# Sources of uncertainty in IBM modelling of sardine off South Africa

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## A: Overview of 3D hydrodynamic model (PLUME) resolution and forcing

| | |
|---|---|
| Domain | Pie-shaped grid, 28°S-40°S 10°E-24°E (Fig. 1) |
| Horizontal resolution | 9km at coast decreasing linearly to 16km offshore |
| Vertical resolution | 20 terrain-following vertical levels, decreasing with depth (1.5m vertical resolution at depth <30m, 6 levels in the top 100m for depths >30m) |
| Topography | ETOPO2 (smoothed) |
| Boundary conditions | Seasonally-averaged outputs (of surrounding ocean conditions) of basin scale ocean model AGAPE (1/3° resolution) |
| Forcings | Heat & salinity fluxes: COADS monthly climatology (1/2° resolution)<br>Wind: ERS½ wind stress scheme, real weekly wind field (1° resolution) |
| Time step | 2 days |
| Temporal range | July 1991 – June 1999 (first two years |

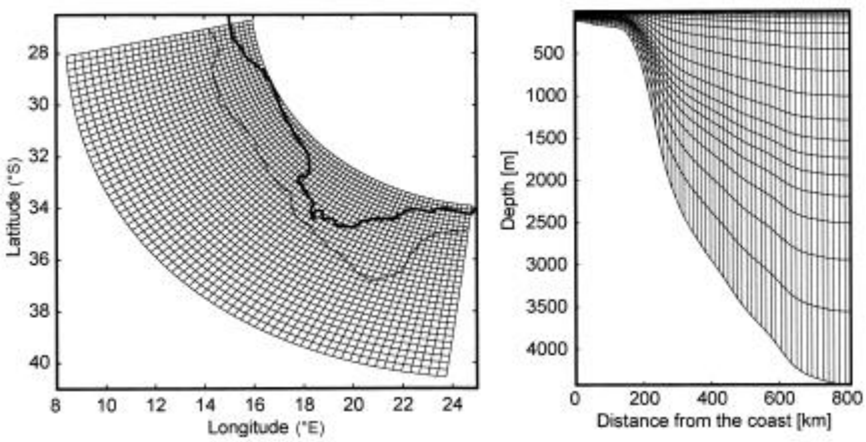


**Figure 1**: The low resolution horizontal grid (left) and the vertical grid used in PLUME (Penven et al 2001)

**B: Overview of the sardine IBM and some of the major assumptions made by the PLUME hydrodynamic model, the particle tracking model and the development model (Miller et al 2006)**

The fixed parameters and variables used in the IBM experiment

| Parameter | Range/value | n |
|---|---|---|
| Fixed parameters | | |
| Number of particles | 10,000 | – |
| Duration of release of particles | 30 days | – |
| Tracking period | 60 days | – |
| | | |
| Variables | | |
| Spawning Area | – | 9 |
| Month | July–June | 12 |
| Depth of release | 0–25, 25–50 and 50–75 m | 3 |
| Year | 1991/1992–1998/1999 | 8 |
| Trial (random factors) | – | 3 |
| Number of simulations | | **864** |

**Assumption Precedent**

Hydrodynamic model

1. The temperature and velocity field outputs realistically represent the dynamics of the ecosystem: Penven et al., 2001; Lutjeharms et al., 2003
2. The weekly wind scheme and monthly heat fluxes produce sufficiently realistic circulation patterns, comparable to that of the actual years being simulated: Blanke et al., 2002
3. The simplistic bathymetry does not significantly affect the accuracy of the circulation patterns: Lutjeharms et al., 2003; Penven, 2000
4. Boundary effects do not significantly hamper the performance of the model: Lutjeharms et al., 2003

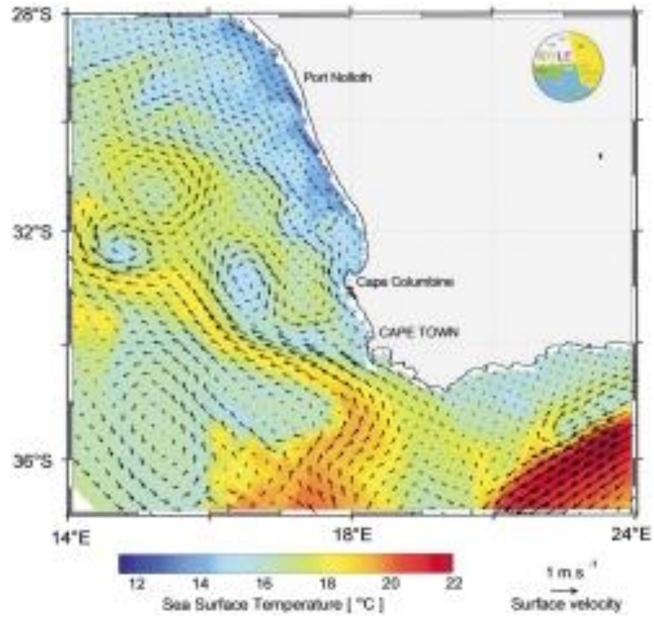


**Figure 2**: Snapshot of the surface structure on 1 September of the second year of the simulation shows the main oceanographic features of the region: 1) the warm and intense Agulhas Current flowing westward in the southern part of the domain, and 2) the coastal upwelling off the west coast. Upwelling filaments off the west coast, a shear edge eddy on the eastern part of the Agulhas Bank as well as eddy shedding in the vicinity of the Agulhas Current, of the Cape Peninsula and of Cape Columbine are examples of the mesoscale activity simulated by the model (from Penven et al 2001).

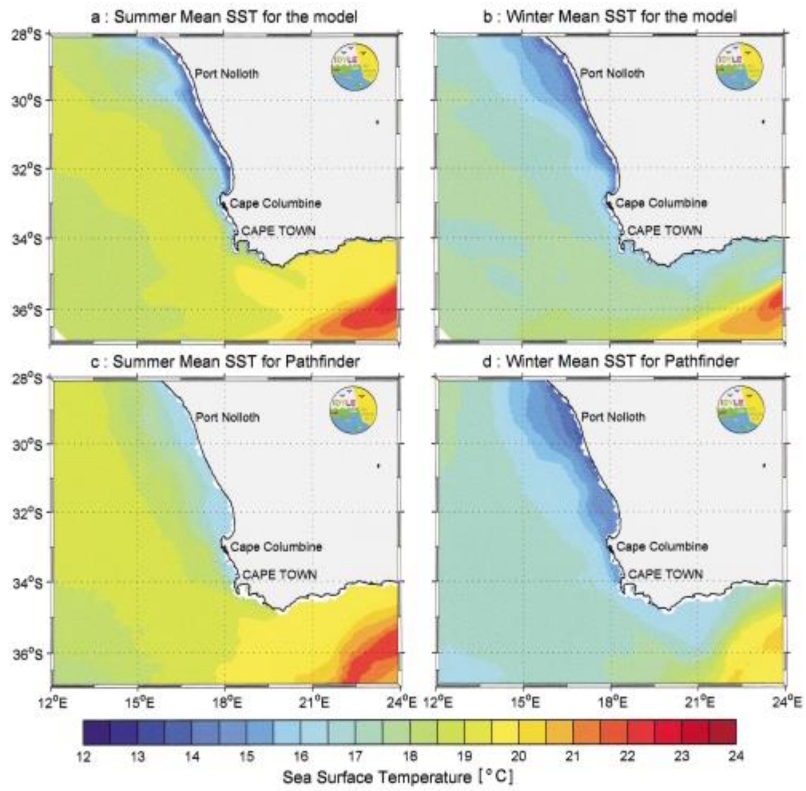


**Figure 3**: Comparison of the seasonal mean spatial structures of sea-surface temperature (°C) from the model and the PATHFINDER satellite SST database (from Penven et al 2001).

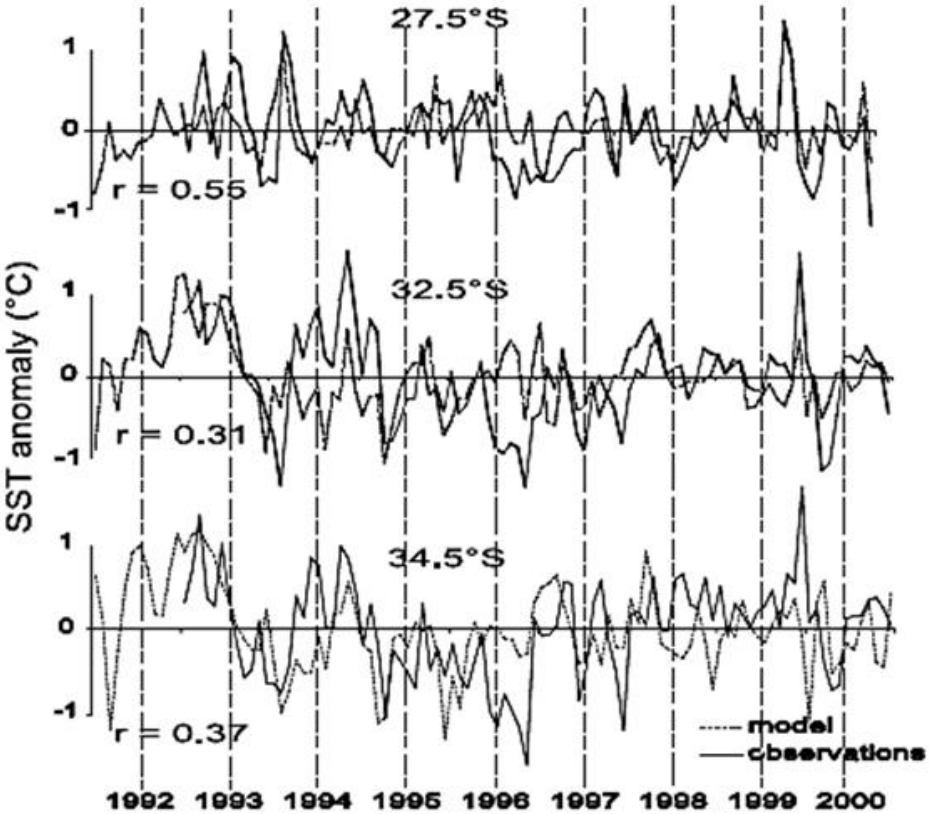


**Figure 4**: Monthly time series of SST anomalies at three selected locations along the continental shelf, for the model (average of Run B and C; dashed line) and for a global analysis of observations (Reynolds and Smith, 1994; solid line). The value of the linear correlation coefficient between both time series is also given. (from Blanque et al 2002).

**Particle tracking model**

1. Particles are transported in a Lagrangian fashion—the effects of diffusion are considered to be negligible: Huggett et al., 2003; Parada et al., 2003; Mullon et al., 2003
2. The number of particles used ensures stability of the IBM outputs and is adequate for statistical testing: Huggett et al., 2003; Parada et al., 2003; Mullon et al., 2003
3. The extensive spatial scale for release of particles is adequate to explore variability in recruitment success: van der Lingen and Huggett, 2003.
4. Frequency and patchiness of spawning is not considered to have a significant effect of the level of recruitment success: Huggett et al., 2003
5. Eggs and larvae are analogous to passive drifters, other abilities and biological properties have a negligible effect on the way they are transported: Huggett et al., 2003

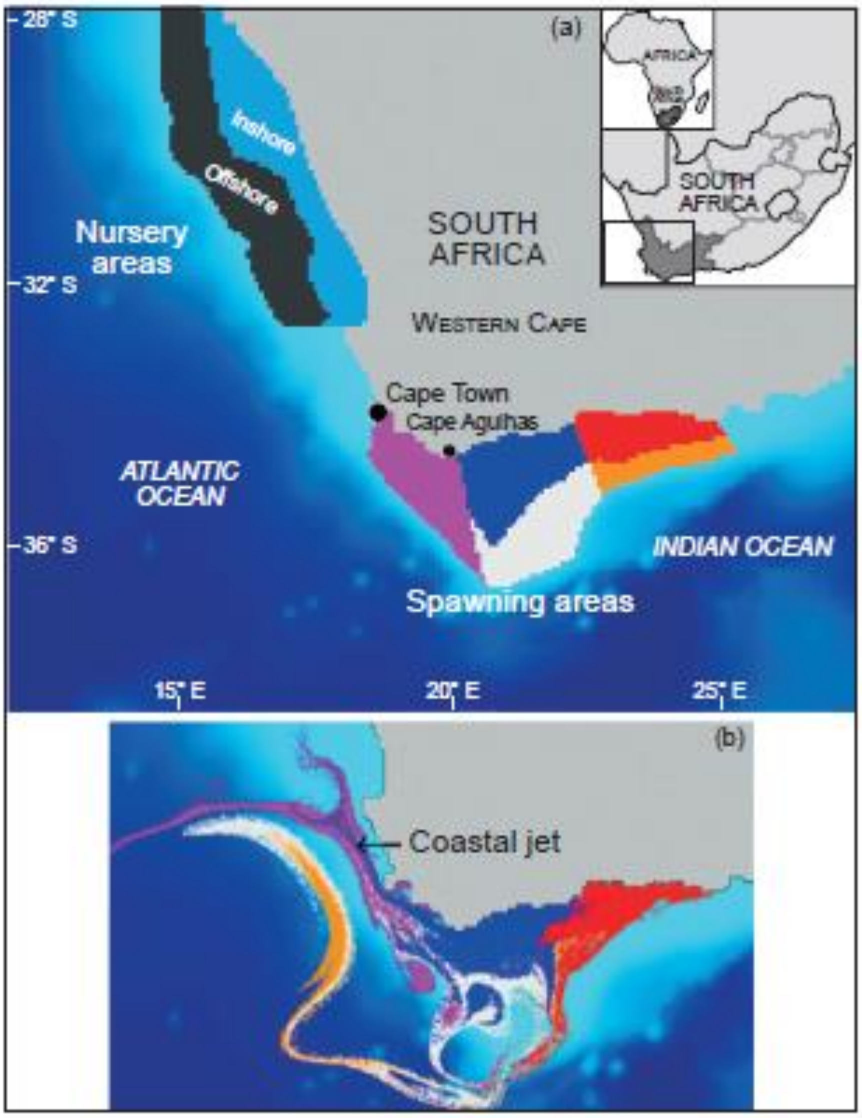


**Figure 5**: (a) Spawning and nursery areas used in most anchovy larval dispersal models developed for the southern Benguela; (b) an example of dispersal patterns obtained after 20 days of passive larval transport, highlighting the coastal jet involved in the alongshore transport of eggs and larvae from spawning to nursery areas. Colours correspond to the different spawning areas shown on (a) (from Lett et al 2015).

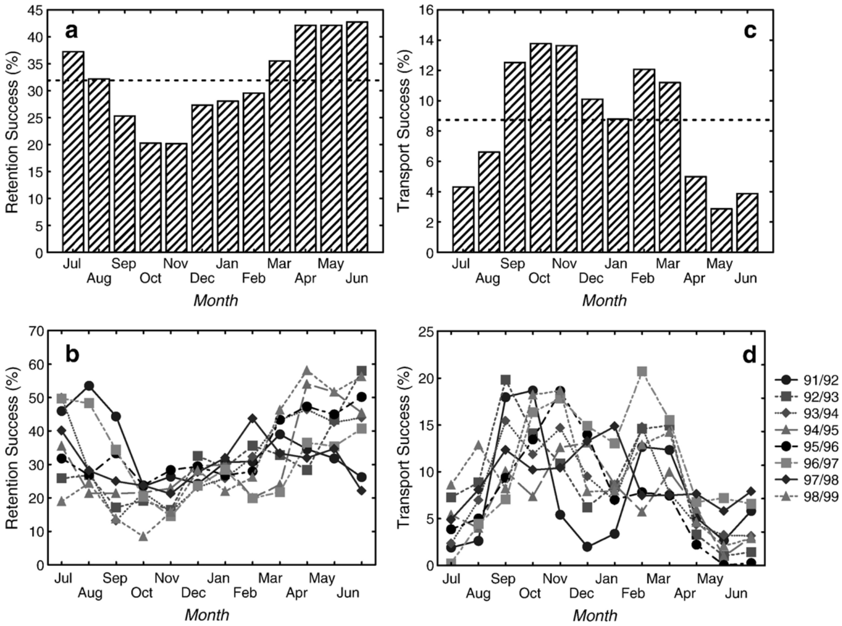


**Figure 6:** Intra-annual (month) patterns of modelled transport/retention success: (a) WC–WC, mean retention success in the west coast nursery area; (b) WC–WC, retention success by month for the 8 years of the time series; (c) SC–WC (less WAB), mean transport success to the west coast nursery area; (d) SC–WC (less WAB), transport success by month for the 8 years of the time series. In (a) and (c), the dotted line (- - -) represents the mean monthly level (from Miller et al. 2006).

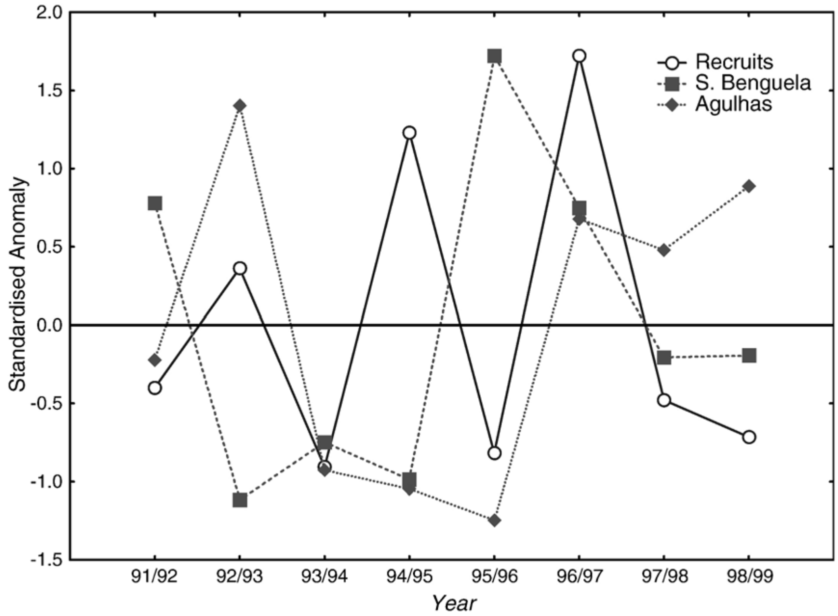


**Figure 7:** Standardised anomalies of the estimated number of sardine recruits and modelled transport/retention success in the southern Benguela (West coast) and Agulhas (South coast) systems for the 8 years of the experiment. Anomalies are calculated as the difference between the value for a given year and the mean over the 8 years, divided by the standard deviation over the 8 years.

## C: Major uncertainties:

1. 3D hydrodynamic model spatial resolution sufficient to capture mesoscale activity (eddies etc) but not sub-mesoscale activity; temporal resolution insufficient to address sub-weekly events (repeat sardine IBM using new 3d hydrodynamic model

(larger spatial coverage and nested models; 1/15° resolution and 100 vertical levels; 6-hourly wind, heat and salinity forcing).

2. Particles representing eggs and larvae are released uniformly (each month) throughout the year and not during peak spawning periods (as inferred from GSI data) for fish off the west and south coasts (but monthly values of transport success have been calculated for each).
3. Sardine IBM has no larval behaviour (e.g. DVM [see Parada et al., 2008] or directed swimming, etc); no larval feeding; and no larval predation.
4. Sardine IBM assumes "transport/retention success" is equivalent to recruitment success

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