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Interactive comment on "Multichannel analysis of correlation length of SEVIRI images around ground-based cloud observatories to determine their representativeness" *by* J. Slobodda et al.

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Dear Reviewers, we like to express our thanks to the reviewer and their helpful comments, which helped to improve the present work.

For a small summary, the following major changes to the manuscript were performed:

-Adding information on different pixel sizes around the ground-based stations

-Adding information on the measurement techniques of SEVIRI

-Adding information on the used cloud mask to distinguish between cloudy and clear

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pixels

-Introducing the influence of three dimensional cloud structures

The authors aim to determine the representativeness of measurements from ground stations for the surrounding area in order to facilitate the evaluation of NWP models. This task is done via the analysis of Meteosat-9 images from one year of data in original temporal resolution, where for each ground station a rectangular field of 300 x 300 km is considered. The representative area is specified via correlation of time-series of surrounding SEVIRI pixels and the center pixel. In the following, the authors analyse the correlation in terms of channels and for different stations across Europe. The representative area (or radius) is higher for IR than for VIS channels and also dependent on the surface' structure. The article is relevant to scientist involved in model evaluation or the validation of SEVIRI-derived parameter.

Generally: The article analyses satellite measurements that are averaged quantities over the SEVIRI pixel size which is about 4 x 6 km in European region. For theses averaged quantities the correlation is determined. Can you explain how this relates to the cloud observation sites with various different instruments where many of them have fields of view that are much smaller than the SEVIRI pixel size? > The motivation of this study is to examine the representativeness of cloud observation at single ground sites for their surrounding area. Therefore we take use of satellite observation (SEVIRI) to characterize the spatial distribution. Of course, the pixel-size of SEVIRI is much larger than the field of view of most ground-based instruments. But with our method, using a function fitted to the actual data, we can also get representativeness radii that are smaller than the pixel size. Since representativeness is not clearly defined anyway, we just give an estimate and therefore the large pixel size should be sufficient at least for comparisons of different weather conditions and stations. To make this point clearer, we modified the abstract. In the other chapters, where the function is introduced, it should be clear enough how the radius is calculated. Abstract: "Cloudy situations are selected to get a time series for every pixel in a 300 x 300 km area centered around

each ground station. Then the Pearson correlation coefficient of each time series to the pixel nearest to the corresponding ground site is calculated. A function is fitted to the data to get the decrease of correlation with distance. The area for which a station is representative is defined by a characteristic radius around each station for each SEVIRI channel, where the average correlation or the fitted function, respectively, falls below 0.9. By using a fitted function it is possible to get a characteristic radius smaller than the pixel size.

The results in terms of different wavelength are valid for SEVIRI and sensors with comparable channels spectral response functions only. Did you also consider other sensors with different spectral responses?

> Certainly the repetition of this study with other sensors in other wavelength regions would be a good addition to our results or in similar wavelength a good confirmation. But only the use of geostationary satellites offer temporally and also horizontally resolved views on the cloud fields around the super sites. And their number is limited.

Major remarks:

p3., l.1: "the impact of all cloud types on the net fluxes are still not known" please be more specific, the global net radiative effect is about -21 W/m2 (Allen, 2011) and measured -13 – 21 W/m2 as measured by ERBE (NASA). Maybe I misunderstood the phrase.

> Thank you for pointing to that inaccuracy. We modified the sentence accordingly: P3,l1: "the impact of the specific cloud types on the net fluxes are still not known "

p.3, ls.7 – 11: Extend this introductory sentence with description and citations on the influence of 3D cloud structure on radiative transfer, the citation you mentioned is not state of the art.

> We added Zinner (2006) as reference and extended the sentence by: p.3 l.7 : "Since real clouds have a complex three dimensional structure leading to shading and bright-

ening effects on the cloud top and . . ."

p.4., ls.25 – 29: The comparison of point measurements and SEVIRI pixels is indeed complicated, since the latter covers a certain area, I understood this would be the subject of this study? This refers to the general remark above.

> Our focus is to study the usefulness of vertical cloud properties from super sites on a broader resolution. Therefore we study the variability of the cloud field depending on the distance to a point measurement. These distances are mostly larger than the length of one satellite pixel. By interpolating the results we either get a representativeness larger than one pixel (in this case satellite and ground data should be comparable) or smaller than one pixel indicating low comparability. We have modified to: " ...The studies discussed above are based on data from time periods that are too short for climatologies. For the present study SEVIRI data from the complete year 2012 was utilized to get at least cloud types typical for all seasons though it is still not long enough for a real climatology. But this time period are sufficiently long to contain all common cloud types over Europe like pre- and postfrontal clouds, convective cumulus and boundary layer stratus. In this study only SEVIRI observations are used to understand the representativeness of the Cloudnet stations for their surroundings. Therefore the SEVIRI pixels nearest to the ground stations are compared to all 101 x 61pixels surrounding them (see Figure 1)."

p.4, l.29: "uncertainties due to different resolutions and dimensions are avoided" not completely, the pixel size of a satellite images varies with the viewing angle, in case of SEVIRI this translates to variation with latitude and longitude. Please give an estimate of this for the locations of your study.

> The pixel size of the region around Potenza (southernmost station in the analysis) is approximately $15km^2$ and around Mace Head (northern- and westernmost station) $22km^2$. We modified: p.4, l.29: Thus uncertainties due to different resolutions and dimensions are minimized. We still have some differences induced by different pixel

sizes around the stations. The southernmost station Potenza is surrounded by pixel of $\sim$15km^2 and the northernmost station Mace Head by pixel of $\sim$22km^2.

p.5, l. 10: Citation for Meteosat and SEVIRI is missing as well as a short description of the measurement principle or the validation of SEVIRI-derived parameter.

> We had explained SEVIRI in the following chapter 2 with the general citation Schmetz 2002 in p. 6. l. 2. We added the phrase in chapter 2: p.5, l. 10: "The images are taken by scanning the earth from east to west (each line) by using the spin of the satellite around its own axis and from south to north by stepwise rotating the scan mirror. The repetition cycle for a whole scan is 15min."

p.5, l. 21: Please describe the cloud net classification and what is calculated there and if the result represents an area or a compilation of point measurements. This would help to motivate the study. Why are particularly the cloud net stations analysed? I assume due to their constant measurement program?

> We not include further information to the cloud net product. We hope after modification of the introduction the focus of the paper is clearer. The stations were indeed chosen because of their constant measurement program and the possibility to combine different instruments there.

p.6, l. 11: Describe the algorithm that is used to produce the cloud mask. How accurate is it and how are the results validated?

> We added the sentence: p.6, l. 11'The cloud mask algorithm is based on a neural network and is supposed to be quite conservative. That means a pixel declared as 'cloudy' is most likely really cloudy, but especially thin clouds are quite often missed (Hamann 2013)'

p.6, l. 18-20: How are the cloud free pixels excluded? Do you exclude complete scenes or just the pixel themselves? If singles pixels are excluded from the scenes, this changes the time-series per pixel for the correlation. How do you treat gaps that

are not useful for a correlation analysis and which (approximate) influence does this have on the study? Also this approach to exclude cloud-free pixel will very likely falsify the results since the considered scenes are not realistic any more. In this respect the provided correlation length refers to fully cloud covered or partly covered pixel over the complete area of interest. This has to be discussed.

> To find scenes for one time step where all pixel in a 300 km x 300 km area are cloudy is quite difficult. Thus we allow up to 10% cloud free pixel. The values of those pixels is set to NA. The time correlations between time series of each pixel to the time series of the center pixel are only calculated from time steps where neither the center pixel nor the compared pixel has NA as value. In this way the we only compare cloudy pixel. Having clear sky pixel in the correlation would clearly reduce the correlations. Since we know, that the ground-based measurement of a cloud doesn't apply to the clear sky a few km away, but perhaps to another cloud at the same distance. This is the quantity we try to estimate.

p.7, l.13: For sake of clarity please state once more that the cloud mask is used for filtering the channel information.

> We modified: p.7, l.13: 'For each pixel the correlation of time series of either fully or half covered scenes, determined by using a cloud mask, ...'

p.8, l.8-9: Not necessarily only variation in COT and effective radius, also the 3D macro-scopic inhomogeneity causes variations even if there are no clear gaps, which probably exceeds the microphysical effects.

> We add: p.8 l.8-9.:'..., though it may be overlayed by effects of the three dimensional structure of the cloud tops. In this case the cloud parameters might be more homogenous than the results suggest.'

No specific place: Did you distinguish between ice and water clouds? If so, did this have an effect on the correlation length.

> We didn't distinguish the cloud phase. Only for the confirmation whether the 3.9μm channel was saturated or not we divided warm and cold clouds. There we saw a clear difference, but the reason was most likely the saturation of the channels when warm clouds are measured.

p.9, l.25: Why does the likelihood of different cloud layers with different heights increase for partly cloudy scenes compared to fully cloudy?

> The completely covered scenes are often part of a large cloud system and rarely the overlap of several smaller clouds with different heights. Still we have to account for multilayer clouds like cirrus over stratus with sharply changing cloud top height at the edges of the cirrus. The partly covered scenes are either approximately half covered with one large system with similar cloud height or covered with many small clouds that leave enough space between them to get a partly cloud cover. In the second case the top height of the different clouds might be quite different and would increase the variability of the top height. But we can not say exactly how often each cloud type exists.

p.10, l.7.: I agree, but do you have an explanation why the decrease in 6.2 mum is more linear than in the other two channels? Please refer to the absorption bands of water vapour. The peak for this channel in figure 6 is quite remarkable.

> As mentioned in the text the 6.2μm channel responds to water vapour fields above the cloud which are more homogeneous than the clouds below. For other channels the reduction of correlation decreases especially in the first kilometers distance. After that a level is reached where the correlations do not change that much. The higher homogeneity in 6.2μm leads to less reduction in the first kilometers and thus to higher linearity. I am not sure if this slow decrease also becomes even slower for distances larger than the investigation area.

p.11, l.1: Any idea why the ozone channel does not show a peak for a in Mace Head?

> But there is a peak for a especially for fully covered cases, so we don't really know why it is there. Maybe it arises from the location of Mace Head. It's the northernmost station and the one furthest to the west and thus has the largest viewing angle from the satellite and thus the largest pixel size. This may include the highest variability within one pixel. But this is only a guess.

p.11, l.14: I would add that a larger database would be needed too if the study would be carried out with respect to cloud type. This would be quite interesting.

> We added: ', but therefore we would need a larger data base to get a sufficient number of all different cases.'

p.12: I think there is a problem with this study. Did you compile the daily means in the same manner as a model would do? That means taking into account only one slot every 3 hours and not the full 15 minutes resolution? If not this will strongly depreciate the results because the influence of sampling will introduce additional inhomogeneity in case the coarse resolution is considered. Averages based on high temporally resolved data are smoother.

> Actually we compared daily means of the satellite data instead of values every few hours to get an impression of the smoothing effects. Additionally we did a study with images from 12UTC only. The motivation for this was to eliminate possible effects of a daily cycle. These study showed more or less identical results as the usage of all possible time steps. Thus taking time steps every three hours would produce results quite similar to the original ones. An explanation is that we anyway select only very few special cases. Taking only images from every three hours just reduces the data pool for the correlations.

p.20: Please add a graph as in figure 3 but for the Alpine region. More spatial variations could be expected there which would be interesting to see.

> We agree that would be interesting, but for this paper we focused on the Cloudnet

stations.

Minor remarks:

p. 2, l.3: Which observations? Please give an example.

> We added: '(e.g. measurements of cloud radars or microwave radiometers)'

p.2, l.17: Delete "like they are".

> We removed the phrase.

p.3, l.1: "(Kie)": the year is missing.

> We checked this citation and the year is not missing.

p.3, l. 4: Extent instead of extend, the same in line 23.

> We changed the typing error.

p.4, l. 23: Remove additionally.

> We removed 'additionally'.

p.5, l.1: What are clear-sky coordinates?

> These are the coordinates where the parallax shift for a high cloud has not been taken into account. For clarification we remove clear-sky.

p.5, l.5: Agreed, but I think you mean diameter instead of area?

> The number of pixel is correct since it is either an area of 600 pixel or a diameter of ∼100Pixel.

p.5, l.13: Meteosat-8 was moved to 9,5âŮę E.

> The Eumetsat homepage says it's 3.5°, but possibly just since Meteosat-10 was launched. We changed it.

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p.6, l.20: Replace eliminate by diminish.

> We replaced 'eliminate' by 'diminish'

p.10, l.21: "... is missing", add "in case of full cloud cover".

> We added 'in case of full cloud cover'.

Citation: Allan, R.: Meteorol. Appl. 18: Combining satellite data and models to estimate cloud radiative effect at the surface and in the atmosphere,324–333 (2011). Interactive comment on Atmos. Meas. Tech. Discuss., 7, 5769, 2014.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/7/C3196/2014/amtd-7-C3196-2014-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 7, 5769, 2014.