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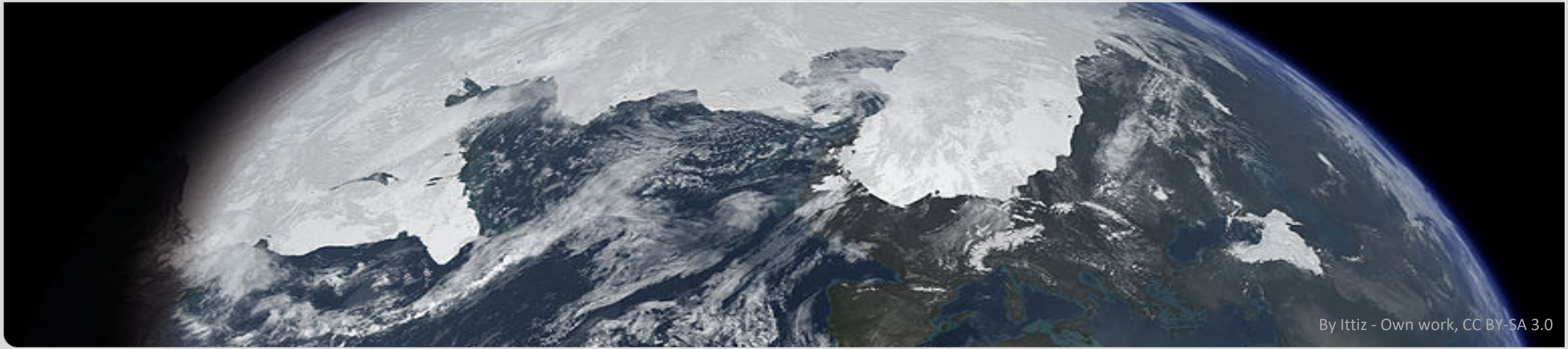
Linkage between dust cycle and loess of the Last Glacial Maximum in Europe

P. Ludwig[1], E. Schaffernicht[2], Y. Shao[2], J. G. Pinto[1]

[1]IMK, Karlsruhe Institute of Technology, Germany; [2]IGMK, University of Cologne, Germany

Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology



Introduction

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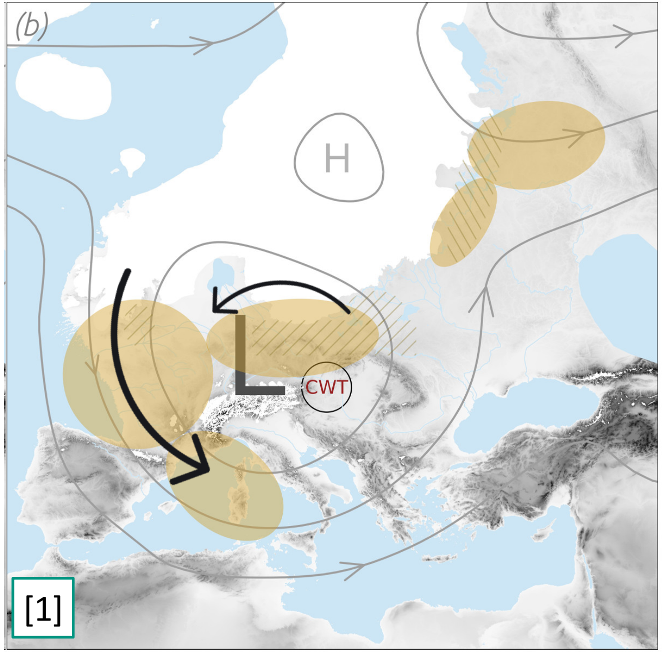
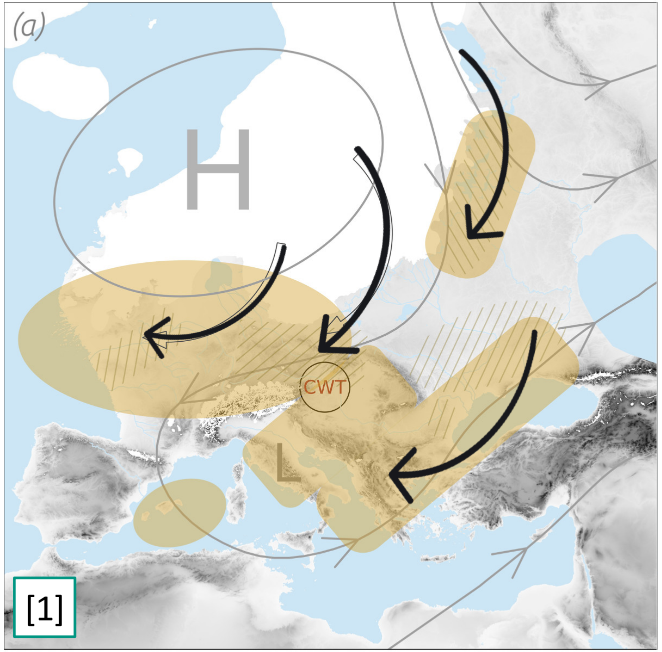


- Loess as a continental proxy to analyse past climates and to validate paleoclimate models
- Rapid and cyclic deposition due to cyclones played a major role in the European loess formation
  (Antoine et al., 2009, QSR)

Introduction



- Loess as a continental proxy to analyse past climates and to validate paleoclimate models
- Rapid and cyclic deposition due to cyclones played a major role in the European loess formation
  (Antoine et al., 2009, QSR)
- East wind layers dated to 36−18 ka BP are abundant in the Dehner Maar sediments
  (Dietrich and Seelos, 2010, ClimPast; Römer et al., 2016 GloPlaCh)
- East sector winds inferred from loess of the Harz Foreland for the LGM
  (Krauß et al., 2016, PPP)

→ Aim: Investigate role of easterly winds for the LGM dust cycle

Atmospheric Circulation during LGM

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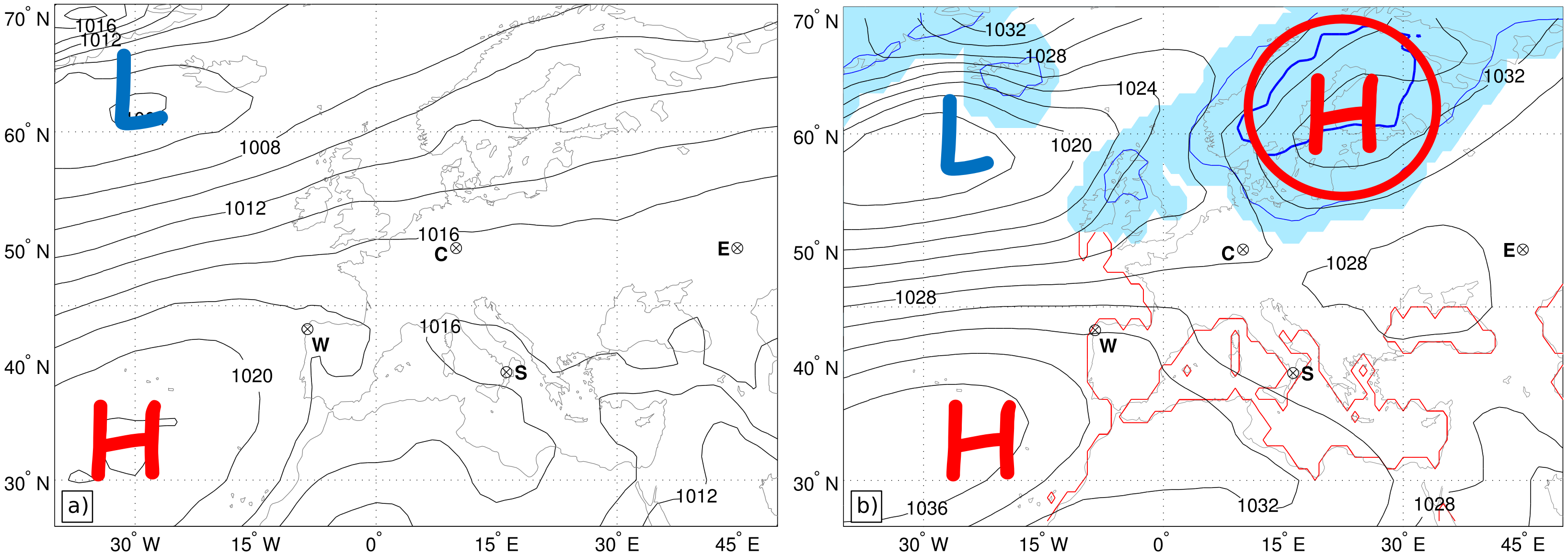

- Similar MSLP pattern over North Atlantic
- Isobars more zonally during LGM
- Glacial anticyclone over Fennoscandian Ice Sheet

→ Analysis of **regional** circulation changes: circulation weather types (CWT)

All Figures: [2]

Atmospheric Circulation - CWTs (Circulation Weather Types)

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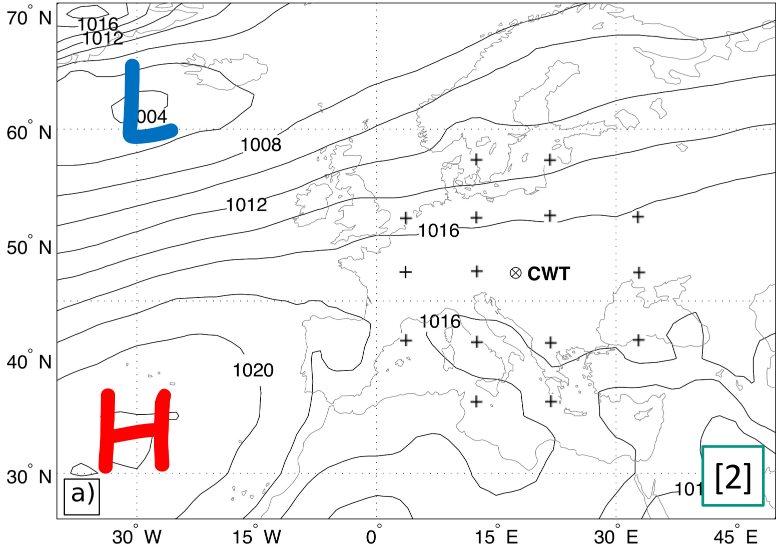

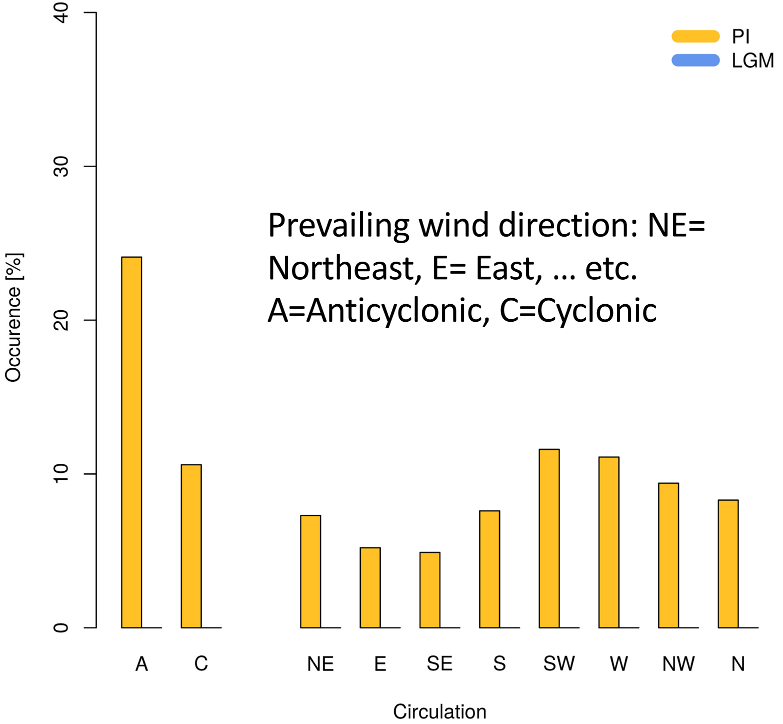

- CWT calculation *(Jones et al, 1993, JClim)*

→16 grid points surrounding central point

Results based on 30yrs of MPI-ESM-P data

Atmospheric Circulation - CWTs

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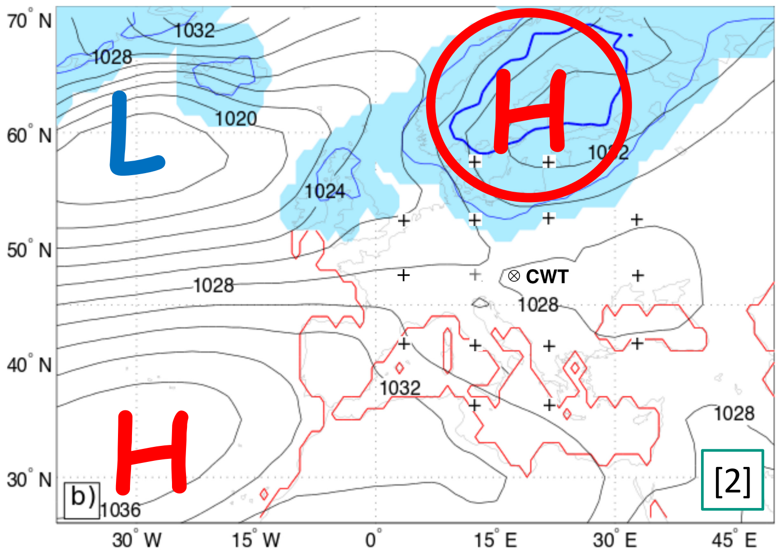
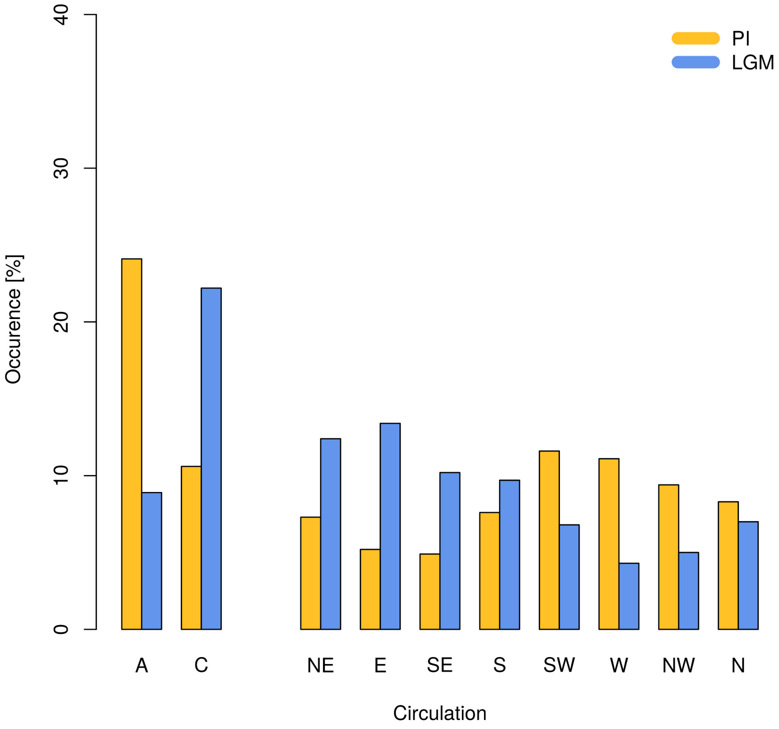


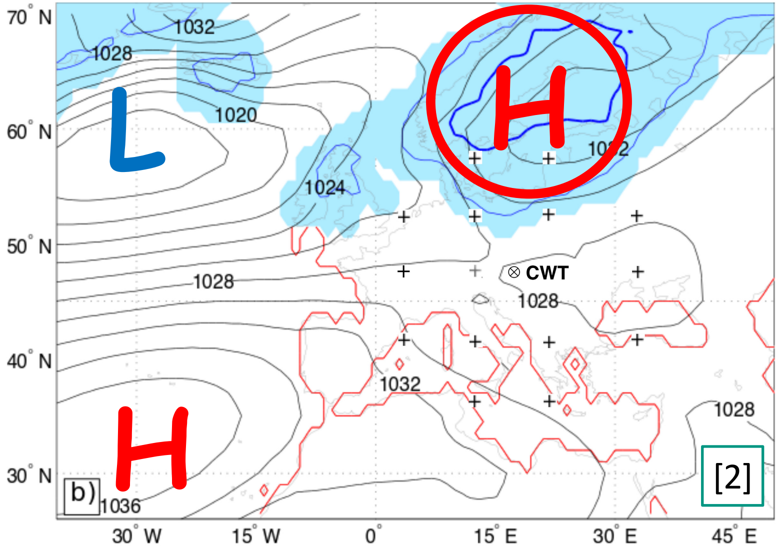


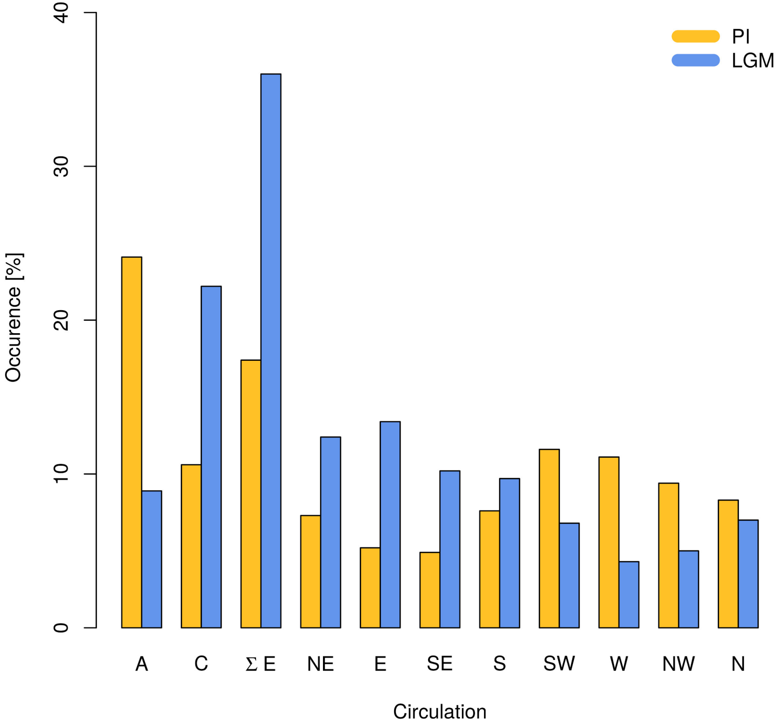
- CWT calculation *(Jones et al, 1993, JClim)*

→16 grid points surrounding central point

LGM: shift to more cyclonic and easterly CWTs

Atmospheric Circulation - CWTs





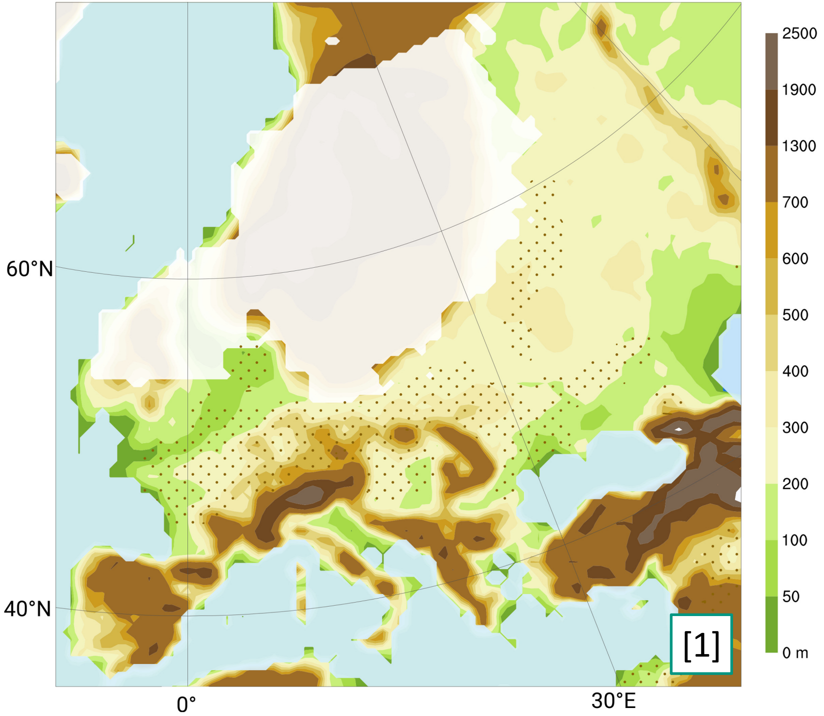
- CWT calculation *(Jones et al, 1993, JClim)*

→16 grid points surrounding central point

CWT Cyc (22%) and CWT Easterly (36%) dominant

Regional Model

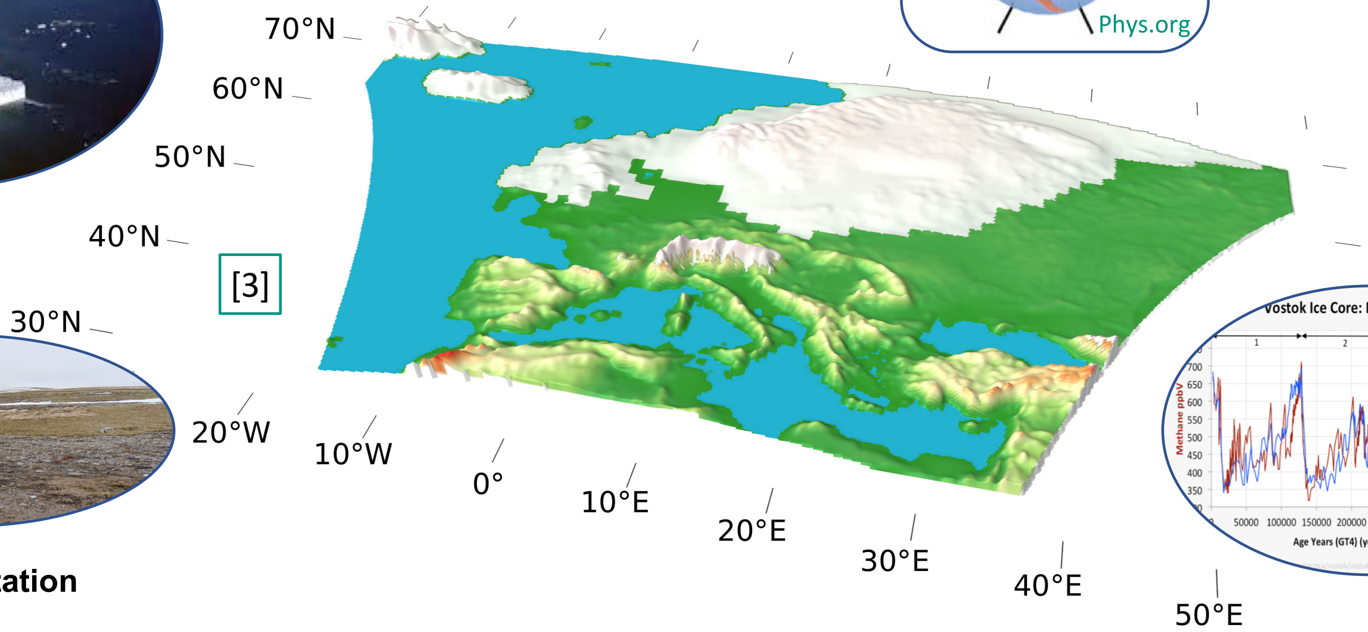
- WRF-Chem V3.5.1
- Dust-only mode (UoC dust scheme)
- 30 years; forced by MPI-ESM-P data
- 50 km horizontal grid spacing
- CWT-based simulations: 13 individual simulations per CWT (130 episodes)
- Dust Sources: Ginoux (2001) – depressions as source areas
- MARs from 70 Loess sites in Europe



Boundary Conditions

Ice Sheets, Landmask
(CLIMAP, PMIP3)

Phys.org



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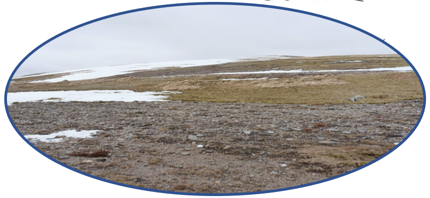
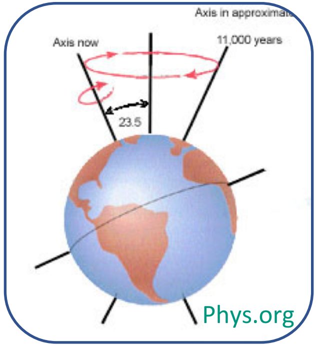
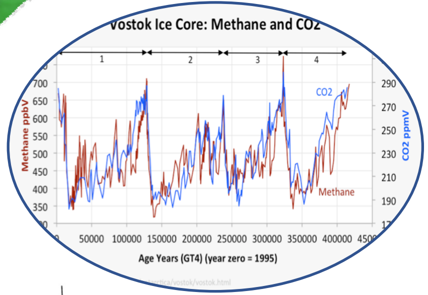


Landuse, Vegetation
(CLIMAP)



Orbital Parameters
(PMIP3)

ncdc.noaa.gov



Trace Gases
(PMIP3)

Results: Simulated dust cycle

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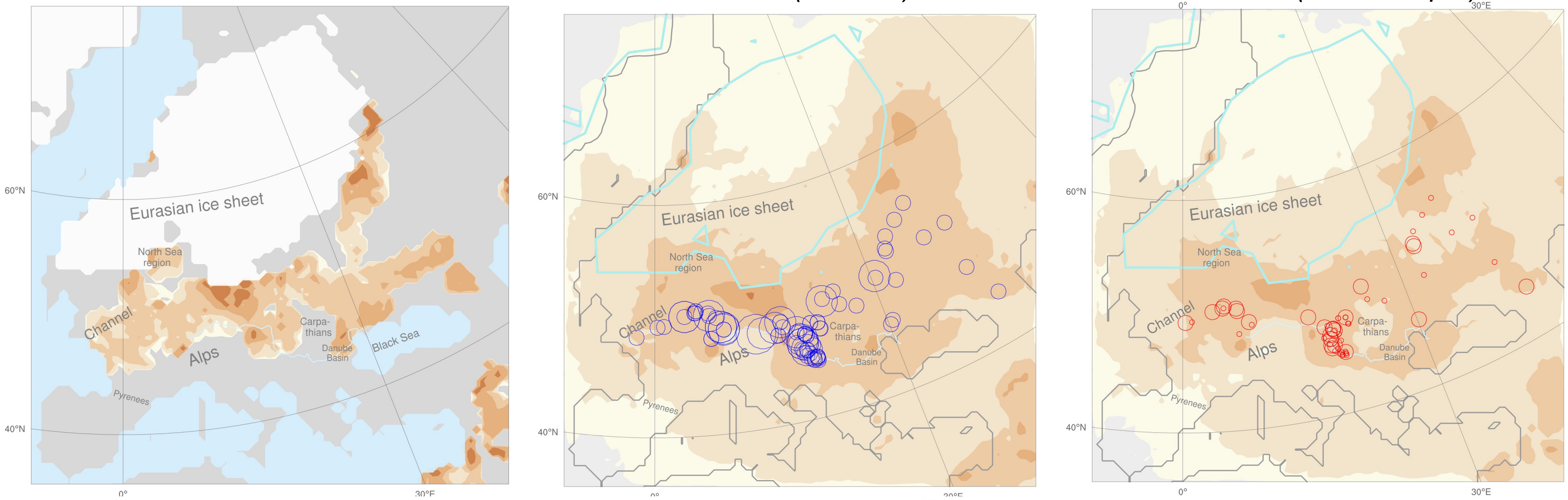
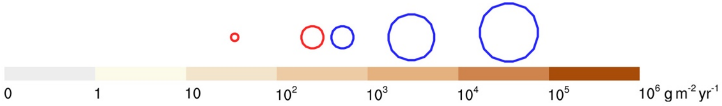
Emission | Deposition (P ≤ 20μm) *(all MAR)* | Deposition (P ≤ 12μm) *(MAR ≤ 10μm)*





P: Particle diameter
MAR: Mass accumulation rate

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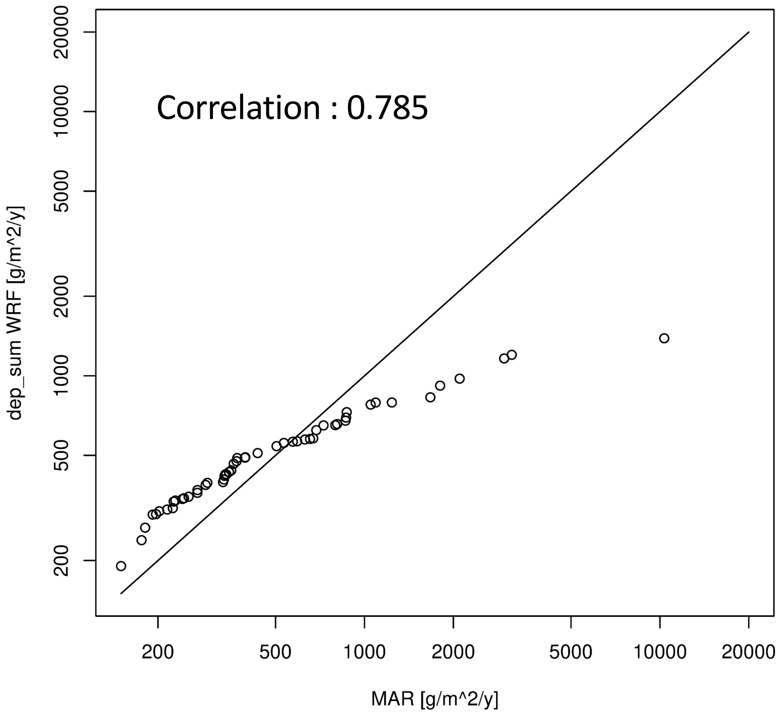
Results: Simulated dust cycle

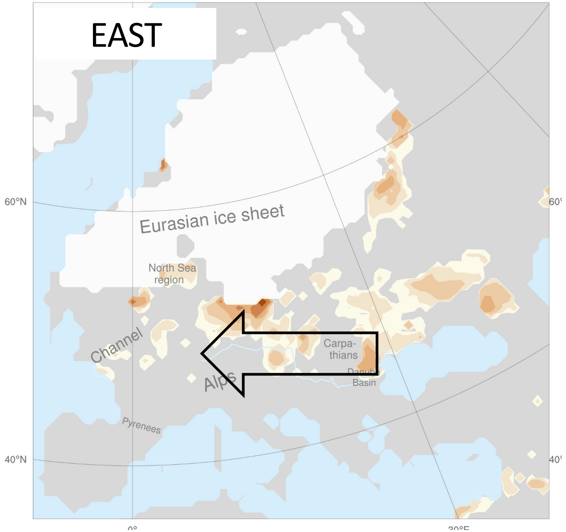


Simulation

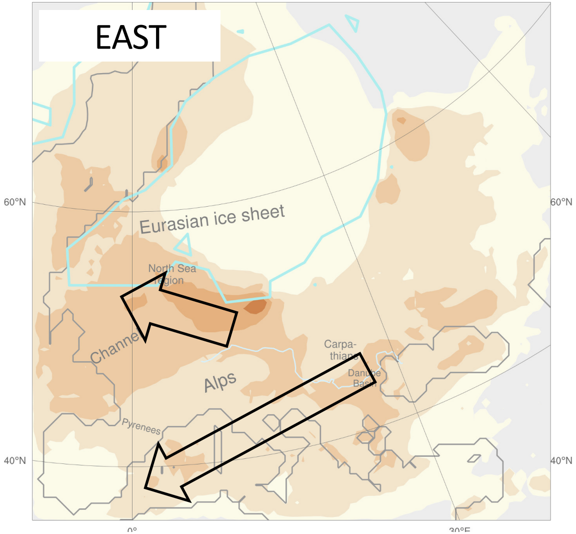
MAR

- Good agreement between simulated deposition and MAR at loess sites
- Underestimation of high MARs: Loess stacks include coarser material (P > 20µm)
- Local dust sources (e.g. river beds) ignored by the WRF-Chem model

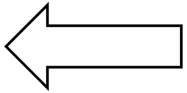
Results: CWT based dust cycle



Emission



Deposition



Prevailing wind direction

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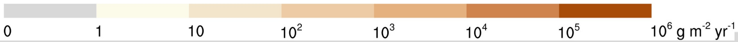
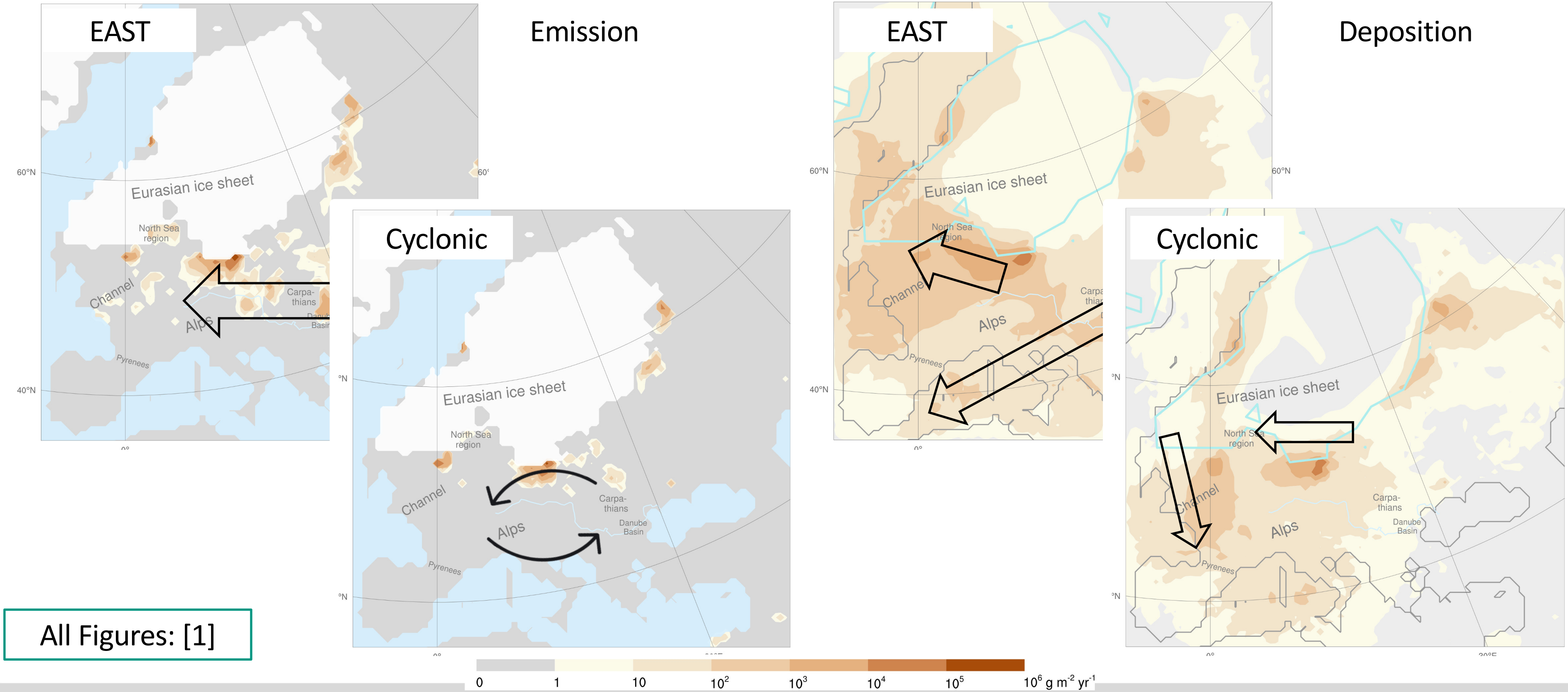


Results: CWT based dust cycle



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Results: Seasonal aspects - DJF

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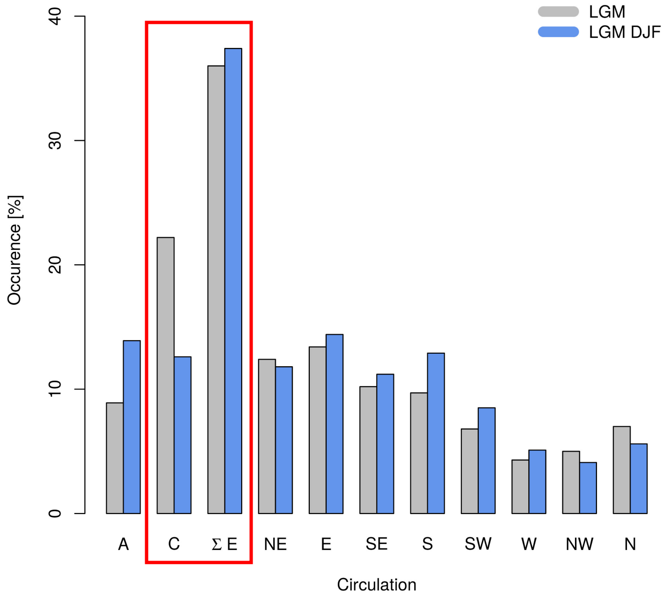

Emission

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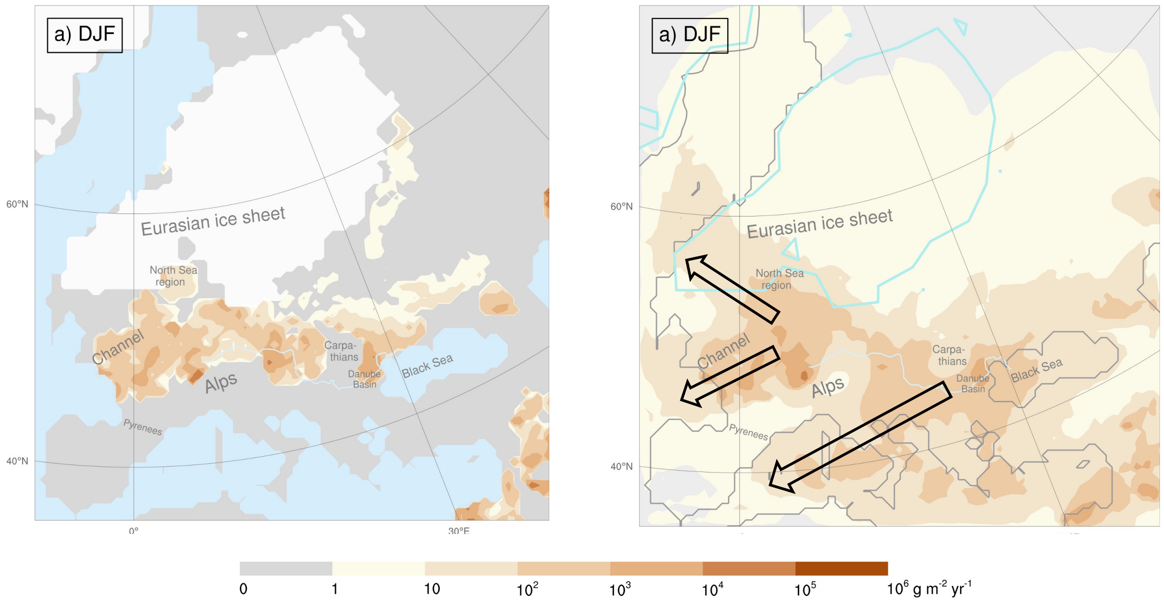
Deposition



∑E=NE+E+SE
sum of easterly circulation patterns

Results: Seasonal aspects - MAM

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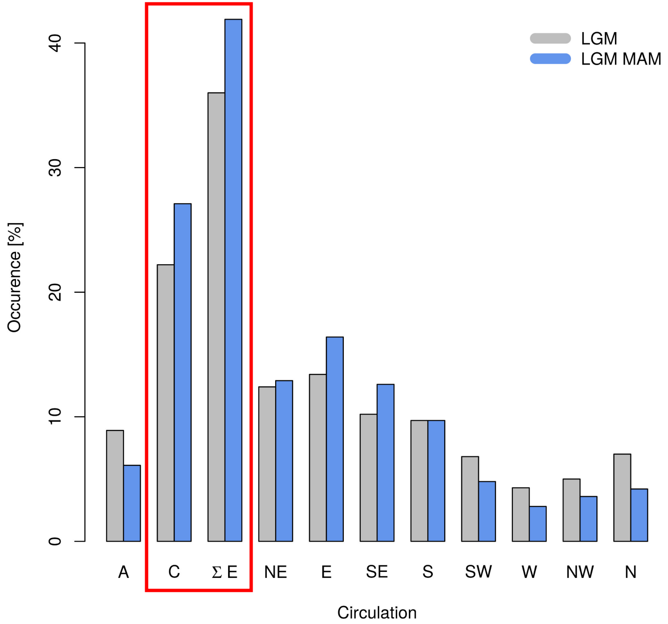

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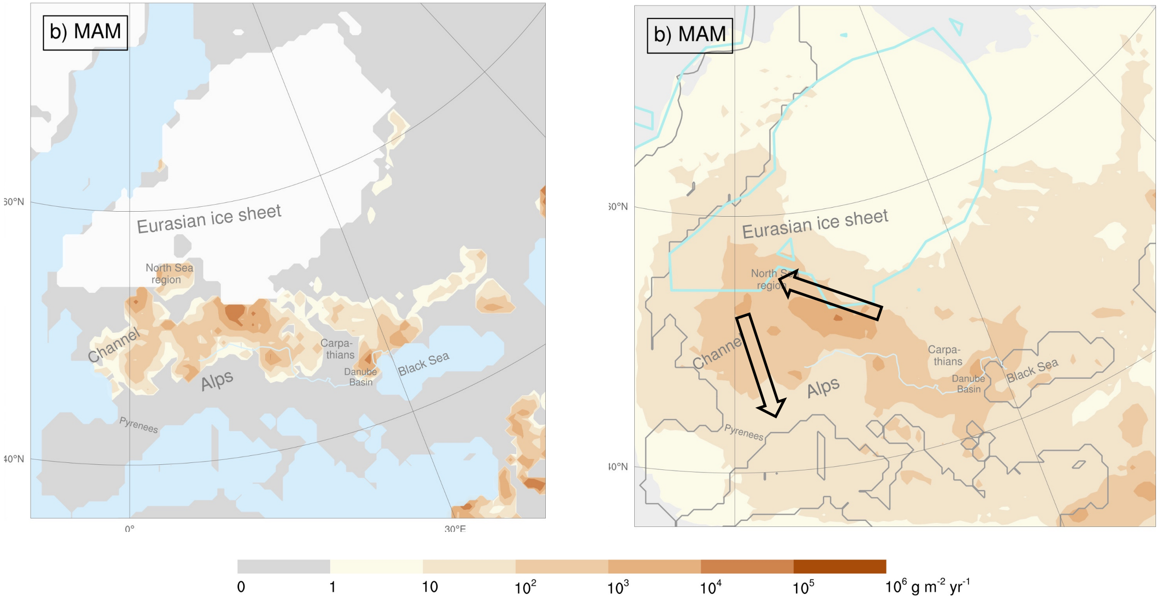

Results: Seasonal aspects - JJA

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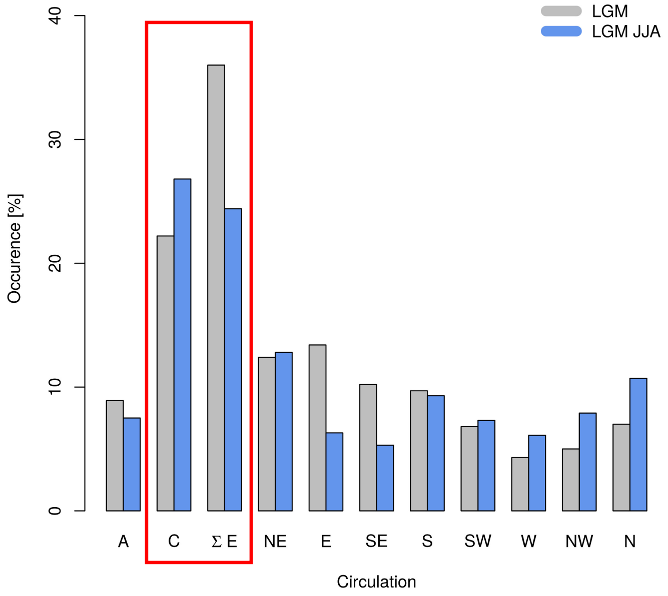

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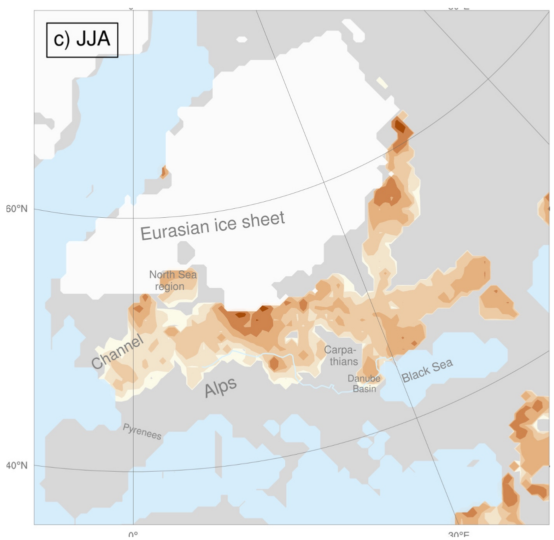

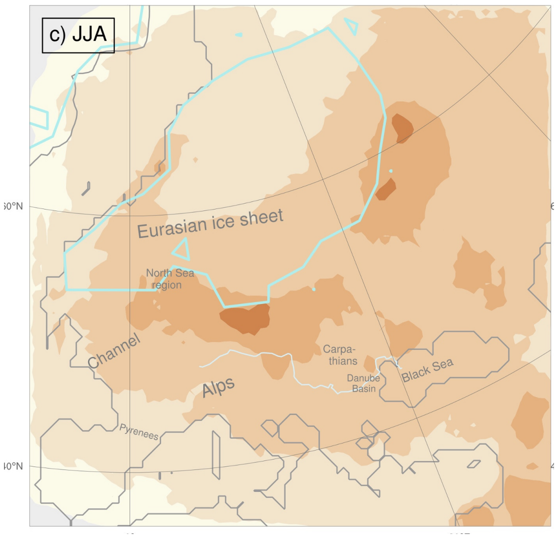

0 1 10 10^2 10^3 10^4 10^5 10^6 g m^{-2} yr^{-1}

Results: Seasonal aspects - SON

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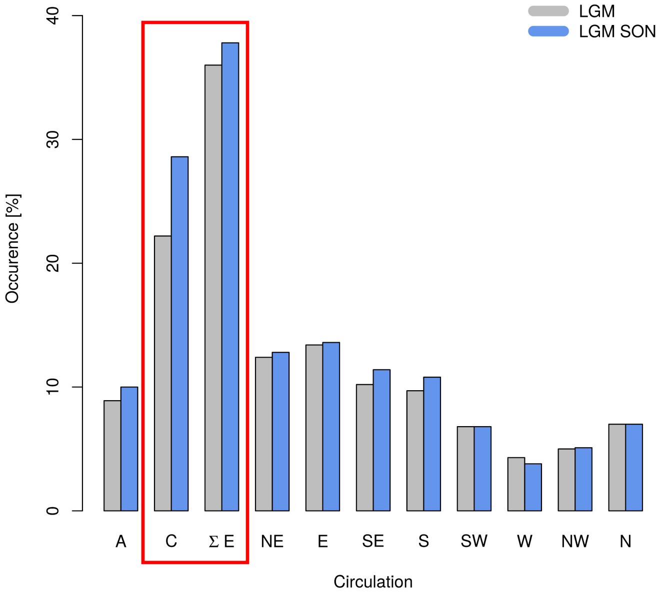

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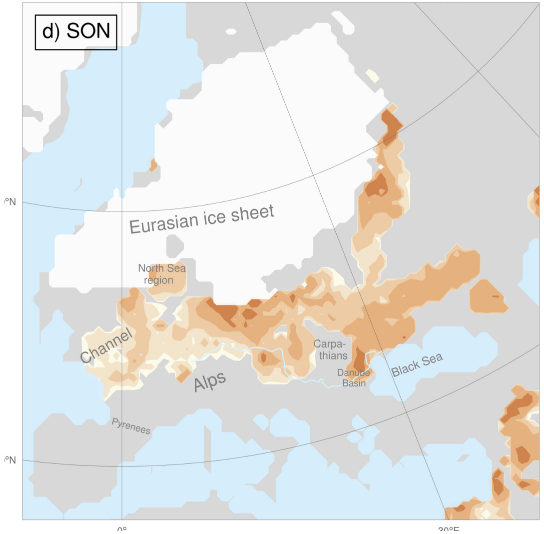
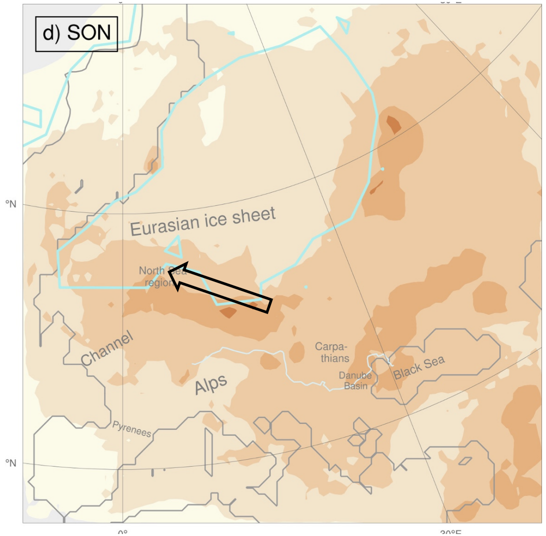
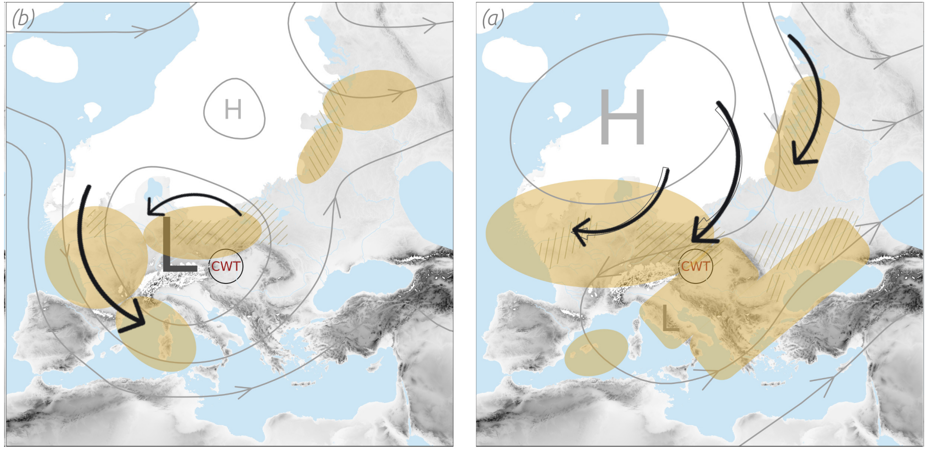




Summary



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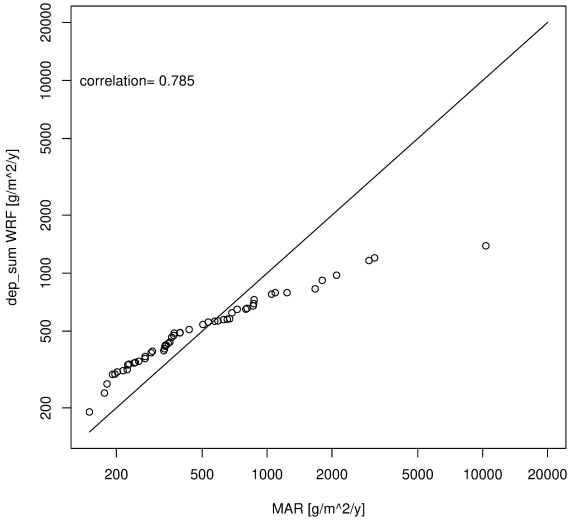
Both cyclones (22.2%) and easterly winds (36.0%) major players for simulated LGM dust cycle

WRF-Chem simulates dust depositions of the same order of magnitude compared to MAR at loess sites

Simulation



MAR

References

[1] Schaffernicht, E. J., Ludwig, P., and Shao, Y. (2020): Linkage between dust cycle and loess of the Last Glacial Maximum in Europe, Atmos. Chem. Phys., 20, 4969–4986, https://doi.org/10.5194/acp-20-4969-2020

[2] Ludwig, P., Schaffernicht, E. J., Shao, Y., and Pinto, J. G. (2016): Regional atmospheric circulation over Europe during the Last Glacial Maximum and its links to precipitation, J. Geophys. Res. Atmos., 121, 2130–2145, https://doi.org/10.1002/2015JD024444

[3] Ludwig, P., Gómez-Navarro, J.-J., Pinto, J.G., Raible, C.C., Wagner, S., Zorita, E. (2019): Perspectives of regional paleoclimate modeling. Annals of the New York Academy of Sciences, 1436, 54-69, https://doi.org/10.1111/nyas.13865