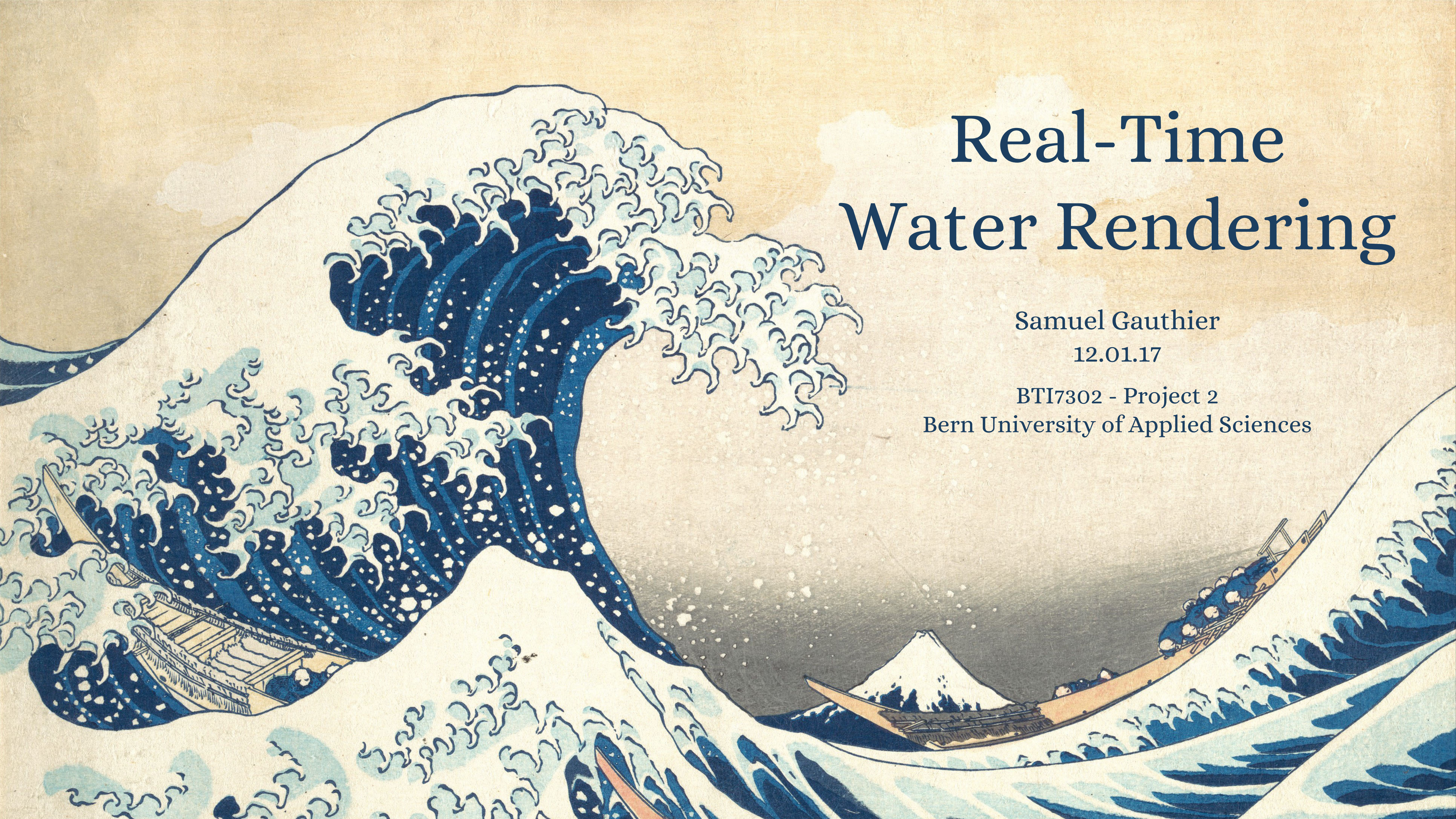

Real-Time Water Rendering

Samuel Gauthier

12.01.17

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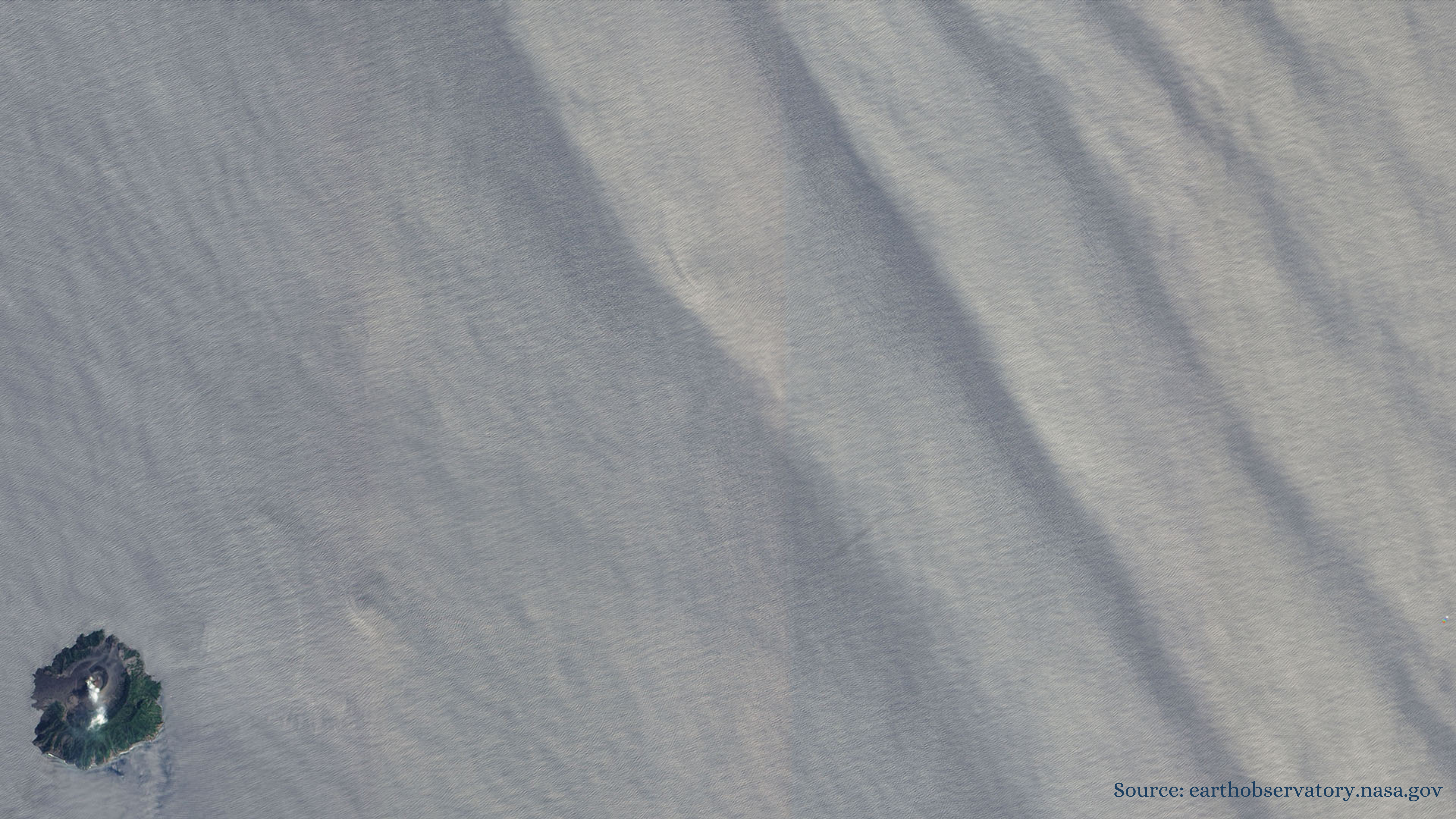
Content

Introduction

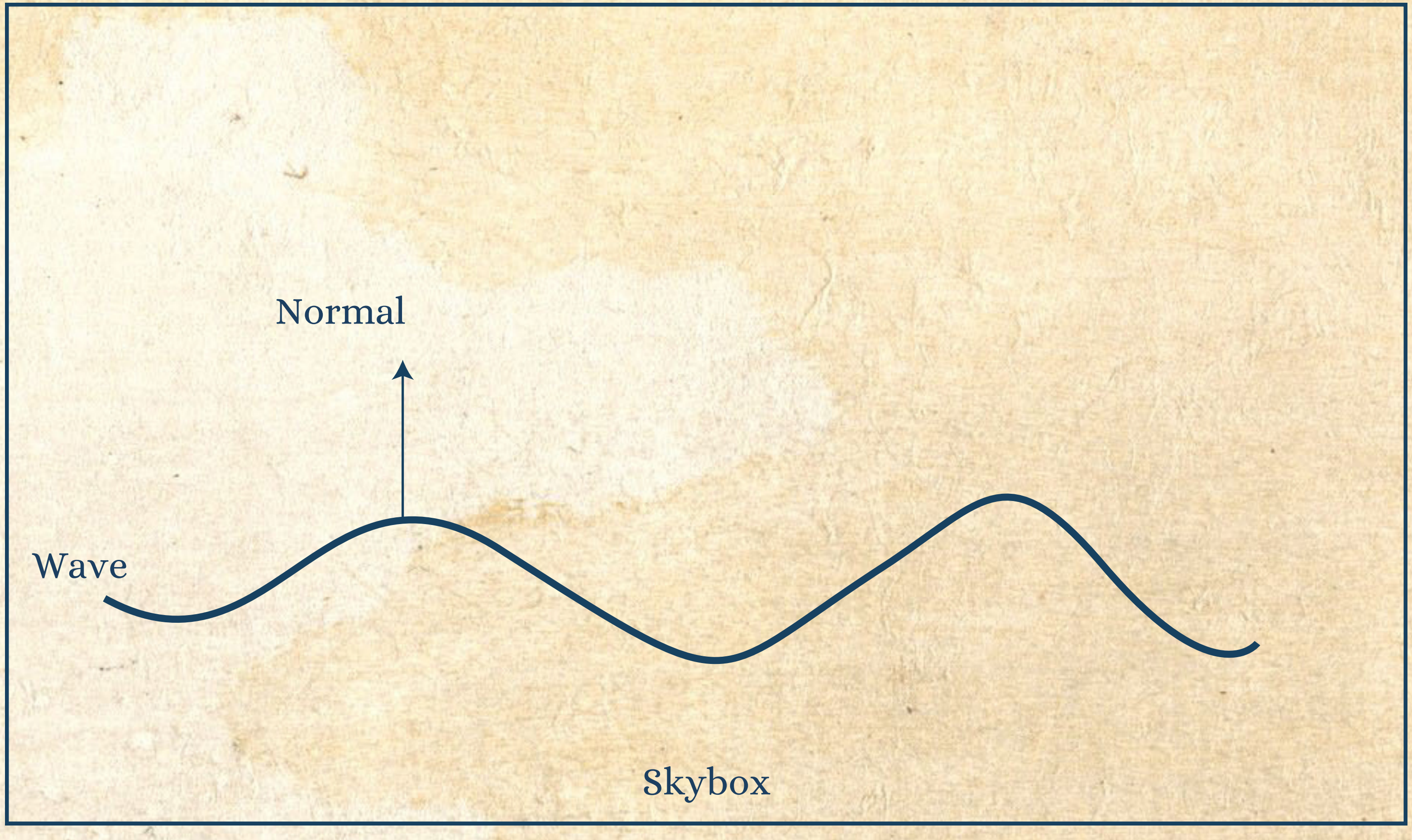
- Exact shape description
- Deep vs shallow water
- Scope: realistic deep water in oceans

Source: scienceblog.eumetsat.int

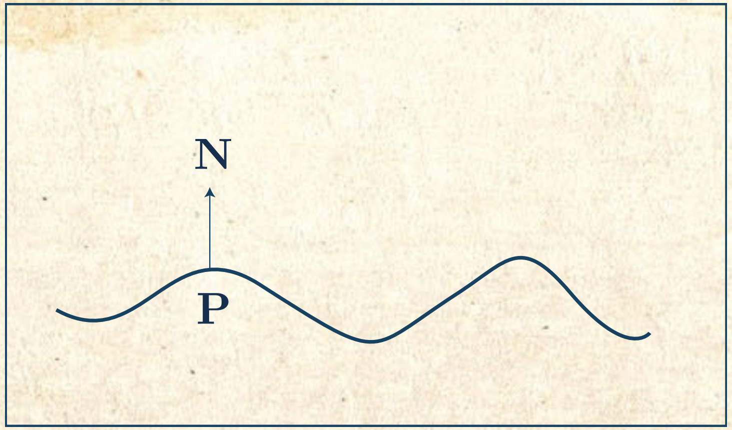


Source: earthobservatory.nasa.gov

Wave Formation



Wave Formation

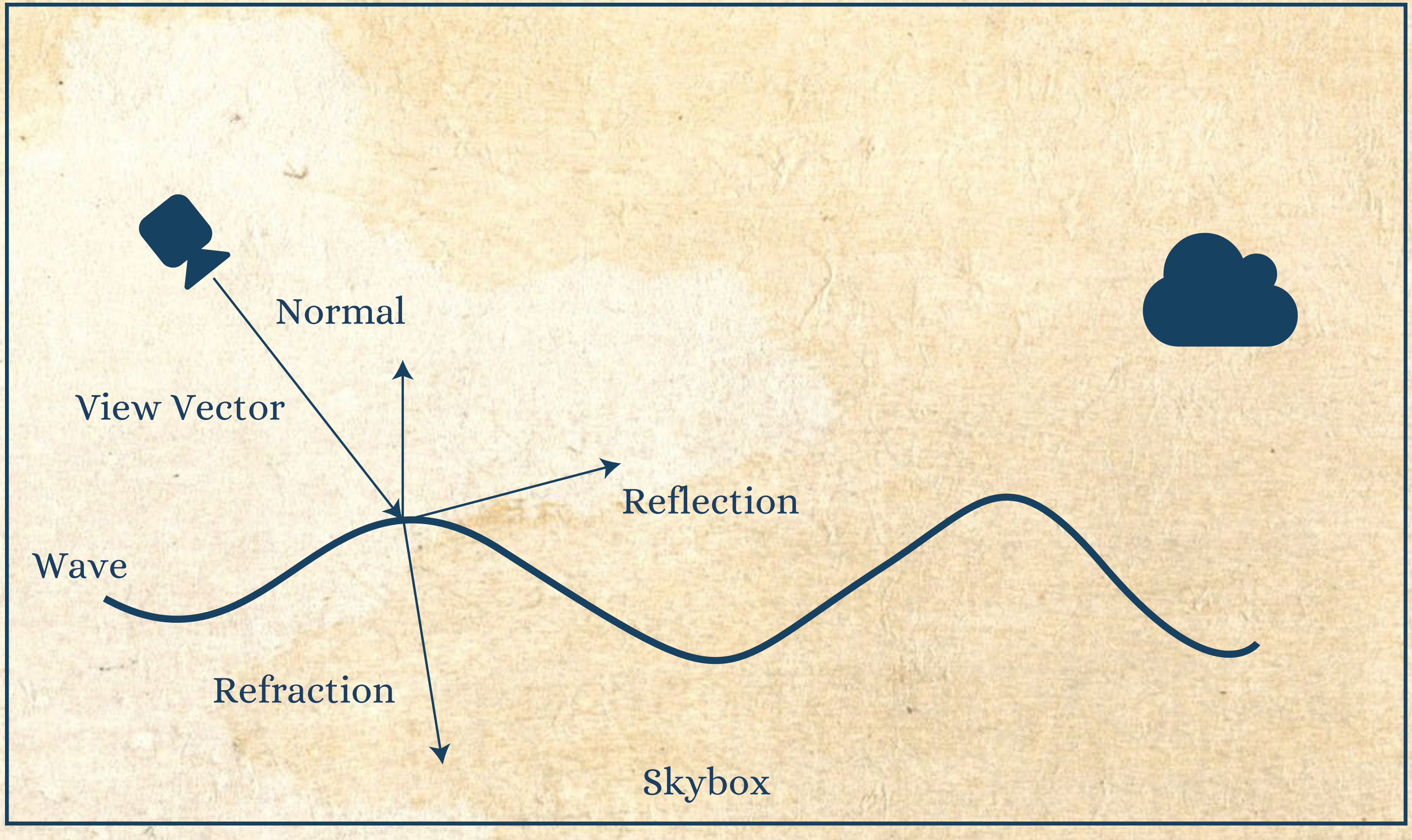


$$\mathbf{P}(x,y,t) = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} x + \sum_i (Q_i A_i \cdot \mathbf{D}_i.x \cdot \cos(\omega_i \mathbf{D}_i \cdot (x,y) + \varphi_i t)) \\ y + \sum_i (Q_i A_i \cdot \mathbf{D}_i.y \cdot \cos(\omega_i \mathbf{D}_i \cdot (x,y) + \varphi_i t)) \\ \sum_i (A_i \cdot \sin(\omega_i \mathbf{D}_i \cdot (x,y) + \varphi_i t)) \end{bmatrix}$$

$$\mathbf{N}(x,y,t) = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -\sum_i (\mathbf{D}_i.x \cdot WA \cdot C(\cdot)) \\ -\sum_i (\mathbf{D}_i.y \cdot WA \cdot C(\cdot)) \\ 1 - \sum_i (Q_i \cdot WA \cdot S(\cdot)) \end{bmatrix}$$

$$\begin{aligned} WA &= \omega_i A_i, \\ S(\cdot) &= \sin(\omega_i \mathbf{D}_i \cdot \mathbf{P} + \varphi_i t), \\ C(\cdot) &= \cos(\omega_i \mathbf{D}_i \cdot \mathbf{P} + \varphi_i t) \end{aligned}$$

Wave Formation



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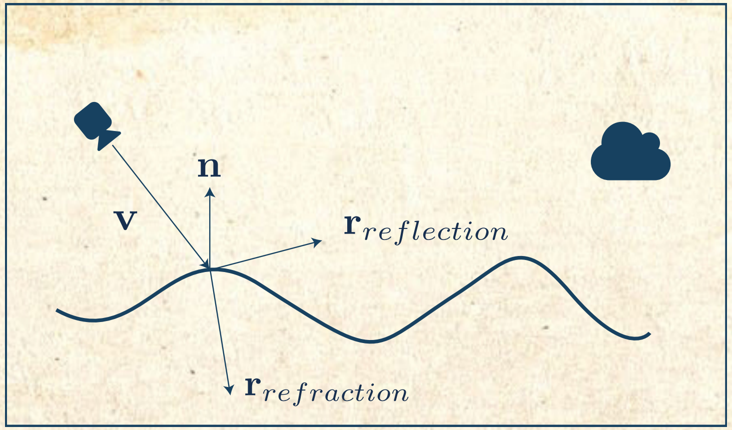
Wave Formation



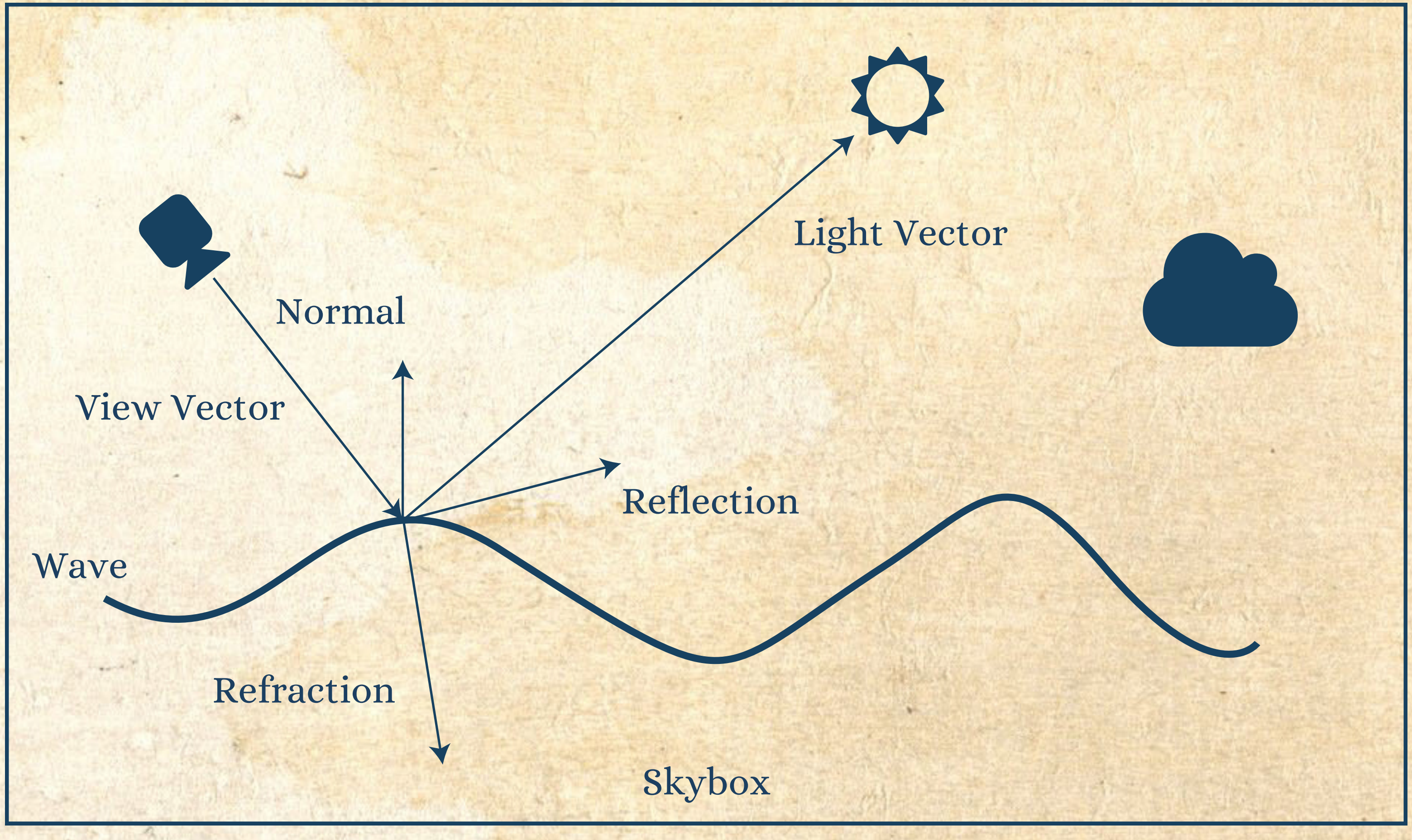
$$\mathbf{r}_{reflection} = \mathbf{v} - 2(\mathbf{v} \cdot \mathbf{n})\mathbf{n}$$

$$\mathbf{r}_{refraction} = \frac{1}{n}\mathbf{v} + (\frac{1}{n}\cos(\theta_v) + \sqrt{1 - \frac{1}{n^2}(1 - \cos^2(\theta_v))})\mathbf{n}$$

$$F(\theta_v) \approx F_0 + (1 - F_0)(1 - \overline{\cos}(\theta_v))^5,$$

$$F_0 = (\frac{n-1}{n+1})^2$$

Wave Formation



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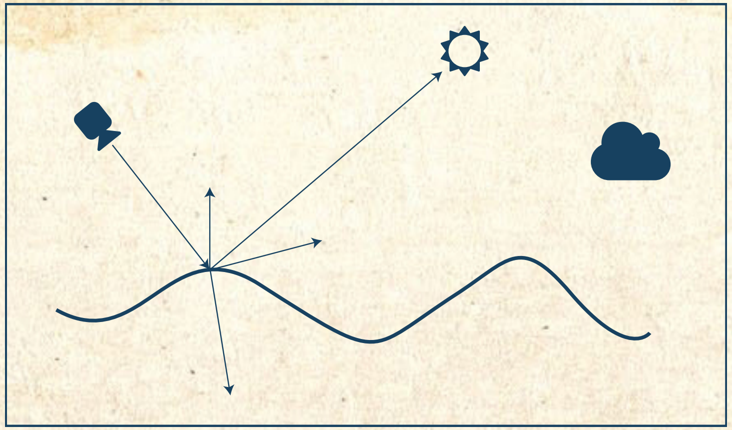
Wave Formation



$$color = f_{specular} + f_{ambient}$$

$$f_{specular} = \frac{F(\mathbf{v}, \mathbf{h}, F_0)G(\mathbf{v}, \mathbf{n}, \mathbf{l})D(\mathbf{n}, \mathbf{h}, \alpha)}{4(\mathbf{n} \cdot \mathbf{l})(\mathbf{n} \cdot \mathbf{v})}$$

$$f_{ambient} = color_{refraction}(1 - F(\alpha_h)) + color_{refraction}F(\alpha_h),$$

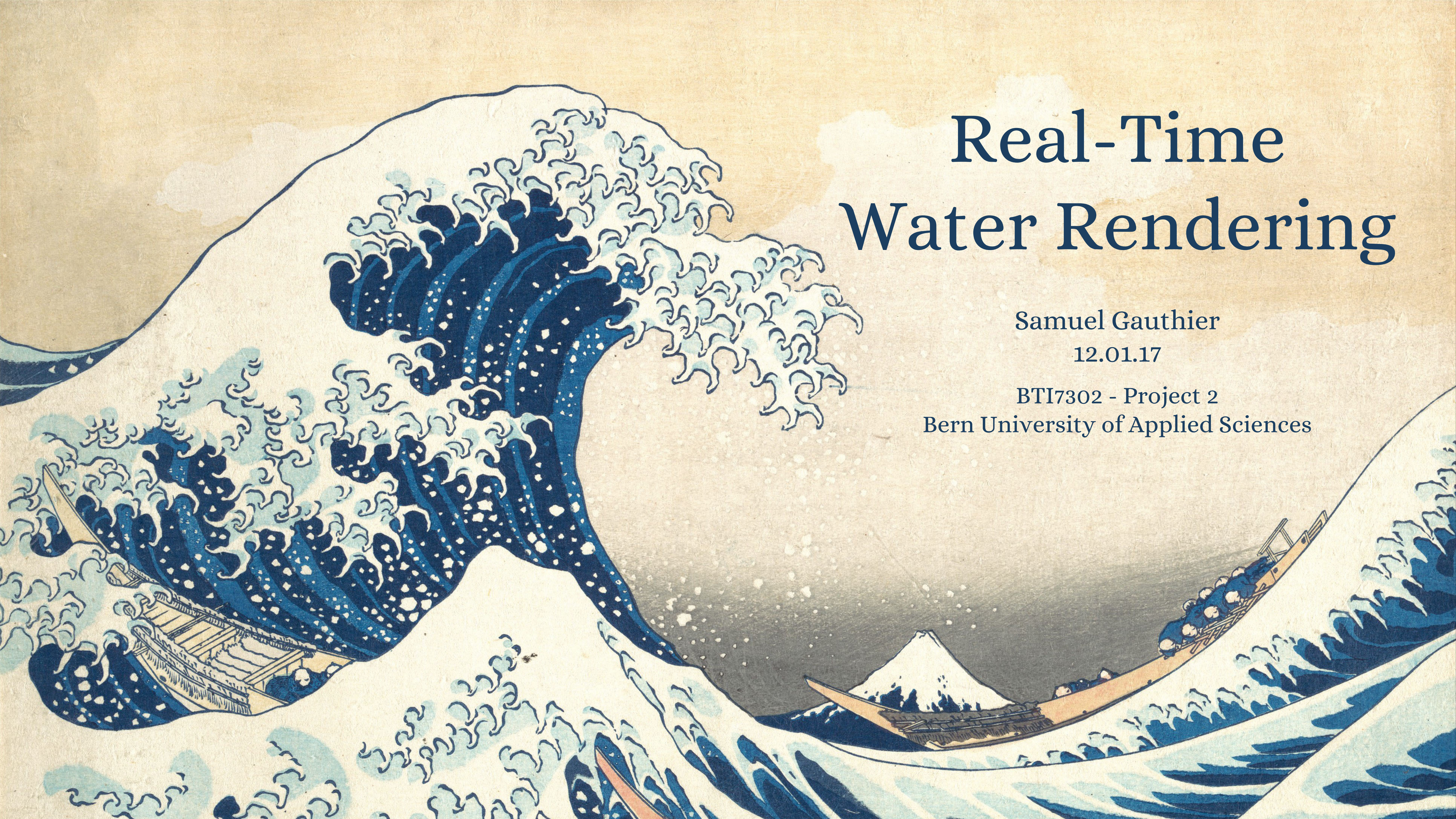
$$F(\alpha_h) = F(\mathbf{v}, \mathbf{h}, F_0)$$

Result

OpenGL®

Further Work

- FFT or Wave Particle approach
- Level of Detail
- Caustics, foam, etc.
- Shallow water
- Embed into bigger application



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Sources

- *A Survey of Ocean Simulation and Rendering Techniques in Computer Graphics*, Darles et al., 2011
- *Effective Water Simulation From Physical Models*, Finch, 2004
- *Ocean Surfaces*, Tessendorf, 2001
- *Sea Surface Visualization in World of Warships*, Kryachko, 2016
- *The Great Wave off Kanagawa*, Hokusai, ca. 1829-1833