Foreword to the Special Issue on COSMO-Skymed First and Second Generation Exploitation

EARTH OBSERVATION (EO) via satellite sensors to image the Earth, day and night and in almost all weather conditions at high-spatial resolution, attracted the scientific and industrial interests in 1950s of the last century [1]. Synthetic aperture radar (SAR) technology advanced in classified and nonclassified formats leading, in the late 1960s, to the well-known Goodyear SAR system [1].

From its early stage, it was clear that SAR was an important tool to help monitoring Earth environment [2], [3]. A SAR is an active microwave high-spatial resolution imaging sensor acting as a microwave transducer of the electromagnetic field scattered by the scene. In other terms, a SAR is a filter that estimates the scene backscattering. Therefore, a SAR image is not a simple and straightforward representation of the geophysical quantity of interest, and the interpretation step calls for a physical modeling and inverse problem to be dealt with [2], [3].

In the first years of SAR era, some satellite scientific missions were launched not only to demonstrate the SAR technology capability but also to promote and foster scientific interpreting skills. The interdependency of technology, science, and user needs is crucial in all SAR systems. This multidisciplinary has allowed extending SAR modes and their use toward operational services.

In 2003, the Agenzia Spaziale Italiana (ASI), supported by the Ministero dell'Università e della Ricerca (MIUR) and the Ministero della Difesa (MD), commissioned and funded the COSMO-SkyMed (COnstellation of small Satellites for the Mediterranean basin Observation) constellation. Thales Alenia Space Italy was the industrial prime contractor for the space segment having direct responsibility for the design, manufacturing, and qualification of the COSMO-SkyMed (CSK) end-to-end system. In the overall project, small-medium sized Italian enterprises also contributed, while the ground segment prime contractor was Telespazio [4], [5].

The four satellite multimode X-band SARs were effectively deployed from June 2007 to November 2010 building up the largest Italian environmental laboratory. The CSK system can be tasked to support user requests that are institutional, scientific, and commercial, ensuring short revisit time and multimode acquisitions [4], [5]. The CSK relevance was witnessed by several international cooperation and a large scientific participation to ASI data calls [5]. The value and benefit of the CSK system in supporting environmental and civil protection actions were further underlined its use in several operational bodies, e.g., the Italian Dipartimento di Protezione Civile, the Italian Ministero dell'Ambiente e della Tutela del Territorio e del Mare, the Italian Ministero degli Interni, the Italian Ministero dei Trasporti, the World Food Program (UN), and the Eduador ETAPA EP, EMSA, and UE JRC.

In view of this success, a follow-on of the CSK system that is meant to integrate and enhance it has been planned. COSMO-SkyMed second generation (CSK-2) is made of two-satellite SAR sensors similar to the ones on-board of the actual system but with some important enhancements, i.e., the coherent dual and full-polarimetric SAR capability [4], [5]. The CSK-2 satellites, funded jointly between MIUR and MD and commissioned by ASI, will be deployed in 2016–2017 to further improve the observing power of the existing constellation.

The national and international scientific community was soon able to publish several scientific papers exploiting CSK SAR data. New specific models and inversion procedures to generate CSK value-added products were proposed. However, no special issue collected on a single journal provides such scientific ideas and outcomes. The interested reader can find these papers mostly in IEEE Geoscience and Remote Sensing publications. The two main topics of interest were marine/maritime and land/urban/vegetation, e.g., [6]–[16]. Several other papers regarding snow, atmosphere applications, and SAR technology were also published in past years, e.g., [17]–[21]. Key scientific results and outcomes were achieved, for instance, in [16], the first ever CSK SAR coseismic interferogram has been published.

In this special issue, the papers provide a reliable summary of the wide spectrum of studies carried on CSK data exploitation. A brief summary follows.

In [22], the authors look to the technological and operational aspects of the CSK mission with special emphasis to user needs and its interoperability, expandability, and capability. This paper illustrates how, since its launch, the CSK system has been continuously qualified and controlled to ensure high-quality performances [22]. In [23], the benefit of high revisit time connected to the CSK constellation is explored to monitor oil spill at sea. The case of the Shell Gannett Alpha platform oil spill occurred in North Sea is detailed. In [24], another marine application is examined with reference to CSK single-polarization stripmap Himage mode: the coastline extraction. It is shown that in the challenging case of low-to-moderate wind regime, the new procedure applies well [24]. In [25], a procedure for sea bathymetry estimation is proposed and tested over CSK SAR stripmap images acquired in Gulf of Napoli, Italy. In [26], another paper dealing with marine environment is presented. The authors describe a novel

Digital Object Identifier 10.1109/JSTARS.2014.2346413

approach to focus moving targets well at sea [26]. CSK SAR images acquired in spotlight mode are exploited to test the procedure [26]. In [27], the coastal management application is considered. Hence, a study based on the exploitation of CSK SAR Ping-Pong mode is proposed and tested to sort out sea, vegetation, and urban areas [27].

The paper [28] illustrates how CSK stripmap mode can be exploited to monitor flood events. Multitemporal and interferometric SAR (InSAR) data are exploited to test the procedure over a flood event occurred in Southern Italy. The denser revisit time due to the CSK constellation system is an unprecedented chance to improve multitemporal SAR data analysis and is exploited also in [29], where a tree-structured Markov random field algorithm is exploited and tested over CSK SAR data. Even in [30], a flood study is accomplished: a combined approach that exploits both CSK SAR data and hydrodynamic modelling. A show case relevant to a flood event occured in 2010 in Albania is examined [30]. Conversely, in [31], semi-arid areas of interest are taken into account. In such environment, the authors look how CSK SAR data can assist the monitoring of small water reservoirs. The study is applied over a semiarid region in Burkina Faso [31].

A different topic is considered in [32]: in view of the Italian-Argentinian SIASGE project, the data fusion of multi-frequency SARs and optical data is examined by means of a support vector machine approach. In [33], a multisensor approach, embodying the use of CSK SAR data, is exploited to monitor a volcano eruption in Chile. In [34], another important environmental case is considered: the Lunigiana (Northern Italy) earthquake. It is shown how differential interferometry SAR (DInSAR) applied over CSK SAR data once assisted by geophysical interpretation is good enough to generate high-quality products of great relevance in civil protection [34]. In [35], the popular Persistent Scatterer SAR Interferometry approach is at the basis of a new approach named Persistent Scatterer Pair (PSP) to exploit CSK high-resolution images. The paper [36] moves to consider urban scenarios. The authors consider the CSK spotlight mode and an automatic technique to extract key information relevant to urban areas [36]. Papers [37] and [38] cover another important topic: SAR tomography, a technique relevant to urban areas monitoring. In [37], the authors propose a new multilook approach for fine-resolution analysis of ground structures that combines SAR tomography, and a method meant for classical DInSAR analysis at coarse resolution. Differently in [38], the authors look at the benefit of compressive sensing (CS) in SAR tomography. In [39], a novel multibaseline InSAR approach is described.

In [40], the authors study the capability of CSK SAR data to monitor agricultural areas. Two agricultural areas in Italy are monitored via CSK SAR data at different stages of the vegetation cycle. Himage and Ping-Pong CSK SAR modes are acquired to assist electromagnetic model interpretation. In [41], an application of Spotlight InSAR to the investigation of a landslide occurred in a rural area is showed.

The Guest Editors would like to thank the IEEE Geoscience and Remote Sensing Society for its support to publish this special issue. Thanks are due to J. Chanussot, JSTARS Editor, and A. McLean, IEEE Staff Editor, for the fundamental support received in the preparation of this special issue. We also thank the reviewers of the papers, who were at the core of the selection process. The Italian Space Agency and all the workers involved in the realization of the CSK and CSK-2 system are acknowledged. Special thanks are due to the ASI COSMO-SkyMed Department and to F. Caltagirone and A. Coletta for their precious support.

ROBERTO BATTISTON, *Guest Editor*
Agenzia Spaziale Italiana
00133 Roma, Italy

MAURIZIO MIGLIACCIO, *Guest Editor*
Dipartimento di Ingegneria, Centro Direzionale
Università di Napoli Parthenope
80143 Napoli, Italy

SALVATORE STRAMONDO, *Guest Editor*
Istituto Nazionale di Geofisica e Vulcanologia
00143 Roma, Italy

REFERENCES

[1] C. A. Wiley, "Synthetic aperture radars," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 21, no. 3, pp. 440–443, May 1985.

[2] C. Elachi, *Spaceborne Radar Remote Sensing: Applications and Techniques*. Piscataway, NJ, USA: IEEE Press, 1987.

[3] W. G. Rees, *Physical Principles of Remote Sensing*. Cambridge, U.K.: Cambridge Univ. Press, 2001.

[4] F. Caltagirone, "Architecture and evolution of COSMO-SkyMed," *Space Mag.*, vol. 2, no. 5, pp. 24–33, 2014.

[5] M. Virelli, A. Coletta, and M. L. Battagliere, "ASI COSMO-SkyMed: Mission overview and data exploitation," *IEEE Geosci. Remote Sens. Mag.*, vol. 2, no. 2, pp. 64–66, Jun. 2014.

[6] M. Migliaccio, F. Nunziata, A. Montuori, and R. L. Paes, "Single-look complex COSMO-SkyMed SAR data to observe metallic targets at sea," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 5, no. 3, pp. 893–901, Jun. 2012.

[7] F. Nunziata and M. Migliaccio, "On the COSMO-SkyMed pingpong mode to observe metallic targets at sea," *IEEE J. Ocean. Eng.*, vol. 38, no. 1, pp. 71–79, Jan. 2013.

[8] F. Baselice and G. Ferraioli, "Unsupervised coastal line extraction from SAR images," *IEEE Geosci. Remote Sens. Lett.*, vol. 10, no. 6, pp. 1350–1354, Nov. 2013.

[9] F. Nunziata, M. Migliaccio, X. Li, and X. Ding, "Coastline extraction using dual-polarimetric COSMO-SkyMed pingpong mode SAR data," *IEEE Geosci. Remote Sens. Lett.*, vol. 11, no. 1, pp. 104–108, Jan. 2014.

[10] H. Zhang, X. Tian, C. Wang, F. Wu, and B. Zhang, "Merchant vessel classification based on scattering component analysis for COSMO-SkyMed SAR images," *IEEE Geosci. Remote Sens. Lett.*, vol. 10, no. 6, pp. 1275–1279, Nov. 2013.

[11] P. T. Brett and R. Guida, "Earthquake damage detection in urban areas using curvilinear features," *IEEE Trans. Geosci. Remote Sens.*, vol. 51, no. 9, pp. 4877–4884, Sep. 2013.

[12] S. Stramondo, M. Chini, C. Bignami, S. Salvi, and S. Atzori, "X-, C-, and L-band DInSAR investigation of the April 6, 2009, Abruzzi earthquake," *IEEE Geosci. Remote Sens. Lett.*, vol. 8, no. 1, pp. 49–53, Jan. 2011.

[13] M. Chini, L. Pulvirenti, and N. Pierdicca, "Analysis, and interpretation of the COSMO-SkyMed observations of the 2011 Japan Tsunami," *IEEE Geosci. Remote Sens. Lett.*, vol. 9, no. 3, pp. 467–471, May 2012.

[14] L. Pulvirenti, N. Pierdicca, M. Chini, and L. Guerriero, "Monitoring flood evolution in vegetated areas using COSMO-SkyMed data: The Tuscany 2009 Case Study," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 6, no. 4, pp. 1807–1816, Aug. 2013.

[15] M. Motagh, J. Beavan, E. J. Fielding, and M. Haghshenas, "Postseismic ground deformation following the September 2010 Darfield, New Zealand, Earthquake from TerraSAR-X,COSMO-SkyMed, and ALOS InSAR," *IEEE Geosci. Remote Sens. Lett.*, vol. 11, no. 1, pp. 186–190, Jan. 2014.
[16] S. Stramondo *et al.*, "Ground deformation imagery of the May Sichuan Earthquake," *Eos*, vol. 89, no. 37, Sep. 9, 2008.
[17] S. Pettinato *et al.*, "The potential of COSMO-SkyMed SAR images in monitoring snow cover characteristics," *IEEE Geosci. Remote Sens. Lett.*, vol. 10, no. 1, pp. 9–13, Jan. 2013.
[18] T. Schellenberger, B. Ventura, M. Zebisch, and C. Notarnicola, "Wet snow cover mapping algorithm based on multitemporal COSMO-SkyMed X-BandSAR images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 5, no. 3, pp. 1045–1053, Jun. 2012.
[19] L. Pulvirenti, F. S. Marzano, N. Pierdicca, S. Mori, and M. Chini, "Discrimination of water surfaces, heavy rainfall, and wet snow using COSMO-SkyMed observations of severe weather events," *IEEE Trans. Geosci. Remote Sens.*, vol. 52, no. 2, pp. 858–869, Feb. 2014.
[20] P. Lombardo, F. Colone, and D. Pastina, "Monitoring and surveillance potentialities obtained by splitting the antenna of the COSMO-SkyMed SAR into multiple sub-apertures," *IEE Proc. Radar Sonar Navig.*, vol. 153, no. 2, pp. 104–116, Apr. 2006.
[21] P. Guccione, A. Monti Guarnieri, and M. Zonno, "Azimuth antenna maximum likelihood estimation by persistent point scatterers in SAR images," *IEEE Trans. Geosci. Remote Sens.*, vol. 52, no. 2, pp. 947–955, Feb. 2014.
[22] F. Caltagirone *et al.*, "The COSMO-SkyMed dual use earth observation program: Development, qualification, and results of the commissioning of the overall constellation," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[23] Y. Cheng *et al.*, "Monitoring of Gannett oil spill trajectories with COSMO-SkyMed X-band SAR images and model simulation," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[24] A. Buono, F. Nunziata, L. Mascolo, and M. Migliaccio, "A multi-polarization analysis of coastline extraction using X-band COSMO-SkyMed SAR data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[25] A. Renga *et al.*, "SAR bathymetry in the Tyrrhenian Sea by COSMO-SkyMed data: A novel approach," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[26] M. Martorella, D. Pastina, F. Berizzi, and P. Lombardo, "Spaceborne radar imaging of non-cooperative maritime targets with the COSMO-SkyMed SAR system," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[27] M. Migliaccio, L. Mascolo, F. Nunziata, M. Sarti, and G. Mazzarella, "COSMO-SkyMed HH/VV PingPong mode SAR data to discriminate among sea, urban and vegetated areas," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[28] A. Refice *et al.*, "SAR and InSAR for flood monitoring: Examples with COSMO-SkyMed data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[29] R. Gaetano *et al.*, "Exploration of multitemporal COSMO-SkyMed data via tree-structured MRF segmentation," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[30] L. Pulvirenti, N. Pierdicca, G. Bonia, M. Fiorini, and R. Rudari, "Flood damage assessment through multi-temporal COSMO-SkyMed data and hydrodynamic models: The Albania 2010 case study," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[31] D. Amitrano *et al.*, "Modeling watershed response in semi-arid regions with high resolution synthetic aperture radars," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[32] N. Pierdicca, M. Chini, and F. Pelliccia, "The contribution of SIASGE radar data integrated with optical images to support thematic mapping at regional scale," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[33] C. Bignami *et al.*, "Multi-sensor satellite monitoring of the 2011 Puyheue-Cordon Caulle Eruption," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[34] S. Stramondo *et al.*, "X- and C-band SAR surface displacement for the 2013 Lunigiana earthquake (Northern Italy): A breached relay ramp?," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[35] M. Costantini *et al.*, "Persistent scatterer pair interferometry on high-resolution COSMO-SkyMed SAR data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[36] G. Di Martino, A. Iodice, D. Riccio, and G. Ruello, "Power spectra of very high resolution SAR amplitude images of urban areas," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[37] G. Fornaro, A. Pauciullo, D. Reale, and S. Verde, "Multilook SAR tomography for 3D reconstruction and monitoring of single structures with COSMO-SKyMed stripmap mode data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[38] A. Budillon and G. Schirinzi, "Tomographic compressive sampling detector tested on COSMO-SkyMed data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[39] F. Baselice, A. Budillon, G. Ferraioli, V. Pascazio, and G. Schirinzi, "Multi-baseline SAR interferometry from complex data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[40] M. Brogioni *et al.*, "The sensitivity of COSMO-SkyMed backscatter to agricultural crop type and vegetation parameters," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.
[41] P. Milillo, E. Fielding, W. Shultz, B. Delbridge, and R. Burmann, "COSMO-SkyMed spotlight interferometry over rural areas: The Slumgullion landslide in Colorado, USA," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, to be published.

Roberto Battiston is the President of the Italian Space Agency (ASI), Rome, Italy. He was the Former President of the INFN National Committee on Astroparticle Physics. He is a Full Professor of Experimental Physics with the Università di Trento, *Trento*, Italy. Jointly with the Nobel Prize Laureate S. C. C. Ting, he developed and leads the Alpha Magnetic Spectrometer (AMS) experiment on International Space Station (ISS). He is a PI or Co-PI of various research projects on magnetic active screens for astronauts protection during exploration mission. He developed new methods to use the Van Hallen belts to monitor earth seismicity from space. He has published more than 435 peer-reviewed journal papers on experimental fundamental and particle physics.

Prof. Battiston is a recipient of a Laurea Honoris Causa from the University of Bucharest, Bucureşti, Romania. He started the series of Space Part International Conferences on Particle and Fundamental Physics in Space.

Maurizio Migliaccio (M'91–SM'00) is a Full Professor of Electromagnetics with the Università di Napoli Parthenope, Napoli, Italy, and an Affiliated Full Professor with the NOVA Southeastern University, Fort Lauderdale, FL, USA.

He has been teaching microwave remote sensing since 1994. He was a Visiting Scientist with the Deutsche Forschungsanstalt fur Lüft und Raumfahrt (DLR), Oberpfaffenhofen, Germany. He lectured in Italy, USA, Germany, Spain, Czech Republic, and China. He is an Italian Delegate with the UE COST SMOS Mode Action. He is the Chairman of the Telecommunication Courses with the Università di Napoli Parthenope. He published more than 110 peer-reviewed journal papers on remote sensing and applied electromagnetics. His research interests include SAR oil slick and man-made target monitoring, remote sensing for marine and coastal applications, polarimetry, inverse problem for resolution enhancement, and reverberating chambers.

Prof. Migliaccio was a member of the Italian Space Agency Scientific Committee. He is a member of ASI CSG panel. He is an Associate Editor of *International Journal of Remote Sensing*, Associate Editor of the IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING Special Issue on CosmoSKyMed, and Member of the *Indian Journal of Radio and Space Physics* Editorial board. He was a Promoter and Organizer of the IEEE GOLD Remote Sensing Conferences and Chairman of the IEEE GRS South Italy Chapter.

Salvatore Stramondo (M'05–SM'14) received the M.S. (laurea) degree in electronic engineering from the University "La Sapienza," Roma, Italy, in 1996, and the Ph.D. degree in geoinformation from the University "Tor Vergata," Roma, Italy, in 2007.

He joined the Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy, in 1997, where he is currently Head of Satellite Earth Observation Data unit. In 2003–2009, he has been an Adjunct Professor of Remote Sensing and Cartography and Topography with the University of Calabria, Rende, Italy. He was an Invited Researcher with the CNR-IRECE, Napoli, Italy, in 1997; IPGP, Paris, France, 1998; JPL, Pasadena, CA, in 2000; and IIT, Bombay, India, in 2001. He is a Scientific and Technical Coordinator of the APhoRISM FP7 project and TERRAFIRMA Tectonic Theme GSE project. He is the author of 50 international papers. His research interests include SAR interferometry techniques and geophysical applications.

Dr. Stramondo has been Chairman and Co-Chairman at several international conferences. He is the Editor of *Remote Sensing* journal, *International Journal of Applied Earth Observation and Geoinformation*, and the Associate Editor of IEEE GEOSCIENCE AND REMOTE SENSING LETTERS. He is a Member of Board of Directors of the Italian Association of Remote Sensing.