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Comment on "Monitoring the atmospheric boundary layer by GPS radio occultation signals recorded in the open-loop mode" by S. Sokolovskiy et al.

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1. Introduction

Sokolovskiy et al. [2006] (hereinafter referred to as S06) presented first results of Planetary Boundary Layer (PBL) detection using open-loop tracking (OL) on the SAC-C radio occultation (RO) receiver. OL is an improvement to closed-loop tracking (CL), allowing more frequent PBL observations. Earlier PBL detection work using the CL CHAMP RO instrument had been presented by the authors of this comment [*von Engeln et al.*, 2005] (hereinafter referred to as E05). Although CL PBL detection depends on receiver software as well as on the actual processing, results show good agreement with the ECMWF PBL top and a fair amount of variability (see E05). Updated CL algorithms even show similar general tracking results as OL [*Beyerle et al.*, 2006].

Within S06 our work is further analyzed. Although most of this has already been covered in E05, several misleading PBL top comparisons and statements are made by S06. In particular, S06 uses five different PBL top altitude definitions without properly addressing their difference. Three of them are atmospheric profile based: (1) a breakpoint altitude z_{BP} in the refractivity N profile; (2) the altitude z_N where the gradient of N with respect to altitude z is minimal; (3) the altitude z_{RH} where the relative humidity gradient with respect to z is minimal. The first two are explicitly mentioned in S06, while three is implicitly included by discussing results of E05. The remaining two definitions are related to the actual Full Spectrum Inversion (FSI) implementation used in S06 and E05 and the altitude where tracking is assumed to be lost, z^{E05}_{Loss} and z^{S06}_{Loss}.

Here we compare these five definitions based on AWI radiosondes [*König-Langlo and Marx*, 1997], on ERA-40 and ERA-40-like ECMWF analysis fields, and on a z_{Loss} analysis for different processing centers. We show that they can lead to significantly different results.

2. Relative Humidity vs. Refractivity Gradient

E05 used z_{RH} to identify the PBL top while S06 used z_{BP} or z_N. Figure 1 shows the difference between z_{RH} and z_N as derived from ECMWF fields (covering the CHAMP years 2001 to 2005). Substantial differences of more than 1 km can be seen in the tropical regions. These differences increase along a transect from stratocumulus (Sc) regions towards the equator, with smaller differences for Sc regions.

The difference between z_N and z_{BP} was estimated by analyzing oceanic AWI radiosondes at latitudes $\leq 35°$; z_{BP} is on average 0.06 ± 0.04 km higher than z_N, maximum difference can be up to 0.3 km (not shown).

3. FSI Processing Altitudes

S06 use z_{BP} in Figure 2 and compare it to z^{S06}_{Loss} of six CHAMP occultations. They show that z_{BP} can either be substantially above z^{S06}_{Loss} or below, depending on atmospheric conditions; they conclude that the method of E05 is not reliable. While we do not doubt that OL will improve PBL top determination and that our method can lead to erroneous identification, as already discussed in E05, several incorrect assumptions are made here that need to be clarified:

(1) E05 validated their results with about 142,000 occultations while S06's discusses 6; (2) Because the oceanic PBL probably has the largest climate impact (due to its strong connection to PBL clouds) and since it does not exceed 3 km (at least not in the tropics and sub-tropics), E05 focused their analysis on $z \leq 3$ km. Profiles D, E, F in S06's Fig. 2 lose tracking above 3 km, thus would have been excluded in E05's discussion; (3) Profiles A, B, C (SO6, Fig. 2) are over land and show 5 to 6 km PBL heights. These seem inconsistent with the times given (01:50, 09:38, 09:01 UTC). It is doubtful that there are local boundary layers 6 km deep, in particular at 01:50 (middle of the night) the PBL would be stable with the stronger gradients close to the surface. It may well be that S06 is detecting the residual layer here; (4) E05 used z_{RH} which is frequently higher than S06's definitions (as shown above); (5) E05 used a FSI processing (MATLAB based) completely independent from the operational GFZ (GeoForschungsZentrum Potsdam, Germany) software of *Wickert et al.* [2005]. S06 do not mention where the six occultations were processed, but they use z^{S06}_{Loss} to discuss our method; hence one should assume that they used this method.

We identified these occultations first in the CDAAC (COSMIC Data Analysis and Archive Center, Boulder, USA) archive [*Kuo et al.*, 2004] (Note: A match for profile C was only found on the 19th; we assume this is a typo.) and then searched for them in our archive. Only four matches were found; CDAAC and GFZ do not necessarily process the same occultations [*von Engeln*, 2006]. Table 1 shows the

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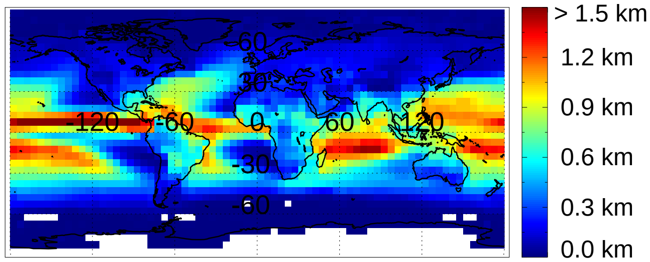

Figure 1. $(z_{RH} - z_N)$ difference based on ECMWF fields. Data is averaged over a 5° latitude longitude grid. White areas indicate either slightly negative differences or temperatures always below 273 K.

Table 1. PBL top altitudes [km]

Profile	$z_{Loss}^{\mathrm{CDAAC}}$	z_{Loss}^{S06}	z_{Loss}^{E05}	z_{RH}
B	1.24	1.50	3.75	4.16
D	5.27	5.20	3.79	1.17
E	6.26	6.10	2.00	1.16
F	4.81	4.80	2.00	1.43

results, $z_{Loss}^{\mathrm{CDAAC}}$ is taken from the CDAAC post processed data and z_{Loss}^{S06} is estimated from Fig. 2 of S06. Our z_{Loss}^{E05} are very different to S06 ones and are closer to z_{RH} as derived from ECMWF; S06 results are closer to $z_{Loss}^{\mathrm{CDAAC}}$. Note that our analysis would have excluded profile B and D.

To show that the actual FSI implementation can lead to a different z_{Loss}, 10,000 randomly selected CDAAC processed CHAMP occultations were selected and the corresponding match in our archive was identified; in total, more than 6,700 matches were found. Figure 2 shows that our archive generally has more occultations at lower altitudes.

4. Conclusion

Within this study we comment on different ways to characterize the PBL top altitude. These different altitudes have been used in S06 to show how an improved tracking algorithm can improve PBL observations. S06 also discussed limitations of an earlier algorithm proposed by E05 that identified the PBL top based on the FSI amplitude; they incorrectly concluded it is unreliable.

While there is no doubt that improved tracking will also improve PBL studies, as can be expected with instrument improvements, S06 also used several simplified PBL top assumptions. We show that these simplifications are unjustified; the correct approach can lead to substantially different results: (1) z_{BP} or z_N are not generally suited to identify the PBL top unambiguously, altitudes can lead to PBL tops different by more than 1 km; (2) the actual occultation processing algorithm can impact z_{Loss} and thus the PBL top as derived from the FSI amplitude.

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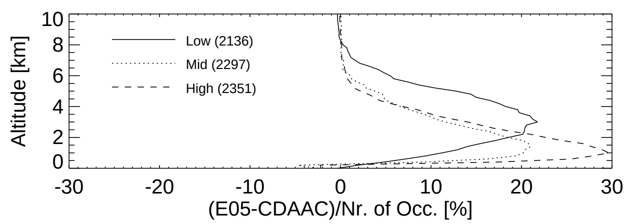

Figure 2. Relative difference of number of processed occultations over altitude for three latitude bands, # of matches in brackets.