The Importance of the Information from the Past for a Planet under Pressure:

Case studies from the Portuguese Margin

Fatima Abrantes

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM

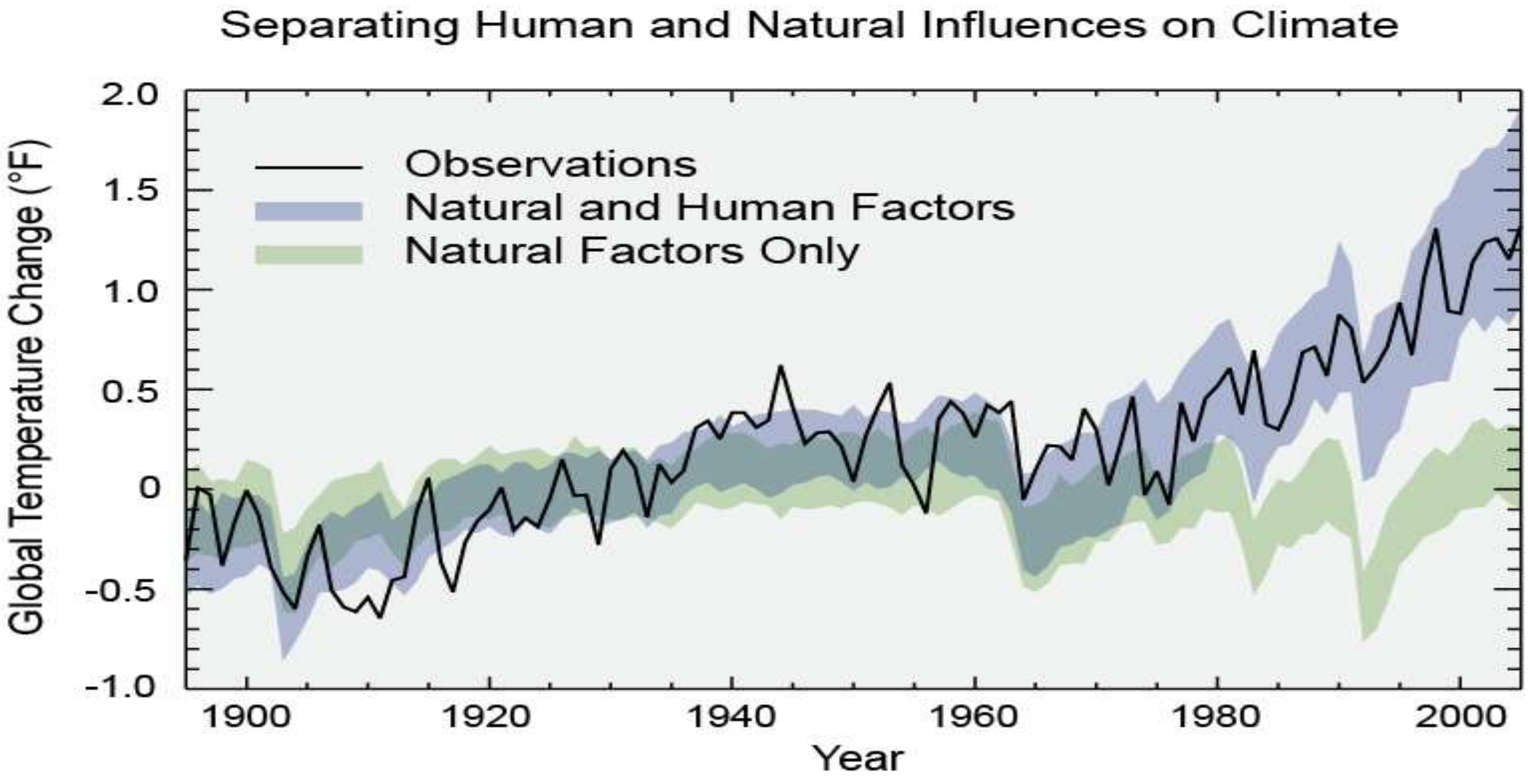
CCMAR Centro de Ciências do Mar Algarve

IPMA

IMPORTANCE OF PALEO STUDIES

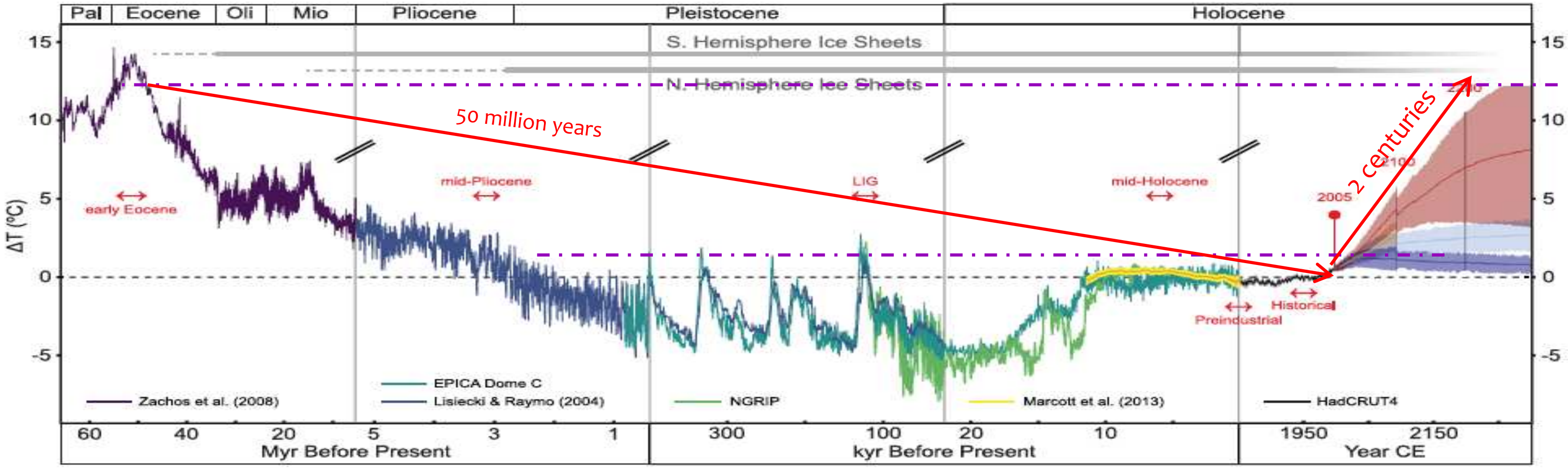
- Instrumental data only available for the last 150yr and it is scattered;
- Satellite data ± 30yr;
- Climate warming started in 1850, so, most instrumental data is from a changing period;

Fundamental to understand natural variability and gain information about the natural climate system before human action.



U.S. Natinal Climate Assessment (2014)

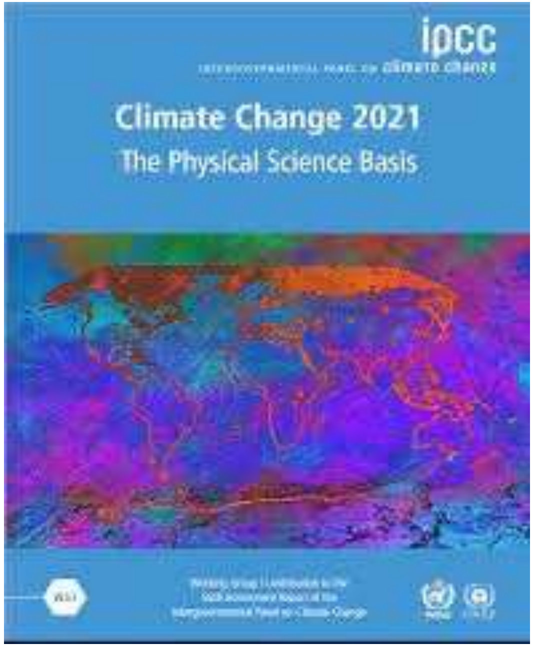
THE CLIMATE OF THE LAST 60 Ma



Burke et al, PNAS 2018

The scale of recent changes is unprecedented in thousands, if not hundreds of thousands of years. Many changes due to past and future greenhouse gas emissions **are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.**

CLIMATE CHANGE IS A REALITY

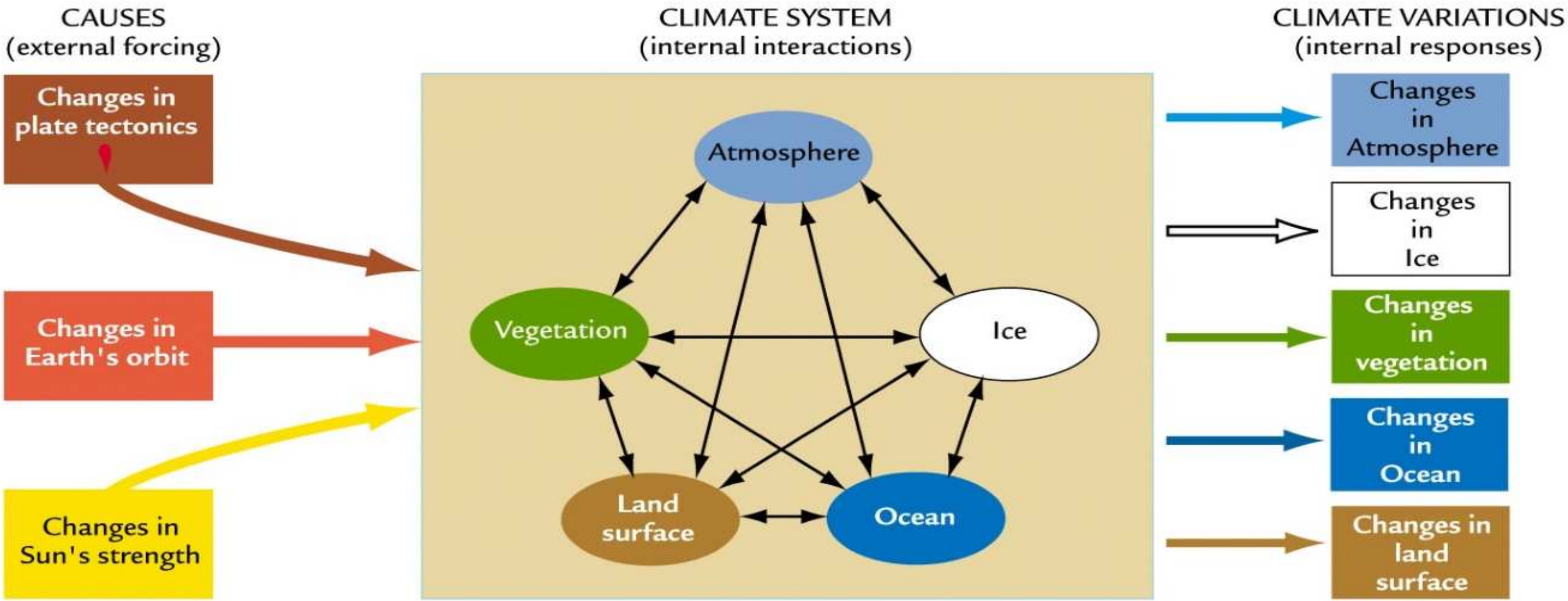


The Intergovernmental Panel on Climate Change (IPCC) Working Group I report, Climate Change 2021

https://public.wmo.int/en/media/press

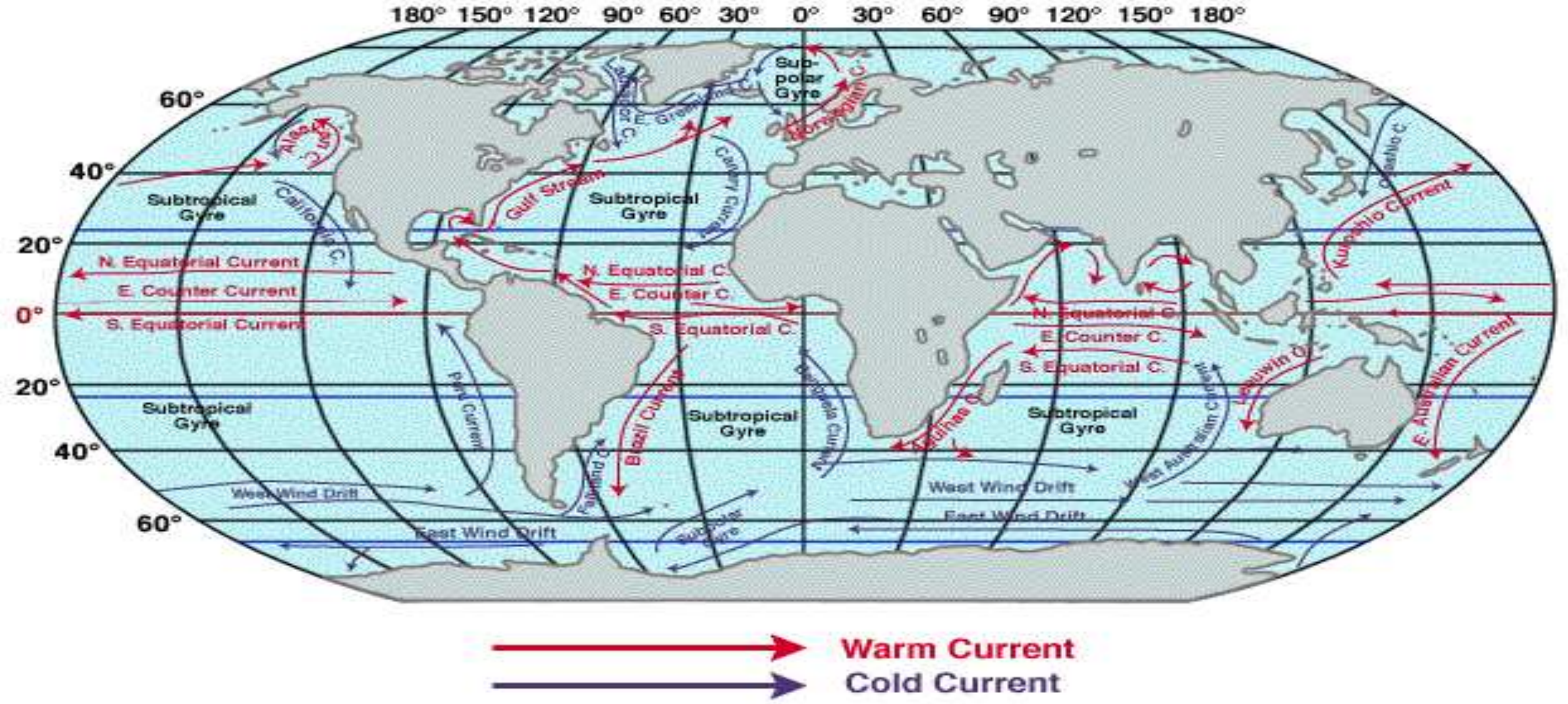
CLIMATIC SYSTEM

EXTERNAL FORCING, INTERNAL INTERACTIONS AND RESPONSES



Rudimman, 2002

OCEAN CIRCULATION - SURFACE



(C. = Current)

TERMOHALINE CIRCULATION

http://www.pucrs.br/cepac/download/CirculacaoOceanica_Villwock.pdf

THE IMPORTANCE OF THE OCEAN

(1) The ocean **covers 71% of the planet;**

(2) The ocean contains 60xs more C than the atmosphere;

(3) The ocean has a **higher thermal capacity than the atmosphere;**

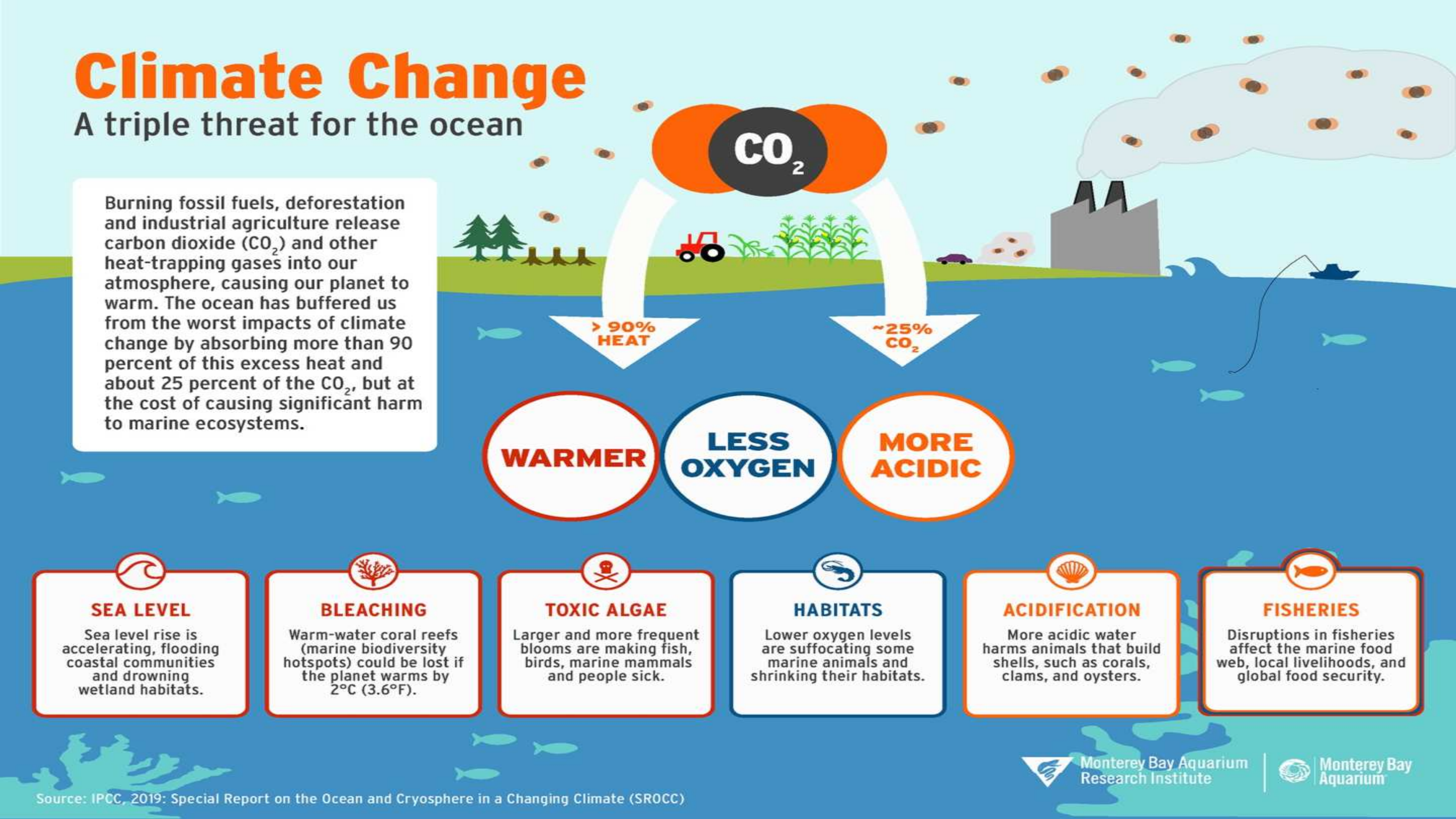
(4) The ocean plays a **regulatory role on climate, and the C and nutrient cycles**;

(5) The ocean contributes **± 50% of the planet's primary production and O_2 production**;

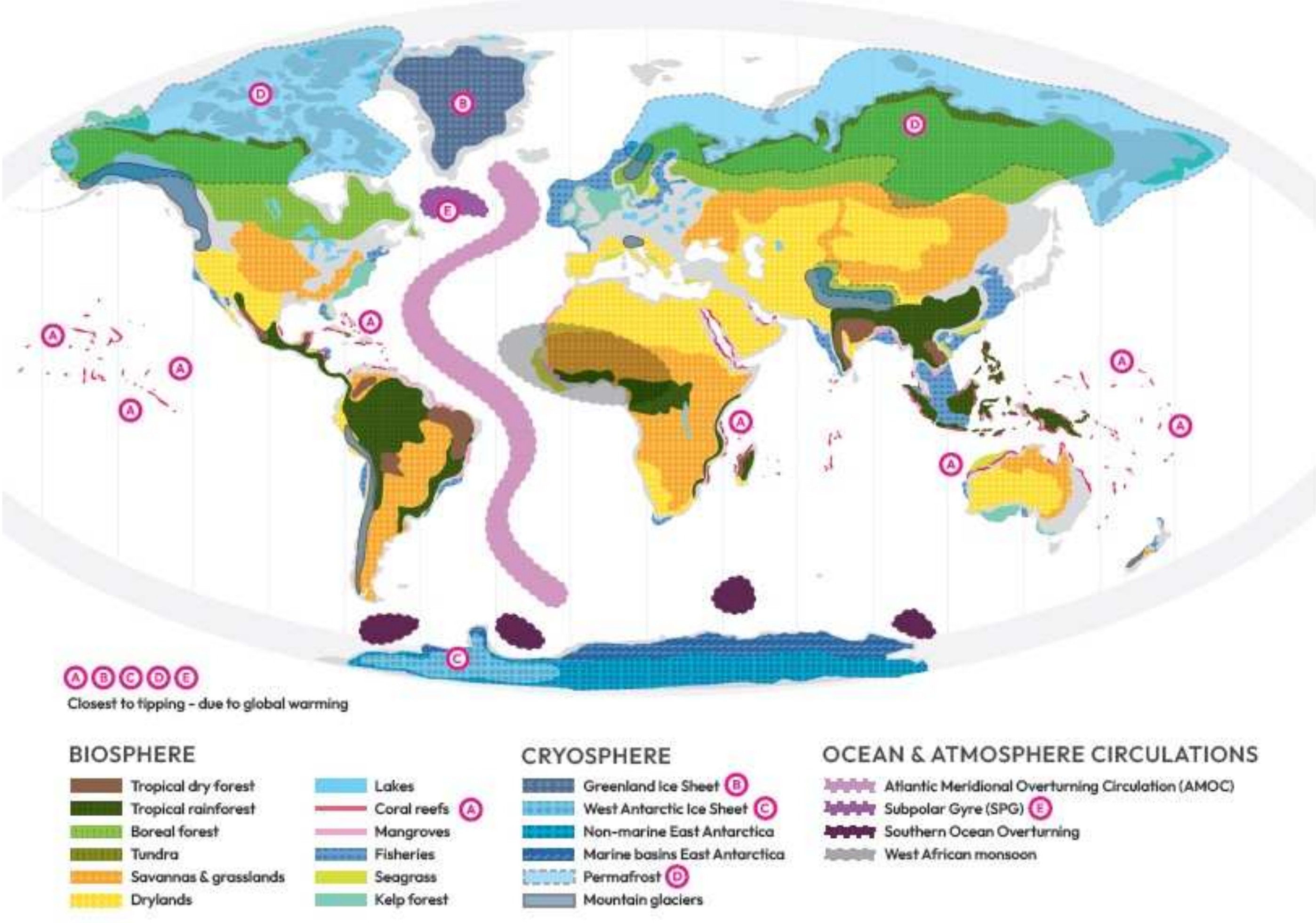
(6) Suports an **enormeous biodiversity**;

(7) Provides social, economic and services (**90% of global value**)

Etc…


Climate Change
A triple threat for the ocean
Burning fossil fuels, deforestation and industrial agriculture release carbon dioxide (CO_2) and other heat-trapping gases into our atmosphere, causing our planet to warm. The ocean has buffered us from the worst impacts of climate change by absorbing more than 90 percent of this excess heat and about 25 percent of the CO_2, but at the cost of causing significant harm to marine ecosystems.
CO_2
> 90% HEAT
~25% CO_2
WARMER
LESS OXYGEN
MORE ACIDIC
SEA LEVEL
Sea level rise is accelerating, flooding coastal communities and drowning wetland habitats.
BLEACHING
Warm-water coral reefs (marine biodiversity hotspots) could be lost if the planet warms by 2°C (3.6°F).
TOXIC ALGAE
Larger and more frequent blooms are making fish, birds, marine mammals and people sick.
HABITATS
Lower oxygen levels are suffocating some marine animals and shrinking their habitats.
ACIDIFICATION
More acidic water harms animals that build shells, such as corals, clams, and oysters.
FISHERIES
Disruptions in fisheries affect the marine food web, local livelihoods, and global food security.
Monterey Bay Aquarium Research Institute
Monterey Bay Aquarium
Source: IPCC, 2019: Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)

GLOBAL TIPPING POINTS



Report Funded by:
BEZOS EARTH FUND
2023

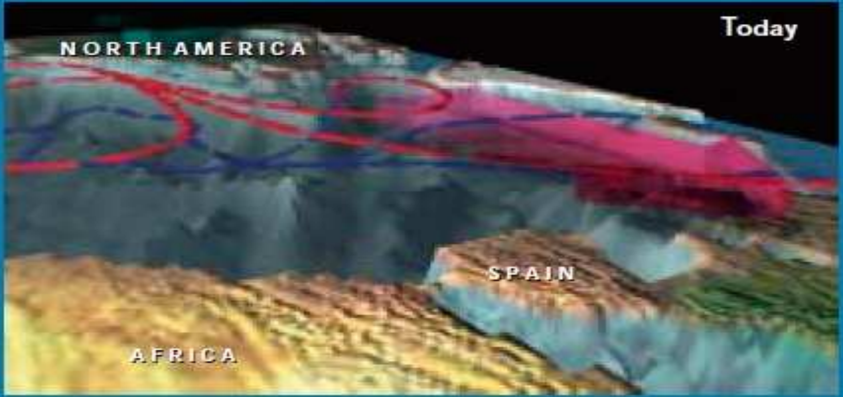
& Led by:
University of Exeter

https://global-tipping-points.org/

CONVEYOR BELT FORCING

Tipping Point

The Conveyor's Achilles' Heel?



The Ocean Conveyor is propelled by the sinking of cold, salty (and therefore denser) waters in the North Atlantic Ocean (blue lines). This creates a void that helps draw warm, salty surface waters northward (red lines). The ocean gives up heat to the atmosphere above the North Atlantic Ocean, and prevailing winds (large red arrows) carry the heat eastward to warm Europe.

If too much fresh water enters the North Atlantic, its waters could stop sinking. The Conveyor would cease. Heat-bearing Gulf Stream waters (red lines) would no longer flow into the North Atlantic, and European and North American winters would become more severe. (See computer animation at www.whoi.edu/institutes/occi/climatechange_wef.html)

European MARINE BOARD
Advancing Seas & Ocean Science

CONSORTIUM FOR Ocean Leadership

THE OCEAN CLIMATE NEXUS

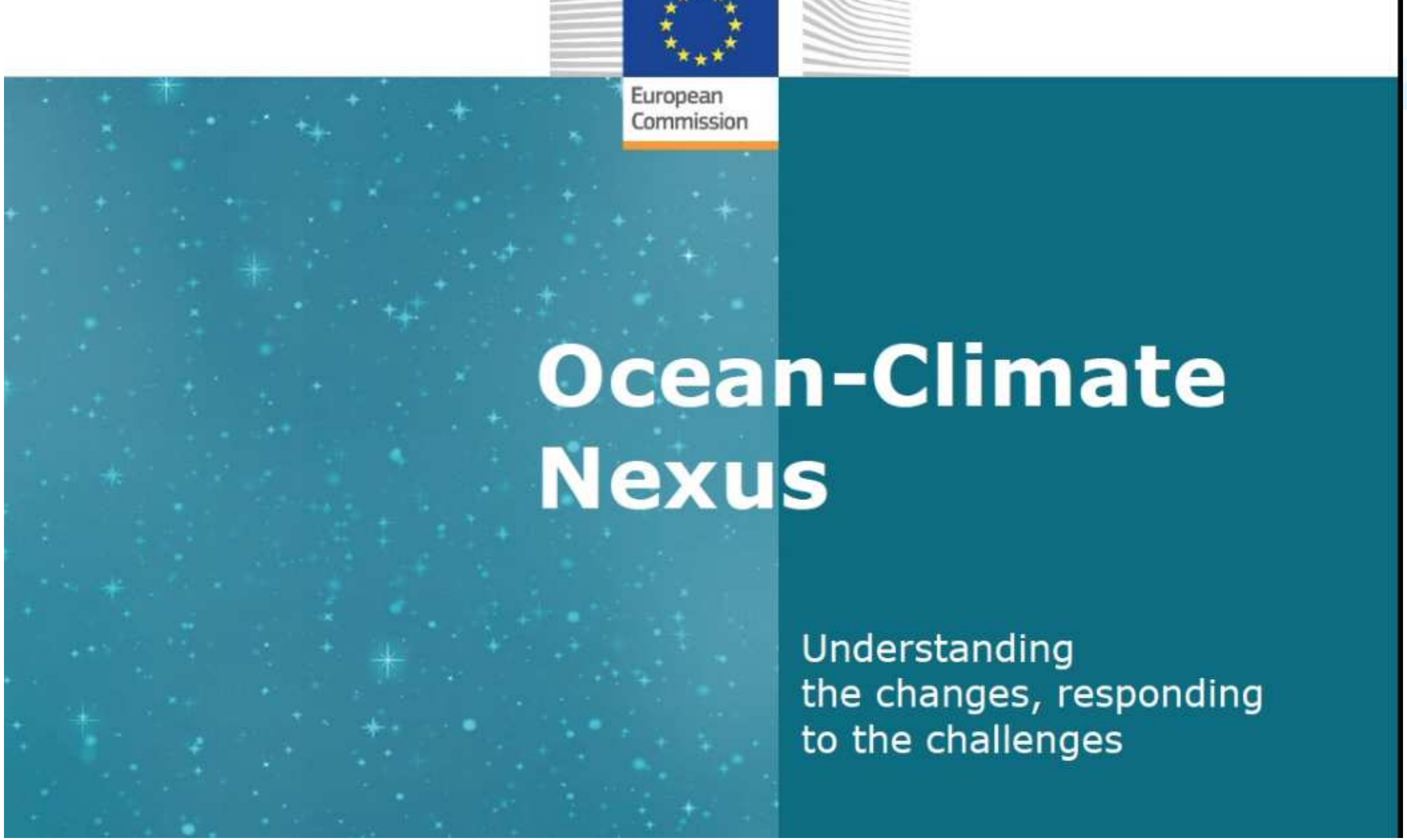
LABEL
PARIS2015
COP21·CMP11

THE CRITICAL ROLE OF OCEAN SCIENCE IN RESPONDING TO CLIMATE CHANGE

A call from the ocean research community

The importance of the ocean-climate connection was recognized for the first time at COP25 in 2019 (Madrid)

Manuscript completed in October 2022.



In the **G7 Ocean Deal** from May 2022, the G7 governments declared the need to *continue to advance our knowledge of the* ***ocean-climate nexus*****.**

A breakthrough for oceans: Scaling Nature-based solutions for ocean-based climate policy at COP28

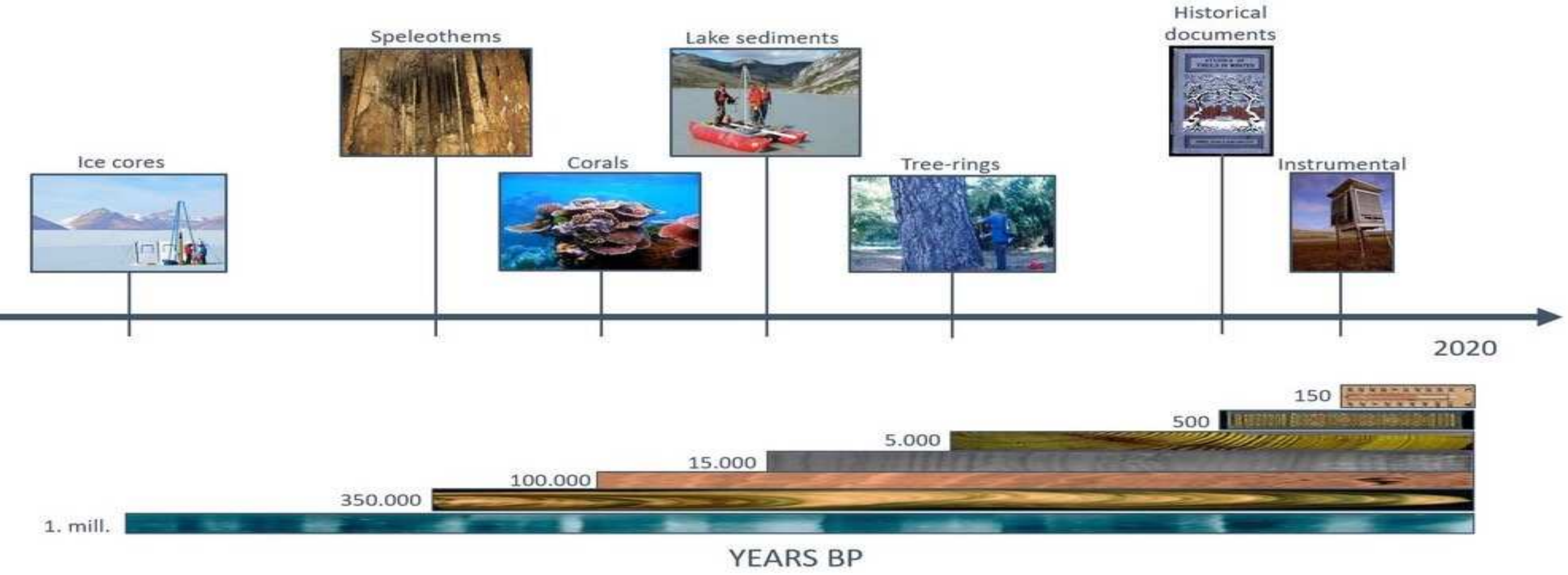
BY KRISTINA RODRIGUEZ, OCEANS & COASTAL ZONE FELLOW | DECEMBER 9, 2023

Joint Declaration on ocean and climate action —the 18 countries of the Ocean Panel were joined by the General Secretariat of the Organization of American States in launching a joint **declaration that recognizes the urgent need to sustainably manage 100% of the ocean under national jurisdictions**. The Declaration also urges countries around the world to join in scaling up ocean-based climate solutions and to **safeguard the long-term health and resilience of the ocean.**

https://climatechampions.unfccc.int/a-breakthrough-for-oceans-scaling-nature-based-solutions-for-ocean-based-climate-policy-at-cop28/

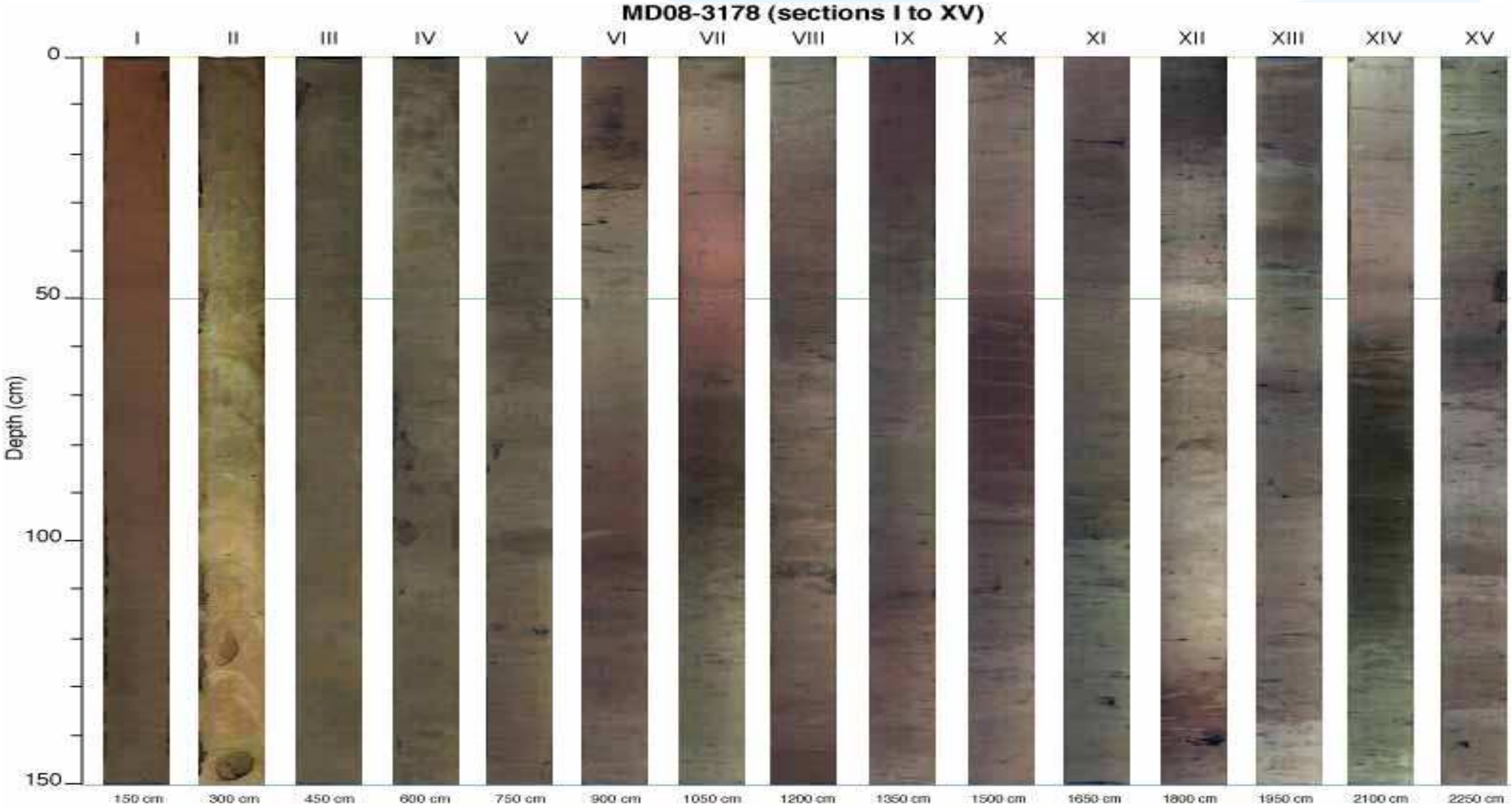
HOW TO EXPAND THE CLIMATE RECORD?

NATURAL CLIMATE ARCHIVES



OCEAN SEDIMENTS

HOW

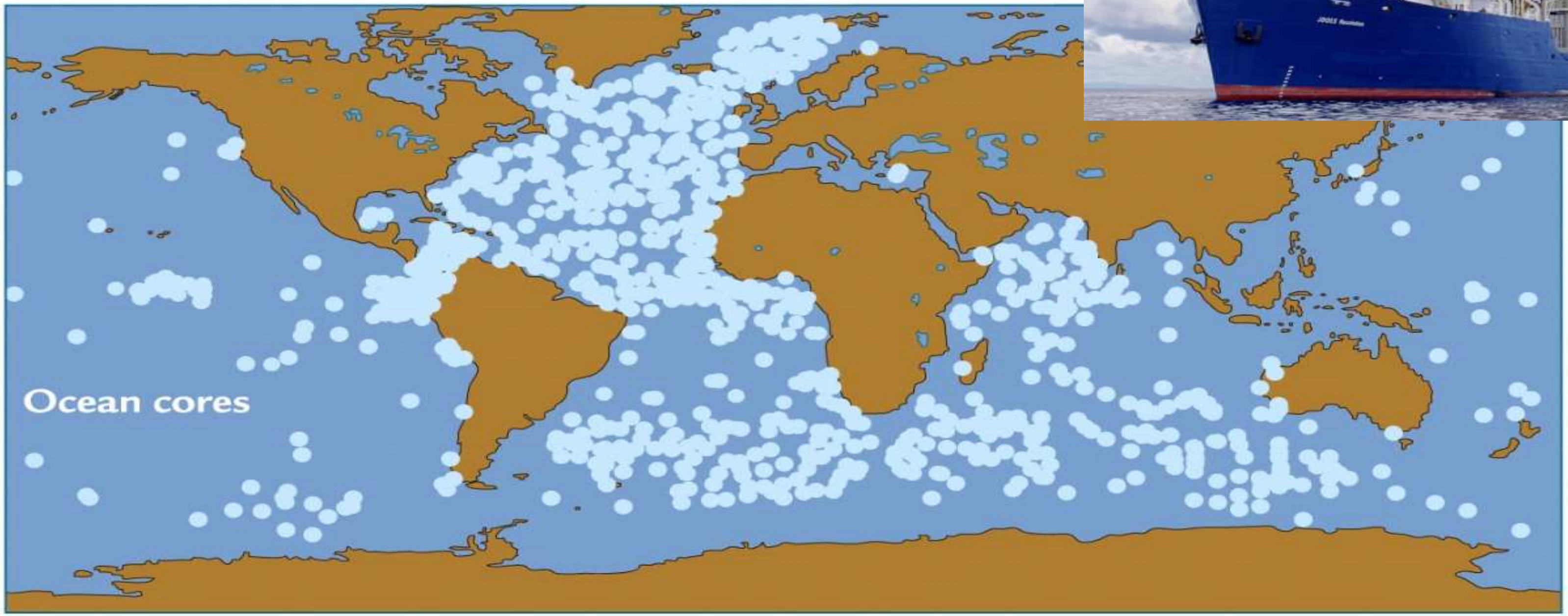


OCEAN SEDIMENT CORES

LONG PISTON CORES (70 m)

HOW

IODP EXPEDITIONS



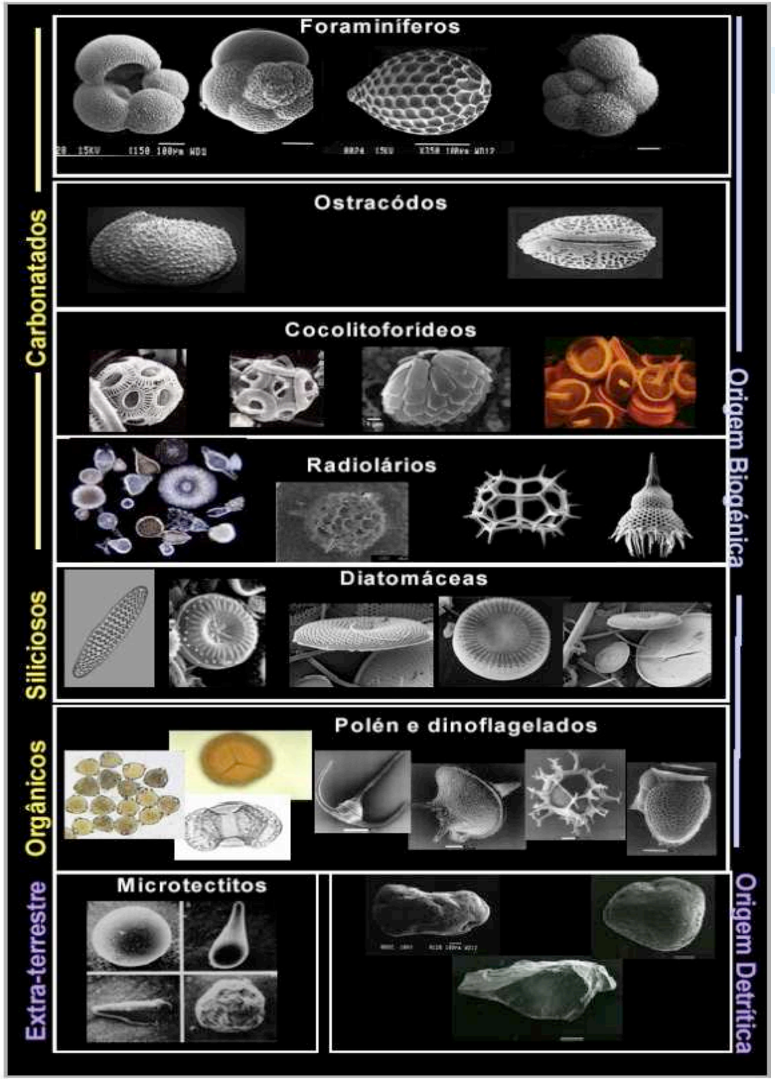
A

HOW

ACEX – IODP ARTIC MISSION

HOW


Continuous Sampling
Every 1cm

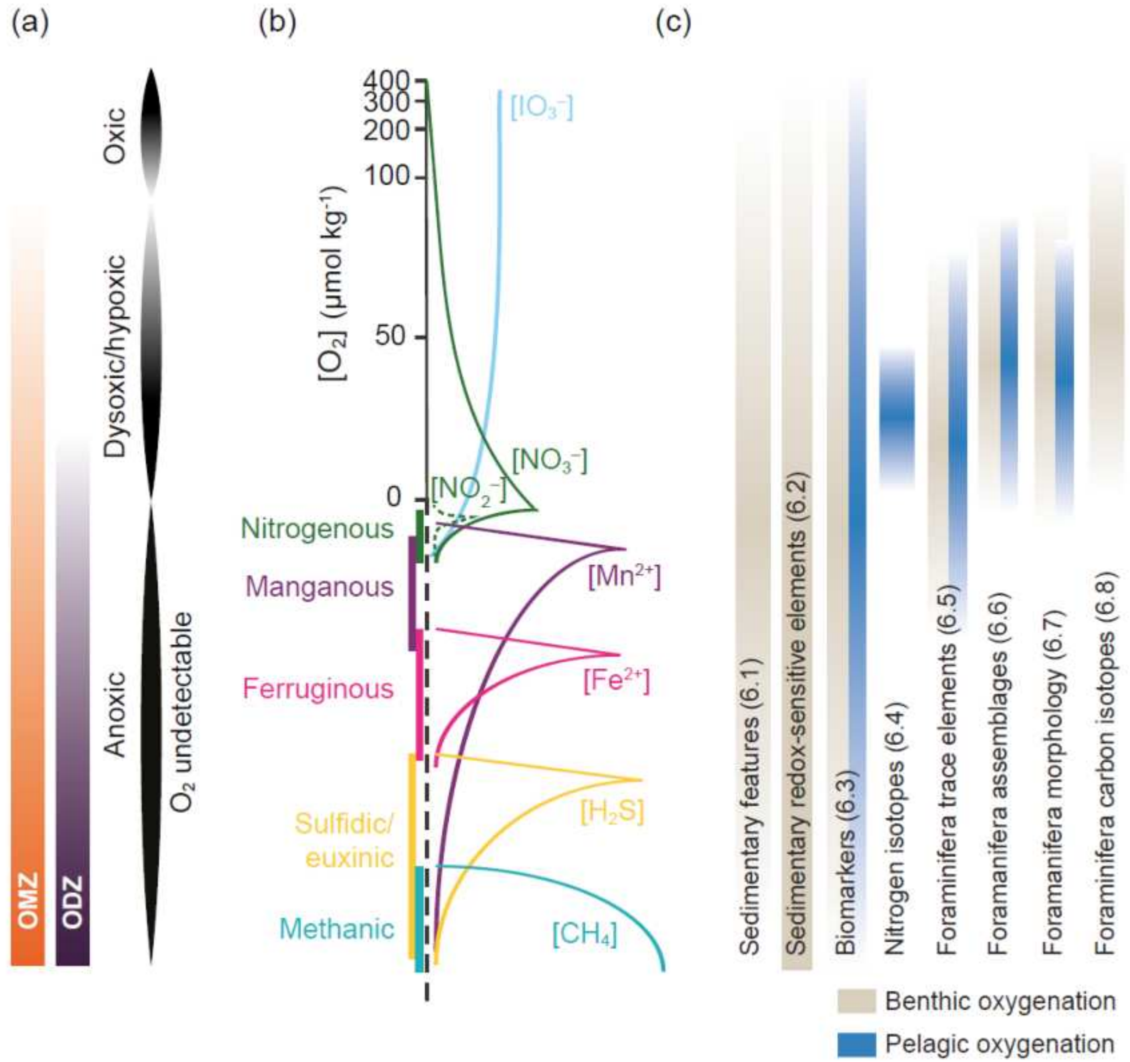


WHAT DO WE BASE OUR RECONSTRUCTIONS ON?

– PROXIES

Any sediment component which origin is known to be related to a specific environment parameter or process, and that can be calibrated to present-day conditions on a wide variety of oceanographic and sedimentologic settings.

- Biologic
- Chemical
- Isotopic

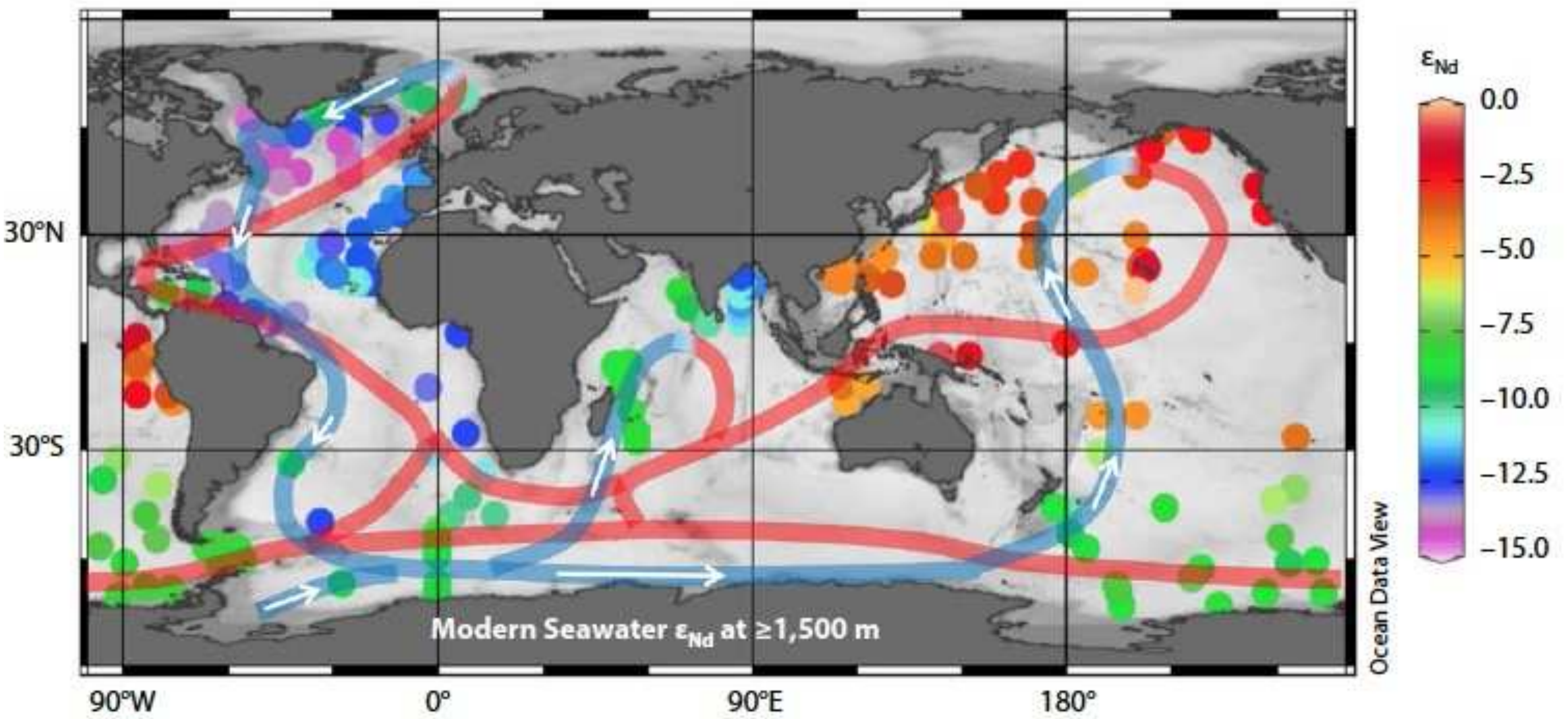


NEW CHALLAGES IMPLY THE SEARCH FOR NEW PROXIES

O_2 Levels

https://doi.org/10.5194/egusphere-2023-2981

RECONSTRUCTION OF OCEAN CIRCULATION BASED ON NEODYMIUM ISOTOPIC COMPOSITION



GEOGRAPHIC LOCATION

UNKNOW AREAS OF THE OCEAN ARE MUCH TOO LARGE

SPECIFIC QUESTIONS DETERMINE THE AREA(S) TO BE STUDIED

AREAS OF SPECIAL INTEREST / KEY REGIONS

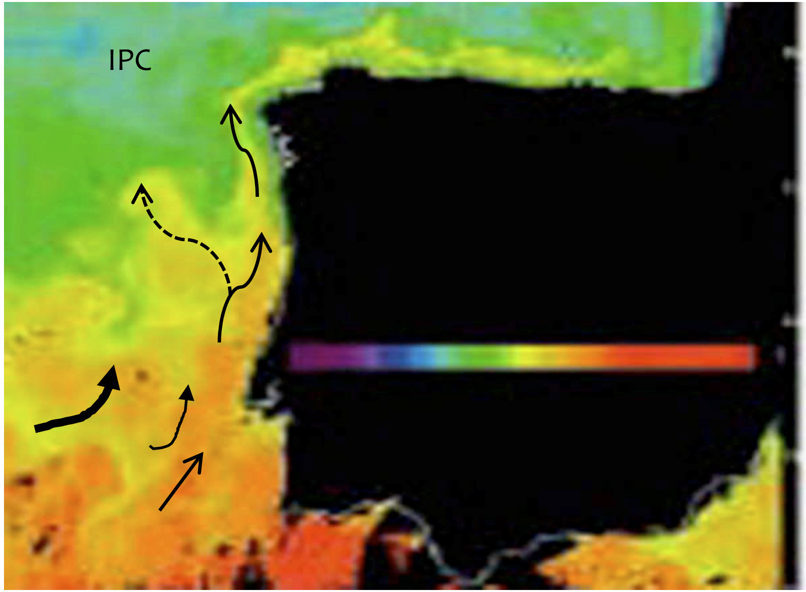
IBERIAN MARGIN

IBERIAN Margin

Present Day Surface Circulation

Winter (DJFM)
POLEWARD WARM CURRENT

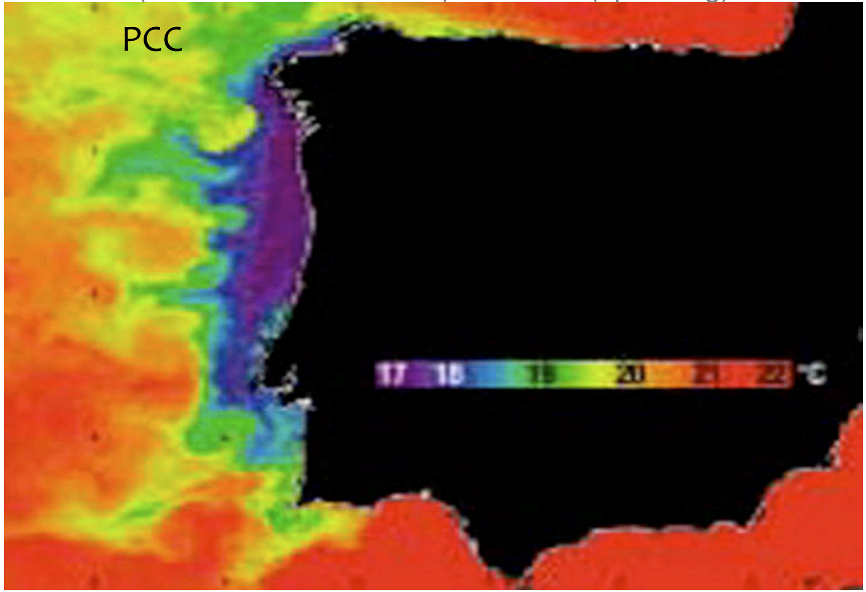
IPC- Iberian Poleward Current



Monthly composite of winter (January 2003) sea surface temperature (SST)

Summer (MJJA)
STRONG COASTAL UPWELLING

PCC-Portugal Coastal Current
(southward cold current) - Summer(upwelling)



Monthly composite of summer(August 1998

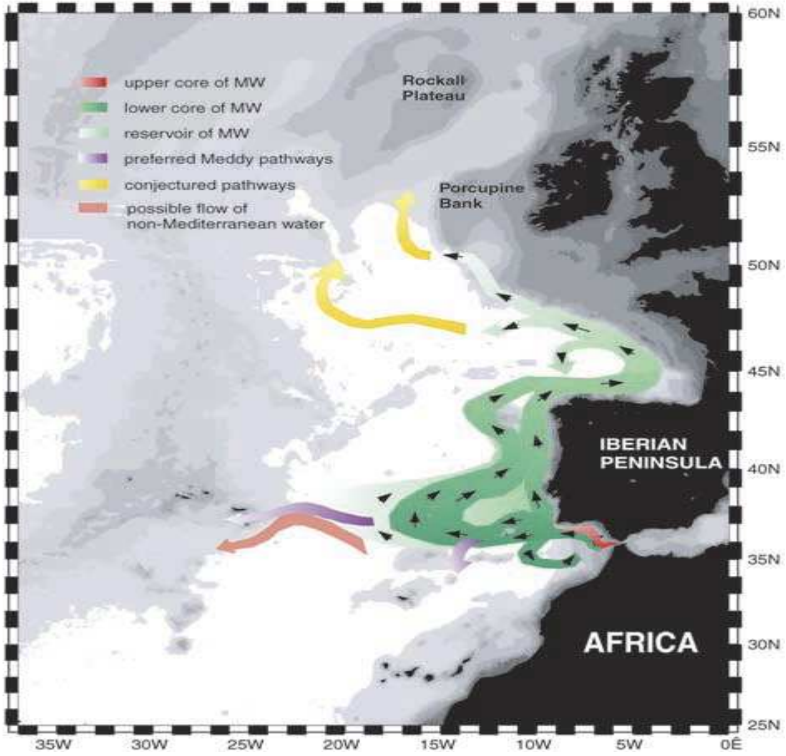
NASA Jet Propulsion Laboratory, Pasadena, CA (http://podaac.jpl.nasa.gov/poet)

IBERIAN Margin

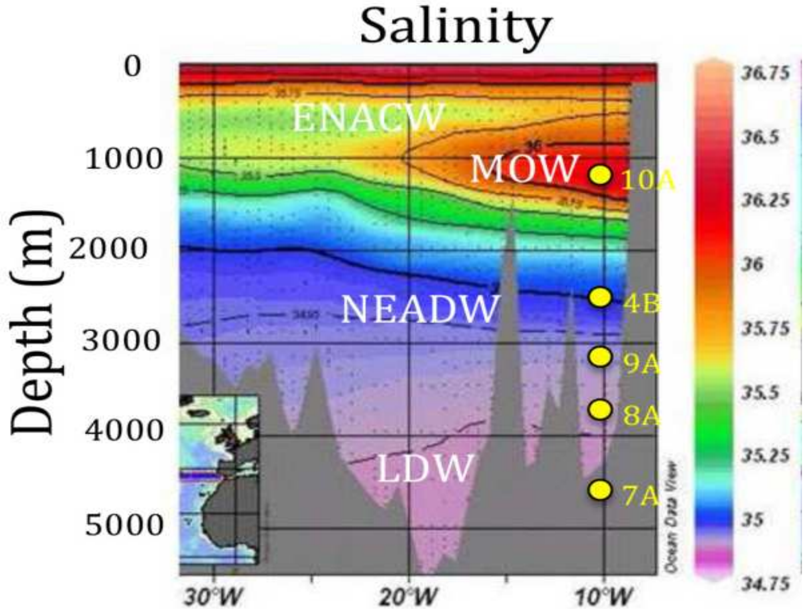
Intermediate & Deep Water Present Day Circulation

A source of heat and salt into the Atlantic

(possible contributor to NADW)

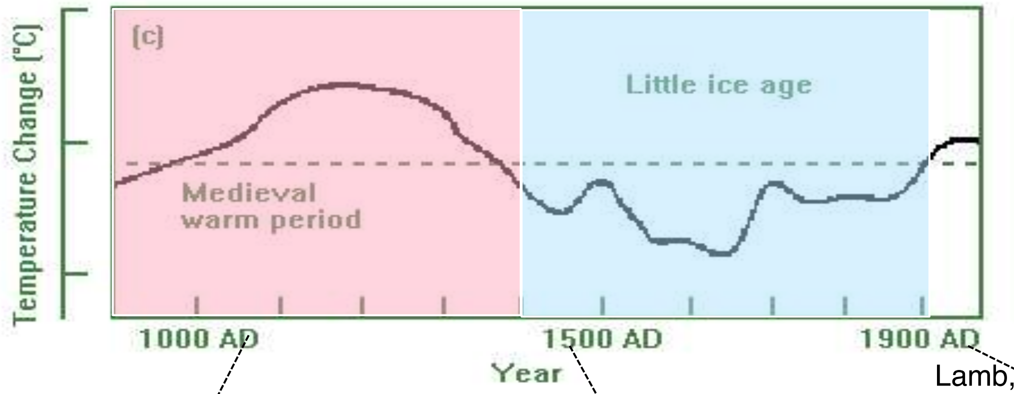


Bower et al., 2002



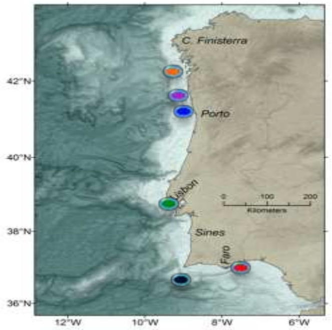
Hodell et al, 2013

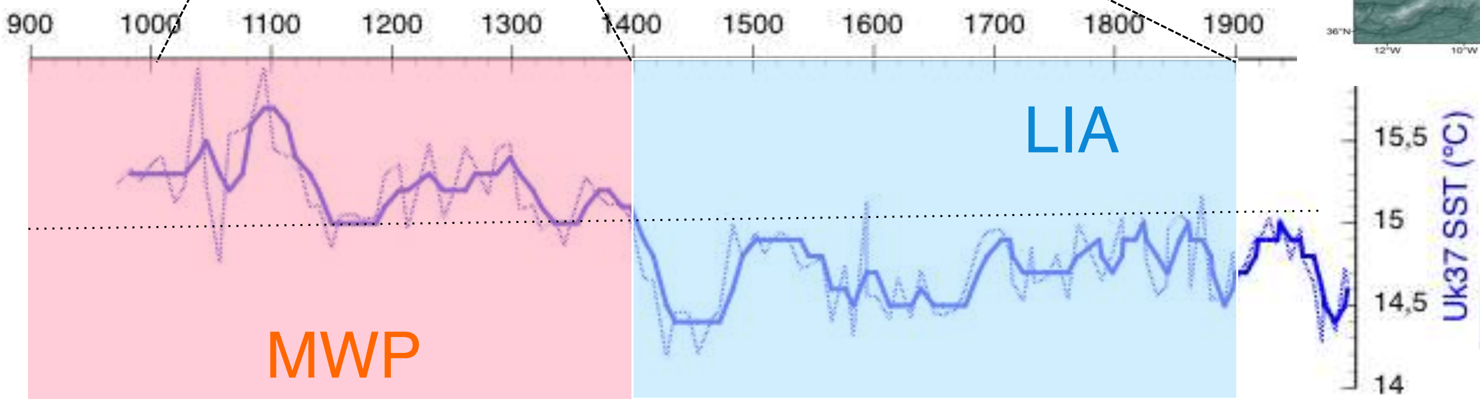
CLIMATIC EXTREMES – HISTORICAL PERIOD



NH average T

Lamb, 1969

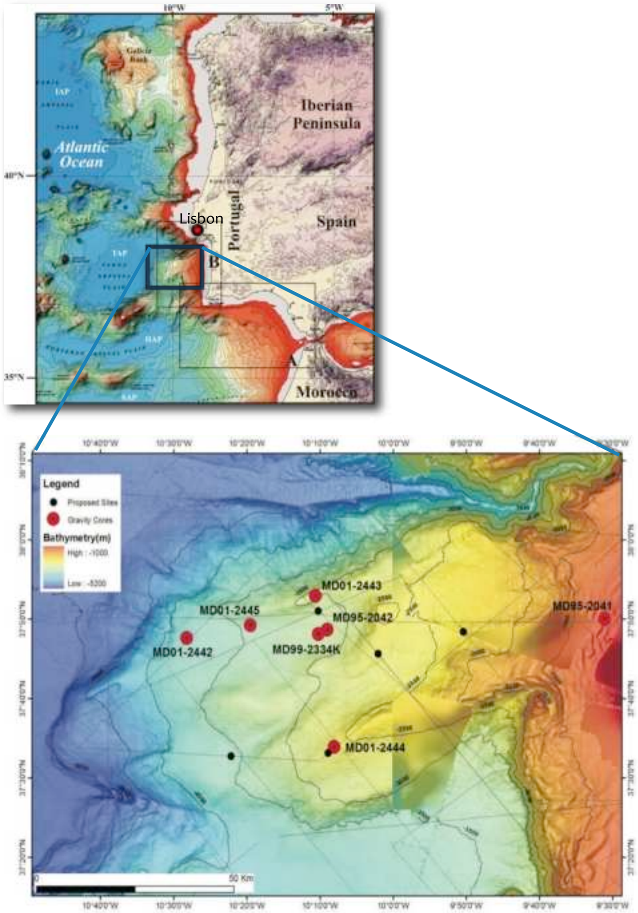




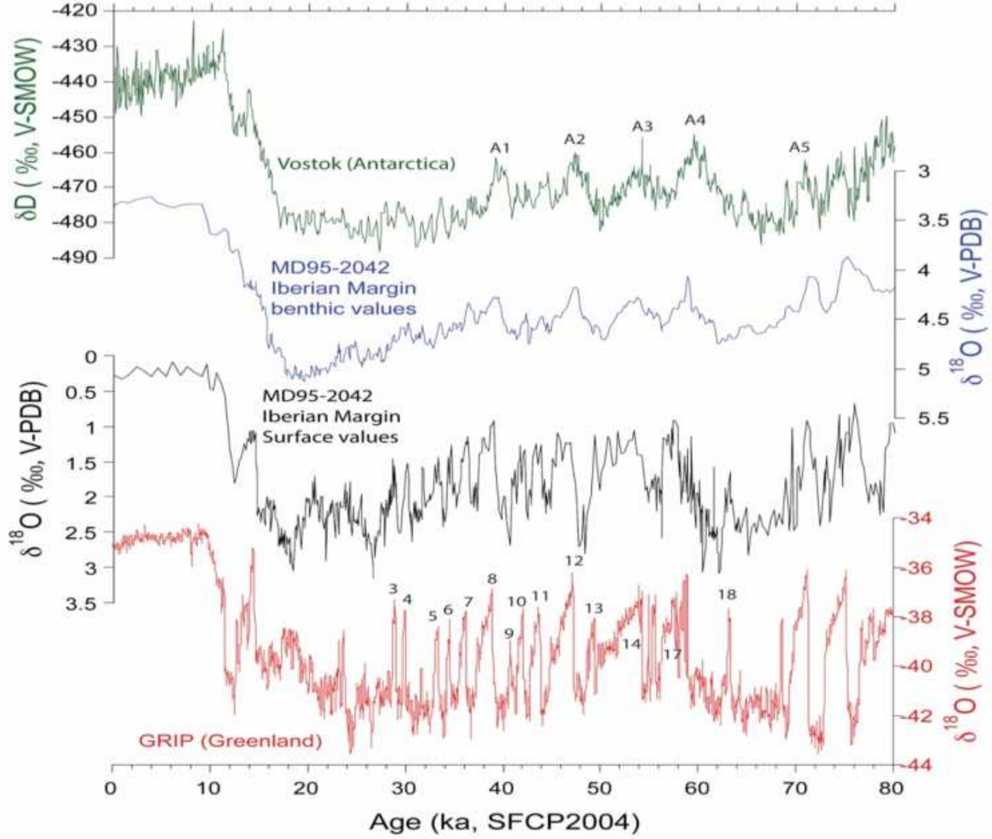
Porto

Abrantes et al, 2012

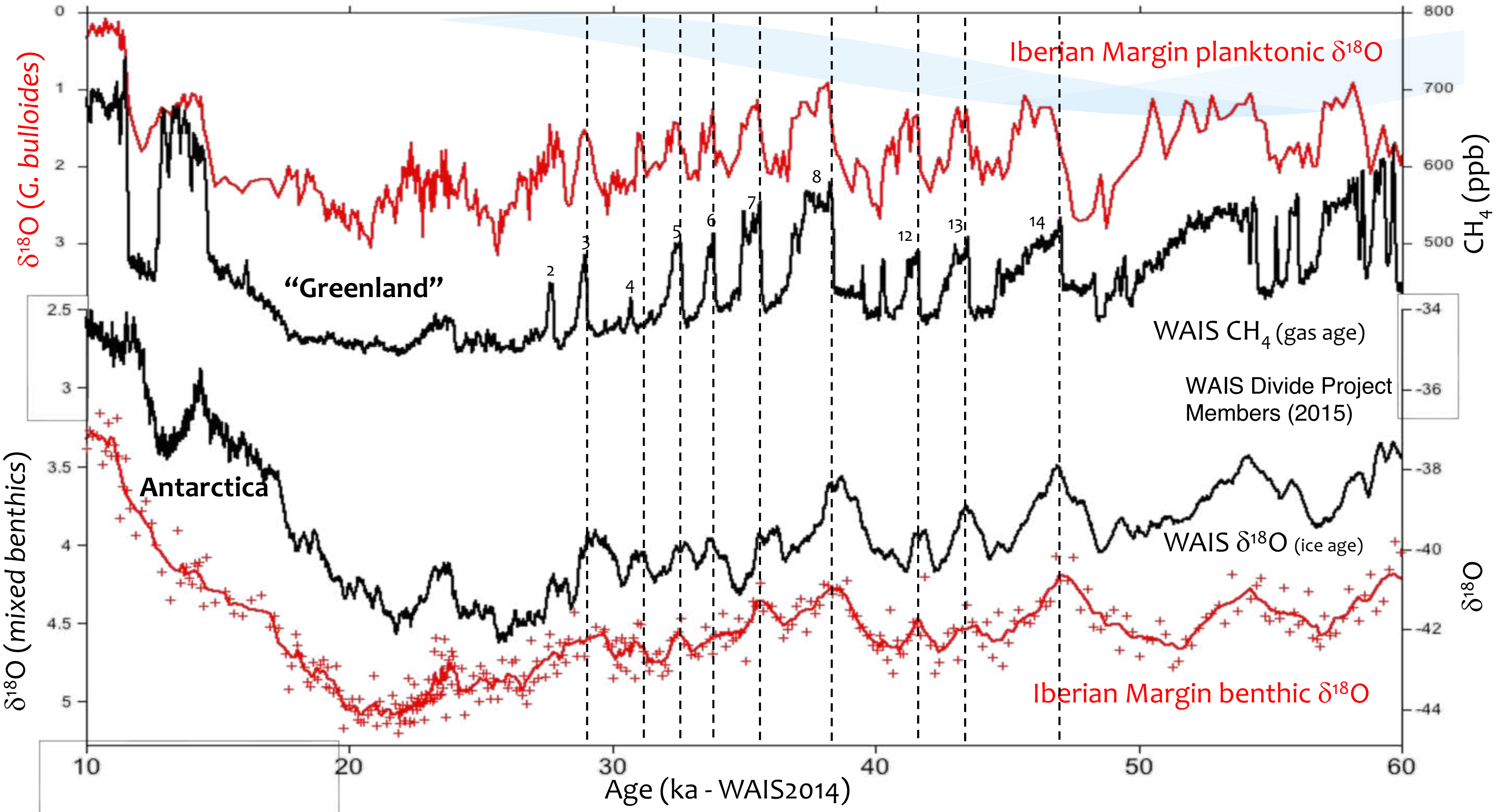
The *Shackleton site*



Core MD95 - 2042



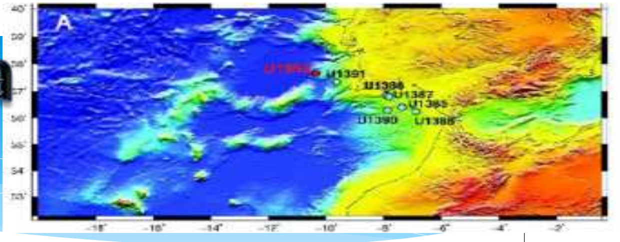
Shackleton et al., 2000

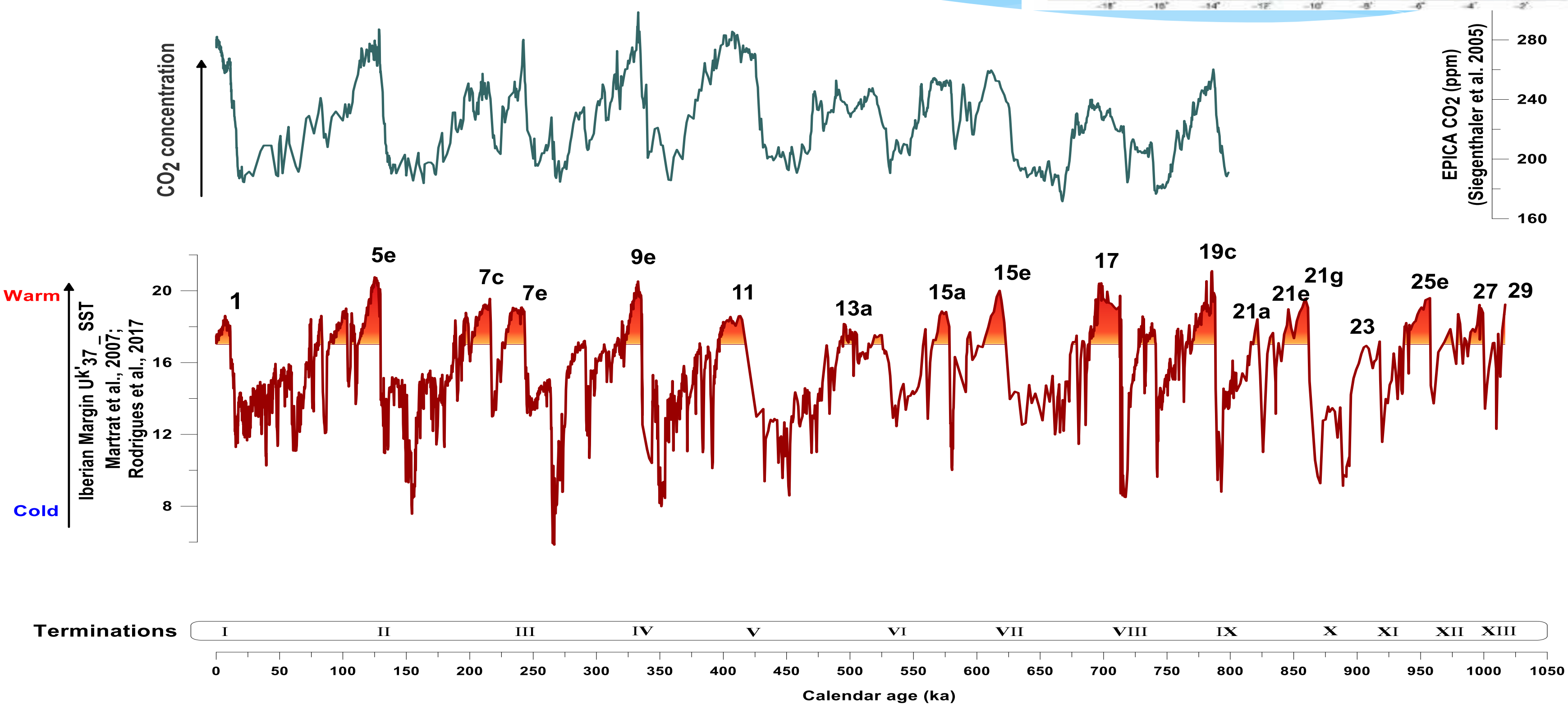


Iberian Margin planktonic δ18O
δ18O (G. bulloides)
CH4 (ppb)
"Greenland"
WAIS CH4 (gas age)
WAIS Divide Project Members (2015)
Antarctica
WAIS δ18O (ice age)
δ18O (mixed benthics)
δ18O
Iberian Margin benthic δ18O
2
3
4
5
6
7
8
12
13
14
10
20
30
40
50
60
Age (ka - WAIS2014)

Climate variability over the last 1 Ma

(IODP Exp339 – Site 1385)



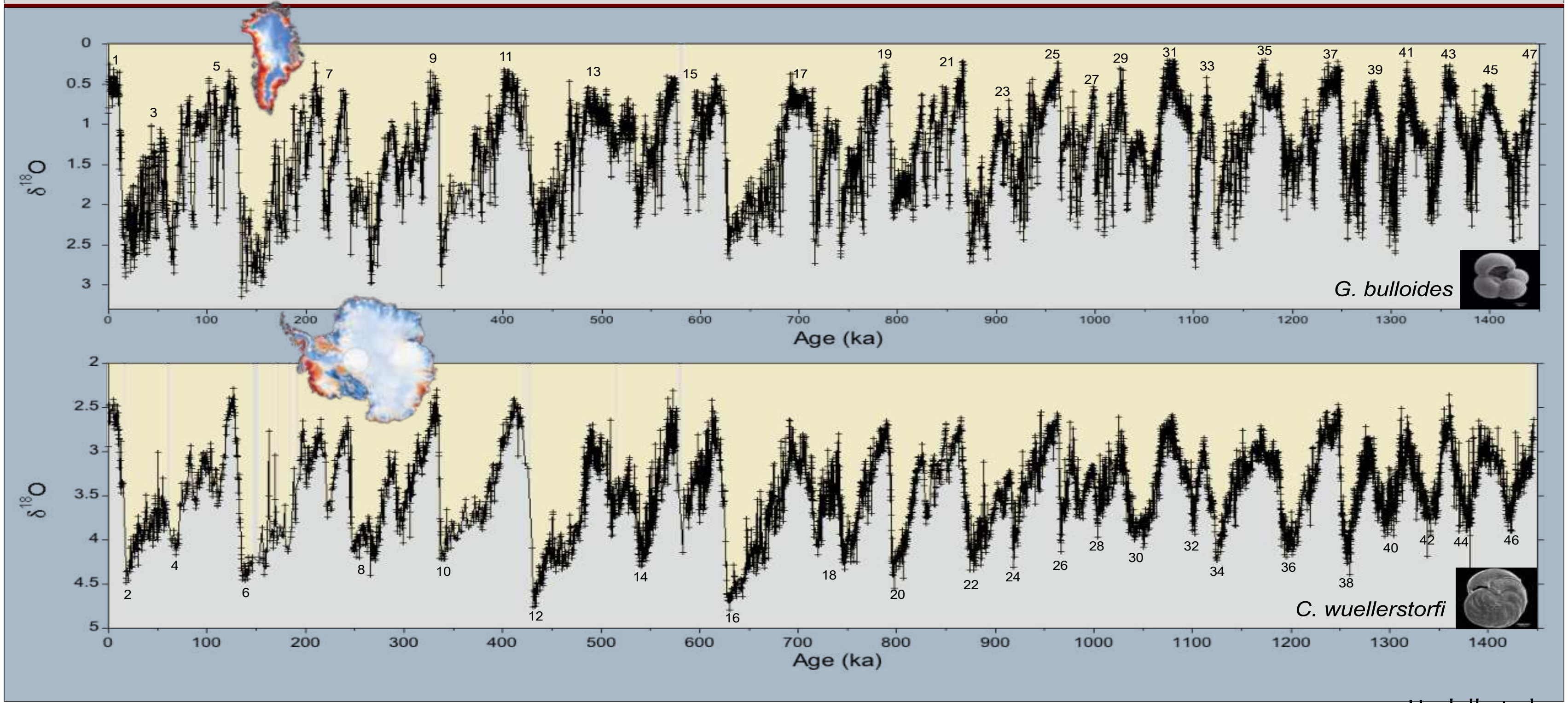


- High temperatures detected during "luke-warm" interglacials

Rodrigues et al., 2017

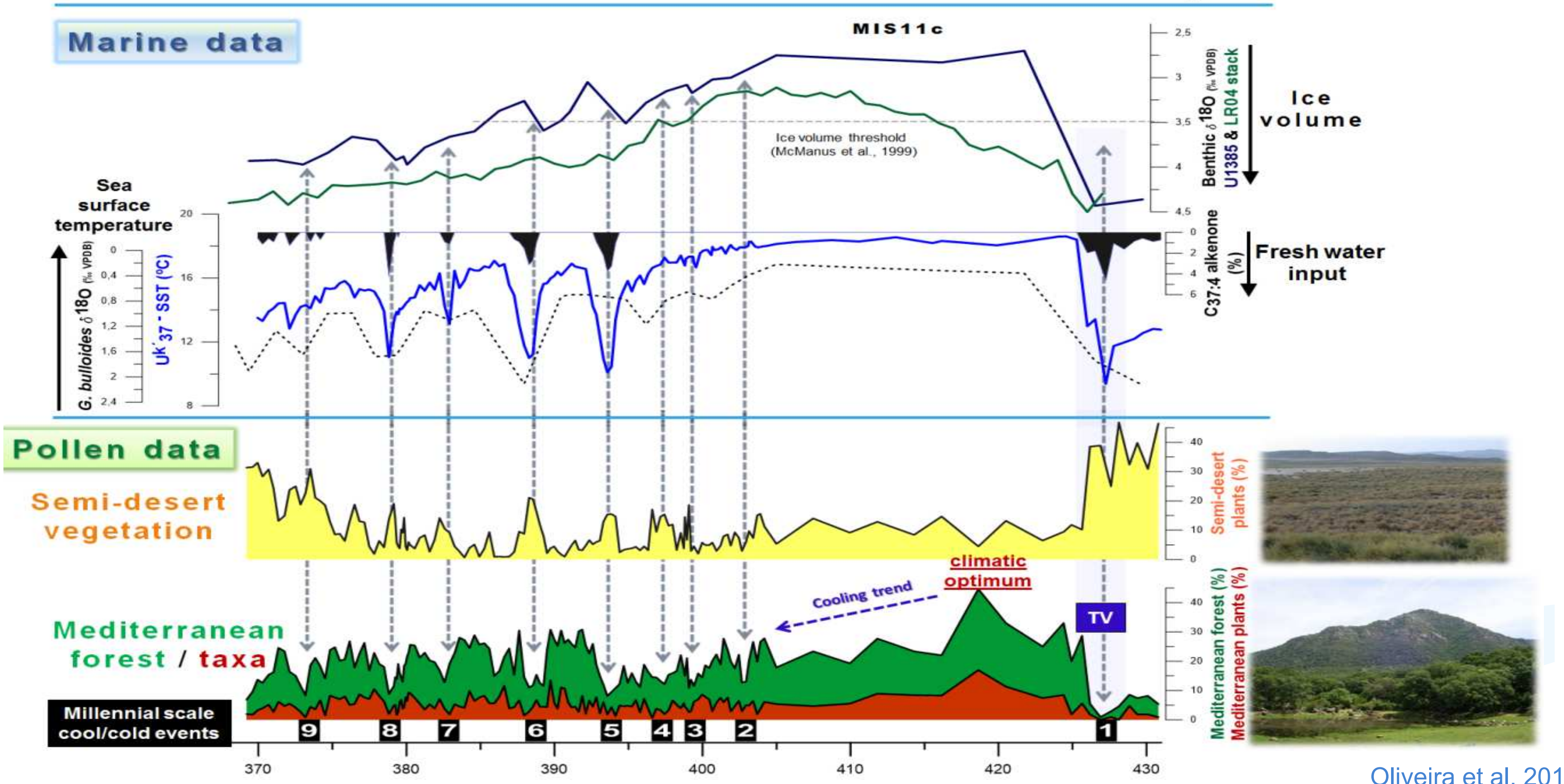
Site 339-U1385

A 1.5-million year record of North Atlantic climate variability from the Iberian Margin



Hodell et al., 2022

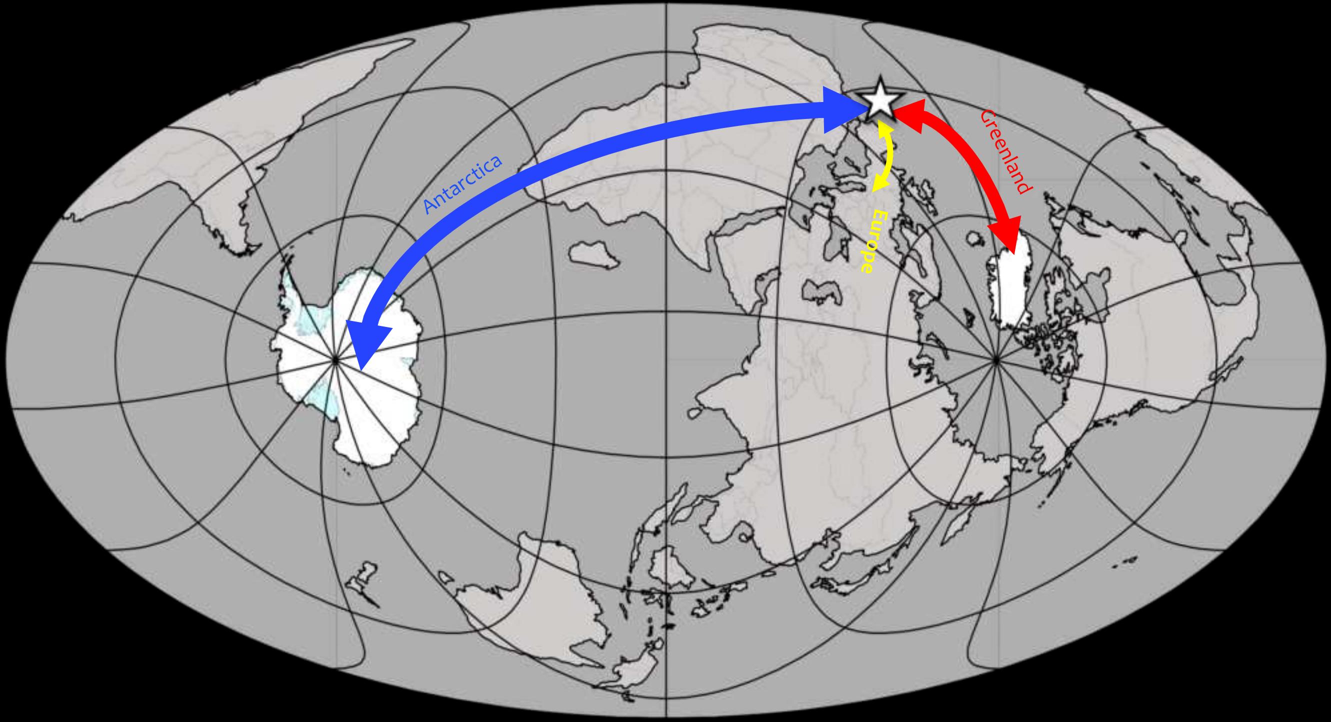
Land-Sea Correlation



Oliveira et al, 2016

Marine Analog for Ice Cores

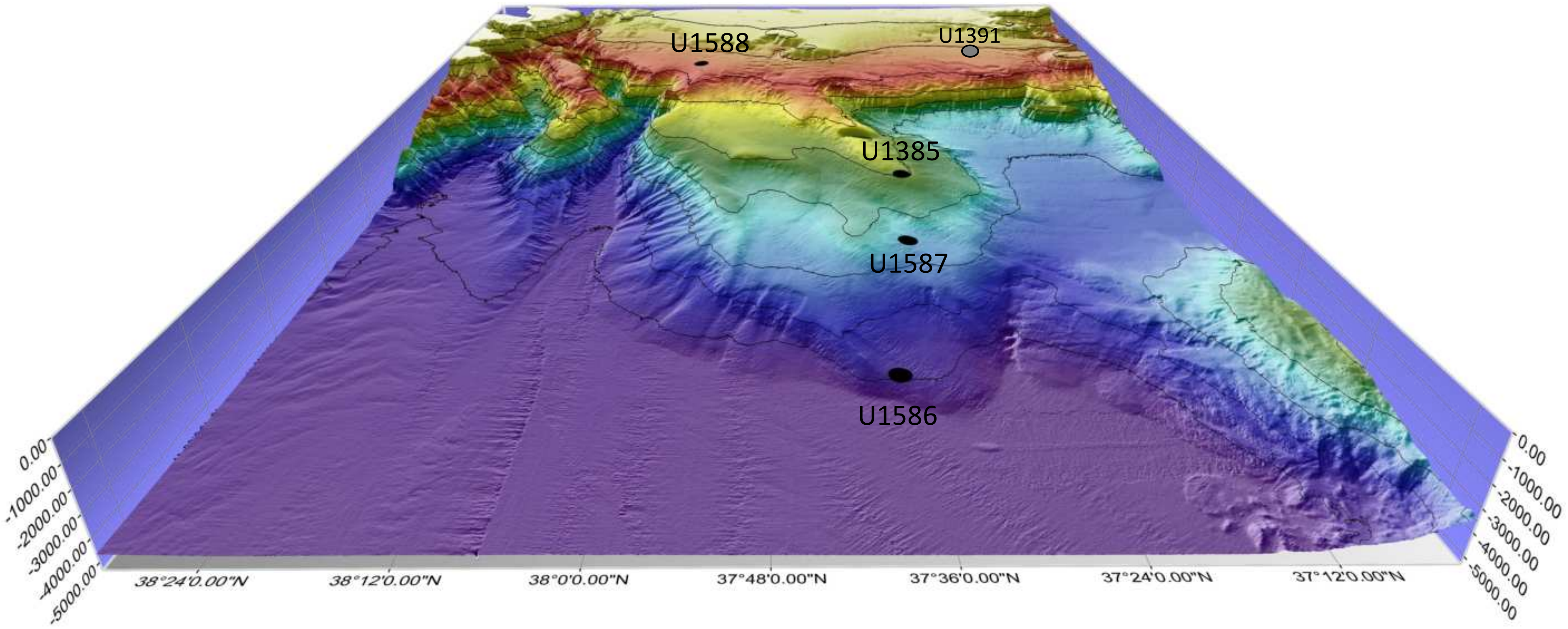
Integrates the marine continental and ice records



“Few, if any, places exist in the world ocean where such detailed linkages between different parts of the climate system are possible.”


IODP EXPEDITION 397
IBERIAN MARGIN PALEOCLIMATE
JOIDES Resolution
DANGER
IODP
INTERNATIONAL OCEAN
DISCOVERY PROGRAM

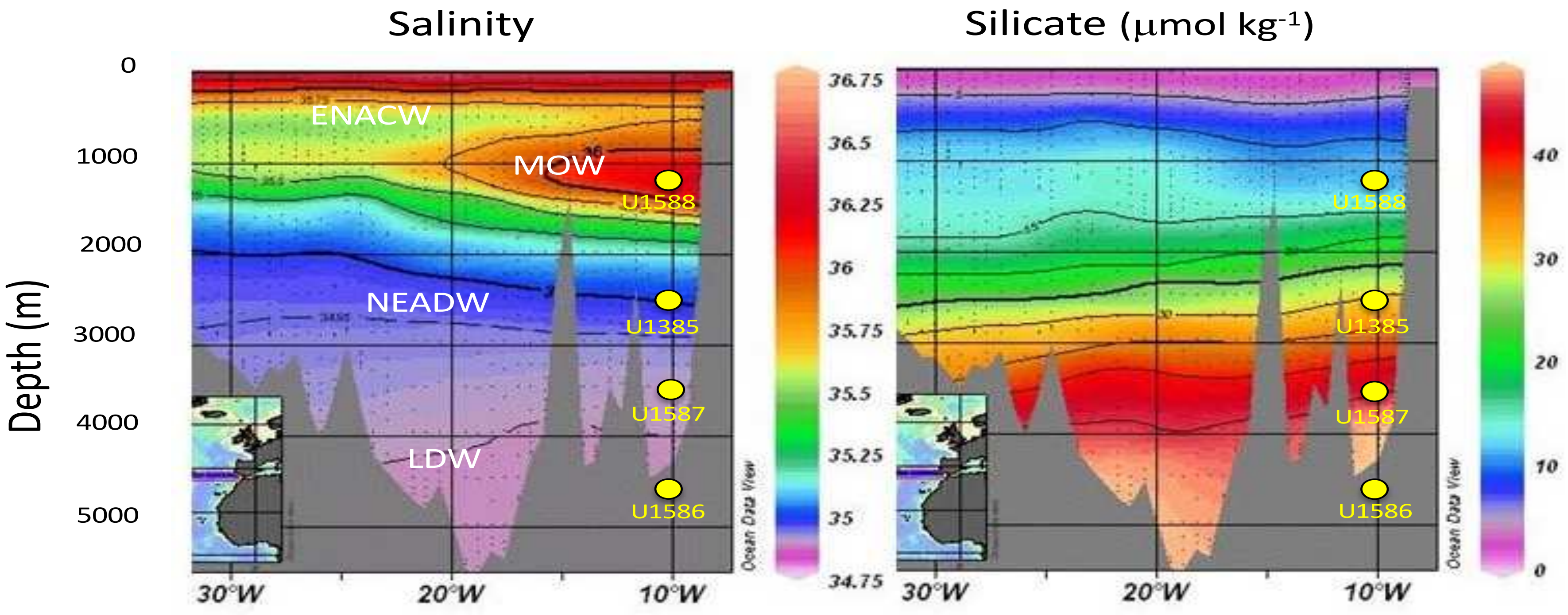
EXP397 DRILLED SITES



by Helder Pereira using Mirone and iVew4D software

Main Objectives

PALEO CTD – Reconstruct the characteristics of the most important water masses of the North Atlantic since the Upper Miocene (7 Ma)



Hodell et al., 2022a

MAIN ACHIEVEMNETS

6176,7 meters of sediment (104% recovery)

Complete Splice in the 4 Sites

Sedimentation Rates **10 (U1587 e U1385) a 20 cm ky^{-1} (U1588)**

Recovery at depths of the most important water masses - Paleo CTD

Millennial Climate Variability (MCV) in Pleistocene at Sites U1587, U1385, U1588

Pliocene transition to North Hemisphere Glaciation in all but U1588

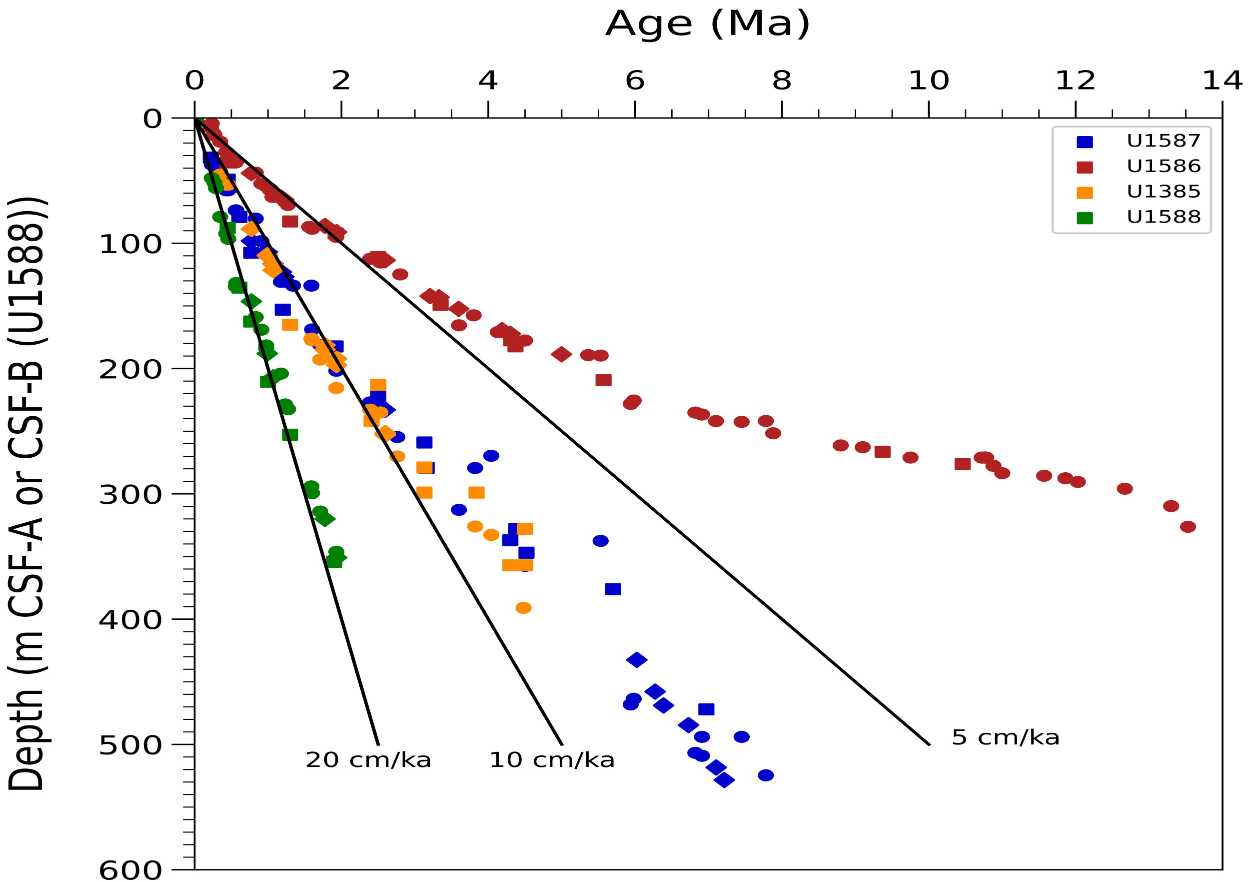
Recovery of a complete Pliocene including the late warm interval, except in U1588

Upper Miocene including a complete Messinian in U1586, U1587

Potential to define a global Cyclostratigraphy

Complete Splice in the 4 Sites

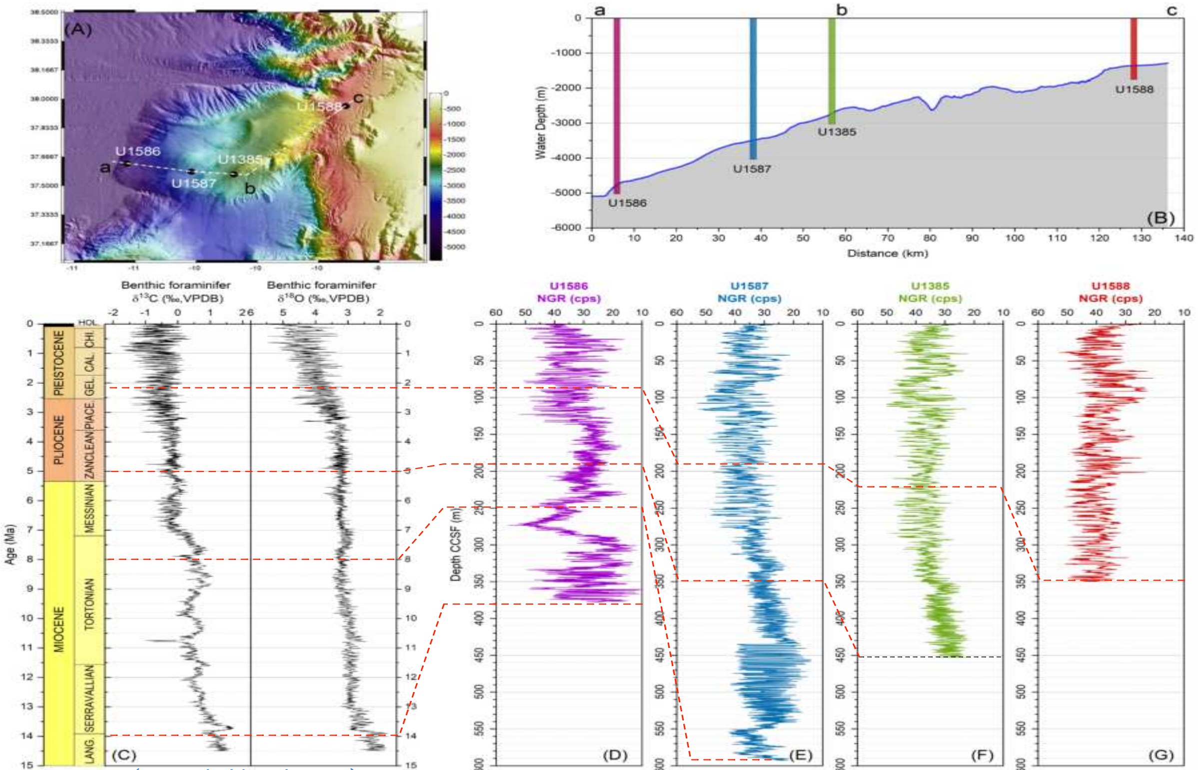
Sedimentation Rates **10 (U1587 e U1385) & 20 cm ky^{-1} (U1588)**



Recovery at depths of the most important water masses - Paleo CTD

Recovery of a complete Pliocene including the late warm interval and transition to NH Glaciation in all but U1588

Upper Miocene including a complete Messinian in U1586, U1587



(Westerhold et al., 2006)

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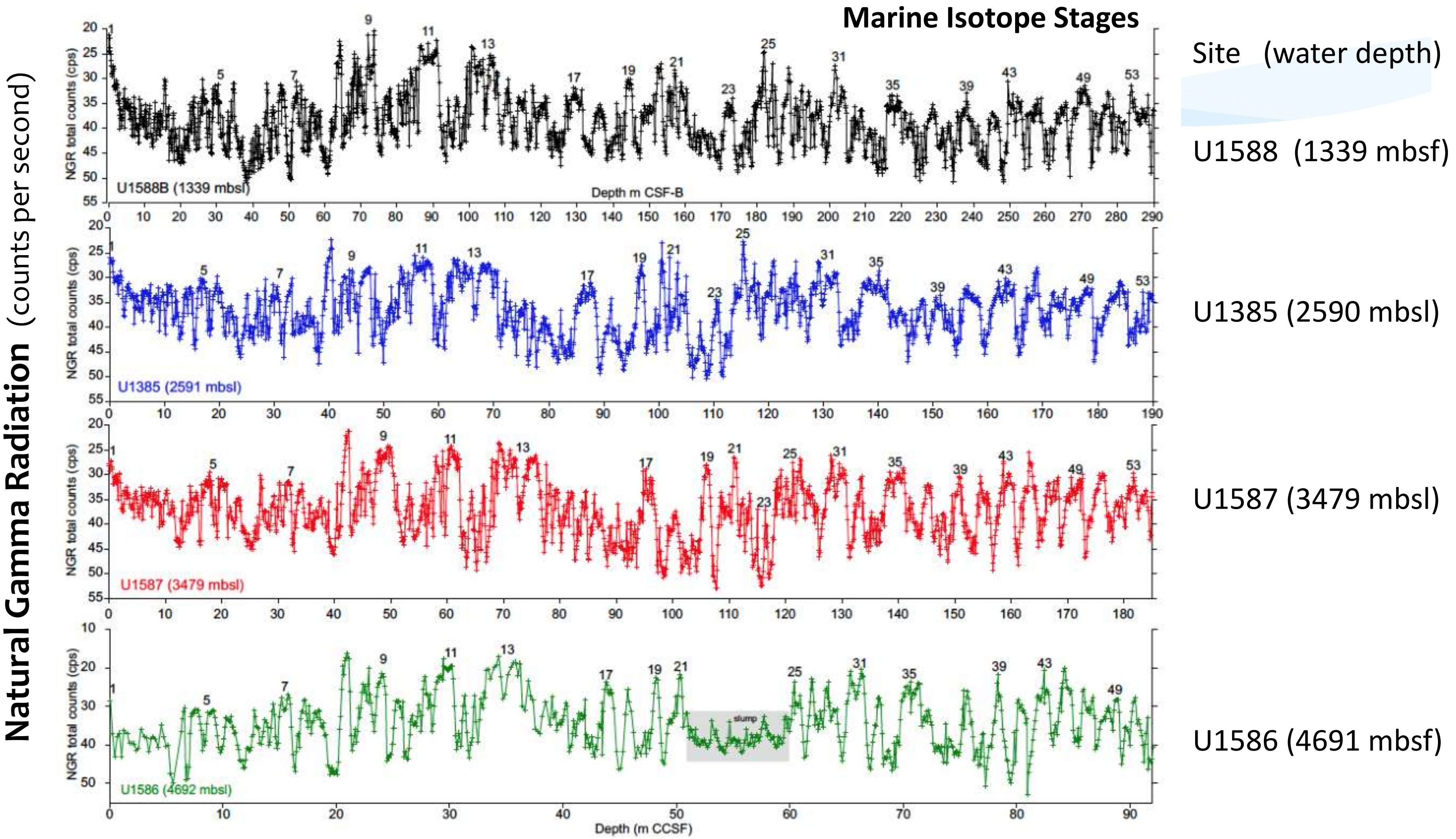
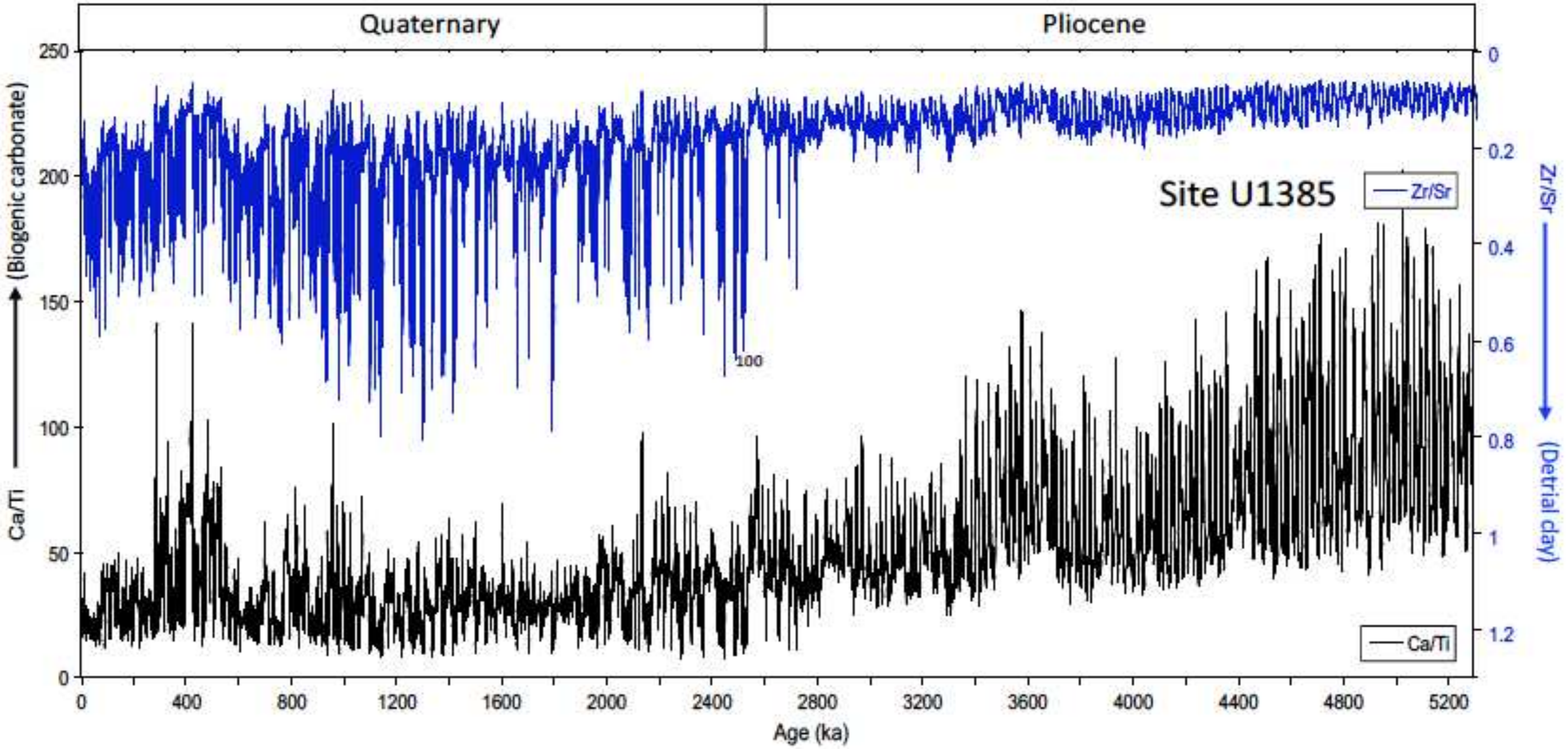


Marine Isotope Stages
Site (water depth)
U1588 (1339 mbsf)
U1385 (2590 mbsl)
U1587 (3479 mbsl)
U1586 (4691 mbsf)
Natural Gamma Radiation (counts per second)
NGR total counts (cps)
U1588B (1339 mbsl)
Depth m CSF-B
U1385 (2591 mbsl)
U1587 (3479 mbsl)
U1586 (4692 mbsl)
slump
Depth (m CCSF)



(Hodell et al., Unpublished)


OBRIGADA
THANK YOU

IMPORTANCE OF PALEO STUDIES

Important Aspects:

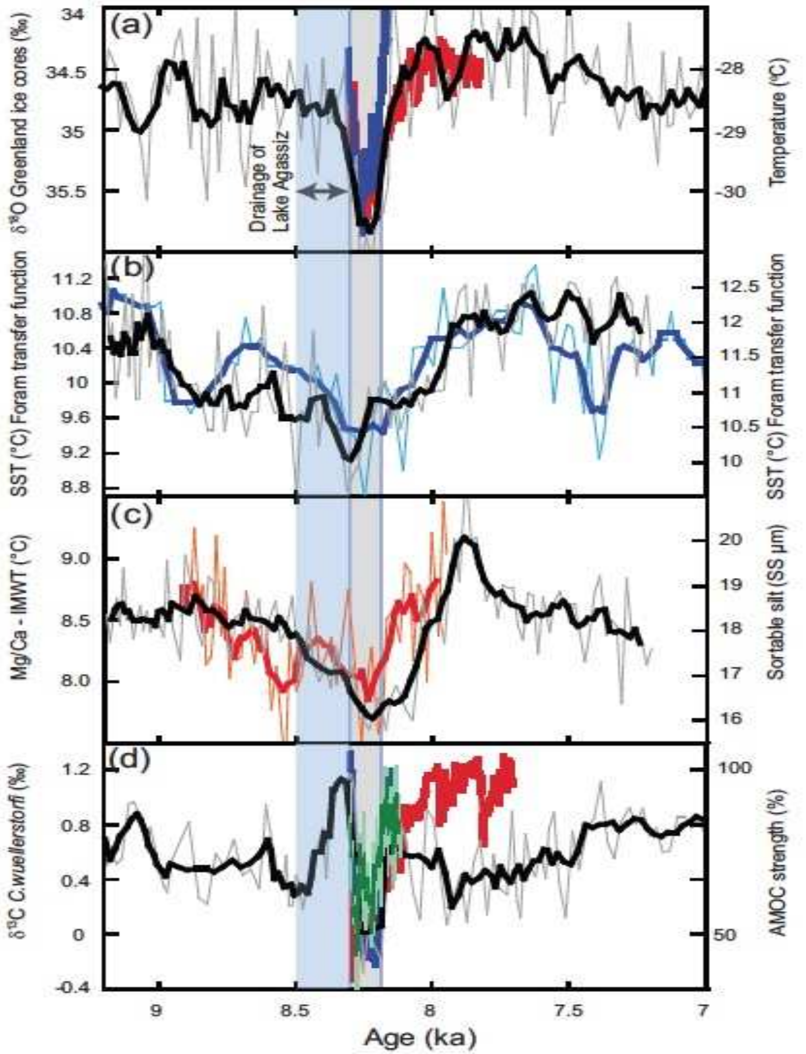
- **To define natural limits and their uncertainties;**
- **To understand the vulnerability, resilience and adaptation capacity of the different subsystems of climate to natural variability;**
- **To determine tipping points;**
- **To improve climate projections for the future;**
- **To identify and define the appropriate descriptors to characterize the ocean state**, what can only be done in a responsible way if using pre industrial base lines (< 1850).

AMOC DISTURBANCE at 8.2 Ka

AMOC recovery time to disturbance imposed by freshwater under boundary conditions equivalent to those at present?

Climate records and simulations indicate:

- Event lasted 100–160 years
- The anomalies are consistent with a reduction in AMOC vigor.
- AMOC recovery time is on the order of 200 years!



(Ellison et al., 2006; Bamberg et al., 2010)

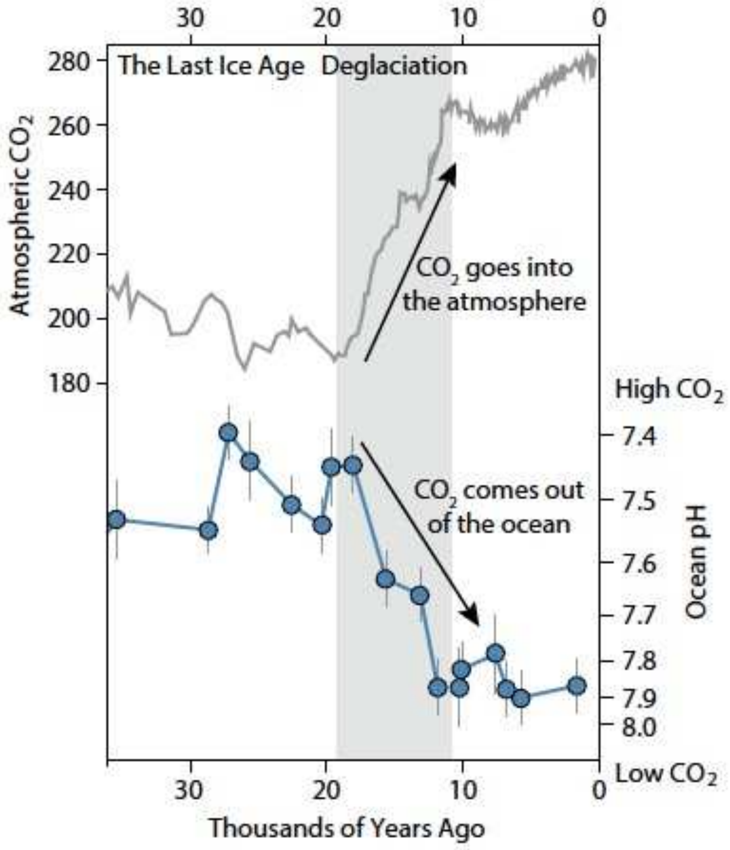


FIGURE 2. Boron isotope analyses of deep-sea corals demonstrates CO_2 release from the deep Southern Ocean to the atmosphere at the end of the last ice age (Rae et al., 2018).

Oceanography | June 2020

BORON ISOTOPES PROVIDE INSIGHTS INTO BIOMINERALIZATION, SEAWATER pH, AND ANCIENT ATMOSPHERIC CO2

pH-dependent speciation of boric acid B(OH)3, and borate ion (B(OH)4.

Modern Calibration - Isotopic offset between boric acid and borate ion