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OCEAN OBSERVATORIES INITIATIVE

DATA PRODUCT SPECIFICATION FOR NANO-RESOLUTION BOTTOM PRESSURE

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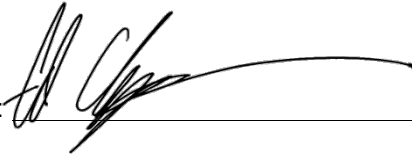
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This document has been reviewed and approved for release to Configuration Management.
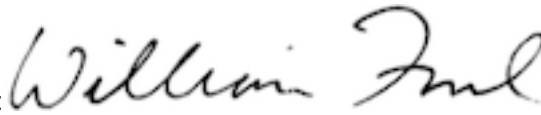
OOI Senior Systems Engineer:

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This document has been reviewed and meets the needs of the OOI Cyberinfrastructure for the purpose of coding and implementation.

OOI CI Signing Authority:

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Table of Contents

1   Abstract

This document describes the OOI Level 1 (L1) Nano-resolution Bottom Pressure (BOTPRES) core data product, derived from data output by the Paroscientific nano-resolution pressure sensor on board the Bottom Pressure Tilt (BOTPT) instruments of the Regional Scale Nodes (RSN) at Axial Seamount. This document is intended to be used by OOI programmers to construct appropriate processes to create the L1 BOTPRES core data product.

2   Introduction

2.1   Author Contact Information

Please contact Orest E. Kawka (kawkaoe@uw.edu) or the Data Product Specification lead (DPS@lists.oceanobservatories.org) for more information concerning the computation and other items in this document.

2.2   Metadata Information

2.2.1   Core Data Products

The following table summarizes the core data products that are produced by the processes described in this document:

Core Data Product Name	Level	Descriptive Name	Core Data Product Abstract (for Metadata)
BOTPRES	L1	Nano-resolution Bottom Pressure	The OOI Level 1 Nano-resolution Bottom Pressure (BOTPRES) core data product is produced by the BOTPT instrument class. The data for this core data product is derived directly from the output of an onboard Paroscientific Digiquartz Pressure Transducer (Model 42.4K-265) enabled for nano-resolution pressure measurements through pairing with a Paroscientific Intelligent Interface Board.

2.2.2   Auxiliary Data Products

The following table summarizes the auxiliary data products that are produced by the processes described in this document and may include engineering data about instruments and data produced directly by the instruments or derived herein which can be used for quality control of the core data products:

Auxiliary Data Product Name	Level	Descriptive Name	Auxiliary Data Product Abstract (for Metadata)
NPTTEMP	AUX	Nano-resolution Pressure Transducer Temperature	The auxiliary data product Nano-resolution Pressure Transducer Temperature (NPTTEMP) is the temperature in °C internal to the Paroscientific Digiquartz Pressure Transducer (Model 42.4K-265) and used for onboard temperature-compensation of the pressure measurements produced by the BOTPT instrument.

2.2.3   Computation Name

N/A

2.2.4 Computation Abstract (for Metadata)

The computation of the OOI Level 1 Nano-resolution Bottom Pressure (BOTPRES) core data product is conducted onboard the BOTPT instrument by the Paroscientific Digiquartz Pressure Transducer (Model 42.4K-265) enabled for nano-resolution pressure measurements by pairing with a Paroscientific Intelligent Interface Board. No other computation is necessary.

2.2.5 Instrument-Specific Metadata

See Section 4.4 for instrument-specific metadata fields that must be part of the output data.

2.2.6 Data Product Synonyms

Synonyms for this computation or data products are the following, or a combination thereof:
- Bottom Pressure
- Temperature-compensated pressure
- Absolute pressure
- Seafloor pressure
- Ambient pressure
- High-resolution bottom pressure

2.2.7 Similar Data Products

Similar products that this data product may be confused with are those derived from pressure transducers onboard instruments other that the BOTPT or outfitted as engineering sensors on OOI platforms. See the document 1340-00000_OOI_Data_Products.pdf for a list of all data products and the Instrument Application in the SAF for specifics of instrument locations/platforms.

2.3 Instruments

For information on the instruments from which the L1 Nano-resolution Bottom Pressure (BOTPRES) core data product inputs are obtained, see the BOTPT Processing Flow document (DCN 1342-00060). This document contains information on the instrument class and make/models; it also describes the flow of data from the BOTPT instruments through all of the relevant automated QC, calibration, and data product computations and procedures.

Please see the Instrument Application in the SAF for specifics of instrument locations and platforms.

2.4 Literature and Reference Documents

The web site of Paroscientific, Inc., the sensor manufacturer, has relevant reference documents.

This web page lists the documents available from their on-line Technical Library:
http://www.paroscientific.com/appnotes.htm

This PDF document describes the methods for making Nano-resolution pressure measurements:
REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES > Nano-Resolution.pdf (Document is also available at http://paroscientific.com/Nano-Resolution.pdf).

This PDF document is the current manual for the Nano-resolution pressure sensor:
REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES > 8819-001.pdf (Document is also available at http://paroscientific.com/manuals/8819-001.pdf).

> NOTE: The above manual is for a previous version of the pressure sensor and does not include some of the commands and functions available in the current version of the sensor to be deployed by the RSN. The manufacturer expects to formally revise the manual some time in 2013.

This PDF document describes the model 42K pressure transducers (series 4000):
REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES >
3000&4000.pdf
(Document is also available at http://www.paroscientific.com/pdf/3000&4000.pdf)

> NOTE: The model (42.4K-265) that is being used is not explicitly listed in
> the linked description. An update to the description and/or additional details
> from the manufacturer has been requested.

This PDF document describes how the pressure transducers calculate pressure:
REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES >
FreqtoPressure.pdf
 (Document is also available at http://www.paroscientific.com/pdf/FreqtoPressure.pdf).

This PDF document describes how the pressure transducers are calibrated at the factory:
REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES > calibration.pdf
(Document is also available at http://www.paroscientific.com/pdf/calibration.pdf).

Other references cited herein are:

Polster, A., Fabian, M. and Villinger, H. (2009), Effective resolution and drift of Paroscientific
    pressure sensors derived from long-term seafloor measurements, *Geochem. Geophys.
    Geosyst., 10, Q08009,* doi: 10.1029/2009GC002532.

2.5   Terminology

2.5.1   Definitions
The following terms are defined here for use throughout this document. Definitions of general OOI
terminology are contained in the Level 2 Reference Module in the OOI requirements database
(DOORS).

temperature-compensation = process for adjusting parameters measured from sensors whose
                    response(s) are directly impacted (biased) by ambient temperature
                    and unaccounted for by direct transforms of the measured values to
                    desired scientific/engineering units.

nano-resolution = term that reflects the computational treatment of pressure measurements to
                attain higher temporal and sensor resolution, effectively parts-per-billion (ppb)
                resolution, as denoted by manufacturer Paroscientific.

2.5.2   Acronyms, Abbreviations and Notations
General OOI acronyms, abbreviations and notations are contained in the Level 2 Reference
Module in the OOI requirements database (DOORS). The following acronyms and abbreviations
are defined here for use throughout this document.

psia = abbreviation for pressure units of pound(s)-force per square inch absolute. This pressure
        is referenced relative to a vacuum and includes the pressures exerted by both the water
        column and the atmosphere.

2.5.3   Variables and Symbols
The following variables and symbols are defined here for use throughout this document.

N/A

3   Theory

3.1   Description

The computations to produce the L1 BOTPRES core data product are conducted onboard the BOTPT instrument by the component pressure sensor, specifically, the paired Paroscientific Digiquartz Pressure Transducer (Model 42.4K-265) and Paroscientific Intelligent Interface Board. The computational technique for this instrument component is detailed in the manufacturer's (Paroscientific) literature as referenced in Section 2.4. No additional computations are performed.

3.2   Mathematical Theory

N/A

3.3   Known Theoretical Limitations

N/A

3.4   Revision History

No revisions to date.

4   Implementation

4.1   Overview

The raw data stream output by the BOTPT instrument contains data records for four (4) individual sensors. The specific data record, tagged with a 4-character ID "NANO" followed by the comma delimiter, is parsed to produce the L1 BOTPRES core data product. No other computation is required.

4.2   Inputs

Inputs are:
- The data record in the raw data stream tagged with the 4-character ID "NANO" followed by the comma delimiter.

Input Data Formats:
The data fields of interest (other than Date/Time) are floating point numbers. The Nano-resolution Bottom Pressure field is a 6 decimal digits floating point number with up to 10 total digits, not all of the 4 integer digits necessarily used. The Temperature field is a 9 decimal digit floating point number, with up to 12 total digits, not all of the 3 integer digits necessarily used. Negative temperature values include a sign, but the number format is not otherwise affected.

The instrument outputs data records in a single line of ASCII text that is comma delimited and ends with a line feed (\n). The intention is to have the sensor operate at 40 Hz, so there would be 40 such output records per second, each with its own date/time stamp. The data format is as follows:

```
NANO,P,2012/03/14 20:53:26.000,12.912863,22.602944614
  |   |      |                     |             |
  |   |      |                     |          Temperature (°C)
  |   |      |                          Nano-resolution Bottom Pressure (psia)
  |   |    Date/Time (YYYY/MM/DD HH:MM:SS.SSS with millisecond precision)
  |   Flag (P=date/time is synced to PPS signal; V=no PPS lock)
 ID tag (NANO=Nano-resolution bottom pressure recorder; Nano-BPR)
```

NOTE: There will also be non-data records (command responses) from the instrument that similarly begin with the "NANO,", but those will have an asterisk (*) immediately after the comma delimiter or later after the comma delimiter following the "date/time field" to distinguish them.

Other ID tags for data from other sensors onboard the BOTPT instrument will include: LILY, IRIS, and HEAT. These data from the other sensors are described in Data Product Specification for Seafloor High-Resolution Tilt (BOTTILT) from the BOTPT Instrument (DCN 1341-00060).

The Nano-resolution Bottom Pressure field above is the L1 Nano-resolution Bottom Pressure (BOTPRES) core data product in psia, and the Temperature field is the Nano-resolution Pressure Transducer Temperature (NPTTEMP) auxiliary data product in degrees Celsius (°C). The temperature values are those recorded in the pressure transducer and are used by the Intelligent Interface Board onboard calculation (temperature-compensation) of the pressure values (see FreqtoPressure.pdf in section 2.4, above).

The Date/Time field is primary and required for follow-on data processing and must be stored/ associated with both the core and auxiliary data products above.

4.3   Processing Flow

The specific steps necessary to create all calibrated and quality controlled data products for the BOTPT core instrument are described in the instrument-specific Processing Flow document (DCN 1342-00060). This processing flow document contains flow diagrams detailing all of the specific procedures (data product and QC) necessary to compute all levels of data products from the instrument and the order in which these procedures are conducted.

The processing flow for the production of the L1 BOTPRES core data product and auxiliary data product (NPTTEMP) is:

Step 1:
Parse the raw data stream and identify the appropriate record (tagged as "NANO,").

Step 2:
The following operations are performed on the NANO data record:
- Extract the Date/Time field and associate this with the core and auxiliary data products described by this DPS.
- Extract the Nano-resolution Bottom Pressure field to produce the L1 BOTPRES core data product.
- Extract the Temperature field to produce the NPTTEMP auxiliary data product.

Step 3:
Store the extracted core and auxiliary data products and associate them with the Date/Time field extracted above.

4.4   Outputs

The outputs of the core data product computation are:
- L1 Nano-resolution Bottom Pressure (BOTPRES) in psia, as double precision floating point number.

The outputs of the auxiliary data product computation are:
- Nano-resolution Pressure Tansducer Temperature (NPTTEMP) in degrees Celsius (°C), as double precision floating point number.

The metadata that must be associated with the above data products are:

- Date/Time as recorded in the Date/Time stamp in the "NANO" raw data record (see Section 4.2 for source and format) with millisecond precision.

See Appendix B for a discussion of the accuracy of the output.

4.5   Computational and Numerical Considerations

4.5.1   Numerical Programming Considerations
There are no numerical programming considerations for this computation. No special numerical methods are used.

4.5.2   Computational Requirements
- This specific sensor of the BOTPT instrument will operate nominally at 40 Hz, so there would be 40 such output records per second, each with its own date/time stamp.

4.6   Code Verification and Test Data Set
A test data set composed of a full suite of the different types of data records (sensor-specific) produced by the BOTPT instrument along with the expected outputs of this DPS is provided in this directory: REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES

The README file in the linked directory provides additional information on the files included.

Appendix A   Example Code

N/A

Appendix B   Output Accuracy

The accuracy of the L1 BOTPRES data product is a function of the pressure transducer accuracy only and any offset associated with sensor drift. The manufacturer Paroscientific lists the typical accuracy and minimal resolution of the Digiquartz series of pressure transducers as 0.01 % and 0.0001%, respectively, of full scale over the operational pressure and temperature range. Full scale for the Model 42.4K-265 pressure transducer, integrated in the BOTPT instrument, is 2400 psia (16.55 MPa absolute), resulting in a nominal accuracy of 0.24 psia (1 kPa absolute).

The resolution with the standard Intelligent Interface board is parts-per-million of full scale (i.e. 0.002 psia) at 1 Hz. In nano-resolution mode, as configured for the BOTPT instrument, the resolution is parts-per-billion or below -165 dB re: full scale at 1 Hz (e.g. 0.00001 psia). The pressure resolution determined under controlled laboratory conditions is specified to be 10^{-8}, i.e. 0.16Pa (equivalent to 0.016mm). However, the effective resolution in a realistic deployment scenario is a combination of both the sensor's noise level and the ambient noise at the seafloor, as noted by Polster et al. (2009). Accordingly, that study determined the noise levels associated with long-term seafloor pressure measurements (118 pressure records over 20 years) and estimated a mean 3σ noise level of about 17.8 ± 0.4 Pa (0.00258 ± 0.0006 psia), which is substantially above the noise levels from the Paroscientific gauges themselves.

Long-term stability tests (ongoing for 19 years) by the manufacturer Paroscientific have indicated a median drift rate of 0.0007 kPa/a for Digiquartz barometers under controlled laboratory conditions. The average long-term, in situ linear drift for ocean bottom pressure sensors is estimated by Polster et al. (2009) to be -0.88 ± 0.73 kPa/a. **NOTE: The L1 BOTPRES data product will not be routinely adjusted for this drift. Drift corrections will be applied only to the higher-level core data products (see L2 BOTSFLU core data products).**

The DOORS accuracy requirement for the pressure measurement by the BOTPT instrument is 7 kPa (0.7 dbar) and equivalent to 1 psia (Requirement L4-RSN-IP-RQ-161, Baseline Version 2.2.3, NSF-CCB-2012-07-03).

The DOORS resolution requirement for the pressure measurement by the BOTPT instrument is 0.07 kPa (0.007 dbar) and equivalent to 0.01 psia (Requirement L4-RSN-IP-RQ-162, Baseline Version 2.2.3, NSF-CCB-2012-07-03).

Reference:
Polster, A., Fabian, M. and Villinger, H. (2009), Effective resolution and drift of Paroscientific pressure sensors derived from long-term seafloor measurements, *Geochem. Geophys. Geosyst., 10, Q08009,* doi: 10.1029/2009GC002532.

Appendix C   Sensor Calibration Effects

This following PDF document (also referenced in section 2.4 above) describes how the pressure transducers are calibrated at the factory:

REFERENCE > Data Product Specification Artifacts > 1341-00070_BOTPRES > calibration.pdf
(Document is also available at http://www.paroscientific.com/pdf/calibration.pdf).