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Interactive comment on "Detecting turbulent structures on single Doppler lidar large datasets: an automated classification method for horizontal scans" *by* Ioannis Cheliotis et al.

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Thank you very much for your comments and for your analytical review. We hope that by addressing your questions we will clarify the aim of this study, as well as our methodology.

Referee comment: As I understand form the first paragraph in the introduction, comprehension of the flow physics it is important for monitoring atmospheric pollution. However, the physics identified here, in the form of coherent structures, are not related with bad pollution conditions, since the latter might fall in the "Other" category, and their physics are not clear from the study. The motivation of the study should be stressed

form the beginning. Only when we arrive to the conclusions we can read some of the potential application of this approach. (line 316 of the text). There are many previous studies on coherent structures, as well as lidar technology, than could be included. The description of the coherent structures that this study aims to identify is a bit vague and needs improvement. In general, the term turbulence and turbulence fields are used frequently in the text, but the range gate resolution of the lidar scanner is 50m at a height of 75m above ground level. Turbulence and its most energetic eddies might fall within this length scale. Almost all turbulence fluctuations are filtered out by the lidar due to spatial averaging. What we can clearly see from lidar observations is medium-to-large scale fluctuations and coherent structures rather than turbulence. The methodology behind data process could be better explained. I miss a paragraph describing how data quality was assured.

Authors' response: We recognize that the first paragraph can be misleading and therefore it will be removed. We will focus only on the effect of turbulent structures in the pollutants' dispersion. In P1 L31-35 the following text will be added: "Several studies have been carried out to examine the effect of the coherent turbulent structures in the dispersion of pollutants by utilizing boundary layer simulations. The results of these studies indicate that the turbulent structures can play a significant role in the pollutants' concentrations (Aouizerats et al., 2011; Soldati, 2005). Furthermore, Sandeepan et al., (2013) have demonstrated via simulations that the pollutants' concentrations can alternate from low to high during coherent turbulent structures events. It is therefore important to be able to identify turbulent structures in the atmosphere and observe them in an efficient and consistent way.". We want to show that it is possible to identify and classify these structures based solely on the patterns from the fluctuations of the radial wind speed data by combining texture analysis and supervised machine learning. For this reason, we will add the following text in the last paragraph: "This study aims to identify the coherent structures on single Doppler lidar horizontal scans and develop an automatic classification process based on the combination of texture analysis and a machine learning technique in order to handle large datasets. There is a lack of long-term studies of coherent structures based on lidar observations and the aforementioned automatic classification process can stimulate the interest in this research field. More particularly, it could facilitate the statistical analysis of the physical parameters of the structures, e. g. the structure size as a function of the planetary boundary layer (PBL) height. Furthermore, it will enable us to study the transitions between structures and how these are associated to the atmospheric conditions. Finally, the impact of the coherent structures on pollutants' dispersion could be examined for long-term studies under stable and unstable conditions." We will replace the term turbulence to the suggested medium-to-large fluctuations and coherent structures (mlf-cs) as we do not observe small scale turbulence and the reader can be confused. Nonetheless, we will state that these stuctures are associated to a turbulent atmosphere. Unfortunately, during the VEGILOT campaign there was no other wind data measurements for comparison. The closest weather station with available data for the same period, as our study, is located in Montsouris, 20 km away from the centre of Paris.

RC: Did you use a CNR/SNR threshold for filtering?

AR: We used the CNR filtering. The radial wind speed values below -27 dB were anomalously high and therefore excluded from the computations. In P4 Line 124 the following sentence will be added "The radial wind speed values for which the carrier-to-noise ratio is lower than -27dB (CNR<-27dB) are disregarded from the study since they were anomalously high, exceeding the values of the rest of the radial wind speed values by two times or higher.".

RC: What was the data recovery rate during the two months of measurements?

AR: The lidar was taking measurements continuously for the two-month period for the scanning sequence presented in Table 2 of the manuscript. There was no pausing of the measurements during this period.

RC: It is not clear from the text how the radial wind speed fluctuations are calculated. What does "stronger radial wind speed" mean? A larger absolute value? It seems to

me that the sign might come from the combination of u and cos (θ). One suggestion is to put this definition as equations.

AR: The radial wind field has values with a positive sign when the wind moves away from the lidar and negative sign when it moves toward the lidar. In order to be consistent throughout the field when we study the fluctuations, we have to make a sign convention that guarantees for example that the radial wind speed with a value of 6 m/s and the radial wind speed with a value of -6 m/s will be part of the same pattern. Therefore, we compared the absolute values and we derive the sign convention of Figure 2b of the manuscript. We will add the following equation in the text as well: u_r'=|u_r (θ)|-|f(θ)|, where f is the fitted function for the corresponding azimuth angle θ.

RC: Since the wind direction is obtained from equation (1) it would be possible to work with the streamwise component u instead of the radial wind speed ur. It is not clear from the results, what is the relative importance of non-distinguishable structures, bad fittings, and bad data (low CNR/SNR signals) in the "Others" category. The authors give some information about what it seems to be the reason of one group of cases to belong to this category (bad fitting of cosine function), but no threshold on this fitting error is given.

AR: We did not perform an extensive analysis of the data for the "Others" category. This category was selected exclusively to separate the not interesting patterns. The bad cases were not selected based on the quality of the fit but rather in the symmetry of the whole radial wind field. For the category "others" in the training ensemble, we selected 53 bad cases with an asymmetrical radial wind field and 7 cases of a symmetrical field where the structures were non-distinguishable. In Figure 3a of the manuscript, it is apparent that the wind field is not symmetrical and that the VAD method would not be applied efficiently. Nevertheless, it can still be applied as you can see in Figure 4 of the supplementary materials (it is the same as Figure 3b of the manuscript along with a cosine fitted function). Since we are interested in the fluctuations (difference between the observation and the fitted curve) it is very difficult to characterize the quality of the fit by using a parameter such as the RMSE that contains these fluctuations. We are currently working on a study for the physical parameters of the structures based on the classification of this study. We found that for 670 out of the 2112 others cases the mean wind speed is lower than 2 m/s. On the other hand, for the streaks it is only 7 out of the 1145 cases, for rolls 0 out of 420 cases and for thermals 67 out of the 900 cases. This is very interesting as the mean wind speed was not one of the classifiers.

RC: I miss more elaboration in the description of the texture parameters used for classification, namely, why they might be relevant and if they were relevant in the end. The feature selection process is also not very clear. Cross validation is well known and well explained, but the text explaining the outcome as well as the figure used in that regard are confusing. A brief description of the machine learning technique used could be useful for clarity.

AR: The description of the texture parameters will be added in the manuscript, in particular: “Correlation indicates the existence of linear structures in the image, with high values associated to a large amount of linear structure in the image. Contrast reveals the local variations in an image, where a large amount of variation leads to high values. Homogeneity is self-explanatory and the high values represent a homogeneous image. Finally, energy measures the uniformity of an image with the highest values corresponding to constant or periodic forms.”. These texture parameters are frequently used in patterns based image classification. As we mention in our manuscript we selected these four parameters inspired by the study of Srivastava et al. (2018). They used the same parameters to distinguish stripes among others patterns. By plotting the texture parameters against the azimuth angle φ (angle of the comparing neighbour points), we observed a prominent peak for the elongated patters when φ is equal to the mean wind direction. The relevant parameters are showcased in Figure 7 of the manuscript. Regarding the feature selection process by the algorithm the following text will be added: ”The greedy algorithm of stepwise forward selection was used in the article, which is the standard and frequently used method of reduction of the fea-

ture space. As indicated in (Sokolov et al., 2020), the feature selection is an iterative procedure when features are divided into two groups - accepted in the classification model and remaining. Features from the second groupset of “remains” are successively added to the model and corresponding classification errors are estimated. The minimum is chosen from the set of error estimations and compared with the error of the previous model, which is based on previously accepted features. If the error reduces significantly, then the corresponding feature is included into the updated model. If the error is not diminishing significantly for any feature from the remaining group then the process stops.” For the specific machine learning technique we utilized, the following will be added in the manuscript: “Quadratic discriminant analysis or normal Bayesian classification (see Hastie et al. 2008) is the parametric approach implying that probability density functions (PDF) belong to the family of normal distributions. It is a classical algorithm of the supervised machine learning, based on the principle of maximum likelihood. The general idea is to estimate the PDF for each class, and then select the most probable class (see Kubat 2017).”

RC:Conclusions section. In my opinion, this section should be read in a positive rather than negative way. Example: it should focus on the relevant parameters discovered (which need a bit more explanation in the corresponding section) rather than the ones excluded by the study. The sections describing the methodology used-which need some improvement-are already clear, and no repetition is needed. Same with the results highlighted.

AR: It is very important for us to stress the positives of this study and therefore we will modify the conclusions to comment on the relevant parameters. The following text will be added in the main part of the manuscript and restated in a modified version in the conclusions: ”The algorithm allowed classifying correctly about 91% of the dataset using five texture analysis parameters as predictors. Analytically these parameters are the amplitude of the 2nd-neighbour homogeneity curve, the integral of the 18th-neihgbour contrast curve, the amplitude of the 4th-neighbour contrast curve, the integral of the 8th-neighbour correlation curve and the symmetry of the 2nd-neigbour homogeneity curve. These results show that the prominent peaks are a distinctive characteristic for the elongated patterns as the amplitude of the homogeneity and contrast curves are two of the significant parameters. Furthermore, the integral or more precisely the sum of the points of the curves for the contrast and for the correlation curves are significant parameters as well. This is important especially for the distinction between the categories thermals and "others" as their amplitude may not differ substantially since the patterns are not towards a specific direction, yet a chaotic area will have higher values of contrast and lower values of correlation compared to an enclosed homogeneous area. Finally, the symmetry of the homogeneity curve as a classifier reveal the urgency to align the radial turbulent wind fields to the mean wind direction and thus align the structures such as streaks and rolls with the mean wind direction in order to be distinguishable from the random positions of the enclosed structures of the thermals or the chaotic structures of the "others". It is also crucial to note that the parameters cover various distances, from the 2nd-neighbour, which in grid points is 100 m to the 18th-neighbour which is 900 m. This is necessary for our classification since streaks and rolls are both elongated patterns but their transverse horizontal sizes differ."

RC: 2 Specific comments Page 1 Line 12. Change "manually" to "visually".

AR: In P1 line 12 the word "visually" will replace the initial "manually".

RC: Page 1 Line 15. Change "and installed" to "installed".

AR: In P1 line 15 the word "and" will be removed with the phrase now reading "by a scanning Doppler lidar (LEOSPHERE WLS100) installed".

Page 1 Line 16. It would be better to reword this sentence, maybe "The turbulent component of radial wind speed is estimated using. . .over 4577 scans.

In P1 line 16 the sentence "The lidar recorded 4577 quasi-horizontal scans for which the turbulent component of the radial wind speed was determined using the veloc-

ity azimuth display method." will be rephrased to "The turbulent component of radial wind speed is estimated using the velocity azimuth display method over 4577 quasi-horizontal scans.".

RC: Page 1 Line 18-21. I am not sure what the sentence describing the training set adds to the abstract if not combined with the next one. It is better to state directly the unsupervised algorithm used instead of using parenthesis. It might be better to rephrase this in a more concise way.

AR: In P1 lines 17-21 the text "The differences between the three types of structures were highlighted by enhancing the contrast of the images and computing four texture parameters (correlation, contrast, homogeneity and energy) that were provided to the supervised machine learning algorithm (quadratic discriminate analysis)." will be rephrased to "The differences between the three types of structures were highlighted by enhancing the contrast of the images and computing four texture parameters (correlation, contrast, homogeneity and energy) that were provided to the supervised machine learning algorithm, namely the quadratic discriminate analysis. The algorithm was able to classify successfully about 91% of the cases based solely on the texture analysis parameters. In particular, the algorithm performed best for the streaks structures with a classification error equivalent to 3.3%.".

RC: Page 1 Line 23. What are the remaining 20

AR: The remaining 20% are the unaligned thermals. We wanted to highlight the results only for the rolls and streaks as we find in literature that the majority of the studies focus on these two types of coherent structures.

RC: Page 2 Line 26. Change "step for" to "step towards".

AR: We will remove the first paragraph of the introduction and instead address only the impact of turbulent structures on pollutants' dispersion.

RC: Page 2 Line 32. A coherent structure is defined according to its phase-averaged rather than its instantaneous vorticity. I also suggest moving the Hussain 1983 reference to this sentence. A coherent structure needs to maintain its phase-averaged vorticity rather than its time-averaged vorticity or form.

AR: Thank you very much for this comment. In P2 line 32 the adverb “instantaneously” was referring to the phase-averaged vorticity. In order to avoid confusion, the text in P2 lines 32-34: “The principal aspect that determines a coherent structure is the instantaneously space and phase correlated vorticity of the turbulent fluid mass over the spatial extend of the flow structure. Furthermore, a coherent structure must maintain its form for a time period sufficient for time-averaged statistics calculations (Hussain, 1983).” will be rephrased to “The principal aspect that determines a coherent structure is the maintenance of the phase-averaged vorticity of the turbulent fluid mass over the spatial extend of the flow structure (Hussain, 1983).”.

RC: Page 2 Line 35. Please specify that this is the case of atmospheric flow. Other structures are observed at laboratory scale (also in the atmosphere but not so relevant for momentum or scalar fluxes), like hairpins, or hairpin trains. Include a reference to Hutchins and Marusic (2006) and Adrian (2007).

AR: It is definitely a good idea to specify that this study is related to the atmospheric flow. We will briefly mention laboratory experiments including references such as Hutchins and Marusic (2006) and Adrian (2007).

RC: Page 2 lines 37-44. Consider reordering the sentences here for a more fluent reading. Maybe starting the paragraph from sentence in line 41?

AR: It is true that by moving the sentence of line 41 to the beginning, the text becomes more fluent so we will apply this suggestion.

RC: Page 2 line 45. How is it that you identify rolls in the mixed layer, with sizes from few to dozen kilometers, with scans at surface layer height (75m) with spatial coverage of less than 2 kilometers?. Is this description coherent with what you are identifying?

AR: In the introduction we give general information about the rolls and we think it is important to address their scale. We will state in our data that the structures we observe are near the surface so at the base of the rolls.

RC: Page 2 lines 57-65. Since you are using lidar instead of radars it would be better to shorten the scanning pattern description using some of the given references, since they have to do only with the history on scanning patterns. There are more recent references of this regarding lidars. Cariou (2007) and Vasiljevic (2016).

AR: Thank you very much for the suggested references. We will include them in our study along with other studies for turbulent structures, such as Newsom et al (2008), Lin et al (2008) and more. The Cariou (2007) reference will also replace the initial “Kumer et al. (2014) and Veselovskii et al. (2016)” references as we realized that it is more relevant for the sentence: “The Doppler shift frequency between the emitted laser beam and the light backscattered by the aerosols is measured by heterodyne detection associated with Fast Fourier Transform as explained analytically by Cariou et al (2007)”.

RC: Page 3 line 72. Replace “by eye” by “visual inspection” or similar.

AR: In P3 line 72 the phrase “visual observation” will replace the initial “by eye”.

RC: Page 3 line 73. More than time-consuming, it might be non-systematic.

AR: This is a very powerful way to phrase it in order to show why it is important to develop an automatic method for the classification. We will include this term in our manuscript.

RC: Page 3 line 74. You meant “A less time-consuming” approach? What height was the met mast?

AR: The term less expensive refers to the sonic anemometers themselves without including the met mast. The data for the Barthlott et al (2007) study was taken at a 30 m tower.

RC: Page 3 line 78. “This study aims to identify turbulent coherent structures from single Doppler lidar horizontal scans”. Also, please introduce here what is texture analysis (roughly maybe) and what what machine learning technique you are using.

AR: Regarding the texture analysis, we will add the following text: ”Texture analysis is an effective way to evaluate the distribution of the values within an image (Castellano et al. 2004). It is widely used for varying scientific fields in order to classify images, covering meteorology (Alparone et al., 1990), medical studies (Holli et al., 2010) and forestry (Kayitakire et al. 2006).” For the machine learning technique, we will add the following text: “Quadratic discriminant analysis or normal Bayesian classification (see Hastie et al. 2008) is the parametric approach implying that probability density functions (PDF) belong to the family of normal distributions. It is a classical algorithm of the supervised machine learning, based on the principle of maximum likelihood. The general idea is to estimate the PDF for each class, and then select the most probable class (see Kubat 2017).”

RC: Page 3 line 83. Section 0 must read section 3, here and in the rest of the text.

AR: “Section 3” will replace “Section 0” throughout the text.

RC: Page 3 line 86-91. It should read “measurement campaign”. Move “in Paris” to the end of the sentence, modified to “in the urban area of Paris”. Remove the url of leosphere to the reference section maybe. More than only sensitive to the radial component, the lidar does measure and it is intended to measure only the radial component. Lidars technology and its operation principle is well known, use references (Cariou, maybe write ts paragraph in amore concise way, being specific in the corresponding table than in the text here, which is a bit confusing.

AR: In P3 line 86 the phrase “A two-month measurement campaign” will replace the initial “A two-months campaign”. The phrase “in the urban area of Paris” will also be inserted in P3 line 88. The Cariou (2007) reference will also replace the initial “Kumer et al. (2014) and Veselovskii et al. (2016)”.

RC: Page 3 line 101. I would say fast instead of short. Also, what type of structures and why this time window?

AR: We refer to coherent structures, in P3 line 101 the sentence “The duration of each scan was 3 minutes which is sufficiently fast for the observation of coherent structures, as their lifespan is several minutes.” will replace the initial “The duration of each scan was 3 minutes which is sufficiently short for the observation of structures.”. The time-window of 3 min is the result of the selection of the 2° azimuth angle resolution. We wanted to combine a high spatial resolution with a time-window that would allow us to observe coherent structures.

RC: Page 4 line 121. What is the reason behind a is small for your case?.

AR: The parameter a is associated to the vertical wind speed, more particularly with the parameter w*cos(phi) of the radial wind speed analysed in its' wind components for a line of sight beam with azimuth angle theta and elevation angle phi: Vr=u*cos(theta)*sin(phi)+v*sin(theta)*sin(phi)+w*cos(phi), where u is the longitudinal, v is the transverse and w is the vertical wind component respectively. The offset is associated to the parameter w*cos(phi) (Thubois et al. 2018, Study of the configurations and scanning strategies of Doppler Lidars for providing wind and aerosol/cloud profiles). In our case the elevation angle is only 1° thus a is around 10 times smaller than the parameter b throughout our data.

RC: Page 5 Figure 2. Why the reach of the lidar is 2 km and no 5 km?.

AR: Due to the CNR<-27dB filtering.

RC: Page 5 line 134. Is it possible to specify the fraction of cases with low winds, and its relative importance to the number of bad fittings?. I miss an analysis of stability conditions, since it seems that stable conditions affect the most.

AR: As we mentioned previously, we examine the symmetry of the radial wind field rather than the individual bad fit for each ring. We are currently working on a separate study for the physical properties of the structures and the atmospheric conditions under their occurrences. We are interested in this result as well, however we have not finished the study yet. Nonetheless, the preliminary results show that low winds (<2 m/s) are the main cause for non-symmetric radial wind fields.

RC: Page 6 line 143. Actually, for rolls, it is the opposite. Ascending motions bring low momentum to higher levels, reducing the speed, and vice versa.

AR: This was a mistake. It will be corrected.

RC: Page 6 line 146. Since rolls and streaks both present areas of alternating low/high momentum with elongated shape, their main difference is their extent. What is the criteria to differentiate between them? The clouds formation shape from MODIS was used, as I understand, only for a fraction of the cases included in the training dataset.

AR: For the training ensemble we combined the patterns of the fluctuations of the radial wind speed field with physical characteristics that indicate the existence of a structure. For streaks we selected cases with wind shear higher than 2 s-1 near the surface and for rolls, cases when clouds streets were formed over Paris as observed from MODIS satellite images. Due to the scarcity of satellite data, in order to select 30 cases of rolls we also included the consecutive cases of the cloud streets ones, as long as the patterns persisted.

RC: Page 6 line 161-165. Wind shear is defined as du/dz with 1/s units, could you clarify what definition you are using here? Additionally, streaks are present in turbulent flow as well, beyond stable conditions, why do you focus in cases with low turbulence energy (stable conditions)? It seems that high shear due to jets is only one among several mechanisms.

AR: The units will be corrected to 1/s. For the computation of the horizontal wind, we used the DBS observations. In particular the horizontal wind was computed by the formula: V_hor=$\sqrt{}$(uˆ2+vˆ2), where u is the zonal and v is the meridional winds.

The wind shear was estimated from the vertical profile of V_hor. We only used night streaks because the wind shear is a clear indication for the existence of streaks. As the algorithm only uses the five texture analysis parameters for the classification (Figure 7 of the manuscript), it shouldn't affect the results.

RC: Page 6 line 166. How many cases did you use for the "Other" category? From table 5 seems that they are around 60, the double. What is the reason for such big number?. Can this influence the final classification output? This is explained in section 4, but it should be clear from here.

AR: We used 60 cases which is double compared to the rest. The reason is that some of the machine learning algorithms are sensitive to the balance of classes in the training data (see Kubat 2017, p 194). If one category is dominant but for the training ensemble all categories are represented by the same number of cases, then the algorithm can overestimate or underestimate a category. Nevertheless, we also tried a training ensemble with all the categories represented by 30 cases and the results were similar.

RC: Page 7 Figure 4. What is the scale of map in (d) and (e)?

AR: We will add the scanning area in the images. Please see Figure 5 of the supplementary material.

RC: Page 7 line 176. Could you introduce what texture analysis is first? Additionally, since "Others" had a poor fitting and then uncertain wind direction, how did you align them with 0 degrees?

AR: As we mentioned above we will include a brief description of the texture analysis in the introduction. The VAD method was used even for the bad cases, as the radial wind field in this case fell in the category of not interesting. Please see Figure 6 of the supplementary materials where it is still possible to fit a cosine function even for a bad fit and how the radial turbulent wind field looks in that case in Figure 4 of the supplementary materials.

RC: Page 7 line 180. Eight bins were chosen for increased contrast. Why eight?, could you develop more on this?. What is the effect of the number of bins in the output?

AR: The scope was to enhance the contrast of the structures for a better visualization of the alternating positive and negative areas in the radial turbulent wind field. The selection of only 2 bins (one positive, one negative) was not very successful and gave a classification error of approximately 18%. In this case the co-occurrence matrix was 2 by 2. It apparent from Equations 2,3 and 4 that the distance between the bins i,j hence the algorithm could not classify the structures quite successfully based on the texture analysis parameters. Similarly, with the selection of the 4 bins (one bin including all the negative values below -0.5 m/s, one bin between -0.5 m/s and 0, one bin between 0 and +0.5 m/s and one bin including all the positive values above +0.5 m/s), we did not really manage to improve the results with the error remaining around 18%. Only when we selected 8 bins we succeeded in reducing the error significantly. The selection of one bin including all the negative values below -0.5 m/s, six bins equally distributed between -0.5 m/s and +0.5 m/s and one bin including all the positive values above +0.5 m/s allows us to enhance the difference between the positive and negative values while keeping the distance between the bins i,j. We selected the values 0.5 as the limit in order to well separate the positive and negative values while having some information near 0. We also tested the limit with 1 and -1 m/s and the classification error was above 14%. We did not increase the number of bins to more than 8 bins because we think that the increase of the number of bins near 0 will not improve the classification error. However, we are interested in the future to develop an algorithm that finds the optimal selection of the bins' limits in order to minimize the classification error.

RC: Page 8 line 185. The procedure for the construction of the CM matrix is a bit confusing. Could you write it in a more concise way?

AR: In P8 line 188 the following sentence "The rows and columns of the CM represent the different wind levels from 1 to 8, whereas the cells contain the frequency of the combination of two neighbour pixels in the image" will replace the initial "The rows and

columns of the CM represent the wind levels from 1 to 8, whereas the cells contain the number of occurrences of neighbour pairs with values corresponding to the row and column index.".

RC: Page 9 line 212. Is it possible to elaborate more on the 4 parameters described?. It is not clear only from the equations what their characteristics are.

AR: The following text will be added in the manuscript: "Correlation indicates the existence of linear structures in the image, with high values associated to a large amount of linear structure in the image. Contrast reveals the local variations in an image, where a large amount of variation leads to high values. Homogeneity is self-explanatory and the high values represent a homogeneous image. Finally, energy measures the uniformity of an image with the highest values corresponding to constant or periodic forms.".

RC: Page 10 Figure 6. The notation of the azimuth angle is different form the text. Why does homogeneity grow after 45 degrees for all categories? The definition of homogeneity says that CMs with large values in the diagonal might result in larger values of this parameter. The diagonal from table 3 to 4 decrease because of azimuth angle. Should homogeneity decrease monotonically from 0 to +/- 90 degrees?. Can you elaborate more on this?. How many cases are represented for each category in the figure? Only one scan? An average from many cases?

AR: The notation of the azimuth angle in the y axis of the Figure 6 will be corrected. The angle also represents the distance between two grid point. For 45° angles or above, the distance between two grid points are n rows whereas below 45° they are n-1, n-2 etc. We have included a pdf file in the supplementary material where we showcase an ideal case. We hope it is clear. Regarding your question whether homogeneity should decrease monotonically from 0 to +/- 90 degrees, the response is that it depends on the case and on the order of the neighbour. When we have elongated patterns then yes we can see the prominent peak at 0° as we see in Figure 6 of the manuscript for the streaks and to some degree for the rolls but not so much for the thermals and the others. Please see also Figure 7 of the supplementary materials where we showcase an ideal case and how the values of the co-occurrence matrix change according to the periodicity of the patterns.

RC: Page 10 line 231. Notation is a bit weird here.

AR: The maximum and minimum refer to the azimuth angle φ. Maybe it would be more clear if written as follows: Hom.Amp(n)=max_φ(Hom(φ,n))-min_φ(Hom(φ,n))

RC: Page 10 line 241. The description of the training set might be better place in section 3. Why is it expected that "other" category should double the rest? Please elaborate more on this.

AR: The preliminary analysis of patterns showed that "others" class is approximately twice abounded than each other class. We decided to double the number of examples "others" class in the training dataset, as some of machine learning algorithms are sensitive to the balance of classes in the training data (see Kubat 2017, p 194).

RC: Page 11 Figure 7. This figure is very confusing and not self-explanatory at all. Please give more information in its caption, relative to the number in parenthesis (neighbor order I suppose), state that they are all or a few of the final parameters used.

AR: In P 11 Figure 7 the following caption will be added: "Parameters selected to minimize the classification error by the QDA method. From left to right: Amplitude of the homogeneity for the 2nd neighbour, integral of the contrast for the 18th neighbour, amplitude of the contrast for the 4th neighbour, integral of the correlation of the 8th neighbour and symmetry of the homogeneity for the 2nd neighbour. " will replace the initial "Figure 7: Texture analysis parameters selected to minimize the classification error of the training ensemble by the QDA method.".

RC: Page 12 Table 5. Change "eye-made" to a better term, like visual classification or similar.

AR: In P 12 Table 5 the word "visual" will replace the initial "eye-made".

RC: Page 12 line 286. It is not clear if streaks were also detected during daytime, since the previous definition of the training set (line 162) says only night-time, but figure 9 says the opposite. Same for rolls and thermals. In summary, the constraint you talk about (day-time rolls and thermals, night-time streaks) does concern only the training set definition?

AR: Up until Figure 7 of the manuscript we showed the results for the training ensemble, where we only considered rolls and thermals during the day and streaks during the night. So the classification error of the algorithm in Figure 7 refers to the training ensemble. The algorithm was able to classify our training ensemble successfully for approximately 91% for the texture analysis parameters of Figure 7. Then we use these parameters to classify all the 4577 scans and the results are presented in Figures 8 and 9 of the manuscript, thus we detect streaks during the day and thermals and rolls during the night.

RC: Page 12 line 292. If I am correct, you tried to explain thermals during night, not others during days. Only the last word in the sentence, "reverse", explains this. Moreover, can you elaborate more on what is the reason behind the erroneous classification of thermal as "others"? During stable conditions turbulent eddies are smaller, structures also show smaller length-scales. However, mean wind can show slight differences with no directional preference, and they can look like thermals (see Shah and Bou-Zeid, 2014).

AR: The category "others" includes the patterns that cannot be classified to one of the three turbulent structures type. It is possible to have a not symmetrical wind field, thus a bad case, during the day as well. In fact, 10 bad cases of the training ensemble for the category "others" occurred during the day. The physics behind the misclassification are very interesting and we are thankful for this insight. However, in our case the misclassification is linked to the shape of the patterns. It is possible that another texture analysis parameter could improve the distinction between these two types.

RC: Page 13 line 295. Stable cases during night show buoyant forces opposing vertical momentum flux and turbulence generation. Mechanical turbulence does die out under stable conditions. Mechanical turbulence destruction by buoyancy is the dominant mechanism, not the opposite.

AR: This is true. We should probably have added in the text that we observe wind shear higher than 2 s-1 near the surface for at least 20 of the 62 days under study. This is the reason we expected the high number of occurrences for streaks during the night.

RC: Page 13 line 314. So thermals are not turbulent?. Why do you separate rolls and steaks form thermals? Does it has to do with pollution transport or something similar?

AR: Rolls and streaks are the focus on many boundary layer studies. In the specific sentence, we wanted to emphasize the regularity of observing coherent structures over Paris during the period of our study. Moreover, in the study we are currently working on with regards to the physics of the structures, the transition between the structures for particular cases (e.g. low level jets, cloud streets etc.) will be one of the focal points.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2020-82, 2020.

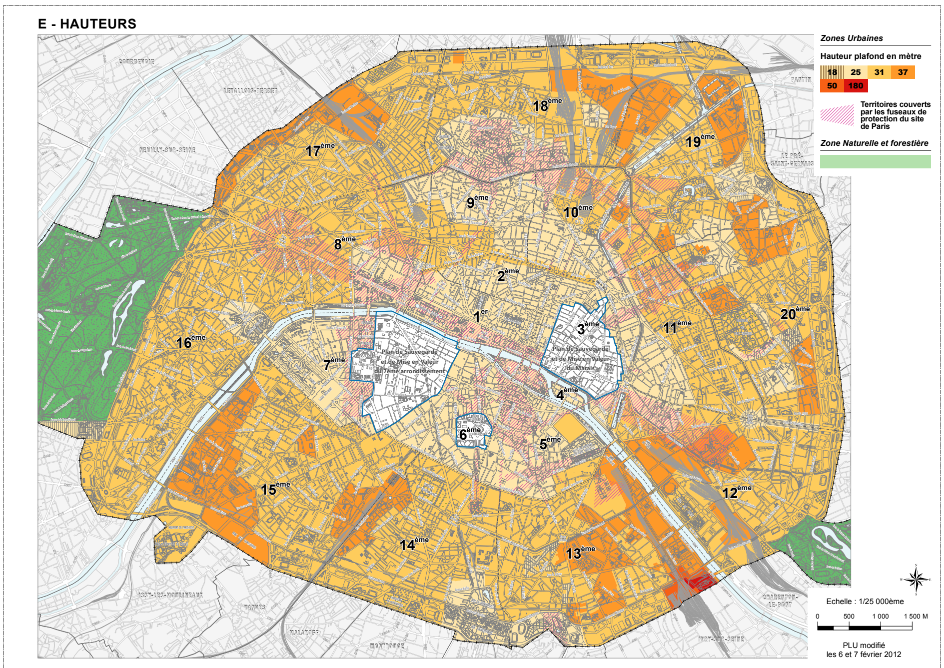

Fig. 1.

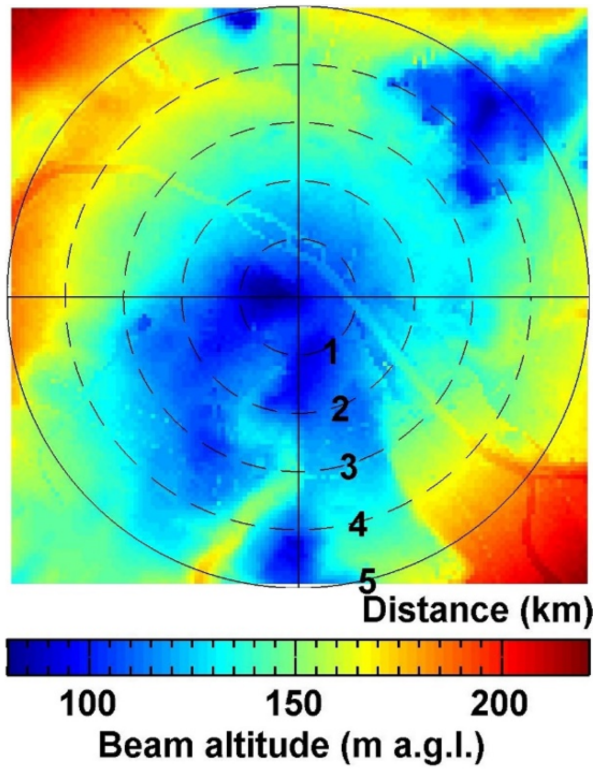
1
2
3
4
5
Distance (km)
100
150
200
Beam altitude (m a.g.l.)

Fig. 2.

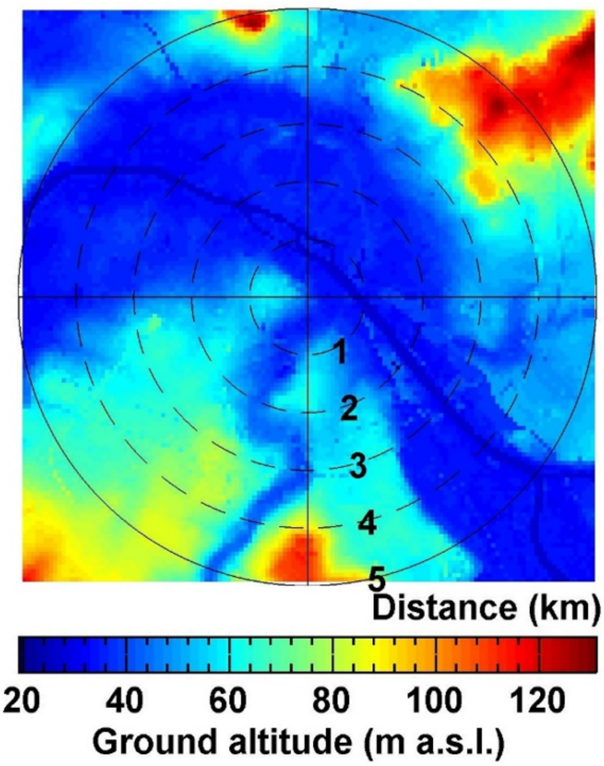
1
2
3
4
5
Distance (km)
20
40
60
80
100
120
Ground altitude (m a.s.l.)

Fig. 3.

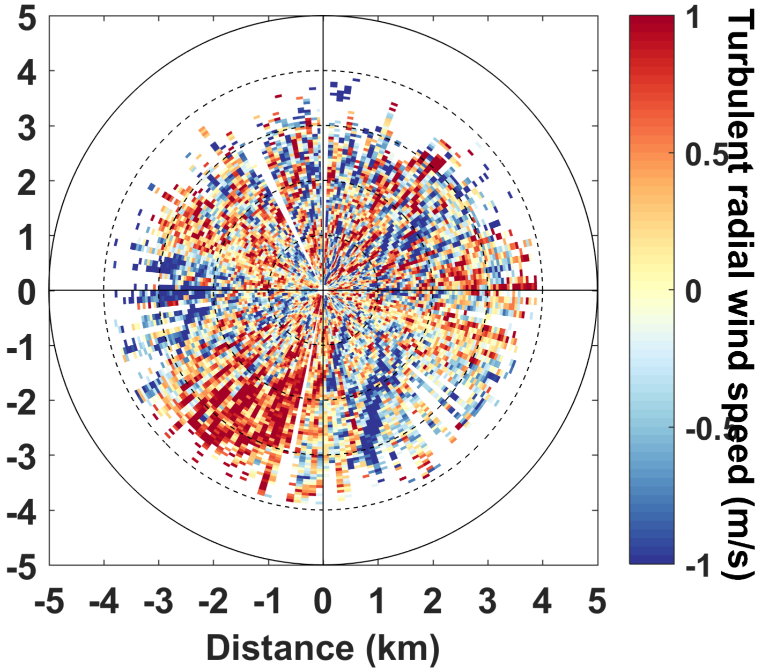

Fig. 4.

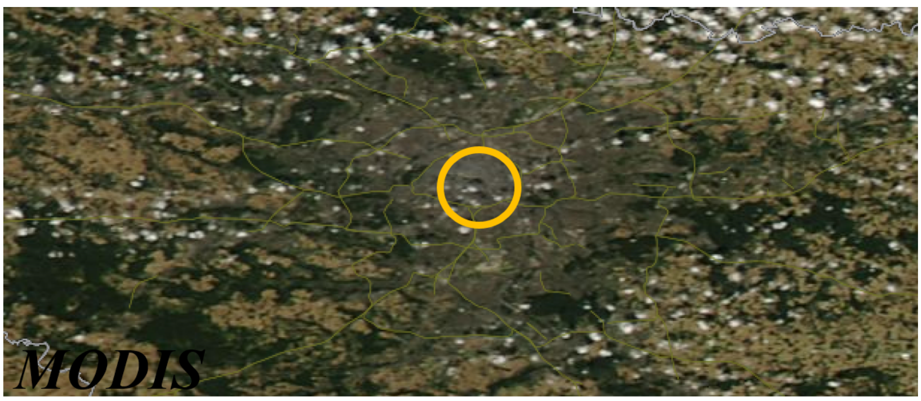

Fig. 5.

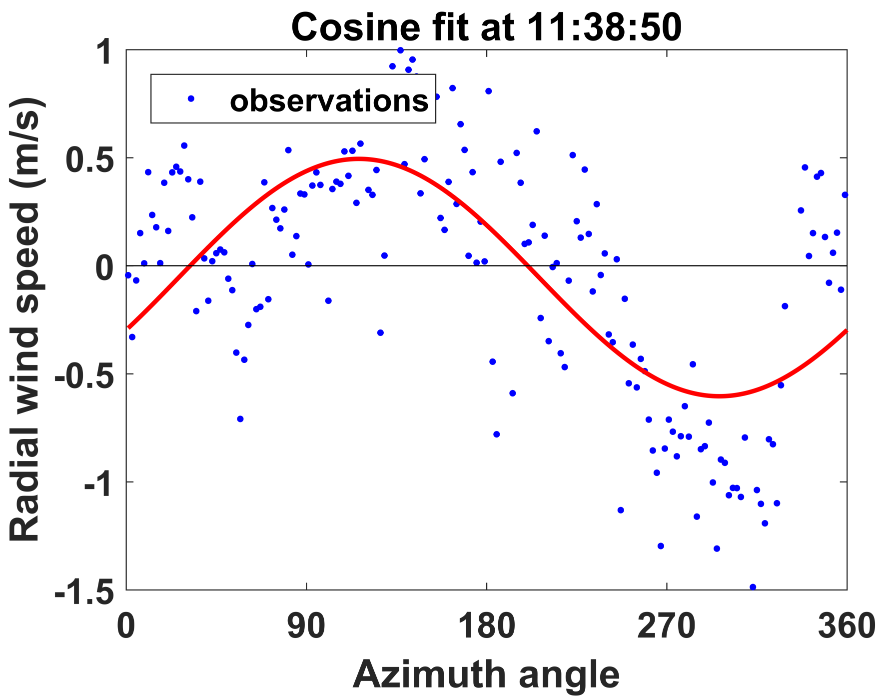
Cosine fit at 11:38:50
observations
Radial wind speed (m/s)
1
0.5
0
-0.5
-1
-1.5
0
90
180
270
360
Azimuth angle

Fig. 6.

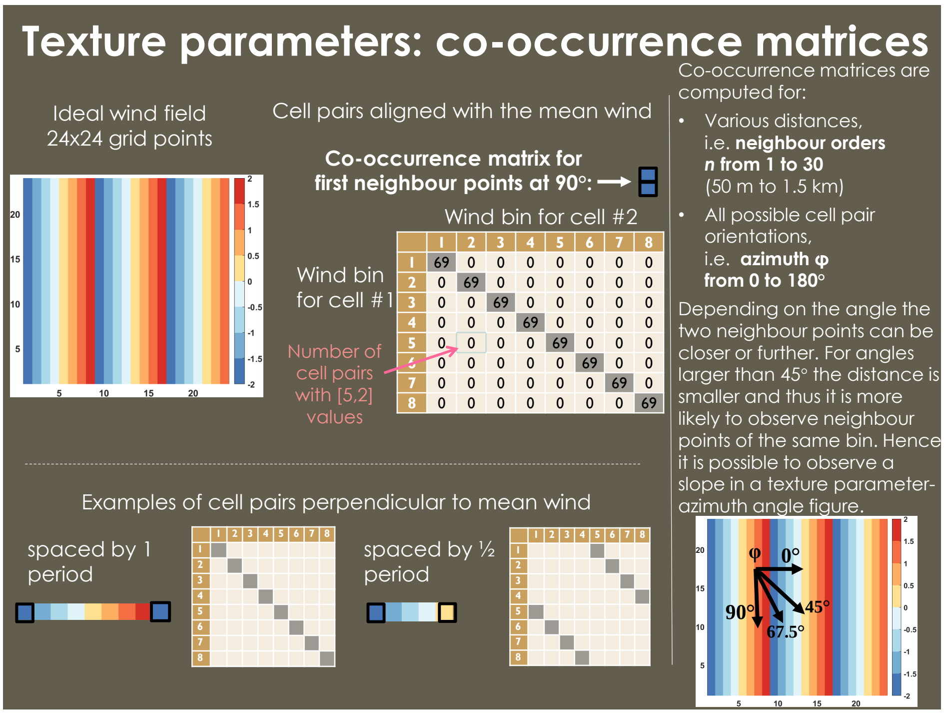
Texture parameters: co-occurrence matrices
Ideal wind field
24x24 grid points
Cell pairs aligned with the mean wind
Co-occurrence matrix for
first neighbour points at 90°:
Wind bin for cell #2
Wind bin
for cell #1
Number of
cell pairs
with [5,2]
values
Co-occurrence matrices are computed for:
• Various distances, i.e. neighbour orders n from 1 to 30 (50 m to 1.5 km)
• All possible cell pair orientations, i.e. azimuth φ from 0 to 180°
Depending on the angle the two neighbour points can be closer or further. For angles larger than 45° the distance is smaller and thus it is more likely to observe neighbour points of the same bin. Hence it is possible to observe a slope in a texture parameter-azimuth angle figure.
Examples of cell pairs perpendicular to mean wind
spaced by 1
period
spaced by ½
period
φ
0°
45°
67.5°
90°

Fig. 7.