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Uncertainty of Copernicus Sentinel-2 AOT, WV and SR retrieval with Sen2Cor

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Sen2Cor is a Level-2A (L2A) processor whose main purpose is to correct mono-temporal Copernicus Sentinel-2 (S2) mission Level-1C (L1C) products from the effects of the atmosphere in order to deliver radiometrically corrected Bottom-of-Atmosphere (BOA) data. Knowledge of uncertainty of products is one major key to foster interoperability through time and with other datasets.

Sen2Cor [1]:

- Atmospheric correction processor tailored to Copernicus Sentinel-2 data, extension to Landsat-8 data processing realized (see poster "Sen2Cor Version 3.0 Processor …" on Thursday).
- Is used for global L2A-processing by Sentinel-2 ground segment (PDGS)
- Can be obtained for user processing from http://step.esa.int/main/third-party-plugins-2/sen2cor/
- This study: Sen2Cor 2.8 with CAMS-fallback (see poster "Sen2Cor version 2.10 …" on Thursday)

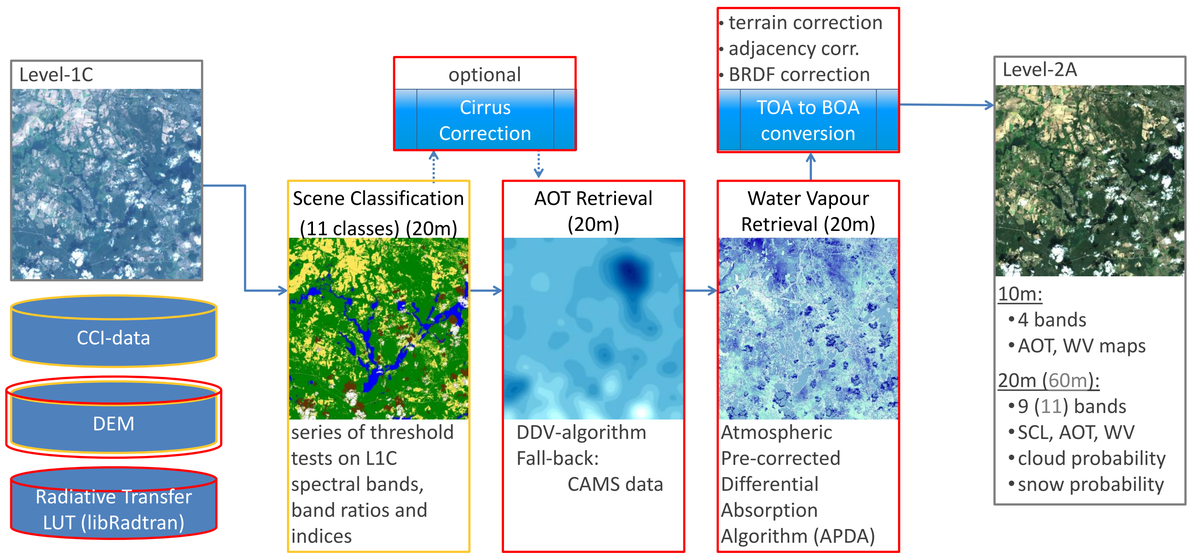


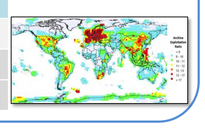
Figure 1: Sen2Cor processing chain

Data and test sites

- S2 L1C-products of year 2020 downloaded from SciHub
- Sen2Cor user processing (SUMMER_RURAL_PlanetDEM90_terrainON_OzoneFromMetadata_cirrusFALSE)
- Site selection: AERONET data available (level ≥ 1.5) within ±15 min to overpass

Table 1: Number of test sites per region

climate zone	N-America	S- America	Europe	Africa	Asia	Australia	Antarctica	No. of sites	No. of Tiles
Polar	2		5		1			**8**	224
Boreal	3		16		3			**22**	758
Midlatitude N	6		10	1	4			**21**	745
Subtropical N	3			2	4			**9**	290
Tropical		3		4	3	1		**11**	189
Subtropical S		2		1		1		**4**	117
Midlatitude S		1		1		2		**4**	60
Austral		1						**1**	14
number of sites	**14**	**7**	**31**	**9**	**15**	**4**	**0**	**80**	**2397**
percentage of sites	**18%**	**9%**	**39%**	**11%**	**19%**	**5%**	**0%**		
⅓ area +⅔ access	17.5%	4.7%	52.8%	7.5%	13.5%	3.9%	3.5%		
data access	17.3%	0.4%	75.5%	0.1%	3.9%	2.8%	0.0%		
area fraction	18%	13%	7%	22%	33%	6%	10%		



Analysis procedure

AOT & WV:

➔ Reference: Spectral interpolation of AOT to 550nm: $AOT_{550} = a0 \cdot 0.55^{a1} + a2$
Temporal average of AERONET data ±15 min of satellite overpass time

➔ Retrieval: Spatial average of AOT_{550} and WV from Sentinel-2 data over 9x9 km² subset around sunphotometer location (mask: vegetated and non-vegetated)

Surface reflectance SR (hemispherical-directional reflectance factor):

➔ Pixel-by-pixel comparison of Sen2Cor retrieval with reference within 9x9 km² subset around sunphotometer location

$$X = \{ \rho_\lambda ; AOT_{550} ; WV \}$$

$$\Delta X = X_{SEN2COR} - X_{REFERENCE}$$

$$u_{sys} = \sqrt{\frac{1}{(n-1)} \cdot \sum_{i=1}^{n} \Delta X_i}$$

$$u_{random} = \sqrt{\frac{1}{(n-1)} \cdot \sum_{i=1}^{n} (\Delta X_i - u_{sys})^2}$$

$$u_{total} = \sqrt{{u_{sys}}^2 + {u_{random}}^2}$$

Uncertainty of AOT retrieval

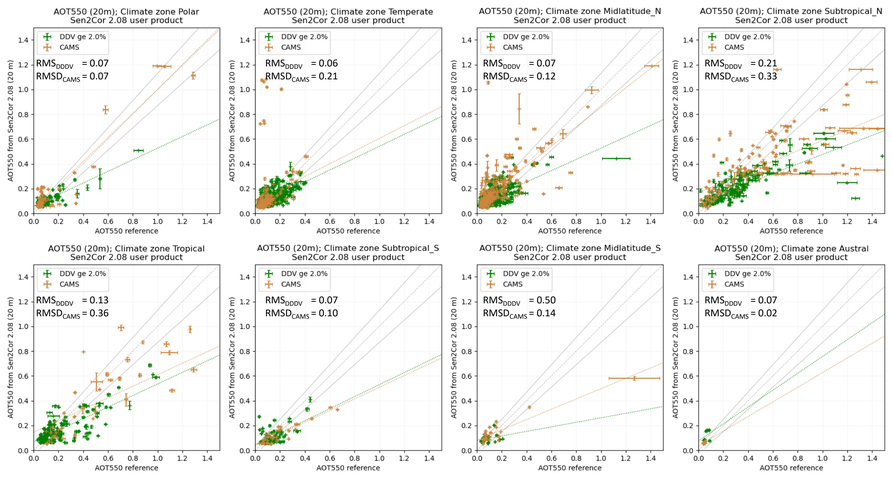


Figure 2: Correlation plots of AOT@550nm (20m) retrieval over reference from AERONET

Table 2: Percentage of products with AOT retrieved within uncertainty goal: $U_{AOT550} \leq 0.1 * AOT550_{ref} + 0.03$

climate zone	DDV	CAMS
Polar	60%	13%
Boreal (Temperate)	59%	36%
Midlatitude N	50%	25%
Subtropical N	33%	10%
Tropical	40%	33%
Subtropical S	57%	32%
Midlatitude S	38%	21%
Austral	17%	

Uncertainty of WV retrieval

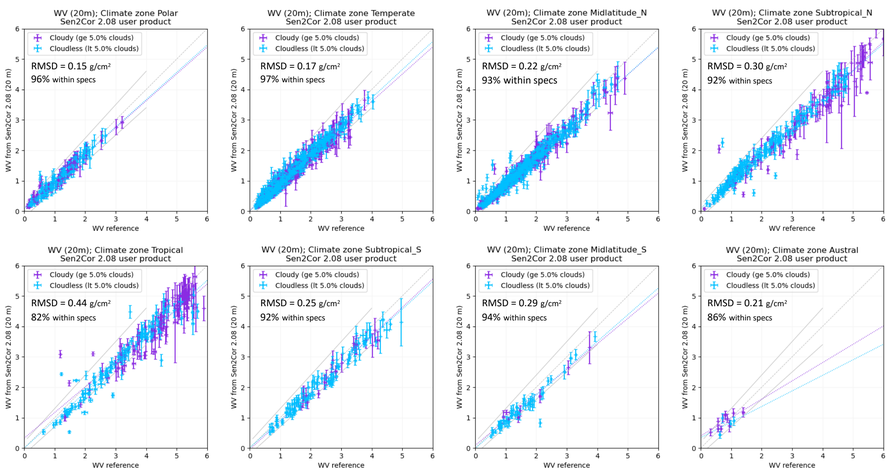


Figure 3: Correlation plots of WV (20m) retrieval over reference from AERONET

Table 3: Percentage of products with WV retrieved within uncertainty goal: $U_{WV} \leq 0.1 * WV_{ref} + 0.2$ g/cm²

climate zone	WV
Polar	96%
Boreal (Temperate)	97%
Midlatitude N	93%
Subtropical N	92%
Tropical	82%
Subtropical S	92%
Midlatitude S	94%
Austral	86%

Uncertainty of SR retrieval due to aerosol retrieval

➔ Reference: Sen2Cor output processed with fixed AOT as input which is set equal to the value provided by AERONET

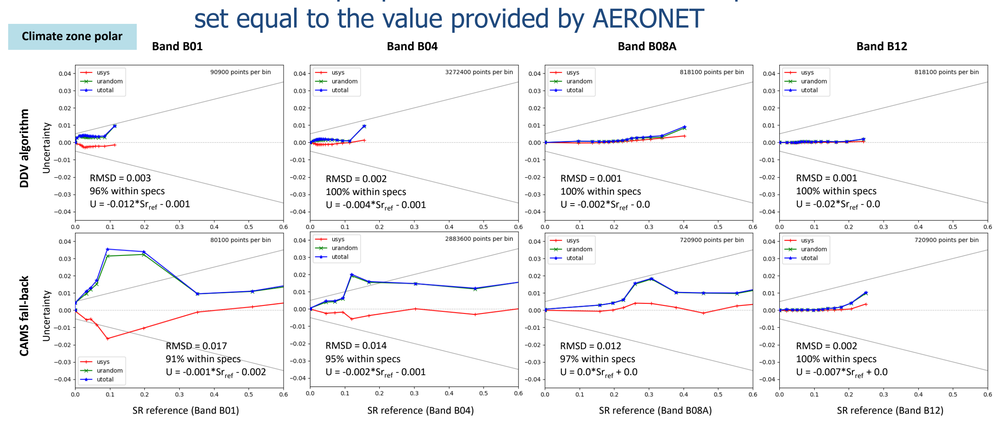


Figure 4: Uncertainty of SR retrieval due to aerosol amount for several Sentinel-2 bands and processing with DDV –algorithm and CAMS fall back, climate zone polar

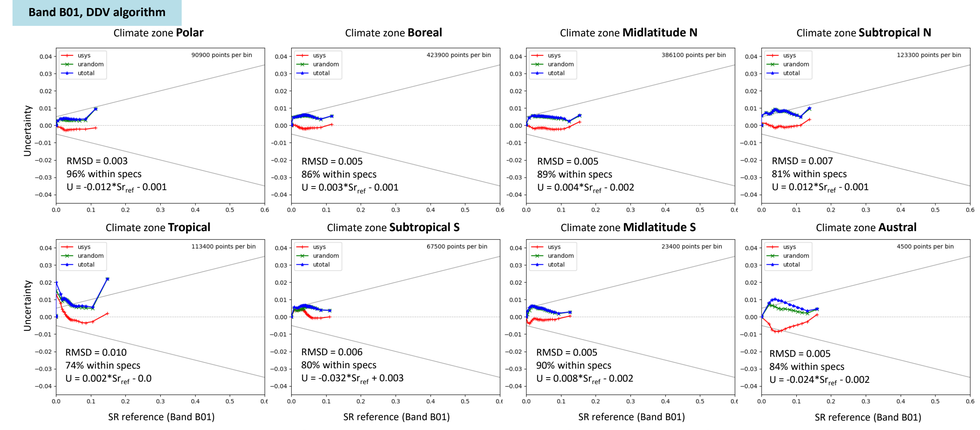


Figure 5: Uncertainty of SR retrieval due to aerosol amount per climate zone for Sentinel-2 bands B01, processed with DDV-algorithm

Uncertainty of SR retrieval due to aerosol type

➔ Reference: Sen2Cor output processed rural aerosols type

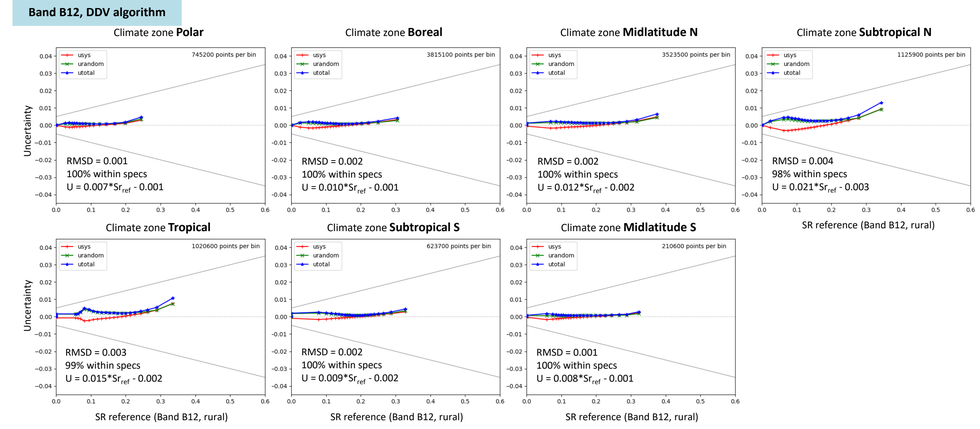


Figure 6: Uncertainty of SR retrieval due to aerosol type per climate zone for Sentinel-2 bands B12, processed with DDV-algorithm and maritime aerosol type

Outcome and credits

- Uncertainty of SR retrieval with Sen2Cor DDV-algorithm due to aerosol retrieval is mostly within uncertainty goal of SR in spite of worse AOT retrieval performance.
- DDV-algorithm gives better results than CAMS fall-back, but it is not compared on the same products.
- Aerosol amount has larger influence on blue bands, aerosol type on SWIR bands.
- Uncertainty due to AOT retrieval is larger than uncertainty due to aerosol type.

The authors thank the PI investigators and their staff for establishing and maintaining the AERONET sites used in this investigation.

#LPS22

[1] "Sentinel-2 Level-2A Algorithm Theoretical Basis Document (ATBD), S2-PDGS-MPC-ATBD-L2A", 2021, issue 2.10. Available: https://sentinel.esa.int/documents/247904/446933/Sentinel-2-Level-2A-Algorithm-Theoretical-Basis-DocumentATBD.pdf/fe5bacb4-7d4c-9212-8606-6591384390c3?t=1618563205231, Accessed on: 5. January 2022

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