Dear Dr. Jie Gong,

Thank you very much for your interest in our study. Please find our replies to your comments below.

Comment ∗ 1

> I think there's a fundamental issue with identification of SCC from CALIPSO level-1 532 nm backscatter. First, from the example given in Fig. 1, this is an convection overshooting, instead of a thin cirrus cloud.

Answer:
In this work, we intended to study lower stratospheric ice clouds, including all ice clouds with the cloud top being located above the tropopause. We didn't distinguish between detections of cirrus, cirrostratus or deep convective clouds. Tropopause penetrating convective clouds as shown in Fig. 1 are included in our study, as deep convection is a major cause for the occurrence of ice in the midlatitude lower-most stratosphere. We would clarify this in revised manuscript.

Comment ∗ 2

> Secondly, stratospheric feature could be aerosol. Why not use Level-2 cloud type from Version 4.X feature classification flag?

Answer:
In this study, we used the Level 2 Vertical Feature Mask data from CALIOP Version 4.X and not the backscatter data to detect the stratospheric ice clouds. The 532 nm backscatter signal in Figure 1 is shown only for illustration. However, we found it would be helpful to also show the Vertical Feature Mask data for this example in the revised manuscript, please see revised Figure 1 below.

Comment ∗ 3

> I really doubt if there's many stratospheric thin cirrus, as there's no immediate mechanism there other the reminiscence of overshooting cloud top. See Avery et al. (2017, https://www.nature.com/articles/ngeo2961) for the overshooting cloud.

Answer: As answered in comment 1, we investigated actually not only thin cirrus clouds but all ice clouds in the lower stratosphere.

Comment ∗ 4

> Thirdly, as tropopause height has 600-1000 m uncertainty in ERA-Interim, I think using 500m as a threshold to determine the separation between troposphere and stratosphere is dangerous. Besides, tropopause is a layer, not a thin interface. This is a minor issue compared with the first and second issue.

Answer:
We are aware that ERA-Interim data have about 600-1000 m vertical resolution in the UT/LS region. Nevertheless, we consider a threshold of 500 m with respect to the tropopause height derived from ERA-Interim to be useful to detect stratospheric ice clouds for the following reasons:

Firstly, the ERA-Interim data have been interpolated to a much finer vertical grid using cubic spline interpolation in order to improve the vertical resolution of the geopotential height estimates of the tropopause. This method has already been applied in Spang et al. (2015) to produce an ERA-Interim-based 'high-resolution' tropopause height data set.

Secondly, Tegtmeier et al. (2020) found lapse rate tropopause (LRT) height differences between ERA-Interim and Global Navigation Satellite System-Radio Occultation (GNSS-RO) observations of about 200 m in the tropics (Figure 8 in Tegtmeier et al. (2020), Figure 2 shown below). This shows that uncertainties in ERA-Interim tropopause heights can be significantly smaller than the vertical resolution of the data. So, the 500 m threshold for ERA-Interim data is reasonable.

Thirdly, 500 m is comparable to thresholds used to detect stratospheric ice clouds in previous studies, e. g. Homeyer et al. (2010) and Pan and Munchak (2011).

Therefore, we consider 500 m as a valid threshold with respect to the tropopause derived from ERA-Interim to detect lower stratosphere ice clouds. We will explain the uncertainties of the ERA-Interim tropopause data more in the revised manuscript.

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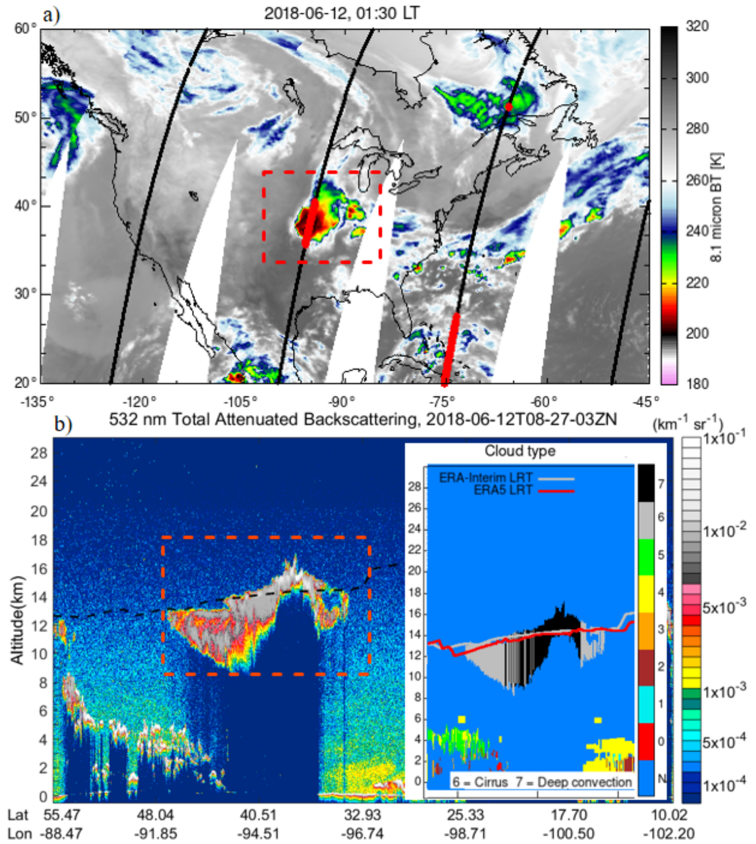

Figure 1: Lower stratosphere ice clouds observed above deep convection on 12 June 2018. a) 8.1 μm brightness temperatures (BT) derived from AIRS overlayed with CALIPSO orbits (black lines). The red circles along the CALIPSO orbits indicate ice clouds with cloud top heights being at least 500 m above the tropopause. b) 532 nm total attenuated backscatter (black dashed line is ERA-Interim LRT) and vertical feature mask data for the clouds of interest.

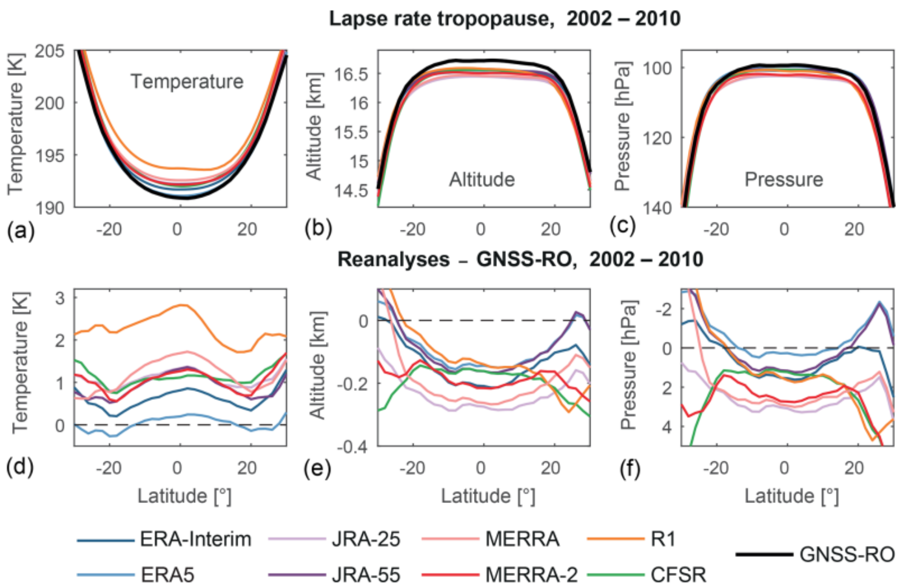

Figure 8. Latitudinal distributions of zonal-mean lapse rate tropopause temperature **(a)**, altitude **(b)**, and pressure **(c)** based on radio occultation data and reanalysis products during 2002–2010 **(a–c)**. Differences between radio occultation and reanalysis estimates are shown in the panels **(d)–(f)**.

Figure 2: Figure from Tegtmeier et al. (2020)