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Nonlinear Processes in Geophysics
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Interactive comment on "Temperature profiles, plumes and spectra in the surface layers of convective atmospheric boundary layers" *by* Keith G. McNaughton and Subharthi Chowdhuri

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1 General Comments

The principal criticism here is that we do not provide enough context for the reader who is not already familiar with convective atmospheric boundary layers. In particular, the reviewer is clearly not familiar with the MOST similarity model widely used by the meteorological community. His perspective has its benefits because he asks us to supply definitions and details that might be useful for readers from other disciplines, even while they may not be needed by meteorological readers. The question is how much meteorological information to include?

We chose to assume that the most readers will be familiar with scaling in turbulent flows, and wrote the paper so that such readers would not require a detailed particular knowledge of convective atmospheric boundary layers for the overall argument of the paper to make sense. At the reviewer's request we now define many terms more carefully in the text, but we still rely on the cited sources for more background and detailed information. We hesitate to reference standard text books because all of them are written from the perspective of the statistical fluid mechanics model of turbulence, in which the actual forms and scaling properties of eddies and plumes play no part. Our approach is to regard the CBL as a dissipative system, and to understand it through its emergent properties, including the properties of eddies and plumes. We have added a

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sentence to the opening paragraph that would be sufficient to orient a reader familiar with Rayleigh-Bénard convection but not CBL flows. It may also be enough for the reader with a more general systems background.

The other general criticism is that we do not take a more mathematical approach to developing our ideas. Our basic approach is laid out in the first paragraph of the paper. We use the words 'emergent properties' to describe eddies and plumes as a signal that we are reaching for things beyond the capabilities of direct mathematical analysis. Some of our responses, below, elaborate on this.

2 Detailed Comments

We thank the reviewer for his many detailed comments on errors and omissions. An outside eye is very useful here. We have adjusted the text to accommodate many of his points. Here we comment on some suggestions we have not followed.

6. "solved analytically". We have not added the word "analytically". The word solve means 'to find an explanation for'. In physics that explanation often takes the form of a compact mathematical expression found by analysis of the governing equations. The word 'analytically' is, at best, redundant. Adding it would have the unfortunate implication that the NS equations can be solved by some other means. What means? Not simulations: they, like experiments, provide numbers but not explanation.

7. We leave the sentence be. Whatever we can learn by scaling analyses, it is not enough to determine the exact form of these patterns of motion and temperature, especially since these patterns are often dynamic.

8. We would like to oblige, but space does not permit. Ours is not the standard model so we would have to explain and justify all of our work since 2004. Instead we give just the information necessary to introduce the arguments in this paper.

11. How to “briefly explain” the background to our paper? We have chosen just to reference our earlier papers. The reason is that there have been no close antecedents for our work beyond what is described in those papers. There have been no other reports of mixed lengths scales for any scalar properties, and no treatment of ‘plumes’ as entities quite distinct from ‘eddies’. Our work has, of course, drawn on a great deal of information from throughout the literatures of boundary-layer meteorology, fluid mechanics and complex systems, but collecting and interpreting these would take an unreasonable amount of space. We reserve that for another time, after we have assembled and interpreted more of the empirical evidence.

20. The speed of the plumes is not relevant in (23).

21. We refer to a transect, not a cross-section. We have added a sentence to explain the connection of length-fraction along a transect and area fraction on a cross sectional plane.

30. The search for scales, the three-range nature of the scales of spectra above the SFL, and the discovery of mixed and doubly mixed scales were all done empirically and in parallel with the development of a conceptual model of the roles of the various kinds of eddies and plumes in CBL turbulence. It would take a substantial amount of space to summarize that work here. Rather, we take the results in Table 1 as given information, traceable through the references, and we attempt to interpret it in terms of the current conceptual model. A basic account of this conceptual model is given in Laubach and McNaughton (op cit), as referenced in the introduction. However, some of the the empirical results in that paper were difficult to interpret, so we performed a new empirical analysis using better data from SLTEST, as reported here. Progress in the present paper is that it extends the conceptual model by elucidating the role of plume cross-sectional areas. The advantage in this development is shown by detecting the error in, and and so correcting the empirical scaling of T spectra and wT given in earlier work. In this we have performed another iteration of the relationship between the compact presentation of empirical results and the associated conceptual model.

31. The reviewer's observation is correct, but the method goes beyond dimensional analysis. It is nonetheless empirical and full of surprises, with constant iteration between the empirical results and the development of a conceptual model. How should we understand the parts of the system and their interactions? The present paper represents a step in that iteration, introducing the idea of the cross-sectional areas of plumes a key explanatory characteristic.

32. There is a rather deep philosophical question here about the role of mathematics in understanding particular dissipative systems. To us, science is about the detection and efficient representation of patterns in the world. Some patterns can be simple and others quite hard to recognize. Some patterns, even quite complicated ones, can be represented very efficiently by causative relationships and mathematical equations, and some not. Turbulent flows are an example where we can write the governing equations very compactly, but they cannot be solved and so give very limited information on the flow beyond gross symmetry properties. Turbulent flows are very interesting and educative systems to work with since we have exact definitions of material properties, energy, entropy and more but must still rely on empiricism to discover the transport properties of these flows. In our work we use mathematics extensively in data analysis, but recognising and interpreting the revealed patterns is a more informal process. Our case relies on how well and how generally our scaling procedures work; any informality in their discovery notwithstanding.

33. Table 1 gives the scale for the velocity variance. The velocity scale is as given.

34. The scales shown in Table 1 are based on their ability to collapse spectra and cospectra onto universal curves in each of three ranges. We look for, and frequently find, self-similar properties of eddy populations. Since the spectra are only as good as the quality of the samples, each spectrum and cospectrum is averaged over many runs to get an ensemble-mean spectrum at each height. The scales must have the dimensions temperature^2 or heat flux, respectively. The scale for the heat flux is clear enough since H is one of our basis parameters. Indeed, H is the only one of our

basis parameters to carry a temperature dimension. We can construct a temperature scale using H divided by a scale velocity, and we find that $(z\epsilon_o)^{1/3}$ does the job well. It is also consistent with our conceptual model that this velocity scale represents the involvement of impinging outer Richardson eddies. In fact we went looking for this scale because $(z\epsilon_o)^{2/3}$ also scales the u spectrum above the SFL. That is to say, we first reviewed our understanding of the system, guessed an answer and then confirmed that answer empirically. This is a bootstrap operation where almost nothing is given ab initio. Dimensionless ratios such as (z/λ) can also be involved, and these are discovered when spectra or cospectra have similar shapes but do not collapse satisfactorily without them. Similarity methods have a long history in fluid mechanics, but in the present work the possibility of mixed scales makes dimensional analysis far less useful.

39. The KY90 relationship is not used in this paper, so we see no need to write it out. Indeed, the KY90 reference could be omitted. Its value is that a reader could more-easily identify the point we reference in Laubach and McNaughton (op cit).

41. See replies to points 30, 32 and 34.

42. The vertical velocity in an attached eddy must go to zero at the ground and at its top, and be maximum somewhere between but not too near either extreme. The $\sim$ symbol traditionally means of the same order as. The key point here is not the factor 2 but the reminder that the height scale is z. It seems unnecessary to make a big point of this, but equally we judge that the reminder does serve a purpose and should be left in.

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