

Review of “A permanent aerosol layer at the tropical tropopause layer driven by the inter-tropical convergence zone” by Bourgeois et al., 2012.

The Tropical Transition Layer (TTL) is a very sensitive region of the atmosphere that can influence the radiative, chemical and dynamical balance of the stratosphere. Being the “entrance door” for tropospheric air into the global stratosphere, any modifications of its physico-chemical properties can have important repercussions on the global climate. Recent field campaigns monitoring clouds, aerosols and gas species in the TTL indicated the frequent occurrence of new particles formation events in the outflow of mesoscale convective systems. High vertical measurements of backscatter aerosol profiles from the space-borne CALIOP lidar have shown the presence of an Asian Tropopause Aerosol Layer during the summertime (Vernier et al., GRL, 2011a).

The authors here have “build up” their analysis based upon the work of this latest study to show that this aerosol layer occur not only during the summertime, but throughout the year following the latitudinal evolution of the Inter-Tropical Convective Zone (between 5E-105E). They have used the CALIOP level 2 aerosol extinction profile product to analyze this feature.

However, due to the lack of deep analysis of the CALIOP level 2 product and issues in the classification of aerosols and clouds near the tropopause in the same product, the authors have miss-interpreted a tropopause aerosol layer that was in fact misclassified cirrus clouds or convective overshooting as stratospheric features that are used to build aerosol extinction profiles. Therefore, layers other than volcanic plume in the TTL don't appear in the CALIPSO level 2 extinction profiles due to the lack of sensitivity of the detection algorithm at the current maximum averaging, 80 km. I will support this statement by providing evidences of this issue in this review that I have included in the supplement material. Therefore, since the authors have felt to analyze rigorously the CALIPSO level 2 aerosol profile product, a major part of the paper, and the modeling tentative to reproduce this feature cannot fit on its own, I thus have to reject this paper for publication in ACP.

\*: Star after a figure number is used to tag the figure made by myself for the review

I have reproduced here the analysis of the authors to support my previous statement.

Figure 1\* is a reproduction of fig.1 of Bourgeois et al., 2012 representing the evolution of the mean aerosol extinction profile from all CALIOP measurements passing through the Indo-Pacific region (5E-105E, 20S-30N) on a daily basis as described in their paper. The red curve (near 16-18 km) is the mean tropopause height calculated from the ancillary GEOS-5 meteorological data provided within the CALIOP level 2 products. It shows the presence of an apparent “permanent aerosol layer” (reported in the paper) near the tropopause. The first remark here is to note that most of the “apparent” aerosol feature is located above the GEOS-5 tropopause (in red). This will be an important information when discussing the classification method used in the CALIOP layer retrieval algorithm.

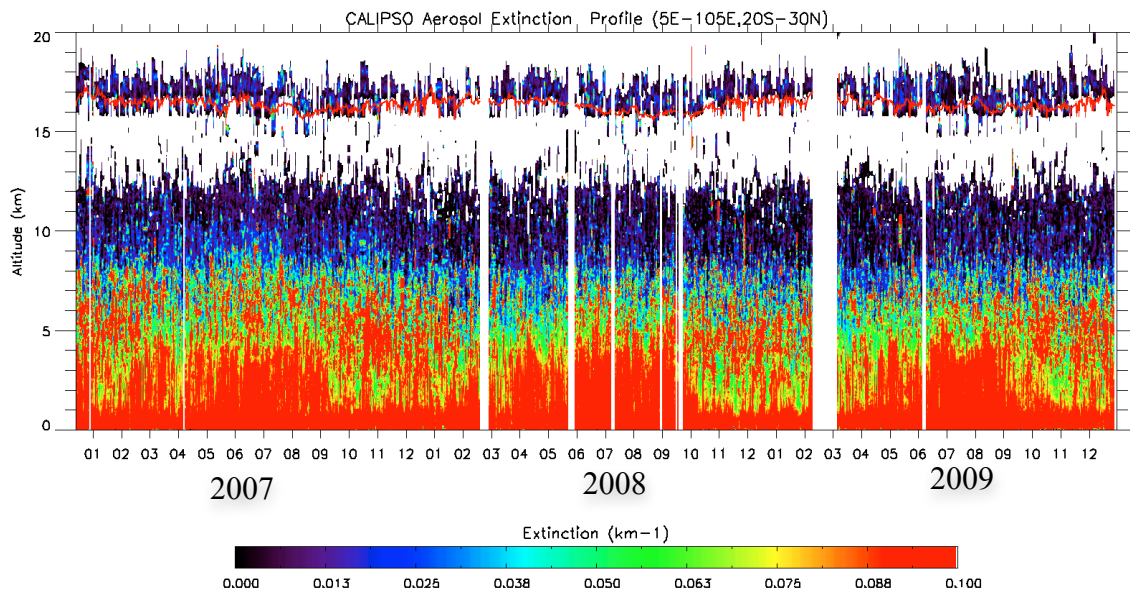


Figure 1\*. Evolution of the daily mean aerosol extinction profile of the CALIOP level 2 aerosol profile product within the geographical region (5E-105E, 20S-30N) as displayed in Bourgeois et al.2012. The tropopause (red line) is produced with the ancillary meteorological data (GEOS-5) provided with the CALIOP measurements.

A deeper analysis of the different optical parameters (not completely done in the paper) is performed in fig.2\* and fig.3\* by looking at the evolution of the mean depolarization ratio and lidar ratio (extinction-to-backscatter ratio) profile to shed light on the possible nature of the layer.

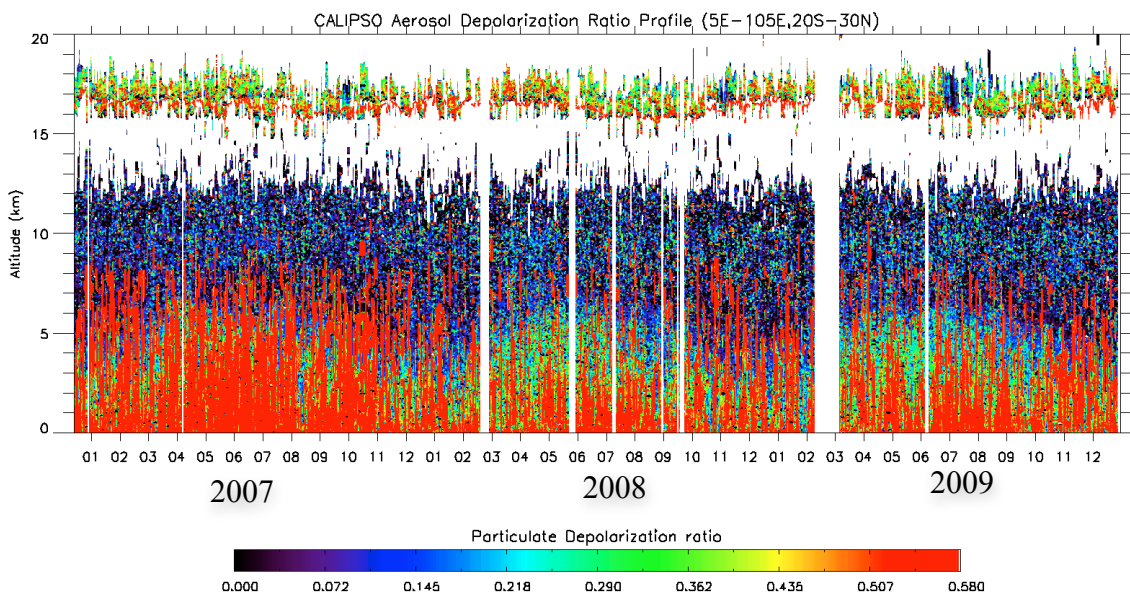


Figure 2\*. Same as fig.1\* but mean particulate depolarization ratio profile evolution.

Figure 2\* shows that the “apparent” aerosol layer (16-18 km) is mainly composed of particles with a mean depolarization ratio greater than 0.3 indicating composed of non-spherical particles. However, there are periods when the depolarization ratio is significantly lower (below 0.2) in Sep-Oct 07, Nov-Dec 08 and July-Aug 09. We will discuss the likelihood origin of these events later on. The mean lidar ratio (extinction-to-backscatter ratio) of the “apparent” aerosol layer as shown in fig.3 is almost constant near 25sr. Interestingly, this values is assigned to derive extinction from backscatter measurements in the CALIOP algorithm either when the layer is considered a cirrus cloud or a stratospheric feature. On the contrary, layers detected as aerosols have a lidar ratio greater than 30 sr with the exception of marine aerosols with a lidar ratio of 20 sr. All these information can be found at : [http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality\\_Summaries/CALIOP\\_L2LayerProducts\\_3.01.html](http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality_Summaries/CALIOP_L2LayerProducts_3.01.html)

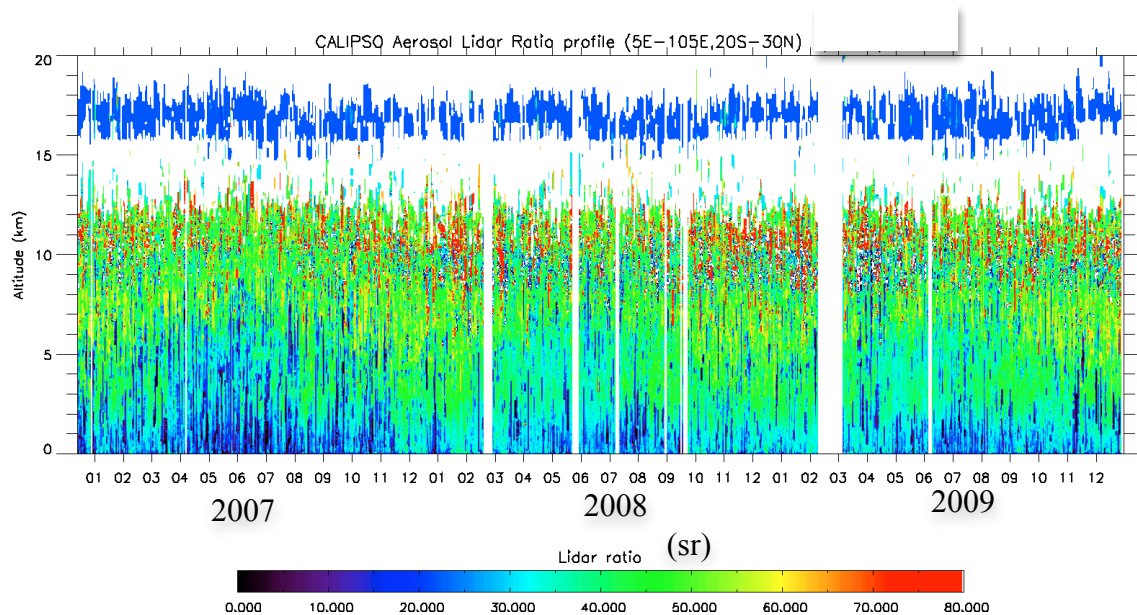


Figure 3. Same as fig.1\* but mean lidar ratio profile

It is important to address here the method of classification of this aerosol layer in term of its lidar ratio. Indeed, since cirrus clouds (with lidar ratio of 25) are utilized to build the Cloud extinction profile product, its means that the “apparent” aerosol layer between 15-18 km with a lidar ratio of 25 was reported by the CALIOP detection algorithm as a stratospheric features.

As mentioned in the quality statement of the CALIOP level 2 aerosol profile ([http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality\\_Summaries/CALIOP\\_L2ProfileProducts\\_3.01.html](http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality_Summaries/CALIOP_L2ProfileProducts_3.01.html)), all features classified as stratospheric aerosol are included in the aerosol extinction profile product. But, the only criteria used to classify such feature is bottom height of the layer. Indeed, if any layer has its bottom height higher than the tropopause height defined by the GOES-5 model, then it is classified as a stratospheric feature.

To summarize about those technicals but fundamental information, almost all features reported in the “apparent” aerosol layer reported in the level 2 aerosol extinction profile, and displayed in fig.1\* were classified in the CALIOP detection algorithm as stratospheric features (since they were assigned with a lidar ratio of 25) because their bottom was above the tropopause as defined by GEOS-5. But Fig 3\* indicates that most of those features have depolarization values greater than 0.3, a number characteristic of the signature of non-spherical ice crystals that could be either cirrus clouds or deep convective clouds.

To verify how robust is the “apparent aerosol layer” after applying a cloud filter (as it is done in the paper), we have plotted in fig.4\*, the mean extinction aerosol profile by excluding layers with a depolarization ratio greater than 0.05. The “residual” aerosol extinction profile shows that the “apparent” aerosol layer (15-18 km) has almost completely disappeared leaving noisy signals near the tropopause. However, we can still distinguish three consistent features at the tropopause in Oct-Nov 07, Nov-Dec 08 and July-Aug 09 that can be also seen in fig.2\* with a mean depolarization ratio lower than 0.1. Interestingly, those three periods have been perturbed by volcanic activity as described in Vernier et al (2009,2011c) following the eruptions of Jebel Al-Tair in September 2007, Kasatochi in August 2008 and Sarychev in June 2009. The plumes of the latest two volcanoes, located in the northern polar region were meridionally transported in the tropical regions after a couple of months explaining the reason why they appear in fig.4 not just after their respective eruption but later on.

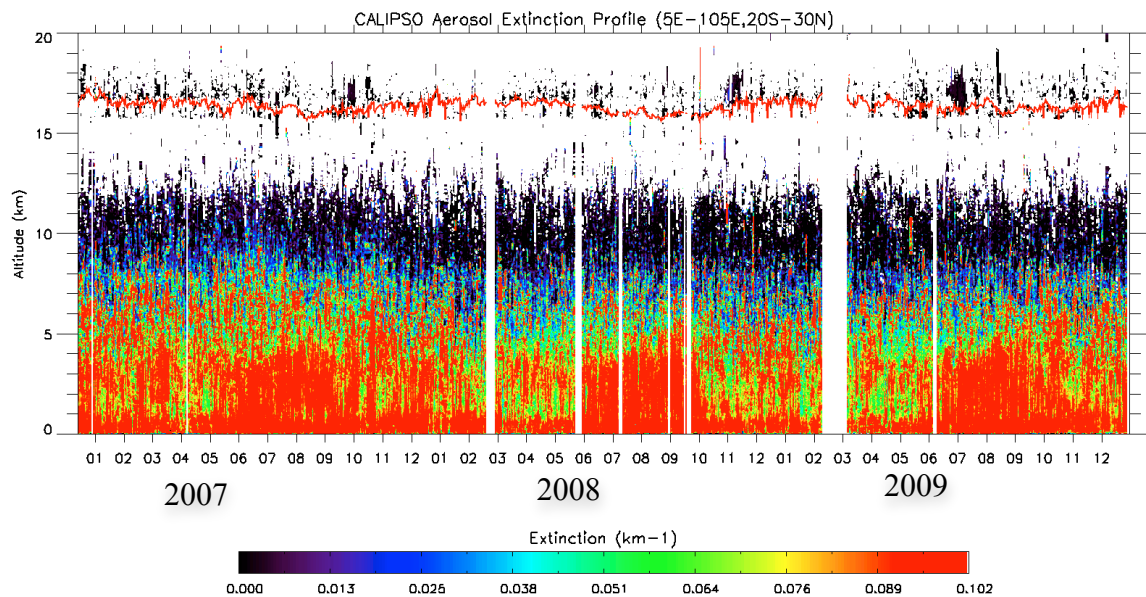


Figure 5\*. Same as fig.1\* but mean aerosol extinction profile after filtering profile when the depolarization ratio is lower than 0.05 as displayed in the form of an average over 3 years in Bourgeois et al. 2012 (fig.3)

In fig. 3 of their paper, Bourgeois et al. 2012 have applied a similar filter and compared the average profile over 3 years before and after applying the filter claiming that the layer was still there. By looking at figure 5\*, we argue that the residual layer seen is mainly due to several small volcanic eruptions occurring during this period, with a depolarization ratio lower than 0.05 consistent with their nature of liquid sulfuric acid droplets.

After detailed analyses of the CALIOP level 2 aerosol profile product that the authors have failed to produce in their paper. It is become clear that most the “apparent” aerosol layer found in the CALIOP level 2 aerosol extinction profile in the Indo-Pacific region is instead misclassified cirrus clouds (depolarization greater than 0.3) as stratospheric features because the bottom of these layers were above the tropopause height as defined by the GOES-5 model. Even after applying a filter to remove ice crystals based on the depolarization ratio, the residual signal is mainly composed of volcanic aerosols that have occurred or being transported in this region (30N-20S) between 2007 and 2009.

Therefore, base upon this conclusion, the authors have failed to analysis rigorously the CALIOP level 2 aerosol extinction profile product. However the classification of the stratospheric features in the CALIOP product based solely on their height is also somewhat misleading.

So, except volcanic plumes near the tropopause that show up in the CALIOP level 2 product, other types of aerosols are not detected by the current layer retrieval algorithm due to very likely the lack of sensitivity for layer with extinction lower than  $5 \times 10^{-3} \text{ km}^{-1}$  (assuming lidar ratio of 50sr commonly used for sulfate).

But a detailed analysis of the level 1 data, averaging more signal to increase the Signal to Noise Ratio have shown such aerosol layer exists but mainly located above the Asian continent during the summertime monsoon (Vernier et al., 2011a). The positive aspect is that the model used in Bourgeois et al. 2012 was able to reproduce this feature during summertime with however extinction likely overestimated but an apparent correct seasonal variation.

Despite this positive aspect, I don't see any other option than rejecting this paper for publication.