



Graphics Interface 2012

May 28th to 30th, Toronto, Ontario, Canada



Interactive Cloud Rendering Using Temporally-Coherent Photon Mapping

Oskar Elek, Tobias Ritschel, Alexander Wilkie, Hans-Peter Seidel

Max Planck Institut Informatik



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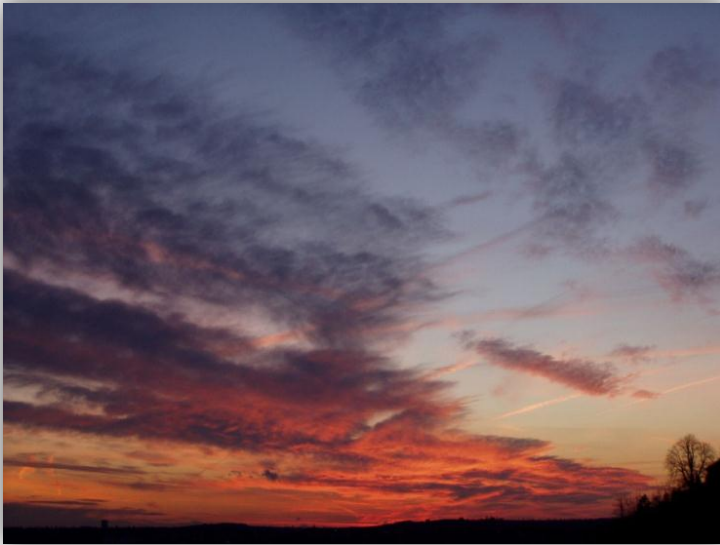


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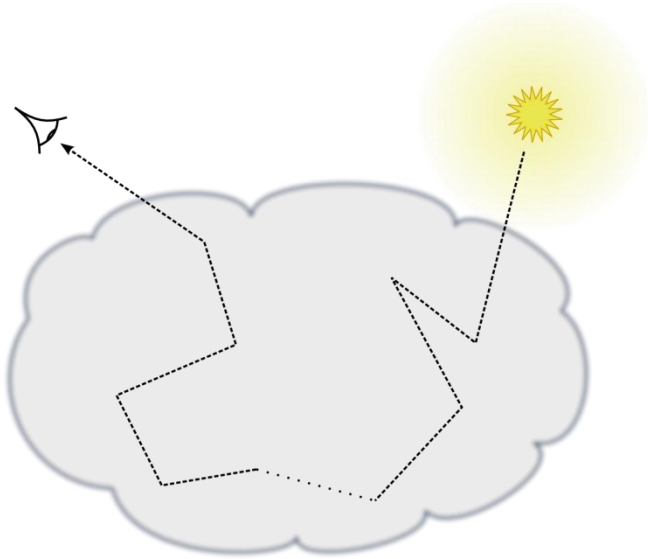


Motivation

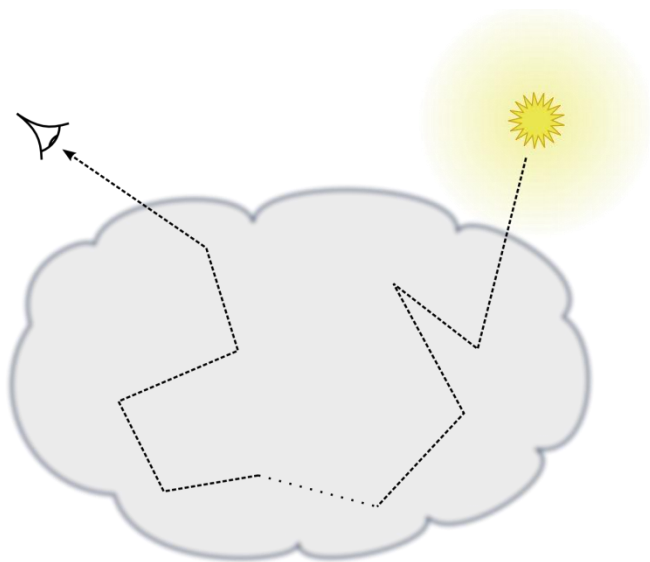


$$\frac{dL(\mathbf{x}, \omega)}{d\mathbf{x}} = -\sigma_t(\mathbf{x})L(\mathbf{x}, \omega) + \sigma_s(\mathbf{x}) \int_{\Omega_{4\pi}} p(\mathbf{x}, \omega, \omega')L(\mathbf{x}, \omega') d\omega'$$

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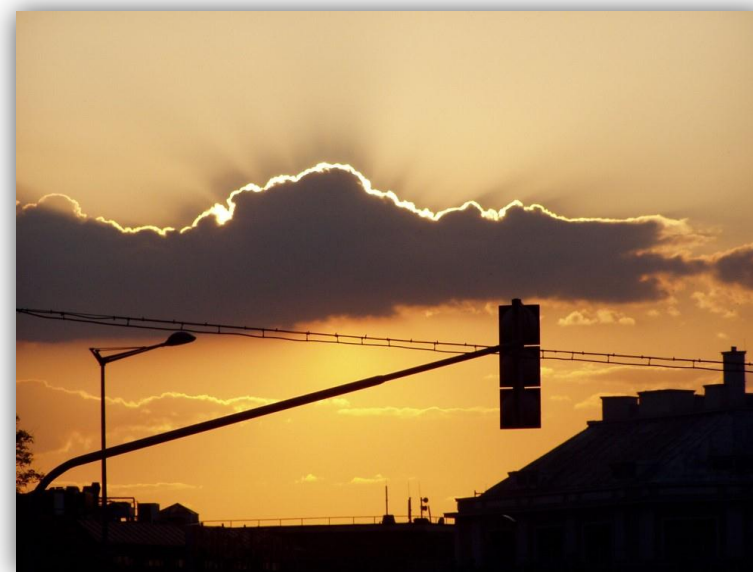
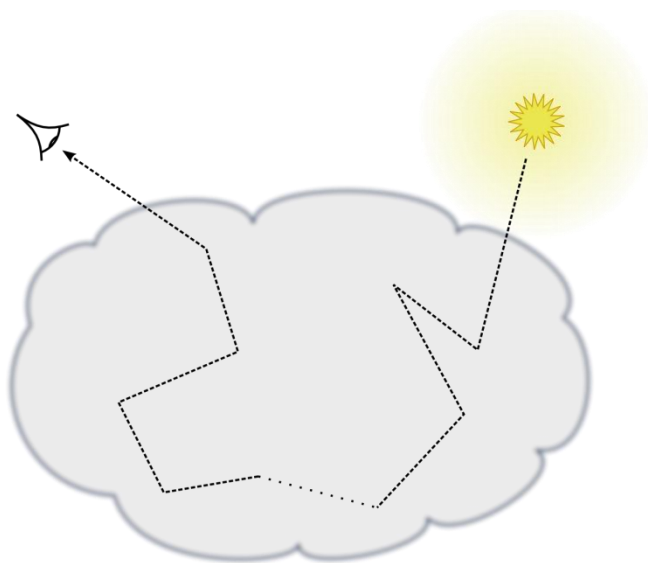
$$\frac{dL(\mathbf{x}, \omega)}{d\mathbf{x}} = -\sigma_t(\mathbf{x})L(\mathbf{x}, \omega) + \sigma_s(\mathbf{x}) \int_{\Omega_{4\pi}} p(\mathbf{x}, \omega, \omega')L(\mathbf{x}, \omega') d\omega'$$



Difficulties

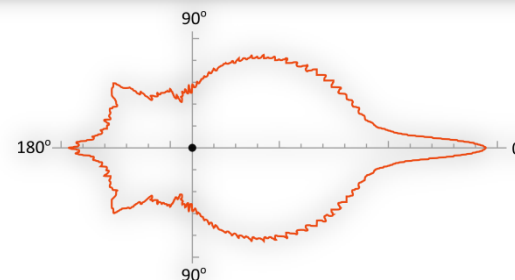
- Unit albedo

$$\frac{dL(\mathbf{x}, \omega)}{d\mathbf{x}} = -\sigma_t(\mathbf{x})L(\mathbf{x}, \omega) + \sigma_s(\mathbf{x}) \int_{\Omega_{4\pi}} p(\mathbf{x}, \omega, \omega')L(\mathbf{x}, \omega') d\omega'$$

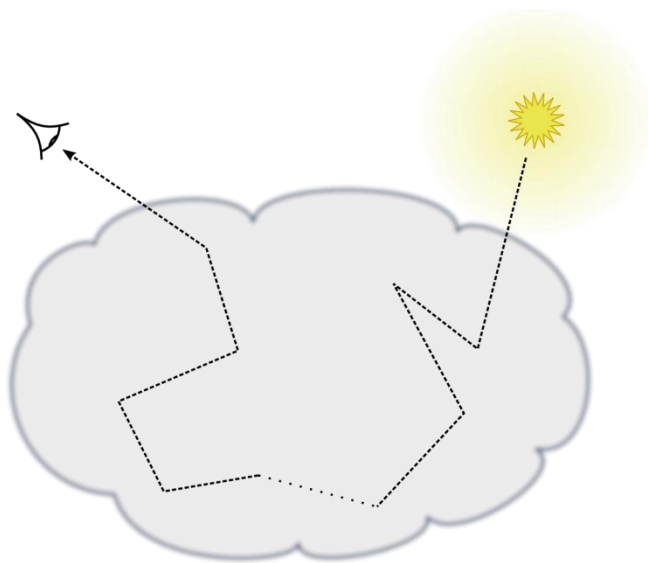


Difficulties

- Unit albedo
- High anisotropy



$$\frac{dL(\mathbf{x}, \omega)}{d\mathbf{x}} = -\sigma_t(\mathbf{x})L(\mathbf{x}, \omega) + \sigma_s(\mathbf{x}) \int_{\Omega_{4\pi}} p(\mathbf{x}, \omega, \omega')L(\mathbf{x}, \omega') d\omega'$$



Difficulties

- Unit albedo
- High anisotropy
- Shape and size

- **Monte-Carlo methods**

- Lafortune and Willems 1996, Pauly et al. 2000, Jensen 1998+, Jarosz 2008+

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 - Lafortune and Willems 1996, Pauly et al. 2000, Jensen 1998+, Jarosz 2008+
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 - Chandrasekhar 1950, Rushmeier and Torrance 1987, Stam 1995, Geist et al. 2004, Fattal 2009

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- **Interactive cloud rendering**
 - Empirical



Wang 2003



Wenzel 2006

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- **Finite-element approaches**

- Chandrasekhar 1950, Rushmeier and Torrance 1987, Stam 1995, Geist et al. 2004, Fattal 2009

- **Interactive cloud rendering**

- Empirical or physically-based



Wang 2003



Wenzel 2006



Szirmay-Kalos
et al. 2005

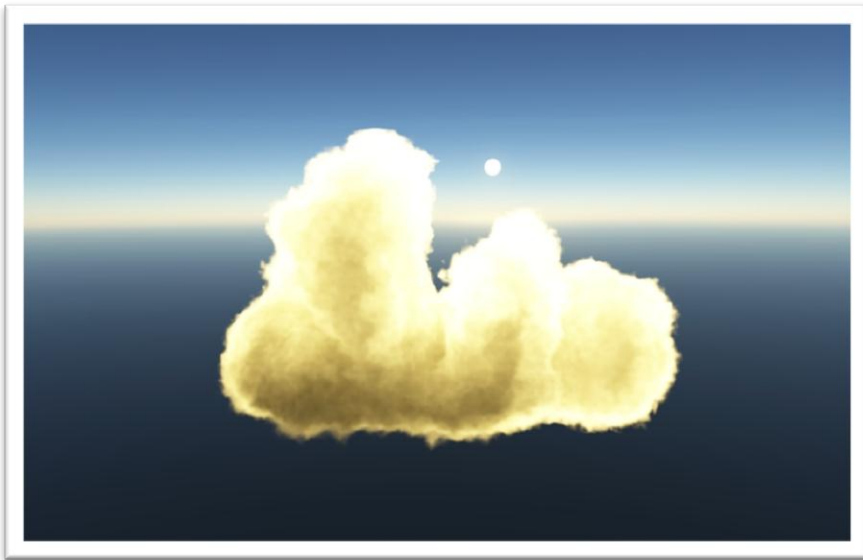


Bouthors et al.
2006/2008

Observations

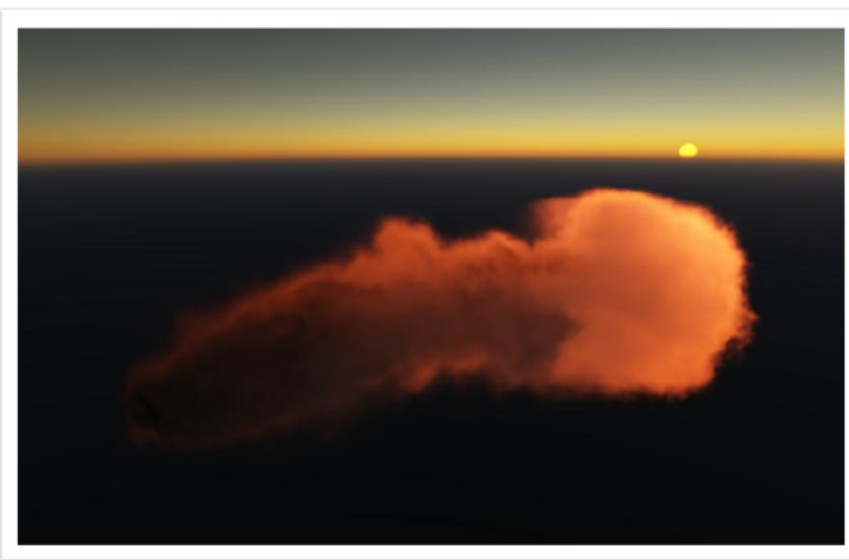
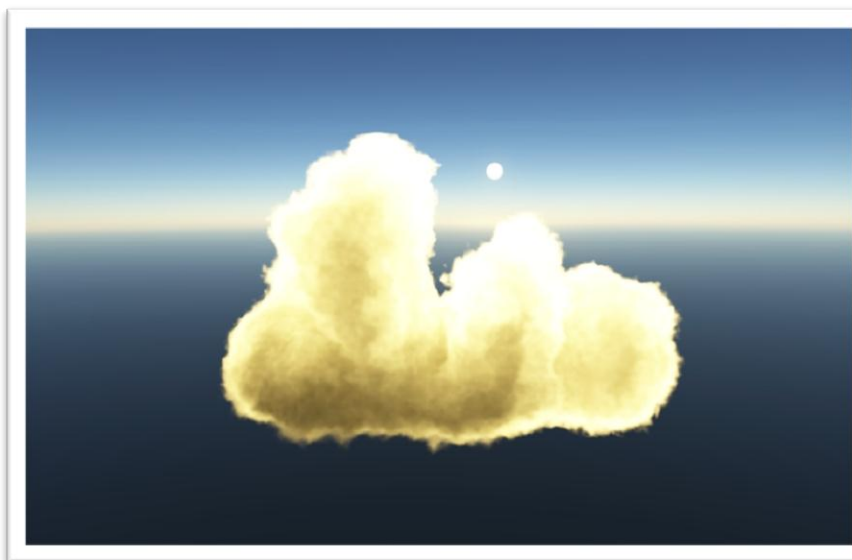
Observations

- One primary light source
- Slow lighting changes



Observations

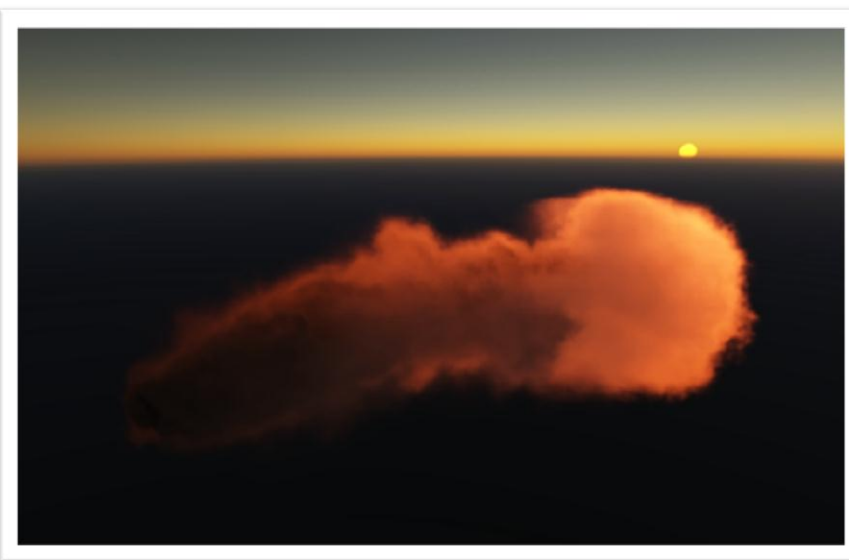
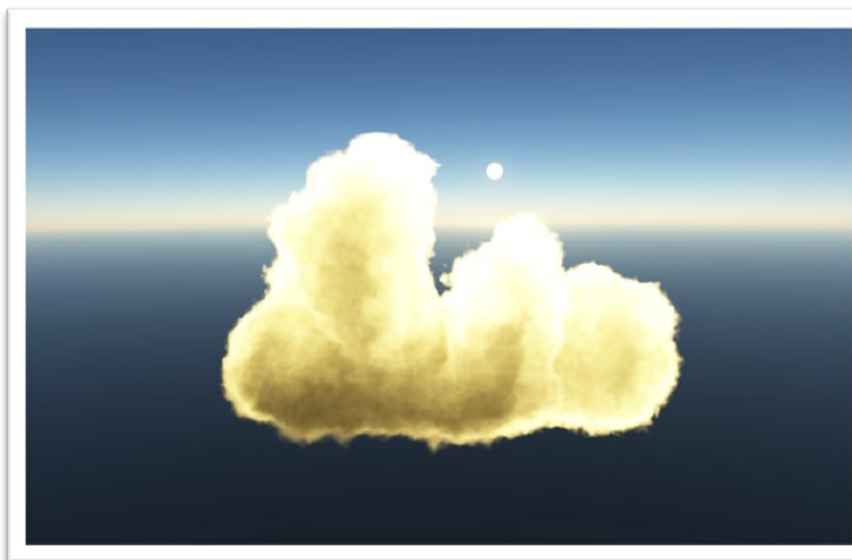
- One primary light source
- Slow lighting changes
- Slow shape development



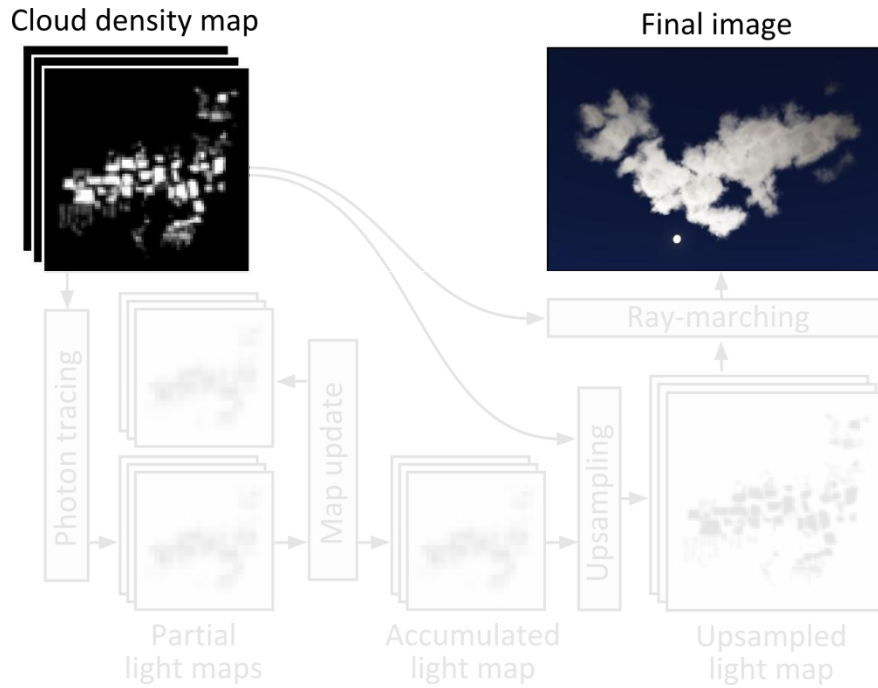
Observations

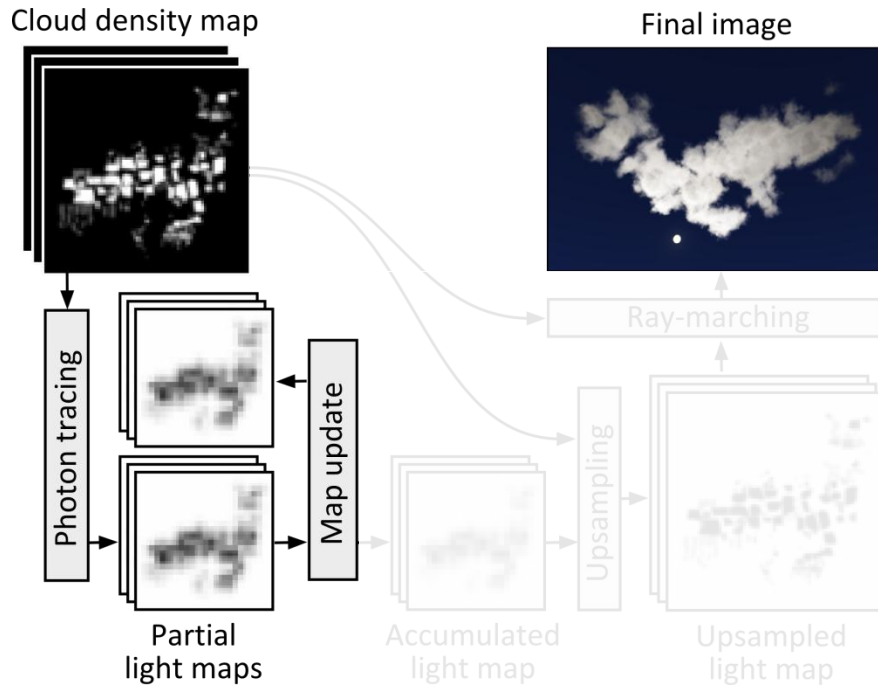
- One primary light source
- Slow lighting changes
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} Temporal coherence

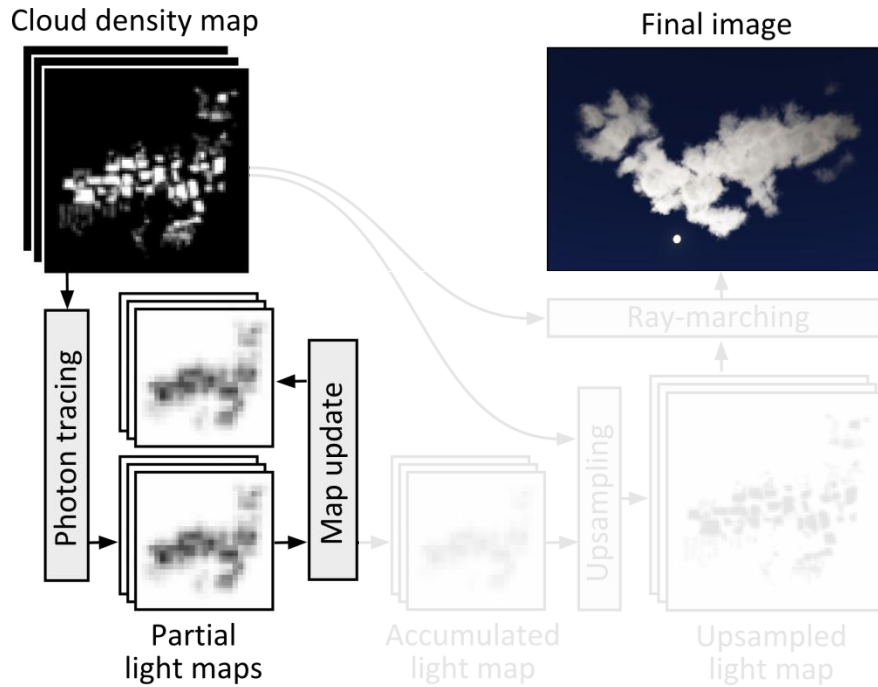


Our approach



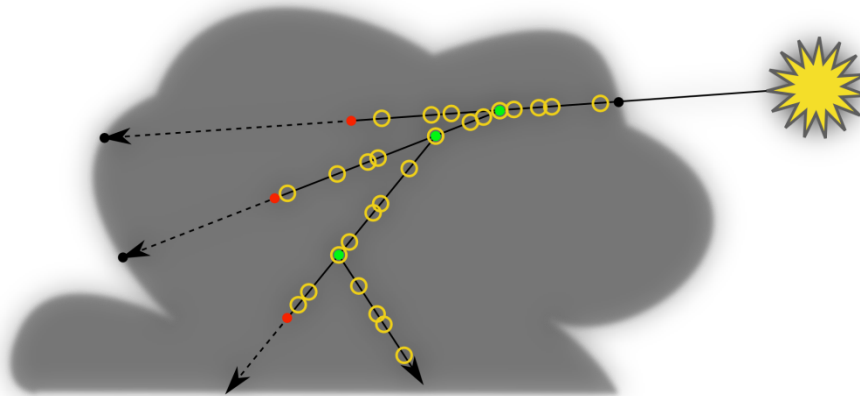


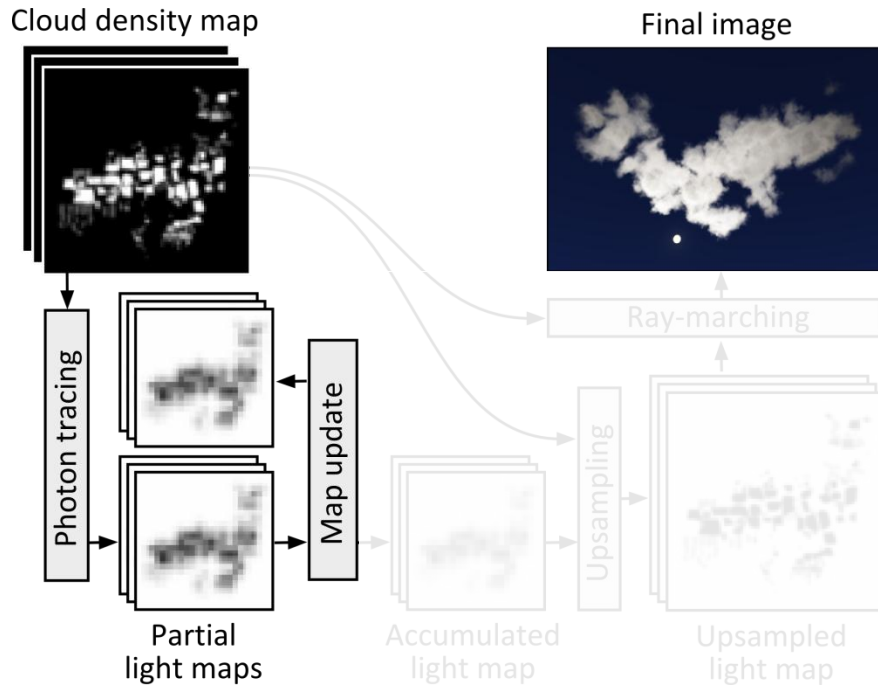
- Photon tracing



- Photon tracing

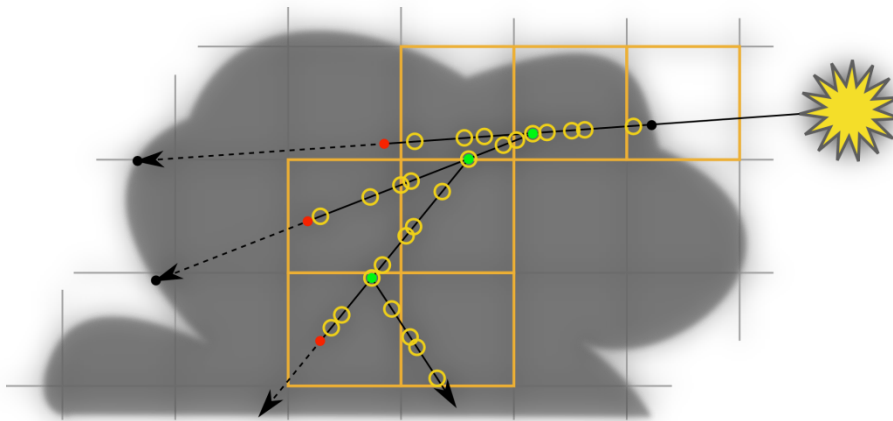
- Photon marching (Jarosz et al. 2011)

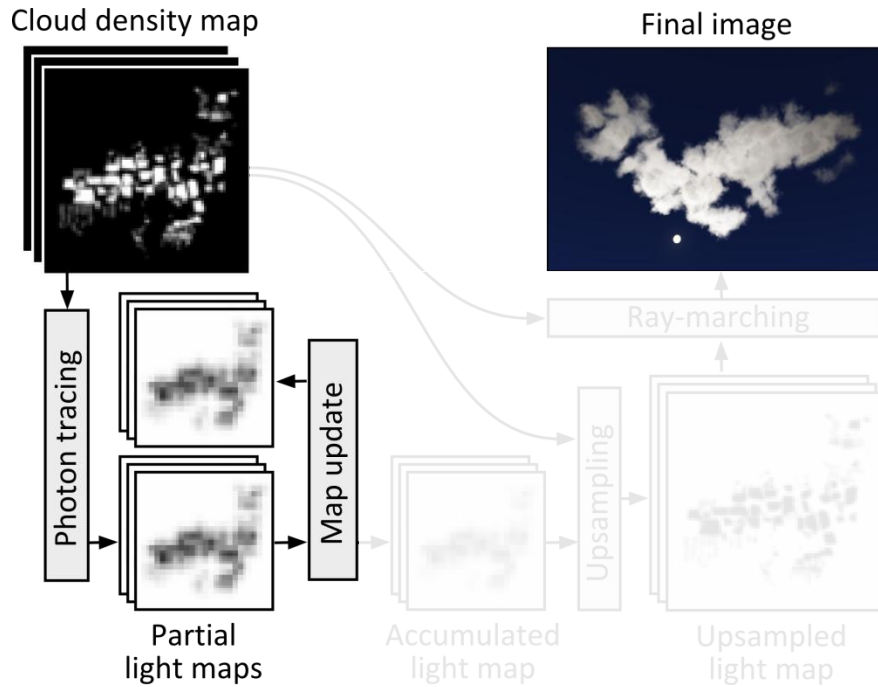




• Photon tracing

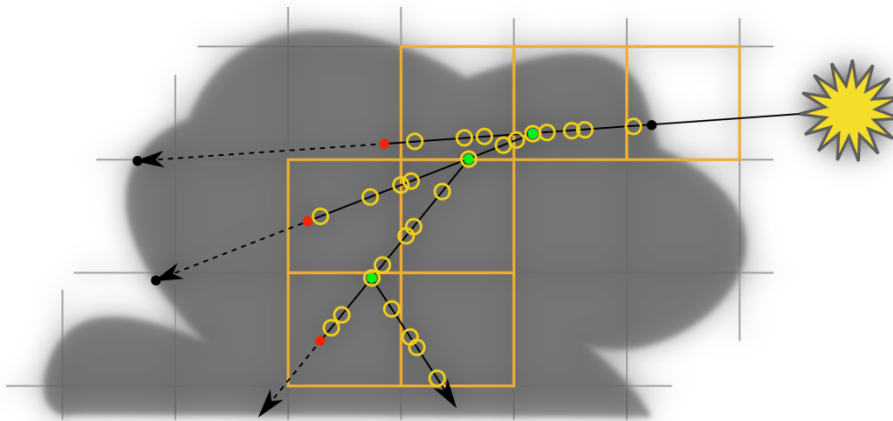
- Photon marching (Jarosz et al. 2011)
- 3D grid caching

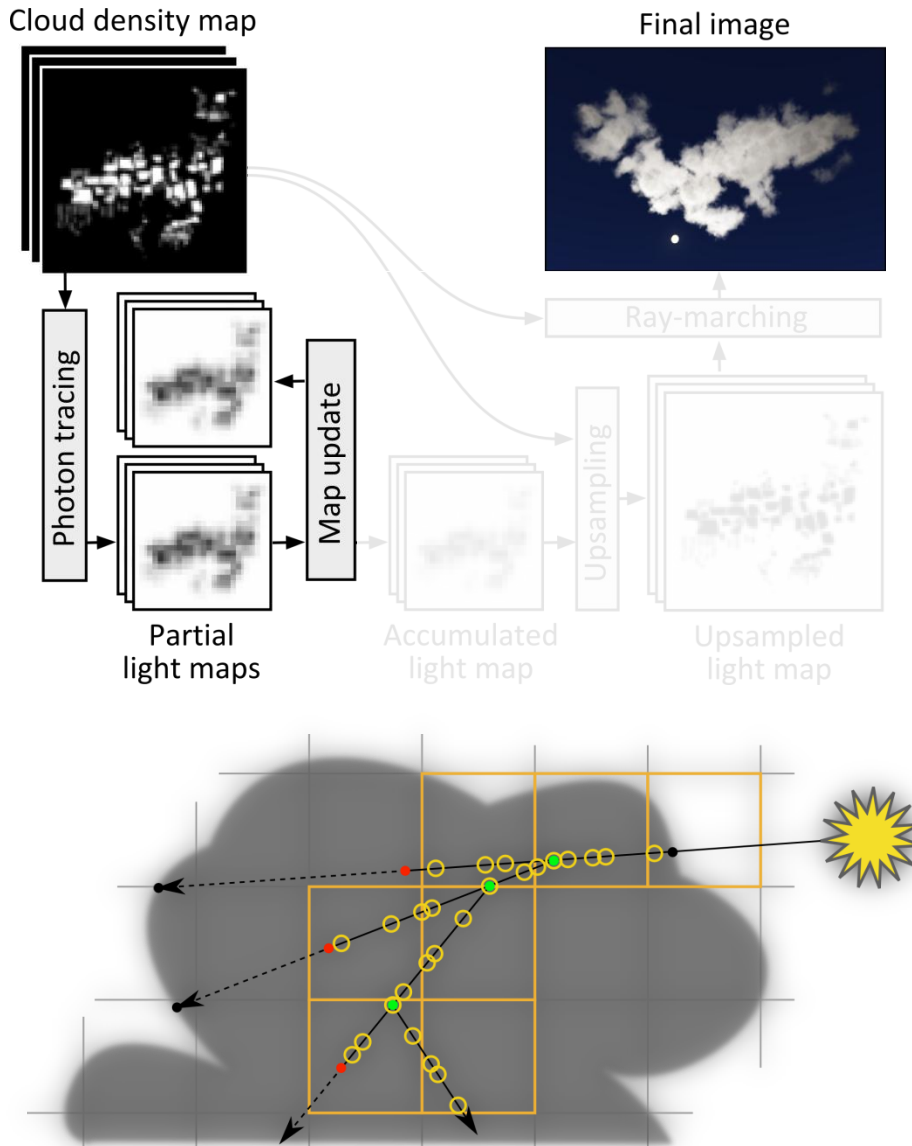




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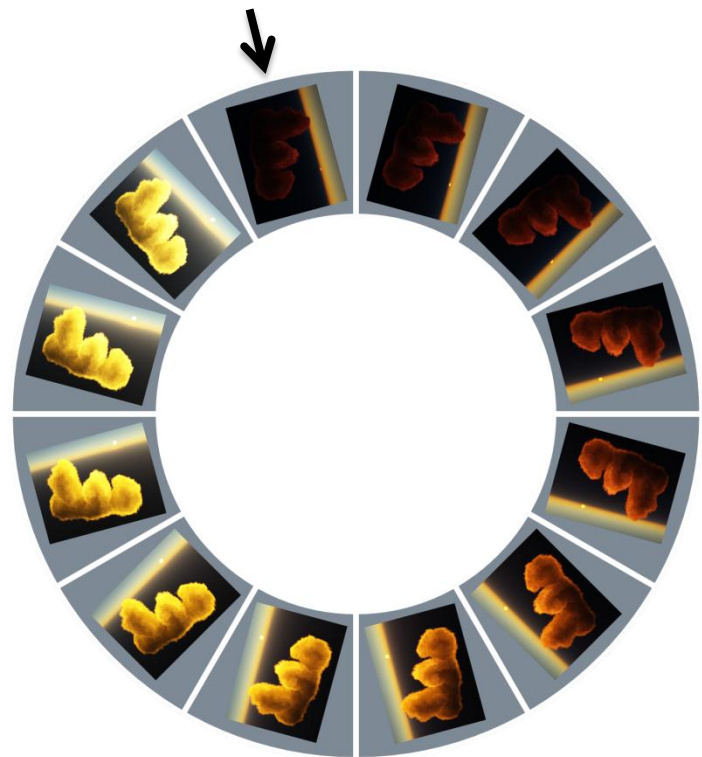
- Photon marching (Jarosz et al. 2011)
- 3D grid caching
- Amortization in time

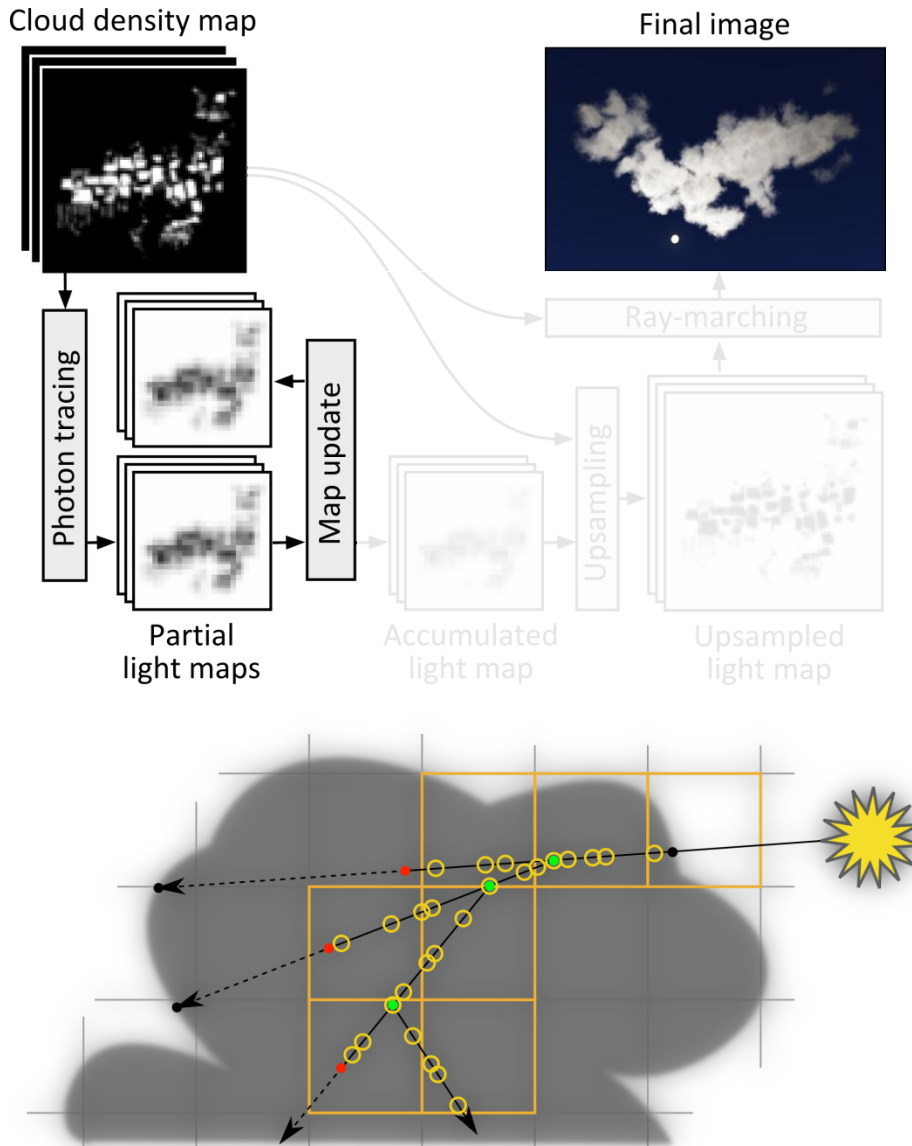




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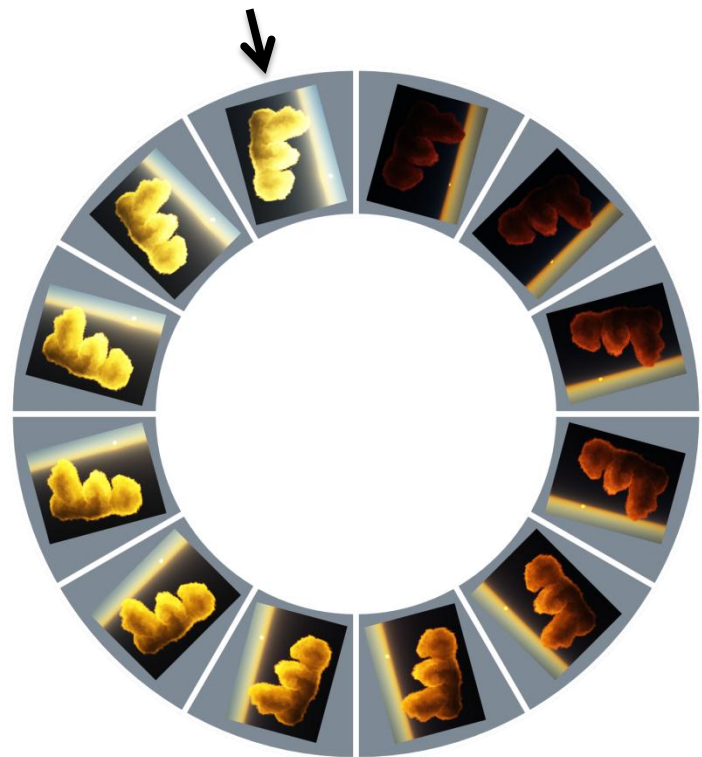
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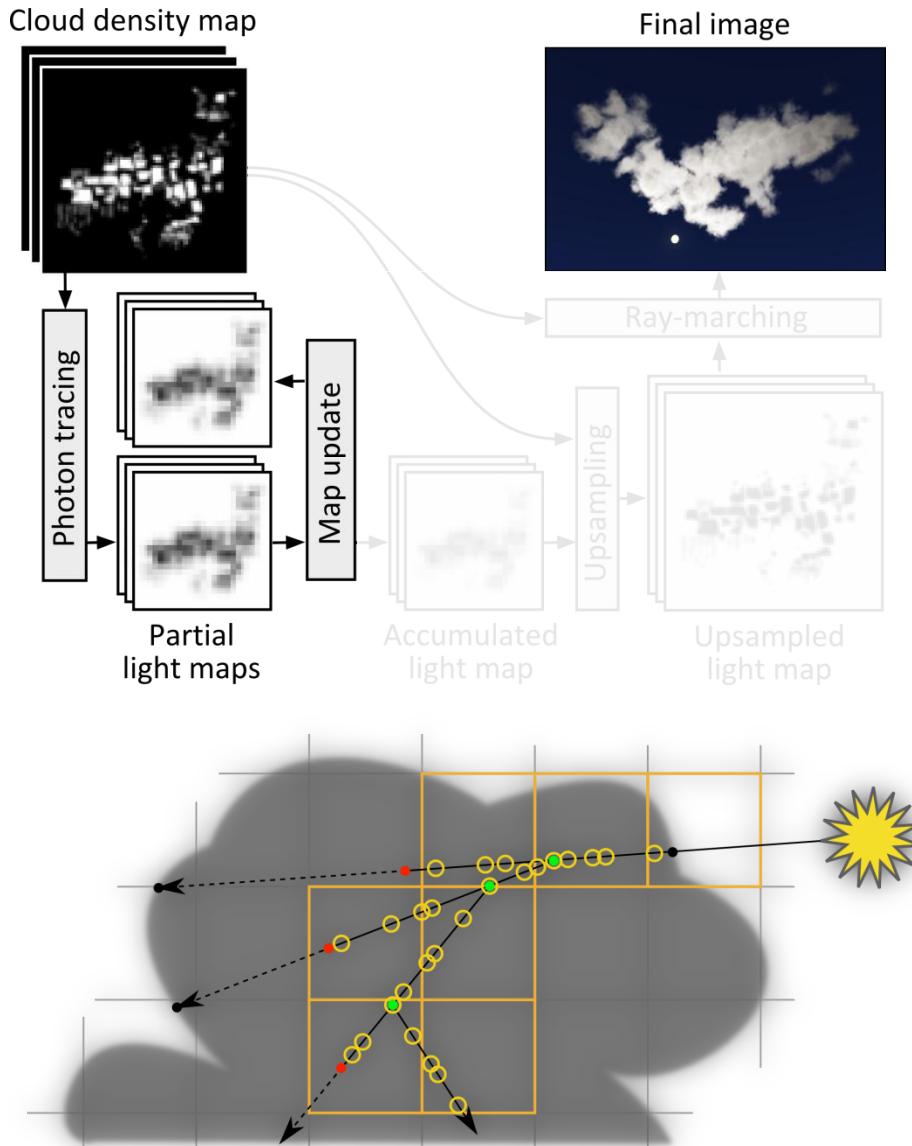




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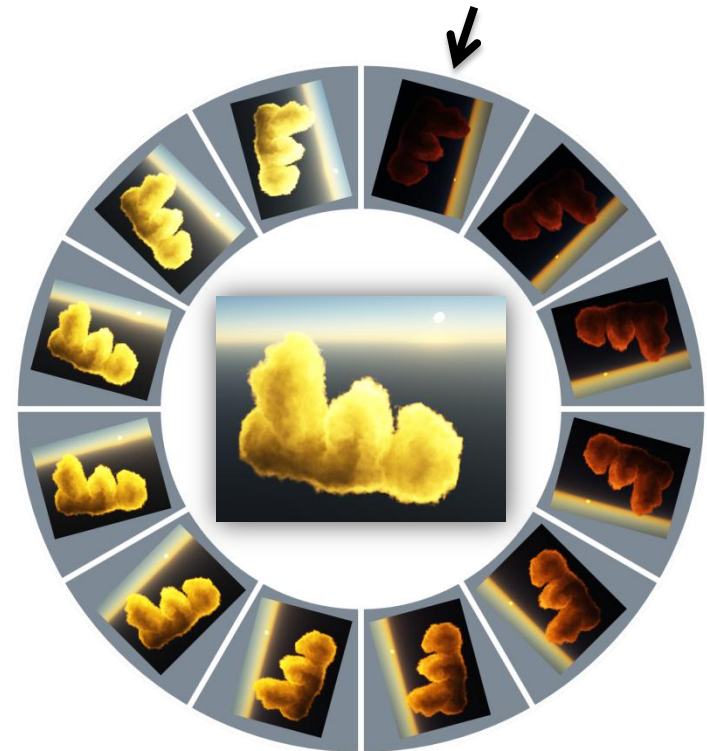
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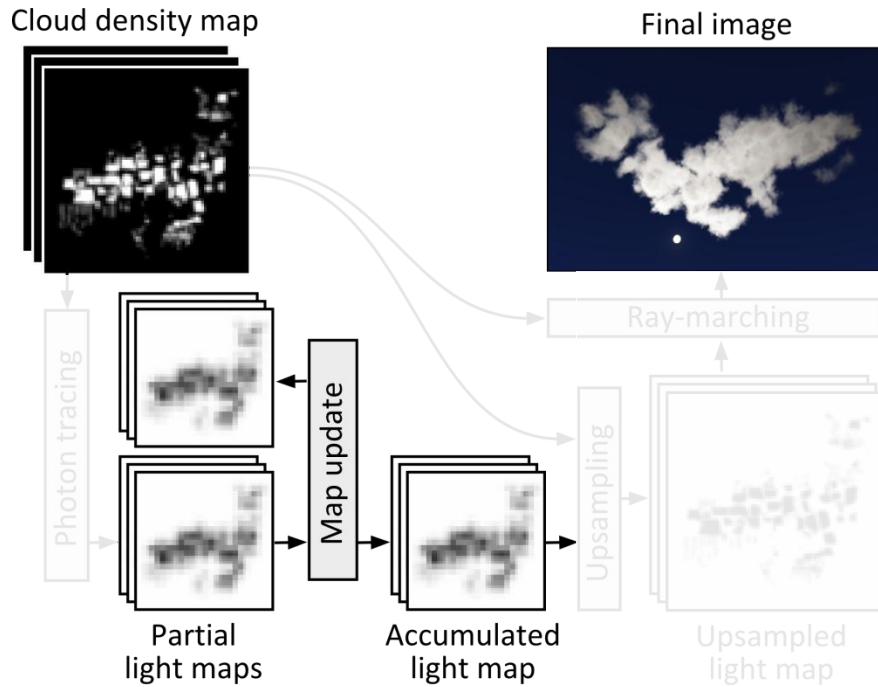




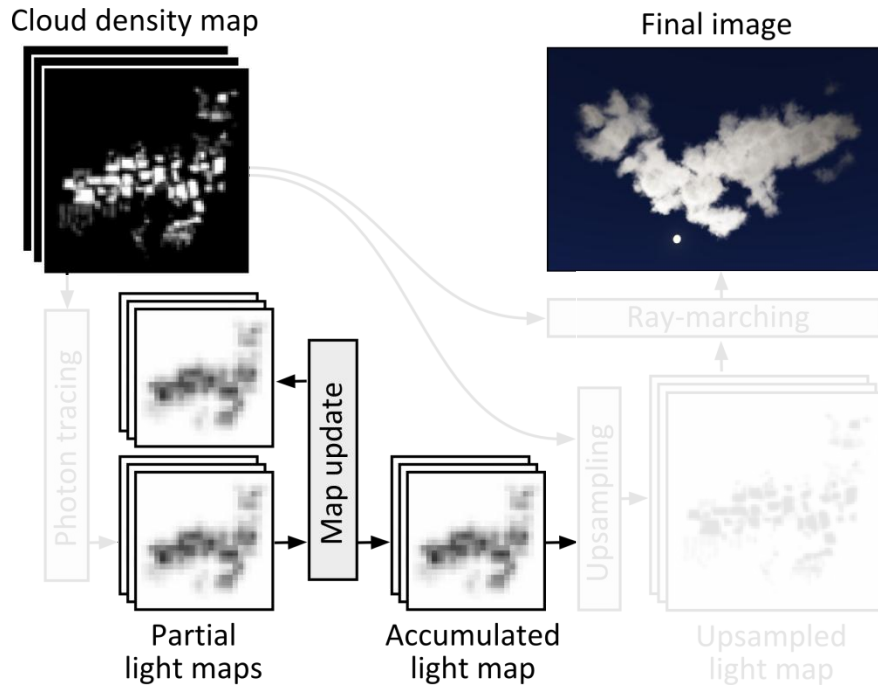
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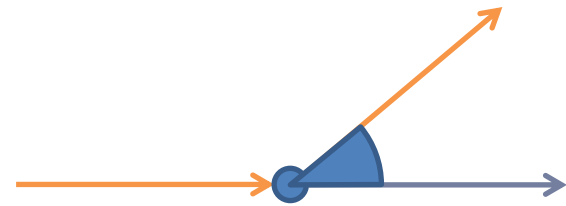


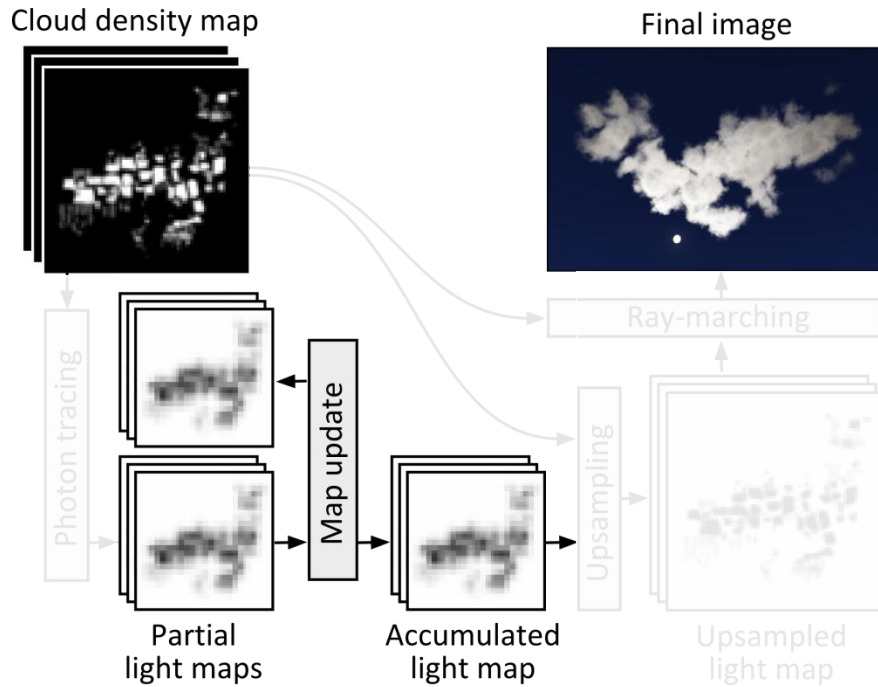


- Photon tracing
- Photon storing

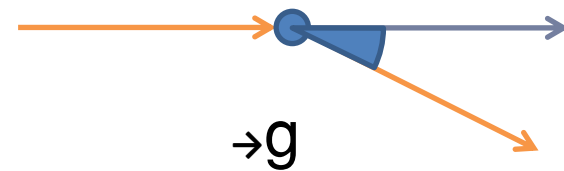


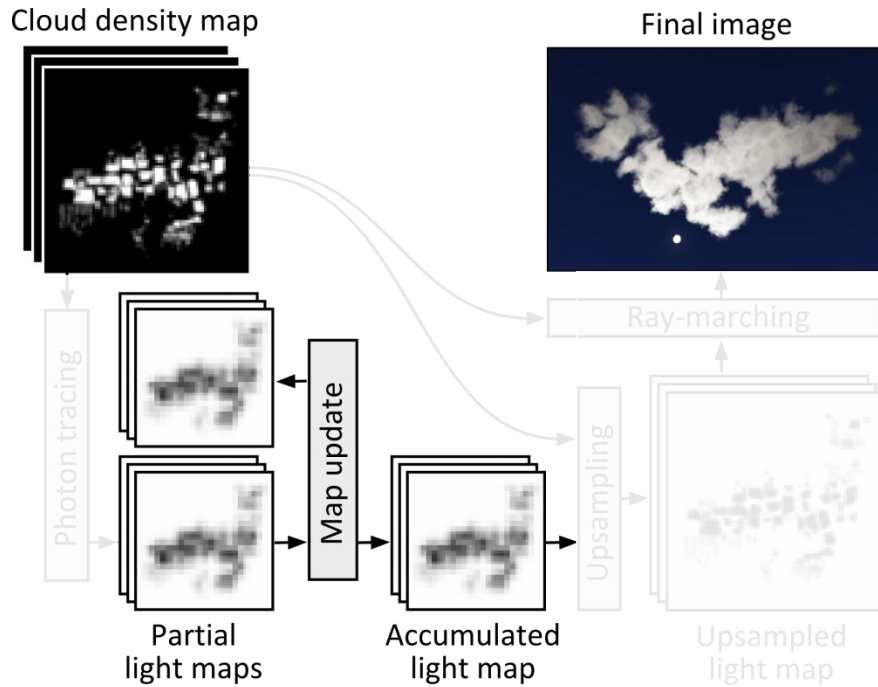
- Photon tracing
- Photon storing
 - Average cosine accumulation



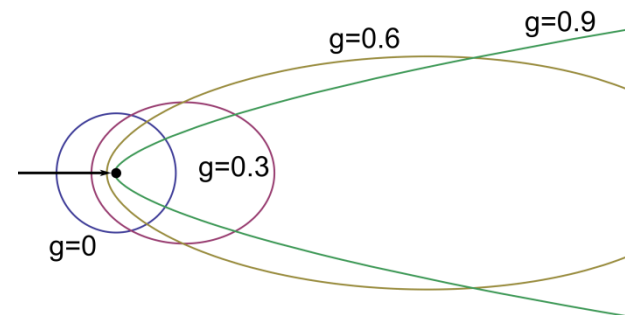
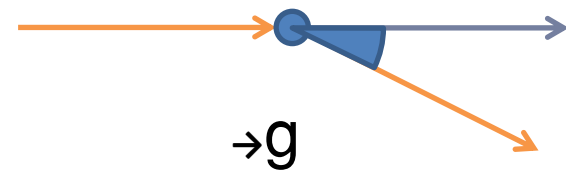


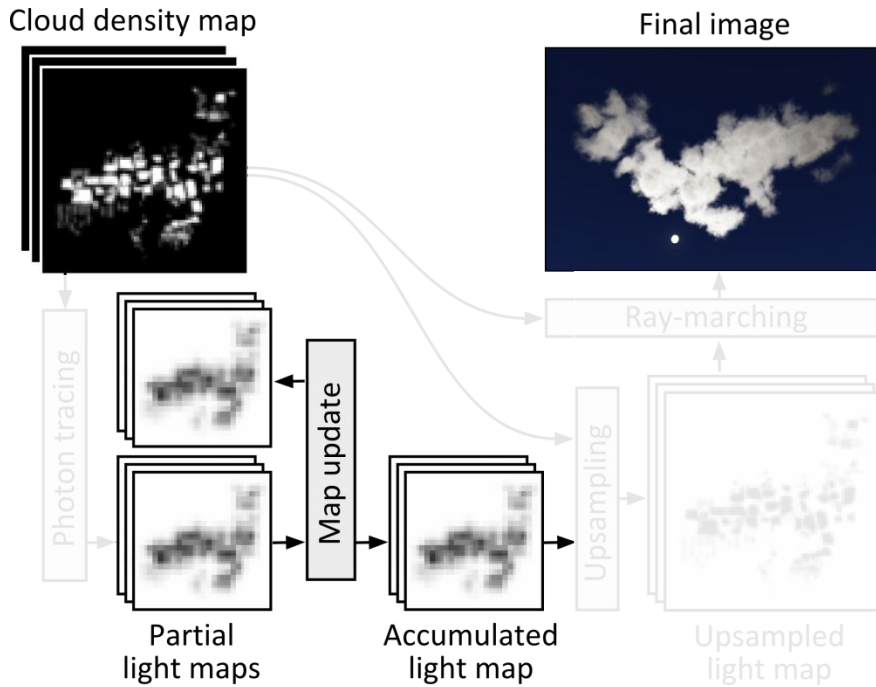
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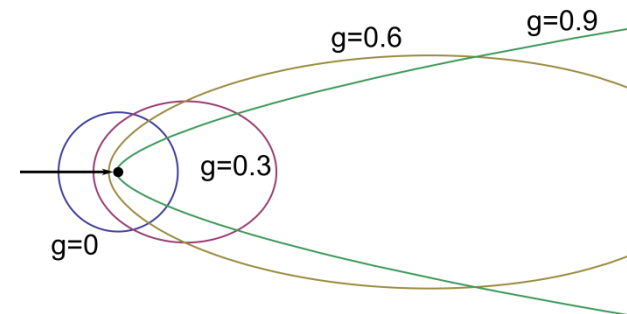
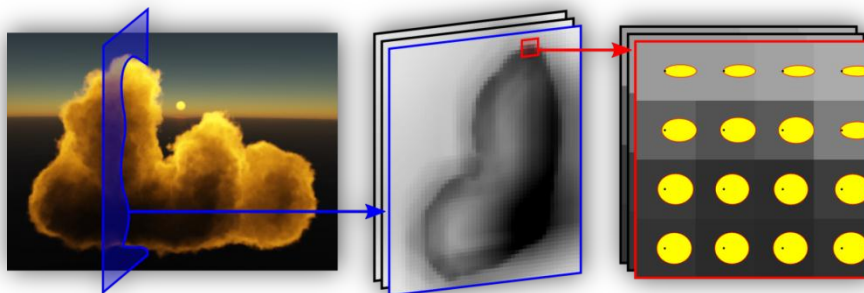
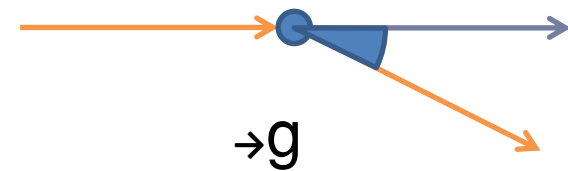


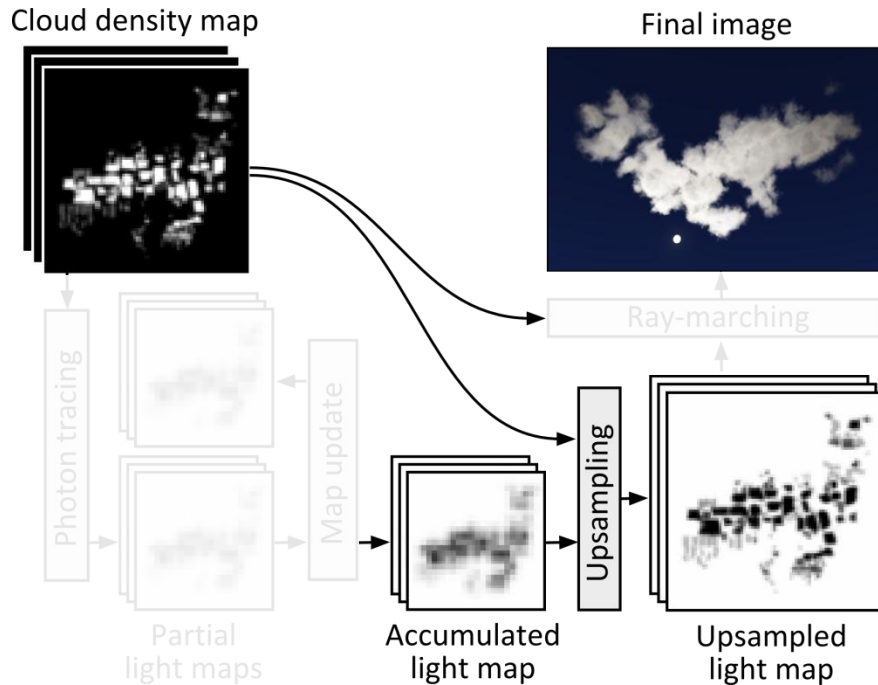
- Photon tracing
- Photon storing
 - Average cosine accumulation
 - Henyey-Greenstein “lobes”



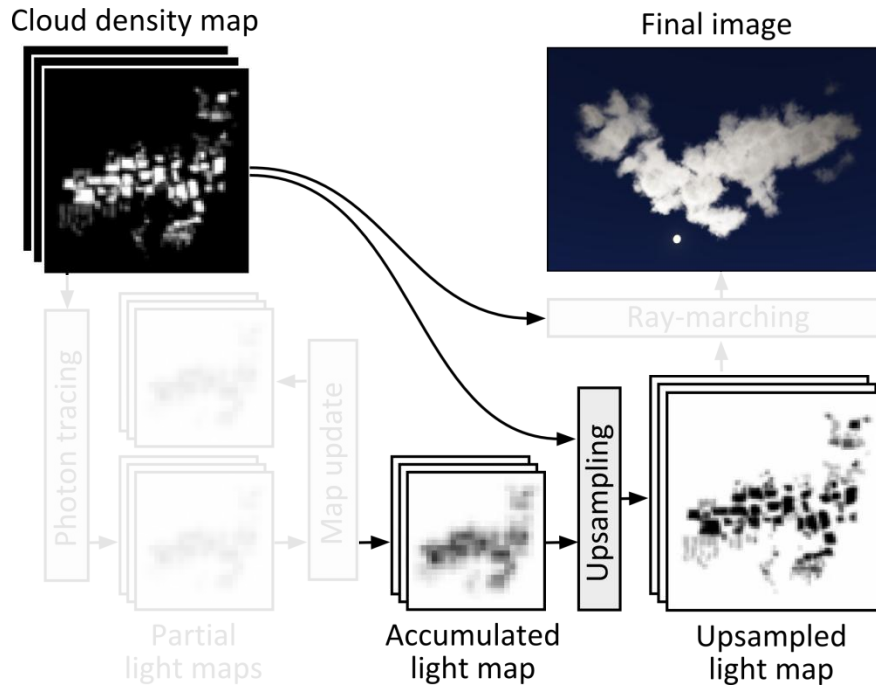


- Photon tracing
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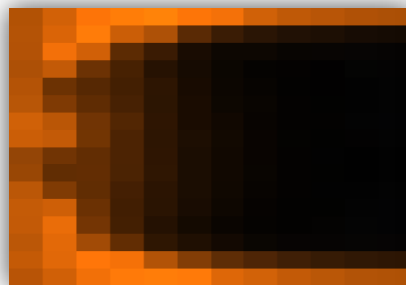




- Photon tracing
- Photon storing
- Solution upsampling



- Photon tracing
- Photon storing
- Solution upsampling
 - JBU (Kopf et al. 2007) in 3D



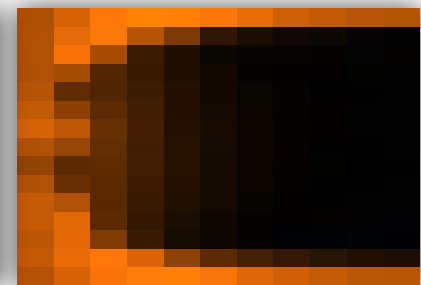
Low-res solution



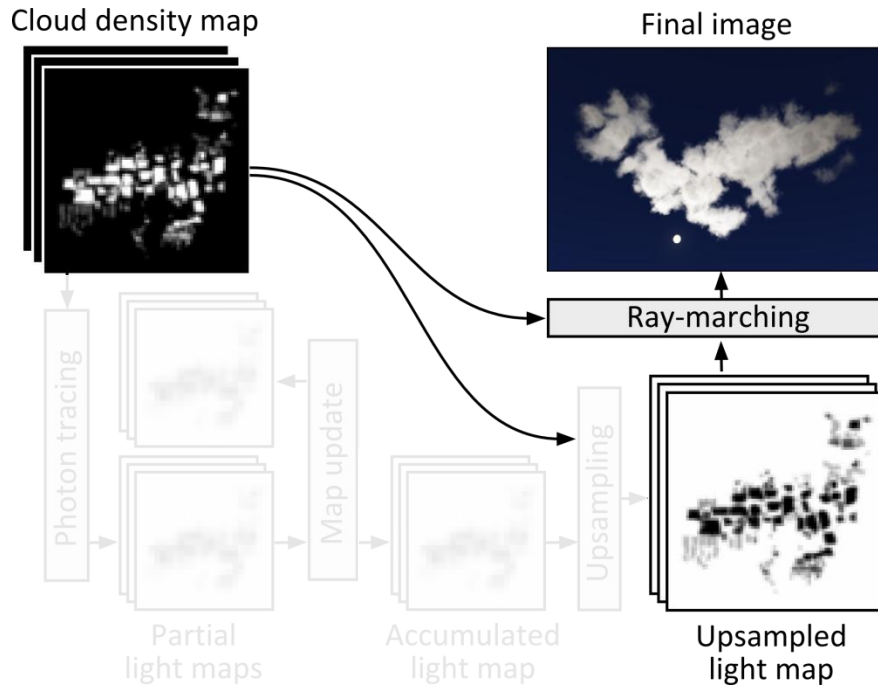
Guiding signal



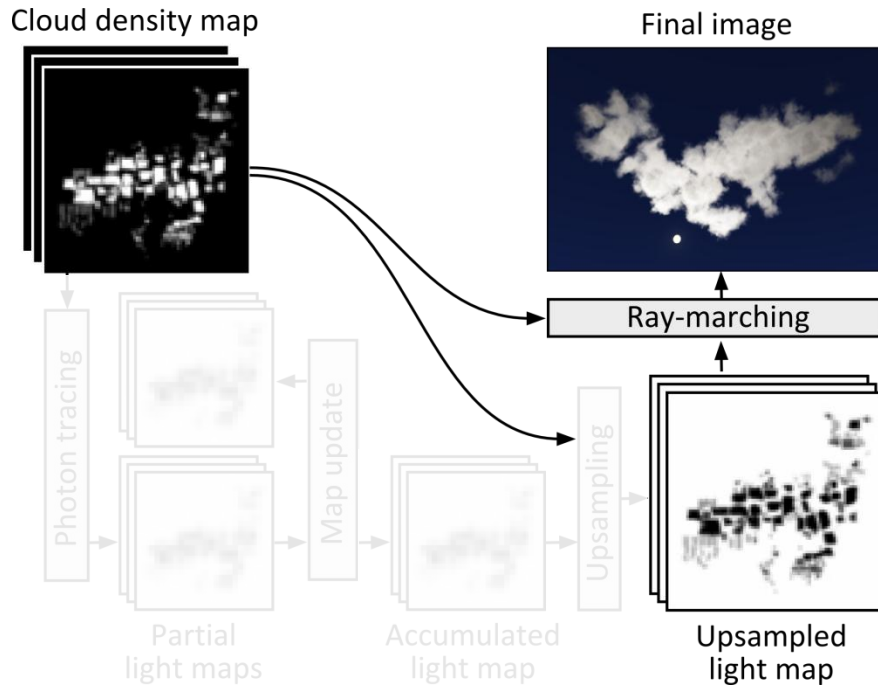
Bilaterally-upsampled solution



Bicubic-upsampled solution

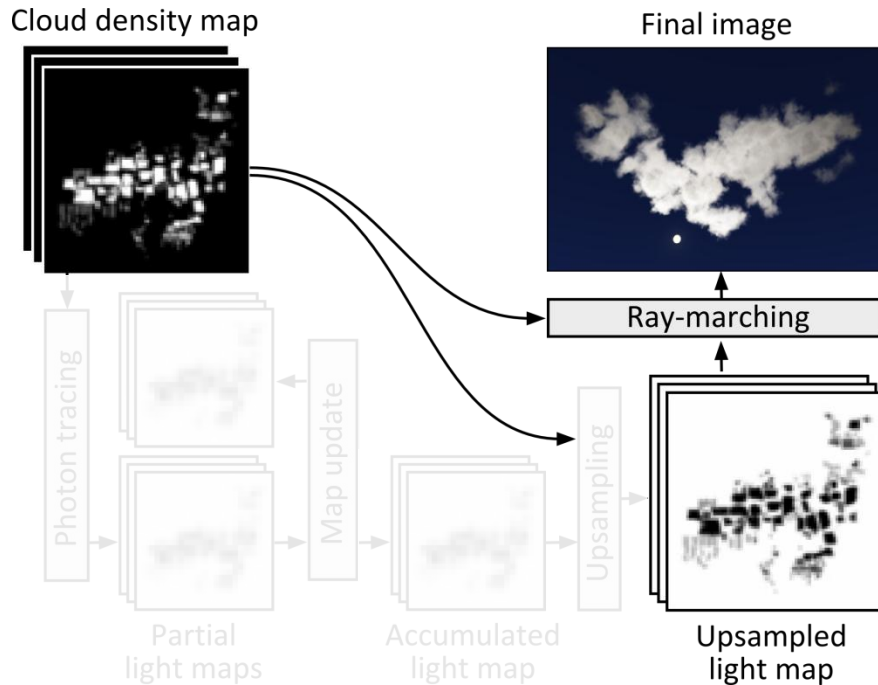


- Photon tracing
- Photon storing
- Solution upsampling
- Ray-marching



- Photon tracing
- Photon storing
- Solution upsampling
- Ray-marching
 - H-G radiance reconstruction





- Photon tracing
- Photon storing
- Solution upsampling
- Ray-marching
 - H-G radiance reconstruction
 - Reduced resolution

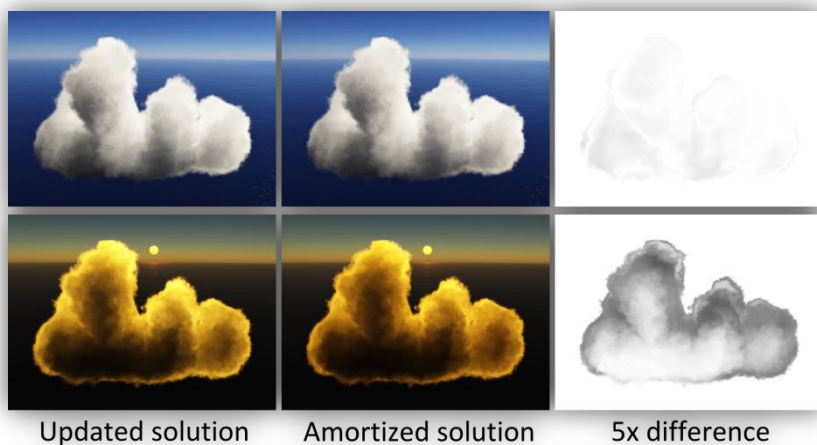
Full-res
1080p
(77 ms)



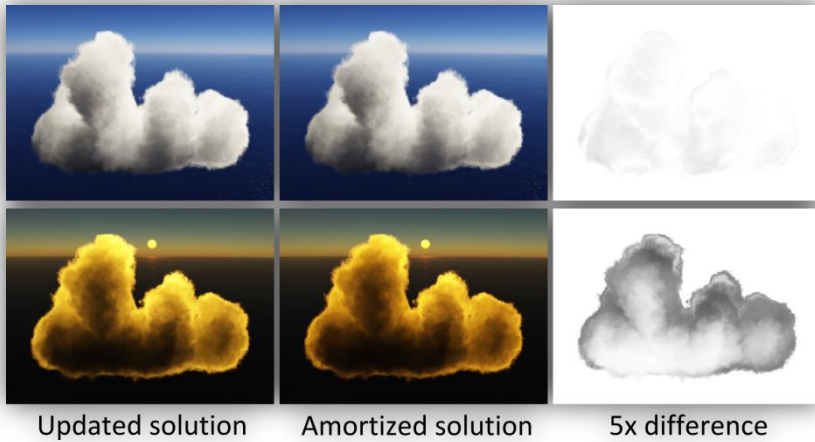
Half-res
(21 ms)



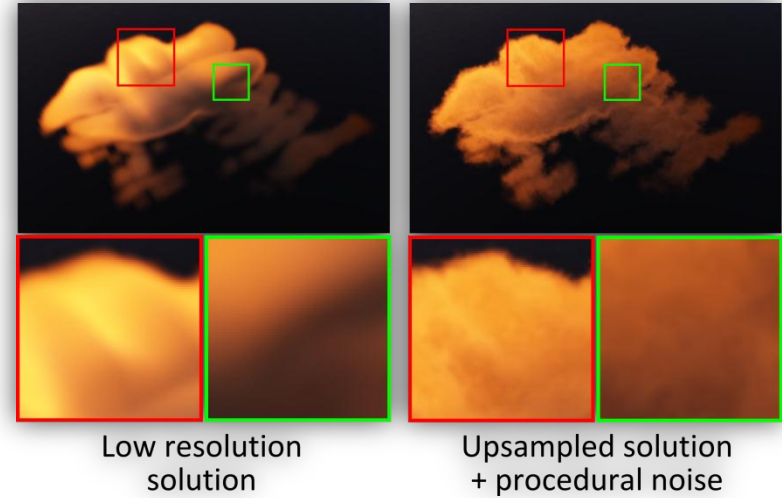
Temporal coherence



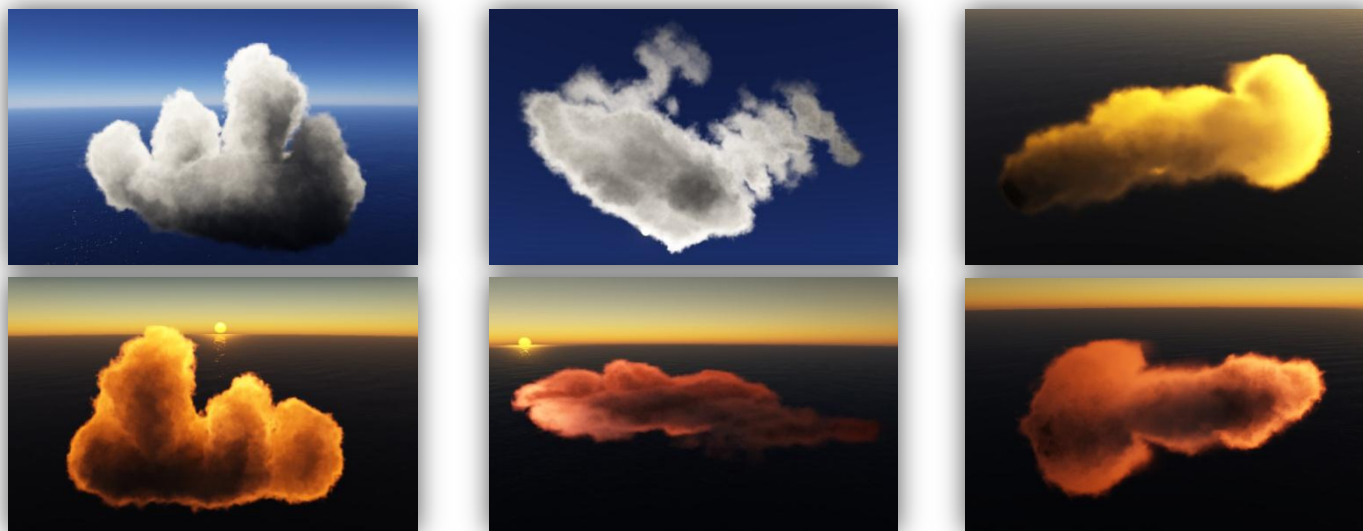
Temporal coherence



Upsampling

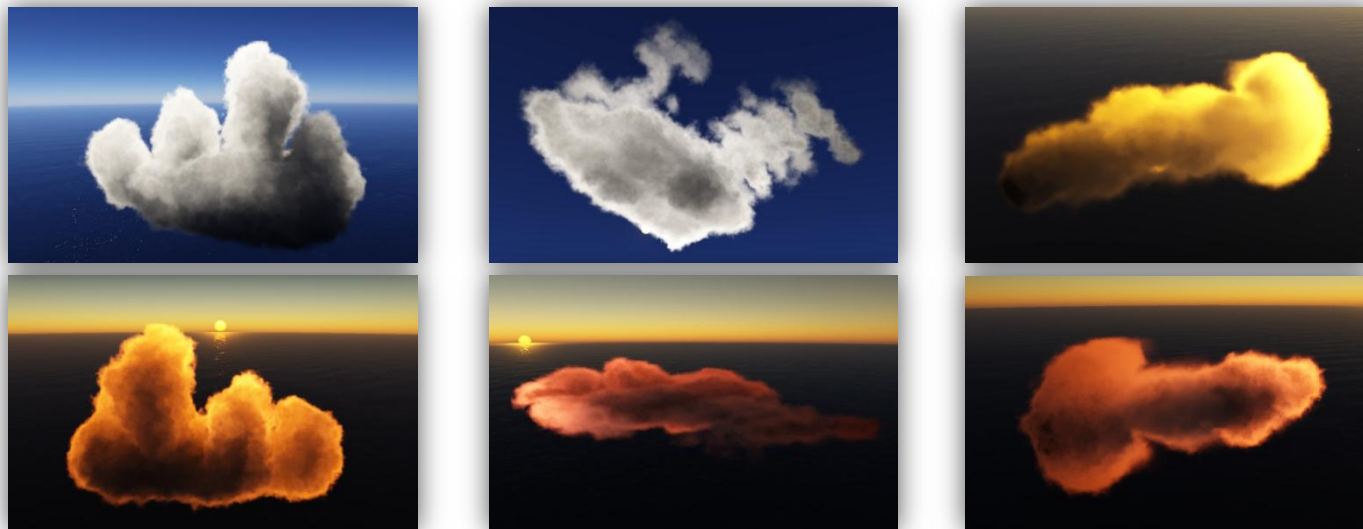


Performance (NV GTX 485M)

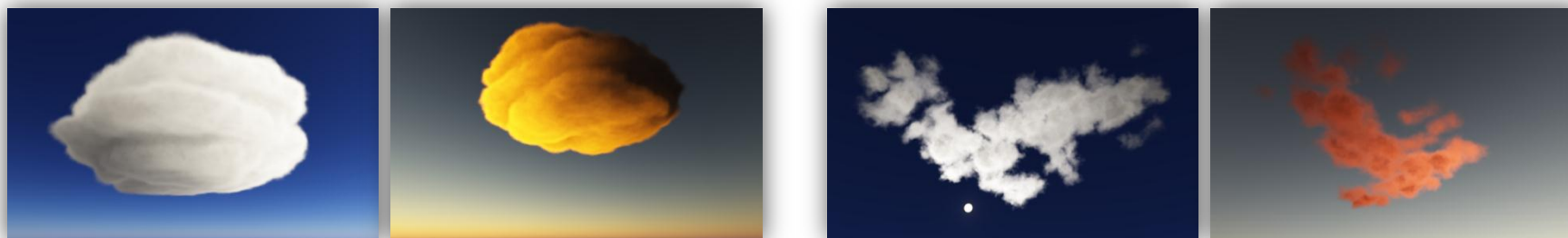


Photon tracing	17.1 ms	9.5 ms	19.7 ms
Upsampling	3.0 ms	2.3 ms	3.3 ms
Ray-marching	20.4 ms	14.0 ms	37.8 ms
Total	40.5 ms	25.8 ms	60.8 ms

Performance (NV GTX 485M)



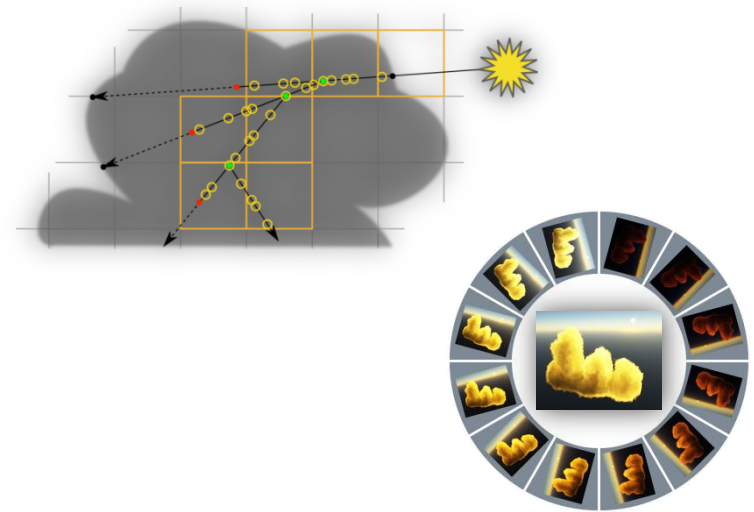
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Contributions

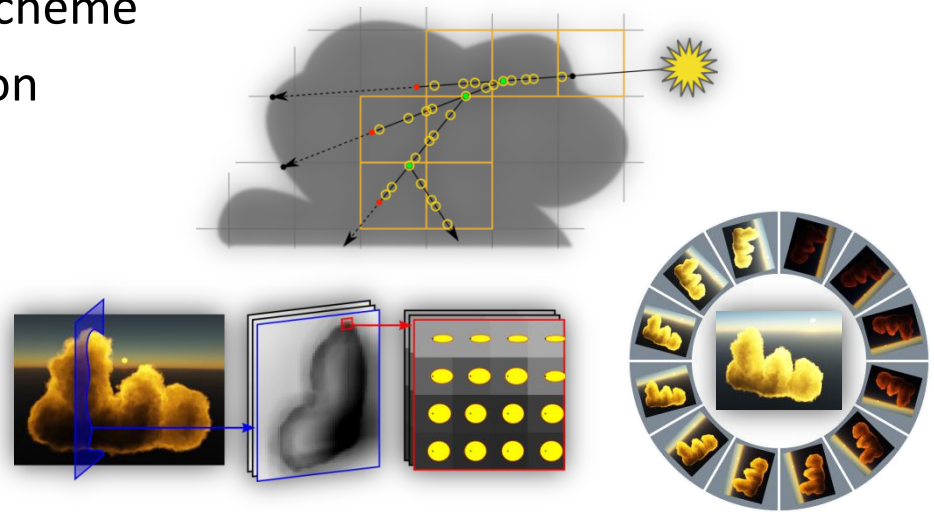
Contributions

- Photon tracing amortization scheme



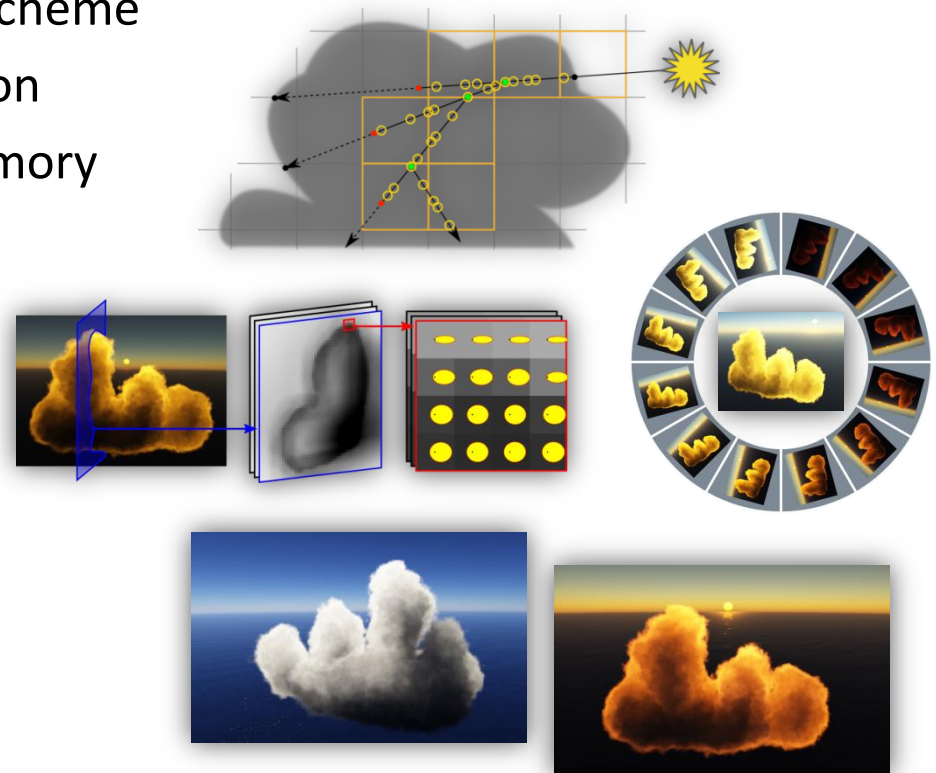
Contributions

- Photon tracing amortization scheme
- H-G illumination representation



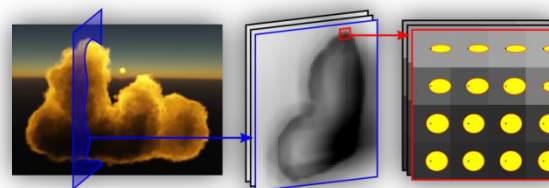
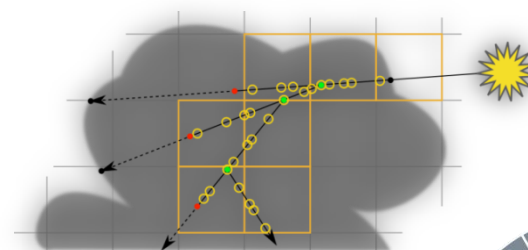
Contributions

- Photon tracing amortization scheme
- H-G illumination representation
- No precomputations, low memory



Contributions

- Photon tracing amortization scheme
- H-G illumination representation
- No precomputations, low memory



Future work

- Convection simulation
- Multiresolution scheme
- Other participating media



