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Cloud Physics: The Role of Clouds in Climate Change

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Clouds

Climate Change





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Cloud changes under climate warming



Simulated changes with observational evidence.



Fig. 7.11 of the IPCC AR5, Part 1.

Observed cloud changes





Figure 3 | Zonal mean change in observed and simulated cloud amount during the period 1983–2009 in seven pressure intervals. a, ISCCP climatological cloud amount. b, Trend in ISCCP cloud amount 1983–2009.

Norris, J., Allen, R., Evan, A. et al. Evidence for climate change in the satellite cloud record. Nature 536, 72–75 (2016) doi:10.1038/nature18273

Observed cloud changes





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FAT (Fixed anvil temperature) hypothesis (Hartmann & Larson, 2002; Kuang and Hartmann, 2007): anvil clouds occur where convective detrainment is maximum, and this is controlled by the vertical gradient of clear-sky radiative cooling (water vapour emissivity).

Cloud radiative effect = $F_{net,SW,TOA}^{with cloud}$ - $F_{net,SW,TOA}^{without cloud}$ + $F_{net,LW,TOA}^{with cloud}$ - $F_{net,LW,TOA}^{without cloud}$



SW: shortwave, LW: longwave, TOA: top of the atmosphere; sign convention: positive downward





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Low cloud reduction:





NASA, MODIS satellite

Schneider, T., Kaul, C.M. & Pressel, K.G. Possible climate transitions from breakup of stratocumulus decks under greenhouse warming. Nat. Geosci. 12, 163–167 (2019) doi:10.1038/s41561-019-0310-1

Low cloud reduction: tipping point?





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Cloud phase feedback







Cloud phase feedback





17 Corinna Hoose The Role of Clouds in Climate Change



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Glaciation: liquid to ice conversion





Why does it matter:

- Latent heat release
- Optical properties change
- Particle size changes -> sedimentation velocity, lifetime



Simulation setup

Semi-idealized COSMO simulations
Δx=110m, 600x600 gridpoints
convection triggered by solar heating in an orographically structured terrain
2-moment, 6-category microphysics
(Seifert & Beheng, 2006)







In-cloud phase distribution





Fingerprints of ice formation processes





Fingerprints of ice formation processes

Fingerprints of secondary ice formation

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Fingerprints of primary ice formation

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Cloud phase feedback and climate sensitivity

Depends on the efficiency of different **ice formation processes**, which is still highly uncertain!

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Cloud changes due to aerosols

IPCC AR3, 2007

Cloud albedo and cloud lifetime effects: ship tracks

 N_{sc} : additional CCN by ship emissions R_{zb} : rain rate at cloud base (contours: 1, 10, 20 mm/day)

Wang & Feingold, 2009

Cloud susceptibility

Oreopoulos and Platnick, 2008

Contrails

Fig.: wikipedia

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IPCC AR5: radiative forcings

Summary

