SBC LTER: Oceans Moored pH data: Instruments and data processing

Author(s): Li Kui, Chris Gotschalk, Clint Nelson, Emily Rivest

Overview/Background: Starting in 2011, continuously recording pH meters were deployed with near-shore oceanographic moorings at some SBC LTER sites along the mainland coast of the Santa Barbara Channel and near of Pt. Conception, and some sites along the channel islands. Sensors are mounted near the CTD at approx. 4 meters depth or 1 m above the bottom in some sites.

This document describes deployment and processing of pH sensor data using the SeaFET pH sensor (based on Honeywell Durafet sensor). Other moored instruments not discussed here include: ADCP (Currents/waves), CTD (Hydrography) and Optics data (Fluorescence, Beam Attenuation, and Volume Scattering Function), and thermistors located near bottom, near surface and mid water column. VSF, fluorometers, and nitrate analyzers were deployed occasionally for specific research investigations. For information about these, see documented protocols for datasets in the mooring series (knb-lter-sbc.200x).

All sensor data from a single site are organized into annual files using the original data collection frequency. CSV versions of these annual files are concatenated. Most processing is performed using Matlab but some sensors require manufacturer's proprietary software to generate machine readable raw data.

Methods:

Field Collection.

Sites with pH sensors maintained by SBC LTER:

Alegria (ALE); Landing Cover (ALC); Arroyo Quemado (ARQ);
Arroyo Quemado Inshore (AQI); Mohawk (MKO); Mohawk Reef Inshore (MKI);
Carpinteria Reef (CPR); Naples Reef (NPR); Prisoners Harbor (PRZ)
Stearns Wharf/Santa Barbara Harbor (SBH)

A typical near-shore mooring is diagramed in Figure 1. Deployment details are maintained internally, contact sbclter@msi.ucsb.edu for more information. Not all instruments are deployed at all sites.

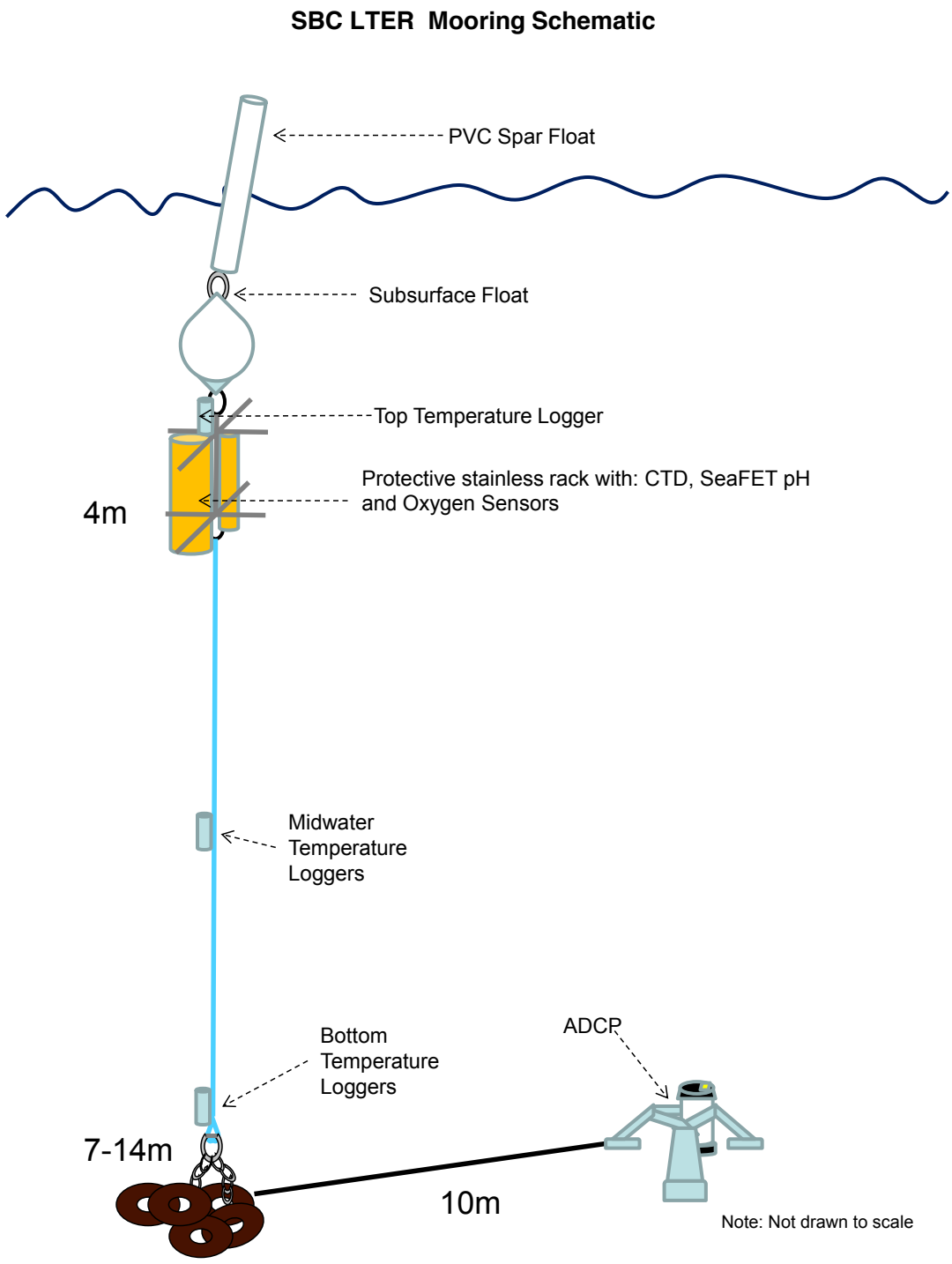

Figure 1. Schematic shows the general layout of an SBC LTER instrument mooring. The ADCP is mounted on the seafloor, approximately 10 meters away and not physically attached to the mooring anchor. pH and oxygen sensors are not deployed at all sites.

List of Moored Instruments (all)

pH: SeaFET, Satlantic Corp.

Instruments with methods and data available elsewhere:

Temperature thermistors: Onset Computer Corp. (TBIC32+4+27) (Hobo UTBI-001),

Acoustic Doppler Current Profiler (ADCP): RDI Instruments (Work Horse, 300, 600, 1200 kHz).

CTD: SeaBird (SBE37).

Fluorometer: WETLabs Inc. (intermittently deployed)

Volume scattering function (VSF): ECO-VSF, WETLabs Inc. (intermittently deployed)

In-situ nitrate auto-analyzer (NAS): W.S. Oceans (intermittently deployed)

Oxygen: D-Optologger, TBD, planned for 2015

Laboratory Processing (SeaFET sensors only).

Moored instruments were and continue to be recovered, downloaded, serviced, and exchanged on a roughly bi-monthly schedule. Typically, the raw sensor data are downloaded from the instruments using the manufacturer software. The raw data files are uploaded to a data entry directory on the file server and archived within subdirectories named with the upload date to allow easy identification of new data files.

Data Processing

Data processing is shown graphically in Figure 2. The process is initiated when the field crew deposits both new SeaFET deployment and benchmark water samples on the file server. Processing is in Matlab, or the USGS-supplied program "CO2Calc". The result is files in two formats: 1) an archive of a processed, calibrated single deployment and a concatenated, time-series file ("ph_allsites_allyears.csv"), suitable for matching to other SBC LTER moored data products in the data catalog.

Data Preprocessing – SeaFET

Time series of pH data from the SeaFET sensors requires an adjustment based on in-situ conditions and hand-collected discrete bottle samples (benchmark samples). We use only the earliest water sample collected after the pH sensor has become conditioned to adjust an entire deployment, although multiple bottle samples may have been collected during a deployment. For the SeaFETs this conditioning period is determined by the difference between the pH values from the internal and external electrodes. If the difference is less than 0.05, the sensor is considered "conditioned".

Benchmark water samples are collected (for more details, http://sbc.lternet.edu/cgi-bin/showDataset.cgi?docid=knb-lter-sbc.75, and protocols therein). pH values from laboratory conditions are adjusted to in-situ values using USGS CO2calc and using either the in-situ temperature recorded by the SeaFET or from the co-located SBE37 CTD. In-situ temperature from the precise time the water sample was collected is used as input to the CO2calc program and the adjusted bottle sample pH output is used to calibrate the SeaFET pH time series. Any out-of-water data is clipped from the beginning and end of each deployment and a Matlab .mat file is saved out containing the raw voltages, calibrated temperature, and adjusted pH time series.

Data Processing, 20-min "Monster file".

In the older version of the pH datasets for individual sites. The "Monster" files are annual files generated from preprocessed moored sensor data collected at one site. Single deployment data that may have been collected at differing sample intervals is 1 hour low-pass filtered (Butterworth filter) to remove noise and then interpolated onto a common 20-minute time base. All monster files for a particular year have the same number of rows and columns. Annual files for a leap year will have time records (rows) for Feb 29 as well. The first data record is always yyyy0101 00:00:00. The last is always yyyy1231 23:40:00. Time records yet to be filled (e.g., in the future) are removed from the concatenated text files but remain in the annual .mat versions. In the most recent version of the pH data that include all site across all years, no re-sampling or filter is conducted to maintain the highest resolution.

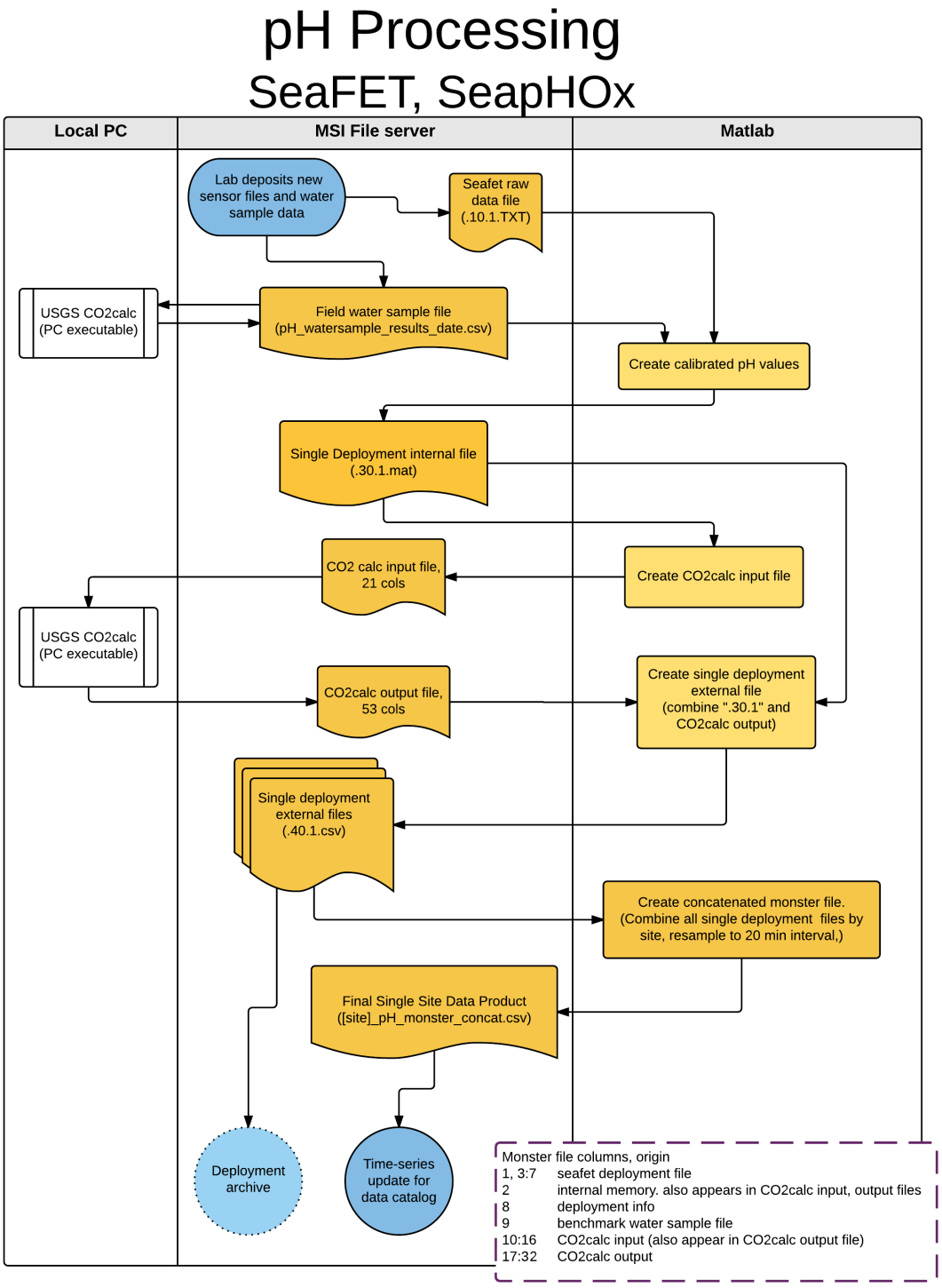

Figure 2. Schematic showing process workflow..

References:

Dickson, A.G., C.L. Sabine, and J.R. Christian (Eds.). 2007. Guide to Best Practices for Ocean CO2 Measurements, PICES Spec. ed.

Dickson, A.G., Millero, F.J., 1987. A comparison of the equilibrium constants for the dissociation of carbonic acid in seawater media. Deep-Sea Research 34, 1733–1743.

DOE. 1994. Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2, A. G. Dickson & C. Goyet, eds. ORNL/CDIAC-74.

Lunden, J., E. Rivest, L. Kapsenberg, T. Martz, P. Bresnahan, Jr., C. Gotschalk, M. O'Brien, C. Blanchette and G. Hofmann. In press. The Marine Ecologist's Guide to the Deployment of Durafet-based pH Sensors: From Benchtop to Benthos. PLOSONE.

Mehrback, C., C. H. Culberson, J. E. Hawley, and R. M. Pytkowicz. 1973. Measurement of the apparent dissociation constants of carbonic acid in seawater at atmospheric pressure, Limnol. Oceanogr., 18, 897 – 907.

Robbins, L.L., M.E. Hansen, J. A, Kleypas and S. C. Meylan. 2010. CO2calc: A user-friendly seawater carbon calculator for Windows, Max OS X, and iOS (iPhone): U.S. Geological Survey Open-File Report 2010-1280, 17 pp.