A MODEL FOR LIGHTNING IN LITTORAL AREAS

Alex Blaj

University of Twente, Enschede, The Netherlands, Email: m.a.blaj@utwente.nl

Frank B.J. Leferink

University of Twente, Enschede & Thales BV Netherlands, Hengelo, The Netherlands, Email: frank.leferink@nl.thalesgroup.com

ABSTRACT

The littoral or coastal areas are different compared to the maritime or continental areas considering lightning. Only the last years some research about these areas has been carried out. The need for a model, regarding the lightning activity in these areas is much needed. And now, with the changes induced by the Global Warming, the thunderstorm models over these areas have and will continue to change. The continental areas are already investigated but the littoral area still needs attention. Because of the changeover between the maritime and continent, the littoral area has some atypical characteristics.

INTRODUCTION

The naval scenario has changed in recent years. For many decades, naval vessels were mainly used to protect vessels on the ocean. This has changed rapidly. Now naval vessels are used near to the coast, in the littoral. At the same time, electronic equipment moved from the protected environment inside the ships hull to the exposed environment on the deck and on top of the ships. Due to the weight restrictions more and more composite materials are introduced, with often no or very thin conducting layers. But a thin conducting layer has limited shielding effectiveness with respect to the high magnetic fields generated by a lighting flash.

One of the steps in lightning protection consists in creating a prediction model for thunderstorms and lightning over certain durations of time and a particular area [1]. The maritime and littoral area is however excluded from [1]. During the last decades, various models for thunderstorms for continental and maritime areas have been created, but on the coastal (littoral) areas only theories where released. However, because of the global warming process, even the existing models need to be updated. Furthermore, we would like to extend the models applied in [1] to the littoral and maritime area. Among the attributes required in [2] is the rate of occurrence, together with the rate of rise, duration, amplitude, spectrum, frequency, source impedance and energy potential. The activity in the littoral area does no influence the general perspective of the global average of lightning strikes, but with this data makes the standard regulation more accurate to this situation.

We might consider the littoral areas not as a special area, but because of the changeover between maritime and continental areas, the way thunderstorms behave here is influenced by outer factors coming from these two neighboring areas.

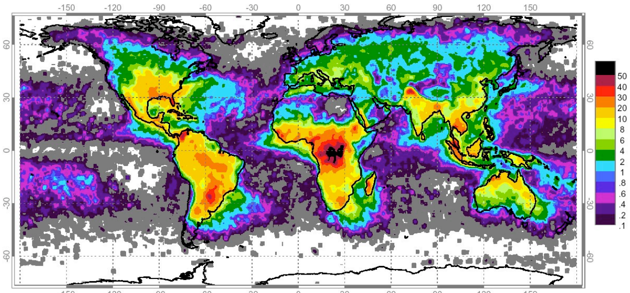

Figure 1 – Global Lightning Frequency on Earth [3].

Figure 1 [3] presents by different colors the variations in lightning activity between areas on Earth. In particular, we can observe the differences between the continental and maritime area and also how these differences influence what takes place in the littoral areas.

A good example of the particularities of littoral areas is the Saharan Air Layer (SAL) that influences dominantly the surrounding environment from West Africa to the western tropical North Atlantic. The images taken from satellites and the live measurements indicate the fact that SAL outbreaks just before the commencement of the tropical storms on eastern tropical Atlantic Ocean [4].

Armed with knowledge from the research done in the past [1÷27], and with the understanding of the climate change phenomena, the work will focus towards an updated model for the risk of lightning and to develop a model for the littoral areas.

THE GLOBAL ELECTRIC CIRCUIT

Generally, the conductivity of Earth surface is good, but because of the poor conductivity on the hot and dry areas or at the poles, earth cannot be seen as a conductor. In the areas with high concentrations of silicate residue the conductivity increases while for the atmosphere, the best conductivity is reached at altitudes exceeding 80km in the upper atmosphere (the ionosphere - considered to be equipotential). Inside thunderclouds and in fair weather regions, the air conductivity is related to the pollution and height as well as of the geomagnetic latitude of that location. Between the ground level and the upper atmosphere layers an imperfect insulator exists – the atmosphere.

There are upward and downward currents travelling between the stratosphere, the atmosphere, and the ionosphere. The thunderstorm conduction currents are considered upward currents while the fair region current has a downward flow. These currents and sources are considered to form the DC circuit of the Earth, while the lightning discharges, forms the AC circuit [5,6,7].

CHARGE FORMATION

The entire cloud electrification cannot be explained by a single phenomenon. All consists in a co-operation between processes with time-dependence dominance and variable effectiveness. For example, during freezing, melting, evaporation and deposition the correlation between the environmental conditions and properties of particles give different charging regimes, thing independent from any pre-existing external field [8].

The charge generation process has various means be realized into an atmosphere made of gas. Starting with the influence of cosmic rays and UV solar radiation and continuing with friction, meteors entering the atmosphere, desert, or volcanic dust, end even cloud charging and atmospheric circulation [9].

Raising the concentration in aerosols, it raises the number of raindrops inside the warm clouds and the total lifespan of the cloud but diminishes the size of the droplets and also the rate of precipitation coming from those clouds [10].

CHARGE LAYERS FORMATION

The Earth allows the formation of charge layers, an important fact not only in the development of thunderstorms but also in the “fair – weather” conditions. Regarding the extreme climate areas, like desert areas for examples, the formation of charge layers is strongly influenced by the ionizing condition existing there.

The presence of charge layers can be observed above the surface of the earth, but also underground reaching the Core. This fact gives the possibility to electromagnetic phenomena to occur. Over the ocean, the electric field at the water surface is bigger then in the case of ground surface, because of the layer of positive charge descended from the upper layers of the atmosphere.

From sea level up to 40 – 50km in the atmosphere, the electrical conductivity is dominated by light ions. The free electrons in the air help realize a good conductivity, with their high mobility and lightness. Up to 100km high, the conductivity makes possible also the formation of macroscopic charges in free space.

In 2007, Markson was considering Hawaii as a miniaturized continental surface, and observed a strengthening of the electric field on the ground area because of the electrode effect [11]. Having a 200m thickness, the charge layer, can be created by the agitated vertical movement of charged particles. Another factor for the layer are the positive charges released during the sea spray. The charges are carried to shore by the air currents flowing at the water surface. The maritime aerosols can have another effect, the reduction of conductivity in the atmosphere over those areas.

Another theory was developed after the miniaturized representation of continents by islands. Williams [12] in 2004 came with the hypothesis to explain the differences in lightning strike frequencies between the continental and oceanic areas by means of differences in temperature between these areas, and the capacity of the soil to heat faster then the water [13]. This faster heating process, on the continental area, increases the instability, convection, and the frequency of flashes.

During the 80’s, Lemon & al. presented the differences between the oceanic and continental convection at the tropics [14]. In the continental area, the updrafts in a thunderstorm goes over 50m/s, while in the case of oceanic area it can reach only 10m/s. This ratio between the two velocities explains the differences in electrification of the thunderstorms and number of flashes in the two areas. All this because of the importance played by the updraft in the electrification and number of flashes in a thunderstorm.

DISCUSSION

The climate, as influenced as it is by the radiation and heat coming from the sun, is tight related to lightning frequency around the globe. For example, at the tropics, during the apex of the sun, the lightning discharges reach their highest levels (frequency and intensity). Not on daily base this time but on seasonal base, the summer days are the most active. Because the “dry” (continental) area is not equally distributed on the face of the Earth, on the northern hemisphere the lightning activity is more intense compared to the south. The difference between continental and oceanic area was explained earlier (‘earlier’ not done in Conclusion). The continuous overheating of the planet and the impact it has on thunderstorms and external conditions raises some serious questions (‘question’ not done in Conclusion). In turn, the modifications of the lightning activity will modify the climate.

By the continuous heating of the soil and the air, the layers of air in the atmosphere get different temperatures according to their position. With different temperatures, the air has also different densities. Mixing of these different masses of air with various densities, and the solar heating, results into atmospheric convection.

Nowadays, the global worming is a fact, and all the debates regarding it can't go around our problem. Raising the temperature at ground level with one degree, because of the dependency between temperature and lightning, the lightning activity increases with 10 to 100% [12]. Greenhouse gases in the atmosphere and the global worming, phenomena influencing the climate system, modify the behavior and content of clouds. After all these changes in the climate, the response from climate comes in the form of modification of cloud properties and the atmospheric electrification. In fair weather regions, the climate change brings modifications to the global circuit and to the microphysical processes inside clouds.

The climate models of the future show thunderstorms with less rain but more active in lightning, and all this because the earth surface looses moisture - a direct effect of global warming.

With the expansion of deserts, and with the surface of the earth getting drier the microphysics inside the clouds of the future is going to be different. Large ions formed from the dust and pollutants are picked up by the winds and carried into the clouds. At a close look, the dry dust particles lighter then the moisturized once. The lack of moisture in the particles prevents them to unite in order to form larger particles with a bigger weight.

Another effect of lack of moisture can be observed in the variations of air pressure. A dryer air translates into less air pressure, so better chances for light dust particles to be lifted into the atmosphere by small wind drafts.

In coastal areas, the cold air from the continent filled with dust, is brought over the water, and the warm moist air from the oceanic area is pushed towards the coast. While warms up, the cold air rises to reach the ionosphere and gathers more ions from the galactic cosmic rays. It results in development of large thunderstorms on the littoral areas.

A model will be developed which will include these effects.

CONCLUSIONS

Not so long ago, global worming was a theory. Now we can feel its effects, and the way it will further influence the thunderstorms and lightning in the future, we presented in the previous paragraphs. A higher frequency of lightning strikes represent more chances for a ship working in the littoral area to be struck by lightning, or for the field generated by lightning to couple into the electronic components. In the future, we will be able to design an adequate lightning protection for the equipments on ships that can stand all these variations in lightning characteristics.

REFERENCES

1. CEI – IEC – 62305 1 – 4 International Standard: Protection against lightning, January 2006;
2. IEC TS 61000-2-5 Electromagnetic compatibility (EMC) - Part 2: Environment - Section 5: classification of electromagnetic environments basic EMC publication, September 1st, 1995;
3. Global lightning strikes from January 1998 to February 2006 from the NASA/MSFC Lightning Imaging Sensor;
4. G. S. Jenkins, A. S. Pratt and A. Heymsfield: Possible linkages between Saharan dust and tropical cyclone rain band invigoration in the eastern Atlantic during NAMMA – 06; Geophysical Research Letters;
5. B. A. Tinsley: The global atmospheric electric circuit and its effects on cloud microphysics; Reports On Progress In Physics, Vol. 71, 2008;
6. R. G. Harrison, F. Märcz; Geophysical Research Letters, Vol. 34, 2007;
7. M. J. Rycroft, R. J. Harrison, K. A. Nicoll, E. A. Mareev: An overview of Earth's global electric circuit and atmospheric conductivity; Space Science Review, Vol. 137, 2008;
8. I. M. Brooks, C. P. R. Saunders, R. P. Mitzeva and S. L. Peck: The effect on thunderstorm charging of the rate of rime accretion by graupel; Journal of Atmospheric Research, Vol. 43, Issue 3, March 1997;
9. G. A. Bazilevskaya, I. G. Usoskin, E. Flückiger et al.: Cosmic ray induced ion production in terrestrial and planetary atmospheres. Space Science Review, Vol. 137, 2008;
10. R. A. Black and J. Hallet: Electrification of the Hurricane; Journal of Atmospheric Sciences, Vol. 56, Issue 12, 15 June 1999;
11. R. Markson, Bulletin of the American Mathematical Society, Vol. 88, 2007;
12. E. R. Williams: Lightning and climate; Atmospheric Research, Volume 76, Issues 1-4, 2005;
13. Colin Price, 2008: Thunderstorms, Lightning and Climate Change; 29th ICLP Proceedings, June 2008;
14. L. R. Lemon, C. A. Doswell III: Severe thunderstorm evolution and mesocyclone structure as related to tornado genesis; Monthly Weather Review, Vol. 109 – Issue 9, 1979;
15. K. L. Aplin, R. G. Harrison, M. J. Rycroft: Investigating Earth's Atmospheric electricity: a role model for planetary studies; Space Science Review, Vol. 137, 2008;

16. R. Mitzeva, J. Letham and S. Petrova; Atmospherical Research Letters, Vol. 82, 2006a;
17. W. A. Fernandes, I. R. C. A. Pinto, O. Jr. Pinto, K. M. Longo, S. R. Freitas: New findings about the influence of smoke from fires on the cloud – to – ground lightning characteristics in the Amazon region; Geophysical Research Letters, Vol. 33, 2006;
18. B. A. Tinsley and L. Zhou: Initial results of a global circuit model with stratospheric and tropospheric aerosols; Journal of Geophysical Research, Vol. 111, 2006;
19. O. Ataratz, O. T. Raisin and Z. Levin; Geophysical Research Letters, Vol. 110, 2005;
20. E. R. Mansel, D. R. McGorman, L. Ziegler and J. M. Straka; Journal of Geophysical Research, Vol. 110, 2005;
21. R. G. Harrison, K. L. Aplin, f. Leblanc, Y. Yair: Planetary Atmospheric Electricity; Space Science Review, Vol. 137, 2008;
22. P. Alpert, T. Ben – Gai, A. Baharad, Y Benjamini, D. Yekutieli, M. Calacino, L. Diodato, C. Ramis, V. Homar, R. Romero, S. Michaelides and A. Manes: The paradoxical increase of Mediterranean extreme daily rainfall in spite of decrease in total values; Geophysical Research Letters, Vol. 29, 2002;
23. Y. Yair: Charge generation and Separation Processes; Space Science Review, Vol. 137, 2008;
24. E. A. Mareev: Formation of Charge Layers in the Planetary Atmospheres; Space Science Review, Vol. 137, 2008;
25. K. Sassen, V. I. Khvorostyanov: Cloud effects from boreal forest fire smoke: evidence for ice nucleation from polarization lidar data and cloud model simulations; Environmental Research Letters, Vol. 3, May 2008;
26. R. A. Treumann, Z. Klos, M. Parrot: Physics of electric discharges in atmospheric gases: An informal introduction; Space Science Review, Vol. 137, 2008;
27. H. R. Pruppacher, J. D. Klett: Microphysics of cloud and precipitation; Reidel, Dordrecht, 1978.