Foreword to the Special Issue on Intercalibration of Satellite Instruments

THE ABILITY to detect and quantify changes in Earth's environment using remote sensing is dependent upon sensors providing accurate and consistent measurements over time. A critical step in providing these measurements is establishing confidence and consistency between data from different sensors and putting the data onto a common radiometric scale. However, ensuring that this process can be relied upon long term and that there is a physical meaning to the information requires traceability to internationally agreed stable reference standards ideally tied to the international system of units (SI). This requires robust ongoing calibration, validation, stability monitoring, and quality assurance, all of which need to be underpinned and evidenced by comparisons involving a reference standard or sensor and a methodology with defined uncertainty (in an absolute or temporal sense). This process can be used to provide calibrations to other sensors (i.e., intercalibration).

Intercalibration and comparisons between sensors have become a central pillar in calibration and validation strategies of national and international organizations. The Global Space-based Inter-Calibration System is an international collaborative effort initiated by the World Meteorological Organization and the Coordination Group for Meteorological Satellites to monitor and harmonize data quality from operational weather and environmental satellites. The Infrared Visible Optical Sensors subgroup of the Committee on Earth Observation Satellites Working Group on Calibration and Validation extends this vision to include all Earth observation sensors and satellite operating agencies. Intercalibration techniques provide a practical means of correcting biases between sensors and bridging any potential data gaps between noncontiguous sensors in a critical time series, and the intercalibration reference serves as a transfer standard. The promotion of the use of robust intercalibration techniques is expected to improve consistency between satellite instruments, reduce overall costs, and facilitate accurate monitoring of planetary changes.

This special issue focuses on how intercalibration and comparison between sensors can provide an effective and convenient means of verifying their postlaunch performance and correcting their measurement differences. The papers contained within this special issue include topics that explore pseudoinvariant calibration sites, instrumented sites, simultaneous nadir observations and other ray-matching comparisons, lunar and stellar observations, deep convective clouds, liquid water clouds, Rayleigh scattering, and sunglint. The intercalibration results focused on rigorous quantification of bias and associated sources of uncertainty from different sensors crucial for long-term studies of Earth. There are 42 papers published in this issue. Eight papers provide general overviews that address the special issue topics, eleven papers pertain to intercalibration of geostationary imagers, seven papers address spectral characteristics in the context of intercalibration, nine papers deal with intercalibration of low Earth orbit infrared and visible optical sensors, and seven papers report the results from intercalibration of microwave instruments. The goal of this special issue is to capture the state-of-the-art methodologies and results from intercalibration of satellite instruments, including full end-to-end uncertainty analysis. Accordingly, it will become a reference anthology for the remote sensing community.

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GYANESH CHANDER, *Guest Editor*
SGT/USGS EROS
Sioux Falls, SD 57198 USA

TIM J. HEWISON, *Guest Editor*
EUMETSAT Eumetsat-Allee
Darmstadt, Germany

NIGEL FOX, *Guest Editor*
National Physical Laboratory
TW11 0LW Teddington Middx, U.K.

XIANGQIAN WU, *Guest Editor*
STAR/NESDIS/NOAA
College Park, MD 20740 USA

Digital Object Identifier 10.1109/TGRS.2013.2240331

XIAOXIONG XIONG, *Guest Editor*
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA

WILLIAM J. BLACKWELL, *Guest Editor*
MIT Lincoln Laboratory
S4-225
Lexington, MA 02420 USA

Gyanesh Chander (M'02) received the M.S. degree in electrical engineering and the Ph.D. degree in geospatial science and engineering with specialization in remote sensing engineering from South Dakota State University, Brookings, SD, USA.

He is currently a Principal Systems Engineer with SGT, Inc., Earth Resources Observation and Science (EROS) Center, U.S. Geological Survey, Sioux Falls, SD. His primary responsibilities at EROS include satellite sensor characterization and calibration research to support on-going radiometric projects. He has played a pivotal role in the calibration of Landsat sensors and development of the Landsat Image Assessment Systems. His current research focuses on intercalibration between various sensors from different platforms for mission continuity, thereby providing consistent measurements of Earth's surface features.

Dr. Chander is a member of the international Committee of Earth Observation Satellites Working Group Calibration Validation and supports the Infrared Visible and Optical Sensor's subgroup. He also serves on the Global Space-based Inter-Calibration System (GSICS) Executive Panel and actively supports the GSICS Research Working Group. He is leading the Group on Earth Observations task on data quality and interoperability. He has demonstrated exceptional national and international leadership in calibration community, chaired sessions, and workshops, participated in review panels, and has maintained a solid scientific publication record. He has also served as a guest editor for the *Canadian Journal of Remote Sensing* and IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING.

Tim J. Hewison (M'96–SM'13) received the B.S. degree in physics with astrophysics from the University of Manchester, Manchester, U.K., in 1989 and the M.Sc. and Ph.D. degrees in meteorology from the University of Reading, West Berkshire, U.K. in 1999 and 2006, respectively.

He had worked in different parts of the Met Office, U.K., on different aspects of observational theory and practice. This included five years specifying, testing, and operating ground-based remote sensing instruments and developing variational methods to retrieve atmospheric profile information from their observations for use in numerical weather prediction. Five years were spent on the radiometric and antenna testing of the Advanced Microwave Sounding Unit (AMSU-B) satellite instrument and its associated calibration. Another seven years was spent in the specification, design, and development of microwave radiometers for use on a research aircraft, including leading various experimental campaigns to measure surface emissivity and validate atmospheric absorption models. He is currently the Chair of the research working group, Global Space-based Inter-Calibration System (GSICS), which is an international collaborative effort initiated in 2005 by the World Meteorological Organization and the Coordination Group for Meteorological Satellites to monitor and harmonize data quality from operational weather and environmental satellites of the Global Observing System. Since 2007, he has been with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany, the organization responsible for operating weather satellites for Europe, on the intercalibration of satellite instruments as part of the GSICS project.

Dr. Hewison has been an active member the Geoscience and Remote Sensing Society since 1996, including writing IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING articles and reviewing. He has previous experience in coordinating a special issue of Meteorologische Zeitschrift on an international field experiment conducted for the European Cooperation in Science and Technology (COST) Action 720.

Nigel Fox received the B.Sc. degree in astronomy and physics and the Ph.D. degree, for work undertaken at the National Physical Laboratory (NPL), Teddington, U.K., dissertation entitled "The Absolute Measurement of Spectral Radiant Power," from the University College London, London, U.K., in 1981 and 1997, respectively.

Since 1981, he has been with the NPL (the U.K. national standards Laboratory), where he is currently an NPL Fellow and Head of Earth Observation. His research efforts have been largely concerned with the realization of primary radiometric scales and methods to improve their dissemination. This has largely been focused on the development and use of detectors and detector-based techniques for optical radiation measurement. In the 30 years since joining NPL, he has published more than 100 scientific papers and filed two patents. His personal research activities have spanned the spectral region from UV to TIR (200–20 000 nm) with an emphasis on detector applications. Over the last two decades, he has taken a strong interest in improving the performance and the calibration of remote sensing instrumentation, both pre- and postlaunch and has proposed a number of new techniques. In this context, he has been an active participant of the Committee on Earth Observation Satellites Working Group on Calibration and Validation (CEOS WGCV) and associated subgroups since 1996 and chair of its Infrared, Visible, and Optical Sensors subgroup since 2006. Although his expertise is focused toward the optical domain, the WGCV plenaries provide significant background and discussion on all sensor and application domains. He and his team has provided calibration support to a number of Earth Observation projects (instruments and subsystems), notably ATSR+, CHRIS, SOLSPEC, SOVIM, GERB, MODIS, HIRDLS, and, currently, EarthCare. Within CEOS and the broader Group on Earth Observations community, he has championed the concept of improved quality assurance and SI traceability, leading a number of subtasks, and played a lead role in the development and continued implementation of Quality Assurance Framework for Earth Observation (QA4EO). He currently has a contract with European Space Agency (ESA) to analyze the level of consistency of the sensors on-board Sentinels 2 and 3 with respect to QA4EO. He has also recently organized four international CEOS comparisons, funded by ESA, including both ground cal/val and satellite sensor to sensor observations. He also now leads a new EC FP7 funded project to establish a virtual "European Metrology Centre for Earth Observation and Climate." In the broader metrology context, he represents the U.K. on a number of international metrology committees including the Consultative Committee for Photometry and Radiometry, the international committee responsible for the SI system units relating to optical radiation measurements, and is also the official liaison between that committee and the World Meteorological Organization. In addition to serving as a normal peer reviewer for a range of journals, he has also provided academic grant application reviews within the U.K. and also internationally.

Dr. Fox has served on the technical organizing committee of a variety of international conferences and workshops (some as chair), where he also provided guest editorial for peer-review journals such as *Metrologia*. He is also on the editorial board of the journal *Measurement*.

Xiangqian (Fred) Wu (M'05) received the B.S. degree in geography from Beijing Normal University, Beijing, China, in 1982 and the M.S. and Ph.D. degrees in meteorology from the University of Wisconsin, Madison, WI, USA, in 1986 and 1990, respectively.

He was a Research Scientist with the University of Wisconsin, where he applied satellite data for climate, oceanic, and meteorological studies such as upper tropospheric humidity, sea surface temperature, and data assimilation for numerical weather prediction. Since 2002, he has been with the Sensor Physics Branch, Center for Satellite Applications and Research (STAR), National Environmental Satellite, Data, and Information Service (NESDIS), National Oceanic and Atmospheric Administration (NOAA), College Park, MD, USA, where he is currently a Physical Scientist. He serves as the Instrument Scientist for the Advanced Very High Resolution Radiometer and for the Imager and Sounder instruments on Geostationary Operational Environmental Satellites (GOES). He chairs NESDIS Calibration Product Oversight Panel that provides calibration support for NOAA's satellite operations, and he also shares his technical and management expertise to support NOAA's future satellite systems including Joint Polar Satellite System and GOES-R. He is a founding member of the Global Space-based Inter-Calibration System Research Working Group and served as its first chair. He regularly reviews manuscripts submitted for journal publication, organizes workshops, and chairs sessions for professional conferences. In 2008, Dr. Wu was a member of the Scientific Programme Committee (SPC) of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Conference on Satellite Meteorology that reviewed 368 abstracts. In 2005, he was a member of the Technical Program Committee, International Geosciences and Remote Sensing Symposium, and served as the Theme Coordinator for Instrumentation and Sensor Techniques that reviewed 101 abstracts and organized them into 13 oral and 4 poster sessions.

Xiaoxiong (Jack) Xiong (M'12) received the B.S. degree in optical engineering from Beijing Institute of Technology, Beijing, China, and the Ph.D. degree in physics from the University of Maryland, College Park, MD, USA.

He is an Optical Physicist with NASA Goddard Space Flight Center (GSFC), working on EOS Terra and Aqua MODIS, NPOESS Preparatory Project, and Joint Polar Satellite System VIIRS sensor calibration and characterization. He is currently serving as the MODIS Project Scientist for the instrument operation and calibration and the technical lead for both MODIS and VIIRS Calibration Support Teams. Before joining the NASA GSFC, he had also worked in the fields of optical instrumentation, nonlinear optics, laser/atomic spectroscopy, and mass spectrometry with private industry and with the National Institute of Standards and Technology.

Dr. Xiong is an active member of the GSICS Research Working Group and the Infrared and Visible Optical Sensors subgroup of Committee on Earth Observation Satellites Working Group on Calibration and Validation. In addition to his research activities, he has served as Chair and Program Committee for SPIE Optics and Photonics Conference on Earth Observing System and SPIE Asia Pacific Remote Sensing Conference on Earth Observing Missions and Sensors: Development, Implementation, and Characterization; Session Chair and Program Committee for SPIE Europe Remote Sensing Conference on Sensors, Systems, and Next-Generation Satellites; editor and reviewer for SPIE conference proceedings; associate editor for the *Journal of Applied Remote Sensing* (JARS) and the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING (TGRS); and reviewer for a number of journals, such as TGRS, *Journal of Geographic Reserarch*, JARS, and IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, and NASA and NOAA research and development proposals.

William J. Blackwell (S'92–M'02–SM'07) received the B.E.E. degree in electrical engineering from the Georgia Institute of Technology, Atlanta, GA, USA, in 1994 and the S.M. and Sc.D. degrees in electrical engineering and computer science from the Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, in 1995 and 2002, respectively.

He is a Senior Member of the technical staff, MIT Lincoln Laboratory, where he leads a number of programs related to Earth Environmental Monitoring for NASA, NOAA, and the Department of Defense. Recent leadership positions include Sensor Scientist for the Advanced Technology Microwave Sounder on the NPOESS Preparatory Project planned for launch in 2011, Atmospheric Algorithm Development Team Leader for the NPOESS Microwave Imager/Sounder, and funded Science Team participation for the Aqua, NPP, and Joint Polar Satellite System missions. He has authored or coauthored over 60 publications related to atmospheric remote sensing, including *Neural Networks in Atmospheric Remote Sensing* (Artech House, 2009).

Dr. Blackwell held a National Science Foundation Graduate Research Fellowship from 1994 to 1997. He is a member of Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi, Sigma Xi, the American Meteorological Society, the American Geophysical Union, Commission F of the International Union of Radio Science. He was a recipient of the 2009 NOAA David Johnson Award for his work in neural-network retrievals and microwave calibration. He is currently an Associate Editor of the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING and the IEEE Geoscience and Remote Sensing Society (GRSS) Newsletter and the Chair of the IEEE GRSS Frequency Allocations in Remote Sensing technical committee.