Geosci. Model Dev. Discuss., 4, C1376–C1388, 2012
www.geosci-model-dev-discuss.net/4/C1376/2012/

Geoscientific Model Development Discussions

Interactive comment on "CELLS v1.0: updated and parallelized version of an electrical scheme to simulate multiple electrified clouds and flashes over large domains" *by* C. Barthe et al.

C. Barthe et al.

christelle.barthe@univ-reunion.fr

Received and published: 19 January 2012

Response to Ted Mansell (Referee)

We would like to thank this referee for his comment that helped to improve the original manuscript.

Summary

The paper presents the latest updates to the electrification parameterizations CELLS *used in Meso-NH. The highlight is on the parallelization of the lightning scheme, which allows flashes to be propagated in parallel processing with domain decomposition. A trade-off in this scheme is that channel points are no longer checked for connectivity, but the results suggest that this is more of an aesthetic issue than a practical one. The rest of the model description follows previous papers, and a sensitivity study is performed that is relevant to the updated lightning scheme. The STERAO case has been simulated before, but the EULINOX case is new.*

Major Points

1. Page 2858, lines 26-27 through Page 2859 lines 1-6: This section is somewhat confusing to me. Is the maximum electric field magnitude found separately for each height (i.e., model level)? Since the triggering threshold varies as a function of air pressure, a smaller field is needed at high altitude. Thus a maximum field at lower altitude might not be enough to trigger lightning, but a lower field aloft might do this but be missed. This would get more difficult with terrain, as the altitude becomes a function of horizontal position, although the levels probably flatten out pretty well above 6 km or so. The examples in the paper use a flat ground, so it has not yet been shown how well the system works with terrain. One could just check each point for whether the field exceeds E_{trig} and build a map, or perhaps use the maximum value of the ratio E/E_{trig} instead of the maximum E.

In the code, the 3D electric field is first computed for each gridpoint of the domain of simulation, and then it is multiplied by $\exp(z/8400)$ to get rid of the pressure/height effect. The next step is to find the location of the maximum electric field to check if it exceeds the threshold value for flash triggering which is 167 $\times$ 1.208 V m^{-1} according to Marshall et al. (1995) and recalled in Eq. 5 of the text. Since the height of each model gridpoint depends on the horizontal position, no particular treatment has to be

GMDD

4, C1376–C1388, 2012

Interactive Comment

done even in the case where orography is present. We performed technical tests to check that the algorithm still works well.

It must also be noted that we do not intend to search for the exact location for flash triggering at this stage of the algorithm. We just want to find a point in this cell from which we can look for the cell extension. Starting from another point of the same cell should not be a problem.

We agree the formulation in the original manuscript was confusing. The second paragraph in Section 2.2.1 has been modified:

”The electric field module is first multiplied by a factor to get free of the height effect. It is noted E_0 and corresponds to the electric field module reduced to the ground level. The peak value of E_0, E_{max}, is sought in each subdomain. Then, the global value of the maximum electric field $E_{max}\_ll = MAX(E_{max})$ is determined and the processor number (IP_{cell}) where $E_{max}\_ll = E_{max}$ is identified. If E_{max}_ll is higher than 200 kV m^{-1}, the electric field threshold for flash triggering at the ground level (see Section 2.2.2), a first electrified cell is detected. The maximum electric field is a natural marker of lightning-triggering cells since a flash is triggered only if $E_{max} >$ 200 kV m^{-1}. The point where $E_{max}\_ll >$ 200 kV m^{-1} is hereafter called the cell center.”

2. Page 2858-2859: The use of r_{tot} and q_{cell} could be elaborated on. How is ”a single cloud” defined? Do you mean within the cloud boundary of a storm? A storm can have multiple cells, and lightning can propagate from one cell into a neighboring cell that have merged cloud boundaries. Considering the charge structure in Fig. 3b, it is not unreasonable for a flash to span two cells, at least through the negative charge. It seems that a flash should only be restricted by the potential, and perhaps a restriction on the potential (as in MacGorman et al., 2001) would work better than one on hydrometeor mixing ratio. How do you think the scheme would handle a larger convective system, like a squall line? I suppose you can wait to refine this aspect when you

GMDD

4, C1376–C1388, 2012

Interactive Comment

get to cases that need it.

The cell identification part is dedicated to the definition of the areas over which the flash can propagate. We assume that a flash cannot propagate out of a cloud boundaries (r_{tot} condition). The second condition ($q_x > q_{cell}$) limits the flash propagation to contiguous points with enough electric charge. We chose to use the electric charge instead of the electric potential, but as you suggest, this aspect of the algorithm could be refined later.

At 70 minutes of simulation (Fig. 3b), the three cells are no more clearly identified, and one individual flash can span two ”cells”. However, up to now, even if we tested our scheme with several case studies (mainly multicellular or supercellular structures), no squall line has been simulated. Our next objectives are to simulate larger systems like tropical cyclones and convective systems in the southeast of France (HyMeX campaign). As you mention, some refinements will probably be necessary to handle such large and long-lived systems.

Minor Points

1. Page 2850, opening sentence of introduction: References for this? I would suggest Goodman et al. (1988) and Wiens et al. (2005) as examples of observational studies linking total lightning (IC+CG) with storm dynamics.

Done.

2. Page 2851: Some of the references to tropical cyclones used CG lightning only, at least Black and Hallett, or very infrequent total lightning (satellite overpasses). Note that these citations are not in the reference list (neither are Darden et al. 2010 nor

GMDD

4, C1376–C1388, 2012

Interactive Comment

Emersic et al. 2011). The recent paper by Fierro et al. (2011) shows results of continuous tracking high-energy IC flashes (narrow bipolar events, or NBEs) in two hurricane eyewalls, which is still not total lightning but is better than CG only or a few minutes per day of total lightning.

You are right, some references do not concern the relation between cloud discharges and tropical cyclones. They are removed in the new version of the manuscript.

3. Page 2851, paragraph starting "Most of the modeling studies": The choice of references could include classic early studies by Takahashi (axisymmetric) and Helsdon (2D and 3D) and Ziegler (1D/3D), which first put the non-inductive graupel-ice mechanism at the forefront. Altaratz (2005) does not seem to be the best reference, as it did not include lightning discharges and only calculated electric fields offline. Hou et al. showed only two charge density fields and without any microphysical or kinematic context, so this reference also seems to have limited relevance.

You are right that references to Altaratz et al. (2005) and Hou et al. (2009) may be misleading because their models were incomplete but we add them to illustrate some of the "blocking points" that accompanied the developments of cloud electricity schemes. However, some references have been added in the revised manuscript.

4. Page 2856, line 1: Hail would only have a water film if it is in a wet growth mode (or melting). In dry growth mode it should be capable of charge separation. There is a UMIST (Saunders?) reference that notes the cessation of charge separation during wet growth.

In the microphysics scheme of Meso-NH, hail is supposed to tay in a wet growth mode (Lascaux et al., 2006). Hail is produced by the fraction of graupel particles which are in the wet growth mode. Only dry graupel particles participate to the NI charging process.

GMDD

4, C1376–C1388, 2012

The UMIST reference that notes the cessation of charge separation during wet growth is: Saunders, C.P.R., and I.M. Brooks, 1992: The effects of high liquid water content on thunderstorm charging. J. Geophys. Res., 97 (D13), 14671-14676.

5. Page 2857, lines 23-24: Surely a Dirichlet boundary condition is used at the ground? I have found that a Dirichlet condition at the top boundary can be more stable than Neumann conditions, provided the top is high enough away from storm top (Mansell et al., 2010, switched to this top boundary condition). (Edit: Note spelling of "Neumann").

We use Neumann boundary conditions for V' since we specify its normal gradient through the electric field E (mirror conditions at the top and the bottom, and fair weather conditions for each lateral face).

The spelling of "Neumann" has been corrected in the revised manuscript.

6. Page 2859, line 13: "to avoid undesirable side effects" This could be more specific, such as "to isolate individual storm cells."

Done.

7. Page 2860, lines 18-19: Note that Helsdon et al. (1992) also used the ambient field to propagate and terminate the channel. They noted that the physical process is actually controlled by the total field, but did not model it that way.

The reference to Helsdon et al. (1992) has been added.

8. Page 2861, lines 14-16: I am not sure what is meant by "physically consistent representation." Do you mean at the microscopic scale? Or just at a different level of parameterization? Practicality and expense depend on the goal, and if the goal is real-time simulations, then certainly it has to be as simple as possible. More complex *parameterizations are not necessarily "technically impractical" on parallel computers, either. (The dielectric breakdown model has been parallelized, for example.)*

"physically consistent representation": here we have in mind the framework of real meteorological simulations, since the new simplified scheme must still represent the gross macroscopic features of the flash (geometry, extension...). Actually reproducing the microscopic developement of a single flash is computationally too much expensive. It requires to update the electric field each time a new segment is added to the flash structure while each flash is composed of hundreds of elementary segments! Even with an efficiently parallelized solver for E, it is not possible to run simulations with electrified storms on large grids with hundreds of gridpoints. Our new algorithm breaks the idea of connecting the successive grid points where a flash propagates. This helps to treat a flash at once since the detailed flash structure is lost (but not its statistical significance as it reflects the fractal law expressed by Eq. 6). The key is that there is no need to iterate over the flash structure to add a new segment using a SINGLE PROCESSOR (this operation is local in the whole domain and by definition it is non-parallelizable).

9. Page 2862, line 22: Keep in mind that although charge density determines the electric potential, it is really the potential that controls the extent of the branching. In simple charge arrangements they are nearly synonymous, but not for complex charge structures.

Since we just want to reproduce the general behavior of the lightning flash, we assume that the charge density allows us to control the extent of the branching. However, it would be interesting to modify the algorithm and use the electric potential to control the branching, and then examine its impact on different charge structures.

10. Page 2863, lines 19-26: Is this procedure only for the second case ($N_{poss} > N_{||}$)?

GMDD

4, C1376–C1388, 2012

If so, that could be clarified, since otherwise I think the statement on line 26 would be that the flash path would contain at most (rather than exactly) $N_{||}$ points.

You are right, this procedure is only for the second case. The statement on line 26 has been modified.

11. Page 2867, line 17: Should the negative ice crystals be obvious in Fig. 3?

You are right. This can not be seen on Figure 3d because the ice crystal charge density is small in the anvil. This is more obvious on other cross sections we plotted and that are not shown. So we added"(not shown)" in the revised manuscript.

12. Page 2868: Charge transfer in IC flashes is difficult to evaluate observationally. I don't see any such values in Shao and Krehbiel (1996). Two relevant references here would be Maggio et al. (2009) and Lu et al. (2011). Another means of evaluation could be to calculate dipole moments.

In Shao and Krehbiel (1996), see page 26,652 right column: "the IC flashes in Figures 9 and 10 transfered an estimated 5.6 and 15.1 C of charge upward during their active stage respectively".

13. Page 2869: The sensitivity to the charge per collision limit is interesting. Another important factor is the graupel-ice collection efficiency. As collection efficiency increases, the charge separation decreases, not only because of fewer rebounding collisions, but also because more charged ice crystals will be collected back onto graupel. What are the settings in the microphysis for this process?

The graupel-ice collection efficiency E_{ig} follows Mansell et al. (2005):

$$E_{ig} = 0.01 \times \exp(0.1 T_c)$$

GMDD

4, C1376–C1388, 2012

Interactive Comment

with T_c the temperature (C) while for graupel-snow and snow-ice collision, it follows Kajikawa and Heymsfield (1989):

$$E_{ig} = 0.25 \times \exp(0.05 T_c)$$

No sensitivity analyses have been done with this parameter.

14. Did the case with multiple cells (early stage in STERAO storm) ever have simultaneous flashes (i.e., flashes in more than one cell in a time step)? Are these flashes somehow labeled with a mask? Or are the flashes actually done sequentially? Section 2.2.2 is a little ambiguous in talking about choosing a point within a cell, but not about which cell.

Yes, there are simultaneous flashes during the multicell stage for the STERAO storm. The triggering point is searched in each cell. If several cells exist in the domain, and if more than one cell contain a triggering point, several flashes can be treated simultaneously since there is a mask that discriminate the different cells in the domain. The flashes are built, and then the electric field is updated. If at least one triggering point is found in the domain, the procedure is repeated. Thus, in a single time step, each cell can generate several flashes.

This is now made clear in Section 2.

Technical Points

1. Incorrect year in the Kuhlman et al. (2006) reference (should be 2006, not 2005)

The year has been corrected.

GMDD

4, C1376–C1388, 2012

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

2. Page 2853, line 21: "imperatively" seems redundant with "must be" and could be deleted.

Done.

3. Page 2858, line 7: Suggest "Good efficiency of the parallelization is provided by a library of high level..."

Done.

4. Page 2860, line 26: Suggest "branched of the leader [propagate] until ... at the tip[s] of the last"

Done.

5. Page 2862, lines 8-9: The wording is a little vague. Suggest "through plastic slabs with [regions of stronger and weaker negative charge density]." Reproducing this discharge behavior was one of our tests of the dielectric breakdown model (Fig. 6 in Mansell et al., 2002), which up to then had only been used in charge-free regions between conductors held at constant potential.

Done.

6. Page 2865, line 7: What is meant by "hardly externalized"? Not able to be run off-line?

It means that the complete electrical scheme is not easily adaptable to other models due to the strong link of cloud electrification with the microphysics. The sentence is modified in the revised manuscript:

"The lightning flash scheme excepted, the computation of the charges and of the

GMDD

4, C1376–C1388, 2012

electric field are not easily adaptable to other models."

7. Page 2865, line 19: Suggest "allows [testing of] the cell ...."

Done.

8. Page 2866, line 17: Maximum radar reflectivity in a column is also known as "composite reflectivity."

Yes, the manuscript has been modified accordingly.

9. Page 2866, line 27: Suggest "...model is fairly successful [in reproducing] the evolution..."

Done.

10. Page 2867, lines 6-7: Suggest "the electric field increased [above] 10 kV m^{-1} " (Delete "module was".)

Done.

11. Page 2874, line 12: Suggest "... efficiency was possibly [degraded] when the supercell..." (rather than "embarassed").

Done.

12. Page 2874, line 18: Suggest "... proportion is clearly [underpredicted] by a factor of 10."

Done.

GMDD
4, C1376–C1388, 2012

13. Page 2875, line 15: Suggest "been [heavily] revised to be run in a..."

Done.

14. Page 2875, lines 17-20: Suggest "... aspect of the channel imposes difficulties for parallelization. [Previously] the growth of the ... recursive description of the [flash propagation into] positive and negative pocket[s] of charge. Here, [recursion] comes from..."

Done.

15. Page 2876, lines 22-23: Suggest "... planned in 2012 [with the] purpose [of studying] the heavy rainfalls ...."

Done.

References

Altaratz, O., Reisin, T., and Levin, Z.: Simulation of the electrification of winter thunderclouds using the three-dimensional Regional Atmospheric Modeling System (RAMS) model: Single cloud simulations, J. Geophys. Res., 110, doi:10.1029/2004JD005616, 2005.

Helsdon, J. H., Wu, G., and Farley, R. D.: An intracloud lightning parameterization scheme for a storm electrification model, J. Geophys. Res., 97, 5865–5884, 1992.

Hou, T., Lei, H., and Hu, Z.: Numerical simulation of the relationship between electrification and microphysics in the prelightning stage of thunderstorms, Atmos. Res., 91, 281–291, doi:10.1016/j.atmosres.2008.04.009, 2009.

Kajikawa, M. and Heymsfield, A. J.: Aggregation of ice crystals in cirrus, J. Atmos. Sci., 46, 3108–3121, 1989.

GMDD

4, C1376–C1388, 2012

Interactive Comment

Lascaux, F., Richard, E., and Pinty, J.-P.: Numerical simulations of three different MAP IOPs and the associated microphysical processes, Quart. J. Roy. Meteor. Soc., 132, 1907–1926, 2006.
Mansell, E., MacGorman, D. R., Ziegler, C. L., and Straka, J. M.: Charge structure and lightning sensitivity in a simulated multicell thunderstorm, J. Geophys. Res., 110, doi:10.1029/2004JD005 287, 2005.
Marshall, T. C., MacCarthy, M. P., and Rust, W. D.: Electric field magnitudes and lightning initiation in thunderstorms, J. Geophys. Res., 100, 7097–7103, 1995.
Shao, X. M. and Krehbiel, P. R.: The spatial and temporal development of intracloud lightning, J. Geophys. Res., 101, 26 641–26 668, 1996.

GMDD
4, C1376–C1388, 2012