Merging altimetry and thermal imagery to estimate velocity in ocean boundary currents

W. Emery [1], J. Wilkin [2], M. Bowen [1]
[1] (University of Colorado, USA)
[2] (National Institute of Water and Atmospheric Research, New Zealand)

The highly variable flows along ocean boundaries are of particular interest due to the extensive use of these regions by humans and marine species. We combine two types of satellite observations, altimeter sea surface heights and velocities derived from tracking thermal patterns, to provide regular maps of sea surface currents. Preliminary results show the regular formation of cyclones and anticyclones in the East Australian Current.

Currents near ocean boundaries are often energetic, changing quickly over short distances and times. The accurate estimates of sea surface height from altimeter data, such as TOPEX/POSEIDON (T/P) and Jason-1, provide valuable insight into flows in these regions, but only along the widely-spaced satellite ground tracks at intervals of 10 days or longer. We aim to improve measurements of currents along ocean boundaries by combining altimeter-derived sea surface height anomalies with current velocities derived from tracking thermal features in radiometer images.

Observations

Strong boundary currents, such as the East Australian Current, bring water of very different temperatures together (figure 1). Velocities can be estimated by tracking patterns between successive thermal images using the maximum cross correlation (MCC) technique [Tokmakian et al 1990, Emery et al 1992]. A 10-day composite of MCC velocities in August 1997 (figure 2a) shows a triangular cyclonic feature, corresponding to the area of colder water in the thermal image, located directly south of where the warmest waters turn away from the East Australian coast. The persistent southward current flowing along the northern coast is also obvious. The altimeter sea surface height anomalies for the same 10 days (comprised of both T/P and ERS-2 tracks) show the cyclone as a distinct low in the sea surface height (figure 2b).

Interpolation Method

The heights and velocities are optimally interpolated to a stream

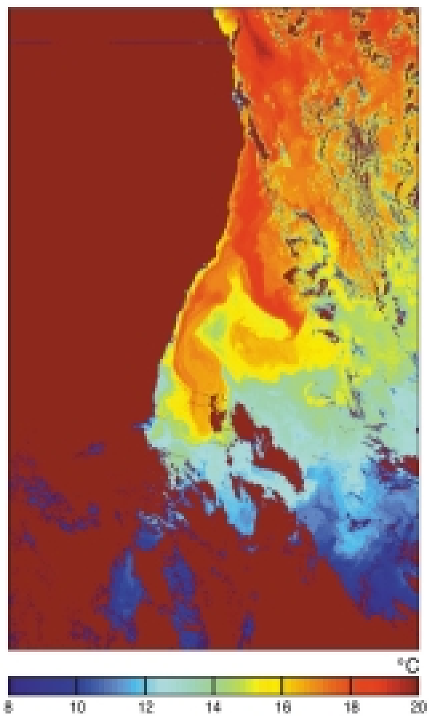

Figure 1: Thermal image of the sea surface temperatures off the east coast of Australia from the AVHRR aboard NOAA 12 on August 15, 1997.

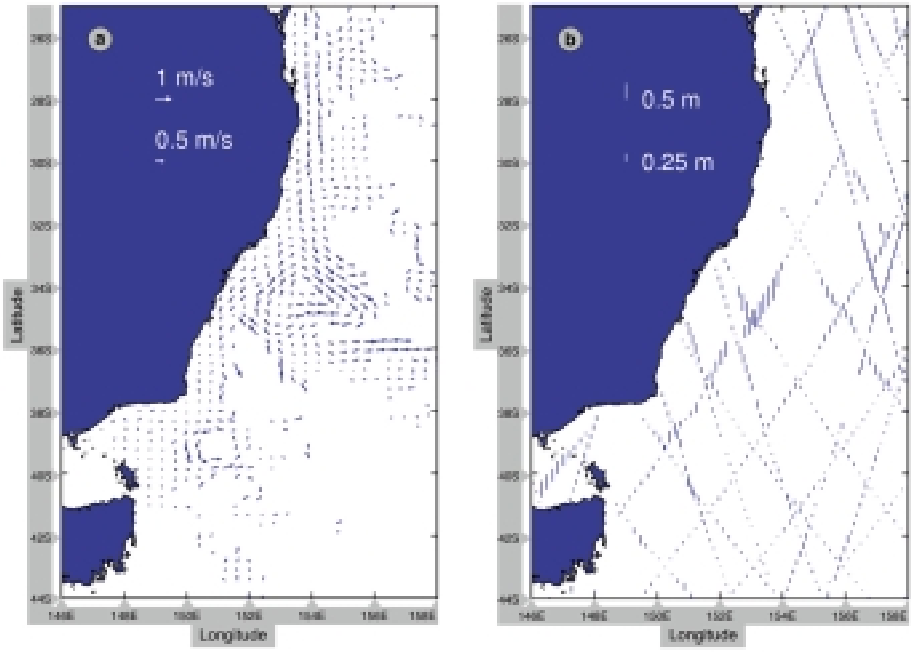

Figure 2: Observations from the two satellite data sets over ten days centered on August 16, 1997. Panel (a) shows a ten day composite of velocities inferred from tracking thermal patterns. Velocities are missing in regions with persistent clouds and weak thermal gradients. Panel (b) shows surface height anomalies from TOPEX/POSEIDON (large diamonds) and ERS-2 (steeper tracks) altimeters over the same time period.

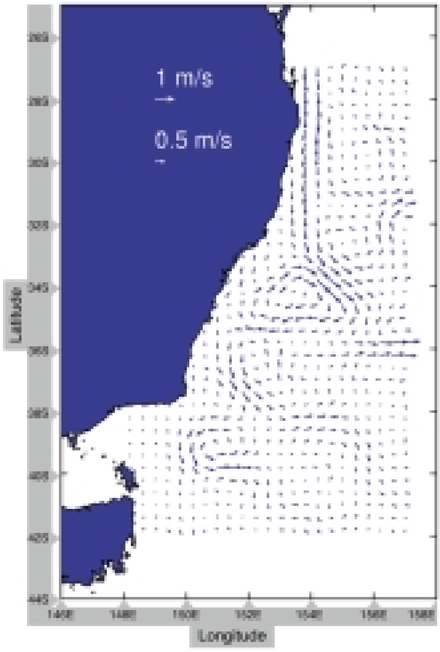

Figure 3: Velocities derived from the optimal interpolation of the two data sets for August 16, 1997, with the mean MCC velocities added to show the persistent current near the coast.

function on a regular grid in time and space using a method similar to Chereskin and Trunnell [1994]. The optimal interpolation requires a priori knowledge of the covariance functions of the signal and measurement noise. Covariances were estimated by computing binned, lagged correlations of MCC velocities and altimeter sea surface heights from the East Australian Current between 1996 and 1999.
The covariances show the mesoscale features have length scales of about 200 kilometres and evolve on a time scale of approximately 10 days.
The sea surface height anomalies and MCC velocity anomalies (three-year mean removed) were mapped into an anomaly stream function. Velocities derived from the stream function and the 3-year mean MCC velocities (figure 3) are an optimal merging of the complimentary data sets.

The East Australian Current

A three year time series of velocities in the East Australian Current was mapped from the observations.
The strongest variability in the current is an approximate 100-day oscillation most evident near 153°E and 34°S. Two snapshots of temperature and velocity separated by 50 days show the formation of a train of cyclonic and anticyclonic circulations (figure 4). Although variability at this frequency has been noted previously in the region [Walker and Wilkin, 1998; Mata et al, 1998], the currents from the interpolation provide an unprecedented coverage in space and time. Measurements from the altimeters over the South Pacific are also essential in investigating the hypothesis that planetary waves propagating across the ocean force the mesoscale activity in the current [Nilsson and Cresswell, 1981].

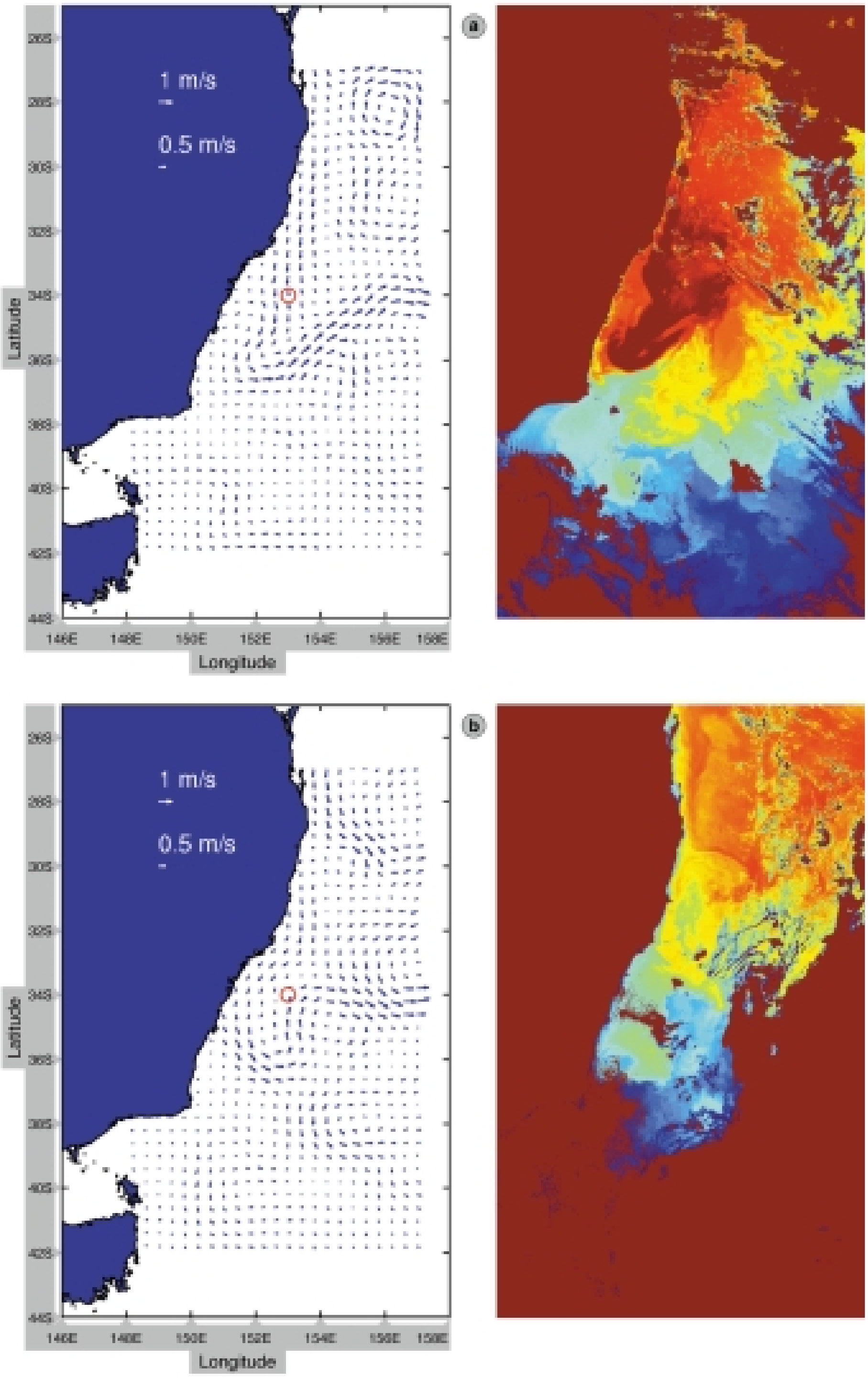

Figure 4: Velocities and corresponding thermal imagery from the East Australian Current show the formation of alternating cyclonic and anticyclonic circulations. Velocities at 153°E and 34°S (red circle) are southward on April 24 (a). A region of northward flow on the seaward edge of the warm feature moves towards the coast, turning the flow northward at the red circle by June 13 (b). Several hundred kilometres seaward the currents are turning southward and will arrive at 153°E 34°S in approximately another 50 days, completing the cycle.

References

Chereskin T.K., M. Trunnell, 1996: Correlation scales, objective mapping, and absolute geostrophic flow in the California Current, *J. Geophys. Res.*, 101, 22 619-22 629.

Emery W.J., C.W. Fowler, C.A. Clayson, 1992: Satellite image derived Gulf Stream currents, *J. Atmos. Ocean. Tech.*, 9, 285-304.

Mata M.M., S. Wijffels, M. Tomczak, J.A. Church, 1998: Direct measurements of the transport of the East Australian Current: a data report from the WOCE Pacific Current Meter Array 3, Technical Report 16, *Flinders Institute of Marine and Atmospheric Sciences*, Adelaide, Australia.

Nilsson C.S., G.R. Cresswell, 1981: The formation and evolution of East Australian Current warm-core eddies. *Prog. in Oceanography*, 9, Pergamon, 133-183.

Tokmakian R.T., P.T. Strub, J. McClean-Padman, 1990: Evaluation of the maximum cross-correlation method of estimating sea surface velocities from sequential satellite images. *J. Atmos. Ocean. Tech.*, 7, 852-865.

Walker A.E., J.L. Wilkin, 1998: Optimal averaging of NOAA/NASA Pathfinder satellite sea surface temperature data, *J. Geophys. Res.*, 103, 12 869-12 883.

**Corresponding author:
William Emery
Colorado Center for Astrodynamic Research, Campus Box 431
University of Colorado
Boulder, CO 80309 - USA
E-mail: Melissa.Bowen@colorado.edu**