The representation of stratocumulus clouds and its impact on the anthropogenic aerosol effect

D. Neubauer, U. Lohmann, C. Hoose, G. M. Frontoso

CFMIP/EUCLIPSE meeting, 10 July 2014, Egmond aan Zee



Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich





Der Wissenschaftsfonds.

Anthropogenic aerosol effect

- Uncertainty sources of anthropogenic aerosol effect
- Natural/anthropogenic emissions most important
- Aerosol processes cause 14% of variance
- Low-level stratified cloud optical depth taken from ISCCP data, not computed



GCM evaluation in stratocumulus regime



- Definition of stratocumulus regime (over ocean; 60N-60S):
 - LTS ≥ 18.55 K
 - w500 ≥ 10 hPa day⁻¹
- Similar areas as in re-analyis data but less frequent/persistent
- CFMIP Observation Simulator Package (COSP)
- 5 year AMIP simulations @ T63/L31 (2006-2010)

Typical stratocumulus cloud biases in a GCM



Left Figure from Laboratoire de Meteorologie Dynamique (LMD)

Changes for stratocumulus clouds in ECHAM6-HAM2 - Increase in vertical resolution

- More vertical levels (VRES47/95; additional levels mostly in boundary layer)
- Clouds are forming higher up at high vertical resolution
- Stratocumulus conditions frequency, low cloud cover and liquid water path are still low

Atmospheric and Climate Science

nstitute fo









Reduced turbulent mixing in stable conditions

 Use 'sharp' stability function in turbulence scheme (STAB)

$$K_{\rm turb} = l * S * \sqrt{TKE}$$

- Increase in cloud cover
- Increase in liquid water path
- More negative cloud radiative effect (stronger cooling)

STAB - REF







mospheric and Climate Science StI:

Aerosol processing in stratiform clouds

• Explicit representation of aerosol particles in cloud droplets and ice crystals in stratiform clouds (AP; Hoose et al. 2008a,b)



- Aerosol load, aerosol size distribution and mixing state change
- Almost no change in cloud properties in stratocumulus regime



Anthropogenic aerosol effect (AAE)

ECHAM6-HAM2 (REF)



- Large anthropogenic aerosol effect in stratocumulus regions
- Global anthropogenic aerosol effect is statistically significant

AAE in stratocumulus regime

ECHAM6-HAM2 (REF)



- Fixed sea surface temperatures and sea ice cover
- Differences in annual mean values
- Six stratocumulus regions \rightarrow weighted average
- Test statistical significance

AAE change by STAB/AP



- Stronger AAE globally with STAB (,sharp' stability function) and in stratocumulus regime
- Changes in LWP are stronger in stratocumulus regime in STAB
- Slightly weaker AAE with AP (aerosol processing) as more background aerosol reduces susceptibility

AAE change by VRES



- Stronger AAE with VRES47 (increased vertical resolution; fewer stratocumulus clouds as in REF)
- Stronger AAE with VRES95 (reduced background aerosol and increased susceptiblity)

Clouds and aerosol in ACI



• Variance due to uncertainty in clouds is comparable to variance due to uncertainty in aerosol

Summary

- Increased vertical resolution improves vertical cloud properties but has otherwise no clear benefits
- Sharp stability function improves cloud cover in stratocumulus regions
- AAE increases by -0.15/-0.65/-1.11 W/m² with STAB/VRES47/95 and decreases by 0.11 W/m² with AP

ospheric and Climate Science

• AAE depends on the representation of stratocumulus clouds in ECHAM6-HAM2

Neubauer et al., ACPD, 2014