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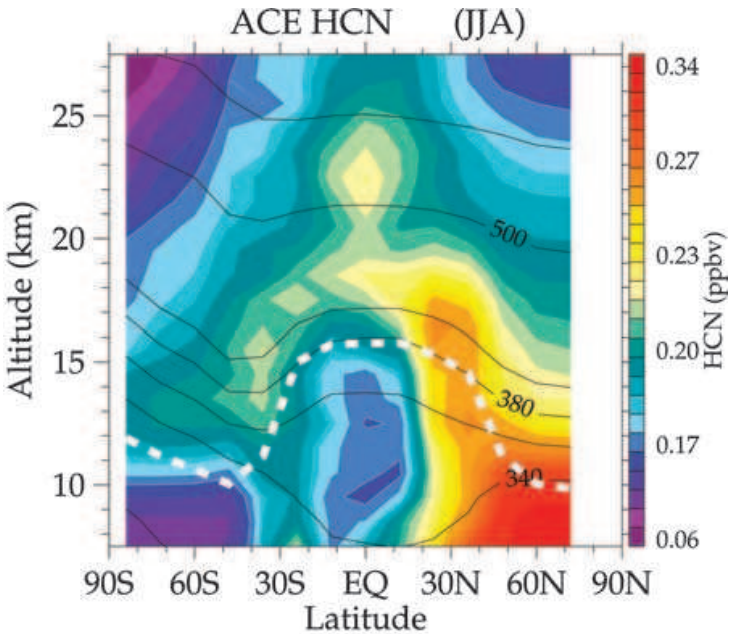
CLaMS simulations of young air masses transported to the tropopause in the Asian monsoon

Bärbel Vogel, Gebhard Günther, Rolf Müller, Gabi Stiller, Jens-Uwe Grooß, and Martin Riese

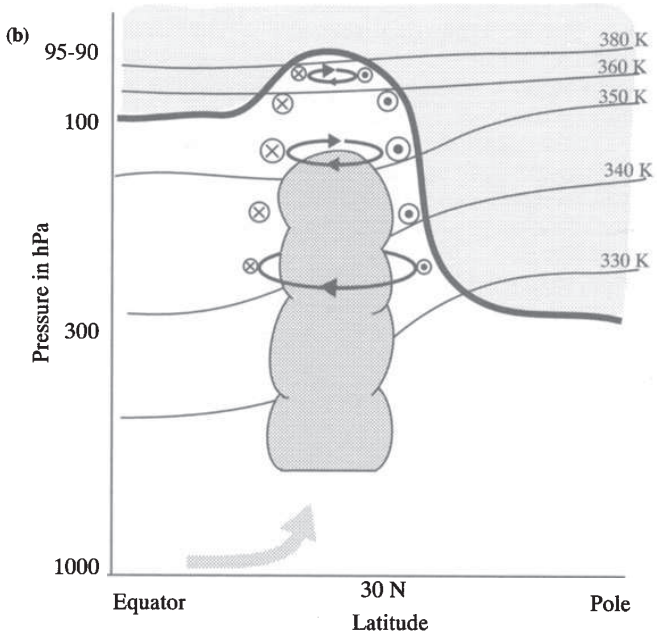
UTLS Asian Monoon | Boulder 7-10 March 2016 | B. Vogel et al.

Asian monsoon anticyclone (AMA)

Transport pathways from AMA into the lower stratosphere?



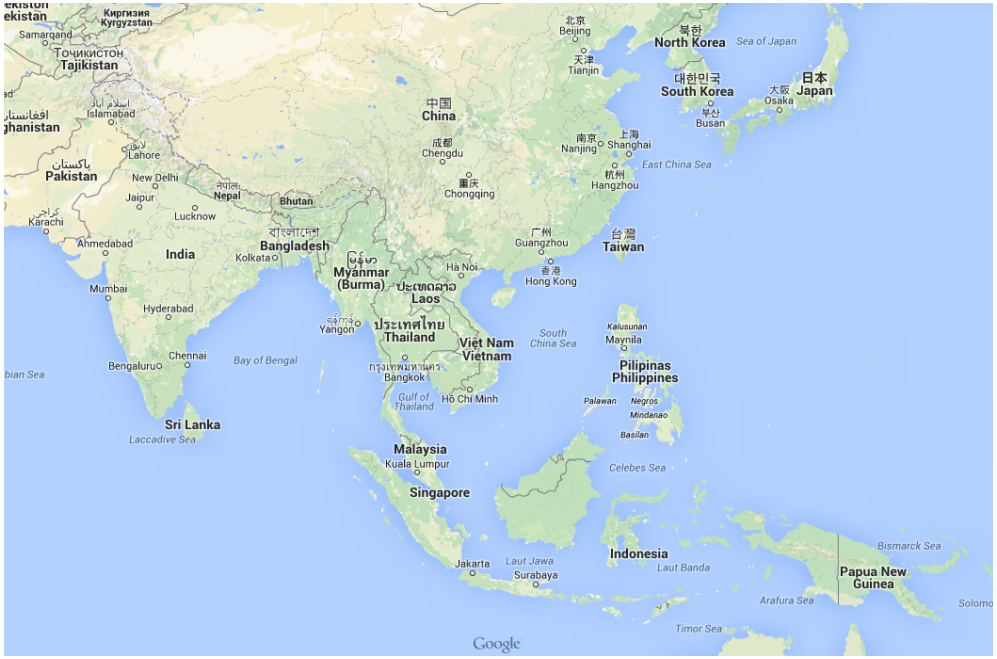
Randel et al., Science, 2010



Dethof et al., Q., J. R. Met. Soc., 1999

- Randel et al.,Science, 2010
- Bourassa et al., Science 2012
- .....

Impact of different Asian sources regions on the composition of Asian monsoon anticyclone (AMA)?



- Bergman et al., 2013: Tibetan Plateau / India (at 100 hPa)
- Chen et al., 2012: tropical Western Pacific region / South China Seas (at tropopause)
- Park et al., 2009: India / Southeast Asia
- Li et al., 2005: Northeast India / Southwest China
- ...
- short periods within the monsoon season or mean values of the entire monsoon season

Content

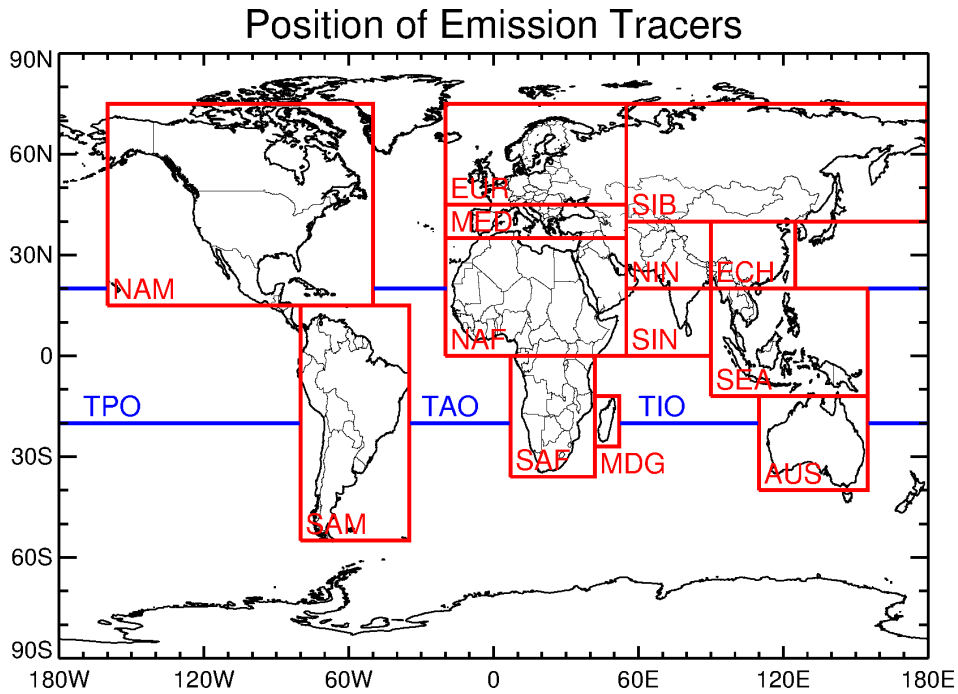
Two main questions:

- What is the impact of different boundary layer source regions in Asia on the composition of air in the Asian monsoon anticyclone during monsoon season 2012?
- Transport across the tropopause above the Asian monsoon anticyclone: Bubble or chimney ?

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



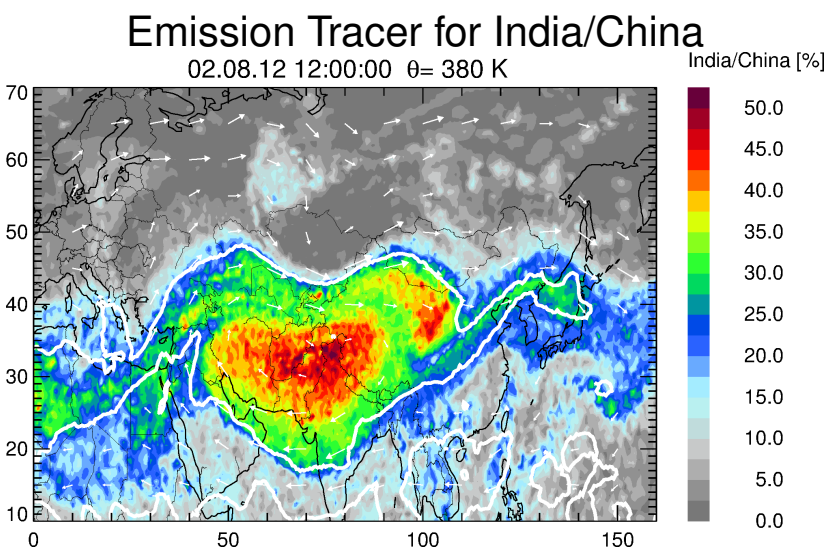
Vogel et al., ACP, 2015

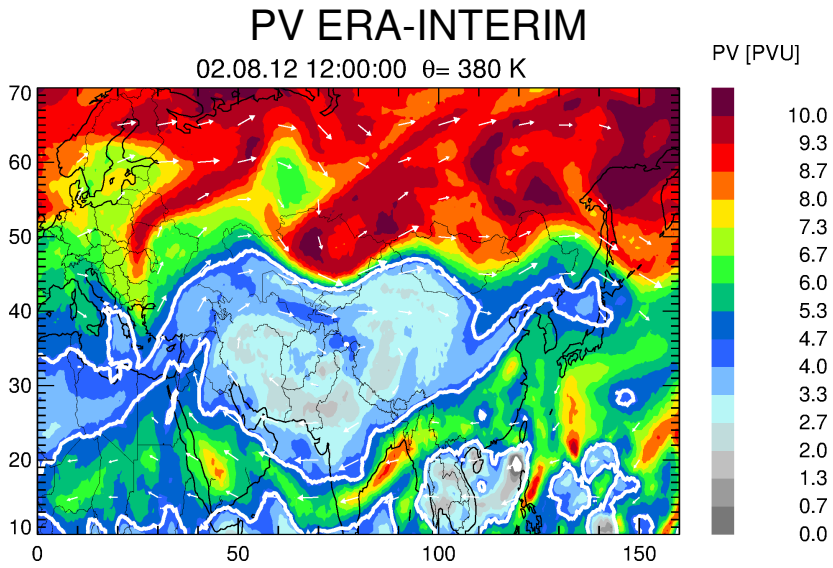
- with artificial emission tracers representing different boundary layer source regions: e.g. North India, South India, East China, Southeast Asia

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

Emission Tracer for India/China

2 Aug 2012 at 380 K (≈ 16 km)



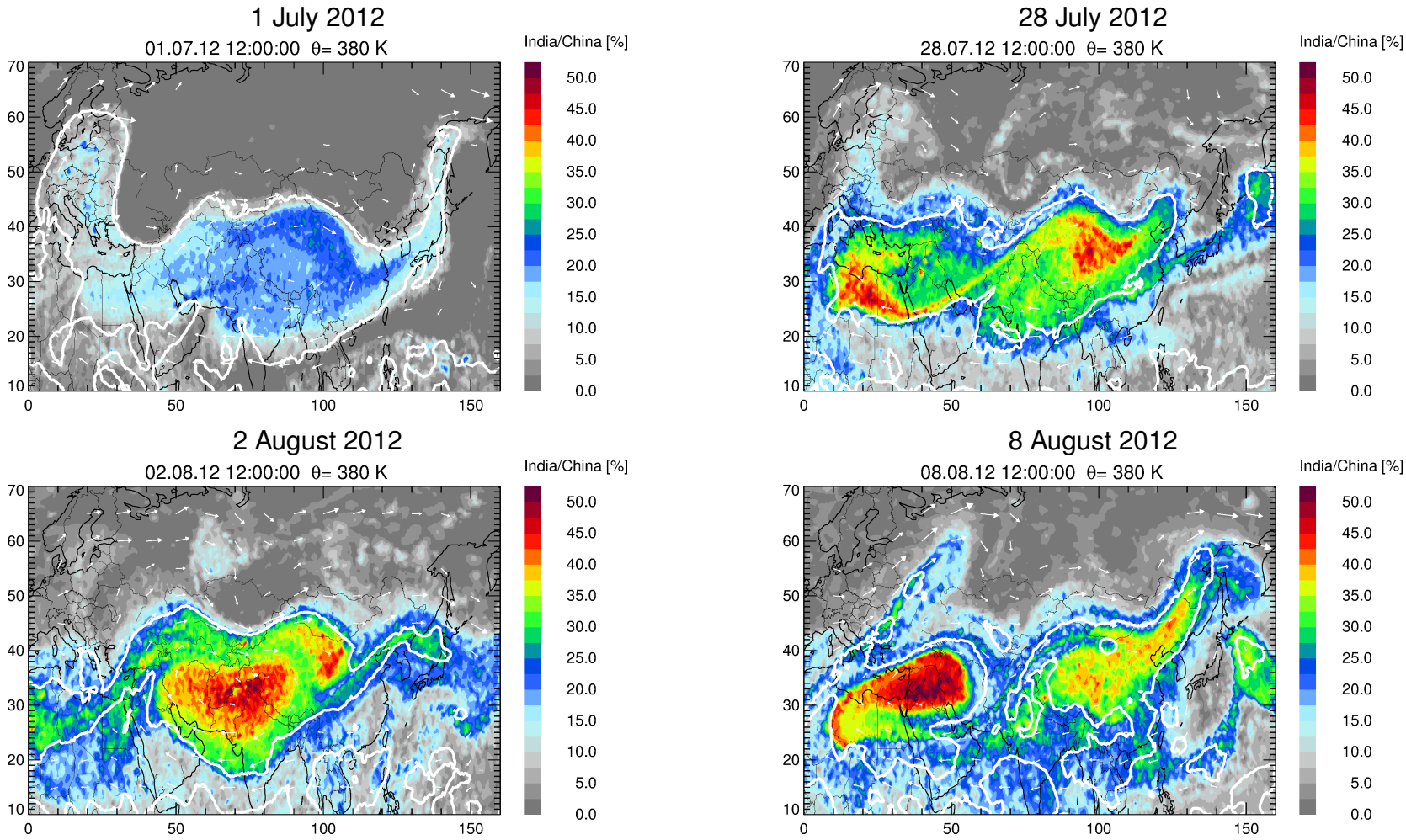


white line: PV = 4.5 PVU (Ploeger et al., ACP, 2015)

- strong pattern correlations between emission tracer India/China and PV r(t)= -0.71 — -0.87 (July - Sep)
- strong pattern correlation at 360-400K (July - Sep 2012) India/China to MLS(CO): r(t)=0.6 — 0.8
- emission tracer for India/China is a good proxy for location and shape of the anticyclone

Variability of the Asian Monsoon Anticyclone

Emission tracer for India/China at 380 K (≈ 16 km)

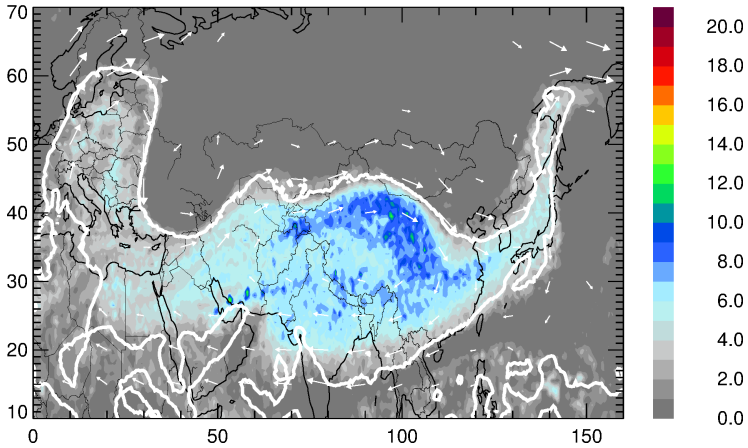


- strong variability in location and shape of the anticyclone

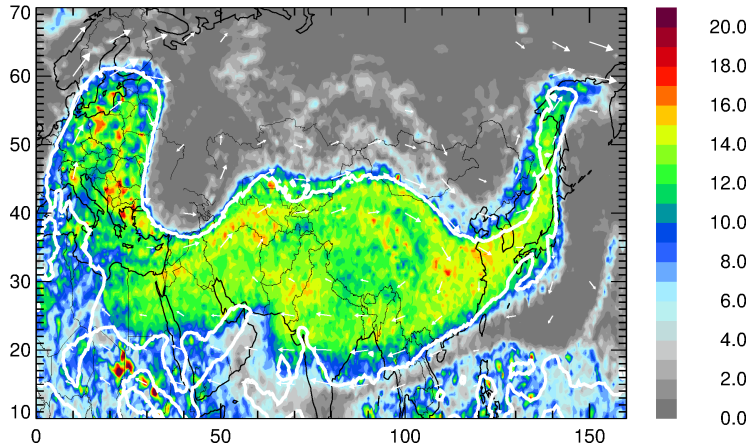
Impact of different emission tracers to the AMA

1 July 2012 at 380 K

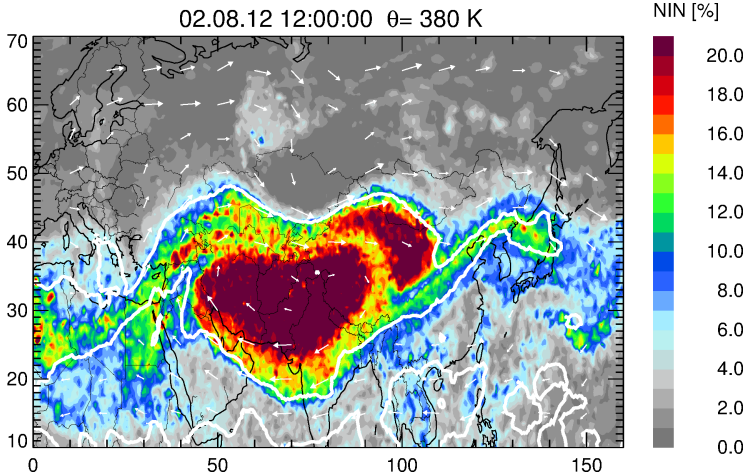
North India (NIN)

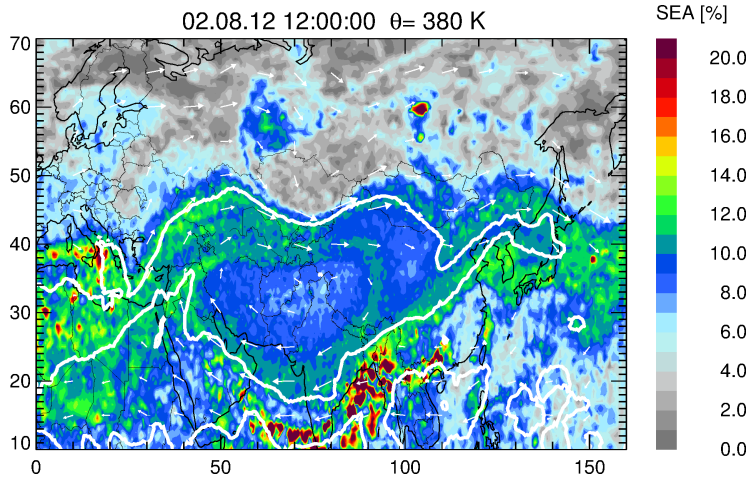


Southeast Asia (SEA)



2 August 2012 at 380 K

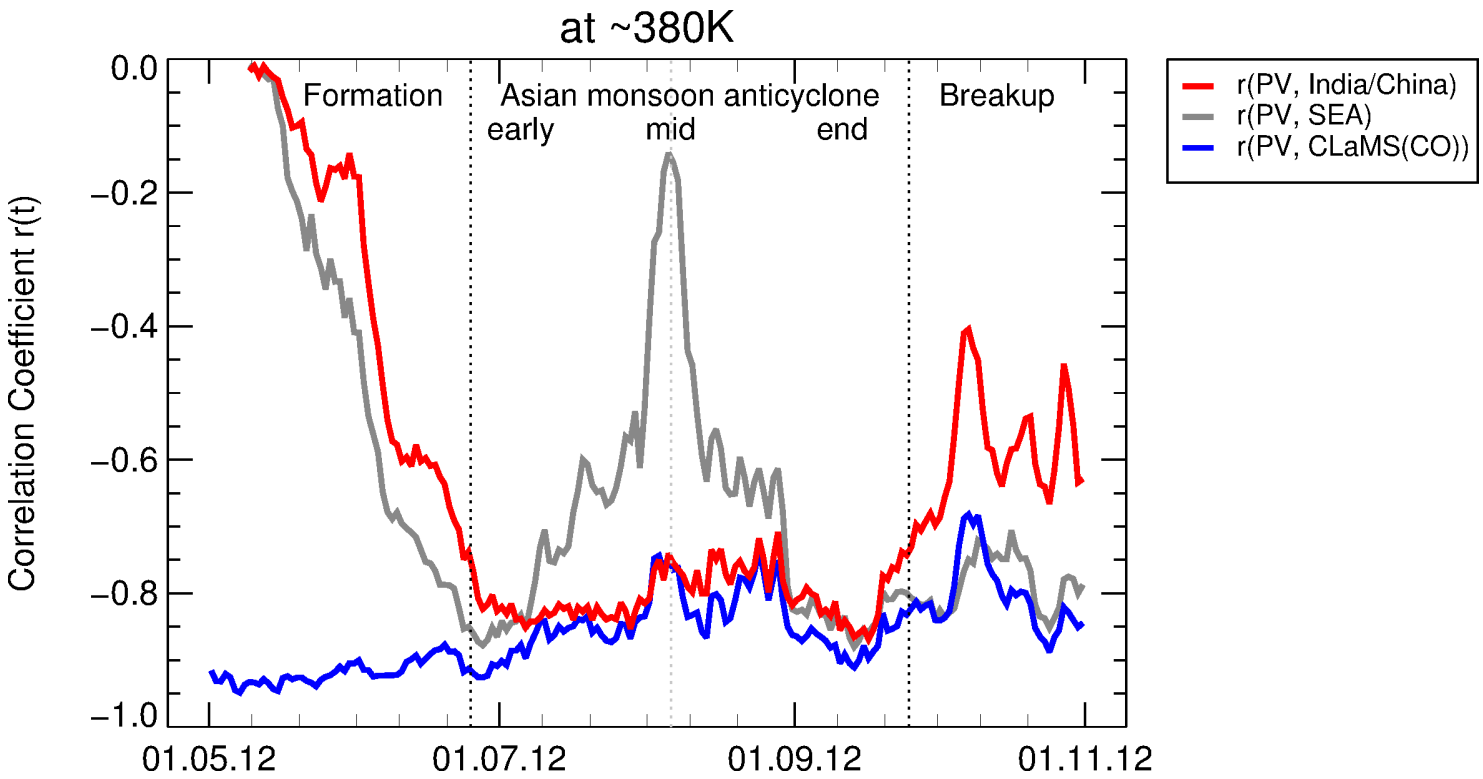




→ strong intraseasonal variability of emission tracers for North India and Southeast Asia

Correlation Coefficients

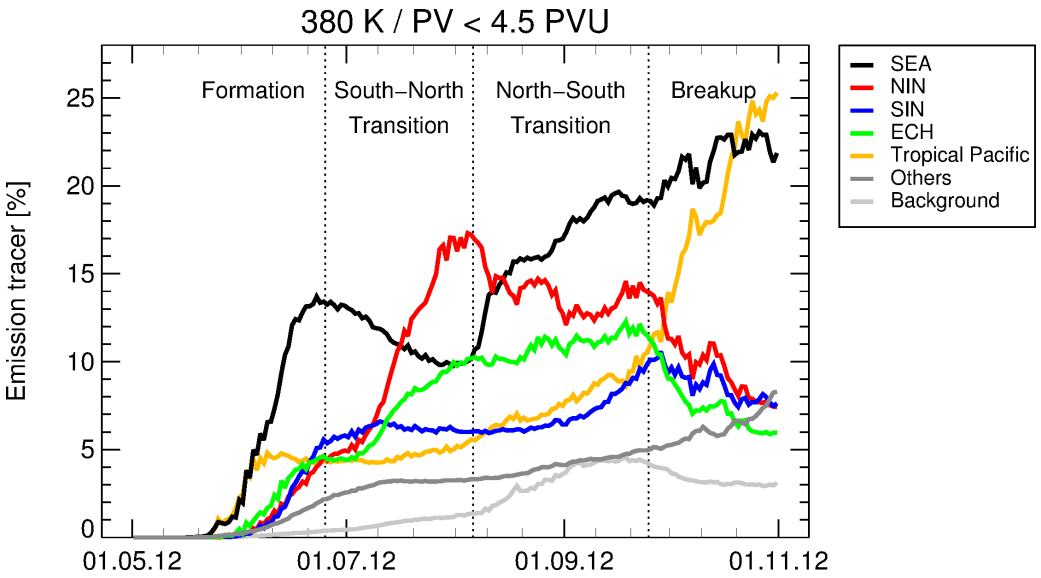
between several emissions tracers with ERA-Interim PV



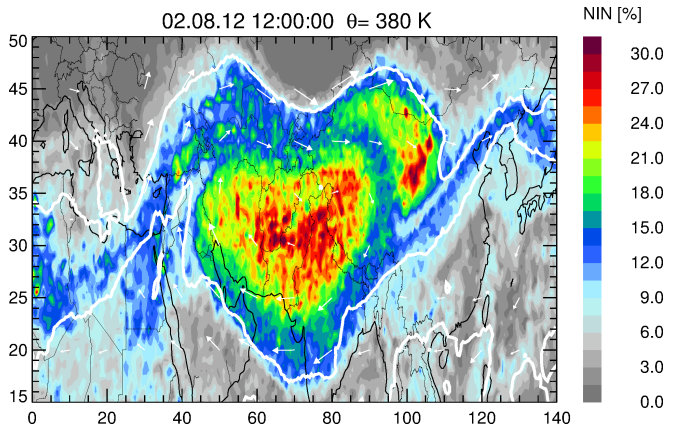
Temporal evolution of different emission tracers

within the Asian monsoon anticyclone at 380 K

Mean value of different emission tracers



Emission tracer for North India



$15 - 50^{\circ}$ N, $0 - 140^{\circ}$ E , 380 K $\pm$ 0.5 K
PV $<$ 4.5 PVU (white line);
Ploeger et al., ACPD, 2015

Southeast Asia North India South India
East China tropical Pacific Ocean

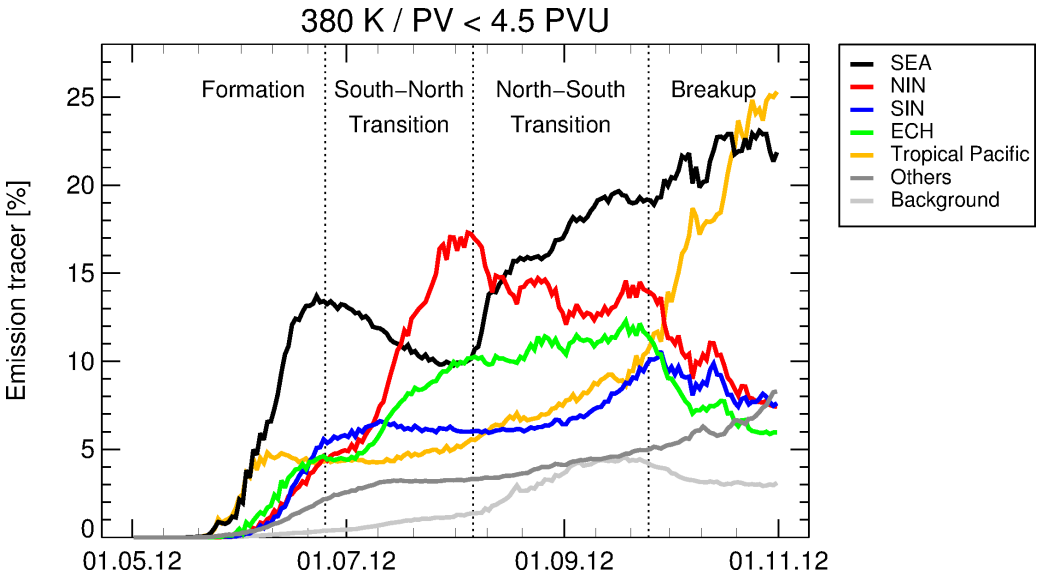
Vogel et al., 2015, ACP

- strong intraseasonal variability: South-North shift
- highest contributions from North India and Southeast Asia
- emissions from other land masses are of minor importance
- composition of AMA is a fingerprint of variation in convective processes

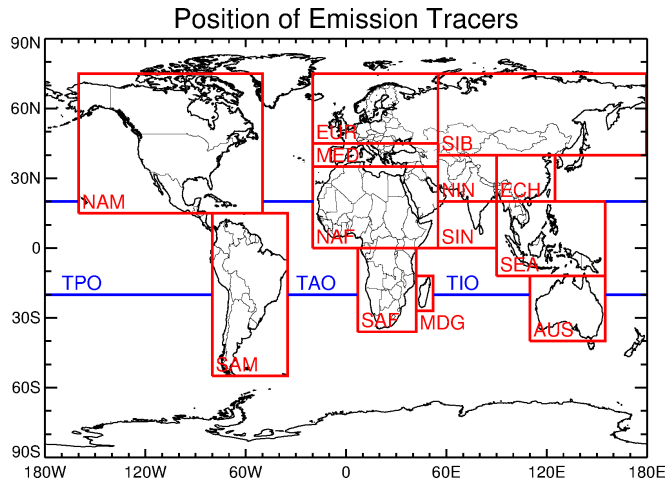
Temporal evolution of different emission tracers

within the Asian monsoon anticyclone at 380 K

Mean value of different emission tracers



Different emission tracers



Southeast Asia North India South India
East China tropical Pacific Ocean

Vogel et al., 2015, ACP

- strong intraseasonal variability: South-North shift
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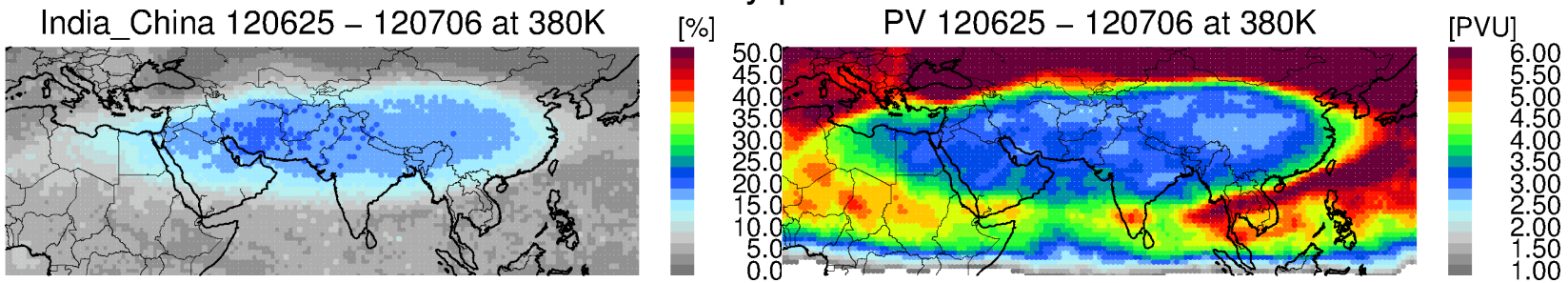
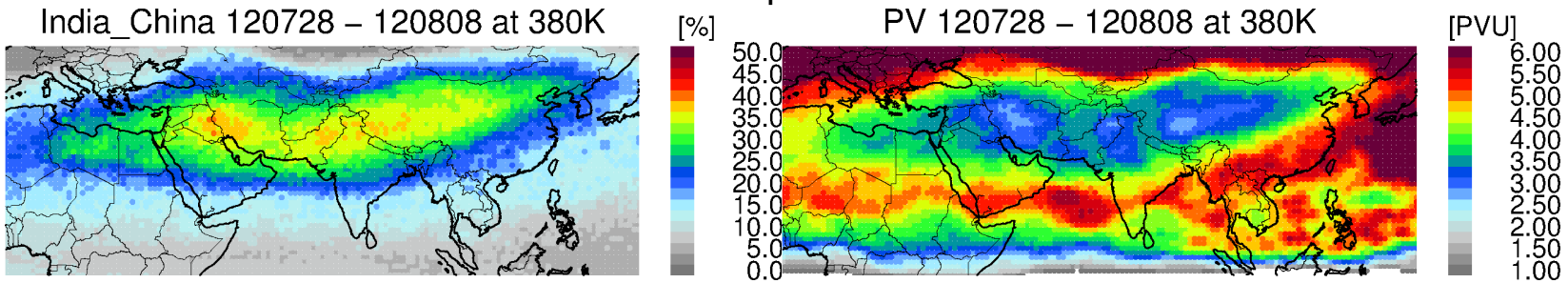
- emissions from other land masses are of minor importance
- composition of AMA is a fingerprint of variation in convective processes

Variation of the position of the Anticyclone

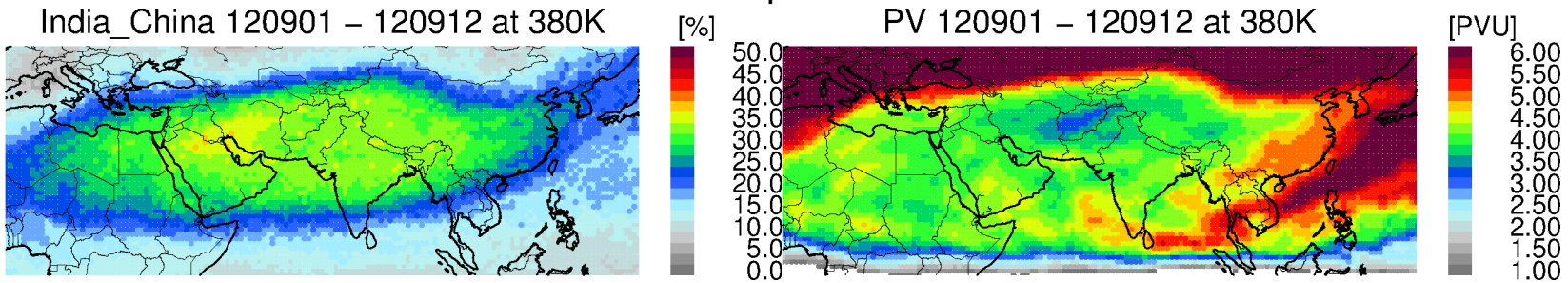
early-phase



mid-phase



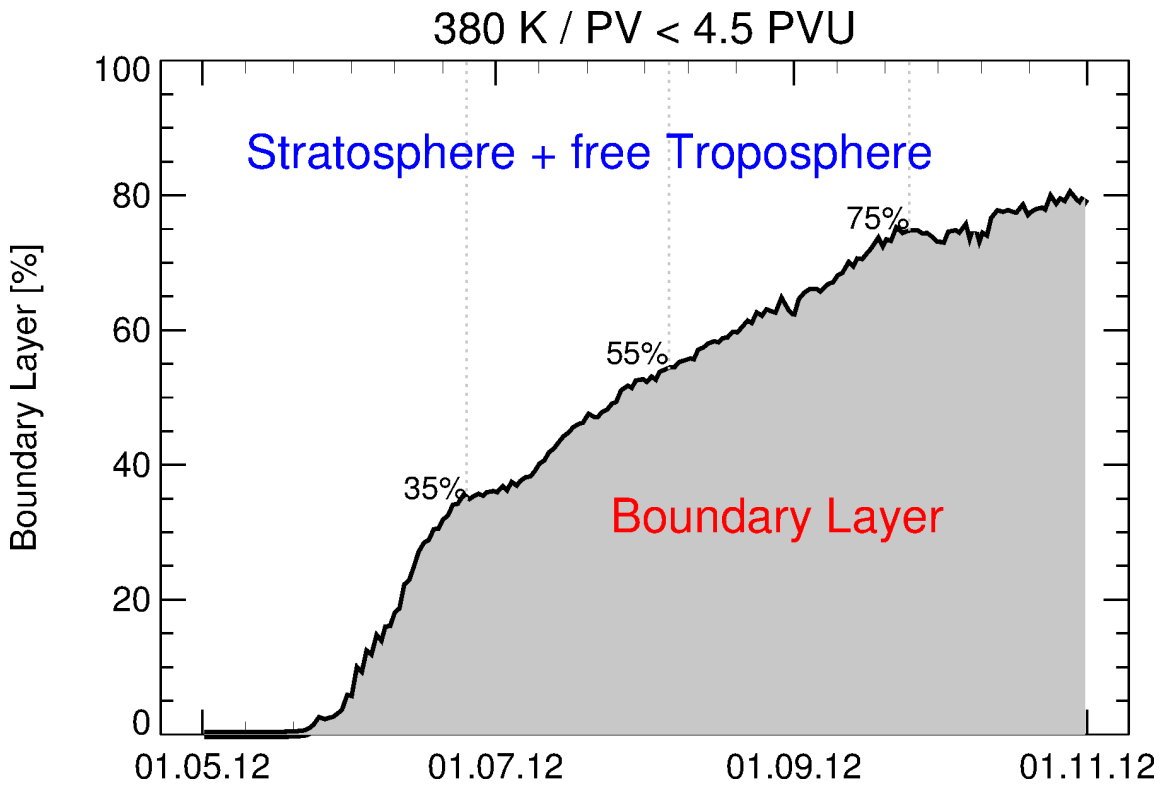
late-phase



- early-phase to mid-phase: North-south shift of the anticyclone
- late-phase: broadening of the Anticyclone

Sum of all emission tracer within the AMA 2012

Contributions from the free troposphere and stratosphere



- contribution of young air masses to the composition of AMA 2012 (since 1 May)
- Asian monsoon effective pathway to transport air from surface to UTLS within a few months

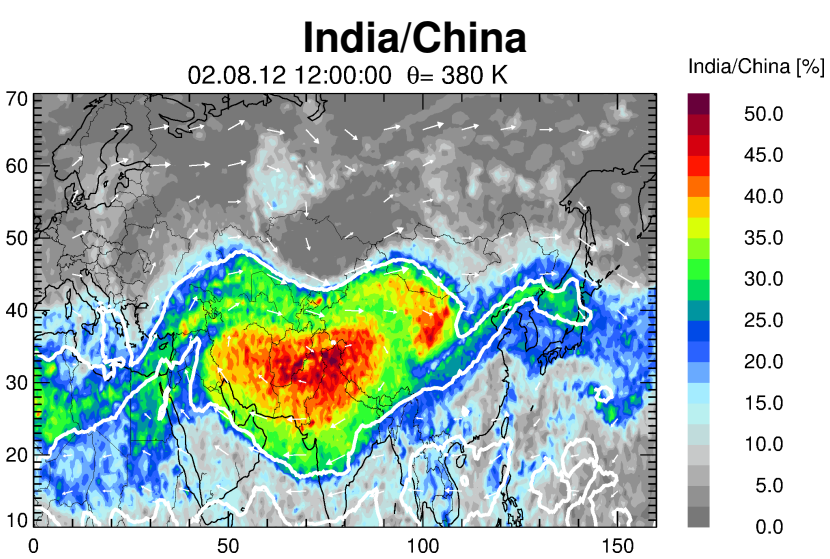
Second question

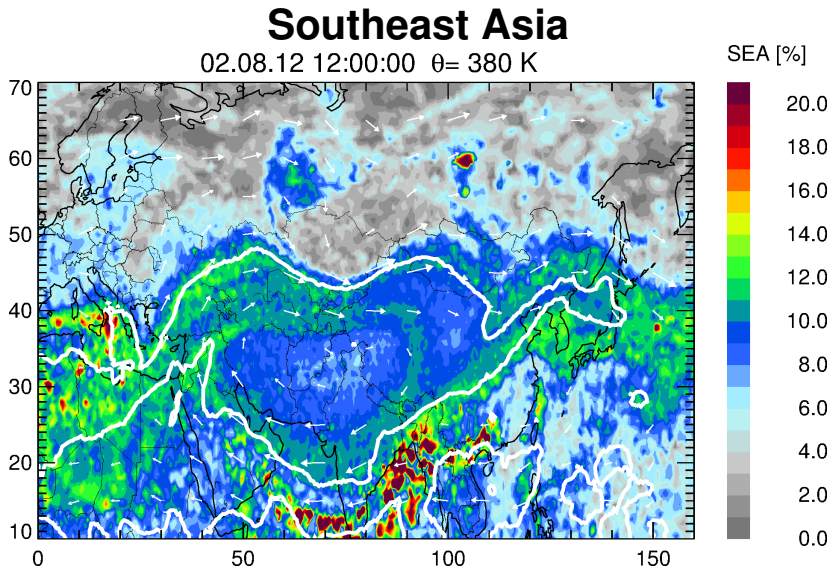
Transport across the tropopause at the top of the Asian monsoon anticyclone:

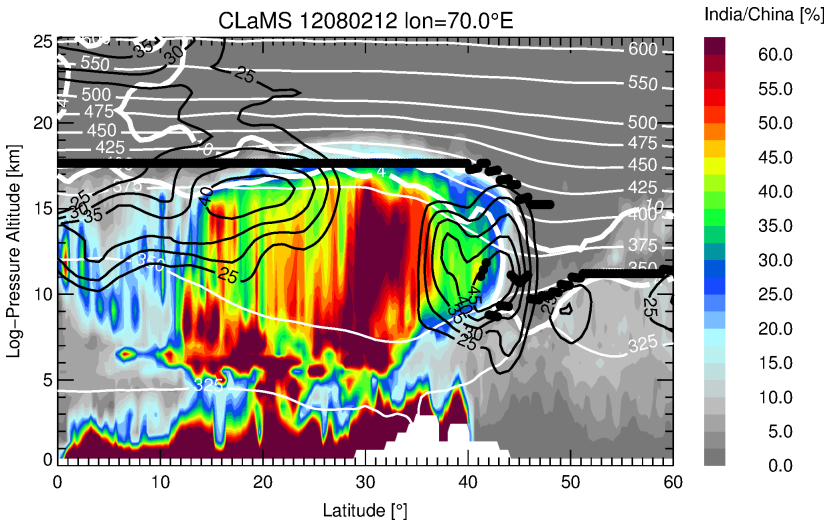
Bubble or chimney ?

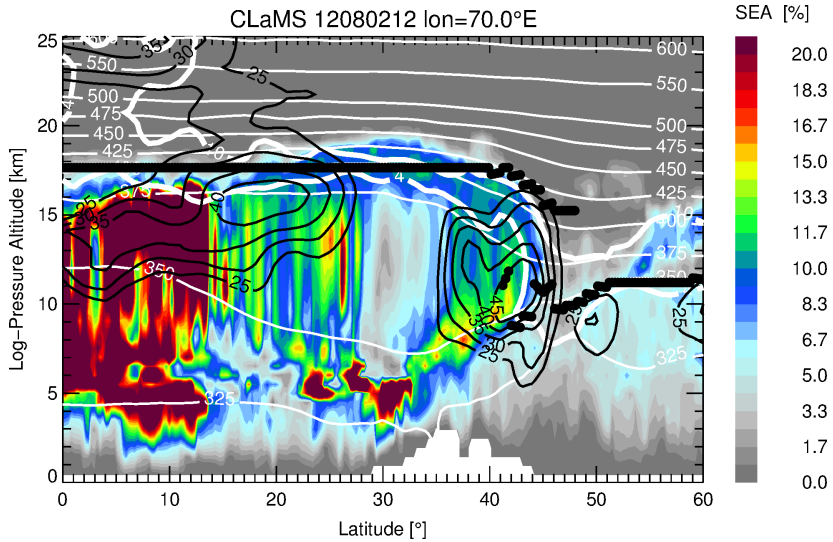
Vertical structure during monsoon season 2012

Confinement of tropospheric trace gases within the AMA: 2 Aug. 2012



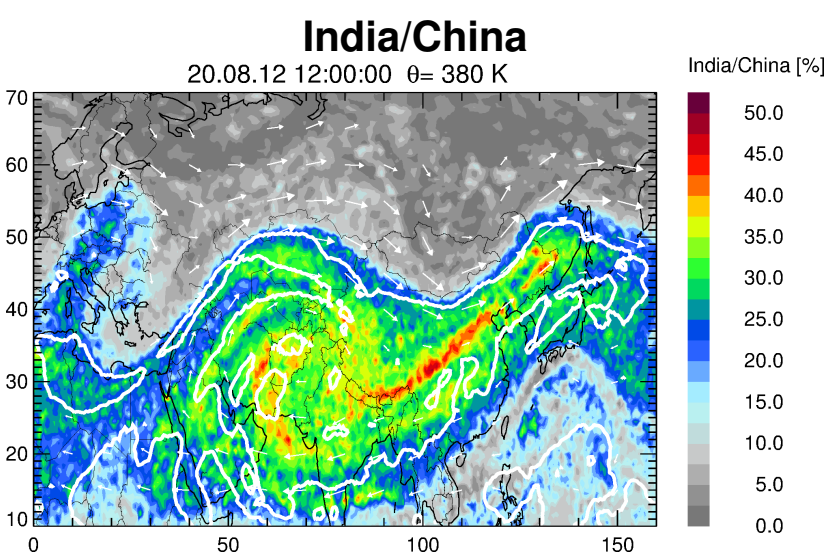


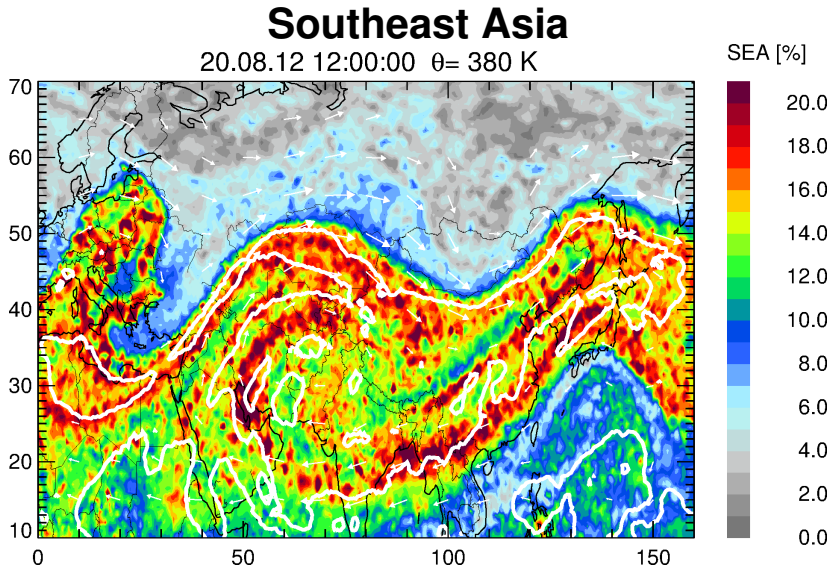


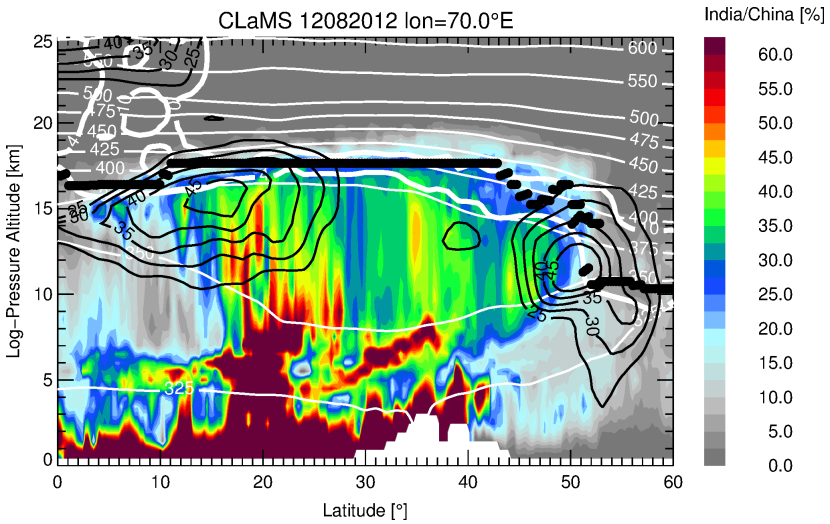


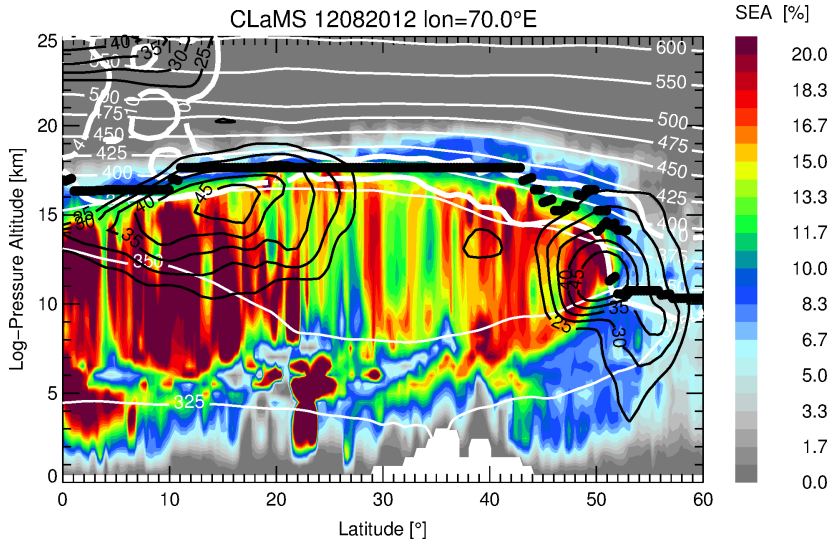
Vertical structure during monsoon season 2012

Late phase of the AMA: 20 Aug. 2012





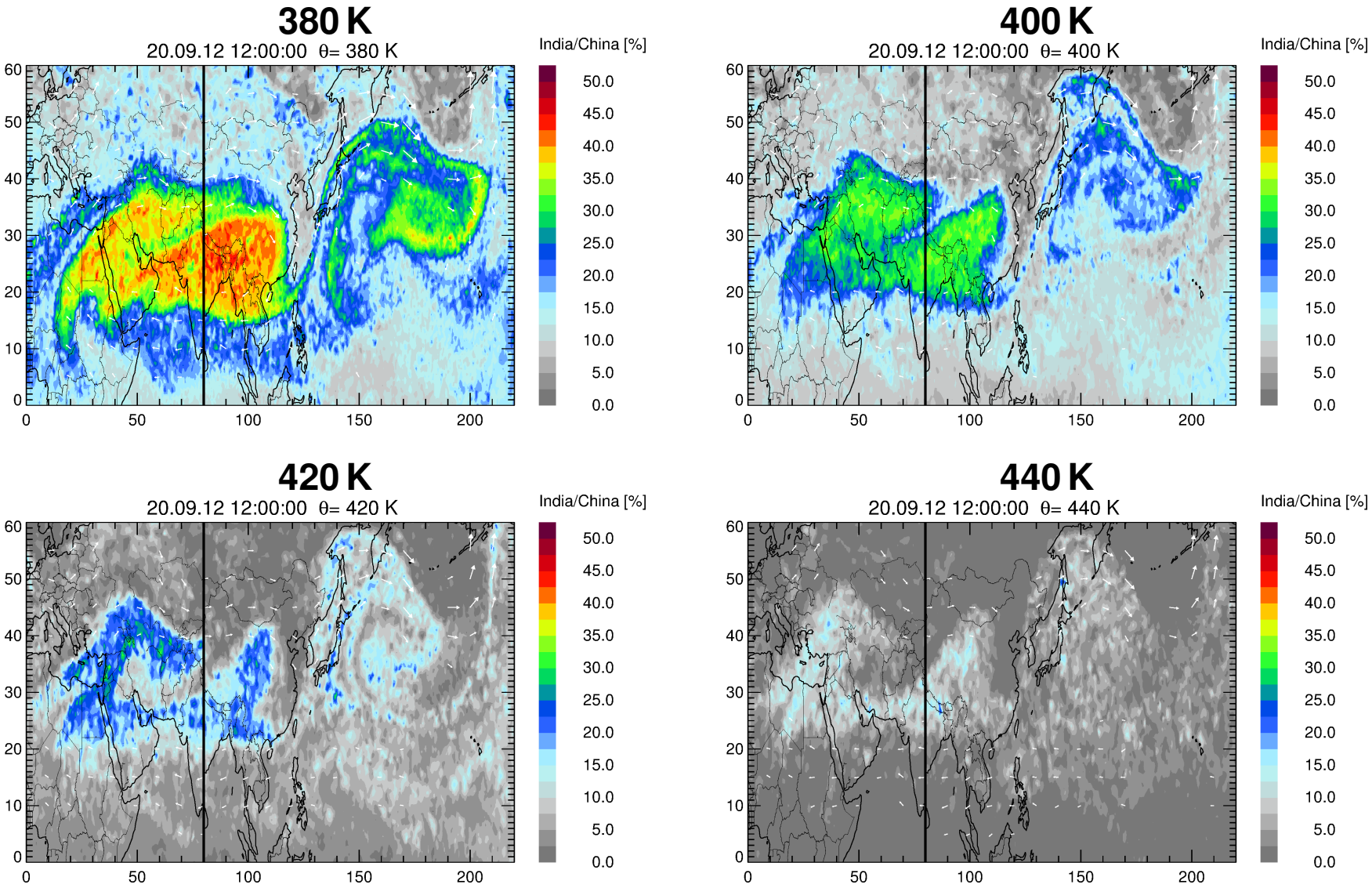




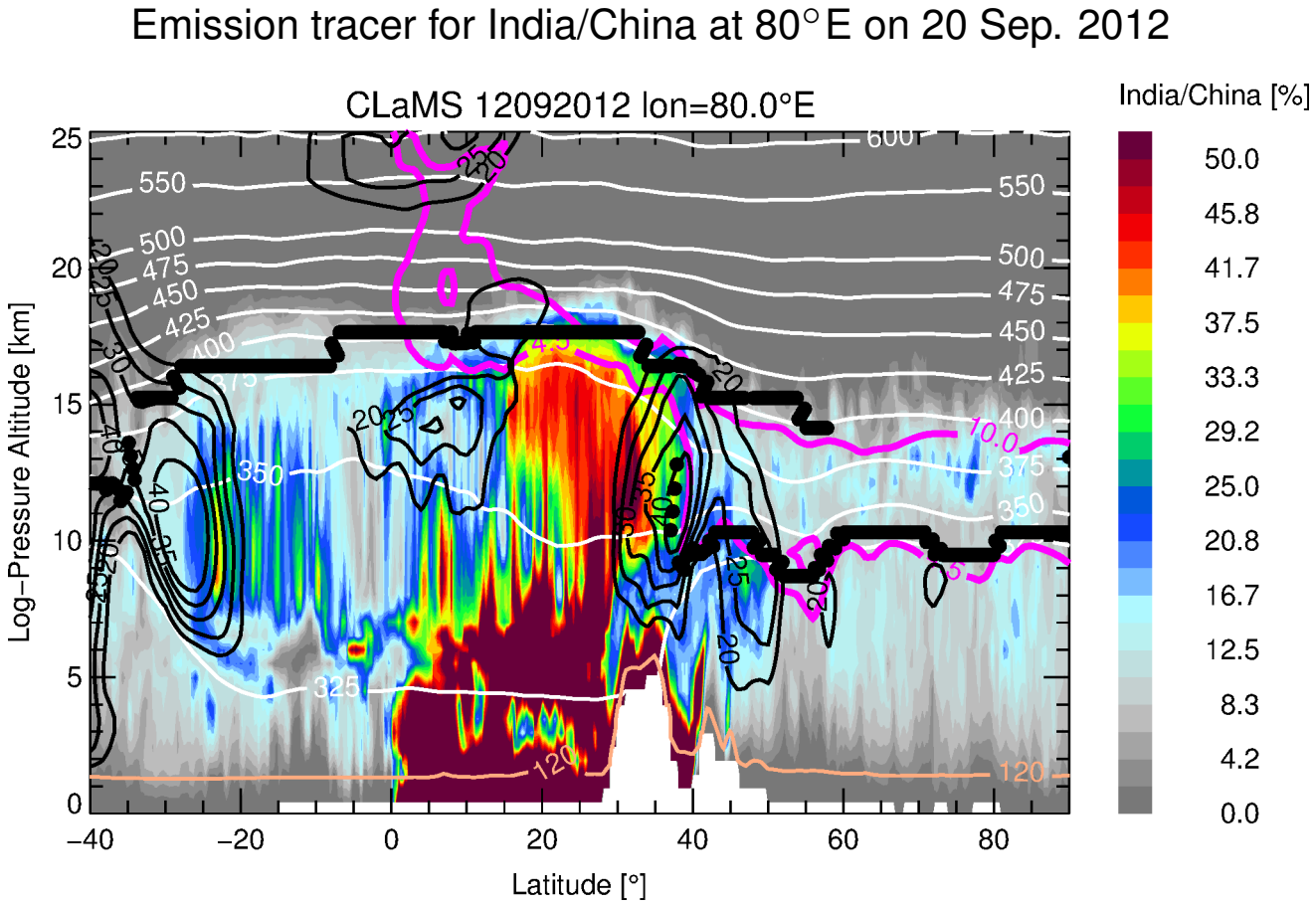
B. Vogel et al.

The Asian Monsoon Anticyclone in Sep. 2012

Emission tracer for India/China

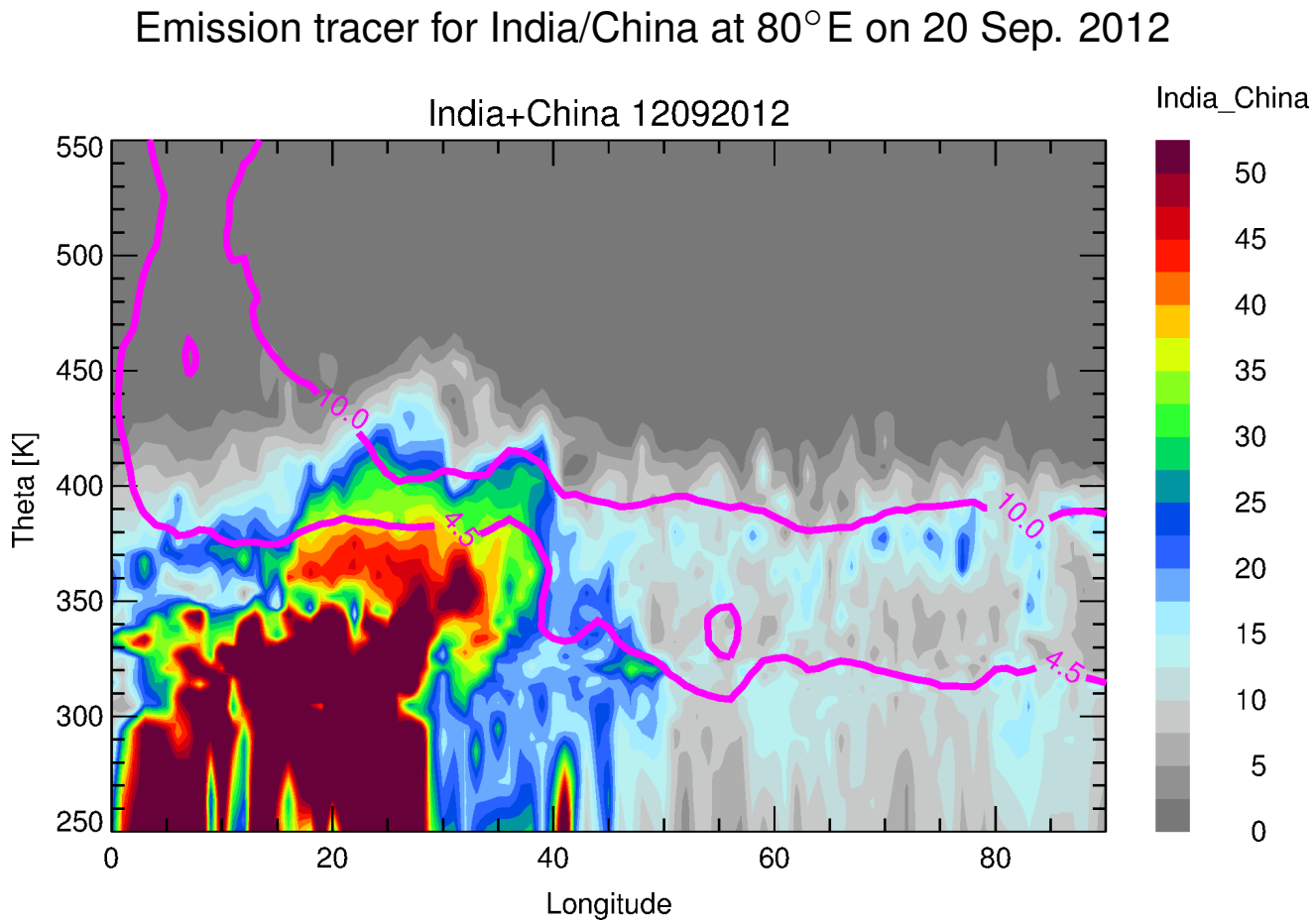


Gateways for stratospheric entry?



- tropopause is vertical transport barrier

Vertical cross-section bases on levels of potential temperature

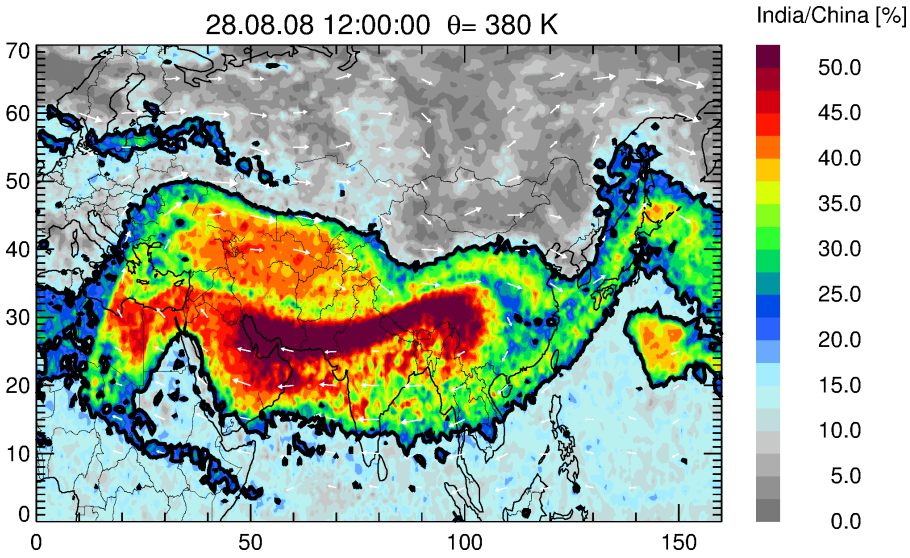


Emission tracer for India/China vs MIPAS HCFC-22

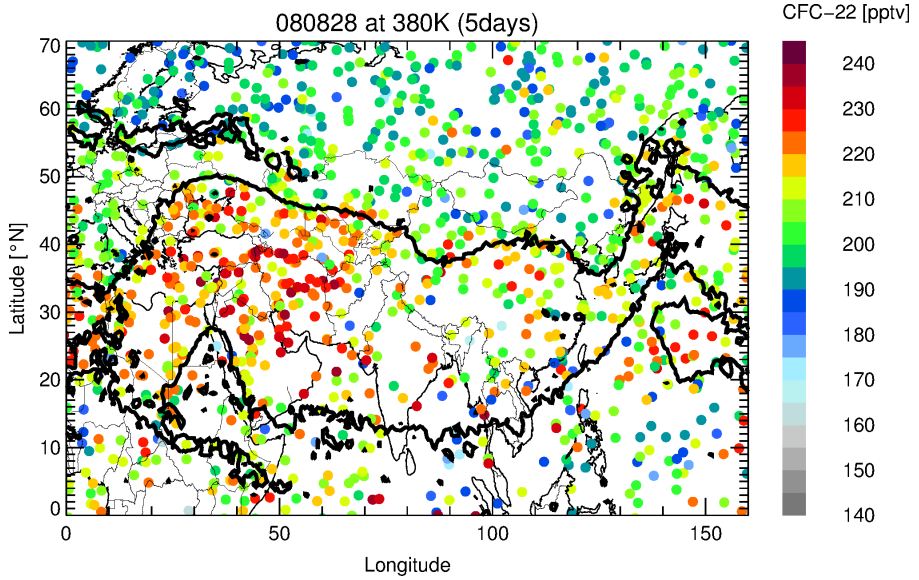
A chemical tracer emitted regionally in India and China

28 August 2008

Emission tracer for India/China at 380 K



MIPAS HCFC-22 at 380 K



- interim replacement gas of CFCs
- MIPAS data synoptically interpolated over 5 days
- black line: emission tracer India/China = 20%

Emission tracer for India/China vs MIPAS HCFC-22

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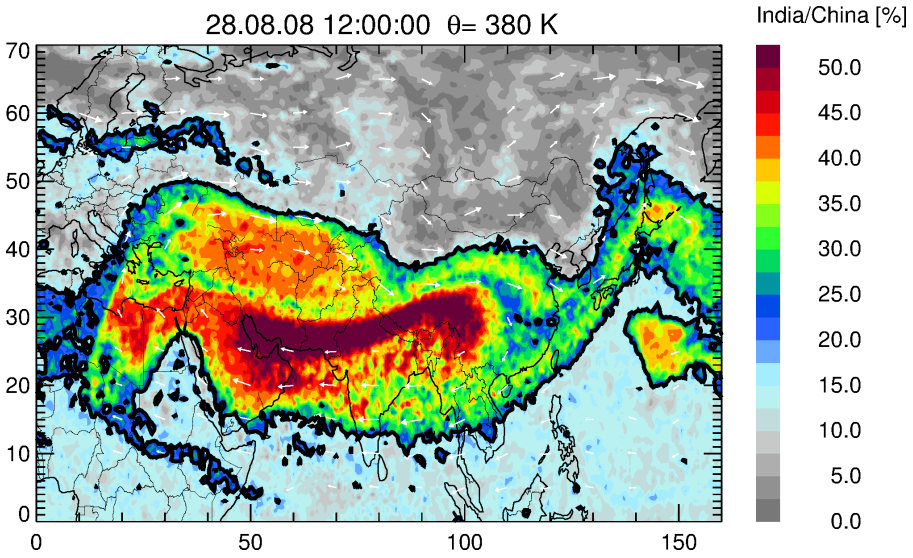
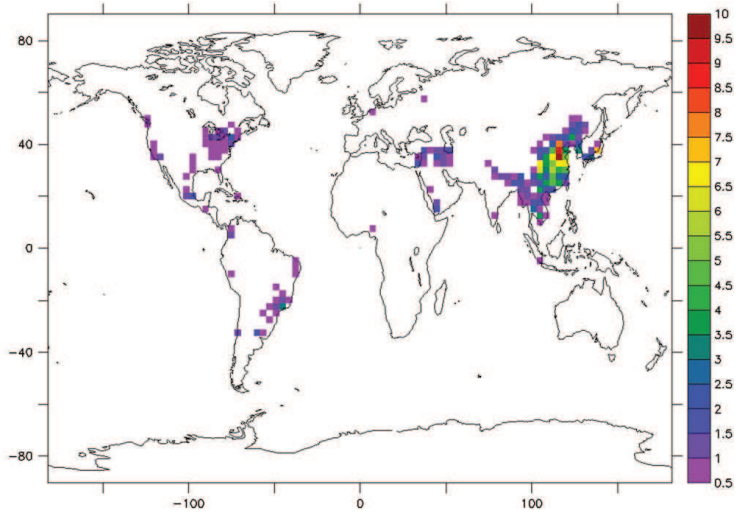


HCFC-22 emissions 2010



Fortems-Cheiney et al., 2013

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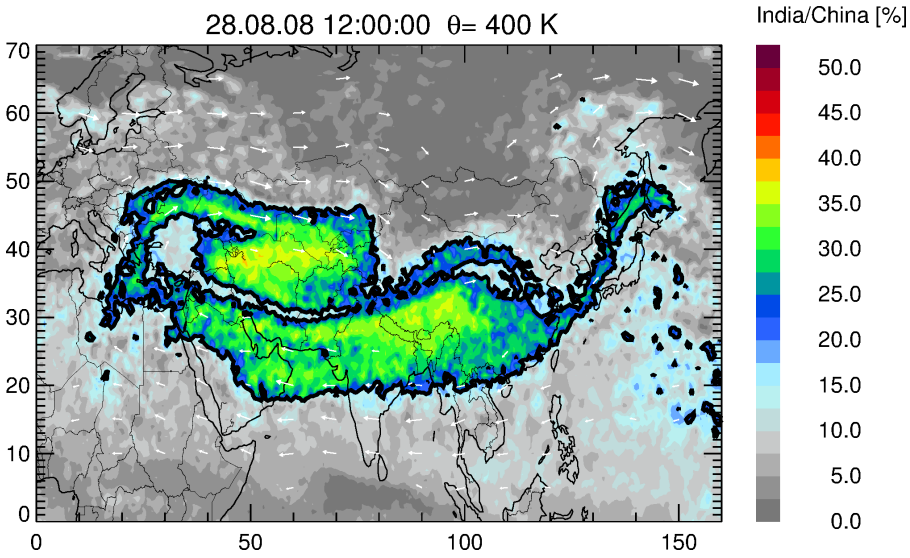
Emission tracer for India/China vs MIPAS HCFC-22

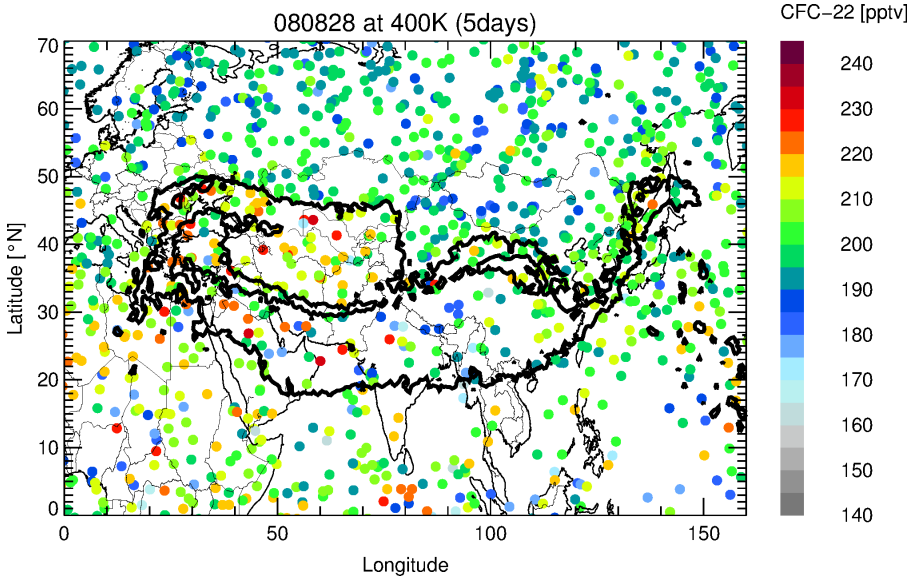
A chemical tracer emitted regionally in India and China

28 August 2008

Emission tracer for India/China at 400 K



MIPAS HCFC-22 at 400 K

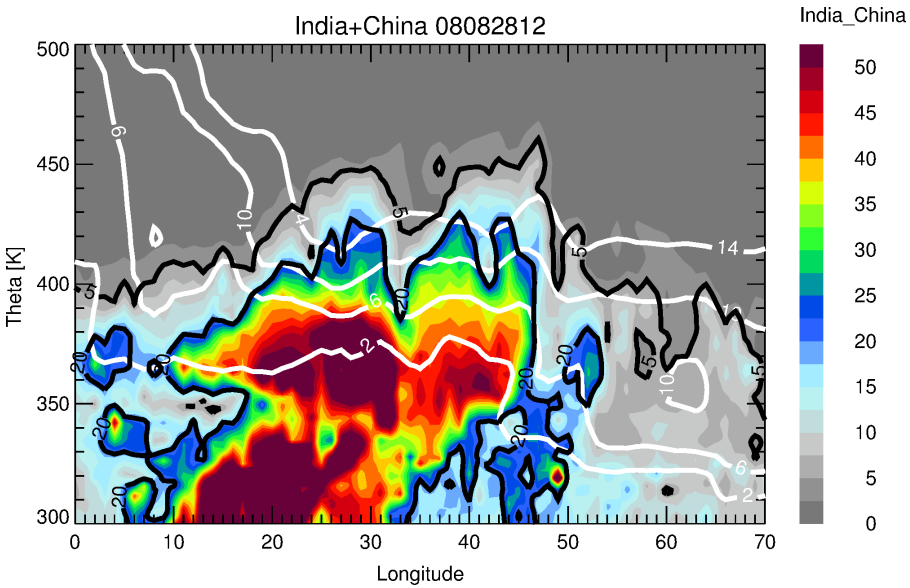


- interim replacement gas of CFCs
- MIPAS data synoptically interpolated over 5 days
- black line: emission tracer India/China = 20%

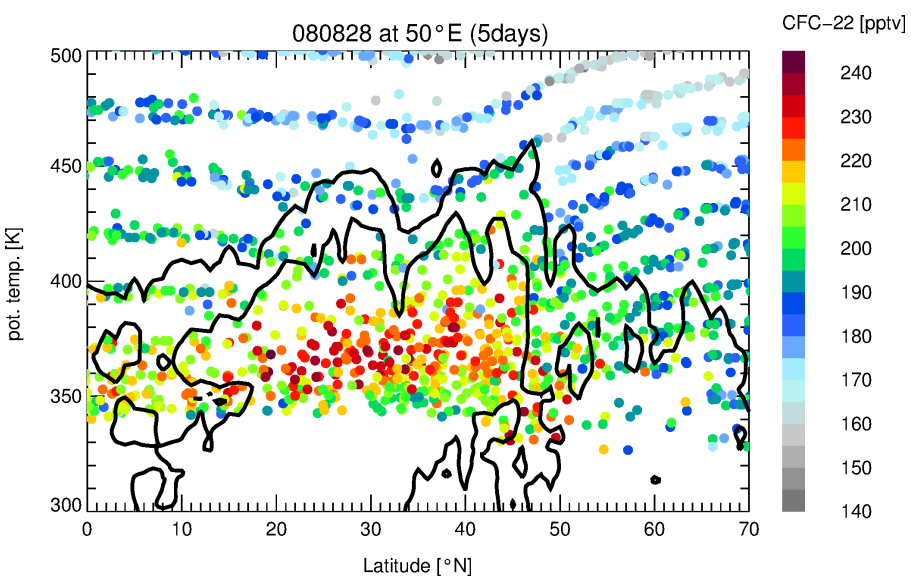
Vertical Transport of MIPAS HCFC-22

28 August 2008

Emission tracer for India/China 50°E



MIPAS HCFC-22 at 40-60°E

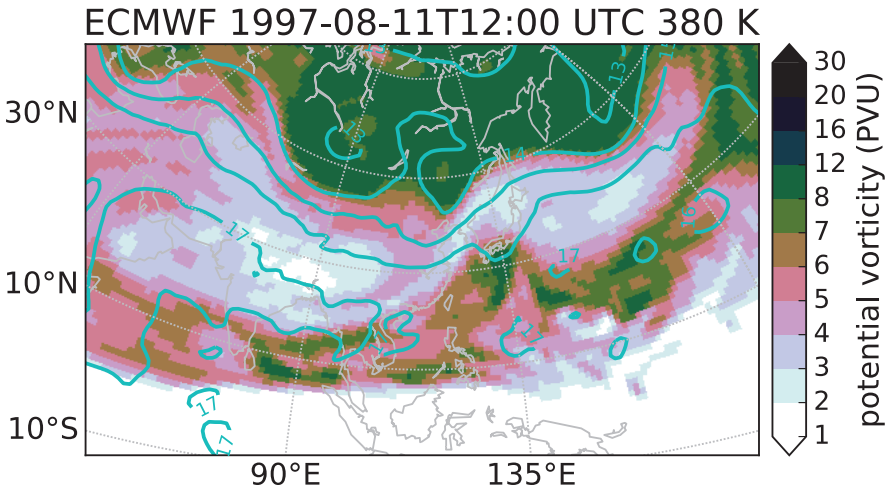


- no significant vertical transport at the top of the Asian monsoon anticyclone
- upward transport of HCFC-22 in the tropics

CRISTA-2 PAN measurements

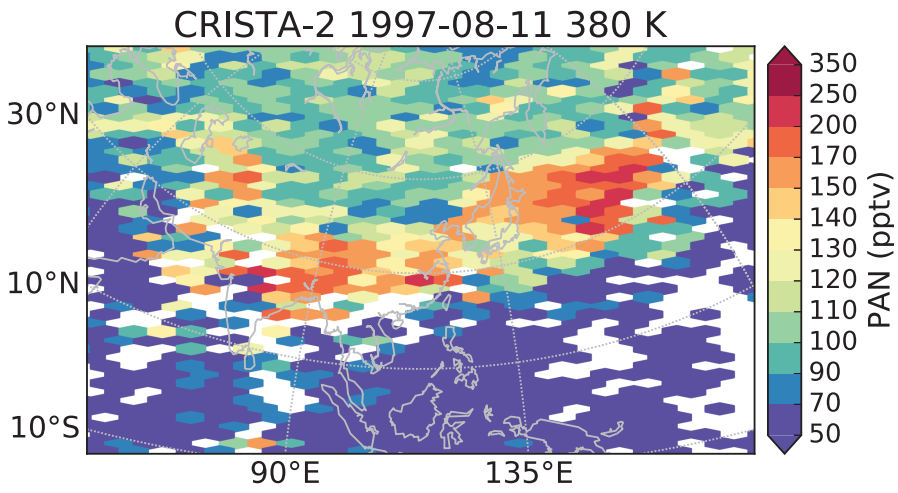
Synoptical interpolation at 380 K 9–13 Aug. 1997

ERA-Interim PV 11 Aug 1997



Ungermann et al., ACPD, 2016

CRISTA PAN 11 Aug 1997



CRISTA:
CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere experiment

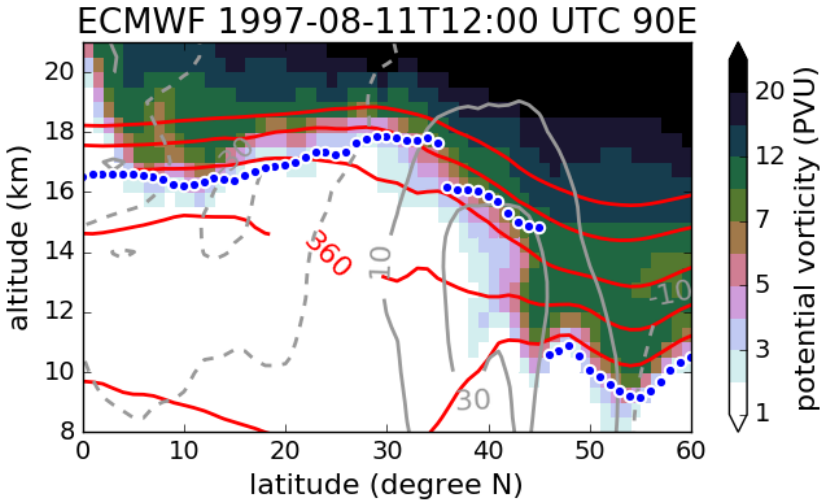
flown on two Space Shuttle missions in November 1994 and August 1997

CRISTA-2 PAN measurements

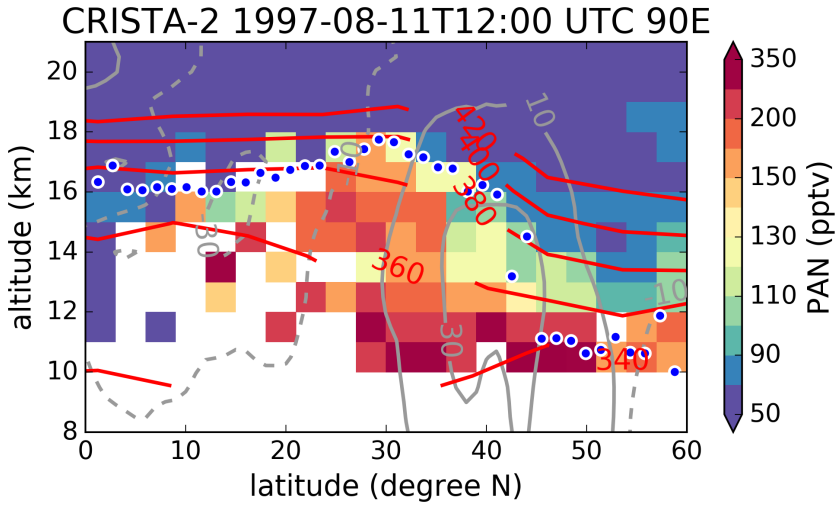
Confinement of PAN within the AMA

11 August 1997 at 90°E

ERA-Interim PV



CRISTA PAN

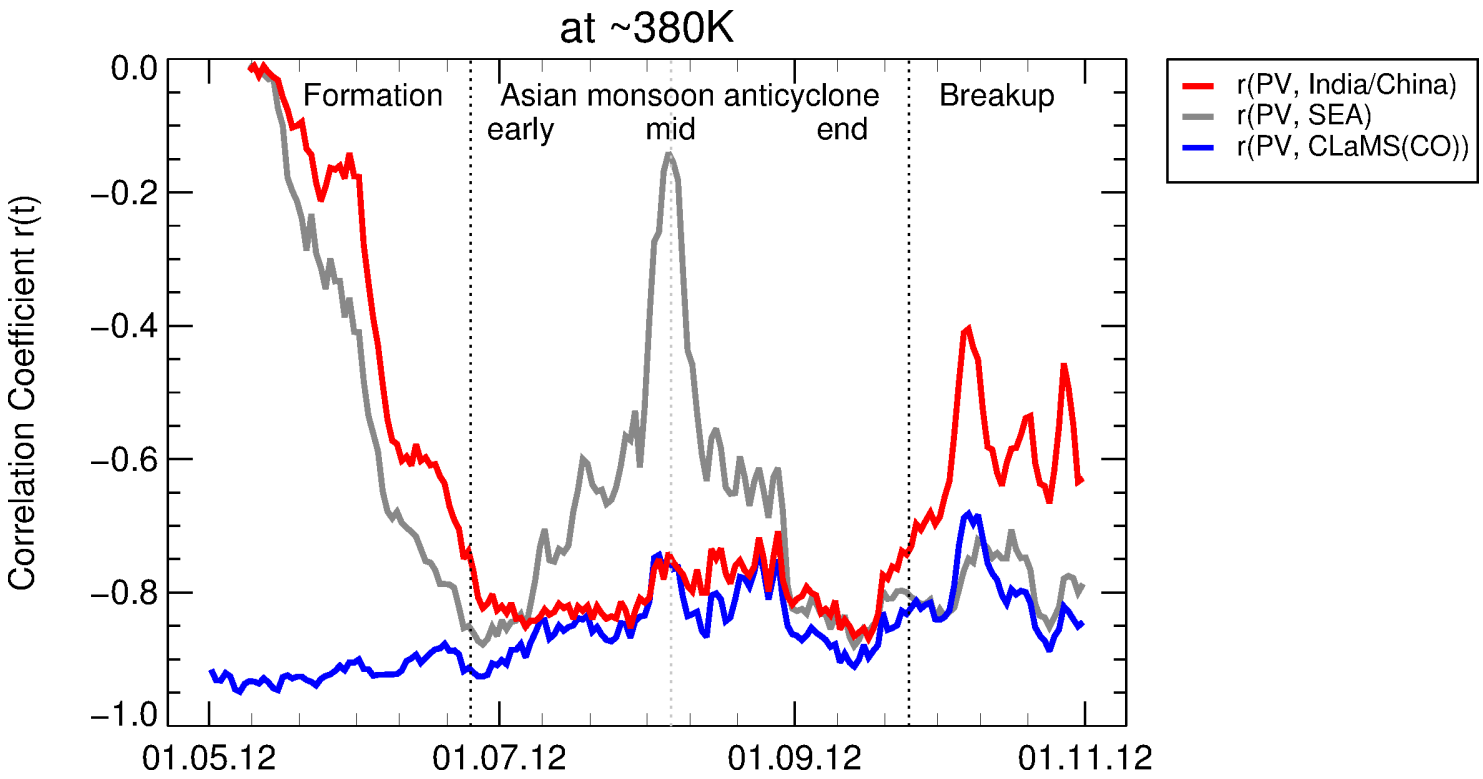


Ungermann et al., ACPD, 2016

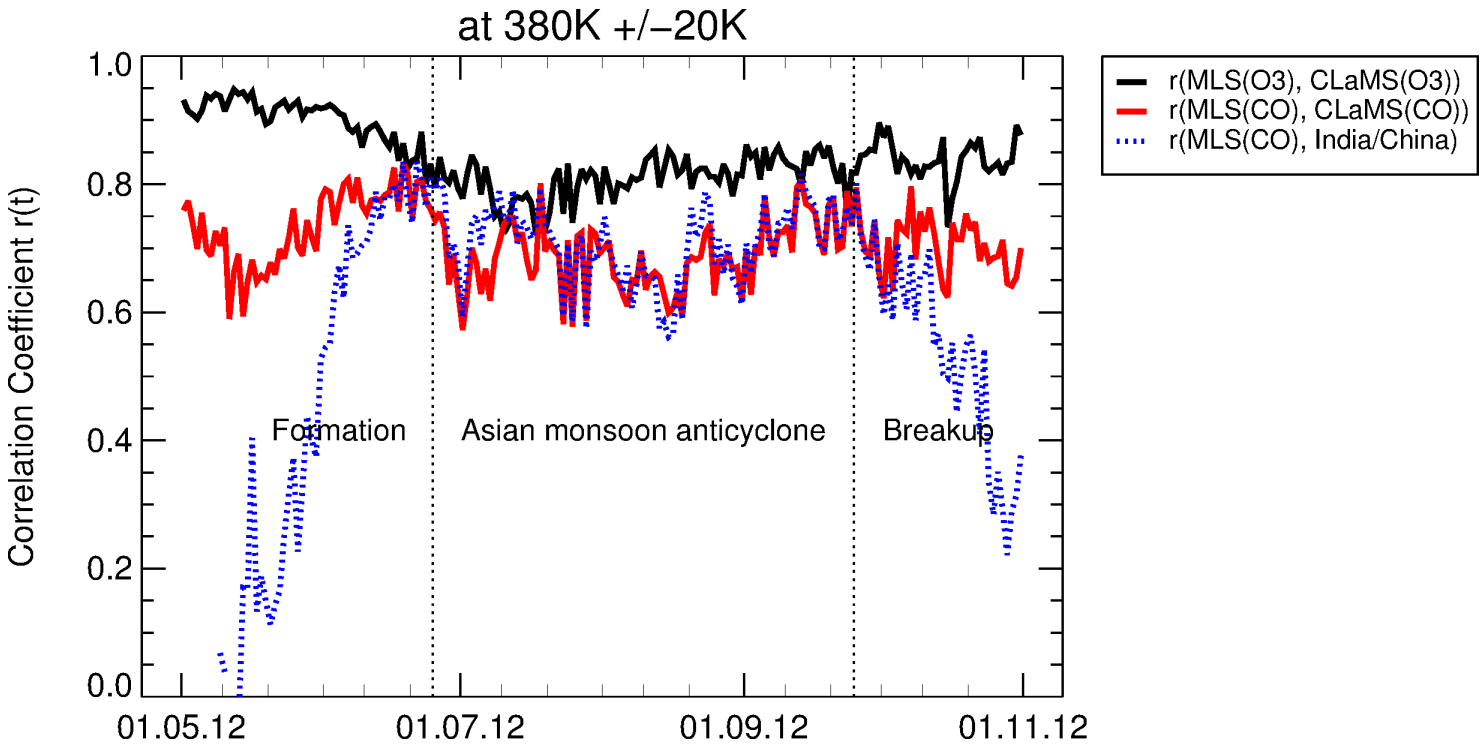
Summary and Conclusions

- The contributions of different boundary source regions to the composition of the Asian monsoon anticyclone strongly depends on its intraseasonal variability (fingerprint of convective areas)
- Highest contributions are from North India and Southeast Asia (minor from East China and South India)
- air parcels from Southeast Asia / Western Pacific circulate clockwise, in an upward spiral, around the anticyclone
- The thermal tropopause at the top the the anticyclone acts as vertical transport barrier (HCFC-22, PAN)

additional material I

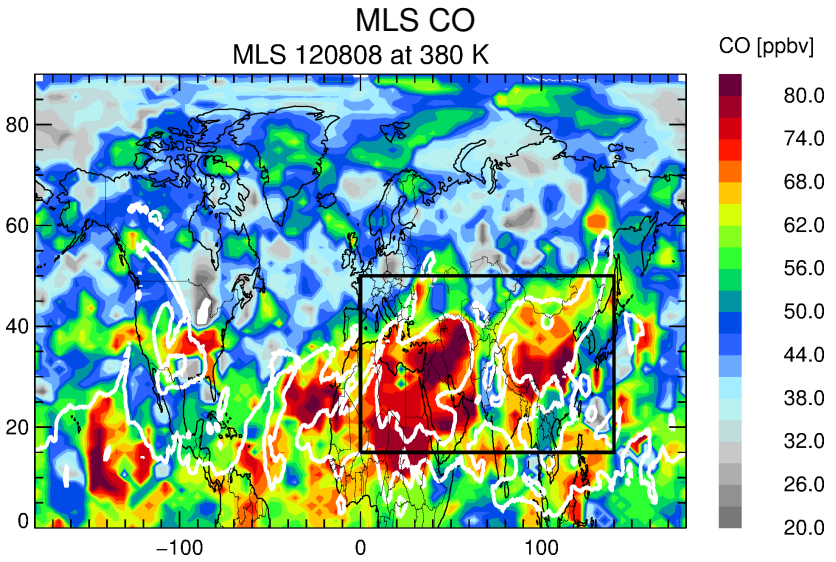


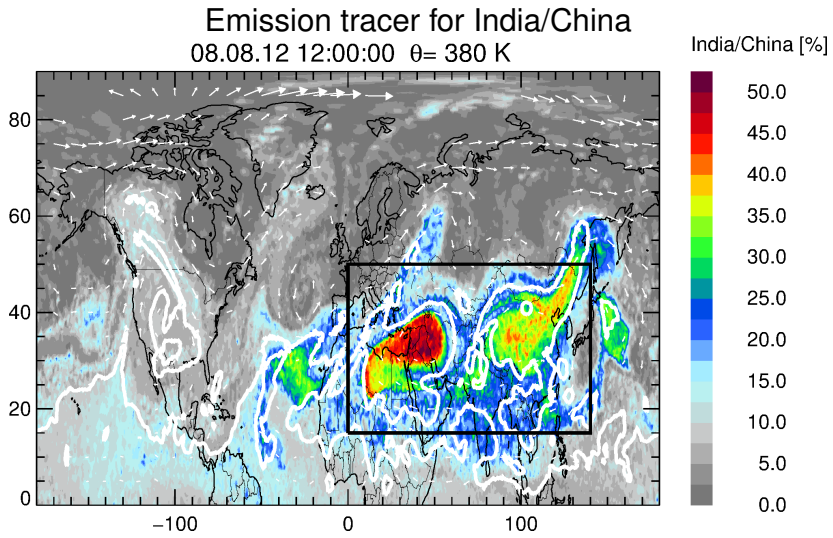
additional material II



CLaMS vs. MLS satellite measurements

8 August 2012 at 380 K





- similar patterns are found in CLaMS and MLS CO and O_3 measurements
- strong pattern correlation at 360-400K (July - Sep 2012)
  India/China to MLS(CO): r(t)=0.6 – 0.8
- emission tracer for India/China is a good proxy for location and shape of the anticyclone