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Pollution trace gas distributions and their transport in the Asian monsoon upper troposphere and lowermost stratosphere during the StratoClim campaign 2017

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Introduction

In this document, supplementary information for retrieved GLORIA trace gases is shown in the figures below (Figs. S1-S10). This is followed by a map of total column HCOOH, measured by the Infrared Atmospheric Sounding Interferometer (IASI; Fig. S11). Then, an exemplary analysis of the temporal evolution of the ATLAS trajectories is shown (Figs. S12-S19), followed by an extended version of Tab. 2 of the main paper (Tab. S1), and a first attempt of a sensitivity study with EMAC (Fig. S20).

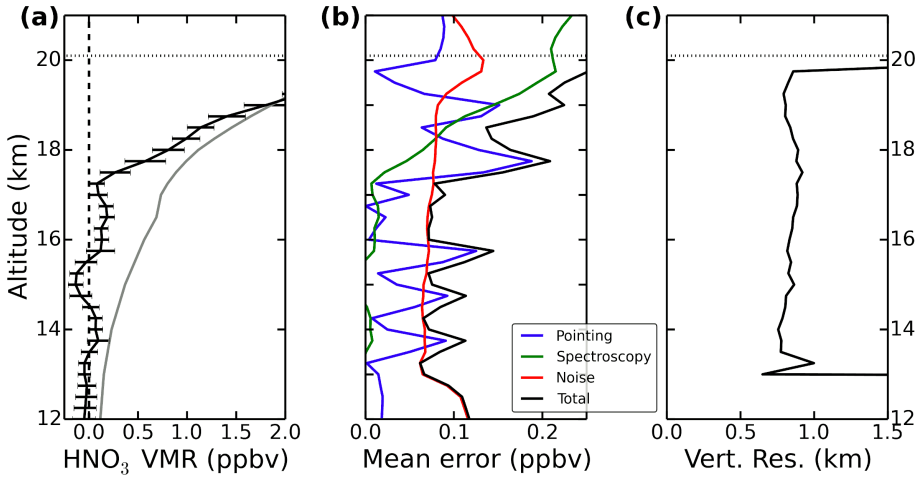

Figure S1: Illustration of the error budget of the HNO_3 retrieval of StratoClim flight 03 on 31 July 2017 for a selected profile at 05:13:14 UTC. **(a)** retrieved vertical profile of HNO_3 with total estimated error (black) and initial-guess profile (gray). The retrieved profile has 10.8 degrees of freedom. **(b)** Total error contributions and estimated total error. **(c)** Vertical resolution of this retrieval result. The dotted line represents the flight altitude of the aircraft.

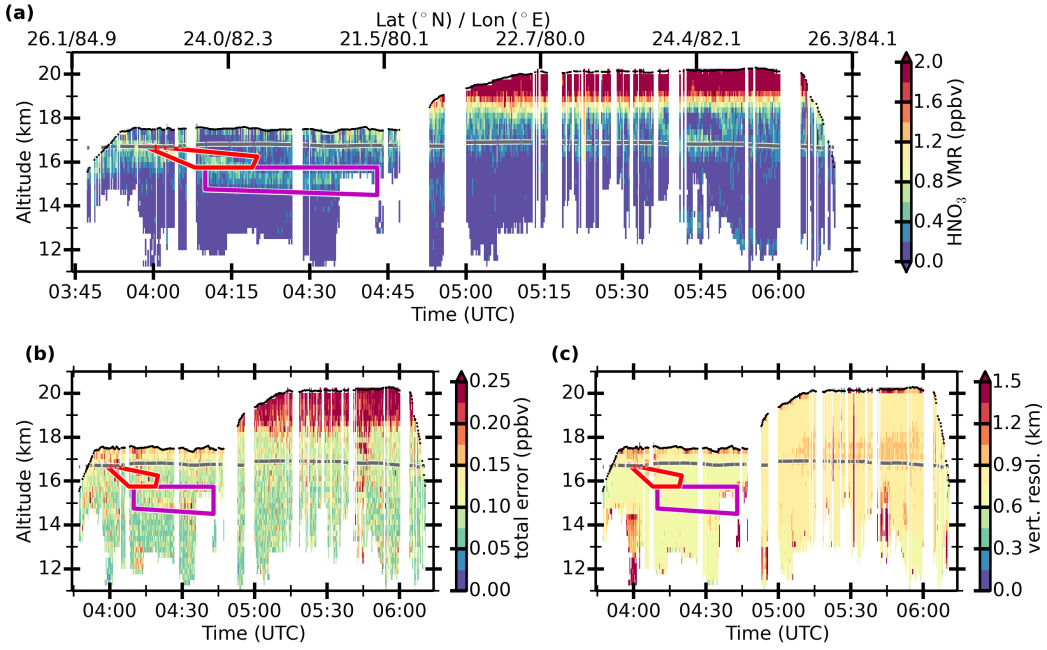

Figure S2: HNO_3 from StratoClim flight 03 on 31 July 2017: Cross section of **(a)** retrieved HNO_3 volume mixing ratio (the ECMWF potential vorticities of 2 and 4 PVU are marked with magenta dashed lines, and the ECMWF 380 K potential temperature level is marked with a green line). Cross sections of **(b)** total estimated error, and **(c)** vertical resolution.

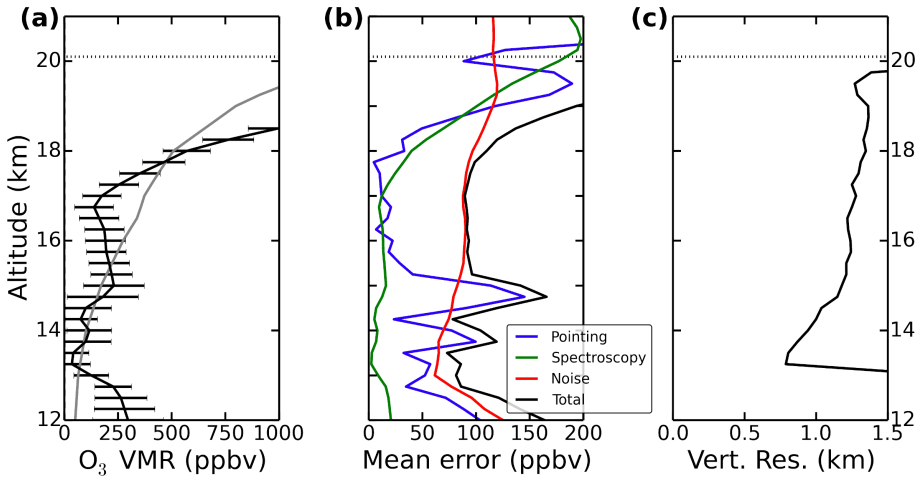

Figure S3: Same as Fig. S1, but for O_3. The retrieved profile has 9.1 degrees of freedom.

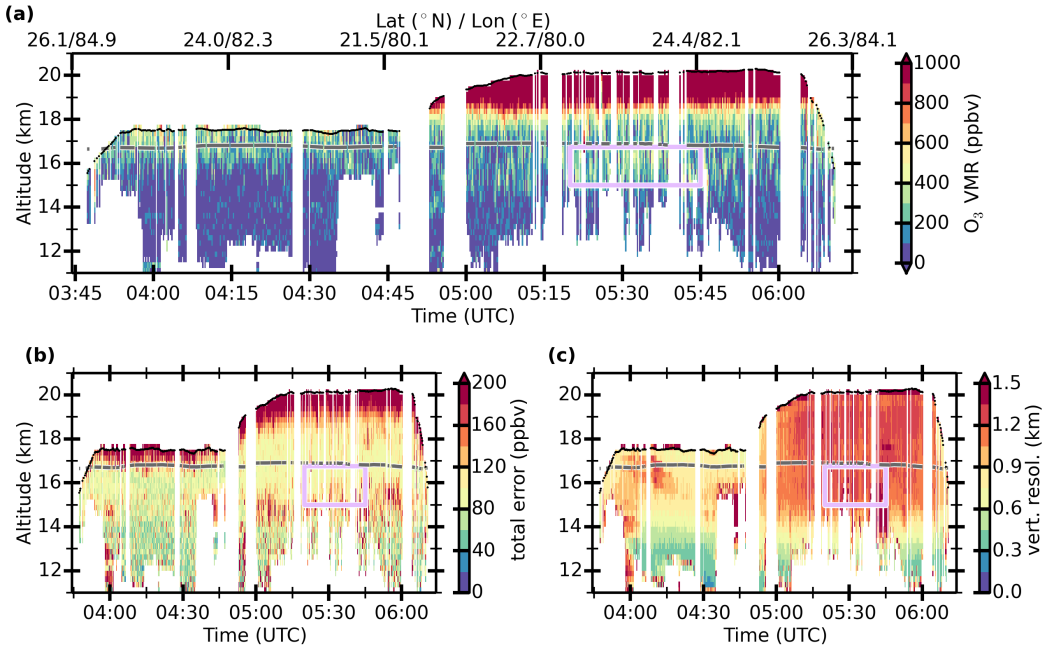

Figure S4: Same as Fig. S2, but for O_3.

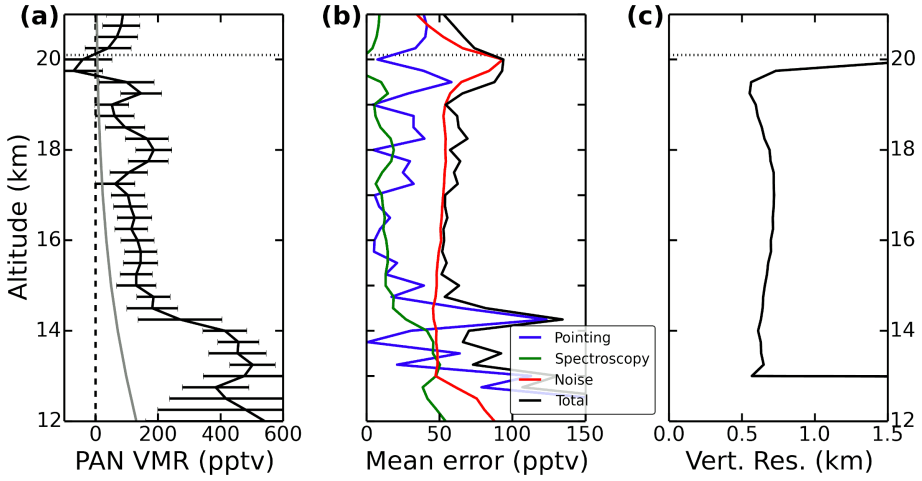

Figure S5: Same as Fig. S1, but for PAN. The retrieved profile has 13.3 degrees of freedom.

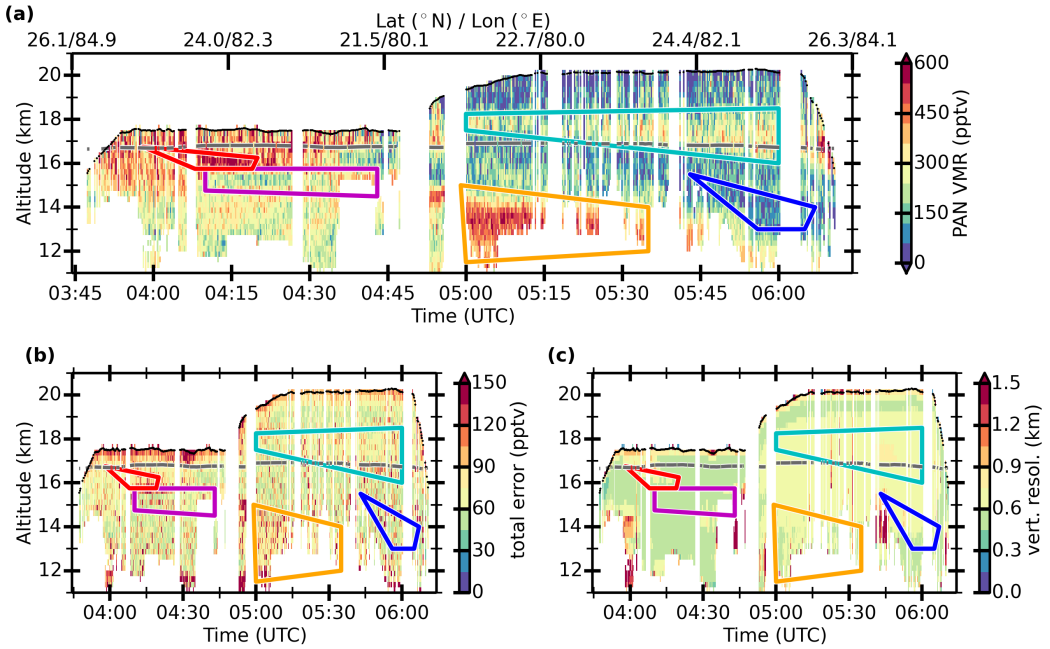

Figure S6: Same as Fig. S2, but for PAN.

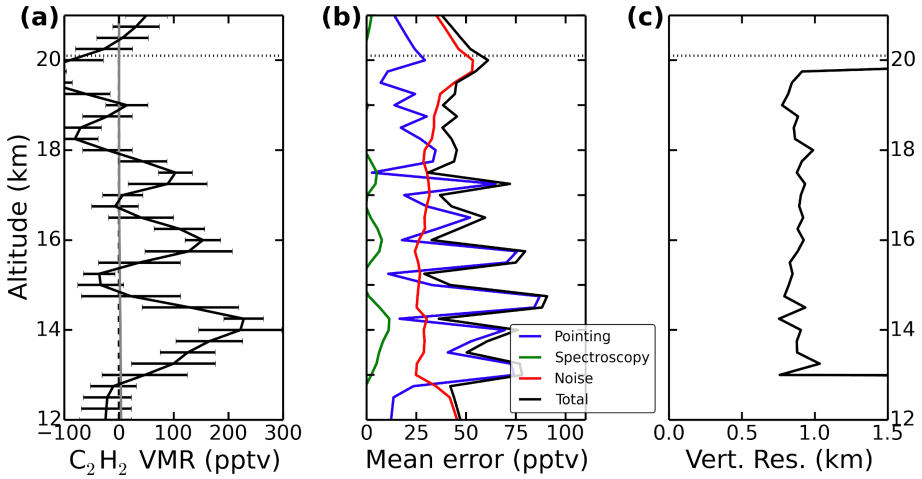

Figure S7: Same as Fig. S1, but for C_2H_2. The retrieved profile has 10.5 degrees of freedom.

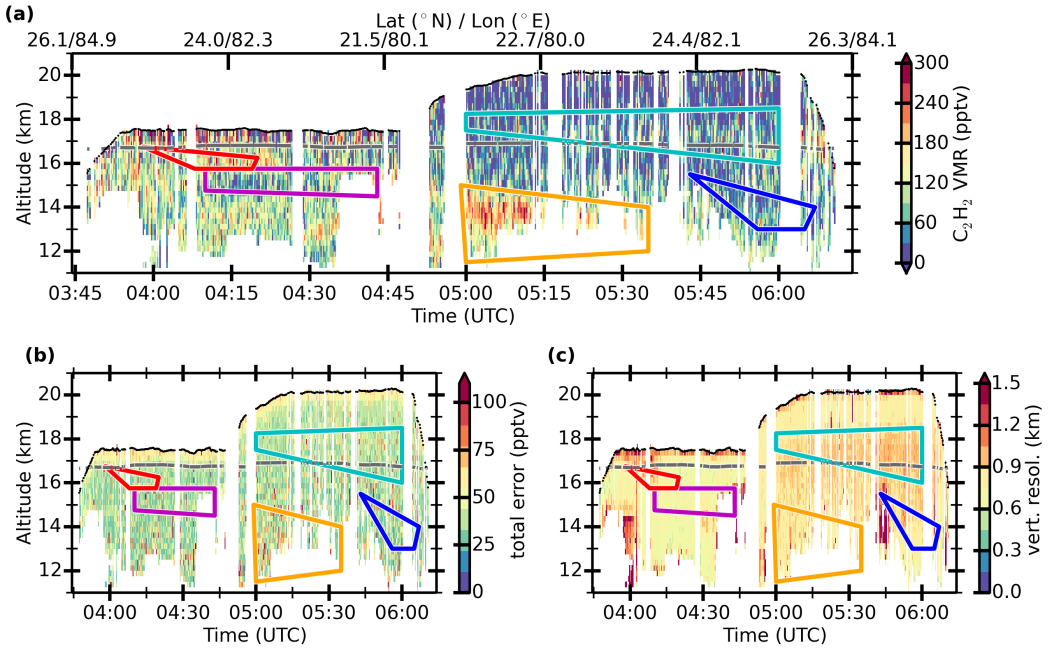

Figure S8: Same as Fig. S2, but for C_2H_2.

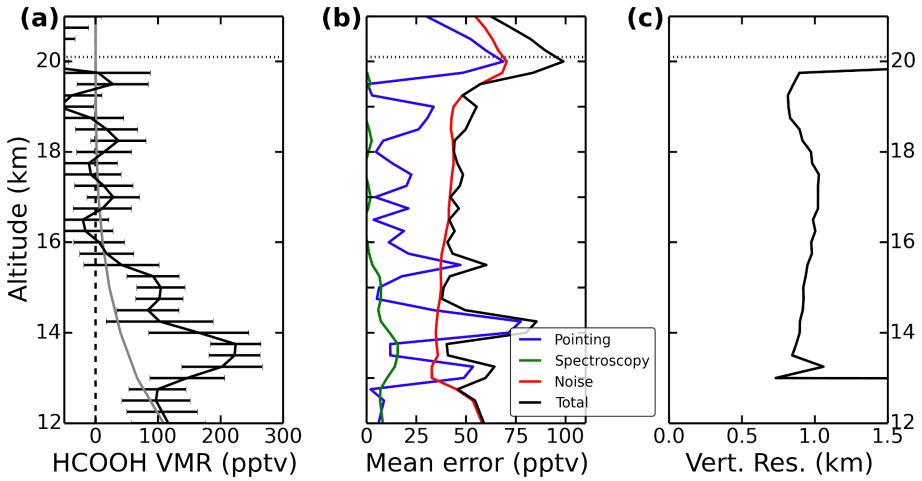

Figure S9: Same as Fig. S1, but for HCOOH. The retrieved profile has 9.9 degrees of freedom.

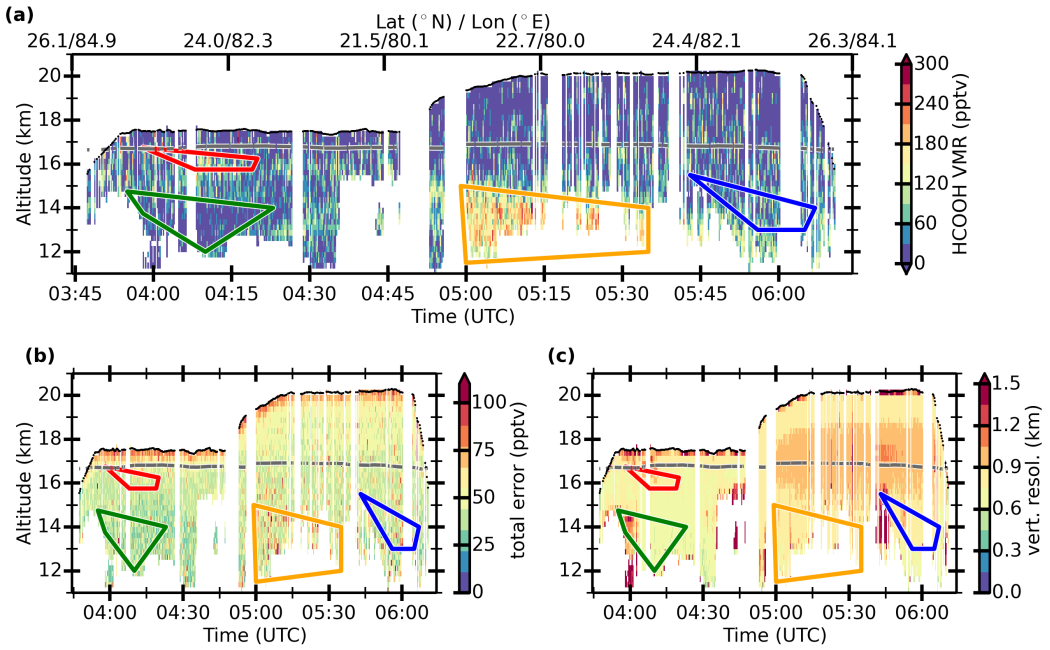

Figure S10: Same as Fig. S2, but for HCOOH.

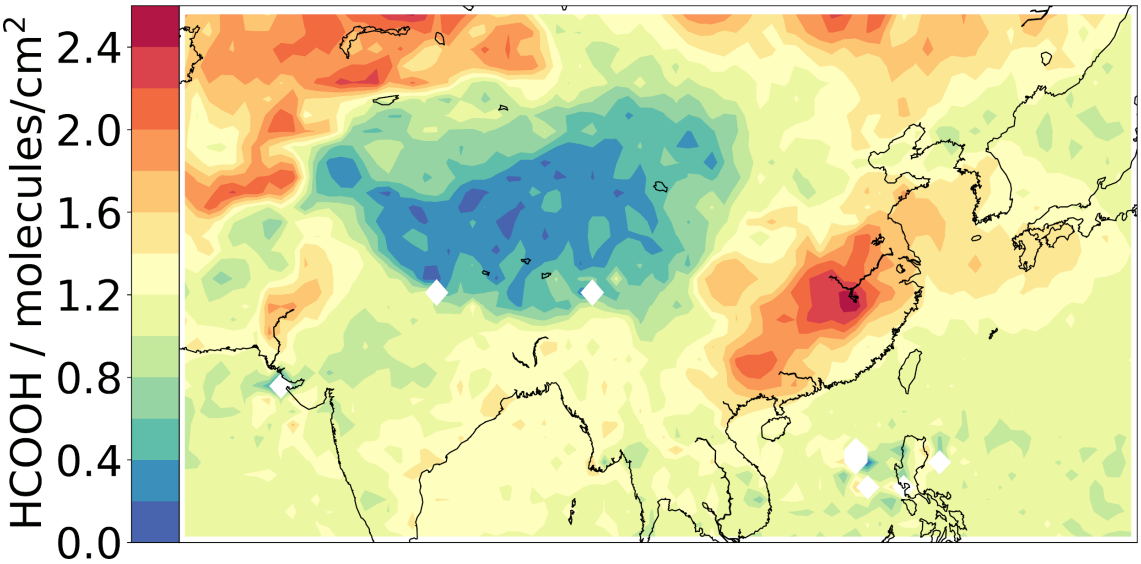

Figure S11: IASI HCOOH column measurements over India and southern Asia, averaged between 2017-07-25 and 2017-07-31. The IASI HCOOH level-2 data was binned and averaged in 1°×1° (latitude × longitude) bins.

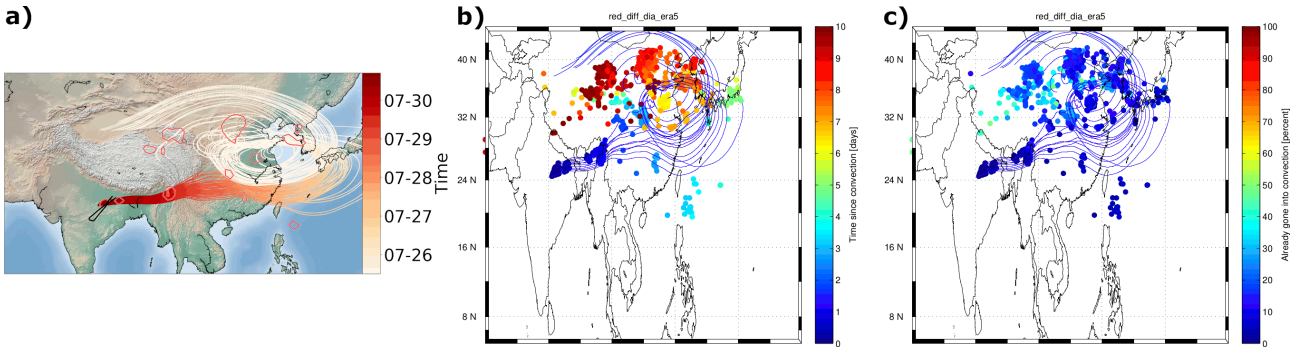

Figure S12: a) ATLAS 10-day backward trajectories starting at GLORIA tangent points and in the red box. Trajectories are color-coded according to date. Isolines mark the same regions as in Fig. 4b of the main paper. All panels display a map centered at South East Asia and show simple backward trajectories (lines, trajectories without convection, i.e. convection scheme switched off). In b) and c), dots mark the location of all convective events experienced by backward trajectories starting in the red region (with the convection scheme switched on). b) is color-coded with the time difference between the convective event and the time of measurement, and c) is color-coded with the percentage of the other backward trajectories that already had experienced convection when the trajectory represented by the dot went into convection.

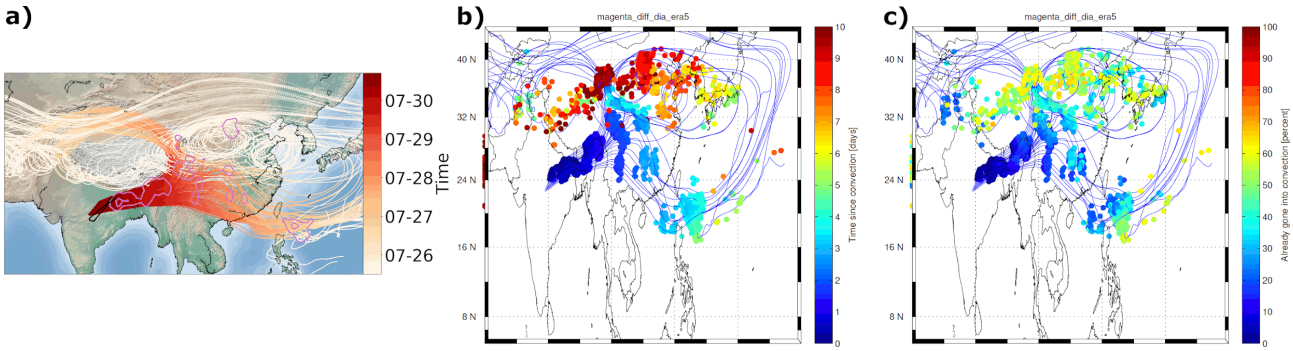

Figure S13: Same as Fig. S12, but for the magenta marked air masses of interest.

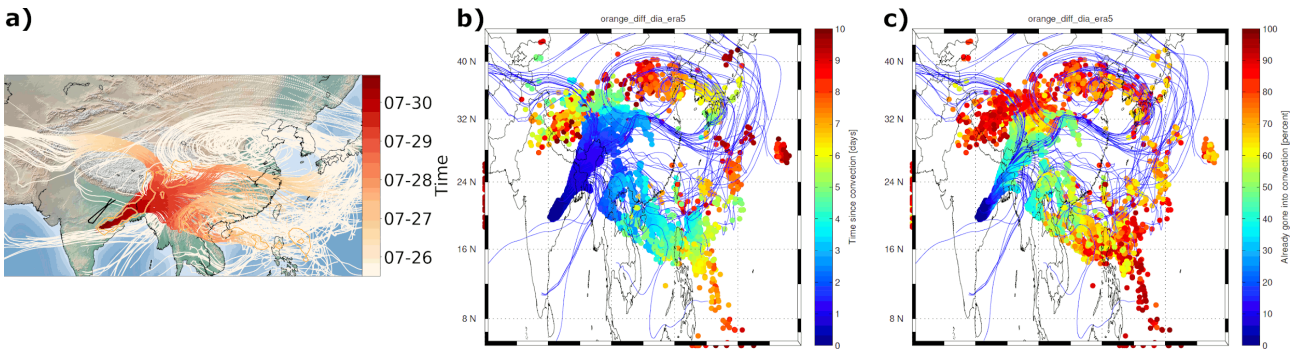

Figure S14: Same as Fig. S12, but for the orange marked air masses of interest.

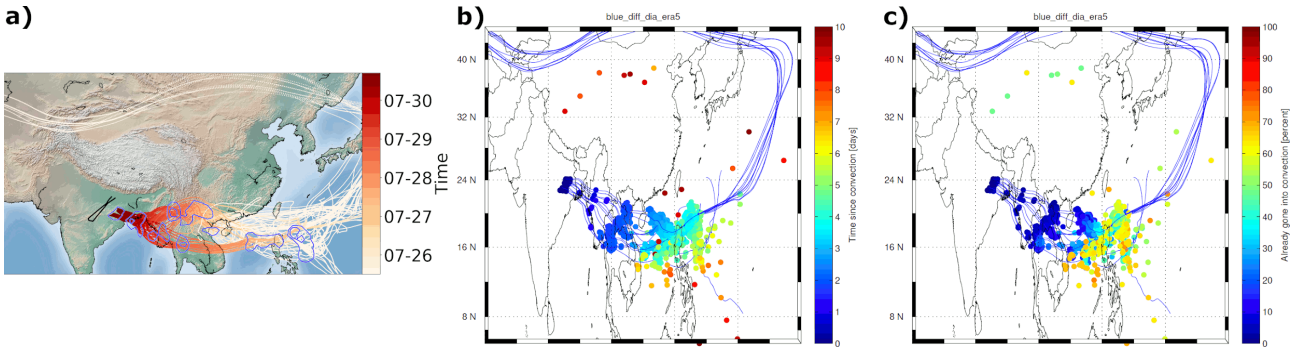

Figure S15: Same as Fig. S12, but for the blue marked air masses of interest.

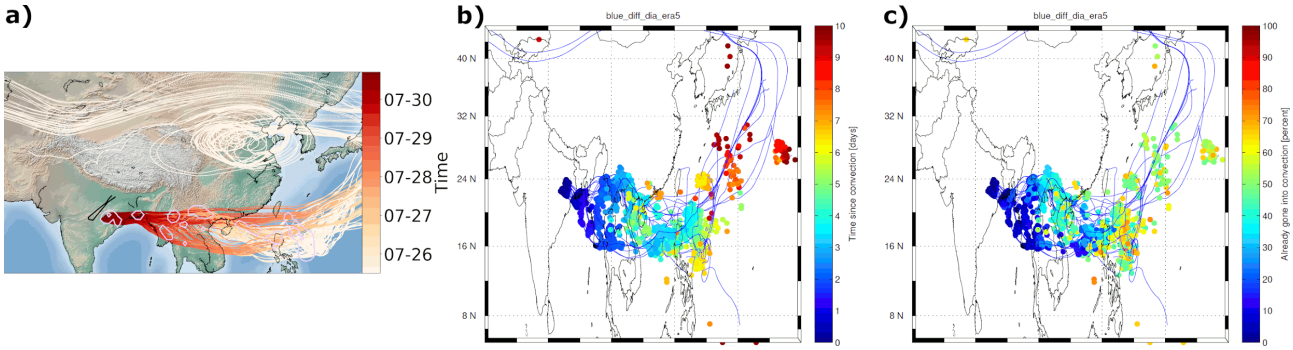

Figure S16: Same as Fig. S12, but for the purple marked air masses of interest.

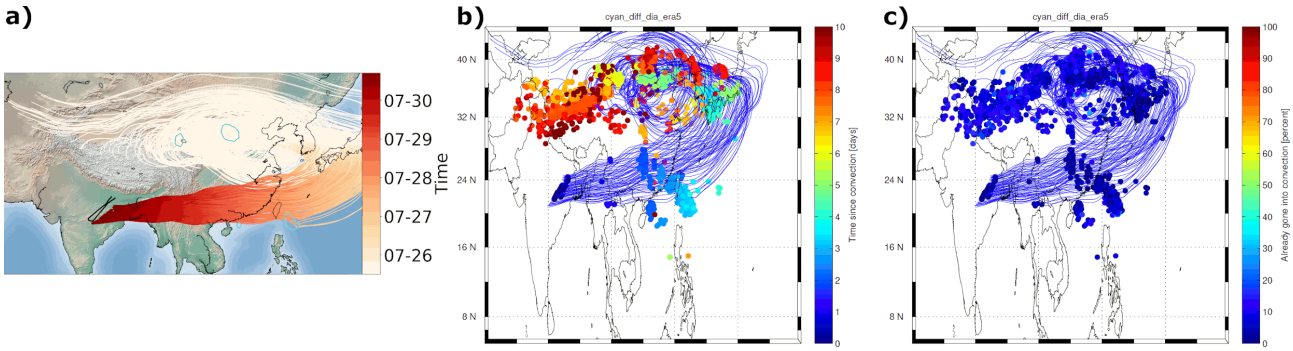

Figure S17: Same as Fig. S12, but for the cyan marked air masses of interest.

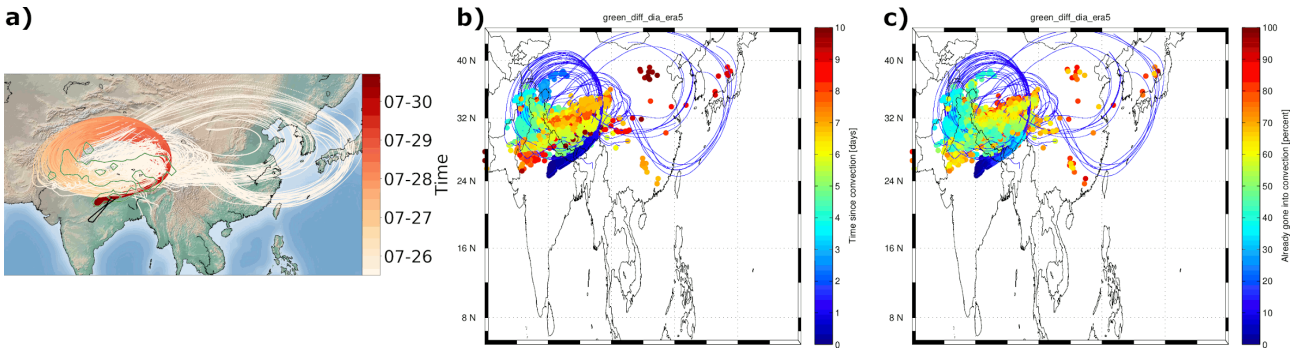

Figure S18: Same as Fig. S12, but for the green marked air masses of interest.

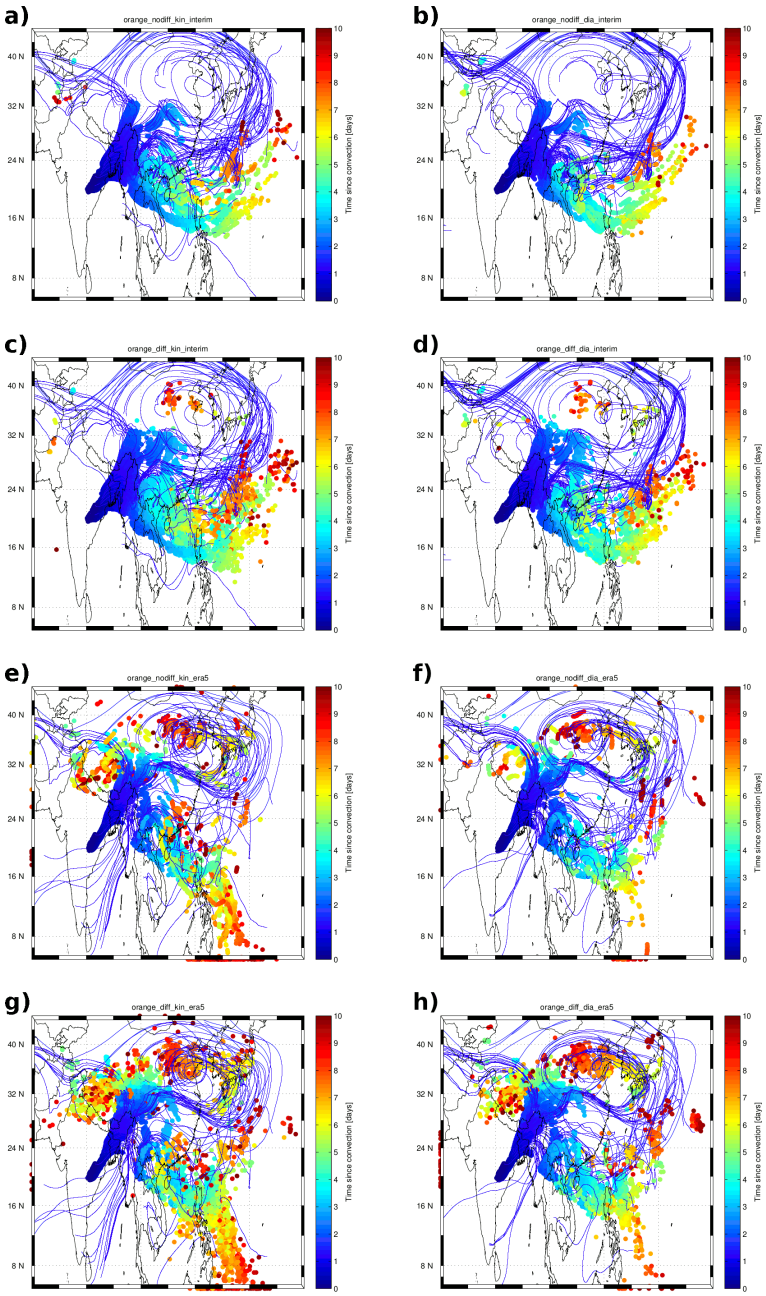

Figure S19: ATLAS 10-day backward trajectories starting at GLORIA tangent points and in the orange box. All panels display a map centered at South East Asia and show simple backward trajectories (lines, trajectories without convection, i.e. convection scheme switched off). As for Figs. S12b-S18b, dots mark the location of all convective events experienced by backward trajectories starting in the orange region (with the convection scheme switched on). Dots are color-coded with the time difference between the convective event and the time of measurement. The upper four panels (a-d) show trajectories driven by ERA-Interim, the lower four panels (e-h) show trajectories driven by ERA-5. The left column panels (a,c,e,g) show kinematic trajectories, the right column panels (b,d,f,h) shows diabatic trajectories. Panels of the first and third row (a,b,e,f) show trajectories without vertical diffusion, panels of the second and fourth row (c,d,g,h) show trajectories with vertical diffusion.

Table S1: Age of air masses of interest marked with colored boxes (see Fig. 2 of the main paper). Regions of origin, as indicated by ATLAS and TRACZILLA (repeated from Tab. 2 of the main paper) are listed together with approximate age of the air masses (time between convection event and measurement).

color	ATLAS	age	TRACZILLA	age
red	north eastern India,	0-1 d		
	eastern China,	6-8 d	eastern China	6-10 d
	central China	9-10 d	central China	2-3 d
magenta	eastern China,	6-8 d	eastern China,	7-10 d
	South China and	3-5 d	South China and	3-5 d
	Philippine Seas,		Philippine Seas,	
	north eastern	0-1 d	Tibetan Plateau	4-9 d
	India		and Kashmir	
orange	eastern India,	0-1 d	eastern India,	0-1 d
	southern China,	2-5 d	southern China,	2-4 d
	South China Sea	3-6 d	South China Sea	3-6 d
blue	Bay of Bengal,	0-1 d	Bay of Bengal,	0-2 d
	Myanmar,	1-2 d	Myanmar,	2-3 d
	South China and	3-6 d	South China and	3-8 d
	Philippine Seas		Philippine Seas	
purple	eastern India,	0-1 d	eastern India,	0-1 d
	South China and	3-6 d	South China and	3-8 d
	Philippine Seas		Philippine Seas	
cyan	South China and	2-4 d	South China and	2-3 d
	Philippine Seas,		Philippine Seas	
	central China	5-8 d		
green	Tibetan Plateau,	0-7 d	Tibetan Plateau,	0-8 d
	Kashmir	3-6 d	Kashmir	3-5 d

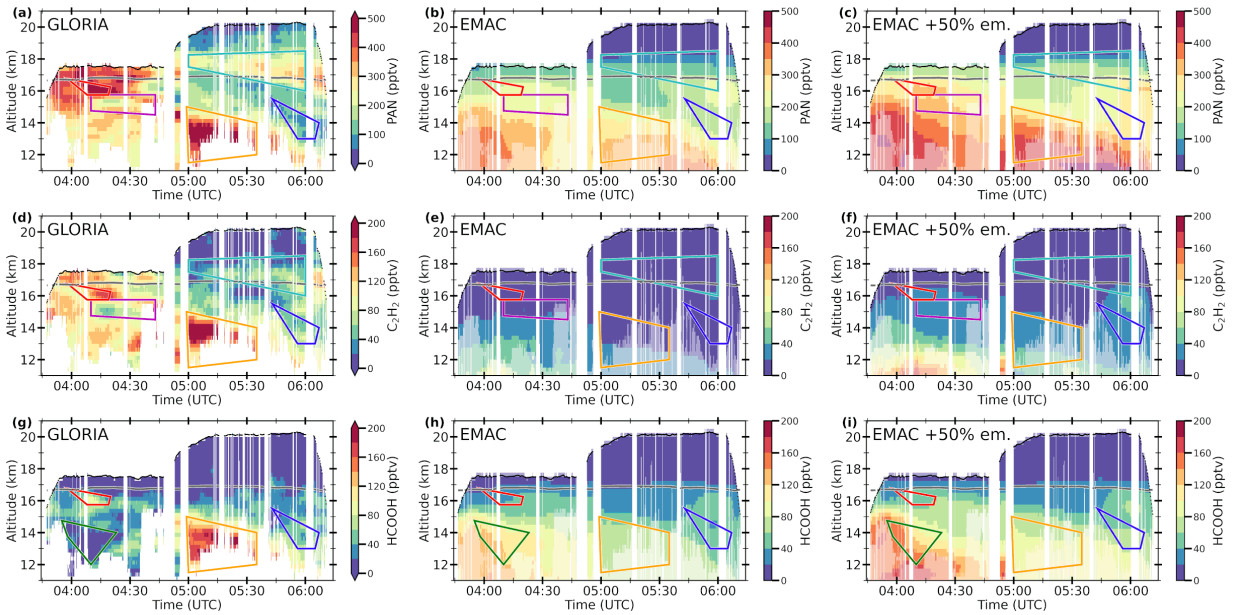

Figure S20: GLORIA (left column, repeated from Fig. 5 of the main paper, again averaged over 33 single profiles), EMAC distributions of the standard simulation (middle column, repeated from Fig. 5 of the main paper), and with NMVOC emissions increased by 50% (right column) of (a-c) PAN, (d-f) C_2H_2, (g-i) HCOOH for StratoClim flight on 31 July 2017. All auxiliary lines as defined in the caption of Fig. 2 of the main paper. Altitudes not measured by GLORIA are marked with a white shadow in the model data.