Real-Time Atmospheric Cloud Rendering System

Parker Ford, Kelvin Sung
University of Washington Bothell, Computing and Software Systems
10/02/2024

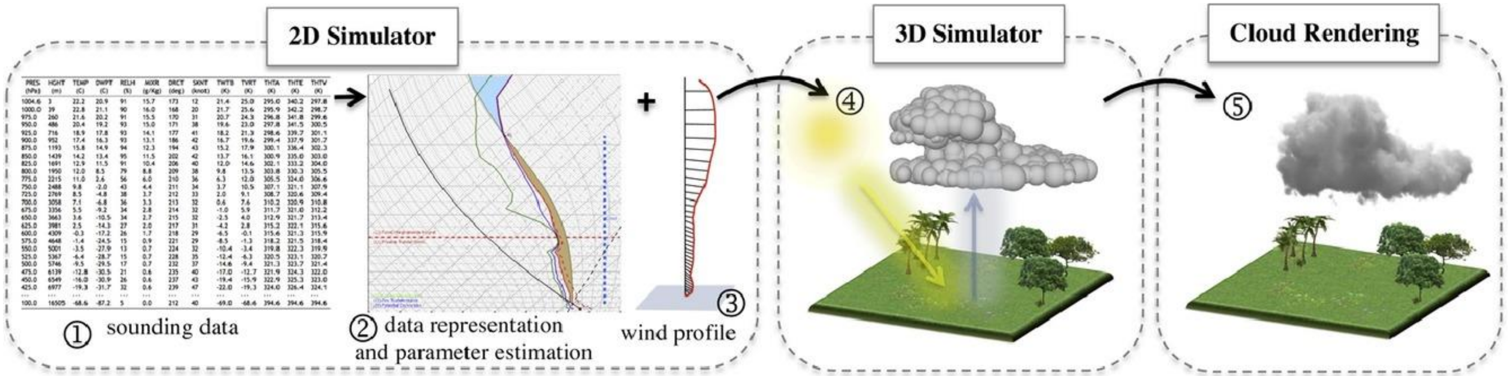
BOTHELL

SIBGRAPI 2024 | 37th Conference on Graphics, Patterns and Images

Introduction

- Rendering realistic appearing clouds is difficult due to their detailed shapes and complicated light interactions.
- Others work in the field includes:
  - Particle based methods
  - Textured billboarding methods

Particle Based Example [3]:



Texture Billboard Example [4]:

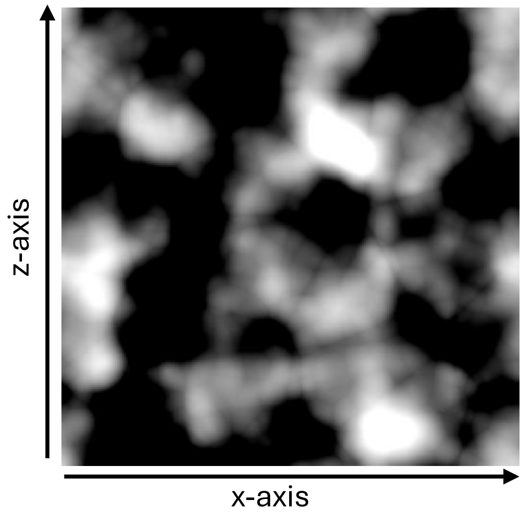
Our Approach

- Our approach has two subprocess:
  - Modeling (defining the cloud volume)
  - Rendering (generating images of cloud volume)
- Modeling approach is based on the work of Schneider
- Rendering approach is based on Fong’s volumetric rendering equation.

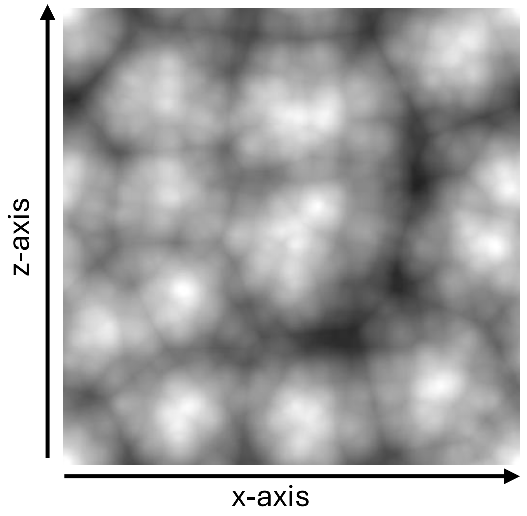
Modeling Method

- We use the following 3 lookup textures:
  - **Cloud Coverage:** Cloud density based on world coordinate
  - **Cloud Type:** Cloud type based on world coordinate
  - **Height Gradient:** Density based on altitude and cloud type

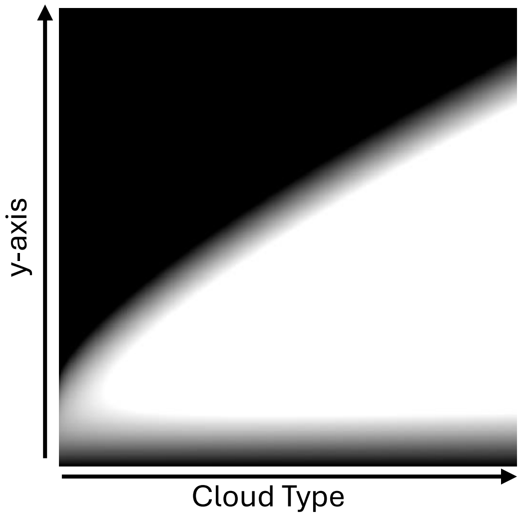
Cloud Coverage Map



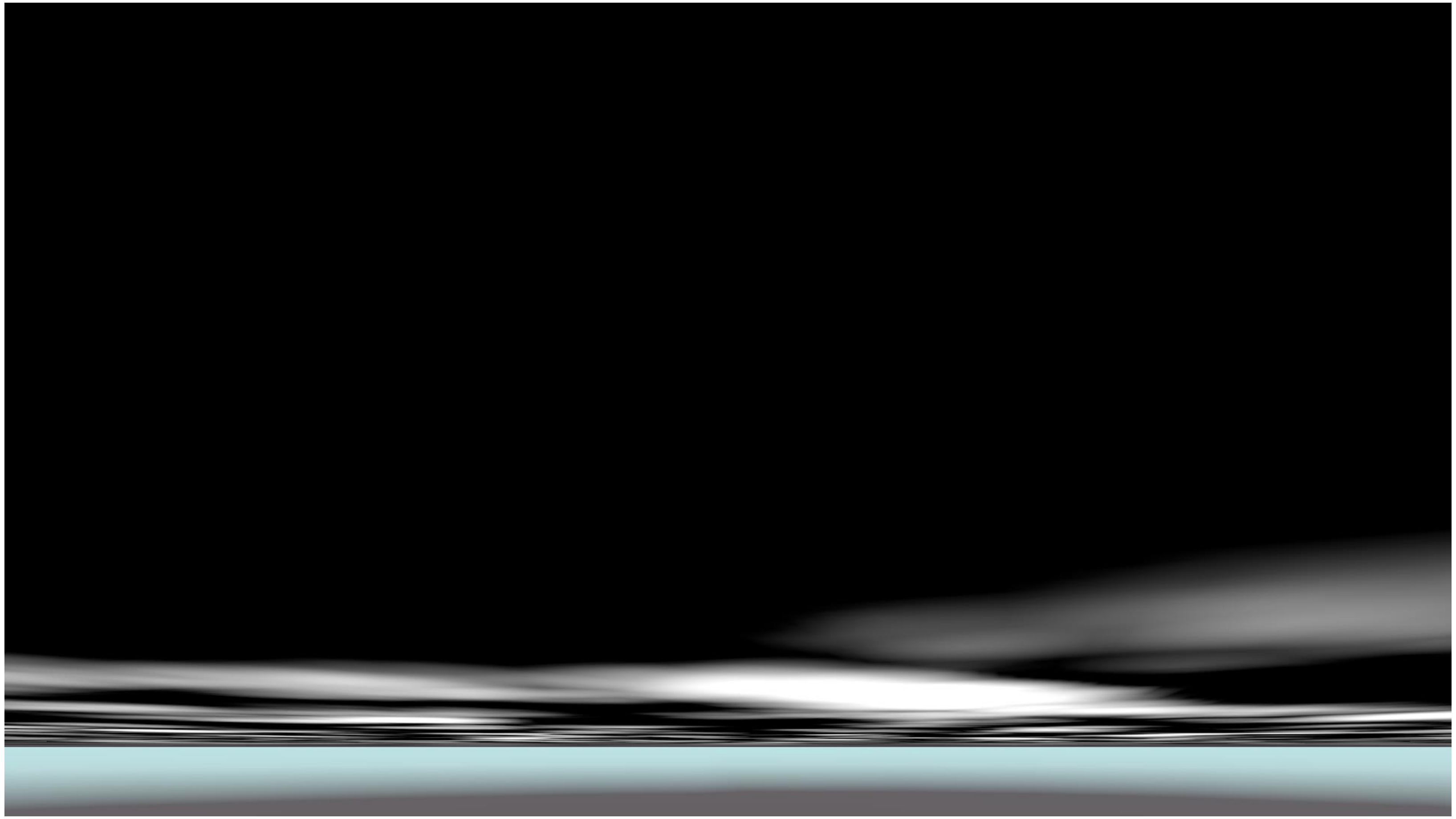
Cloud Type Map



Cloud Height Gradient

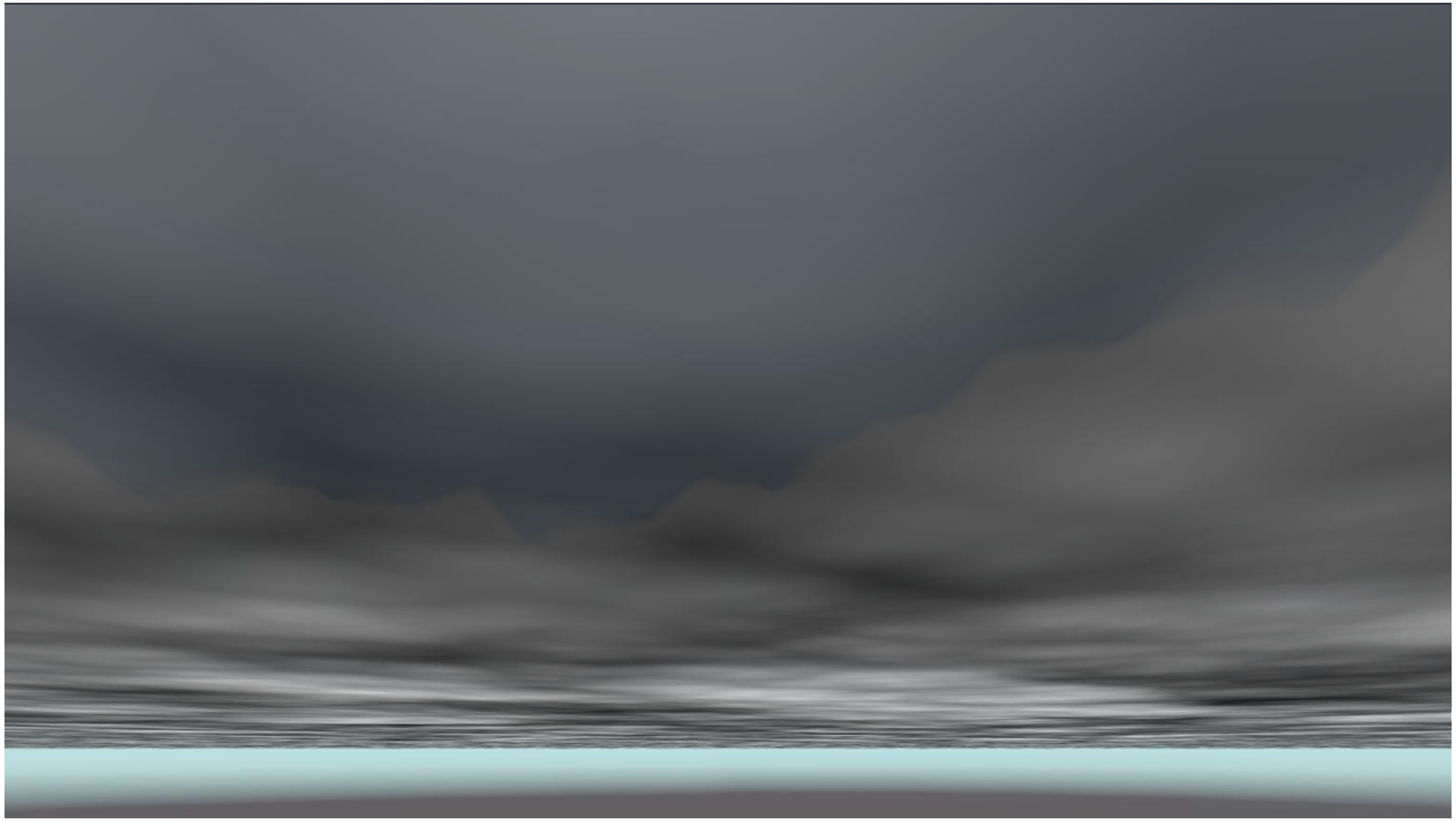


Coverage Map



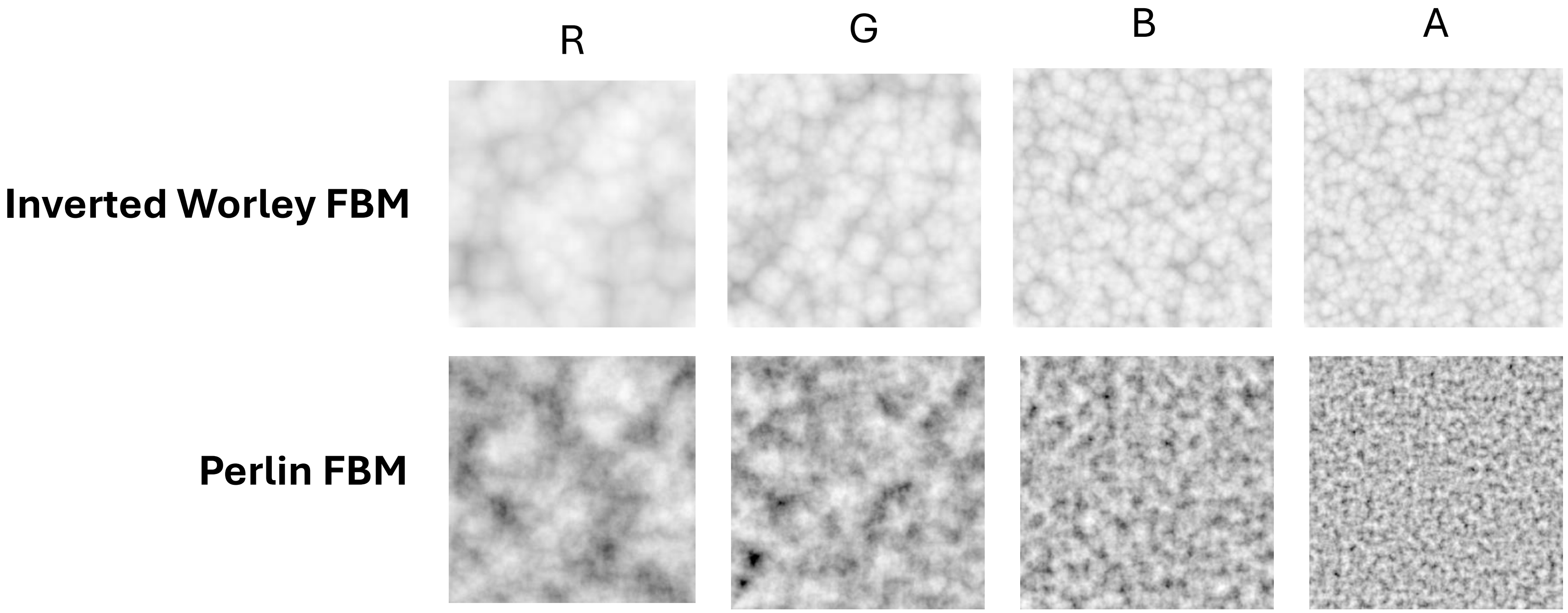
Type Map

Dimensional Profile

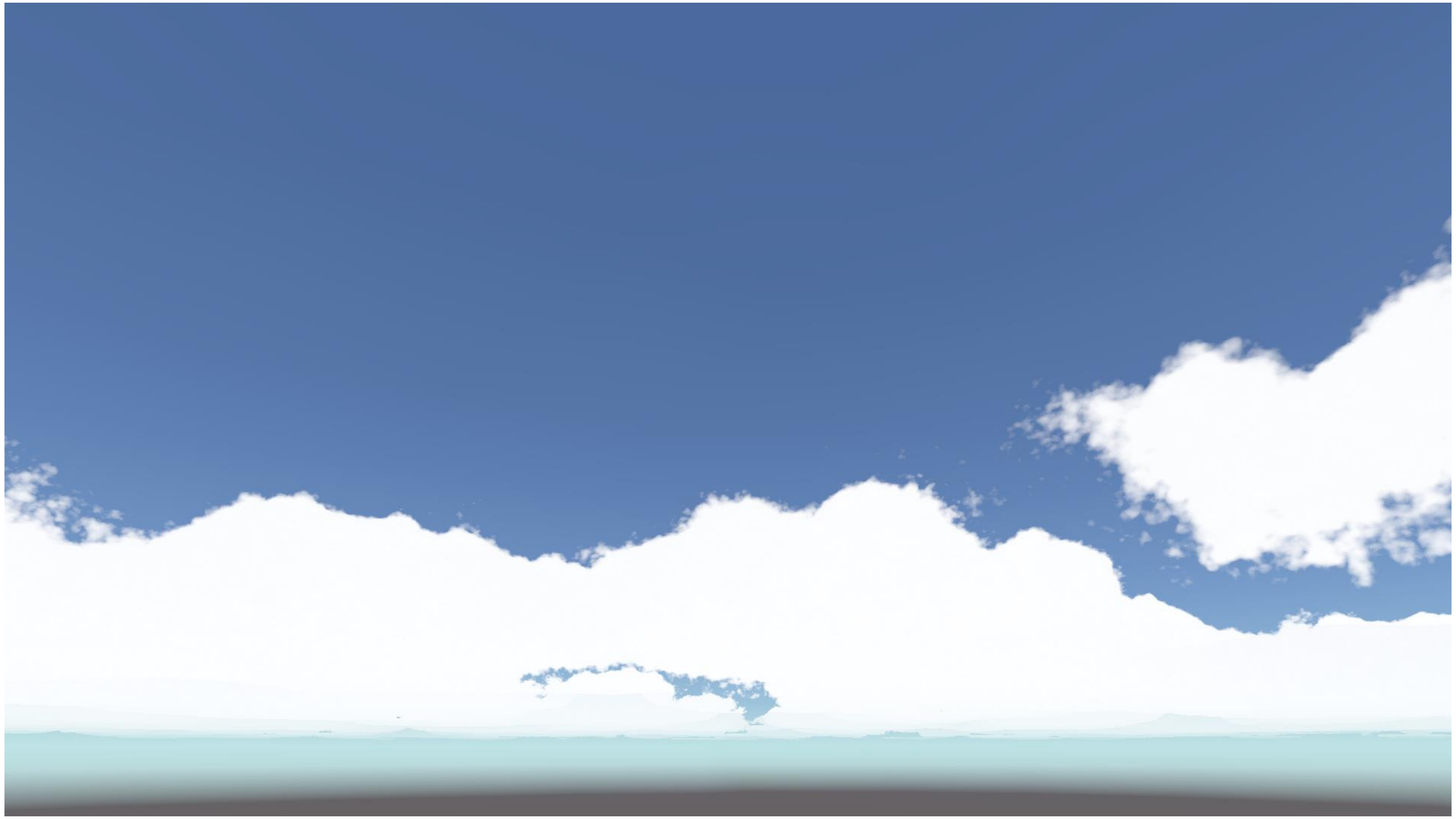


Cloud Nosie 3D Textures

- 3D noise is used to add cloud-like variations in density

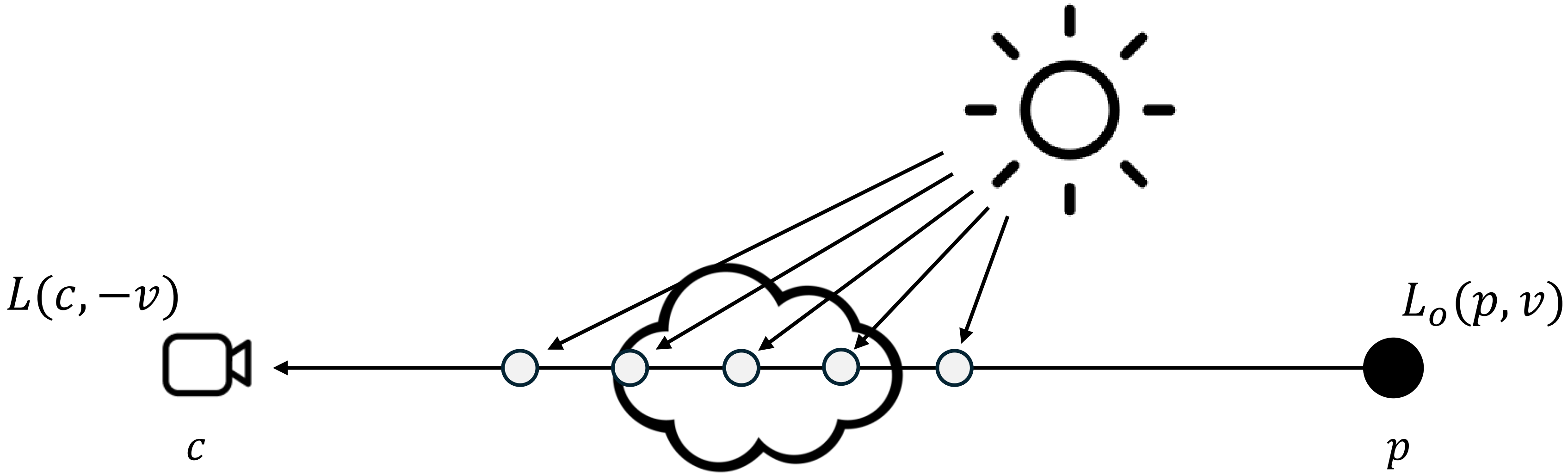


Cloud Density

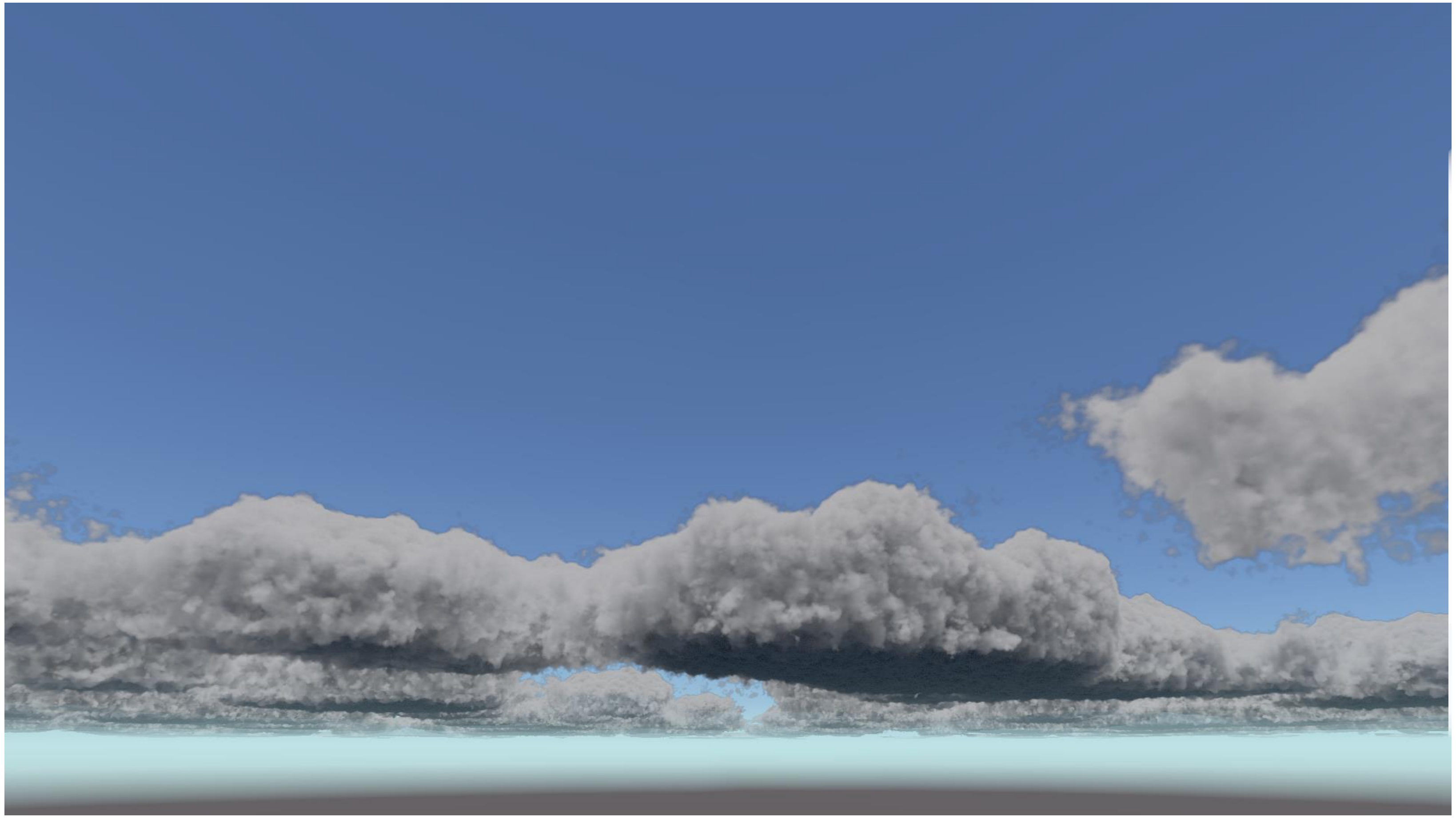


Fong's Radiance Equation

$$L(c,-v) = Tr(c,p)L_o(p,v) + \int_{t=0}^{||p-c||} Tr\,(c, c - vt)L_{scat}(c - vt, v)\sigma_s dt$$



Volumetric Render



Multiple Scattering Approximation

$$L(c,-v) = Tr(c,p)L_o(p,v) + \int_{t=0}^{||p-c||} Tr\,(c, c - vt) L_{scat}(c - vt, v)\sigma_s dt$$

$$L(c,-v) = Tr(c,p)L_o(p,v) + \int_{t=0}^{||p-c||} Tr\,(c, c - vt) L_{mult}(c - vt, v)\sigma_s dt$$

Multiple Scattering Approximation

Single Scattering Equation

$$L_{scat}(x, v) = p(v, l)e^{-\tau}$$

Wrenninge's Multiple Scattering Equation [6]

$$L_{mult}(x, v) = \sum_{i=0}^{N-1} L_i(x, v)$$

$$L_i(x, v) = b^i p(v, l)e^{-a^i \tau}$$

$$0 \leq a < 1$$

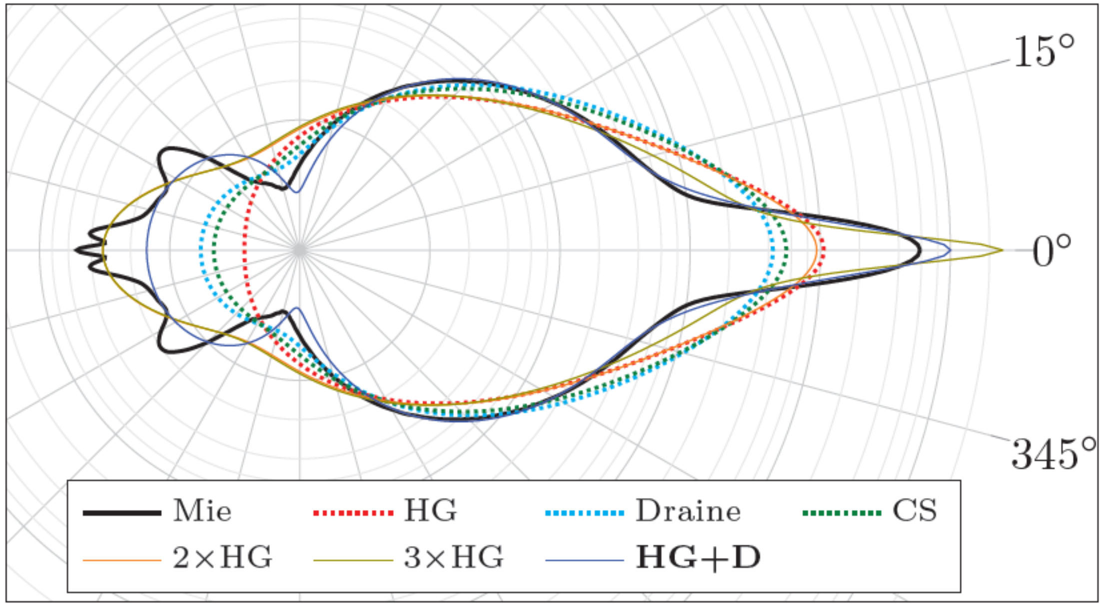
$$0 \leq b < 1$$

Multiple Scattering

Phase Functions

Jendersie & d'Eon's Phase Function [7]:

$$p(\theta, \alpha, g_{hg}, g_d, w) = (1 - w)\, p_{hg}(\theta, g_{hg}) + w\, p_d(\theta, \alpha, g_d)$$



Parameters based on diameter:

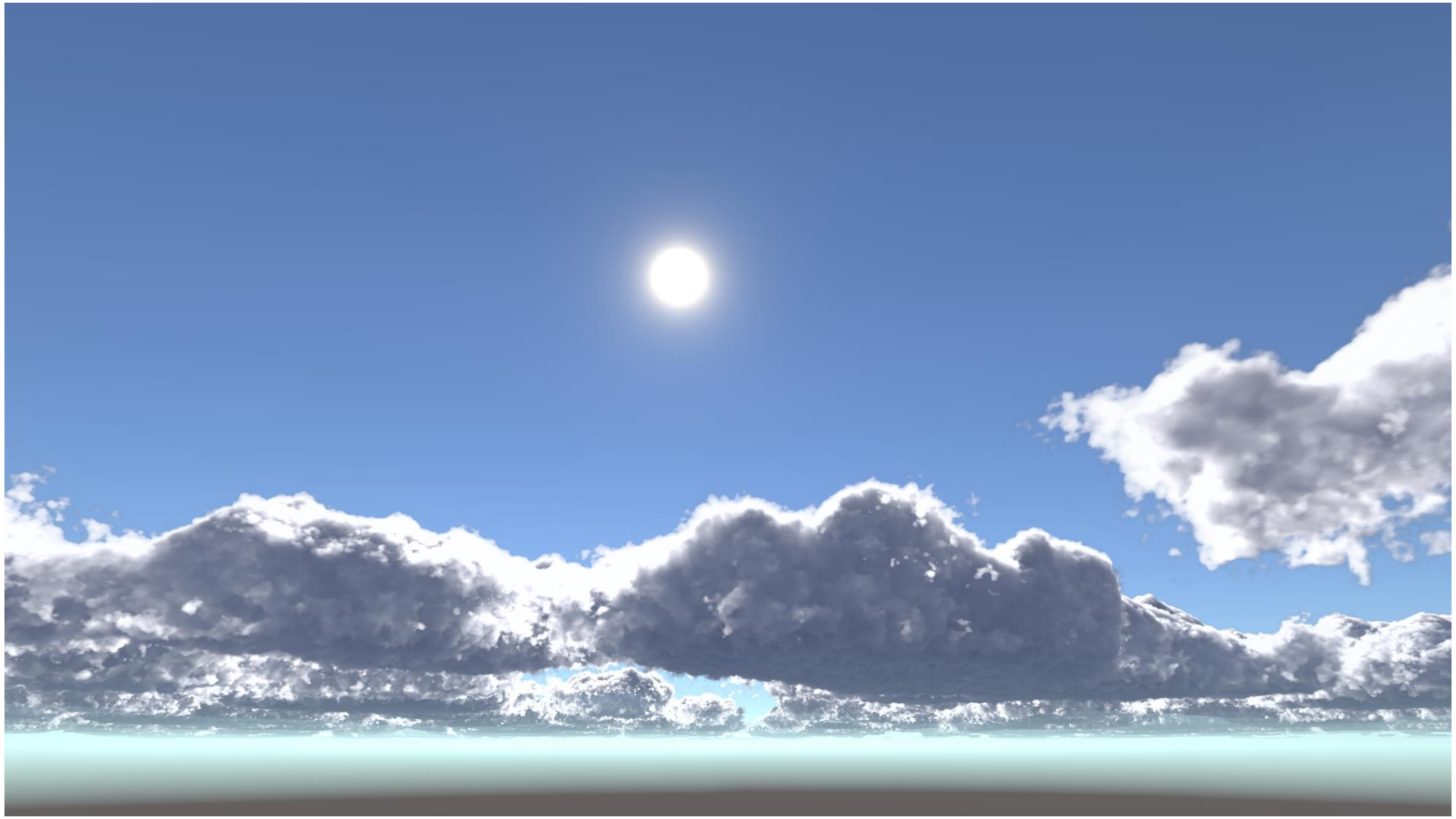
$$g_{hg}(20) = 0.9881$$

$$g_d(20) = 0.5567$$

$$\alpha(20) = 21.9955$$

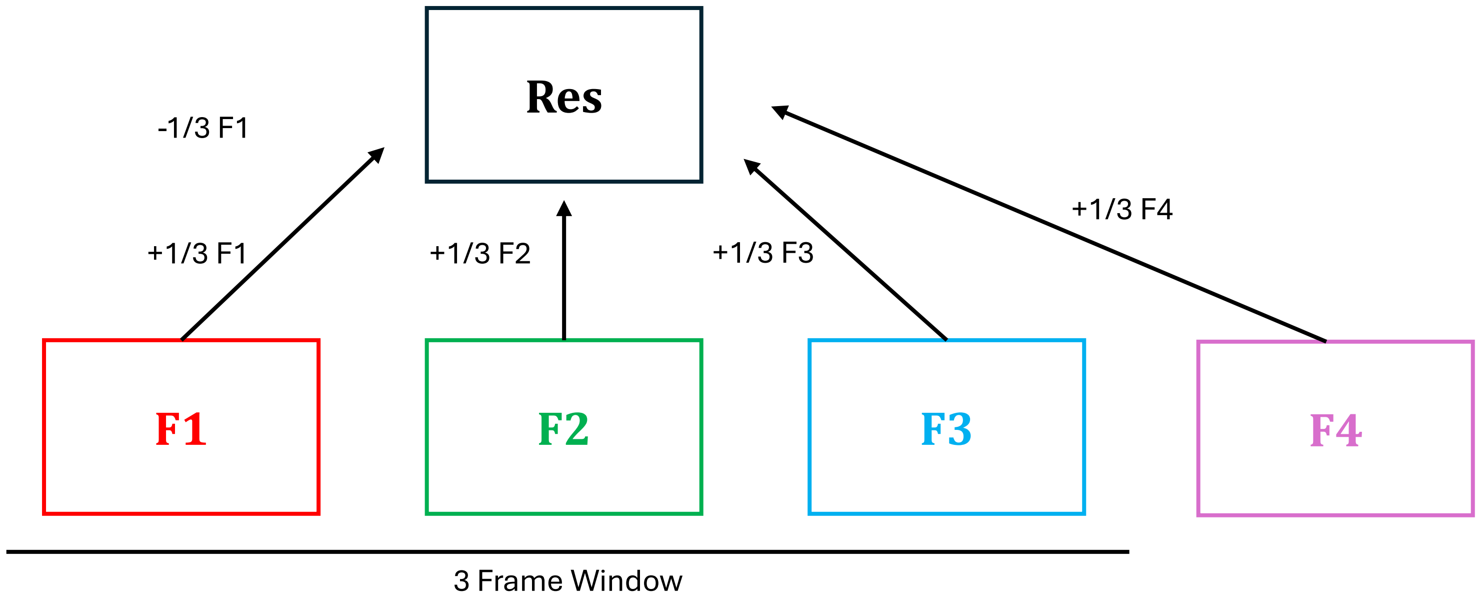
$$w(20) = 0.4824$$

Phase Function



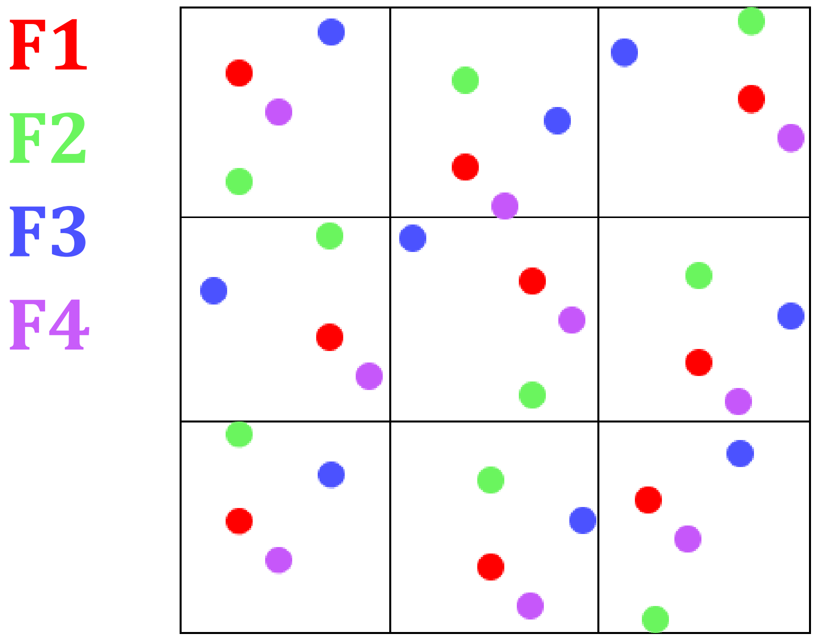
Unified Temporal Anti Aliasing

- Temporal Anti Aliasing refers to the combination of frames over the time domain.
- We accomplish this using a sliding window approach



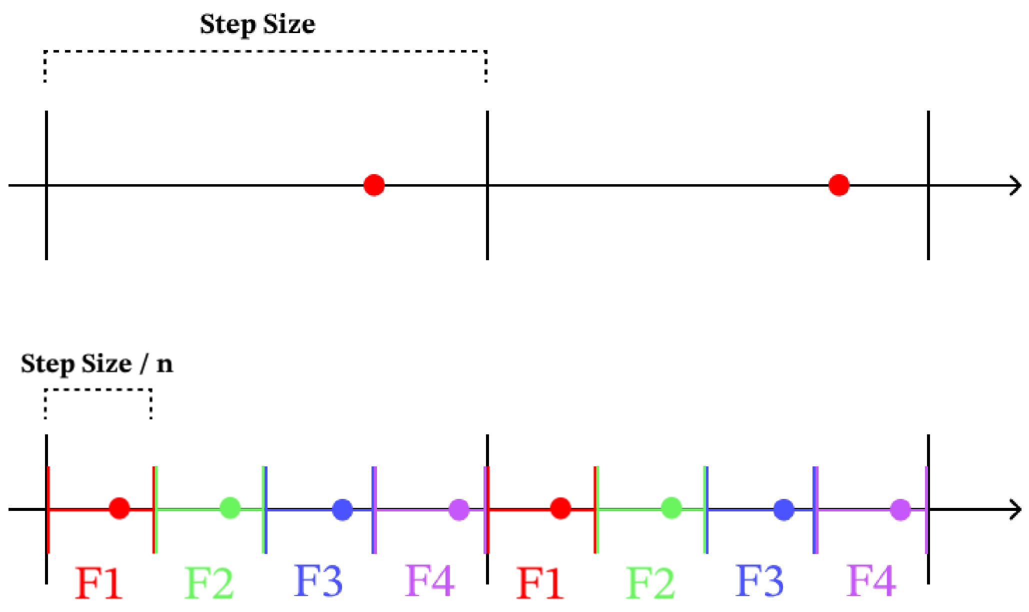
Pixel Area TAA

- Each pixel sample position begins at its blue noise offset, then is shifted according to pre-compute N-Rooks offsets

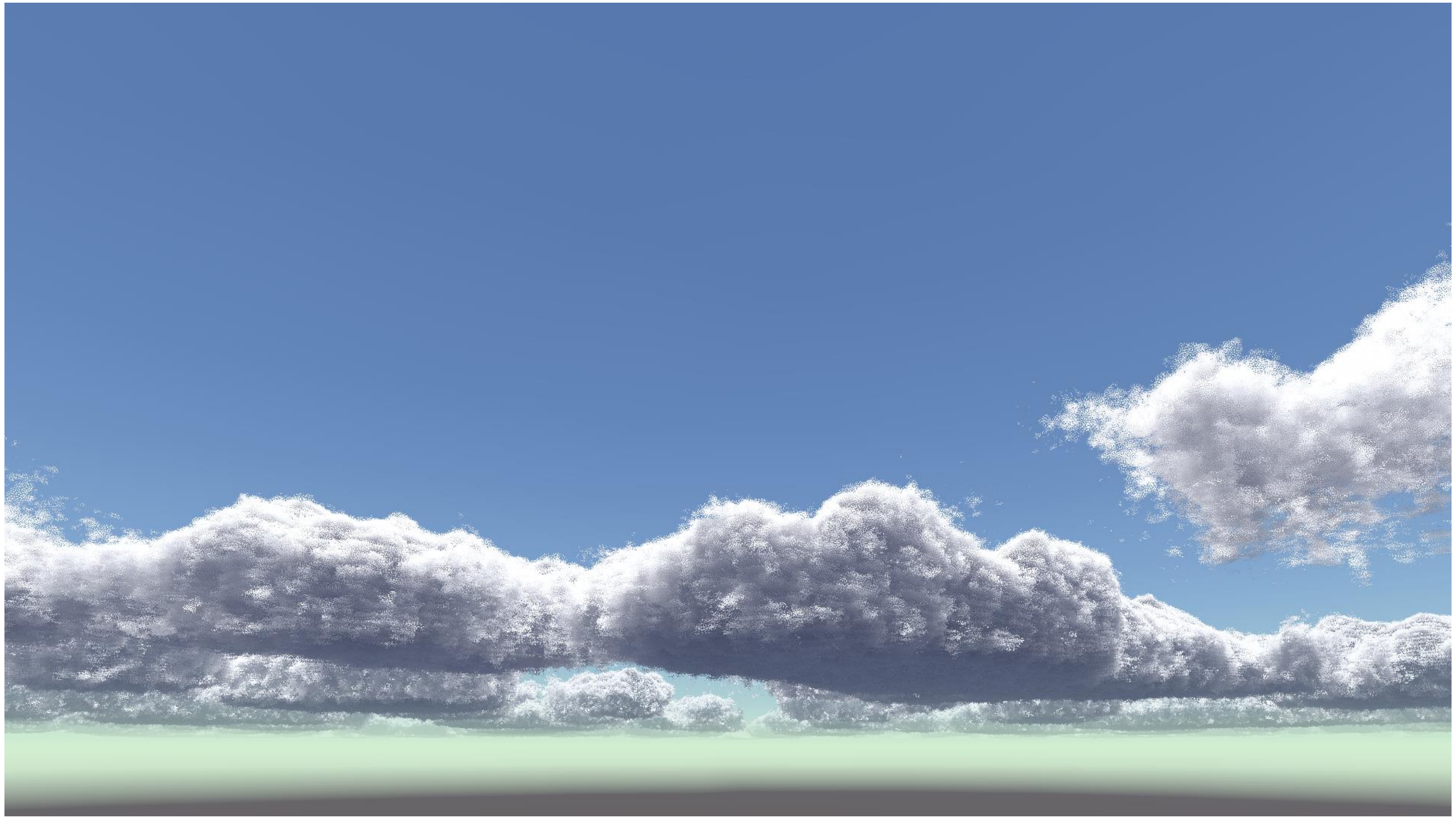


Volumetric TAA

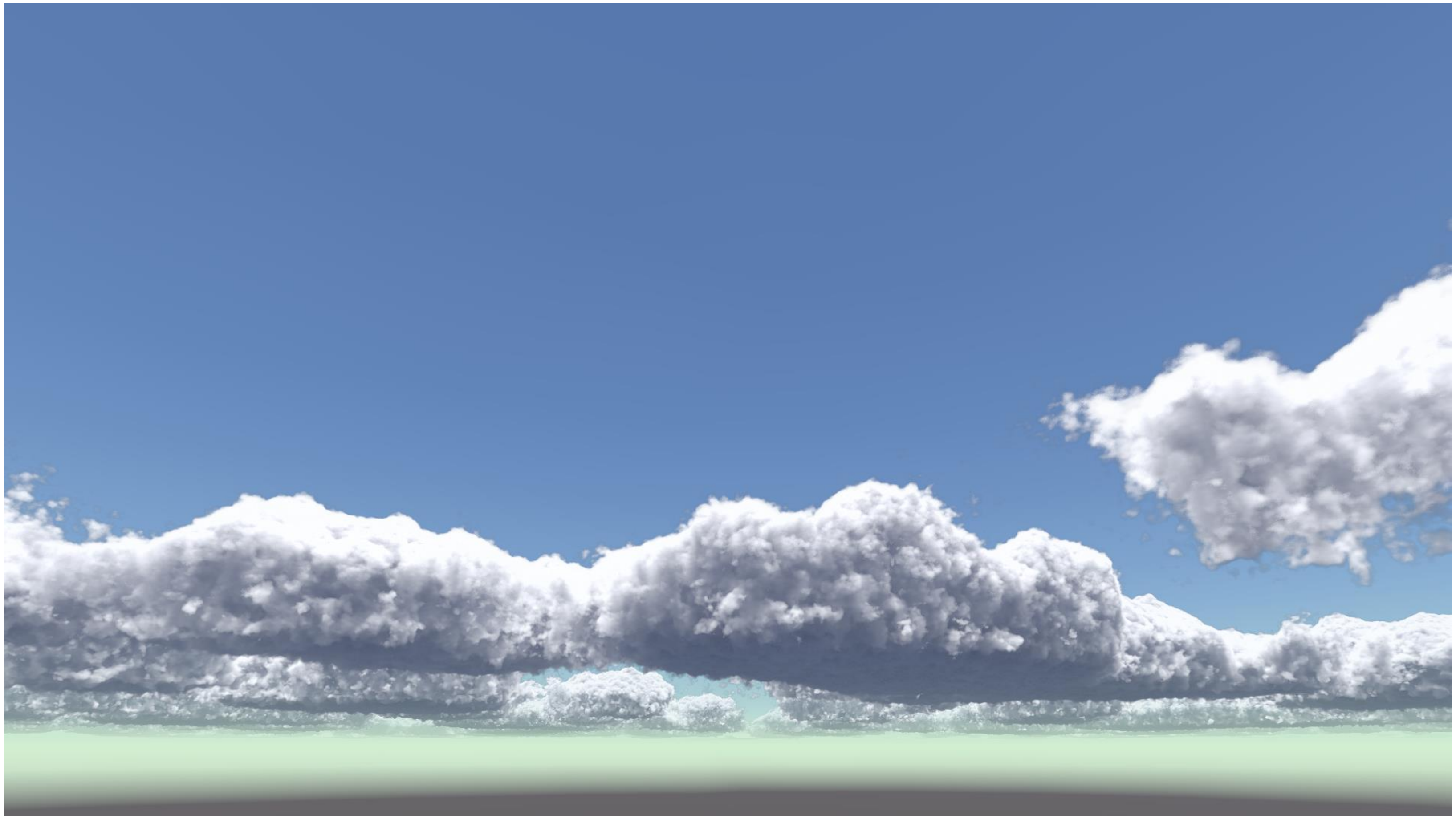
- Each segment is split into smaller frame segments.
- Each frame samples within its corresponding frame segment.



Improved Scattering Integration



Temporal Anti-Aliasing



Conclusion

- Our system:
  - Captures cloud’s complex shapes and lighting interactions
  - Dynamically responds to environment
  - Runs in real time
- We provide:
  - A starting off point for further research into real time cloud rendering
  - A novel Unified Temporal Anti Aliasing strategy
- Code publicly available at: https://github.com/parker-ford/Real-Time-Atmospheric-Cloud-Rendering-System

Real-Time Atmospheric Cloud Rendering System

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Thank you!

Questions?