Current Science Reports

Forecasting Lightning
WRF model simulations

Lightning kills thousands in India every year. Nearly 30% of the deaths are in Maharashtra. This lightning-flash prone region is covered by a lightning detection network installed by IITM, Pune. The network uses twenty Earth Network Lightning Sensors to detect intra-cloud and cloud-to-ground flashes. Could data from the network help predict pre-monsoon lightning events in Maharashtra?

To find out, scientists from IITM Pune and the Ministry of Earth Sciences collaborated with an American scientist and simulated lighting events.

'Inside clouds, there are connective updrafts. In the supercooled area in clouds, rebounding collisions between water droplets, ice, hail, snow and particles with a mixture of water, ice and snow generate charges necessary for lightning,' explains R. S. Nanjundiah, IITM Pune.

Image: G. Stampalia via Wikimedia Commons

The researchers used the Weather Research and Forecasting model with additional parameters. The model was set up with four horizontal resolutions, ranging from 1 to 29 kilometres. The vertical height for the simulations was set to about 19 kilometres. The team defined initial and boundary conditions in the model using data from available resources.

To evaluate the simulated rainfall and atmospheric water content, the researchers used data from the Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis and the European Centre for Medium-Range Weather Forecasts. In most cases, the model captured rainfall pattern and accumulated rainfall amounts.

To estimate lightning flashes, there are different diagnostic calculation and dynamic methods. And there are different methods for lightning parameterisation. The team tested them all for their ability to predict lightning by simulating four pre-monsoon lighting events – 29 April 2016, 5 May 2016, 15 March 2017 and 25 May 2017.

They compared predictions from the simulation with observed lightning flash count data from the lightning detection network. Thus, they could identify the best diagnostic calculation method, dynamic method and lightning parameterisation to forecast lightning.

Encouraged, the team proceeded to use the model for real-time operational forecasting of lightning over India from 2019 at a three kilometre horizontal resolution. The simulations were comparable with the observations.

The model can now predict lightning with reasonable accuracy and is useful for early warning so that people can take precautions against lightning strikes.

Aerosols over South Asia
Sources and distribution

Aerosols – dust and smoke particles – affect health and climate. To control aerosol emissions and to reduce aerosol-induced uncertainties, high-resolution data of aerosols in space and time are required.

Tirthankar Banerjee from BHU and an international team explored the nature of aerosols over South Asia to understand the distribution and sources.

Aerosol optical depth is a proxy for atmospheric pollution, where higher values indicate more pollution.

The team combined high resolution aerosol optical depth data from MODIS and multi-angle imaging radiometer sensors as well as data from the ground-based AERONET, a network of sun photometers used to measure aerosol particles. With the combined dataset, the researchers identified geo-spatial and seasonal trends and identified the Indo-Gangetic plains and the east coast of India as aerosol hotspots.

Over South Asia, aerosol optical depth peaks during the monsoon and in summer, possibly due to different reasons. In the monsoon the presence of high moisture increases particle size. In summer, the increase is due to re-suspension of dust by wind. Dust from deserts in India and Pakistan also adds to atmospheric aerosols.

'The increasing number of small aerosol particles in winter suggests human influence,' says Alaa Mwahish, BHU.

Burning crop residue in northern India also increases aerosol levels. A steady release of aerosols from mining industries increases small particles over the eastern coast.

'We could identify pixel-sized urban aerosol hotspots,' says Chandan Sarangi, IIT Madras.

'The findings will help better aerosol-climate-health modelling,' says Tirthankar Banerjee.

The research also helps identify aerosol types – dust, smoke – and their possible sources which will be useful to develop an actionable policy for reducing atmospheric aerosols.

Ganga and Groundwater
Wells in Varanasi

Varanasi is highly populated. Built-up area stops surface water from percolating to groundwater. However, the Ganga, flowing next to the city, can still replenish groundwater. So researchers from IIT Kharagpur teamed up with the British Geological Survey to assess how the river influences groundwater there.

To observe groundwater, they selected nine piezometric wells in the city: seven shallow and two deep aquifers. To study groundwater chemistry they chose more than 150 wells. They correlated water depth in the wells and in the river to investigate the influence. The annual variation of the water-level was about 4 metres for wells, and 6 metres for the river. There was seasonal variability in the water level in the wells. Wells closer to the river were most influenced.

'Oxygen isotope content in shallow groundwater corresponded with that in the Ganga. This reflects the interaction

between the river and shallow aquifers,' says Abhijit Mukherjee, IIT Kharagpur.

Deep wells responded to changes in water levels in the Ganga more slowly. Clay layers in deeper aquifers make it difficult for river water to percolate, say the researchers.

'River water infiltration plays an important role in aquifer recharge. But it adds pollutants – iron, nitrate and total dissolved solids,' says Prerona Das, IIT Kharagpur.

Overexploiting groundwater aquifers and dumping sewage and agricultural waste in rivers makes shallow aquifers vulnerable to pollution. To sustainably ensure safe water for Varanasi, local water authorities must monitor groundwater extraction and waste disposal.

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Uranium Sequestration
Using bacteria

The Tummalapalle uranium mine in Andhra Pradesh uses alkaline pressure leaching to extract the element from the ore. But the process releases toxic uranium with the alkaline wastewater as effluent. While microbes that remediate uranium from acidic water have been discovered, they are of no use when it comes to alkaline wastewater containing uranium.

Recently scientists from the Indira Gandhi Centre for Atomic Research and the Bhabha Atomic Research Centre, Kalpakkam started searching for an efficient microbial partner for uranium bioremediation from such alkaline wastewater. They explored microbes at the mining site and identified ten bacterial isolates in the alkaline water samples. Most of the isolates were uranium tolerant.

One of the isolates, TP03 *Bacillus* sp., could sequester nearly 70% of the uranium from wastewater with a loading capacity of 4.3 milligrams uranium per gram of dry bacterial biomass. It was effective in sequestering uranium even at low concentrations.

'This strain of *Bacillus* species can be a promising candidate to remove uranium from alkaline wastewater for safe release into the environment,' says B. Uday Kumar, IGCAR.

'If we can understand the mechanism of uranium sequestration by these microbes, we could perhaps be able to enhance the bioremediation process,' adds T. Subba Rao, BARC.

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Fruit-rot Disease
Areca triandra

Some years ago, during the monsoon, villagers in the Sullia taluk of Karnataka observed heavy nut fall in *Areca triandra*, an ornamental wild palm species. The palm's wood is used as timber and the seeds as chewing nuts. So the excessive fall of immature nuts worried farmers there.

Image: Alialb via Wikimedia Commons

Researchers at the regional research station of the ICAR-Central Plantation Crops Research Institute in Vittal, Karnataka knew about the rotting of nuts in other palm species. But not in *Areca triandra*. So, they collaborated with other regional research stations of ICAR-CPCRI to unravel the mystery.

The symptoms resembled infection by *Phytophthora palmivora*, an oomycete, a fungus-like pathogen. To verify, the team grew the pathogen in the lab. Under the microscope, they spotted typical ellipsoid- to ovoid-shaped sporangia with distinct papillae protruding from mycelia.

To confirm the identity of the species, the researchers isolated and compared the DNA sequence with known DNA sequences in databases.

'Molecular analysis confirmed our suspicions. The fruit-rot pathogen infecting *Areca triandra* was indeed *Phytophthora palmivora*,' says Shivaji Hausrao Thube, ICAR-CPCRI, Karnataka.

'We tried infecting healthy nuts with the spores. There was a typical whitish growth on the inoculated nuts,' says R. Thava Prakasa Pandian, ICAR-CPCRI, Karnataka.

'Probably the right temperature range and excess humidity and rainfall are conditions that favour the infection,' adds Bhavishya, his colleague.

Besides palms, the fungus also infects papaya, cocoa and rubber plants. 'This is the first report of *Phytophthora palmivora* infecting *Areca triandra*,' says Vinayaka Hegde, ICAR-CPCRI, Kasaragod.

Extension educators need to inform farmers about the symptoms of the infection by the pathogen and help them use targeted fungicides to reduce crop loss.

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Treating Tilapia
With tamarind seeds

The bacteria, *Edwardsiella tarda,* cause severe illness in Tilapia fish and in humans. Edwardsiellosis in tilapia has a disastrous effect on fish aquaculture.

Antibiotics can keep the bacteria at bay, but that has environmental consequences. Can the use of antibiotics be minimised by plant-based alternatives?

Last fortnight, researchers from the Vellore Institute of Technology (VIT), Tamil Nadu, used seed extract from tamarind seeds to fight *E. tarda* in tilapia.

'Spectrometric analysis of tamarind seed extracts shows that they are rich in bioactive compounds which are antibacterial,' says Natrajan Chandrasekaran, VIT.

The researchers grew one group of tilapia after inoculating with the bacteria, another group which was inoculated but also treated with tamarind seed extract and a third group, without inoculating the bacteria, as control.

After fifteen days, infected tilapia, treated with seed extracts, survived better than those not treated. The fish

treated with tamarind extract also had better metabolism than infected fish. Various oxidant and antioxidant assays confirmed a strong antioxidant response to treatment.

'Tilapia farmers can use tamarind seed extract instead of antibiotics to treat fish infected with *Edwardsiella tarda*,' says Mrinal Seth, VIT.

Image: P. Krishna via Wikimedia Commons

'The disease affects not only tilapia but many other aquaculture fish. We expect that the tamarind seed extract treatment would be widely applicable in aquaculture,' adds John Thomas, VIT.

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Wearable Device Detects TB
Toluene biomarker from skin

Existing diagnostics for tuberculosis require expert handling of samples in the lab. So, we miss cases, especially those that do not get tested in time.

In people with infections, volatile compounds emitted from skin change due to altered metabolism. Is it possible to detect these volatiles to diagnose TB?

A lab in Israel, working on health care diagnosis, had designed a porous pouch made of a polymer to trap volatiles in breath. Collaborating with Indian and South African medical researchers, they used the pouches containing a porous polymer of 2,6-diphenylphenylene oxide to trap volatiles from the skins of tuberculosis patients and healthy people.

They analysed the absorbed volatiles using gas chromatography–mass spectrometry. In both countries, toluene was consistently higher in TB patients than in controls.

To detect the biomarkers instantly, without using complex equipment, the researchers developed a sensor: a film of gold nanoparticles capped with different organic compounds on a two-dimensional network of single-walled carbon nanotubes. In effect, there were 22 sensors with distinct responses to toluene.

To make sense of the varied responses, the researchers used machine learning. The sensors could detect higher and lower amounts of toluene from the skin of TB patients.

Along with the algorithm, the sensor automatically detected active TB cases.

Encouraged by the results, the researchers made a wearable device that can be attached to the forearm. This device containing eight sensors was tested in various countries. Active TB cases could be identified with about 90% accuracy.

Considering the reduced screening time and cost, the device can be used for mass screening and be a game-changer for epidemiological studies.

Identifying active TB cases in a population can prevent thousands of deaths from this preventable and curable disease.

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Elements in Diabetic Patients
X-ray fluorescence analysis

Analysing chemical elements in body fluids and tissues can reveal a lot about metabolism and disease conditions. But biological samples with low concentrations of elements pose a challenge.

Synchrotron radiation X-ray fluorescence can detect low element concentrations with high sensitivity. Can the technique be used to detect pathology from biological samples?

P. Sarita from GITAM University, Visakhapatnam, and collaborators from various institutes across India, recently investigated using X-ray fluorescence to distinguish between serum samples from type-2 diabetes patients and healthy controls.

After extracting blood, the researchers centrifuged it to separate the serum, and freeze-dried and loaded the samples into a synchrotron radiation X-ray fluorescence spectrophotometer. In the spectrophotometer, under high vacuum conditions, the samples were irradiated with high-energy monochromatic X-rays. The fluorescence spectra of the samples revealed the concentrations of the serum's constituent elements.

Patients with diabetes, the team found, had lower concentrations of potassium, calcium, chromium, manganese and zinc. But iron, copper, selenium and lead were elevated.

A larger data set from different geographic locations is required before we generalise the conclusions to all ethnic populations, caution the researchers.

Synchrotron radiation X-ray fluorescence is a non-destructive technique with easy sample preparation. If we have accurate data of unbalanced elements in the body due to various diseases, diagnostics will improve. Type 2 diabetes is perhaps just a beginning.

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Hot Spices
Health benefits

Apart from imparting flavour and aroma, spices contain phytochemicals with pharmaceutical properties. They can be used to develop potent nutraceuticals, substances in food that have medicinal and health benefits. But what are the best methods to extract the bioactive phytochemicals from spices?

Suparna Mandal Biswas and her team from the Indian Statistical Institute, Kolkata explored six hot spices: ginger, chilli, java long pepper, black pepper, clove and carom.

They used hexane, ethyl acetate, acetone and methanol to extract the bioactive compounds from the six spices.

After extracting and purifying the different fractions of the spices, they assessed the levels of flavonoids, tannins and total phenols in different extractions. Cloves contained the highest amount of phytochemicals, followed by ginger.

Phenolics were found in all fractions of cloves, but the highest yield was from the ethyl acetate fraction. There were also more flavonoids from cloves in the ethyl acetate fraction. But there were more tannins in the methanol and acetone fractions. In ginger, however, more phenolics were extracted in the hexane fraction, flavonoids in the

acetone fraction and tannins in the ethyl acetate fraction.

By comparing and contrasting the phytochemicals in different extracts of the six spices and by investigating the antioxidant, antimicrobial and DNA-damage protecting properties of each extract, the researchers identified the best extraction methods for each nutraceutical property. Pharma and food industries can now use the insights to optimise the nutraceutical yields from the six spices.

Platinum Nanoparticles
Made in red seaweed extract

Platinum nanoparticles possess antioxidant, anticancer and antibacterial properties. But, produced commercially, they are expensive and can even be toxic. Can synthesising the nanoparticles using biological extracts improve therapeutic efficacy without toxicity, wondered Ganesan Sathiyaraj and team from the Alagappa University, Tamil Nadu.

To find out, they investigated *Halymenia dilatata*. This red seaweed is abundant on India's southeast coast and is known to have various secondary metabolites and bioactive compounds.

Image: Ria Tan via Flickr

Collaborating with researchers from the University of Madras and the Republic of Korea, the team synthesised platinum nanoparticles by mixing aqueous extracts of *Halymenia dilatata* with varying concentrations of hexachloroplatinic acid, a commercial source for platinum. An antioxidant assay revealed that the nanoparticles had high radical scavenging activity.

Evaluated against breast cancer cells, a nanoparticle concentration of 50 micrograms per millilitre was enough to kill the cancer cells.

The nanoparticles significantly inhibited the growth of bacteria such as *Streptococcus pneumoniae*, which infect the respiratory tract, and *Aeromonas hydrophila*, which cause gastrointestinal disorders.

'The platinum nanoparticles penetrate bacterial cells leading to protein leakage,' says Ganesan Sathiyaraj, Alagappa University.

The nanoparticles had low toxicity when tested on brine shrimp. Eighty-two per cent of the shrimps survived at concentrations of 150 micrograms per millilitre. The antioxidant, antibacterial and anticancer activities require much lower doses.

'Further research on the efficacy in *in vivo* systems is needed before clinical trials on breast cancer and bacterial infections,' says N. M. Prabhu, Alagappa University.

Functional Textiles
To adsorb organic volatiles

Vehicles, paint products and industrial processes emit toxic volatile organic compounds. Such pollutants can be captured by porous materials such as activated carbon, zeolites and metal organic compounds. Among metal organic frameworks, those containing zinc or cobalt tetrahedrally connected with 2-methylimidazole groups, have high moisture and thermal stability. Structurally, they resemble zeolites and are known as zeolitic imidazolate frameworks or ZIF. ZIF-8 and ZIF-67 could be attached to cotton fabric for absorbing the toxic volatiles. However, attaching metal organic frameworks to cotton is tricky.

Researchers from IIT Delhi thought of carboxymethylating cotton fabric using an acid base solution to make the fabric anionic, so that it could be amenable for attachment with the metals. They immersed cotton fabric pieces in zinc nitrate hexahydrate and cobalt

nitrate hexahydrate for one minute to attach the metals. Then they immersed the fabric in 2-methylimidazole for the metal organic frameworks to self-assemble. The frameworks grew uniformly on the entire surface of the cotton.

A UV-VIS spectrophotometer showed rapid absorption of three test aromatic pollutants: aniline, benzene and styrene. Cotton fabric with ZIF-8 had higher effective surface area and, therefore, absorbed more aromatic pollutants.

The researchers tested how the fabrics performed under toxic concentrations. The fabric with ZIF-8 could capture 70% of the three aromatic pollutants within two hours. The unfunctionalised fabric could only absorb less than 20%.

'The absorbed pollutants did not diffuse out from the functionalised fabric when tested under vacuum,' says Manjeet Jassal, IIT Delhi.

'The imidazole ring of ZIF compounds effectively traps the pollutants,' explains Saswata Bhattacharya, his colleague.

'But the fabric can be reused over several cycles,' adds Arunima Singh.

'By heating the treated fabric to 120°C, we could regenerate the absorptive function of the fabric,' says Hardeep Singh Jhinjer, another researcher on the team. This is evident from the nearly complete desorption of the pollutants.

'Textile industries can adopt this approach to manufacture protective garments, air purification membranes, and to control indoor air pollution,' says Ashwini Agrawal, IIT Delhi.

Reports by: **Tahera Arjumand, Ravindra Jadav**, **Aradhana L. Hans, K. Sri Manjari, D. C. Jhariya, Shwetakshi Mishra, Ravi Mishra, Archana Singh, Sileesh Mullasseri,** and **Pushp Sen Satyarthi**

scienceandmediaworkshops@gmail.com