The Asian UTLS

observations and modelling of chemistry, transport, and mixing

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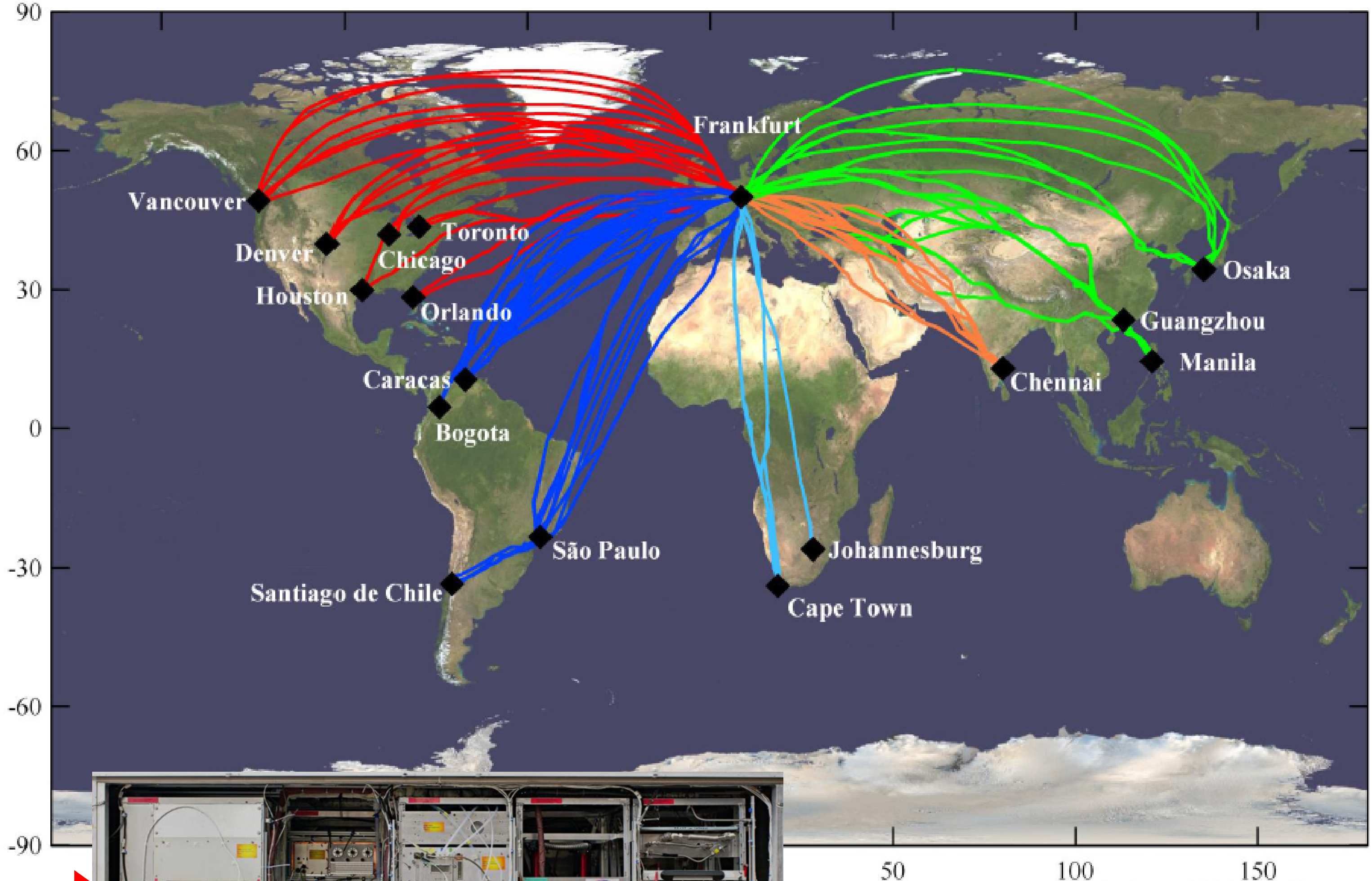
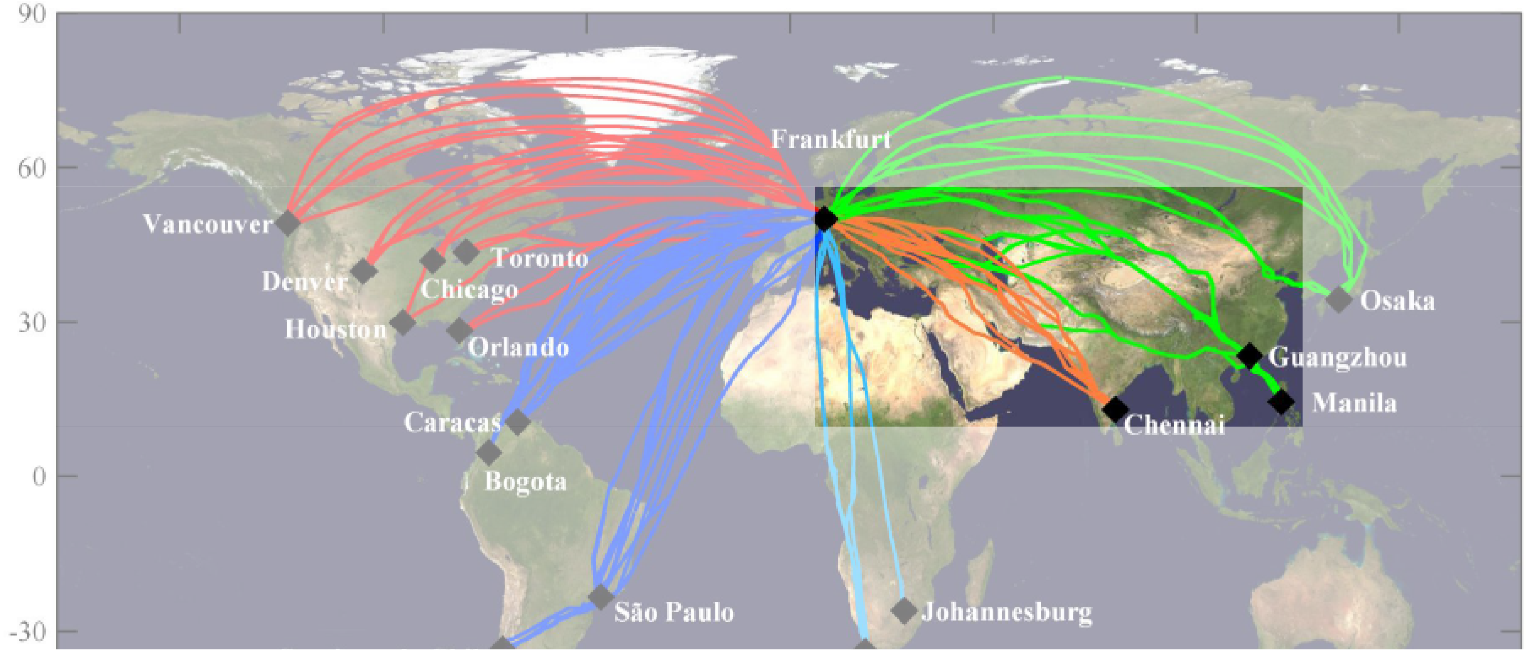
CARIBIC flights 2005 - 2010

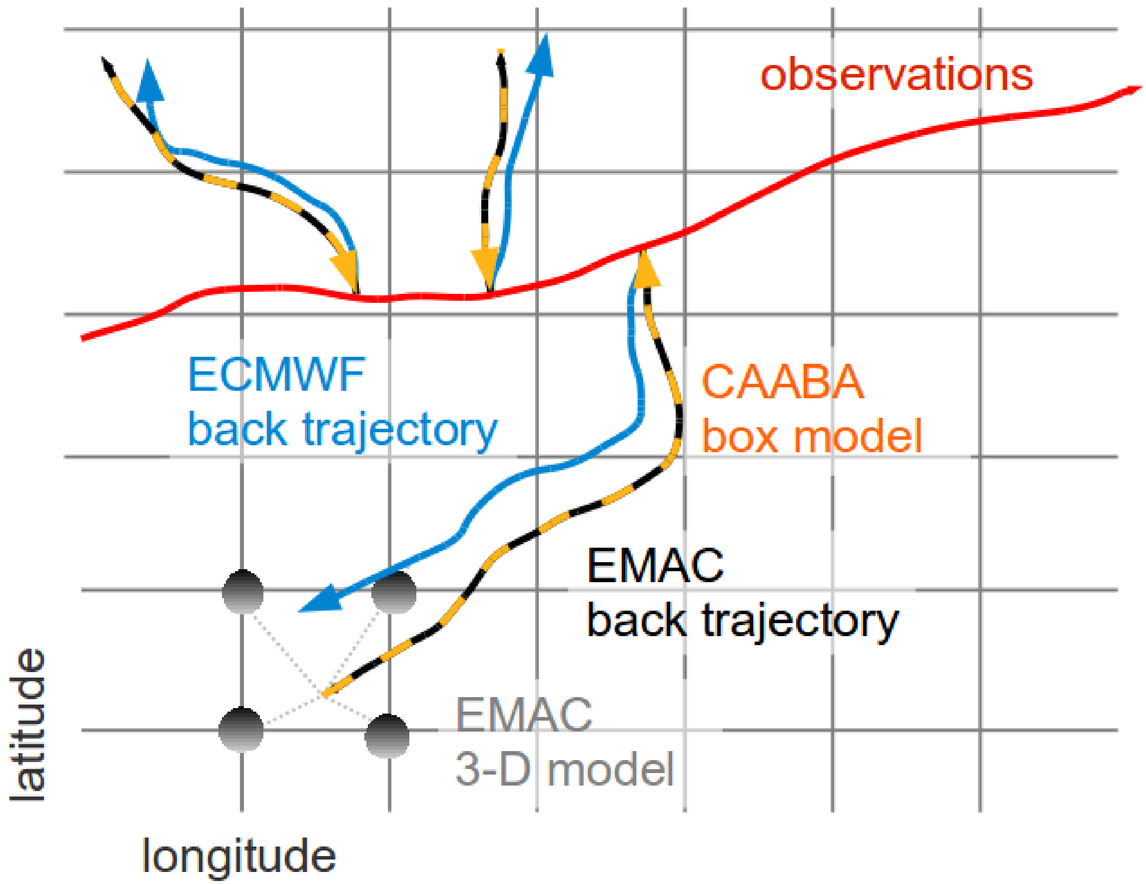


CARIBIC flights to China



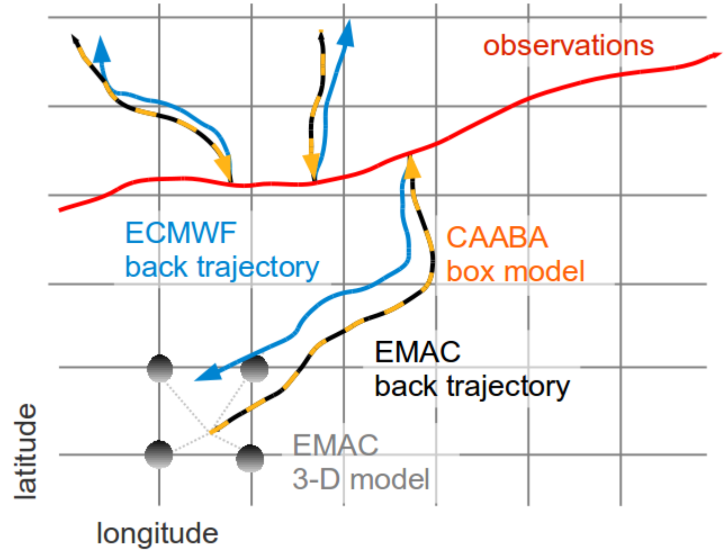
- 81 flights Frankfurt ↔ Guangzhou ↔ Manila between 05/2005 and 03/2008
- typical cruising altitude ~200 hPa
- continuous measurements of about 15 compounds and flask samples of about 50 compounds, including SF_6, CO, O_3, NO_y to NMHCs
- here: focus on CO

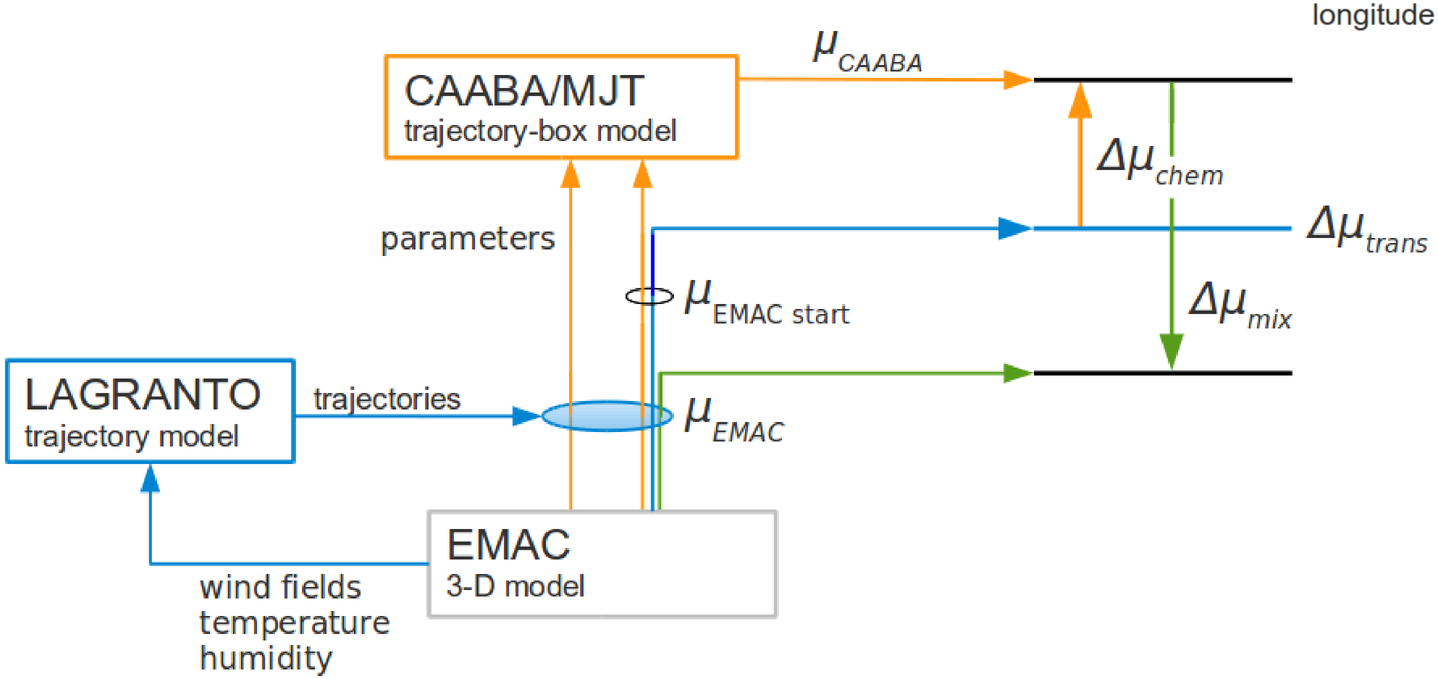
Data and models



- observations and models in different "dimensions"
- CARIBIC (observations) → 1-D "truth"
- EMAC (global, nudged AC GCM) → modelled 3-D environment
- CAABA (trajectory-box model) → off-line analysis of EMAC

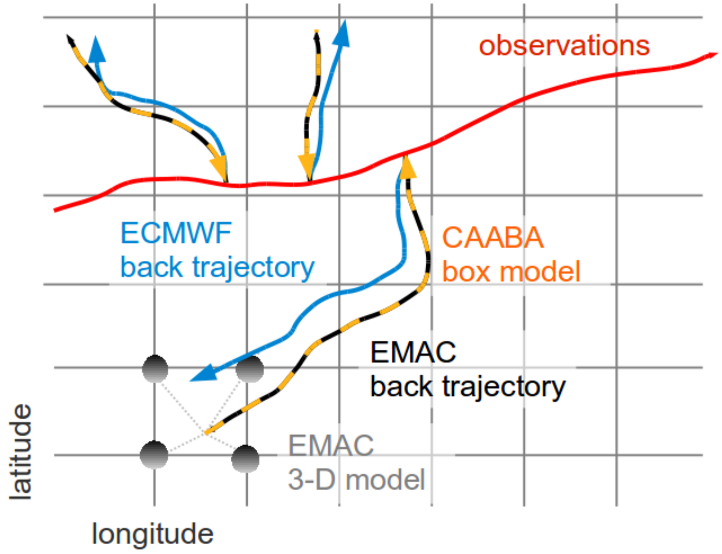
Quantifying

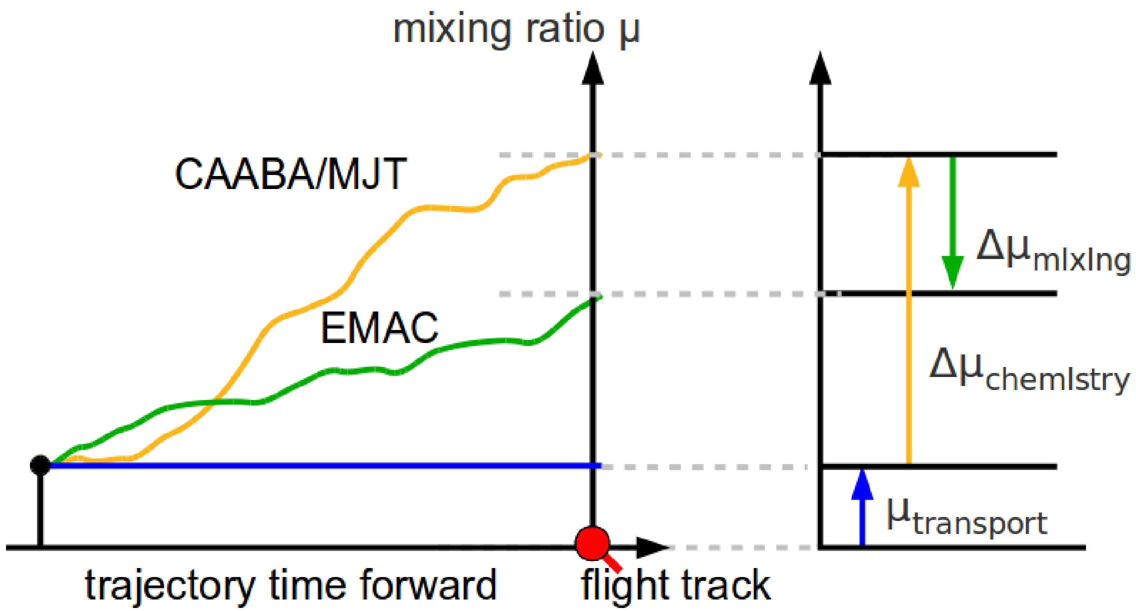




Quantifying

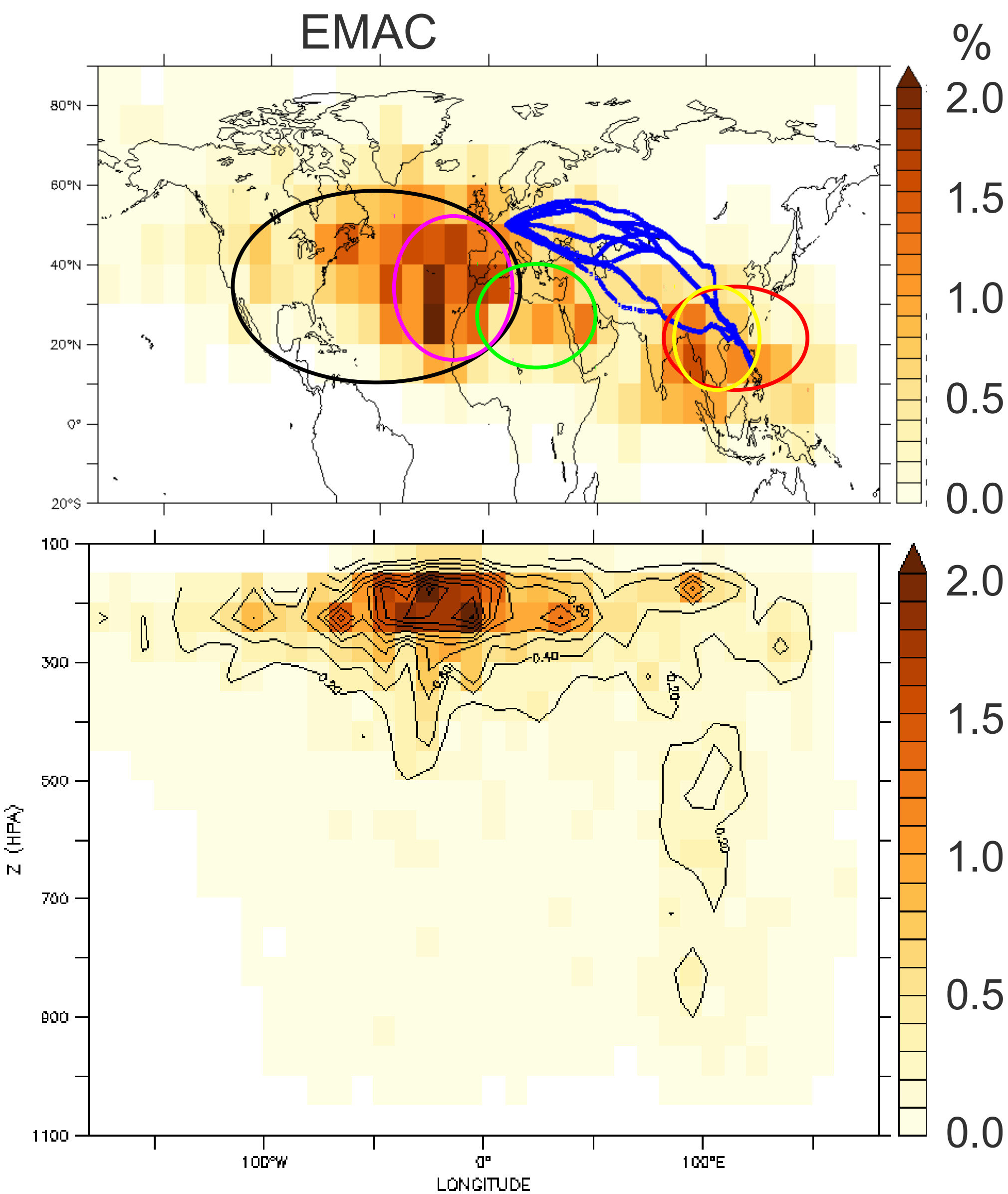
- high consistency between trajectory-box model and 3-D model (**M**odular **E**arth **S**ubmodel **Sy**stem) in transport and chemistry
- individual for each species
- dependent on trajectory travel time





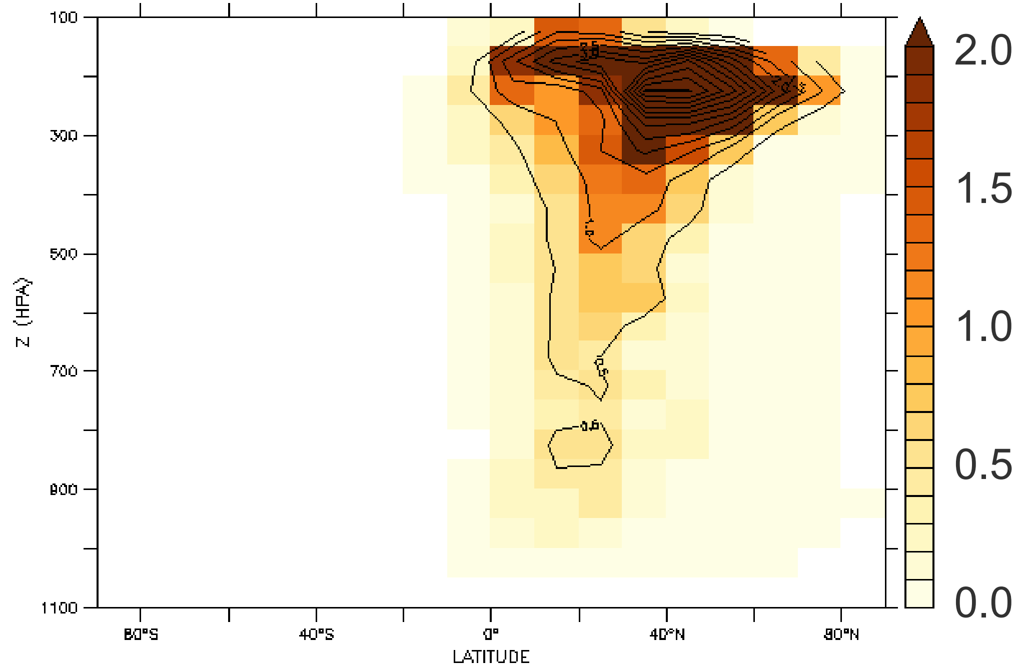
Riede et al, GMD, 2009

Transport patterns

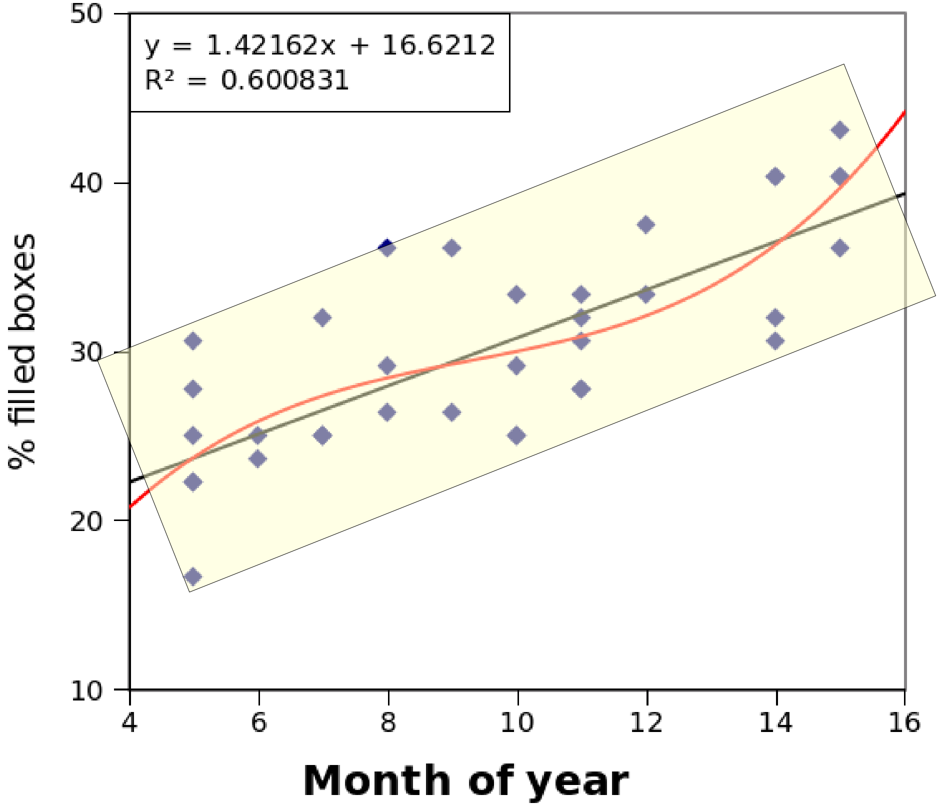


flight track longitudes

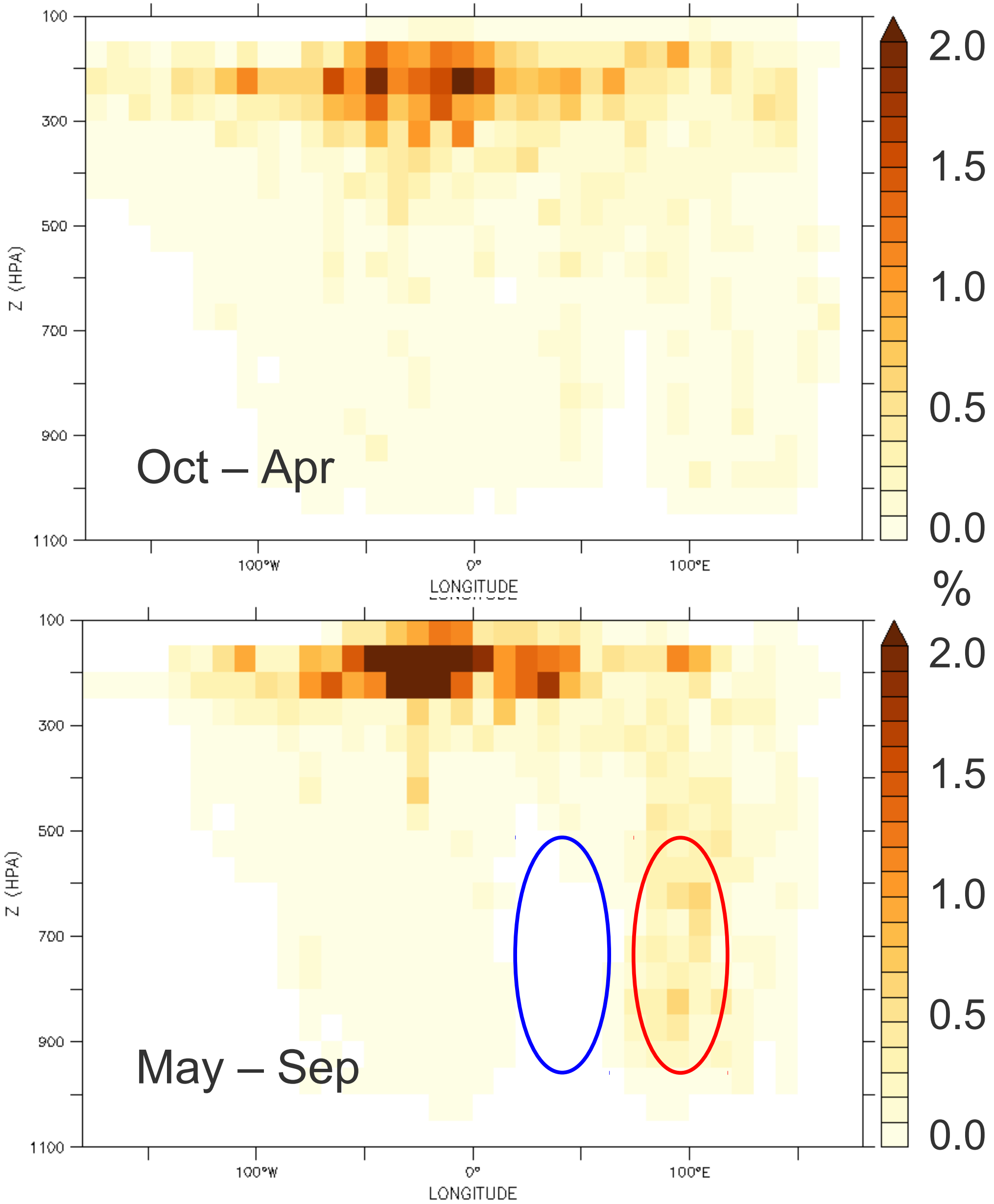
black	0 – 50	Europe
magenta	50 – 80	Asian plains
green	80 – 100	Himalayas
yellow	100 – 110	China
red	110 – 130	China coast – Philippines



Transport patterns

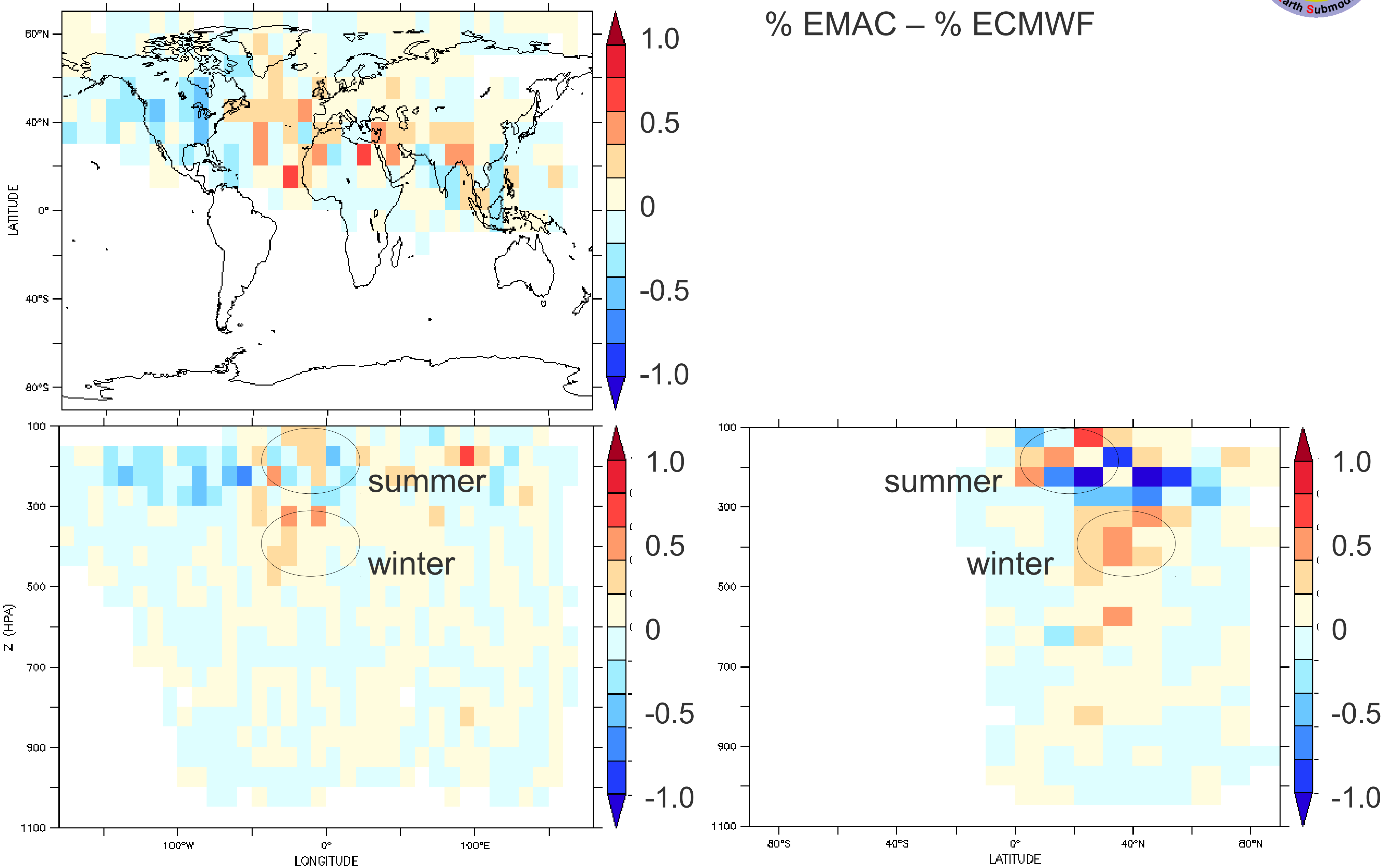


- horizontal catchment area size

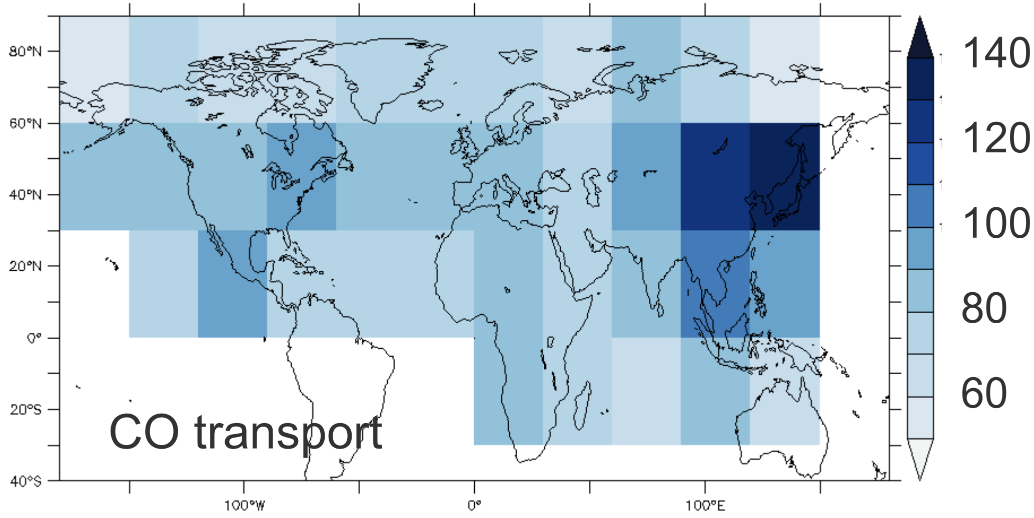


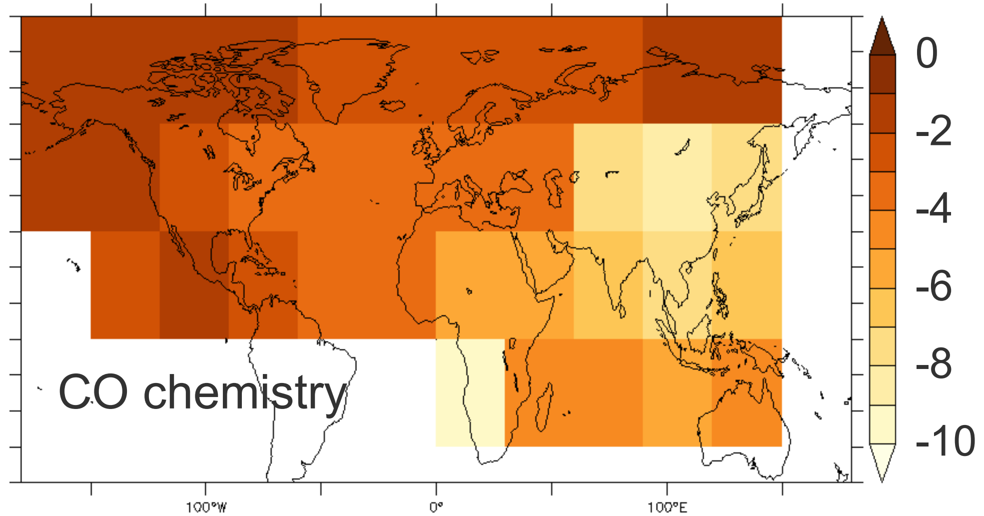
Transport patterns

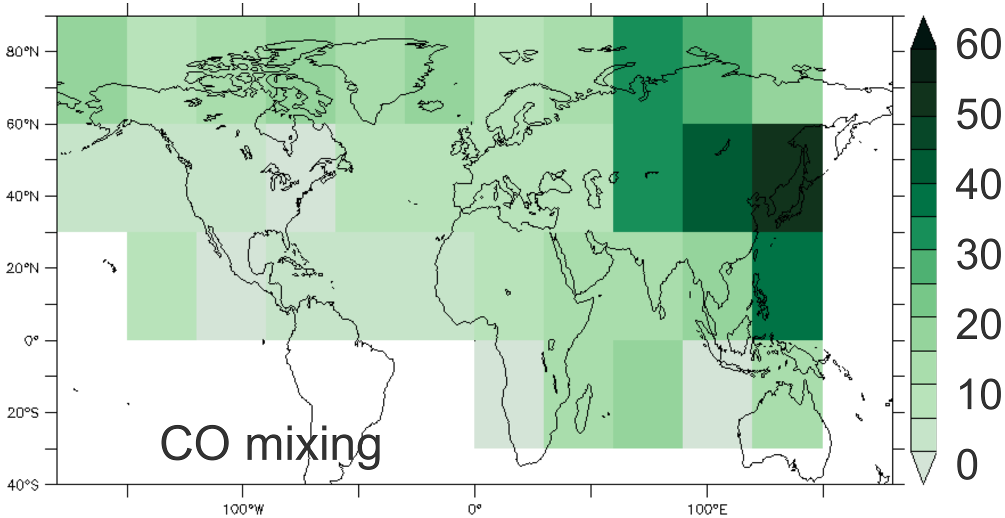
% EMAC – % ECMWF



CO transport, chemistry, mixing

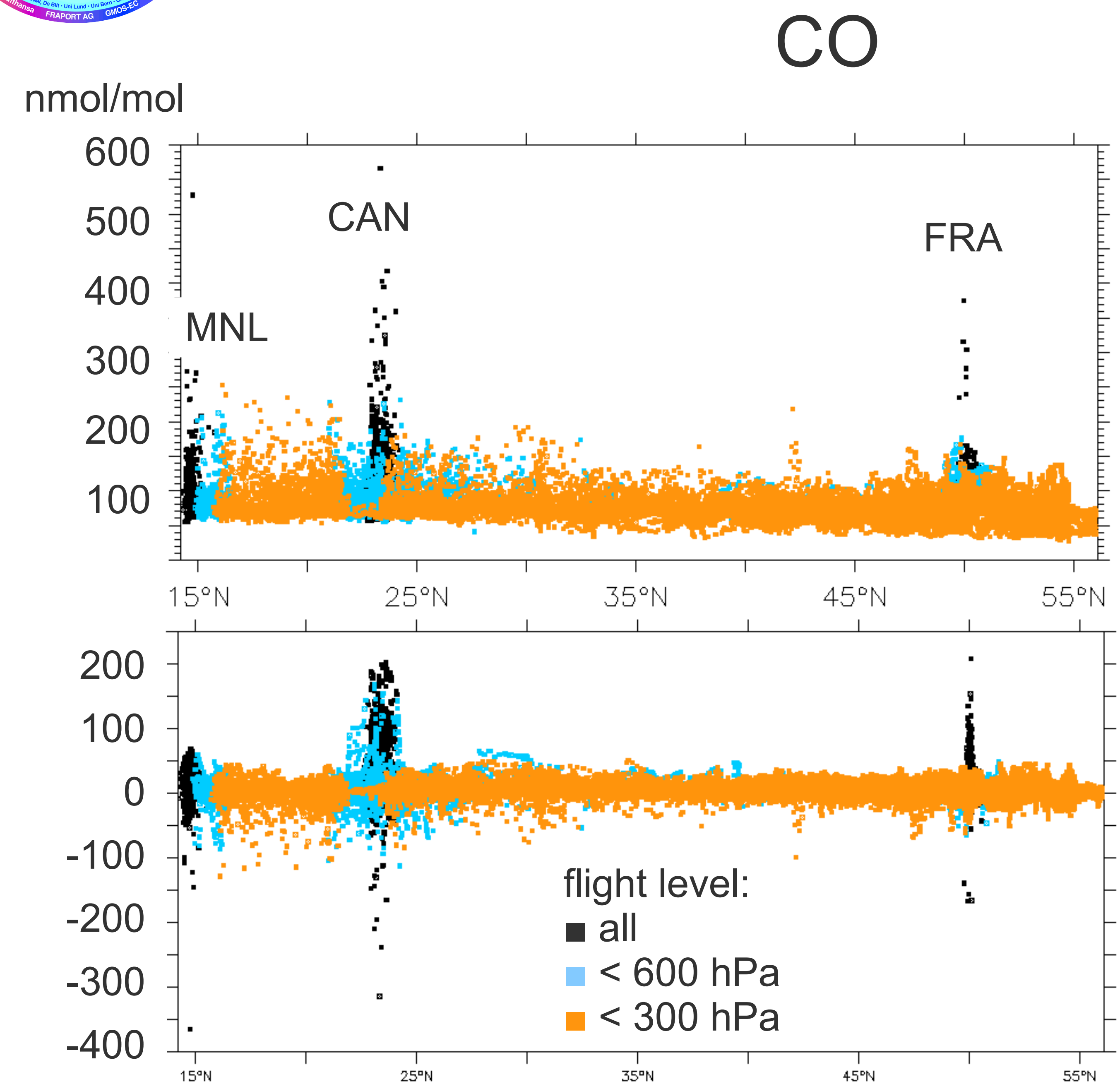






- all values in nmol/mol (ppbV)
- transport and mixing

CO transport & mixing



transport

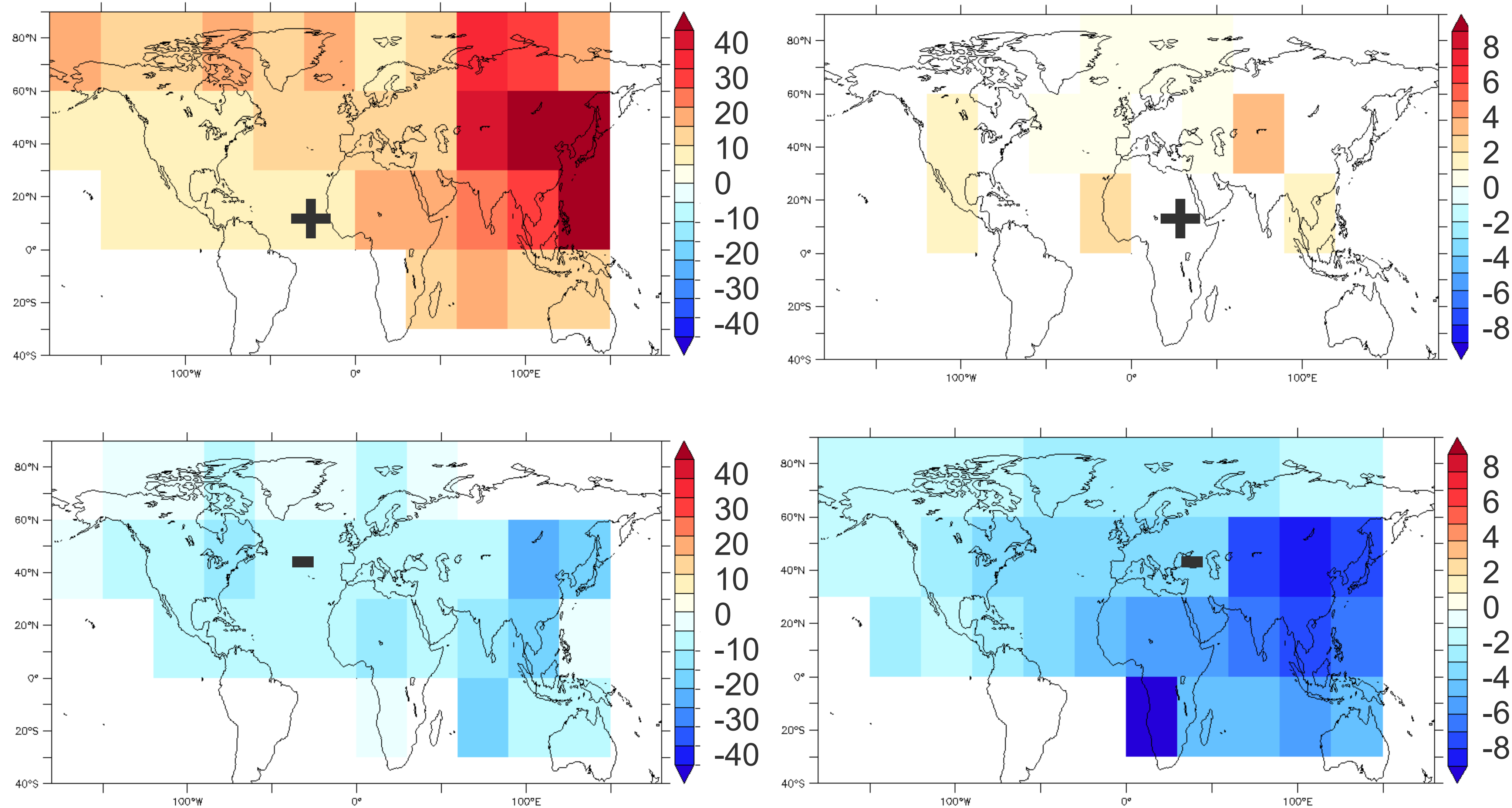
mixing

~ 24000 trajectory clusters

→ ~ 185000 trajectories

Contributions mixing & chemistry

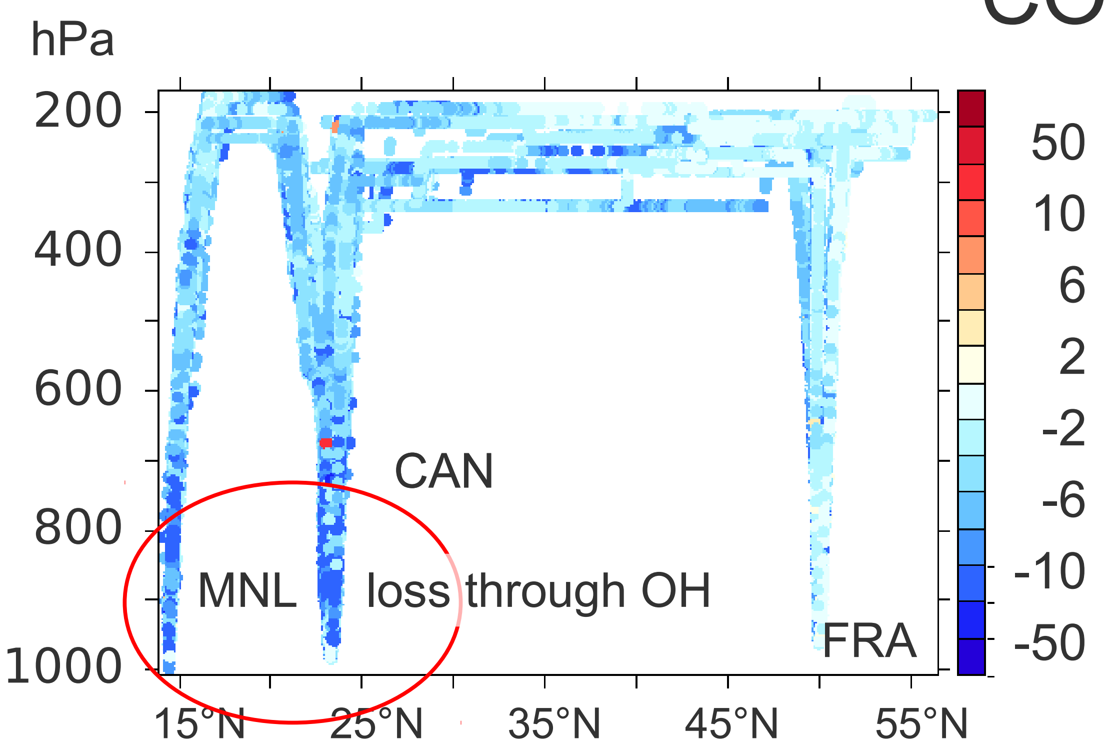
CO

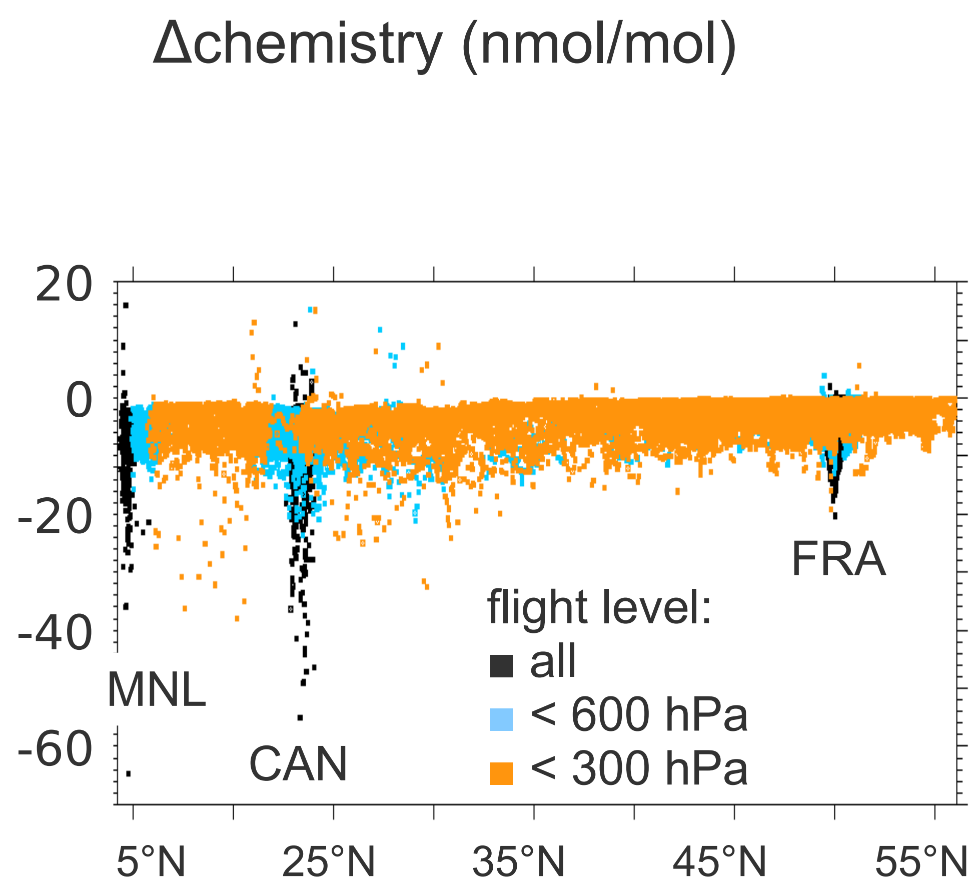


values in nmol/mol

China - chemistry hotspot

CO

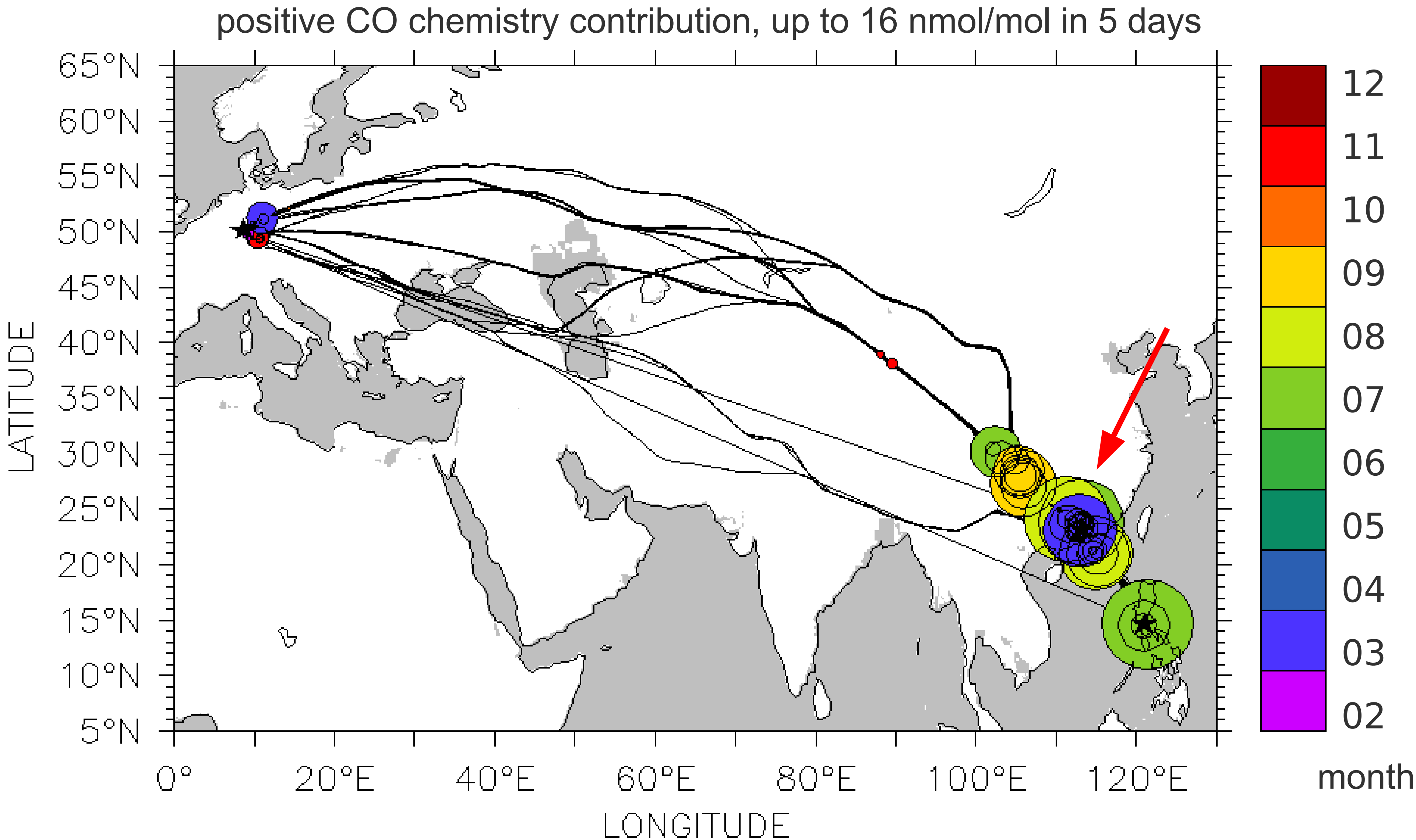




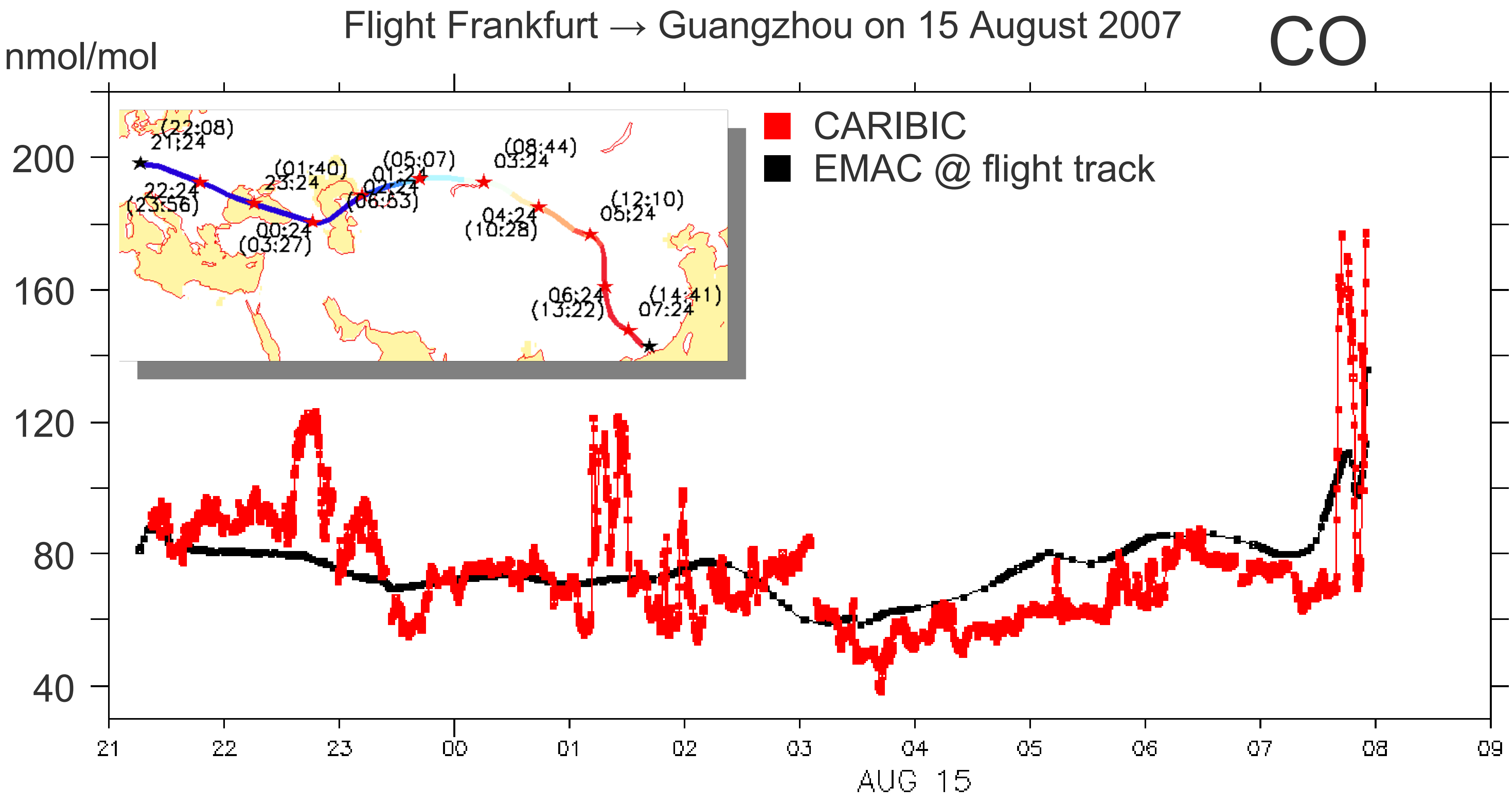
- only 0.2 – 0.4 % positive CO chemistry contribution
- in clusters as well as single trajectories, no special cluster bundles

→ are those few interesting?

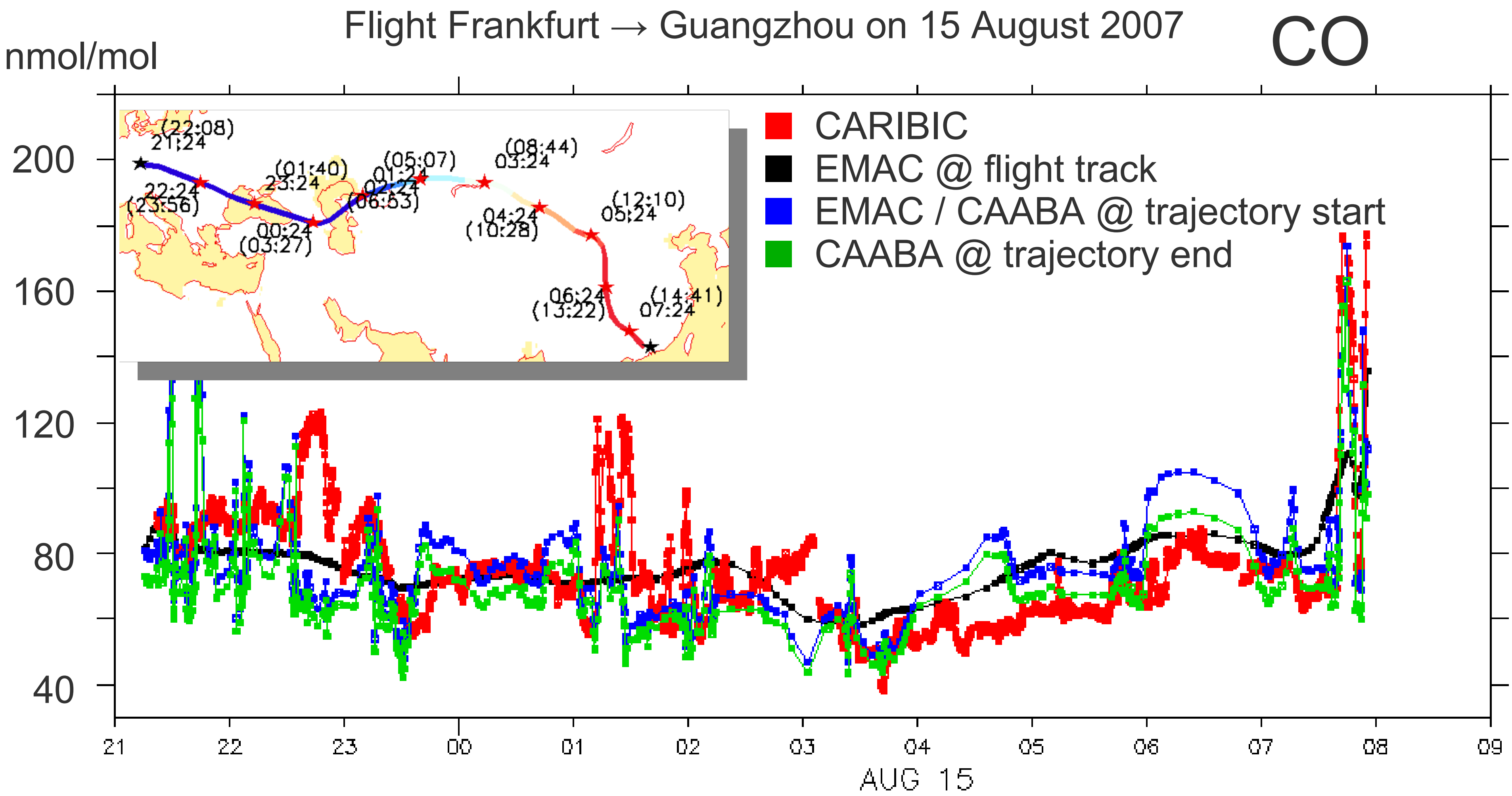
China - chemistry hotspot



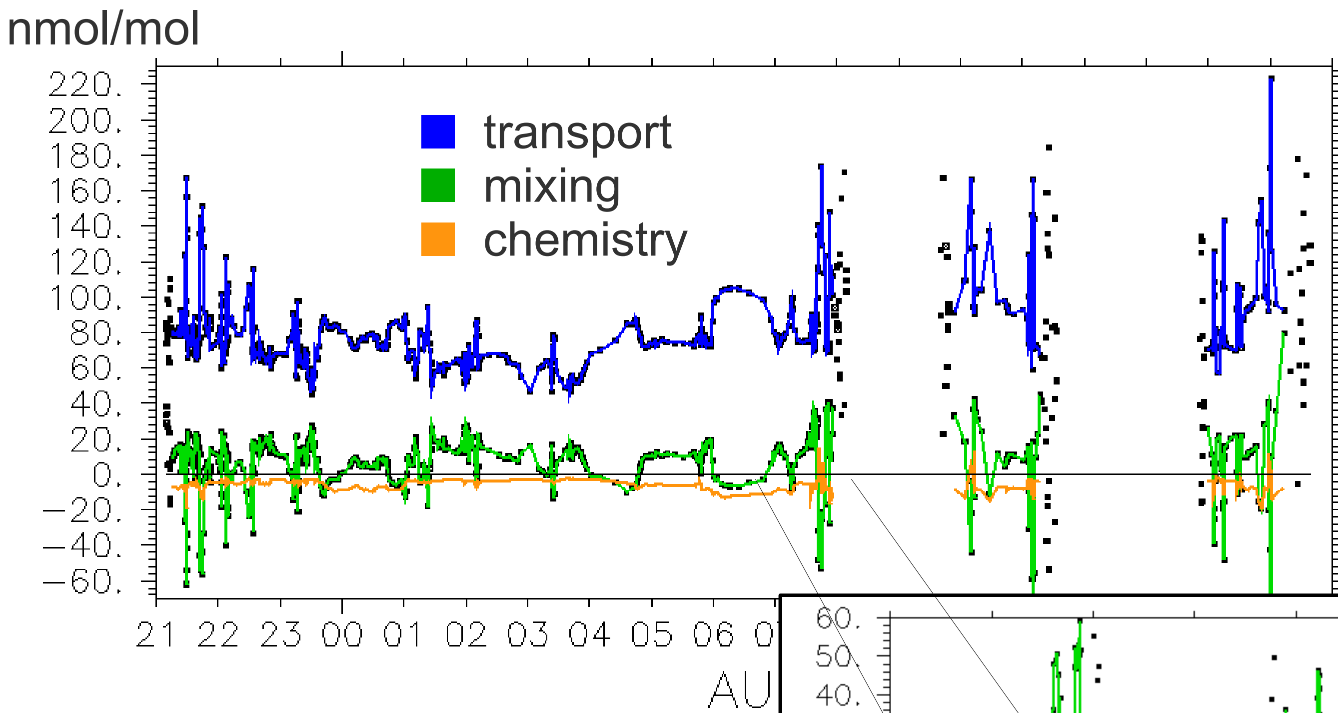
Single flight

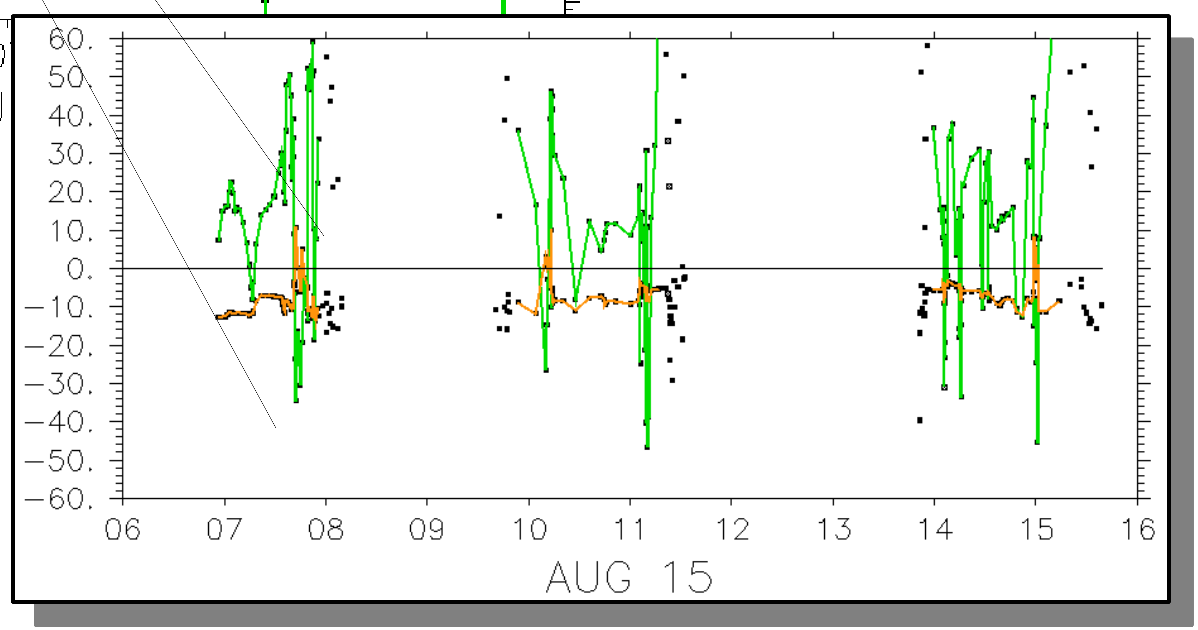


Single flight



Single flight

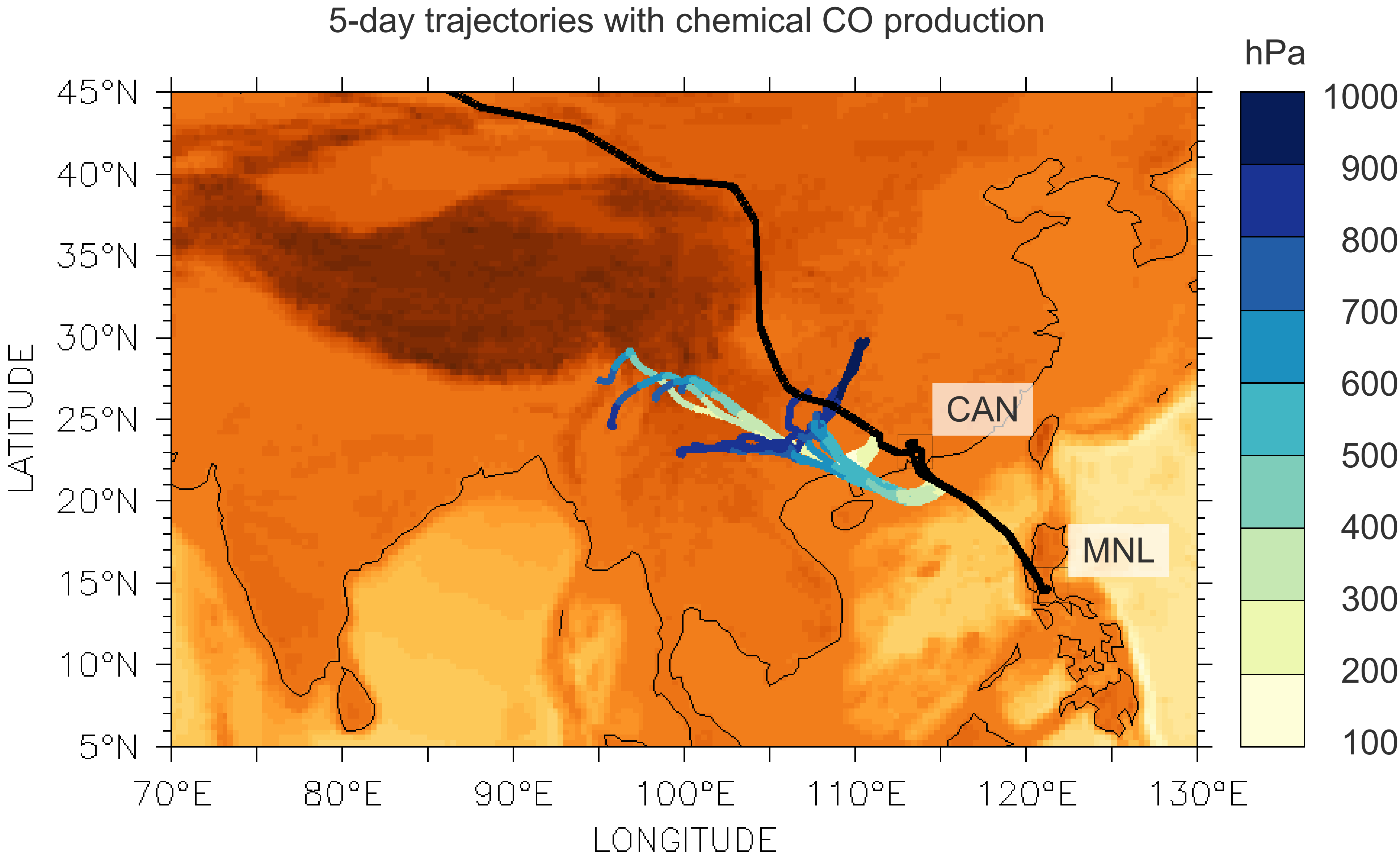




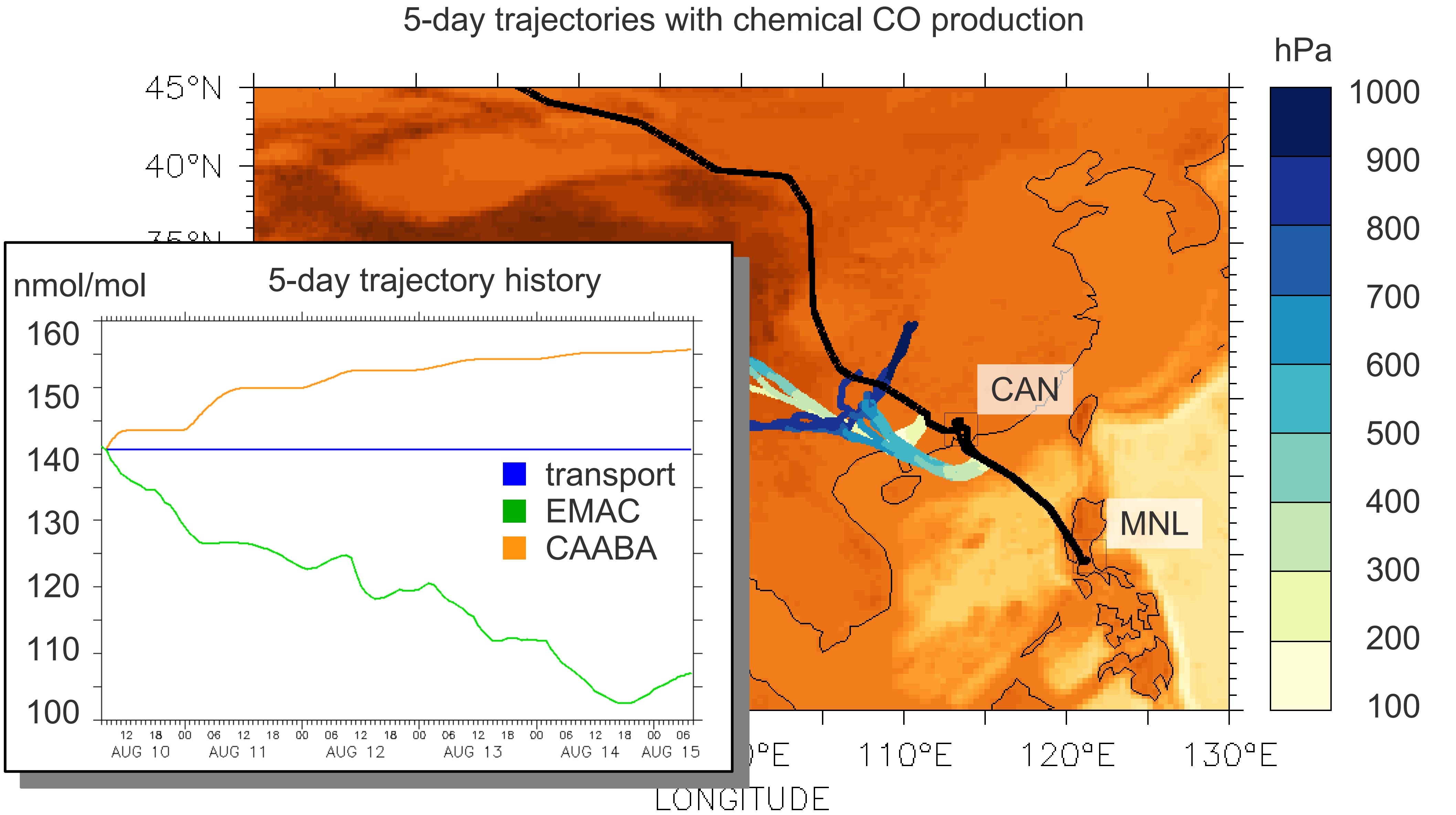
CO

- chemistry contribution up to 10 % of transport

China - catchment area



China - catchment area



Chemical lifetimes

	chemically active < 600 hPa	average (median)	reduction by %	min	max
NO	56 sec	30 (4) min	97	20 sec	3 days
HCHO	4 h	9 (6) h	55	3 h	6 days
NO2	4 h	18 (14) h	80	3 min	4 days
CH_3COCH_3	12 days	40 (20) days	70	8 days	3 years
CO	25 days	5 (3) months	80	12 days	20 years
O_3	15 days	450 (300) days	97	6 days	20 years

$HCHO + h\nu \rightarrow CO + H_2$

$HCHO \rightarrow CO + H_2O_2$

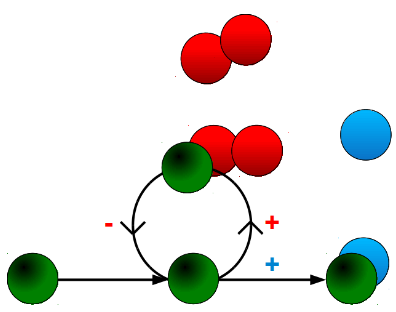
$HCHO + O_3 \rightarrow CO + H_2O + 2\ O_2$

photolysis, HO_x

$CO + O_3 \rightarrow O_2 + CO_2$

$CO + 2\ O_2 \rightarrow O_3 + CO_2$

and NOx chemistry



- identifying catalytic cycles
- identifying important pathways

R. Lehmann, J. Atmos. Chem., 2004

Summary

- CAABA in trajectory mode is an analytical tool to interpret 3-D model data from EMAC off-line
- observation-model comparisons → helps to understand why differences occur between model and observations
- it supplies additional information about the history of observed air masses

- EMAC (nudged) and ECMWF show similar transport patterns, EMAC is less variable
- relatively coarse model resolution → overestimated mixing in EMAC
- typical transport pattern and seasonal outflow (monsoon) of species lead to exceptional chemical activity
- hot spots of chemistry cause exceptional variations in chemical lifetimes

Thank you for your attention!

Atmospheric Chemistry Department

Chemistry due to mixing