Social and Economic Impact of Earth Sciences. Vineet K. Gahalaut and M. Rajeevan (eds). Indian National Science Academy, Springer, 152 Beach Road, #21-01/04 Gateway East, Singapore 189721. 2023. 432 pages.

Today, humanity is under the changing climate and pressure to enhance and maintain the growing population's demand for better life/livelihood. In such a scenario, the knowledge of Earth Science and the services to the society for coping with Earth's environment and protecting life and livelihood from natural disasters have become more important. The book under review provides an excellent narration of the services provided for various stakeholders in India and neighbouring countries by the institutions of Ministry of Earth Sciences (MoES). The services provided range from short to long-term forecasts of weather and other natural phenomena like glacial melt, ocean waves, ocean currents, sea level, air pollution, landslides, etc. and early warnings on tsunamis, storm surges, harmful algal blooms, etc. The editors have taken special care to capture all those aspects through 21 contributed articles presented in the book. The articles narrate different services, and some also discuss their socioeconomic impact. That justifies the title of the book.

I enjoyed going through this book because it portrays the emergence of Earth Sciences in India from a mere descriptive science a few decades ago to a quantitative predictive science. In other words, the book well documented Indian Earth Science's capabilities in observing, understanding and predicting natural phenomena and providing the necessary information to various stakeholders, starting from the commoner who wants to know the weather in his locality to high technology industries like windmills, solar power farms, offshore oil and natural gas companies, defence applications and for policy and decision-makers. The negligible number of deaths reported these days during very severe tropical cyclones testify to the improvements achieved by the cyclone prediction by the India Meteorology Department (IMD) of MoES. The tsunami early warning service is another notable example.

Considering the importance of weather and climate services for sectors like agriculture, water management, shipping, aviation, entertainment, pilgrimage, defence, etc. Ten out of 21 articles have been dedicated to weather and climate-related services. The first article by Mohapatra *et al.* reports on forecasting and forewarning short and medium-range weather phenomena like cyclones, thunderstorms, heavy rainfall, flooding, heat and cold waves, fog, etc. The article describes how the forecasts are made and converted as services and how they are continuously improved. The socioeconomic impacts/benefits of sectors like agriculture, disaster management, power, etc. are also discussed. The article concludes by identifying the gap areas and future plans for additional services.

Sreejith *et al.* deal with the operational seasonal forecasting of the southwest monsoon rainfall, a forecast that significantly impacts India's economy and social life. The article provides a brief history of seasonal forecasting in India and narrates how the prediction of southwest monsoon rainfall by IMD has evolved from the usage of a single parameter of snow cover in 1886 to statistical and numerical models that make use of multiple parameters and data all over the globe. A comparison between the currently used Statistical Ensemble Forecast System and the Monsoon Mission Climate Forecast System based on a dynamic model is also provided.

Mukhopadhyay *et al*. and Ashrit *et al.* provide an account of the development and improvements of numerical models at IITM, Pune and NCMRWF, Noida, for the prediction of severe weather like lightning, thunderstorm, tropical cyclones, extreme rainfall, heat and cold waves, etc. in India with a lead time. IITM developed a high-resolution (12.5 km) 21-member ensemble prediction system by modifying the Global Forecast System (GFS) to reliably predict thunderstorms in 24–48 h lead time and tropical cyclones and other severe weather events with 5–6 days lead time. The numerical models developed at NCMRWF are based on the UK Met Office NCUM model and Ensemble Prediction System. The predictions evaluated against the observations are used in the operational services of IMD and for disaster management.

Kulkarni and Rao have presented intraseasonal and interannual variability in monsoons as seen in a 119-year-long data set. Using a suite of 25 models used in IPCC reports, the trends in monsoon rainfall over India and their projected changes in different sectors under RCP4.5 and RCP8.5 (Representation Concentration Pathways) scenarios are discussed together with their likely impacts on socio-economy.

Mitra describes the importance of synoptic data from remote sensing satellites for monitoring weather phenomena and assimilation in NWP models to control forecast errors. After discussing the advantages of higher temporal and spatial resolution data from rapid scanning sensors and vertical sounders for the analysis of fast-changing weather phenomena, the author lists the planned new payloads in future missions that would help in meeting the growing demand for weather and climate monitoring and forecasting at administrative block levels with improved skills.

The article by Saji Mohandas is an overview of weather and climate modelling in general. It starts by providing the philosophy of NWP, its advantages and challenges. The strategies like unified modelling adopted in improving weather prediction by the UK Met Office and earth system models for climate modelling are highlighted.

Pattanaik *et al.* provide a vivid picture of how IMD started extended range forecasts (ERF, 3–4 weeks) in 2008, using data from empirical and dynamical models, following drought years in 2002 and 2004 and the status of the current operational ERF system of IMD developed at IITM based on ocean–atmosphere coupled CFSv2 adopted from NCEP, USA and integrated with Global Data Assimilation System run at NCMRWF and Global Ocean Data Assimilation System run at INCOIS. After presenting Monsoon 2019 as a typical case to highlight the performance of ERF, the article narrates the applications of ERF for agriculture, disaster management, health, hydrology and energy sectors, which has enormous socio-economic impacts.

The increasing frequency and magnitude of heat and cold waves in recent decades are a grave concern for all due to their impacts on life, livelihood and the environment. They often cause deaths and damage the crops, environment and economy. In

India, 2081 and 1061 people died due to the heat wave in 2015 and 1985, respectively. Nair *et al.* present the frequency and magnitude of heat and cold waves over India and the associated trends in different regions based on the analysis of 50-year-long data. The analysis also brought out the linkages between the heat and cold waves over India and ENSO.

Growing incidences of air pollution and fog concern India and others due to their impacts on health, crops and the economy. Ghude *et al.* present the impacts of air pollution in various states of India on health, agriculture, economy, etc. The fog and air pollution in winter months widen the economic losses to the aviation sector. It is estimated that the airlines lost about 1.78 million USD in 2013–14 due to fog-caused disruptions, which were brought down drastically by implementing DGCA-IMD-AAI guidelines and predictions based on satellite data products since 2014–15.

Nair *et al.* and Baliarsingh *et al.* narrate the services pertaining to the ocean, which were absent in the country before the establishment of INCOIS. Nair *et al.* narrate the services and products pertaining to the ocean provided to wide-raging users like fishermen to high technology maritime industries, the Navy and shipping. Ocean State Forecasts include the ocean waves, currents, temperature, salinity, depth of mixed layer (well-mixed top layer of the ocean due to winds, waves, water density, etc.) and the depth of thermocline (depth at which the ocean temperature cools rapidly). They are generated using numerical models having good skills. The potential fishing zone advisories, popular among fishermen, are generated using near-real-time satellite data on surface temperature and chlorophyll content in the seawater. In addition, the article narrates several customized advisories, warnings, alerts and products that aid search and rescue at sea, predict oil spill tracks, make specific forecasts for ports, etc. The article also presents the validation of forecasts and advisories and the use of modern ICT to disseminate information to end users. User feedback and future plans are also included. The article by Baliarsingh *et al.* on ecological services includes alerts on coral bleaching and harmful algal blooms generated based on satellite data and empirical relations.

The article by Jalihal gives an overview of available and emerging technologies for desalination. It presents the details of 1 lakh litres/day desalination plants established by NIOT in Kavaratti in 2005, Agatti and Minicoy in 2011 using environment-friendly Low-Temperature Thermal Desalination (LTTD) technology. Discussions on the impacts of LTTD-based plants on the drinking water scenario of Lakshadweep and possible solutions for mainland India and Andaman & Nicobar Islands would have enhanced the usefulness of the article.

The articles by Vedachalam *et al.* and Atmanand *et al.* are similar because both highlight the development and applications of ocean technology. The first article narrates the importance of the blue economy and the high-end technologies developed/being developed at NIOT for sea bed mining, remotely operable vehicles for various applications, including hydrocarbons, platforms to access the offshore wind energy potential, seawater desalination, offshore cage culture of fish and aquaculture, marine biotechnology for pharmaceuticals, platforms and instrumentation for ocean observations and hazard monitoring, etc. In addition to highlighting technology developments, the second article summarizes the resource potential (energy, minerals, fisheries, freshwater, etc.) in the Indian EEZ.

Murthy *et al.* describe the unique, innovative natural solutions developed and implemented by NCCR and NIOT to restore the eroded beaches in Pondicherry and Kadalur–Periyakuppam and how they impacted the local community.

Kurian and Roy discuss the three deep marine resources, polymetallic nodules, polymetallic sulphides and cobalt-rich Fe–Mn crusts in the world oceans, with special emphasis on the Indian Ocean. The article also reports on the two exploration contracts signed by India with the International Seabed Authority and the activities undertaken by MoES to meet the objectives of the contract.

Kumar *et al.* describe the tsunami early-warning system established at INCOIS in October 2007, its components, and its role as a regional tsunami service provider for the Indian Ocean rim countries under the aegis of IOC/UNESCO. The article also provides an overview of the SOP followed, the performance of the system during earthquakes in Indian and other oceans and the dissemination of early warnings to India and Indian Ocean rim countries through fax, e-mail, SMS, direct broadcast, etc. The article concludes by presenting the efforts in risk assessment, promoting societal awareness and future plans for improvement.

The article by Jayakumar *et al.* describes the potential morphological, geological, meteorological and anthropogenic factors conducive to landslides and presents the possible prediction of landslides using forecasts of heavy rainfall.

Mishra *et al.* report on the seismic microzonation maps generated for several Indian cities at 1 : 10,000 and 1 : 25,000 scales and their integration with geophysical and geotechnical aspects to make them useful for town planners, construction engineers and disaster managers. The successful examples of using such maps in Delhi-NCR, Bengaluru, Guwahati, Kolkata, Jabalpur and Sikkim for town planning and design of safer structures are given. The article concludes by highlighting the need for such maps for other cities in India to be resilient during an earthquake.

The final article in the book by Gahalaut describes the real-time earthquake monitoring in India using a 150-seismological network and its efficiency in providing information to the public and government by the National Centre for Seismology. Such information has helped in allaying the panic in the affected areas.

In conclusion, the book presents a collection of articles covering the services and developments in earth sciences in the country, with highlights on socio-economic benefits. However, some of the articles, though informative, do not gel well with the book's scope, which is 'Social and economic impact of earth sciences'. Highlighting the developments and achievements in providing forecasts and warnings about natural phenomena and their impacts on society and economy using the Earth Sciences knowledge developed in India during the recent decades is a great service, and the book has achieved that.

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