Computer Simulation of the Escape oil from the wreck of the PRESTIGE

Contents

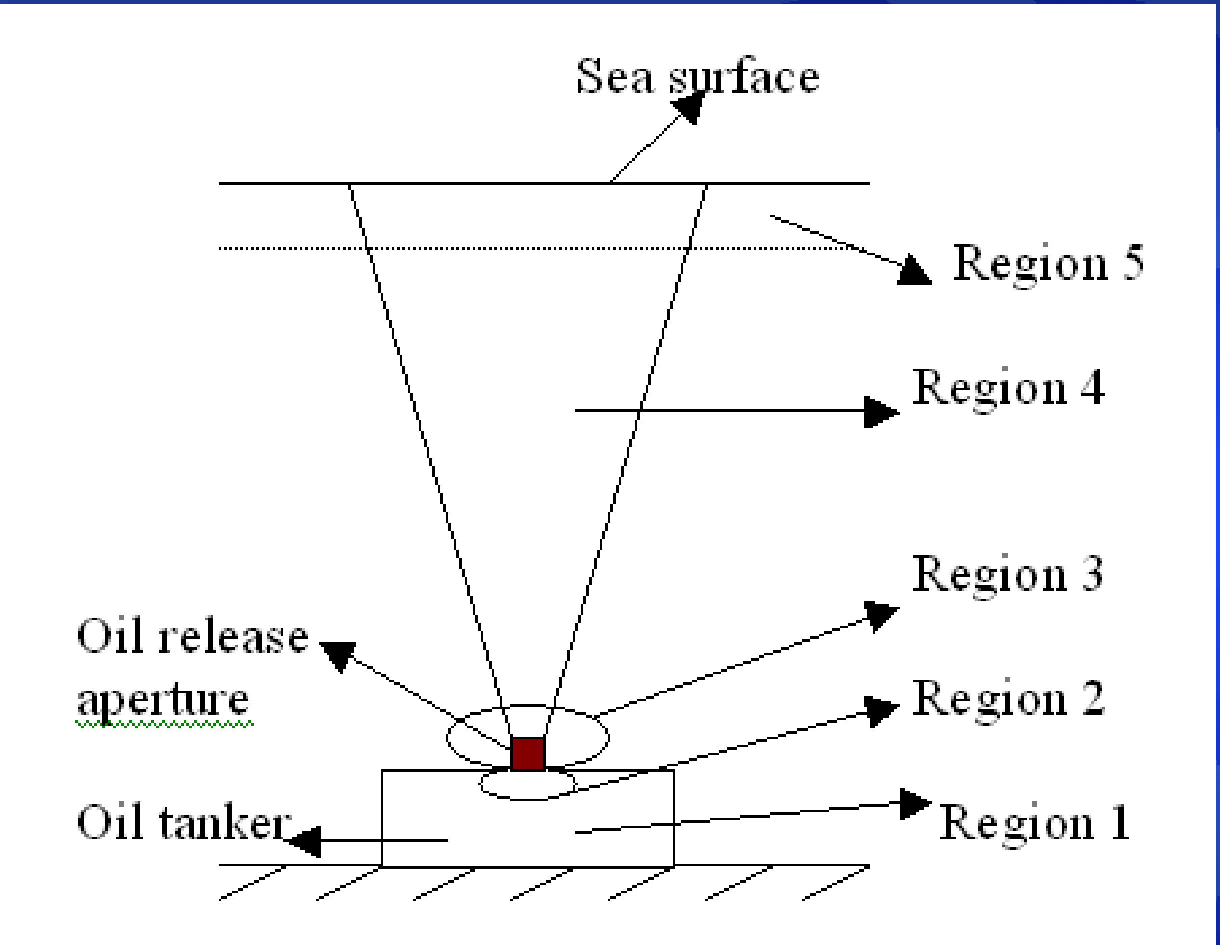
1. Introduction

- The Prestige oil tanker broke into two in water off northwest Spain November 19 2002 and went down with some 70,000 tonnes of fuel oil on board.
- The wreck of the PRESTIGE lies on the floor of the Atlantic, 3.5 kilometres below the surface, and it is known that its cargo of oil has been leaking through tanks' breathers.

1. Introduction (cont.)

- Because its density is slightly less than that of sea-water, the oil is bound to rise to the surface ; but the damage to the environment will depend on how much time this ascent will take, on the size of the resulting droplets or blobs and their drift and spreading.
- CHAM & ARCOFLUID, funded by SHOM, have been using PHOENICS in order to simulate the ascent process. The work has been planned in several stages, of which the first two have been completed and are briefly reported here.

2. Tasks



- Region 1, the interior of the oil tanker
- Region 2, the region just upstream of the aperture through which the oil escapes
- Region 3, the region just downstream of the aperture through which the oil escape.
- Region 4, the region covering the ascending plume of water-oil mixture
- Region 5, the layer beneath the sea surface.

2. Tasks (cont.)

- Region 1, the interior of the oil tanker where the possible effect of the internal temperature distribution of the tanker on the oil release rate may be investigated.
- Region 2, the region just upstream of the aperture through which the oil escapes. The effect of the geometry of the aperture and the oil viscosity on the oil release rate may be investigated.
- Region 3, the region just downstream of the aperture through which the oil escape. In this region, the fragmentation of oil filaments may be investigated.

2. Tasks (cont.)

- Region 4, the region covering the ascending plume of water-oil mixture.

- Region 5, the layer beneath the sea surface. The possible effect of the temperature distribution in this layer and the effect of the horizontal current on the oil ascent may be investigated.

The scope of the present work is confined to Regions 4 and 5.

3. Work performed for Region4

For Region 4,

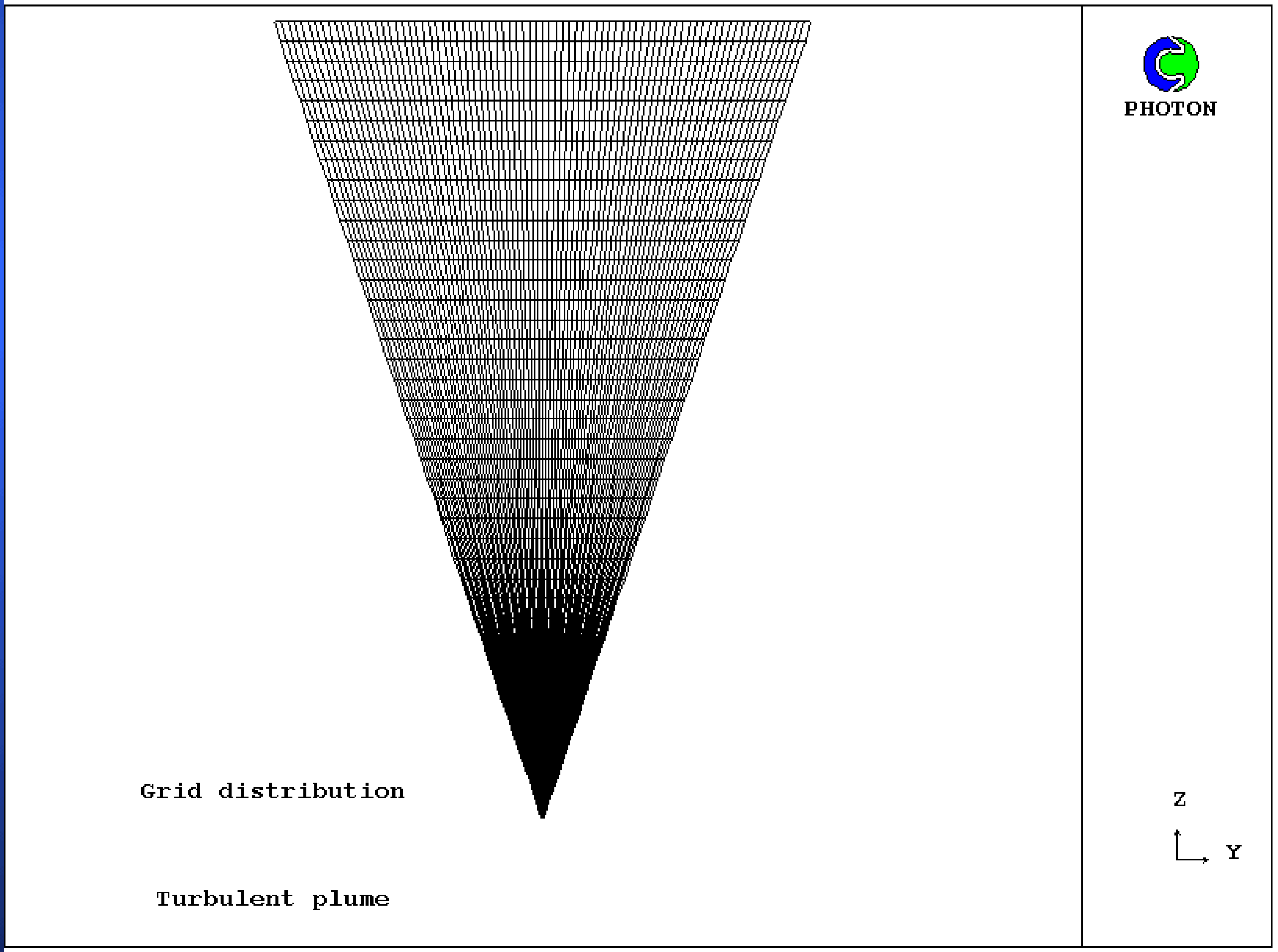
• The calculation is steady with a uniform oil release rate.

• The parabolic mode with an expanding grid is employed for both economy and accuracy.

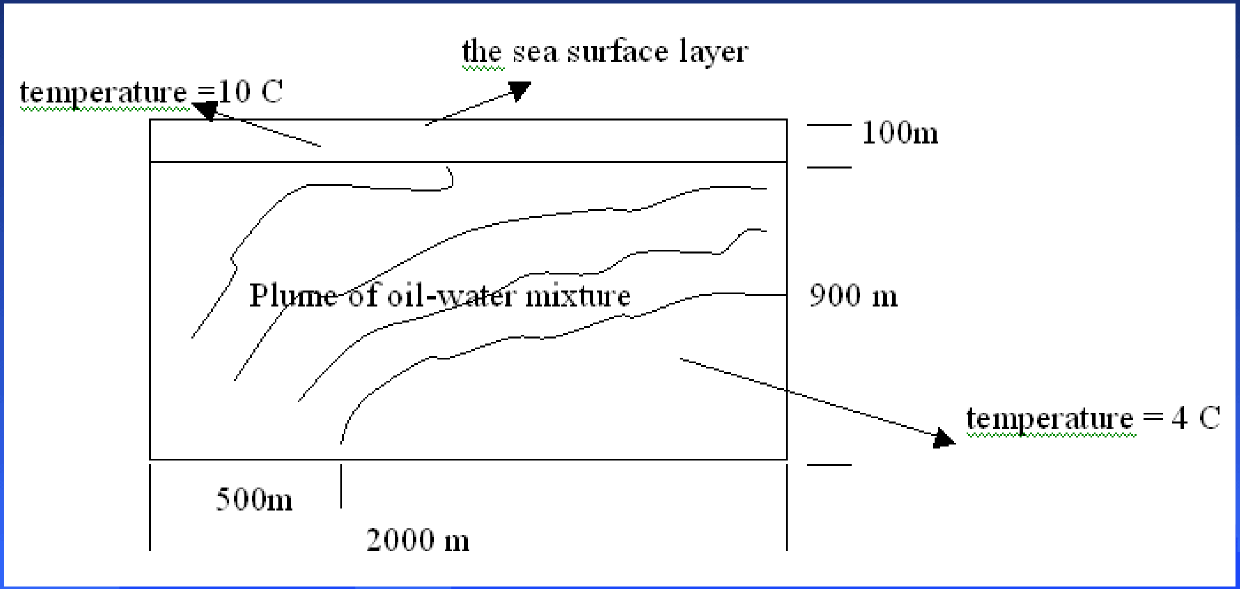
•The calculation includes a solution of a residence-time equation.

• Calculations are performed over a wide range of flow rates, from 20 tonnes per day to 70,000 tonnes per day, and with sufficiently fine grids, to demonstrate grid independence.

An expanding grid of 40x200 is used for parabolic calculations covering 3500 m in vertical direction with 1100 m radius at the top from axis.



3. Work performed for Region 5



For region 5,

- A steady-state elliptic calculation is performed.
- A temperature equation is solved.
- The buoyancy force is a linear function of both oil and concentration and temperature.
- Provision is made for a temperature distribution at the remote from spill boundary which represents a higher temperature near the sea surface.

4. The CFD Models

The model is summarised below.

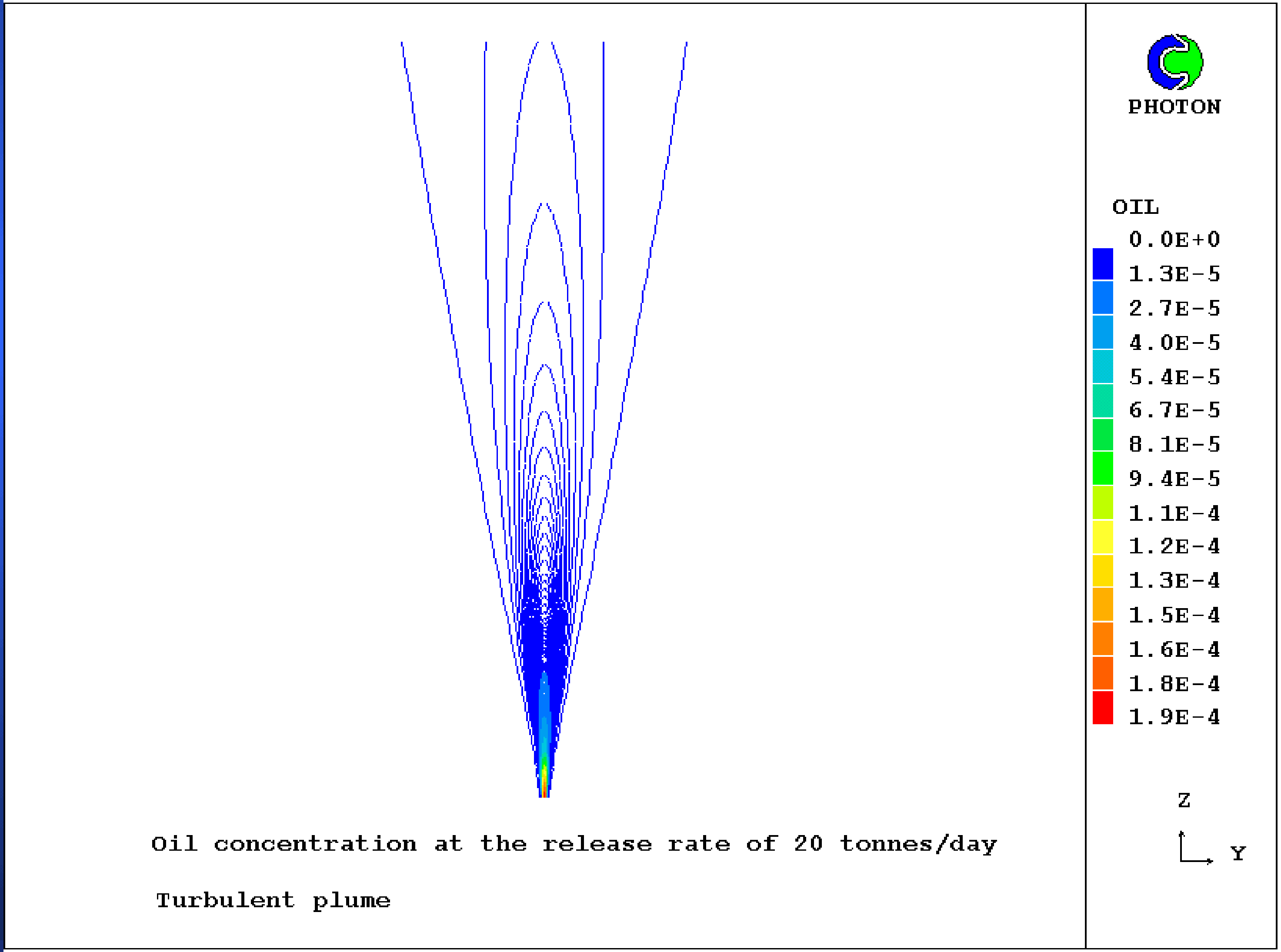
- because the distances are so large, and the Reynolds Number likewise, the flow in the plume of water and oil above the vessel will be turbulent;
- the size of the oil fragments will be much smaller than the width of the plume;
- the velocity of these fragments relative to the surrounding water will be negligible compared with the velocity of both.

4.The CFD model (cont.)

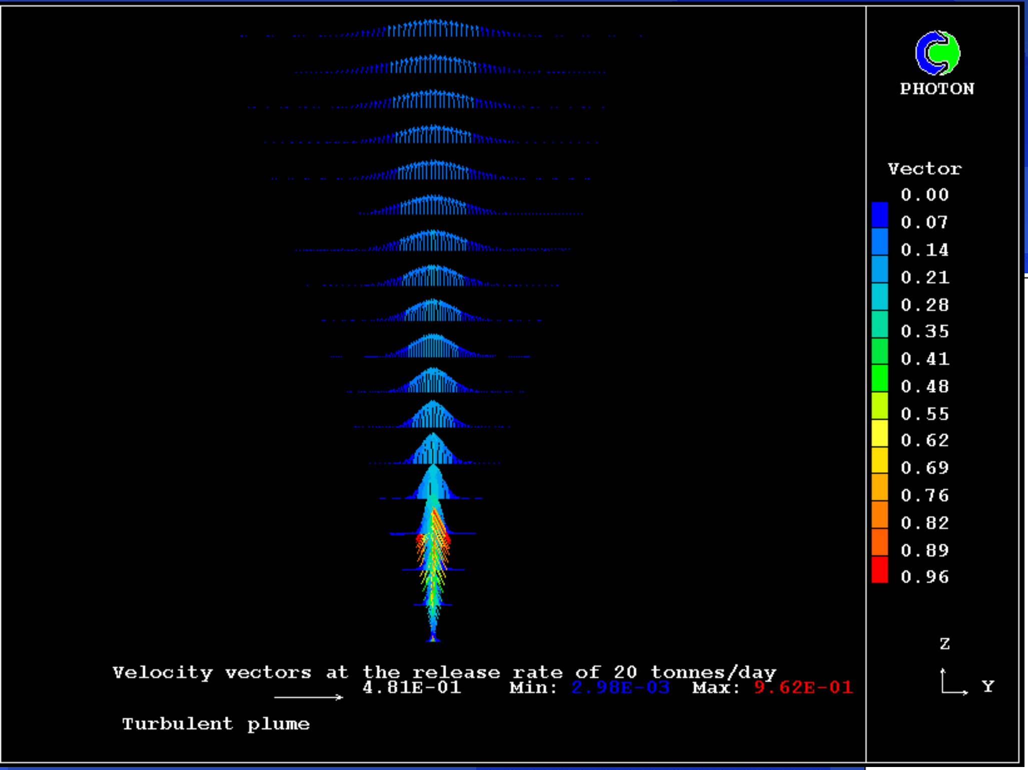
- This has permitted the use of the one-phase option of PHOENICS rather than the two-phase one.
- As a consequence, it has been possible to presume that the density of the oil-water mixture is dependent only on the mass fraction of the oil in the mixture.
- Influences of pressure and temperature on the density have been neglected.

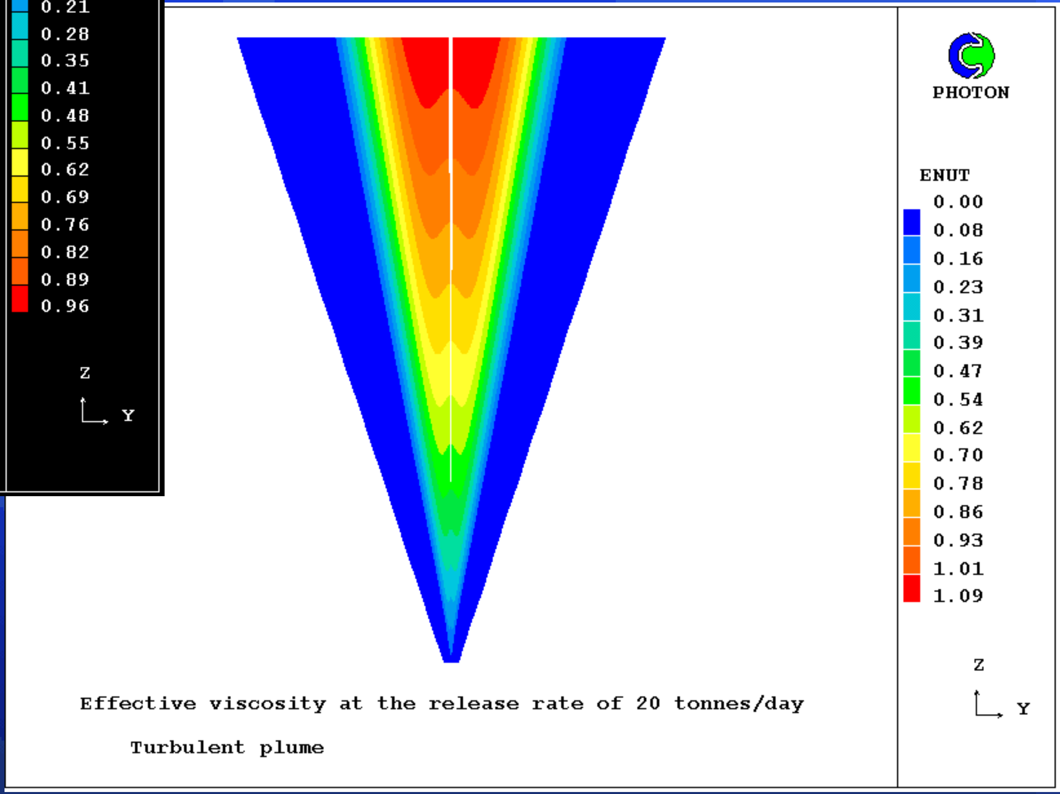
5. Presentation of the results of calculations for Region 4

The oil concentration (20 tonnes/day)

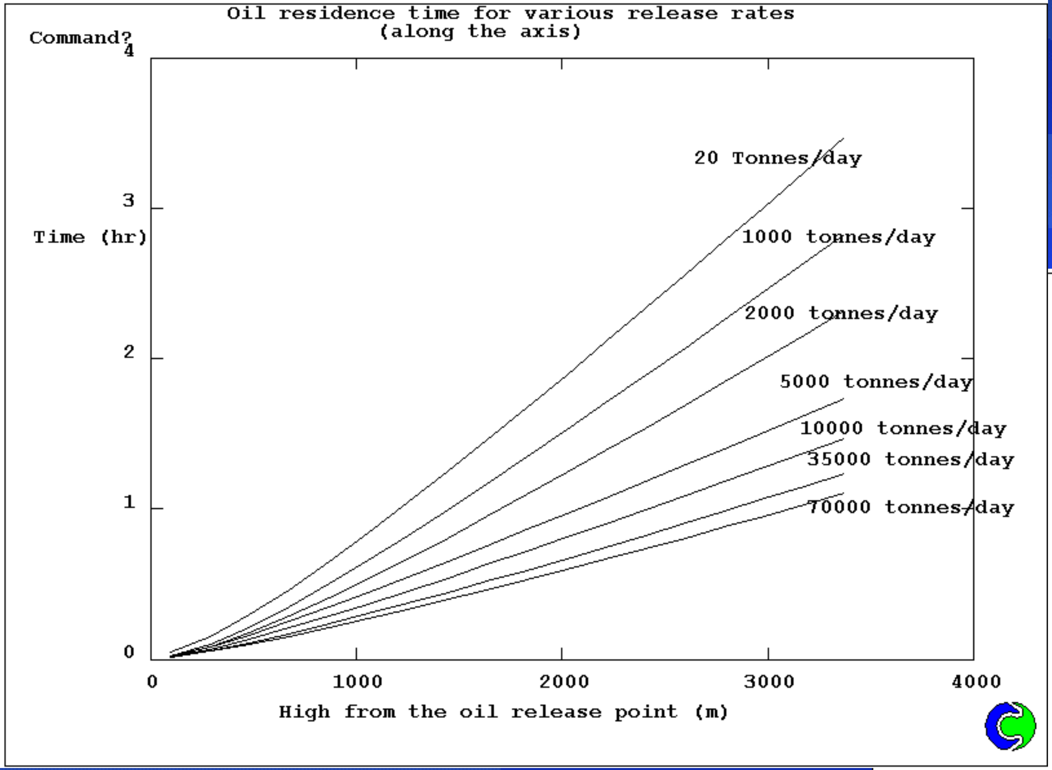


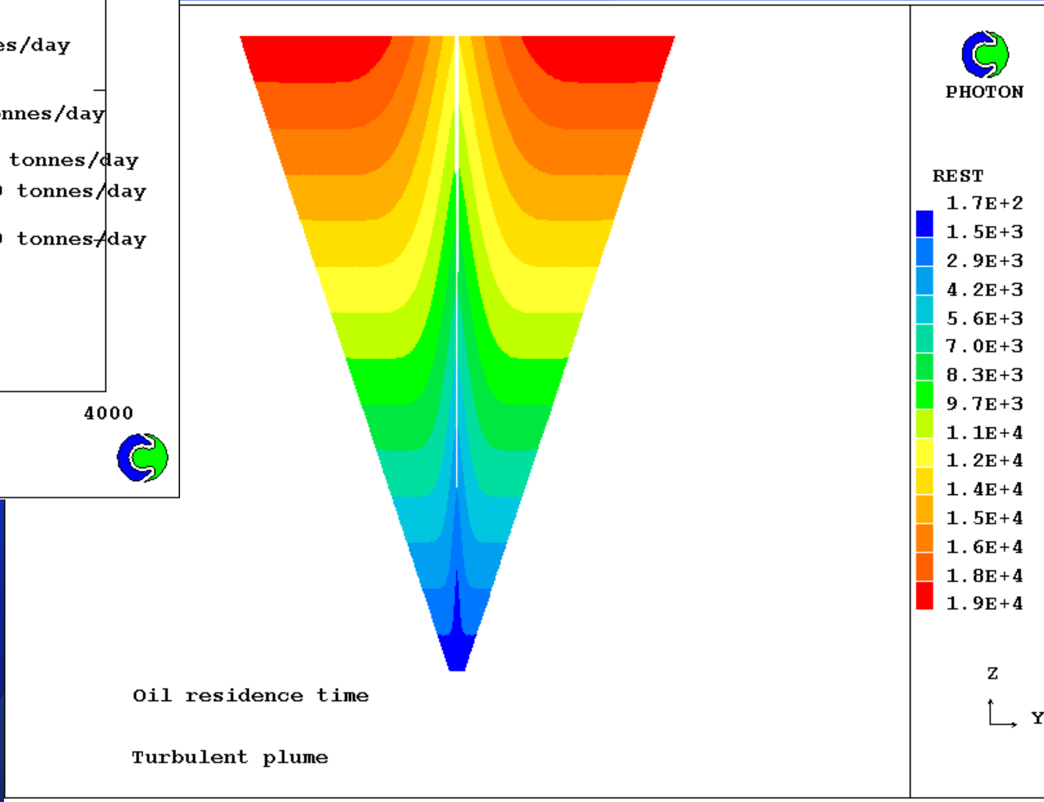
Velocity vectors and Effective viscosity





Oil residence time





Two-phase calculation

- The mathematical expression for the inter-phase drag coefficient used in this calculation is empirical as follows.

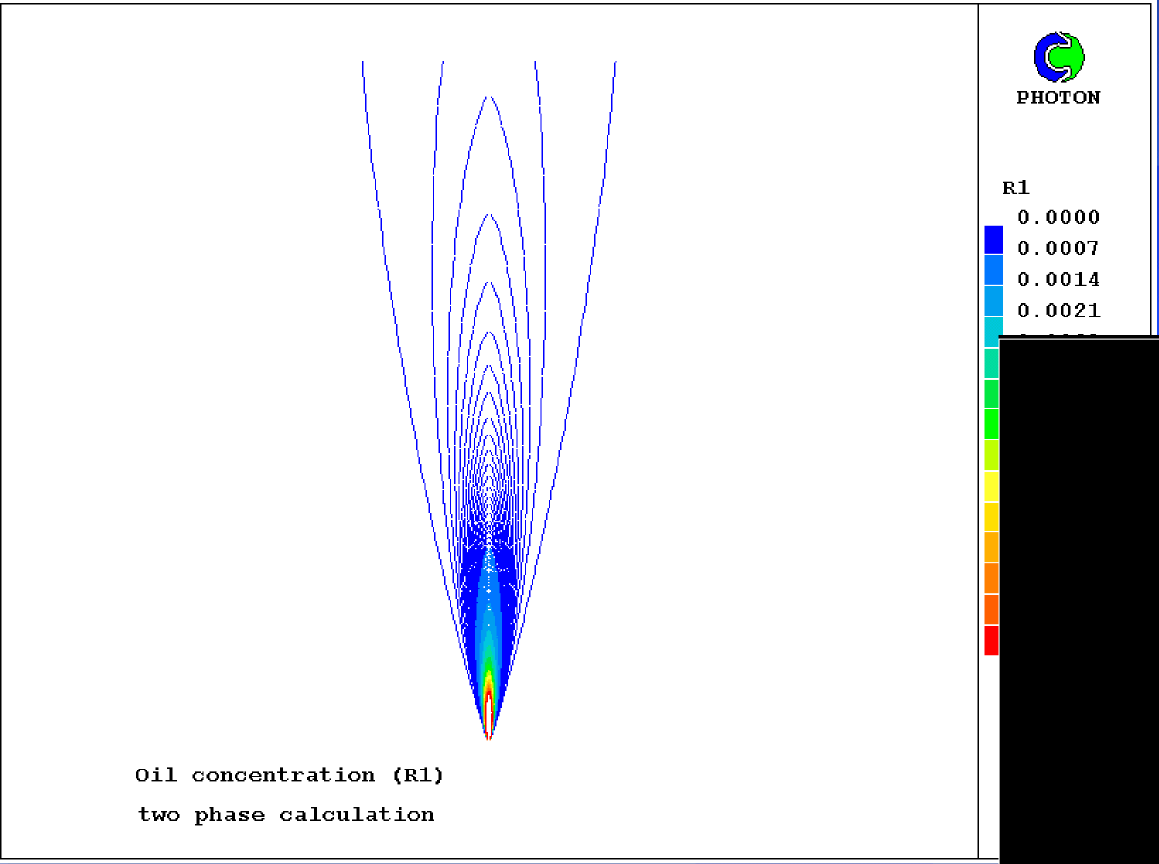
  FIP = 0.75*Cd*RHO1*R2*R1*Vol*/Dp

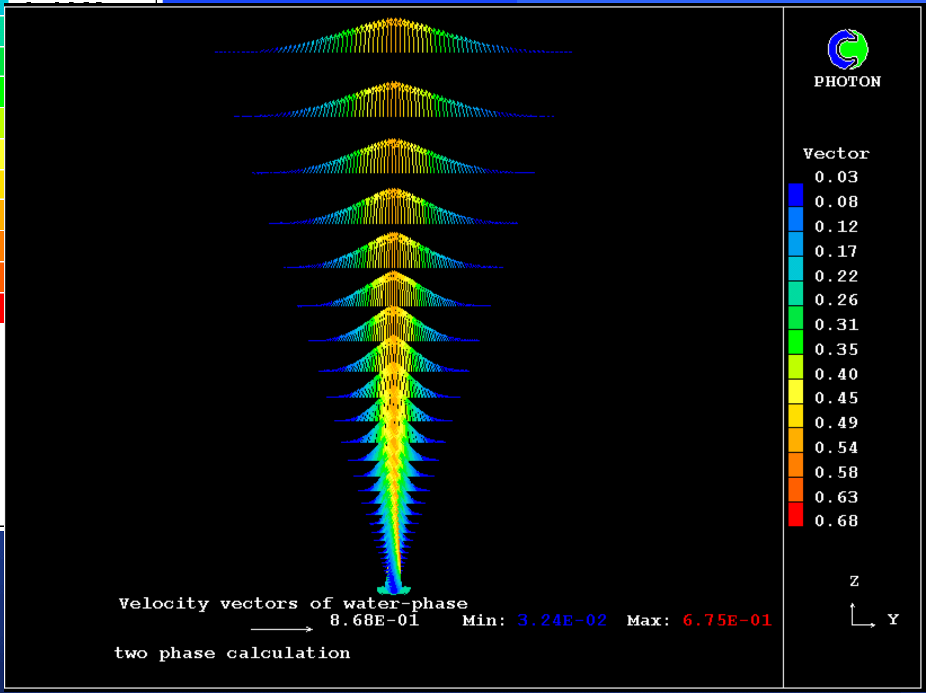
  where Cd uses a standard drag curve coefficient [Ref 4], Vol is the cell volume, R1 and R2 are the volume fraction of oil and water respectively, Dp is the diameter of the oil droplets which is a function of the mean volume fraction of oil over the calculation domain as follows

  Dp= Dpo * R1 **0.33

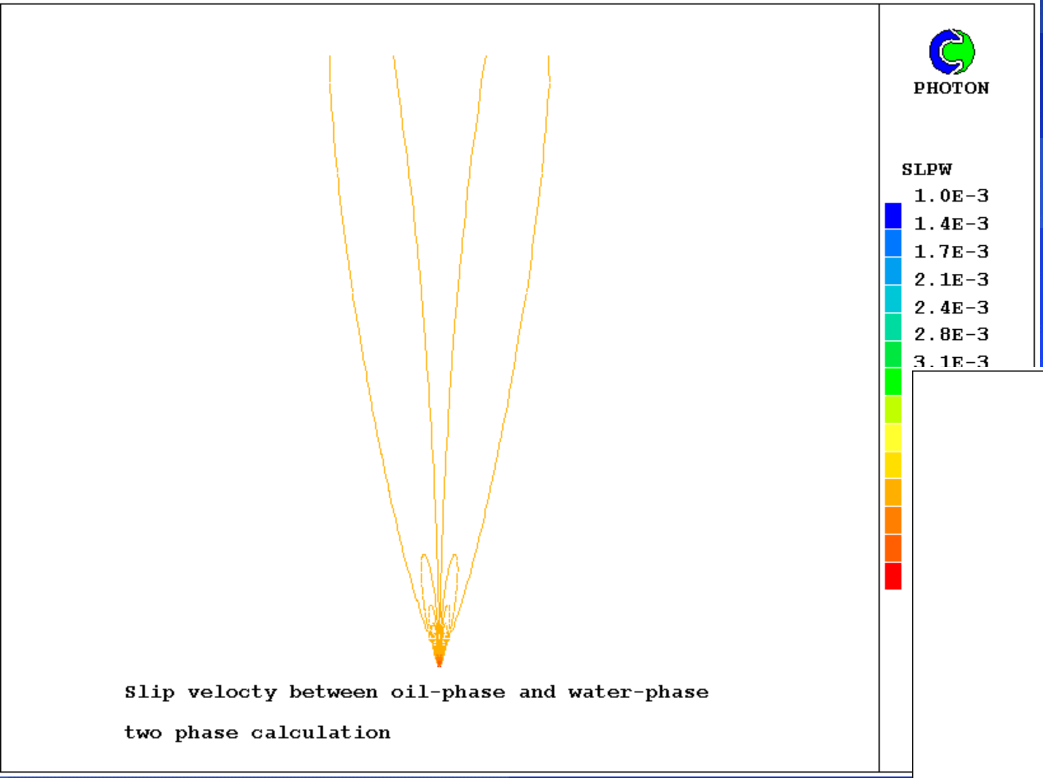
  where the Dpo is the droplet diameter at the oil release point and 10% of the aperture diameter is taken for Dpo and the mean volume fraction of the oil-phase is 1.e-4 which is based on the result from the single-phase calculation.

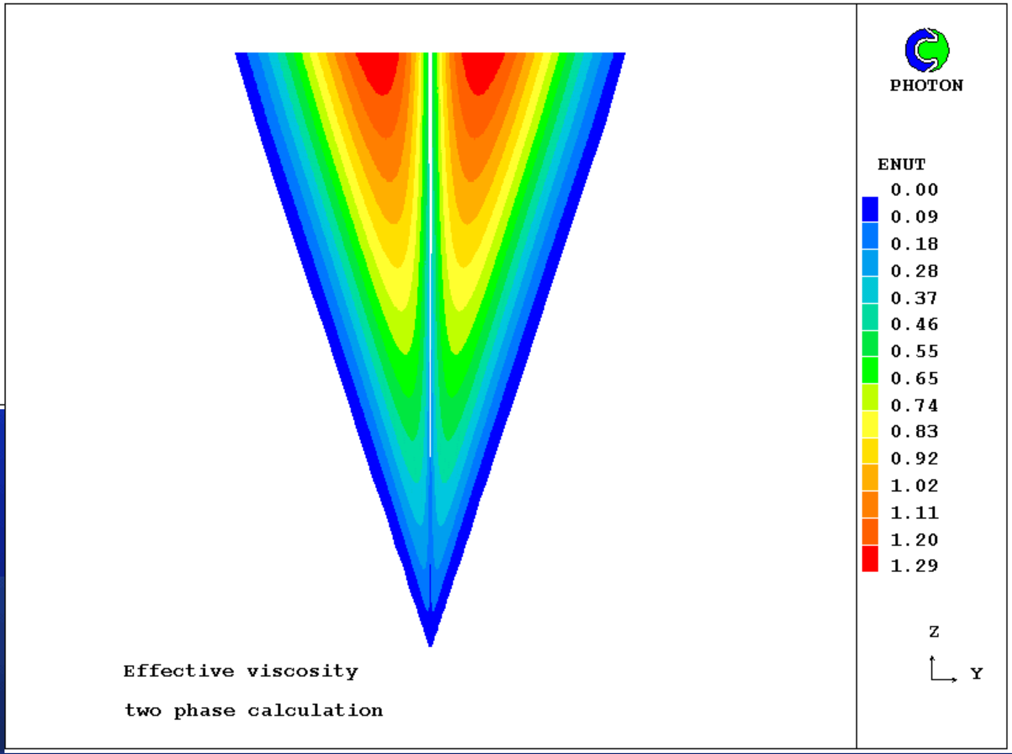
The results from the two-phase calculation are generally consistent with those from the single-phase calculation.





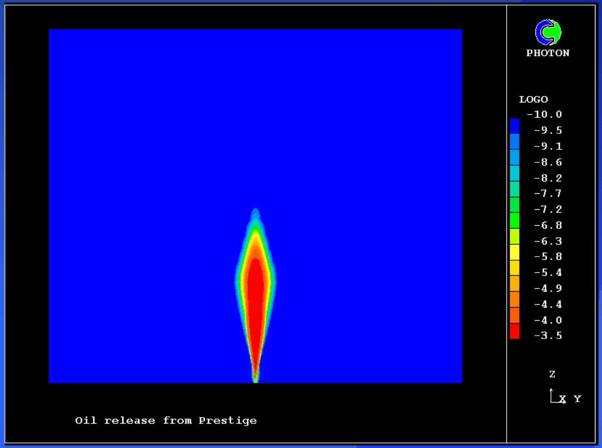
The value of the slip velocity is very small ranging from1.e-3 to 6.e-3 m/s.



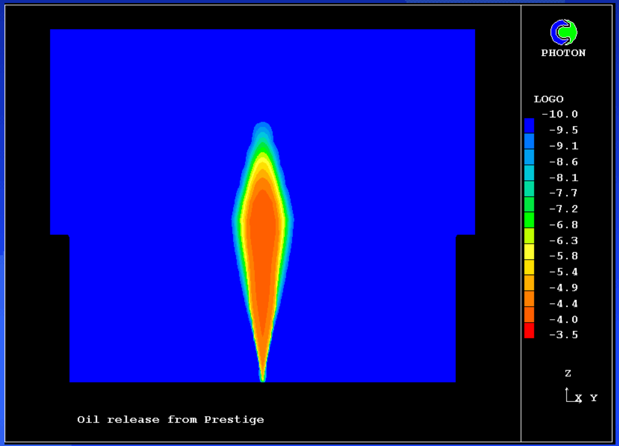


Unsteady calculation

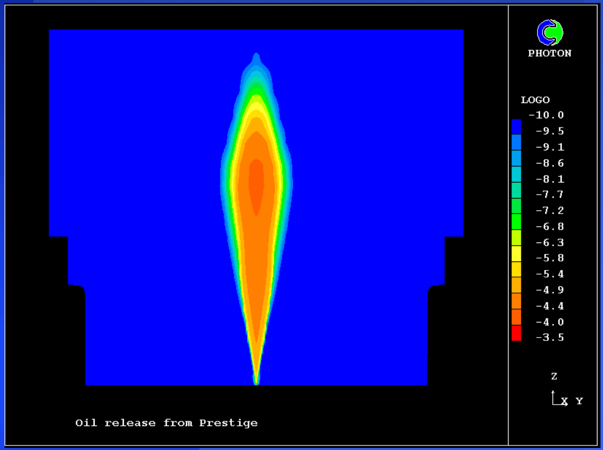
Oil concentration at various time



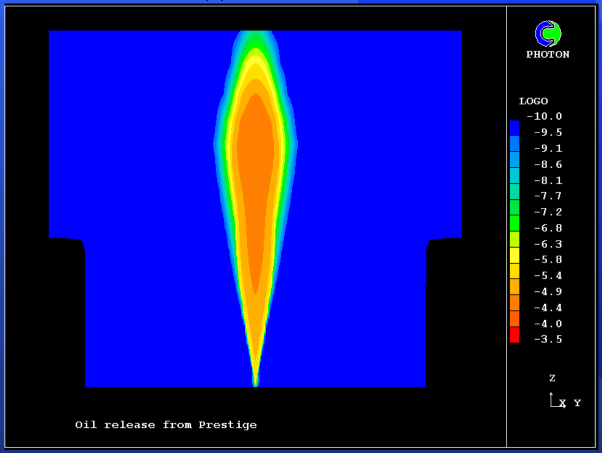
(1) Time = 4320 s



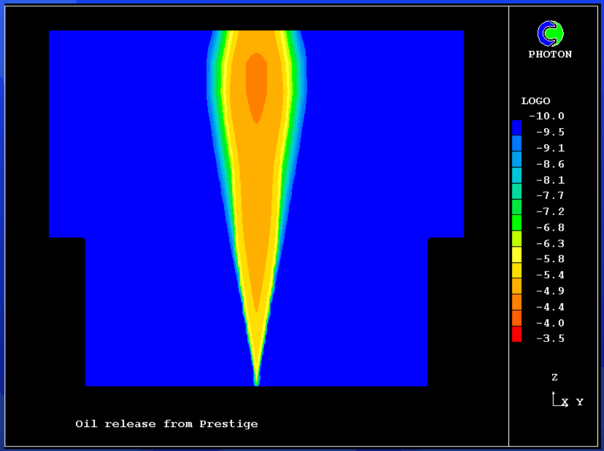
(2) Time = 8640 s



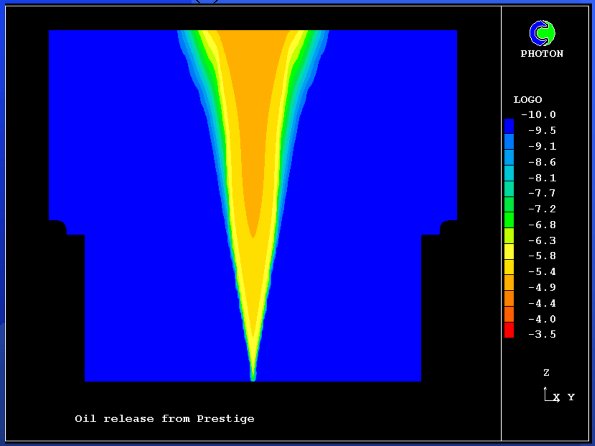
(3) Time = 12960 s



(4) Time = 17280 s



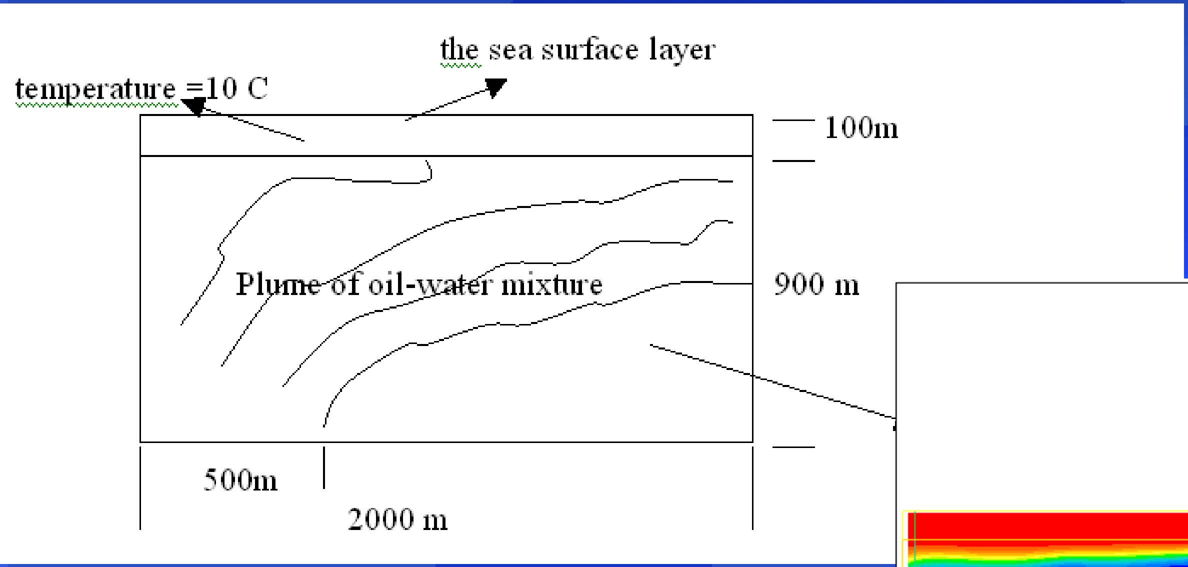
(5) Time = 28080 s

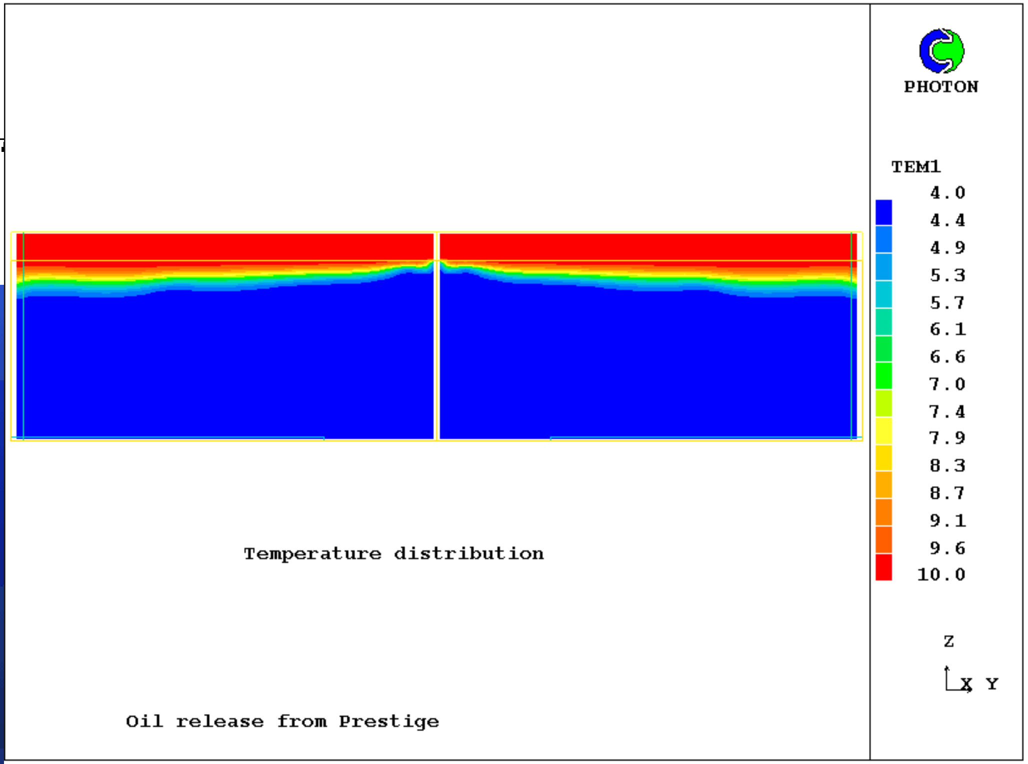


(6) Time = 34560 s

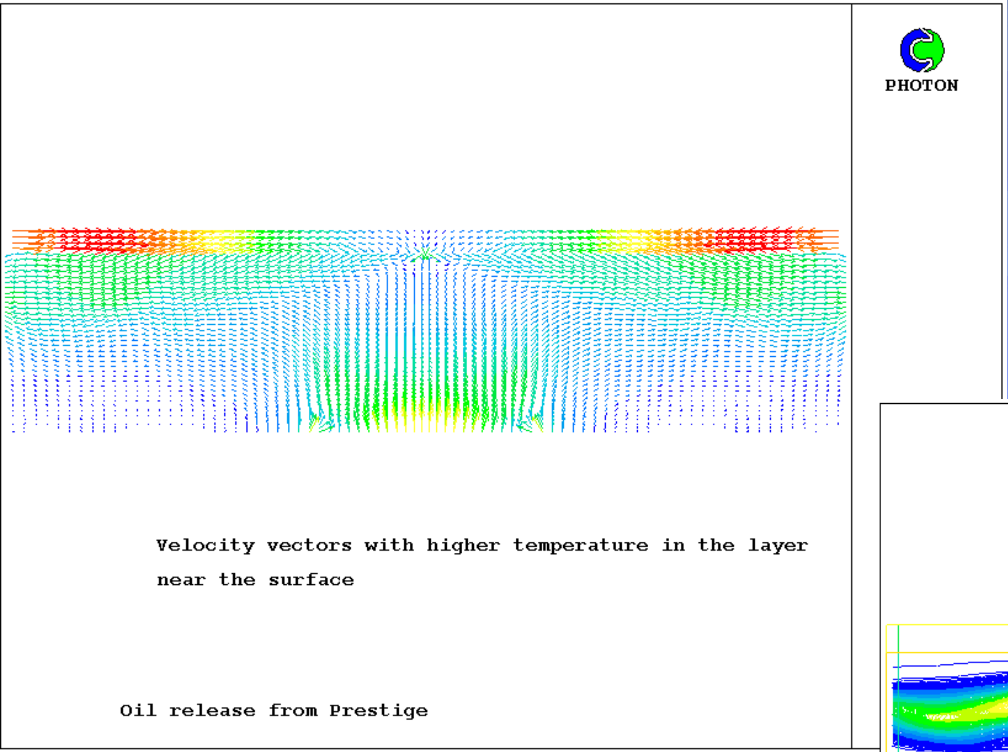
5. Presentation of the results of the calculation for Region 5.

Temperature contours

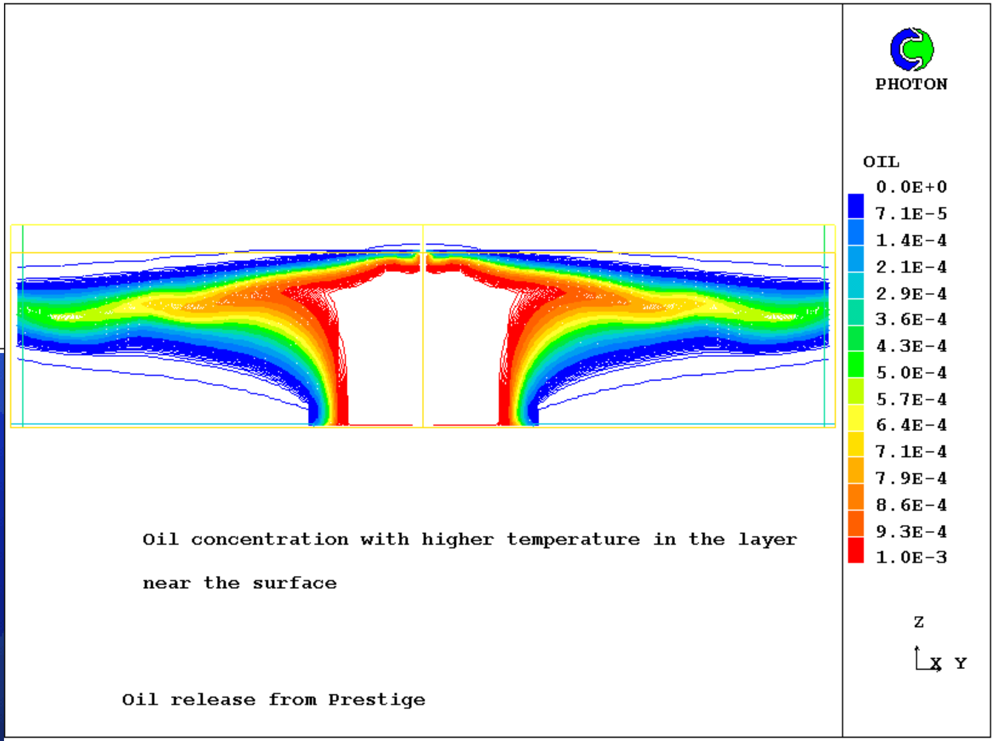




Velocity vectors. (the largest velocity is 0.035 m/s) and oil concentration contours



The plume flows horizontally out through the boundary



6. Discussion

- Computer simulations incorporating this fact showed that the smaller density of the thermocline water prevented the oil-water plume from reaching the surface at all.
- Instead, having reached the level at which its density was no longer smaller than that of the undisturbed ocean, it spread horizontally, as can be seen from the accompanying figures.
- This conclusion can be regarded as rather agreeable; for it suggests that the oil from the PRESTIGE may not ever pollute the shore.

6. Discussion (cont.)

- However this condition rests on the supposition that the oil is sufficiently finely divided not to “slip” significantly relative to the surrounding water.
- This supposition is believed indeed to be correct for the upward rising plume;
- but, in the horizontally spreading near surface layer, in which the residence time will become very long, it may well not be.

7. Acknowledgements

The computer model used in this study was proposed by Professor D B Spalding and the project was sponsored by SHOM, France.

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