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A satellite stand-alone procedure for deriving net radiation by using SEVIRI and MODIS products

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ABSTRACT

In this study, a new stand-alone satellite approach for the estimation of net surface radiation (R_n) has been implemented and validated for the Italian territory. The method uses the MODIS and MSG-SEVIRI time series products and it is independent of the use of ancillary data (i.e. ground measurements). A database of daily measurements of R_n, provided by 9 stations of the FLUXNET network, was used to validate the method in different ecological scenarios in the period 2010-12.

The R_n modelled by the proposed approach and the corresponding FLUXNET measurements were in good agreement, with RMSE and R^2 of 19.8 Wm^{-2} and 0.87, respectively, at 8-days scale, and 23.3 Wm^{-2} and 0.92, respectively, at daily scale.

Therefore, the proposed approach can be considered effective for the estimation of spatial and temporal variability of R_n, which is a key variable related to the management of water resources, agriculture, ecology and climate change.

1. Introduction

Net surface radiation (R_n) is the main driver for energy balance involved Earth processes, encompassing the total energy available for most of physical and biological activities (Carmona et al., 2015; Pan et al., 2015; Soltani et al., 2017). In numerical terms, R_n consists of the sum of 4 components: the downward/incoming short ($R_{ss\downarrow}$) and long ($R_{sl\downarrow}$) wave radiation and the upward/outgoing long ($R_{sl\uparrow}$) and short ($R_{ss\uparrow}$) wave radiation. An accurate determination of R_n is critical for the assessment of R_n-dependent processes (such as evapotranspiration, ET), since any error in its estimation will derive in miscalculations. R_n calculation is not an easy task, since multiple time and space changing atmospheric and land surface parameters are involved in it, including surface albedo (α), surface emissivity (ε_0), and land surface temperature (T_s).

Traditionally, R_n has been measured using field instruments (such as, pyrradiometer, pyranometer, pyrgeometer and net radiometer). Several ground-based networks for radiation measurements are spread around the world, as Global Energy Balance Archive (GEBA, Ohmura et al., 1989; Gilgen and Ohmura, 1999); Word Radiation Monitoring Center - Baseline Surface Radiation Network (WRMC-BSRN, Ohmura et al., 1998); Surface Radiation Budget Network (SURFRAD, Augustine et al., 2000, 2005); and FLUXNET (Baldocchi et al., 2001). In particular, GEBA is a database for surface energy fluxes measurements, maintained by the Institute for Climate and Atmospheric Sciences at ETH Zurich. It contains more than 2500 stations worldwide distributed, providing monthly averages of the surface energy balance components. BSRN became operational in 1992 and it consists on 48 stations placed all around the world in different climatic zones that provide observations of the short- and long-wave surface radiation fluxes with a high sampling rate. Established in 1993, SURFRAD is composed by 7 operational stations that provide long-term measurements of the surface radiation budget over the United States. FLUXNET global network consists of more than 500 micro-meteorological tower sites that measure the exchanges of carbon dioxide, water vapour, and surface energy fluxes between terrestrial ecosystems and the atmosphere.

Nevertheless, the data provided by ground measurements refers only to point-scale and their quality is greatly affected by instrumental error and/or maintenance faults (uncorrected sensor configurations or calibration), and land surface and atmosphere heterogeneities (Llasat

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Table 1
Summary of the spatial and temporal information of MODIS and SEVIRI products used in this study.

Data input	Sensor	Pixel size (km)	Temporal resolution	
			Daily	8-day
T_s (day-night), ε_o	MODIS	1	MOD11 A1	MOD11 A2
α		0.5		MCD43A3
$R_{ss\downarrow}$	SEVIRI	4	DIDSSF LSA-09	
$R_{sl\downarrow}$			DIDSLF LSA-12	

Table 2
FLUXNET data availability (X) within Italy region into the reference period 2010–12.

Site Code	Site Name	2010	2011	2012
IT-CA1	Castel d'Asso 1			X
IT-CA2	Castel d'Asso 2			X
IT-CA3	Castel d'Asso 3			X
IT-Col	Collelongo	X	X	X
IT-Lav	Lavarone	X	X	X
IT-MBo	Monte Bondone	X	X	X
IT-Ren	Renon	X	X	
IT-Ro2	Roccarespampani 2	X	X	
IT-Ro4	Roccarespampani 4			X

and Snyder, 1998; Wilson et al., 2002; Foken et al., 2006; Foken, 2008; Jacobs et al., 2008). In addition, it is difficult to extend the measurements made at specific locations up to regional scales (Blad et al., 1998), due to the strong influence of surface heterogeneity. Despite these limitations, the quality assurance and the data quality control performed at these networks allow their use for validating and evaluating satellite-based estimates of surface radiative fluxes.

Unlike ground-based observations, remotely sensed observations have the advantage of global coverage. In the last decades, a wide number of radiation products derived from satellite has been developed, highlighting: Earth Radiation Budget Experiment (ERBE, Smith et al., 1977; Jacobowitz et al., 1979, 1984; Barkstrom and Smith, 1986); Clouds and the Earth's Radiant Energy System (CERES, Wielicki et al., 1998); International Satellite Cloud Climatology Project (ISCCP, Zhang et al., 2004); Geostationary Earth Radiation Budget Project (GERB, Harries et al., 2005); and Surface Radiation Budget project (SRB, Cox et al., 2006). In addition, several surface radiation products have been derived from multispectral sensors such as Spinning Enhanced Visible and Infrared Imager (SEVIRI) aboard METEOSAT Second Generation (MSG) satellites; Visible Infrared Spin Scan Radiometer (VISSR) and Advanced Baseline Imager (ABI) on board Geostationary Operational Environmental Satellites (GOES); and Moderate Resolution Imaging Spectroradiometer (MODIS) aboard TERRA and AQUA satellites. However, one of the main limitation of approaches estimate R_n by using satellite data is that they usually requires ancillary data (i.e. ground measurements, such as maximum and minimum air temperature).

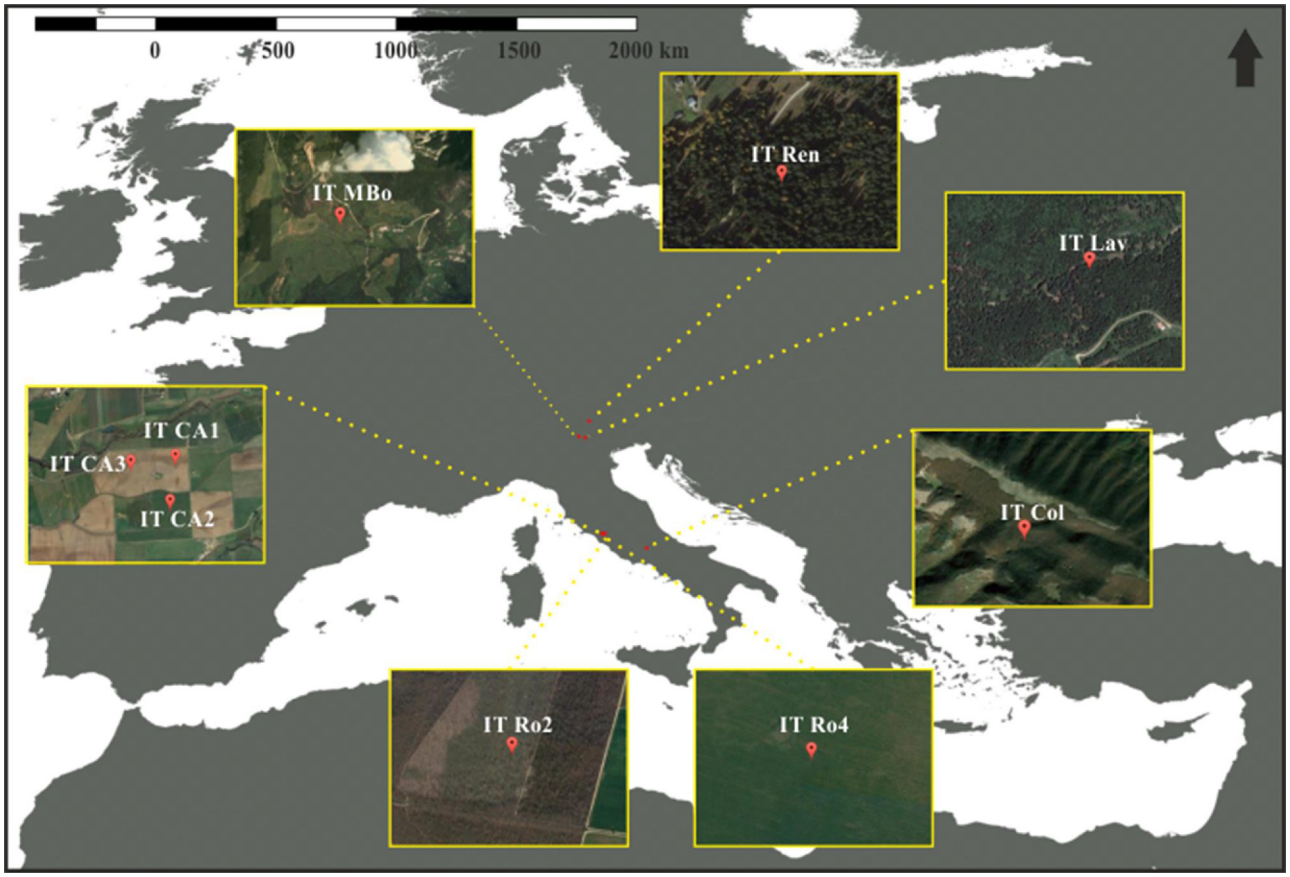

Fig. 1. FLUXNET sites selected in the study area within the reference period 2010–12.