Deutsches Zentrum
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Lagrangian Transport of Water Vapor and Cloud Water in the ECHAM4 GCM and its Impact on the Cold Bias

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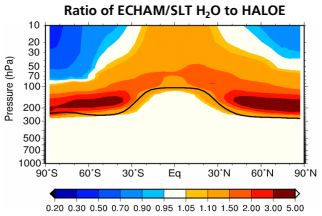
Introduction

The GCM ECHAM4.L39(DLR) exhibits a serious **"wet bias"** in the extratropical lowermost stratosphere (LMS). Compared to HALOE observations (right figure) the simulated water vapor mixing ratios are overestimated by a factor of 3-5.

The operational semi-Lagrangian transport (**SLT**) scheme shows a considerable numerical diffusion in case of sharp gradients and tends to produce smooth tracer concentrations. Full Lagrangian approaches like the transport scheme **ATTILA** are numerically non-diffusive and strictly mass conserving. Results from passive tracer studies indicate that the simulated wet bias in the extratropical LMS might be caused by numerical diffusion of the operational SLT scheme.

This leads to the question, whether the simulated wet bias in the extratropical LMS contributes to a systematic cold temperature bias in this region (**"cold bias"**) due to infrared absorption characteristics of water vapor.



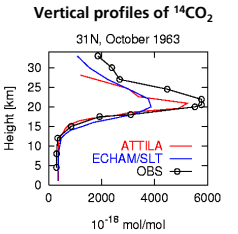
The Model System ECHAM4.L39(DLR) / ATTILA

ECHAM4.L39(DLR)

- spectral global circulation model
- 39 vertical levels, top layer centered at 10 hPa
- horizontal resolution T30
- parameterizations of clouds, radiation, precipitation, convection, diffusion
- **semi-Lagrangian transport (SLT) of water vapor, cloud water and passive tracers**

ATTILA

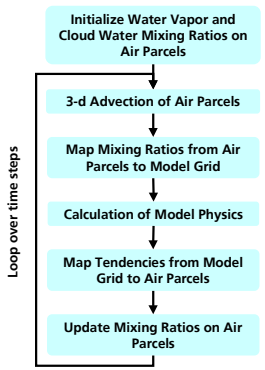
- **Lagrangian transport scheme for ECHAM**
- numerically non-diffusive and strictly mass conserving
- about 500,000 air parcels of equal mass
- 3-d advection using ECHAM wind fields
- parameterizations of diffusion, boundary layer mixing, convection
- steeper and more realistic gradients than the operational SLT scheme (right figure)



Lagrangian Transport of Water Vapor and Cloud Water

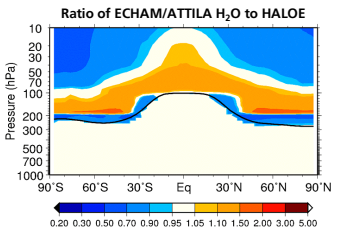
Implementation

The Lagrangian scheme ATTILA has been applied for the transport of H_2O and cloud water instead of the SLT scheme. In case of "active" species like H_2O, a transformation between air parcels and model grid is required, since physical processes like convection, radiation and cloud formation are calculated on the ECHAM grid.

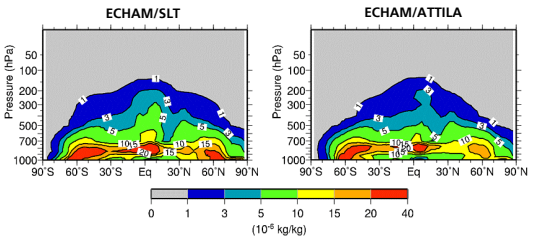


- ECHAM/ATTILA: significant reduction (-70%) of H_2O in extratropical LMS, better agreement with HALOE
- ECHAM/ATTILA: overall reduction (≈2 ppmv) of stratospheric H_2O caused by colder tropical tropopause
- underestimation of H_2O above 70 hPa due to missing CH_4 oxidation
- similar cloud water distribution in both models

Water Vapor



Cloud Water



Impact on Model Dynamics

Impact of the improved H_2O distribution in ECHAM/ATTILA on model dynamics:

Temperature

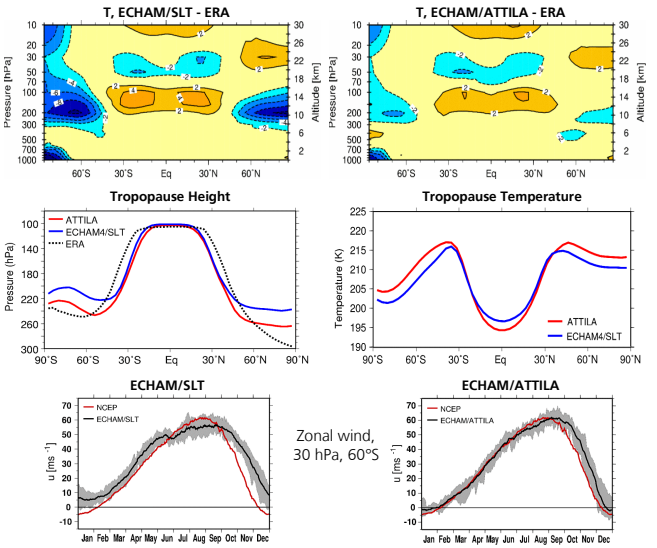
- significant reduction of simulated **cold bias** in the extratropical LMS of more than **50%**
- slight reduction of the cold temperature bias in the Antarctic stratosphere above 30 hPa (**cold pole**)

Thermal Tropopause

- extratropical tropopause in ECHAM/ATTILA lower (30 hPa) and warmer (3 K) ⇒ much better representation than in ECHAM/SLT
- tropical tropopause 2-3 K colder in ECHAM/ATTILA than in ECHAM/SLT ⇒ **reduced H_2O entry level**

Zonal wind, 30hPa, 60°S

- ECHAM/ATTILA shows **wind reversal in summer**
- annual cycle of zonal wind in ECHAM/ATTILA in good agreement with NCEP analyses



Zonal wind, 30 hPa, 60°S

References

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Conclusions

- Simulated wet bias in ECHAM/SLT caused by an exceptional high numerical diffusion of the SLT scheme. **ECHAM/ATTILA shows a remarkably reduced wet bias** in the extratropical LMS (-70%) as well as a steeper meridional gradient in the subtropics.
- The improvements in water vapor cause a **significant reduction of the simulated cold bias** in the extratropical LMS. These temperature changes result in an **improved representation of the tropopause**, especially in the extratropics, and stratospheric winds.
- Lagrangian transport of water vapor and cloud water does not only constitute major improvements with respect to modeled dynamics, but is also a significant contribution to climate modeling in general, e.g. climate impact studies, coupled chemistry-climate models.

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