# Stratification of surface waters during the last glacial millennial climatic events: a key factor in water mass dynamics

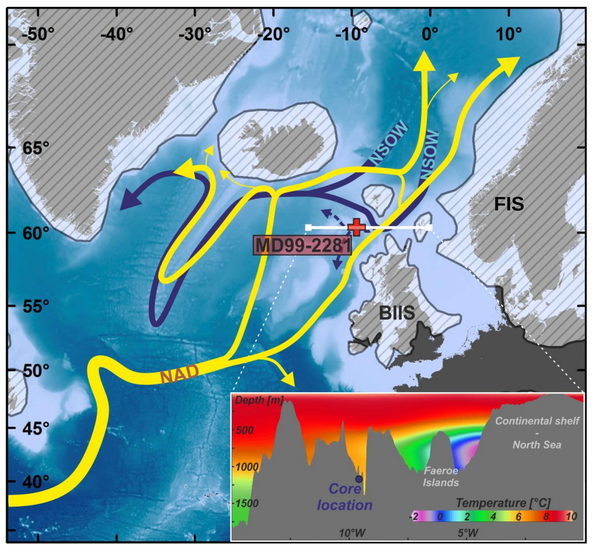

**Wary Mélanie (1), Eynaud Frédérique (1), Sabine Marjolaine (1), Zaragosi Sébastien (1), Rossignol Linda (1), Malaizé Bruno (1), Palis Edouard (2), Zumaque Jena (2), Caulle Clémence (2), Penaud Aurélie (3), Michel Elisabeth (4), Charlier Karine (1), Castéra Marie-Hélène (1)**

(1) **« EPOC » Laboratory , UMR CNRS 5805, Université de Bordeaux** – (2) **Former students from EPOC** – (3) UMR 6538, Domaines Océaniques, IUEM-UBO, F-29280 Plouzané, France – (4) UMR 8212, LSCE (Laboratoire des Sciences du Climat et de l'Environnement), CEA/CNRS-INSU/UVSQ, 91198 Gif-sur-Yvette cedex, France


*Figure 1 :*

*General map of the studied area, showing the location of the studied core MD99-2281 (red cross), the maximal last glacial extension of European ice-sheets (hatched areas), the major pathways of the Atlantic inflow (yellow arrows) and of the Nordic overflow (dark blue arrows), and the location (white line) of the east-west profile of oceanic temperatures shown in the lower right corner*

Data sources : *Ehlers & Gibbard*, 2007; *Orvik & Niiler*, 2002; *Stanford et al.*, 2011; *Boldreel et al.*, 1998; *Kuijpers et al.*, 1998, 2002; *Howe et al.*, 2006; *Locarnini et al.*, 2006.




## 1 – Context , objectives and analytical approach

❖ **Context: the last glacial period** (≈ 60-10 ka BP)

- Occurrence of abrupt climate events: Heinrich events (HEs) and Dansgaard-Oeschger cycles (DO).

❖ **Objectives: to decipher the oceanic responses SW off Faeroes to millennial climate variability**

- Key study area as it coupled climatic, oceanic and atmospheric dynamics during the last glacial period.
- Oceanic nodal point, with influence of (1) warm and salty Atlantic sub-surface water inflow (North Atlantic Drift – NAD) and (2) overflow of deep and cold water from Nordic Seas (Norwegian Sea Overflow Water – NSOW; Fig 1).

❖ **Analytical approach: multi-proxy + high temporal resolution**

- Geochemical, micropaleontological, and sedimentological analyses.
- Appropriate sedimentation rate (≈ 66 cm/ka) for investigations at sub-millennial scales.

## 2 – Hydrological variations SW off Faeroes

❖ **General trends?**

- Very sensitive response of very-surface (0-50 m), sub-surface (~ 0-300 m) and bottom water-mass dynamics to the millennial abrupt events (HEs and DO).
- Strong stratification of surface waters during a large portion of the studied period.

❖ **Hydrological signature during MIS3 abrupt events?**

- DO interstadials:
  - Progressively milder very-surface conditions
  - Relatively active Atlantic inflow
  - Gradual intensification of deep overflow
- DO stadials:
  - Deterioration of very-surface conditions
  - Strong stratification of the water column
  - Weaker overturning circulation

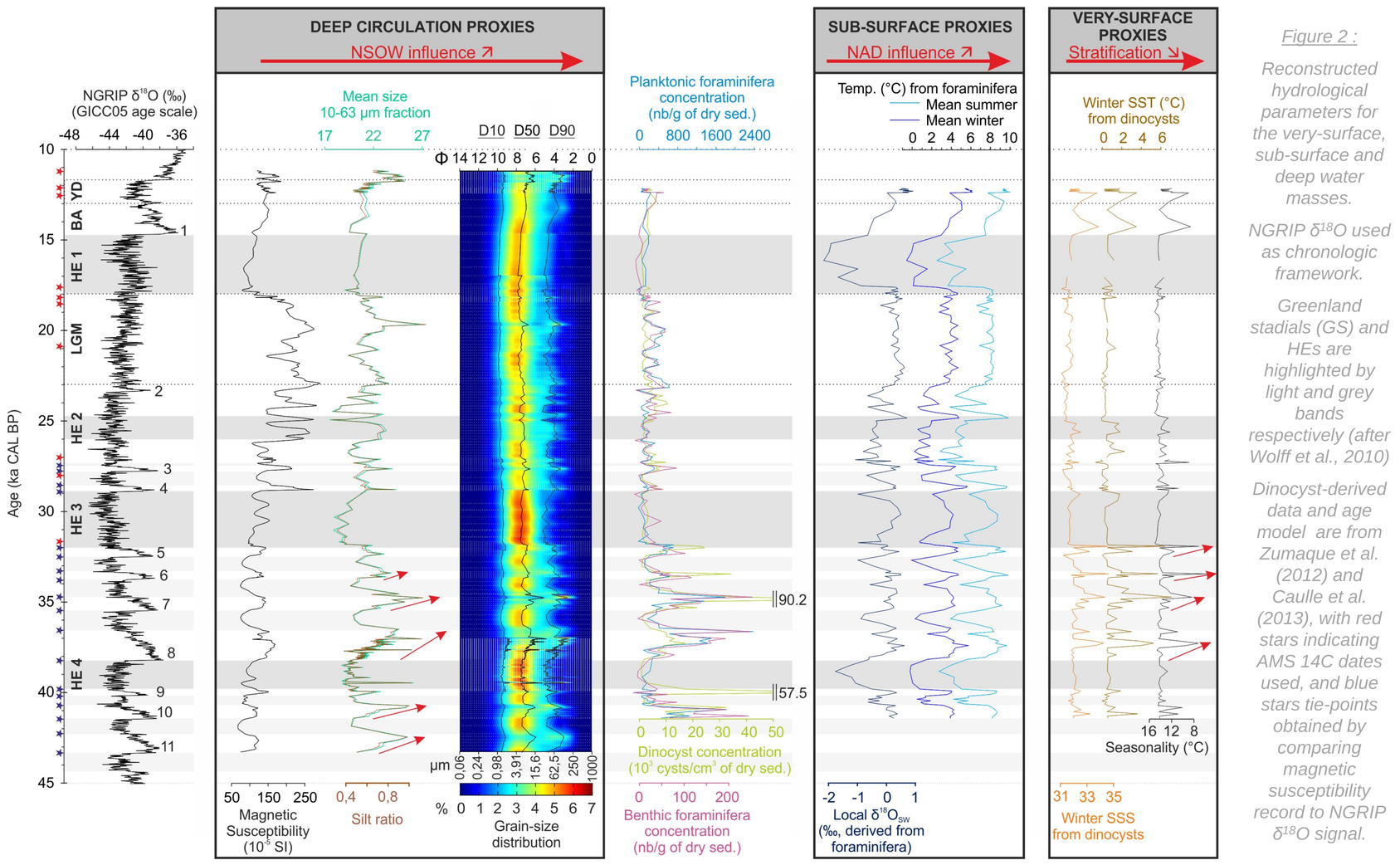



*Figure 2 :*

*Reconstructed hydrological parameters for the very-surface, sub-surface and deep water masses.*

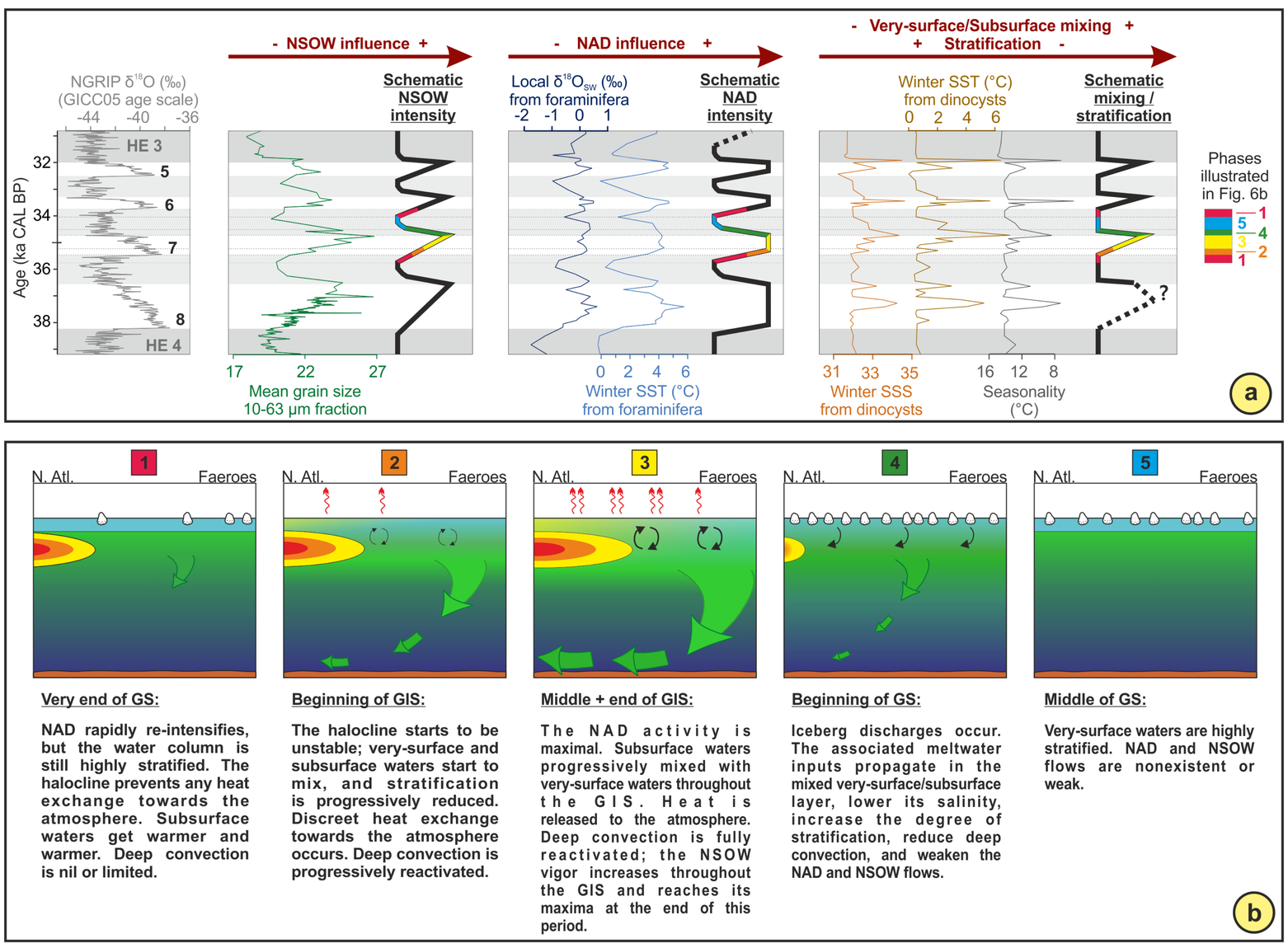
*NGRIP $\delta^{18}O$ used as chronologic framework.*

*Greenland stadials (GS) and HEs are highlighted by light and grey bands respectively (after Wolff et al., 2010)*

*Dinocyst-derived data and age model are from Zumaque et al. (2012) and Caulle et al. (2013), with red stars indicating AMS 14C dates used, and blue stars tie-points obtained by comparing magnetic susceptibility record to NGRIP $\delta^{18}O$ signal.*

*Figure 3 :*

*Synthetic figure illustrating the hydrological processes occurring during DO cycles at the study site. (a) Zoom in on DO 8, 7, 6 and 5 showing the evolution of some selected proxies shown in Figure 2, as well as the schematic evolution through DO cycles of the NSOW activity, the NAD vigor, the intensity of mixing between surface and subsurface waters, and the degree of surface stratification. (b) Conceptual representation of the hydrological processes occurring during the different phases within DO cycles depicted in Figure 3a.*




## 3 – Oceanographical scheme SW off Faeroes during MIS3 DO

❖ **Coupled water mass dynamics**

- DO interstadials:
  - Coupling of very-surface and deep hydrological processes (progressive trends)
  - Decreasing surface stratification
- DO stadials:
  - Coupled sub-surface and deep circulations (sharp weakening at the beginning of stadials)
  - High surface stratification

❖ **Controlling role of surface stratification on water mass dynamics**

- Surface stratification seems to have played a key role in the evolution and interactions of hydrological processes during DO
- Proposition of an oceanographical scheme taking into account this controlling role (Fig 3b).


References: *Boldreel et al.* (1998), Marine Geology, 152(1-3), 129-140. – *Caulle et al.* (2013), Journal of Quaternary Science, 28(3), 217-228. – *Ehlers & Gibbard* (2007), Quaternary International, 164-165, 6-20. – *Howe et al.* (2006), Marine and Petroleum Geology, 23(2), 165-181. – *Kuijpers et al.* (1998), Marine Geology, 152(1-3), 75-99. – *Kuijpers et al.* (2002), Marine Geology, 188(1-2), 147-164. – *Locarnini et al.* (2010), World Ocean Atlas 2009, Volume 1: Temperature, http://www.nodc.noaa.gov/OC5/WOA09/netcdf_data.html – *Orvik & Niiler* (2002), Geophysical Research Letters, 29(19), 2-1. – *Stanford et al.* (2011), Global and Planetary Change, 79(3-4), 244-254. – *Wolff et al.* (2010), Quaternary Science Reviews, 29(21-22), 2828-2838. – *Zumaque et al.* (2012), Climate of the Past, 8(6), 1997-2017.



Financial supports: French INSU programs LEFE-EVE « RISCC » and LEFE-IMAGO « ICE-BIO-RAM » – ARTEMIS $^{14}C$ AMS French project.