MEASURING AND MODELLING SPECTRAL COMPOSITION OF EQUATORIAL LIGHT

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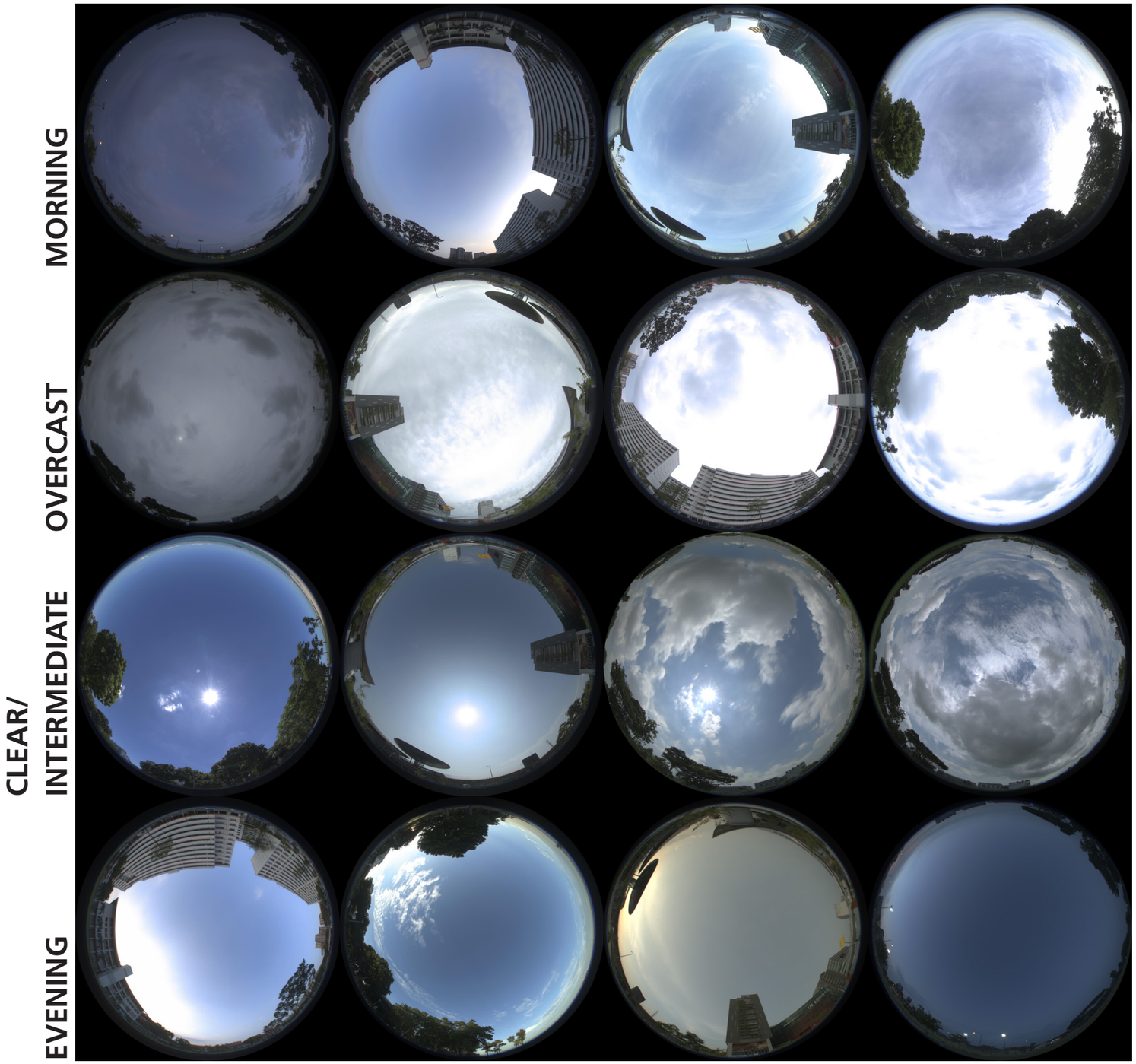
Spectral reflectance of the surface properties of buildings, vegetation and ground

Spectral characteristics of the Sky --- the source of light

Photo by **Phil**, Flickr, Rochor Centre, Singapore

Introduction

Varying spectral characteristics of the Singapore skies



This source of light is not constant, rather it changes in both intensity and its spectral distribution with time of the day as well as the atmospheric conditions.

Singapore in particular positioned close to the equator---one can experience partly blue skies, uniform overcast skies, cloudy grey skies to clear blue morning and evening skies with warm orange undertones all within a span of a day.

Clear sky with direct sunlight

Heavily clouded grey overcast sky

Morning Sky

Evening Sky

The changing spectral properties of the sky is what changes the tints, tones and shades of the colours we see. In cases of sunrise and sunsets it also changes our perception of the hues around us.

Our perceptions of time and scale, emotional and cultural responses of visual quality and identity also changes with the changing qualities of light and colour.

Plaster colour - beige and brown

Plaster colour - white and grey

19:05, 28th March 2018, Singapore

19:05, 24th August 2018, Singapore

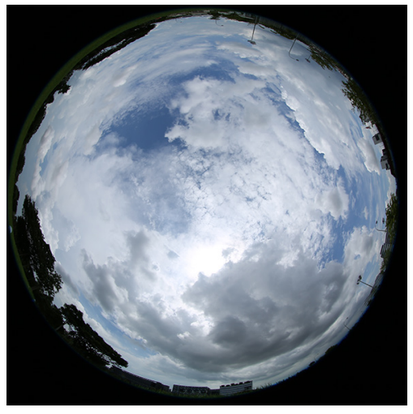
Current daylight simulation practices

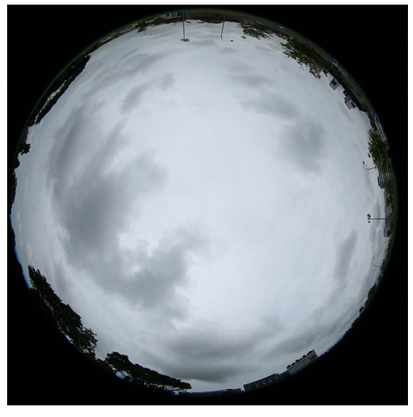
Clear Sky 11:50

Intermediate Sky 13:50

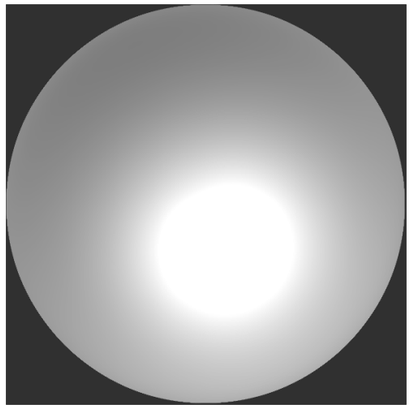
Overcast Sky 11:55

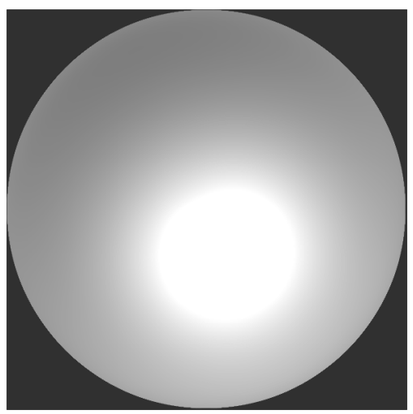
SINGAPORE SKIES

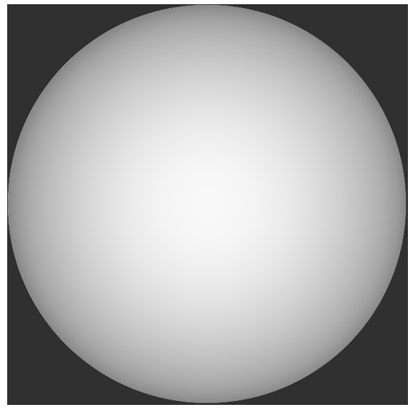




CIE SKIES





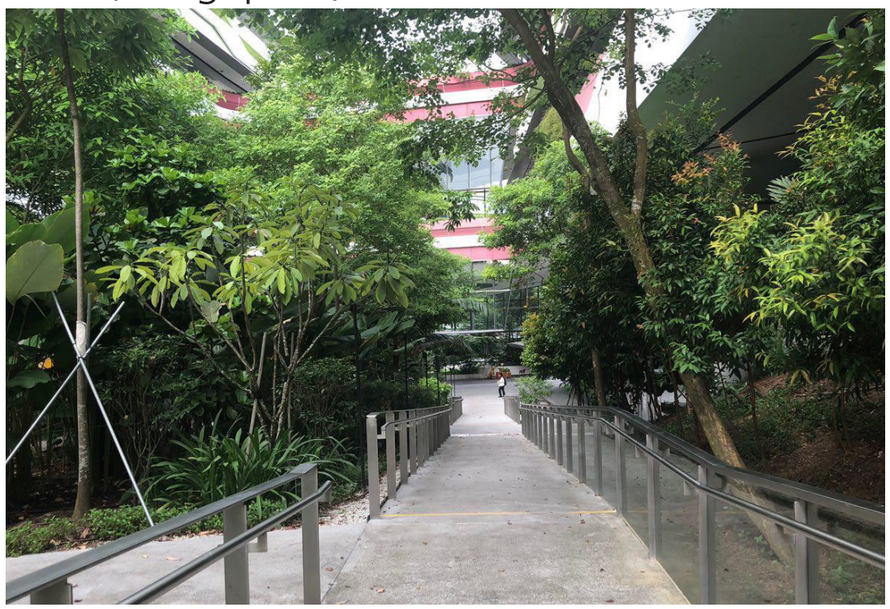


Architectural rendering versus Reality

Punggol digital district, Singapore, render

source: asiaone.com

SUTD, Singapore, built



Renderings of architectural projects do not represent the contextual colour and materiality.

Al Bahr Towers, Abu Dhabi, render

source: designboom.com

Al Bahr Towers, Abu Dhabi, built

source: archdaily.com, aedas

Introduction

Photo by **Liao Yusheng**, ArchDaily---Salk Institute, California

Architects are particular about the materials and colours they use--- but it takes an experienced intuition to mix ‘n’ match as well as chose based on contextual information.

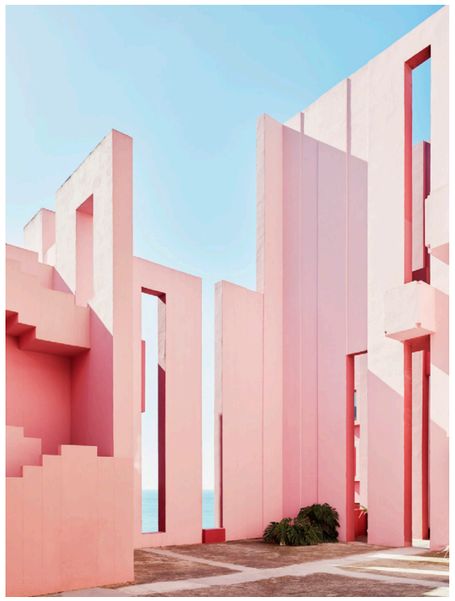
.. “Lou didn’t like the first samples he was seeing from California---they were too green, too blue, not warm enough....” and he finally chose “ ..the warmest tone---pinkish like...”

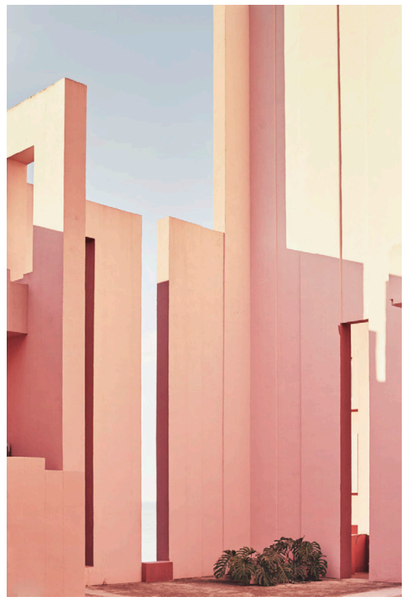
Fred Langford on Louis Kahn’s choice of choosing a cement colour for the concrete to use in the Salk Institute.

Goals

The red wall, housing project, Spain, designed by Ricardo Bofill, Photo source: ArchDaily

Especially in cases where there are more than two or three bold colours working in confluence to contrast as well as synchronize against the local backgrounds.





The red wall, housing project, Spain, designed by Riccardo Bofill, Photo source: Ricardo Bofill

Goals

Can predictive renderings for daylight also represent physically accurate colour perceptions in the scene?

- Measure and analyze changes in colour and spectra in complex urban environments with different materiality.

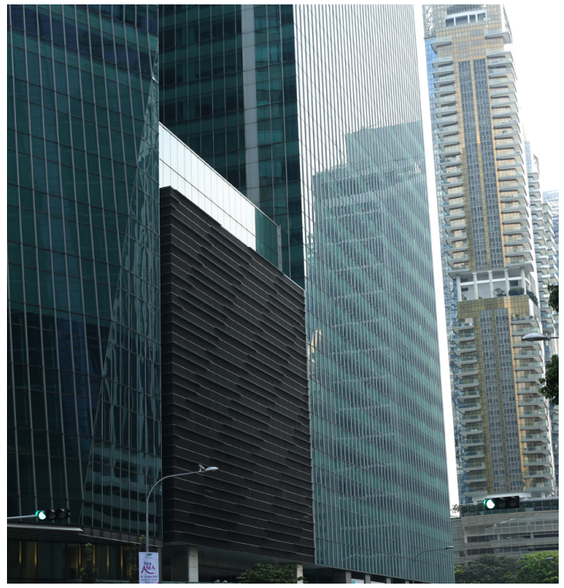
- Validate two spectral simulation softwares developed to predict non-visual quality of light for visual difference in both colour and spectra of light in these urban environments.

Choosing different sites in Singapore

Urban materiality in Singapore

PLASTER

VEGETATION



REFLECTIVE/ GLASS

25% of Singapore's urban areas constitute the Housing Development Board (HDB) units which are essentially plaster facades. 80% of the population in Singapore live in these HDB's

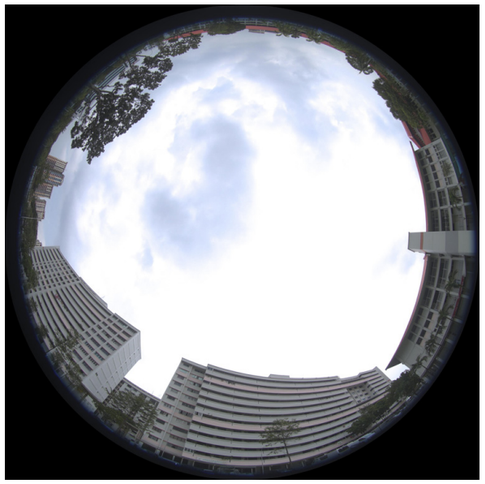
30% of the urban areas are covered by vegetation.

The central business districts and the business parks all constitute of reflec-

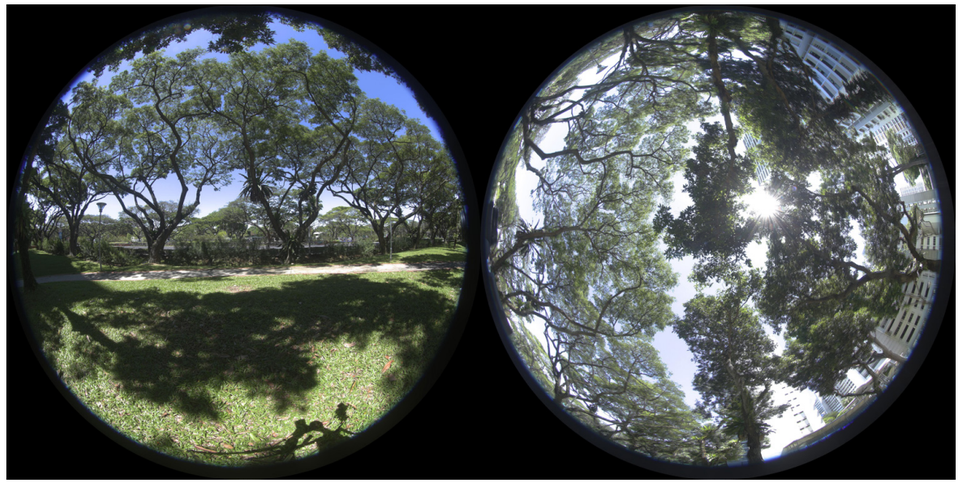
Open sky

PLASTER

~ 5 to 8 minutes



VEGETATION



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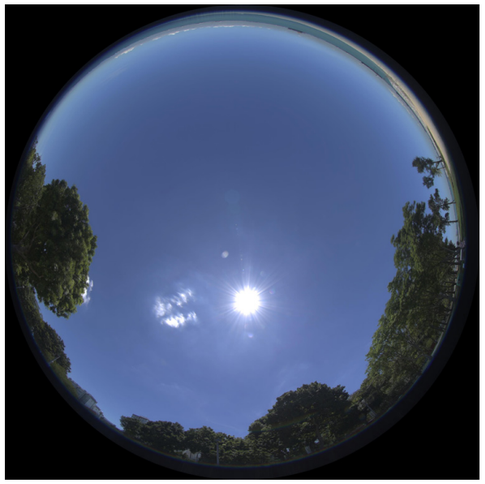
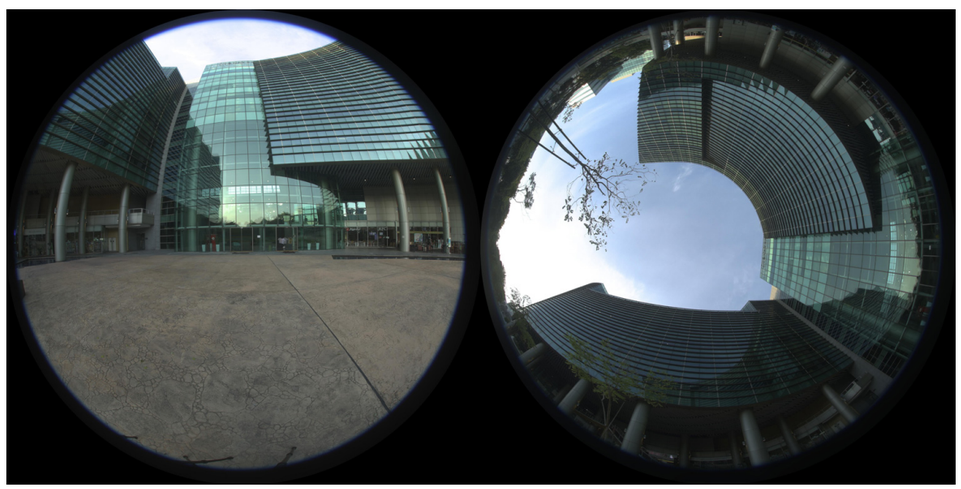


REFLECTIVE / GLASS



~ 5 to 8 minutes

The sites are chosen such that these urban materials enclose the space .

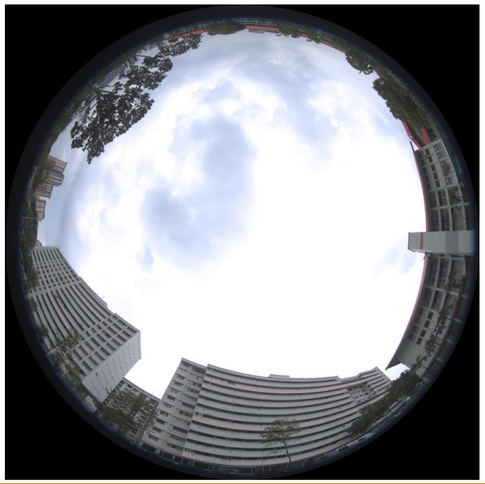
Also that with a 5 to 8 mins walk there is an open to sky site where the global spectral irradiance measure-ments of the sky can be taken.

Choosing different sites in Singapore

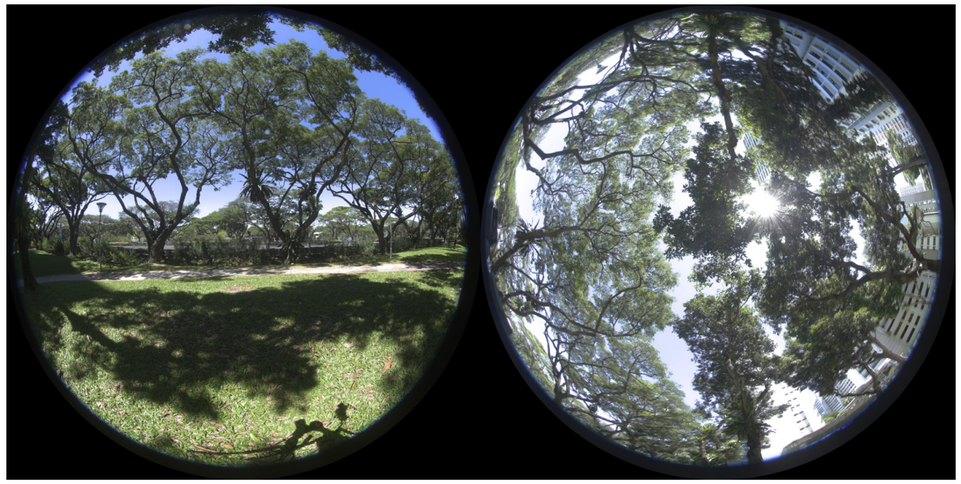
Open sky

PLASTER

~ 5 to 8 minutes



VEGETATION



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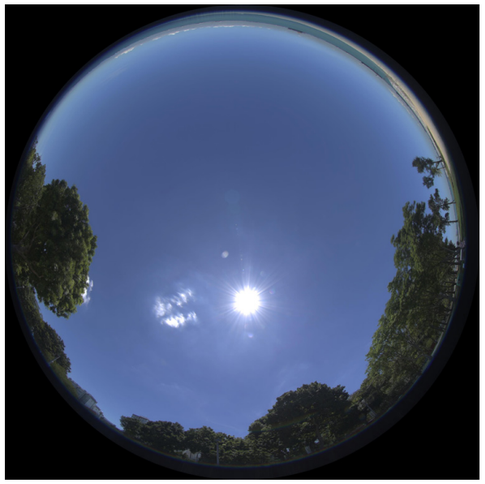
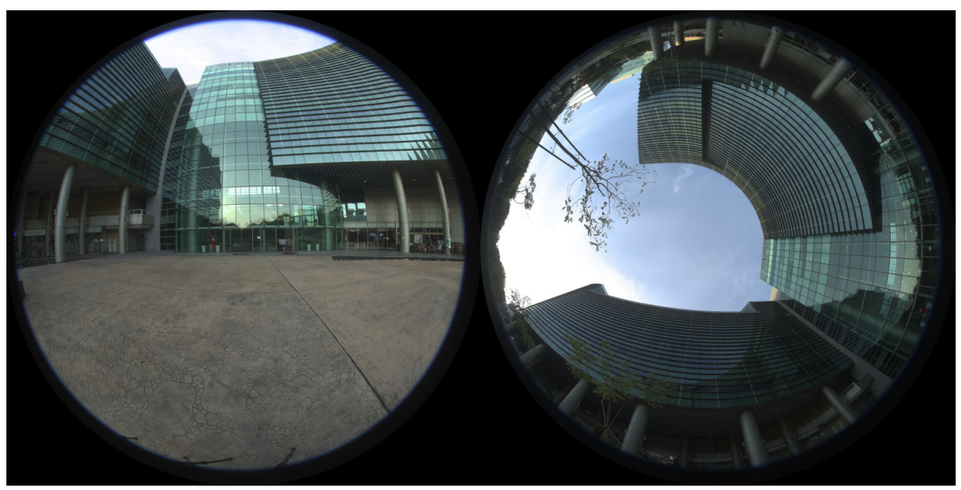


REFLECTIVE / GLASS



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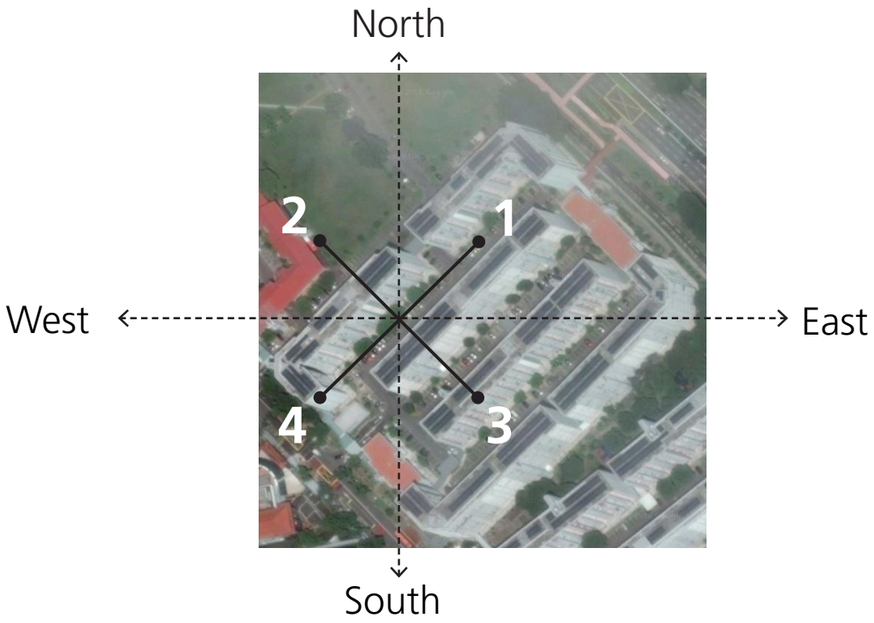


Measurements are taken looking at four directions

PLASTER

NORTH EAST

NORTH WEST

SOUTH EAST

SOUTH WEST

CLEAR

INTERMEDIATE

EVENING

MORNING

Measurements are taken in four different sky conditions---clear, intermediate/overcast, evening and morning sky.

Vertical spectral measurements---urban surfaces

Spectrophotometer measures global spectral distribution

HDR photography with fish eye lens

Horizontal spectral measurements---open sky

Spectrophotometer measures global spectral distribution

HDR photography with fish eye lens

Konica Minolta 2600d spectrophotometer to measure spectral reflectance of materials

Spectral simulation platforms currently available

LARK and ALFA

SPECTRAL SIMULATION PLATFORMS

LARK
SPECTRAL LIGHTING

Based on Radiance

ALFA

Adaptive Lighting for Alertness
A new circadian lighting design software.

Based on radiative transfer library called libRadtran

INPUTS

Spectral global spectral irradiances of the sky (W/m^2) from 360nm - 780nm

Gendaylit input
Latitude, longitude, time, month, hour and **global horizontal irradiation.**

Spectral reflectance of the material 360nm to 800nm

Geometry

LARK 9 - CHANNEL SIMULATIONS

Blue channel simulation
380 nm - 422 nm
422 nm - 460 nm
460 nm - 498 nm

Green channel simulation
498 nm - 524 nm
524 nm - 550 nm
550 nm - 586 nm

Red channel simulation
586 nm - 650 nm
650 nm - 714 nm
714 nm - 780 nm

OUTPUTS

INPUTS

Precomputed sky based on location

Location, month, hour

Sky condition
Clear, overcast, hazy,

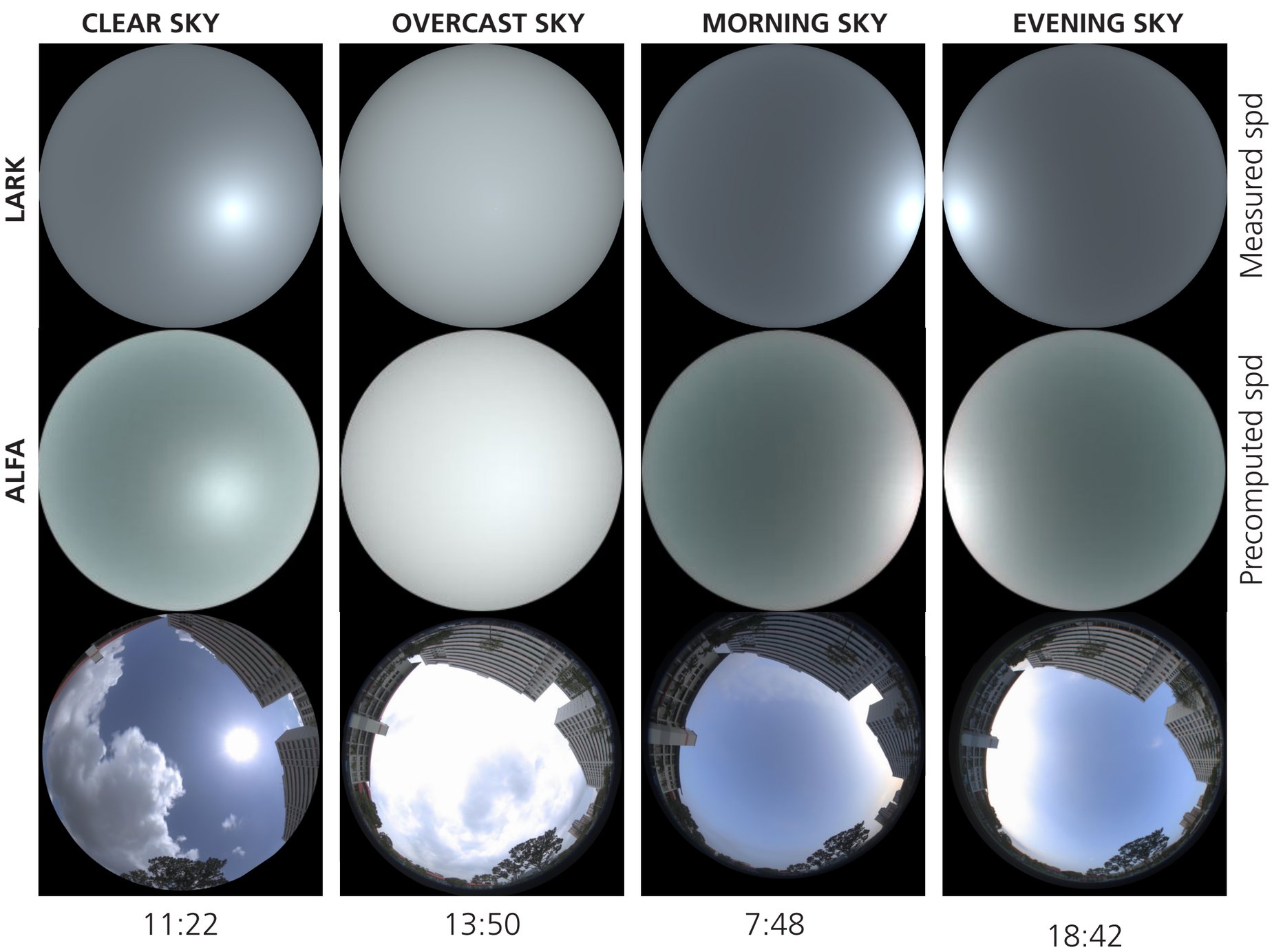
Spectral reflectance of the material 360 to 800nm

Geometry

ALFA - LIBTRAN COLOURED SKY SIMULATIONS

OUTPUTS

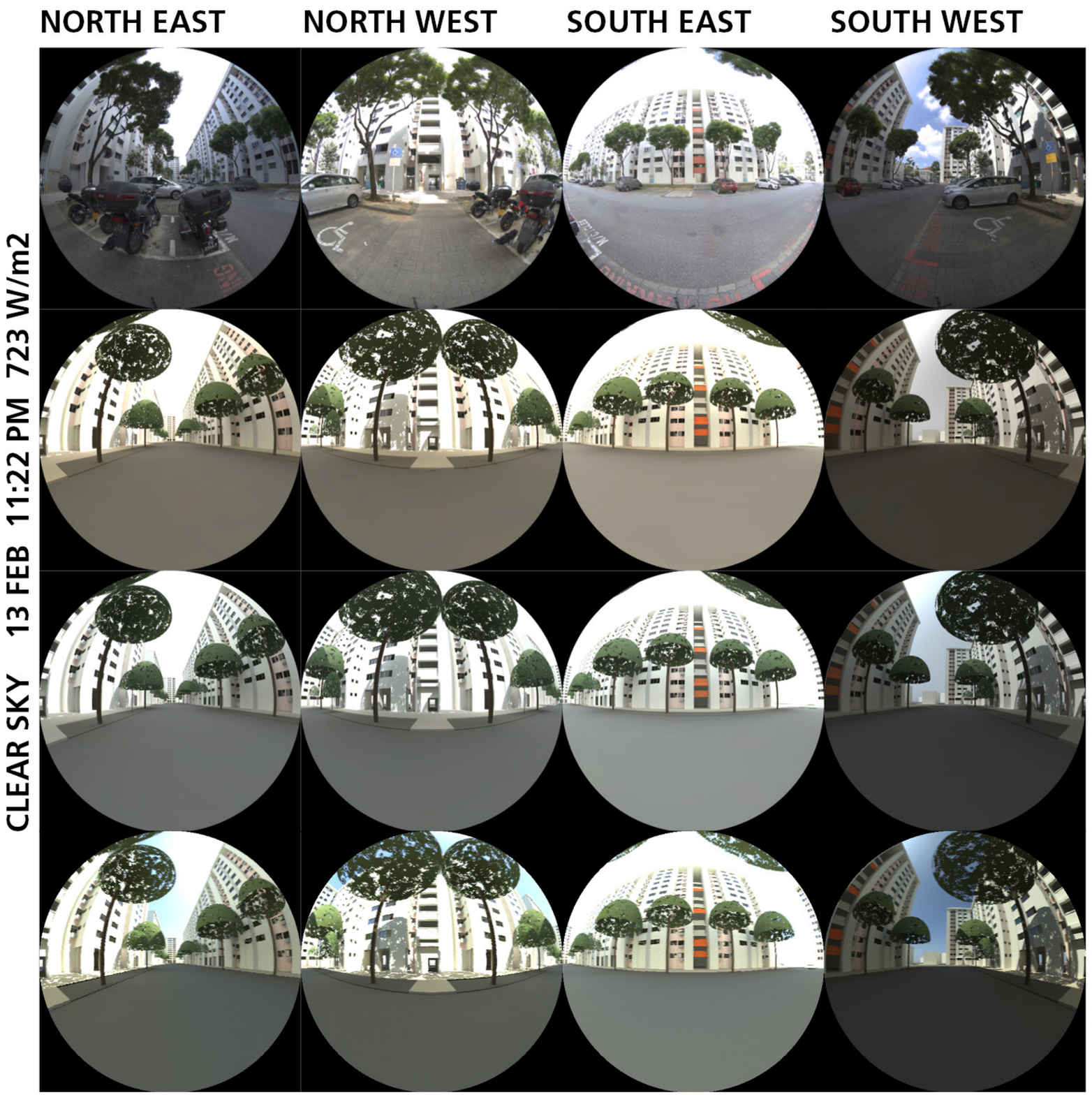
Difference between LARK and ALFA

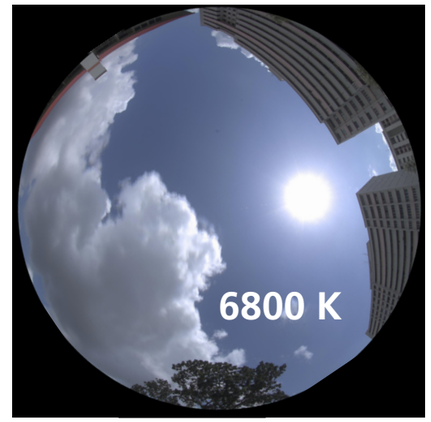


Lark uses measured global spectral irradiance and ALFA uses precomputed skies.

The sun in LARK is an equal energy white source whereas in ALFA the sun is colored.

Visual Comparisons



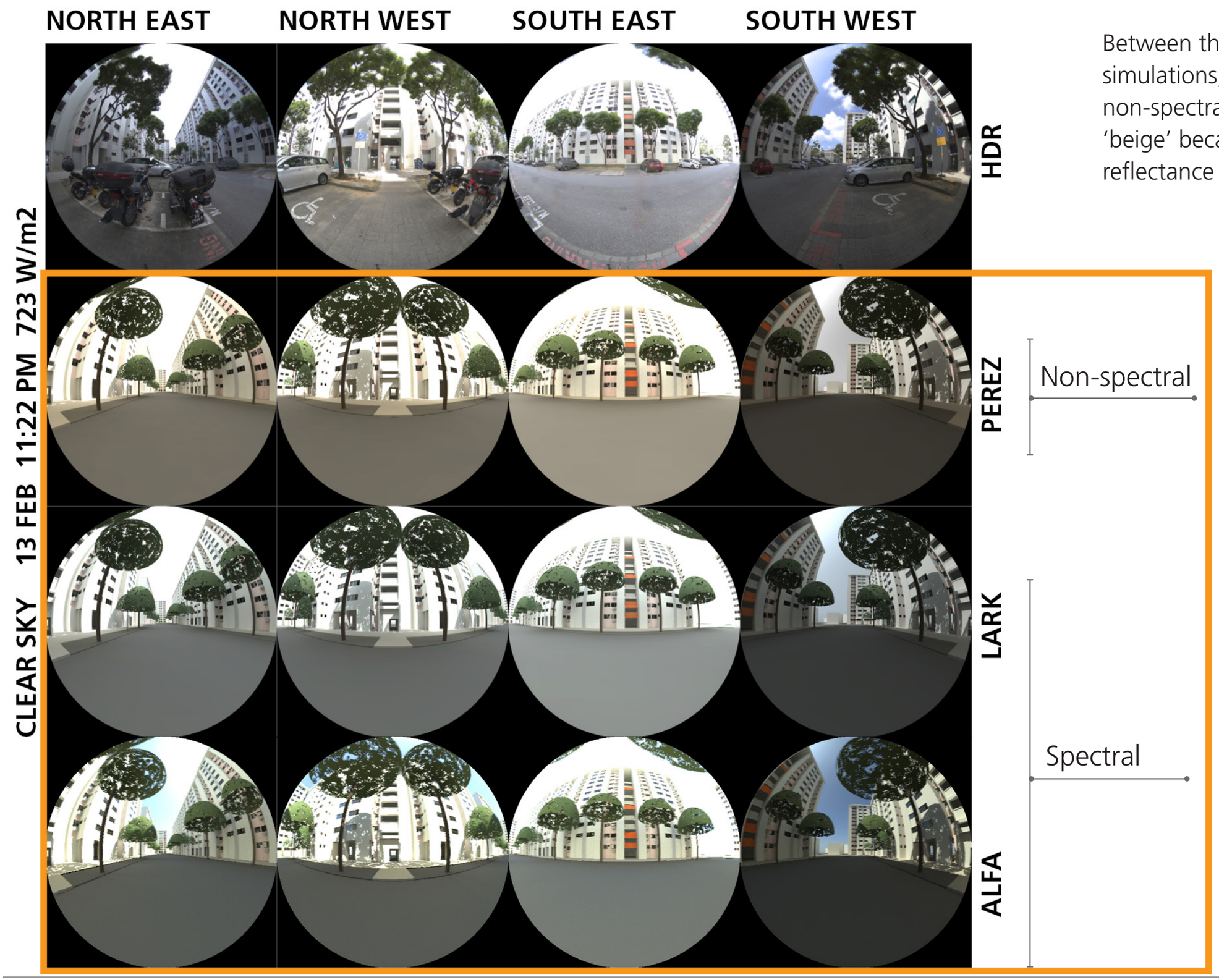


Non-spectral

Gendaylit luminance values

Spectral

Visual Comparisons

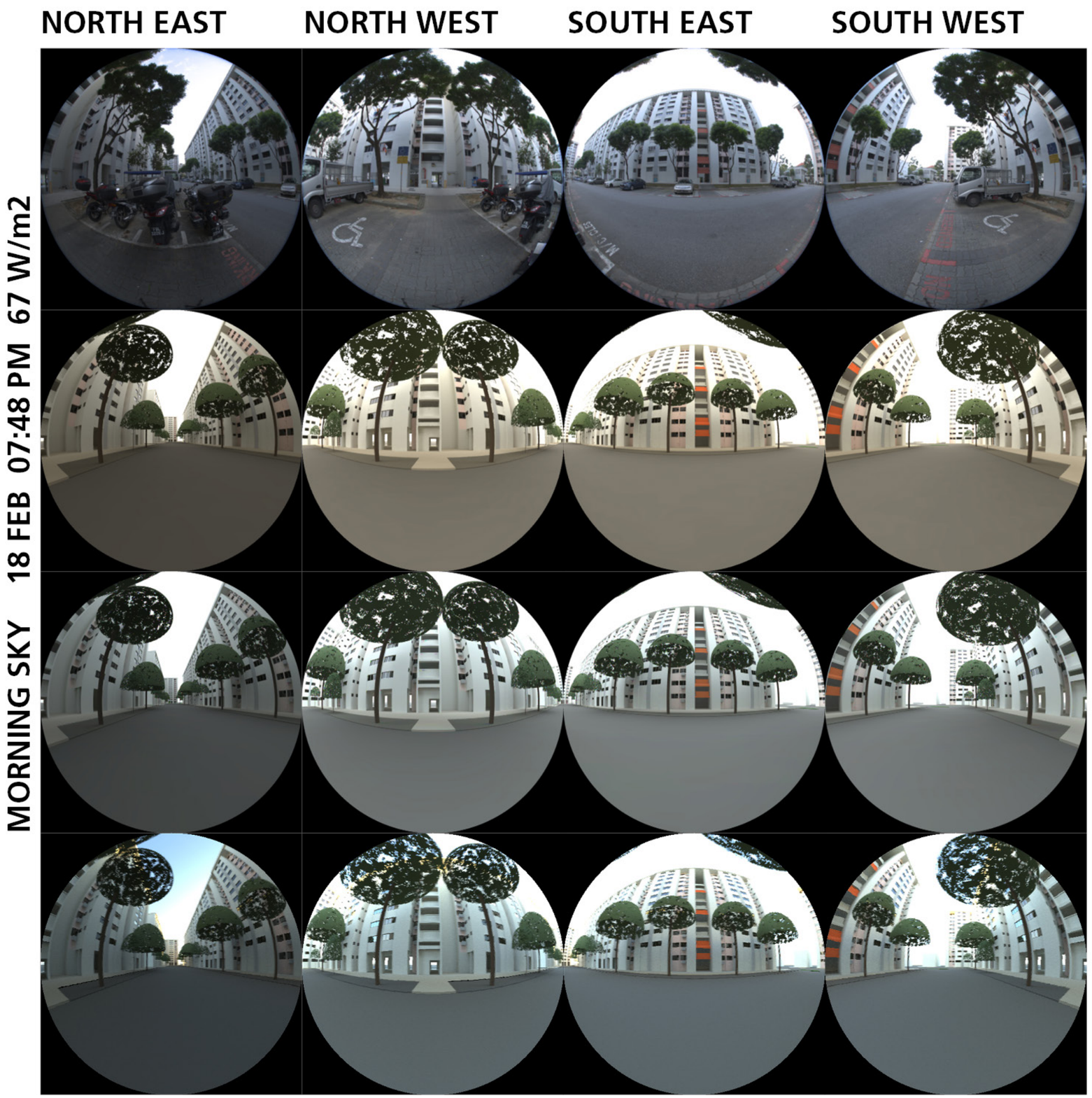


Between the spectral and non-spectral simulations, it is visually clear that the non-spectral simulations appears more ‘beige’ because of the lack of blue reflectance from the sky dome.

Results

Blue reflectance from the diffuse part of the sky.

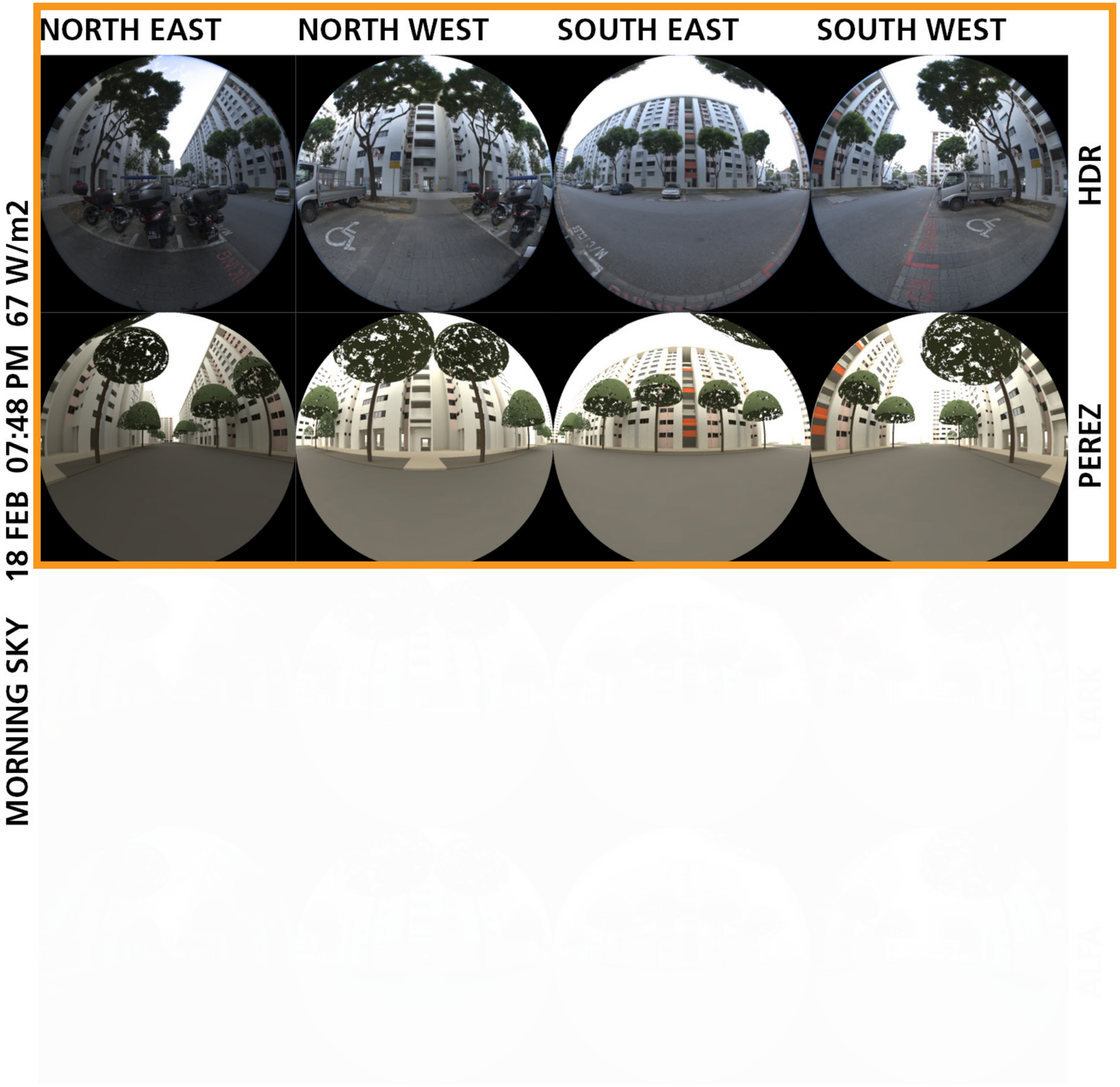
The bluish reflectance from diffuse sky component is also not represented in PEREZ and very slightly in ALFA and LARK.



Non-spectral

Spectral

Visual Comparisons



In the morning sky scenario, all the facades appear bluish and PEREZ simulations appear as a stark contrast.

Visual Comparisons

Between LARK and ALFA, ALFA has a stronger blue reflectance than LARK.

Visual Comparisons

NORTH EAST NORTH WEST SOUTH EAST SOUTH WEST

EVENING SKY 18 FEB 18:42 PM 51 W/m2

HDR

PEREZ

LARK

ALFA

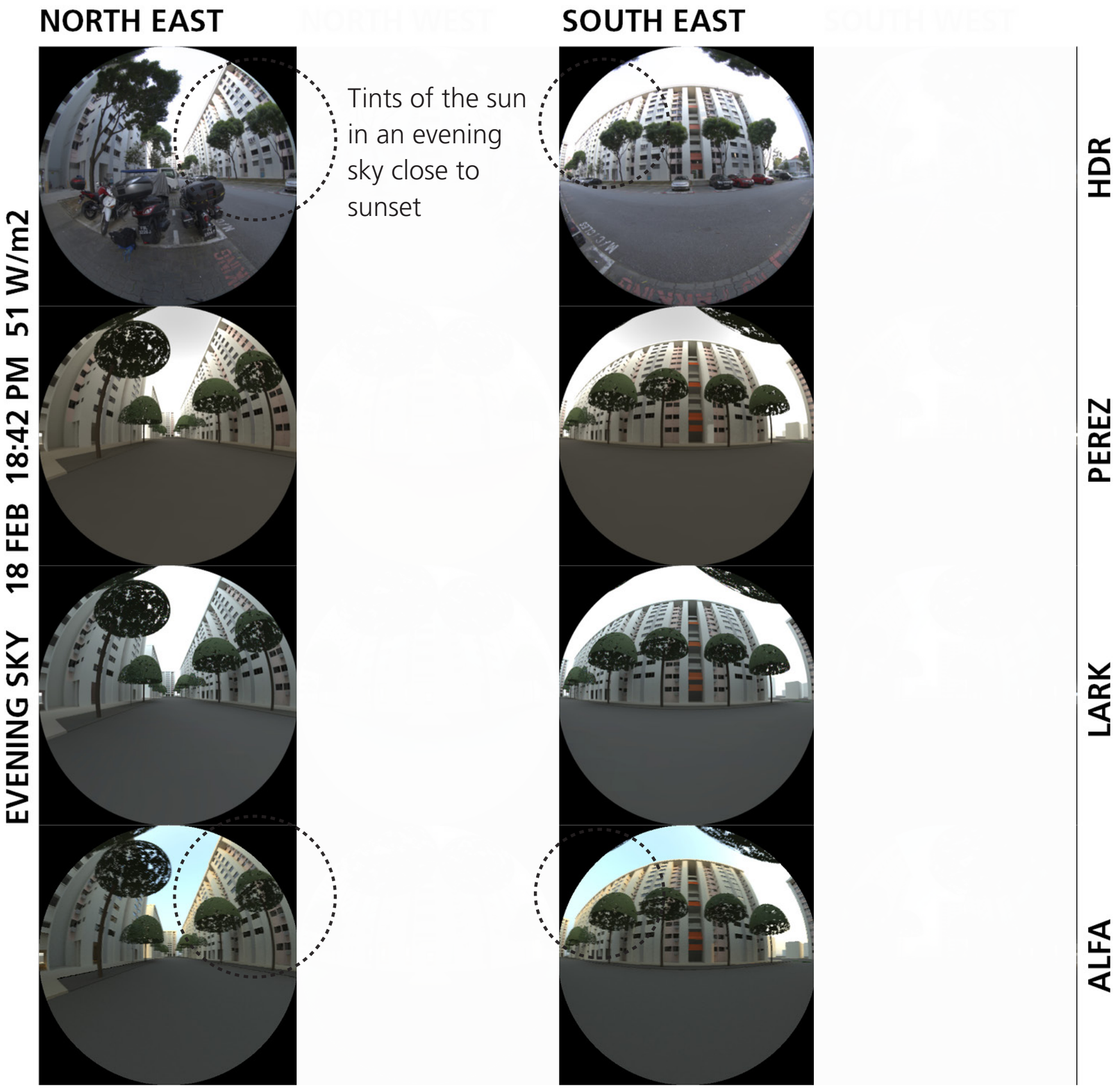
Non-spectral

Spectral

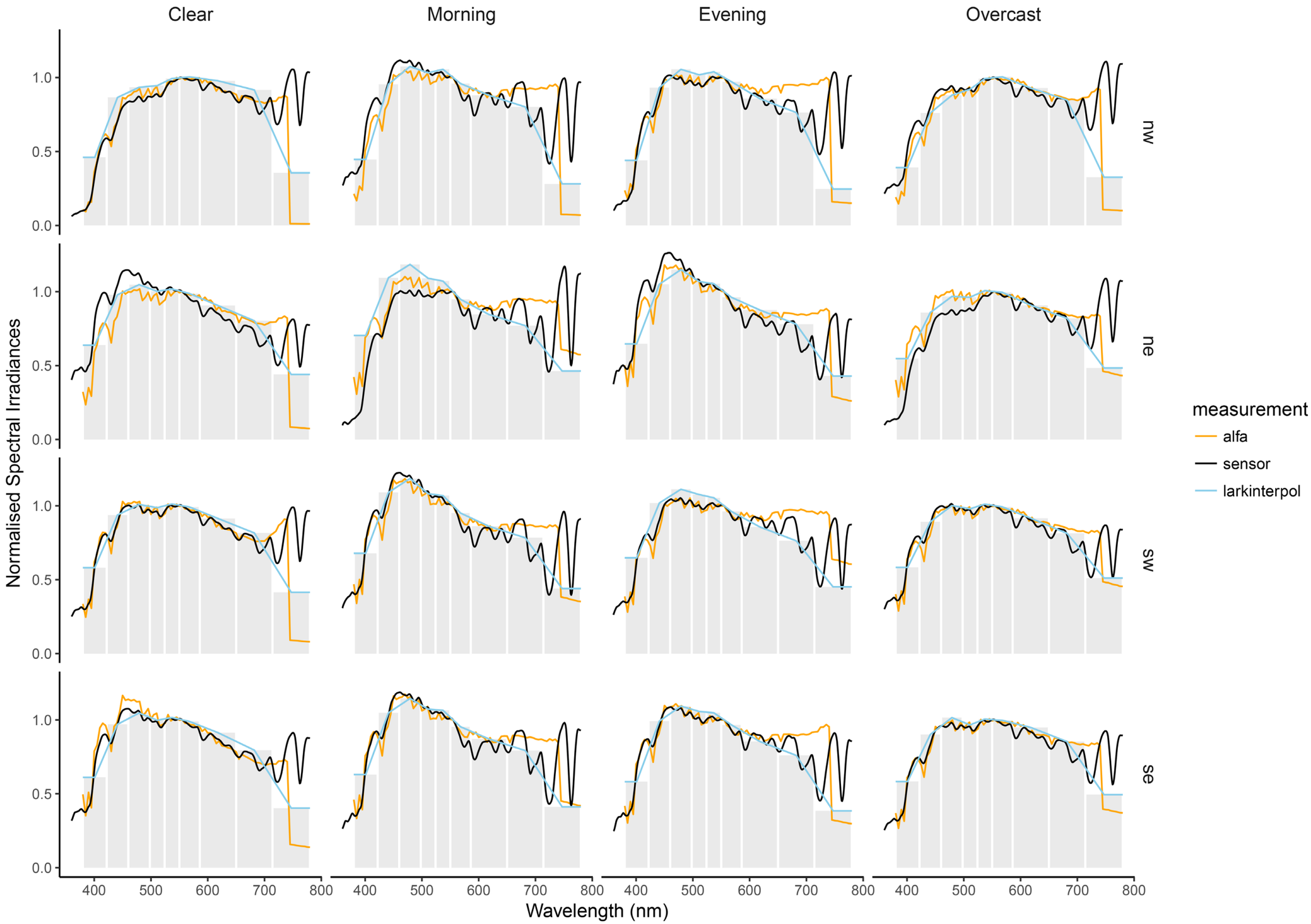
Visual Comparisons

Results

The orange reflectance of the sun is only seen ALFA because the sun is coloured in ALFA.



Spectral distribution comparisons



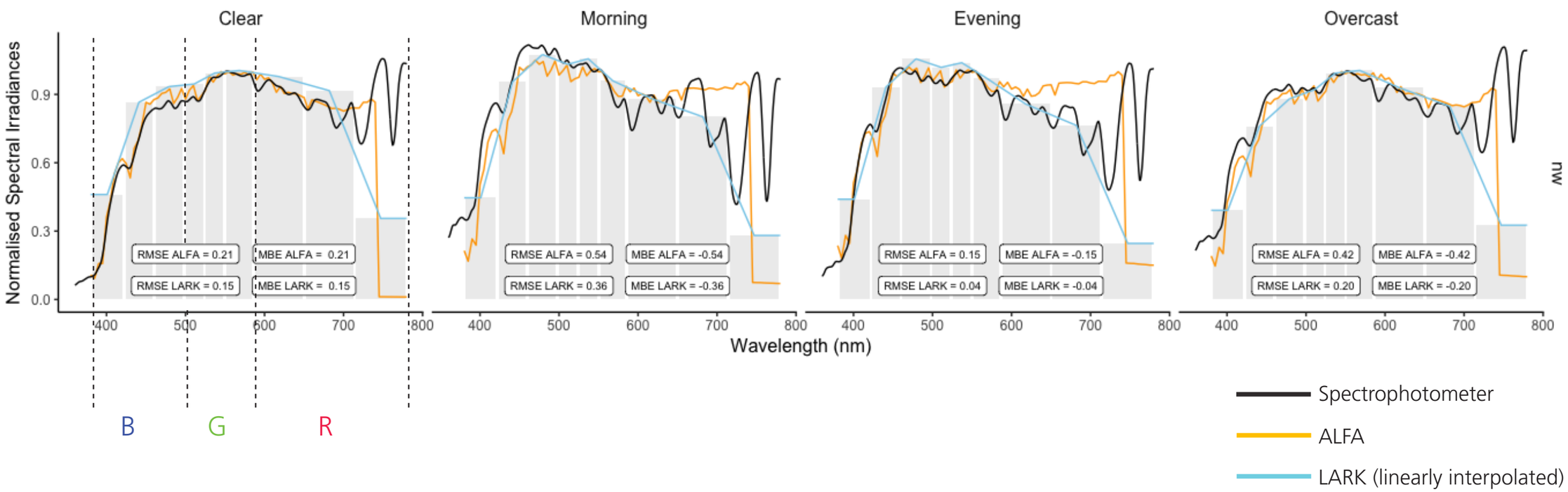
Spectral distribution comparisons

North West is the view that has the least sky exposure and LARK has lower RMSE values than ALFA.

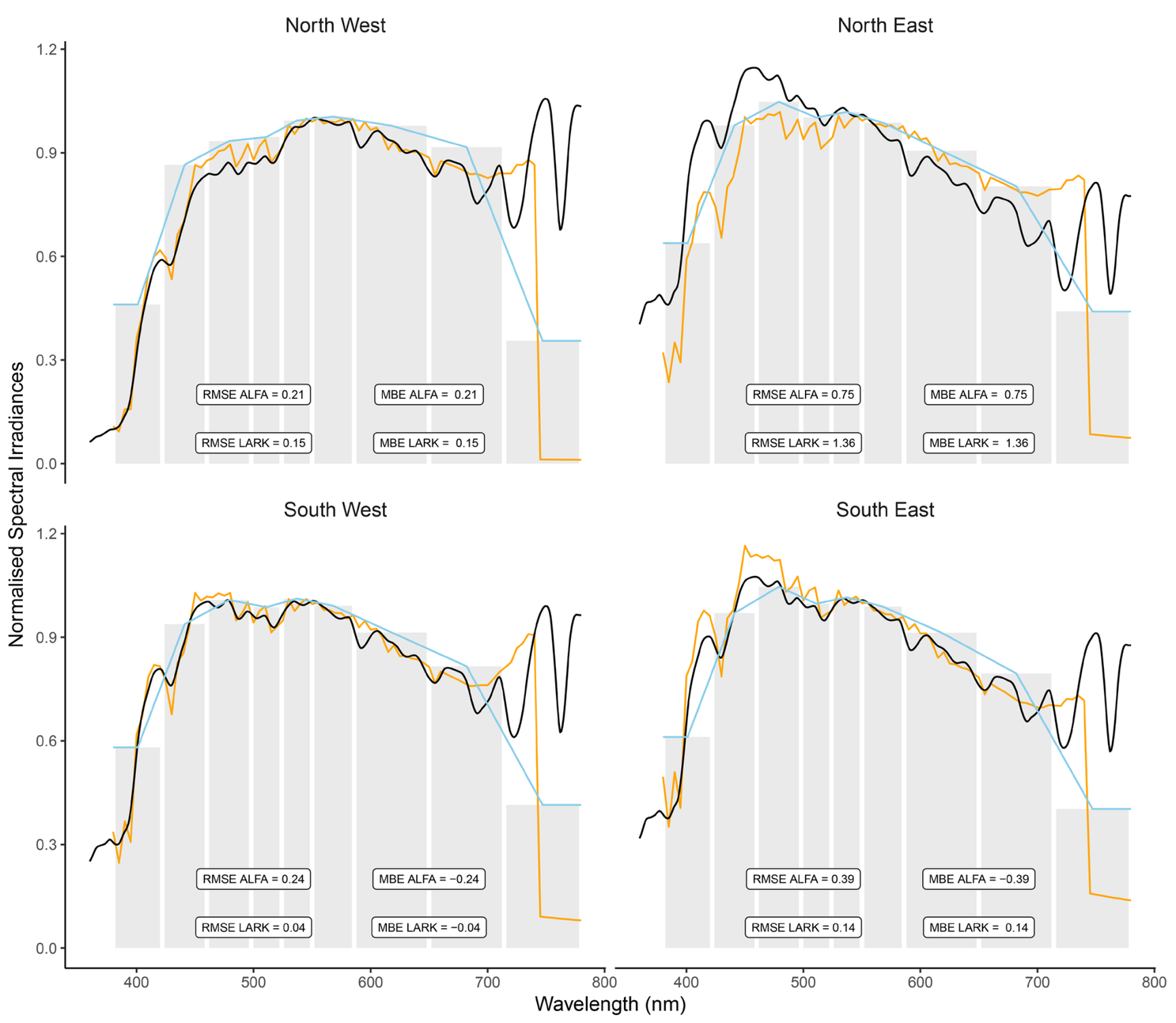
For the morning and evening sky ALFA has a relatively higher spectral irradiance values in the red region because of the colour of the sun.

Lark drops in the red bandwidths because its equal energy white sun.

North West



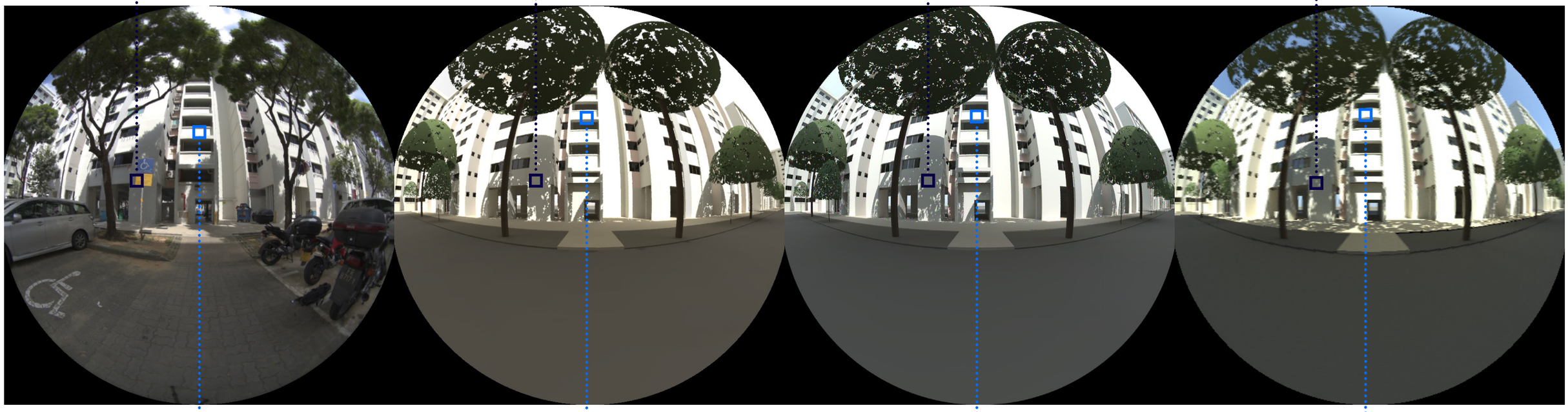
Spectral distribution comparisons



Colour difference comparisons

colours in shade

HDR	PEREZ	LARK	ALFA
L = 56.6 a = 0.19 b = 2.05	ΔL = -6.2 Δa = 0.1 Δb = 1.4 **ΔE = 6.5**	ΔL = -8.2 Δa = -1.4 Δb = -2.2 **ΔE = 8.7**	ΔL = -7.9 Δa = -2.2 Δb = 0.7 **ΔE = 8.2**

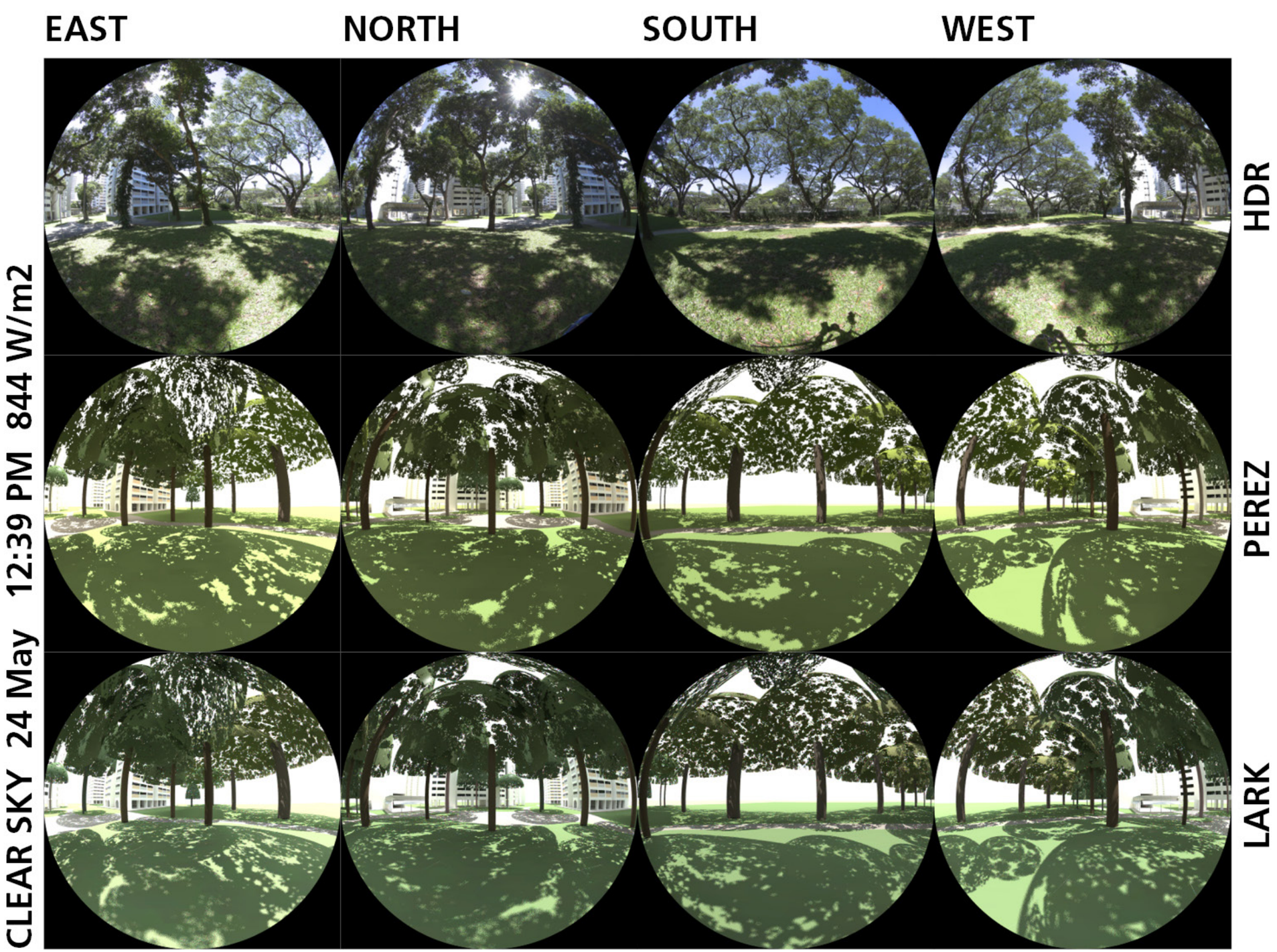


L = 58.9 a = -0.8 b = 4.5	ΔL = 3.8 Δa = -0.7 Δb = 4.7 **ΔE = 6.0**	ΔL = -2.0 Δa = -1.2 Δb = 1.0 **ΔE = 2.6**	ΔL = 1.2 Δa = -2.0 Δb = 4.5 **ΔE = 5.1**

colours in direct light

Colour Difference $\Delta E = \sqrt{(L1 - L2)^2 + (a1 - a2)^2 + (b1 - b2)^2}$

Work in Progress ....



Thank You

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