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Outstanding Student & PhD candidate Presentation contest

Decomposing the direct and indirect radiative effects by mineral dust aerosols in CMIP6

Clouds, Aerosols, Radiation and Precipitation (General Session) EGU 2022 May 26th

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Acknowledgement to all the modelers submitting simulations to AerChemMIP

UNIVERSITY OF OSLO

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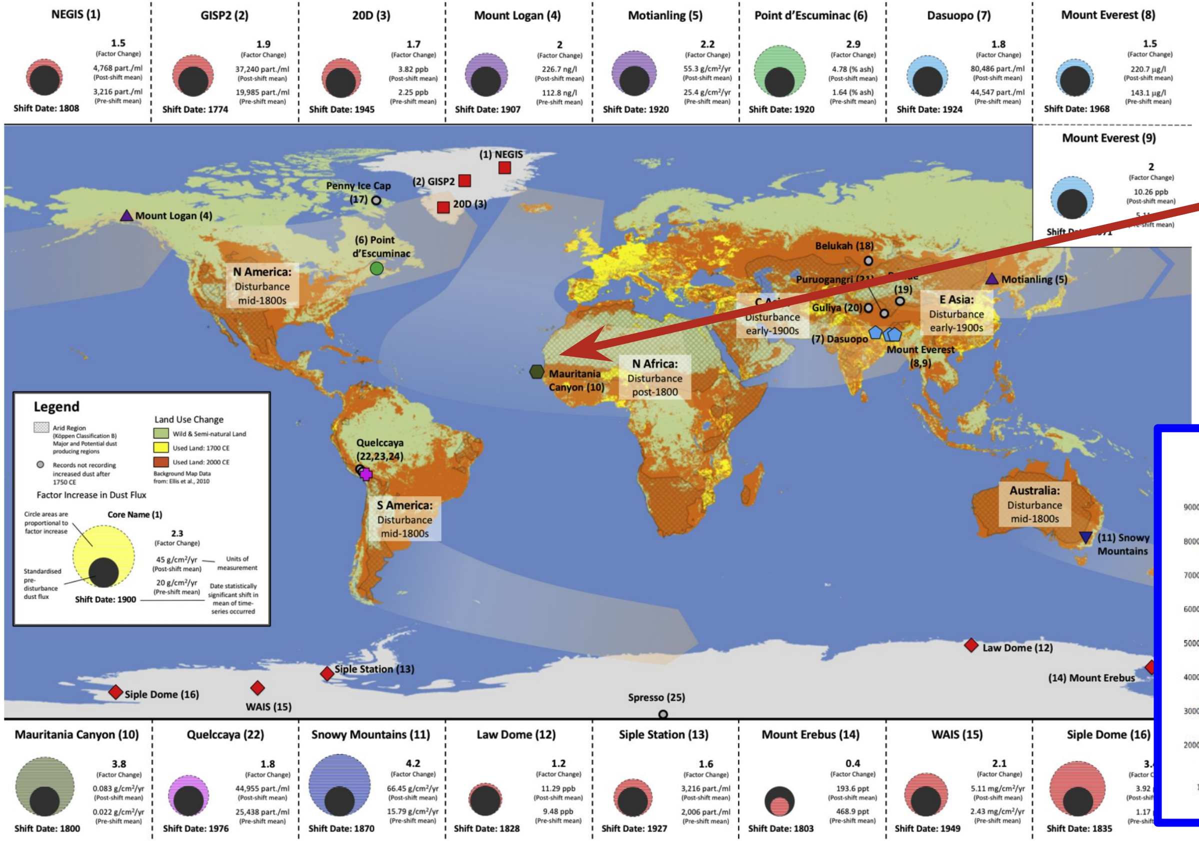
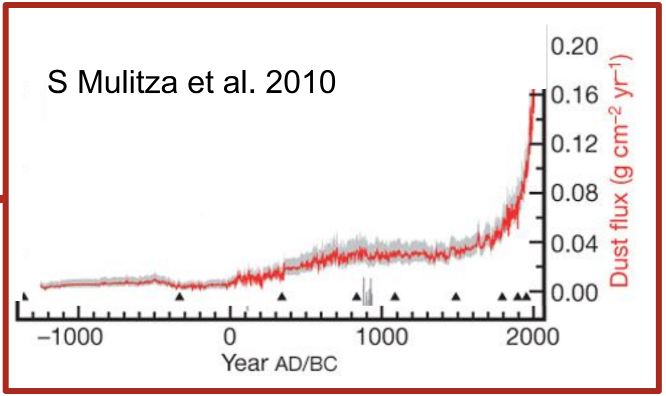
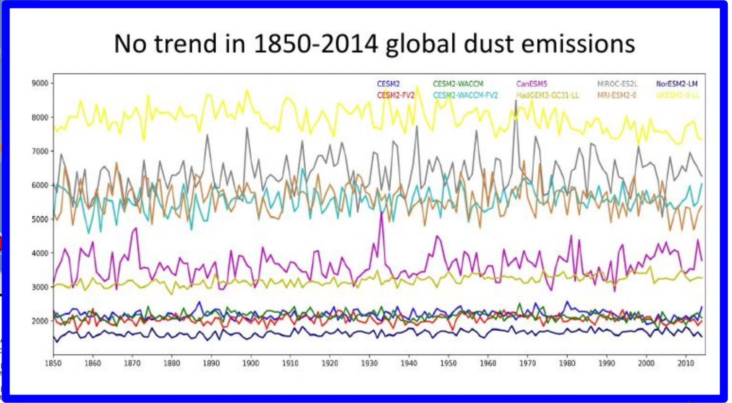
Norwegian Meteorological Institute

Evidence for strong increase in dust emissions since the pre-industrial: **not captured by the CMIP6 models.**



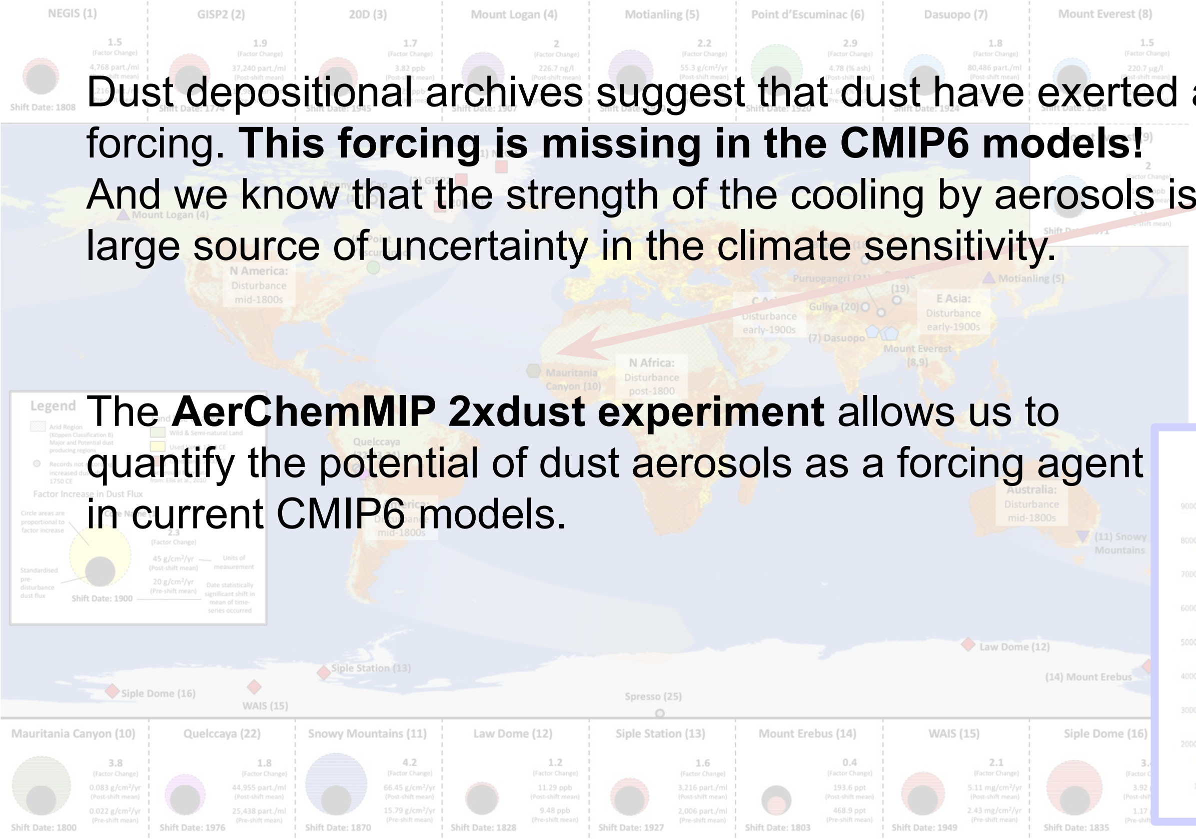
Hooper & Marx 2018



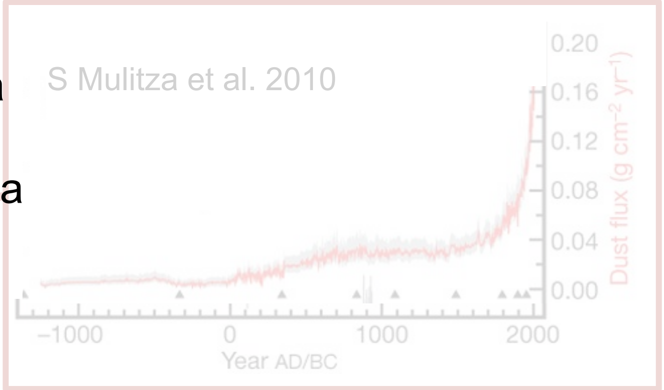


Alcide Zhao, Tri-MIP workshop dec 2021

Evidence for strong increase in dust emissions since the pre-industrial: **not captured by the CMIP6 models.**



Dust depositional archives suggest that dust have exerted a forcing. **This forcing is missing in the CMIP6 models!** And we know that the strength of the cooling by aerosols is a large source of uncertainty in the climate sensitivity.



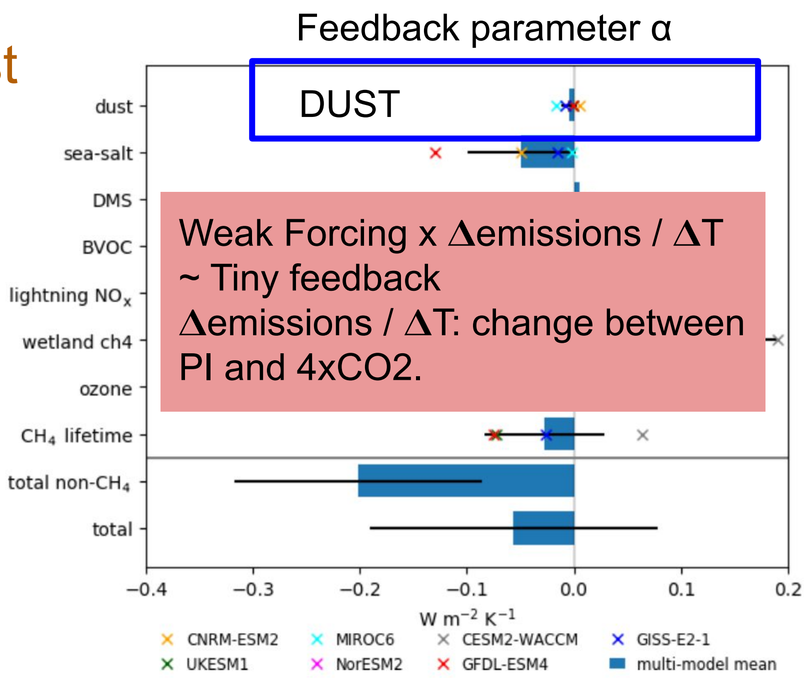
The **AerChemMIP 2xdust experiment** allows us to quantify the potential of dust aerosols as a forcing agent in current CMIP6 models.

Hooper & Marx 2018

Weak forcing: models insensitive to dust perturbations or compensating direct or indirect effects due to dust?

- Thornhill et al 2021 found very small feedback parameter and forcing in the AerChemMIP models. Why?

- Now we have 3 additional models, how will that affect the conclusion?



	CNRM-ESM2-1	UKESM1	MIROC6	NorESM2	GFDL-ESM4	GISS-E2	Multi-model
ΔEmission2*xdust* (Tg yr^{-1})	2877	8185	1065	1397	1989	1236	
ERF 2*xdust* (W m^{-2})	0.09 ± 0.03	0.03 ± 0.03	0.18 ± 0.04	-0.14 ± 0.07	-0.00 ± 0.03	-0.10 ± 0.04	-0.05 ± 0.1
ΔEmission/ΔT (Tg yr^{-1} K^{-1})	65 ± 4	-109 ± 15	70 ± 7	-6 ± 6	181 ± 10	64 ± 9	44 ± 88
α emissions (W m^{-2} K^{-1})	0.0020 ± 0.0007	-0.0004 ± 0.0004	-0.012 ± 0.003	0.0007 ± 0.0007	-0.0004 ± 0.0027	-0.0052 ± 0.0021	-0.0026 ± 0.0048

Thornhill et al 2021

Methodology

Effective radiative forcing* due to dust:

#N models

Change in TOA imbalance between piClim-2xdust and piClim-control:
ERFt = ΔF_{Net}[TOA] = Δ(*rsut* + *rlut* - *rsdt*)

x 9

Direct radiative forcing* due to dust:

Difference between ERFt and ERFtaf (ERFt aerosol free):
F_{ari} = ERFt - ERFtaf = ERFt - Δ(*rsutaf* + *rlutaf* - rsdt)

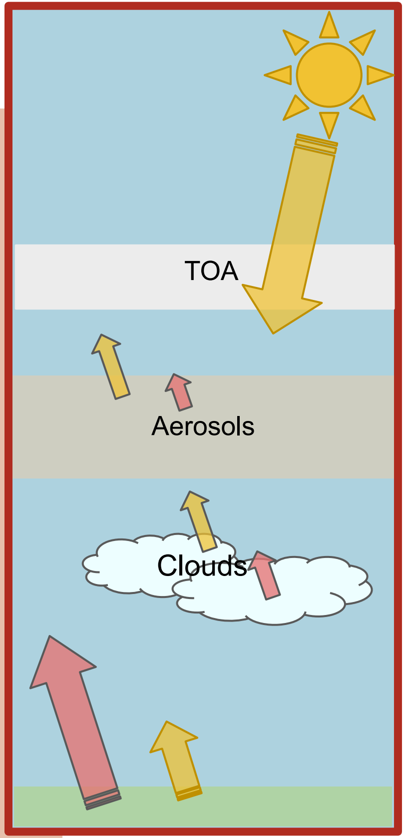
x 5

Cloud radiative forcing* due to dust:

Difference between ERFtaf - ERFtcsaf (ERFt clear sky aerosol free):
F_{aci} = ERFtaf -ERFtcsaf = ERFtaf - Δ(*rsutcsaf* + rlutcsaf - rsdt)

x 5

*Requires two calls to the radiation code



9 models give stronger negative total dust radiative forcing:
due to more negative direct forcing.

	SW Fari	LW Fari	Fari	SW Faci	LW Faci	Faci	ERF total
* CNRM-ESM2-1	**0.026**	**0.024**	**0.049**	-0.031	-0.013	-0.044	0.089
EC-Earth3-AerChem	**-0.574**	**0.011**	**-0.563**	**0.246**	-0.082	0.164	**-0.416**
* GFDL-ESM4							-0.004
* GISS-E2-1-G							-0.087
IPSL-CM6A-LR-INCA							-0.236
MPI-ESM-1-2-HAM	**-0.729**	**0.186**	**-0.543**	0.222	-0.071	0.158	**-0.301**
* NorESM2-LM	**-0.458**	**0.017**	**-0.441**	**-0.544**	**0.651**	0.108	-0.146
* UKESM1-0-LL	**-0.259**	**0.190**	**-0.070**	0.137	-0.026	0.111	0.031
* MIROC6							-0.185
Multi-model*	**-0.399**	**0.086**	**-0.313**	0.006	0.092	**0.099**	**-0.139**

Decomposition of dust radiatve radiative forcings W m-2

** Thornhill: -0.05*

Bold means that the forcing is greater than interannual variability of the model / (*) greater than standard error of the model means

Weak influence on ice water path with increased dust concentrations

	Ice Water Path g m-2	Cloud cover (%)	Liquid Water Path g m-2	Precipitation g m-2 s-1
CNRM-ESM2-1	-0.003	0.068	0.081	2.31e-06
EC-Earth3-AerChem	-0.012	-0.125	**-0.371**	2.75e-05
GFDL-ESM4	0.018	-0.108		-8.56e-05
GISS-E2-1-G	-0.643	-0.014		**-9.55e-05**
IPSL-CM6A-LR-INCA	-0.040	0.015		-7.39e-05
MPI-ESM-1-2-HAM	-0.008	-0.014	-0.490	-3.30e-05
NorESM2-LM	**0.316**	**0.525**	0.096	**-2.01e-04**
UKESM1-0-LL	-0.054	-0.127	-0.109	-2.52e-05
MIROC6		-0.009		-1.47e-05
Multi-model *	-0.053	0.023	**-0.159**	**-5.55e-05**

Absolute change between control and 2x-dust

NorESM2-LM is the exception

Bold means that the forcing is greater than interannual variability of the model / (*) greater than standard error of the model means

Conclusion

- Analysing the full AerChemMIP model ensemble suggest a **stronger negative dust forcing** than Thornhill et al 2021.
- Positive dust cloud forcing:
  - **NorESM2,** increase of ice clouds -> positive longwave forcing.
  - **Other models,** reduction of LWP -> positive shortwave forcing.
- Weak relationship between dust emission and temperature:
  - We need a better understanding of the impact of land use change and climate change on dust emissions.
- The decomposition showed that the **dust cloud forcing and emission changes** are the **largest uncertainties in the dust feedback.**

	Δ emission / ΔT Tgyr-1 K-1	α emissions Wm-2 K-1
CNRM-ESM2-1	69.9	0.002
EC-Earth3-AerChem	-28.2	0.014
GFDL-ESM4	191.1	0.002
GISS-E2-1-G	68.5	0.003
IPSL-CM6A-LR-INCA		
MPI-ESM-1-2-HAM	-106.2	**0.027**
NorESM2-LM	-11.6	0.002
UKESM1-0-LL	-136.9	-0.001
MIROC6	66.1	-0.013
Multi-model	14.1	**0.004**

Emission emission change per temperature change and Feedback parameter

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Questions?

- Please get in touch with me at: oveh@met.no
- The analysis code is available on github: https://github.com/Ovewh/Climaso

References

Ghan, S. J. 2013. “Technical Note: Estimating Aerosol Effects on Cloud Radiative Forcing.” Atmospheric Chemistry and Physics 13 (19): 9971–74. https://doi.org/10.5194/acp-13-9971-2013.

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