ALGORITHM THEORETICAL BASIS DOCUMENT (ATBD) ABOVE CANOPY AND UNDERSTORY/SNOWPACK PHENOLOGY CAMERA

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1 DESCRIPTION

Contained in this document are details concerning automated phenology and snowpack measurements made at all NEON sites. Above canopy phenology, understory phenology and snowpack will be measured via the Stardot NetCam SC CAM-SEC5IR-B. Specifically, the processes necessary to provide imagery for use in phenological studies and their associated uncertainties are described.

1.1 Purpose

This document details the process for creating NEON Level 1 data product from Level 0 data, and ancillary data as defined in this document (such as calibration data), obtained via instrumental measurements made by the Stardot NetCam SC CAM-SEC5IR-B. It includes a detailed discussion of measurement theory and implementation, appropriate theoretical background, data product provenance, quality assurance and control methods used, approximations and/or assumptions made, and a detailed explanation of uncertainty resulting in a cumulative reported uncertainty for this product.

1.2 Scope

The theoretical background and entire algorithmic process used to derive Level 1 data from Level 0 data for the automated digital phenology cameras (i.e. above canopy phenology and understory/snowpack phenology) are described in this document. It is expected that the automated digital camera employed at all NEON tower sites is the Stardot NetCam SC CAM-SEC5IR-B (NEON P/N: 0303510000). This document does not provide computational implementation details.

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2 RELATED DOCUMENTS, ACRONYMS AND VARIABLE NOMENCLATURE

2.1 Applicable Documents

AD[01]	NEON.DOC.000001	NEON Observatory Design
AD[02]	NEON.DOC.005003	NEON Scientific Data Products Catalog
AD[03]	NEON.DOC.002652	NEON Level 1-3 Data Products Catalog
AD[04]	NEON.DOC.005005	NEON Level 0 Data Products Catalog
AD[05]	NEON.DOC.000782	NEON ATBD QA/QC data consistency
AD[06]	NEON.DOC.011081	ATBD QA/QC plausibility tests
AD[07]	NEON.DOC.000783	ATBD QA/QC Time Series Signal Despiking for TIS Level 1 Data Products
AD[08]	NEON.DOC.000802	NR01 – Net Radiometer Calibration/Validation Procedure
AD[09]	NEON.DOC.001423	C^3 Digital Camera
AD[10]	NEON.DOC.000927	NEON Calibration and Sensor Uncertainty Values[1]
AD[11]	NEON.DOC.000785	TIS Level 1 Data Products Uncertainty Budget Estimation Plan
AD[12]	NEON.DOC.000751	CVAL Transfer of standard procedure
AD[13]	NEON.DOC.000746	Evaluating Uncertainty (CVAL)
AD[14]	NEON.DOC.002002	Engineering Master Location Sensor Matrix
AD[15]	NEON.DOC.001113	Quality Flags and Quality Metrics for TIS Data Products

[1] Note that CI obtains calibration and sensor values directly from an XML file maintained and updated by CVAL in real time. This report is updated approximately quarterly such that there may be a lag time between the XML and report updates.

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2.2 Reference Documents

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms

2.3 Acronyms

Acronym	Explanation
ATBD	Algorithm Theoretical Basis Document
CVAL	NEON Calibration, Validation, and Audit Laboratory
DAS	Data Acquisition System
DP	Data Product
L0	Level 0
L1	Level 1

2.4 Verb Convention

"Shall" is used whenever a specification expresses a provision that is binding. The verbs "should" and "may" express non-mandatory provisions. "Will" is used to express a declaration of purpose on the part of the design activity.

3 DATA PRODUCT DESCRIPTION

3.1 Variables Reported

The above canopy and understory/snowpack camera related L1 DPs are provided in the file: phe_datapub_NEONDOC001789.txt.

3.2 Input Dependencies

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Table 3-1 details the above canopy and understory/snowpack phenology-related L0 DPs used to produce L1.

Table 3-1: List of digital camera related L0 DPs that are transformed into L1 DPs.

Description	Sample Frequency	Units	Data Product Number
Image captured in the infrared spectrum	15 minutes	NA	NEON.DOM.SITE.DP0.00033.001.01796.HOR.VER.000
Infrared metadata stream	15 minutes	NA	NEON.DOM.SITE.DP0.00033.001.02051.HOR.VER.000
Image captured in the RGB color space	15 minutes	NA	NEON.DOM.SITE.DP0.00033.001.01797.HOR.VER.000
RGB metadata stream	15 minutes	NA	NEON.DOM.SITE.DP0.00033.001.02052.HOR.VER.000

3.3 Product Instances

A Stardot NetCam SC CAM-SEC5IR-B will be deployed on all core and re-locatable towers at the tower top (Above Canopy Phenology) and a second camera at the tower bottom (Understory/Snowpack Phenology).

3.4 Temporal Resolution and Extent

Every 15 minutes both the Above Canopy Phenology Camera and the Understory/Snowpack Phenology Camera capture back to back RGB and IR images separated by 30 seconds.

3.5 Spatial Resolution and Extent

A Stardot NetCam SC CAM-SEC5IR-B will be deployed on all core and re-locatable towers at the tower top (Above Canopy Phenology) and a second camera at the tower bottom (Understory/Snowpack Phenology). The Above Canopy Phenology Camera will capture images of the dominant vegetation type on site. The Understory/Snowpack Phenology Camera will capture images of the snowdepth stakes and any ancillary plant phenology information.

4 SCIENTIFIC CONTEXT

Phenology is the study of reoccurring life cycle events that are driven by environmental factors (Morrisette et al., 2009). In the context of this document, the targeted events are related to seasonal

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changes in overstory and understory vegetation (e.g. onset of growth and leaf senescence). The timing of these events is driven by both short- and long-term variability in climate and is therefore valuable in understanding the effects of climate change (Richardson et al., 2006 and references therein).

Automated repeat digital images of plant canopies provide data for the extraction of indices (e.g. green chromatic coordinate (g_{cc}) and excess green (ExG)) that can be used to quantify changes in phenological events over time (Sonnentag et al., 2011).

4.1 Theory of Measurement

The Stardot NetCam SC CAM-SEC5IR-B is an automated digital camera capable of capturing RGB and IR images. The Above Canopy and Understory/Snowpack Phenology Camera both capture continuous digital images of the selected areas of interest (i.e. the canopy and snowdepth stakes, respectively).

4.2 Theory of Algorithm

5 ALGORITHM IMPLEMENTATION

Data flow for signal processing of L1 DPs will be treated in the following order.

1. L0 DPs (image and metadata will be sent to the PhenoCam Network)
2. L0 DP images will undergo QA/QC tests per PhenoCam protocols (see Richardson *et al.* (in prep.))
3. L0 images that pass PhenoCam QA/QC are then considered L1 DP images

6 UNCERTAINTY

Uncertainty of measurement is inevitable; therefore, measurements should be accompanied by a statement of their uncertainty for completeness (JCGM 2008; Taylor 1997). To do so, it is imperative to identify all sources of measurement uncertainty related to the quantity being measured. Quantifying the uncertainty of TIS measurements will provide a measure of the reliability and applicability of individual measurements and TIS data products. Because the L0 and L1 DPs are images, no uncertainty estimates provided. Uncertainty estimates for higher level data products that are functions of L1 images, e.g., greenness index, snowpack, etc., will be explained and derived in future ATBDs.

7 FUTURE PLANS AND MODIFICATIONS

Sensor (camera) degradation and drift may be addressed in the uncertainty section.

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8 BIBLIOGRAPHY

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9 CHANGELOG

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