separation electric fields. N. V. Rao (NARL, Gadanki) presented the probing of Venusian plasma, magnetic boundaries and its topside ionosphere through a radio sounder. Yoshifumi Futaana (SISP, Sweden) reviewed the findings by Analyser of Space Plasma and EneRgetic Atoms (ASPERA-4) on VEX. Sakshi Gupta (IISER, Kolkata) talked about understanding the environments of Venus-like exo-planets crafted by evolving stellar magnetic activity.

The session on 'Interplanetary dust science' had four talks. Apostolos Christou (Armagh Observatory, UK) showed that Venusian meteors tend to be brighter but shorter-lived than terrestrial meteors. Jayesh Pabari (PRL, Ahmedabad) delivered a talk on the heliocentric dependence of interplanetary dust particle density in light of the latest Solar Orbiter observations. He showed the momentum of ring particles in the orbit of Venus and also the comet as a possible source of particles detected by Solar Orbiter. Yanwei Li (University of Stuttgart, Germany) talked about interplanetary dust particles, various types of dust detectors and a calibration facility of 2 MV Van-de-Graaff dust accelerator at Institute of Space Systems (Stuttgart). Ingrid Mann (AUN, Norway) discussed interplanetary dust inside 1 AU, and presented model calculations for smaller-sized, charged particles which are affected by solar radiation pressure as well as Lorentz force.

There was a session covering short video presentations by 18 participants. Another session had three talks on Venusian data analysis, more important in context to the future Indian mission to Venus. Dinesh Kumar (SWRI, USA) talked about detecting lightning signatures using PVO and VEX datasets. Tripathi (SPL, Thiruvananthapuram) spoke on Akatsuki RO data analysis, time-domain analysis, Doppler as well as power analysis and frequency residuals. Sinha (PRL, Ahmedabad) discussed the emplacement pattern of lava-flow channels in the Henwen Fluctus region.

There were open sessions at the end of each major session, where the experts discussed various topics, including the following.

- Several research areas related to Venusian science emerge, like the evolution of the surface, unknown UV absorber, lightning, super-rotation, interplanetary dust/ring and space weather.
- Possibility of subsequent work on great climate transition, remote seismology and surface study was deliberated.
- Research on SO_2 content, unknown absorbers, possibilities of ballooning experiments and difficulties of multiple altitude measurements was debated.
- The methods of lightning detection, instruments needed and requirements of *in situ* measurements of the middle atmosphere were discussed.
- The effect of interplanetary dust on the atmosphere, characterization of dust ring, atmospheric escape and solar wind interaction with Venus were discussed.

In summary, despite some similarities regarding certain aspects of research on different planets, Venus has been of interest to space scientists for different reasons. Its exploration started from the time of Venera missions (1960s), and subsequently, many other missions like Mariner, Pioneer Venus, Vega, Magellan, Venus Express, Akatsuki and IKAROS have provided a wealth of information about the planet. Unintended missions like Galileo, Cassini, MESSENGER, Parker Solar Probe, BepiColombo and Solar Orbiter have also provided flyby observations. The Venus-SC-2022 conference covered diversified research areas from the surface to the upper atmosphere and beyond. More than 172 delegates had registered for the conference, and there were 24 oral presentations from institutions outside India as well as 15 oral presentations from Indian institutions. Such a gathering provides research avenues to students and an opportunity for the research community to interact/collaborate.

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COMMENTARY

Climate change impacts on the coastal regions

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In recent years, the Intergovernmental Panel on Climate Change (IPCC) has brought out three reports, including chapters that deal with assessments of climate change and its impacts on the coastal regions. They include a chapter in SROCC; in the IPCC *Special Report on Oceans and Cryosphere in a Changing Climate* (ref. 1, chapter 4) and two chapters in the Sixth Assessment Report (AR6) of IPCC (ref. 2, chapter 9 and ref. 3, chapter 3 respectively). These reports provided assessments of the changes and projections of global mean sea-level rise and extreme sea level and their impacts in the coastal regions.

More than 90% of the heat generated by global warming gets absorbed in the ocean. One of the significant changes in the ocean is the increase in marine heat waves (MHWs). These are large increases in temperature over a region, which persist for a few weeks or longer. For instance, using sea surface temperature (SST) data, Chatterjee and Shenoy[4] showed an increase in the occurrence of MHWs in the Arabian Sea during the period 1982–2019. MHWs cause coral bleaching, and they are harmful to other marine organisms. Besides, ocean acidification due to the increased absorption of carbon dioxide in the ocean also affects the marine ecosystem.

Warming of the ocean causes an increase in the mean sea level. Thermal expansion, as well as melting of glaciers and ice sheets (Antarctica and Greenland) are the main contributors to sea-level rise. The global mean sea level rose by 0.20 m from 1901 to 2018. Projections for global mean sea-level rise for 2100 (relative to 1995–2014) could vary from 0.28 to 0.55 m for a very low greenhouse gas emission scenario and by 0.63–1.01 m for a high emission scenario[2].

A major concern is the increase extreme sea-level events in the coastal regions worldwide. They occur mainly due to storm surges generated by cyclones. Assessments in SROCC[1] and AR6 (refs 2, 3), based on studies of statistical projections using historical tide-gauge records and assuming a uniform sea-level rise, showed that extreme sea-level events that were occurring once in 100 years historically could occur once in 100 years or once a year by 2100, depending on the location.

Apart from extreme sea-level events, instances of minor flooding, often called 'nuisance flooding', which are associated with large spring tides, have also been reported in many regions over the globe; for instance, along the coast of USA[5]. Though they may not be causing catastrophic impacts, their frequencies are projected to increase in the future[2].

It has been widely recognized that low-lying countries, such as the Netherlands and Bangladesh, are highly vulnerable to sea-level rise. Besides, low-lying small islands, such as the Maldives, are also highly vulnerable to sea-level rise. Vinayachandran *et al*.[6] have provided an overview of coastal climate change with case studies from Seychelles and Bangladesh. Regional cases of extreme sea-level, waves and flooding have been discussed in the literature; for instance, for the north Indian Ocean[7].

India has a long coastline of more than 7500 km. Many anthropogenic activities, such as the removal of sand from the beaches, marine pollution and infrastructure development near the coasts, have been causing a deterioration of the coastal environment. Sea-level rise caused by global warming enhances the impacts in the coastal regions. The east coast of India is low-lying and prone to extreme sea-level events caused by cyclones. Moreover, the deltas, such as the Ganga–Brahmaputra–Meghna delta along the northeast coast of India and the coast of Bangladesh, undergo subsidence, and deltaic regions are highly vulnerable. Sea-level rise and deltaic subsidence in the Ganga–Brahmaputra–Meghna delta has been discussed in SROCC[1]. In the Arabian Sea, an increase in the number of depressions in recent decades has been reported in many studies. The main reason for this is the rapid warming of the Indian Ocean[8], which favours the genesis as well as the intensification of low-pressure systems. A few of these systems develop into cyclones or even severe cyclones and cross the land along the west coast of India.

In coastal management, long-term planning is needed to tackle the impacts of climate change. In India, early-warning systems established to monitor and forecast cyclones, tsunamis, have helped in evacuation of affected people during episodic events. However, economic losses do remain a concern. Excess groundwater extraction in megacities also needs to be managed. Coastal managers need to develop long-term planning for infrastructure development, taking into account the mean sea-level rise. With the increase in population in the coastal regions, sea-level rise will exacerbate already existing problems of inundation during extreme events. Inundation will be more significant when either surges or large high tides (perigean spring tides, in regions of large semi-diurnal tides) also occur simultaneously.

The global average temperature has increased by about 1.1°C above the pre-industrial period. The Paris Agreement of 2015 proposed to limit the rise in temperature to below 2°C, preferably to 1.5°C, for which large commitments on reductions in emissions will be required. Cooley *et al*.[3] have pointed out that adaptation is a good option for coastal regions, especially for low-end emission scenarios. However, for high-end climate scenarios, intensive adaptation is necessary to manage the impacts of sea-level rise and extreme events in coastal regions. Various methods, including constructing sea walls, are available, but this method leads to beach erosion in the adjoining areas. Ecosystem-based approaches, such as planting mangroves, offer natural resistance to extreme waves and storm surges while aiding carbon sequestration.

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