Atmos. Chem. Phys. Discuss., 9, C527–C535, 2009
www.atmos-chem-phys-discuss.net/9/C527/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Lightning characteristics observed by a VLF/LF lightning detection network (LINET) in Brazil, Australia, Africa and Germany" *by* H. Höller et al.

Anonymous Referee #2

Received and published: 5 May 2009

Review of the manuscript to ACPD entitled 'Lightning characteristics observed by a VLF/LF lightning detection network (LINET) in Brazil, Australia, Africa and Germany' by H. Höller et al.

General Comments:

The paper concerns the important issue of lightning characteristics in four different geographic locations on Earth in tropics and extra-tropics with distinct storm activity characteristics.

The authors made use of the unique possibility to compare data of the same light-

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ning detection system (LINET) which was operated during various field campaigns with nearly the same geometrical configuration and working regime. LINET is a VLF system for the detection and location of both CG and IC lightning discharges with high detection efficiency.

The data were analyzed statistically on the basis of the daily lightning totals for the detection areas. For selected days the detected lightning data were combined with radar observations of the clouds.

The distribution of the peak current amplitudes for IC and CG lightning was discussed. Finally, the production of nitrogen oxide (NOx) by lightning of the various types was estimated on the base of the current amplitude distributions. This allows for a comparison of the NOx production potential of storms in regions with different climatic regimes.

The authors give a short description of the lightning detection system, however, more information is needed about the nature of the different types of lightning discharges detected by the system. This holds particularly for the characteristics of the detected intracloud lightning data.

Some specific comments are given below concerning the methodology of analysis and the presentation details. Particularly the use of fitting and integrating function lines is unsuitably and may mislead the interpretation in some places.

The paper is written well, in an intelligible and systematic style. Overall, it is somewhat lengthy. This is partially attributed to the large material. Nevertheless, the authors may consider to shorten same passages.

The content of the paper is of high relevance for the storm and lightning research community. It is a original and valuable contribution to the understanding of the lightning and storm climatology.

I recommend the paper for publication after minor revision, which takes into account the specific comments given below.

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Specific Comments:
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Intracloud-CloudtoGround lightning

The LINET lightning detection system is able to detect both intracloud and cloud to ground lightning. Some additional explanation of the sources of the detected events would be helpful.

1. Interpretation of the IC and CG events.
How the single IC and CG events have to be interpreted? Is there a short time correlation (1sec) of the CG and IC flashes? Do the ground flashes consist of several return strokes? Are the IC events parts of one large cloud flash? If not, what point of the IC flash channel is detected and given as horizontal position? Is there a different interpretation for horizontally extended IC lightning? Are the CG flashes associated with cloud flashes?
If possible, provide numbers or ratios for these quantities, because this is important for the interpretation of the IC numbers and the IC/CG ratio.

2. Amplitude distribution functions
Fig.28 and text:
The amplitude distribution functions differ from the figures usually reported in the literature. Mean values for the peak current amplitude are usually around 23kA, this paper reports much lower values. Moreover, the fraction of positive ground flashes seems to be larger than usually reported.

The authors should address this issue and give a short discussion if and how the characteristics of the LINET produce this result? Can the differences between the pre-

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sented picture and the 'usual' results be explained consistently by the higher sensitivity of the LINET to weaker lightning?

3. Polarity of the IC lightning.
What part of the cloud discharge process is detected by LINET (leader or recoil processes)? How does LINET detect the polarity of IC flashes and how is this to be interpreted? VHF systems respond differently to leaders of different polarities. Is this also true for LINET?

p6093-9pp:
'.. Negative strokes are supposed to transfer charge between an upper negative and a lower positive charge center whereas positive strokes are due to opposite charge configuration.'

Please, explain this statement. Why should the IC polarity depend on charge *configuration* of the cloud? Generally, leader processes of both polarity initiate the discharge process between the cloud charge regions. The resulting recoil discharge will transport negative charge due to its higher mobility.
What is the base for the derivation of the charge structure from the polarity of the events detected by LINET?

'Trend line', running mean of daily totals

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p6071-19pp:
The time series of the daily lightning totals are given in the Figures 4, 10, 16, 23, 27. These figures also show 'trend lines' which were calculated as polynomial fits of 3rd order.

What is the purpose of these lines?

Firstly, the terminus 'trend line' may be misleading here. These lines are rather a fit to the overall data set, which is arbitrarily calculated as a 3rd order polynom. I doubt, if an overall fit of this kind should be applied here.

Lightning data are highly intermittent and characterized by the time scales of the producing processes. The daily totals are dominated by the number of storms in the detection area, the intensity and lifetime of the storms. These storm characteristics are determined by the circulation pattern, atmospheric stability, etc. and by the time scales of these underlying processes.
Hence, for certain locations the time series is always determined by few days with highest activity and periods without or weak storm activity. The authors have observed this for Darwin and Germany.
Any 'trend line' will fail to describe such a behavior, since it will be always below the time series for days with expressed storm activity and above the time series for days with no lightning.

Additionally, the displayed 'trend lines' show some artifacts on the various figures:

- fig.4, p6071: The text notes a 5-10 day oscillation. This is in contradiction to the fit of the whole time series with one 3rd oder polynomial. The trend line does not support the interpretation, particularly for the ALL data it seems to be strongly affected by the few days with maximum lightning numbers.
- fig16: The 'trend line' for CG and IC after mid of September is based on just 1 day. The trend line for these data should not go beyond September. The strong decline in November is supported by ALL data. The pulsation in the IC and CG time series is not reflected in the trend lines.
- p6085, fig23: The trend lines at the edges behave very mysteriously. The edge data points seem not to support the strong decline of the trend curve.

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The ’trend lines’ are interpreted and discussed with the necessary caution in the text. However I doubt, if this fitting line is necessary at all, and I recommend to omit it. The discussion of the pulsations and changes in storm activity can be given without the ’trend lines’.

NOx-Production

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p6095-1pp:
The NOx-production per flash is calculated by the formula of Wang et al. This formula was derived as a fit to second order in current amplitude from laboratory measurements on sparks. The authors extrapolate the formula to larger current amplitudes. This can lead to an overestimation of the NOx production at the large amplitudes. The authors should justify the application of the formula (Nox proportional to the squared amplitude) by dimensional arguments or energy considerations.

p6097-2pp:
The channel length could not be taken into account in the NOx estimation. However, particularly the relation between the CG and the IC contributions may change completely if the lengths are introduced. While for ground strokes a mean length can be anticipated, this is much harder for the IC lightning.
In view of this open question, I doubt, that the *relative importance of IC and CG* can be estimated.

Integration of the NOx

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p6095pp and fig.33-34:

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The discussion of the contribution of the NOx as a function of the peak current amplitude is instructive. However the presentation of the integrated curve starting from -infinity is inconvenient and unnecessary.
The authors have to keep in mind the bimodal character of the current distribution. A more appropriate procedure would be a running integration for the *absolute value* of the current, starting from the strongest amplitudes of both polarities and extending to the weakest amplitude (or vice versa). This would be also consistent with Wang's formula, which doesn't account for the polarity.
This integration curve poses a lot of difficulties for interpretation. E.g.

- Intermediate values along the curve are to be interpreted as (e.g. at +20kA): NOx for all negative flashes and the lowest (<20kA) positive flashes. What is the value of this information for the reader?
- How should the end value of the integral curves be interpreted and compared between the 4 regions? As total NOx per storm, per day? Since the basis was the normalized amplitude distribution (percentage of flashes), the NOx distribution is distorted. It would be appropriate to normalize the integral curves to a equal final (right) values. A mathematical formulation of the curves would clarify this.
- The error bars are intended to represent the variability in fig.33-34. However they increase monotonically towards large positive amplitudes due to the integration procedure. Again this may mislead the interpretation.

The integrated curves are misleading and hard to understand. I strongly recommend to omit these 'integration' lines. All the interpretation and discussion in the text can be made on the distribution functions alone. For a separation of the contribution from 4 types of lightning the totals over the complete amplitude ranges might be given. In order to characterize the variability the authors might consider to display the frequency distribution function of the daily total NOx production instead of the error bars.

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Minor Remarks

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p6066:23-24:
Explain please, what do this numbers relate to? Is this the contribution from all storms of this type, or for a certain part of the globe?

p6069:21pp, Fig.3b) and similar figures:
What quantity is displayed, is it a density measure? What is the unit, events per km2 per year?

p6073-15pp, Fig.6:
Why is the IC-fraction equal 1 during no-lightning periods? You might omit this parameter for these periods or increase the time base for calculation. Can you give an uncertainty measure for the IC ratio? I suppose it will fluctuate largely.

p6074-28pp:
Can you explain the large difference in position error for CG (40m) and IC (340m) lightning in this case?

p6081-26pp: Fig.15(trace), Fig.17:
The shift of the daily mean position with latitude is a striking feature and one is tempted to interpret this as the shift of the ITCZ. However, is the network area large enough for doing this conclusion? The 'mean position' might not correspond to a real center of the storms of the much larger ITCZ region.
A similar motion of a mean position might be found for most other locations on Earth. It reflects gradual shifts of storm activity areas influenced by geographical features and circulation pattern.

Fig.25b:

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Typo, x-axis must be probably distance.

section 3.1, Fig.27:
The figure puts together (for comparison) the daily lightning totals for the 4 regions as a function of the observation days. This type of presentation makes no sense for me. What information should the reader get from this combined plot? The data should not be displayed along the 'time axis' of observation days, which is completely arbitrary and moreover of different length.
More instructive for the reader could be a frequency distribution of the daily totals for the different regions.

Fig.28:
Explain, what quantity was averaged? The percentage curves for each day? How are the mean values calculated: for the whole data or from the daily percentages? The choice of the method affects the result mostly for regions with strong variations in storm activity. What is the bin size of the classes?

p6099-9pp:
"..The Brazil and Benin lightning was found to behave very similar to each other in terms of total LNOx production which was found nearly a factor of two less efficient." What does this mean? Does a storm in Brazil, Benin produce less NOx? I suppose, the authors want to express that *the normalized lightning distribution is a factor 2 less efficient* due to the IC/CG ratio and the discharge altitude. For total NOx production the total lightning number has to be multiplied. The authors should clarify this point.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 6061, 2009.