

The Transport of Oil in Water Bodies Subjected to Waves

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

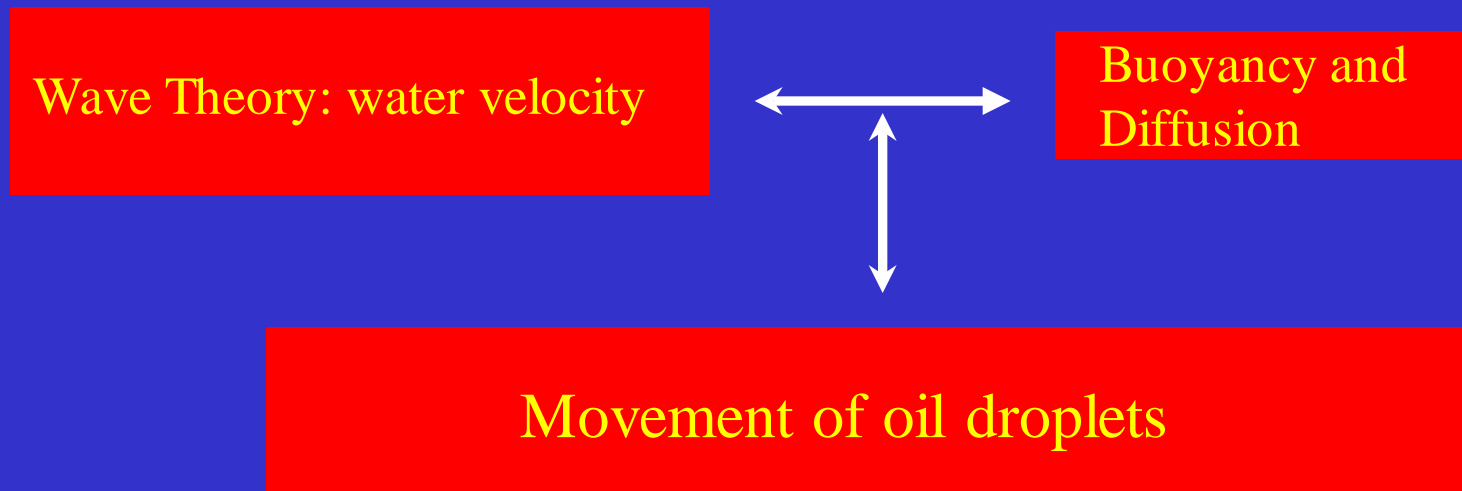
and

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

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

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

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

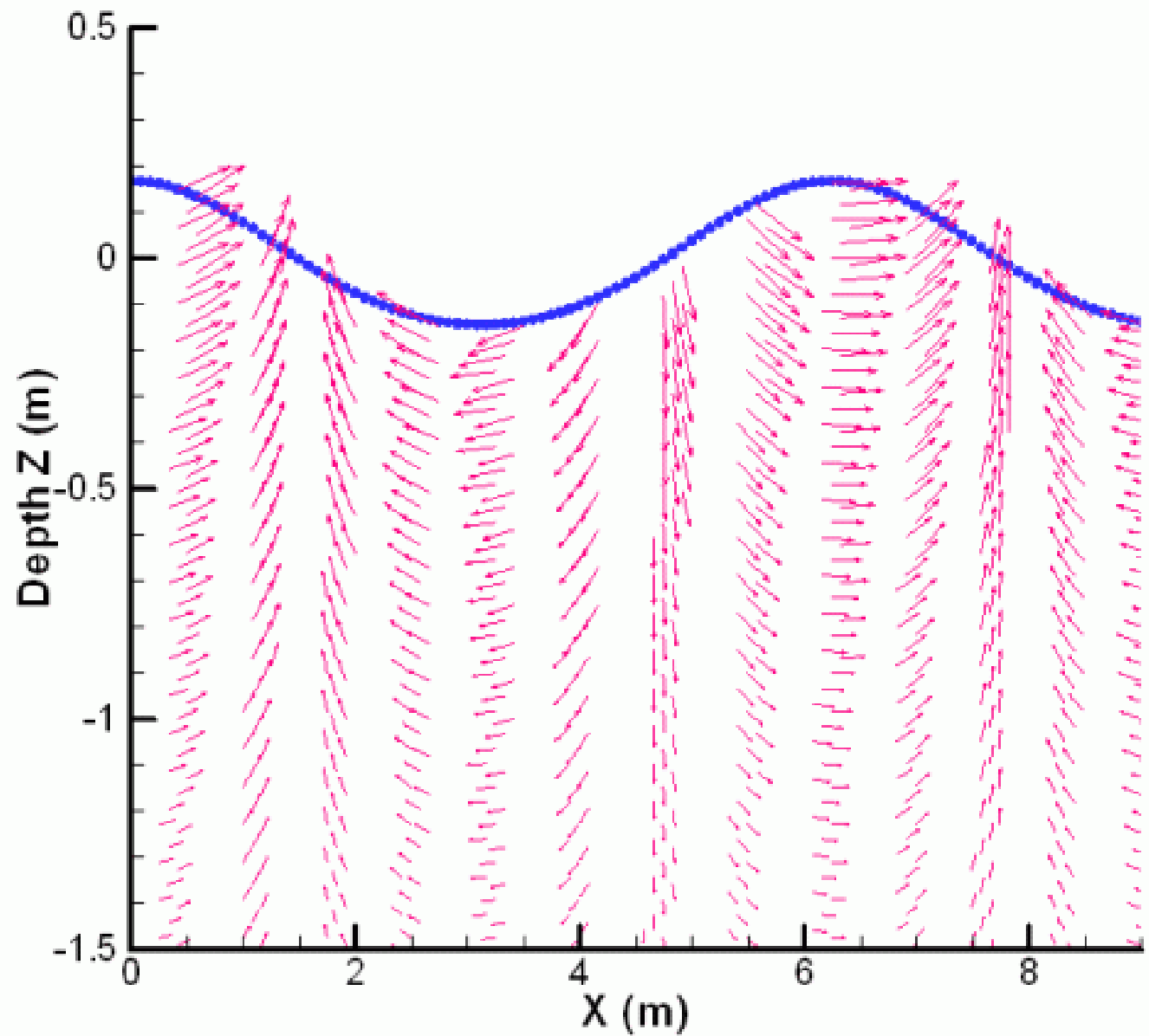
$$x = \frac{x^*}{L}; z = \frac{z^*}{L}; t = \frac{t^*}{T}; h = \frac{h^*}{L}$$

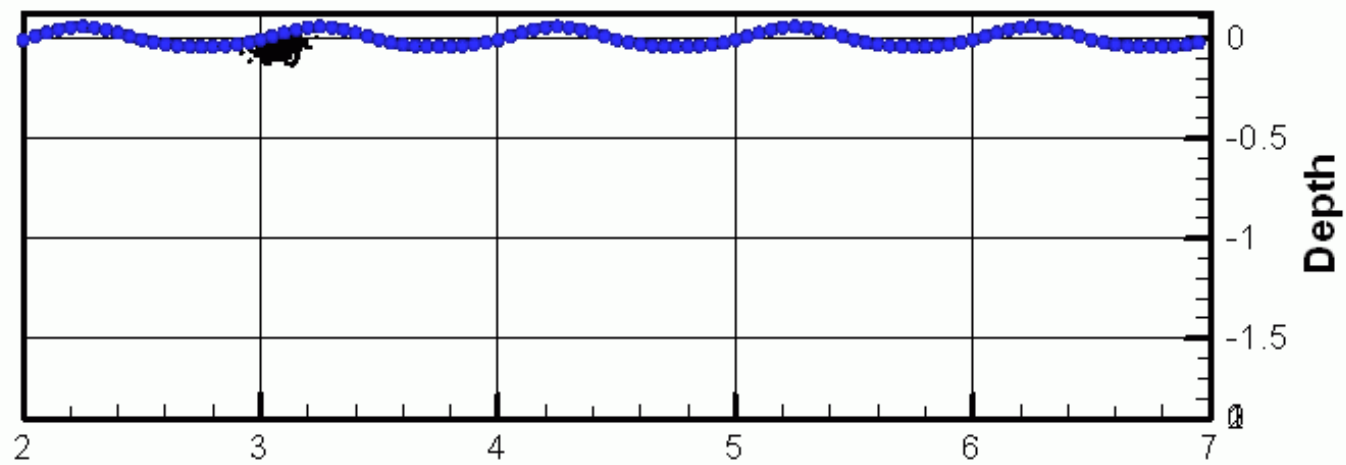
$$u^* = \frac{Hgk}{2\sigma} e^{kz^*} \cos(kx^* - \sigma t^*) + \frac{3H^2\sigma k}{16} e^{2kz^*} \cos 2(kx^* - \sigma t^*)$$

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

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

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





Horizontal Distance (Wavelengths)

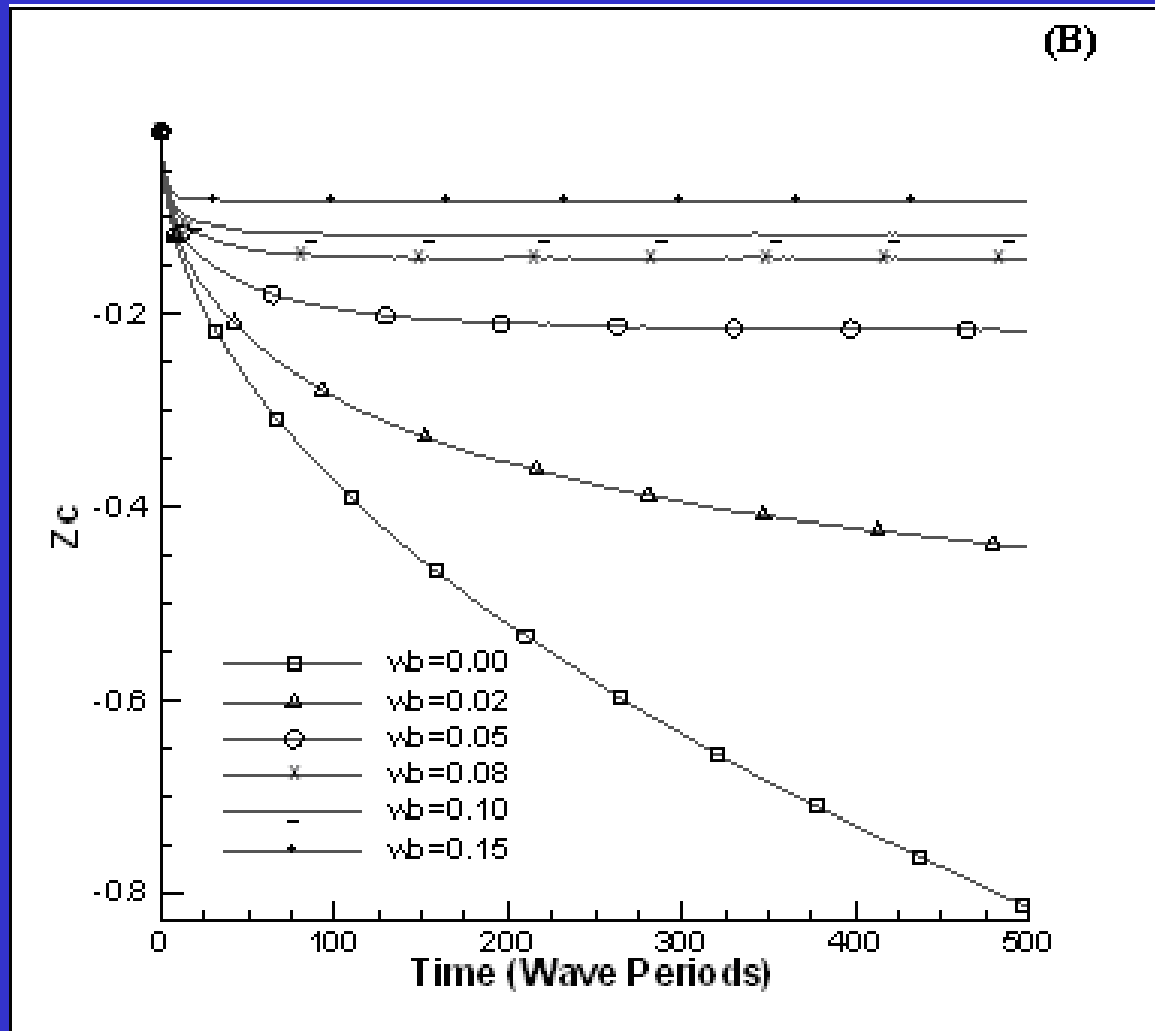
Monte Carlo Simulation

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

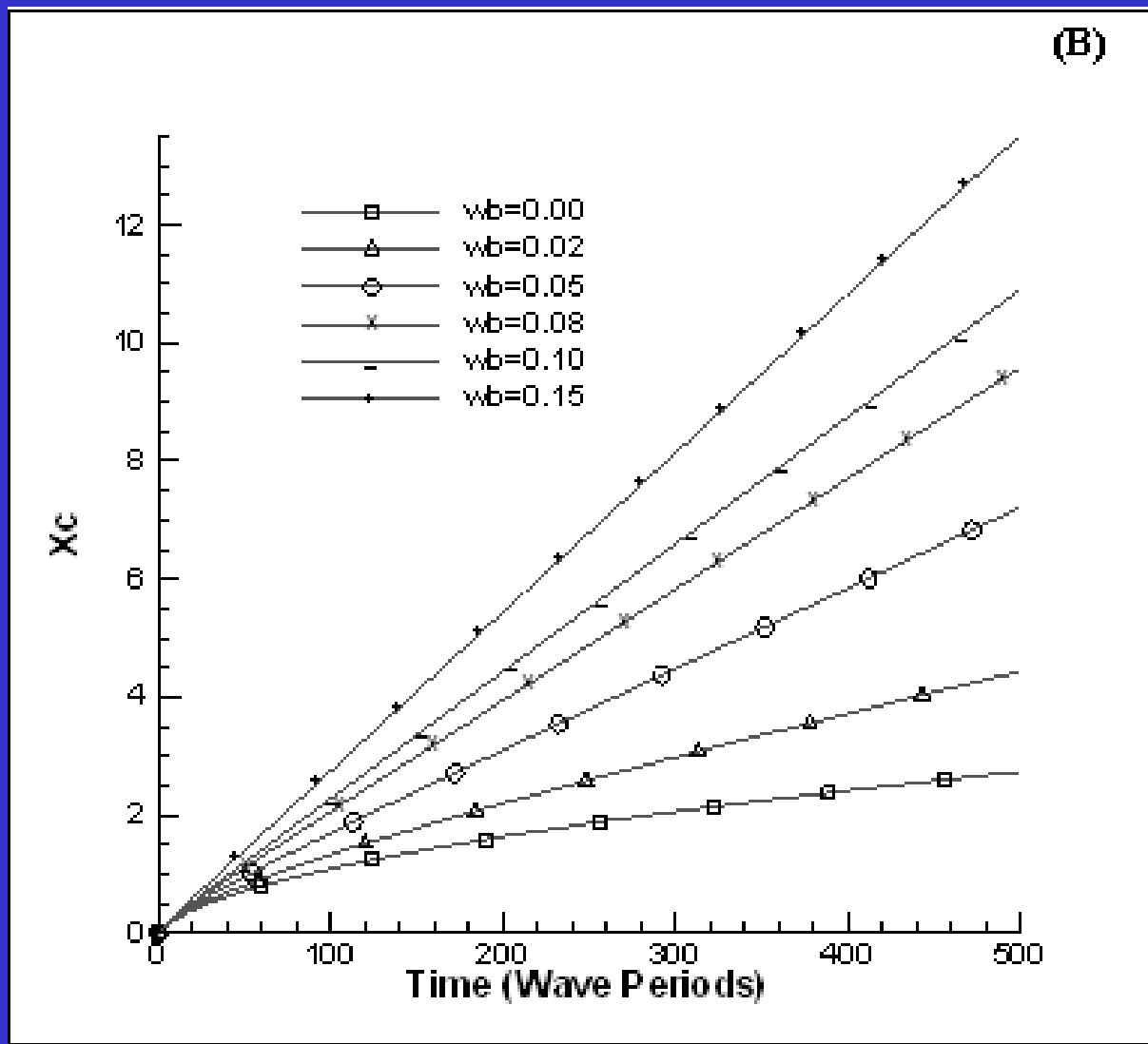
$$w_b = \frac{w_b^*}{H} = 0.0; 0.02; 0.05; 0.08; 0.1; \text{ and } 0.15$$
$$T$$

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

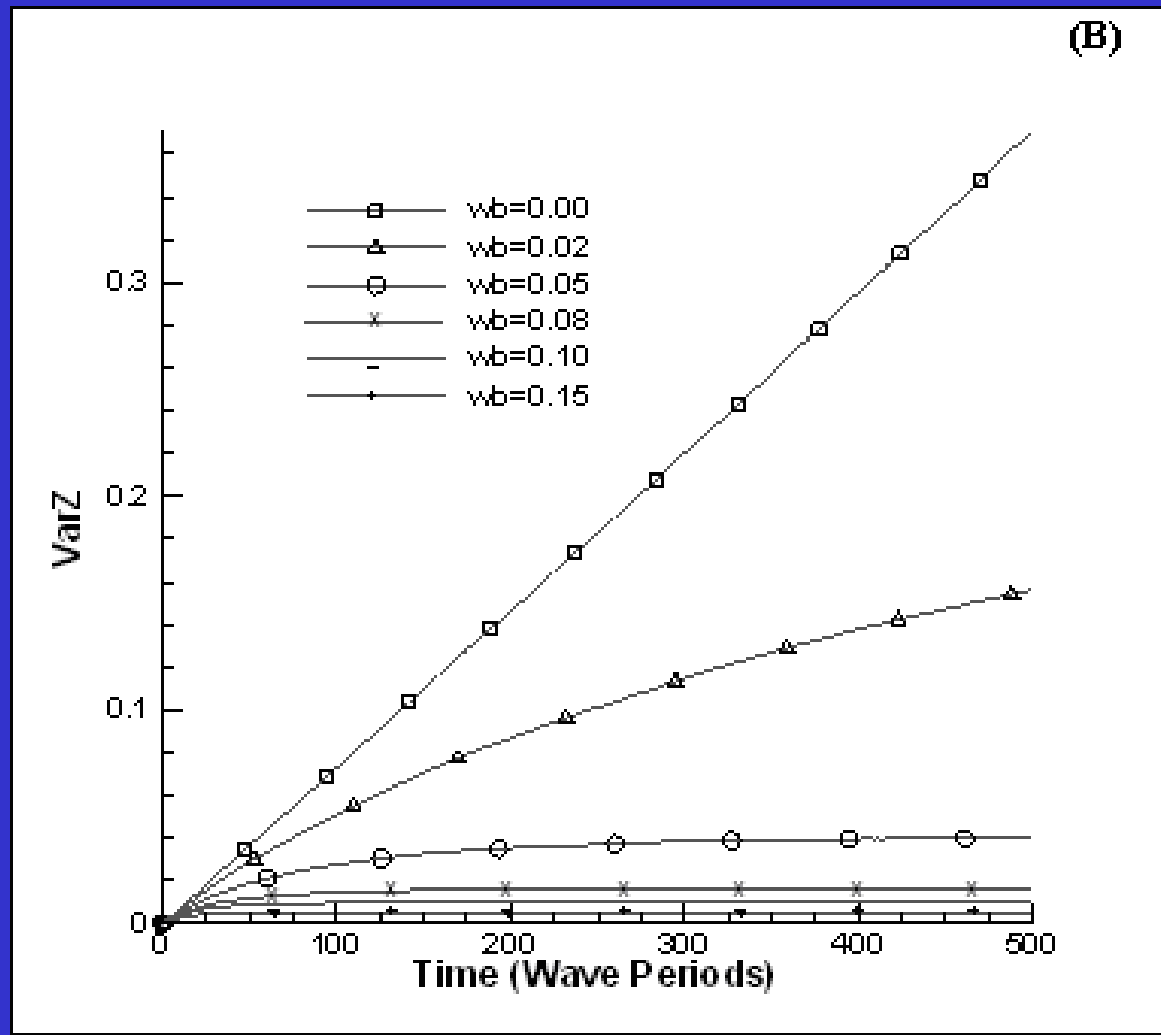
600 particles and 500 wave periods



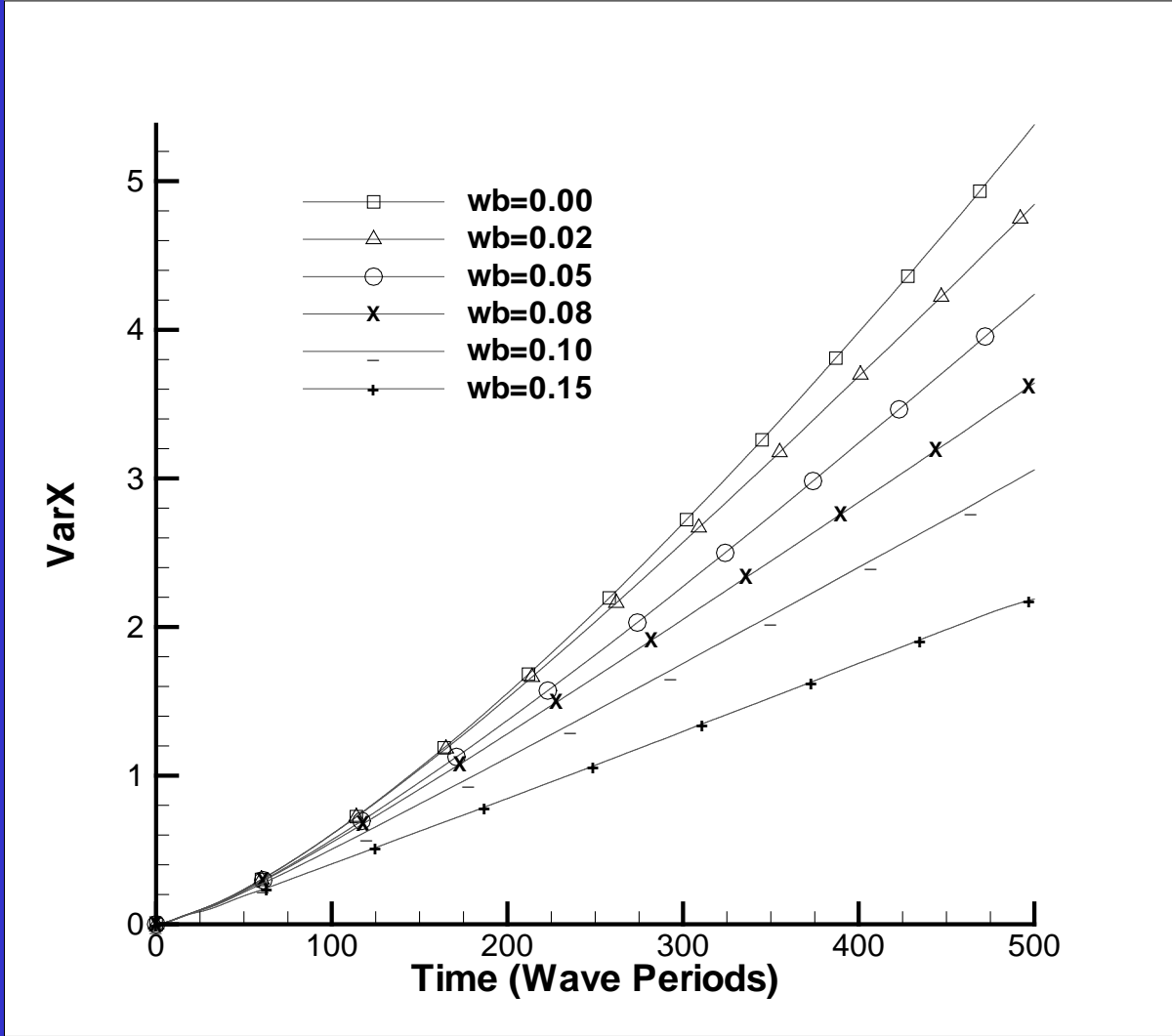
Effect of buoyancy on the vertical location of the centroid, Z_c for $H/L=\varepsilon=0.1$.
The initial location was at $Z_c=-0.01$. The depth is expressed in units of wave length.



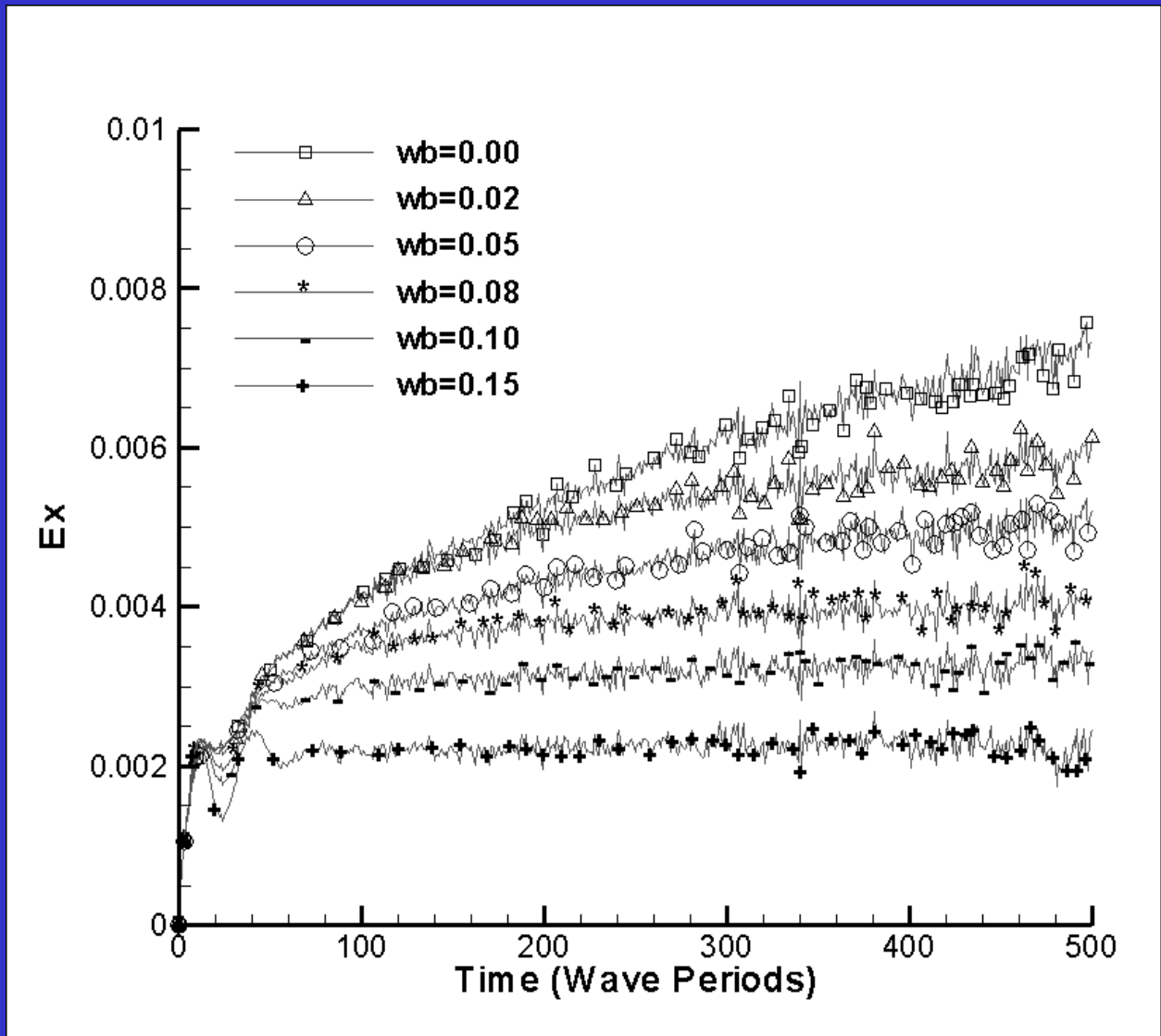
Effect of buoyancy on the horizontal location of the centroid, X_c for $H/L = \epsilon = 0.1$. The initial location was at $X_c = 0.0$. The horizontal distances are expressed in units of wave length.



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



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



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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