

3D Simulation of Cloud Formation in Virtual Proving Ground & Training Center

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Objectives

- Simulate the process of cloud formation in Virtual/Mixed Reality (VR/MR).
- Create a consistent and controllable physical sky and cloud system in Unity.
- Integrate the VR/MR module into the virtual Proving Ground and Training Center (VPGTC).

Results

- The morphology of various types of clouds has been simulated in VR/MR (Fig. 1).
- The sky is rendered at a minimum of 72 FPS on mobile VR devices.
- The simulation can be adapted for integration into multiple modules.

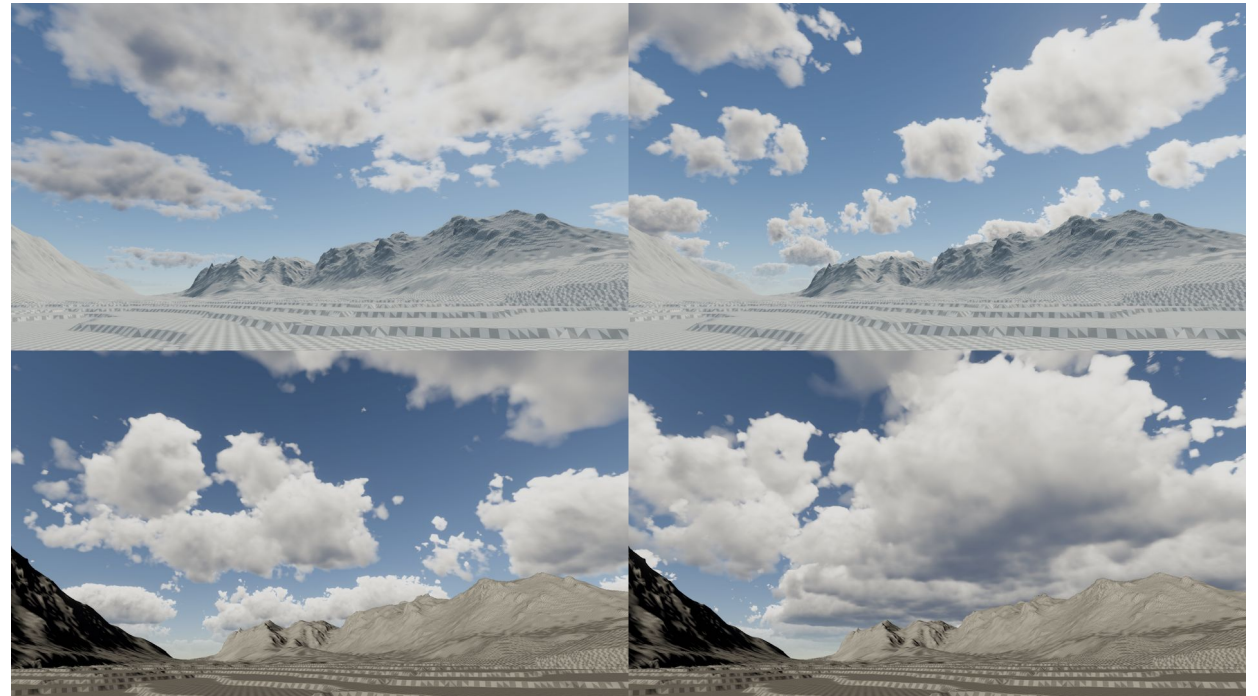


Figure 1. Stratus, stratocumulus, and cumulus clouds

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Cloud Modeling

- To model the clouds, we use 3D noise textures to build our shape (raymarching technique by Andrew Schneider)
- A wind vector simulates cloud lift and other motions
- Clouds are controlled by temperature, humidity, and a cloud nuclei density field
 - These parameters simulate cloud coverage and type, which are stored inside the red and green channels of the weather map
 - The raymarcher will sample the weather texture and apply coverage and type
- Demo: <https://bit.ly/4lv9UGx>

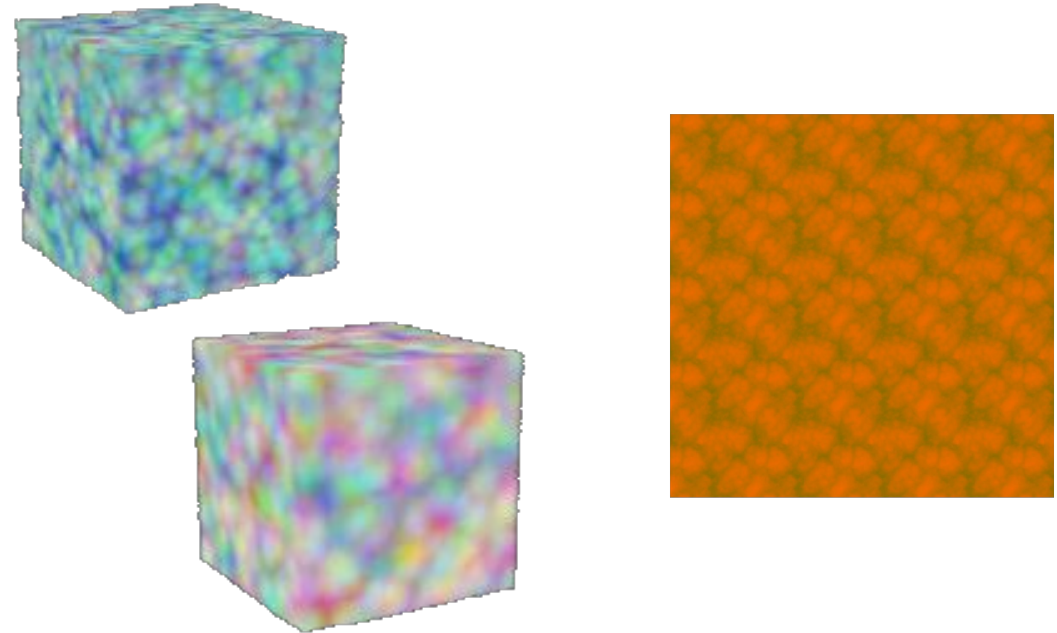


Figure 2. Base and detail noise textures and example weather map

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Future Work

- Improve the base noise and lighting model.
- Add high-altitude clouds (e.g., cirrus, altostratus).
- Simulate the vertical structure of cumulonimbus (Fig. 3).
- Develop an interactive module to visualize the cumulonimbus formation process (condensation, starting from water vapor and dust to cloud droplets (Fig. 4).

References

- Andrew Schneider, 2015, *The Real-time Volumetric Cloudscapes of Horizon: Zero Dawn*, SIGGRAPH.
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<https://doi.org/10.1017/9781108963688>.
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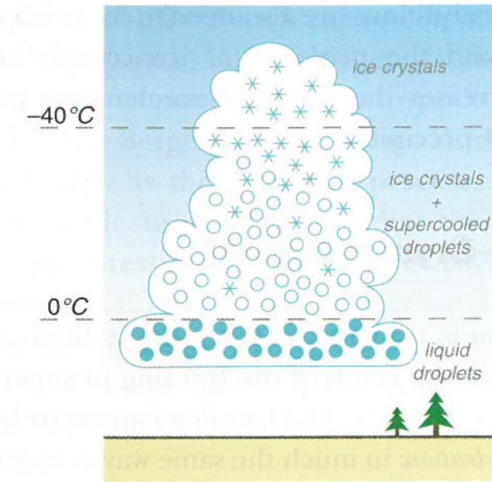


Figure 3. Distribution of liquid water (blue), supercooled droplets (white), and ice crystals (stars). [Hakim and Patoux, 2021]

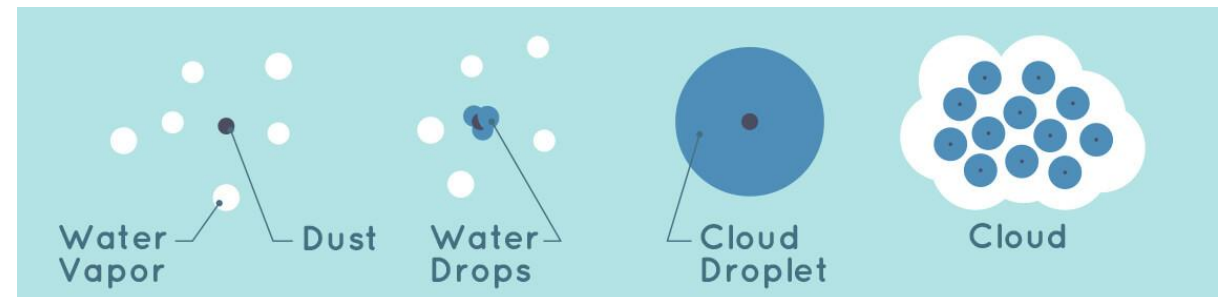


Figure 4. Condensation process. Image credit: NASA/JPL-Caltech/Alex Novati