Atmos. Chem. Phys. Discuss., 9, C10764–C10774, 2010
www.atmos-chem-phys-discuss.net/9/C10764/2010/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Assessment of parameters describing representativeness of air quality in-situ measurement sites" *by* S. Henne et al.

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Received and published: 13 February 2010

1. What is finally the representativeness of the considered stations?

It did not become clear how the "parameters of representativeness", i.e. average and variability of the integrated population density or dry deposition velocity, quantify representativeness? For instance, does low variability mean high representativeness?

The link between parameters describing representativeness and representativeness itself was briefly discussed on page 20030 lines 3-6: "Low absolute population will indicate that a site can be seen as a remote background site, while low variability

within a more populated grid cell allows the conclusion that the site is representative of a certain population density and will not experience large variability due to the direction of advection", and in the conclusions (P20046, L4-12). We agree that this discussion needs to be extended and moved to a more prominent position within the text. Furthermore, we will integrate an additional paragraph in the manuscript that will clarify the expressions used in the manuscript and show links between them but also indicate the limitations of these parameters in assessing representativeness in a quantitative way. Instead of speaking of parameters of representativeness, which was used loosely in the current version, we will stick to the expression "parameters describing representativeness" as used in the title. In doing so, we would like to emphasize that not a single of these parameters is sufficient to describe a site's representativeness in a precise way according to this term's definition by Nappo et al. (1982), but that rather the combination of the presented set of parameters gives a station's "fingerprint" on representativeness.

How do the six regimes differ in their representativeness? Which of the stations is more suited for model and satellite evaluation or data assimilation? These questions are not satisfactorily answered.

One statement that is made in the manuscript is that representativeness cannot be an individual number for a site or data series (P20022, L22-24), bur varies with time and observed species. Furthermore, a quantitative estimate of representativeness would only be possible from high resolution model or observational data. Our discussion of different parameters describing representativeness based on proxy surface fluxes we attempted to cover a range of factors that influence representativeness. This method can therefore only compare representativeness of stations relative to each other. Typical parameters describing representativeness of the six categories were discussed in section 3.4. The current description will be extended to include a statement on representativeness for each category.

As mentioned before, an example of how to use the parameters describing representativeness in data comparison was given on P20046, L4-12. In general the derived categorisation can be used to group sites in data comparison studies. One would expect that the categories that are less influenced by surface fluxes would agree better with model or satellite data. If this is not the case it is probably a hint that some specific problem exists that might be revealed through this kind of grouped comparison.

In the revised manuscript we will further highlight that our parameters of representativeness are only a first step towards a precise description of representativeness and give a general and temporal average estimate. There is potential to further validate these parameters by independent surface measurements, model studies or from satellite data.

The catchment area as such would describe the potential area of surface influence but, as pointed out by the authors, its size alone does not account for the varying impact of surface fluxes. An interesting exercise would be to investigate in which category an "urban" AQ-stations would fall, when it would be characterized in the same way. Would its parameters be very different from the values of a nearby background station?

The method was not intended to analyse representativeness on the local ($<$ 1 km) scale since a) detailed advection is not resolved by the meteorological input for the LPDM calculations and b) the used proxy data have limited resolution as well (1 and 4 km, respectively). We will emphasize this in the revised manuscript. However, as suggested by the referee, we performed additional FLEXPART calculations for two urban background sites that are close to two of the already selected sites: Munich Lohstrasse (total population 1,400,000, 55 km from Hohenpeissenberg) and Freiburg Mitte (total population 200,000, 10 km from Schauinsland). The same set of parameters of representativeness was derived for these additional sites and both sites were added to the clustering procedure.

While the catchment areas were very similar for both pairs of urban vs. non-urban sites, the parameters describing representativeness differed largely for Munich compared to Hohenpeissenberg but were similar for Freiburg and Schauinsland, though showing slightly larger total burdens and variability for the urban site. When using the two additional sites in the categorisation all previous categories remained unaltered. Only the site Munich was put into an additional category, while the site of Freiburg was categorised as "rural", the same as Schauinsland. This finding corroborates the general performance of our categorisation method but also shows its limitations to distinguish between rural and urban sites for medium sized cities like Freiburg on spatial scales smaller 10 km. Hence, we again would like to mention that the method with its current resolution of the underlying LPDMs and emission proxies is not suited for urban sites. We therefore prefer not to include the detailed results of the two urban sites in the revised manuscript, but will only mention the general tendency of urban sites.

2. What do we learn from such a detailed classification?
The (sub-) classification of the rather uniform (in comparison to urban or traffic stations etc.) group of background stations seems to be a bit excessive. What do we learn from the fact that a station belongs to the "remote coastal/high altitude", "semi-remote coastal/high altitude" or "very remote coastal" category. Easy to comprehend characteristics like "coastal" or "high altitude" are used in several category labels, which undermines the meaningfulness of the classification. The scepticism against this too detailed categorisation is also motivated by the well discussed sensitivity of the classification to parameter choice, scaling, temporal variability etc. I would recommend a smaller number of categories, more distinct category names and a better description of the specifics of each group.

Considering the large differences in estimated parameters describing representativeness we don't think that our analysis yielded too many groups. Already in the current version of the manuscript we describe how two of the groups might be merged with others so that only 4 categories remain.

To further clarify the clustering process we will include a clustering diagram (dendrogram) in the revised manuscript that will show how groups can be merged and how a less detailed categorisation could be derived (draft of the figure is attached to this reply). We agree with the reviewer that the presented category names are somewhat confusing and do not reflect the clustering process. With the use of the cluster dendrogram we developed revised category names that are oriented along the observed differences in parameters describing representativeness as observed at each merge in the clustering process. Starting at the top of the dendrogram the first distinction that is made between sites can clearly be identified as sites **influenced** by surface fluxes and sites with no-to-weak surface fluxes, which are commonly called **remote**. The next separation is along the same dimension of surface flux influence and splits the influenced sites into two sub-categories, which can be called **weakly influenced** and **strongly influenced**. The strongly influenced sites are again split according to smaller and larger surface fluxes and we identify these two groups as **rural** and **agglomeration**. Moving from 4 to 5 groups the remote category decomposes into a group with **generally** low influence of surface fluxes and a group showing intermittent influence of surface fluxes, which thus can be called **mostly** remote. Sites in this sub-category are for example the well established high altitude sites Jungfraujoch, Sonnblick and Pic Du Midi that are known to be characterised by mainly free tropospheric air masses interrupted by transport events from the European atmospheric boundary layer. The last subdivision that yields a total of 6 groups separates sites within the weakly influenced category according to amount of deposition variability. Therefore, these sub-categories can be called **constant deposition** and **variable deposition**.

Thus, we will revise the previous 6 category names as follows:

rural $->$ rural

remote coastalhigh altitude $->$ mostly remote

polluted rural $->$ agglomeration

semi-remote coastalhigh altitude $->$ weakly influenced, constant deposition

very remote coastal $->$ generally remote

rural coastal $->$ weakly influenced, variable deposition

3. Mountain sites
It seems that high altitude sites have the smallest catchment areas (see table 1 and 2a/b/c) but it would not be correct to conclude that these stations have a small area of representativeness. For mountain sites, it is interesting to know from which part of the atmosphere the sampled air originated. In other words, the vertical representativeness of the mountain site is often unknown, which complicates the use of these data. The presented trajectory approach seems to be very suitable to gain more insight in the vertical representativeness of the mountain observations.

The catchment area cannot be seen as the area of representativeness, not even as the maximal extent of the area of representativeness. Mountain sites have a small catchment area because the 3-dimensional structure of the advection towards the sites was taken into account. A large fraction of transport towards a mountain site takes place above the atmospheric boundary layer, therefore the area in which surface fluxes significantly influence a mountain site must be small according to our concept. Folini et al. (2009), using the same LPDM technique as described here, estimated that about 60 % and 45 % of the observations at Jungfraujoch are unaffected by boundary layer contact in winter and summer, respectively. However, regional emissions within the catchment area of a mountain site are often small, therefore the local "noise" in concentration measurements is low and signals from outside the catchment area might still be detectable at those sites.

Furthermore, mountain sites show little contribution of total population and deposition influence and have an overall larger representativeness and are therefore grouped together with remote coastal sites.

It was not the intention of this study to focus on the vertical representativeness of mountain sites and indeed the trajectory technique does not necessarily provide additional information to solve this question. It would be more useful to compare the high altitude measurements with profile measurements in the vicinity.

The simulation of the PBL seems to be vital for the determination of the surface influence. How does the simulation of the PBL differ between COSMO and Flexpart. Was there a difference in the catchment area for night and day conditions? How is the choice of the trajectory starting point (80 m) motivated? To what extent did the model orographies resolve the high altitude sites?

FLEXPART and COSMO LPDM use two different boundary layer schemes for the description of turbulence in the Langevin equation. As mentioned in the supplement, we find considerable differences between the models so that we used a bias correction for total annual residence times. Although it would deepen our understanding, a detailed analysis of the performance of the two different turbulence schemes is beyond the scope of the current manuscript.

Following the suggestion of the referee we estimated catchment areas separately for day- and night-time (9, 12, 15, 18 and 21, 00, 03, 06 UTC, respectively) simulations. Considerable differences in size and total residence time within the catchment were only observed for the 12 h catchments. Night-time catchment areas were somewhat smaller and total residence times larger for sites in flat terrain as could be expected

from generally smaller wind speeds in shallow night-time surface inversions accompanied with little vertical mixing. For the elevated sites the picture was not as conclusive. While some spread was observed between day- and night-time parameters of representativeness no clear tendency to smaller or larger values could be estimated for the population parameters and the deposition variability. Total deposition influence within the 12 hour catchment area was increased at night for sites with generally large deposition influence. For 24 and 48 hour catchments the differences in catchment area size, total residence time and parameters of representativeness, were minor. We will incorporate these findings in the discussion within the revised manuscript.

80 m above ground level refers to high altitude sites that were simulated using COSMO LPDM. The horizontal resolution of the input fields for COSMO LPDM was 7 km by 7 km, therefore the topographic height in the model is rather close to the real altitude. The absolute start altitude will be added to table 1. Sensitivity tests for the site CH01 showed that a release 80 m above model ground yielded the best performance in terms of simulated CO time series (Folini et al., 2008). Starting 80 m above model ground also ensures that particles (trajectories) are not trapped in the lowest model level.

In data assimilation, the representativeness is often explained in terms of correlation length or radii of influence. How could these parameters be determined for each site with the given approach?

These are two different concepts that should not be mixed up. Strictly speaking they cannot be determined since the catchment area is not equal to the area of representativeness. However, typical radii might be derived for the different categories from experience.

It is known that GAW observations are sometimes filtered to exclude influence from local sources. Has this been considered in the study.

Whenever possible we included all available station data in our study and only excluded data that was flagged invalid. All flags concerning background or non-background were treated in the same way for deriving site mean and variance.

A bit more details on how the explained percentage of variance of the concentrations medians was determined (section 3.5) would help to better understand this important check of the classification.

We added the additional information on page 20039 following line 26: A one-way analysis of variance (Dalgaard, 2002, e.g.) was performed to determine if category means were significantly different from each other. The fraction of explained variance was estimated as the variation within groups divided by total variance.

Tables 2a/b/c contain a lot of detail but it is difficult obtain a more general message. Would it be possible to add station altitude and to sort the data according to an important parameter. Two of the tables could also be moved to the supplement.

We added the station altitude and sorted each table according to the total population influence. However, since no preference can be given to any of the catchment areas we prefer to not move any of the tables to the supplement.

The labels are very small and font size should be increased. Plotting station labels should be avoided in Figure 2 and only be kept in Figure 4 if the labels are

readable. Figure captions: Use same name and label of parameters in all figure captions.

We will change the figures according to the suggestions of the reviewer.

Wording: The wording would benefit from a check by a native speaker. Repetitions of "derived" in connection with "parameter" as in e.g. p. 20020 l. 18 should be avoided.

We will have the revised manuscript checked by a native speaker before resubmission.

References

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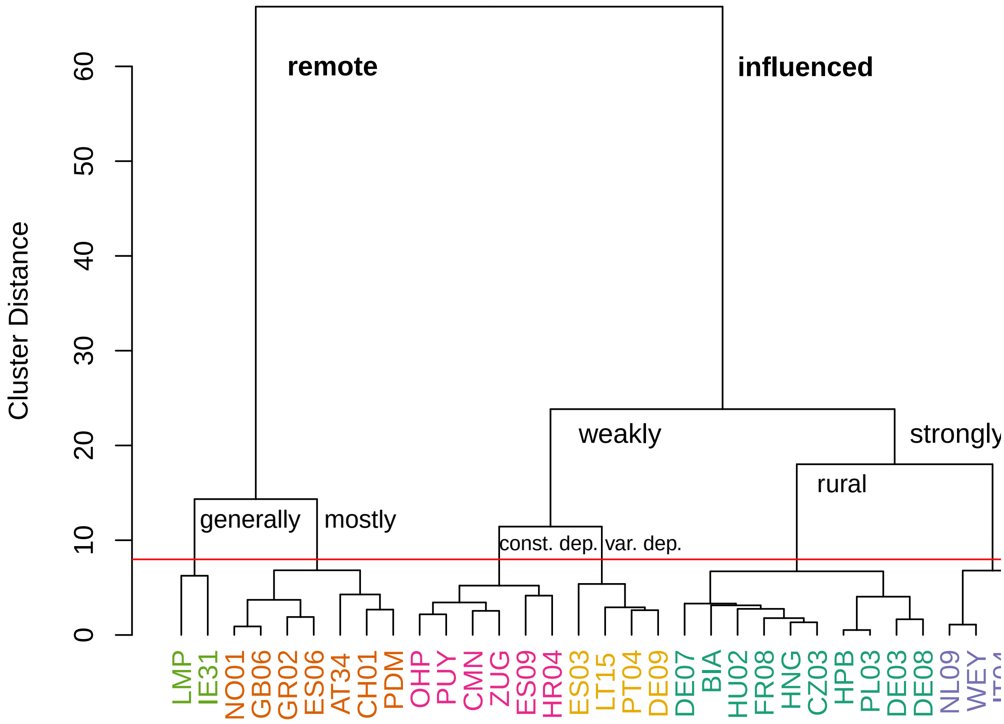

Fig. 1. Clustering dendrogram for site categorisation.