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Long term CM-SAF satellite global and beam irradiance validation

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Satellite based irradiance data validation

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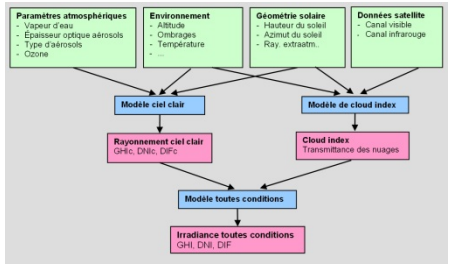
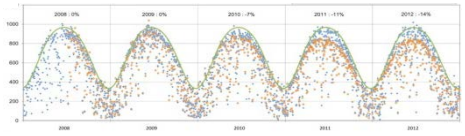
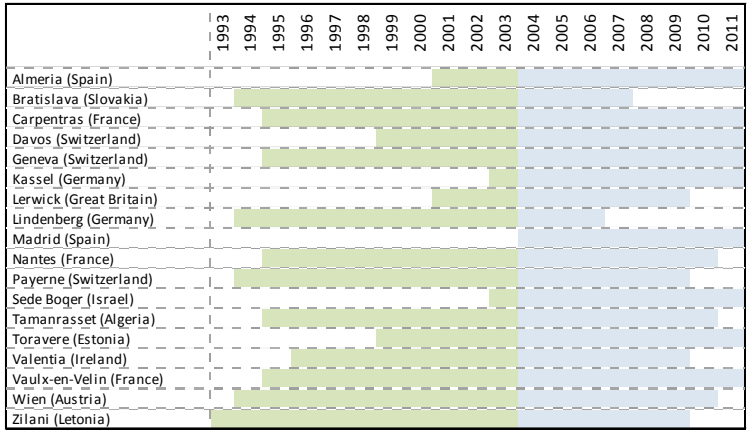
Validation background

- validation of 14 global irradiance models of which 9 derive also the beam component, including CM-SAF
- 18 sites, in Europe and Mediterranean region, 110 sites-years, 475’000 hourly, 43’500 daily and 1’700 monthly values
- latitude: 20° -> 60°, altitude: 0m -> 1600m
- validation over 8 years, global, diffuse and normal beam components
- hourly, daily and monthly values
- average time series (TMY) and real time data (nowcasting)
- interannual variability analysis







Real time and average time series

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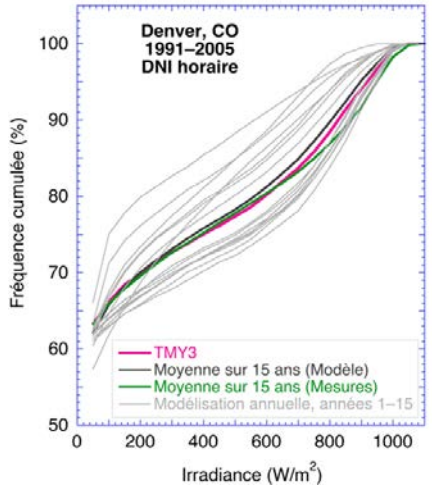
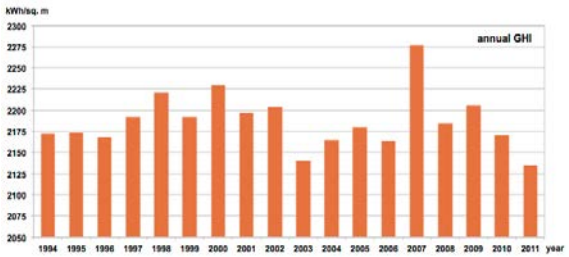
Real time data or nowcasting

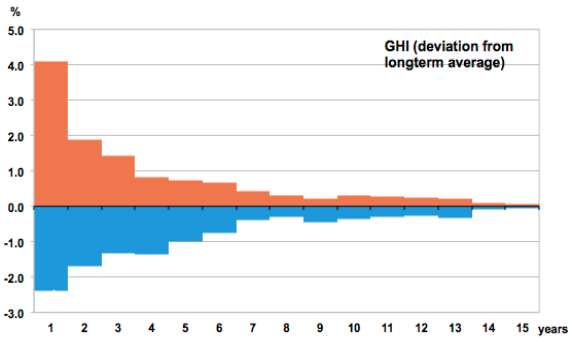
- on line processing, next day availability
- 1994 – 2004 hourly data from MFG
- since 2004 every 15 minutes from MSG
- applications:
  - power plants follow-up
  - short term forecasting

Average and typical year TMY (climatic)

- representative year of the climate
- evaluated over 20 years (satellite)
  - average month
  - moving window
- parameters weighted depending on the application
- extreme situation are not represented
- applications
  - climate change
  - site definition
  - pre-projects







Data quality control

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Time stamp validation (acquisition time)

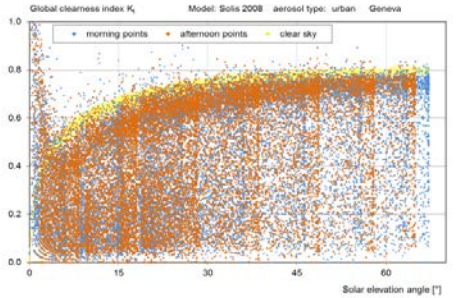
- solar time symmetry (irradiance or clearness index K_t)

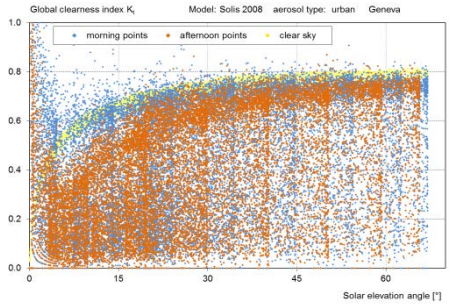
Data absolute calibration

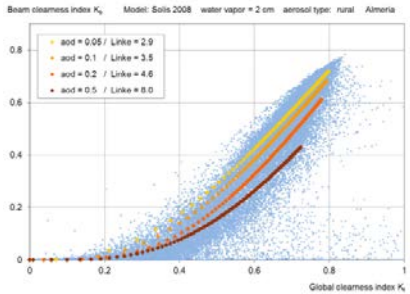
- comparison with ancillary data (aeronet, nearby site, etc.)
- year to year comparison (stability)

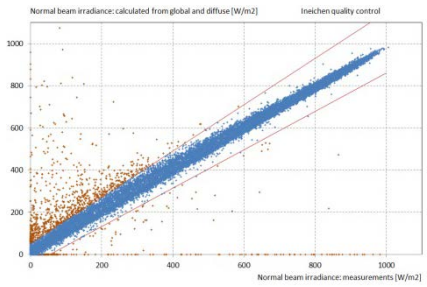
Components coherence

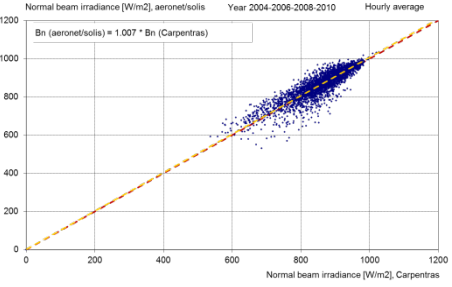
- 3 components: «*closure equation*»: global = direct + diffuse
- 2 components: coherence region

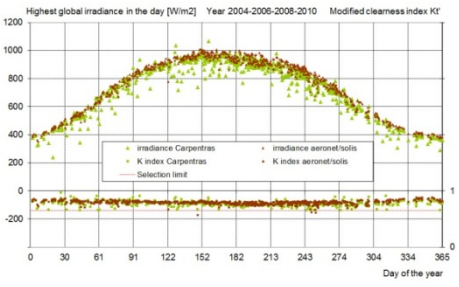


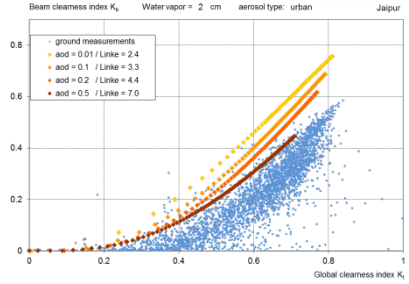


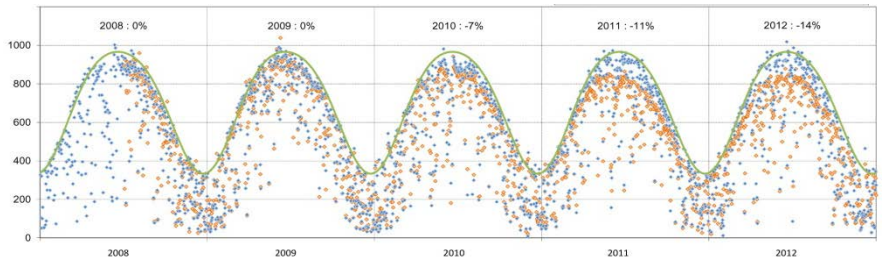


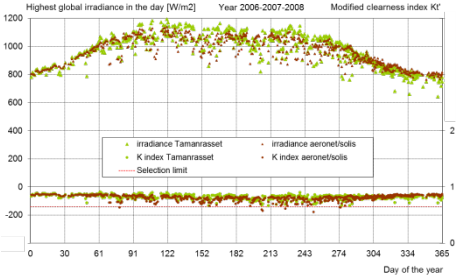












Validation statistics

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Validation statistics

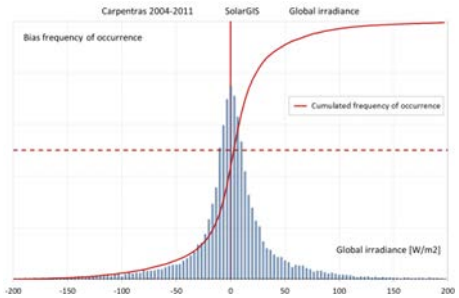
- mean bias difference (*mbd*)
- mean absolute bias difference (*mabd*)
- root mean square difference (*rmsd*)
- standard deviation (*sd*)
- correlation coefficient (*R or R^2*)
- Kolmogorov-Smirnov integral (*KSI*)
- standard deviation of the biases

$$mbd = \frac{\sum(G_{sat} - G_{mes})}{N}$$

$$rmsd = \sqrt{\frac{\sum(G_{sat} - G_{mes})^2}{N}}$$

$$sd = \sqrt{\frac{\sum(G_{sat} - \overline{G_{mes}})^2}{N}}$$

$$R = \frac{\sum(G_{sat} - \overline{G_{sat}})(G_{mes} - \overline{G_{mes}})}{\sqrt{(\sum(G_{sat} - \overline{G_{sat}})^2)(\sum(G_{mes} - \overline{G_{mes}})^2)}}$$



Including the dispersion induced by:

- ground measurements uncertainty
- comparison period length
- algorithms precision
- quality of the input data (*aod*, *w*, etc.)
- comparison of data with different granularities

$$KSI = \int_{G_{min}}^{G_{max}} |F_c(G_{sat}) - F_c(G_{mes})| \cdot dG_{mes}$$

Results presentation

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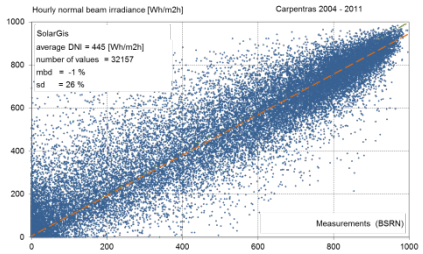
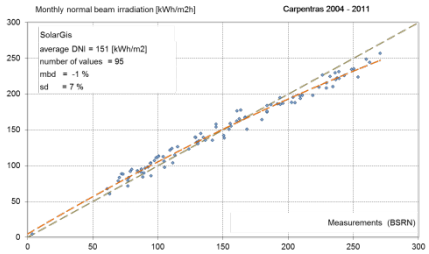
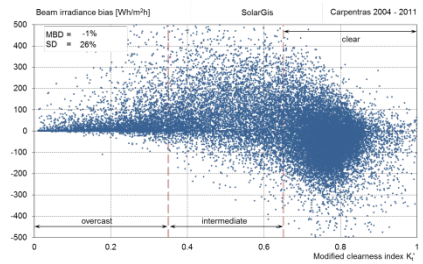
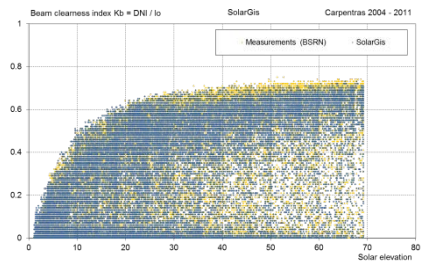
Results presentation

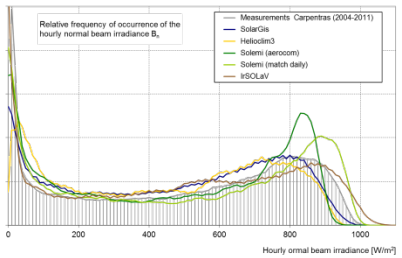
- scatter plots (G_h, D_h, B_n)
- bias dependence (sky type, *aod*)
- clearness index versus solar elevation
- frequency distribution
  - irradiance, K_t, cumulated
  - bias around the 1:1 axis
- interannual variability of the monthly values
- tables, histograms, etc.

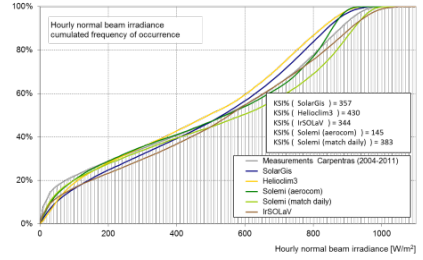


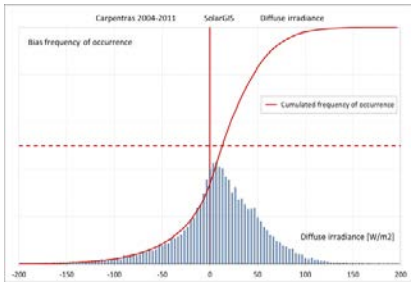


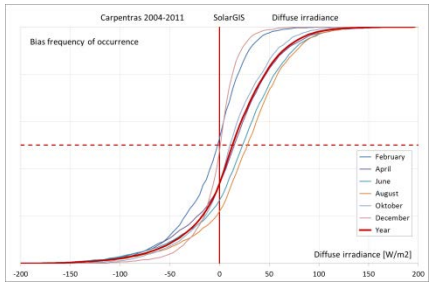


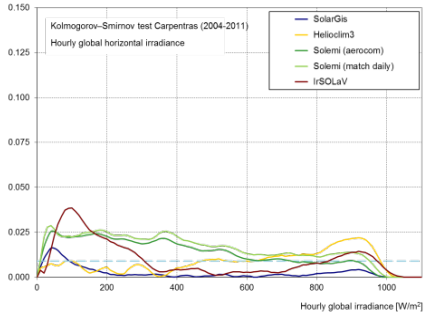


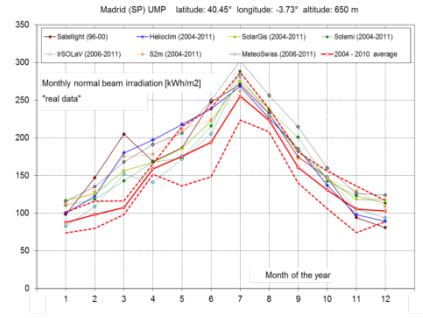












Results: quality control

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QC main discrepancies

- Davos
  - closure equation
  - calibration
- Tamanrasset
  - calibration
- Vaulx-en-Velin
  - calibration
- Zilani

Site	year per year comparison		aeronet comparison	Remark	Closure equation	Interannual	
	global irradiance	beam irradiance	G_h and B_n			Gh	Bn
Almeria (Spain)	2001-2011	2001-2011	n/a	none	93%	100%	100%
Bratislava (Slovakia)	1994-2007	1994-2007	n/a	none	n/a		
Carpentras (France)	1995-2011	1995-2011	2003-2011	G_h(aero/solis) > G_h(bsrn) [around 2%] Gh(aero/cpcr2) ≈ Gh(bsrn)	83%	99%	98%
Davos (Switzerland)	1999-2011	1999-2011	2006-2011	Bn 20% to high from Dec. 1999 to Feb 2000 Aeronet Gh 5% higher in spring than in autumn	68%	91%	97%
Geneva (Switzerland)	1995-2011	1995-2011	n/a	Gh compatible with Payerne and Vaulx-en-Velin	n/a	99%	94%
Kassel (Germany)	2003-2011	2003-2011	n/a	none	91%	98%	98%
Lerwick (Great Britain)	2001-2009	2001-2009	n/a	none	98%	94%	89%
Lindenberg (Germany)	1995-2006	1995-2006	n/a	none	91%	100%	100%
Madrid (Spain)	2004-2011	2004-2011	2012	Gh and Bn within 2-3% with aeronet Bn: too many missing data for interannual validation	84%	99%	86%
Nantes (France)	1995-2010	1995-2010	n/a	none	n/a	97%	94%
Payerne (Switzerland)	1994-2009	1994-2009	n/a	Gh compatible with Geneva	81%	100%	97%
Sede Boqer (Israel)	2003-2011	2003-2011	1996-2010	Bn(aero)<Bn(bsrn) [2% summer] Gh 2% to high from 2005-2008	90%	100%	94%
Tamanrasset (Algeria)	1995-2010	1995-2010	2006-2009	Gh, very clear conditions, at noon, 5% underestimation by aeronet/solis 1% overestimation by aeronet/cpcr2	90%	100%	99%
Toravere (Estonia)	1999-2011	1999-2011	2002-2009	none	88%	100%	98%
Valentia (Ireland)	1996-2009	1996-2009	n/a	none	n/a	97%	94%
Vaulx-en-Velin (France)	1995-2011	1995-2011	n/a	1995-2004 Gh and Bn to high (5-9%)	90%	96%	95%
Wien (Austria)	1994-2010	1994-2010	n/a	none	n/a	100%	97%
Zilani (Letonia)	1993-2009	1993-2009	n/a	Gh 10% to low in 1999 Gh 15% to high in 2003	91%	99%	98%

Quality control

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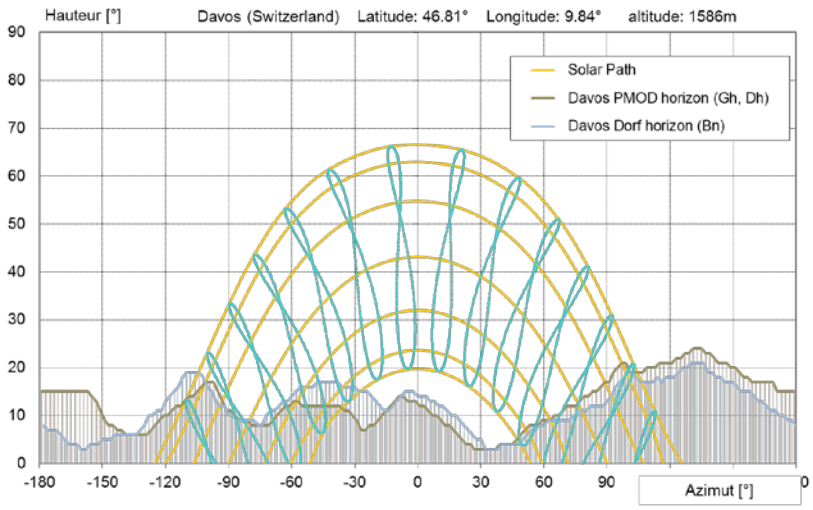
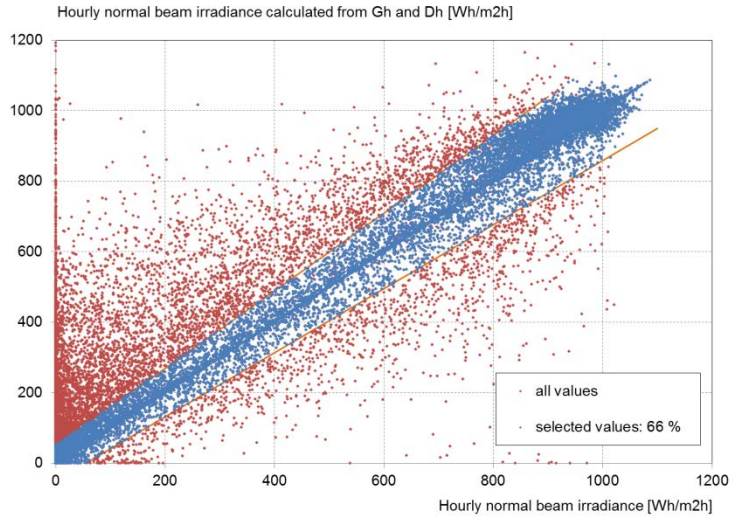
Site of Davos

- «closure equation»: 34% rejection
  - 280m between the sites
  - horizon: beam obstruction
  - snow: reflection





Quality control

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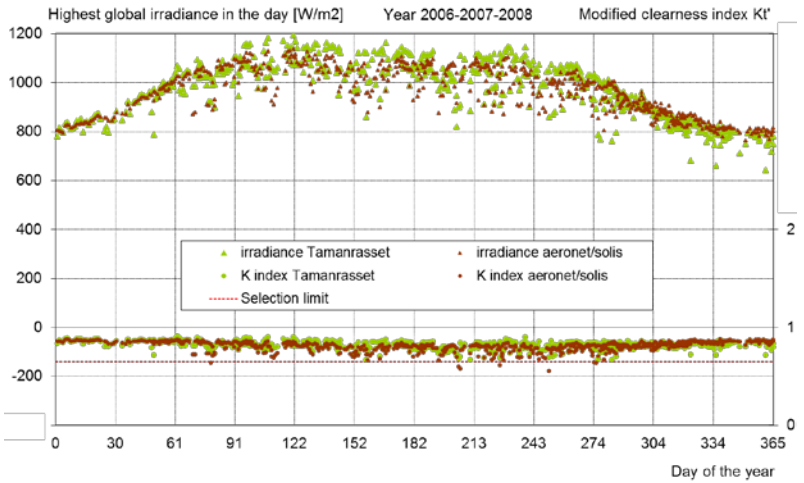
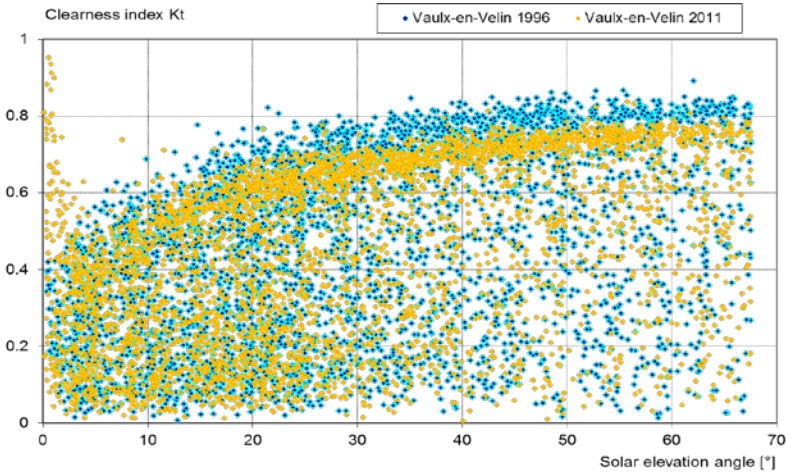
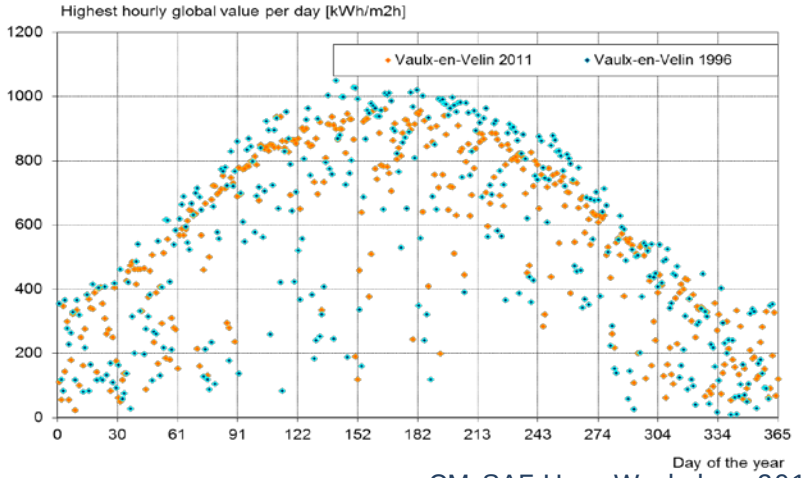
Calibration

- Tamanrasset:
  lower aeronet values during summer
  clear sky model ?
  aerosol type ?

- Davos, Vaulx-en-Velin et Zilani:
  drift, breakdown?







Quality control

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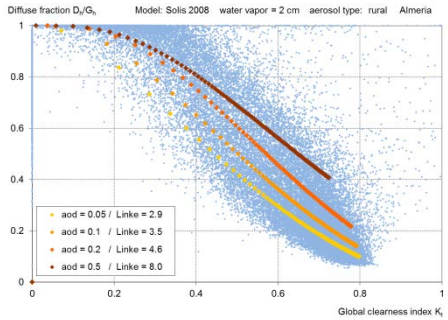
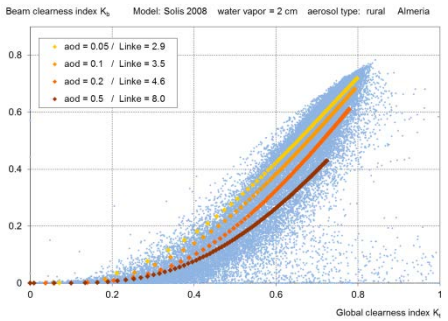
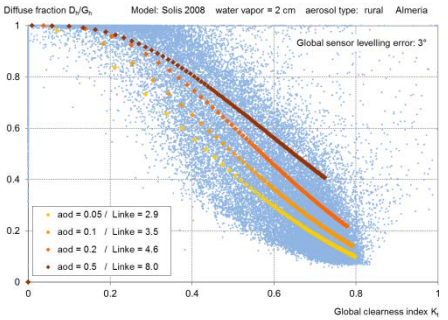
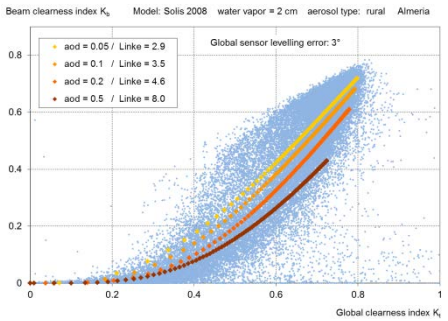
Site of Madrid

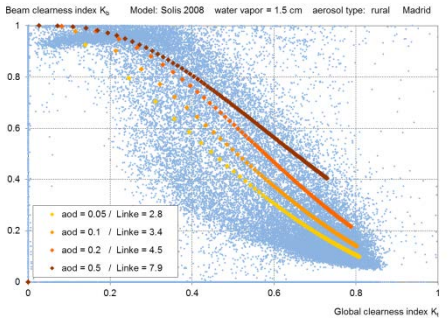
- components coherence:
  - sensor levelling ?

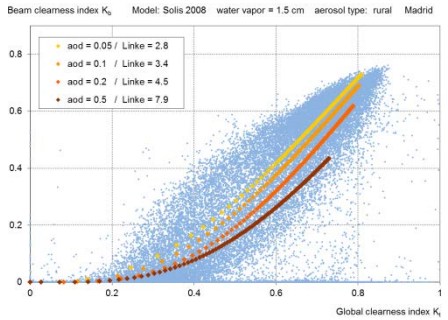












Validation

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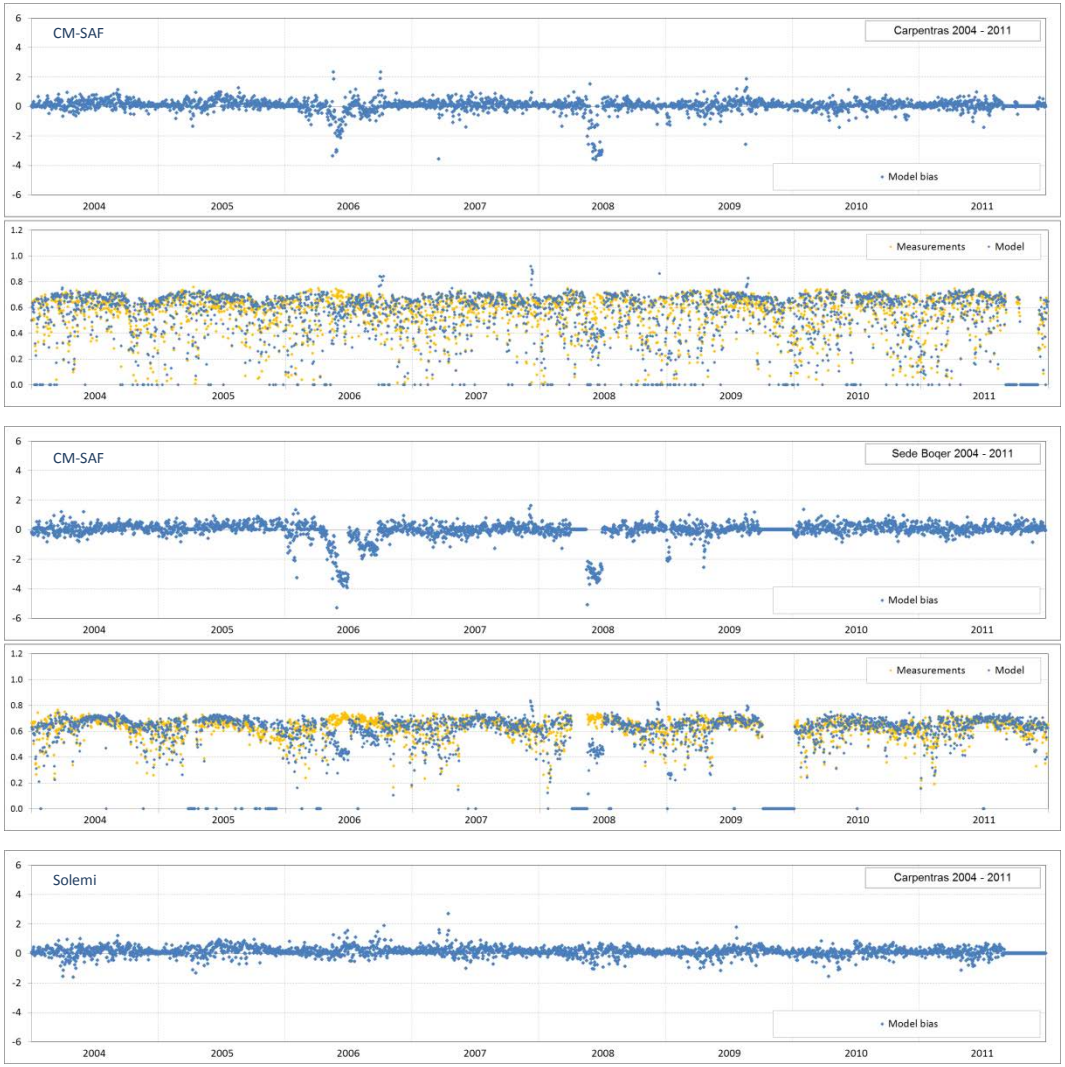
CM-SAF algorithm

- 2006 and 2008 pattern:
  - site specific ?
  - unusual conditions ?
  - meteosat problem ?
  - turbidity episode ?

Turbidity retrieval

- based on ground beam irradiance
- retrofit of the aod and the Linke turbidity with solis and esra model
- -> daily values



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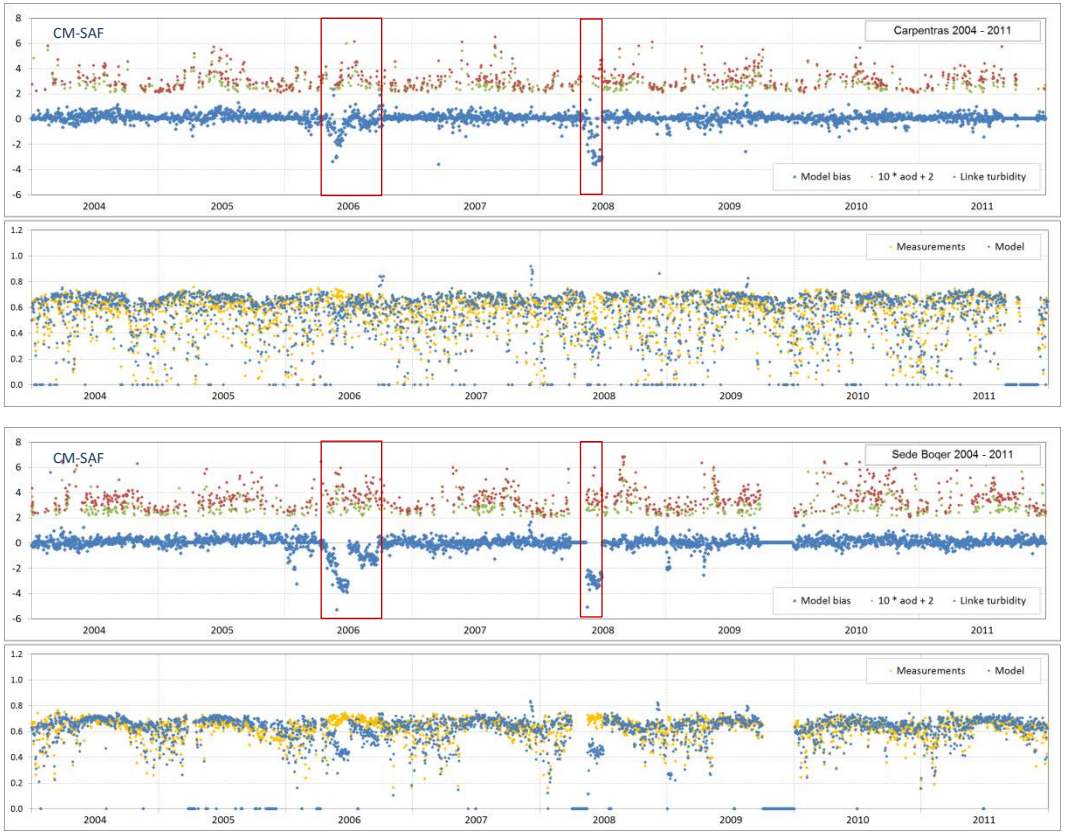

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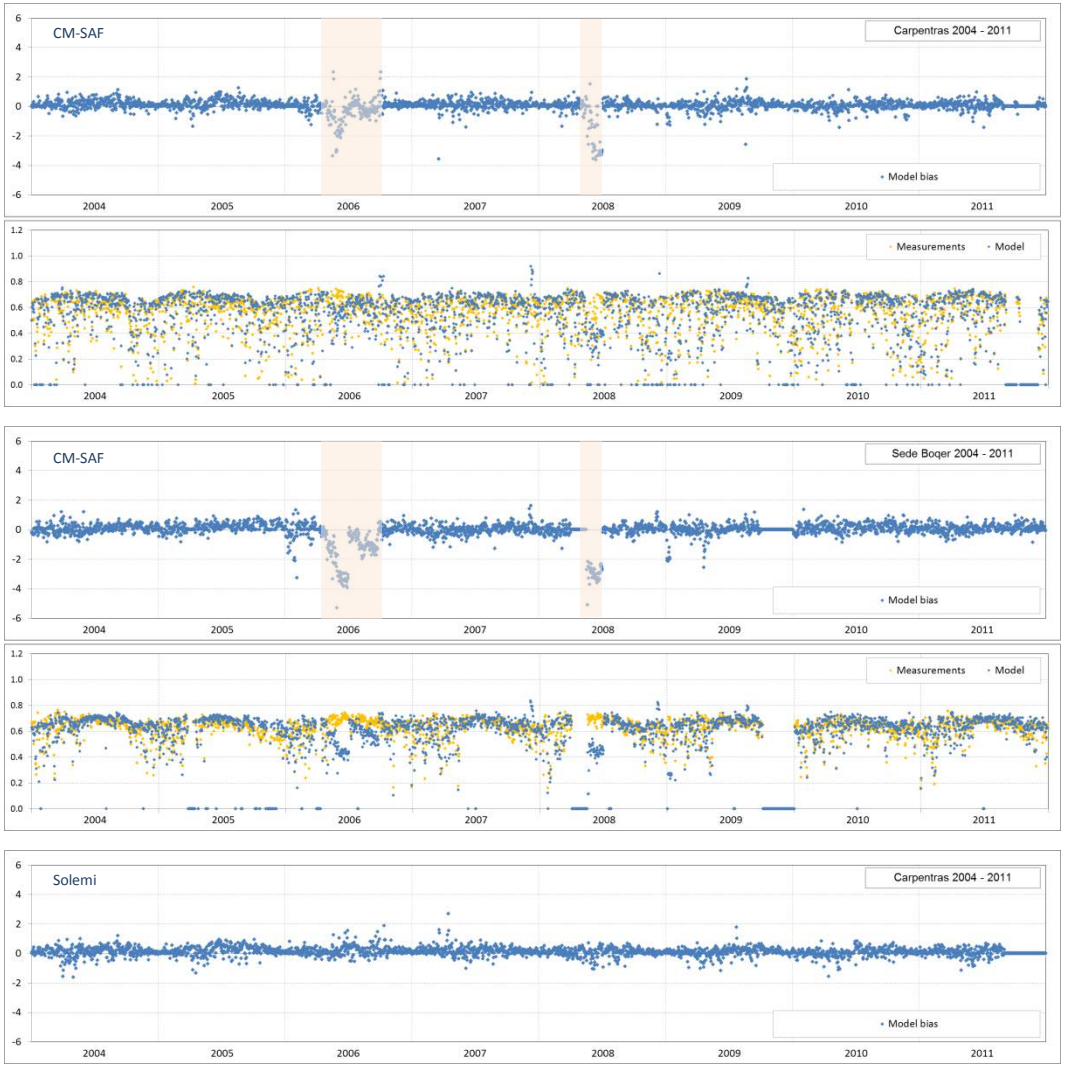
Excluded zones from the validation



Validation

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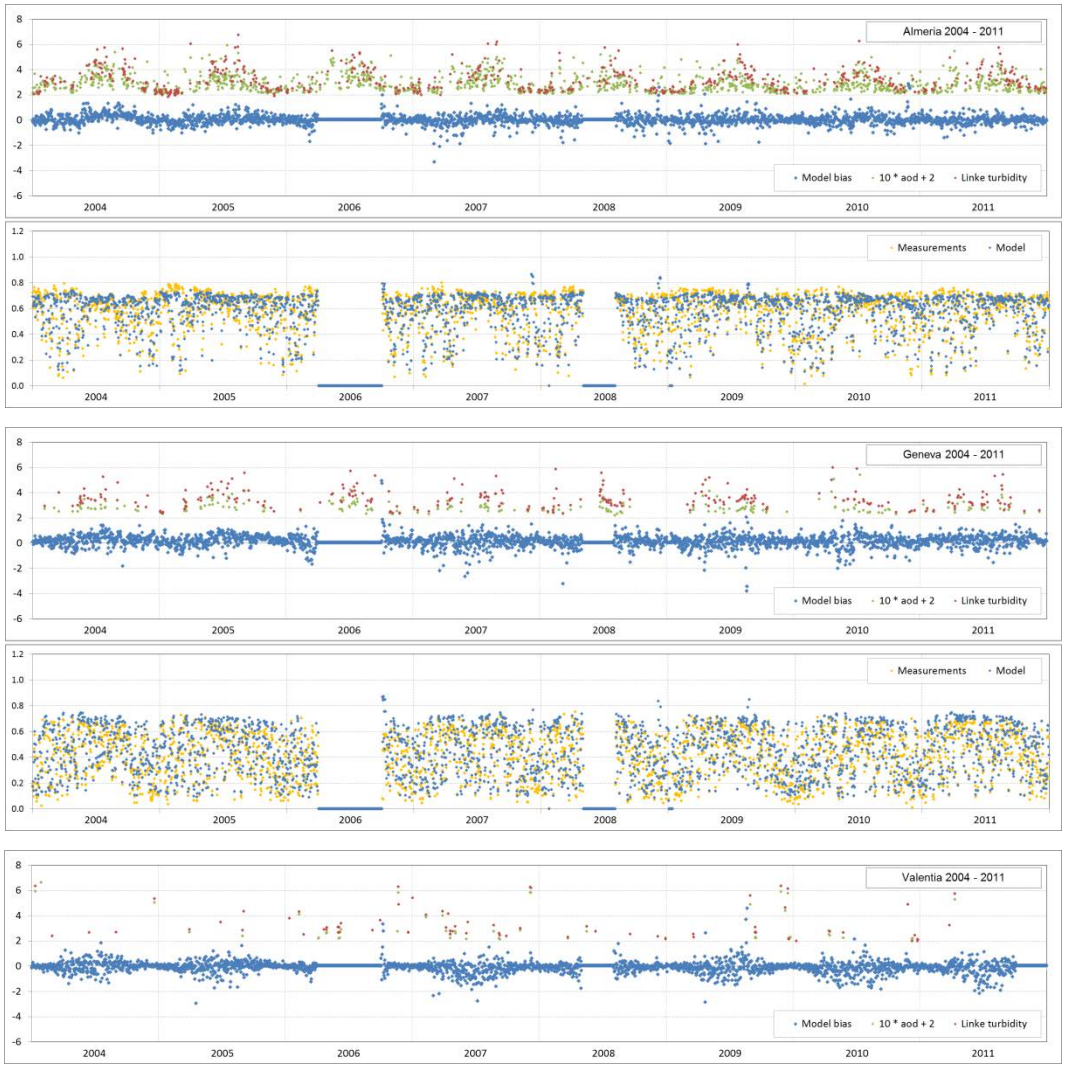
CM-SAF algorithm

- different algorithms
  - 2004 - 2005
  - 2006 - 2011
- different climatologies
  - 2004 - 2007
  - 2008 – 2010
  - 2011

No significative differences



Validation

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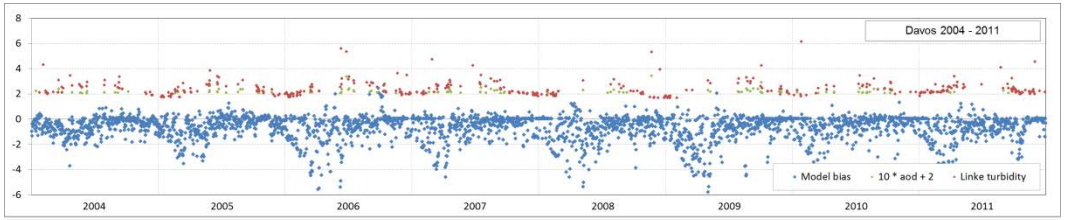
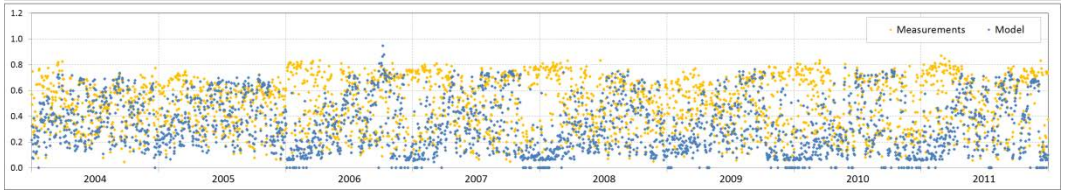
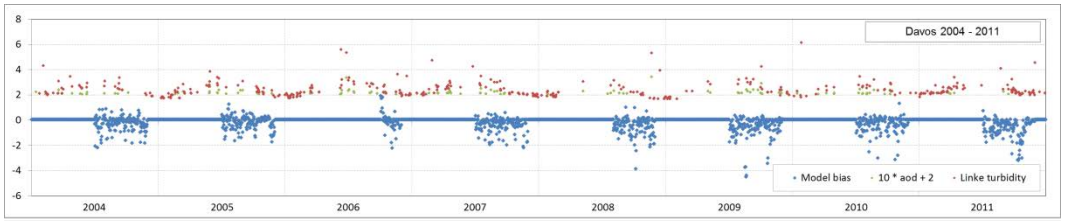
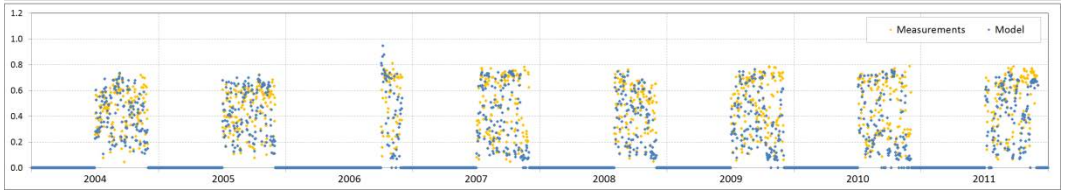
Davos

- high altitude site
- snow
  - December – June
  - reflection









Validation

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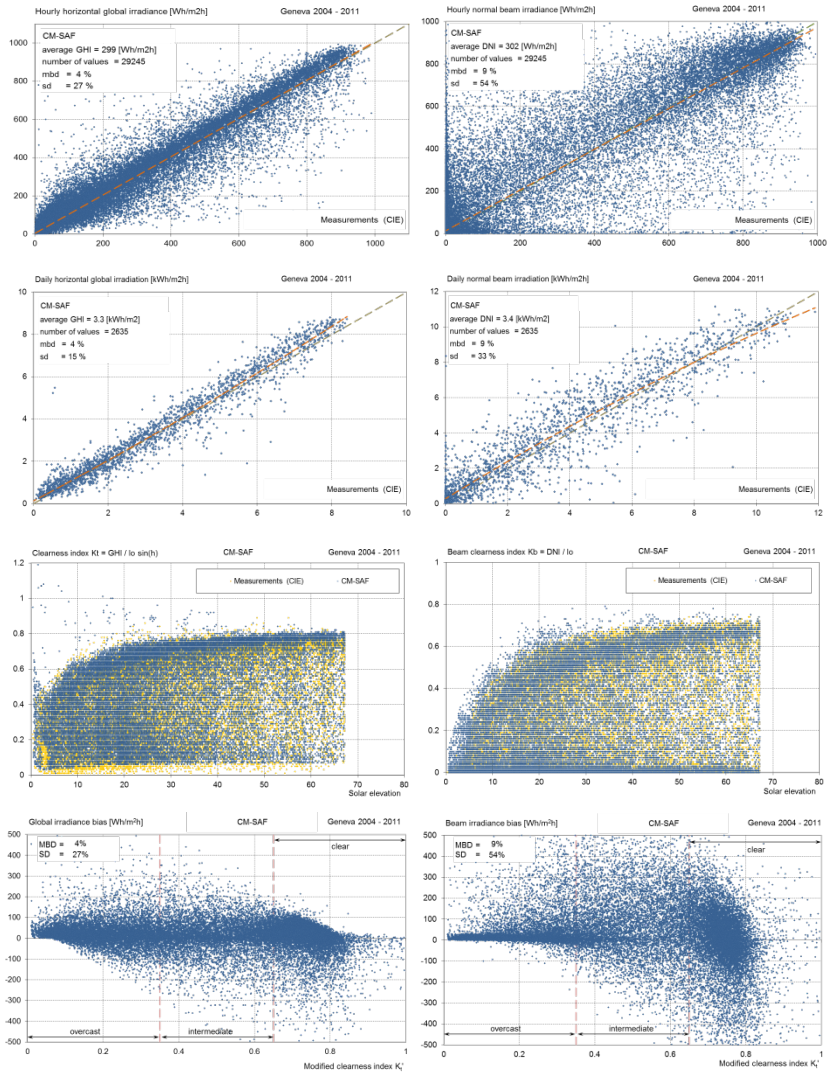
CM-SAF algorithm

- scatter plots
  - global, beam and diffuse
  - hourly, daily and monthly
- clearness index/solar elevation
  - upper limit: clear sky model
- dependance with sky type
  - same pattern for all the sites



Validation

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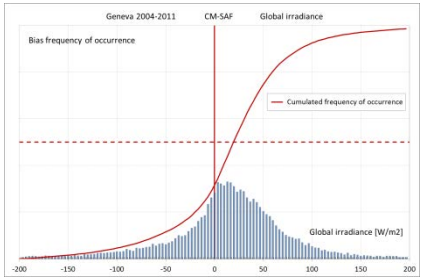
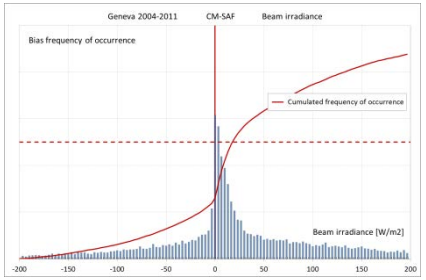
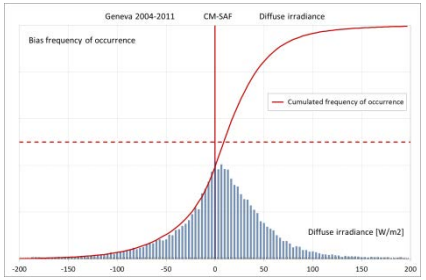
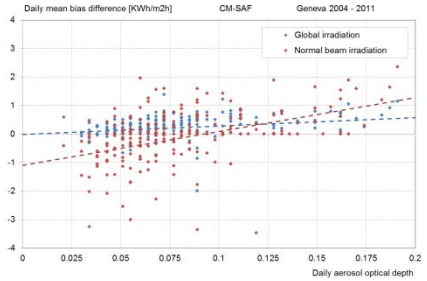
CM-SAF SIS and SID

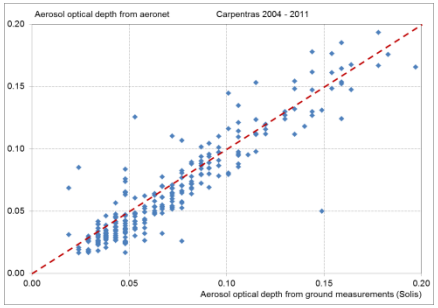
- bias distribution
  - not exactly a normal distribution
  - caution with the interpretation of the statistics
- dependence with the *aod*
  - same pattern for all sites
  - artefact ?

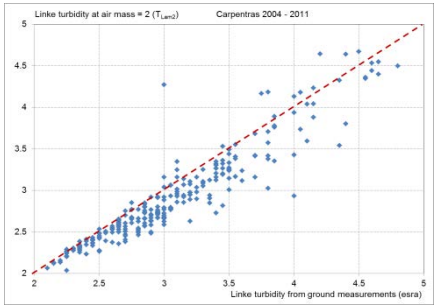












Validation

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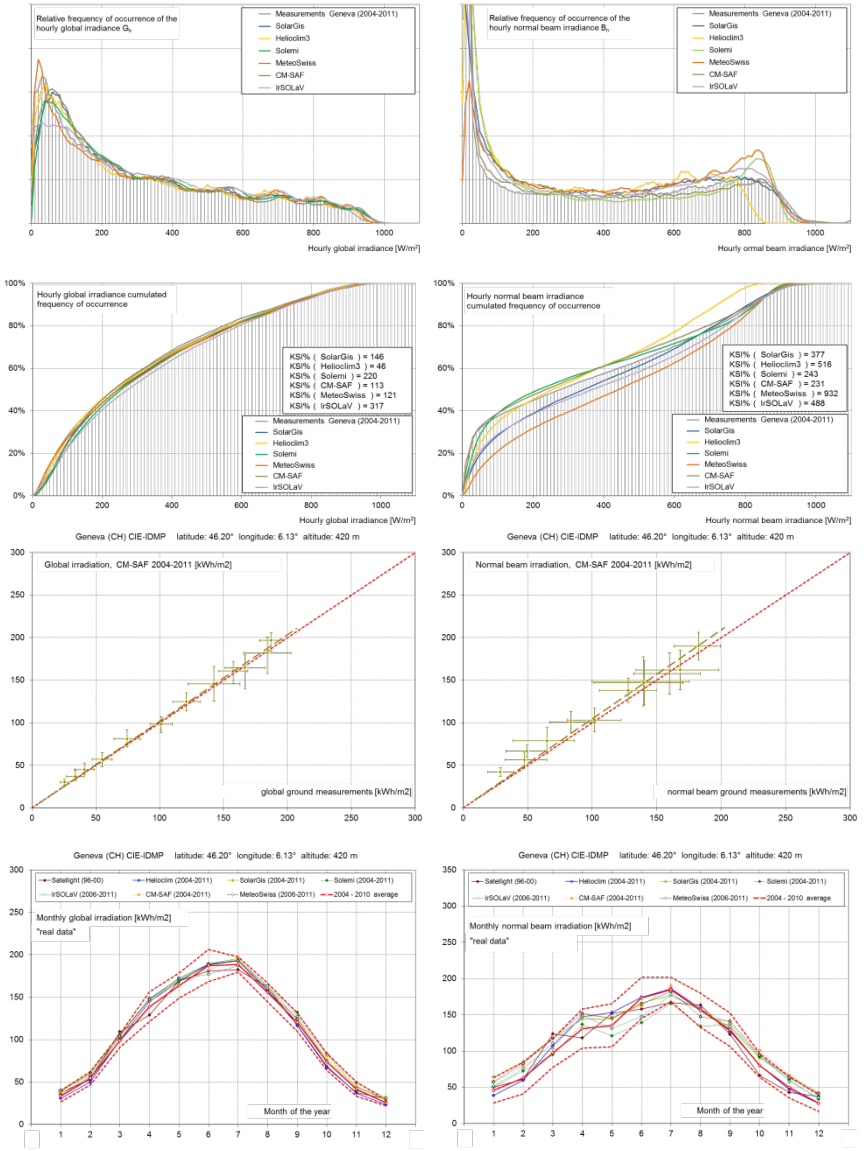
CM-SAF algorithm

- frequency of occurrence distribution
  - versus irradiance level
  - versus clearness index
  - cumulated curves
- monthly statistics



Results

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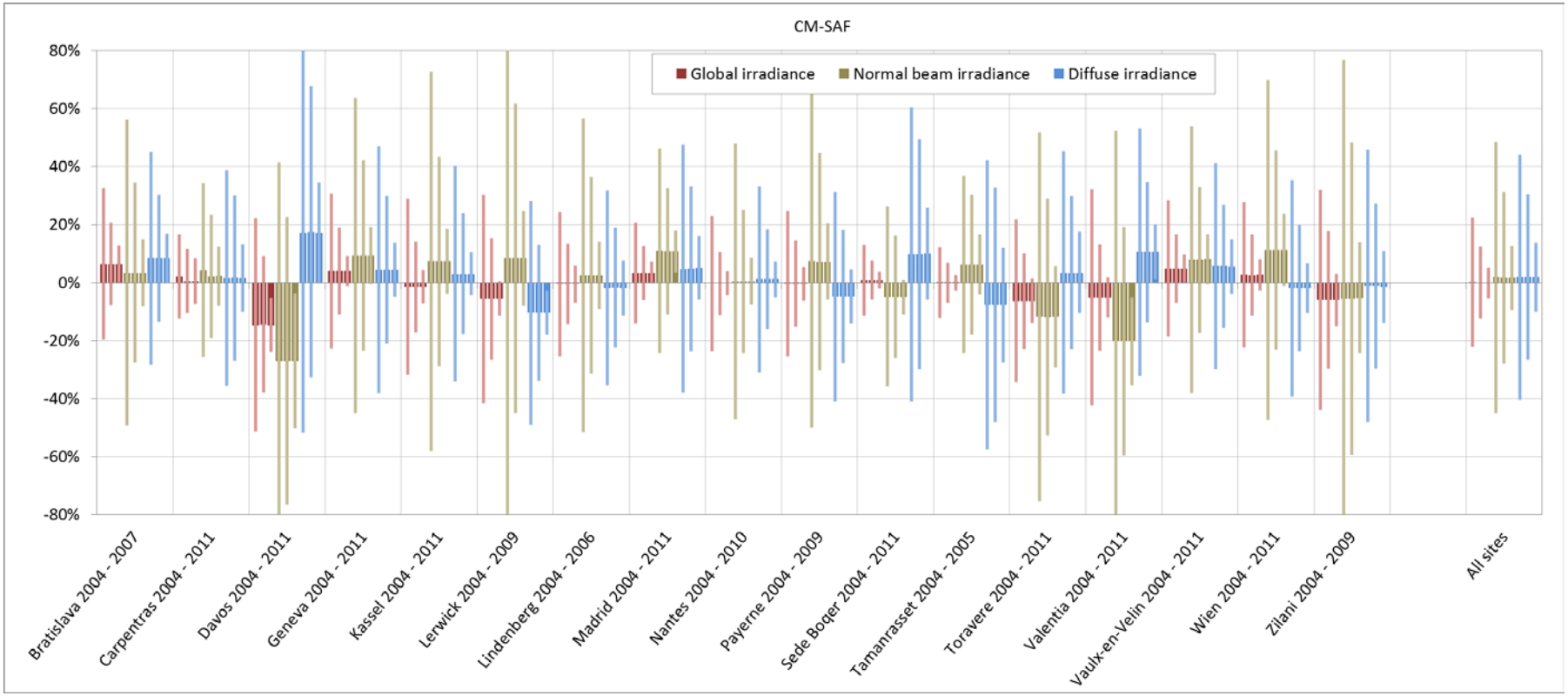
Site by site results:

- low relative sd for sunny sites
- more important for high latitude sites, snow in Davos
- negligible overall bias



Results

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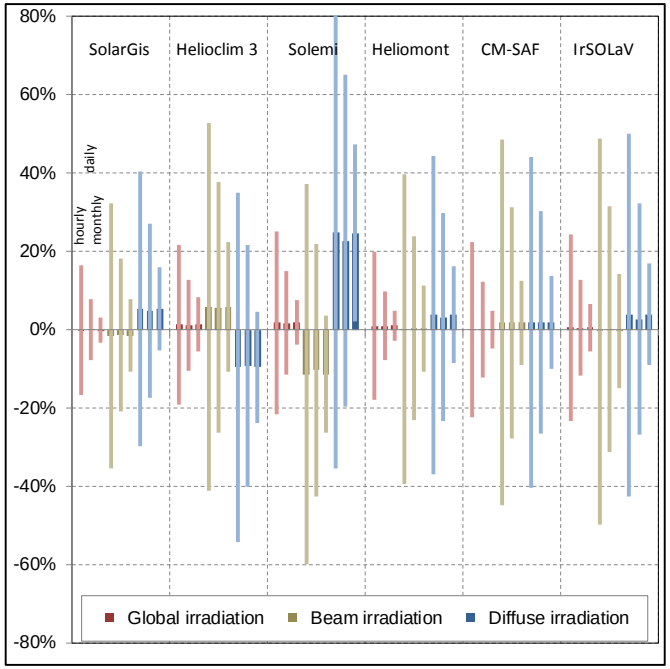
Overall validation results:

- CM-SAF performance over all the data (110 site-year, 475'000 hourly values, 43'000 daily values, 1'700 monthly values)
  - hourly: no bias, sd(G_h) = 22%, bias 2%, sd(B_n) = 47%
  - daily: no bias, sd(G_h) = 12%, bias 2%, sd(B_n) = 30%
  - monthly: no bias, sd(G_h) = 5%, bias 2%, sd(B_n) = 11%

	SolarGis						Helioclim 3					
	Gh		Bn		Dh		Gh		Bn		Dh	
	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd
hourly [Wh/m2h]	341		351		134		345		354		134	
	0	57	-6	119	7	47	5	70	21	166	-13	60
	0%	17%	-2%	34%	5%	35%	1%	20%	6%	47%	-10%	45%
Daily [kWh/m2]	3.73		3.83		1.46		3.81		3.91		1.49	
	0.00	0.29	-0.05	0.75	0.07	0.32	0.05	0.44	0.22	1.25	-0.14	0.46
	0%	8%	-1%	20%	5%	22%	1%	12%	6%	32%	-9%	31%
Monthly [kWh/m2]	108.5		111.4		42.5		109.3		112.1		42.8	
	-0.1	3.6	-1.7	10.4	2.3	4.5	1.5	7.5	6.6	18.6	-4.1	6.1
	0%	3%	-2%	9%	5%	11%	1%	7%	6%	17%	-10%	14%
bias sd	2.1%		5.9%		7.5%		5.1%		13.9%		14.2%	

	Solemi						Heliomont					
	Gh		Bn		Dh		Gh		Bn		Dh	
	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd
hourly [Wh/m2h]	342		350		134		346		354		135	
	6	80	-40	170	33	80	4	66	0	140	5	55
	2%	23%	-11%	49%	25%	60%	1%	19%	0%	39%	4%	41%
Daily [kWh/m2]	3.73		3.82		1.46		3.75		3.85		1.47	
	0.07	0.49	-0.39	1.23	0.33	0.62	0.04	0.33	0.02	0.90	0.05	0.39
	2%	13%	-10%	32%	23%	42%	1%	9%	0%	23%	3%	27%
Monthly [kWh/m2]	108.8		111.3		42.5		107.6		110.3		42.1	
	2.0	6.2	-12.6	16.6	10.5	9.6	1.1	4.2	0.3	12.1	1.6	5.2
	2%	6%	-11%	15%	25%	23%	1%	4%	0%	11%	4%	12%
bias sd	4.8%		14.5%		25.2%		3.6%		9.3%		9.6%	

	CM-SAF						IrSOLaV					
	Gh		Bn		Dh		Gh		Bn		Dh	
	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd
hourly [Wh/m2h]	337		354		131		340		353		134	
	0	75	7	165	2	55	2	81	-1	174	5	62
	0%	22%	2%	47%	2%	42%	1%	24%	0%	49%	4%	46%
Daily [kWh/m2]	3.56		3.73		1.38		3.60		3.73		1.41	
	0.00	0.43	0.07	1.10	0.03	0.39	0.02	0.44	0.00	1.17	0.04	0.41
	0%	12%	2%	30%	2%	28%	0%	12%	0%	31%	3%	30%
Monthly [kWh/m2]	104.2		109.4		40.5		104.3		107.9		40.8	
	0.1	5.0	2.0	11.7	0.8	4.8	0.6	6.4	-0.3	15.8	1.6	5.3
	0%	5%	2%	11%	2%	12%	1%	6%	0%	15%	4%	13%
bias sd	3.7%		9.1%		6.3%		4.2%		12.0%		13.8%	



Interannual variability

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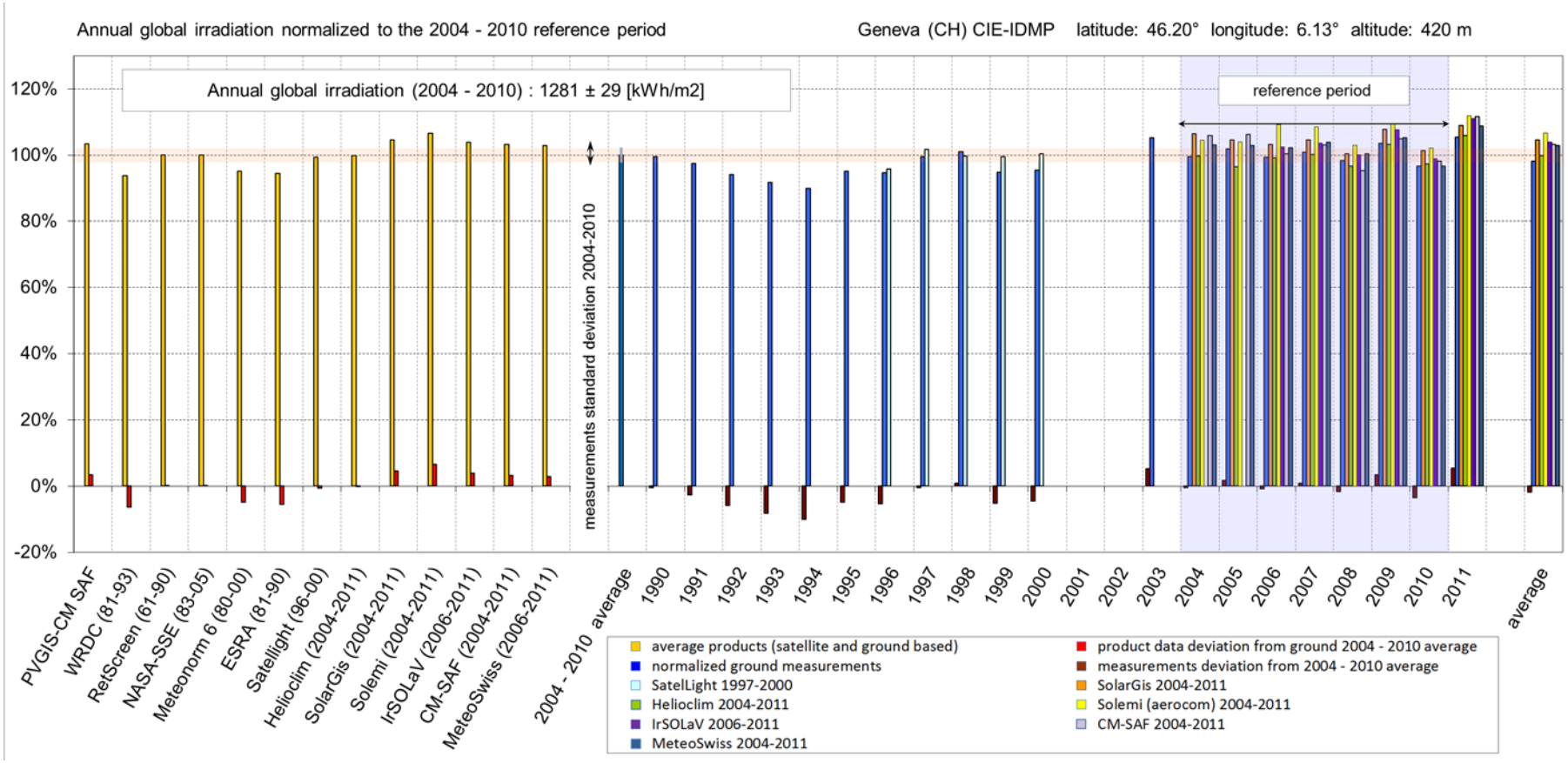
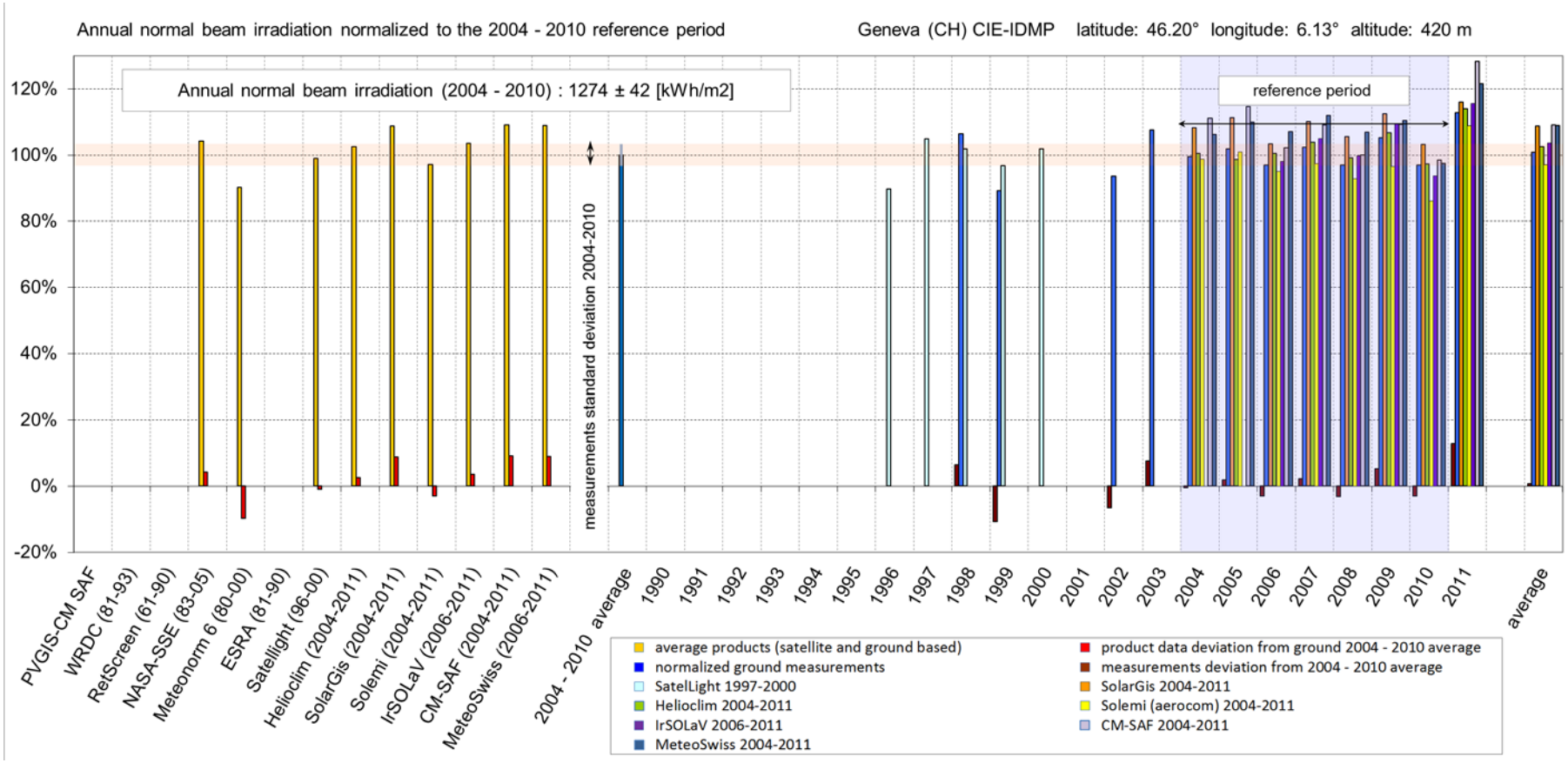
Histograms of the annual total



Interannual variability

GENERGIE University of Geneva

Histograms of the annual total



Variabilité interannuelle

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Table des résultats: biais systématique en relation avec la variabilité interannuelle

- G_h: tous les modèles en « temps réel » dans un écart standard
- G_h: années typiques: 2 modèles sur 6 dans un écart standard
- B_n: excepté Solemi, tous les modèles dans un écart standard

	Yearly total [kWh/m2] average over 2004-2010	standard deviation over 2004-2010	PVGIS-CM SAF	WRDC (1981-1993)	RetScreen (1961-1990)	NASA-SSE (1983-2005)	MN 7 (1980-2000)	ESRA (1981-1990)	Satellight (1996-2000)	SolarGis (2004-2011)	Helioclim (2004-2011)	Solemi (2004-2011)	Heliomont (2006-2011)	CM-SAF (2004-2011)	IrSOLaV (2006-2011)	Yearly total [kWh/m2] average over 2004-2010	standard deviation over 2004-2010	NASA-SSE (1983-2005)	MN 7 (1980-2000)	Satellight (1996-2000)	SolarGis (2004-2011)	Helioclim (2004-2011)	Solemi (2004-2011)	Heliomont (2006-2011)	CM-SAF (2004-2011)	IrSOLaV (2006-2011)
Sites			Global irradiation, mean bias difference *mbd*															Beam irradiation, mean bias difference *mbd*								
Almeria	1850	2.5%	1.8%		-8.1%	-8.1%	-3.0%		4.9%	0.4%	6.1%	3.0%	3.2%	-0.1%	0.3%	2126	5.5%	-3.8%	-11.1%	15.1%	-1.9%	12.1%	-3.0%	6.3%	2.0%	-3.9%
Bratislava	1176	2.9%	3.2%	1.0%	1.1%	-1.0%	1.7%	4.3%	-3.5%	3.2%	-0.2%	5.4%	2.8%	6.5%	4.4%	1191	7.4%	-4.0%	-7.5%	-11.9%	-9.6%	-2.1%	-21.8%	-15.3%	3.5%	9.1%
Carpentras	1587	2.1%	2.5%	-4.8%	-15.0%	-6.0%	-2.8%	-5.4%	0.4%	0.3%	0.6%	2.7%	1.6%	2.1%	1.2%	1884	4.1%	0.4%	-10.1%	4.9%	-1.8%	-0.3%	-4.2%	3.0%	4.4%	-1.6%
Davos	1383	1.3%	-0.8%		-2.7%	-7.9%	2.1%	-2.9%	-17.5%	-4.2%	11.5%	-13.2%	-4.4%	-14.5%	-7.1%	1420	8.4%	-8.0%	18.1%	-26.2%	-2.8%	21.9%	-33.6%	-9.5%	-27.0%	-36.9%
Geneva	1282	2.3%	3.5%	-6.3%	0.1%	0.1%	-4.9%	-5.5%	-0.6%	4.2%	0.1%	6.4%	3.5%	4.1%	5.3%	1274	3.3%	4.3%	-9.8%	-0.9%	7.0%	1.9%	-4.2%	8.6%	9.4%	4.0%
Kassel	1048	2.7%	0.6%		-5.6%	-5.6%	-5.8%	-6.6%	-5.9%	-0.1%	-3.4%	0.8%	-2.9%	-1.4%	4.0%	874	6.4%	1.0%	-7.9%	-5.1%	2.0%	10.2%	-19.4%	-4.4%	7.4%	21.8%
Lerwick	810	4.7%		-4.3%	9.2%	9.1%	-3.5%	-4.4%	-2.5%	0.7%	5.4%	3.8%	-3.2%	-5.5%		580	13.3%	55.5%	18.2%	0.8%	6.9%	50.4%	-11.5%	21.6%	8.5%	
Lindenberg	1120	3.8%	-3.7%	-3.8%	-3.8%	-9.8%	-3.9%	-12.3%	-4.5%	-3.1%	-2.1%	-3.5%	-4.8%	-0.5%	-0.4%	1026	9.6%	-8.1%	1.4%	-0.4%	-6.4%	5.8%	-27.9%	-15.1%	2.6%	30.5%
Madrid	1697	4.9%	3.5%		-5.2%	-5.2%	-3.1%	-2.5%	1.7%	1.4%	4.4%	5.7%	5.6%	3.4%	1.9%	1798	5.2%	10.0%	-0.8%	14.1%	5.4%	8.6%	4.8%	16.4%	11.0%	-2.3%
Nantes	1266	3.4%	1.5%	-5.2%	-3.4%	-6.7%	-2.2%	-0.9%	-2.7%	-3.3%	0.4%	3.3%	0.7%	-0.2%	1.3%	1307	6.7%	-12.1%	-9.6%	-8.8%	-8.4%	2.7%	-11.1%	4.2%	0.6%	0.7%
Payerne	1278	2.4%	1.7%	-8.4%	-2.5%	0.4%	-1.9%	-8.3%	-2.8%	0.7%	-6.4%	1.8%	-0.1%	-0.3%	4.8%	1191	4.4%	11.1%	5.9%	2.0%	7.0%	-3.4%	-5.8%	6.1%	7.5%	12.5%
Sede Boqer	2114	1.2%	-9.2%	0.5%	-6.7%	-3.9%	-4.0%			0.6%	-6.1%	3.4%	4.7%	0.9%	-1.7%	2382	3.6%	4.6%	-5.4%		-4.6%	-16.9%	-8.7%	-3.1%	-4.8%	-7.8%
Tamanrasset	2345	1.8%	-2.8%	0.8%	2.6%	-8.1%	0.9%			-1.2%	2.1%	-1.8%	-1.0%	0.0%		2355	4.0%	6.1%	18.1%		2.5%	14.7%	-10.5%	-9.2%	6.3%	
Toravere	981	3.8%			3.1%	3.1%	-0.1%		4.6%	-2.3%	2.1%	-1.5%	-4.4%	-6.3%	-0.8%	1028	8.8%	8.4%	2.4%	7.2%	-6.5%	7.2%	-28.4%	-14.3%	-11.7%	1.9%
Valentia	1021	4.6%	9.4%	-3.9%	-4.8%	8.0%	-5.3%	-4.7%	-4.2%	-3.6%	4.1%	3.2%	1.8%	-5.1%	1.4%	992	13.4%	10.7%	-21.5%	-21.3%	-21.6%	3.3%	-25.1%	-2.3%	-20.1%	1.9%
Vaulx-en-Velin	1304	4.4%	3.4%	-7.8%	-4.0%	-3.0%	-6.3%	-3.3%	0.4%	3.1%	2.6%	7.3%	5.9%	5.0%	3.6%	1359	5.3%	-2.1%	-11.6%	-0.5%	-0.9%	4.2%	-4.7%	10.1%	7.9%	-0.5%
Wien	1175	2.7%	0.5%	-6.8%	-6.0%	-0.8%	1.0%	-7.0%	-1.4%	-0.3%	-3.0%	3.4%	0.4%	2.7%	0.7%	1112	8.0%	2.9%	-3.1%	-2.5%	-2.3%	4.0%	-12.7%	-3.5%	11.3%	15.0%
Zilani	1024	3.3%	-6.1%	-3.2%		2.5%	-2.6%		6.0%	-1.4%	10.9%	-3.2%	-2.6%	-5.9%	-17.6%	1000	9.1%	13.4%	-0.1%	20.5%	-0.2%	31.9%	-26.5%	-7.3%	-5.5%	-13.6%
All sites	1359	2.9%	0.1%	-3.5%	-3.5%	-3.3%	-2.3%	-4.5%	-1.6%	-0.1%	1.4%	1.8%	1.0%	0.1%	0.5%	1383	6.3%	3.8%	-1.6%	-0.1%	-1.6%	5.9%	-11.3%	0.1%	1.9%	-0.4%
All sites absolute mean bias			3.4%	4.0%	5.1%	5.1%	3.0%	5.1%	3.9%	1.7%	3.9%	3.9%	2.9%	2.7%	3.0%			7.5%	9.3%	9.5%	4.8%	10.0%	12.0%	7.8%	7.5%	7.8%
Standard deviation of *mbd*			4.6%	4.6%	6.5%	6.3%	3.4%	5.7%	5.9%	2.1%	5.1%	4.8%	3.6%	3.7%	4.2%			9.0%	11.9%	13.2%	5.9%	13.9%	14.5%	9.3%	9.1%	12.0%

mbd within one standard deviation | *mbd* within two standard deviations | *mbd* higher than two standard deviations

Results

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Global irradiance	Hourly values																													
	SolarGIS					Helioclim 3					Solemi (aerocom)					MeteoSwiss					CM-SAF					IrSOLaV				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	448	32562	0.980	0%	13%	449	32142	0.971	6%	15%	448	32545	0.971	3%	15%	449	32263	0.978	3%	13%	443	28841	0.964	0%	17%	460	23554	0.965	0%	16%
Bratislava 2004 - 2007	270	17254	0.977	3%	19%	278	16421	0.970	0%	22%	273	17125	0.949	5%	29%	329	11605	0.965	3%	21%	262	14401	0.961	7%	26%	293	8010	0.966	4%	21%
Carpentras 2004 - 2011	432	26768	0.982	0%	11%	433	26485	0.977	1%	14%	434	26437	0.977	3%	13%	432	26449	0.981	2%	12%	423	23373	0.972	2%	15%	431	19802	0.967	1%	17%
Davos 2004 - 2011	371	19735	0.948	-4%	23%	373	19398	0.905	11%	31%	370	19740	0.718	-13%	53%	371	19493	0.948	-4%	23%	345	8925	0.877	-15%	37%	399	11623	0.831	-7%	40%
Geneva 2004 - 2011	304	33602	0.977	4%	18%	308	32966	0.974	0%	19%	304	33603	0.957	6%	25%	304	33263	0.974	3%	20%	299	29245	0.951	4%	27%	315	23939	0.954	5%	25%
Kassel 2004 - 2011	258	31387	0.968	0%	22%	261	30715	0.966	-3%	23%	257	31392	0.950	1%	28%	258	31148	0.960	-3%	25%	248	27160	0.942	-1%	30%	265	22632	0.946	4%	28%
Lerwick 2004 - 2009	189	22355	0.958	1%	29%	211	19465	0.930	5%	35%	189	22356	0.934	4%	36%	199	20827	0.937	-3%	34%	180	17928	0.933	-6%	36%					
Lindenberg 2004 - 2006	306	10430	0.969	-3%	18%	310	10117	0.960	-2%	21%	306	10432	0.942	-4%	25%	307	10308	0.954	-5%	22%	289	7947	0.945	0%	25%	319	3220	0.939	0%	25%
Madrid 2004 - 2011	422	25440	0.981	1%	13%	423	25125	0.976	4%	15%	421	25454	0.975	6%	15%	423	25227	0.977	6%	15%	419	21649	0.966	3%	17%	431	19320	0.972	2%	15%
Nantes 2004 - 2010	286	25672	0.979	-3%	17%	289	25194	0.952	0%	26%	286	25702	0.959	3%	24%	288	25418	0.973	1%	20%	281	20961	0.959	0%	23%	299	15950	0.935	1%	28%
Payerne 2004 - 2009	350	20825	0.973	1%	17%	354	20452	0.962	-6%	19%	350	20824	0.951	2%	22%	352	20620	0.968	0%	18%	341	17134	0.938	0%	25%	293	21005	0.953	5%	26%
Sede Boqer 2004 - 2011	535	28380	0.985	1%	9%	537	28051	0.982	-6%	10%	536	28379	0.979	3%	11%	536	28135	0.983	5%	10%	527	25255	0.975	1%	12%	533	21386	0.968	-2%	14%
Tamanrasset 2004 - 2011	594	30159	0.984	-1%	9%	597	25818	0.971	2%	13%	597	29252	0.978	-2%	11%	595	29904	0.977	-1%	11%	596	26866	0.971	0%	12%					
Toravere 2004 - 2011	252	30386	0.968	-2%	21%	272	27674	0.938	2%	29%	252	30426	0.955	-1%	26%	252	30258	0.947	-4%	28%	245	25710	0.947	-6%	28%	256	22129	0.948	-1%	27%
Valentia 2004 - 2011	237	33292	0.961	-4%	26%	235	33748	0.949	4%	30%	240	32870	0.928	3%	34%	243	32334	0.932	2%	34%	238	27952	0.911	-5%	37%	257	23218	0.925	1%	33%
Vaulx-en-Velin 2004 - 2011	300	30271	0.979	3%	17%	303	29771	0.970	3%	20%	304	29846	0.962	7%	23%	301	29920	0.974	6%	20%	302	28530	0.961	5%	24%	303	20935	0.963	4%	22%
Wien 2004 - 2011	278	33556	0.975	0%	19%	282	32754	0.970	-3%	21%	280	33344	0.957	3%	26%	278	33173	0.967	0%	23%	270	29152	0.961	3%	25%	291	23953	0.958	1%	24%
Zilani 2004 - 2009	250	22767	0.962	-1%	25%	263	21217	0.922	11%	36%	249	22852	0.941	-3%	31%	256	21918	0.940	-3%	30%	239	17995	0.912	-6%	38%	268	13730	0.892	-18%	38%
All sites	341	26381		-0.1%	17%	345	25418		1.4%	20%	342	26255		1.8%	23%	346	25682		1.0%	19%	337	22169		0.1%	22%	340	18401		0.5%	24%
All sites absolute bias				1.7%					3.9%					3.9%					2.9%					2.7%					3.0%	
Standard dev. of the bias				2.1%					5.1%					4.8%					3.6%					3.7%					4.2%	

Global irradiance	Hourly values																													
	SolarGIS					Helioclim 3					Solemi (aerocom)					MeteoSwiss					CM-SAF					IrSOLaV				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	448	32562	0.980	1.9	56.6	449	32142	0.971	27.2	69.1	448	32545	0.971	13.3	67.6	449	32263	0.978	14.3	59.5	443	28841	0.964	-0.6	74.1	460	23554	0.965	1.6	72.7
Bratislava 2004 - 2007	270	17254	0.977	8.7	51.6	278	16421	0.970	-0.6	61.3	273	17125	0.949	14.6	77.9	329	11605	0.965	9.2	70.5	262	14401	0.961	17.1	68.7	293	8010	0.966	12.8	61.6
Carpentras 2004 - 2011	432	26768	0.982	1.5	49.5	433	26485	0.977	2.4	59.6	434	26437	0.977	11.5	56.3	432	26449	0.981	6.7	51.2	423	23373	0.972	8.9	61.5	431	19802	0.967	5.3	74.2
Davos 2004 - 2011	371	19735	0.948	-15.6	86.1	373	19398	0.905	42.8	116.4	370	19740	0.718	-49.0	196.3	371	19493	0.948	-16.3	86.2	345	8925	0.877	-50.1	126.9	399	11623	0.831	-28.2	158.0
Geneva 2004 - 2011	304	33602	0.977	12.8	55.6	308	32966	0.974	0.2	58.6	304	33603	0.957	19.3	75.3	304	33263	0.974	10.5	59.3	299	29245	0.951	12.1	79.6	315	23939	0.954	16.6	78.5
Kassel 2004 - 2011	258	31387	0.968	-0.2	57.1	261	30715	0.966	-8.8	59.3	257	31392	0.950	2.1	71.2	258	31148	0.960	-7.5	64.5	248	27160	0.942	-3.4	75.2	265	22632	0.946	10.5	74.2
Lerwick 2004 - 2009	189	22355	0.958	1.4	54.5	211	19465	0.930	11.3	73.5	189	22356	0.934	7.1	68.2	199	20827	0.937	-6.5	67.7	180	17928	0.933	-10.0	64.7					
Lindenberg 2004 - 2006	306	10430	0.969	-9.4	54.9	310	10117	0.960	-6.5	64.1	306	10432	0.942	-10.8	75.8	307	10308	0.954	-14.8	67.3	289	7947	0.945	-1.3	71.7	319	3220	0.939	-1.4	80.3
Madrid 2004 - 2011	422	25440	0.981	5.8	56.5	423	25125	0.976	18.4	63.2	421	25454	0.975	24.1	64.8	423	25227	0.977	23.7	62.4	419	21649	0.966	14.3	72.9	431	19320	0.972	8.3	66.6
Nantes 2004 - 2010	286	25672	0.979	-9.5	47.6	289	25194	0.952	1.2	73.9	286	25702	0.959	9.5	68.5	288	25418	0.973	2.0	56.5	281	20961	0.959	-0.6	65.7	299	15950	0.935	3.8	84.6
Payerne 2004 - 2009	350	20825	0.973	2.6	58.0	354	20452	0.962	-22.5	68.2	350	20824	0.951	6.2	78.7	352	20620	0.968	-0.3	63.8	341	17134	0.938	-1.1	85.4	293	21005	0.953	14.1	76.2
Sede Boqer 2004 - 2011	535	28380	0.985	3.0	50.6	537	28051	0.982	-33.0	56.2	536	28379	0.979	18.4	60.3	536	28135	0.983	25.0	53.6	527	25255	0.975	4.9	64.6	533	21386	0.968	-9.0	75.3
Tamanrasset 2004 - 2011	594	30159	0.984	-7.2	55.8	597	25818	0.971	12.4	75.2	597	29252	0.978	-10.7	66.9	595	29904	0.977	-6.1	65.6	596	26866	0.971	0.2	73.3					
Toravere 2004 - 2011	252	30386	0.968	-5.8	54.1	272	27674	0.938	5.8	79.1	252	30426	0.955	-3.8	65.1	252	30258	0.947	-11.2	70.2	245	25710	0.947	-15.4	68.7	256	22129	0.948	-2.0	69.7
Valentia 2004 - 2011	237	33292	0.961	-8.7	61.8	235	33748	0.949	9.7	71.1	240	32870	0.928	7.7	82.7	243	32334	0.932	4.3	81.5	238	27952	0.911	-12.1	88.6	257	23218	0.925	3.6	84.4
Vaulx-en-Velin 2004 - 2011	300	30271	0.979	9.2	51.7	303	29771	0.970	8.0	61.6	304	29846	0.962	22.2	70.7	301	29920	0.974	17.7	60.4	302	28530	0.961	15.0	71.1	303	20935	0.963	10.8	67.8
Wien 2004 - 2011	278	33556	0.975	-0.8	53.5	282	32754	0.970	-8.5	60.4	280	33344	0.957	9.5	71.4	278	33173	0.967	1.0	63.2	270	29152	0.961	7.3	67.4	291	23953	0.958	2.0	70.1
Zilani 2004 - 2009	250	22767	0.962	-3.6	61.3	263	21217	0.922	28.7	94.1	249	22852	0.941	-8.1	76.9	256	21918	0.940	-6.5	77.4	239	17995	0.912	-14.1	90.7	268	13730	0.892	-47.1	102.2
All sites	341	26381		-0.4	56.6	345	25418		4.7	70.5	342	26255		6.2	79.8	346	25682		3.5	65.5	337	22169		0.3	75.2	340	18401		1.8	80.8

Documents

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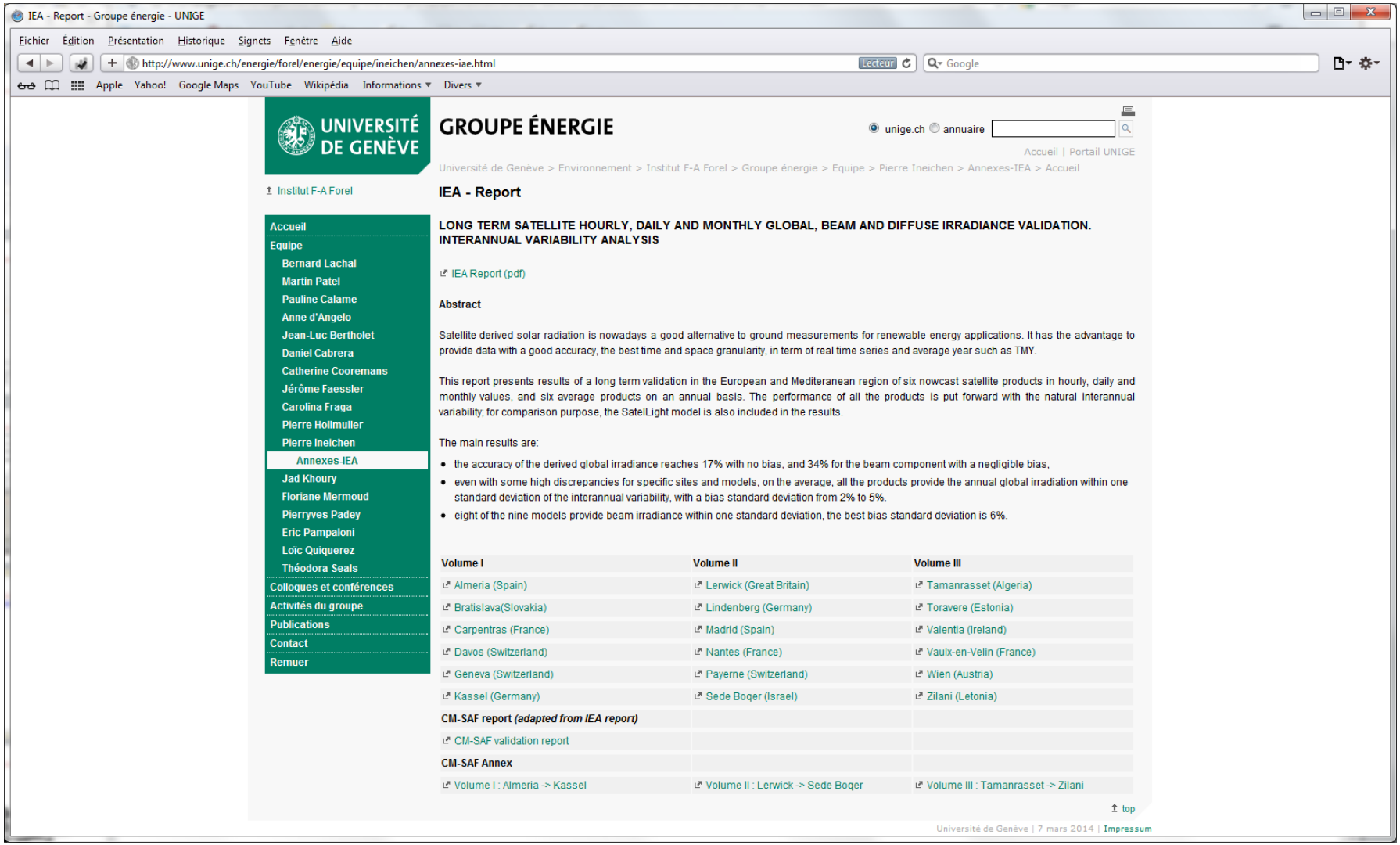
http://www.unige.ch/energie/forel/energie/equipe/ineichen/annexes-iae.html




Thank
you
Merci
Graciasgracias
Arigato
Dankscheen
Mehrbani
bolzïn
Shukuria
Tashakkur
Maketai
Paldies
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Wabeeja
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Mersi
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Tingki
Komapsumnida
Maake
Denkauja
aniha
Aguyjo
Spassibo
gozaimashita
Fakaaue
Spasibo
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Ekhmet
Nenachalhya
Baiika
Yuspagaràtam
Minmonchar
Atto
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ekoju
Tavtapuch
Sikomo
Gui
Yaqhanyelay
Efcharisto
Shukria
Biyan
Grazie
Snachalhuya
Juspaxar
muhan
Merastawhy
lah
Dhanyabaad
Chaltu

Validation results, other models

GENERGIE University of Geneva

Validation results

- helioclim 3: poor clear sky model taken into account in the final model
- better results with daily input parameters instead of monthly climatic data banks
- similar behavior for all the models
- Better snow management in Heliomont and SolarGis