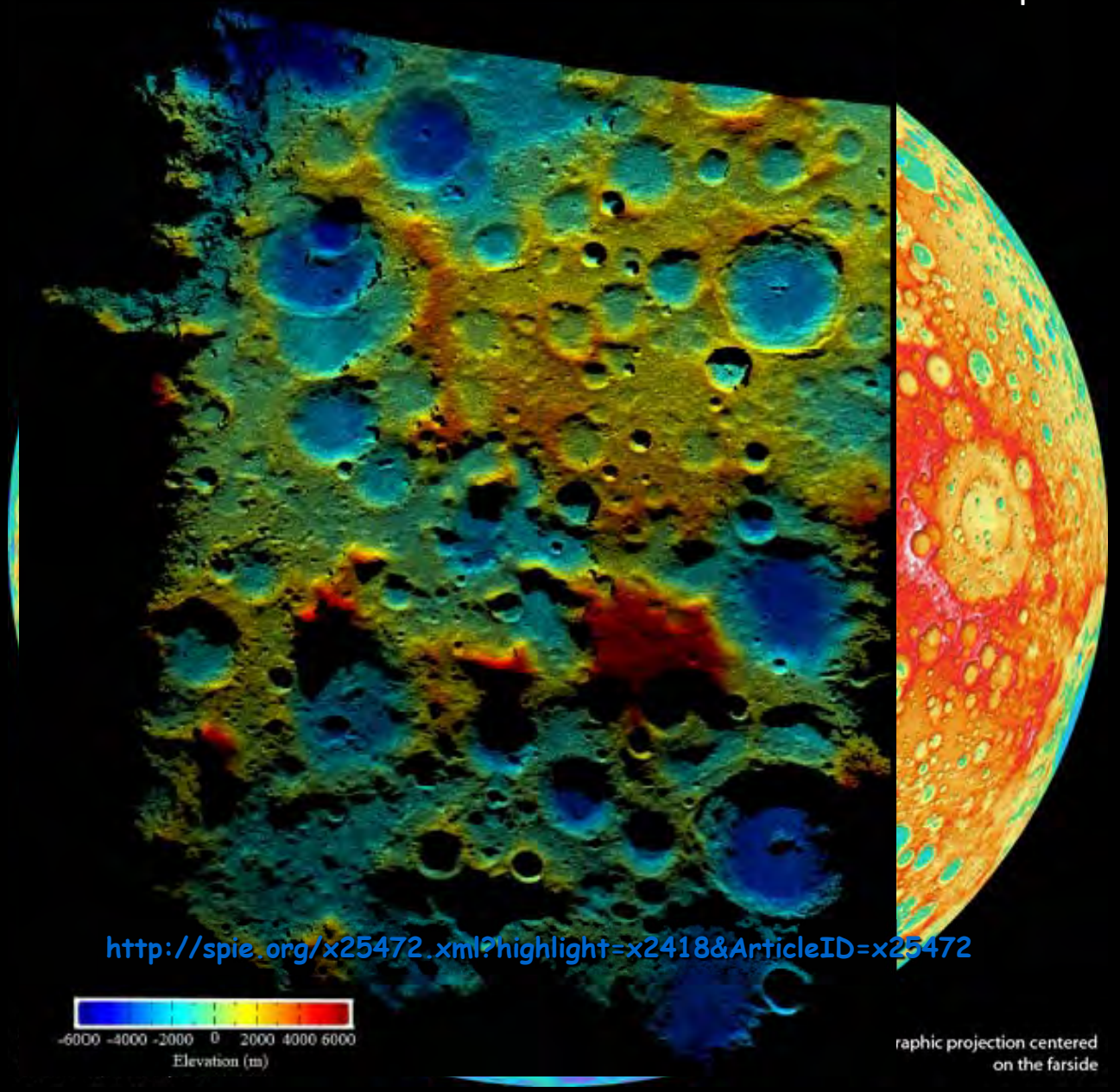
Total Cost:
$2.28 Billion

Lunar Reconnaissance Orbiter

THE MOON

100m pixel resolution

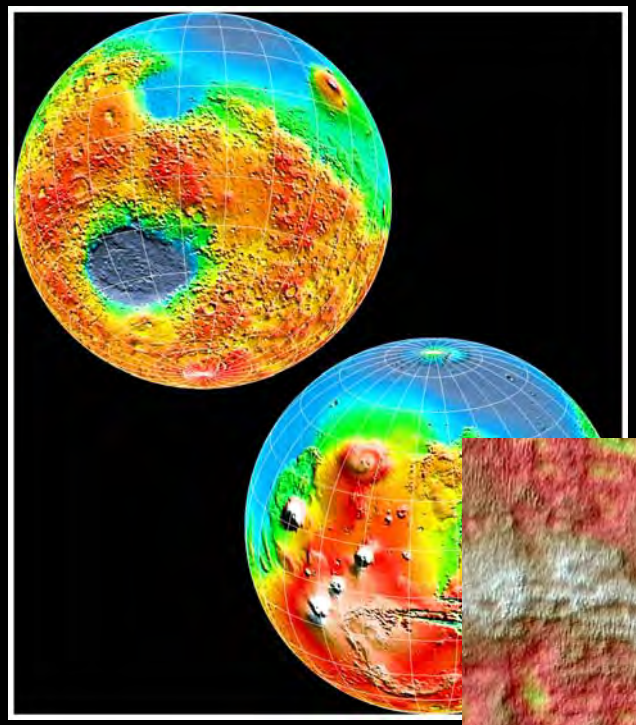
~$600M



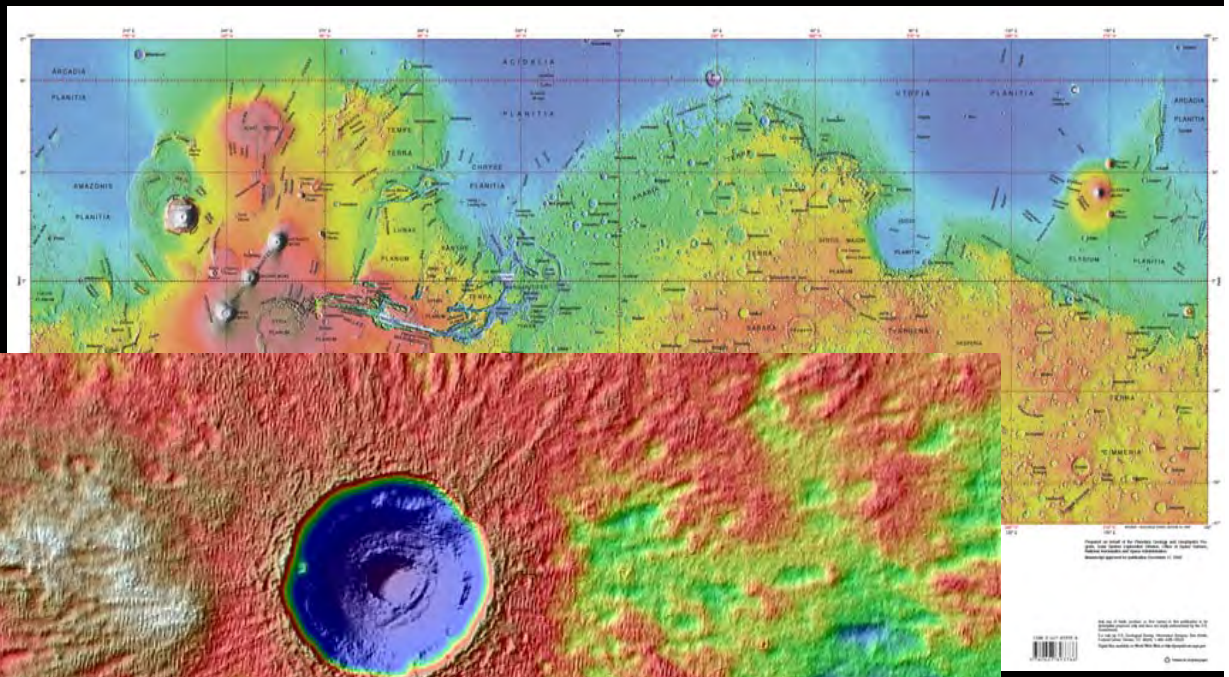
http://spie.org/x25472.xml?highlight=x2418&ArticleID=x25472

http://www.nasa.gov/mission_pages/LRO/news/lro-topo.html

TOPOGRAPHY OF MARS



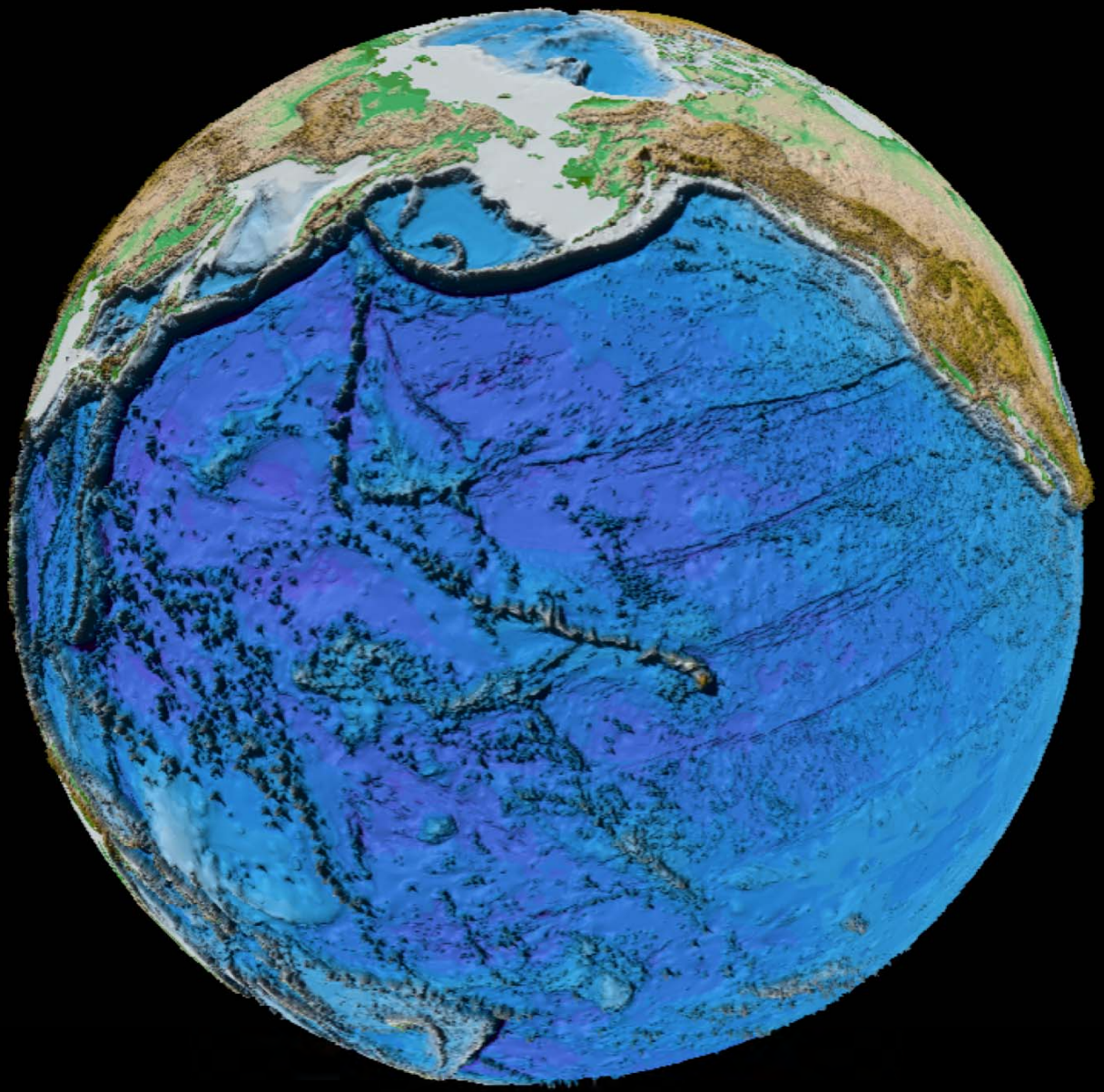
http://tharsis.gsfc.nasa.gov/global_pa



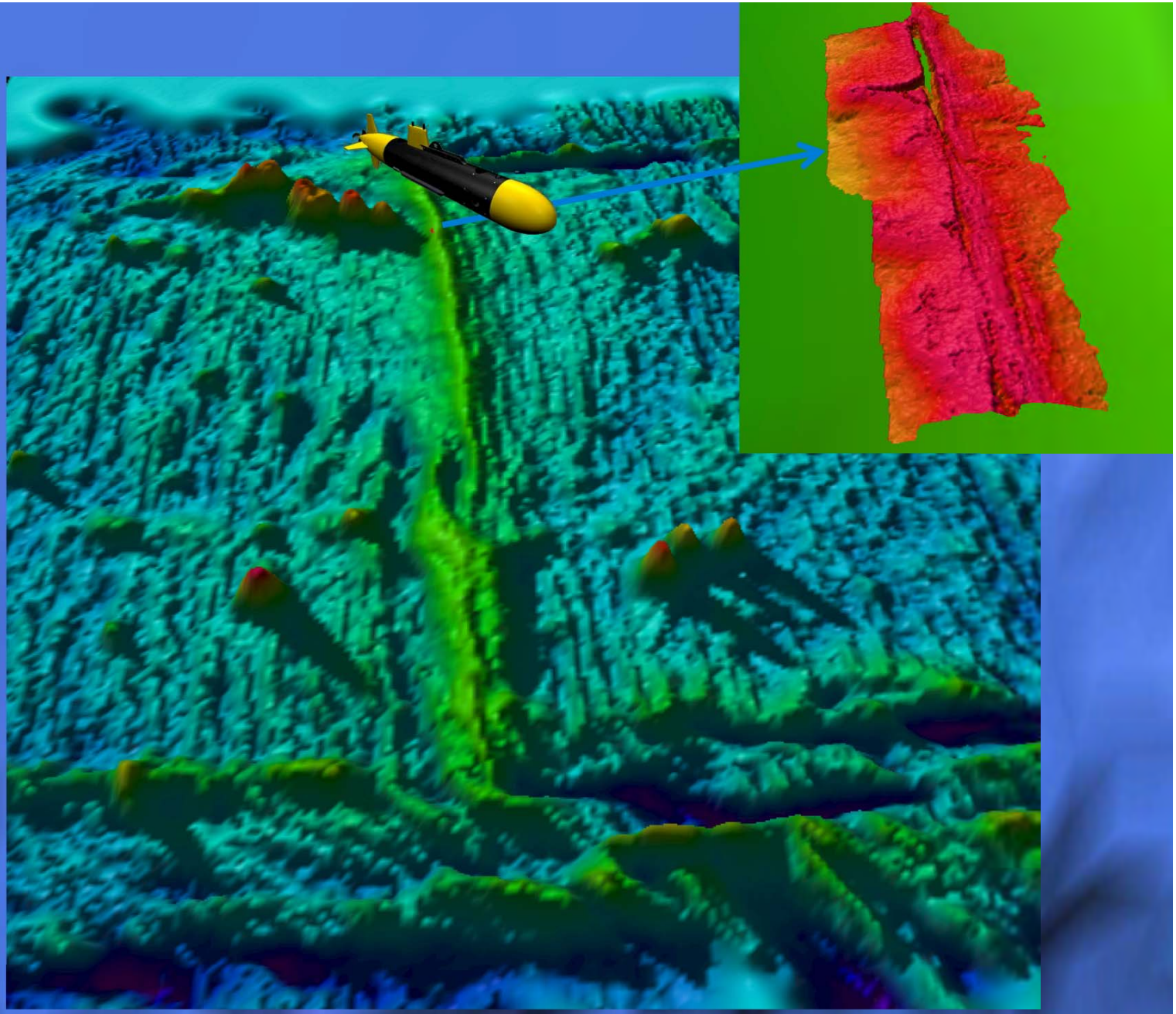
HIRISE Imagery NASA/JPL/UAriz/USGS
http://www.uahirise.org/dtm
1 m DTMs

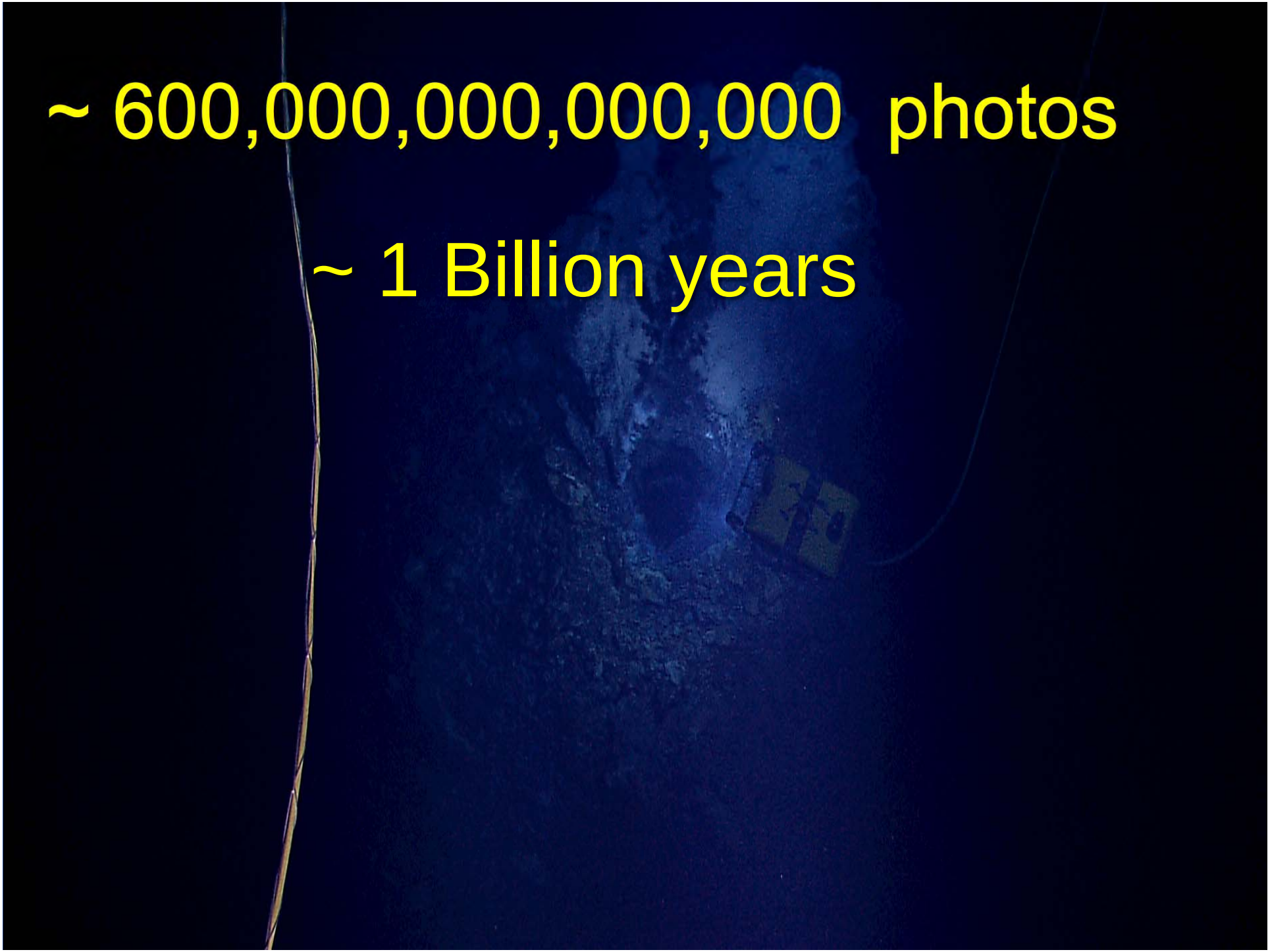
2-3 B$

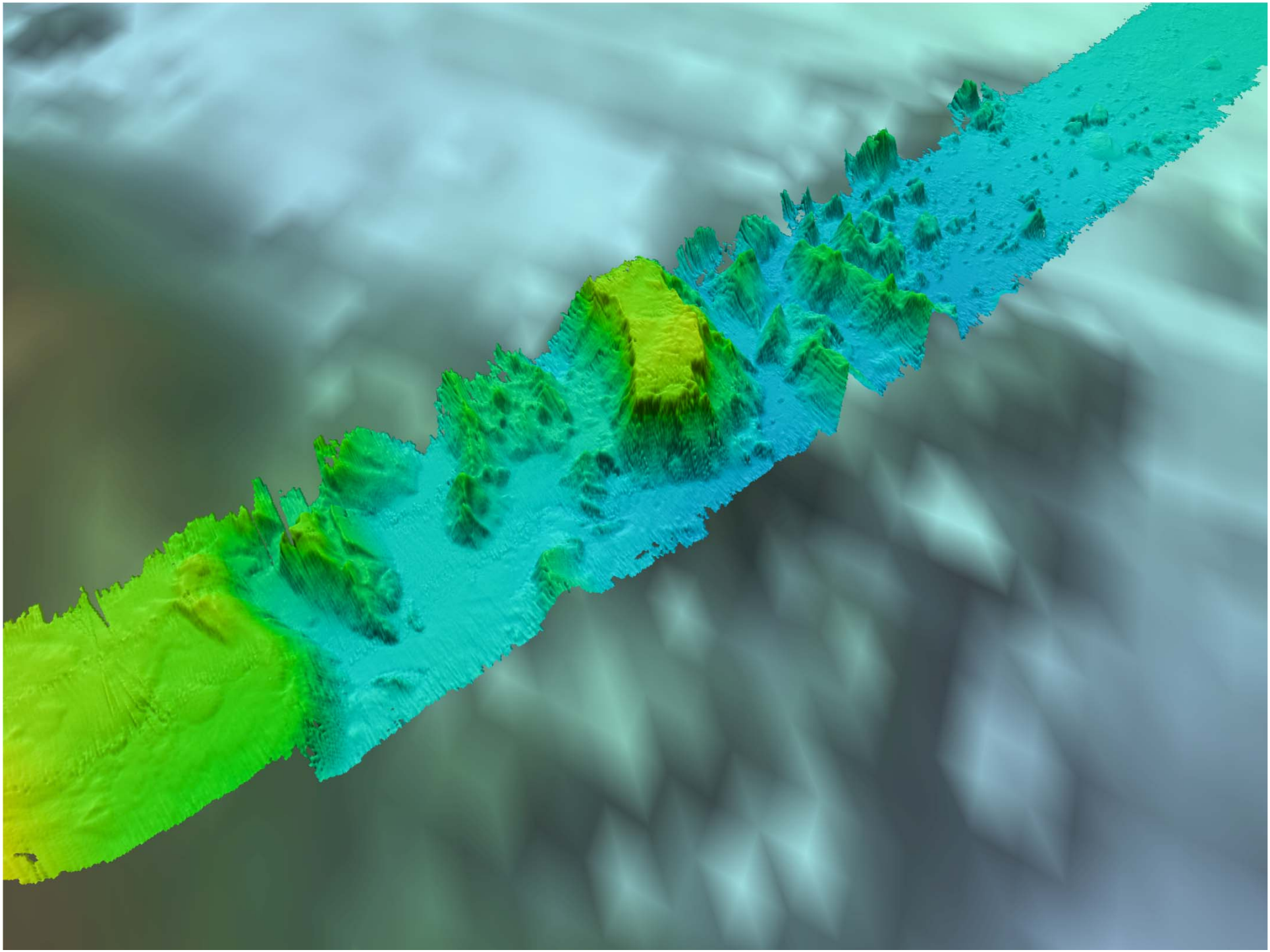
And Earth?



And Earth?




~ 600,000,000,000,000 photos
~ 1 Billion years



There is so much more to explore right here at home!