CALIBRATION SYSTEM STABILITY PLANS FOR A LONG-TERM ECOLOGICAL AIRBORNE REMOTE SENSING PROJECT

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1. INTRODUCTION

An imaging spectrometer, small footprint waveform LiDAR and high-resolution digital camera will be used by the National Ecological Observatory Network (NEON) Airborne Observation Platform (AOP) to observe both the human drivers of climate change and the biological consequences of environmental change at a continental scale for a 30 year period [1], [2]. To be meaningful as an ecological climate data record, the AOP data set must have a continuous and consistent calibration effort [3]. This requires a robust calibration and validation plan to ensure data continuity from instrument-to-instrument, flight-to-flight, and year-to-year over the lifetime of the NEON project.

All NEON data products will be available to the public and will include appropriate uncertainties along with necessary calibration and validation metadata information. All instruments will be calibrated against a set of recognized physical standards and whenever possible, these standards will be traceable to national standards. Radiometric sources will be traceable to NIST standards of spectral irradiance. It is important to perform calibrations on a regular basis and provide a means for long-term system performance analysis [4]. AOP sensors will undergo yearly maintenance and calibration at the AOP Sensor Technical Facility (STF) before they go into the field. Absolute calibration and creation of the various required calibration coefficients (e.g. radiance coefficients) will occur prior to each new season after yearly required maintenance has been performed. Every year a vicarious calibration campaign will be implemented early in the season to validate laboratory radiometric, spectral and spatial coefficients and knowledge of the optical boresight pointing directions of all sensors. This campaign is also imperative to establish instrument biases and to cross-calibrate between the sensors. Several checks will be set in place while the instruments are in the field to ensure that the calibrations remain valid. If it is found that a calibration is falling out of specification, a decision will be made to send the instrument back to the AOP STF for recalibration, if necessary.

2. CALIBRATION OF THE AOP SENSOR SUITE

There are three identical payloads that will each fly on three separate aircraft. Each sensor suite consists of the NEON Imaging Spectrometer (NIS), a waveform LiDAR (wLiDAR), high-resolution digital camera and inertial measurement unit (IMU) and global positioning system (GPS). The NEON Imaging Spectrometer (NIS) will undergo maintenance and calibration in the laboratory prior to each flight season. Laboratory calibrations include pixel-to-pixel uniformity, radiance coefficient determination, radiometric spectral response, spectral uniformity, spectral scale, linearity, stray light and out of band characterization [5]. A detector-based method will be implemented with the use of a well-characterized and extremely stable NIST traceable transfer radiometer. Solar Radiation Based Calibrations (SRBC) will be performed during laboratory testing as an independent check. The NIS has an on-board calibrator (OBC) that will be used in the laboratory as a side-by-side comparison during radiometric testing. Monitoring flat field imagery in-flight from the OBC and watching for changes over time will determine radiometric stability. Laboratory calibrations will be independently tested by overflying various calibration targets throughout the season and cross-calibration with multispectral satellite sensors [6], [7]. The waveform LiDAR will undergo yearly maintenance, timing/ranging calibration and performance verification at the vendor. Waveform intensity and pulse shape calibrations will be performed at the AOP STF along with laser stability measurements [8]. At vicarious calibration campaigns—flown over well-characterized targets—waveform and ranging performance in the lab will be validated. Well-characterized targets will also be utilized during vicarious calibration to determine any losses in the outgoing and incoming waveform intensity or changes in transmitted pulse shape. The high-resolution digital camera will undergo yearly maintenance at the vendor and pixel-to-pixel uniformity, radiance and radiometric spectral response calibrations in the AOP STF. Radiance coefficients and spectral response will be checked throughout the flight season.

It is important that the calibration facility sources and methods are monitored for stability during every calibration and over the lifetime of AOP. To ensure stability in AOP calibrations from year-to-year detailed procedures for each test will be developed and followed in order to minimize systematic errors. This will be specifically important to geometric calibrations and the waveform LiDAR characterization. It will be important to use the transfer radiometer to characterize every piece of equipment in order to tie all calibrations back to the lab and to help monitor stability of calibrations within a flight season. Pre-flight calibrations in the field with SRBC and lamp-panel-sensor setups will allow for the monitoring of NIS and digital camera radiometric calibration drift. Each highly integrated sensor suite will undergo boresite measurements in the lab and diagnostic testing in the field of positioning measurements to ensure that measurements from the three sensors are made simultaneously and the ground pixel locations are accurately co-registered. During vicarious calibration campaign the payloads will be flown over well-located ground points (i.e. buildings and other man-made structures). During the mission season, differential GPS is used to reduce the uncertainties in geolocation information. In addition, a perpendicular path will be flown across the research flight lines at each site to be used as a diagnostic tool to determine that the IMU is still working properly [9]. The GPS/IMU units will go back to the vendor for yearly maintenance and calibration.

The yearly laboratory radiometric calibrations and spatial tests will be independently tested by flying over calibration targets located throughout the domains that are easily flown during operations. These calibration targets (i.e. asphalt surfaces, parking lots, playas, and other uniform non-changing surfaces) will be sampled throughout the year. Ground characterization of these sites will take place every 5 years; in-between ground characterizations, imagery from a 20 – 30 meter moderate resolution spectral imager, can be used to determine the stability of the site. It is also planed that AOP flights will coincide with satellite overpasses whenever possible, especially vicarious calibration flights. This gives an additional independent check on instrument calibratiosn and validation for NEON data products.

3. SUMMARY

Effective calibration for a sensor suite such as that being developed by the AOP depends on thorough planning, careful execution, and effective monitoring, verification and validation. The NEON approach to calibration follows commonly accepted procedures and methodologies where they exist. All measurements will be traceable to laboratory calibrations and national standards. The AOP calibration and validation process is a continuous scheme throughout the lifetime of the project and works to create a consistent data product from instrument-to-instrument, domain-to-domain, and year-to-year, and over the 30-year lifetime of the project. In order to facilitate stability of data sets no matter which of the three payloads is used for the measurement collection, cross-calibration between all AOP instrumentation, as appropriate, will occur during the vicarious calibration campaigns. A calibration technical working group consisting of outside experts will be utilized by AOP to provide input and oversight to the development of the calibration and validation plan for the AOP remote sensing suite. NEON, funded by the National Science Foundation, is a continental-scale ecological observation platform for discovering, understanding and forecasting the impacts of climate change, land-use change, and invasive species on ecology. NEON will gather long-term data on ecological responses of the biosphere to changes in land use and climate, and on feedbacks with the geosphere, hydrosphere, and atmosphere [10].

11. REFERENCES

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