A NOVEL TOOL FOR ADAPTING LAND ATMOSPHERIC CORRECTION TO WATER

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DLR

Atmospheric correction

Land vs. water

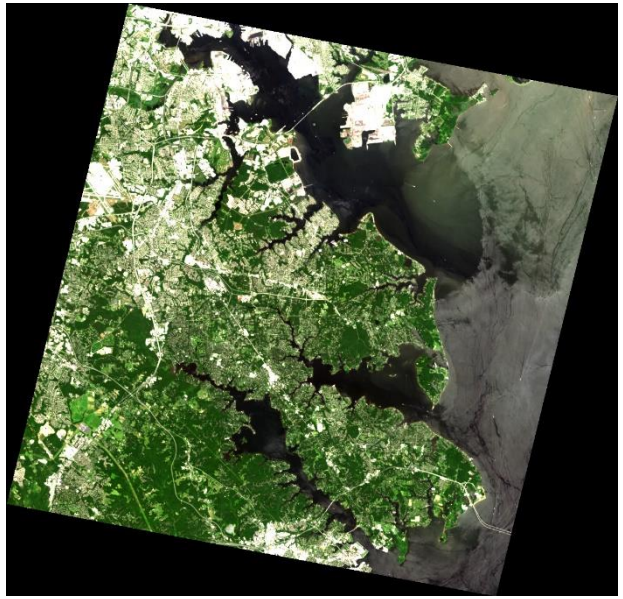
Top of atmosphere radiance

Level 1

Atmospheric correction

Bottom of atmosphere reflectance

Level 2A



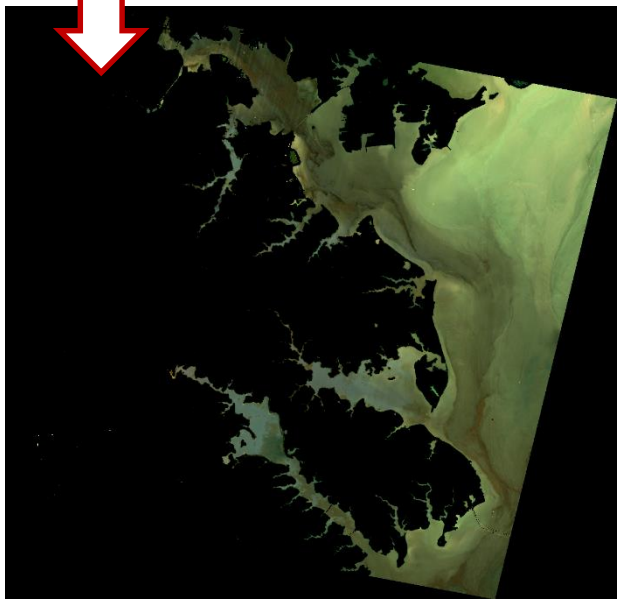
EnMAP Level 1 image from Chesapeake Bay 2022-07-22

AC land

AC water

Level 2A Land Product

Rrs tool



Level 2A Water Product

Atmospheric correction

Software for land satellite sensors to create Level-2A data

Software used by sensor operators to convert data from Level-1 to Level-2A

Sensor	Operator	Land AC	Water AC
Sentinel-2	ESA	Sen2Cor (Modtran)	-
Landsat-8/9	NASA / USGS	LaSRC (Internal)	-
PRISMA	ASI	LUT (Modtran)	-
DESIS	DLR / Teledyne	PACO (Modtran)	-
EnMAP	DLR	PACO (Modtran)	MIP (FEM)

Software used by scientists or companies to convert Level-1 to Level-2A water

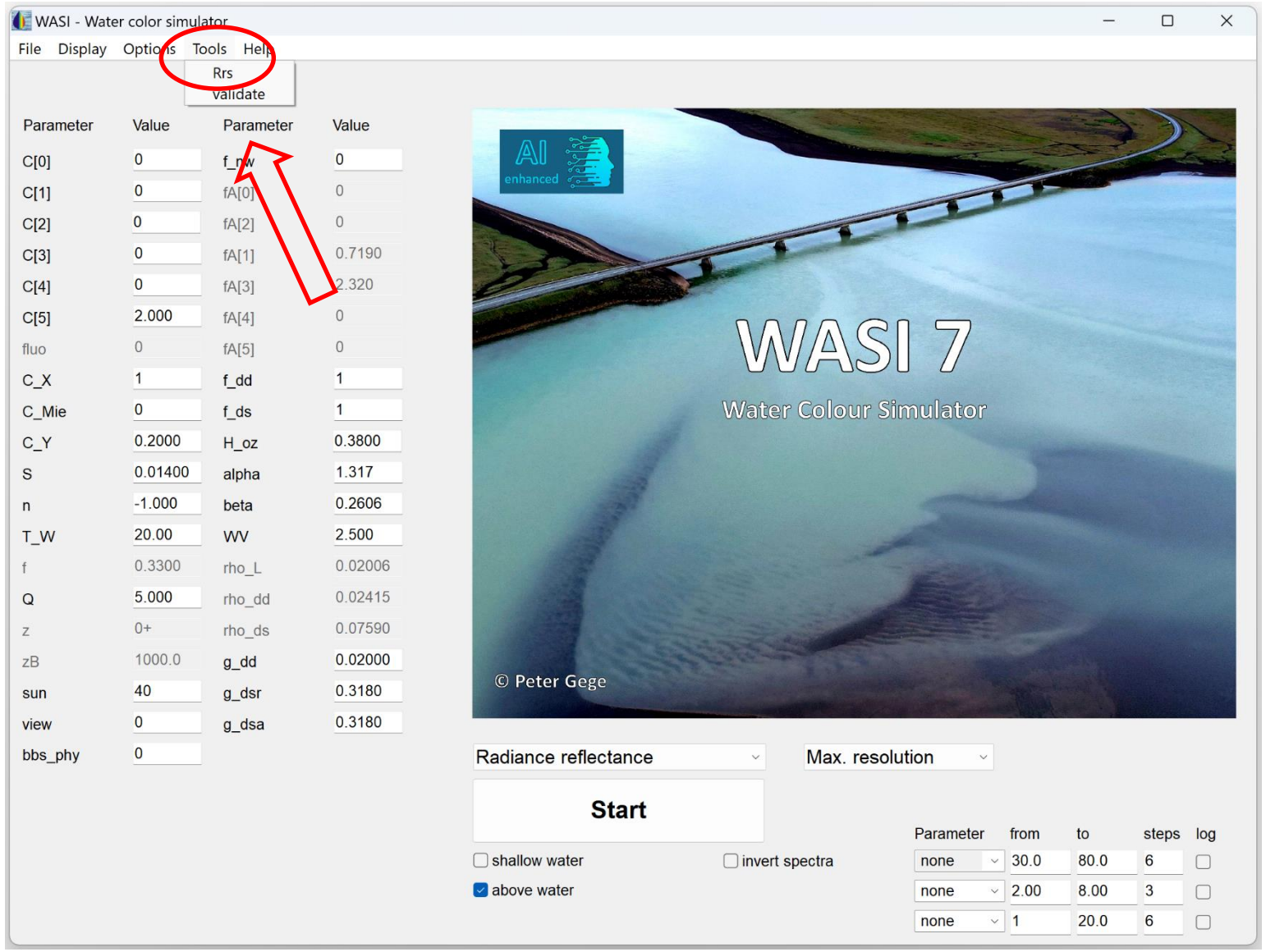
ACOLITE, C2RCC, DSF, hGRS, L2gen, POLYMER, iCOR, MIP, …

Software used here to convert Level-2A land to Level-2A water

WASI [1] [2]

[1] Gege, P. (2004): The water colour simulator WASI: An integrating software tool for analysis and simulation of optical in-situ spectra. *Computers & Geosciences 30*, 523–532.
[2] Gege, P. (2014): WASI-2D: A software tool for regionally optimized analysis of imaging spectrometer data from deep and shallow waters. *Computers & Geosciences 62*, 208-215.

WASI Rrs tool



Download:
https://ioccg.org/resources/software/

Glint model

Glint is the ratio of reflected sky radiance ($L_{sky}(\lambda)$) to downwelling irradiance ($E_d(\lambda)$):

$$R_{rs}^{surf}(\lambda) = \rho_L \frac{L_{sky}(\lambda)}{E_d(\lambda)}.$$

ρ_L: Fresnel reflectance

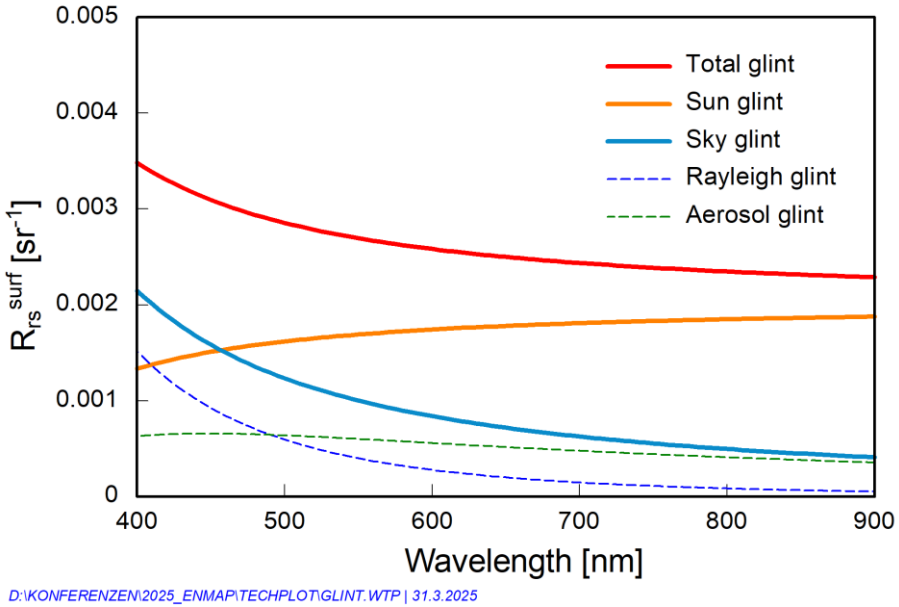
Reflected sky radiance is treated as sum of three "light sources" with known spectral dependencies $E_i(\lambda)$ and potentially unknown relative contributions g_i:

$$L_{sky}(\lambda) = g_{dd}\, E_{dd}(\lambda) + g_{dsr}\, E_{dsr}(\lambda) + g_{dsa}\, E_{dsa}(\lambda).$$

dd: direct downwelling from direction of Sun **(Sun glint)**

dsr: diffuse downwelling from Rayleigh scattering **(Rayleigh glint)**

dsa: diffuse downwelling fromaersosol scattering **(Aerosol glint)**



Simulation of glint for the following conditions:

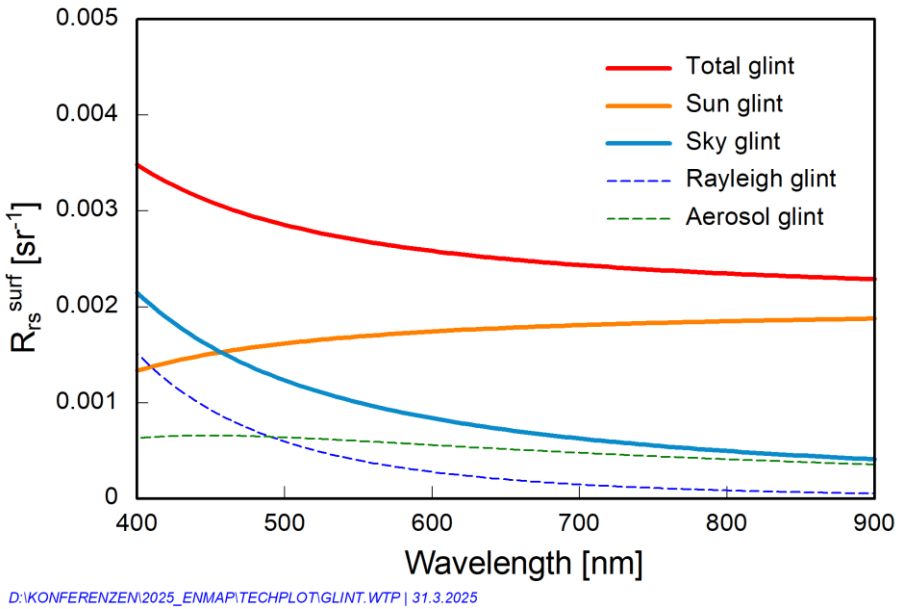
SZA = 40°
H_oz = 0.3 cm
WV = 2 cm
AOT = 0.1
Angström exponent = 1.32
g_{dd} = 0.1 sr^{-1}
$g_{dsr} = 1/\pi$
$g_{dsa} = 1/\pi$

Glint model

$E_i(\lambda)$ are computed using model of Gregg and Carder [3] and spectral atmospheric data of Gege [4] which were derived using Modtran-3.

g_{dd} is usually fit parameter

g_{dsr} and g_{dsa} are usually set $1/\pi$, representing isotropic irradiance



Spectral shapes of sun glint and sky glint are complementary

Spectral shape of sky glint identical to that of path radiance

➔ errors of path radiance can be corrected by glint correction

➔ "glint" = surface reflections + remnants of path radiance

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[3] Gregg, W.W., Carder, K.L. (1990). A simple spectral solar irradiance model for cloudless maritime atmospheres. *Limnology and Oceanography 35*, 1657–1675.
[4] Gege, P. (2012). Analytic model for the direct and diffuse components of downwelling spectral irradiance in water. *Applied Optics 51*, 1407-1419

Glint correction

Steps: [5]

1. Apply inverse modelling to $\rho(\lambda)$ with fitting g_{dd} and few fit parameters for $R_{rs}(\lambda)$

Bio-optical model of Albert [6] [7] *for remote sensing reflectance,* $R_{rs}(\lambda)$.

Large path radiance errors may further require to adjust or fit g_{dsr} *and/or* g_{dsa}

$$\frac{1}{\pi}\rho(\lambda) = R_{rs}(\lambda) + R_{rs}^{surf}(\lambda).$$

$\rho(\lambda)$: Surface reflectance from Level 2A land processor

2. Subtract fit result for $R_{rs}^{surf}(\lambda)$ from surface reflectance:

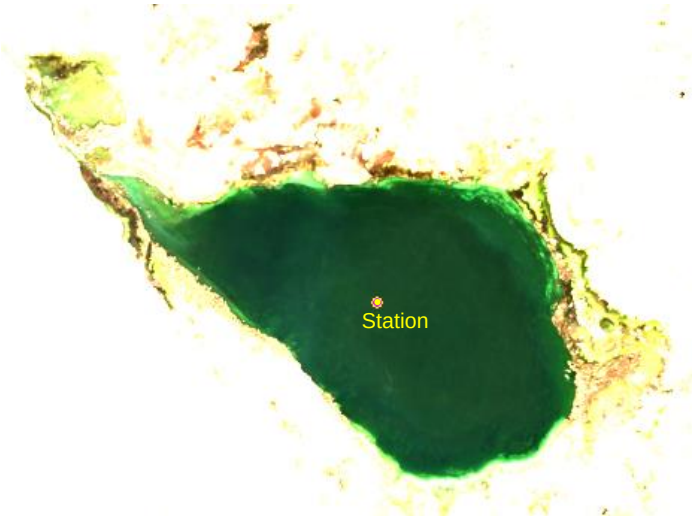
$$R_{rs}(\lambda) = \frac{1}{\pi}\rho(\lambda) - R_{rs}^{surf}(\lambda).$$

[5] Gege, P., Grötsch, P. (2016): A spectral model for correcting sunglint and skyglint. *Proc. Ocean Optics XXIII, 23.-28. Okt. 2016, Victoria, Kanada*. https://elib.dlr.de/108100/
[6] Albert, A., Mobley, C.D. (2003): An analytical model for subsurface irradiance and remote sensing reflectance in deep and shallow case-2 waters. *Optics Express 11*, 2873-2890.
[7] Albert, A. (2004): Inversion technique for optical remote sensing in shallow water. *Ph.D. Dissertation, Universität Hamburg, Hamburg, Germany*, 188pp.

Results

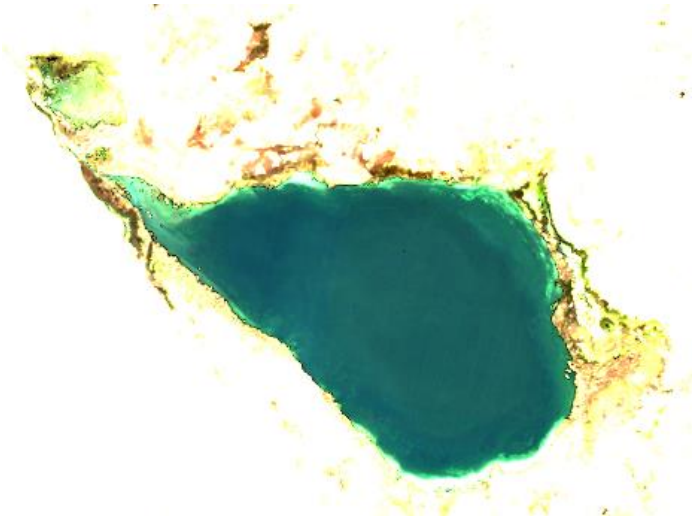
Sentinel-2B: Lake Junin, Peru, 2023-06-24

L2A product from Sen2Cor

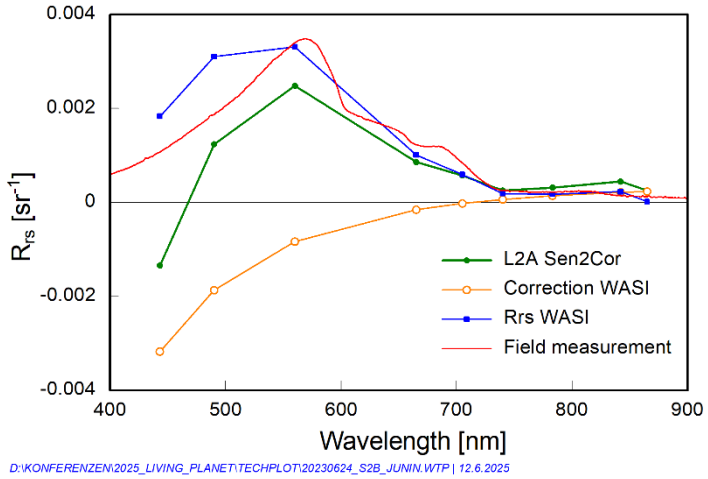


Glint + Path radiance

Result of Rrs tool



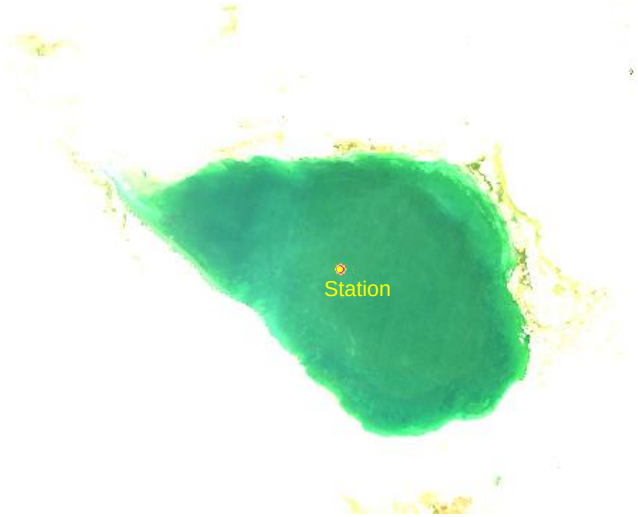
- Conditions: Water is very dark, lake at 4080 m a.s.l.
- Sen2Cor: Overcorrection leads to negative Rrs in band 1
- Validation: correspondence with field data is bad for bands 1 and 2, but very good for all other bands



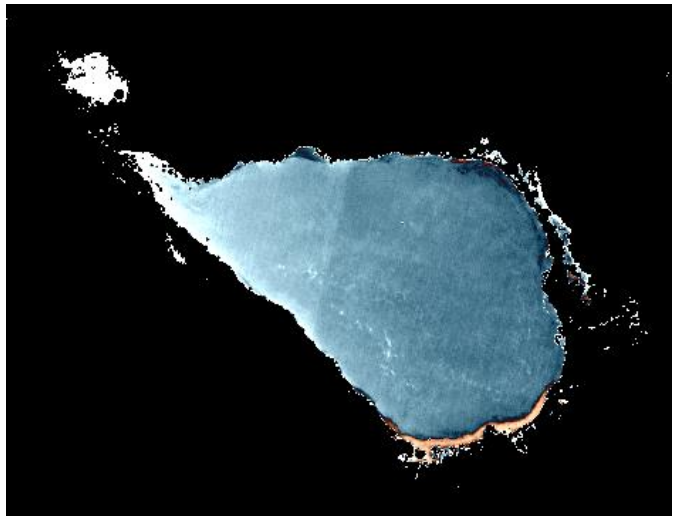
Results

Sentinel-2B: Lake Junin, Peru, 2023-06-24

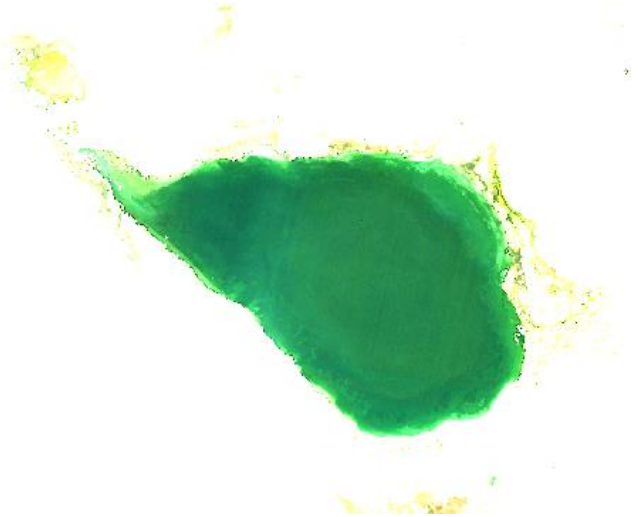
L2A product from ACOLITE



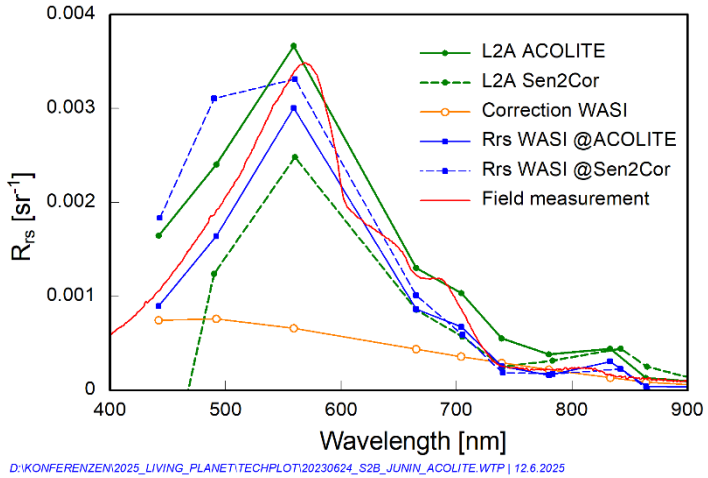
Glint + Path radiance



Result of Rrs tool



- Conditions: Water is very dark, lake at 4080 m a.s.l.
- ACOLITE: Much better than Sen2Cor
- Rrs tool: Glint pattern is removed
- Validation: Good correspondence with field data for all bands

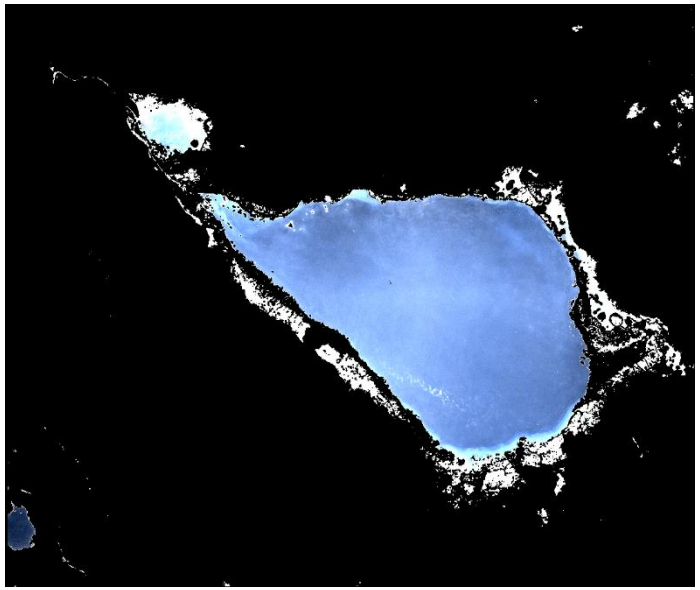


Results

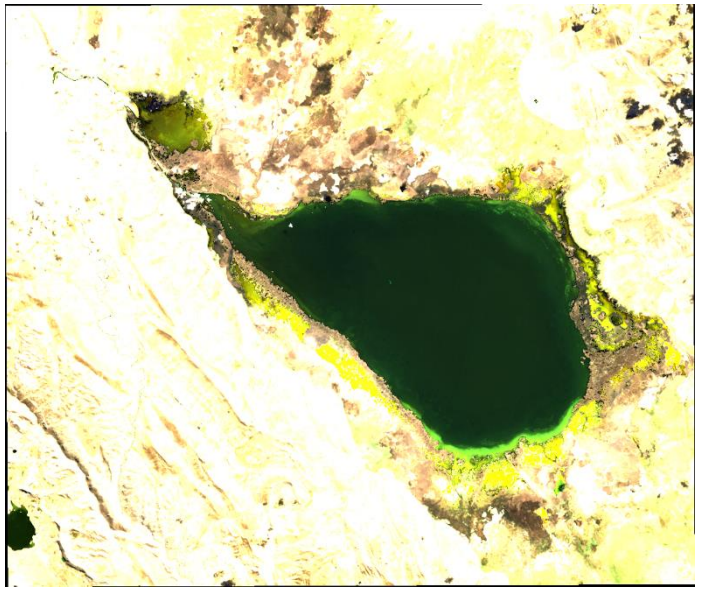
Landsat-8: Lake Junin, Peru, 2023-07-14

L2A product from ACOLITE

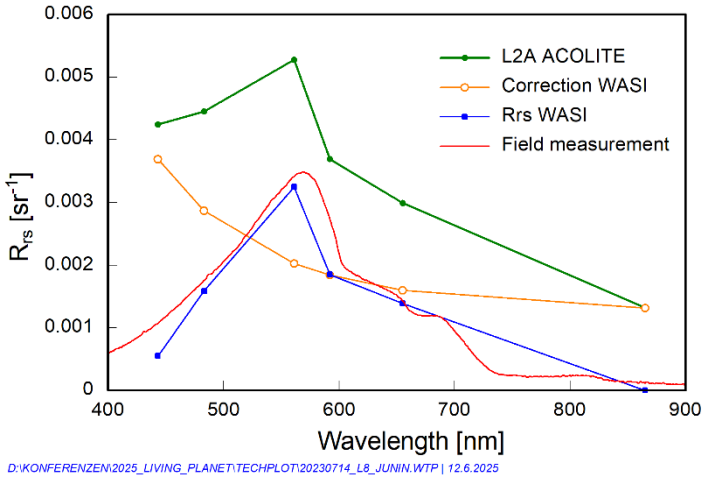
Glint + Path radiance



Result of Rrs tool



- Conditions: Water is very dark, glint comparable to Rrs
- Rrs tool: Glint pattern is completely removed
- Validation: Good correspondence with field data



Results

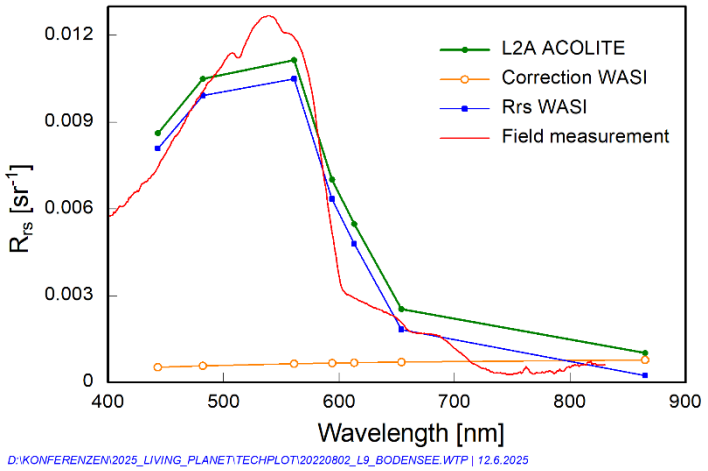
Landsat-9: Lake Constance, Germany/Austria/Switzerland, 2022-08-02

L2A product from ACOLITE

Glint + Path radiance

Result of Rrs tool

- Conditions: Glint very low in most parts of the lake
- Rrs tool: Minor corrections
- Validation: Good correspondence with field data

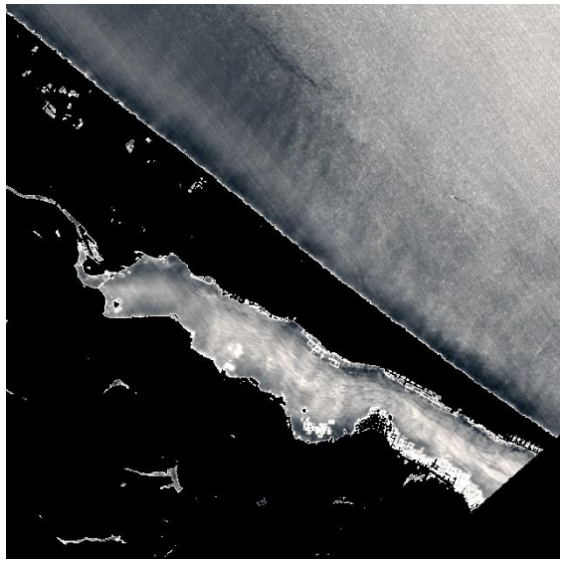


Results

DESIS: Tam Giang Lagoon, Vietnam, 2023-05-03

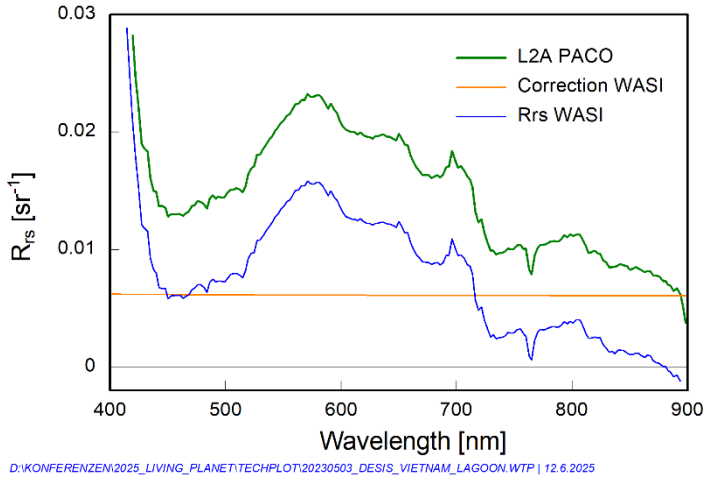
L2A product from PACO

Glint + Path radiance



Result of Rrs tool

- Conditions: Glint in lagoon low
- Rrs tool: Glint pattern is completely removed
- Validation: no in-situ data available



Results

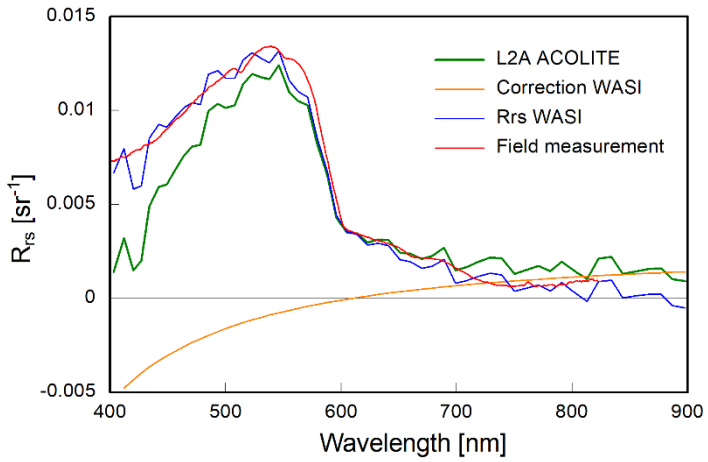
PRISMA: Lake Constance, Germany/Austria/Switzerland, 2022-08-02

L2A product from ACOLITE

Glint + Path radiance

Result of Rrs tool

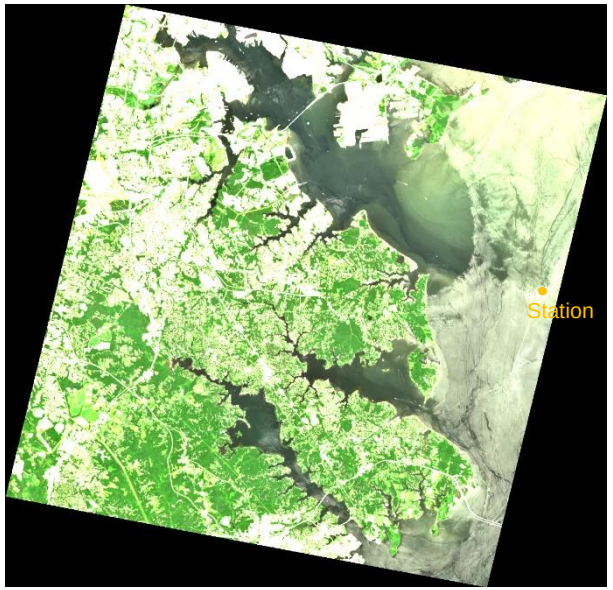
- Conditions: Glint medium
- ACOLITE: Path radiance overcorrected
- Rrs tool: Glint pattern is completely removed
- Validation: Excellent correspondence with field data



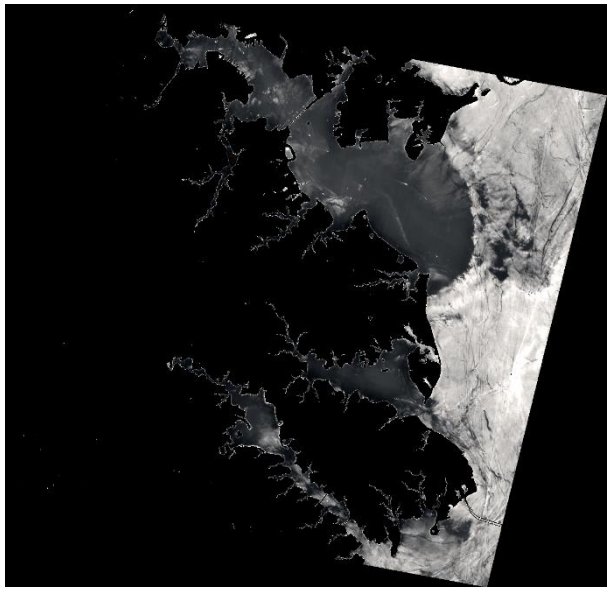
Results

EnMAP: Chesapeake Bay, USA, 2022-07-22

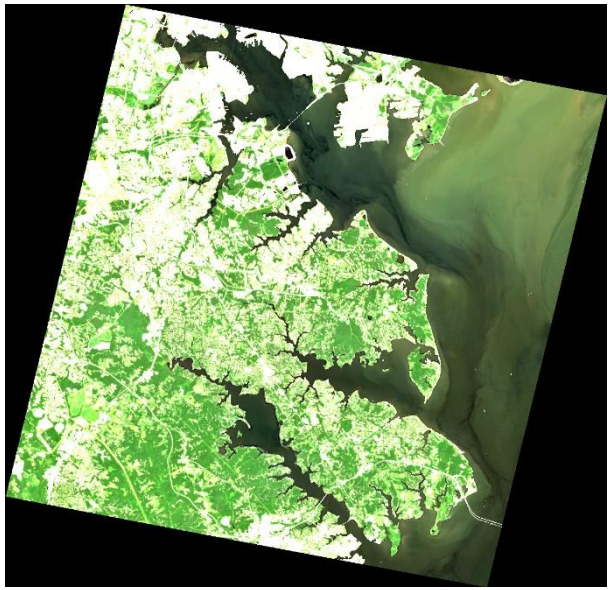
L2A product from PACO



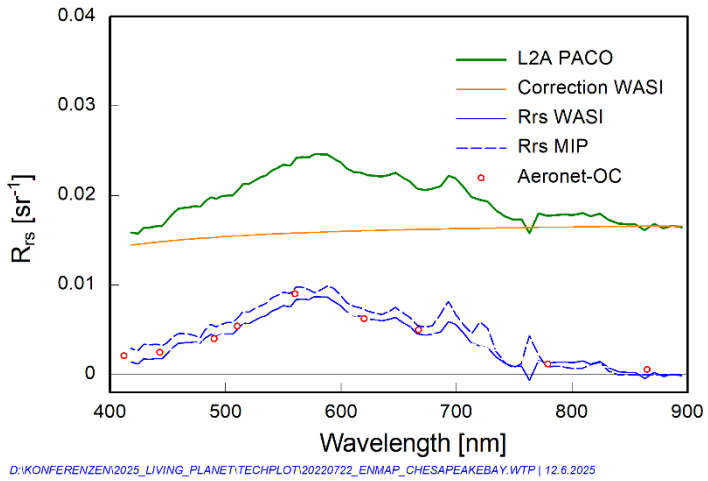
Glint + Path radiance



Result of Rrs tool



- Conditions: Glint at station much larger than Rrs
- Rrs tool: Glint pattern is completely removed
- AC comparison: Good correspondence with MIP
- Validation: Excellent correspondence with field data

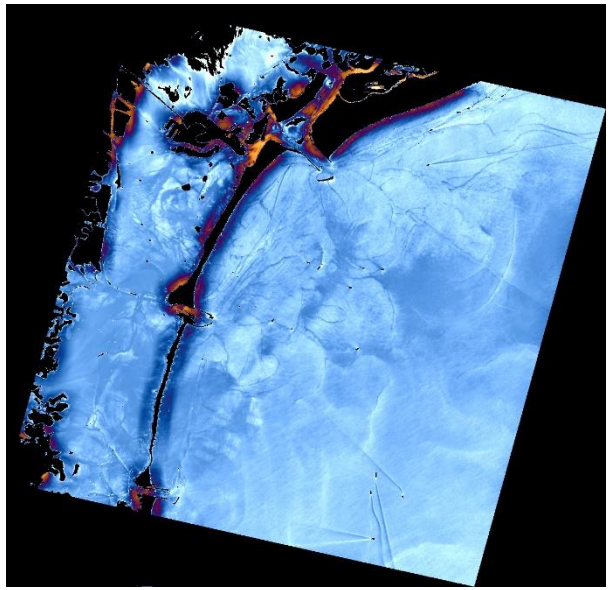


Results

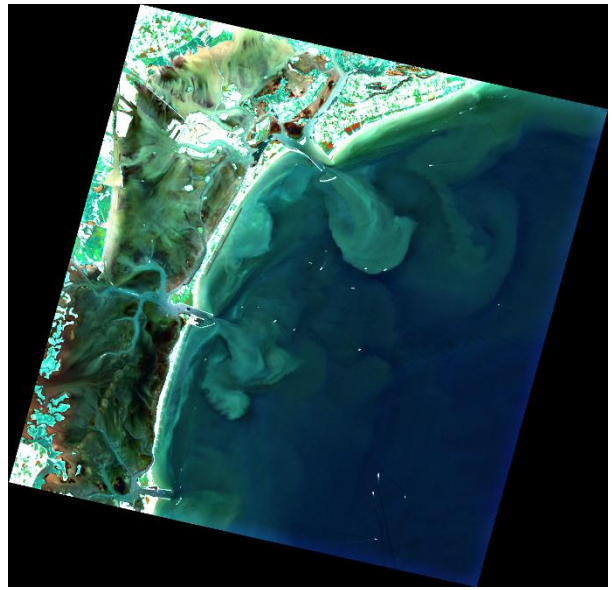
EnMAP: Venice Lagoon, Italy, 2022-07-16

L2A product from PACO

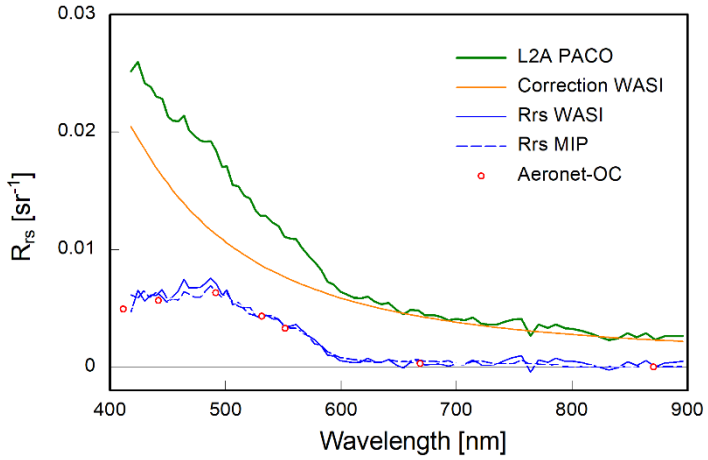
Glint + Path radiance



Result of Rrs tool



- Conditions: Glint much larger than Rrs
- PACO: Modified version (aerosol retrieval different)
- Rrs tool: Glint pattern is completely removed
- AC comparison: Excellent correspondence with MIP
- Validation: Excellent correspondence with field data



Outlook

- Quantitative validation and comparison with different AC softwares for water is ongoing for EnMAP data (ACIX-III Aqua)
  - ➢ See presentations by A. Bracher and C. Giardino in Session B.02.09, June 26, 14:00-15:30 h

- Algorithm will be adopted to ESA's CHIME-L2A processor
  - AC for land is based on ATCOR/PACO
  - Python version of Rrs tool ready
  - Automatization ongoing
  - Fine-tuning ongoing
  - ➢ See presentation by R. De Los Reyes in Session C.03.03, June 25

Summary

- Rrs tool corrects for sky glint, sun glint and path radiance errors of AC software
- Based on combined spectral model of water and surface; no geometry parameters
- Developed to adapt land AC software to water
- Can also be used to improve results of water AC software
- Good correspondence of derived Rrs with field measurements except for large errors of input L2 data

Thank you for your attention!