NORTH ATLANTIC TREATY ORGANIZATION

Ionospheric situational awareness for critical infrastructures

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As part of its efforts to support space situational awareness, NATO's Science for Peace and Security (SPS) Programme is co-funding a project to establish a unique network of existing high-precision ground-based ionospheric sounders in Europe which allows coordinated monitoring of the ionosphere to predict the propagation of waves and warn users of any irregularities. The project will be launched at the 11th European Space Weather Week taking place in Liège, Belgium, from 17 to 21 November 2014.

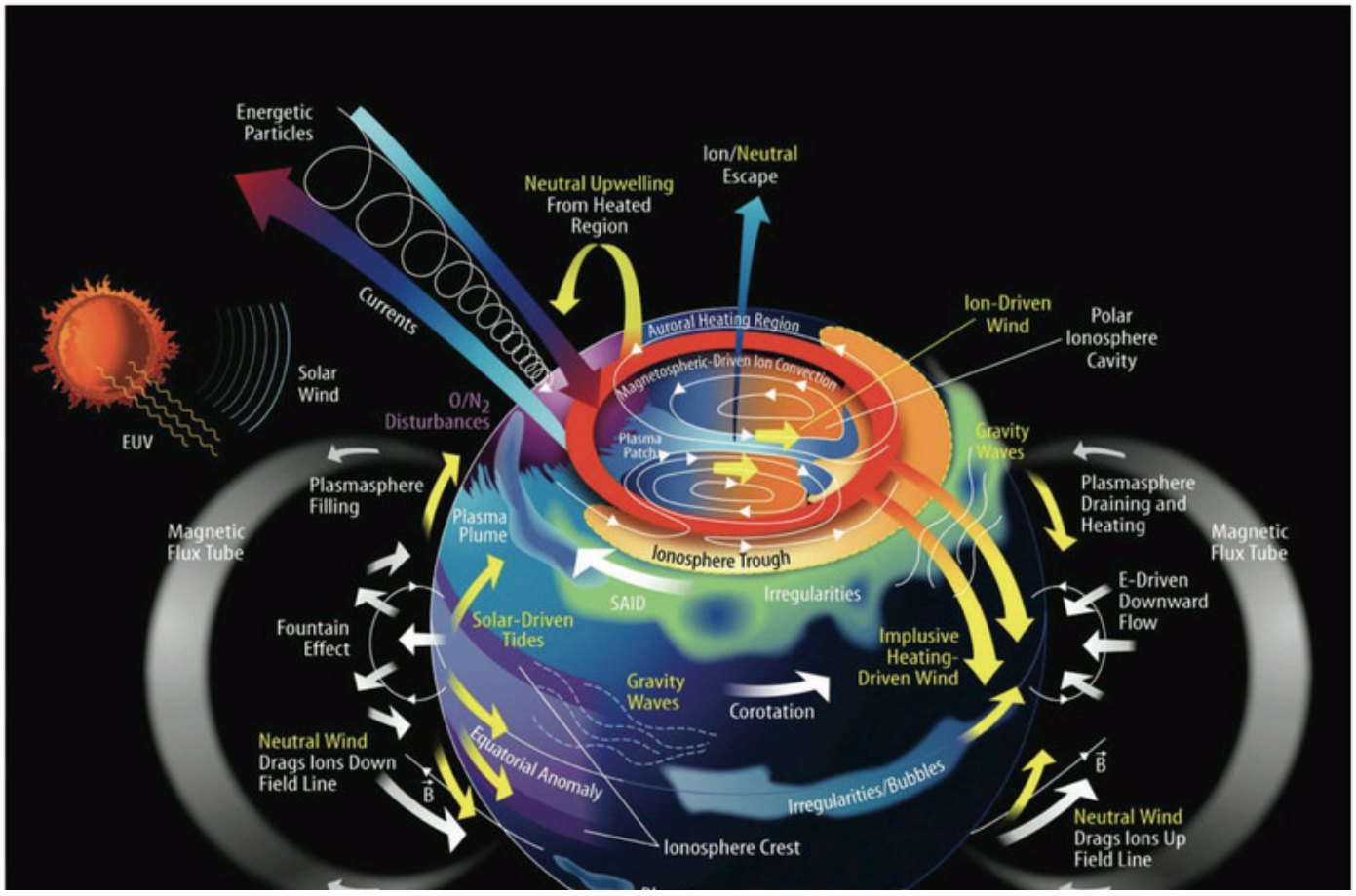

Figure: The complexity of the ionosphere-thermosphere-mesosphere system of planet Earth and the range of physical processes operating. Credit: NASA/J. Grobowsky

The ionosphere is a charged ("ionised") region of the upper atmosphere that affects waves travelling through it. Phenomena originating from the sun and from lower atmospheric layers significantly disturb the ionosphere posing a threat to peace and security as this may result in the malfunctioning of critical infrastructure in the field of international communication, navigation, surveillance, money and stock trade, air travel and power supply. In some cases, such as radio communication and broadcasting systems, the ionosphere is an unavoidable part of the system; in other cases, such as the transionospheric radio communication and navigation systems, the ionosphere is a fundamental nuisance. In both instances, an account of the ionosphere is crucial to support the smooth operation of critical infrastructures on which our modern high-tech world relies.

The "Halloween magnetic storm"

In October 2003, just before the Halloween celebration, a series of extreme phenomena resulting from the solar-terrestrial interaction have been recorded by networks monitoring the geospace. A bundle of concentrated magnetic energy emerged from the sun's interior, forming a large sunspot, followed by enormous solar flares. On 28 October, the sunspot abruptly ejected a concentrated mass of electrically conductive solar wind, flinging it into interplanetary space toward the Earth. A day later, a geomagnetic storm disrupted the Earth's protective magnetosphere. This series of phenomena is known as the "Halloween magnetic storm".

The storm, one of the largest of its kind in the past 60 years, produced a number of complicated effects on technological systems around the world, which scientists continue to analyse even today. GPS accuracy was significantly degraded, affecting land and ocean surveys, as well as commercial and military aircraft navigation. Civilian and military satellites were put into a protective operating mode, other satellites were damaged, and a Japanese scientific satellite was permanently disabled. Communication interference forced the United States Department of Defense, for instance, to cancel a maritime mission. Interference with over-the-horizon radio communication also made polar routes inaccessible for airplanes.

Mitigating the threats

Several countries have dedicated services and technologies to monitor the ionosphere, leading to a significant progress in predicting the large-scale ionospheric disturbances. However, for critical systems requiring higher accuracy (such as the satellite-based augmentation systems or SBAS), the prediction of small-scale disturbances, such as atmospheric gravity waves, instabilities and fluctuations in ionospheric plasma, is necessary. These phenomena occur through solar flares, auroral electroject activity, as well as other geophysical phenomena (earthquakes, tropical cyclones) and anthropogenic effects (rocket

launches), because the ionosphere is not only affected by the solar activity but has important influences from the mesosphere. Consequences of the disturbances include disruption of the detection and tracking of aircraft, missiles, and unmanned aerial vehicles (drones), satellites, and other targets, distortion of communication, navigation, as well as global command, control, and surveillance operations.

NATO is making an important contribution towards supporting ionospheric situational awareness through its SPS Programme, which is establishing a pilot network between existing ground-based ionospheric stations covering Australia, Belgium, the Czech Republic, Germany, Greece, Spain and the United States. These stations are able to perform observations of high quality and precision required for the detection of travelling disturbances. Over the next three years, existing stations will be upgraded, technical personnel will be trained and protocols will be established ensuring that the experts have, at all times, a complete and high-resolution picture of the ionosphere. The monitoring system will also allow the communication of disturbances in a prioritised and harmonised manner, to avoid misinterpretation or confusion. This early warning system could serve as a model for further regions across the globe, including Japan that is already involved as an observer.

Possible end-users of the information from the ionospheric monitoring system include the National Oceanic and Atmospheric Administration Space Weather Prediction Center, the United States Air Force Research Laboratory, the European Space Agency and the Defence Science and Technology Organisation of Australia’s Department of Defence. The system can warn of hazards for ground-to-space and space-to-space data communication, and detect blasts from bombs or industrial accidents, adding information to the conventional ground monitoring systems that have been put in place under the International Atomic Energy Agency.