EISCAT_3D - Our eye on the environment between earth and space

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The earth and the sun

The sun plays a fundamental role in relations to the earth's environment. Not only does it provide direct heat and light, it also provides the necessary energy to power the convective motions in the atmosphere and oceans, determining weather patterns and climates.

Mostly invisible to the human eye, the sun also produces solar winds, that is, a fast stream of charged particles travelling from the sun outwards, throughout the solar system. The magnetic field associated to solar winds interacts with the earth's inherent magnetism to form the magnetosphere. As a result, solar-terrestrial physics consist in the scientific investigation of the diverse aspects of the connection between the sun and the earth, including the processes responsible for the conversion of energy from one form to another and how their combination might affect our environment.

In order to cover all implications of such a broad topic, solar-terrestrial physics overlap with many other areas of science, such as atmospheric physics and chemistry, solar and plasma physics. This presents us with several practical fields of application, such as enhancing ionosphere models' potential for communications or global positioning applications and clarifying the natural variability's short-term and long-term contributions to global change.

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The world is increasingly dependent on space-based systems for much of our everyday communications and travel while space weather processes have come into focus to a larger extent. Space weather indeed refers to conditions in the environment of the magnetosphere and ionosphere (ie. the uppermost part of the atmosphere that is partially ionised by the sun and solar winds and has the potential to influence the reliability of space and ground-based technological systems and services). The search for improvements in the prediction and mitigation of space weather effects is now at the top of the scientific and political agenda globally and solar-terrestrial physics thus stands to make a significant contribution to XXIth century science.

A driving factor of progress in the field of solar-terrestrial physics lies in our ability to make observations. Continual variations in the solar-terrestrial system and the complexity of the processes involved limit tour capacity to apply current theoretical models in predicting how the environment will respond to solar influence. This calls for high-quality observational data, covering all key regions of the sun-earth system, with particular focus on the ionosphere, as it connects the earth's magnetosphere and lower atmosphere.

To that end, systems applying the incoherent scatter radar technique are the most powerful instruments available for ionospheric observations.

Incoherent scatter radar technique
Like all standard radar techniques, the incoherent scatter radar technique involves the transmission of a radio signal towards a target and the detection and analysis of the return signal. In our case, the targets are ionospheric electrons, in sucha volume as to fill the whole radar beam. The resulting echo signal is very weak (only 0.0000000000000000001% of the transmitted power is typically returned), so that the transmitted radio pulse must be powerful and the receivers sensitive enough for the return signal to be sufficiently strongand cancel out background noise. High-power radars with a large aperture (HPLA) are systems fitted with the powerful transmitters and large antennas necessary to satisfy such conditions and are as a result the preferred instrument for incoherent scatter radar measurements.

The parameters typically obtained from an incoherent scatter radar measurement include as functions of time and distance from the receiver, electron density, electron and ion temperatures and bulk plasma velocity along the radar beam. By using three or more geographically separated receivers looking at the same volume of the ionosphere, it is also possible to determine the full three-dimensional bulk plasma flow velocity within that shared volume. Thus, a radar system using the incoherent scatter radar technique may function as a plasma weather station and provide detailed observations of the state of the ionosphere in a volume well beyond the reach of a traditional system.

EISCAT Scientific Association
The EISCAT Scientific Association is an international research organisation currently operating three radar systems (in Northern Fenno-Scandinavia and the Svalbard archipelago), to produce incoherent scatter measurements. Established in 1975 and headquartered in Kiruna, Sweden itsthe radar operations started in 1981. Since then, EISCAT facilities have been continuously developed and extended. Thanks to successful operations, EISCAT has played a prominent role in the development of new and innovative techniques for radar experiments and data analysis. EISCAT regularly participates in international campaigns involving other radars, ground-based instrumentation and satellites -- noticeably the Incoherent Scatter World Days coordinated by the International Union of Radio Science (URSI). Currently, EISCAT gathers associates amongst leading research institutions and science councils in China, Finland, Japan, Norway, Sweden and the United Kingdom, while further platforms in France, Russia, Ukraine and South Korea also contribute to the operational funding. As a result, scientists from more than fifty countries worldwide use EISCAT data.

EISCAT_3D
The next step for EISCAT will be to develop the EISCAT_3D system, which will enable three-dimensional mapping of the dynamics of large volumes in near-space and the upper atmosphere.
This is made possible by the fact an EISCAT_3D radar site consists of flexible arrays of antennas, in contrast to the very large

Figure 1: The present EISCAT radar facilities near Tromsø, Norway. (Photo: Craig Heinsel

and slow-moving antenna dishes of present EISCAT systems. This also allows the EISCAT_3D system to produce continuous measurements for the detection of longer trends, to be compared with the mostly campaign-based observations offered by present systems.
As an integral part of the Scientific Association, EISCAT_3D will be operated by EISCAT. It will be located in the Northern auroral oval, where northern

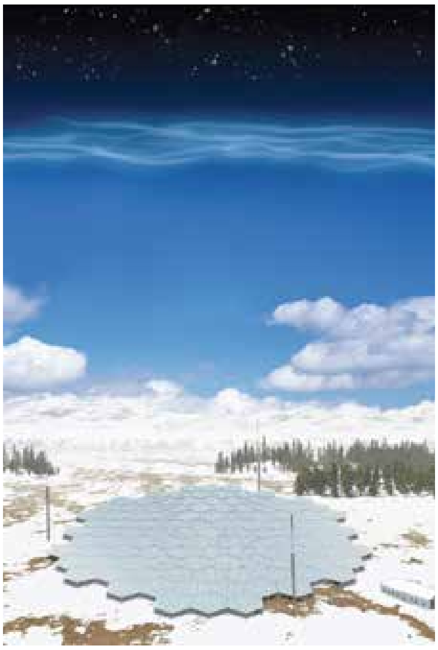

Figure 2: Sketch of a future EISCAT_3D site. (Image: NIPR)

lights are most prominent and at the edge of the winter polar vortex, one of the main features controlling the atmosphere over the Arctic and Northern Europe. In its fullest implementation, the radar system will be distributed over five sites. A radio wave transmitter with several megawatts of peak power will be placed at a site near Skibotn (Norway) and the return signal will be measured from all sites, some of which are located up to 250 km away from the transmitter. Each site will hold 9919 stationary antennas grouped into 109 hexagonal arrays, covering an area roughly 70 m across.
At present, preparations for the three first EISCAT_3D sites have been initiated and a tendering process is underway for the construction of a first test sub-array dedicated to technical tests and evaluations.

The construction of EISCAT_3D will generate new technical and organisational challenges for EISCAT, which is where ENVRIplus insight would be particularly valuable to us.

EISCAT and ENVRIplus
The EISCAT Scientific Association has matured in terms of its access and data management practices and procedures,through negotiations conducted between members of the association spanning over the 35 years EISCAT has been operating radars. Nevertheless, the construction of EISCAT_3D will generate new technical and organisational challenges for EISCAT, which is where ENVRIplus insight would be particularly valuable to us.
An operational EISCAT_3D site will produce a lot more raw data than present EISCAT systems, due to the fact it will demultiply data sources by a factor of around ten thousand. In addition, the raw data produced will also require significantly more processing before it can beuseful to scientists. As a result, optimizing data processing and storage architecture are prerequisites of any future development.
We anticipate the demand for data will be larger when EISCAT_3D goes online, partly because of its potential in providingcontinuous environmental monitoring data. In particular, the system will likely need to offer near real-time data services to fit into earth observations global systems. Similarly, the system's extension of operation hours for monitoring purposes hints to a larger need for systematic quality control of data systems and their harmonization across all research infrastructures.

It has been historically difficult for EISCAT to keep track of where and how its data has been used, which may be remedied through the implementation of a system for data identifiers. Streamlining processes for users will be necessary, to gain observation time on the EISCAT_3D system, in particular since it may be possible to provide interleaved experiments, as well as access to more than one experimenter at any giventime. Finally, sharing best practices with other environmental research infrastructures will allow EISCAT to gain insights from areas of expertise outside of its traditional activities. Such are some of the areas in which ENVRIplus recommendations, services and solutions would certainly serve EISCAT.