Improved representation of marine stratocumulus clouds and the anthropogenic aerosol effect

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Der Wissenschaftsfonds.

Typical stratocumulus cloud biases in a GCM



Left Figure from Laboratoire de Meteorologie Dynamique (LMD)



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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 \rightarrow
- Better compare in-regime values to observations
- 5 year AMIP simulations @ T63/L31 (2006-2010)

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Low clouds in stratocumulus regime



- Fewer low coulds in ISCCP data
- CALIPSO is taken as reference
- CFMIP Observation Simulator
 Package (COSP)
- Underestimation by COSP-ECHAM6-HAM2



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Increase in vertical resolution

- More vertical levels (VRES47/95; additional levels mostly in boundary layer)
- Clouds are forming higher up at high vertical resolution

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 Frequency of stratocumulus conditions, low cloud cover and liquid water path are still low







1000

0.00

0.02

0.04

5 ©

0.08

0.10

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0.06

Changes for stratocumulus clouds in ECHAM6-HAM2 - 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)

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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 ⁶⁰
 mixing state change
- Almost no change in cloud properties in stratocumulus regime





Summary I

- Typical stratocumulus cloud biases reduced in stratocumulus regime
- Sharp stability function improves cloud cover in stratocumulus regions
- Increased vertical resolution improves vertical cloud properties but has otherwise no clear benefits
- No simple solution to 'stratocumulus problem'

Anthropogenic aerosol effect (AAE)

ECHAM6-HAM2 (REF)



- Large anthropogenic aerosol effect in stratocumulus regions
- Changes for stratocumulus clouds affect the anthropogenic aerosol effect (also in other regions)

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AAE in stratocumulus regime



- Internal variability due to changing number of sampled grid boxes
- Standard deviation of monthly Sc-number is 9-25% of mean value
- Standard deviation of annual Sc-number is only 3-5% ightarrow
- Annual values are more robust

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AAE in stratocumulus regime

ECHAM6-HAM2 (REF)



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

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AAE change by STAB/AP



- Stronger AAE globally with STAB and in stratocumulus regime
- Changes in LWP are stronger in stratocumulus regime in STAB
- Slightly weaker AAE with AP as more background aerosol reduces susceptibility

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AAE change by VRES



- Stronger AAE with VRES47 (less stratocumulus clouds as in REF)
- Stronger AAE with VRES95 (reduced background aerosol and increased susceptiblity)

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Summary II

- AAE in the stratocumulus regime is generally stronger than in the global mean
- Model changes not only alter clouds but also aerosol
- AAE depends on the presentation of stratocumulus clouds in ECHAM6-HAM2

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