Stratification of surface waters SW off Faeroe during the last glacial millennial climatic events: a key factor in subsurface and deep water mass dynamics

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French INSU program EVE/LEFE "RISCC"

Projet INSU LEFE/IMAGO INTERRVIE

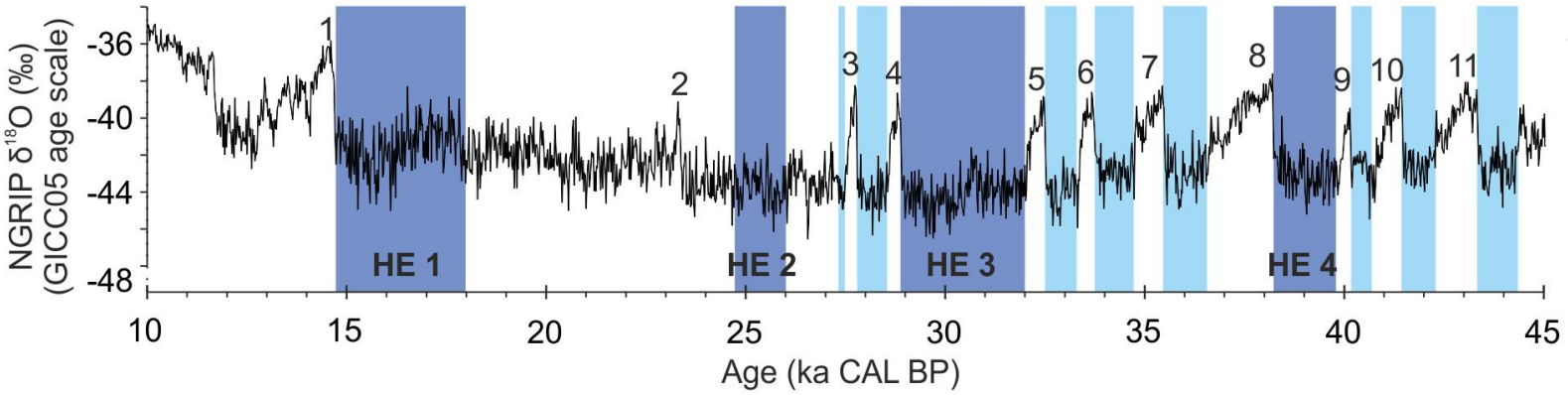
ICE-BIO-RAM

➢ Climatic context

Last glacial period (≈ 10-60 ka BP) :

↳ punctuated by **abrupt climatic events**:

- **Heinrich events**
- **Dansgaard-Oeschger cycles**



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➢ Interests and problematic

Many paleoreconstructions and model experiments…

… BUT : processes still poorly understood + different mechanisms evoked.

Prevailing theories:

↳ Changes in North Atlantic oceanic circulation:

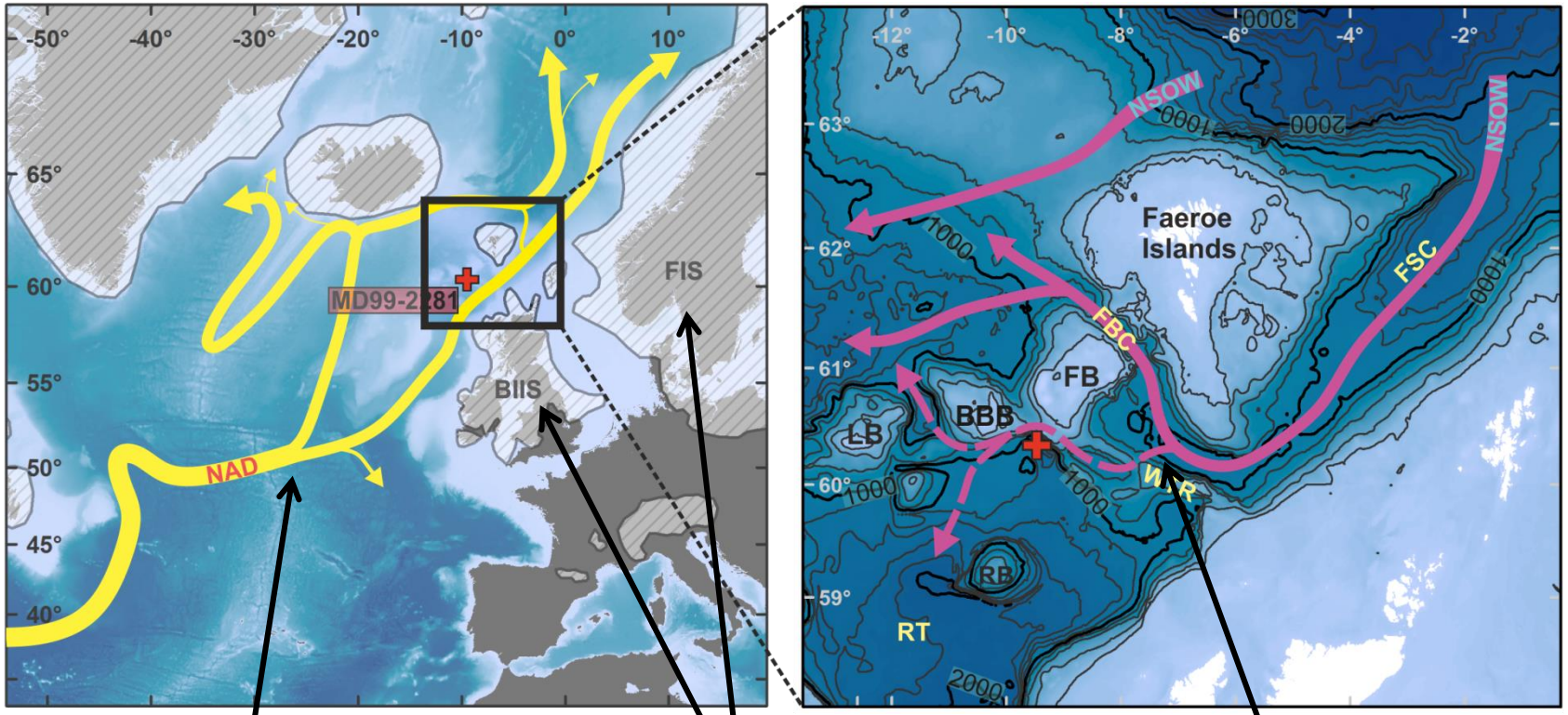
→ Cause(s)

→ Consequence(s)

➔New hydrological paleoreconstitutions are needed:

- Key study area
- High temporal resolution
- Multiproxy approach

➢ Key study area: SW off Faeroe



Sub-surface : **warm and salted atlantic waters** (North Atlantic Drift - NAD)

Two proximal **ice-sheets**: british (BIIS) and fennoscandian (FIS)

Bottom : **deep and cold water masses** (Norwegian Sea Overflow Waters - NSOW)

Sources : *Ehlers & Gibbard*, 2007; *Orvik & Niiler*, 2002; *Stanford et al.*, 2011; *Boldreel et al.*, 1998; *Kuijpers et al.*, 1998, 2002; *Howe et al.*, 2008; *Locarnini et al.*, 2006.

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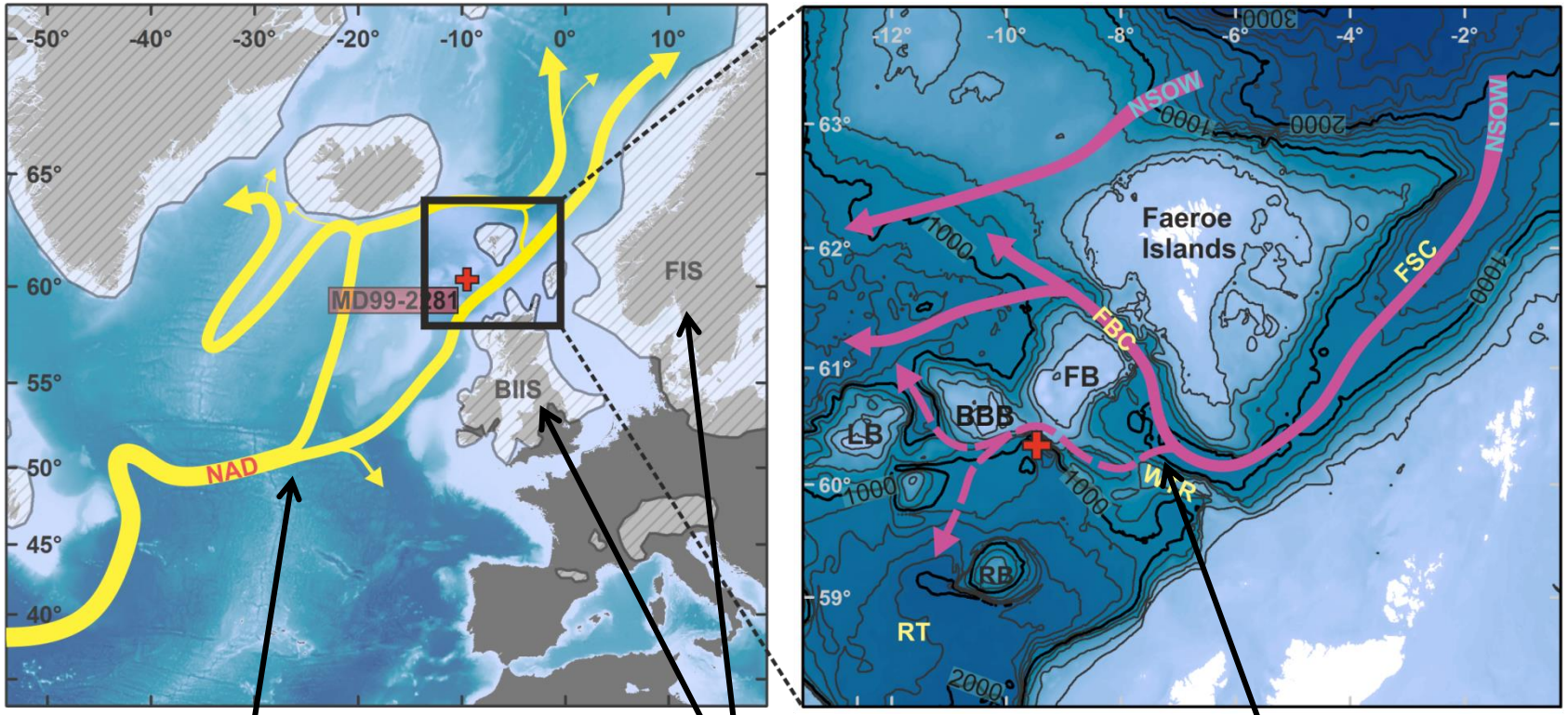

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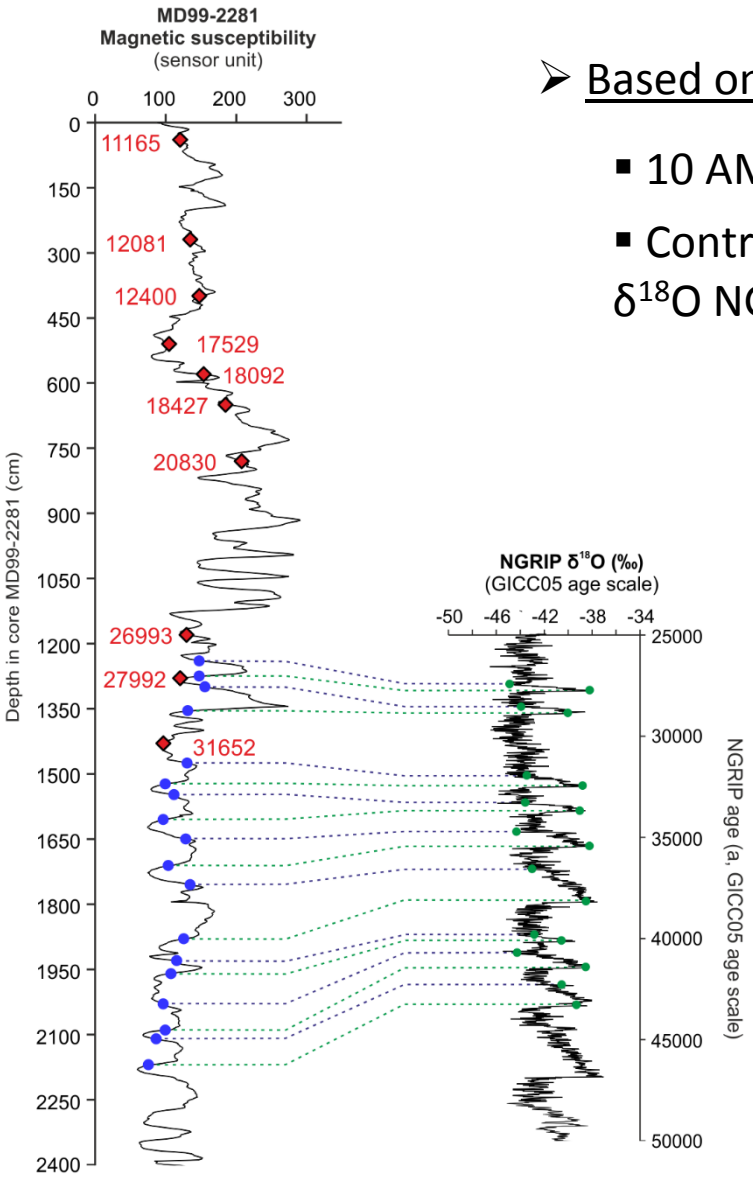
MD99-2281, ≈ 80 cm/ka → infra-millennial scale (mean resolution ≈ 165 year)

➢ Age model

➢ <u>Unchanged since:</u> Zumaque *et al.* (2012) and Caulle *et al*. (2013).



➢ <u>Based on:</u>

- 10 AMS ^{14}C dates (◆)
- Control points: magnetic susceptibility (●) ↔ $\delta^{18}O$ NGRIP (●) → Kissel *et al.*, 1999, 2008

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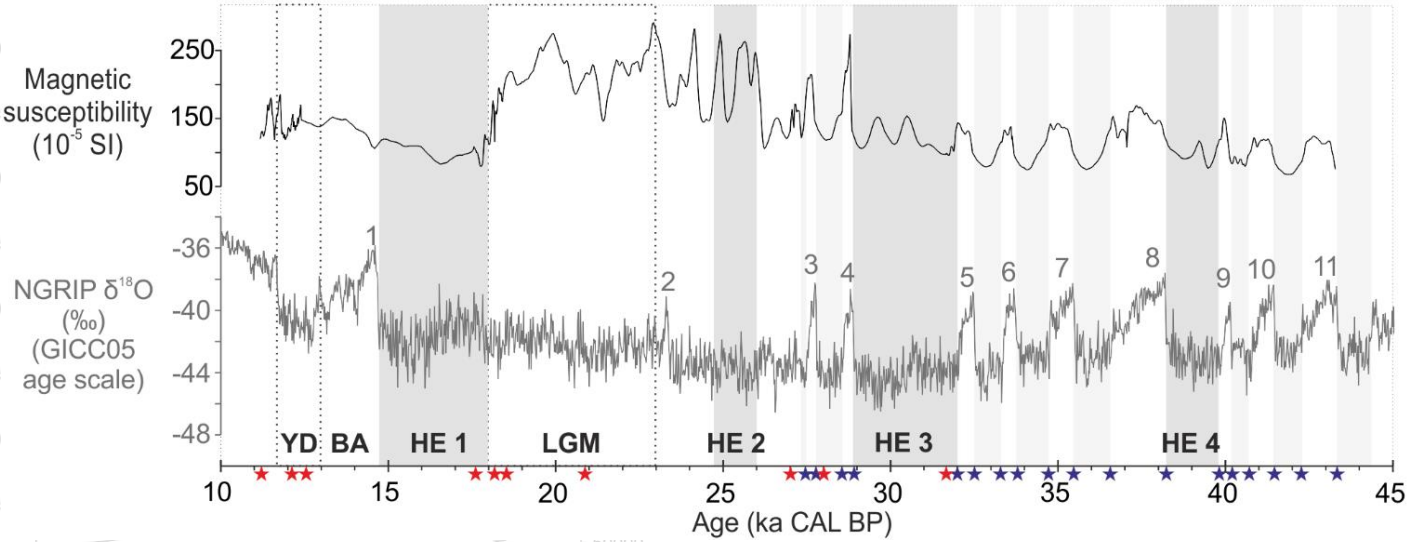
➢ ~ 10 – 43 ka CAL BP

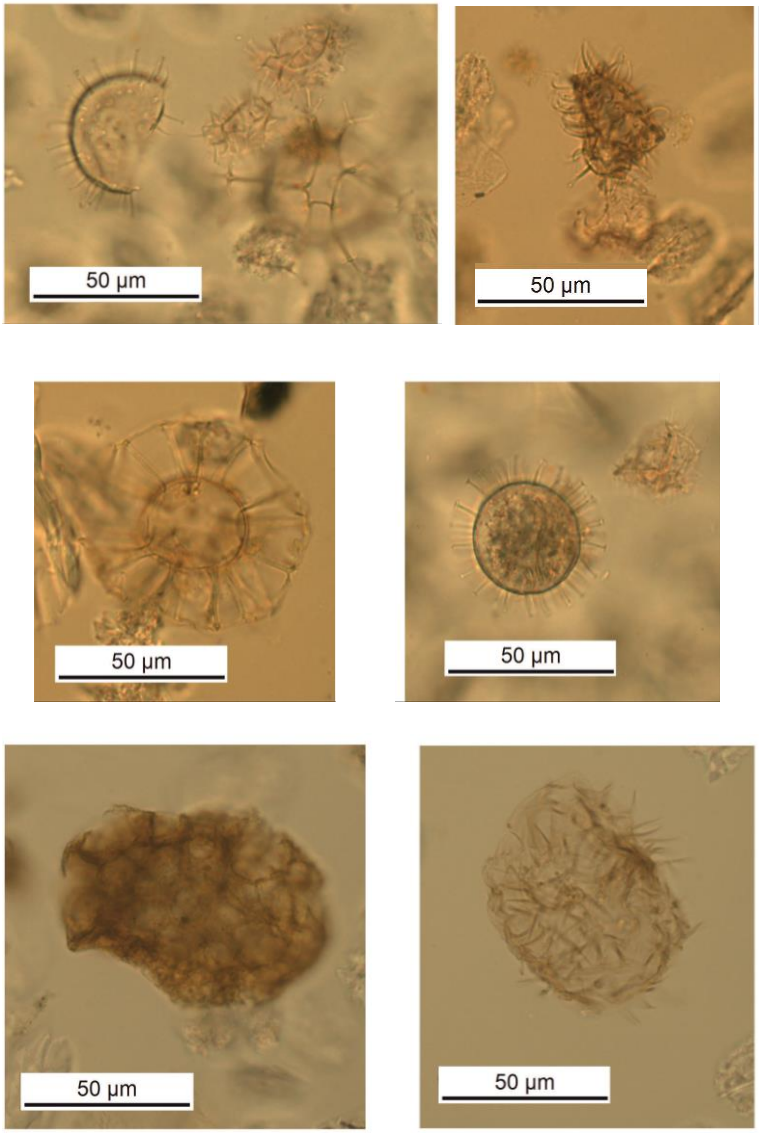


➢ Multiproxy approach

Reconstitution of hydrological conditions:

- Surface (0-50 meters)
- « Sub-surface » (0-300 meters)
- Sea floor

➢ Surface proxy : dinocysts



➢ Assemblages + transfer function:

↓

Quantitative estimation of **surface** (0-50 mètres) **hydrological parameters** (temperatures + salinities)

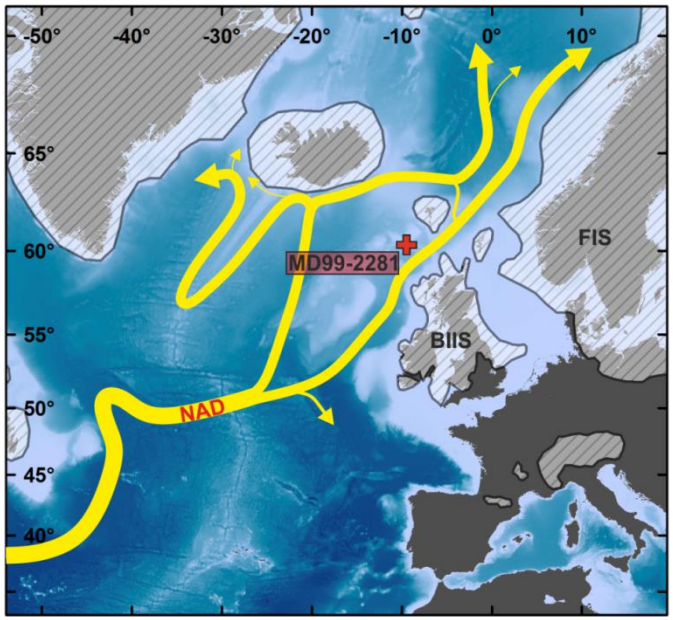
↓

Degree of surface water stratification

➢ Sub-surface proxies: planktonic foraminifera

➢ Assemblages + transfer function: quantitative estimation of **sub-surface temperatures**

➢ $\delta^{18}O$: qualitative estimation of **sub-surface salinities**



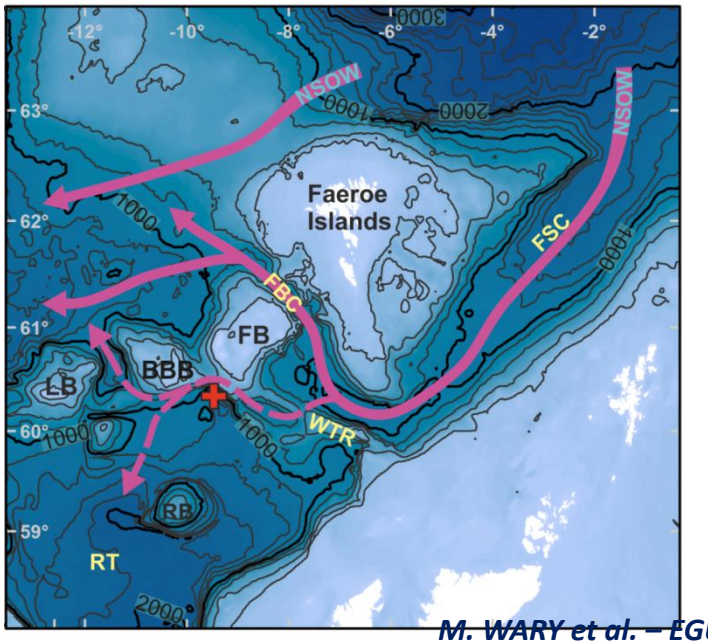
Relative variations of the North Atlantic Drift intensity
(warm and salted waters)

➢ Deep proxies : sedimentological tools

➢ **Grain-size measurements** (e.g. McCave *et al.*, 1995) **:**
- ↳ preferential effect on the silt fraction (10-63 µm)
- ↳ stronger current → coarser silt fraction

➢ **Magnetic susceptibility** (e.g. Kissel *et al.*, 1999) **:**
- ↳ stronger current → higher MS

Relative variations of bottom current intensity



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➢ Stratification of the water column ?

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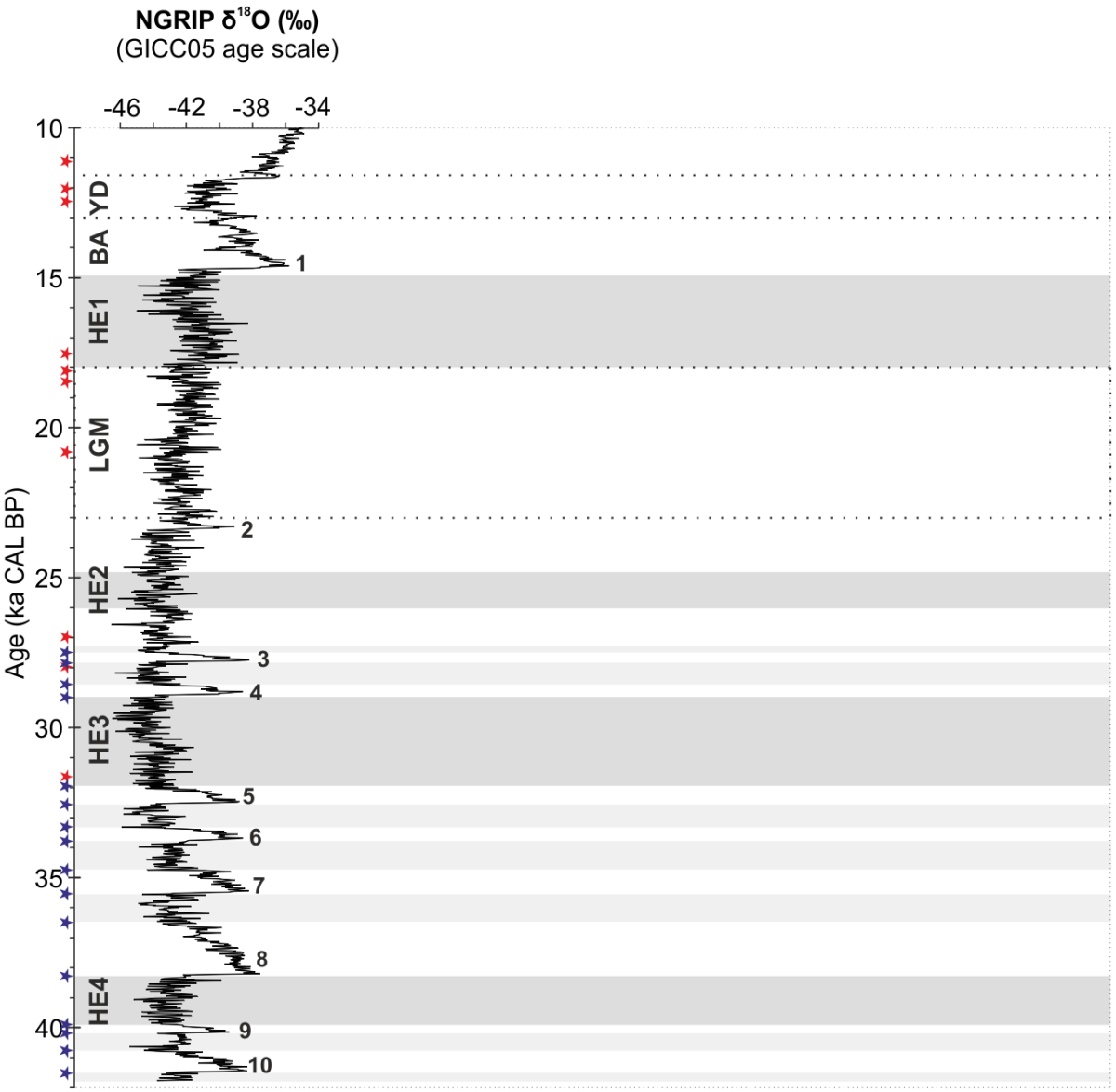
Hydrological parameters derived from dinocysts



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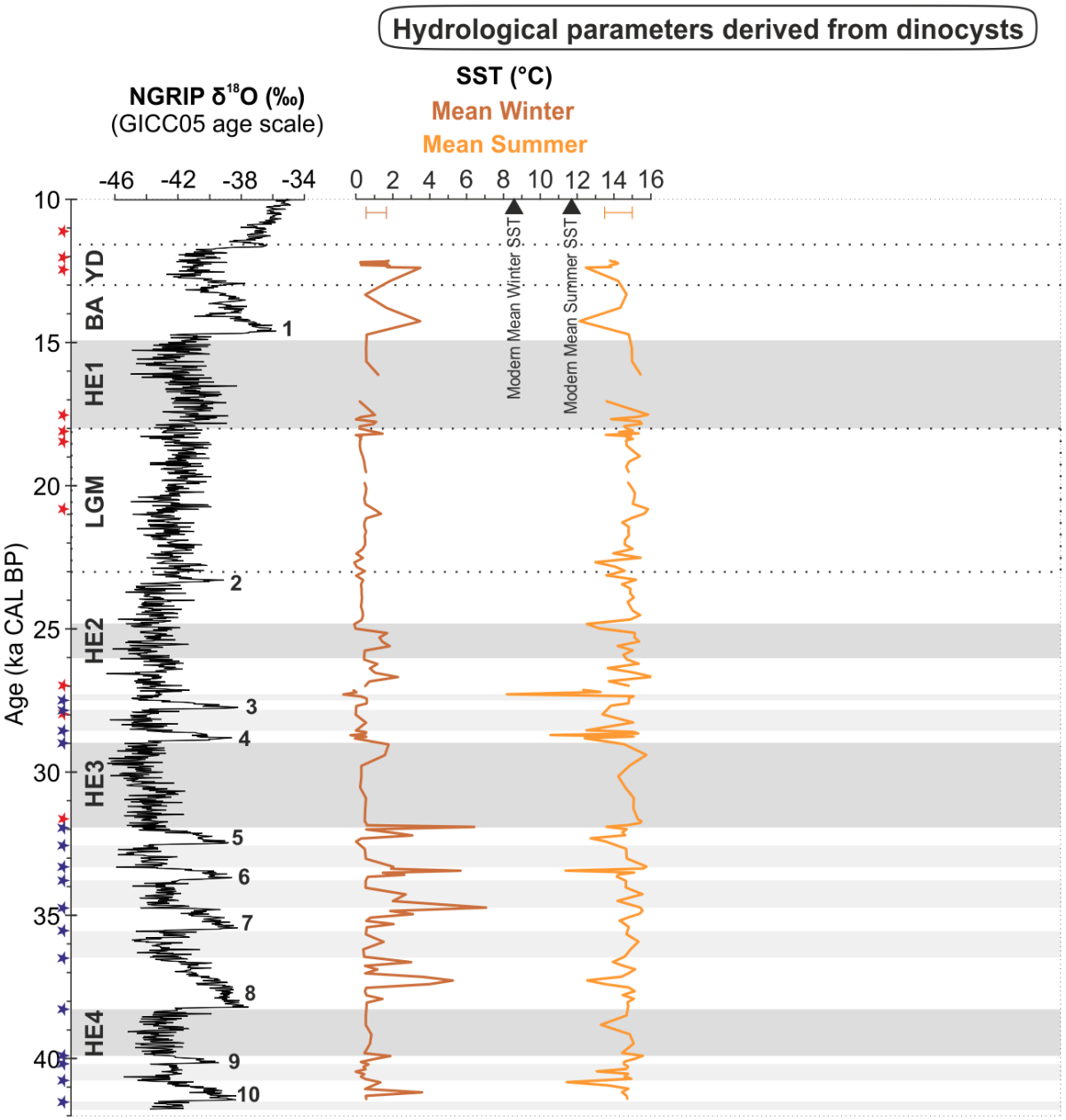

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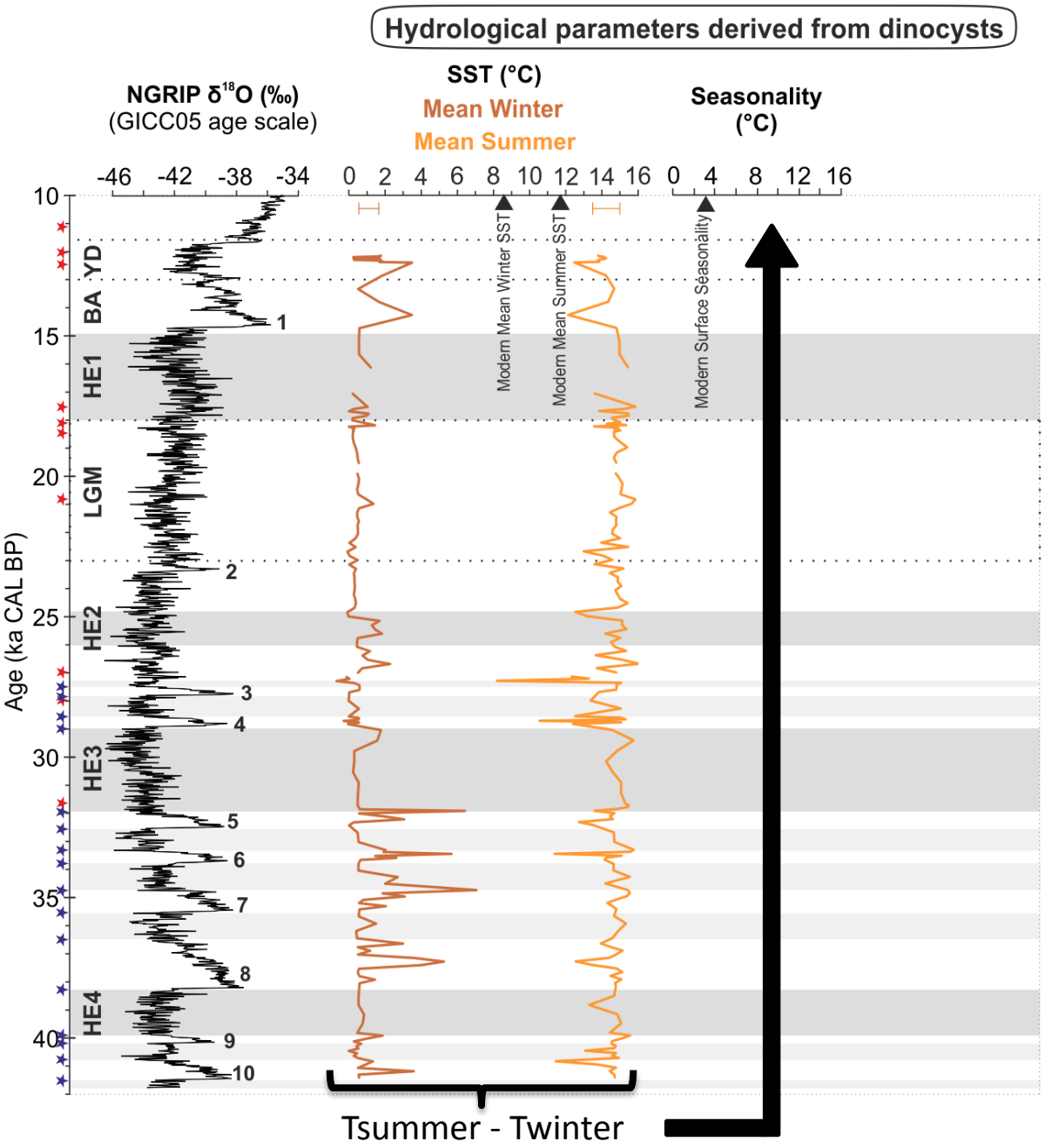

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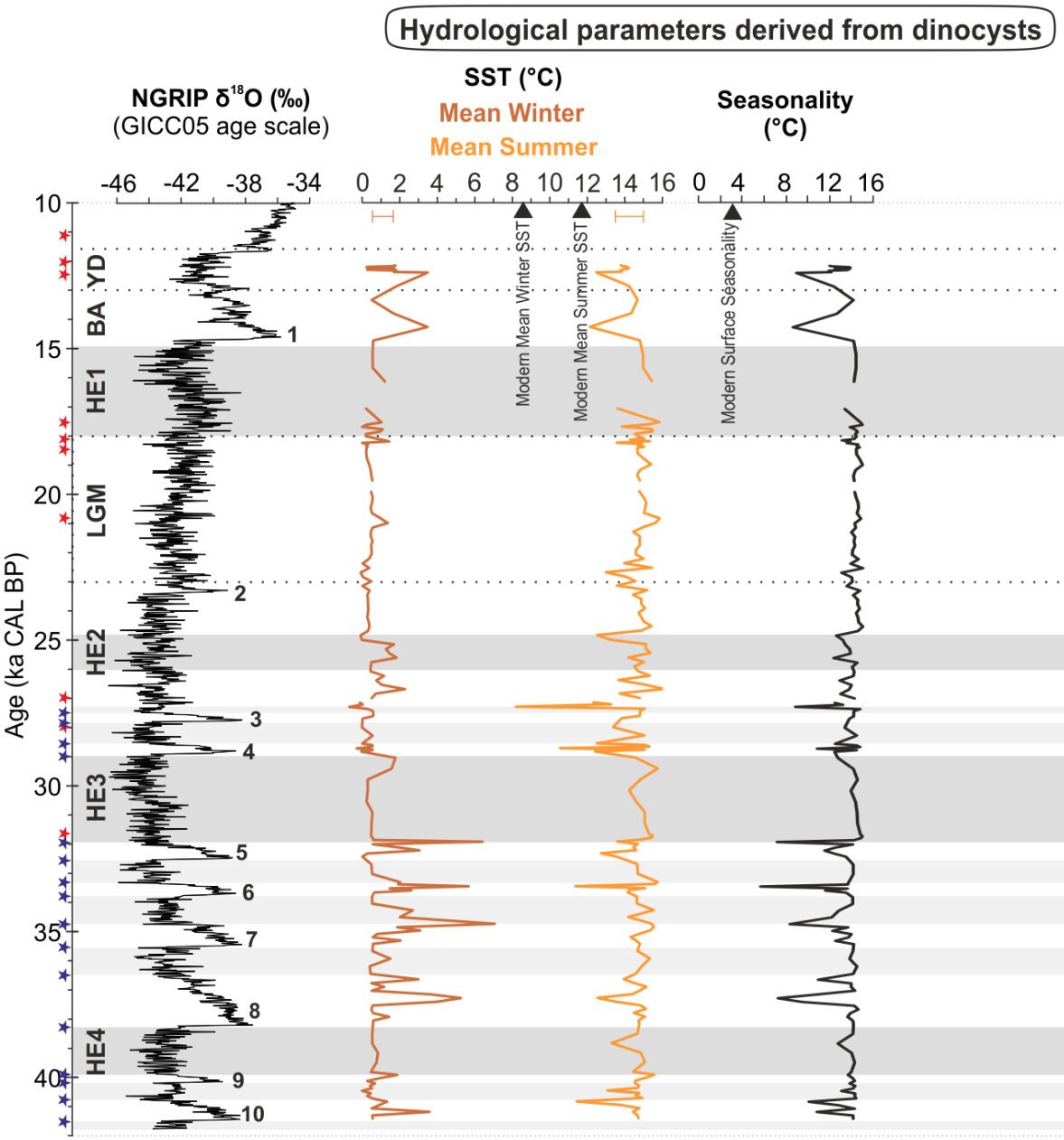

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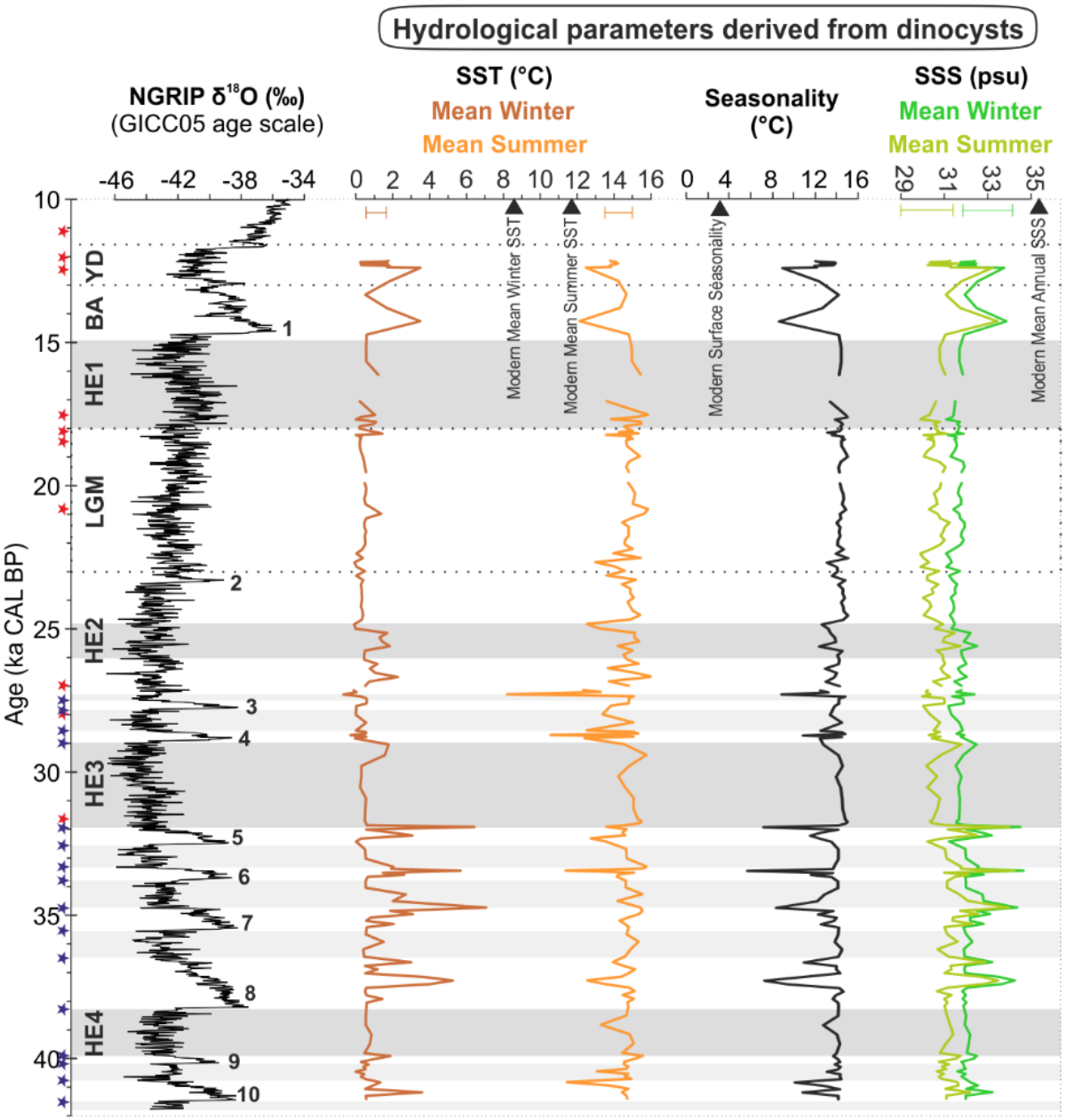

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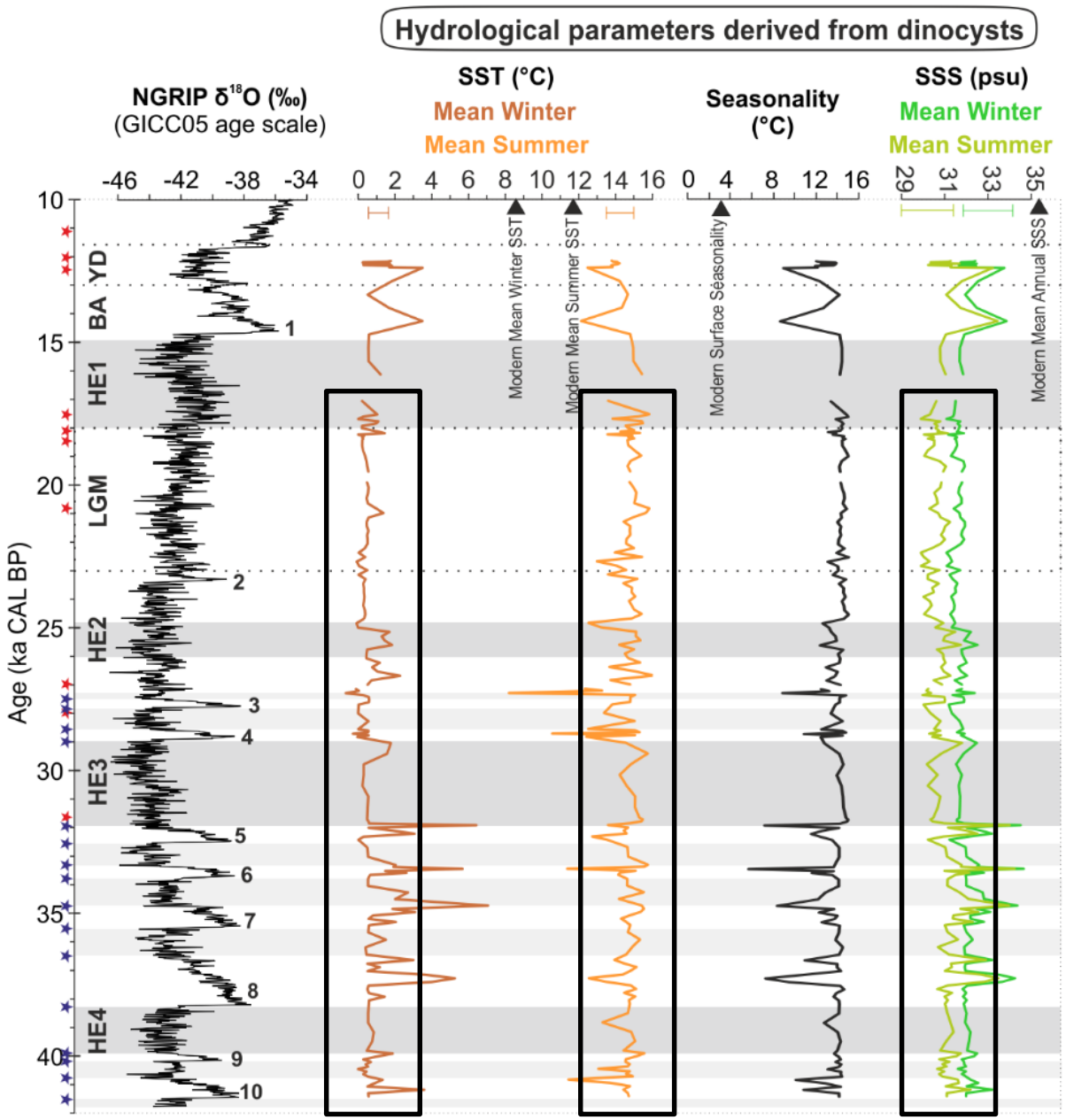

Thin surface layer of freshwater with low thermal inertia

Stratification + strong seasonality

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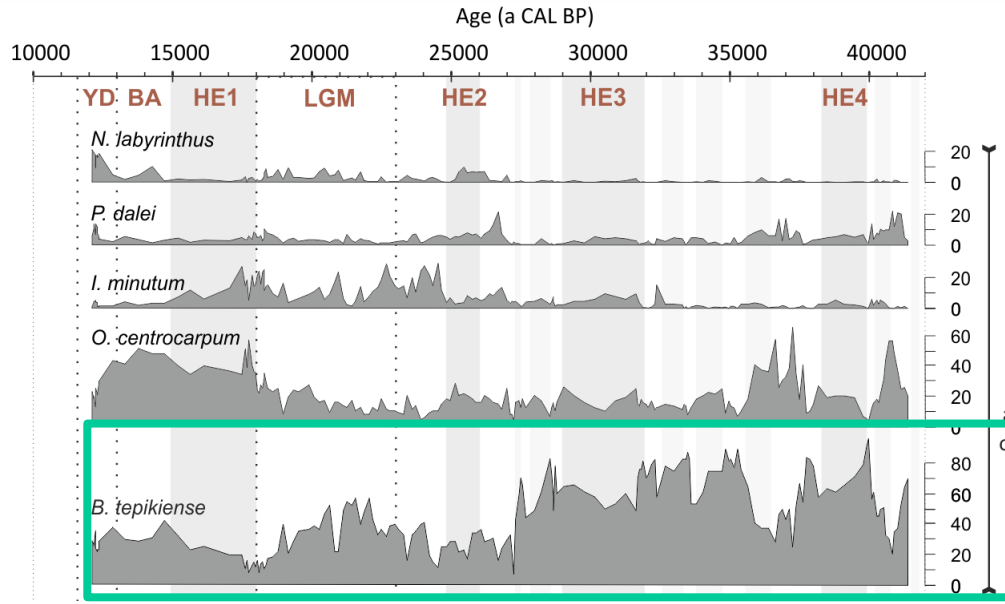

Nlab	Cold/warm waters mix
Pdal	Subpolar to polar
Imin	Sea-ice
Ocen	NAD pathway
Btep	Stratification + seasonality

Stratification + strong seasonality

➢ Hydrological signatures during MIS3 abrupt events ?

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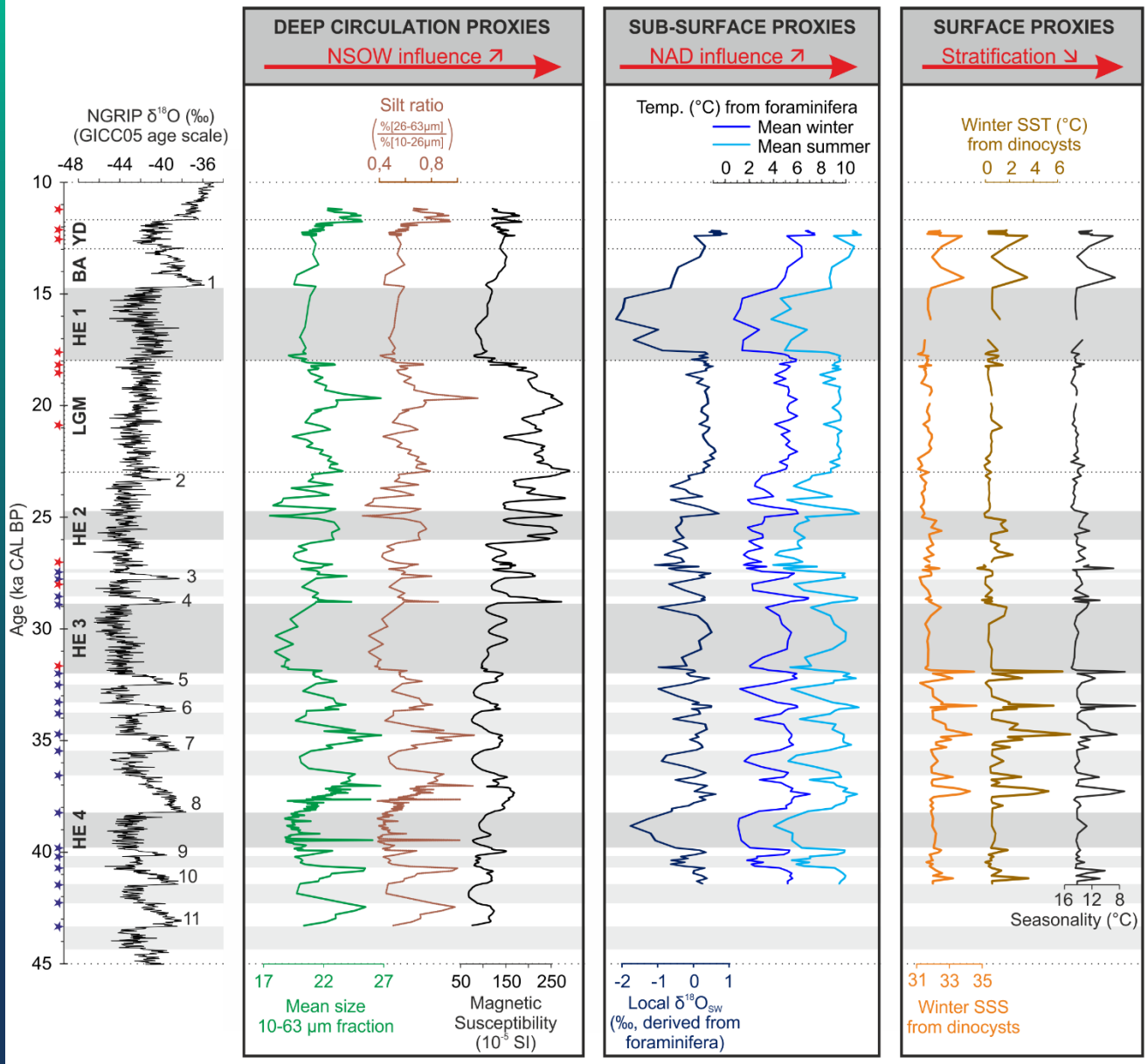

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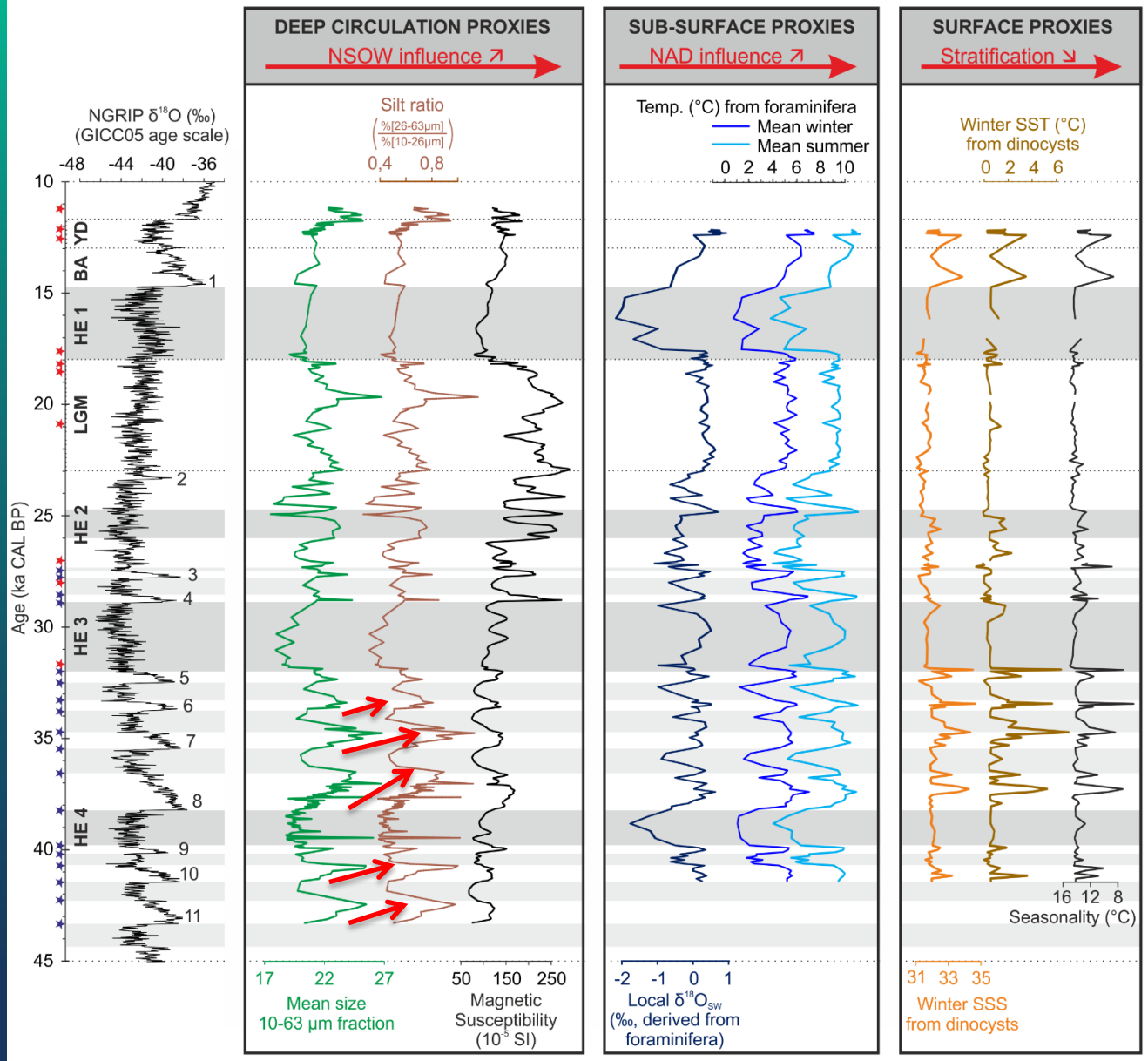

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- NSOW progressive Intensification

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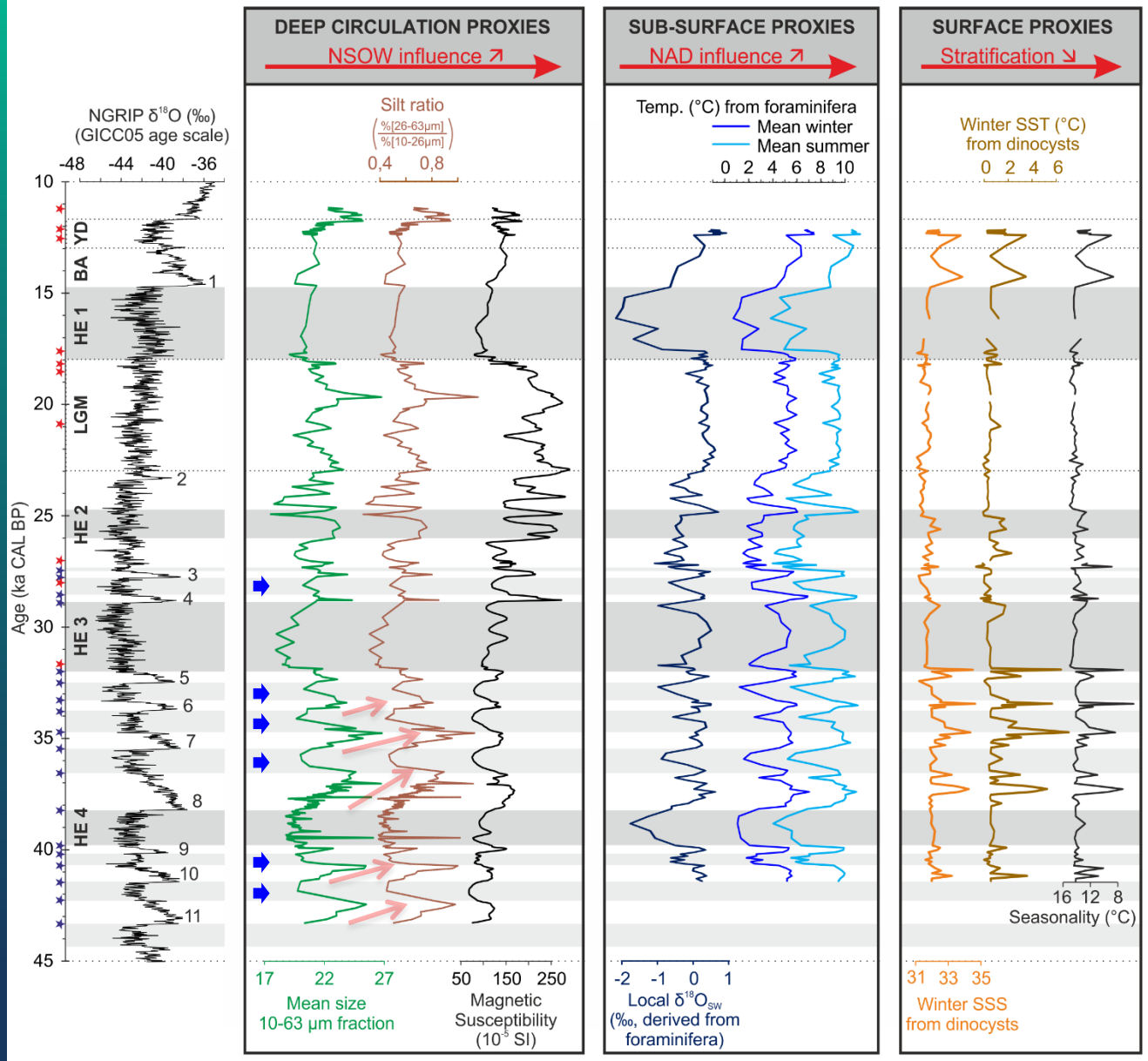

➢ **Interstadials :**

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➢ **Stadials :**

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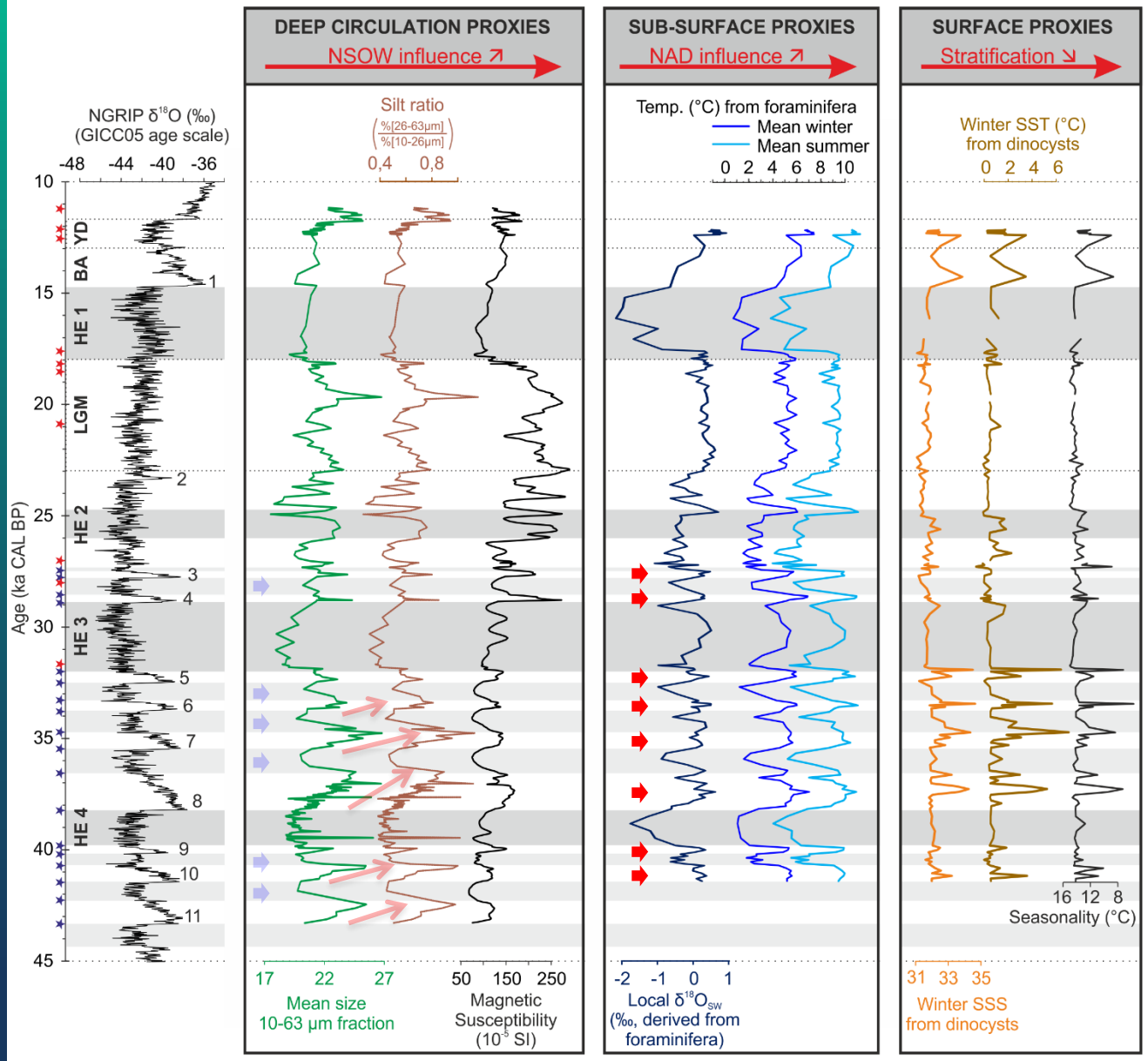

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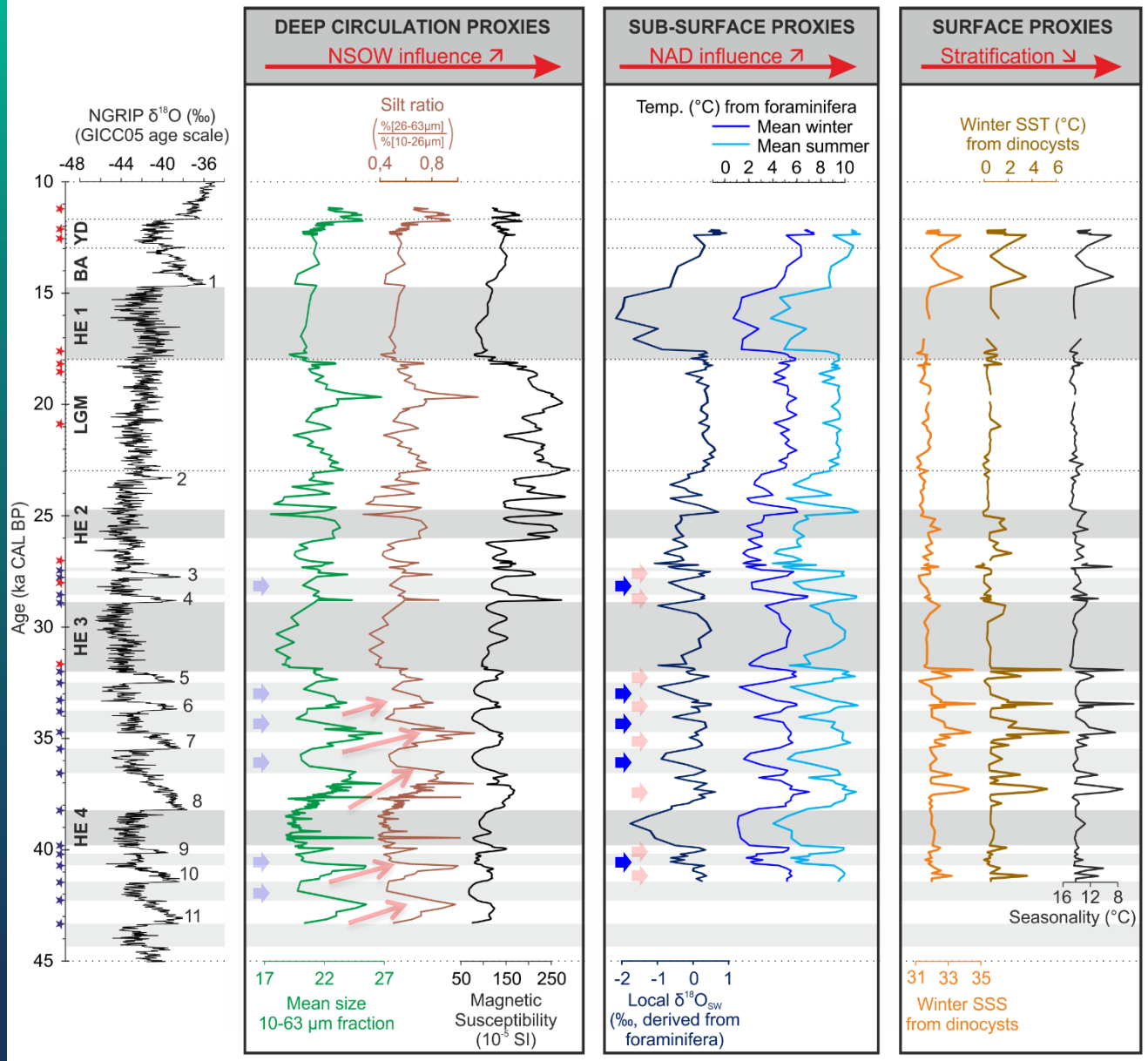

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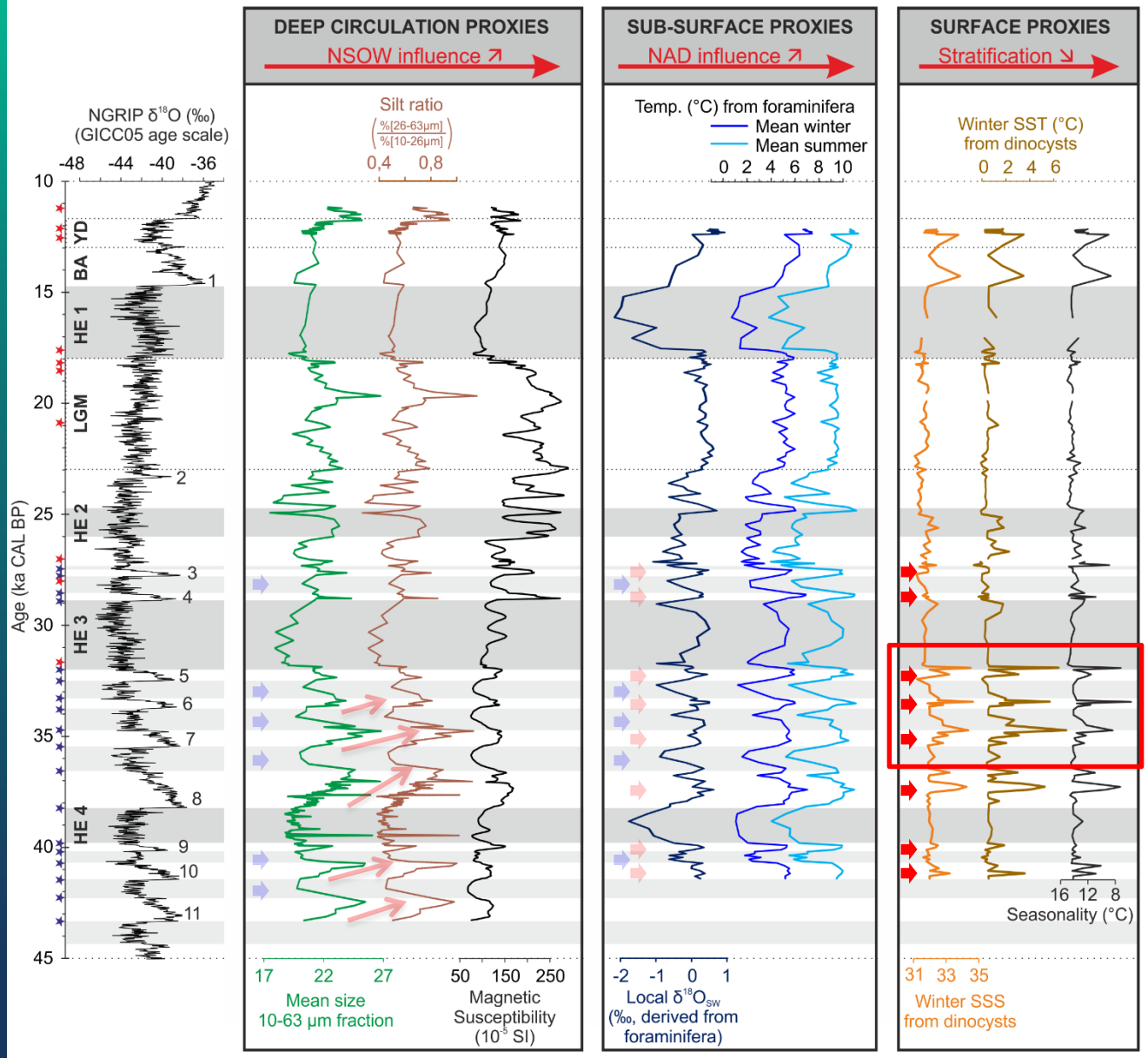

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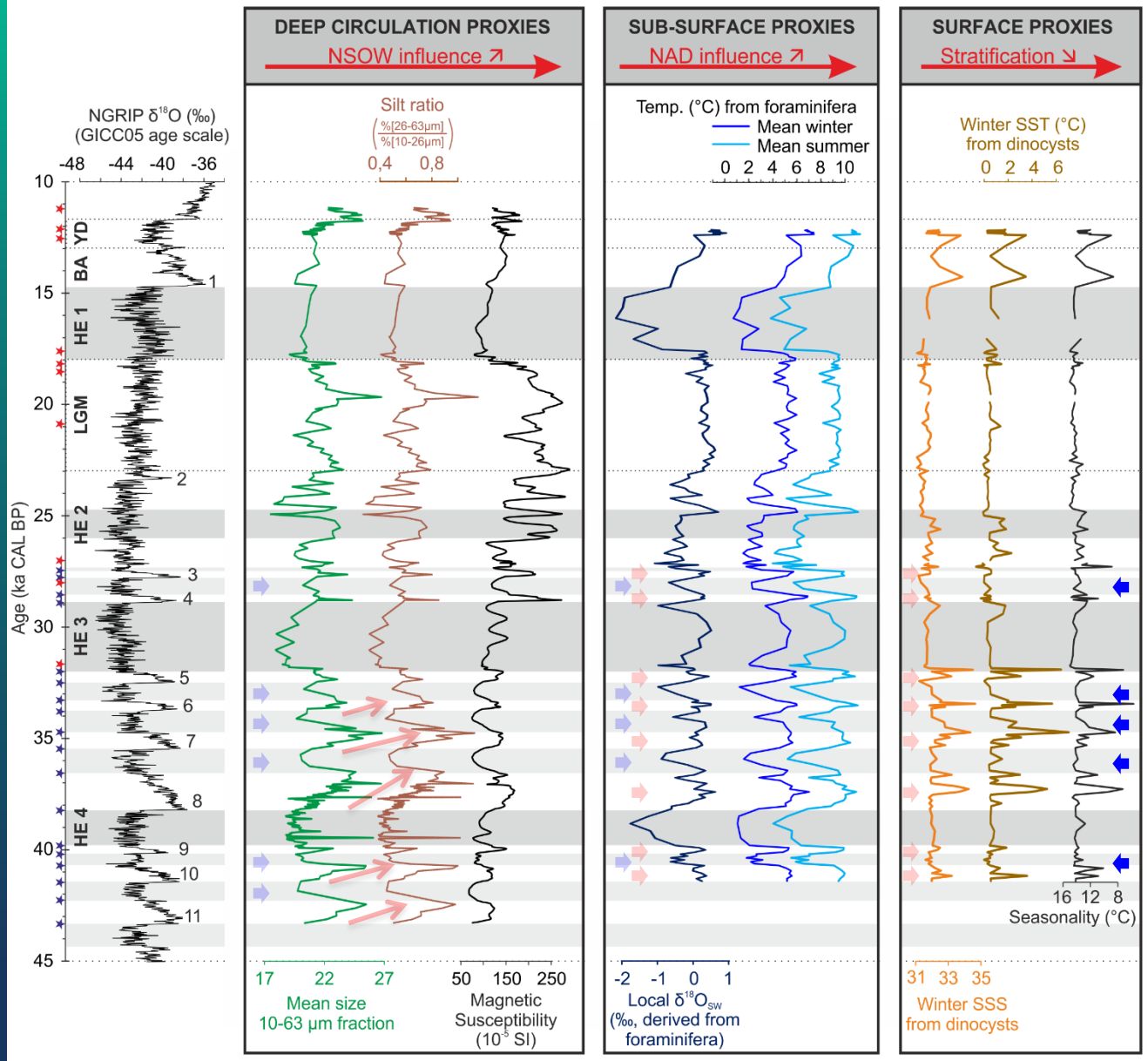

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➢ **Stadials :**

- Weak NSOW
- Weak NAD
- Strong surface stratification

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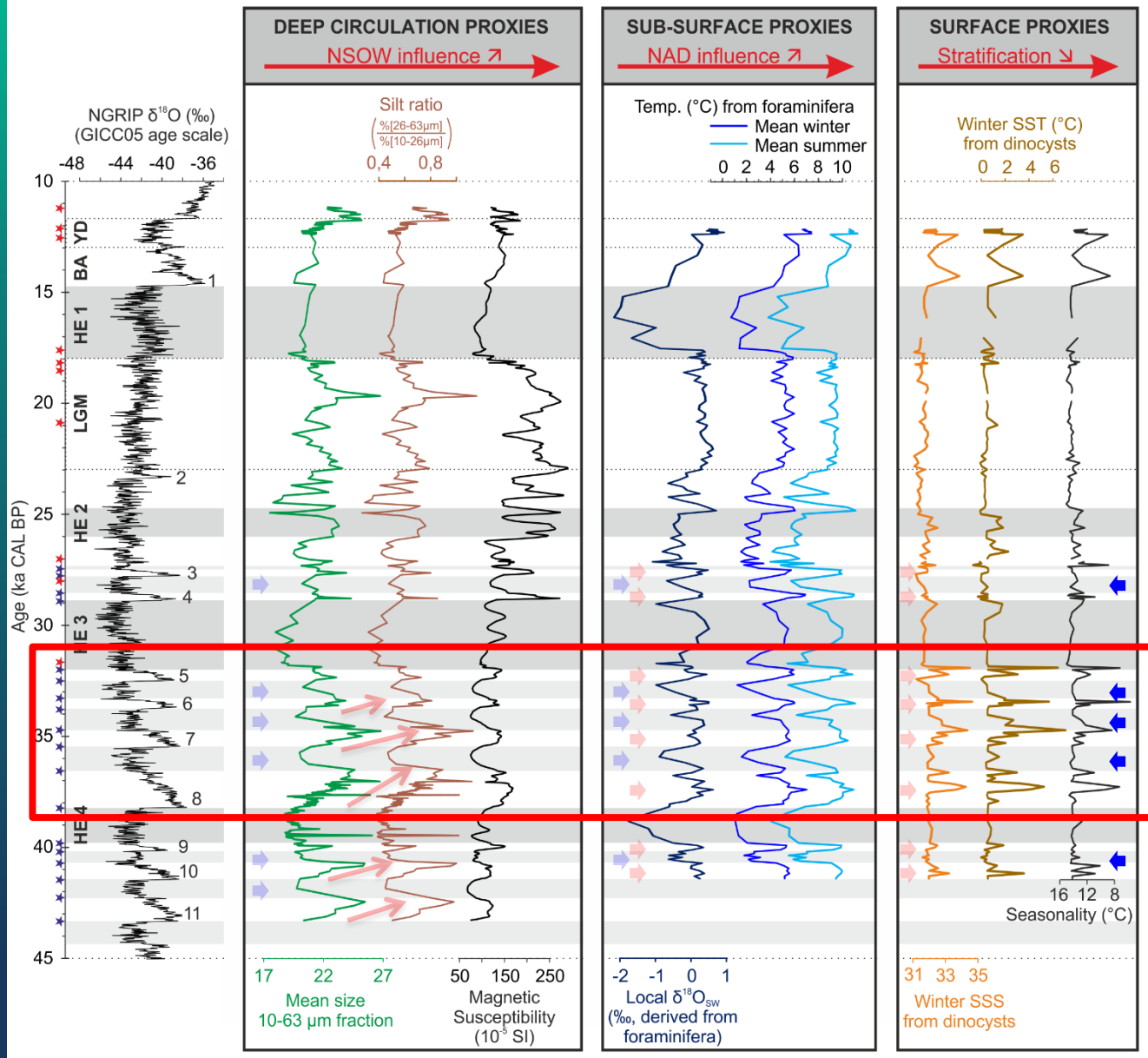
➢ Role of surface stratification?



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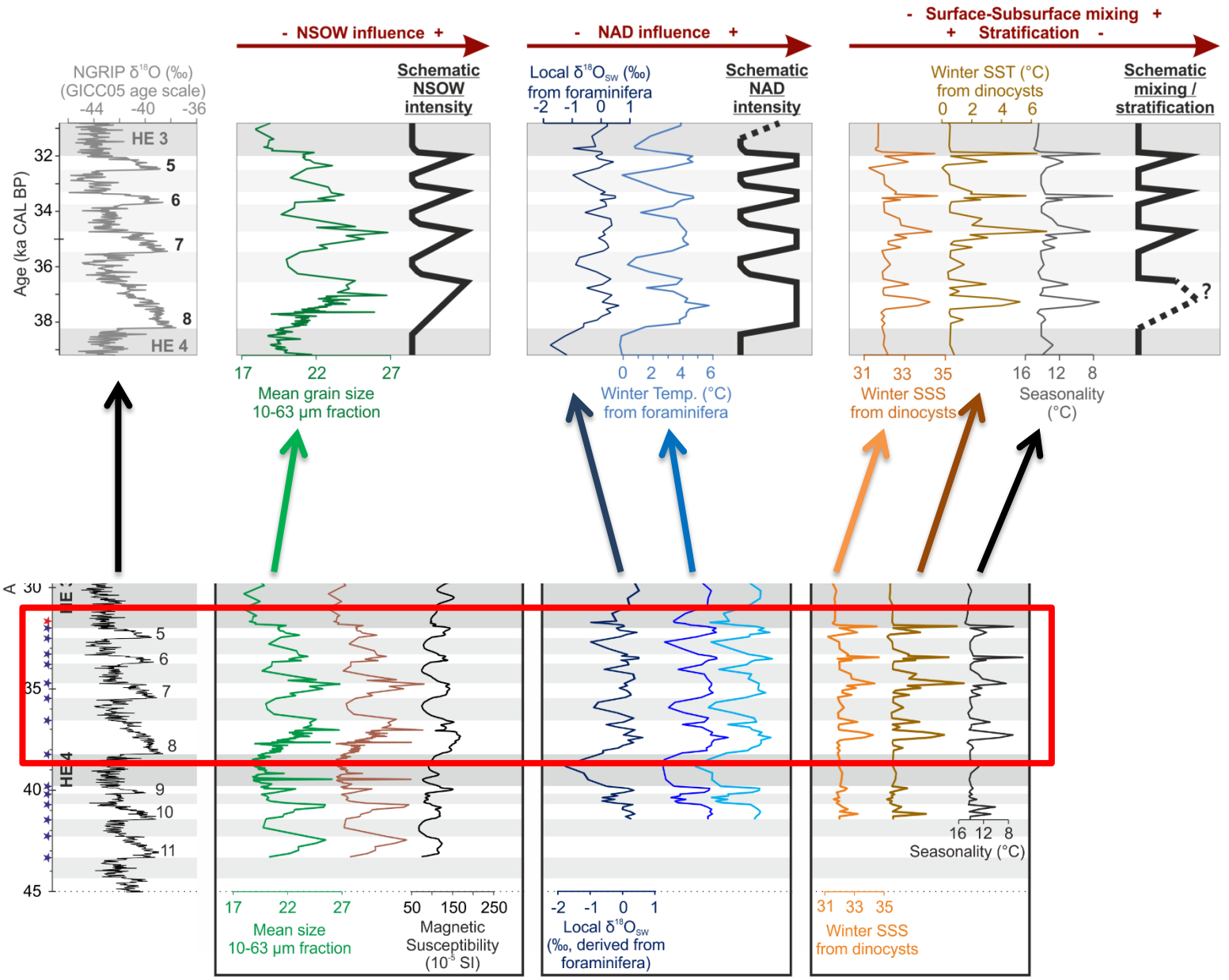

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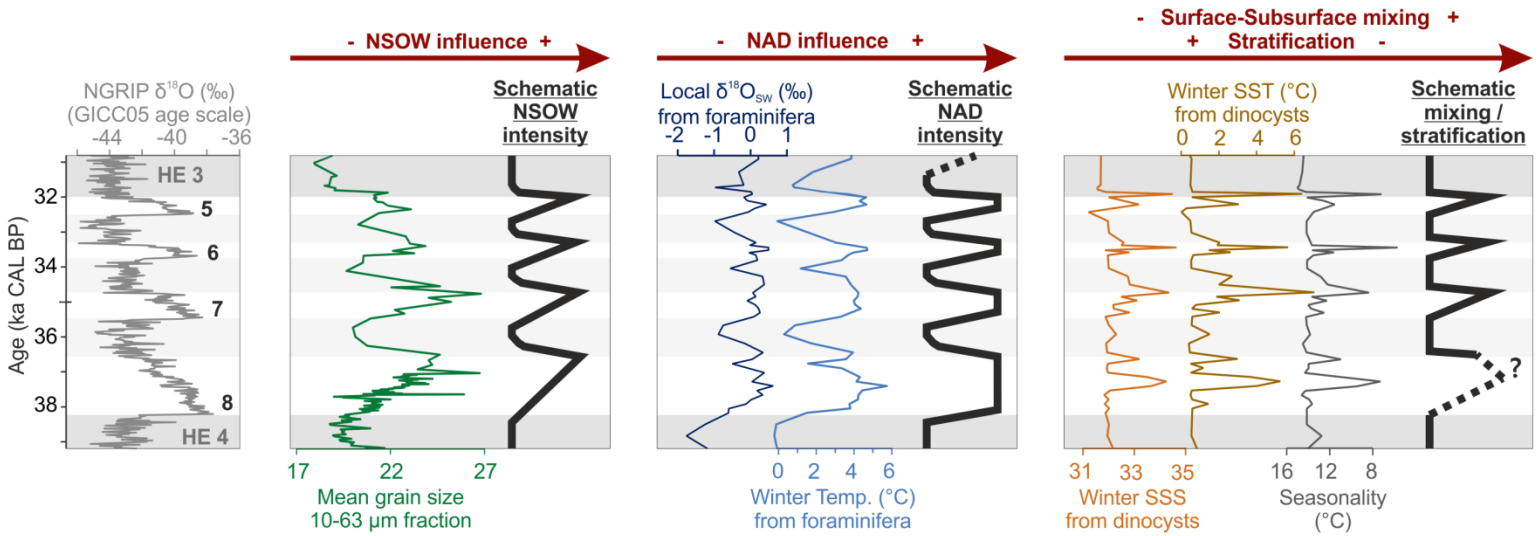
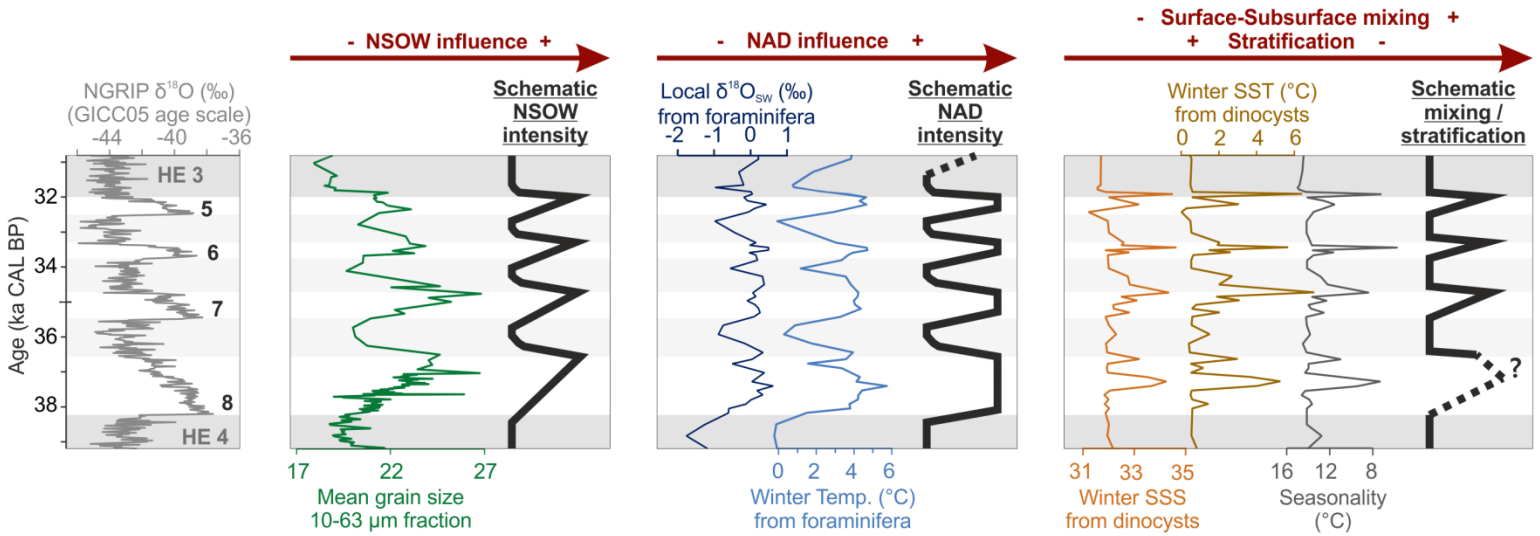


➢ Strong stratification (stadials) : coupling of sub-surface and bottom oceanic circulations

➢ Weak stratification (interstadials) : coupling of surface and bottom water mass dynamics

➢ Role of surface stratification?



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<u>Important role of surface stratification on water mass dynamics during MIS3 abrupt events</u>

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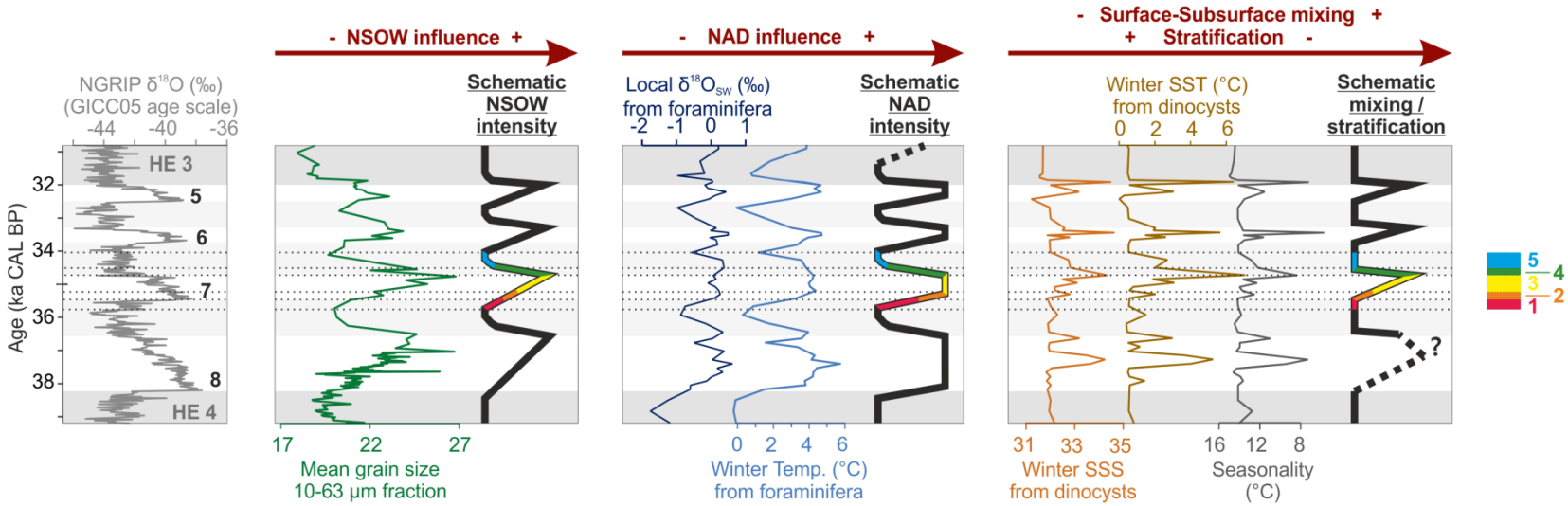

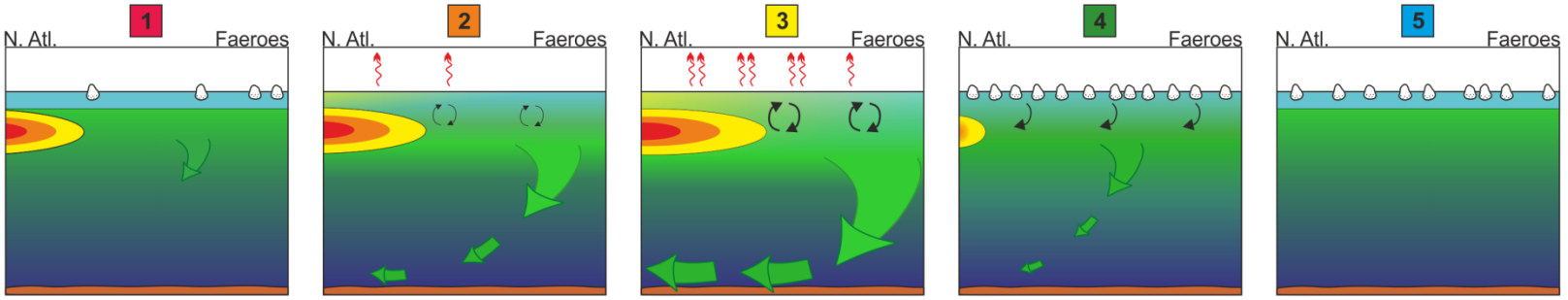

Very end of GS:

NAD rapidly re-intensifies, but the water column is still highly stratified. The halocline prevents any heat exchange towards the atmosphere. Subsurface waters get warmer and warmer. Deep convection is nil or limited.

Beginning of GIS:

The halocline starts to be unstable; surface and subsurface waters start to mix, and stratification is progressively reduced. Discreet heat exchange towards the atmosphere occurs. Deep convection is progressively reactivated.

Middle + end of GIS:

The NAD activity is maximal. Subsurface waters progressively mixed with surface waters throughout the GIS. Heat is released to the atmosphere. Deep convection is fully reactivated; the NSOW vigor increases throughout the GIS and reaches its maxima at the end of this period.

Beginning of GS:

Iceberg discharges occur. The associated meltwater inputs propagate in the mixed surface-subsurface layer, lower its salinity, increase the degree of stratification, reduce deep convection, and weaken the NAD and NSOW flows.

Middle of GS:

Surface waters are highly stratified. NAD and NSOW flows are nonexistent or weak.

➢ Conclusion

➢ Dinocysts = useful tool → direct access to the past characteristics of the surface water masses (0-50m)

➢ Advantages to couple different proxies → track hydrological processes at different depth of the water column

➢ Important role of surface stratification on the oceanic circulation during the abrupt climatic events of the last glacial period (and vice versa)

Thanks for your attention !