

Project: **1115**

Project title: **Frontier Simulations for the Monsoon Region**

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Report period: **2025-05-01 to 2026-04-30**

Progress Report:

We present our progress within this project on Frontier Simulations for the Monsoon Region originally conducted within the HGF-ESM project. This DKRZ-project is used as a pure data project during the reporting period, no model simulations were performed. The purpose of this project is to analyze the results of the frontier simulations and prepare a publication (Brinkop et al., 2026). The data consist of one model simulation comprising the chemistry-climate model EMAC and two Lagrangian models in a consistent framework and an additional shorter simulation, where tracer convection was switched off:

- EMAC (Eulerian model) with and without convective transport of tracers,
- ATTILA (Lagrangian Model coupled to EMAC) also with and without Lagrangian convection of tracer mass

and

- CLaMS (also coupled to EMAC), which has no convection of Lagrangian parcels.

All simulations used the same model set up (T42L47) with specified dynamics and therefore EMAC, ATTILA and CLaMS are driven by exactly the same meteorology. Technically, only 2 simulations were performed: one simulation with EMAC, ATTILA and CLaMS, where tracer convection was enabled for EMAC and ATTILA and a second (shorter) simulation with EMAC and ATTILA, where tracer convection was disabled.

Besides analyzing the origin of trajectories in the Asian Monsoon Anticyclone (AMA), we also use the emission tracer concept as described in Vogel et al. (2016), so that a tracer can be directly related to its tracer emission region. Note, that we consider 12 (tracer) source regions in the monsoon area and one for rest of the globe. In sum, we have 13 source regions (\equiv 13 tracer), 5(+2) tracer life times (2 extra inert tracer), and we differentiate between nudged and emitted tracers (at the surface). This results in 182 different tracers for each model component. The boundary of the AMA was estimated by calculating the strength of the AMA in terms of geopotential height anomaly following Nützel et al. (2022).

The following scientific questions were answered with our analysis, using nudged emission tracers with 5, 25, 50 and 90 days e-folding time as well as an inert tracer:

- We estimated the contribution of different emission regions to the air in the AMA analysing EMAC, ATTILA, CLaMS
- We specified the influence of three applied **analysis methods** on the results:
 - a. We analyzed **trajectories** (from ATTILA only) starting in the AMA at 150 hPa by following them backwards in time to their boundary layer origin similar as described in Nützel et al. (2022).
 - b. We analyzed the **tracer mixing ratios on the trajectories** from ATTILA and CLaMS in the AMA and calculated the resulting tracer mixing ratios mean within the AMA. This amount is weighted with the number of trajectories in the AMA (divided by the total amount of trajectories in the AMA during the season).
 - c. We analyzed the **tracer mixing ratio in the grid of EMAC**. For this purpose, the LG tracer mixing ratios on the trajectories (ATTILA and CLaMS) are mapped onto the EMAC grid in the first step and then the total amount in the AMA is calculated as a mean over the grid boxes and inter-compared for EMAC, ATTILA and CLaMS
- We estimated the influence of fast convective transport on the contribution of different emission regions to the air in the AMA for EMAC and ATTILA.

- We calculated the probability density of transit times of trajectories from the PBL to the AMA with and without convective tracer transport (see Fig.1).

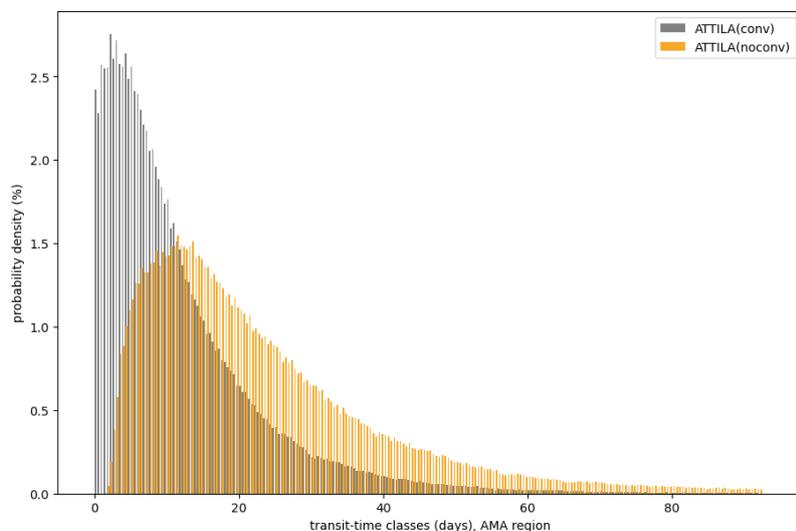


Figure 1: Probability density of transit times from ATTILA with and without convection for the years 2005-2009.

Reference

Brinkop, S., Nützel M., Jöckel, P, Vogel, B. and Müller, R. (2026): Why is the simulated amount of boundary layer air from different emission regions in the Asian summer monsoon anticyclone so uncertain? in preparation for ACP.

Nützel, M., Brinkop, S., Dameris, M., Garny, H., Jöckel, P., Pan, L. L., and Park, M.: Climatology and variability of air mass transport from the boundary layer to the Asian monsoon anticyclone, *Atmos. Chem. Phys.*, 22, 15659–15683, <https://doi.org/10.5194/acp-22-15659-2022>, 2022.

Vogel, B., Günther, G., Müller, R., Groß, J.-U., Afchine, A., Bozem, H., Hoor, P., Krämer, M., Müller, S., Riese, M., Rolf, C., Spelten, N., Stiller, G. P., Ungermann, J., and Zahn, A.: Long-range transport pathways of tropospheric source gases originating in Asia into the northern lower stratosphere during the Asian monsoon season 2012, *Atmos. Chem. Phys.*, 16, 15301-15325, <https://doi.org/10.5194/acp-16-15301-2016>, 2016.