DKRZ – Project 854:

Simulations and aircraft observations of the Asian summer monsoon

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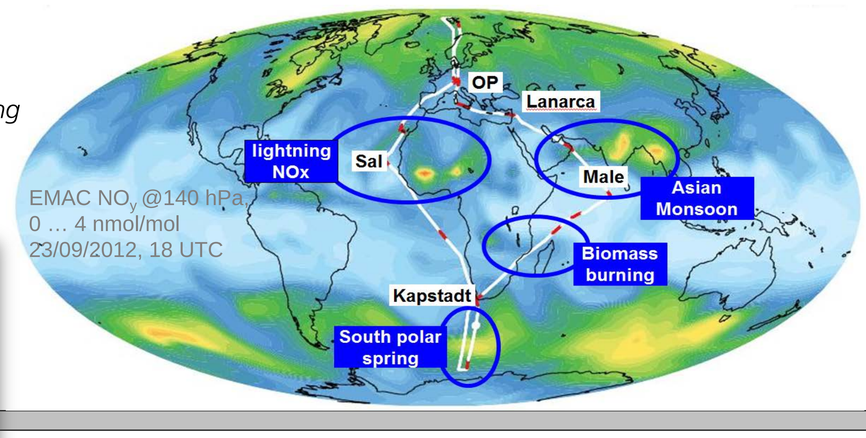
Abstract

The main objective of the ESMVal field experiment using the HALO research aircraft was to sample observational data for the evaluation of Earth system models, in particular the ECHAM/MESSy Atmospheric Chemistry (EMAC) model. The HALO mission included pole to pole survey observations of trace gas distributions in the UTLS from Spitsbergen in the Arctic to the boundary of the Antarctic continent, and detailed profile measurements for sampling of air masses impacted by specific dynamical and chemical processes. During a flight on 18 Sept. 2012 from the Maledives to Cyprus the outflow of the Asian summer monsoon anticyclone in the upper troposphere was successfully sampled. The origin of the air masses probed is polluted boundary layer air from northern India and the Gulf of Bengal, convectively uplifted to the measurement altitudes. In addition, these air masses partly mixed with air of stratospheric origin in the monsoon anticyclone. We present the HALO observations and accompanying EMAC simulations.

ESMVal HALO campaign

Flight path of the HALO research aircraft during the ESMVal campaign, with dives into the lower troposphere (red), stop overs and atmospheric phenomena.

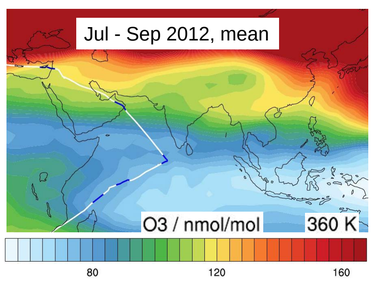


EMAC Simulations

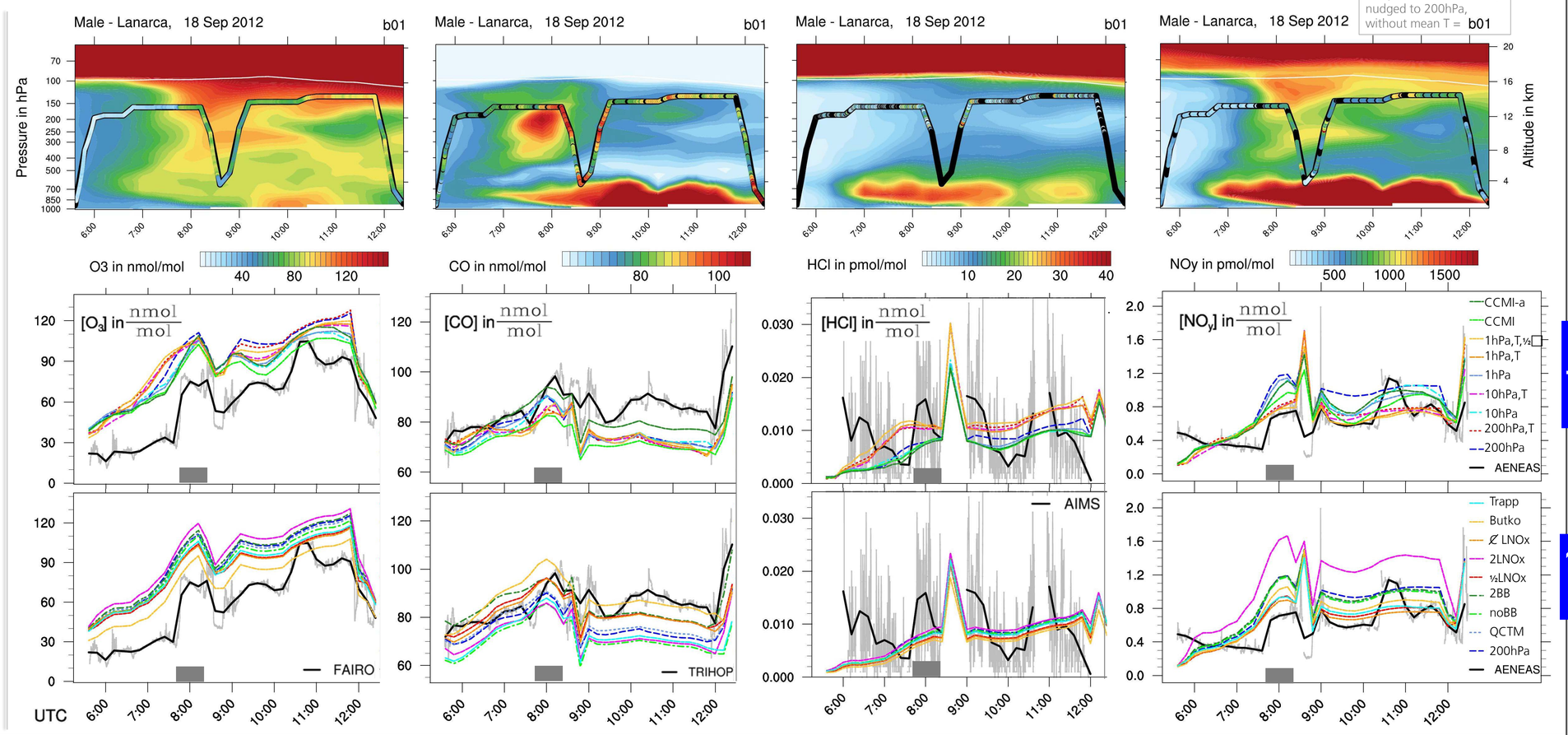
The EMAC [4] setup is based on CCMI Ref-C1SD [2], in T42L90MA resolution. Synoptical scale dynamics in the free troposphere was nudged towards ECMWF re-analyses. Sensitivity simulations tested the effects of nudging top height and nudging of mean T or not. The QCTM mode [1] is used to analyse small chemical perturbations, with modifications to Biomass Burning (BB) & Lightning NOx emissions, to the chemical mechanism and scavenging. Data are output along the flight track with the highest possible accuracy, limited only by grid resolution and time step length.

Comparisons of the monsoon flight to simulation results

Upper tropospheric air originating in the monsoon anticyclone is climatologically expected to be dominated by trace gas signatures typical for lower atmospheric layers, e.g. low O_3 & high CO. However, high O_3 was measured.

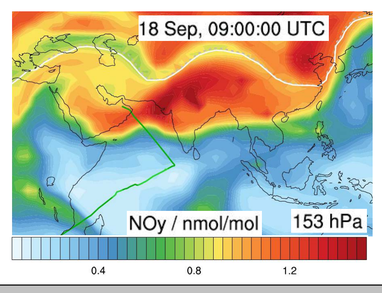


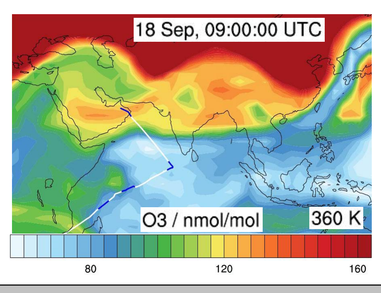
All simulations qualitatively ~reproduce the along-track signatures, thus allowing for interpretation of the measurements. HO_2+NO→HNO_3 [3], modified traffic emissions (CCMI-a), & mean-T-nudging have the biggest impact.

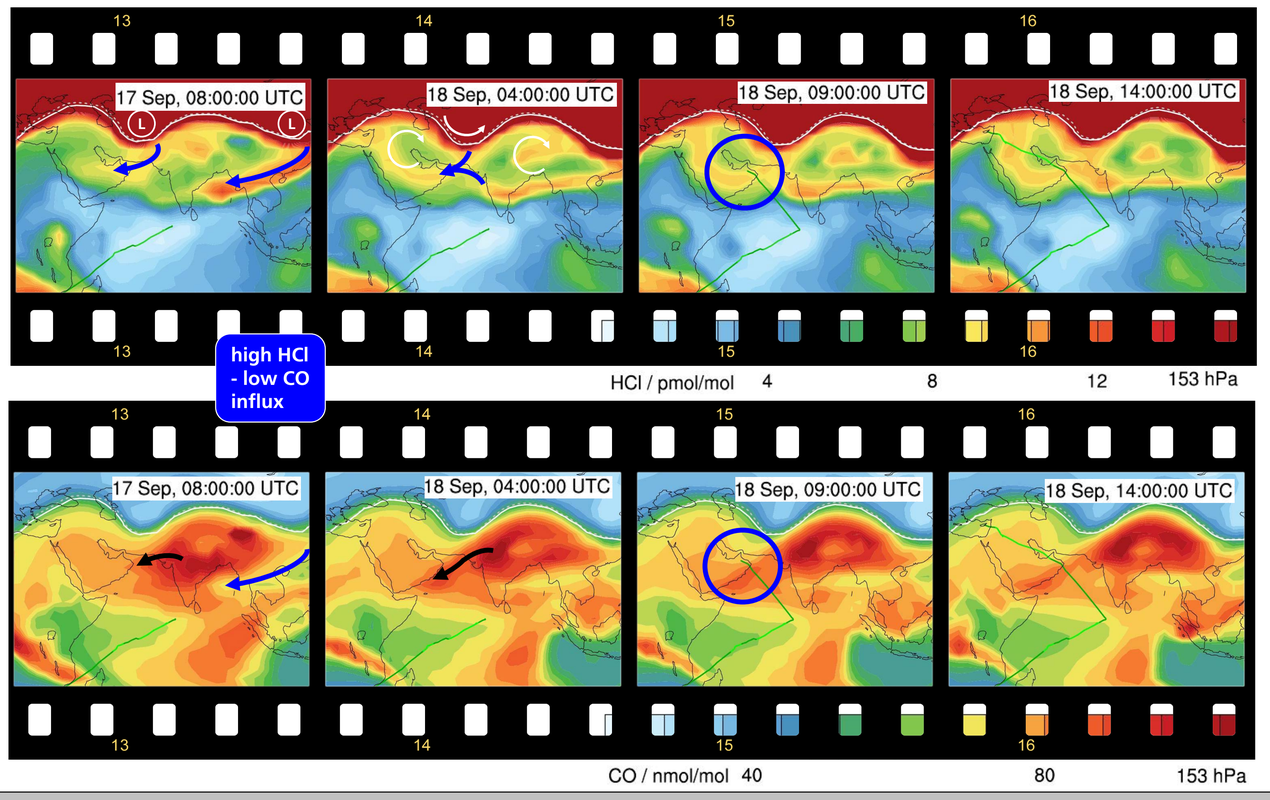


Interpretation of the observations

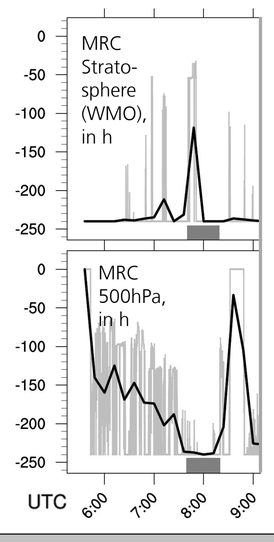
HCl [5] as stratospheric tracer turned out to be good for tracing back the observed signature. It was drafted from the stratosphere at two synoptic disturbances interacting with the monsoon anticyclone. Finally both low-CO - intrusions fed an anticyclone over the Arabic peninsula, just separating from the Indian anticyclone . Here it mixed with boundary layer air (high CO) that had been lifted up in the monsoon. This interpretation is supported by back-trajectories that show a recent contact to the stratosphere. Air from the lower troposphere must have been contained in the upper parts of the anticyclone for longer. NOy seems to be mostly from inside the Indian monsoon anticyclone.







Most recent contacts (MRC) of 250h-back-trajectories (ECMWF), starting at the flight track. Trajectory data courtesy of M. Sprenger & H. Wernli, both ETH Zürich.



References

[1] Deckert et al.: A quasi chemistry-transport model mode for EMAC, GMD, 4, 195–206, 2011. **[2]** Eyring et al.: Overview of IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) Community Simulations in Support of Upcoming Ozone and Climate Assessments, SPARC Newsletter No. 40, p. 48-66, 2013. **[3]** Gottschaldt et al.: Global sensitivity of aviation NO_x effects to the HNO_3-forming channel of the HO_2+NO reaction, ACP, 13, 3003-3025, 2013. **[4]** Jöckel et al.: Development cycle 2 of the Modular Earth Submodel System (MESSy2), GMD, 3, 717-752, 2010. **[5]** Jurkat et al.: A quantitative analysis of stratospheric HCl, HNO_3, and O_3 in the tropopause region near the subtropical jet, Geophys. Res. Lett., 41, 2014.

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