SENTINEL 2
Mission Performance Centre

INTEGRATION AND ASSIMILATION OF METEOROLOGICAL (ECMWF) AEROSOL ESTIMATES INTO SEN2COR ATMOSPHERIC CORRECTION

IGARSS 2018

FERIA VALENCIA | VALENCIA | SPAIN

24 JULY 2018

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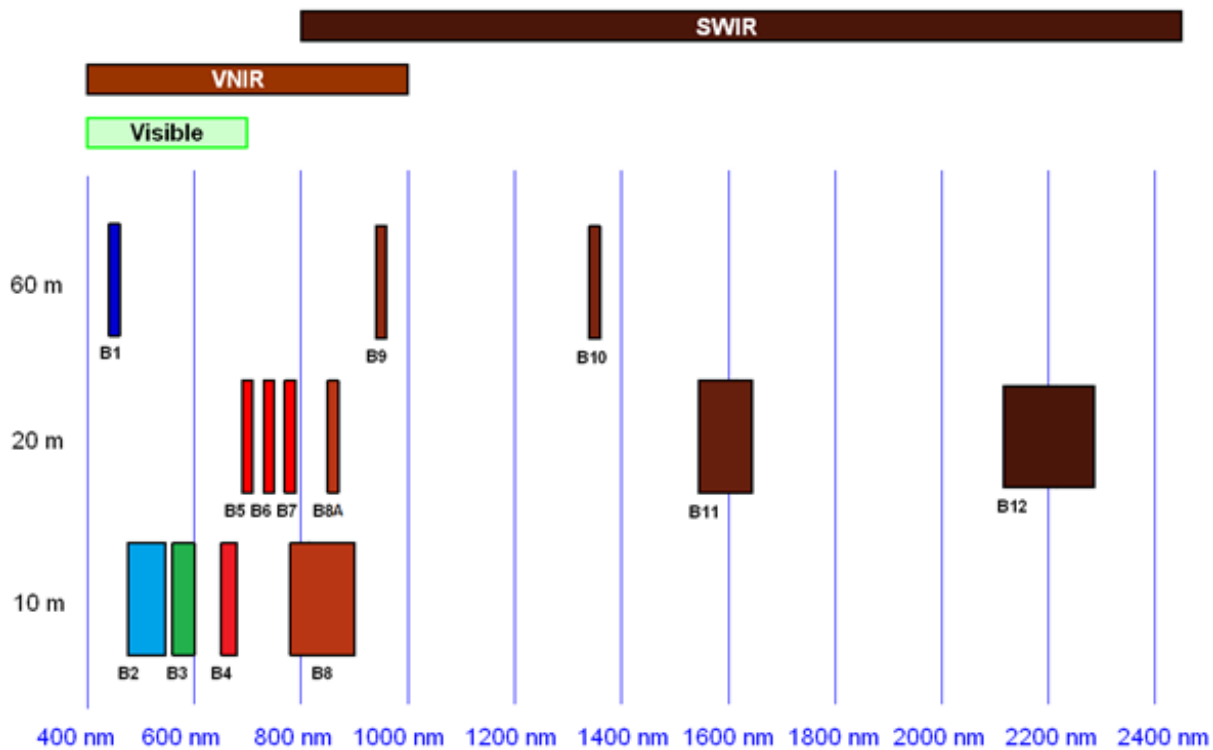
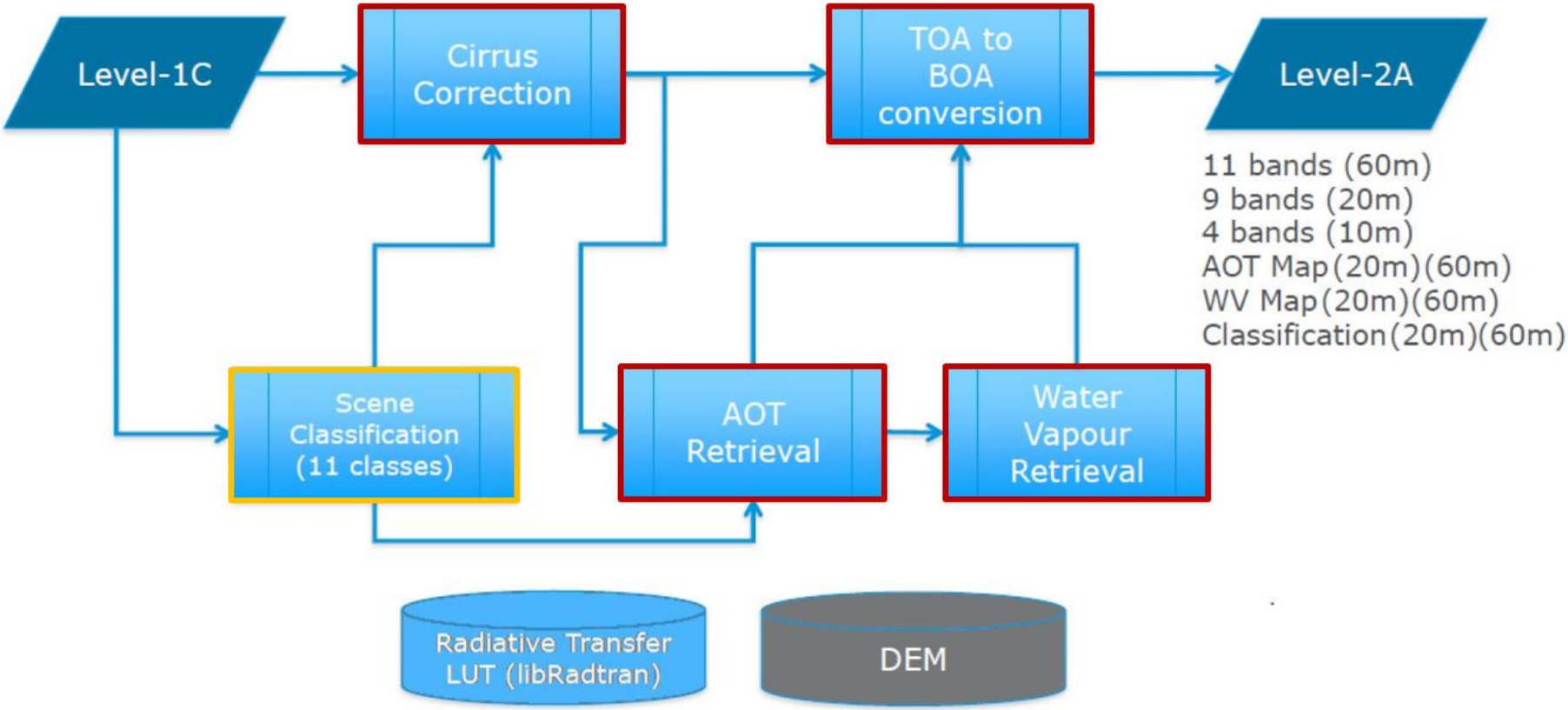
SENTINEL-2 MISSION

- Optical mission for land and coastal region monitoring and emergency services
- Constellation of 2 satellites S2A and S2B
- Polar, Sun-synchronous orbit: altitude 786.13km with LTDN 10h30 AM
- Swath of 290km
- Global coverage with 5 days or less revisit period with both satellites



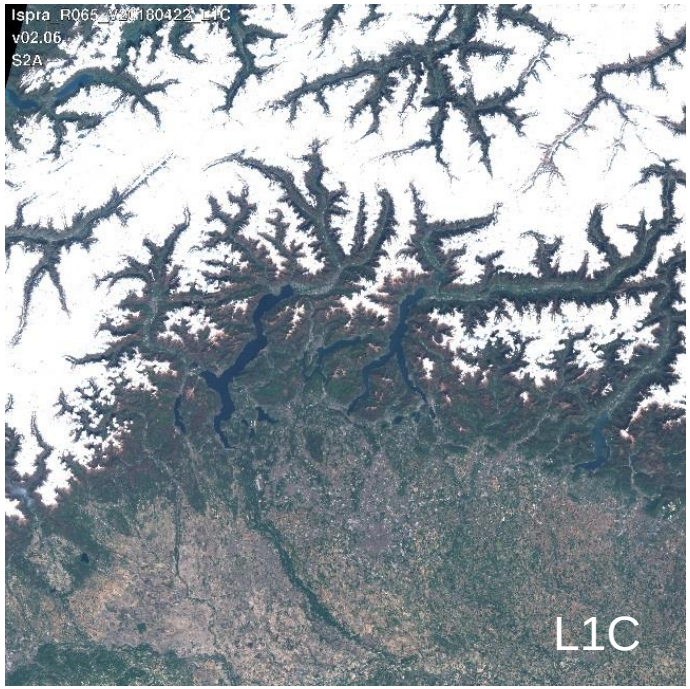
13 spectral bands
spatial resolution
10 m, 20 m, 60 m.

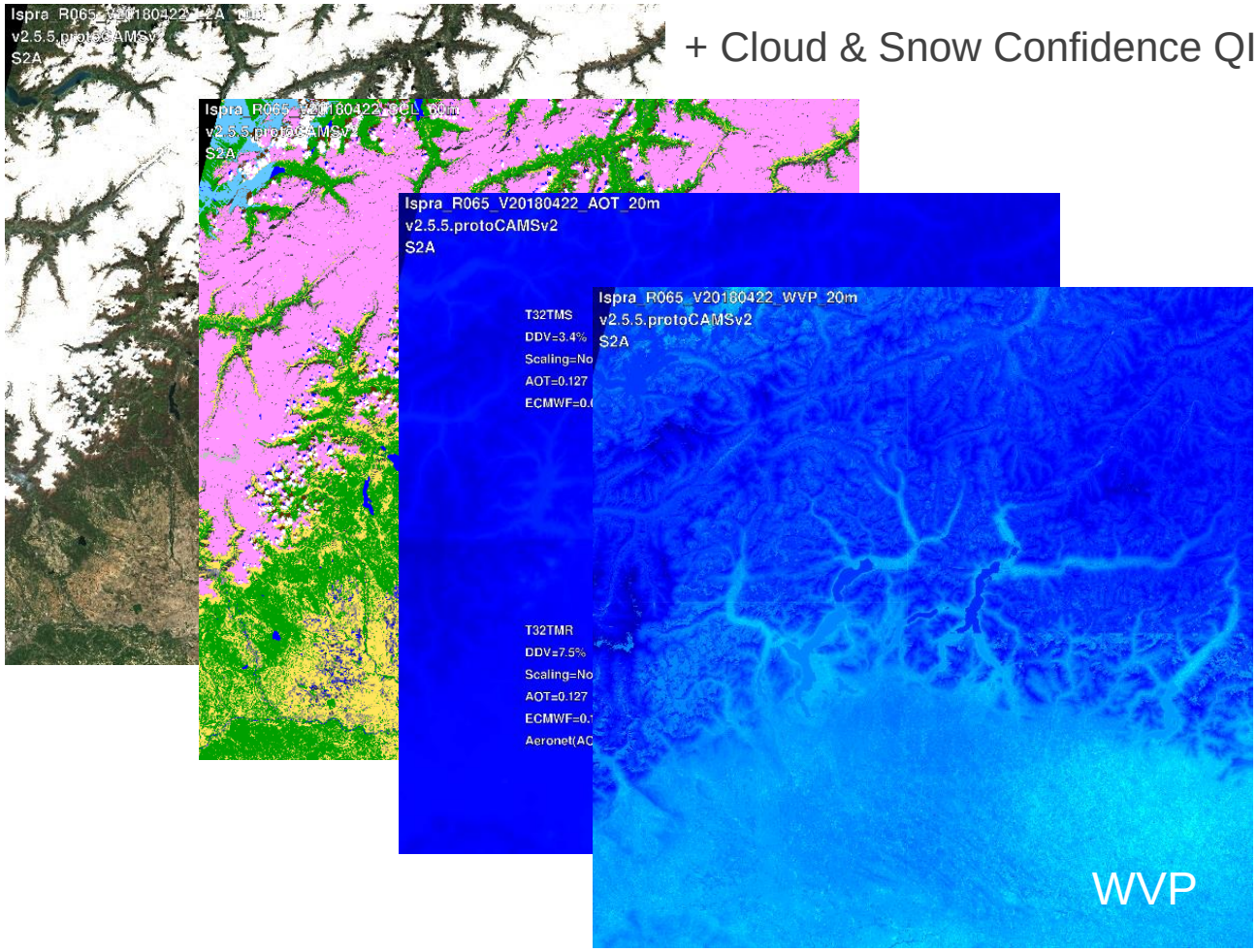
LEVEL-2A PROCESSING STEPS



- Two main modules : Scene Classification (SCL) and Atmospheric Correction (AC)
- Set of Look-Up Tables (LUTs) generated with libRadtran
- AOT derived at 550nm based on the DDV (Dense Dark Vegetation) algorithm
- WV retrieval based on the Atmospheric Pre-corrected Differential Absorption Algorithm (APDA)

L2A Processor Outputs

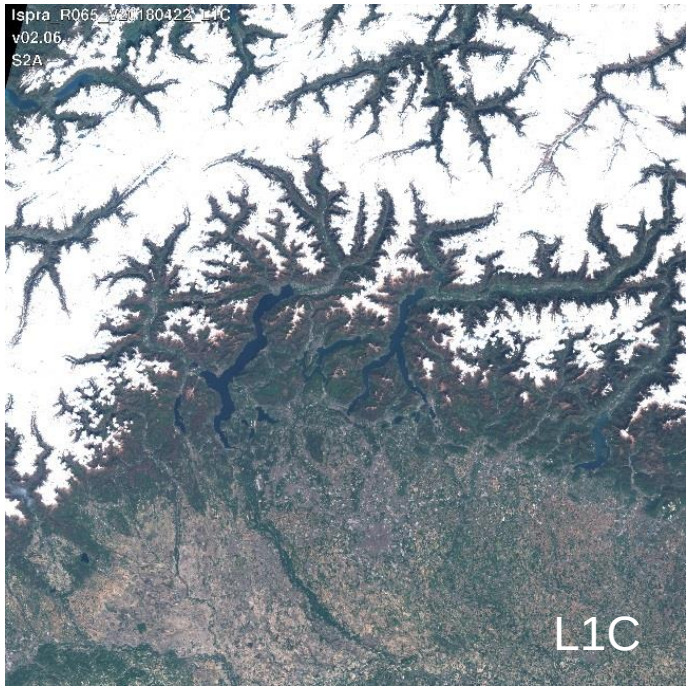


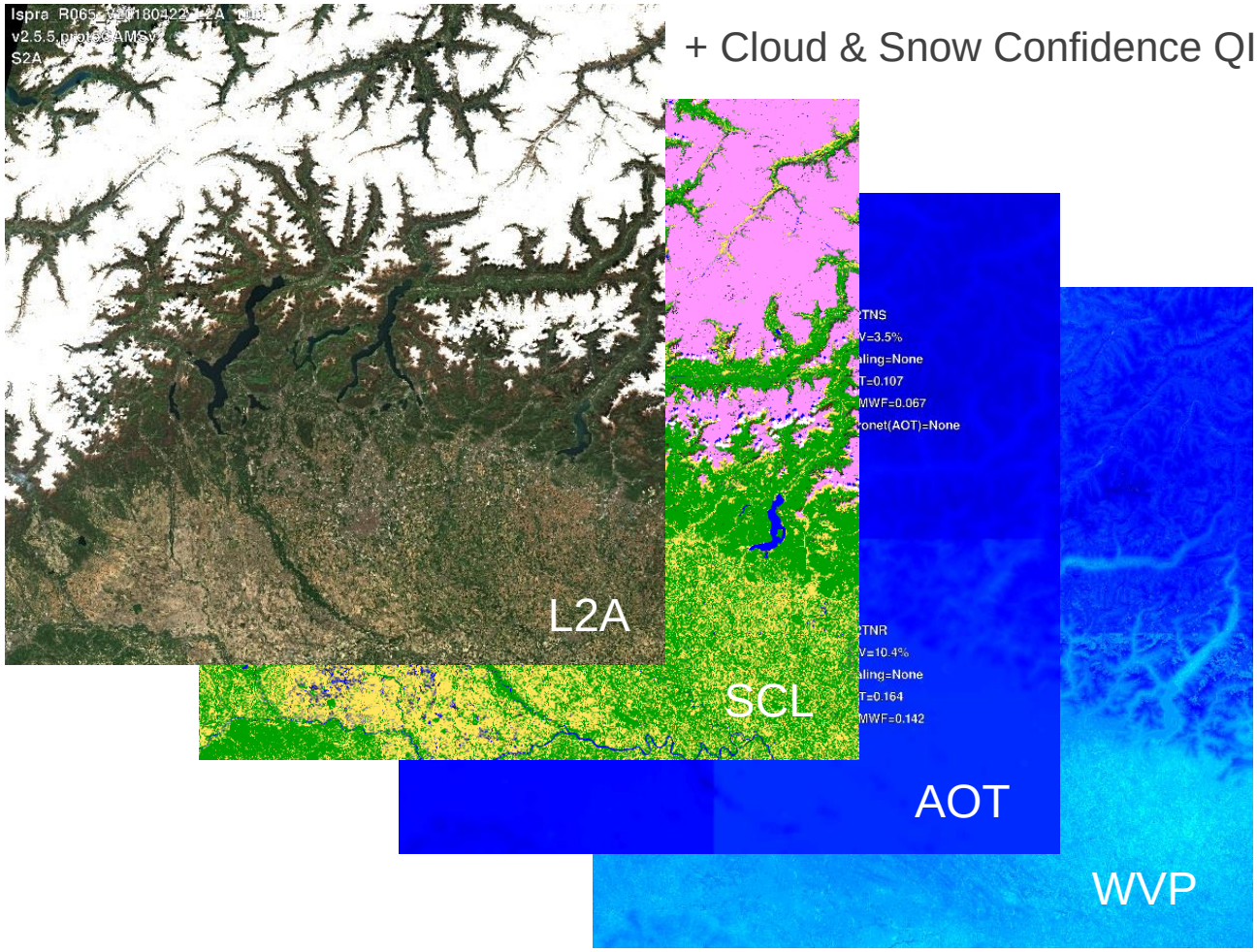


+ Cloud & Snow Confidence QI

Sentinel-2A product
Four tiles
North of Italy
22 April 2018

L2A Processor Outputs

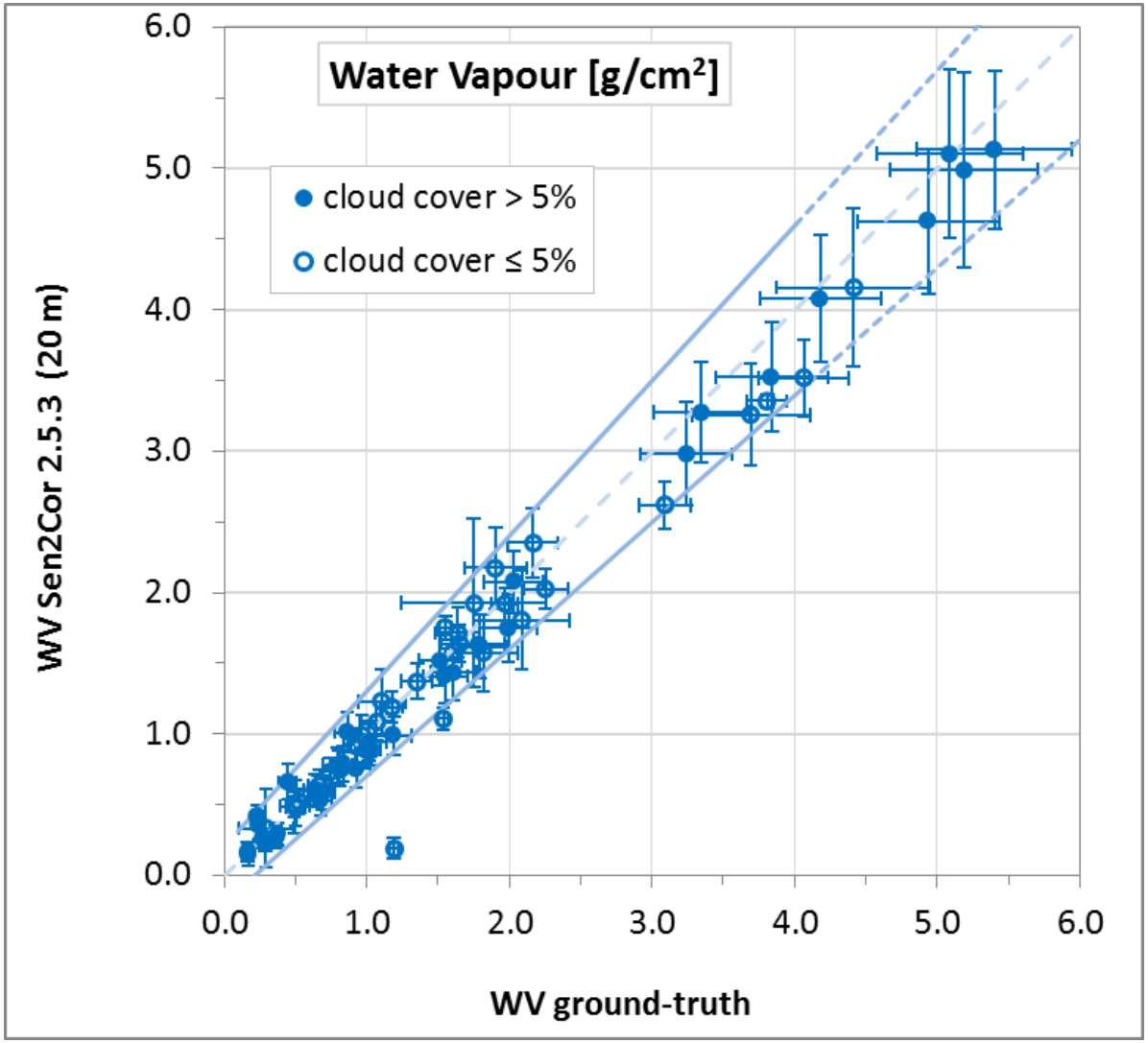




Sentinel-2A product
Four tiles
North of Italy
22 April 2018

L2A Validation Results Sen2Cor 2.5 public: WV product

➔ Scatter plot of Sen2Cor WV output at 20 m resolution versus WV reference from AERONET stations. ACIX-1 data set (water sites excluded).



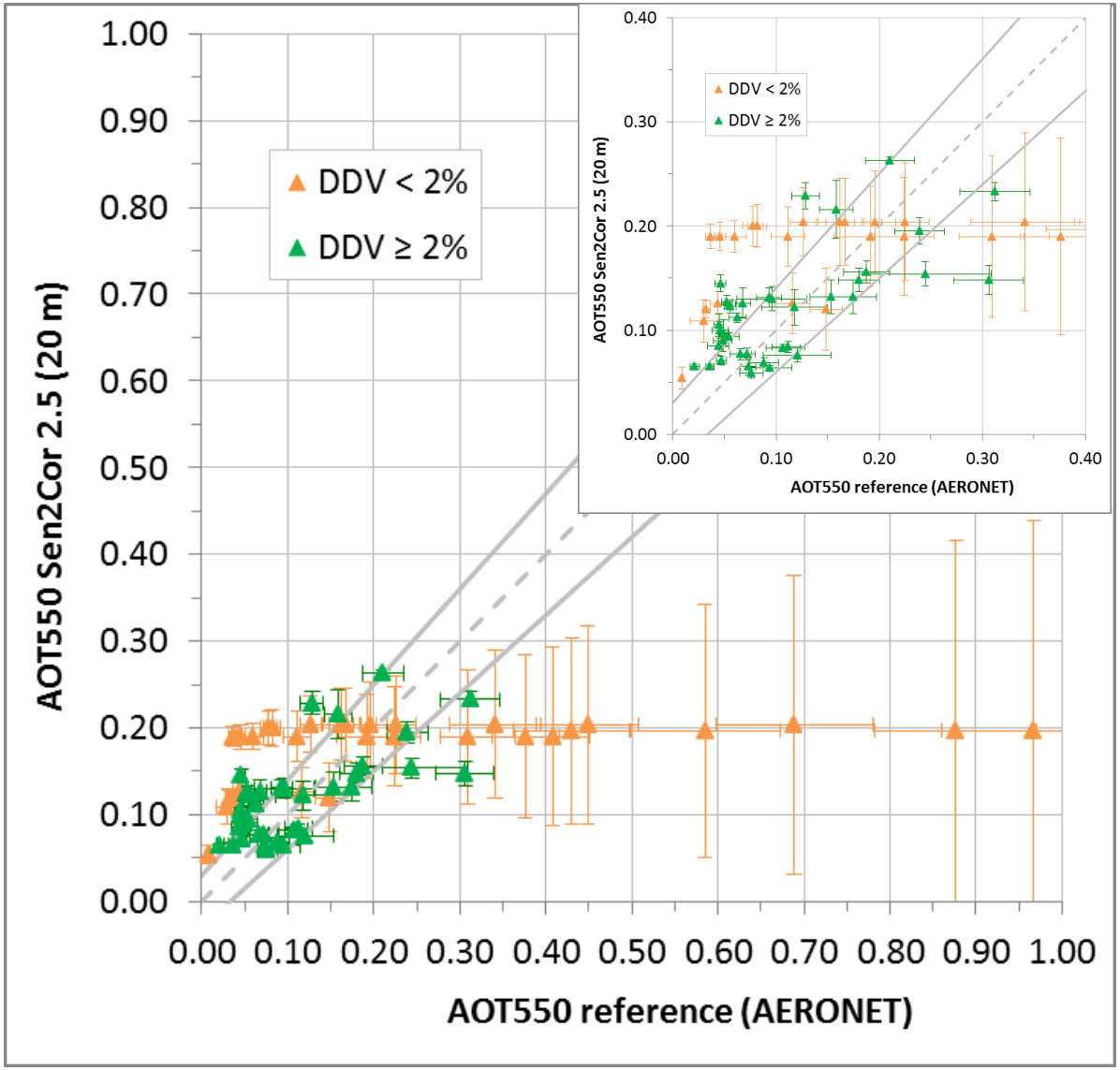
› Accuracy requirement (solid lines): $|\Delta WV| \leq 0.1 * WV_{ref} + 0.2$

› Dashed line: Sen2Cor_output = Reference

➔ Very good accuracy of WV estimation by Sen2Cor 2.5

L2A Validation Results Sen2Cor 2.5 public: AOT product

➔ Scatter plot of Sen2Cor AOT_{550} output at 20 m resolution versus AOT_{550} reference from AERONET station. ACIX-1 data set (water sites excluded).



- Accuracy requirement (solid lines): $|\Delta AOT550| \leq 0.1 * AOT550_{ref} + 0.03$
- Dashed line: Sen2Cor_output = Reference
- Green triangles: Results for DDV-algorithm
- Orange triangles: Results for fall-back processing with configured start VIS=40 km

➔ DDV-algorithm slightly overestimates AOT_{550}

➔ Current fall-back processing gives many large outliers

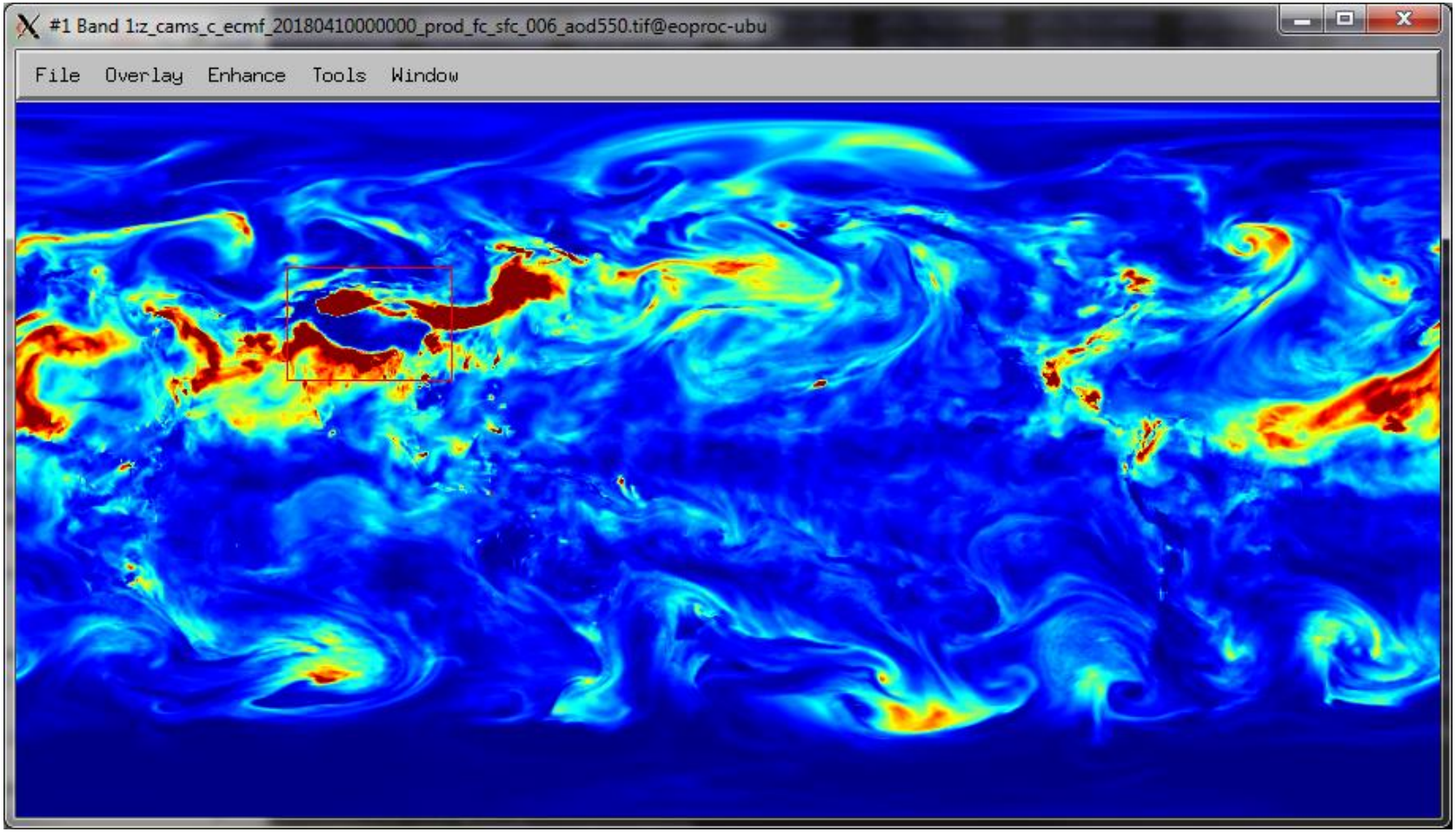
L2A PROTOTYPE: ECMWF-CAMS AOD AT 550 NM FALLBACK

- Fall back solution when DDV pixels are missing in the image.
  - ECMWF-CAMS Total AOD at 550 nm short term forecast (< 12 hours)
  - Data available on Operational FTP with short-term rolling archive (~ 3 days)
  - CAMS data is collected daily
  - CAMS data quality is controlled above L2A calibration test sites.

- Sen2Cor CAMS prototype developed by TPZ F
- First validation performed by DLR on ACIX dataset

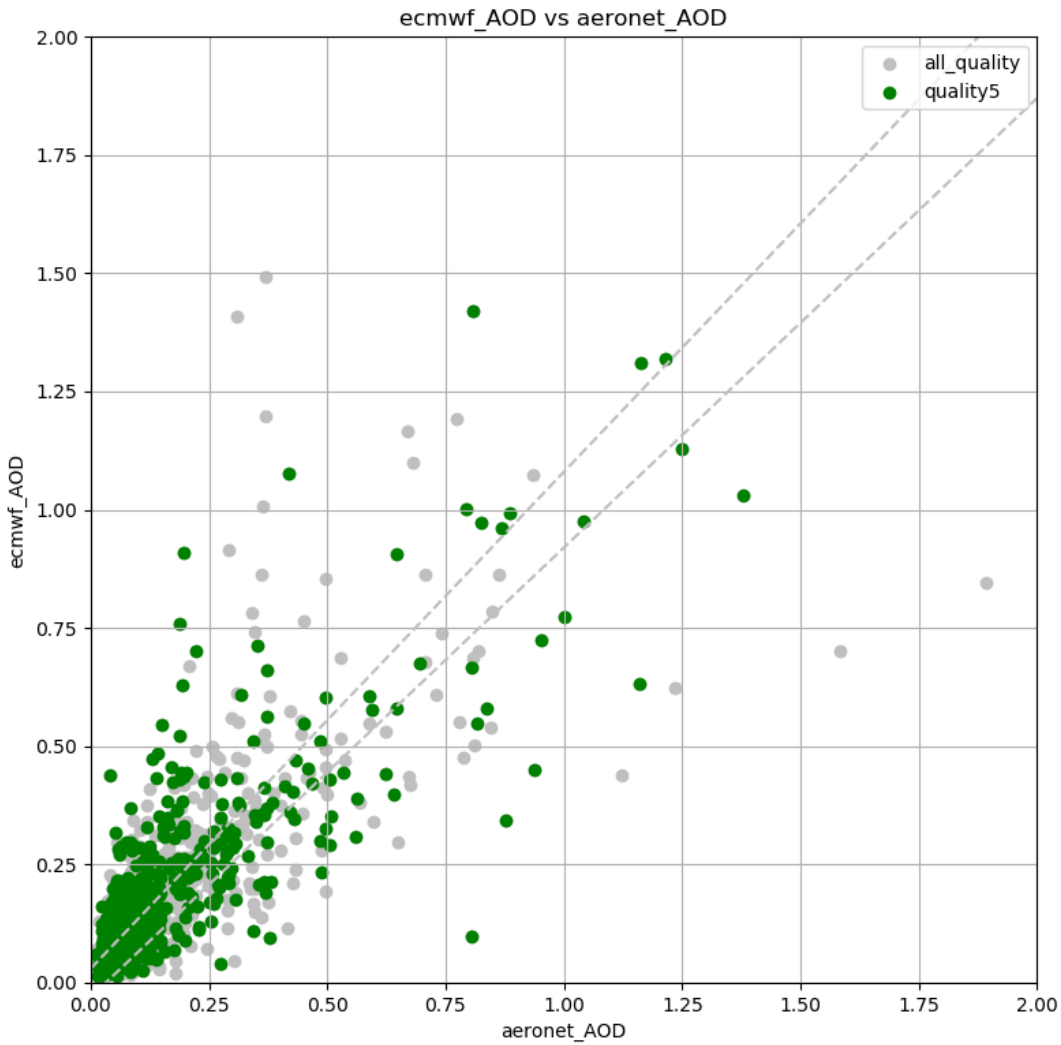
Copernicus Atmosphere Monitoring Service (CAMS) website:
https://atmosphere.copernicus.eu/

L2A: CAMS-ECMWF AOD AT 550 NM SAMPLE



Example of CAMS product retrieved from operational FTP
0.4 x 0.4 deg lat-lon grid

L2A: ECMWF-CAMS AOD AT 550 NM ASSESSMENT



Filtering using:

Aeronet quality (number of aeronet measurements around S2 acquisition time)

Nsamples: 547

Pearson's corr. Coeff R(all): 0.80

Slight overestimation for lower aerosol loads < 0.25

L2A PROTOTYPE: MAIN PROCESSING STEPS

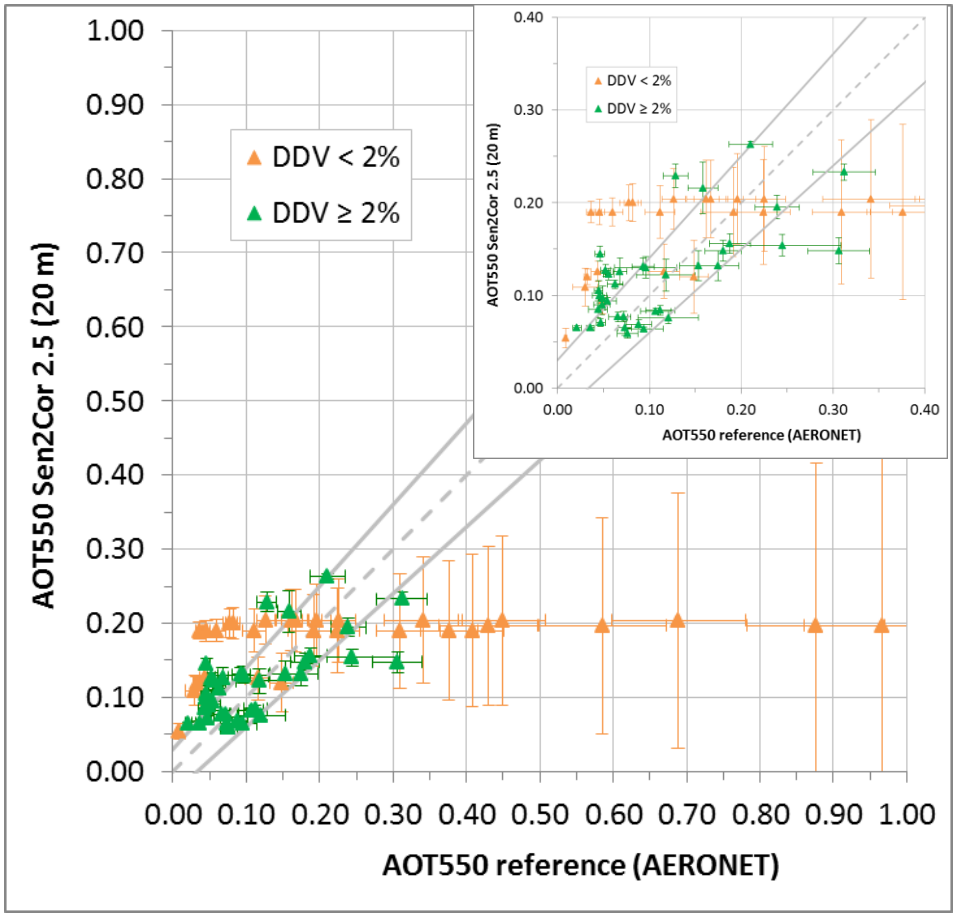
➔ Sen2Cor CAMS prototype based on 02.05.05 (public version)

- AOD inputs from CAMS NEAR_REALTIME (FTP) or MACC data from API server
- CAMS AOD data used in AC processing only **when not enough DDV are present**
- CAMS AOD converted to **visibility** (km) using the altitude of the CAMS DEM.
- Visibility spatially and temporally interpolated to S2 geometry and S2 acquisition time.
- Visibility parameter then used in the radiative transfer equations together with Sen2Cor Digital Elevation Model information (PlanetDEM for operational L2A)
- Iterative negative reflectance check performed afterwards:
  If too many negative surface reflectance pixels -> visibility slightly increased (⇔AOD decrease) to reduce the amount of negative reflectance pixels.

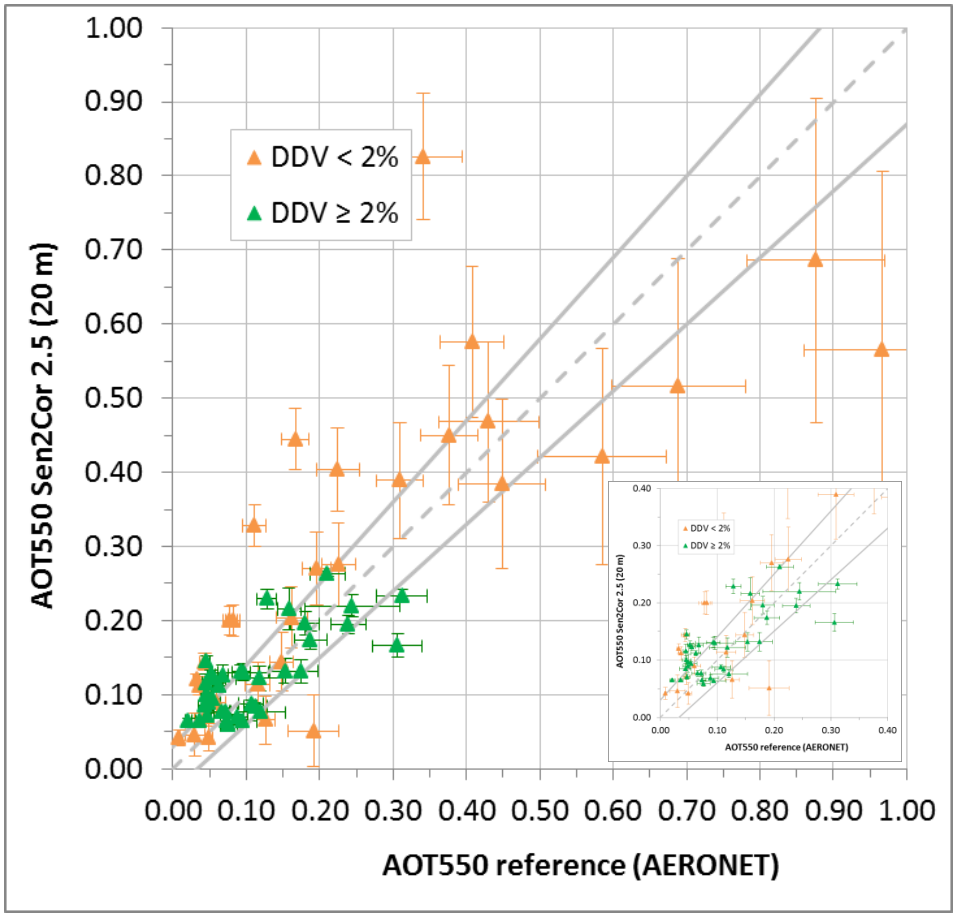
L2A Validation Results Sen2Cor 2.5 CAMS: AOT product

- Correlation plot of Sen2Cor AOT_{550} output at 20 m resolution over AOT_{550} reference from AERONET on basis of the ACIX-1 data set (water sites excluded).

Sen2Cor 2.5, fall-back solution = start VIS



Sen2Cor 2.5, fall-back solution = CAMS data

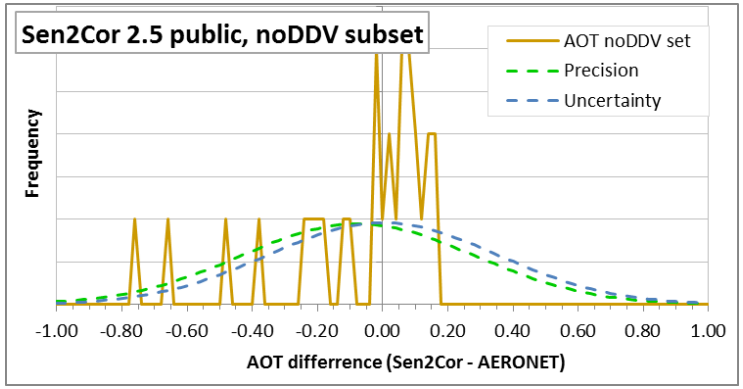


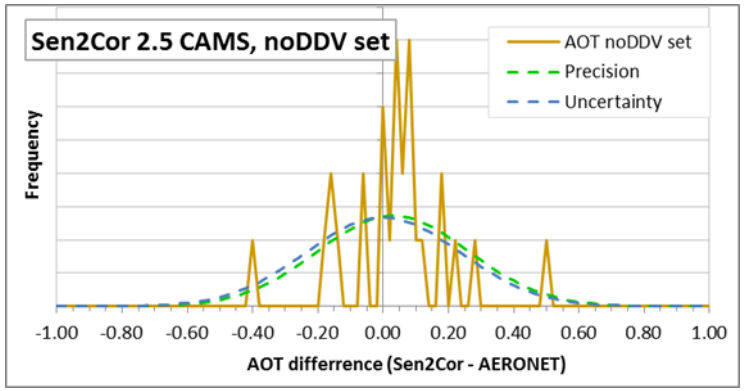
- Using CAMS data as fallback solution in case there are no DDV-pixels in the image looks much better

L2A Validation Results Sen2Cor 2.5 CAMS: AOT product

- Sen2Cor 2.5 public in comparison to Sen2Cor 2.5 CAMS; ACIX (water sites excluded)

AOT statistics	noDDV set 2.5 public		noDDV set 2.5 CAMS
Total no. of products	30		28
Products within requ.	27%		36%
R^2 (Coefficient of variation)	0.19		0.60
r (Pearson's correlation coeff.)	0.43		0.77
MA (Median Accuracy value)	-0.08		0.04
MD (Median deviation)	0.08		0.05
MP (Median Precision value)	0.25		0.16
U (Uncertainty)	0.25		0.17
Max AOT_{550} difference	0.77		0.48
95.4% Quantile	0.14		0.26
68.3% Quantile	0.07		0.07

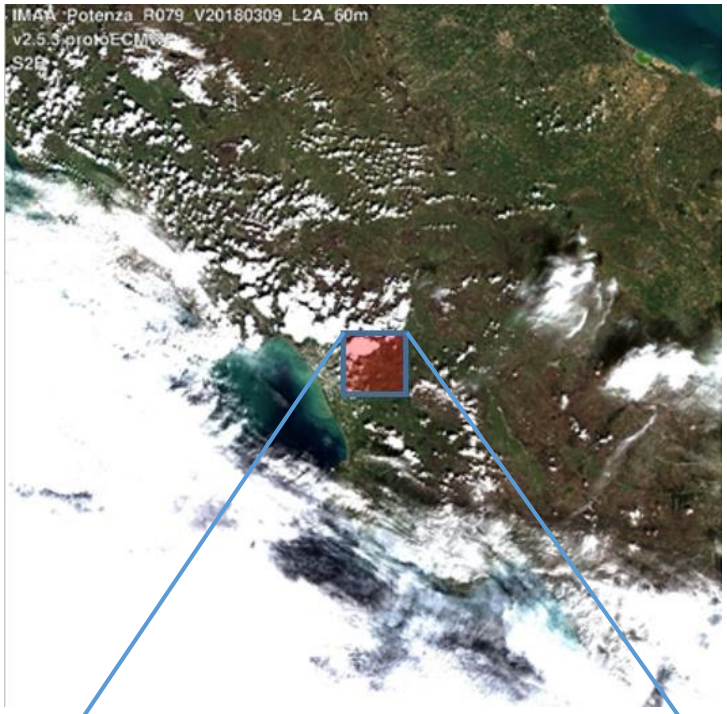


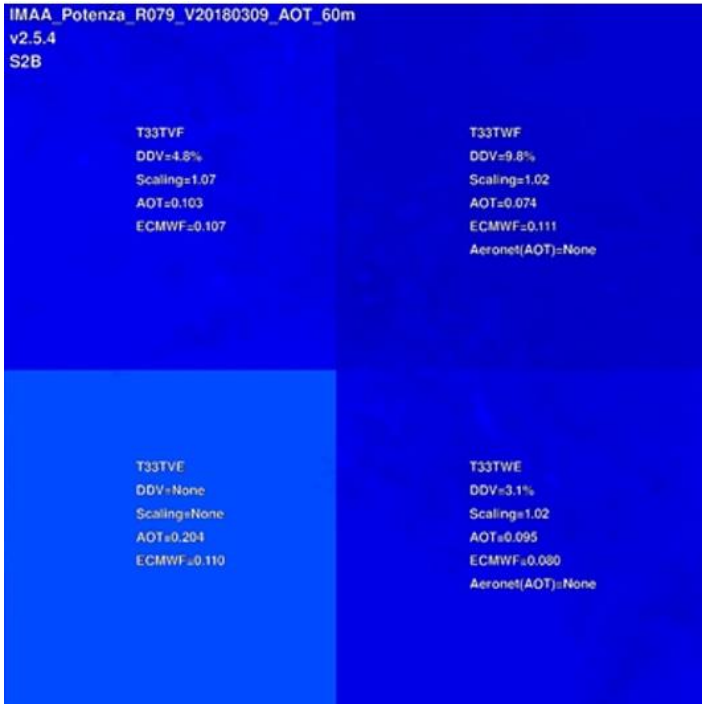


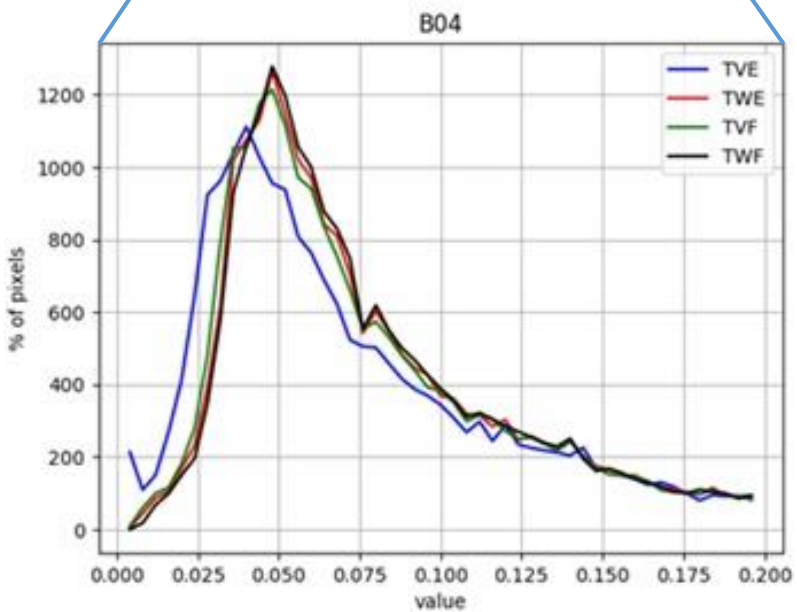
Median Deviation = median (|Sen2Cor - reference|)

- Much higher correlations, remarkable lower MP, U and Max AOT550 difference, lower A
- More products within requirement

L2A CAMS FALLBACK: SEN2COR 2.5 ORIGINAL



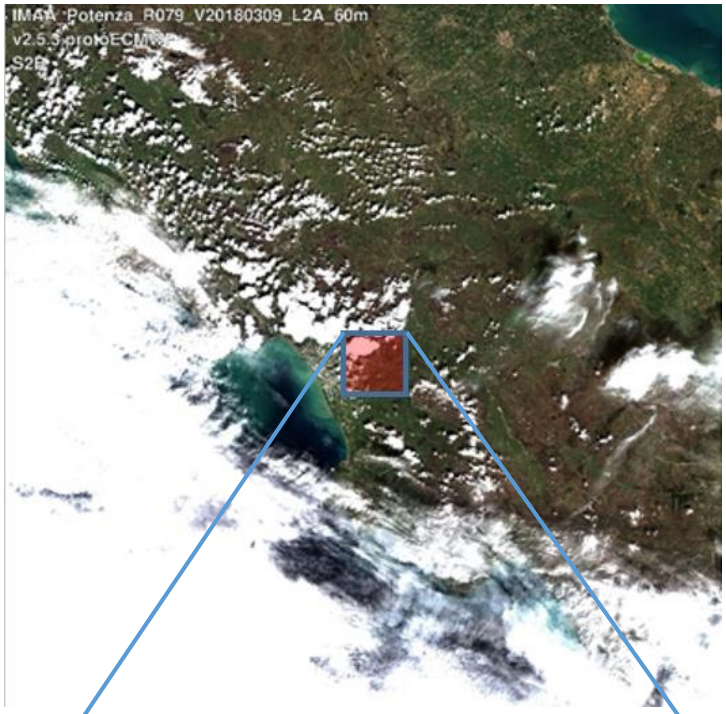


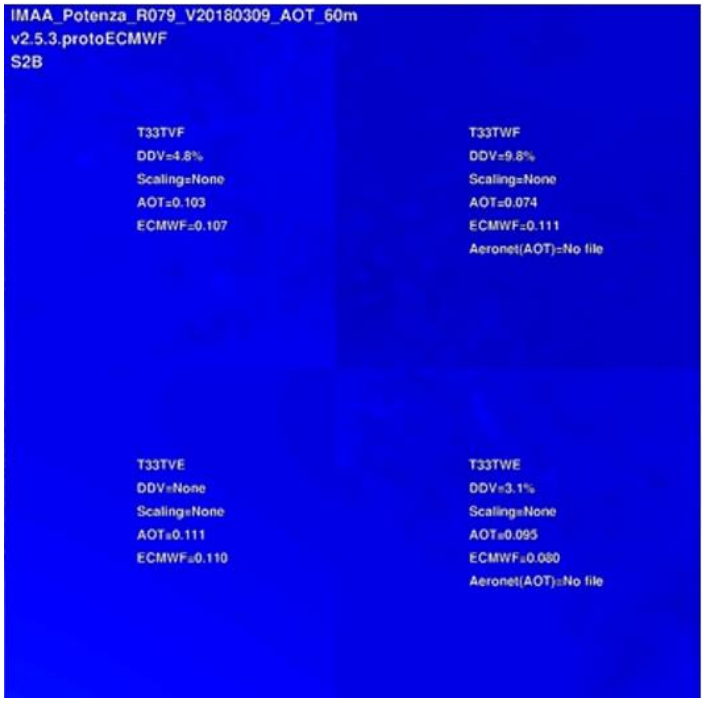


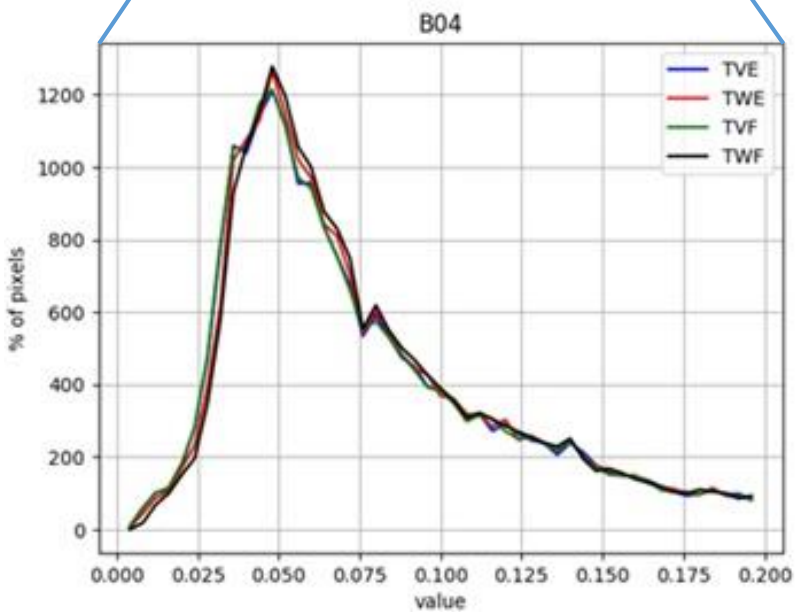
Sentinel-2B product
Four tiles
Naples, Italy
9 March 2018

Overlap region in red : 980 x 980 pixels

L2A CAMS FALLBACK: SEN2COR 2.5 CAMS PROTOTYPE







Sentinel-2B product
Four tiles
Naples, Italy
9 March 2018

Overlap region in red : 980 x 980 pixels

CONCLUSION AND OUTLOOK

- Sen2Cor CAMS prototype based on public Sen2Cor version 2.5
- Promising results for the improvement of AOT retrieval in case DDV pixels are missing in the image
- CAMS data quality monitoring over L2A calibration sites to be continued
- Further investigations foreseen:
  - using CAMS forecasts for different aerosol types
  - merging CAMS forecasts with Sen2Cor AOT estimates

    (in case DDV are present in the image)


VALENCIA
20/07/2018
L1C

ACKNOWLEDGEMENTS
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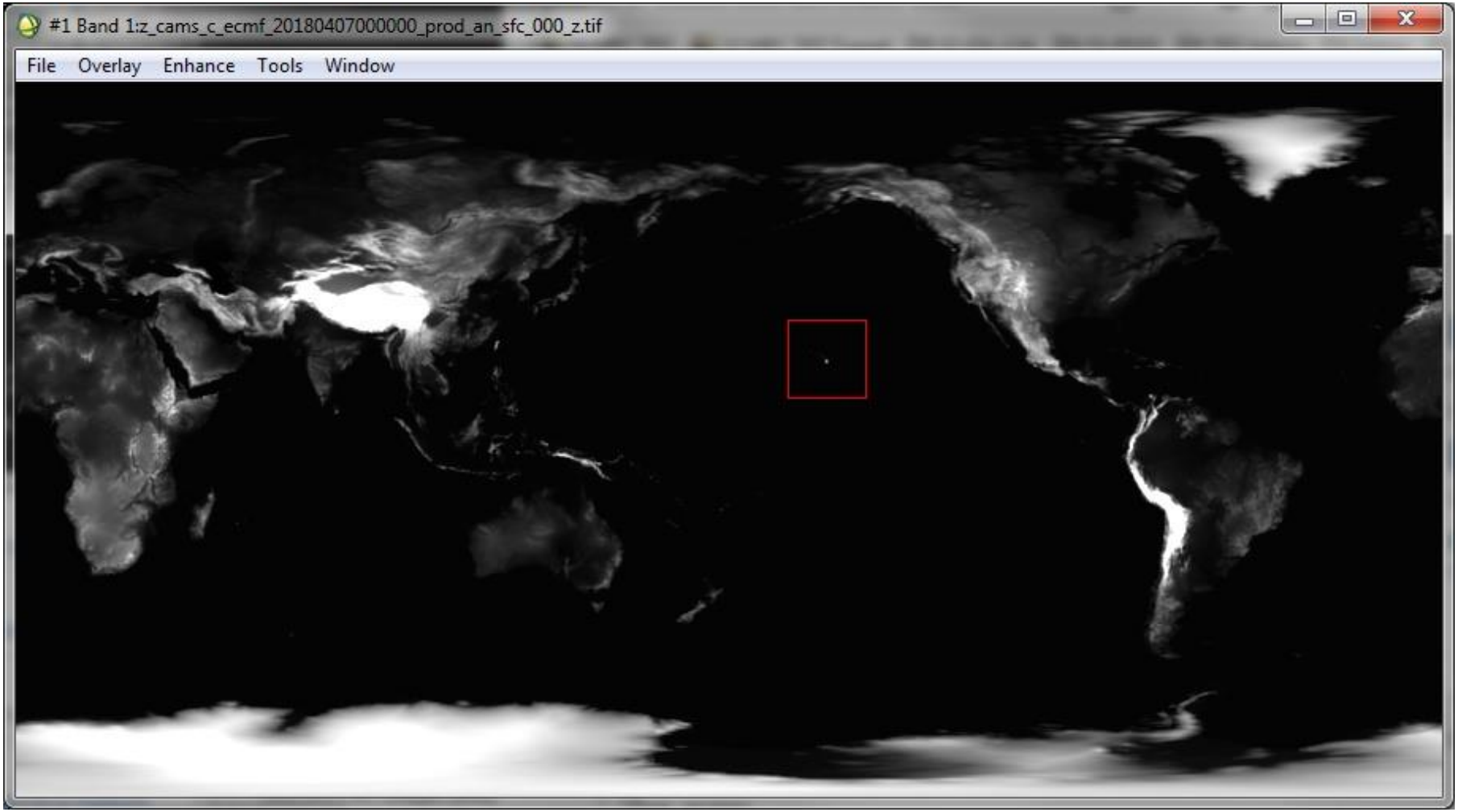
Vincent Debaecker
Uwe Müller-Wilm

Bringfried Pflug
Magdalena Main-Knorn

jerome.louis@telespazio.com

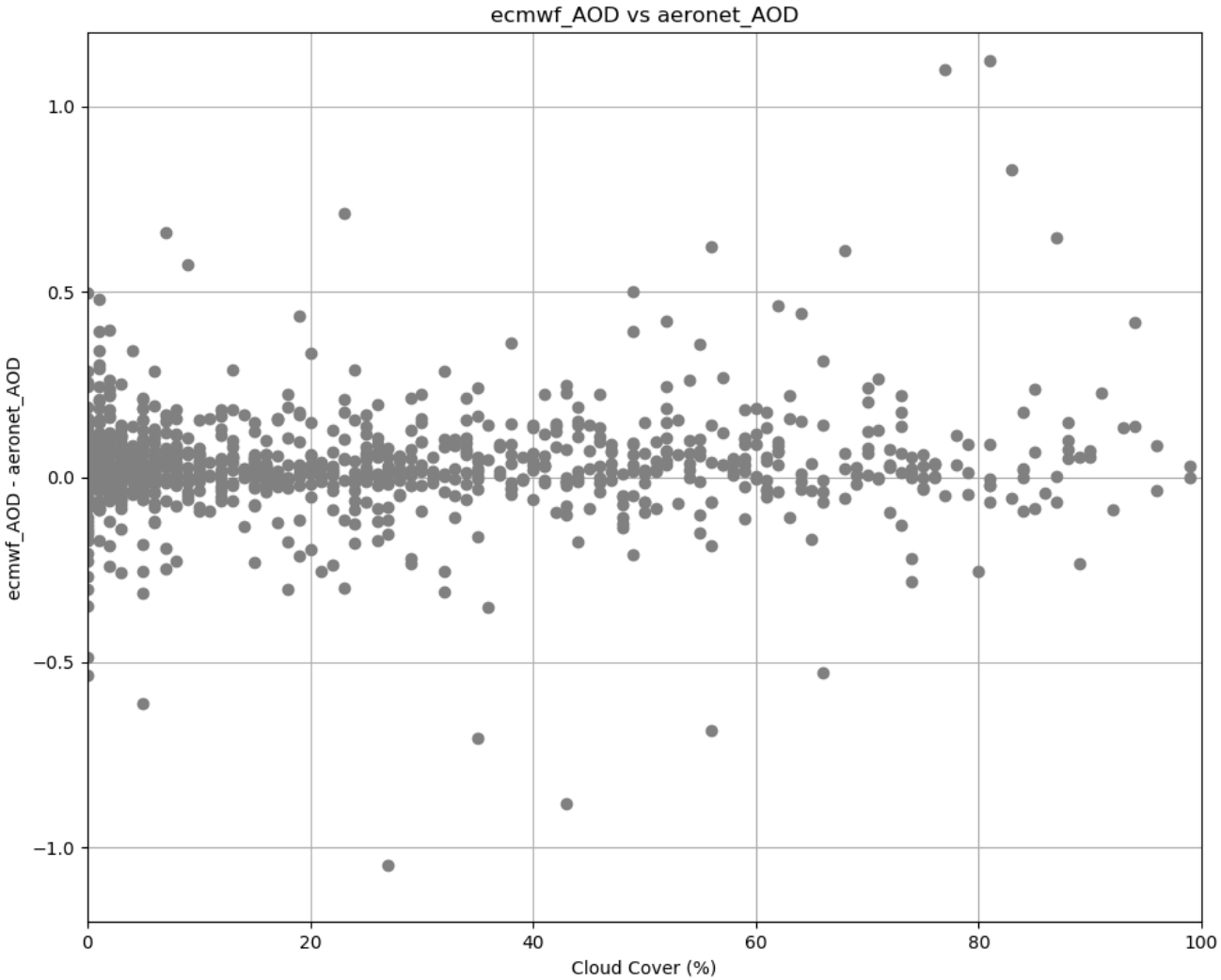
L2A Calibration Activities: CAMS-ECMWF AOT



CAMS geopotential used to calculate elevation
elevation = surface geopotential / 9.80665

Resolution 0.4 x 0.4 deg

L2A: ECMWF-CAMS AOD AT 550 NM ASSESSMENT



No direct correlation between cloud coverage and CAMS aod uncertainty

Qualitative analysis of outliers shows that these are often related to a large weather front approaching the aeronet site.

VALIDATION PROCEDURE

- AOT & WV validation procedure:
  - direct comparison with AERONET as reference
  - AERONET: satellite overpass time ±30 min
  - Sentinel-2: average over
    - 9km x 9km area around sunphotometer of all vegetated and not-vegetated pixels
- SR validation procedure:
  - Pixel-by-pixel comparison with AERONET corrected (surface reflection) data as reference
  - SR reference computed from [Eric Vermote]
    - Sentinel-2 L1C (TOA) data with
    - 6S radiation transport model using
    - aerosol parameters from AERONET as input
  - AERONET: satellite overpass time ±30 min
  - Sentinel-2:
    - 9km x 9km area around sunphotometer with
    - only non-saturated, non-cloudy and non-missing pixels considered

VALIDATION PROCEDURE

- Statistical metrics:
  - $X_i = SR_{i,\lambda}, AOT^{550}{}_i; WV_i$ (i:=pixel; λ:= Band)
  - $\Delta X_i = X_{i,\,SEN2COR} - X_{i,\,reference}$
  - Median Accuracy value (median differerence to reference value)

    $$\mathbf{MA} = Median_{i=1}^{n}(\Delta X_i)$$

  - Median absolute Deviation:

    $$\mathbf{MD} = Median_{i=1}^{n}(|\Delta X_i|)$$

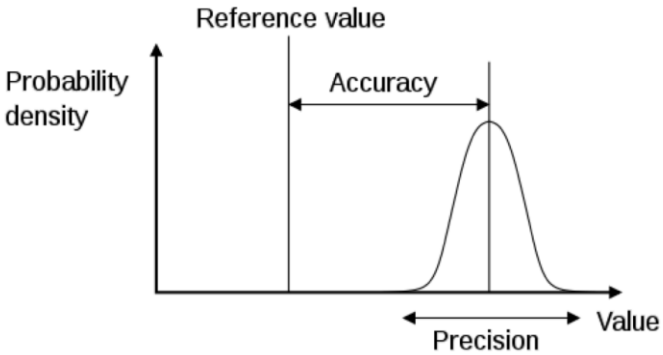
  - Median Precision value (rms around MA)

    $$\mathbf{MP} = \sqrt{\frac{1}{(n-1)} \cdot \sum_{i=1}^{n}(\Delta X_i - MA)^2}$$

  - Uncertainty U (rms around reference value)

    $$\mathbf{U} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\Delta X_i)^2}$$

  - SR per band:
    - MA, MP and U are computed per 0.02-SR-bins and
    - overall values for entire SR range



High accuracy, low precision

high precision, low accuracy