

AGU Chapman Conference on the Effects of Thunderstorms and Lightning in the Upper Atmosphere.

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The conference was held at the Penn State University, State College, Pennsylvania, USA, during the 10-14 May 2009 time period. The conference was laid out into four days of talks and discussions divided into the broad theme areas 1. Observations of Transient Luminous Events (TLEs), 2. Theory of TLEs, 3. ELF/VLF Effects of Lightning and TLEs, and 4. Energetic Radiation From Lightning and Terrestrial Gamma Ray Flashes (TGFs). The excellent organization brought together the majority of scientists working in this new field, therefore allowing to cover all aspects of these phenomena, discuss the most recent results achieved and pave the way for tackling the challenges ahead. The participation to the conference led to a major improvement in my understanding of the theory and observations of the field through a series of review talks, updated information of recent results and direct discussion with colleagues. A brief summary of what was learned at the conference is reported below.

The first day was dedicated to the observations of TLEs, particularly important for my research. D. Sentman gave an overview of the observation of TLEs, discussing the scientific environment that preceded the serendipitously discovery of sprites and the following intense TLE research. Long after Wilson's prediction in 1925, in the 1980s it was becoming clear that the electric effects of thunderstorms extended into the upper atmosphere, ionosphere and magnetosphere, with X-ray emissions testifying the presence of energetic particles within the thunderstorm. Interestingly, Wilson had already understood that thunderstorms were an essential element of the atmosphere, both as a player of the atmosphere electricity and as source of energetic processes (see also talks by M. Rycroft and E. Williams later in the week).

The 1989 discovery of sprites, followed by that of other TLEs and TGFs, greatly improved the old picture of the electric atmosphere leading to variety of results discussed at the conference. The first global climatology of TLEs as seen by the Imager of Sprites and Upper Atmospheric Lightning (ISUAL) presented by A. Chen was based on more than 12,000 TLE observations. Elves are the most commonly observed TLEs (9,500) by the satellite, followed by sprites and halos (1,000 each) and gigantic jets (33). A statistical analysis showed that the occurrence of elves is determined by high sea surface temperature, which increases updraft, and therefore lightning with high peak current. Seasonal variations following the inter-tropic convergence zone (ITCZ) and deep updraft regions. On the contrary, the occurrence of sprites matches that of lightning activity at low latitudes and of thunderstorm tracks during winter (see also talk by C. Kuo).

The atmosphere-ionosphere coupling will be studied by the TARANIS micro-satellite mission together with the associated energetic emissions, whose status was discussed by F. Lefeuvre, and by the ASIM-ISS mission which will also focus on the cloud-climate interactions, as discussed by T. Neubert. It however important to understand the needed synergy with ground based observations, because of the relatively small time-window and time bias of the observations available through satellite missions. This was made clear by the contribution of ground based observational studies (see also Arnone and Ignaccolo): e.g. the multiyear campaigns in Israel following the Space Shuttle-MIDEX experiment (Y. Yair), or those in North America (H.

Stenbaek-Nielsen, T. Lang), South America (F. Sao-Sabbas), Europe (S. Soula, J. Montanyà), Japan (Y. Matsudo), all improving the relationship between the characteristics of the TLE-producing thunderstorm, of the atmospheric background, and those of the observed TLEs (see also T. Suzuki on Wednesday). Advances are achieved by refining the methods for analyzing “simple” optical images, e.g. fitting the circular disposition of column sprites disposed in crown (P-D. Pautet, Y. Yair), using triangulation to define the height of ignition and spatial characteristics, associating time delays with sprite-type (e.g. short delays with column sprites and long delays with carrot sprites), or by focusing on particular regions and season (e.g. winter TLEs over the Mediterranean and Japan seas). Much can be achieved by other kind of non optical-imaging observations, e.g. looking at infrasound emissions (T. Farges), using array photometry (R. Newsome), perturbations induced by gravity waves (E. Blanc, C. Siefring), streamer formation and splitting in high-frame rate observations (M. Montanyà, M. McHarg), transient emissions in the mesospheric airglow layer (T-Y. Huang) and spectroscopy of the instantaneous emissions (J. Morril) and of their long term chemical effects (E. Arnone).

These observational studies proceed together with the advances in the modeling and theory of TLEs discussed in the second day. Remarkable advances were brought forward since the 1989 discovery, as highlighted by the review talk by V. Pasko. In the last years, a great deal of improvement has come from the modeling and laboratory simulations of streamer processes (U. Ebert, N. Liu, S. Nijdam, C. Li, S. Celestin) which are a key basic component in theoretical and modeling studies dedicated to sprites and blue jets (Y. Raizer) and halos (A. Luque, Y. Hiraki), of their emissions (e.g. UV flashes detected by the Tatiana satellite, M. Shneider) and their chemical effects (F. Gordillo-Vazquez,). The scaling of laboratory experiments to mesospheric heights allow also to improve our interpretation of the observed TLE streamers, e.g. with the aid of 3D imaging which shows for example that often the observed recombination of streamers does not occur: these studies will hopefully lead to the much needed description of how much of the background mesospheric air is actually impacted by TLE streamers.

Advances in understanding the thunderstorm-atmosphere-TLE-ionosphere system are coming from studies that focus on the distribution of charges and on the electricity of these processes (M. Rycroft, J. Rioussset, S. Davydenko), showing the specific conditions and thresholds needed for these discharges to occur, and leading to estimates of the related emissions (e.g. ELF/VLF) which are well in agreement with the observations (see review by U. Inan, and talks by S. Cummer, R. Marshall, E. Greenberg, C. Haldoupis, M. Kelley, J. Li, S. Kumar, O. van der Velde, J. Thomas, C. Croskey, E. Lay, S. Klimov). Because of the global range of these low frequency emissions, it is becoming possible to obtain global distribution of TLEs from non-optical measurements (M. Sato).

As anticipated in some talks, the high energy processes related to thunderstorm activity were the focus of the last day of the conference, with theories of runaway breakdown related to discharges in thunderstorms (see review by G. Milikh) building up on the early ideas by Wilson (E. Williams). Much of the interest in studying terrestrial gamma-ray flashes is directed towards the generation mechanism able to generate the needed runaway energies (see the relativistic feedback by J. Dwyer, and the models by J. Colman and O. Chanrion). The observations of TGFs have made tremendous progress since the early detections in 1992-1994 (J. Fishman). As with TLEs, we can now study the characteristics of these emissions and of their producing thunderstorms (D. Smith, M. Marisaldi, H. Rassoul), using ground recorded sferics (X. Shao, M. Fullekrug), correcting for deadtime biases (N. Ostgaard, T. Gjesteland) and fit these observations with models (B. Carlson, B. Hazelton). Related emissions such as increases in fluxes of x-Ray and neutrons (L. Babich, C. Nguyen) will be the target of the previously mentioned TARANIS and ASIM mission and especially of upcoming Russian missions (M. Panasyuk). Unfortunately, the successfully launched RISING satellite which could be already jointly studying TLEs and TGFs is currently not working and attempts are made to recover its functionality (Y. Takahashi).

The conference has clearly highlighted the broadness of the processes directly and indirectly connected to TLEs and TGFs, and of their coupling to the atmosphere, thunderstorm processes and the ionosphere. Not to mention the dependence of their production, evolution and impact on the variety of atmospheric and solar-terrestrial processes. The complexity of these processes and the advances that their interdisciplinary study can bring to our knowledge of the atmosphere was shown also but the amazing variety of expertise present at the conference. This meeting was an essential step in building a new approach to what only a few years ago was buried into the “ignosphere”.