The impact of Asian monsoon convection as seen from combining the SAFNWC cloud products and Lagrangian calculation using ERA5 reanalysis

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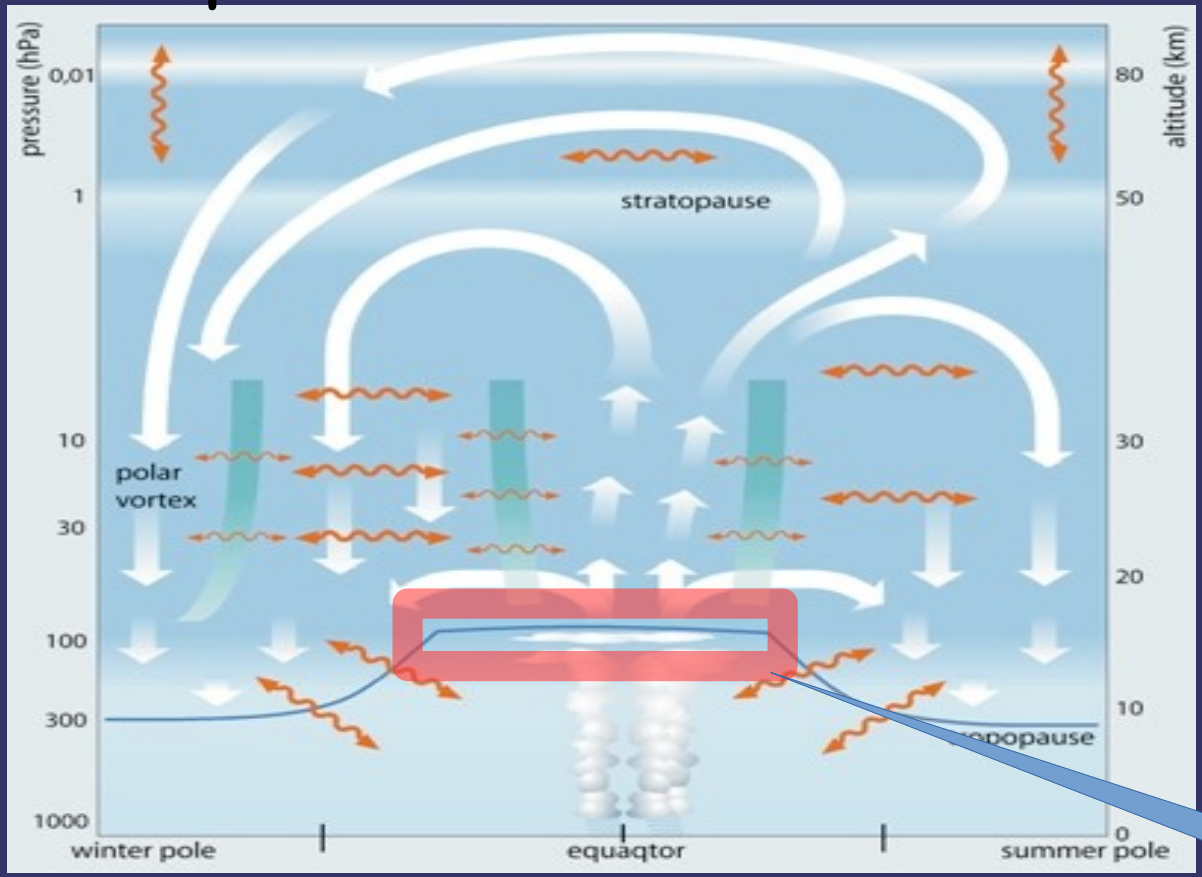
The tropical tropopause is the gate for air entering the Stratosphere and the Brewer-Dobson circulation



It was realized that the transition between the convectively dominated troposphere and the stratospheric Brewer-Dobson circulation does not occur abruptly but that there is a progressive transition marked by several characteristic levels.

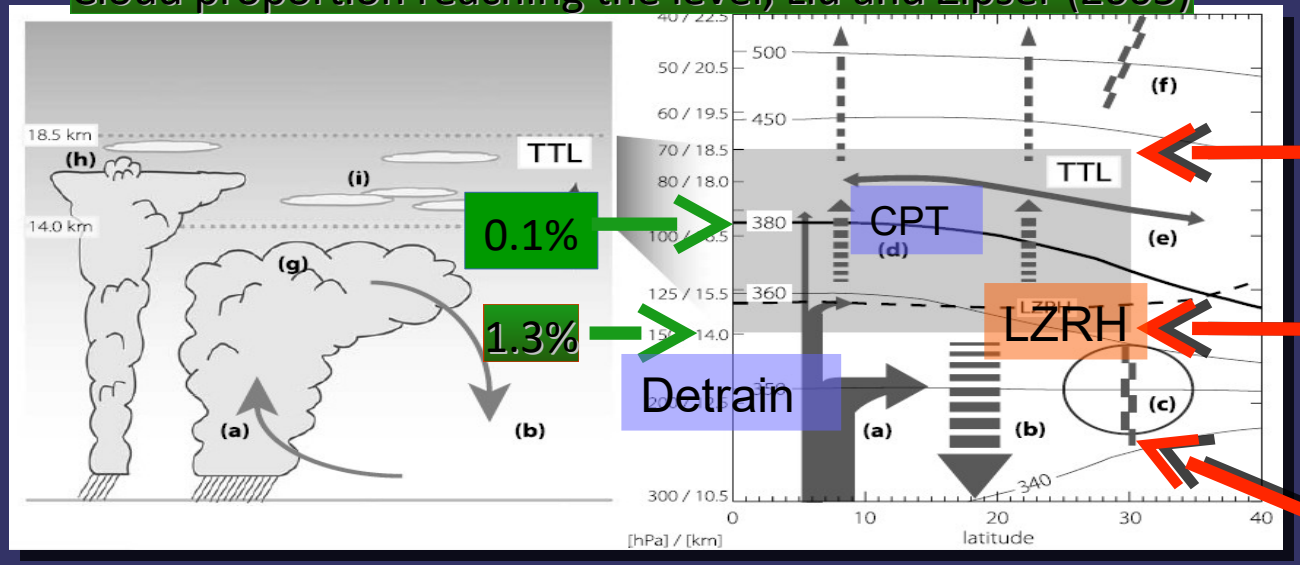
Highwood & Hoskins, QJRMS, 1998
Folkins et al., JGR, 1999

TTL

Definition of the TTL by Fueglistaler et al., RG, 2009

based on the large-scale dynamic and thermodynamic structure

Cloud proportion reaching the level, Liu and Zipser (2005)



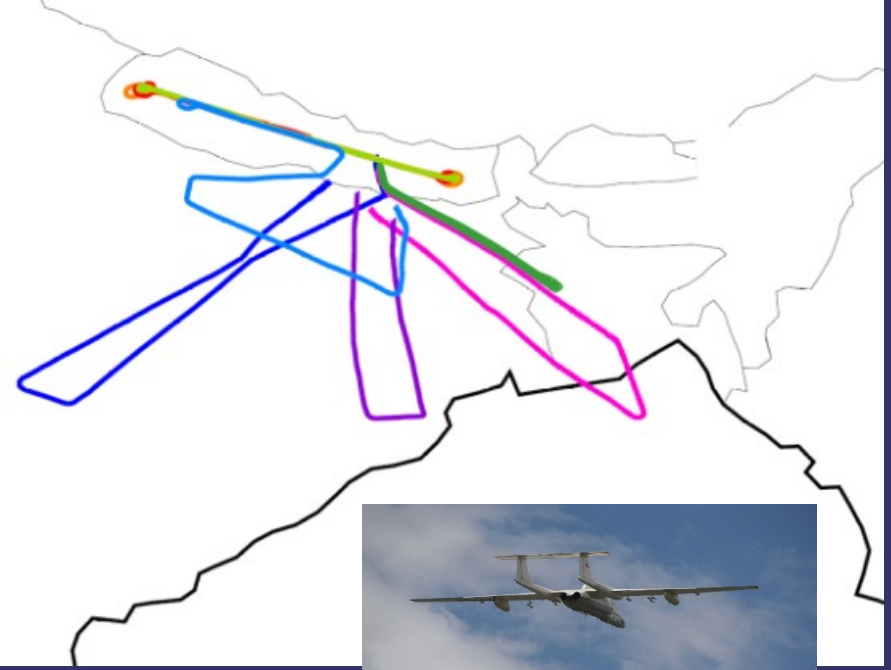
(adapted from Fueglistaler and al., 2009)

70 hPa :
Circulation no more influenced by geographical distribution of convection and the static stability is maximum.

150 hPa :
longitudinal temperature anomalies and radiative heating change sign : deep convection looses domination.

In latitude :
zonal subtropical jets

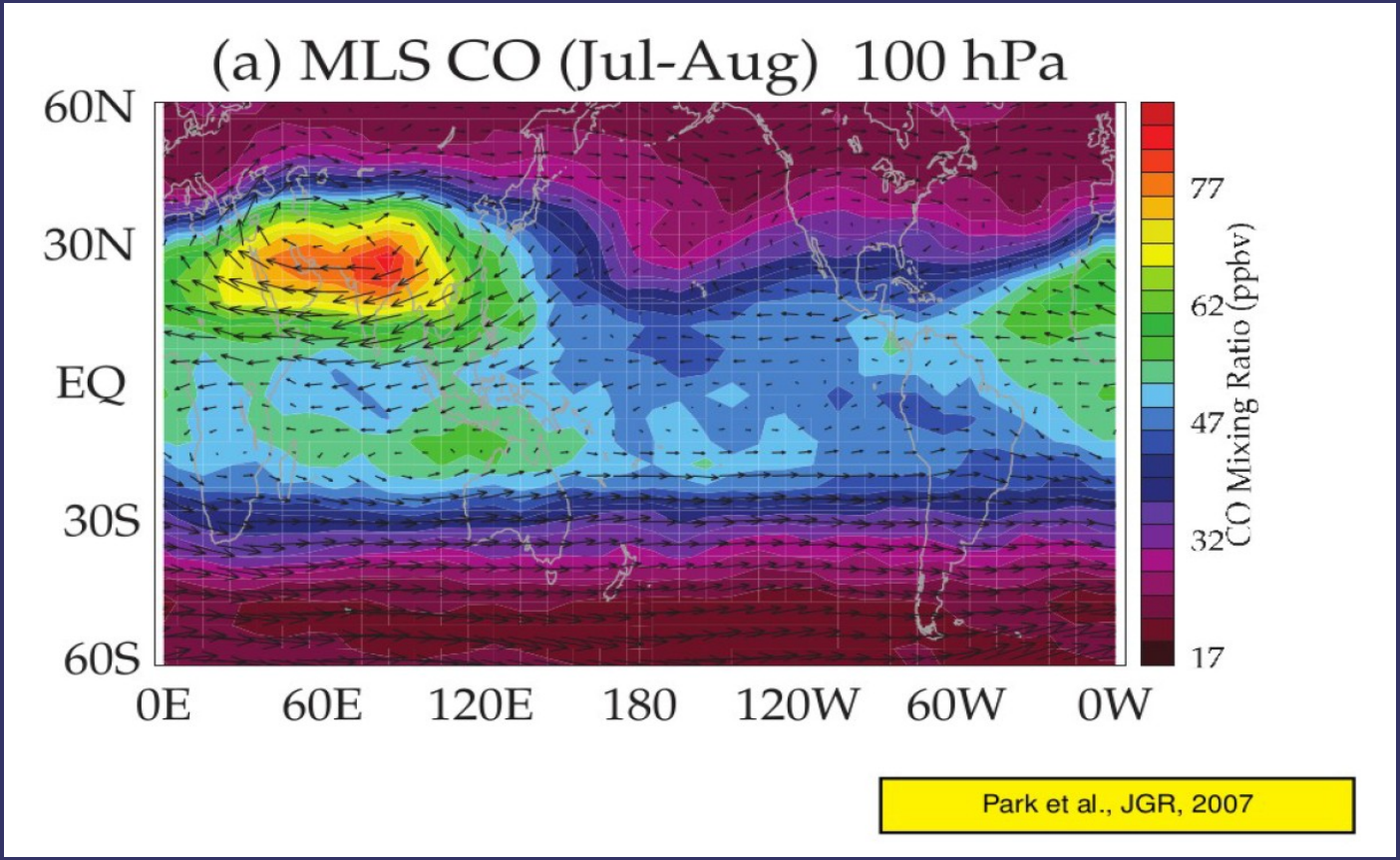
CPT: cold point tropopause
LZRH: level of zero radiative heating



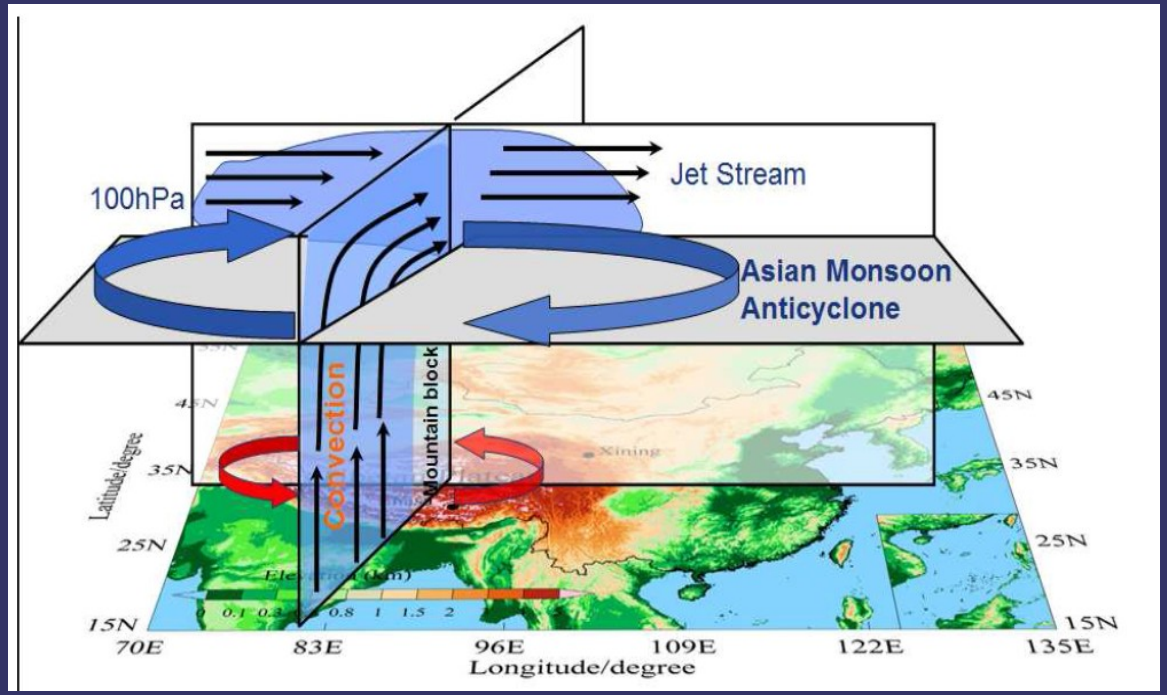
STRATOCLIM campaign (Khatmandu 2017) :
8 flights from 27/07/2017 to 10/08/2017

Objectives :
- Inside and edge of the Asian Monsoon Anticyclone
- Output flux of monsoon convection
- Impact of pollution on the composition of the upper troposphere and lower stratosphere
- Distribution of aerosols in the TTL and impact
- Transport and mixing
- Transport across the TTL
- Cirrus
- Hydration and dehydration of the TTL
- Impact of tropical cyclones on the TTL

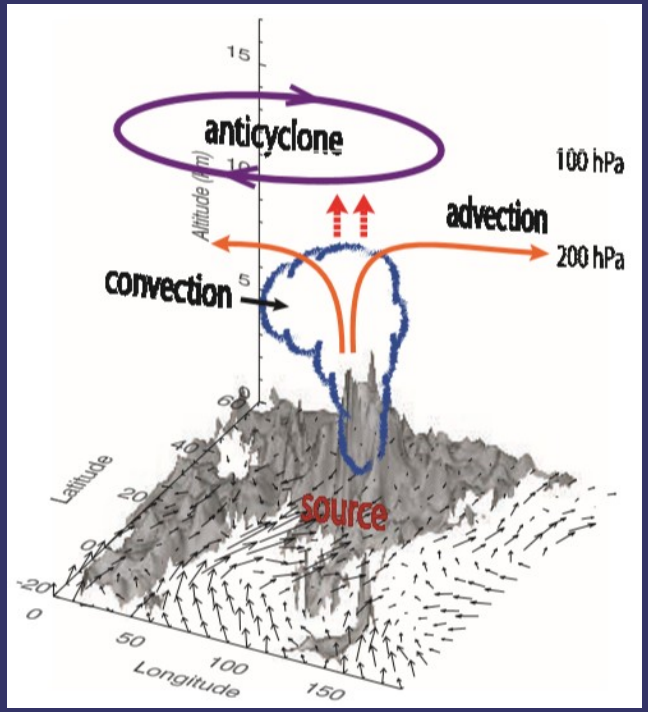
During summer season a large upper layer anticyclonic circulation over Asia and Middle-East traps tropospheric compounds in the TTL and favors tropics – extratropics exchanges



The upper level Asian monsoon anticyclone is ventilated by the convection beneath its easterly branch.



courtesy of Yong Wang

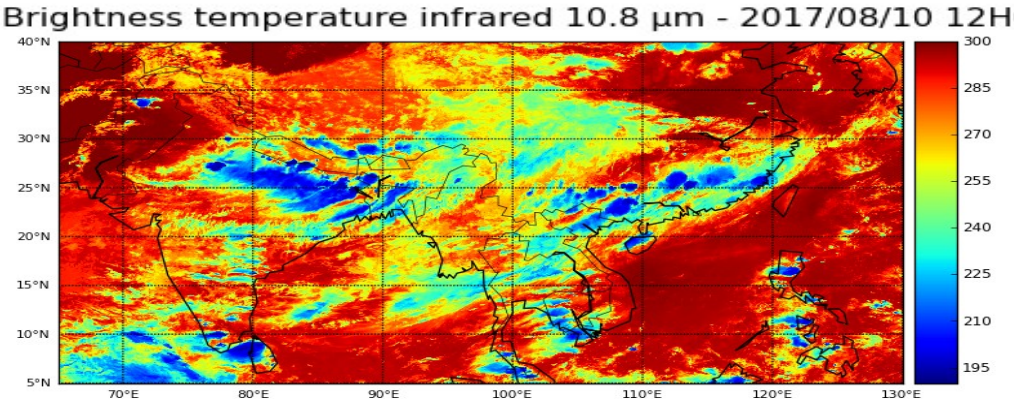


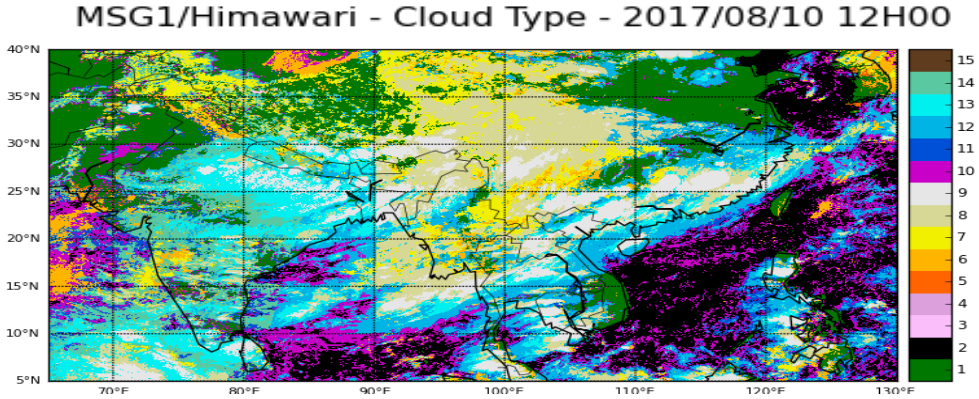
Park et al., JGR, 2009

The SAFNWC product in the Asian monsoon region

Combining MSGA-1 and Himawari-8

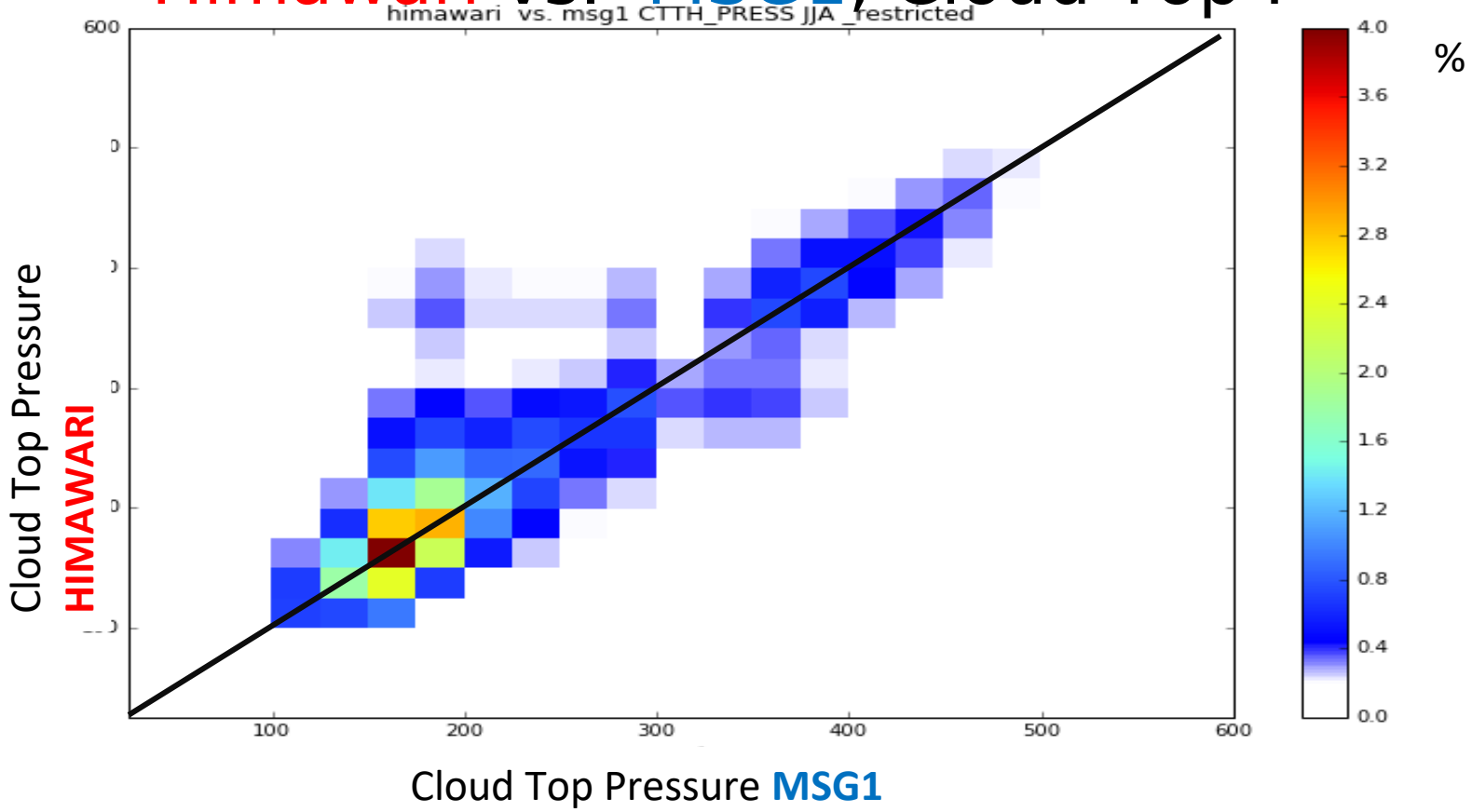
MSG and Himawari merged CT



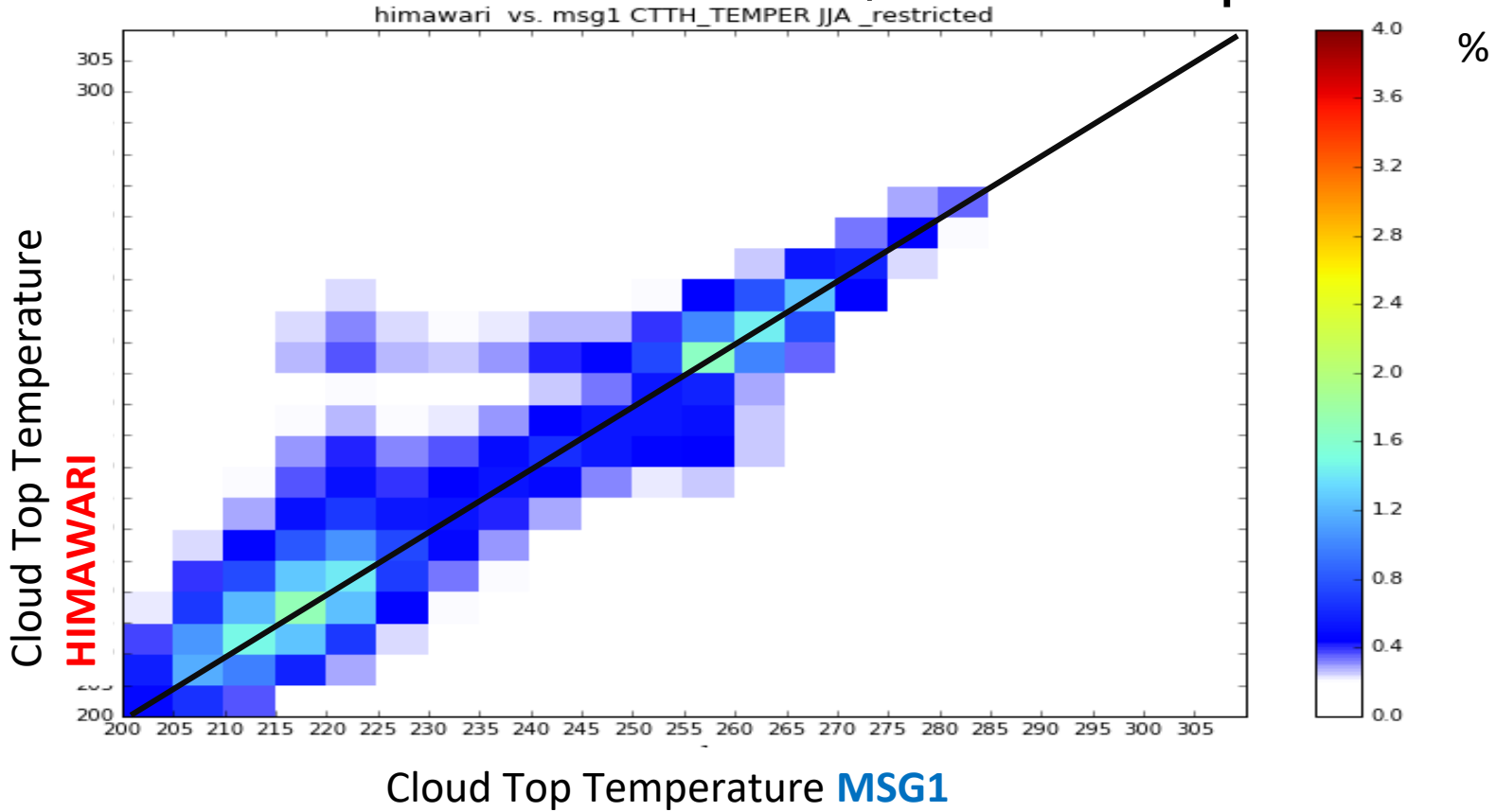


1 : Cloud free land, 2 : Cloud free sea, 3 : Snow over land, 4 : Snow over sea,
5 : very low clouds, 6 : Low Clouds, 7 : Mid-level clouds, 8 : High opaque clouds,
9 : Very high opaque clouds, 10 : Fractional clouds, 11 : High semitransparent thin clouds,
12 : High semitransparent meanly thick clouds, 13 : High semitransparent thick clouds,
14 : High semitransparent above low or medium clouds, 15 : High semitransparent above snow/ice

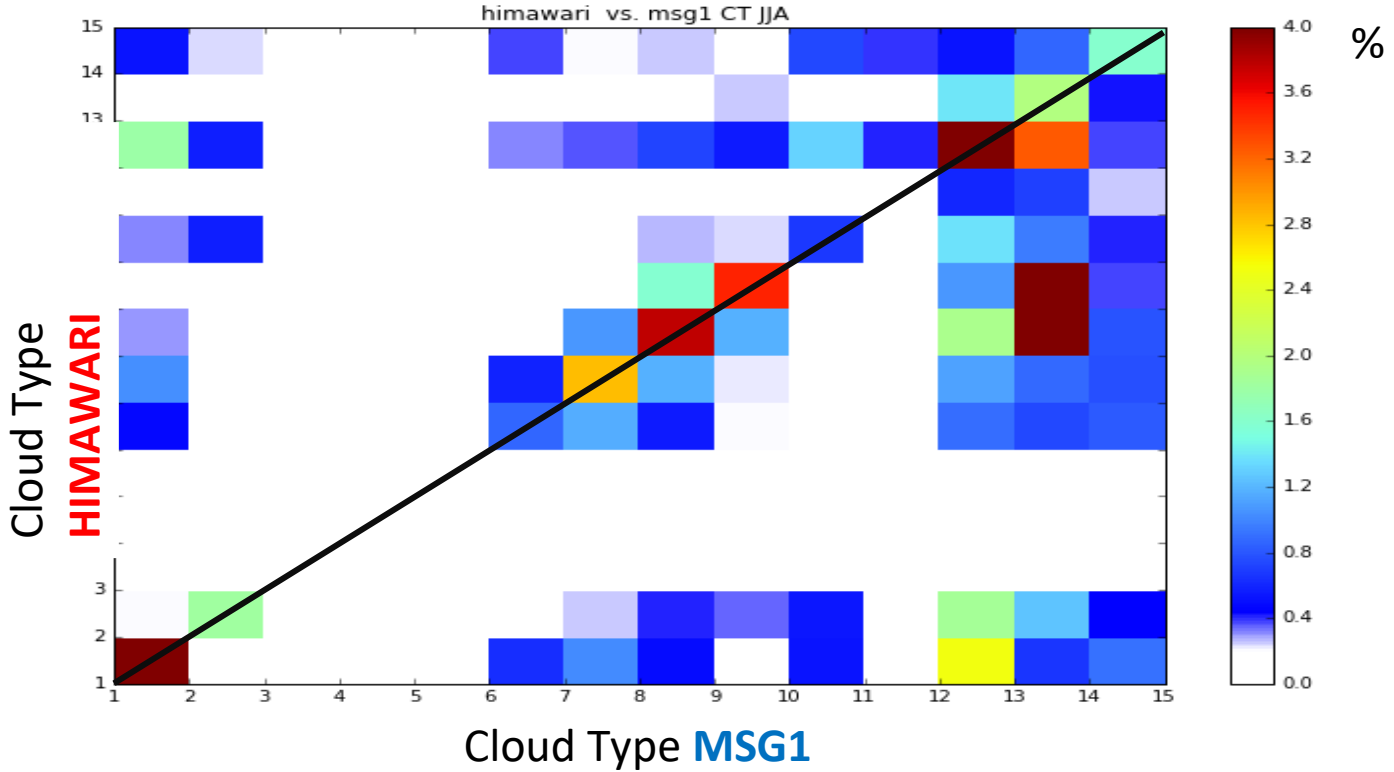
Himawari vs. MSG1, Cloud Top P



Himawari vs. MSG1, Cloud Top T



Himawari vs. MSG1, CT



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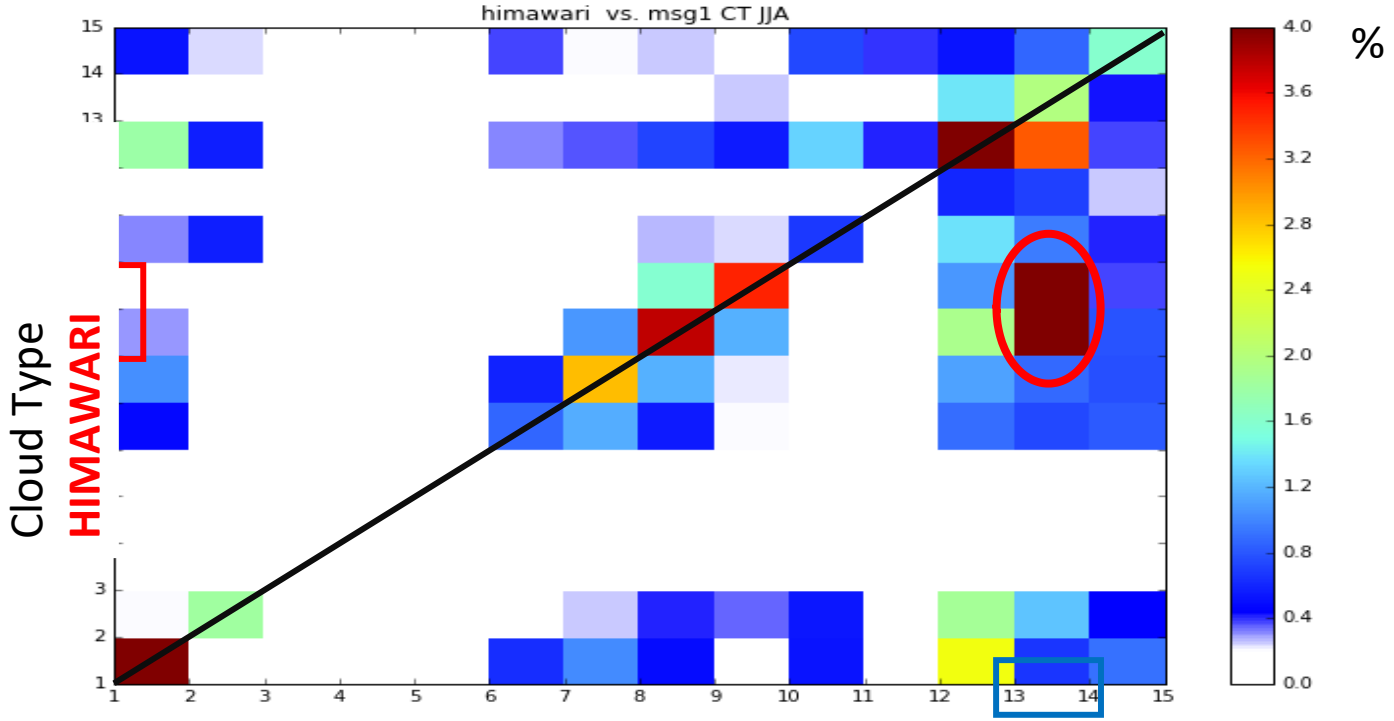
Himawari vs. MSG1, CT



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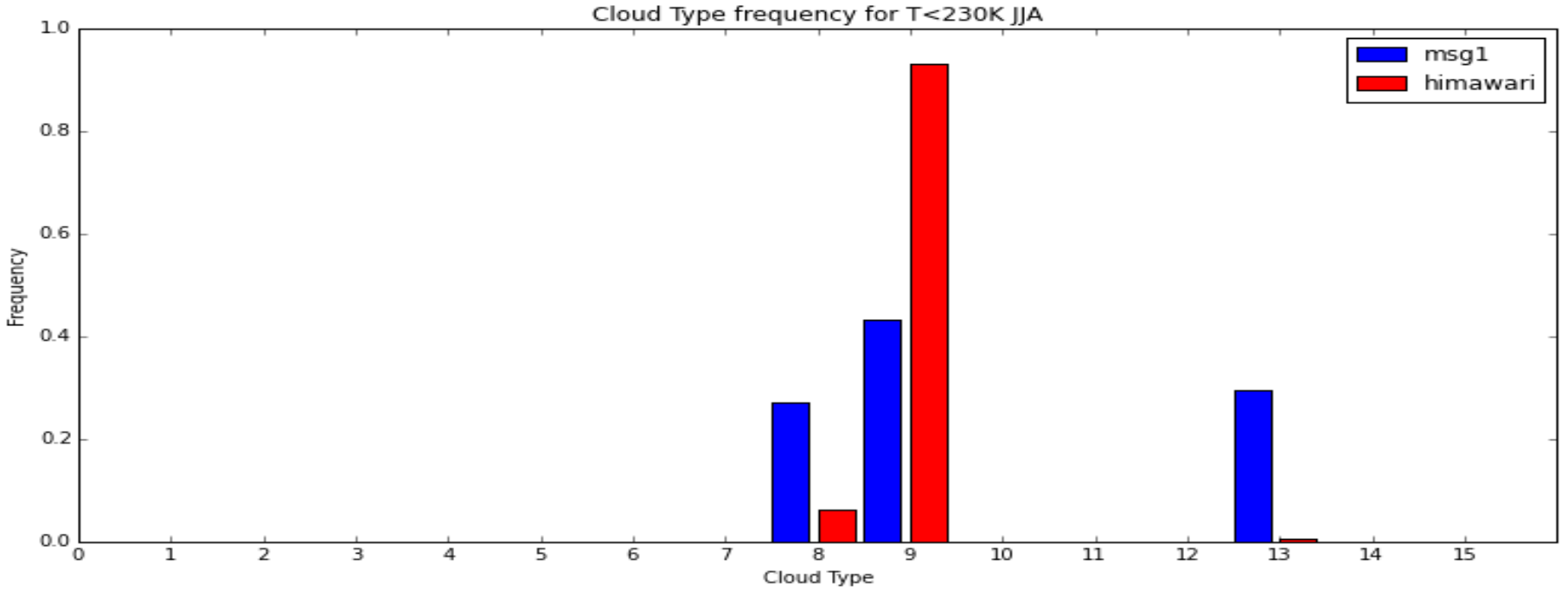
Himawari + MSG1 vs. ECMWF estimate

Which Cloud Types corresponds to this convection diagnostics?



High (8) and Very High (9, Himawari) Opaque clouds and High semitransparent thick clouds (13, **msg1**)

Special processing of the SAFNWC product for the StratoClim project

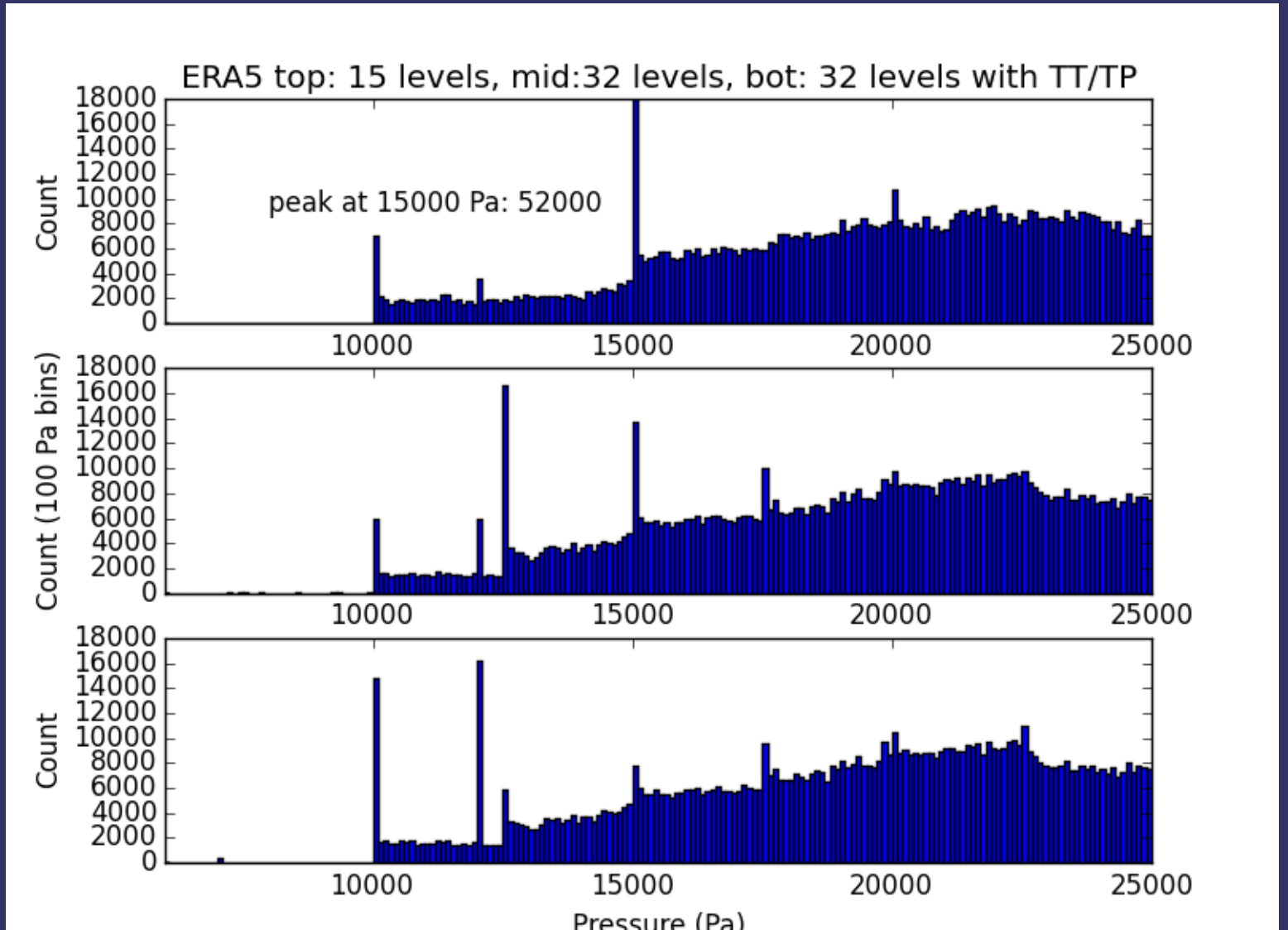
Restricted to the Asian monsoon domain and the two satellites MSG-1 and Himawari-8

Using ERA-5 instead of ARPEGE for NWP input.

- 37 pressure levels
- hourly sampling
- 0.25° horizontal resolution
- Calculated cold tropopause and tropopause temperature

All other auxilliary data as in the standard product.

Run for summer 2017 based on the SAFNWC package V2016


ERA5 top: 15 levels, mid:32 levels, bot: 32 levels with TT/TP
peak at 15000 Pa: 52000
Count
Count (100 Pa bins)
Count
Pressure (Pa)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
10000
15000
20000
25000

Method : Lagrangian forward and backward trajectories from and to clouds

Using

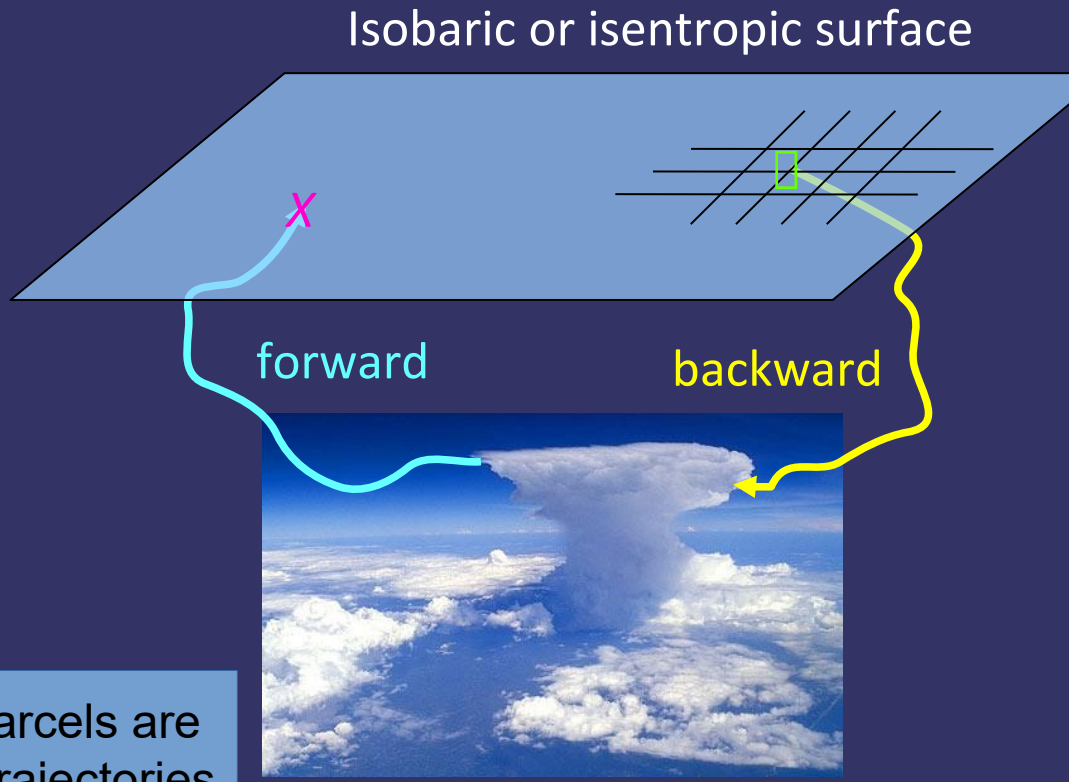
- ERA5 : 0.25°x0.25°, 137 levels, hourly

in the AMA domain 10W-160E, 0-50N

- ERA-Interim : 1°x1°, 60 levels, 3-hourly in the AMA and global domain
- Diffusive trajectories D = 0.1 m^2/s

Clouds characterized by

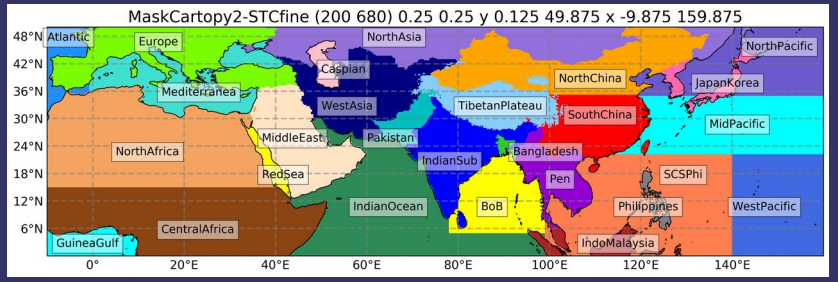
- SAFNWC/Eumetsat cloud top altitude from MSG1 (45.5E) and Himawari 8 (140E) (Derrien & Le Gléau, I. J. Remote Sensing, 2010) [improved from operational product]

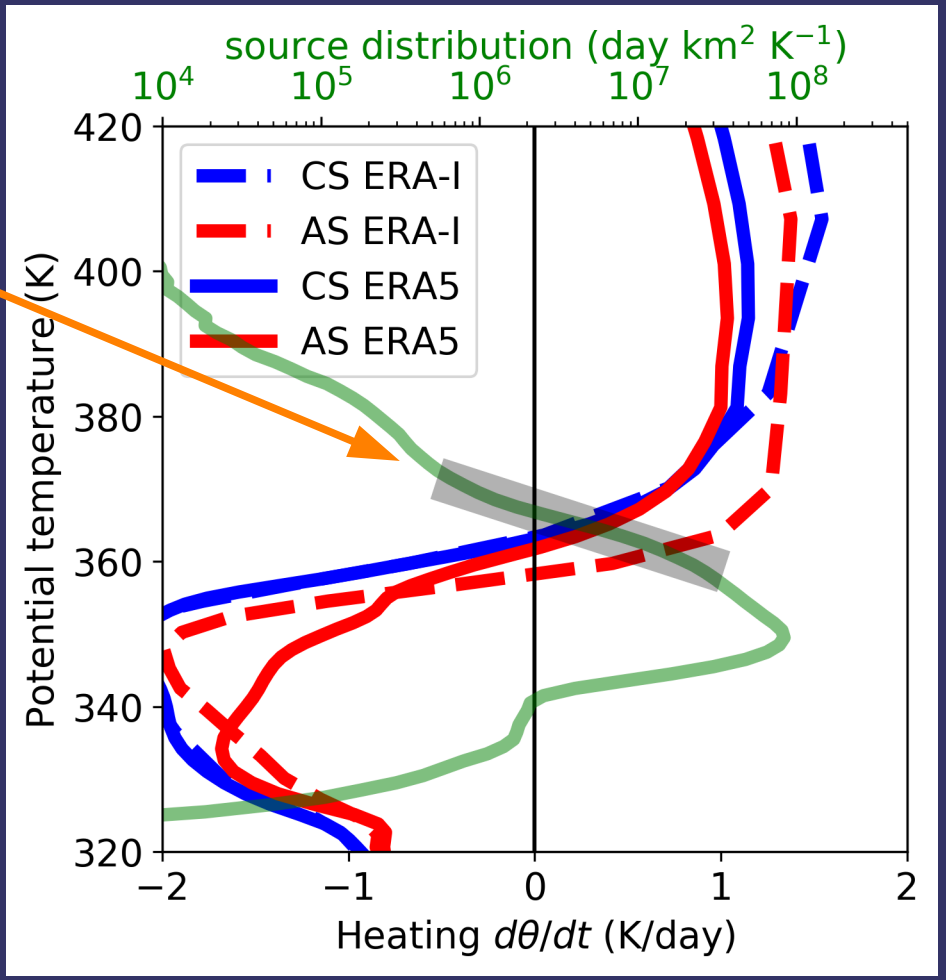


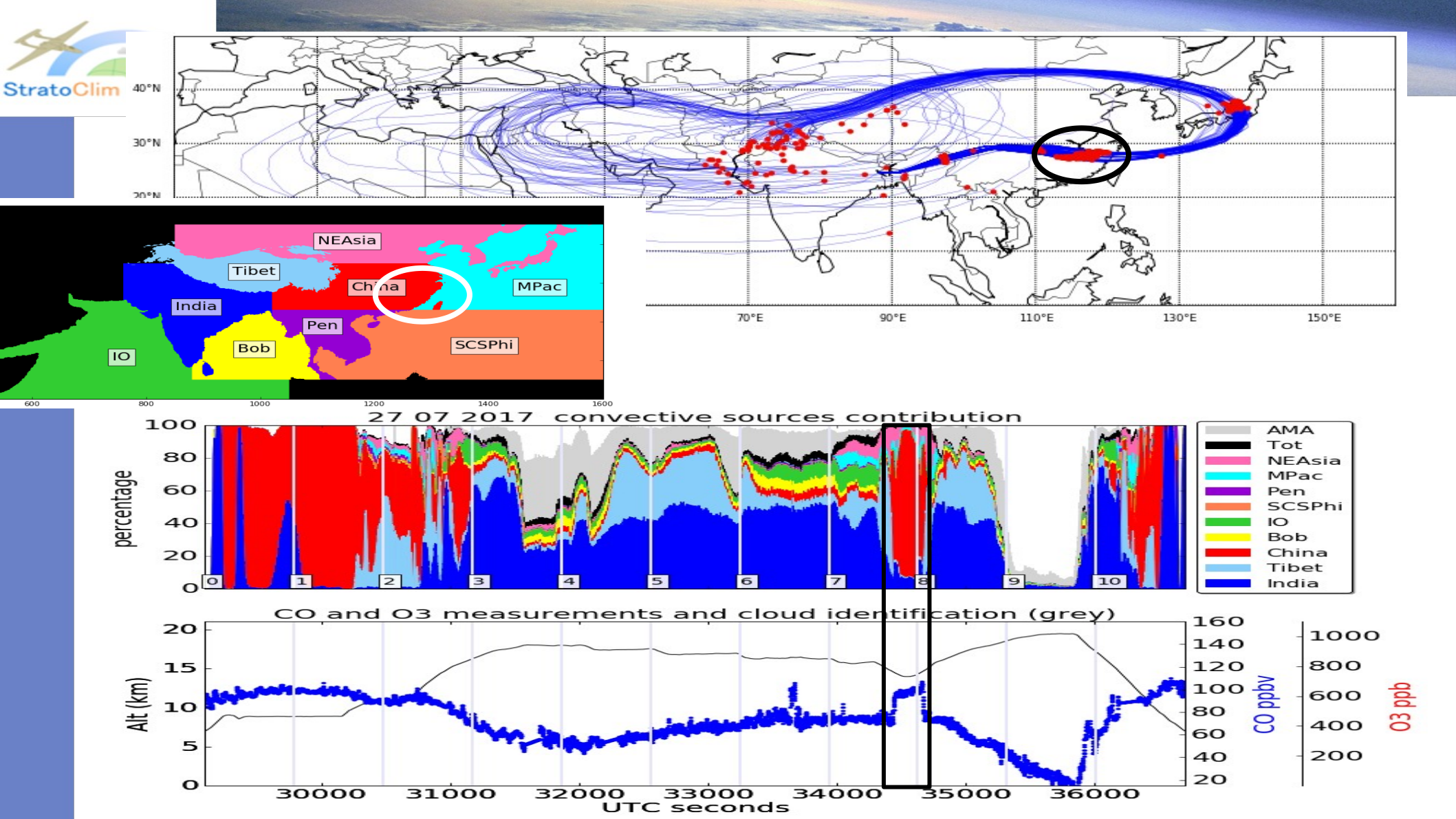
For the purpose of analyzing campaign data, parcels are launched from the flight track (1000 per s) and trajectories are integrated backward until they meet a convective cloud

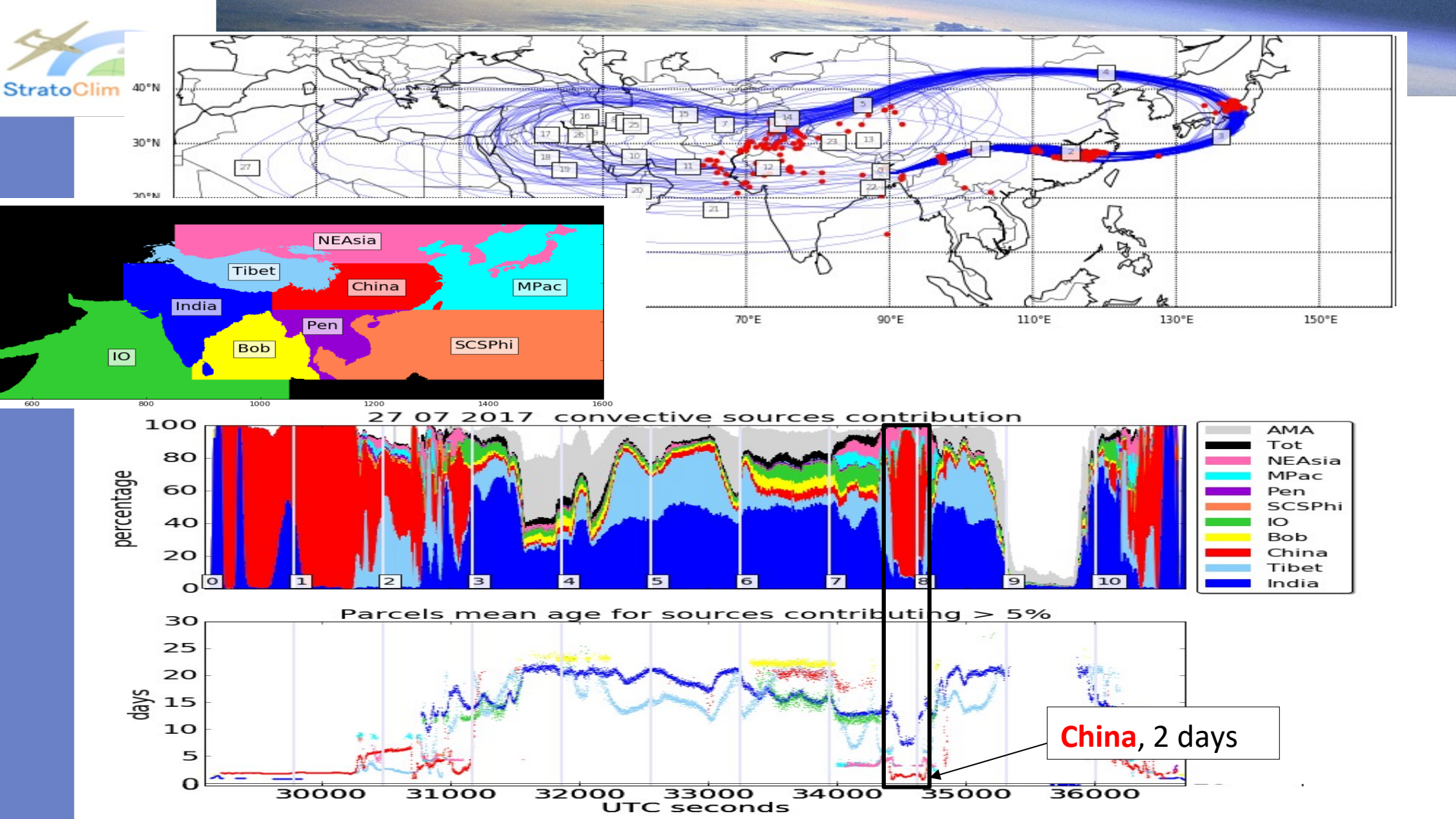
Vertical distribution of sources
And heating rates

High clouds
~ exp(-β θ)
β = 0.33 K^{-1}






StratoClim
40°N
30°N
70°E
90°E
110°E
130°E
150°E
NEAsia
Tibet
China
MPac
India
Pen
Bob
SCSPhi
IO
600
800
1000
1200
1400
1600
27 07 2017 convective sources contribution
percentage
AMA
Tot
NEAsia
MPac
Pen
SCSPhi
IO
Bob
China
Tibet
India
CO and O3 measurements and cloud identification (grey)
Alt (km)
CO ppbv
O3 ppb
UTC seconds


StratoClim
40°N
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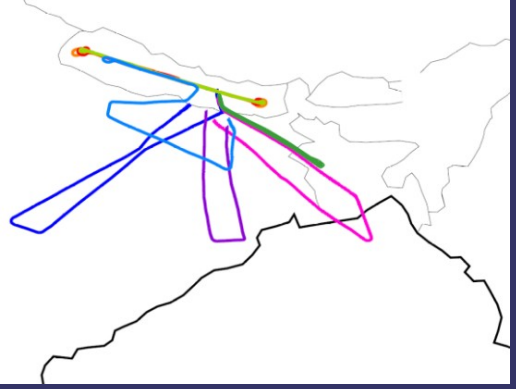
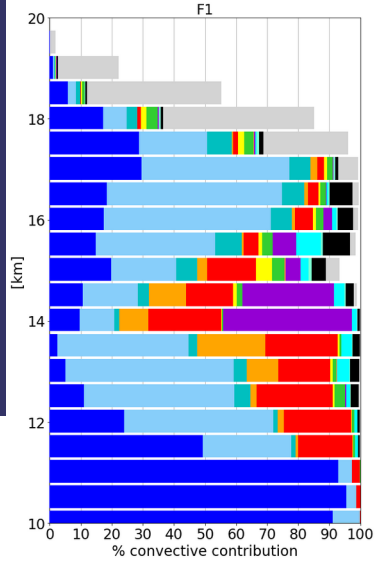
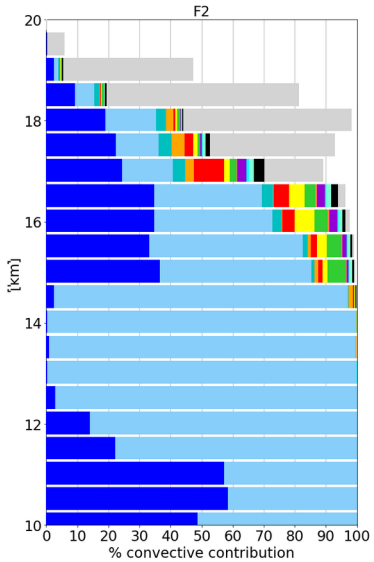
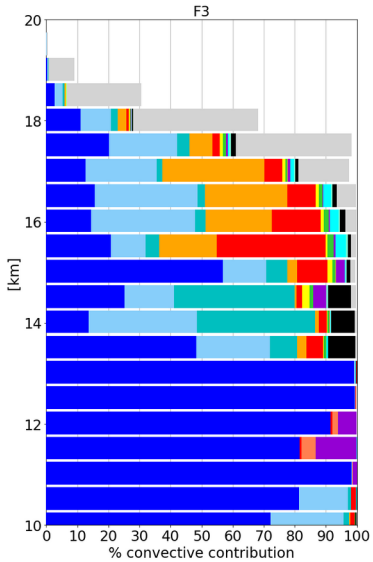
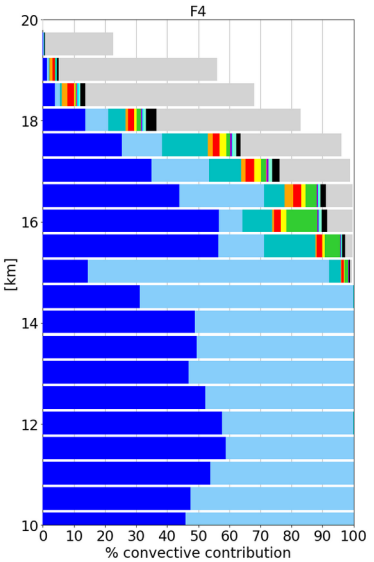
NEAsia
Tibet
China
MPac
India
Pen
SCSPhi
IO
Bob
600
800
1000
1200
1400
1600
27 07 2017 convective sources contribution
percentage
AMA
Tot
NEAsia
MPac
Pen
SCSPhi
IO
Bob
China
Tibet
India
Parcels mean age for sources contributing > 5%
days
UTC seconds
China, 2 days

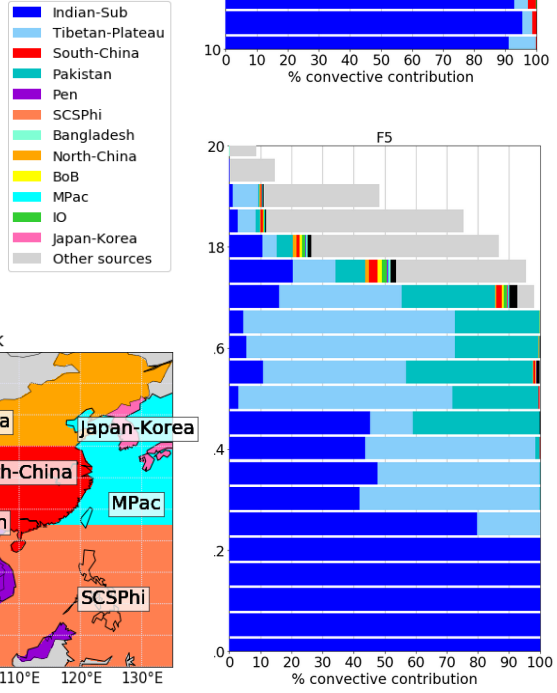



F1
[km]
% convective contribution

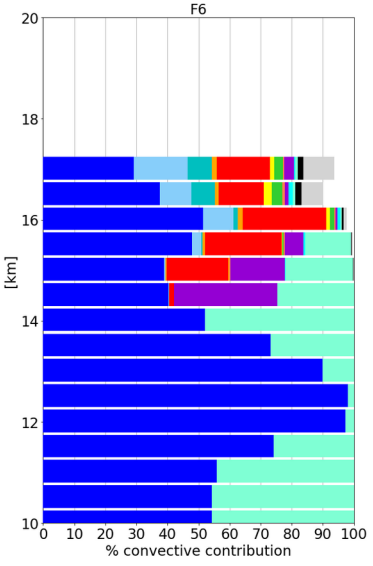

F2
[km]
% convective contribution

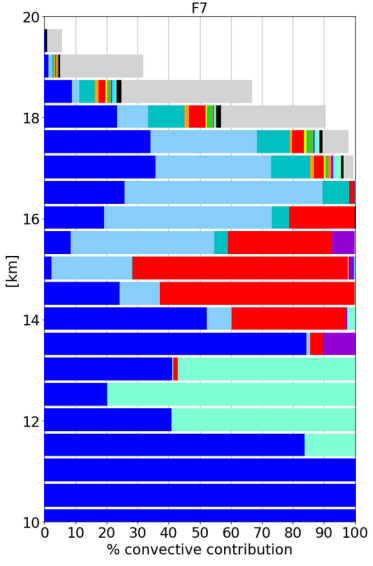

F3
[km]
% convective contribution

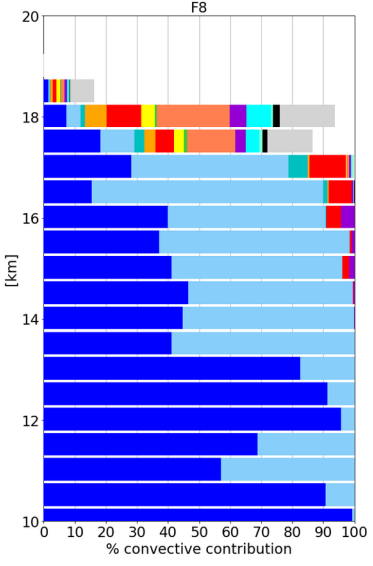

F4
[km]
% convective contribution

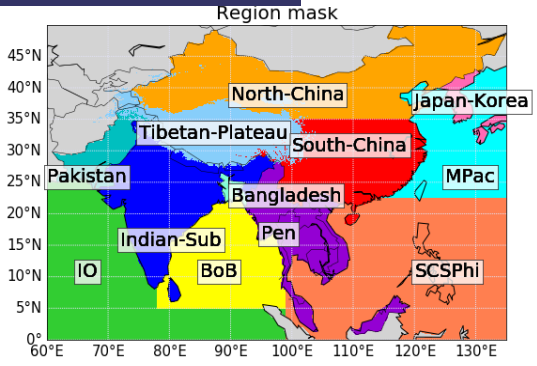

Indian-Sub
Tibetan-Plateau
South-China
Pakistan
Pen
SCSPhi
Bangladesh
North-China
BoB
MPac
IO
Japan-Korea
Other sources

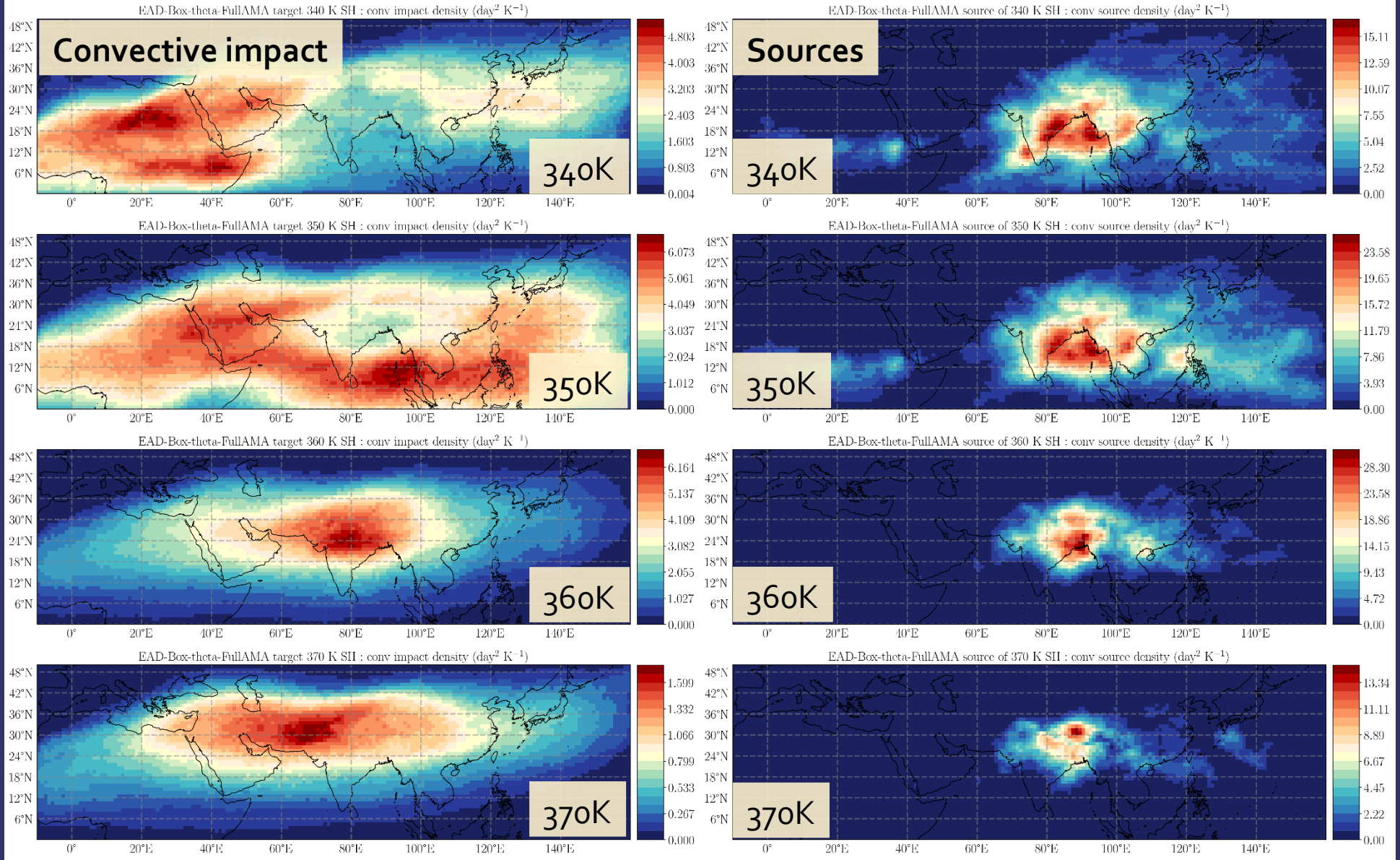
F5
% convective contribution


F6
[km]
% convective contribution


F7
[km]
% convective contribution


F8
[km]
% convective contribution


Region mask
North-China
Japan-Korea
Tibetan-Plateau
South-China
Pakistan
MPac
Bangladesh
Indian-Sub
Pen
IO
BoB
SCSPhi

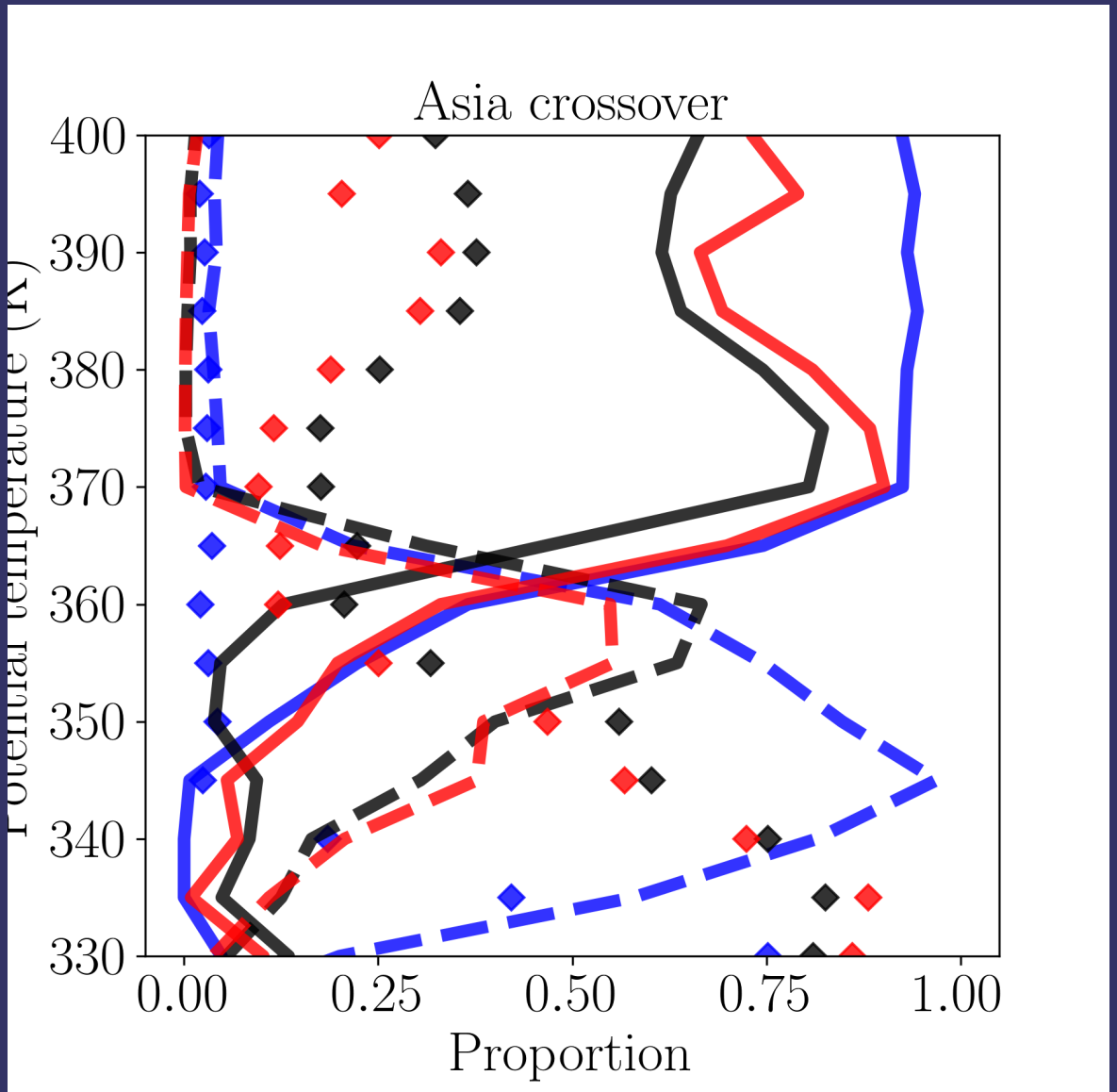

EAD-Box-theta-FullAMA target 340 K SH : conv impact density (day^2 K^{-1})
Convective impact
340K
EAD-Box-theta-FullAMA source of 340 K SH : conv source density (day^2 K^{-1})
Sources
340K
EAD-Box-theta-FullAMA target 350 K SH : conv impact density (day^2 K^{-1})
350K
EAD-Box-theta-FullAMA source of 350 K SH : conv source density (day^2 K^{-1})
350K
EAD-Box-theta-FullAMA target 360 K SH : conv impact density (day^2 K^{-1})
360K
EAD-Box-theta-FullAMA source of 360 K SH : conv source density (day^2 K^{-1})
360K
EAD-Box-theta-FullAMA target 370 K SH : conv impact density (day^2 K^{-1})
370K
EAD-Box-theta-FullAMA source of 370 K SH : conv source density (day^2 K^{-1})
370K

Crossover ascending / descending over Asia

ERA5	ERA-I
363.9 K	361.7 K

Solid: proportion going upward
Dash: proportion going downward
Dots: proportion staying within 2.5 K

ERA5 diab in FullAMA domain
ERA-I diab in FullAMA domain
ERA-I diab in global domain



	Land	Ocean	TP
High clouds	27 %	68 %	5 %
AMA impact	55 %	23 %	22 %
Global impact	39 %	53 %	8 %

Limitations: cloud radiative effect in reanalysis, estimations of cloud tops from satellites, convection over TP, overshoots above the anvils

Cold point tropopause ~380 K

Heating 1.1 K day^{-1}

AMA
Escape rate α = 0.75 day^{-1}

?

High clouds

11 %

2,6 %

Crossover 364 K

LZRH 358 K

Mean convective detrainment 350 K

Monsoon convection

Hadley-Walker circulation

Sahara , SH subtropics

Questions ?