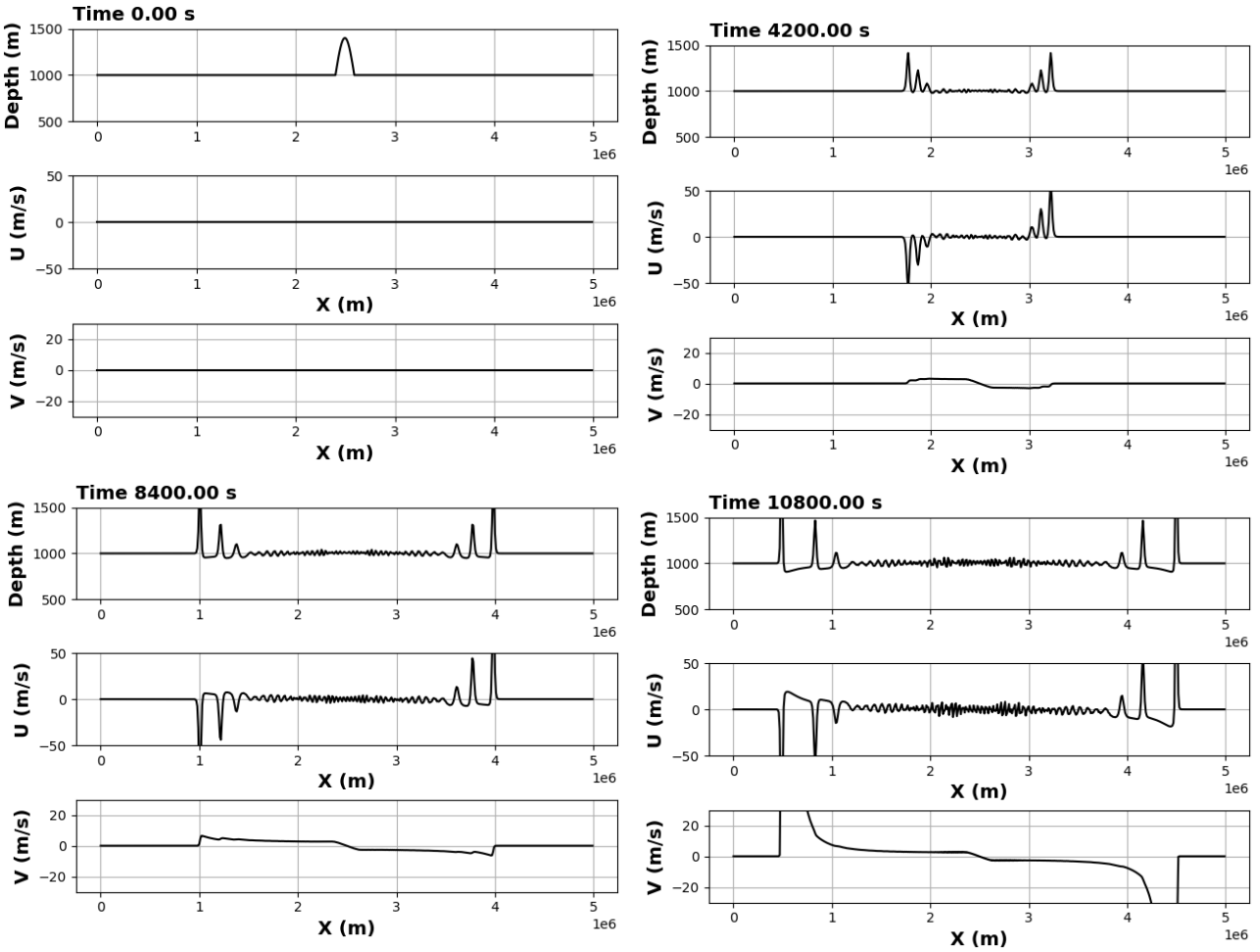
4.

a) See the q4_shallow_water directory in HW2_solns of the class github. With the addition of Earth's rotation, the v wind component grows at the expense of the u wind component.



b) Longer time steps have additional oscillations that tend towards explosion as the time step becomes too long (>10 s).

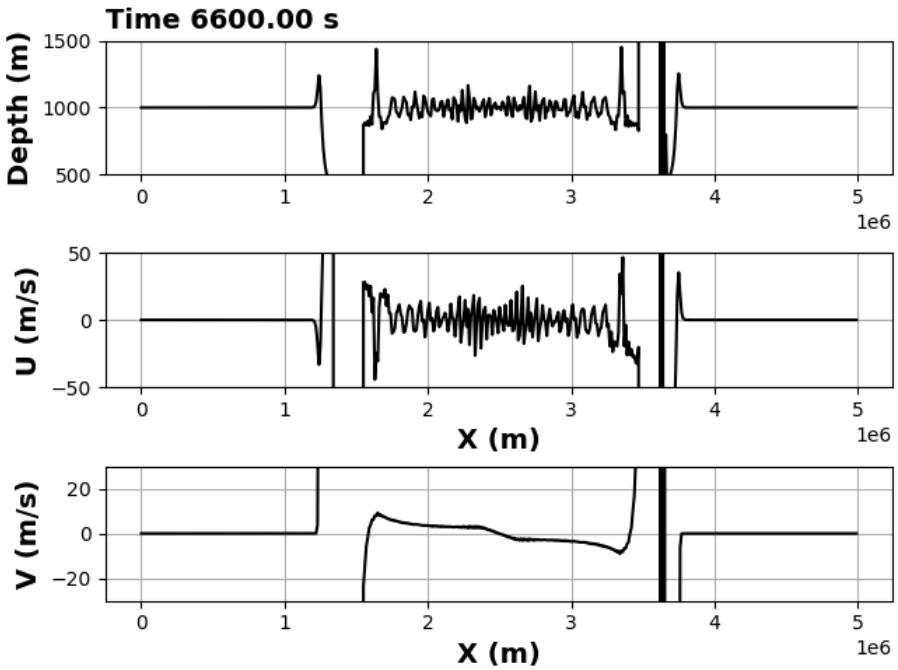


Figure: Model with 10 s time step at 6600 s.

c) The model explodes very quickly at 1000 m and less grid spacing.

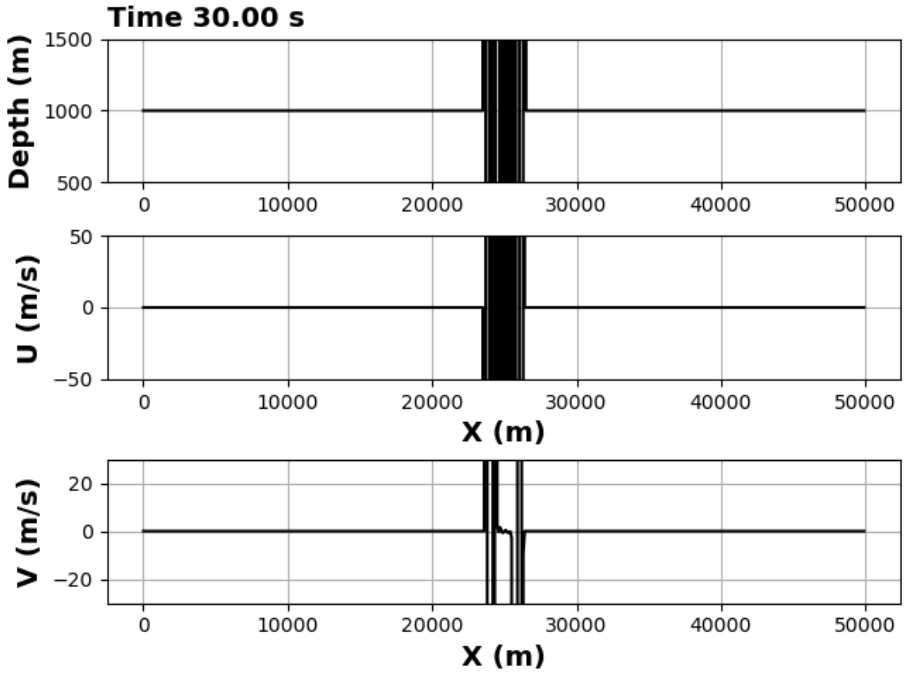


Figure: 100 m grid spacing model with 5 s time step. Model breaks down very quickly.

d) The maximum wind seen in the default model settings (5 s time step, 10 km grid spacing) is around 50 m/s. For the leap frog scheme with R-A filter and γ=0.2, the CFL criterion is λ<0.8.

$\lambda = c\Delta t/\Delta x$

For the default settings, the maximum CFL is 0.025. If the model spacing decreases to 100 m, then the CFL becomes 2.5 for these conditions. To preserve model stability, the time step must adjust with the grid spacing. The simplest change is to decrease the time step to 0.05 s, to mimic the 100-fold decrease in grid spacing. The maximum time step though can be found by solving for Δt in the CFL criterion:

$$\Delta t = (0.8)(\Delta x)/(c)$$

$$\rightarrow \Delta t = 1.6 \text{ s}$$

This same logic can be used for longer time steps by using the CFL criterion to compute the new minimum grid spacing.