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## The versatile Heliosat-V method for estimating downwelling surface solar irradiance from satellite imagery

**Benoit Tournadre**, Benoit Gschwind, Yves-Marie Saint-Drenan, and Philippe Blanc

O.I.E. - Centre Observation, Impacts, Energy, MINES ParisTech, PSL Research University, Sophia Antipolis, France

(benoit.tournadre@mines-paristech.fr)

Downwelling surface solar irradiance (DSSI) is one of the Essential Climate Variables defined by the Global Climate Observing System. The knowledge of its space and time variabilities is of primary importance for different applications, including Earth sciences, agriculture and renewable solar energies. To characterize such variabilities, the retrieval of long time series and of a dense kilometric global spatial coverage is required. The Heliosat methods are developed by Mines ParisTech since the mid-1980's to estimate DSSI from the imagery produced by geostationary meteorological satellites. A challenge today is to use imagery from different satellites, including non-geostationary. This raises a number of issues, related among others to the different viewing geometries and spectral sensitivities of the sensors. These issues motivate the evolution of the Heliosat methods toward a more flexible version: the versatile Heliosat-V method. Other difficulties, mainly of operational types, such as massive data retrieval/processing, geometric correction, radiometric cross-calibration, missing data, seamless mosaicking, etc. are out of the scope of this communication.

Heliosat-V is designed to produce estimates of DSSI that can cover a wide variety of satellite optical sensors that have at least one radiometric channel with sensitivity in the 400-1000-nm part of the electromagnetic spectrum. The method is capable of using calibrated imagery from geostationary and also non-geostationary satellites. External remote-sensed data of surface reflectance anisotropy (Ross-Li model parameters derived from the imagery of the Moderate-Resolution Imaging Spectroradiometer (MODIS)) and atmospheric composition (ozone, water vapour and aerosol types and optical depths) from coupled meteorological and chemical transport models (Copernicus Atmospheric Monitoring Services) are used to produce fast radiative transfer simulations. Typical reflectances of cloudy scenes at the top of the atmosphere are produced via look-up tables derived from a radiative transfer model (libRadtran). They can adapt to the spectral sensitivity of the satellite channel, and to the solar and viewing geometries. This algorithm setup allows its use without past data, which were necessary for previous Heliosat methods. This is a real asset for its implementation to non-geostationary satellites.

We test the validity of the method, by comparing DSSI estimates derived from one year of Meteosat Second Generation 0° imagery, with ground-based pyranometer measurements from 10 stations of the Baseline Surface Radiation Network, on different continents and environments. Our

results show root-mean square errors of 15-min averaged DSSI between 12% and 35% (71 and 133  $\text{W m}^{-2}$  in absolute value), similarly to existing surface irradiance products based on Heliosat-2 or Heliosat-4.