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KERNEL

Editorial

Robotic avatars. Delivery drones. Remote learning labs. Read more about the futuristic challenges being pursued by a new technology innovation hub at IISc.

Stories in this issue of *Kernel* also describe new species of vine snakes across peninsular India, a greywater recycling system installed in a remote Karnataka village, and the influence of unusual midlatitude disturbances on the Indian summer monsoon. We also profile the work of an earth scientist who seeks to unravel the secrets of the ground beneath our feet.

ARTPARK: INNOVATION AT PLAY

Autonomous drone charging pad developed at ARTPARK/RBCCPS (Photo courtesy: RBCCPS)

NEW TECH HUB FOR AI AND ROBOTICS AT IISc AIMS TO ADDRESS SOCIALLY AND ECONOMICALLY RELEVANT PROBLEMS

"I hope patients will be comfortable in speaking with me, and would consider me not just as a machine, but as a friend," announced Asha, a first-of-its-kind robotic nurse in the country, making its debut at the Bengaluru Tech Summit in November 2020.

Asha, who is learning to speak Kannada, Hindi and English, is the brainchild of a team of IISc researchers. The robot is being developed in collaboration with TCS and Hanson Robotics, as part of a mission-mode project under the new AI and Robotics Technology Park (ARTPARK) established recently at the Institute.

Asha is not meant to replace a human nurse, but to be a "tool" that can be used by the nurse to assist a patient who might be far away, explains

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Asha with the research team (Photo: Samarth Hada)

Bharadwaj Amrutur, Professor and Chair of the Robert Bosch Centre for Cyber-Physical Systems (RBCCPS) at IISc, who leads this initiative. “The nurse could operate this robot assistant to deliver care without physically coming to the [patient’s] home.” This can be especially helpful during pandemics like COVID-19.

Asha works via virtual reality. A headset and a pair of gloves capture the human nurse’s facial expressions and hand movements, and relay them to the robot. As the nurse physically moves their hands around – to open a pill bottle or take a patient’s temperature – the robot performs the same action.

In the future, the interaction could be made more intuitive, through voice commands, for example. “Five or 10 years from now, we will have very good communication networks. I could just speak through the smartphone, instructing the robot,” says Amrutur. “That’s a really challenging research problem. No one in the world has done it.” In theory, a nurse sitting in one state or country might be able to control a robot next to a patient in another state or country. The team behind Asha is also working on developing technologies that will allow the robot to display more human-like emotions, and understand and speak in multiple Indian languages.

Assistive robots like Asha are one of several research challenges that ARTPARK has undertaken under the broad theme of AI and robotics. It has been set up as a non-profit company with seed funding of Rs 170 crore from the Department of Science and Technology’s National Mission on Interdisciplinary Cyber Physical Systems and Rs 60 crore from the Karnataka state government. Its goal is to provide a platform to translate academic research to industry and startups faster and more seamlessly.

ARTPARK will focus largely on mission-mode projects that are relevant to society and the economy as well as “technologically audacious,” says Umakant Soni, the newly appointed CEO of ARTPARK and co-founder of venture studio AIfoundry, IISc’s collaborator in this initiative. “AI and robotics is going to lead to close to 15.7 trillion dollars of new economic value. But India’s share might be a mere one trillion dollars, whereas China’s would be eight trillion. If we need to reach 10 trillion dollars as an economy ... we need to take these technology moonshots.”

Another example of a socially-relevant project that ARTPARK plans to pursue, titled “Project Eklavya,” is the setting up of remotely connected labs to help students in rural areas watch and perform science experiments in real time. “One of the big challenges is that in government schools in rural areas, the labs will not be working or the instruments will be broken,” says Soni. Instead of taking new equipment to these areas which may be difficult and expensive to maintain in the long run, ARTPARK will focus on setting up remote labs in urban areas where robots will operate the apparatus or equipment, but students in rural schools can be given access to control the robots remotely so that they can perform their experiments.

Yet another area of research that ARTPARK is involved in is using drones to safely deliver medicines, food or other items in urban areas. It plans to set up “Dronery” facilities to build these drones and also work with industry and government partners to map out air routes or corridors for drones to move smoothly across large distances. “We could set up these corridors somewhere from the north of the airport to the IISc Challakere campus, and have these drones routinely deliver things to show that we can do this kind of delivery in a safe way,” explains Amrutur. “This will involve multiple institutions, including the Ministry of Civil Aviation ... companies like Swiggy and Flipkart may also be interested.”

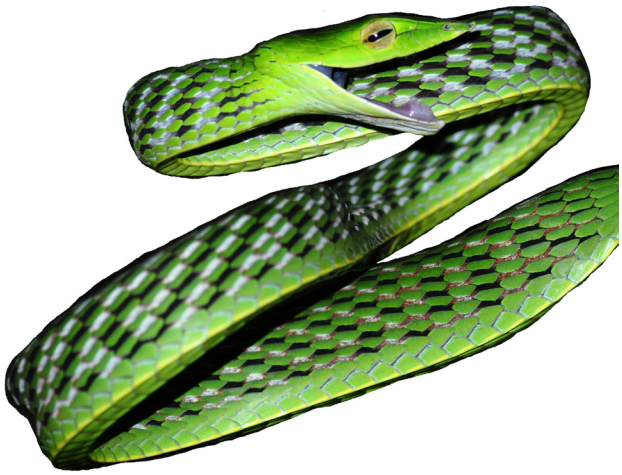
All of these initiatives will require developing new technologies, including those related to 5G networks, autonomous vehicles and manufacturing processes, for which testbeds will be set up at both IISc and Challakere campuses. Other technologies, such as speech-to-speech translation for robotics and mechanisms for sharing confidential data securely, are also planned.

In addition to cutting-edge research, a major focus of ARTPARK will be “Technopreneurship” – spawning deep-tech companies in the domains of AI and robotics, says Soni. “We are planning to set up a venture studio in ARTPARK. Its role will be to create ventures out of these pathbreaking mission problems that we are solving. We are also creating a $100 million venture fund to support these companies.” Student fellowships, courses and workshops for students and industry professionals are also on the horizon.

What sets ARTPARK apart from other technology innovation hubs around the country is that it brings together academic research, industry translation and entrepreneurship under the same roof, according to Soni. “In Silicon Valley, research can travel all the way [from academia] to the market in a structured manner,” he says. He highlights the example of how Google was born out of research at Stanford University. “If we need to come up with a company like Google in AI and robotics, we need to build that research translation ecosystem in India, and IISc has to be a pioneer in that.”

- Ranjini Raghunath

Ahaetulla farnsworthi and *Ahaetulla sahyadrensis* (Photos: Ashok Kumar Mallik, N S Achyuthan and Vivek Philip Cyriac)



DISENTANGLING VINES

A MULTI-INSTITUTIONAL TEAM HAS DISCOVERED FIVE NEW SPECIES OF VINE SNAKES ACROSS PENINSULAR INDIA

Vine snakes are among the most common snakes in peninsular India, found even in many peri-urban areas wherever there is some greenery. This species was believed to be widespread throughout the drier parts of the peninsula as well as in the Western Ghats. But new research shows that this species actually comprises several different species.

Based on extensive sampling across peninsular India, a team of researchers from the Centre for Ecological Sciences (CES) has now described several new species of vine snakes from the region. Led by former student Ashok Mallik as part of his doctoral research, the team carried out field visits across India to collect morphological data, tissue samples and specimens to understand the patterns of distribution and diversification of vine snakes.

Asian vine snakes, distributed throughout the continent, belong to the genus *Ahaetulla* and the recently described *Proahaetulla.* Once the team started its research, they were surprised to discover that the common green vine snake *(Ahaetulla nasuta)* in India was a complex of several species. They found four distinct small-bodied and short-nosed species: the Northern Western Ghats vine snake *(Ahaetulla borealis),* Farnsworth's vine snake *(Ahaetulla farnsworthi),* Malabar vine snake *(Ahaetulla malabarica)* and Wall's vine snake *(Ahaetulla isabellina)* in the Western Ghats rainforests alone. These species were superficially similar in their morphology (what they look like) but separated by geographic (or ecological) barriers. Another morphologically distinct and much larger species, the long-nosed vine snake *(Ahaetulla oxyrhyncha),* was distributed in the lowlands and drier parts of peninsular India.

"All the vine snakes were assigned names related to the locality or based on a morphological character, but we named the species *Ahaetulla farnsworthi* after my favourite mad scientist who inspired me to become one, Dr Hubert Farnsworth from [the cartoon] Futurama. In fact, the snake also looks a lot like him," says Achyuthan Srikanthan, a researcher at CES who was part of the team.

The researchers also delineated the Travancore vine snake *(Ahaetulla travancorica),* separated by morphology and a geographic barrier from the Gunther's vine snake *(Ahaetulla dispar).* In addition, they recognised distinctions between the brown vine snake in the Western Ghats and the one found in Sri Lanka, and gave the Western Ghats form a new name *(Ahaetulla sahyadrensis).* There are now six species of vine snakes endemic to the Western Ghats.

"Widely distributed species may comprise many cryptic species, which can only be detected by genetic analysis," says Mallik. "Our earlier discovery of another deeply divergent vine snake, *Proahaetulla antiqua,* suggests that the entire lineage of vine snakes *(Ahaetulla)* evolved around 26 million years ago during the mid-Oligocene from its sister group *Proahaetulla."*

Kartik Shanker, Associate Professor at CES says, "The discovery helps us document species diversity but also sheds light on the evolutionary history of vine snakes in South Asia. *Ahaetulla nasuta* is one of the first snake names that we learned as aspiring herpetologists. One almost feels sad that we had to assign it to the Sri Lankan population, but it is far more exciting that we have all these new species in India."

The study, published in the journal *Zootaxa,* was carried out in collaboration with researchers SR Ganesh from the Chennai Snake Park, Saunak Pal from the Bombay Natural History Society, and Princia D'souza from IISc.

- Kartik Shanker's lab

New toilets at Berambadi using recycled and treated greywater (Photo courtesy: Plasma lab, CST, IISc)

DECENTRALISED TREATMENT AND RECYCLING OF GREYWATER

A SYSTEM INSTALLED IN A REMOTE KARNATAKA VILLAGE SCHOOL HAS HELPED REUSE LARGE AMOUNTS OF GREYWATER

Researchers at the Centre for Sustainable Technologies (CST) have developed an efficient decentralised wastewater treatment and recycling system at a primary school in the remote village of Berambadi in Karnataka.

A new study shows how the system has, over the past year, enabled the reuse of wastewater and reduced dependence on freshwater resources. "We have demonstrated for the first time that decentralised wastewater treatment systems can be economically put into practice in a rural setting," says Lakshminarayana Rao, Assistant Professor at CST and a senior author of the paper published in the *Journal of Water Process Engineering.*

The research team operated the greywater treatment system for a year and monitored different characteristics at the entry and exit points. The performance of every treatment stage was quantified in terms of removal efficiencies (REs) of turbidity, Total Suspended Solids, nitrate, total phosphorus, Biological Oxygen Demand, Chemical Oxygen Demand and faecal coliforms. Overall, the system showed high REs – more than 90% for most of the parameters. About 667 litres of greywater was treated daily using the system, saving around 1,80,000 litres of water annually.

At Berambadi Primary School, greywater is produced at the hand wash and kitchen wash mostly during the lunch hours.

The treatment system first passes the greywater from the hand wash sinks through strainers that screen out large food particles from water. "Then, the water goes through three anaerobic sand biofilters – tanks filled with locally available coarse gravel, medium gravel and sand, where bacterial biofilms help in the breakdown of nutrients in greywater to reduce nutrient levels of water," explains PS Ganesh Subramanian, a former Project Assistant at CST and the first author of the paper.

The greywater from the kitchen sinks, on the other hand, is first passed through a grease trap to strip off the top layer of oil and grease from water. After this, water flows through an anaerobic sludge bioreactor followed by a stratified biofiltration chamber. Finally, the filtered water from both hand wash sinks and kitchen sinks enters an aeration tank followed by an ozonation tank, where it is treated with ozone for disinfection.

The ozone is generated using a cold plasma ozonator designed specifically for disinfection of wastewater. "Ozonation removes odours and colours from water, and eliminates faecal coliforms, thereby disinfecting the water while leaving no harmful by-products. [It also] enhances the Dissolved Oxygen concentration of the water," explains Subramanian. The treated water stored in an overhead tank is then readily available for reuse by the students and staff of the school for domestic non-potable purposes such as toilet flushing and gardening.

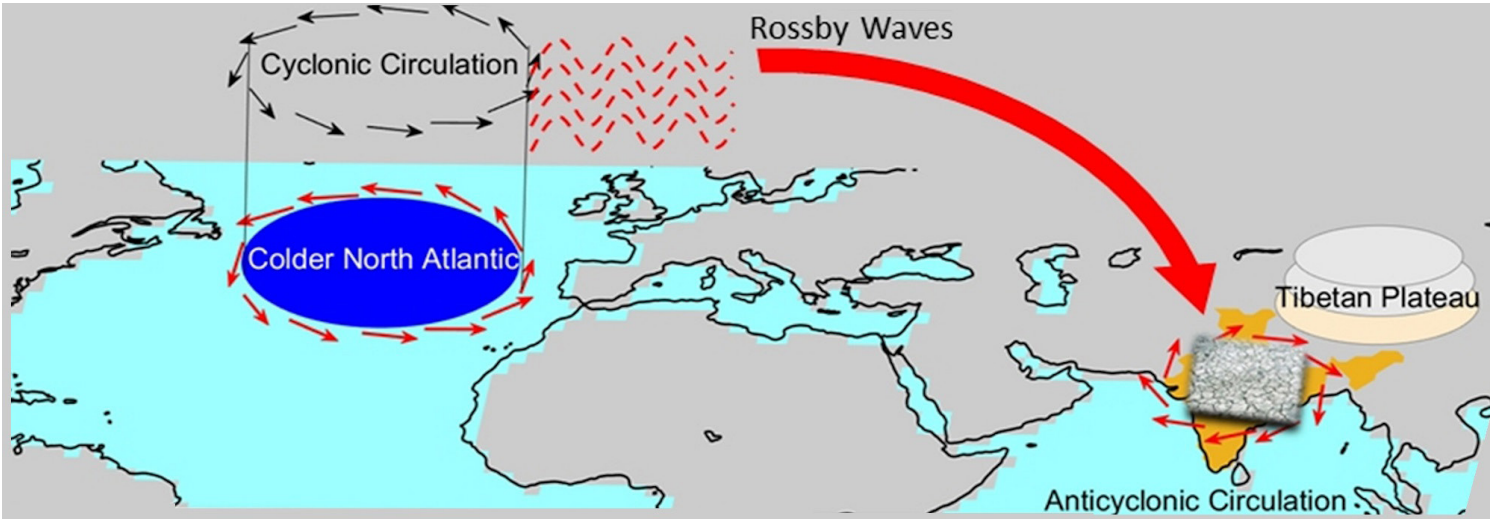
"Here, plasma technology is used to create a high throughput solar powered ozonator for cleaning up the water effectively," says Rao. The ozonator used in the system works with ambient air as the input gas – instead of oxygen – to generate ozone. "This completely eliminates the need for hazardous oxygen cylinders, thus allowing the system to be easily operated and maintained by the staff at the school," he says.

The authors suggest that a robust wastewater management system like this can be replicated in both rural and urban settings after taking into consideration factors such as space limitations, baseline greywater quality and daily flowrates. "The people from Berambadi village are very happy with the system. Based on the success of this sustainable wastewater management project, several other schools in Karnataka have approached us to duplicate it in their schools," says Rao.

The study was carried out in collaboration with the Ashoka Trust for Research in Ecology and the Environment, and the University of Glasgow and James Hutton Institute in the UK.

- Shatarupa Sarkar

Image: Pritam Jyoti Borah



DROUGHTS IN INDIA INFLUENCED BY NORTH ATLANTIC AIR CURRENTS

ATMOSPHERIC DISTURBANCES FROM THE MIDLATITUDES APPEAR TO DERAIL THE INDIAN SUMMER MONSOON

Nearly half of the droughts during the Indian summer monsoon in the past century may have been driven by atmospheric disturbances from the North Atlantic region, finds a new study published in *Science.* It was conducted by researchers at the Centre for Atmospheric and Oceanic Sciences (CAOS).

More than a billion people in the Indian subcontinent depend on the annual summer monsoon, which brings copious rain to large swathes of the country between June and September.

When it fails, and most of the country is plunged into drought, the usual suspect is El Niño, a recurring climate event during which abnormally warm equatorial Pacific waters pull moisture-laden clouds away from the subcontinent. But 10 out of 23 droughts in India in the past century occurred during years when El Niño was absent. What, then, could have caused them?

The IISc study shows that these droughts were a consequence of a sudden and steep drop in rainfall in late August. This drop was linked to an atmospheric disturbance in the midlatitude region over the North Atlantic Ocean, creating a pattern of atmospheric currents that swoop in over the subcontinent and "derail" the monsoon.

"As early as the 1980s, people have looked at these droughts individually. But they have not collated and pooled them together, and deduced that these droughts may all have a different type of evolution than El Niño droughts, as well as a common cause, which is this midlatitude influence," says V Venugopal, Associate Professor at CAOS and a senior author.

The research team looked closely at daily rainfall during both El Niño and non-El Niño drought years, and noticed stark differences in the patterns between June and September. El Niño droughts follow a standard pattern. The rainfall deficit – departure from a long-term average – sets in around mid-June and becomes progressively worse. By mid-August, the deficit spreads across the country and a drought is inevitable.

Surprisingly, the non-El Niño droughts, when analysed together, also seemed to follow a common pattern. First, there was a moderate slump in June. Then, during mid-July to mid-August, the monsoon showed signs of recovery and rainfall increased. However, around the third week of August, there was a sudden steep decline in rainfall, resulting in drought conditions.

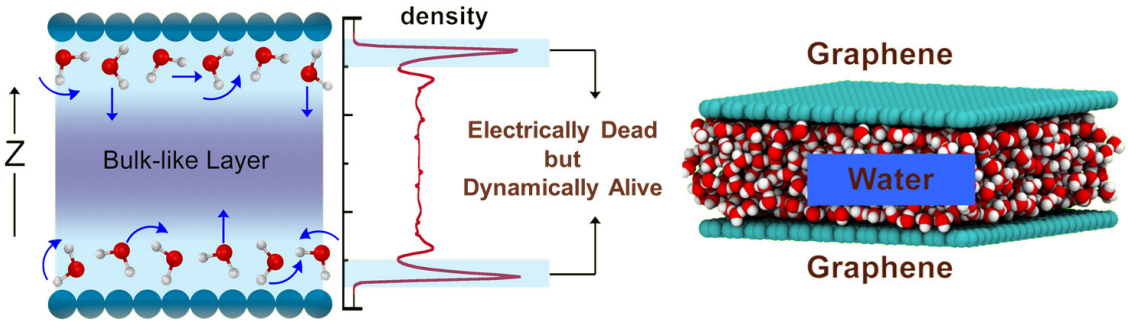
"The question was: why does the break occur this late in August?" says Jai Sukhatme, Associate Professor at CAOS and another author. "We tried to see if we could trace it back to a forcing agent or system that influences the behaviour over India. We looked at the winds that were prevalent in these non-El Niño drought years."

That was when they noticed an unusual midlatitude disturbance, which emerged from winds in the upper atmosphere interacting with a deep cyclonic circulation above abnormally cold North Atlantic waters. The resulting wave of air currents, called a Rossby wave, curved down from the North Atlantic – squeezed in by the Tibetan plateau – and hit the Indian subcontinent around mid-August, suppressing rainfall and throwing off the monsoon trying to recover from the June slump. The wave's usual course is to go from west to east, but not towards the equator, explains Sukhatme. "This inward curving was the peculiar thing that we noticed during these particular years."

The findings underscore the importance of also considering influences on the Indian monsoon from outside the tropics, which current forecast models focus heavily on. "The Indian Ocean and Pacific Ocean seem to be at the forefront of all discussions surrounding Indian monsoon droughts," says Venugopal. "It is perhaps time to focus just as much on midlatitude influences, which might aid in getting a better handle on enhanced predictability of monsoon variability."

- Ranjini Raghunath

Image: Sayantan Mondal



INSIGHTS INTO WATER LAYERS AT HYDROPHOBIC SURFACES

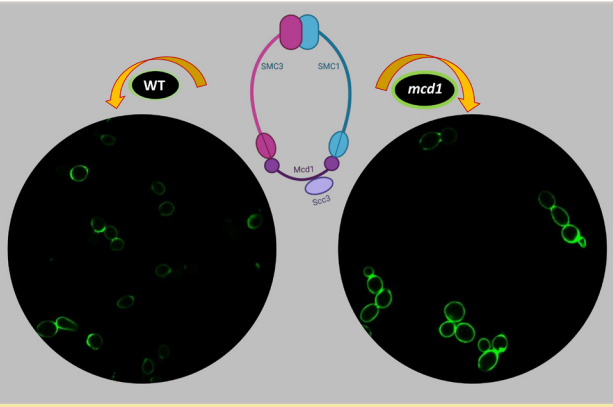
Water confined between parallel graphene sheets exhibits several interesting anomalies, one of which is a low static dielectric constant. A new study carried out by researchers in the Solid State and Structural Chemistry Unit has unraveled the origin of this anomaly using linear response theory, a capacitor model and computer simulations.

The researchers find that the water layers at the interfaces between the liquid and sheets, with a substantially weakened dielectric permittivity, make a disproportionately large contribution, reducing the effective value of dielectric constant of the entire system.

The team also studied the dynamics of water molecules at a microscopic level. They found that the water molecules residing in these so-called "electrically dead" layers align in the same orientation and yet remain dynamically active, residing only for a short time in the layer. While these timescales are not substantially different compared to those of water molecules at distant layers, the dipole moment fluctuations of the interfacial layer molecules are quenched.

The study provides new insights into the dielectric anomaly of nanoconfined water, a topic of great current interest.

Image: Shikha Laloraya



COHESIN HELPS MAINTAIN CELL WALL IN BUDDING YEAST CELLS

Mutations in proteins needed to maintain the structure of the yeast cell wall may weaken it, threatening the cell's survival. A study in *Genetics* by researchers at the Department of Biochemistry has explored the role of a protein complex called cohesin.

Cohesins attach to various parts of the cell's chromosomes, and help organise and distribute genetic material during cell division. A previous study in *PNAS* by the team described a unique mechanism by which cohesin represses the expression of subtelomeric genes, even when they are present away from sites known to be silenced.

In the new study, the researchers found that yeast cells with mutations in cohesin proteins had distinctive characteristics. Their cell walls were resistant to an enzyme called zymolyase, and showed large depositions of chitin, known to fortify cell walls. They were also more sensitive to chemical inducers of cell wall stress and elevated temperature; interestingly temperature sensitivity could be remedied by altering the osmotic stress. This hinted at the presence of cell wall defects. A compensatory stress signalling pathway is activated in these mutants – important for their survival during elevated cell wall stress.

Cohesins, therefore, are vital for regulating both chromosome segregation during cell division and cell wall maintenance, independently.

- Anoushka Dasgupta

Photo courtesy: Attreyee Ghosh

ROCKING THE WORLD OF SCIENCE

ATTREYEE GHOSH AND HER TEAM DIG DEEP TO UNRAVEL THE SECRETS OF THE GROUND BENEATH OUR FEET

When Carole King sang, "I feel the earth move under my feet," she didn't mean it in a literal sense. But she was right: the planet's interior is dynamic. Yet, we seem to know little about what is happening deep inside – even as we explore other faraway planets and stars – although we are occasionally reminded of its intense activity whenever an earthquake or a tsunami strikes.

Attreyee Ghosh, Associate Professor at the Centre for Earth Sciences (CEaS) at IISc, agrees. "We still know very little about the structure of Earth," she says. Besides its inaccessibility, the reason why we are so ignorant about the interior of our planet, according to her, is that it is "freaking complicated." It has multiple layers, both liquid and solid, and each layer consists of several different minerals and rocks. "Each [layer] has different properties," she says, and each of them is subjected to multiple forces. It is therefore not surprising that Earth Sciences encompass not just geology but also physics, chemistry and biology.

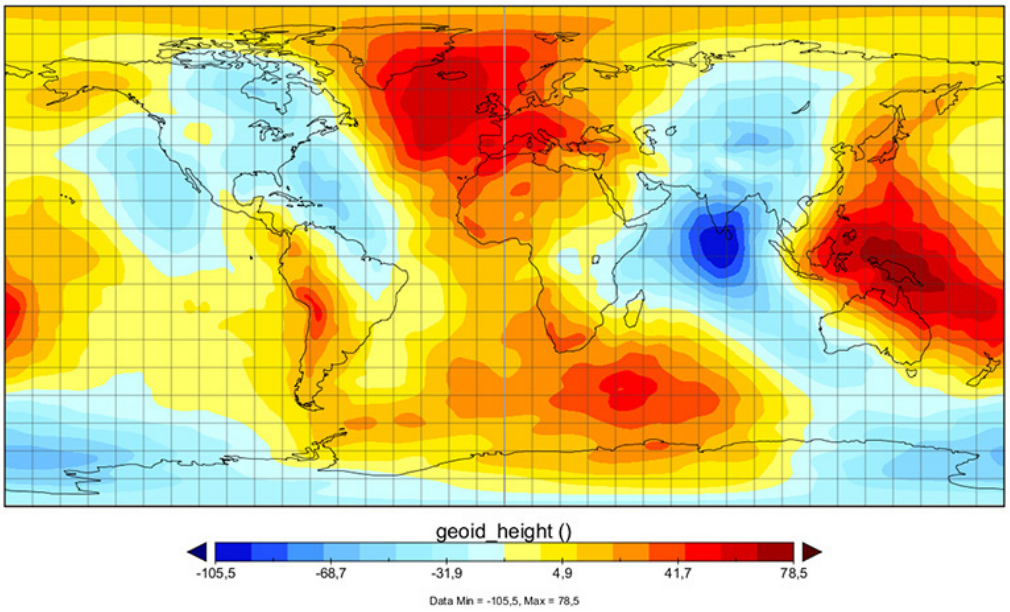
Attreyee's research interest lies in understanding the physical processes taking place inside Earth and how they affect what we see on the surface. Using satellite and field data, she and her team build numerical models to understand these processes. This area of research is known as computational geodynamics. "I am very interested in how the deep interior talks to the surface," she says.

One such surface feature that scientists have observed is the uneven face of Earth. The bumpiness results from the effects of gravity stemming from the unevenly distributed mass deep within Earth's interior. If there were no tides or currents, all the water in the oceans would settle on this uneven surface giving Earth a peculiar shape that geophysicists call the "geoid". An example of such an irregularity is seen just south of the subcontinent in the Indian Ocean where the ocean surface drops by over 100 m. Using satellite data, which record small fluctuations in the gravity field, Attreyee's group has discovered the cause of this "geoid low", which has in the past been a subject of much speculation. "There is a lot of low-density hot material in the mantle [layer of rocks between the core and Earth's crust], and this low-density structure is causing the dip in the geoid surface," she explains.

Yet another surface phenomenon, one that all of us are familiar with, are earthquakes, which have also attracted the attention of Attreyee's lab. About nine out of 10 earthquakes occur at the boundaries of tectonic plates, the rigid blocks of the outermost part of Earth called the lithosphere. But sometimes, anomalous earthquakes happen in the middle of the plate, far away from plate boundaries. An example of such an intraplate earthquake was the devastating Gujarat earthquake of 2001. Attreyee's work has shown that stresses originating at plate boundaries can travel through the plate interior and trigger such quakes.

Attreyee's investigations, as well as those of others in her field, will help us better understand the structure of Earth's interior. Besides generating more realistic 3D models of the ground beneath our feet, it will also aid seismologists in their quest for what she refers to as the "holy grail of geophysics": prediction of earthquakes. These models will

Observed geoid anomaly on Earth showing the big "hole" in the northern Indian Ocean; scale in metres (Image courtesy: European Space Agency)



also be of tremendous help to design policies related to how we manage disasters, including safety regulations for construction and evacuating people.

Attreyee has come a long way in her career as an earth scientist. But she may not have ventured into the world of rocks had it not been for a gift she received from her father when she was still in school. It was a book titled *Antarctica,* written by Sudipta Sengupta, a geologist and former professor at Jadavpur University, and one of the first Indian women to go on a voyage to the icy continent. Reading about Sudipta's experiences in the South Pole and how she became a geologist played a crucial role in shaping her own career, reminisces Attreyee. "I got interested in the subject after reading the book. At that age, I found it really fascinating. I knew I wanted to do science, but I didn't exactly know which career to choose. That book helped me to channel my interest in this field [Earth Sciences]."

Attreyee did her PhD in geophysics from Stony Brook University in the USA and her postdoctoral research from the University of Southern California and Stony Brook University before she moved to CEaS as Assistant Professor in 2012. The transition from postdoctoral studies where she focussed mainly on her own research to running her own lab at IISc has been challenging. "You cannot just think about a single project, you have to think about multiple students engaged in various different projects. Along with this comes administrative roles, and finding ways to fund your research," she says. However, over the years, she has eased into the role and looks forward to an exciting future – one in which she wants to continue to explore the relationship between deep and shallow forces in the interior of Earth and how they shape the surface. She is also grateful for the support that she received at an early age to pursue this path, and hopes that she can find ways to inspire more young girls to take up science.

- Gouri Patil

Attreyee Ghosh's students displaying exhibits at IISc's Open Day (Photo: IISc Photography Club)

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