

Our skies are too grey: where is the colour?

Just think for a moment about the last time you enjoyed a sunrise or sunset, with its dark blues and oranges, or the last time you looked up at a clear blue sky admiring its colourfulness. Did it lift your mood? Boyce¹ wrote in his opinion piece: Wellbeing, Mood and Uncertainty, that the '*interference from aspects of life other than the visual environment*' should not be neglected when it comes to the impact of lighting on mood. We could not agree more. We are aware that many aspects can play an influential role in our subjective experiences of daylight perception and assessment. Still, imagine those experiences under a grey or overcast sky compared to those under a blue sunny sky. Daylighting conditions, its spectral qualities, intensities and colourfulness, create an emotional, perceptual and physiological difference in many ways.

Yet, when we describe daylight in its spectral quality and colourfulness, our most frequently used reference in lighting design, research and application is the benchmark Daylight Illuminant D65. This is a CIE-standardised spectral power distribution with a correlated colour temperature of 6500 K.² D65 is representative of the colour of daylight under clear sky conditions, where a high proportion of warmer white direct sunlight is combined with a lower proportion of cool white skylight from a clear sky. However, the human perception of daylight mentioned above is largely influenced by the sky vault and its spatial spectral distribution. Assuming a uniform spectral distribution over the sky vault, the use of D65 would mean that all our experiences of skylight are evaluated under an overcast, cloudy, greyish, white light.^{3,4} Thus, D65 will underestimate the potential of a blue sky, not represent the spatial spectral distribution of a dark blue, orange and pink sky at sunrise, for instance, and overestimate the correlated colour temperature of the sun.

To us, it seems therefore necessary to look at the spectral characteristics of daylight as a whole and as separate components of skylight and sunlight. The colour of daylight and its spectral characteristics influence our mood⁵, the colour appearance of objects and materials⁶⁻⁸, the perception of our surroundings⁹, and the magnitude of its non-image forming (NIF) effect.¹⁰⁻¹² This research is recent and upcoming. It indicates that there are several relevant parameters in the macro- and microclimate related to the spectral composition of daylight that might impact our psychological and physiological responses. These parameters are mainly the contribution of the sun to the daylight, the visible portion of the sky, the presence of green trees, and the spectral reflectance of room surfaces and furniture.

What is clear is that, when available, the sun's contribution is dominant. Kenny's research highlights this by stating: '*The direct solar component produced a very different result, dominating in both intensity and spectral character but also relatively static in its spectral properties.*'.¹¹ The spectral characteristics of sunlight are well known both from spectral measurements and models, especially those obtained and developed for atmospheric research and by the photovoltaic community. Standardised spectral profiles for the sun are also provided and available from the CIE.¹³

However, the other component of daylight, skylight, can be significantly more blue, pink or orange than CIE's spectral profile for daylight, the Daylight Illuminant D65. Unlike sunlight, various factors influence skylight colour and spectral composition. First and foremost, the variability of the sky colour is primarily due to unpredictable cloud movements and weather conditions. In addition, the contributing sky region, seasonal changes and solar altitude impact the spectral composition of skylight.

Various lighting design and research tools are currently being developed and employed to take account of the spectral properties of daylight. These tools often work with *standardised* spectral distributions of daylight on a horizontal plane or a spectral sky using *default atmospheric profiles* in physics-based radiative transfer models. They are either incapable of providing the spatial spectral distribution of skylight or their suitability for localised analyses is posing challenges. The latter is an additional aspect to consider. There are geographical differences in the colour of skylight. This was observed by researchers as early as the 1960s and practically confirmed by Hohnbaum, who travelled around the world in 2006 to find the world's "best blue sky"; she found, for example, the bluest sky in Brazil.¹⁴

A solid (alt: accurate, extensive, reliable, representative?) database of measurements is required to draw conclusions about geographical, seasonal and diurnal differences in the occurrence, prevalence and representability of daylight spectral properties and to develop a framework that lighting designers and researchers can work with. For this purpose, a team of researchers are participating in a worldwide measurement campaign as part of CIE Technical Committee TC 3-60 "Spectral Daylight Characteristics". Within this framework, SKYSPECTRA was launched, an open-source data package with spectral daylight measurements collected from various sources worldwide.¹⁵ An initial analysis of these measurements confirms that geographical differences do not allow a "one-size-fits-all" spectral sky to reproduce representative or predominant sky colours in different locations.

Some argue whether localised sets of daylight spectra or spectral skies are necessary. Then again, we are used to working with geographical differences in the lighting community, from simple sun position calculations to higher-level approaches. Consider the Perez All-Weather Sky Model¹⁶, which works with irradiance values for specific sites to describe the luminance distribution of the sky. Also, EN 17037 – Daylight in Buildings¹⁷ uses a differential target daylight factor based on daylight availability in different locations. So why would it be different for the colour of the sky?

In line with these approaches, we aim to provide a set of representative local spectral power distributions of daylight tailored to bring more colour into lighting design, research and application. To this end, further work is required to record and analyse measurements of spectral characteristics of daylight globally. The CIE Technical Committee 3-60 "Spectral Daylight Characteristics" continues to recruit new members (alt: expand its membership as), part of a broader initiative to promote international collaboration and to expand the dataset on the colour of the sky.

References

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