Models of the Mediterranean outflow

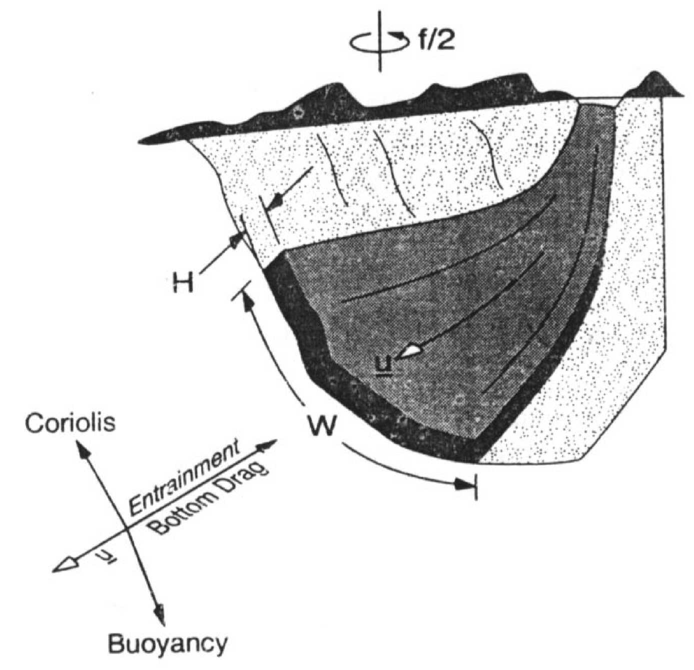
Southampton Oceanography Centre

Ocean Circulation and Climate Advanced Modelling Project
OCCAM
James Rennell Division
Southampton Oceanography Centre

Overview

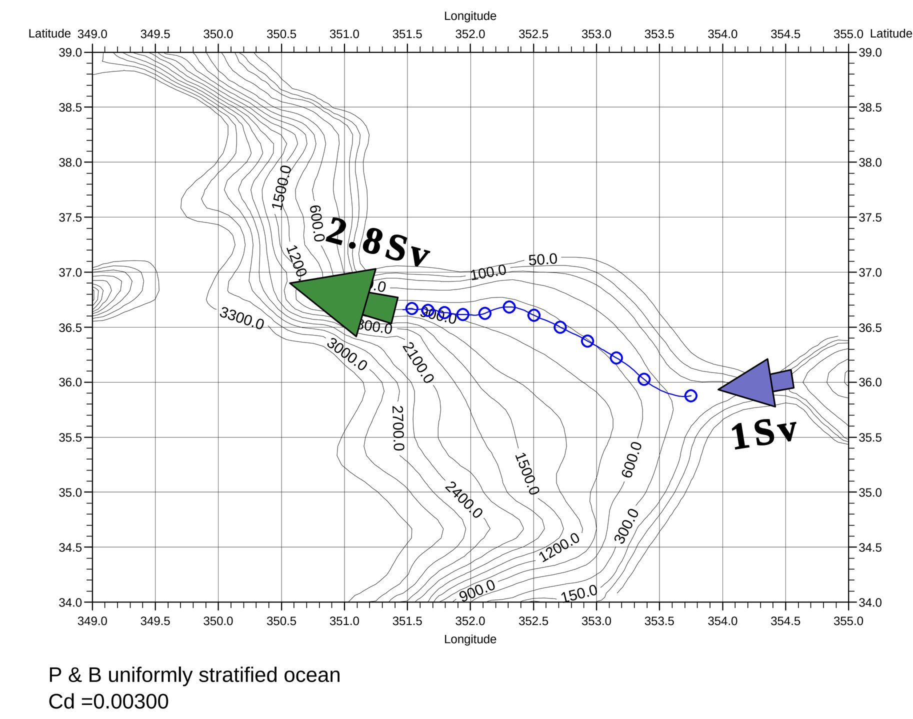
The **OCCAM** global ocean model is a 1/4x1/4° resolution model of the entire World's oceans with 36 levels in the vertical. This includes the Mediterranean Sea and the Straits of Gibraltar are open (albeit a little wider than reality). Even at this resolution important processes near the Straits which determine the properties of the water spreading into the North Atlantic are not fully resolved. This high salinity water is an important component of the global thermohaline circulation that maintains our current climate. The computing power is not yet available to run climate models with ocean components at the resolution of or finer than the OCCAM model. Therefore an important use of the model is to test out how such key processes can be parameterised in models which are less able to represent them.

The OCCAM model maintains a realistic volume flux of high salinity water out of the Mediterranean (figure 4) and this forms a tongue of high salinity water a suggestion of which can be seen in figure 5. Given that the mixing and entrainment processes are not well represented it is likely that this water is "over−mixed" and simulations over longer time periods would result in a water mass less dense than that observed in reality. One idea being investigated is to couple a "stream−tube" model to the Ocean General Circulation Model (**OGCM**).



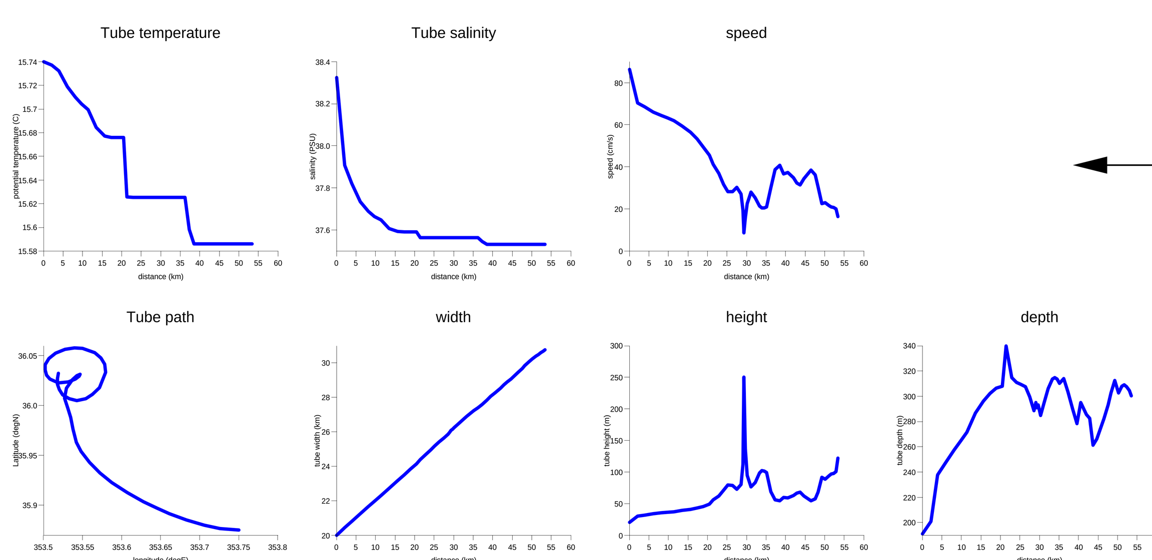
1.

Figure 1.: The stream−tube model of Price and Baringer (1994). Note that along−tube pressure gradients due to changes in the height are ignored and properties are assumed to be constant across the width of the tube.



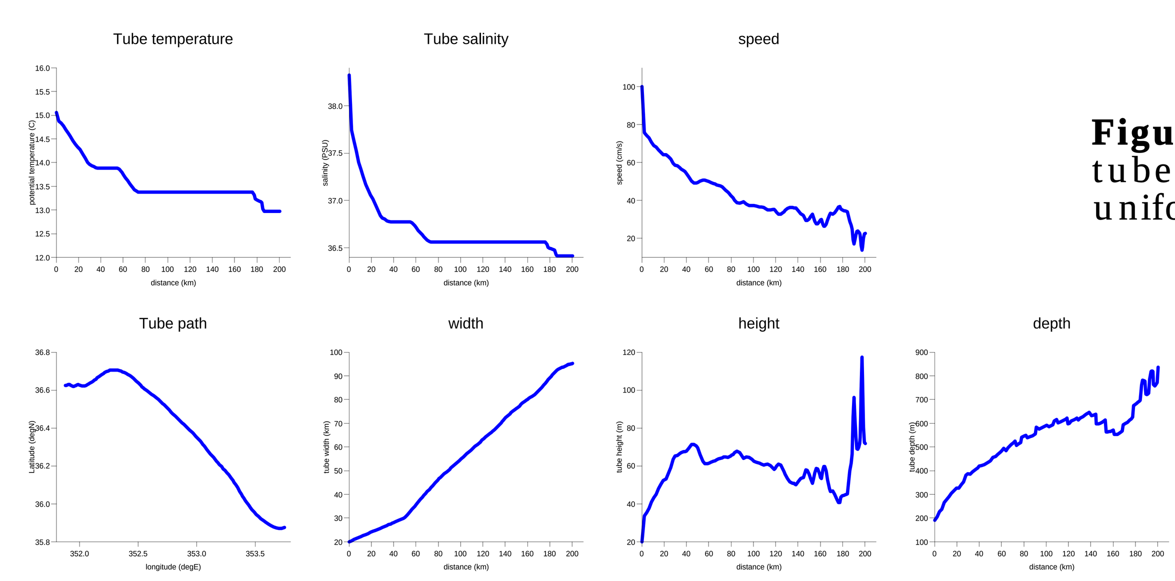
2a.

Figure 2a: The predicted path of the stream−tube for a uniformly stratified ocean. The centreline of the tube is plotted (blue) with closed circles marking half−day intervals. The path is overlaid on the topography of the region. Water is entrained along the path of the stream−tube swelling the volume flux from 1Sv (1Sv = $10^6 m^3 s^{-1}$) at the straits to 2.8Sv at the point where the tube water density becomes indistinguishable from that of the surrounding waters.



3.

Figure 3 shows the tube properties for a typical case where the back−ground fields are set by the OGCM. For such cases the tube can easily stall leading to sudden and un−realistic increases in the height of the tube.



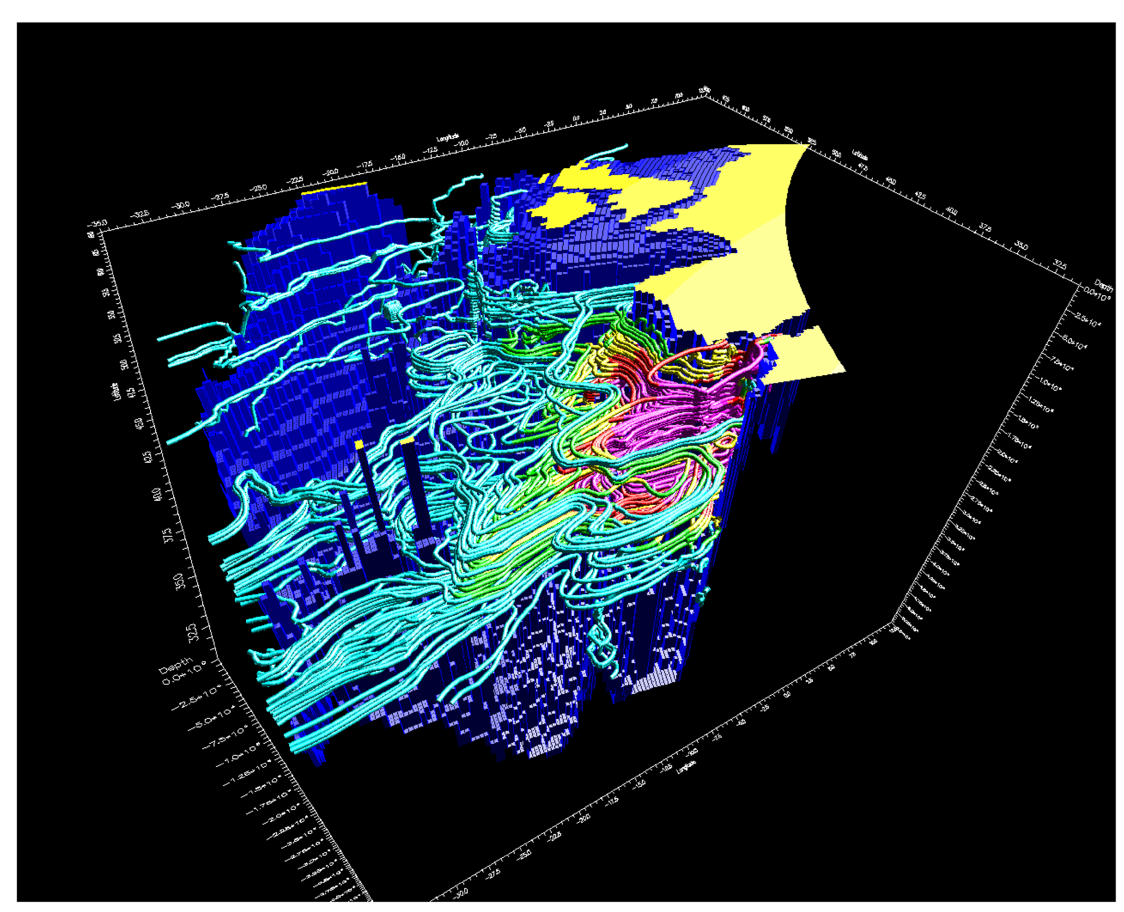
2b.

Figure 2b: The variations along the tube of several properties for the uniformly stratified test case.

A version of the Price and Baringer (1994) stream−tube model (fig. 1) has been coded in a form suitable for use in OGCMs. This model is designed to use topographic information at finer resolutions than the OGCM grid and to model a plume descending through ambient fields set by the OGCM. Entrainment is permitted but detrainment (and hence feedback to the OGCM) occurs only through the end of the tube.

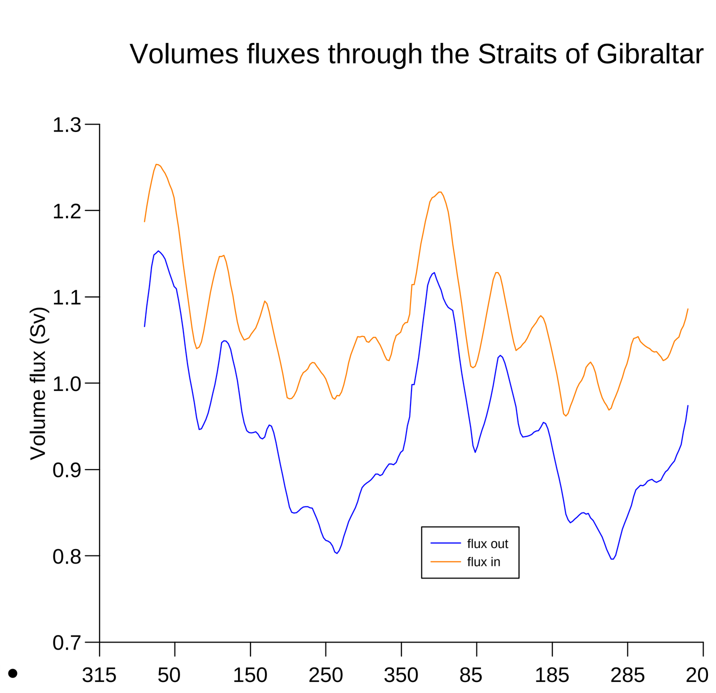
The test cases, reported by the originators, are reproducible (e.g. figure 2) but, so far, attempts with ambient fields containing horizontal density gradients fail (fig 3.).

A recent report, Emms (1997), highlights deficiencies in the stream−tube parameterisation and details the unstable behaviour that may result as a consequence. It is unlikely that a 1D parameterisation, such as the stream−tube idea illustarted here, will be sufficiently robust for general application. The next stage to be attempted will be the introduction of a fully 2−dimensional bottom boundary layer which can be used to model turbulent events happening within a small fraction of the height of the bottom box (Killworth and Edwards 1997).



5.

Figure 5: Simulated trajectories of Mediterranean water in the OCCAM model. The highest salinity water (pink and red) can clearly be seen flowing along the Iberian coast and forming the high salinity tongue which extends out into the N. Atlantic. 10^3 trajectories are shown each transporting 0.01Sv out of the Mediterranean.



4.

Figure 4 The volume fluxes through the Straits of Gibraltar as predicted by the OCCAM global ocean model using monthly climatological surface forcing.

Another example of a use of the model results is shown in figure 5. Here a multi−year average of the 3−dimensional model fields has been used to compute trajectories for water parcels leaving the Mediterranean. The trajectories shown are for parcels with salinity greater than 36.5 PSU (pink). The trajectories are followed until they leave the domain of interest or are diluted to salinities less than 35.5 PSU (blue). The validation and extension of the technique used to compute these trajectories forms the basis of a new EU project: TRACMASS due to start in February 1998. The technique will be extended to include seasonality, diffusive processes and eddy −induced advection as well as the purely advective component shown here.

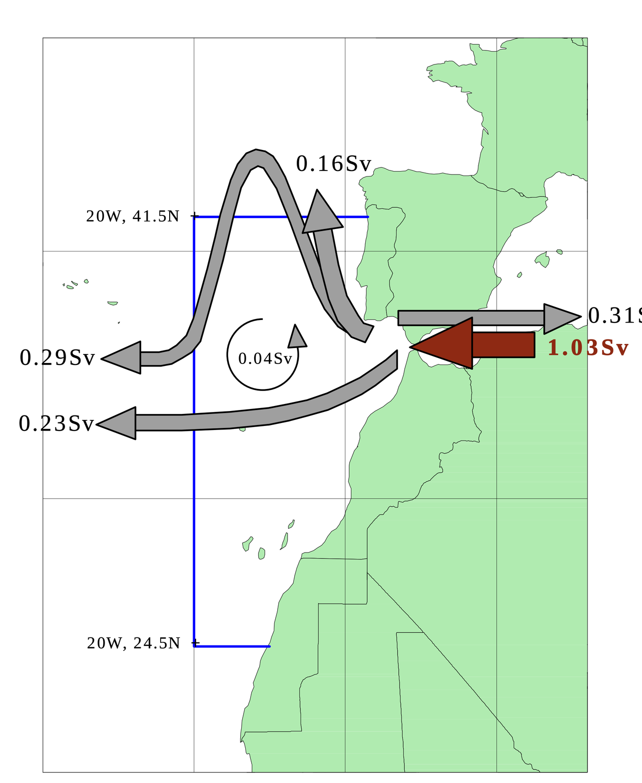
Comparisons of the predicted fate of the Mediterranean water with observations is also of interest to several on−going EU projects. A preliminary study of the fluxes across some completed observational sections is shown in figure 6.

References:

KILLWORTH, P.D., EDWARDS, N.R. 1997 A turbulent bottom boundary layer code for use in numerical ocean models. (Extended abstract: submitted to J. Phys. Oceanogr.). Ocean Modelling, No.114, 6−9 14−16. (Unpublished manuscript)

EMMS, P.W. 1997 Streamtube models of gravity currents in the ocean. Deep−Sea Research I, 44(9/10), 1575−1610.

PRICE, J. F., BARINGER, M. 1994. Outflows and deepwater production by marginal seas. Prog. Oceang., 33,161−200



6.

Figure 6: Schematic summary of the distribution of Mediterranean water as given by the trajectories shown in figure 5. The number of trajectories crossing each hydrographic line may be counted to give the total flux of Mediterranean water across each line. Note that of the 0.45Sv originally travelling north, 0.29Sv returns to exit through the western face.