Copernicus Sentinel-2 Calibration and Validation

Copernicus, the European Commission’s (EC) Earth Observation Program launched the Sentinel-2A and Sentinel-2B satellites in 2015 and 2017, respectively. The Copernicus program, formerly called the Global Monitoring for Environment and Security (GMES), started in 1998 with the overarching aim to become Europe’s operational Earth Observation monitoring system providing data and information services. An essential part of the program is the space component, which is managed by the European Space Agency (ESA), responsible for the Copernicus Sentinel Satellite Constellations.

One of them, the Copernicus Sentinel-2 optical mission (S2) systematically collects multispectral land surface imagery by two satellites with a revisit cycle of 5 days at 10 m, 20 m and 60 m spatial resolutions. Their single instrument is the Multispectral Imager (MSI) that collects data in 13 spectral bands using a pushbroom technology with a wide field of view (290 km).

This special issue covers initial calibration and validation activities related to S2 mission. The Mission Performance Centre (MPC) as part of the European Space Agency’s S2 ground segment carries out the routine S2 calibration and validation activities operationally. In order to guarantee the required data quality as established in the S2 Mission Requirements Document (Drusch, Gascon, & Berger, 2010) (Table 1), the quality of the mission data is monitored by the S2 Quality Working Group (QWG) where Copernicus Services are represented.

In addition, EC and ESA agreed to have their activities complemented and supported by independent studies collecting additional and independent validation evidence and providing valuable feedback on the mission core products. Experts involved in these receive an invitation to become part of the so-called Sentinel-2 Validation Team (S2VT). Their recommendations go directly to the S2 QWG and, where appropriate, proposed to the mission responsible (EC and ESA) for implementation.

The S2VT met for the first time in 2016 and this special issue dwells on the broad portfolio of aspects covered during this initial meeting. At that time, only the first Sentinel-2 satellite, called “Sentinel-2A”, had been launched and therefore, this issue focuses on results of this satellite unit. Sentinel-2B reached orbit in 2017 and will be included in future issues.

S2VT work presented here mainly focused on Level-1C product type. However, certain authors (Gorroño et al., 2018; Ariza, Irizar, & Bayer, 2018; Keukelaere et al., 2018; Ressl & Pfeifer, 2018) also worked on other product levels (−1B, −2A). For the sake of clarity, a brief outline of these levels is as follows:

Product Level-1B – data are in Top of Atmosphere (ToA) radiance in sensor geometry, dark signal, pixel response non-uniformity, defective pixels interpolation and restoration is done for radiometric corrections, while coarse registration among bands and among staggered detectors and a refined geometrical viewing model based on the Global Reference Image are done for image geometry. This level of data is usually not distributed by ESA and only available upon a reasoned request.

Product Level-1C – data are based on the Level-1B data and they are provided to the users as ToA reflectances in cartographic geometry (UTM/WGS84). The products are orthorectified based on a 90 m spatial resolution global Digital Elevation Model (PlanetDEM90).

Product Level-2A – data are based on Level 1C data and are atmospherically corrected to Bottom of Atmosphere (BoA) reflectance. As of January 2019, they are systematically produced by ESA, just like the above described level 1C products. Users can still generate their own BoA data from Level 1C using the open access Sen2Cor processor. Level 2A data include (as an additional output from the Sen2Cor algorithm) aerosols optical thickness map, water vapour map and a basic scene classification map.

The calibration activities by the MPC include the regular updates of on-board and on-ground configuration data, while during the validation, they assess the quality of the generated data products.

In this special issue, we publish articles on radiometric calibration, such as Revel et al. (2019) cross calibration measurements with earlier (Spot, Landsat, Meris) and current satellite missions (Landsat-8, Sentinel-3) to ensure the S2A spectral bands absolute calibration or Barsi et al. (2018) cross calibration works on the MSI (S2A) and the OLI (Landsat-8) sensors. In terms of validation, Lamquin, Bruniquel, & Gascon, (2018) introduced a new algorithm, called Deep Convective Cloud, to monitor the impacts of...
the ageing of the MSI sensor(s), while Gorroño et al. (2018) presented the Radiometric Uncertainty Tool to estimate (and define a method) the error correlation structure in spatial, temporal and spectral dimensions within a region of interest. Ariza et al. (2018); Keukelaere et al. (2018) both investigated the viability of various atmospheric correction models in coastal zones, where Ariza et al. (2018) compared the Empirical Line, ATCOR and Sen2Cor models in a tropical archipelago area, while Keukelaere et al. (2018) tested the performance of the iCOR model in coastal, and in inland and transitional waters. Interestingly, during the first S2VT meeting, the geometric calibration activities got a smaller exposure, and thus, we present here; Reissl and Pfeifer (2018) work, dealt with the evaluation of the PlanetDEM based Level-1C orthophotos height accuracy over a mountainous terrain. Quality control is a very important part of any of the Copernicus missions, but especially for S2 with its 4TB per day data products. Clerc, Bévy, Jackson, Papadopoulou, & Garcia-Soto (2018) describe a data sampling strategy for quality control checks with a dedicated tool. The S2check tool not only helps MPC’s human operators with automatic product retrieval, generation of quicklook images and production of quality indicators, but increased the efficiency and traceability of the process as well.

Since the inception of this special issue, the S2 mission has considerably advanced in both quality and volume of data produced and can now be considered one of the Worlds leading providers of optical earth observation imagery. Highest possible standards in calibration and validation are indispensable to maintain this role, which underpins the importance of the work performed by the MPC, the S2QWG and the S2VT. The near future will see further significant improvements e.g. with the activation of the orbital refinement leading to increased geometric accuracy and stability (precision), lunar calibrations for an enhanced absolute radiometric accuracy, and more exhaustive per pixel quality metrics. The S2VT will reconvene in March 2019 in Toulouse, France.

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Table 1. Sentinel-2 Level-1C quality targets (Top of the Atmosphere)*.

| Radiometric Requirements                                                                 | Geolocation Requirements                                                                 |
|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| radiometric accuracy at TOA                                                             | Absolute geolocation uncertainty                                                           |
| inter-band radiometric calibration                                                      | Multi-temporal registration                                                               |
| Linearity knowledge accuracy                                                            | Multi-spectral registration (any two bands)                                               |
| Multi-temporal relative radiometric uncertainty                                         | 20 m 2σ w/o GCPs, 12.5 m 2σ with GCPs                                                    |
| Channel-to-channel cross-talk                                                          | 0.3 pixel 2σ                                                                             |
| Modulation Transfer Function                                                            | 0.3 pixel 3σ                                                                             |
| <0.5%                                                                                   | < 0.45 (20 m and 60 m bands)                                                             |
| 0.15 to 0.3 (10 m bands)                                                                |                                                                                          |

*Based on (Drusch et al., 2010).
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Zoltan Szantoi
European Commission, Joint Research Centre (JRC), Ispra, Italy
Department of Geography and Environmental Studies, Stellenbosch University, Matieland South Africa
zoltan.szantoi@ec.europa.eu
http://orcid.org/0000-0003-2580-4382

Peter Strobl
European Commission, Joint Research Centre (JRC), Ispra, Italy
http://orcid.org/0000-0003-2733-1822