

## Hydrostation S funding history

### NSF Project Awards

#### Division of Ocean Sciences

OCE-2122606	(most recent)
OCE-1633125	
OCE-1153693	
OCE-0648016	^
OCE-0138353	
OCE-9617785	
OCE-9115853	^
OCE-8613904	
OCE-8116410	

#### Division of Atmospheric and Geospace Sciences

AGS-7722814	
AGS-7515025	(earliest)

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**Award:** OCE-2122606  
**Project:** **The Panulirus Hydrographic Stations (Hydrostation S): Years 70-74**  
**PI:** Nicholas Bates  
**Co-PI:** Rodney Johnson  
**Award Institution:** Bermuda Institute of Ocean Sciences  
**Start Date:** 2022-03-01  
**End Date:** 2027-02-28  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2122606&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2122606&HistoricalAwards=false)

#### NSF Award Abstract (OCE-2122606):

This project continues hydrographic observations at Hydrostation S, extending the time-series of ocean data to almost 70 years. Hydrostation S (formerly known as the Panulirus site), located about 25 km southeast of Bermuda in the North Atlantic Ocean, is one of the longest open-ocean hydrographic stations in the world. This program of repeat biweekly hydrographic observations began in 1954 and now, in its seventh decade, has proved to be the catalyst for numerous studies of ocean physics, biological processes and biogeochemistry. Sustained observations of the ocean, such as those from Hydrostation S, remain critically important to establish rates of change to provide quantitative empirical data for myriad regional and global ocean synthesis and modeling of ocean processes and future ocean change. Hydrostation S program and its data are considered as a service to the community, being openly distributed and subsequently have been an invaluable resource in understanding processes and patterns of variability in the ocean, as well as education, mentorship and outreach activities.

The major objective of the proposal is to continue Hydrostation S into the eighth decade with numerous questions related to warming and cooling, salinification and freshening, deoxygenation and insights on biogeochemical changes over time. This program constitutes frequent water column sampling of temperature, salinity, and dissolved oxygen (and indirectly, sampling of important ocean carbon time-series) of the North Atlantic subtropical gyre at the Hydrostation S site. Such work is

complementary to other sustained observations such as the Bermuda Atlantic Time-series Study (BATS) and Ocean Flux Program (OFP). The project entails a similar sampling format that has been followed for the past 68 years. Hydrostation S also supports the longest global ocean CO<sub>2</sub> and acidification time-series (from 1983 to present).

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**Award:** OCE-1633125  
**Project:** **The Panulirus Hydrographic Stations (Hydrostation S): Years 65-69**  
**PI:** Nicholas Bates  
**Co-PI:** Rodney Johnson  
**Award Institution:** Bermuda Institute of Ocean Sciences  
**Start Date:** 2017-03-01  
**End Date:** 2022-02-28  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=1633125&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1633125&HistoricalAwards=false)

**NSF Award Abstract (OCE-1633125):**

The physical properties of the ocean from the surface layers to the abyssal water masses are changing in concert with natural and anthropogenically influenced physical forcing and sustained observations of the ocean are critically important to establish these rates of change. One of the longest open-ocean hydrographic stations in the world is maintained at the Hydrostation S site (formerly known as the Panulirus site) located about 25 km southeast of Bermuda in the North Atlantic Ocean. This repeat biweekly hydrographic observations was initiated by Henry Stommel and co-workers in 1954. Now, in its seventh decade, it continues to be recognized as one of the most important sustained ocean time-series and provides an invaluable metric for the long-term state of the North Atlantic subtropical gyre in relation to the meridional overturning circulation, western boundary transport, and gyre recirculation. For example, the upper ocean warming trend has strengthened (about 0.8° C since the 1970's) while the deep Labrador Sea has cooled by a few tenths of a degree. The signature of deoxygenation has been observed at Hydrostation S in the upper ocean (about 7 micro-moles/kg/decade decrease in dissolved oxygen) as well as an intensification and expansion of the oxygen minimum zone. These changes suggest that the North Atlantic subtropical gyre is experiencing deoxygenation as in the Pacific Ocean as a result of increased upper ocean stratification and reduced solubility of oxygen in warmer waters. The Hydrostation S program and its data set are managed as a service to the ocean community, being openly distributed and used as a resource in understanding processes and patterns of variability in the ocean, as well as for education, mentorship and outreach activities. The Hydrostation S project will contribute to the research and training of six research specialists and research technicians at BIOS and contribute to the research projects of at least three Ph.D. students through on-going educational partnership with Princeton University and the University of Southampton in the U.K. The one-day Hydrostation S research cruises are an ideal platform for testing new sensors and for providing hand-on training to undergraduate students enrolled in summer programs.

The Hydrostation S project is designed to address the overarching hypothesis that the physical properties of the upper-ocean to deep-ocean are changing in concert with natural and anthropogenically influenced physical forcing. Sustained observations of the ocean, such as those from Hydrostation S, remain critically important to establish rates of change to provide quantitative empirical data for myriad regional and global ocean synthesis and modeling of ocean processes and future ocean change. The major objective of Hydrostation S into the seventh decade is to continue the frequent water column sampling of temperature, salinity, and dissolved oxygen (and indirectly, sampling of important ocean carbon time series) of the North Atlantic subtropical gyre. Such work is

complementary to other sustained observations such as the Bermuda Atlantic Time-series Study (BATS) and Ocean Flux Program (OFP). As for the past five years, two CTD profiles will be conducted to better capture the deep-water variability while maintaining all the previous discrete depths. The first CTD cast will profile to full ocean depth (3,200-3,500 m) while the second CTD cast will profile from the surface to 500 m to allow for biogeochemical instrumentation not rated for full ocean depth and to support ancillary studies of ocean physics, biological processes and biogeochemistry. A secondary objective will be to build upon the collaborative comparison of physical data collected as part of two autonomous sensor projects. In the latter stages of the project, as ocean glider deployment becomes more sustainable and reliable, collaborative and comparative efforts will be used to test the capability of ocean gliders to provide data of sufficient quality to detect long-term oceanic change in a "virtual" mooring time-series mode. The robust and highly accurate Hydrostation S data will be used to test the capability of emerging technologies over the next five to ten years.

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**Award:** OCE-1153693  
**Project:** **The Panulirus Hydrographic Stations: Years 59-64**  
**PI:** Nicholas Bates  
**Co-PI:** Rodney Johnson  
**Award Institution:** Bermuda Institute of Ocean Sciences  
**Start Date:** 2012-04-01  
**End Date:** 2017-03-31  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=1153693&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1153693&HistoricalAwards=false)

**NSF Award Abstract (OCE- 1153693):**

Intellectual Merit:

Hydrostation 'S' located some 25 km south east of Bermuda in the Sargasso Sea represents the site of the longest maintained oceanographic hydrography timeseries. Initiated by oceanographer Henry Stommel and co-workers in 1954, this invaluable biweekly timeseries has been in existence for nearly 58 years. Historically, the Hydrostation 'S' program through its core hydrography measurements and other ancillary work has facilitated a diversified measurement program. The dominant theme of these studies has been long term change relating to climate issues using the unprecedented near six decades of physical hydrography. These data clearly show substantial inter-annual and decadal variability throughout the full water column although significant long term trends exist in the thermohaline properties of both the upper ocean and deep waters. For waters consistent with subtropical mode water at this site (~300 m depth), the long term trend in temperature and salinity is + 0.009 C per year and 0.002 salinity units per year, respectively, while for deeper waters consistent with Labrador Sea Water, the observed trends are -0.005 C per year and -0.001 salinity units per year. Interestingly, for the past five years, the observed trends for these water masses are opposite to the long term trends. Hydrostation 'S' data have been an important resource in helping understand variability in the various water masses of the subtropical gyre by establishing links to climate state (North Atlantic Oscillation) and large scale mass transport (Atlantic Meridional Overturning Circulation). As a result of collaboration with other investigators, the Hydrostation 'S' program continues to deliver a broad research list and complementary to the core hydrography, these ancillary projects have yielded the longest time-series of carbon dioxide (now 29 years old), tritium and helium and trace organics.

Perhaps one of the more important aspects of this timeseries is the support framework and multi-decadal synthesis context it provides for other oceanographic programs in this region. These data are considered as a service to the community as a whole being openly distributed and subsequently an

invaluable resource for understanding ocean processes. All data for this current award have been processed and data through December 2010 are available for full access while data through July 2011 can be accessed as preliminary data. This renewal will maintain the same sampling program of near biweekly sampling consisting of deep CTD casts and discrete samples for salinity and dissolved oxygen.

**Broader Impacts:**

Hydrostation 'S' cruises have played a large role in education at BIOS by providing students one day trips to the Sargasso Sea such that these cruises now routinely host large student groups (e.g., Princeton University graduates). Hydrostation 'S' cruises have also proved to be a key platform for resident undergraduate, graduate and local high school students, for gaining experience and conducting independent research projects. Due to their short duration, Hydrostation 'S' cruises continue to prove useful for both local and international media reporters. During this past year media teams from Time Magazine, National Geographic and NBC News have participated on Hydrostation 'S' cruises resulting in articles and documentaries highlighting this time-series and its role in helping understand ocean variability and climate change. In the past few years, there has been a large increase in educational and outreach activities on these cruises primarily due to the arrival of the R/V Atlantic Explorer at BIOS.

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<b>Award:</b>	OCE-0648016
<b>Project:</b>	<b>The Panulirus Hydrographic Stations: Years 54-59</b>
<b>PI:</b>	Nicholas Bates
<b>Co-PI:</b>	Rodney Johnson, Anthony Knap (former PI)
<b>Award Institution:</b>	Bermuda Institute of Ocean Sciences
<b>Start Date:</b>	2007-04-01
<b>End Date:</b>	2012-03-31
<b>Award URL:</b>	<a href="https://www.nsf.gov/awardsearch/showAward?AWD_ID=0648016&amp;HistoricalAwards=false">https://www.nsf.gov/awardsearch/showAward?AWD_ID=0648016&amp;HistoricalAwards=false</a>

**NSF Award Abstract (OCE-0648016):**

This project will extend the now 52 year long series of the ocean hydrographic station near Bermuda, known as Station S or the Panulirus Station for another 5 years. These time-series data have already been extensively used by investigators in many disciplines to examine fluctuations at periods from weeks to years in the western Atlantic Ocean and producing over 100 publications over the past 10 years. Hydrostation S allows a bi-weekly context for the biogeochemical measurements that are part of the more complex multi-disciplinary Bermuda Atlantic Time-series Station program and also helps provide a better understanding of the short term variability associated with mesoscale eddy dynamics in this region. Patterns of long term change and decadal variability have emerged from these data. In particular, long term warming of the deeper ocean (especially at the depth of mode water 200-400m) has been documented. However, a similar long term increase has not occurred in the surface temperature record over the whole 52 year period although there have been significant trends in both temperature and salinity over decadal time scales. Thus these data show the importance of sampling the full ocean depth over very long time periods rather than just using sea surface temperature for proxies of climate change. These data have proven to be an important link in global ocean monitoring and have allowed scientists to establish direct linkages with climate change. The extension of this time series will further deduce the significance of these climate related signals and to further understand processes effecting ocean variability. The bi-weekly sampling periodicity is essential to resolve various oceanographic processes and the unique position of this site off Bermuda means that each full ocean

depth station can be accomplished with just one ship day. In addition to the core measurements, ancillary users have enhanced the measurements at this site to provide a rich array of data available to the ocean sciences community. The investigators propose to actively continue this collaboration. The only change to this time-series project is to sample the full ocean depth (~3300m) rather than the current bottom depth of 2600m. This change will require an additional CTD cast and will generate another six discrete depths for water samples. The availability of the new BBSR vessel R/V Atlantic Explorer will allow us to effectively implement this change without any impact on cruise logistics or funding amounts.

#### Broader Impacts

During the past 5 years, numerous student programs have used the Hydrostation S project as resource for training and conducting student fieldwork. This interest continues to grow such that there are now have several Universities seeking to make use of the BBSR vessel R/V Atlantic Explorer and the Hydrostation S program as explicit part of their course work. This project will continue and extend this facilitation and further, a graduate student component will be added to this program. Hydrostation S cruises have also proved to be an invaluable resource for training oceanography technicians form BBSR (over 15 in past 5 years) and other institutions and this activity will also continue. Another advantage of the single day cruises is that it lends itself for the inclusion of journalists and media personnel from both Bermuda and international locations.

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<b>Award:</b>	OCE-0138353
<b>Project:</b>	<b>The Panulirus Hydrographic Stations (Hydrostation S): years 48-53</b>
<b>PI:</b>	Anthony Knap
<b>Co-PI:</b>	None
<b>Award Institution:</b>	Bermuda Institute of Ocean Sciences
<b>Start Date:</b>	2007-04-01
<b>End Date:</b>	2012-03-31
<b>Award URL:</b>	<a href="https://www.nsf.gov/awardsearch/showAward?AWD_ID=0138353&amp;HistoricalAwards=false">https://www.nsf.gov/awardsearch/showAward?AWD_ID=0138353&amp;HistoricalAwards=false</a>

#### NSF Award Abstract (OCE-0138353):

Funding is provided to continue the now 47-year long series of (3000m depth) ocean hydrographic stations near Bermuda, known as Station S or the Panulirus Stations. The data have already been used by investigators in several disciplines to examine fluctuations at periods from weeks to years in the western Atlantic Ocean. Changes over periods of decades are starting to appear. The on-going dataset has proven to be an important link in global ocean monitoring for both climate research and for evaluating temporal changes of many parameters. Ancillary users have, through this program, enhanced the measurements at this site to provide a rich array of data available to the ocean sciences community. This time series is a contribution to the U.S. Climate Variability and Predictability Program (CLIVAR).

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<b>Award:</b>	OCE-9617785
<b>Project:</b>	<b>The Panulirus Hydrographic Stations Years 43-47</b>
<b>PI:</b>	Anthony Knap
<b>Co-PI:</b>	None
<b>Award Institution:</b>	Bermuda Institute of Ocean Sciences

**Start Date:** 1997-06-01

**End Date:** 2002-05-31

**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=9617785&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=9617785&HistoricalAwards=false)

**NSF Award Abstract (OCE-9617785):**

It is proposed to continue the now 41 year long time series of the deep (3000 m) ocean hydrographic station near Bermuda known as Station S or the Panulirus Station. Data collected to date have been used by investigators in several disciplines to examine fluctuations at periods from weeks to decades in the western Atlantic Ocean. This continuous and on-going data set has proven to be an important link in global ocean monitoring for both climate research and for evaluating temporal changes of many parameters.

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**Award:** OCE-9115853

**Project:** **The Panulirus Hydrographic Station at Station 'S'**

**PI:** Anthony Knap

**Co-PI:** None

**Award Institution:** Bermuda Institute of Ocean Sciences

**Start Date:** 1992-03-01

**End Date:** 1997-08-31

**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=9115853&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=9115853&HistoricalAwards=false)

**NSF Award Abstract (OCE-9115853):**

The 37 year oceanographic time series at the "Panulirus" hydrographic station at station S, southeast of Bermuda will be extended for another five years. The data gathered, calibrated, archived at the Bermuda Biological Station for Research is available to the scientific community for studies of long-term changes in oceanic climate.

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**Award:** OCE-8613904

**Project:** **The Panulirus (STATION S) Hydrographic Stations**

**PI:** Anthony Knap

**Co-PI:** None

**Award Institution:** Bermuda Institute of Ocean Sciences

**Start Date:** 1987-01-01

**End Date:** 1992-06-30

**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=8613904&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=8613904&HistoricalAwards=false)

**NSF Award Abstract (OCE- 8613904):**

None listed

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**Award:** OCE-8116410  
**Project:** **Panulirus Hydrographic Stations**  
**PI:** Anthony Knap  
**Co-PI:** None  
**Award Institution:** Bermuda Institute of Ocean Sciences  
**Start Date:** 1981-12-01  
**End Date:** 1987-09-30  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=8116410&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=8116410&HistoricalAwards=false)

**NSF Award Abstract (OCE-8116410):**

None listed

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**Award:** AGS-7722814  
**Project:** **Panulirus Hydrographic Stations**  
**PI:** Elizabeth Schroeder  
**Co-PI:** Bruce Warren  
**Award Institution:** Woods Hole Oceanographic Institution  
**Start Date:** 1977-11-01  
**End Date:** 1981-10-31  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=7722814&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=7722814&HistoricalAwards=false)

**NSF Award Abstract (AGS-7722814):**

None listed

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**Award:** AGS-7515025  
**Project:** **Panulirus Hydrographic Stations**  
**PI:** Bruce Warren  
**Co-PI:** None  
**Award Institution:** Woods Hole Oceanographic Institution  
**Start Date:** 1975-10-01  
**End Date:** 1979-04-30  
**Award URL:** [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=7515025&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=7515025&HistoricalAwards=false)

**NSF Award Abstract (AGS-7515025):**

None listed