Assessing uncertainties on the stability of the AMOC during Heinrich events using simulations from one Earth System model.

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Heinrich Stadials (HS1)

HS1

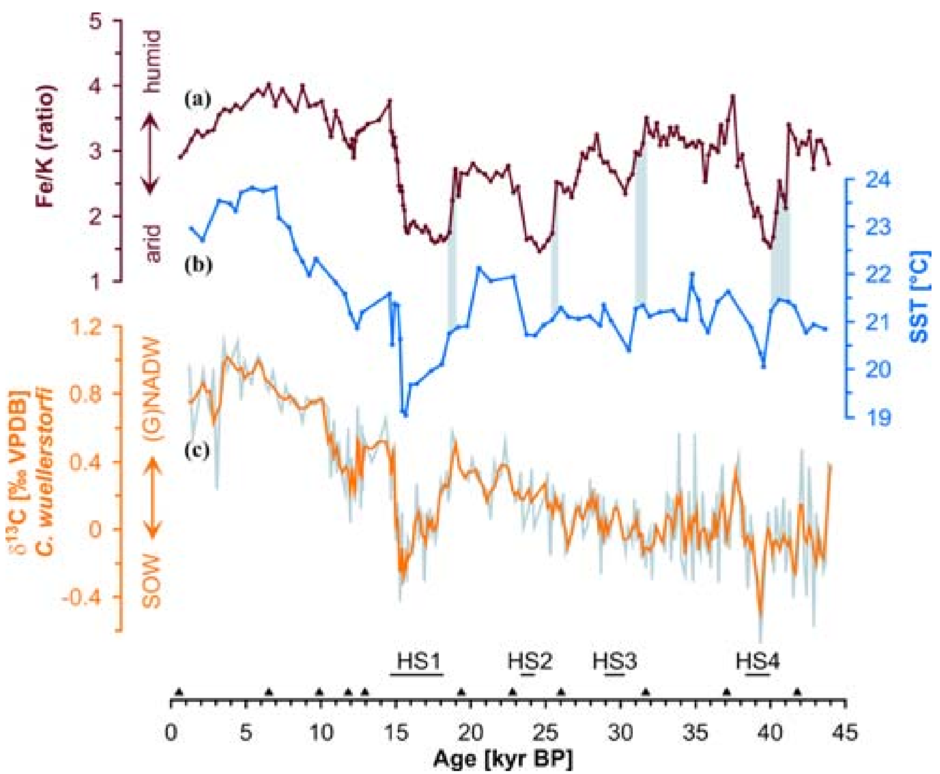
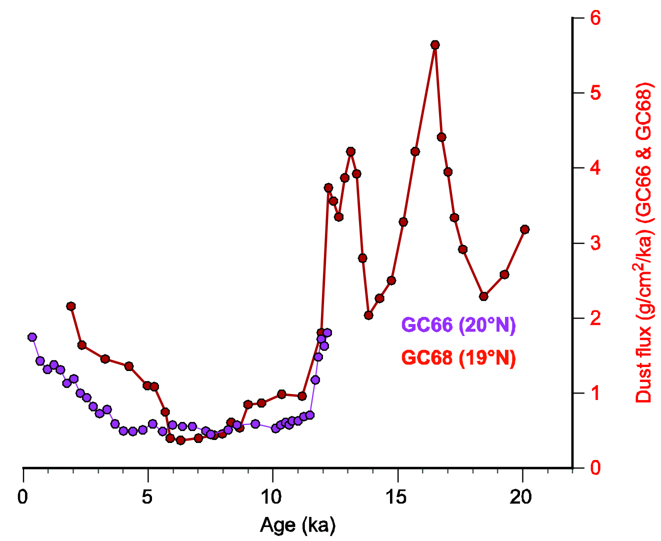


Fig. 2 from Niedermeyer et al. (2009)

HS1



Adapted from Fig. 4 from McGee et al. (2013)

Heinrich Stadial events are millennial scale cooling events associated with the drying in the northern tropics (Mulitza et al., 2008; Niedermeyer et al., 2009).

Increased dust over the north Atlantic. (Mulitza et al., 2008; Niedermeyer et al., 2009). HS1 dust fluxes over the North Atlantic were a factor of ~2.6 higher than mean 0–2ka fluxes .

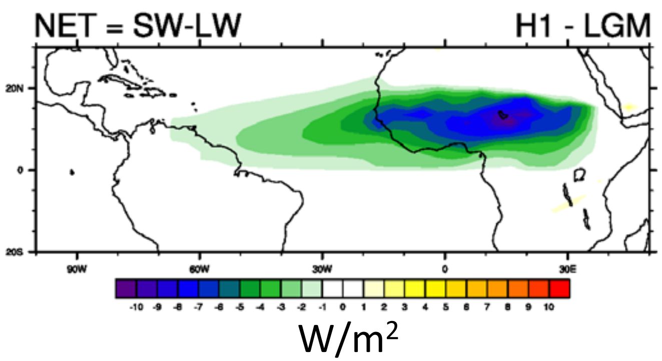
Model experiments

Objective: What is the impact of the enhanced dust loading on ocean circulation during HS1?

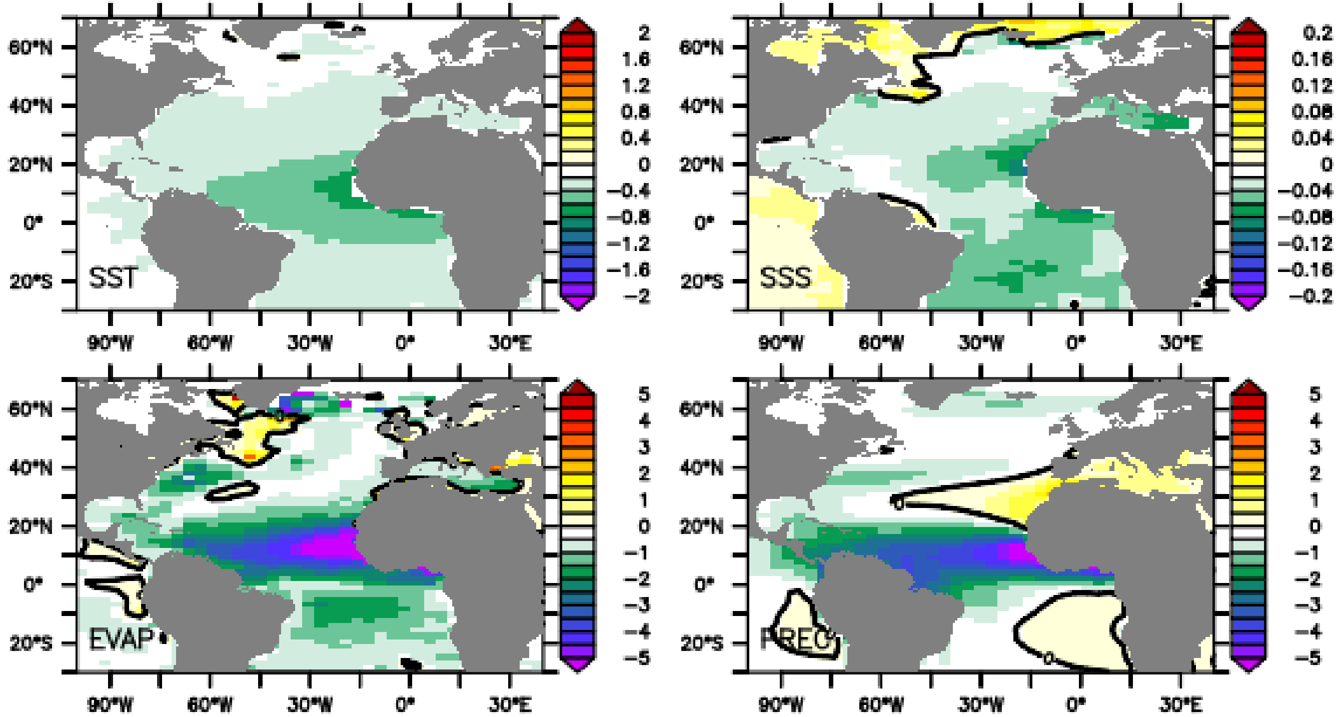
- University of Victoria Earth system model (UVic2.9).
- 1000 year simulations with at least 3000 years of spinup under LGM boundary conditions.
- HS1 FW forcing applied as a virtual flux hosing between 45°N and 65°N.

The Role of African Dust in Atlantic Climate During Heinrich Events
(*Murphy, Goes, and Clement, Paleoceanography 2017***).**

Dust cools and freshens the North Atlantic

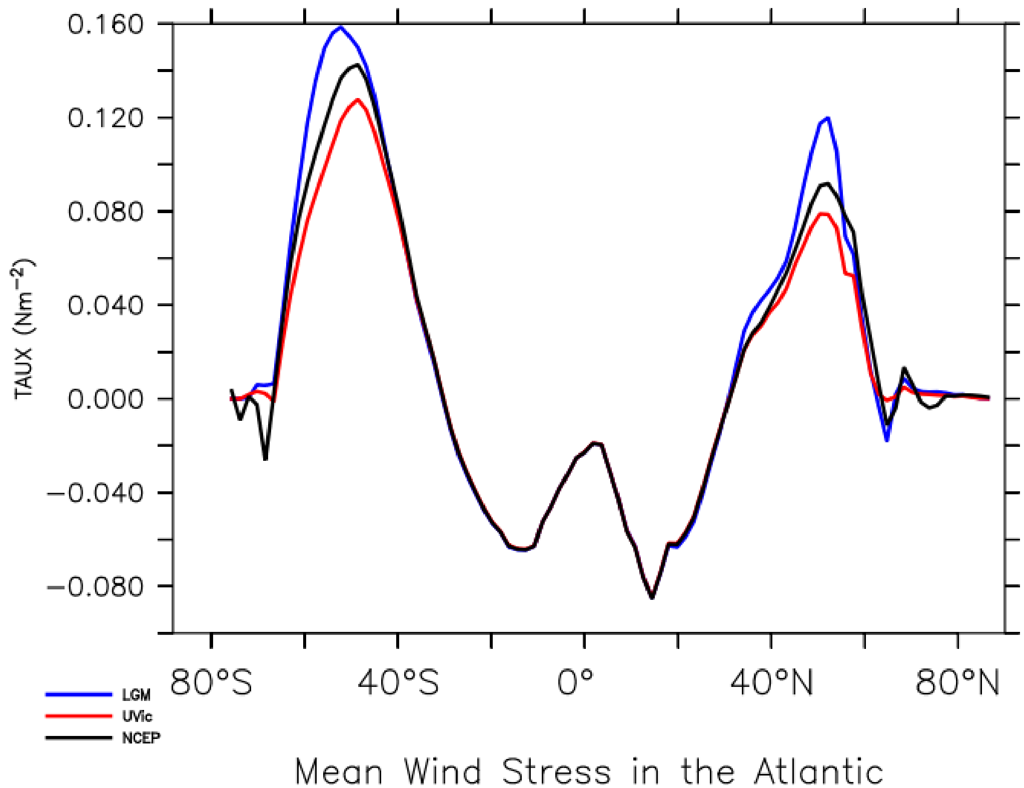


The shortwave fluxes due to Saharan dust are parameterized as a perturbation of the local surface albedo (α_s). Outgoing (TOA) and surface longwave radiation follow surface albedo changes (α_s).



Dust feedbacks can potentially amplify Heinrich events by cooling and freshening the North Atlantic.

Uncertainties: Wind forcing

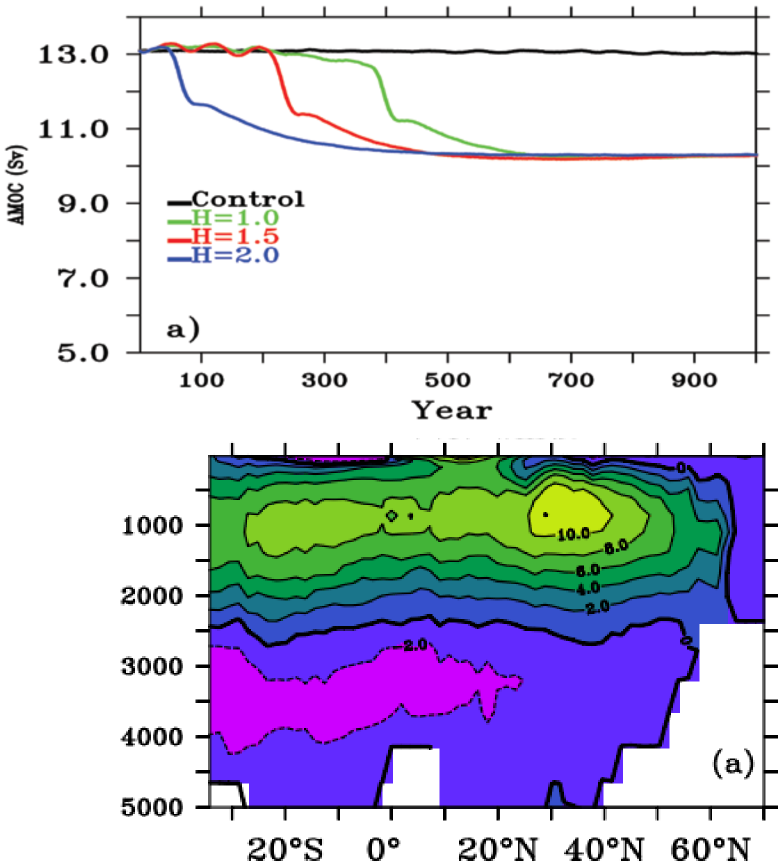


CAM LGM Winds – Derived from CAM4 anomalies (LGM – PI).
Uvic LGM winds – Calculated in Uvic.
NCEP PD winds – NCEP reanalysis climatology.

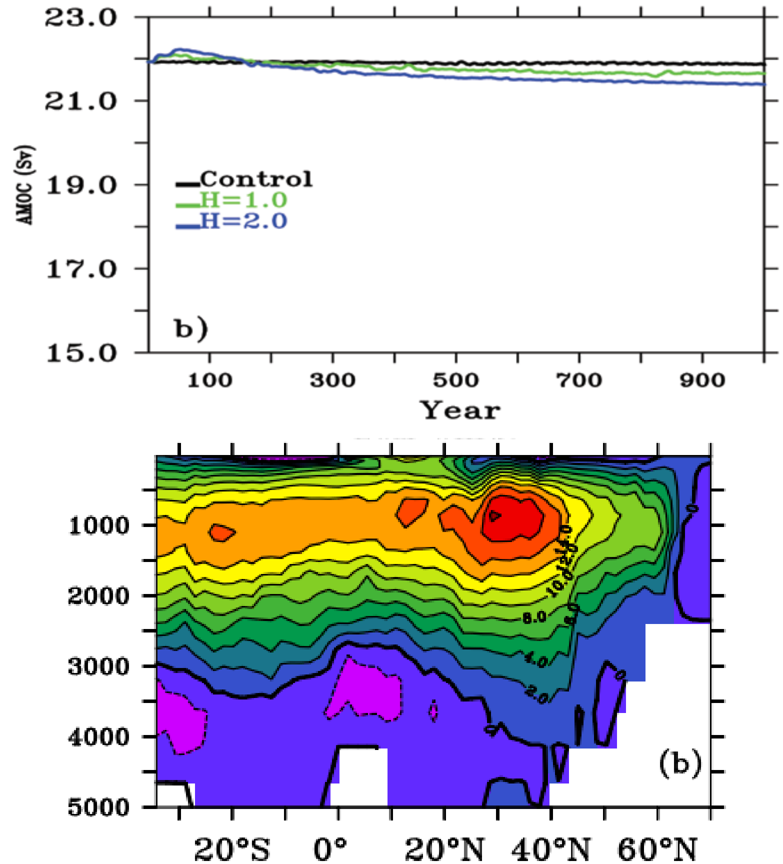
Two wind forcing:
i) Standard **UVic** winds;
ii) **CAM4** SLP anomalies (LGM – PI; Murphy et al., 2014). Wind anomalies are calculated using a geostrophic/ diffusive approximation (Goes et al., 2014).

Uncertainties: Dust forcing

UVic winds



CAM winds



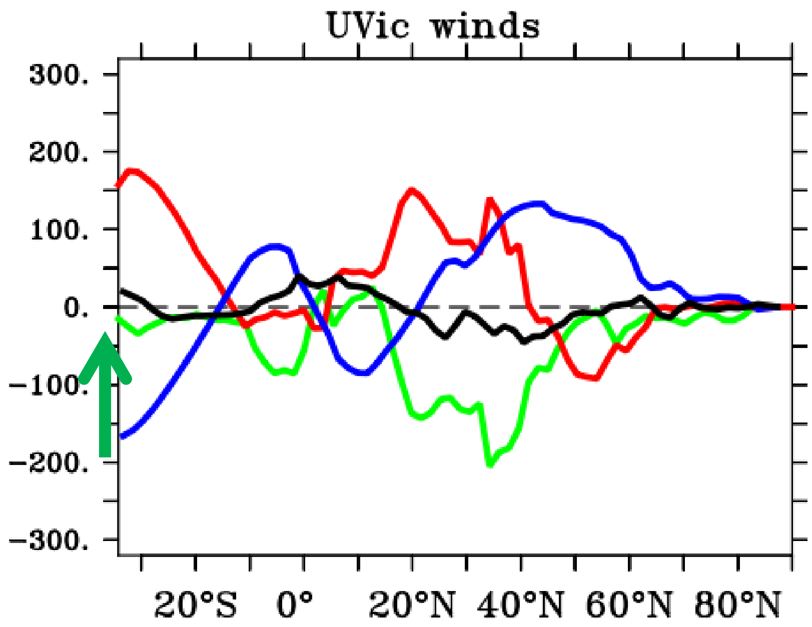
- **Effect of dust radiative forcing dependent on the state of the AMOC**

Uvic winds: Weaker AMOC (13 Sv). Dust decreases strength by 20-25%.

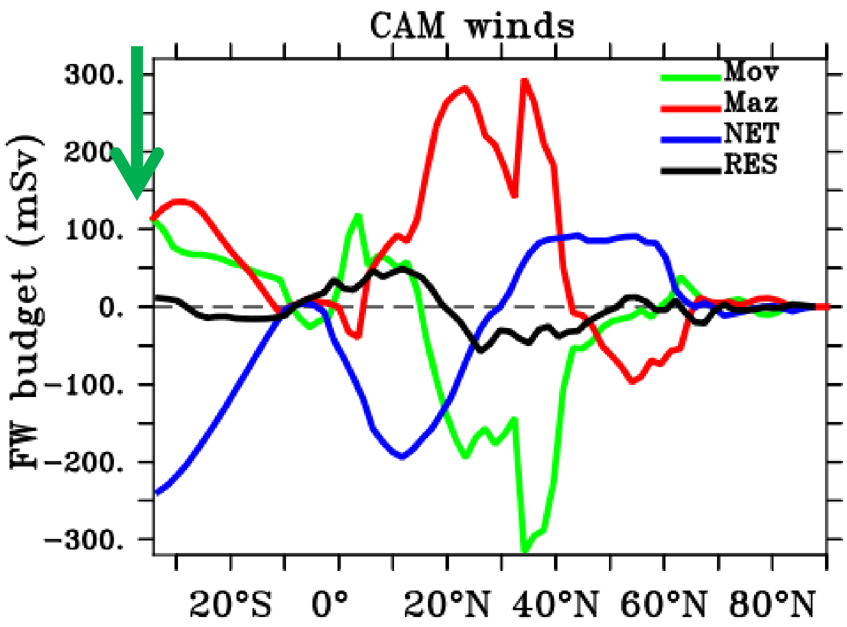
CAM winds: Stronger AMOC (22Sv). Negligible difference.

Mean freshwater fluxes

MOV (Meridional overturning FW transport)
MAZ (Gyre FW transport)
E NET (E-P-R)
RES (Residual)



Bistable

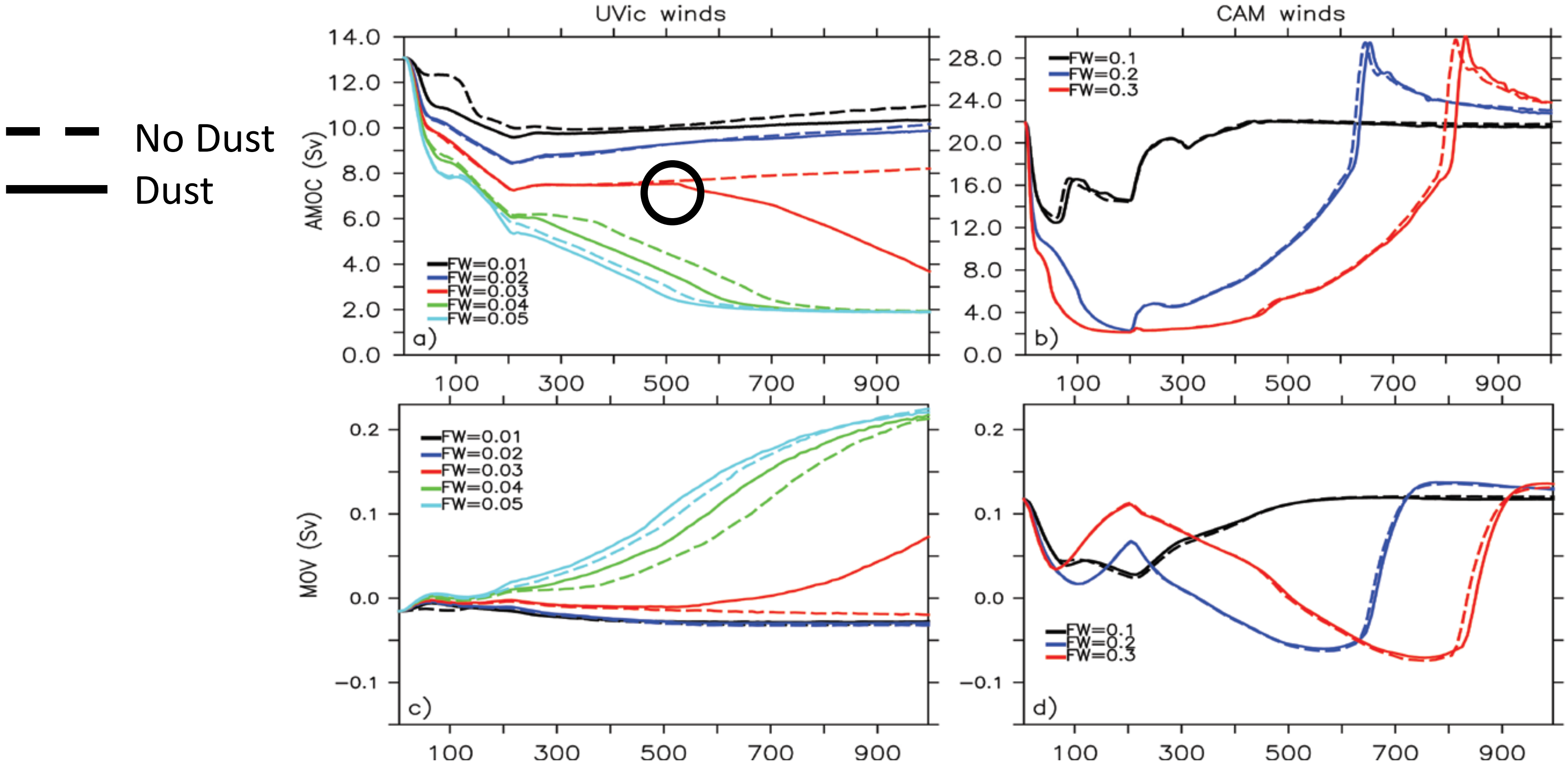


Monostable

$$FWCA = \frac{1}{S_0}\frac{\partial S'}{\partial t} = Mov + Maz - E_{NET} + Res = 0$$

Uncertainties: FW forcing (hosing)

Different amount of hosing applied for 200 years.



Mov becomes positive (imports freshwater) in collapsed cases.

Mov reduces or becomes negative before recovering.

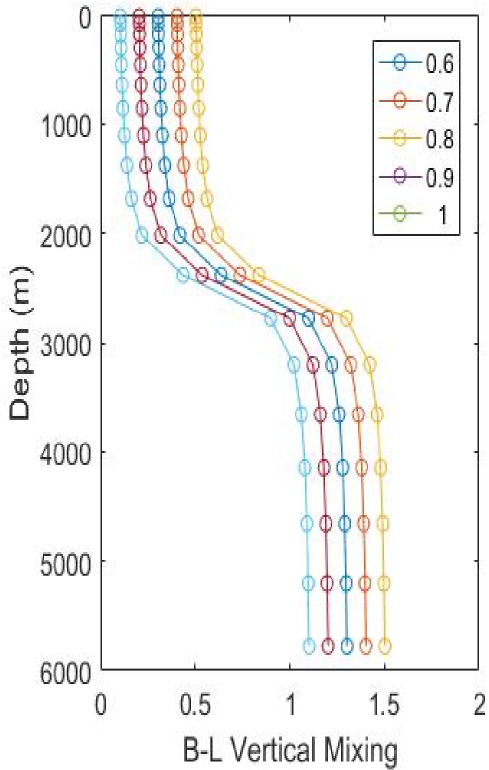
- Bifurcation may occur from dust feedback in Uvic winds (bistable).
- Dust may delay the recovery for a couple decades in CAM winds (stable).
- All simulations consistent with salinity feedback.

Assessing the uncertainties of the AMOC strength on the AMOC stability

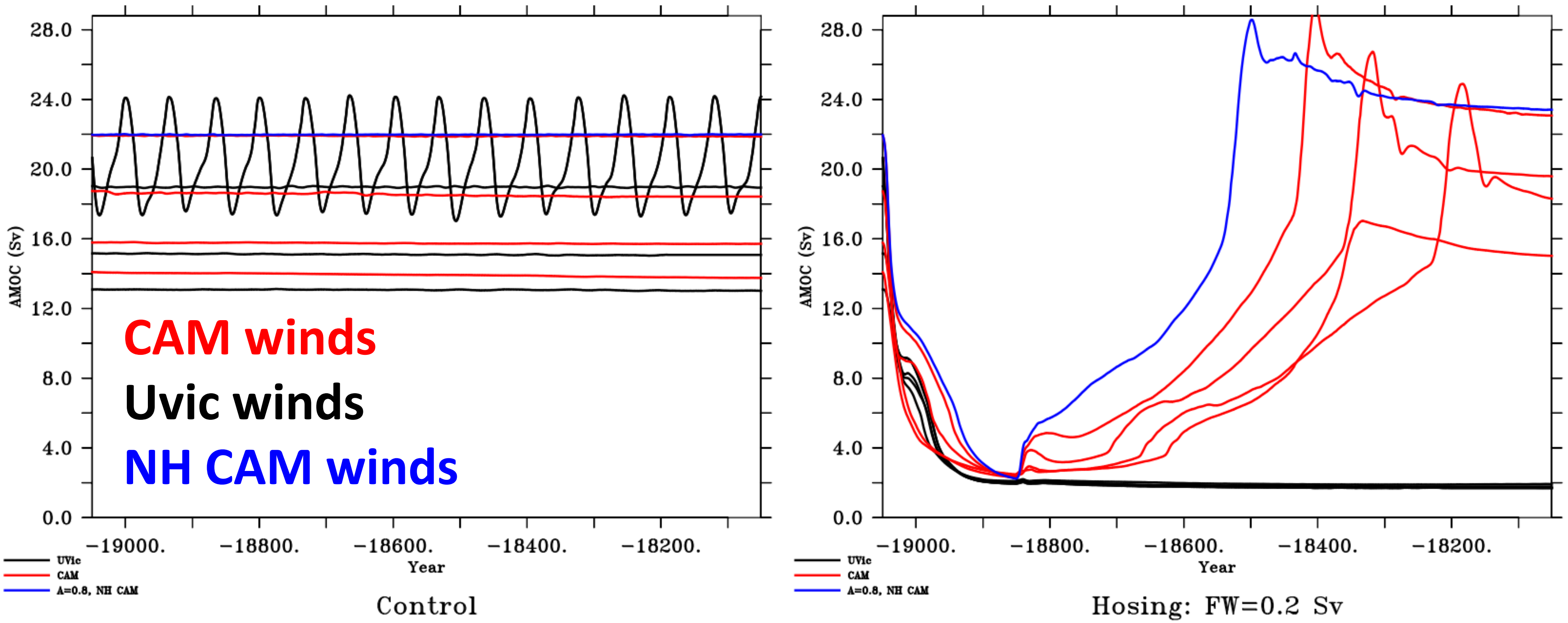
- LGM boundary conditions (~19ka).
- 2 Background wind forcings: Uvic x CAM.
- Hosing experiments: 0.2 Sv applied to the North Atlantic between 45°N-70°N.
- Background vertical mixing: Brian-Lewis parameterization with variable α values:

$$Kv = \alpha + \frac{\beta}{\pi}.\arctan\gamma(z - z_0)$$

Range (units): α ~ 0.6-1.0 X 1e^{-4} m^{2}s^{-1}



Hosing FW=0.2 Sv

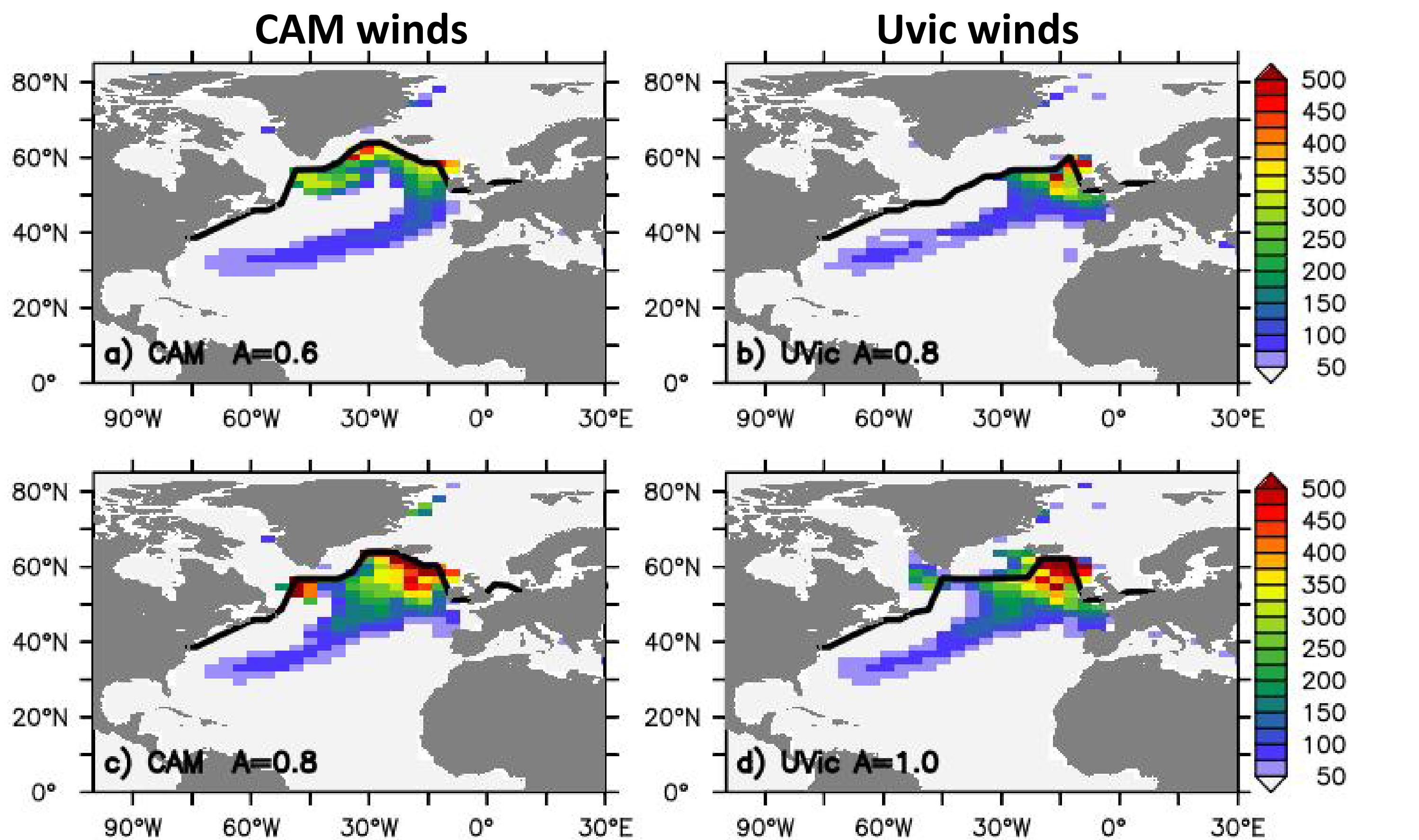


- AMOC *collapses* in all simulations using **Uvic winds**.
- AMOC *recovers* in all simulations using CAM winds, with recovery time shorter for stronger Kv.
- Stronger **NH winds** shortens the recovery time.

Control ventilation depth

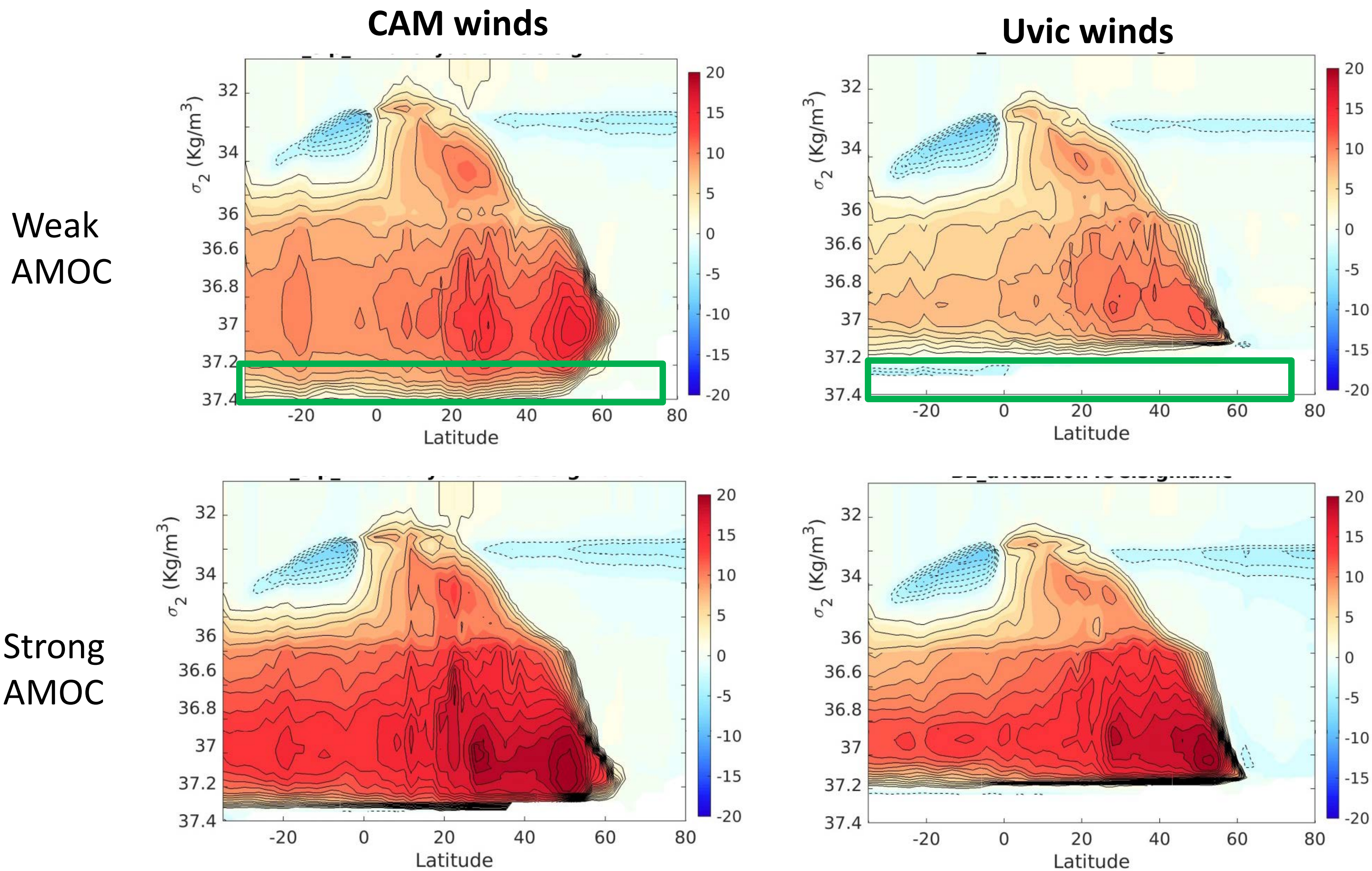
Weak AMOC

Strong AMOC



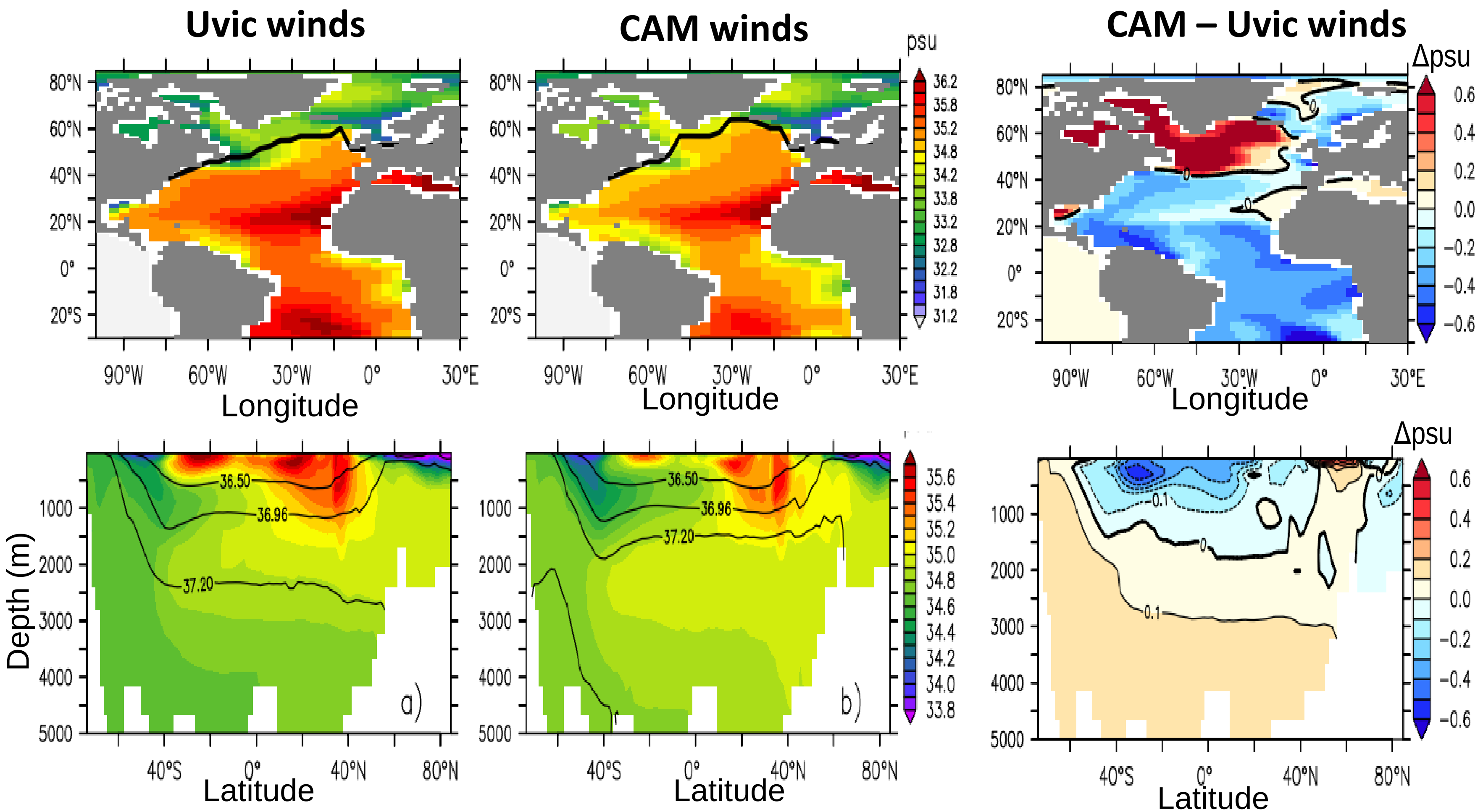
- Stronger CAM winds shifts ice edge and ventilation depth northward relative to Uvic winds.

AMOC in density space



- The AMOC in CAM winds shows the NADW in a denser range.
- NADW flows further southward.

Salinity differences (CAM-UVic)



- Stronger NH winds increase evaporation in the North Atlantic and salinity in the northern subpolar gyre (positive feedback).
- Stronger SH winds increase upwelling of the AAIW in the tropics, decreasing salinity there (negative feedback).

Summary

- **NH winds** drive the stability of the AMOC, strengthens depth stratification and deepens the NADW.
- Stronger **SH winds** have a destabilizing effect on AMOC. Results suggest that they increase the AAIW and upwelling in the tropics, freshening the surface. However, it is a secondary effect.
- **Vertical mixing** changes the mean state of the AMOC, but not its structure/stratification.

Thank you