

Which cloud microphysical processes are dispensable in a global aerosol climate model?

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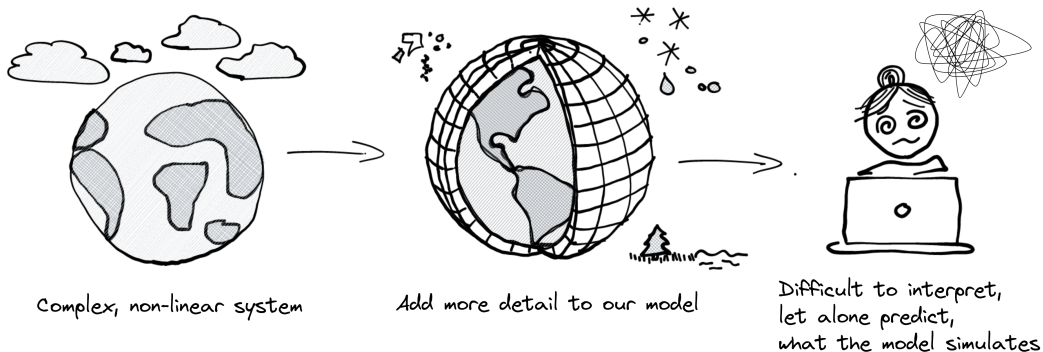
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HAMMOZ

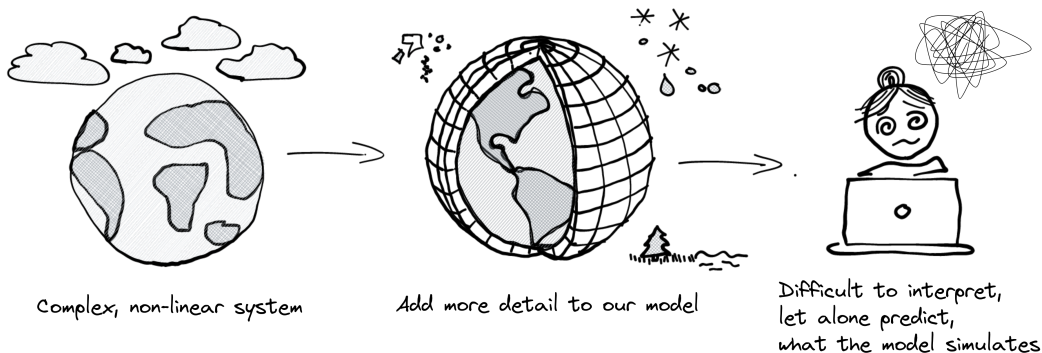
AEROSOL & ATMOSPHERIC CHEMISTRY MODULES FOR ECHAM

Motivation



- ▶ more detail $\rightarrow$ more parametric uncertainty $\rightarrow$ underdetermined system (Reddington et al., 2017)
- ▶ danger of overinterpreting those processes that are represented in detail while neglecting those that are not represented (Mülmenstädt and Feingold, 2018)
- ▶ simpler models are easier to interpret and assumptions are more traceable (Koren and Feingold, 2011; Mülmenstädt and Feingold, 2018)

Motivation

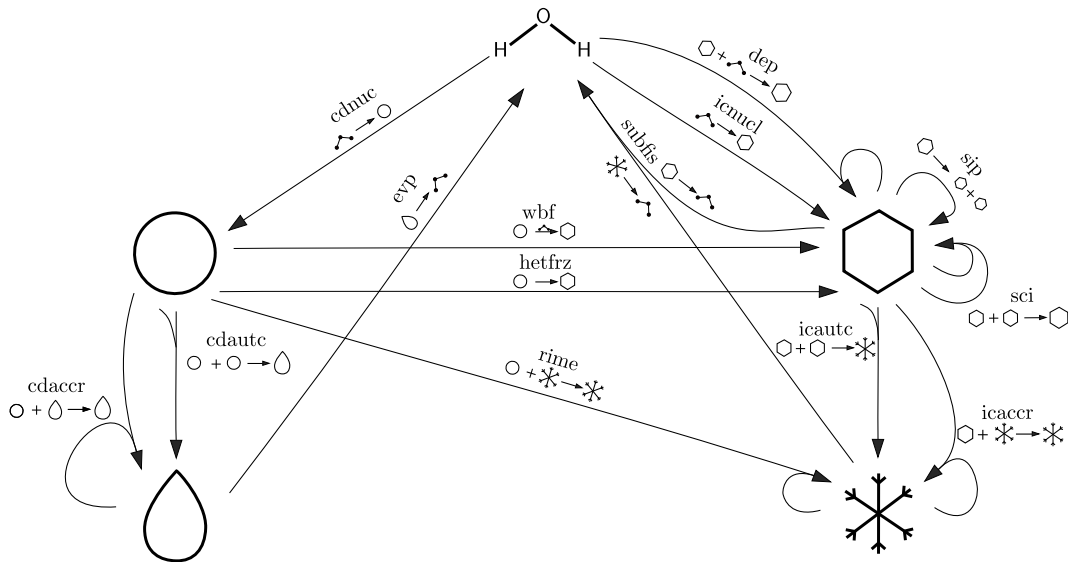


Goals

- Understand how single cloud microphysical (CMP) processes influence the model
- Is there potential for simplification?

Note: we are looking at the model, not reality!

Cloud microphysical process in the ECHAM-HAM 2M scheme



Methods: perturbations

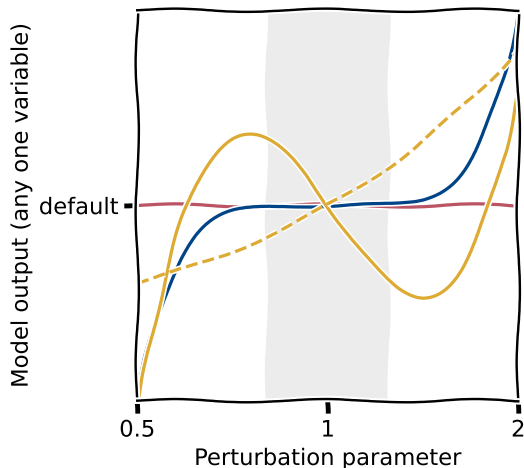
We perturb the effect that the CMP process has on output variables, e.g.

ICNC =

$\text{ICNC}_0 + \eta_{\text{icautc}} \cdot \Delta \text{ICNC}_{\text{icautc}}$,

with $\eta_{\text{icautc}} \in [0.5, 2]$

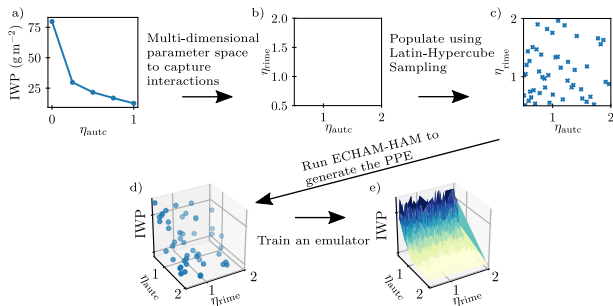
ICNC: ice crystal number concentration



- process dispensable
- process necessary but no need for accuracy
- process needs accurate representation
- - - process needs accurate representation

Methods

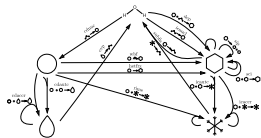
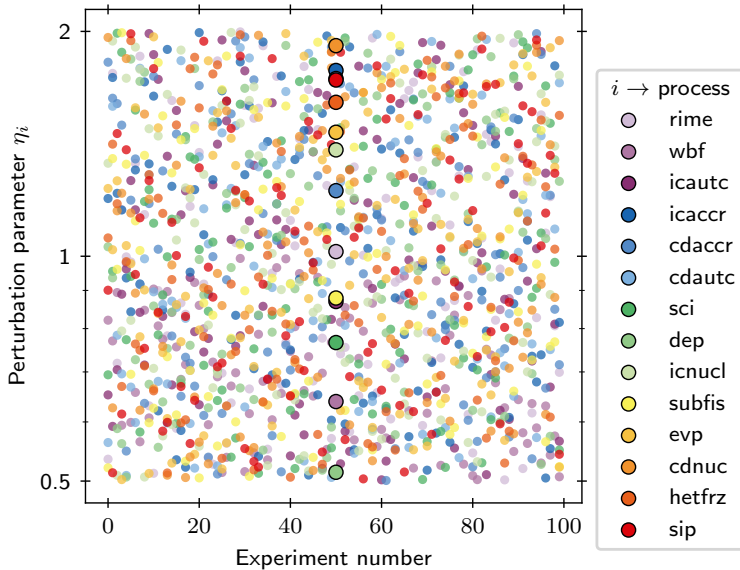
- ▶ Global simulations with ECHAM-HAM
- ▶ Year 2003, 3 months spin-up
- ▶ Diagnose annual mean values
- ▶ Perturbations in the two moment cloud microphysics within the stratiform cloud scheme → perturbed parameter ensemble with ≈ 100 members



Proske et al. (2021, Fig. 2)

Analogous to Proske et al. (2021)

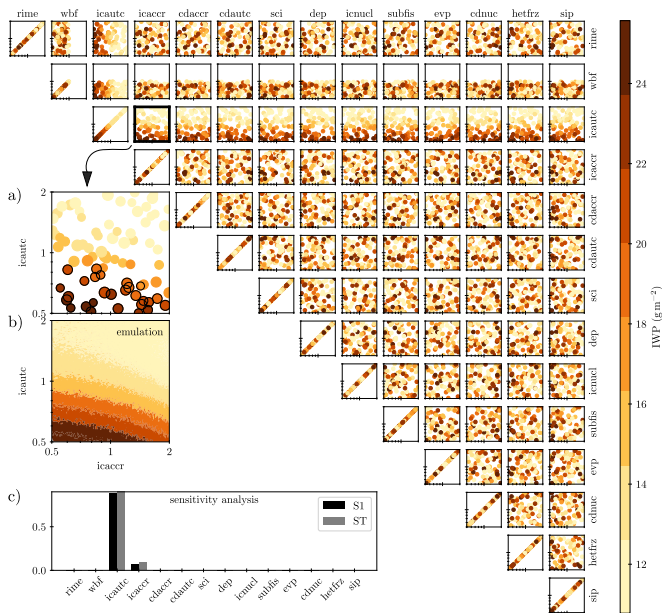
Methods: creating a perturbed parameter ensemble (PPE)



Emulating the PPE

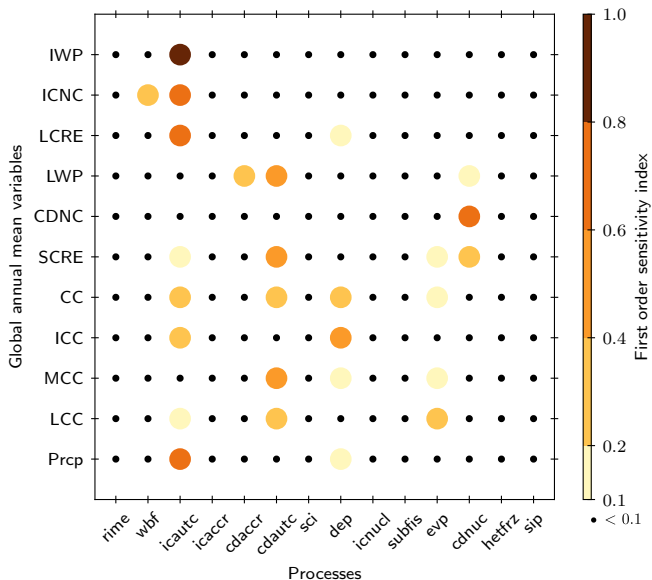
- The response of the model to perturbations can be seen in any global annual mean output variable (e.g. ice water path) as a function of the 14 dimensional parameter space (triangle of small plots)

- The plot with the most order shows the processes with the largest influence for this variable (e.g. *icautc* and *icaccr*)
- The response in the 14 dimensional space is emulated (using the ESEm package (Watson-Parris et al., 2021))
- Global variance based sensitivity analysis is applied to the emulated response to quantify the influence of each perturbed process (S1: first order, ST: total sensitivity index)

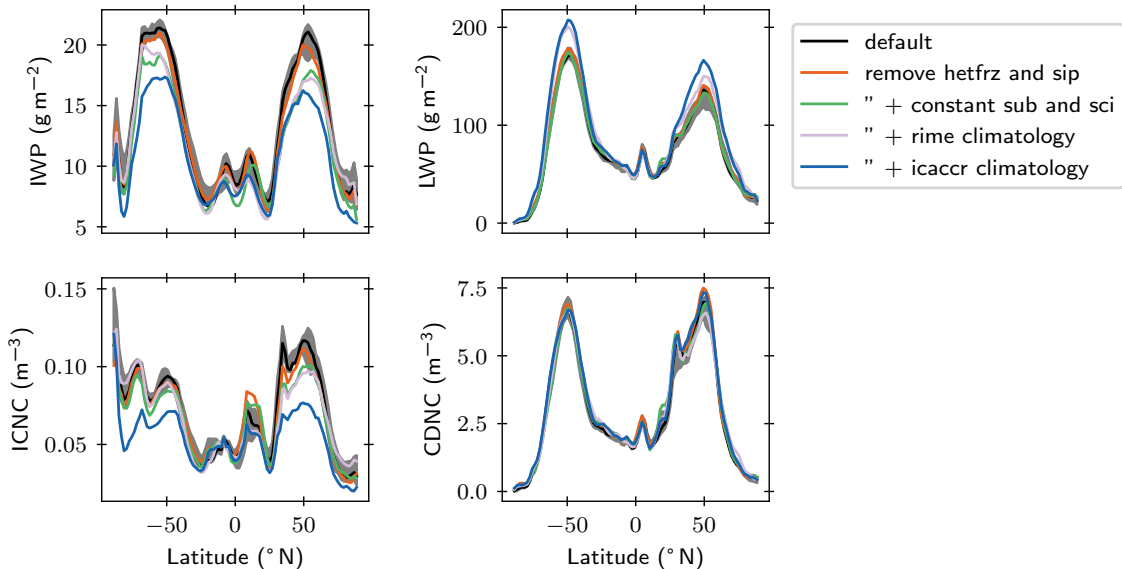


Sensitivity analysis

LCRE/SCRE: long-/ short-wave
cloud radiative effect
CDNC: cloud droplet number
concentration
CC: cloud cover (Liquid,
Mixed-phase and Ice)
Prcp: precipitation



Simplifications

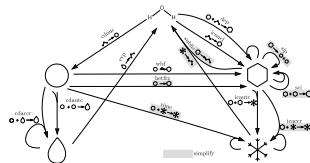
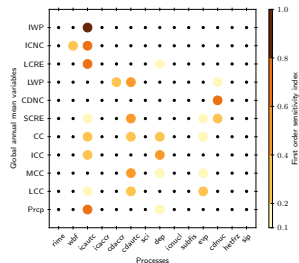


Conclusions

- ▶ Utilizing a sensitivity analysis on an emulated PPE of CMP processes, we can characterize the process influences in the CMP module
- ▶ Which processes are important depends on the variable of interest
- ▶ Caveat: this analysis holds only for ECHAM-HAM in our present version

Tried simplifications

- ▶ Remove hetfrz and sip
- ▶ Set sublimation of falling ice and snow, and self-collection of ice crystals constant
- ▶ Zonal mean climatologies for riming and icnuc



Bibliography I

- ▶ Koren, Ilan and Graham Feingold (2011). “Aerosol–Cloud–Precipitation System as a Predator-Prey Problem”. In: *Proceedings of the National Academy of Sciences* 108.30, p. 7. DOI: 10.1073/pnas.1101777108.
- ▶ Mülmenstädt, Johannes and Graham Feingold (2018). “The Radiative Forcing of Aerosol–Cloud Interactions in Liquid Clouds: Wrestling and Embracing Uncertainty”. In: *Current Climate Change Reports* 4.1, pp. 23–40. ISSN: 2198-6061. DOI: 10.1007/s40641-018-0089-y.
- ▶ Proske, Ulrike, Sylvaine Ferrachat, David Neubauer, Martin Staab, and Ulrike Lohmann (2021). “Assessing the Potential for Simplification in Global Climate Model Cloud Microphysics”. In: *ACPD* submitted. DOI: 10.5194/acp-2021-801.
- ▶ Reddington, C. L. et al. (2017). “The Global Aerosol Synthesis and Science Project (GASSP): Measurements and Modeling to Reduce Uncertainty”. In: *Bulletin of the American Meteorological Society* 98.9, pp. 1857–1877. ISSN: 0003-0007, 1520-0477. DOI: 10.1175/BAMS-D-15-00317.1.

Bibliography II

- ▶ Watson-Parris, Duncan, Andrew Williams, Lucia Deaconu, and Philip Stier (2021).
“Model Calibration Using ESEm v1.0.0 – an Open, Scalable Earth System Emulator”.
In: *Geoscientific Model Development Discussions*, p. 24. DOI:
10.5194/gmd-2021-267.