Merging Infrared Sea Surface Temperature with Satellite Altimetry to map Ocean Currents in two Coastal Domains

John Wilkin
University of Auckland

Bill Emery, Melissa Bowen, Becky Knewtson, Dan Baldwin, Bryan Shannon
University of Colorado

Ian Barton
CSIRO, Hobart

Introduction

Satellite techniques make the first truly global measurements of quasi-synoptic surface ocean currents possible. Surface currents have been inferred for many years from patterns in daily radiometer images (~1 km resolution) of sea surface temperature (SST) using a variety of methods. More recently altimeters have provided estimates of geostrophic velocity from measurements of ocean surface height, usually every 10 days with along-track resolution of 1 km and track separations of 100 km. We aim to combine velocity information from radiometers and altimeters using dynamic constraints that will allow the respective sampling distribution, and type of observation, to complement each other. The analysis focuses on two coastal regions, one off the east coast of Australia and the other off the west coast of North America, which contain strong and highly variable mesoscale features, and in which extensive historical in situ measurements are available for validation. Ultimately, applying these techniques to many years of archived satellite data can elucidate the spatial and temporal scales of the mesoscale features that dominate these regions. Here we present the initial steps in refining the estimates of velocity from SST and a comparison of these velocities with those derived from sea surface height.

Velocities from the Maximum Cross Correlation (MCC) Method

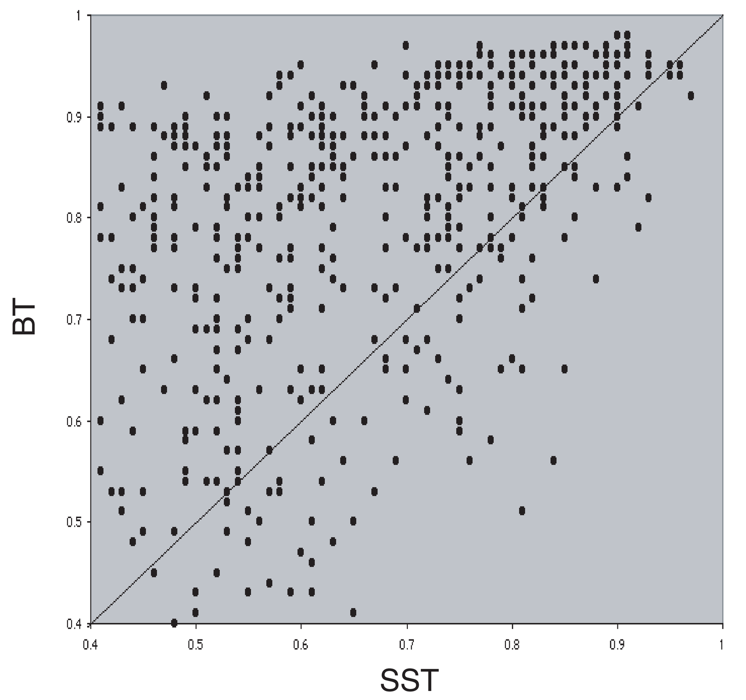
Surface currents can be estimated from SST patterns using the maximum cross correlation between windowed portions of successive images. Results have been shown to compare well with velocities derived using other techniques (Ninnis et al 1989; Emery et al., 1986; Emery et al 1992). The objective nature of the MCC method is advantageous for automating the routine analysis of large data sets.

We are presently improving the MCC method to make its application more automated and robust in the computation of ocean surface currents.

A. Comparison of MCC Velocities using Brightness Temperature (BT) and SST

The MCC analysis was performed on images off the east coast of Australia and the west coast of the US. In many instances the velocity vectors derived from BT and SST fields differed in direction. The cross correlation distributions of the BT and SST fields had similar structures, but the maxima occur in slightly different places, leading to the difference in vector direction.

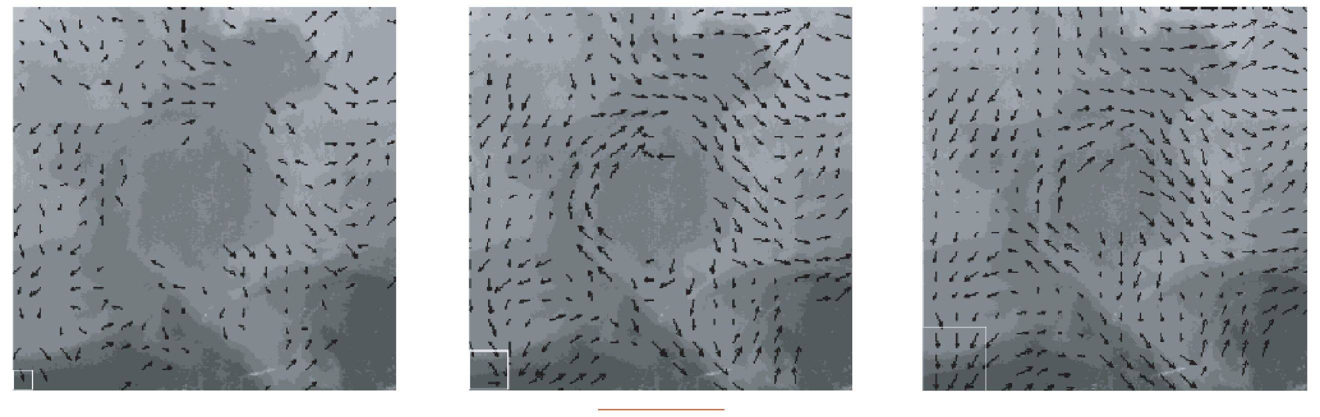
Correlation Coefficients for each Velocity Location



The maximum correlation coefficients from the BT fields were consistently higher than the those from the SST fields computed for 5 image pairs from the East Australian region (above), suggesting that BT fields provide a more reliable MCC velocity than SST. The lower correlation coefficients from the SST fields are hypothesized to be due to the introduction of noise through the differencing of radiometer channels in the algorithm used to derive SST.

B. Optimizing parameter choices for the MCC Analysis

Two SST images from the Sea of Japan were used to examine the sensitivity of the MCC technique to the size and overlap of the template windows and the range of displacements allowed between the images. MCC velocities (black arrows) are shown for a 200 km by 200 km portion of the SST images, centered on a mesoscale feature (darker gray indicates higher temperatures), for a range of template sizes (indicated by white box in lower left). The template window from image one is moved around image 2 to find the maximum correlation.

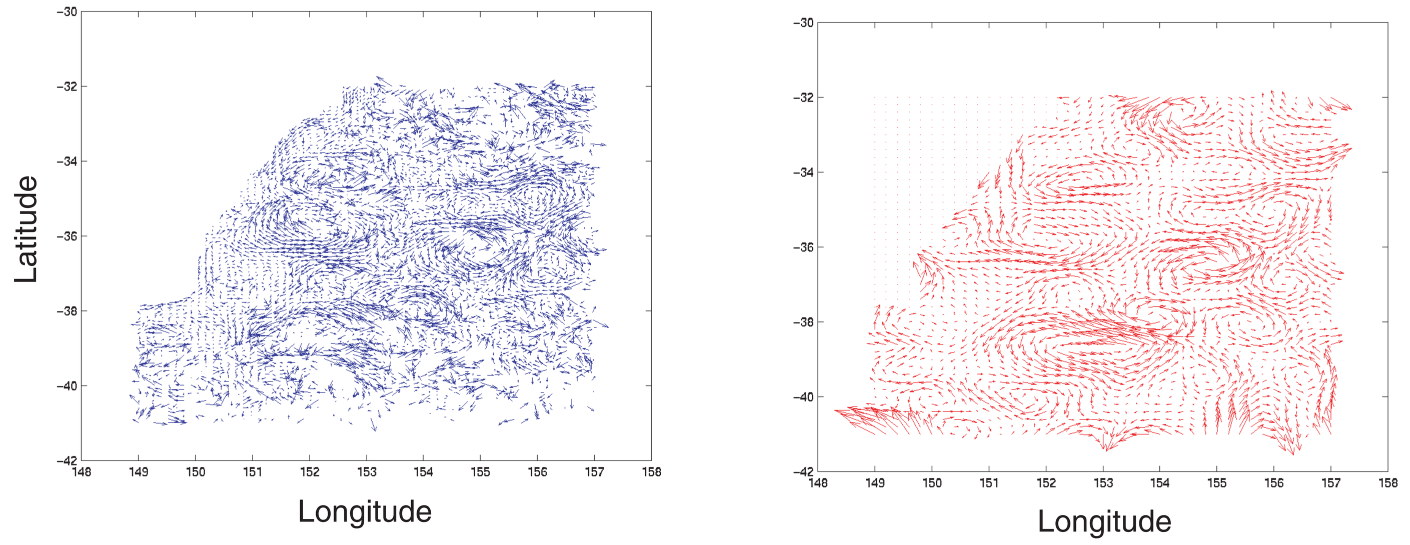


100 km

The smallest template size (left panel) produces a velocity field with little coherent structure. As the size of the template window is increased (middle panel), an anticyclonic circulation appears around the edge of the warm feature. The direction and magnitude of the circulation is not sensitive to a further increase in the template size (right panel). The size of the template window determines the size of the features being tracked. The range of displacements of the template windows is determined by the expected velocity of the features. Overlapping the template windows produces a smoother velocity field but adds no new information. Future work will formalize these results and their applicability to other ocean regions.

C. Optimum Interpolation (OI) of the MCC Velocities

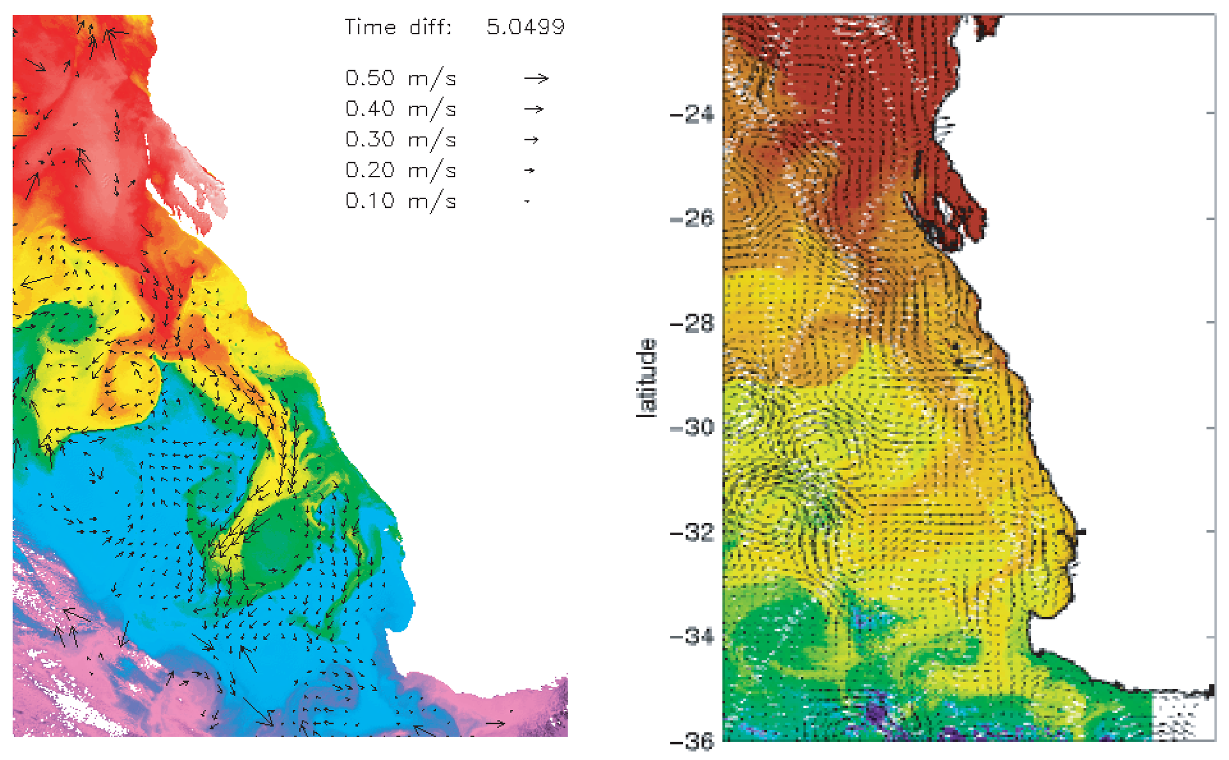
The MCC velocities can be placed on a regular grid and constrained dynamically using an optimum interpolation (OI) of the velocity data to a stream function model (Emery and Thomson, 1997). This OI was applied to MCC velocities from a pair of SST images off the east coast of Australia (left panel) to produce non-divergent, regularly-spaced velocities (right panel).



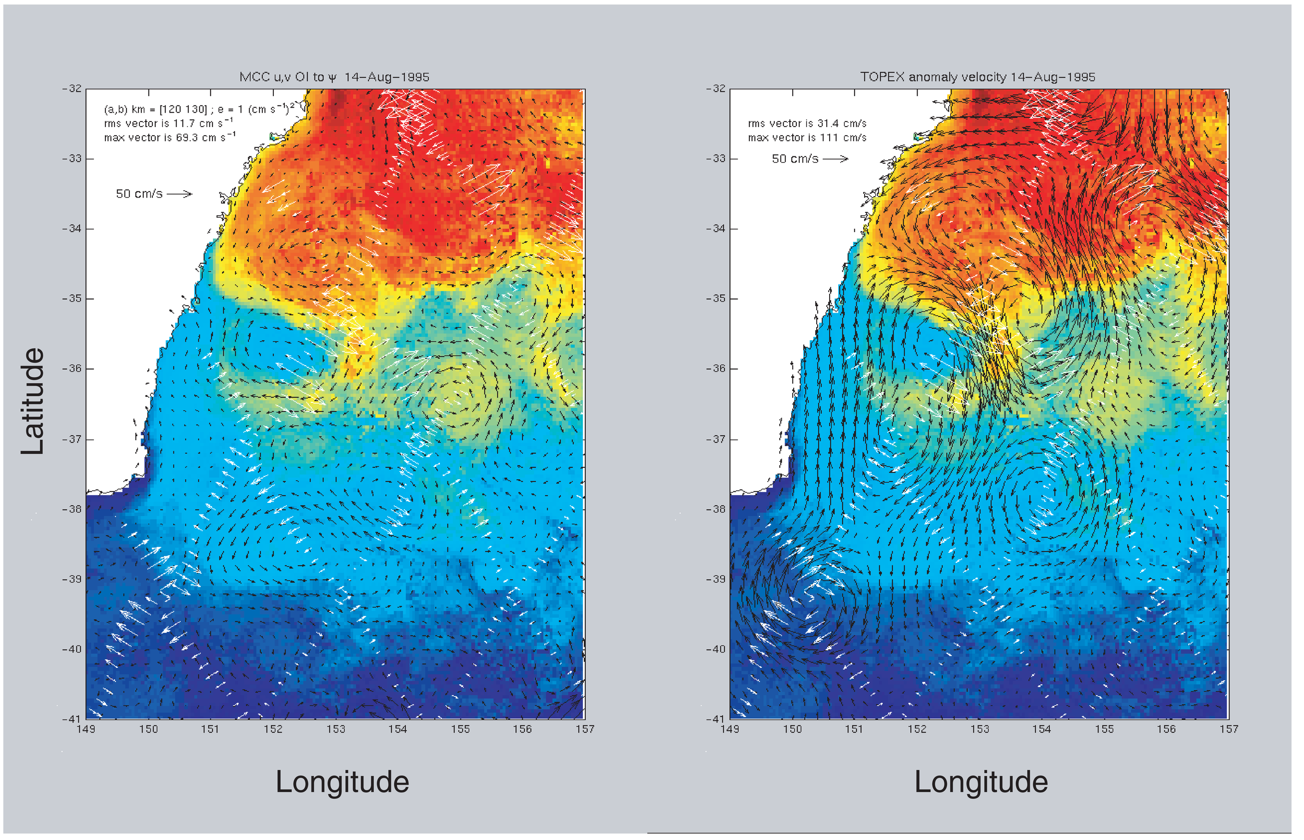
Comparison of Velocities Derived from SST and from Sea Surface Height

The following set of figures from the Leeuwin Current off the west coast of Australia illustrates the complementary nature of the space and time scales contained in the two types of velocity information.

MCC velocities from radiometer images separated by 5 hours (left panel) capture movement of the stream along the coast, the turn off-shore, and the strong jet in the center of the vortex pair. Velocities from an OI of the altimeter height (black vectors; white vectors are altimeter cross-track velocities) show the along-shore current but do not capture the off-shore jet in the center of the vortex pair present in the MCC analysis.



OIs were used to map MCC velocities (left panel) and altimeter-derived velocities (right panel) in the East Australian Current. As with the western Australia surface currents the features in the MCC current field are not identical with the geostrophic surface currents computed from the altimeter data. This is in part due to the higher spatial resolution provided by the infrared SST images which resolve the smaller scale current structures of the coastal region.



Future Work

Future work will focus on merging the two types of velocity information to create a robust method that can be used to automatically map coastal surface currents. Two approaches are being explored: (1) a simple physical inverse model and (2) the addition of a velocity potential to the streamfunction fit in the optimum interpolation of altimeter and MCC velocities to include flow divergence resolved by the data. We will apply the final method to map 8 - 10 years of surface currents in these two coastal regions.

Summary

1. MCC velocities should be estimated using infrared Brightness Temperature (BT) instead of Sea Surface Temperture (SST) to suppress noise.

2. Velocity fields computed using larger template windows are spatially more coherent and well behaved.

3. Optimum interpolation of the MCC velocities to a two-dimensional stream function produces spatially consistent and smooth velocity fields that with a slightly lower spatial resolution.

4. MCC velocities map ageostrophic surface currents that are missing from geostrophic velocity fields computed from altimeter sea surface heights. The complementary nature of the two data sets suggests that there is an optimal way of combining the two to derive the surface ocean circulation.

Acknowledgements

We wish to acknowledge the financial support of the JASON Program of the National Aeronautics and Space Administration (NASA), Eric Lindstrom program manager. Satellite infrared data were kindly supplied by the Division of Marine Research of CSIRO, in Hobart, Tasmania, Australia.

References

Emery, W.J., A.C. Thomas, M.J. Collins, W.R. Crawford, and D.L. Mackas, 1986: An objective method for computing advective surface velocities from sequential infrared satellite images. J. Geophys. Res., 91, 12,865 - 12,878.

Emery, W.J., C. Fowler and C.A. Clayson, 1992: Satellite image derived Gulf Stream currents compared with numerical model results. J. Atm. Ocean. Tech., 9, 286 -304.

Emery, W. J. and R.E. Thomson, 1998: Data analysis methods in physical oceanography, Pergamon Press, Oxford, 634 pp.

Ninnis, R.M., W.J. Emery and M.J. Collins, 1986: Automated extraction of pack ice motion from Advanced Very High Resolution Radiometer imagery. J. Geophys. Res. 91, 10,725 - 10, 734.