SHALLOW WATER FRONTS, RIVER PLUMES AND STRONG FORCING- PRELIMINARY RESULTS FROM INTENSIVE SURVEYS OF THE NORTHERN ADRIATIC

Craig M. Lee [1]*, Burton H. Jones [3], Robert Arnone [2], Jason Gobat [1], Mauro Marini [4], Mirko Orlic [5], Zoran Pasaric [5], Hartmut Peters [6], Pierre Poulain [7], Dietmar Thaler [8], Damir Vilicic [5]

[1] Applied Physics Laboratory, University of Washingto, USA - * craig@apl.washington..edu
[2] Naval Research Laboratory, Stennis Space Center, USA
[3] Department of Biology, University of Southern California, USA
[5] University of Zagreb, Croatia
[6] Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA
[7] L'Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
[4] Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine-Sezione Pesca Marittima, Ancona, Italy
[8] Austrian Military Weather Service, Austria

Abstract

Quasi-synoptic, three-dimensional surveys of physical and optical variability characterize the mesoscale features that dominate the Northern and Central Adriatic, following their response to strong forcing events. During winter (February), sampling emphasized the response to episodic Bora wind events. Although springtime (May) measurement program was designed to sample during the Po River spring freshette, freshwater discharge rates were more than a standard deviation below the 12-year mean and winds remained weak throughout the survey period, leading to a study of weakly forced dynamics in a strongly stratified, shallow water regime. Wintertime sampling included surveys of a strong shallow-water front and a prominent extension of the Po River plume. The surveys captured the evolution of a nearly vertical, compensated front that tilts as the strong Bora winds weaken. A broad survey of the northern basin characterized the structure of a Bora-driven Po plume extension and reveals cyclonic (anticyclonic) circulation to the north (south) of the plume, consistent with the response found in previous numerical experiments.

Key Words: Adriatic Sea, fronts, mesoscale, optics, watermass formation

Introduction

Winter and spring surveys executed as part of the U.S. Office of Naval Research sponsored DOLCE VITA (Dynamics Of Localized Currents and Eddy Variability In The Adriatic) Experiment focused on the response of mesoscale fronts and filaments to strong atmospheric forcing by Bora events and riverine buoyancy input. Wintertime sampling extended from 31 January to 24 February and included three strong Bora events. The spring field program took place between 26 May and 15 June, during a period of weak wind forcing. Although the springtime surveys were timed to coincide with the climatological Po River spring freshette, May 2003 discharge rates were over one standard deviation below the 12-year mean. In the absence of strong forcing, small-scale internal variability dominated the northern and central Adriatic.

Methods

Directed by real-time satellite remote sensing (sea surface temperature and ocean color) and dedicated synoptic meteorological forecasts, we employed an adaptive sampling strategy to characterize the evolution of selected mesoscale features through periods of strong wind and buoyancy forcing (Fig. 1). Repeated, quasi-synoptic surveys using a hybrid SeaSoar (TriSoarus) towed profiling vehicle provided full-depth, three-dimensional measurements of physical and bio-optical variability. Along-track resolutions ranged between 200 – 1500 m (depending on profile depth), with typical cross-track separations of 3 km. Additional measurements included velocity and turbulence profiles from a 5-beam, bottom moored ADCP, hydrographic stations (nutrient, pigment and phytoplankton analysis), optical profiles, microstructure profiles and short-term surface drifter deployments.

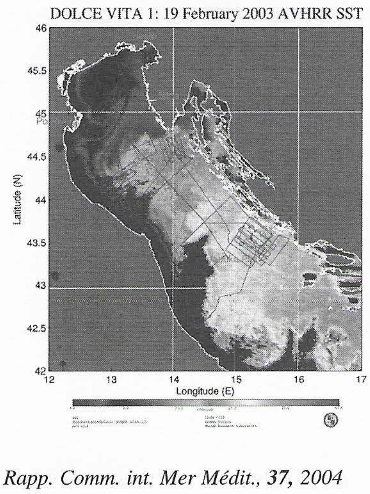

Fig. 1. Remotely sensed AVHRR sea surface temperature (23 February) with a black line marking the wintertime survey track.

Preliminary results

Prominent features present during the wintertime measurement period included a strong front extending westward from the tip of the Istrian peninsula (visible primarily in sea surface temperature, Fig. 1) and an extension of the Po River plume that stretched northeastward from the river delta to the Istrian coast (visible in both ocean color and sea surface temperature imagers). During one strong Bora wind event, sampling focused on the strong shallow water (50 m) 'Istrian front'. Frontal temperature and salinity contrasts were largely compensating and occurred over extremely small scales (1 °C over 100 m). The interface remained nearly vertical during the period of strong wind forcing, but began to tilt as the winds subsided. This could be driven by slumping, distortion by shear in the upper layer flow or distortion by the deep offshore-moving return flow that balances wind-driven downwelling off the tip of Istria. A narrow band of anomalously dense water occupied the frontal interface. Elevated levels of chlorophyll fluorescence and beam attenuation were also associated with the dense-water regions. Although cabelling can produce density anomalies across sharp temperature-salinity interfaces, the observed density contrasts are too large to be explained by this mechanism alone. The associated optical signal and strong westward flow along the front hint that advection may play a role in establishing the observed density structure.

Another set of intensive surveys sampled the double gyre pattern and eastward (upwind) extension of Po River water generated by windstress shear between the two Bora jets that extend from Trieste and Senj [1]. A filament of Po River water reaches across the basin to the Istrian coast, beginning as a narrow, buoyant plume that broadens and weakens with distance from the Po delta. A broadscale survey revealed cyclonic circulation in the northern basin, with an anticyclonic gyre occupying the region south of the Po extension, consistent with expectations derived from numerical results. In contrast to our expectations that barotropic, basin-scale features would dominate wintertime variability, towed profiling surveys revealed energetic small- and meso-scale features that evolved rapidly in response to atmospheric forcing..

Acknowledgements

We thank Captain Colburn, Captain Silva, and the crew of the R/V Knorr for their skilled, enthusiastic assistance. Dr. Vlasta Tutis and colleagues at the Croatian Meteorological Service provided custom forecasts and access to their data. Tim McGinnis, Eric Boget and Marlene Jeffries kept TriSoarus running under difficult conditions. Lindsay Pender and colleagues at CSIRO generously shared their knowledge and engineering expertise to assist with SeaSoar modifications. This research has been supported by the Office of Naval Research.

References

1 - Orlic, M., M. Kuzmic, and Z. Pasaric, 1994: Response of the Adriatic Sea to the bora and sirocco forcing. *Continental Shelf Research*, **14:** 91-116.