ALGORITHM THEORETICAL BASIS DOCUMENT: QUANTUM LINE SENSOR

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CHANGE RECORD

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	08/28/2013	ECO-00980	Initial Release

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1 DESCRIPTION

The LI-191 Quantum Line Sensor will be deployed in the soil array at NEON TIS sites to measure photosynthetically active radiation (PAR) at the soil surface. Contained in this document are details concerning PAR measurements made at all NEON sites. Specifically, the processes necessary to convert "raw" sensor measurements into meaningful scientific units and their associated uncertainties are described.

1.1 Purpose

This document details the algorithms used for creating NEON Level 1 (L1) data products (DP) from Level 0 data, obtained via instrumental measurements made by Licor LI-191 Quantum Line Sensor [NEON P/N: 0300300000]. It includes a detailed discussion of measurement theory and implementation, theoretical background, data product provenance, quality assurance and control methods used, assumptions, and a detailed estimation of uncertainty resulting in a cumulative uncertainty budget for this product.

1.2 Scope

This document describes the theoretical background and entire algorithmic process for creating L1 DPs from input data (L0). It does not provide computational methodology to implement the details of the approaches presented here, except for cases where they stem directly from algorithmic/mathematical choices explained here.

2 RELATED DOCUMENTS AND ACRONYMS

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.005004	NEON Level 1-3 Data Products Catalog
AD[04]	NEON.DOC.005005	NEON Level 0 Data Products Catalog
AD[05]	NEON.DOC.000782	ATBD QA/QC Data Consistency
AD[06]	NEON.DOC.011081	ATBD QA/QC plausibility tests
AD[07]	NEON.DOC.000783	ATBD De-spiking and time series analyses
AD[08]	NEON.DOC.000746	Evaluating Uncertainty (CVAL)
AD[09]	NEON.DOC.000603	NEON Sensor Command, Control, and Configuration - Quantum Line Sensor
AD[10]	NEON.DOC.000785	TIS Level 1 Data Products Uncertainty Budget Estimation Plan
AD[11]	NEON.DOC.000927	NEON Calibration and Sensor Uncertainty Values (CVAL)
AD[12]	NEON.DOC.000752	Line Quanta PAR Calibration Fixture L2R400
AD[13]	NEON.DOC.011071	FIU Site Specific Sensor Location Matrix
AD[14]	NEON.DOC.001113	Quality Flags and Quality Metrics for TIS Data Products

2.2 Reference Documents

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	LI-COR Terrestrial Radiation Sensors Instruction Manual	
RD[04]	LI-191SA Line Quantum Sensor Brochure	
RD[05]	Comparison of Quantum Sensors with Different Spectral Sensitivities, Technical Note #126	

2.3 Acronyms

Acronym	**Explanation**
ATBD	Algorithm Theoretical Basis Document
CI	NEON Cyberinfrastructure project team
CVAL	NEON Calibration, Validation, and Audit Laboratory
DAS	Data Acquisition System
DP	Data Product
FIU	Fundamental Instrument Unit
GRAPE	Grouped Remote Analog Peripheral Equipment
L0	Level 0
L1	Level 1
QA/QC	Quality Assurance/Quality Control
TIS	Terrestrial Instrument System

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

Level 1 data products that will be produced from this ATBD are shown in Table 1.

Table 1. List of Level 1 data products that will be produced from this ATBD. Note: The '0XX' in the eighth field of the Data Product ID refers to the horizontal location of the sensor in the soil array. '001' refers to the sensor closest to the tower infrastructure.

Data product	**Averaging Period**	**Units**	**Data stream ID**
1-minute mean soil PAR (Mean_ $PAR\text{-}soil_1$)	1-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.001.00X.001
1-minute minimum soil PAR (Min_ $PAR\text{-}soil_1$)	1-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.002.00X.001
1-minute maximum soil PAR (Max_ $PAR\text{-}soil_1$)	1-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.003.00X.001
1-minute soil PAR Variance (σ^2_ $PAR\text{-}soil_1$)	1-min	(µmol s^{-1} $m^{-2})^2$	NEON.DXX.XXX.DP1.00066.001.004.00X.001
1-minute soil PAR Skewness (Sk_$PAR\text{-}soil_1$)	1-min	Unitless	NEON.DXX.XXX.DP1.00066.001.005.00X.001
1-minute soil PAR Kurtosis (Ku_ $PAR\text{-}soil_1$)	1-min	Unitless	NEON.DXX.XXX.DP1.00066.001.006.00X.001
1-minute soil PAR QA/QC Summary ($Qsum\_PAR\text{-}soil_1$)	1-min	Text	NEON.DXX.XXX.DP1.00066.001.007.00X.001
1-minute soil PAR QA/QC Report ($Qrpt\_PAR\text{-}soil_1$)	1-min	N/A	NEON.DXX.XXX.DP1.00066.001.008.00X.001
30-minute mean soil PAR (Mean_ $PAR\text{-}soil_{30}$)	30-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.001.00X.002
30-minute minimum soil PAR (Min_ $PAR\text{-}soil_{30}$)	30-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.002.00X.002
30-minute maximum soil PAR (Max_ $PAR\text{-}soil_{30}$)	30-min	µmol s^{-1} m^{-2}	NEON.DXX.XXX.DP1.00066.001.003.00X.002
30-minute soil PAR Variance (σ^2_ PAR-	30-min	(µmol s^{-1} $m^{-2})^2$	NEON.DXX.XXX.DP1.00066.001.004.00X.002

soil$_{30}$)			
30-minute soil PAR Skewness (Sk_*PAR-soil$_{30}$*)	30-min	Unitless	NEON.DXX.XXX.DP1.00066.001.005.00X.002
30-minute soil PAR Kurtosis (Ku_ *PAR-soil$_{30}$*)	30-min	Unitless	NEON.DXX.XXX.DP1.00066.001.006.00X.002
30-minute soil PAR QA/QC Summary (*Qsum_PAR-soil$_{30}$*)	30-min	Text	NEON.DXX.XXX.DP1.00066.001.007.00X.002
1-minute soil PAR QA/QC Report (*Qrpt_PAR-soil$_1$*)	1-min	N/A	NEON.DXX.XXX.DP1.00066.001.008.00X.002

3.2 Input Dependencies

A summary of the inputs required to produce the Level 1 data product are shown in Table 2.

Table 2. Level 0 data products that are used to produce the Level 1 data product in this ATBD.

Data product	**Sample Frequency**	**Units**	**Data stream ID NEON.DOM.SIT.DPL.PRN.REV.SPN.HOR.VER.REP**
PAR sensor voltage (E_{out})	1 Hz	V	NEON.DOM.SIT.DP0.00066.001.001.00X.000.001

3.3 Product Instances

Three quantum line sensors will be deployed at each site and shall reside within the soil plots.

3.4 Temporal Resolution and Extent

One- and thirty-minute averages of PAR at the soil surface will be calculated to form L1 DPs.

3.5 Spatial Resolution and Extent

The spatial resolution will depend on the placement of the quantum line sensor in the soil array. To maximize spatial coverage, quantum line sensors will be deployed in three (i.e., one sensor per plot) out of five soil plots that comprise the soil array at each TIS site. Their measurements will be representative of the point in space where they are located. A description of how the sensors are located within plots is described in AD[13].

4 SCIENTIFIC CONTEXT

Radiation in the 400 nm to 700 nm waveband represents most of the visible solar radiation. This waveband is utilized directly by plant biochemical processes in photosynthesis to convert light energy into chemical energy, which can be stored in the molecular bonds of organic molecules (e.g., sugars). This specific waveband is defined as Photosynthetically Active Radiation (PAR). PAR is also often referred to as Photosynthetic Photon Flux Density (PPFD), and estimated in quanta per unit area and per unit time, or µmol m^{-2} s^{-1}.

PAR measured via the quantum line sensor will provide information on the light availability at the ground level. This has significant ecophysiological applications as the light at the ground is patchy due to sunflecks, i.e., spots on the ground where direct (or near direct) solar radiation is incident. Many understory plants take advantage of these sunflecks through adaptation of their activation energy to charge the photosystems I and II (Jones, 1992; Salsbury and Ross 1978). While this ATBD describes the conversion of L0 to L1 data products, the data from the quantum line sensors is used in conjunction with the vertical profile of PAR sensors from the top to bottom of the tower structure. Ultimately, quantum line sensor data will inform higher-level data products and contribute to our understanding of energy balance and radiation transfer into and within the canopy. This will help to foster energy balance research by helping to answer various questions, such as how much radiation is attenuated or absorbed by the plant canopy and how much remains for biochemical processes.

4.1 Theory of Measurement/Observation

LI-COR191 Quantum Sensor is designed for measuring PAR in applications where the solar radiation to be measured is spatially inhomogeneous, e.g., below plant canopies. Rather than using multiple detectors, the LI-191 uses a one meter long quartz rod under a diffuser to conduct light to a single high quantum sensor (RD[03]). The integrated horizontal measurement of PAR at the ground portrays a more representative measure than a single 'point' sensor.

The dashed black line in Figure 1 shows the ideal relative response of a quantum sensor in terms of sensitivity to photons: the sensor has no sensitivity (clear cutoffs) to light below 400 nm and above 700 nm, and a constant sensitivity to all photons across the 400 to 700 nm wavelength ranges. The sensitivity of the LI-191 (the solid blue line in Figure 1) oscillates around the ideal quantum responses and has sharp cutoffs below 400 and above 700 nm (RD[05]). Output of the LI-191 is not biased significantly at either the blue or red ends of the spectrum. The actual area under each deviation from ideal is small and errors tend to cancel (RD[05]).

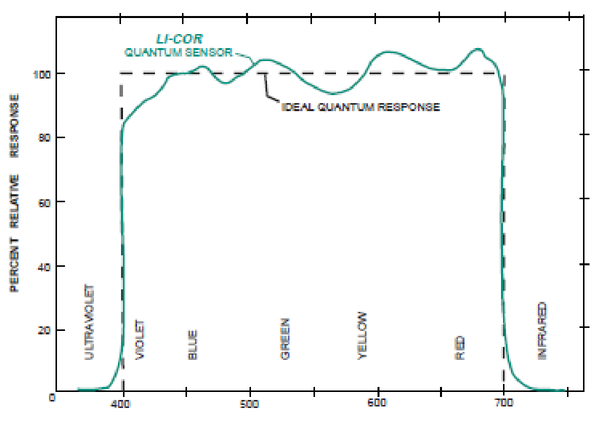

Figure 1. Relative spectral response of LI-191 quantum sensor (solid blue line) and ideal quantum sensor (dashed black line). Source: RD[04].

4.2 Theory of Algorithm

The LI-191 sensor is a current output device. However, the current will be converted to voltage through a fixed resistor (1250 ohms, provided by ENG) in the sensor which will require an independent calibration coefficient for each sensor. The calibration coefficient for each sensor will be determined by CVAL according to AD[12]. Using the sensor calibration coefficient and voltage output from the sensor, PAR is obtained in the required SI units (µmol m^{-2} s^{-1}) by:

$$PAR_i = C_1 * E_i \tag{1}$$

Where:

PAR_i = Individual (1 Hz) PAR at the soil surface (µmol m^{-2} s^{-1})
E_i = Individual Li-191 sensor output (V)
C_1 = LI-191 sensor calibration coefficient (µmol m^{-2} s^{-1} V^{-1}, provided by CVAL and sensor specific)

After PAR is determined, one-minute ($E_{PAR_{1min}}$) and thirty-minute ($E_{PAR_{30min}}$) averages and associated descriptive statistics (i.e., skewness and kurtosis) will be determined accordingly to create L1 DPs:

$$\overline{PAR_1} = \frac{1}{n}\sum_{i=x}^{n} PAR_i \tag{2}$$

where, for each minute average, n is the number of measurements over time T, which is defined as 0 ≤ T < 60 seconds

and

$$\overline{PAR_{30}} = \frac{1}{n}\sum_{i=x}^{n} PAR_i \tag{3}$$

where, for each thirty-minute average, n is the number of measurements in the averaging period T and averaging periods are defined as 0 ≤ T < 1800 seconds.

Note: The beginning of the first averaging period in a series shall be the nearest whole minute less than or equal to the first timestamp in the series.

Skewness ($SkE_{PAR_{Tmin}}$) and kurtosis ($KrE_{PAR_{Tmin}}$), both of which provide information on the symmetry and peakedness of a distribution, will be determined for both one-minute and thirty-minute averaging periods.

Skewness is obtained by:

$$Sk_{PAR_T} = \frac{1}{n} \cdot \frac{\sum_{i=1}^{n}(PAR_i - \overline{PAR_T})^3}{\left(\sigma^2_{PAR_T}\right)^{3/2}} \tag{4}$$

Kurtosis is obtained by:

$$Ku_{PAR_T} = \frac{1}{n} \cdot \frac{\sum_{i=1}^{n} (PAR_i - \overline{PAR_T})^4}{\left(\sigma_{PAR_T}^2\right)^2} \quad (5)$$

Where:

$\overline{PAR_T}$ = One-minute or thirty-minute PAR average
n = Number of measurements over T
$\sigma_{PAR_T}^2$ = Variance of PAR over T

5 ALGORITHM IMPLEMENTATION

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

1. 1 Hz data will be converted to PAR (µmol m^{-2} s^{-1}) using to Eq. (1) as described in section 4.2.
2. QA/QC Plausibility tests will be applied to the data stream in accordance with AD[06]. The details are provided below.
3. Signal de-spiking and time series analysis will be applied to the data stream in accordance with AD[07].
4. One- and thirty-minute PAR averages will be calculated using Eq. (2) and (3) and descriptive statistics (i.e. minimum, maximum, variance, skewness, and kurtosis) will be determined for both averaging periods.
5. QA/QC consistency tests will be applied to one- and thirty-minute average in accordance with AD[05].
6. QA/QC Summary (Qsum) will be produced for one- and thirty-minute averages according to AD[14].

<u>**QA/QC Procedure**</u>:

1. **Plausibility Tests** AD[06] - All plausibility tests will be determined for PAR. Test parameters will be provided by FIU and maintained in the CI data store. Test parameters will be provided by FIU and maintained in the CI data store. All plausibility tests will be applied to the sensor's converted L0 DPs and associated quality flags (QFs) will be generated for each test.

2. **Signal De-spiking and Time Series Analysis** – The time series despiking routine will be run according to AD[07]. Test parameters will be specified by FIU and maintained in the CI data store. Quality flags resulting from the despiking analysis will be applied according to AD[07].

3. **Consistency Analysis** – A QA/QC flag for data consistency will be applied according to the redundancy analysis outlined in AD[05], and a pass/fail flag will be generated to reflect this analysis. Assume soil type and ground cover are the same among soil plots at a given site and assume that the position of sensors are located within the soil array as shown in the Figure 2(a). To evaluate PAR at the soil surface for consistency, L1 PAR from a given LI-191 quantum line

sensor (a quantum line sensor at position 2) will first be compared to the LI-191 sensor at position 1. If a difference between the two PAR measurements is less than the defined limits (provided by FIU and maintained in the CI data store) then the sensor will have passed its consistency analysis. Alternatively, a PAR difference between the LI-191 sensors outside the defined limits will result in a failed test. A failed test between the sensors in position 1 and 2, will result in the g LI-191 sensor at position 2 being compared to the sensor at position 3. If this too results in a failed test, then the LI-191 sensor will have failed the consistency test and be flagged as such (Figure 2(b)). If the LI-191 sensor fails the first test but passes the second then it will have passed the consistency test. This test structure helps to ensure that non-functional sensors (e.g., sensors that are faulty or due for service) do not bias the test, since a resulting failed test will allow the sensor to be compared to the other one. Accordingly, the sensors at position 1 and 3 will be first compared to the nearby sensor (sensor at position 2) and then to each other. L1 DPs that fail the Consistency Analysis will continue to be reported, but will have an associated failed flag that will be included in the QA/QC summary. Note that the evaluation procedures of PAR at the soil surface for consistency may not be applied if soil type and ground cover are not consistent amongst the soil plots.

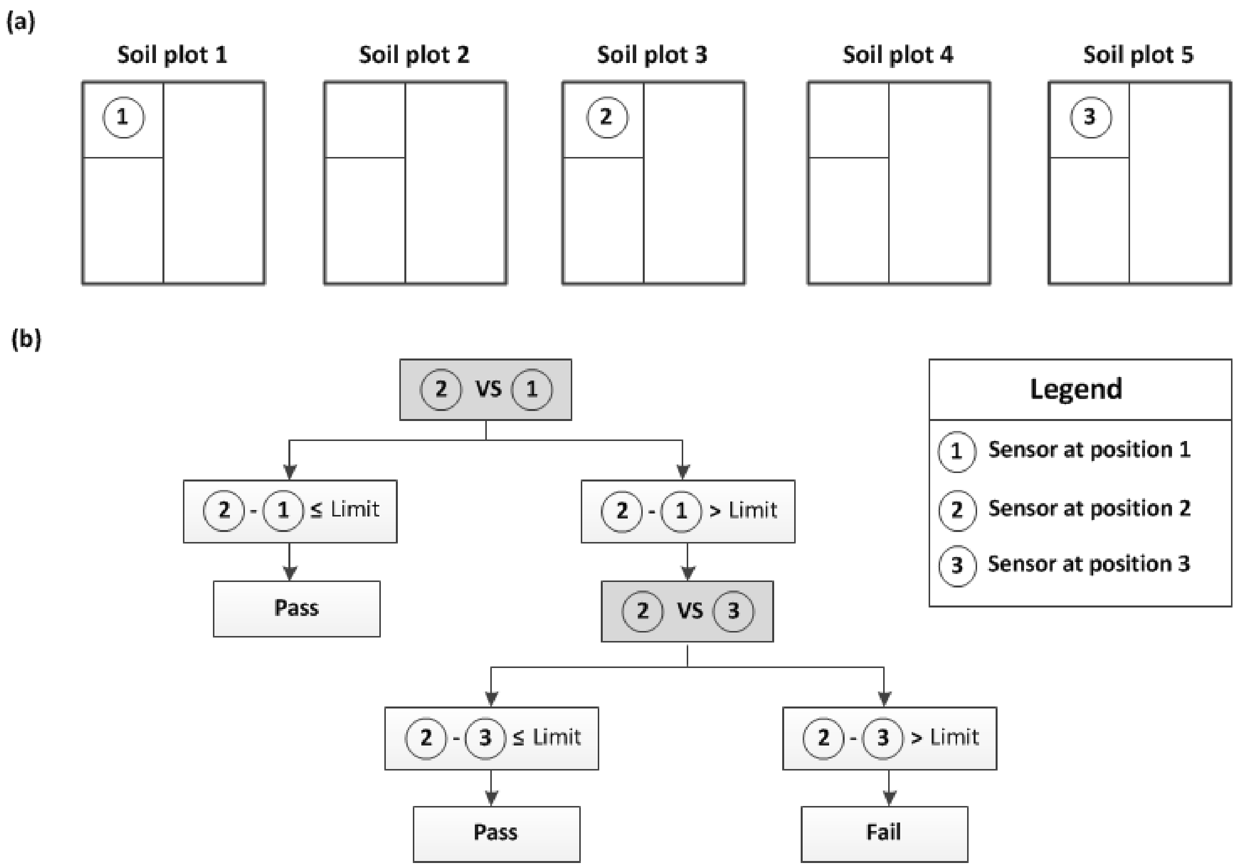

Figure 2. (a) Diagram of the position of the LI-191 sensors within the soil array and (b) consistency test flow diagram for the LI-191 sensor deployed at position 2.

4. **Quality Flags (QFs) and Quality Metrics (QMs)** AD[14] – If a datum has one of the following flags it will not be used to create a L1 DP, $\underline{QF_R}$ and $\underline{QF_D}$. α and β QFs and QMs will be determined for the following flags QF_R, QF_σ, QF_δ, QF_S, QF_N, QF_G, and QF_D. All L1 DPs will have an associated final quality flag, QF_{NEON}, and quality summary, Qsum, as detailed in AD[14]. Flags that may be associated with the quantum line sensor measurements, as well as information maintained in the CI data store can be found below in Tables 3 and 4.

Table 3. Flags associated with the quantum line sensor.

Tests	**Flags**
Range	QF_R
Sigma (σ)	QF_σ
Delta (δ)	QF_δ
Step	QF_S
Null	QF_N
Gap	QF_G
Signal Despiking and Time Series Analysis	QF_D QF_o QF_I
Consistency Analysis	QF_V
Final quality flag	QF_{NEON}

Table 4. Information maintained in the CI data store for the quantum line sensor.

Tests/Values	**CI Data Store Contents**
Range	Minimum and maximum values
Sigma (σ)	Time segments and threshold values
Delta (δ)	Time segment and threshold values
Step	Threshold values
Null	Test limit
Gap	Test limit
Signal Despiking and Time Series Analysis	Time segments and threshold values
Calibration	CVAL sensor specific calibration coefficients
Uncertainty	AD[11]
Consistency Analysis	Test limits
Final Quality Flag	AD[14]

6 UNCERTAINTY

Uncertainty of measurement is inevitable (JCGM 2008, 2012; Taylor 1997). It is crucial that uncertainties are identified and quantified to determine statistical interpretations about mean quantity and variance structure; both are important when constructing higher level data products (e.g., L1 DP) and modeled processes. This portion of the document serves to identify, evaluate, and quantify sources of uncertainty relating to L1 mean DPs. It is a reflection of the information described in AD[10], and is explicitly described for the quantum line assembly in the following sections.

6.1 Uncertainty of PAR Measurements

Uncertainty of the quantum line sensor assembly is discussed in this section. Sources of uncertainties include those arising from the sensor, calibration procedure, and DAS noise (Figure 3).

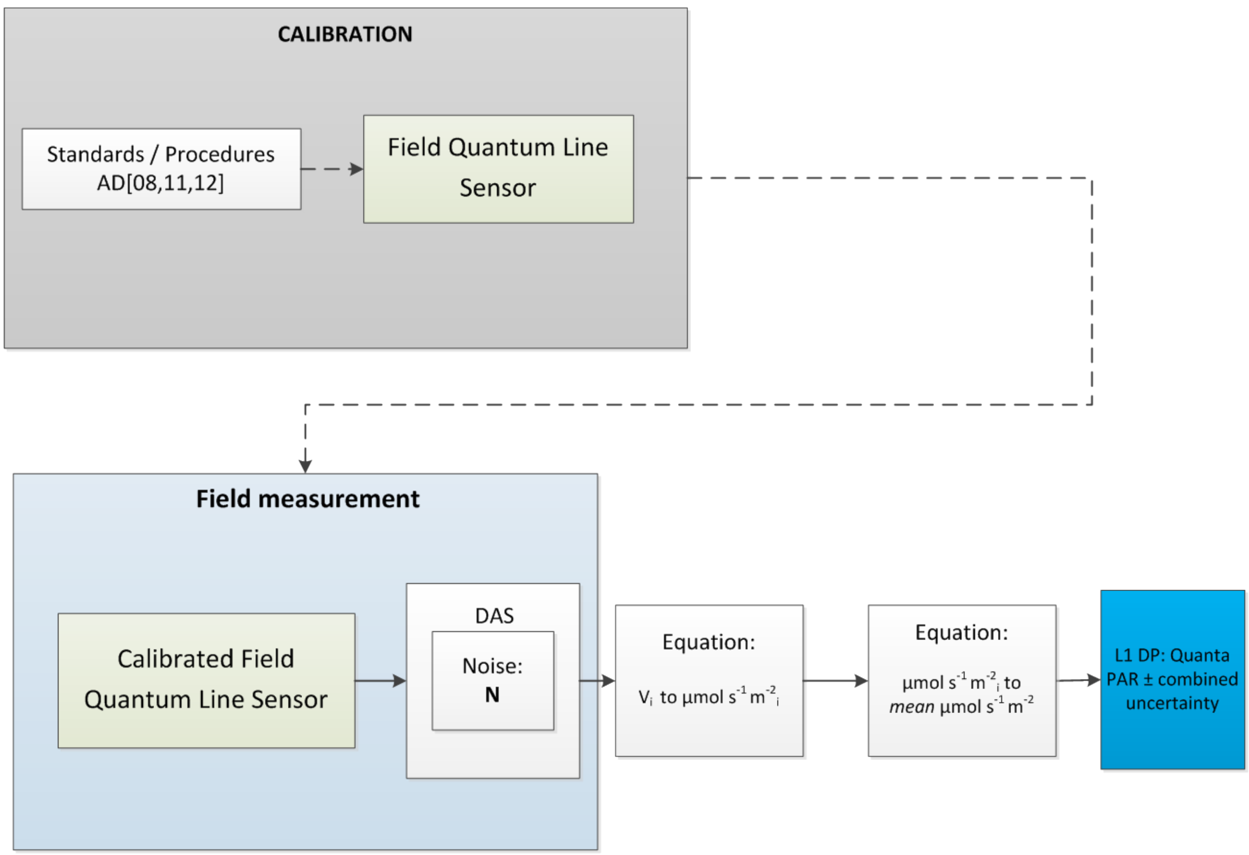

Figure 3. Displays the data flow and associated uncertainties of L1 quanta PAR DPs. For more information regarding the methods by which the PAR sensor is calibrated, please refer to AD[08,11,12].

6.1.1 Calibration

Uncertainties associated with PAR sensors and their calibration processes are combined into an individual, *relative* uncertainty $u_r(P_{CVAL})$ by CVAL. It represents i) the variation of an individual sensor from the mean of a sensor population, ii) uncertainty of the calibration procedures and iii) uncertainty of coefficients used to convert voltage to calibrated PAR (refer to Eq. (1)). It is a relative value [%] that will be provided by CVAL (AD[11]) and stored in the CI data store. After converting from [%] to measurement units, it will be applied to all PAR measurements (that is, it does not vary with any specific sensor, DAS component, etc.)

The standard combined uncertainty will be calculated by CI as a function of the *relative* uncertainty and value of the L1 PAR DP for the respective temporal period:

$$u_c\left(P_{CVAL_i}\right) = u_r(P_{CVAL}) * PAR_i \quad [\mu mol\ m^{-2}\ s^{-1}] \tag{4}$$

6.1.2 DAS

To quantify DAS noise, a *relative* uncertainty value, $u_r(\mathrm{V}_{DAS})$ will be provided by CVAL and stored in the CI data store. This value must be converted into a *standard* uncertainty value:

$$u\left(\mathrm{V}_{DAS_i}\right) = (u_r(\mathrm{V}_{DAS}) * I_i) + O_{DAS} \quad [V] \tag{5}$$

Where $u\left(\mathrm{V}_{DAS_i}\right)$ represents the standard uncertainty of an *individual,* raw, voltage measurement, E_i, and O_{DAS} is the offset imposed by the DAS. The offset accounts for readings of 0.00 V; its value will be provided by CVAL and maintained in the CI data store. This individual, standard uncertainty is then multiplied by the absolute value of Eq.(1)'s partial derivative with respect to E_i:

$$\frac{\partial PAR_i}{\partial E_i} = C_1 \tag{6}$$

$$u_E(PAR_i) = \left|\frac{\partial PAR_i}{\partial E_i}\right| u(E_i) \quad [\mu mol\ m^{-2}\ s^{-1}] \tag{7}$$

Where, $u(I_i) \equiv u\left(\mathrm{V}_{DAS_i}\right)$

6.2 Combined Uncertainty

Deriving a combined uncertainty for our L1 mean PAR DPs can be completed in two steps. Firstly, the combined uncertainty of *individual*, valid (i.e., *those that are not flagged and omitted*) observations made during the averaging period is calculated.

$$u_c(PAR_i) = \left(u_c{}^2\left(P_{CVAL_i}\right) + u_E{}^2(PAR_i)\right)^{\frac{1}{2}} \quad [\mu mol\, m^{-2}\, s^{-1}] \tag{8}$$

The resulting value is multiplied by the partial derivative of the L1 DP. Since the DP is a temporal average, the partial derivative with respect to an individual measurement is simply:

$$\frac{\partial \overline{PAR}}{\partial PAR_i} = \frac{1}{n} \tag{9}$$

Where n represents the number of valid observations made during the averaging period. The absolute value of Eq. (9) is then multiplied by Eq. (8):

$$u_{PAR_i}(\overline{PAR}) = \left|\frac{\partial \overline{PAR}}{\partial PAR_i}\right| u_c(PAR_i) \quad [\mu mol\, m^{-2}\, s^{-1}] \tag{10}$$

Finally, the combined uncertainty of the L1 mean DP is calculated via quadrature:

$$u_c(\overline{PAR}) = \left(\sum_{i=1}^{n} u_{PAR_i}{}^2(\overline{PAR})\right)^{\frac{1}{2}} \quad [\mu mol\, m^{-2}\, s^{-1}] \tag{11}$$

6.3 Expanded Uncertainty

The expanded uncertainty for L1 PAR DPs can be derived with the following equations:

$$V_{eff\,PAR_i} = \frac{u_c{}^4(PAR_i)}{\frac{u_c{}^4\left(P_{CVAL_i}\right)}{Veff_{P_{CVAL}}} + \frac{u_E{}^4(PAR_i)}{Veff_{V_{DAS}}}} \tag{12}$$

Where $Veff_{P_{CVAL}}$ and $Veff_{V_{DAS}}$ are functions of the number of tests conducted by CVAL during calibration – their values will be stored in the CI data store.

Second, the effective degrees of freedom must be calculated for our L1 mean PAR DP:

$$V_{eff\,\overline{PAR}} = \frac{u_c{}^4(\overline{PAR})}{\sum_{i=1}^{n}\left(\frac{(u_c(PAR_i)/n)^4}{V_{eff\,PAR_i}}\right)} \tag{13}$$

Finally, the expanded uncertainty is calculated:

$$U_{95}(\overline{PAR}) = k_{95} * u_c(\overline{PAR}) \quad [\mu mol\, m^{-2}\, s^{-1}] \tag{14}$$

Where k_{95} is the coverage factor obtained with the aid of:

- Table 5 from AD[10]
- $V_{eff_{\overline{PAR}}}$

6.4 Uncertainty Budget

The uncertainty budget is a visual aid detailing i) quantifiable sources of uncertainty, ii) means by which they are derived, and iii) the order of their propagation. Individual uncertainty values denoted in this budget are either provided here (within this document) or will be provided by other NEON teams (e.g., CVAL) and stored in the CI data store.

Table 3: Uncertainty budget for L1 quanta PAR DPs. Shaded rows denote the order of uncertainty propagation (from lightest to darkest).

Source of uncertainty	**Standard uncertainty component $u(x_i)$**	**Value of standard uncertainty** $[\mu mol\, m^{-2}\, s^{-1}]$	$c_i \equiv \frac{\partial f}{\partial x_i}$	$u_i(Y) \equiv \lvert c_i \rvert u(x_i)$ $[\mu mol\, m^{-2}\, s^{-1}]$	**Degrees of Freedom**
L1 PAR DP	$u_c(\overline{PAR})$	Eq. (11)	--	--	Eq. (13)
1 Hz PAR	$u_c(PAR_i)$	Eq. (8)	Eq. (9)	Eq. (10)	Eq. (12)
Sensor/calibration	$u_c(P_{CVAL_i})$	Eq. (4)	1	Eq. (4)	AD[14]
Noise (DAS)	$u(I_i)$	Eq. (5) [V]	Eq. (6)	Eq. (7)	AD[14]
					k_{95}: $V_{eff_{\overline{PAR}}}$ & Table 5 of AD[10] $U_{95}(\overline{PAR})$: Eq. (14)

7 FUTURE PLANS AND MODIFICATIONS

Future system flags may be incorporated into the data stream and included in the QA/QC summary DP (*Qsum*$_{1min}$ and *Qsum*$_{30min}$) that summarizes any flagged data that went into the computation of the L1 DP.

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