Oceanographic instrumentation and technology (OCN-664): course justification.

1. Introduction.

In-situ measurements constitute a major component of any oceanographic program. Despite advances in satellite measurements, collecting in-situ data remains a necessity to measure parameters not accessible remotely and to develop calibration algorithm for satellite instruments. It is important to introduce oceanography graduate students to these instrumentation techniques.

With the advent of powerful parallel computers running numerical models of the ocean, there has been a nationwide tendency over the past few years to neglect this component of graduate education. This shortcoming was analyzed in detail by a panel appointed UCAR and the AMS. One of the recommendations was that

> "(departments) should provide more comprehensive curricula on experimental methods, ..., including sensor and system technologies, data and their inherent limitations relate to physically meaningful information"†.

The course proposed here is an attempt to respond to this recommendation.

2. Course objectives.

The main objectives of this course is to expose students to state-of-the-art oceanographic instrumentation, to introduce them to the methods of observational physical oceanography, and to prepare them to use these techniques in their own research.

The course is a combination of lectures on the principles of the instruments, on the physical processes involved and on the different sensors and systems available; of discussions of key papers from the published literature; and of laboratory work scheduled separately for each student. Instruments in each category are provided to work with and conduct small research projects.

Additional objectives are to train students to search the scientific literature and report on a series of topics, to evaluate and debate scientific concepts, and to formulate and test their own hypotheses in the course of their research project. These additional objectives are emphasized as they constitute a valuable training for research.

---

†

‘‘Study on observational systems: a review of meteorological and oceanographic education in observational techniques and the relationship to national facilities and needs,’’ *Bull. Am. Met. Soc.*, vol. 72, pp. 815-825 (1991).

3. Relation to the curriculum.

OCN-664 Oceanographic Instrumentation and Technology is one of two courses on instrumentation recommended to physical oceanography students. The other proposed instrumentation course, OCN-663 Satellite Oceanography, is outlined in a separate proposal. OCN-664 is an elective for all oceanography students and counts towards category IV courses (Physical Oceanography) in the Oceanography Department degree requirements.

This course has been taught experimentally as one of the sections of OCN-760 Topics in Physical Oceanography (see section 11 below). However, since this course is now offered regularly, a separate entry in the catalog is needed to properly advertise its content.

A closely related course coordinated by Prof. R. Lukas (presently listed as OCN-760 section 002, Topics in Physical Oceanography) uses the monthly cruise of the Hawaii Ocean Time Series to provide students with an opportunity to accumulate sea-going time (30 days of which are required by the Oceanography Department) and to gain hands-on experience related to the concepts studied in OCN-664.

No old course will be deleted if this new course is approved, since several other faculty members will still teach other topics under the OCN-760 entry. The faculty teaching load will not be affected. There is no overlap with other UHM graduate courses.

4. Prerequisite and credits.

OCN-620, Introduction to Physical Oceanography, is the only prerequisite for this course. This prerequisite may be waived with the instructor's consent.

Three credits are given for this class, corresponding to three contact hours weekly: two hours of lecture and discussions, and one hour to review the progress of the laboratory projects.

5. Course syllabus.

The class meets weekly with the instructor for one 2-hour lecture and discussion session. Each session has two parts:

part 1: formal lecture on the principles of the instruments, the physical processes involved and the different sensors available;

part 2: the class reads key papers from the refereed literature; students take turns to present them to the class, to lead a discussion and to wrap up conclusions in a written essay; a final summary is given by the instructor (the papers are initially assigned by the instructor, but are progressively chosen by the students as they become familiar with the literature).

The following topics are covered on the following weeks:

- 1,2 time and position measurements (clocks, time signals, ground- and satellite-based navigation, attitude sensors)
- 3 data logging (analog and digital recorders, telemetry, memory and recording media)
- 4 underwater acoustics (transponders, SOFAR and RAFOS navigation, acoustic tomography)
- 5-8 water properties measurements (temperature, conductivity, oxygen, optical properties, tracers and dyes)
- 9-11 current measurements (mechanical, acoustic, electromagnetic, optical, radar, drifters)
- 12 pressure and sea level measurements
- 13 meteorological measurements (wind, humidity, temperature, rain, radiation sensors)
- 14 mechanical technology (materials: metals, plastics, glass, corrosion, cables, winches, buoys, anchors, releases, towers)
- 15 sampling and analysis strategies (temporal sampling, time series analysis, spatial sampling, array design, spatial data analysis, data assimilation)

6. Research project.

To conduct their laboratory projects, the students have access to a laboratory in the Marine Science Building (presently MSB-105), and to instruments lent by various research groups.

Individually (or by groups of 2 or 3), their laboratory work emphasizes one (or more) of the following aspects (see examples in section 11):

- developing a new instrument or sensor, interfaced to data loggers and computers;
- testing of existing sensors, to analyze their response to various environmental conditions;
- conducting a short field deployment of an instrument, and analyzing the resulting data

In addition to the lectures, the class meets weekly with the instructor for one hour to discuss the progress of the laboratory projects. During the examination week, each student gives a 15-min presentation on the results of his projects. A term paper describing the project is required from all students.

7. Books

The following books are used as reference for the course; copies are put on reserve at the library for the length of the semester. The students are not required to purchase any of these books.

Handbook of ocean and underwater engineering, McGraw-Hill Book Co., New York (1969).

Baker, D.J., ‘‘Ocean instruments and experiment design,’’ in *Evolution of physical oceanography*, ed. B.A. Warren and C. Wunsch, pp. 396-433, The MIT Press, Boston (1981).

Berteaux, H.O., *Buoy engineering,* pp. 1-319, John Wiley & sons, New York (1975).

Bowditch, N., *American practical navigator*, U.S. Defence Mapping Agency (1984).

Dobson, F., L. Hasse, and R. Davis, *Air-sea interactions: instruments and methods,* pp. 1-801, Plenum Press, New York (1980).

Laque, F.L., *Marine corrosion: causes and prevention,* pp. 1-332, John Wiley & sons, New York (1975).

Miles, D.C. and J.H. Briston, *Polymer technology,* Chemical Publishing co., New York (1965).

Ulrick, R.J., *Principles of underwater sounds*, pp. 1-384, McGraw-Hill Book Co., New York (1975).

8. Journals.

The following journals cover most of the oceanographic instrumentation literature. Students are encouraged to browse regularly through these journals to discover topics of current interest and chose papers for discussion.

Journal of Geophysical Research (Ocean), American Geophysical Union.

IEEE Journal of Oceanic Engineering, Institute of Electrical and Electronics Engineers.

Journal of Oceanic and Atmospheric Technology, American Meteorological Society.

Deep-Sea Research, section B, Instruments and Methods, Gordon and Breach.

9. Student evaluation.

Students are evaluated for 50% on the papers from the literature that they have presented during the semester (oral presentation 25%, written wrap-up 25%), and for 50% on their laboratory projects (oral presentation 25%, term paper 25%).

10. Qualifications of the instructors.

This new course is being proposed by Dr. P. Flament, who is conducting research in the field of physical oceanography. His Ph.D. was awarded for a study of mesoscale structures in the California Current, using a combination of satellite and in-situ observations. Dr. Flament has extensive sea-going experience, and has conducted field work as principal investigator using most of the instruments to be covered in this class.

The course is implemented in close collaboration with Prof. R. Lukas, who is also a physical oceanographer. Prof. Lukas has been chief scientist on numerous oceanography cruises, and is the principal investigator of the World Ocean Circulation Experiment component of the Hawaii Ocean Time Series program (HOTS).

Some lectures are also taught by Drs. M. Atkinson, E. Firing, C. Winn and other faculty from the School of Ocean and Earth Sciences and Technology, who have specialized expertise in some specific areas of oceanographic instrumentation.

11. Prior offerings.

This course has been taught previously under the course heading OCN-760, Topics in Physical Oceanography, in Fall 1988 by Prof. Lukas and in Fall 1992 by Dr. Flament. The syllabus proposed here is based on these two prior offering. Appendix A contains the course evaluations from these offerings, as well as specific comments made by students.

The following laboratory projects were performed during the 1992 offering:

Asghar, S., J. Potemra, and D. Sadler, *Development of a rain temperature sensor* (1993).

Bower, J., S. Krothapalli, and S. McCarthy, *An examination of oxygen sensor response time: Beckman and Morita* (1993).

Frankel, A., *Acoustic tracking of whales* (1993).

Lumpkin, R., *Seiche frequencies in Honolulu harbor* (1993).

Sawyer, M., *Acoustic signature of an underwater lava flow* (1993).

The following papers from the refereed literature were discussed (this list is indicative of the papers used in the class, but are continuously updated to reflect advances in this field):

Beardsley, R.C., ‘‘A comparison of the VACM and new E.G.&G. Inc., VMCM on a surface mooring in CODE-1,’’ *J. Geophys. Res.*, vol. 92, pp. 1845-1859 (1987).

Bennett, A.S., ‘‘The calibration of thermistors over the temperature range 0-300C,’’ *Deep-Sea Res.*, vol. 19, pp. 157-163 (1972).

Berteaux, H.O. and R.G. Walden, ‘‘CTD lowering mechanics,’’ *Deep-Sea Res.*, vol. 31, pp. 181-194 (1984).

Chereskin, T.K., E. Firing, and J.A. Gast, ‘‘Identifying and screening filter skew and noise bias in acoustic doppler current profiler measurements,’’ *J. Atm. Oceanic Tech.*, vol. 6, pp. 1040-1054 (1989).

Dantzler, H.L., ‘‘Dynamic salinity calibration of continuous salinity/temperature/depth data,’’ *Deep-Sea*

Res., vol. 21, pp. 675-682 (1974).

Davis, R.E., ‘‘Drifter observations of coastal surface currents during CODE: the method and descriptive view,’’ *J. Geophys. Res.*, vol. 90, pp. 4741-4755 (1985).

Fairall, C.W. and J.B. Edson, ‘‘Inertial-dissipation air-sea flux measurements: a prototype system using real time spectral computations,’’ *J. Atm. Oceanic Tech.*, vol. 7, pp. 425-453 (1990).

Finke, M. and G. Siedler, ‘‘Drag coefficients of oceanographic mooring components,’’ *J. Atm. Oceanic Tech.*, vol. 3, pp. 255-264 (1986).

Flagg, C.N. and S.L. Smith, ‘‘On the use of the acoustic doppler current profiler to measure zooplankton abundance,’’ *Deep-Sea Res.*, vol. 36, pp. 455-474 (1986).

Fozdar, F.M., G.J. Parker, and J. Imberger, ‘‘Matching temperature and conductivity sensor response characteristics,’’ *J. Phys. Oceanogr.*, vol. 15, pp. 1557-1569 (1985).

Geyer, W.R., ‘‘Field calibration of mixed-layer drifters,’’ *J. Atm. Oceanic Tech.*, vol. 6, pp. 333-342 (1989).

Giles, A.B. and T.J. McDougall, ‘‘Two methods for the reduction of salinity spiking of CTDs,’’ *Deep-Sea Res.*, vol. 33, pp. 1253-1274 (1986).

Gregg, M.C., ‘‘The effects of bias error and system noise on parameters computed from C, T, P and V profiles,’’ *J. Phys. Oceanogr.*, vol. 9, pp. 199-217 (1979).

Gregg, M.C. and W.C. Hess, ‘‘Dynamic response calibration of Sea-Bird temperature and conductivity probes,’’ *J. Atm. Oceanic Tech.*, vol. 2, pp. 304-313 (1985).

Gregg, M.C., J.C. Schedvin, W.C. Hess, and T.B. Meagher, ‘‘Dynamic response calibration of the Neil Brown conductivity cell,’’ *J. Phys. Oceanogr.*, vol. 12, pp. 720-742 (1982).

Gregg, M.C., J.C. Schedvin, and T.B. Meagher, ‘‘Dynamic response calibration of the Neil Brown conductivity cell,’’ *J. Phys. Oceanogr.*, vol. 15, pp. 1557-1569 (1982).

Hayes, S.P. and H.B. Milburn, ‘‘TOPS: A free-fall velocity and CTD profiler,’’ *J. Atm. Oceanic Tech.*, vol. 1, pp. 220-236 (1984).

Horne, E.P.W. and J.M. Toole, ‘‘Sensor response mismatches and lag correction techniques for temperature-salinity profilers,’’ *J. Phys. Oceanogr.*, vol. 10, pp. 1122-1130 (1980).

Irish, J.D., W.S. Brown, and T.L. Howell, ‘‘The use of microprocessor technology for the conditional sampling of intermittent ocean processes,’’ *J. Atm. Oceanic Tech.*, vol. 1, pp. 58-68 (1984).

Katsaros, K.B. and J.E. DeVault, ‘‘On irradiance measurement errors at sea due to tilt of pyranometers,’’ *J. Atm. Oceanic Tech.*, vol. 3, pp. 740-745 (1986).

Krauss, W., J. Dengg, and H.-H. Hinrichsen, ‘‘The response of drifting buoys to currents and wind,’’ *J. Geophys. Res.*, vol. 94, pp. 3201-3210 (1989).

Krauss, W., J. Dengg, and H.-H. Hinrichsen, ‘‘Reply,’’ *J. Geophys. Res.*, vol. 95, pp. 801-803 (1990).

Lueck, R.G., O. Hertzman, and T.R. Osborn, ‘‘The spectral response of thermistors,’’ *Deep-Sea Res.*, vol. 24, pp. 951-970 (1977).

Lueck, R.G. and J.J. Picklo, ‘‘Thermal inertia of conductivity cells: observations with a sea-bird cell,’’ *J. Atm. Oceanic Tech.*, vol. 7, pp. 756-768 (1990).

Niiler, P.P., R.E. Davis, and H.J. White, ‘‘Water-following characteristics of a mixed layer drifter,’’ *Deep-Sea Res.*, vol. 34, pp. 1867-1881 (1987).

Owens, W.B. and ., R.C. Millard Jr, ‘‘A new algorithm for CTD oxygen calibration,’’ *J. Phys. Oceanogr.*, vol. 15, pp. 621-631 (1985).

Pederson, A.M. and M.C. Gregg, ‘‘Development of a small in-situ conductivity instrument,’’ *IEEE J.*

Oceanic Eng., vol. OE-4, pp. 69-75 (1979).

Perkin, R.G. and E.L. Lewis, ‘‘Design of CTD observational programs in relation to sensor time constants and sampling frequencies,’’ *Can. Tech. Rept. of Hydrog. Ocean Sci.*, vol. 7, p. 47 (1982).

Pike, J.M., ‘‘Realistic uncertainties in pressure and temperature calibration reference values,’’ *J. Atm. Oceanic Tech.*, vol. 1, pp. 115-119 (1984).

Pinkel, R. and J.A. Smith, ‘‘Repeat-sequence coding for improved precision of doppler sonar and sodar,’’ *J. Atm. Oceanic Tech.*, vol. 9, pp. 149-163 (1992).

Poulain, P.-M. and P.P. Niiler, ‘‘Comment on "The response of drifting buoys to currents and wind" by Krauss et al.,’’ *J. Geophys. Res.*, vol. 95, pp. 797-799 (1990).

Scarlet, R.I., ‘‘A data processing method for salinity, temperature, depth profiles,’’ *Deep-Sea Res.*, vol. 22, pp. 509-515 (1975).

Seaver, G.A. and S. Kuleshov, ‘‘Experimental and analytical error of the expendable bathythermograph,’’ *J. Phys. Oceanogr.*, vol. 12, pp. 592-600 (1982).

Serafin, R., B. Heikes, D. Sargeant, W. Smith, E. Takle, and R. Wakimoto, ‘‘A review of meteorological and oceanographic education in observational techniques and the relationship to national facilities and needs,’’ *Bul. Am. Met. Soc.*, vol. 72, pp. 815-826 (1991).

Topham, D.R. and R.G. Perkin, ‘‘On the transient behavior of conductivity sensors,’’ *J. Atm. Oceanic Tech.*, vol. 1, pp. 201-219 (1984).

Weinheimer, A.J. and R.L. Schwiesow, ‘‘A two-path, two-wavelength ultraviolet hygrometer,’’ *J. Atm. Oceanic Tech.*, vol. 9, pp. 407-419 (1992).

Weller, R.A. and R.E. Davis, ‘‘A vector measuring current meter,’’ *Deep-Sea Res.*, vol. 27A, pp. 565-582 (1980).

Williams, A.J., J.S. Tochko, R.L. Koehler, W.D. Grant, T.F. Gross, and C.D. Dunn, ‘‘Measurement of turbulence in the oceanic bottom boundary layer with an acoustic current meter array,’’ *J. Atm. Oceanic Tech.*, vol. 4, pp. 312-327 (1987).

Wilson, C.D and E. Firing, ‘‘Sunrise swimmers bias acoustic doppler current profiles,’’ *Deep-Sea Res.*, vol. 39, pp. 885-892 (1992).

Zachmann, G.W., in *GPS accuracy for civil marine navigation*, Magnavox, Torrance, CA (1988).