Ocean Surface Simulation

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Revised Notes and Slides

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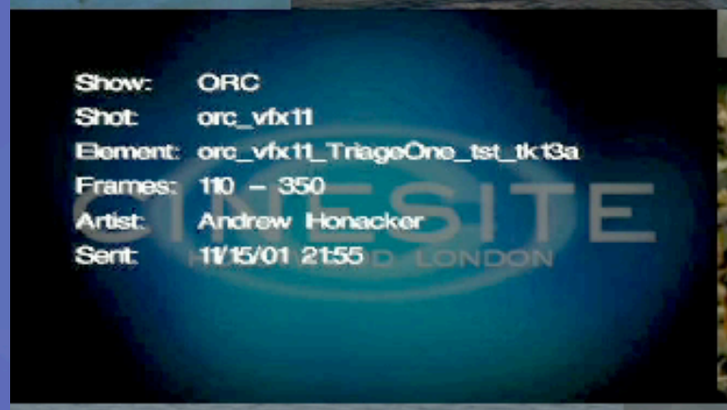
Waterworld
Truman Show
Hard Rain
Contact
Cast Away
13 Days
Cat in the Hat
13th Warrior
Titanic
Deep Blue Sea
Virus
World Is Not Enough
Peter Pan
Orange County
Fifth Element
Double Jeopardy
Devil's Advocate
20K Leagues
X2 Xmen United
Around the World in 80 Days
Sphere
Laura Croft Tomb Raider
A Simple Wish
Air Force One
Pearl Harbor
Austin Powers International Man of Mystery
Austin Powers Goldmember
Deep Rising
Al's Lads





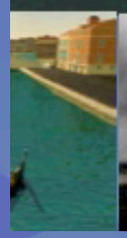
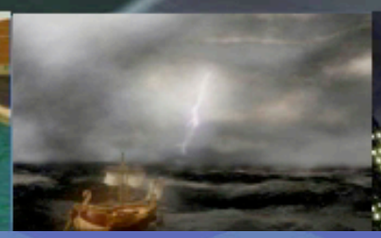


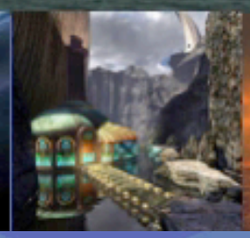
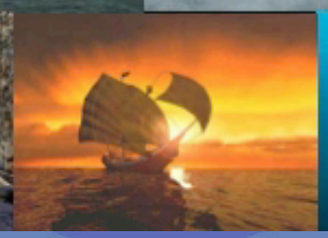
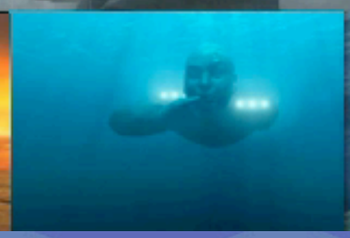









Harry Potter and the Sorcerer's Stone
The Last Samurai
Guliver's Travels
The Prince of Egypt

Sinbad Beyond the Veil of Mists
Treasures of the Royal Captain
Dawson's Creek

Myst III: Exile
Munch's Odysee
Grim Fandango
Lost Ships

Its all about
Dispersion

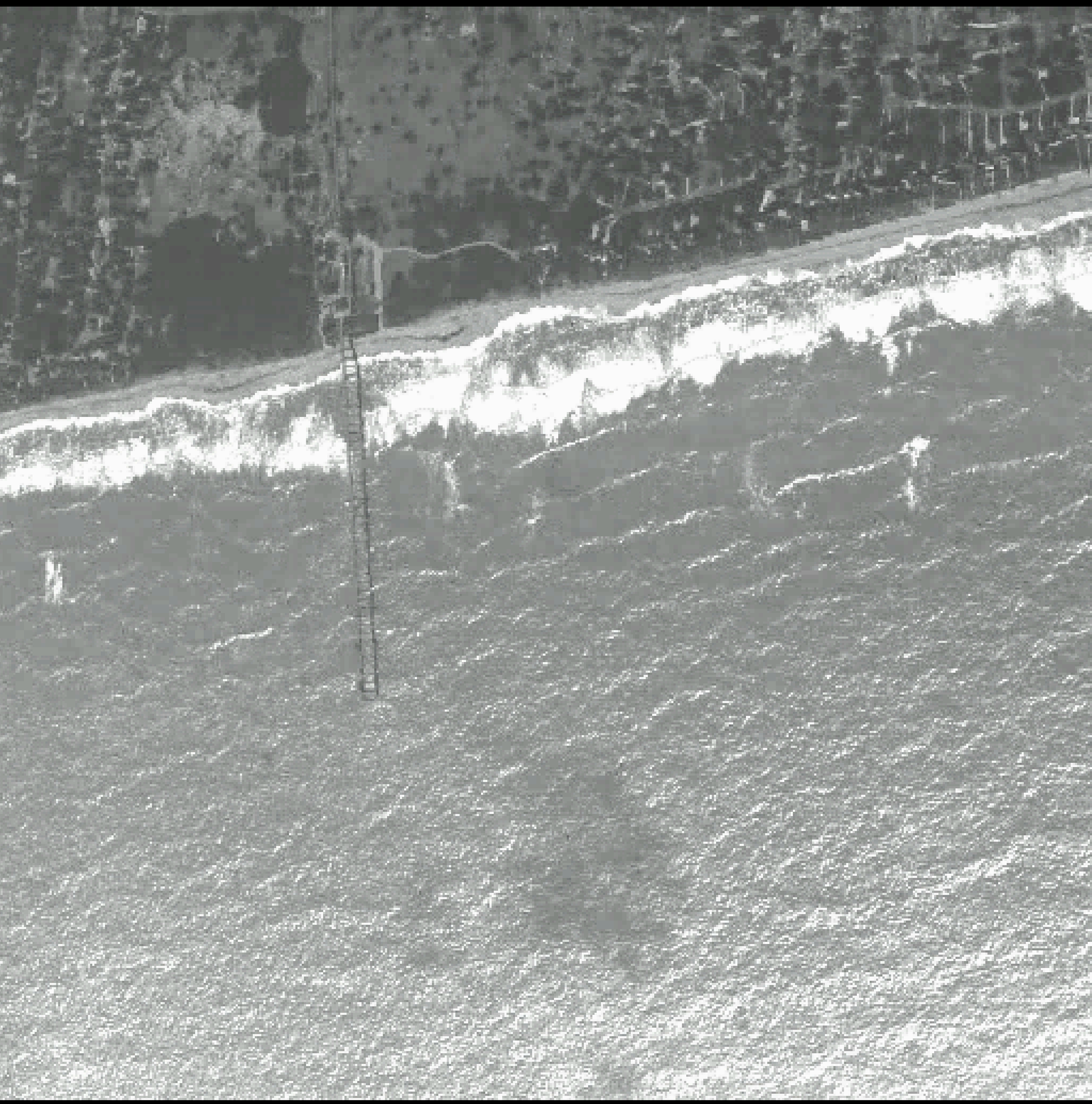
- A wavy surface is composed of sinusoidal waves of various wavelengths
- The speed of each wave depends on its wavelength.
- In the open ocean, longer waves have higher speed.
- **Dispersion** is the relationship between wavelength L, frequency ω and gravity g.
  - $\omega^2 = 2\pi g/L$ deep water
  - $\omega^2 = 2\pi g/L \tanh(2\pi d/L)$ shallow water depth d
  - $\omega^2 = 2\pi g/L \ (1+(\lambda/L)^2)$ capillary waves λ

AROSS

Airborne Remote Optical Sensing System

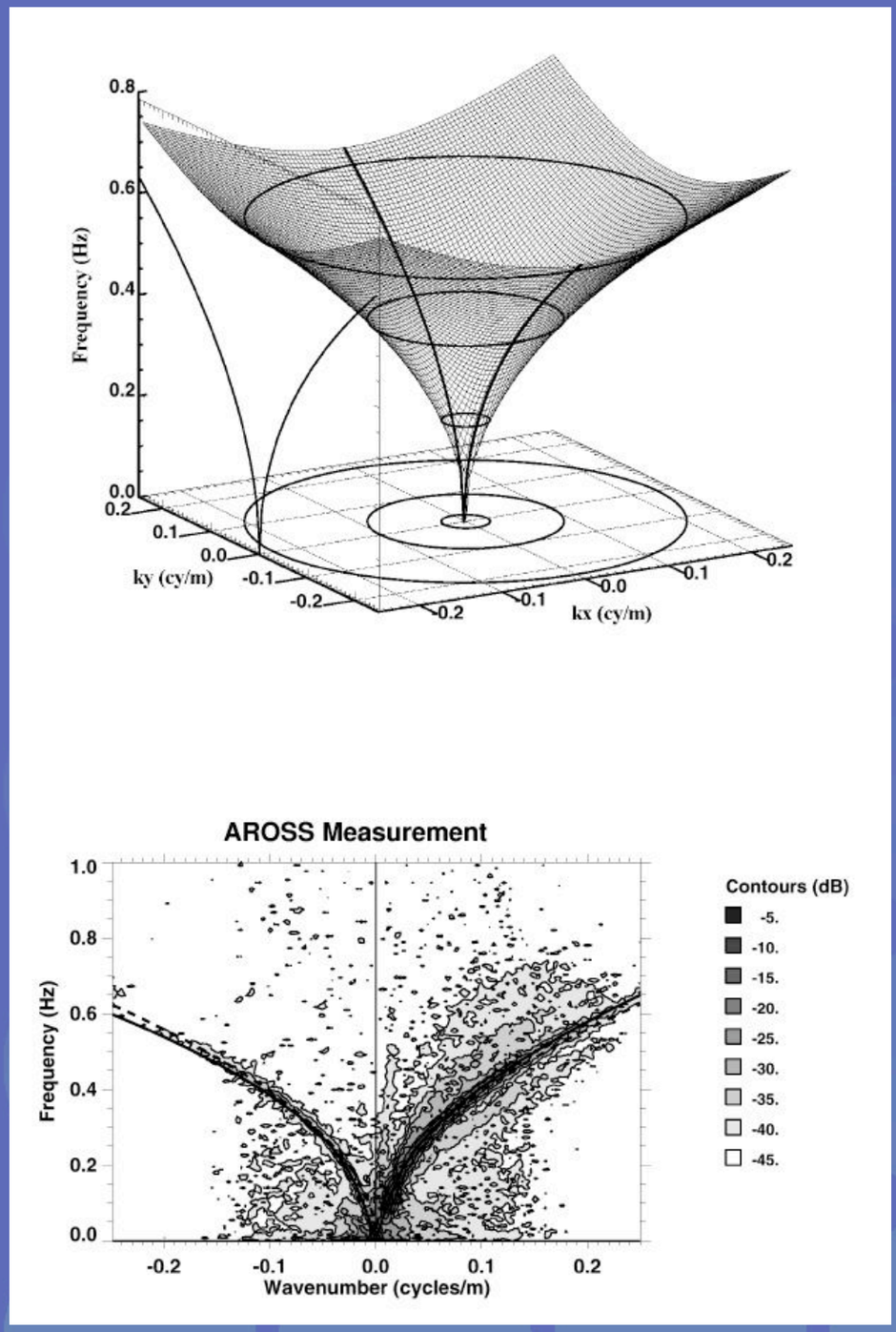
SIGGRAPH2004

- Small plane with an instrumented camera mounted on its nose.
- GPS, INU on the camera
- High bit depth (12 bits) for quantitative dynamic range.
- Builds on past research of many groups.



Dispersion in the Real World

- Image time series transformed to 3D *Power Spectral Density* (power vs frequency and wavelength)
- Dispersion in PSD is on a curved surface in the 3D Fourier Space.
- Dispersion easily detected in data.



Building a Wave Field

SIGGRAPH2004

Sinusoidal wave w/ wavelength L, amplitudes A & B

$$h(x,t) = A\sin\left(\frac{2\pi x}{L} + \omega(L)t\right) + B\sin\left(\frac{2\pi x}{L} - \omega(L)t\right)$$

Building a Wave Field

SIGGRAPH2004

Sinusoidal wave w/ wavelength L, amplitudes A & B

$$h(x,t) = A\sin\left(\frac{2\pi x}{L} + \omega(L)t\right) + B\sin\left(\frac{2\pi x}{L} - \omega(L)t\right)$$

Two waves w/ wavelengths L_0, L_1, amplitudes A_0, B_0, A_1, B_1

$$\begin{aligned} h(x,t) &= A_0\sin\left(\frac{2\pi x}{L_0} + \omega(L_0)t\right) + B_0\sin\left(\frac{2\pi x}{L_0} - \omega(L_0)t\right) \\ &+ A_1\sin\left(\frac{2\pi x}{L_1} + \omega(L_1)t\right) + B_1\sin\left(\frac{2\pi x}{L_1} - \omega(L_1)t\right) \end{aligned}$$

Building a Wave Field

For N waves

$$h(x,t) = \sum_{i=1}^{N} A_i \sin\left(\frac{2\pi x}{L_i} + \omega(L_i)t\right)$$

$$+ \sum_{i=1}^{N} B_i \sin\left(\frac{2\pi x}{L_i} - \omega(L_i)t\right)$$

Most efficient when using Fast Fourier Transforms for points x on a regular rectangular grid.

Ocean Surface as a Noise

- Amplitudes A_i, B_i built from oceanographic noise model.
- Variance of random amplitude depend on wavelength L_i
- Octaves, power law, other details
- For any frame, propagate using dispersion relationship.
- Efficiently handled with Fast Fourier Transforms (FFT).

Propagation is a linear filter.

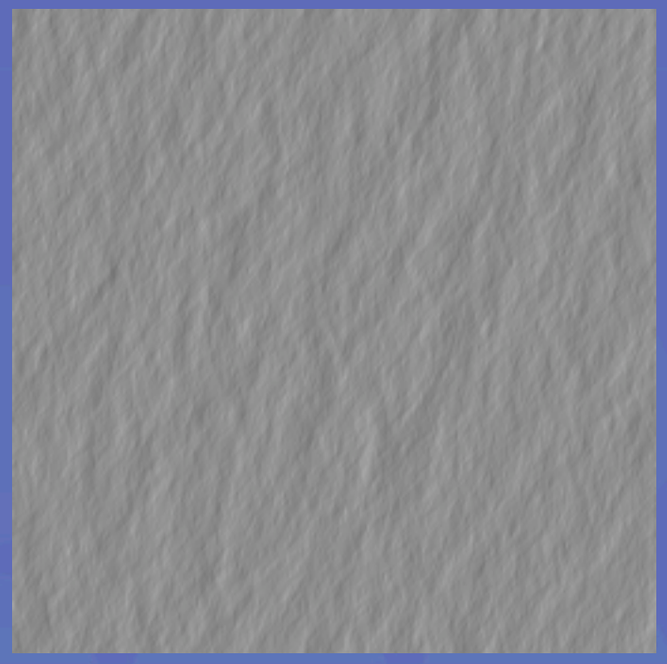
Surface Data Components as Animated Textures

SeaMonster

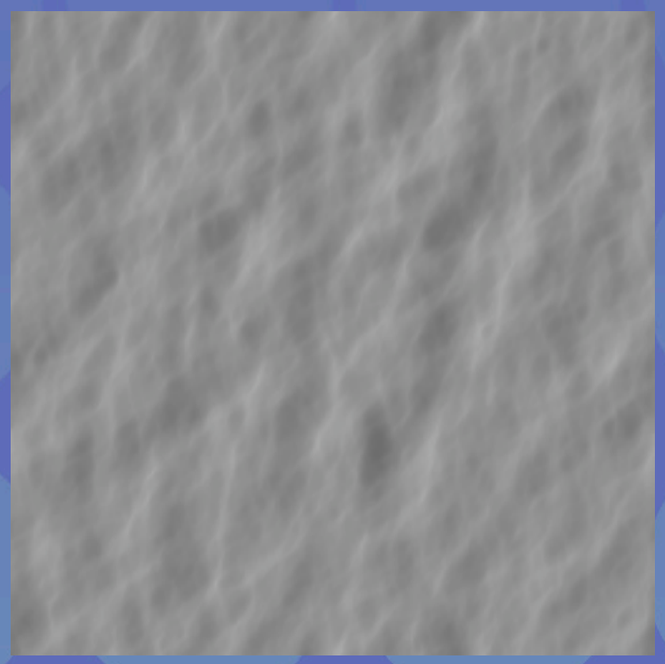
SIGGRAPH2004

Height

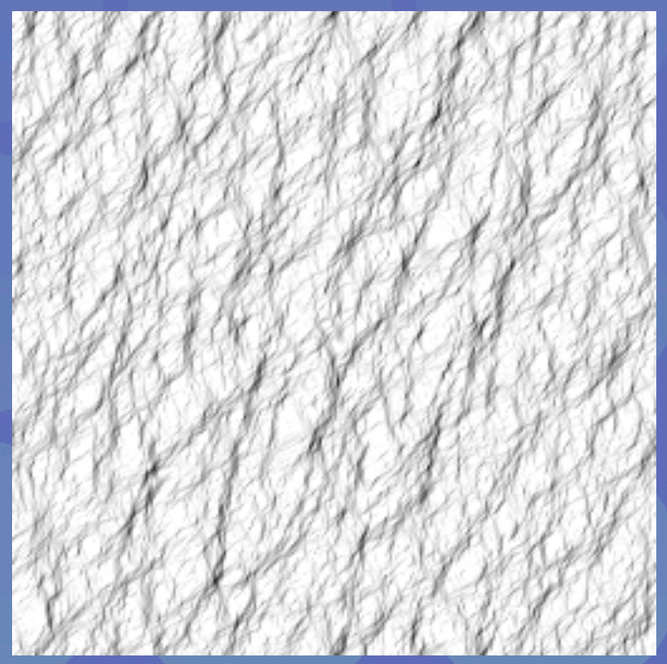
Slope



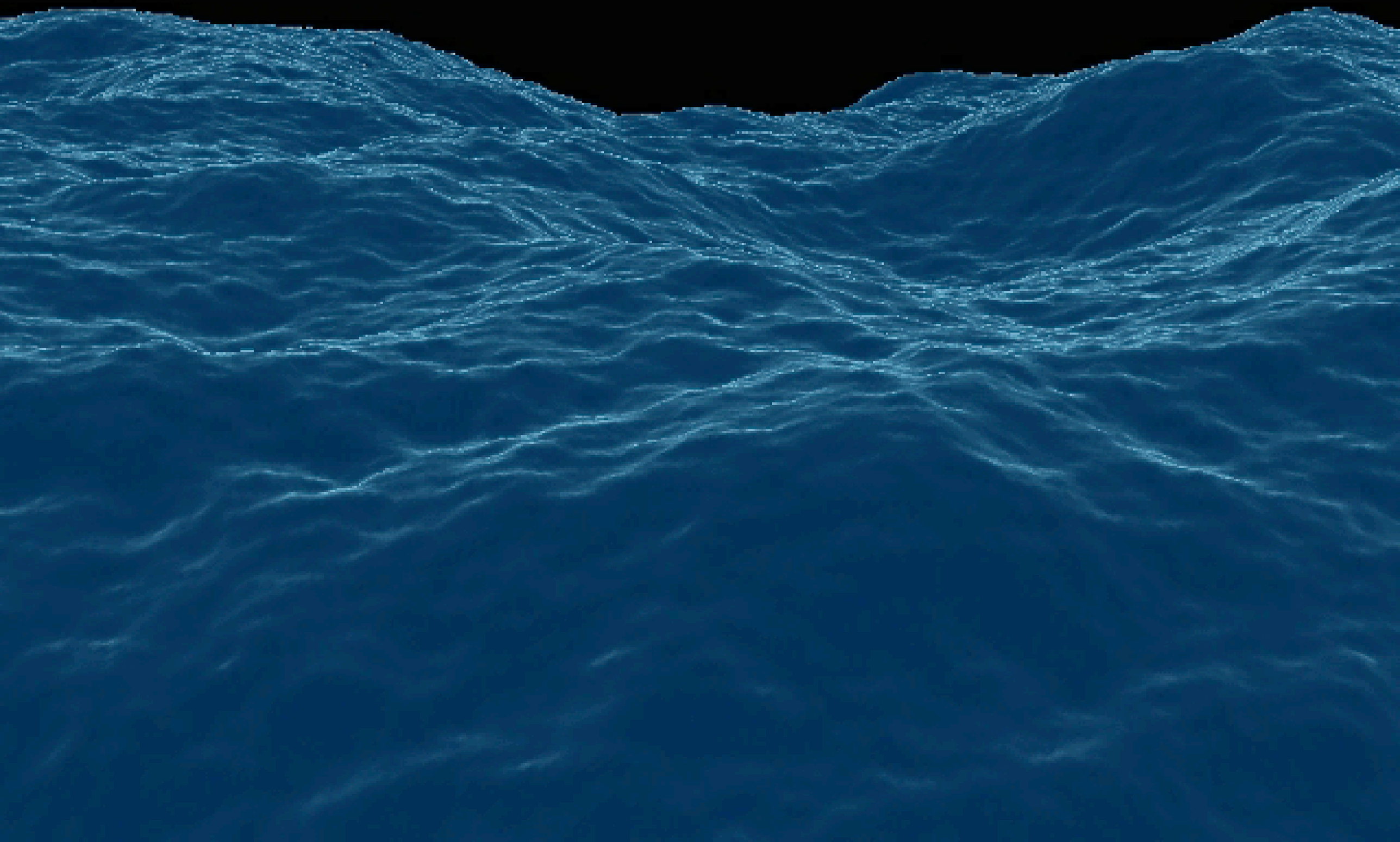
Remapped Height



Minimum Eigenvalue



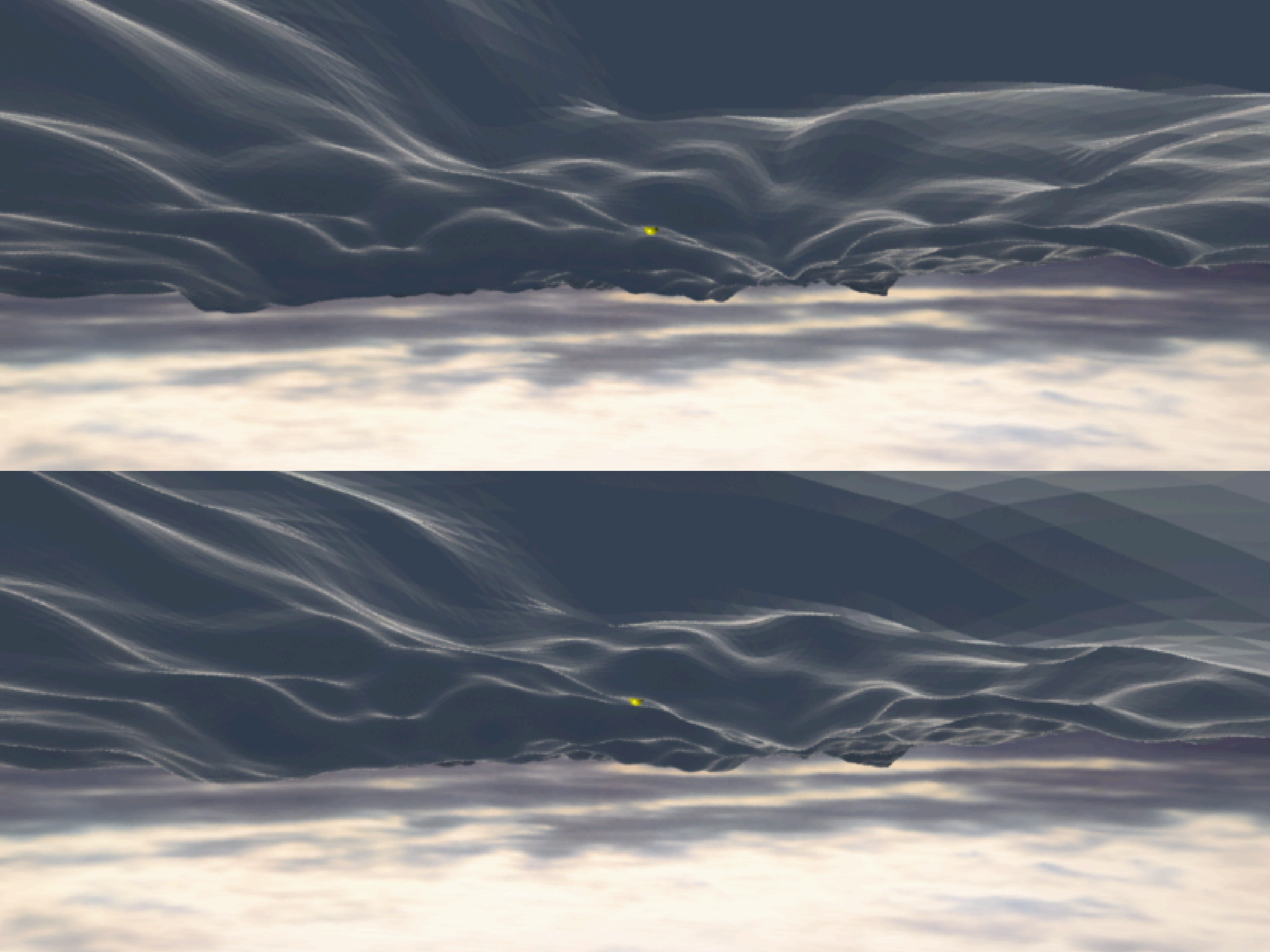
Courtesy Bradley Morris, 2001



Choppy Waves

- Horizontal displacements from height.
- Follows from *Gerstner waves* and a complex theoretical guess.
- Sharp peaks and round troughs.
  - Peak heights & locations unaltered.
- Drives splash, foam, spray algorithms.

$$\vec{D}(x,t) = \frac{1}{\sqrt{-\nabla^2}} \nabla\, h(x,t)$$



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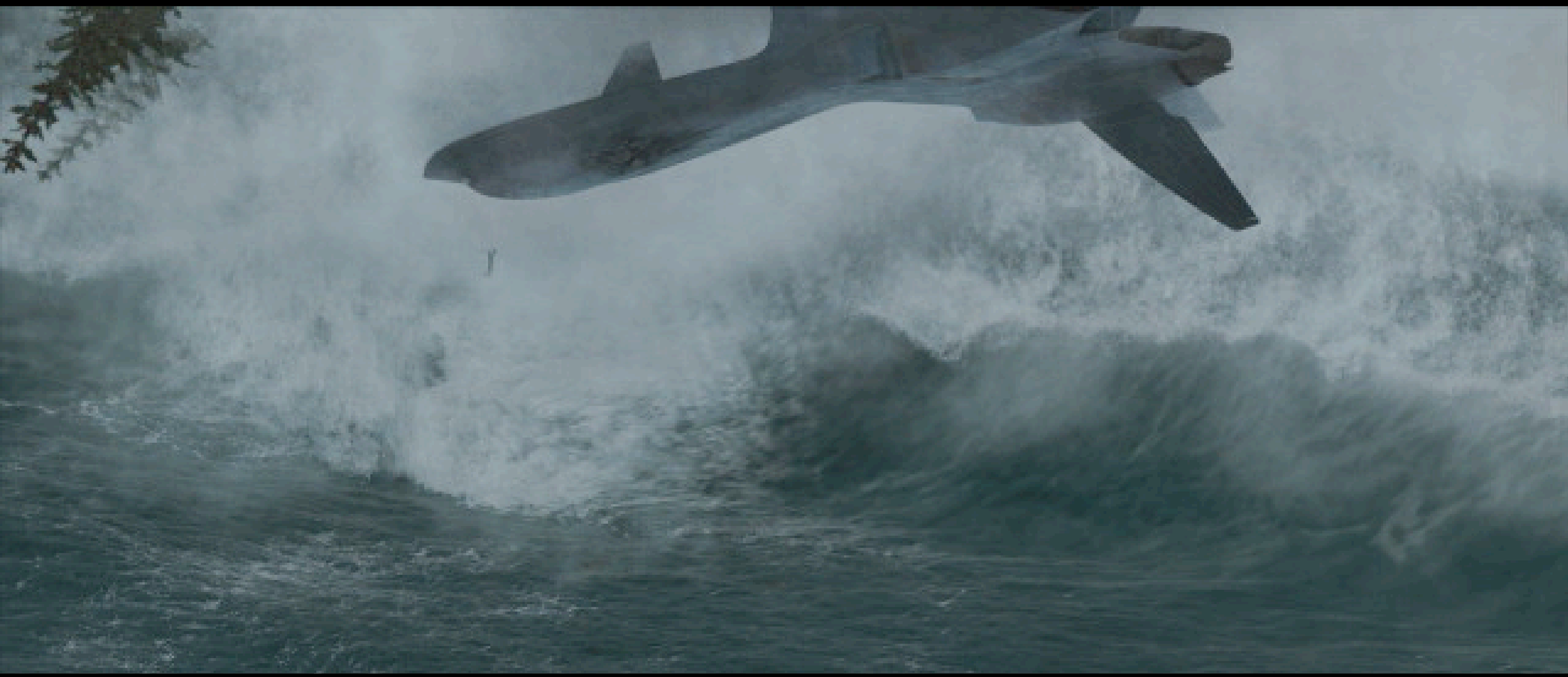
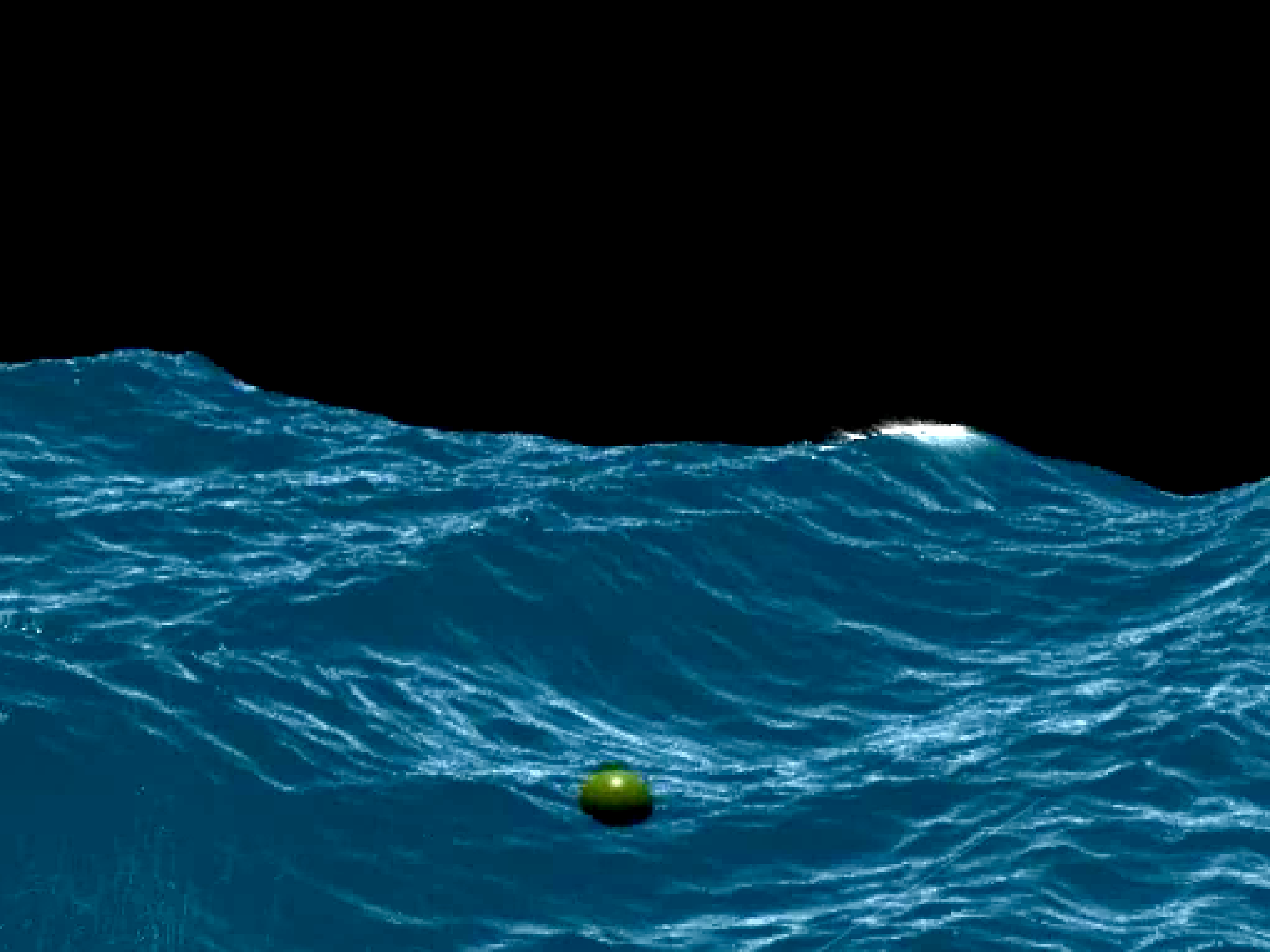
Hydrous Tools

Houdini VEX-based geometry/shader





iWave

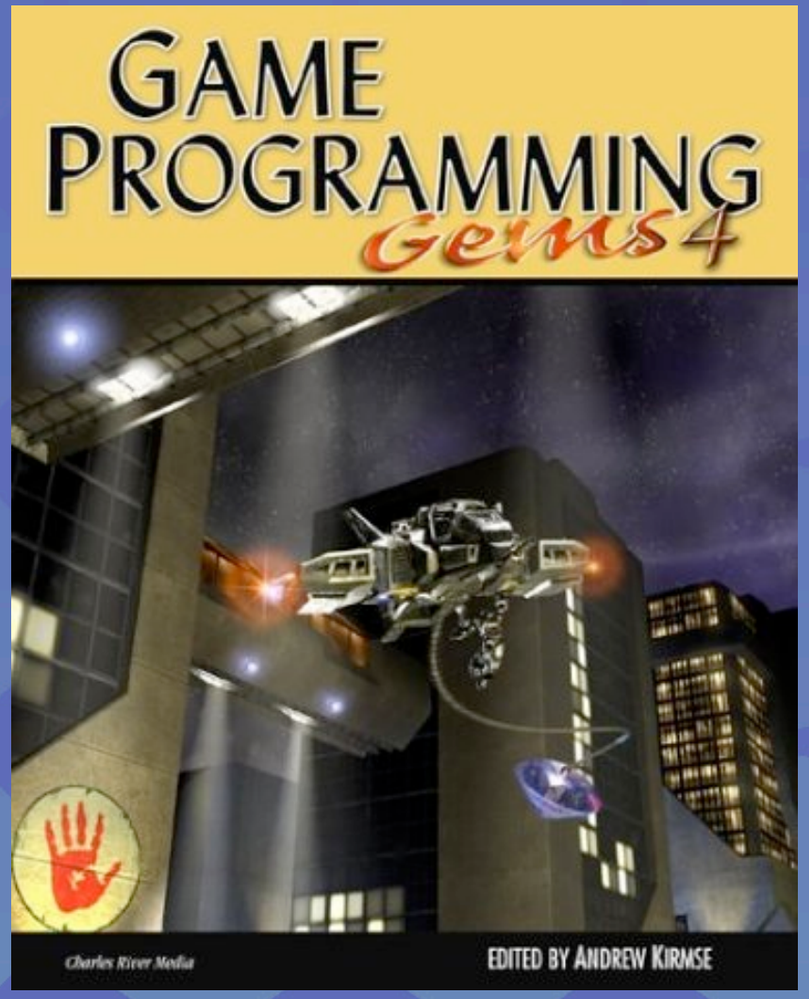
Totally interactive water surface waves

SIGGRAPH2004

- Alternate filter for propagation
  - 13x13 moving window real space convolution

Booth 2019

- Very simple & fast interaction
  - obstructions intersecting the water
  - sources (wakes)
  - shallow water (not possible with fft)




S.S. CARMEN

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