Assessment of cloud geometry in ERA-Interim and ERA-20C over the Southeast Pacific using satellite observations

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1. Introduction

The Southeast Pacific stratocumulus clouds represent a critical but poorly understood component of the coupled climate system. This region is characterized by strong coastal upwelling and is one of the driest regions on Earth land inwards, i.e. the Atacama desert. The Collaborative Research Center "Earth at its dry limit" funded by German Science Foundation overarching goal is to understand the moisture supply to the Atacama desert which is largely affected by stratocumulus clouds moving inland. Here we use satellite data to prove the following hypotheses:

(1) Reanalyses (ERA-Interim, ERA-20C) yield plausible cloud heights

(2) Cloud heights follow a seasonal cycle with a location dependent amplitude

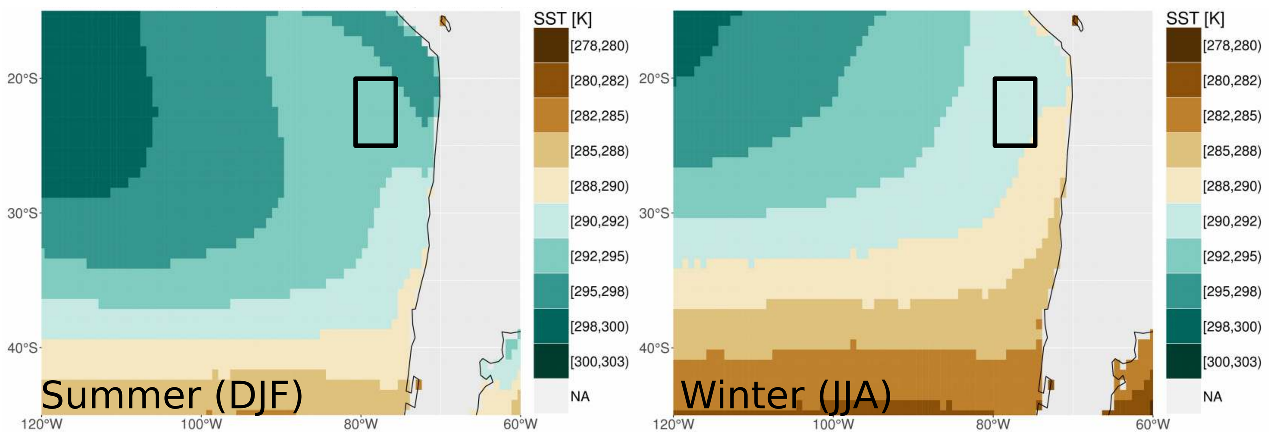


***Fig. 1**: Mean sea surface temperature (SST) between 2001 and 2016 for austral summer (DJF) (left) and austral winter (JJA) (right) derived from ERA-Interim.*

2. Methodology

Cloud heights are retrieved from the Multi-angle Imaging SpectroRadiometer (MISR) and from ECMWF Reanalysis products ERA-Interim for 16 years (2001 - 2016) and ERA-20C for 10 years (2001 - 2010). The MISR CBH retrieval algorithm has been validated against ceilometer data in a previous study which was carried out over a region covering the continental United States of America. Here the retrieval method is introduced briefly.

(1) MISR cloud base height (CBH) retrieval

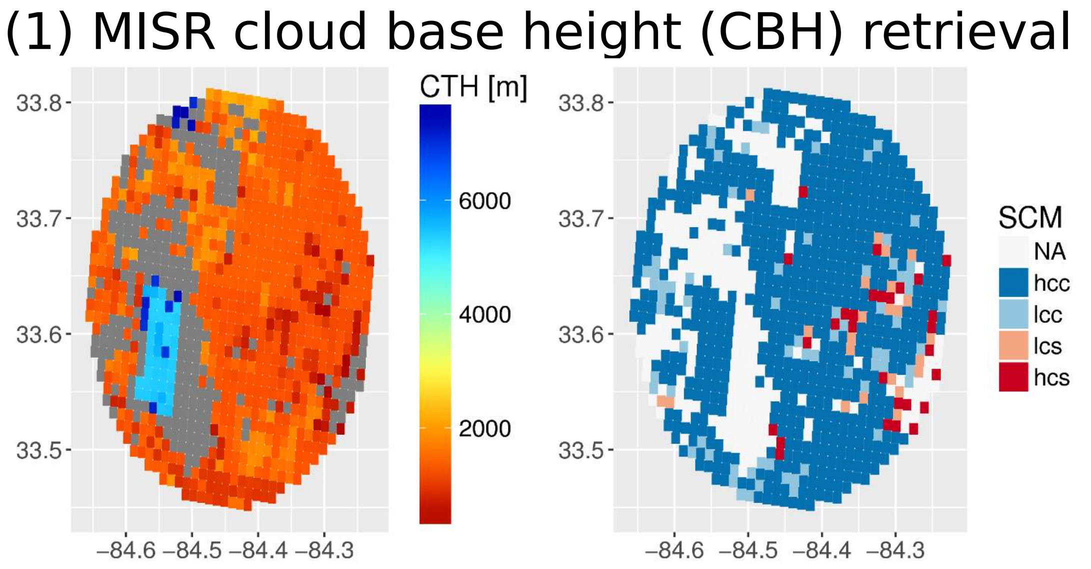


***Fig. 2**: MISR MIL2TCSP-product for a circular area with a 20 km radius centered at Atlanta, Georgia, USA from 21 August 2015. Left: Cloud top height (CTH). Right: Stereo derived cloud mask (SCM) with high confidence cloud (hcc), low confidence cloud (lcc), low confidence surface (lcs) and high confidence surface (hcs) classification.*

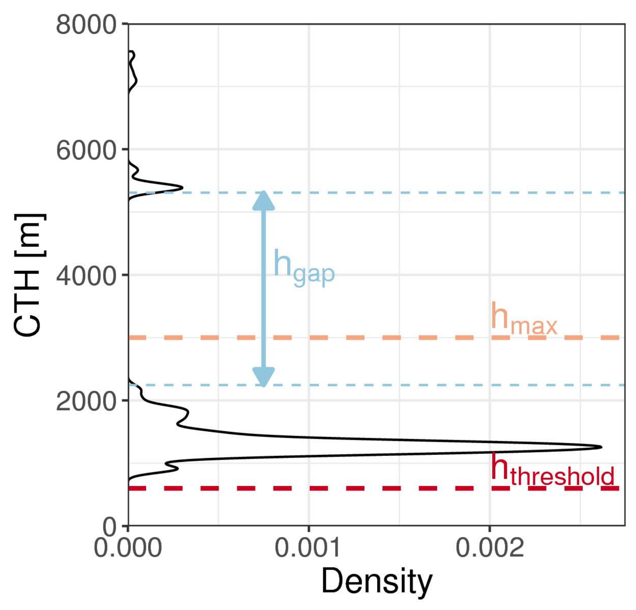


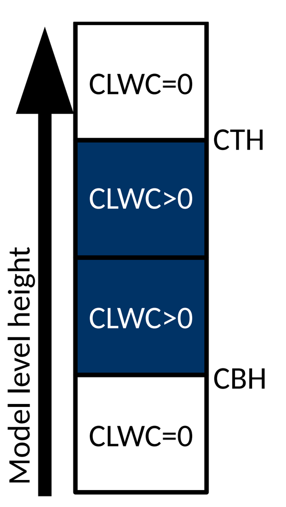
***Fig. 3**: MISR MIL2TCSP-product for a circular area with a 20 km radius centered at Atlanta, Georgia, USA from 21 August 2015. Density of the CTH retrievals (hcc) enclosed within the specified area.*

MISR retrieval recipe

- Cloud layer distinction distance $h_{gap} = 500\text{m}$
- In multi layer case select bottom layer for further analysis
- MISR threshold height for distinction between surface and cloud: $h_{threshold} = 560\text{m} + h_{terrain} + 2\,\sigma_{terrain}$
- Consider only high confident cloud (hcc) pixels
- CBH and CTH are yielded by the 5th and 95th percentile of the MISR retrieval distribution, respectively.

(2) ECMWF Reanalysis cloud height retrieval

CBH and CTH are determined from the modeled cloud liquid water content (CLWC). The bottom height of the lowest layer with a CLWC greater 0 is taken as CBH. The bottom height of the lowest layer above the CBH with a CLWC equal to 0 is taken as CTH.



3. Cloud height climatology

Time series of cloud heights

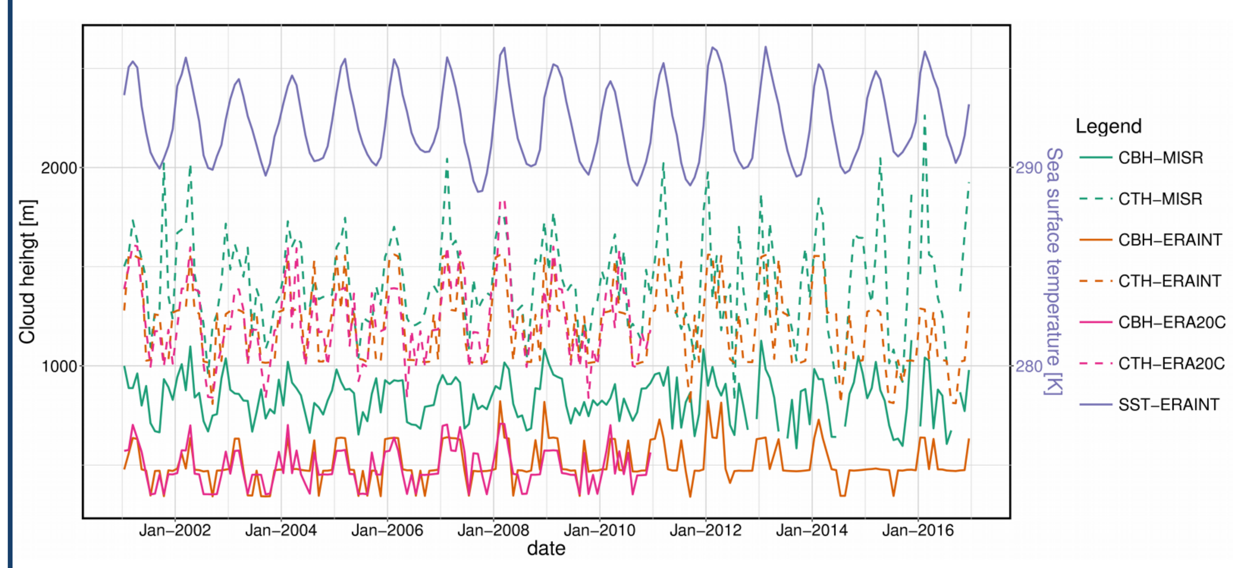


***Fig. 4**: Monthly median cloud top height (CTH), cloud base height (CBH) and SST averaged for the region 75°W-80°W and 20°S-25°S (rectangle in Fig 1).*

- Annual variation of CTH is greater than CBH.
- Higher CTH are observed for higher SSTs.
- Lower CBH for ERA could possibly be due to MISR retrieval method.

Austral summer (DJF) and winter (JJA) cloud heights

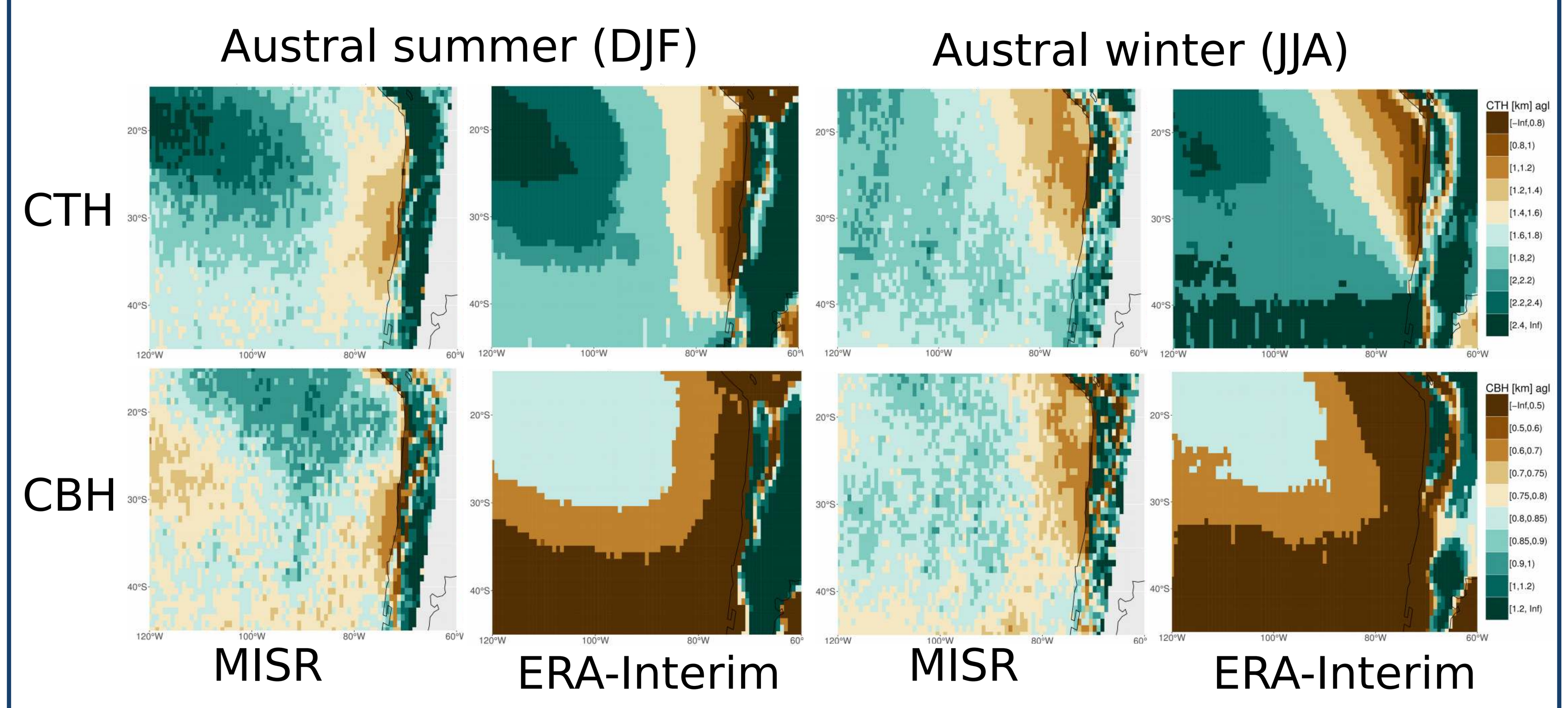


***Fig. 5**: Seasonal cloud height climatology (2001 – 2016) on a 0.75°x0.75° grid.*

Annual cycle amplitude

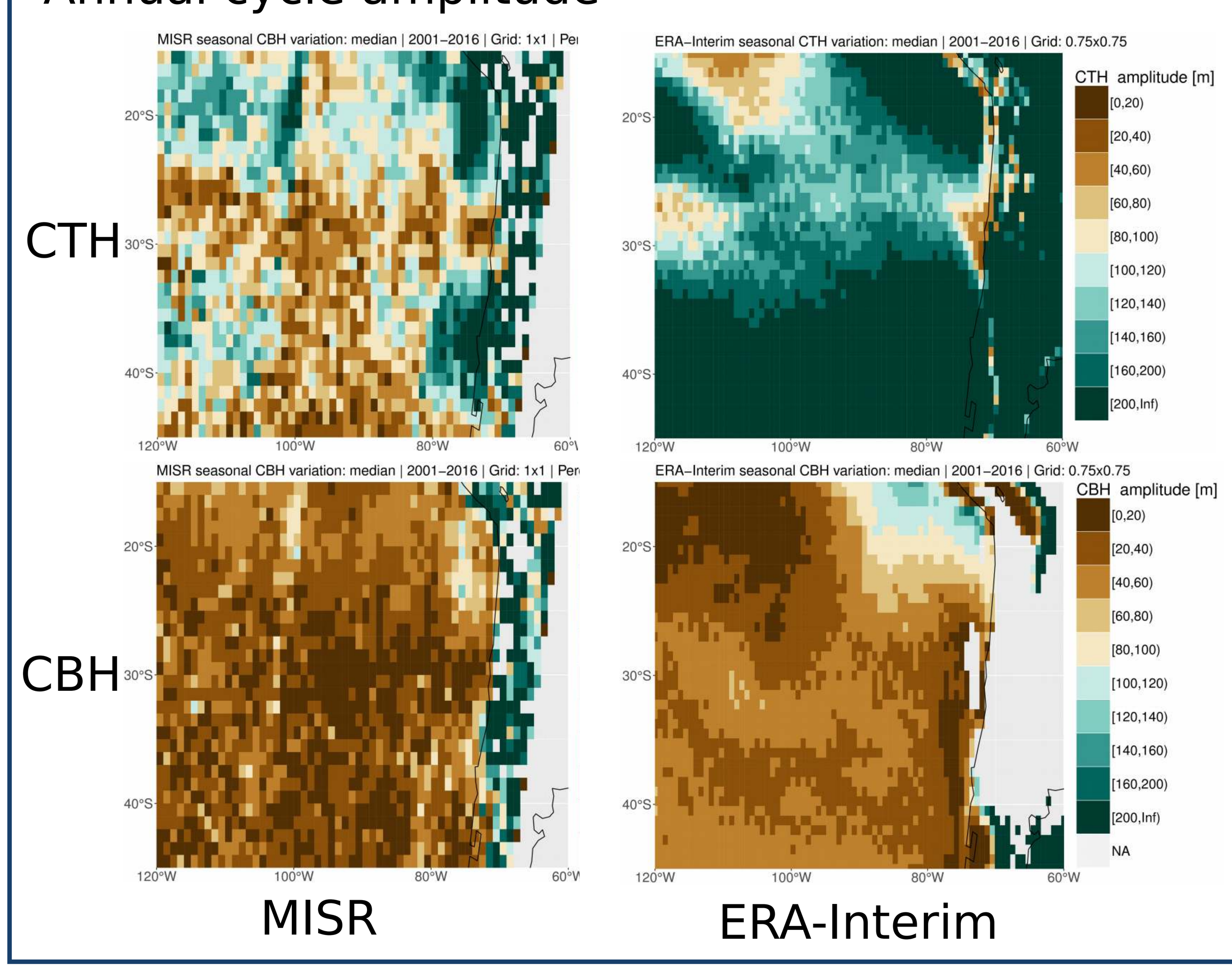


***Fig. 6**: Annual cycle amplitude of cloud heights. Monthly median cloud heights on a 1°x1° (MISR) and 0.75°x0.75° (ERA) grid transferred into the frequency spectrum using a Fast Fourier Transformation (FFT). Amplitudes are shown for a frequency of one per annum.*

- CTH shows greater amplitude than CBH.
- Annual cycle of CTH is less pronounced between 25°S - 30°S.
- ERA-Interim yields a greater amplitude than MISR for the majority of the area.

4. ERA and MISR comparison

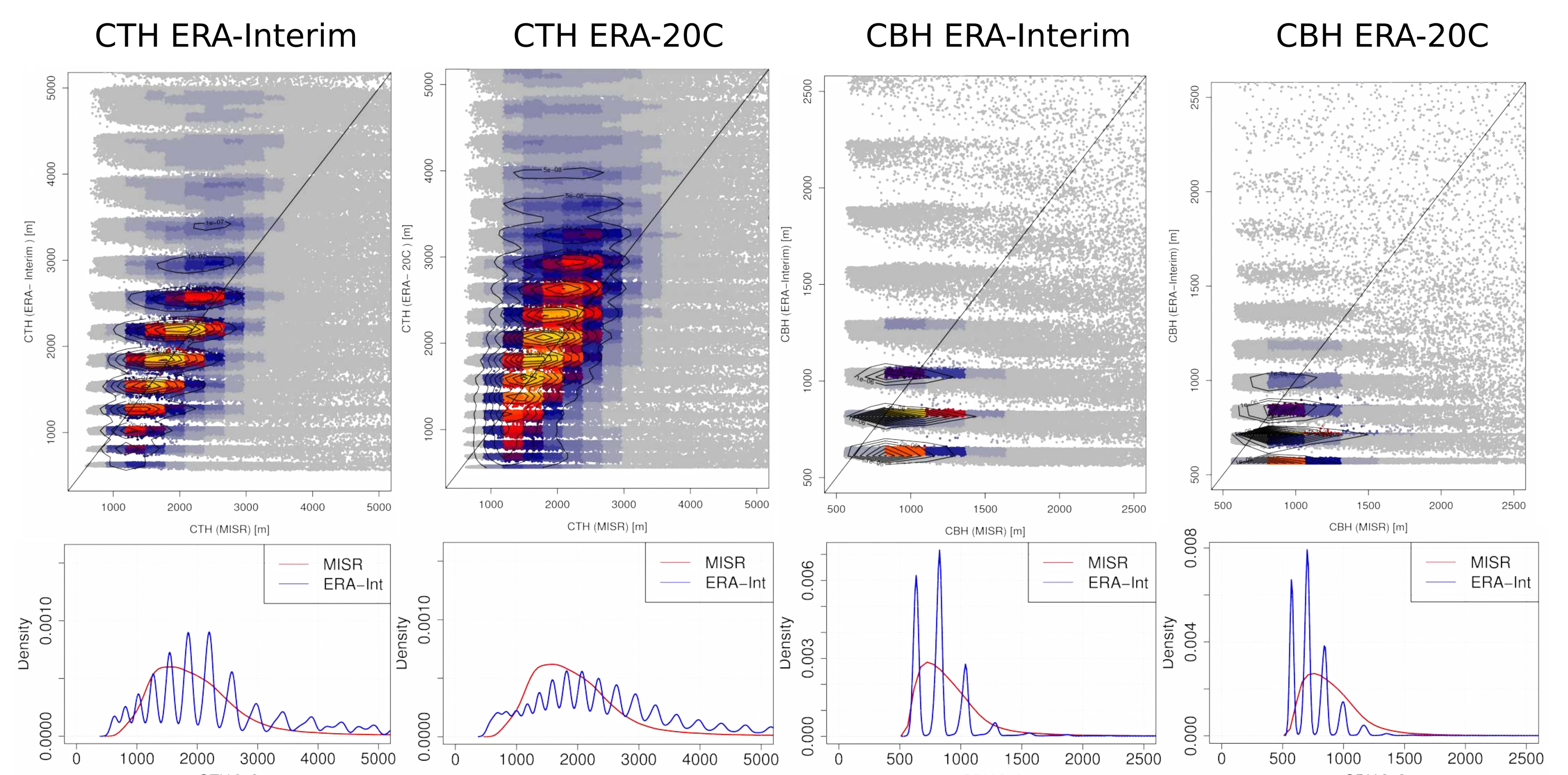


***Fig. 7**: Top row: Density of ERA cloud heights over corresponding MISR cloud heights. Cloud heights for corresponding grid cells are matched by the retrieval date. From ERA the 18 UTC output is taken and CBHs less than $h_{threshold}$ (560m) are discarded. Bottom row: Density of the retrieval distribution.*

- On average MISR CTH agrees with ERA-Interim (bias of 114m) and ERA-20C (bias of 224m).
- CBH comparison is more difficult due to limitations of the MISR retrieval method at low heights.

2017 5th International Conference on Reanalysis, Rome, Italy, 13-17/11/2017