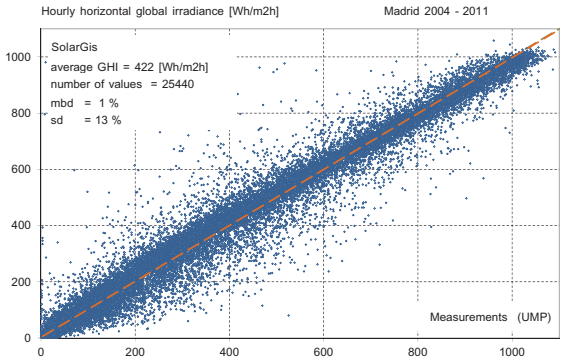
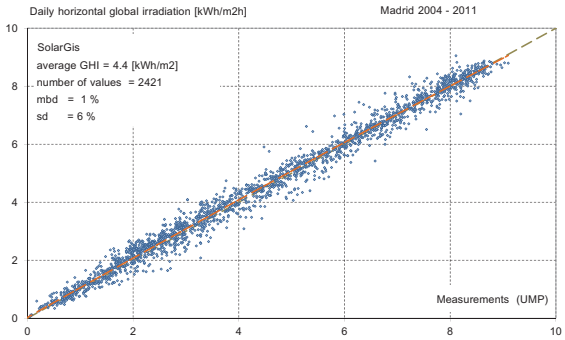
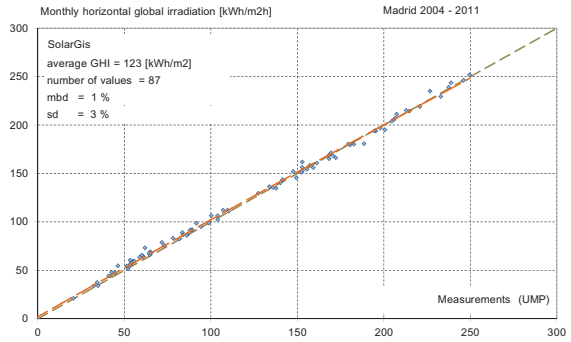
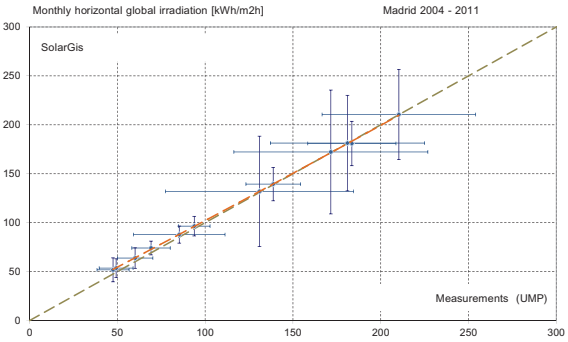
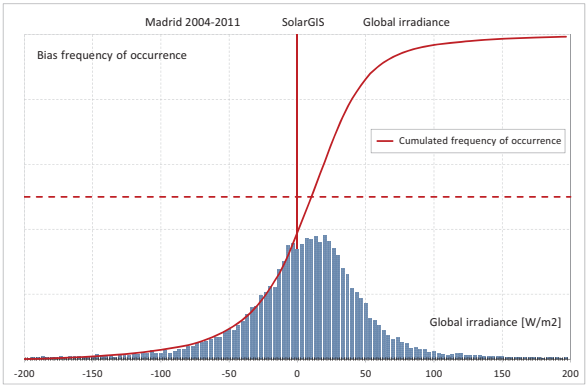
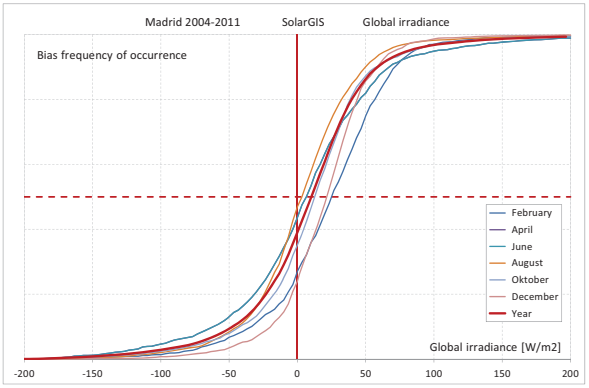

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
SolarGis
average GHI = 422 [Wh/m2h]
number of values = 25440
mbd = 1 %
sd = 13 %
Measurements (UMP)

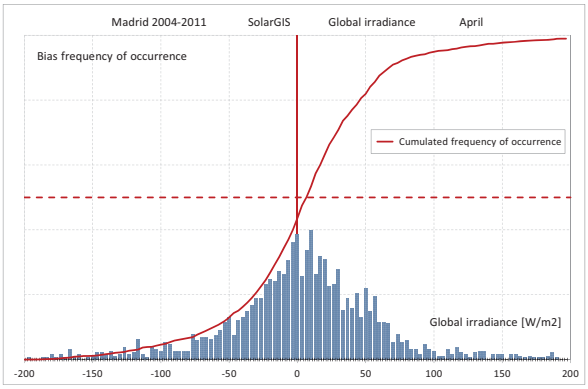

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average GHI = 4.4 [kWh/m2]
number of values = 2421
mbd = 1 %
sd = 6 %
Measurements (UMP)

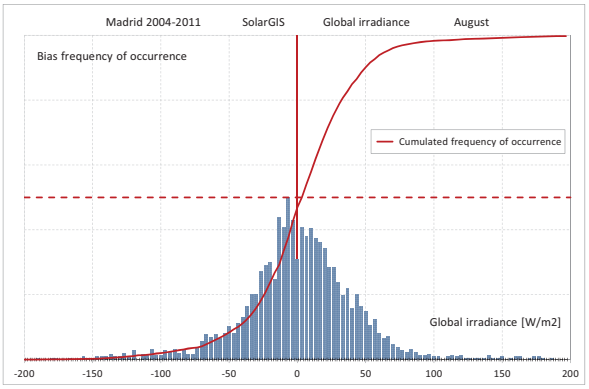

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average GHI = 123 [kWh/m2]
number of values = 87
mbd = 1 %
sd = 3 %
Measurements (UMP)

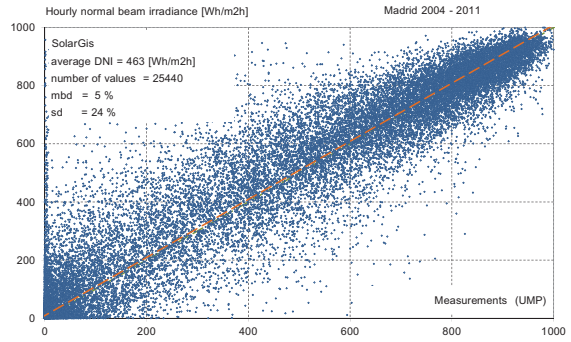

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
Measurements (UMP)

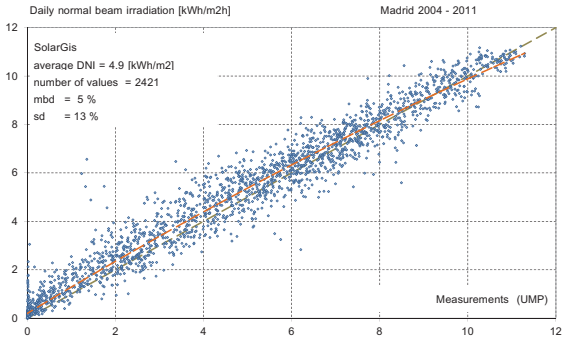

Madrid 2004-2011
SolarGIS
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

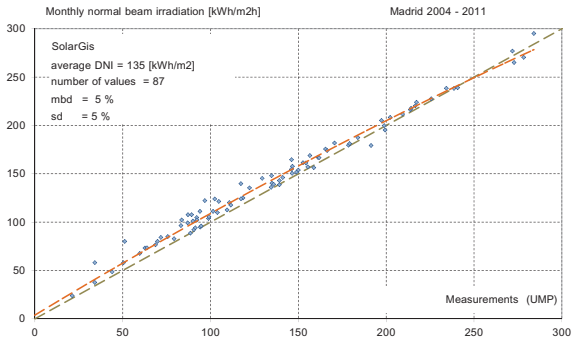

Madrid 2004-2011
SolarGIS
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

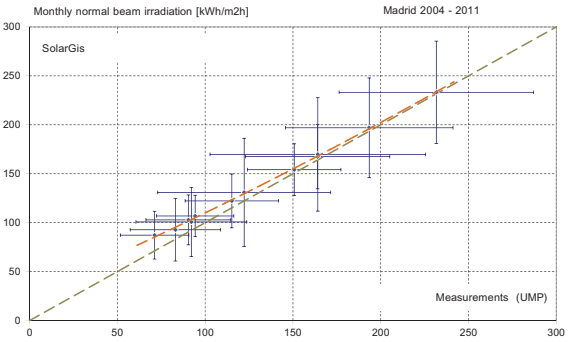

Madrid 2004-2011
SolarGIS
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

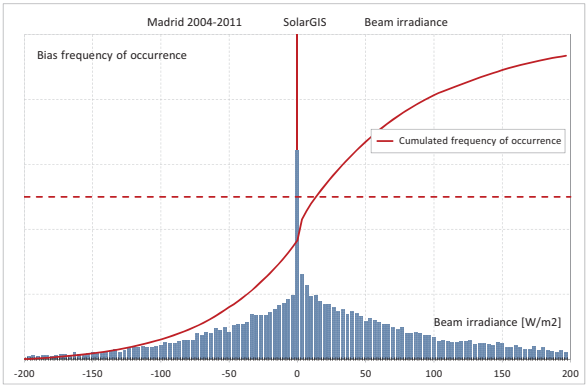

Madrid 2004-2011
SolarGIS
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

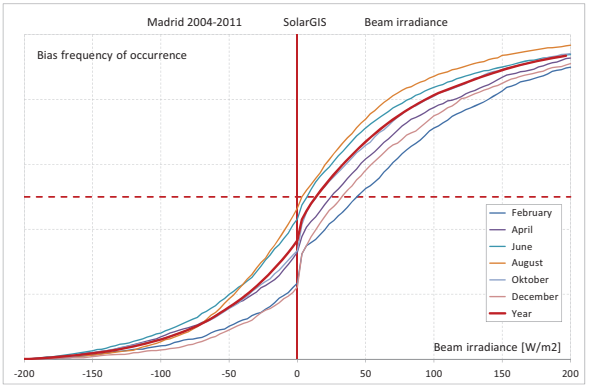

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
SolarGis
average DNI = 463 [Wh/m2h]
number of values = 25440
mbd = 5 %
sd = 24 %
Measurements (UMP)

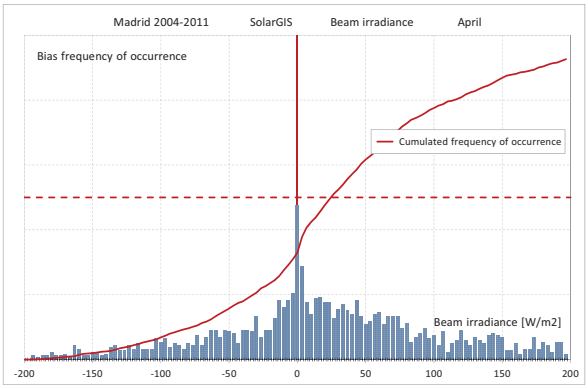

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average DNI = 4.9 [kWh/m2]
number of values = 2421
mbd = 5 %
sd = 13 %
Measurements (UMP)

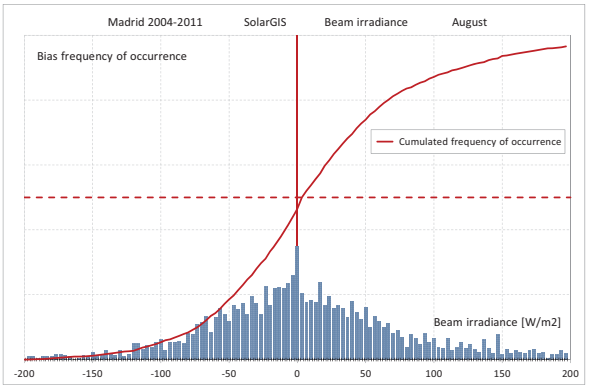

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average DNI = 135 [kWh/m2]
number of values = 87
mbd = 5 %
sd = 5 %
Measurements (UMP)

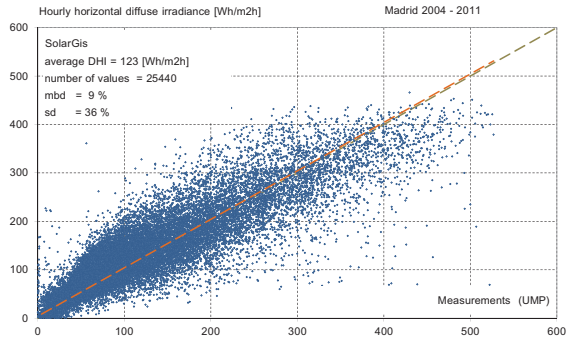

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
Measurements (UMP)

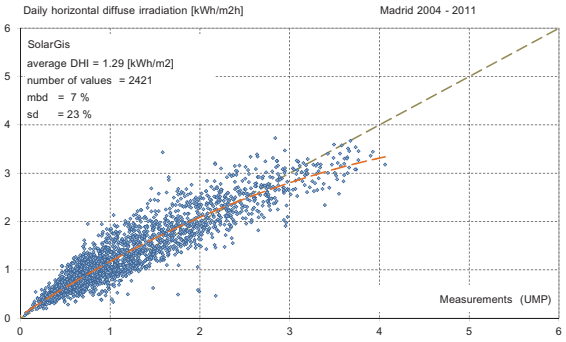

Madrid 2004-2011
SolarGIS
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

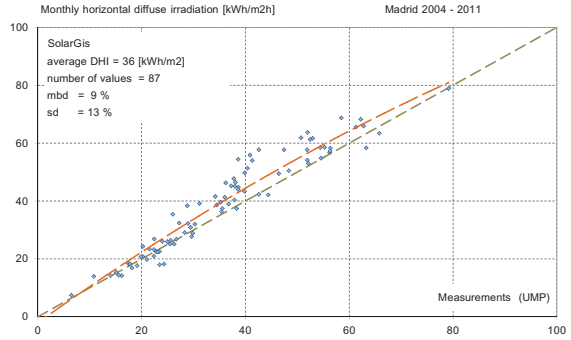

Madrid 2004-2011
SolarGIS
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

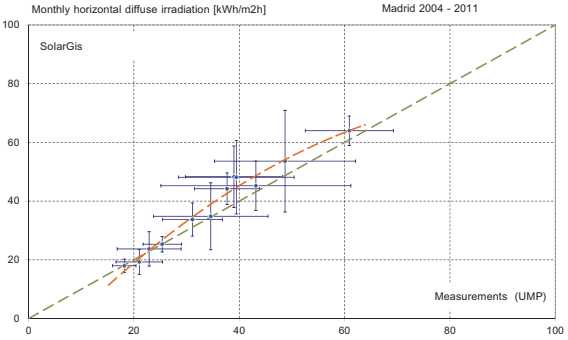

Madrid 2004-2011
SolarGIS
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

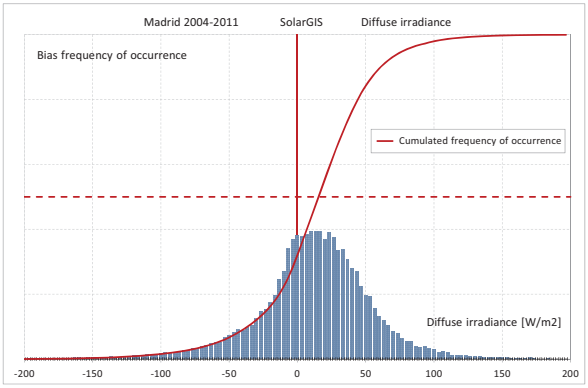

Madrid 2004-2011
SolarGIS
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

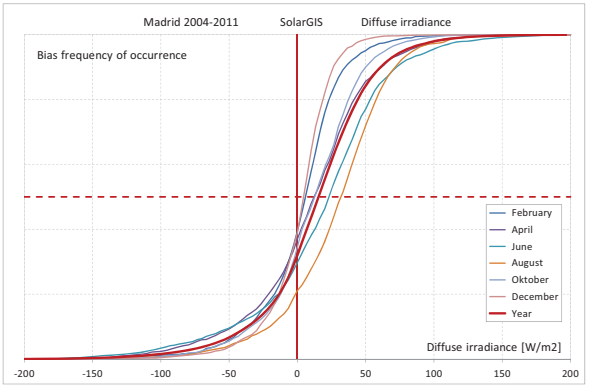

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
SolarGis
average DHI = 123 [Wh/m2h]
number of values = 25440
mbd = 9 %
sd = 36 %
Measurements (UMP)

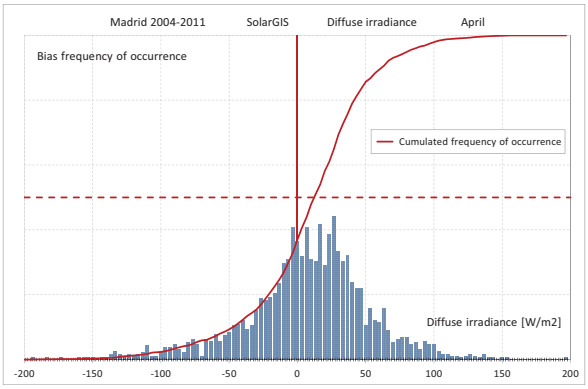

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average DHI = 1.29 [kWh/m2]
number of values = 2421
mbd = 7 %
sd = 23 %
Measurements (UMP)

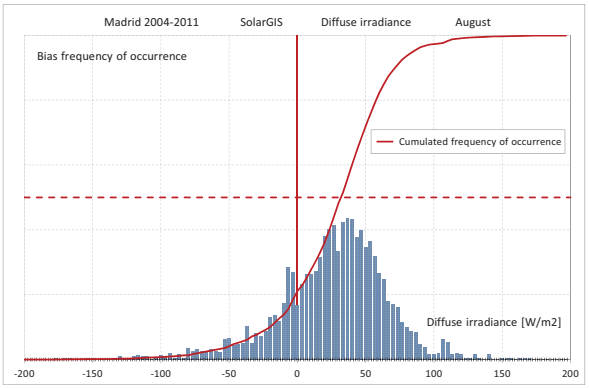

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
average DHI = 36 [kWh/m2]
number of values = 87
mbd = 9 %
sd = 13 %
Measurements (UMP)

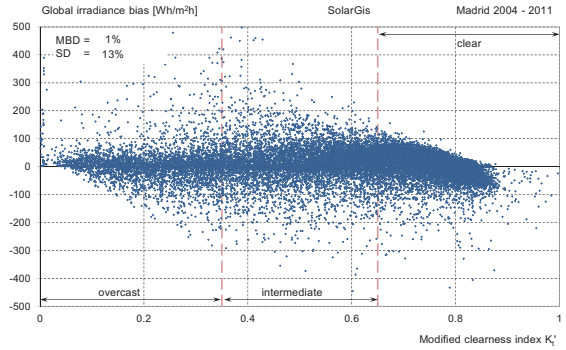

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
SolarGis
Measurements (UMP)

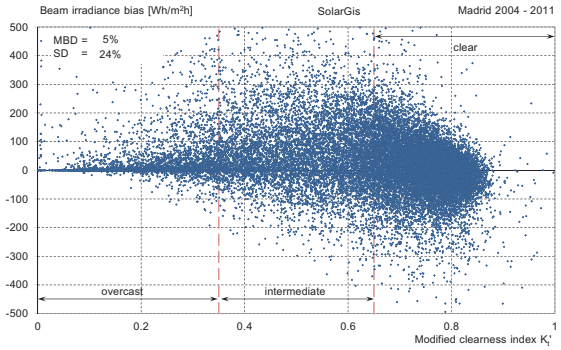

Madrid 2004-2011
SolarGIS
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

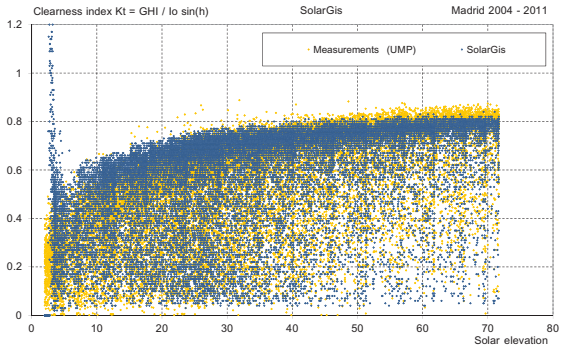

Madrid 2004-2011
SolarGIS
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

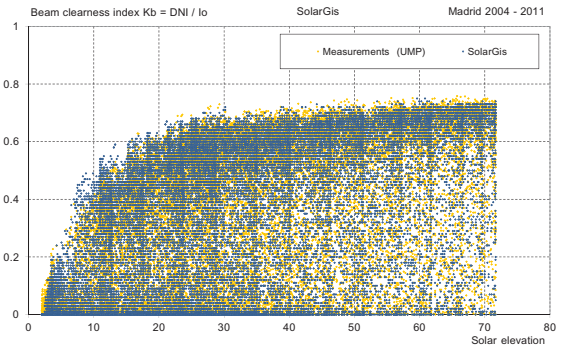

Madrid 2004-2011
SolarGIS
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

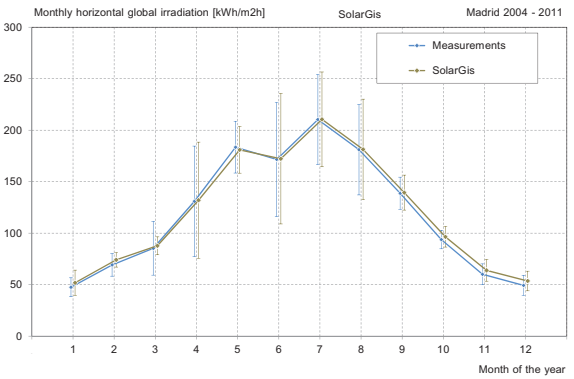

Madrid 2004-2011
SolarGIS
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

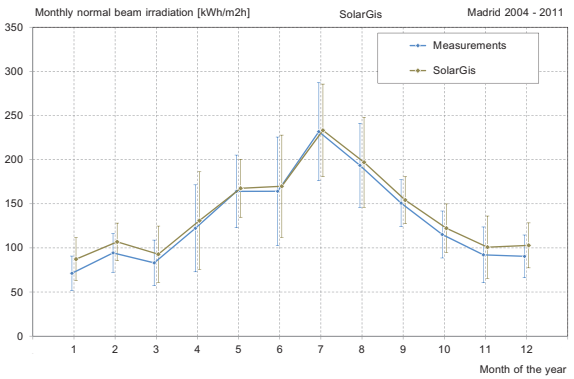

Global irradiance bias [Wh/m²h]
SolarGis
Madrid 2004 - 2011
MBD = 1%
SD = 13%
clear
overcast
intermediate
Modified clearness index Kt'

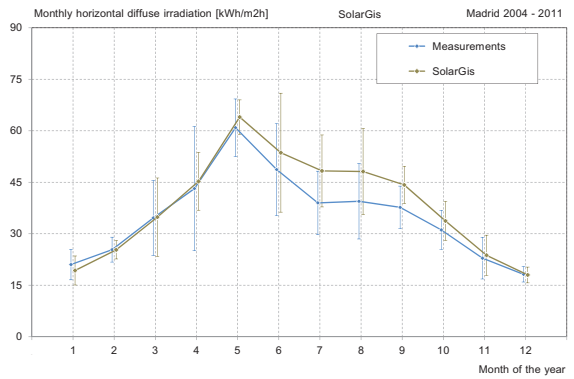

Beam irradiance bias [Wh/m²h]
SolarGis
Madrid 2004 - 2011
MBD = 5%
SD = 24%
clear
overcast
intermediate
Modified clearness index Kt'

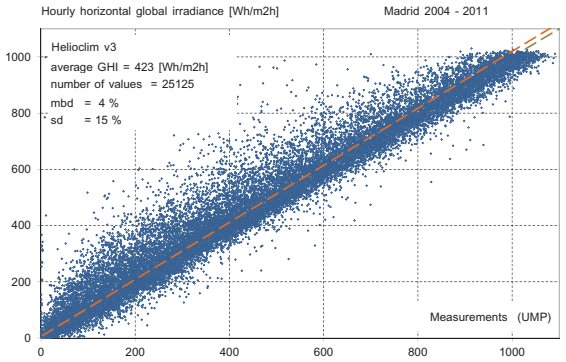

Clearness index Kt = GHI / Io sin(h)
SolarGis
Madrid 2004 - 2011
Measurements (UMP)
SolarGis
Solar elevation

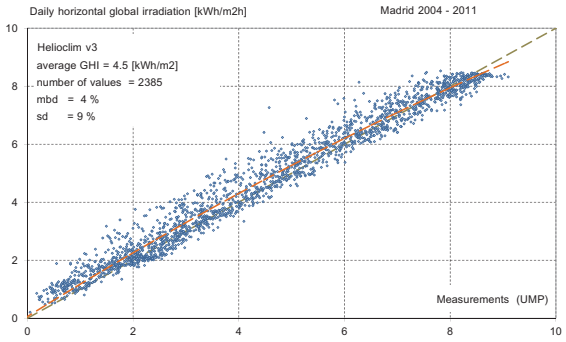

Beam clearness index Kb = DNI / Io
SolarGis
Madrid 2004 - 2011
Measurements (UMP)
SolarGis
Solar elevation

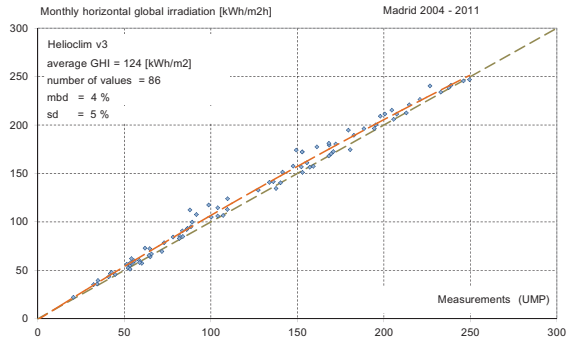

Monthly horizontal global irradiation [kWh/m2h]
SolarGis
Madrid 2004 - 2011
Measurements
SolarGis
Month of the year

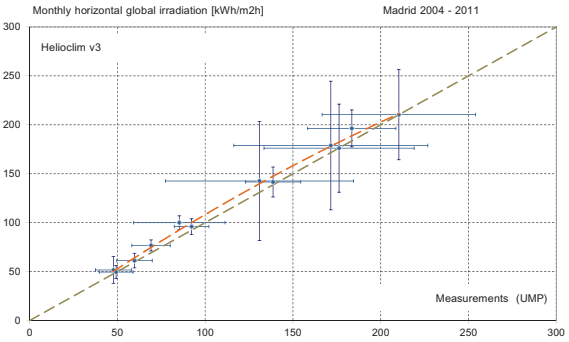

Monthly normal beam irradiation [kWh/m2h]
SolarGis
Madrid 2004 - 2011
Measurements
SolarGis
Month of the year

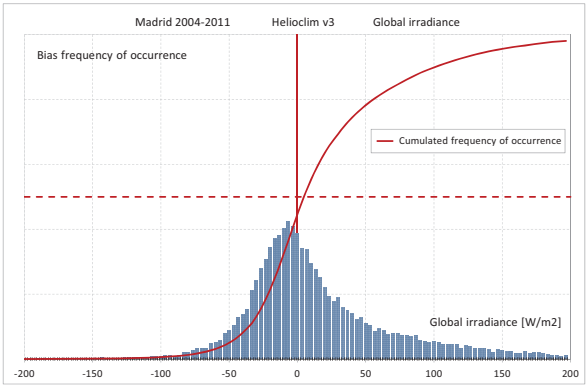

Monthly horizontal diffuse irradiation [kWh/m2h]
SolarGis
Madrid 2004 - 2011
Measurements
SolarGis
Month of the year

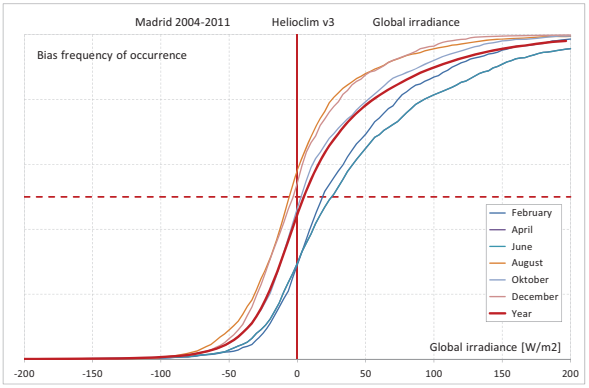

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
Helioclim v3
average GHI = 423 [Wh/m2h]
number of values = 25125
mbd = 4 %
sd = 15 %
Measurements (UMP)

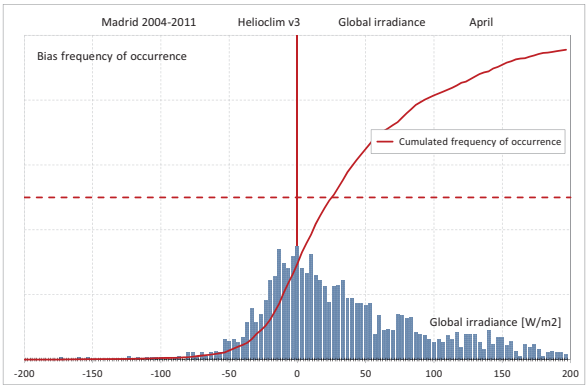

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average GHI = 4.5 [kWh/m2]
number of values = 2385
mbd = 4 %
sd = 9 %
Measurements (UMP)

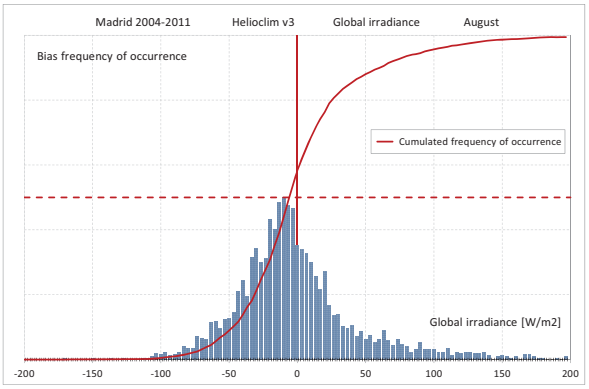

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average GHI = 124 [kWh/m2]
number of values = 86
mbd = 4 %
sd = 5 %
Measurements (UMP)

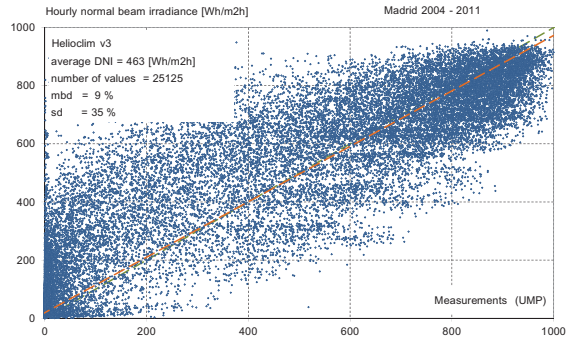

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
Measurements (UMP)

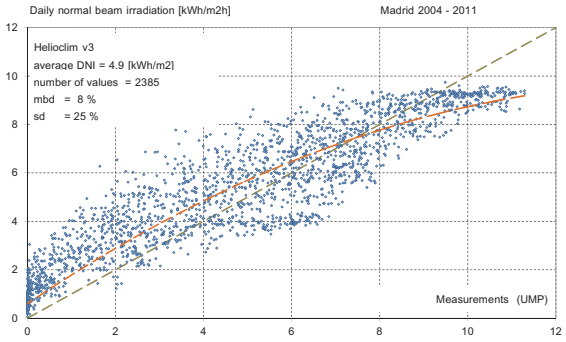

Madrid 2004-2011
Helioclim v3
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

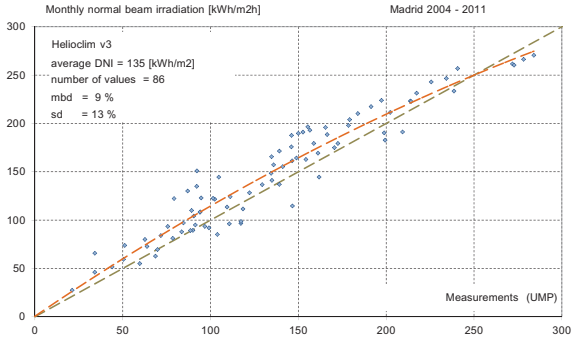

Madrid 2004-2011
Helioclim v3
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

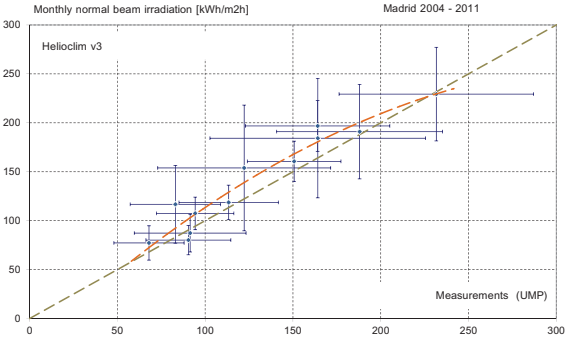

Madrid 2004-2011
Helioclim v3
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

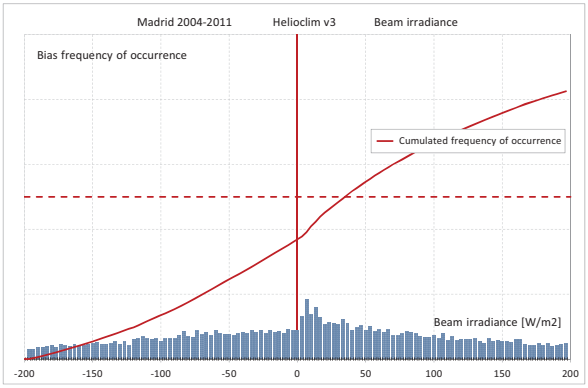

Madrid 2004-2011
Helioclim v3
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

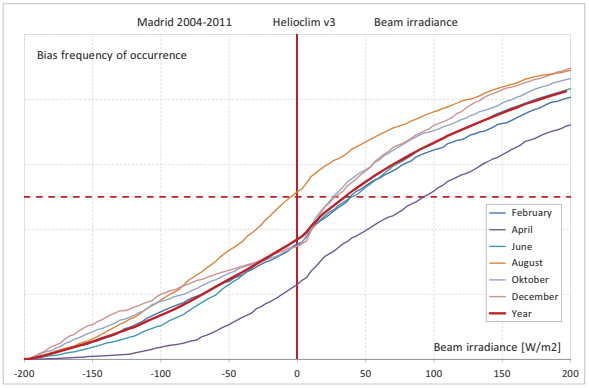

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DNI = 463 [Wh/m2h]
number of values = 25125
mbd = 9 %
sd = 35 %
Measurements (UMP)

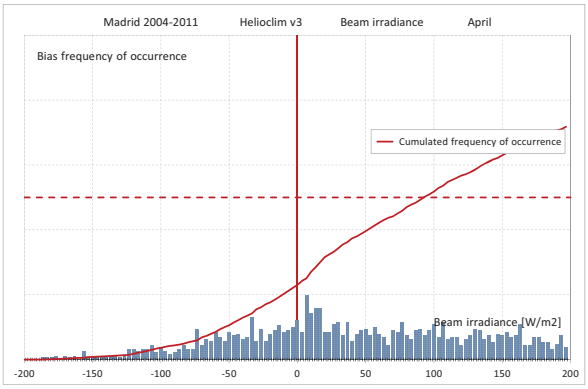

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DNI = 4.9 [kWh/m2]
number of values = 2385
mbd = 8 %
sd = 25 %
Measurements (UMP)

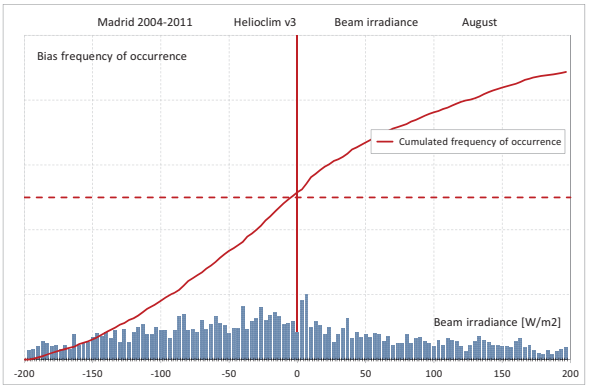

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DNI = 135 [kWh/m2]
number of values = 86
mbd = 9 %
sd = 13 %
Measurements (UMP)

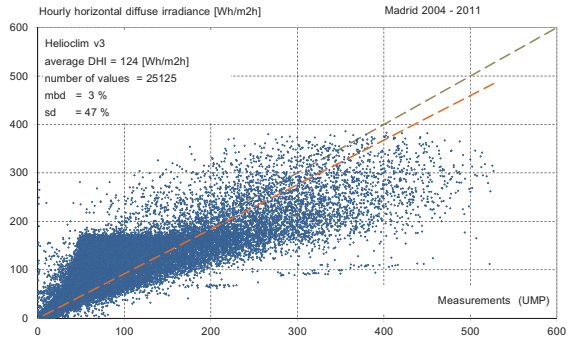

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
Measurements (UMP)

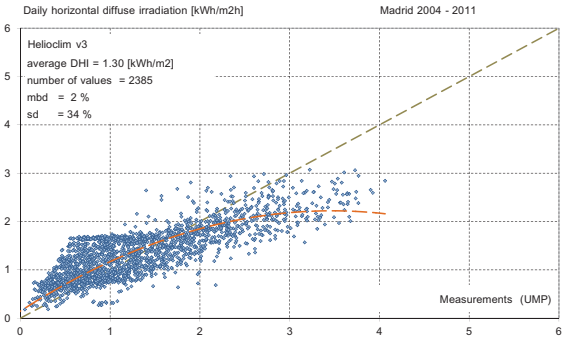

Madrid 2004-2011
Helioclim v3
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

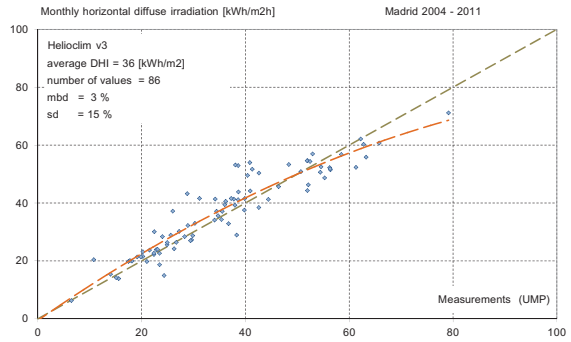

Madrid 2004-2011
Helioclim v3
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

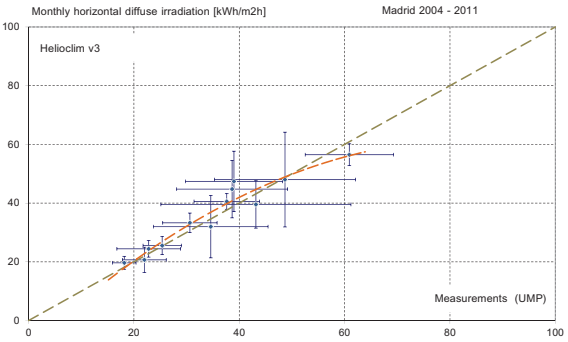

Madrid 2004-2011
Helioclim v3
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

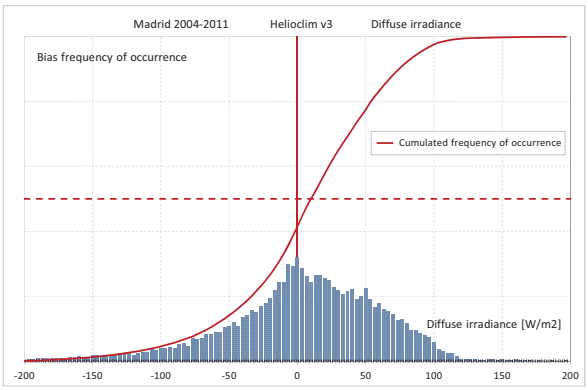

Madrid 2004-2011
Helioclim v3
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

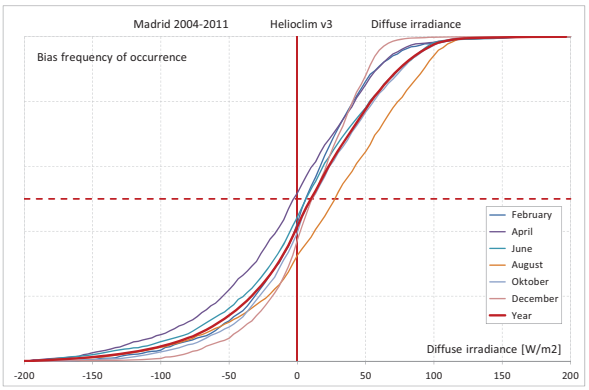

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DHI = 124 [Wh/m2h]
number of values = 25125
mbd = 3 %
sd = 47 %
Measurements (UMP)

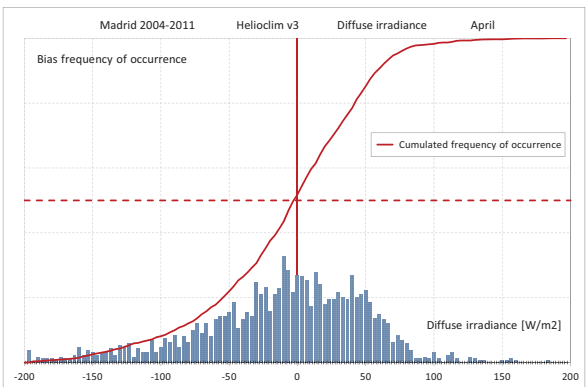

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DHI = 1.30 [kWh/m2]
number of values = 2385
mbd = 2 %
sd = 34 %
Measurements (UMP)

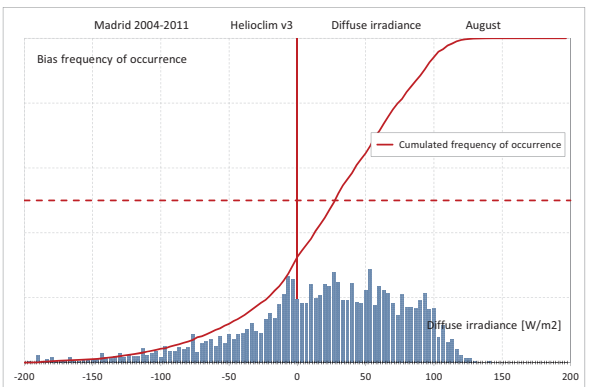

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
average DHI = 36 [kWh/m2]
number of values = 86
mbd = 3 %
sd = 15 %
Measurements (UMP)

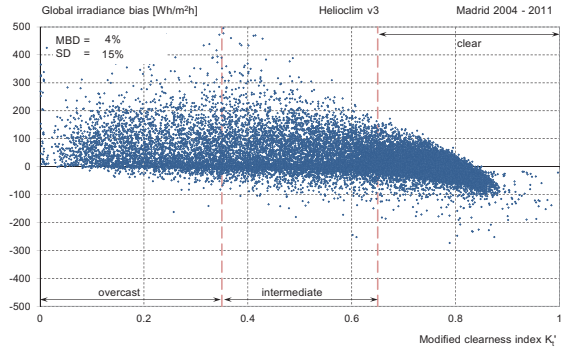

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Helioclim v3
Measurements (UMP)

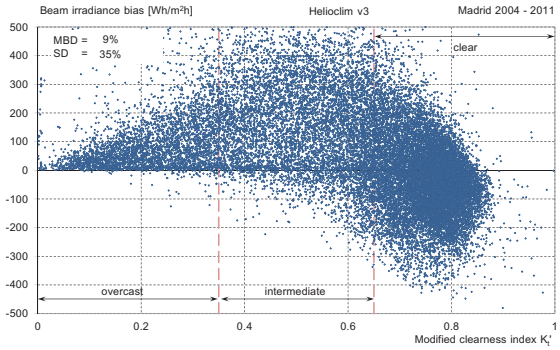

Madrid 2004-2011
Helioclim v3
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

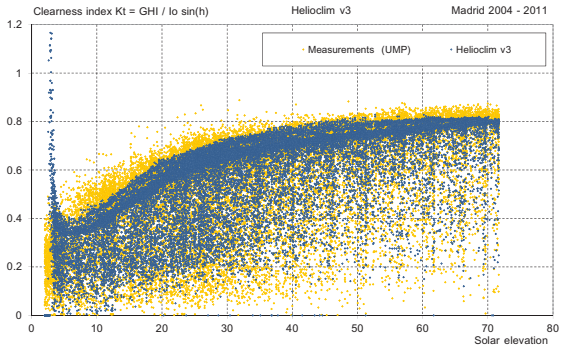

Madrid 2004-2011
Helioclim v3
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

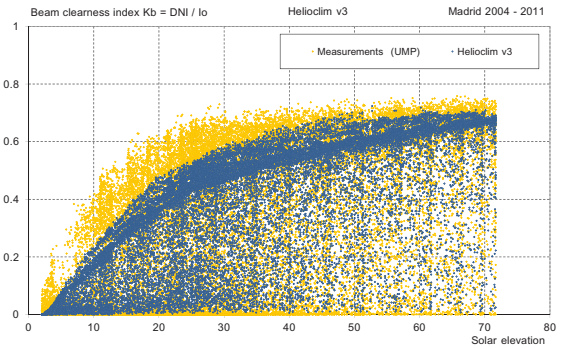

Madrid 2004-2011
Helioclim v3
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

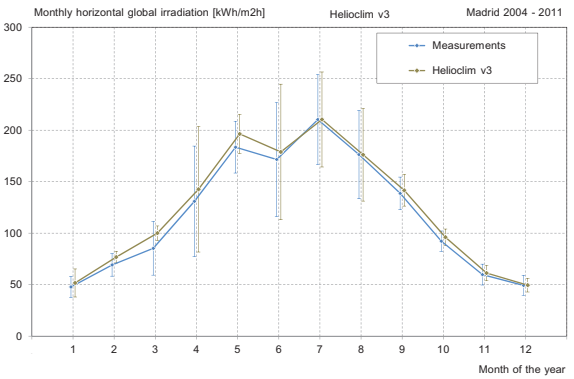

Madrid 2004-2011
Helioclim v3
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

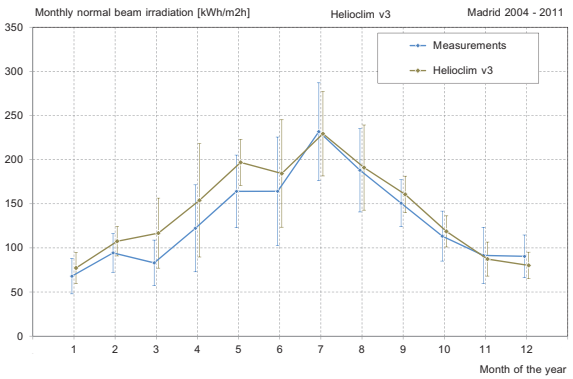

Global irradiance bias [Wh/m²h]
Helioclim v3
Madrid 2004 - 2011
MBD = 4%
SD = 15%
clear
overcast
intermediate
Modified clearness index Kt'

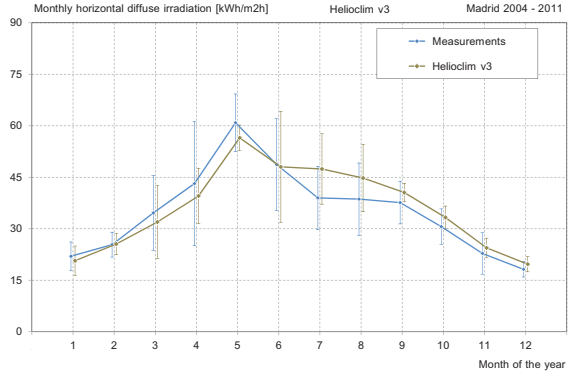

Beam irradiance bias [Wh/m²h]
Helioclim v3
Madrid 2004 - 2011
MBD = 9%
SD = 35%
clear
overcast
intermediate
Modified clearness index Kt'

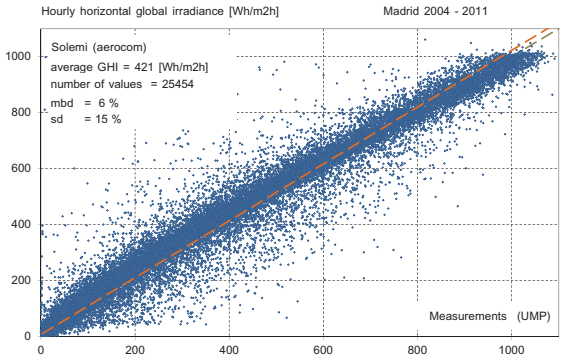

Clearness index Kt = GHI / Io sin(h)
Helioclim v3
Madrid 2004 - 2011
Measurements (UMP)
Helioclim v3
Solar elevation

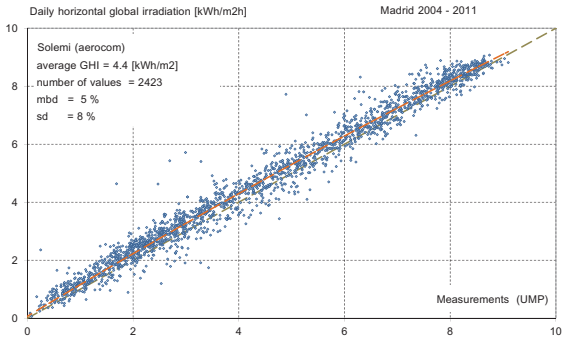

Beam clearness index Kb = DNI / Io
Helioclim v3
Madrid 2004 - 2011
Measurements (UMP)
Helioclim v3
Solar elevation

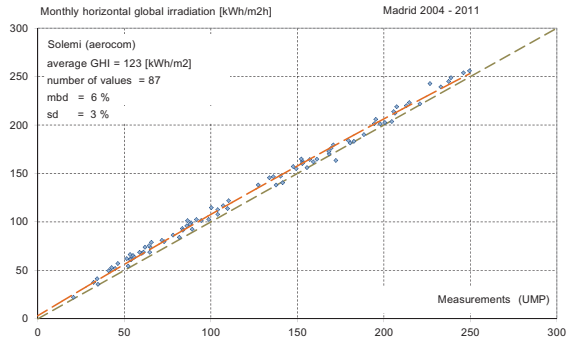

Monthly horizontal global irradiation [kWh/m2h]
Helioclim v3
Madrid 2004 - 2011
Measurements
Helioclim v3
Month of the year

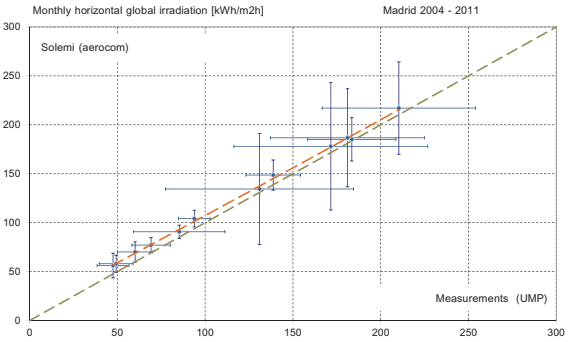

Monthly normal beam irradiation [kWh/m2h]
Helioclim v3
Madrid 2004 - 2011
Measurements
Helioclim v3
Month of the year

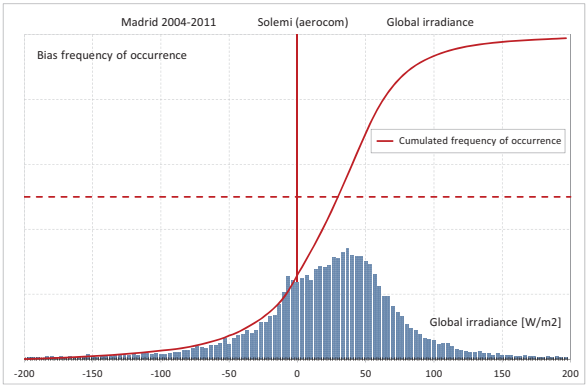

Monthly horizontal diffuse irradiation [kWh/m2h]
Helioclim v3
Madrid 2004 - 2011
Measurements
Helioclim v3
Month of the year

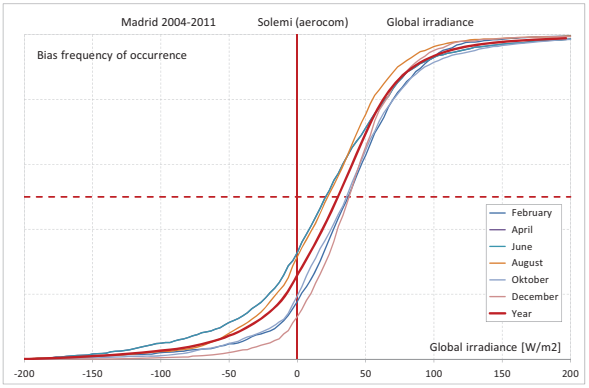

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average GHI = 421 [Wh/m2h]
number of values = 25454
mbd = 6 %
sd = 15 %
Measurements (UMP)

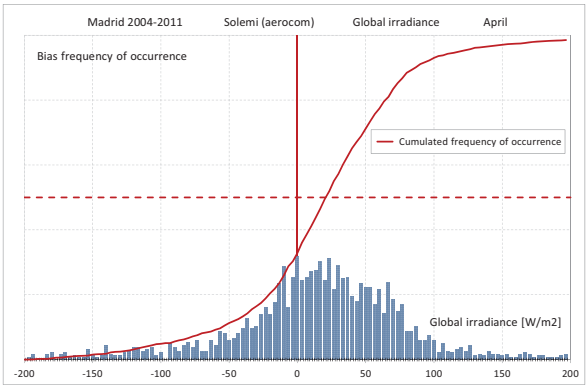

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average GHI = 4.4 [kWh/m2]
number of values = 2423
mbd = 5 %
sd = 8 %
Measurements (UMP)

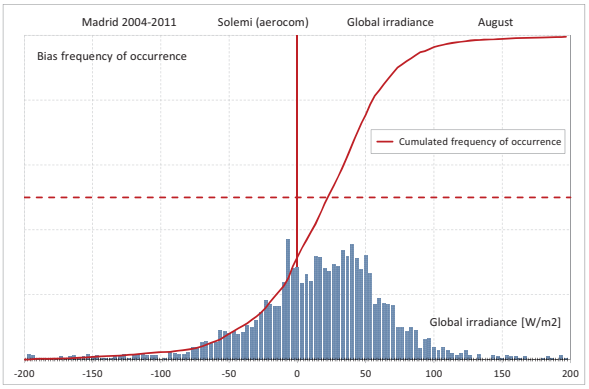

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average GHI = 123 [kWh/m2]
number of values = 87
mbd = 6 %
sd = 3 %
Measurements (UMP)

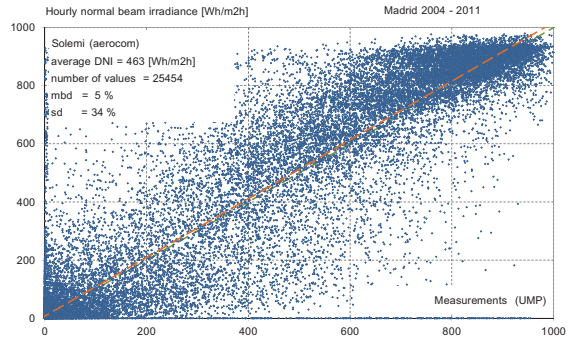

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
Measurements (UMP)

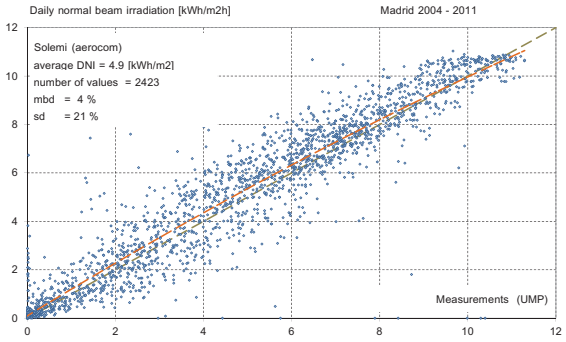

Madrid 2004-2011
Solemi (aerocom)
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

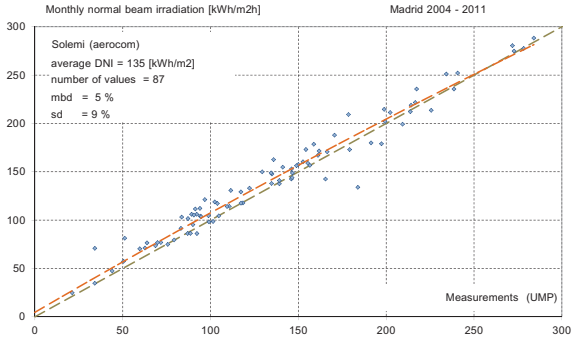

Madrid 2004-2011
Solemi (aerocom)
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

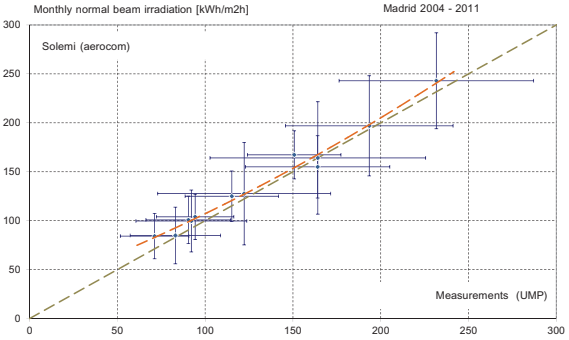

Madrid 2004-2011
Solemi (aerocom)
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

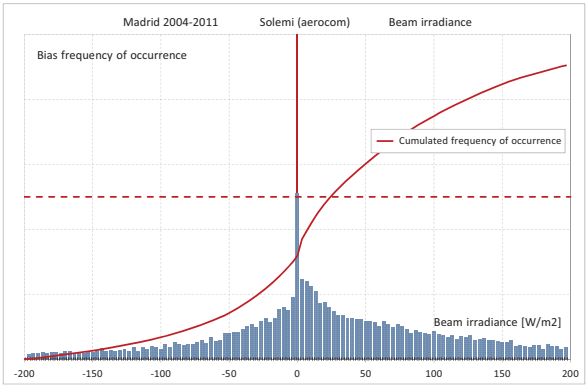

Madrid 2004-2011
Solemi (aerocom)
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

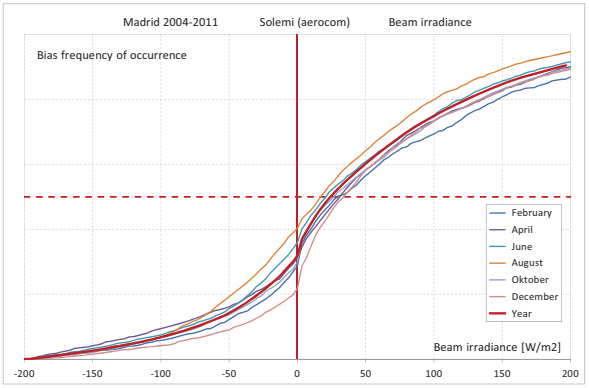

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DNI = 463 [Wh/m2h]
number of values = 25454
mbd = 5 %
sd = 34 %
Measurements (UMP)

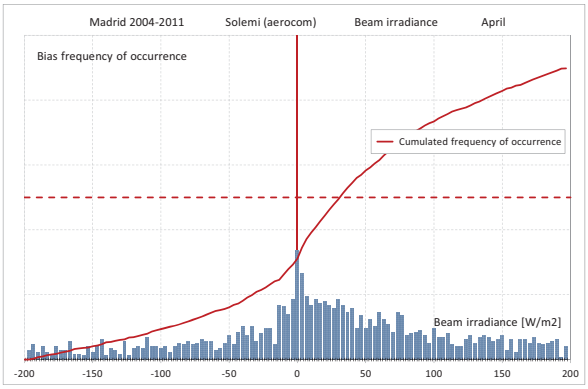

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DNI = 4.9 [kWh/m2]
number of values = 2423
mbd = 4 %
sd = 21 %
Measurements (UMP)

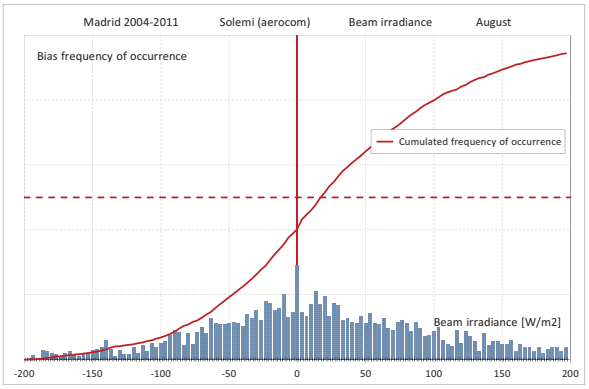

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DNI = 135 [kWh/m2]
number of values = 87
mbd = 5 %
sd = 9 %
Measurements (UMP)

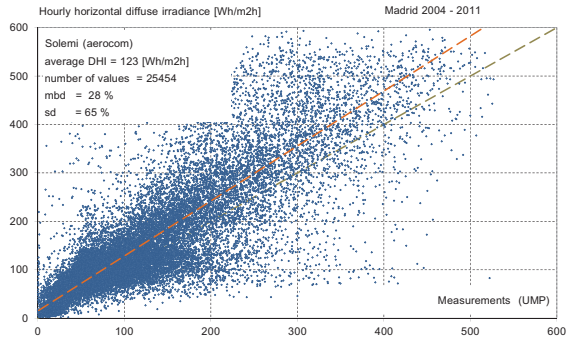

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
Measurements (UMP)

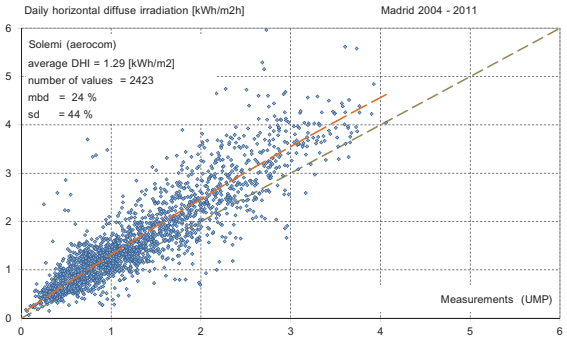

Madrid 2004-2011
Solemi (aerocom)
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

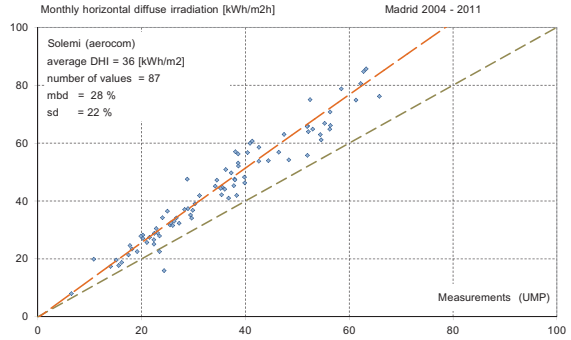

Madrid 2004-2011
Solemi (aerocom)
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

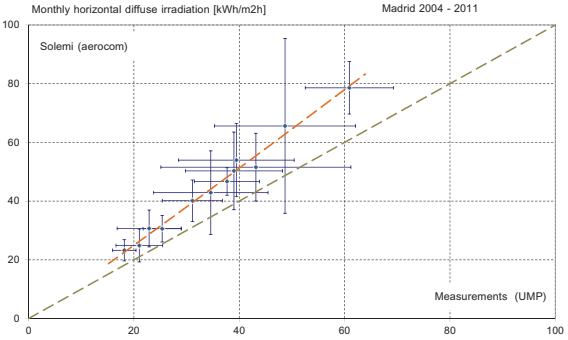

Madrid 2004-2011
Solemi (aerocom)
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

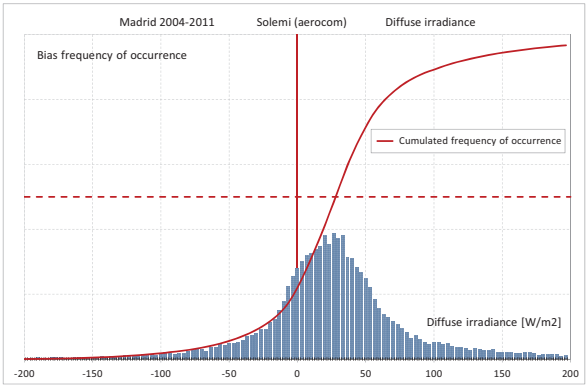

Madrid 2004-2011
Solemi (aerocom)
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

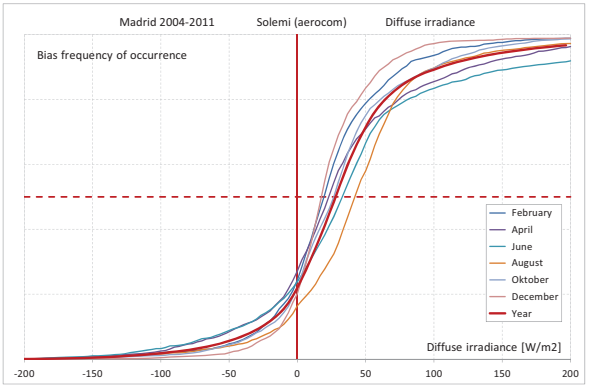

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DHI = 123 [Wh/m2h]
number of values = 25454
mbd = 28 %
sd = 65 %
Measurements (UMP)

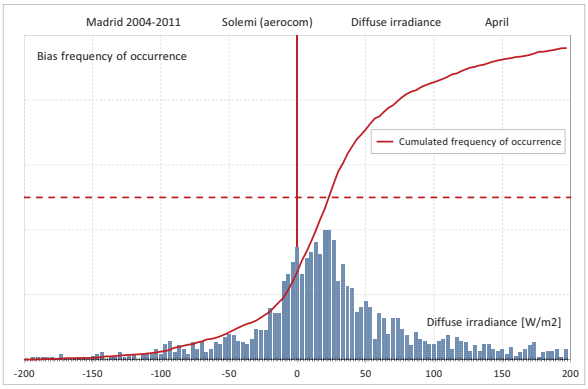

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DHI = 1.29 [kWh/m2]
number of values = 2423
mbd = 24 %
sd = 44 %
Measurements (UMP)

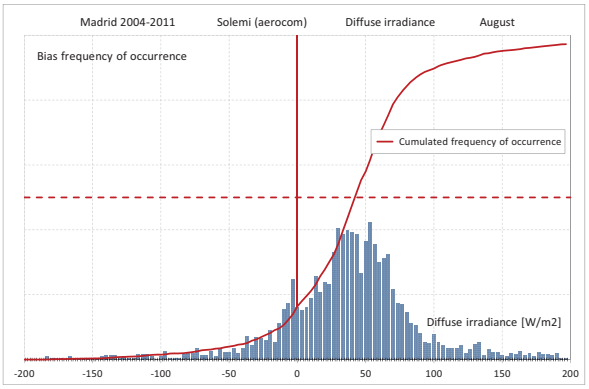

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
average DHI = 36 [kWh/m2]
number of values = 87
mbd = 28 %
sd = 22 %
Measurements (UMP)

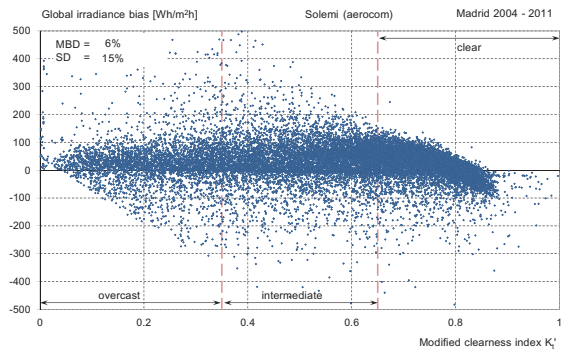

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
Solemi (aerocom)
Measurements (UMP)

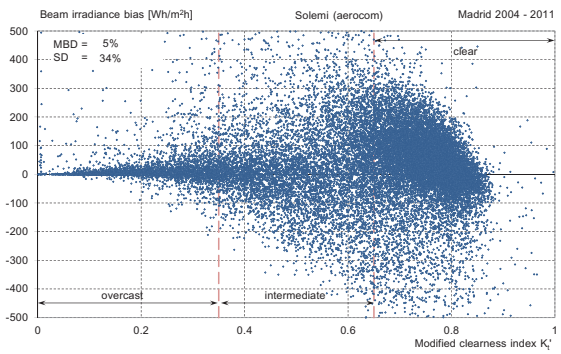

Madrid 2004-2011
Solemi (aerocom)
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

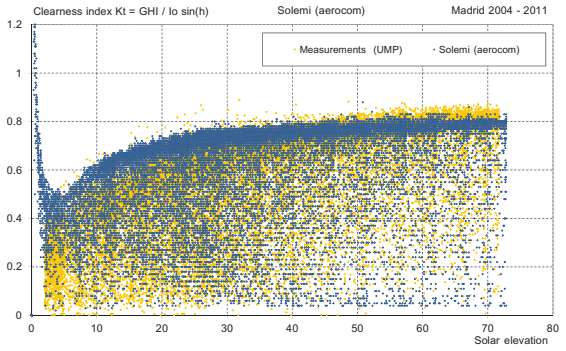

Madrid 2004-2011
Solemi (aerocom)
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

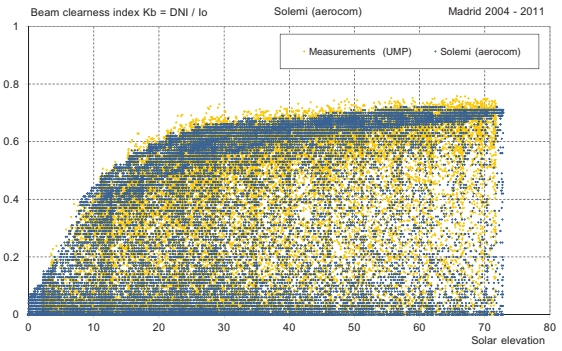

Madrid 2004-2011
Solemi (aerocom)
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

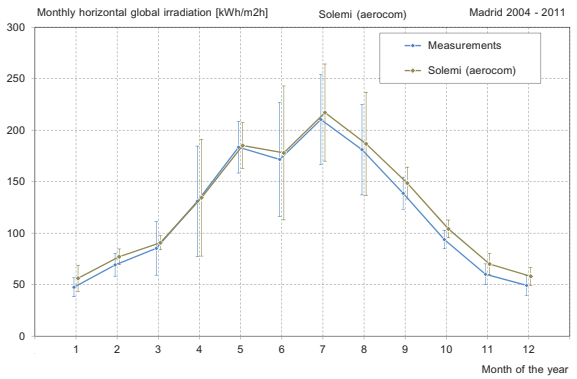

Madrid 2004-2011
Solemi (aerocom)
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

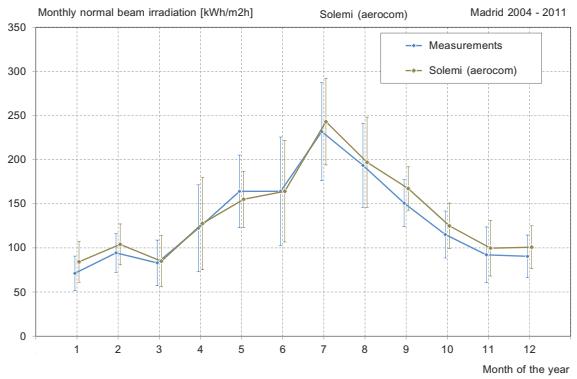

Global irradiance bias [Wh/m²h]
Solemi (aerocom)
Madrid 2004 - 2011
MBD = 6%
SD = 15%
clear
overcast
intermediate
Modified clearness index Kt'

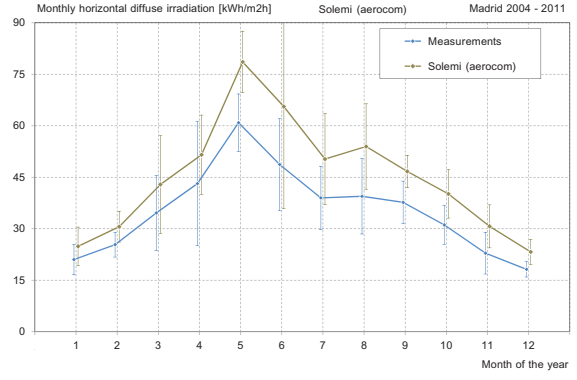

Beam irradiance bias [Wh/m²h]
Solemi (aerocom)
Madrid 2004 - 2011
MBD = 5%
SD = 34%
clear
overcast
intermediate
Modified clearness index Kt'

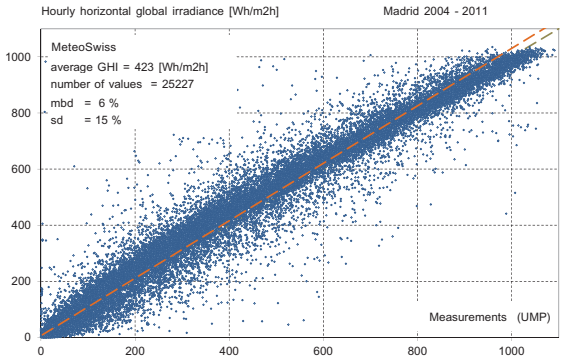

Clearness index Kt = GHI / Io sin(h)
Solemi (aerocom)
Madrid 2004 - 2011
Measurements (UMP)
Solemi (aerocom)
Solar elevation

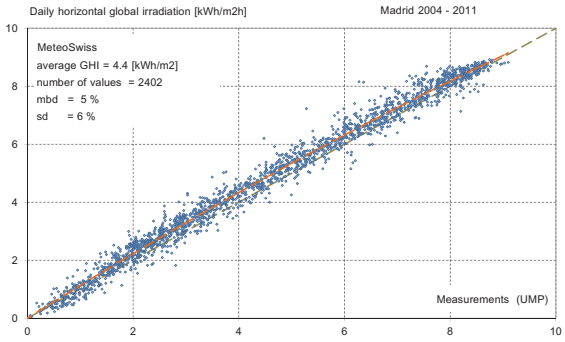

Beam clearness index Kb = DNI / Io
Solemi (aerocom)
Madrid 2004 - 2011
Measurements (UMP)
Solemi (aerocom)
Solar elevation

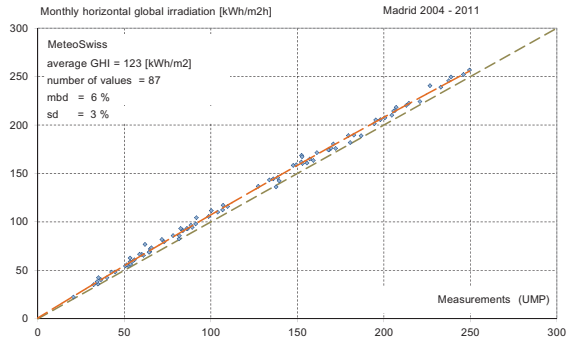

Monthly horizontal global irradiation [kWh/m2h]
Solemi (aerocom)
Madrid 2004 - 2011
Measurements
Solemi (aerocom)
Month of the year

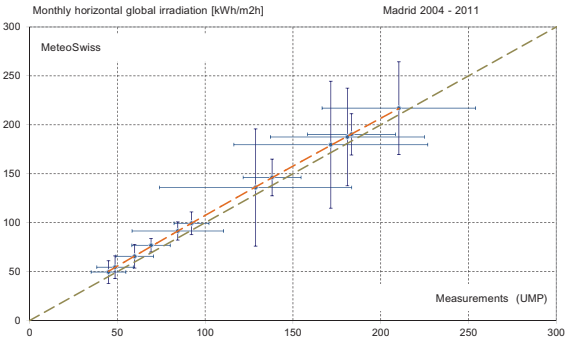

Monthly normal beam irradiation [kWh/m2h]
Solemi (aerocom)
Madrid 2004 - 2011
Measurements
Solemi (aerocom)
Month of the year

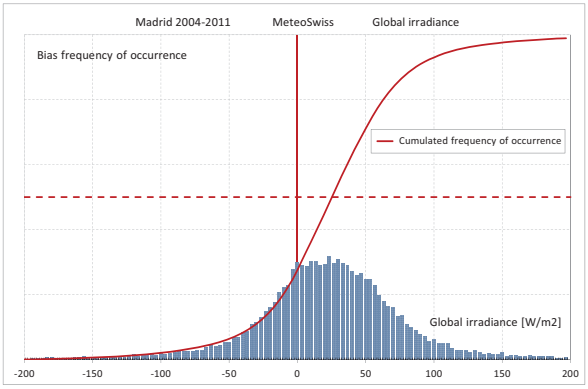

Monthly horizontal diffuse irradiation [kWh/m2h]
Solemi (aerocom)
Madrid 2004 - 2011
Measurements
Solemi (aerocom)
Month of the year

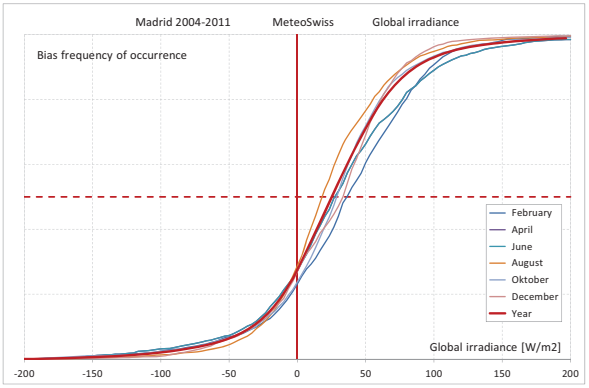

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average GHI = 423 [Wh/m2h]
number of values = 25227
mbd = 6 %
sd = 15 %
Measurements (UMP)

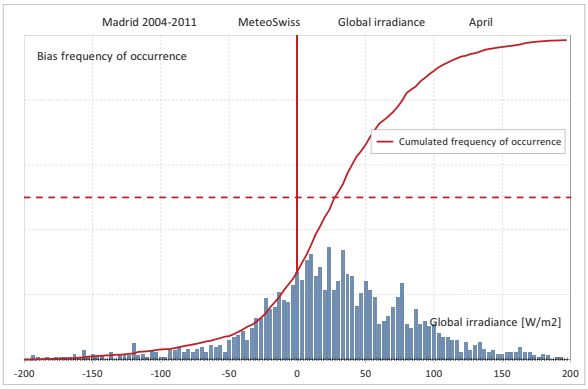

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average GHI = 4.4 [kWh/m2]
number of values = 2402
mbd = 5 %
sd = 6 %
Measurements (UMP)

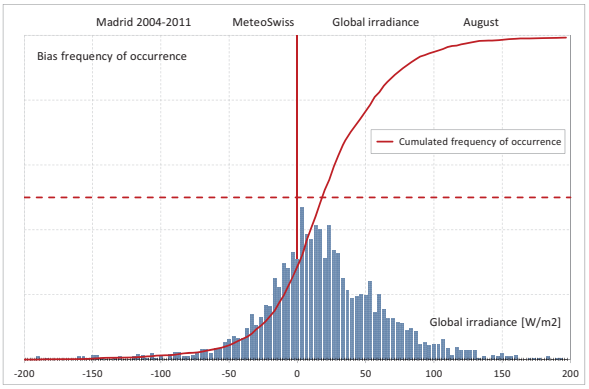

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average GHI = 123 [kWh/m2]
number of values = 87
mbd = 6 %
sd = 3 %
Measurements (UMP)

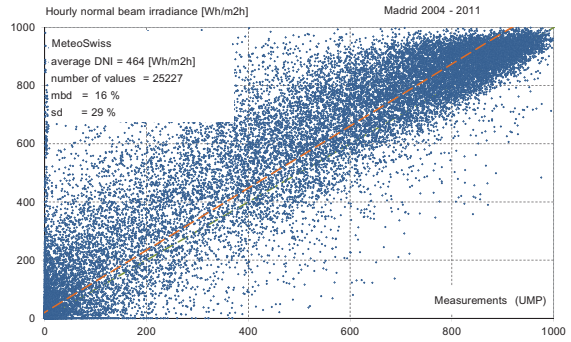

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
Measurements (UMP)

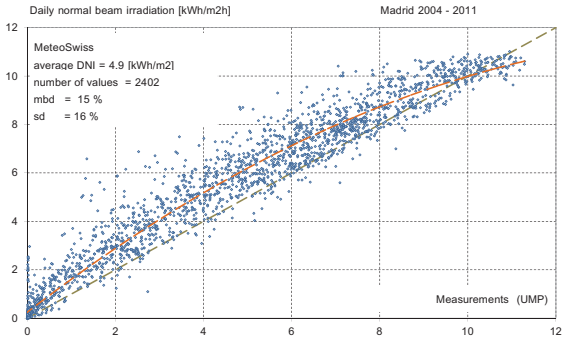

Madrid 2004-2011
MeteoSwiss
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

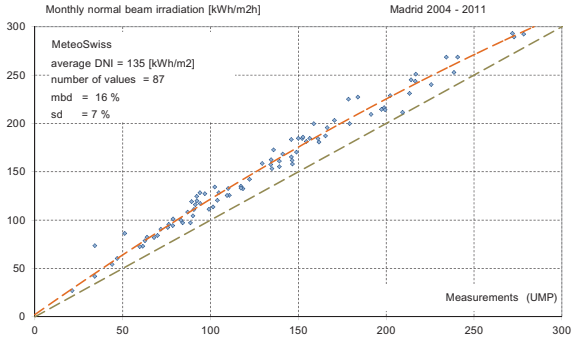

Madrid 2004-2011
MeteoSwiss
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

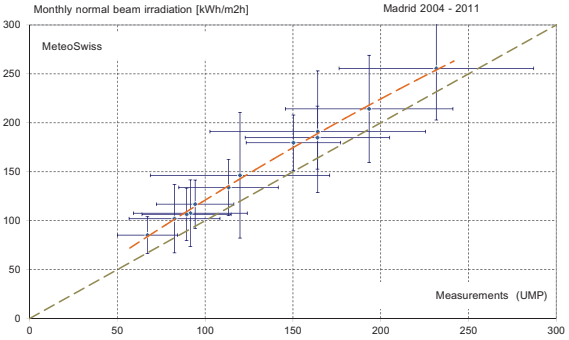

Madrid 2004-2011
MeteoSwiss
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

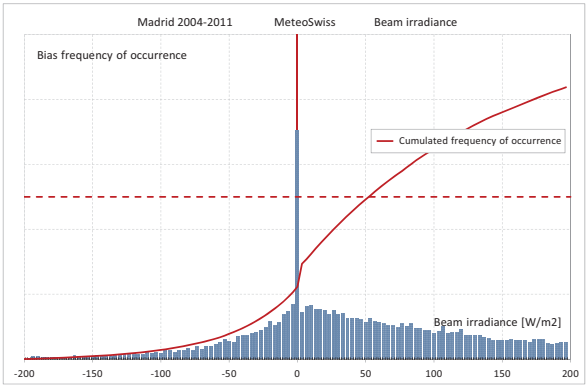

Madrid 2004-2011
MeteoSwiss
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

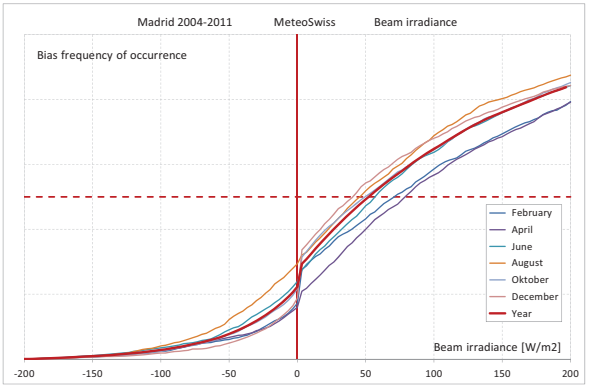

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DNI = 464 [Wh/m2h]
number of values = 25227
mbd = 16 %
sd = 29 %
Measurements (UMP)

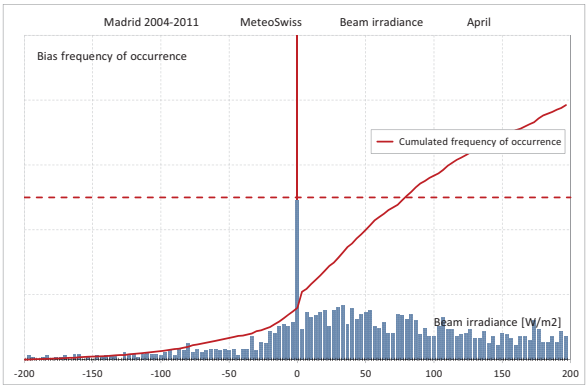

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DNI = 4.9 [kWh/m2]
number of values = 2402
mbd = 15 %
sd = 16 %
Measurements (UMP)

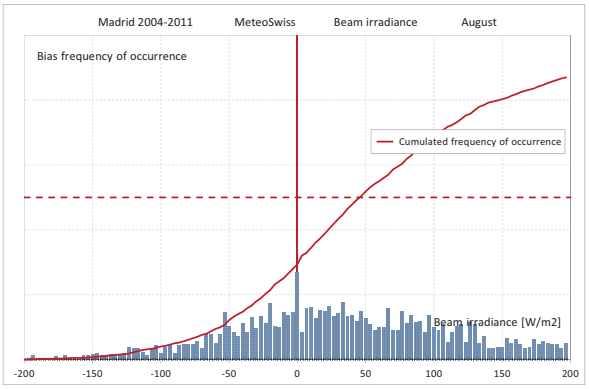

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DNI = 135 [kWh/m2]
number of values = 87
mbd = 16 %
sd = 7 %
Measurements (UMP)

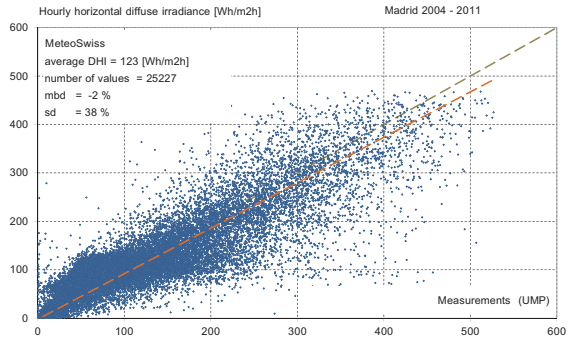

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
Measurements (UMP)

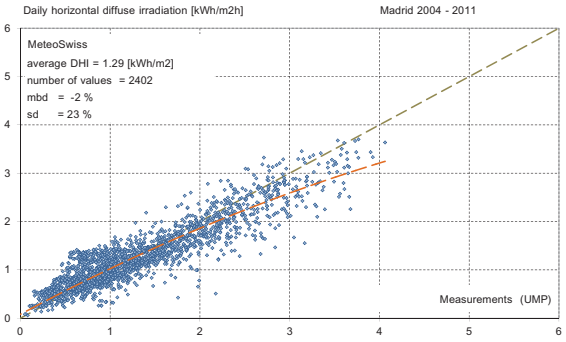

Madrid 2004-2011
MeteoSwiss
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

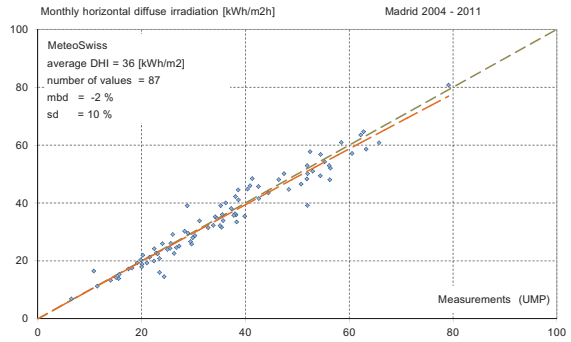

Madrid 2004-2011
MeteoSwiss
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

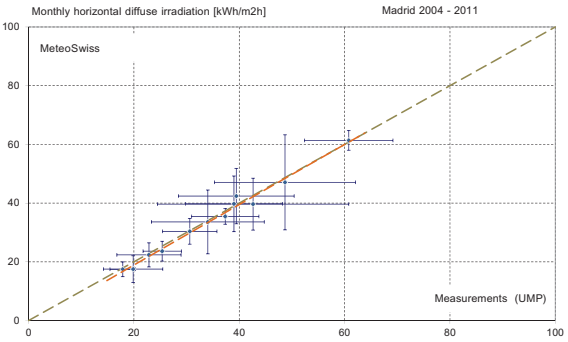

Madrid 2004-2011
MeteoSwiss
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

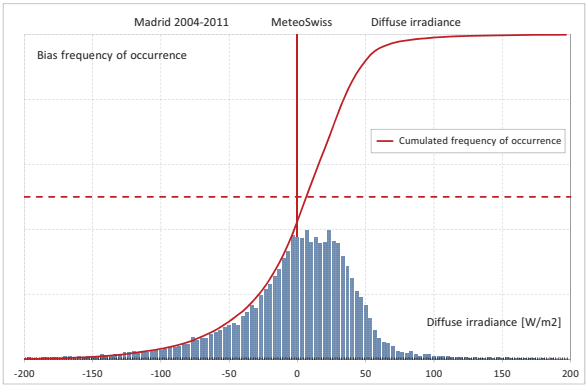

Madrid 2004-2011
MeteoSwiss
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

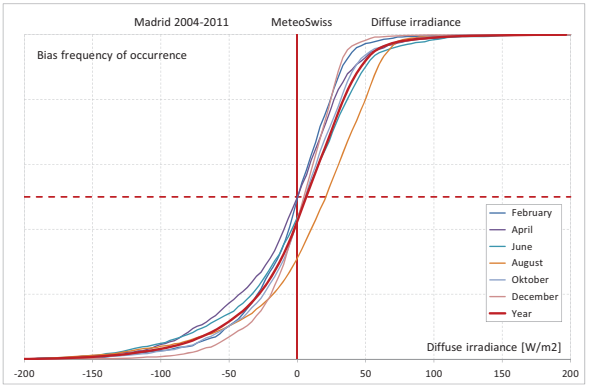

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DHI = 123 [Wh/m2h]
number of values = 25227
mbd = -2 %
sd = 38 %
Measurements (UMP)

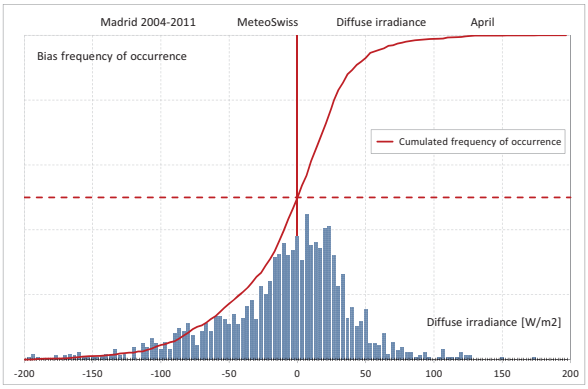

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DHI = 1.29 [kWh/m2]
number of values = 2402
mbd = -2 %
sd = 23 %
Measurements (UMP)

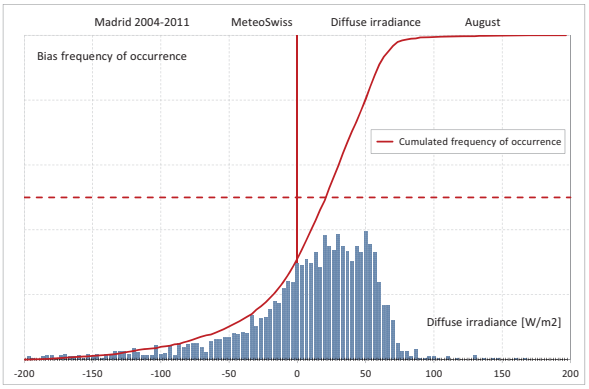

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
average DHI = 36 [kWh/m2]
number of values = 87
mbd = -2 %
sd = 10 %
Measurements (UMP)

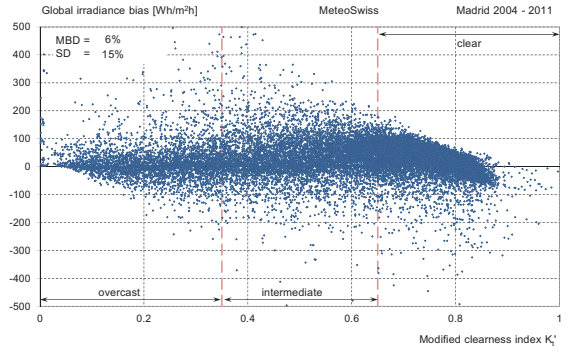

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
MeteoSwiss
Measurements (UMP)

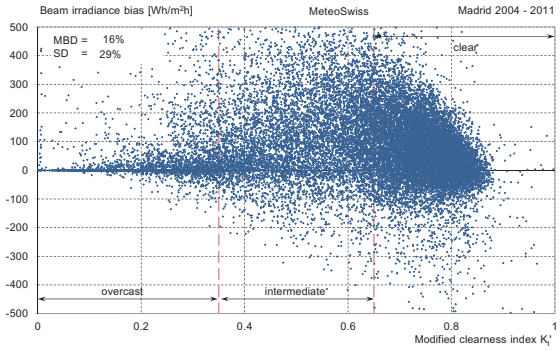

Madrid 2004-2011
MeteoSwiss
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

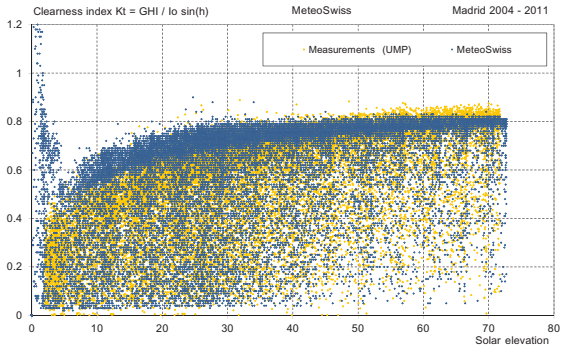

Madrid 2004-2011
MeteoSwiss
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

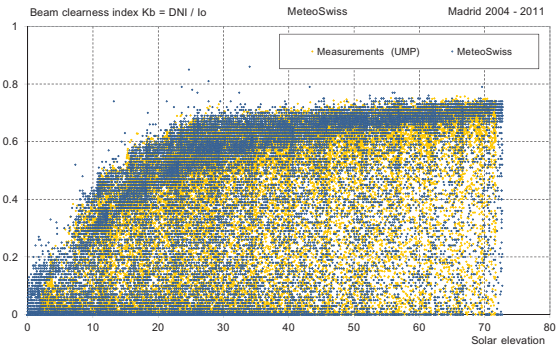

Madrid 2004-2011
MeteoSwiss
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

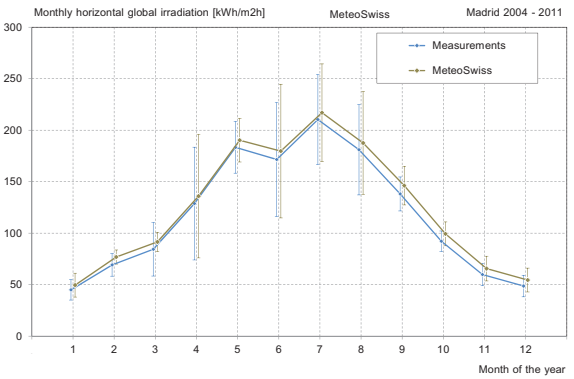

Madrid 2004-2011
MeteoSwiss
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

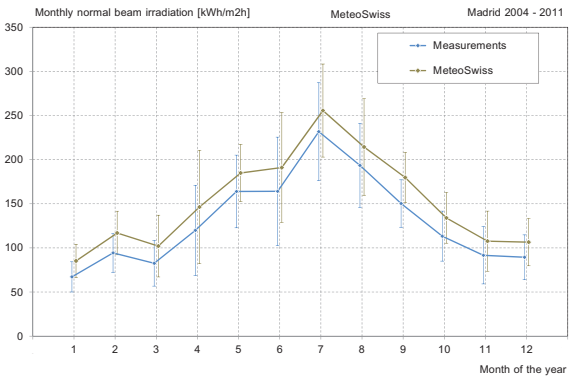

Global irradiance bias [Wh/m²h]
MeteoSwiss
Madrid 2004 - 2011
MBD = 6%
SD = 15%
clear
overcast
intermediate
Modified clearness index Kt'

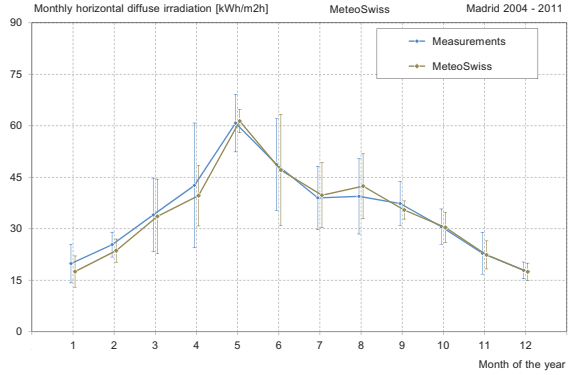

Beam irradiance bias [Wh/m²h]
MeteoSwiss
Madrid 2004 - 2011
MBD = 16%
SD = 29%
clear
overcast
intermediate
Modified clearness index Kt'

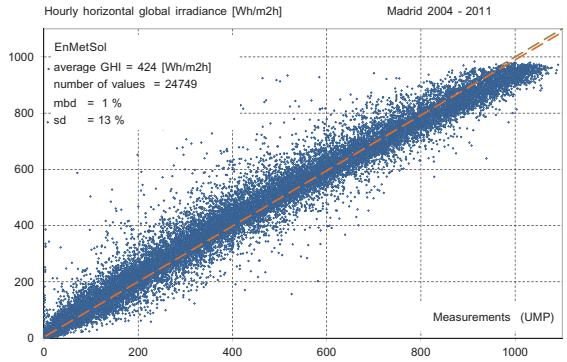

Clearness index Kt = GHI / Io sin(h)
MeteoSwiss
Madrid 2004 - 2011
Measurements (UMP)
MeteoSwiss
Solar elevation

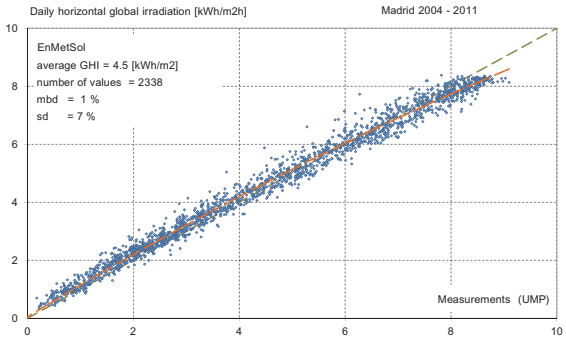

Beam clearness index Kb = DNI / Io
MeteoSwiss
Madrid 2004 - 2011
Measurements (UMP)
MeteoSwiss
Solar elevation

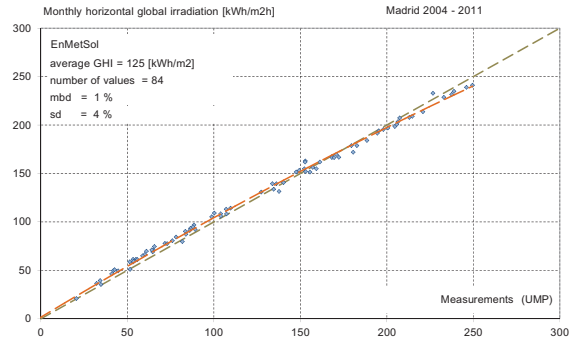

Monthly horizontal global irradiation [kWh/m2h]
MeteoSwiss
Madrid 2004 - 2011
Measurements
MeteoSwiss
Month of the year

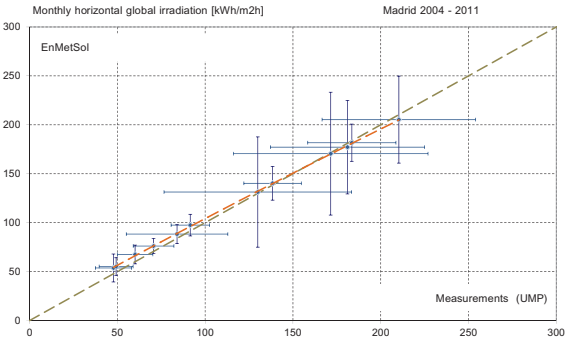

Monthly normal beam irradiation [kWh/m2h]
MeteoSwiss
Madrid 2004 - 2011
Measurements
MeteoSwiss
Month of the year

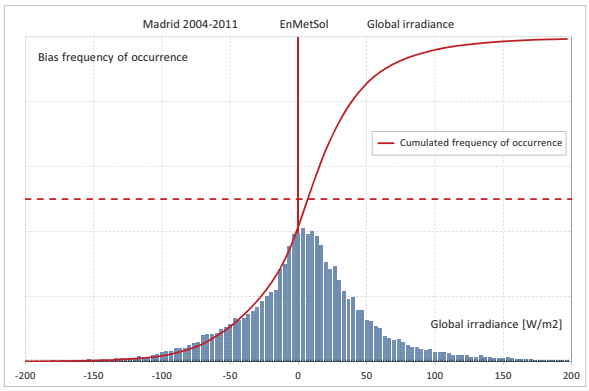

Monthly horizontal diffuse irradiation [kWh/m2h]
MeteoSwiss
Madrid 2004 - 2011
Measurements
MeteoSwiss
Month of the year

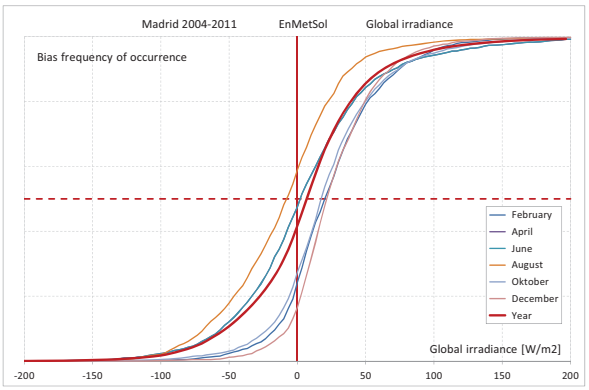

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
EnMetSol
average GHI = 424 [Wh/m2h]
number of values = 24749
mbd = 1 %
sd = 13 %
Measurements (UMP)

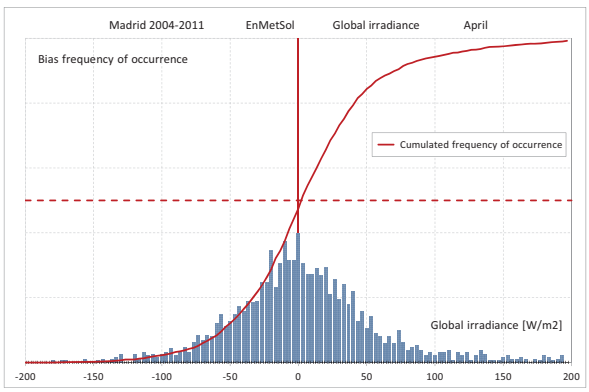

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average GHI = 4.5 [kWh/m2]
number of values = 2338
mbd = 1 %
sd = 7 %
Measurements (UMP)

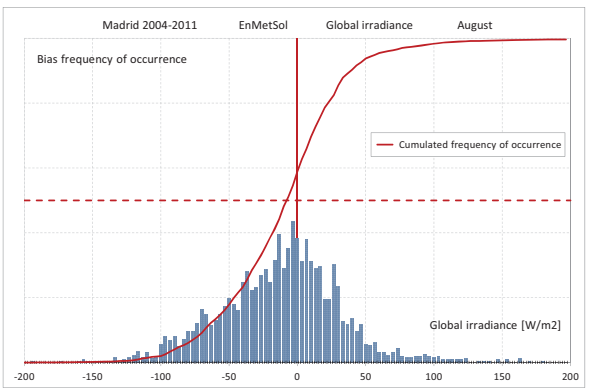

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average GHI = 125 [kWh/m2]
number of values = 84
mbd = 1 %
sd = 4 %
Measurements (UMP)

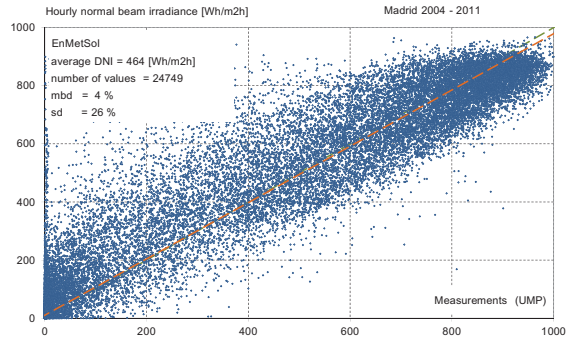

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
Measurements (UMP)

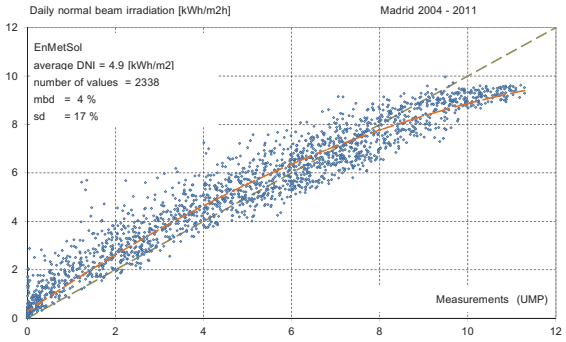

Madrid 2004-2011
EnMetSol
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

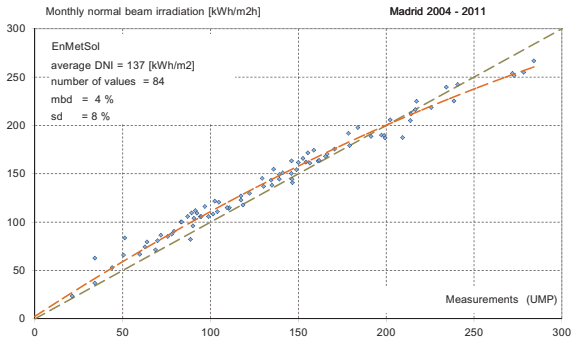

Madrid 2004-2011
EnMetSol
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

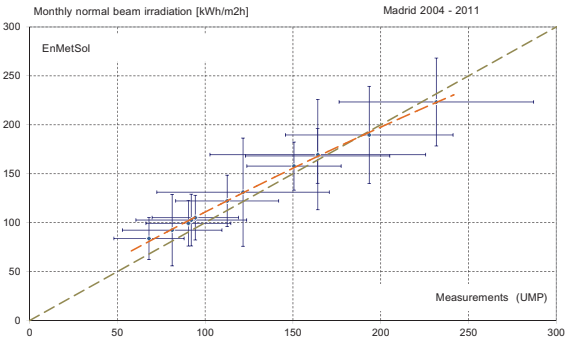

Madrid 2004-2011
EnMetSol
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

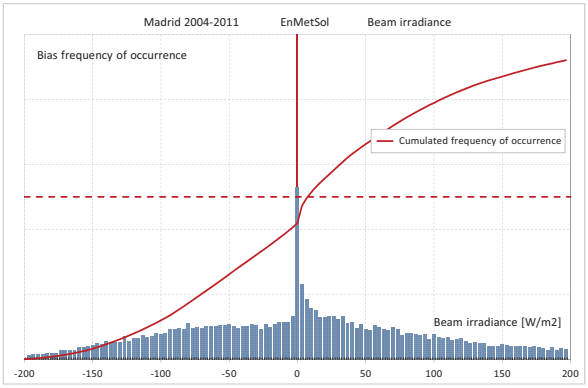

Madrid 2004-2011
EnMetSol
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

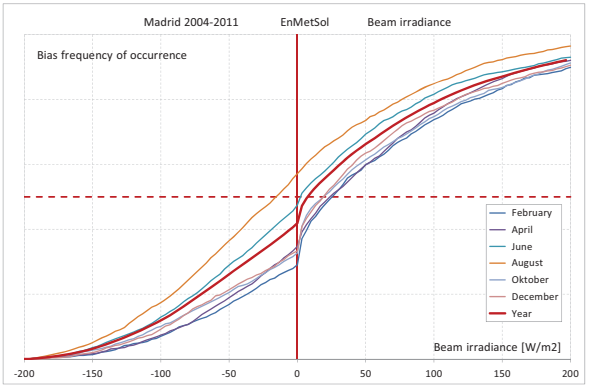

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
EnMetSol
average DNI = 464 [Wh/m2h]
number of values = 24749
mbd = 4 %
sd = 26 %
Measurements (UMP)

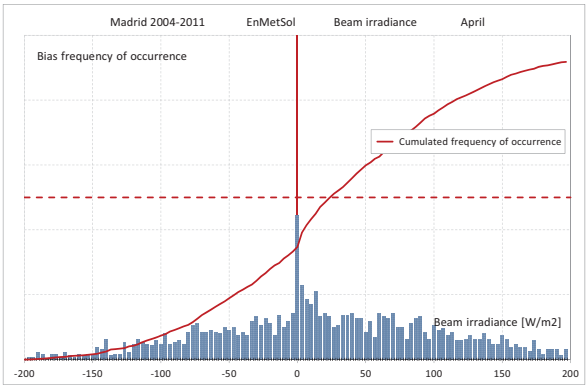

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average DNI = 4.9 [kWh/m2]
number of values = 2338
mbd = 4 %
sd = 17 %
Measurements (UMP)

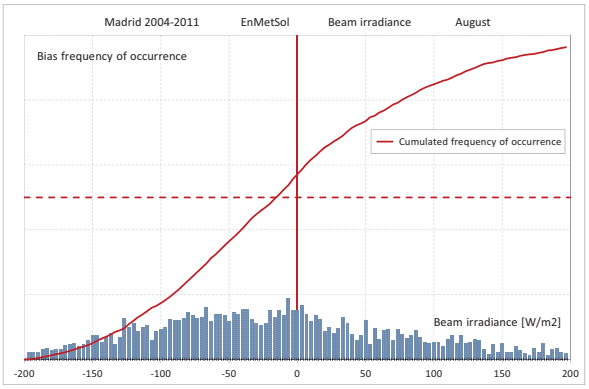

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average DNI = 137 [kWh/m2]
number of values = 84
mbd = 4 %
sd = 8 %
Measurements (UMP)

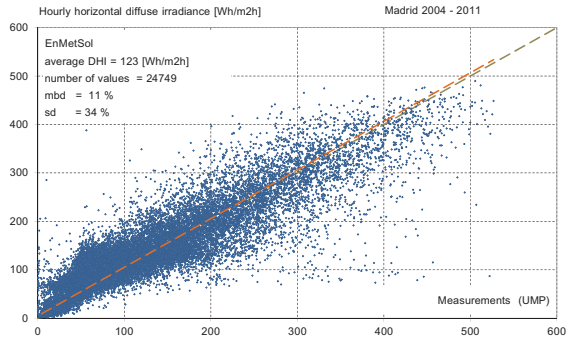

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
Measurements (UMP)

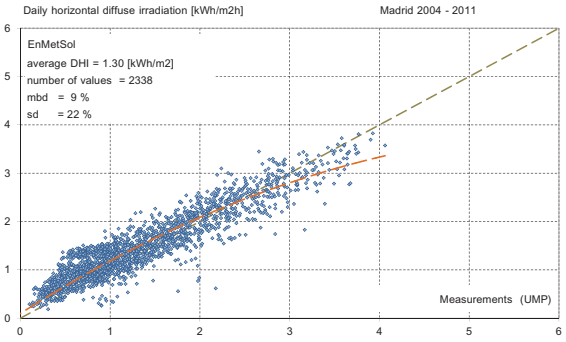

Madrid 2004-2011
EnMetSol
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

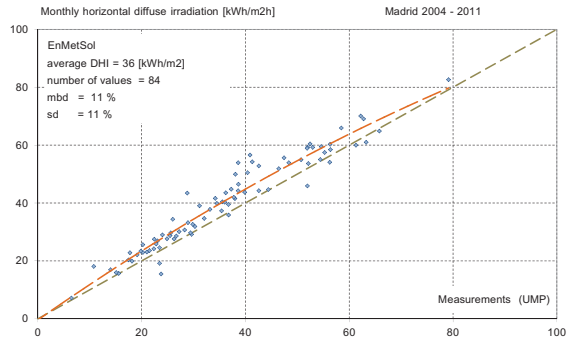

Madrid 2004-2011
EnMetSol
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

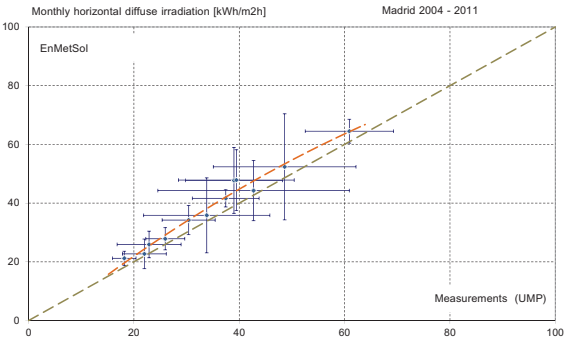

Madrid 2004-2011
EnMetSol
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

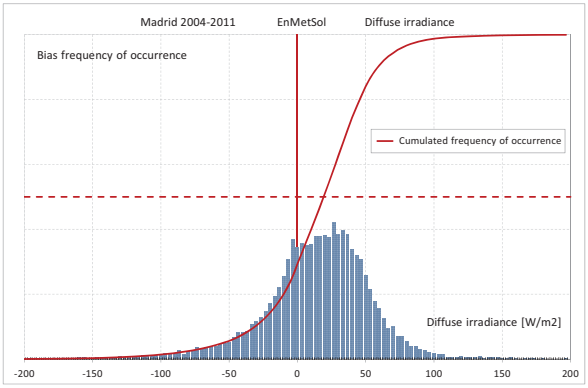

Madrid 2004-2011
EnMetSol
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

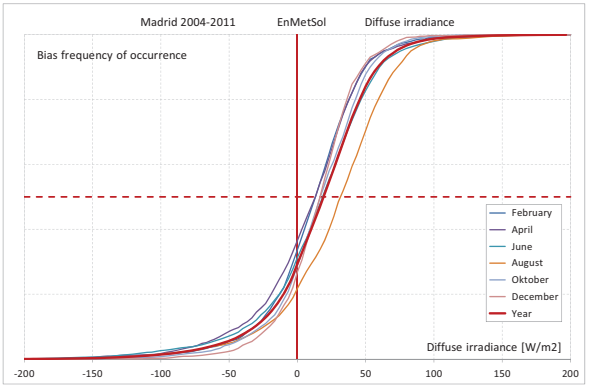

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
EnMetSol
average DHI = 123 [Wh/m2h]
number of values = 24749
mbd = 11 %
sd = 34 %
Measurements (UMP)

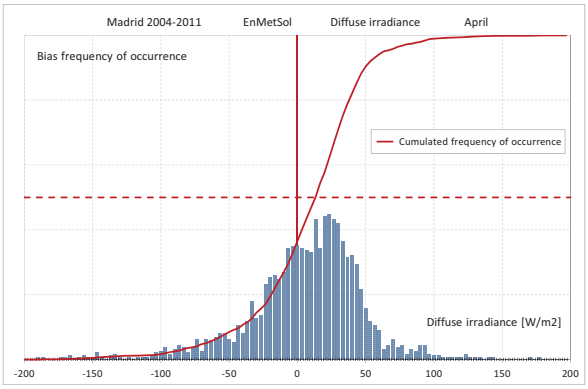

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average DHI = 1.30 [kWh/m2]
number of values = 2338
mbd = 9 %
sd = 22 %
Measurements (UMP)

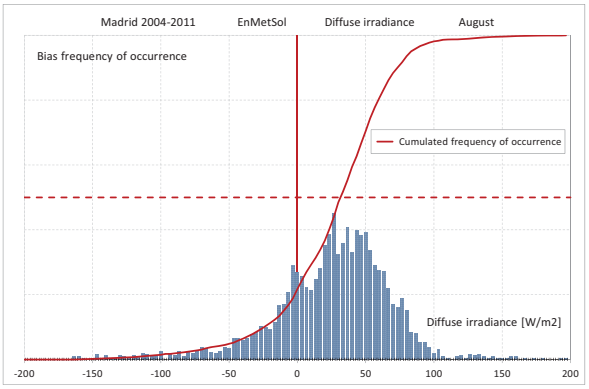

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
average DHI = 36 [kWh/m2]
number of values = 84
mbd = 11 %
sd = 11 %
Measurements (UMP)

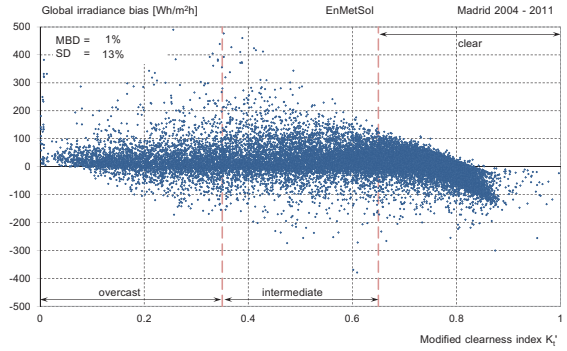

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
EnMetSol
Measurements (UMP)

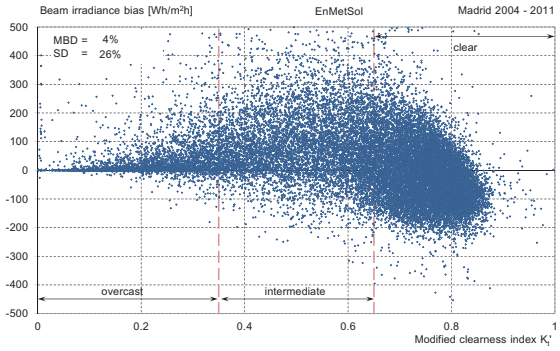

Madrid 2004-2011
EnMetSol
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

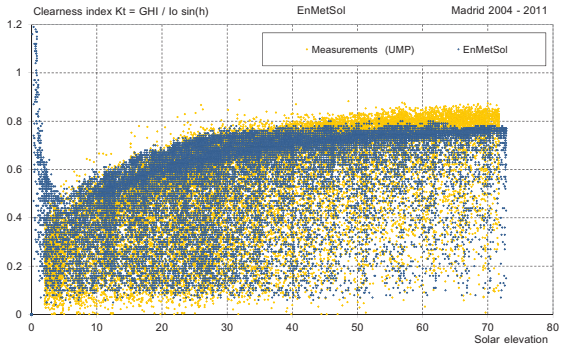

Madrid 2004-2011
EnMetSol
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

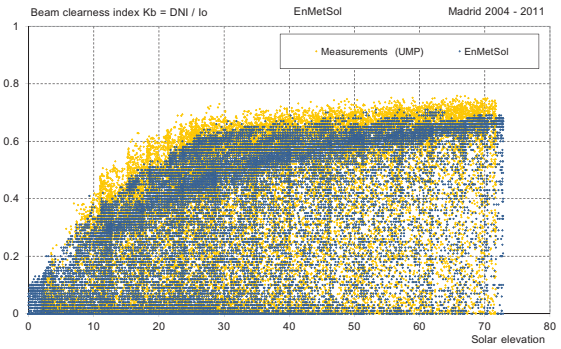

Madrid 2004-2011
EnMetSol
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

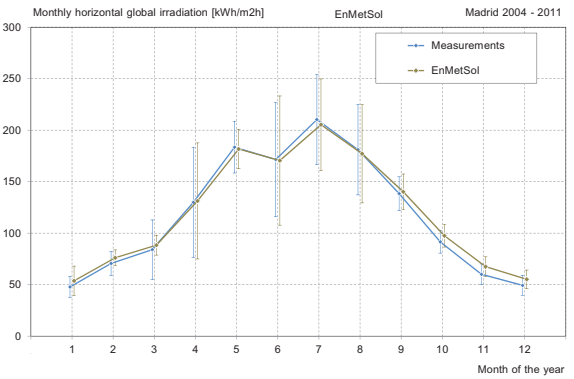

Madrid 2004-2011
EnMetSol
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

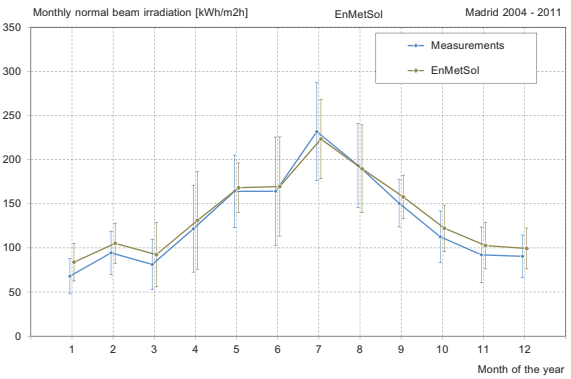

Global irradiance bias [Wh/m²h]
EnMetSol
Madrid 2004 - 2011
MBD = 1%
SD = 13%
clear
overcast
intermediate
Modified clearness index Kt'

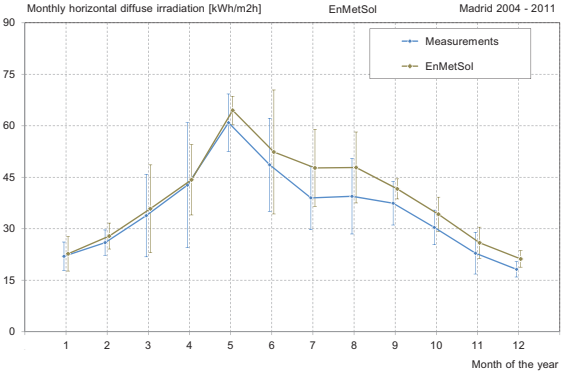

Beam irradiance bias [Wh/m²h]
EnMetSol
Madrid 2004 - 2011
MBD = 4%
SD = 26%
clear
overcast
intermediate
Modified clearness index Kt'

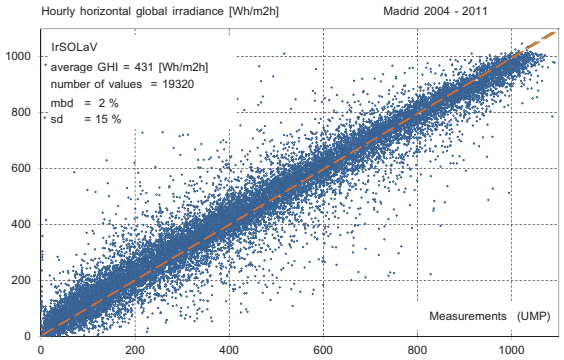

Clearness index Kt = GHI / Io sin(h)
EnMetSol
Madrid 2004 - 2011
Measurements (UMP)
EnMetSol
Solar elevation

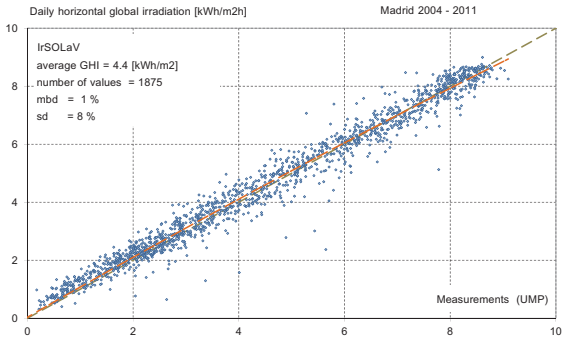

Beam clearness index Kb = DNI / Io
EnMetSol
Madrid 2004 - 2011
Measurements (UMP)
EnMetSol
Solar elevation

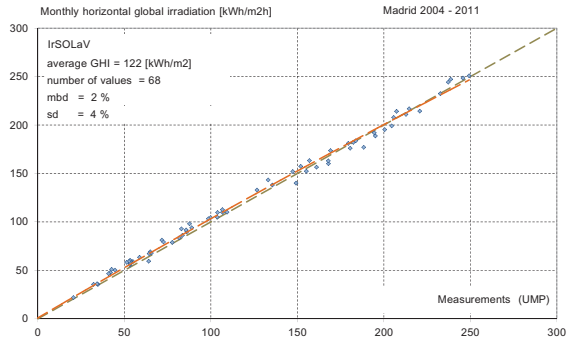

Monthly horizontal global irradiation [kWh/m2h]
EnMetSol
Madrid 2004 - 2011
Measurements
EnMetSol
Month of the year

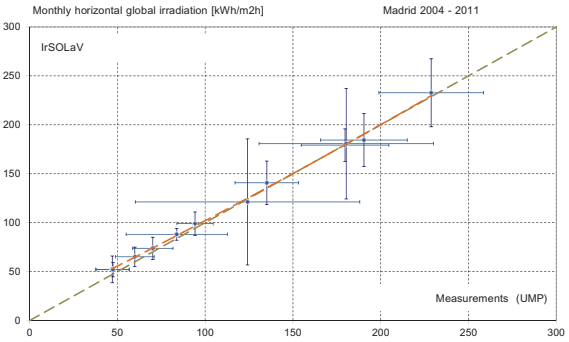

Monthly normal beam irradiation [kWh/m2h]
EnMetSol
Madrid 2004 - 2011
Measurements
EnMetSol
Month of the year

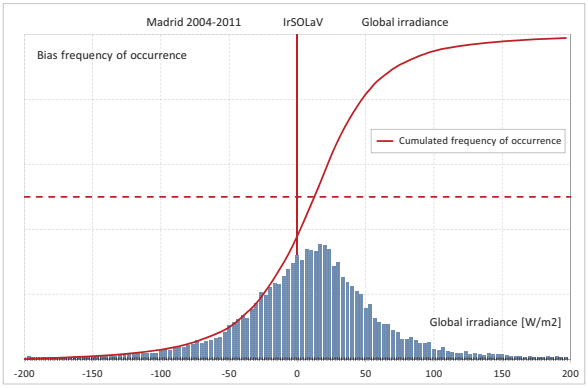

Monthly horizontal diffuse irradiation [kWh/m2h]
EnMetSol
Madrid 2004 - 2011
Measurements
EnMetSol
Month of the year

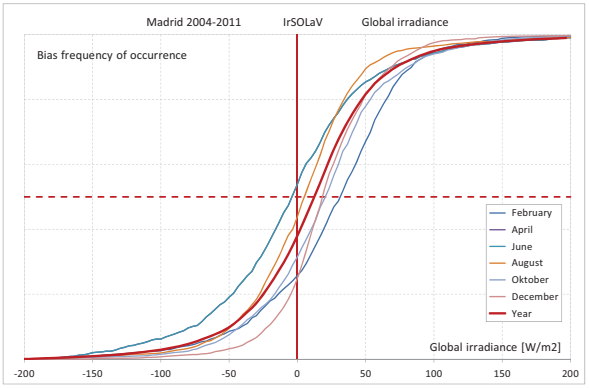

Hourly horizontal global irradiance [Wh/m2h]
Madrid 2004 - 2011
IrSOLaV
average GHI = 431 [Wh/m2h]
number of values = 19320
mbd = 2 %
sd = 15 %
Measurements (UMP)

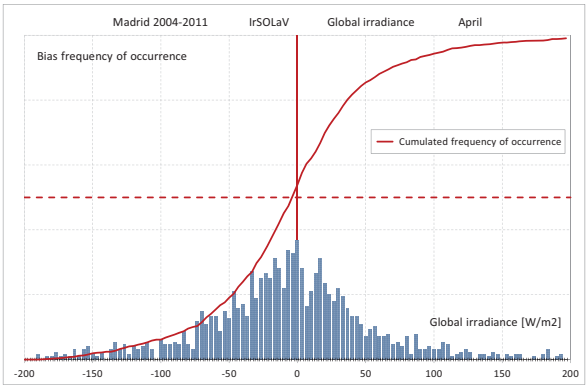

Daily horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average GHI = 4.4 [kWh/m2]
number of values = 1875
mbd = 1 %
sd = 8 %
Measurements (UMP)

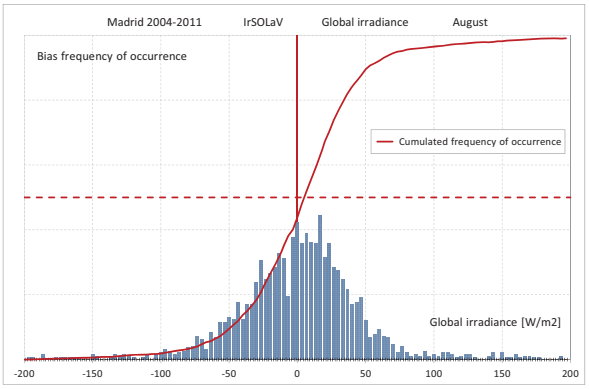

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average GHI = 122 [kWh/m2]
number of values = 68
mbd = 2 %
sd = 4 %
Measurements (UMP)

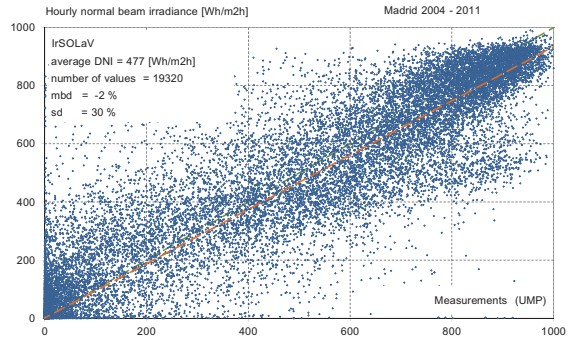

Monthly horizontal global irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
Measurements (UMP)

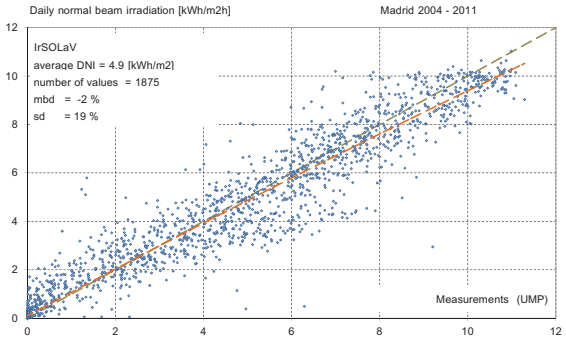

Madrid 2004-2011
IrSOLaV
Global irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

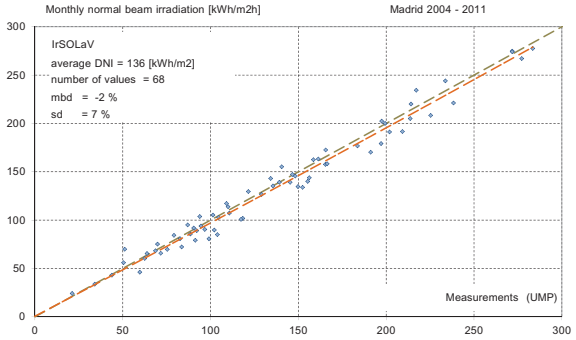

Madrid 2004-2011
IrSOLaV
Global irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Global irradiance [W/m2]

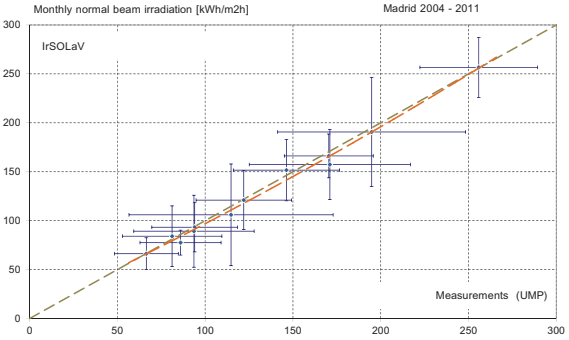

Madrid 2004-2011
IrSOLaV
Global irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

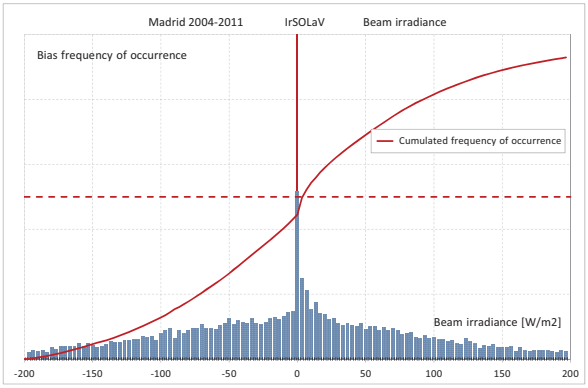

Madrid 2004-2011
IrSOLaV
Global irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Global irradiance [W/m2]

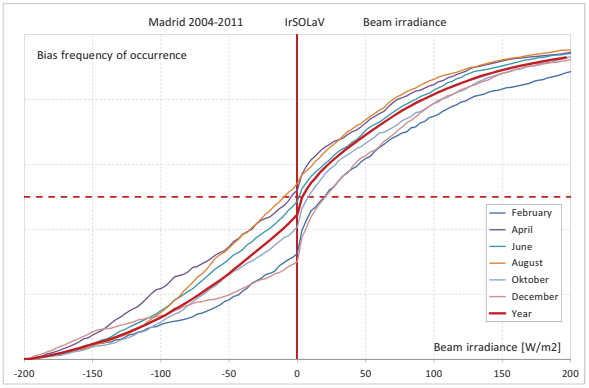

Hourly normal beam irradiance [Wh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DNI = 477 [Wh/m2h]
number of values = 19320
mbd = -2 %
sd = 30 %
Measurements (UMP)

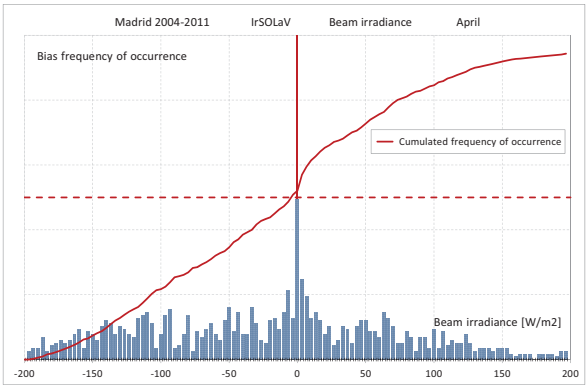

Daily normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DNI = 4.9 [kWh/m2]
number of values = 1875
mbd = -2 %
sd = 19 %
Measurements (UMP)

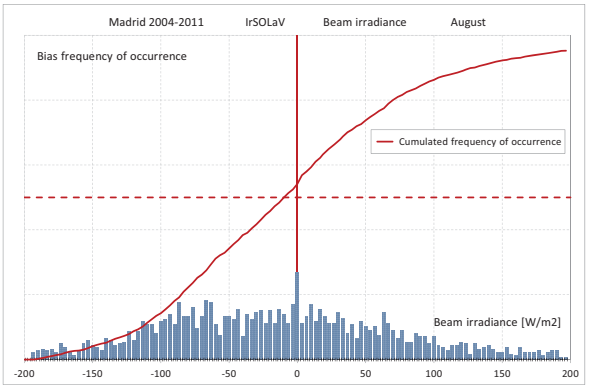

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DNI = 136 [kWh/m2]
number of values = 68
mbd = -2 %
sd = 7 %
Measurements (UMP)

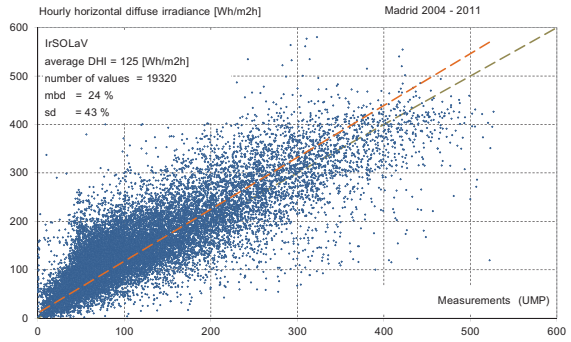

Monthly normal beam irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
Measurements (UMP)

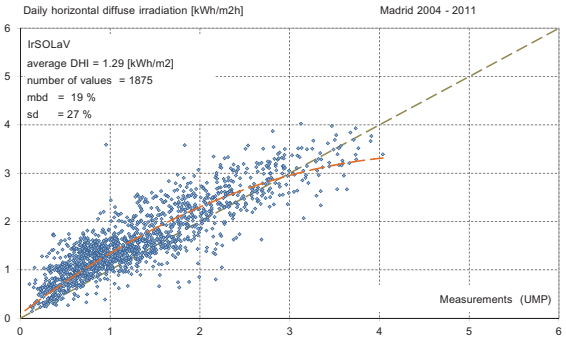

Madrid 2004-2011
IrSOLaV
Beam irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

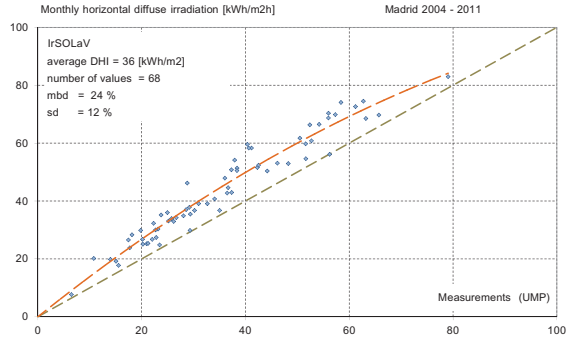

Madrid 2004-2011
IrSOLaV
Beam irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Beam irradiance [W/m2]

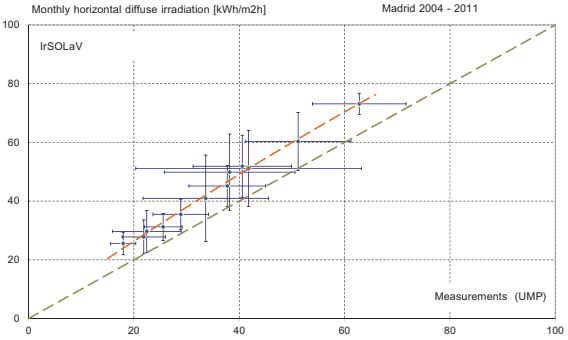

Madrid 2004-2011
IrSOLaV
Beam irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

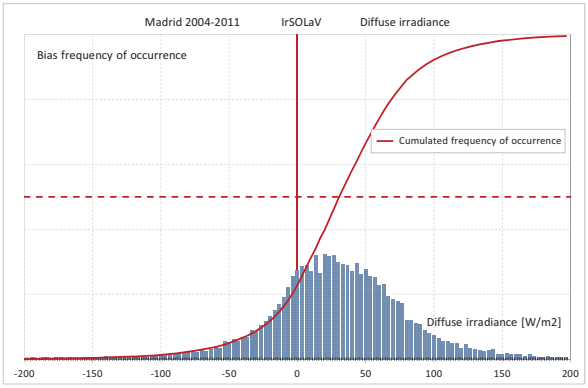

Madrid 2004-2011
IrSOLaV
Beam irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Beam irradiance [W/m2]

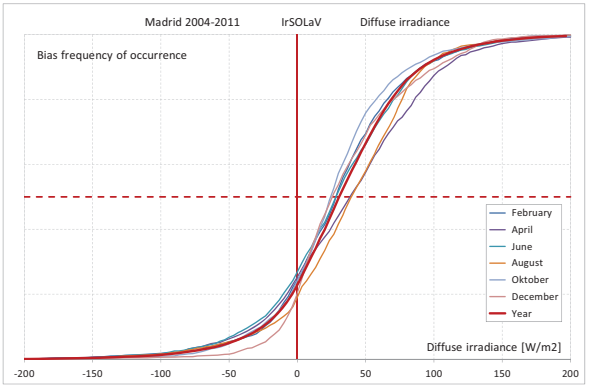

Hourly horizontal diffuse irradiance [Wh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DHI = 125 [Wh/m2h]
number of values = 19320
mbd = 24 %
sd = 43 %
Measurements (UMP)

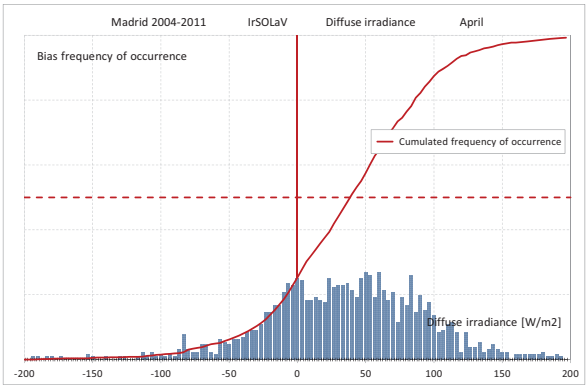

Daily horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DHI = 1.29 [kWh/m2]
number of values = 1875
mbd = 19 %
sd = 27 %
Measurements (UMP)

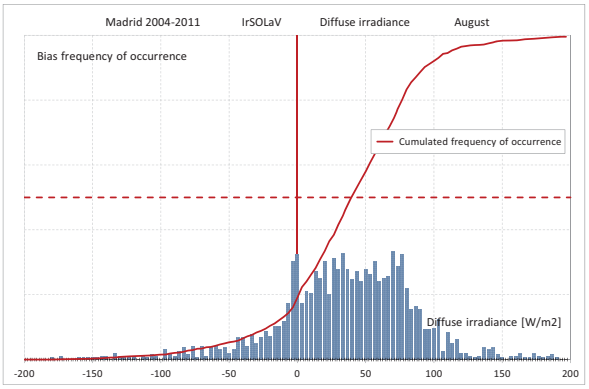

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
average DHI = 36 [kWh/m2]
number of values = 68
mbd = 24 %
sd = 12 %
Measurements (UMP)

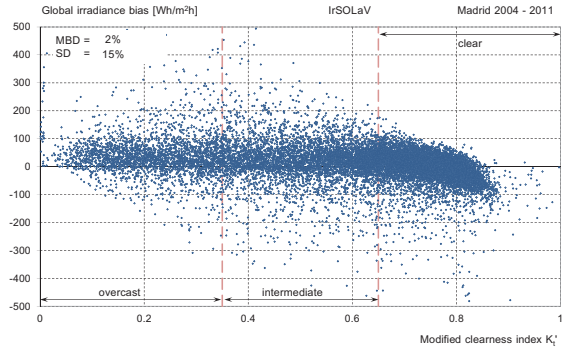

Monthly horizontal diffuse irradiation [kWh/m2h]
Madrid 2004 - 2011
IrSOLaV
Measurements (UMP)

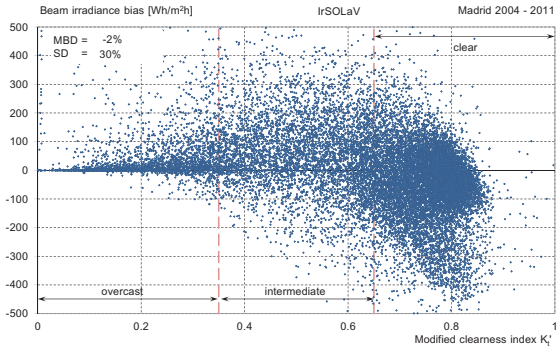

Madrid 2004-2011
IrSOLaV
Diffuse irradiance
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

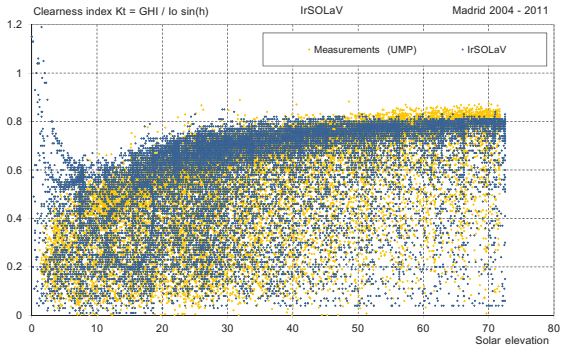

Madrid 2004-2011
IrSOLaV
Diffuse irradiance
Bias frequency of occurrence
February
April
June
August
Oktober
December
Year
Diffuse irradiance [W/m2]

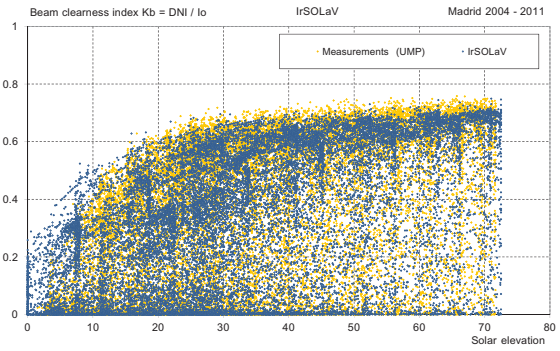

Madrid 2004-2011
IrSOLaV
Diffuse irradiance
April
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

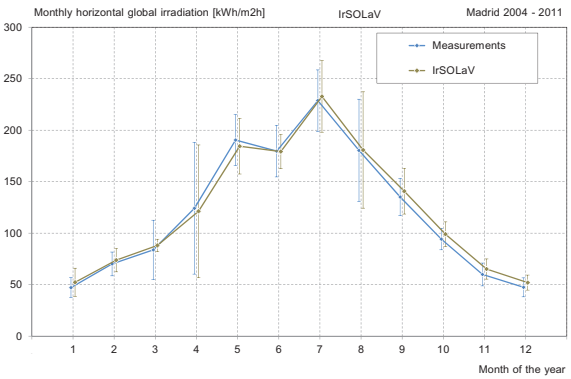

Madrid 2004-2011
IrSOLaV
Diffuse irradiance
August
Bias frequency of occurrence
Cumulated frequency of occurrence
Diffuse irradiance [W/m2]

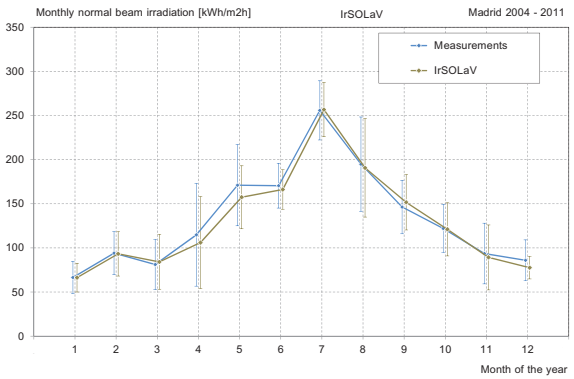

Global irradiance bias [Wh/m²h]
IrSOLaV
Madrid 2004 - 2011
MBD = 2%
SD = 15%
clear
overcast
intermediate
Modified clearness index Kt'

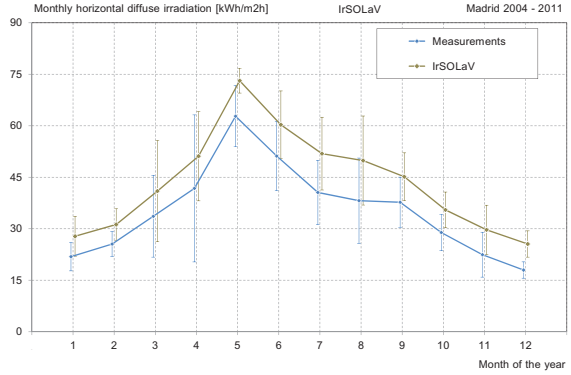

Beam irradiance bias [Wh/m²h]
IrSOLaV
Madrid 2004 - 2011
MBD = -2%
SD = 30%
clear
overcast
intermediate
Modified clearness index Kt'

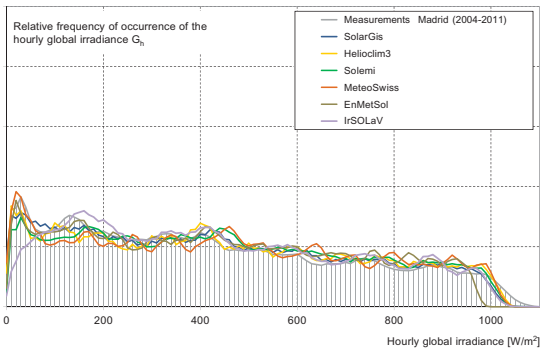

Clearness index Kt = GHI / Io sin(h)
IrSOLaV
Madrid 2004 - 2011
Measurements (UMP)
IrSOLaV
Solar elevation

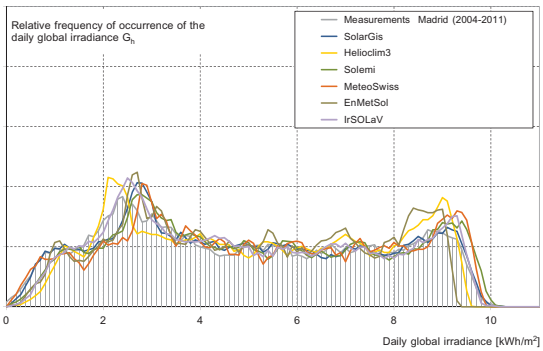

Beam clearness index Kb = DNI / Io
IrSOLaV
Madrid 2004 - 2011
Measurements (UMP)
IrSOLaV
Solar elevation

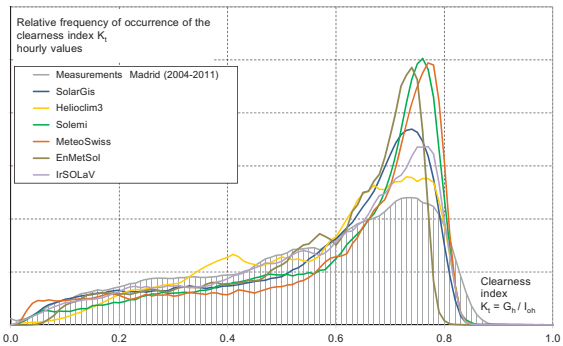

Monthly horizontal global irradiation [kWh/m2h]
IrSOLaV
Madrid 2004 - 2011
Measurements
IrSOLaV
Month of the year

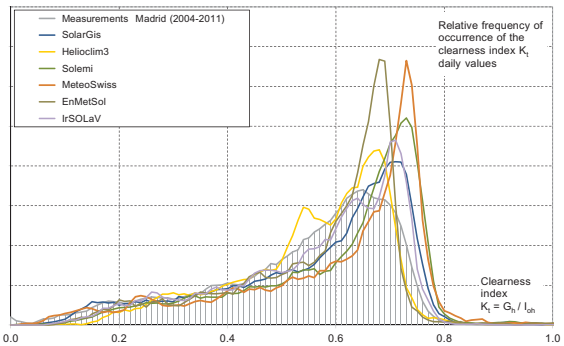

Monthly normal beam irradiation [kWh/m2h]
IrSOLaV
Madrid 2004 - 2011
Measurements
IrSOLaV
Month of the year

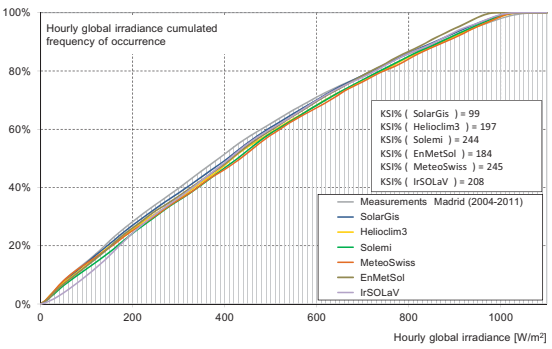

Monthly horizontal diffuse irradiation [kWh/m2h]
IrSOLaV
Madrid 2004 - 2011
Measurements
IrSOLaV
Month of the year

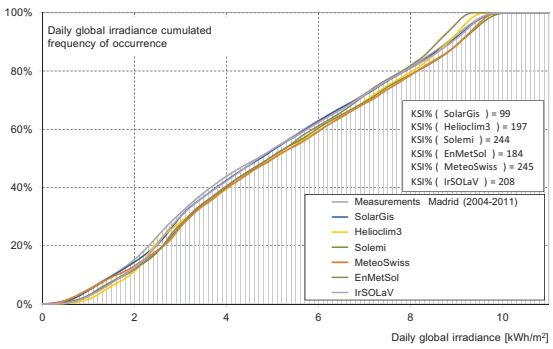

Relative frequency of occurrence of the hourly global irradiance G_h
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
0
200
400
600
800
1000
Hourly global irradiance [W/m²]

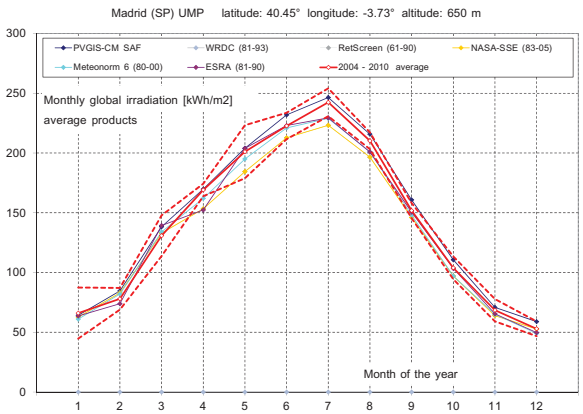

Relative frequency of occurrence of the daily global irradiance G_h
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
0
2
4
6
8
10
Daily global irradiance [kWh/m²]

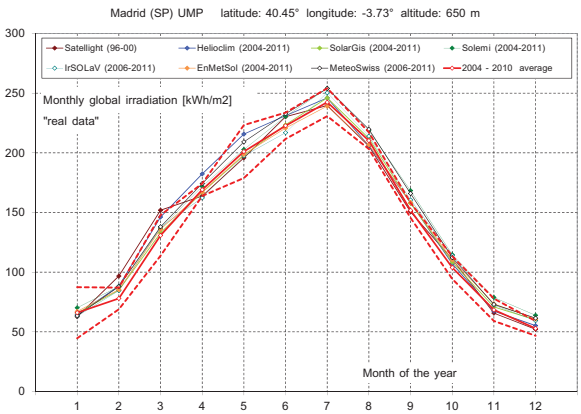

Relative frequency of occurrence of the clearness index K_t hourly values
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
Clearness index $K_t = G_h / I_{oh}$
0.0
0.2
0.4
0.6
0.8
1.0

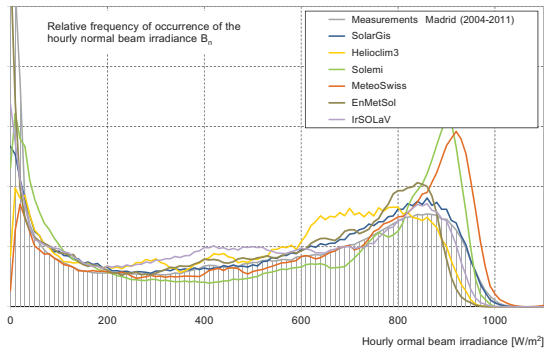

Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
Relative frequency of occurrence of the clearness index K_t daily values
Clearness index $K_t = G_h / I_{oh}$
0.0
0.2
0.4
0.6
0.8
1.0

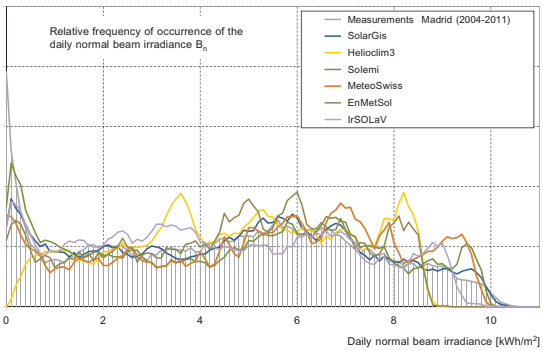

Hourly global irradiance cumulated frequency of occurrence
KSI% (SolarGis) = 99
KSI% (Helioclim3) = 197
KSI% (Solemi) = 244
KSI% (EnMetSol) = 184
KSI% (MeteoSwiss) = 245
KSI% (IrSOLaV) = 208
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
100%
80%
60%
40%
20%
0%
0
200
400
600
800
1000
Hourly global irradiance [W/m²]

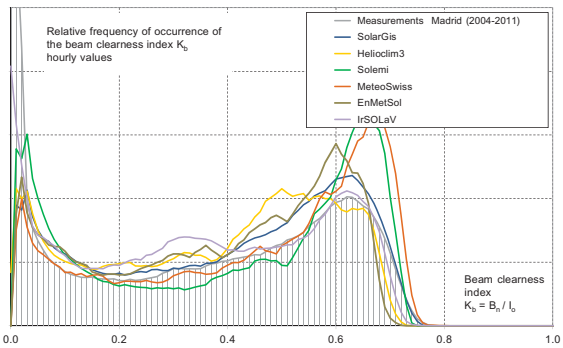

Daily global irradiance cumulated frequency of occurrence
KSI% (SolarGis) = 99
KSI% (Helioclim3) = 197
KSI% (Solemi) = 244
KSI% (EnMetSol) = 184
KSI% (MeteoSwiss) = 245
KSI% (IrSOLaV) = 208
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
Daily global irradiance [kWh/m²]

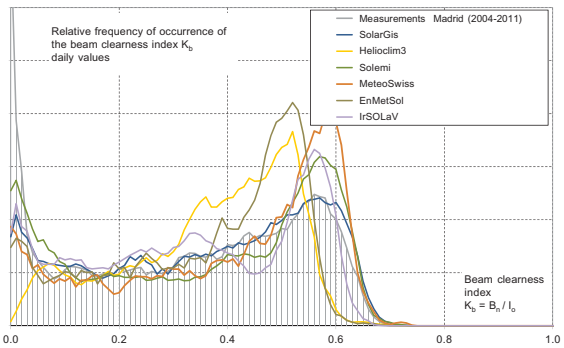

Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
PVGIS-CM SAF
WRDC (81-93)
RetScreen (61-90)
NASA-SSE (83-05)
Meteonorm 6 (80-00)
ESRA (81-90)
2004 - 2010 average
Monthly global irradiation [kWh/m2]
average products
Month of the year
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12

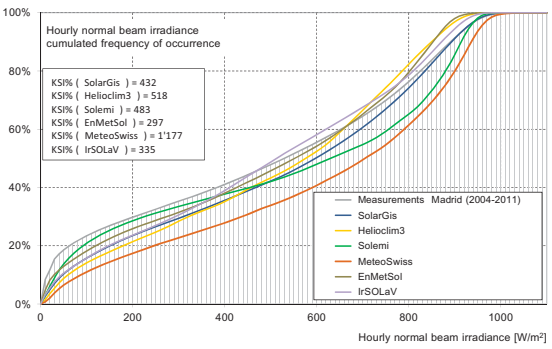

Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
Satellight (96-00)
Helioclim (2004-2011)
SolarGis (2004-2011)
Solemi (2004-2011)
IrSOLaV (2006-2011)
EnMetSol (2004-2011)
MeteoSwiss (2006-2011)
2004 - 2010 average
Monthly global irradiation [kWh/m2]
"real data"
Month of the year
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12

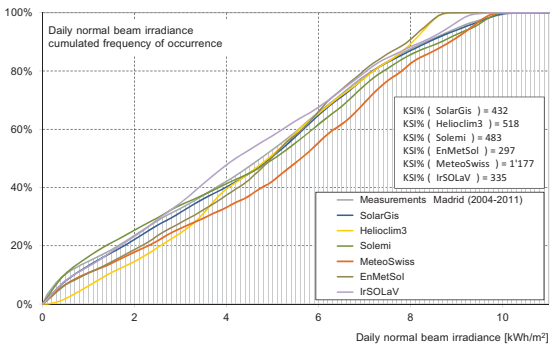

Relative frequency of occurrence of the hourly normal beam irradiance B_n
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
0
200
400
600
800
1000
Hourly ormal beam irradiance [W/m²]

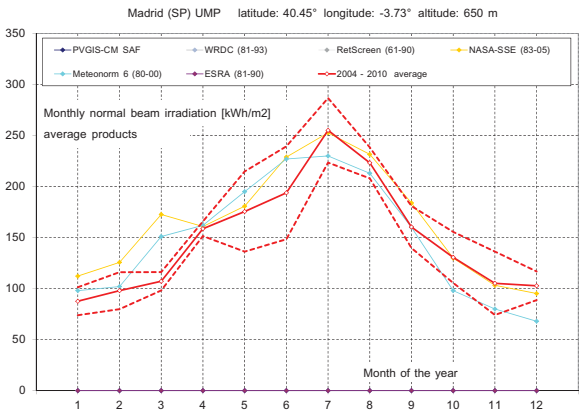

Relative frequency of occurrence of the daily normal beam irradiance B_n
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
0
2
4
6
8
10
Daily normal beam irradiance [kWh/m²]

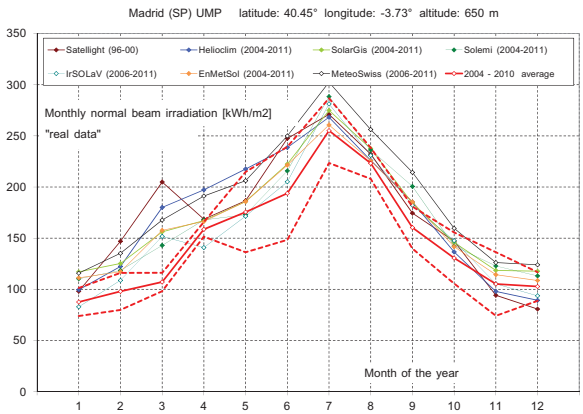

Relative frequency of occurrence of the beam clearness index K_b hourly values
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
Beam clearness index
$K_b = B_n / I_o$
0.0
0.2
0.4
0.6
0.8
1.0

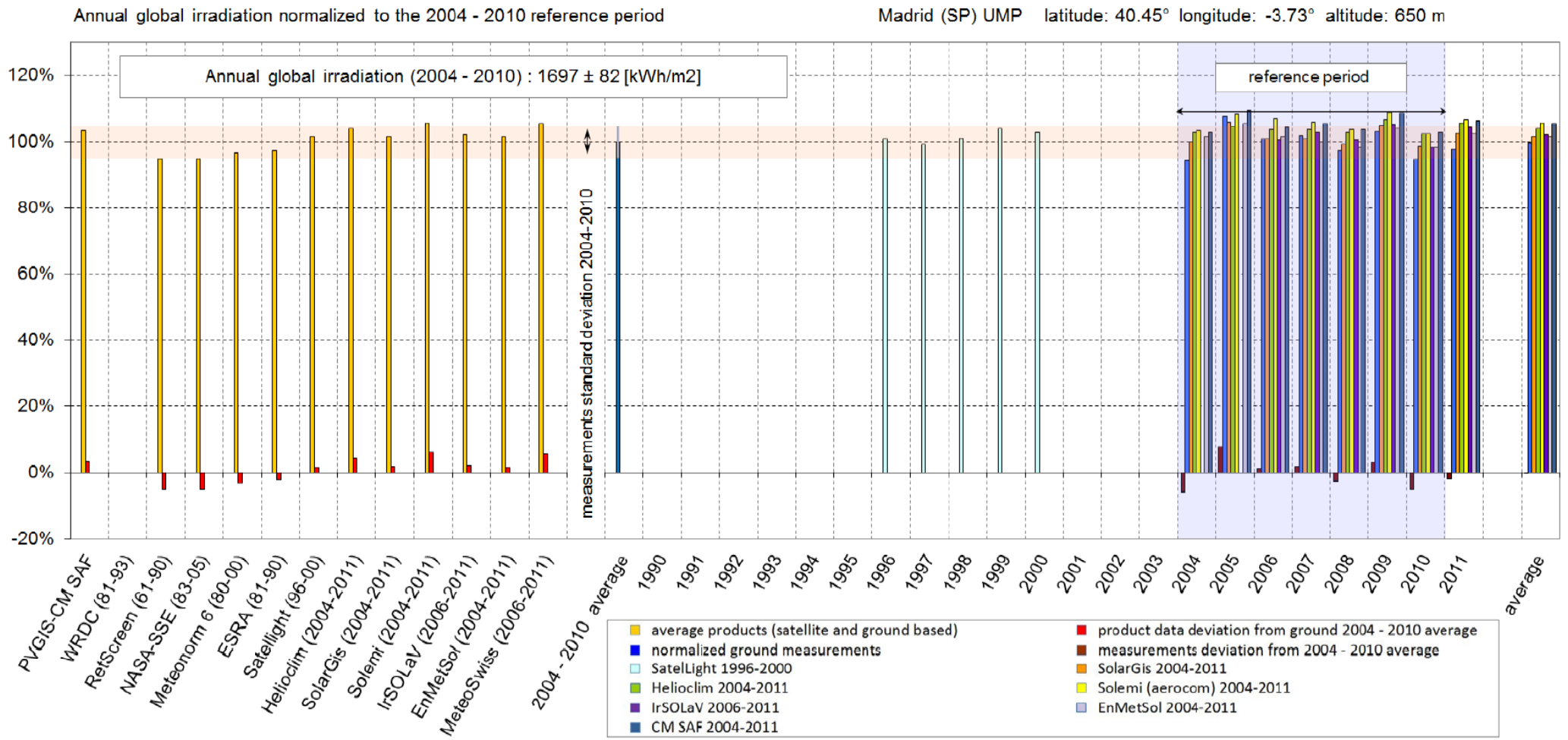

Relative frequency of occurrence of the beam clearness index K_b daily values
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
Beam clearness index
$K_b = B_n / I_o$
0.0
0.2
0.4
0.6
0.8
1.0

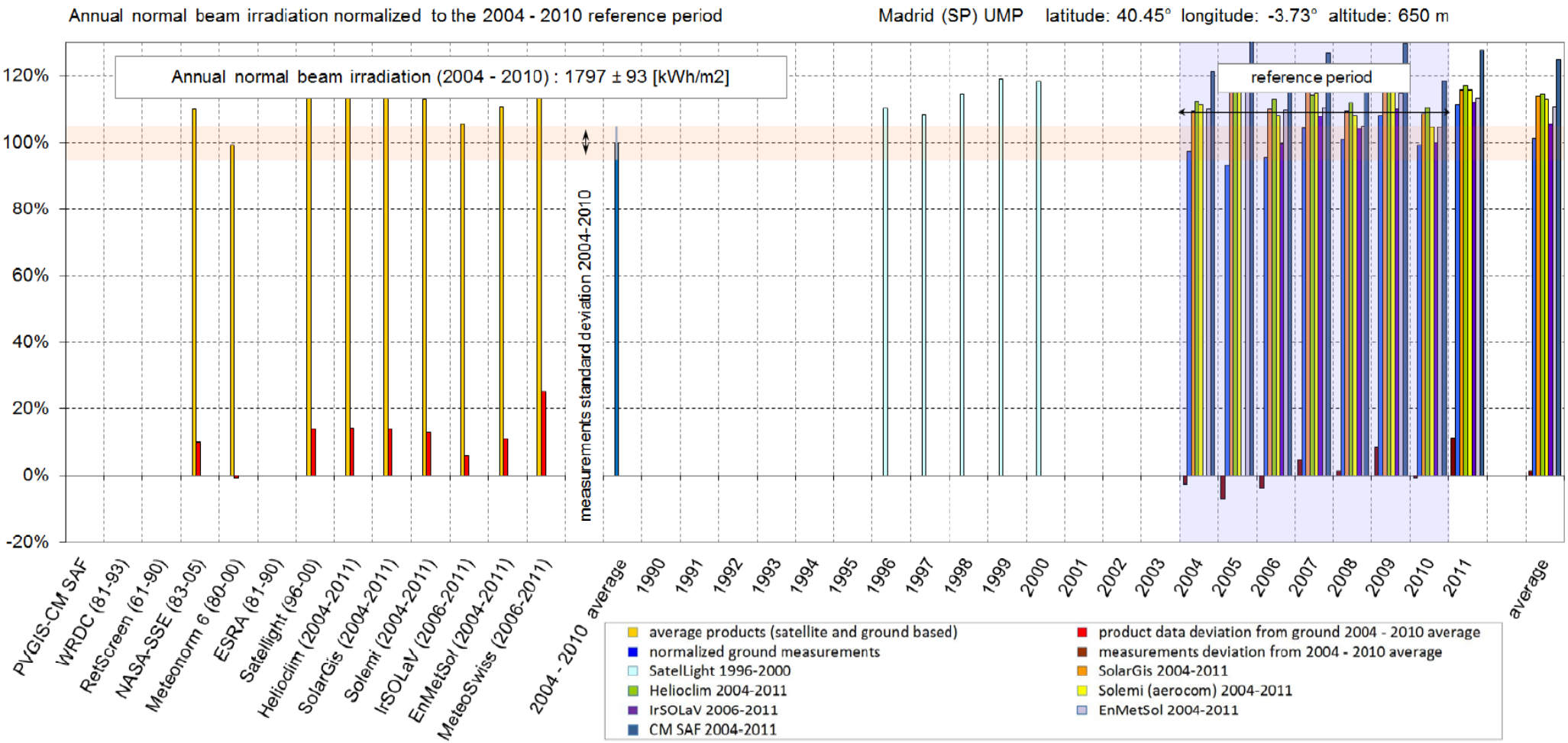

Hourly normal beam irradiance cumulated frequency of occurrence
KSI% (SolarGis) = 432
KSI% (Helioclim3) = 518
KSI% (Solemi) = 483
KSI% (EnMetSol) = 297
KSI% (MeteoSwiss) = 1'177
KSI% (IrSOLaV) = 335
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
100%
80%
60%
40%
20%
0%
0
200
400
600
800
1000
Hourly normal beam irradiance [W/m²]


Daily normal beam irradiance cumulated frequency of occurrence
KSI% (SolarGis) = 432
KSI% (Helioclim3) = 518
KSI% (Solemi) = 483
KSI% (EnMetSol) = 297
KSI% (MeteoSwiss) = 1'177
KSI% (IrSOLaV) = 335
Measurements Madrid (2004-2011)
SolarGis
Helioclim3
Solemi
MeteoSwiss
EnMetSol
IrSOLaV
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
Daily normal beam irradiance [kWh/m²]


Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
PVGIS-CM SAF
WRDC (81-93)
RetScreen (61-90)
NASA-SSE (83-05)
Meteonorm 6 (80-00)
ESRA (81-90)
2004 - 2010 average
Monthly normal beam irradiation [kWh/m2]
average products
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
Month of the year


Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
Satellight (96-00)
Helioclim (2004-2011)
SolarGis (2004-2011)
Solemi (2004-2011)
IrSOLaV (2006-2011)
EnMetSol (2004-2011)
MeteoSwiss (2006-2011)
2004 - 2010 average
Monthly normal beam irradiation [kWh/m2]
"real data"
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
Month of the year


Annual global irradiation normalized to the 2004 - 2010 reference period
Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
Annual global irradiation (2004 - 2010) : 1697 ± 82 [kWh/m2]
reference period
measurements standard deviation 2004-2010
120%
100%
80%
60%
40%
20%
0%
-20%
PVGIS-CM SAF
WRDC (81-93)
RetScreen (61-90)
NASA-SSE (83-05)
Meteonorm 6 (80-00)
ESRA (81-90)
Satellight (96-00)
Helioclim (2004-2011)
SolarGis (2004-2011)
Solemi (2004-2011)
IrSOLaV (2006-2011)
EnMetSol (2004-2011)
MeteoSwiss (2006-2011)
2004 - 2010 average
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
average
average products (satellite and ground based)
normalized ground measurements
SatelLight 1996-2000
Helioclim 2004-2011
IrSOLaV 2006-2011
CM SAF 2004-2011
product data deviation from ground 2004 - 2010 average
measurements deviation from 2004 - 2010 average
SolarGis 2004-2011
Solemi (aerocom) 2004-2011
EnMetSol 2004-2011


Annual normal beam irradiation normalized to the 2004 - 2010 reference period
Madrid (SP) UMP latitude: 40.45° longitude: -3.73° altitude: 650 m
Annual normal beam irradiation (2004 - 2010) : 1797 ± 93 [kWh/m2]
reference period
measurements standard deviation 2004-2010
120%
100%
80%
60%
40%
20%
0%
-20%
PVGIS-CM SAF
WRDC (81-93)
RetScreen (61-90)
NASA-SSE (83-05)
Meteonorm 6 (80-00)
ESRA (81-90)
Satellight (96-00)
Helioclim (2004-2011)
SolarGis (2004-2011)
Solemi (2004-2011)
IrSOLaV (2006-2011)
EnMetSol (2004-2011)
MeteoSwiss (2006-2011)
2004 - 2010 average
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
average
average products (satellite and ground based)
normalized ground measurements
SatelLight 1996-2000
Helioclim 2004-2011
IrSOLaV 2006-2011
CM SAF 2004-2011
product data deviation from ground 2004 - 2010 average
measurements deviation from 2004 - 2010 average
SolarGis 2004-2011
Solemi (aerocom) 2004-2011
EnMetSol 2004-2011