Atmospheric Measurement Techniques Discussions

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Reply on RC1

Abhiram Doddi et al.

Author comment on "Instabilities, Dynamics, and Energetics accompanying Atmospheric Layering (IDEAL): high-resolution in situ observations and modeling in and above the nocturnal boundary layer" by Abhiram Doddi et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-173-AC1, 2021

Doddi et al. provide a manuscript about the IDEAL measurement campaign. The IDEAL program and the associated campaign target a very relevant and interesting topic of atmospheric research, which is the structure of the lower troposphere in strongly stable conditions. New ways of sampling stability and turbulence with multiple UAS were explored in the campaign which could contribute significantly to a better understanding of the dynamics under such conditions.

I think the authors are not very clear with the concept of the manuscript. While the title and abstract suggest a focus on the observational campaign, the introduction and section 5 suggest that they want to give an overview of the research program IDEAL as a whole. I think the manuscript should be revised in either of the two directions. If the authors decide to focus on the observations, I request some major revisions as described in the general and specific comments below, before I can recommend the manuscript to be published in AMT. If they decide to describe the whole research program, they might want to consider resubmitting to ACP instead.

[Author Response]: Our objective is to present an overview of the IDEAL program (as described in the penultimate paragraph of the Introduction section) with emphasis on the observation phase (phase I) that has already been carried out, and its scope in guiding the DNS during Phase II. The last paragraph of the introduction section states that the article focuses on the field campaign and related topics. For the revision we plan to explicitly state the implications of the measurements in guiding DNS during Phase II. The authors believe this will more clearly keep the focus on the field campaign while still explaining how DNS is proposed to be conducted.

Further, the authors believe that it is common for field campaigns, like IDEAL, to present a paper detailing the campaign, its objectives, and present the dataset outlining the preliminary results before following up with a detailed look at the synthesis and findings. AMT does not preclude such articles. We intend to follow up with papers discussing the data processing and analysis techniques, and significant findings on various issues of scientific relevance addressed by the campaign.

General comments:

- The introduction is very much focused on the sheet & layer research. If the focus of the paper should be the description of the observational campaign and in particular the UAS measurement system and flight strategies, there should also be some references to similar campaign setups and other UAS systems. UAS have been excessively used in boundary-layer research for vertical profiling, but also turbulence measurements and even combinations of both with multiple systems operating simultaneously. The IDEAL campaign should be put into some context, including not only other DataHawk campaigns.

[Author Response]: The literature review conducted by the authors has not revealed any field campaigns which focused exclusively on S&L observations (except perhaps the ShUREX2016-2017 campaigns employing the DataHawk UAS; Here, exploring the S&L dynamics was one of the main objectives besides BL observations and turbulence emanating from convection sources in the free-atmosphere). However, numerous authors have reported observations of S&L events from the measurements of radiosondes, instrumented towers, tethered lifting systems (balloons, kites, etc.), VHF and UHF radars, and combinations of these instruments during field campaigns perhaps designed to observe other atmospheric phenomena. Putting this perspective into the context of IDEAL campaign, we feel, is necessary because IDEAL observation program was conceived with the sole purpose of characterizing S&L dynamics and accompanying turbulence.

However, the point that DH2 measurements during IDEAL set out to observe S&L structures exclusively was not made apparent to the reader. The paragraph on line 52 of introduction feels like a natural place in the article to do so.

The authors will include additional literature describing observations of S&L using various instruments including UAS and use that information to put the objectives of the IDEAL observation campaign into perspective in the introduction section.

- Section 2 gives a lot of details about the UAS which reads a bit like a datasheet or advertisement. On the other hand, the dataset is not very well presented. For a description of the campaign, I expect at least a list of days of measurements with corresponding conditions and flight strategies. It is mentioned later that several different flight strategies were performed with aircraft A2 and A3, but it is never presented when and how often they were performed. This would be important to understand the database better.

[Author Response]: The DataHawk UAS employs an inhouse developed Autopilot system utilizing custom electronics. The UAS is equipped with a suite of sensors that best meet various measurement demands set by the science goals of different observation campaigns. Since the DataHawk configuration used during IDEAL observation campaign was different (and unique to IDEAL) from its predecessors, the authors deemed it necessary to describe, in detail, the platform’s characteristics and capabilities. Similar examples can be found in the literature: Scipion et al. 2016 and Kantha et al. 2017.

Reference: Scipión, D. E., Lawrence, D. A., Milla, M. A., Woodman, R. F., Lume, D. A., and Balsley, B. B.: Simultaneous observations of structure func-tion parameter of refractive index using a high-resolution radar and the DataHawk small airborne measurement system, ann-geophys.net,34, 767–780, https://doi.org/10.5194/angeo-34-767-2016, www.ann-geophys.net/34/767/2016/, 2016.

Reference: Kantha, L., Lawrence, D., Luce, H., Hashiguchi, H., Tsuda, T., Wilson, R., Mixa, T., and Yabuki, M.: Shigaraki UAV-Radar Ex-periment (ShUREX): overview of the campaign with some preliminary results, Progress in Earth and Planetary Science, 4, https://doi.org/10.1186/s40645-017-0133-x, 2017.

We concur that the article is deficient in describing the UAS and radiosonde datasets described in the article. A table listing the background conditions, flight location, dates and time of flight, brief description of observed features, and flight strategy for all UAS sorties (and radiosonde deployments) will be included in the revised manuscript.

Line 210 attempted to describe, vaguely, the sampling strategy employed by aircraft A2 and A3. Currently the paragraph starting on line 209 informs the readers as to why A2 and A3 were deployed but fails to describe how often the lateral sampling was carried out.

Lateral sampling using one or two aircraft was carried out during each UAS sortie. Thus, every UAS sortie consists of two or three aircraft including a vertical sounding aircraft and one or two lateral sounding aircraft.

Including the previously described table (containing UAS dataset information assorted by sorties) would therefore aid in describing the flight operations and the dataset.

- The figures in the manuscript look a lot like copy and pasted from quick looks of the individual instruments. Labels are often small, much information is included that is not described in the caption. I think the authors can do better to prepare them adequately well for a publication. There is also no consistent nomenclature. Examples are zonal and meridional wind vs. eastward and northward wind. Figure labelling is sometimes wind direction, sometimes w_dir. Although the latter are minor issues, they make the manuscript hard to read.

[Author Response]: Figures 3, 4, 5, and 7 are quick look plots relayed by different teams (radar, radiosonde, etc.) to the UAS team in real-time. The authors will use quality-controlled datasets (unlike the raw data which is presented in these figures) to recreate publication quality images to replace all these figures in the revised manuscript.

- It appears to me that all the examples of measurement data are from 6 November 2017, but they are mostly presented separately without connecting them. It would be nice to maybe give an introduction to the conditions on this day which serves as a case study and then lead the reader through the findings from different instruments.

[Author Response]: Figure 3 presents the SNR, vertical velocity and wind information measured by the VHF radar on the 1st of November. This figure intended to show a possible Kelvin-Helmholtz Instability (KHI) event observed during the campaign.

To better connect sections 2.2 and 2.3 to the following section (section 3), figure 3 will be updated with VHF radar SNR, vertical velocity, and wind from the 6th of November.

- The section about DNS is very much detached from the rest of the manuscript. If the authors decide to focus on the observational campaign, I think the section is not really necessary. If they decide to present the whole project, including the simulations, they should better connect the goals or the findings of the campaign to the presented simulations. I think this is not done very well.

[Author Response]: Section 5 presents results from two previously conducted DNS to study the formation of S&L structures arising from superpositions of convectively stable gravity waves (GW) and dynamically stable mean shears. The first DNS experiment featured a GW of amplitude 0.5 (relative to vertical gradient of local potential, i.e.,) and an intrinsic frequency of N/10 (where N is the Brunt Vaisala Frequency) at Reynolds Number of 50,000. The second DNS experiment designed to study the Kelvin Helmholtz Instability (KHI) assumed a Reynolds number of 5000 and a minimum Richardson Number of 0.1 with a random white noise background velocity field (superimposed to stimulate instability growth leading to KH billows). Figures 17 and 18 present relevant results from these two DNS.

These DNS of multiscale dynamics (MSD) suggested that the resulting KHI tubes and knots (T&K) dynamics are likely major contributors to the S&L structures which ubiquitously occur in the atmosphere. Thus, these DNS studies presented in section 5 provided the motivations for the IDEAL observation program. In phase II of the IDEAL project, we plan to expand such DNS studies to explore the implications of IDEAL measurements.

This section, as the reviewer points out, is misplaced. It serves our purpose better to present the motivations provided by DNS upfront – within the introduction section. We intend to restructure the implications of these initial DNS studies and present them as motivations within the introduction section.

- The conclusions are very brief and vague. Are there any lessons-learned from the campaign? What were the highlights? What can be done with the dataset as a whole, not only with slanted UAS flights?

[Author Response]: Section 3 intends to present preliminary findings from the field campaign as detailed analysis of the UAS datasets are still underway. The article serves the purpose of describing the UAS dataset and the conditions during which the observations were made. The authors will first work on improving the findings presented in section 3 and use that information to discuss and draw conclusions in the final section.

Specific comments:

p.2, l.47: I am not sure what is meant by "dexterity" of measurement platforms.

[Author Response]: We intend to convey that UAS provide flexible (dexterous) sampling strategies, both vertically and laterally, when compared to other in-situ measurement platforms (radiosondes, instrumented towers, etc.).

p.2, l.48f: I agree that spatial information could yield many new insights beyond single-point vertical profiles. However, the only data that are presented later in Section 4 are such vertical profiles.

[Author Response]: Preliminary analysis was conducted exclusively on vertical sounding aircraft from each UAS sortie mainly due to the familiarity in analyzing and interpreting the vertical sampling aircraft data as this is a typical flight strategy used by fixed-wing aircraft.

Analysis and interpretation of observation data from lateral sounding aircraft is complicated by horizontal winds which laterally advect the S&L structures being observed. Consequently, it is difficult to draw concrete conclusions about the lateral structure of S&L from only preliminary results.

However, the manuscript will be revised to contain 2D scatter plots from one lateral flight showing T/RH, wind components, potential temperature, TKE dissipation rate, and temperature structure function parameter plotted as functions of Latitude vs Longitude, Altitude vs Longitude and Longitude vs Time (lateral measurements were made along 1Km legs roughly aligned East-West). These three figures will help to highlight the spatial structure and temporal evolution (if evident) of the underlying S&L structures from the lateral surveys, as an example of the type of analysis that we (and others) may wish to conduct on this dataset.

p.3, l.58: 72 flights in which time frame? Does this mean single flights, or flights with three UAS in parallel?

[Author Response]: The term ‘flight’ is used for an individual aircraft flight and the term ‘sortie’ has been used for a coordinated set of flights deployed simultaneously. In this context, we refer to the total number of UAS flights carried out during the IDEAL observation program.

Figure 1: If an elevation map is available, it would be really nice to show the site with contour lines, or color-coded elevation.

[Author Response]: The addition of elevation map would certainly be beneficial. We will update figure 1 to show elevation contour lines.

p.5, l.86: "Unbreakable wing trailing edges" - unbreakable seems a bit unrealistic.

[Author Response]: “Unbreakable” will be replaced with “resilient” in the revised manuscript.

p.5, l.97: when wind speed exceeds airspeed, the aircraft moves backwards with respect to the ground. What does it mean that the flight is stabilized in that case? If airspeed is controlled, there is in general no flight stability issue, but maybe an issue with navigation.

[Author Response]: When course heading is controlled, this reverses sign as the wind exceeds the airspeed, causing the aircraft control to command a 180 degree change in heading, destabilizing the flight. Instead, on the DH2 compass heading is the controlled variable, and this is computed from desired course heading and wind estimates using the wind triangle to produce a “wind-aware” guidance law that causes robust tracking of a desired GPS course in high wind.

p.5, l.98: Synoptic wind means geostrophic wind? What is meant by "aloft"? And why does it limit the ceiling to 3 km exactly?

[Author Response]: Yes, in this context we mean geostrophic winds. We see why this creates confusion because it is vague. Instead, the sentence should say, “synoptic winds above 3000m [AGL] typically exceeded 20m/s which limited the flight ceiling to this altitude.”

p.6, l.116ff: Is there a reference for this procedure?

[Author Response]: The calibration is a simple linear least squares regression between CW measured voltage and the collocated SHT temperature measurements, and as such there is no specific reference for this procedure. This point will be explicitly mentioned in the revised manuscript.

p.7, l.124ff: As above, a reference that describes the sensor fusion and turbulence measurement would be great.

p.7, l.128f: Is there a reference to the wind algorithm? With GPS and airspeed only, the wind can typically not be retrieved.

[Author Response]: The procedures employed to compute turbulence parameters of TKE dissipation rate and temperature structure function parameter, and the estimates of horizontal wind vector components are novel. These estimation algorithms were developed as part of the lead author's (Abhiram Doddi) doctoral thesis and are yet unpublished. The authors are currently working to describe turbulence and wind estimation procedures in upcoming research articles. References to the lead author's thesis will be made as necessary.

Lawrence and Balsley 2013, Luce 2019 (citations given below) describe the general framework of the estimation procedures utilized for computing wind and turbulence parameters presented in this article.

Table 2:

- How can the resolution of the vector wind be 0.001 m/s, if airspeed can only be resolved at 0.05 m/s?

[Author Response]: This resolution of vector wind should be 0.05 m/s and not 0.001 m/s.

- unit for dissipation rate and structure parameter accuracy missing. What does the range-value mean in this case?

[Author Response]: TKE dissipation rate is in [m^2/s^3] and CT2 is in [K^2 $m^{-2/3}$]. Range is the high end of these parameters than can be measured with the instrument that avoids noise floor and power supply limitations.

- degree symbol missing for all temperature units.

[Author Response]: The revised manuscript will be updated to include these.

Figure 3: It would be great if a better quality of the figures could be provided.

[Author Response]: The quick look plots in figures 3, 4, 5, and 7 will be replaced with publication quality images using quality-controlled data.

Figs. 4&5: I do not think these figures are really necessary if they are only there to illustrate data that is presented at weather briefings.

[Author Response]: The data presented in figure 3 is from the ISS operated VHF radar (915 MHz wind profiler). This information was relayed to the UAS team (in 1-hour installments) periodically during flight operations (between 2:00 – 8:00 am LT).

The weather briefings consisted of observation data from the 445 MHz radar located ~20 Km away from both deployment sites (shown in Figure 1 of the manuscript). The observation data shown in figure 5 was presented to the UAS team at the weather briefings along with the WRF simulation forecasts is shown in figure 4.

Collectively, figures 4 and 5 present the data available to the UAS team before flight deployment on each operational day. The information on synoptic scale flows forecasted in figures 4 and the real-time measurements shown in figure 5 was critical to decide the flight location and flight ceiling, and its inclusion here is meant to accurately describe the operational aspects of the campaign.

p.10, l.170f: The top right panel of Figure 6 does not show wind speeds. It cannot be read from the figure where the first week starts and ends.

[Author Response]: The text here should be changed to 'bottom tile'.

Figure 6: I think it is a bit irritating that the x-axis shows sequential soundings

and - to my understanding - does not give any information about the time of these soundings. It should at least be clearly indicated which soundings are released in close succession and where there are larger time gaps. It looks as if the plots even feature some interpolation between the profiles, which does not make much sense if the time spacing is not equidistant. I also do not understand why the colormap range is so large for temperature and wind speed.

[Author Response]: These figures will be replotted with convenient colormaps and show dates on the X-axis instead of the sounding number. Data interpolation, if used, will be described as necessary.

p.12, l.178f: Where can the stability be seen in the plots and where the intermittent turbulence and sheet structures?

[Author Response]: This statement was made based on the plots presented in figures 12 & 14 and should contain a reference to these figures and not figure 3. Therefore, reference to figures 12 and 14 will be made at the end of this statement.

p.13, l.191: I assume "Granite Peak" equals "Granite Mountain"?

[Author Response]: Will be changed to read 'Granite Mountain' consistently throughout the manuscript.

Figure 7, caption: I do not see a hodograph as is written in the caption.

[Author Response]: Text referring to the hodograph will be removed. Figure 7 is a quick look plot provided. This will be replotted along with figures 3, 4 and 5 to provide publication quality figures using quality-controlled data.

p.14, l.207: In Figures 8,9,10 it looks like the UAS are ascending/descending continuously during the racetrack patterns, but in the text it sounds like they were supposed to stay at dedicated heights. What is correct? Probably what is shown in the figure, but in that case, I do not fully understand the strategy.

[Author Response]: The objective of A2 and A3 aircraft was to fly racetracks while continuously ascending and descending within a narrow altitude range (the depth of turbulent layers ~200-500m). But for the flights on November 6^{th} (the two flights presented in the text), we decided to fly racetracks in the entire altitude range as the two sheets were separated. This distinction will be made apparent to the reader in the revised manuscript.

p.16, l.210: Ok, so now it is mentioned that the flight strategies for A2 and A3 vary significantly. This was not so clear before and should maybe be mentioned at the beginning of the section.

[Author Response]: The flight strategy presented in figures 8, 9 and 10 likely caused this confusion. The description of flight strategy presented in this figure will be presented upfront for clarity.

p.17, l.219: "DH2 identified": How were the stable sheet structures identified? What are the criteria, how is the data processed. A description of this is missing.

[Author Response]: "DH2 identified" is ambiguous. This text will be replaced with "58 individual stable sheets and Layers structures were identified…. from the DH2 measured high-resolution CW data".

The criterion we used to identify a sheet was the same as in Muschinski et al 1998. The text will include, briefly, this criterion with reference to the appropriate article.

p.17, l.223: "Altitude undulations": In the flight path? Is this shown somewhere? Is it reflected in wind or temperature measurements as well?

[Author Response]: The waterfall plots in figures 12 and 14 show multiple ascent and descent flight legs. The second tile in Figures 12 and 14 (showing N^2) suggest that the observed stable sheets (elevated N2 regions at 800m and 1500m in Figure 12; ~800m and 1500m in Figure 14) undulate. It is this undulating motion that we are referring to in this sentence. This information in apparent from the temperature, and the potential temperature measurements but not the wind measurements.

p.18, l.225: I think this enlarged inset in Figure 12 is not very conclusive. What is this supposed to show?

[Author Response]: The inset was presented to suggest that the high-resolution measurements of temperature (800Hz CW temperature) reveal very thin, highly stable sheets that are not often measured by other in-situ instruments.

p.18, l.228: In my opinion the nighttime inversion layer only extends to approximately 100 m. Interestingly, the UAS and radiosonde measurements differ quite significantly in this area. This should be discussed.

[Author Response]: The NBL can be very shallow as the reviewer points out and as such it is unlikely to be horizontally homogeneous, especially on scales of tens of kilometers given the terrain near and around Granite Mountain. Radiosondes were launched at a site ~10 km east from the site of UAV deployment and therefore, differences are to be expected. The emphasis in the campaign is not just the NBL but also the free stable atmosphere above the NBL. Radiosondes are to provide additional information about the state of the free atmosphere.

p.18, l.230: Unit missing for N^2

[Author Response]: This will be fixed in the revised manuscript.

p.18, l.231f: I do not see from these plots, where undulating temperature and humidity is observed at 800m and especially 1300m.

[Author Response]: Same explanation for the undulations as in comment "p.17, l.223".

p.23, l.248: Why is an analysis of A2 and A3 flights not presented? I think this is the essential and new part of the experiment, right?

[Author Response]: Yes, we agree that we need to present preliminary analysis plots for this flight strategy. We will include 2D scatter plots from one lateral flight showing T/RH, wind components, potential temperature, TKE dissipation rate, and temperature structure function parameter plotted as functions of Latitude vs Longitude, Altitude vs Longitude and Longitude vs Time (NOTE: The lateral measurements were made along 1Km legs roughly aligned East-West).

Figures 11-14: The time evolution of the profiles is not really discussed. I wonder if it would not be easier to read the plots if only single profiles were shown.

[Author Response]: Plots showing timeseries of measured parameters are useful and an example plot for T/RH, winds, potential temperature, TKE dissipation rate, and temperature structure function parameter will be included for one of the A2 (or A3) flights in the revised manuscript.

p.24, l.253f: What DNS code is employed? I realize the references, but if the simulations are introduced here, it would be good to give some basic information.

p.25, l.262: "expanded such MSD studies are contributing" - something seems wrong here.

Figure 17: It would be good to explain somewhere, why the plots are tilted.

[Author Response]: This section on DNS, as the reviewer points out, is misplaced (see comment on DNS above). In light of this recommendation, the authors will restructure the implications of these initial DNS studies and present them as motivations within the introduction section and discard the dedicated section on DNS (section 5).