Computational Fluid Dynamics 5
Errors

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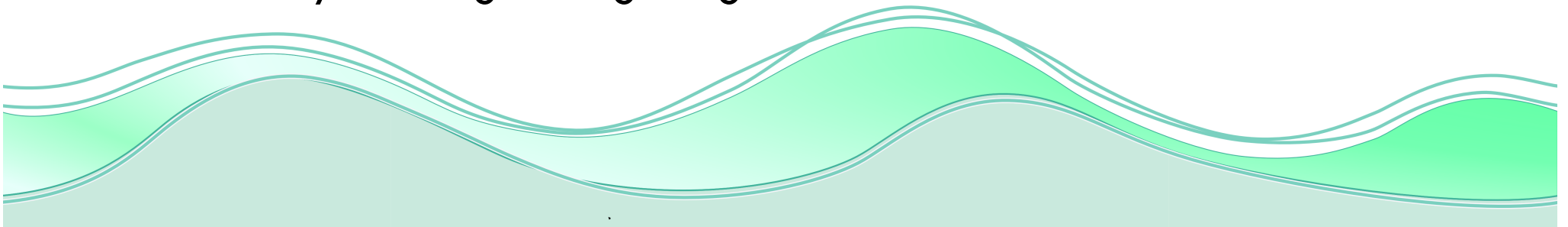
School of Engineering

# Main sources of error

- **Physics**
  - Have you chosen the right model (equations, BC, IC)
- **Grid resolution**
  - Is it sufficiently fine?
- **Time Step**
  - Is it sufficiently small?
- **Convergence**
  - Have you performed enough iterations?
- **Round off**
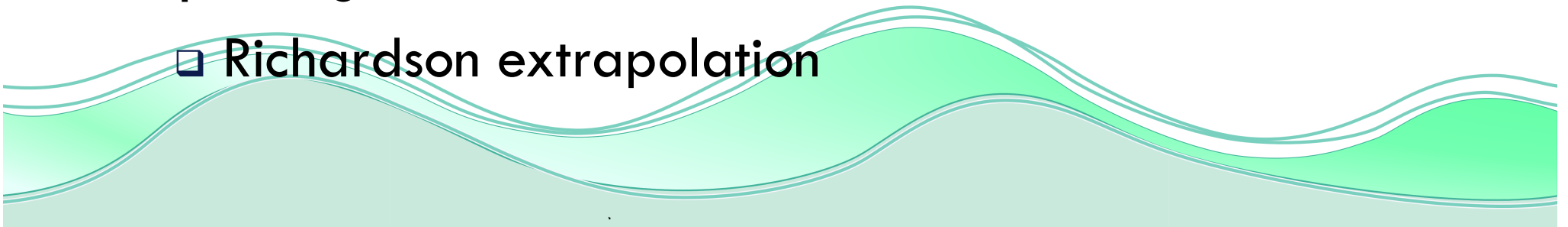 - Are you using enough digits?

Physics

- ☐ Compressibility

- ☐ Turbulence (which turbulence model?)

- ☐ Multi-phase

- ☐ Wall geometry and surface finish

- ☐ Velocity and pressure at the boundaries

- ☐ Initial velocity and pressure
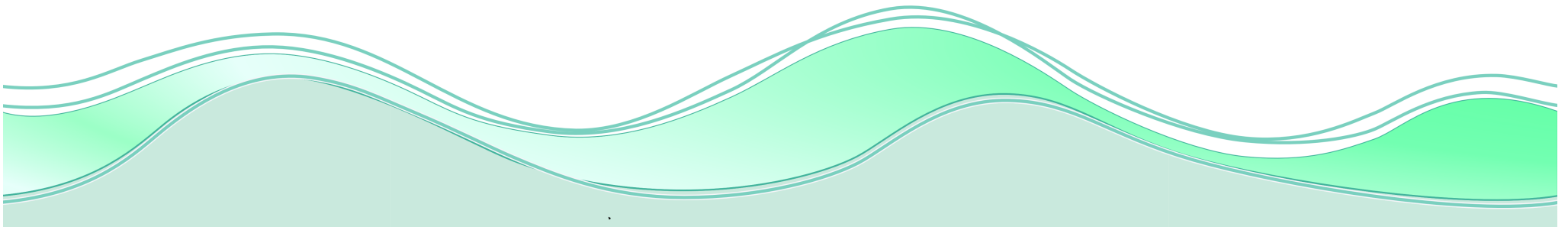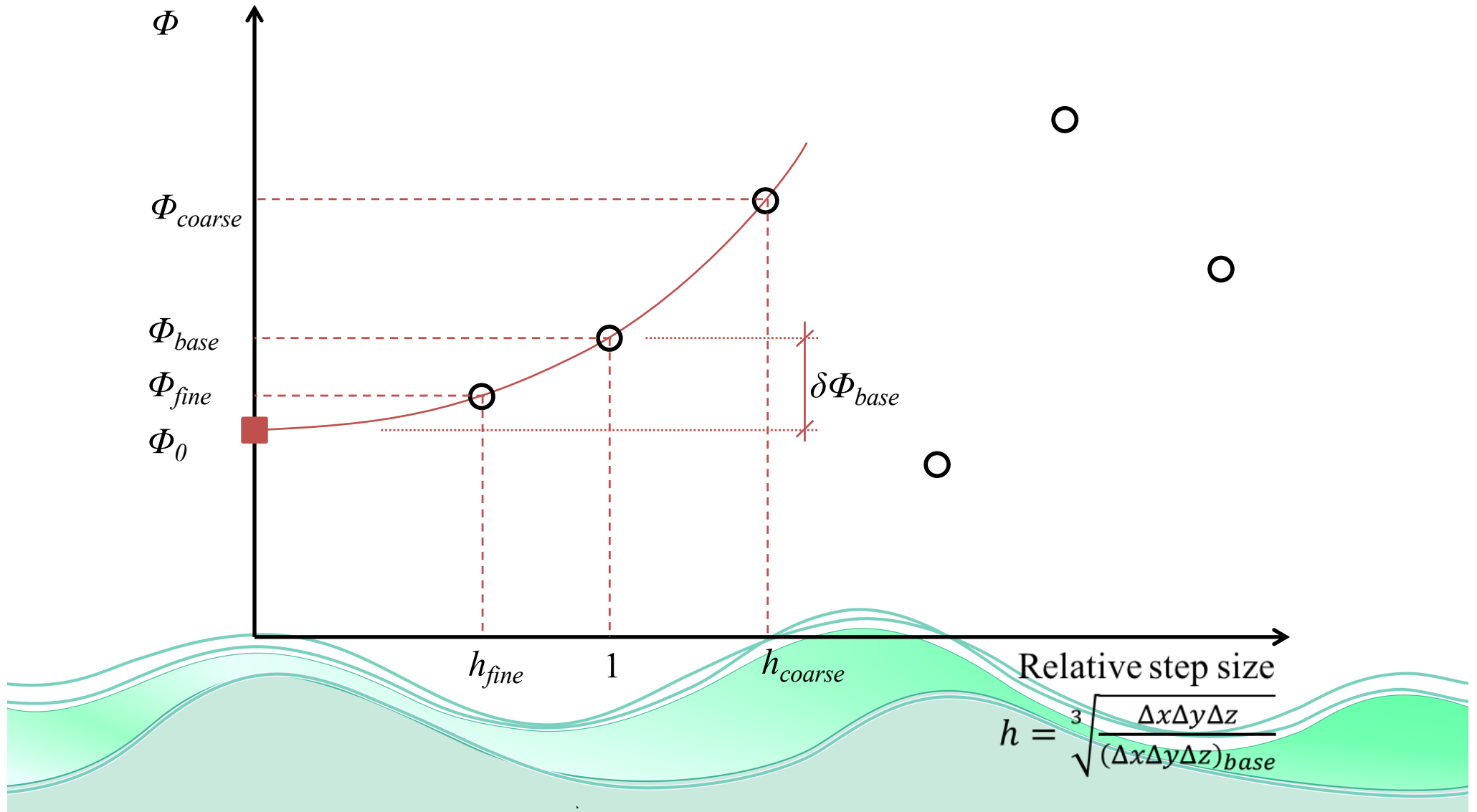
Grid resolution

- Test the grid resolution by varying the grid resolution
  - Vary the distribution of grid density based on the solution
  - Refine the grid uniformly (double every cell in two steps)
- Plot your solutions and extrapolate to grid spacing of zero
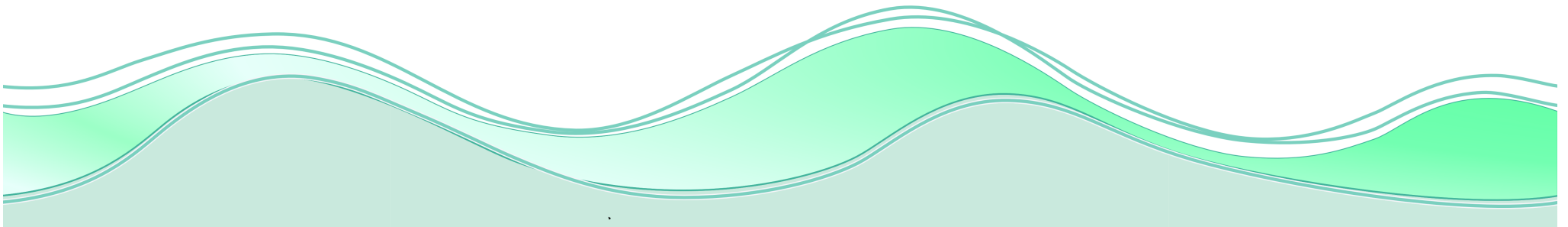 - Richardson extrapolation

Extrapolation

For any computed quantity ϕ

Φ

Φ_{coarse}

Φ_{base}

Φ_{fine}

Φ_0

$\delta\Phi_{base}$

h_{fine} 1 h_{coarse}

Relative step size

$$h = \sqrt[3]{\frac{\Delta x \Delta y \Delta z}{(\Delta x \Delta y \Delta z)_{base}}}$$

Grid and wall treatment

□ If you use a wall function, the first cell centre should be in the log region. In practice the finer mesh should have $y^+ \approx 70$

□ If you do not use a wall function, the first cell centre should be smaller than the viscous length, i.e. $y^+ < 1$
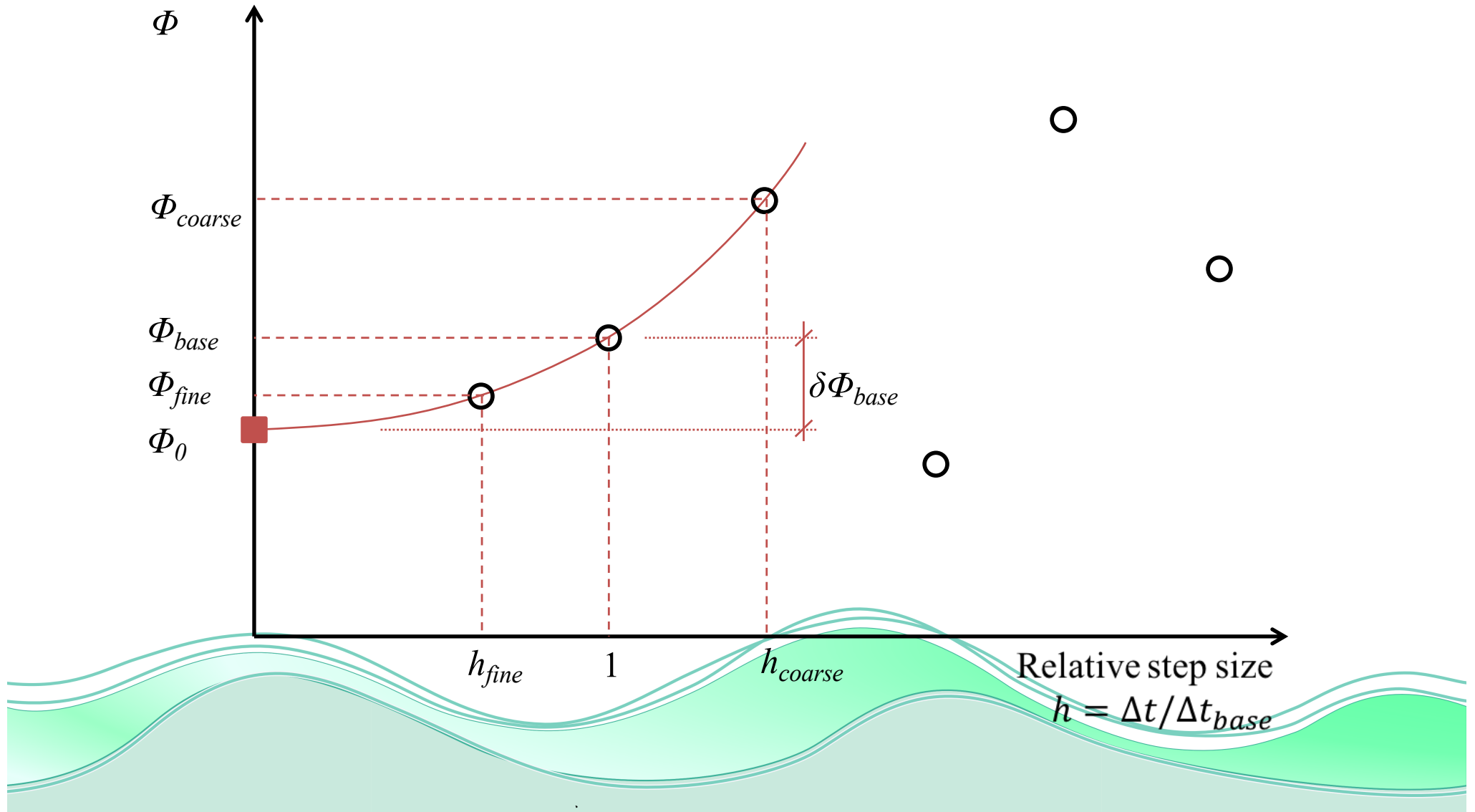
Time step

- Test the time resolution by varying the time step
  - Double and halve the time step several times
- Plot your solutions and extrapolate to zero time step
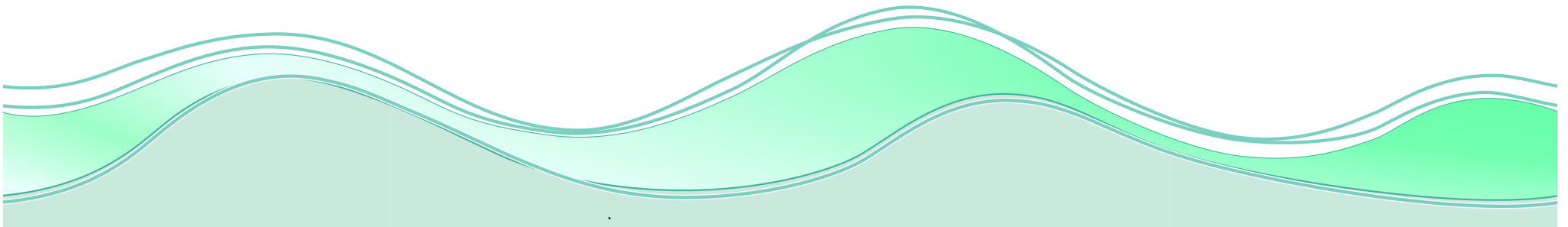 - Richardson extrapolation
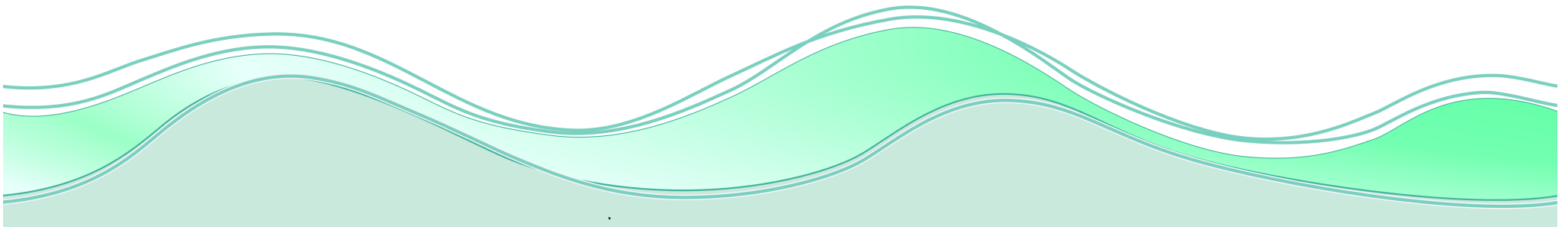
Extrapolation

For any computed quantity ϕ

Discretisation of the equations

- Order of solution is that of the first missing term in the expansion (discretisation) of the pde

- 1st order can give sufficiently good results in some cases

- 2nd order is required for most cases

- If solutions with high degree of accuracy are required 4th order can be used

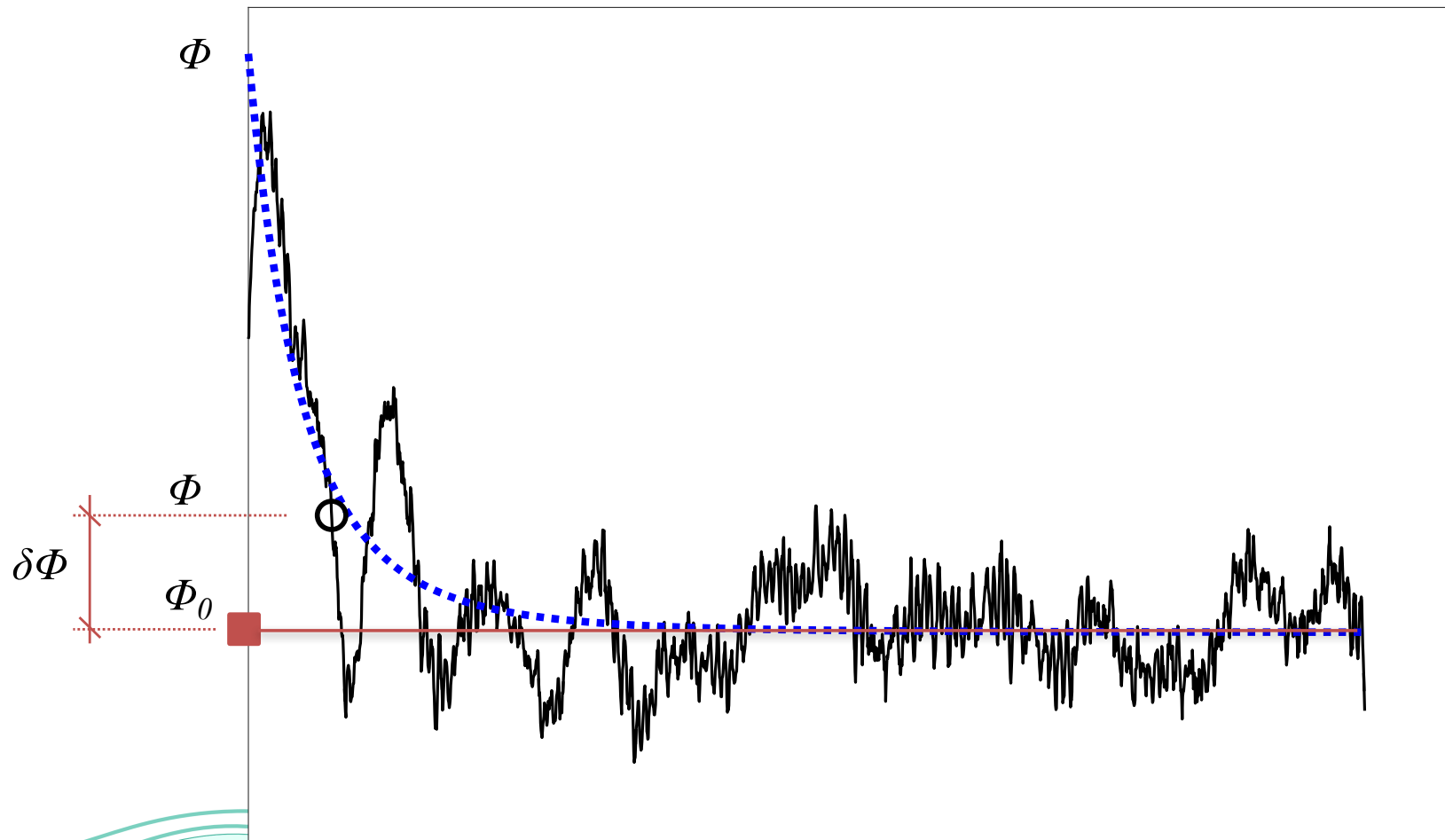- Solution order and grid refinement, or time step, can be balanced

Convergence

☐ Test the convergence by solving more iterations

☐ Plot your solutions and extrapolate to zero time step

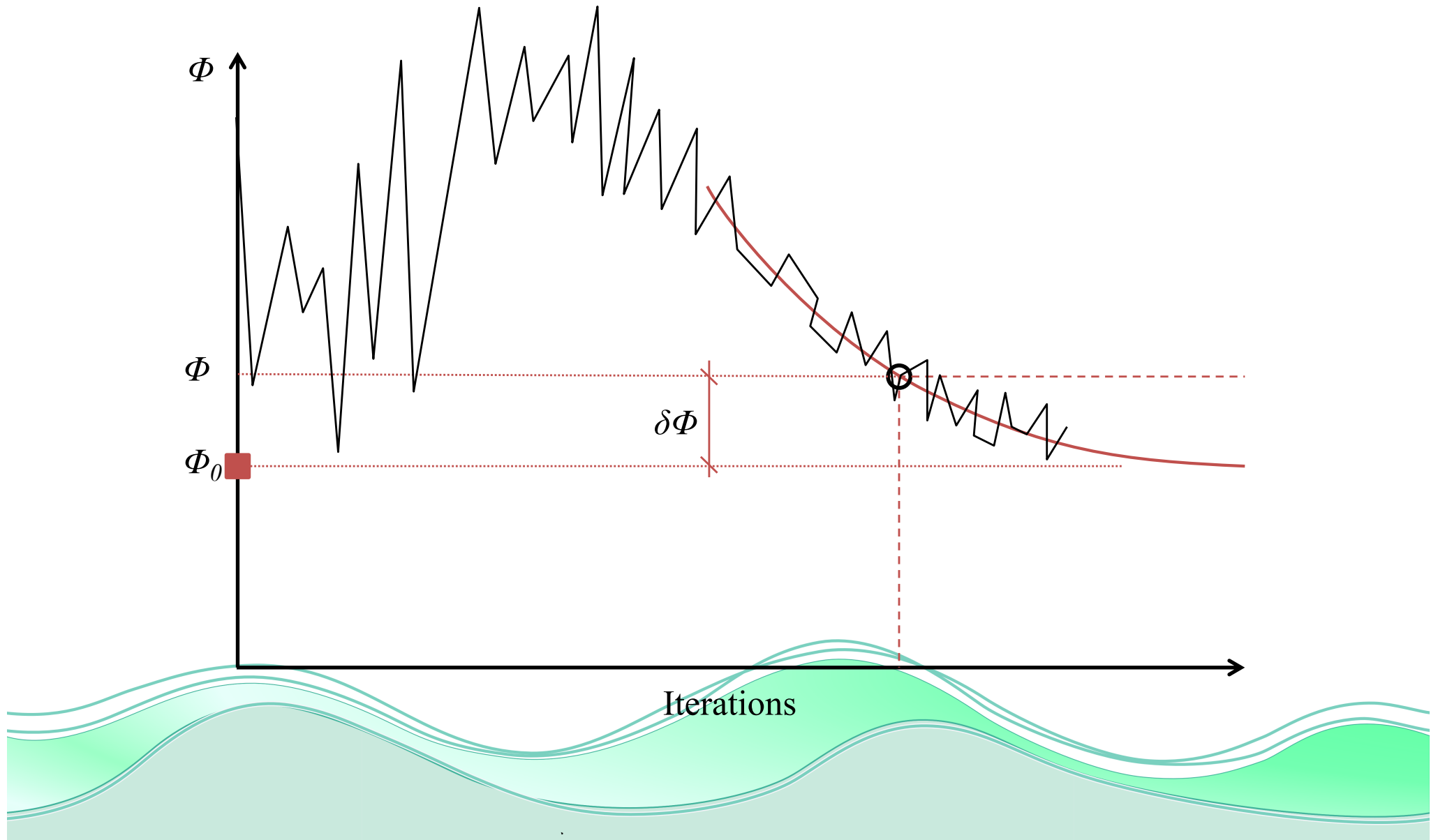   ❑ Richardson extrapolation
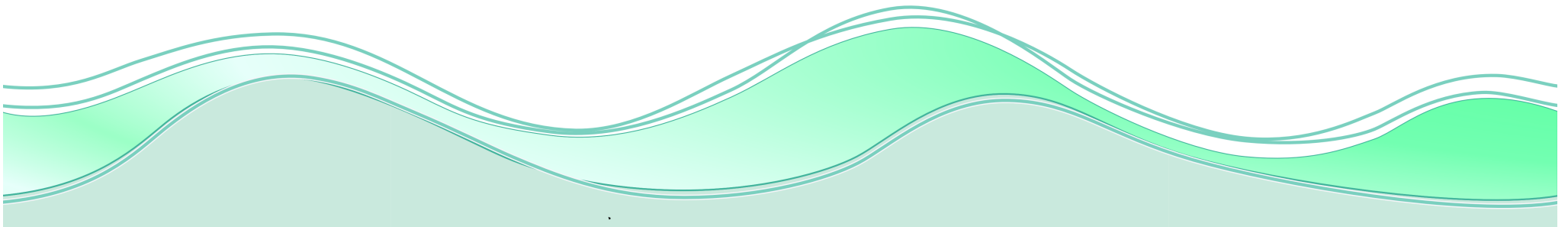
Convergence

Iterations

Convergence

Numerical errors

- Single precision, 32bits, 6-9 digits accurate
- Double precision, 64 bits, 15-17 digits accurate
- Star is mixed precision (32bits for position and 64bits for other variables) or double precision
- Test the difference
- Note that Star uses *real* reals, i.e. does not scale the problem to fit the arithmetic to the processor
  - Use non dimensional values of the order of one