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Revisiting global satellite observations of stratospheric cirrus clouds

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OUTLINE

1. Background

2. Dataset and method

3. Stratospheric cirrus clouds in CALIPSO

4. Stratospheric cirrus clouds in MIPAS

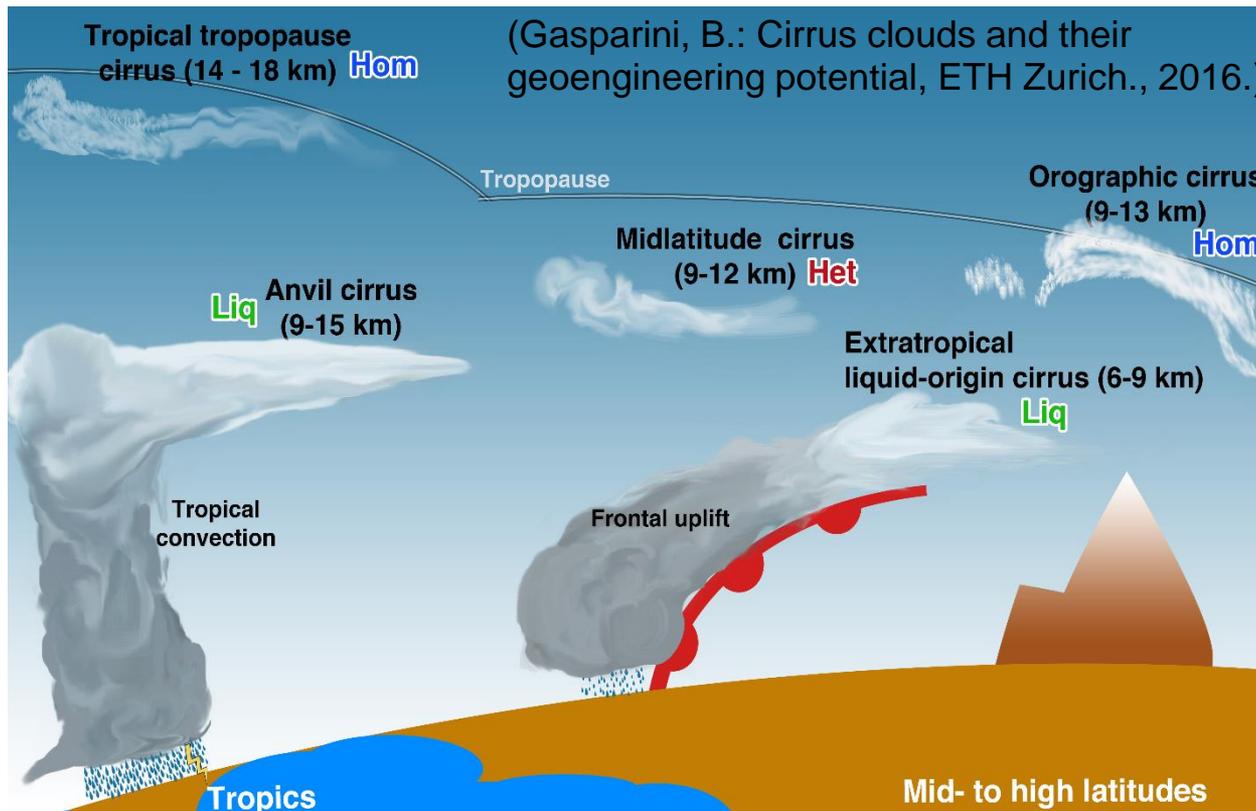
5. Summary



BACKGROUND

Formation of cirrus clouds

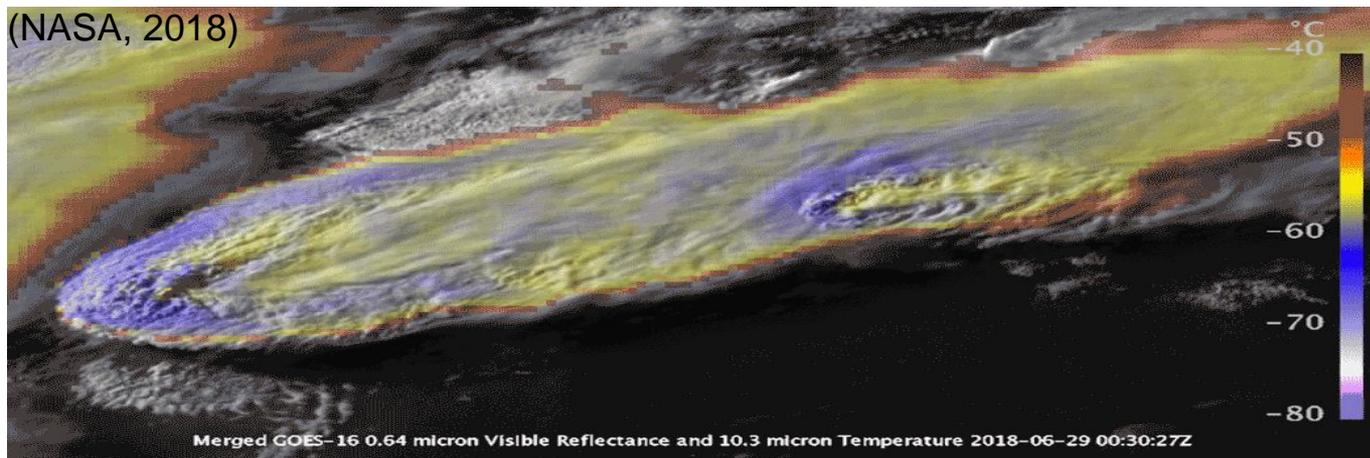
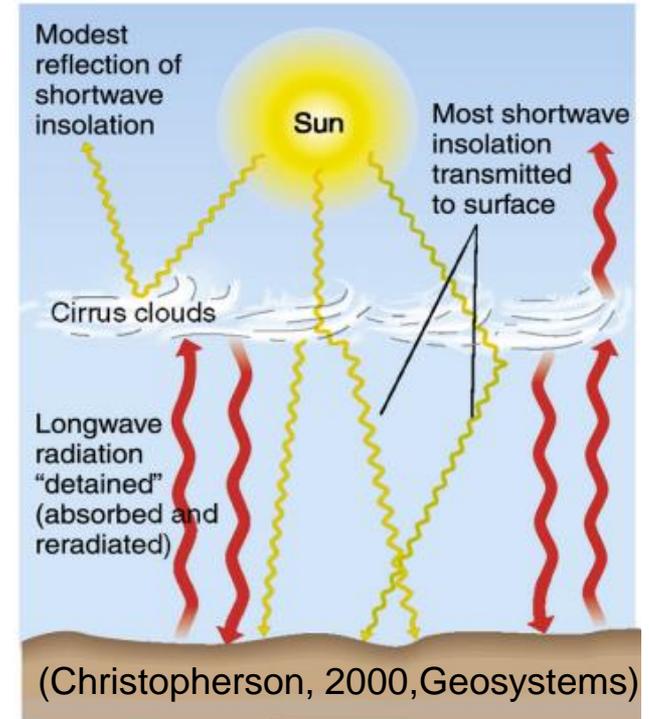
- Cirrus clouds are optically thin ice clouds that form at cold temperatures in the middle and upper troposphere.



BACKGROUND

Effects of cirrus clouds

- Cirrus clouds have the ability to both reflect solar radiation and trap outgoing longwave radiation.
- Cirrus plume above the Anvil represent transport of ice and water vapor into the stratosphere.



DATASET AND METHODS

CALIPSO: Vertical Feature Mask-V4.x June 2006-April 2012

MIPAS: MIPAS-L1-V8.03 June 2006-April 2012

Tropopause:

WMO first thermal tropopause from ERA-Interim ~300m bias

Stratospheric cirrus clouds:

cloud top heights (CTHs) being 500m above the tropopause

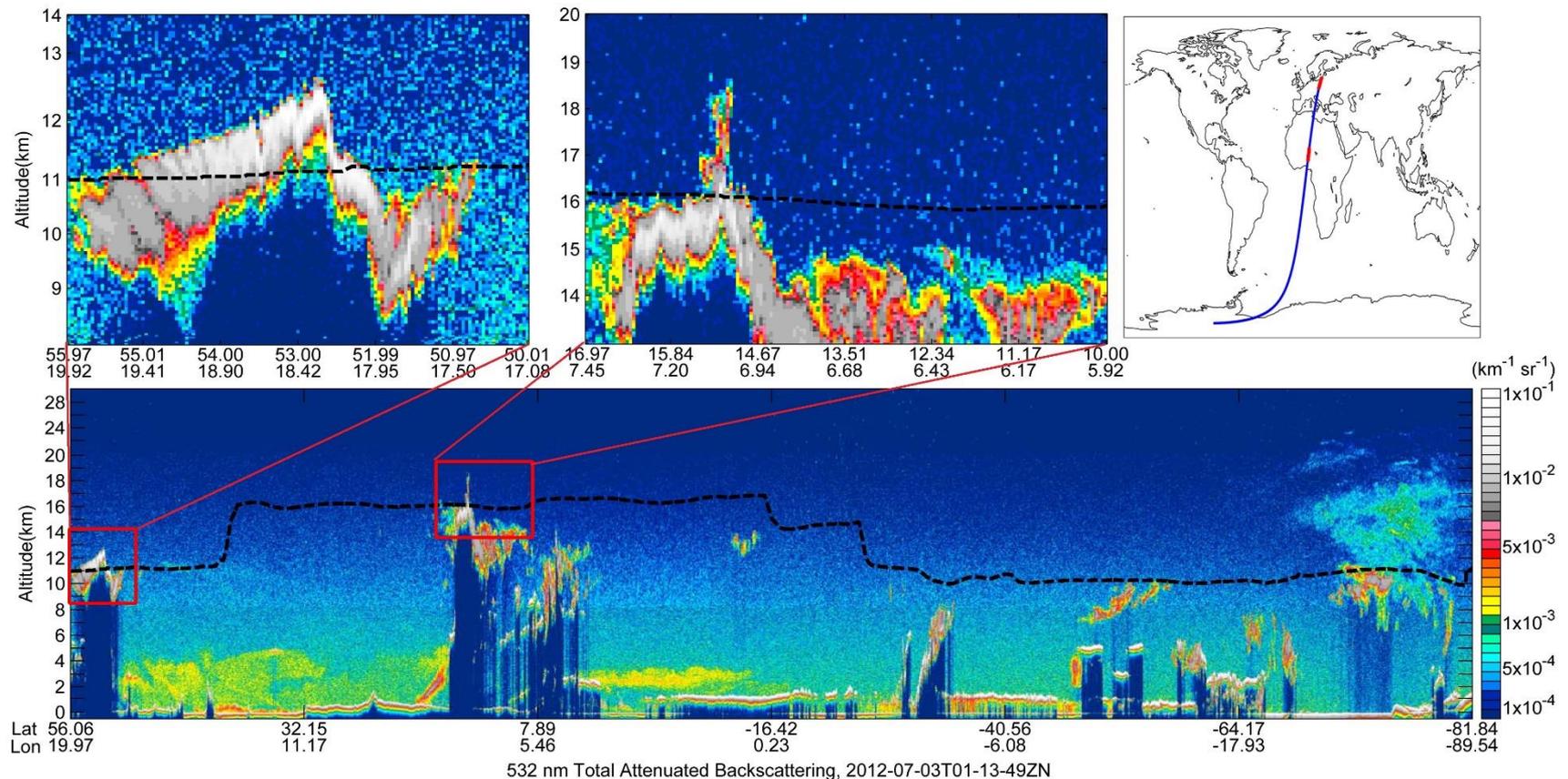
Occurrence frequency:

ratio of number of CTH detections to the total number of profiles

DATASET AND METHODS

Examples of stratospheric cirrus clouds

- Two examples of stratospheric cirrus clouds from CALIPSO measurement at tropics and middle latitudes.



STRATOSPHERIC CIRRUS CLOUDS IN CALIPSO

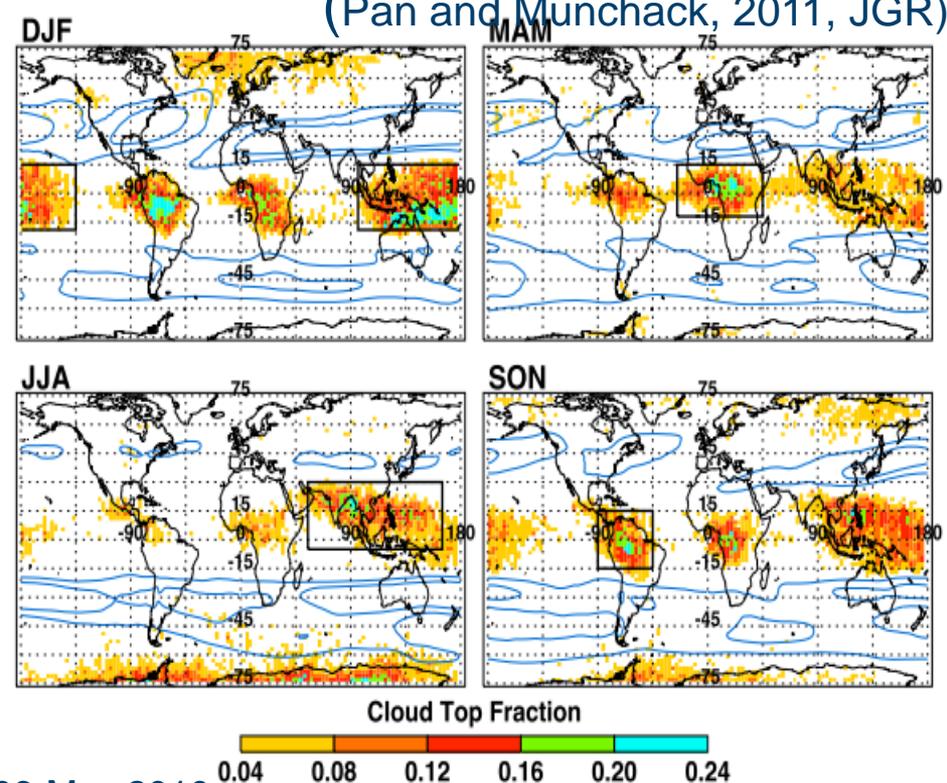
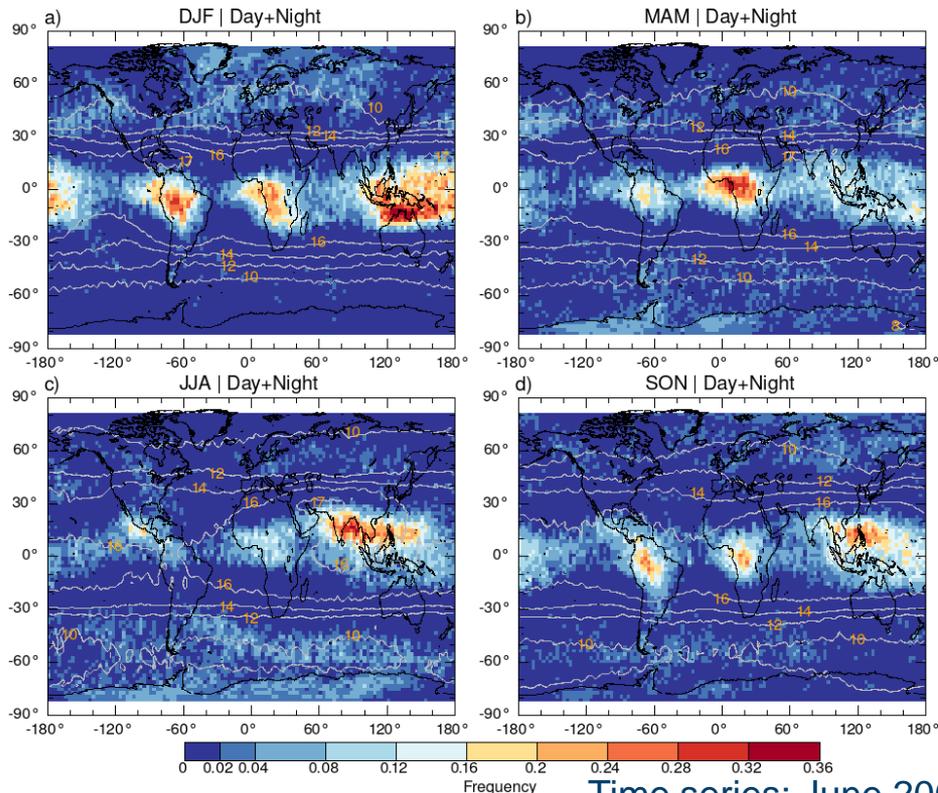
Comparison with previous study

- Similar occurrence patterns are observed in two studies, but higher statistics are detected in the latest CALIPSO data version (V4.x).

VFM-Standard-V4.x (our results)

Clay-Standard-V3

(Pan and Munchack, 2011, JGR)



Time series: June 2006-May 2010

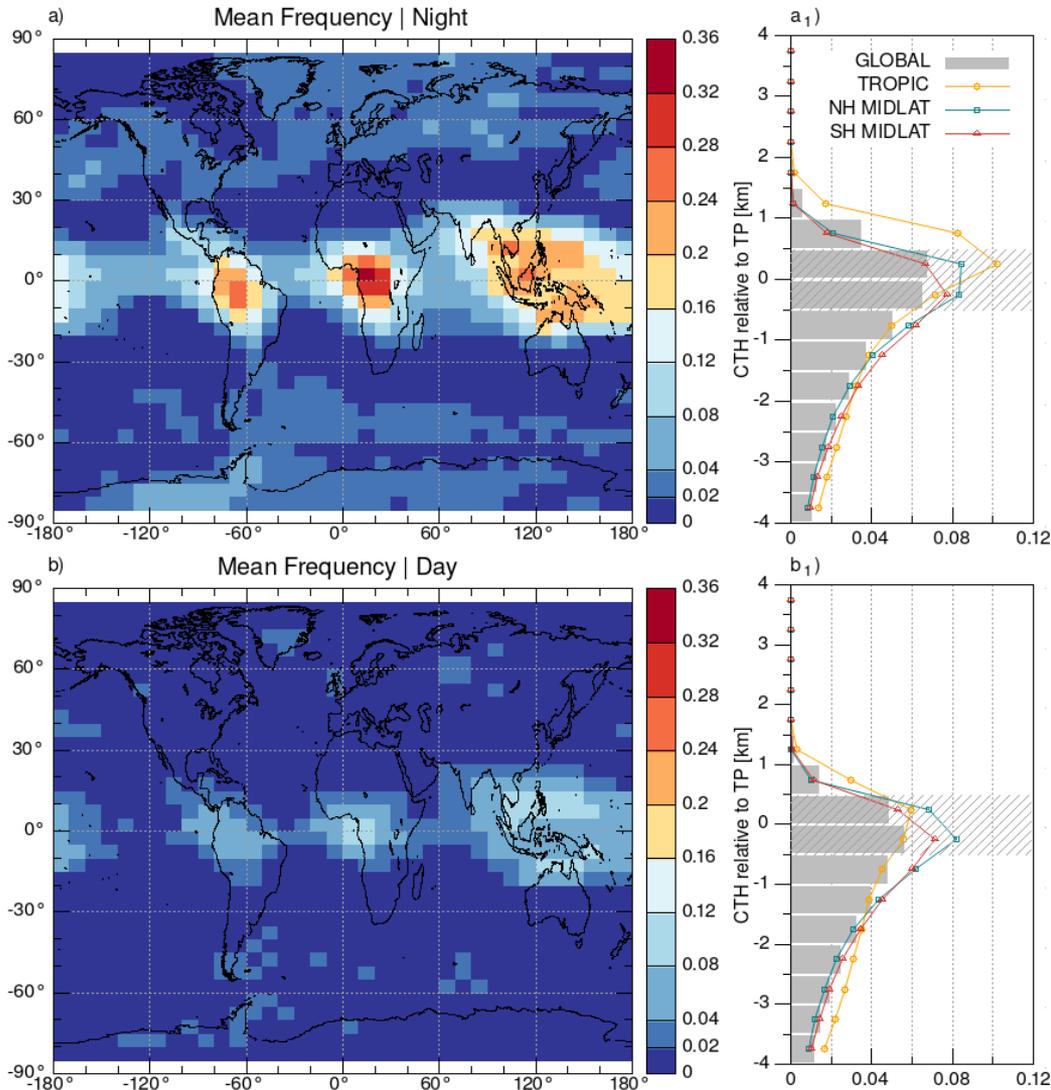
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STRATOSPHERIC CIRRUS CLOUDS IN CALIPSO

Nighttime and daytime occurrence frequency

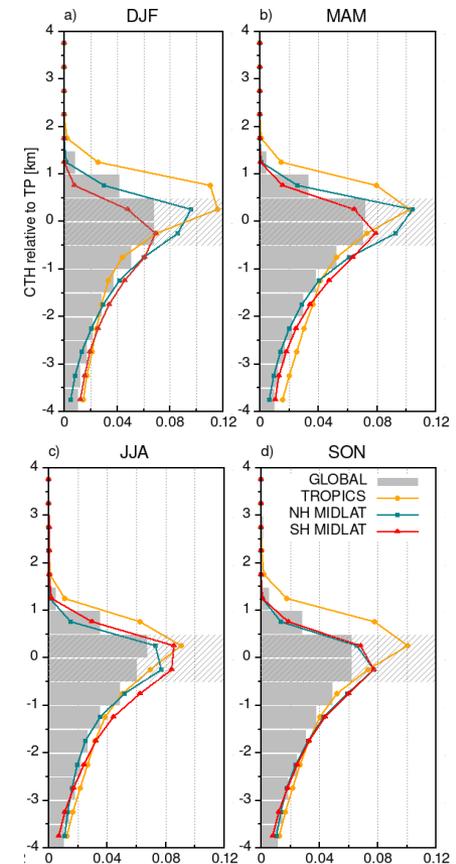
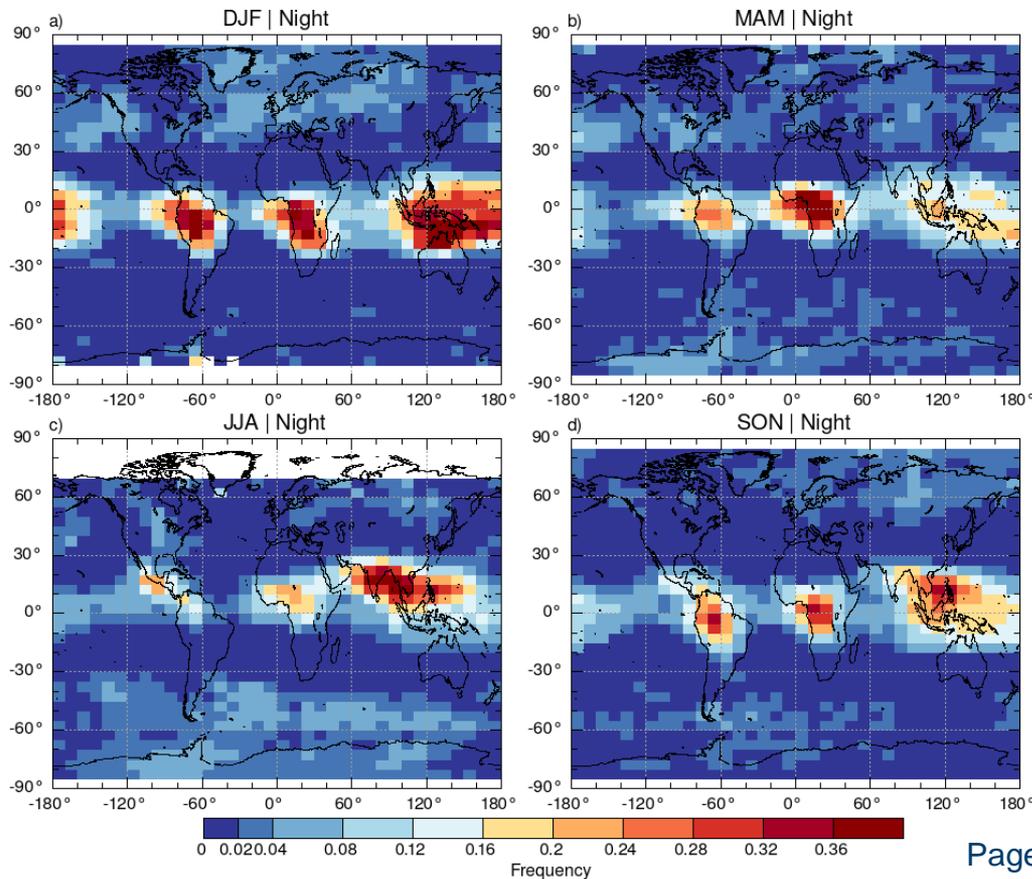


- 2-3 times higher frequencies of stratospheric cirrus clouds are detected at nighttime than at daytime.
- Detection sensitivity of the CALIOP 532-nm channel is better at night than during day (Winker et al., 2009).

STRATOSPHERIC CIRRUS CLOUDS IN CALIPSO

Seasonal nighttime occurrence frequency

- High occurrence frequency are observed in the tropics in four seasons.
- At middle and high latitudes, stratospheric cirrus clouds are more often detected in local winter season.

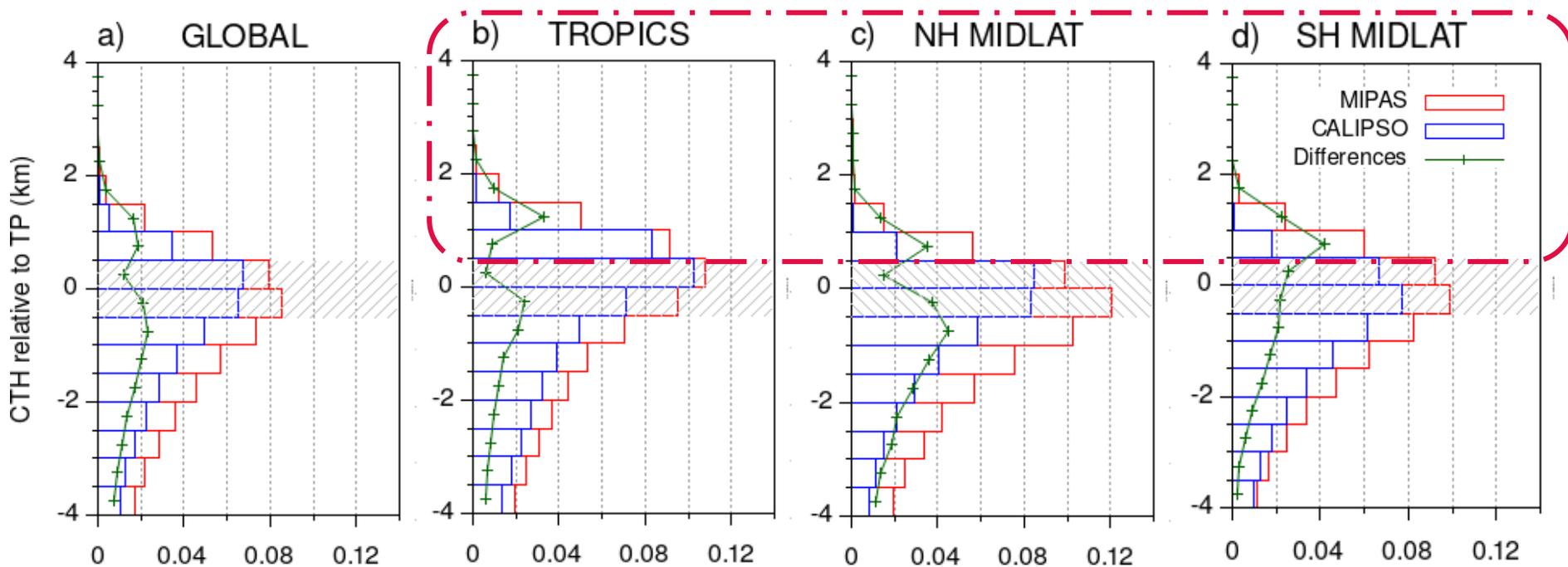


CTHs RELATIVE TO TROPOPAUSE

WHY??

CALIPSO vs MIPAS

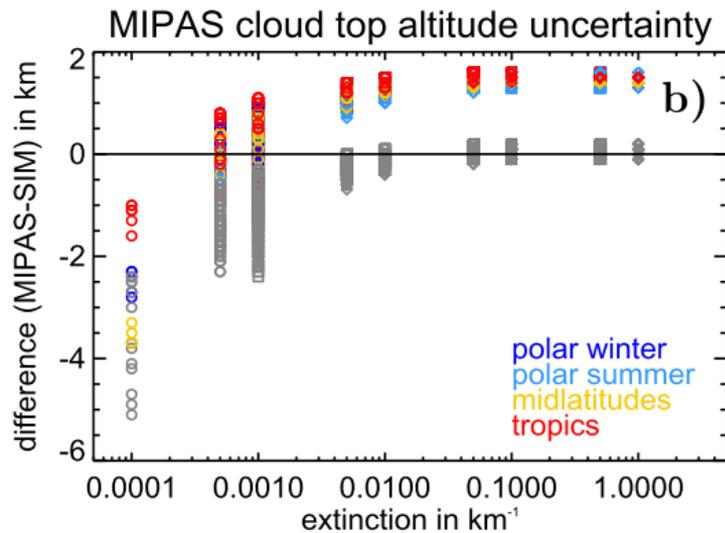
- MIPAS generally detects more cirrus clouds than CALIPSO.



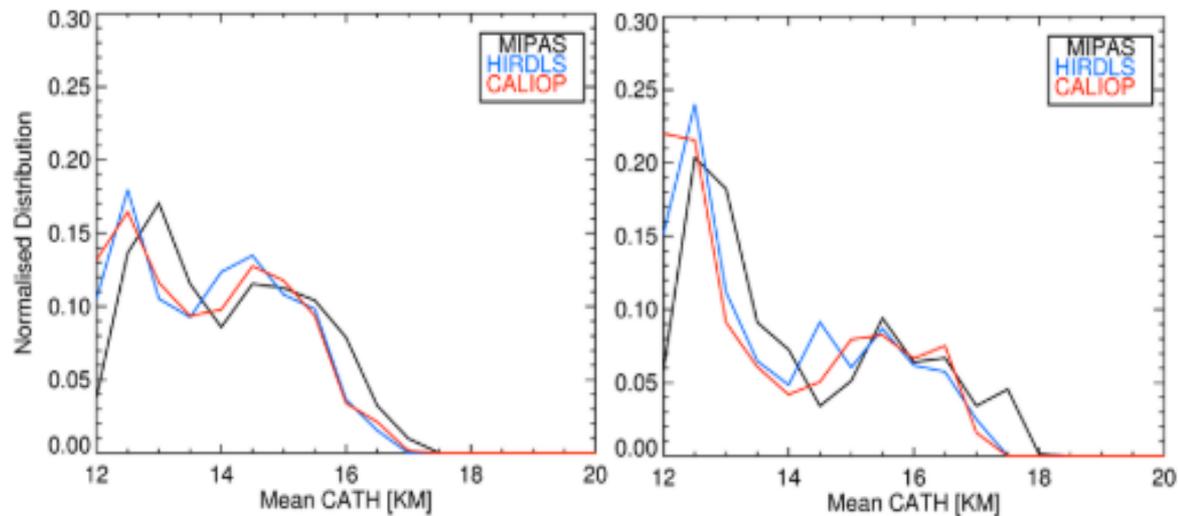
MIPAS: CTHs UNCERTAINTY

Overestimation of CTHs in MIPAS

- MIPAS cloud altitudes are approximately **0.75 km** higher than CALIOP on average (Sembhi et al., 2012).
- For the optically thickest clouds (with extinction of 1km^{-1}), the CTH uncertainty ranges from -0.1 to 1.6 km (Griessbach et al., 2020).



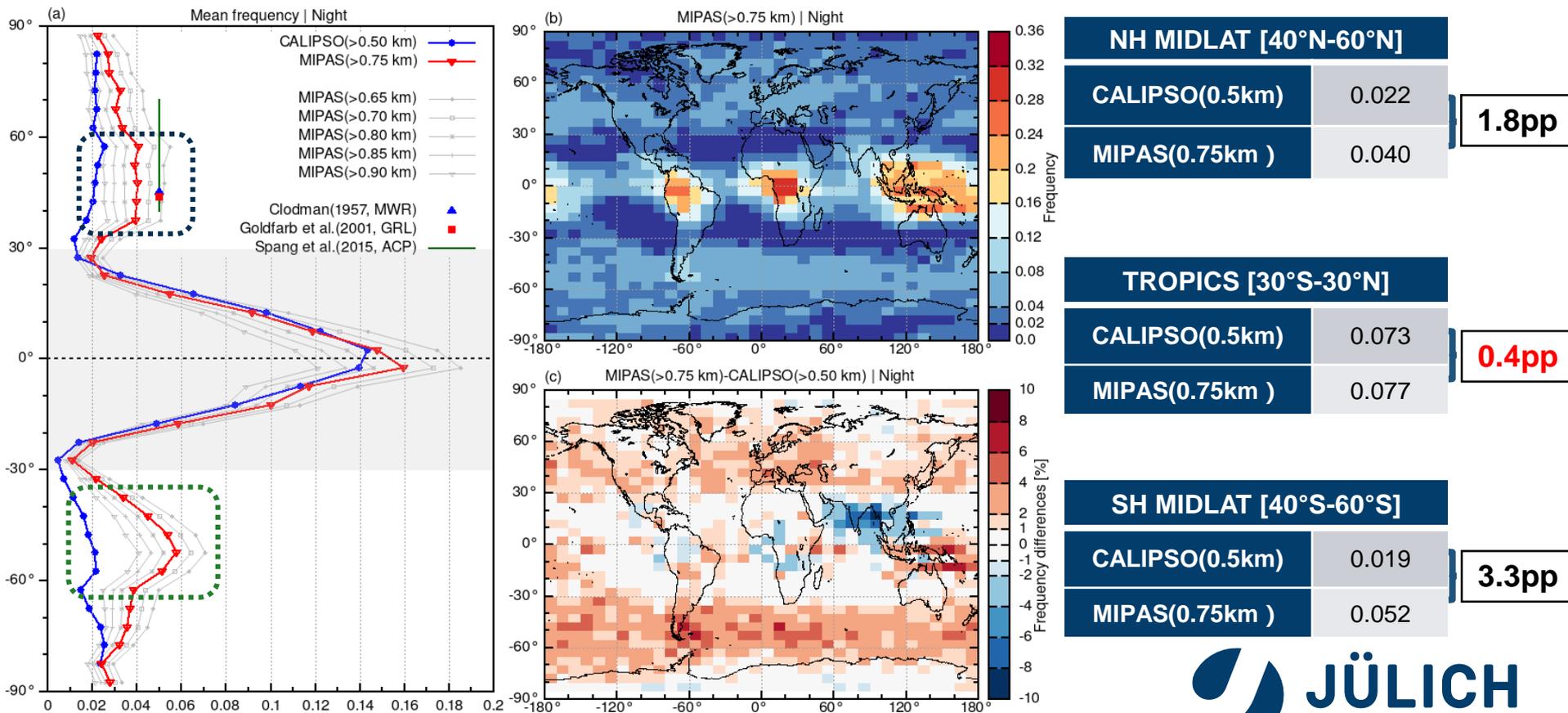
(Griessbach et al., 2020, AMT)



(Sembhi et al., 2012, AMT)

Stratospheric cirrus clouds in MIPAS

- The minimum difference in **tropics** between CALIPSO and MIPAS is **0.4** percentage point (pp) when the tropopause threshold in MIPAS is **0.75 km**.



NH MIDLAT [40°N-60°N]	
CALIPSO(0.5km)	0.022
MIPAS(0.75km)	0.040

1.8pp

TROPICS [30°S-30°N]	
CALIPSO(0.5km)	0.073
MIPAS(0.75km)	0.077

0.4pp

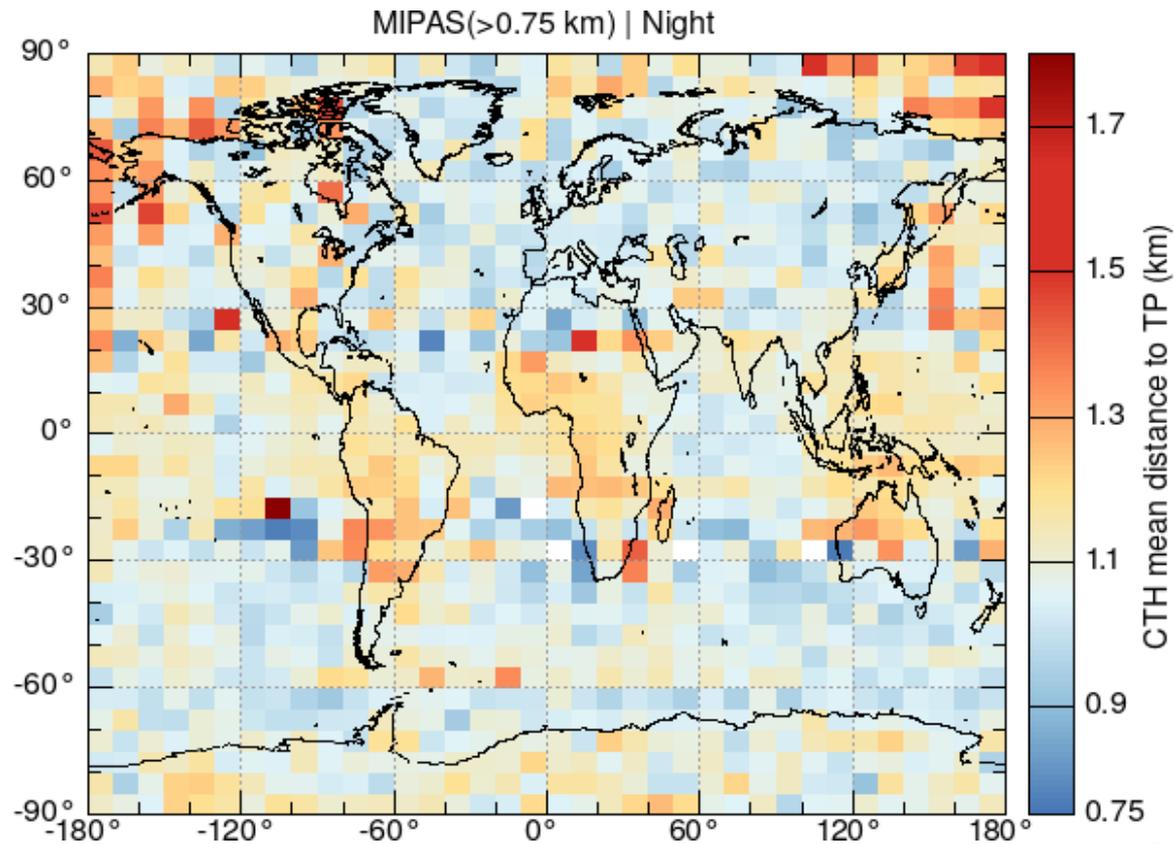
SH MIDLAT [40°S-60°S]	
CALIPSO(0.5km)	0.019
MIPAS(0.75km)	0.052

3.3pp

MIPAS: CTHs UNCERTAINTY

Sensitivity tests

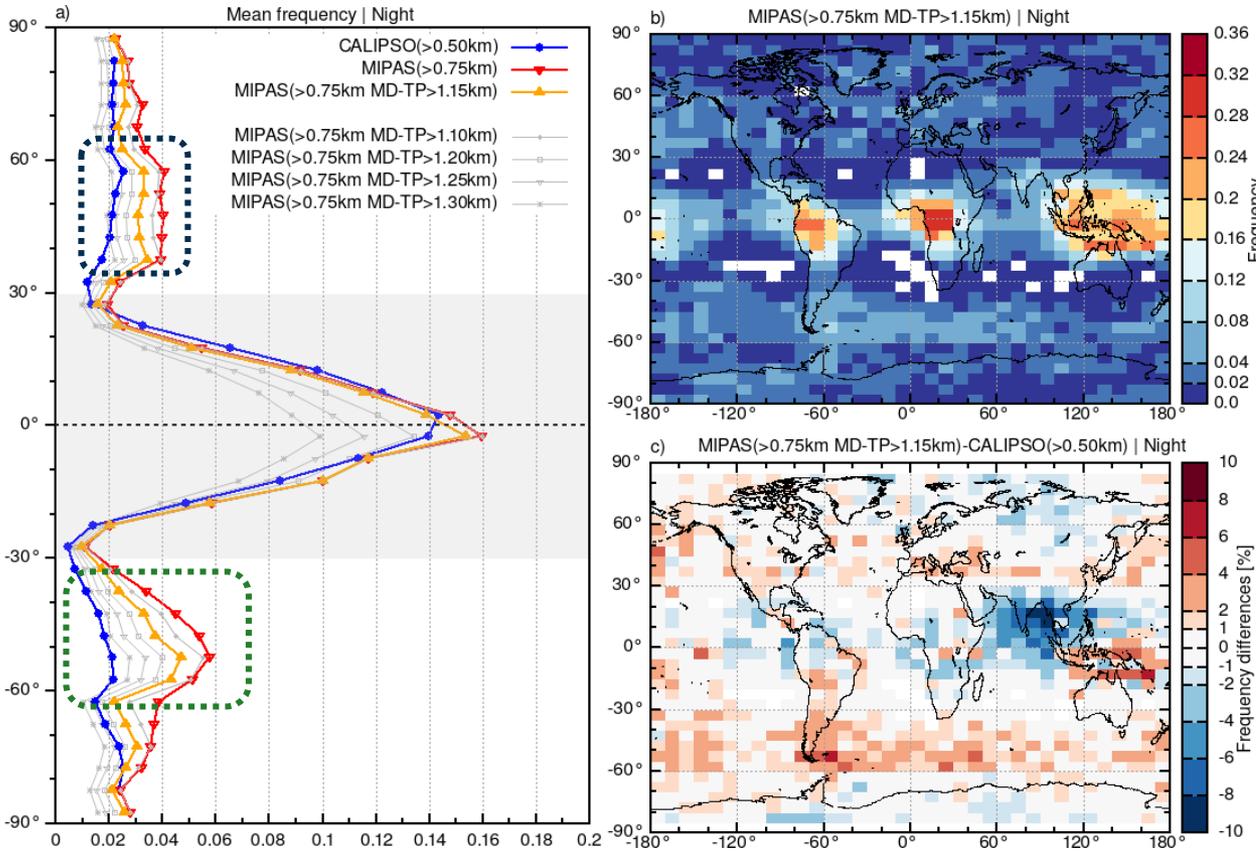
- The mean distances of the CTHs of the stratospheric cirrus clouds to the tropopause (MD-TP).



MIPAS: CTHs UNCERTAINTY

Sensitivity tests

- Remove the lowest CTHs in each grid box until the required mean distance to the tropopause is reached.
- The overall stratospheric cloud occurrence patterns in this figure remain the same as before sensitive test.



NH MIDLAT [40°N-60°N]	
CALIPSO(0.5km)	0.022
MIPAS(0.75km)	0.040
MIPAS (0.75 km MD-TP>1.15)	0.032

TROPICS [30°S-30°N]	
CALIPSO(0.5km)	0.073
MIPAS(0.75km)	0.077
MIPAS (0.75 km MD-TP>1.15)	0.074

SH MIDLAT [40°S-60°S]	
CALIPSO(0.5km)	0.019
MIPAS(0.75km)	0.052
MIPAS (0.75 km MD-TP>1.15)	0.040

SUMMARY

- By using the combination of CALIPSO V4.x data and ERA-interim, more stratospheric cirrus clouds were detected in comparison to previous study.
- More stratospheric cirrus clouds are observed in MIPAS and that are optically too thin to be detected by CALIPSO, especially at middle latitudes (2% in CALIPSO, 4-5% in MIPAS)
- At global scale, stratospheric cirrus clouds were more often detected at the tropics than at middle and high latitudes. Highest CTH occurrence frequencies of stratospheric cirrus clouds were found in the tropics over the continents of Equatorial Africa, South and Southeast Asia, and South America and the western Pacific warm pool.

THANK YOU FOR YOUR ATTENTION!