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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Growth of ice particle mass and projected area during riming" *by* E. Erfani and D. L. Mitchell

Anonymous Referee #2

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This paper provides a way to evolve m-D and A-D relationships during riming with the goal of being able to improve riming in models that rely on these m-D and A-D parameterizations for different ice categories. The authors use their own previous data fit to compare with observations from the Sierra Cooperative Pilot Project. They show that riming increases the mass of ice and argue that this increase in mass can be parameterized without changing the beta coefficient in the m-D relationships. They also provide collection efficiency parameterizations for both planar and columnar ice based on numerical calculations. While the goal of this paper is to improve models by using observations, this paper has major issues that need addressed before it can be published. Major issues: Perhaps be more specific about how to use this method to improve models that rely on different ice categories. It seemed hard to follow just how and when rimed snow would become spherical or hexagonal graupel using this

framework.

By assuming graupel forms when the mass of ice has increased approximately three fold, assumptions about the type of graupel and it's density are being made and this should be clarified.

Perhaps the introduction needs an extra section on the treatment of riming in models after talking about the characteristics of riming. Also, perhaps the riming rate equation needs to be introduced (at least qualitatively) in the introduction before talking about riming and collection efficiencies.

m-D relationships are parameterizations which reduce the dimensionality of complex ice shapes. More discussion is needed on alpha and beta and what they mean. Alpha can be considered to contain density and thickness information, thus certainly it can contain all the change to m-D during riming, but others could argue that because shape changes during riming beta should change at some point. The current ideas in this paper and comparison to observations are useful because they link theory with modeling and confirm the idea that light and moderate riming can be modeled with assuming fixed beta, and this method should improve models. But where does, for example, the fixed beta assumption break down? What are the limitations of the method?

General comments. Why not show a plot of alpha evolving or d alpha/dt? Page 3 Line 4 "mass of snow collected" Lines 7-8 perhaps change "snowfall rate" to "precipitation rate" Line 10 40% (extra space) Line 13 (QPEs) Line 14 remove (SGM) as it is only used one other time and not often Line 18 change to "mass sink" Line 21 change word "powerful" General comment: watch the spacing between number and deg C or other units Line 29 what is considered the western Arctic? Page 4 Lines 1-2 are confusing, reword Line 3 remove "tracks", make storms on the previous line plural Line 6 this doesn't limit understanding of riming, instead it limits understanding of phase partitioning Line 9 riming peaks at -10.5C for low LWCs. Also, the reason is partly due to different collection efficiences for planar versus isometric ice Line 13 remove "pro-

cess" Line 14 "with a spherical shape" Lines 14-16 both sentences start with "In this". Change Line 23 give a better definition of alpha and beta Page 5 Line 6 make clear that these are all different for different ice types Line 20 autoconversion isn't an actual word, so maybe just use conversion Line 20 "hydrometeor category to another" Line 24 "abrupt microphysical changes" to what? Line 28 This isn't necessarily 4-moment because rime fraction and rime volume are not moments of the size distribution. You may want to ask Dr. Morrison about this. Line 29 there is no need to note about aggregation as it is not discussed in this paper Page 6 Lines 1-2 you may want to better describe the method of MG09 Line 23 put Re in parentheses Line 24 what is a free fallspeed Line 25 "that were exposed to" Line 26 "Although d ranged" Page 8 Line 21 "from the Sierra" Line 29 and following line both start with Also Page 9 Line 15 remove hyphens after moderately and heavily Line 17 add a year to the Magono and Lee citation Page 10 Line 3 the binning intervals description is confusing. Line 7 Do the results change if lightly rimed ice is assumed to be in the rimed ice category? Figure 1 what density is assumed for the solid ice spheres? Lines 14-15 This is shown in Figure 2 and this should be noted Page 11 Line 8 20-30% is less than other get and is less than the value of about a doubling of mass you use later in the paper. How can you explain this? Line 15 perhaps start of by talking about methods that assume constant beta (MG09) and then corroborate their results Page 12 Eq 3 Can you also plot best fit values assuming Dˆ3? What reduced density values would you get if you assumed Dˆ3 and is this reasonable? Lines 9-10 Put these statements in better context. Perhaps talk about how bulk models use graupel categories (Dˆ3) and some assume spherical snow, but other assume snow goes as Dˆ2. Then talk about how beta should change in nature and the best way to parameterizing riming snow in models. Line 16 Again, if you assumed spherical graupel, what density would it have and could you also plot that m-D curve? Page 13 Line 5 "beta as constant during the riming process (until spherical) for both" Line 8 perhaps use "number distribution" instead of "number density" Line 9 remove "because it is a function only of D" Lines 12-18 seem out of place Line 20 this value is inconsistent with the 20-30% from earlier. Explain. Page 14 Lines 1-3 you can

probably just say this is due to errors in classification Page 15 Line 10 Is this also justified because beta is approximately 2? Line 19 The value of 3.3 will depend on things like rime density. Under what conditions does using this value work? Page 17 Line 5 again the value of 2.4 will depend on a lot of variable. When do you expect the model to break down? Page 22 Line 5 doesn't increasing size also lead to increasing Re? Line 11 "as a conservative underestimate" Line 19 perhaps "number distribution" Line 21 it is assumed to be negligible, not zero Page 23 Line 7 "microphysical and therefore optical" Page 24 Line 11 is it really dˆ13? Page 25 Line 11 should this be "representing ice particle m and D"? Page 26 Line 1 change SGM to simple growth model

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