JÜLICH
FORSCHUNGSZENTRUM

Export of air masses from the Asian monsoon anticyclonc circulation to the Northern Hemisphere midlatitude stratosphere

Bärbel Vogel, Gebhard Günther, Rolf Müller, Jens-Uwe Grooß, and Martin Riese
In-situ measurements:
Peter Hoor, Stefan Müller, Heiko Bozem, Martina Krämer, Christian Rolf, Andreas Zahn

UTLS Asian Monsoon | Boulder 7-10 March 2016 | R. Müller and B. Vogel et al.

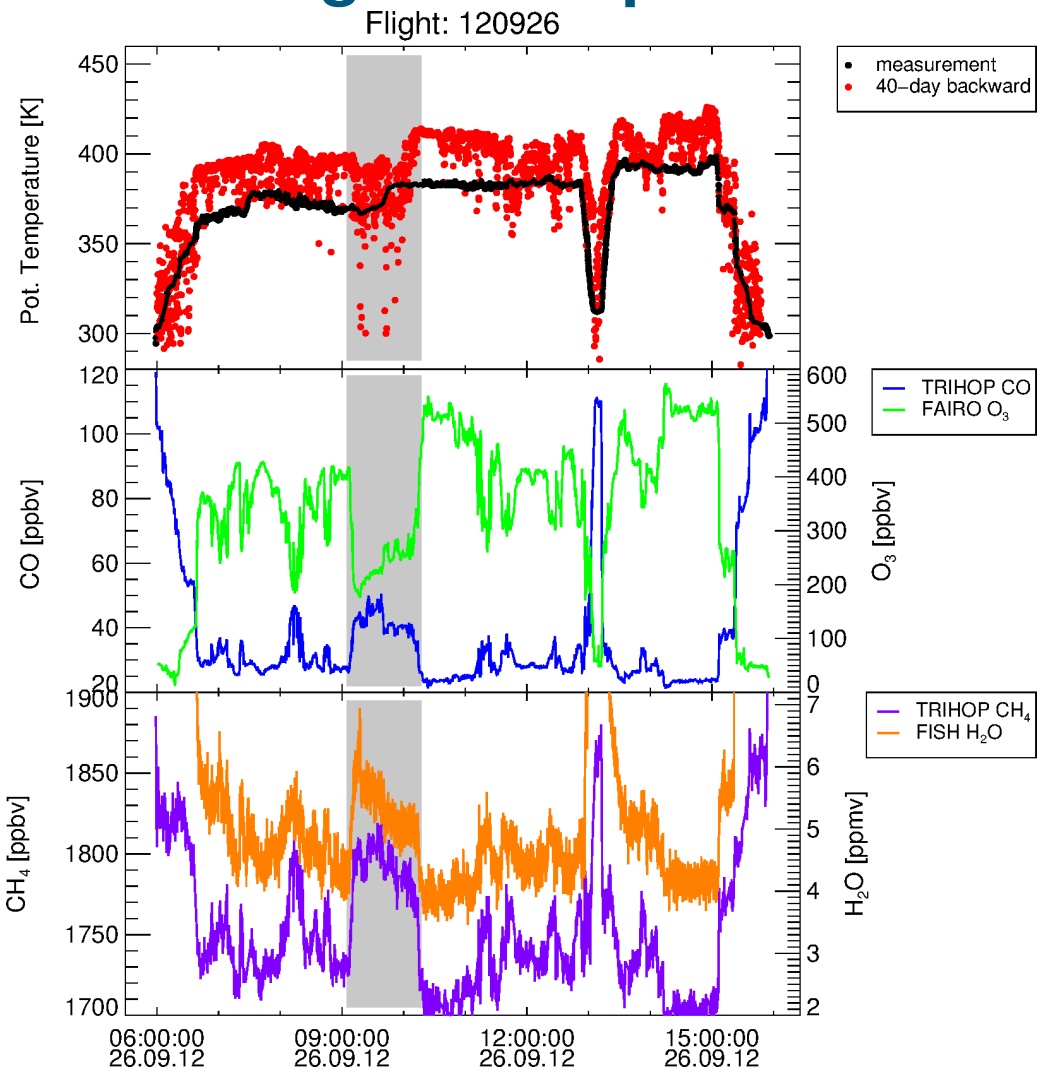
Overview

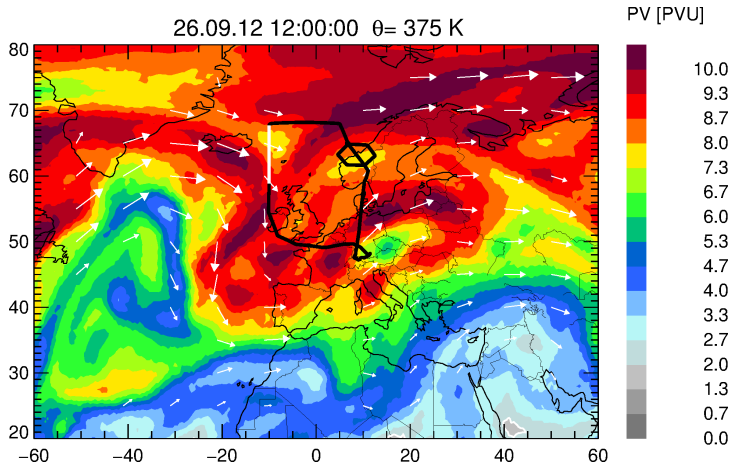
Main questions

- Which source regions in Asia affect the chemical composition of the extra-tropical lowermost stratosphere?
- What are the transport pathways through the the Asian monsoon anticyclone?

- Part I: trajectory calculations
  purely advective transport
- Part II: 3-dimensional CLaMS simulations with synthetic artificial emission tracers representing global boundary layer sources
  advection + mixing

TACTS Flight 26 September 2012



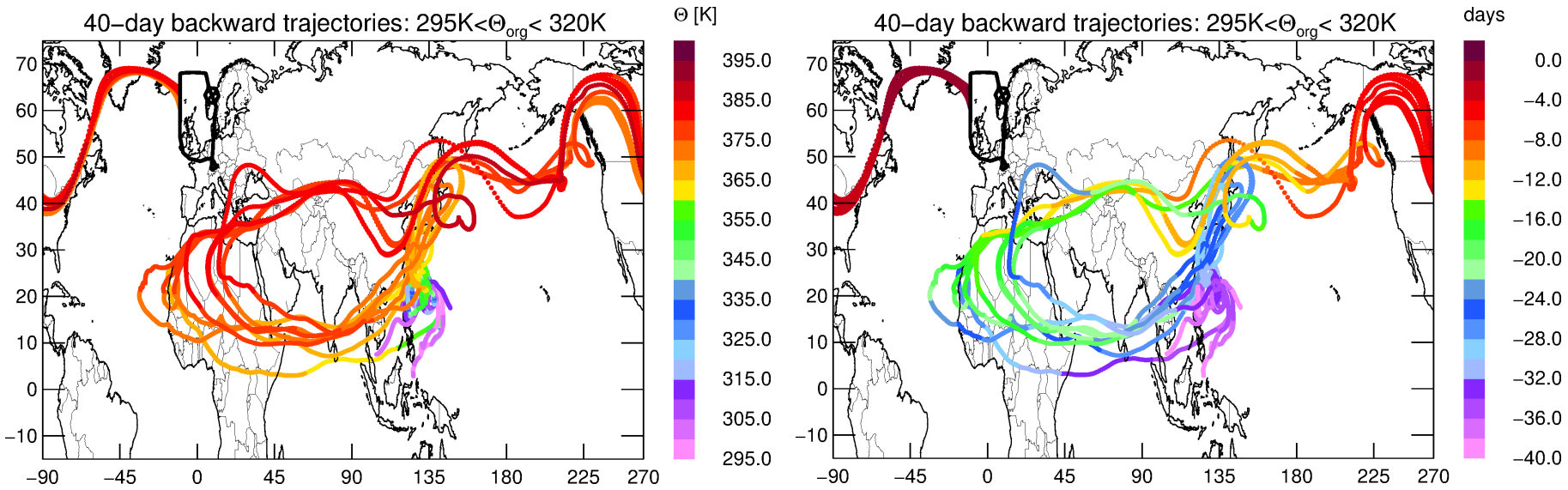


- region of interest
- in the stratosphere at 370 K – 380 K
- enhanced CO, CH_4, H_2O
- reduced O_3
- 40-day backward trajectories

Vogel et al., ACP, 2014

40-day backward trajectories: 1st level

air mass origin: 295 K $< \Theta_{org} <$ 320 K ($\approx$ boundary layer)



- air masses are affected by the Asian monsoon anticyclone
- clockwise circulation around the core of the AMA (upward spiral)
- separation from AMA $\approx$ 8 – 14 days before flight (26.09.12)

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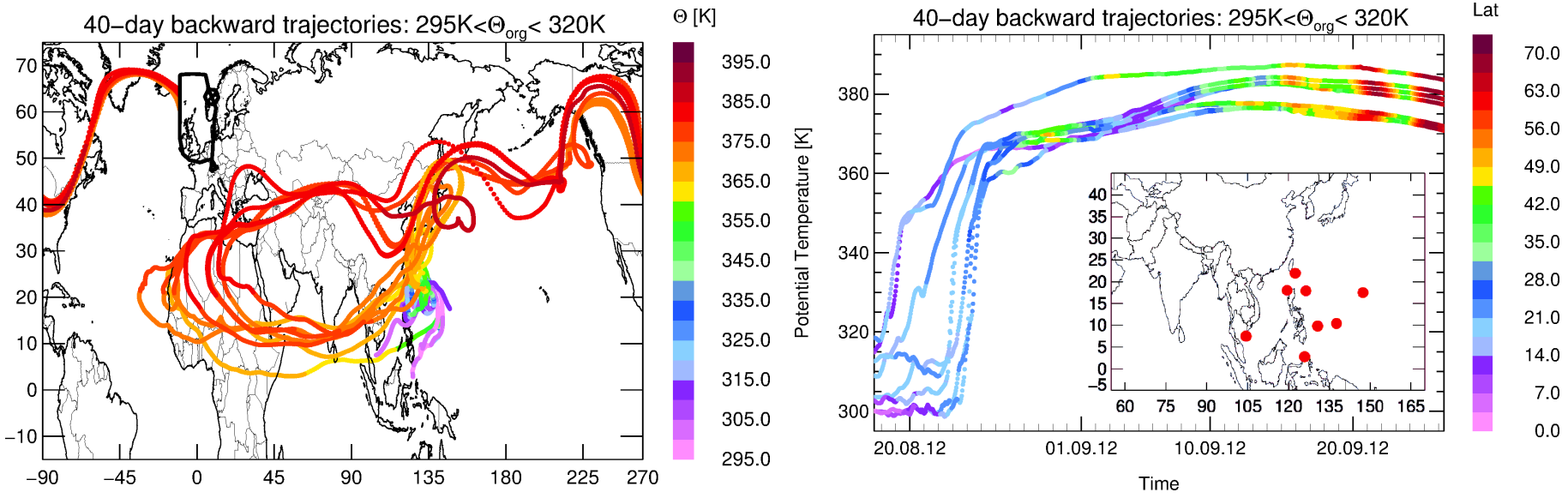
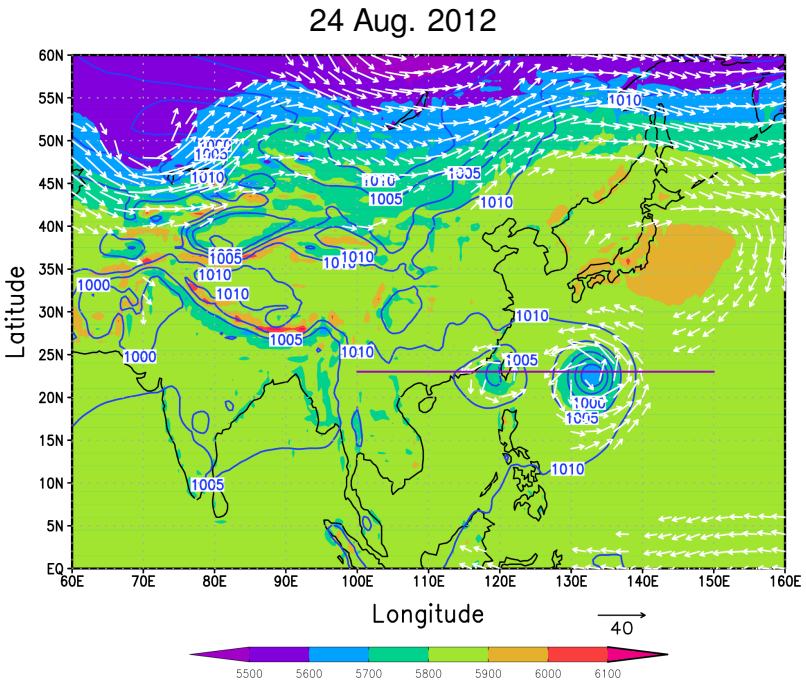


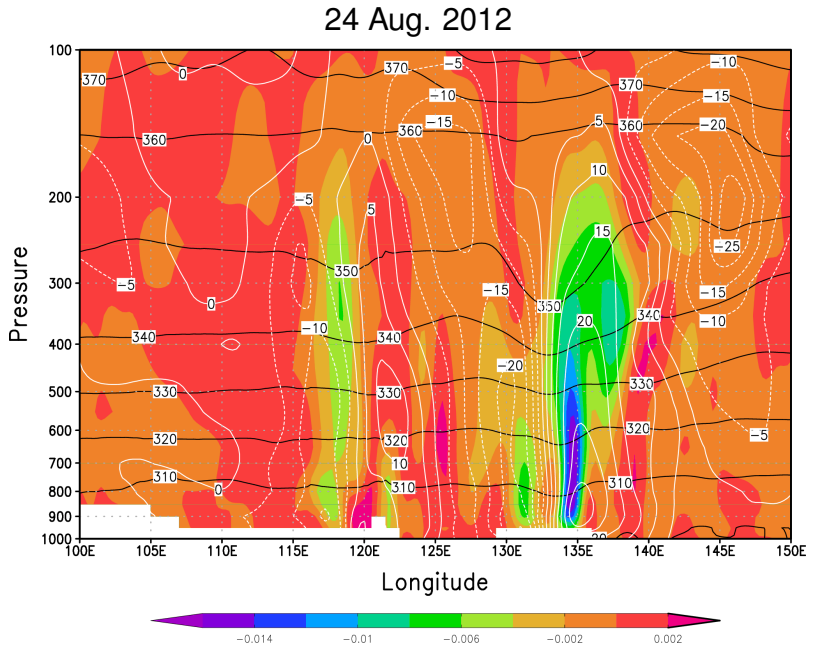
- air masses are affected by the Asian monsoon anticyclone
- clockwise circulation around the core of the AMA (upward spiral)
- separation from AMA $\approx 8-14$ days before flight (26.09.12)
- origin of air masses: Southeast Asia / boundary layer
- very rapid uplift up to 41 K/day (= 523 hPa/day)

Very rapid uplift in typhoons

Typhoon Tembin and Bolaven on 24 August 2012
category 4: Saffir–Simpson hurricane wind scale



geopotential height [m] at 500 hPa (color)
mean sea level pressure [hPa] (blue lines)

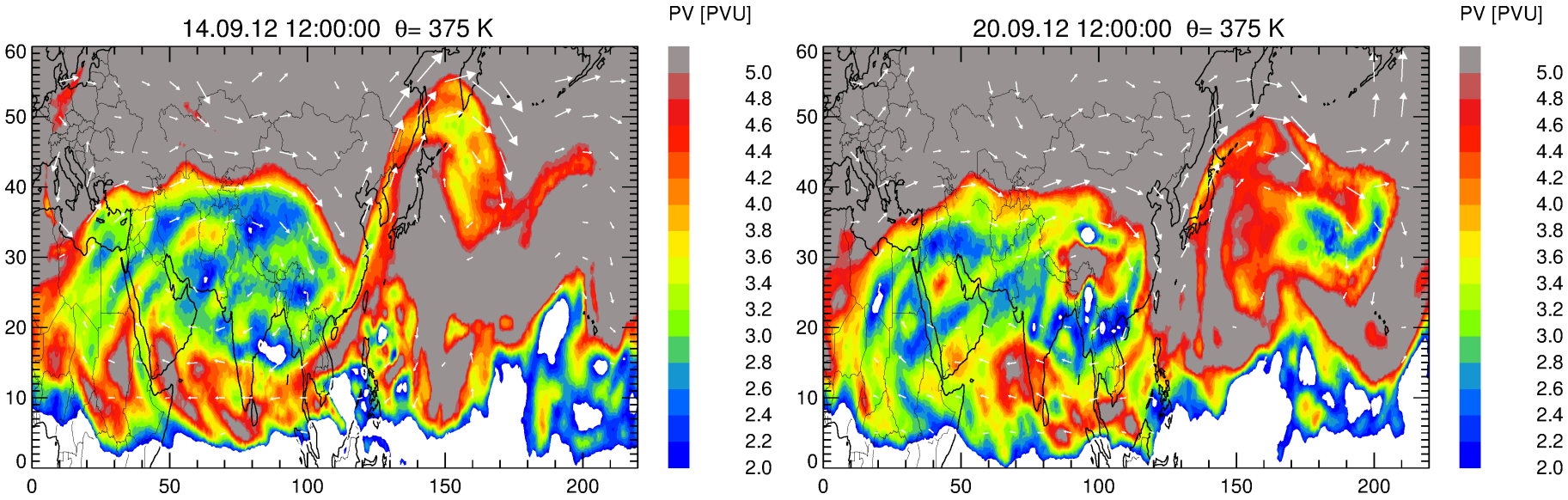


vertical velocity (ω) [hPa/s] (color) at 23° N
horizontal winds [m/s] (white lines)

→ Very rapid uplift at the eastern flank of typhoon Bolaven (≈135° E)

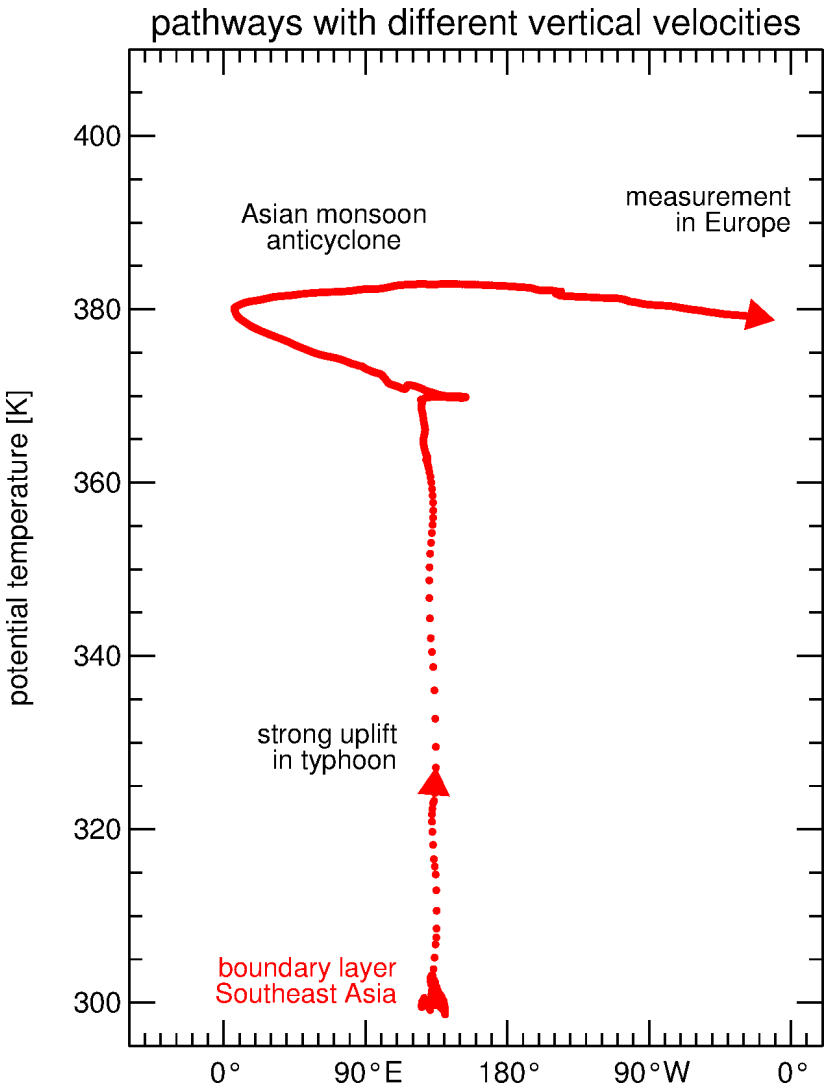
→ and at the western flank of typhoon Tembin (≈118° E)

Separation of air masses from the Asian monsoon anticyclone



- separation of filaments at the northeastern flank of the Asian monsoon along the subtropical jet
- eastward eddy shedding on 20 September 2012
- transport of tropospheric air with low PV (water vapour, pollutants,...) to Pacific Ocean

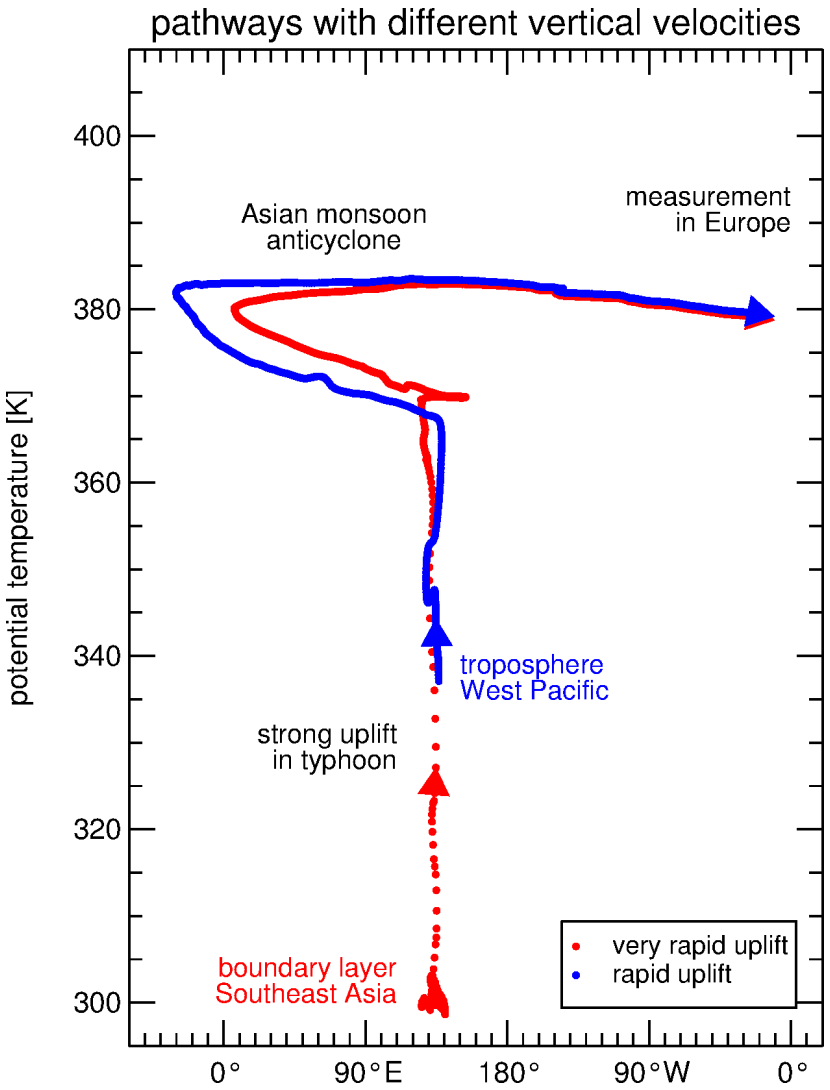
Transport pathways with different vertical velocities



- 295-320 K: very rapid uplift (2%)
  boundary layer
  Southeast Asia
- 320-360 K: rapid uplift (3%)
  troposphere
  mainly West Pacific
- 360-370 K: moderately rapid uplift (12%)
  AM anticyclone
  mainly South Asia / North Africa
- 370-380 K: moderate uplift (22%)
  UTLS
  edge of AMA
- 380-420 K: mainly decent (61%)
  lower stratosphere
  northern hemisphere

→ a mixture of air masses with different origins was probed during flight on 26 Sep. 2012

Transport pathways with different vertical velocities



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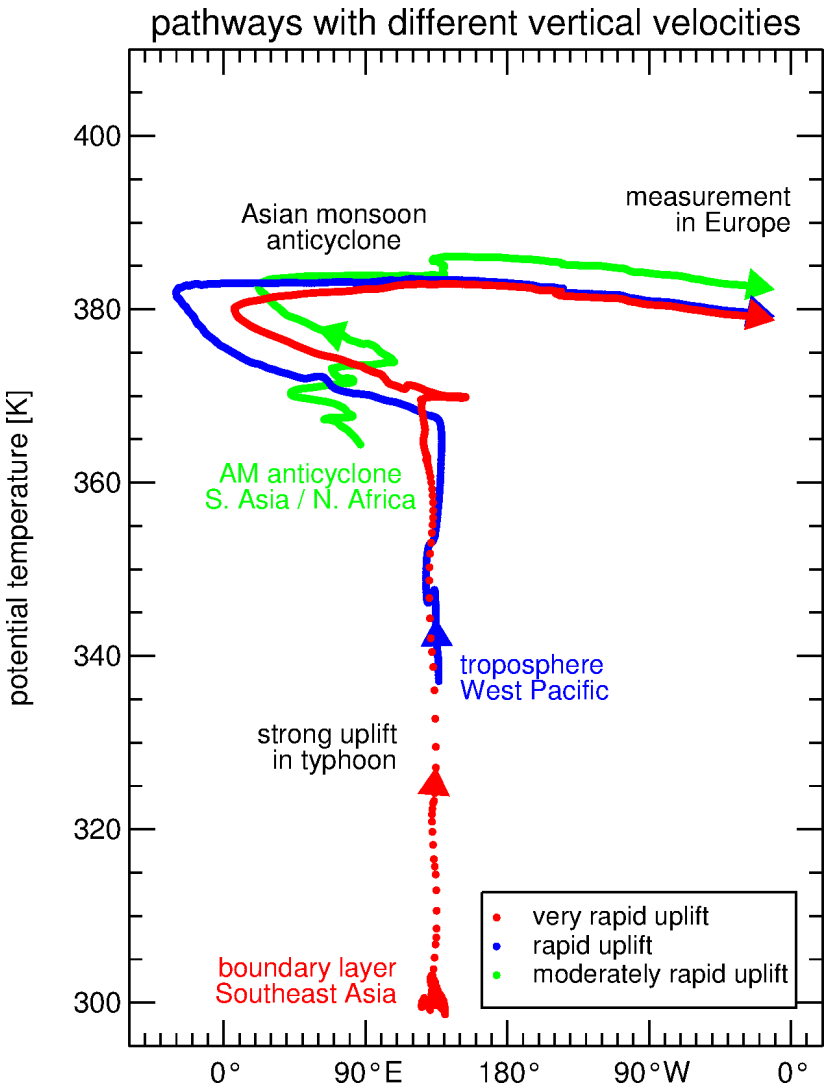

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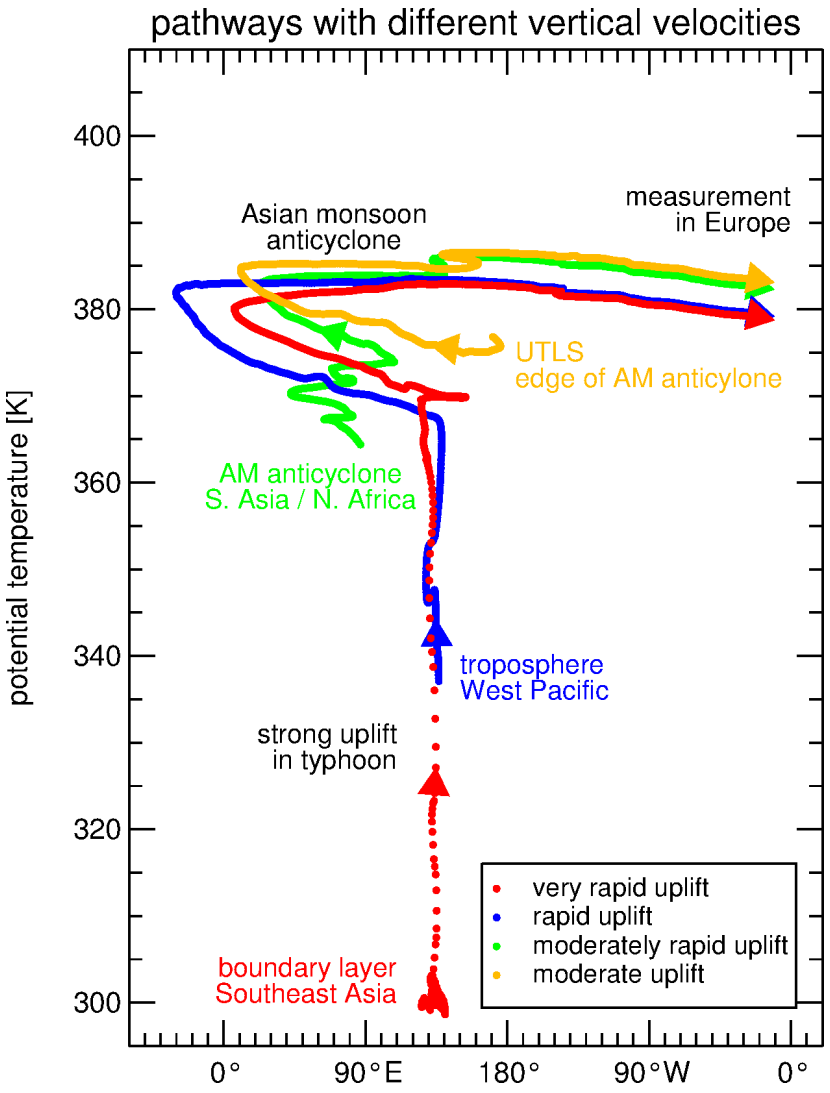

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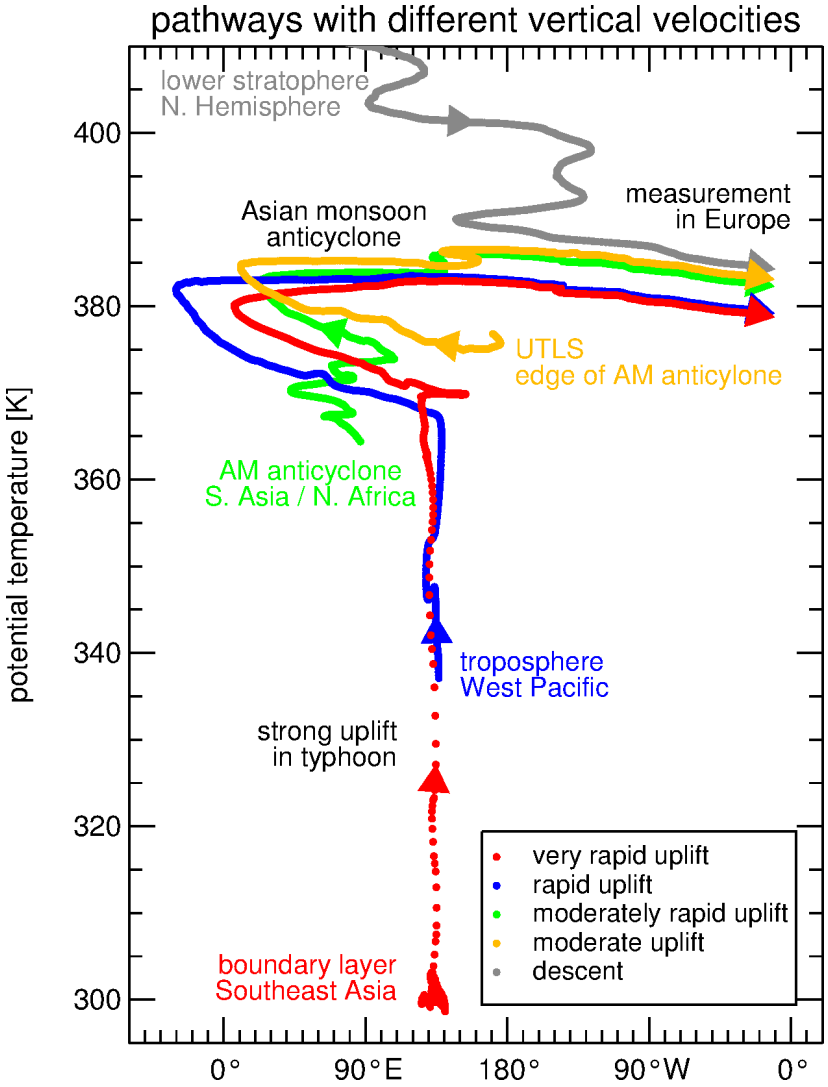

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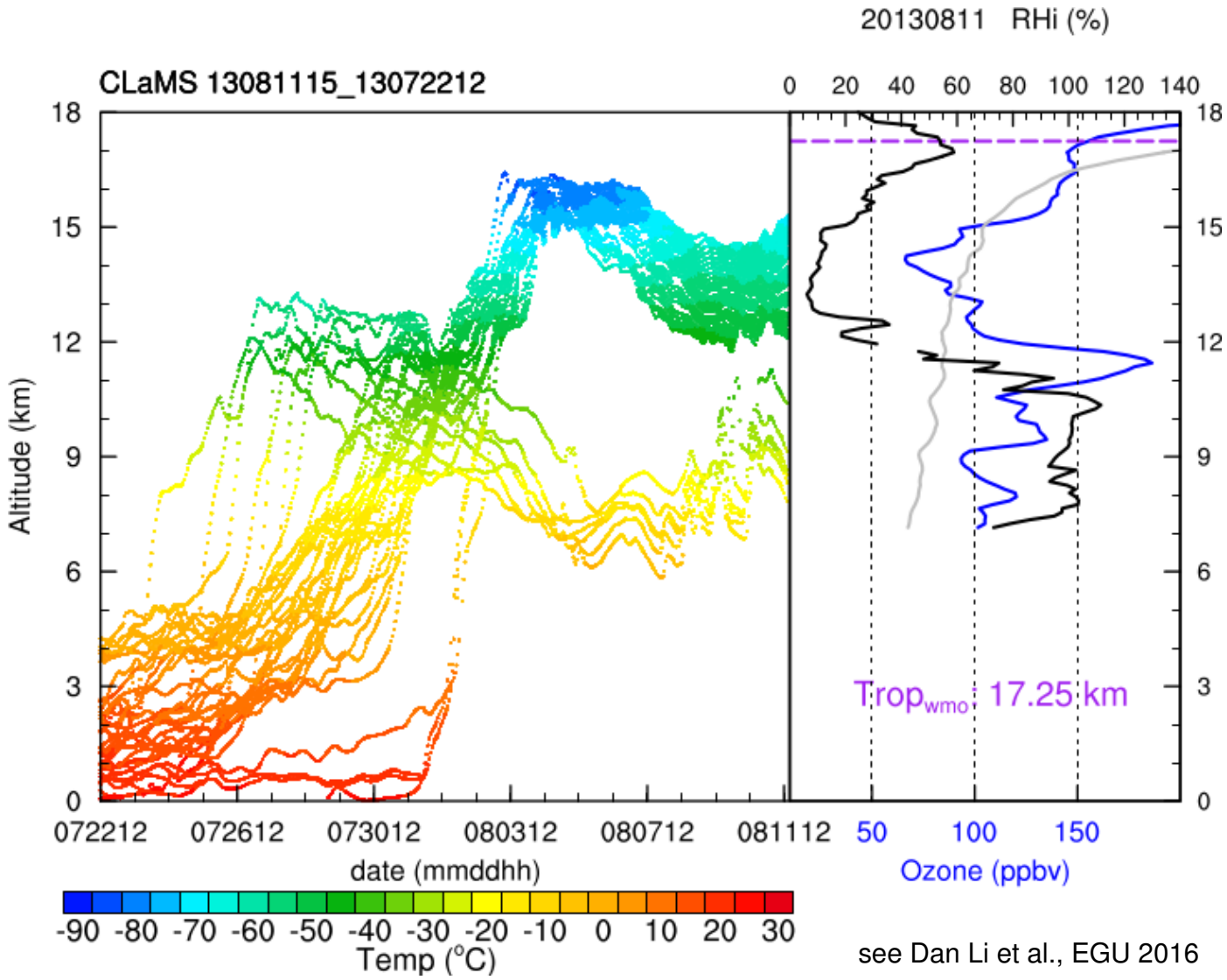
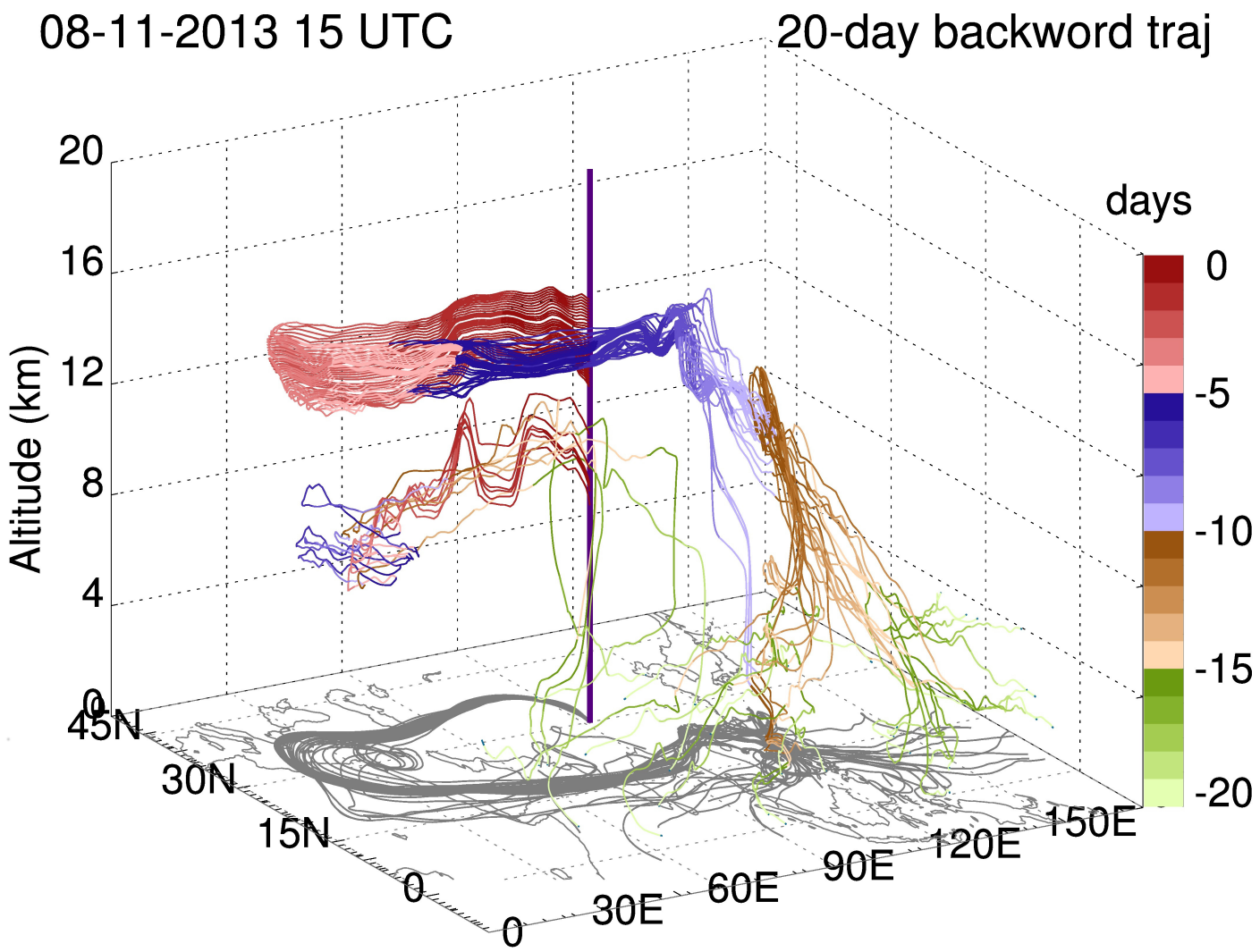
Impact of typhoon Jebi on AMA

Balloon measurements from Lhasa 13 Aug. 2013 (PI Jianchun Bian, Beijing)



see Dan Li et al., EGU 2016

Impact of typhoons on chemical composition of AMA



see Dan Li et al., EGU 2016

Part II

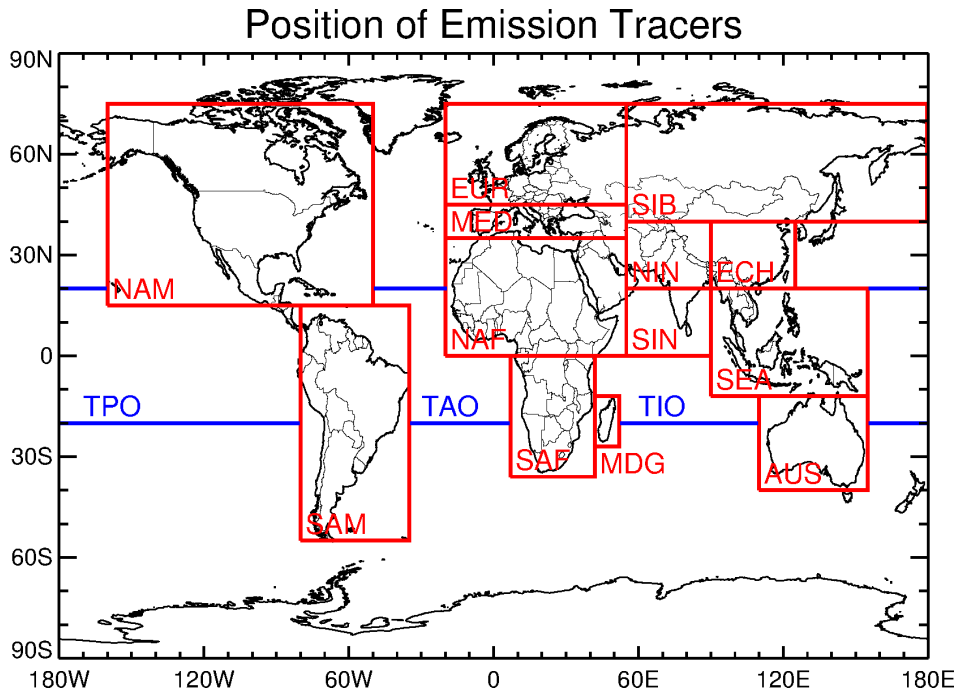
3-dimensional CLaMS simulations with synthetic artificial emission tracers representing global boundary layer sources:

advection + mixing

CLaMS simulation for Asian monsoon season 2012

CLaMS = Chemical Lagrangian Model of the Stratosphere

- 3-D global CLaMS simulation (May - Oct. 2012)
- driven by ERA-Interim
- 100 km horizontal resolution / max. vertical resolution at tropopause ≈ 400 m
- with full stratospheric chemistry



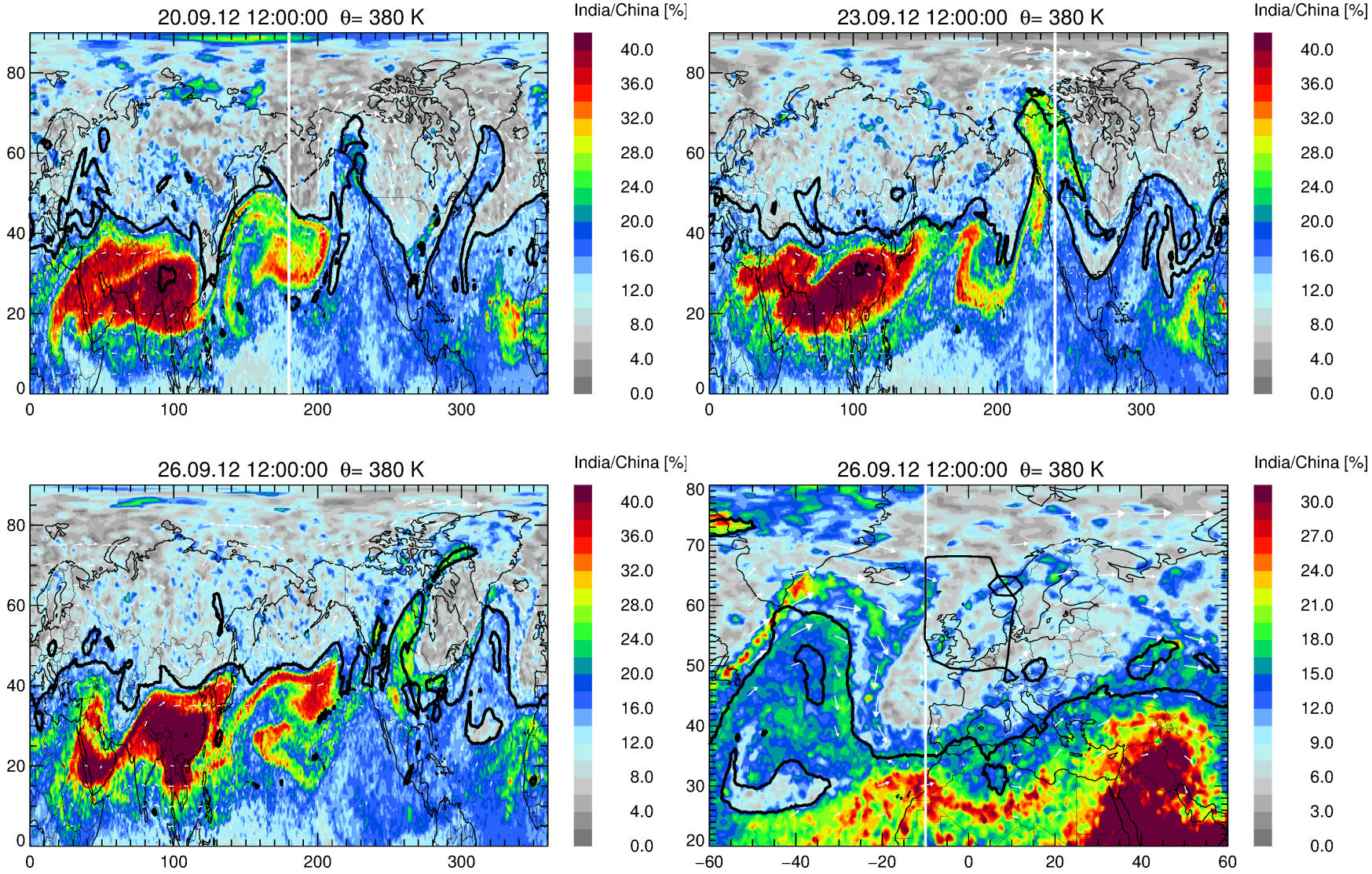
Vogel et al., ACP, 2015

- with artificial emission tracers representing different boundary layer source regions: e.g. North India, South India, East China, Southeast Asia

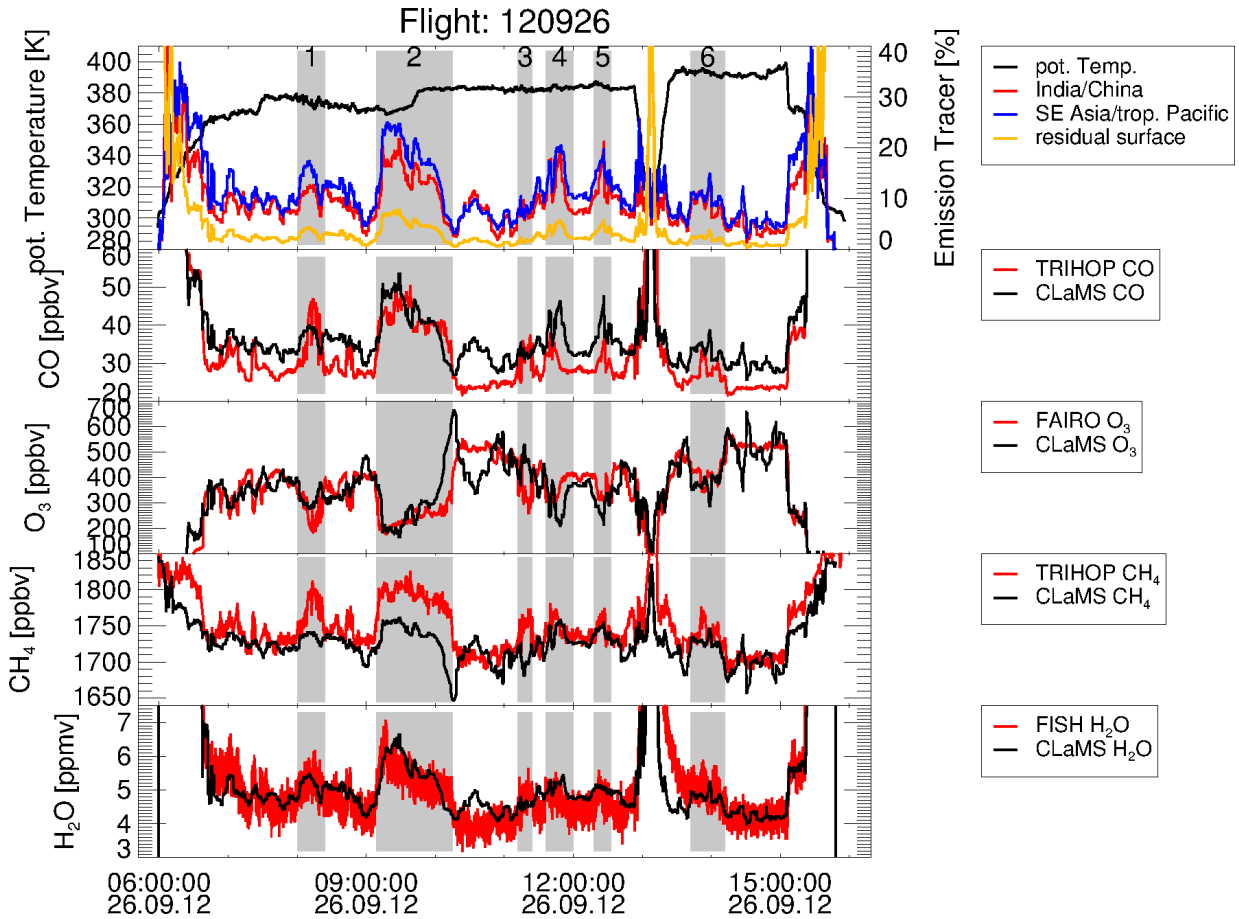
(Günther et al, 2008; Vogel et al., 2011)

Long-range transport to Northern Europe

Separation of Filaments and eastward eddy shedding

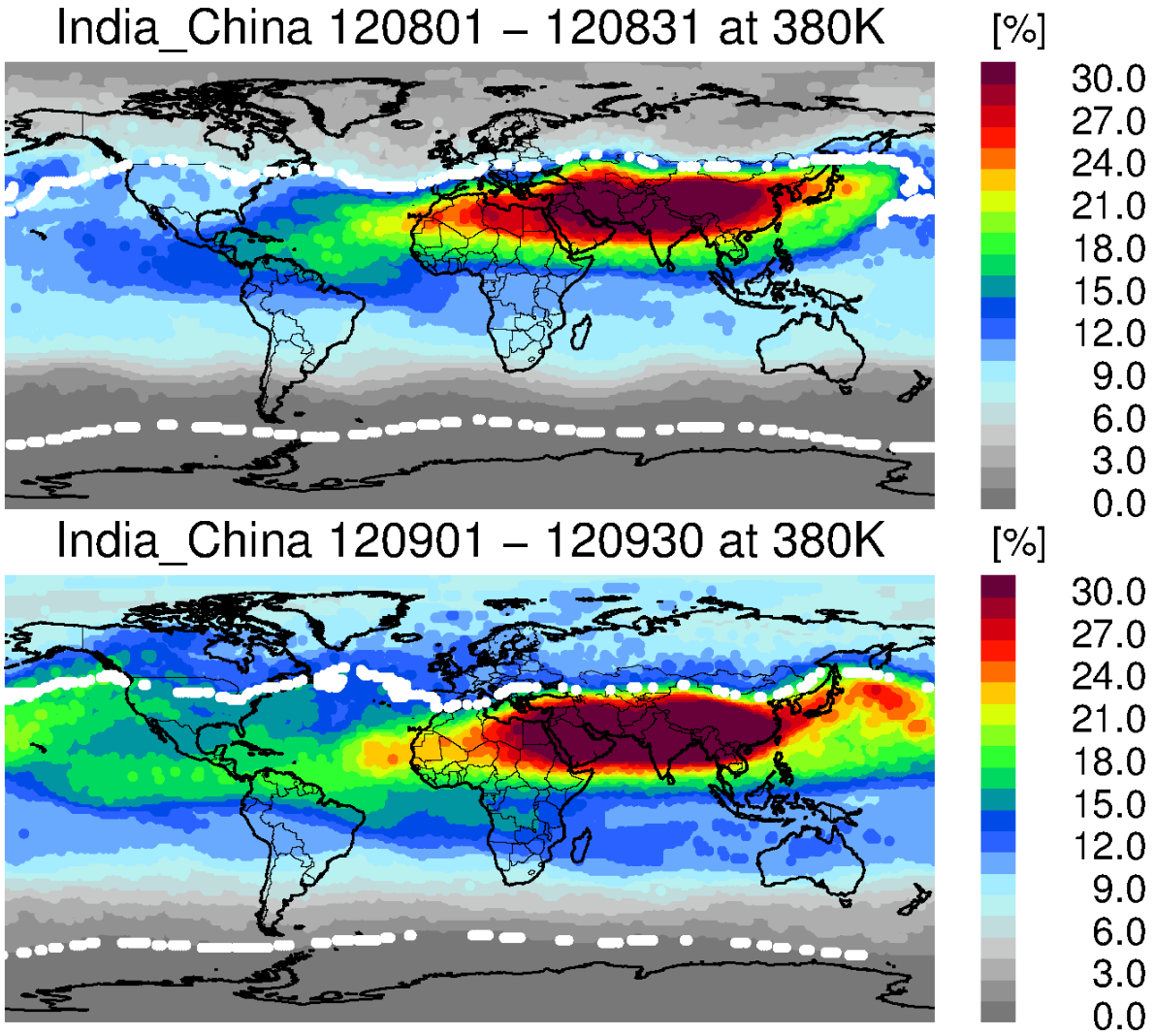


CLaMS vs. in-situ measurements on 26 Sep 2012



- enhanced contributions of emissions from India/China (up to 22 %) and Southeast Asia / tropical Pacific Ocean (up to 24 %)
- the sum of all other surface regions are below 7 %
- good agreement between CLaMS results and in-situ measurements

Horizontal transport pathway into the ExLS



Aug. 2012

Sep. 2012

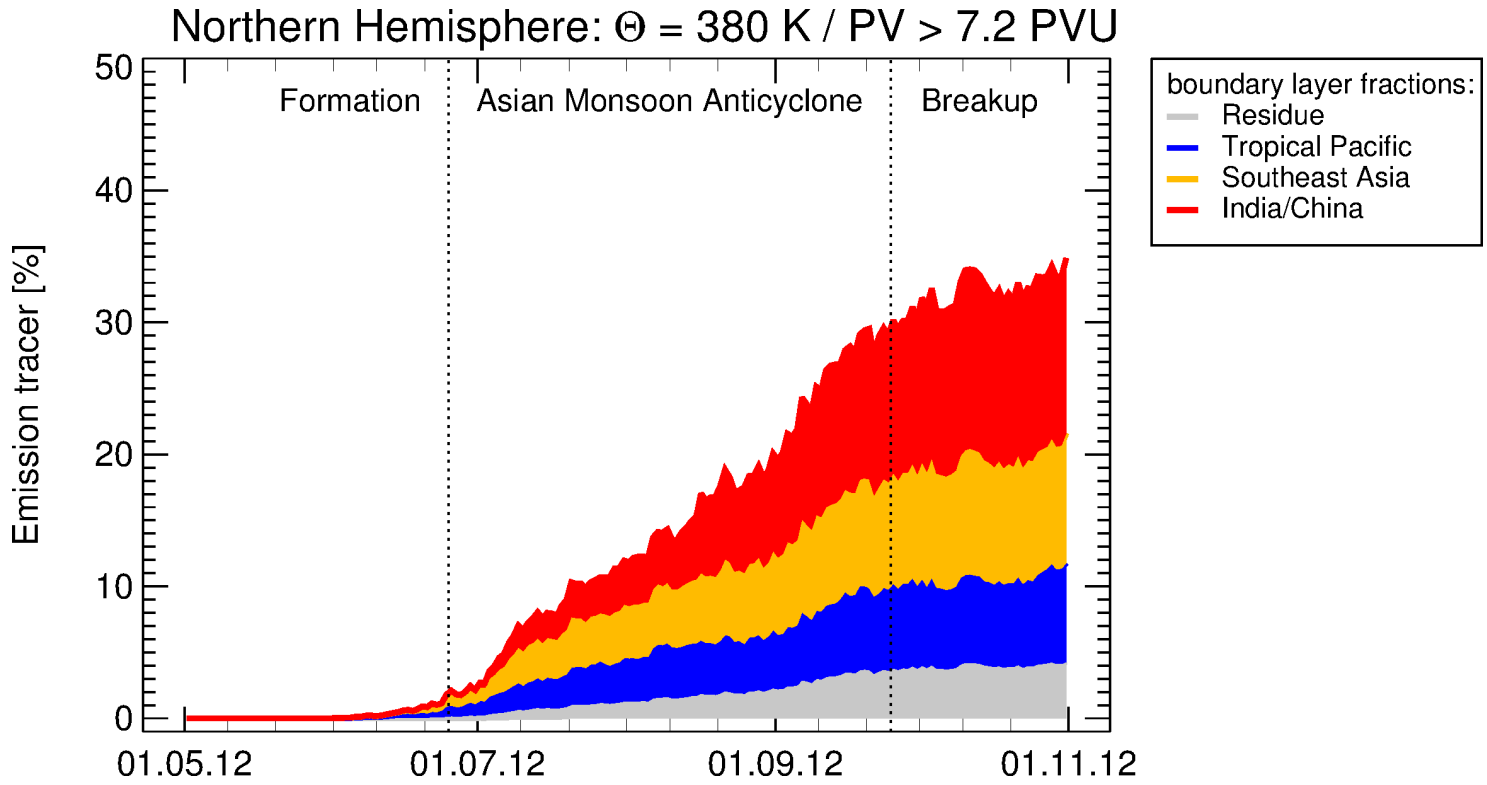
Vogel et al., ACP, 2016,

to be submitted

PV = 7.2 PVU at 380 K climatological isentropic transport barrier in summer NH (Kunz et al., JGR, 2015)
PV = -11.5 PVU at 380 K in southern hemisphere

Contributions of different source regions to the ExLS

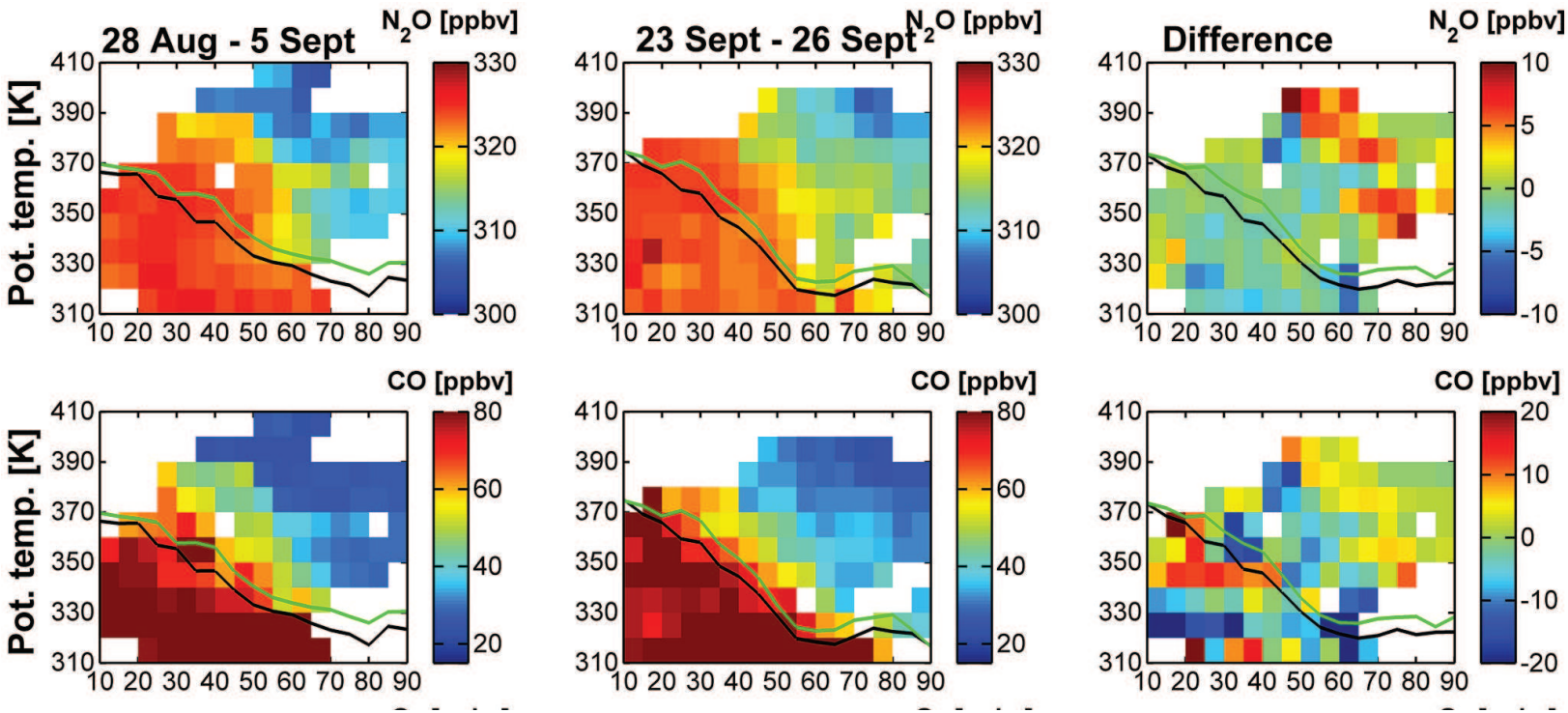
Flooding of the Northern Hemisphere in Sep/Oct 2012



- Asian Monsoon Anticyclone (India/China)
- Air mass from Southeast Asia and Tropical Pacific circulating around the AMA
- Other source regions have minor impact

TACTS N2O and CO measurements

Flooding of the Northern Hemisphere in Sep/Oct 2012



Stefan Müller et al, ACPD, 2015

Summary and Conclusions

- fast transport (5 weeks) from boundary sources in Southeast Asia to Northern Europe caused by the combination of rapid uplift by a typhoon and eastward eddy shedding from the Asian monsoon anticyclone
- transport pathway from AMA eastwards along subtropical jet afterwards transport into ExLs most likely by Rossby wave breaking events
- air parcels from Southeast Asia / Western Pacific circulate clockwise, in an upward spiral, around the anticyclone
- Air masses from Asia have a significant impact on the chemical composition of the northern lowermost stratosphere in Sep 2012

Vogel et al., 2014, ACP ; Vogel et al., 2016, ACP, to be submitted