Transport of bromoform from the Indian Ocean to the stratosphere during Asian summer monsoon

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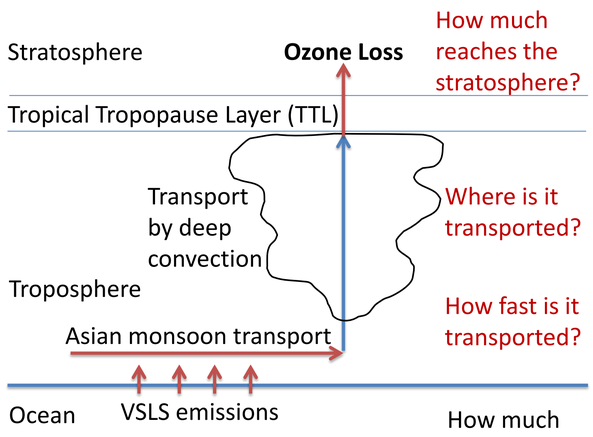
Why is the Asian monsoon important?

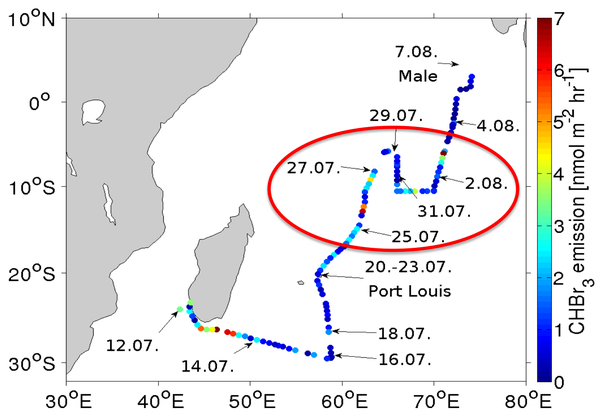
Bromoform and other halogenated very short-lived substances (VSLS, atmospheric lifetime less than half a year) are naturally produced in the ocean and emitted to the atmosphere. If transported to the stratosphere, they take part in ozone depletion. The Asian summer monsoon circulation and the deep convection over India may provide an efficient pathway for compounds from the Indian Ocean.
We use the Lagrangian transport model FLEXPART with ERA-Interim meteorological fields to discern transport properties during Indian summer monsoon season.



Asian summer monsoon circulation visible in the monthly average of surface wind in July 2015 from ERA-Interim.

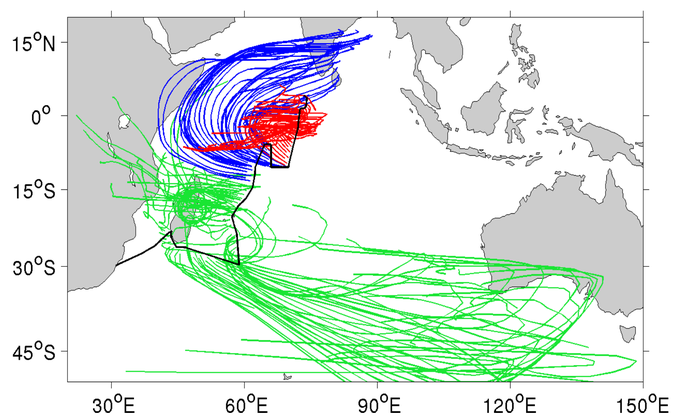
Trajectory calculations with FLEXPART and ERA-Interim fields

Bromoform emissions on the OASIS-SONNE cruise in July and August 2014



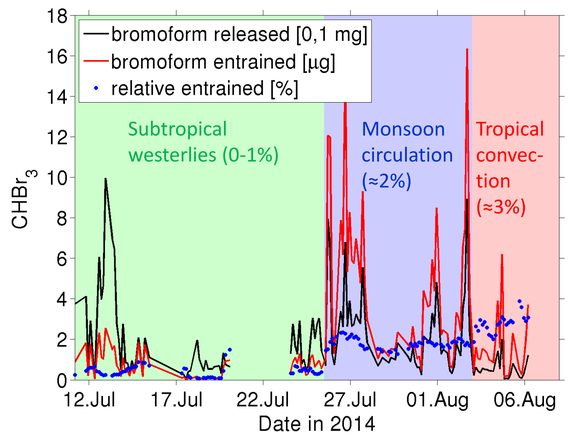
High bromoform emissions were measured south of Madagascar and between 5°S and 15°S.

10-day forward trajectories for bromoform emissions from OASIS-SONNE



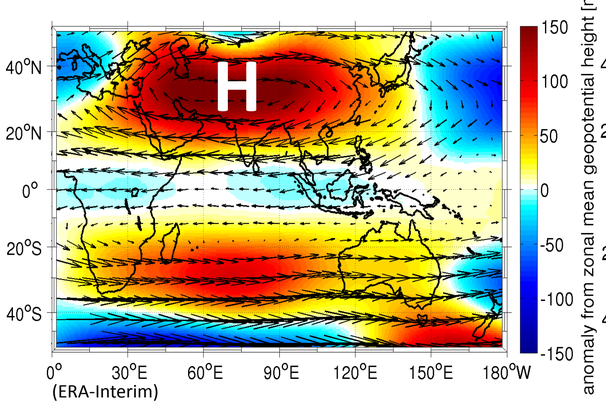
Three transport regimes are discerned: Subtropical westerlies, the summer monsoon circulation toward India and Bay of Bengal, and tropical convection.

Modeled entrainment of bromoform above 17 km from OASIS-SONNE



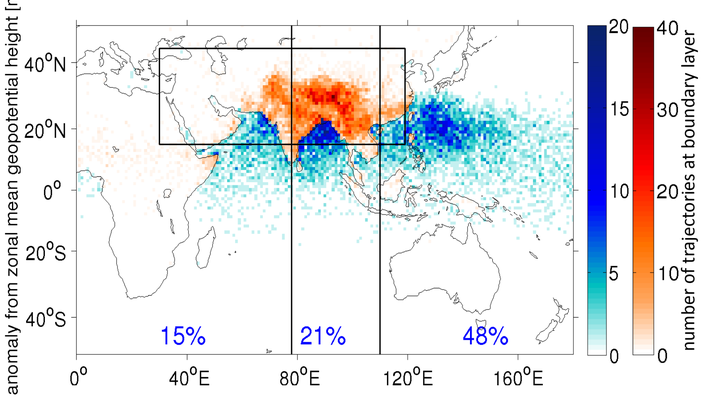
Under the influence of the monsoon circulation about **2%** of emitted bromoform is entrained. The monsoon winds connect strong source regions with convective areas.

Asian monsoon anticyclone at 100 hPa: geopotential height and horizontal winds



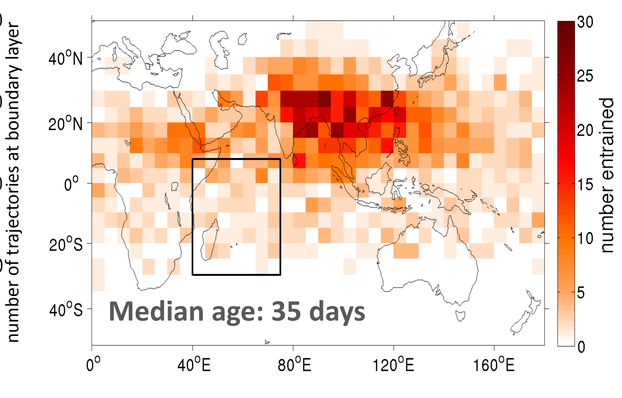
The Asian monsoon anticyclone confines tropospheric air masses and slowly lifts them into the stratosphere.

Monsoon anticyclone source regions from trajectories released at 17 km (backward)



48% of boundary layer air masses originate from the ocean, 52% from land. Entrainment from Bay of Bengal and tropical West Pacific is even larger than from West Indian Ocean.

Density of trajectories at 17 km height released from the black square



Air masses from the Central East Indian Ocean surface are mainly entrained in the **eastern flank of the Asian monsoon anticyclone**.

Conclusions

The subtropical and tropical Indian Ocean is a **strong source** region for bromoform and other VSLS (posters of Kirstin Krüger; Birgit Quack).

During north hemispheric summer the Asian monsoon **connects** source regions in the Indian Ocean with the convective region over India and Bay of Bengal.

Boundary layer air masses enter the stratosphere at the eastern flank of the Asian monsoon anticyclone.

We found more entrainment from the Indian Ocean than from the equatorial Atlantic (1 %) but less than from the tropical West Pacific (3-10 %; not shown here).

Generally, high stratospheric bromine mixing ratios above the Asian monsoon anticyclone result from high bromoform emissions from the **Bay of Bengal**, **Arabian Sea** and **tropical Indian Ocean**.

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