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Stochastic Models of Lightning and Lightning Observation on Venus

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Abstract

Many observations regarding lightning on Venus are mutually discrepant, with widely varying rates and intensities and many negative reports. A model of lightning as a purely random process with a uniform rate appears to be incompatible with the observation set. While a plausible thesis is that one or more observations are 'wrong' in asserting an interpretation, here I explore models of possible temporal and/or spatial variability of lightning in an attempt to maximize agreement with observations while minimizing the number of model parameters.

1. Introduction

The first-order analysis of any phenomenon not unreasonably posits a Poisson process with a single, uniform occurrence rate λ. An observation is then a set T of Bernouilli trials (detect ? Y/N) which attempt to constrain λ as ~Y/T. A major challenge in reconciling observations to date is that the detection threshold (typically, a top-of-atmosphere light flash energy) is not always accurately quantified, and is typically different for different searches, and without taking this into account (wherein the population of lightning events has some distribution that yields different counts for different thresholds) the comparisons are largely meaningless.

Some progress has been made in recent years in addressing analogous challenges in planetary meteorology, namely assessing the population of dust devils on Earth and Mars. A simple and physically based observation- dependent threshold detection with a plausible (power law) distribution of dust devil diameters [1] was able to reconcile reported dust devil occurrence rates (devils/km2/day) which differed by four orders of magnitude! These surveys were all conducted, however, at locations/times expected a priori to have dust devils, and typically with long enough periods that day-to- day variations were averaged out. Inspection of dust devil occurrences (e.g. the number of devils in single orbital Mars images) shows a strongly non-Poisson distribution, with the number of 'many-devil' images disproproportionate to an extrapolation given the number of single- and few-devil images.

In other words, there is at least one 'hidden variable' determining whether conditions are favorable for dust devils or not (typically the ambient wind speed).

This paradigm seems appropriate for lightning on Venus, if it exists, as indeed it seems to be true for lightning on Earth. Casual observation indicates that if one sees one lightning flash, one is likely to see many, because there is a storm, whereas overall storms are rare.

Even with very poor statistics (7 flashes), the optical survey by Hansell et al. [3] found '*an indication that Venus undergoes quiet times and noisy times*' since on four nights (3.75 hours) of observation the counts were [2,2,0,3], with the last 3 occurring within 10 minutes of each other. On the other hand, in part such stochasticity may also be due to variations in the detection efficiency (such as the claimed dependence of Venus Express magnetometer signatures of lightning on the geometry of the magnetic field lines) : Russell et al. [4] note only 61 detections in some 12,223s of observation, but consider that the observations only access Venus 1/4 of the time, and over only a few hundred km (0.027% of the planet's area) : their extrapolation of a 18/s global flash rate (20% of Earth) based on the wholly unsupported assumption that the flash rate is uniform.

Although ultimately it may be necessary to develop a spatial variability model to explicitly track the migration of "storms" and the intersection of those lightning-favorable regions with an observation process, a first step is simply to posit two additional variables – a characteristic duration S of a storm, and an occurrence rate R, and to adopt λ as a conditional quantity (i.e. $\lambda=\lambda o$ during a storm, $\lambda=0$ otherwise). If (as is presently the case) the observation duty cycle is small, it is possible to find many nondetections that are not inconsistent with a few high-rate detections.

2. Summary and Conclusions

Efforts are underway to develop a reasonably parsimonious model of lightning variability and detection on Venus to reconcile at least some observation claims. This modeling will help interpret results from the Lightning and Airglow Camera (LAC) on the Akatsuki Venus Climate Orbiter.

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