Fast Response Hygrometer Instrument Specification

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Coastal and Global Scale Nodes
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Signature Page

This document has been reviewed and approved for release.

OOI Senior Systems Engineer: ______________________________

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1.0 General

1.1 Ocean Observatories Initiative (OOI) Overview

Although the ocean is central to the habitability of our planet, it is largely unexplored. Biological, chemical, physical, and geological processes interact in complex ways in the ocean, at the seafloor, and at the air-sea interface. Our ability to learn more about these processes is severely limited by technical infrastructure, and developing a more fundamental scientific understanding of these relationships requires new and transformational approaches to ocean observation and experimentation.

The Ocean Observatories Initiative (OOI) will lay the foundation for future ocean science observations. OOI will enable powerful new scientific approaches by transforming the community's focus from expedition-based data gathering to persistent, controllable observations from a suite of interconnected sensors. The OOI's networked sensor grid will collect ocean and seafloor data at high sampling rates over years to decades. Researchers will make simultaneous, interdisciplinary measurements to investigate a spectrum of phenomena including episodic, short-lived events (tectonic, volcanic, oceanographic, biological, and meteorological), and more subtle, longer-term changes and emergent phenomena in ocean systems (circulation patterns, climate change, ocean acidity, and ecosystem trends).

The OOI will enable multiple scales of marine observations that are integrated into one observing system via common design elements and an overarching, interactive cyberinfrastructure. Coastal-scale assets of the OOI will expand existing observations off both U.S. coasts, creating focused, configurable observing regions. Regional cabled observing platforms will 'wire' a single region in the Northeast Pacific Ocean with a high speed optical and high power grid. Global components address planetary-scale changes via moored open-ocean buoys linked to shore via satellite. Through a unifying cyberinfrastructure, researchers will control sampling strategies of experiments deployed on one part of the system in response to remote detection of events by other parts of the system.

A more detailed discussion of the Oceans Observatories Initiative can be found in the OOI Final Network Design.

1.2 Document Scope and Purpose

The purpose of this specification is to provide the requirements for a fast response hygrometer to be used as an integral part of the direct covariance flux system (DCFS) instrument package to be purchased for use on the Coastal and Global Scale Nodes (CGSN) of the Ocean Observatories Initiative. The fast response hygrometer will be acquired separately from a commercial source by CGSN and provided to the vendor selected to build the DCFS units for integration. Direct covariance flux instrument packages will be mounted on surface buoys that will be deployed in both coastal regions (depths up to ~600 m) and open ocean regions (at latitudes above 40 degrees). Coastal and Global buoys will include a tower for mounting sensors at a height of ~3-5 m above water level. Buoys will be designed to orient themselves relative to the wind.

This document describes the physical, functional and electrical characteristics of the fast response hygrometers required by CGSN for incorporation into the DCFS.

Direct covariance flux systems measure the vertical fluxes associated with eddies in the flow over the ocean. When done well, they provide a direct measure of vertical transports or fluxes. The bulk meteorological system provides a second way to measure the air-sea fluxes, but the bulk method relies on parameterizations. These parameterizations and hence the accuracy of the bulk methods are not well known in high winds (>20 m s^{-1}) and energetic and/or changing surface wave conditions. Thus, the OOI requires the DCFS to ensure the requirements to observe the air-sea fluxes are met in high wind and sea state conditions.

At the heart of a DCFS is the ability to measure the fluctuating or turbulent components of the wind (u', v', and w' which are respectively the turbulent east, turbulent north, and turbulent vertical wind velocity components) and the desired fluctuating scalar quantity (e.g. T', q', CO_2', where these are temperature, specific humidity and CO_2 fluctuations, respectively). The challenge for a buoy-mounted DCFS system is that it measure wind in the moving reference frame of the buoy, so the buoy DCFS must correct relative turbulent wind for the rotation and translation of the buoy. The measurements of the turbulent components and the corrections are done at a rate of about 10 to 20 Hz.

A buoy-based eddy covariance flux system thus consists of a 3-axis sonic anemometer logging fast wind components (u,v,w) and sonic temperature (Ts) at 10 to 20 Hz plus a fast hygrometer (also 10 to 20Hz). A fast platform motion-measuring system is required to remove wave-induced motions and rotate the wind components into a fixed-earth coordinate system. The motion system must measure 3-axis linear accelerations and 3-axis angular rates with software to integrate these to 3-axis linear motions and pitch, roll, and heading angles. Motion corrections must be done to the raw sonic time series. A typical fast hygrometer uses nod-dispersive IR (NDIR) absorption along an optical path of 10-20 cm. Contamination of the optics by sea spray and other sources (e.g., birds) may rapidly degrade performance. The fluxes are obtained by cross-correlating the true vertical velocity with the true horizontal wind components, fast temperature, and fast humidity. Additional variables (mean air temperature, humidity, and pressure) may be required to interpret/correct the fluxes.

Because fast response hygrometers are also used in land-based direct covariance flux systems, there are commercial sources for these instruments addressing a marketplace much larger than that of buoy and ship-based DCFS systems. Continued evolution and improvement is anticipated in fast response hygrometers, so the approach taken in developing an OOI specification of a DCFS is to specify a buoy-based system with sonic anemometer, motion measurement and correction, and ancillary mean sensors for humidity, temperature, and pressure that is plug-and-play compatible with commercially available fast response hygrometers. The acquisition of the fast response hygrometer from a commercial source also allows for specifying the calibration, refurbishment, repair, and upgrades services to be needed by the OOI to be part of the acquisition of the fast response hygrometer, removing the significant burden of supporting the least robust component of the DCFS system from the OOI DCFS supplier. This is important because the market for buoy and ship DCFS systems is small, and potential respondents to an RFP for a buoy-based DCFS may not have their own capability to support and service the fast response hygrometer.

1.3 Documents

1.3.1 Informational

The documents listed in this section are for informational purposes only and may not have been referenced in this specification.

- Consortium for Ocean Leadership, Inc. 2010. *Final Network Design.* Washington, DC. [Online] Available: http://www.oceanleadership.org/programs-and-partnerships/ocean-observing/ooi/network-design/

- Burba, G. and D. Anderson (2010) A Brief Practical Guide to Eddy Covariance Flux Measurements: Principles and Workflow Examples for Scientific and Industrial Applications. www.licor.com. 213 pp.
- Campbell Scientific, Inc. (1998) Instruction Manual: Eddy Covariance System CA27 and KH20, www.campbellsci.com.
- Edson, J. B., A. A. Hinton, K. E. Prada, J. E. Hare, and C.W. Fairall (1998) Direct Covariance Flux Estimates from Mobile Platforms at Sea. Journal of Atmospheric and Oceanic Technology, 15, 547-562.
- Frederickson, P. A., K. L. Davidson, F. K. Jones, and T. Neta, (2001) Naval Postgraduate School FLUX Buoy Data Report for the MUSE Deployment, August-September 2000, Monterey Bay, California. Technical Report, Naval Postgraduate School, 19 pp.
- Launiainen, S., J, Rinne, J. Pumpanen, L. Kulmala, P. Kaori, P. Keronen, E. Silviola, T. Pohja, P. Hari, and T. Vesala (2005) Eddy covariance measurements of CO_2 and sensible and latent heat fluxes during a full year in a boreal pine forest trunk-space. Boreal Environment Research, 10, 569-588.

1.3.2 Applicable

N/A

1.4 Definitions

1.4.1 Glossary and Acronyms

- **Accuracy** – Closeness of the agreement between the result of a measurement and the value of the measurand (or true value of the measurement). (Taylor and Kuyatt, 1994)
- **Burst Sampling** – Intermittent rapid sampling at or near the maximum sampling rate for short intervals between longer quiescent periods.
- **CGSN** – Coastal and Global Scale Nodes
- **DCFS** – Direct Covariance Flux System
- **EIA** – Electronics Industries Association
- **Instrument** – A device that contains one or more sensors and a method for converting the information from the sensor into a transmittable and storable form.
- **Objective Value** – The desired value of a technical parameter. This value, if provided, may be more challenging to achieve than the Threshold value. It is a goal, not a requirement, for the instrument.
- **OOI** – Ocean Observatories Initiative
- **Operate** – Correctly performing designed functionality.
- **Precision** – The closeness of agreement between independent measurements obtained under stipulated conditions of repeatability, generally expressed as a standard deviation (or standard uncertainty) of measurement results (Taylor and Kuyatt, 1994). Used as a measure of stability of an instrument/sensor and its capability of producing the same measurement over and over again for the same input signal.

- **Resolution** – The smallest amount of input signal change that the instrument/sensor can detect reliably.
- **Response Time** – The time required for an output to reach a specified fraction of its final value as a result of a step change in input.
- **PSS** – Practical Salinity Scale, the UNESCO Practical Salinity Scale of 1978 (PSS78) defines salinity as a dimensionless conductivity ratio.
- **RMS** – Root Mean Square
- **Sensor** – A device that will convert a physical phenomenon into an electrical signal that can in turn be digitized through the use of an analog to digital converter. A sensor is normally housed in an instrument. Data coming from sensors is normally raw and needs to be calibrated.
- **Survive** – Experience an event without major loss of hardware. System may experience loss of functionality requiring repair to return to normal mode functionality. An example of this is knockdown of a global mooring or loss of some part of the mooring resulting in the instrument descending to the bottom. Any internal memory in the instrument shall remain accessible, but the sensors may need to be replaced to return to normal functionality.
- **Sustain** – Experience an event (environmental extreme or condition) without permanent loss of normal mode functionality. System may experience reduction of functionality during event.
- **Threshold Value** – The minimal limiting acceptable performance value that this item must meet of a technical parameter. If this item does not meet the performance as specified by the threshold value it may not be sufficient for inclusion in the OOI system.

1.4.2 Conventions

All values contained in this document are Threshold Values unless specifically stated otherwise.

Specification items are assigned unique identification numbers specific to this document. Items tied directly to requirements maintained in the OOI requirements database are followed by the requirement number in brackets (e.g., [L4-CG-IP-RQ-XXX]). The requirement number is intended for internal OOI use only.

2.0 Specifications

2.1 Measurement

Values provided are threshold unless otherwise stated.

2.1.1 Turbulent humidity fluctuations

a) Measurement with unit(s)

Water vapor density (g/m^3)

b) Minimum Value

THUM-001 Turbulent humidity instruments shall measure water vapor density to a minimum value of 0 g/m^3. [L4-CG-IP-RQ-640]

c) Maximum Value

THUM-002 Turbulent humidity instruments shall measure water vapor density to a maximum value of 42 g/m^3. [L4-CG-IP-RQ-640]

d) Accuracy

THUM-003 Turbulent humidity instruments shall have a water vapor density accuracy of +/- 0.5 g/m^3. [L4-CG-IP-RQ-638]

e) Precision

N/A

f) Resolution

THUM-004 Turbulent humidity instruments shall have a water vapor density resolution of 0.01 g/m^3. [L4-CG-IP-RQ-639]

g) Drift

THUM-005 Turbulent humidity instruments shall have a water vapor density drift of less than 0.3% of the measured value per °C. [L4-CG-IP-RQ-641]

h) Response Times

N/A

i) Sampling Frequency

THUM-006 Turbulent humidity instruments shall be capable of sampling rates of 1 Hz to 20 Hz, respectively. [L4-CG-IP-642]

j) Dependencies

N/A

2.2 Operational

2.2.1 Operational Depth Range

N/A

2.2.2 Environmental

a) Salinity

N/A

b) Temperature

OPER-001 Instruments shall be capable of making air-sea measurements within an ambient air temperature range of -30° C and +45° C. [L4-CG-IP-RQ-432]

c) Biofouling

OPER-002 Sensors shall utilize bio-fouling mitigation to enable nominal operations over the defined maintenance interval. [L4-CG-IP-RQ-446]

d) Icing

OPER-003 Instruments mounted in air shall sustain periods of icing. [L4-CG-IP-RQ-405]

2.2.3 Service Requirements

N/A

2.2.4 Calibration Requirements

OPER-004 Sensors should maintain their calibration over the required deployment intervals. This is an objective. [L4-CG-IP-RQ-286]

2.2.5 Deployment Interval

OPER-005 The designed deployment interval for instrument packages on moored assets shall be 13 months. [L3-CG-RQ-168; L3-CG-RQ-496; L3-CG-RQ-497]

2.2.6 Duty cycle

OPER-006 The fast response hygrometer shall be capable of being duty cycled. For example, operating for a period of minutes (0 to 20) every hour as needed to achieve average power consumption over one hour of less than 5 Watts. [L4-CG-IP-RQ-657]

2.3 Mechanical/Physical

2.3.1 Materials

MECH-001 Instrument electronics housings shall be designed to be corrosion resistant. [L4-CG-IP-RQ-288]

MECH-002 The instrument package and components mounted on surface buoys shall be capable of surviving immersion in seawater to a depth of 5 m. [L3-CG-RQ-886]

2.3.2 Size

N/A

2.3.3 Weight

N/A

2.4 Electrical

2.4.1 Interference Requirements

N/A

2.4.2 Voltage

N/A

2.4.3 Current

N/A

2.4.4 Power

ELEC-001 Power consumption when on continuously shall not exceed 10 Watts. [L4-CG-IP-RQ-643]

2.4.5 Grounding

N/A

2.4.6 Battery Life

N/A

2.4.7 Modes/State of Operation

ELEC-002 Instruments shall return to a defined operational state upon being depowered and repowered. [L4-CG-IP-RQ-447]

2.4.8 Isolation

N/A

2.5 Data Storage and Processing

2.5.1 Storage Capacity

DATA-001 Instruments should internally store calibration and sensors serial numbers. This is an objective.

2.6 Software/Firmware

SOFT-001 Serial instruments requiring a break signal should be capable of emulating the break by a software character sequence. This is an objective.

2.7 DCFS Interfaces

2.7.1 Mechanical

N/A

2.7.2 Electrical

INTF-001 The instrument package shall connect to the DCFS for power and communications (the connector types on the CGSN DCFS are TBS and will be detailed in an interface control document).

INTF-002 The fast response hygrometer shall operate from a supply voltage in the range of 10-30 VDC.

2.7.3 Data and Communication

a) Timing

N/A

b) Clock Synchronization

N/A

c) Data Rate

INTF-003 The fast response hygrometer should be capable of baud rates between 4,800 and 56,700 This is an objective.

d) Data Format

N/A

e) Protocols

N/A

f) Physical Interface

N/A

g) Electrical Interface

INTF-004 The fast response hygrometer shall be capable of serial communications (RS-232, RS-422, RS-485).

h) Remote Access

INTF-005 Instruments should support remote firmware installation. This is an objective.

i) Modes

N/A

2.8 Compliance

COMP-001 To the greatest extent practical, all CGSN infrastructure shall be compatible with applicable national and international standards, including those of the IEEE, ANSI, and IEC.

2.9 Safety

N/A

2.10 Shipping and Storage

2.10.1 Shipping

SHIP-001 Instruments shall be provided with a reusable transportation case with shock mounting.

SHIP-002 Instrument Transportation Cases must fit within an ISO shipping container. [L3-CG-RQ-494]

SHIP-003 Instruments in their transportation cases shall be capable of surviving shipping conditions defined by ASTM D4169 truck assurance level 1. [L3-CG-RQ-432]

2.10.2 Storage

SHIP-004 Instruments should be capable of being stored with out damage or degradation between -20° and 50° C for periods of up to 12 months. This is an objective.

2.10.3 Safe Handling

SHIP-005 Instrument transportation cases shall have external labels specifying safe handling precautions.

2.11 Identification

2.11.1 Physical Markings

IDNT-001 The fast response hygrometer shall be marked indelibly on an exterior surface. Marking shall include:

- Manufacturer's part number
- Unit serial number
- CGSN part number as defined below:
  - P/N 3305-00018-00001

2.12 Quality

2.12.1 Product Quality

QUAL-001 Instrument packages shall be manufactured in accordance with the manufacturer's best practices. Records of quality assurance tests and inspections shall be available for review by the purchaser.

QUAL-002 A First Article Testing report shall be provided with each first article unit delivered.

QUAL-003 A certificate of compliance shall be provided with each delivered unit. The certificate of compliance shall be supported with copies of the Factory Acceptance Test report and calibration records for each sensor following integration into the unit.

QUAL-004 The materials used in construction of the instrument packages shall be chosen and treated in such a way as to reduce the levels of wear, corrosion and deterioration to allow multiple deployments of each unit.

3.0 Documentation and Support

N/A

4.0 Appendices

N/A