BODAS

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BLUElink> OCEAN DATA ASSIMILATION SYSTEM

BLUElink> *Ocean Forecasting Australia* is a partnership between the Commonwealth Bureau of Meteorology (CBoM), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Royal Australian Navy (RAN). The primary objective of *BLUElink* is to develop an operational forecast system for the mesoscale ocean circulation around Australia. The major components of this forecast system are the Ocean Forecasting Australia Model (OFAM), a global configuration of MOM4.0 with 0.1 degree resolution around Australia, and the BLUElink Ocean Data Assimilation System (BODAS) that is described here.

BODAS is an ensemble-based multivariate optimal interpolation system[4,1] that combines observations of sea-level anomalies (SLA), temperature and salinity with a 3-D forecast from OFAM. BODAS is built within the framework of an ensemble Kalman filter (**Figure 1**), and solves the following equations:

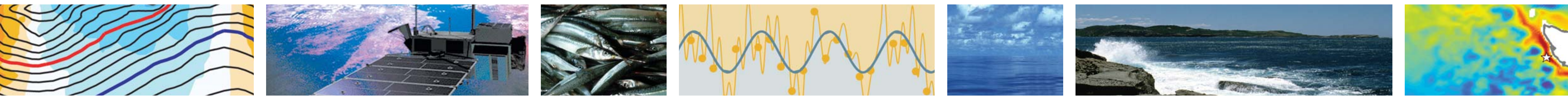
(1) $$\mathbf{W} = \left[\mathbf{T}^T \quad \mathbf{S}^T \quad \mathbf{U}^T \quad \mathbf{V}^T \quad \eta^T\right]^T$$

(2) $$\mathbf{A} = \alpha\left[\mathbf{W}_1', \mathbf{W}_2', \ldots, \mathbf{W}_n'\right]$$

(3) $$\mathbf{W}^a = \mathbf{W}^f + \mathbf{A}(\mathbf{HA})^T\left(\mathbf{HA}(\mathbf{HA})^T + \mathbf{R}\right)^{-1}\left(\mathbf{W}^o - \mathbf{HW}^f\right)$$

(4) $$= \mathbf{W}^f + \alpha \sum_{i=1}^{n} c_i \mathbf{W}_i'$$

The vector **W** in **(1)** has over 2×10^8 elements (all variables at all grid locations); **A** is a matrix of n=48 anomaly vectors that are derived from a single model integration (**Figure 1**); α in **(2)** is a scalar; super-scripts *o, f* and *a* in **(3-4)** denote observation, forecast and analysis; from **(3-4)**, an analysis is a forecast plus an increment, where the increment is a linear combination of anomalies; **H** interpolates from model-to observation-space; **R** is (n-1) times the observation error covariance matrix.



IN PRACTICE:

- the anomalies in **(2)** are anomalies from the model's seasonal cycle (**Figure 1**).
- the matrix inversion in **(3)** is approximated by a pseudo-inverse using a truncated singular value decomposition.
- the condition of the system is improved by normalising **(3)** by the observation error variance; and by decomposing the model grid into 60 sub-domains.
- the forecast error covariances, $\mathbf{AA}^T/(n-1)$, are localized[2,3] around each observation. This increases the rank of **A** and results in a better fit to the observations. Some examples of correlations between anomalies in **A** are shown in **Figure 2**.
- analyses are calculated for every second horizontal grid point and then interpolated to the full model grid.
- observations of SLA are sourced from ERS, T/P, Geosat, Jason-1, Envisat and tide gauges. Observations of temperature and salinity are sourced from ARGO, WOCE, TAO, IOTA and other experiments.

RESULTS:

An example of a forecast, analysis and increment in the Tasman Sea is shown for surface height and currents at 255 m depth in **Figure 3**; and for potential density and meridional current along 32ºS in **Figure 4**.

FUTURE DIRECTION:

A ten-year reanalysis is currently being run under *BLUElink*. This reanalysis combines OFAM with observations of SLA, temperature and salinity. At the completion of the *BLUElink* project, the *BLUElink* forecasting system will be implemented operationally at CBoM. The first operational forecasts are scheduled for 2006.

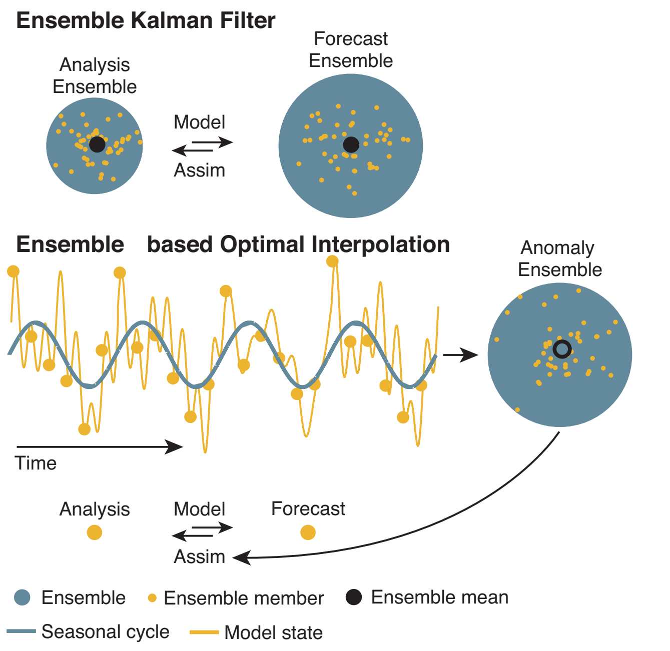


Figure 1: Schematic comparison between an Ensemble Kalman filter (EnKF) and Ensemble-based Optimal Interpolation (EnOI). The EnKF evolves multiple states in time and uses their spread to estimate the forecast error covariances (FECs); EnOI evolves only one state in time and uses the stationary anomaly ensemble to estimate the FECs. In both methods the FECs are used to calculate the analyses in **(3)**.

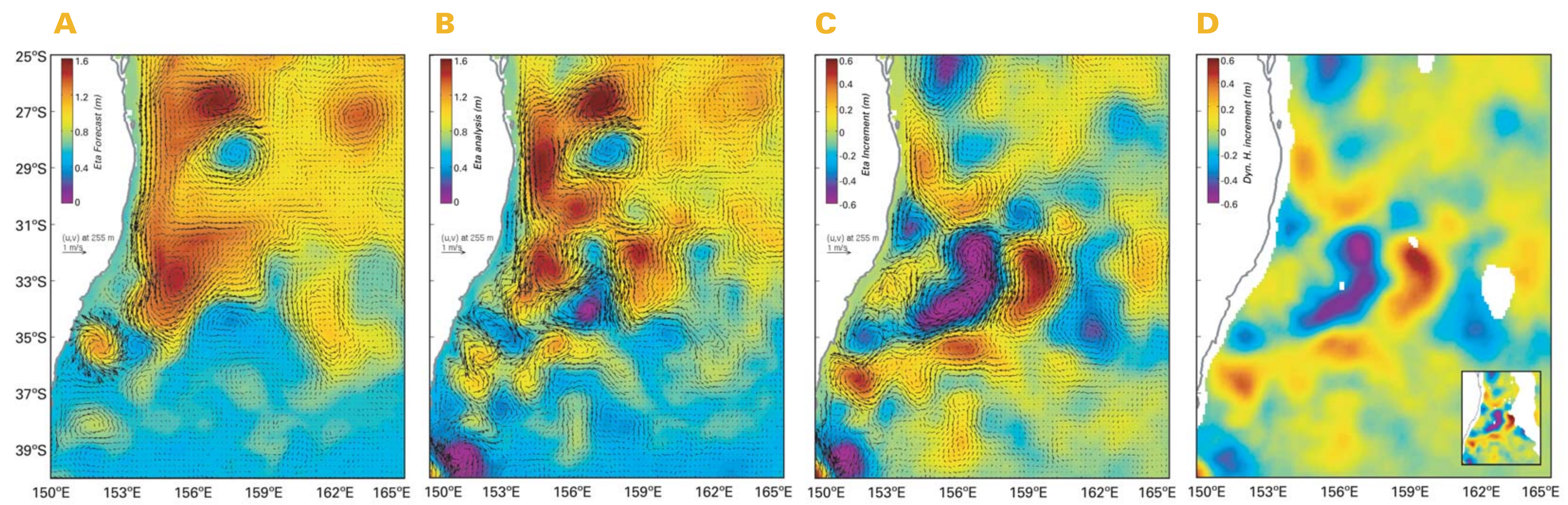


Figure 3: (a) Forecast, (b) analysis and (c) increment for surface height and currents at 255 m depth showing every second vector in the Tasman Sea. Panel (d) shows the increment in dynamic height relative to 1000 m (and 2000 m in the inset) demonstrating that the increments to surface height and sub-surface temperature and salinity are consistent. The RMS of the forecast and analysis innovations for SLA is 12 cm and 3 cm respectively.

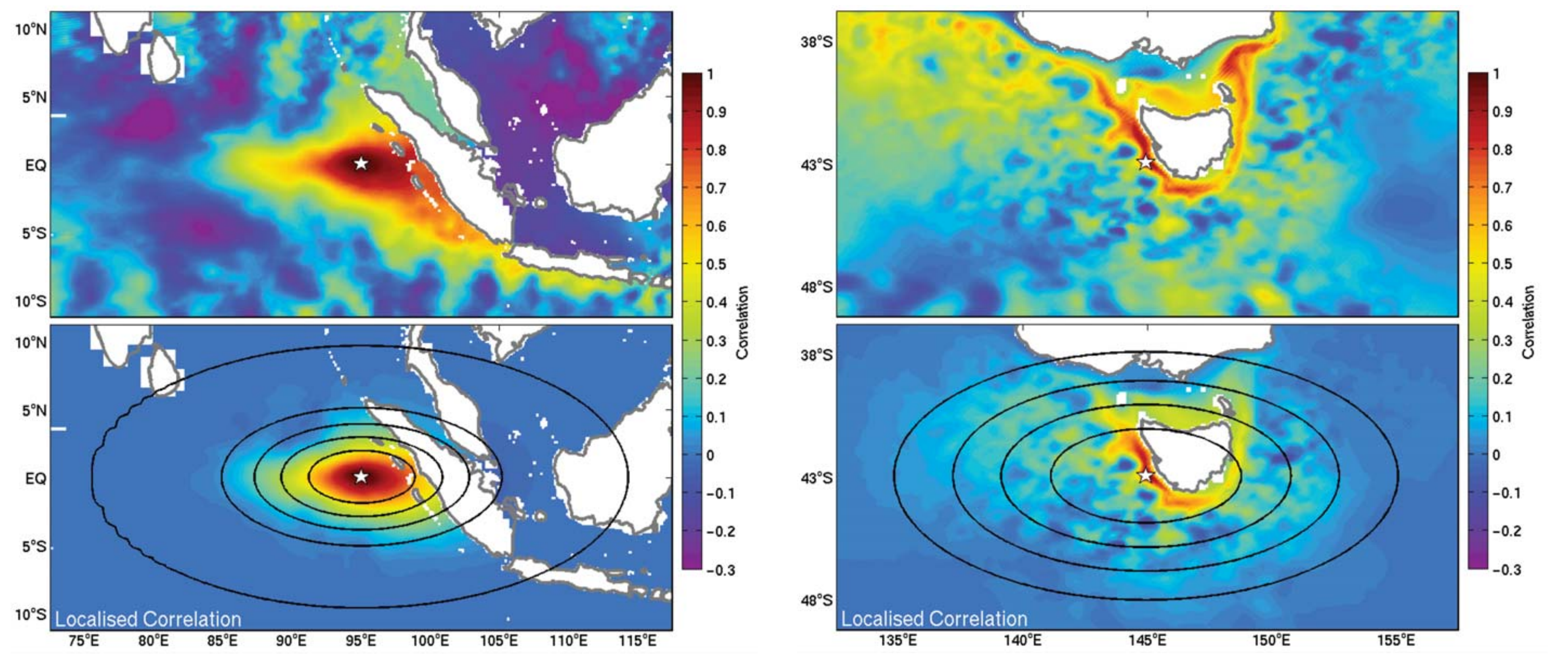


Figure 2: Examples of raw (top) and localized (bottom) correlations between surface height at a reference location (denoted by the star) and surface height in the surrounding region for an example in the Equatorial Indian Ocean (left) and off Tasmania (right). Contours of the localizing mask are shown for both examples (contour interval is 0.2). These examples show the long length-scales near the equator and the short, coastally aligned correlation scales in coastal regions. This also demonstrates that localisation eliminates distant correlations that are likely to be due to sampling error.

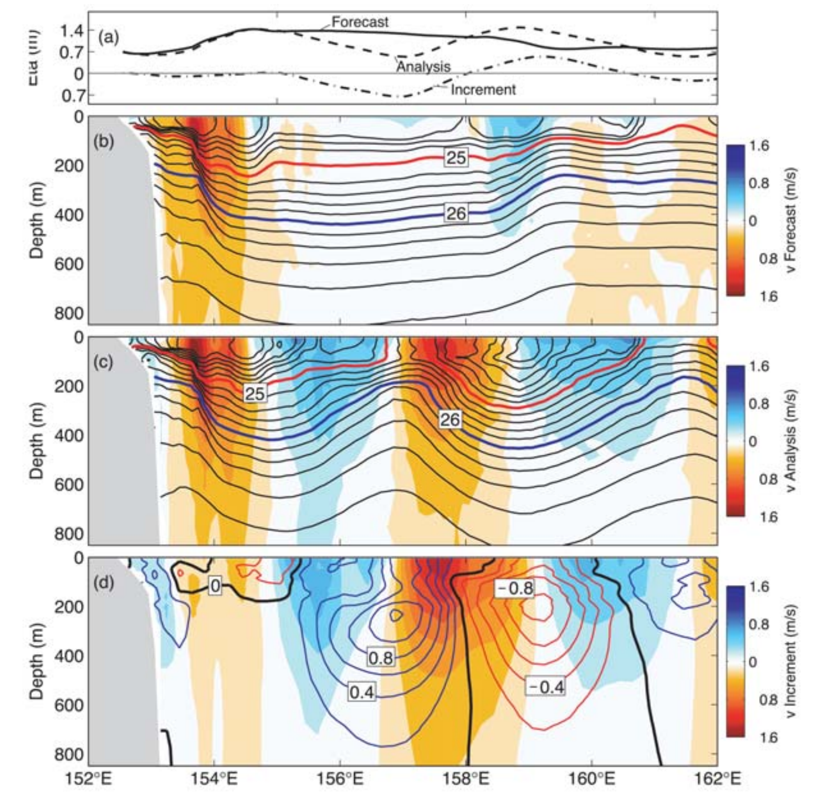


Figure 4: Zonal section at 32ºS off Eastern Australia showing (a) surface height forecast, analysis and increment; and (b) forecast, (c) analysis and (d) increment for zonal current (coloured; red is southward, blue is northward) and potential density (contoured; contour interval is 0.2).

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