# Science Last Fortnight

## Magnetic Storms

*Ionospheric response*

The sun becomes active every 11 years on an average and spews out particles as coronal mass emissions. When this happens, charged particles in solar wind increase from an average of 5 to 40 particles per cubic centimetre and the solar wind picks up speed from an average 400 kilometres per second to go up to 2000 kilometres per second!

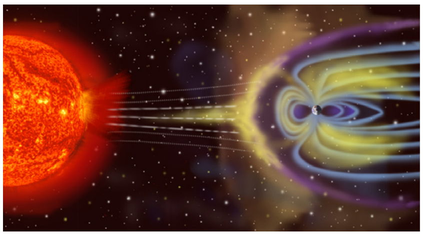

Image: NASA, via Wikimedia Commons

When the magnetic field associated with the solar wind is oriented perpendicular to the planetary ecliptic and is oriented southward, it interacts with the Earth's magnetic fields to cause magnetic storms. This is associated with travelling disturbances in the ionosphere. These electrical and magnetic phenomena can interfere with satellite communications besides impacting the earth's weather systems.

Recently, K. Venkatesh from the National Atmospheric Research Laboratory, Gadanki and G. K. Seemala from the Indian Institute of Geomagnetism, Mumbai collaborated with scientists from Brazil to investigate the impact of the magnetic storms on the day-to-day variability of the equatorial and low latitude ionosphere.

The team used Brazil's network of 82 dual frequency global positioning system receivers for continuous monitoring for global navigation through satellite system. The network can also help estimate total electron count over one square metre of atmospheric column. These receivers are distributed over Brazilian latitudes and longitudes. Moreover, they have three ionosondes on the periphery of the GPS system that can be used for monitoring the ionosphere – a very useful system to study the ionosphere near the equator.

The researchers examined data from 16 to 18 January 2013 when the sun was active. There was a magnetic disturbance starting on the 17th at 00:04 universal time which reduced by 11:00. However, there was no magnetic storm or solar wind at this time. Later, at 14:00 hours universal time, there was a solar wind that caused a moderate magnetic storm. The magnetic disturbance subsided rapidly and reached negative values by about 01:00 hours on the 18th.

The researchers compared the magnetically quiet conditions with magnetic storm conditions. They generated maps of vertical total electron count every 3 minutes to make a stop motion video of the quiet and geomagnetically disturbed days. As a response to the magnetic storm, the ionosphere became swollen on both sides of the equator, more than 20 degrees north and south. This ionospheric positive phase moved equatorward as a wave on both sides, losing strength in the process.

Normally, at the equator, there is an anomalous swelling of the ionosphere which waxes and wanes during the day. An equatorial ionospheric anomaly crest that was developing at that time interacted with the waves coming from north and south. The equatorial ionospheric anomaly became stronger and lasted longer, though by this time, about four hours after its formation on both sides of the equator, the travelling ionospheric disturbance had weakened.

From the data, the researchers could make out that the wave from the south is not originating from the Antarctica, but from somewhere in the southern African sector.

The team examined the minimum virtual height of the ordinary wave trace of the entire F region of the ionosphere (50–1000 kilometres above sea level) and found that it did not change much. However, the critical frequency of the ordinary wave of the F2 layer (300–400 kilometres in height) increased.

The researchers looked at data from 18 GPS receivers approximately along a magnetic meridian, perpendicular to the geomagnetic equator. They found that the travelling ionospheric disturbances merged with the eastern sector first and only later with the western sector. Moreover, the positive ionospheric phenomena lasted longer and extended to a greater area in the eastern sector.

The team also examined data from six GPS stations near the magnetic equator. And found something not noticed before: when the geomagnetic storm started subsiding from 23:00 universal time, there was a westward wave with high electron content travelling at more than 200 metres per second in the ionosphere.

Usually the ionospheric plasma moves eastward. The physical mechanism behind this reversal is puzzling, say the researchers.

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## Counting Glaciers

*Study in the Himalayan region*

There are thousands of glacial lakes in the Himalayan region. Owing to the rise in average global temperatures and human interference, the number of glacial lakes is increasing. There is an immediate need to accurately estimate and monitor glacial lakes to prevent possible disasters.

Image: T. R. Shankar Raman, via Wikimedia

Presently, remote sensing is used to monitor changes in glacial movements. But, the spectral nature of shadow and water in a satellite image results in wrong estimates of glacial lakes.

To overcome this problem, Prateek Verma and Sanjay Kumar Ghosh from the Indian Institute of Technology, Roorkee used a combination of two other algorithms to identify lakes from satellite data and segregated shadow pixels from water areas. The double-window flexible pace search algorithm sets a threshold beyond which it marks pixels from data as water and the edge detection algorithm filters out remaining shadow pixels from water pixels. This way the scientists ensure they can accurately identify and track the number of glacial lakes in an area.

The scientists used multispectral images of the Gangothri basin from the database of the Sentinel 2A, a European Space Agency satellite. Using these, the scientists were able to estimate a total of 101 glacial lakes in the Bhagirathi Basin which was in agreement with data from reports using other techniques.

While the accuracy of the method depends on the data and quality of satellite images, the technique is definitely a major progress in identifying glacial lakes for preventing potential hazards.

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## Aerosols from Biomass Burning

*A case study over northern India*

The carbonaceous aerosol level remains a major challenge in atmospheric science. It can negatively affect health and the Earth's surface temperature. However, our understanding of the production and distribution of aerosols from biomass burning is incomplete.

Image: Neil Palmer – via Flickr

Recently, scientists from ISRO, IMD, the Kumaun University and the Punjabi University used multi-satellite data to observe the impact of biomass burning on regional aerosol optical properties in northern India. Moderate Resolution Imaging Spectrometer (MODIS) data from Terra and Aqua satellites provide estimates of aerosols and active fires. Data from the ozone monitoring instrument (OMI) on board the Aura satellite also provides estimates of aerosols under cloud-free conditions.

Examining data from January 2003 to December 2017, they found that the number of active fires was least in August, but maximum in March and November. Punjab and Haryana led in biomass burning, accounting for more than a quarter of fires, followed by central India. Two seasonal peaks of activity were detected, representing the burning of *rabi* crop residue in April–May and *kharif* residue during October–November. Paddy crop residue is burned four to five times more than wheat residue. There is an increasing trend of about 4% in post-monsoon fires in the region, say the scientists.

Fires were detected in the southern Peninsula also. But biomass burning was much lower than in the north. The western parts showed minimum fires. After taking these areas into consideration, the increasing trend of annual fires over India comes to more than 2%.

The researchers took data from the CALIPSO (Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations) spacecraft to estimate the vertical extent of smoke aerosols. They also collected data from ground-based instruments. ISRO has set up a network of instruments to measure aerosol radiative forcing over India (ARFINET). NASA has its aerosol robotic network (AERONET) of sun-sky scanning spectro-radiometers all over the world, including one in Kanpur, to take measurements every 15 minutes. Then there is the IMD's sky radiometer network that monitors air quality and aerosols.

The researchers focused on four areas in northern India where ground measurements are available: Dehradun, Patiala, Delhi and Kanpur. The ground-based data confirmed trends seen in MODIS data. But MODIS data tends to overestimate aerosols during monsoon, perhaps because of interference by cloud condensation, say scientists.

The other parameter that complicates inferences from satellite data is the phenomenon of dust storms which adds magnitudes to the estimates of pre-monsoon aerosols, especially in Patiala. Dehradun, at higher altitudes, without interference from dust storms and not in the downwind direction from massive agro-waste burning, showed less aerosol density. Delhi and Kanpur, on the other hand, show an abundance of mineral dust before monsoon and carbonaceous aerosols in the atmosphere after monsoon.

Smoke plumes tend to rise. The vertical height can extend to 3 kilometres and more. Smoke plumes also spread as they rise and extend to central India. Smoke plumes are carried by winds. So though the Patiala area has more fires, the aerosols are carried east by winds.

So the researchers used the Hysplit model which can estimate the position of a three-dimensional air mass with time. Modelling by Hysplit revealed that, most of the time, the air mass moves eastwards and then curves to the south to cover Uttar Pradesh, Bihar, Bengal and the Bay of Bengal. There are occasional cases where the air mass moves north-east towards the Tibetan plateau.

Thus, biomass burning is not a problem for farmers in the source region alone. It is also affects people in the Gangetic Plains which house 70% of our I.3 billion population. It will remain a burning problem unless adequate steps are taken to change traditional practices and to adopt modern composting methods.

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## Floods and Fertility

*Dam and biodiversity*

Floods cause destruction, death, and disease. But there is a good side to floods too. Flood plains are the most productive of all ecosystems and provide diverse habitats for various life forms to thrive.

To control the damage by floods, we develop dams and build embankments. We divert water for irrigation and set up habitat constructions in the flood plains… These can reduce nutrient inputs from recurrent floods, and threaten many species. They also lead to loss of habitat for many more, reducing biodiversity.

Last fortnight, Swades Pal and Swapan Talukdar from the University of Gour Banga, West Bengal reported researching flood-prone areas along the Punarbhaba River after the construction of the Komardanga Dam.

Image: Anup Sadi, via Wikimedia Commons

The Punarbhaba, located on the Teesta Fan, is a meandering single channel river flowing between Bangladesh and West Bengal. Heavy monsoon rains cause flooding in the river and its tributaries. So, in 1992, the Komardanga Dam was installed.

The team used 30-metre resolution Landsat-4–5 and Landsat-8 remote sensing data from 1982 to 2016. The data of the past thirty-four years helped identify and monitor the changes. To model the flood plains, the researchers employed the Shuttle Radar Topography Mission's digital elevation model.

The team collected daily water flow data of Punarbhaba and its major tributary, the Tangon river from gauge stations. To estimate missing flow and simulate flood prone areas in different periods, they used the architecture geographic information system, ArcGIS, and the Hydrologic Engineering Center's river analysis system.

The scientists calculated the average water level at different seasons for both pre- and post-dam periods. They computed the water level gap by deducting the water level of the post-dam phase from the pre-dam phase in each season. They thus identified water level gaps in each month and season between pre- and post-dam periods. They say that there is a probability of floods every 2, 10, 25 and 50 years.

After the installation of the dam in 1992, flood-prone areas reduced by forty per cent due to the lateral squeezing of inundated areas. The areas that used to get deeply flooded are gradually having lower flood water depth and those that had lower flood water are now flood free zones. Without inundation water in the last 30 years, the wetlands in the agrarian landscapes are going through ecological transformation, say the researchers.

Only half of the total wetland of the post-dam period receives flood water at least once every five years and the rest of the wetland is struggling for survival, say Swades Pal, University of Gour Banga.

In the next ten years, a forty square kilometre area, and, in the next twenty-five years, a sixty-six square kilometre area may also be threatened, adds Swapan Talukdar, his colleague.

The construction of the Komardanga Dam has reclaimed wetland areas for agriculture benefitting people in the area. But it has also stopped the regular supply of fertile silts to agriculture lands.

River regulation needs to weigh the ecological benefits of floods. At least some flow should be allowed downstream for normalizing the floodplain processes, say the scientists.

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### Abiotic Stress Tolerance

*In early flowering rice*

Image: Public Domain, pixabay.com

Rice cultivation in India depends primarily on the monsoon, especially since irrigation facilities are limited. But, in some places, water rains down only for a short period. To overcome the problem of cultivating rice in such places, early-flowering mutant varieties are being produced in several laboratories. However, along with shortening the period for flowering, these mutants may become more vulnerable to abiotic stresses such as drought, salinity and heavy metal pollution.

N. K. Singh and team from the Motilal Nehru National Institute of Technology, Allahabad, therefore, started looking for rice mutants resistant to abiotic stress. They selected three mutants of early flowering varieties of rice genotypes. The Pusa basmati rice variety was used as control. The team germinated the seeds in Petri plates and transplanted the seedlings into culture pots containing nutrient solution in a growth chamber.

Two mutants started flowering in 20 days while the third flowered in 10 days and the control took 140 days to flower.

The researchers added a mixture of stress-inducing agents: mannitol, sodium chloride, zinc sulphate and zinc oxide nanoparticles, to the roots of one-week-old mutants. After incubating the control and treated mutant samples for two more weeks, they evaluated the effect of induced drought, salinity, heavy metal and nanoparticles on the growth of rice seedlings.

All three early flowering rice mutants performed similarly under different stress conditions with biomass decline. The scientists found that root length decreased by up to 75% and shoot length by more than 60%. The dry matter values decreased linearly with increasing stress conditions and type. They also found a decline in pigment contents under stress.

The percentage of cell viability decreased with stress. One of the mutants had a significantly higher percentage of cell viability. The team also found that antioxidant activity in the mutants correlated with their ability to withstand the stresses. Eventually, they identified one of three mutants as most stable. The mutant variety now requires extensive field trials.

We also have to detect candidate genes for stress tolerance, says Nandan Kumar Singh, Motilal Nehru National Institute of Technology, Allahabad.

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## Coal to Methane

*The bacterial way*

Generating methane from coal reservoirs is an environment-friendly process. Hence there is a growing interest in coal bed methane to meet the clean energy demand. India has high methane generating potential but lacks the technology for biological methane generation from coal reservoirs.

Tripod Stories, via Wikimedia Commons

Therefore, Meeta Lavania, TERI, New Delhi and her team decided to study the bacterial community structure in coal bed reservoirs. Most studies on methane generation by microbes from coal have been done in mesophilic conditions. The team suspected that there are thermophilic microbes that can be a part of the methanogenic bacterial consortium.

So they selected their samples from the Jharia coalfield in Jharkhand, a prime source for the bituminous coal used in blast furnaces. An underground fire has been going on in parts of the area for more than a century.

For isolating the bacteria, they took stored coal samples from a coal bed methane well and samples of water associated with coal from a bore well with a well-depth of around 670 metres. The temperature of the collection point was around 49°C. They also collected gas samples from the well head to analyse methane and carbon dioxide concentrations.

Some bacteria are easily cultured for identification. But others are not easily grown under laboratory conditions and require amplification of 16s ribosomal DNA for identification. The team used both methods to understand the diversity of bacteria in coal bed mines.

While they could culture only 14 groups of bacteria and 3 groups of archaebacteria, they could identify a total of 32 different groups of bacteria and 14 groups of archaebacteria from 192 clones in coal bed mines. Quite a few of them were evidently methanogenic.

To enrich the useful consortium, they added some water from the coalmine bed to a culture medium specifically for methanogenic activity and kept it at higher temperatures. They used the indigenous coal as one of the substrates and checked methane production. After six such enrichment cycles, they felt that they had a consortium that they could use. The consortium had 14 operational taxonomic units of bacteria and 3 of archaea. The methane production was more than a thousand micromoles per gram of coal at 45°C.

They suggest a method by which a consortium of bacteria act together to produce methane. First, the protein-degrading bacteria degrade the protein in the nutrient medium and produce acetate, hydrogen gas and carbon dioxide. Archaebacteria then use these by-products to produce methane.

So far there are no reports on native microbial communities in high temperature coal reservoirs in India and their potential for biological methane production. Most coal in the Jharia basin is not amenable to extraction by mining. But with the identification of the consortia that can generate methane from coal beds, the possibility of extracting biogenic methane from the coal belt becomes technologically easier.

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