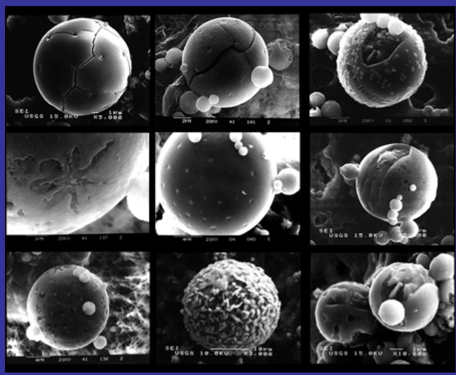
Advanced Optics for Realistic Rendering

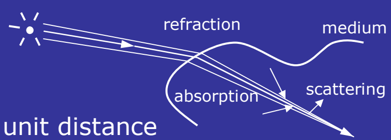


Denver Microbeam Lab
Volcano Smoke Particles From Hawaii

Presenter:
Jeppe Revall Frisvad

What we need to render participating media

- Index of refraction
  - Real part: Slowing down of light in the medium
  - Imaginary part: Absorption of light in the medium



- Scattering properties
  - Scattering coefficient: Total per unit distance
  - Phase function: Directional

How to obtain scattering properties

- Measurement
  - Different equipment for different wavelengths
  - Material must be available in real life
  - Difficult to change the contents of the material
- Manual adjustment
  - Where to start?
- Computation
  - How? Advanced optics !

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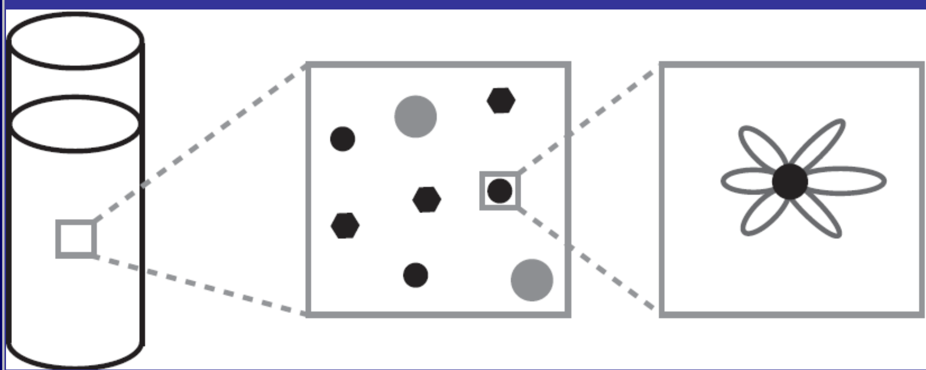
Macroscopic scattering



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Combining particle-specific properties

- Assuming that particles scatter light independently, we simply sum the contributions
- For every particle type, integrate over particle radii

$$\sigma(\lambda_0) = \int_{r_{\min}}^{r_{\max}} C(r, \lambda_0) N(r)\, \mathrm{d}r$$

- σ is the scattering or extinction coefficient
- C is the corresponding cross section
- N is the distribution of number densities

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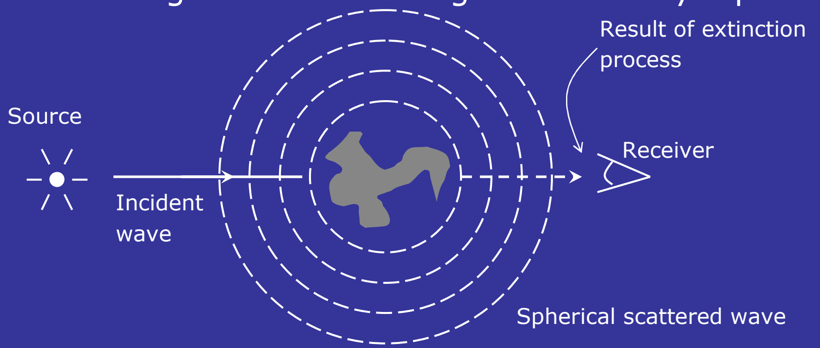
Small particles

- Scattering of an electromagnetic wave by a particle



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Scattering by milk

Red on forward scattering, subtle blue on side scattering, white on back scattering

Natural water

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Icebergs

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Computing optical properties

- Needed for the computation
  - Particle composition (volume fractions)
  - Refractive index for host medium
  - Refractive index for each particle type
  - Size distribution for each particle type
- Plug it in the Lorenz-Mie theory and out comes the optical properties of the bulk (code will be available)

Particle compositions (examples)

- Milk
  - Host: Water and dissolved vitamin (and many other things)
  - Fat globules (~1.5 wt.-%) and casein micelles (~3.0 wt.-%)
- Natural water
  - Host: Pure water
  - Minerals and algae (both around $5 \cdot 10^{-5}$ %)
- Icebergs
  - Host: Pure ice
  - Brine pockets, air bubbles, minerals, and algae

Common size distributions

- The log-normal distribution of volume frequency

$$r^3 N(r) = \frac{1}{r\beta\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln r - \alpha}{\beta}\right)^2}$$

$$\alpha = \ln \mu - \frac{1}{2} \ln\left(\frac{\sigma^2}{\mu^2} + 1\right) \quad , \quad \beta = \sqrt{\ln\left(\frac{\sigma^2}{\mu^2} + 1\right)}$$

- The power law distribution (for larger particles)

$$N(r) = N_* r^{-\alpha}$$

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The milk components (rendered)

water   water + B2 vitamin   protein   fat

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Different types of milk (rendered)

skimmed   reduced   whole

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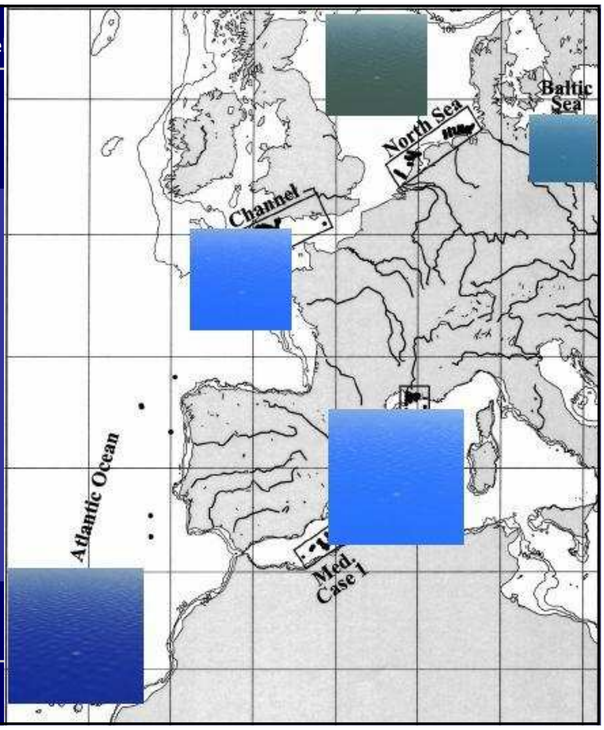
Oceanic and coastal waters (rendered)



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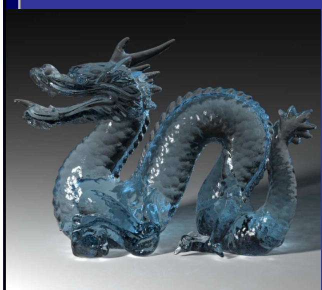
Ice sculptures (rendered)



pure ice

compacted snow

white ice

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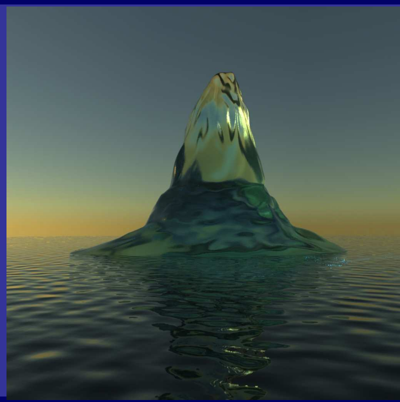
Green icebergs (rendered)

10 am



7 pm

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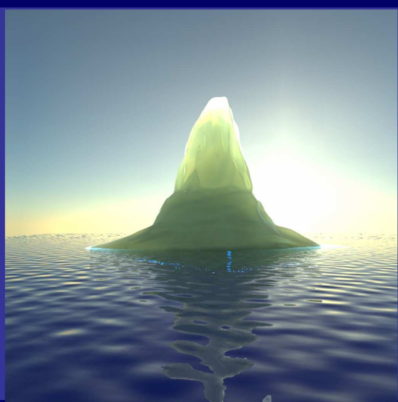
Algal ice



Green algae on iceberg.
(Photo courtesy Gerhard Dieckmann)

Thank you for your attention

- Questions/comments?

- Reference:
  J. R. Frisvad, N. J. Christensen, and H. W. Jensen. Computing the Scattering Properties of Participating Media Using Lorenz-Mie Theory. *ACM Transactions on Graphics (Proceedings of SIGGRAPH 2007)*, August 2007. To appear.