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Spatio-temporal analysis of lightning activity over Greece — Preliminary results derived from the recent state precision lightning network

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ABSTRACT

Lightning is a natural phenomenon in the atmosphere, being a major cause of storm related deaths, main trigger of forest fires and affects many electrochemical systems of the body. Significant scientific interest has come up in the last decades, as numerous lightning detection networks have been established in operational basis, providing lightning data to assess and mitigate lightning impact to the local society by spatio-temporal analysis.

In this study, a preliminary analysis of spatial and temporal variabilities of recorded lightnings over Greece during the period from January 2008 to December 2009 is presented. The data for retrieving the location and time-of-occurrence (TOA) of lightning were acquired from the Hellenic National Meteorological Service (HNMS). An operational precision lightning network (PLN) has been established since 2007 by HNMS, consisting of eight time-of-arrival (TOA) sensors, spatially distributed across Greek territory.

The spatial variability of lightnings revealed their incidence within specific geographical sub-regions while the temporal variability concerns the seasonal and monthly distributions. All the analyses were carried out with respect to cloud to cloud (CC), cloud to ground (CG) and ground to cloud (GC) lightnings, within the examined time period. During the autumn season, lightning activity was the highest, followed by summer and spring. Higher frequencies of stokes appear over Ionian Sea and Aegean Sea than over land during winter period against continental mountainous regions during summer period.

1. Introduction

Lightning is an atmospheric discharge of electricity accompanied by thunder and considered as one of the most powerful and spectacular natural phenomena in the atmosphere. Because of the unpredictability and random nature of a lightning strike, cloud-to-ground (CG) lightning can kill and injure people (Cooray et al., 2007) by direct or indirect means. In the United Kingdom almost 3 fatalities and more than 50 injuries are caused every year due to lightning activity (Elsom, 2000). Additionally, in the USA a research from 1968 to 1981 revealed that 2566 lost their lives and more than 6720 got injured (Bernstein, 1982) and in global scale more than 1000 people got lost due to lightning every year (Mackerras, 1992).

The scientific interest is not limited to aforementioned correlations but lightning observations inspired numerous scientists from broad geoscience topics to investigate lightning relationship with fires in forest landscapes (Drobyshev et al., 2010; Liu et al., 2010; Peterson et al., 2010; Lang and Rutledge, 2006; Arabas et al., 2006), and the ozone (Pfister et al., 2008; Ryu and Jenkins, 2005). The mountain terrain elevation is highly related to the lightning incidence. Chen et

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al. (2010) found that the density of negative cloud-to-ground (CG) flashes increases as the surface terrain rises, with the highest density convergent to the main mountain peak areas. On the contrary, the density of positive CG is inversely proportional to the surface terrain elevation. Bourscheidt et al. (2009) suggested that terrain slope has more influence than altitude on the thunderstorm occurrence and lightning activity over south Brazil. Deep convective weather during the warm season is highly associated with cloud-to-ground lightning (Soriano et al., 2001a). Pan et al. (2010) studied the spatial and temporal characteristics of lightning activities in seven super typhoons from 2005 to 2008 over the Northwest Pacific. Besides, Pineda et al. (2007) examined the relationship between lightning and precipitation in case studies over North Western Mediterranean region. In a recent study carried out by Tinmaker et al. (2010), it is shown that a significant link between lightning activity over Peninsular India and sea surface temperature in the bordering seas (Arabian Sea and Bay of Bengal) exists. The approximate range of increase of flash density per 1 °C rise in temperature is 20 to 44% (Kandalgaonkar et al., 2005).

New techniques have been applied for lightning detection such as the long-range (≤6000 km) global lightning geo-location using a Very Low Frequency (VLF) radio atmospheric waveform bank (Said et al., 2010). An experimental Very Low Frequency (VLF) World-Wide Lightning Location Network (WWLLN) has been developed through collaborations with research institutions across the world, providing global real-time locations of lightning discharges (Rodger et al., 2006). Besides, during the Eurosprite 2005 campaign, an infrasound miniarray has been set up in France (Farges and Blanc, 2010) to measure the characteristics of infrasound from lightning and sprites when these kinds of sources were close to the sensors (that is, for lightning distances lower than 100 km and sprite distances lower than 300 km). Instead of the WWLLN there are national lightning detection networks such as the United States Precision Lightning Network (USPLN), the North American Precision Lightning Network (NAPLN) and the Canadian Lightning Detection Network (CLDN) covering Canada, Alaska, Hawaii, Mexico, Central America, the Caribbean and northern South America. Moreover, there are also the experimental long-range lightning detection network Zeus, with receivers located in Europe and Africa (Chronis and Anagnostou, 2003, 2006; Lagouvardos et al., 2009), the Lightning Position And Tracking System (LPATS) over southern Germany (Bent and Lyons, 1984), and the LIghtning detection NETwork (LINET), which is a particularly sensitive network working at VLF/LF range with 3D capability, designed by the University of Munich (Betz et al., 2004; Schmidt et al., 2004; Betz et al., 2008).

The spatial and temporal variations of lightning over specific regions are of great scientific interest, because of the adverse impacts of this extreme weather event. Significant number of studies has been carried out analyzing the characteristics of lightning using different lightning detector networks developed in many countries; namely, Estonia (Enno, 2011), Czech Republic (Novak and Kyznarova, 2010), Romania (Antonescu and Burcea, 2010), Hong Kong (Chen et al., 2010), Canada (Kochtubajda and Burrows, 2010), Taiwan 1998–2006 (Liou and Kar, 2010), South Korea 2000–2001 (Hyun et al., 2010), Finland (Tuomi and Mäkelä, 2008), Indonesia (Hidayat and Zoro, 2007), Mexico (Raga and Rodríguez, 2006), Saudi Arabia (Shwehdi, 2005), India (Kandalgaonkar et al., 2005), Alaska (Dissing and Verbyla, 2003), United States of America (Orville and Huffines, 2001; Zajac and Rutledge, 2001), Java (Hidayat and Ishii, 1998), a lightning climatology for Europe and the UK (Holt et al., 2001) and Mediterranean countries (Soriano et al., 2001b, 2002; Altaratz et al., 2003; Fakitsas et al., 2010).

The Hellenic National Meteorological Service established a Precision Lightning Network (HNMS-PLN) at the end of 2007, consisting of 8 Precision Lightning Sensors (PLS), encompassing the Greek region. The HNMS-PLN data are important not only for the operational forecasters of HNMS but also for the Greek scientific community, as the archive data can robust any spatial and temporal analyses of lightning activity over Greece. In the next section the characteristics of HNMS-PLN are presented in detail.

The goal of this paper is to present a preliminary analysis of the spatio-temporal variability of lightning activity over Greece (CG, CC, GC) during the period from January 2008 to December 2009, along with seasonal density analysis of CG stokes per 1 km^2. Characteristics and efficiency of HNMS-PLN are presented in brief in Section 2. In Section 3, the results and discussion are presented, while Section 4 summarizes our findings.

2. The Hellenic National Meteorological Service Precision Lightning Network

Lightning detection is operationally used by many national weather services in severe weather now-casting and early warnings. In the late of 2007, the Hellenic National Meteorological Service (HNMS) established a Precision Lightning Network (PLN). The HNMS-PLN consists of 8 Precision Lightning Sensors (PLS) covering wider Greece (Fig. 1), encompassing the Greek continental and islandic peninsula (Nastos and Matsangouras, 2010; Chronis, 2012). The network has been used in operational now-casting since January 14, 2008, and until now it is the only operational network dedicated to the lightning detection over Greece.

The PLS were engineered and manufactured by the TOA Systems Inc. (http://www.toasystems.com). Lightning detection networks based on the TOA/PLS technology are presently also operational in the US (USPLN) and Canada (CLDN). The PLS consist of a 1 m whip electrical field receiver accompanied by a GPS antenna that provides the timing and location information. The GPS is synchronized at 1 kHz frequency and returns a timing accuracy of 18 ns (approximately 5 m of spatial accuracy). With the PLS sensitivity ranging from 1.5 kHz to 400 kHz (Low Frequency–Very Low Frequency), the HNMS-PLN is designed to primarily detect CG. Cloud-to-cloud (CC) strokes are partially detected based on the electrical signal return time (threshold to peak voltage < 10 μs; Neilley and Bent, 2009).

The HNMS-PLN retrieves the stroke location based on the of time-of-arrival method (Lee, 1986; Koshak and Solakiewicz, 2001; Hu et al., 2010), a fact that guarantees and enhances the independence from any electrical interferences such as high-voltage power lines, power plants, street lights and similar electrical interferences. Similar to the geographical location retrieval method, the CG peak current is also extracted from a mathematical model (Transmission line) that relates the sensor's recorded electric potential (i.e. V/m) to the electrical