Project: 1115
Projecttitle: Frontier Simulations for the Monsoon Region
Principal Investigator: Sabine Brinkop
Report Period: 2024-07-01 to 2025-04-30

1 Project Progress

We present our progress within this project on Frontier Simulations for the Monsoon Region by summarizing some of our work and results. This project is a pure data project, no model simulations were performed. Since the last request for computing resources in 2024, we analyzed the results for a tracer with 90 days life-time calculated on EMAC model-grid and on Lagrangian trajectories. Our climate simulations (already performed before 2021 within the HGF-ESM project) were performed with

- EMAC 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 model climate. Technically, only 2 simulations were performed: 1. EMAC, ATTILA and CLaMS together, EMAC and ATTILA with tracer convection. 2. EMAC and ATTILA together, but without tracer convection and over a shorter period.
Besides analysing the origin of trajectories in the AMA (Asian Monsoon Anticyclone), we also use the air-mass origin 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) emission regions in the Monsoon area and one for rest of the globe. In sum, we have 13 emission regions ($\equiv$ 13 tracer), 5(+2) different life times, 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 so far with our analysis, using the nudged emission tracers with 90 days half-life time:

- Influence of the three applied **analysis methods** on the results:
    1. 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) and did an inter-comparison.
    2. We analyzed the **tracer mixing ratios on the trajectories** from ATTILA (done) and ClaMS (not finished) 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.
    3. 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.
- Estimating the influence of the background meteorology (specified dynamics vs. free-running) on the results: In the paper of Nützel et al. (2022) we could not specify the influence of a different background meteorology on the contribution of different regions to the air in the AMA, using method 1 (see above). This analysis is now finished, but not shown here.
- We estimated the contribution of different emission regions to the air in the AMA analysing EMAC, ATTILA, CLaMS using method 3 (see above and see Figure 1, left).

- We estimated the contribution of different emission regions to the air in the AMA analysing EMAC, ATTILA but omitting tracer convection by using method 3. Omitting the convective tracer transport most often reduces the total transport into the AMA, (see Figure 1). This is most pronounced for EA-East Asia, EIO-East Indian Ocean and the Tibetan plateau - WT (west) and ET (east). CLaMS, which has no tracer convective transport shows qualitative similar results compared to ATTILA and EMAC simulations without tracer convection except WT and ET.

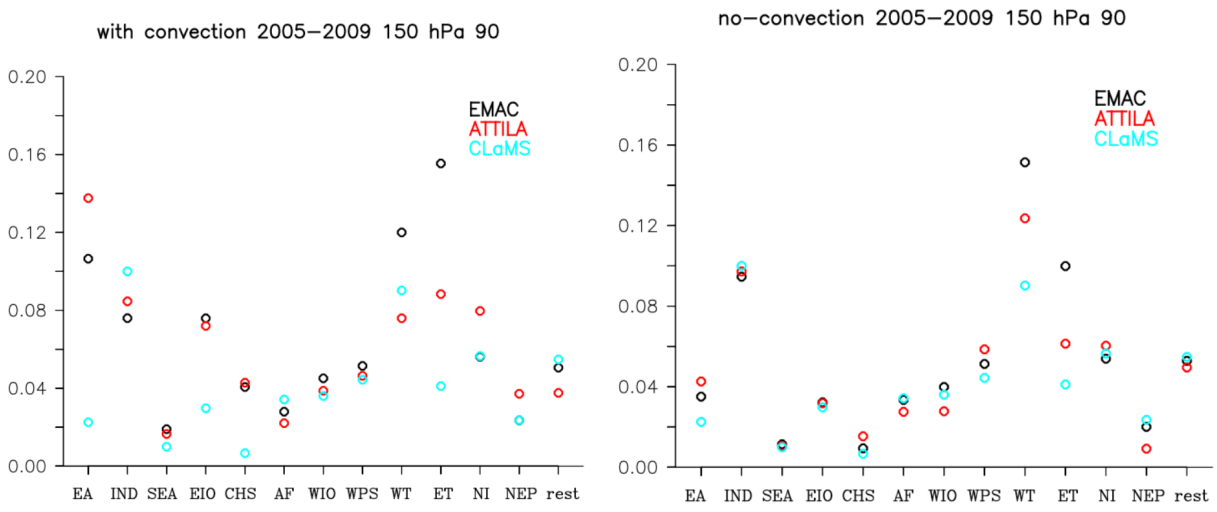

Figure 1: Contribution of nudged tracer emissions from different emission regions to the air mass in the AMA (at 150 hPa) in [%/100] using method 3. Left figure: with convection of tracer mass (EMAC and ATTILA, CLaMS has no convective transport of tracer mass and is therefore similar on both figures). Right figure: all models have no convection of tracer mass. The tracer has a half-life time of 90 days.

References

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., Grooß, 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.