

## ***Interactive comment on “Simultaneous occurrence of polar stratospheric clouds and upper-tropospheric clouds caused by blocking anticyclones” by M. Kohma and K. Sato***

**Anonymous Referee #4**

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The study by Kohma and Sato statistically examines the simultaneous appearance of polar stratospheric clouds and upper tropospheric clouds using CALIPSO data over five austral winters of 2007-2011. From their analyses they try to find a correlation between PSCs at 15-25 km and upper-tropospheric clouds at 9-11 km. Further, they find that the occurrence of simultaneous PSCs and upper-tropospheric clouds is frequently associated to blocking anticyclones.

The CALIPSO data set applied here is very valuable for such a study. However, the paper needs major revisions before it can be considered for publication in ACP. First of all, it is difficult to understand how the data has been treated and how they

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draw their conclusions from their analyses. Secondly, there are several inconsistencies and flaws in their study as well as that their findings contradict to a certain part with previous studies. E.g. why are tropospheric clouds to be assumed to be at 9-11 km when the tropopause is at 7-8 km? Tropospheric clouds are located in the troposphere though they may penetrate the tropopause and reach into the stratosphere. Further, why should the simultaneous occurrence of tropospheric clouds and PSCs be connected to blocking anticyclones? Although blocking anticyclones can cause a lifting of the tropopause they consist of a rather cloud free area. Thus, if there is a connection to blocking anticyclones one would only expect a PSC but not additionally tropospheric cloud. Furthermore, the simultaneous occurrence of PSCs and upper tropospheric clouds is rather connected to cyclones, thus to deep tropospheric cloud systems as it was shown by Wang et al. (2008) and Adhikari et al. (2010) for the Antarctic as well as by Achtert et al. (2012) for the Arctic. I cannot understand why Kohma and Sato did not tie their study to these previously published studies. By applying for years of CALIPSO data they would have a significantly advantage over these studies since these only applied data sets on a much shorter time scale.

### **Major comments:**

Title: Since this study is on the Antarctic it should be reflected in the title.

### **Abstract:**

p20008, 17-8: Tropospheric clouds are not located around the tropopause and slightly above rather than in the troposphere. Tropospheric clouds form and stay in the troposphere though they can penetrate the tropopause. This so-called overshooting convection occurs rather in tropical and midlatitudinal cyclones than in polar cyclones. PSC presence/formation has been associated to deep tropospheric cloud systems, thus clouds that extend over several kilometers altitude in the troposphere.

### **Manuscript text:**

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P2008, I10: Do you mean here that the blocking highs lift the tropopause up to 15 km or that there bulging effect is visible up to 15 km?

P2008, I13: There have never any PSC been observed outside the polar vortex. PSC form within the Antarctic and Arctic vortices. In both hemispheres, outside the vortex the temperatures are too high for PSC formation.

P2009, I9-11: From the Teitelbaum et al. (2001) study it becomes not clear if they looked at cyclones or anticyclones. Thus, the text referring to this study should be changed and it should be written as in the Teitelbaum conclusion that they find a connection between PSCs and miniholes to synoptic-scale dynamics or synoptic scale tropospheric cyclogenesis. Further, cyclones or anticyclones do not appear near or around the tropopause, they extend over the entire troposphere.

P2009, I22: Studies as the McDonald et al. (2009) study performed for the Arctic should be discussed here as well.

P20010, I25 ff: Also Arctic studies on this topic as e.g. the study by Achtert et al. (2012) should be discussed here.

P20010, I28: There is no need for inventing an abbreviation for blocking highs. Blocking highs should be referred to as blocking highs and not as BHs.

P20011, I4: Tropospheric clouds are definitely in the troposphere. Otherwise these would be stratospheric clouds.

P20011, I15: What actually is done here? It sounds like your algorithm is not able to differentiate between tropospheric and stratospheric clouds. How can you then derive the simultaneous occurrence of tropospheric and stratospheric clouds if you

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even don't know what has been measured?

P20012, I1: If the tropopause is located at 7-8 km, the altitudes of 9-11 km are in the lower stratosphere. Thus, how can you then refer to this altitude region as UT/LS?

P20012, I2: In 9-11 km one can expect solely stratospheric clouds. To get tropospheric clouds one has to consider the altitude regions below.

P20012, I4-5: In figure 1 CALIPSO level 1 and level 2 data are compared, but why does this figure show that the algorithm works also for the lower stratosphere? What is the difference between the level 1 and level 2 data? If CALIPSO level 2 data allows a characterization into "clear air", "cloud" and "stratospheric" why isn't this data been used? It would at least allow to differentiate between stratospheric and tropospheric clouds which the applied algorithm obviously cannot.

P20012, I11: How can you get the PSC type if you even don't know if a PSC or a UC was measured?

P20012, I18-19: "Thus, the PSC composition below 15 km ( 400 K) is not examined in the present study". Why? With excluding this altitudes a large amount of PSCs is neglected. As can be seen in Pitts et al. and other studies, PSCs extend in the Antarctic frequently down to 10 km. When the algorithm for characterization works in in higher altitudes why shouldn't it be able to do it in lower altitudes. To my knowledge the Pitts et al. algorithm can characterize any PSC independent at which altitude it was measured.

P20012, I20-25: What was the reason that Gettelmann et al (2011) came to the conclusion that the PV definition for the tropopause may not be appropriate and why do you nevertheless apply this tropopause definition. Wouldn't especially for your

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study a tropopause definition as accurate as possible be unambiguous?

P20013, l25: If the typical tropopause height is generally at 7-8 km which is lower than the UC altitudes than you are definitely not considering tropospheric clouds. These are obviously stratospheric clouds. What is done here is a correlation between polar stratospheric clouds in two different altitude regions. Tropospheric clouds are in this study not considered at all.

P20014, l1: Before the clouds at 15-25 km were referred to as PSCs, now they are PSCs/UCs which it is said they will be referred to as PSCs and the one between 9-11km as UCs. Thus a strict differentiation between PSCs and UCs (though at these altitudes only PSCs are found). Nevertheless, in the following text the expression PSC/UC is consequently used so that one hardly can follow which altitude region is considered.

P20014, l10-13: Rephrase the sentence and be more precise. The seasonal variation in PSC altitude is simply due to the fact that they descend to lower altitudes during the course of the winter.

P20014, l14-24: I don't see a correlation at all. Can one seriously call a correlation coefficient of 0.1 or 0.2 a correlation? Doesn't it show the opposite that there is no correlation at all?

P20014, Figure 2 and 3: These figures make no sense. What is correlated here? Why is the correlation symmetric? If there would be a connection between clouds in two different altitude regions a unsymmetric correlation should be found, showing a maximum at high altitudes in the e.g. x-range and according a maximum at low altitudes on the y-range. In this figure the correlation coefficient is highest for exactly the same altitudes in the x- and y-range.

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P20015, l6: It is not clear if these clouds are UCs or PSCs. Further, I don't see any correlation at all.

P20015, l19-20: Since I do not understand the figure and further do not see a correlation and thus one cannot follow your conclusion.

P20015, 23-24: As mentioned before tropospheric clouds are located in the troposphere. There is overshooting convection, but this is more common in the tropics and midlatitudes than in the polar regions. As I understood this analyses the authors haven't checked for every day and measurement where the tropopause location was. Maybe they should do that and then maybe they will find that the tropopause was located higher than 7-8 km and thus they could get clouds in the troposphere. However, the tropopause won't nevertheless be higher than 10 km and thus they still wouldn't get any tropospheric clouds.

P20015, General comment: I would suggest that the authors difference the clouds in the troposphere into cloud types (cirrus, deep tropospheric clouds etc) as it was done in Achtert et al. (2012).

P20016, l1: I still have difficulties to follow what kind of clouds are exactly in this PSC/UC group. If there is a gap, than it seems that there is a clear separation between tropospheric clouds and stratospheric clouds and that these are thus not occurring in one single layer. This is also something I would expect. At least it is like that in the Arctic. There is a gap of a few km between tropospheric clouds and stratospheric clouds since only in higher altitudes temperatures become low enough for PSC formation.

P20017, l19: Do you results imply that Wang et al. (2008) are wrong or do you

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results show that additional to cyclones also anticyclones can induce PSC formation?

P20017, I24: "stratosphere mixing process". Please rephrase. It is not clear what you mean.

P20017, I20-30: The cooling process which leads in connection with the anticyclones to a cooling of the stratosphere is not properly explained. Further, more H<sub>2</sub>O would mean more PSC formation. Thus, the injection of H<sub>2</sub>O rich air cannot be the explanation for the cloud gap.

General comment: I would recommend the authors to check some previously published studies of PSC measurements, especially from lidar which show that the PSCs tend to occur in two layers and also that there is usually a gap between PSCs and UCs. Thus, there is no real need to explain this gap by a dynamic process. Tropospheric clouds are found up to the tropopause and stratospheric clouds somewhere above depending on where it is getting cold.

P20018, I15-18: You derive just 15

P20018, I20: I still don't understand why both CALIPSO data sets are used. What is the difference between Level 1 and Level 2 data? Why isn't just the one used which is more suitable for this study?

P20019, I7: As long as the tropopause is at 7-8 km this two layers are in the stratosphere and thus stratospheric clouds and not tropospheric clouds. Unless you can't show that the tropopause was higher and that these clouds at 9-11 km were in the troposphere your conclusion on a connection cannot hold.

P20019, I20: This seems to be quite variable and only in some years high correlation coefficients are found. Thus, this does not provide a clear picture.

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P20019, I23-24: Since PSC occur solely within the polar vortex this result is not astonishing. However, I cannot understand how can you get a correlation of PSCs and UCs outside the vortex if there are no PSCs outside the vortex? The analyses needs definitely to be revised. It seems that there is something wrong.

P20020, I5-9: I am sorry, but I still not convinced that you have shown a connection between blocking highs and simultaneous PSC and UC occurrence. Although

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P20021, I12: I am still convinced that you just have looked on PSCs in different altitude layers. The altitudes 9-11 km are much too high for tropospheric clouds. If there was a significant lifting of the tropopause during certain days you first have to proof this.

P20022, I4-6: A water vapour entrainment from the troposphere into the stratosphere cannot explain the cloud gap. If water vapour is enhanced due to cross tropopause mixing PSC formation would rather be enhanced when suppressed since water vapour is needed for their formation (especially for ice particles).

**Tables and Figures:** Table 1: How can you now state which clouds where exactly simultaneously observed when you cannot exactly differentiate between tropospheric and stratospheric clouds? Doesn't this table exactly show that blocking highs seem to have no influence at all. The numbers for simultaneous PSC and UC clouds are nearly the same for each year independent of the presence or absence of blocking highs.

Further, numbers are highest for occurrence of PSCs without any underlying UCs and presence of blocking highs showing that the major mechanism is a different one like e.g. synoptic cooling.

Figure 2: I would expect one axes to be the altitudes of PSCs and the other for

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UCs. Which axes is showing which altitudes and why is the distribution symmetric? One would expect and unsymmetric distribution if there is a connection between PSCs at 15-25 km and UCs below.

Figure 4: At which longitude is the reference latitude? Is it the same for all cases or are the blocking highs found at different locations? Since only clouds above 9 km are considered and PSC occur down to these altitudes in the Antarctic it seems for me that these frequencies are solely PSCs without any UCs.

Figure 5d: Is the colour scheme really equivalent latitude? What is the purpose of the figure? What exactly is shown here.

**Minor comments:** p2008, l2: state already here that CALIPSO data is used.

P20010, l4,5 and further in the text: "Höphner" should be "Höpfner".

P20011, l10-11: "range up to...." from which altitude? Write 40 km instead of 40.0 km.

P20017: What is meant with "other regions"? Please be more precise.

P20016, l8: "at" instead of "in".

P20016, l11 and 27: Rephrase, don't start the sentences with "next".

P20018. l19: add "layer" after two.

**References:** Achtert et al. (2012), On the linkage between tropospheric and Polar Stratospheric clouds in the Arctic as observed by space-borne lidar, *Atmos.*

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Adhikari et al. (2010), Microphysical properties of Antarctic polar stratospheric clouds and their dependence on tropospheric cloud systems, *J. Geophys. Res.*, 115, doi:10.1029/2009JD012125, 2010.

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