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Cloud-aerosol interactions in ECHAM5-HAM: sensitivity studies

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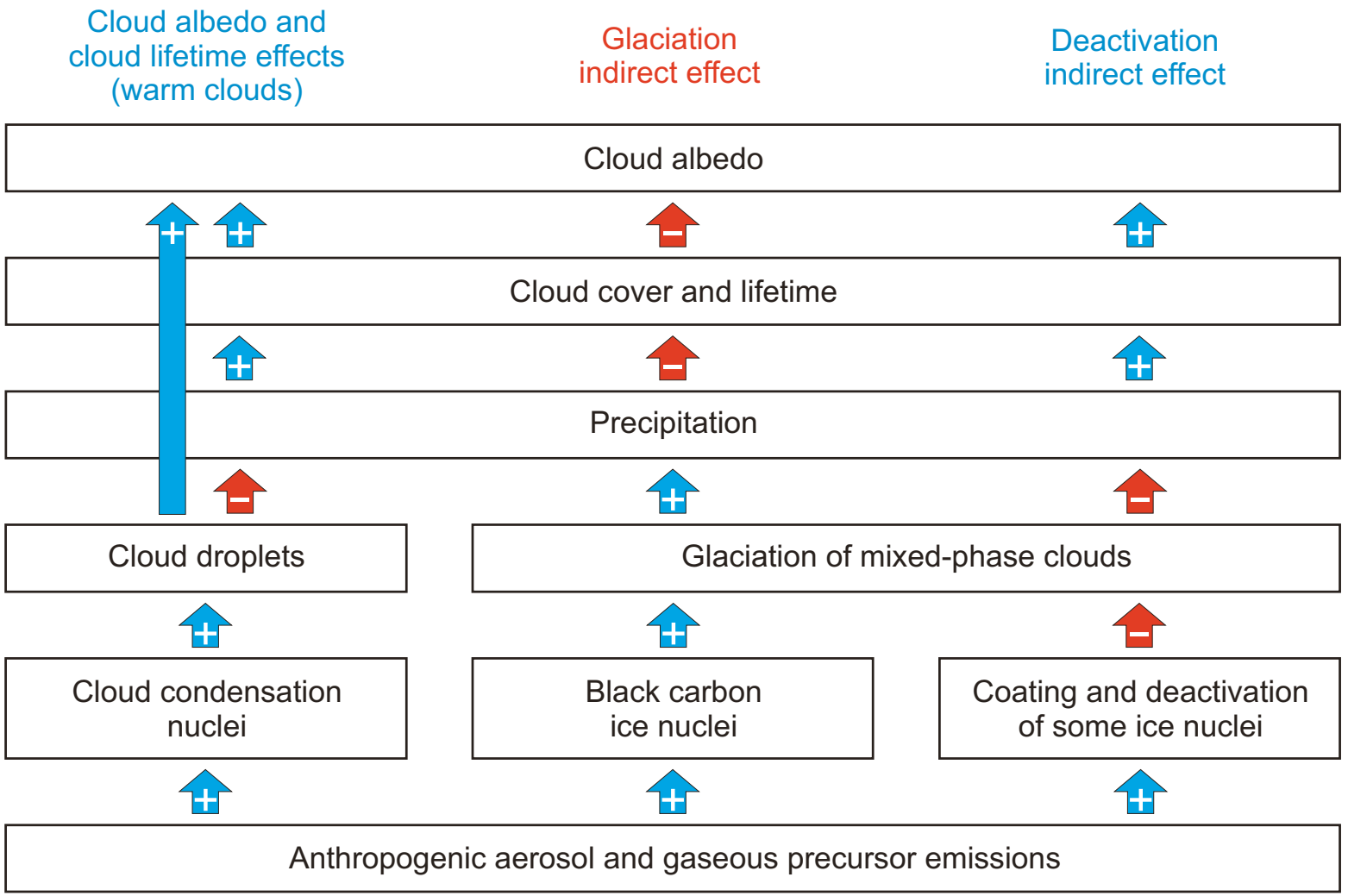
Presented by S. Ferrachat (1)

Glaciation and deactivation effects



This figure and all following ones (excepted when specifically mentionned) from Lohmann & Hoose, ACPD 2009

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Model description

- ECHAM-HAM5.5.00_rc2 (rev. 1259):
  - 2-moments cloud microphysics in stratiform clouds (Lohmann et al. 2008)
  - HAM aerosol scheme (Stier et al. 2005)
  - Empirical cloud cover (Sundqvist et al. 1989)
  - Aerosol-size dependent below-cloud scavenging (Croft et al 2009)
  - Water uptake scheme following Petters & Kreidenweis (2007) (D. O'Donnel & S. Kinne, pers. comm.)
  - Nucleation scheme taking into account gal. cosmic rays and org. vapors (J. Kazil)
  - Resolution: T42L19, 30min
  - Nudged and climatological simulations

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Improved modelling of the Bergeron-Findeisen process (1)

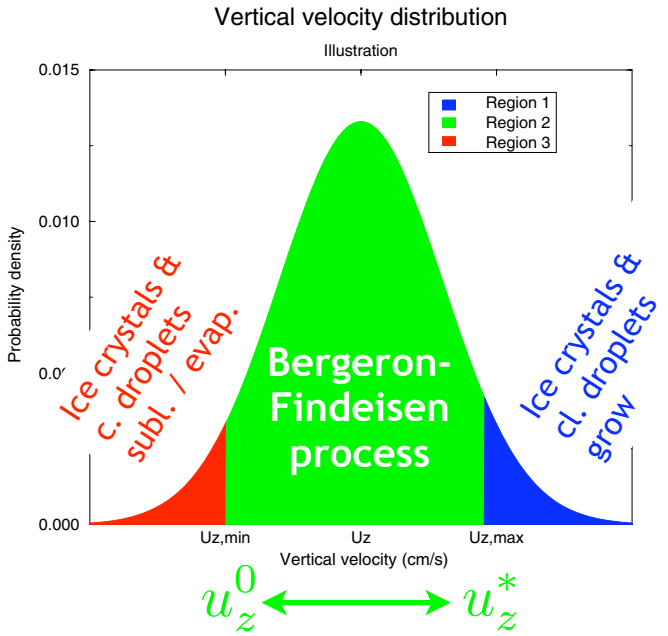
- Bergeron-Findeisen process:
  - ice crystals grow at the expense of cloud droplets when:

$$e_s > e > e_i$$

- The above equation holds true if (Korolev & Mazin, 2003):

$$u_z^0 < u_z < u_z^*$$

u_z: updraft velocity



Modified after Storelvmo et al, Env. Res. Letters 2008

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Improved modelling of the Bergeron-Findeisen process (2)

- Standard version of the Bergeron Findeisen process in ECHAM5-HAM:
  - BF if: $\begin{cases} -35°C < T < 0°C \\ e_s > e > e_i \end{cases}$

- Improved BF modeling:
  - BF if: $\begin{cases} -35°C < T < 0°C \\ u_z < u_z^* \end{cases}$

where: $u_z = \begin{cases} \bar{u}_z + 1.33\sqrt{TKE}, & \text{for stratiform clouds} \\ \bar{u}_z + 1.33\sqrt{TKE} + \sqrt{CAPE}, & \text{for convective clouds} \end{cases}$

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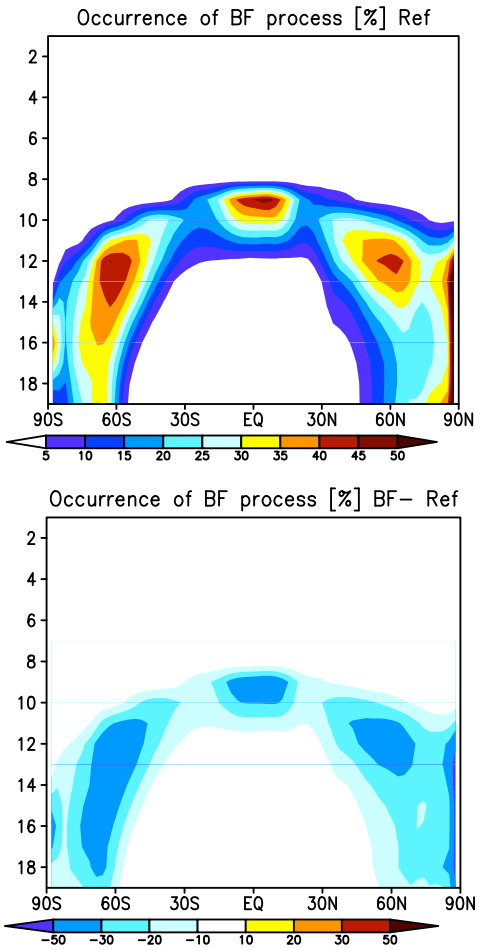
Results: Bergeron-Findeisen process (1)

More stringent Bergeron-Findensen process ...

... More liquid water content and higher altitude of freezing

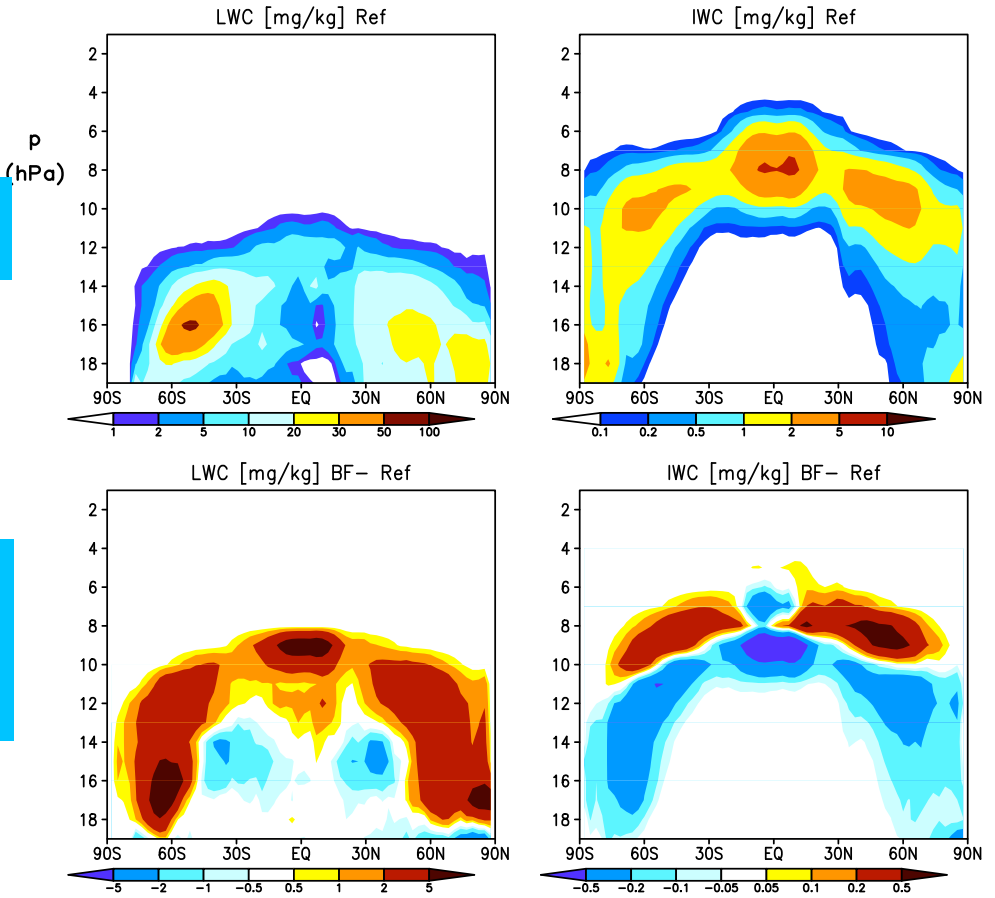
Ref

BF - Ref



LWC

IWC



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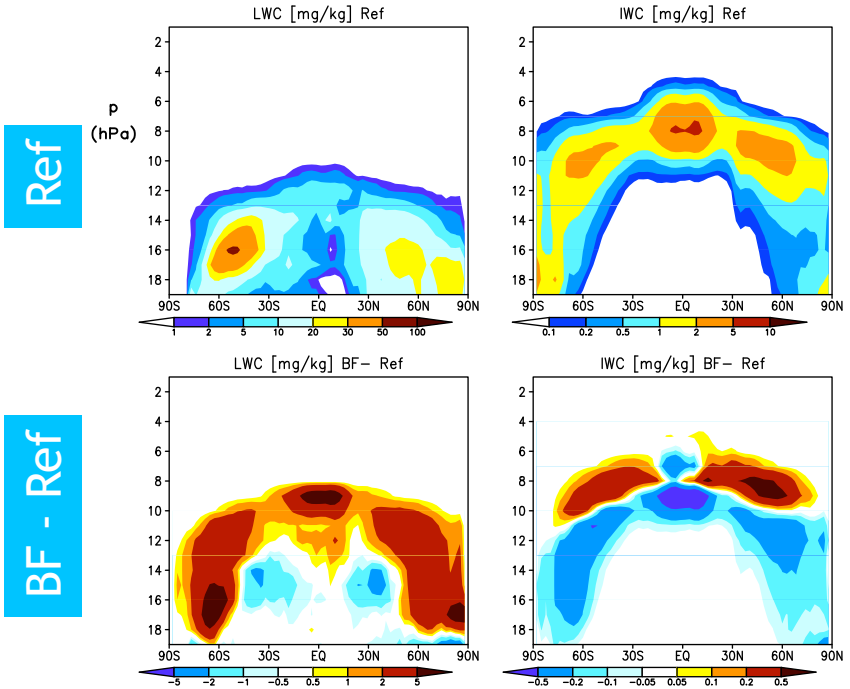
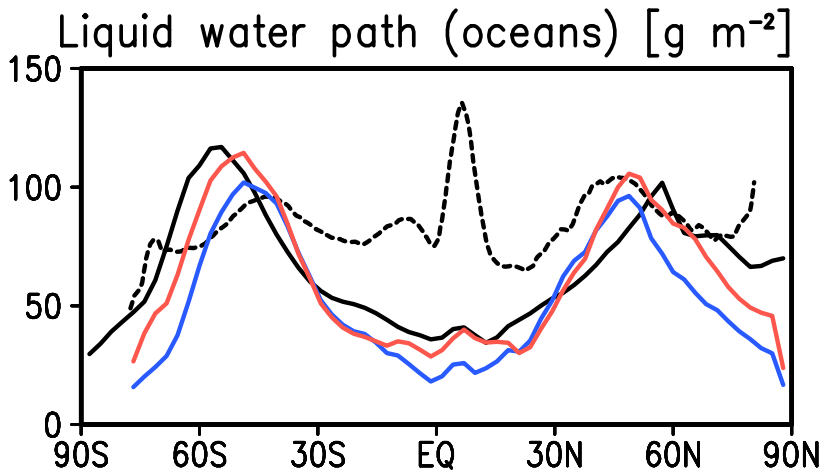
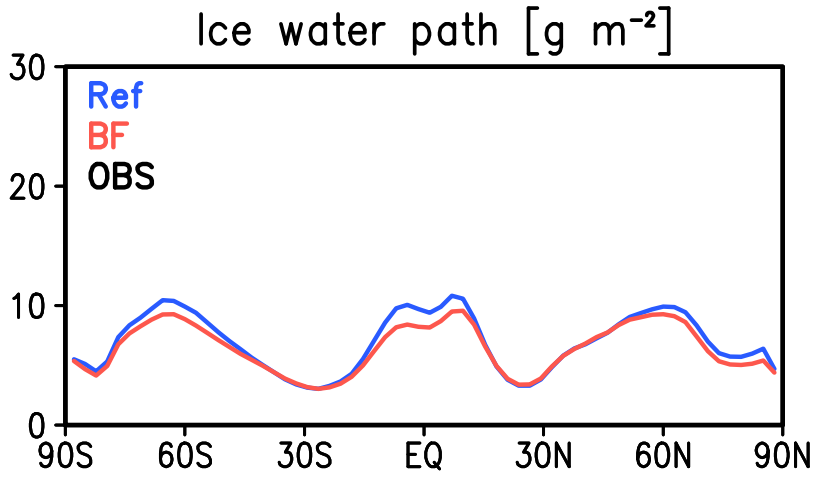
Results: Bergeron-Findeisen process (2)







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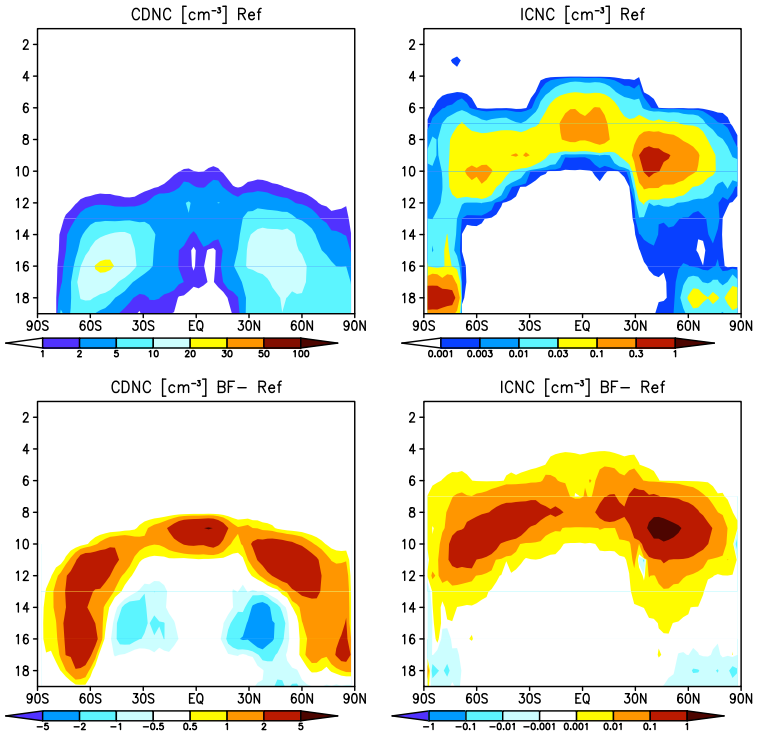
Results: Bergeron-Findeisen process (3)

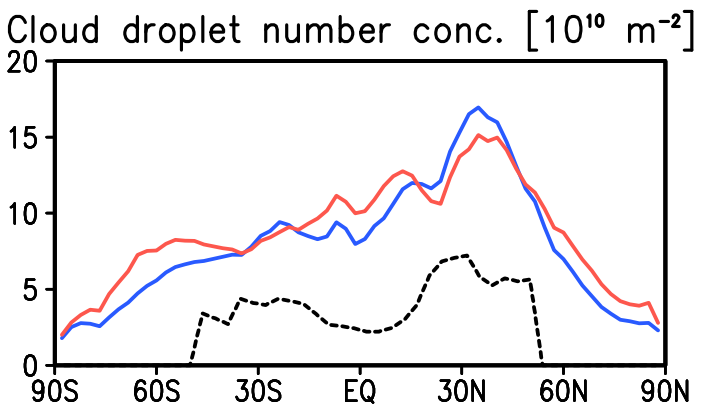
Cloud droplet number conc.

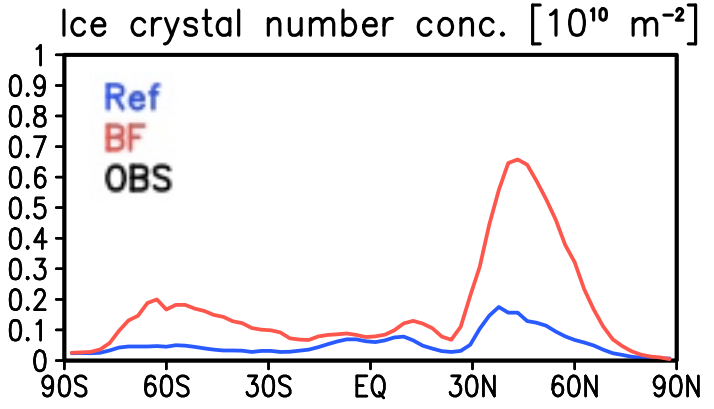
Ice crystal number conc.

Ref

BF - Ref







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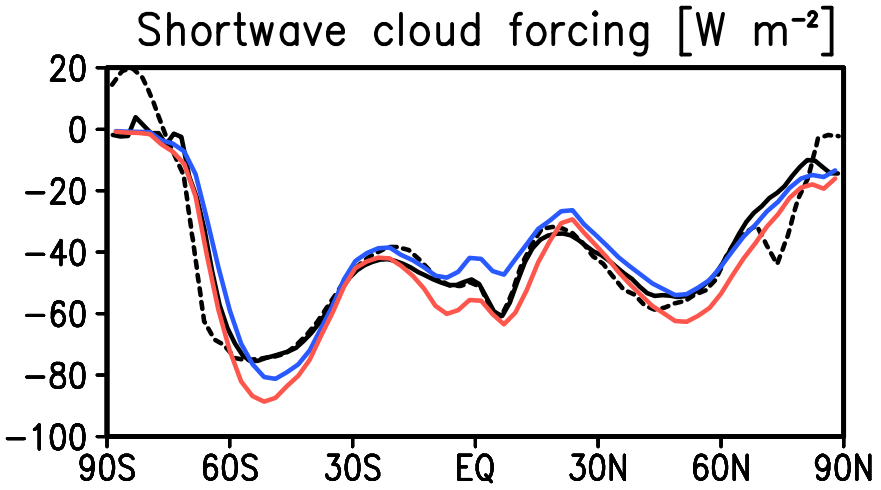
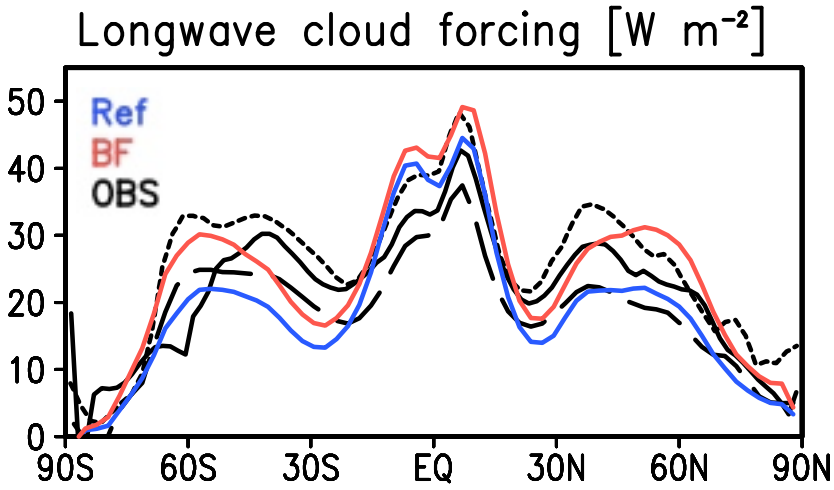
Results: Bergeron-Findeisen process (4)

Larger cloud forcing





Total anthropogenic effect (not shown here):

BF (PD-PI) yields a reduction by 0.27 W.m^{-2} of the tot. anthrop. effect as compared to Ref (PD-PI) (-1.02 W.m^{-2})

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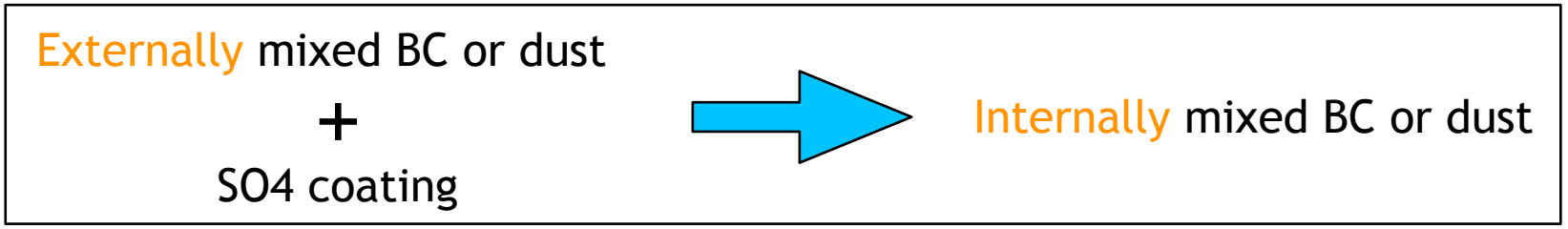
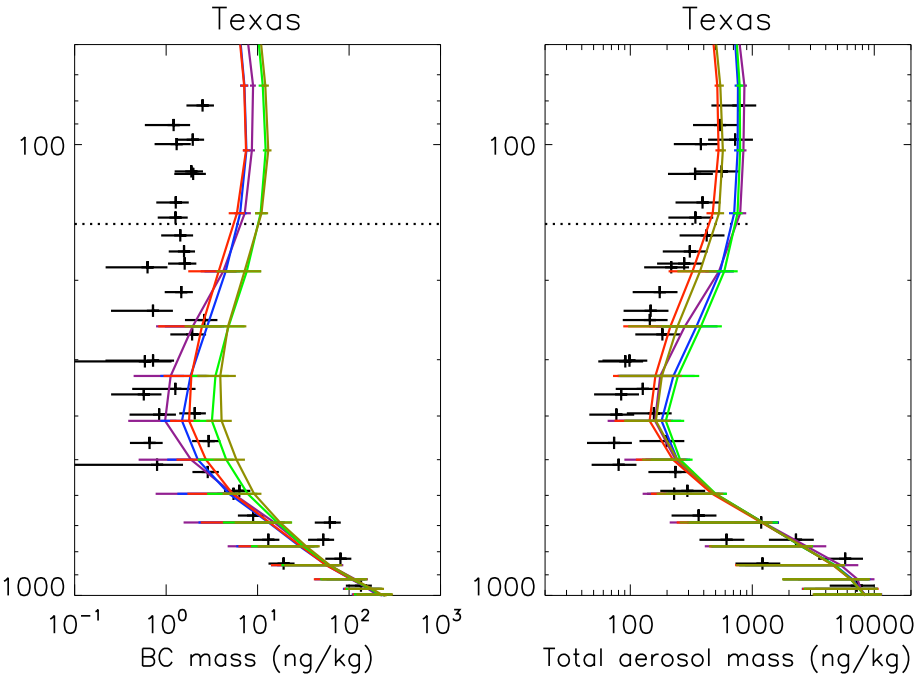
Setup of the sulfate coating sensitivity study

- M7 model:

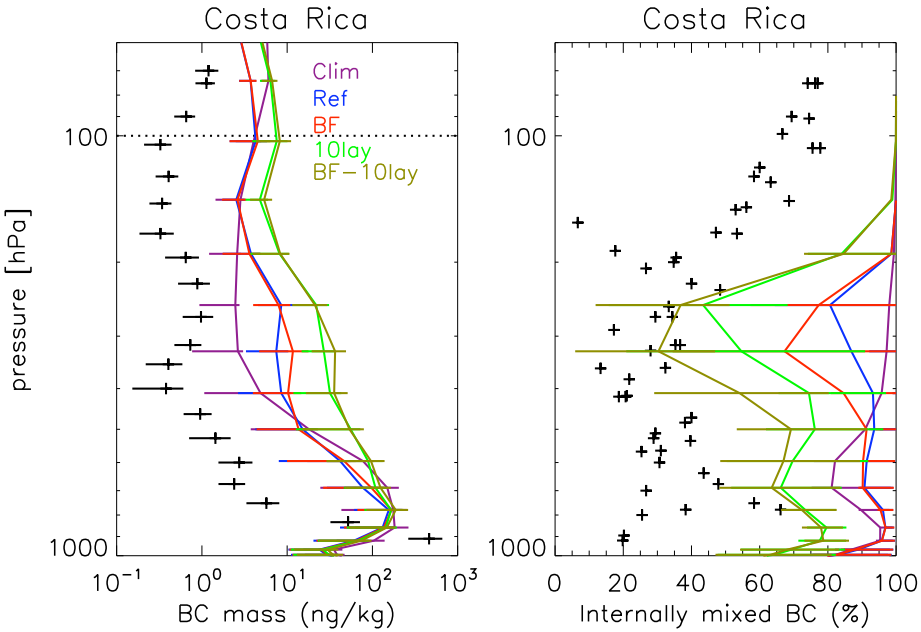


- Standard model:
  - 1 mono-layer of SO_4 is sufficient for conversion to internally mixed-particles
- Sensitivity experiment:
  - 10 mono-layers of SO_4 are now required

Comparisons with observations: vertical mmr's in Texas and Costa Rica



More sulfate coating yields worse agrement with obs



Ref	2000, nudged
Clim	2000-2009, clim
BF	Same as Ref, with modif BF
10-lay	Same as Ref, with modif sulfate coating
BF-10lay	Same as Ref + BF + sulfate coating

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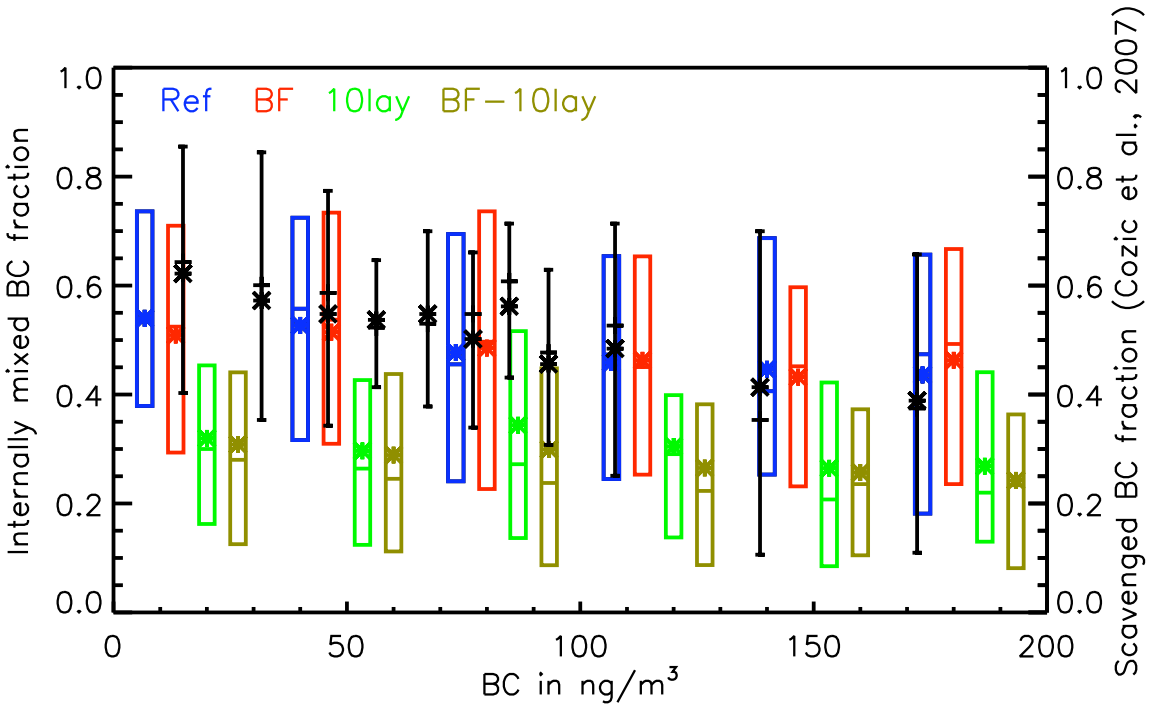
Comparison with observations: scavenged fraction at Jungfraujoch



Conclusion

- Bergeron-Findeisen sensitivity experiment (improved modeling):
  - less frequent Bergeron-Findeisen process than in standard exp
  - higher altitude of freezing

    ➡ Reduced total anthropogenic effect by 0.27 $W.m^{-2}$

- Sulfate coating sensitivity experiment:
  - worse agreement with observations when delayed conversion from externally mixed to internally mixed dust and BC particles is imposed

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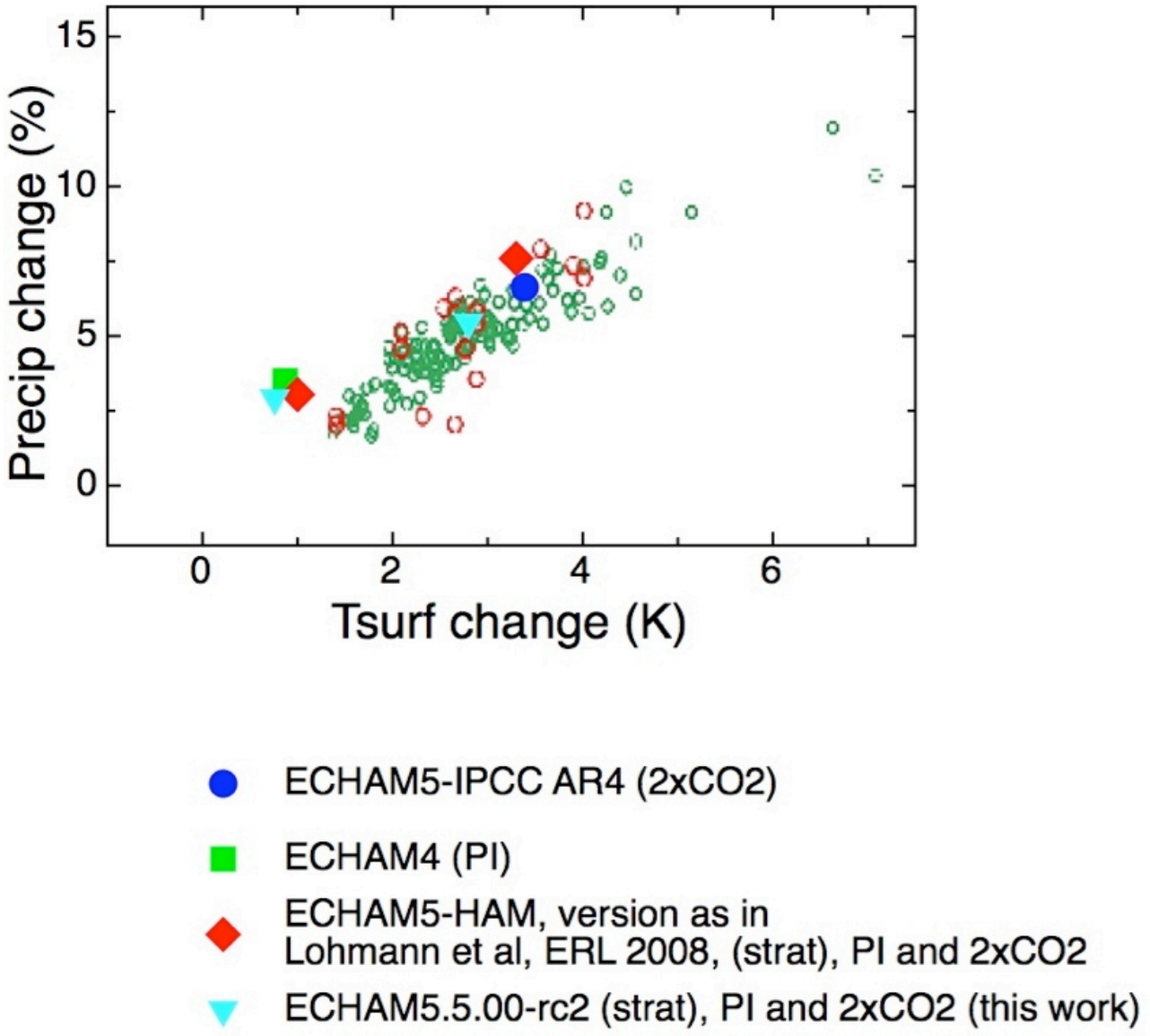
Annexes

Precip vs temperature change at equilibrium (mixed layer ocean)



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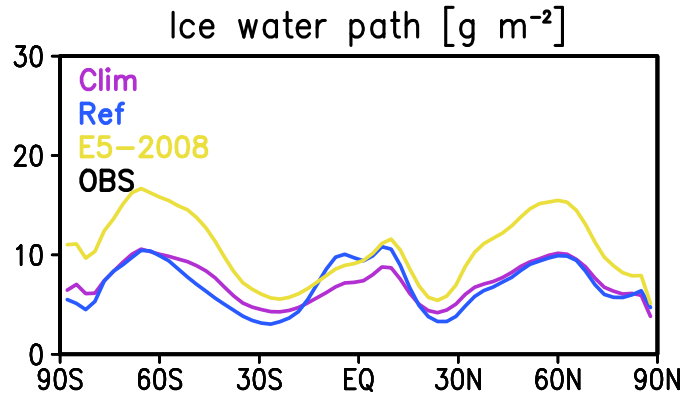
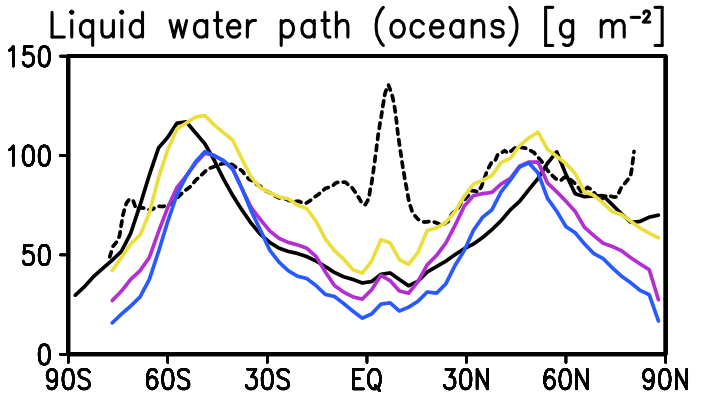
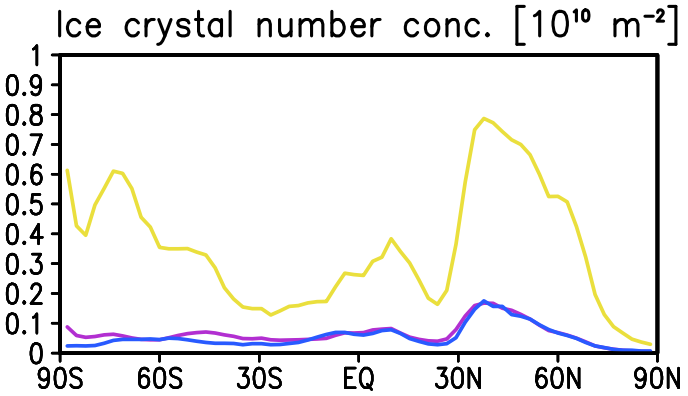
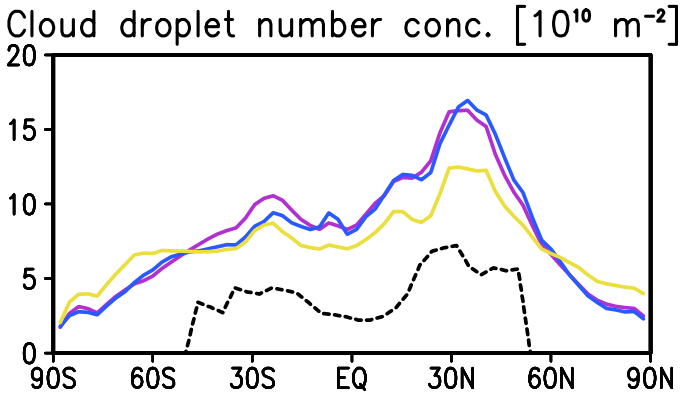
Model validation and comparison with previous version(1)



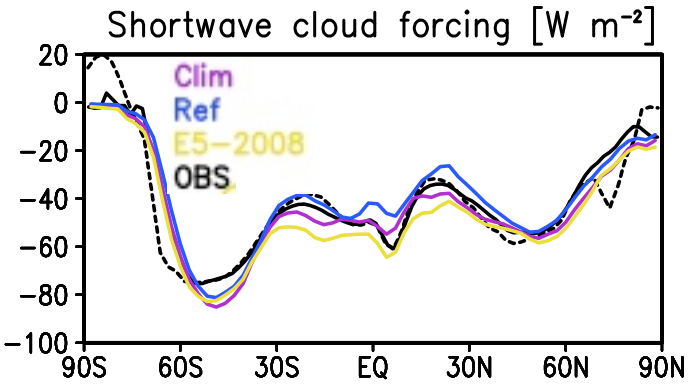


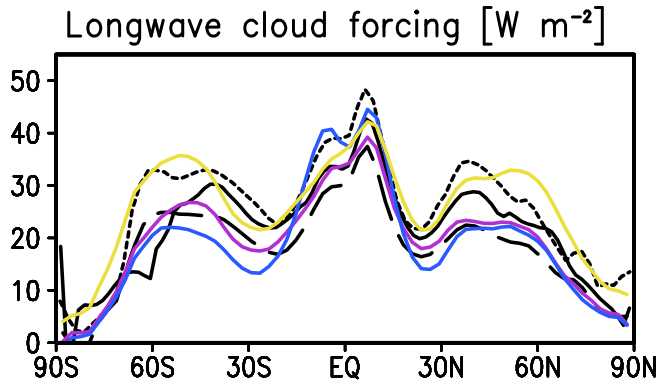


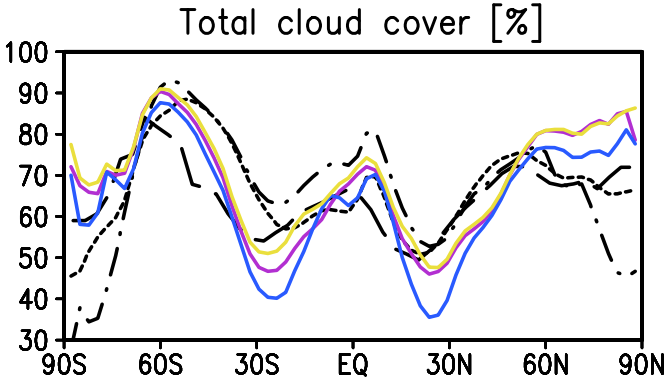


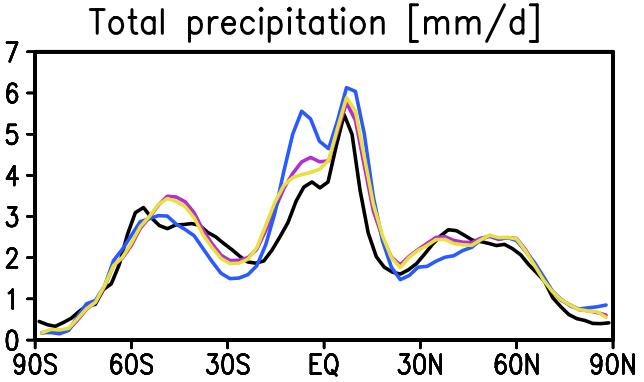
Ref	2000, nudged
Clim	2000-2009, clim
E5-2008	Same as clim, older version of ECHAM5-HAM

Model validation and comparison with previous version(2)

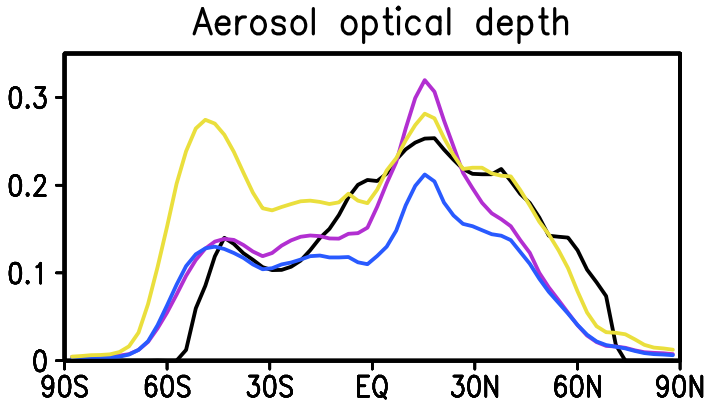








Ref	2000, nudged
Clim	2000-2009, clim
E5-2008	Same as clim, older version of ECHAM5-HAM



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Outline

- Introduction:
  - Glaciation and deactivation effects
- Method:
  - General model description (short)
  - Improved modeling of the Bergeron-Findeisen process
  - Setup of the sulfate coating sensitivity study
- Results:
  - Model validation in comparison with a previous model version
  - Sensitivity study of the Bergeron-Findeisen process
  - Sensitivity study of the sulfate coating
- Conclusion

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