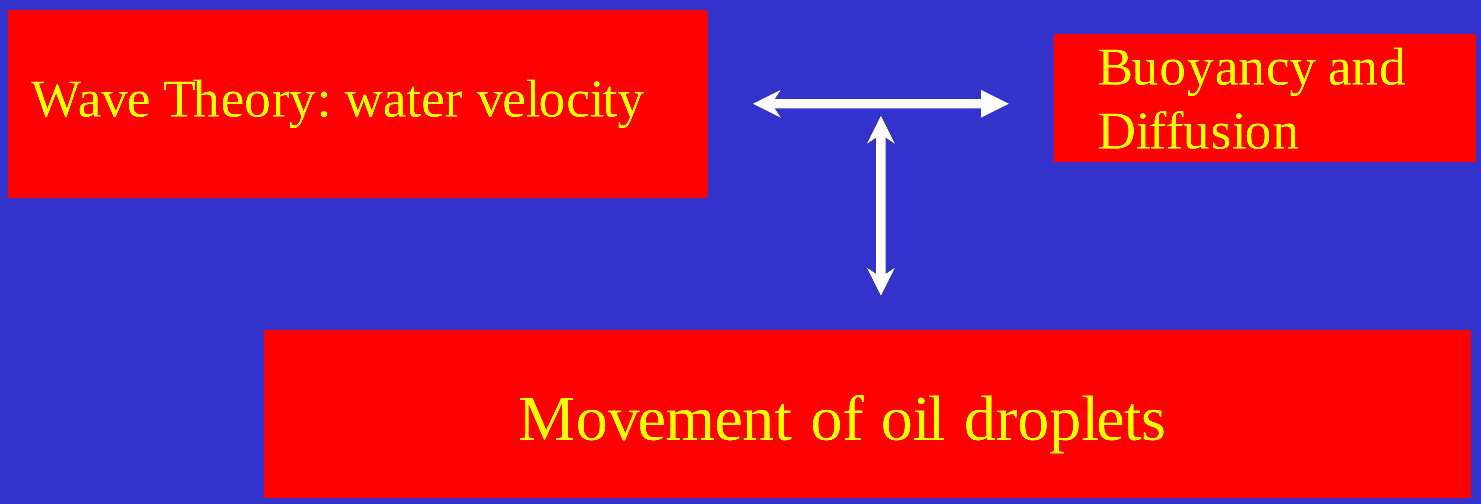
The Transport of Oil in Water Bodies Subjected to Waves

Michel C. Boufadel, PhD, PE
Temple University, Philadelphia PA
boufadel@temple.edu

and

James W. Weaver, PhD
National Exposure Research Lab, Athens GA

NUMERICAL MODEL



- Boufadel, Bechtel, and Weaver , Marine Pollution Bulletin, 2006
- Boufadel, Du, Kaku, and Weaver, Environmental Modeling & Software, 2006

PROBLEM STATEMENT

- Traditional oil spill models focused on large-scale

-The physics of the waves was not accounted for

-Studies could not be generalized.

Particle Tracking

$$x_{n+1} = x_n + u\Delta t + \varepsilon R\sqrt{2D\,\Delta t}$$

$$z_{n+1} = z_n + \varepsilon\left[w + w_B\right]\Delta t \ + \varepsilon R\sqrt{2D\,\Delta t}$$

$$\varepsilon = \frac{H}{L}; \qquad D = \frac{D^*}{D_o} = \frac{D^*}{\frac{H^2}{T}}; \qquad w_B = \frac{w_B^*}{\frac{H}{T}} = \frac{w_B^*}{\varepsilon\frac{L}{T}}$$

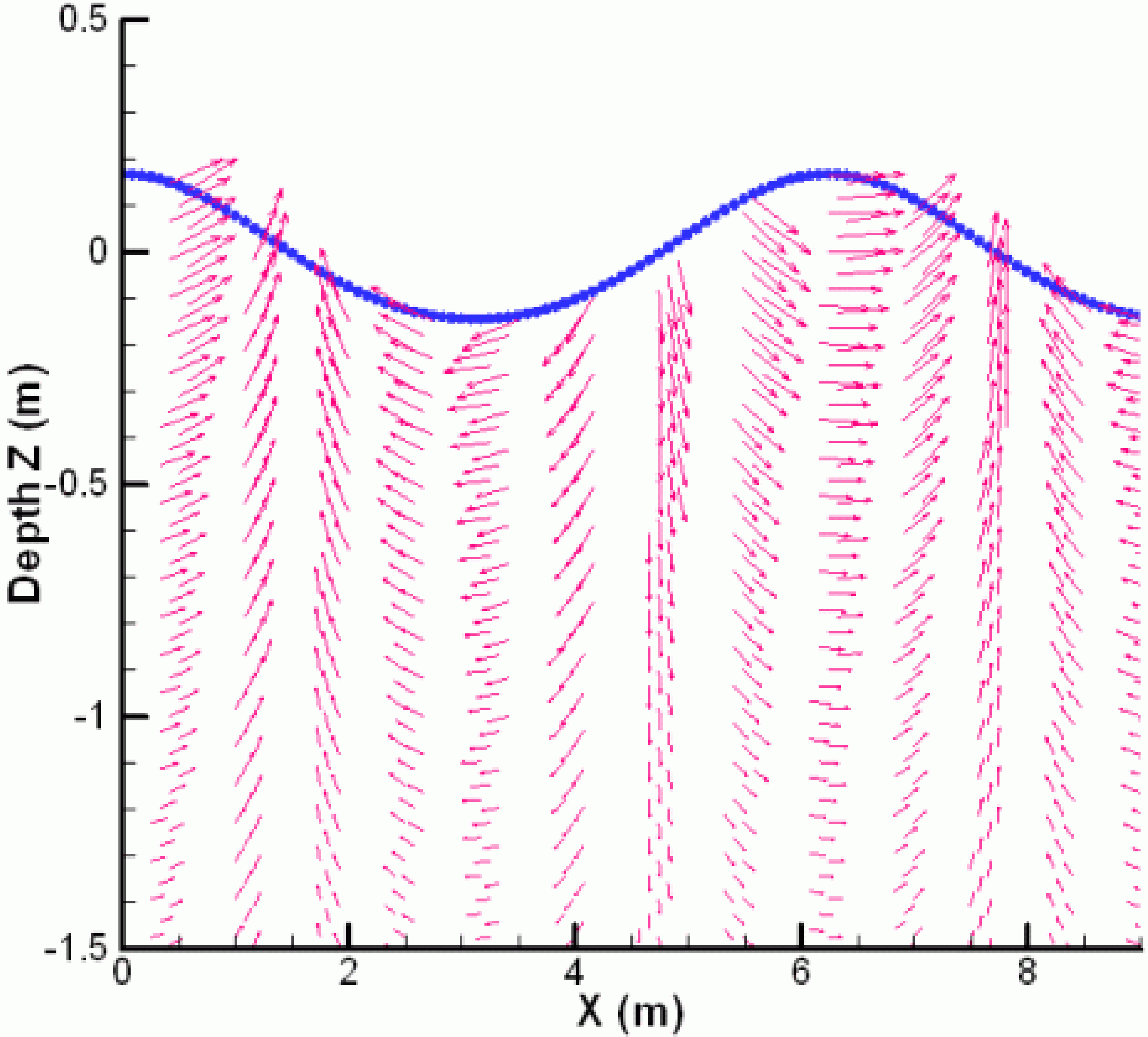
$$x = \frac{x^*}{L}; z = \frac{z^*}{L}; t = \frac{t^*}{T}; h = \frac{h^*}{L}$$

$$u^* = \frac{Hgk}{2\sigma} e^{kz^*} \cos(kx^* - \sigma t^*) + \frac{3H^2\sigma k}{16} e^{2kz^*} \cos 2(kx^* - \sigma t^*)$$

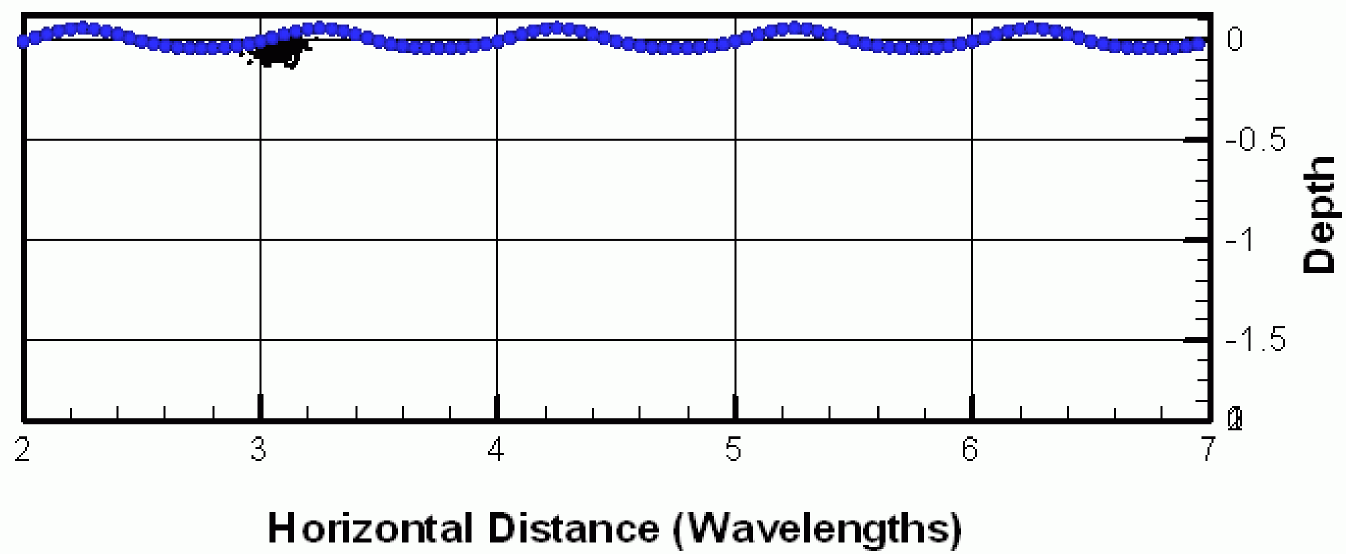
$$w^* = \frac{Hgk}{2\sigma} e^{kz^*} \sin(kx^* - \sigma t^*) + \frac{3H^2\sigma k}{16} e^{2kz^*} \sin 2(kx^* - \sigma t^*)$$

$$u = \frac{u^*}{\frac{L}{T}}; w = \frac{w^*}{\frac{H}{T}};$$

$$k = \frac{2\pi}{L}; \ \sigma = \frac{2\pi}{T}$$



0.5
0
-0.5
-1
-1.5
Depth Z (m)
0
2
4
6
8
X (m)


0
-0.5
-1
-1.5
Depth
2
3
4
5
6
7
Horizontal Distance (Wavelengths)

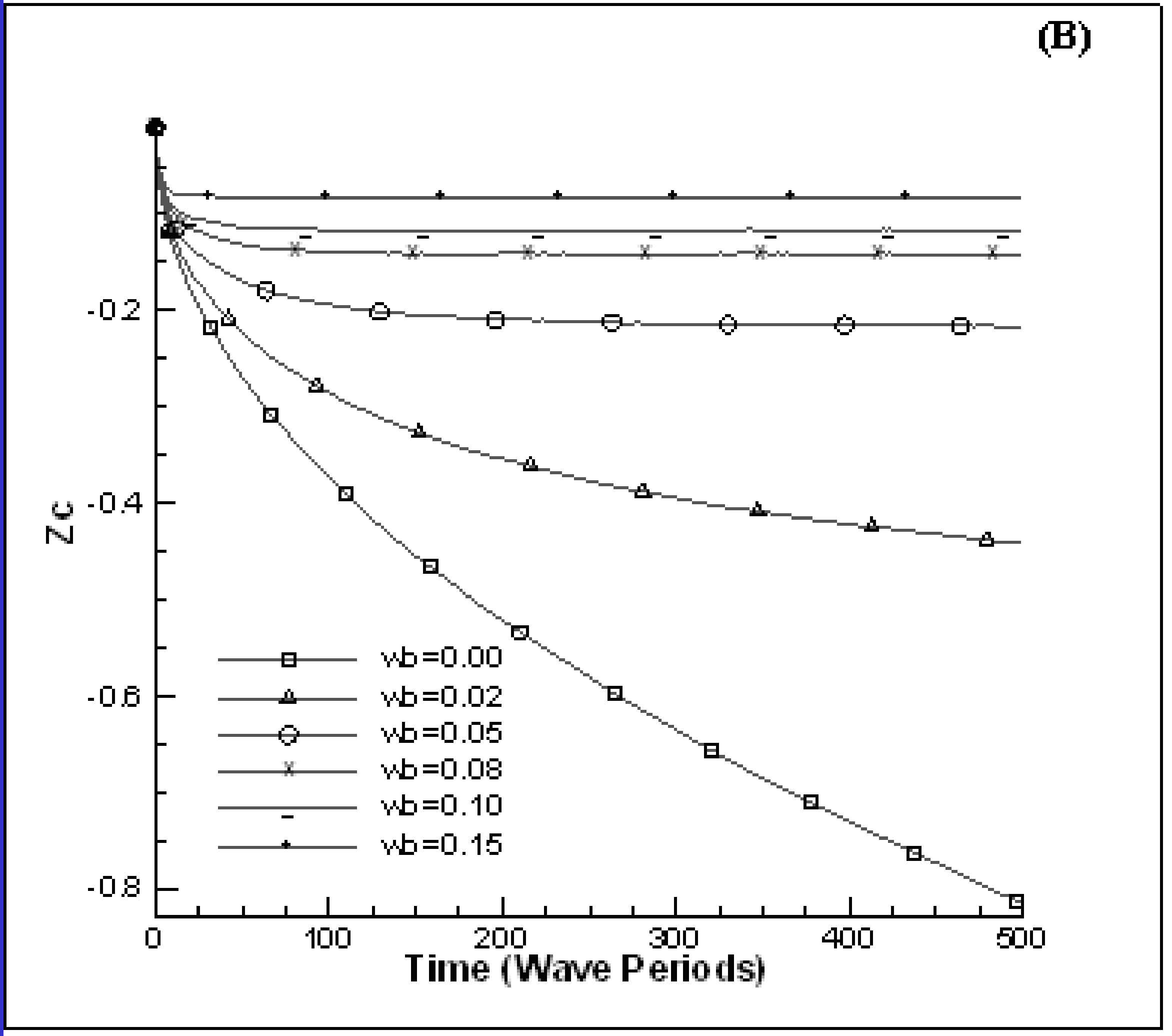
Monte Carlo Simulation

$$\varepsilon = \frac{H}{L} = 0.05 \; and \; 0.1$$

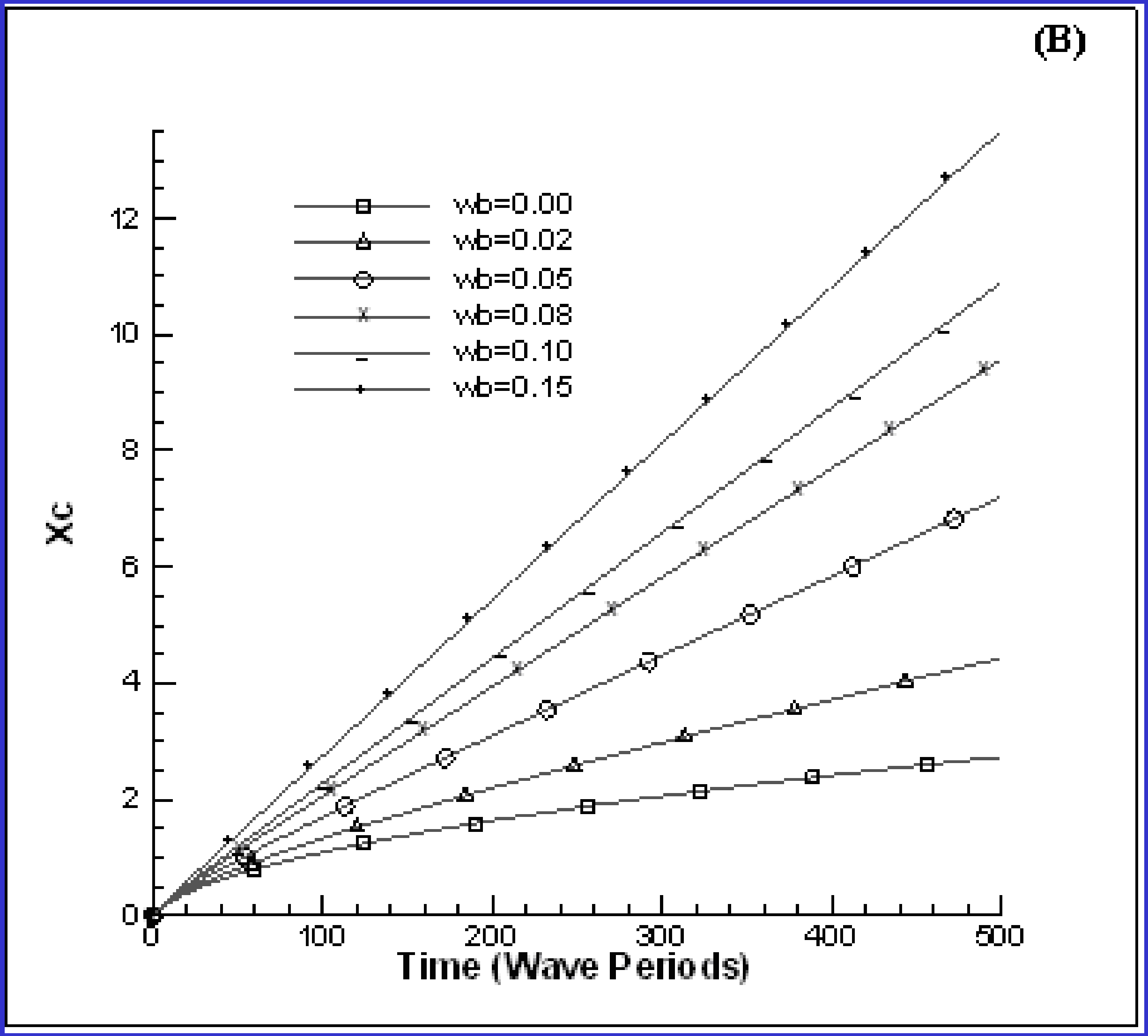
$$w_b = \frac{w_b^*}{\frac{H}{T}} = 0.0;\ 0.02;\ 0.05;\ 0.08;\ 0.1; \; and \; 0.15$$

$$D = \frac{D^*}{\frac{H^2}{T}} = 0.1$$

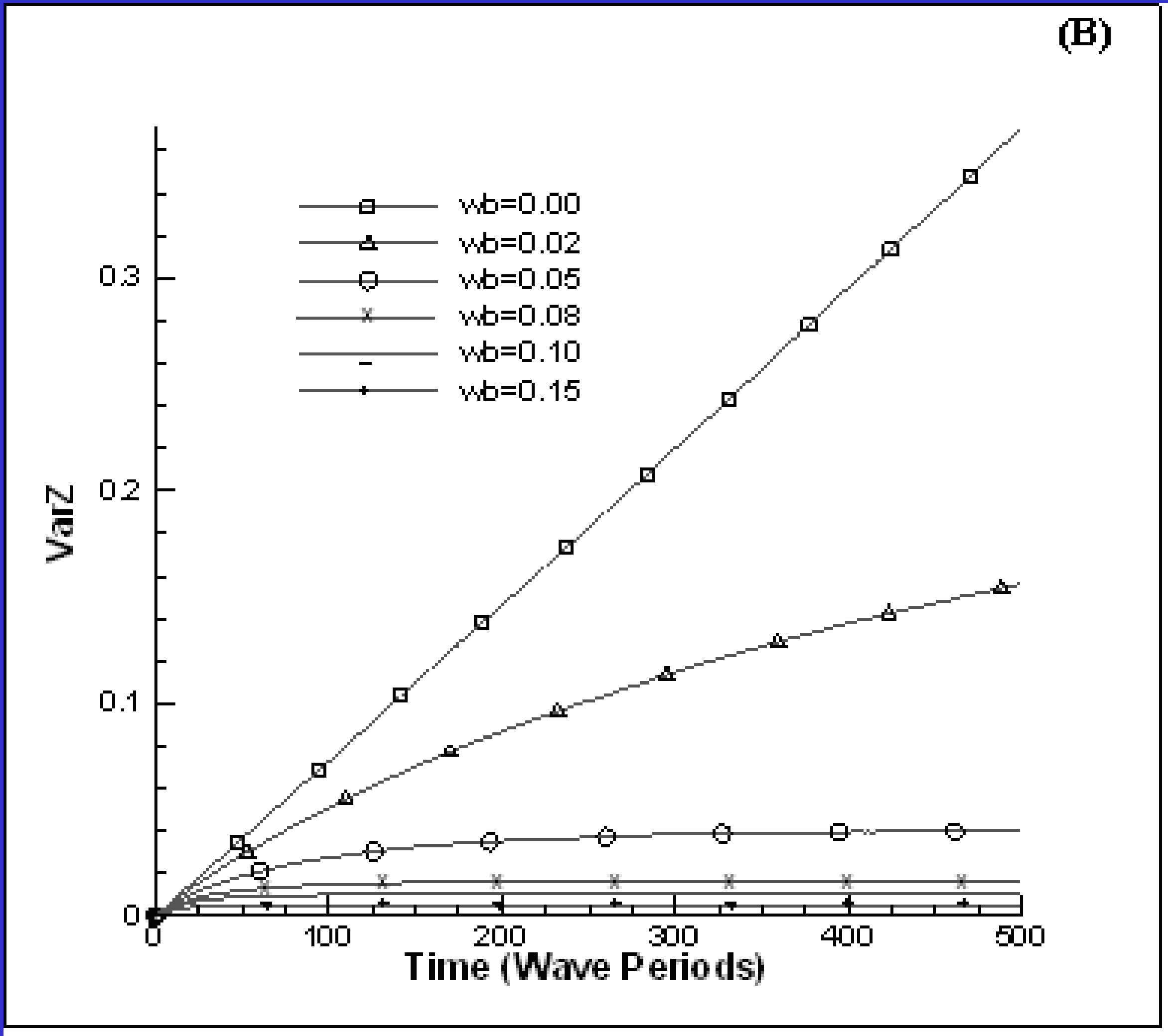
600 particles and 500 wave periods



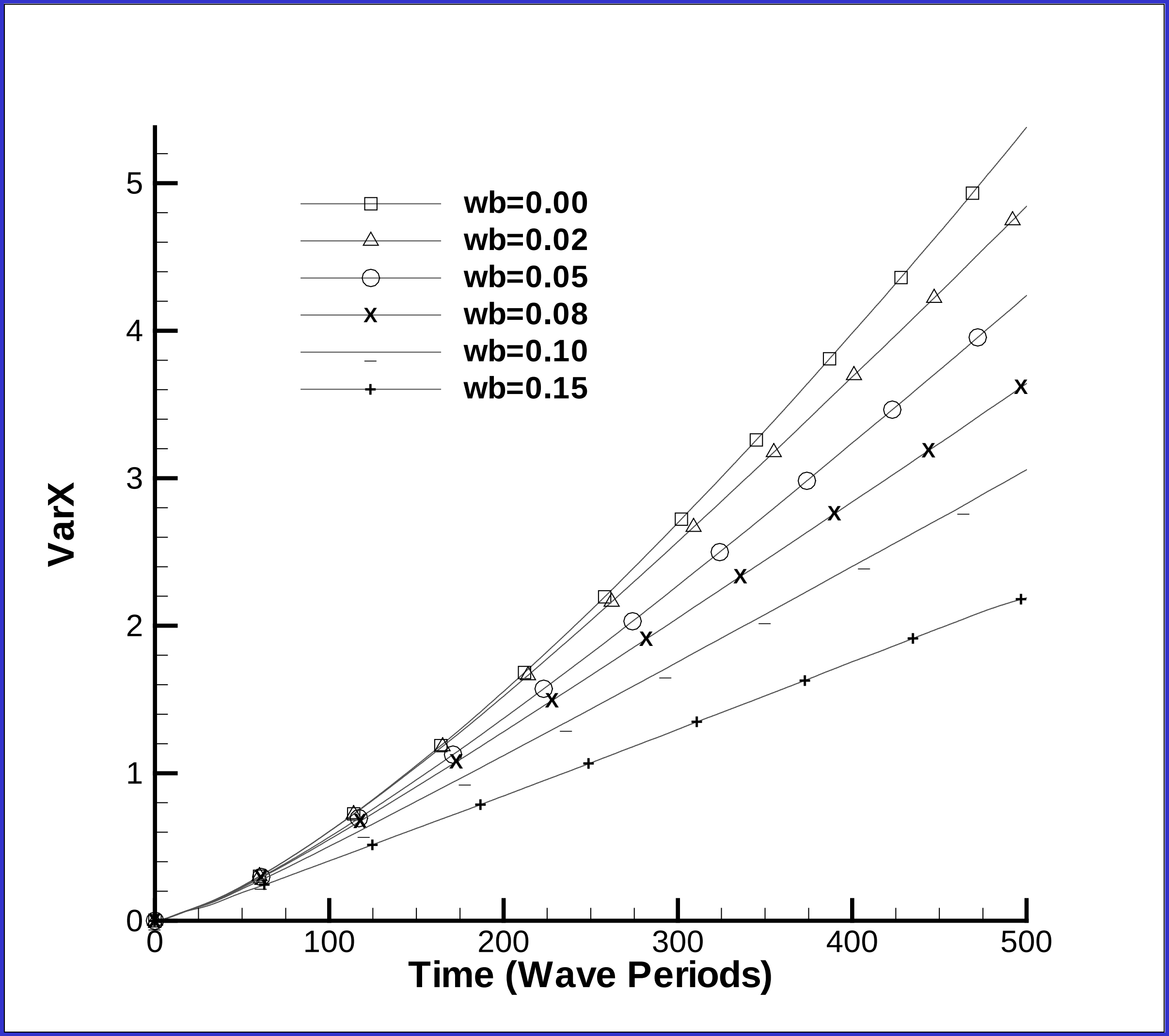
Effect of buoyancy on the vertical location of the centroid, Zc for H/L=ε=0.1.
The initial location was at Zc=-0.01. The depth is expressed in units of wave length.



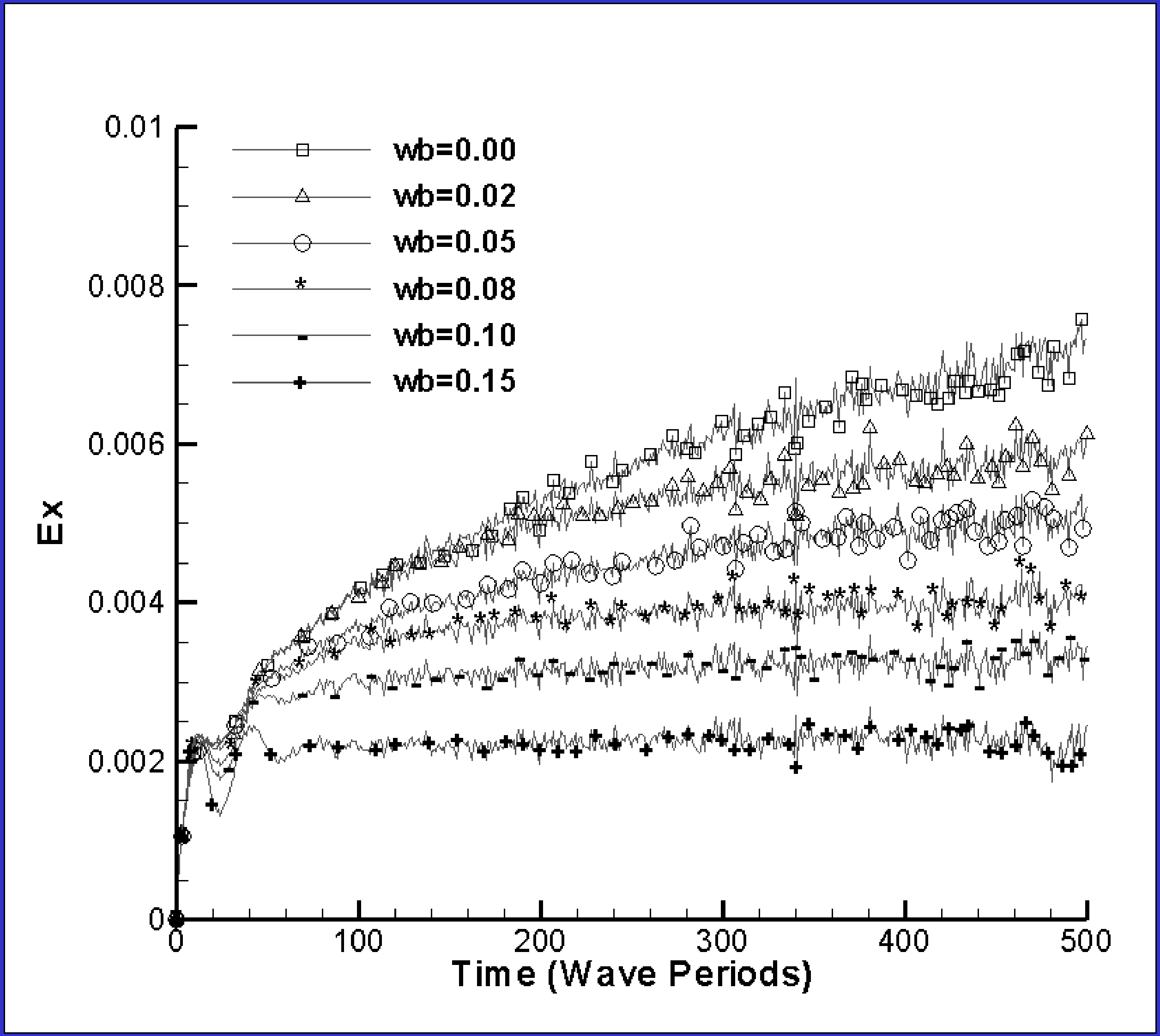
Effect of buoyancy on the horizontal location of the centroid, Xc for H/L= ε =0.1. The initial location was at Xc=0.0. The horizontal distances are expressed in units of wave length.



Effect of buoyancy on the dimensionless vertical variance, σ_z^2 for H/L= ε=0.1.



Effect of buoyancy on the dimensionless horizontal variance, σ_x^2 for ε=0.1.



Dimensionless spreading coefficients E_x as function of time for H/L 0.10.

CONCLUSIONS

- For the same size distribution, light oils moves faster but spread less than heavy oils.

- In fairly general conditions, the oil droplets become well mixed in the top 5 meters of the water column within 15 to 20 minutes.

- A novel dimensionless formulation to generalize the results to any oil was introduced.

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