Supplementary Material for:

Recent Advances in Aerosol Optical Depth Measurements in Polar Regions: Insights from the Polar-AOD Program

As shown in Tables 1 and 2, several sites in polar regions have multiple photometer models installed, providing researchers with an excellent opportunity to evaluate the effectiveness of aerosol measurements in these remote environments. In the Arctic, two stations have multiple photometers: (i) Barrow, which is equipped with a CIMEL CE318 and a Carter Scott SP02, and (ii) Ny-Ålesund, which has a CE318, an SP1A, and a PFR. In Antarctica, two stations also have multiple photometers: (i) Marambio, located in the Antarctic Peninsula, with a CE318 and a PFR, and (ii) the South Pole, on the Antarctic Plateau, with a CE318 and an SP02.

A multi-model comparison analysis was conducted, focusing on the Arctic region. Only daily measurements from overlapping periods were included in this analysis: specifically, from March 2001 to October 2016 at Barrow, for a total of 643 days, and from June 2017 to September 2023 at Ny-Ålesund, with a total of 298 daily measurement.

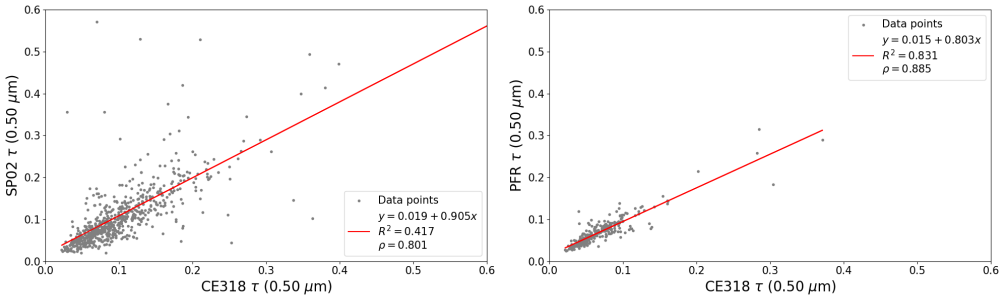

Fig. S1. Regression analysis: (i) at Barrow (left panel) between CE318 and SP02; (ii) at Ny-Ålesund (right panel) between CE318 and PFR. The legend also presents the Pearson's (R^2) and Spearman's (ρ) correlation coefficients.

As shown in Fig. S2, there is a good agreement between the SP02 and CE318 τ measurements at Barrow, especially during periods of clean air when $\tau(0.50, \mu m)$ values were lower than 0.1. The left panel of Fig. S1 shows that the correlation between these two instruments was strongly influenced by measurements with high $\tau(0.50, \mu m)$ values. In some cases, high values recorded by the CE318 corresponded to low or modest values from the SP02. The Spearman's coefficient of 0.80 indicates that as the measured values of τ increase from the CIMEL, the SP02 values also increase accordingly. However, a modest Pearson's coefficient of 0.42 suggests that the relationship between the variables is not linear. These discrepancies are likely due to different screening procedures applied to the SP02 compared to the CIMEL CE318, which is considered the reference model for a robust analysis procedure.

A different situation was observed in Ny-Ålesund, where the PFR seems to perform much better than the SP02 (see Fig.S3). Despite the fact that the common measurement days were 298 over just 5 years, the regression analysis for Ny-Ålesund shows a Pearson correlation coefficient of 0.83 (more than double that obtained in Barrow), and a Spearman coefficient of 0.89. In this case, as can be seen from the right panel of Fig.S1, the number of extreme values, where one instrument records high τ values while the other records much lower values, is absent.

These results show, first of all, that despite the potential technical differences between various photometer models (solar tracker, field-of-view, pointing modes, and acquisition techniques), they should all be considered valid instruments for studying aerosol properties in polar environments. However, the instrument calibration procedures and cloud-screening techniques adopted by different research groups or networks can cause significant differences in τ values (as the

underestimation of τ by the SP02).

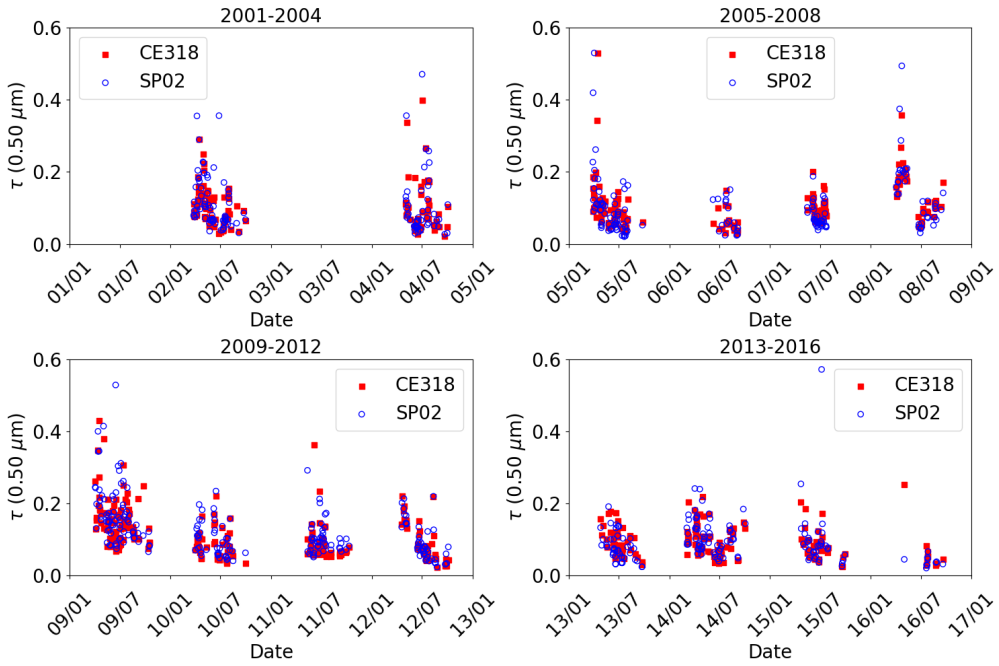

Fig. S2. Daily averages of $\tau(0.50, \mu m)$ for the period 2001-2016 at Barrow. To enhance viewing convenience, the scatter plot has been divided into four panels.

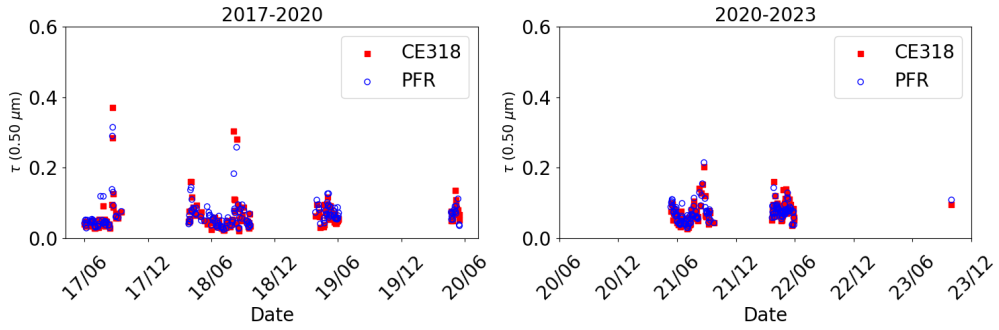

Fig. S3. Daily averages of $\tau(0.50, \mu m)$ for the period 2017-2023 at Ny-Ålesund. The scatter plot has been divided into two panels.

Arctic Cruises	Oceanic Sectors	Measurement Period
Amundsen 2008, 2009, 2014, 2021 Araon 2021 Around the Americas 2009 Healy 2011, 2015, 2022, 2023	NAA	March 2008 - July 2023 [85]
Alliance 2021 Arctica 2023 Azimuth 2023 Jan Mayen 2009 Knorr 2008 Kronprins Haakon 2024 Oceania 2011-2020, 2022, 2023 Oceania Summer 2007, 2009, 2010 Oden 2018, 2023 Polarstern 2015, 2017, 2020 Polarstern Summer 2012	GNS	July 2007 - August 2024 [168]
Ak Fedorov 2013 Healy 2015 Knorr 2008 Kronprins Haakon 2024 Oden 2018 Polarstern 2015, 2017, 2018, 2020 Polarstern Summer 2012	BES	April 2008 - July 2024 [27]

Table S1. List of the three Arctic oceanic sectors defined for the ship-borne level 2.0 sun-photometer measurements conducted from 2004 to 2024. The total number of observations for each sector is provided in parentheses.

Antarctic Cruises	Oceanic Sectors	Measurement Period
Ak Fedorov 2008, 2009, 2010, 2014 Ak Treshnikov 2017, 2020 Araon 2020 Tangaroa 2018	PAC	January 2008 - December 2020 [60]
Ak Fedorov 2014 Ak Treshnikov 2013 Hesperides 2009	APE	February 2009 - February 2014 [8]
Agulhas 2015 Ak Fedorov 2007-2019 Ak Treshnikov 2013, 2014, 2017-2020 Araon 2020 Aurora Australis 2018 Hesperides 2009 Polarstern 2008 Agulhas 2008, 2012-2014 Tangaroa 2018	ATL	December 2007 - December 2020 [376]
Ak Fedorov 2007-2019 Ak Treshnikov 2014, 2017-2019 Aurora Australis 2018, 2019	IND	December 2007 - December 2019 [141]

Table S2. List of the four Antarctic oceanic sectors defined for the ship-borne level 2.0 sun-photometer measurements conducted from 2004 to 2024. The total number of observations for each sector is provided in parentheses.

Stations	DJF				MAM				JJA				SON			
	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th
Alert	-	-	-	-	0.059	0.043	0.053	0.065	0.055	0.036	0.048	0.064	0.046	0.023	0.038	0.066
	-	-	-	-	1.115	0.997	1.169	1.286	1.446	1.370	1.514	1.603	1.223	1.027	1.368	1.584
Andenes	0.053	0.030	0.039	0.069	0.073	0.043	0.057	0.079	0.085	0.042	0.068	0.109	0.065	0.031	0.045	0.073
	0.791	0.532	0.751	1.086	1.200	0.988	1.231	1.453	1.534	1.364	1.575	1.763	1.335	1.132	1.419	1.600
Barentsburg	-	-	-	-	0.088	0.065	0.084	0.104	0.094	0.051	0.072	0.096	0.073	0.048	0.062	0.098
	-	-	-	-	1.316	1.061	1.292	1.557	1.227	1.019	1.229	1.452	1.279	1.228	1.299	1.459
Barrow (CIMEL)	0.066	0.055	0.064	0.067	0.083	0.059	0.080	0.098	0.175	0.044	0.079	0.170	0.054n	0.036	0.043	0.066
	0.844	0.628	0.926	0.971	1.163	0.0887	1.201	1.458	1.730	1.577	1.761	1.916	1.170	0.793	1.319	1.500
Barrow (SP02)	0.097	0.062	0.084	0.119	0.160	0.088	0.120	0.160	0.086	0.053	0.074	0.107	0.067	0.040	0.051	0.082
	1.053	0.730	1.081	1.317	1.134	0.897	1.168	1.371	1.308	1.052	1.356	1.574	1.195	0.917	1.189	1.507
Cambridge Bay	-	-	-	-	-	-	-	-	-	-	-	-	0.037	0.028	0.032	0.047
	-	-	-	-	-	-	-	-	-	-	-	-	1.059	0.754	0.955	1.416
Cape Baranova	-	-	-	-	0.078	0.063	0.084	0.096	0.083	0.045	0.065	0.077	-	-	-	-
	-	-	-	-	1.496	1.220	1.664	1.753	1.805	1.739	1.824	1.879	-	-	-	-
Eureka (OPAL)	0.074	0.048	0.069	0.091	0.087	0.057	0.073	0.098	0.108	0.043	0.066	0.100	0.058	0.039	0.046	0.058
	0.792	0.596	0.746	1.052	1.232	0.999	1.324	1.493	1.407	1.247	1.445	1.606	1.153	1.025	1.211	1.384
Hornsund	-	-	-	-	0.096	0.063	0.083	0.112	0.074	0.041	0.058	0.082	0.066	0.035	0.051	0.083
	-	-	-	-	1.390	1.228	1.457	1.629	1.423	1.234	1.492	1.690	1.291	1.049	1.314	1.575
Ittoqqortoormiit	0.032	0.023	0.026	0.031	0.063	0.043	0.055	0.069	0.064	0.034	0.046	0.075	0.046	0.031	0.039	0.055
	0.734	0.692	0.783	0.904	1.240	1.080	1.309	1.466	1.442	1.253	1.491	1.671	1.171	0.974	1.214	1.428

Table S3. Statistics for Arctic station studied in the paper. The values of $\tau(0.50\mu m)$ are shown in green, while the values of α are shown in white. For each season — DJF (Winter), MAM (Spring), JJA (Summer), and SON (Autumn) — the mean, 25th, 50th, and 75th percentiles are presented.

Stations	DJF				MAM				JJA				SON			
	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th
Kangerlussuaq	0.044	0.026	0.034	0.054	0.060	0.041	0.052	0.071	0.077	0.035	0.052	0.093	0.057	0.034	0.046	0.074
	1.084	0.860	1.168	1.391	1.098	0.894	1.141	1.334	1.516	1.353	1.541	1.730	1.359	1.194	1.406	1.595
Matorova	0.039	0.023	0.027	0.044	0.064	0.043	0.055	0.072	0.070	0.037	0.054	0.086	0.042	0.027	0.035	0.047
	1.149	0.791	1.291	1.507	1.159	0.958	1.205	1.403	1.622	1.469	1.645	1.828	1.343	1.205	1.390	1.559
Ny-Ålesund (CIMEL)	0.062	0.053	0.062	0.070	0.078	0.057	0.071	0.088	0.063	0.036	0.048	0.065	0.058	0.041	0.052	0.070
	1.078	0.875	1.164	1.255	1.390	1.252	1.477	1.617	1.548	1.448	1.631	1.752	1.269	1.002	1.343	1.597
Ny-Ålesund (SP1A)	-	-	-	-	0.069	0.044	0.062	0.085	0.056	0.027	0.039	0.064	0.055	0.026	0.042	0.074
	-	-	-	-	1.377	1.197	1.403	1.566	1.481	1.278	1.499	1.672	1.342	1.193	1.385	1.547
Ny-Ålesund (PFR)	-	-	-	-	0.094	0.067	0.085	0.111	0.068	0.041	0.055	0.078	0.060	0.034	0.046	0.077
	-	-	-	-	1.362	1.217	1.410	1.554	1.455	1.327	1.496	1.633	1.395	1.241	1.448	1.616
Oliktok	0.066	0.047	0.051	0.056	0.085	0.060	0.074	0.097	0.130	0.052	0.071	0.122	0.066	0.031	0.057	0.093
	0.833	0.799	0.919	1.023	1.233	1.053	1.327	1.469	1.446	1.272	1.508	1.686	1.018	0.663	1.187	1.378
Resolute Bay	-	-	-	-	0.065	0.046	0.056	0.073	0.114	0.041	0.062	0.104	0.077	0.044	0.067	0.109
	-	-	-	-	1.162	0.952	1.183	1.397	1.479	1.263	1.518	1.715	1.353	1.216	1.348	1.548
Sodankylä	0.102	0.046	0.062	0.099	0.071	0.047	0.059	0.084	0.090	0.043	0.064	0.115	0.050	0.027	0.035	0.063
	0.960	0.690	1.015	1.160	1.260	1.050	1.305	1.515	1.667	1.505	1.705	1.874	1.121	0.879	1.090	1.378
Thule	0.040	0.030	0.035	0.043	0.080	0.051	0.066	0.092	0.064	0.035	0.045	0.072	0.059	0.032	0.044	0.086
	0.659	0.534	0.646	0.805	1.315	1.150	1.383	1.554	1.551	1.428	1.568	1.728	1.418	1.270	1.412	1.652
Toolik Lake	0.038	0.026	0.035	0.038	0.076	0.052	0.067	0.087	0.184	0.052	0.082	0.180	0.061	0.031	0.053	0.085
	1.281	1.207	1.345	1.380	1.239	1.106	1.292	1.425	1.581	1.456	1.773	1.581	1.405	1.330	1.446	1.577

Table S4. Statistics for Arctic station studied in the paper. The values of $\tau(0.50\mu m)$ are shown in green, while the values of α are shown in white. For each season — DJF (Winter), MAM (Spring), JJA (Summer), and SON (Autumn) — the mean, 25th, 50th, and 75th percentiles are presented.

Stations	JJA				SON				DJF				MAM			
	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th
Dome C	-	-	-	-	0.025	0.021	0.022	0.025	0.028	0.019	0.024	0.032	-	-	-	-
	-	-	-	-	1.650	1.637	1.759	1.811	1.597	1.345	1.648	1.908	-	-	-	-
Escudero	0.087	0.070	0.093	0.100	0.081	0.056	0.066	0.107	0.082	0.044	0.074	0.104	0.094	0.059	0.085	0.112
	0.644	0.579	0.643	0.745	0.314	0.223	0.301	0.434	0.817	0.427	0.706	1.258	0.514	0.235	0.475	0.763
Juan Carlos I	-	-	-	-	-	-	-	-	0.078	0.052	0.070	0.084	0.094	0.081	0.092	0.102
	-	-	-	-	-	-	-	-	0.483	0.377	0.467	0.591	0.310	0.246	0.321	0.360
Marambio (CIMEL)	0.058	0.035	0.048	0.078	0.033	0.020	0.028	0.042	0.039	0.025	0.034	0.044	0.035	0.021	0.032	0.045
	0.799	0.417	0.651	0.980	1.264	0.753	1.157	1.716	1.241	0.735	1.205	1.679	1.275	1.010	1.225	1.443
Marambio (PFR)	0.050	0.035	0.046	0.059	0.039	0.026	0.034	0.046	0.034	0.023	0.029	0.039	0.030	0.019	0.024	0.034
	0.773	0.598	0.746	0.956	1.080	0.850	1.085	1.310	1.264	0.922	1.303	1.624	0.976	0.725	0.991	1.192
Mirny	0.021	0.015	0.018	0.026	0.024	0.016	0.021	0.030	0.024	0.017	0.021	0.028	0.020	0.013	0.017	0.027
	1.026	0.540	0.835	1.354	0.944	0.662	0.871	1.184	1.256	0.924	1.192	1.506	1.344	0.949	1.269	1.591
Neumayer	-	-	-	-	0.031	0.024	0.029	0.032	0.041	0.030	0.035	0.042	0.038	0.033	0.036	0.038
	-	-	-	-	0.946	0.904	0.981	1.103	1.042	1.015	1.083	1.156	0.971	0.864	0.994	1.195
Syowa	0.030	0.019	0.026	0.036	0.026	0.019	0.024	0.032	0.024	0.016	0.021	0.029	0.022	0.013	0.019	0.027
	0.837	0.576	0.837	1.067	1.174	0.809	1.133	1.501	1.431	1.032	1.406	1.875	1.130	1.795	1.091	1.427
South Pole (CIMEL)	-	-	-	-	0.022	0.014	0.016	0.021	0.024	0.016	0.020	0.026	-	-	-	-
	-	-	-	-	0.574	0.373	0.548	0.800	1.036	0.788	1.028	1.299	-	-	-	-
South Pole (SP02)	-	-	-	-	0.093	0.020	0.035	0.075	0.073	0.016	0.022	0.034	0.061	0.030	0.047	0.077
	-	-	-	-	0.797	0.359	0.720	1.179	1.217	0.751	1.278	1.614	0.612	0.293	0.513	0.911

Table S5. Statistics for Antarctic station studied in the paper. The values of $\tau(0.50\mu m)$ are shown in green, while the values of α are shown in white. For each season — DJF (Summer), MAM (Autumn), JJA (Winter), and SON (Spring) — the mean, 25th, 50th, and 75th percentiles are presented.

Stations	JJA				SON				DJF				MAM			
	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th	mean	25th	50th	75th
Troll/Trollhaugen	0.037	0.027	0.034	0.043	0.026	0.020	0.024	0.031	0.025	0.018	0.023	0.028	0.022	0.016	0.020	0.025
	0.964	0.778	0.952	1.129	1.285	1.105	1.307	1.485	1.466	1.327	1.526	1.654	1.352	1.193	1.372	1.544
Utsteinen	-	-	-	-	0.019	0.014	0.015	0.017	0.020	0.012	0.015	0.021	-	-	-	-
	-	-	-	-	0.984	0.904	0.990	1.172	1.197	0.899	1,228	1,498	-	-	-	-
Vechernaya	-	-	-	-	0.029	0.022	0.027	0.034	0.033	0.022	0.026	0.035	0.031	0.023	0.026	0.032
	-	-	-	-	2.261	2.031	2.256	2.611	1.650	1.433	1.705	1.912	1.178	1.012	1.275	1.439

Table S6. Statistics for Antarctic station studied in the paper. The values of $\tau(0.50\mu m)$ are shown in green, while the values of α are shown in white. For each season — DJF (Summer), MAM (Autumn), JJA (Winter), and SON (Spring) — the mean, 25th, 50th, and 75th percentiles are presented.