

## **Satellite Oceanography (OCN-663): course justification.**

### **1. Introduction.**

Satellite oceanography is the study of the instruments and methods for observing the oceans from orbiting (and airborne) platforms. These instruments can be passive (using radiometers to detect natural radiation emitted or reflected by the ocean) or active (using lasers or radars to infer properties of the ocean surface). They are further classified according to the electromagnetic wavelength used: microwave, infrared or visible light.

Satellite instruments have become critical tools to monitor global climate changes, because only satellites can provide global continuous temporal coverage of the earth. However, interpreting these remote measurements is delicate, because the relationships with traditional in-situ properties of the ocean are generally complex.

Introducing graduate students to these new tools has become a necessity.

### **2. Course objectives.**

The main objectives of this course are to expose students to state-of-the-art remote sensing instruments, to introduce them to the methods of satellite oceanography, and to prepare them to use these techniques in their own research.

To that effect, lectures on the principles of ocean remote sensing are given, students read and discuss key papers in the field, and conduct small research projects working on satellite data sets.

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 projects. These additional objectives are emphasized as they constitute an important training for research.

### **3. Relation to the curriculum.**

OCN-663 Satellite Oceanography is one of two courses on instrumentation recommended to Physical Oceanography students. The other proposed instrumentation course, OCN-664 Oceanographic Instrumentation and Technology, is outlined in a separate proposal. OCN-663 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.

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 research projects.

#### **5. Course syllabus.**

The class meets weekly with the instructor for one 2-hour lecture and discussion session. Each subdisciplines of remote sensing is covered in 3 lessons according to the following schedule:

- lesson 1: formal lecture by the instructor on the principles of the techniques, the physical processes involved and the different sensors and satellite systems available;
- lessons 2,3: 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 until the students become familiar with the literature).

The overall schedule of the class is:

week	topic	lecture type
1	infrared and microwave radiometers (surface temperature)	lecture
2	(same)	discussion
3	(same)	discussion, summary
4	visible radiometers (ocean color, chlorophyll, aerosols)	lecture
5	(same)	discussion
6	(same)	discussion, summary
7	altimeters (surface topography)	lecture
8	(same)	discussion
9	(same)	discussion, summary

10	scatterometers (wind)	lecture
11	(same)	discussion
12	(same)	discussion, summary
13	synthetic aperture radars (wind, waves)	lecture
14	(same)	discussion
15	(same)	discussion, summary

## 6. Research project.

To conduct their research projects, the students have access to the facilities of the University of Hawaii Satellite Oceanography Laboratory (a description of which is found in appendix A), and to the workstation laboratory of the Physical Oceanography Division of the Department of Oceanography (located in MSB 314).

An extensive library of CD-ROMs containing a variety of satellite data sets is made available to the students. All data sets are clean and calibrated into scientific units, so that small research projects can be completed in about 3 months.

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

## 7. Reserve 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. Student majoring in Physical Oceanography are recommended to purchase the book by Stewart, other students are recommended to purchase the book by Robinson.

Houghton, J.T., F.W. Taylor, and C.D. Rodgers, *Remote sounding of atmospheres*, Cambridge University Press (1984). HL QC871 .H78 1984

Maul, G.A., *Introduction to satellite oceanography*, Martinus Nijhoff (1985). HL GC10.4 .R4 M38 1984

Robinson, I.S., *Satellite Oceanography*, John Wiley & Sons (1985). HL GC10.4 .R4 R6 1985

Stewart, R.H., *Methods of satellite oceanography*, University of California Press (1985). HL GC10.4 .A8 873 1985

Ulaby, F.T., R.K. Moore, and A.K. Fung, *Microwave remote sensing: active and passive (3 vol.)*, Addison Wesley (1982). G70.6 .U4 V.3

## **8. Journals.**

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

*International Journal of Remote Sensing*, Remote Sensing Society.

*IEEE Journal of Remote Sensing*, Institute of Electrical and Electronics Engineers.

*Remote Sensing of Environment*, Elsevier.

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

*Journal of Atmospheric and Oceanic Technology*, American Meteorological Society.

*Journal of Physical Oceanography*, American Meteorological Society.

## **9. Student evaluation.**

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

## **10. Qualifications of the instructors.**

This new course is being proposed by Dr. P. Flament, whose C.V. is attached (Appendix C). Dr. Flament 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 established a facility for receiving and processing satellite images of the ocean at the University of Hawaii, the resources of which are made accessible to the students. Dr. Flament is also a member of the NASA Shuttle Imaging Radar science team.

Some lectures are taught by Prof. Roger Lukas, Dr. Gary Mitchum and Dr. Robert Bidigare, who are also using satellite oceanography techniques in their research. Prof. Lukas and Dr. Mitchum are members of the NASA TOPEX-POSEIDON Altimeter Science Team, whereas Dr. Bidigare is a member of the NASA SeaWifs Ocean Color Science Team.

## **11. Prior offerings.**

This course has been taught three times by Dr. Flament, under the course heading OCN-760, Topics in Physical Oceanography, in Fall 1989, Spring 1991 and Spring 1993. The syllabus has evolved and matured through these three offerings, and this proposal reflects the experience gained by this process. Appendix B contains the aggregate course evaluations from these three offerings, as well as specific comments made

by students.

The following term projects were completed:

Baker, M.K., *Ocean features in a SPOT image* (1990).

Bigelow, K., X. Chiappa-Carrara, C. Hieronymus, and E. Parnell, *Satellite observations of an oceanic mesoscale eddy off the southwest coast of the island of Hawaii, with estimates of diurnal surface warming and wind conditions* (1991).

Greene, S., *Diurnal warming in the lee of the Hawaiian islands* (1991).

Letelier, R.M., *Study of the possible use of AVHRR images on the detection of Tichodesmium blooms around the Hawaiian Islands* (1991).

Porter, J.N., *The influence of volcanic aerosols on satellite SST measurements* (1989).

Shinoda, T., *Wind speed and water vapor variations in the western equatorial Pacific* (1989).

Ulmer, W., *Registration of land values relative to coastlines* (1989).

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):

Beal, R.C., T.W. Gerling, D.E. Irvine, F.M. Monaldo, and D.G. Tilley, "Spatial variations of ocean wave directional spectra from the SEASAT synthetic aperture radar," *J. Geophys. Res.*, vol. 91, pp. 2433-2449 (1986).

Brown, O.B., J.W. Brown, and R.E. Evans, "Calibration of AVHRR infrared observations," *J. Geophys. Res.*, vol. 90, pp. 11667-11678 (1985).

Cornillon, P. and L. Stramma, "The distribution of diurnal warming events in the Western Sargasso Sea," *J. Geophys. Res.*, vol. 90, pp. 11811-11815 (1985).

Flament, P., L. Armi, and L. Washburn, "The evolving structure of an upwelling filament," *J. Geophys. Res.*, vol. 90, pp. 11,765-11,778 and 11,835-11,836 (1985).

Flament, P., J. Firing, M. Sawyer, and C. Trefois, "Amplitude and horizontal structure of a large diurnal sea surface warming event during the Coastal Ocean Dynamics Experiment," *J. Phys. Oceanog.* (1994). (in press)

Flament, P., P.M. Kosro, and A. Huyer, "Mesoscale variability off California as seen by the GEOSAT altimeter," *Proceedings of IGARSS'89*, vol. 2, pp. 1063-1068 (1989).

Fu, L.L., "On the wave number spectrum of oceanic mesoscale variability observed by the SEASAT altimeter," *J. Geophys. Res.*, vol. 88, pp. 4331-4342 (1983).

Fu, L.L. and B. Holt, "Some examples of detection of oceanic mesoscale eddies by the SEASAT SAR," *J. Geophys. Res.*, vol. 88, pp. 1844-1852 (1983).

Fu, L.L. and B. Holt, "Internal waves observations in the Gulf of California: observations from a spaceborne radar," *J. Geophys. Res.*, vol. 89, pp. 2053-2060 (1984).

Gerling, T.W., "Fine scale structure of the surface wind field from the SEASAT SAR," *J. Geophys. Res.*, vol. 91, pp. 2308-2320 (1986).

Gordon, H.R. and ...., "Phytoplankton pigment concentration in the Middle Atlantic Bight," *Applied Optics*, vol. 22, pp. 20-36 (1983).

Hunt, G.E., "Radiative properties of terrestrial clouds at visible and infrared thermal window

- wavelengths," *Quart. J. R. Met. Soc.*, vol. 99, p. 346 (1973).
- Johnson, D., P. Flament, and R. Bernstein, "High resolution satellite imagery for mesoscale meteorological studies," *Bull. Am. Met. Soc.* (1994). (in press)
- Kelly, K.A., "The influence of winds and topography on the sea surface temperature patterns over the northern California slope," *J. Geophys. Res.*, vol. 90, pp. 11783-11798 (1985).
- Kelly, K.A., "An inverse model for near-surface velocity from infrared images," *J. Phys. Oceanog.*, vol. 19, pp. 1845-1864 (1989).
- Kelly, K.A. and R.E. Davis, "An analysis of errors in SST in a series of infrared images from NOAA-6," *J. Geophys. Res.*, vol. 91, pp. 2633-2644 (1986).
- Llewellyn-Jones, D.T., P.J. Minnett, R.W. Saunders, and A.M. Zavody, "Satellite multi-channel infrared measurements of sea surface temperature of the NE Atlantic Ocean using AVHRR/2," *Quart. J. R. Met. Soc.*, vol. 110, pp. 613-631 (1984).
- McClain, C.R., J. Ishizaka, and E.E. Hofmann, "Estimation of the processes controlling variability in phytoplankton," *J. Geophys. Res.*, vol. 95, pp. 20213-20235 (1990).
- Morel, A., "Optical modeling of the upper ocean in relation to its biogenous matter content," *J. Geophys. Res.*, vol. 93, pp. 10749-10768 (1988).
- Parke, M.E., R.H. Stewart, D.F. Farless, and D.E. Cartwright, "On the choice of orbits for an altimetry satellite to study ocean circulation and tides," *J. Geophys. Res.*, vol. 92, pp. 11,693-11707 (1987).
- Phoebus, P.A. and J.D. Hawkins, "The impact of water vapor attenuation on the interpretation of altimeter-derived ocean topography in the northeast Pacific," *J. Geophys. Res.* (1989).
- Tai, C.K., "On determining the large-scale ocean circulation from satellite altimetry," *J. Geophys. Res.*, vol. 88, pp. 9553-9565 (1983).