

Science Last Fortnight

Monitoring Cyclone Intensity

Using remote sensing data products

Recently, *Fani* and *Vayu* grabbed the headlines. Cyclones – movements of large air masses over low pressure zones and warm waters – create havoc in coastal areas. Can we monitor cyclone development from satellites? Which are the best data products for the purpose?

To find out, Chinta Veeranjanyulu and A. A. Deo from the Indian Institute of Tropical Meteorology, Pune compared remote sensing data product, QuikScat, with the Reanalysis product, ERA-Interim. They looked at data on five cyclonic storms from the last decade: *Nargis*, *Mala* and *TC02B* (2004) in the Bay of Bengal and *Gonu* and *Mukda* in the Arabian Sea.

They examined upper ocean parameters such as currents, sea level, heat content and temperature. Differences in sea-surface temperature can initiate movements of air masses. An upward latent heat flux from the sea surface increases the energy to form cyclones.

Sea currents are seen to diverge on the storm track. This creates an upwelling of the water column from the depths. Cyclones mix the water column, causing 'cold wakes' – patches of cold salty water rise to the surface. Because of the rotation of inertial forces resonating with the turning of cyclonic winds to the right of the track, cooling is seen to the right of the track. *Nargis*, for example, left the wake cooler by three degrees. The cooling effect extended to about 700 kilometres.

The team found that *Gonu*, the strongest of the cyclones, generated the maximum cooling in its wake while *Mukda*, the weakest, produced the lowest cooling. The magnitude of cooling also varied with the duration of the cyclone. *Nargis* lasted longer whereas *TC02B* (2004) was shorter. Slow moving and longer duration storms influence the underlying ocean more strongly.

The team also noticed a reduction in sea surface height in all cases. But this

did not correlate with cyclone intensity. *Nargis* reduced the height by 10 centimetres!

Using the Reanalysis data, the researchers monitored sub-surface temperatures and currents up to a depth of 250 metres. They found that cyclones impacted up to 100 metres of the sea. Usually, the temperature of the water reduces with depth. But, after the cyclone, the researchers saw a layered thermal structure below the cyclones, often decreasing at certain depths and then increasing again.

The team, by analysing and comparing all these factors in the data from satellite and Reanalysis products, concluded that satellite data is more realistic and preferable if available, for monitoring cyclones.

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Gully Erosion Management

Machine learning algorithms

The Pathro River Basin in the Chota-Nagpur Plateau has an undulating topography and loose soils. The region gets high rainfall during the monsoon and, therefore, the area has high erosion rates. Erosion often creates gullies, making the land unproductive.

With each rainy season, new gullies open up. Mapping the zones susceptible to gully erosion is very important for landscape planners and policy makers. There are several machine algorithms available for gully erosion susceptible zone mapping. But which algorithm is most suited for the purpose?

Gayen and Saha from the University of Gour Banga, West Bengal collaborated with researchers from China, Iran, the Netherlands and Australia to identify the most suitable algorithm for mapping zones susceptible to gully erosion. The team investigated four existing algorithms – multivariate additive regression splines, flexible discriminant analysis, random forest and support vector machine.

What kind of data should we feed these algorithms? From extensive literature search, the researchers selected twelve variables. Elevation,

slope, and slope aspect were the primary topographical attributes. Slope length, profile curvature and topographical wetness index were secondary, but important factors to be considered.

Since lineament, roads and rivers influence erosion, distances to these as well as drainage density were the other attributes selected. Soil type, land use and land cover were the other important factors considered as input to the algorithms.

The researchers went around the area and identified 174 gully erosions. They allocated 70% of the cases for training and 30% for validating the effectiveness and accuracy of the algorithms.

First they confirmed that the twelve factors that they had taken into account were truly independent of each other. Then using the four algorithms and the input variables – some of which were accessed from secondary data – they generated four gully erosion maps.

They tested the sensitivity and accuracy of the maps. Though all four algorithms were found to be useful, the team reported that the mapping with the random forest algorithm was the best. The second best was multivariate additive regression splines.

In the process of testing the four algorithms, the scientists have generated a gully erosion susceptibility map for the Pathro River Basin, Chota-Nagpur Plateau. The map can be used for soil conservation and for sustainable land use in the area, says Amiya Gayen, University of Gour Banga, West Bengal.

The Pathro River Basin, Chota-Nagpur Plateau is only a case study. We can now use random forests to generate such susceptibility maps of other regions susceptible to gully erosion.

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Phosphorus Scarcity

Is India vulnerable?

Phosphorus is an essential nutrient for plants. Rock phosphate, the main

source of phosphorus, is a non-renewable resource. India, the second largest consumer of phosphorus, depends on phosphorus-based fertilizers for its intensive crop systems. With most phosphorus being imported, will the global phosphorus supply scarcity affect food security in India?

Last fortnight, Madhuri Nanda and Arun Kansal from the TERI School of Advanced Studies, New Delhi and Dana Cordell from the Institute of Sustainability Futures, Australia reported assessing India's vulnerability to phosphorus scarcity.

First, they identified all relevant indicators for phosphorus vulnerability in India. Next, they interviewed several stakeholders to collect appropriate indicators. Field visits were also conducted to assess ground realities. A total of hundred and forty indicators were identified from vulnerability data. Among these, only eighteen significant indicators were shortlisted for the study.

The scientists found that India is highly vulnerable as the supply is dependent on imports. Farmers have low purchasing power and limited access to institutional credit. Most farmers have small holdings and intensive farming practices have lowered soil fertility levels. These factors contribute to the low resilience of the system and high vulnerability to phosphorus scarcity, say the researchers.

The team analysed government schemes such as soil health card, doubling farmers' income and providing credit packages. They conclude that a combination of these schemes, if well implemented, may bring the vulnerability index down to the 'medium' category in a few years.

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Seed Quality Improvement

Gamma radiation on wheat grains

To increase yield, gamma irradiation has been tried on various crops. Gamma radiation has been found to increase germination percentage. It is now known that Gamma radiation in low doses can initiate defence mechanisms and that can improve crop performance in rice, broccoli, etc.

In wheat, heat stress affects wheat grain quality and quantity. Can gamma irradiation help ameliorate heat stress? What is the optimal irradiation dose for inducing heat tolerance in wheat, without the accompanying mutation creating a deleterious effect?

Scientists from various institutes around the nation set out to check the amount of gamma radiation needed to protect developing wheat endosperm from oxidative damage by balancing trade-offs between the defense network and grain quality.

They pre-treated dry wheat seeds of two strains, HD3118 and HD3086, with different doses of gamma radiation – 0.20, 0.25 and 0.30 KiloGray. After three days of treatment, the seeds were germinated and planted in pots with adequate fertilisers and water. When the grains had reached the milky stage, the researchers exposed the plants to heat stress.

The scientists found that gamma radiation had a positive effect on the width, length and weight of the grains under heat stress. They found that a radiation intensity of 0.25 KiloGray in HD3118 and 0.20 KiloGray in HD3086 produced a desirable effect.

The team then analysed gene expression and biochemical parameters associated with heat tolerance, as well as grain quality using quantitative Real-Time PCR, and statistical methods.

Antioxidant activity was seen to be higher in wheat from irradiated seeds than in control plants.

They found a reduction in the enzymes that break down amylose and an increase in gliadin proteins which explains why the grains had filled out.

The variety HD3118 was more responsive to gamma irradiation than HD3086. The scientists say that the experiments require to be repeated for a larger set of germplasm to establish the correlation and to validate the findings.

Gamma irradiation of seeds is a cheap and user-friendly technology to improve wheat productivity. Testing this technology at bigger scales is required to meet the requirements of our increasing population.

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Red Cell Distribution Width

Predictor of neonatal sepsis mortality

Many new-born babies die due to sepsis as clinicians fail to diagnose it early. Sepsis is diagnosed using blood microbial culture, complete blood count and assay of C-reactive protein. But these methods are time-consuming. Moreover, they do not help us understand the severity or predict mortality due to sepsis.

Recently, Malay B. Mukherjee and team from the National Institute of Immuno-haematology, Mumbai showed that variations in red cell sizes, or red cell distribution width, can be used as marker for mortality risk in neonatal sepsis. They took data on 251 septic new-borns from the KEM Hospital, Mumbai. The babies had no other health disorder or family history of blood-related disorders.

The team collected venous blood from the babies and performed complete blood count, C-reactive protein assay and blood microbial culture. They compared the red cell distribution width values of these babies and normal babies of comparable gestational age and weight. The values were significantly higher in babies with sepsis.

In fact, these values were higher in babies that did not survive than in those who survived. Babies with red cell distribution width values above 20% had higher risk of mortality, say the researchers.

The research took an adequate sample size to confirm what was suspected earlier. Since red cell distribution width can be easily and quickly assessed, it can be used in clinical practice to initiate treatment early, reducing neonatal mortality.

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Gum-based Composite Scaffolds

Bone tissue engineering

Scaffolds and implants for bone restructuring should be non-toxic and mimic the properties of natural bone. Hydroxyapatite, a component of bone tissue, along with gellan gum, has been explored for the purpose of reconstructing the trabecular bone region. Guar gum has also been tried

with hydroxyapatite. But if we use both guar gum and gellan gum with hydroxyapatite, what ratio would be ideal?

Last fortnight, Amit Kumar Jaiswal and team from the Vellore Institute of Technology reported tackling the problem. Using freeze drying, they fabricated a scaffold with the two polysaccharide gums and hydroxyapatite. Non-toxic sodium trimetaphosphate was used as crosslinker.

The team tried different ratios of these constituents for strength and other essential properties such as biodegradation and bio-compatibility. And they found gellan gum, guar gum and hydroxyapatite in a ratio of 2 : 1 : 5.44 most suitable.

X-ray diffraction analysis revealed that the scaffolds were amorphous with characteristic peaks of crystalline hydroxyapatite.

Using Fourier-transform infrared spectroscopy, the researchers found that the characteristic peaks of the constituents were retained in the composite – the constituents' chemical nature had not changed.

When tested for mechanical and compression strength under pressure-load, the scaffolds displayed high mechanical and compressive strength – equivalent to that of human bone, says Arunai Nambiraj, Vellore Institute of Technology.

Using scanning electron microscopy, the team found that the scaffolds were highly porous with evenly distributed pores. A moisture transmission study showed that the scaffolds were permeable to moisture.

The researchers checked the composite's biocompatibility. It was non-toxic and supported cell adhesion and growth.

The scaffold should slowly disappear as new bone replaces it. So the team checked the scaffold for *in vitro* degradation, incubating it in phosphate buffer saline solution for three weeks. Degradation was slow. After three weeks, only 13.7% was degraded – sufficient time for new bone formation.

The scaffold with gellan, guar gum and hydroxyapatite, in a 2 : 1 : 5.44 ratio, had adequate structural support and sufficient stability, says Dhivyaa Anandan, Vellore Institute of Technology.

The surface area for cell adhesion and porosity for the efficient exchange of nutrients and waste were similar to those of natural bone tissue.

Of course, the scaffolds need to be tested in animal models to evaluate the material's performance in complex physiological environments before clinical trials, says Amit Jaiswal.

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Navigation in Traffic By autonomous vehicles

Autonomous, driverless vehicles have increased in recent times. These autonomous vehicles need to detect traffic around them in real time. How the vehicle has to behave depends on the type of vehicles around. So researchers are searching for the most appropriate algorithms to use in supporting the navigation of driverless vehicles.

Last fortnight, Baljit Kaur and Jhilik Bhattacharya from the Thapar Institute of Engineering and Technology, Punjab reported developing a deep network based on convolutional feature maps to address the problem. They took RGB images of traffic with depth data by optical flow to improve object detection accuracy.

When the vehicle is moving, images of surrounding traffic may become blurred. To make the technique more accurate, the duo pre-processed the data on the scenes using Fast Fourier Transform and key frame selection. Since GoogLeNets and ResNets have improved after the use of a per region classifier, the researchers adopted the technique. They also trained the network on convolutional feature architecture using multimodal features obtained from normal as well as blurred data. They fused the convolution feature maps of individual columns to reduce the computation required. Features extracted from the fifth convolutional layer of a pre-trained network were fused using RGB images and orientation features from optical flow images.

The team conducted extensive experiments on different convolutional classification architectures with various learning rates. To improve the learning rate, they divided the dataset into three

parts. The results of the training of the first part were used as weight in training the second part and the results were fed into training the third part.

Ultimately, they chose a spatial convolutional network followed by three fully connected layers for the system. Training the networks on convolutional feature maps helped increase accuracy by 15%. Multimodal features computed for training normal as well as blurred Networks on Convolutional Feature Maps proved to be beneficial and also outperformed other features. Data pre-processing and adding a convolutional layer enhanced vehicle classification accuracy by 18%.

This network classified scenes in traffic regions more accurately than existing techniques, says Baljit Kaur, Thapar Institute of Engineering and Technology.

The confidence of the detection rate of a particular object at different distances and the performance of multiscale features for accurate detection need to be analysed and examined, says Jhilik Bhattacharya, her colleague.

The strategy is a step towards improving driverless vehicle technology in India.

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Urban Structures as Heat Islands Climate-sensitive planning

Population explosion expands urban areas and increases the height of urban structures. The surfaces of these structures trap incoming solar radiation, inhibit cooling and increase surface temperature to form heat islands. This is particularly so for Mumbai, a mega city.

Understanding the relationship between urban structures and their thermal profiles can help us adopt a climate-sensitive approach for urban development.

So, Surabhi Mehrotra, supported by Ronita Bardhan and Ramamritam from IIT Bombay looked into thermal variations within heterogeneous urban structures in Mumbai. They categorised urban structures using principal component analysis based on hierarchical clustering.

Based on field and weather data, the team generated a thermal profile using

cooling potential, humidex and mean radiant temperature that collectively define heat stress risk. They classified the heat risk assessment of the structures into five categories, based on the type of building.

The team found that medium-rise compact buildings are not only exposed to high mean radiant temperature, but also have the lowest cooling rate, leading to high discomfort levels throughout the day. People living in such high-rises have the highest risk of heat stress.

While high-rise open structures have high mean radiant temperature and humidex from 12 to 2 p.m., their high cooling potential reduces the thermal impact of the structures during the cooling hours from 6 to 8 p.m.

This research assessment provides a policy variable for framing climate-sensitive urban development regulations.

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Photovoltaics with Copper-oxygen Controlling the configuration

Copper-oxide is a photovoltaic material. It is abundant and, therefore, low-cost. But the photovoltaic efficiency of thin films depends on copper-oxide's microstructure and that, in turn, depends on the bonding configurations of copper and oxide. After all, copper can join with oxygen as cuprous oxide, cupric oxide and Cu_4O_3 .

Recently, Shaik Mohammad Rafi and his student, Sathish, explored the growth of copper and oxygen microstructures and bonding configurations in thin films that they grew in their lab. They wanted to determine optimum combinations of radio-frequency power and substrate temperature, factors that lead to the production of either cuprous oxide or cupric oxide or Cu_4O_3 .

So they made copper reactively sputter onto a thin crystalline silicon substrate. Copper, when heated with different radio-frequency powers, bonds with oxygen and then settles into a thin film on a substrate.

The density of atoms and energy available while bonding determine

which structure will evolve in the thin film substrate. Once the phase changes, there is another bonding combination. The electrical resistivity, optical transmittance and band gap energy also change. Using X-ray diffraction, Fourier-transform infrared spectroscopy and Raman spectroscopy, the team studied phase changes.

At 400°C and at 80 Watts radio frequency power, the film grows to cuprous oxide. But, at 40 Watts, the film grows to cupric oxide. For a fixed power, the films deposited at high substrate temperature lean towards cuprous oxide, they found.

Thus, the team identified methods to grow thin films with different copper-oxygen bonding configurations. The results can now be used to grow the desired copper-oxide as thin films for photovoltaic applications.

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Titanium Nanoflower Evolution Optimum morphology for solar cells

Titanium dioxide has been used in dye-sensitised solar cells for more than two decades now. But the material responds to light in the ultraviolet range only. Dyes – typically, ruthenium – help extend absorption to the visible range. But such dyes are costly. And their photoconversion efficiency is low.

P. N. Bhosale and team from the Shivaji University, Kolhapur reasoned that tweaking titanium dioxide's morphology can improve solar cell efficiency. Titanium dioxide nanorods and nanowires transfer electrons easily. Nanoflower morphology increases surface area for absorbing light and loading dye. However, it is difficult to create nanoflowers of specified shapes. Last fortnight, the team reported overcoming the problem.

They took titanium tetraisopropoxide as precursor for titanium dioxide. And dissolved it to super saturation in an aqueous solution of hydrochloric acid. For the self-assembly of titanium dioxide crystals,

a fluorine-doped tin oxide substrate was provided. The solution was kept at 130 degrees centigrade.

The researchers took out samples at three, five, seven and nine hours to examine the morphology of the crystals. The crystals grew as highly ordered nanostructures. At three hours, the titanium dioxide deposition resembled a bottlebrush flower. The morphology of titanium dioxide deposition was time dependent. At nine hours of incubation, the nanorods clustered into cauliflowers.

The team used betanin vegetable dye as photosensitizer. Betanin anchors well to titanium dioxide. Photons absorbed by the dye change its electronic configuration and these electrons are also transferred to the titanium dioxide. Thus, the photoconversion efficiency of the dye-sensitised nano-cauliflowers increased to 14.21%.

The efficiency decreased slightly to 12.01% after 5 weeks. However, the cells were still stable.

The team thus showed that it is possible to create titanium dioxide nanoflowers with specified morphologies and, hence, specific properties. Cauliflower-shaped nanostructures harvest solar energy better.

Given the low cost of producing such dye-sensitised solar cells and increasing efficiencies, the technology may not take long to appear on roof tops.

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Reports by: **Michelle Fernandes, Lavkush Patel, Kshama Lakshman, Sileesh Mullasser, Sudhir Verma, T. Divya David, Archana Singh, Syed Mohammad Saalim, Ravindra Jadav and Vandana Vinayak**

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scienceandmediaworkshops@gmail.com