Electrical Properties of Regular Versus Anomalous Polarity Cells Observed With the SAETTA LMA Over the Corsican Island

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The north-western Mediterranean basin often experiences thunderstorms with heavy precipitation, strong wind, lightning activity and sometimes waterspouts/tornadoes. One of the objectives of the EXAEDRE (EXploiting new Atmospheric Electricity Data for Research and the Environment) project is to better monitor the thunderstorms in this area through a better understanding of the physical processes that drive the dynamics, the microphysics and the electrical activity of the convective systems. Characteristics of the electrical activity such as flash rate, charge layer distribution, flash type and polarity are good proxies for thunderstorm monitoring and good evidences of the storm severity.

This study evaluates the characteristics of Corsican storms at the electrical cell scale. Hence, observations of the LMA (Lightning Mapping Array) SAETTA network, deployed in Corsica, are used to document in 3D the total lightning activity. Complementary 2D lightning observations recorded by the French national lightning detection network METEORAGE are also investigated. We also use weather radar data from the Météo France network to document the rain rate/cumulative rainfall associated to each electrical cell. A clustering algorithm is applied on the lightning data to i) identify and track the cells, and ii) to document the evolution of several lightning-related parameters during the lifetime of each cell. We also apply a recently published method based on lightning leader velocity to automatically infer the vertical structure of the electrical charge regions within each cell. These algorithms allowed us to create a database of hundreds of electrical cells in Corsica from september 2018 until now.

We first introduce the different observations and methodologies applied here. Then we compare the electrical properties associated to different vertical charge structure configuration. Anomalous (regular) cells could at some period during the cells life time show regular (anomalous) polarity configuration but in general they differed in terms of electrical properties. Anomalous electrical cells produced less cloud-to-ground lightning flashes, less cumulative rainfall (but higher RLR) and produced less lightning jumps. We also show that anomalous cells tend to produce shorter flashes which in general weren't detected by the 2D lightning locating system. The relationship between number of CGs and accumulated rain at the cell scale in Corsica is linear and in accordance with the literature.

Observation on Lightning and Thunderstorm Over the Southeastern Tibetan Plateau

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The Tibetan Plateau is the largest and highest plateau in the world. It is called the Roof of the World or the Third Pole. It is from the southern edge of the Himalayas in the south, to the Kunlun Mountains, Altun Mountains, and the northern edge of the Qilian Mountains in the north, the Pamirs and Karakoram Mountains to the west, and the western part of the Qinling Mountains and the Loess Plateau in the east and northeast, and lies at latitude from 26°00'-39°47' N and longitude from 73°19'-104°47' E. It has long been recognized as an important region impacting on global water reallocation and climate changes. The Tibetan Plateau with its highest elevation and local orography, interacting with the prevailing wind and the surface thermodynamics are favorable for the genesis of thunderstorm convection and lightning activities in some regions. Observation at Naqu (31°29.0'N, 92°03.0'E, 4508m) in the central Tibetan Plateau and Datong (101°34.9'E, 37°3.8'N, 2650 m) in the northeast Tibetan Plateau in the early 2000s suggested that thunderstorm there shows unique charge structure and lightning activities. To further reveal the charge structure and electrification inside the thunderstorm over the Plateau, lightning observations were conducted successively in Lhasa (29°38.4' N, 91°02.4' E, 3640 m) and Daocheng (29°21.10' N, 100°08.71' E, 4412 m) by using the state-of-the-art technology since 2019. The main instruments included two-site broadband interferometers several kilometers apart with capability of 3D mapping on lightning discharge channel, fast antenna, slow antenna and high-speed video camera. This paper will report and compare the main results at two sites in 2021 observation and the outstanding finding in the early 2000s, focusing on the evolution of lightning activities through the thunderstorm lifetime.

Increasing Upper Tropospheric Water Vapor Over the Arctic Circle

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The effect of global warming over the Arctic Circle is alarming. The fraction of lightning strokes above 65°N to total global strokes grew by a factor of 3 with an increase of 0.3 °C increase in global temperature anomaly (Holzworth et al., 2021). In the last decade, the monthly average specific humidity in the Arctic upper troposphere at 300hPa also increased significantly. The summertime (JJA months) lightning data from WWLLN and specific humidity data from ECMWF (SON months) shows the maximum temporal correlation with a three-month lag. While comparing the Arctic Upper Tropospheric Water Vapor (UTWV) to the Northern Hemisphere (NH) temperature anomaly data derived from GISS, the correlation coefficient becomes 0.65. The increase in UTWV is around 4%, corresponding to an NH temperature increase of 0.8°C. The surface forcing plays a significant role in controlling the convective mass flow in the upper troposphere. The effect of this increase of UTWV requires systematic investigation to understand the role of positive feedback in further warming in the Arctic and global climate change.

Comparing and Combining Thunder Hours Derived from TLN, GLM, and LIS

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Lightning data are often used to measure the location and intensity of thunderstorms. A thunder hour is defined as an hour during which thunder can be heard from a given location, and thunder hours can be calculated from global and regional lightning observations. Thunder hours are an intuitive measure of thunderstorm frequency where the one-hour interval corresponds to the life span of most thunderstorms, and the hourly temporal resolution of the data also represents long-lived systems and the diurnal cycle well. Examining long-term convective patterns in the context of thunder hours lends insight into thunderstorm activity without being heavily influenced by network performance, making thunder hours particularly useful for studying climatology. This study presents 7 years of data from the Earth Networks Total Lightning Network (TLN) in the form of thunder hours and compares them with thunder hours derived from satellite-based lightning observations from the Geostationary Lightning Mapper (GLM) and the Lightning Imaging Sensor (LIS). We demonstrate that the thunder hour methodology can be used to combine observations from different lightning detection technologies to produce a reliable, long-term, global thunderstorm climatology.

Lightning, Biology, and Evolution

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Most electrical activity in vertebrates and invertebrates occurs at extremely low frequencies (ELF), with characteristic maxima below 50 Hz. The origin of these frequency maxima is unknown and remains a mystery. We propose that over billions of years during the evolutionary history of living organisms on Earth, the natural electromagnetic resonant frequencies in the atmosphere, continuously generated by global lightning activity, provided the background electric fields for the development of cellular electrical activity. In some animals, the electrical spectrum is difficult to differentiate from the natural background atmospheric electric field produced by lightning. In this paper, we present evidence for the link between the natural ELF fields and those found in many living organisms, including humans. Furthermore, recent experiments show links between the ELF fields and photosynthesis in plants.

Coarse Sea Spray Inhibits Lightning

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The known effects of thermodynamics and aerosols can well explain the thunderstorm activity over land, but fail over oceans. Here, tracking the full lifecycle of tropical deep convective cloud (DCC) clusters shows adding fine aerosols significantly increases the lightning density for a given rainfall amount over both ocean and land. In contrast, adding coarse sea salt (dry radius > 1 µm), known as sea spray, weakens the cloud vigor and lightning by producing fewer but larger cloud drops, which accelerate warm rain at the expense of mixed-phase precipitation. Adding coarse sea spray can reduce the lightning by 90% regardless of fine aerosol loading. These findings reconcile long outstanding questions about the differences between continental and

marine thunderstorms, and help to understand lightning and underlying aerosol-cloud-precipitation interaction mechanisms and their climatic effects.

Examining Lightning Activity as a Proxy for Cold-pool Heterogeneity During the PERiLS Field Project: Introducing a QLCS Tracking and Sampling Method for Surface, Lightning, and Radar Measurements

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In this study we present a method to track the motion and orientation of quasi-linear convective systems (QLCS) using GOES-16 GLM (Geostationary Lightning Mapper) data and sample radar (e.g., reflectivity, spectrum width), surface measurements (e.g., surface temperature deficits, surface wind gusts) and lightning activity (e.g., flash extent density, mean flash area) for examining how they covary and correlate in time and space. By making use of GLM level-2 processed datasets, objects are defined using group centroid densities (GCDs) to identify the convective regions of linear storms associated with lightning production in any time increment (e.g., every 5 minutes). The largest GCD objects are used to define the storm's spatial footprint and allow for tracking of its motion, orientation, and size. Ellipses are then defined around each tracked GCD object and their semi-major axes are used to define sample points spanning its width (from focal point to focal point) at various spatial increments, as each ellipse is allowed to expand and contract with the storm evolution. Results of this method allow for a unique examination of how radar-derived storm properties and surface conditions vary with flash rates and other lightning characteristics (e.g., flash energy and area) at specific storm-relative points following the storm motion through a domain of interest. Furthermore, statistics of how these exact samples covary and correlate in space and time may be used to identify important changes in a storm's meteorological and electrical environments leading up to severe weather events. Preliminary results derived from GLM, WSR-88D, and surface Oklahoma Mesonet data for two storms that occurred over central Oklahoma on June 12 and October 27 of 2021 (one non-tornadic and one tornadic) showed that point specific comparisons of lightning data to radar and surface measurements provide insight into how lightning data may be used as a proxy for cold-pool heterogeneity in QLCS of interest to warning operations, and findings will be applied to data collected during the PERiLS (Propagation, Evolution, and Rotation in Linear Storms) field campaign.

Geometric Effects on Hydrometeors Electrification in the Noninductive Relative Growth Rate Charging Mechanism

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The noninductive relative growth rate charging (NI) mechanism is one of the main processes to contribute to the charge structure in a thunderstorm. However, laboratory and modelling studies show that there are still several uncertainties concerning the NI mechanism. A relevant component to this issue is the geometry of the particles. Variations in the geometry of ice hydrometeors are not usually accounted for and can affect the relative growth rate estimate and consequently the magnitude and polarity of charge transferred in collisions that could lead to small scale spatial heterogeneity in electrification regimes in the mixed phase region. The focus of this study is to investigate how the depiction of various shapes of graupel and ice crystals affect their interactions and charges with temperature, liquid water content, collision efficiency, particle sizes and relative fall velocity as the main parameters with range constrained by values in the literature. An alternative way to represent diversity in ice hydrometeor shape configurations and their gradual change is to express them as manifolds where the shapes are generated by radial functions. We use numerical methods for solving partial differential equations on curved surfaces starting from the sphere to more heterogeneous curvatures. The results compare the hydrodynamical flow responses by quantitative differences in the structure of the flow on the particles and the range of positive and negative graupel charging based on the relative diffusional growth rate for the spherical case against the evolving derived radial manifolds in the parameter space. This approach presents insights into the contributions of evolving shapes on hydrometeor electrification and the method's viability is discussed.

Pair-difference Analysis of Lightning Strokes

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In this work we analyze temporal sequences of lightning strokes, as detected by an LF/VLF based network, over the Eastern Mediterranean. Differently from previous studies, we analyze the strokes' raw data, without grouping them into flashes using pre-determined thresholds. We introduce the distance-versus-time differential space, which looks at the intervals between successive strokes. It loses the information on the specific time and location of the strokes and instead it clusters common properties of the intervals between them. Pair-analysis is done per each cluster on this new space. This allows us to detect key Spatio-temporal characteristics of flashes that are common to all events. Three distinct clusters are emerging on this differential space, separating a flash scale, recharging between flashes scale, and the characteristic distances between lightning events.

Intercomparisons of Space-Based Optical and Ground-Based RF Global Observations of Lightning for Constructing a Lightning Climatology

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Observations of lightning are commonplace worldwide and recent satellite instruments provide enhanced coverage. Lightning can be used for monitoring severe convection and precipitation, improving estimates of severe storm development, evolution and intensity, and hence provide early warnings for severe weather phenomena. In addition, lightning itself impacts the global climate by producing nitrogen oxides (NOX), a strong greenhouse gas. For climate variability and change monitoring, lightning has been shown to follow trends and extremes in convective storms (convective mode, flash rate, flash extent) and track global surface air temperature on many natural time scales. Given this relevance and potential as a climate variable, lightning has been added to the list of Essential Climate Variables (ECV) in the Global Climate Observing System Implementation Plan (IP), including a first attempt to define the requirements for climate monitoring with lightning measurements. A Task Team on lightning observations for climate applications completed an initial study that summarizes the work done and covers key aspects of needed lightning observations for climate applications. It explains the relevance of lightning observations, describes the current status of observations, discusses gaps and open research questions and provides suggestions for monitoring requirements for lightning, including metadata requirements. The Task Team is seeking relevant data sets to address climate questions using information about lightning. In this presentation we present an initial look at the lightning climatology maxima and regional trends as depicted by space-based and ground-based systems, and considerations for the production of a community climate data set for lightning.

Response of Clouds and Surface Pressure to Jz.

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The responses of high-latitude stratus-type clouds, and high and mid-latitude surface pressures, to changes in the downward flow of current density, Jz, in the global electric circuit, have been clarified with new analyses. Observation and theory point to the involvement of space charge layers in these clouds. The charge asymmetries on condensation nuclei and ice nuclei affect their collision rates with droplets. Electro-anti-scavenging of the smallest condensation nuclei has the cumulative effect over several days of cloud processing of increasing their concentration. It is postulated that this gives increased concentration of droplets of smaller size, which increases cloud radiative forcing in cold seasons. Electro-scavenging of the larger ice nuclei increases contact ice nucleation and conversion of supercooled water to ice; again with consequences for radiative forcing. The threshold for significant day-to-day oscillations of surface pressure depend on the amplitude and period of ionospheric potential oscillations driving Jz; either due to internal (thunderstorm and electrified shower cloud) or external (solar wind electric field) global circuit inputs. For the weaker external input there is evidence that the presence of trains of oscillations, of sufficient amplitude and length, with the 27-day solar rotation period, nudge internal atmospheric pressure oscillations into phase coherence.

Predominant Periodicities Observed in the Potential Gradient Recorded at Several Ground-base Stations

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The potential gradient (PG) from ground-based stations presents well known daily and annual periods. Less common PG periods are the 7-day, 27-day and semi-annual cycles, which are likely to have their origin in global and/or local effects. However, determining their source is challenging. Thus, timeseries and spectral analysis of PG at several stations are required. In this paper, we performed PG spectral analysis of data recorded at several stations: Vostok, Concordia, Halley and Casleo (Southern Hemisphere), and Sodankyla and Reading (Northern Hemisphere). We use the Lomb-Scargle Periodogram and the Wavelet Transform techniques. For all PG sites we found periodicities of 0.5, 1, ~180 and 365-days. Our results show that the 0.5-day (1-day) periodicity is more prominent during the months of June-July-August (December-January-February). Evidence of ~27- and ~45-day periods was also observed at multiples sites. Further analysis using the cross-wavelet transform (XWT) for PG versus cosmic rays, PG versus Madden-Julian Oscillation indexes, and PG versus meteorological parameters, show clues that the 27- and 45-day periods are likely related to the solar rotation and Madden-Julian Oscillation, respectively. Furthermore, our results show that during the passages of co-rotating interaction regions, the 27-day period for PG vs cosmic rays XWT is stronger than for the other XWT analysis.

Interdisciplinary Researches for Atmospheric Electricity at the Summit of the Mt. Fuji, Japan

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Japan Meteorological Agency announced that Mount Fuji Weather Station (3776 m a.s.l.) would be automatically operated without human manual resource after 2004, which implied that the facility would be partly disassembled. Terminating the observatory means losing the precious knowledge of high mountainous station maintenance. Once lost, this knowledge is difficult to recover. This highest point of Japan is the perfect site for a variety of research, in particular for atmospheric electricity research, that utilizes the benefits of the high altitude, as well as for weather observation.

In other countries, an array of achievements has been made by research conducted in high-altitude bases, such as the Mauna Loa Observatory in Hawaii which is noted for greenhouse gas observations, the High Altitude Research Station Jungfraujoch in Switzerland, which conducts astronomical research, and the Monte Rosa Laboratory in Italy, which is famous for high altitude medicine. In this field, Japan is far behind.

With this as the background, we established non-profit organization (NPO) Mount Fuji Research Station, with more than 250 members including researchers and mountaineers in order to make good use of the former Mt. Fuji Weather Station. The organization began observation and research at the Mount Fuji Weather Station after receiving permission to use the facilities from the Japan Meteorological Agency in the summer of 2007, when the station became available for summer research work by the private sector. Since 2007, research studies have been conducted at the Mount Fuji Weather Station, on themes including atmospheric chemistry, high altitude medical sciences, atmospheric electricity, ecology, etc. The researchers who took part in the Mt. Fuji project have been increasing in number yearly.

Concerning the atmospheric electricity, we recently conduct the following researches at and around Mount Fuji: 1) Survey of the electric connection between Mount Fuji Research Station and the grounding earth for the lightning protection, and research on upward lightning using the body of Mt. Fuji. 2) Observation of lighting-generated and thunderstorm-generated energetic radiation. 3) Optical and electromagnetic observation of Transient luminous phenomena and lightning. 4) Testing of a newly-developed device of atmospheric electric field measurement. 5) Monitoring of extreme meteorological events in the Tokyo metropolitan area. 6) Atmospheric electric field fluctuations generated during snowstorms. 7) Atmospheric chemical reaction due to lightning such as NOX, NOY, and O3.

This presentation is the summary of our published papers.

Atmospheric Measurements with a Modernized Programmable Ion Mobility Spectrometer

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The Programmable Ion Mobility Spectrometer (PIMS) is a miniaturised, multifunctional Gerdien condenser for air conductivity and atmospheric ion spectrum measurements. Its multimode electrometer and computerised control permit ion measurement in two modes, as an aspirated cylindrical capacitor for current measurement, and as a relaxation probe, for which voltage decays are measured. This capability for self-calibration removes the difficulties associated with providing a well-characterised ion environment for calibration. Two additional modes for measuring temperature-sensitive leakages and biases improve the instrument's accuracy and are particularly relevant for outdoor usage. The PIMS, initially developed in the early 2000s, has recently been re-engineered and modernised, with surface mount and higher specification electronics and an up-to-date microcontroller. In this presentation the instrument, its design, development and laboratory testing will be described. Its first atmospheric measurements at the Nagycenk Geophysical Observatory, Hungary (47.632°N,16.718°E) will also be presented. At Nagycenk, the atmospheric conductivity data will complement existing instrumentation measuring the potential gradient. With this new addition, changes in the electric field due to variation of local conditions can be more reliably separated from the field component arising from the global ionospheric potential. This allows for a site like Nagycenk to contribute more to answering open scientific questions on space weather, cosmic ray effects on weather and climate, the contribution of different weather systems to charging the global electric circuit, and dynamical interactions between the measurable atmospheric electric field and the activity of the living environment.

The Atmospheric Electric Potential Gradient at Nagycenk, Hungary 1962–2009 — a Dataset to Study Long Term Changes in the Global Electric Circuit

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There is a global framework of electric currents in the atmosphere connecting the ground and the lower ionosphere. This framework of electric currents is known as the Global Electric Circuit (GEC). One of the main parameters of the GEC is the atmospheric electric potential gradient (PG), which is the reverse of the vertical atmospheric electric field, a quasi-DC quantity measured in Vm-1 units usually near the ground most often at 1–3 m heights. In order to get useful information about the long-term variations of the GEC, long-term fair weather PG records are needed from a relatively undisturbed site. Therefore, long-term, ideally homogeneous PG measurements are of high importance in atmospheric electricity research.

There are only very few PG datasets available around the globe which have been recorded continuously for several decades. One of the datasets that fulfil these requirements has been recorded in the Széchenyi István Geophysical Observatory, Nagycenk, Hungary (NCK, 47°38' N, 16°43' E). In this study, variation of fair-weather PG at NCK between 1962 and 2009 is exhibited and discussed. The distributions, trends, and statistical parameters of PG time series taken from different parts of the day and from different seasons are studied. Special attention is paid to the diurnal variation of the PG at NCK which is a measure of global representativeness when compared to the Carnegie-curve. Spectral characteristics of the PG time series recorded at NCK are also discussed in detail.