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New York, 23rd August 2019

Improving Solar Data in CIBSE Climate Files

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Prof John Mardaljevic
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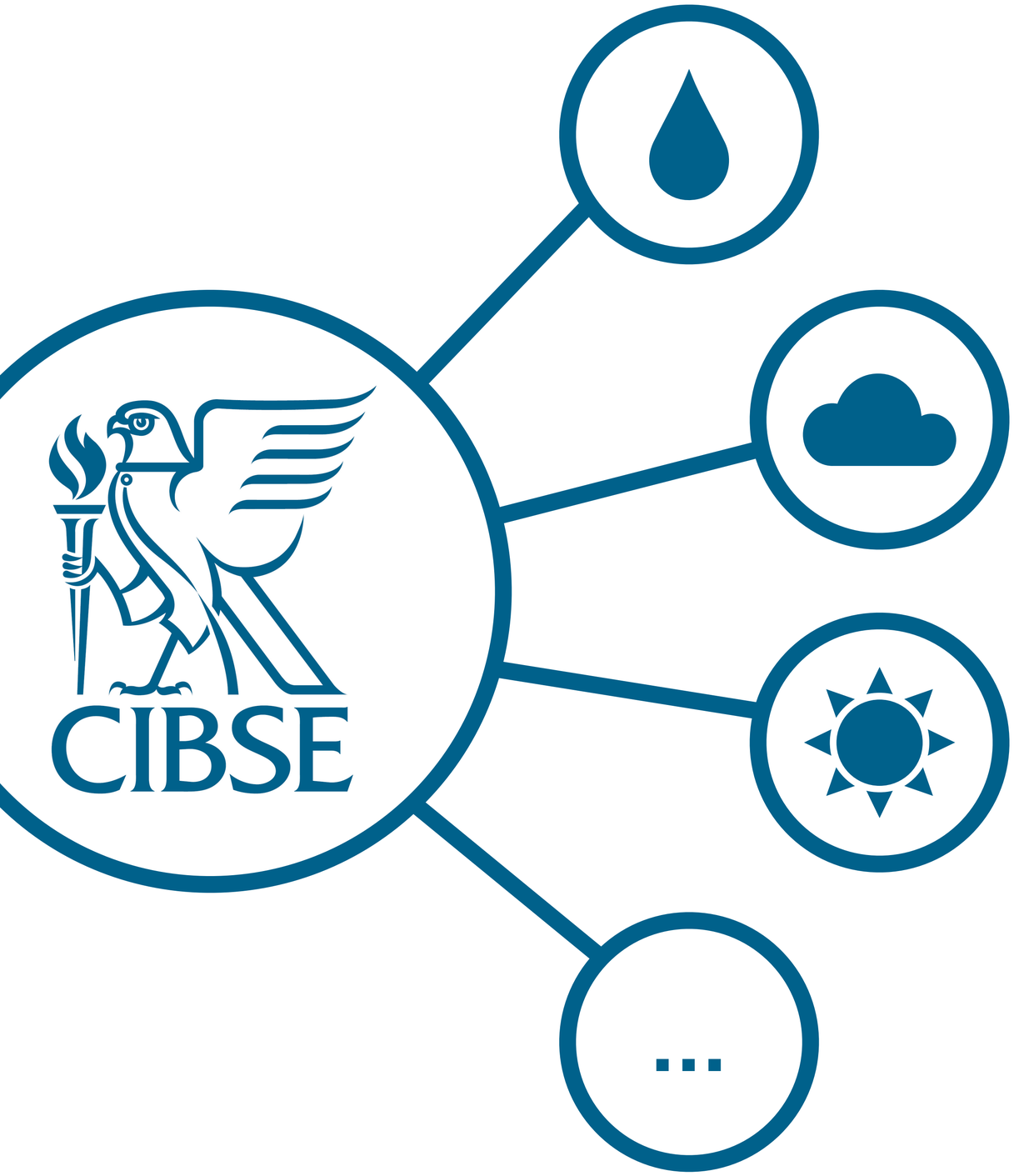
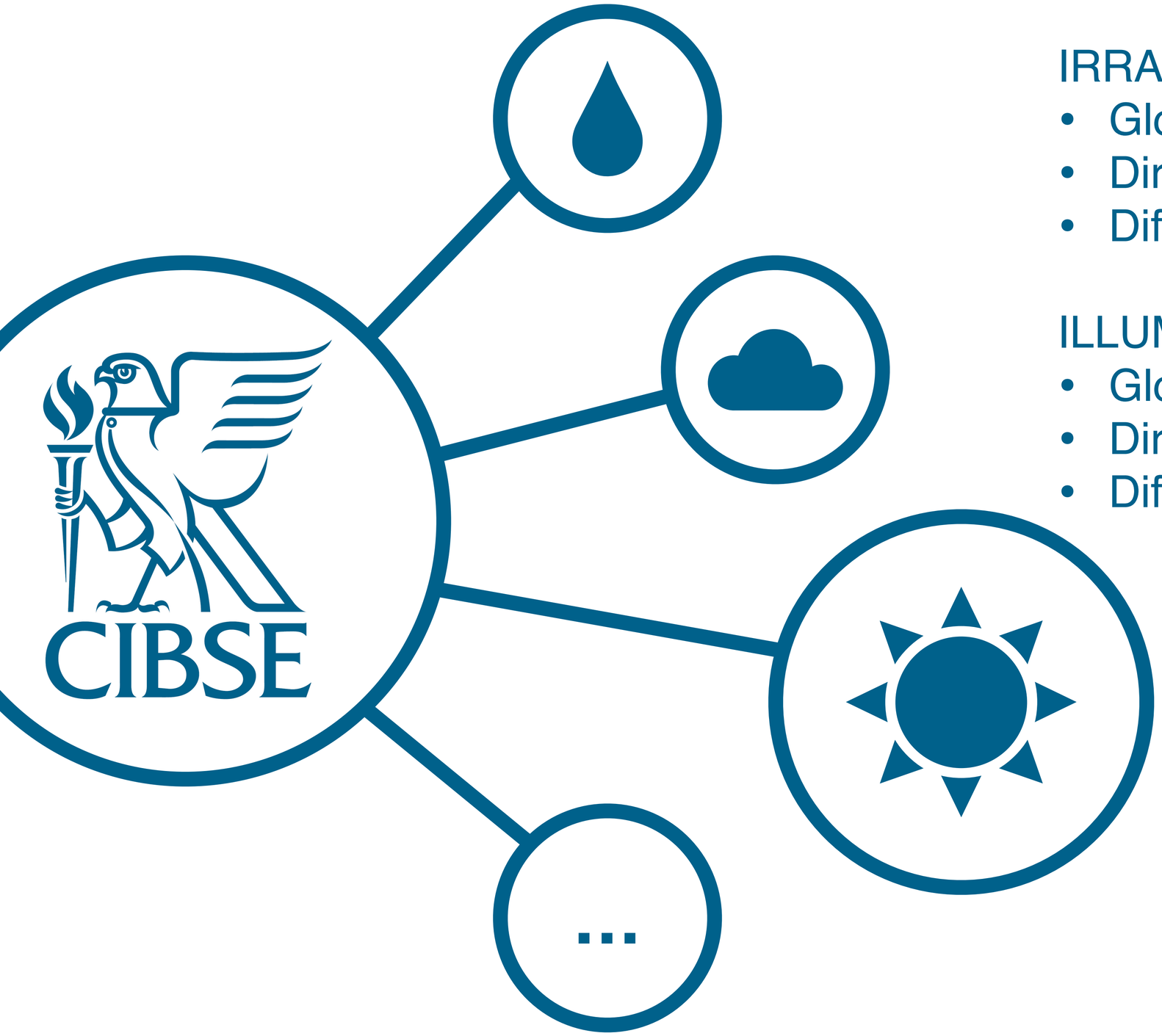
Loughborough University

CIBSE



- TRY (Test Reference Years) [= TMY]
- DSY (Design Summer Years)
- Future projections
  - 2020s, 2050s, 2080s
  - low, medium, high emission scenarios
  - 10%, 50%, 90%

CLIMATE FILES IN EPW FORMAT



IRRADIANCE

- Global horizontal irradiance [W/m2]
- Direct normal irradiance [W/m2]
- Diffuse horizontal irradiance [W/m2]

ILLUMINANCE

- Global horizontal illuminance [lx]
- Direct normal illuminance [lx]
- Diffuse horizontal illuminance [lx]

CLIMATE FILES IN EPW FORMAT

0

1

2

3

4

5

6

7

8

(9)

0

1

2

3

4

5

6

7

8

(9)

www.metoffice.gov.uk/guide/weather/observations-guide/how-we-measure-cloud

0

1

2

?

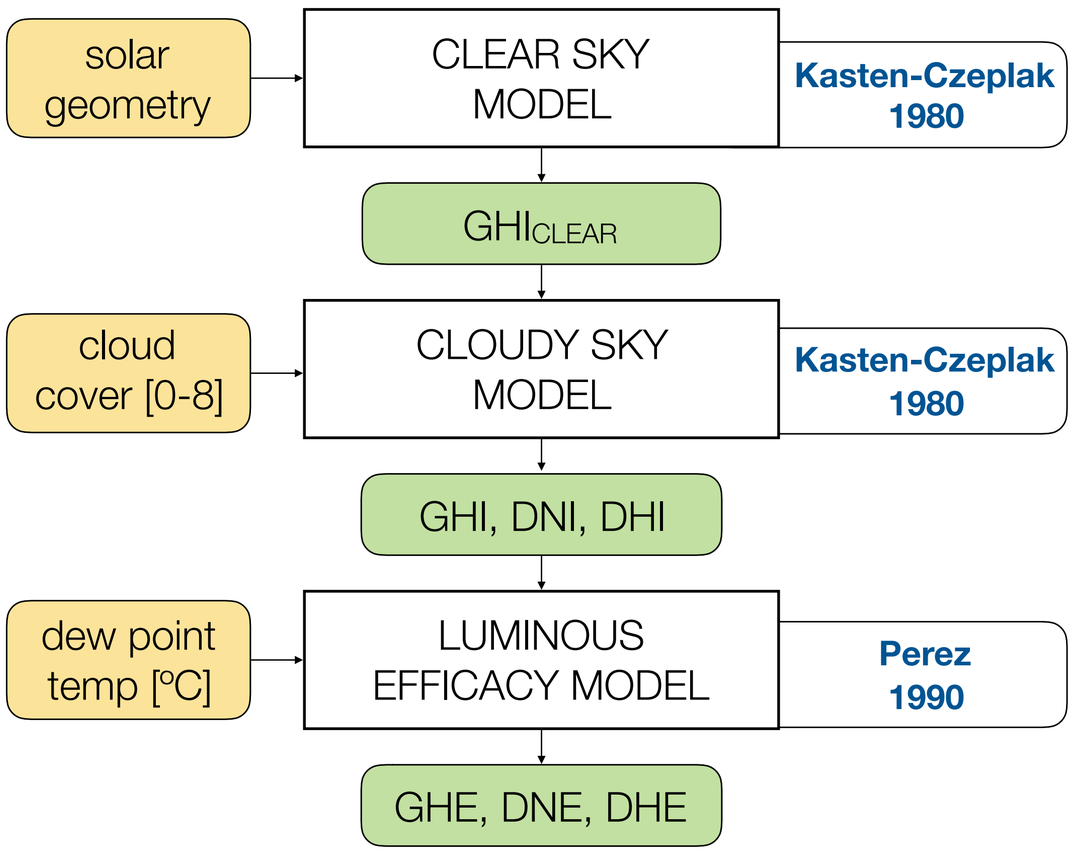
/

8

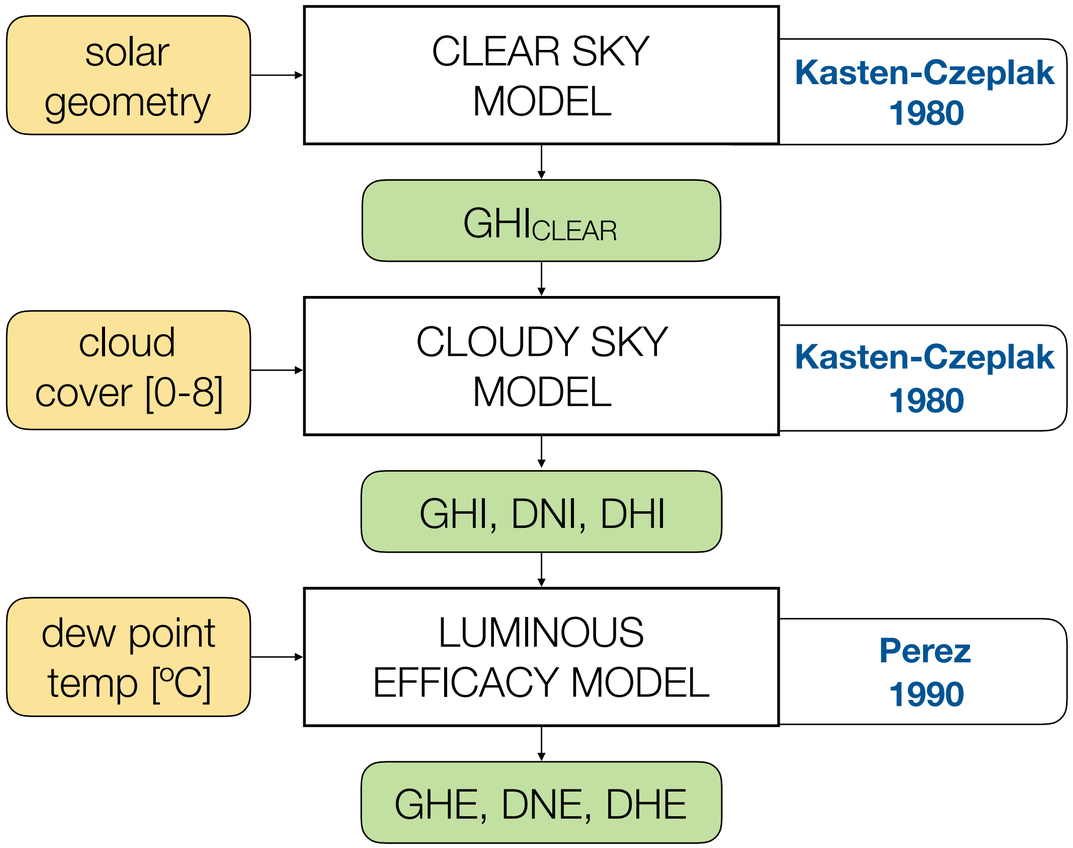
(9)

www.metoffice.gov.uk/guide/weather/observations-guide/how-we-measure-cloud

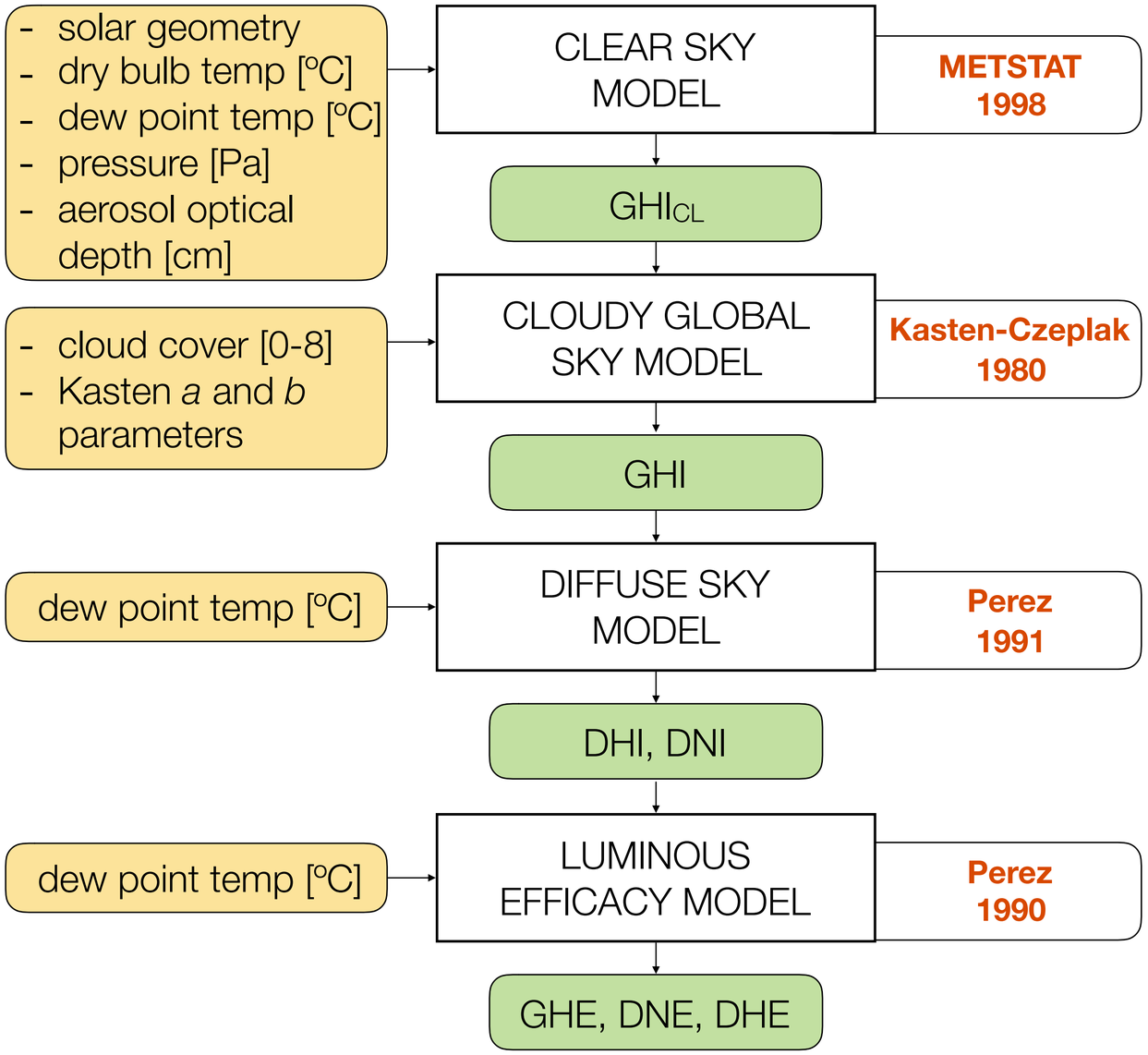
CIBSE TRY


solar geometry
CLEAR SKY MODEL
Kasten-Czeplak 1980
GHICLEAR
cloud cover [0-8]
CLOUDY SKY MODEL
Kasten-Czeplak 1980
GHI, DNI, DHI
dew point temp [°C]
LUMINOUS EFFICACY MODEL
Perez 1990
GHE, DNE, DHE

CIBSE TRY



ASHRAE IWEC



Radiation Skartveit-Olseth (RSO)

1

GHI from Met Office

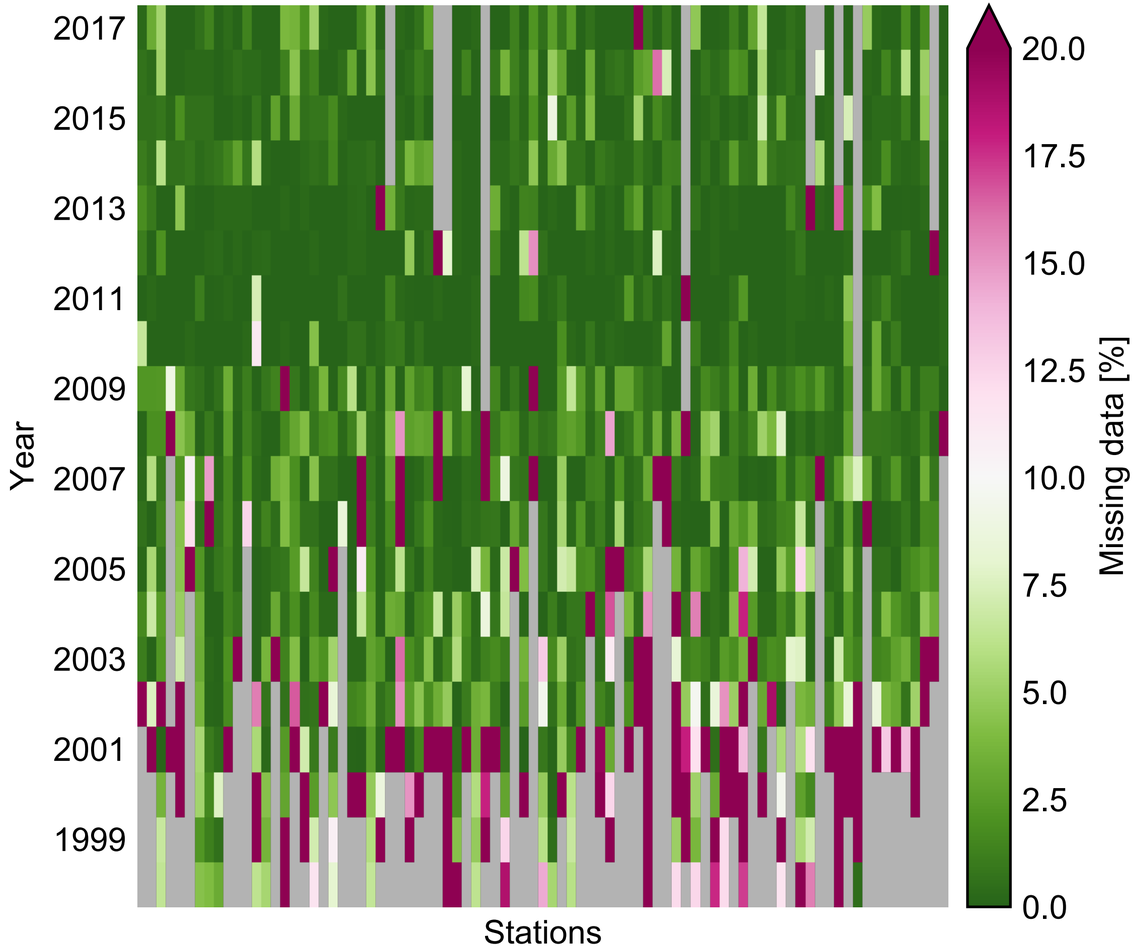
2

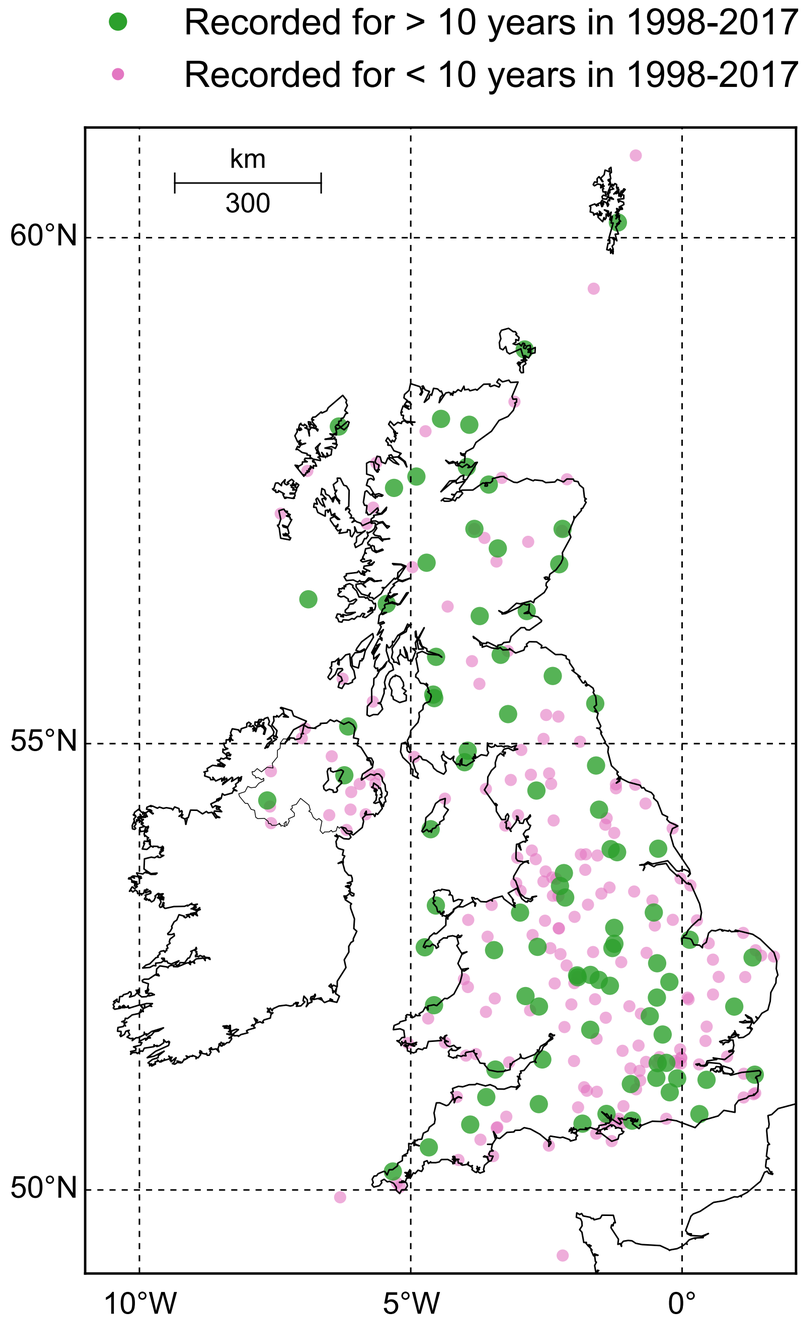
Separation model (Skartveit-Olseth) -> DNI and DHI

3

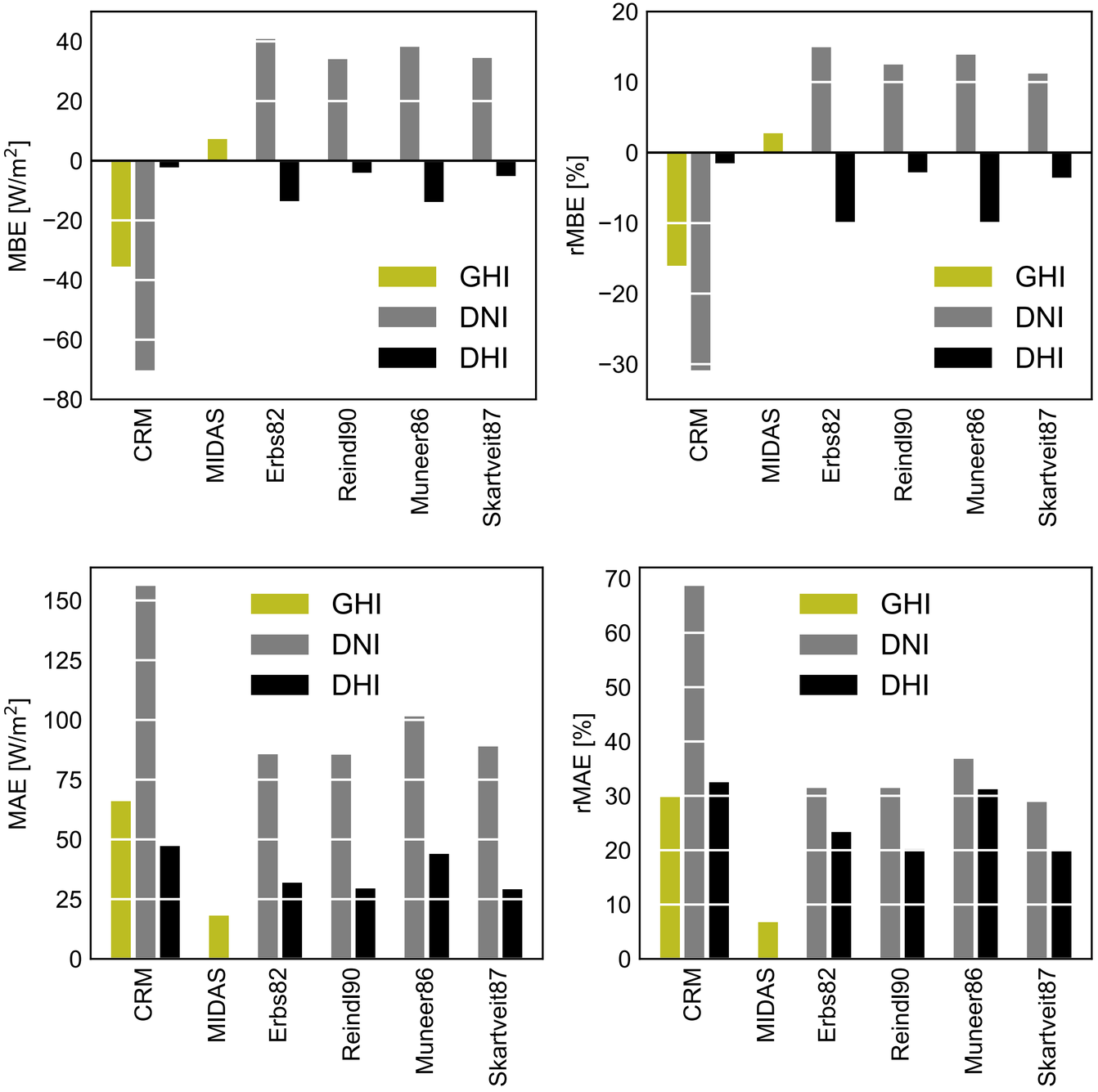
Luminous efficacy model (Perez) -> GHE, DNE, DHE

Proposed approach: Radiation Skartveit Olseth model (RSO)





Proposed approach: Radiation Skartveit Olseth model (RSO)



SEPARATION MODELS

Skartveit model
(Skartveit and Olseth, 1987)

Camborne (2016)

CLOUD COVER:
Met Office
1 hour

IRRADIATION (GHI, DNI, DHI):
BSRN
1 minute

IRRADIATION (GHI):
Met Office
1 hour

ILLUMINATION (GHE):
Public Health England
5 minutes

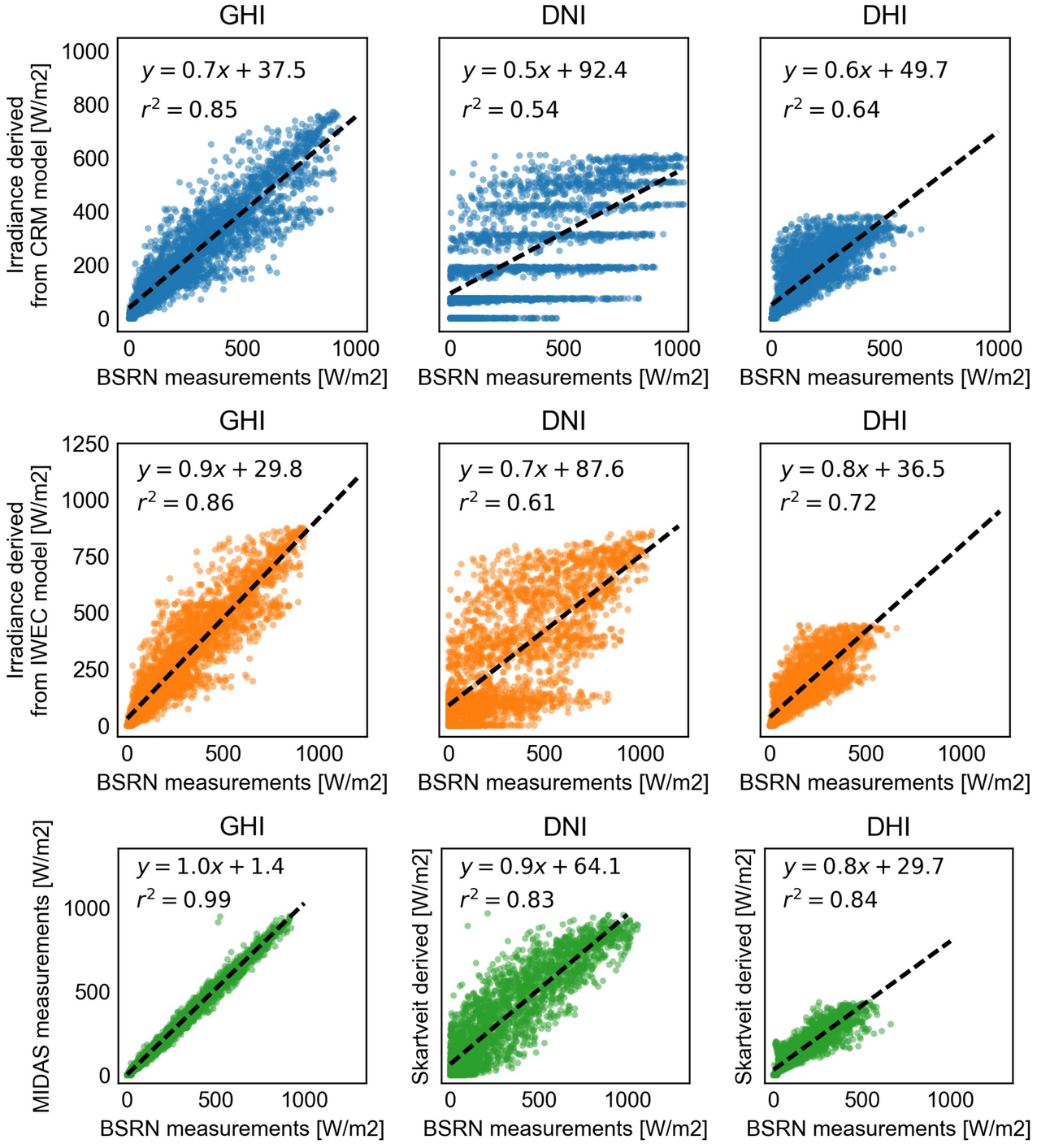
Camborne (2016)

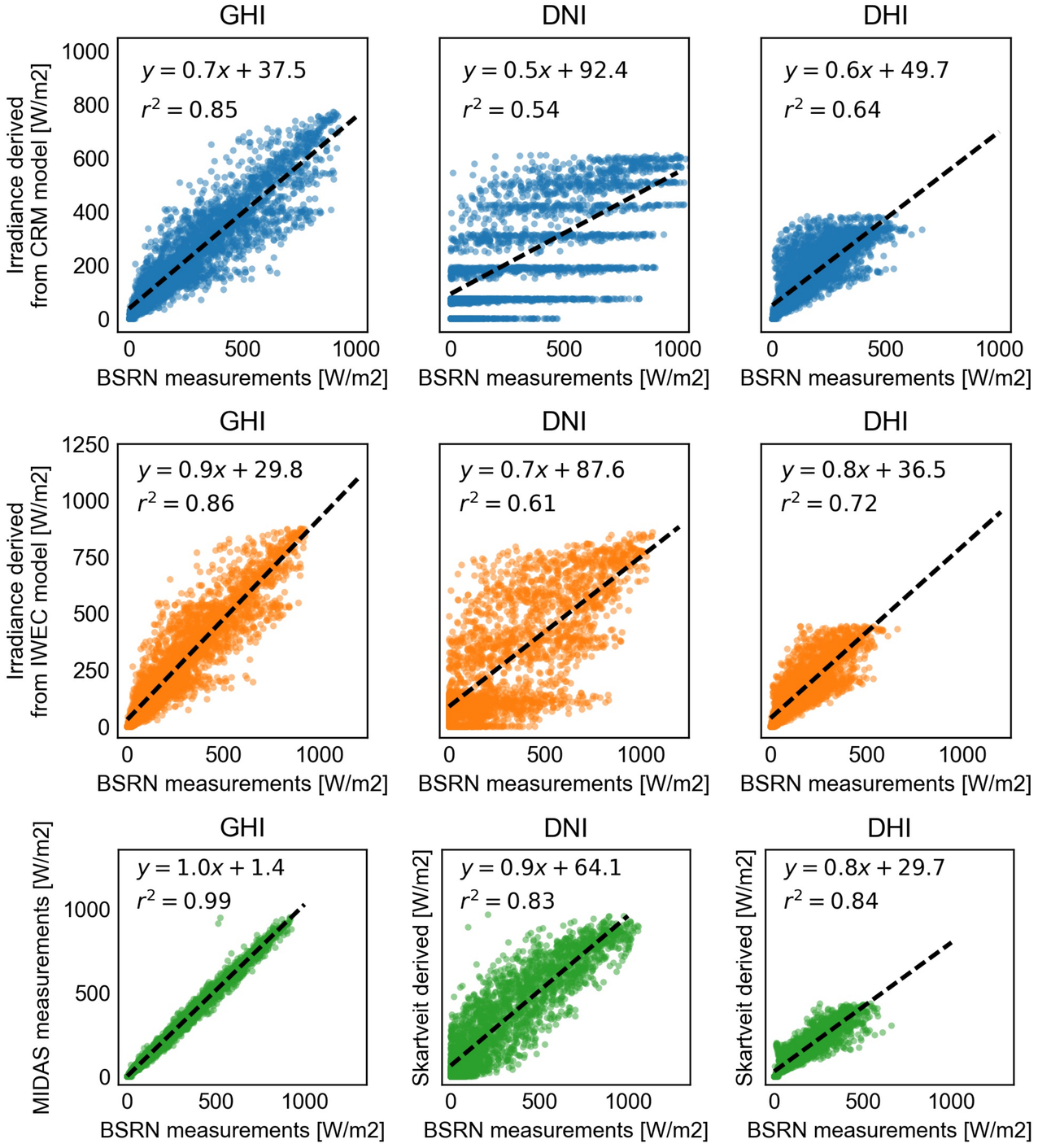
Baseline Surface Radiation Network
(GHI, DNI, DHI)

- Cloud Radiation Model (CRM)
- International Weather for Energy Calculation (IWEC)
- Radiation Skartveit-Olseth (RSO)

Public Health England
(GHE)

- Perez luminous efficacy model (Perez 1990)


GHI
DNI
DHI
$y = 0.7x + 37.5$
$r^2 = 0.85$
$y = 0.5x + 92.4$
$r^2 = 0.54$
$y = 0.6x + 49.7$
$r^2 = 0.64$
Irradiance derived from CRM model [W/m2]
BSRN measurements [W/m2]
$y = 0.9x + 29.8$
$r^2 = 0.86$
$y = 0.7x + 87.6$
$r^2 = 0.61$
$y = 0.8x + 36.5$
$r^2 = 0.72$
Irradiance derived from IWEC model [W/m2]
$y = 1.0x + 1.4$
$r^2 = 0.99$
$y = 0.9x + 64.1$
$r^2 = 0.83$
$y = 0.8x + 29.7$
$r^2 = 0.84$
MIDAS measurements [W/m2]
Skartveit derived [W/m2]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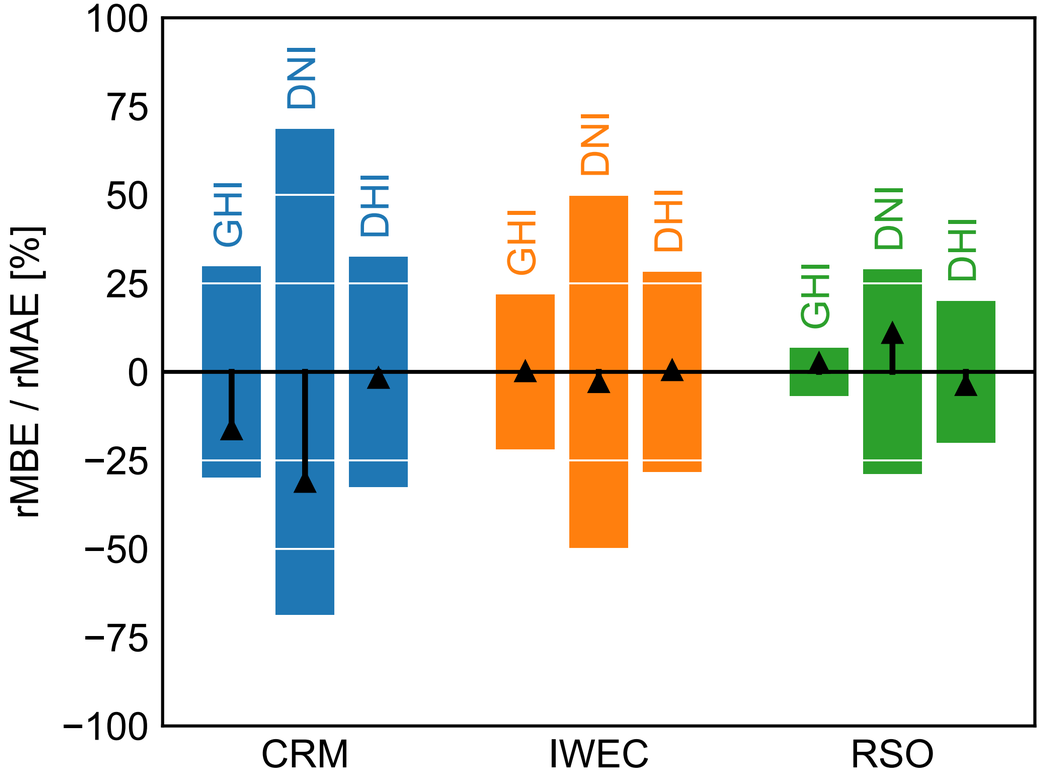
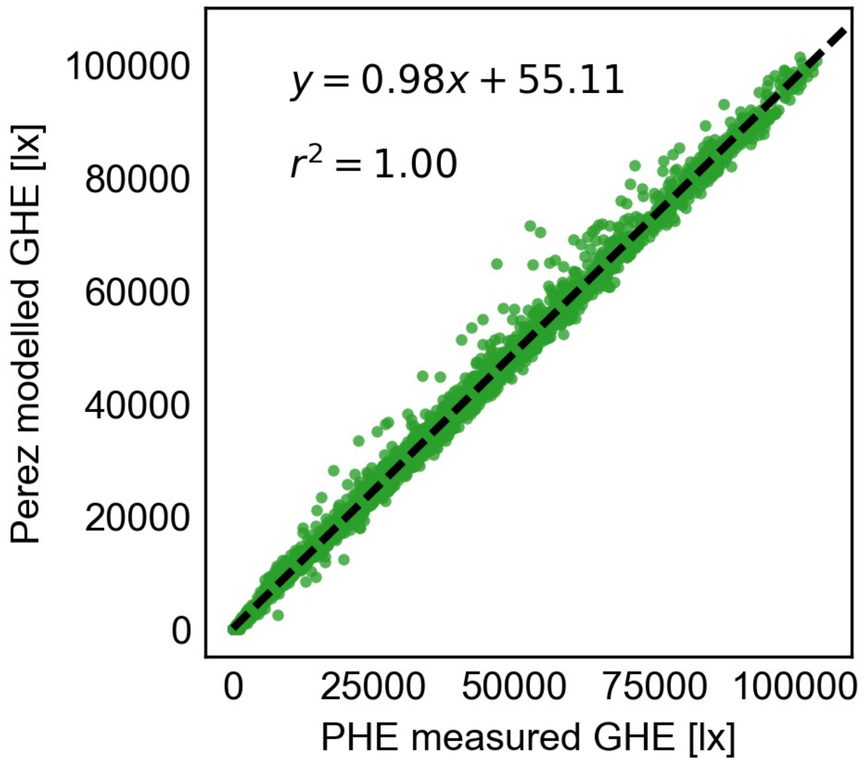

rMBE / rMAE [%]
GHI
DNI
DHI
CRM
IWEC
RSO

Perez luminous efficacy model



Perez v Public Health England illuminance
rMBE = -2.27%
rMAE = 4.39%

Case Study room L3

Perez All-Weather sky model

`gendaylit / gendaymtx`

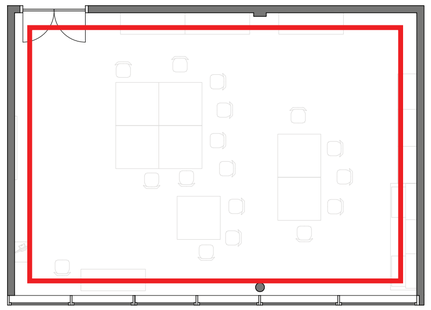
Global illumination:

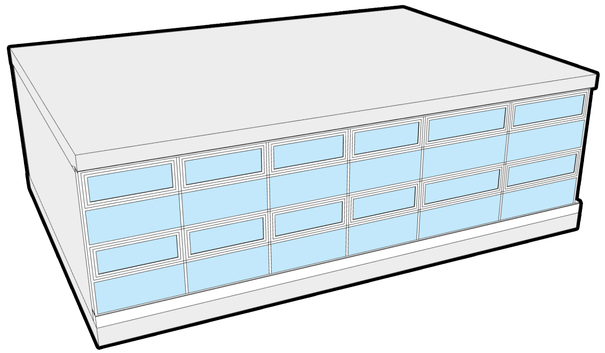
`2-phase method`

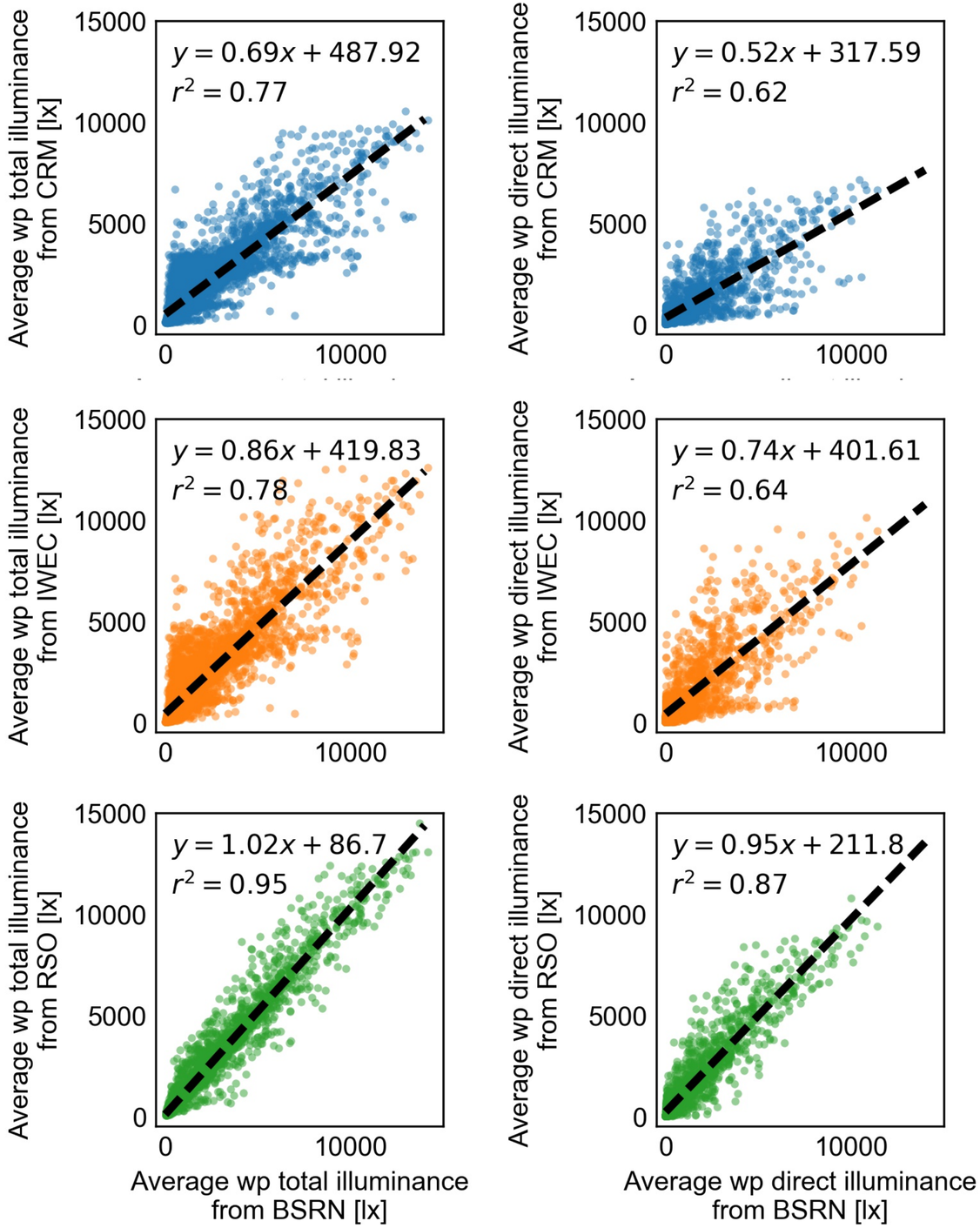
`MF:6`

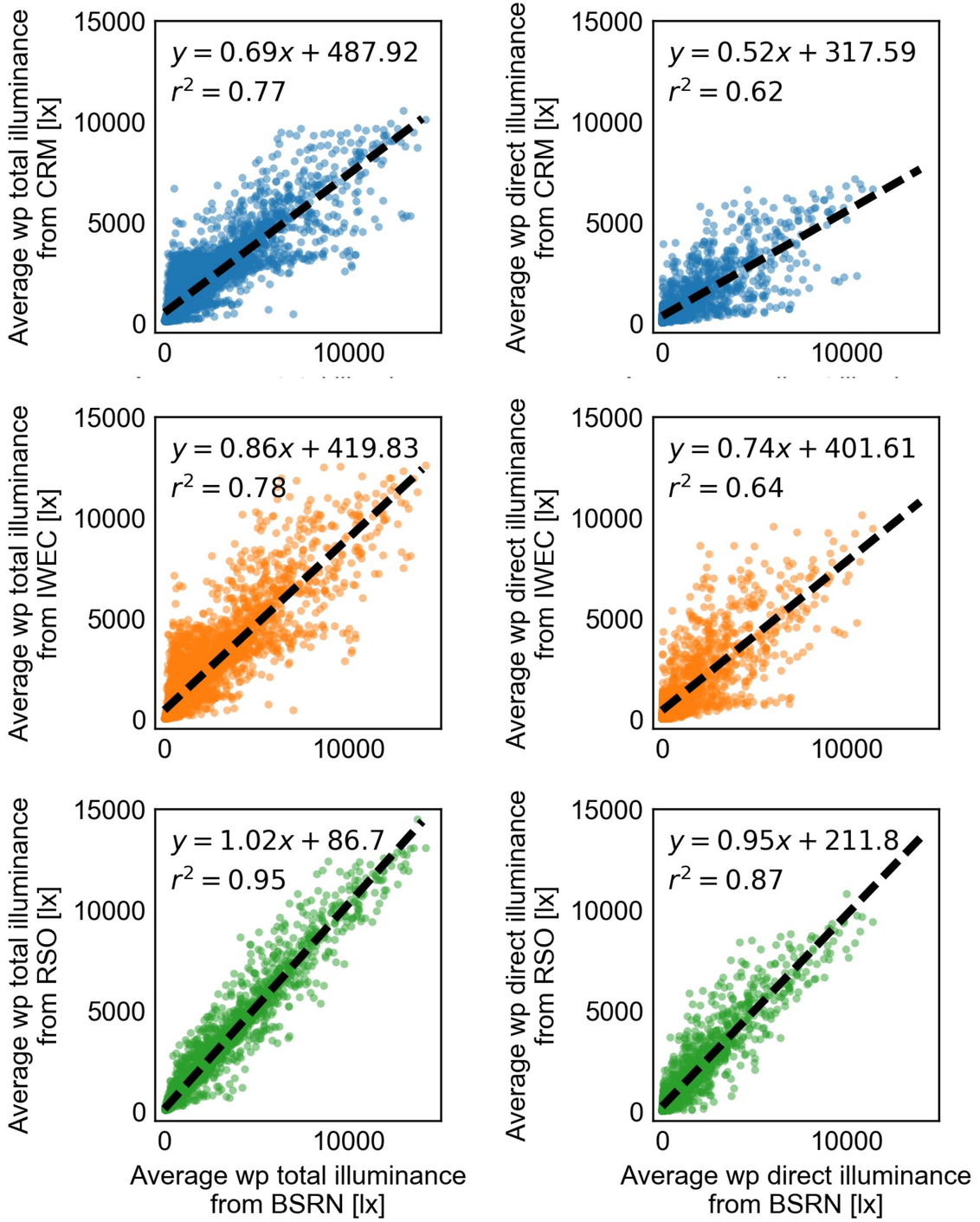
Direct sunlight illumination:

`rtrace -ab 0`






Average wp total illuminance from CRM [lx]
$y = 0.69x + 487.92$
$r^2 = 0.77$
Average wp direct illuminance from CRM [lx]
$y = 0.52x + 317.59$
$r^2 = 0.62$
Average wp total illuminance from IWEC [lx]
$y = 0.86x + 419.83$
$r^2 = 0.78$
Average wp direct illuminance from IWEC [lx]
$y = 0.74x + 401.61$
$r^2 = 0.64$
Average wp total illuminance from RSO [lx]
$y = 1.02x + 86.7$
$r^2 = 0.95$
Average wp direct illuminance from RSO [lx]
$y = 0.95x + 211.8$
$r^2 = 0.87$
0
5000
10000
15000
Average wp total illuminance from BSRN [lx]
Average wp direct illuminance from BSRN [lx]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0
5000
10000
15000
Average wp total illuminance from BSRN [lx]
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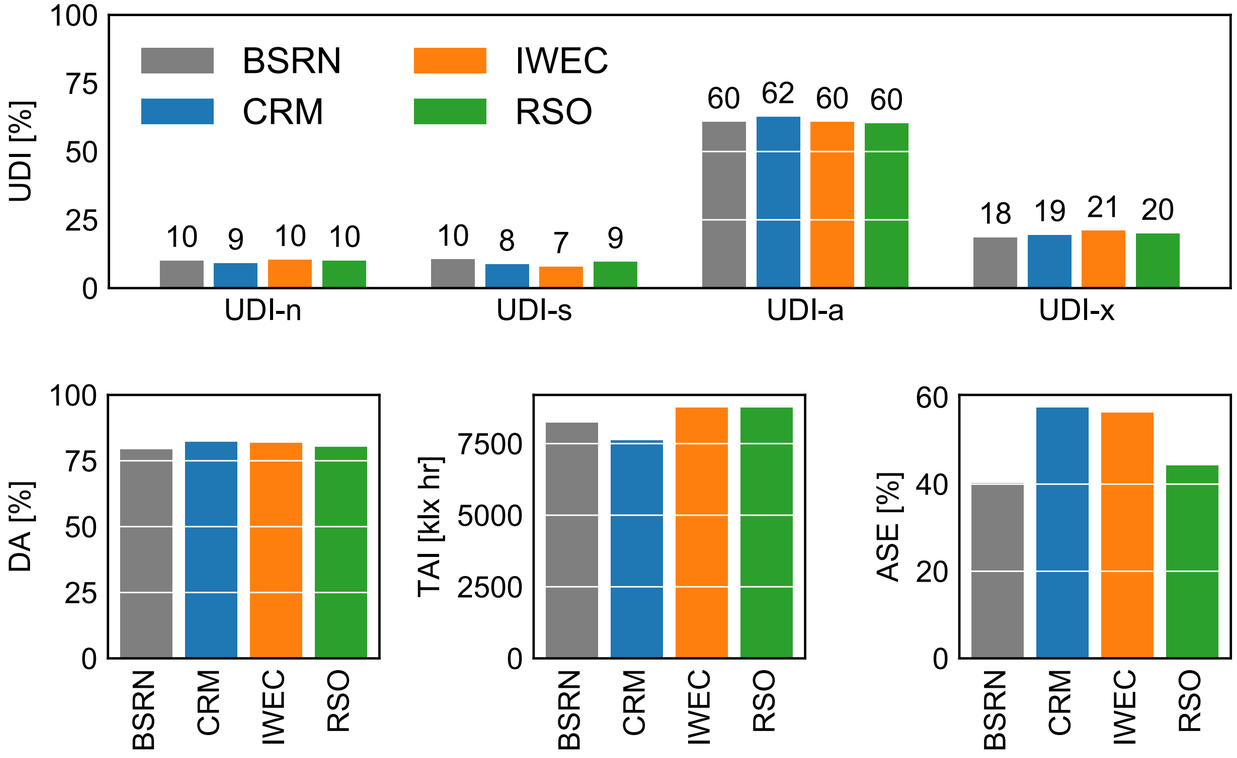

UDI [%]
BSRN
CRM
IWEC
RSO
10 9 10 10
10 8 7 9
60 62 60 60
18 19 21 20
UDI-n
UDI-s
UDI-a
UDI-x
DA [%]
TAI [klx hr]
ASE [%]
BSRN
CRM
IWEC
RSO

MIT Reference Room

Perez All-Weather sky model

`gendaylit / gendaymtx`

Vertical Illuminance:

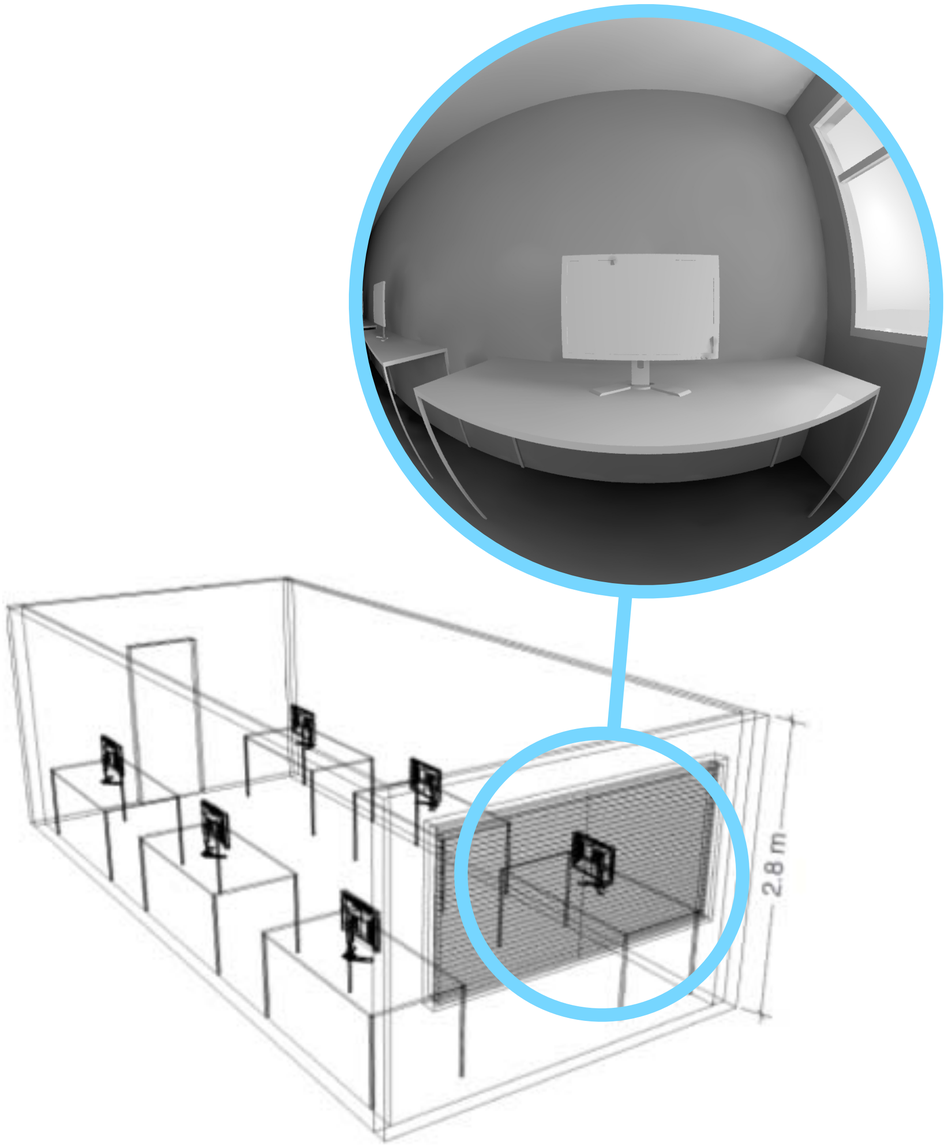
`2-phase method`

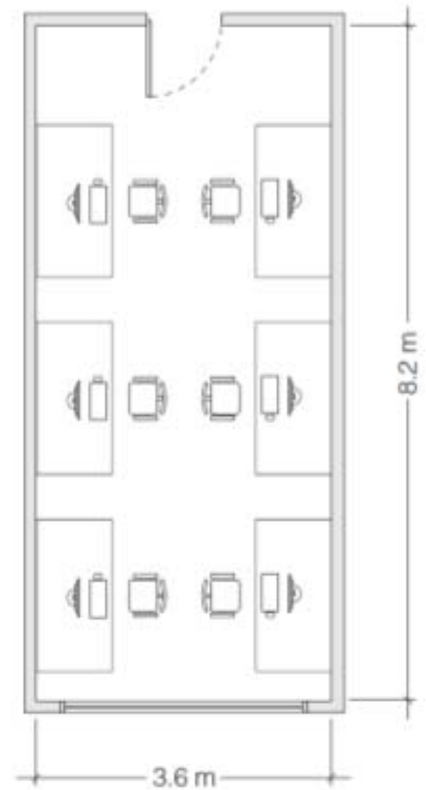
`MF:6`

Luminance images:

`rtrace -ab 0`

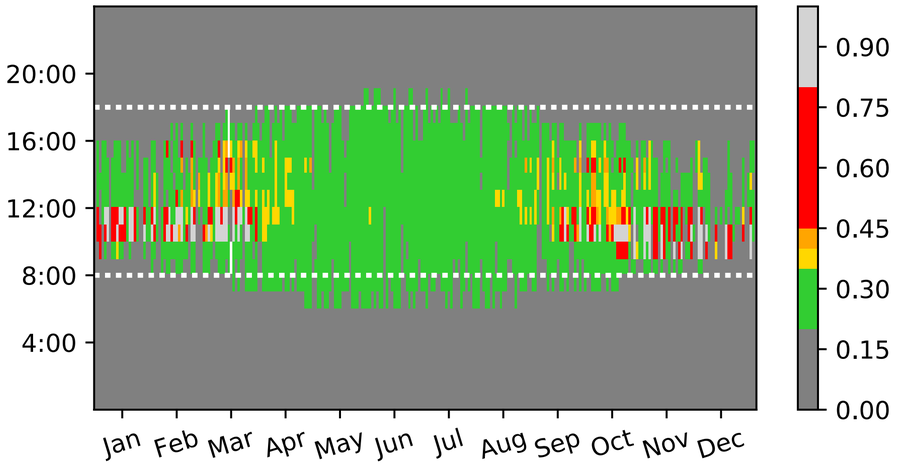
`evalglare -b 2000`



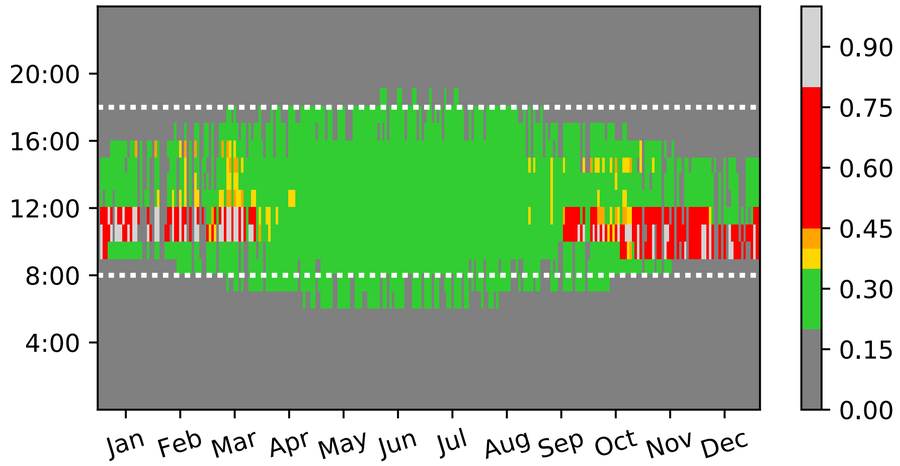


C.F. Reinhart, J.A. Jakubiec, D. Ibarra, Definition of a Reference Office for Standardized Evaluations of Dynamic Façade and Lighting Technologies, in: BS2013 13th Conf. Int. Build. Perform. Simul. Assoc., Chambéry, France, 2013: pp. 3645–3652. http://www.ibpsa.org/proceedings/BS2013/p_1029.pdf.

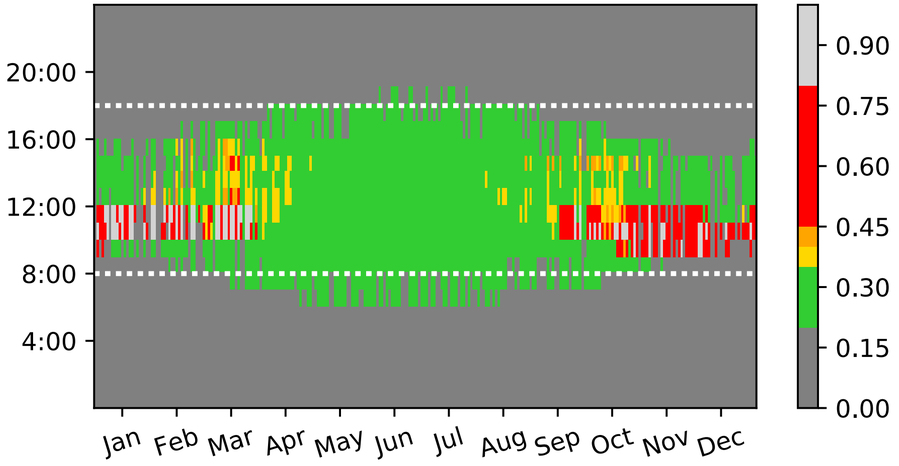
BSRN



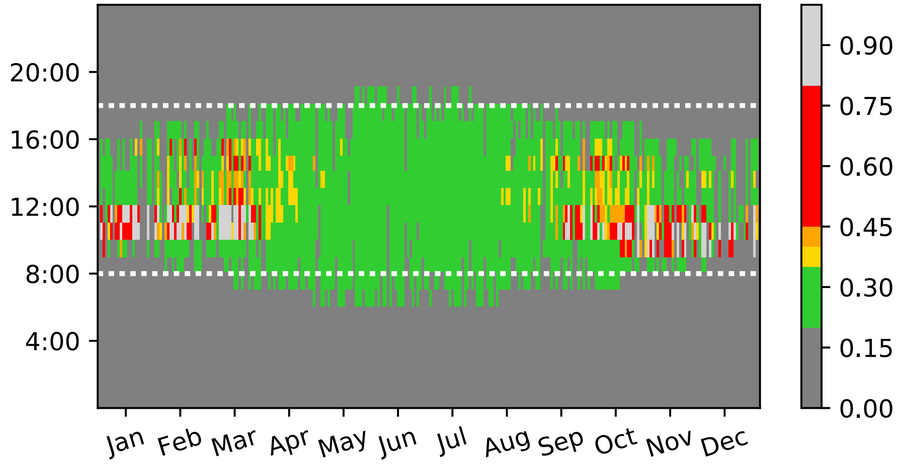
CRM

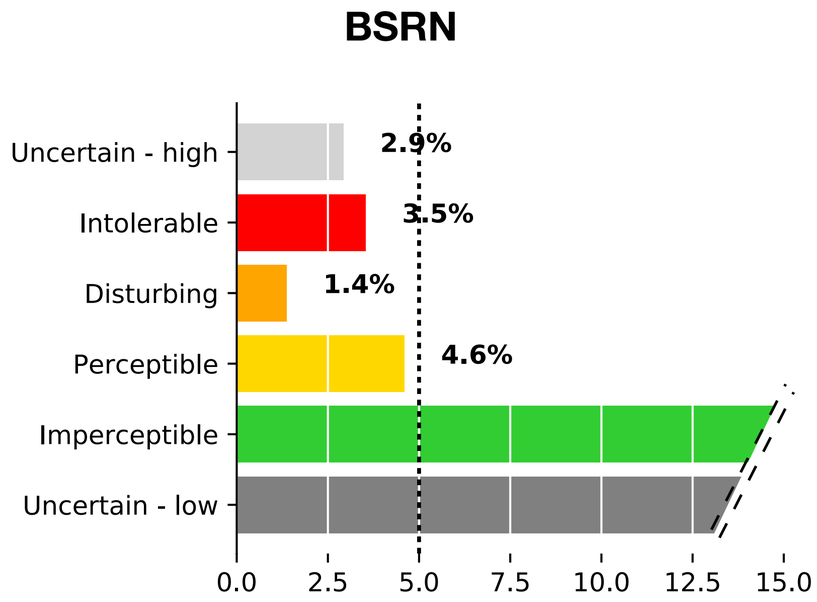


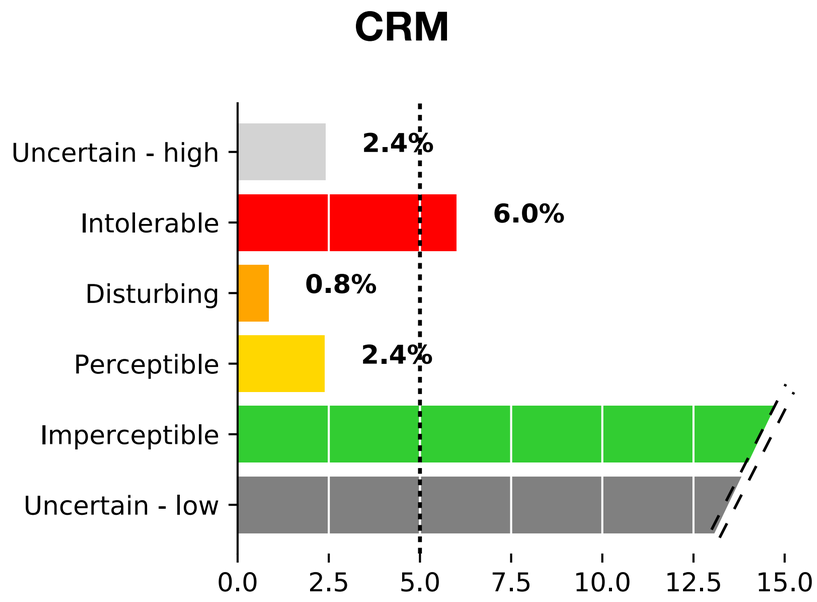
IWEC

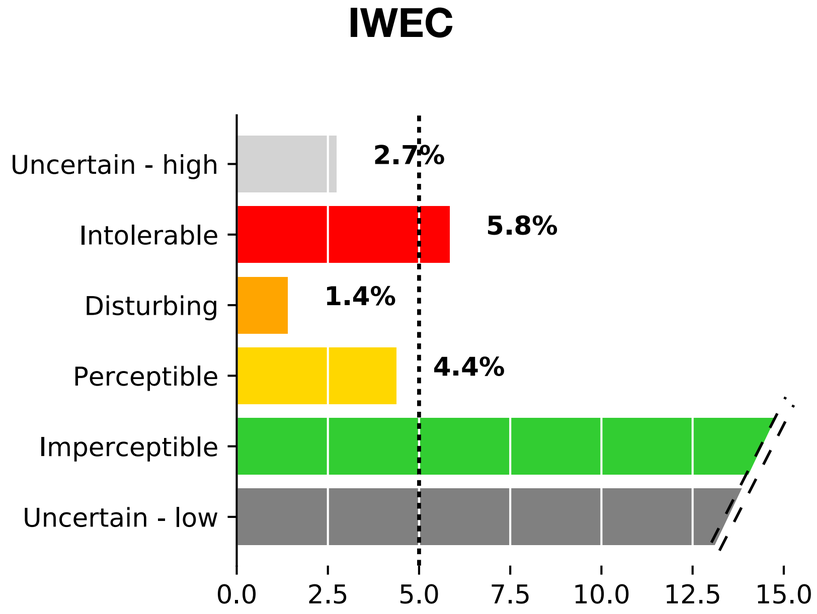


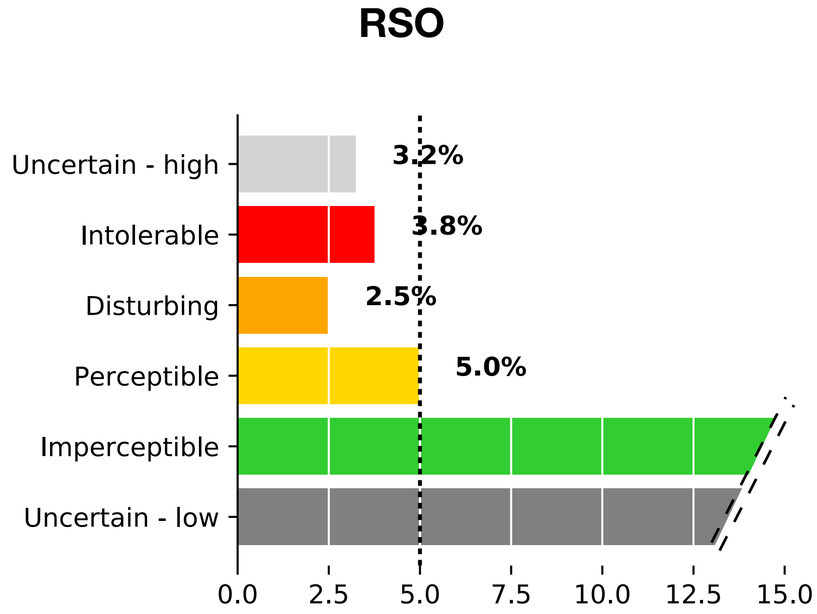
RSO




BSRN
Uncertain - high
Intolerable
Disturbing
Perceptible
Imperceptible
Uncertain - low
2.9%
3.5%
1.4%
4.6%
0.0
2.5
5.0
7.5
10.0
12.5
15.0


CRM
Uncertain - high
Intolerable
Disturbing
Perceptible
Imperceptible
Uncertain - low
2.4%
6.0%
0.8%
2.4%
0.0
2.5
5.0
7.5
10.0
12.5
15.0


IWEC
Uncertain - high
Intolerable
Disturbing
Perceptible
Imperceptible
Uncertain - low
2.7%
5.8%
1.4%
4.4%
0.0
2.5
5.0
7.5
10.0
12.5
15.0


RSO
Uncertain - high
Intolerable
Disturbing
Perceptible
Imperceptible
Uncertain - low
3.2%
3.8%
2.5%
5.0%
0.0
2.5
5.0
7.5
10.0
12.5
15.0

Conclusions

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- Direct sunlight is always the most difficult component to model

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- Using measured data is preferable

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- RSO model reduces errors of a third from those found for the CRM

Conclusions

- Direct sunlight is always the most difficult component to model
- Using measured data is preferable
- RSO model reduces errors of a third from those found for the CRM
- Accurate simulation engines deserve accurate input data

www.newyorker.com/magazine/2015/11/23/writers-in-the-storm

Thank you!

Any question?

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E.Brembilla@lboro.ac.uk

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- Dr Matt Eames, Exeter University
- The MetOffice for MIDAS data
- Public Health England, who kindly supplied their data under the Open Government Licence
- The World Radiation Monitoring Center (WRMC) for BSRN data