<u>Splinter Session 12</u>: Satellite Instrument Pre- and Post-Launch Calibration

<u>Co-Chairs</u>: Gerhard Meister (NASA) and Bertrand Fougnie (CNES)

The session was attended by about 25 participants. The introduction was given by Bertrand Fougnie from CNES. In addition to providing the background for this session, the point was made that it is important not to restrict our efforts to pure instrument calibration, but to include instrument characterization as well. In the first part of the session, representatives from several space agencies (ISRO, ESA, KIOST, NASA, JAXA) presented short descriptions of their instruments, the main calibration methods used, and the lessons learned from either pre-launch or on-orbit characterization and calibration efforts. Each talk was followed by a few questions from the audience.

Samir Pal from ISRO described an extensive prelaunch calibration effort for OCM-2. OCM-2 is a multispectral radiometer with 8 different bands with wavelengths mostly similar to those of SeaWiFS. The spatial resolution of 250m is achieved by using CCD detectors. One difficulty encountered during pre-flight characterization was the non-uniformity of the integrating sphere (about 4%) for the calibration of the full field-of-view of the instrument. The sensitivity of the CCD detectors is trended on-orbit with an LED source. However, the LED light does not use the full optical path, therefore another calibration mechanism is needed. Since 2010, OCM-2 has acquired 3 lunar images. A comparison of the lunar irradiances measured with these images to those predicted by the ROLO model (calculated by USGS, provided to ISRO via NASA) allows a full calibration of the instrument. So far, three maneuvers were performed. The low frequency of maneuvers is dictated by requirements of the other sensor on the Oceansat-2 mission (a scatterometer).

Steven Delwart and Ludovic Bourg presented for ESA. The sensors MERIS (on ENVISAT, operational from 2002 to 2012) and OLCI (on Sentinel-3, to be launched in 2014 or later) and the calibration approaches for them are so similar that they will be described here together. The instrument calibration relies mainly on in-flight calibration, more than pre-flight calibration. Consequently, no transfer to orbit was done and the main calibration approach was based on in-orbit evaluation using two solar diffusers. Both are well protected from solar radiation, except during the calibration measurements. One crucial aspect is the pre-flight characterization of the BRDF of both diffusers, especially for the viewing geometries that will be operated in orbit. One of the solar diffusers on MERIS was used so infrequently that its reflectance degraded by about 0.2% or less. The radiation is detected by a two-dimensional CCD, where one dimension is the spatial (across track) direction, the other the spectral dimension. Accuracies for the measurement of the top-of-atmosphere (TOA) radiances on the order of a few tenths of a percent require a careful characterization of CCD characteristics (like e.g. straylight and smearing). These characterization measurements are challenging, and often a combination of instrument model and prelaunch characterization measurements are used to produce operational corrections. The wavelength dispersion on the CCD is monitored via several mechanisms: an erbium doped solar diffuser, Fraunhofer lines, and the O2A line. The angular sampling for the prelaunch characterization measurements of the solar diffuser was enhanced for OLCI relative to MERIS in order to get a more representative sampling of the incidence angles for the on-orbit solar diffuser measurements. A schematic view of what is called the "system vicarious calibration" was presented in order to highlight the risk of an insufficient characterization (pre- or in-flight) on the ocean color level-2 products.

Seongick Cho (KIOST) presented a summary of GOCI. GOCI acquires its images by a CCD. The FOV is directed sequentially to 16 different slots via a pointing mechanism, the 8 (412nm to 860nm) different wavelengths are selected using a filter wheel. The on-orbit temporal trending for GOCI is achieved using a transmissive solar diffuser (note that all other solar diffusers discussed in today's session are reflective). Overall, very little gain degradation has been detected so far by the GOCI calibration team, the sensors radiometric gains are remarkably stable. However, there are seasonal oscillations in the gains (correlated to the solar angles) that are not fully understood yet. One possible explanation could be a problem with the knowledge or aging of the diffuser's BRDF. For GOCI-II, the calibration approach will be enhanced by a second solar diffuser and lunar calibrations.

Gerhard Meister presented details of the MODIS sensors (on the Aqua and Terra platforms) and VIIRS (Suomi-NPP mission). In the MODIS prelaunch characterization, the official documentation of the setup did not document the configuration during the polarization characterization sufficiently well, which lead to significant errors in the on-orbit polarization correction in the early phase of the mission. In the MODIS design, the primary optical element (the scan mirror) is relatively exposed. In both MODIS instruments, there has been significant scan-angle dependent degradation at 412nm (more than 10%), which is an issue for the calibration because the calibration sources (lunar measurements and a solar diffuser) are available at only two selected scan angles. On MODIS Terra, a prelaunch contamination incident caused an even stronger degradation than for MODIS Aqua, which also led to a strong change of the polarization characteristics with time. An additional problem with MODIS on Terra is that the solar diffuser door is open permanently (after a mechanism malfunction in 2003), which leads to an increase in the rate of degradation of the solar diffuser BRDF. The situation for VIIRS is similar, the solar diffuser is protected only by a screen (VIIRS design choice). Note that the solar diffuser door on MODIS Aqua is still operating without problems. NASA's ocean color processing uses SeaWiFS and MODIS Aqua data to cross-calibrate MODIS Terra. NASA MODIS Calibration Support Team uses desert reflectances to improve the MODIS Aqua calibration of the shorter wavelengths (currently 412nm and 443nm).

Hiroshi Murakami from JAXA presented the calibration approach for SGLI, which may launch as early as 2015. SGLI has multiple on-board calibration functions: a solar diffuser, a lamp (LED), and a black body. A maneuver is planned for evaluating the BRDF of the solar diffuser after launch. Additionally, the GCOM-C satellite will perform a monthly pitch maneuver so that SGLI can measure the lunar irradiance at a constant phase angle. Pre-launch characterizations such as polarization sensitivity, SNR, and straylight aspects haven been completed for the engineering model.

In the second part of the session, Tim Hewison and Ewa Kwiatkowska (both from EUMETSAT) presented potential frameworks for further calibration work: GSICS (Global Space-based Intercalibration System) and a new inter-agency task force on satellite sensor calibration, respectively. GSICS is an international collaborative effort initiated in 2005 by WMO and the CGMS. Its goal is to intercalibrate TOA radiances for different sensors mainly for Climate and Meteorological purposes. The GSICS group has a successful history with Infrared sensors and Geostationary sensors. Its plans for low earth orbit sensors intercalibration are in an early stage. The calibration teams of each ocean color sensor are encouraged to join GSICS to help develop these plans.

The INSITU-OCR white paper suggested the creation of a permanent calibration task force (this point was also highlighted on the recent IOCCG Report#13). It should have close interaction with the extended ocean colour community to take into account the community's feedback and recommendations regarding the accuracy and quality of calibration and characterization of individual instruments. Calibration and characterization expert activities should include interactions on specific technical problems, hands-on work with data and prototyping, and delivery of solutions and transfer of the solutions to operations. These suggestions provoked a lively discussion, which will be summarized in the following paragraphs.

There was consensus that we are working on common issues, and that sharing expertise would be beneficial for all involved. We do need a platform to share information and go into detail for focused tasks. There was agreement that we should meet regularly, e.g. by regular web meetings, plus at least for each IOCS meeting. In-person meetings were generally viewed as more productive, especially for hands-on work on specific problems, but most members find it difficult to get international travel approved in a time of tight budgets. It was decided to have an initial telecon to define future activities, e.g. instrument characterization issues are an obvious area that received widespread support from all involved. It is important to note that we will not just work on radiometric calibration, but on instrument characterization in general (such as e.g. straylight, polarization, spectral response, BRDF, etc.). Furthermore, it is very important that the space agencies clearly support this kind of activity. In the case the work is to be carried out by contractors, such work should be included in the contract language.

No consensus was reached on the exact goals of the task force. Mentioned in the discussion were: a) Improve instrument characterization (e.g. straylight, polarization, etc.) b) Absolute calibration c) Vicarious calibration d) Intercalibration e) Essential

Climate Variables f) Documentation. It is likely that the group will focus to work on improving instrument characterization first and expand its activities to other tasks later.

Even more controversial was the most appropriate framework for the group. Everybody agreed on the fact that we need to avoid duplication. Regarding existing groups, one option would be a new group under the CEOS-IVOS working group or under the CEOS OCR-VC. Feedback from CEOS-IVOS mentioned that that group is not focused on ocean colour, which could be problematic because radiometric characterization may not be as crucial for them as it is for ocean colour. So a potential option could be to simply join CEOS-IVOS by creating a dedicated sub-group. Another option is a task force directly related to IOCCG/INSITU-OCR. No consensus was reached - our group needs further guidance from the IOCCG on the most appropriate framework.