Role of African Dust in the Atlantic Meridional Overturning Circulation during Heinrich events

Marlos Goes[1,2]
Lisa N. Murphy[3], and Amy Clement[3]

1 Univ. Miami - CIMAS
2 NOAA/AOML
3 Univ. Miami - RSMAS

Heinrich Stadials

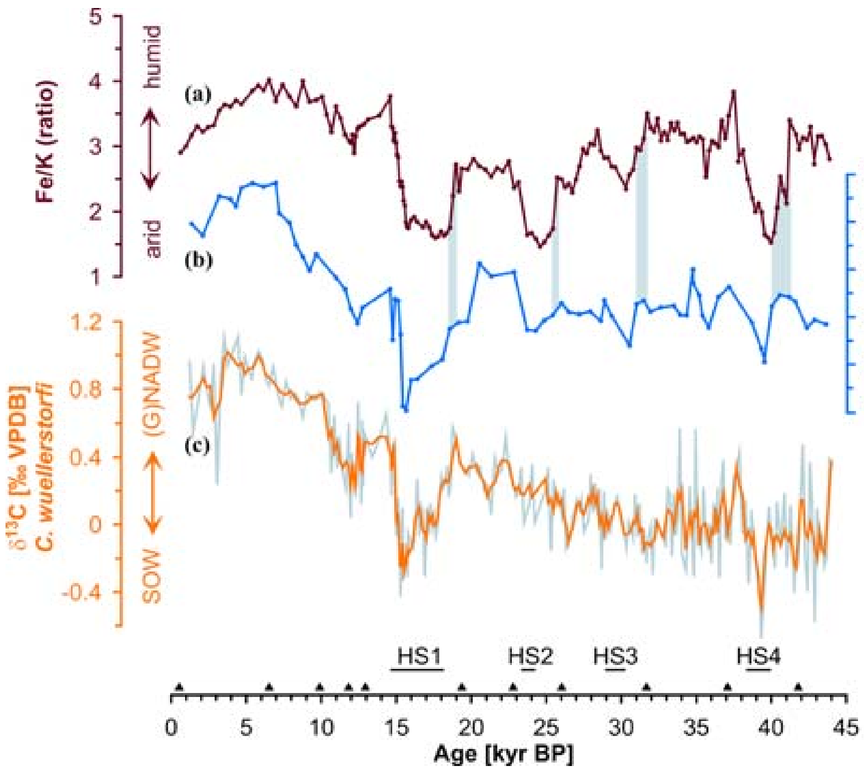
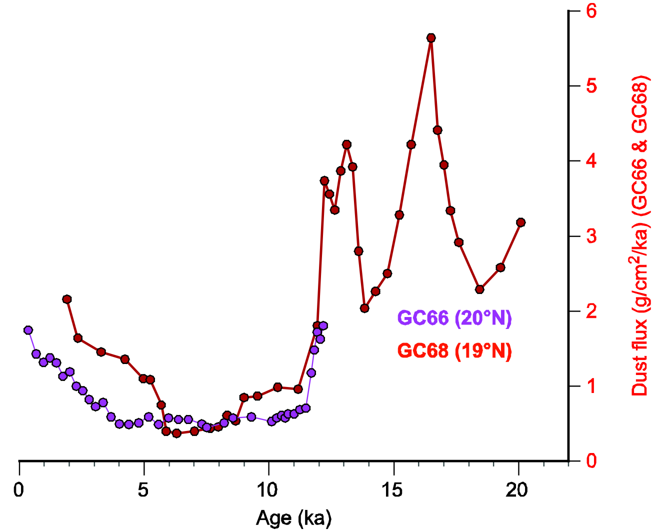


Fig. 2 from Niedermeyer et al. (2009)



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

Objectives

- Examine the impact of increased Saharan dust load on the Heinrich Stadial 1.
- Investigate the dust impact on the AMOC, heat and freshwater budgets taking into account uncertainties in wind, dust and freshwater forcing (hosing).

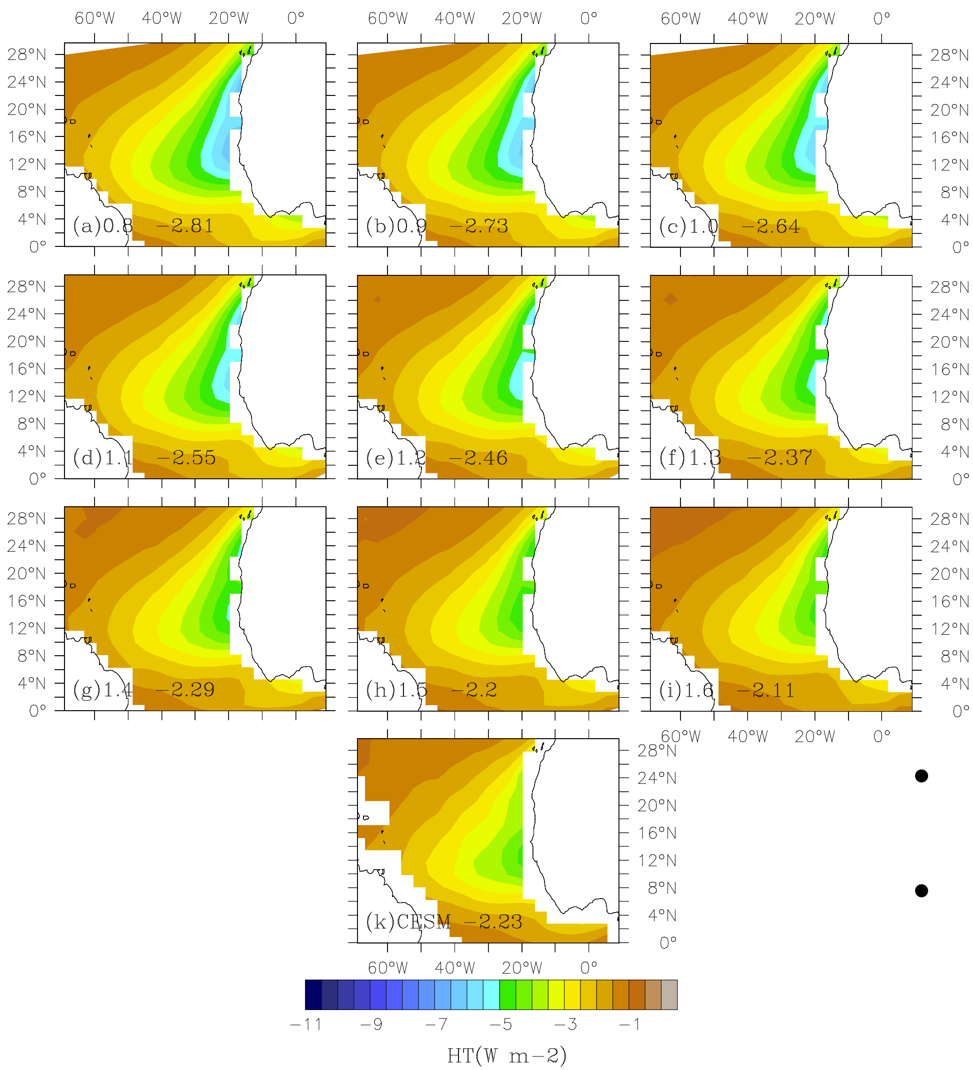
Model experiments

- 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.
- Two wind forcing:

i) one using standard “UVic” winds;

ii) CAM4 SLP anomalies (LGM – PI; Murphy et al., 2014). Wind anomalies are calculated using a geotrophic/ diffusive approximation (Goes et al., 2014).

Parameterization of Saharan dust



The shortwave fluxes due to dust are parameterized as a perturbation of the local surface albedo (α_s):

$$\Delta\alpha_s = H\beta_s\tau(1-\alpha_s)^2\cos(Z_{eff})$$

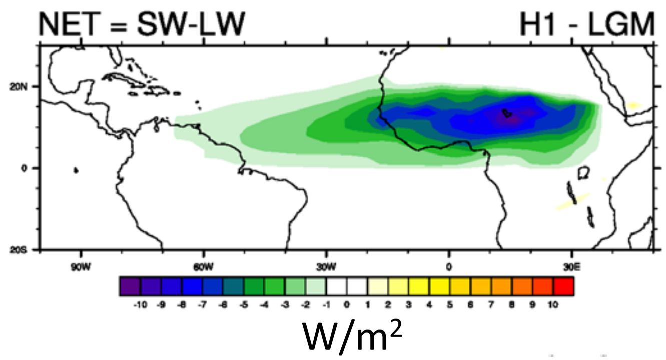
Outgoing (TOA) and surface longwave radiation follow surface albedo changes (α_s):

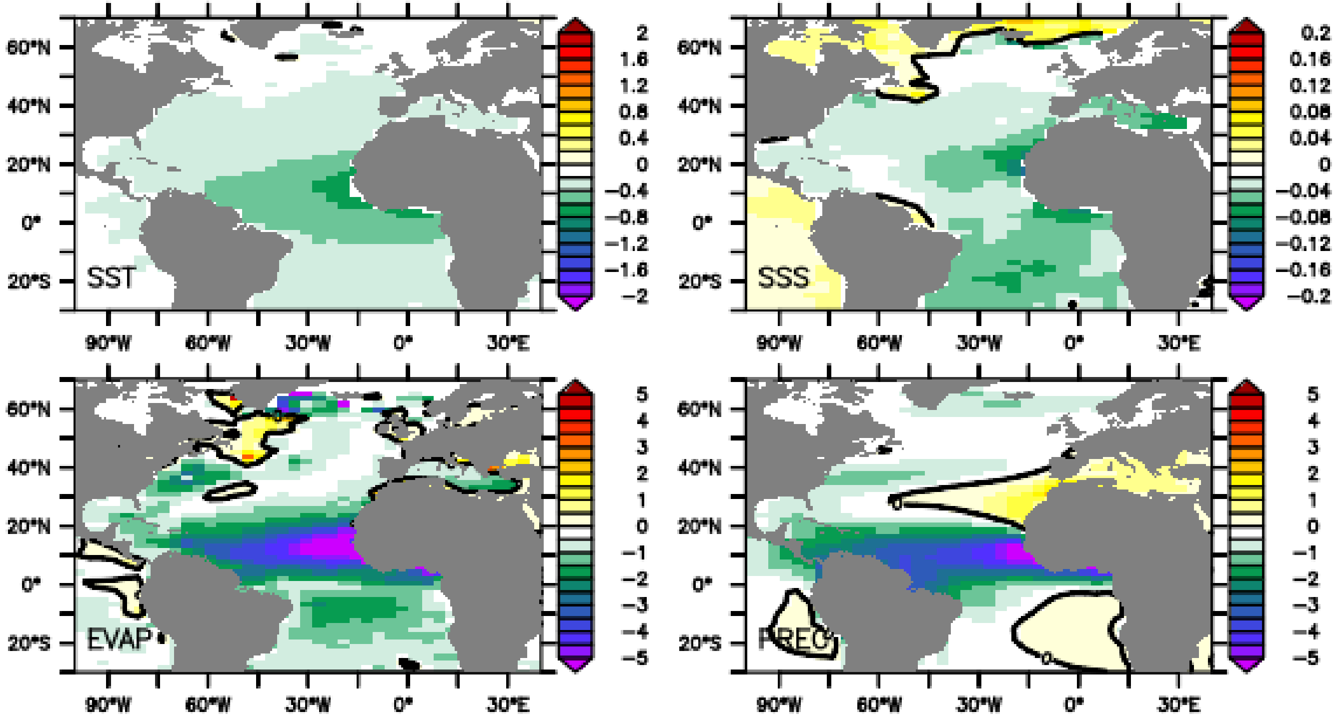
$$\Delta OLR = OLR * max(0,(1.0 - \beta_o * \Delta\alpha_s))$$

$$\Delta LWR = LWR * max(0,(1.0 - \beta_L * \Delta\alpha_s))$$

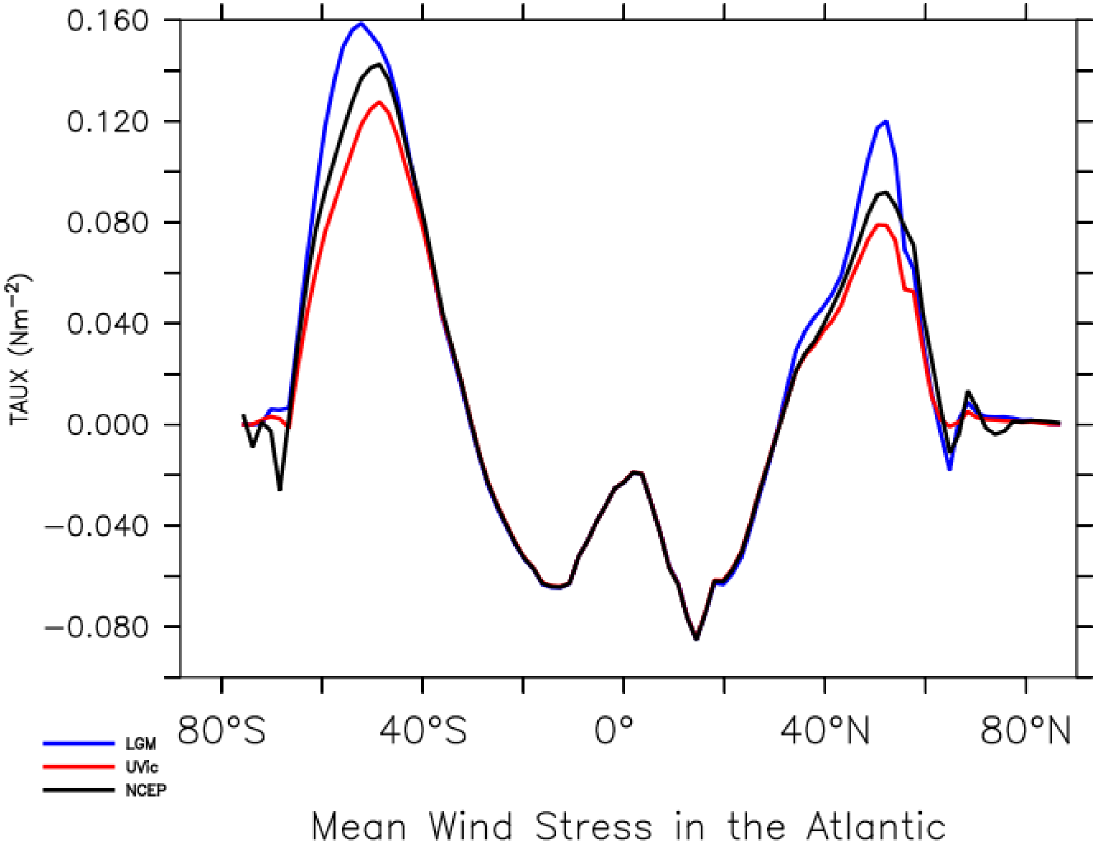
- Parameters $\boldsymbol{\beta_s}$ $\boldsymbol{\beta_o}$ $\boldsymbol{\beta_L}$ are adjusted to match heat fluxes from the CAM model.
- Parameter **H** is a scale factor for the strength of the dust forcing.

Effect of Dust on surface properties





Wind forcing



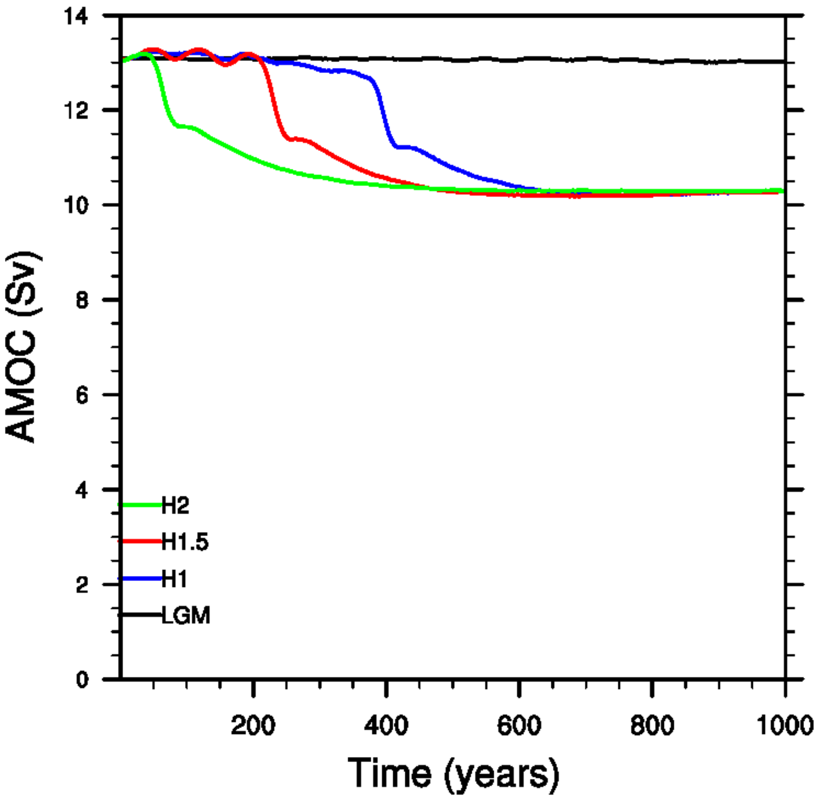
CAM LGM Winds – Derived from CAM4 anomalies (LGM – PI).

Uvic winds – Calculated in Uvic.

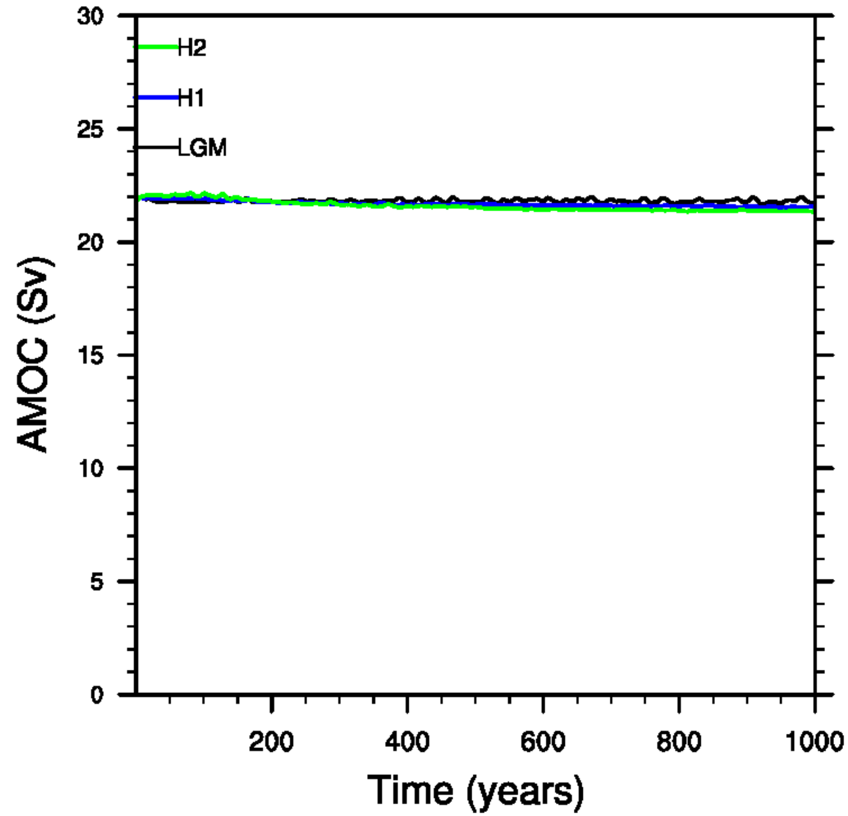
NCEP winds – NCEP PD climatology.

Dust effect on AMOC

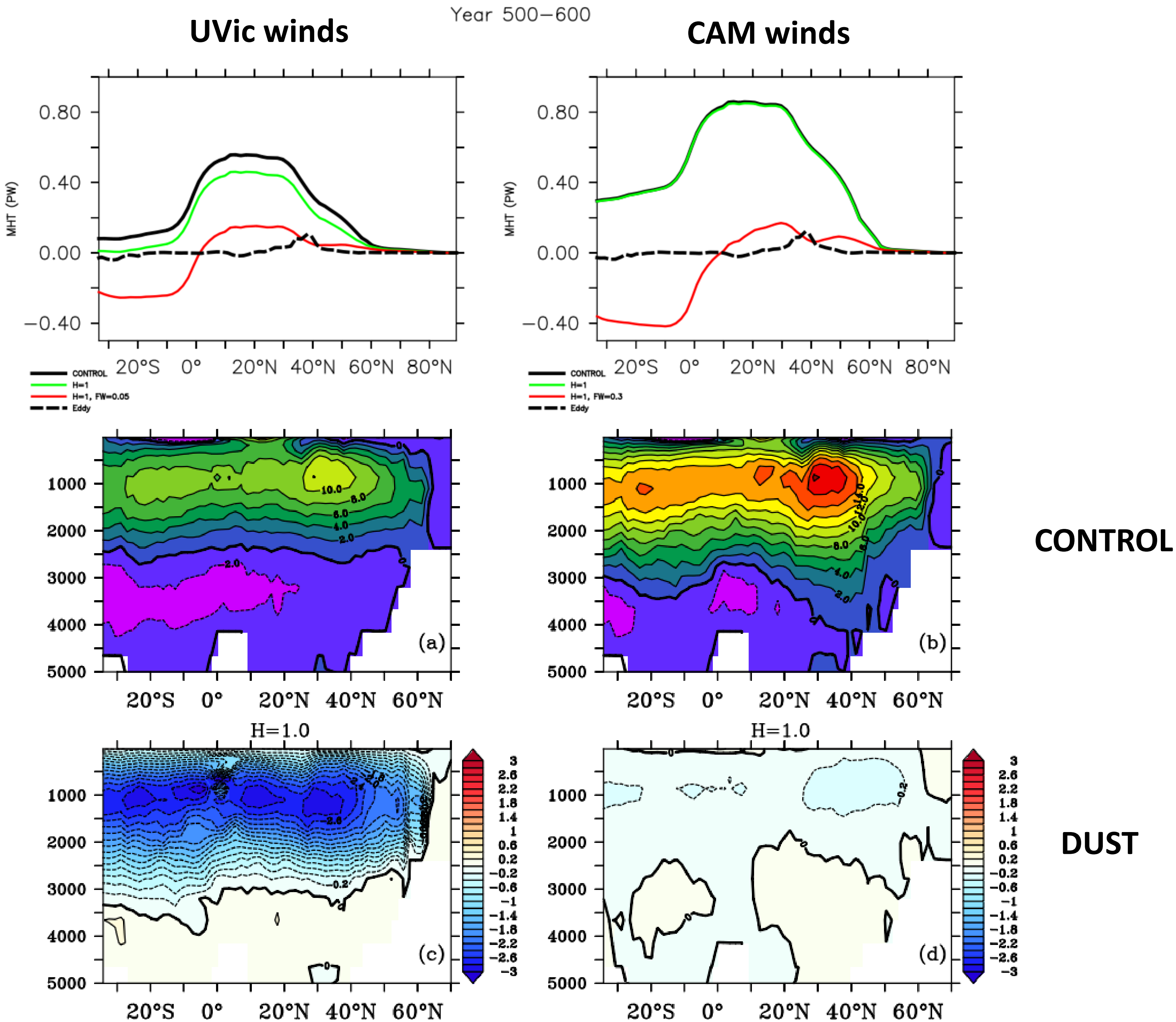
UVic winds



CAM winds

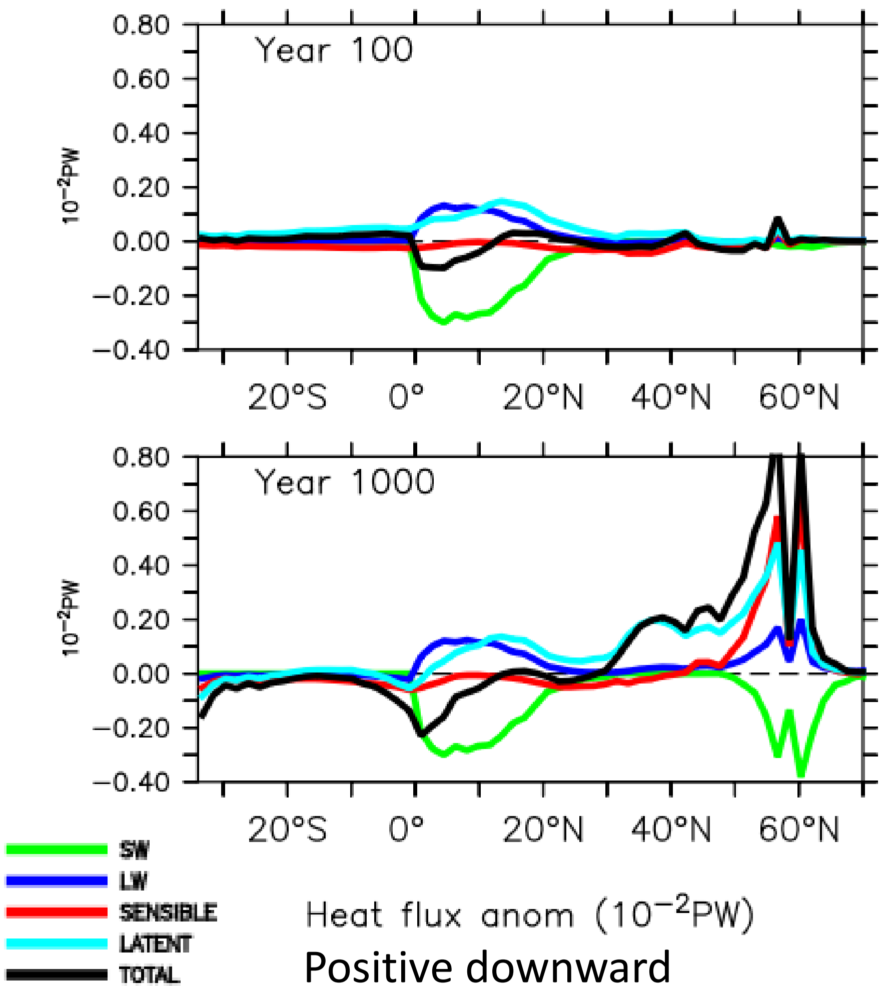


Uvic winds: A decrease of 20-25%
CAM winds: Negligible difference.


Year 500−600
UVic winds
CAM winds
MHT (PW)
0.80
0.40
0.00
−0.40
20°S 0° 20°N 40°N 60°N 80°N
CONTROL
H=1
H=1, FW=0.05
H=1, FW=0.3
Eddy
1000
2000
3000
4000
5000
20°S 0° 20°N 40°N 60°N
(a)
(b)
(c)
(d)
H=1.0
CONTROL
DUST
3
2.6
2.2
1.8
1.4
1
0.6
0.2
−0.2
−0.6
−1
−1.4
−1.8
−2.2
−2.6
−3

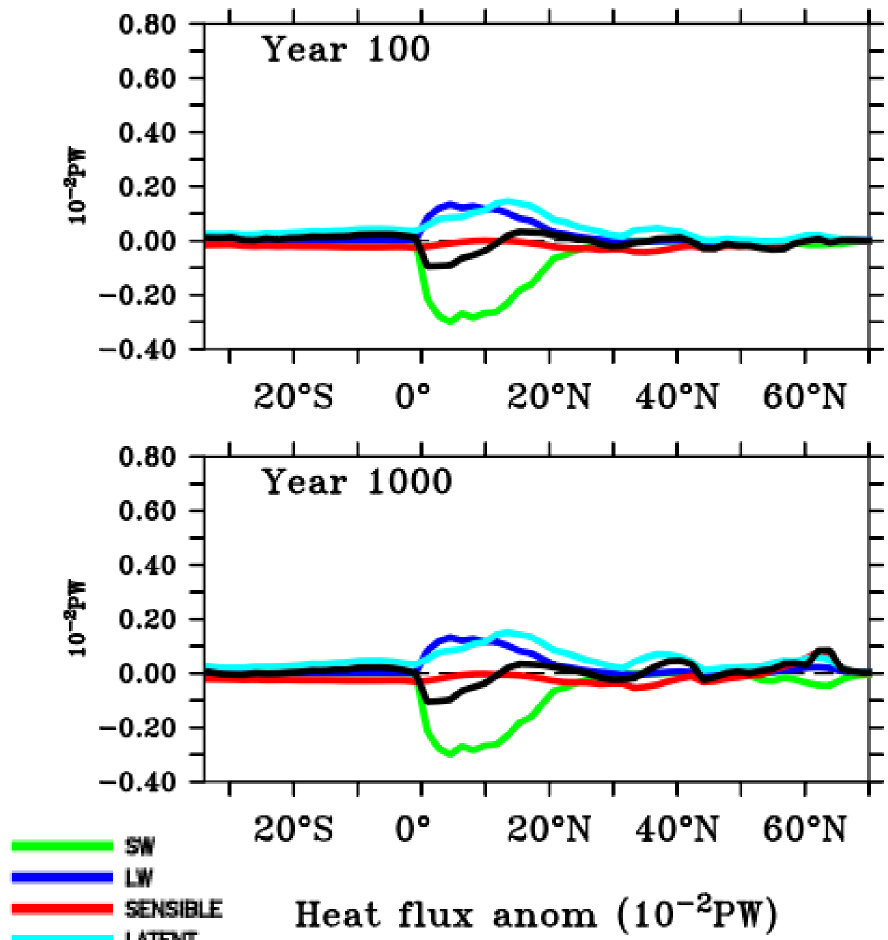
Dust Surface Heat fluxes

UVic winds



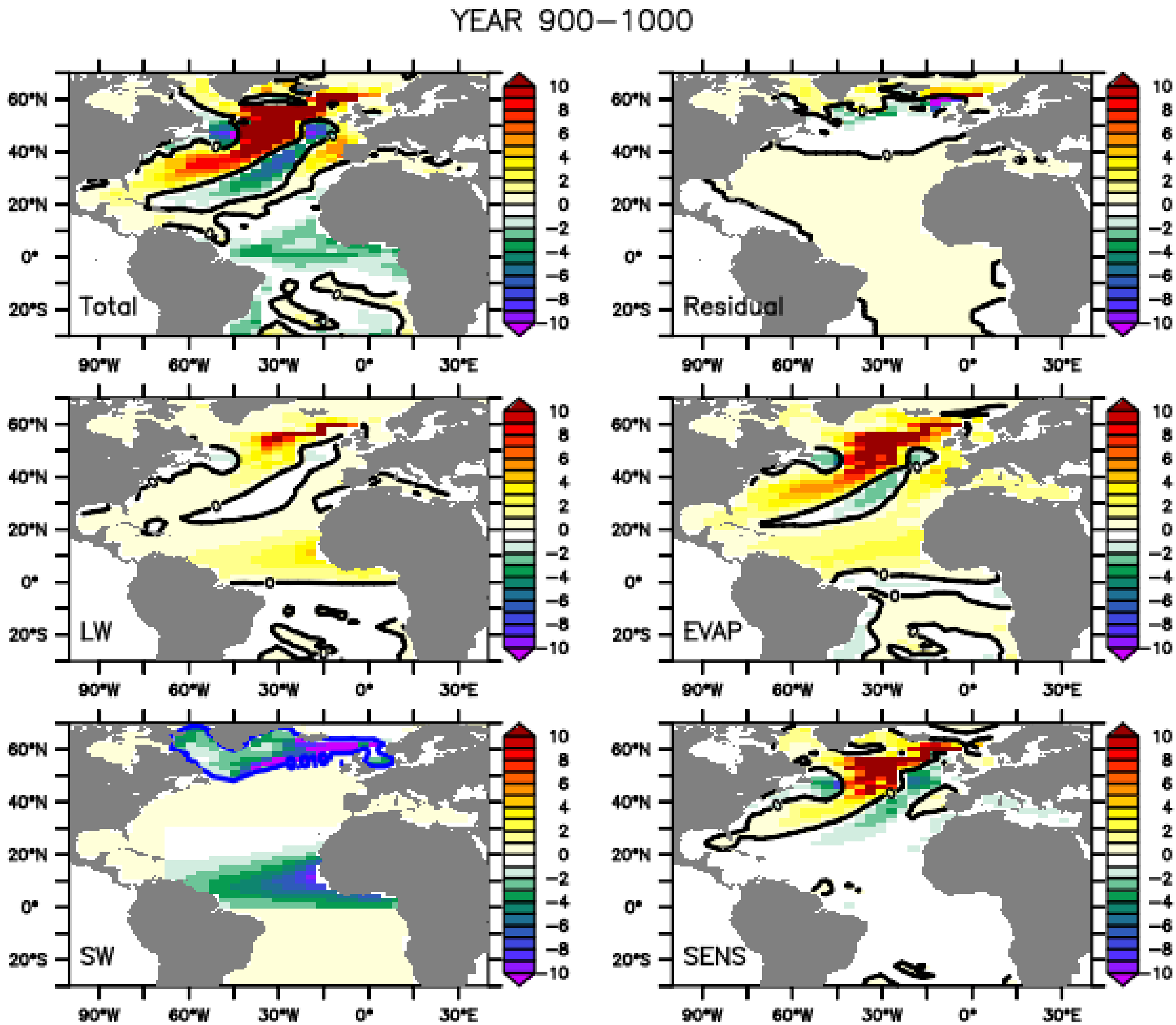
Positive downward

CAM winds



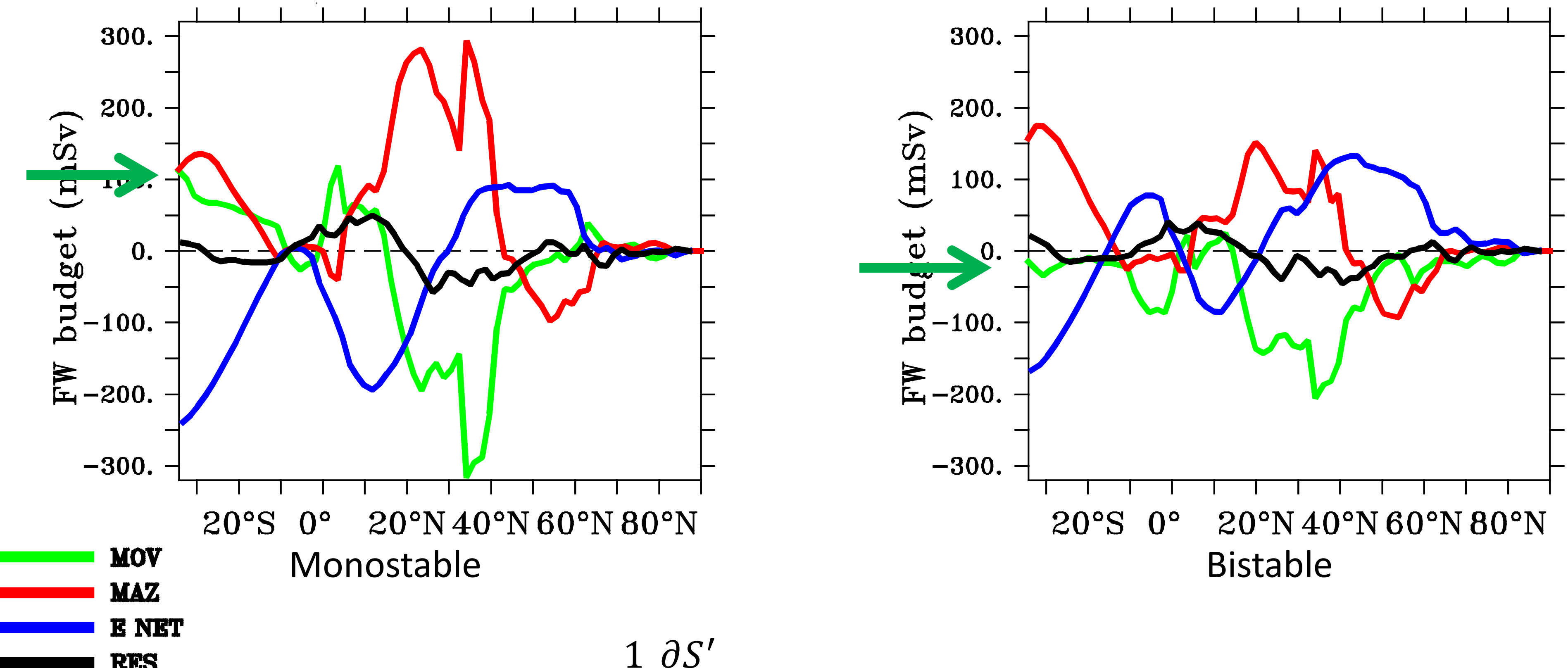
Positive downward

Heat anomalies - Uvic winds



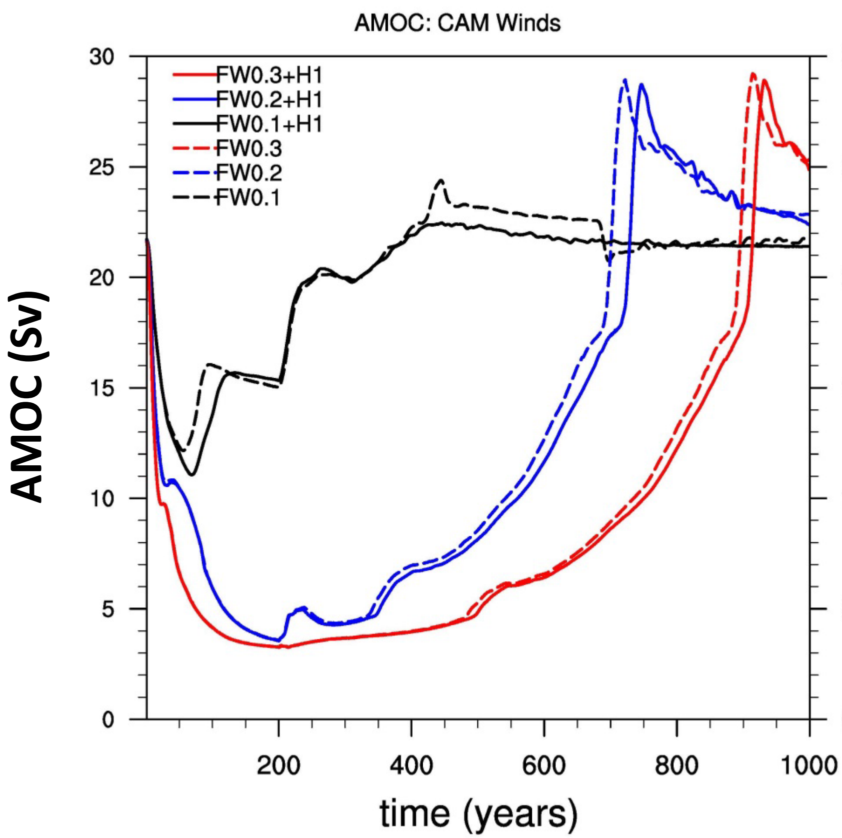
Mean freshwater fluxes

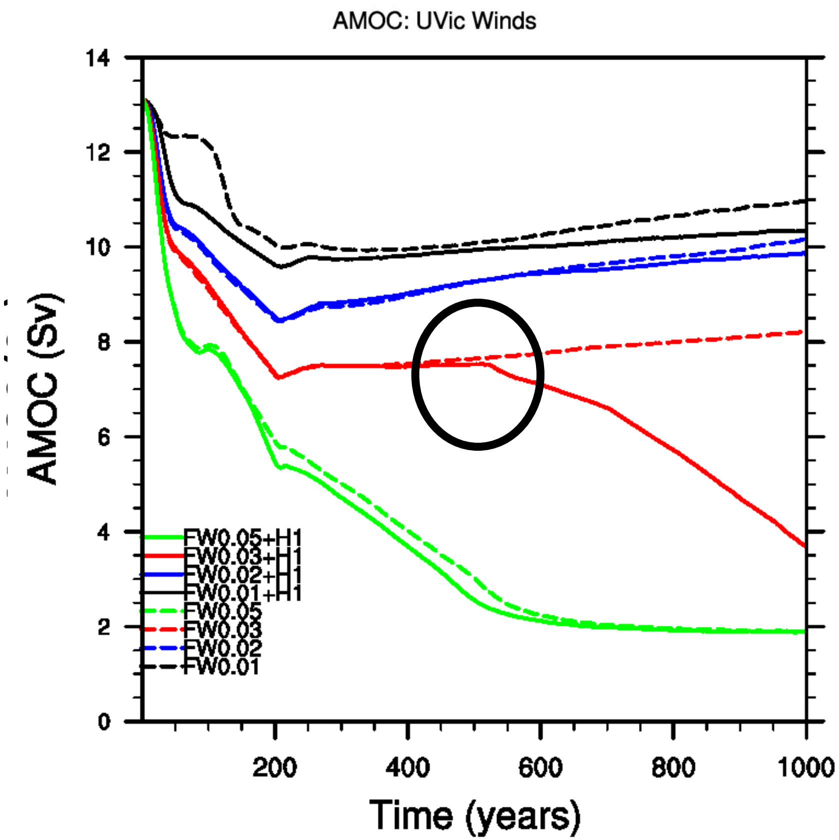
CAM winds | **UVic winds**



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

HS1: Dust + hosing





Hosing applied for 200 years.

No Dust

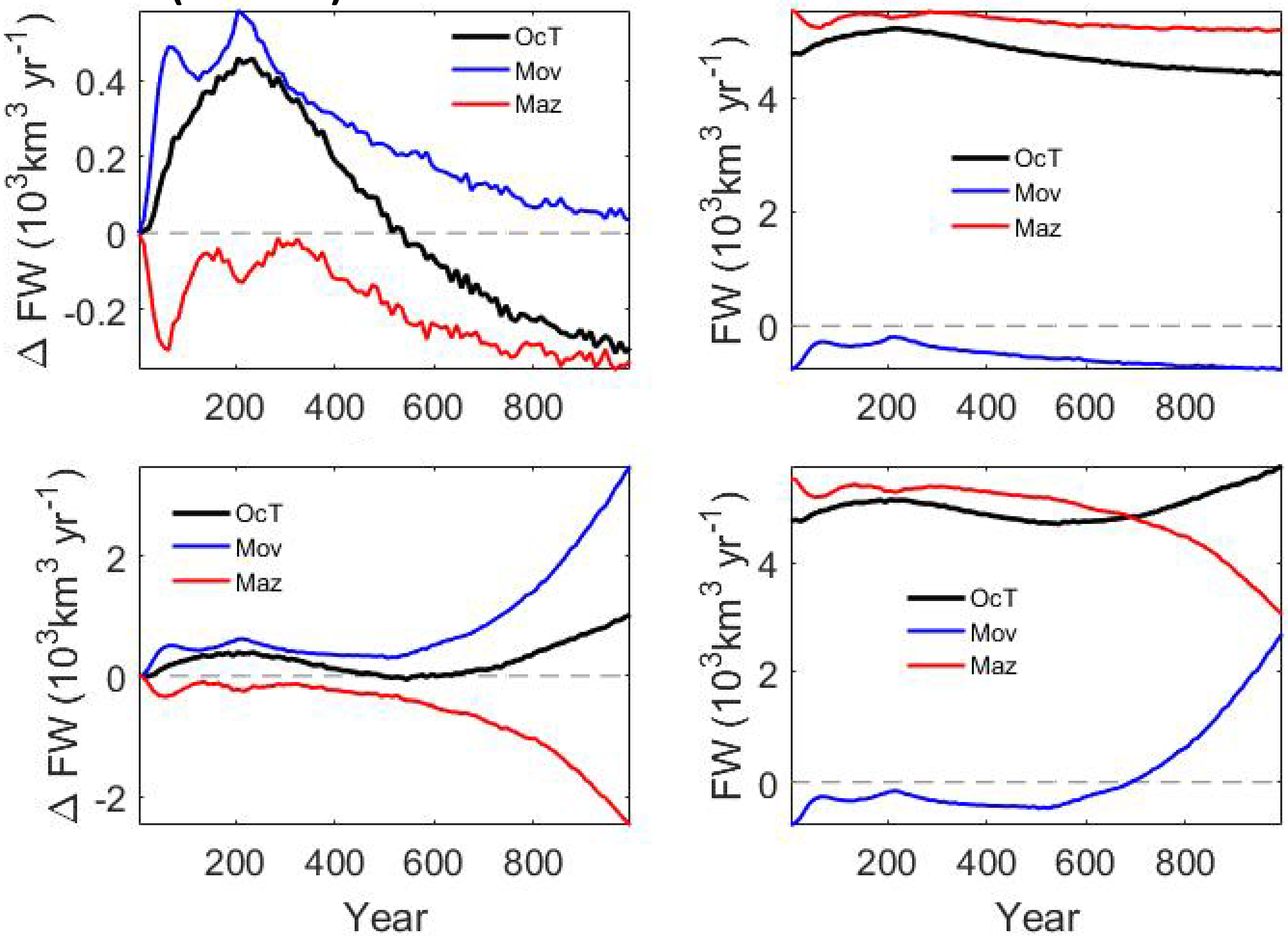
Dust

Freshwater budget

(FW0.03) - Control | FW0.03

No Dust

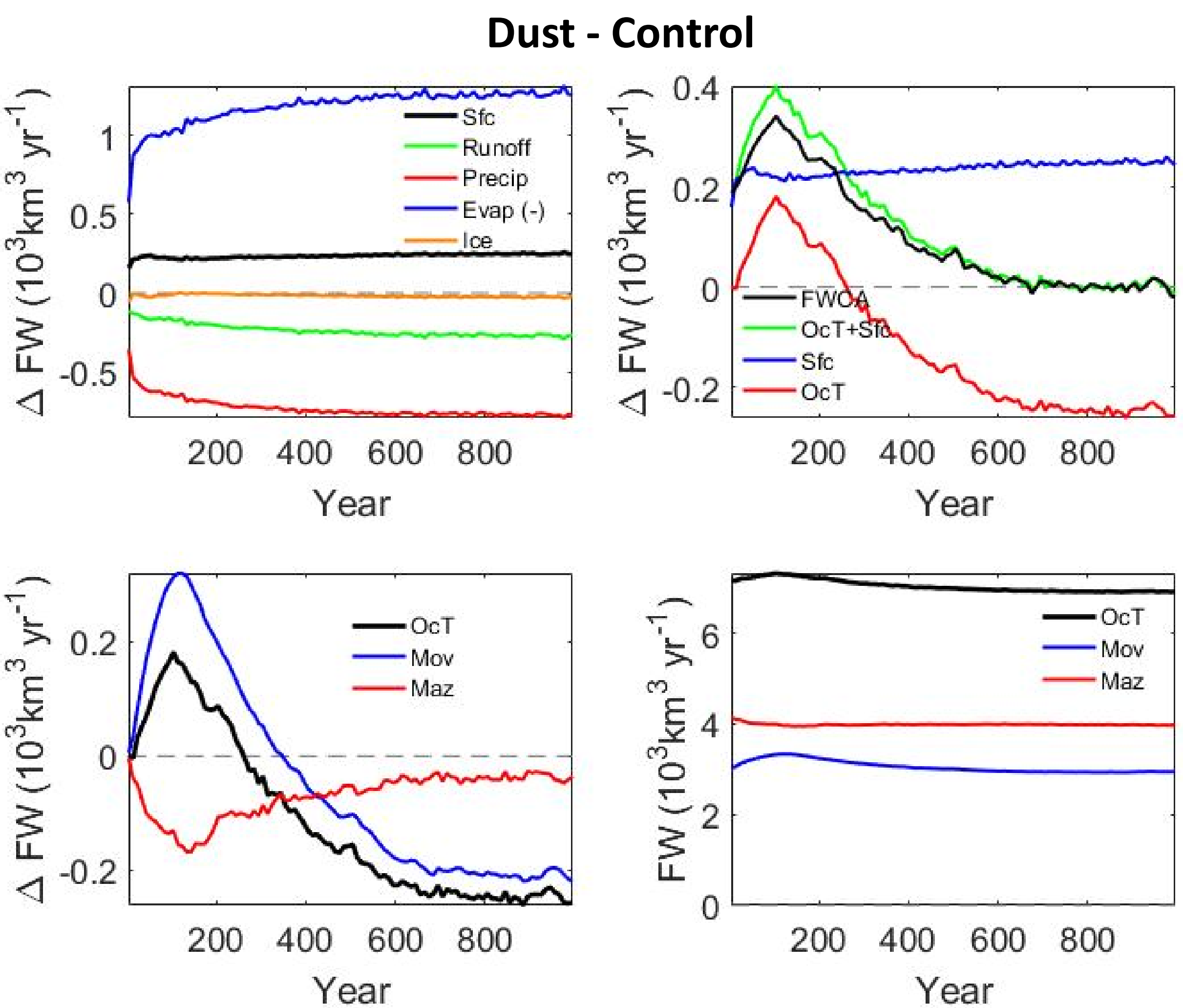
Dust



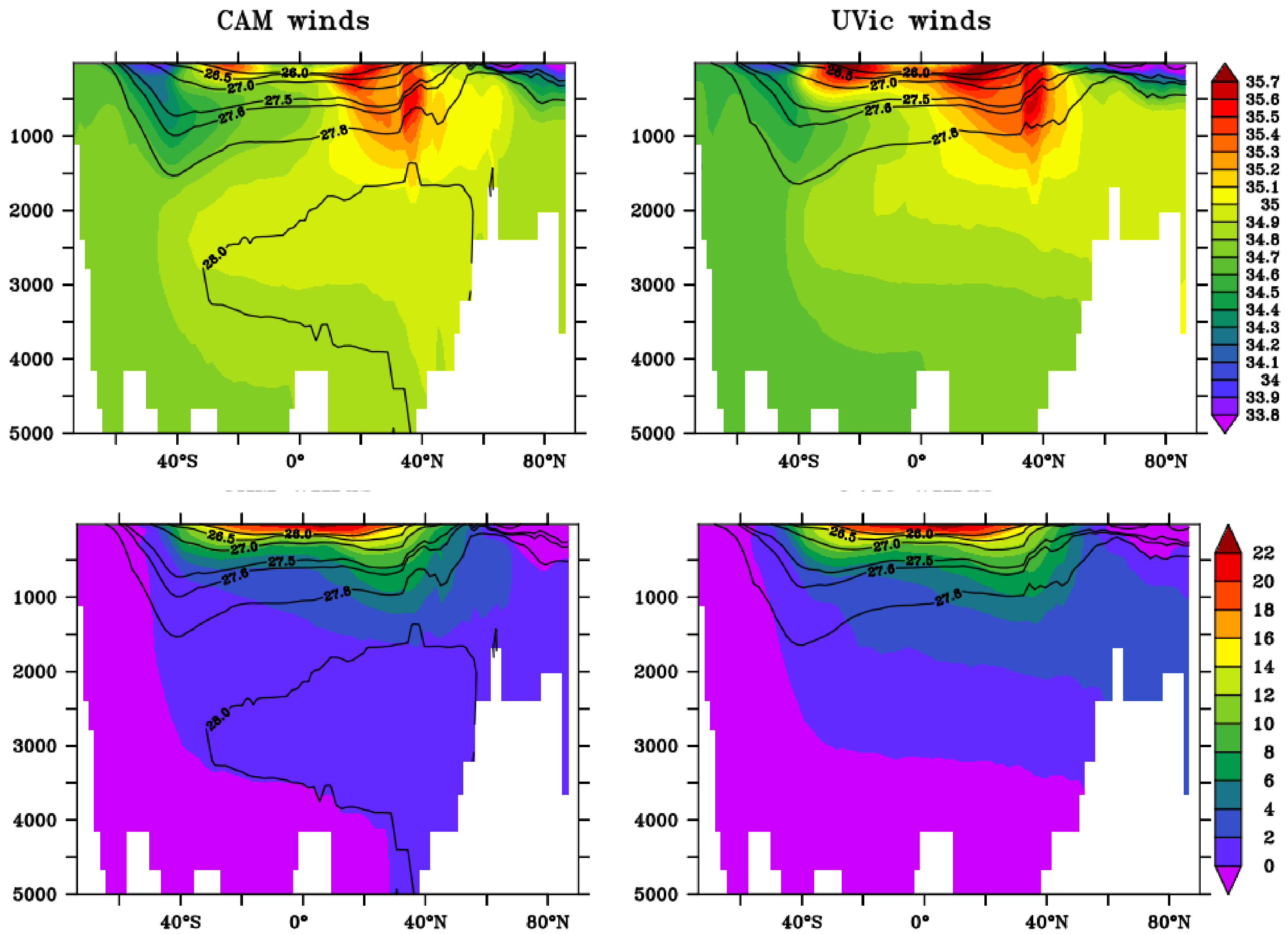
Conclusions

- Dust feedbacks can potentially amplify Heinrich events by cooling and freshening the North Atlantic.
- When AMOC is in a bistable state (Mov < 0), dust can reduce the AMOC by ~ 25%, and may trigger bifurcations in the AMOC recovery.
- When AMOC is in a stable state (Mov > 0), dust may delay the recovery, but not significantly.

Freshwater budget – CAM winds



Mean State



CAM winds
UVic winds
1000
2000
3000
4000
5000
40°S
0°
40°N
80°N
26.5
26.0
27.0
27.5
27.6
27.8
28.0
35.7
35.6
35.5
35.4
35.3
35.2
35.1
35
34.9
34.8
34.7
34.6
34.5
34.4
34.3
34.2
34.1
34
33.9
33.8
22
20
18
16
14
12
10
8
6
4
2
0