Answers to RC1

The manuscript "Observing atmospheric convection with dual-scanning lidars" by Duscha et al. introduces a lidar measurement and data processing approach for the observation of atmospheric convection. Principles of the introduced approach were tested in two experimental campaigns, allowing for the conclusion that the approach is suitable for the defined objective.

The manuscript is generally well written and describes both the proposed methodology and the obtained results in more than sufficient detail. Stating this, however, I have found two major points of critique which should be addressed for the manuscript to be acceptable for publication:

1. *The (final) measurement approach is proposed as being optimal for the objective. This is described in much detail but, I think, it would be very helpful to also introduce a clear set of criteria the evaluations of which allows this conclusion. I understand that a verification is very difficult but I wounder if the authors can find some other performance criteria that may underline the superiority of the methodology.*

Answer: Thank you very much for this suggestion. We have formulated the following performance criteria to clarify the goal of the study.

- During convective conditions, the approach should capture convection. To be precise, the dual-lidar cross-section should intersect the flow field of convective structures throughout the structures' life cycle
- The retrieved flow field must provide the basis for a clear identification of convective parameters that can be used to make meteorological implications about the convective structure and the convective boundary layer. To achieve this, the approach must achieve:
- Spatial resolution: The approach should resolve convective circulation, present in the convective boundary layer in sufficient detail.
- Spatial continuity: Given the resolved convective structure, the discrete points should describe a continuous flow field, undisturbed by noisy or erroneous features
- Spatial coverage: To cover a convective structure an entire wavelength of the structure should be within the analysis domain.
- Temporal resolution: Provided sufficient spatial resolution, coverage and continuity, the approach should capture major changes in the convective circulation (e.g. clear distinction of onset/break down/different phases)

As convection has only been observed in sufficient time resolution by point or along profile/ horizontal line (which limits the information on the convective structure), successfully adding a spatial dimension is the superiority to proof. Utilizing the two processing procedures enables the dual-lidar setup to achieve the above defined performance criteria.

To point out the goal (behind the performance criteria) of the study, we include the following sentence to the first paragraph of the Introduction:

"This study aims to provide a combined measurement and processing technique to achieve observations that cover the spatial and temporal scales necessary to resolve convection."

Further, we propose to edit the paragraph in the Introduction starting with "Motivated by […]" and include the criteria defined above.

"Motivated by the shortcomings of earlier attempts, we develop and optimize a methodology for the use of dual-scanning Doppler lidars to probe the atmospheric convection. Superior to conventional meteorological instrument setups, this dual-lidar approach extends the observations of the convective boundary layer by a spatial dimension. As the main goal of the study, we investigate the performance of the proposed measurement and processing technique to capture convective structures and resolve essential characteristics of the convective flow field sufficiently in space and time. We define the following criteria to achieve this goal: The dual-lidar retrieval should resolve convective circulation in sufficient detail on the cartesian retrieval grid; The retrieval section should extend at least over one wavelength of the convective circulation, such that both up- and downdraft are captured; The retrieval of the flow field should be continuous, undisturbed by noise or erroneous features; Though the emphasis is on the performance of the approach in space, it should not be at the cost of sufficient temporal resolution needed to describe the evolution of the convective circulation. We evaluate the performance of the proposed dual-lidar approach and evaluate the benefit of improved filtering and temporal interpolation of the lidar scans, as a proof-of-concept based on two cases obtained during convective days at two small airports in Norway."

In the conclusion, we state the performance corresponding to each of the defined criteria for each test case (See the answer to last comment).

In addition to this, the wording may be adjusted at some points in the text: only in l. 420 the study is referred to as "proof-of-concept", for instance. In the abstract (l. 7) it says the setup was "tested" but it is unclear here if this is already a demonstration. Maybe "proof-of-concept" is also a better term here – however, it should be clarified then if the used parameters (lidar settings) are considered already an optimal solution which should be recommended also for future studies of this style.

Answer: See answers to minor comments

2. *The structure is in my opinion not sufficiently clear. Some sub-sections may be introduced better or re-arranged – see my following comments for some suggestions.*

Answer: Thank you very much for your suggestions, we edited the manuscript, based on your comments as follows:

Minor comments (in order of their appearance in manuscript):

(l. 3) It is not clear to me what the "novel [..] approach" comprises – e.g., using two scanning lidars, their scan strategies, detailed timing of scans, data filtering, and/or reconstruction. This should be further specified not least to justify the term "novel".

Answer: The novelty of the method is to observe convection using the dual-scanning lidar approach (with settings optimized for this purpose) combined with a data filtering approach (which has not been used for this purpose before) and temporal interpolation. Convection has not been sampled in this way, which enables time series of near-instantaneous, two-dimensional cross-sections through convective cells.

As the abstract has only a limited number of allowed words, we clarify this fact in the introduction (see comment to l.20) and remove “novel” from the abstract.

(l. 7) Here it is not clear what “tested” really means – e.g., demonstration, verification or just proof-of-concept.

Answer: It is both a demonstration and a proof-of-concept. We demonstrated the methodology with the help of two case studies. We prove that we can meet the requirements in terms of temporal and spatial resolution and representation for these two case studies with the chosen settings. For verification, observations of similar (or higher) coverage, spatial and temporal resolution are required, yet to our knowledge there is no state-of-the-art measurement technique presented in the literature that the presented approach could be verified with.

To clarify this, we’ve changed the corresponding sentence in the abstract to:

“We deployed the dual-lidar setup at two Norwegian airfields in a different geographic setting and demonstrate its capabilities as a proof-of-concept.”

(l. 8) What are the two (“both”) pre-processing procedures referred to here?

Answer: “Both” refers to data filtering and temporal interpolation. These terms are introduced as pre-processing procedures in l.3-l.4. To avoid confusion, we replaced “Both pre-processing procedures” by “The advanced data filtering and temporal interpolation approaches”.

(l. 20) Not sure I understand what “resort” here means. Please be more specific.

Answer: “to resort to sth” as it is used here is a synonym/more specific term for “use”.

We specify the paragraph, changing it from:

“Given the complex three-dimensional and short-lived nature of convection, conventional meteorological instrumentation is often unsuitable (Kunkel et al., 1977; Geerts et al., 2018) and we have to resort to Large-Eddy Simulations (LES) to constrain and validate parametrizations (Brown et al.,2002; Siebesma et al., 2007). Hence, there is a demand for high-resolution and long-term observations of the multi-dimensional character of convection to reveal its structural evolution. Here, we propose and assess a setup for such observations based on dual-scanning lidars.”

To:

“Conventional meteorological instrumentation usually provides in situ point measurements, profiles (meteorological masts, radiosondes, or ground-based remote sensing) or measurements along an aircraft track of limited spatio-temporal resolution and coverage. Given the complex three-dimensional and short-lived nature of convection, such conventional instrumentation setups are often unsuitable to be used to constrain or validate convection parameterization schemes (Kunkel et al., 1977; Geerts et al., 2018). Instead, we must resort to Large-Eddy Simulations (LES) that resolve the three-dimensional dynamics of convection to guide such parametrizations (Brown et al.,2002; Siebesma et al., 2007). Yet, also LESs used to constrain the convection parametrization schemes lack sophisticated observations to be validated against. Hence, there is a demand for high-resolution and long-term observations of the multi-dimensional character of convection. This study aims to provide a combined measurement and processing technique to achieve observations that cover the spatial and temporal scales necessary to resolve convection. Here, we propose and assess a novel methodology based on a dual-scanning lidar retrieval combined with an advanced filtering and a temporal interpolation approach."

(Introduction – in general) *Generally, the Introduction could be better structure. In (l. 36) I'd propose to insert a "Here, .. [we propose]" but I also think that literature review and components of new study are too much mixed – so better move this sentence to another place.*

Answer: Here, we put our study into the perspective of past studies to highlight what is new in the study compared to previous work. Hence, we would like to keep this sentence in its original place. The sentence also forms a bridge to the subsequent paragraph. To differentiate stronger between our own study and past studies, we begin the sentence with "In our study, […]"

The last paragraph (starting l. 60) reads like a conclusion; instead, I'd propose to introduce the structure of the manuscript here.

Answer: The last paragraph gives an outlook on how a successful performance of the proposed algorithm can contribute to solving current problems corresponding to atmospheric convection. This can but does not necessarily need to be a part of the introduction. Given the relevance of this information, we decided to merge the paragraph into the conclusions.

Introducing the manuscript's structure at the end is a matter of style. Most of the structure of the manuscript is already introduced in the paragraph starting with "Motivated by the shortcomings […]". We prefer not to duplicate this information and hence we prefer to leave the introduction of the structure of the manuscript out. The reader can easily navigate the manuscript through the section headings.

(l. 62) Should be "parametrization schemes" (no "s").

Answer: Done

(l. 67) Introduce short intro text to section between section and sub-section heading.

Answer: We've formulated the following introduction to the section:

"The data collected for this study originates from an experimental setup of similar composites at two sites. The instrumentation installed at these two sites, the measurement strategy of the lidars, which are the main instrumentation of the setup, and the challenges, which were met during the experiment at each site are introduced in the following sections."

(l. 117) Delete "a".

***Answer**: Done*

(l. 121) Delete "out".

***Answer**: Done*

(l. 125) DBS scan was already mentioned above, so maybe no need to detail it again.

Answer: Here we specify the position of the DBS scan within the schedule, which has not been defined in the first paragraph of subsection 2.3. We hence decided to keep this statement about the DBS schedule.

(l. 141) Add "in [Sect. 6]".

Answer: Done

(ll. 158) Also introduce sub-section (with their numbers) here.

Answer: This section is already introduced. From our perspective, the subsection titles should be sufficient to introduce and summarize the section's content. Citing the subsection numbers in the section's introduction is again a matter of style, which should be decided by the editor.

(ll. 289) Also introduce sub-section (with their numbers) here.

Answer: See comment above

(l. 335) I believe "1" and "2" should be indices/sub-scripts.

Answer: That is correct, we have now used 1 and 2 as subscripts here.

(ll. 362) Also introduce sub-section (with their numbers) here.

Answer: See comment above

(ll. 415) Also introduce sub-section (with their numbers) here.

Answer: See comment above

(Figure 6 -- caption)   "Diurnal"

Answer: Done

(l. 568) I'd suggest to add "Discussion" to the section title.

Answer: We specified the discussed topics in the respective subsection titles and in the introduction to the section, and renamed the Section to "Discussion"

The introduction to the section: " In the following we discuss the performance of the presented approach and its potential and limitations to sample convection in instantaneous cross-section of high temporal and spatial resolution. We also discuss and summarize our experiences gained throughout the two presented case studies and interpret the local variability of the convective properties for the two selected sites, as well as the benefit of complementary meteorological observations."

This section is quite lengthy; I'd suggest to add a sub-structure / sub-sections levels to it.

Answer: Thank you for this suggestion. We shortened the section, by removing information, which we found to be of minor relevance at this point of the manuscript and by merging redundant paragraphs. Further, we restructured the order of some of the section's paragraphs to include fitting subsection titles:

7.1 Lidar setup

7.2 Retrieval and Processing

7.3 Spatial and temporal resolution

7.4 Local variability of convective properties

7.5 Complementary meteorological observations

(l. 685) Please specify here (again) what the proposed setup comprises – see my comment above.

Answer: We include specific statements of the performance of the presented methodology to the conclusions section corresponding to the criteria defined above:

“We demonstrated that our dual-lidar setup and retrieval approach captures the flow field of convective structures projected onto a two-dimensional plane for a clear-sky and a cloud-topped case at two independent sites.

All tested angular resolutions yielded sufficient spatial resolution to resolve the details of the convective circulation, allowing to prioritize an increased temporal resolution. To ensure that the setup captures at least one wavelength of the convective circulation at any point in time, the distance between the two lidars should be increased compared to the presented setups. Utilizing an advanced filter successfully removes erroneous features and noise, yielding spatial continuity in dual-lidar retrieval. Temporal interpolation further reduces errors that would amplify in the dual-lidar retrieval and yields an increased temporal resolution. These two processing techniques simultaneously increase data availability while significantly reducing errors compared to conventionally used methods. In particular, these processing techniques enable the estimate of secondary convective parameters, such as the origin, depth, width, and strength of the convective updrafts, that contribute to the transport of heat, moisture, momentum, and aerosols, as well as boundary-layer deepening, or are at least responsible for the maintenance of the boundary-layer depth."

Answers to RC2

The paper is overall well written and presents interesting results from dual-Doppler lidar scans in the convective boundary layer (CBL) at two different sites. The approach itself is not really novel per se but the authors tested different scanning and data processing strategies that allow improved resolution of flow structures and error quantification. I have two major concerns that resulted in my assessment that major revisions of the paper are needed:

Answer: We'll answer the following comment point by point.

- *I am not convinced that the applied DBSCAN noise filtering technique is adequate. The example presented highlights, that the clustering favors the range of velocities that is to be expected in the CBL and then clusters a significant number of data points with low SNR values but filters out data points that would traditionally be considered to be good data. What is the justification for this? I am concerned that interesting features may be filtered out, while noisy data are being retained.*

Answer: The clustering of points below –27dB is desired as these points are **not** noise. We show that in Figure 4 and reflect on it in the corresponding discussion. Here, no noise is retained, as the points recovered below –27 dB follow the same radial velocity patterns as the surrounding non-noisy points above the –27dB threshold (see Figure 4a and d); Hence, they do not fall into the noisy category. The algorithm only filters out data points that are not dense in the scatter of vr against SNR, meaning, if SNR is higher overall, the cluster moves to high SNR values. This is for example the case for the observations at Vaksinen. The DBSCAN dynamically adjusts to the valid SNR and vr range.

Also, the filtering/ discarding of the points that are scattered thin above - 27dB is desired. Conventional filters would consider these points above - 27dB as "good data". However, a substantial part of these points is not, as they correspond to erroneous features, such as range-folded ambiguities or obstacles on the ground. We show that noise and erroneous features are removed by the DBSCAN algorithm (Figure 4d), but not by the conventionally used SNR threshold filter (Figure 4c). We agree that some of the discarded points (above -27 dB) also correspond to data from within the highly reflective cloud that could be considered as good data. Additionally, there are some rarified scatterers above –27dB, which are classified as noise, but do not fall into the feature category. However, the overall data potentially "lost" here is smaller than 2% (cloud) and smaller than 3% (noise), which is much smaller than the gain of "good data" additionally recovered below -27 db (+48%) by the DBSCAN algorithm.

This recovered data covers the center of the convective circulation, while the cloud is only at the edge. The distinction between "discarded because of noisy" and "discarded because of potential erroneous features" was not highlighted by Figure 3 and 4. To clarify, we separated "noise and features" in the plot and in the corresponding caption (see attached supplement). Further development (e.g. machine learning) could probably even distinguish which of the features are desired and which not. As the desired features only make up a negligible part of the studied area, we decided that implementing such an additional distinction algorithm would exceed the scope of this study.

For the retrieval to work, it is critical to remove the points that correspond to erroneous features and large spatial patches of the noise. Figure 4 and the corresponding discussion show that this is achieved by the DBSCAN algorithm and not achieved by the conventional SNR threshold filter at the same time. Even if a small number of “good” points that are distributed throughout the cross-section are missing, the retrieval is not affected. The retrieval methodology also works even if some data points within the polar coordinate system are missing, as long as there are sufficient number of vr points from each lidar available within distance R from the cartesian retrieval grid point. As these two statements are not clearly communicated in the manuscript, despite their importance, we decided to follow the reviewer’s comment below and changed the order of Section 3 and 4 and include these statements to the radial velocity filter subsection.

To conclude, only a negligible part of non-erroneous features (below 2%) or potentially wrongly classified noise (<3%) was discarded. Erroneous range-folded ambiguities and obstacles that strongly impact the quality of the retrieval were removed and no noise was retained, while a substantial part of good data below –27dB was recovered. We believe this justifies the usage of the DBSCAN algorithm.

- *The authors need to provide additional information about how they determined the values for the density radius*

Answer: The density radius and number of samples is dependent on the number of points in the analyzed section where the number of samples can be adjusted with the total number of points in the section. Keeping the density radius constant, the range of the number of samples that could be applied was rather wide. The criterium for choosing the combination of density radius and number of samples was that only one main cluster was identified. Any secondary cluster needed to be at least 3-density radius apart. We have included this explanation in the manuscript.

- *and number of samples and why the data points with SNR values >-27 DBZ with v_r~0 should all be considered noise.*

Answer: For the displayed example, not all data > -27 dB are considered as noise or features. Here, the cluster detected by DBSCAN also covers data > -27 dB, comprising 14% of the whole data, in contrast to 5% that were not within the cluster. The data remaining in the scan is sufficient to retrieve u and w velocity components on a cartesian grid (as the retrieval also considers all points within a certain radius around the grid point)

- *It also appears this filtering was only applied to the RHI scans but not to the DBS scans. If though, why is this the case?*

Answer: Thank you very much for pointing out that this information is missing in the manuscript.

Before the retrieval of the wind profile, the DBSCAN algorithm is also applied to the DBS scans. We apply the algorithm to the 10-minute series of each lidar beam individually with adjusted number of samples at constant density radius (see above), depending on the number of points (number of range gates times number of time steps). To retrieve the 3D wind profile, all values from the 10min intervals are also used (over constrained equation system, solved using least-squares). Since we use a composite of the 10-minute intervals it is not necessary to apply temporal interpolation.

We added this explanation to the radial velocity filtering subsection.

- *And, how does this type of filtering affect SNR based CBL height detection algorithms?*

Answer: SNR determines the quality of the radial velocity, but not the other way around (SNR is dependent on the laser's properties and the aerosol concentration). The DBSCAN algorithm uses SNR to identify which points need to be filtered. However, the filtering is only applied to the radial velocity values and not the SNR values. Hence, the filtering does not affect the CBL height detection. The sub-section title specifies and also within the subsection we specify multiple times that we apply a filter to the "radial velocity".

- *The data analysis and discussion of results included in the paper primarily just focuses on the detection of updrafts and downdrafts in the CBL. While the detection and tracking of these flow structures is interesting, the paper falls short in providing new insights about turbulence statistics in the CBL. Does the presented method really have the potential to provide new knowledge about physics in the CBL and data that can be used to evaluate parameterization schemes?*

Answer: The main purpose of the paper was not to provide turbulence statistics in the CBL, but to demonstrate that the presented measurement and processing technique is capable of capturing convective circulations in time and space. The focus on demonstrating and evaluating the methodology is due to the choice of the journal "Atmospheric Measurement Techniques".

The presented measurement and processing technique provides convective flow fields in time and space, which are not provided by any other state-of-the-art measurement techniques. Multidimensional flow fields to guide Parametrization schemes for convection are currently only provided by LES simulations, which also provide information about the convective flow field on a cartesian grid. Hence the observations provided by the proposed method and LES can be directly compared on a multi-dimensional level.

Demonstrating and evaluating the capabilities of the technique (with some sneak peek into the meteorological implications found for two case studies) is the stepping stone towards designing more extensive field campaigns and developing further studies about detailed statistics of convection in the atmospheric boundary layer. Such statistics would also require a larger database as available here and exceed the scope of this manuscript and is, therefore, material for further studies.

We have specified these points in the Introduction (See next comment) and the Conclusion. As some of these points are more an Outlook, we renamed the "Conclusions" to "Conclusions and Outlook"

A few additional minor comments:

P1,around l20: the discussion switches here from limitations of conventional instrumentation to LES and then back to a need for better observations. The authors should expand and re-organize these points a bit and add more details about the modeling approaches for the CBL, where conventional observations have limitations, what gaps can be filled by LES, but where does LES fall short and we still have a need for new information.

Answer: We have clarified the statements connecting LES and observations as follows:

"Given the complex three-dimensional and short-lived nature of convection, such conventional instrumentation setups are often unsuitable to be used to constrain or validate convection parameterization schemes (Kunkel et al., 1977; Geerts et al., 2018). Instead, we have to resort to Large-Eddy Simulations (LES) that resolve the three-dimensional dynamics of convection to guide such parametrizations (Brown et al.,2002; Siebesma et al., 2007). Yet, also LESs used to constrain the convection parametrization schemes lack sophisticated observations to be validated against. Hence, there is a demand for high-resolution and long-term observations of the multi-dimensional character of convection. This study aims to provide a combined measurement and processing technique to achieve observations that cover the spatial and temporal scales necessary to resolve convection. Here, we propose and assess a novel methodology based on a dual-scanning lidar retrieval combined with an advanced filtering and a temporal interpolation approach."

This first paragraph of the Introduction states the Motivation for the study. Parametrizations and LES are not evaluated in the manuscript and corresponding details can be found in the cited literature. The goal of the manuscript is to evaluate the presented measurement and processing technique (see comment above). Going into more detail about modelling approaches would divert attention from this goal.

Sections 2.3 and 3 could be better organized. I think the section would flow better if the authors first introduced the general strategy (section 4.1), and then addressed the different sources of errors and how they are addressed in their retrieval.

Answer: See answer to first comment above

Sections 6.3 and 7 are rather long and could be shortened.

Answer: We shortened Section 6.3 and 7, by removing information, which we found to be of minor relevance at this point of the manuscript and by merging redundant paragraphs.

List of relevant changes

Abstract:

- Removed novel, see answer to reviewer 1
- Clarified "tested" to " We deployed the dual-lidar setup at two Norwegian airfields in a different geographic setting and demonstrate its capabilities as a proof-of-concept.", see answer to reviewer 1
- Clarify "both pre-processing procedure", by explicitly naming them " The advanced data filtering and temporal interpolation approaches", see answer to reviewer 1

Introduction:

- 1. Paragraph: Clarify the connection between measurements, parametrization schemes an LES and clarify the goal of the study (see answers to reviewers 1 and 2)
- 2. Paragraph: Included additional references to literature to extend the overview of available studies
- 3. Paragraph, last sentence: Specified our approach, compared to earlier studies
- 5. Paragraph: Included the definition of the performance criteria, see reviever 1
- Removed 7. Paragraph in correspondace to reviewer 1

Section 2:

- Included introducing paragraph between section heading and first subsection (see reviewer 1)
- Section 2.2, last paragraph: Corrected spelling: Aerosols > aerosols
- Section 2.3, first paragraph: clarified description of DBS scanning pattern: of perpendicular or opposed > perpendicular at
- Section 2.2, 4. paragraph: Improved spelling/ grammar (see reviewer 1)
- Section 2.4, first paragraph: Improved grammar (see reviewer 1)

Section 3:

- Exchanged position of section 3 and 4
- Adjusted introduction to Section to fit the new position in the manuscript, improved grammar and wording
- Section 3.1, 3. paragraph: Clarified which points are used in the retrieval
- Section 3.1, 4. paragraph: Added reference that specifically uses least squares approach for a dual-lidar retrieval; Added information on retrival in cartasian points that do not include valid v_r points for both lidars
- Section 3.1, 2. paragraph: adjusted to fit the new position in the manuscript
- Section 3.1, equation 6: corrected subscripts (see reviewer 1)
- Section 3.1, 3. paragraph: adjusted to fit the new position in the manuscript, grammar

Section 4:

- Exchanged position of section 3 and 4

- Introducing paragraph: Removed redundant definition of u and w (was already defined in section 2.3, 2. Paragraph)
- Section 4.1: Clarified description and discussion of DBSCAN filter (answering to reviewer 2)
- Figure 3 and 4: highlighted features to destinguish them from noise. Adjusted Figure captions respectively (corresponding to reviewer 2)
- Section 4.2, first paragraph: adjusted to fit the new position in the manuscript
- Section 4.2, 3. paragraph: clarify meaning of maximum time lag
- Section 4.2, 7. paragraph: corrected spelling
- Section 4.2, 8. paragraph: corrected spelling

Section 5:

- Section 5.1, first paragraph: clarified that non-filtered (unrocessed) data was used
- Section 5.1, 2. paragraph: removed definition that was never used again later in the manuscript
- Section 5.3: Clarified estimation of potential temperature to the one utilized in the final estimation of the variable (exchanged placeholder/remnant of earlier analysis)

Section 6:

- Introducing paragraph: Added statement about requirements for going beyond the proof-of-concept presented
- Section 6.1, 2. paragraph: Specified “ground flux” to “ground heat flux”
- Section 6.1, last paragraph: Added figure reference for improved orientation
- Figure 6, caption: corrected spelling Dirunal > Diurnal (see reviewer 1)
- Figure7: Corrected radial velocity colorbar ticks
- Section 6.2, last paragraph: corrected spelling
- Section 6.3: Shortened discussion of Figure 10, corresponding to comment by reviewer 2

Section 7:

- Renamed to Discussion, split into subsections, rearranging paragraphs (see reviewer 1)
- Included introducing paragraph (see reviewer 1)
- Shortened by removing mostly redundant paragraphs (see reviewer 2)

Conclusions:

- Renamed to conclusions and outlook
- Included how approach performs corresponding to performance criteria defined in introduction (see reviewer 1)
- Included information from (former) last paragraph of introduction as outlook (see reviewer 1)
- Removed “physical” (corresponding to comment by reviewer 2)