



Double tropopause characteristics from the full radio occultation record

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Outlook

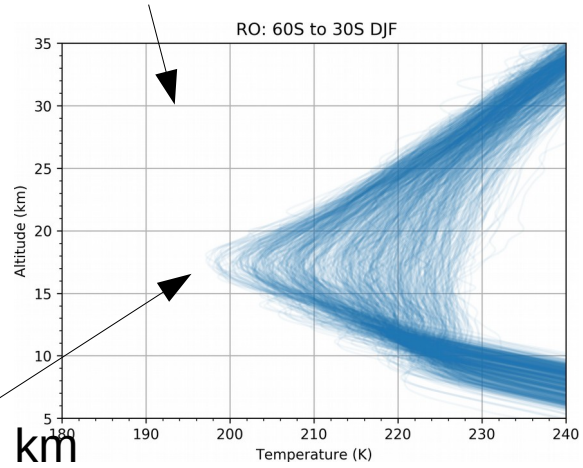
- Double tropopauses (DT)
- Global view
- Global view – seasons
- DT – time lines
- Some details



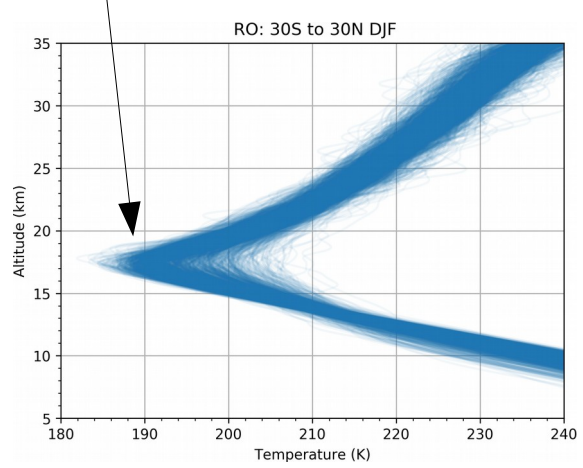
The thermal tropopause



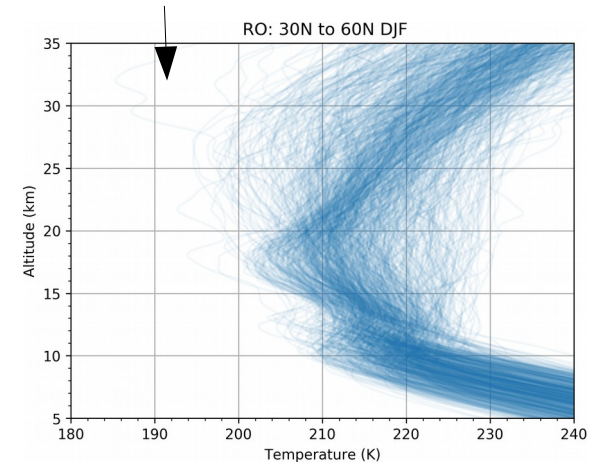
Summer



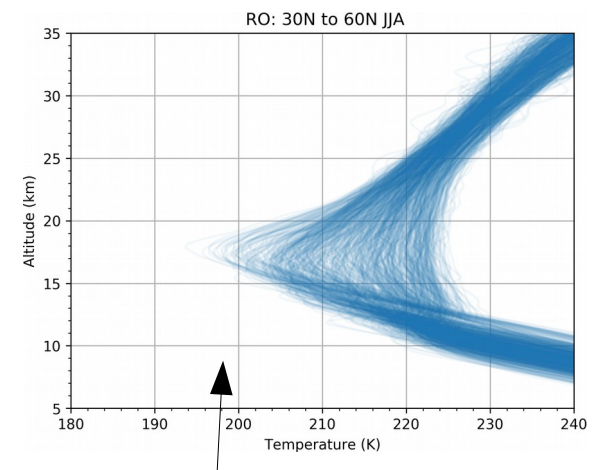
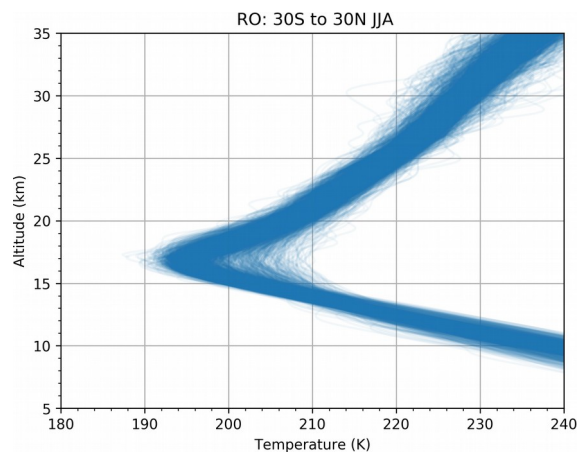
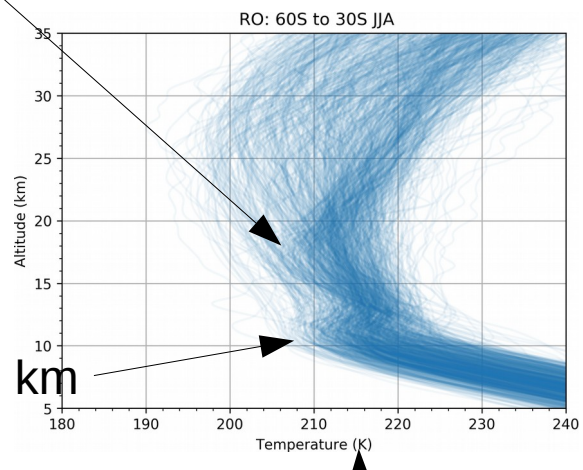
There it is!



Winter



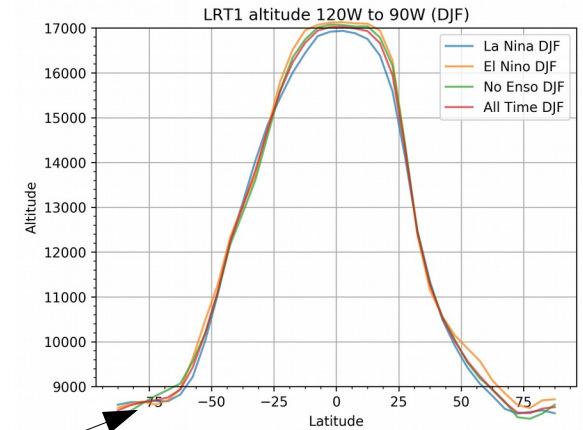
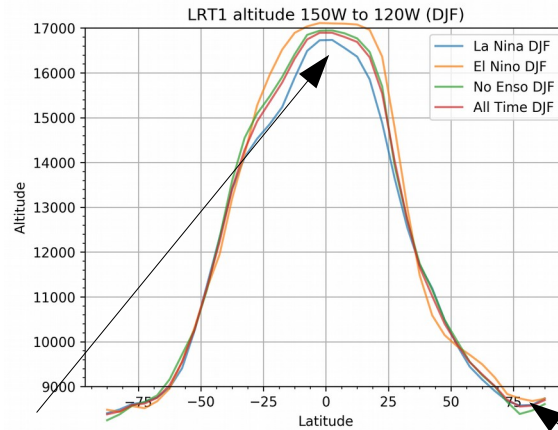
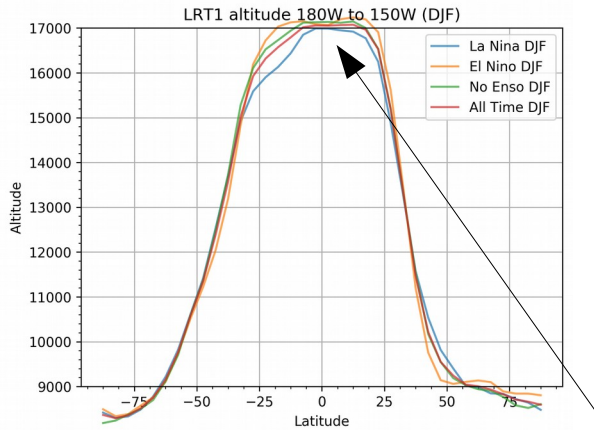
~10 km



Winter

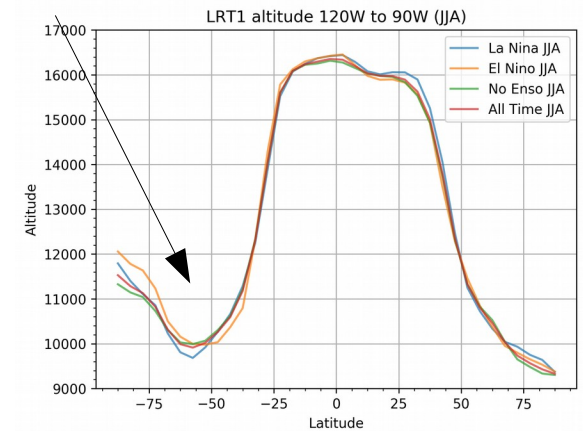
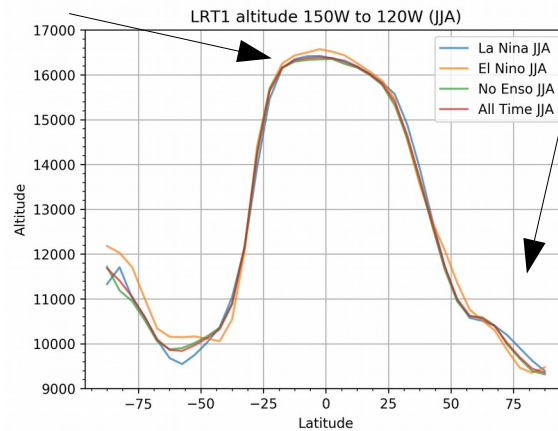
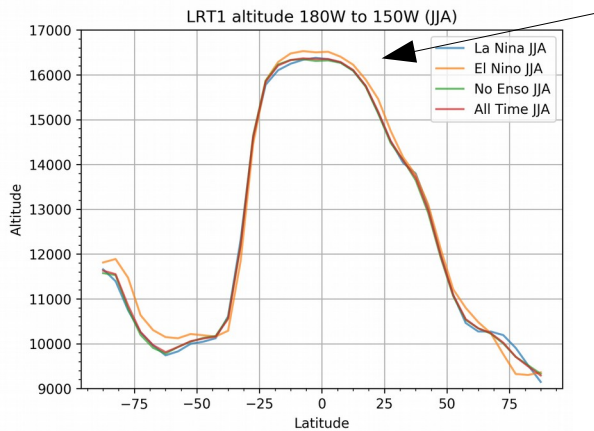
Summer

Mean height of first lapse rate tropopause is latitude dependent



Topical

Polar



WMO lapse rate tropopause definition



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First tropopause

Smoothing without smoothing

Second or more tropopauses

in the meantime. The new definition of tropopause is as follows :

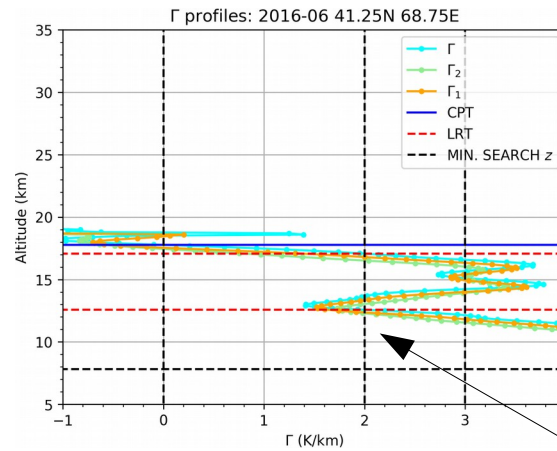
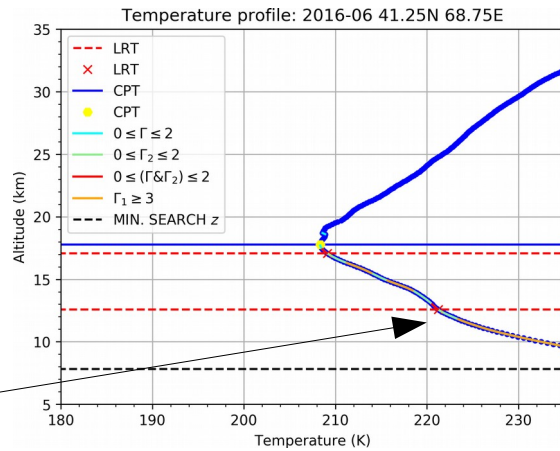
- (a) The first tropopause is defined as the lowest level at which the lapse rate decreases to 2° C/km or less, provided also the average lapse rate between this level and all higher levels within 2 km does not exceed 2° C/km.
- (b) If above the first tropopause the average lapse rate between any level and all higher levels within 1 km, exceeds 3° C/km, then a second tropopause is defined by the same criterion as under (a). This tropopause may be either within or above the 1 km layer.

On the question of significant levels, the commission considered that they

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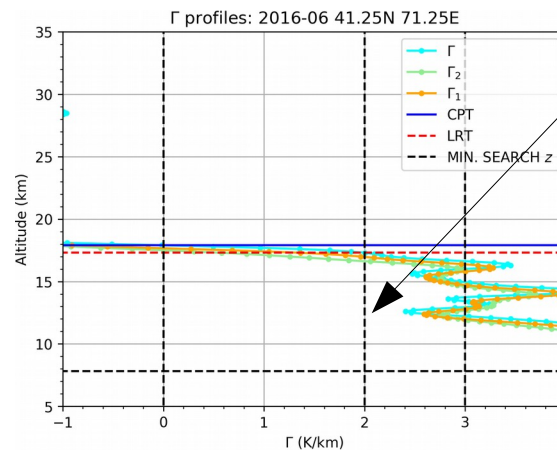
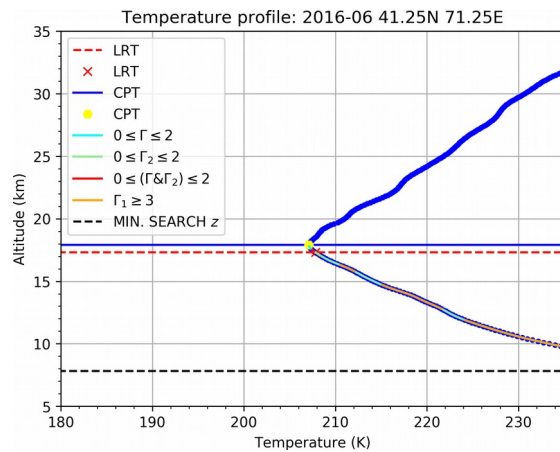
Source: WMO 1957

“That is not a tropopause”



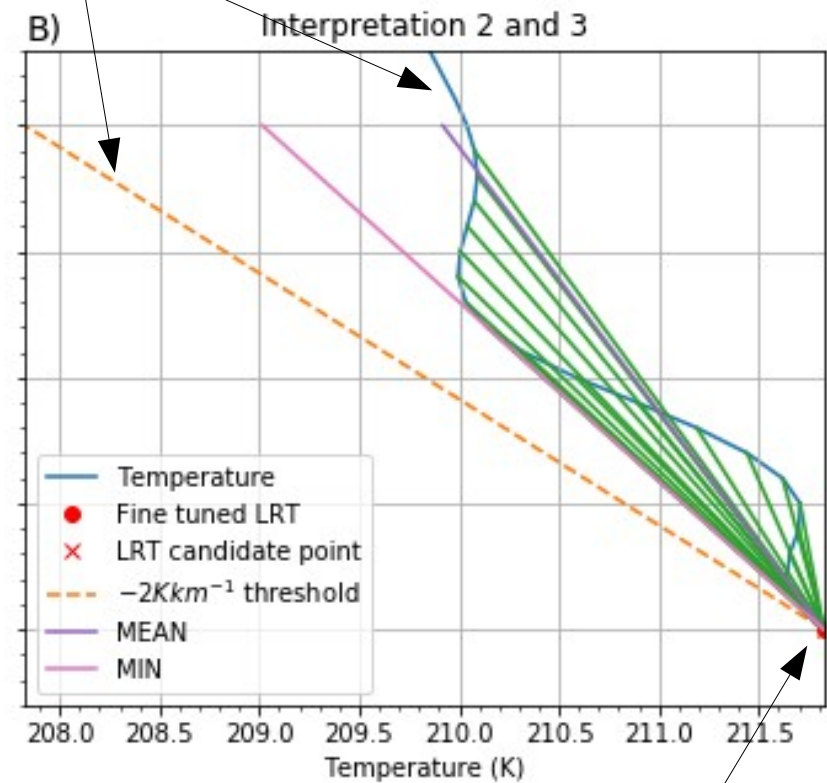
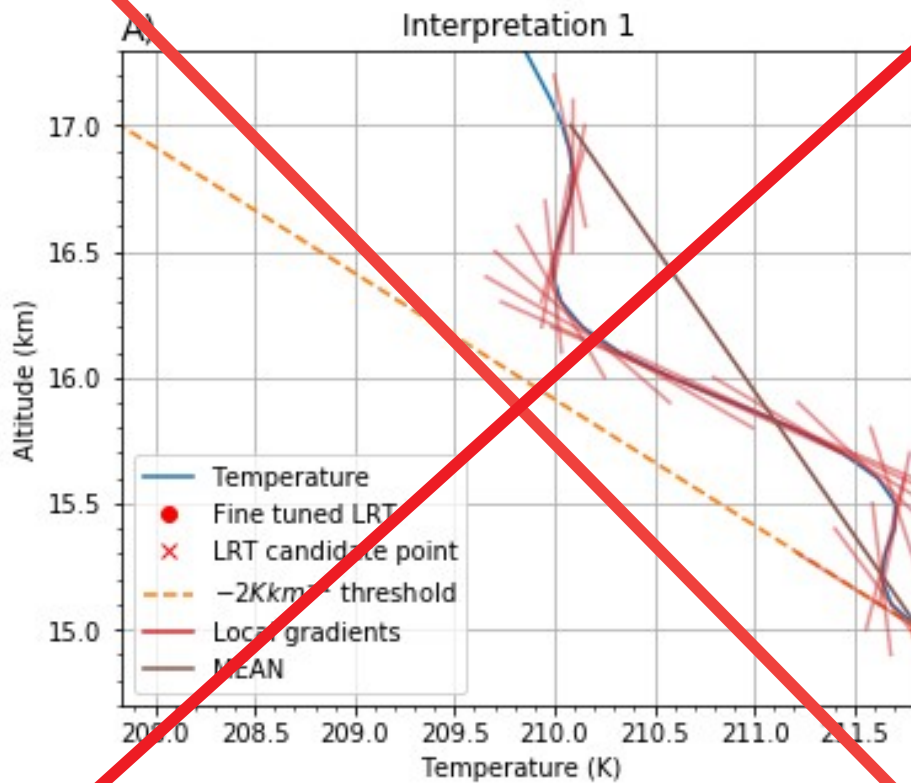
**WRONG!
THAT IS NOT A
TROPopause!**

Step function



The interpretation used in this work

These two lines may not meet
for 2 km above the candidate point



LRT candidate point

Double tropopauses



- Tropical tropopause domain extend over the polar tropopause domain
- Polar tropopause domain extend under the tropical tropopause domain
- Along the jet streams (especially during winter)
- Stratosphere troposphere exchange
- Rossby wave braking events
- Warm Conveyor Belts
- Mountain gravity waves (lee waves)
- Cloud tops

Method

- Temperature profiles from the WegC OPSv5.6 data record (with some exceptions). 100 m vertical resolution.
- WMO 1957 Lapse rate tropopause definition on all temperature profiles (QC=0)
- Lower limit: $6.25 \text{ km} + 1.25 \text{ km} \times \cos(\phi)$ ← Latitude
- Upper limit: 25 km ← (way above the tropopause)
- 5 deg latitude x 5 deg longitude grid cells
- $\text{DT \%} = 100 \times \frac{N_2}{N_1}$ ← Number of 2nd tropopauses
← Number of 1st tropopauses

Global view

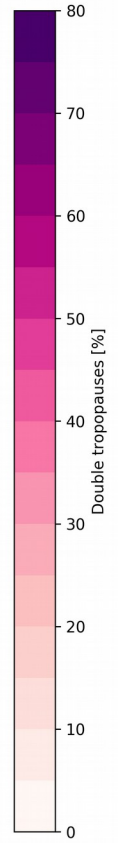
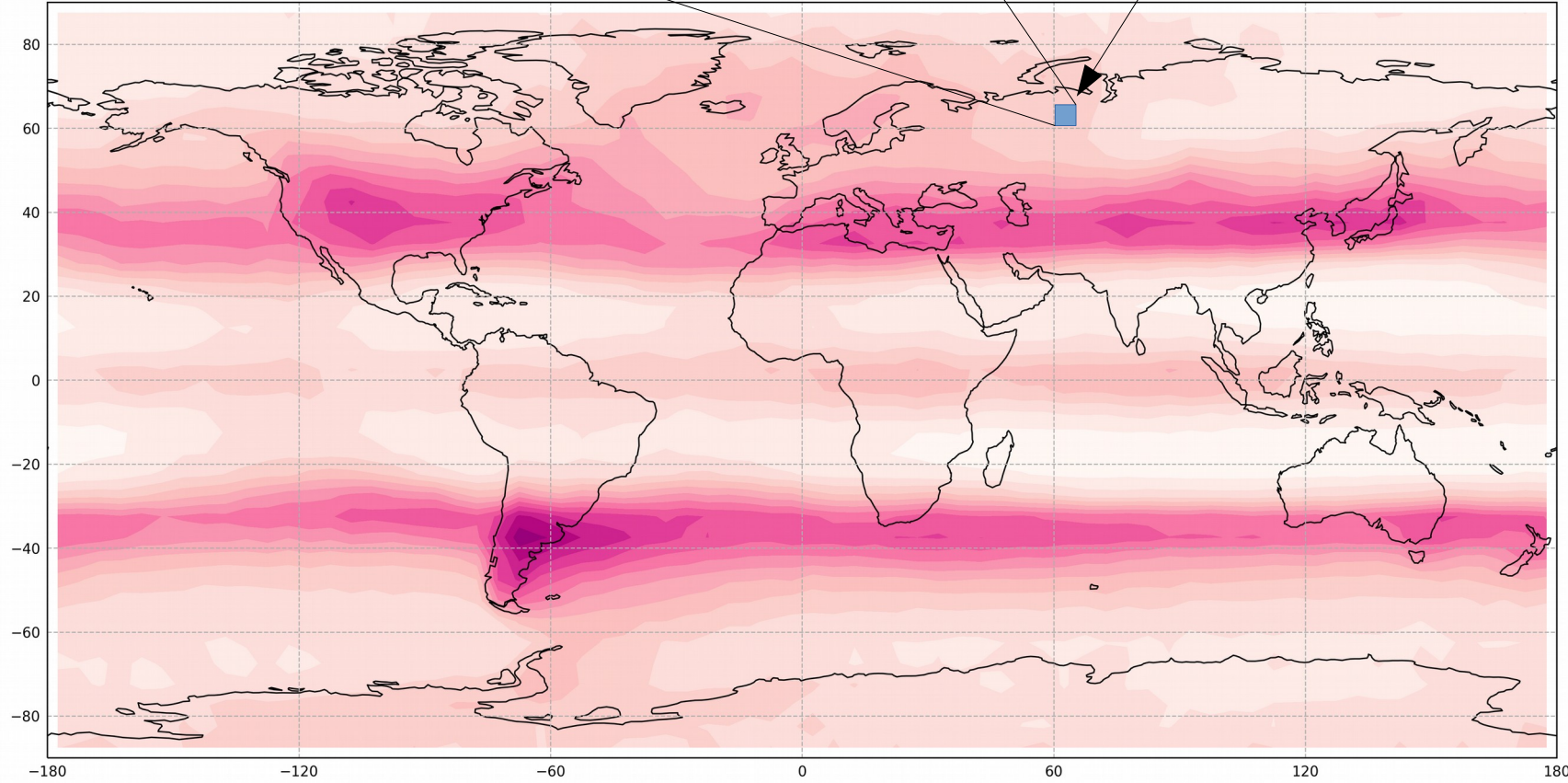
$$100 \times \frac{N_2}{N_1}$$

All 2nd tropopauses

All 1st tropopauses

LRT2PCT all | All Time [208]

5 lat x 5 lon



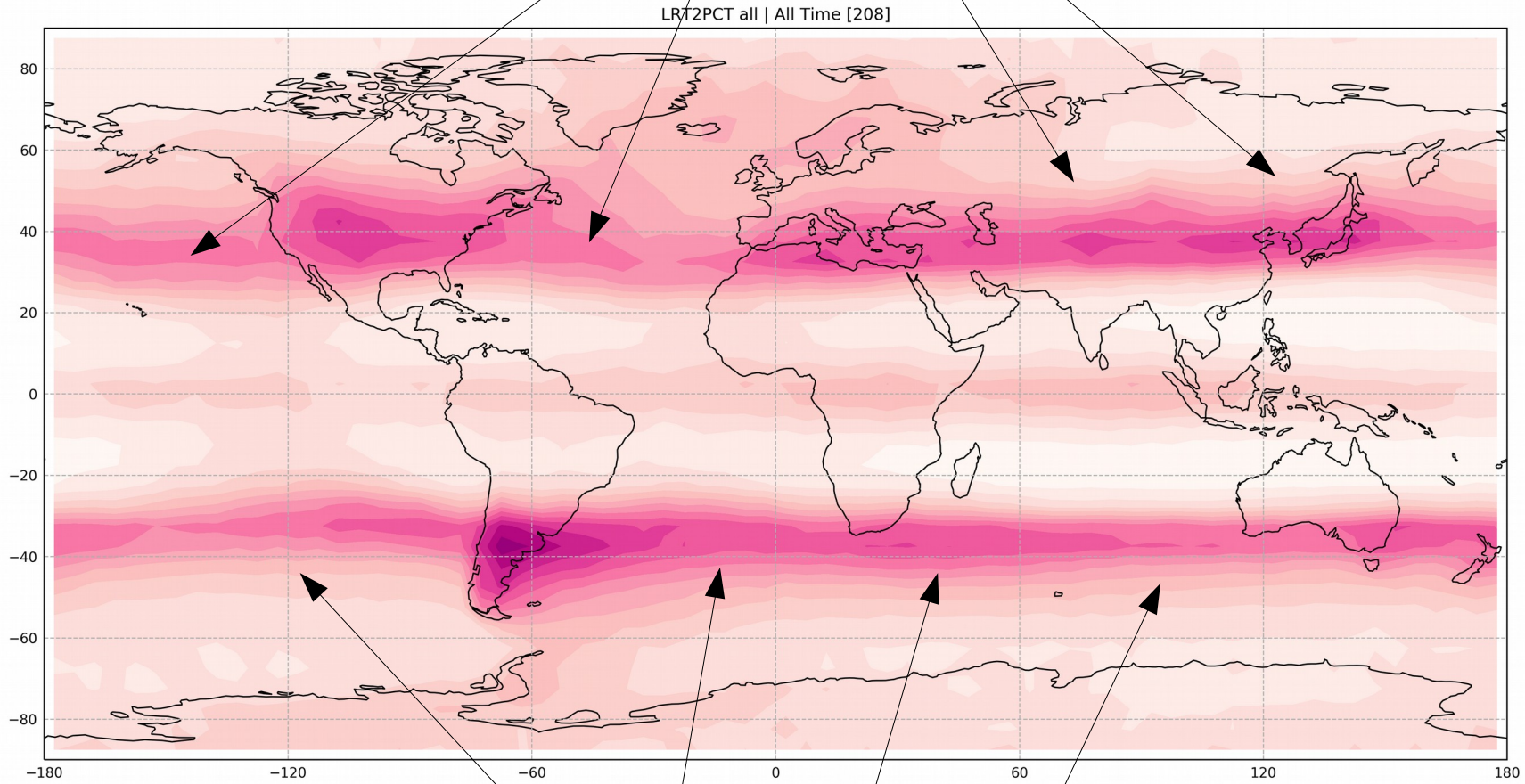
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Global view



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Along the jets streams



Along the jets streams

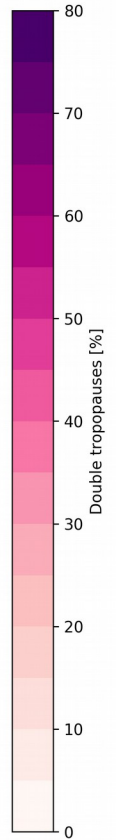
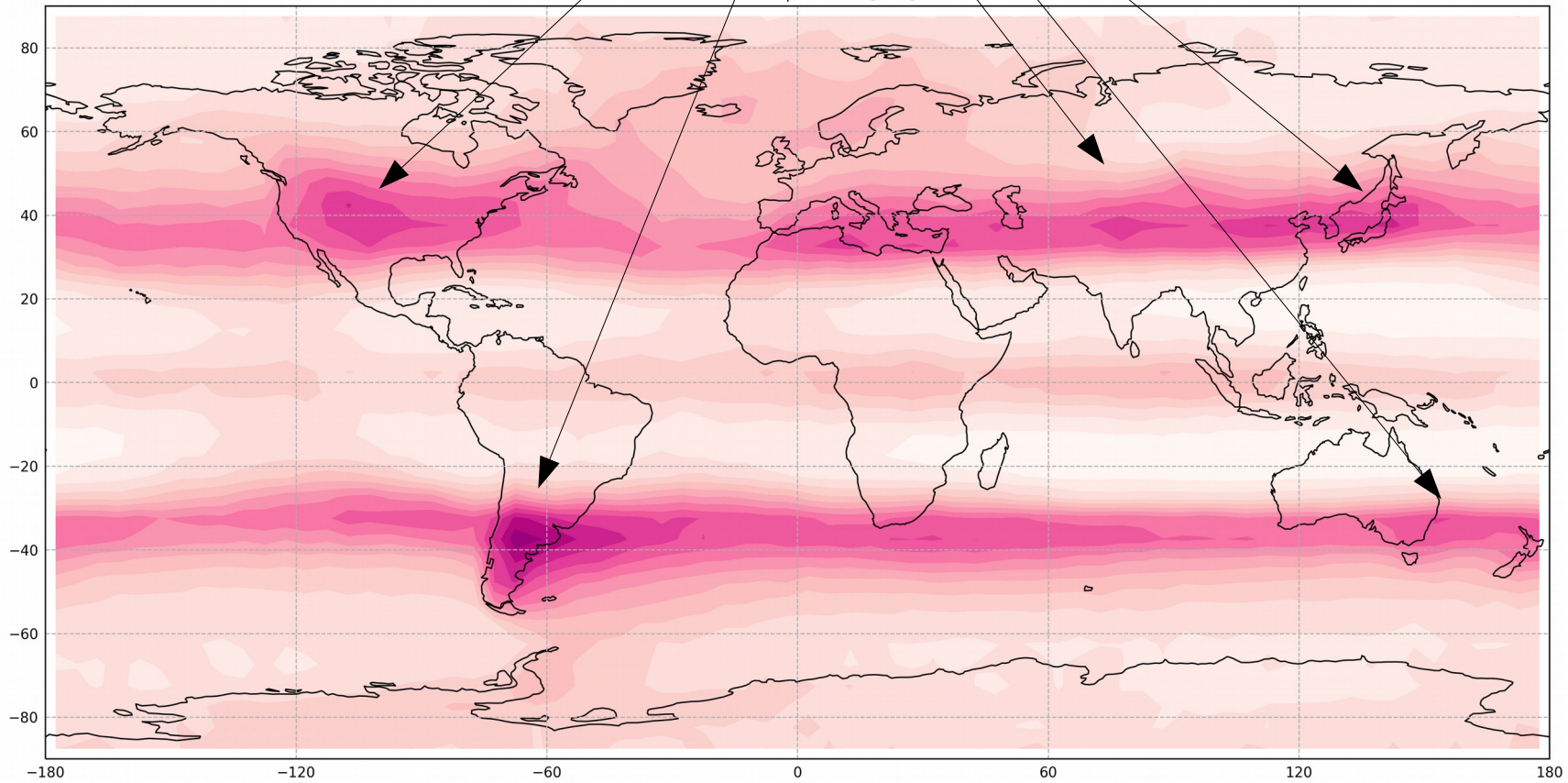
Global view



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Hotspots

LRT2PCT all | All Time [208]



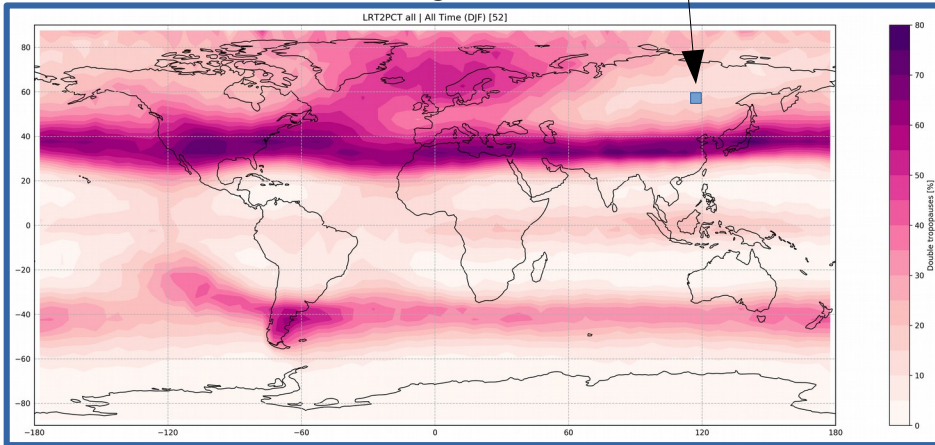
Seasons

All profiles within the grid cell,
for the corresponding season included

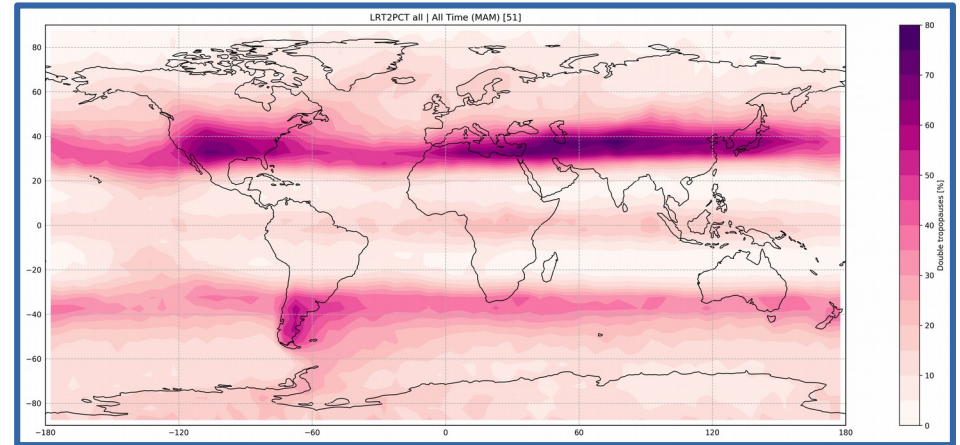


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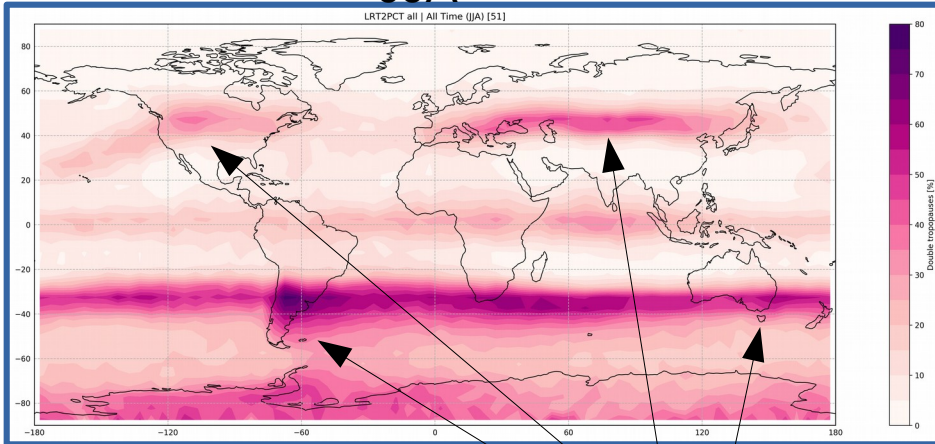
DJF



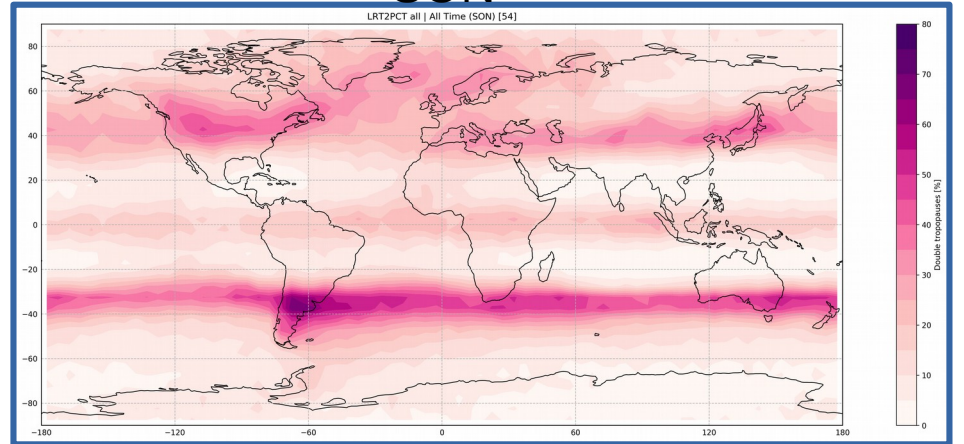
MAM



JJA



SON



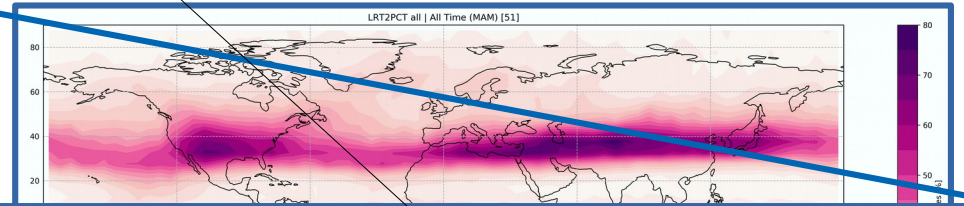
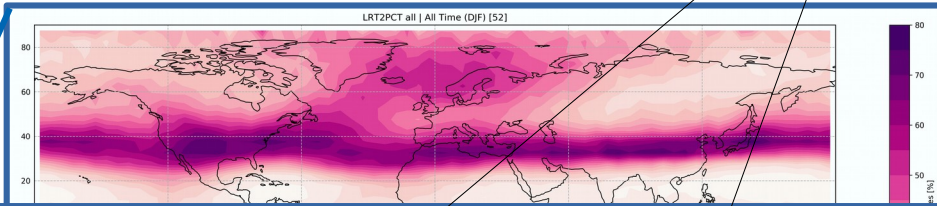
All year

Seasons - DJF

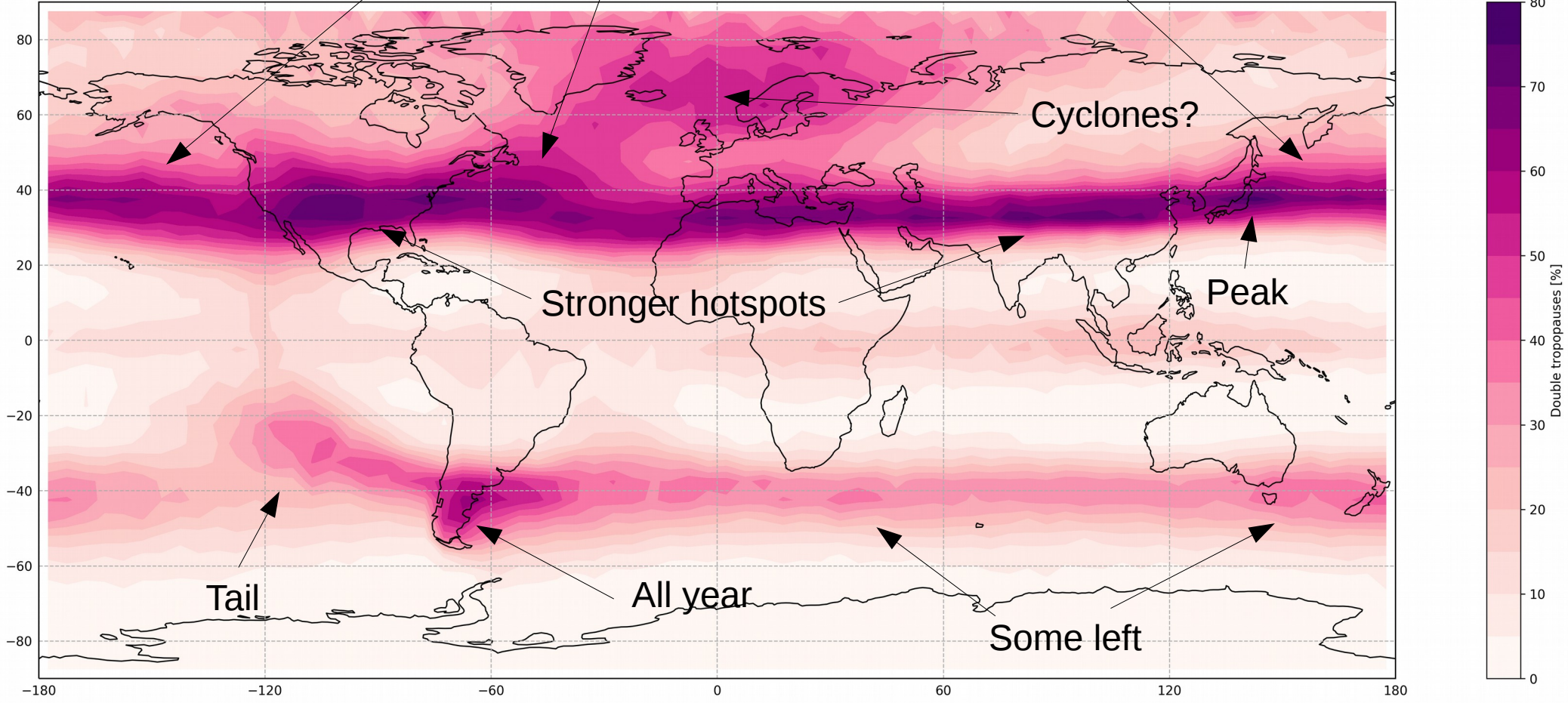
Along the jets streams



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LRT2PCT all | All Time (DJF) [52]



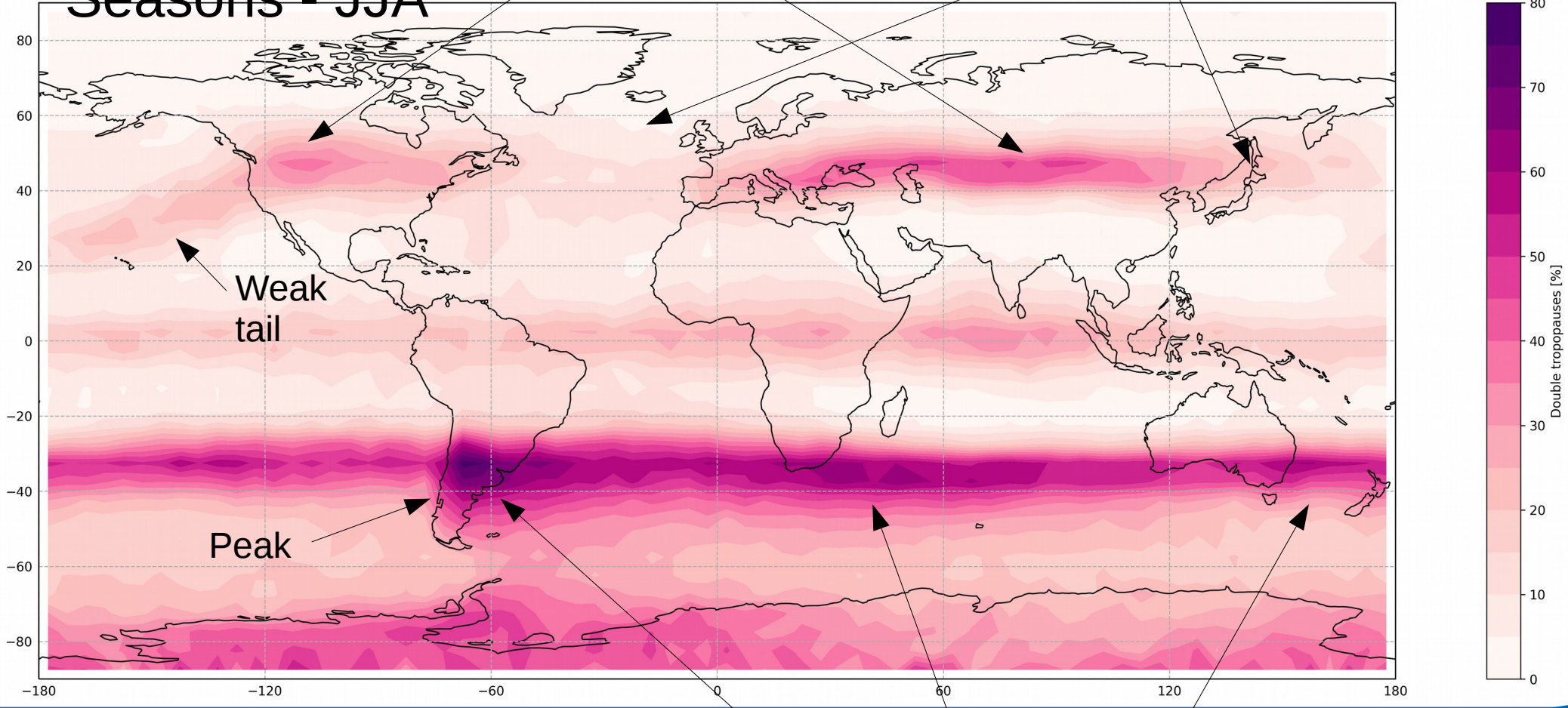
Still some left

Gone



Seasons - JJA

LRT2PCT all | All Time (JJA) [51]

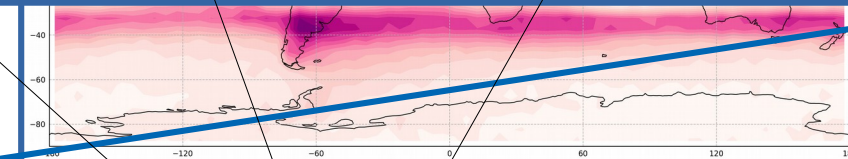
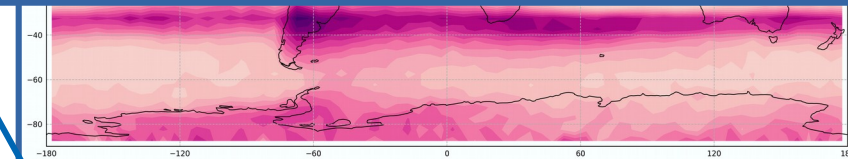


Double tropopauses [%]

Weak tail

Peak

Hotspots stronger



Timelines



Peaks connected to QBO winds at 70 hPa

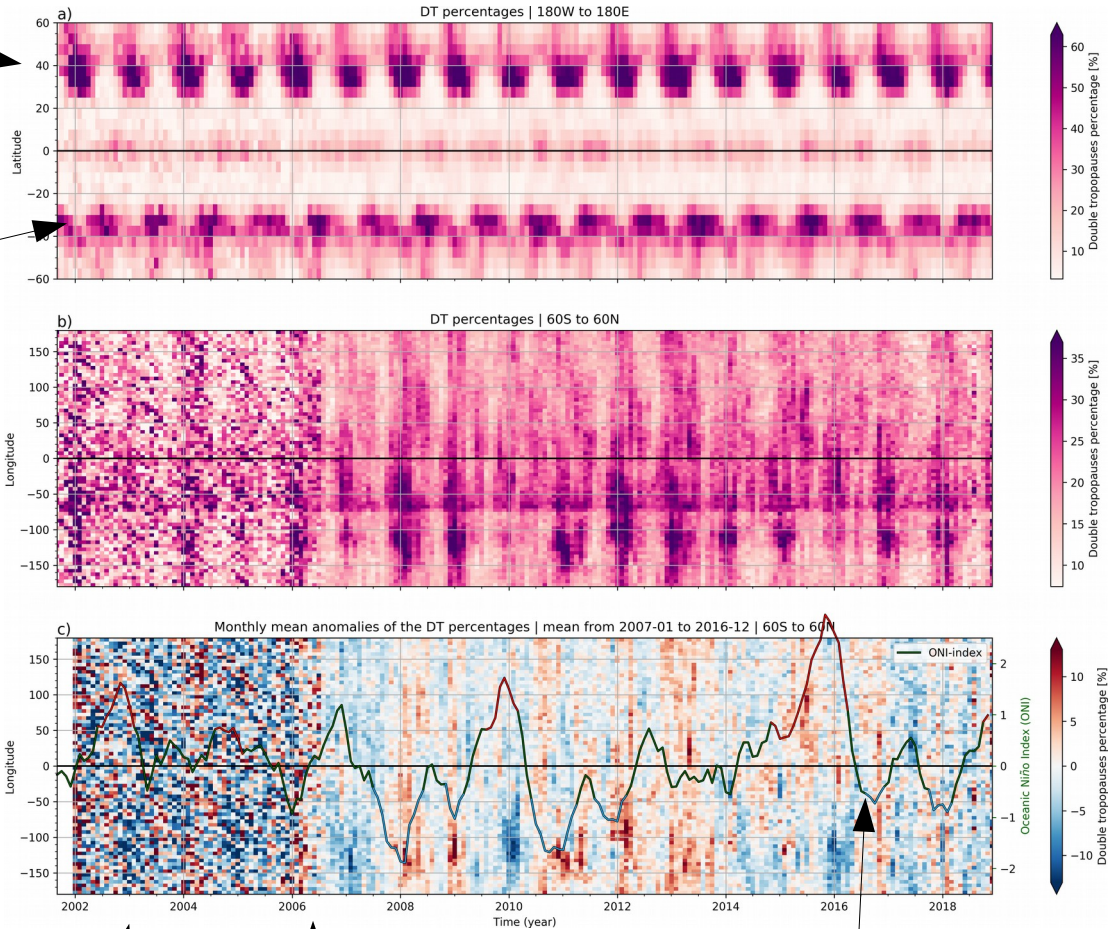
Latitude

Peaks connected to QBO winds at 80 hPa

Longitude

Longitude (monthly mean anomalies)

Seasonal pattern



CHAMP period (fewer measurements)

Welcome COSMIC!

Oceanic Niño Index (ENSO)

La Niña (DJF only)

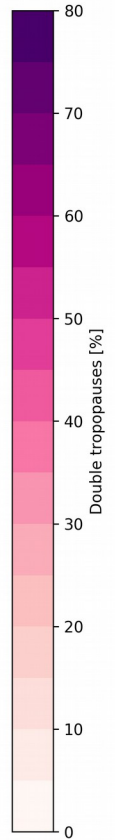
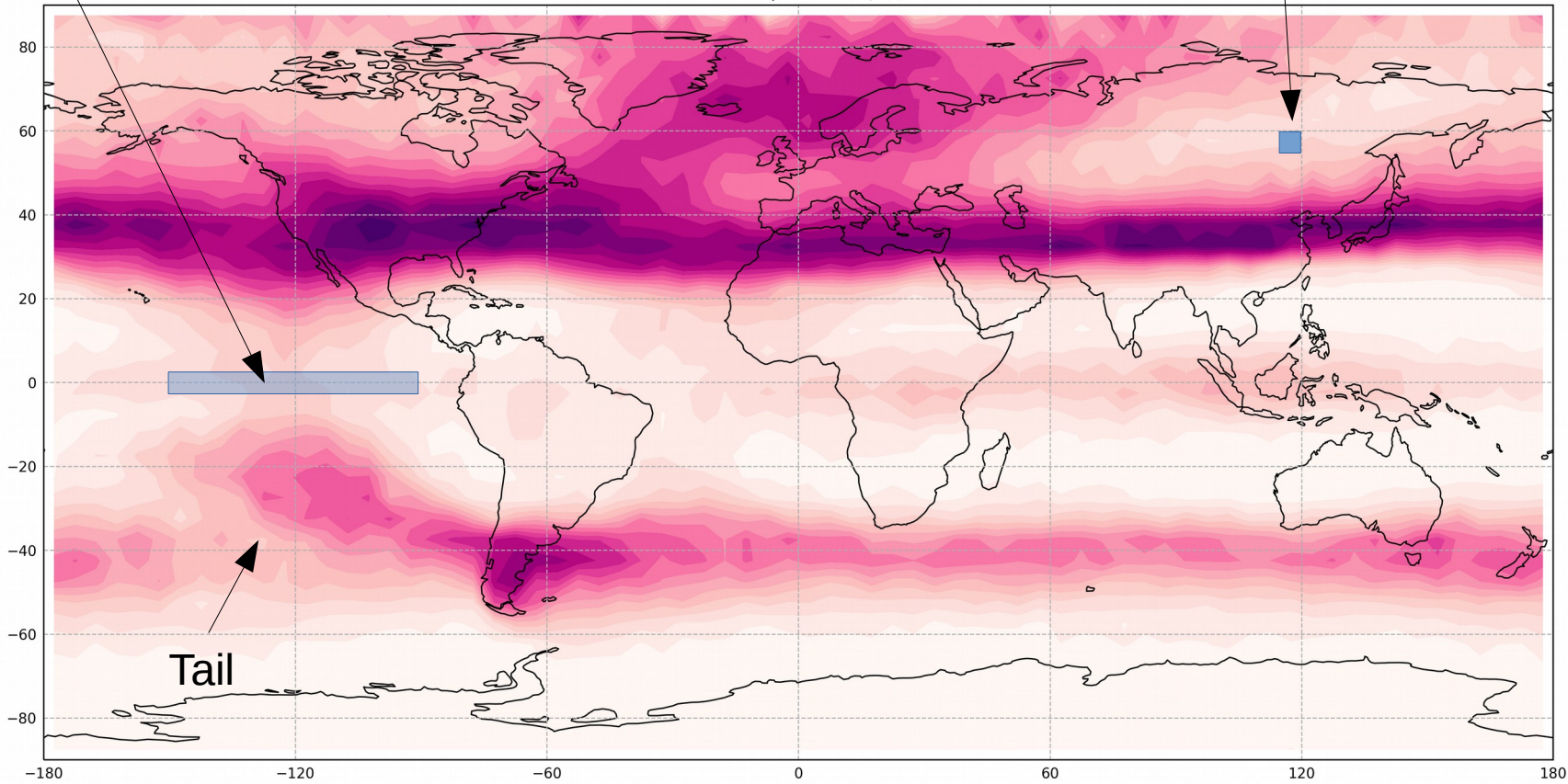


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Niño3-region

All profiles within the grid cell during DJF La Niña included

LRT2PCT all | La Nina (DJF) [16]



El Niño (DJF only)

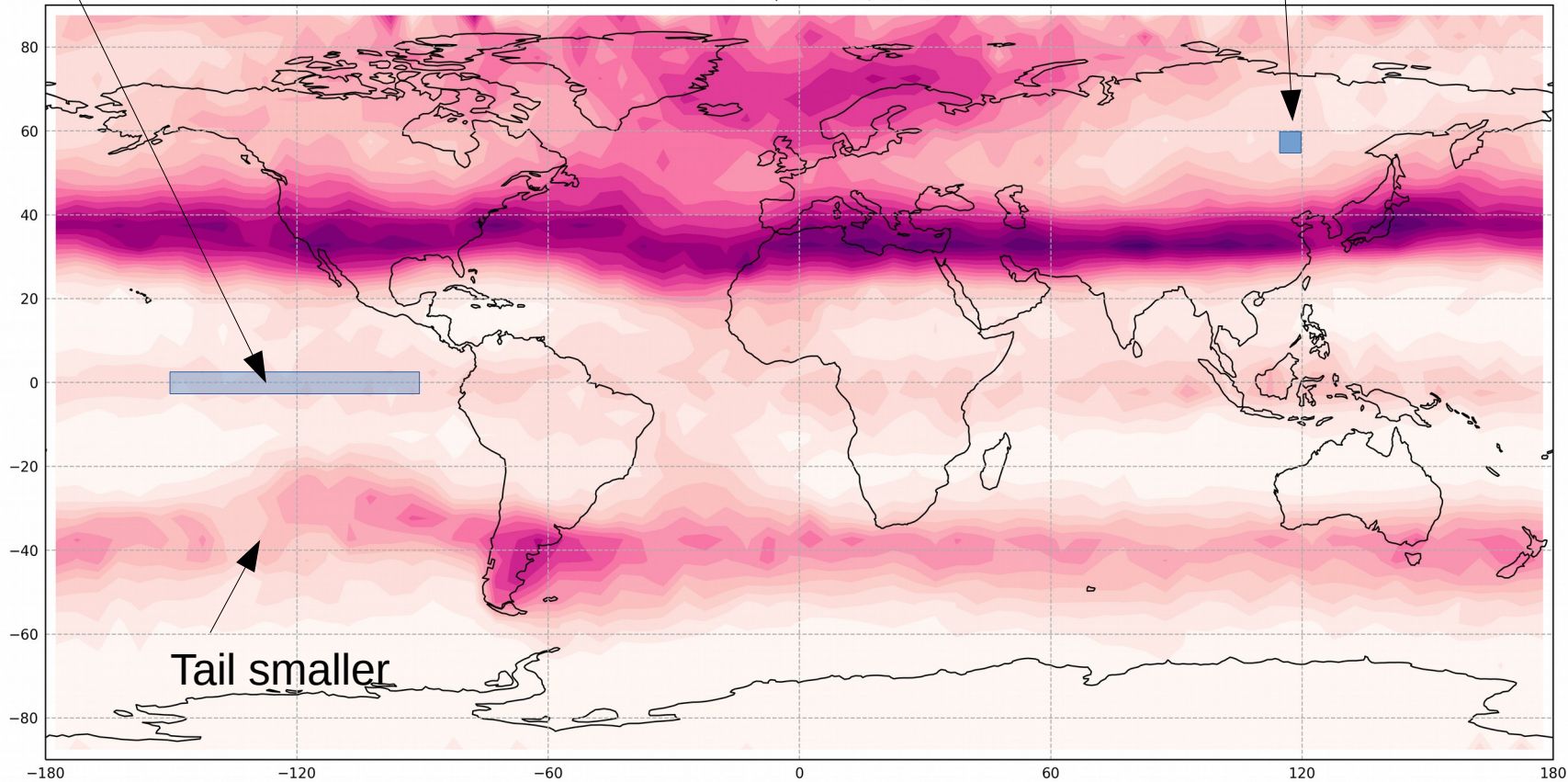


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Niño3-region

All profiles within the grid cell during DJF El Niño included

LRT2PCT all | El Nino (DJF) [16]



La Niña (DJF only) – El Niño (DJF only)



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Increased during
La Niña

More during La Niña

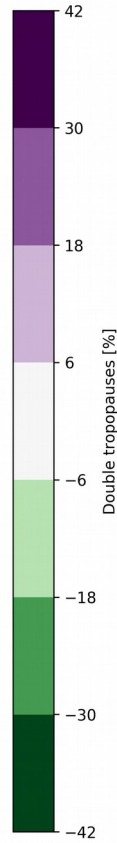
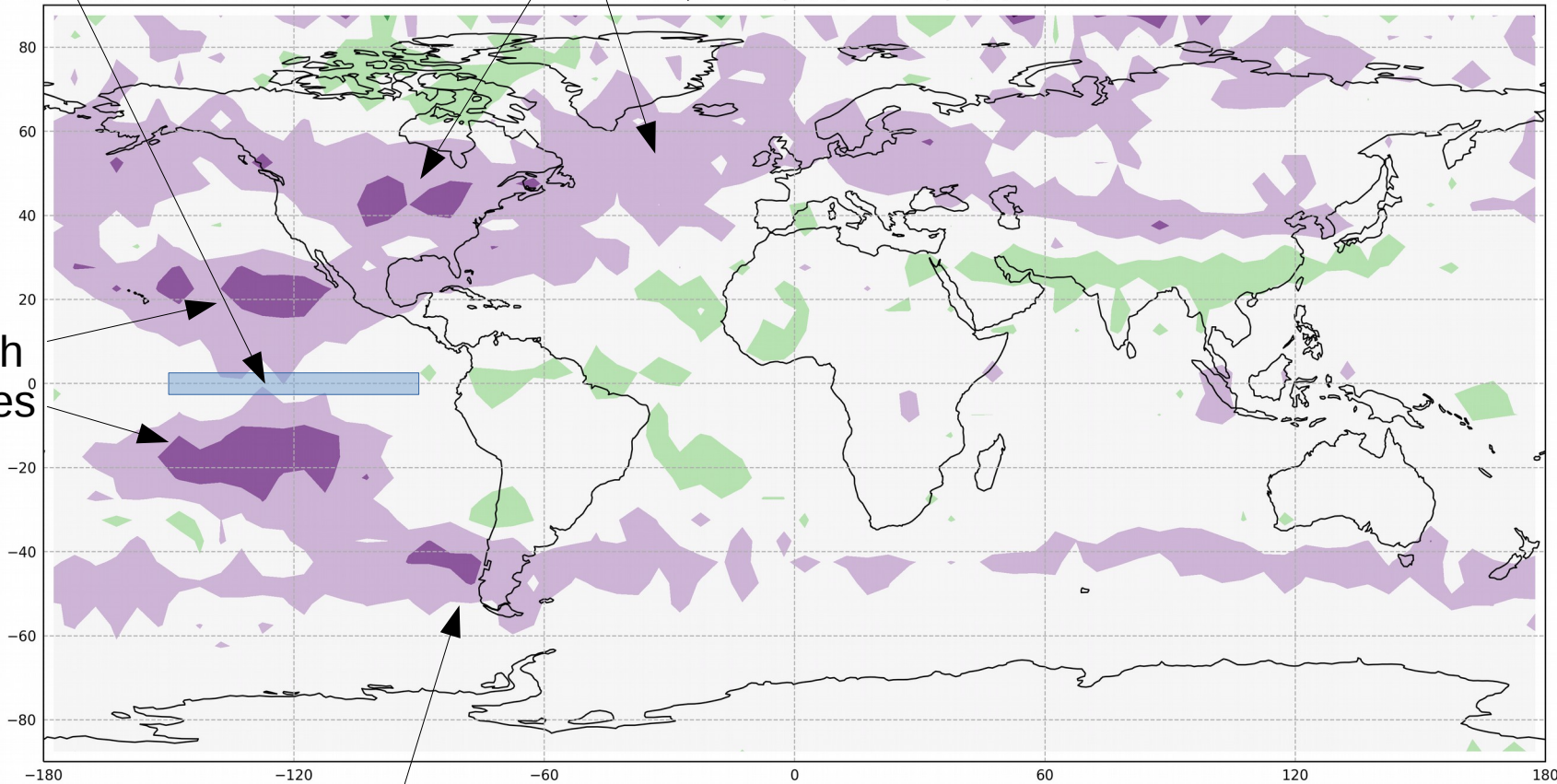
Niño3-region

Both
sides

Other side

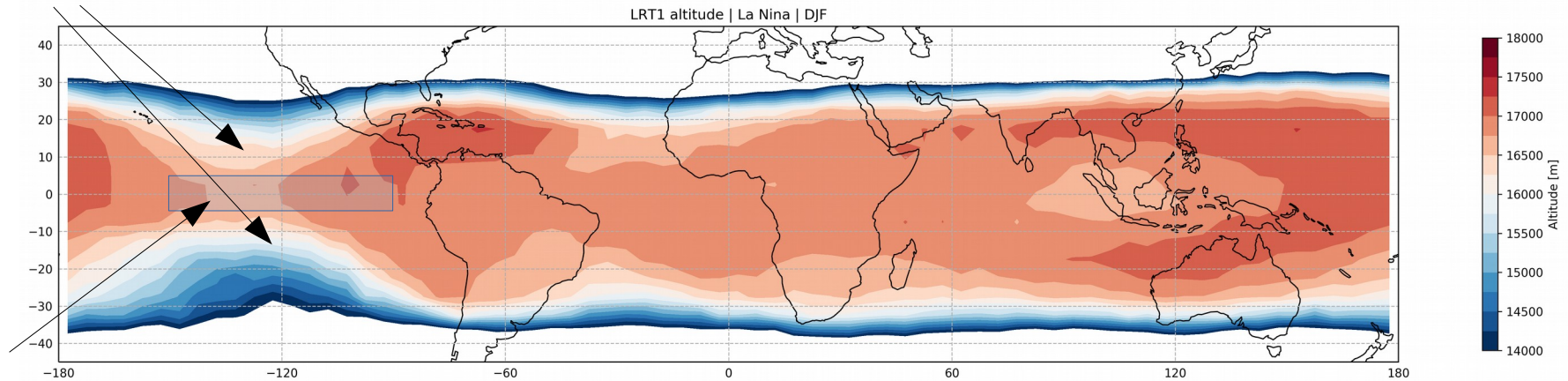
More during El Niño

LRT2PCT all | La Nina (DJF) [16] - El Nino (DJF) [16]

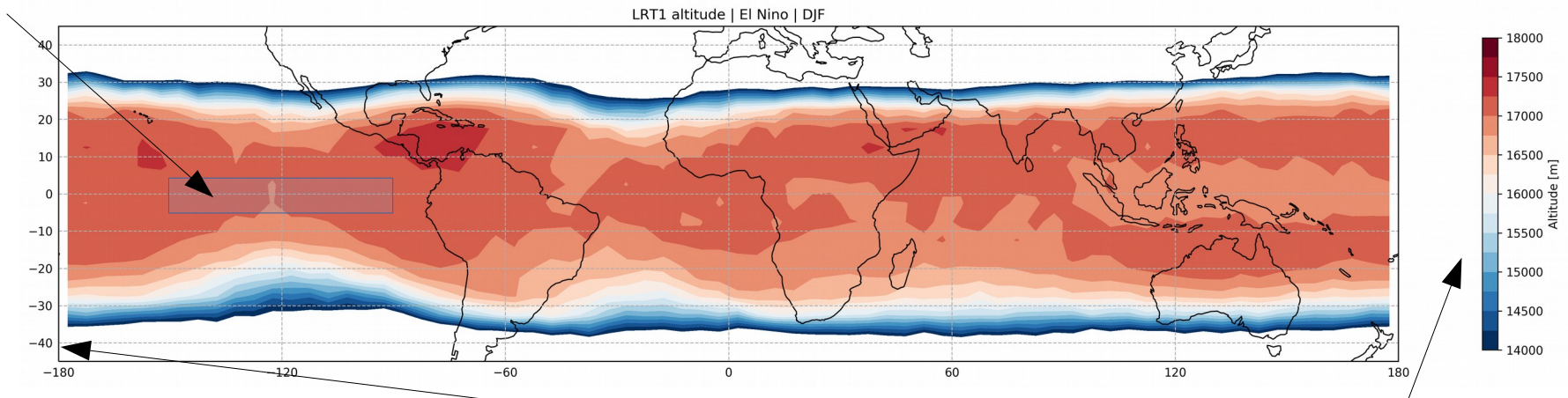


Height of the first lapse rate tropopause: DJF La Niña and DJF El Niño

DIP (on both sides of the Niño3-region)

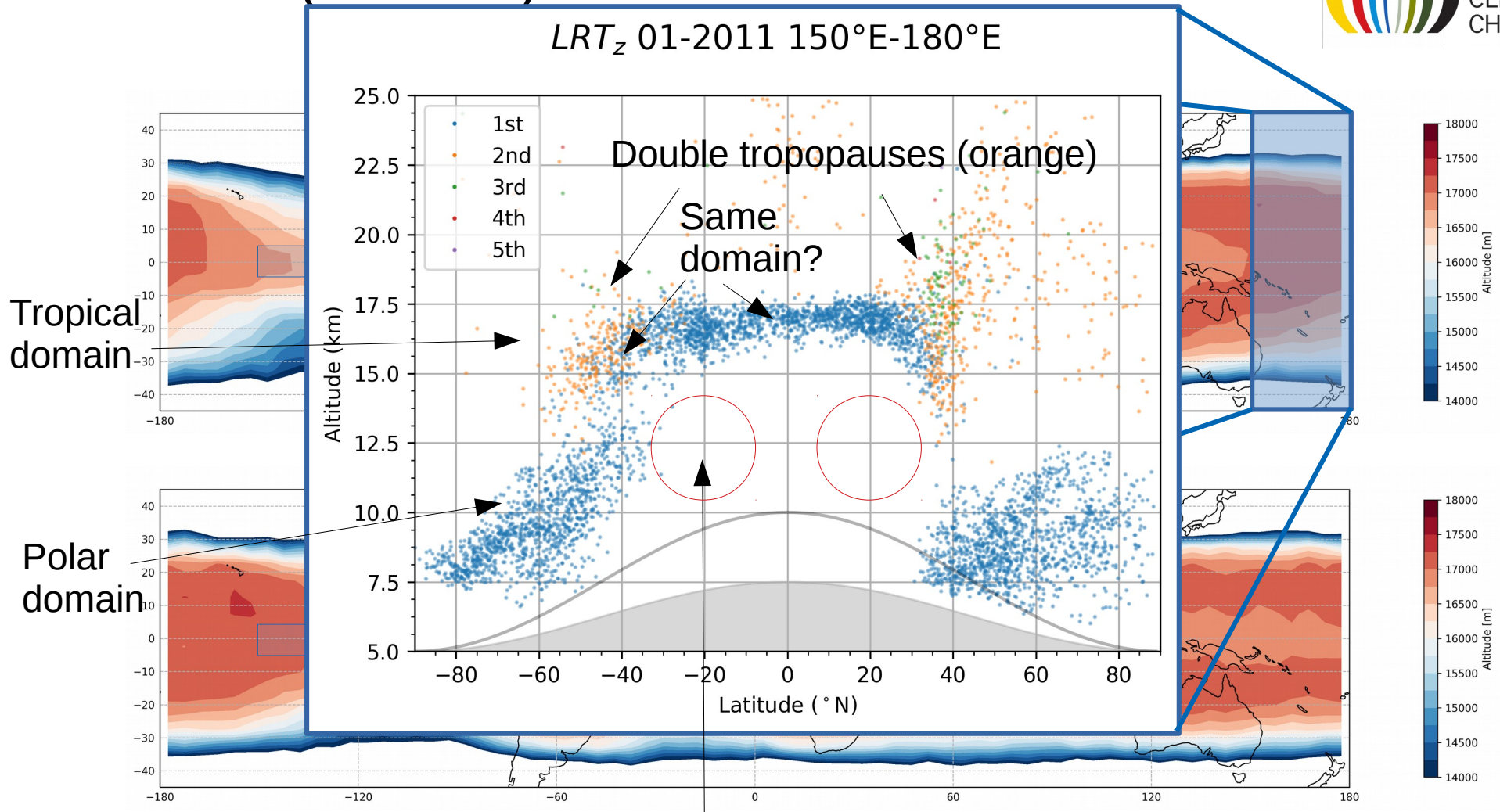


Niño3-region



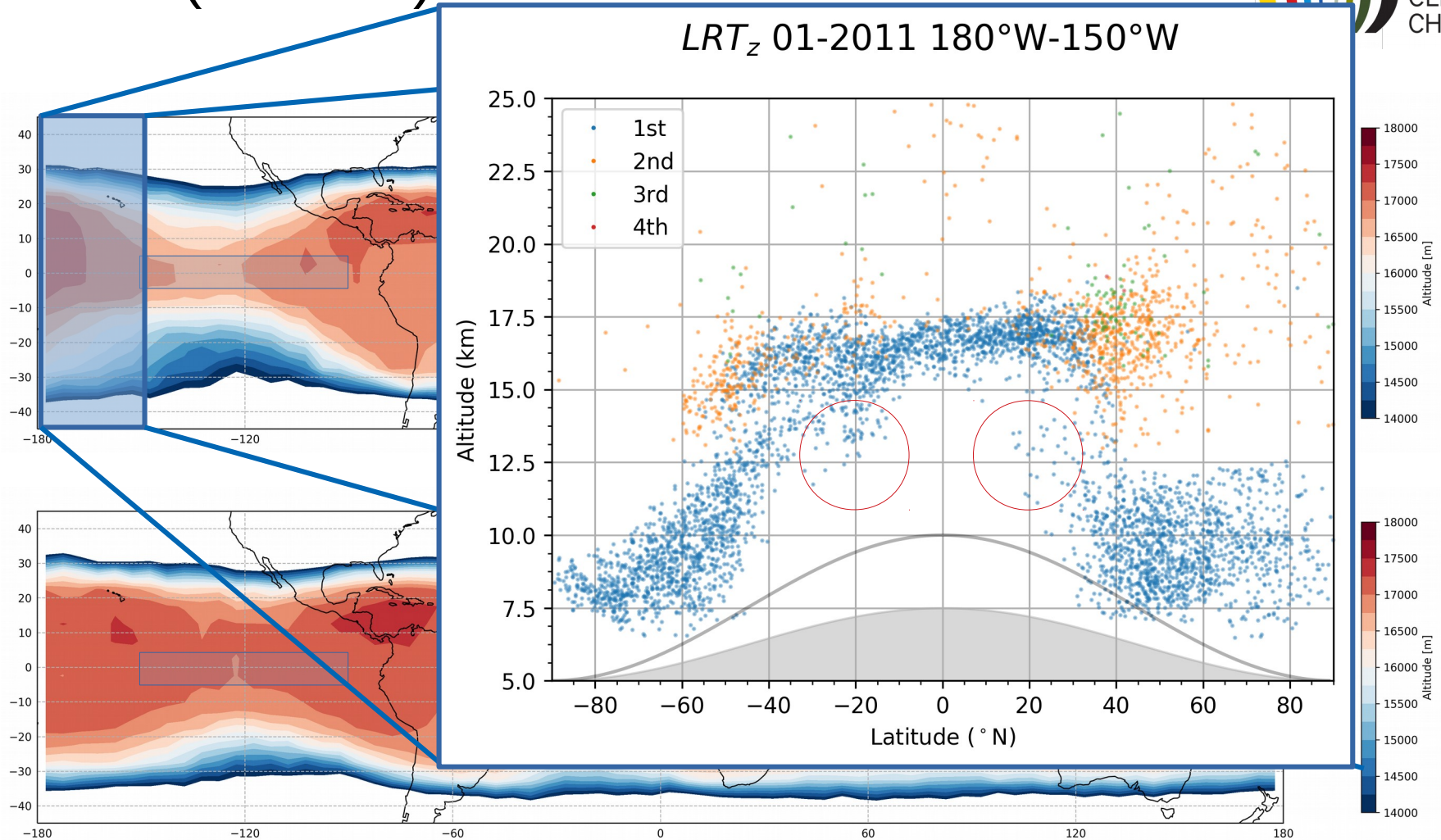
Limited ranges
to see details

Height of the first lapse rate tropopause: 2011-01 (La Niña)

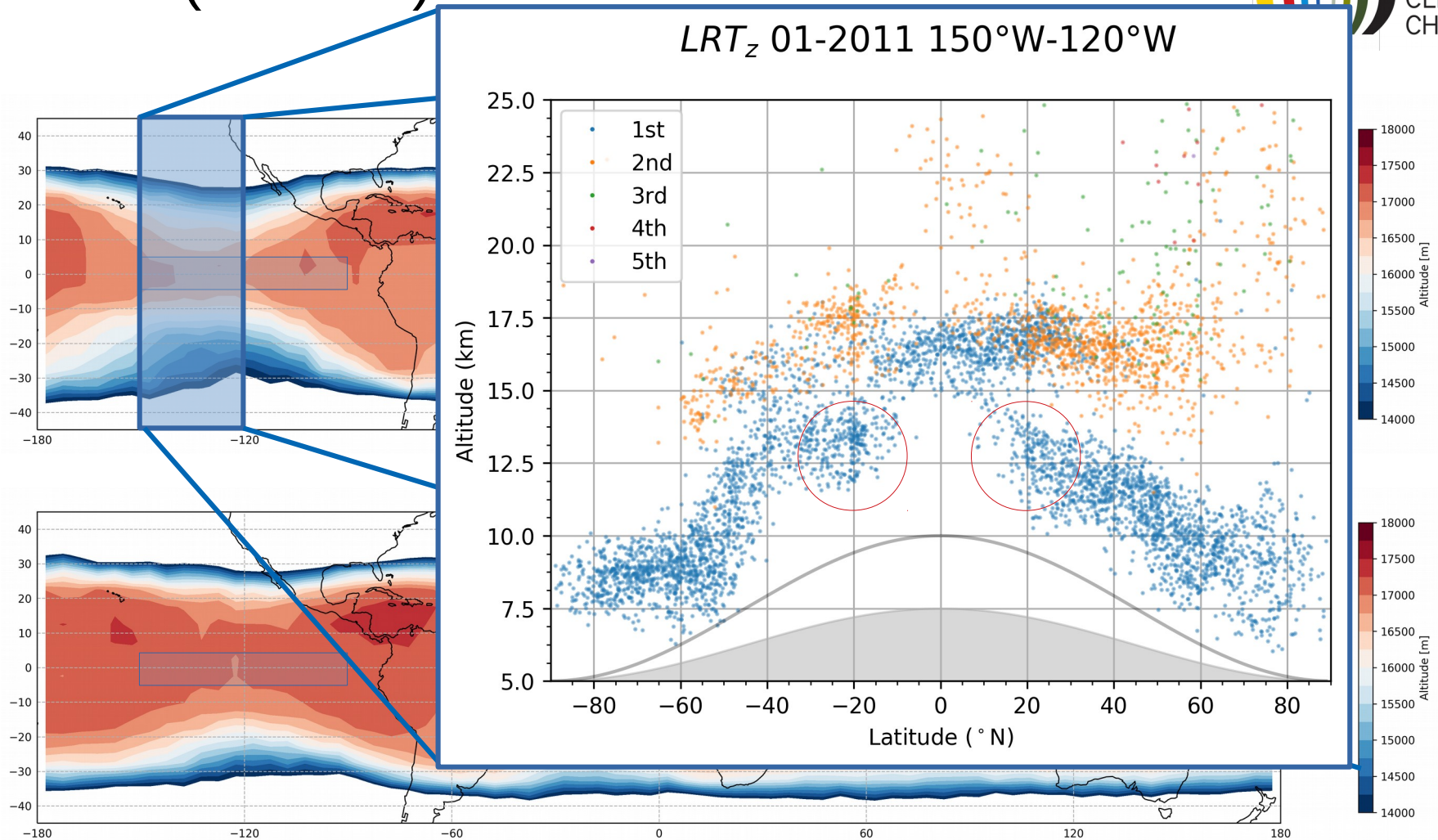


No tropopauses detected

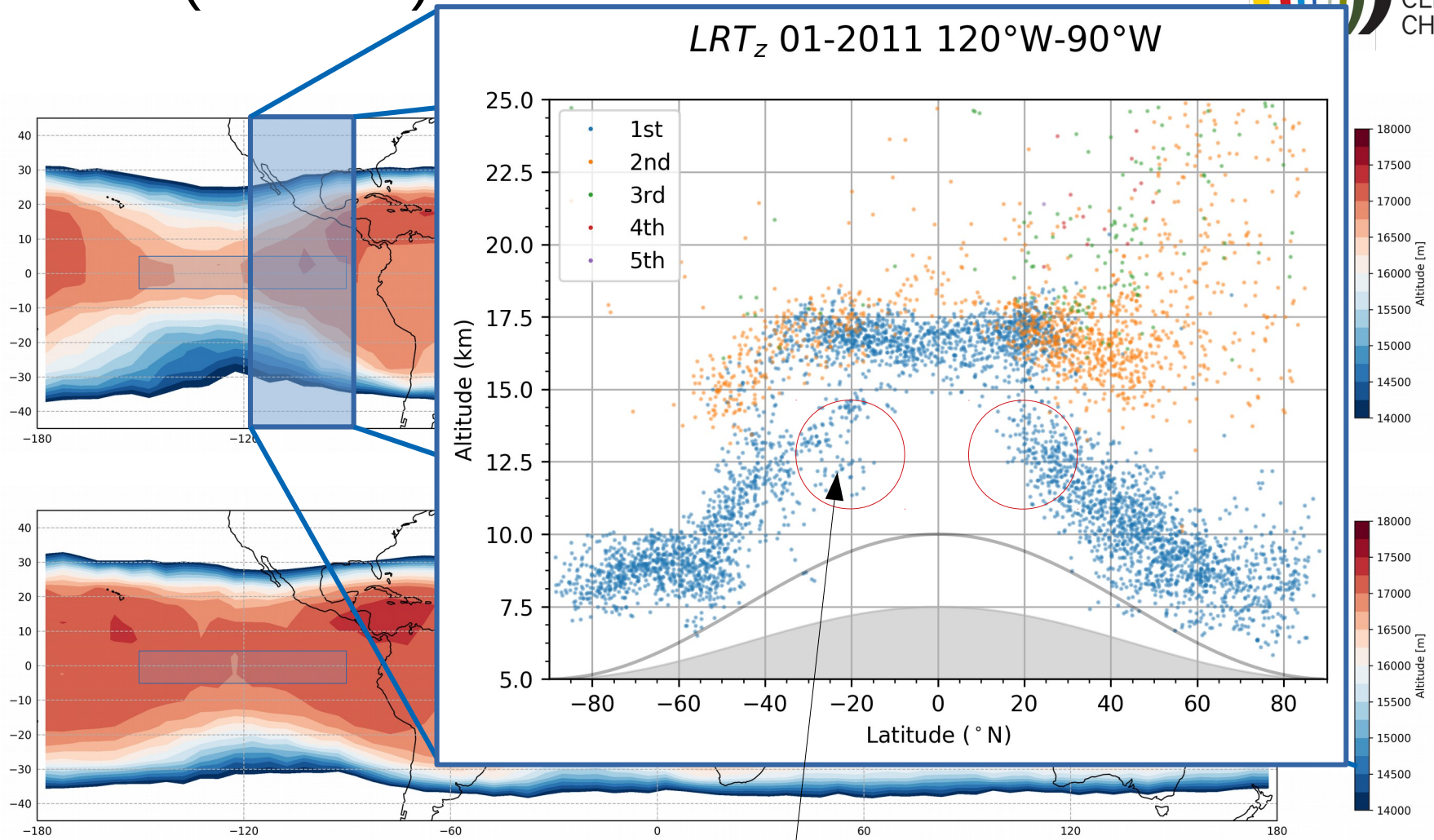
Height of the first lapse rate tropopause: 2011-01 (La Niña)



Height of the first lapse rate tropopause: 2011-01 (La Niña)

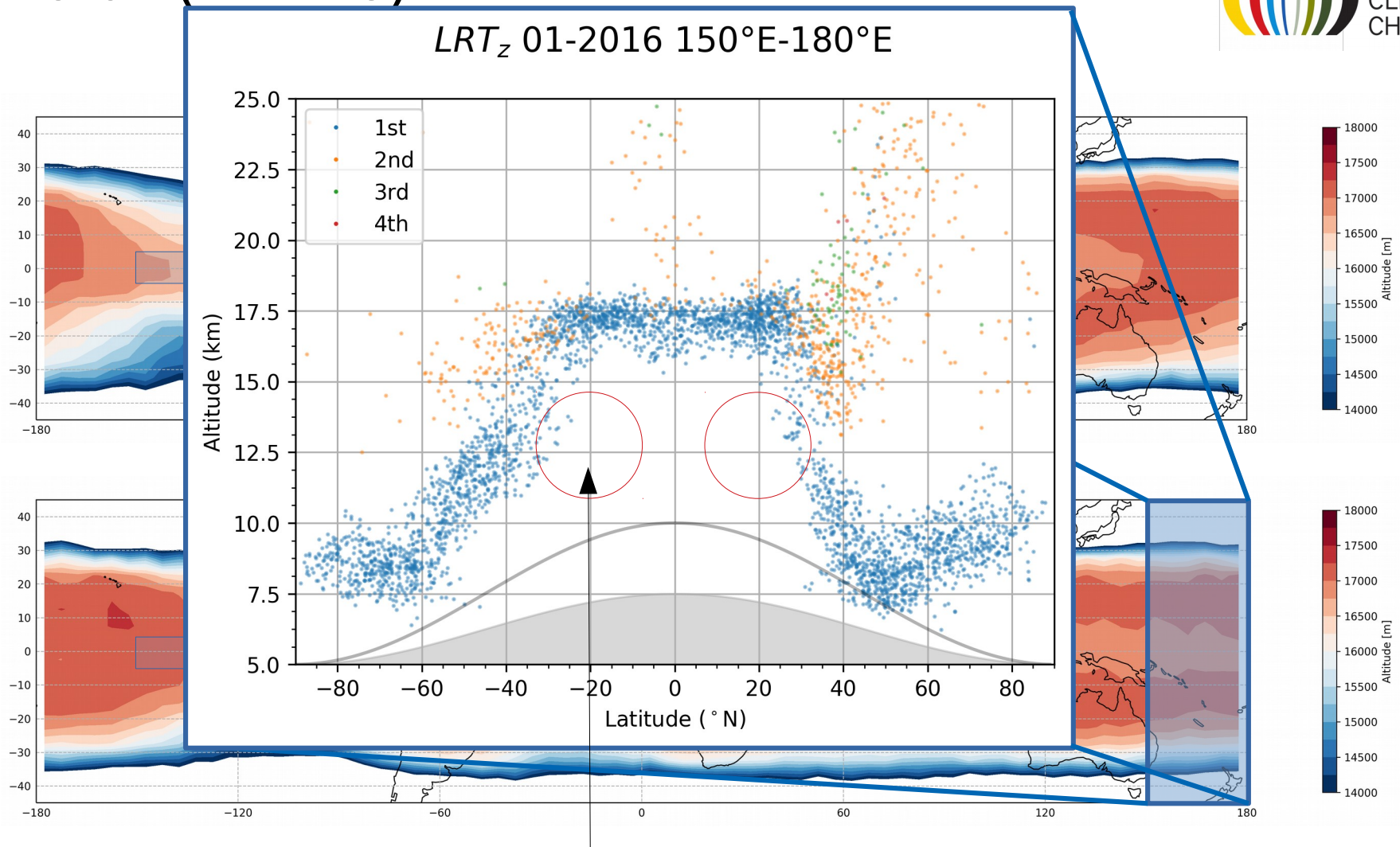


Height of the first lapse rate tropopause: 2011-01 (La Niña)



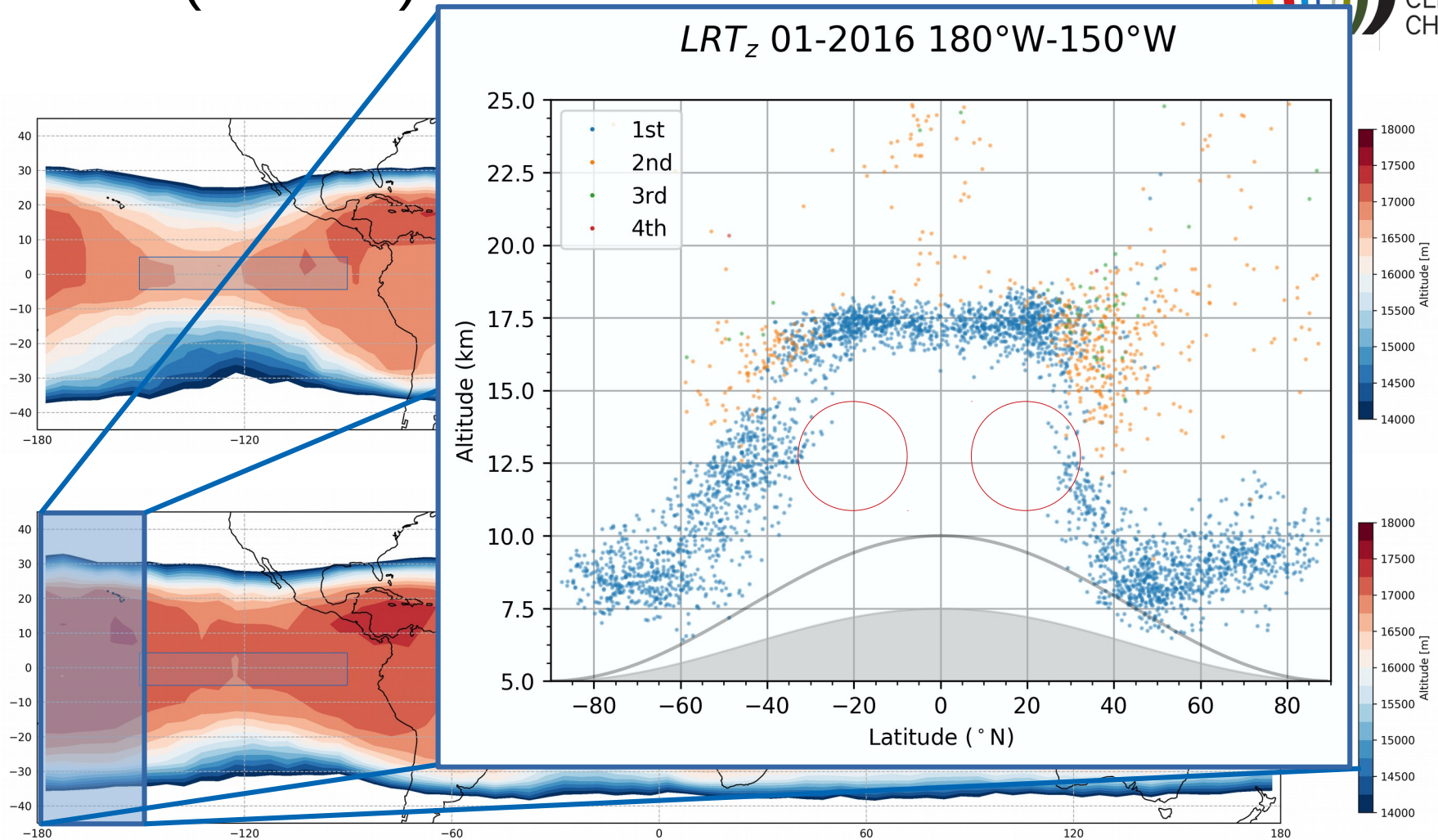
Almost back to normal

Height of the first lapse rate tropopause: 2016-01 (El Niño)

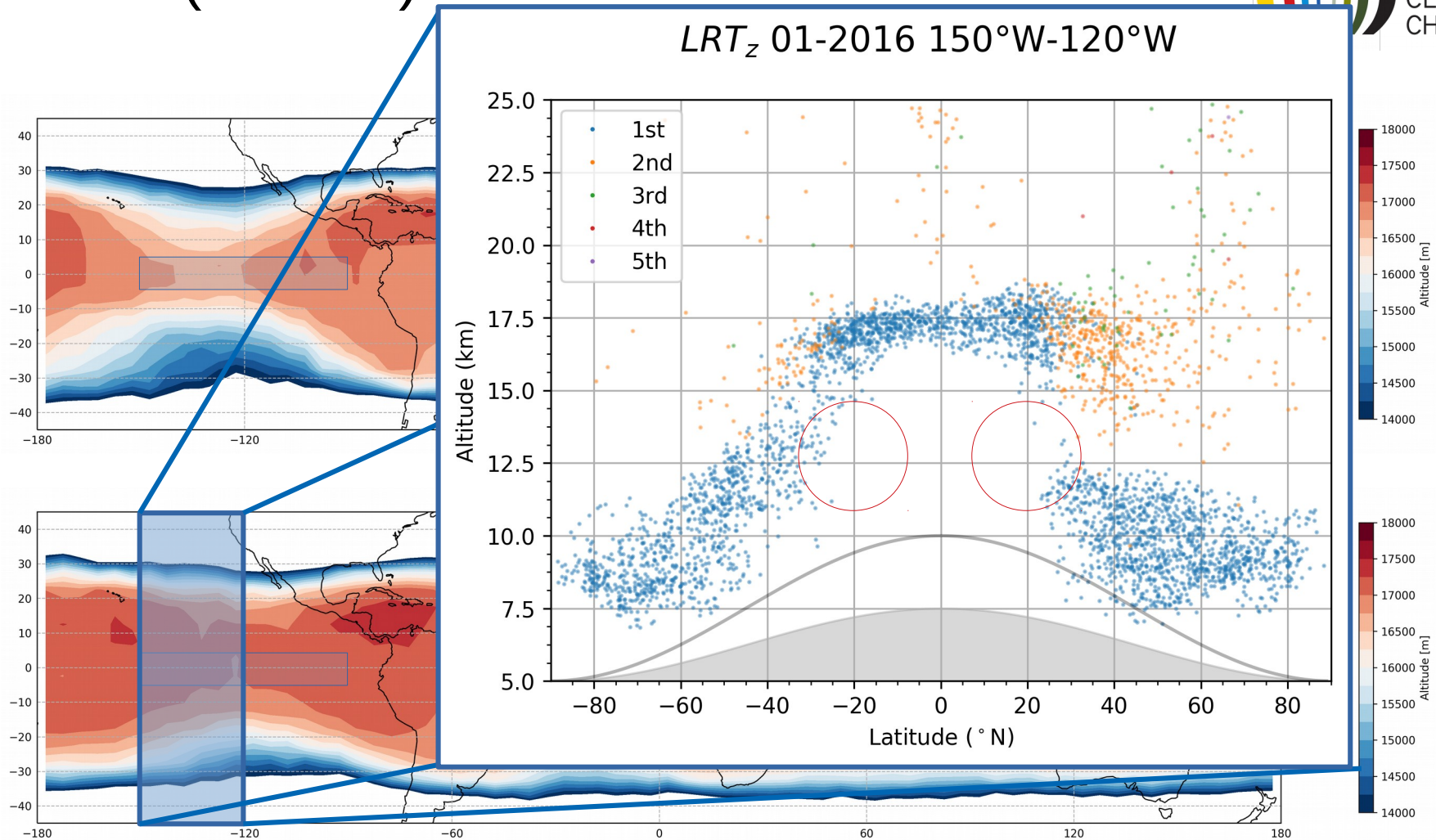


No tropopauses
detected

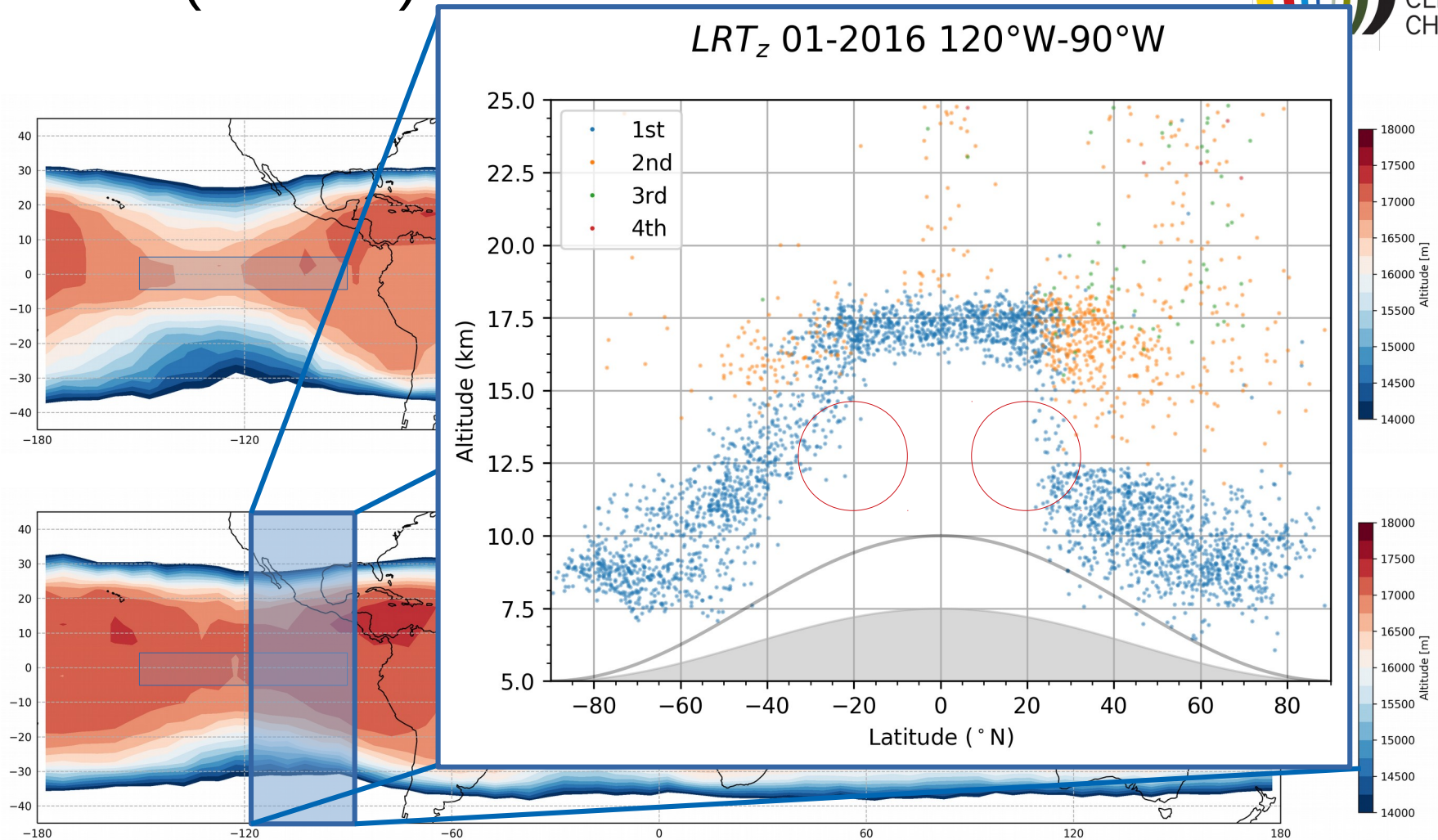
Height of the first lapse rate tropopause: 2016-01 (El Niño)



Height of the first lapse rate tropopause: 2016-01 (El Niño)



Height of the first lapse rate tropopause: 2016-01 (El Niño)



Summary



- Double tropopauses of “the whole” RO data record (WegC OPSv5.6)
- During La Niña, there are generally more double tropopauses than during El Niño
- During La Niña, extra tropopauses appear below the climatological tropopause just poleward of the Niño3-region



THANKS!