Within ESA's Climate Change Initiative (CCI), the Aerosol_cci+ project (3/2018 – 5/2022) aimed at evolving and qualifying aerosol retrieval algorithms for the dual-view radiometer sensor line covering the periods 1995 – 2012 and since 2016 (ATSR-2 onboard ERS-2, AATSR onboard ENVISAT; SLSTR onboard SENTINEL-3A and SENTINEL-3B). Aerosol_cci+ built on the legacy of a decade of Aerosol_cci(2) projects since 2010 and worked to benchmark algorithms for future operational use in the Copernicus Climate Change Service. The project works with two algorithms of different maturity to provide Aerosol Optical Depth (AOD) and Fine Mode AOD: A mature algorithm from Aerosol_cci2 (by Swansea university) has been improved to overcome some of its core weaknesses (reduction of the bias by ~ one third). A second innovative algorithm CISAR (by Rayference) has been adapted to SLSTR and allows combined retrievals of aerosol and clouds without relying on an external cloud mask (as shown in Figure 1, California wildfires, which has no gap between clouds and aerosols while the center of the aerosol plume with very high aerosol loading is miss-classified as cloud). However, the second evaluation shows that this innovative algorithm has significantly improved but now suppresses high AOD values (miss-classified as clouds); this needs further analysis and algorithm improvement.

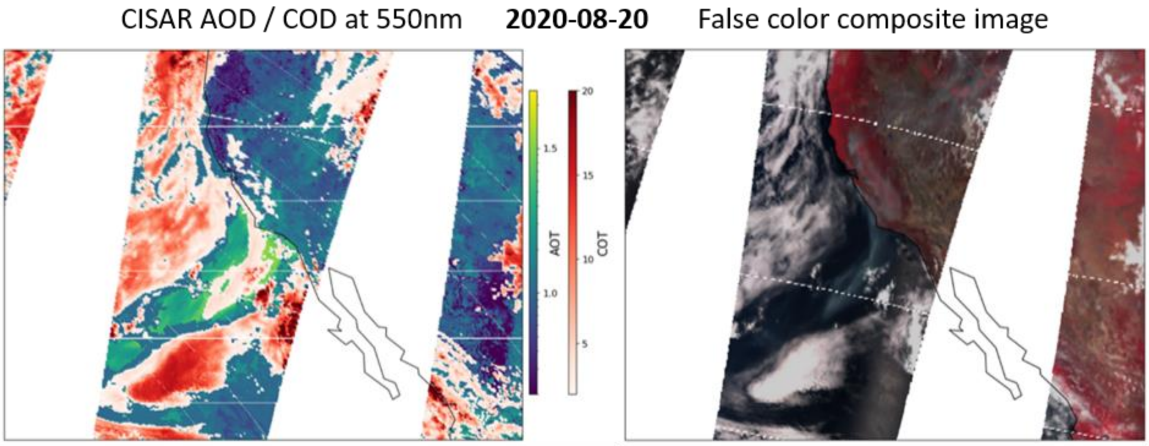

Figure 1: Combined Aerosol / Cloud retrieval by CISAR for the major California forest fire episode in August 2020

Within Aerosol_cci+ limited test datasets are processed to allow a systematic evaluation comprising of validation against ground-based AERONET measurements and inter-comparisons to other satellite aerosol datasets. In the third project year, Aerosol_cci+ has evaluated the final Climate Research Data Package – the validation proves improvements for both algorithms under development / all sensors (Table 1 shows statistics for the largest improvements achieved). Aerosol_cci+ scientists continued to contribute significantly to coordinating the International Satellite Aerosol Science Network AEROSAT where the international aerosol retrieval community together with its model users discuss progress, challenges and potential developments of the retrieval algorithms to better meet the various user needs and work out best practices (as for example for uncertainty propagation and the quantitative evaluation of pixel-level uncertainties in the products; see Popp & Mittaz, 2021).

Further overview assessment from user perspective have been conducted to assess the potential and limitations of the improved datasets for data assimilation into the CAMS global atmospheric model (towards climate services and re-analysis) and for climate science applications through calculating radiative forcing aerosol direct and indirect effects. The analysis showed that Swansea SLSTR monthly patterns agree reasonably with the CAMS reanalysis, but the full ATSR-2 / AATSR / SLSTR record still shows inconsistencies (high SLSTR bias) and has an over-estimated fine mode aerosol fraction for all sensors as compared to other datasets; for CISAR monthly gridded data now exhibit a significant under-estimation of major plumes. The use of Aerosol_cci+ test datasets in its user case studies is documented in a paper (Kinne, et al. 2021, in review) and a science blog (Benedetti, et al., 2022)

Table 1: Validation statistics for different algorithm versions where most significant improvements were achieved

year	sensor	Algorithm version	area	bias	stdv	Pearson corr	GCOS Fraction [1)]
2008	AATSR	SU_v4.33	land / Southern hemisphere	0.06	0.10	0.83	34.9
2008	AATSR	SU_v4.35	land / Southern hemisphere	0.04	0.09	0.79	40.1
2008	AATSR	SU_v4.33	ocean / Northern hemisphere	0.03	0.12	0.84	56.2
2008	AATSR	SU_v4.35	ocean / Northern hemisphere	0.02	0.08	0.88	56.6
2019	SLSTRA	SU_v1.11	land	0.05	0.15	0.73	35.2
2020	SLSTRA	SU_v1.14	land	0.03	0.12	0.80	42.7
2019	SLSTRA	SU_v1.11	ocean	0.05	0.08	0.86	40.3
2020	SLSTRA	SU_v1.14	ocean	0.04	0.08	0.83	52.4
2019	SLSTRA	RF_v2.0.0.	land	0.08	0.41	0.17	23.0
2020	SLSTRA	RF_v2.1.1	land	0.00	0.14	0.45	38.6
2019	SLSTRA	RF_v2.0.0.	ocean	0.14	0.35	0.28	19.0
2020	SLSTRA	RF_v2.1.1	ocean	0.05	0.11	0.59	38.7

[1)] GCOS fraction is defined as the percentage of pixels which fulfil the GCOS requirement: AOD difference to a reference measurement within max(0.03, 0.1*AOD)

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