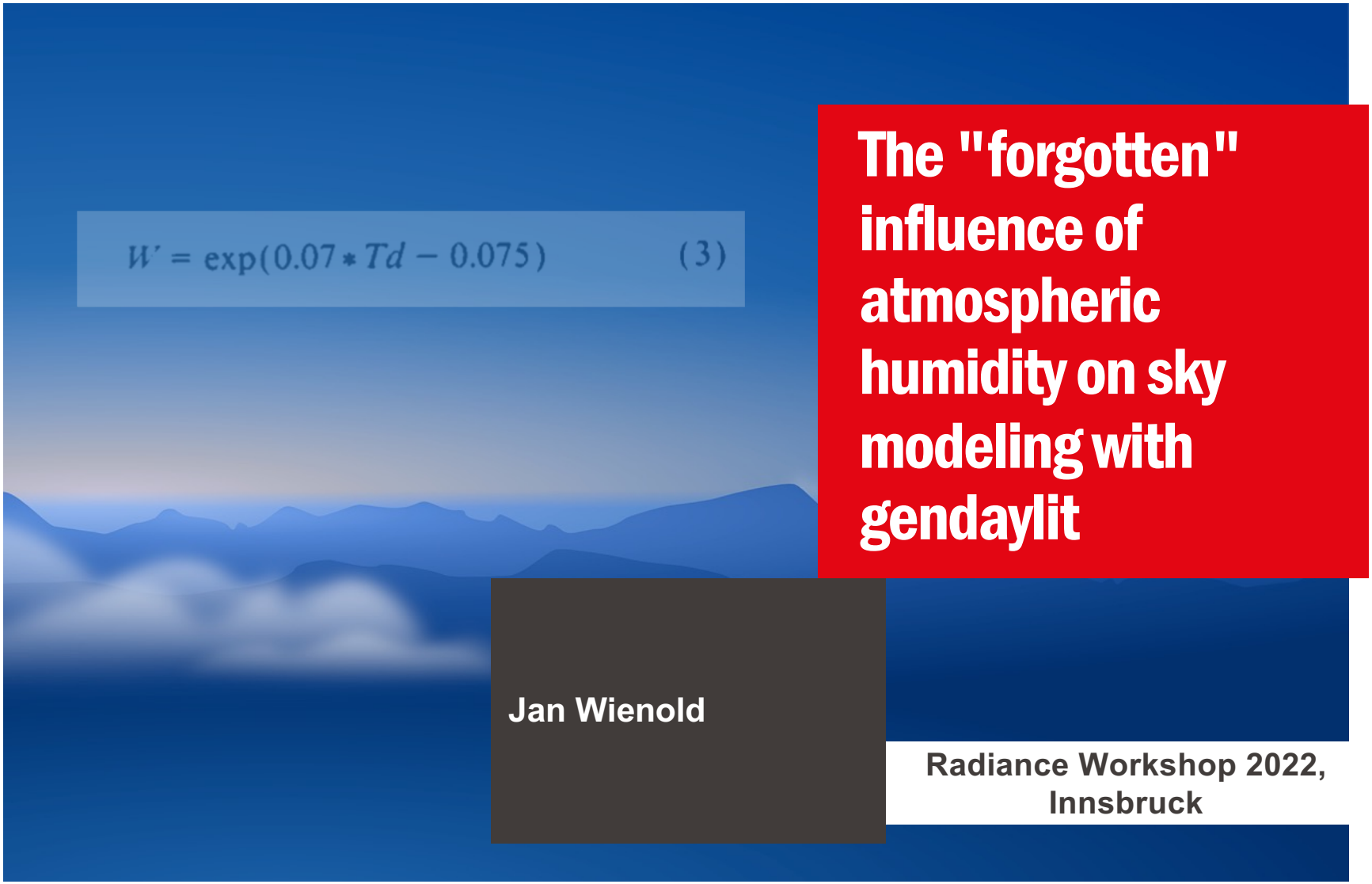

The "forgotten" influence of atmospheric humidity on sky modeling with gendaylit

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Radiance Workshop 2022, Innsbruck

LIPID
Laboratory of Integrated Performance in design

Forgotten ????

Back in 2019 I received an email from Zack Rogers:

"*I believe gendaylit uses the Perez **luminous efficacy models**, which along with radiation and sun position are a **function of dewpoint temperature**. What do you assume for dewpoint temp as it is not an input for gendaylit?*"

Fact

Luminance values depend on atmospheric humidity.

But: No-one in the daylight community has ever considered it….

All existing implementations of the Perez sky model ignored that influence so far, and this since 1994 (release year of gendaylit)…

Basically: 30 years of daylight simulations ignoring this effect….

Basics

Luminance efficacy depends on precipitable water content in the atmosphere (because of selective water vapor absorption and aerosol scattering):

- Publication of the luminance efficacy model:
  Richard Perez, Pierre Ineichen, Robert Seals, Joseph Michalsky, Ronald Stewart;
  Modeling daylight availability and irradiance components from direct and global irradiance,
  Solar Energy, Volume 44, Issue 5,1990, https://doi.org/10.1016/0038-092X(90)90055-H

> (4) The atmospheric precipitable water content, denoted W (cm), and given by
>
> $$W' = \exp(0.07 * Td - 0.075) \qquad (3)$$
>
> where Td (°C) is the three-hourly surface dew point temperature.

- precipitable water content is given as a function of the dew-point temperature at ground level.

Gendaylit

- Implementation of the Perez luminance sky model
- AND the Perez luminance efficacy model
- Implemented by J-J. Delaunay in 1994 at Fraunhofer ISE

- What was in the source code:

```
/* definition of the sky conditions through the Perez parametrization */
double  skyclearness = 0;
double  skybrightness = 0;
double  solarradiance;
double  diffuseilluminance, directilluminance, diffuseirradiance, directirradiance, globalirradiance;
double  sunzenith, daynumber, atm_preci_water,Td=10.97353115;
```

```
      atm_preci_water=exp(0.07*Td-0.075);
```

⇒ right equation, but with a fixed value of the dewpoint temperature of around 11° !!!!

In January 2021 the *–d Td* option was implemented into gendaylit

But...

- What is the impact when (not-)considering the dewpoint temperature?
- Does this effect matter when compared to measured data?

What is the dewpoint temperature?

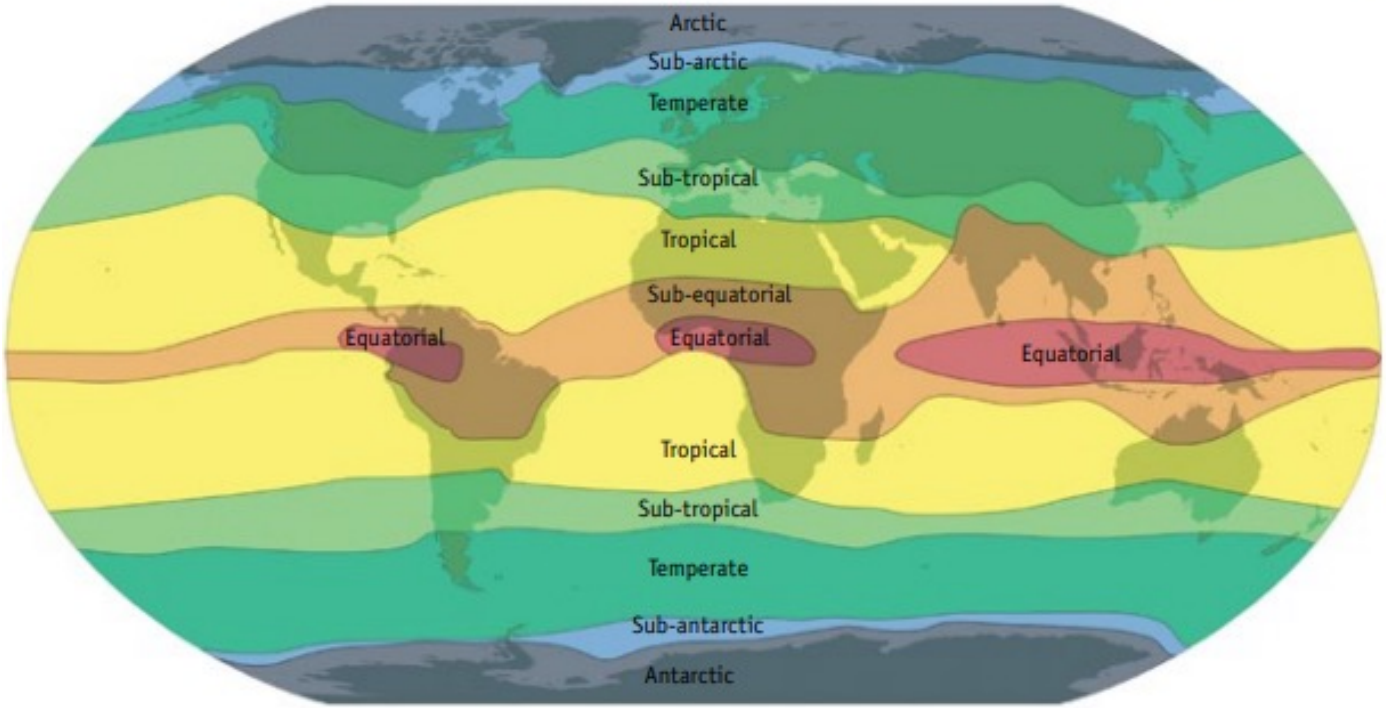
- Measure of the absolute water content of air
- The higher the content to more light is scattered (and absorbed)

This study investigates

- In which climate under which condition this effect is “significant”
- If this effect improves the correlation between measured and simulated data (“validation”)

Climate impact

- Selection of different climates: Seven climatic zones based on Alisov

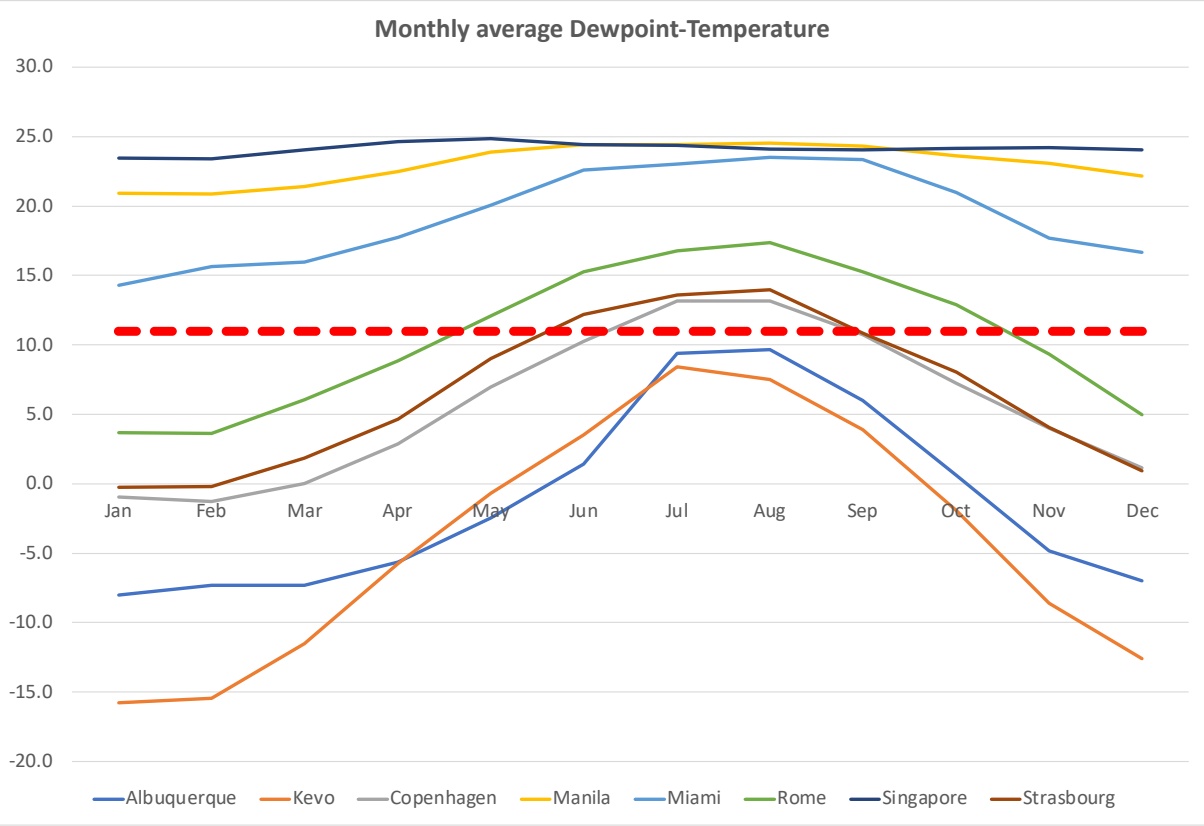


Climate impact

- Selection of different climates: Weather files from meteonorm (v 8.0),
- Stations, where irradiation, temperature and humidity is measured

Sub-artic:	Kevo(Finland)
Temperate 1:	Copenhagen Taastrup (Denmark)
Temperate 2:	Strasbourg (France)
Sub-tropical:	Rome Ciampino (Italy)
Sub-tropical dry:	Albuquerque (USA)
Tropical:	Miami (USA)
Sub-equatorial:	Manila (Philippines)
Equatorial:	Singapore

Dew point temperatures for the climates



- the largest differences can be expected in Singapore and Kevo

Evaluation

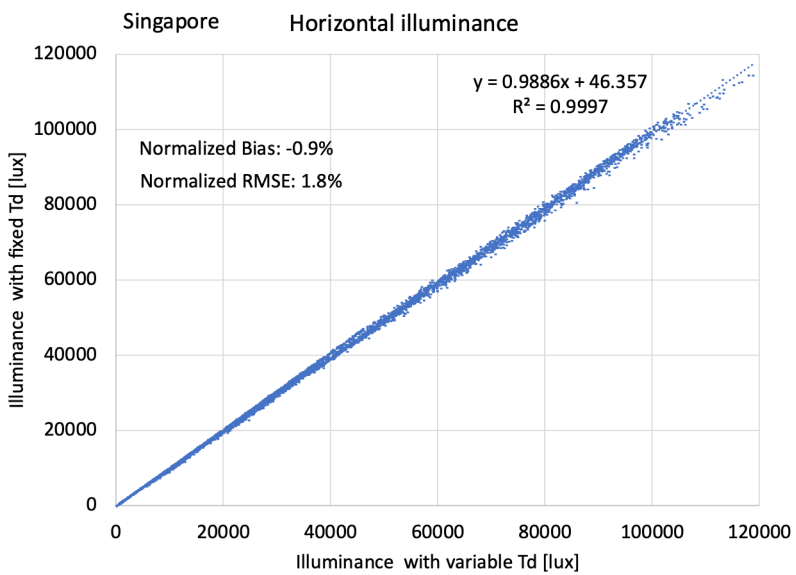
- Horizontal illuminance
- Vertical illuminance in for directions (N,E,S,W), without ground reflectance
- Global, Direct and diffuse values
- Sky luminance at zenith and at α=25°

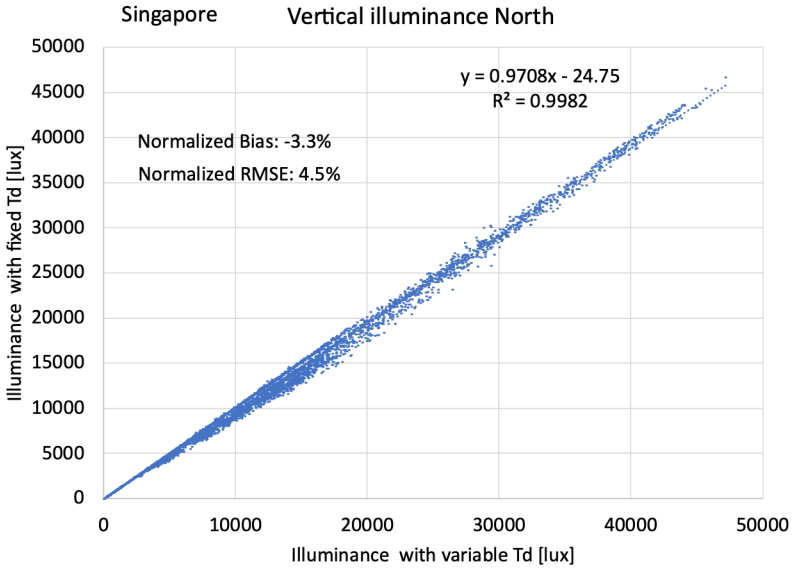
- Spearman correlation between “with dewpoint” and “fixed dewpoint”
- Normalized bias error (leaving out “0” data)
- Normalized RMSE (leaving out “0” data)

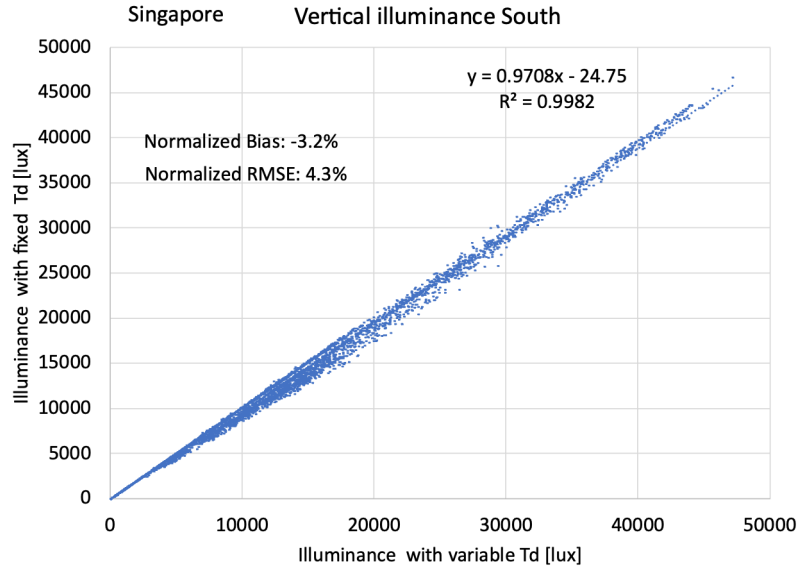
Results

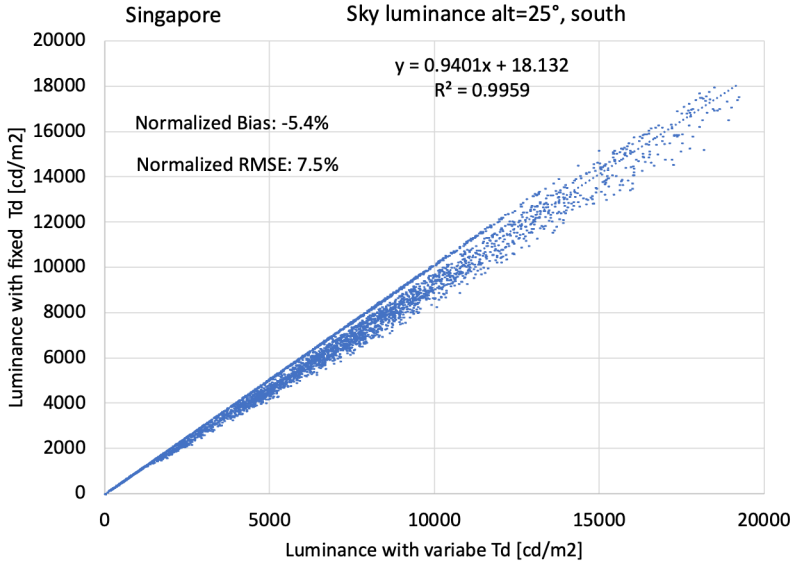
Singapore

Global values





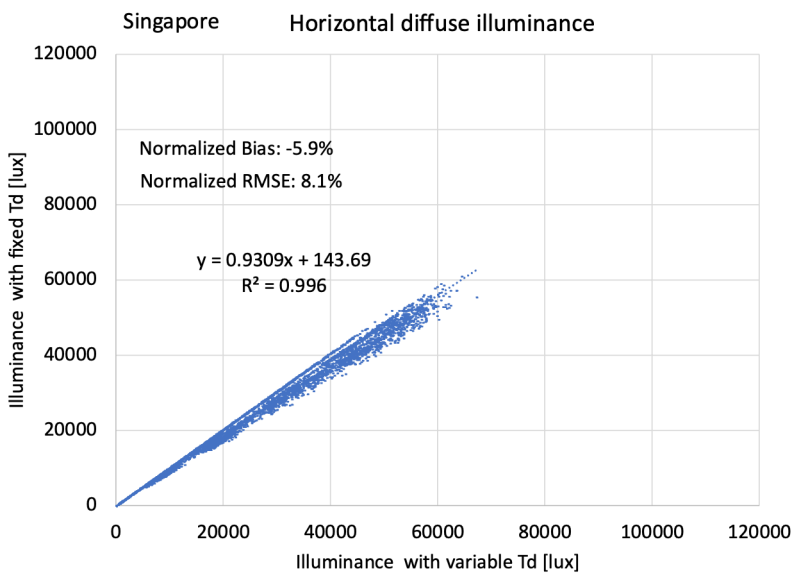


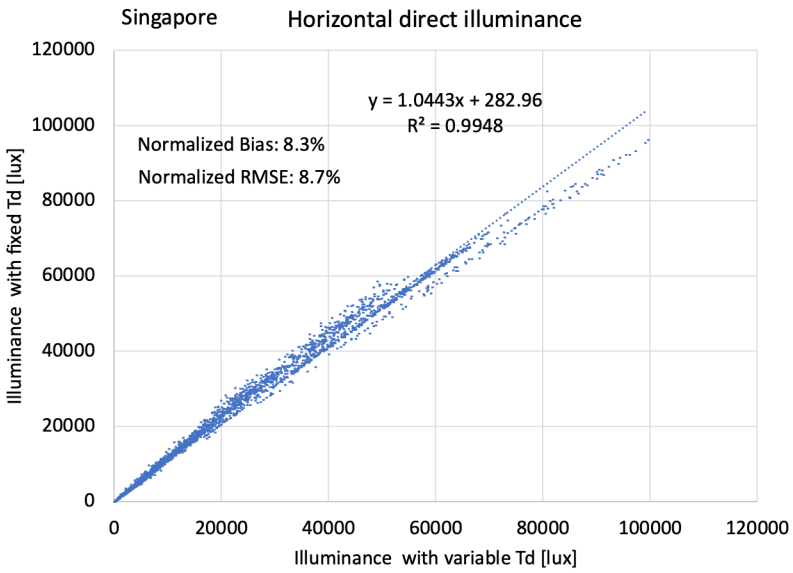


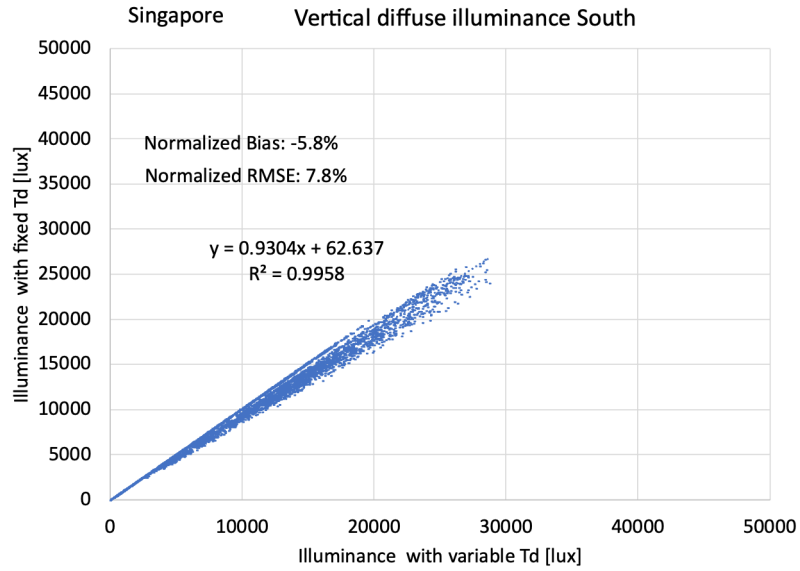
Results

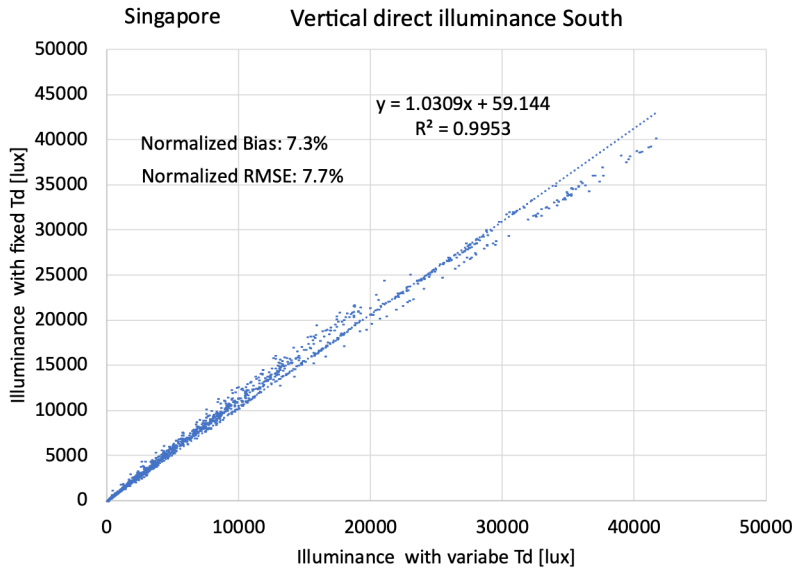
Singapore

Direct and diffuse values





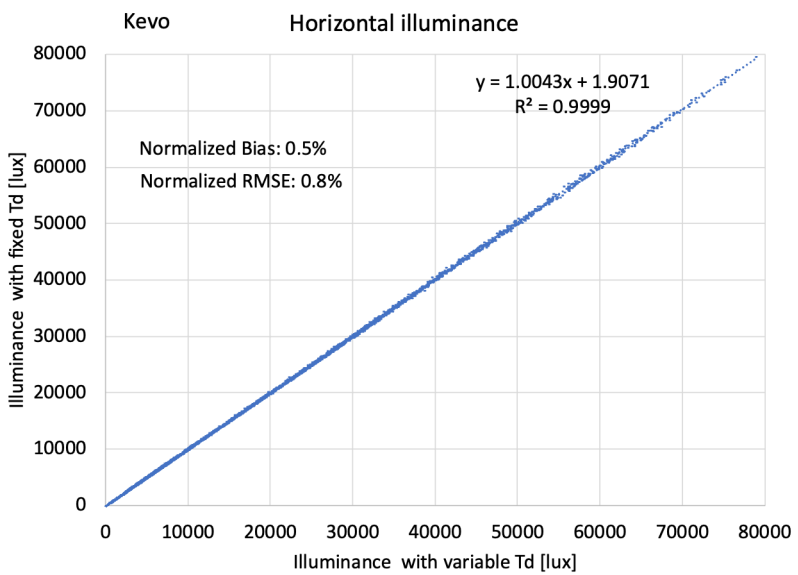


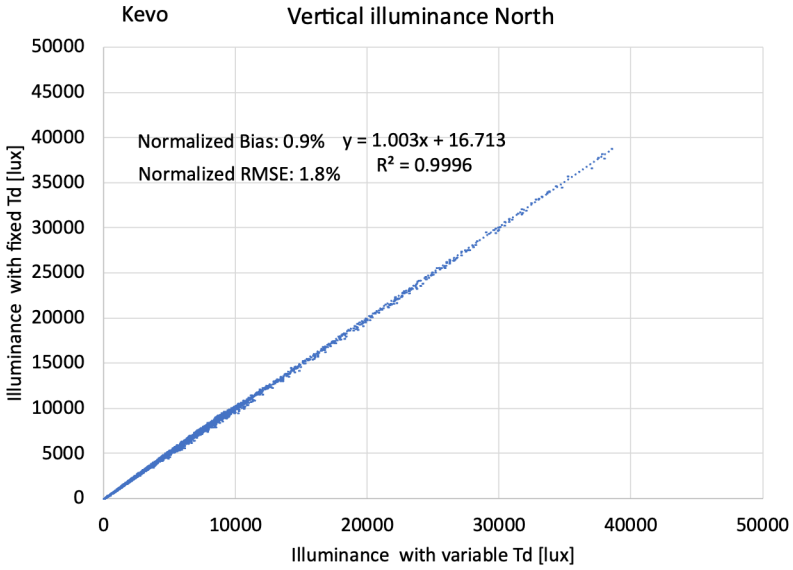


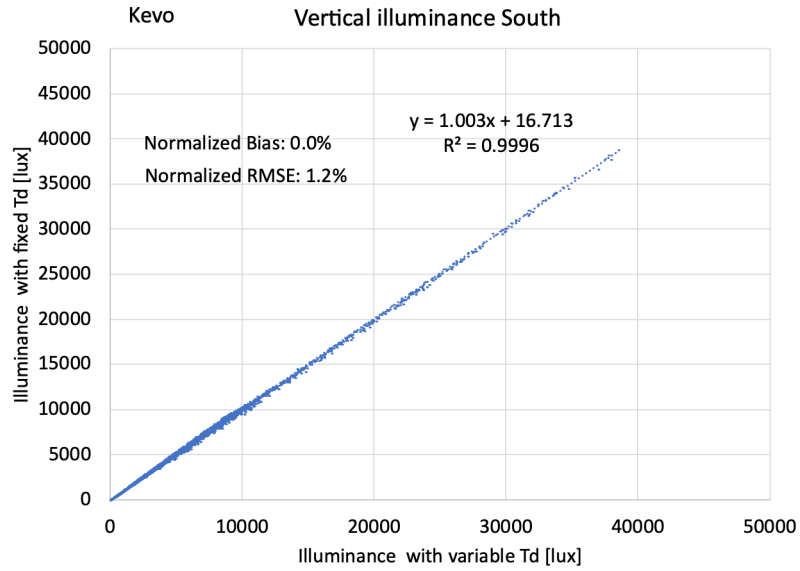
Results

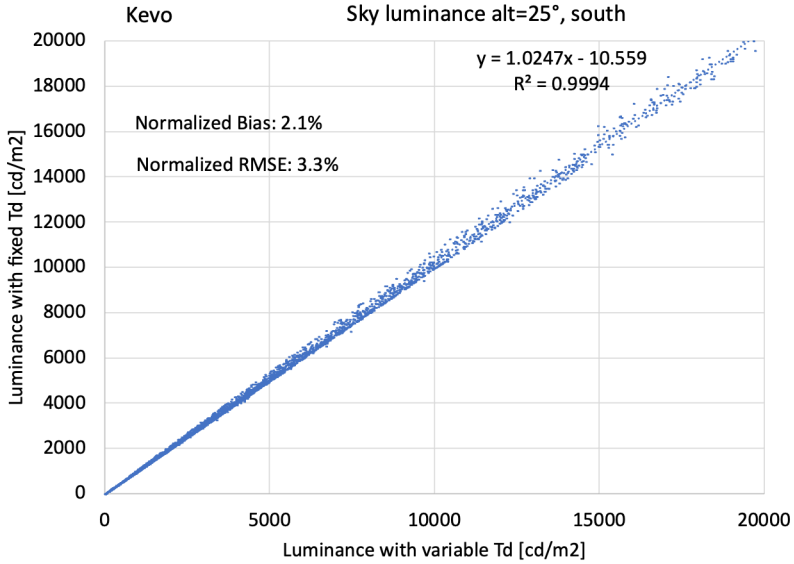
Kevo

Global values





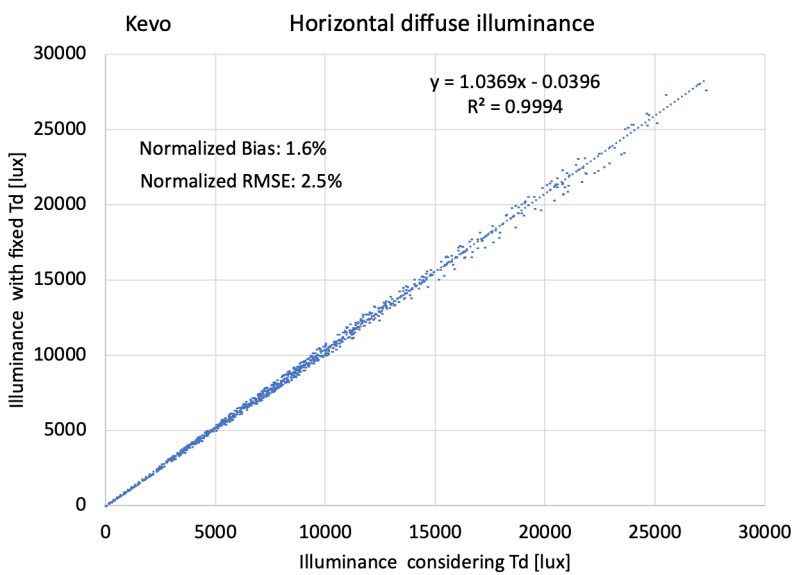


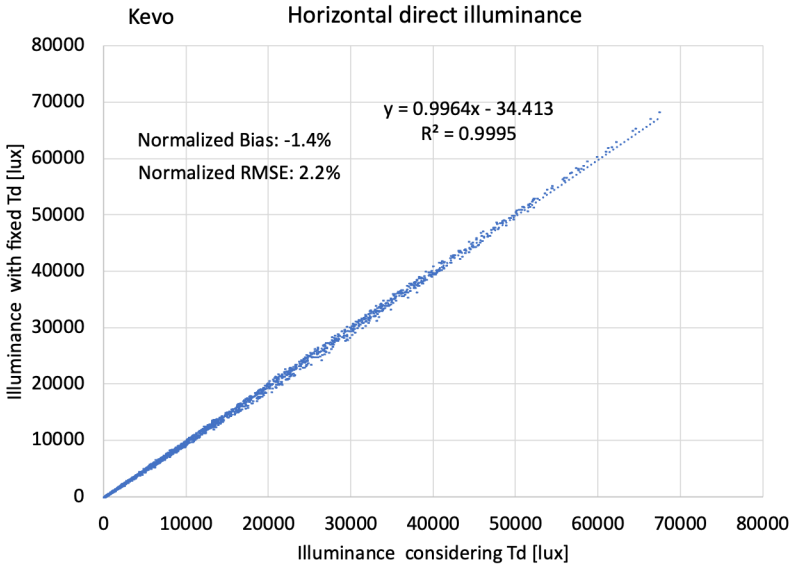


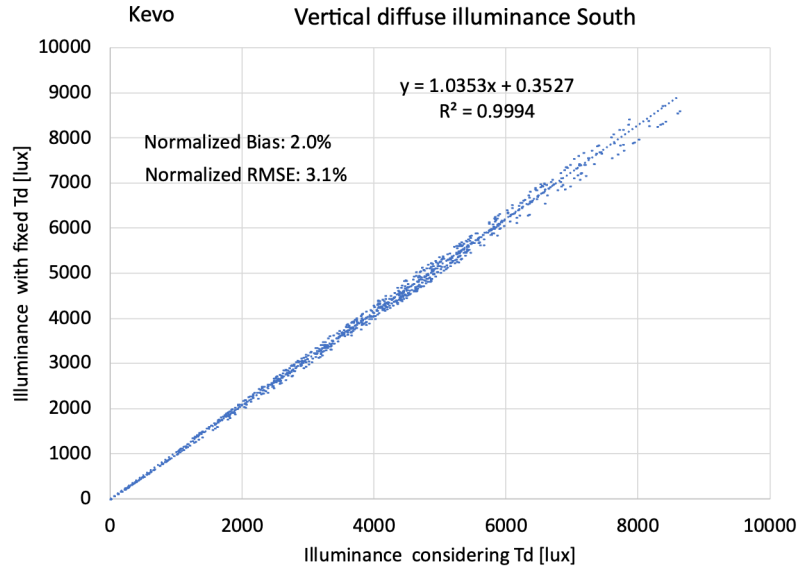
Results

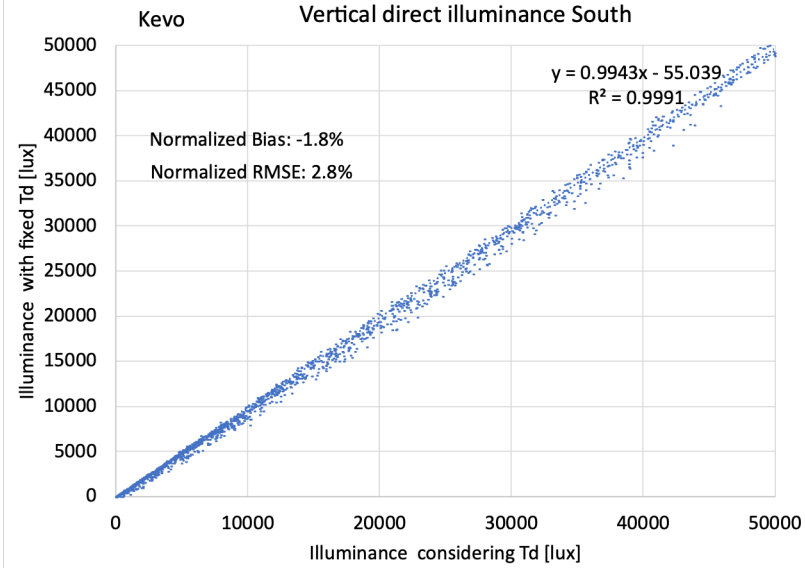
Kevo

Direct and diffuse values



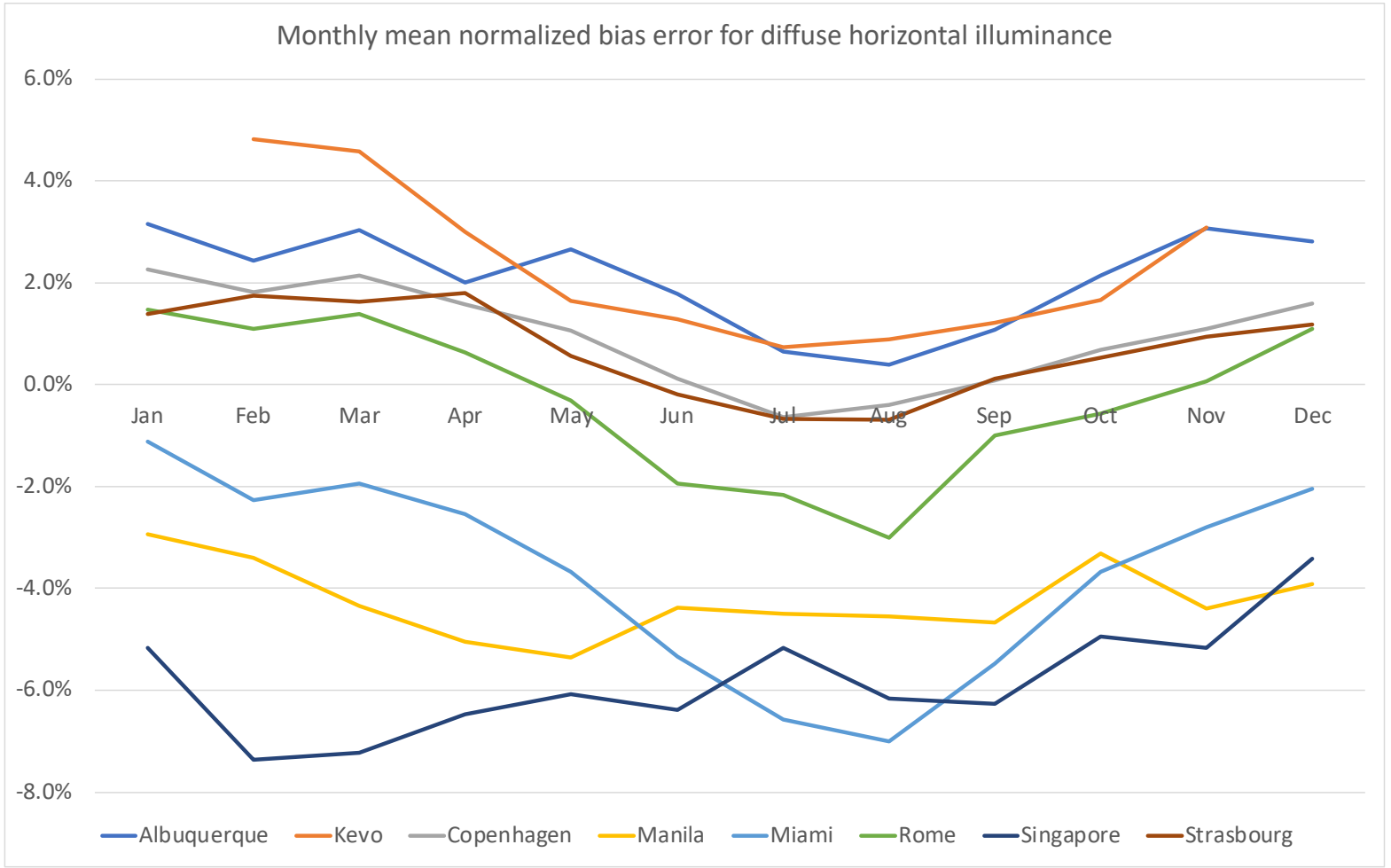






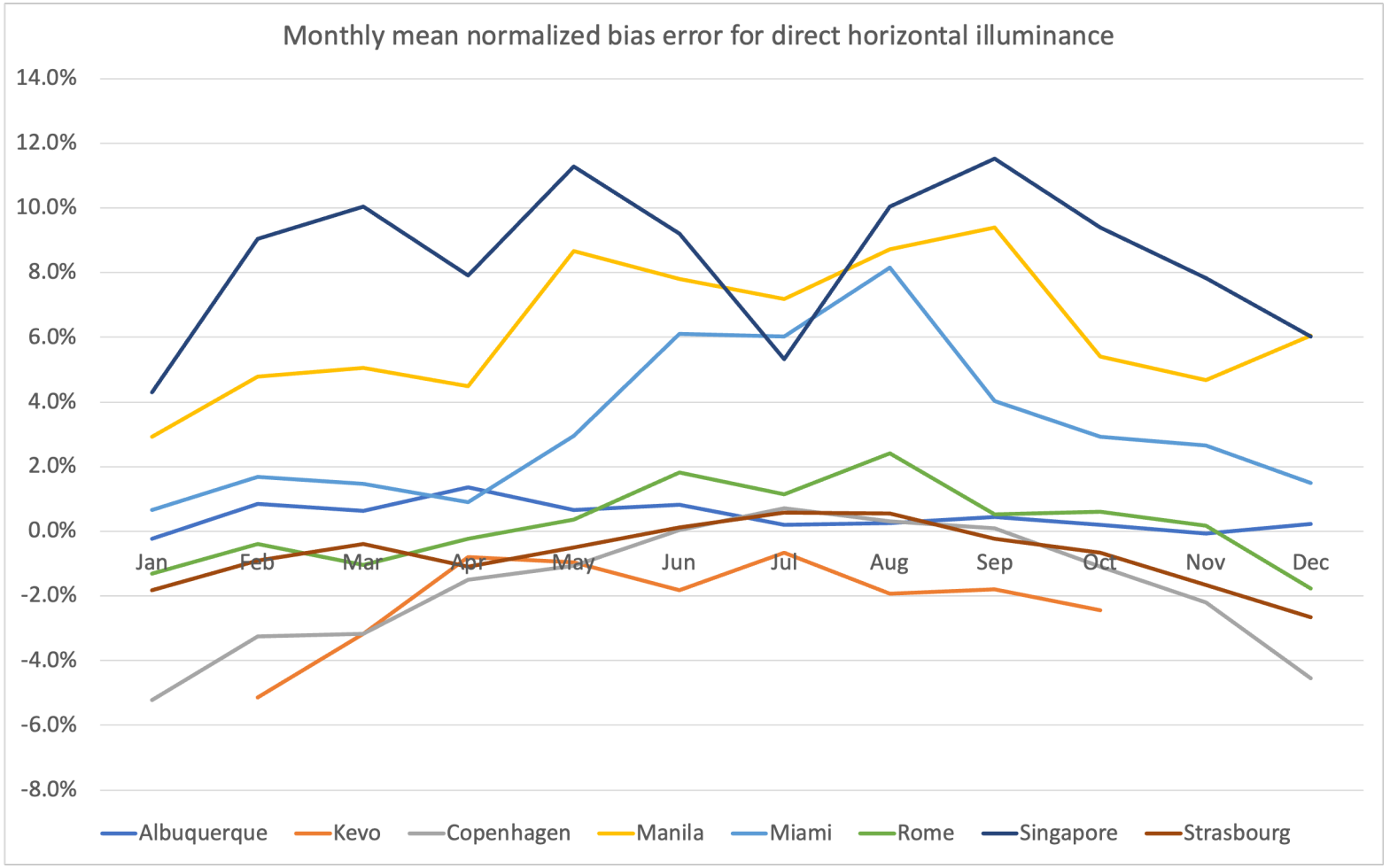
Monthly effects – mean normalized bias

Diffuse



Monthly effects – mean normalized bias

Direct



First conclusions

Deviations small for non-extreme climates

In tropical climates diffuse light is underestimated by 4-8% (max. 15% on hourly basis).

In tropical climates direct light is overestimated by 4-12%

For dry, cold climates (Copenhagen, Kevo) the direct light is underestimated by around 5% in winter

What about the validation part (comparison with measured data)?

Comparison with measured data

A weather station with highly resolved data were used

At ENTPE close to Lyon, France, one minute resolution from 2022

The weather-station was part of the international daylight measurement program IDMP from the early 90s.

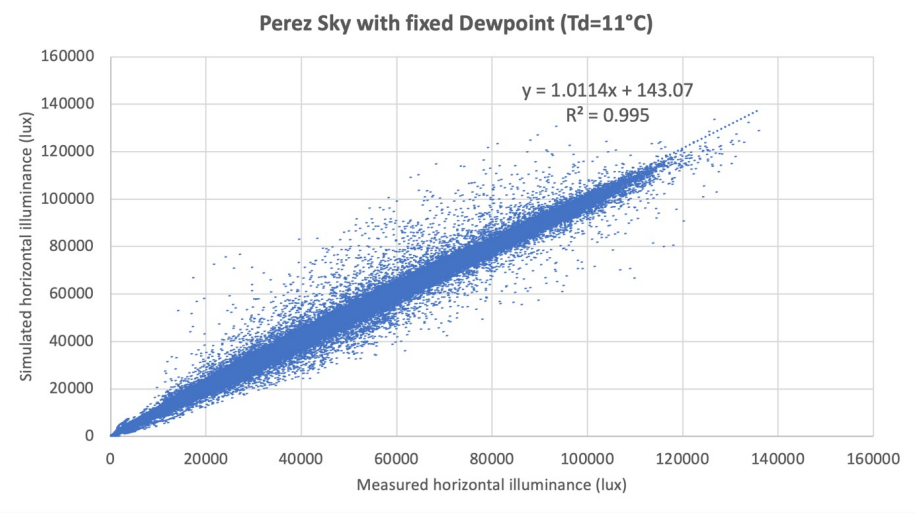
Acknowledgements

ENTPE for providing weather data on their website https://idmp.entpe.fr/
Dominique Dumortier at ENTPE for answering questions regarding the weather station

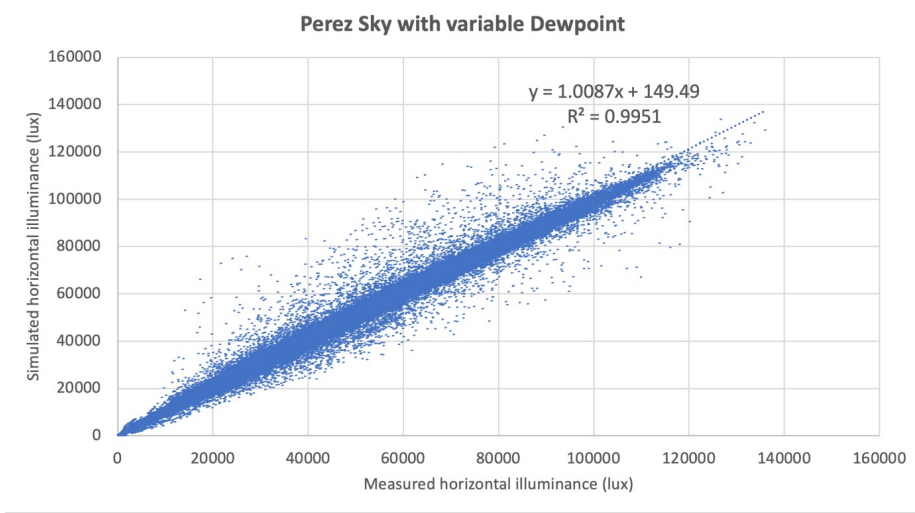
Measurements used

- Irradiation: Direct Normal, Global Horizontal
- Dry bulb temperature
- Relative humidity
- Illuminances: Horizontal illuminance, Diffuse illuminance (shadow-band),
  4 vertical illuminance sensors without ground reflectance (through honeycomb construction)

Comparison horizontal illuminance

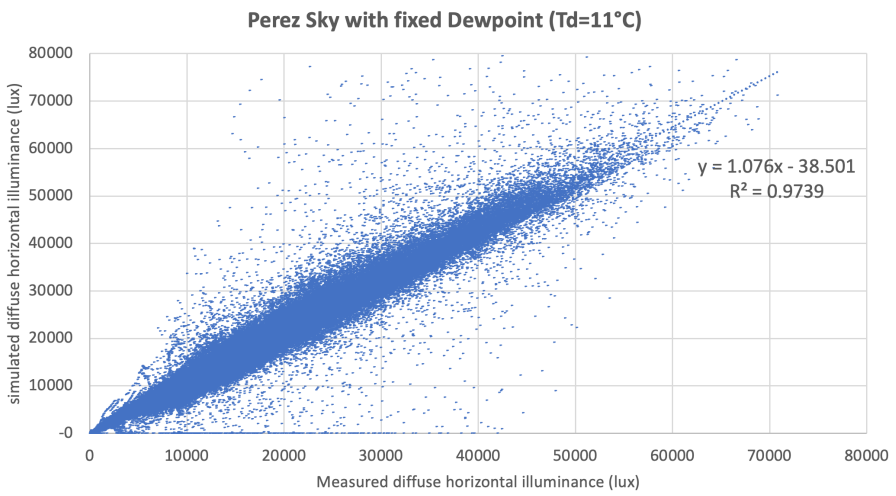


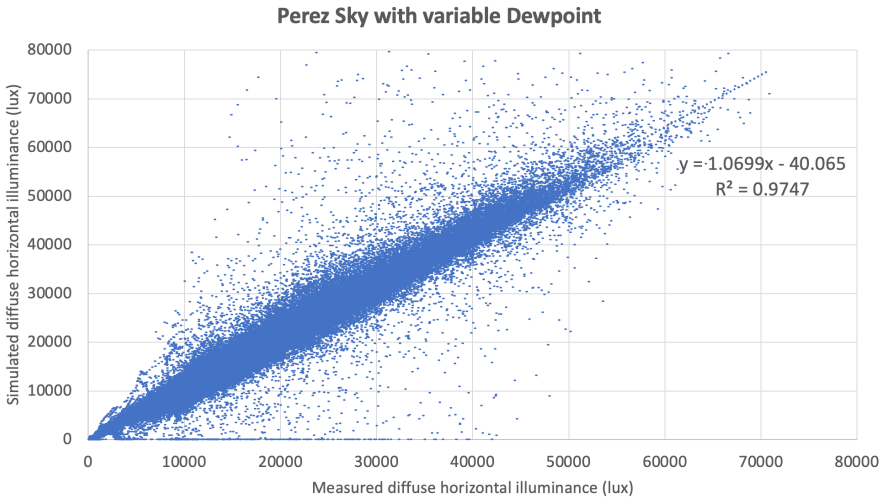
bias:	637 lux
n-bias:	2.28%
RMSE:	2472 lux
n-RMSE:	6.43%



bias:	575 lux
n-bias:	2.06%
RMSE:	2436 lux
n-RMSE:	6.33%

Comparison diffuse horizontal illuminance





bias:	974 lux
n-bias:	6.99%
RMSE:	2982 lux
n-RMSE:	16.7%

bias:	885 lux
n-bias:	6.35%
RMSE:	2883 lux
n-RMSE:	16.2%

Comparison with vertical illuminance data

		Fixed Dewpoint(Td=11°)	Variable dewpoint
North	r^2	98.7%	98.7%
	nBIAS	2.5%	3.0%
	nRMSE	15.8%	15.8%
East		99.0%	99.1%
	nBIAS	-3.5%	-3.7%
	nRMSE	11.0%	11.1%
South	r^2	98.9%	99.0%
	nBIAS	1.3%	1.1%
	nRMSE	9.0%	8.8%
West	r^2	96.3%	92.7%
	nBIAS	0.0%	0.1%
	nRMSE	9.4%	9.3%

Conclusion measurement comparison

- Perez model works reasonably well
- Due to the climate, the impact of a variable dew point is very small and no conclusion can be drawn

Overall conclusions

Deviations small for non-extreme climates

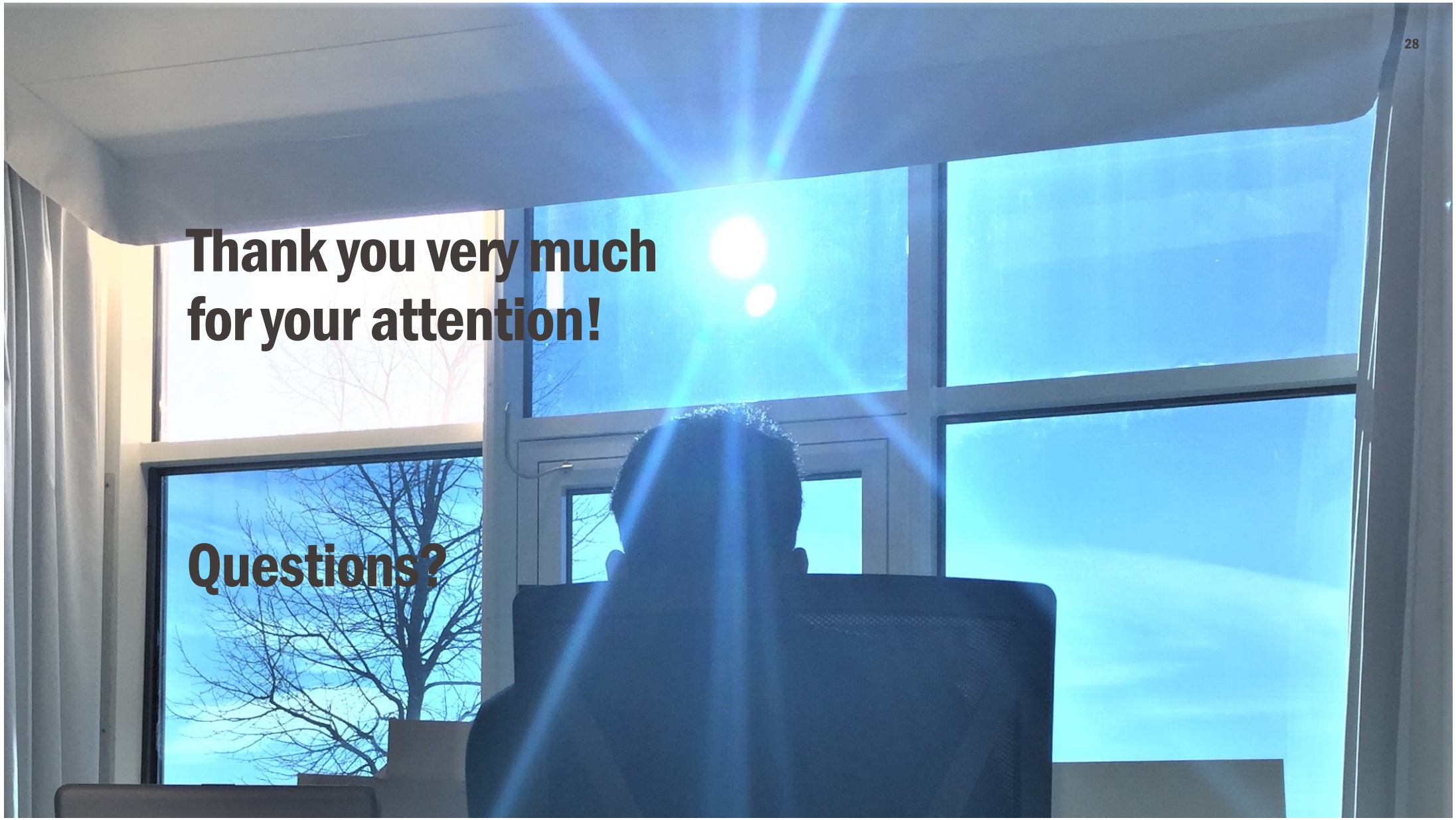
For extreme climates, monthly average deviations can be in the range of 5-10%

In tropical climates diffuse light is underestimated

In tropical climates direct light is overestimated

For dry and cold climates the direct light is underestimated

Comparison with weather data in extreme climates (tropical, dry & cold) would be useful



Thank you very much for your attention!

Questions?