ANSWER TO REFEREE 1:

We are grateful to this reviewer for a very good question, which has prompted us to take another look at the dataset. We hope our response to this question as well as new text in the revised manuscript is sufficient for this reviewer.

There is one issue that I would like the authors to discuss a little more. It is about the observation that the stable clouds are water clouds and optically thin. The stable stratification is consistent with optically thin clouds, because the clouds are too thin to experience destabilization from cloud top cooling. But how are these water clouds maintained; why do they not glaciate? In the thick radiatively destabilized clouds, there is often a liquid layer at the top that is maintained by the continuous supply of liquid water from condensation in the cloudy updraughts. Such a mechanism does not exist for optically thin stable clouds. So how are these water clouds maintained. I would expect them to glaciate rather quickly without a turbulent regeneration mechanism. The authors could perhaps discuss this in the paper.

This is a very good question, and we are grateful to the reviewer for posing it. We have attempted to discuss this further in the revised manuscript, although briefly because of length restrictions.

However, since this study is a statistical analysis on the characteristics of the three cloud states, it inherently does not include information regarding how a cloud state develops over time. Hence we can only speculate. One key may be that we also found that these clouds usually are accompanied by low concentrations of cloud condensation nuclei (CCN); they occur in air that presumably has a low concentration of aerosols in general. Previous studies (e.g. Prenni et al. 2007) have shown that the presence of sufficient ice nuclei (IN) is critical to whether clouds glaciate or not. We speculate that in the low aerosol concentration air there are not enough IN present to initiate ice particle formation. The fact that these clouds are most often very low also means that the temperature is usually only slightly below freezing in summer.

One such case was studied in detail in Mauritsen et al. (2011); the frequent presence of a so-called “fog bow”, a halo-like optical phenomenon, strengthens the assumption there are no ice crystals present and the cloud consists of few but large spherical droplets. That they are large is due to the low CCN concentration; the cloud dissipates as the droplets become large enough to sediment out of the cloud, thereby feeding back on the low CCN concentration.

Two additional examples shown below, which illustrate some potential paths for stable clouds’ evolution. The first case (Figure 1 below) focuses on an optically thin stably-stratified cloud, with LWP ~15g/m^2 and IWP ~0.11 g/m^2 that occurs on DoY234 (~5.00am). With time this cloud gets lower and thinner, while surface turbulence becomes weaker until it can no longer reach the cloud layer; eventually this cloud layer has dissipated by DoY 235.

The second case (Figure 2 below) refers to an initially optically thick stable cloud, with LWP ~65g/m^2, on DoY 219, 9.30am. At the beginning, this cloud appears stably-stratified and capped by the inversion. With time the cloud thickens and starts extending towards the inversion, while the stable stratification becomes weaker. After a couple of hours, when eventually the cloud extends in and above the inversion, a transition to a coupled state occurs; the weakening of the stable stratification and the transition to the coupled state is also accompanied by a gradual increase in LWP. For this case, it is hypothesized that the lack of incloud mixing is due to fact that the liquid may be homogenously distributed across the cloud layer, not allowing the destabilization of the cloud. As the cloud extends above the inversion and gains more liquid condensate, this distribution changes allowing differential cooling.

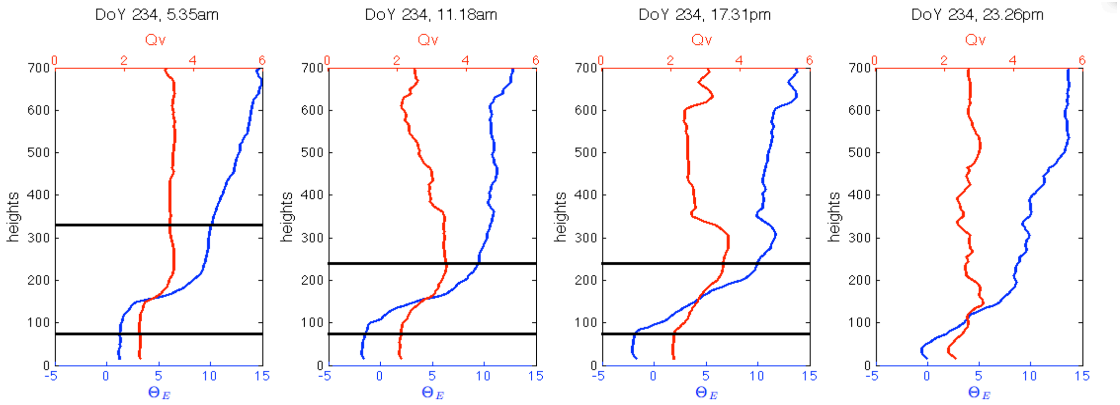

Fig 1: Radiosonde profiles of equivalent potential temperature (Θ_E) [^{o}C] (blue) and specific humidity (Q_v) [g/kg] (red) for case study 1: DoY 234 (Aug 21th, 5.00am) – DoY 235(Aug 22nd, 00.00am). Black solid lines represent the cloud boundaries.

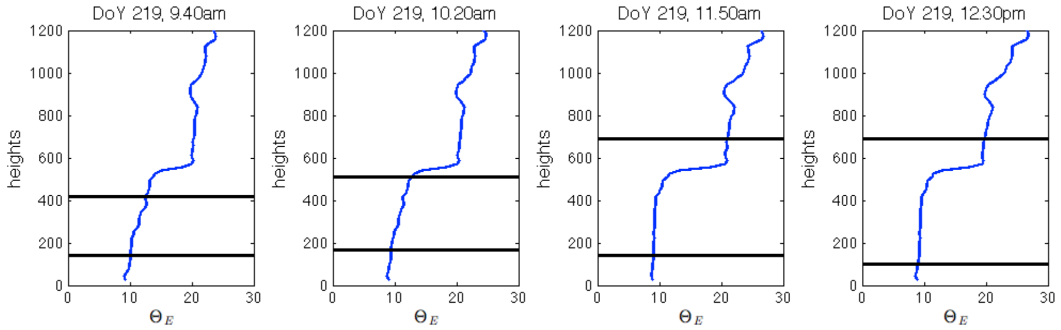

Fig 2: Scanning radiometer profiles of equivalent potential temperature (Θ_E) [^{o}C] for case study 2: DoY 219 (9.30am - 12.30pm). Black solid lines represent the cloud boundaries.

These case studies indicate two potential development paths for the stable clouds; (1) they become even more tenuous with time until they dissipate (they probably can be maintained up to a day with this type of stratification). (2) They gain more liquid condensate (e.g. through vertical or horizontal advection) that leads to the redistribution of the liquid across the cloud layer or to the thickening of the cloud, so that eventually they become thick enough to drive turbulent mixing.

A description of the above two cases of stable cloud state and their possible evolution are included in Section 4 of the revised manuscript, although without showing the plots above.