Global Lightning Activity and Its Relation to the Atmospheric Variability Measured by ELF Observations at Syowa Station

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Lightning discharges can excite strong electromagnetic (EM) waves in the wide frequency range from a few Hz to several hundreds of MHz. Schumann resonances are the lowest frequency range EM waves excited by lightning discharges. As the attenuation rate and the wavelength are the low (~0.3 dB/Mm) and long, respectively, we can monitor the global lightning activities from the Schumann resonance measurements even at one observation site. In 1990's, lightning-associated transient luminous events (TLEs), such as sprites, elves and blue jets, are discovered. These transient discharge events occurring in the stratosphere and mesosphere are excited by strong lightning discharges at the active thundercloud. Recently, it was shown that the intensity development of typhoons is strongly related to the time variation of the lightning activities in the typhoon clouds. In order to measure Schumann resonances, continuously monitor the global lightning activity, and identify the relation between global lightning activities and global atmospheric variability, we started the continuous observations of EM waves in the frequency range of 1-100 Hz (ELF range) at Syowa station since February 2000.

Figures 1(a)-1(c) show the pictures of the ELF observation system at Syowa station. We use two horizontal search coil magnetometers to detect magnetic field component of the EM waves (Figure 1(a)). The output signals from the magnetometers are amplified by the ELF main amplifier (Figure 1(b)), and the output waveforms from the amplifier are continuously recorded by the data recording system with GPS time signals (Figure 1(c)). Figure 2 shows the 1-day dynamic spectrum of the ELF magnetic field waveform data obtained on July 5, 2003. Since the electromagnetic noise level at Syowa station is quite low, the Schumann resonance waves are acquired with the extremely high signal-to-noise ratio, as shown in Figure 2. Until now, we are conducting the ELF measurements at Syowa station without any system malfunction, and the total data volume becomes ~2.7 TB.

So far, we obtained many results, and some examples of these results are shown in Figures 3 and 4. Figure 3(top) shows the long-term intensity variation of Schumann resonance waves measured at Syowa station [*Sato et al.*, 2005]. In this figure, both 1-year variation and more longer variation (gradual decrease from 2006 to 2010, and gradual increase from 2010 to 2015) can be clearly seen. In addition there are short-term periodicity in this intensity variation of Schumann resonance waves. Figure 3(bottom) shows the periodgram of the intensity variation, and there is ~30-day periodicity in the global lightning activities. As this periodicity is close to the rotation period of the sun, there may be the relation between the solar activity and global lightning activity. Figures 4(a)-(d) shows the lighting and sprite images measured by the GLIMS cameras onboard the International Space Station [Sato et al., 2015, 2016]. In this lightning events, sprite emissions were confirmed as shown in

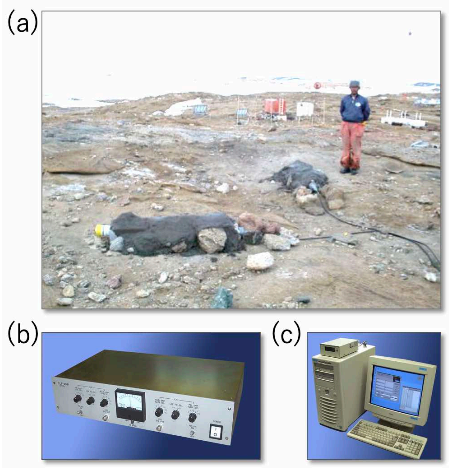

Figure 1. Picture of the ELF observation system at Syowa station. (a) Two search coil magnetometers, (b) ELF main amplifier, and (c) data recording system.

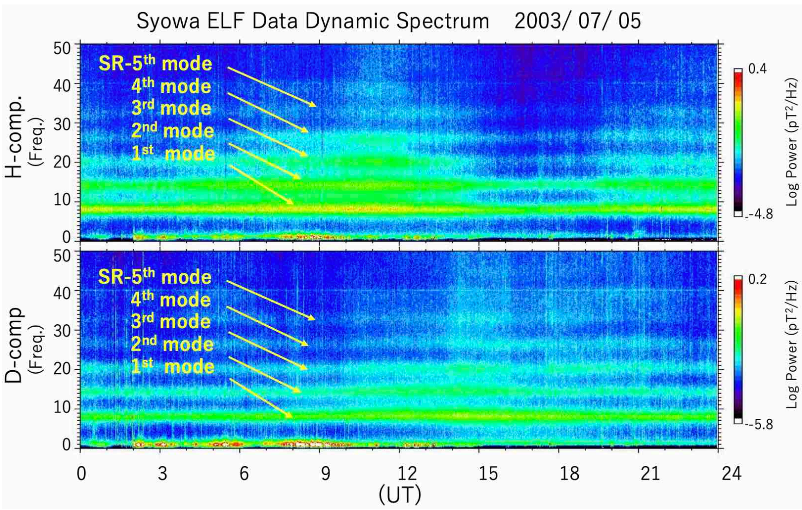

Figure 2. 1-day dynamic spectrum of the ELF waves measured at Syowa station. In the frequency range of 8-45 Hz, spectral peaks of Schumann resonance can be clearly seen.

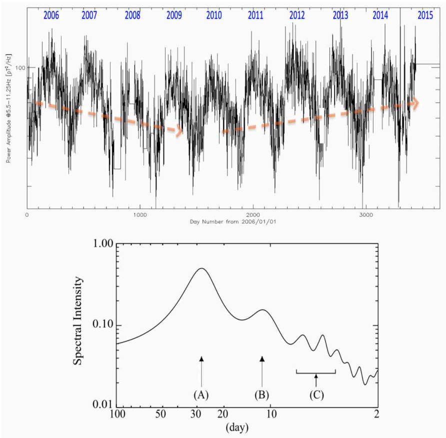

Figure 3. (top) Long-term intensity variation of Schumann resonance waves in the period of 2006-2015. (bottom) Periodogram of the long-term intensity variation of Schumann resonance waves.

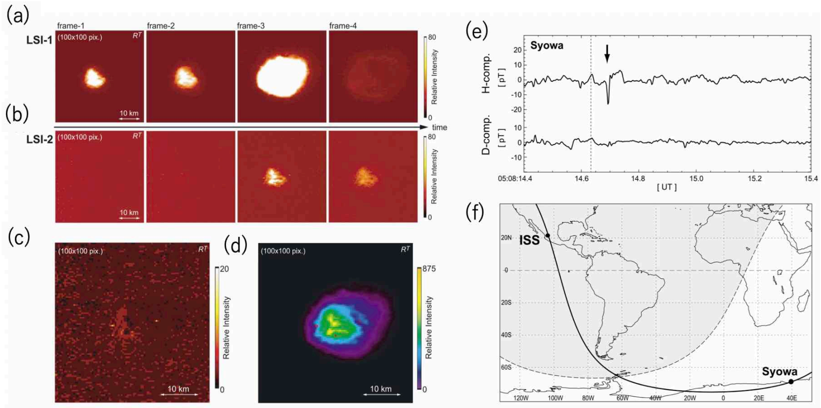

Figure 4. (a) Lightning and sprite images measured by the GIMS wideband camera (LSI-1) and narrowband camera (LSI-2). (c), (d) Results of the image subtraction between LSI-1 and LSI-2. Dot structures corresponding to sprite emissions can be confirmed in Figure 4(d). (e), (f) ELF waves excited by the sprite-producing lightning discharges.

Figure 4(d). At the same time, strong impulsive ELF wave was detected at Syowa station as shown in Figures 4(e) and 4(f). From this ELF data, we can determine the electrical characteristics of the sprite-producing lightning discharges.

In the next phase X of the Japanese Antarctic Research Projects, we will continue the ELF observations at Syowa stations. From the world-top and high-quality observational data, we can contribute future satellite projects dedicated for the lightning and TLEs observations from space, such as TARANIS and ASIM. In addition, we can clarify the relation between the regional lightning activities and severe weather including torrential rain, tornado, downburst, and typhoon.

References

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