Transport across the TTL and convection

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An update of Tissier and Legras, ACP, 2016

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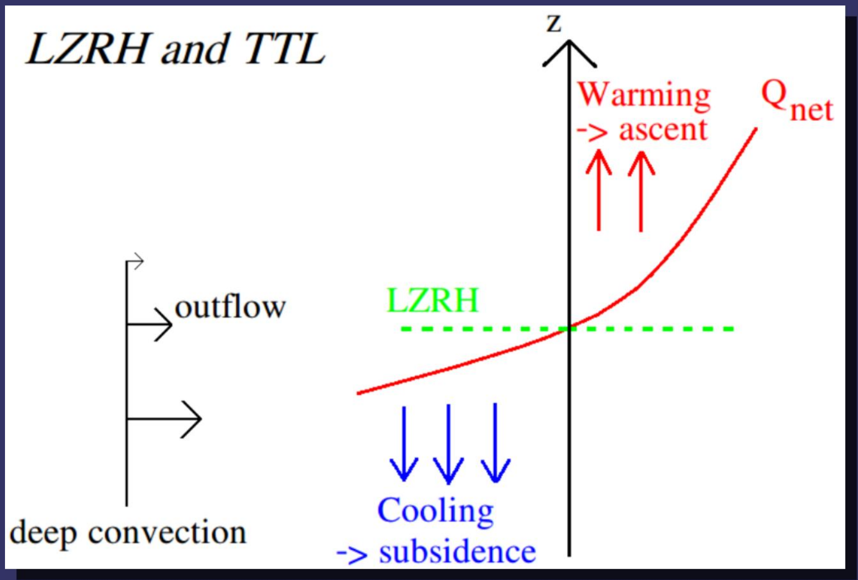
Transition of radiative heating in the TTL from negative to positive values : a transport barrier ?



Schematic of troposphere-to-stratosphere transport pathway.

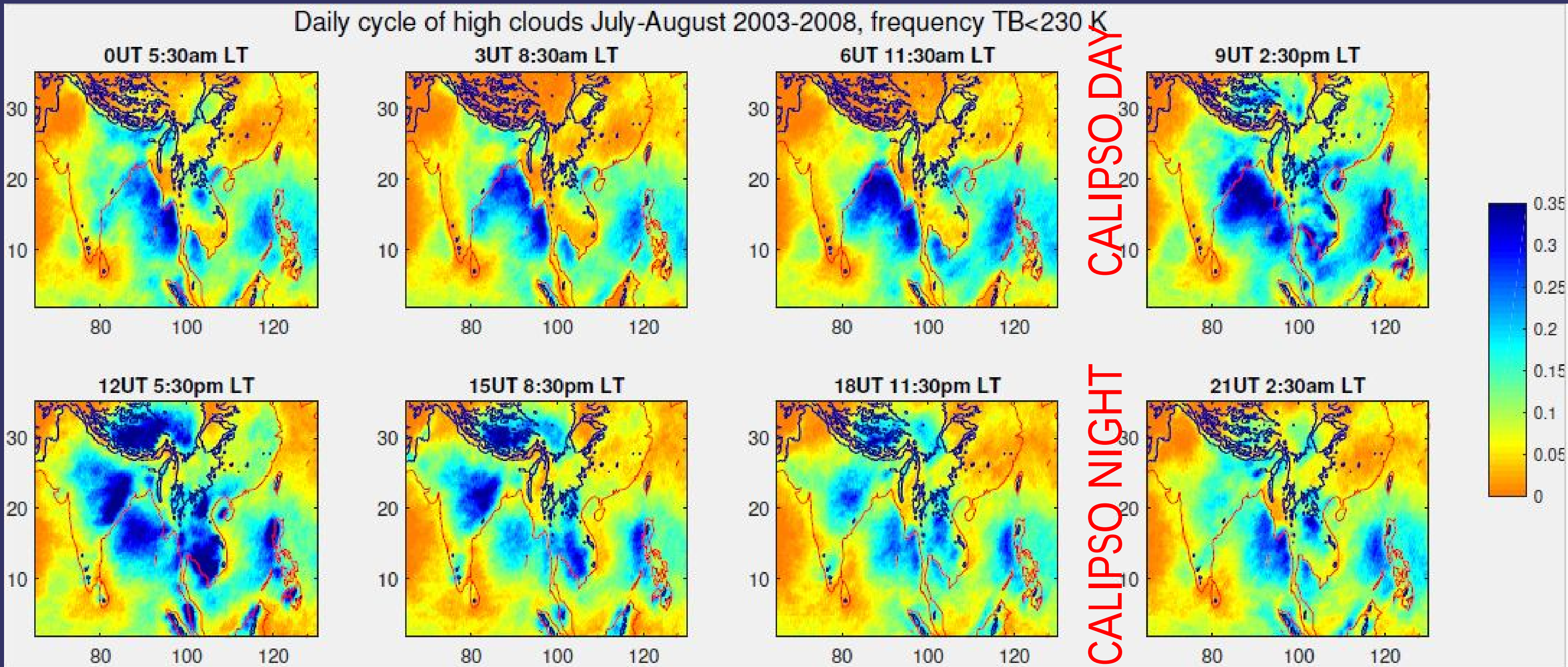
The clear sky Level of Zero Radiative Heating is above the mean level of convective outflow. It divides ascending (above) and descending (below) motion. (Corti et al., 2006)
The all sky LZRH is located above or below the clear sky depending whether clouds are cooling or heating the TTL.

General questions

- What is the distribution of convective sources in the TTL?
- Is the zero level of radiative heating a barrier ?
- What is the residence time of parcels within the TTL ?
- What is the sensitivity to calculated heating rates (differences among reanalysis and with calculations based on observed clouds)?

T=230K 250 hPa – 11 km at 6N
210 hPa – 12 km at lat >24 N

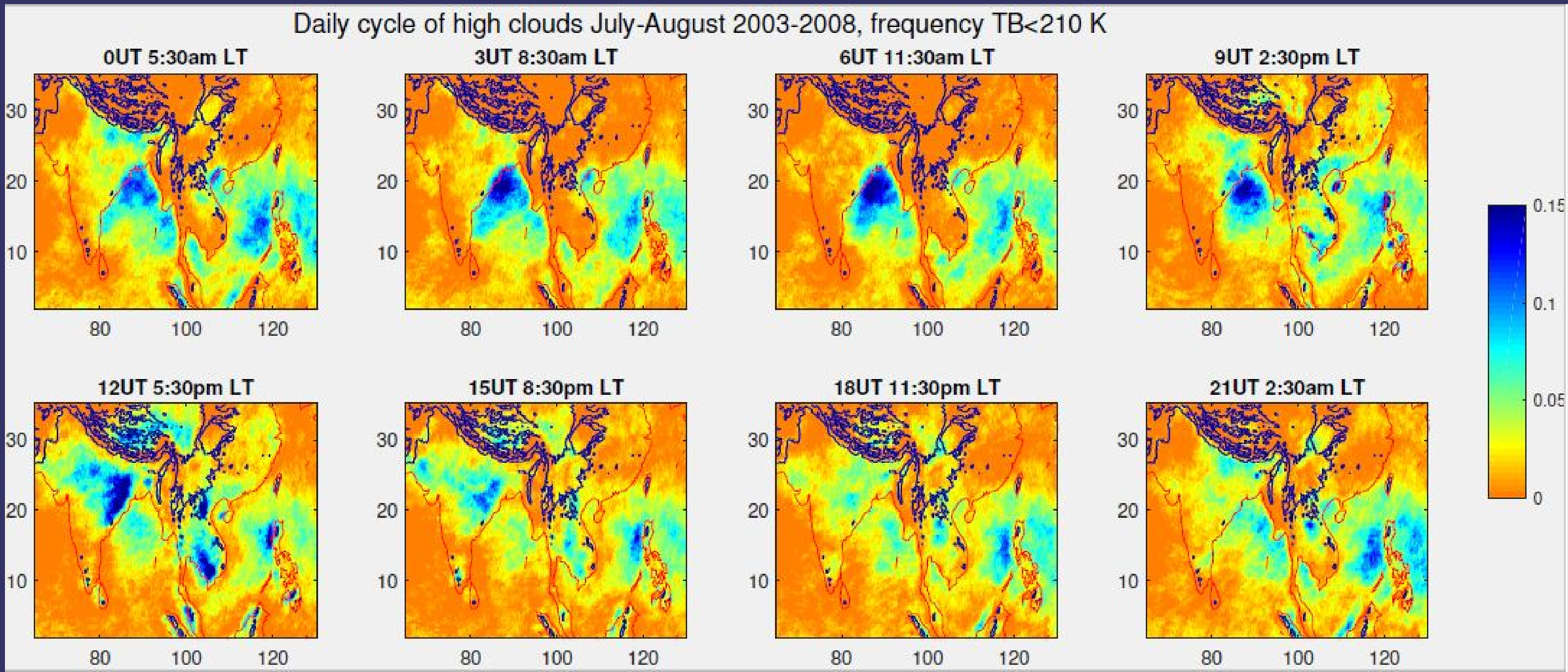
Daily cycle of the distribution of high couds in the Asian monsoon region
Brightness temperature from CLAUS
Frequency of T<230K



Maritime convection most intense at mid-day but persists overnight
Continental convection most intense in the late afternoon (not well sampled by CALIPSO)
Gap in high clouds over the Himalayan slope (a lot of rain however).

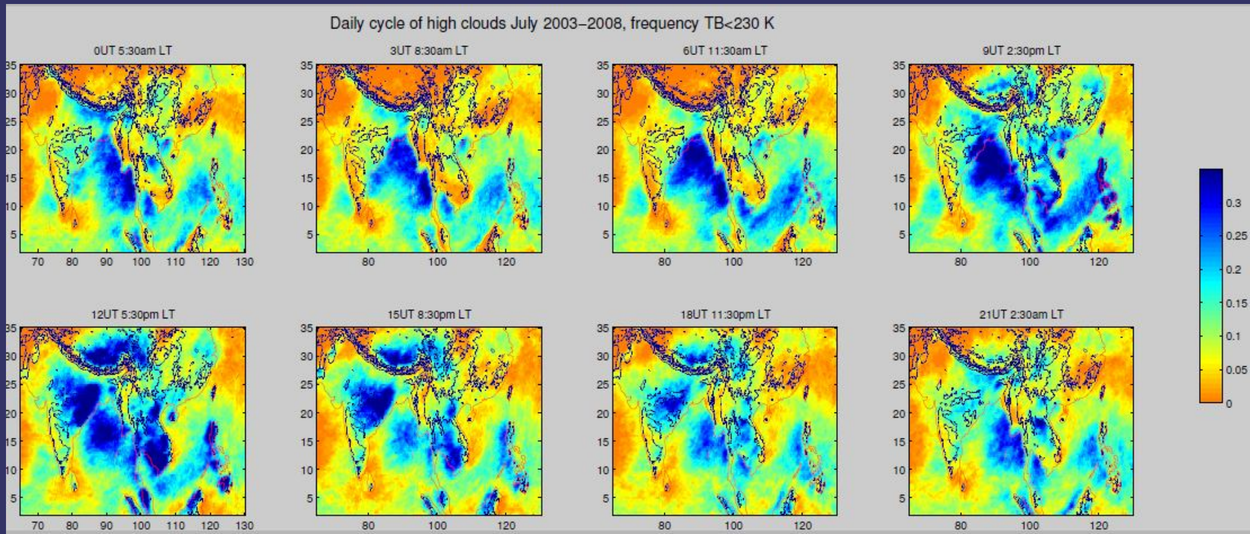
T=210K 160 hPa – 13.5 km at 6N
140 hPa – 15 km at 30 N

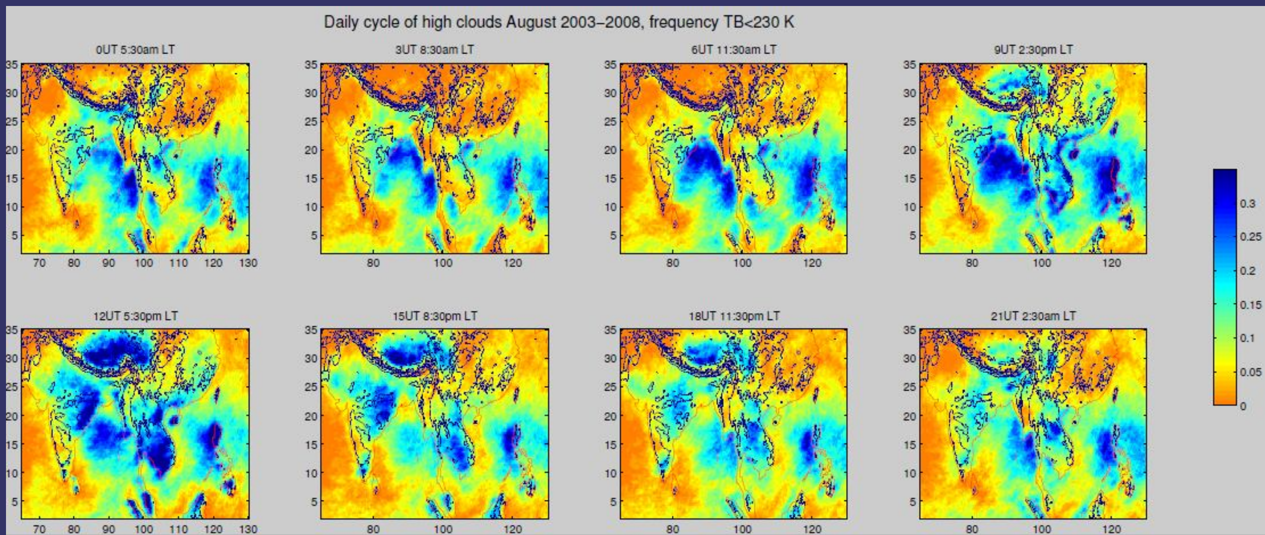
Frequency of T<210K



Very high clouds are more frequent over maritime regions (North of BoB and around Philippines.
Over continental regions, max frequency over India

Deep convective patterns are similar between July and August.
Lower frequency in August but around the Philippines.

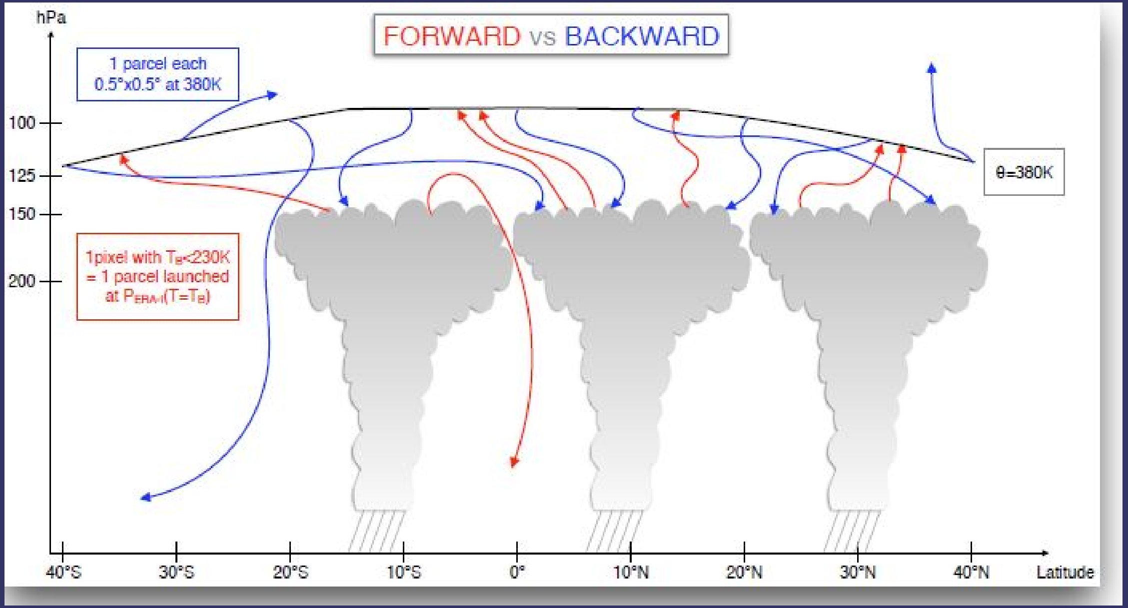




Trajectory calculations with TRACZILLA

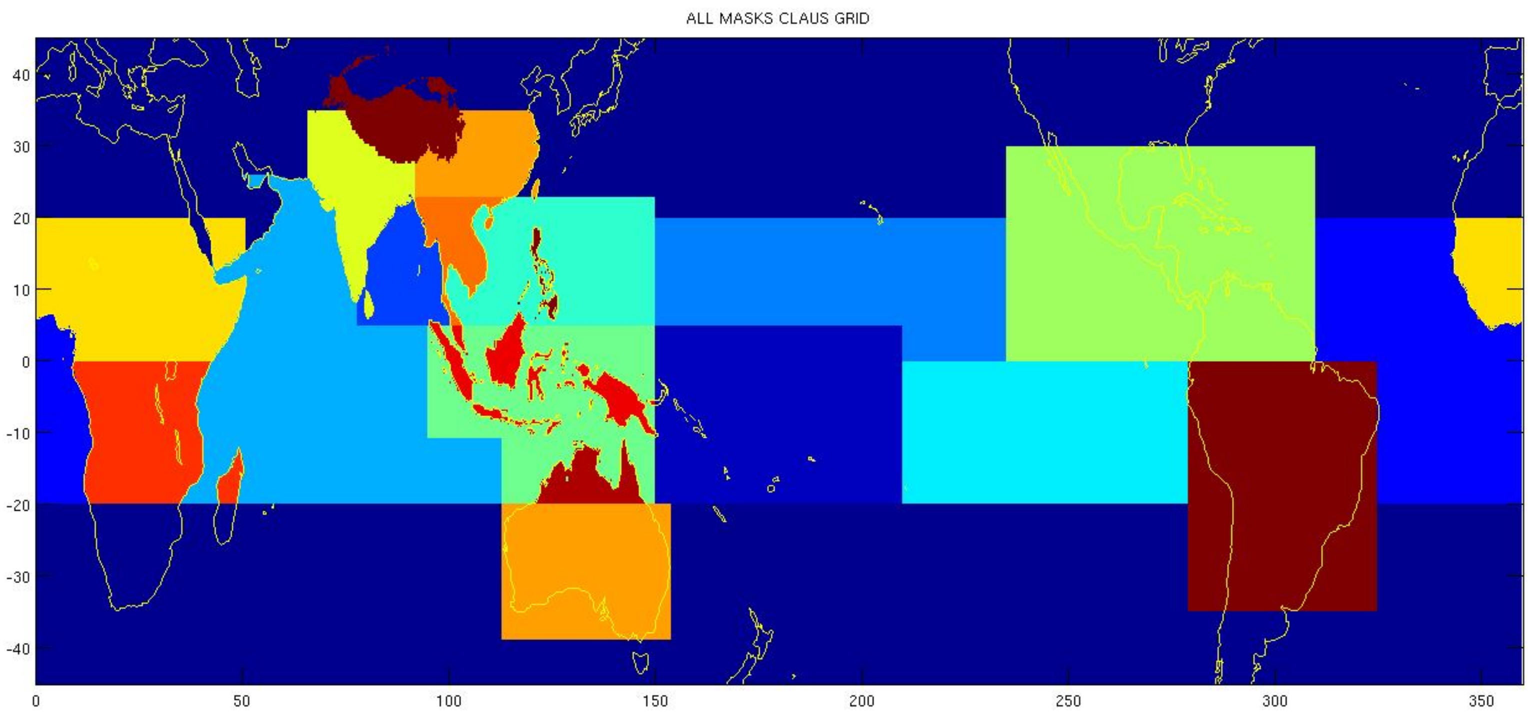
- TRACZILLA : modified version of FLEXPART ([Stohl and al, 2005], [Pisso and Legras,2008])
- Calculations of forward diabatic and backward diabatic trajectories.
- Trajectories are updated every 15 minutes.
- Horizontal part of the movement : calculated using wind fields of ERA-Interim.
- Vertical part of the movement : calculated using radiative heating rates of ERA-Interim.
- No latent heat.

Diabatic trajectories :
Horizontal motion due to horizontal wind
Vertical displacement by heating rates using potential temperature θ as coordinate.
3-hourly data for ERA-Interim and MERRA, 6-hourly for JRA-55
Reference surface θ=380K
3-month trajectories



Backward launching : 1 parcel on 0.5°x0.5° grid on 40S-40N every two days, stopped at first encounter of cloud top + 1km
Forward launching : 1 parcel at cloud top +1km for each CLAUS pixel (3h and 30km resolution) at T<230K, stopped at first encounter of 380K surface

Regional boxes are defined over the major contributing sources, with an accent on the Asian monsoon region, separating continental from maritime regions and partitioning Asian continental regions.



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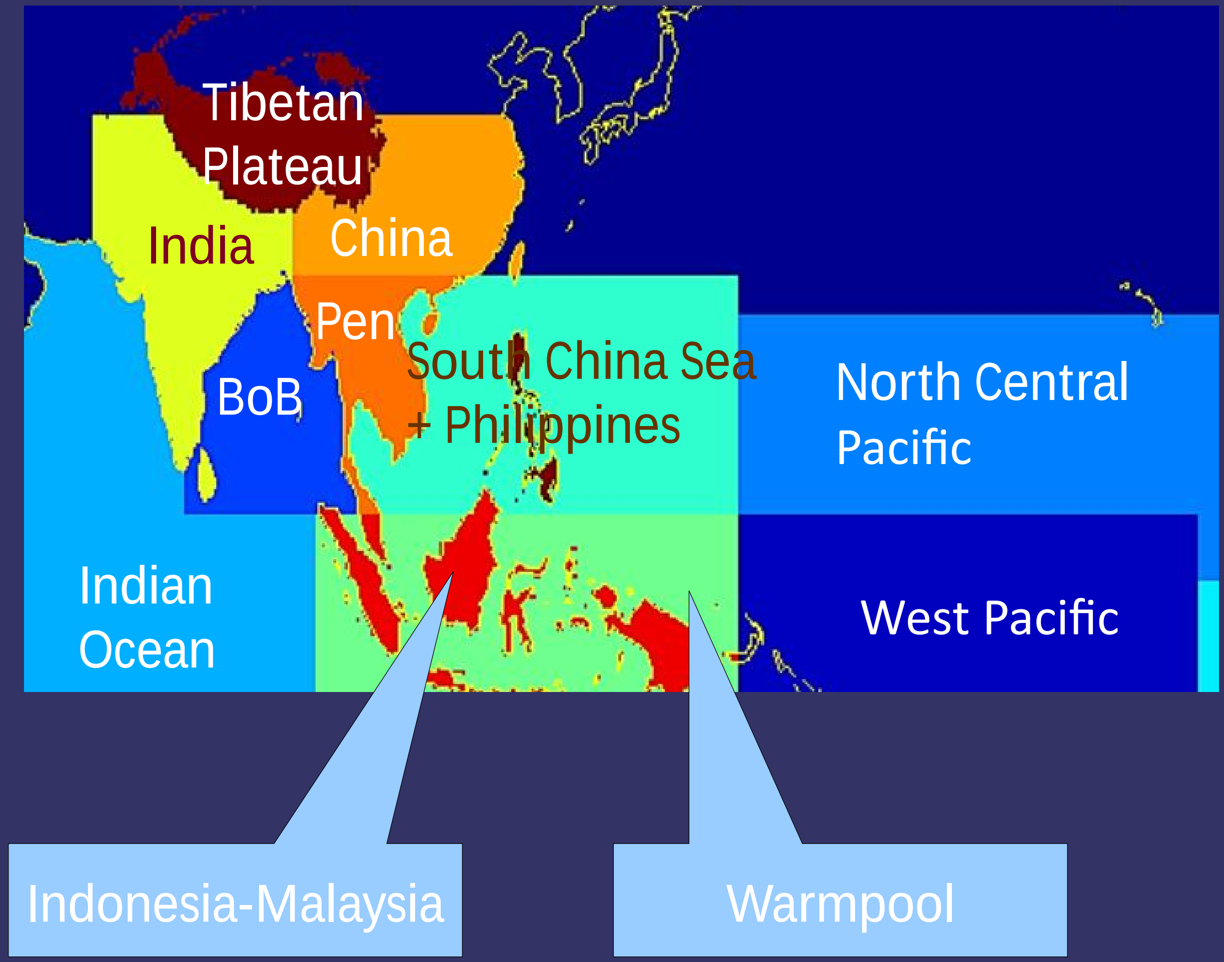
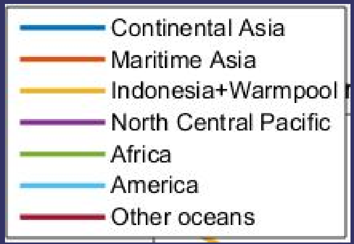


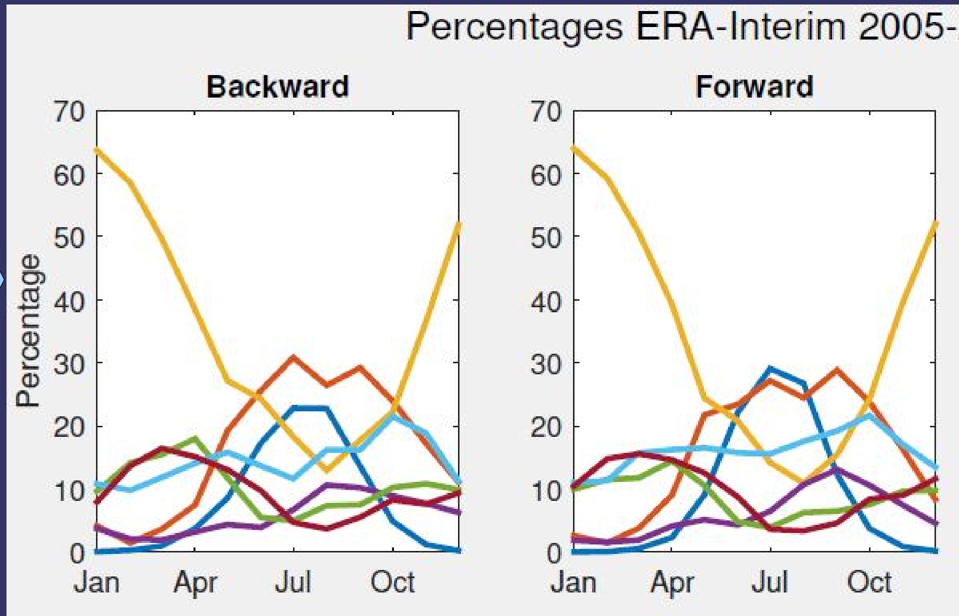
Origin of air parcels that cross the θ=380K surface, ERA-Interim

All year

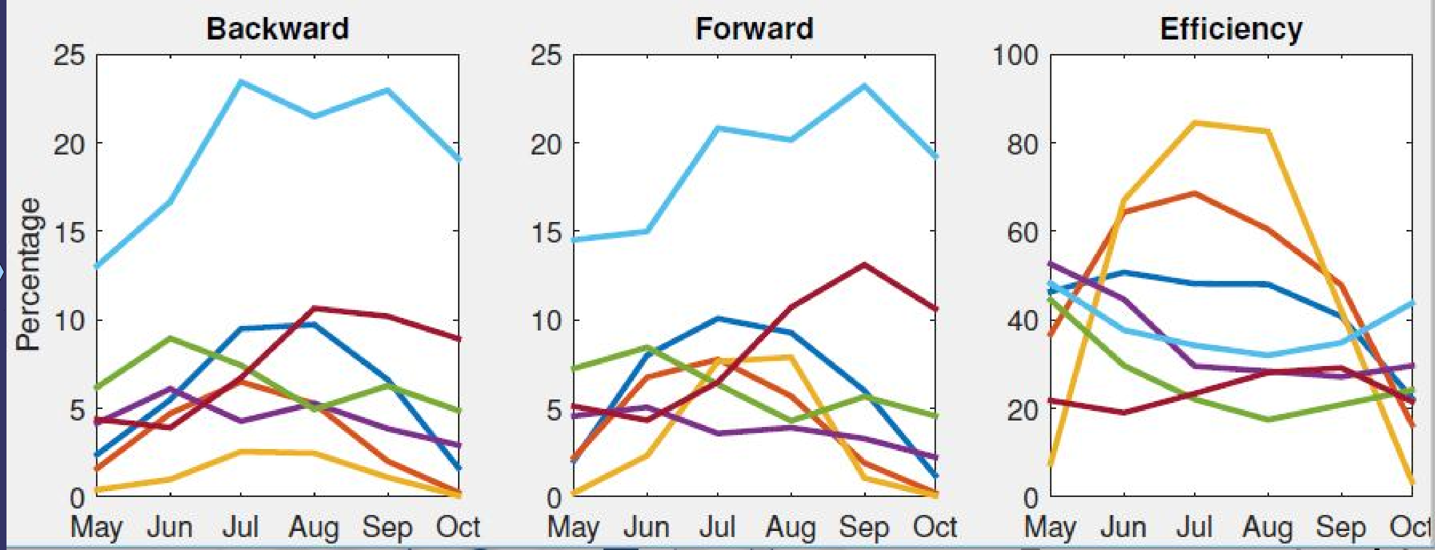


82 % of backward trajectories from the θ=380K surface (40S-40N) reach a convective cloud within 3 months.

Summer



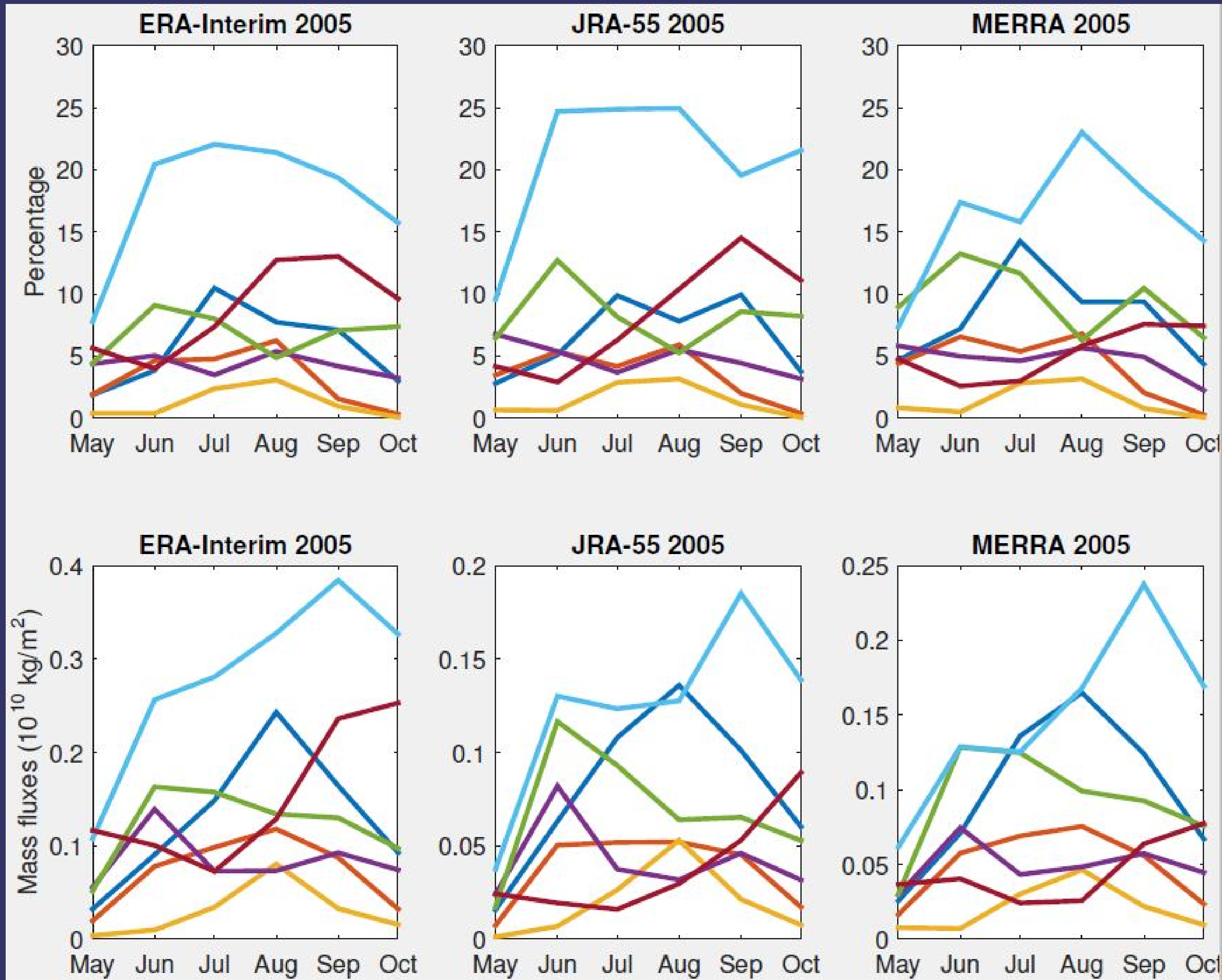
During summer, the largest source is the South China Sea + Philippines Sea region. Largest efficiency (proportion of parcels reaching 380K) over Tibetan Plateau and China.



Distribution of sources in percentages quite similar among reanalysis.

Diabatic mass fluxes in ERA-Interim are about twice that of the two other reanalysis.

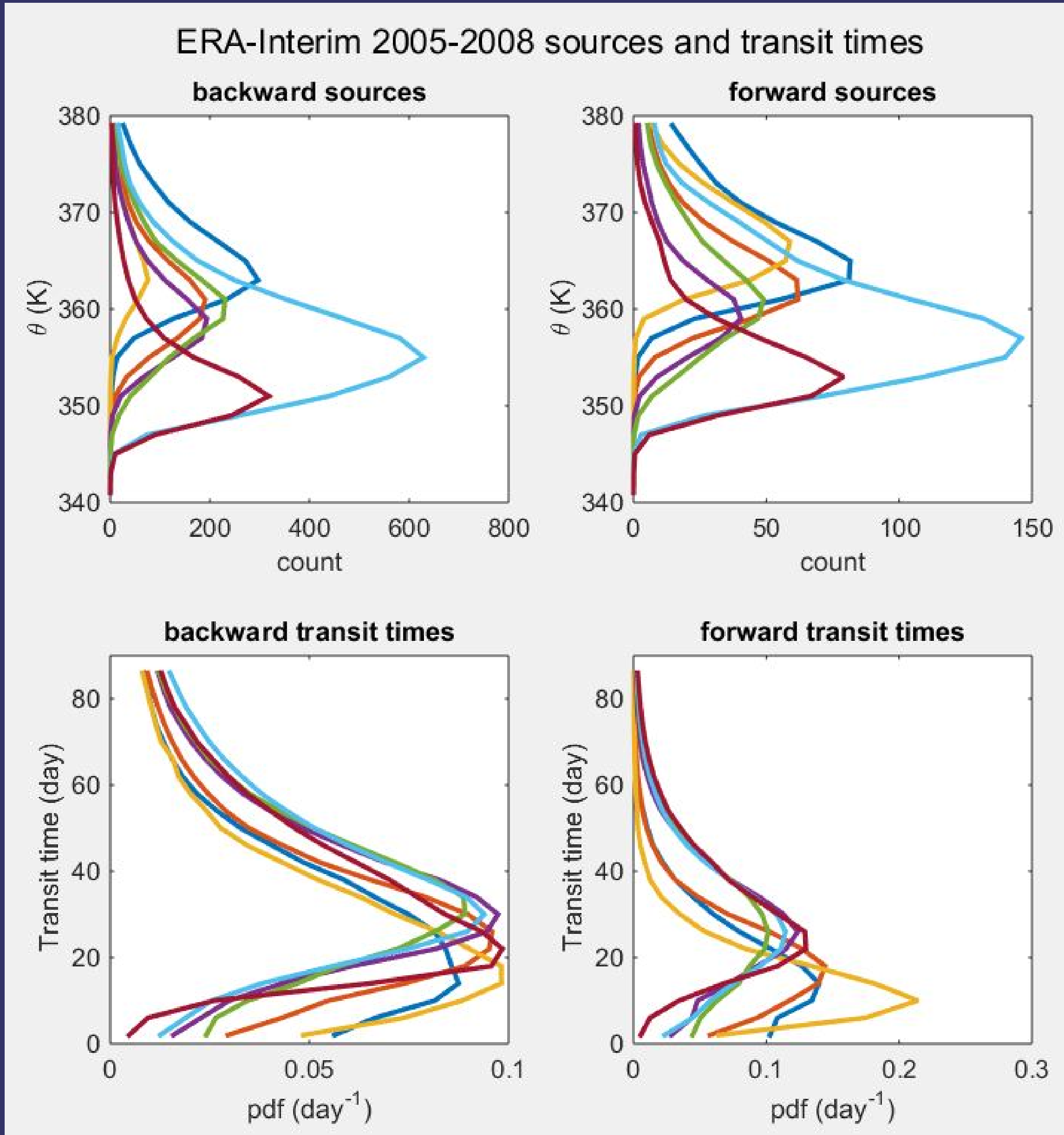
Origin of air parcels that cross the θ=380K surface
In percentage and in mass flux over 2005



Vertical distribution of sources and transit times in the ERA-Interim for JJA

The maritime sources of North Pacific, Philippines Sea and Sea of China are located under 360K (like the warmpool in winter). BoB and continental sources exhibit forward peaks above 360K. Highest sources above India and the Tibetan Plateau.

Most of the sources (~80%) located above the LZRH (not shown) except Tibetan plateau (50%)
(Tissier & legras, ACP, 2016)

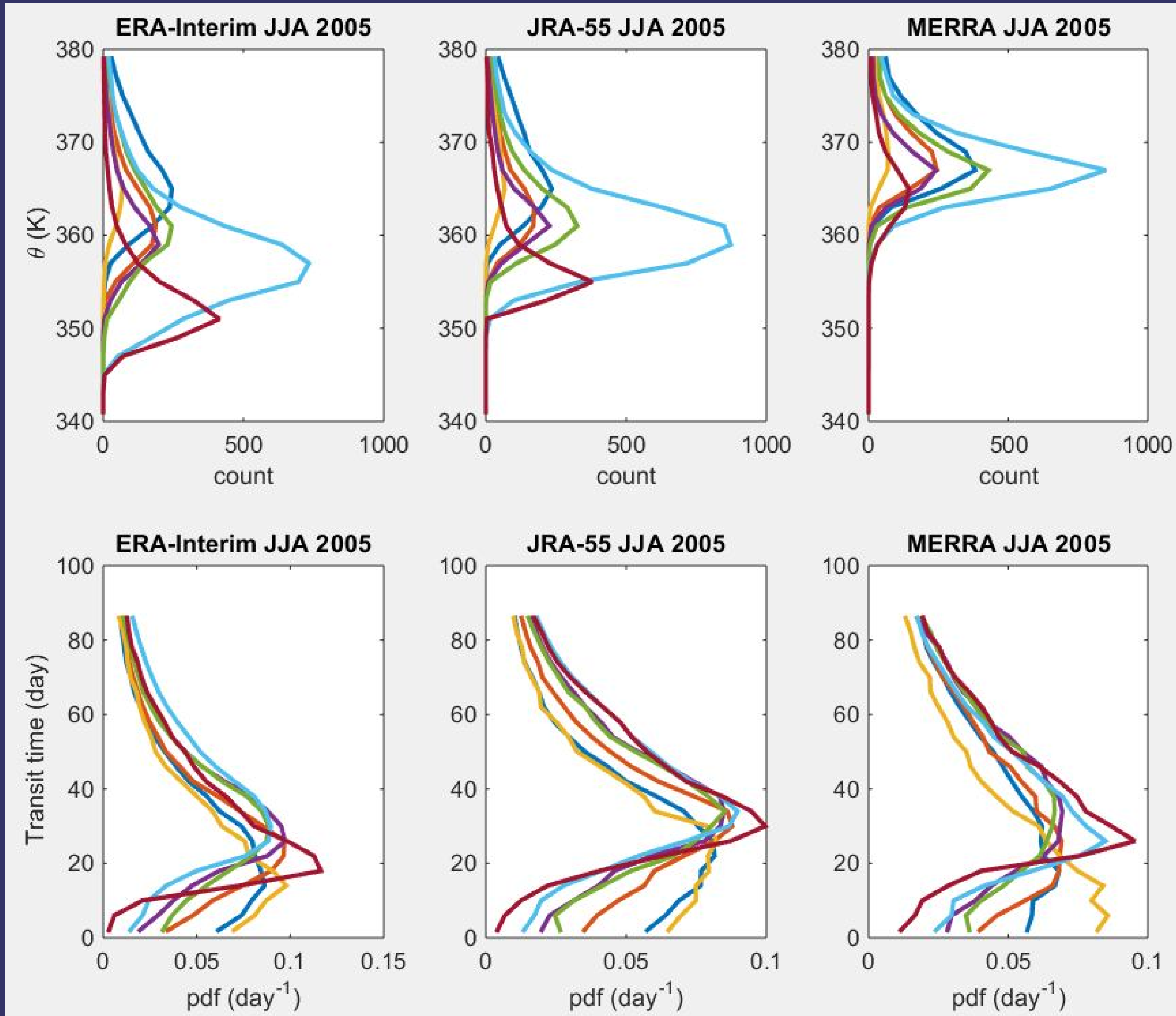


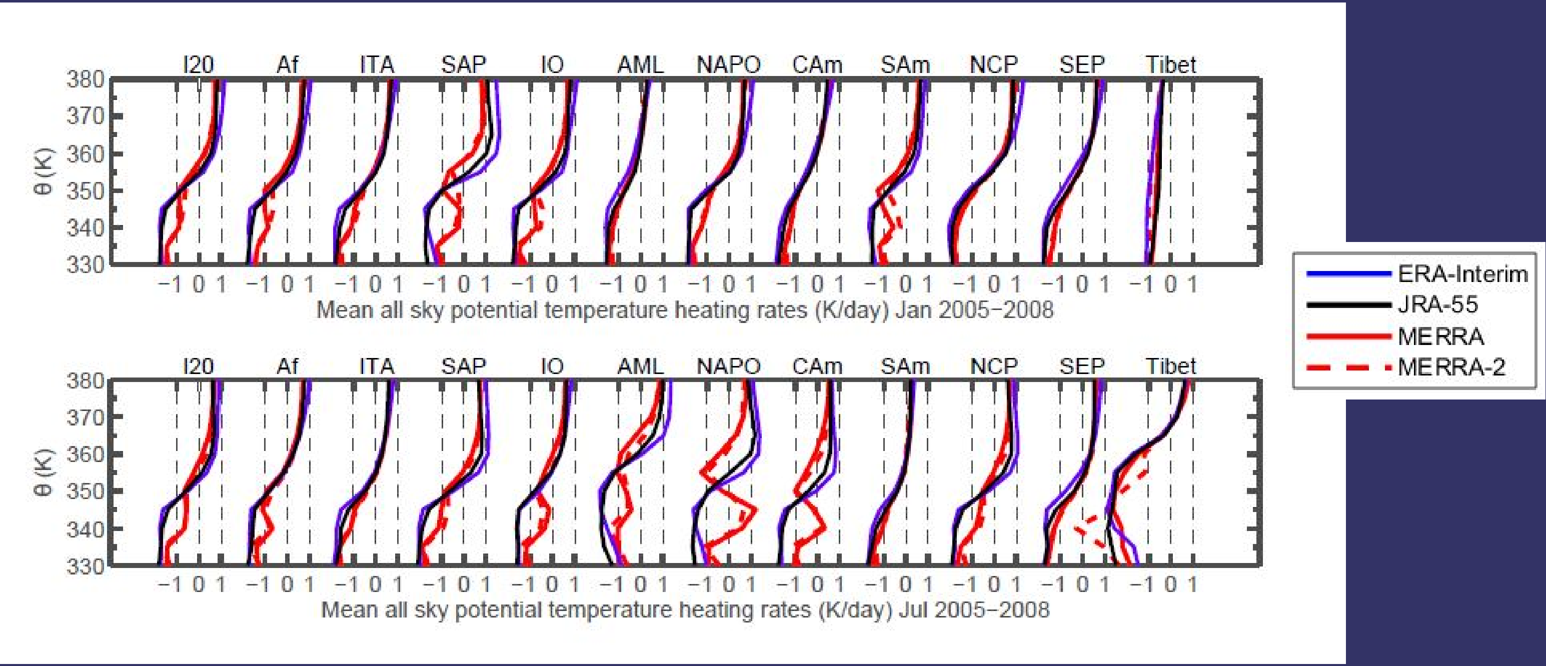
Transit times are shorter for highest sources.

Comparison between the three renalysis. Sources and transit times for back traj.

Sources are located higher in JRA-55 than ERA-Interim and much higher in MERRA.

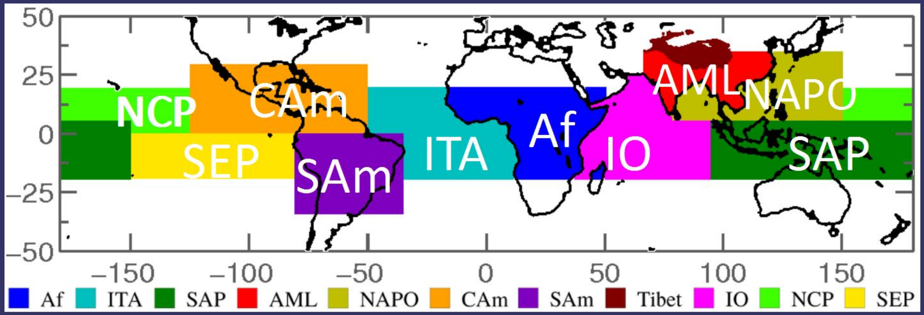
Transit times are, however, often longer in MERRA and JRA-55 .



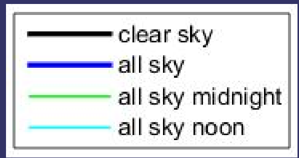


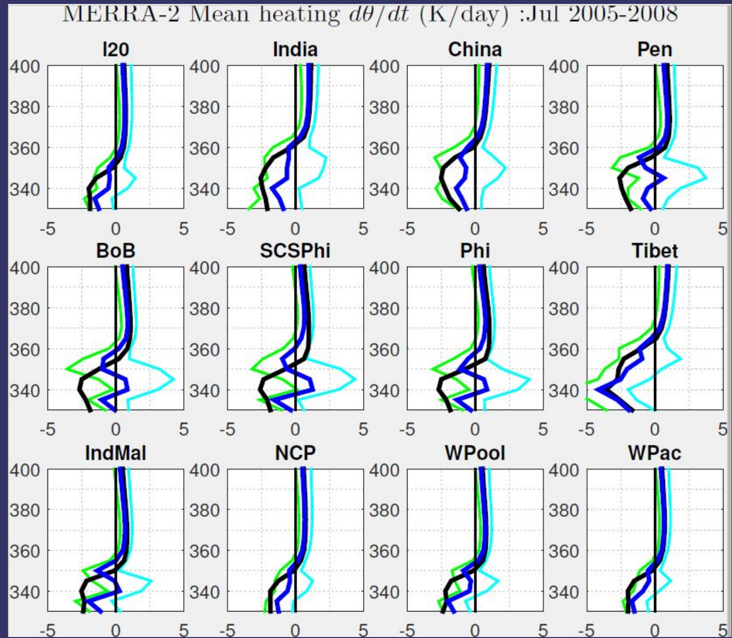
The three reanalysis all sky heating rate agree only over non convective regions. The heating rates from MERRA/MERRA-2 depart significantly from ERA-Interim/JRA-55 over convective region, especially over the Asian monsoon region.

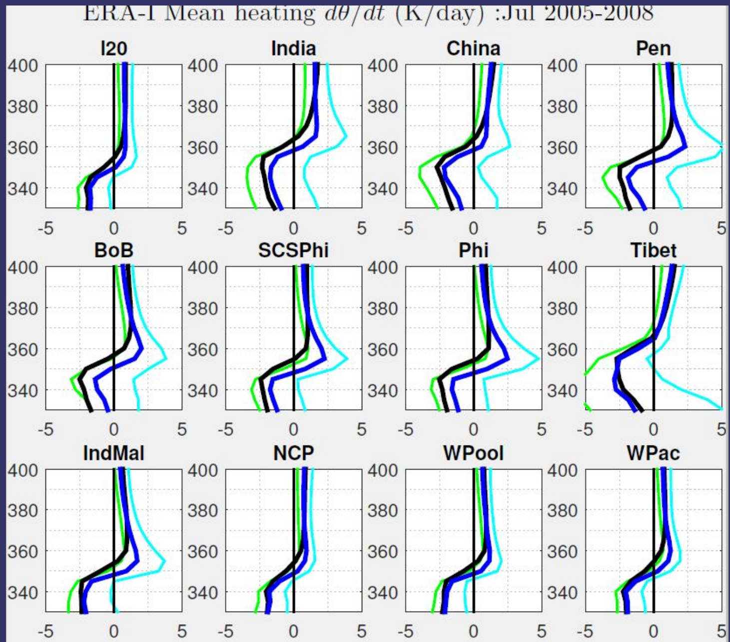
Tissier & Legras, ACP, 2016

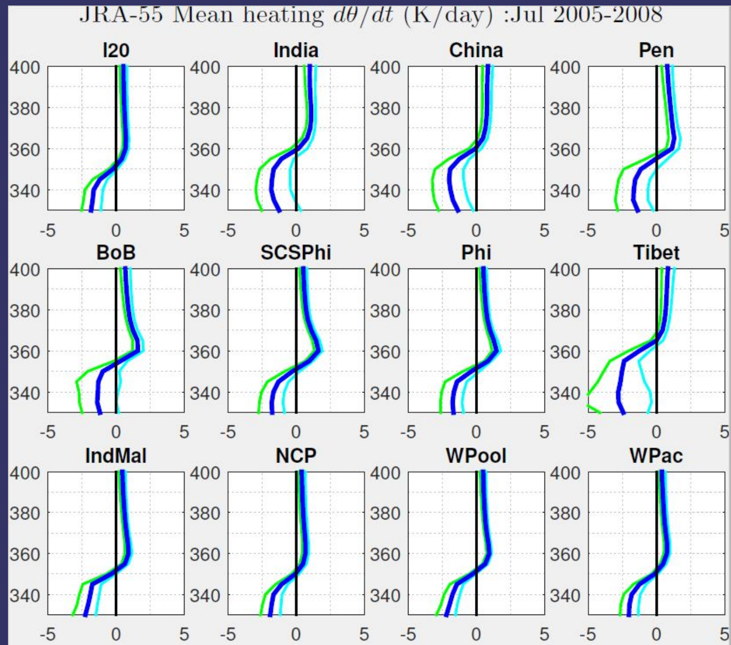


Heating rates over Asian regions

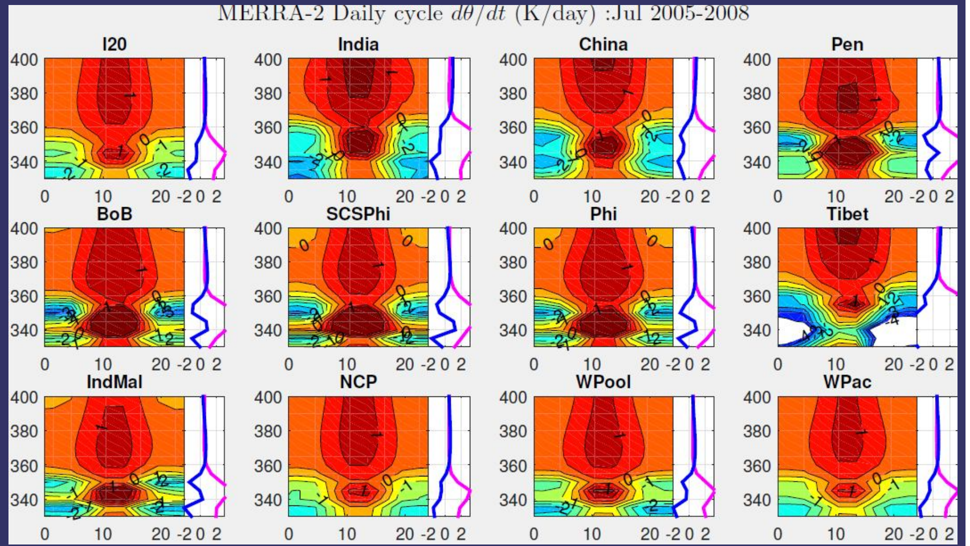


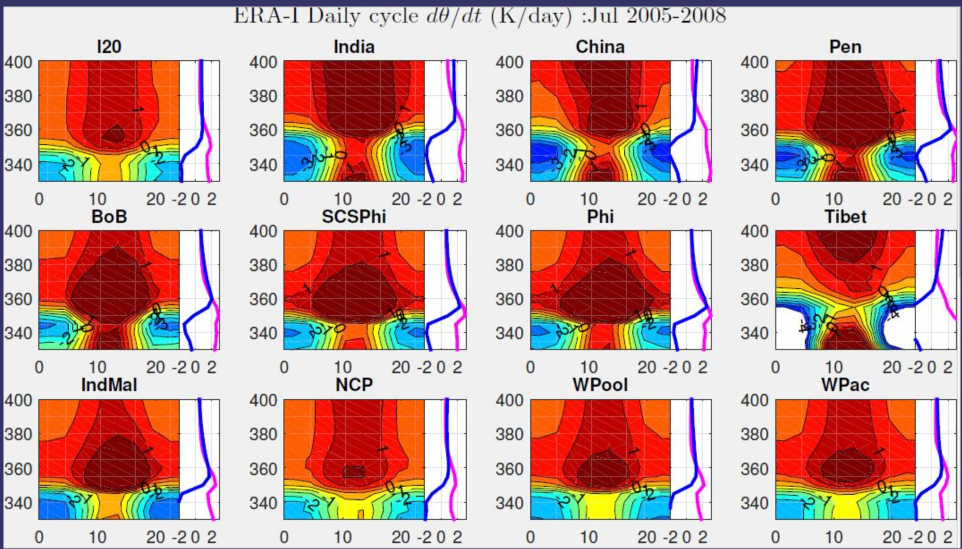


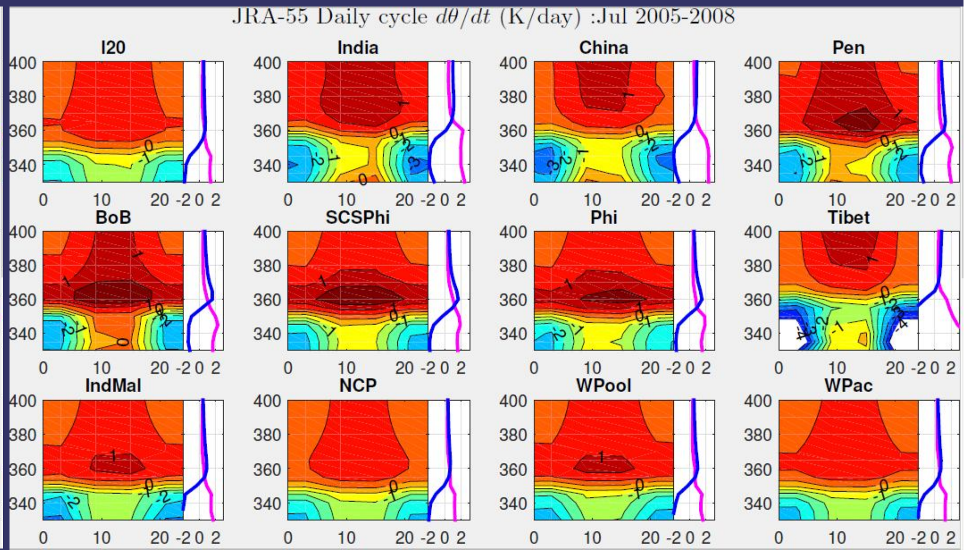


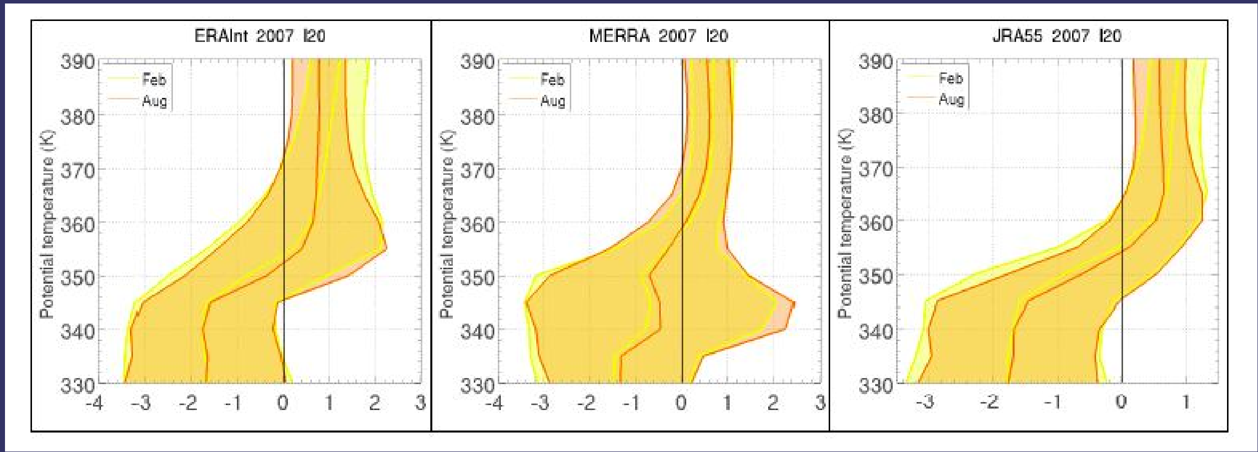


Daily cycle of the all sky heating rates (in local time)

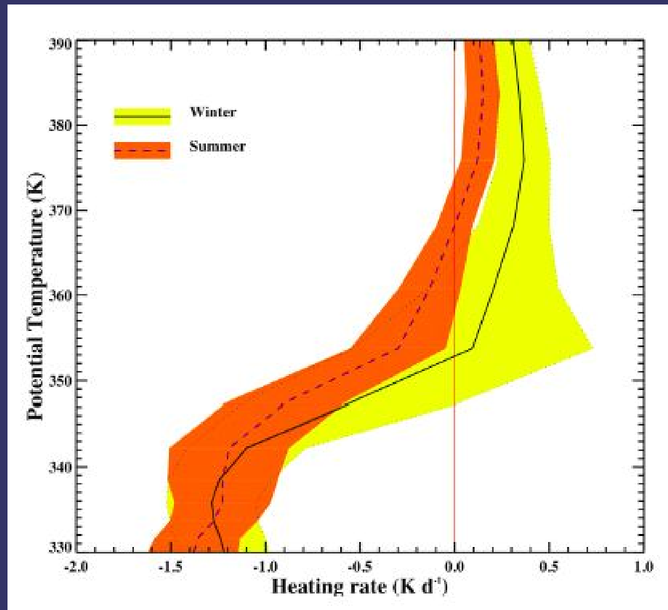




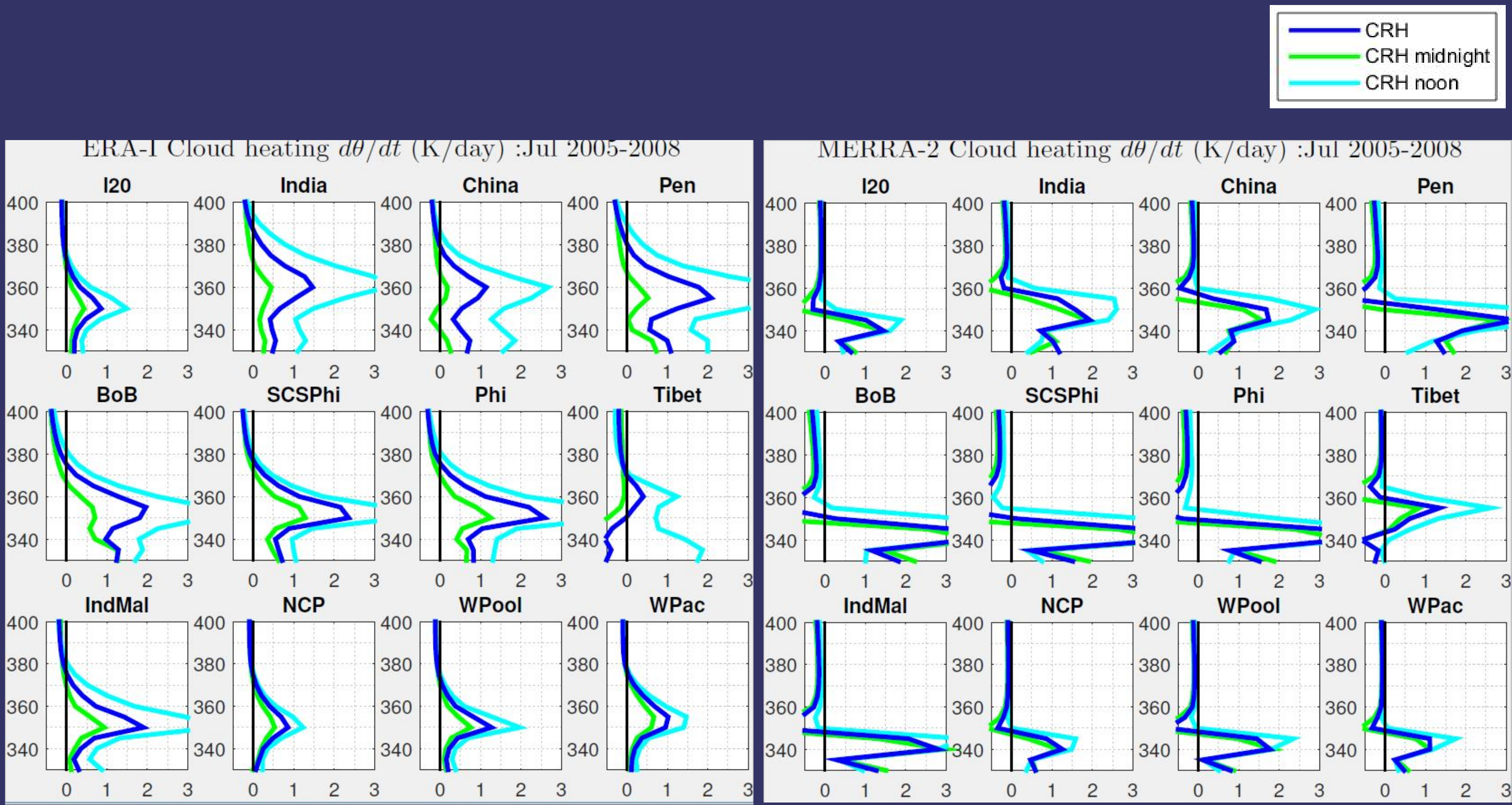




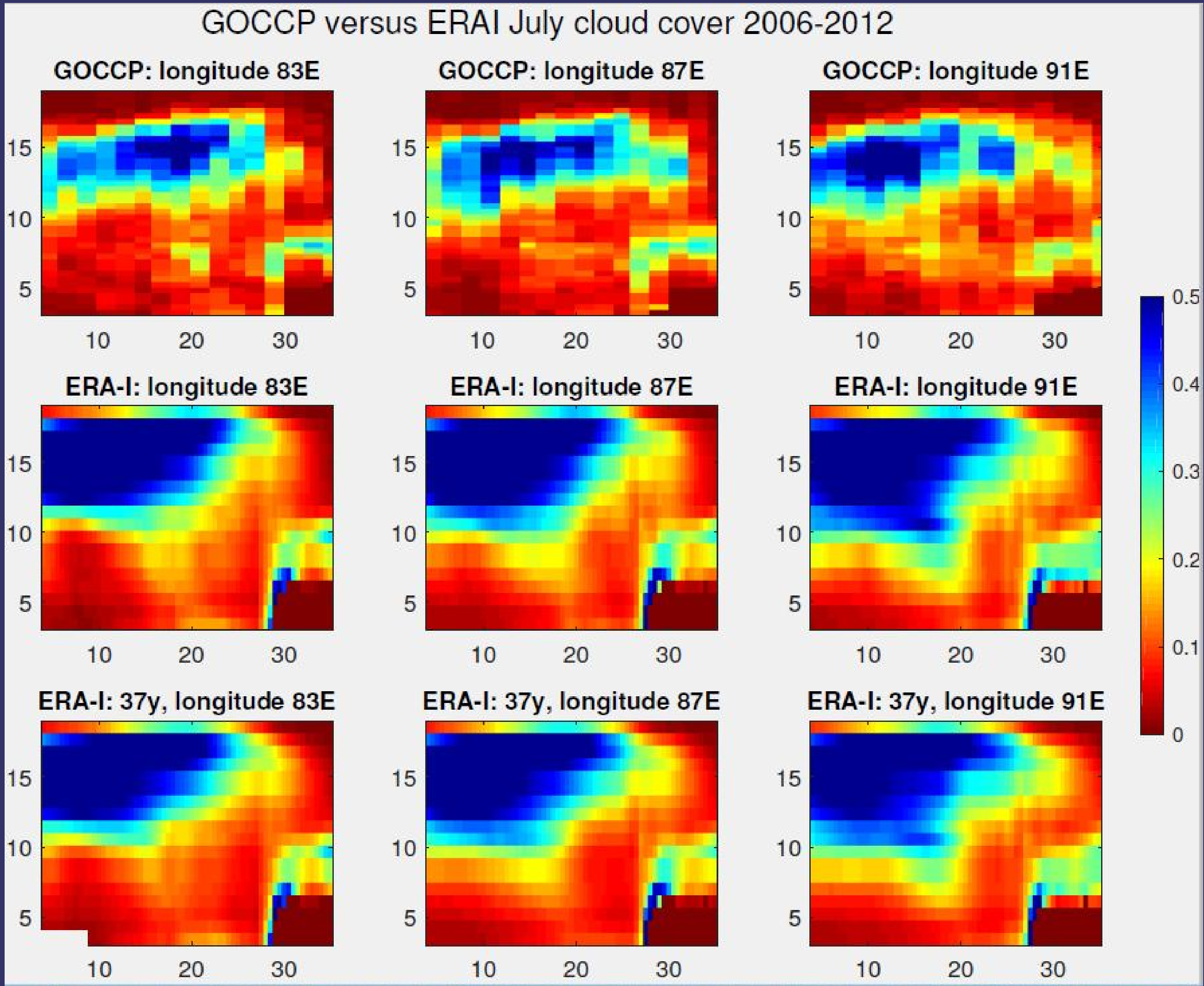
Mean heating rates +- 1 std deviation for the three reanalysis in the tropical band and for Bergman et al., JGR, 2012 using heating rates from Yang et al., JGR, 2010 based on CALIPSO + ISCCP cloud cover



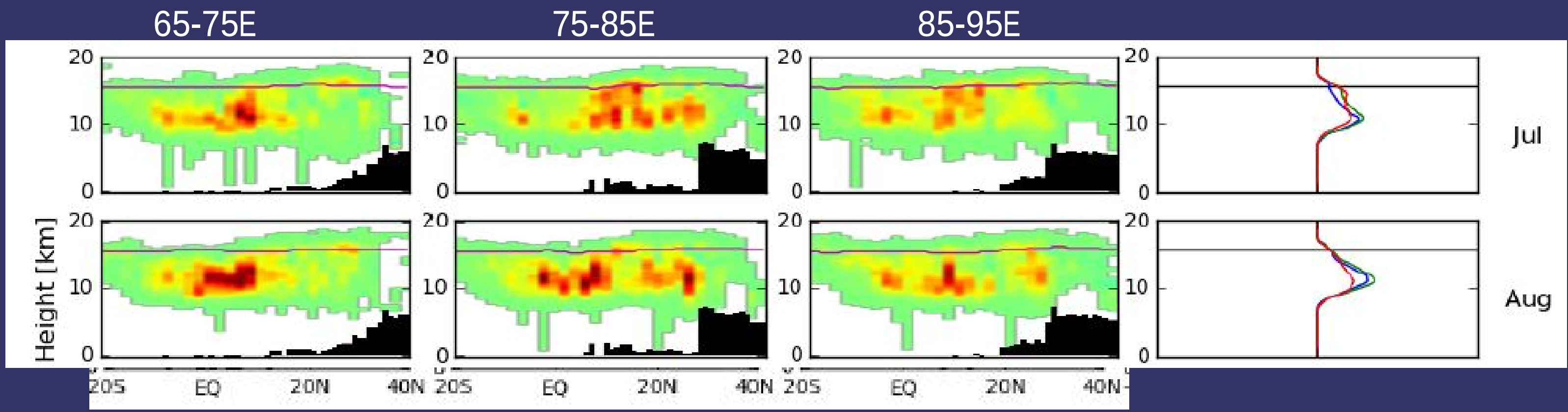
Cloud heating rate in the ERA-Interim and MERRA-2



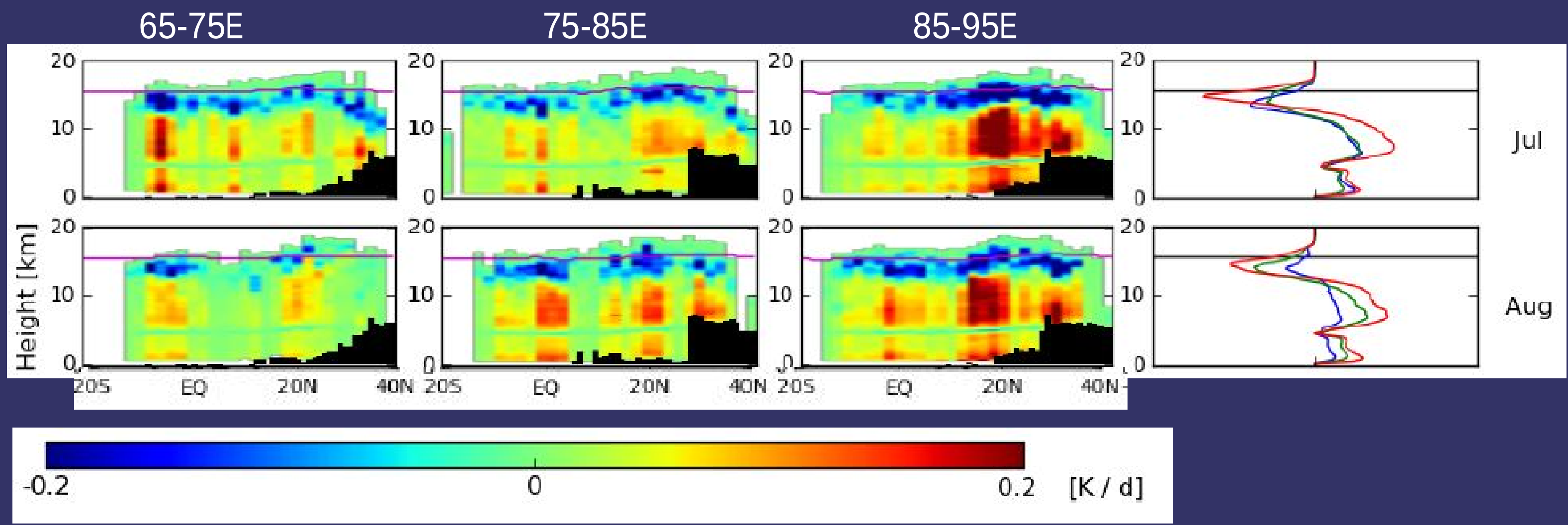
CALIPSO cloud cover (GOCCP, Cesana & Chepfer, JGR, 2013) against ERA-Interim



Heating rate due to high altitude clouds (cirrus)

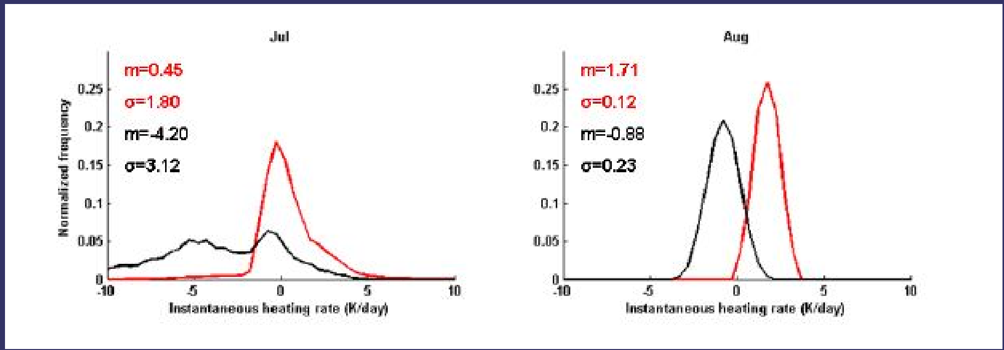


Heating rate due to convective clouds (opaque deep anvils)



Adapted from Johansson et al., ACP, 2015 using FLXHR heating rates based GEOPROF-2B-LIDAR (CLOUDSAT Science Team products)

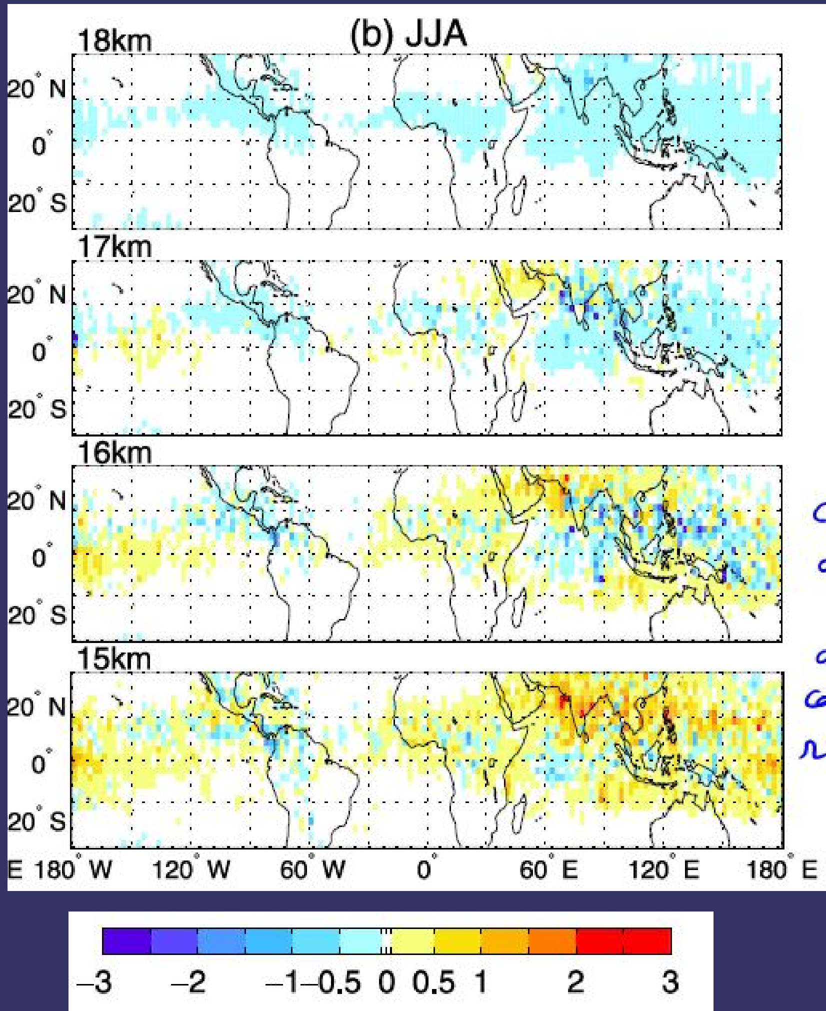
Distribution of heating rates in the Asian monsoon region above the LZRH
Johanssson et al., ACP, 2015



Black : convective clouds
Red : high clouds (cirrus)

Yang et al. find mostly cooling above 16 km while Johansson et al. find dominating warming above the clear sky LZRH.

All sky heating rate from Yang et al., JGR, 2010



Discussion

The Sea of China and the Sea of Philippines are the first contributors to the convective sources during the Asian monsoon, followed, in terms of mass flux, by India and the Bay of Bengal.

Parcels released at convective top with TB<230K over the Tibetan plateau are the most likely to cross the 380K surface. Consistent with previous findings of a vertical conduit (Bergman et al., 2012). The Tibetan plateau remains however a minor contributor to the mass flux across the 380K surface.

Mass fluxes vary by a factor two among the reanalysis. The part of monthly upward mass flux at the 380K surface due to parcels originating from convection reaches about 80% for ERA-Interim.
In spite of this discrepancy in the total fluxes, the distribution among source regions is similar among reanalysis.

In all reanalysis, the sources are vertically distributed in the vicinity of the all sky level of zero radiative heating but mostly above (75-80% in ERA-I) except for Tibet (50% in ERA-I) , that is well above the mean level of convective outflow. The LZRH and sources are higher over continental convection. Therefore, the LZRH acts quite effectively as a vertical transport barrier.

The vertical distribution of sources is located higher in MERRA than in JRA-55 and ERA-Interim.

Differences between reanalysis are largely due to the radiative role of clouds. On the average, produce heating in the ERA-Interim and cooling in MERRA/MERRA-2.
Opposite effects in the TTL of cloud anvils (cooling above) and cirrus (mostly warming).
Calculations based on observed clouds by CALIPSO are themselves ambiguous.
More work is needed to understand the reasons of these discrepancies and improve our understanding of the heating rates in the TTL, hence of the transport properties.