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Report of the Second Ocean-Systems for Chemical, Optical, and Physical Experiments (O-SCOPE) Workshop

University of South Florida, St. Petersburg, FL
February 18-19, 1999

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Introduction

The second workshop for the National Ocean Partnership Program (NOPP) sponsored Ocean-Systems for Chemical, Optical, and Physical Experiments (O-SCOPE) program was held at the University of South Florida February 18-19, 1999. The O-SCOPE Partners and their contributions are presented in Table 1. The second workshop built upon the planning, which is described in considerable detail in the first NOPP O-SCOPE Workshop Report. Briefly, the O-SCOPE program is focusing on the development and testing of new interdisciplinary instrumentation to improve the variety, quantity, quality, and cost-effectiveness of observations in anticipation of a network of strategically placed moorings and other platforms. These technologies will be used to quantify 1) trends in biogeochemical and bio-optical variables and 2) seasonal, interannual, and decadal changes in upper ocean biogeochemical and bio-optical variability and carbon fluxes. The O-SCOPE interdisciplinary sensor suites (e.g., pCO2 and pH sensors, nitrate analyzers, and optical sensors) are being tested on testbed moorings near Bermuda and Monterey Bay. The newly developed systems will also be placed on the new NOPP mooring located at Ocean Weather Station Papa (OWS "P") in the North Pacific in the fall of 1999. The discussions of the second O-SCOPE workshop centered on relatively detailed planning concerning instrumentation and testing.

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1. Finalization of First Workshop Report

The first O-SCOPE Workshop Report was discussed and a few additions and corrections were required. In addition, responses to the Oversight Committee were discussed and included for completeness in the Report. The report is available on the O-SCOPE website developed by Cathy Cosca (PMEL) at http://www.pmel.noaa.gov/oscope/.

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2. Group Progress Reports

Nick Bates

Lilianne and the CARIOCA pCO2 sensor with renewable dye (Thymol Blue pumped through every hour?). There were 2 successful 40 day deployments- one in June of 1997 and one in Dec./Jan., 1998. Lilianne is repairing the CARIOCA. When the batteries were replaced for the November 1998 deployment, it wasn't sealed well enough and there was a leak filling the sensor with seawater. Nick showed plots comparing data from the CARIOCA and ship data at BATS. Several people commented they had noticed a "settling in" period of about a day for the pCO2 sensor. This could explain the noise in the beginning of the data. The CARIOCA is deeper and is thus more damped in response. On the last deployment the CARIOCA looked 20-30 micrograms too high. Nick expects the paper with Lilianne to be out soon.

Bob Byrne and Erik Kaltenbacher

Erik discussed the progress and status of the SEAS project. Nick asked if the transmissions could be increased to once/hr. Erik said this could be taken care of in the software and should not be difficult. Dave asked if memory capacity is a problem. Erik said no, because there are 4Mgbytes onboard. Bob added that there is potentially the capability to do iron. The length of the liquid wave core can be increased to increase the path length. Tommy asked if they were planning on trying this to which Bob replied that it was an either/or type of situation. There may be more flexibility in the future by using a multiplexer and cycling reagents. Filter/biofouling issues were discussed. The waveguide has in I.D. of 500 micrometers and Dick suggested this might plug up easily. Erik said they were going to test it with a coarse filter in-line. Casey suggested keeping it in a toxic environment with something like copper cladding. USF plans to deploy SEAS systems on NOPP "P" and BTM moorings.

Francisco Chavez

Diagrams for the pCO2 sensor and nitrate analyzer are on the web. Francisco requested Hugh send a protocol for the communications system. pCO2 and nitrate data will be transmitted. For the deep depth sensor (depth required to avoid bubbles), telemetering will be a problem. Jason will come to MBARI for training on pCO2 and nitrate systems.

Gernot Friederich

Gernot showed post El Nino pCO2 data. Thirty to fifty percent of the variability in delta pCO2 is not accounted for by temperature alone. The biology has a strong influence. Salinity is an important parameter to measure. Trends can usually be explained by either temperature or salinity; usually you don't have to invoke both. On the equator it is a different story. Salinity must be determined in order to sort out the biological effects. Salinity tells how long a process has been going on for. The water mass' salinity doesn't change much since it is upwelling. Gernot discussed his IR instrument. It does not have the resolution of the Li-Cor IR analyzer. There is no temperature control and the mean error is about 0.5 ppm (10 times worse than Li-Cor). The advantages of the system are that it is small and lightweight and requires low power.

Dick Feely

Dick covered plans for groundtruthing around the NOPP mooring. Goals include defining geochemical parameters for the ship and making sure the profiling systems include all the necessary analyzers. Underway measurements include salinity, CO2, DIC, alkalinity, temperature, pH, nutrients, chlorophyll, and oxygen. Water column measurements include salinity, CO2, DIC, temperature, nutrients, and oxygen. Different options on how best to do the survey were discussed. One possibility was to do a 200km x 200 km square around the station with 29 vertical profiles each 500 meters deep. This would result in a total sampling and transit time of 84 hours. Dick will coordinate with Frank Whitney on the IOS sampling program (IOS goes out 4 times a year).

Nick suggested using sea level anomaly (SLA) to look for anticyclonic features and to determine spatial heterogeneity. Tommy pointed out that SLA can miss subsurface eddies. Francisco brought up the idea of doing a smaller box - perhaps 25 km on each side of the mooring in order to be at least 2 and a half times the decorrelation length scale which is ~10 km. Nick asked how many stations would be done. Every 5 kilometers would take about 10 hours to go east to west. The ship must stay at least 2 km away from the mooring. They are hoping to use the O2 sensor from the Seabird. The issue of nutrient measurements came up. Freezing samples would cost as much as bringing Calvin out ($15,000).

Dick also discussed the O-SCOPE webpage. It is not online yet but is currently being designed. (Note: that since the meeting the website is now online and Cathy Cosca is leading this activity. Visit the website: http://www.pmel.noaa.gov/oscope/)

Rik Wanninkhof

Rik will probably deploy the O2 sensor on BTM in July. There will be no telemetry. Data will be internally logged. A three-month lifetime is expected. He is considering a copper "T" at the bottom with a shutter with anti-fouling paint to combat biofouling.

Casey Moore

Casey's sensors include a turbidity sensor, chlorophyll fluorescence sensor, and a volume scattering function (VSF) probe (measuring an important inherent optical property). The turbidity sensor measures 90 degree scatter. The VSF sensor has 3 emitters set at 110, 125, and 155 degrees from the center. For example, one sensor measures scattering at 3 angles for one wavelength. These three points will define the curve and b_b can be determined. (b_b is a term often loosely used. Often scattering at 140, 110, or 90 degrees can act as a good proxy for b_b). Additionally, you should be able to get all the information from the VSF that you can get from the turbidity meter. Turbidity meter data are a subset of the VSF data.

Data size was discussed next. One sample will equal 7 bytes: real-time stamp, check sum, and 2 bytes data. WETLabs controls the shutter. The instrument sends a command to signal when it is all right to proceed. More detailed information on this aspect of the project is presented in Appendix III.

Derek Manov

Derek described the current plans for optical instrumentation on the mooring. At the surface, irradiance will be measured at 3 wavelengths. Radiance and irradiance will be measured at 3 wavelengths at 7m and 15m. In addition, fluorescence and VSF will be measured at 2m, 7m and 15m. These will be sampled hourly throughout the 12 daylight hours with one sample being taken at midnight for background subtraction. Rik said there wouldn't be an O2 sensor going on because of its 3-month lifetime. Most sensors will be placed fairly shallow. If everything is kept shallow, the instrumentation can be hard wired instead of requiring an inductive modem. It was decided that Casey's instrumentation would go into Tommy's controller.

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3. General Discussion of Mooring and Groundtruthing Plans (including Scheduling)

MBARI

Francisco asked who would like to put instrumentation on the MBARI mooring. M1 is where most development goes on. It has a fast turn-around with monthly servicing by divers. There are 12 ship trips made. The ship has a transmissometer, CTD, and measures nutrients and oxygen samples. In addition, there are 12 small dive boat trips. Groundtruthing occurs monthly throughout and mooring turnarounds are scheduled for May 12-14, July 12, and October 1, 1999. MBARI can provide quick release clamps. If signal is analog it can come back in real-time. They have several analog channels available. If the signal is digital, software will be needed. Casey will put instrumentation out. Bob doesn't want to add anything. Rik may want to put something self-contained out for testing in May-June. Tommy will add something self-contained in Nov.-Dec.

BTM

The next BTM deployment is scheduled for March 29, 1999. It will be possible to get instruments back before the "P" deployment. On the last Deployment, 3 ARGOS transmitters were added. There are no plans to add more instruments to the telemetry datalogger. Casey said he is probably interested in adding a self-contained fluorescence and turbidity meter at the MVMS depth (24m). Nick mentioned that BATS does groundtruthing within the first 2 weeks of every month (April-Dec.) and twice per month Jan.-April. The number of supplementary cruises close to BTM is approximately 18-20 per year. Nick will email the validation cruise dates.

OWS "P"

The first NOPP mooring was deployed September 16, 1998. It was a taut line mooring with no safety buoyant glass balls. The ADCP is on a different mooring 3 km away. Hugh warned everyone to allow some extra time for flying into Dutch Harbor, Alaska because one of three flights doesn't make it because of fog. There will be no CT data on the NOPP/OSCOPE mooring so it would be advantageous to keep it close to other moorings in the region. Hugh said that if anyone had extra C and T sensors these could be put on. Sensor interface was discussed next. Sensors will be polled 3 minutes after each hour by the controller. The CPU is good to within a second of GPS. Typically you can expect a drift in the clock of approximately 1-minute per year. They are authorized to transmit 1 minute per hour. The window to transmit with GOES starts ~18 minutes after the hour. GOES wants ASCII and runs at 100 baud. Instruments should just give raw data. Time doesn't have to be sent. Buffer lengths don't have to be the same length. The battery pack is 800 D cells. Up to 1300 cells can fit. It would be best however if all self contained and internal logging instruments have their own batteries.

The schedule is:
July 1: testing at PMEL
August 1: all instruments should be in Seattle
August 20: slow boat to Kwajalein
September 25: depart Kwajalein
~October 8: Dutch Harbor, AK
October 18: deploy
October 28: return to Seattle

Real-time data will be available after Kwajalein, and the time between Kwajalein and Dutch Harbor can be considered a test time period.

Dick outlined the revised "P" line survey strategy. CTD's will be taken every 2 km to 10 km then every 5 km after that with XBT's interspaced. Twenty-nine stations at 2 hours each is 58 hours. Adding 10 hours for transit time gives a total of 68 hours.

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4. Visit of USF labs

The group toured several of the USF labs including those of Bob Byrne, Ken Carder, Paula Coble and the Technology Center. Considerable information was exchanged and future communications were established for coordinating our activities.

5. Discussion of data issues

The topic of data exchange was discussed. There is a sense that we want to maximize collaboration and make data available in a timely way, especially in regard to the real-time goals. There will be some unique data sets which members of the group will prefer to retain for major papers. There are several models (e.g., JGOFS) for data exchange policy and the group will likely follow one of these. All data must be submitted to NODC or equivalent repository within 2 years of collection.

6. Discussion of Plans for Presentations of Results

National meetings, such as the next AGU/ASLO (San Antonio), are targeted for formal presentation (possible Special Volume) of results. Coordinated sets of papers may also be attractive for the group. This will be discussed at next Workshop as we get closer to having results.

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7. Assignment of Tasks

1. Write up a summary of differences and similarities between pCO2 sensors - Nick, Rik, and Gernot
2. Develop a common statement to go in all papers written out of this acknowledging O-SCOPE/NOPP -Tommy in consultation with Cynthia Decker
3. Dick will coordinate with Frank Whitney about doing other/additional measurements during the year.
4. Everyone was reminded to invoice regularly. First year money doesn't have to be spent in the first year. It can be carried over. Contact Derek Manov about this.
5. Nick will email the BATS validation cruise dates.
6. Does anyone have extra C and T sensors that can be put on the NOPP/OSCOPE mooring? Everyone please check on this item.
7. Dick will see what can be done to provide real-time data for "educational use."
8. Names for those people going on the ship must be given to Hugh by July 1
9. Attendees are to check their calendars to see if everyone is available in the first week of December (the Thursday-Friday before the AGU meeting) for the Third O-SCOPE meeting.
10. Determine plans of Lilianne for more CARIOCA deployments at BTM - Dave
11. Construct timelines for each mooring site and for each shipboard groundtruthing cruise schedule - All Partners are responsible for providing information to Cathy Cosca for posting on O-SCOPE Website.
12. Contact Chuck McClain about "P" mooring groundtruthing possibility - Tommy (DONE)
13. Prepare Table for optical sensors (type, where and when to be deployed) - Casey and Dave

14. Contact Mike DeGrandpre about deploying his system at NOPP "P" - Francisco, followed by interaction with Tommy and Hugh
15. Check on plans for optical sensors (PAR, Fluorometer, transmissometer) for CTD profiling at NOPP "P" site - Dick, followed by interactions with Tommy and Casey for instruments if needed.

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8. Programmatic Issues and Plans for Next Meeting

General comments and suggestions

1. It was announced that Mike DeGrandpre wants to add a pCO2 sensor for the OWS "P" deployment. Francisco will be in contact with Mike.
2. Casey Moore suggested establishing a timeline. Group agrees.
3. Dick also talked about projecting forward. Cynthia Decker mentioned at the last meeting that there would be no more continuations. There may be funds to tide the project over into the U.S. Carbon Cycle Research Program. This is a global combined land/ocean/atmosphere program involving NSF, DOE, NOAA, USGS, and Forestry Service that will start in 2001. A major ocean component early-on in the project is moored sensors. So if funding can be maintained until that program, it will be a good transition. There is pressure for high latitude emphasis. O-SCOPE will be good for proving that it is possible to deploy in these conditions. Ideas for getting bridging money were then discussed. Francisco suggested focussing on the science more. MBARI will probably be putting more emphasis on integrated observing systems. It was suggested that measurements should be added such as measuring zooplankton and trace metals (in situ-getting away from sampling).

Next Meeting

The Third O-SCOPE Workshop will be held at MBARI in approximately the first week of December 1999.

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Acknowledgements

The O-SCOPE program is funded by the National Ocean Partnership Program (NOPP). Cynthia Decker of NOPP has provided valuable input for the group. Several USF scientists made important contributions to the workshop. Bob Byrne and Erik Kaltenbacher are thanked for hosting this second O-SCOPE workshop. Laura Dobeck acted as rappeteur and did an excellent job of recording the discussions and editing the report.

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Appendix I - Meeting Agenda

THURSDAY FEBRUARY 18
9:00 Local arrangements and logistics - Bob Byrne
9:15 Discussion of agenda and purpose of the meeting - Tommy Dickey
9:30 Review and adoption of First O-SCOPE Workshop Report - Tommy Dickey
10:00 Break

Summary of Partners' Progress Reports (15 min each)

10:30 BBSR, Nick Bates
10:45 USF, Bob Byrne
11:00 MBARI, Francisco Chavez
11:15 PMEL, Richard Feely
11:30 AOML, Rik Wanninkhof
11:45 WET Labs, Casey Moore
12:00 UCSB, Derek Manov

12:15 LUNCH

1:30 MBARI Mooring program overview and general technical issues -Francisco Chavez
MBARI Groundtruthing issues - Francisco Chavez/Gernot Friederich
2:00 Bermuda Testbed Mooring program and general technical issues - Tommy Dickey
BTM Groundtruthing issues - Nick Bates/Rik Wanninkhof

2:30 Break

3:00 NOPP Ocean Station "P" program and general technical issues - Hugh Milburn/Dick Feely
OWS "P" Groundtruthing issues - Dick Feely/ Rik Wanninkhof
3:30 Tours of USF Labs and informal discussions - Bob Byrne
5:00 End Day 1

Evening Group Dinner at Restaurant of Bob Byrne's choice!

FRIDAY FEBRUARY 19
9:00 General review of Day 1 discussions/revisit agenda items
9:30 Biofouling discussion - Casey Moore
10:00 Mooring technical discussion -Hugh Milburn
11:00 Ship and mooring scheduling - Dick Feely et al.

12:00 Lunch

1:30 Telemetry issues - High Milburn
2:00 Data issues - Dick Feely
3:00 Break
3:30 Discussion of plans for presentations of results -Tommy Dickey
3:45 Project review feedback/impressions and discussion of Scott Doney's comments from First O-SCOPE Workshop - Group
4:30 General discussion of any new or old items - Group
Programmatic issues and plans for next O-SCOPE Workshop (location, dates, etc.).
5:00 ADJOURN

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Appendix II - Attendees

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Appendix III - WETLabs Detailed Report

OSCOPE WORKSHOP

Progress Report

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Casey Moore

2/12/99
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Progress Summary

WET labs is presently developing three sensors for potential incorporation in the OSCOPE test moorings. The suite of instruments consist of a scatter sensor for turbidity determination, a chlorophyll fluorescence sensor, and a sensor for determining the optical backscattering. The sensors carry common characteristics. They incorporate anti-fouling shutters and non corrosive operation. They can intelligently sample and have a programmable interface for configuring the meters' operational sequencing. They can provide data in both real time as well as self store data. They are designed for low power operation. They share the same compact form factor.

We plan to have the first of these sensors ready for field-testing and deployment by March, 1999. We should have all of the instruments delivered for field trials by the end of July, 1999.

This report updates readers on current efforts, and outlines upcoming work and scheduling as we move towards delivery of units for field deployment.

Sensors

Turbidity Sensor - The turbidity sensor provides a measurement of the suspended particulate mass in the water volume by means of a simple scattering measurement. The turbidity measurement is used widely in the field of environmental monitoring but, not as extensively in ocean sciences. It's primary disadvantage is that it is more typically calibrated to scattering "standards" and it's output is only of marginal value in radiometrically characterizing water environments. Moreover the scattering measurement is subject to variations in the particle size distribution of the suspended mass in the water. This ultimately leads to some error in determining absolute quantities of the particulates.

In the ocean sciences, the instrument of wider choice for this type of measurement is the transmissometer. A transmissometer measures losses from a collimated beam of light transmitted through a fixed distance in the water. These losses are caused by absorption and scattering by the water and dissolved and particulate matter contained therein. From this measurement one can make an absolute radiometric determination of the total light losses within the water expressed as the beam attenuation coefficient c, which is the sum of the absorption, **a**, and scattering, **b**, coefficients (**c = a+b**). These coefficients are known as inherent optical properties (**IOP**). Since the scattering typically dominates light losses in natural waters, and since the scattering coefficient represents the totaled scattered light, the value of **c** makes a superior determination of total suspended mass, and can be used for direct measurement of particulate organic carbon and other parameters. The major drawbacks of the transmissometer lie in the fact that for a good measurement one needs to see transmittance changes on the order of 0.05% or better. (25 cm path) With this level of precision the instrument is highly subject to fouling. Moreover having two windows opposing each other makes implementation of mechanical wipers twice as complicated. Depending upon gain settings and required dynamic range, the scatter sensor requires precision of only 0.1% - 1%. It's compact optical configuration makes it simpler to implement an antifouling scheme. Finally there is the issue of costs. The turbidity probe is about a factor of three cheaper.

Chlorophyll fluorometer - The chlorophyll fluorometer is probably the most widely used device for *in situ* bio-optical measurement in modern oceanography. The measurement incorporates a similar right angle measurement to that used in the turbidity probe. The difference in the measurement is that the fluorometer emits light in the blue portion of the spectrum (approximately 450 nm). The receiver blocks the blue light and only detects light in the deep red (685 nm). These emitter/receiver wavelengths correspond to the wavelengths of excitation and fluorescence emission for phytoplankton containing chlorophyll-a.

Although widely used, the chlorophyll fluorescence measurement is not an ideal proxy for chlorophyll, phytoplankton concentrations or chlorophyll absorption. However much like the turbidity sensor, the fluorometer holds numerous practical advantages. It's compact, it easily incorporates anti-fouling shutters, it's low power, and it is relatively low in cost.

VSF back - The VSF sensor is a scatter sensor that incorporates three emitters and one receiver to produce three separate backscattering measurements at three unique angles. VSF stands for Volume Scattering Function. The VSF describes the scattering of light from water and the particulates therein as a function of angle. By measuring the VSF in the backward direction one can determine the backscattering coefficient, bb. This parameter is particularly useful for providing information about the water leaving radiance detected by ocean color satellites. While b- can be estimated from measuring scattering at a single angle, the multiple angle measurement proves superior because it accounts for changes in the VSF itself.

Status

Sensor development - We presently have an OEM version of the shuttered turbidity probe in production. This device has no internal logging capabilities, and requires remote operation of the shutter control. However the instrument's veracity is well established and it provides us with a platform to develop the NOPP turbidity sensor and the shuttered probes in general.

We are in the last stages of developing the flush mount optical head for the new chlorophyll fluorometer. We presently have sensitivity to desired levels and are focusing upon noise and ambient light signal reduction.

The VSF back probe is derived from previous ONR efforts to develop sensors for the determination of the VSF. This VSF sensor leverages both the ONR work and the turbidity sensor efforts. While it will require special circuitry to sequence through the three sources, basic analog circuitry is very similar to the other sensors and requires no further modifications. Initial optical heads are now in production with field tests of prototypes scheduled for March 99.

Data Loggers - Data logger prototyping is complete except for drive details on the shutter assemblies. Boards are scheduled for PC manufacture by March 1st. Prototypes are now functioning with the preliminary command set. We are presently investigating doubling memory capacity, but time constraints may prohibit this before the first board set generation.

Shutter assemblies - The antifouling shutter assemblies used on the NOPP sensors will be similar to those incorporated on out OEM turbidity probes. They will however, differ in significant ways. They will incorporate a larger more robust motor. They will incorporate a new less ambiguous positioning feedback system. They will use more sophisticated shutters for control of bio-fouling and particulate build-up. We also plan to control shutter operation locally at the sensor. This requires special drive circuitry now under development. These final efforts are now in process with finished assemblies scheduled for testing by March 10.

Schedule for Deliveries

March - April	Turbidity Probes/Fluorometer	2 ea.
June	VSF Probe	2 ea.
July	All Sensors	5 Fluor, 3 VSF, 3 turb.

Deliveries

Where	Turbidity	Fluor	VSF
BTM	2	2	1
MBARI	2	2	1
OWS (UCSB)	1	3	3

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Table 1. Partnership Information

Partner Institution	Principal Investigator	Partnership Role
UCSB	Tommy Dickey	Project coordination; interdisciplinary systems includ bio-optical, chemical, and physi sensors and telemetry technolo
NOAA/PMEL	Dick Feely	Geochemical measurem telemetry, and data disseminati
NOAA/AOML	Rik Wanninkhof	Geochemical measurements, th verification, and their relation t global climate change
MBARI	Francisco Chavez	Chemical sensors
BBSR	Nick Bates	Geochemical sensors, measurements, groundtruthing sensors
USF	Robert Byrne	pCO2, pH, and alkalinity senso
WET Labs	Casey Moore	Bio-optical sensors

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