IFE

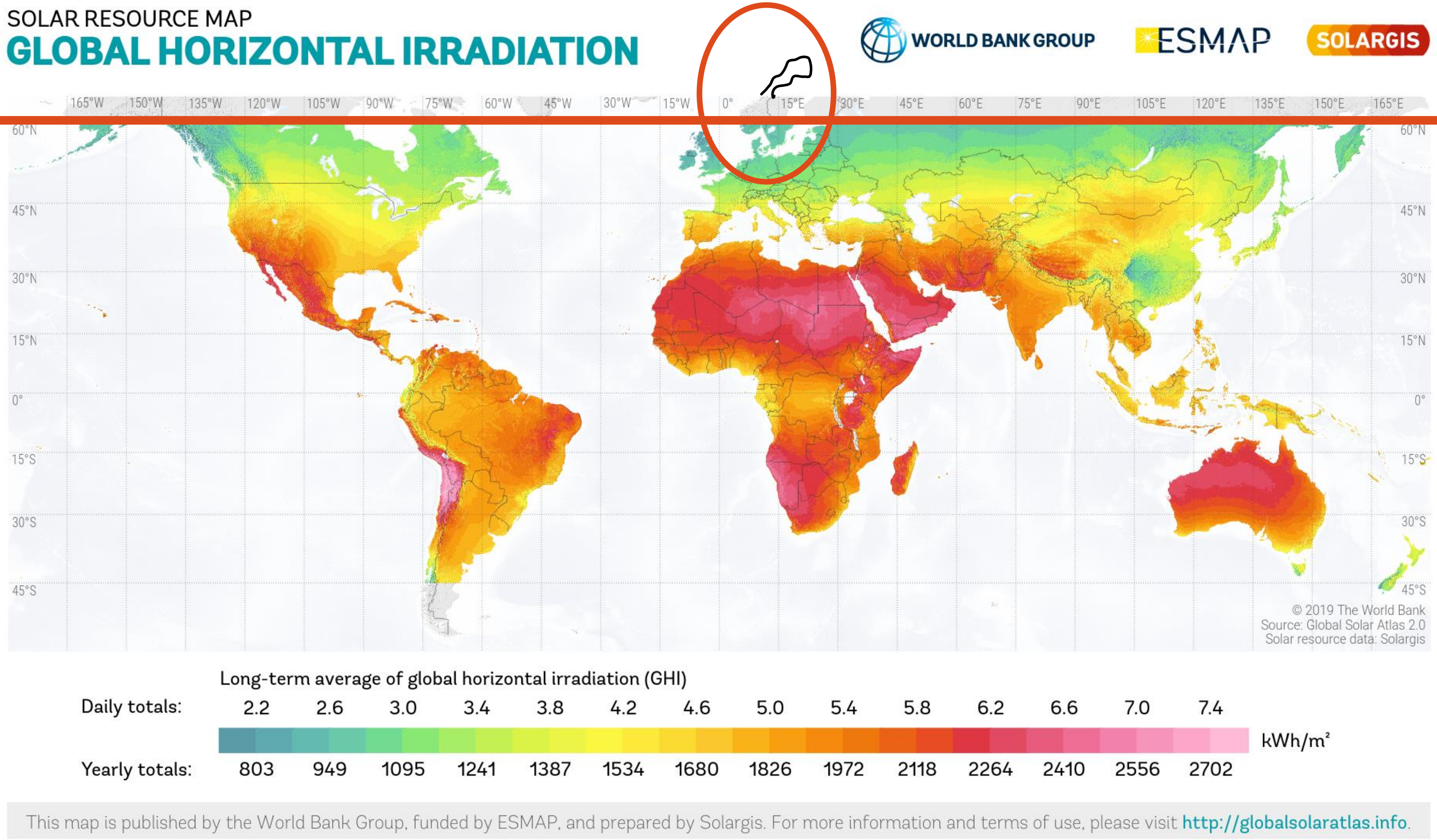
13.02.2024

ÅPENT

Benchmark of six irradiation products in Norway

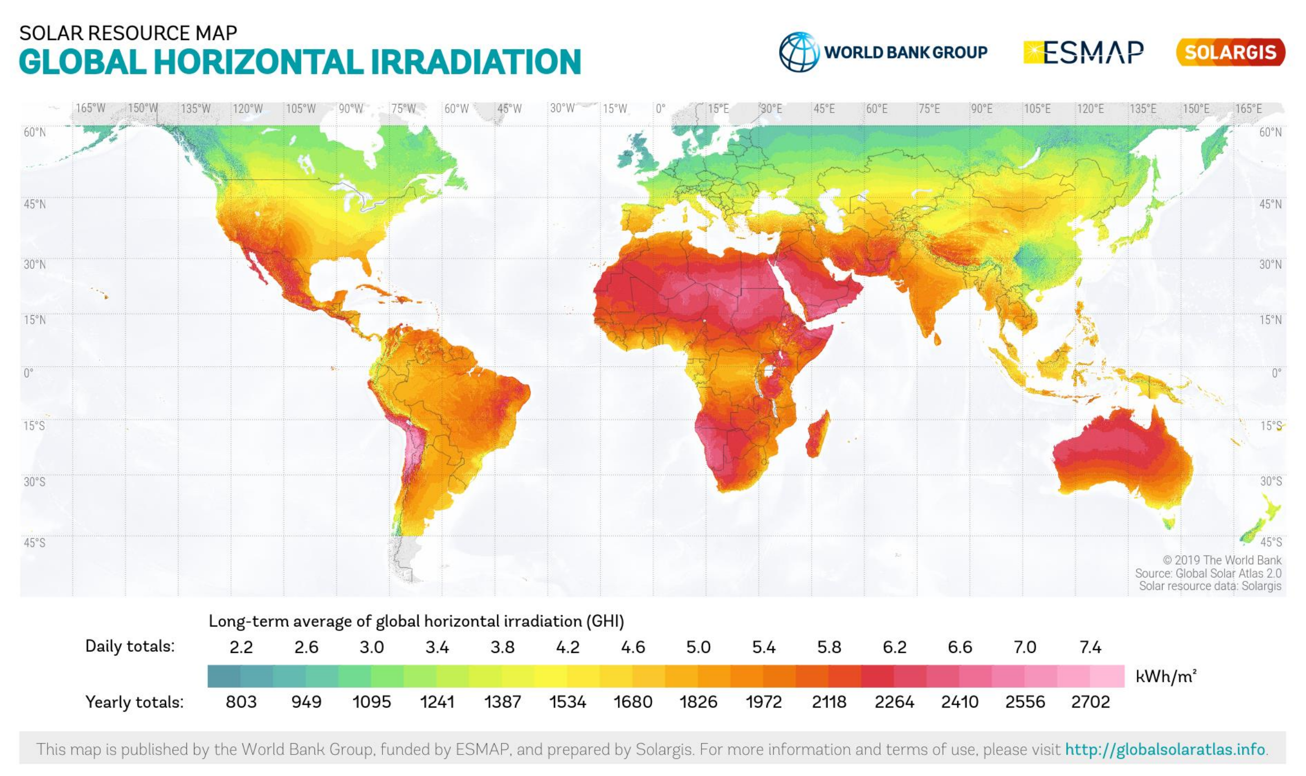
Heine Nygard Riise (IFE), Andreas Dobler (MET Norway), Bjørn Aarseth (IFE),
Magnus Moe Nygård (IFE), Erik Berge (MET Norway)

60°N


SOLAR RESOURCE MAP
GLOBAL HORIZONTAL IRRADIATION
WORLD BANK GROUP
ESMAP
SOLARGIS
165°W 150°W 135°W 120°W 105°W 90°W 75°W 60°W 45°W 30°W 15°W 0° 15°E 30°E 45°E 60°E 75°E 90°E 105°E 120°E 135°E 150°E 165°E
60°N 45°N 30°N 15°N 0° 15°S 30°S 45°S
© 2019 The World Bank
Source: Global Solar Atlas 2.0
Solar resource data: Solargis
Long-term average of global horizontal irradiation (GHI)
Daily totals: 2.2 2.6 3.0 3.4 3.8 4.2 4.6 5.0 5.4 5.8 6.2 6.6 7.0 7.4
kWh/m²
Yearly totals: 803 949 1095 1241 1387 1534 1680 1826 1972 2118 2264 2410 2556 2702
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info.

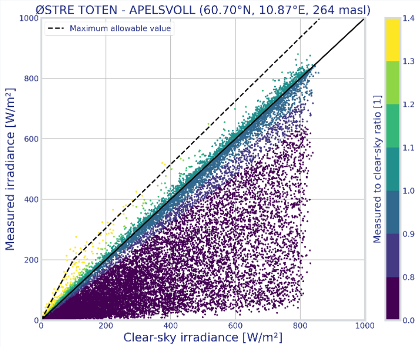
The data products

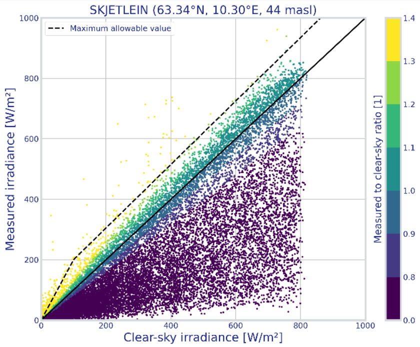
- We have benchmarked 6 products that are in regular use in Norwegian projects
  - CAMS-RAD (geo-stationary satellite, 66°N)
  - PVGIS Sarah-2 (geo-stationary satellite, 65°N)
  - Solargis (geo-stationary satellite, 65°N)
  - Meteonorm (ground measurements – interpolation with satellite and NWP, global coverage)
  - PVGIS ERA5 (NWP, global coverage)
  - NASA POWER (geo-stationary+polar orbit satellite/NWP, global coverage)



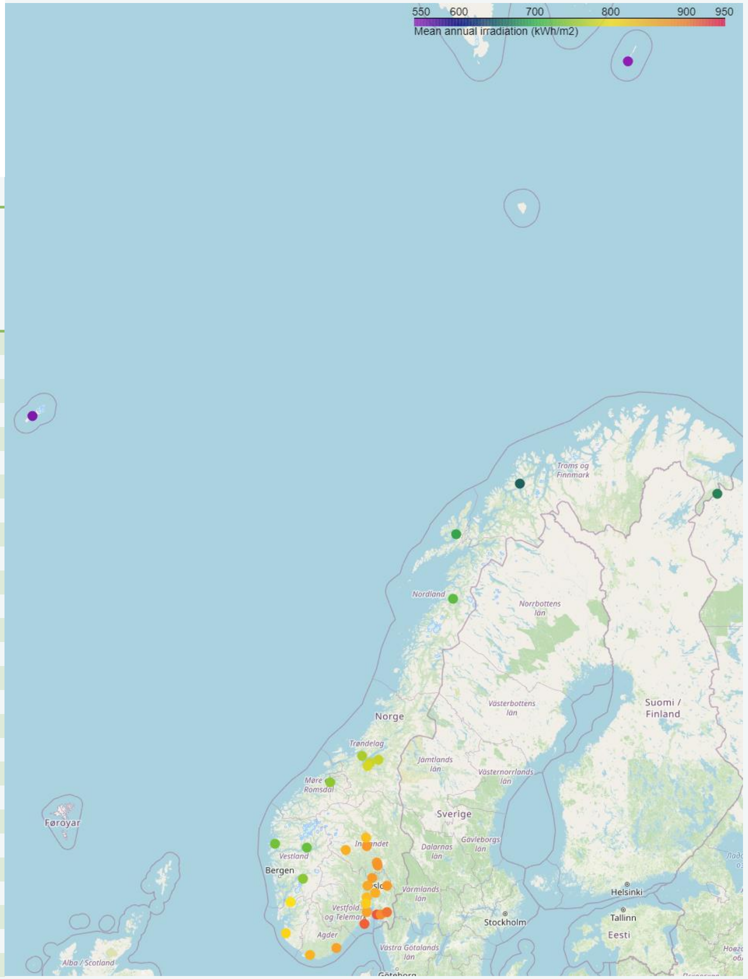
Ground station network

- Agricultural meteo service
  - Rregularly cleaned
  - Serviced bi-annually
  - https://lmt.nibio.no/
- 34 stations passed QC
  - 7 automatic tests for physical limit (2xmax, 2xmin, 2xvariability, offset) – expanded BSRN-tests
  - Coverage
  - Manual checks for shading, drift, misalignment
  - Pyranometer class A



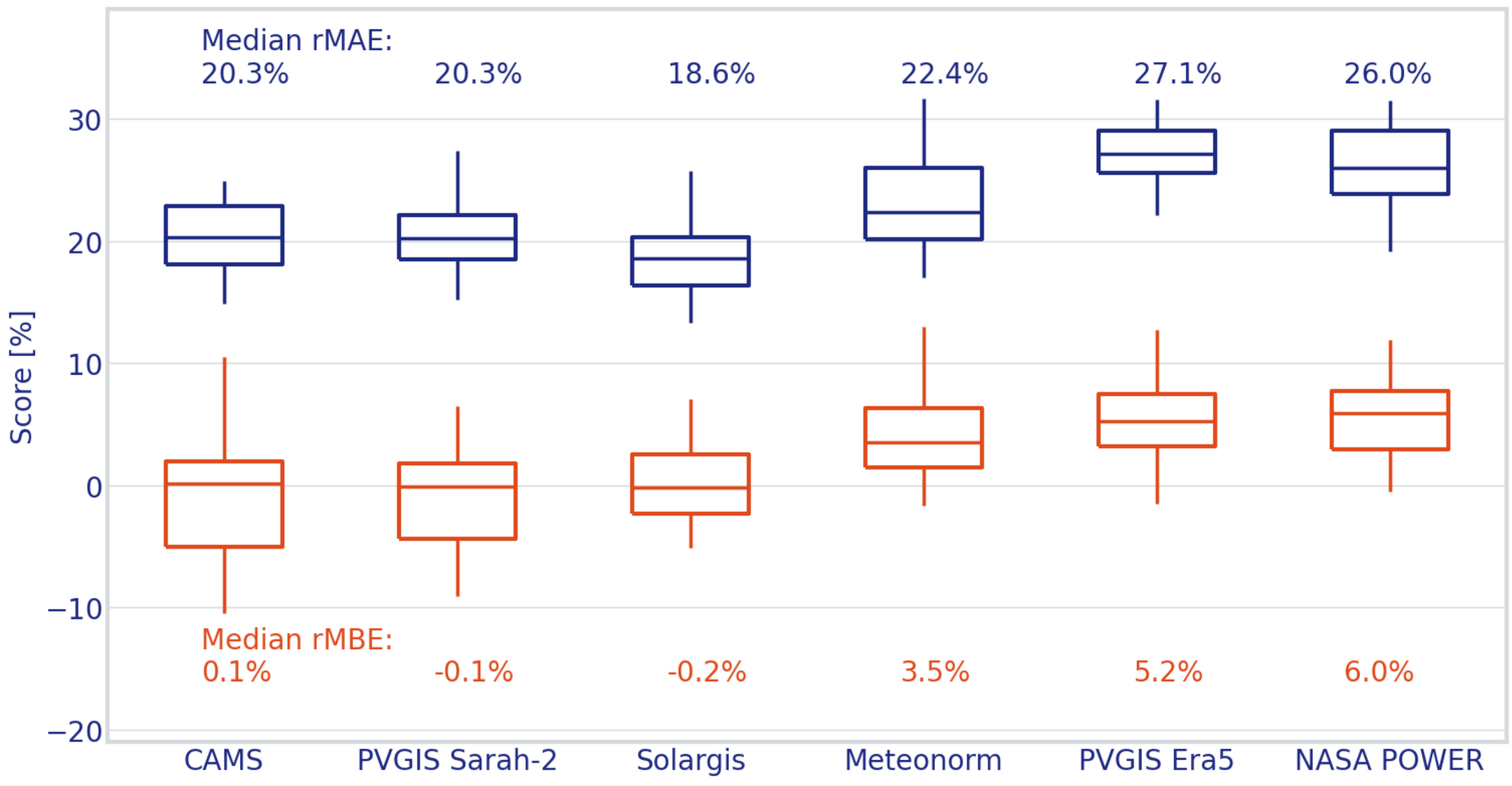


Station Name	Latitude (°N), Longitude (°E)	Altitude (masl)	Mean Annual Irradiation (kWh/m²/yr)	Months per year with median snow depth > 0 cm	Köppen –Geiger Climate Zone	Median clearness index
Lyngdal	58.14, 7.05	6	847	0	Cfb	0.30
Landvik	58.34, 8.52	6	867	1	Cfb	0.31
Særheim	58.76, 5.65	87	815	0	Cfb	0.29
Tjølling	59.05, 10.13	19	917	0	Cfb	0.36
Råde – Tomb	59.32, 10.81	12	921	0	Cfb	0.36
Øsaker	59.32, 11.04	45	888	0	Cfb	0.35
Ramnes – Kile Vestre	59.38, 10.24	39	865	3	Cfb	0.33
Rakkestad	59.39, 11.39	100	907	2	Cfb	0.33
Sande – Galleberg	59.62, 10.22	60	822	4	Cfb	0.29
Etne II	59.66, 5.95	8	799	0	Cfb	0.30
Lier	59.79, 10.26	39	840	3	Dfb	0.31
Oslo – Blindern	59.94, 10.72	94	853	2	Dfb	0.33
Årnes	60.13, 11.39	160	874	4	Dfb	0.33
Hønefoss – Hverven	60.14, 10.27	126	859	4	Dfb	0.34
Ullensvang Forsøksgard	60.32, 6.65	12	741	0	Cfb	0.24
Gran	60.36, 10.56	245	872	4	Dfb	0.35
Østre Toten – Apelsvoll	60.70, 10.87	264	881	4	Dfc	0.33
Kise på Hedmark	60.77, 10.81	128	874	4	Dfb	0.32
Løken i Volbu	61.12, 9.06	521	853	6	Dfb	0.32
Njøs	61.18, 6.86	45	724	0	Cfb	0.24
Gausdal – Follebu	61.22, 10.26	375	875	5	Dfc	0.34
Fureneset	61.29, 5.04	7	729	0	Cfb	0.24
Fåvang	61.46, 10.18	200	836	5	Dfc	0.31
Tingvoll	62.91, 8.19	23	742	0	Dfc	0.28
Skjetlein	63.34, 10.30	48	779	3	Cfc	0.33
Trondheim – Gløshaugen	63.42, 10.41	60	773	3	Cfb	0.33
Kvithamar	63.49, 10.88	27	771	3	Cfb	0.29
Rissa III	63.59, 9.97	23	757	0	Cfc	0.30
Valnesfjord	67.28, 15.10	20	717	4	Dfc	0.30
Sortland – Kleiva	68.65, 15.28	14	691	5	Dfc	0.28
Pasvik – Svanvik	69.46, 30.04	27	671	6	Dfc	0.28
Tromsø – Holt	69.65, 18.91	20	654	7	Dfc	0.26
Jan Mayen	70.94, -8.67	10	556	No data	ET	0.23
Hopen	76.51, 25.01	6	541	No data	ET	0.26



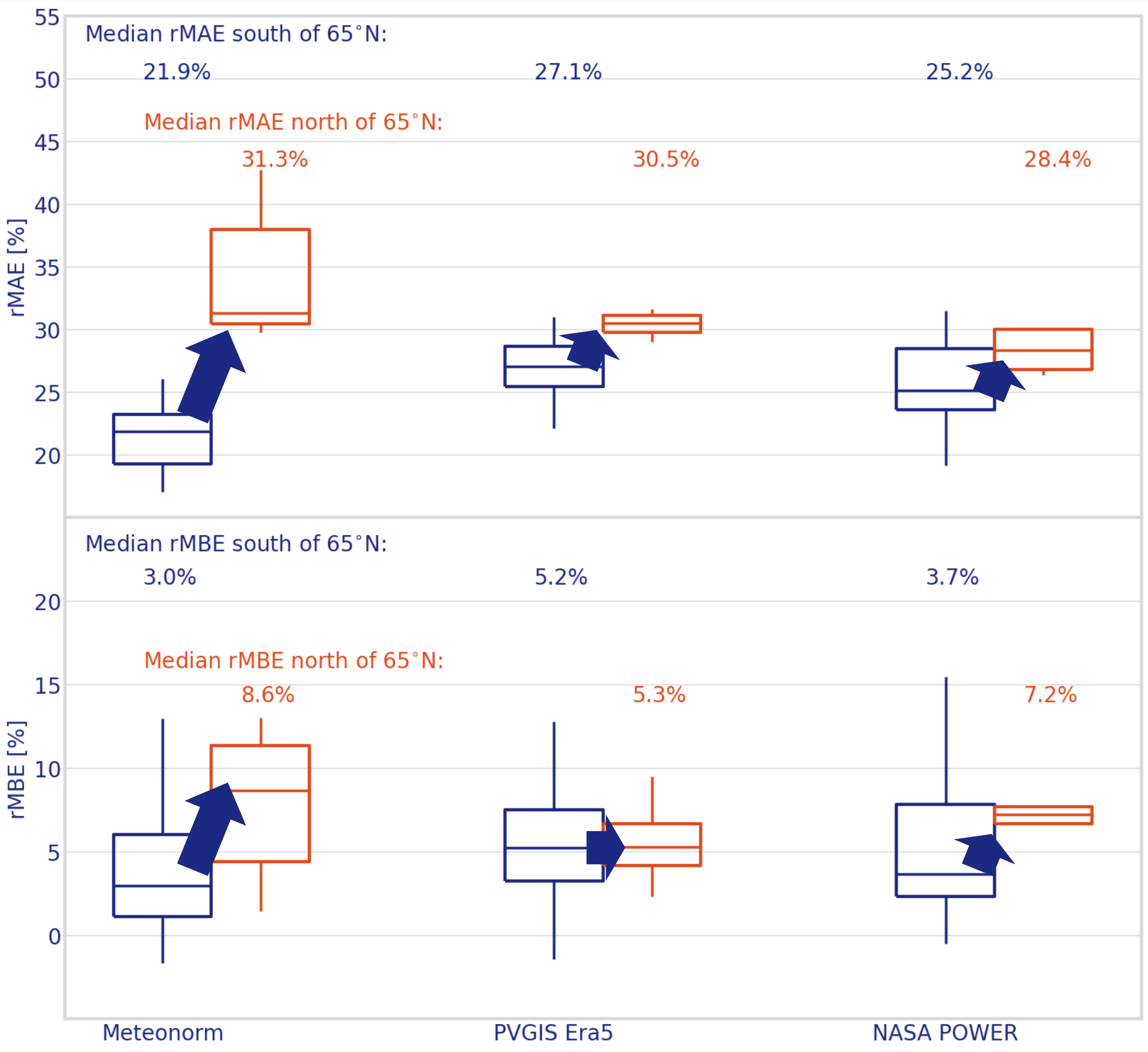
Overall results

- Hourly comparison of 5 years of data 2016-2020
- Mean Absolute Error and Mean Bias Error
- r = normalization to mean irradiance value
- Median of rMAE/rMBE from distribution of stations
- Solargis, PVGIS Sarah-2, CAMS has ~0 % bias
- Meteonorm, PVGIS Era5 og NASA POWER has non-negligible, positive bias
- Absolute error is also larger for Meteonorm, Era5 and NASA



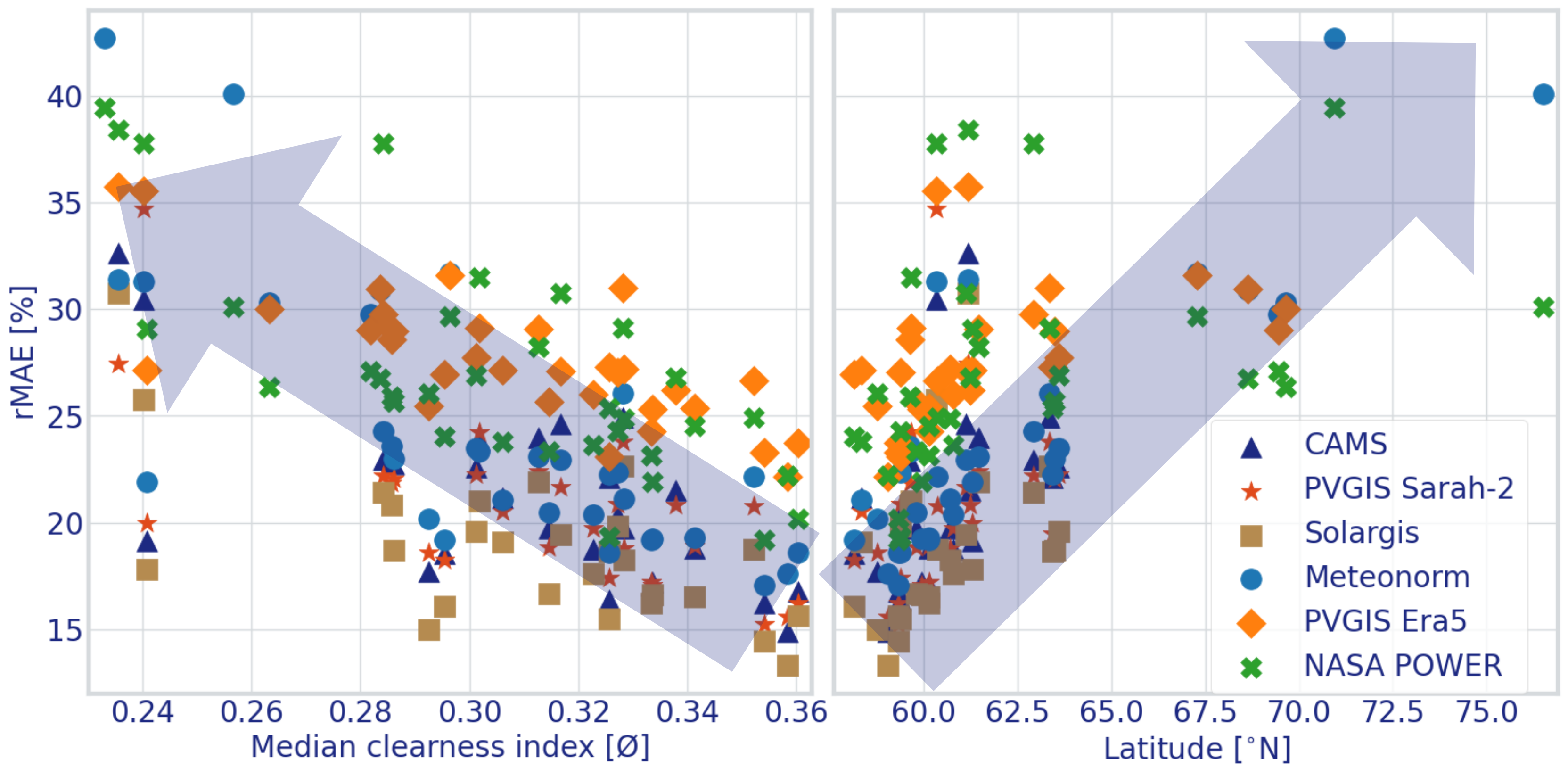
South vs North

- Blue boxes is south, orange is north
- Meteonorm has largest change in performance South vs North
  - 9 % medianbias
- All three products have lower accuracy in the North
- Likely causes:
  - No geo-stationary observations
  - More cloudy weather
  - More snowy conditions



Latitude and cloudiness

- Cloudiness and latitude both affect the performance
- On the left: rMAE as a function of clearness index
  - More cloudy -> lower accuracy
- On the right: rMAE as a function of latitude
  - Higher latitude -> lower accuracy



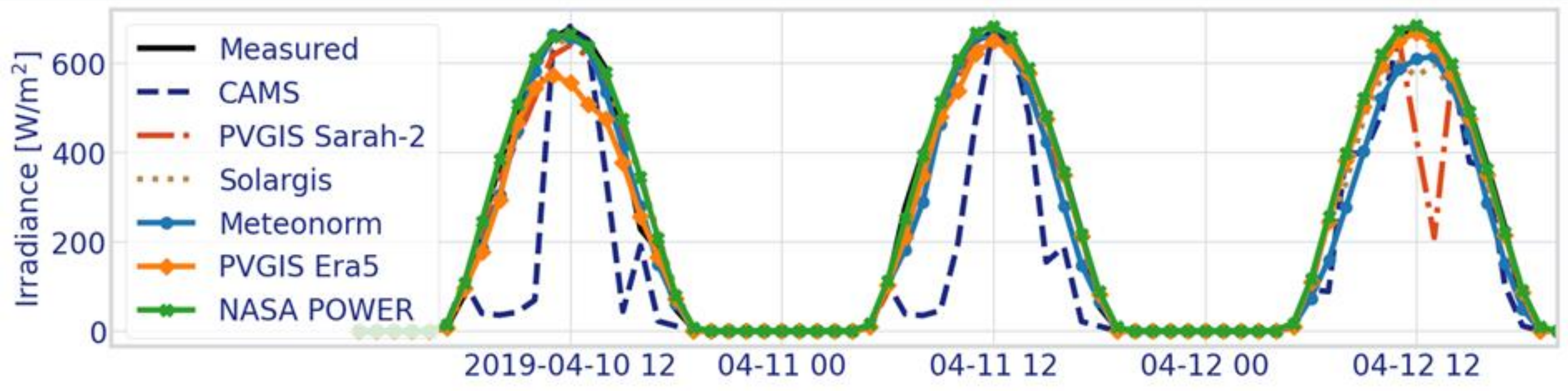
More cloudy Less cloudy Lindesnes Svalbard

Snow

- All the products lower performance at snowy stations
- Geostationary satellite products underestimate
  - Misinterpretation of snow as clouds
- All the products have higher rMAE at snowy stations
  - Snow causes estimation problems

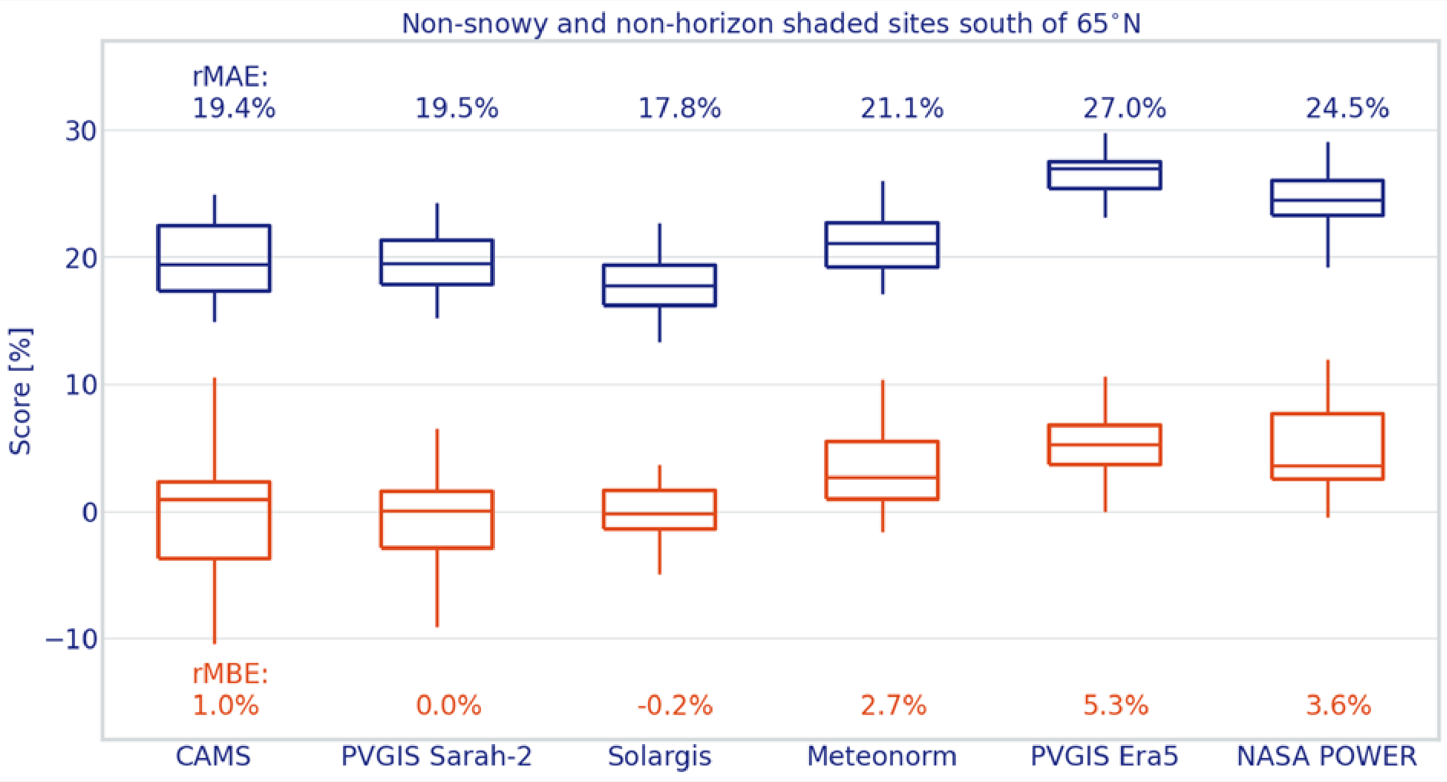
How does snow cause problems?

- Example from clear sky days in central Norway with snow ground cover
- Geo-stationary satellite products
  - CAMS underestimates the first two days
  - PVGIS Sarah-2 and Solargis slight underestimation on day three
  - Illustrates that estimation from satellite is challenging with snow ground cover
  - Sensitive to slight changes in imagery and snow detection algorithms



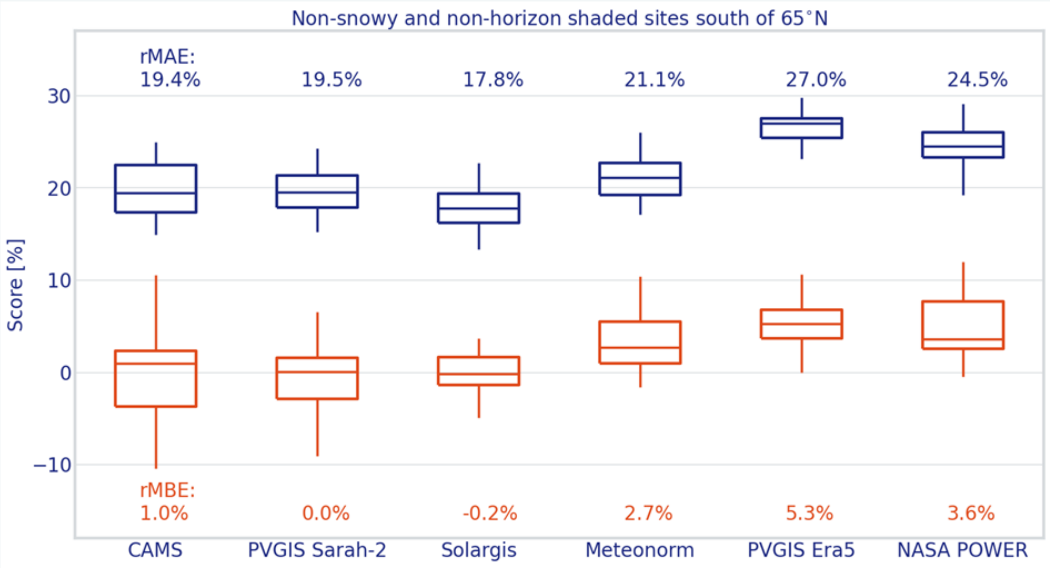
Stations with no «problems»

- Snow, distinct horizon and latitude affects products differently
- Here a comparison without these «problems»
- Geo-stationary satellite products highest performance
- PVGIS Era5 and NASA POWER high rMAE and rMBE



Conclusions

- It is challenging to estimate the solar resource in Norway
- We have conditions that complicate estimation
  - High cloudiness
  - High latitude
  - Snow
  - Topography leading to horizon shading
- All the data products in the comparison have a reduced accuracy due to these challenges
- Decoupling these challenges in the comparison
  - Geo-stationary satellites most accurate
  - Above 65°N, Era-5 arguably gives most representative estimates



Thanks for your attention

Heine Nygard Riise
Senior Scientist

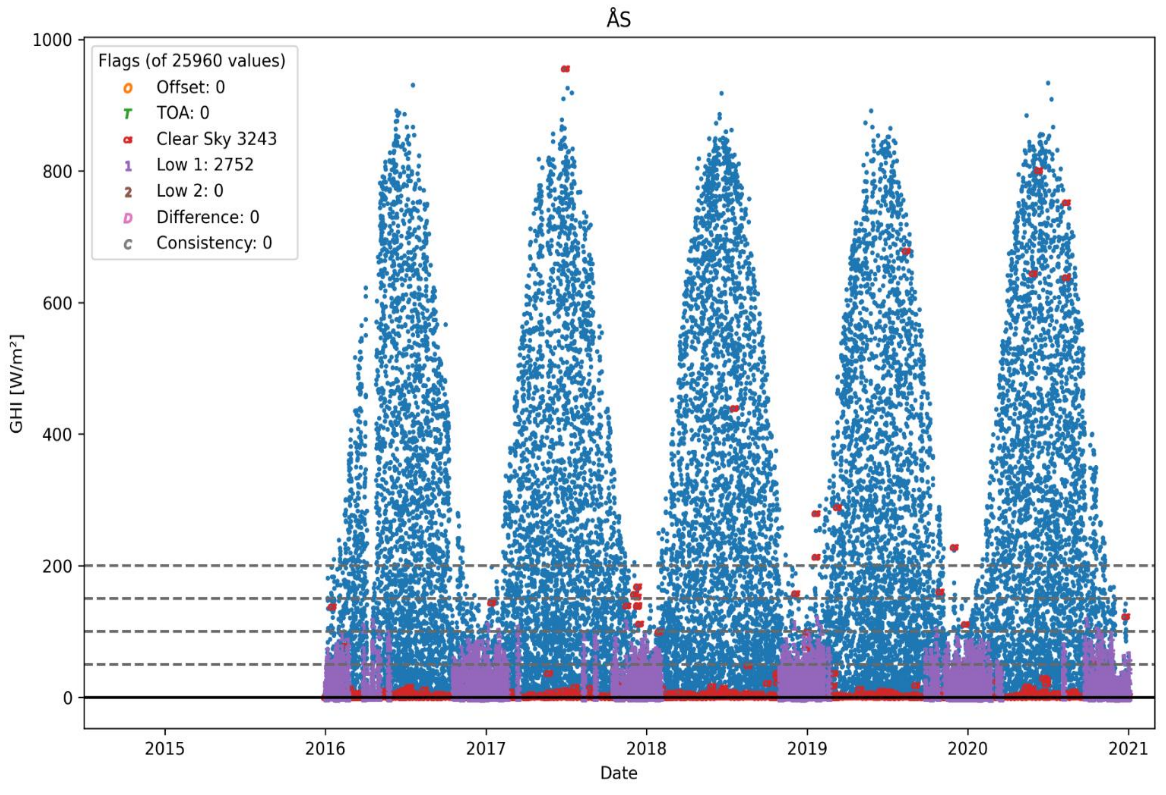
ife.no

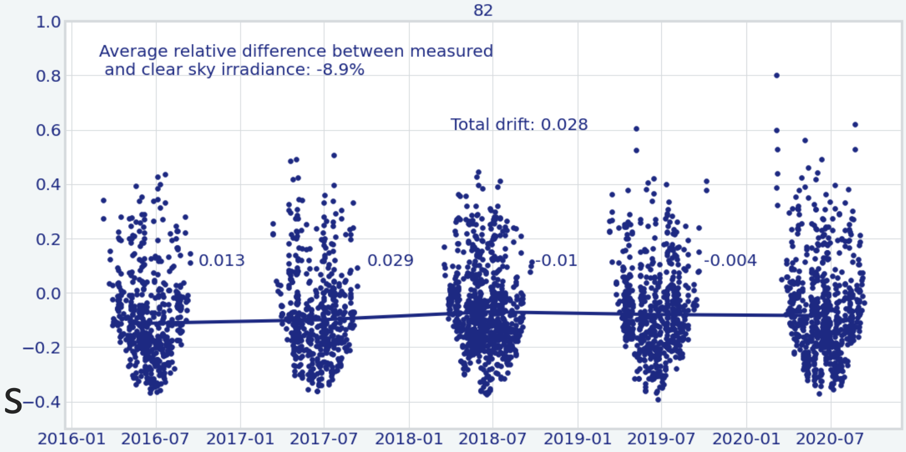
+47 948 68 828
Heine.riise@ife.no

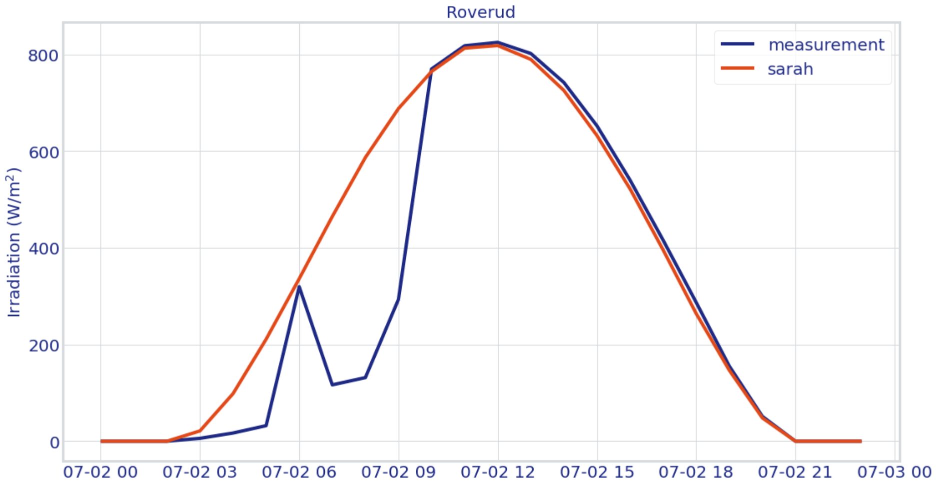
Modelled solar irradiance product	CAMS radiation	PVGIS Sarah-2	Solargis	Meteonorm	PVGIS Era5	NASA POWER
Source	High-resolution geosynchronous satellite imagery	High-resolution, geosynchronous satellite imagery	High-resolution, geosynchronous satellite imagery	Ground stations, satellite interpolation between stations, and atmospheric reanalysis interpolation above 62°N	Atmospheric reanalysis	Satellite imagery
Spatial coverage	Up to 66°N	Up to 65°N	Up to 65°N	Whole Norway	Whole Norway	Whole Norway
Spatial resolution	Interpolated to point of interest	0.05°x0.05°	Interpolated to point of interest	Interpolated to point of interest	0.25°x0.25°	1°x1°
Highest temporal resolution	1 min	0.5 h	1 min	1 h	1 h	1 h
Available time periods	2004-2 days ago	2005-2020	1994-2021	2008-1 month ago	2005-2020	1984-7 days ago
Relevant resources	[1, 2], https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-solar-radiation-timeseries	[4], https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis_en	https://solargis.com/docs	https://meteonorm.com/en/meteonorm-documents	[5], https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis_en	https://power.larc.nasa.gov/

Quality control

- Filtering based on Sigbjørn Grini's master work
  - 8 tests
  - To make sure the values are physical
- Coverage
  - 80 % (+ 60 % all months)
- Filtering + coverage reduced # of stations from 102 to 55
- Visual inspection
  - Shading
  - Drift
  - Misaligned sensor
  - Clear sky level
  - **<u>Pyranometer class</u>**
- Left with ~~42~~ 35 stations

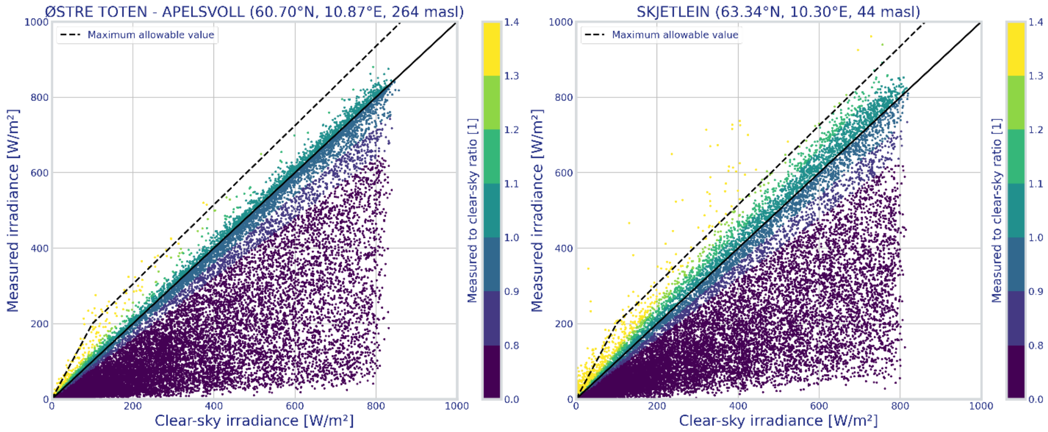


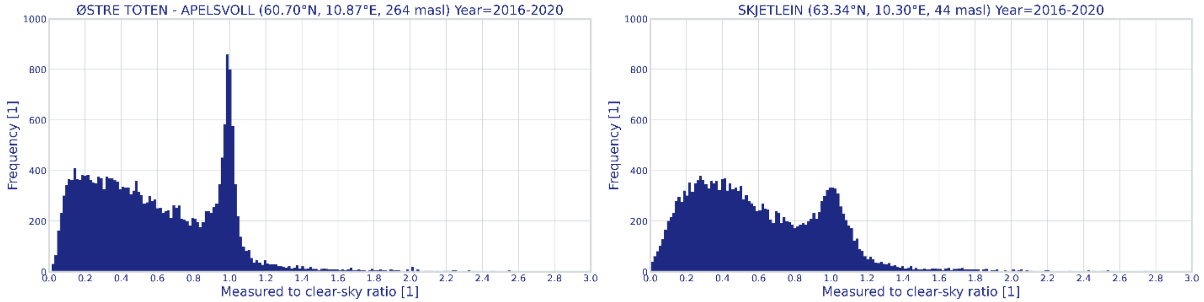




Filtrering/flagging

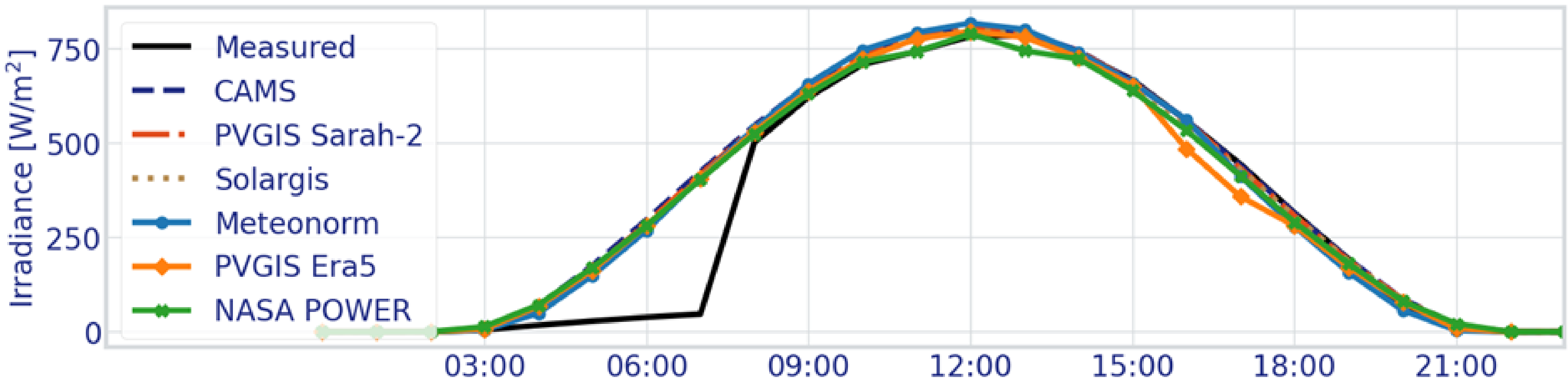
- Artikkelen gir også ein detaljert beskrivelse av flaggeprosedyren som Andreas har vidareutvikla
- Med grafiske eksempel på kva testane fangar opp





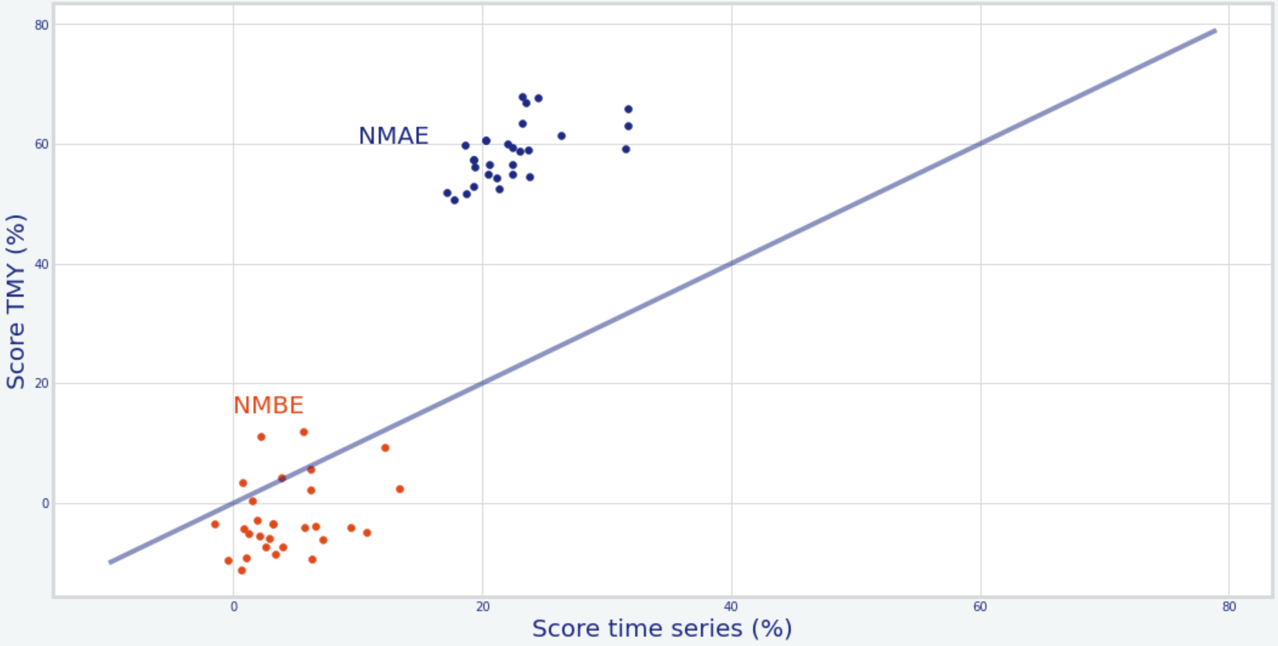
Horisont

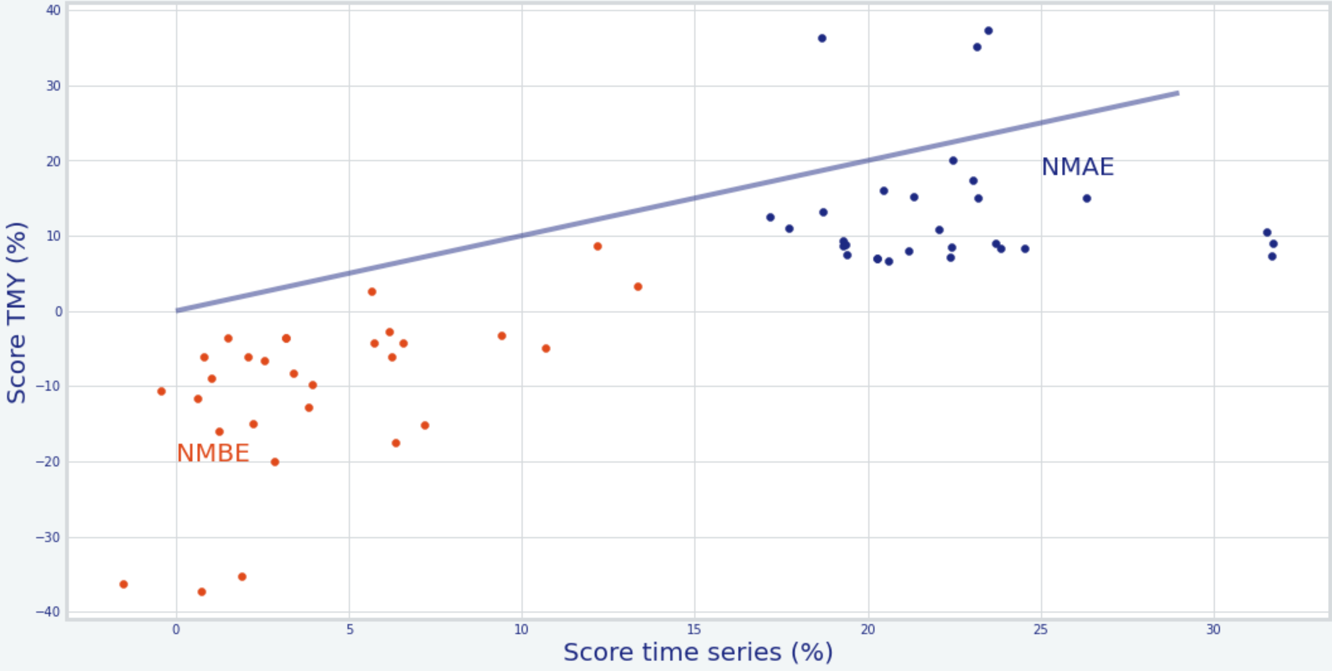
- Nokre stasjonar har problem med horisontskugging. Her Njøs i Sognefjorden
- Dette er ikkje estimert av DB
  - Solargis, Meteonorm, PVGIS og CAMS har moglegheit, men NASA tilbyr ikkje
  - For å ha ein god samanlikning, droppa vi horisontmodellane
- Det fører til litt dårlegare presisjon på horisontskugga stasjonar (Vestlandet)
- Illustrerar viktigiheit av å ta hensyn til horisont viss ein vurderar anlegg i Noreg



How do you compare TMY to time series?

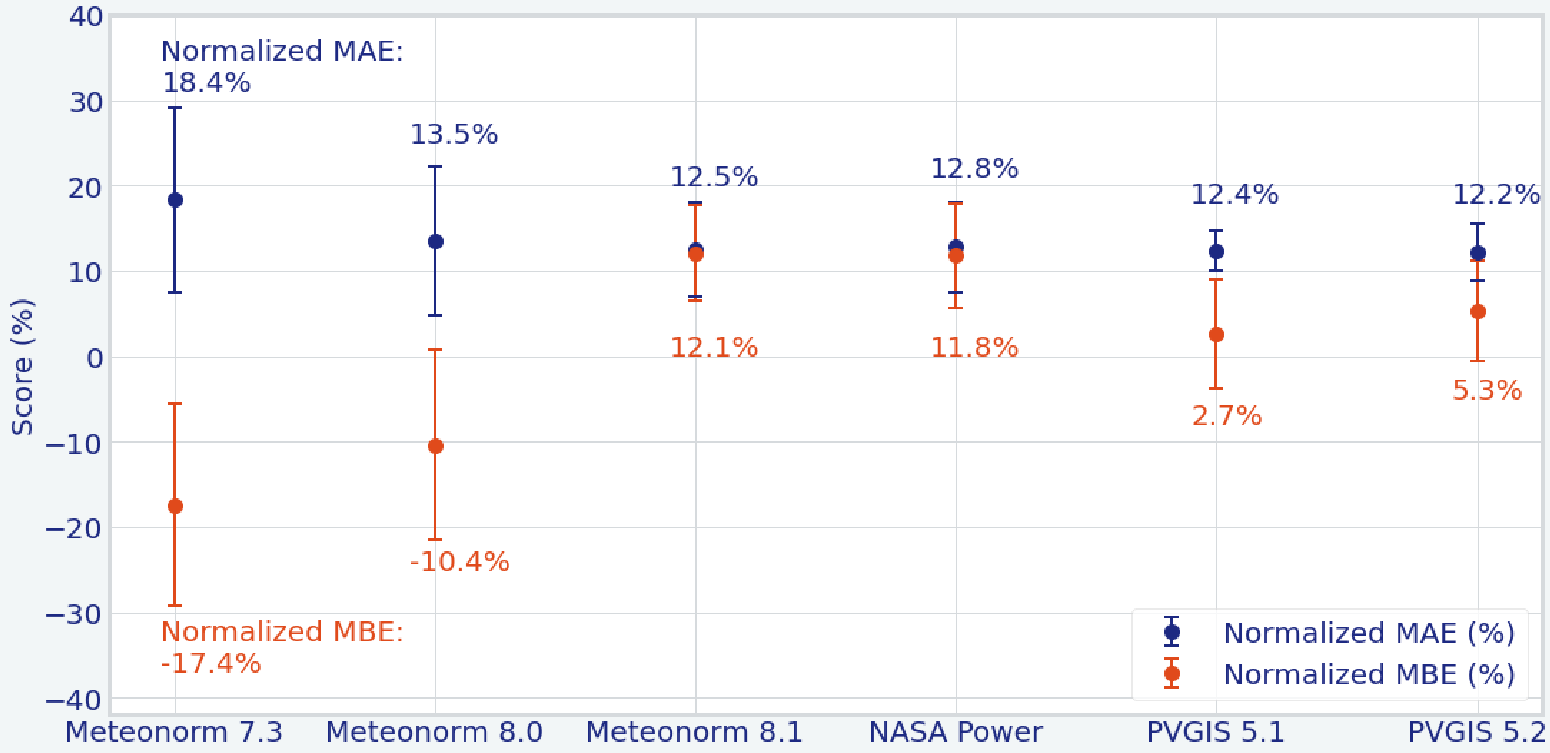
- The NMAE and NMBE from comparing Meteonorm TMY w/5 year TMY ***hour by hour*** is plotted against NMAE and NMBE of time series data in top figure
- The NMAE and NMBE from comparing Meteonorm TMY w/5 year TMY ***on monthly aggregates*** is plotted against NMAE and NMBE of time series data in bottom figure
- I.e. TMY is useful for monthly comparisons, not hourly





Comparison TMYs

- Meteonorm has recently updated TMY-methodology
  - Comparing here MN 7.3, MN 8.0 and MN 8.1
- PVGIS also have two ways of calculating
  - PVGIS 5.1 and PVGIS 5.2
- Both Meteonorm and PVGIS version changes are related to which years form the basis of the calculation



- Comparison w/ time series
- **Meteonorm 8.1**
  - **NMAE: 24.3 % -> 12.5 %**
    TS TMY
  - **NMBE: -4.9 % -> 12.5 %**
    TS TMY
- **Meteonorm 8.0**
  - **NMAE: 24.3 % -> 13.5 %**
    TS TMY
  - **NMBE: -4.9 % -> -10.5 %**
    TS TMY
- **Meteonorm 7.3**
  - **NMAE: 24.3 % -> 18.3 %**
    TS TMY
  - **NMBE: -4.9 % -> -17.4 %**
    TS TMY

- Comparison w/ time series
- **NASA**
  - **NMAE: 27.7 % -> 12.8 %**
    TS TMY
  - **NMBE: 6.9 % -> 11.8%**
    TS TMY

- Comparison w/ time series
- **PVGIS 5.1**
  - **NMAE: 21.1 % -> 12.4 %**
    TS TMY
  - **NMBE: 0.0 % -> 2.7 %**
    TS TMY
- **PVGIS 5.2**
  - **NMAE: 21.1 % -> 12.2 %**
    TS TMY
  - **NMBE: 0.0 % -> 5.3 %**
    TS TMY

Conclusions TMY

- NMAE generally reduced TMY vs time series
- NMBE generally increased (negatively)
- What can we understand from that?
  - Daily bias nulled out when aggregating, i.e. smoothing effect
  - Seasonal bias exaggerated when aggregating?
- Update from Meteonorm 7 to 8 seems to have reduced bias and absolute error
- PVGIS looks like a decent option also when considering TMY