Bio Optical Profiler Data from R/V Thomas G. Thompson TT045, TT053, TT054 cruises in the Arabian Sea in 1995 (U.S. JGOFS Arabian Sea project)

Website: https://www.bco-dmo.org/dataset/2555
Version: final
Version Date: 1998-05-29

Project
» U.S. JGOFS Arabian Sea (Arabian Sea)

Program
» U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

Contributors	Affiliation	Role
Trees, Charles C.	San Diego State University (SDSU)	Principal Investigator
Chandler, Cynthia L.	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

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Dataset Description

Bio Optical Profiler Data

Methods & Sampling

See Platform deployments for cruise specific documentation

These data contain radiometric profile data binned to unit value meters, and include downwelling irradiance (E_d), upwelling irradiance(E_u) if available, upwelling radiance(L_u), and the corresponding derived diffuse attenuation coefficients (K_d, K_u, and L_u).

Also included is the particulate beam attenuation coefficient, (660nm) minus C_water(660nm), the stimulated in-situ chlorophyll fluorescence, and the sea surface incident irradiance (E_s).

Arabian Sea bio-optics data

Process Cruises 2, 6 and 7

The transmissometer showed symptoms of photodiode decay and therefore we assumed that the air calibrations decreased throughout these deployments. Unfortunately, air calibration values were missing for Process Cruises 6 and 7. The effective air calibration values were adjusted to remove negative particle attenuation coefficients for the deeper of part of the profiles (150-200m). In addition, the

transmissometer window had been scratched sometime during the deployments or shipping, making the factory calibration values invalid. In an attempt to correct the problem, the transmissometer was compared to two other transmissometers in the CHORS laboratory to generate a new, vicarious factory air calibration factor.

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Bio-optical Calibration and Measurements Protocols for U.S. JGOFS Equatorial Pacific Cruises

Charles C. Trees and Curtiss O. Davis

The accurate determination of in-water upwelled (E_u) and downwelled (E_d) spectral irradiances and upwelled spectral radiance (L_u) require adherence to strict calibration and measurement protocols. NASA sponsored a workshop (8--12 April, 1991) to establish calibration standards, protocols, and sampling strategies for ocean optical measurements to be used for SeaWiFS baseline algorithm development and system validation. Calibration and measurement protocols for JGOFS EqPac cruises will follow those protocols. This document gives a brief overview; for a more detailed review refer to the proceedings (Mueller and Austin, 1991) from that workshop. There are two major sources of measurement errors in determining E_d, E_u and L_u; (1) the perturbation of the in-water radiant energy field caused by the ship and (2) the estimation of quantitative corrections for atmospheric variability in the radiant energy incident on the surface during the in-water measurements. To correct for these potential problems the following protocols will be followed during the transect and time series cruises.

Participants:

Transect Cruises:
Spring: Charles Trees (CHORS) Fall: Daniel Sullivan (CHORS)
James Aiken (PML, U.K.) Ian Bellan (PML, U.K.)

Time Series Cruises:
Spring: Curtiss Davis (JPL) Fall: Joseph Rhea (JPL)
Joseph Rhea (JPL) Michael Hamilton (JPL)

1. The bio-optical profiling systems for the transect and time series cruises are similar in that they include a Biospherical spectroradiometer (MER 1032 and 1048), a Sea Tech transmissometer (660 nm) and a Sea Tech fluorometer. Both MERs have also been adapted to measure solar stimulated fluorescence [(L_u(683 nm)]. The two surface incident irradiance detectors are different in that one was built by Biospherical (Dr. Davis') whereas we built out own. The MERs and surface incident irradiance detectors will be calibrated before and after each cruise. The calibration of these optical instruments will be performed at the CHORS Calibration Facility, using standard sources traceable to the National Institute of Standards and Technology (NIST). In addition, both MERs will be optically characterized to define their performance characteristics. This characterization includes linearity, cosine response of the irradiance detectors, field of view of radiance detectors, irradiance and radiance immersion factors, spectral response, wavelength calibration and instrument stability and precision checks. The CHORS MER has already been characterized and will go through a second characterization prior to the first transect cruise in Jan. 1992. Dr. Davis' MER will be shipped back to CHORS after his first time series cruise (June, 1992) for a post-cruise calibration and its first characterization. Characterization needs to be performed every 3--5 years.

   Dr. James Aiken will deploy his towed multi-sensor Undulating Oceanographic Re-corder (UOR), which measures downwelled and upwelled spectral irradiance (cosine collectors), fluorescence and beam transmission (660 nm) during its undulations from near surface to *ca* 70 meters. The UOR irradiance sensors will be calibrated at CHORS before and after each cruise. In addition, a partial characterization of the sensors will be performed to document their cosine responses, immersion factors, linearity and spectral responses.

   QA/QC: CHORS Calibration Facility has a complete capability for characterizing and calibrating environmental radiometers, following the procedures described in the NASA report (Mueller and Austin,

1991). These procedures have been routinely applied to our own equipment, as well as characterizing and calibrating ocean radiometer systems for NOARL, the Naval Oceanographic Office and Dalhousie University (Dr. Marlon Lewis' expendable L_U meter). We have cross-checked MER instrument calibrations with Dr. Ken Voss at the University of Miami and with Biospherical Instruments, Inc. and realized agreements in irradiance calibrations within <5 % with both, and also agree with the University of Miami for radiance within <5 %. In 1989, we compared a Multispectral Airborne Radiometer System radiance calibration using our facilities, with a calibration performed at Goddard Space Flight Center, and obtained agreement within 5 %.

2. Between the laboratory calibrations of the MER's, secondary checks of the instruments performance will be performed using stable lamps in rugged fixed geometric configurations. These portable secondary calibrations in the field will provide a record of the instruments stability and will assist in evaluating possible corrections to the optical data if inconsistencies appear later. More importantly these sources would give advance warnings of potential problems, which could be corrected in the field. The CHORS Portable Secondary Standard (PSS) will be taken on the transect cruises. Intercalibration using the standard will be performed on Dr. Davis' MER prior to the departure of the time series legs. Because of prior commitments, the PSS has to be shipped back to CHORS after each transect cruise.

3. The profiling spectroradiometers (MER 1032 and 1048) will be deployed from the stern using the starboard crane fully extended (65 ft). In addition the ship will be positioned with the sun off the stern and will maintain that orientation throughout the optical cast (approximately 30 minutes). These two measurement protocols will help to minimize the errors in the determination of $E_{\square}$, E_U, and L_U caused by ship shadow. At least one bio-optical profile should be made daily with the cast being close to local apparent noon (LAN) as long as the solar zenith angles are greater than 10 degrees. At angles less than this errors can be introduced in measurements of E_U and L_U by the instrument's own shadow. There will be times during these cruises when measurements will have to be made a few hours before of or after LAN to minimize this self-shadowing effect.

4. The dark current of optical sensors is frequently temperature dependent and as a consequence, collection of accurate optical data requires careful attention to dark current variability. We will make dark current measurements before and after each cast and we will ordinarily use the post-cast dark readings, when the instrument temperature is closer to ambient conditions. When there is a large temperature difference between the instrument on the deck and the water temperature, the instrument will be allowed to equilibrate with the water temperature at the beginning of each cast.

5. Surface incident spectral irradiance will be measured during the optical cast to correct for atmospheric variability in radiant energy incident on the sea surface. This instrument will be mounted as high up on the ship as possible and away from any structures that might cause a shadow on or a reflection into the instrument.

6. The windows on the Sea Tech transmissometers will be cleaned with lens cleaner and a tissue, then rinsed with distilled water, and finally rinsed with isopropyl alcohol and wiped dry. Cleaning of the windows and reading of these ``on-deck air calibrations'' will be performed before each cast to verify that the windows are clean. An air calibration to check for temporal degradation in the transmissometer's source and detector will be performed in the laboratory before and after each cruise. In addition a characterization of the A-to-D system in the MER's will be performed so that a known input voltage generates a predicted output voltage. For transmissometers used on the CTD, an end-to-end check of the instrument is required unless the CTD A-to-D channels are also calibrated. Transmissometer data collected with the CTD will be corrected for temperature, salinity and pressure using the algorithm provided by Sea Tech. In addition, the data will be evaluated for temperature hysteresis effects which, if deemed significant, will be corrected for using a modified algorithm developed by Bishop (1986).

7. The windows on the fluorometers will be cleaned with lens cleaner and rinsed with distilled water. Since the

measurements of fluorescence are in relative units no additional calibration is planned, except that the voltage measuring A-to-D system recording the fluorescence must be characterized as described for the transmissometers.

8. The MERs have scalar PAR (photosynthetically available radiation) collectors for measuring broad banded radiation from 400--700 nm. Because of the difficulty in calibrating and accurately measuring radiant energy over this broad spectral band (Gordon and McCluney, 1975; Kirk, 1983), PAR will be calculated (Morel and Smith, 1974) from the downwelling spectral irradiance data ($E_{\square}$).
9. Sky radiance will be estimated by occulting the sun's image on the deck cell measuring incident spectral irradiance. This measurement is useful for estimating the mean cosine at the surface and can be used with profile measurements of $E_{\square}$, E_{U}, and c to estimate by (Gordon, 1990). The ability to exploit this and similar relationships will greatly enhance both the development and verification of bio-optical algorithms.
10. All-sky photographs will be taken before each optical cast to document the cloud cover. This information is important for identifying measurements made under questionable environmental conditions.

Literature Cited

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Estimation of the depth of sunlight penetration in the sea for remote sensing. *Applied Optics*, **14(2)**:413--416.

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Estimation of inherent optical properties from irradiance measurements: Monte Carlo simulations, pp. 49--54, **In:** *Ocean Optics X, Proc. SPIE 1302*, R.W. Spinrad (ed.).

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Mueller, J.L. and R.W. Austin (1992).

Ocean Optical Protocols for SeaWiFS Validation. *SeaWiFS Technical Report Series*, Volume 5, NASA Technical Memorandum 1044566.

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Parameters

Parameter	Description	Units
event	event number from event log, as MMDDhhmm	
sta_std	Arabian Sea standard station identifier	
sta	station number from event log	
lat_n	latitude (negative = south)	decimal degrees
lon_n	longitude (negative = west)	decimal degrees
cast_type	downcast or upcast	
depth	depth of measurement	meters
Es_XXX	sea surface incident irradiance at wavelength XXX	micro W/(cm^2 nm)
Ed_XXX	downwelling irradiance at wavlength XXX Ed radiometric depth offset = -70.0cm	micro W/(cm^2 nm)
Lu_XXX	upwelling radiance at wavelength XXX Lu radiometric depth offset = 0.0cm	micro W/(cm^2 sr nm)
Kd_XXX	diffuse attenuation coef. for Ed_XXX	meters^-1
Kl_XXX	diffuse attenuation coef. for Lu_XXX	meters^-1
beam_cp	particle beam attenuation coefficient	meters^-1
fluor	chlorophyll_a fluorescence	volts

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Instruments

Dataset-specific Instrument Name	Bio-Optical Profiling System
Generic Instrument Name	Bio-Optical Profiling System
Generic Instrument Description	Bio-Optical Profiling System (BOPS) is an updated version of the BOPS originally developed by Smith et al. (1984) and is used to collect optical data. The heart of the BOPS is a Biospherical instruments MER-1048 Spectroradiometer which measures up and downwelling spectral irradiance and upwelling spectral radiance. The MER-1048 also has sensors for Photosynthetically Available Radiation (PAR), depth, tilt and roll. In addition, temperature and conductivity are measured with a Sea-Bird CTD, chlorophyll fluorescence is measured with a Sea Tech fluorometer and beam transmission with a Sea Tech 25-cm transmissometer. The Mer-1048 acquires all the data 16 times a second, averages it to four records a second and sends it up the cable to a deck box and a Compaq-286 computer which stores the data on the hard disk. Additionally, a deck cell measures the downwelling surface irradiance in four spectral channels. Also surface PAR is measured continuously using a Biospherical Instruments QSR-240 Integrating PAR sensor. The profile data is commonly filtered to remove obvious data spikes and then binned into one-meter averages. Raymond C. Smith, Charles R. Booth, and Jeffrey L. Star, "Oceanographic biooptical profiling system," Appl. Opt. 23, 2791-2797 (1984).

Dataset-specific Instrument Name	SeaTech Fluorometer
Generic Instrument Name	Sea Tech Fluorometer
Dataset-specific Description	The windows on the fluorometers will be cleaned with lens cleaner and rinsed with distilled water.
Generic Instrument Description	The Sea Tech chlorophyll-a fluorometer has internally selectable settings to adjust for different ranges of chlorophyll concentration, and is designed to measure chlorophyll-a fluorescence in situ. The instrument is stable with time and temperature and uses specially selected optical filters enabling accurate measurements of chlorophyll a. It can be deployed in moored or profiling mode. This instrument designation is used when specific make and model are not known. The Sea Tech Fluorometer was manufactured by Sea Tech, Inc. (Corvalis, OR, USA).

Dataset-specific Instrument Name	SeaTech Transmissometer
Generic Instrument Name	Sea Tech Transmissometer
Dataset-specific Description	A Sea Tech transmissometer (660 nm) was used to measure the extinction coefficient of the atmosphere, and for the determination of visual range. The windows on the Sea Tech transmissometers will be cleaned with lens cleaner and a tissue, then rinsed with distilled water, and finally rinsed with isopropyl alcohol and wiped dry. Cleaning of the windows and reading of these ``on-deck air calibrations' will be performed before each cast to verify that the windows are clean.
Generic Instrument Description	The Sea Tech Transmissometer can be deployed in either moored or profiling mode to estimate the concentration of suspended or particulate matter in seawater. The transmissometer measures the beam attenuation coefficient in the red spectral band (660 nm) of the laser lightsource over the instrument's path-length (e.g. 20 or 25 cm). This instrument designation is used when specific make and model are not known. The Sea Tech Transmissometer was manufactured by Sea Tech, Inc. (Corvalis, OR, USA).

Dataset-specific Instrument Name	Spectroradiometer
Generic Instrument Name	Spectroradiometer
Dataset-specific Description	The profiling spectroradiometers (MER 1032 and 1048) will be deployed from the stern using the starboard crane fully extended (65 ft). In addition the ship will be positioned with the sun off the stern and will maintain that orientation throughout the optical cast (approximately 30 minutes).
Generic Instrument Description	A Spectroradiometer or Spectraradiometer is an instrument that measures the intensity and nature of electromagnetic radiation. An ocean color radiometer makes the measurements in a manner optimized for the determination of ocean chlorophyll concentration.

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Deployments

TT045

Website	https://www.bco-dmo.org/deployment/57706
Platform	R/V Thomas G. Thompson
Start Date	1995-03-14
End Date	1995-04-10
Description	**Methods & Sampling** PI: Chuck Trees of: San Diego State University dataset: Bio Optical Profiler Data dates: March 27, 1995 to April 08, 1995 location: N: 18.9928 S: 14.4425 W: 57.9921 E: 64.8985 project/cruise: Arabian Sea/TTN-045 - Process Cruise 2 (Spring Intermonsoon) ship: Thomas Thompson These data contain radiometric profile data binned to unit value meters, and include downwelling irradiance (E_d), upwelling irradiance(E_u) if available, upwelling radiance(L_u), and the corresponding derived diffuse attenuation coefficients (K_d, K_u, and L_u). Also included is the particulate beam attenuation coefficient, (660nm) minus C_water(660nm), the stimulated in-situ chlorophyll fluorescence, and the sea surface incident irradiance (E_s). Arabian Sea bio-optics data Process Cruises 2, 6 and 7 The transmissometer showed symptoms of photodiode decay and therefore we assumed that the air calibrations decreased throughout these deployments. Unfortunately, air calibration values were missing for Process Cruises 6 and 7. The effective air calibration values were adjusted to remove negative particle attenuation coefficients for the deeper of part of the profiles (150-200m). In addition, the transmissometer window had been scratched sometime during the deployments or shipping, making the factory calibration values invalid. In an attempt to correct the problem, the transmissometer was compared to two other transmissometers in the CHORS laboratory to generate a new, vicarious factory air calibration factor. Charles C. Trees Center for Hydro-Optics and Remote Sensing San Diego State University chuck@chors.sdsu.edu Bio-optical Calibration and Measurements Protocols for U.S. JGOFS Equatorial Pacific Cruises Charles C. Trees and Curtiss O. Davis The accurate determination of in-water upwelled (E) and downwelled (E) spectral irradiances and upwelled spectral radiance (L) require adherence to strict calibration and measurement protocols. NASA sponsored a workshop (8--12 April, 1991) to establish calibration standards, protocols, and sampling strategies for ocean optical measurements to be used for SeaWiFS baseline algorithm development and system validation. Calibration and measurement protocols for JGOFS EqPac cruises will follow those protocols. This document gives a brief overview; for a more detailed review refer to the proceedings (Mueller and Austin, 1991) from that workshop. There are two major sources of measurement errors in determining E, E and L; (1) the perturbation of the in-water radiant energy field caused by the ship and (2) the estimation of quantitative corrections for atmospheric variability in the radiant energy incident on the surface during the in-water measurements. 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Dr. James Aiken will deploy his towed multi-sensor Undulating Oceanographic Re-corder (UOR), which measures downwelled and upwelled spectral irradiance (cosine collectors), fluorescence and beam transmission (660 nm) during its undulations from near surface to ca 70 meters. The UOR irradiance sensors will be calibrated at CHORS before and after each cruise. In addition, a partial characterization of the sensors will be performed to

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TT053

Website	https://www.bco-dmo.org/deployment/57714
Platform	R/V Thomas G. Thompson
Start Date	1995-10-29
End Date	1995-11-26
Description	**Methods & Sampling** PI: Chuck Trees of: San Diego State University dataset: Bio Optical Profiler Data dates: October 29, 1995 to November 25, 1995 location: N: 24.3322 S: 10.0831 W: 56.492 E: 67.1374 project/cruise: Arabian Sea/TTN-053 - Process Cruise 6 (bio-optics) ship: Thomas Thompson These data contain radiometric profile data binned to unit value meters, and include downwelling irradiance (E_d), upwelling irradiance(E_u) if available, upwelling radiance(L_u), and the corresponding derived diffuse attenuation coefficients (K_d, K_u, and L_u). Also included is the particulate beam attenuation coefficient, (660nm) minus C_water(660nm), the stimulated in-situ chlorophyll fluorescence, and the sea surface incident irradiance (E_s). Arabian Sea bio-optics data Process Cruises 2, 6 and 7 The transmissometer showed symptoms of photodiode decay and therefore we assumed that the air calibrations decreased throughout these deployments. Unfortunately, air calibration values were missing for Process Cruises 6 and 7. The effective air calibration values were adjusted to remove negative particle attenuation coefficients for the deeper of part of the profiles (150-200m). In addition, the transmissometer window had been scratched sometime during the deployments or shipping, making the factory calibration values invalid. In an attempt to correct the problem, the transmissometer was compared to two other transmissometers in the CHORS laboratory to generate a new, vicarious factory air calibration factor. Charles C. Trees Center for Hydro-Optics and Remote Sensing San Diego State University chuck@chors.sdsu.edu Bio-optical Calibration and Measurements Protocols for U.S. JGOFS Equatorial Pacific Cruises Charles C. Trees and Curtiss O. Davis The accurate determination of in-water upwelled (E) and downwelled (E) spectral irradiances and upwelled spectral radiance (L) require adherence to strict calibration and measurement protocols. NASA sponsored a workshop (8--12 April, 1991) to establish calibration standards, protocols, and sampling strategies for ocean optical measurements to be used for SeaWiFS baseline algorithm development and system validation. Calibration and measurement protocols for JGOFS EqPac cruises will follow those protocols. This document gives a brief overview; for a more detailed review refer to the proceedings (Mueller and Austin, 1991) from that workshop. There are two major sources of measurement errors in determining E, E and L; (1) the perturbation of the in-water radiant energy field caused by the ship and (2) the estimation of quantitative corrections for atmospheric variability in the radiant energy incident on the surface during the in-water measurements. To correct for these potential problems the following protocols will be followed during the transect and time series cruises. Participants: Transect Cruises: Spring: Charles Trees (CHORS) Fall: Daniel Sullivan (CHORS) James Aiken (PML, U.K.) Ian Bellan (PML, U.K.) Time Series Cruises: Spring: Curtiss Davis (JPL) Fall: Joseph Rhea (JPL) Joseph Rhea (JPL) Michael Hamilton (JPL) The bio-optical profiling systems for the transect and time series cruises are similar in that they include a Biospherical spectroradiometer (MER 1032 and 1048), a Sea Tech transmissometer (660 nm) and a Sea Tech fluorometer. Both MERs have also been adapted to measure solar stimulated fluorescence [(L(683 nm)]. The two surface incident irradiance detectors are different in that one was built by Biospherical (Dr. Davis') whereas we built out own. The MERs and surface incident irradiance detectors will be calibrated before and after each cruise. The calibration of these optical instruments will be performed at the CHORS Calibration Facility, using standard sources traceable to the National Institute of Standards and Technology (NIST). In addition,

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TT054

Website	https://www.bco-dmo.org/deployment/57715
Platform	R/V Thomas G. Thompson
Start Date	1995-11-30
End Date	1995-12-28
	Methods & Sampling PI: Chuck Trees of: San Diego State University dataset: Bio Optical Profiler Data dates: December 01, 1995 to December 25, 1995 location: N: 22.5148 S: 9.9946 W: 57.7955 E: 68.773 project/cruise: Arabian Sea/TTN-054 - Process Cruise 7 (Early NE Monsoon) ship: Thomas Thompson These data contain radiometric profile data binned to unit value meters, and include downwelling irradiance (E_d), upwelling irradiance(E_u) if available, upwelling radiance(L_u), and the corresponding derived diffuse attenuation coefficients (K_d, K_u, and L_u). Also included is the particulate beam attenuation coefficient, (660nm) minus C_water(660nm), the stimulated in-situ chlorophyll fluorescence, and the sea surface incident irradiance (E_s). Arabian Sea bio-optics data Process Cruises 2, 6 and 7 The transmissometer showed symptoms of photodiode decay and therefore we assumed that the air calibrations decreased throughout these deployments. Unfortunately, air calibration values were missing for Process Cruises 6 and 7. The effective air calibration values were adjusted to remove negative particle attenuation coefficients for the deeper of part of the profiles (150-200m). In addition, the transmissometer window had been scratched sometime during the deployments or shipping, making the factory calibration values invalid. In an attempt to correct the problem, the transmissometer was compared to two other transmissometers in the CHORS laboratory to generate a new, vicarious factory air calibration factor. Charles C. Trees Center for Hydro-Optics and Remote Sensing San Diego State University chuck@chors.sdsu.edu Bio-optical Calibration and Measurements Protocols for U.S. JGOFS Equatorial Pacific Cruises Charles C. Trees and Curtiss O. Davis The accurate determination of in-water upwelled (E) and downwelled (E) spectral irradiances and upwelled spectral radiance (L) require adherence to strict calibration and measurement protocols. NASA sponsored a workshop (8--12 April, 1991) to establish calibration standards, protocols, and sampling strategies for ocean optical measurements to be used for SeaWiFS baseline algorithm development and system validation. Calibration and measurement protocols for JGOFS EqPac cruises will follow those protocols. This document gives a brief overview; for a more detailed review refer to the proceedings (Mueller and Austin, 1991) from that workshop. There are two major sources of measurement errors in determining E, E and L; (1) the perturbation of the in-water radiant energy field caused by the ship and (2) the estimation of quantitative corrections for atmospheric variability in the radiant energy incident on the surface during the in-water measurements. To correct for

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Project Information

U.S. JGOFS Arabian Sea (Arabian Sea)

Website: http://usjgofs.whoi.edu/research/arabian.html

Coverage: Arabian Sea

The U.S. Arabian Sea Expedition which began in September 1994 and ended in January 1996, had three major components: a U.S. JGOFS Process Study, supported by the National Science Foundation (NSF); Forced Upper Ocean Dynamics, an Office of Naval Research (ONR) initiative; and shipboard and aircraft measurements supported by the National Aeronautics and Space Administration (NASA). The Expedition consisted of 17 cruises aboard the R/V Thomas Thompson, year-long moored deployments of five instrumented surface buoys and five sediment-trap arrays, aircraft overflights and satellite observations. Of the seventeen ship cruises, six were allocated to repeat process survey cruises, four to SeaSoar mapping cruises, six to mooring and benthic work, and a single calibration cruise which was essentially conducted in transit to the Arabian Sea.

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Program Information

U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

Website: http://usjgofs.whoi.edu/

Coverage: Global

The United States Joint Global Ocean Flux Study was a national component of international JGOFS and an integral part of global climate change research.

The U.S. launched the Joint Global Ocean Flux Study (JGOFS) in the late 1980s to study the ocean carbon cycle. An ambitious goal was set to understand the controls on the concentrations and fluxes of carbon and associated nutrients in the ocean. A new field of ocean biogeochemistry emerged with an emphasis on quality measurements of carbon system parameters and interdisciplinary field studies of the biological, chemical and physical process which control the ocean carbon cycle. As we studied ocean biogeochemistry, we learned that our simple views of carbon uptake and transport were severely limited, and a new "wave" of ocean science was born. U.S. JGOFS has been supported primarily by the U.S. National Science Foundation in collaboration with the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the Department of Energy and the Office of Naval Research. U.S. JGOFS, ended in 2005 with the conclusion of the Synthesis and Modeling Project (SMP).

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Funding

Funding Source	Award
Office of Naval Research (ONR)	unknown Arabian Sea ONR

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