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Time for Time Series

BY SIMON BOXALL

In this issue of *Oceanography*, Holliday and Cunningham (2013) extol the significance of long-term data sets in understanding the marine environment and, in particular, climate change. The 1950s were the years of exploration, dividing the ocean up into bite-sized chunks to explore as part of the International Geophysical Year(s). The 1960s and '70s were the technological years, or at least the period when we moved from mercury thermometers and clockwork current meters to *advanced* electronics in the ocean. The 1980s and '90s were the big program years, tackling everything from world ocean circulation to the North Sea, though not necessarily fully resolving them. Throughout this long line of programs there have been few long time series. As Holliday and Cunningham point out, the 1990s were nearly the end of the line—quite literally—for the Ellett Line, which only survived through dogged determination and support from the World Ocean Circulation Experiment (WOCE). There are several other long-term measurement campaigns that rely heavily on individuals keeping them alive, often by fitting in with other higher-profile programs. The Atlantic Meridional Transect (AMT), the Continuous Plankton Recorder (CPR) tracks of the Sir Alistar Hardy Foundation for Ocean Science (SAHFOS), and the moorings of the Atlantic Meridional Overturning Circulation are but a few of them. The first two of these programs make use of existing research ship programs or commercial routes to gather valuable data.

The curation of time series has not had the allure and cachet that large-scale process studies carry, which makes them prone to cuts in a financially tight environment. This is ironic, as most key science programs rely on good a priori knowledge without which evidence of issues such as climate change, overfishing, and ocean pollution would be weak.

All well and good, I hear you say, but what has all of this to do with education? Much of the work on these time series involves students. There is a fantastic time series spanning over 20 years of plastics in the western Atlantic, for example, that students from the Sea Education Association in Woods Hole collect on an annual basis (Law et al., 2010) as part of their undergraduate field work. Students also form a significant cohort on AMT cruises, and many work analyzing CPR data with SAHFOS. The Scottish Association of Marine Science provides a summer internship for "practical oceanography" (The Neil MacDougall Bursary), which often gets students onto the Ellett Line cruises and involves them in preparing equipment for the measurements. These long-term monitoring programs get students engaged in the preparation and execution of sea-going research and in data handing and management. The work is always carried out alongside experienced staff, accomplishing a transfer of skills and knowledge that is hard to replicate in the classroom. The fact that the data are to be used for critical tasks also focuses the student in a way that it is difficult to do with a standard class experiment (in the lab or at sea).

A key point of a time series is its reproducibility. The measurements made today have to be at least as well calibrated as those taken 30 or 40 years ago for the series to be of any worth. The students need to understand how scientists arrive at salinity and other derived parameters today, and how that process has evolved over decades. It will involve reprocessing of older data so that they can compare like with like. This means that the data and protocols are well prescribed and students have a good template for their work. It requires a rigor of data reporting that many have not developed in the classroom!

Every year we take over 100 undergraduates into the Southwest English Channel for their main oceanography

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and marine biology field course. They spend two weeks working on a number of vessels gathering a wide range of multidisciplinary data and information. The students input the data into a database that they can then all access to tackle a marine science issue of their choosing. Herein the problems start. I have a wonderful archive of data going back to 1990 for the region, all collected by students. Up until recently, I have taken the approach that students learn by setting things up for themselves, and they benefit from their subsequent mistakes as much as their successes. This is possibly true, but it does make for a terrible data set, and I will hold my hands up and say I'm not sure they are learning from these mistakes.

From Year One of our degree course, my draconian approach to data management and labeling is at the fore. They lose 5% for every minor data reporting infringement, with many a poor novice left without a mark to their report. Does it work? By the main field course, they will report time in seconds to two decimal places but won't have ensured that every instrument has been synchronized and will usually leave out the date and year (probably more important than the time anyway). One student will use the computer to calculate density with the full Equation of State, and another will use some archaic short calculation from the days of pocket calculators that fits easily into an Excel spreadsheet. Neither student will enlighten you as to which method they used. By the time individuals come to work with the data, a third of it is of dubious quality. Do they learn from this exercise and improve? Last year's database led to new lows of data abuse—forget 5% per misdemeanor. We are talking long custodial sentences. This year the students will be given a rigid data format, as I now believe they need clear examples rather than experimental discovery—and we could also use a reliable time series of data in the region for research-level science.

The training provided by working at sea to gather routine time series is invaluable. It is also exciting for the student. An established scientist may not be as stimulated to repeat the same profile month upon month, but to a student this data collection is all new. It is impossible, sadly, to get every student around the world to spend time on the established time series projects—though where students are undertaking routine classes at sea, there is always scope for a new series. However, a long-term data set is also an educationist's dream for getting students involved with data handing. There are now many data sets, from those mentioned to the Argo network, and an almost inexhaustible amount of data are available from the NASA Earth Observation archives. They enable the professor to get students into issues of file handling, aliasing, data precision, and accuracy; these data sets are a gift for education. As a part of our own field course we use a data set produced by the Marine Biological Association and Plymouth Marine Labs (E1 and L4 data moorings). These two long-term campaigns help students put their two weeks of observations into the bigger picture, gaining insight on the temporal variability of the region (inter- and intra-annual) to go with their detailed spatial observations.

The exercise is not just about handing the data; it is about mining these invaluable resources for new discoveries. Students can undertake observational oceanographic research vicariously, benefiting from data sets that no one team could hope to gather, and investigate interconnections between ocean and atmospheric phenomena. Along the infinite monkeys at typewriters leading to the works of Shakespeare concept, think of the potential given a finite but large group of intelligent and focused students with computers working with these time series, most online and up to date. I would estimate that about half of our undergraduate and master's level students base their dissertations on archive data from long time series stations or observations—sea surface temperature and hurricane trends in the tropics, changes in freshwater flux from the Arctic, or patterns of plastic concentration in the Pacific gyre. All viable investigations with real research outcomes. There will, of course, be some student who uses the power of statistics to find a link between the number of eggs served on board the research vessel and the El Niño-Southern Oscillation index, but then I guess one of those infinite monkeys could also type the Abba songbook.

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