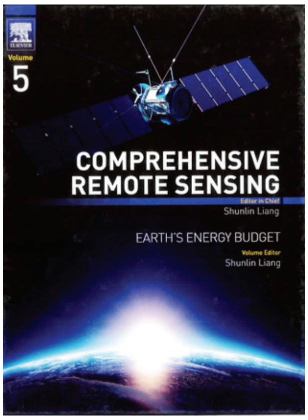
hydrocarbons. The debate as to which synthetic contaminant – pest-control chemicals or plastics – best characterizes the anthropogenic era still continues. The volume has rightly stated that while anthropogenic contaminants are increasing at an alarming rate, the old ones are slow to be retired. Also, while long-lived chemicals in the environment are problematic down the road, even short-lived chemicals have harmful effects (e.g. proliferation of pharmaceuticals and personal-care products in waterways). The volume argues that despite successes like the Montreal Protocol, most regulatory systems have been unsuccessful and remain bound to industrial interests.

These volumes succinctly summarize our knowledge on how human intervention with natural systems is affecting the basic framework of our environment and what our responsibilities are to protect the Earth. The volumes must be on the shelves of all libraries.

S. PRIYA

(S. Ramaseshan Fellow)
e-mail: priya@ias.ac.in



Comprehensive Remote Sensing: Vol. 5 – Earth's Energy Budget. Shunlin Liang (ed.), Elsevier, Radarweg 29, PO Box 211, 1000 AE Amsterdam, The Netherlands. 2018. xxii + 331 pages. Price not mentioned.

The regional climate of planet Earth is controlled by the amount of energy received from the Sun and the way it is dispersed or redistributed. The Sun, like other stars, is a variable star emitting varying energy due to sunspot and magnetic activity cycles. The amount of solar energy incident at a location on Earth is constantly modulated on a variety of timescales ranging from millennia to seasons due to periodic changes in the Earth's orbital precession, eccentricity, obliquity, etc., and the changing environmental conditions. The Earth receives maximum heat from the Sun over the tropics and distributes it polewards through atmospheric and oceanic circulations.

This book presents a multi-faceted description of satellite-based techniques on the Earth's energy balance and also provides information on various available satellite-based products and data sources. Further, it emphasizes the challenges in addressing the issue of climate change in terms of continuity of long-term accurate and calibrated records of different components of energy balance. Authors are experts in the field of satellite remote sensing and their views represent state-of-the-art in this field. The articles in the book provide recent estimates and an understanding of the Earth's energy balance of top of atmosphere (TOA), and radiative and energy budget at the surface.

Earth's energy budget refers to the balance of energy incident on the Earth system from the Sun at TOA and the energy lost to space. We require knowledge on what is the incoming shortwave radiative flux from the Sun and how much of it are reflected shortwave and emitted long-wave fluxes from the Earth. The amount of absorbed solar radiation by the Earth system plays an important role in balancing the energy during the process. The amount of solar radiation absorbed by the Earth is a function of total solar irradiance integrated over all wavelengths at the mean Earth–Sun distance and the planetary albedo of the Earth.

With the increase in population and industrialization, concentration of greenhouse gases (GHGs) in the atmosphere is increasing over the decades resulting in significant global warming. Global warming in the lower atmosphere and on the surface is because of the reduced outgoing longwave radiation (OLR) and net positive imbalance of energy due to greenhouse effects. This warming continues until the TOA energy is balanced reaching a new equilibrium state. Further, the internal and external causes are associated with many positive and negative feedbacks. The climate system is, therefore, an extremely complex one with nonlinear interactions between its components.

It is challenging to study the Earth's energy balance through accurate measurements of different radiative fluxes. Satellite observations have helped in quantifying the variations in energy balance over a range of space- and time-scales. Major concerns are in the uncertainties of estimated quantities. The book accounts for various methods of estimating the TOA energy balance as well as surface radiation budget. It provides an informative review on how meteorological satellite systems have significantly advanced the understanding of the Earth through global measurements from the Earth Radiation Budget (ERB), Earth Radiation Budget Experiment (ERBE), Clouds and Earth's Radiant Energy System (CERES), etc. This includes Geostationary Earth Radiation Budget (GERB) sensors, Broadband Bolometric Oscillation (BOS) sensor and Scanner for Radiation Budget (ScaRaB) sensor operated from various satellite missions.

Inter-sensor calibration and long-term stability in the data are important for their use as essential climate variables (ECVs). The ECVs refers to a well-characterized, long-term data record, usually involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of products that are accurate and stable, in both space and time, to support climate applications.

Implementation plan for the global observing system for climate by the Global Climate Observing System (GCOS) has emphasized the need of continuity, homogeneity and overlap of satellite observations with special emphasis on calibration and instrument characterization, and validation of products. ERB is considered as one of the most important ECVs where satellite observations can make significant contributions. Other ECVs include more than 50 geophysical parameters in the domain of atmosphere, ocean and land.

The ERB which describes the over all balance between incoming energy from the Sun and outgoing thermal (longwave) and reflected (shortwave) energy from the Earth is required to relate to the amount of radiative forcing significant with respect to global GHG forcing.

The radiation balance at the TOA is the basic radiative forcing of the climate system. Measuring its variability in space and time over the globe provides insight into the overall response of the climate system to this forcing.

The satellite measurements include solar irradiance observations as well as the broadband directional measurements of reflected solar and outgoing longwave radiation. The TOA ERB gives an important overall constraint on the surface radiation budget. Observations on cloud, temperature and water vapour profiles, aerosols, trace gases and surface properties are required for computation of surface radiation budget. Achieving the requirements for surface radiation budget, particularly the longwave surface radiation fluxes is a challenging task.

This book is systematically organized and caters to the demand of the general reader who is interested in an overview of the Earth's energy balance, as well as those researchers who are developing algorithms on any component of the energy budget. It contains informative overview by the editor, followed by chapters with specific details on algorithms and satellite data product availability on each energy balance component. It covers both TOA radiation budget and surface energy balance, and includes a review on progress regarding major components of energy balance such as total solar irradiance, surface incident shortwave radiation, surface downward longwave radiation, surface shortwave net radiation, etc. The book also brings out the complexity of satellite-based retrieval of surface geophysical parameters such as albedo (both land and sea), land surface emissivity and land surface temperature (LST). However, discussion on physical basis of detection of thermo-physical parameters and required instrumentation design needs greater attention than given in the book.

Land surface albedo is a key factor in climate models as it regulates Earth radiation balance. However, the effects of anthropogenic impacts (deforestation, intensive irrigation, urbanization, etc.) on land surface albedo change and its radiative forcing are still uncertain and need further studies. More accurate long-term global records of albedo are required to improve our understanding of surface radiative forcing (snow albedo feedback) and their long-term climate effects. The physical model and parametrization should improve, especially for large solar/view angle for better retrievals. Improving the accuracy of LST is an equally important area of research as it is a direct driving force in exchange of longwave radiation. To estimate evapotranspiration with accuracy better than 10%, it is required to know LST at an accuracy of 1K or better, which is difficult from satellite-based measurements. Atmospheric effects are a major source of noise in such applications. LST and emissivity separation from radiometric measurements in the thermal infrared region is another complex issue; this needs measurements in more number of channels and requires constraints to be imposed to reduce the number of unknowns that need to be estimated.

From the past experience, it is clear that an integrated observing system that depends upon both *in situ* and satellite-based measurements is needed in the future. The system should (a) provide information on state of the global climate system and its variability, (b) monitor the forcing of the climate system, including both natural and anthropogenic contributions, and (c) enable projection of global climate change information down to regional and local scales.

R. P. SINGH

Land Hydrology Division,
Space Applications Centre,
ISRO,
Ahmedabad 380 015, India
e-mail: rpsingh@sac.isro.gov.in