ALGORITHM THEORETICAL BASIS DOCUMENT (ATBD)
BAROMETRIC PRESSURE

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	08/02/2013	ECO-00796	Initial Release
B	05/04/2016	ECO-03727	Updated document to reflect L0 and L1 data product renumbering. Revised *Algorithm Implementation* and *Uncertainty* Sections. Changes include: Added *soil plot pressure* data products and input dependencies. Added HMP155 dependent L1 data products to calculate elevation corrected pressure. Aquatic meteorology station information added. Removed dynamic calculations of effective degrees of freedom and implementing a standardized coverage factor of k=2 to calculate an expanded uncertainty at 95% confidence Added footnote to CVAL reference Moved mentions of Consistency analyses to the Future Updates Section in Each ATBD Added logic table for inputs to corrected pressure equation(s)

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 DESCRIPTION

1.1 Purpose

This document details the algorithms used for creating NEON L1 DP from L0 DP for tower-based measurements of barometric pressure, and ancillary data (such as calibration data), obtained via instrumental measurements made by the Vaisala BAROCAP® Digital Barometer PTB330. 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 exposition of uncertainty resulting in a cumulative reported uncertainty for this product.

1.2 Scope

This document describes the theoretical background and entire algorithmic process for creating the NEON L1 data product for barometric pressure, NEON.DOM.SITE.DP1.00004.001 from input data. It does not provide computational implementation details, except for cases where these stem directly from algorithmic 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.005505	NEON CVAL Technical and Operating Requirements
AD[06]	NEON.DOC.000735	Atmospheric Pressure Calibration Fixture
AD[07]	NEON.DOC.000782	ATBD QA/QC Data Consistency
AD[08]	NEON.DOC.011081	ATBD QA/QC plausibility tests
AD[09]	NEON.DOC.000783	ATBD De-spiking and time series analyses
AD[11]	NEON.DOC.000785	TIS Level 1 Data Products Uncertainty Budget Estimation Plan
AD[12]	NEON.DOC.000646	NEON Algorithm Theoretical Basis Document: SAATs
AD[13]	NEON.DOC.000746	Evaluating Uncertainty(CVAL)
AD[14]	NEON.DOC.000927	NEON Calibration and Sensor Uncertainty Values[1]
AD[15]	NEON.DOC.000735	CVAL Barometric Pressure Calibration Fixture
AD[16]	NEON.DOC.001113	Quality Flags and Quality Metrics for TIS Data Products
AD[17]	NEON.DOC.011083	NEON Algorithm Theoretical Basis Document – Soil CO_2 concentration
AD[18]	NEON.DOC.001446	C^3 AQU Barometric Pressure
AD[19]	NEON.DOC.000851	NEON Algorithm Theoretical Basis Document – Relative Humidity

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
AGL	Above Ground Level
ASL	Above Sea Level
ATBD	Algorithm Theoretical Basis Document
CVAL	NEON Calibration, Validation, and Audit Laboratory
DAS	Data Acquisition System

[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.

DP	Data Product
FDAS	Field Data Acquisition System
L0	Level 0
L1	Level 1
LR	Lapse Rate
N/A	Not Applicable

2.4 Variable Nomenclature

The symbols used to display the various inputs in the ATBD, e.g., calibration coefficients and uncertainty estimates, were chosen so that the equations can be easily interpreted by the reader. However, the symbols provided will not always reflect NEON's internal notation, which is relevant for CI's use, and or the notation that is used to present variables on NEON's data portal. Therefore a lookup table is provided, Table 1, in order to distinguish what symbols specific variables can be tied to in the following document.

Symbol	**Internal Notation**	**Description**
C_0	CVALA0	CVAL calibration coefficient
C_1	CVALA1	CVAL calibration coefficient
C_2	CVALA2	CVAL calibration coefficient
u_{A1_P}	UCVAL_A1	Standard combined uncertainty of station pressure; provided by CVAL.
u_{A3_P}	UCVAL_A3	Calibration uncertainty of station pressure; provided by CVAL.
$u_{A3_{T_s}}$	UCVAL_A3	Calibration uncertainty of station temperature; provided by CVAL.
$u_{A3_{T_d}}$	UCVAL_A3	Calibration uncertainty of dewpoint; provided by CVAL.

2.5 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

Pressure related L1 DPs provided by the algorithms documented in this ATBD are displayed in the accompanying file, bar_datapub_NEONDOC002884.txt.

3.2 Input Dependencies

Table 3-1 details the barometric pressure related L0 and L1 DPs used in this ATBD.

Table 3-1: List of DPs used to derive L1 DPs within this ATBD.

Description	Sample Frequency	Units	Data Product Number
Station Pressure	0.1 Hz	*kPa*	NEON.DOM.SITE.DP0.00004.001.01311.HOR.VER.000
One-minute mean station pressure	NA	*kPa*	NEON.DOM.SITE.DP1.00004.001.00451.HOR.VER.001
One-minute station pressure final quality flag	NA	*binary*	NEON.DOM.SITE.DP1.00004.001.00490.HOR.VER.001
One-minute station pressure expanded uncertainty	NA	*kPa*	NEON.DOM.SITE.DP1.00004.001.00456.HOR.VER.001
thirty-minute mean station pressure	NA	*kPa*	NEON.DOM.SITE.DP1.00004.001.00451.HOR.VER.030
Thirty-minute station pressure final quality flag	NA	*binary*	NEON.DOM.SITE.DP1.00004.001.00490.HOR.VER.030
Thirty-minute station pressure expanded uncertainty	NA	*kPa*	NEON.DOM.SITE.DP1.00004.001.00456.HOR.VER.030
One-minute mean temperature (soil plot HMP155)	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00693.HOR.000.001
One-minute temperature final quality flag (soil plot HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00732.HOR.000.001
One-minute temperature expanded uncertainty (soil plot HMP155)	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00698.HOR.000.001
One-minute mean temperature (tower HMP155)	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00693.000.VER.001
One-minute temperature final quality flag (tower HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00732.000.VER.001
One-minute temperature expanded uncertainty (tower HMP155)	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00698.000.VER.001
Thirty-minute mean temperature (soil plot HMP155)	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00693.HOR.000.030
Thirty-minute temperature final quality flag (soil plot HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00732.HOR.000.030
Thirty-minute temperature expanded uncertainty (soil	NA	$^{\circ}C$	NEON.DOM.SITE.DP1.00098.001.00698.HOR.000.030

plot HMP155)			
Thirty-minute mean temperature (tower HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00693.000.VER.030
Thirty-minute temperature final quality flag (tower HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00732.000.VER.030
Thirty-minute temperature expanded uncertainty (tower HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00698.000.VER.030
One-minute mean dewpoint temperature (soil plot HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00733.HOR.000.001
One-minute dewpoint temperature final quality flag (soil plot HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00772.HOR.000.001
One-minute dewpoint temperature expanded uncertainty (soil plot HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00738.HOR.000.001
One-minute mean dewpoint temperature (tower HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00733.000.VER.001
One-minute dewpoint temperature final quality flag (tower HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00772.000.VER.001
One-minute dewpoint temperature expanded uncertainty (tower HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00738.000.VER.001
Thirty-minute mean dewpoint temperature (soil plot HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00733.HOR.000.030
Thirty-minute dewpoint temperature final quality flag (soil plot HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00772.HOR.000.030
Thirty-minute dewpoint temperature expanded uncertainty (soil plot HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00738.HOR.000.030
Thirty-minute mean dewpoint temperature (tower HMP155)	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00733.000.VER.030
Thirty-minute dewpoint temperature final quality flag (tower HMP155)	NA	*binary*	NEON.DOM.SITE.DP1.00098.001.00772.000.VER.030
Thirty-minute dewpoint temperature expanded	NA	˚C	NEON.DOM.SITE.DP1.00098.001.00738.000.VER.030

uncertainty (tower HMP155)			
Barometer's Latitude	NA	*deg. N*	CI data store
Barometer's elevation	NA	*m*	CI data store
uncertainty of Barometer's elevation	NA	*m*	CI data store
Center of Soil Plot 1 elevation	NA	*m*	CI data store
uncertainty of Soil Plot 1 elevation	NA	*m*	CI data store
Center of Soil Plot 2 elevation	NA	*m*	CI data store
uncertainty of Soil Plot 2 elevation	NA	*m*	CI data store
Center of Soil Plot 3 elevation	NA	*m*	CI data store
uncertainty of Soil Plot 3 elevation	NA	*m*	CI data store
Center of Soil Plot 4 elevation	NA	*m*	CI data store
uncertainty of Soil Plot 4 elevation	NA	*m*	CI data store
Center of Soil Plot 5 elevation	NA	*m*	CI data store
uncertainty of Soil Plot 5 elevation	NA	*m*	CI data store

3.3 Product Instances

Barometric pressure will be recorded at all core and relocatable sites through a Vaisala BAROCAP® Digital PTB330 Class A barometer.

3.4 Temporal Resolution and Extent

Barometric pressure will be recorded at a rate of 0.1 Hz for L0 DPs, and these L0 DPs will be used to calculate the L1 DPs, one- and thirty-minute averages of station and sea level pressure, as well as one-minute averages of soil plot pressure.

3.5 Spatial Resolution and Extent

At terrestrial sites the pressure sensor will be located on the tower infrastructure at a site specific installation height (h) above ground level (AGL). At aquatic sites the pressure sensor will be located on a field-based met station (tripod) at a standard installation height of above ground level. Lake sites will have an additional pressure sensor located on a buoy at a standard installation height above water level (AWL), but at a different sampling frequency and that data will be handled in a separate ATBD. Therefore, barometric (station) pressure will represent the point in space at which the barometer is located.

4 SCIENTIFIC CONTEXT

Barometric pressure, or static atmospheric pressure, is a vital measurement for NEON. Barometric pressure is significant in influencing weather conditions as well as aqueous chemistry (e.g. the amount of gas that can dissolve in solution). Recording static atmospheric pressure will allow atmospheric gas mixing ratios to be converted into mass quantities. Barometric pressure will be recorded over NEON's entire operational range and the accuracy and precision requirements can be found in Dynamic Object-Oriented Requirements System.

4.1 Theory of Measurement

Simply stated, barometric pressure is the weight exerted on a given location by the atmosphere above it, per unit area. Barometric pressure has long been determined using mercury barometers, which relate the weight of the atmosphere to the weight of a column of mercury. While mercury barometers are common for many historical applications, digital, aneroid barometers are becoming much more prevalent. This is mainly attributed to their ruggedness and ability to be automated while still maintaining high accuracy and stability (Van der Meulen 1992).

Aneroid barometers operate on the principal of converting pressure proportionally to electrical voltage through the use of transducers (i.e. silicon diaphragm), microprocessors, and sensors. In the Vaisala BAROCAP® barometer, pressure is determined from changes in the capacitance of a silicon crystal sensor. CVAL's calibration process to meet NEON's accuracy and precision requirements can be found in AD[06].

4.2 Theory of Algorithm

Pressure will be presented as station pressure, p_s, pressure corrected to sea level, p_0, pressure corrected to the elevation of each TIS soil plot, and pressure corrected to the elevation of each aquatic sensor set location. Station pressure will first be determined applying calibration coefficients, supplied by CVAL, to the "raw" sensor output as follows:

$$p_{s_i} = C_2 * p_i^2 + C_1 * p_i + C_0 \tag{1}$$

Where:

p_{s_i}	= Individual (0.1 Hz) station pressure (kPa)
C_2	= Calibration coefficient provided by CVAL ((kPa)$^{-1}$)
C_1	= Calibration coefficient provided by CVAL (unitless)
C_0	= Calibration coefficient provided by CVAL (kPa)
p_i	= Individual (0.1 Hz) pressure output from sensor (kPa)

One-minute averages of station, soil plot, and sea level pressure will be determined following Eq. (2), and thirty-minute averages of station and sea level pressure will be determined following and (3) to create the L1 DPs listed in listed in file bar_datapub_NEONDOC002884.txt. Here we let p represent station, sea level, and soil plot pressure since they will be averaged the same way to create the L1 DPs according to Eq. (2) and (3). Individual calibrated measurements, i.e. 0.1 Hz pressure, will be made available upon request.

$$\overline{p_1} = \frac{1}{n}\sum_{i=1}^{n} p_i \tag{2}$$

where, for each 1-minute average, n is the number of measurements during the averaging period and p_i is a 0.1-Hz pressure measurement taken during the 60-second averaging period [0, 60). For a 1-minute average, n = 60 if all data points are included.

and,

$$\overline{p_{30}} = \frac{1}{n}\sum_{i=1}^{n} p_i \tag{3}$$

where, for each 30-minute average, n is the number of measurements during the averaging period and p_i is a 0.1-Hz pressure measurement taken during the 1800-second averaging period [0, 1800).

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.

Due to the effects that temperature and altitude have on pressure, readings are often normalized to sea level so that they are analogous among locations. In addition, the pressure at the surface of each soil plot, which usually differ in elevation from the barometer, are needed to apply a compensation to the soil CO_2 concentration sensor measurements (AD[17]).

Barometric pressure at the water surface influences the rate of gas exchange between the water and atmosphere. Corrected Pressure should be derived to properly calculate the reaeration (gas exchange) rate, which is necessary to determining ecological parameters such as whole stream metabolism (Johnson, 2013). Provided here is a method for pressure correction; however barometric pressure corrected to the water surface will not be provided within the current NEON Data Product Catalog nor offered as a published level 1 data product.

The WMO (2008) presents Eq. (4), which is used to adjust station pressure to different atmospheric heights and sea level. Although other algorithms exist, the algorithm provided by the WMO (2008) is considered the standard method:

$$p_\Lambda = p_s * e^{\left(\frac{Z_\Phi * \frac{g_0}{R_d}}{\overline{T_v}}\right)} = p_s * e^{\left(\frac{Z_\Phi * \frac{g_0}{R_d}}{T_s + \frac{\alpha * Z_\Phi}{2} + e_v * C_h}\right)} \quad (4)$$

Where:

Z_Φ = Geopotential Height of barometer (gpm) Above Sea Level (ASL)
g_0 = Standard acceleration of gravity = 9.80665 (m s^{-2})
R_d = Gas constant of dry air = 287.05 (J kg^{-1}·K^{-1})
$\overline{T_v}$ = Mean virtual temperature (K)
α = Standard Atmospheric Lapse Rate of temperature = 0.0065 (K m^{-1})
p_Λ $= \begin{cases} p_0 & \text{when calculating sea level pressure} \\ p_{soil} & \text{when calculating soil surface pressure} \end{cases}$ (kPa)
p_s = Station pressure (kPa)
T_s = Station temperature (K)
e_v = Vapor pressure (kPa)
C_h = Lapse rate of vapor pressure = 1.2 (K kPa^{-1}; Rao 1957, 1958)

According to Wallace and Hobbs (2006), the calculation of Z_Φ is:

$$Z_\Phi \equiv \frac{\Phi(z)}{g_0} = \frac{1}{g_0}\int_c^z g(\theta, z')dz' \quad (5)$$

where:

Z_Φ = Barometer's geopotential Height (gpm) above reference level
$\Phi(z)$ = Geopotential (m^2 s^{-2}) at barometer's elevation
g_0 = Globally averaged gravity (9.81 m s^{-2})
z = Barometer's elevation (m ASL)
$g(\theta, z')$ = Local gravity as a function of elevation and latitude of the barometer (m s^{-2})
z' = Integration constant
c = elevation of converted pressure reference level (m)
$\begin{cases} 0 & \text{when calculating sea level pressure} \\ h_{soil} & \text{when calculating soil surface pressure} \end{cases}$
$h_{soil,i}$ = elevation of the center of soil plot *i* (m ASL), stored in the CI data store.

The horizontal and vertical distances between the barometer on the tower and each soil plot are always <300 m, and <75 m, respectively. The difference in pressure in horizontal space is assumed to be negligible since pressure changes are considerably smaller in the horizontal relative to the vertical (Ahrens 2007). The algorithm for soil surface pressure, p_{soil}, accounts for the difference in the geopotential height (vertical distances) of the barometer and the soil plot surface.

The local gravity (m s^{-2}) at barometer height z (m), can be approximated as follows (Jursa 1985):

$$g(\theta, z) = 9.780356[1 + 0.0052885 \sin^2\theta - 0.0000059 \sin^2(2\theta)] - 0.003086 * (\frac{z}{1000}) \quad (6)$$

where:
θ = latitude of barometer (radians), provided in the CI data store

Combining Eqns. (5) and (6):

$$Z_\Phi * g_0 \equiv \frac{\Phi(z)}{g_0} * g_0 \equiv \Phi(z) \approx h' * g(\theta, z) \quad (7)$$

Where:

$$h' = z - c \quad (8)$$

h' = Barometer's elevation (m) above reference level c

Substituting, Eq. (4) becomes:

$$p_\Lambda = p_s * e^{\left(\frac{Z_\Phi * g_0}{R_d\left(\overline{T_s} + \frac{\alpha * Z}{2} + e_v * C_h\right)}\right)} \approx p_s * e^{\left(\frac{h' * g(\theta, z)}{R_d\left(\overline{T_s} + \frac{\alpha * Z}{2} + e_v * C_h\right)}\right)} \quad (9)$$

Vapor pressure, e_v, which is a function of dew point, is simply the pressure that atmospheric water vapor exerts on the atmosphere (Wallace and Hobbs 2006). Values of e_v are rarely > 3 kPa in mid-latitude regions, but can occasionally reach slightly higher values in the Subtropics and Tropics where concentrations of atmospheric water vapor are high. Vapor pressure will be derived using dewpoint data derived from either a) the soil plot hygrometer at terrestrial sites (TIS), or b) the met station hygrometer at aquatic sites (AQU); this process is the detailed in Eq. (10).

$$\overline{e_v} = 10^{\left(\frac{7.5}{\frac{237.3}{\overline{T_d}} + 1}\right) - 0.21411} \quad (10)$$

Where:

$\overline{e_v}$: One- or thirty-minute mean vapor pressure (kPa)

$$\overline{T_d} := \begin{cases} \text{NEON.DOM.SITE.DP1.00098.001.00733.HOR.VER.001} & (1 - minute) \\ \text{OR} & \\ \text{NEON.DOM.SITE.DP1.00098.001.00733.HOR.VER.030} & (30 - minute) \end{cases}$$

The final equation for reduction of station pressure will be:

$$\bar{p}_{\Lambda} = \bar{p_s} * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)} \quad (11)$$

where:

$$\bar{p}_{\Lambda} = \begin{cases} \bar{\mathrm{p}}_0 & \text{when calculating sea level pressure (kPa)} \\ \bar{\mathrm{p}}_{\mathrm{soil,i}} & \text{when calculating soil surface pressure (kPa), i = soil plot number} \\ \bar{\mathrm{p}}_{\mathrm{water,i}} & \text{when calculating water surface pressure (kPa), i = sensor set number} \end{cases}$$

$$\bar{p_s} = \begin{cases} \mathrm{NEON.DOM.SITE.DP1.00004.001.00451.HOR.VER.001} \quad (1 - minute) \\ \mathrm{OR} \\ \mathrm{NEON.DOM.SITE.DP1.00004.001.00451.HOR.VER.030} \quad (30 - minute) \end{cases}$$

$$\overline{T_s} = \begin{cases} \mathrm{NEON.DOM.SITE.DP1.00004.001.00693.HOR.VER.001} \quad (1 - minute) \\ \mathrm{OR} \\ \mathrm{NEON.DOM.SITE.DP1.00004.001.00693.HOR.VER.030} \quad (30 - minute) \end{cases}$$

L1 mean temperature (converted to Kelvin; Eq. (12)) and dew point DPs with corresponding temporal resolutions to corrected sea and surface pressures (i.e., one or thirty minute averages) shall be used as inputs to correct station pressure as shown in Eq. (10) and (11).

$$\overline{T_s} = (\overline{T_1} \text{ or } \overline{T_{30}}) + 273.15 \quad (12)$$

Table 4-2 details which HMP155 sensor shall be used when deriving corrected pressure.

Table 4-2: Logic Table for corrected pressure calculations at terrestrial sites. *Val* represents value, e.g., temperature, and whether or not n ≥ 1 for the given averaging period. QF represents the final quality flag of said data product. *T* represents temperature, and T_d represents dew point.

No.	Soil Plot				Tower				T QF	T_d QF	Note
	T		T_d		T		T_d				
	Val	QF	Val	QF	Val	QF	Val	QF			
1	present	0	present	0					0	0	Both ground present and both QF=0
2					present	0	present	0	0	0	Both tower

											present and both QF=0
3	present	0/1	present	0/1					0/1	0/1	Both ground present but either QF=1
4					present	0/1	present	0/1	0/1	0/1	Both tower present but either QF=1
5	Do not compute										

At aquatic sites the one-minute mean SAAT L1 DP from the aquatic met station will be used as station temperature ($\overline{T}_s$). If the temperature measurement is unavailable for the time period, the one-minute mean RH temperature from the HMP155 sensor will be used as station temperature. Since barometric pressure is recorded at a rate of 0.1 Hz, nominally 6 pressure measurements will be associated with a single one-minute SAAT mean.

5 ALGORITHM IMPLEMENTATION

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

1. The barometer L0 DPs will be converted into station pressure by applying calibration coefficients through Eq. (1).
2. QA/QC Plausibility tests will be applied to the data stream in accordance with AD[08]. The details are provided below.
3. Signal de-spiking will be applied to the data stream in accordance with AD[09].
4. One- and thirty-minute station barometric pressure averages will be calculated using Eq. (2) and (3).
5. Descriptive statistics, i.e. minimum, maximum, and variance, will be determined for both one- and thirty-minute averages of station pressure.
6. Quality metrics, quality flags, and the final quality flag will be produced for one- and thirty-minute station pressure averages according to AD[16].
7. One- and thirty-minute averages of station pressure will be converted to corrected sea and surface pressures through Eq. (11).

8. QA/QC sensor flags will be applied to the data stream for corrected sea and surface pressures, details provided below.
9. The final quality flag for corrected sea and surface pressures will be produced as detailed below.

QA/QC Procedure:

1. **Plausibility Tests** AD[08] – All plausibility tests will be determined for the barometer. 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. **Sensor Flags** – Barometric pressure corrected to sea level (i.e., corPres) and surface level (i.e., surfacePres) require ambient temperature and dew point measurements as inputs. In the event this ancillary data is unavailable or flagged the following quality flags shall be set accordingly.

   a. Temperature:

   tempQF= { 1 if temperature sensor measurements are missing or flagged (details in Section 4.2)
   0 otherwise

   b. Dew Point:

   dewPointQF= { 1 if dew point sensor measurements are missing or flagged (details in Section 4.2)
   0 otherwise

3. **Signal De-spiking**– Time segments and threshold values for the automated despiking QA/QC routine will be specified by FIU and maintained in the CI data store. QFs from the despiking analysis will be applied according to AD[09].

4. **Quality Flags (QFs) and Quality Metrics (QMs)** AD[16] – If a datum fails one of the following tests it will not be used to create a L1 DP, ***range***, ***persistence***, and ***step.*** α and β QFs and QMs will be determined for station pressure using the flags in Table 5-1. In addition, station pressure L1 DPs will have a QA/QC report and quality metrics associated with each flag listed in Table 5-1, as detailed in AD[16]. Ancillary information needed for the algorithm and other information maintained in the CI data store is shown in Table 5-2. Since corrected sea and surface pressures are determined by converting the mean station pressure their quality information only includes temperature, dew point, and final quality flags. The final quality flag for station pressure, pressure corrected to sea level, and pressure corrected to surface level will be determined accordingly.

a. Final Quality

i. **Station Pressure** – The final quality flag for station pressure (i.e., staPresFinalQF) shall be set as well as detailed in AD[16].

ii. **Pressure Corrected to Sea Level** – The final quality flag for pressure corrected to sea level shall be set to one if the final flag for station pressure was 1 or, determined accordingly as shown below.

$$\text{corPresFinalQF} = \begin{cases} 1 \text{ if staPresFinalQF} = 1 \text{ or tempQF} = 1 \text{ or dewPointQF} = 1 \\ 0 \text{ otherwise} \end{cases}$$

iii. **Pressure Corrected to Surface Level**– The final quality flag for pressure converted to surface level shall be set to one if the final flag for station pressure was 1 or, determined accordingly as shown below.

$$\text{surfacePresFinalQF} = \begin{cases} 1 \text{ if staPresFinalQF} = 1 \text{ or tempQF} = 1 \text{ or dewPointQF} = 1 \\ 0 \text{ otherwise} \end{cases}$$

Table 5-1: Flags associated with station pressure measurements.

Tests
Range
Persistence
Step
Null
Gap
Signal Despiking
Alpha
Beta
Final quality flag

Table 5-2: Information maintained in the CI data store for barometric pressure.

Tests/Values	CI Data Store Contents
Range	Minimum and maximum values
Persistence	Window size, threshold values and maximum time length

Step	Threshold values
Null	Test limit
Gap	Test limit
Signal Despiking	Time segments and threshold values
Calibration	CVAL sensor specific calibration coefficients
Uncertainty	AD[14]
Final Quality Flag	AD[16]

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. This portion of the document serves to identify, evaluate, and quantify sources of uncertainty relating to individual, calibrated pressure measurements as well as L1 mean pressure DPs. It is a reflection of the information described in AD[11], and is explicitly described for the barometric assembly in the following sections.

6.1 Uncertainty of Atmospheric Pressure Measurements

Uncertainty of the pressure assembly is discussed in this section. This section discusses two topics. The first informs the sources of *measurement* uncertainty, i.e., those associated with *individual measurements*. The second details uncertainties associated with temporally averaged data products. A diagram detailing the data flow and known sources of uncertainty are displayed in Figure 2.

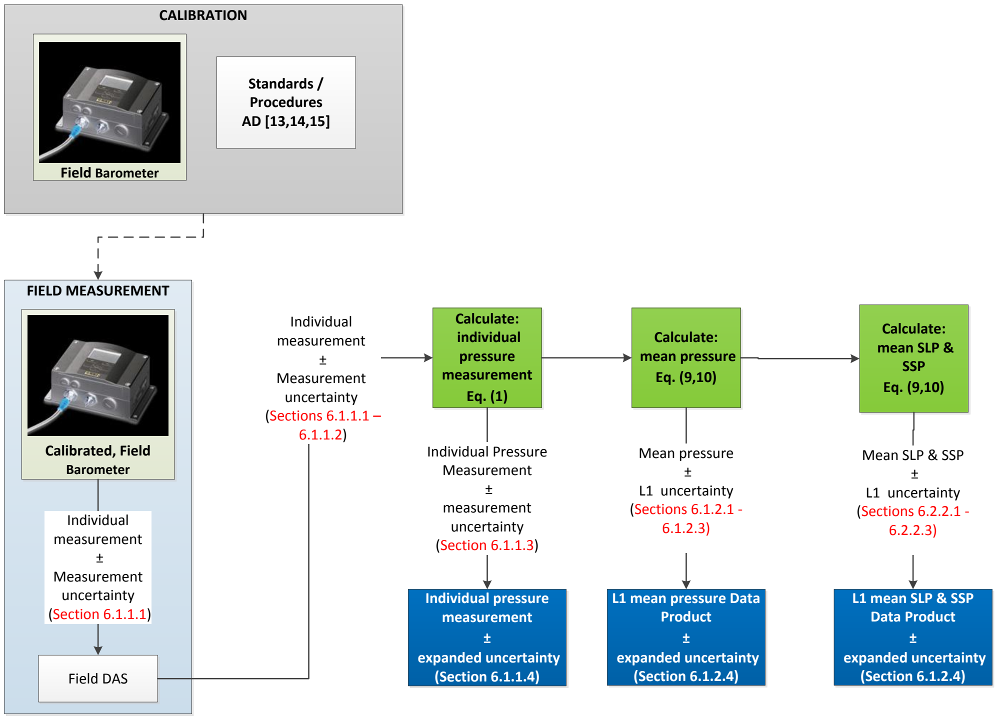

Figure 1: Displays the data flow and associated uncertainties of individual pressure measurements and L1 pressure DPs. Sea level pressure is represented by *SLP,* and soil surface pressure is represented by *SSP*. For more information regarding the calibration procedure, please refer to AD [13,14,15].

6.1.1 Measurement Uncertainty

The following subsections present the uncertainties associated with *individual pressure observations*. It is important to note that the uncertainties presented in the following subsections are *measurement uncertainties*, that is, they reflect the uncertainty of an *individual* measurement. These uncertainties should not be confused with those presented in Section 6.1.2. We urge the reader to refer to AD[11] for further details concerning the discrepancies between quantification of measurement uncertainties and L1 uncertainties.

NEON calculates measurement uncertainties according to recommendations of the Joint Committee for Guides in Metrology (JCGM) 2008. In essence, if a measurand *y* is a function of *n* input quantities $x_i\ (i = 1, \dots, n),\ \ i.e., y = f(x_1, x_2, \dots, x_n)$, the combined measurement uncertainty of *y*, assuming the inputs are independent, can be calculated as follows:

$$u_c(y) = \left(\sum_{i=1}^{N} \left(\frac{\partial f}{\partial x_i} \right)^2 u^2(x_i) \right)^{\frac{1}{2}} \quad (13)$$

where

$\frac{\partial f}{\partial x_i}$ = partial derivative of *y* with respect to x_i

$u(x_i)$ = combined standard uncertainty of x_i.

Thus, the uncertainty of the measurand can be found be summing the input uncertainties in quadrature. For temperature measurements, the sources of uncertainty are depicted in Figure 1. The calculation of these input uncertainties is discussed below.

6.1.1.1 Station Pressure

This Section details measurement uncertainties relating to individual *station* pressure measurements.

6.1.1.1.1 Calibration

Uncertainties associated with the barometer's calibration process propagate into a standard, combined measurement uncertainty. This combined uncertainty, u_{A1_p}, represents i) the repeatability and reproducibility of the sensor and the lab DAS and ii) uncertainty of the calibration procedures and coefficients including uncertainty in the standard (truth). It is a constant value that will be provided by CVAL (AD[14]), stored in the CI data store, and applied to all *individual measurements* (that is, it does not vary with any specific sensor, DAS component, location, etc.). A detailed summary of the calibration procedures and corresponding uncertainty estimates can be found in AD[13,14,15].

6.1.1.1.2 Field DAS

This barometer has an internal A/D converter and outputs data in digital form. Because of this, uncertainty introduced by the field DAS is considered negligible.

6.1.1.1.3 Dynamic Pressure (wind-induced uncertainties)

When measuring atmospheric pressure, the goal is to quantify the *static* pressure, s, of the atmosphere. The static pressure can be thought of as atmospheric pressure free from the effects of wind loading or wind-induced pressure changes (error); this phenomenon is often referred to as *dynamic pressure*, d. Atmospheric pressure can be represented by *total* pressure, t, because the effects of dynamic pressure cannot be accurately quantified.

$$s = t - d \tag{14}$$

Dynamic pressure produces a pressure error:

$$u_d(s) = \frac{\rho u^2}{2} \tag{15}$$

Where,

$u(s)$ = uncertainty of static pressure introduced by dynamic pressure (kPa); equation modified from Brock and Richardson (2001)

ρ = density of the air (kg m^{-3})

u = wind velocity (m s^{-1})

According to Vaisala (2012) high wind speeds can induce noticeable pressure instability when quantifying atmospheric pressure via the PTB300. The extent to which dynamic pressure affects NEON's atmospheric pressure measure measurements is currently beyond the scope of this document. As NEON's vector component wind data are analyzed, the magnitudes of dynamic pressure influences may be better understood.

6.1.1.1.4 Combined Measurement Uncertainty

Because CVAL's uncertainty is the sole uncertainty associated with station pressure, the combined uncertainty for an individual measurement is simply equal to u_{A1_p}.

6.1.1.1.5 Expanded Measurement Uncertainty

The expanded measurement uncertainty is calculated as:

$$U_{95}(p_{s_i}) = k_{95} * u_{A1} \quad (16)$$

Where:

$U_{95}(p_{s_i})$ = expanded measurement uncertainty at 95% confidence (kPa)

k_{95} = 2 (unitless); coverage factor for 95% confidence

6.1.2 Uncertainty of L1 Mean Pressure Data Product

The following subsections discuss uncertainties associated with L1 mean data products. As stated previously, it is important to note the differences between the *measurement uncertainties* presented in Section 6.1.1 and 6.1.2 and the uncertainties presented in the following subsections. The uncertainties presented in the following subsections reflect the variance of a mean value, that is, they reflect the uncertainty of a distribution of temperature measurements collected under non-controlled conditions (i.e., those found in the field), as well as any uncertainty, in the form of trueness, introduced by the field DAS and those associated with the calibration process.

6.1.2.1 Station Pressure

6.1.2.1.1 Repeatability (natural variation)

To quantify the uncertainty in the L1 mean station pressure attributable to random effects, the distribution of the individual measurements is used. Specifically, the *standard error of the mean (natural variation),* is computed. This value, given in units of kPa, reflects the repeatability of station pressure measurements for a specified time period:

$$u_{NAT}(\bar{p}_s) = \frac{s(p_s)}{\sqrt{n}} \quad (17)$$

Where $s(p_s)$ is the experimental standard deviation of individual station pressure observations for the specified averaging period and n represents the number of observations used to calculate $\overline{p_s}$.

6.1.2.1.2 Calibration

The uncertainty detailed here is similar to that described in Section 6.1.1.1. However, the uncertainty of the mean DP, u_{A3}, does not consider i) individual sensor repeatability, or ii) the variation of sensors' responses over a population (reproducibility). This component estimates the calibration uncertainty, a quantity which is not captured by the standard error of the mean. It is a constant value that will be provided by CVAL (AD [14]) and stored in the CI data store. Please refer to AD[11] for further justification regarding evaluation and quantification of this combined uncertainty.

6.1.2.1.3 Combined uncertainty (mean Station Pressure)

The combined uncertainty for our L1 mean station pressure data product, $u_c(\bar{p}_s)$, given in units of kPa, is computed by summing the uncertainties from Sections 6.1.2.1.1 and 6.1.2.1.2 in quadrature:

$$u_c(\overline{p_s}) = \left(u_{NAT}^2(\overline{p_s}) + u_{A3_p}^2\right)^{\frac{1}{2}} \quad (18)$$

6.1.2.1.4 Expanded uncertainty (mean Station Pressure)

The expanded uncertainty is calculated as:

$$U_{95}(\overline{p_s}) = k_{95} * u_c(\overline{p_s}) \quad (19)$$

Where:

$U_{95}(\overline{p_s})$	= expanded L1 mean, station pressure, data product uncertainty at 95% confidence (kPa)
k_{95}	= 2 (unitless); coverage factor for 95% confidence

6.1.2.2 Elevation Corrected Pressure

This Section details elevation corrected pressure data products. Level 1, mean, station pressure DPs will be corrected to sea level via Eq. (11), a slightly altered version of WMO's (2008) standard method. This equation comprises a great deal of uncertainty because it abides by the concept of the "standard atmosphere." Additionally, atmospheric constants (i.e., R_d and α) are subject to their own uncertainties (Henrion and Fischhoff 1986).

6.1.2.2.1 Station Pressure

The partial derivative of Eq. (11) with respect to $\overline{p_s}$ must be calculated in order to identify the sensitivity coefficient of station pressure:

$$\frac{\partial \bar{p}_\Lambda}{\partial \overline{p_s}} = e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)} \tag{20}$$

To derive the partial uncertainty of elevation corrected pressure as a function of station pressure, the absolute value of this sensitivity coefficient is multiplied by the combined uncertainty of station pressure u_{A1}:

$$u_{\overline{p_s}}(\bar{p}_\Lambda) = \left|\frac{\partial \bar{p}_\Lambda}{\partial \overline{p_s}}\right| * u_c(\overline{p_s}) \quad [kPa] \tag{21}$$

Where, $u_c(\overline{p_s})$ is the combined uncertainty of the L1, mean, station pressure DP and is defined by:

$$u_c(\overline{p_s}) = U_{95}(\overline{p_s})/k_{95} \quad [kPa] \tag{22}$$

$$U_{95}(\overline{p_s}) = \begin{cases} \mathrm{NEON.DOM.SITE.DP1.00004.001.00456.HOR.VER.001} & (1 - minute) \\ \mathrm{OR} & \\ \mathrm{NEON.DOM.SITE.DP1.00004.001.00456.HOR.VER.030} & (30 - minute) \end{cases}$$

6.1.2.2.2 Elevation of Barometer and Corrected Pressure Reference Level

The barometer's and soil plot's elevations Above Sea Level (ASL) are also sources of uncertainty that propagate into the combined uncertainty of elevation corrected pressure. These uncertainties will be provided by SYS ENG and maintained in the CI data store.

The sensitivity coefficient with respect to the barometer's elevation ASL is approximately:

$$\frac{\partial \bar{p}_\Lambda}{\partial z} \approx \frac{4 * g(\theta,z) * \overline{p_s} * (\overline{T_s} + \overline{e_v} * C_h) * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)}}{\left(\alpha * z + 2(\overline{T_s} + \overline{e_v} * C_h)\right)^2 * R_d} \tag{23}$$

Where the approximation arises from the assumption that $\frac{\partial}{\partial z}(z * g(\theta,z)) \approx g(\theta,z)$.

The partial uncertainty of pressure corrected to the reference level is:

$$u_z(\bar{p}_\Lambda) = \left|\frac{\partial \bar{p}_\Lambda}{\partial z}\right| * u(h') \quad [kPa] \tag{24}$$

Where,

$$u(h') = \left(u^2(z) + u^2(c)\right)^{\frac{1}{2}} \quad [kPa] \tag{25}$$

6.1.2.2.3 Acceleration of Gravity

As displayed in Eq. (6), local gravity is a function of station elevation ASL and latitude. Given the current technology of GPS, and noting that even relatively large (~1000 m) changes in elevation in the lower atmosphere result in minute changes in local gravity (~0.1 m s^{-2}), we argue that the uncertainty of local gravity is negligible.

6.1.2.2.4 Dry Air Constant

A minor pitfall associated with using the dry air constant within any equation is that it assumes the atmosphere is free of water vapor. It can be said that the use of the dry air constant could cause asymmetric (systematic) uncertainty within an equation because it always assumes a completely dry atmosphere. However, in the case of correcting station pressure to a different elevation, this systematic uncertainty is corrected through the use of virtual temperature, which accounts for atmospheric moisture. In theory, the pressure of a region can be expressed as:

$$p = \rho R_d T_v = \rho R_m T \tag{26}$$

where ρ is the density of the air, R_m is the moist air constant, and T is temperature.

The dry air constant, R_d, is the gas constant for 1 kg of dry air. It is a function of the *universal gas constant* $R*$ (8.3145 J K^{-1} mol^{-1}) and the apparent molecular weight of dry air M_d (28.97 g)

$$R_d = 1000\frac{8.3145}{28.97} = 287.05\,J\,K^{-1}\,kg^{-1} \tag{27}$$

Since it is a constant, it is considered to be a true value. We know from JCGM (2008) that a true value can never be measured, and universal constants will always comprise a level of uncertainty (Henrion and Fischhoff 1986). However, the magnitude of this uncertainty is most likely minimal, especially when compared to those of the other variables comprising Eq. (11). Thus, we can assume that the uncertainty of pressure due to the dry air constant is negligible.

6.1.2.2.5 Station Temperature

The uncertainty of the L1 mean temperature DP will be calculated via the algorithms discussed in AD[12]. This uncertainty should represent the same temporal averaging period as the resulting L1 pressure DP. For example, when calculating the *one-minute* L1 mean station pressure DP, the corresponding *one-minute* L1 mean temperature DP should be used.

The sensitivity coefficient of Eq. (11) with respect to $\overline{T_s}$ is:

$$\frac{\partial \bar{p}_\Lambda}{\partial \overline{T_s}} = \frac{-4g(\theta,z) * \overline{p_s} * z * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)}}{\left(\alpha * z + 2(\overline{T_s} + \overline{e_v} * C_h)\right)^2 * R_d} \tag{28}$$

The partial uncertainty of elevation corrected pressure as a function of station temperature is then:

$$u_{\overline{T_s}}(\bar{p}_\Lambda) = \left|\frac{\partial \bar{p}_\Lambda}{\partial \overline{T_s}}\right| * u_c(\overline{T_s}) \quad [kPa] \tag{29}$$

Where, $u_c(\overline{T_s})$ is the combined uncertainty of the L1, mean temperature data product from the HMP155 used to correct station pressure and is defined by:

$$u_c(\overline{T_s}) = u_{95}(\overline{T_s})/k_{95} \quad [kPa] \tag{30}$$

If using data from the soil plot HMP155:

$$U_{95}(\overline{T_s}) = \begin{cases} \text{NEON.DOM.SITE.DP1.00098.001.00698.HOR.000.001} & (1 - minute) \\ \text{OR} \\ \text{NEON.DOM.SITE.DP1.00098.001.00698.HOR.000.030} & (30 - minute) \end{cases}$$

If using data from the tower HMP155:

$$U_{95}(\overline{T_s}) = \begin{cases} \text{NEON.DOM.SITE.DP1.00098.001.00698.000.VER.001} & (1 - minute) \\ \text{OR} \\ \text{NEON.DOM.SITE.DP1.00098.001.00698.000.VER.030} & (30 - minute) \end{cases}$$

6.1.2.2.6 Lapse Rate of Temperature

As mentioned before, the standard atmospheric lapse rate is 0.0065 K m^{-1} (WMO 2008). Although this can be considered as "constant", it holds a great deal of uncertainty because it is somewhat fictitious in nature. Atmospheric lapse rates (LR) can vary between 0.005 K m^{-1} (moist adiabatic lapse rate) and 0.01

K m^{-1} (dry adiabatic lapse rate), and can occasionally reach extremes on either side (Wallace and Hobbs 2006). To account for these variations we take a fairly liberal approach and assume this lapse rate is reliable to 80% and derive a relative uncertainty estimate of 20%:

$$u(\alpha) = \alpha * 0.20 = 0.0065 * 0.20 = 0.0013 \tag{31}$$

The partial derivative of Eq. (11) with respect to α is:

$$\frac{\partial \bar{p}_\Lambda}{\partial \alpha} = \frac{-2g(\theta,z) * \bar{p}_s * z^2 * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)}}{\left(\alpha * z + 2(\overline{T_s} + \overline{e_v} * C_h)\right)^2 * R_d} \tag{32}$$

The partial uncertainty of elevation corrected pressure as a function of temperature's lapse rate is then:

$$u_\alpha(\bar{p}_\Lambda) = \left|\frac{\partial \bar{p}_\Lambda}{\partial \alpha}\right| u(\alpha) \quad [kPa] \tag{33}$$

6.1.2.2.7 Vapor Pressure

Because vapor pressure is back calculated from dewpoint measurements made throughout NEON's Observatory (see Eq. (10)), the combined uncertainty of the one-minute, mean dewpoint data product (soil plot or AQU met station) will propagate through to vapor pressure.

The derivative of corrected pressure with respect to vapor pressure can be partitioned as follows:

$$\frac{\partial \bar{p}_\Lambda}{\partial \overline{T_d}} = \frac{\partial \bar{p}_\Lambda}{\partial \overline{e_v}} * \frac{d\overline{e_v}}{d\overline{T_d}} \tag{34}$$

Where,

$\frac{\partial \bar{p}_\Lambda}{\partial \overline{T_d}}$ = derivative of Eq. (11) with respect to $\overline{T_d}$

$\frac{\partial \bar{p}_\Lambda}{\partial \overline{e_v}}$ = partial derivative of Eq. (11) with respect to $\overline{e_v}$

$\frac{d\overline{e_v}}{d\overline{T_d}}$ = derivative of Eq. (10) with respect to $\overline{T_d}$

Total and partial derivatives are derived below.

$$\frac{\partial \bar{p}_\Lambda}{\partial \overline{e_v}} = \frac{-4\bar{p}_s * g(\theta,z) * C_h * z * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)}}{\left(\alpha * z + 2(\overline{T_s} + \overline{e_v} * C_h)\right)^2 * R_d} \quad (35)$$

To show how this uncertainty affects that of vapor pressure, the partial derivative of Eq. (10) with respect to dewpoint must be derived:

$$\frac{\partial \overline{e_v}}{\partial \overline{T_d}} = \frac{1779.75 * \ln(10) * 10^{\left(\frac{7.5}{\frac{237.3}{\overline{T_d}}+1}\right)-0.21411}}{\left(\frac{237.3}{\overline{T_d}} + 1\right)^2 * \overline{T_d}^2} \quad (36)$$

The partial uncertainty of an individual corrected pressure measurement with respect to ambient dewpoint is thus:

$$u_{\overline{T_d}}(\bar{p}_\Lambda) = \left|\frac{\partial \bar{p}_\Lambda}{\partial \overline{T_d}}\right| u_c(\overline{T_d}) \quad [kPa] \quad (37)$$

Where, $u_c(\overline{T_d})$ is the combined uncertainty of the L1, mean dew point temperature data product from the HMP155 used to correct station pressure and is defined by:

$$u_c(\overline{T_d}) = u_{95}(\overline{T_d})/k_{95} \quad [°C] \quad (38)$$

If using data from the soil plot HMP155:

$$U_{95}(\overline{T_d}) = \begin{cases} \text{NEON.DOM.SITE.DP1.00098.001.00738.HOR.000.001} \quad (1-minute) \\ \text{OR} \\ \text{NEON.DOM.SITE.DP1.00098.001.00738.HOR.000.030} \quad (30-minute) \end{cases}$$

If using data from the tower HMP155:

$$U_{95}(\overline{T_d}) = \begin{cases} \text{NEON.DOM.SITE.DP1.00098.001.00738.HOR.VER.001} \quad (1-minute) \\ \text{OR} \\ \text{NEON.DOM.SITE.DP1.00098.001.00738.HOR.VER.030} \quad (30-minute) \end{cases}$$

Overall, the impact of vapor pressure is quite small when compared to other variables in the elevation corrected pressure equation (WMO 1964).

6.1.2.2.8 Lapse Rate of Vapor Pressure

The lapse rate of vapor pressure is adapted by the WMO (1964) and incorporated into the sea level reduction equation. It is based on seasonal variation of vapor pressure within the lower atmosphere (Rao 1958). Like that of temperature, the lapse rate of vapor pressure is considered to hold a great deal of uncertainty. This is especially true over large elevation ranges. Here we take a similar, liberal approach to that of quantifying the uncertainty of temperature lapse rate and use a relative uncertainty of 20%:

$$u(C_h) = C_h * 0.20 = 1.2 * 0.20 = 0.24 \tag{39}$$

Its associated sensitivity coefficient is:

$$\frac{\partial \bar{p}_{\Lambda}}{\partial C_h} = \frac{-4\bar{p}_s * g(\theta, z) * \overline{e_v} * z * e^{\left(\frac{h' * g(\theta,z)}{R_d\left(\overline{T_s} + \frac{\alpha * z}{2} + \overline{e_v} * C_h\right)}\right)}}{\left(\alpha * z + 2(\overline{T_s} + \overline{e_v} * C_h)\right)^2 * R_d} \tag{40}$$

And its propagating term is:

$$u_{C_h}(\bar{p}_{\Lambda}) = \left|\frac{\partial \bar{p}_{\Lambda}}{\partial C_h}\right| u(C_h) \quad [kPa] \tag{41}$$

6.1.2.2.9 Combined Uncertainty (mean Corrected Pressure)

The combined uncertainty for our L1 mean elevation corrected pressure data product, $u_c(\overline{p}_{\Lambda})$, given in units of kPa, is computed by summing the uncertainties from Sections 6.1.2.2.1 and 6.1.2.2.8 in quadrature:

$$u_c(\overline{p}_{\Lambda}) = \left(u_{\overline{p}_s}^2(\overline{p}_{\Lambda}) + u_z^2(\overline{p}_{\Lambda}) + u_{\overline{T}_s}^2(\overline{p}_{\Lambda}) + u_{\alpha}^2(\overline{p}_{\Lambda}) + u_{\overline{T}_d}^2(\overline{p}_{\Lambda}) + u_{C_h}^2(\overline{p}_{\Lambda})\right)^{\frac{1}{2}} \tag{42}$$

6.1.2.2.10 Expanded Uncertainty (mean Corrected Pressure)

The expanded uncertainty is then calculated as:

$$U_{95}(\bar{p}_{\Lambda}) = k_{95} * u_c(\bar{p}_{\Lambda}) \tag{43}$$

Where:

$U_{95}(\bar{p}_{\Lambda})$ = expanded uncertainty at 95% confidence (kPa)
k_{95} = 2 (unitless); coverage factor for 95% confidence

6.2 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. Uncertainty values denoted in this budget are either derived within this document or are provided by other NEON teams (e.g., CVAL), and stored in the CI data store.

Table 6-1: Uncertainty budget for individual station pressure measurements.

Source of measurement uncertainty	Measurement uncertainty component $\boldsymbol{u(x_i)}$	Value of measurement uncertainty	$\boldsymbol{\frac{\partial f}{\partial x_i}}$	$\boldsymbol{u_{x_i}(Y) \equiv \left\lvert\frac{\partial f}{\partial x_i}\right\rvert u(x_i)}$ [kPa]
Station pressure	u_{A1}	u_{A1} [kPa]	n/a	n/a

Table 6-2: Uncertainty budget for L1 mean station and elevation corrected pressure data products. Shaded rows denote the order of uncertainty propagation (from lightest to darkest). Note that although $u_c(\overline{T_s})$ is in terms of ^{o}C in AD[17], the uncertainty value in K is equivalent.

Source of uncertainty	Uncertainty component $\boldsymbol{u(x_i)}$	Value of uncertainty	$\boldsymbol{\frac{\partial f}{\partial x_i}}$	$\boldsymbol{u_{x_i}(Y) \equiv \left\lvert\frac{\partial f}{\partial x_i}\right\rvert u(x_i)}$ [kPa]
Station pressure	$u_c(\overline{p_s})$	Eq. (18) [kPa]	n/a	n/a
Natural variation	$u_{NAT}(\overline{p_s})$	Eq. (17) [kPa]	1	Eq. (17)
Station Pressure[CAL]	u_{A3_p}	u_{A3_p} [kPa]	1	u_{A3}
Corrected pressure	$u_c(p_{A_i})$	Eq. (42) [kPa]	n/a	n/a
Station pressure	u_{A1}	u_{A1} [kPa]	Eq. (20)	Eq. (21)
Elevation[1]	$u(h')$	Eq. (25) [m]	Eq. (23)	Eq. (24)
Temperature	$u_c(\overline{T_s})$	AD[12] [K]	Eq. (28)	Eq. (29)
Temperature LR	$u(\alpha)$	0.0013 [K km-1]	Eq. (32)	Eq. (33)
Vapor pressure[2]	$u_c(\overline{T_d})$	AD[19] [°C]	Eq. (34)	Eq. (37)
Vapor pressure LR	$u(C_h)$	0.24 [K kPa-1]	Eq. (40)	Eq. (41)
Corrected pressure	$u_c(p_{A_i})$	Eq. (42) [kPa]	n/a	n/a

[1]soil plot / water surface pressure
[2]propagation of dewpoint
[CAL]Calibration uncertainty

7 FUTURE PLANS AND MODIFICATIONS

Details concerning the evaluation and quantification of Sensor drift will be added to the uncertainty section.

QA/QC tests may be expanded to include consistency analyses among similar measurement streams.

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