CALIBRATION AND WHAT IT MEANS

Calibrated Optics

There are two main types of calibration that are relevant to imaging sensors. The first type is meant to precisely characterize which pixel in the focal plane array a photon from a given direction in space will hit. This is dependent on the physical dimensions of the focal plane array and on the optics used in the sensor. Sometimes people talk of "calibrated optics" when referring to this form of calibration.

Radiometric Calibration

When using a camera for scientific, industrial, or agricultural applications, there is another type of calibration. This is meant to precisely quantify the sensitivity of the sensor to radiation. Frequently when we image an object, the value we are most interested in is the "reflectance" of the object's surface. This is the probability that a photon of a given wavelength will be reflected by the surface (as opposed to passing through or being absorbed by the object). As an example, the variables that appear in the equations for different vegetation indices are surface reflectances at different wavelengths of light. A camera cannot measure surface reflectance directly. A camera measures "at-sensor irradiance", which is the intensity of light hitting the sensor in each spectral band. This is output by the camera in the form of a Digital Number (DN) for each pixel in an image. There is a fixed mapping from irradiance to DN for an image, so in principal one can invert this mapping and get estimates of irradiance for each pixel in an image. If the intensity of the light hitting the surface is known, this irradiance measurement can be used to compute surface reflectance.

Unfortunately, most cameras are not designed for scientific applications and the mapping from irradiance to DNs is typically unknown. What is worse is that many consumer cameras apply complex image processing to collected images to make them look better to the human eye. This processing generally makes it impossible to estimate irradiance. Additionally, the mapping from irradiance to DN changes whenever you change camera settings or optics. When one performs "radiometric calibration" on a camera, they are estimating the function that maps irradiance to DN. This is what allows them to take an image from that camera and estimate at-sensor irradiance for each pixel. This calibration typically involves a calibrated light source that emits a precisely known amount of radiation in each band, or a separate calibrated camera or spectral radiometer with which to compare. This calibration must be done for all different combinations of camera settings and optics, and it must be done separately for each band. Then the correct mapping must be retrieved for each image and each band when computing vegetation indices. This form of calibration is often skipped and raw DNs are used when computing vegetation indices. This results in vegetation indices that show fictitious changes whenever the optics or camera settings are changed, and which may be significantly different from the "true" values of those indices that one would get by taking careful measurements on the ground.

GEMS Calibration

The GEMS sensor is calibrated in both of the ways discussed above. It is radiometrically calibrated for each band across all camera settings, and it uses calibrated optics. In addition to this, the GEMS system has on-board navigation sensors which must be calibrated and aligned with the optical axes of the cameras

to support Geo-registration. In addition to optical and radiometric calibration, each GEMS unit goes through the following stages of calibration: gyro calibration, accelerometer bias/misalignment/scale-factor estimation, hard and soft iron anomaly estimation and correction, and sensor and camera alignment. All of this information is utilized transparently to the user in the GEMS post-processing software to ensure the highest reliable vegetation indices are computed.

When a vendor says that they have a "calibrated sensor", end users should be sure to inquire precisely what this actually means. A good question to ask is if they provide vegetation indices did they use DNs, irradiance estimates, or reflectance estimates when computing the indices?