We would like to thank the Anonymous Referee #1 for her/his comments and suggestions, which helped us to better focus the paper and improve its overall structure and readability.

Please notice that the referee's comments below are in blue, while authors' replies are in black. At the end of the document we also provide a table summarizing the changes we propose to make to the paper structure.

Anonymous Referee #1

(A) General comments:

A case study is presented for a thermally driven wind in an Alpine valley based on airborne and surface observations. The study is similar to a previous paper published in another journal. Although the data is unique and deserves to be published, the analysis needs to be better focused on new aspects not treated in the previous papers. At least a critical comparison of current and previous results is necessary. Connected to this critique, the research goals need to be more specific. The structure of the manuscript (sections and content) need to be improved. Questions arise on the representativity of the observed cross-valley features in data-sparse regions close to the terrain. Some of the cross-valley variations are rather small and might be blurred by noise. I suggest major revisions.

Reply. All of these issues have been carefully examined, and changes are proposed accordingly in the replies to the specific comments below.

(B) Specific comments:

1. It is not clear how this manuscript differs from the cited paper Laiti et al. (2013b; published in Atmospheric Research). The titles of these two papers are very similar and the results mentioned in the abstracts are nearly identical. From a reader's perspective it appears that the two case studies only differ in the analyzed dataset (different cases) but not in the general results. In the conclusions on page 19148 (line 3) the authors state that "all the above findings are consistent with previous results contained in Laiti et al. (2013a,b)". Hence, the reader will

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<u>Reply.</u> Laiti et al. (2013b) examines two flights performed in different days, covering different weather situations, but with similar timings and flight patterns. Therefore, in that paper the analysis concentrates on the atmospheric boundary layer (ABL) features characterizing the afternoon phase (mature stage) of the *Ora del Garda*, as well as on the effects of different weather conditions at the various valley cross sections explored.

Instead the present paper:

1. takes advantage from a couple of flights performed on the same day, under the same weather conditions, but one in the morning and one in the afternoon, thus allowing an insight into the diurnal development of the circulation at the explored sections;
2. examines in much more detail the coastal and the gap flow area; accordingly, the analysis for these two regions is richer with respect to Laiti et al. (2013b).
3. includes data from an intensive field campaign performed in the gap flow area during the time of flights, which provided additional information about local surface processes;
4. includes observations from a larger number of routinely operated surface stations, which in particular allowed a better characterization of the breeze front propagation in the coastal area and of the *Ora del Garda* arrival in the Adige Valley.

In order to meet the Referee's requests and better focus our study:

a. we propose to change the title of the paper to "*Analysis of the diurnal development of a lake-valley circulation in the Alps based on airborne and surface observations*";
b. we better focused the key results reported in the abstract, highlighting the additional value of the new manuscript according to the points listed above;

c. we added a summary of key findings from Laiti et al. (2013b) in the new "Introduction" section, as well as highlights from the critical comparison between the two papers in the new "Discussion" section;

d. we improved the focus of the manuscript on new aspects treated with respect to Laiti et al. (2013b) throughout the whole text.

2. The abstract is long and discursive. Only about 20% of the lines contain results. The last paragraph fits better to the section "conclusions".

Reply. We reduced and modified the abstract, expanding the part focusing on the results. The last paragraph was originally included following the recommendations of ACP author guidelines: "After a brief introduction of the topic, the summary recapitulates the key points of the article *and mentions possible directions for prospective research*"[1]. However, we fully agree to remove it, if the Editor approves. As an alternative, we may reformulate it as:

"The improved knowledge of the characteristic Ora del Garda flow patterns and associated ABL structures provided by the present paper will be useful for future applications, such as microclimate and air quality studies in the target area. Moreover, the 3D meteorological fields produced by RK interpolation will represent an excellent basis for the comparison with future high-resolution numerical simulations of the flight day".

3. Similarly, the conclusion is long and discursive. I suggest to split this section into two: a discussion (e.g., also containing a comparison to previous literature) and a discrete, concise conclusion containing the main findings.

Reply. In the revised manuscript the "Conclusions" section was split into a new "Discussion" section and a more concise "Conclusions" section recapping the main findings.

4. Introduction and section 2, page 19123-19128: The authors should provide more specific goals or research questions (e.g., see so-called SMART goals). They should also highlight differences in these goals/questions compared to the ones in Laiti et al. (2013b). Usually

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[1] Source: http://www.atmospheric-chemistry-and-physics.net/submission/manuscript_preparation.html

these goals are formulated at the end of the literature review (section 1). In the present manuscript, however, the aims are mentioned in section 1 between two parts of literature review. Moreover, section 2 is partly a repetition of section 1 as it also contains a literature review. I suggest to combine these two sections followed by the goals of the study. The literature review could also be reduced by referring to Laiti et al. (2013b). It could also be focused on new aspects relevant in the present study but not treated in the previous paper (e.g. propagation of the lake-breeze front).

Reply. We merged sections 1 and 2, reducing at the same time the length of the first part of the literature review, using Laiti et al. (2013a, 2013b) as a reference. A (brief) new literature review part was added, dealing specifically with two topics: the propagation of lake-breeze fronts and the occurrence of hydraulic jumps associated with gap flows and/or downslope windstorms (in connection with the flow pattern developing across the Terlago gap). Moreover, we reformulated the research questions in view of the so-called "SMART goals" criteria and moved them at the end of the new "Introduction section", immediately before the description of the paper structure. The new research goals are:

1. The analysis of the diurnal development and evolution of the Ora del Garda wind and associated ABL thermal structures, taking advantage from the availability of two flights exploring the target area (in the southeastern Italian Alps), which were performed on a well-developed Ora del Garda day, one in the morning and one in the afternoon.

2. Investigate, in more detail than *Laiti et al.* (2013b), the coupled surface and ABL processes occurring in the two key areas for the Ora del Garda development, i.e. the Lake Garda shoreline area and the junction between the Lakes Valley and the Adige Valley. These processes include the lake-breeze front propagation and the phenomena associated with the gap flow at the Lakes Valley end. Their detailed analysis is made possible by the larger number of available surface stations compared to Laiti et al. (2013b) and by observations from an intensive field campaign held in the gap area.

Accordingly, in the same section we also reformulated the motivations for the present paper:

1. The presented dataset, including both routine and intensive surface data, as well as data from a dedicated airborne measurement campaign, is unique for it allows the

analysis of wind, temperature and sensible heat fluxes at the surface, as well as 3D ABL thermal structures, associated with a lake-valley mountain wind.

2. Our results can be extended to similar geographic configurations, e.g. other Alpine lakes or mountain valleys with relatively large water bodies at their bottom.

3. This paper sheds new light on the atmospheric processes occurring in two key areas for the Ora del Garda development (i.e. the lake shoreline and especially the gap north of Trento), which were not the focus of Laiti et al. (2013b).

4. The results represent an excellent basis for the validation of high-resolution numerical model simulations that we are going to carry out soon. Indeed, the improvement of atmospheric models requires that boundary layer schemes be tested against experimental datasets (see Baklanov et al., 2011).

5. A good characterization of local wind and ABL coupled processes will be of great importance for the study of pollution transport and dispersion in the target area, especially for the urban area of Trento at the Adige Valley floor.

5. The authors mention on page 19127 a number of small lakes located north of Lake Garda. I am wondering how these lakes influence the valley wind and the boundary layer structure observed by surface stations and the aircraft. A discussion of this aspect in the results section is missing. This could also be a specific research question.

Reply. We assume that these lakes are too small (~1 km^{-2}) to develop their own breeze systems. The Ora del Garda up-valley wind probably overcomes these minor flows, and the small lakes' effect is limited to the local stabilization of the lowest ABL when the prevailing up-valley advection is not too intense (cf. Laiti et al., 2013a, 2013b). However, we reconsidered the manuscript parts previously dealing with the small lakes and we concluded that in fact the available data do not allow a satisfactory analysis of their influence on the local wind and ABL processes. Therefore, we removed those parts and mentioned this aspect in the "Conclusions" as an open research question for future high-resolution numerical simulations.

6. Introduction, results and conclusions: The references and the interpretation of results regarding the heating of the valley atmosphere are somewhat biased. Heating is explained as

a result of compensating subsidence in the center of the valley (e.g., page 19138, 19139, 19146, 19148) and papers are cited that propose this mechanism. These papers are mainly based on the analysis of vertical profiles (observed and modeled). However, in recent years studies have been published that propose another approach based on the heat budget analysis for the whole valley volume. They tried to clarify the role of the volume effect. I strongly suggest to integrate and discuss ideas of both perspectives. These two different perspectives are not necessarily contradictory and data gained by one or the other method are not wrong. It is often a matter of the right interpretation.

Reply. Unfortunately, we cannot evaluate a volume budget on the whole valley volume, as we do not have data from the slope regions. Most of our flights are representative only of the core valley region, where subsidence is the main mechanism for (early) daytime heating, as supported also by recent papers adopting the volume approach, e.g. Schmidli and Rotunno (2010) at lines 8-11, pag. 3046. We included these considerations, as well as a citation of this paper in the references.

7. The structure of the manuscript is not ideal: Section 3.3 "Weather conditions" should not be part of section 3 "Experimental dataset". It should be rather part of section 5 "Results", first explaining the synoptic background conditions before focusing on the regional and local scales. The section title "discussion of results" is somewhat misleading. Usually the section "discussion" follows the section "results". The division of the section 5 in various subsections with partly the same title (e.g., "Lower Sarca Valley ...") causes repetitions and, hence, is somewhat tedious. I suggest to introduce a new structure by combining different datasets (weather stations and aircraft data) in order to draft a comprehensive picture of wind and boundary layer structure for each sub-region.

Reply. We moved section 3.3 "Weather conditions" to the new "Results" section. We also reorganized the results on the basis of the different geographic subareas forming the target area (the lower Sarca Valley, the Lakes Valley, the Adige Valley), combining results based on surface and airborne observations for each of them.

8. Section 4.2 on page 19132-19134: On one hand the section is too short for actually understanding the details of the kriging technique. On the other hand most of it is presumably already mentioned in more detail in Laiti et al. (2013a,b). Hence, I suggest to reduce this section and the previous one to a minimum by referring to the former paper or to expand it (or at least the critical parts) to explain the technique in more detail.

Reply. We removed the old "Methods" section, and added instead a few lines at the end of each of the two paragraphs describing the dataset ("Experimental dataset" section), presenting very briefly the methods used in the analysis of airborne ("Measurement flight" paragraph) and surface data ("Surface observations" paragraph) by referring to adequate references (e.g. Laiti et al., 2013a for the kriging technique).

9. Section 5.1.1. on page 19134 and Figs. 3-4: Explain the weak southeasterly winds at Monte Terlago between about 0830 and 1030 LST already before the onset of up-valley winds at Lake Garda (RDG). Is this pattern a cross-gap circulation before the actual up-valley flow establishes at Monte Terlago? Explain the earlier decay of the up-valley flow at RDG in comparison to Monte Terlago. Discuss the contradictory feature of a nighttime down-valley flow at the shoreline (RDG) and a lake temperature that is cooler throughout the whole day than the air temperature at RDG (which would favor an up-valley flow).

Reply. The following explanations were added in the revised manuscript, in the "Results" and "Discussions" sections.

1. The weak SE wind observed at Monte Terlago between 0830 and 1030 LST, before the onset of the up-valley wind at RDG, is a morning up-slope circulation developing along the NW (SE-facing) valley sidewall, due to the progressive overheating of the slope. Indeed, Monte Terlago station does not lie at the valley floor center, but close to above-cited lateral slope. From 1030 LST on, the up-valley wind component begins to strengthen, producing a gradual clockwise rotation of wind vectors.

2. The earlier decay of the Ora del Garda at RDG than at Monte Terlago may be explained by the fact that the lake-breeze and the up-valley wind system have different response times. When the lower Sarca Valley (cf. RDG station) gets shaded in the late afternoon or early evening, the local water-land temperature gradient weakens rather quickly, leading to a quite sharp breeze reversal at the shoreline, which is typical of

sea/lake breezes (Defant, 1951; Simpson, 1994). On the contrary, the negative pressure gradient along the valley persists for longer. In particular, for a few hours after sunset the air above the Terlago saddle remains potentially cooler than air found at the same level in the Adige Valley. When the balance is reached, the wind at Monte Terlago sharply shifts to a steady down-slope direction, while in the Adige Valley the westerly (cross-valley) flow at RON and GAR ceases.

3. RDG station is placed over the dock of a small harbor, while the water temperature is measured 8 m away from the breakwater at 50 cm depth. An explanation for the low water temperature is that on 18-19 August 2001 predominant northerly (i.e. off-shore) winds blew, possibly inducing the upwelling of deeper (colder) water close to the shore. This may explain why the water temperature dropped from 24 to 13°C. Then the water started to slowly heat up again, but reached only ~21°C by 23 August 2001. At the same time, the mean air temperature did not change a lot (see Fig. 1). This explains why the water-air temperature difference did not reverse between day and night on the flight day (differently from what observed for example on 12-16 August 2001).
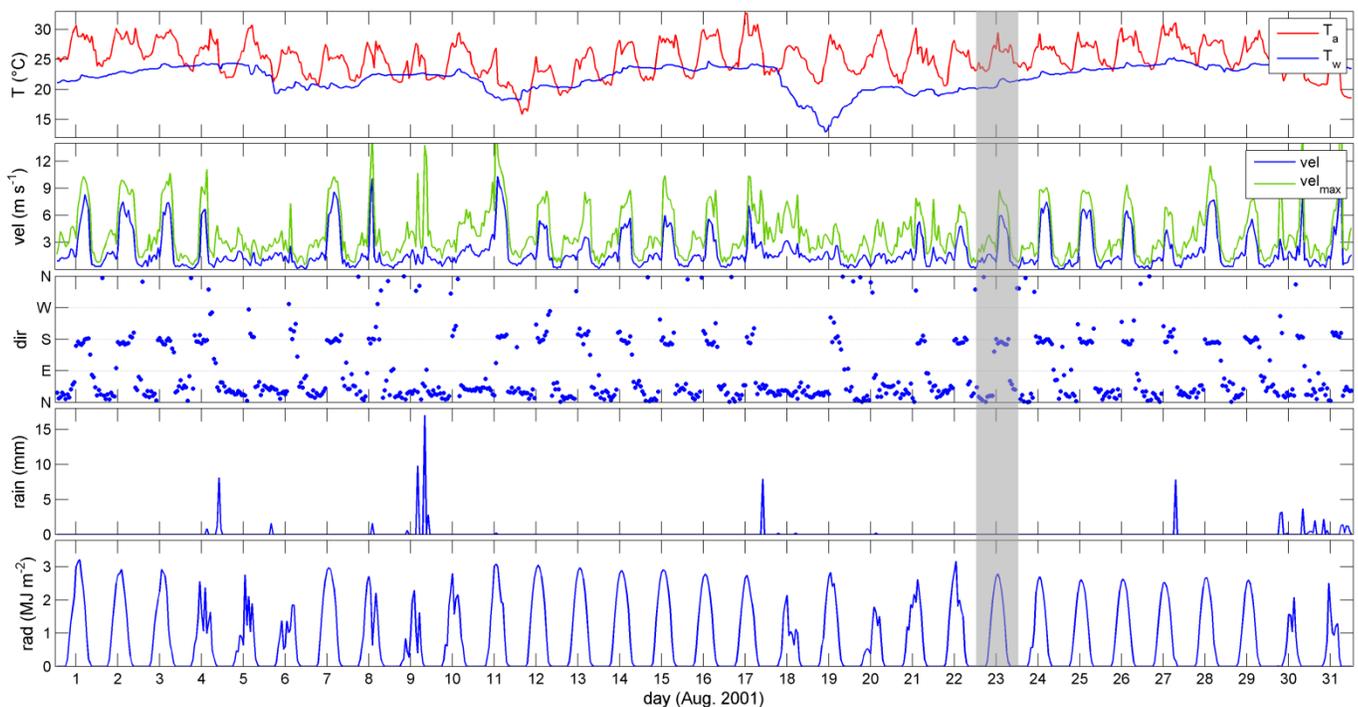

Figure 1. August 2001 observations at RDG. From top to bottom: air (T_a) and water (T_w) temperature, mean (vel) and maximum (vel_{max}) wind speed, wind direction, rainfall, global radiation. The grey band shows 23 Aug 2001.

However, on the flight day the reversal of the air temperature (pressure) gradient along the valleys did occur (cf. temperature observations at RDG, TOR, ARC and DRO). Accordingly, although a "true" land breeze was not likely to arise, a nocturnal down-valley wind developed regularly, propagating also above the lake surface (i.e. off-shore). Indeed, the lower Sarca Valley, the Lakes Valley and also some of their tributary valleys are expected to drain into the Lake Garda basin. In addition, the relatively warm nocturnal conditions registered at RDG (compared with lake water) may depend on some local effects, e.g. the fact that a urbanized area lies immediately north of the station (i.e. up-stream during nighttime). In fact, nocturnal temperatures at TOR are lower and comparable to the observed lake water temperature.

10. Section 5.3, page 19141, line 12 and elsewhere in the manuscript: A standard deviation of the interpolated (residual) values of 0.00-0.25 K raises the question if the cross-valley structure in terms of variations of the heights of the isentropes shown in Figs. 8-12 are significant. The precision of the temperature measurement (not the theoretical one in the laboratory but in the real one in the atmosphere) together with the instrument's time lag in air and the artificial heating due to air impinging on the sensor (which is not constant as the air speed varies) may introduce noise and obscure the true structure (e.g., the maximum variation in potential temperatures in Fig. 8 at a certain altitude is only about 0.5 to 0.75 K). Further, in several of the cross-valley transects shown in Figs. 8-12 the interpolated potential temperature field is extended to the slopes. However, due to aircraft safety reasons the horizontal distance between the slope and the nearest data point is in the order of 500 to 1000 m. Hence, the slope wind layer is not captured and the interpolated (or rather extrapolated) fields close to the terrain do not represent the reality.

Reply. In order to assess the relationship between the interpolation error and the standard deviation provided by RK, we carried out a preliminary cross validation analysis (as extensively discussed for instance by Arlot and Celisse, 2010) on a dataset from airborne measurements similar to that used for this paper (this analysis provided the subject for a manuscript that is going to be submitted soon for publication). The method evaluates cross-validation errors, i.e. the difference between the value measured at one point and the estimates provided by RK at the same point excluding, from the subset of values used for the

interpolation, those lying within increasingly larger neighborhood around that point. For neighborhood radii smaller than half the semivariogram range, the average ratio between the square cross-validation error and the kriging variance is smaller than 1 (fig. 2). This indicates that, for interpolation points within vertical distances of ~125 m and horizontal distances of ~500 m from the flight trajectory, RK overestimates the interpolation error (even by a factor of 10 close to the trajectory points; see fig. 2). This can be explained by the fact that the measurements are not strictly independent one from another in time and space; indeed, due to the fact that the observations are not taken at randomly distributed locations but along a "continuous" trajectory, the correlation between subsequent data is stronger than the simple spatial correlation of the field.
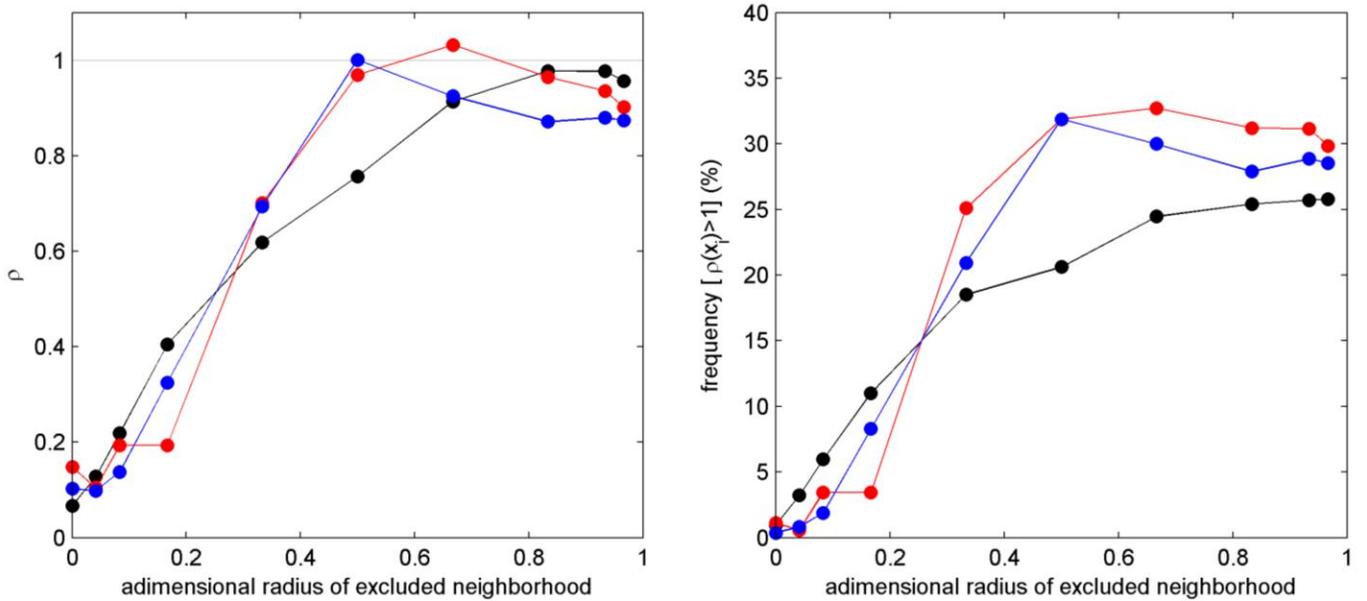

Figure 2. Left: variation of ρ parameter with the adimensional radius of the excluded neighborhood in the cross-validation analysis. Right: as in the left panel, but for the percentage of observation points x_i where the absolute cross-validation error (Err_{CV}) exceeds the kriging standard deviation (σ_{RK}). Here ρ is defined as follows:

$$\rho = \frac{1}{N}\sum_{i=1}^{N}\frac{\left[Err_{CV}\left(x_i\right)\right]^2}{\sigma_{RK}^2\left(x_i\right)},$$

where N is the total number of observations forming the dataset. The adimensional radius of the excluded neighborhood is defined as the ratio between the dimensional radius and the omnidirectional semivariogram range. The results are reported for three different flights, indicated by different colors.
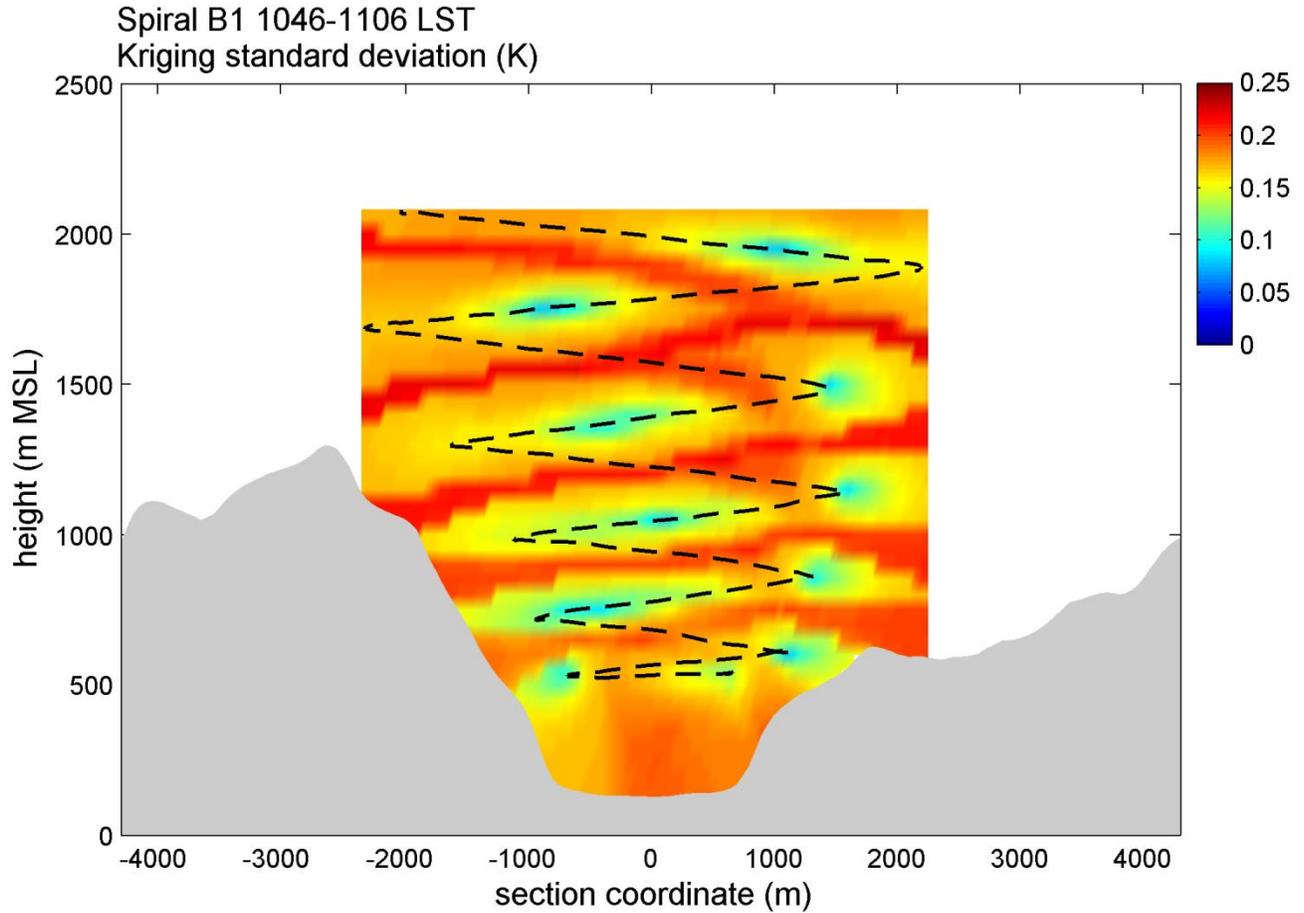
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Figure 3. Vertical cross section of the RK-predicted standard deviation field for spiral B1 from flight #1 (lower Lakes Valley). The vertical plane adopted here is the same used for the potential temperature field shown in Fig. 10 in the manuscript. Notice that the standard deviation is lower where the plane crosses the flight trajectory, i.e. closer to the observation points.

Furthermore, notice that 0.25 K is the maximum value shown by the kriging standard deviation, which is usually found only at points far from the trajectory (cf. Fig. 3). Looking at actual RK standard deviation fields, and keeping in mind the above considerations, we can infer that the "true" interpolation error is by far lower than 0.25 K at most grid points. It follows that the interpolated values and the isentrope patterns are reliable at most grid points. However, we believe that our hypotheses about ABL structures and flow patterns drawn from the interpolation results are not conclusive, and need to be supported by future numerical simulations results.

Airborne measurements were all taken by means of the same instruments. As reported in de Franceschi et al. (2003), the thermometer was certified with an accuracy of 0.03 K and the barometer with an accuracy of 0.5 hPa, leading to an estimated accuracy between 0.07 and 0.09 K for potential temperature. Since we are mainly interested in temperature gradients, i.e. temperature differences, inaccuracies are less relevant. In addition, prior to the interpolation, data were corrected to remove the time lag error due to the temperature sensor time constant, as indicated by Rampanelli (2004). No correction was needed to compensate for artificial (adiabatic compression) heating, because the latter was found to be negligible for the rather low aircraft speed. We added the above details about data pre-processing in the section "Experimental dataset".

We agree that the interpolated fields close to the lateral slopes maybe not truly representative of the slope layer. Indeed, the flights were not able to adequately sample these layers. Based on a scale analysis of data from Schumann (1990), we got an estimate for the average depth of the slope wind layer in the order of 200 m. Accordingly, we decided to remove from Figures 8-12 the extrapolated values falling into a 200 m buffer around local orography. We also removed the interpolated values in the first 100 m above the valley floors, as a reasonable estimate of the ABL surface layer, where we do not know the vertical profile of potential temperature. Above this layer we can hypothesize the presence of a well-mixed layer with constant potential temperature, when its existence is captured by the lowest data of the spiral.

11. Figure 8 and page 19142, line 9-14: I do not see the described asymmetry. For example, the isentrope near 1500 m (302.25 K) is about at the same altitude on the eastern valley side as on the western valley side. Instead of an asymmetry it appears that the central part of the valley atmosphere is slightly cooler than about 1-1.5 km east and west of the center.

Reply. We agree that the vertical section we extracted from the interpolation grid does not display very clearly the asymmetry cited in the text. Therefore, we chose a slightly different cross-valley section from the interpolation grid volume, which better displays the features discussed in the manuscript text (fig. 4; see the associated potential temperature anomaly field shown in fig. 5). The position of the two sections is shown in Fig. 6.
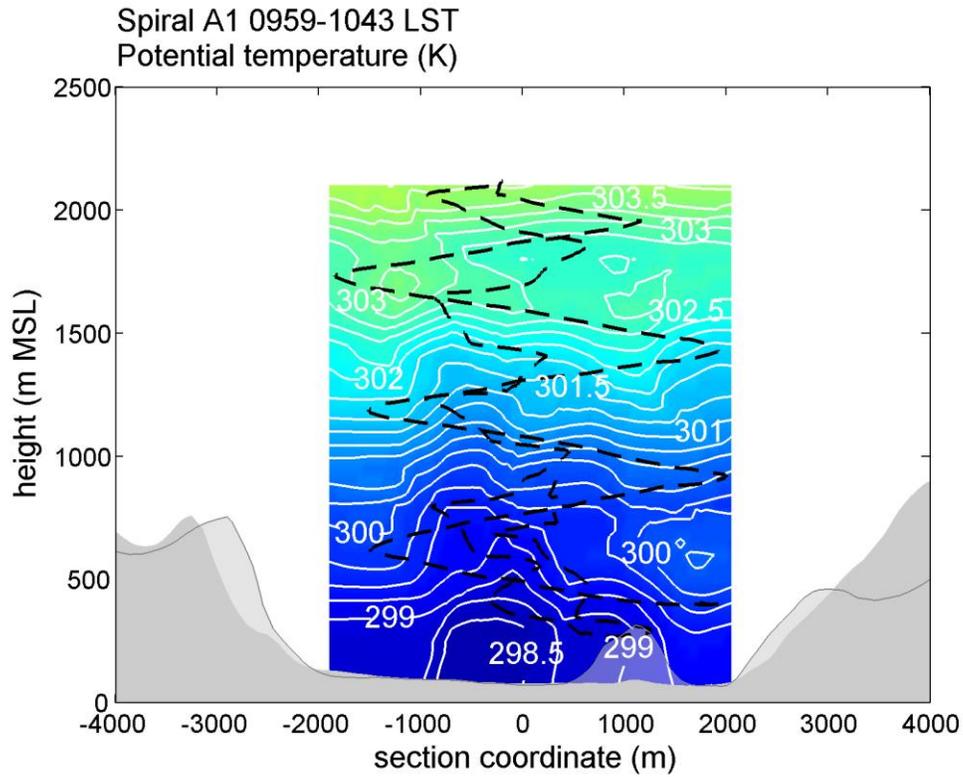
Figure 4. Potential temperature field shown by new figure 8 in the revised manuscript. Contour interval is 0.25 K.
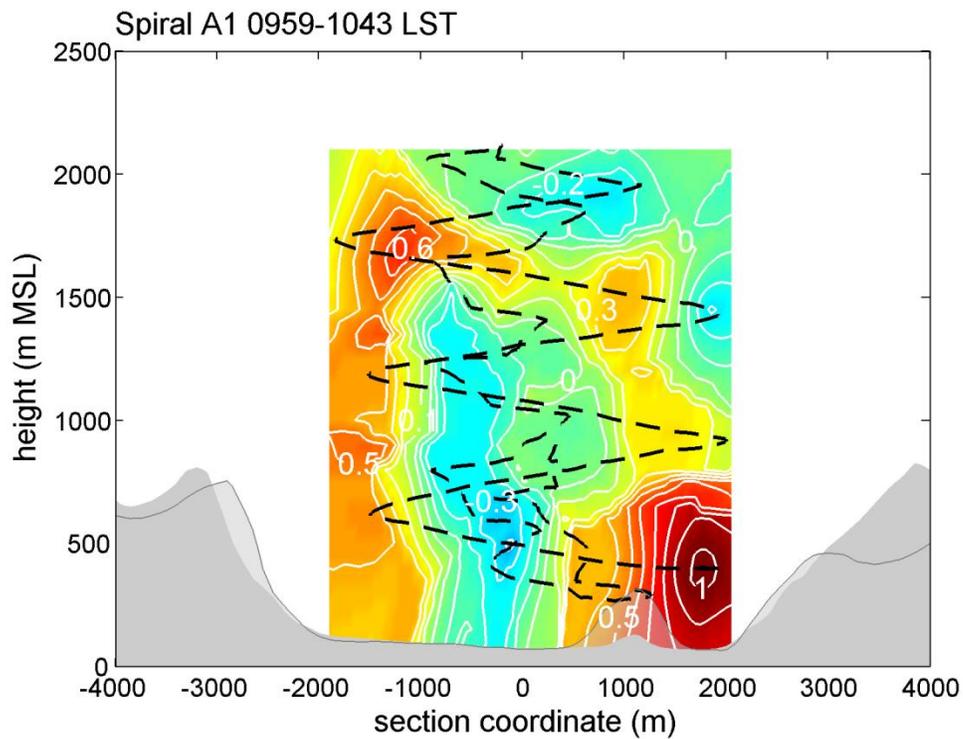

Figure 5. Potential temperature anomaly (i.e. RK-interpolated residual field) corresponding to fig. 4. Red is positive anomaly, green is null anomaly, blue is negative anomaly; contour interval is 0.1 K.
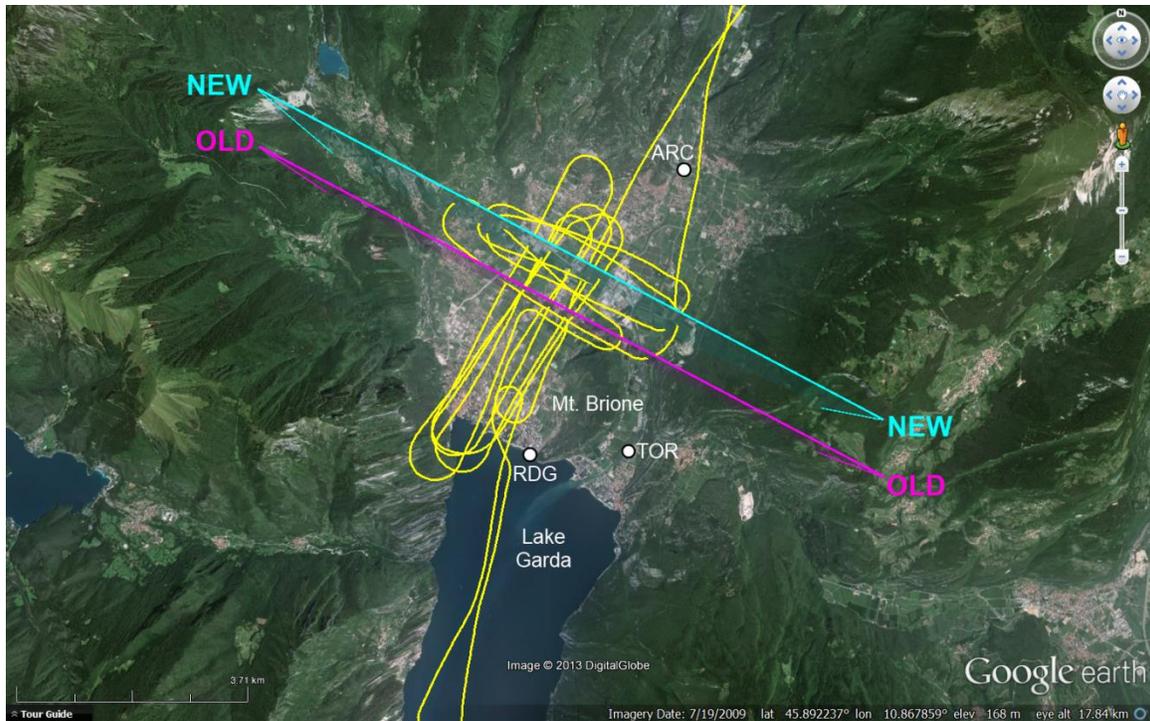
Figure 6. Positions of old (magenta) and new (cyan) vertical planes adopted for the representation of the potential temperature field in Figure 8 in the manuscript. The distance between the two planes is 300 m. The yellow line is the flight trajectory. Background map: courtesy of @ 2013 GoogleEarth, @ 2013 DigitalGlobe.

12. A comprehensive discussion and interpretation of Fig. 9 (along-valley transect) is missing.

Reply. In the new manuscript version we added a comprehensive discussion and interpretation of Figure 9. Indeed, both surface data and RK-interpolated field of potential temperature, display negligible along-valley gradients similarly to what shown for the afternoon phase in Figs. 6 and 7 in Laiti et al. (2013b). This suggests that the lake-breeze front has already propagated along the western Sarca Valley, where the spiral was flown, and moved further up-valley. In the lowest layers a locally warmer region, very likely associated with the presence of Mt. Brione, is found downstream of this rocky hill.

13. Figure 12 and page 19143, line 23-28 and following page: How significant are the features represented by extrapolated data close to the slopes? The closest data point is about 500 to 1000 m located horizontally from the slope. See also comment further above.

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<u>Reply.</u> We removed the extrapolated values close to the slopes from the figures showing RK results. See also the reply to Comment 10 at pag. 12.

(C) Minor and technical comments:

1. Title: "Analysis . . . based on airborne ..." would be better than "... from airborne ..."

<u>Reply.</u> We proposed to change the title of the manuscript according to this suggestion (see the reply to Comment 1 at pag. 2).

2. Section 1, page 19124, line 16: "thermotopographically-driven" is a misleading expression.

<u>Reply.</u> We substituted the above cited expression with "thermally-driven".

3. Section 1, page 19124, line 28-29: "Extended Sea Breeze" is explained/mentioned twice.

<u>Reply.</u> We removed the literature review part containing this expression.

4. Section 2, page 19128, line 17-21: I assume that the times of the flow reversal and the outbreak into the Adige Valley strongly depend on the season. Information on this dependency is needed, or at least information of the season for the indicated times.

<u>Reply.</u> We thank the referee for pointing out the seasonal dependency. We added this information in the revised text, based on preliminary climatological analyses partially presented at the First Annual Conference of the Italian Society for Climate Sciences (23-24 Sep. 2013, Lecce, Italy; see Giovannini et al., 2013a). The following histograms (Figs. 7-10) show the frequency distribution of the Ora del Garda onset and cessation times at RDG and GAR stations, on monthly basis, for the years 2003-2012. As the referee can see, in August at Lake Garda shoreline the Ora del Garda typically arises between 1100 and 1200 LST (being the observations hourly averages, this actually means between 1000 LST and 1200 LST) and ceases between 1700 and 1900 LST (i.e. between 1600 and 1900 LST). On the other hand, at the junction between the Lakes and the Adige valleys, the Ora del Garda

arrival in August is usually observed at 1500 LST (i.e. between 1400 and 1500 LST) and its cessation at 2000 LST (i.e. between 1900 and 2000 LST).
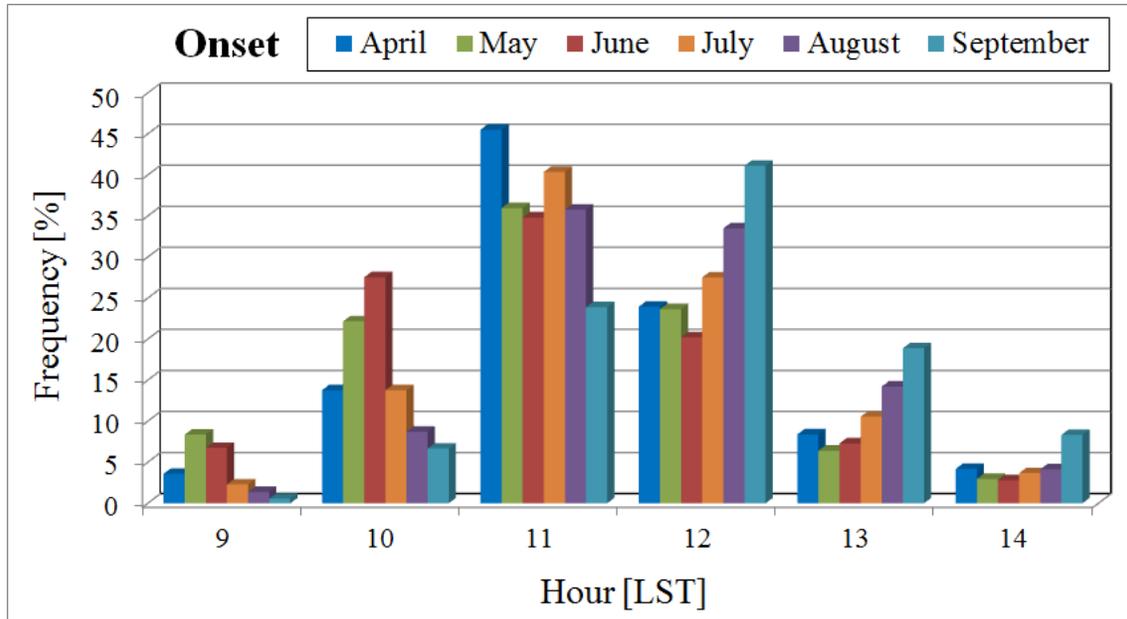

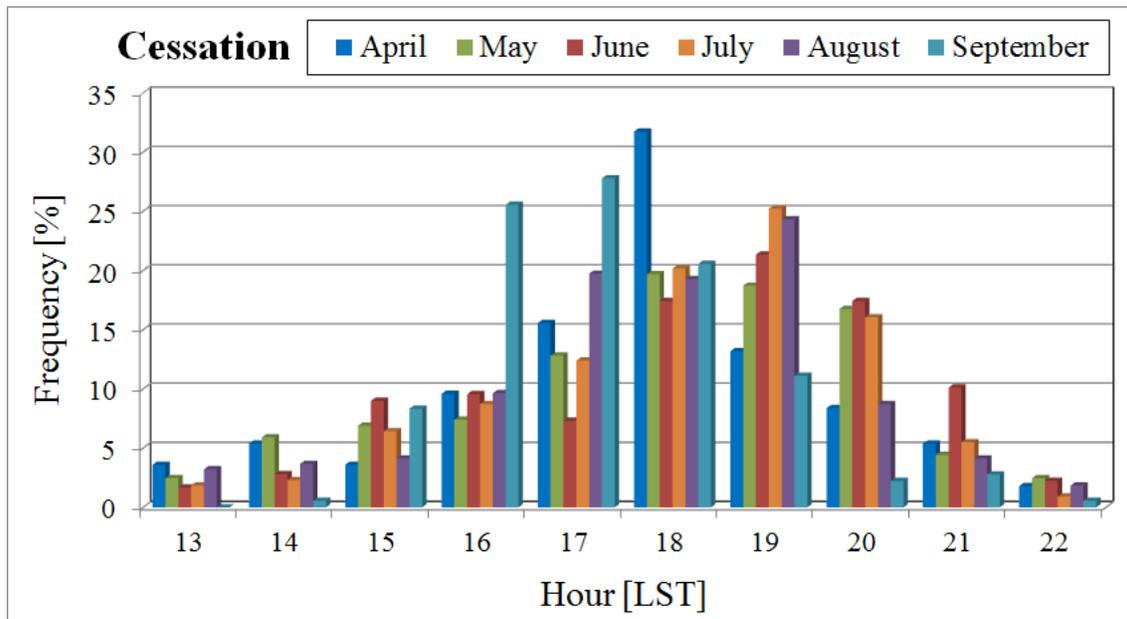**Figure 7.** Monthly distribution of the Ora del Garda onset time at RDG.

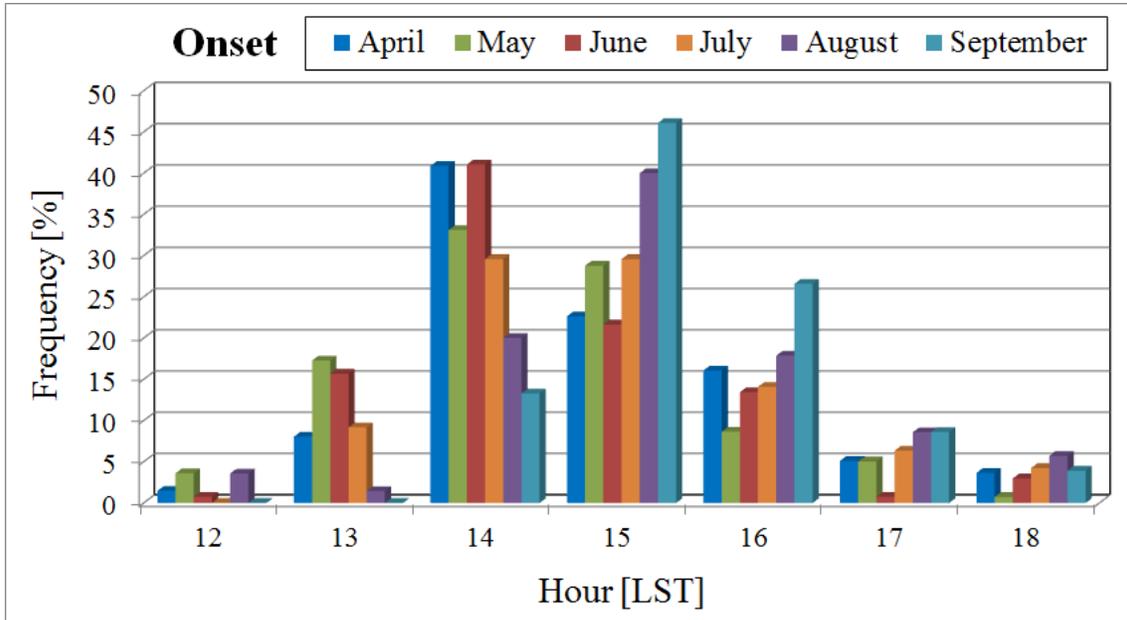**Figure 8.** Monthly distribution of the Ora del Garda cessation time at RDG.

Figure 9. Monthly distribution of the Ora del Garda onset time at GAR.
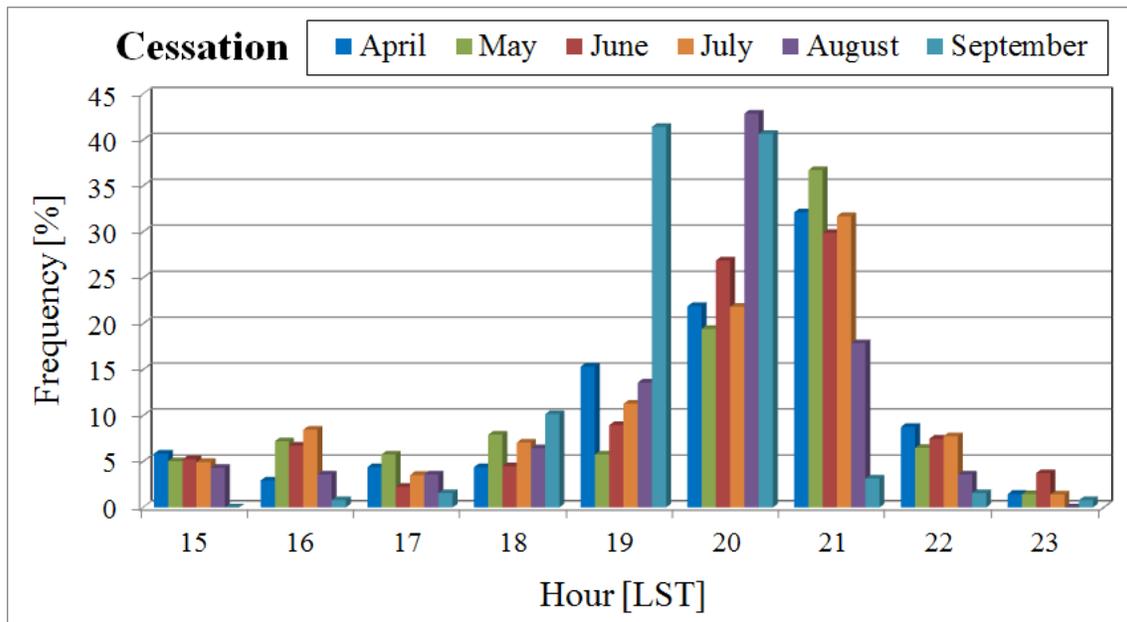

Figure 10. Monthly distribution of the Ora del Garda cessation time at GAR.

5. Table 1: Add date of flight in the caption. Explain symbol "[-]" in the caption.

Reply. We added the date of the flights in the caption. The symbol [-] stands for missing latitude and longitude data; we modified and clarified this aspect in the table, as well as in its caption.

Reply. We originally used MSL and AGL, but the ACP editorial service converted them into m.s.l. and a.g.l. throughout the manuscript. Hence we assume this is the standard for ACP. Accordingly, we adapted the figures.

Reply. The variability refers to a single spiraling trajectory, not to the entire flight. For the sake of clarity, at lines 21-24 we changed the sentence:

"since each *single valley section explored by the instrumented motorglider* was flown in less than 30 min (with the only exception of A1 spiral; see Table 1), the temporal variability over the single *section* can be neglected, as no appreciable evolution of the ABL structure took place during the overflight time"

into

"since each *spiraling flight leg exploring a single valley section* was flown in less than 30 min (with the only exception of A1 spiral; see Table 1), the temporal variability over the single *spiral* can be neglected, as no appreciable evolution of the ABL structure occurred during the overflight time".

Reply. In our calculations the data falling into the moving window were simply given equal weights. Indeed, assigning different weights according to their distance from the window

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center would require the definition of a completely arbitrary weighting function. We clarified this in the text, explaining that the average applied is a centered and simple moving average.

9. Section 4, page 19133, line 1-4: I do not understand this sentence. Explain better or skip and refer to technical paper Laiti et al.(2013a).

Reply. We skipped the entire sentence, as suggested. Laiti et al. (2013a) was used as reference for RK method implementation in the new "Experimental dataset" section.

10. Figure 3 and corresponding text on page 19133-19134: I suggest to indicate the times of onset and decay of up-valley winds at different stations. Also describe gray shaded area in the caption of Fig. 3.

Reply. We modified Fig. 3 by using a different color for up-valley wind phases at each station. We also enlarged the figure to make it clearer. We also mentioned this in the revised manuscript when referring to Fig. 3. In the caption we added the sentence: "The duration of flights #1 and #2 is indicated by the grey bands", as in Fig. 4.

11. Figure 4: Part of the dashed/dotted lines are rather hard to distinguish. Further, I suggest to use potential temperature instead of air temperature in order to facilitate a comparison of stations at different altitudes.

Reply. We modified Fig. 4 by using a different color for each station time series in the panels, to ensure an easier readability. Unfortunately, pressure observations are available at some surface stations only, and potential temperature is not defined for water; therefore, we decided to maintain the use of simple temperature in the graph.

12. Page 19134, line 2: Is this 6 m/s wind speed a one-hour average? Be careful when relating this wind speed to wind speeds at other stations with a shorter averaging period.

Reply. Yes, the wind speed value at line 2 of pag. 19134 is a 1-h average value. We specified this in the revised text. However, the different time resolution of the surface station is recalled

at page 19130 at lines 11-13. Table 2 also lists the time resolution for each station. Please notice the data taken at the stations with a higher sampling frequency show that the analyzed phenomena evolve slow enough to be captured comparably well by hourly averages, as can be seen from Fig. 11. Moreover, the Ora del Garda in its mature stage displays rather steady wind speed and direction, so 15-min averages and 1-h averages return very similar values.
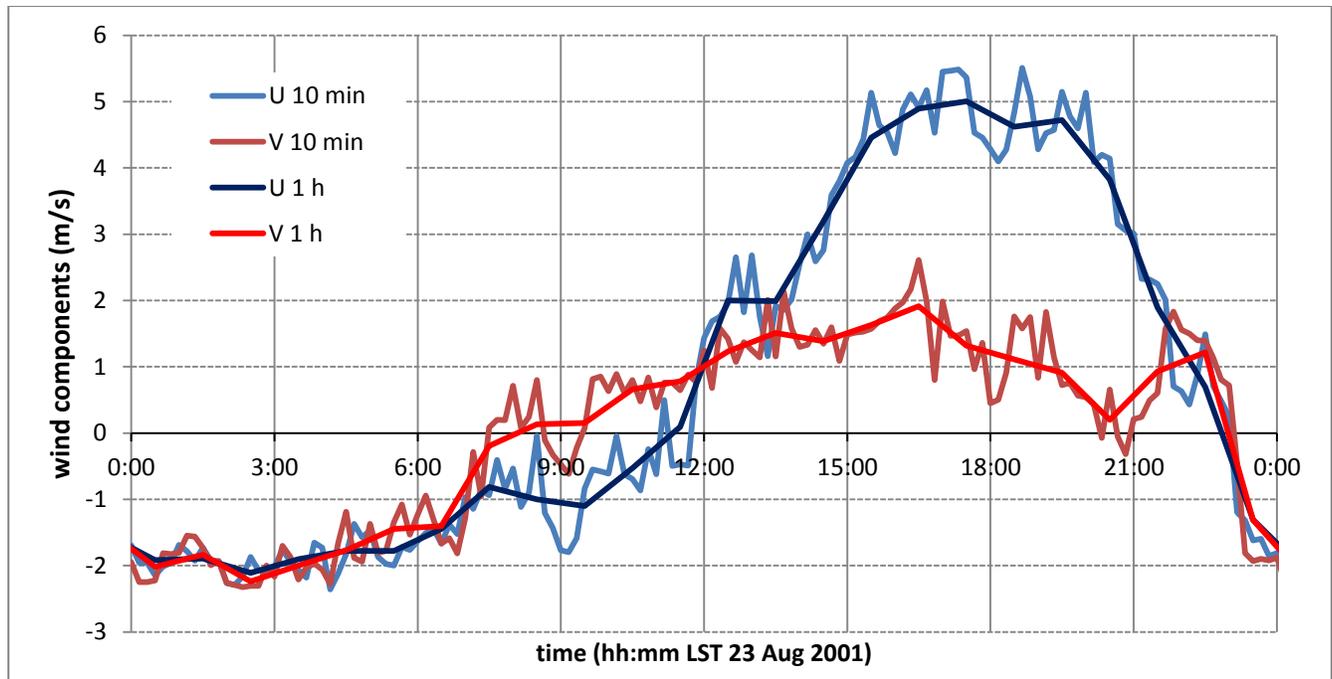

Figure 11. Comparison between 10 min and 1 h average values of easterly (U) and northerly (V) wind components at Monte Terlago station on 23 Aug 2001.

13. Page 19134, line 24-26: Provide an appropriate reference for the "standard" diurnal cycle.

Reply. In the revised manuscript we cited Fig. 9 from Giovannini et al. (2013b), which shows the diurnal cycles of temperature observed in the Adige Valley south of Trento on a typical clear-sky summer day (at TNS and Rovereto stations). We also clarified in the text that by "standard" temperature cycle we mean the typical temperature cycle observed in a mountain valley without any lake at its bottom. This includes a relatively fast heating phase after sunrise, a peak occurring in the mid-afternoon and a slow nocturnal cooling phase continuing until the early morning.

14. Page 19136, line 3-7: Is there any effect of the "anomalous southward channeling" on the temperature shown in Fig. 4 (e.g., an abrupt decrease)? If not, why?

Reply. In the original paper we cited what reported in Schaller (1936) and de Franceschi et al. (2002) regarding the southward propagation of the Ora del Garda in the Adige Valley. They speculated that the southward-propagating branch of the Ora del Garda could reach the areas south of Trento city. However, at pag. 104-110 Giovannini (2012) suggested that the Ora del Garda seldom reaches those areas. Accordingly, the weak northerly wind observed in the early evening hours could also represent the incipient phase of a regular down-valley flow. In the revised manuscript, we commented that TNS station is located too much south of the Terlago gap area to display any effect (on temperature) due to the Ora del Garda anomalous channeling in southward direction.

15. Section 5.2, page 19137: Udine (LIPD) is mentioned in the text but not shown in Figs. 6-7. Are the soundings shown in these figures the ones used in the kriging algorithm ("vertical drift")? I suggest to mention this again.

Reply. We deleted the reference in the text to Udine (LIPD) radiosoundings. We also specified in the text that Milan (LIML) radiosoundings are not used in the kriging algorithm, but only for comparison between our airborne observations in the valleys and the atmosphere over the Po plain.

16. Section 5.2.1, page 19138, line 14 and several other places in the manuscript: "lapse rate" is the rate of decrease of height of some parameter. As potential temperature increases on average with height, the expression "lapse rate" is misleading. I suggest to use "vertical gradient".

Reply. We substituted "lapse rate" with "vertical gradient" throughout the whole revised paper.

17. Page 19142, line 25: instead of "the local cross-section is very narrow" rather "the valley is very narrow".

Reply. We accepted the referee's suggestion.

18. Page 19142, line 27: Notice that rock usually has a higher albedo than forest and, hence, less net shortwave downward radiation which might reduce the heating of the air. However, there is less (or no) latent heat flux above rock compared to vegetation and hence more energy available for sensible heat flux at the surface.

Reply. With all probability, the main reason for the thermal asymmetry detected here is the fact that the eastern slopes are not well sunlit during the morning (i.e. when the flight was performed). However, it is also very likely that in the central hours of the day the sensible heat flux (per unit surface area) is greater above the rocky and steeper (western) sidewall than over the opposite vegetated and more gentle (eastern) slopes. This is ascribable to the fact that above rock there is no partitioning between sensible and latent heat flux, as no evaporation occurs, as well as to the different steepness of the two sidewalls. We clarified better these concepts in the revised manuscript in the "Discussion" section.

19. Page 19144, line 2 and page 19147, line 21: Explain "turbulent recirculation". Is this a sort of wave breaking or turbulence in a hydraulic jump-like feature?

Reply. Based on RK results contained in this paper and in Laiti et al. (2013b), as well as on preliminary (unpublished) numerical simulations of the Ora del Garda wind, we think this is turbulence in a hydraulic jump-like feature. However, this aspect will be clarified only by future numerical simulations we will carry out for the flight days analyzed here and in Laiti et al. (2013a, 2013b). In the revised paper we substituted the expression "turbulent recirculation" with "turbulent mixing" throughout the whole text.

20. Page 19144, line 20: I do not understand "obstruction exerted by ...".

Reply. We modified the text as follows:

"This marks the transition between the supercritical current pouring from the Lakes Valley along the Adige Valley western sidewall and the subcritical flow regime found downstream, i.e. in the eastern half of the Adige Valley."

21. Page 19148: Line 14-23: Do we really need this long list of references at the very end of the paper? Some of the papers should be rather cited in the introductory part as a motivation.

Reply. We reduced the references listed in the "Conclusions" section and deleted the ones already cited in the "Introduction" section.

22. Figures 8-12: Ticks on x- and y-axis are hidden by the gray area.

Reply. We corrected the figure.

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Structure of the paper

OLD STRUCTURE	NEW STRUCTURE	NOTES
1 Introduction **2 The Ora del Garda wind**	**1 Introduction**	• Literature review reduction using Laiti et al. (2013a, 2013b) references • (Brief) literature review on breeze fronts and gap winds / hydraulic jumps • Summary of key results from Laiti et al. (2013b) • Formulation of SMART goals and motivations
3 The experimental dataset	**2 The experimental dataset**	
3.1 Measurement flights	2.1 Measurement flights	• Airborne data analysis method: Laiti et al. (2013a)
3.2 Surface observations	2.2 Surface observations	• References for eddy correlation technique
3.3 Weather conditions	3.1 Weather conditions	• was moved to new Results section
4 Methods 4.1 Extraction of pseudo-soundings from airborne data 4.2 Residual kriging mapping of airborne data	Removed	

5 Discussion of results	3 Results	• "Weather conditions" was added
5.1 OdG diurnal cycle at surface	3.2 Lower Sarca Valley	Formed by parts of old:
5.1.1 Lower Sarca Valley		• 5.1.1
5.1.2 Lakes Valley		• 5.2.1
		• 5.3.1
5.1.3 Adige Valley – south of Trento	3.3 Lakes Valley	Formed by parts of old:
5.1.4 Adige Valley – north of Trento		• 5.1.2
5.2 Dominant vertical structure of ABL		• 5.2.1
		• 5.3.2
5.2.1 Lower Sarca and Lakes Valley		
5.2.2 Interaction area		
5.3 Fine-scale 3-D structure of the ABL	3.4 Adige Valley	Formed by parts of old:
5.3.1 Lower Sarca Valley – Spiral A1		• 5.1.3 and 5.1.4
5.3.2 Lakes Valley – Spirals B1 and C1		• 5.2.2
		• 5.3.3
5.3.3 Interaction area – Spirals D2 E2		
6 Conclusions	4 Discussion	• Formed by parts of old sec. 5-6
		• Critical comparison with results from Laiti et al. (2013b)
	5 Conclusions	• More concise than old Conclusions section