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

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Heinrich Stadials

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 $\sim$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 ($\alpha_s$):

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

Outgoing (TOA) and surface longwave radiation follow surface albedo changes ($\alpha_s$):

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

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

- Parameters $\beta_s, \beta_o, \beta_L$ 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**: A decrease of 20-25%

**CAM winds**: Negligible difference.
UVic winds  

CAM winds

Year 500–600

CONTROL

DUST

(a)  

(b)  

(c)  

(d)
Dust Surface Heat fluxes

UVic winds

CAM winds

Heat flux anom ($10^{-2}$PW)
Positive downward

Year 100

Year 1000

Heat flux anom ($10^{-2}$PW)
Positive downward
Heat anomalies - Uvic winds
Mean freshwater fluxes

\[ \text{FWCA} = \frac{1}{S_0} \frac{\partial S'}{\partial t} = \text{Mov} + \text{Maz} - E_{\text{NET}} + \text{Res} = 0 \]
HS1: Dust + hosing

Hosing applied for 200 years.

- No Dust
- Dust
Freshwater budget

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

Dust - Control

\[
\Delta \text{FW} \quad (10^3 \text{km}^3 \text{yr}^{-1})
\]

\[
\text{Year}
\]

\[
\Delta \text{FW} \quad (10^3 \text{km}^3 \text{yr}^{-1})
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\[
\text{Year}
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