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Report on instrumentation needs of atmospheric electricity community

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By Working Group 5 – Instrumentation, of COST Action Ca15211
"Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems"

http://www.cost.eu/COST_Actions/ca/CA15211

Compiled by Working Group 5 Chair, Dr Keri Nicoll

Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems (ELECTRONET)

An atmospheric electric field (AEF) of 100 V/m to several kV/m exists in the atmosphere, resulting from a global electric circuit extending from the surface to the lower ionospheric layers. The study of many environmental processes relates to atmospheric electricity. Such processes include, but are not limited to, earthquakes, aerosols / clouds and climate, sun-earth interactions, air pollution, lightning etc. Further, there is emerging evidence that AEF variations may interfere with biological processes, including human brain function. To overcome the lack of coordination of different research efforts in these fields, this COST Action involves and integrates existing resources in the field of atmospheric electricity, builds a network, enhances interaction and creates the necessary critical mass of researchers and facilities to advance knowledge, introduce new techniques, transfer know-how among different fields. By these means the Action will advance our understanding of a number of processes that lie at the interface of solid earth, environmental, biological, climatic and solar/terrestrial sciences.

ELECTRONET website: http://atmospheric-electricity-net.eu/

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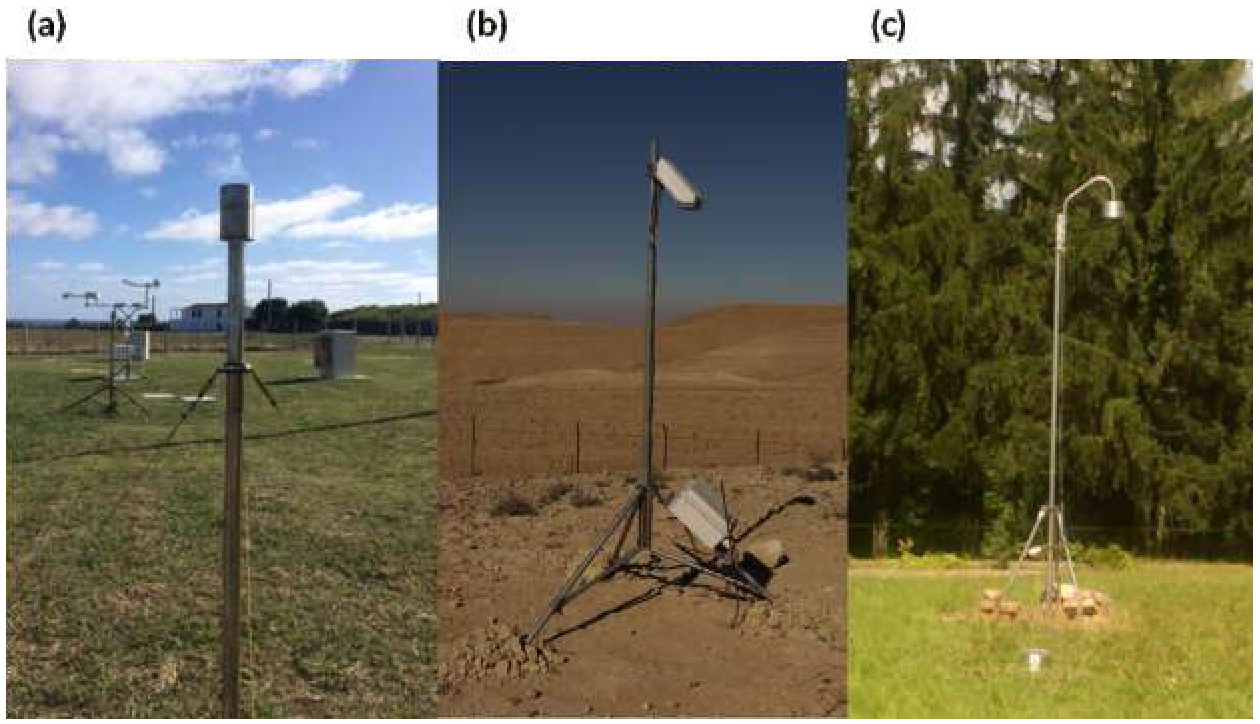
Atmospheric electricity is one of the oldest fields in geophysical science, dating back to the 1750s, and therefore has a substantial history of instrumentation development. It encompasses a huge range of physical variables, requiring a number of different physical measurement techniques. Advances in electronics and the commercial availability of components mean that the range and accuracy of atmospheric electricity instrumentation is greater now than it has ever been, but there remain a number of challenges in respect to instrumentation in this field. These challenges are discussed below:

1. Atmospheric electricity encompasses a large number of measurement parameters including current, voltage, electric field, ion conductivity, ion mobility, and ionisation all of which require different measurement techniques.
2. Atmospheric electrical parameters span many orders of magnitude, for example, currents span at least 20 orders of magnitude (from 10^{-15} A to 1000A), therefore a variety of sensors is required to measure the entirety of this range.
3. The vertical extent of atmospheric electrical parameters ranges from the surface to the ionosphere, therefore measurements are required at the surface as well as aloft. This generally requires different sensor characteristics depending on the measurement platform used.
4. Sensors must be deployed in all areas of the globe, ranging from desert conditions to polar environments, hence sensor robustness requirements vary depending on location.



Example of atmospheric electric field instrumentation which is widely commercially available. (a) Chilworth JCI131 at Graciosa, Azores; (b) Campbell CS110 at the Wise Observatory, Israel, and (c) Boltek EFM100 at Nagycenk, Hungary.

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1. Developments required for existing sensors

The general instrumentation development requirements of the atmospheric electricity community are as follows:

- Smaller sensor size and weight
- Commercial availability of sensors (and low cost)
- Robustness (e.g. can operate in polar, desert and rainy environments)
- Inbuilt data logging capabilities (to enable rapid deployment in the field)
- Fast sensor response times
- Optimisation of sensors for low power operation
- Airborne capability (i.e. small, lightweight, inexpensive, disposable)
- Network capabilities (i.e. requires small, inexpensive sensors) (especially for electric field mills, conductivity sensors, VHF lightning sensors)
- Robustness of sensors to animal interference (e.g. birds, insects)

Example of current developments in miniaturised atmospheric electricity sensors.
New hand held radioactivity/cosmic ray detector developed by the University of Oxford, UK, giving particle counts and energy and suitable for use on a variety of platforms including ground based networks, balloons and aircraft.
http://www2.physics.ox.ac.uk/news/2017/12/20/wireless-radiation-detector-new-invention.

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Specific desires for new instrumentation developments are:

- Disposable balloon borne electric field sensor for ionospheric potential measurements (i.e. temperature stable and high sensitivity)
- Small, low cost electric field sensor for surface network measurements (preferably commercially available, with simple output (i.e. voltage) which can be connected to a variety of data logging systems)
- Miniaturized, disposable conductivity sensors for surface network and airborne use
- All-weather ion counter for continuous measurements of ion concentration and mobility (ideally resistant to rain and dust)
- Instrumentation to measure very young air ions
- Fast response, high sensitivity radon detectors to detect low radon concentrations
- Miniaturised cosmic ray sensor for radiosondes (variability of GCRs in time and space), ideally with energy discrimination, commercially available
- Miniaturised, low cost radon sensor for near surface vertical profiles
- Improved instrumentation for air-Earth current (Jz) measurements (i.e. for long term use and robust to environmental conditions, ideally commercially available)
- Commercially available broadband radio receiver networks (>10 instruments) and VHF mappers which can be easily deployed in the field for lightning research (i.e. rugged, low cost, user friendly, easy-to transport radio receivers)
- Improved accuracy of radio receiver networks to achieve amplitude resolution of ~10-100 nV/m and timing accuracy down to ~100 ps

Related to the development of new instrumentation is the requirement for better data logging capability. Desirable data logging characteristics are:

- Requirement for sensor outputs to be sufficiently general to be compatible with many data logging solutions
- High frequency data logging for e.g. fast electric field measurements at 100Hz
- Low power data loggers which have a range of communication options (e.g. wi-fi, phone network, usb)
- Simple time synchronisation options between data loggers
- Option of buying a sensor with an integrated data logger with simple communication options

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In addition to specific instrumentation requirements, there are a number of instrument related desires from the atmospheric electricity community. These include:

- Instrument comparison experiments which assess the similarities (or differences) in the performance of sensors measuring the same parameter
- recommendations for good scientific operating principles for instruments. This will assist in the setup of new measurement sites and will help to ensure good data quality between sites
- research into alternative methods of electric field measurement is required (i.e. alternative to power hungry electric field mills)
- remote detection of charge and electric fields would also enable much greater global coverage than is currently possible with in-situ observations.

2. Instrument development of interest to the general public

As well as sensor developments of interest to the atmospheric electricity community there are a number of sensors which may also be of interest to the general public. These include:

- Low-cost miniaturized hand held electric field sensors for lightning warning (e.g.for climbers, construction firms, electricity network maintenance climbers)
- De-charger of surface charges from e.g. vehicles
- Ability to use the radio antenna of mobile phones as lightning detectors (e.g. Nokia patent)

3. Potential funding routes for instrument development

There are several barriers which inhibit the sensor development suggestions reported here. From an academic research point of view these include:

- a lack of funding available for instrument development from national research councils
- time commitment constraints on the academic research community, which makes commercial exploitation of sensor designs difficult
- university IP ownership difficulties

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The alternate route to instrument development is through commercial companies, but this also represents a number of challenges, such as:

- Identification and demonstration of a market requirement for sensors is generally required before a company will be interested in specific instrument development
- Inexpensive sensors are generally unattractive to companies as there is often not much overhead profit (requiring sensors to be sold in vast quantities).

Commercialisation funds for sensors within individual countries are common, but these require previous instrument development work to a relatively high level of technology readiness, as well as a detailed business case. The initial funding required to develop instrumentation to such a level of technology readiness (e.g. through technology proof of concept funding calls) is much more difficult to obtain, where funding calls are often rare. This is therefore a serious barrier to future instrument development, and should be addressed by the research councils.

Summary

The most important instrumentation requirements for the fair weather atmospheric electricity community are the miniaturisation of electric field sensors to allow deployment of low cost surface sensor networks, as well as airborne profiles from balloon and Unmanned Aerial Vehicles (UAVs). There is also a strong desire to increase the range of atmospheric electrical sensors which are currently commercially available, which will only help to drive forward fundamental research in this field. Finally, it is recognised that there are a number of barriers which make the recommendations suggested here difficult to achieve. Collaboration between the academic research community and commercial companies is therefore the most promising route to success.

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