Impact of deep convection and dehydration on stratospheric bromine loading

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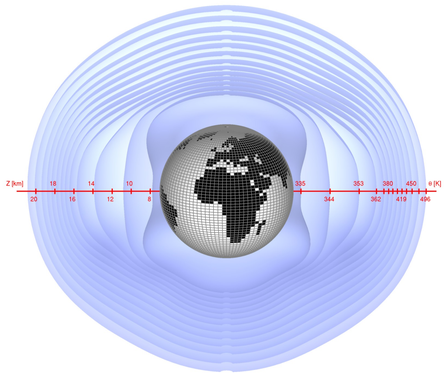
Introduction

Recent studies have shown the importance of bromine very short-lived substances (VSLS) for the stratospheric bromine budget and their potential impact on ozone depletion. The main questions regarding VSLS can be summarized as follows:

- **How much bromine from short-lived sources reaches the stratosphere?**
- **Which region represents the most important gateway for VSLS into the tropopause?**
- **How will the impact of VSLS change in the future, especially under climate change conditions?**

Model Description

- 3D CTM driven by ECMWF ERA-Interim
- Resolution: 2.5° lat. x 3.75° lon, 29 isentropic levels (330–2700 K), time step 30 minutes
- Explicit treatment of convective transport based on ERA-Interim detrainment rate
- Twofold approach for tracers and chemistry: Idealized and complex chemistry scheme

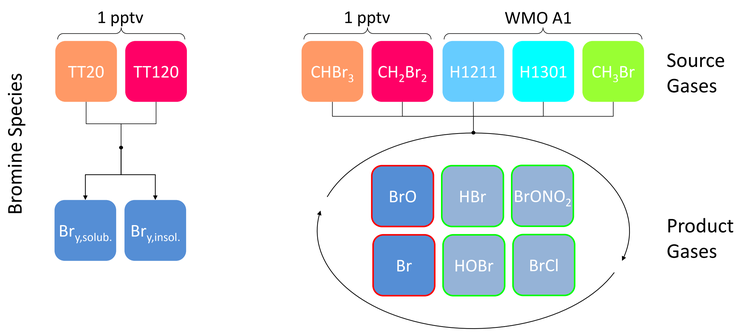


Idealized Approach

few idealized tracers and simplified chemistry

Complex Chemistry Approach

more realistic chemistry scheme with 59 species and ≈180 photochemical reactions



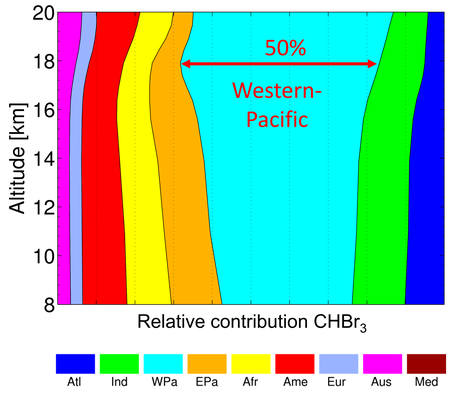
References

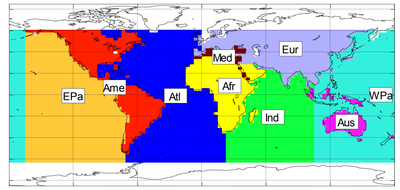
Aschmann, J., Sinnhuber, B.-M., Atlas, E. A. and Schauffler, S. M.: Modeling the transport of very short-lived substances into the tropical upper troposphere and lower stratosphere, Atmos. Chem. Phys., 9, 9237-9247, 2009

Aschmann, J., Sinnhuber, B.-M., Chipperfield, M. P., and Hossaini, R.: Impact of deep convection and dehydration on bromine loading in the upper troposphere and lower stratosphere, Atmos. Chem. Phys., 11, 2671-2687, 2011.

Regional Transport Efficiency

There are specific regions which are especially important for the transport of short-lived source gases into the stratosphere. If one assumes a uniform source in the model it is possible to isolate the impact of local transport efficiency with respect to VSLS, yielding valuable information about which region is the most import gateway into the tropopause region. To extract this information the model domain is divided into nine source areas with individual tracers for each region, which are exclusively emitted inside their respective area.

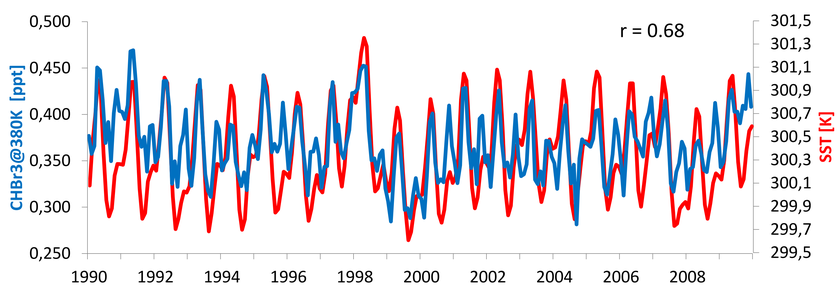




Left: Relative contribution of the individual source regions to global bromoform distribution. Clearly, the Western-Pacific region is the most important region with respect to VSLS transport, contributing roughly 50% to the total distribution.

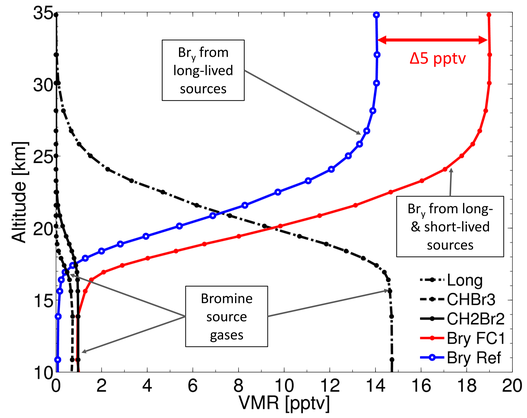
Time Variation of VSLS Injection

The amount of VSLS reaching the stratosphere varies over time. It can be shown that one important process controlling the transport of this species is deep convection which in turn is affected by sea surface temperatures. The timeseries below illustrates the correlation between the amount of bromoform at the tropopause with sea surface temperatures which can be useful in assessing the future impact of VSLS under conditions of climate change.

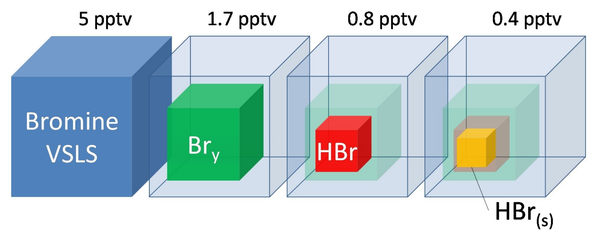


Impact of Dehydration on Stratospheric Bromine Loading

The contribution of very short-lived substances to stratospheric bromine loading is 5 pptv. The profiles below show tropical averages from the complex chemistry model run.



Dehydration has no apparent impact on inorganic bromine in the tropopause region. The complex chemistry model run suggests that dehydration is not a efficient loss process for Br_y.



Why is the impact of dehydration negligible?

1. Total available bromine from VSLS sources at the tropopause is 5 pptv.
2. Only a fraction of 1.7 pptv is in the form of inorganic bromine or Br_y.
3. Roughly the half amount of Br_y is HBr which can be efficiently adsorbed on ice particles.
4. Actually the available surface area density limits the amount of HBr on ice to 0.4 pptv.
5. The small possible loss of Br_y on ice (0.4 pptv) is completely negated by heterogeneous chemistry.