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Interactive comment on "iGen: the automated generation of a parameterisation of entrainment in marine stratocumulus" *by* D. F. Tang and S. Dobbie

D. F. Tang and S. Dobbie

daniel.tang@manchester.ac.uk

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We would like to thank both referees for their comments on this paper.

It is clear from the comments that many parts of the discussion paper were not clearly written. In order to rectify this the paper has now been re-structured, many parts have been re-written and more detail has been added.

Our response to the specific points raised by the referees are as follows:

Referee #1

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"First, I hoped I would learn in detail how the approach detailed in TD1 can be applied

to a system as complicated as 2D fluid flow model applied to a very specific situation of stratocumulus entrainment. But the paper devoted a really small section to this problem and it is unclear to me how this is actually done. My suggestion is to significantly expand section 5 and to provide details on how iGen is used to simplify the entrainment rate prediction. And this should be done in the spirit of TD1, that is, explaining iGen application as it was done using simple examples there."

- An extra section "Analysing the wrapped model using iGen" has been added which describes how iGen analysed the model. The analysis followed the same method as that described in TD1, any additions or differences are described in the extra section.

"Second, description of the model and specific aspects of the particular case takes a lot of space and detracts the reader from the original goal of the paper, which is the application of iGen. I wonder if the description of the model should be removed from the paper and presented in another publication, perhaps with a suite of tests documenting its performance (using, for instance, past test cases of the GCSS Boundary Layer Clouds Working Group)."

- While it would be nice to spend time fully testing the LES model against GCSS data, and writing it up as another paper, constraints on time and funding do not allow this at the moment. For the purposes of this paper, a description of the LES model is necessary to show that it is a full model of 'realistic complexity' rather than a simplified or idealised model, and to show exactly which physical processes were included in iGen's analysis so that the reader can get an idea of the program structures that iGen has analysed. The comparison with the DYCOMS-II is included to confirm that the model captures the relevant physical processes of entrainment.

"More specifically, and perhaps related to 1 above, I do not understand the discussion in section 3. Why the depth of the boundary layer needs to be kept constant? Why does one need to modify grid point values of total water, liquid-water potential temperature and buoyancy? The averages evolve on much longer time scales, so why one needs to adjust? Why this is part of wrapping the model by iGen? The discussion on pages 977-980 and what role it plays in application of iGen is not clear to me. I suggest the authors revise this part of the presentation significantly."

- This section has now been completely re-written to be clearer and to contain much more detail. All the points above are now made clear.

"1. The authors refer to the fluid flow model they use as a cloud resolving model. I do not think this is consistent with the traditional nomenclature. Models with gridlength of a few tens of meters are typically referred to as large-eddy simulation models. A subset of 2D LES models (which really are not LES models as they cannot simulate 3D turbulence) are often called eddy-resolving models. I think the paper by Moeng et al. 1996 (referred to in text) applies such terminology."

- This terminology has now been changed. We decided to use "LES" as this seems to be the most widely used and understood terminology.

"2. How the entrainment rates derived in the study compare to GCSS results published over the last decade or so? I think a reference to these estimates would be desirable to show the context of this work."

- Comparison with GCSS results would certainly be interesting and worthwhile. However, the central point of the present paper is to show that iGen can generate an accurate parameterisation of the LES, rather than to validate the parameterisation (and, by implication, the LES) against data. It is hoped that future work will allow the parameterisation to be tested further against more data and its performance to be assessed in-place in a GCM, leading to further publication.

"3. P. 974. I do not think the "specific water content" is the correct term. Do you mean total water mixing ratio?"

- Yes, thanks for pointing that out. This has been changed.

"4. P. 978-979. What are the reasons for specific choices of timescales involved in the

formulas presented in the discussion?"

- These decisions are now justified in the section "wrapping the LES".

"5. I think sensitivity to initial conditions (bottom of p. 981 and top of p. 982) should not be surprising. Does this call for an ensemble of simulations? How long a single simulation needs to be run to obtain meaningful statistics?"

- Sensitivity of the high-resolution state to initial conditions is not surprising, but it surprised us how much this sensitivity affected the average entrainment. The mathematical relationship between the wrapped model and an ensemble of simulations is now explicitly stated, and related to the length of a single run, in the section "Wrapping the LES".

"6. Figs. 5 and 6 show increase of the mean cloud top. Is that correct? If so, why the vertical axis refers to it as the total entrainment? And why the cloud top rises in the first place? I thought the methodology was aiming at maintain the cloud top in place."

- Figures 5 and 6 show total entrainment i.e. entrainment velocity (m/s) integrated over time to give meters. The cloud-top height did not raise in relation to the simulated domain as it was held constant by controlling the large-scale divergence. However, the large-scale divergence gives rise to a mean downward velocity of air at cloud-top, the entrainment of free-atmosphere air into the boundary layer counteracts this downward flow keeping cloud-top height constant. So the figures show total entrainment, not mean cloud-top height.

Referee #2

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"1) The rationale for using a 2D cloud-resolving model instead of a 3D model is not provided. Are there technical challenges applying iGen to 3D models? As stated in Sect. 3.1, iGen is used on a single model realization and not a large ensemble. Sect. 5 notes that it took 28 days to process on a rather underpowered PC. One assumes that it was the 6 hour 2D CRM simulation that was being analyzed and this needs to be explicitly stated in the text. There should also be discussion of what numerical cost can be expected from analysis of a 3D run. This would serve to explain why a 2D model was chosen for analysis with iGen. For example, how long is the 6 hour CRM run on this PC without the iGen wrapper and analysis?"

- All these points are now discussed in sections 2 and 7

"Of interest to the reader is how iGen would perform on complex problems and there is very little information provided. Given the aggregate nature of the input and output fields and similar source code morphology in the 2D and 3D CRMs, it is not clear why an extra spatial degree of freedom would by intractable on a PC, if indeed that is the case."

- This is now discussed in section 7

"2) Figure 4 shows a time dependent total entrainment but the discussion in Sect. 3.1 refers to the wrapped model output being the average over the last 4 hours of the 6 hour simulation. It is unclear from the text and caption what Figure 4 is showing since it is not a set of constants for the six parameters specified on lines 16 through 19 on page 981. It appears that this is the instantaneous model output unrelated to iGen analysis. This should be made clear in the text. The actual iGen results should be explicitly included in this section."

- Indeed, Figure 4 shows the total entrainment at 12 second intervals of the 6 hour simulation that occurred when the wrapped model was executed. This was intended to demonstrate the sensitivity of the wrapped model to small perturbations in the high-resolution start state, rather than anything about iGen. This has now been made more clear in the paper.

"How does the ensemble simulation described in Sect. 3.1 contribute to the error bounds provided by iGen? According to the companion paper ("iGen: a program for

the automated generation of models and parameterisations"), iGen provides an error bound, yet this value is not given. Is the ensemble spread larger or smaller than the iGen error bound for?"

- Yes, this was not made very clear in the original paper. The discussion in section 5 now makes this clear and adds some extra detail.

"3) As in Sect. 3.1 it is not clear what the iGen output was in Sect. 4. Figure 5 must refer to the instantaneous CRM output (this should be made explicit in the text and caption). How does the spread between the different curves compare to the iGen error bounds on the reference simulation?"

- Yes, figure 5 shows the total entrainment at 12 simulated second intervals from executions of the wrapped model. This was intended to show the insensitivity of the wrapped model to domain geometry, rather than anything about iGen. This is now made clear in the text.

"4) How does the iGen analysis depend on the duration of the simulation and domain? Sections 3.1 and 4 include some discussion of the uncertainty of the CRM but there is no analysis of the behaviour of iGen. Was the choice of a six hour reference simulation justified by convergence of the iGen machine parameterization? Here convergence can include some bounded variation for different integration times. Would iGen be highly sensitive to changes in geometry? For example, would the duration of the model integration need to be changed significantly."

- These points are now dealt with in section 4

"In other words, does iGen exhibit sensitivities unrelated to the physics of the CRM but related to the source code analysis process? The paper is about iGen and not the CRM so such questions should be at the very least discussed when iGen is applied to a complex system."

- The polynomial that iGen generated was shown to have converged to the wrapped model to within the levels of noise generated by the inherent sensitivity to initial conditions. To within these bounds iGen will not show any behaviour that is not present in the wrapped model itself, so any sensitivities must be those of the model.

Interactive comment on Geosci. Model Dev. Discuss., 4, 971, 2011.