PV module degradation rates in Norway

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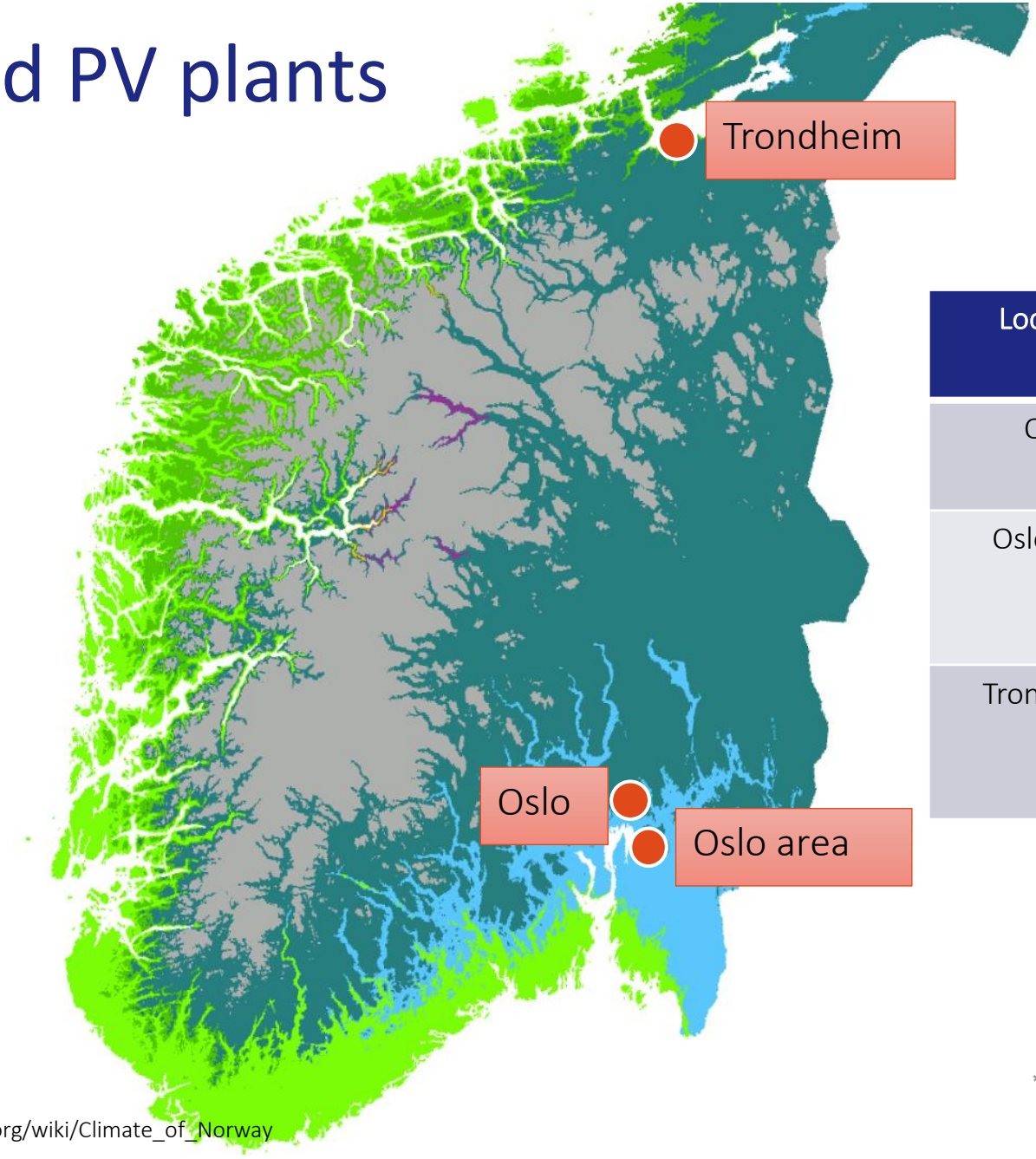
Norway's climate

- Maritime climate along the coast
- Continental climate inland
- Polar climate in the mountains and north

Image: https://en.wikipedia.org/wiki/Climate_of_Norway

Analyzed PV plants



Location	Climate zone	Installation type, tilt	Data availability
Oslo	Dfb	Flat roof top, 10 deg	2017-2023
Oslo area	Dfb	Flat roof top, 10 deg	2015-2023
Trondheim	Cfb	Flat roof top, 10 deg	2017-2023

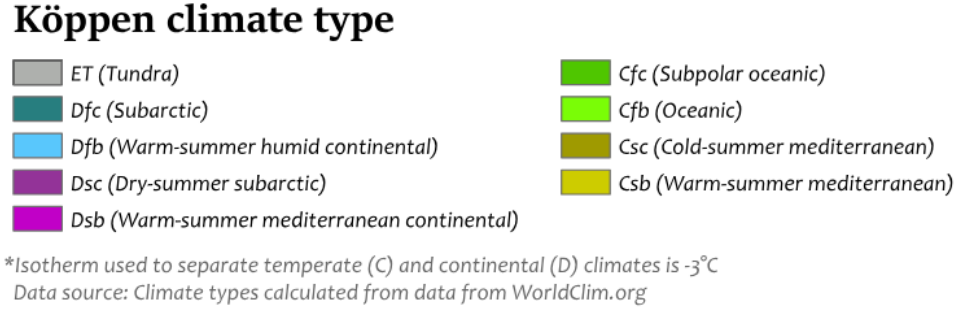
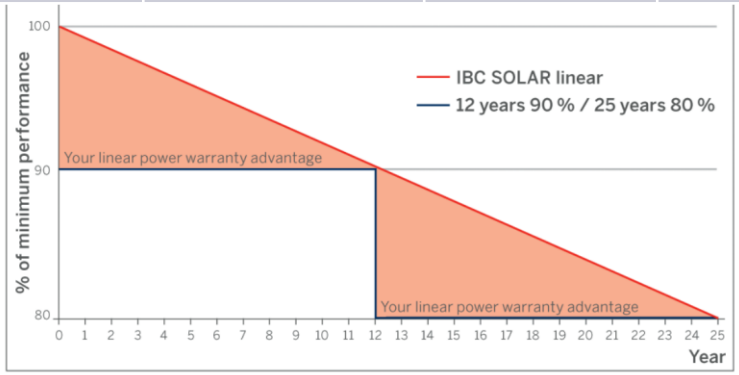


Image: https://en.wikipedia.org/wiki/Climate_of_Norway

PV plant details

Location	Climate zone	Module type	Orientation	Tilt	Installed capacity [kW]
Oslo	Dfb	IBC Solar PolySol 265 CS4	124/304	10	720
Oslo area	Dfb	IBC Solar PolySol 250 CS	90/270	10	370
Trondheim	Cfb	IBC Solar PolySol 265 CS4	108/288	10	450

- **Modules**: IBC PolySol 250 CS
  - 60 cell poly-Si modules
  - Glass/Backsheet
  - IBC Solar : degradation rate <0.83 %/a

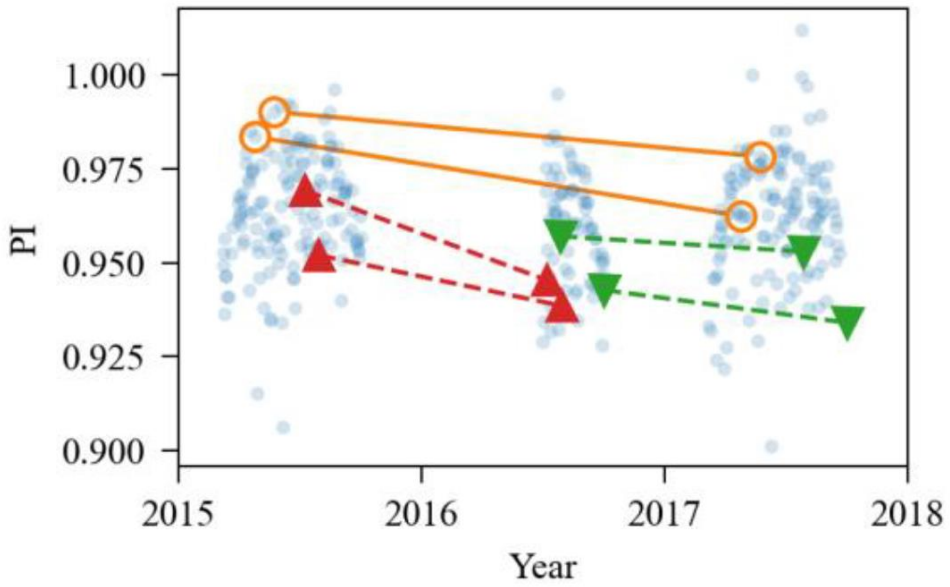


Site instrumentation

- Reference cells in modules POA
  - Meteocontrol SI-12TC reference cell
  - Temperature measurements from reference cell

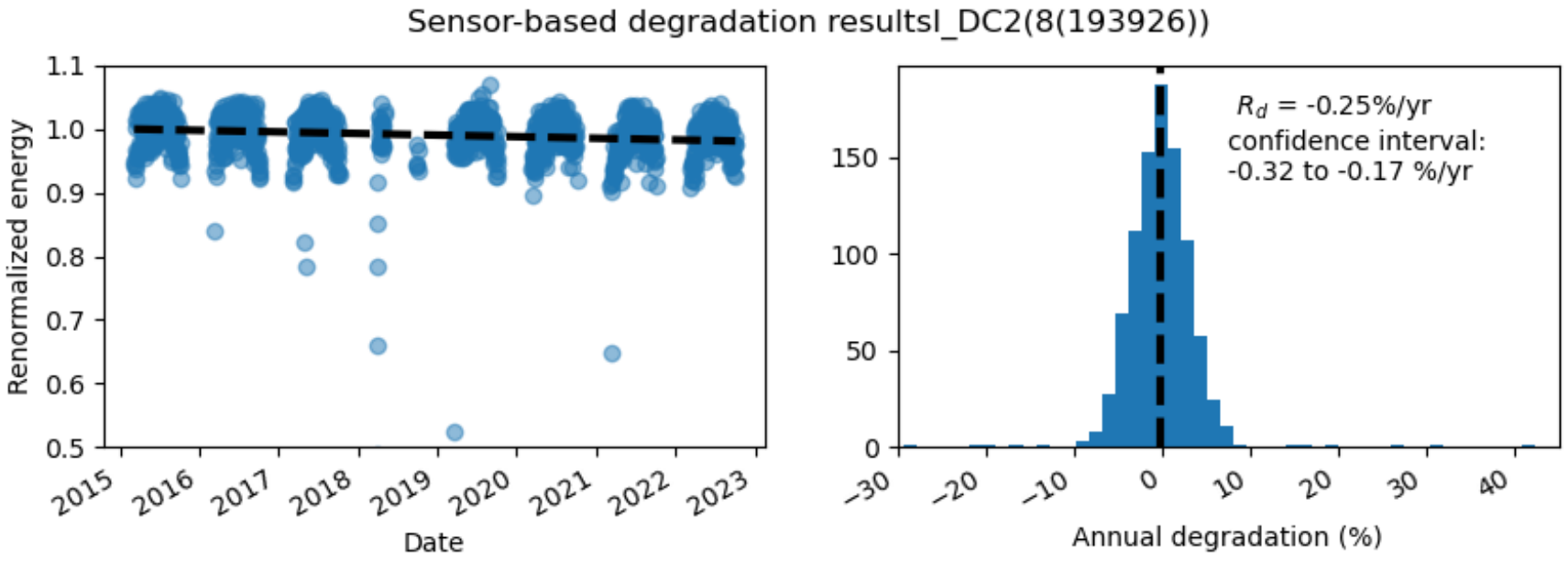
RdTools YOY degradation

- Steps
  - Normalization of power production
  - Filtering
    - POA irradiance: 200-1200 W/m2
    - Temperature: low=-50 [C], high=110 [C]
    - Normalized filter: normalized energy is less than 1%
    - Clipping filter
  - Aggregation to daily irradiance weighted average
  - Calculation of yoy degradation

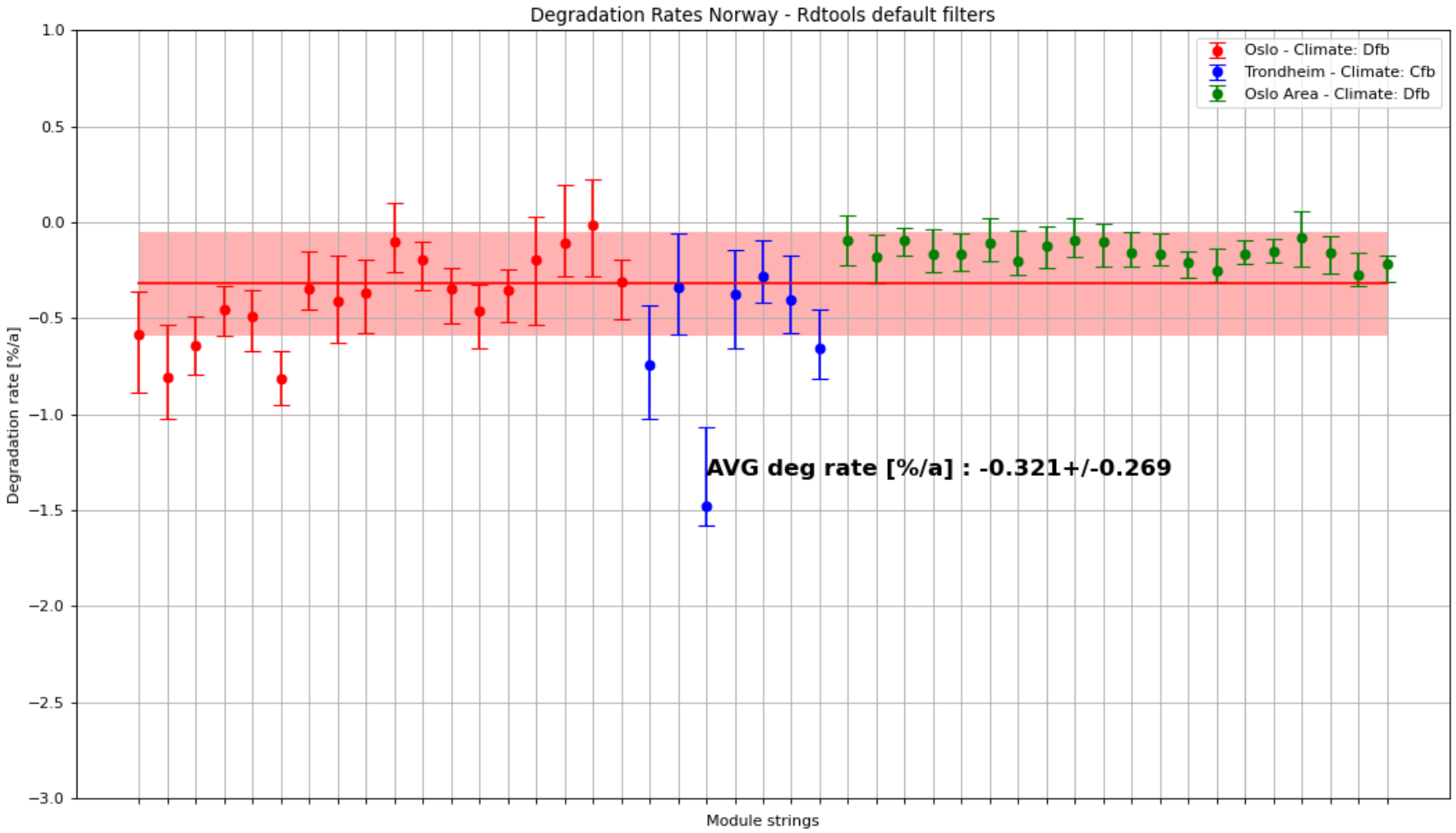


Picture: “PV SYSTEM DEGRADATION RATES IN THE NORDICS”, Eivind Sveen et al, EUPVSEC proceedings, 2020, https://doi.org/10.4229/EUPVSEC20202020-5CV.3.36

Analysis with RdTools default filters

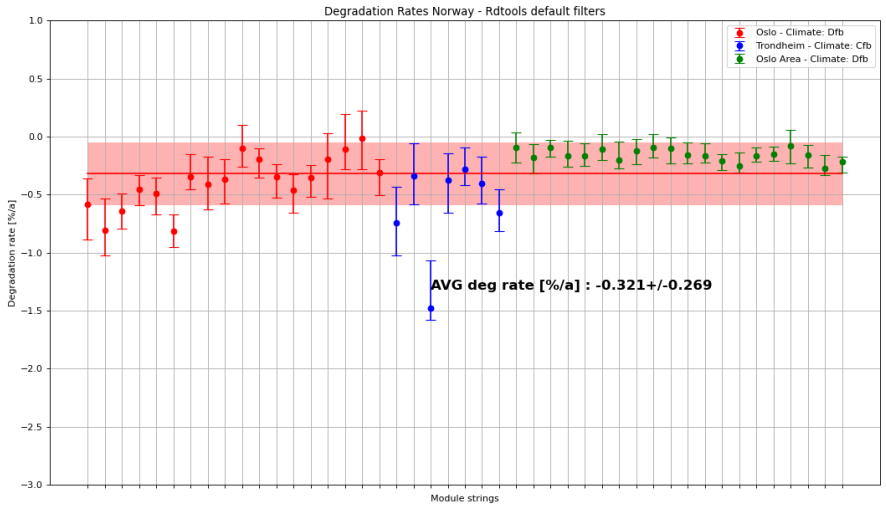


Rdtool default filters



Rdtool + extended filters

- Extended filters
  - AOI filter: AOI < 60 degree
  - Rolling median: filter values that deviate more than 2 std from 9 valu rolling median
  - Outlier: filter outliers outside of interval between first and third quantile



EUPVSEC 2019

PV SYSTEM DEGRADATION RATES IN THE NORDICS

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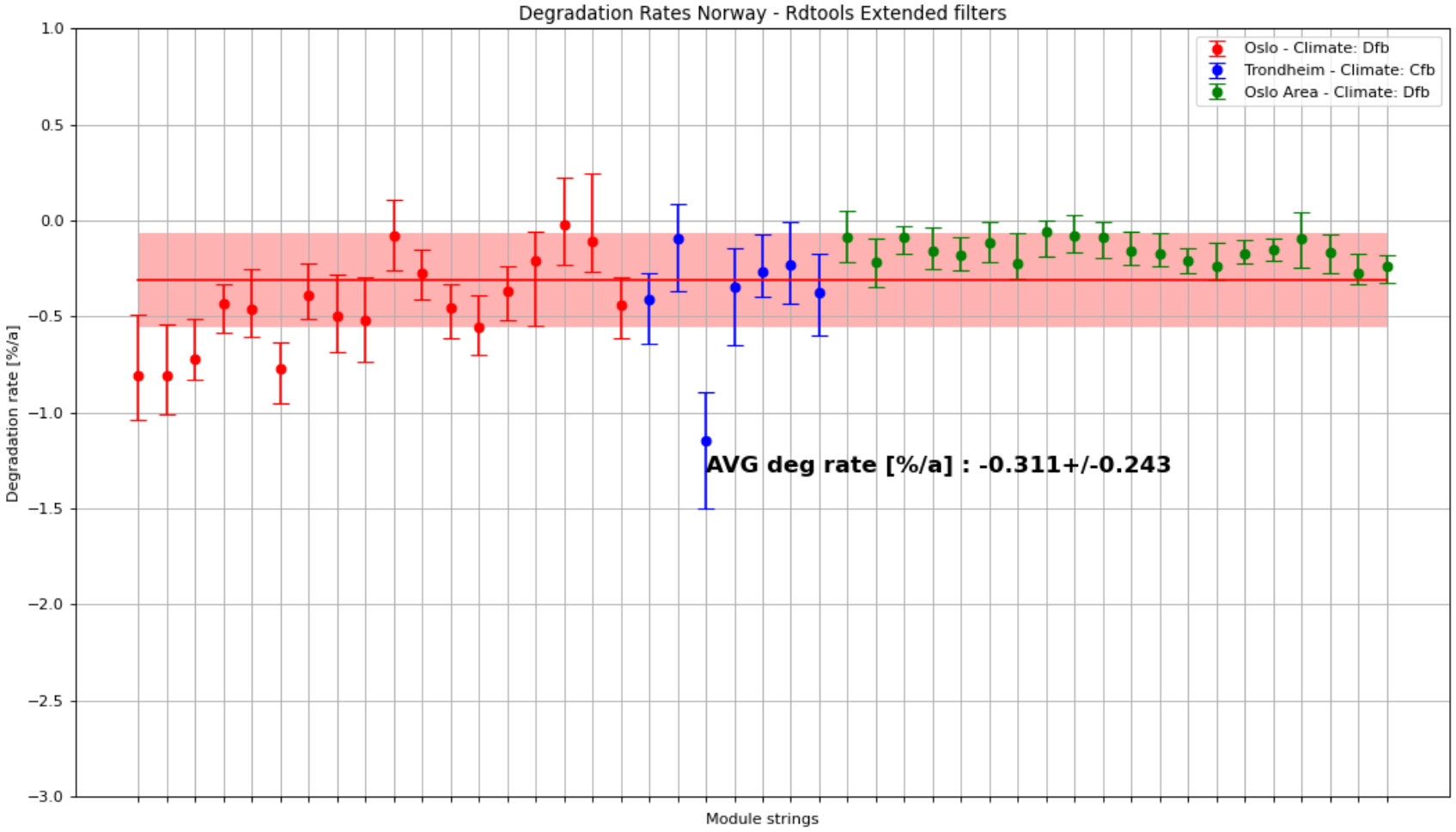
5 RESULTS

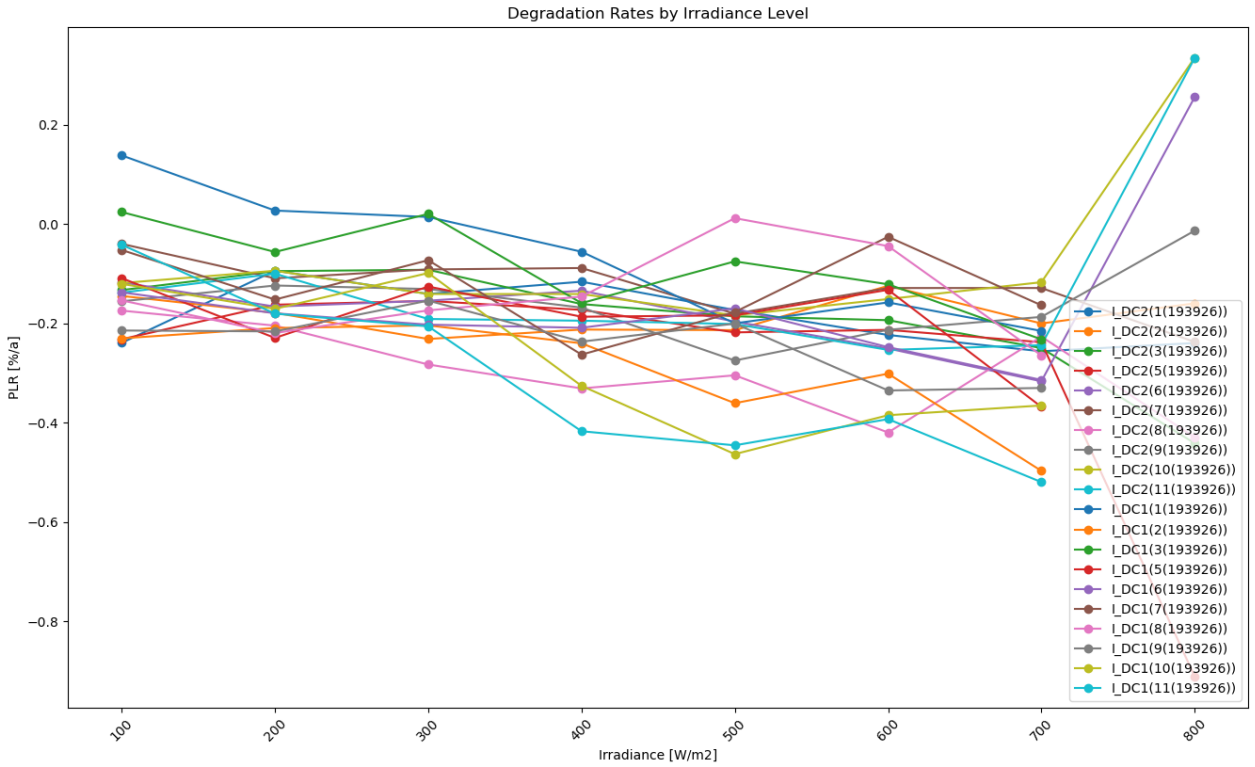
The estimated degradation rates for each subarray individually and all subarrays combined, are shown in Figure 3 with 95% confidence intervals. The estimated degradation rates for all the subarrays are 0.19, 0.10 and 0.14%/year for the *standard*, *modified* and, *dynamic YOY* methods, respectively. This agrees well with a degradation rate of around 0.2%/year, or below, of systems located in the same KG climate zone based on modelling work [15]. The model included the combined effect of temperature, humidity, and ultraviolet irradiation.

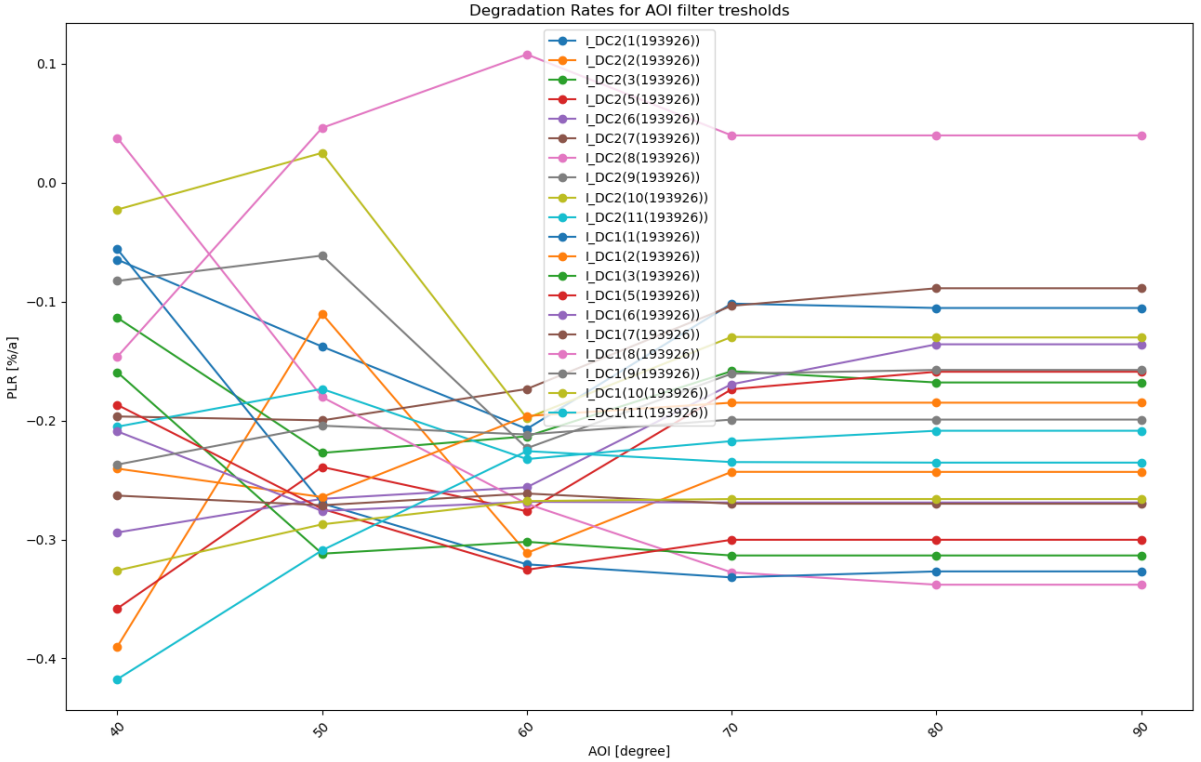
Rdtools + extended filters



Rdtool yoy with dynamic filter thresholds

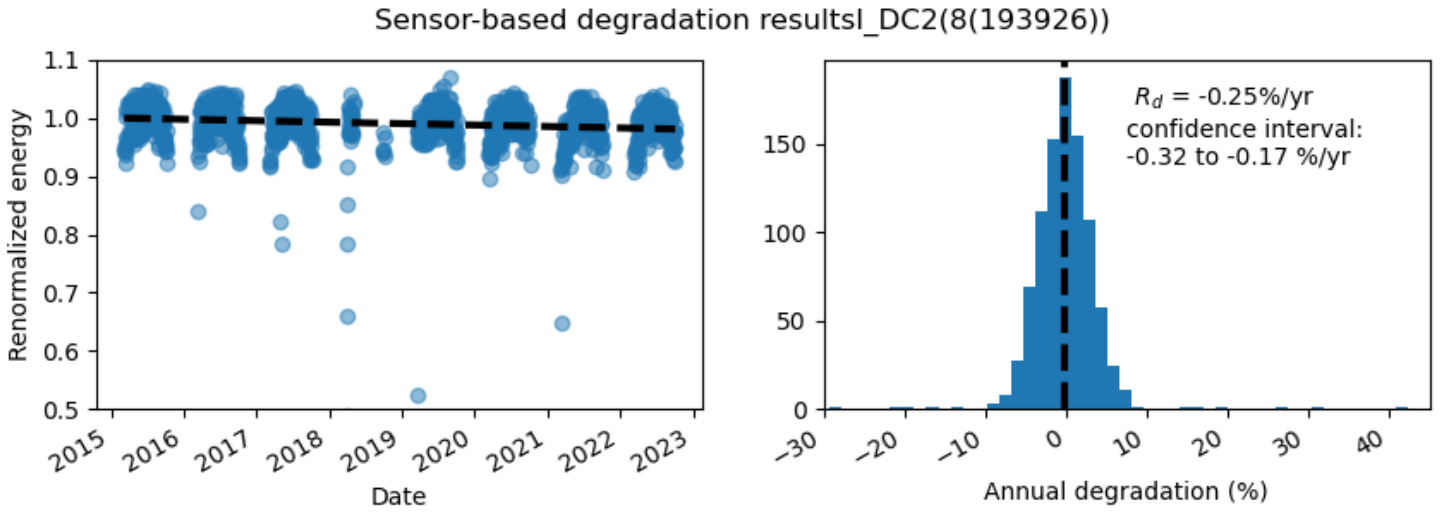
- Impact of filter threshold on resulting degradation rate



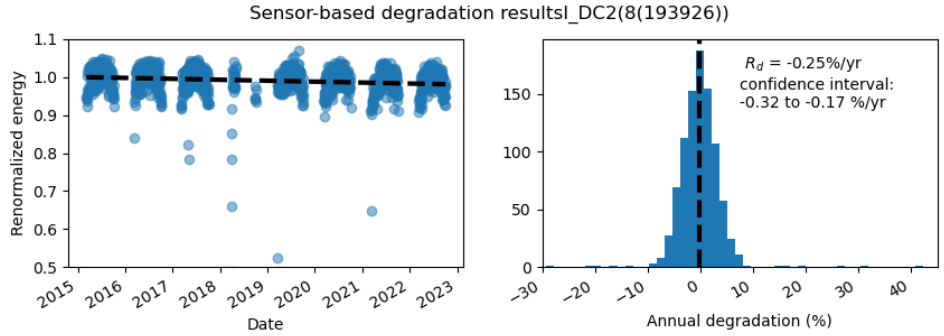


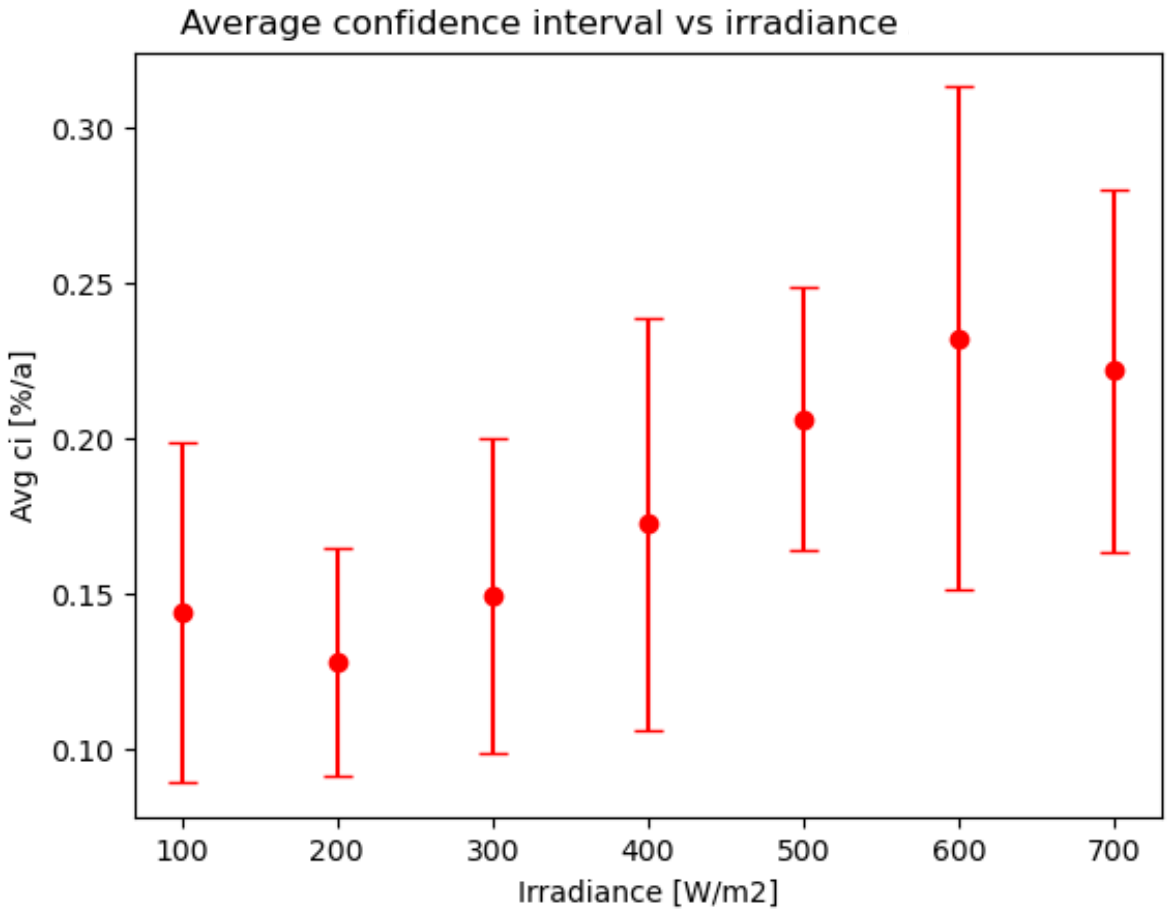
Rdtool yoy with dynamic filter thresholds

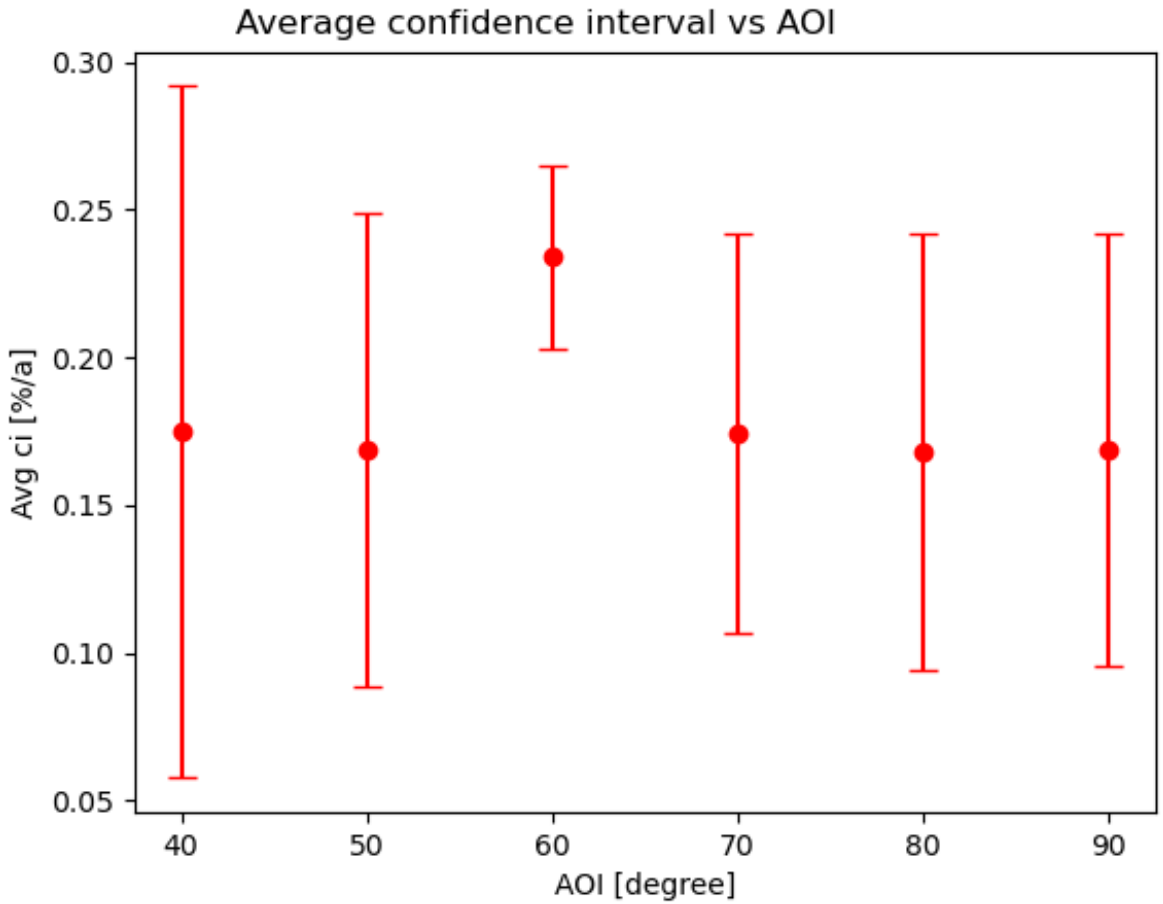
- Choose irradiance and AOI threshold to minimize confidence interval



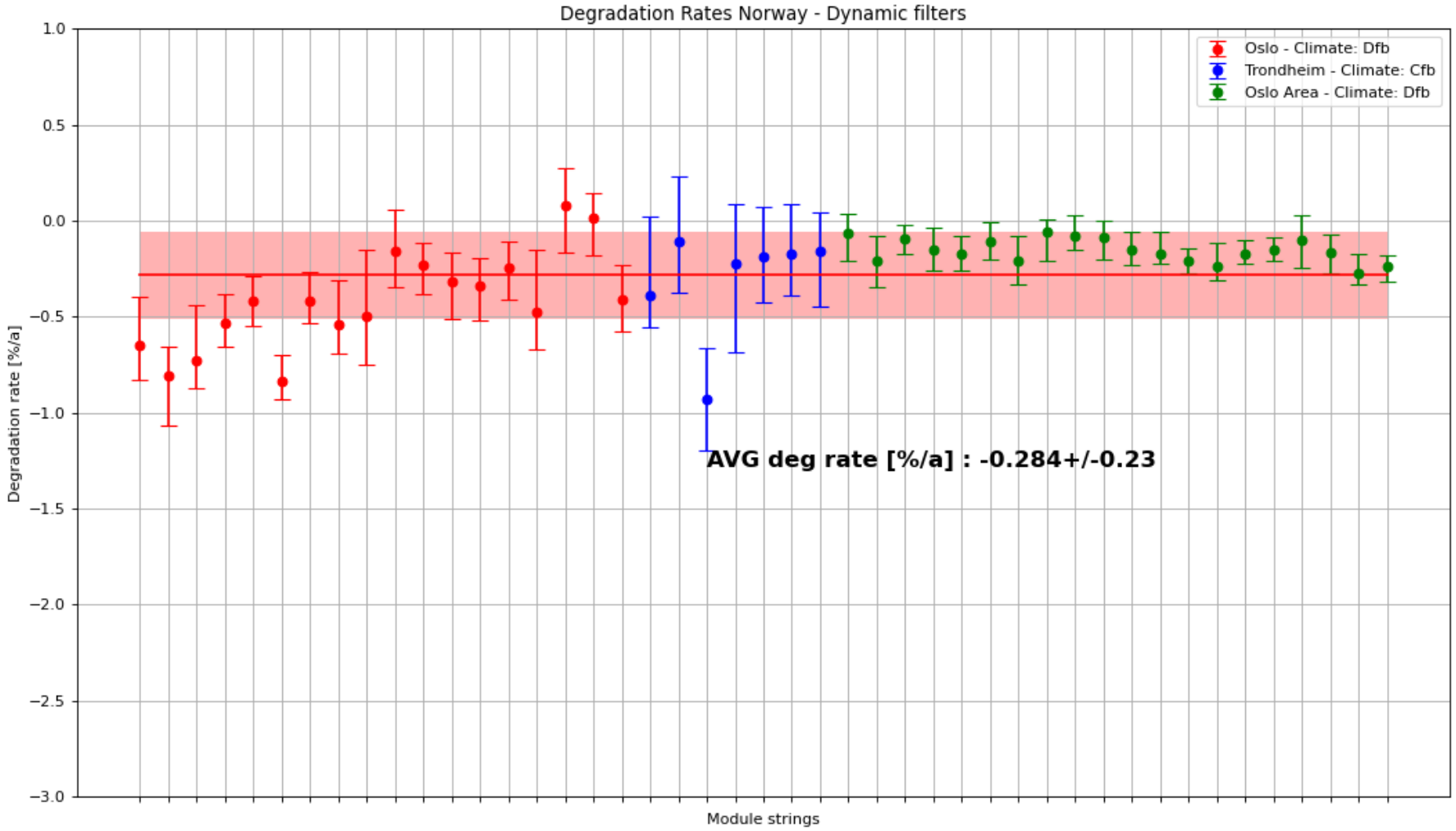
Dynamic filtering





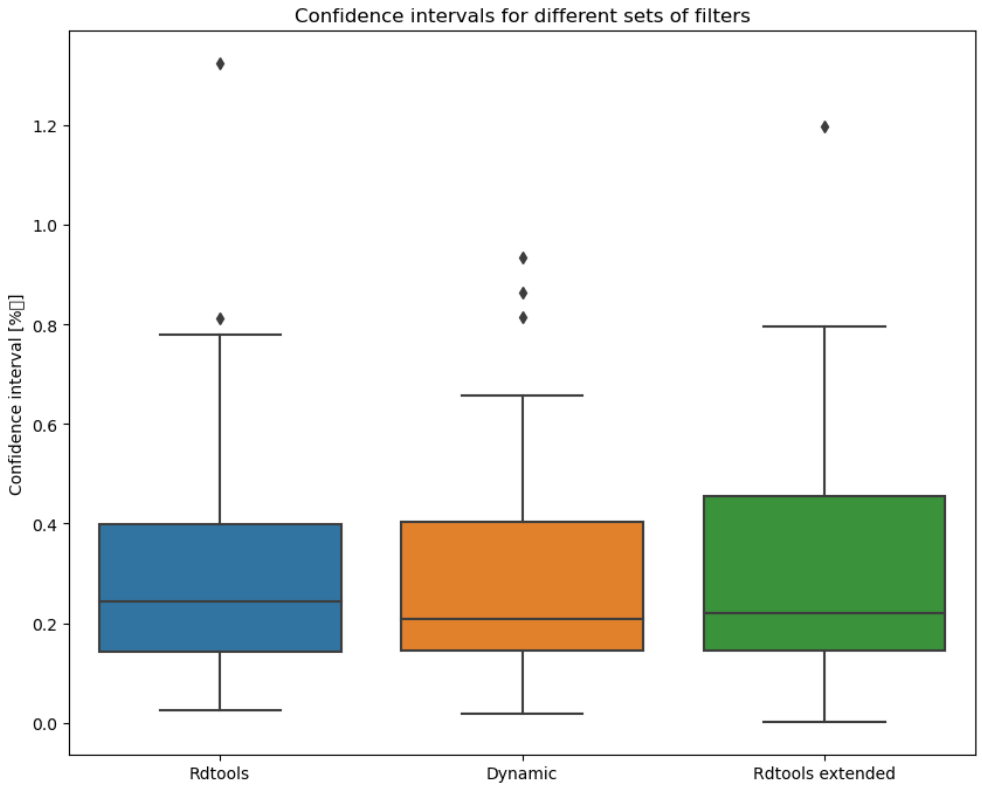


Rdtools + dynamic filtering

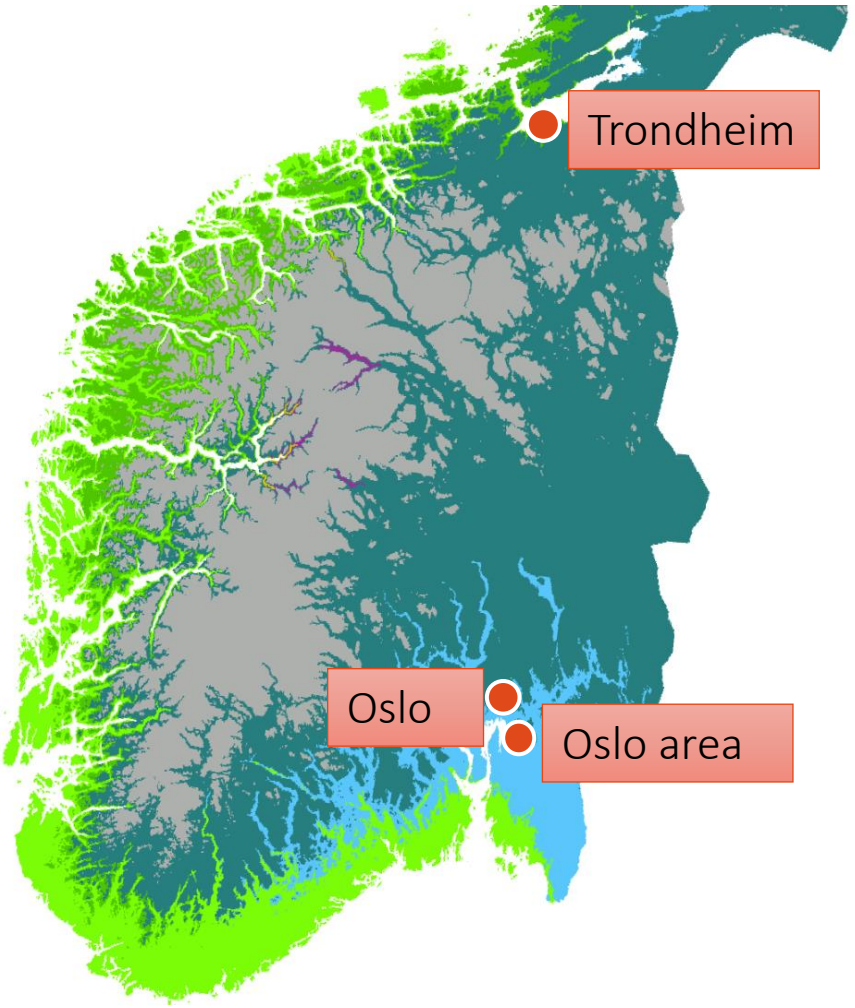


Results

- Degradation rates in Norway low in global comparison
  - RdTools YOY degradation: -0.32 +/- 0.27 [%/a]
  - RdTools +AOI + outlier filters: -0.31 +/- 0.24 [%/a]
  - Dynamic filters (Irr & AOI): -0.28 +/- 0.23 [%/a]



Module temperatures



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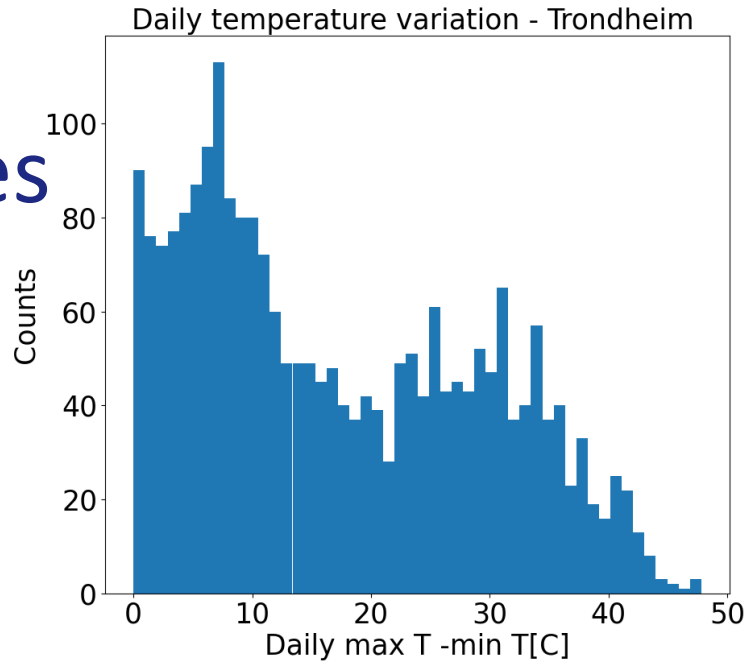

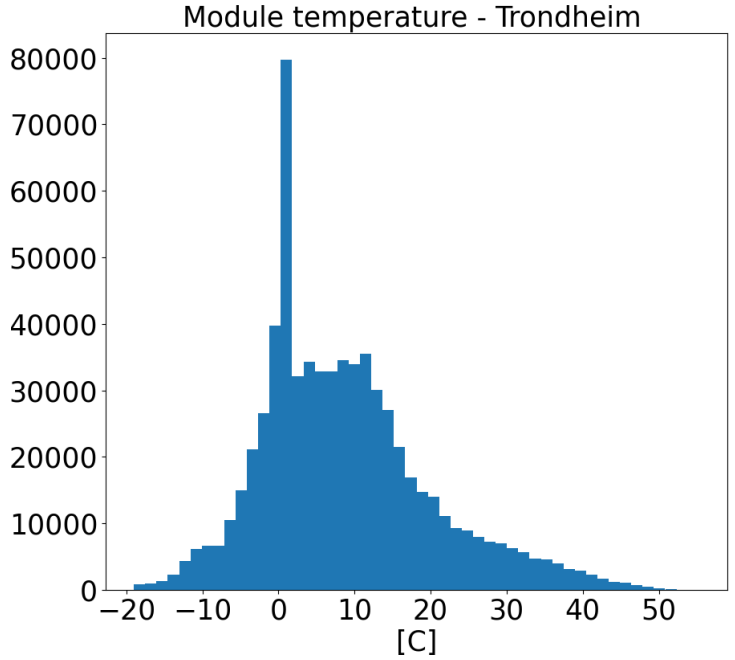

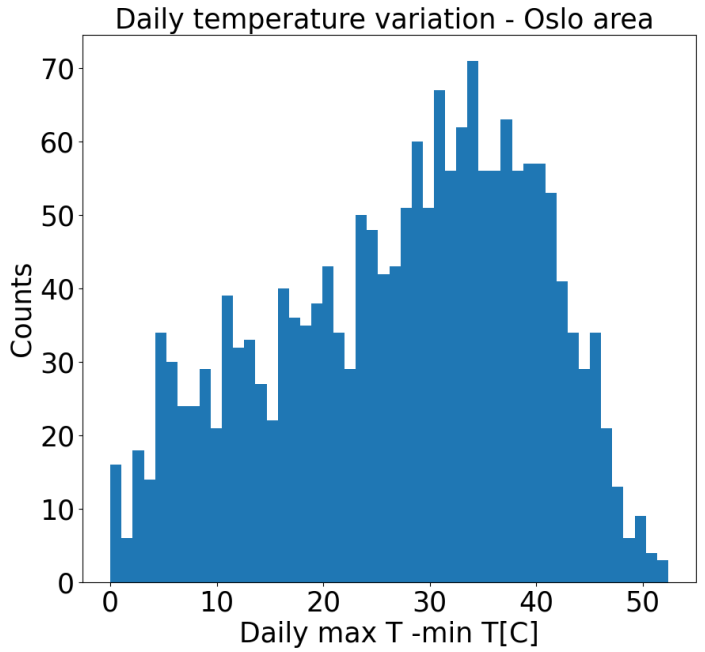

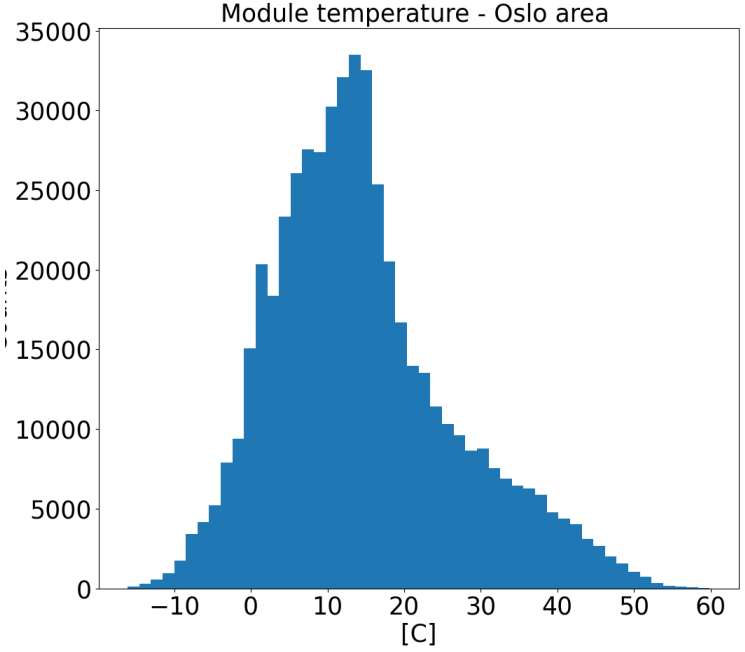

Thank you

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