Rapid adjustments in the abrupt-solm4p experiment of CMIP6

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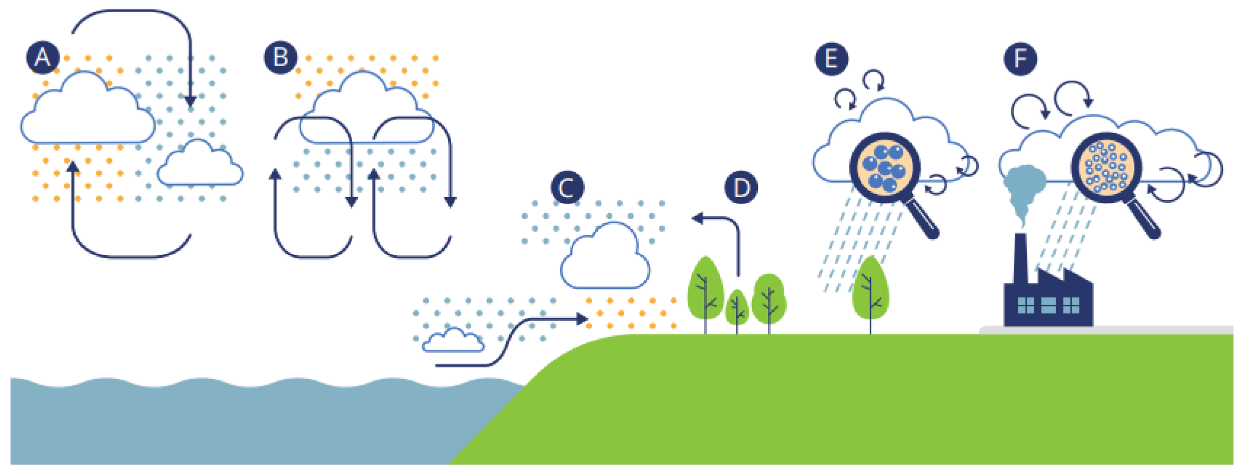
Motivation

Rapid adjustments

Changes to the **atmospheric state** that occur in reaction to a **radiative forcing**, and are **independent** of **global-mean surface temperature change** [1]

$$N = \mathrm{IRF} + \mathrm{RA} - \sum_i \lambda_i \Delta T_s = \mathrm{ERF} - \sum_i \lambda_i \Delta T_s$$

Net TOA Energy Budget — Instantaneous Radiative Forcing — Rapid Adjustments — Effective Radiative Forcing — Feedbacks



Rapid adjustments include changes in horizontal (A) and vertical (B) heating gradients, land-ocean circulation (C), plant physiology (D), and aerosol-cloud-interactions (E) and (F). [2]

Aim of study

- Identify characteristic **rapid adjustments signals** to a well defined, **instantaneous** and **constant forcing**
- Based on data from **reduced solar constant** simulations with **global climate models**

Methods

Abrupt-solm4p experiment of the **Cloud Forcing MIP (CFMIP)** [3] of the Coupled Model Intercomparison Project phase 6 **(CMIP6)**:

- **Instant reduction** of **solar constant** by **4%**, **branched** from piControl on **01/01/1850**
- **Anomaly = solm4p_run - piControl_run**
- Climate variables like surface and atmospheric temperature, precipitation, cloud cover, radiative fluxes and humidity
- **4 participating models** (1 run per model; 3hr, daily or monthly output):

CanESM5 **IPSL-CM6A-LR** **CESM2** **MRI-ESM2-0**

Results

Short-term development (adjustments)

Atmospheric temperature:

- Strong stratospheric cooling due to reduced sw uptake
- Slight tropospheric cooling, stronger than surface cooling → destabilisation, except in high latitudes

Surface temperature:

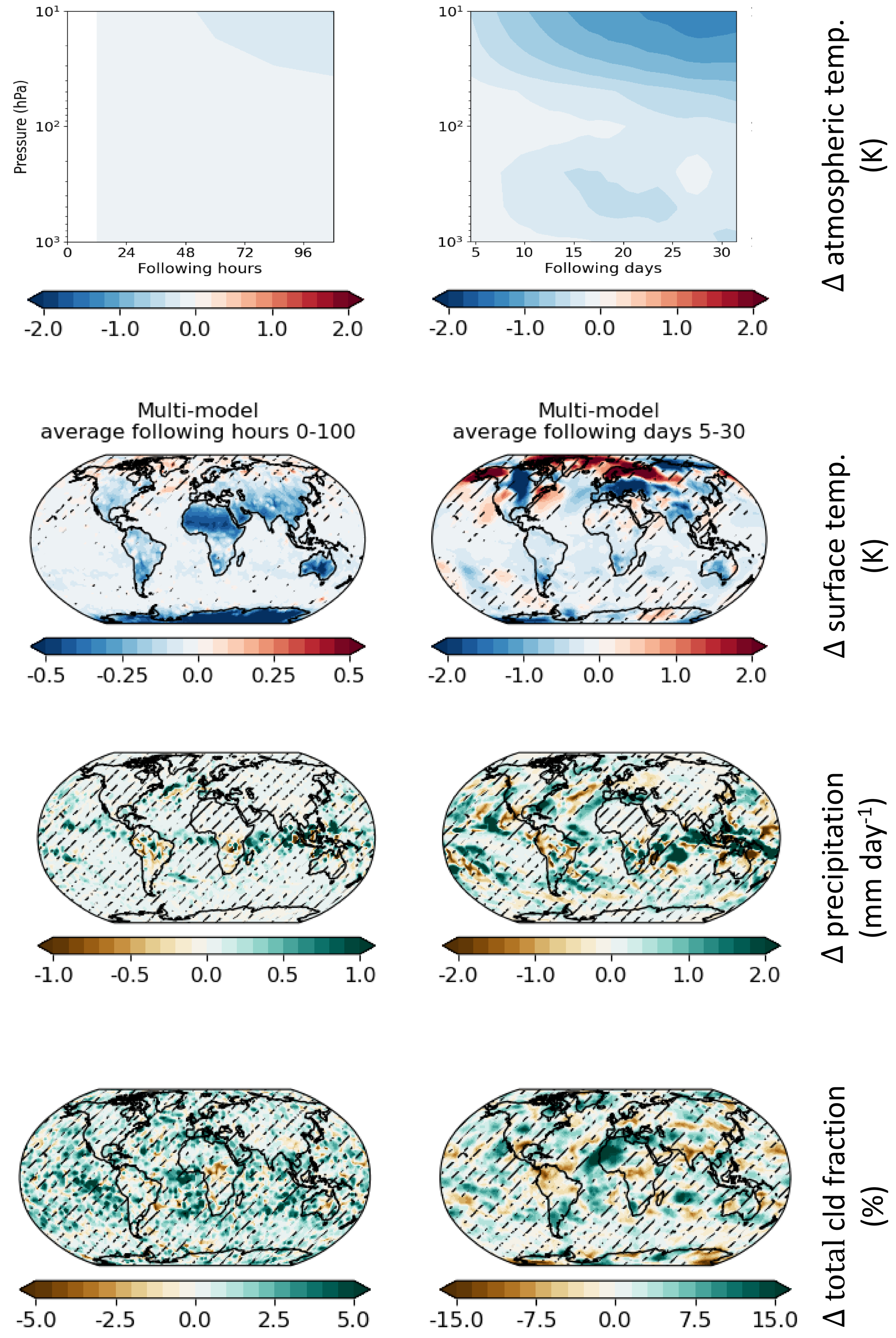
- Cooling due to reduced sw uptake, strongest in areas of low heat capacity
- BUT: warming in Arctic latitudes due to increased cloud cover (lw effect)

Precipitation:

- Excess water vapour due to cooling of atmosphere and destabilisation
  → more convection
  → increased precipitation in areas of strong precipitation

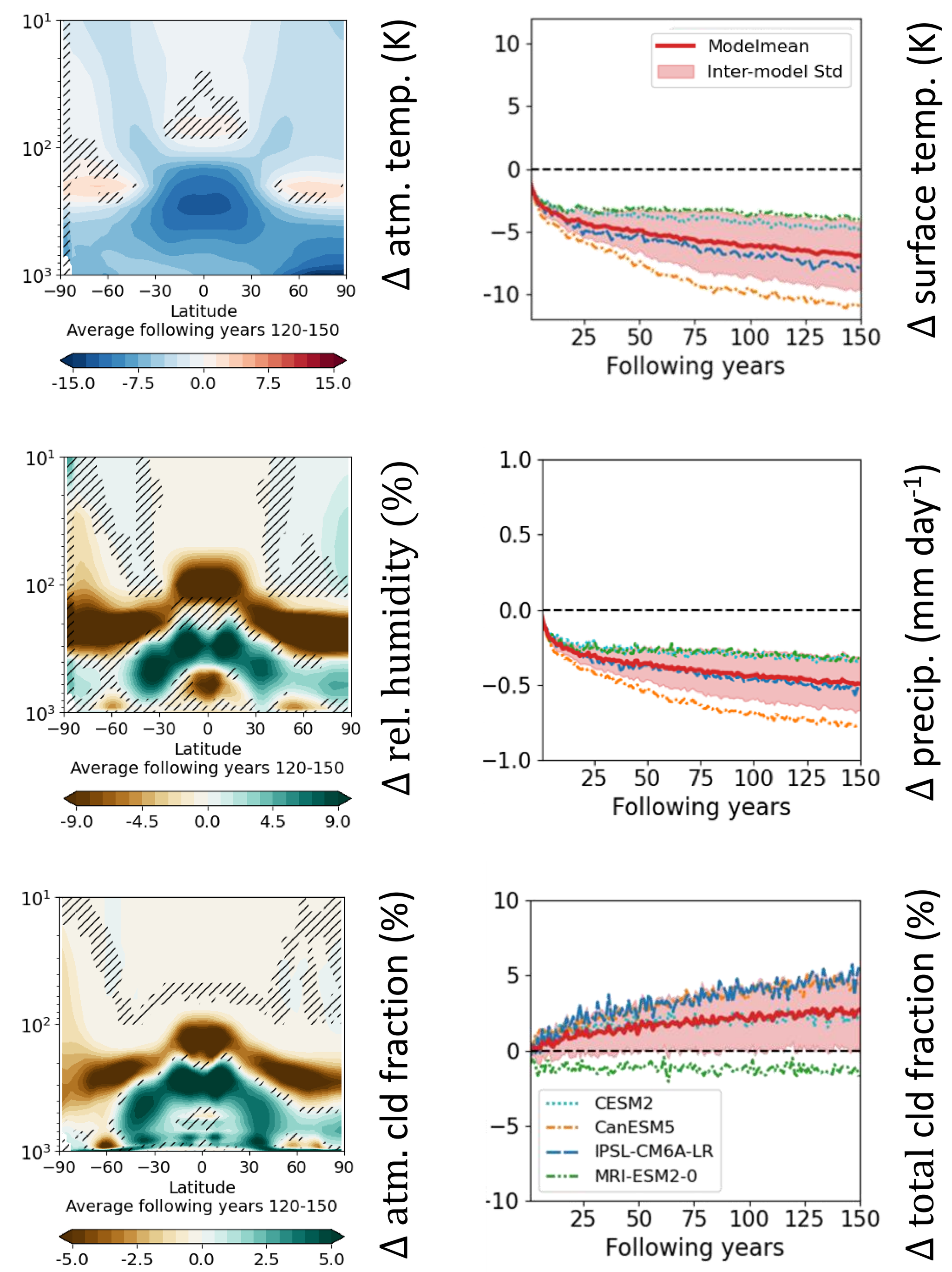
Cloud fraction:

- Increased condensation due to cooling → increase in cloud fraction
- overall positive cloud radiative effect, partly counteracting initial radiative forcing



Long-term development

- Decrease in surface and atmospheric temperature, downward shift of UTLS, destabilisation in tropics
- Decrease in precipitation
- Increase in low- and mid-level clouds, decrease in high level clouds
- Models disagree on sign of total cloud cover anomaly



Conclusions

- **Reduced solar constant** leads to **rapid adjustments** in **land-surface** and **atmospheric temperature, precipitation** and **cloud cover**
  → **abrupt-solm4p** is a valuable tool to examine **rapid adjustments** on **different timescales**
- **Long-term effects** show **similarities** to **strong volcanic eruptions** (e.g. temperature decrease)
- **Comparing abrupt-solm4p** and **volc-pinatubo-full (VolMIP)** could lead to **new insights** regarding **rapid adjustments** after **volcanic eruptions**

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References

[1] Sherwood, S. C., S. Bony, O. Boucher, C. Bretherton, P. M. Forster, J. M. Gregory, and B. Stevens, 2015: Adjustments in the Forcing-Feedback Framework for Understanding Climate Change. Bull. Amer. Meteor. Soc., 96, 217–228, https://doi.org/10.1175/BAMS-D-13-00167.1.

[2] Quaas, J., and G. Myhre (2020). State-of-the-art understanding of rapid adjustments. Knowledge Gains: Summary and Implication Report 2. The CONSTRAIN Project, doi: 10.5281/zenodo.3711986.

[3] Webb, M. J., Andrews, T., Bodas-Salcedo, A., Bony, S., Bretherton, C. S., Chadwick, R., Chepfer, H., Douville, H., Good, P., Kay, J. E., Klein, S. A., Marchand, R., Medeiros, B., Siebesma, A. P., Skinner, C. B., Stevens, B., Tselioudis, G., Tsushima, Y., and Watanabe, M.: The Cloud Feedback Model Intercomparison Project (CFMIP) contribution to CMIP6, Geosci. Model Dev., 10, 359–384, https://doi.org/10.5194/gmd-10-359-2017, 2017.