Science Last Fortnight

Warming and Weather

Solar stimulations

A fortnight ago, in the last issue of *Current Science*, Indian scientists published a General Article on page 2232 which provides evidence to show that tropospheric temperatures, from 60°N to 60°S, varied in tune with solar activity in the 24-solar cycle (from 2008 to 2015).

They used Global Positioning System Radio Occultation that provides reliable atmospheric profiles under all weather conditions. Data from a constellation of six microsatellites at an altitude of 800 km provided the grounds for their reconstruction of temperature variations in the atmosphere.

Their results showed warming in the lower troposphere of both equatorial and tropical regions during solar maximum years. But above 7.5 km, the equatorial region is more affected. At 1.5 km, temperature during 2007 and 2008 was about 2°C – less than the average of 9 years, while from June 2010 to 2014, it was more by 1.5°C.

Following up on the heels of the study, another, by Russian scientists[1], in the January issue of the *Journal of Atmospheric and Solar-Terrestrial Physics*, made the link between the earth and the sun from another perspective and reached the same results.

The researchers used data related to sea surface temperatures and data related to surface winds from open databases of climate monitoring networks. They also examined the geomagnetic activity index (aa-index), closely related to the interactions of the magnetic fields carried by fast solar wind and the earth's magnetic field.

The scientists created daily maps for pressure and temperature anomalies of the high-latitude troposphere in the Northern Hemisphere, immediately after high geomagnetic events. And found significant increases in air temperatures in the blocking regions at high latitudes on the fourth day after the events. Though the effect is evident to more than 11 km height, maximum temperature change is seen at about 3 to 5 km in the high latitude regions, say the researchers.

How can a minor increase in solar radiation, of the order of 0.1%, lead to such increases in atmospheric temperatures?

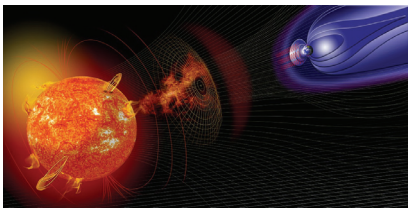

Image: NASA via Wikimedia Commons

Now, two Canadian scientists and a Slovak scientist say that there is more[2]. They detect rapid intensification of tropical cyclones in response to high speed solar wind. They took satellite data of near-earth detection of coronal mass ejections from the sun from 1996, data related to ionospheric currents, travelling electronic disturbances, data related to tropical cyclones from 1995 to 2006 and analysed the epochs by superimposing them.

From these data, the scientists explain how tropical storm Catarina, tropical cyclone Gafilo and typhoons and hurricanes in the North Pacific in August 2015 were intensified, increasing the sustained wind to more than 15 m per second within 24 hours.

In the *Journal of Atmospheric and Solar-Terrestrial Physics*, available online on 28 December, they show that when high-speed solar winds, from coronal holes or mass ejections, interact with the earth's atmosphere at the aurora and polar cap, atmospheric gravity waves are generated at high latitudes. Horizontal wavelengths greater than 1000 km propagate in the thermosphere at horizontal velocities between 400 and 1000 m/s.

These atmospheric gravity waves are propagated from the lower thermosphere and are observed in the ionosphere as travelling ionospheric disturbances in lower latitudes. By ray tracing methods, the researchers show that these atmospheric gravity waves are ducted to the lower atmosphere to trigger moist instabilities, leading to convective bursts. Convective bursts, in turn, lead to intensification of tropical cyclones, explain the scientists.

It appears that, perhaps, higher atmospheric temperatures and freak weather are caused not by solar irradiance, but are triggered by arrivals of high speed solar wind.

[1]**DOI**: 10.1016/j.jastp.2018.12.003
[2]**DOI**: 10.1016/j.jastp.2018.12.009

Groundwater Sustainability

Fuzzy-based index

The most populous continent, Asia, is the largest groundwater user. Asian cities are witnessing a rapid rise in population and consequent change in water use. Groundwater depletion has more than doubled during the last decades. Without a reliable, resilient and sustainable system to manage groundwater, groundwater sustainability in Asian cities is under threat.

To address this, Shashidhar and his associates from the IIT-Hyderabad along with researchers from the International Water Management Institute, Nepal and the Asian Institute of Technology, Thailand developed an index for estimating groundwater sustainability: a fuzzy-based groundwater sustainability index. Fuzzy methods are necessary when we lack requisite numeric data for interpretation and only have linguistic descriptions.

The researchers organised two workshops to finalise twenty-four indicators of groundwater, including quantity and quality, management, policy, infrastructure, facilities and participation of groundwater developers. The index based on these indicators has five dimensions of sustainability: environmental, social, economic, mutual trust and institutional dimensions.

The team applied the index to five Asian cities – Hyderabad in India, Lahore in Pakistan, Bangkok in Thailand, Ho Chi Minh City in Vietnam and Yangon in Myanmar. They collected all available data related to all the indicators. The results show that the status of groundwater sustainability in Hyderabad is highly sustainable, whereas, in Lahore, Bangkok, Ho Chi

Minh City and Yangon, groundwater is only moderately sustainable.

This model will help policy and decision makers provide a reliable and resilient management system in the cities by identifying suitable indicators of sustainability. According to the researchers, there is need for long-term policy legislation, stakeholder participation and monitoring of groundwater in Hyderabad.

DOI: 10.1016/j.scs.2018.09.027

Pest of Pomegranate

Punishing Aphis punicae

In 2016–17, India had 200,000 ha cultivating pomegranate. Though India can produce nearly two and half million megatonnes of the fruit, the efforts are often foiled by *Aphis punicae*, a small yellowish-green aphid. The pomegranate aphid reproduces throughout the year parthenogenetically, without sexual reproduction. And it does not lay eggs but gives birth to young ones. When the conditions are right, it switches to sexual reproduction.

These aphids typically colonise the upper sides of mature leaves of pomegranate, concentrated along the midribs and around leaf margins; also found on flowers and, at times, on young fruits. They suck the juice out of the plants leading to loss of quality and yield of the fruit.

Mandeep Pathania and team at the Punjab Agricultural University were concerned about such losses of pomegranate under the semi-arid conditions of south-western Punjab. What are the conditions that influence these aphid populations? Which pomegranate cultivar is more susceptible and which more resistant? What can be done?

The Regional Research Station at Abohar had a 7-year-old pomegranate orchard with five varieties to serve as their laboratory. Every week they examined the terminal twigs of the trees, counted the aphids and took samples of leaves to test the variations in nutrition that may be responsible for rise in the aphid population. They noticed that the aphids started infecting the plants towards the end of January, when temperatures started increasing. And they are seen on the trees for the next 13 weeks. The insect seemed to be comfortable in the temperature range of about 8° to 30° and preferred a relative humidity of about 40% or more.

The cultivar, Bhagwa, was more susceptible. Mirdula, Ganesh and Phule Arkata were less so. The researchers find a correlation between infestation and leaf contents of the cultivars. Bhagwa, with higher percentage of nitrogen and lower percentage of potassium in leaves, had higher infestation. Phule Arkata, with significantly lower leaf N and higher leaf K, was least affected.

Using meteorological variables, the researchers developed a model that could predict the aphid population and tested it the next year. The model helps understand the timing for pesticidal action. Though the response to different chemical pesticides varied in the initial days after spray application, Flonicamid at 0.7 ml/l was found most effective after 14 days, reducing the population by about 96%. Horticulture Mineral Oil at 12.5 ml/l reduced nearly 85% of the population and azadirachtin at 7.5 ml/l brought it down by 80%.

Considering the collateral damage to the natural enemies of the pest by the chemical pesticides, the researchers suggest incorporating Horticulture Mineral Oil and azadirachtin in integrated pest management.

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Alzheimer's Disease

Bergenin brings benefits

Alzheimer's, a degenerative brain disease, is the most common type of dementia. Inside the brains of patients with Alzheimer's, there is loss of a neurotransmitter molecule, acetylcholine. Consequently, there is destruction of acetylcholine-dependent signalling cells. Scientists also find plaques of amyloid β and tangles of τ protein. The resulting progressive memory loss has enormous impact on the elderly and their caregivers.

Treatment for Alzheimer's includes using inhibitors of the enzyme that breaks down acetylcholine–acetylcholine esterase. Symptomatic relief, however, is associated with various side-effects.

The limitations of current therapies led to a growing interest in preventive approaches. Last fortnight, Priyal Barai and her team from the Nirma University, Gujarat in collaboration with Sanjeev Acharya from the SSR College of Pharmacy, Silvassa reported a plant molecule, bergenin, as protection against Alzheimer's disease.

Bergenin is isolated from rhizomes of the *Bergenia* species. It is a trihydroxybenzoic acid glycoside.

Image: Magnus Manske via Wikimedia Commons

'Under *in vitro* conditions, bergenin doses, of up to 500 nM, showed about 90% of the cells to be viable. And had neuroprotective action against N-methyl D-aspartate induced cell death. At 10 mM concentration, bergenin demonstrated antioxidant capacity and inhibited acetylcholinesterase and butyrylcholinesterase. Comparable to reference drugs', says Priyal Barai, Nirma University.

For *in vivo* studies, the researchers took rat models of Alzheimer's disease, using scopolamine and streptozotocin. They observed that pretreating rats with bergenin, at 80 mg/kg daily, prevented scopolamine-induced amnesia. At 80 mg/kg, it prevented streptozotocin-induced damage. And, at 40 mg/kg, onset was delayed. The team observed that, as they increased the dose of bergenin, amyloid β and τ protein levels reduced.

The researchers performed an *in silico* molecular docking study using genetic optimisation of ligand docking, with the help of GOLD software, to examine the binding interactions of bergenin with various known targets for which Alzheimer's drugs are

currently approved – donepezil, physostigmine, and galanthamine.

'Bergenin showed high GOLD score and fitness values against all the targets. This indicates strong binding interactions of bergenin in the binding pockets', says Sanjeev Acharya, SSR College of Pharmacy, Dadra and Nagar Haveli.

'Our study provides a preliminary understanding about the role of bergenin in signalling pathways for neuroprotective action', says Hardik Bhatt, Nirma University.

DOI: 10.1016/j.bbr.2018.08.010

Therapeutic Targets

Taming tuberculosis

Tuberculosis, caused by *Mycobacterium tuberculosis*, is among the top ten causes of death worldwide, as per the WHO. In 2017, more than fifteen lakh people died from the disease worldwide. Multidrug, extreme drug and even total drug resistance in the tuberculosis pathogen worsen the odds. To address this bleak picture, we need to identify new target molecules to develop new inhibitors for therapy.

Last fortnight, Bishwajit Kundu and his team from the IIT Delhi reported bacterial L-asparaginase, the enzyme that catalyses the breakage of L-asparagine into L-aspartic acid and ammonia, as potential target molecule in the tuberculosis pathogen. They noticed that the asparaginase of the tuberculosis pathogen was quite different from that of humans. Thus, inhibitors of the enzyme would act on *M. tuberculosis* asparaginase specifically and not on its human counterpart, qualifying it as potential target molecule.

So, the researchers developed a 3D model for *M. tuberculosis* asparaginase and compared it with known asparaginases of other bacteria to identify the active site of the enzyme.

Next, they screened three drug libraries – the Traditional Chinese Medicine database, the ZINC database and the FDA approved drug database – against the active site of *M. tuberculosis* asparaginase to identify specific inhibitors. They could identify fifteen inhibitor molecules from these databases. These molecules had lower free energy when bound to *M. tuberculosis* asparaginase than to human asparaginase. The lower the binding free energy, the better the docking and, hence, the inhibition of the enzyme.

Then, the researchers studied the antimycobacterial activity of five of the inhibitors, using a colorimetric assay to assess cellular metabolic activity. They used *M. smegmatis*, a fast-growing, non-pathogenic, model organism for *Mycobacterium* species, in the presence of the inhibitors and determined survival rate.

They noticed that, out of the five inhibitors, two from the ZINC database and one from the FDA-approved database, could effectively inhibit the growth of *M. smegmatis.* These findings were supported by microscopic examination and a test to determine the drug resistance of *Mycobacterium*.

L-asparaginase has already been identified as a molecular target for other pathogens such as *Leishmania donovani*, the parasite that causes *Kala-azar* in humans. The researchers claim that these inhibitors may be used against other intracellular pathogens, such as *Salmonella typhi* and *Helicobacter pylori*, apart from *M. tuberculosis.* However, further studies on the identified inhibitors, including animal trials, are required before initiating clinical trials.

DOI: 10.1002/jcb.27169

Religion and Spirituality

For congenital heart disease?

Congenital heart disease is acquired at birth mainly due to genetic reasons. It is a major cause for birth-related deaths. The survivors need lifelong specialised cardiac care. Coping with the condition requires a lot of mental strength.

What keeps some patients with congenital heart conditions going strong in spite of these challenges? Recently, an international collaboration of twenty-seven scientists, including Raghavan Subramanyan of the Dr K. M. Cherian Heart Foundation, Chennai investigated whether social determinants, such as religion and spirituality, impact patient-reported outcomes.

The consortium of scientists conducted a cross-sectional study to assess patterns of patient-reported outcomes in adults with congenital heart disease. The researchers chose a sample of more than four thousand patients with congenital heart ailments across 15 countries. They asked the patients about their perceived health status, psychological functioning and health behaviour as well as quality of life.

Image: Pass a Method, via Wikimedia Commons

The team also asked about religious and spiritual orientation. Did the patients consider themselves religious or spiritual? How important was religion and spirituality in their life? And, if religious, to what religion did they belong? The researchers also used a Gallup world poll to assess the country level status of religion and spirituality.

They found patient-reported outcomes complex. Interestingly, the outcome depended on the country of the patient, and on whether the state was religious or secular. Spiritually or religiously oriented patients had higher satisfaction in life, despite suffering from physical and mental problems, low health status and high anxiety. However, if a country was religious, there was not much difference between the mental health of believers and non-believers. But, if a country was secular or moderately religious, mental health and health behaviour were better in patients who were not religious.

Patients from Argentina depended on religion and spirituality the most, followed by patients from Malta, the USA and India. The lowest

dependence on religion and spirituality was seen in patients from Japan followed by those from Sweden, France and Norway.

Depending on social acceptability, a prudent approach to religion and spiritual intervention could become a part of healthcare, say the researchers.

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Methane from Rice Straw

Hydrilla to harness the potential

Rice, a widely grown crop of South and Southeast Asia, leaves behind huge quantities of straw. The residue rots or is burned, resulting in loss of organic carbon and affecting air quality.

Rice straw can also be used for mushroom farming, as livestock feed, and for composting. Now, researchers are attempting to produce biogas from it. But, being lignocellulosic with low nitrogen, rice straw alone cannot be used as substrate.

Image: Yercaud-elango, via Wikimedia Commons

Recently, Jyoti Kainthola and team from the IIT Guwahati reported overcoming the problem by co-digesting rice straw with hydrilla. Hydrilla is an easily degradable, common aquatic weed which improves nitrogenous content. Anaerobic microorganisms, from degassed cow dung, served as inoculum. The team noted an increase in digestion efficiency, in the presence of hydrilla as co-substrate.

The team tested variables such as pH, moisture, total volatile solids, total solids, soluble chemical oxygen demand, carbon and nitrogen contents in straw, hydrilla and cow dung samples. Then, they optimised these parameters using response surface methodology to explore the relationships between the input variables and response variables. Thus, Jyoti and her group derived the parameters affecting methane production: the substrate to microbe ratio, carbon to nitrogen ratio and pH. The scientists demonstrated the strong relationships between these three parameters and methane yield.

Rice straw, an agricultural waste, and hydrilla, an invasive alien weed in fresh water bodies, provide an environment-friendly solution to harness renewable energy efficiently.

DOI: 10.1016/j.fuel.2018.07.094

Bendable Antenna

For 5G communication

Network congestion in the lower frequencies and smaller bandwidths are primary among the many shortcomings of current 4G communication technologies. Moreover, present day antennas are omnidirectional which results in power wastage. Data transmission over larger wavelengths requires bigger antennas to minimise spatial power wastage. To implement safety applications, higher bandwidths enable vehicles to relay raw sensor data. Hence, there's a need for 5G antennas that can operate at higher frequencies and can support gigabit-per-second data rates to transmit large amounts of data.

However, existing antenna models for the 5G spectrum are planar and have small bandwidths. While the highest bandwidth achieved in a planar antenna is 11.7 GHz, Usha Devi and Rukmini from the Vignan's Foundation for Science, Technology and Research, in collaboration with Madhav from the Koneru Lakshmaiah University, Guntur, have raised this bar. The team proposed a conformal antenna model – a bendable structure – with a bandwidth of 17.65 GHz which is 1.52 times better than the previous best.

The team proposed an offset-fed staircase structure to gradually vary impedance over a long distance between the antenna and the receiver electronics to achieve larger bandwidth. The whole module, along with a 45-degree dipole antenna, is fabricated on a liquid crystal polymer substrate to make it flexible. The conformal nature of the antenna allows it to be integrated on any surface and at any angle on a vehicle's body. The team observed that the antenna transmits over 90% of the power over its operating bandwidths.

The gain of the conformal models between 20° and 80° ranges from 5.82 to 6.81 dB – an improvement over the gain achieved by the proposed planar model, say the researchers. The results from the High-Frequency Structure Simulator – a CAD package used to characterise the electromagnetic behaviour of radiation structures – matched results they obtained from empirically integrating the module on the windscreen of a car. However, the researchers observed a slight degradation in the measured gain and reflection coefficients. They attribute this to interferences caused by the vehicle's metallic surfaces.

The module is very compact and flexible. The entire device fits within about 1 cm^2 and can be integrated on any surface without compromising on the performance, say the scientists. Moreover, unlike previous models, this one operates at all the frequencies authorised by the FCC for 5G communication viz. 28, 33, 37 and 39 GHz. The antenna is also suitable for operating at 51 GHz for satellite communications, claim the researchers.

DOI: 10.1088/2053-1591/aae549

A Sign of the Times?

The *PNAS* stopped printing the journal this year. The online version gives scientists more space. The IASc started *Dialogue* last year as an online journal. A sign of the times to come?

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