

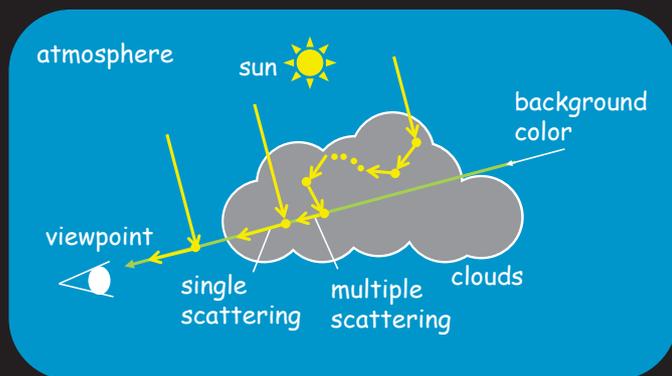
## Rendering of Clouds

## Rendering of Clouds

- Scattering/absorption due to cloud particles
- Multiple scattering
- Atmospheric effects



## Intensity of clouds



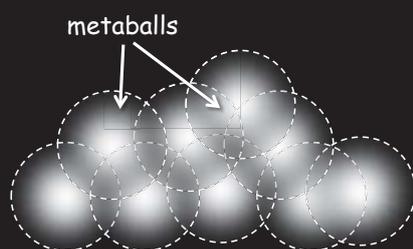
Computationally expensive

## Rendering of Clouds

- Single scattering & atmospheric effects
  - two-pass splatting approach for clouds
  - volume rendering for atmosphere
- Multiple scattering
  - precomputation-based approach for multiple scattering
  - Monte Carlo method

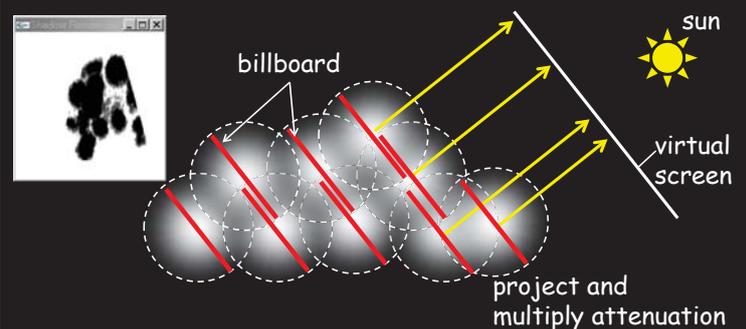
## Single Scattering

- Two-pass splatting approach
  - Representing clouds using metaballs



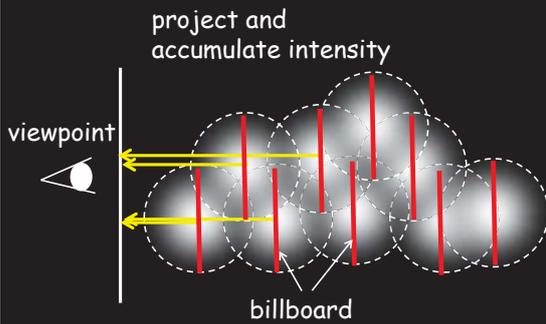
## Single Scattering

- Two-pass splatting approach
  - pass1: render clouds viewed from the sun



## Single Scattering

- Two-pass splatting approach
  - pass2: render clouds viewed from viewpoint

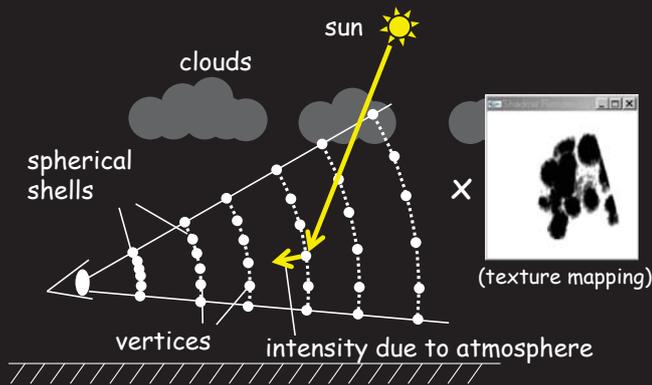


## Single Scattering

- Result



## Atmospheric Effects



## Examples



shafts of light (daytime)



shafts of light (evening)

simulation: 0.5 [sec]

rendering: 15 [sec]

voxel size: 256x256x20 image size: 640x480  
(PentiumIII 733Mhz, NVIDIA GeForce256)

## Examples



simulation: 0.3 [sec] rendering: 10 [sec]

voxel size: 256x256x10 image size: 640x480  
(PentiumIII 733Mhz, NVIDIA GeForce256)

## Multiple Scattering

- Precomputation-based approach
  - prorpcress
    - compute shading of clouds with different lighting conditions
    - store the results in a database after compressing them by orthogonal basis functions (spherical harmonics or wavelets)
  - real-time process
    - extract shading corresponding to the current lighting condition
    - render image

## Multiple Scattering

- Precomputation-based approach



cloud illuminated by lightning



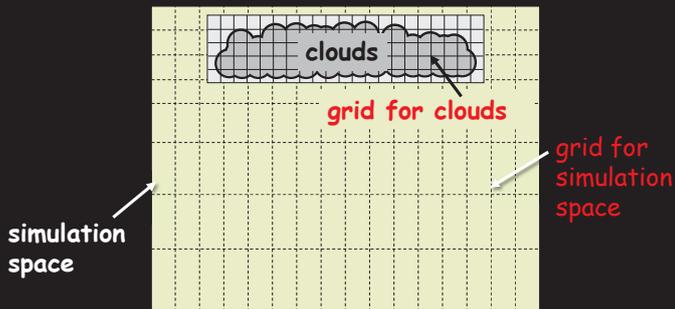
dynamic clouds (periodical)

## Clouds illuminated by lightning

- Arbitrary shapes of lightning
- Anisotropic multiple scattering
- Consisting of preprocess and real-time process
- Use of wavelet transform for drastically accelerating intensity calculation
- Assumption: Static clouds

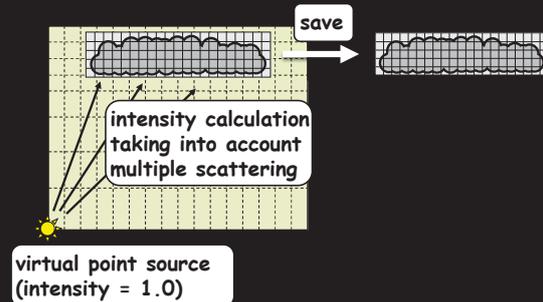
## Clouds illuminated by lightning

- Two separate grids



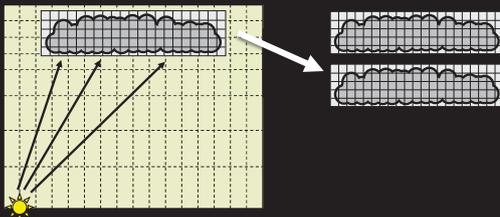
## Clouds illuminated by lightning

- Preprocess: computation of basis intensities



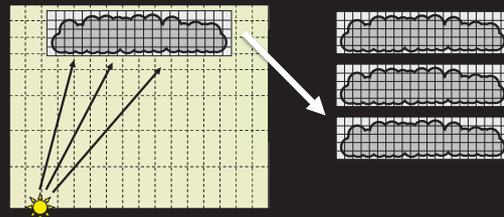
## Clouds illuminated by lightning

- Preprocess: computation of basis intensities



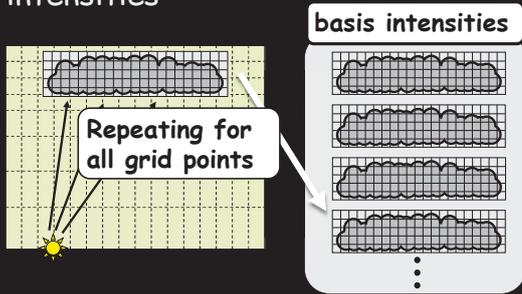
## Clouds illuminated by lightning

- Preprocess: computation of basis intensities



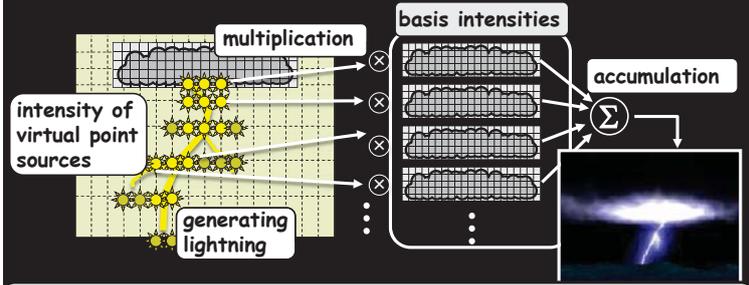
## Clouds illuminated by lightning

- Preprocess: computation of basis intensities



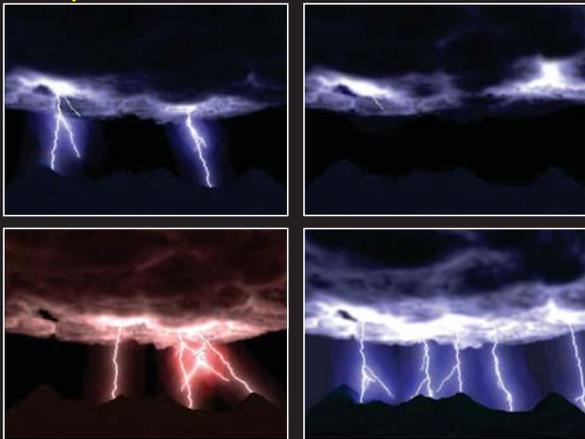
## Clouds illuminated by lightning

- Real-time process: rendering of clouds



- Fast but cost proportional to number of grid points
- Further acceleration by using wavelets

## Examples



## Animation

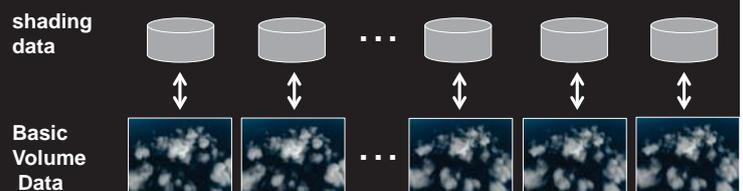


## Dynamic Clouds

- Real-time rendering of endless cloud animation
- volume data for clouds is generated at run-time
- real-time rendering of clouds illuminated by sunlight and skylight with single and multiple scattering
- GPU implementation

## Dynamic Clouds

- Precomputation



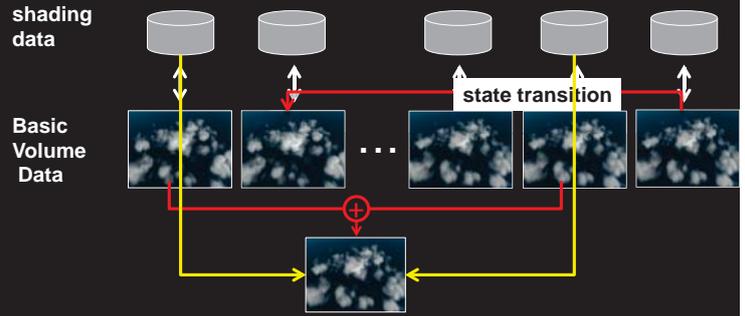
# Dynamic Clouds

## ■ Rendering process



# Dynamic Clouds

## ■ Rendering process



# Results



# Multiple Scattering

## ■ Monte Carlo Method



# Out-of-core rendering

## ■ Large-scale clouds

[movie](#)



0.7 km



10 km



150 km



600 km