Space Weather: A Multi-Disciplinary Approach

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Space weather refers to conditions on the sun and in the solar wind, the Earth's magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. As our society continues to rely more on such advancing technologies, space weather will increasingly play a significant role in human activities, approaching that of terrestrial weather.

The study of space weather has traditionally been carried out using standard techniques and tools found in space physics such as time series correlational analyses. These techniques, although having the advantage of being fast and simple, are sometimes not adequate or complete because the Sun-Earth system is a complex nonlinear system. On the other hand, researchers in the fields of mathematics, information science, computer science, machine learning, data mining, have developed, over the last several decades, tools that can handle complex nonlinear systems and are eager to apply these new tools to new difficult problems.

The aim of this workshop is to bring together researchers from space weather, space physics, mathematics, computer science, information science, machine learning, data mining, etc. to foster symbiosis and cross-fertilization across the fields.

The topics that have been discussed include: Information theory and system science approaches to the solar-terrestrial problem; Pattern recognition, deep learning, and general feature selection in solar forecasting; Data mining and machine learning for Space Weather.

One important outcome of the discussions between solar physicists and machine learning experts was the idea to craft and pose a Solar Prediction Grand Challenge to machine learning practitioners in the trending mold of Kaggle.com. Workshop participants crafted the initial design for such a challenge during the meeting and formed a coordinating committee to develop and deliver a final product.
Self-organizing working groups formed during the week following an un-conference format, focusing on specific, well-defined problems, which can be generally divided into:
• Algorithms to automatically identify events (e.g. magnetic reconnection in planetary magnetospheres, or features such as active regions, coronal holes, coronal mass ejections in solar images) to be used in place of traditional, time-consuming, and non-reproducible manual selection;
• Knowledge discovery: methods to study causality and relationships within highly-dimensional data, and to cluster similar events, with the aim of deepening our physical understanding;
• Forecasting: machine learning techniques capable of dealing with large class imbalances and/or significant data gaps to forecast important Space Weather events from solar images, solar wind and geospace in-situ data.
• Information theory: a powerful method to discover causalities and nonlinear relationships in the dat; applications of information theory to solar and Earth's magnetospheric data were discussed.

All participants appreciated the unconventional format of the workshop, and the office space at their disposal. Many small groups formed to work on specific space weather topics and these groups will continue working even after the workshop ended.

A follow-up meeting or workshop is expected to take place within a couple of years.

Another, long-term proposal discussed during the workshop was the idea to write a white-paper on this topic, to circulate within funding agencies. A general consensus was reached that progress will require multi-disciplinary cooperation and targeted funding.

Finally, a paper summarizing the meeting has been submitted to the Earth and Space Science magazine of the American Geophysical Union (EOS) to spotlight the event. EOS is a leading

magaznie that covers the latest Earth and space science news and publishes the magazine in print as well as online (https://eos.org/).

Enrico Camporeale (Amsterdam, The Netherlands)
Jay Johnson (Berrien Springs, MI, USA)
Simon Wing (Laurel, MD, USA)