Aerial Surveys of the Ocean and Atmosphere off Central California

Steven R. Ramp, Jeffrey D. Paduan, and Curtis A. Collins
Department of Oceanography, Code OC/Ra
Naval Postgraduate School
Monterey, CA 93943-5122
phone: (831) 656-2201 fax: (831) 656-2712 email: sramp@nps.navy.mil

Wendell Nuss
Department of Meteorology, Code MR/Nu
Naval Postgraduate School
Monterey, CA 93943-5122
phone: (831) 656-3239 fax: (831) 656-2712 email: nuss@met.nps.navy.mil

Grant #s: N0001403WR20002, N0001403WR20006, N0001403WR20209

LONG-TERM GOAL

The long-term goal is to enhance our understanding of air/sea interaction in the littoral zone by means of applying simple dynamical theories to high-quality observations obtained in the field. The Monterey Bay serves as our natural laboratory for these purposes. The grant is one of a continuing series of programs to study the bay funded by the National Ocean Partnership Program (NOPP) and the ONR Naval Ocean Modeling and Prediction (NOMP) Program.

OBJECTIVES

The objective of this project is to observe the half-dozen or so "characteristic states" of Monterey Bay air/sea system and the associated adjacent coastal ocean and atmosphere. These states include onset and retreat of summer upwelling, the advance and retreat of the Monterey Bay Eddy, the passage of winter fronts and storms, the diurnal monsoon, poleward propagating events in the atmosphere and ocean, and the occasional anomalous passing atmospheric systems. The observations will be used to enhance and improve existing and future coupled models of the coastal air/sea system.

APPROACH

A time series of forty (40) aircraft flights are being conducted over the Monterey Bay and adjacent waters between March 2003 and March 2004 to make high resolution maps of critical parameters in the ocean and atmosphere. The mapping portion of the flight path is being flown at a constant altitude of 33 m off the sea surface (Figure 1), beneath the usual regional stratus deck. Additionally, two sawtooth transects, elevating to 1500 m offshore, will be flown to map the height of the atmospheric inversion layer at the northern and middle sections of the region (Figure 1). The flights are being conducted nominally every two weeks, with a concentration of flights during August 2003 in support of the ONR Autonomous Ocean Sensing Network Phase Two (AOSN-II) experiment in the Monterey Bay. Flight times were adjusted slightly to coordinate with cruises in the bay, primarily on the research vessel POINT SUR, which provided ground truthing for remote sensors, and supported operational education for U.S. Navy Officer Students at the Naval Postgraduate School.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Aerial Surveys of the Ocean and Atmosphere off Central California	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Oceanography, Code OC/Ra,,Naval Postgraduate School,,Monterey,,CA, 93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

The aircraft is being provided the NPS Center for Remotely-Piloted Aircraft Studies (CIRPAS), housed locally at the Marina Municipal Airport. The TWIN OTTER aircraft flew when available, including during August 2000, and the smaller payload PELICAN aircraft (a modified Cessna Skymaster) is used when the TWIN OTTER is committed to different projects. A basic suite of sensors is being deployed on all flights to include air temperature, dew point temperature, atmospheric pressure, and sea surface temperature. The TWIN OTTER will additionally carry a LIDAR altimeter, atmospheric turbulence sensors, aerosol sensors, and a hyperspectral radiometer.

The flights will produce an unprecedented time series of high-resolution air/sea observations for use in verifying Navy models such as COAMPS. We will cooperate with NRL MRY and NRL SSC on model initialization and verification issues.

WORK COMPLETED

To date, twenty seven flights have been conducted including fifteen during the AOSN-II intensive operation period (IOP) spanning August 4 - September 8, 2003. The hyperspectral radiometers were procured and successfully integrated into the data stream of both the PELICAN and TWIN OTTER. Computer-controlled digital cameras were also added to the TWIN OTTER payload. During the IOP, the aircraft SST data were delivered to the Harvard and Cal Tech modeling groups within four hours of landing for assimilation into the next day's numerical predictions. The wind vector maps at 100m are being compared with the special 3-km COAMPS runs conducted by NRL during the IOP. Ramp and Paduan participated in the daily AOSN Real-time Operations Committee (RTOC) discussions at MBARI. Several oral presentations have been given, however manuscript preparation has only just begun.

RESULTS

Nature was kind to the AOSN-II experiment by providing nearly ideal conditions for the program. Three extended upwelling events took place during August 6-19, 23-30, and September 4-8 separated by 3-4 days of weak or poleward winds. The surface temperature time series began with record highs near 20ºC on August 5-6, followed by the development and spreading of the upwelling centers near Pigeon Point and Point Ano Nuevo. This cold band ultimately spread all the way across the mouth of the bay isolating it from the California Current water offshore. During the relaxation event on August 20-22, colliding currents at the south end of the bay near Point Pinos caused the cold water to squirt offshore along 36.60ºN (Figure 1, top). Despite this southerly jet location, most of the cold water in it originated from the north side of the bay.

Surface chlorophyll distributions were calculated using the standard SeaWiFS algorithm. High plant pigments always occurred on the cold side of the upwelling front and were bounded remarkably well by the 16ºC surface isotherm. Within this boundary, the biology was consistently much patchier than the SST with scales typically less than 10-15 km. The highest concentrations near Pigeon Point and Ano Nuevo were observed on August 20, the day after extended upwelling ceased (Figure 1, bottom). Other biological hot spots include both the north and south corners of the bay and in the cold water offshore, following a phase lag of 2-3 days. The offshore patches show signs of both in situ development and horizontal advection by the mean flow.

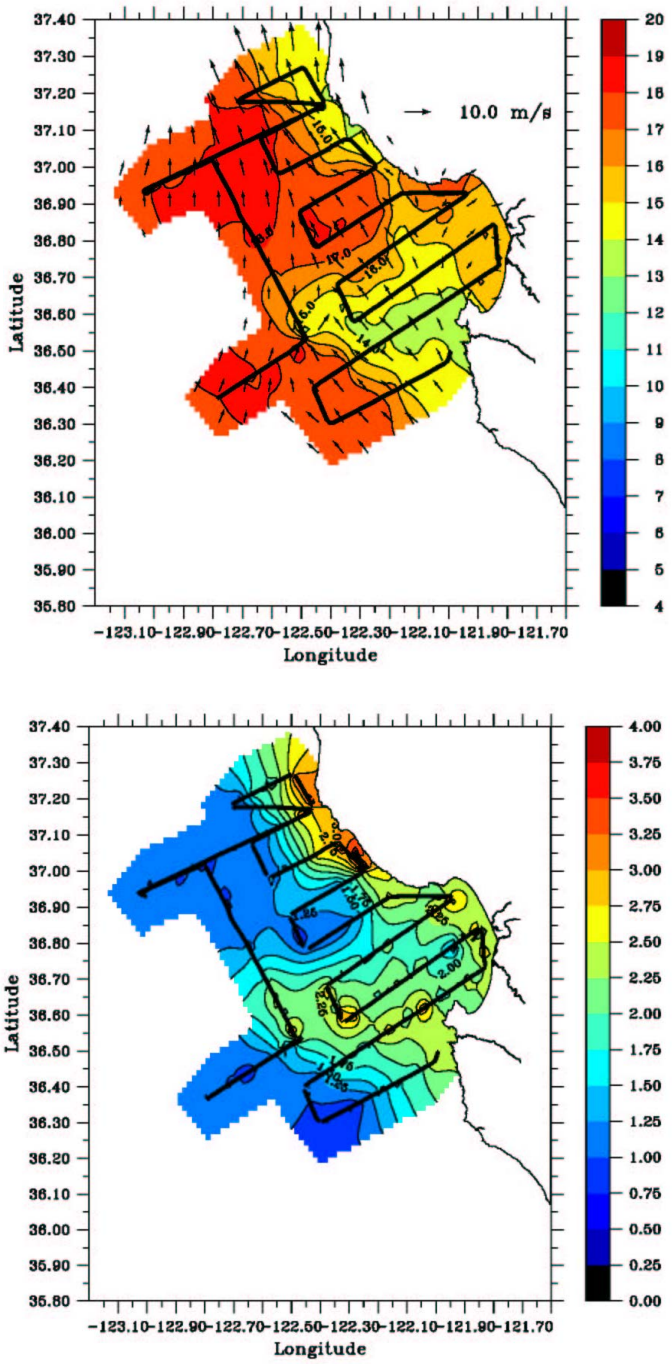

Figure 1. A typical map of the flight track, wind vectors at 33 m height, and sea surface temperature as sensed by the TWIN OTTER aircraft on 20 August 2003 (top) and the distrubution of chlorphyll-a for the same flight (bottom). This was for a wind relaxation event, immediately following a prolonged (10-day) upwelling event.

IMPACT/APPLICATION

The aircraft flying below the clouds for a time series of flights throughout the year provides and unprecented view of the characteristic states of the Monterey Bay air/sea system. We know of no other data set capable of rigorously testing the 3-km COAMPS model under such a wide variety of atmospheric conditions. The three-dimensional maps of inversion layer height will also allow improved understanding and prediction of atmospheric visibility (i.e. fog), one of the Oceanographer of the Navy's top five priority needs for FY2003. We will cooperate with I. Shulman (USM), funded under an associated AOSN-II grant to continue development of the NOPP/ICON triply-nested model.

This program utilizes many sensors, both in-situ and remote, which are of interest to the Navy for innovation in MIW and expeditionary warfare. The sensors being used are all small, light, and inexpensive enough to be deployed on UAVs in areas of operational interest. The sensors provide an improved picture of the battlespace environment for tactical advantage.

RELATED PROJECTS

- Paduan (NPS) – Center for Integrated Marine Technology (CIMT) (NOAA)
- Wang (NPS) – Turbulent fluxes from the five-hole probe (ONR 322MM)
- Sancturary Integrated Monitoring Network (SIMoN) (NOAA)
- Cal State - Center for Integrative Coastal Observation and Research (CI-CORE) (NOAA)
- Bellingham (MBARI) (AOSN-II)
- Haddock (MBARI) (AOSN-II)
- Shulman (USM) (AOSN-II)
- Rice (NPS/SPAWAR)
- Horner (NPS) (NWDC)
- Frantantoni (WHOI) (AOSN-II)
- Robinson (Harvard) (AOSN-II)
- Healey (NPS) (NOMP)
- Leonard (Princeton) (AOSN-II)
- Bishop (NRL) (AOSN-II)
- Case (UCSB) (AOSN-II)

PUBLICATIONS

Ramp, S. R., J. D. Paduan, and R. T. Bluth, 2002: The utility of aircraft observations in coastal ocean observing systems. The 49th annal Eastern Pacific Ocean Conference, Mt. Hood, OR, September 2002.

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Ramp, S. R., J. D. Paduan, C. A. Collins, W. Nuss, A. Healey, and L. K. Rosenfeld, 2002: NPS priority research and education activities during AOSN-II. ONR AOSN-II planning workshop, MBARI, Moss Landing, CA 6-7 April 2002.

Shulman, I., J.D. Paduan, L. K. Rosenfeld, S. R. Ramp, and J. C. Kindle, 2003: Modeling study of the coastal upwelling system of the Monterey Bay area during 1999 and 2000. Terrain-Following Ocean Models Users Workshop, Seattle, WA, August 4-6, 2003.

Shulman, I., J.D. Paduan, L. K. Rosenfeld, S. R. Ramp, and J. C. Kindle, 2003: Modeling study of the coastal upwelling system of the Monterey Bay area during 1999 and 2000. The 31st Conference on Radar Meteorology and the Fifth Conference on Coastal Atmospheric and Oceanic Prediction and Processes (Joint Session, Coastal Weather and Ocean Processes), Seattle, WA, August 6-7, 2003.