Quantifying pollution transport from the Asian monsoon anticyclone into the lower stratosphere

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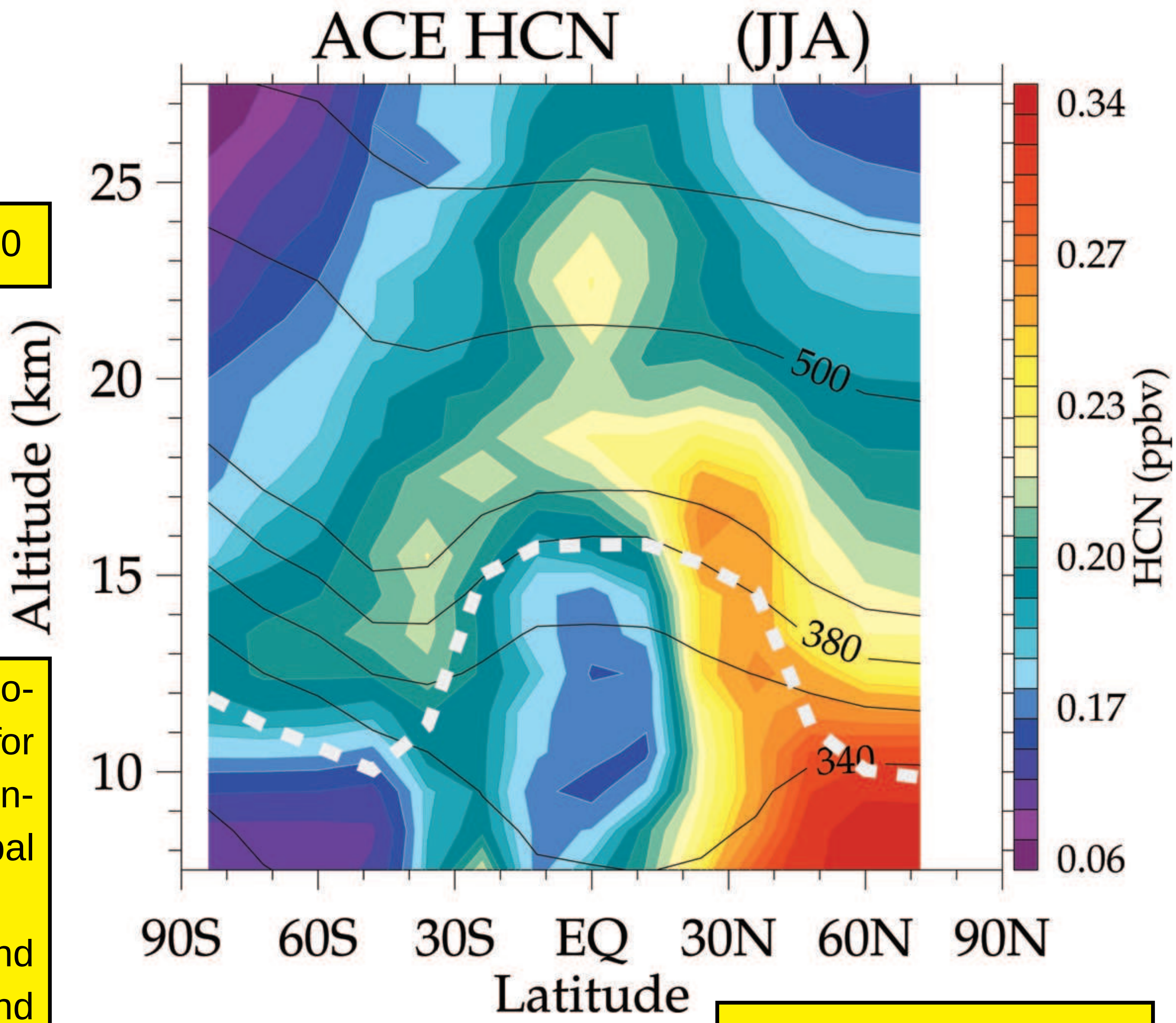
http://www.fz-juelich.de/SharedDocs/Personen/IEK/IEK-7/EN/konopka_p.html .

ASM ⇒ stratosphere: Why we should care?

Randel et al., Science, 2010



...monsoon circulation provides an effective pathway for pollution from Asia, and Indonesia to enter the global stratosphere...

...mainly CO, HCN, SO_2 and aerosols but also CO_2 and H_2O

HCN averaged between 0 and 100^0E

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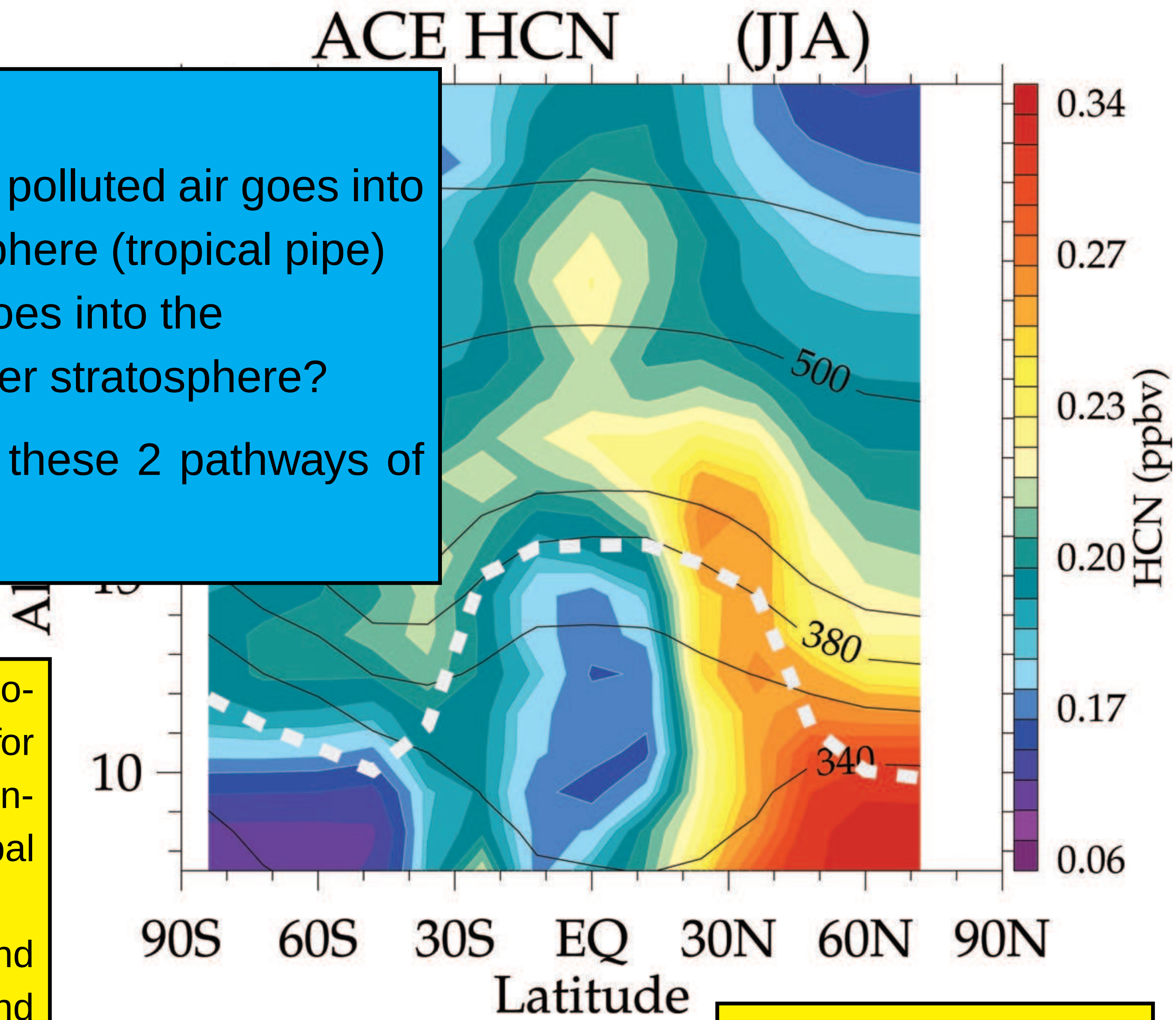
Questions:

- How much of the polluted air goes into the deep stratosphere (tropical pipe) and how much goes into the extra-tropical lower stratosphere?
- Can we quantify these 2 pathways of transport?



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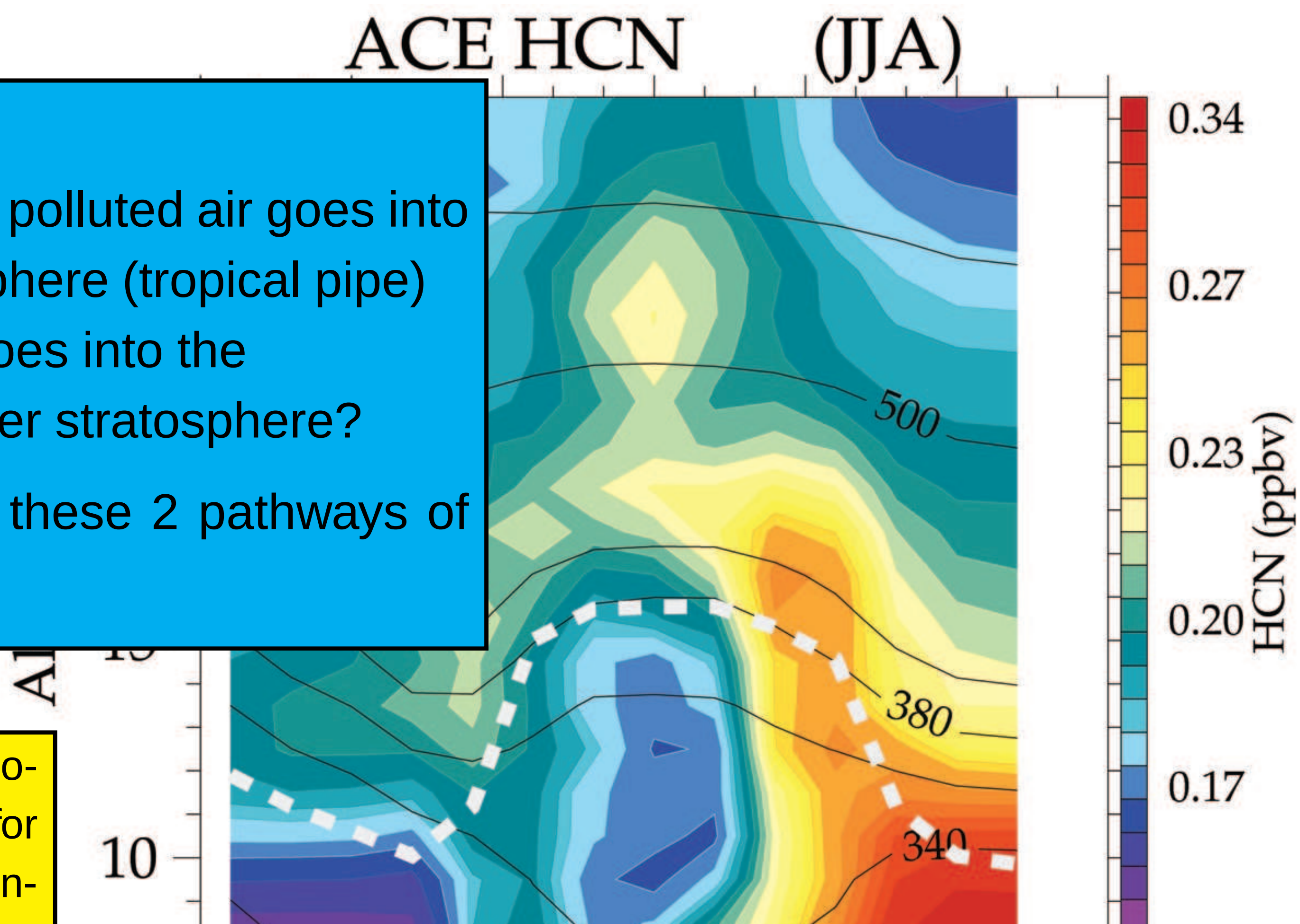

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..some previous work:

- “strongest transport directly into the tropical stratosphere (32%)” (Garny and Randel, 2016)
- “isentropic and tropopause crossing transport into the extra-tropical lower stratosphere dominates” (Orbe et al.„ 2015)

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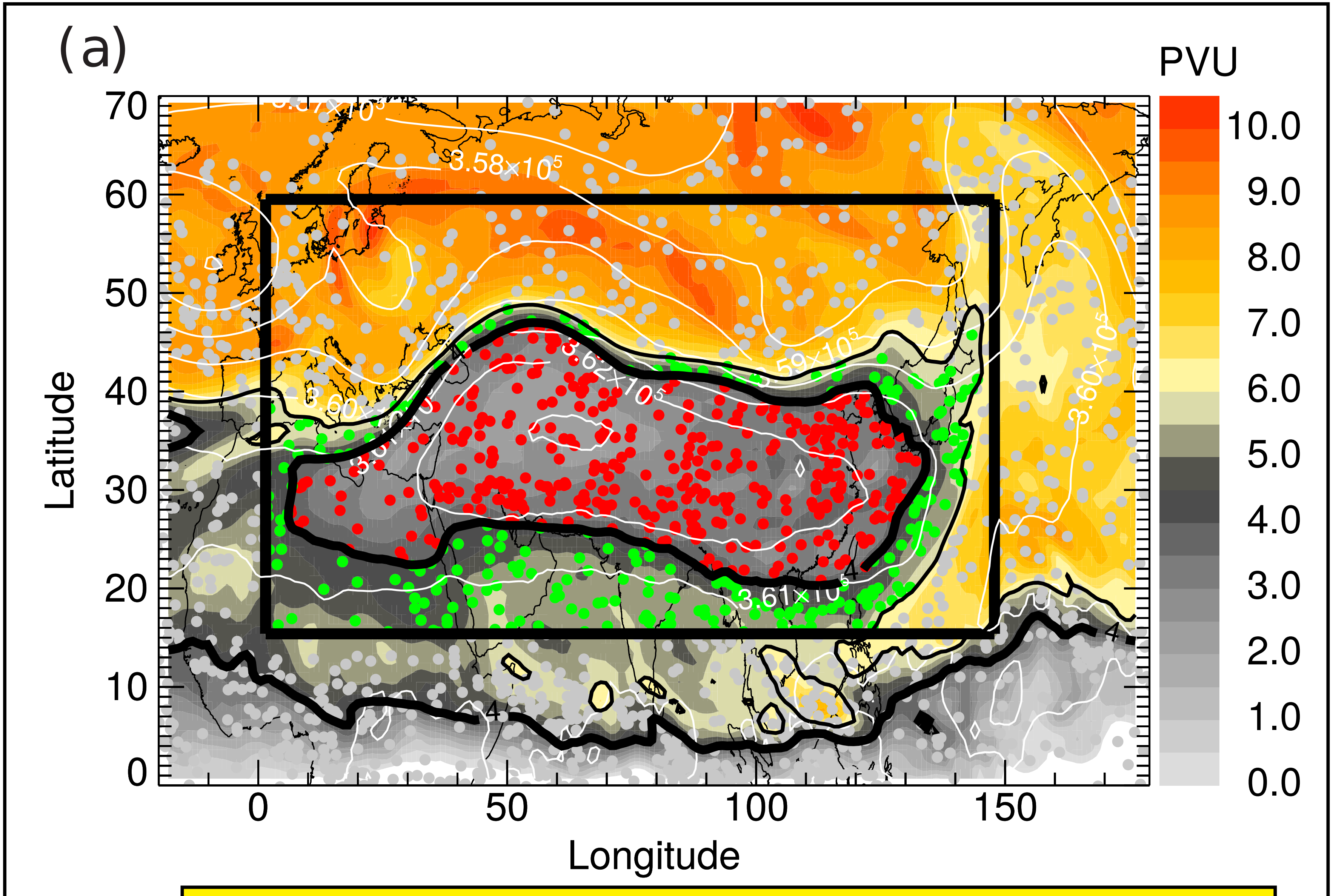
Method

- Lagrangian chemistry transport model CLaMS

  diabatic trajectories + chemistry + mixing

  (McKenna et al., 2002, Konopka et al., 2004, Pommrich et al., 2014)
- isentropic vertical coordinate throughout the UTLS
- horizontal winds and total diabatic heating rates from ERA-Interim (Dee et al., 2011)
- resolution (100km - horizontal, 400m - vertical)
- anticyclone tracer:
  - every day between July and August of the years 2010-2013
  - in the anticyclone core between 370 and 380 K
  - edge of the anticyclone defined from the maximum of the PV gradient (“Nash criterion for vortex edge”, Ploeger et al., 2015)

Method



Time-averaged PV field at 380 K. Air parcels between 370 and 380 K and within the PV-barrier are set to 1 (from 1.07 until 31.08)

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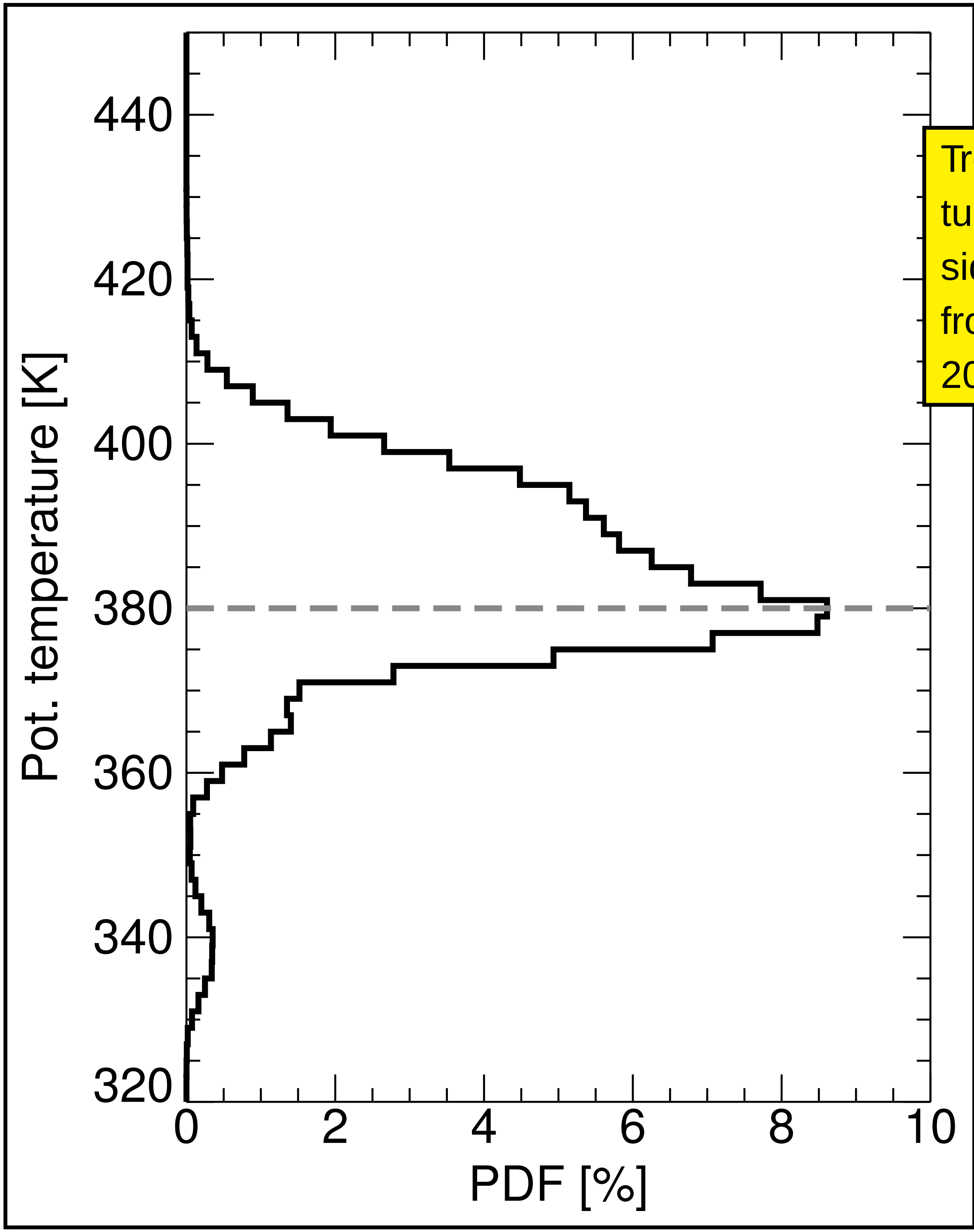

Tropopause potential temperature frequency of occurence inside the monsoon anticyclone from all days during July-August 2010-2013

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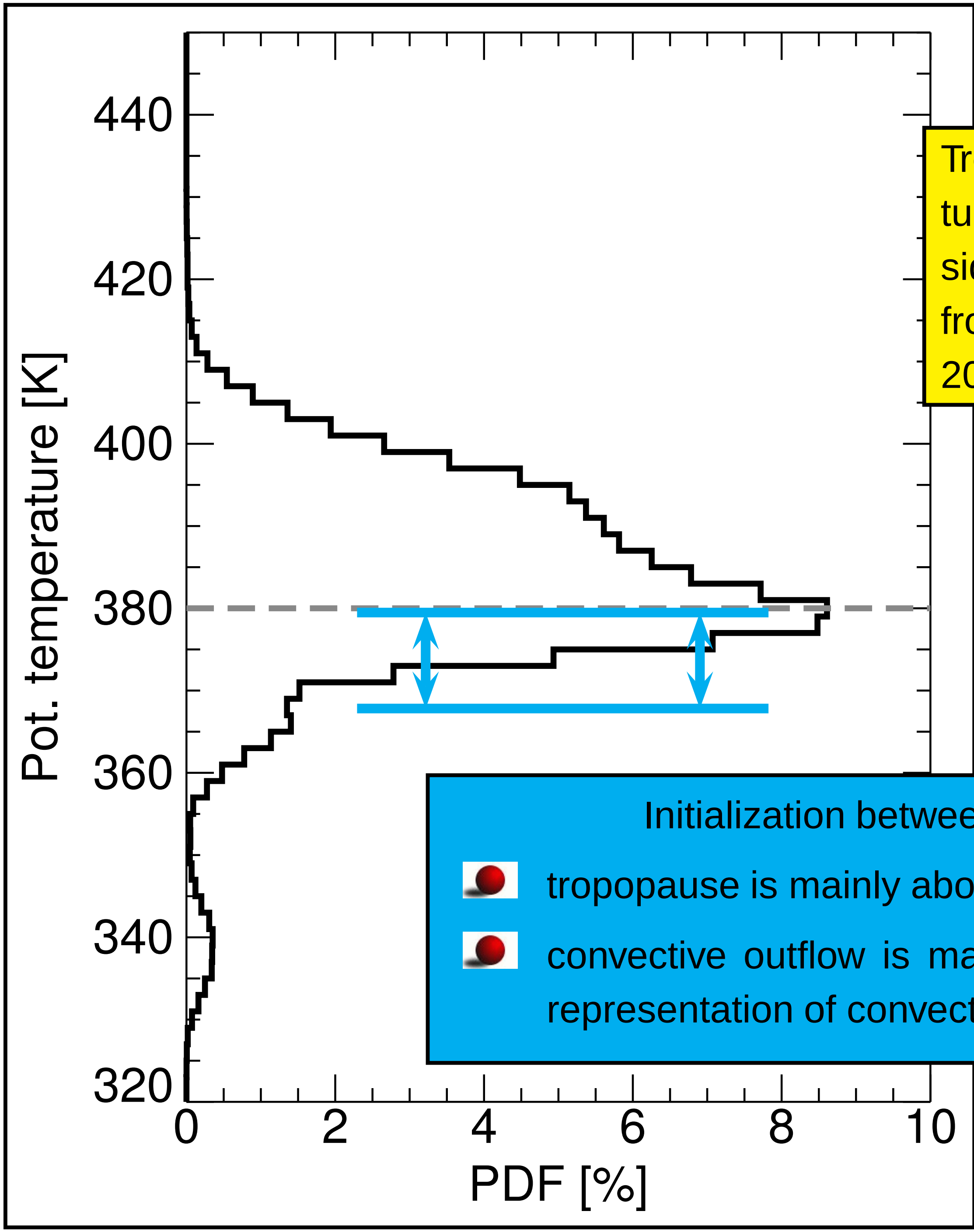

Tropopause potential temperature frequency of occurence inside the monsoon anticyclone from all days during July-August 2010-2013

Initialization between 370 and 380 K:

- tropopause is mainly above (more than 75% cases)
- convective outflow is mainly below (to avoid a weak representation of convection in the reanalysis)

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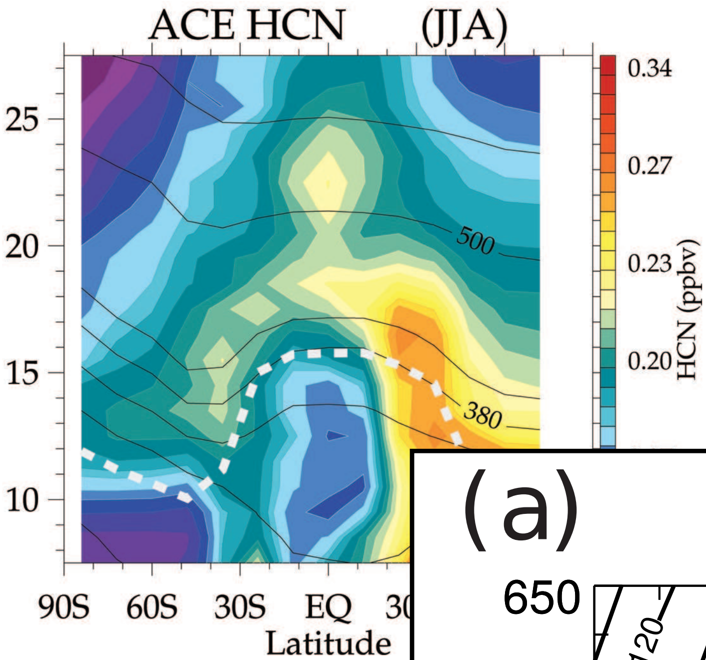
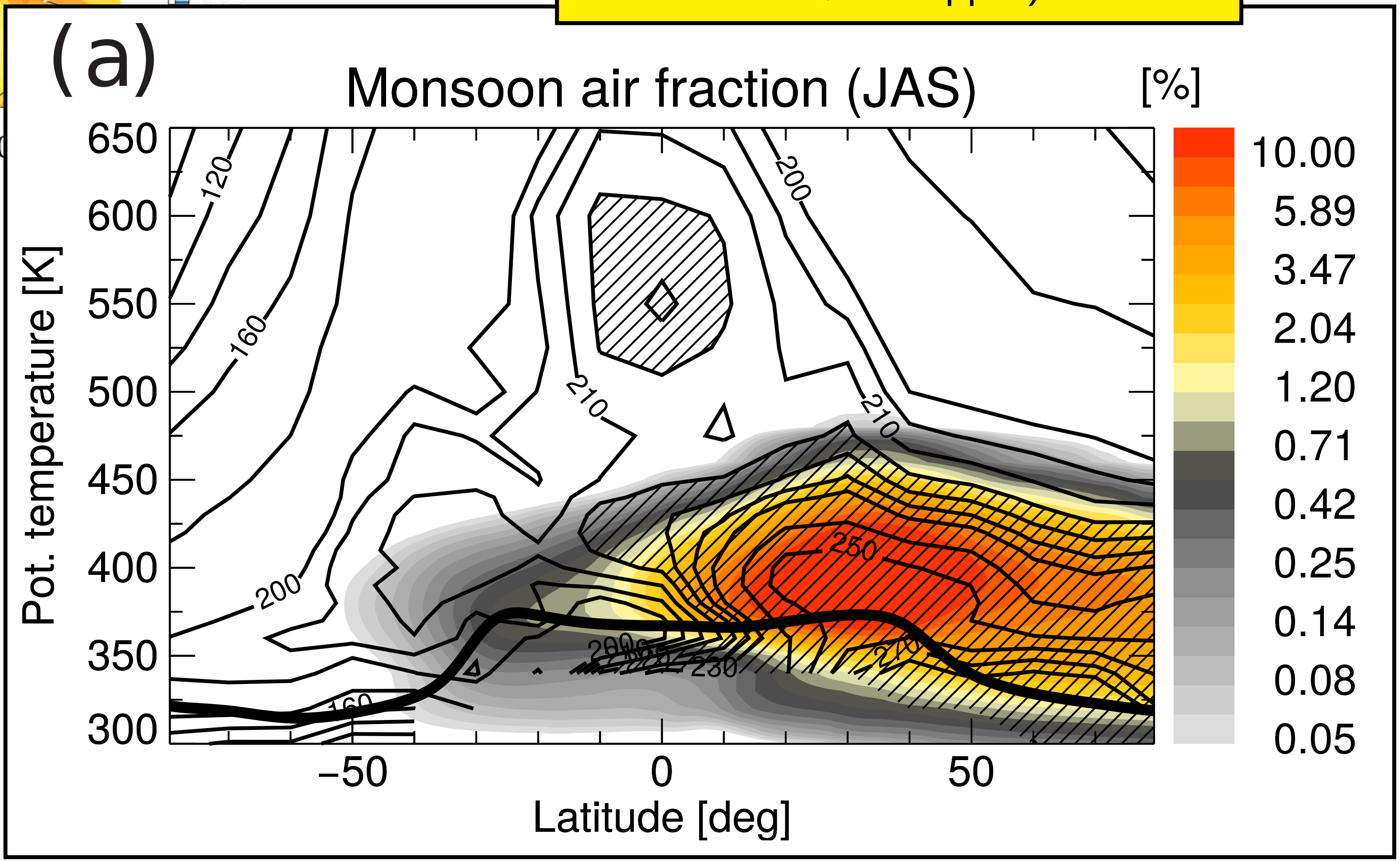
CLaMS versus HCN: seasonal evolution



Zonal mean monsoon air fraction from CLaMS (colour-coded) and HCN from ACE-FTS (black contours, hatched HCN > 215 pptv.)



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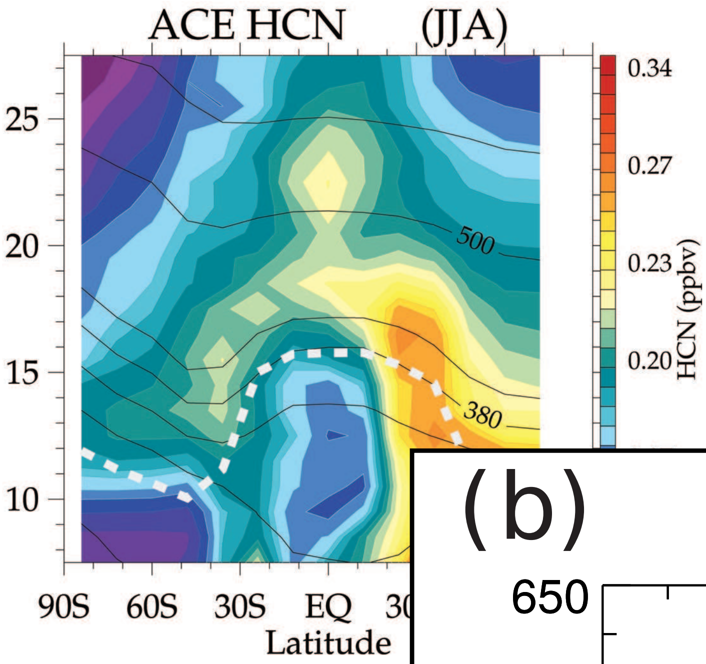

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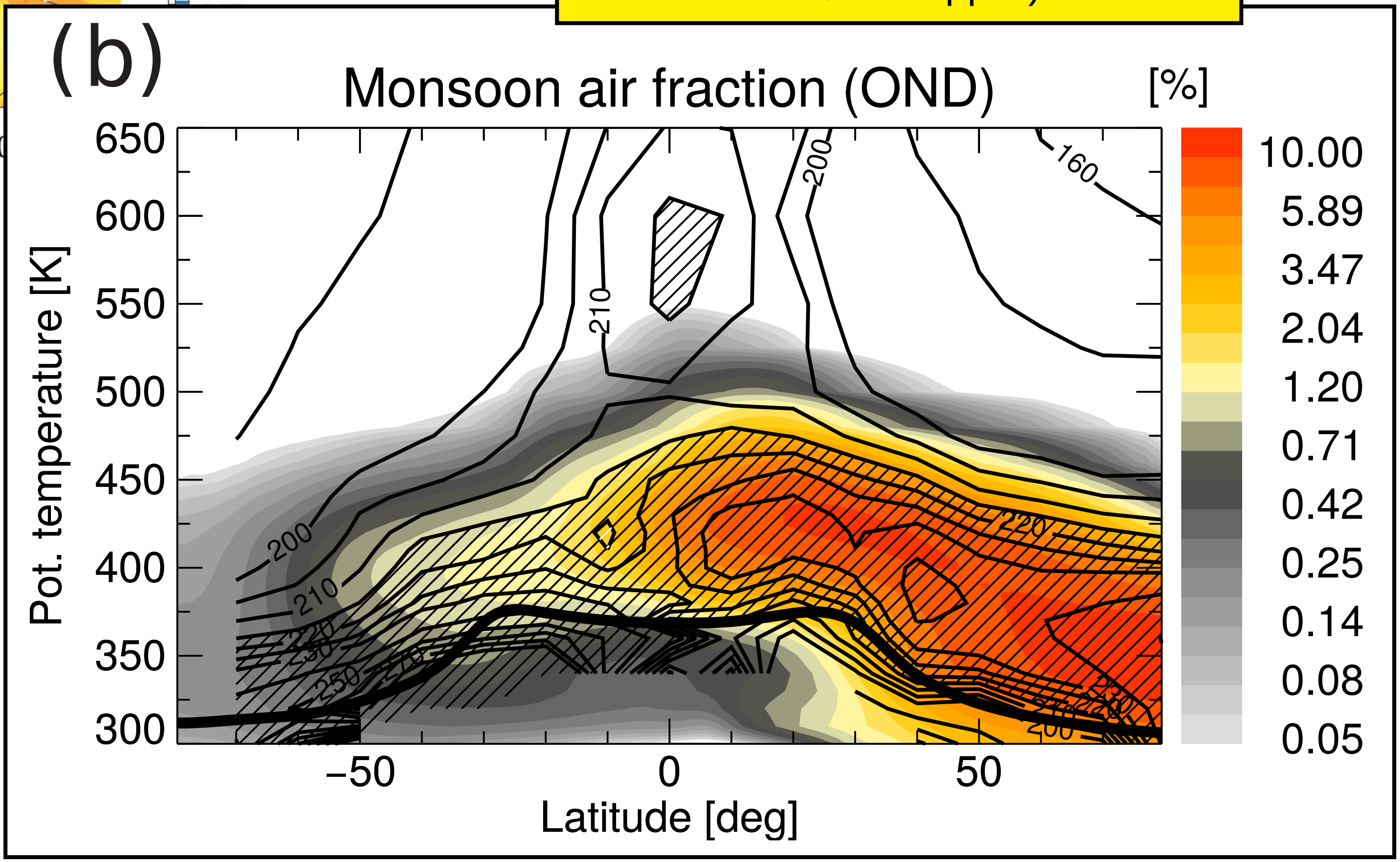

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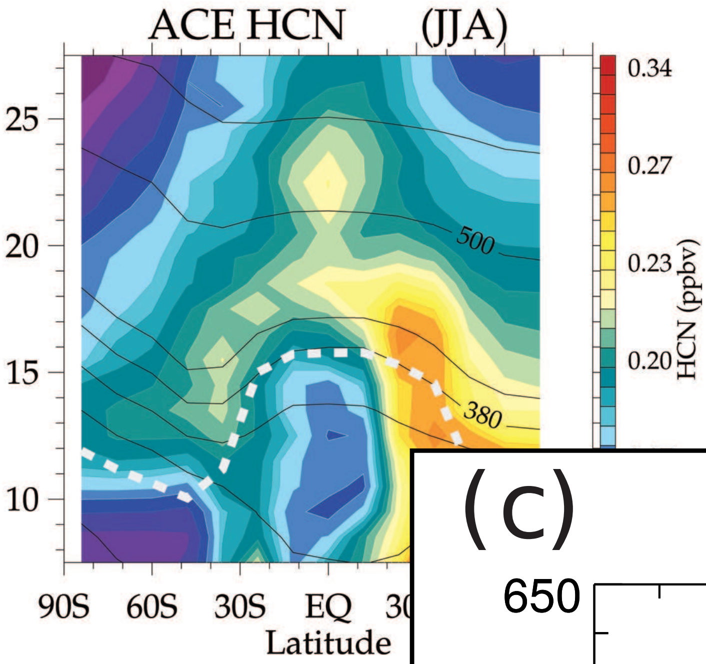

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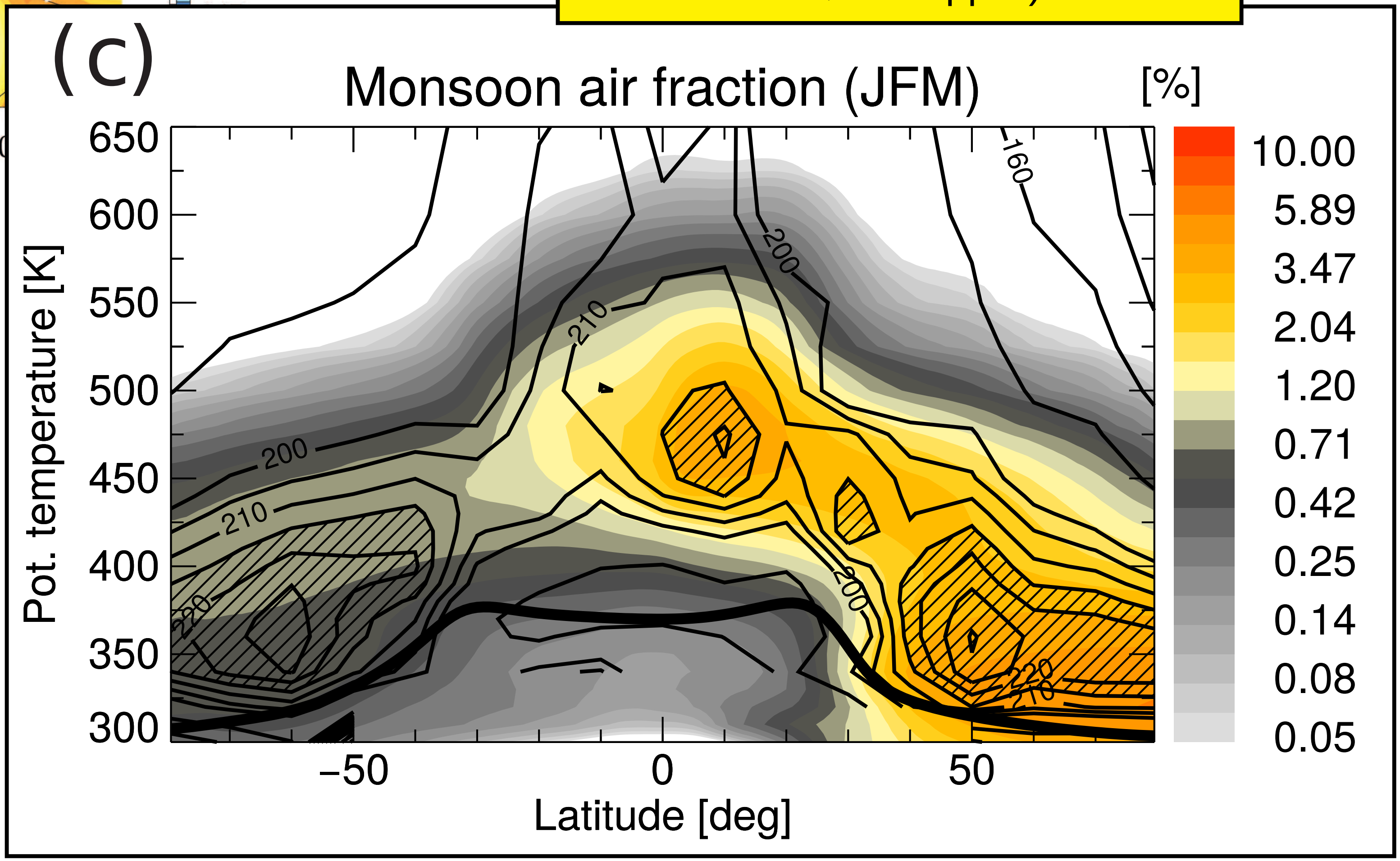

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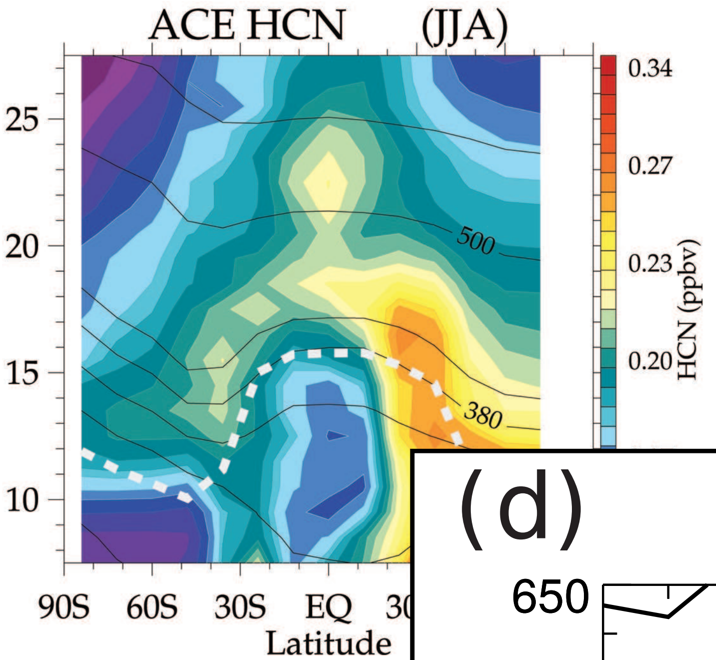

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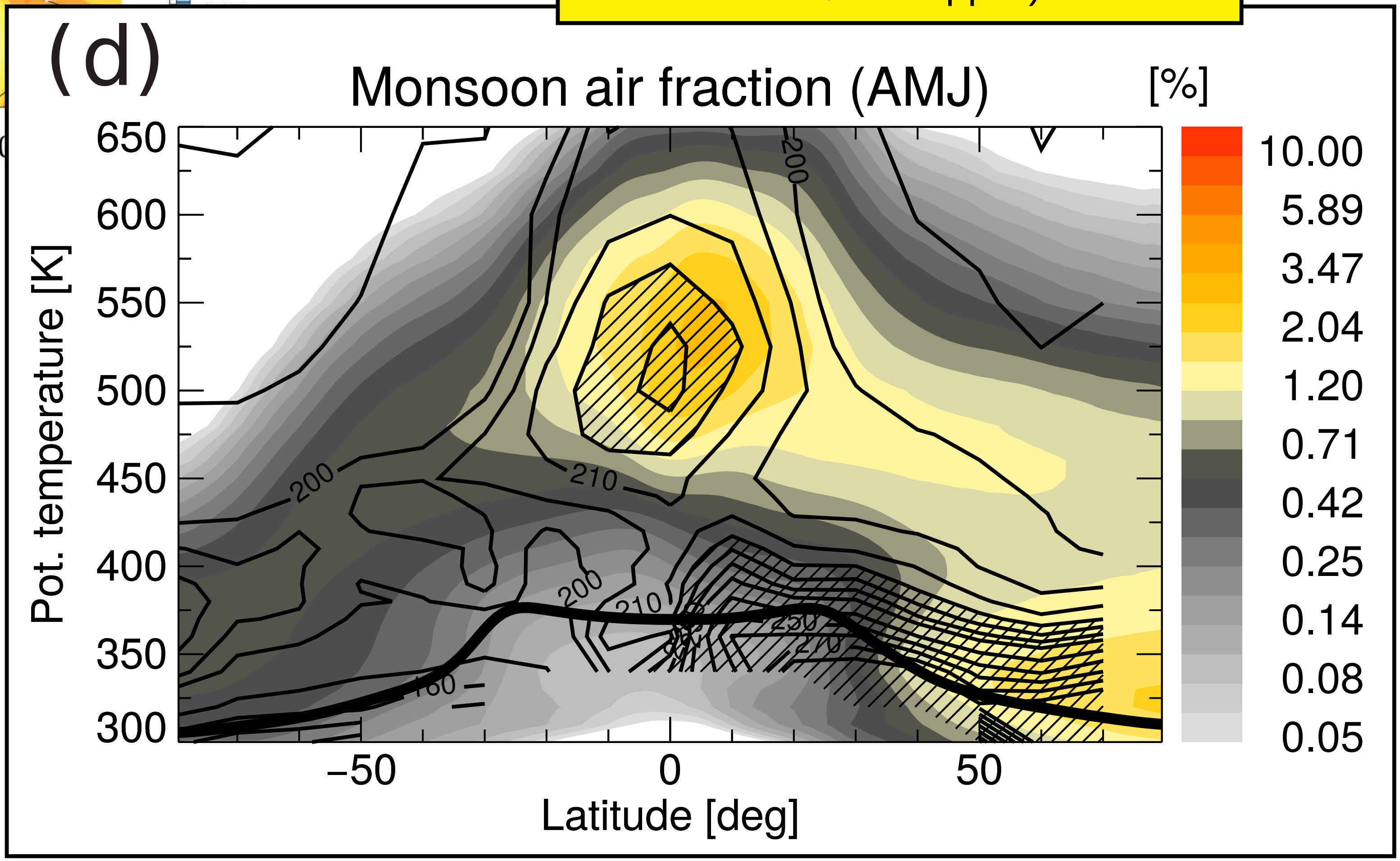

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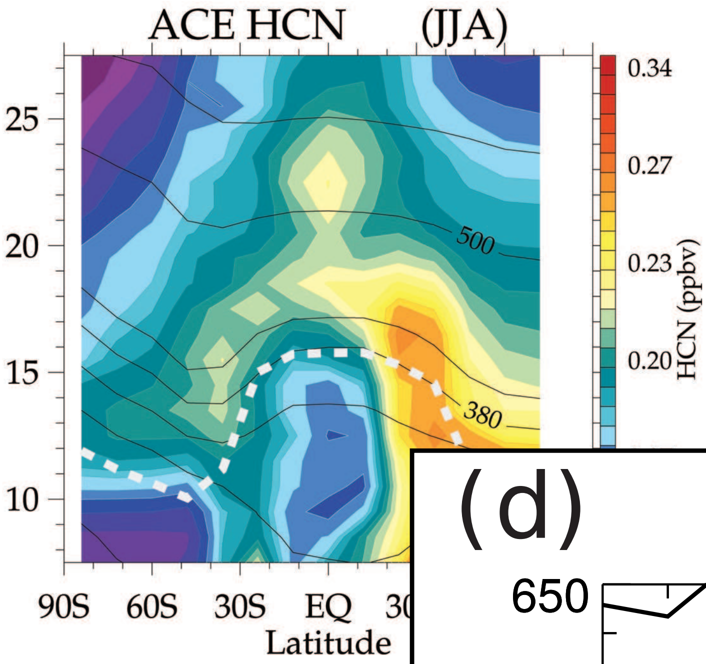

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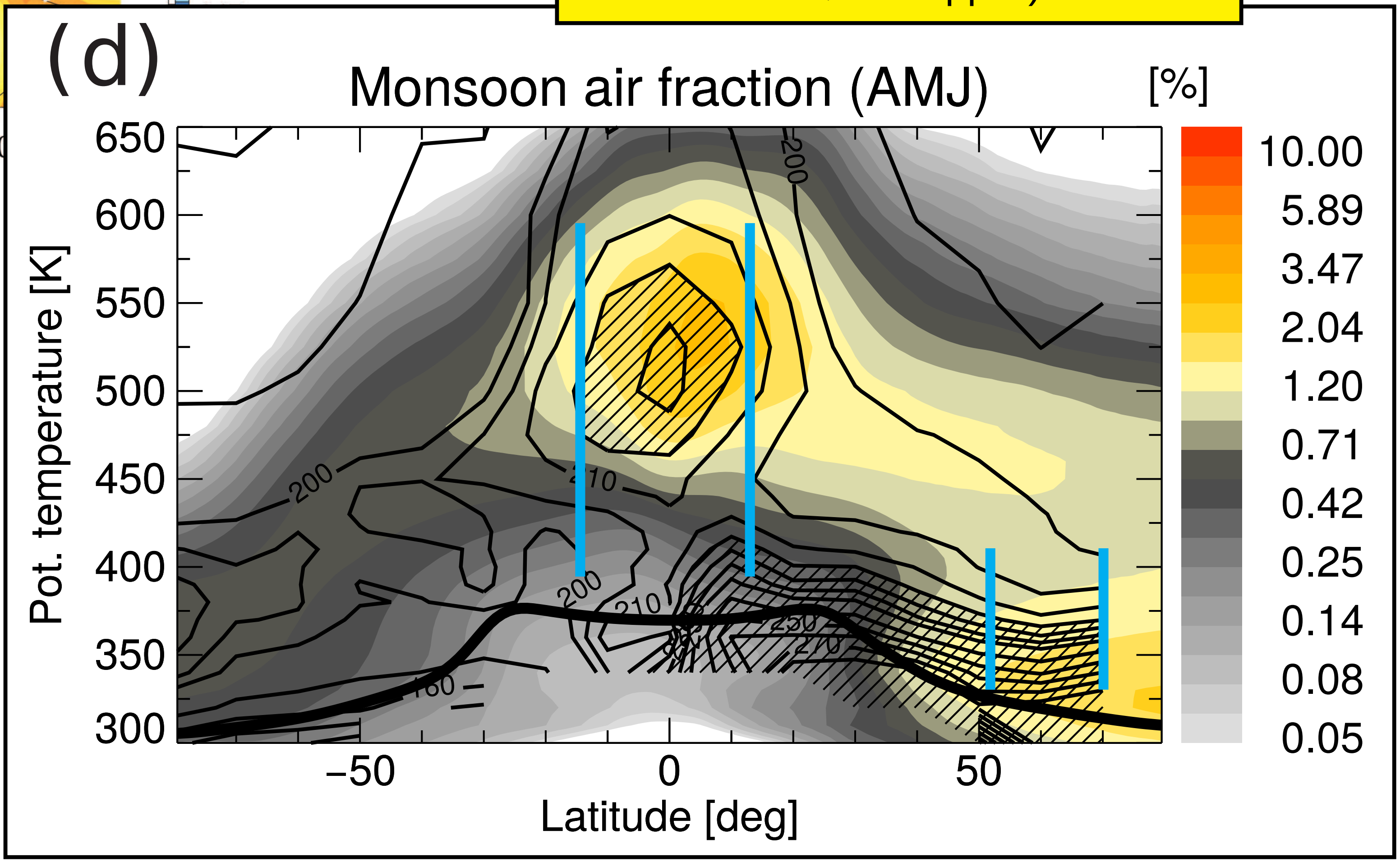

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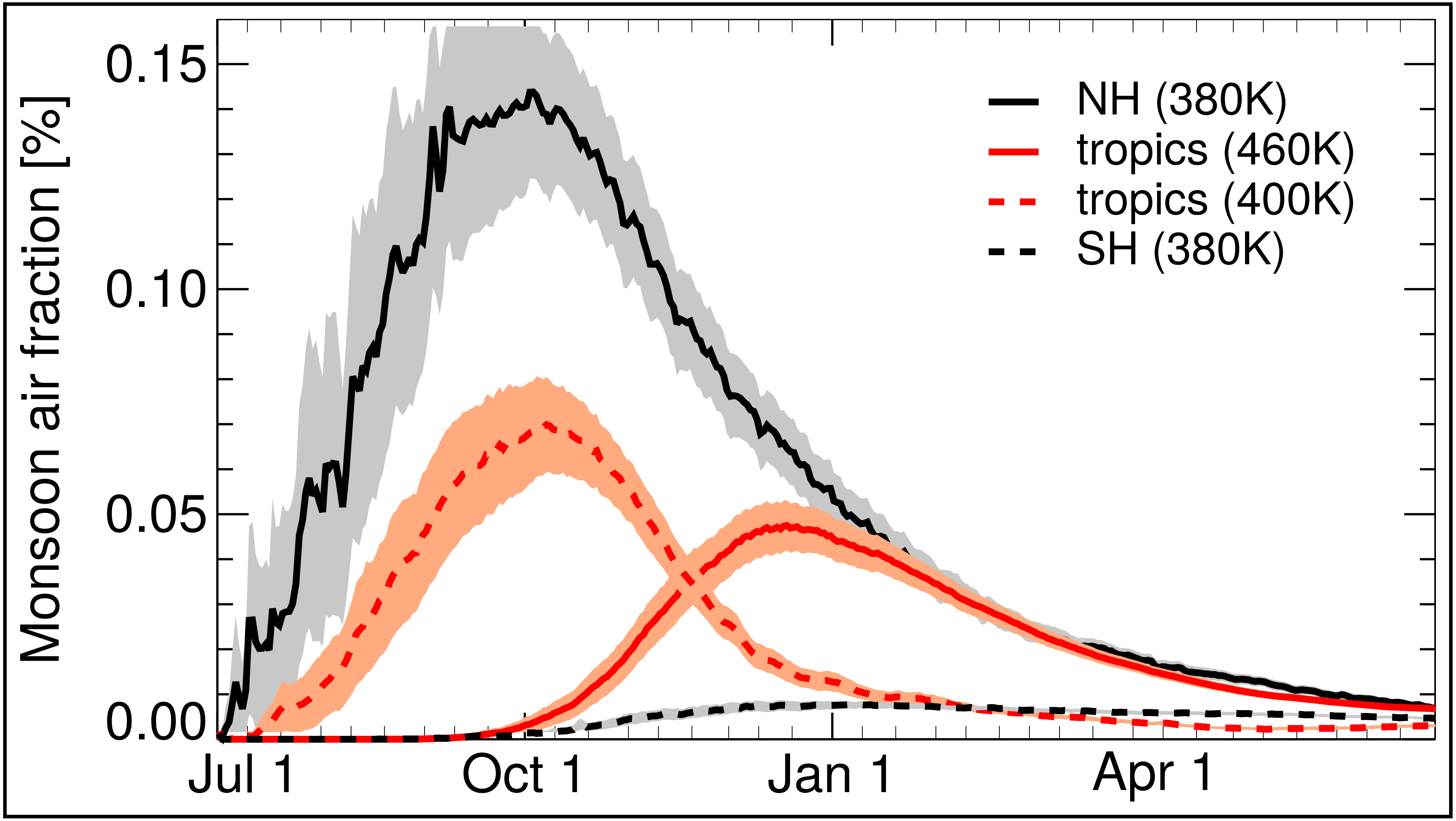
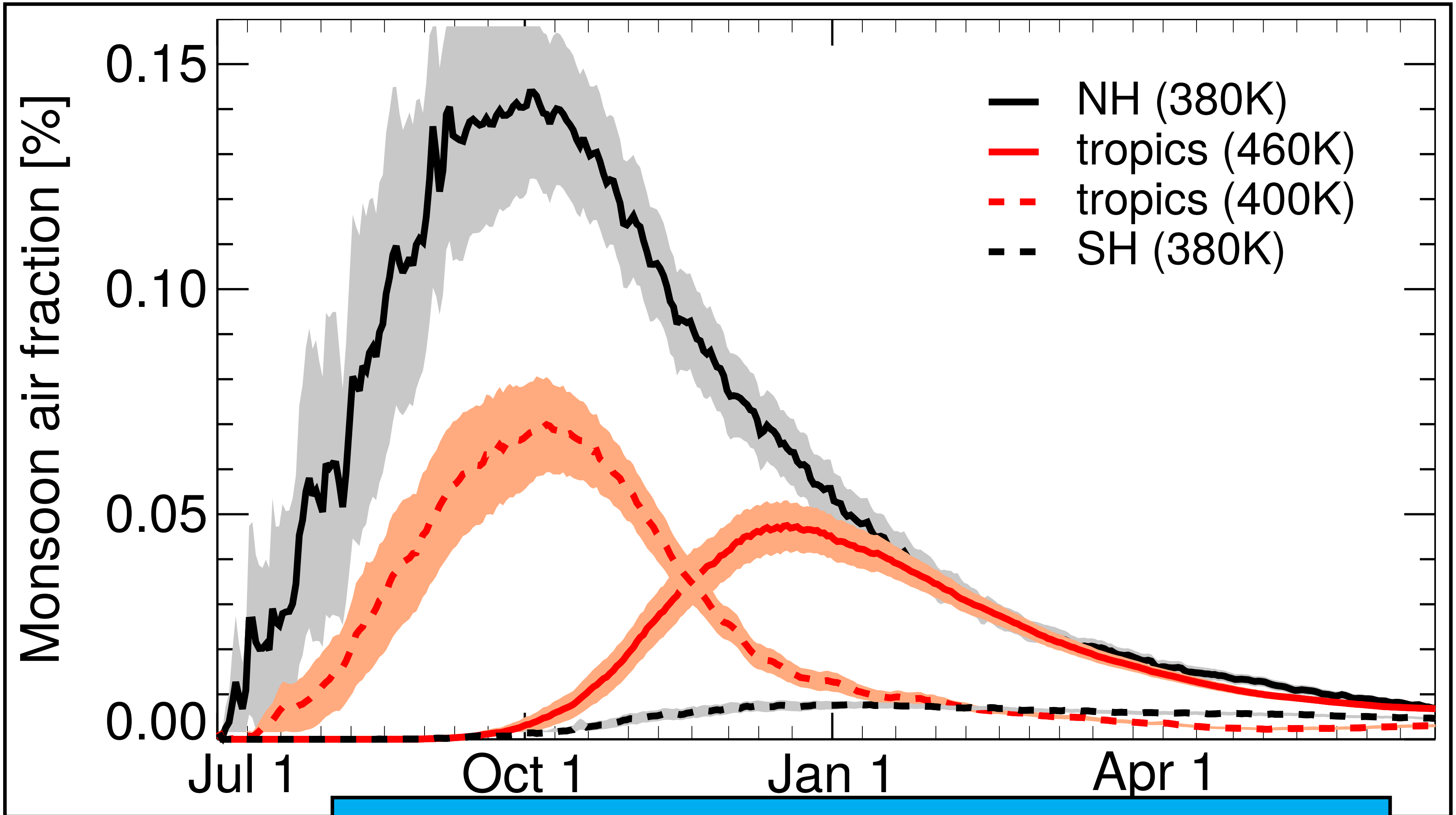
Time evolution



Time series of monsoon air mass fraction at few selected locations. Shading shows the variability (mean standard for the zonal average).

Time evolution



- Strongest contribution in the NH extra-tropical lowermost stratosphere ($\sim 15\%$)
- Transport into the tropical pipe less than ($\sim 5\%$)

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Asian monsoon anticyclone chimney or blower? (Pan et al., 2016)

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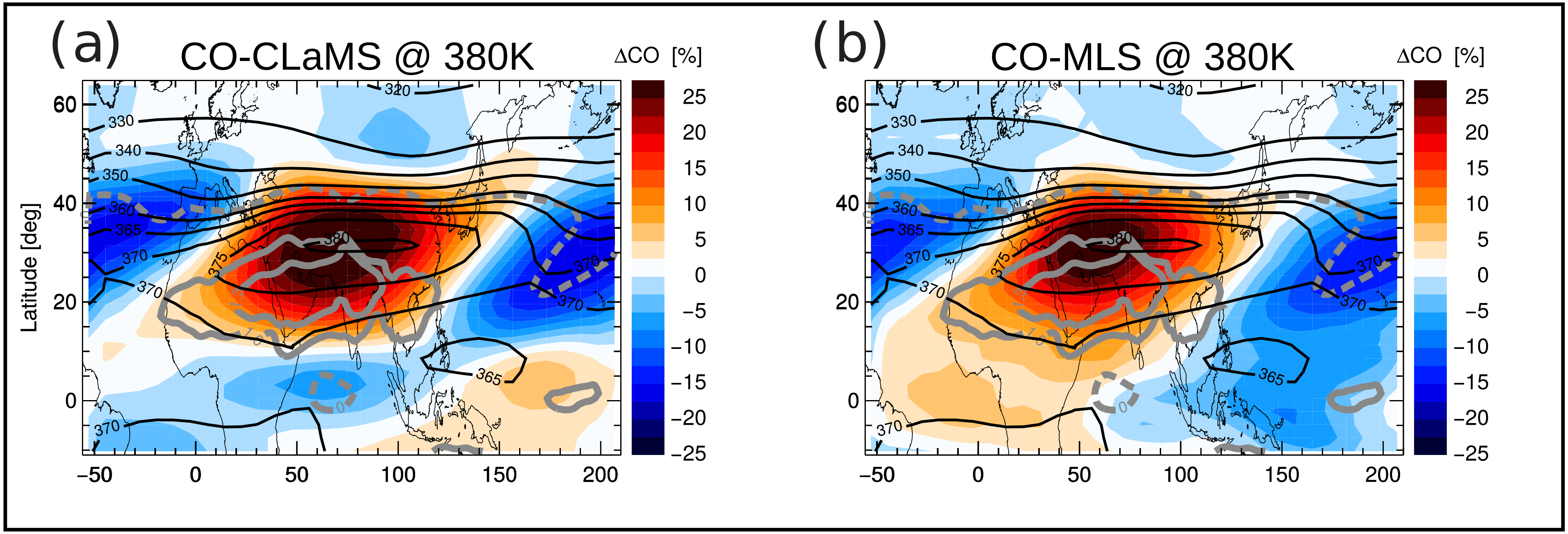
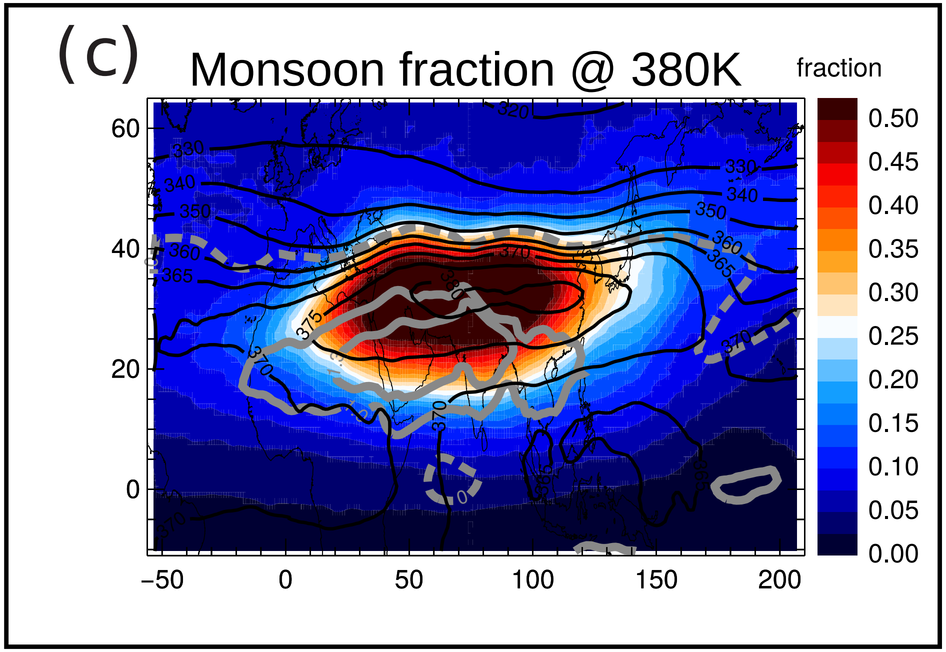
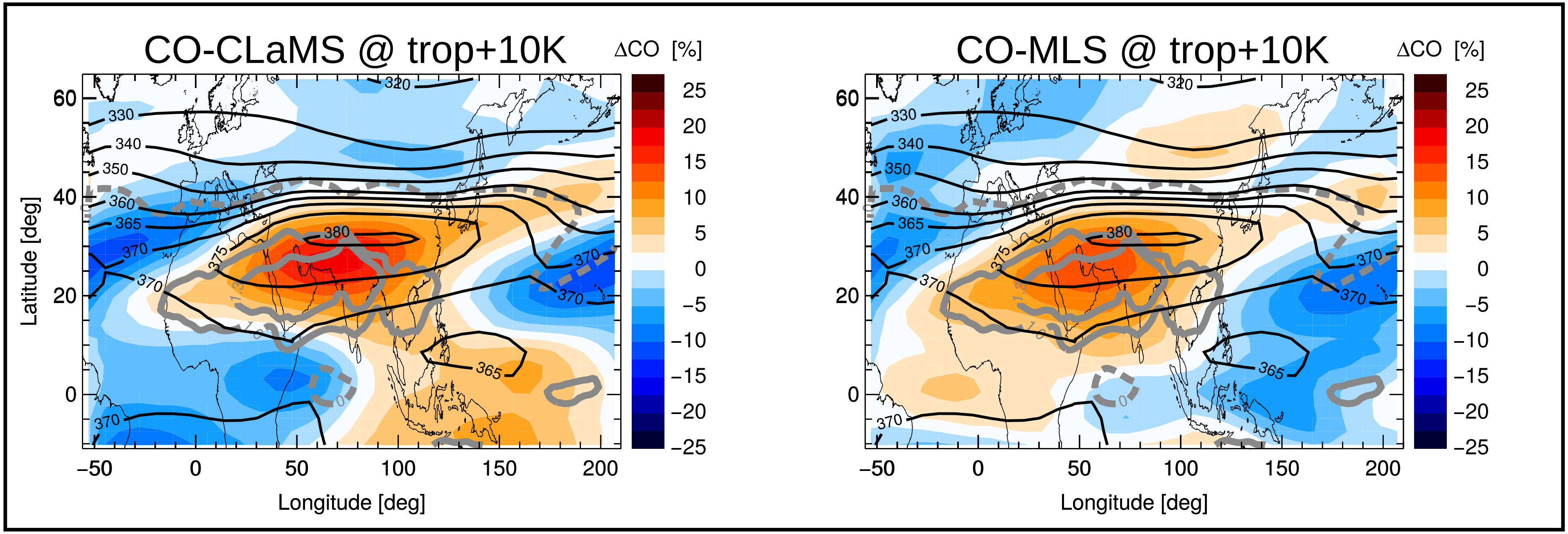
CO: CLaMS versus MLS





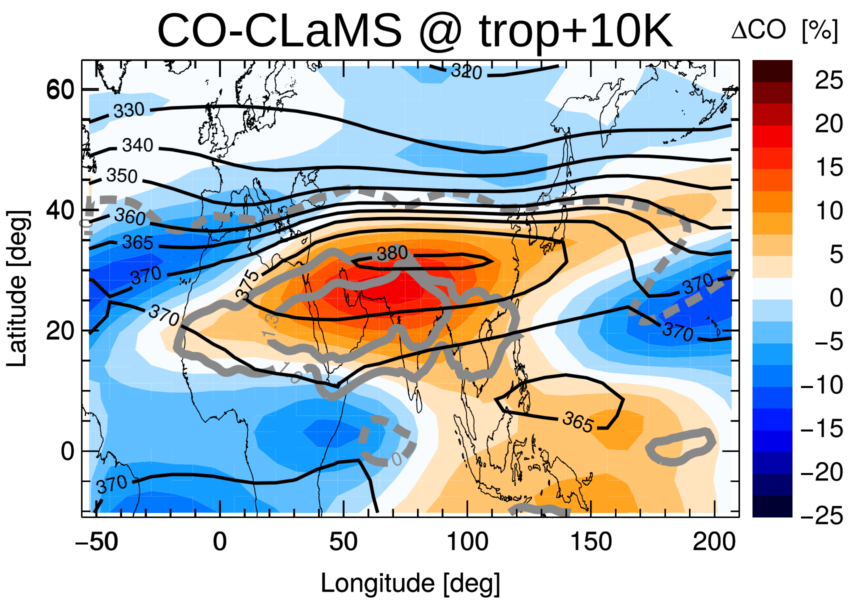
July-September climatologies: Because CLaMS reproduces MLS observations fairly well, we trust the air mass fraction climatologies derived from CLaMS!

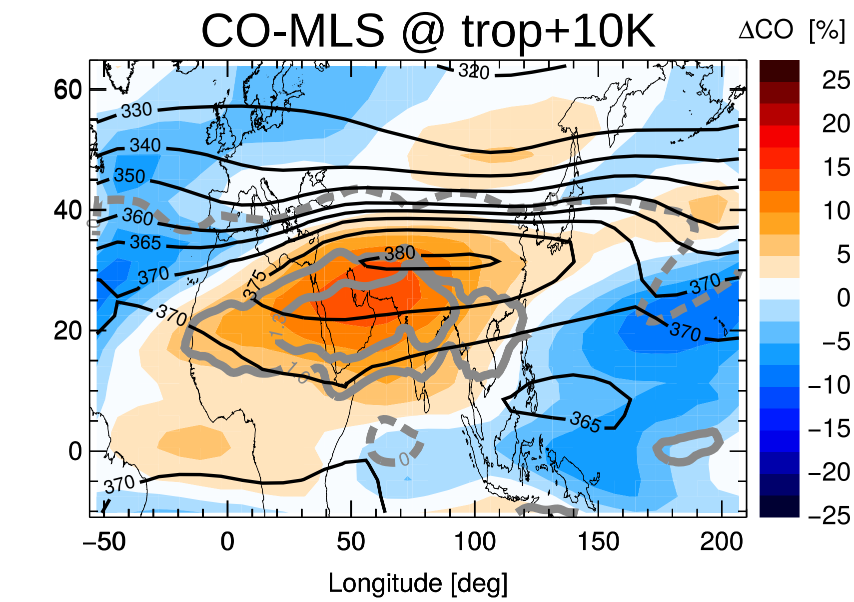
CO: CLaMS versus MLS

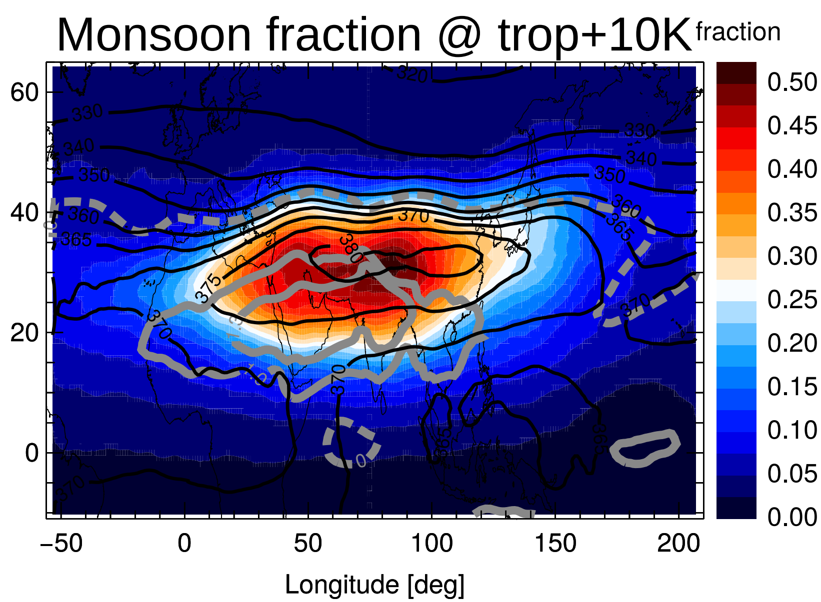


Tropopause-based coordinates (Birner et al., 2002, 2006)

CO: CLaMS versus MLS







...however:

- clear signatures even 10 K above the local tropopause
- ⇒ chimney crosses the local tropopause!

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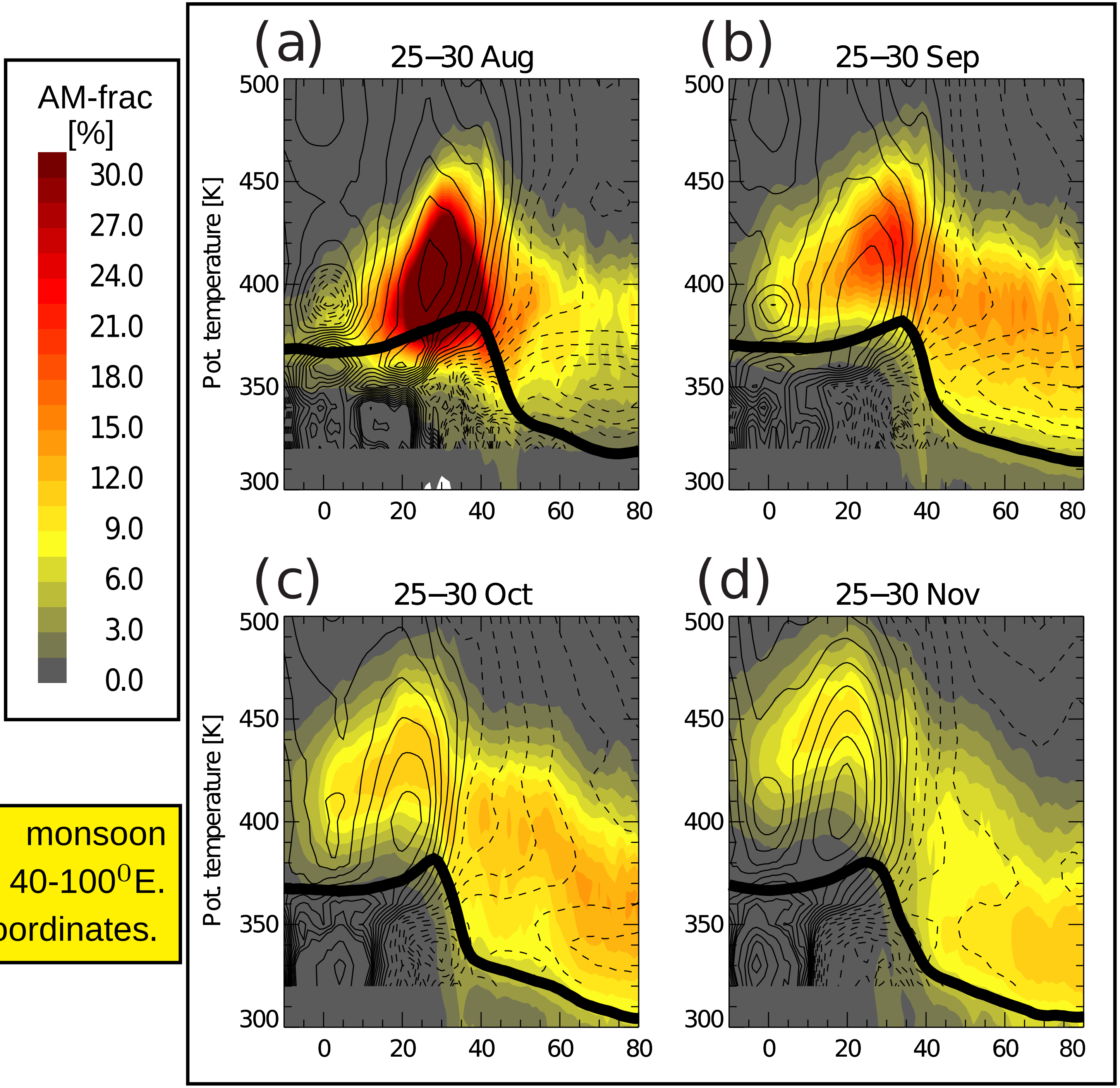
Vertical view



Latitude section of monsoon air mass fraction, 40-100^{0}E. Tropopause-based coordinates.

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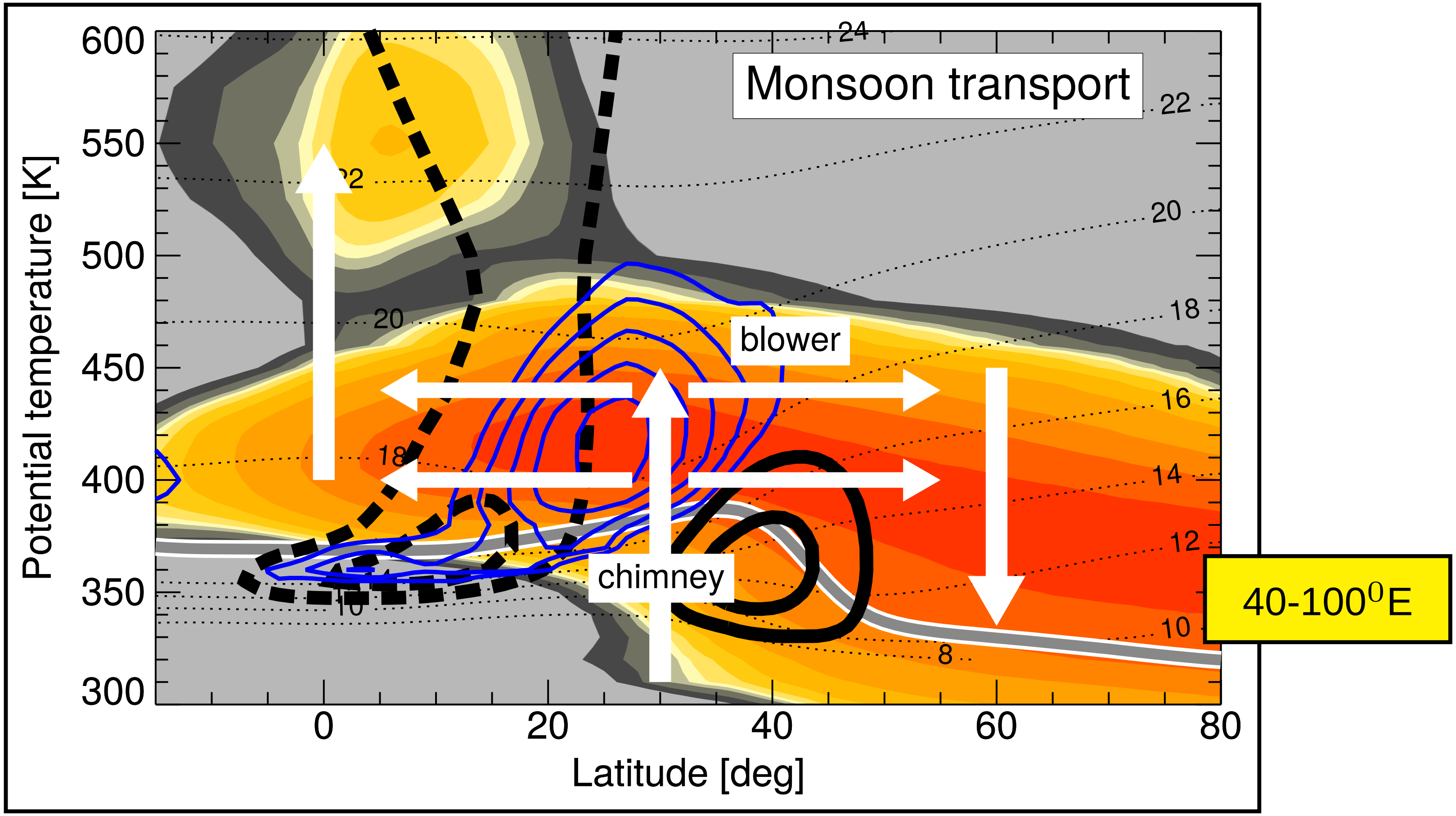
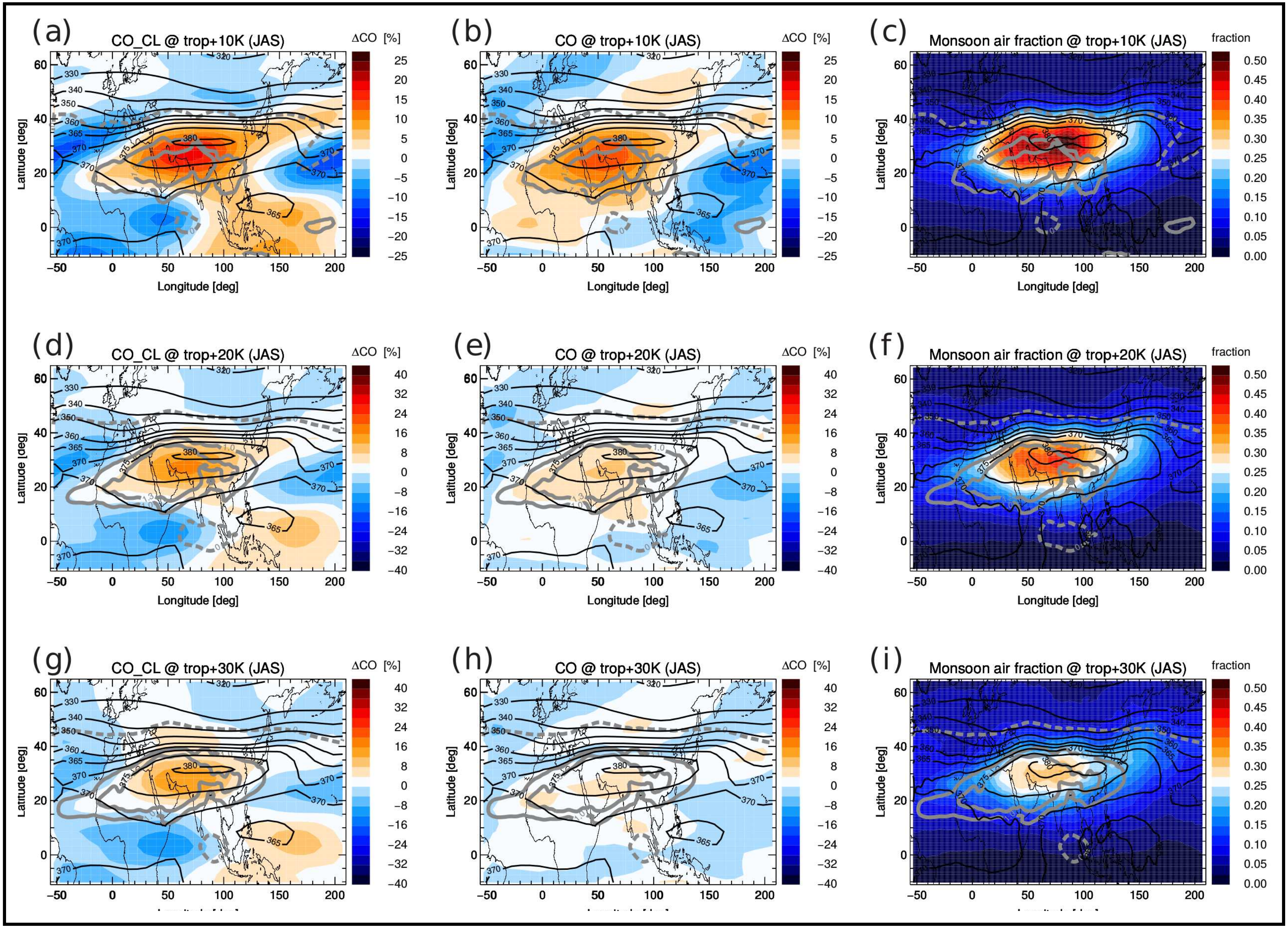
Conclusions:

- Vertical transport across the tropopause (chimney) consistent with Garny and Randel, 2016, but much more isentropic transport into the NH extra-tropical lowermost stratosphere (15%) than into the tropical pipe (5%)
- This strong isentropic transport (blower) consistent with Orbe et al., 2015 and Pan et al., 2016. However, it occurs mainly above the tropopause

Ploeger et al., ACP, 2017 (accepted)



Chimney



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