Cloud-to-Ground lightning location using TOGA of sferics

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1 INTRODUCTION

Lightning measurements have been extensively utilized by power companies, meteorological offices as well as by the scientific community in general. As opposed to the Intra–Cloud (IC) discharge, the Cloud-to-Ground (CG) lightning stroke is a major safety hazard. In CG lightning stroke, the stepped leader descending from the base of a thundercloud triggers the first return stroke. This stroke is responsible for most of the charge transfer within few tens of microseconds causing a current of tens of kA. In this report, we present a novel CG stroke location system, which uses fewer stations but gives an enhanced location accuracy of ~2 km.

Lightning emits a wide spectrum of electromagnetic radiation during its breakdown. These radio impulses, commonly referred as sferics, are associated with CG strokes and have the highest spectral density in the VLF band (3 – 30 kHz) with the peak at about 10 kHz, whereas the IC emissions occur in the VHF band (30 - 300 MHz). The sferic radiation propagates with little attenuation in the Earth–Ionosphere waveguide (EIWG) to large distances by multiple reflections. The EIWG disperses the lower frequency component of the sferic to a wave train lasting few milliseconds. Different types of lightning (positive and negative CGs, IC) have been monitored using CGR3 counters (Jayaratne and Ramachandran, 1998) to determine the relative occurrence of IC and CGs.

Lightning location techniques depend on the type of lightning. Lightning Imaging Sensor (LIS) and Optical Transient Detector (OTD) which are flown on a lower earth orbit satellite or on geostationary satellite, map the changes in the tops of clouds (NASA, 2002). The images of LIS and OTD give the global distribution of lightning activity, but they cannot differentiate IC against CG flashes. There are two main classes of ground-based CG lightning location systems that use networks of radio receivers. The first class determines the direction of the lightning at each receiving station by monitoring the magnetic field associated with the lightning. These directions are then extrapolated to locate the lightning. The second class uses the difference in the Times-of-Arrival (ToA) of the electric field of the lightning sferics at an independent pair of receiving stations. One of the widely used techniques in ground-based lightning location combines the direction finding and measurements of the ToA of VLF sefrics at several stations as used by the US National Lightning Detection Network (NLDN) (Cummins *et al.,* 1998). Lightning location from a single station has been reported by Nagano *et al.* (2002), who measured two orthogonal horizontal magnetic components with two sets of loop antennas, while the vertical electric component of the VLF sferics is measured with a vertical wire antenna. The first pulse received is due to sferic produced by the return stroke that determines the direction of the stroke. The subsequent pulses are due to multiple reflections in the EIWG and the range of the stroke is determined from their ToA. Nagano *et al.* (2002) reported that the system can locate CG strokes within several hundred km with an accuracy of ~5 km.

2 EXPERIMENTAL SET UP

The University of the South Pacific is one of the 13 Universities/Institutions, which is participating in the global lightning detection programme under the World Wide Lightning Location (WWLL) network. The WWLL network uses a novel technique for the location of lightning. The WWLL network uses the Time Of Group Arrival (TOGA) of the VLF radiation form the return stroke to locate the position of the lightning strike. Long range detection requires use of EIWG propagation in the ELF/VLF band. As the wave period at such low frequencies is of the order of tens of microseconds, no sharp edge appears for precise arrival timing. The receiving system consists of a 1.5 m whip antenna and a GPS antenna. The amplified VLF signal and the GPS Pulse Per Second (PPS) are fed to the sound card of a computer. The sound card continuously samples the output voltage of the VLF receiver and each sferic is processed at the receiving site and the TOGA is determined relative to GPS at the site. The real time data is transmitted via Internet to the WWLL centre in Otago, New Zealand, where they are processed for world wide lightning detection. If a minimum of four stations recorded the event, then lightning occurrence is confirmed. This procedure statistically eliminates both detection of spurious signals and the disruption of the transmitted data in the identification of the CG strokes. The location is identified from the difference in TOGA at pairs of stations. The accuracy of the location is within 2 km (Dowden *et al.,* 2002).

Fiji islands comprises of many small island groups of which Viti Levu and Vanua Levu, the two larger islands, occupying landmasses of 10,388 km^2 5,536 km^2 respectively, other smaller islands occupy 2,406 km^2. On global scale, the total area of the Fiji islands is very small. The accuracy of the detection system however permits us to locate the individual lightning strokes.

3 RESULTS AND ANALYSIS

In a typical data for one day (9 March 2003), the total number of CGs over the entire globe was 287,117 of which 166,330 were in the Southern Hemisphere. Viti Levu recorded 12 strokes.

The occurrence of CG strokes in the latitude range of 17.25°–18.25° S and longitude 177.25°–178.65° E (these ranges encompass the whole of Viti Levu) during February, March and April 2003 were analysed.

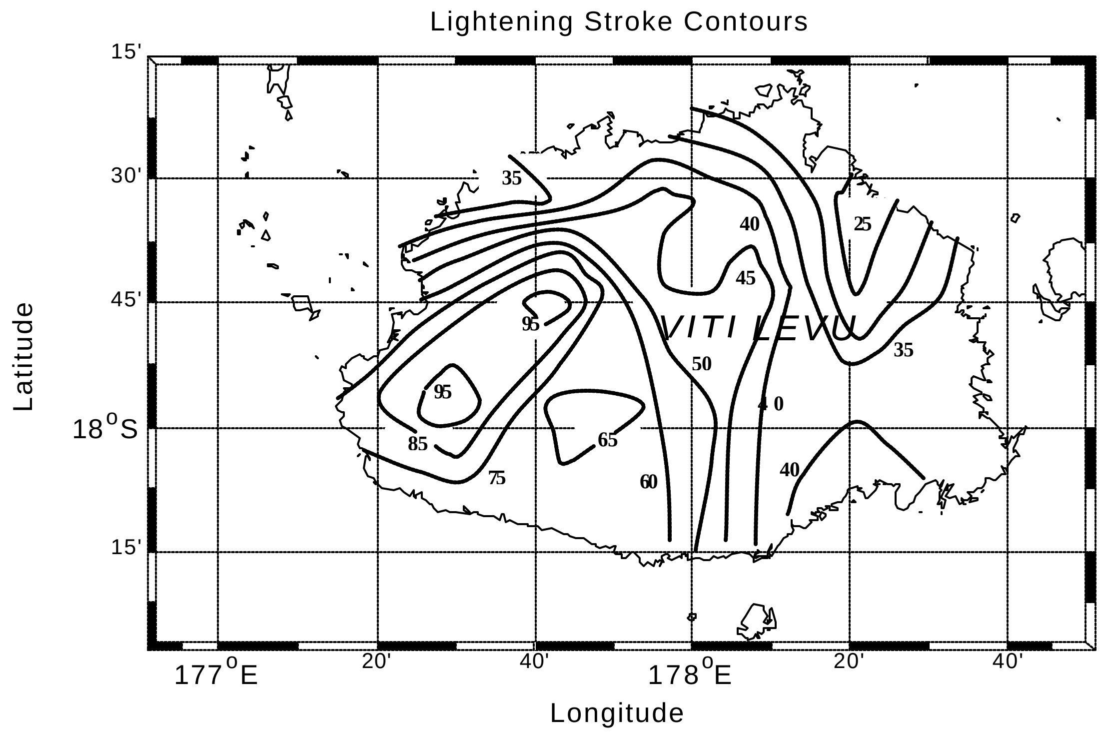

Figure 1 Spatial distribution of CG strokes (Feb.–April '03).

To find the spatial distribution, increments of 0.2° were considered for both the latitude and longitude. This corresponds to a land area of (~20 km × 20 km). The number of CG strokes in each of these grid areas was grouped. Figure 1 shows the contour of the spatial distribution of CG strokes in Viti Levu during the period Feb.-Apr.'03. The distribution shows a good correlation between the topography of the island and the lightning incidence. It is apparent that the CG flash incidence in the west of Viti Levu is significantly high and there are two pockets with a total of 95 strokes.

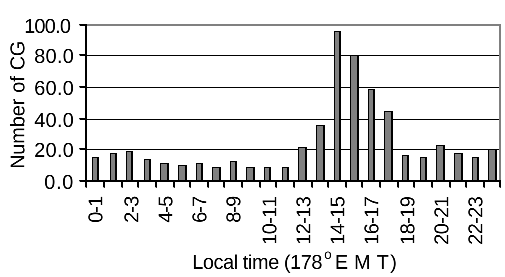

Figure 2 Diurnal variation of CG strokes

The average diurnal variation of the CG strokes in Viti Levu obtained from the three months data is shown in figure 2. It is evident that lightning activity is more pronounced after 13:00 hrs local time. This may be due to the formation of convective updraft after the ground surface is warmed by solar radiation.

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