# Can We Model Skies For Image Based Lighting?

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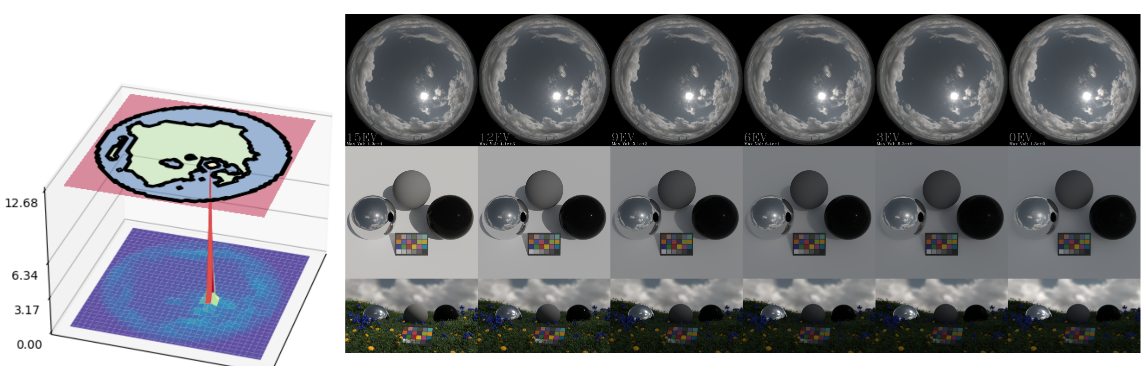
## 1 Introduction

Illumination plays an important role in human understanding and perception of physical spaces in both the real- and virtual-world. This importance is reflected in media and film where the coherence of illumination can be key in distinguishing a real- vs. virtual-scene, in particular, when subject to 'natural' outdoor illumination. Though parametric skydome luminance models for scientific and engineering applications have existed for the better part of a century, color models were only introduced with the advent of the digital age and, most recently, all-encompassing models capable of weathered skies were introduced with the advent of Deep Neural Networks (DNNs). Alshaibani & Li (2021); Moon (1940); Nishita et al. (1993).

Early parametric models combined physically-captured data from varied sources, but meaningful comparisons to physically-captured data have all but disappeared from recent literature. In this work, we evaluate recent all-encompassing models to demonstrate the continued importance of evaluating sky models with reference to physically-captured data. We demonstrate incongruities with the characteristics of physically-captured data, and illustrate the impact on scenes rendered via Image Based Lighting (IBL). Reinhard et al. (2010).

## 2 Background

High Dynamic Range Imagery (HDRI) is integral to the photorealistic rendering of outdoor scenes. Indeed, to faithfully capture the highlights and shadows of an average real-world outdoor scene, an estimated 22 f-stops of exposure are required. As illustrated in Fig.1a, this dynamic range is primarily required for sun pixels which represent less than 5° of the




(a) June 7th, 2016 at 1:54PM. 13.4-EV.

(b) Impact of DR on scene illumination. Each column illustrates the impact of incrementally clipping DR with exposure equalization to the 15EV ground truth.

Figure 1: Dynamic Range and Environment Map Illumination

Table 1: Quantitative Comparison of Sky Model HDRI. Ground Truth CLIP-IQA is 0.36, and Text2Light Ground Truth CLIP-IQA is 0.38

| | LDR $L_1 \downarrow$ | HDR $L_1 \downarrow$ | LPIPS $\downarrow$ | CLIP-IQA $\uparrow$ | DR $I_f/I_r$ | $\oiint_I I_f/I_r$ |
|---|---|---|---|---|---|---|
| SkyNet | 0.05 | 0.07 | 0.16 | 0.50 | 0.39 | 0.55 |
| DeepClouds | 0.01 | 0.07 | 0.21 | 0.54 | 0.36 | 0.59 |
| SkyGAN | NA | NA | NA | 0.36 | 0.96 | 0.71 |
| Text2Light | 0.16 | 1.39 | 0.44 | 0.39 | 2.42 | 3.55 |

skydome angular field-of-view, but 60% of illumination, making them paramount to Image Based Lightning. The remainder of the skydome illumination, e.g. clear sky and atmospheric formations, represents the remaining third of the sky's irradiance through multiple scatterings of solar irradiance within the atmosphere and with the earth's surface. Stumpfel et al. (2006); Jensen et al. (2001); Reinhard et al. (2010); Stumpfel et al. (2006).

As illustrated in Fig.1b, assessing the quality of HDRI is difficult, with visually appealing and photorealistic skydomes being indistinguishable, often both visually and through provided metrics. When used for illumination in rendering lambertian and other test scenes, HDRI flaws in the capture- or generation-process surface, including changing illumination, surface albedos, shadows, and light transmission by materials.

## 3 Results

We propose to evaluate of dynamic range as $EV = log_2(|I|_{max} - |I|_{min})$ and propose to quantify global-skydome-illumination as Integrated Illumination $\oiint_I(I) = \sum \Omega|I|$. This characterizes skydome radiance as linear luminance ($|I|$) per the BT.709 standard while accounting for angular field-of-view (solid angles, $\Omega$). Union (2015).

We recreate state-of-the-art GAN model SkyNet and train it on the Laval HDR sky database alongside author provided sources for DeepClouds and SkyGAN. Additionally, we evaluate the diffusion model Text2Light per author-trained checkpoints trained on the Laval Outdoor Dataset. Hold-Geoffroy et al. (2019); Satilmis et al. (2022); Mirbauer et al. (2022); Chen et al. (2022); J.-F. Lalonde, L.-P. Asselin, J. Becirovski, Y. Hold-Geoffroy, M. Garon, M.-A. Gardner, and J. Zhang (2016).

We summarize the bulk of our findings in Table 1, finding that commonly reported comparative metrics ($L_1$ and LPIPS in LDR and/or HDR space) match visual skydome comparison but are otherwise insensitive to skydome characteristics. Extending evaluation to include our proposed DR and $\oiint_I$, evaluates models as if visualized per the renders in Fig.1b, demonstrating gross under- and over-illumination in generated skydome radiance. This is well demonstrated through the unconditional model SkyGAN, where despite the best DR and illumination, CLIP-IQA reflects only the poor visual quality of of generated skydomes.

## 4 Conclusion

Modelling the extreme dynamic range of skydomes is a tremendous challenge which we identify as tangential to current literature for generative HDR models. All evaluated state-of-the-art models break the HDR assumption, failing to preserve HDR scene-reference and/or producing an alien spectrum of illumination, generating HDRI grossly unviable for Image Based Lighting rendering. As such, significant challenges remains before DNNs replace parametric luminance models and emerge as viable substitutes for physically captured HDRI.

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