Ocean Wave Simulation

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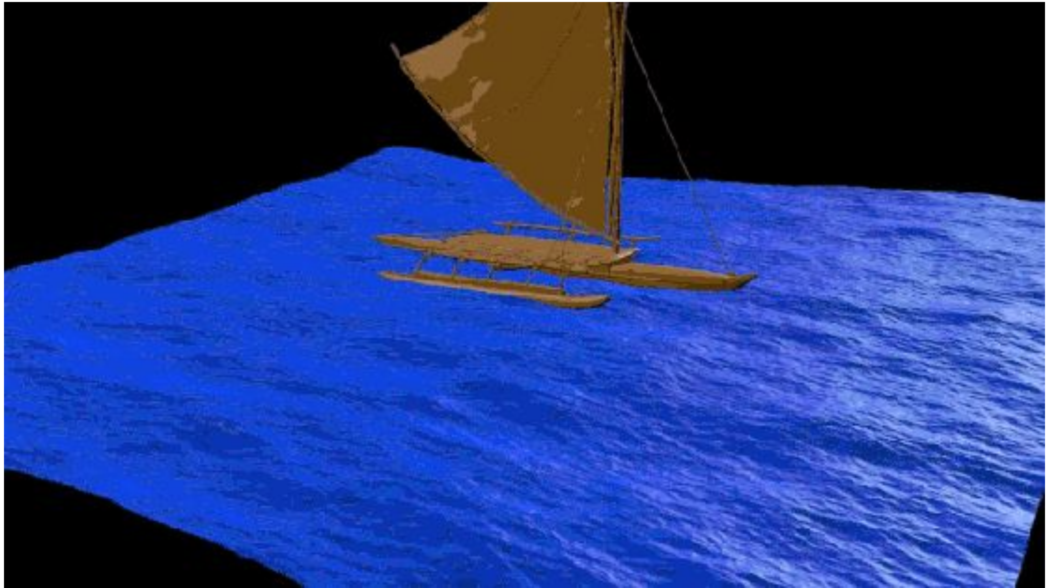
FPS: 86.96
Simulated time: 19:30 8/22/2011


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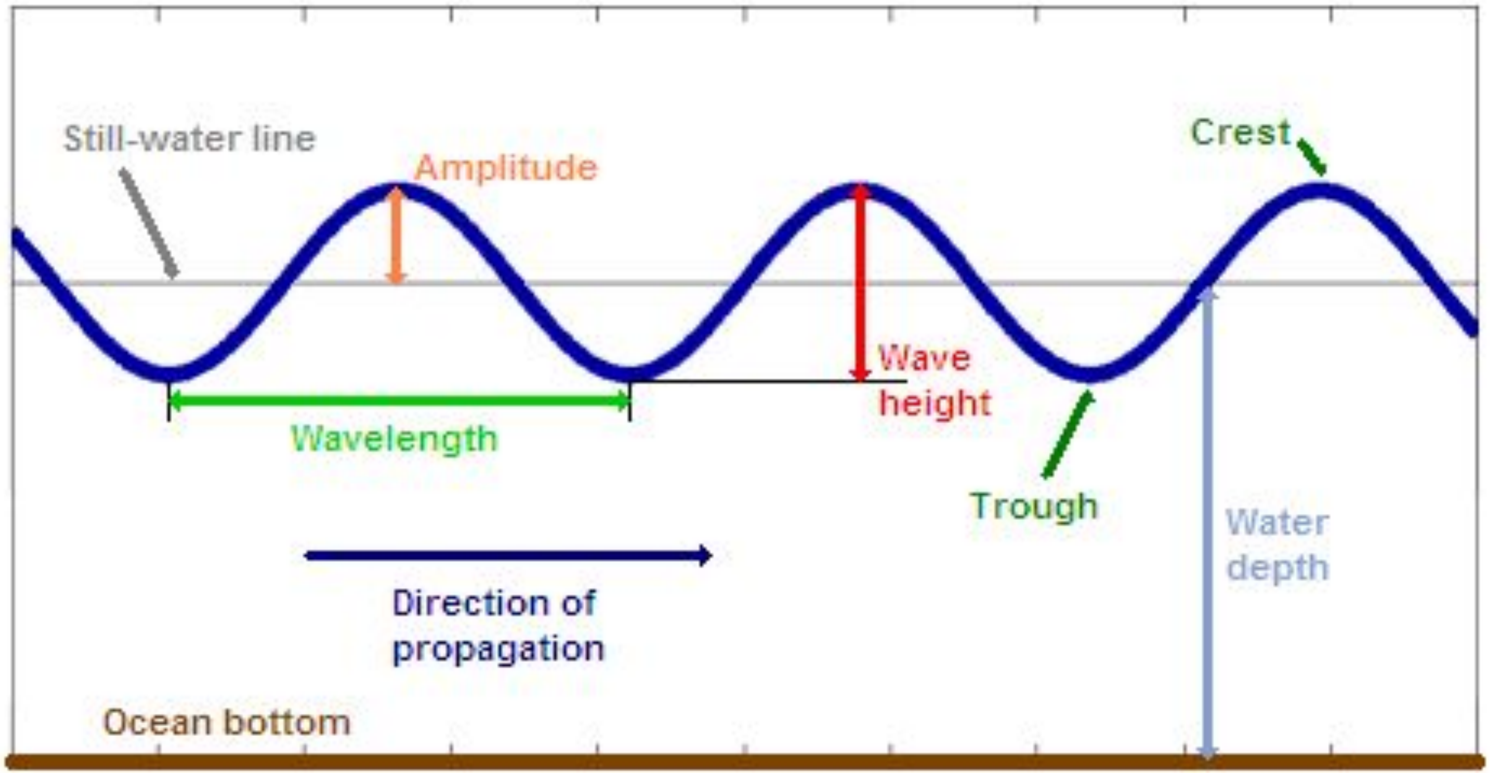
Wave Properties

Wave Dynamics



Wave Dynamics

Deep-water

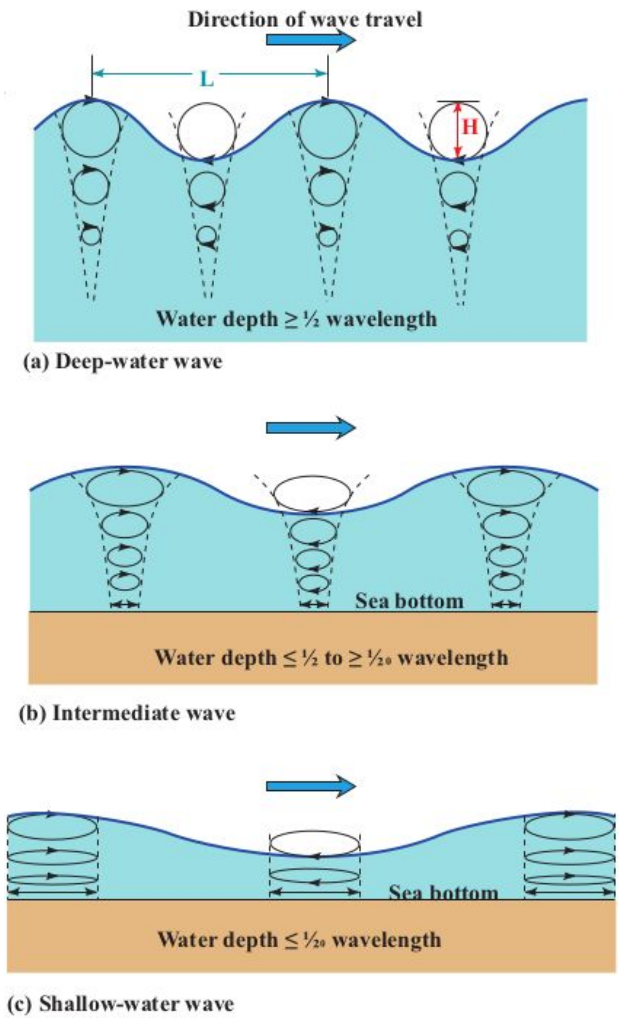
Depth ≥ 1/2 L

Intermediate

1/2 L > Depth > 1/20 L

Shallow-water

Depth ≤ 1/20 L



Wave Generation

Question: What causes a wave?

Wave Generation

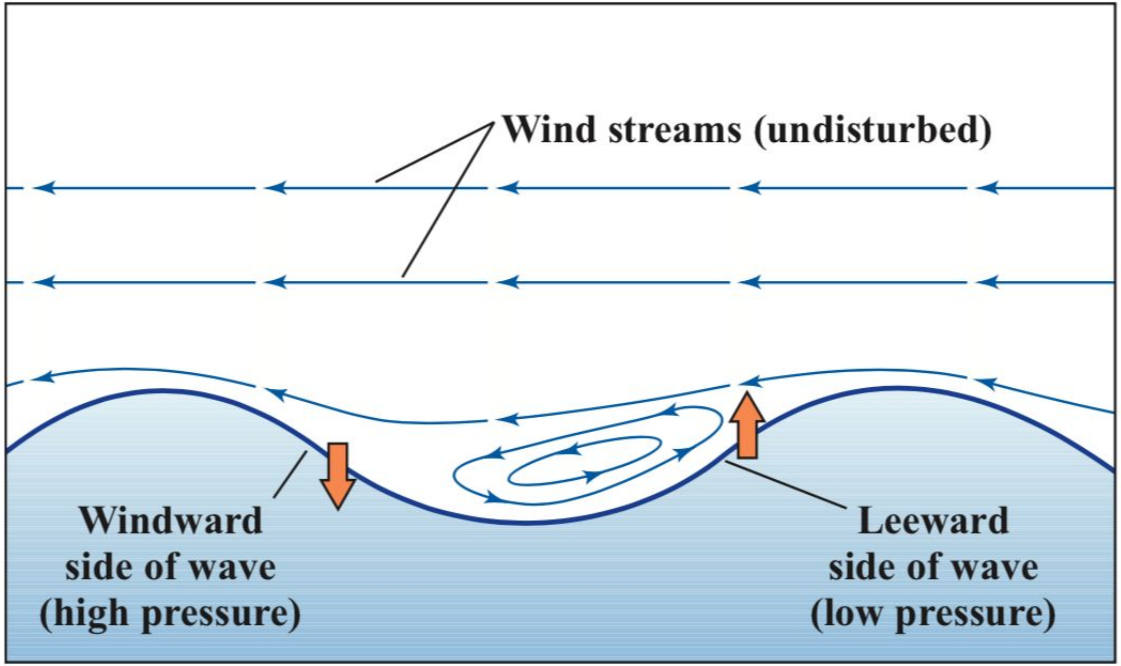
Question: What causes a wave?

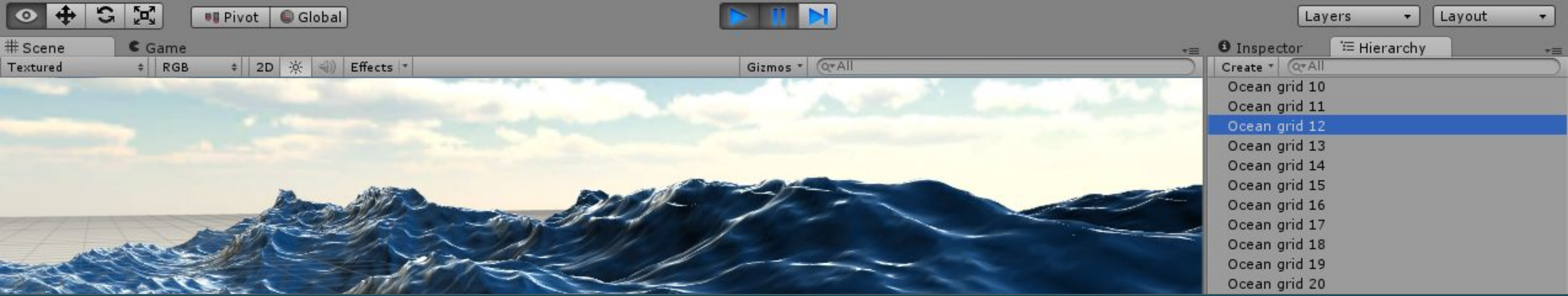
> Wind

> Boats

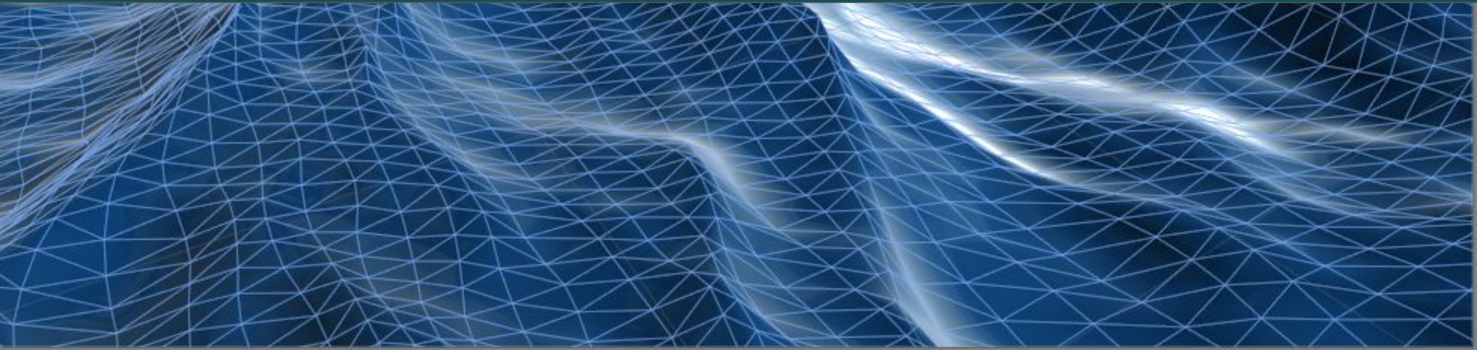
> Earthquakes

> Gravitational pull





Wave Functions



Spinoff Studio

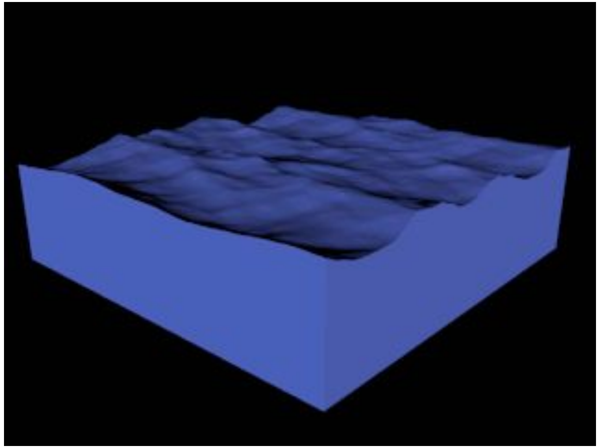
Models

Elevation Model

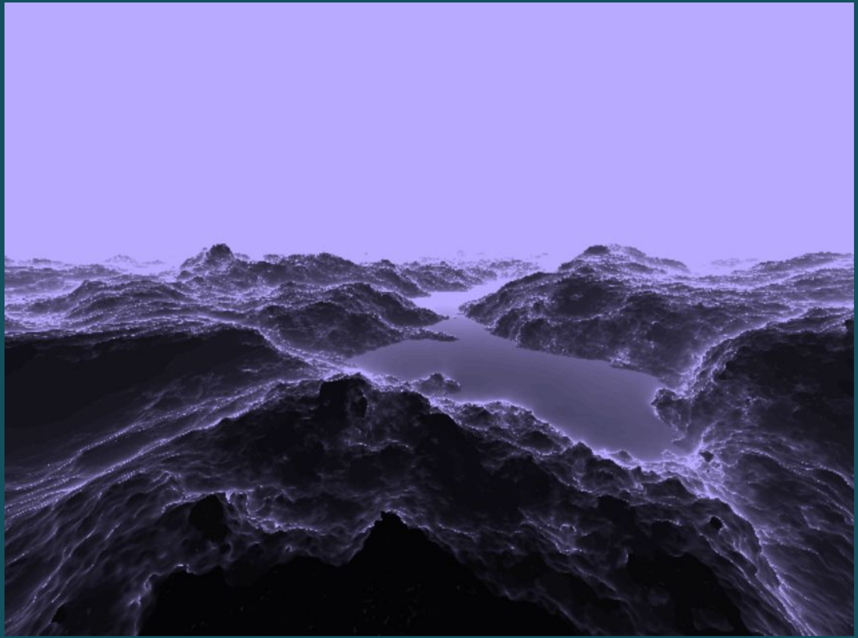
Heightmap - 2D regular grid, each cell represents the surface height

Volumetric Model

Voxel - 3D regular grid, each cell is assigned a material index



Simplex Noise



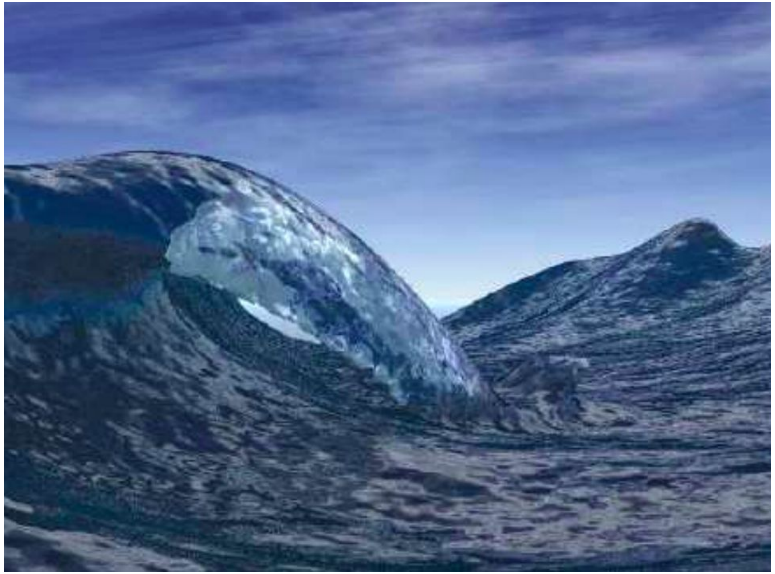
Similar to Perlin noise

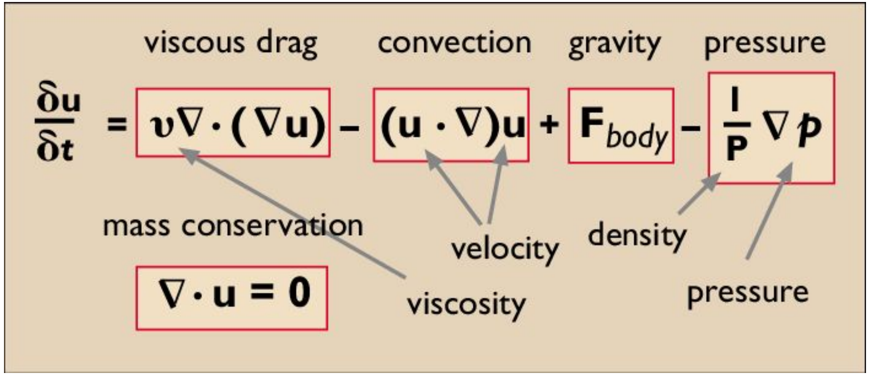
Generates a height map which can be applied to other wave functions to provide a more realistic texture

Navier-Stokes

Multiple equations describing motion of viscous fluids

Often used to capture breaking waves near shore

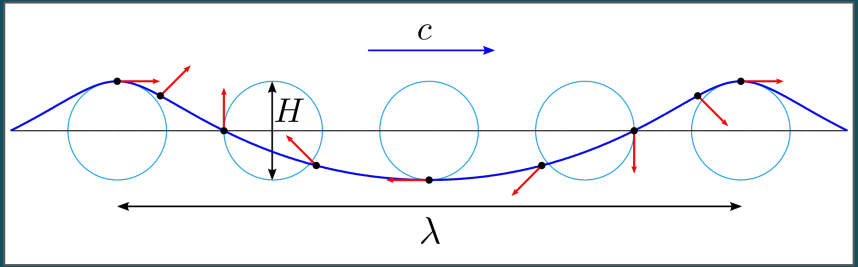


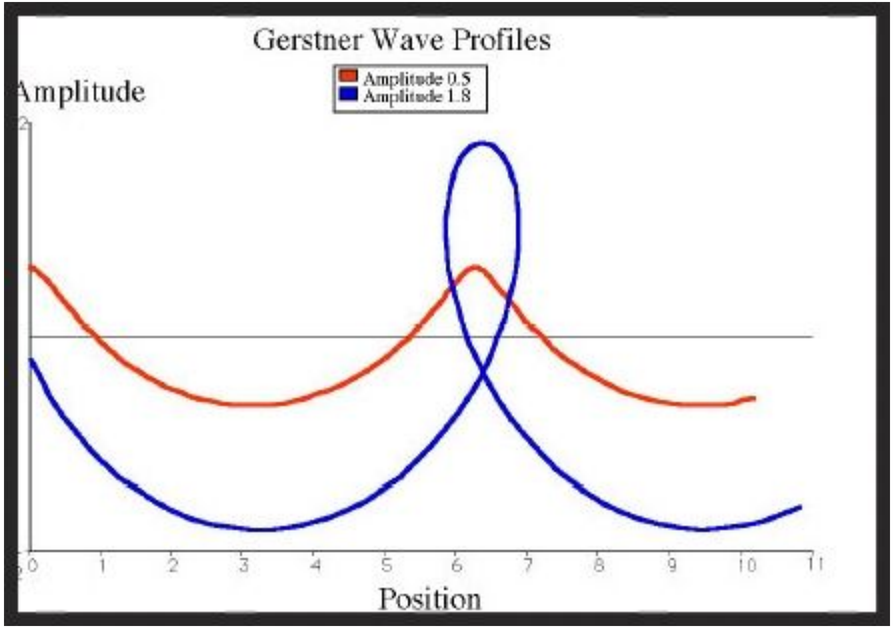


Gerstner Waves

Modified sine wave with sharper peaks and flatter valleys

Controlled by manipulating amplitude, direction and speed



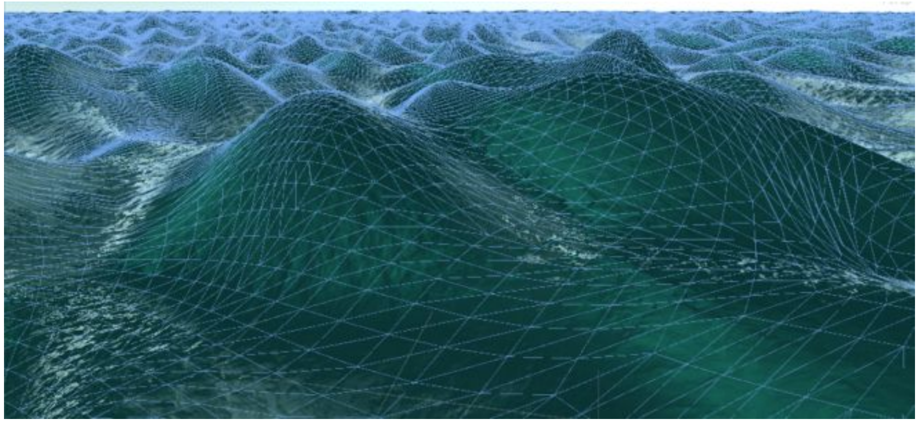


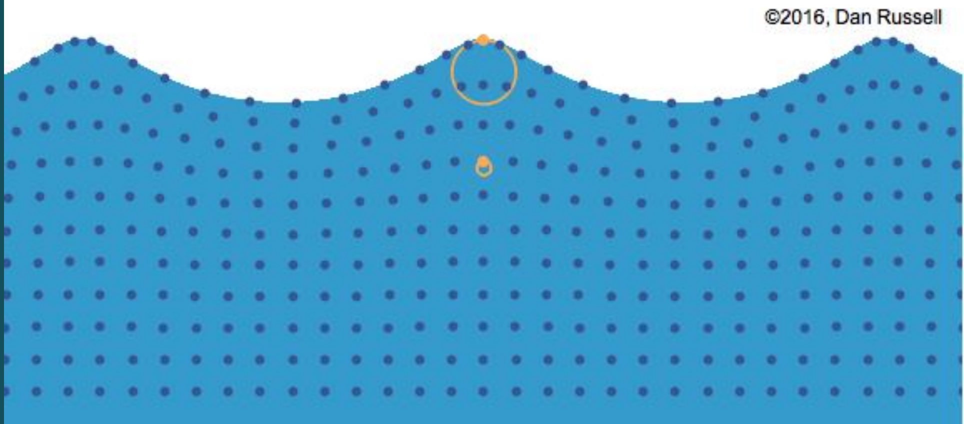
$$\mathbf{P}(x,y,t) = \begin{pmatrix} x + \sum \left(Q_i A_i \times \mathbf{D}_i.x \times \cos\left(w_i \mathbf{D}_i \cdot (x,y) + \varphi_i t \right) \right), \\ y + \sum \left(Q_i A_i \times \mathbf{D}_i.y \times \cos\left(w_i \mathbf{D}_i \cdot (x,y) + \varphi_i t \right) \right), \\ \sum \left(A_i \sin\left(w_i \mathbf{D}_i \cdot (x,y) + \varphi_i t \right) \right) \end{pmatrix}.$$

Gerstner Waves

Particles of water are described with circular/elliptical stationary orbits

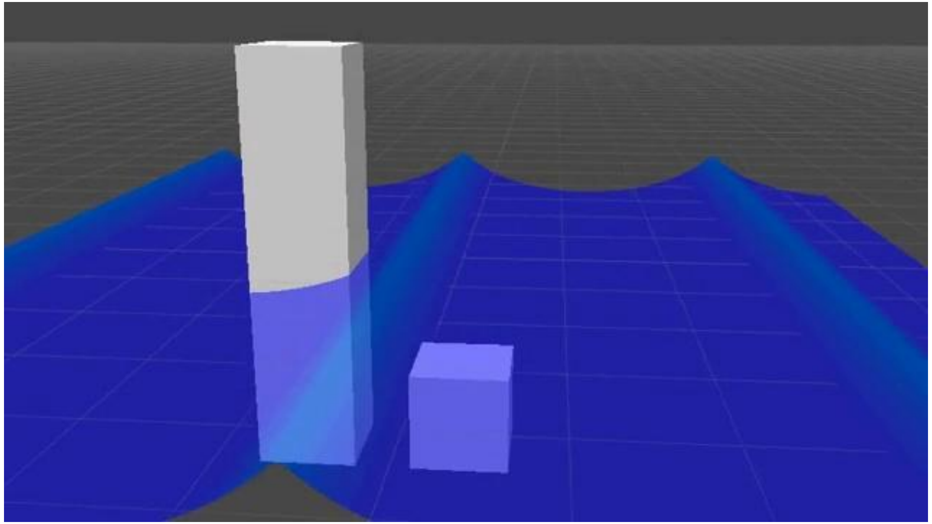
Moving vertices toward each crest forms sharper crests





Gerstner Waves

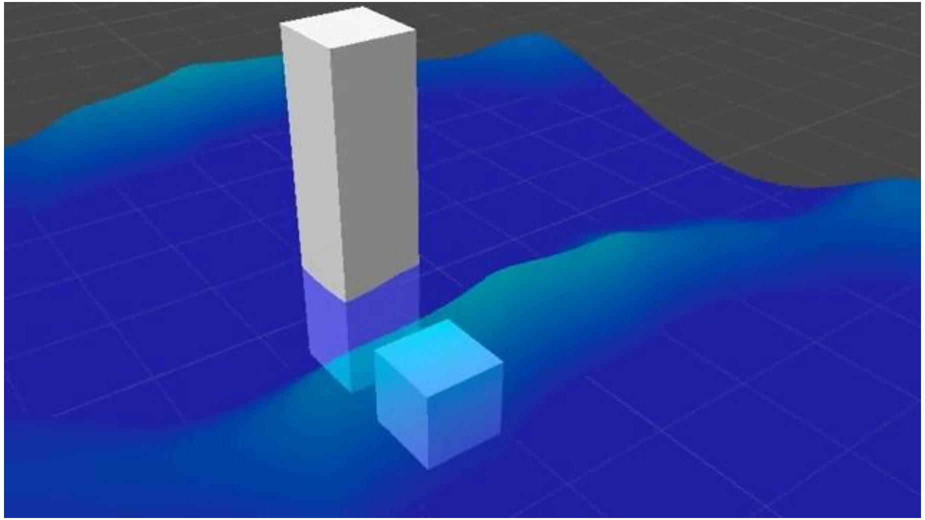
Question: How can we make this more realistic?



Gerstner Waves

Question: How can we make this more realistic?

> Add waves with varying properties



4 waves!

Flags and Waves - SIGGRAPH 1986

"A Simple Model of Ocean Waves"

Based on Gerstner Waves

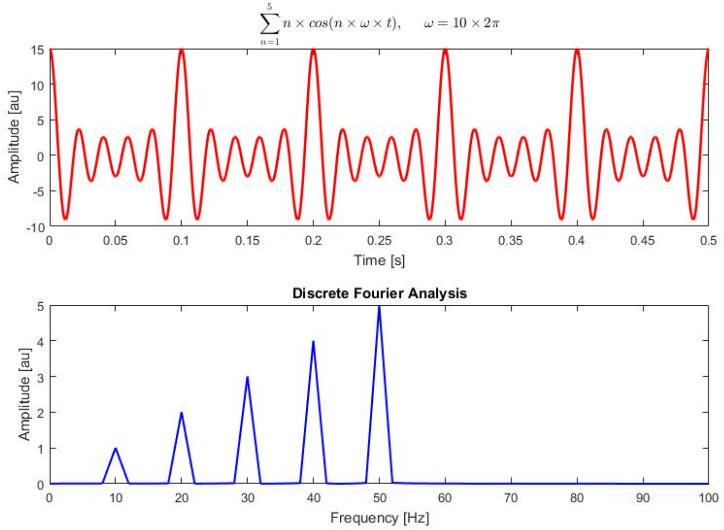
A parametric surface made up of position at rest (x0 , y0) and time

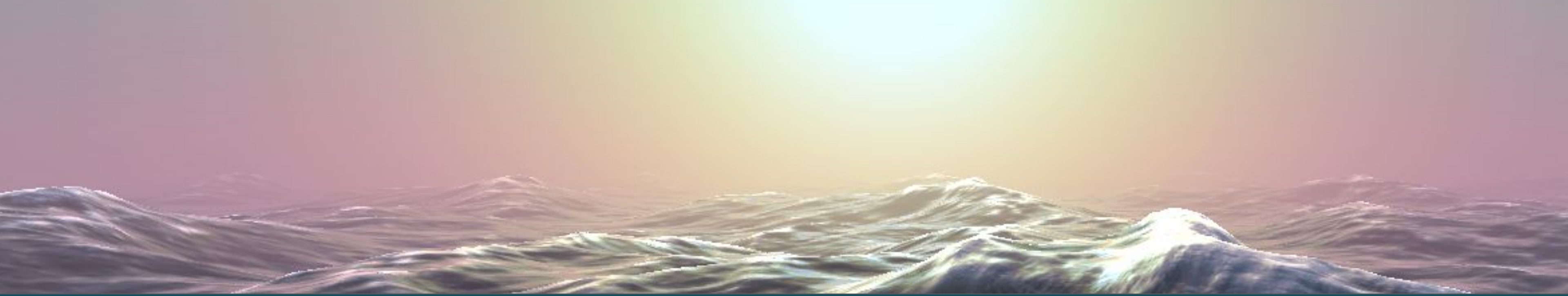
Incorporates effects of wave direction, depth and shore distance

Fast Fourier Transforms

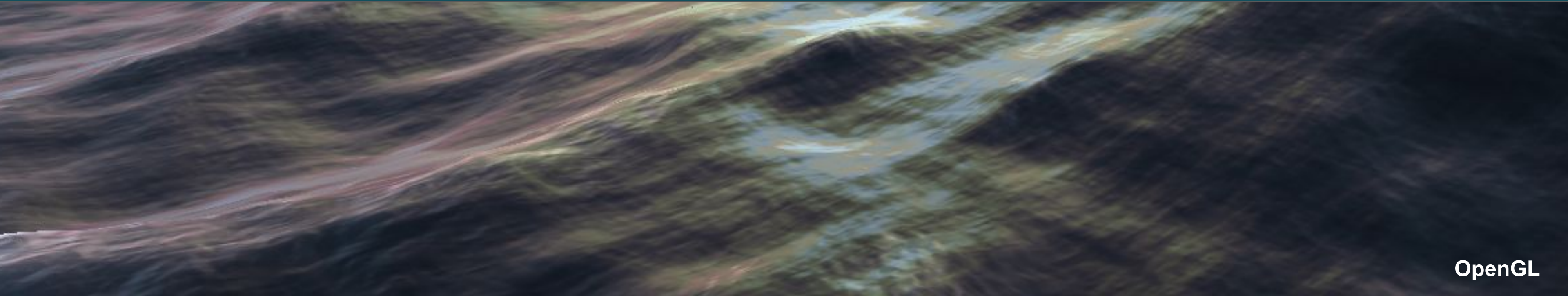
Statistical model where wave height is considered a random variable of horizontal position and time, h(x, t)

Reasonable representation of naturally occuring wind-waves





Ocean Phenomena



Foam and Spray

1. Semi-transparent textures

Foam spawns near tops of big waves

```
For a given vertex:

    Compute difference in slope
    between vertex and neighbors

    If difference < threshold:
        Increase foam amount
    Otherwise
        Decrease foam amount
```

Figure 3-13. Water spray generated when two waves of opposite direction meets.

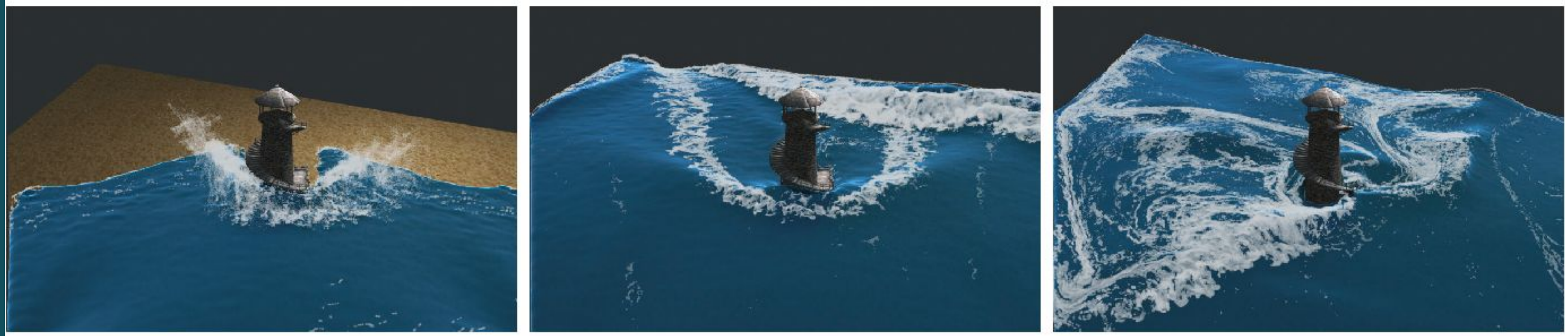
Foam and Spray

2. Particle systems

More realistic but more costly

Spray subsystems are generated based on velocity of water particles and wave amplitude

Result is rendered as cloud points



Radiosity

```
L_above = reflection(L_sun + L_sky)
          + transmission(L_under)
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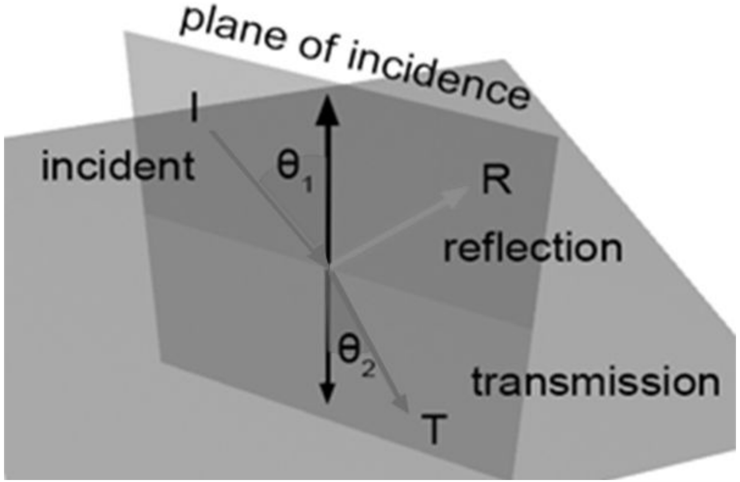
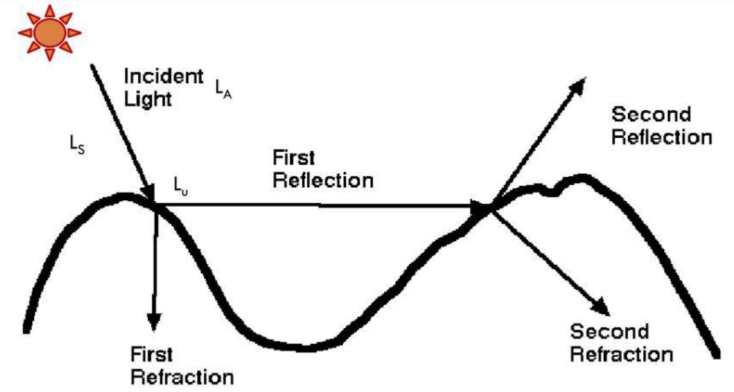
Specular reflection from direct sunlight and skylight

Transmission of incident light through surface

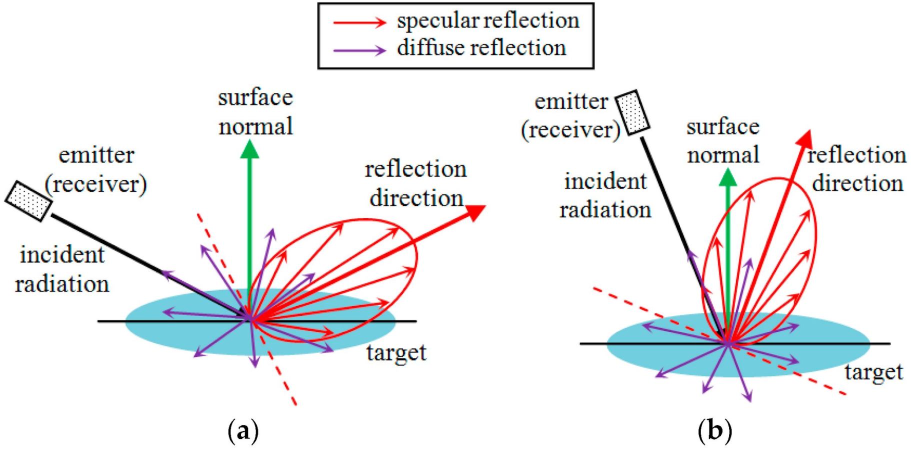
(More reflection / refraction from previously reflected / refracted light)





Specular Reflection

For a ray intersecting the surface, the direction of the reflected ray depends only on the **incident direction** and the **surface normal**

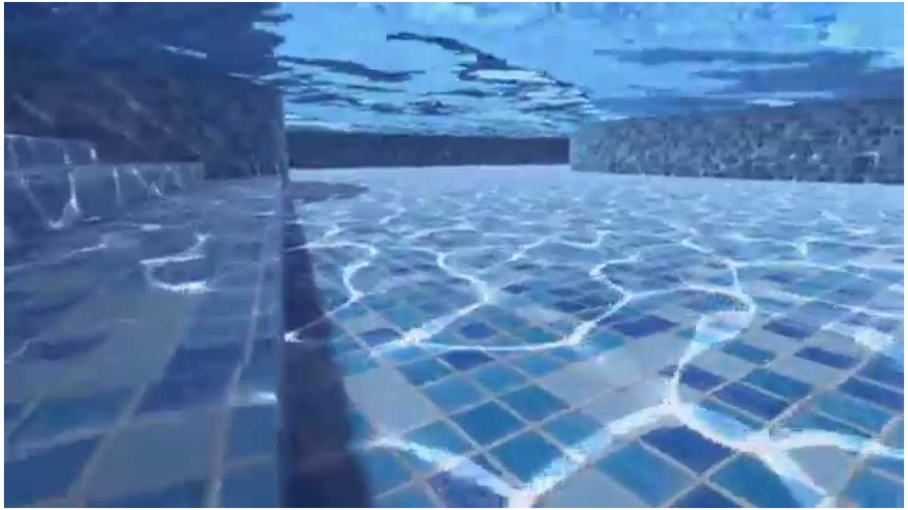


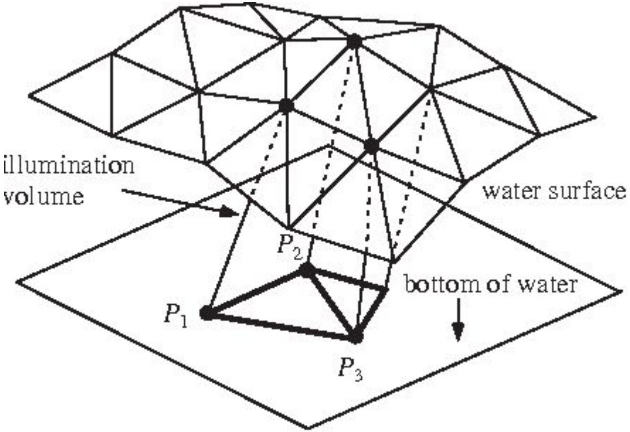
Caustics

Snell's Law determines how refracted light will bend the trajectory

As light advances deeper into the water the intensity attenuates

Eventually light strikes the ocean floor





Color

Based on reflected and refracted light

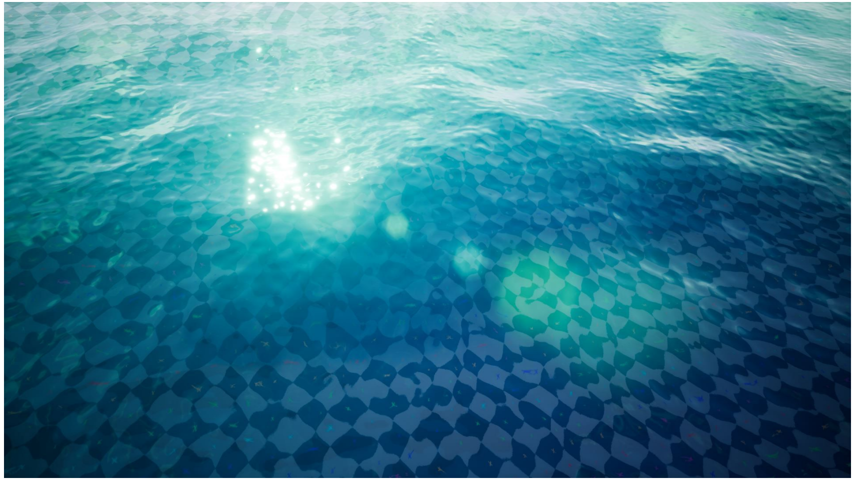
Opacity of water

Function of depth

Viewing angle

Tint of reflection

Environment mapping



Thank you! Questions?

Unity: Crest