Dziekanat Wydziału Fizyki UW
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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Earth System Research Laboratory
325 Broadway – David Skaggs Research Center
Boulder, Colorado 80305-3337

November 1st 2013

Prof. Teresa Rząca-Urban
Dean of the Faculty of Physics
University of Warsaw
Hoża 69, 00-681 Warsaw
Poland

Dear Prof. Rząca-Urban:

Re: Review of Doctoral Dissertation entitled:

"Elements of Modern Cloud Modelling" by Sylwester Arabas

I have completed a thorough reading of the doctoral thesis submitted by Sylwester Arabas and prepared some comments, which I am enclosing below.

The primary goal of this dissertation is to espouse a completely new approach to cloud modelling. There are two aspects to this approach: The first is the Lagrangian treatment of microphysical processes, which has the advantage that it does not suffer from numerical diffusion; the second is a fairly radical change in the software engineering approach to cloud modeling, built on fundamental tenets of transparency, reproducibility, and maintainability. Overall I find the thesis unique, thoroughly and thoughtfully presented, and potentially revolutionary in the field of cloud modeling. The modeling approach and tools are laid out clearly and concisely. The candidate (Sylwester Arabas) has successfully applied these tools to cloud modelling examples ranging from aerosol activation to full particle based coupled Eulerian/Lagrangian frameworks. Comparisons with observations from the Rain in Cumulus over Oceans (RICO) experiment are also presented. The candidate demonstrates superior facility with numerical codes, solvers, libraries and other software engineering modules. He also demonstrates excellent knowledge of basic warm microphysical processes. I note that prior to embarking on his PhD research, the candidate performed an interesting analysis of aircraft data sampled during RICO. This, together with his PhD work rounds out his education/training and I am confident that he will make significant contributions to the field of cloud microphysics.

My assessment is that the candidate has taken the lead role in all of the papers that constitute Appendices A.1, A.2, and A.3, as confirmed by statements in the thesis and supporting letters

I warmly recommend that Sylwester Arabas be admitted to the next stages of conferring of a PhD degree in Physics.

Finally, I would like to mention that this thesis exudes a level of quality that is rarely seen in work by a scientist at this early stage of his career. The candidate demonstrates a combination of attention to detail, clarity of thought and, frankly, a degree of courage in promoting a new approach to cloud modelling when many in the field are set in their ways.

Some general comments on Appendices

Appendix A.1

This previously published paper (Arabas and Pawlowska 2011) is a very nice example of an application of an adaptive numerical method, developed in a different field, to a cloud modelling problem. Efforts such as these are wonderful for "cross-pollination" of methods and ideas from other fields. The paper demonstrates very clearly that the adaptive method, while numerically intensive, has much superior convergence properties than existing models. If one compares models with similar precision, it is in fact less expensive than a standard model.

Appendix A.2

The methodology of "superdroplets" is applied in this paper (Arabas and Shima, 2013) to one of the GCSS modeling cases – the RICO trade-wind cumulus case. The significant achievement of this work is that it demonstrates successful simulation of the RICO case with a highly sophisticated modeling framework. The particle-based method ensures that there is no numerical diffusion in the microphysical calculations. This is one of the few models of its kind in the world and the candidate should be congratulated for successfully integrating this code. Sensitivity tests examine the extent to which the number density of superdroplets, and grid size influence results.

Appendix A.3

The third Appendix is a paper in preparation for submission to Geophysical Model Development (Arabas et al. 2013). It lays out in more detail the software engineering aspects of the modeling approach, arguing for careful methodologies to ensure repeatability and reproducibility of results. Three examples are given: a simple bulk microphysical model, a two-moment microphysical model and finally the superdroplet model. All are coupled to a 2-D kinematic framework. The reader is introduced to the C++ code, libraries, and methodology. In each case, the candidate systematically leads the reader through the model set-up and an example simulation. The strengths and weaknesses of the various models come through very clearly.

Sincerely,

Graham Feingold, PhD