PROGRAMME OF THE EUROPEAN UNION

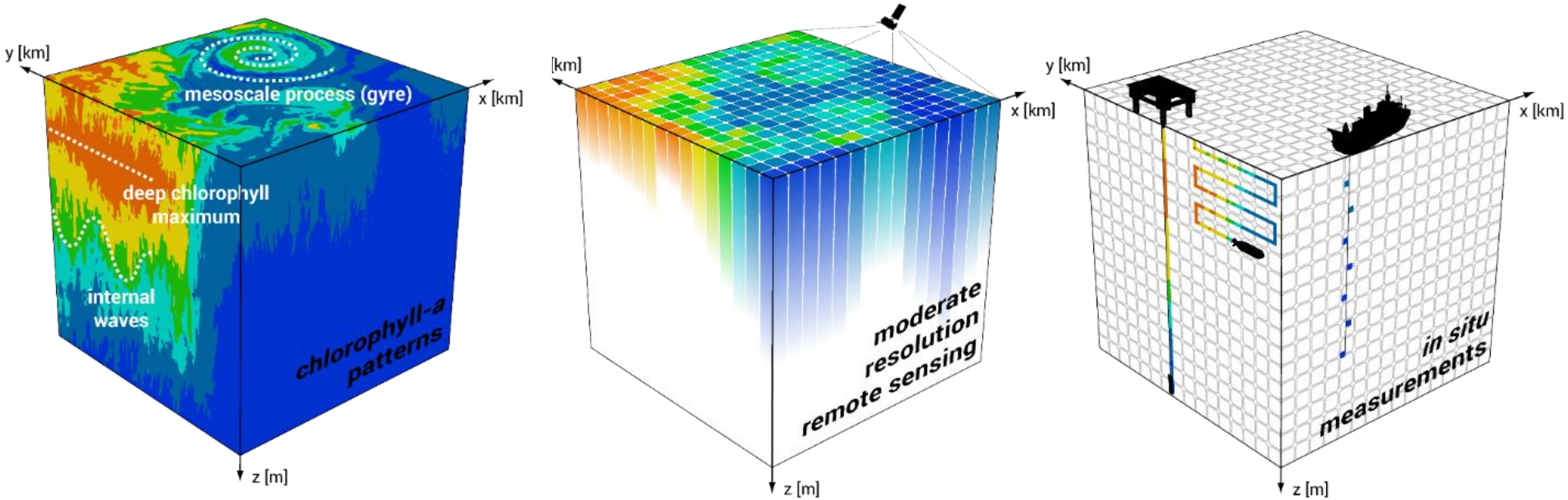
co-funded with

Validation of Sentinel-2 MSI Atmospheric Correction Products Over Perialpine Lakes Using Automated Radiometers and Field Campaign Data

Mortimer Werther[1], Abolfazl Irani Rahaghi[1,2], Mariano Bresciani[3], Marina Amadori[3,4], Claudia Giardino[3], Vittorio Brando[5], Daniel Odermatt[1,2]

[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland
[2]University of Zürich, Zürich, Switzerland
[3]IREA-CNR, Milan, Italy
[4]University of Trento, Trento, Italy
[5]ISMAR-CNR, Rome, Italy

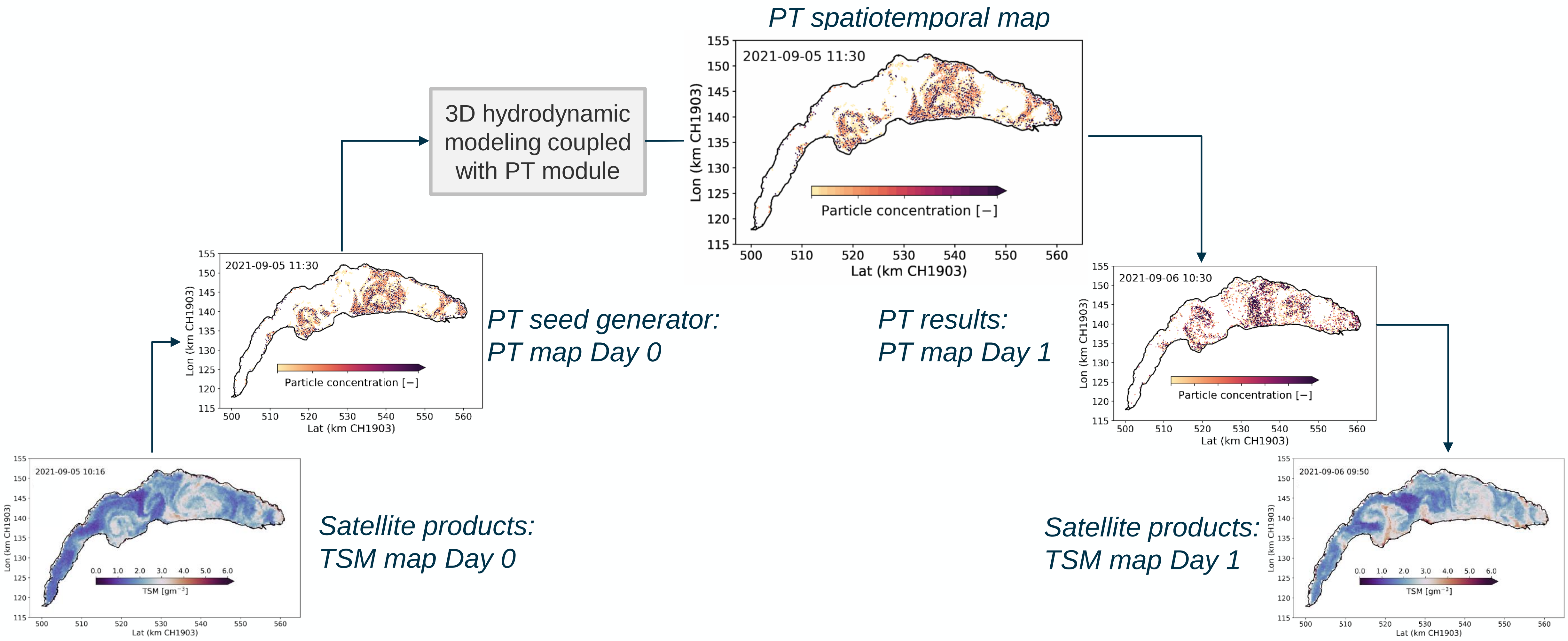
Modelling complex biogeochemical patterns



eawag aquatic research
UNIVERSITY OF TRENTO - Italy
esa
ALPLAKES

Alplakes: integrate information from remote sensing, *in situ* measurements and 3D hydrodynamic modelling

PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
co-funded with esa

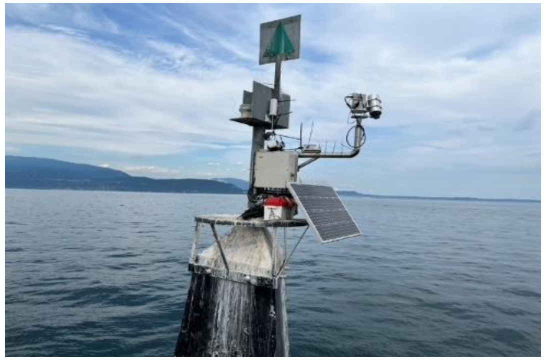


Alplakes: sites

Lakes with diverse morphological and hydrological features, trophic status, and climatic conditions located in the northern and southern Alps

Alplakes: automated radiometry

Lake Geneva (Switzerland/France)
LéXPLORE platform
(i) WaterInsight WISPstation
(ii) Satlantic HyperOCR
(iii) PML So-Rad



Lake Garda (Italy)
Pilone Sesarole
(i) HYPSTAR

Greifensee (Switzerland)
Eawag research platform
(i) WaterInsight WISPstation
(ii) JB Hyperspectral RoX

In situ radiometry

Lake	Time frame	Radiometer	Type
Aegeri	06/2022	WISP3	Campaign
Caldonazzo	2019 - 2023	HyperOCR	Campaign
Garda	2015 – 2023	HyperOCR/WISP3	Campaign
Geneva	09/2022 – 07/2023	WISPStation	Automated radiometer
Greifensee	04/2022 – 07/2023	WISPStation	Automated radiometer
Morat	07/2022	WISP3	Campaign
St. Moritz	07/2022	WISP3	Campaign
Zurich	08/2022	TriOS Ramses	Campaign

Research questions

1. What is the impact of MSI spatial resolution on atmospheric correction (AC) algorithm performance for the Alplakes sites?

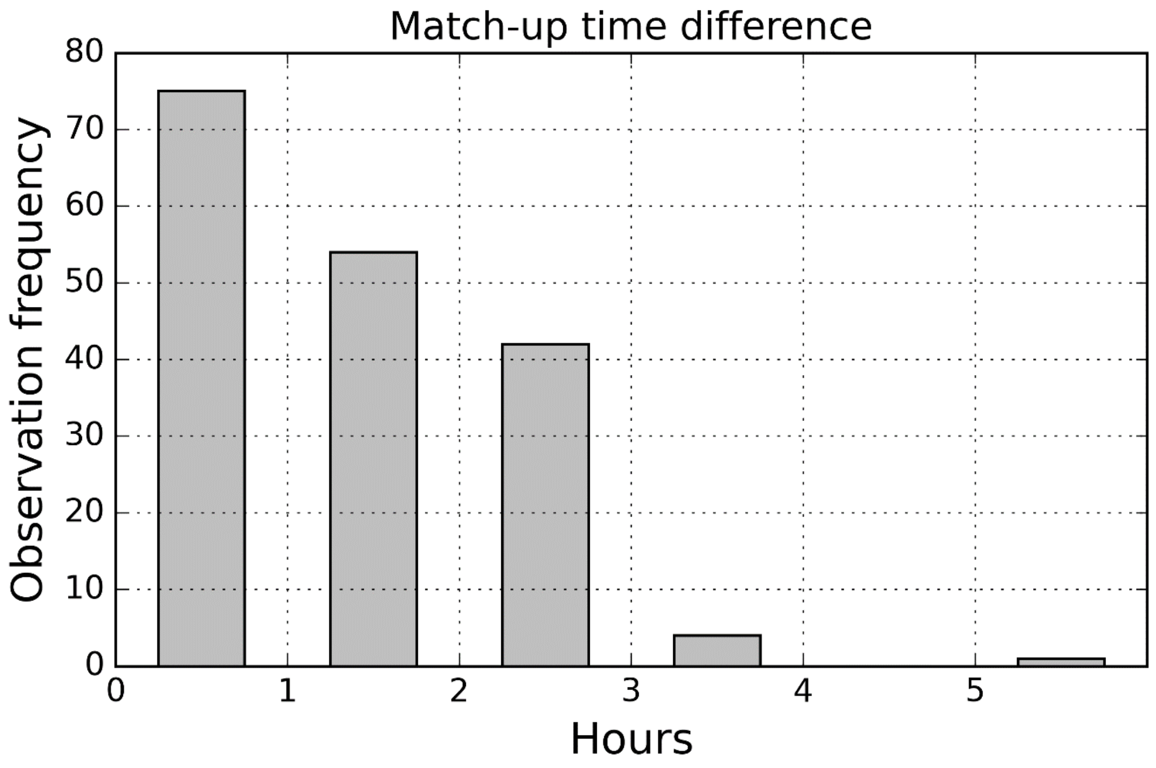
2. How does a single center pixel compare to 3x3 pixel aggregation?

3. Is a generalized Alplakes AC feasible or do we require lake-specific AC selection?

Match-up process

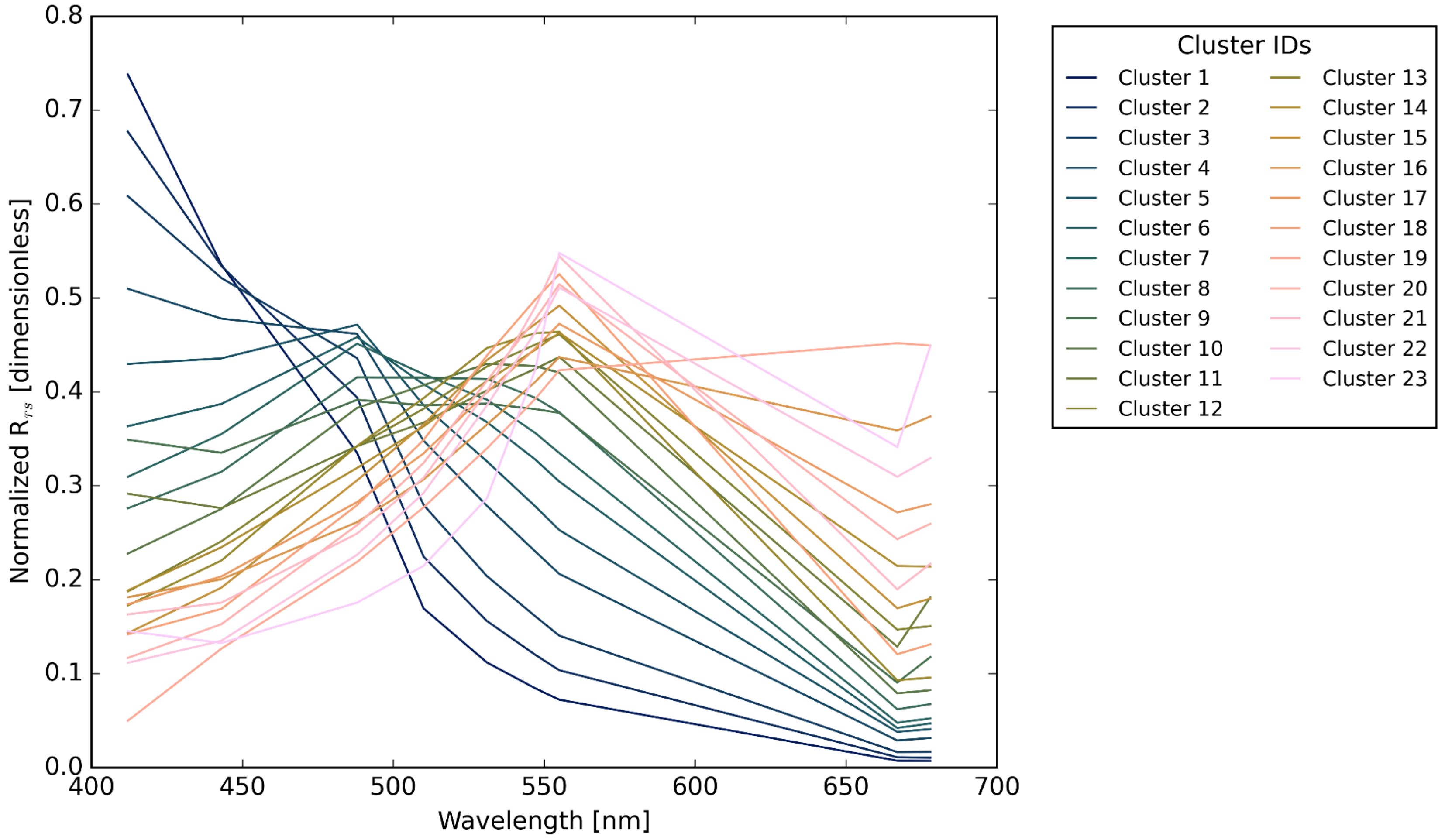
Sentinel-2 MSI:

- 20m, 60m
- 1x1 (centre location), 3x3 (median of nine valid pixels)
- ACs: C2RCC, POLYMER, ACOLITE
- Valid water pixel identification through IdePix (Brockmann Consult; Skakun et al., 2022)
- R_{rs} quality scoring



Skakun, S., Wevers, J., Brockmann, C., Doxani, G., Aleksandrov, M., Batič, M., Frantz, D., Gascon, F., Gómez-Chova, L., Hagolle, O., López-Puigdollers, D., Louis, J., Lubej, M., Mateo-García, G., Osman, J., Peressutti, D., Pflug, B., Puc, J., Richter, R., Roger, J.-C., Scaramuzza, P., Vermote, E., Vesel, N., Zupanc, A., Žust, L., 2022. Cloud Mask Intercomparison eXercise (CMIX): An evaluation of cloud masking algorithms for Landsat 8 and Sentinel-2. Remote Sensing of Environment 274, 112990.

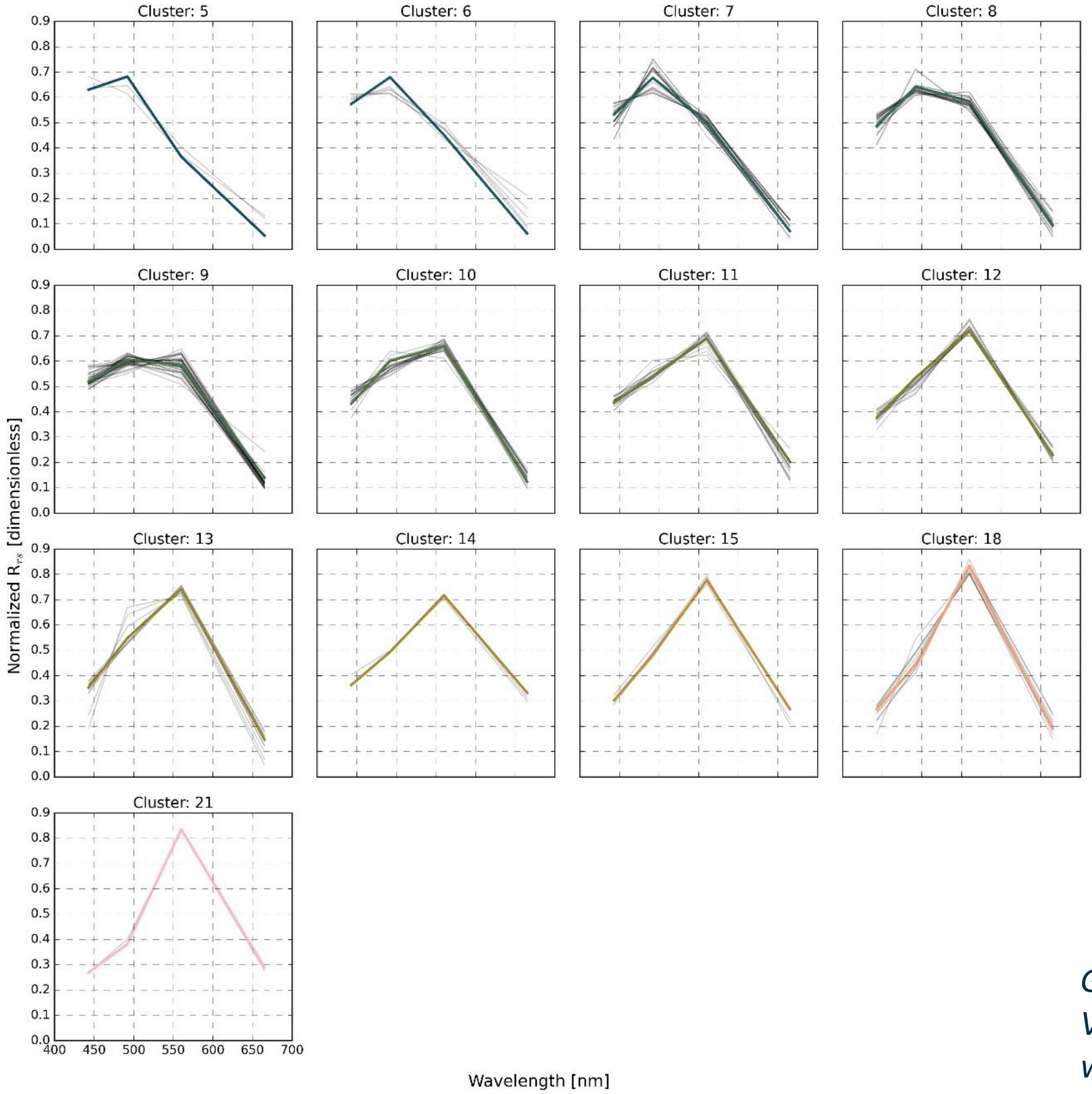
R_{rs} quality assurance – Wei et al. 2016

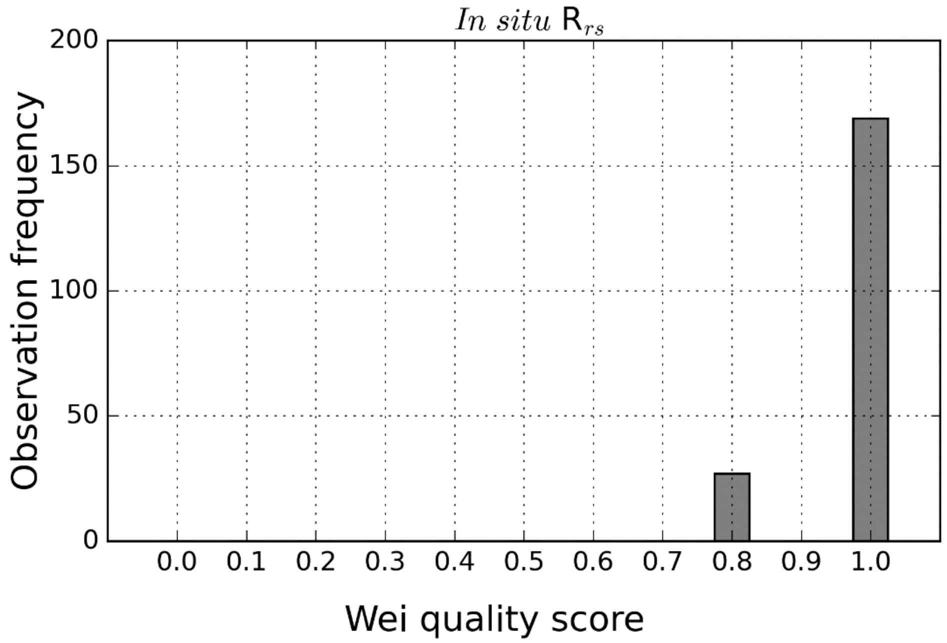


- Scoring against 23 simulated OWTs (open ocean and coastal waters)
- 0 – 1 score, <= 0.5 poor quality
- Original band settings SeaWiFS, MODIS, VIIRS, Landsat-8
- Only 443 nm from MSI directly comparable

Wei, J., Lee, Z., Shang, S., 2016. A system to measure the data quality of spectral remote-sensing reflectance of aquatic environments. Journal of Geophysical Research: Oceans 121, 8189–8207.

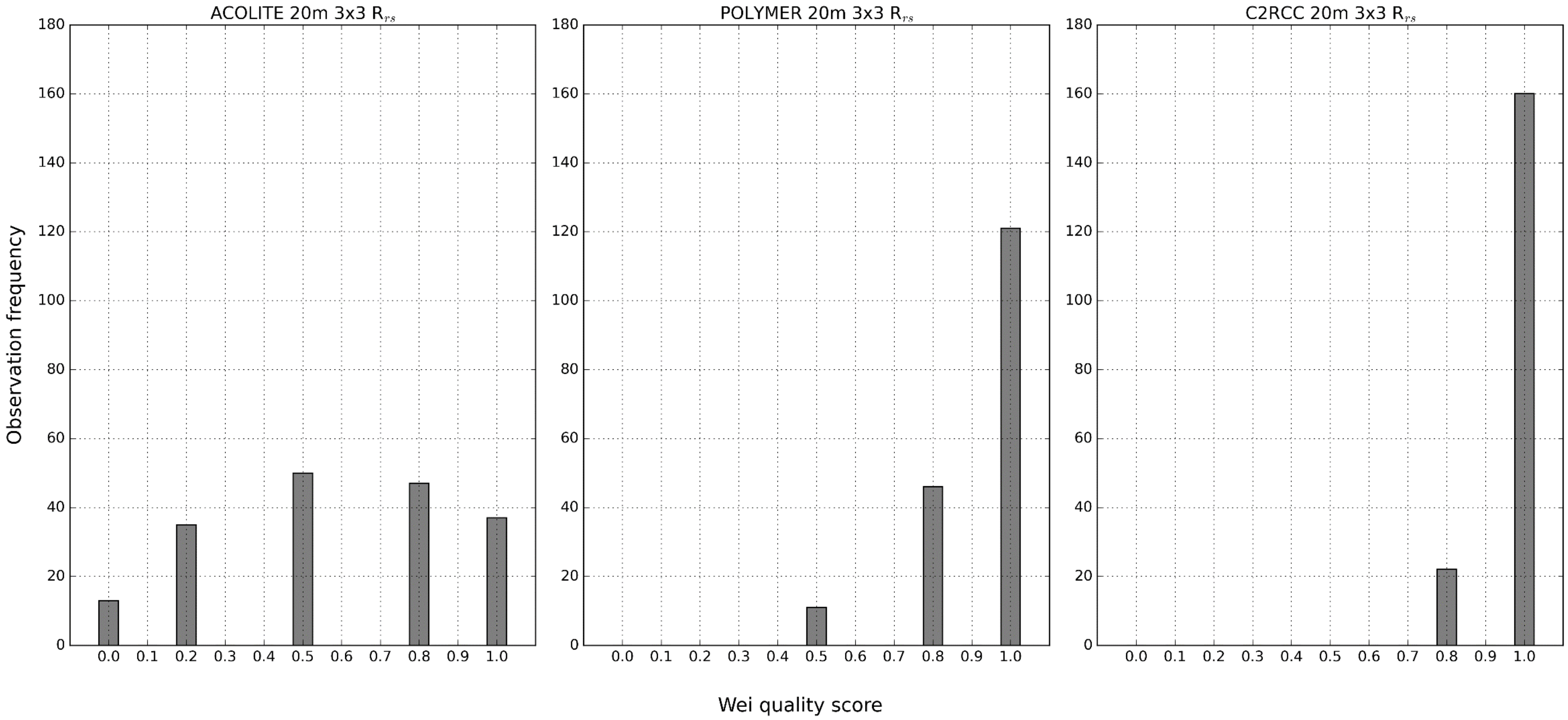
R_{rs} quality assurance – Wei scoring





Groetsch, P.M.M., Gege, P., Simis, S.G.H., Eleveld, M.A., Peters, S.W.M., 2017. Validation of a spectral correction procedure for sun and sky reflections in above-water reflectance measurements. Opt. Express, OE 25, A742–A761.

R_{rs} quality assurance – Wei scoring



Assessment of ACs

12 combinations:

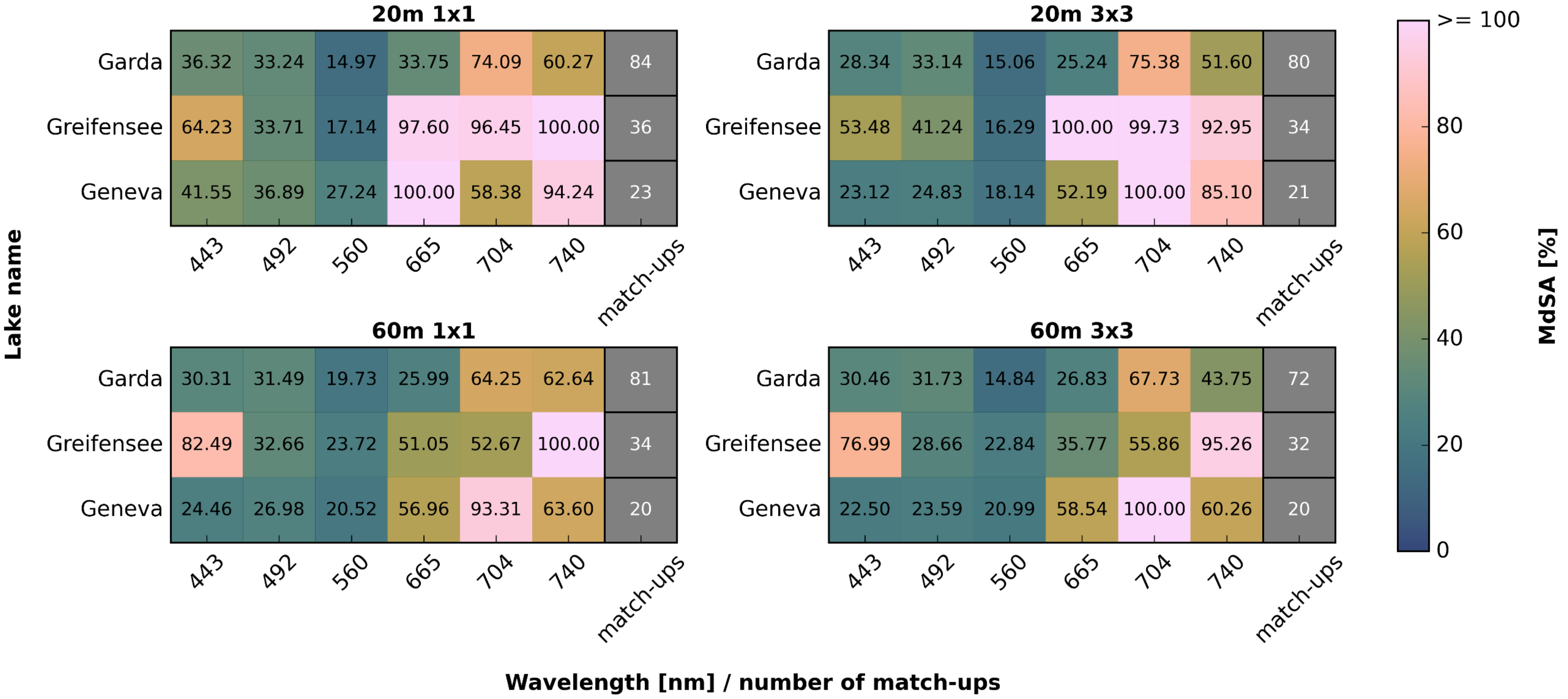
- 3x AC (C2RCC, ACOLITE, POLYMER)
- 2x match-up box (1x1, 3x3)
- 2x spatial resolution (20m, 60m)

Comparison of median symmetric accuracy (MdSA [%]) per lake per band per AC:

$$MdSA[\%] = \left(10^{median(|\,log_{10}(\frac{e}{o})|)} - 1\right) \times\ 100$$

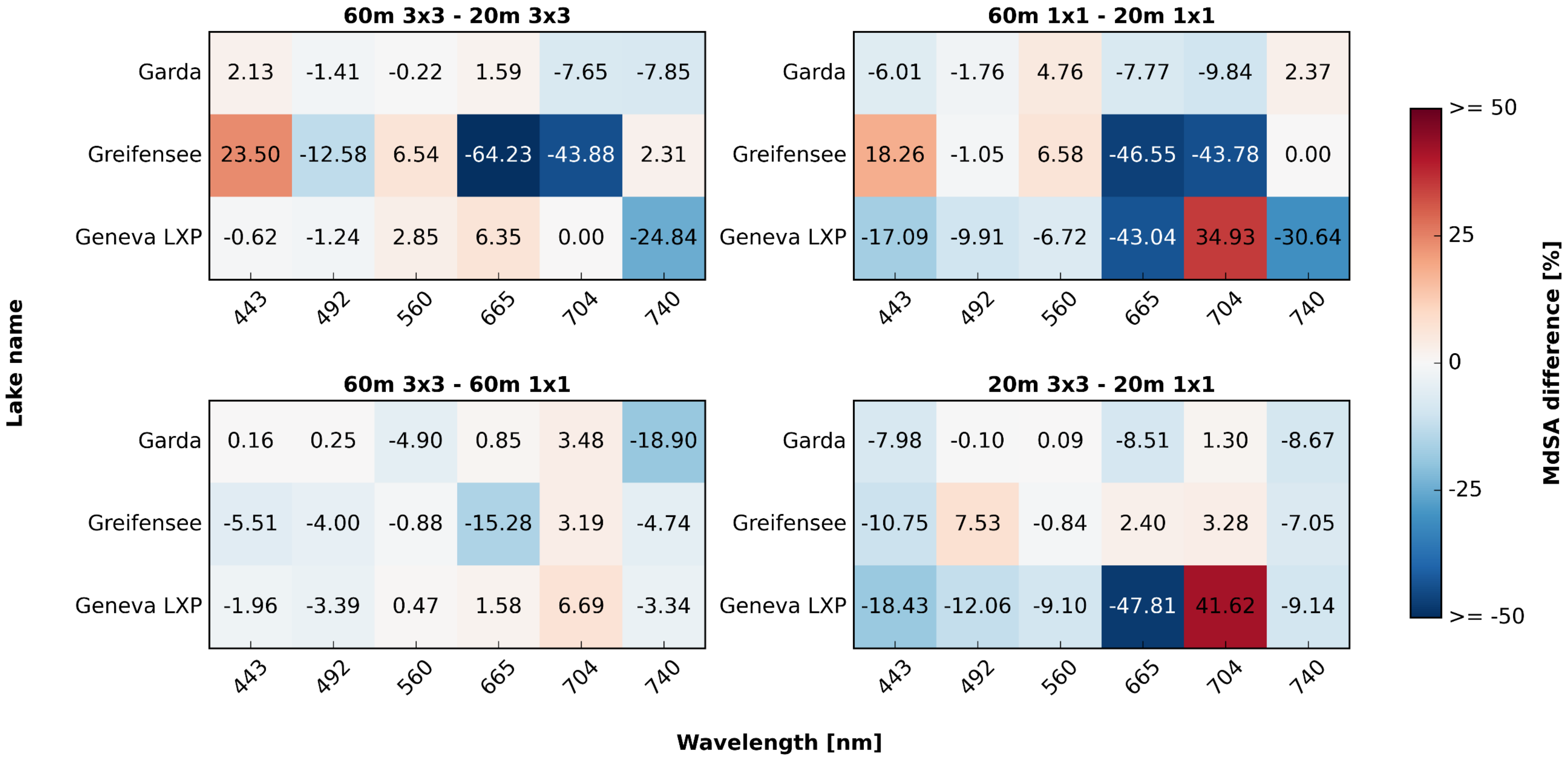
Morley, S.K., Brito, T.V., Welling, D.T., 2018. Measures of Model Performance Based On the Log Accuracy Ratio. Space Weather 16, 69–88.

Lowest MdSA per lake per band from an AC



MdSA difference between configurations

PROGRAMME OF THE EUROPEAN UNION



Lowest MdSA: corresponding AC

Lake name / Wavelength [nm]

20m 1x1

Lake name	443	492	560	665	704	740
Garda	C	A	C	P	C	P
Greifensee	C	A	A	P	A	P
Geneva LXP	P	C	P	A	P	P

20m 3x3

Lake name	443	492	560	665	704	740
Garda	C	A	C	P	C	P
Greifensee	C	A	A	P	A	P
Geneva LXP	P	P	P	P	C	P

60m 1x1

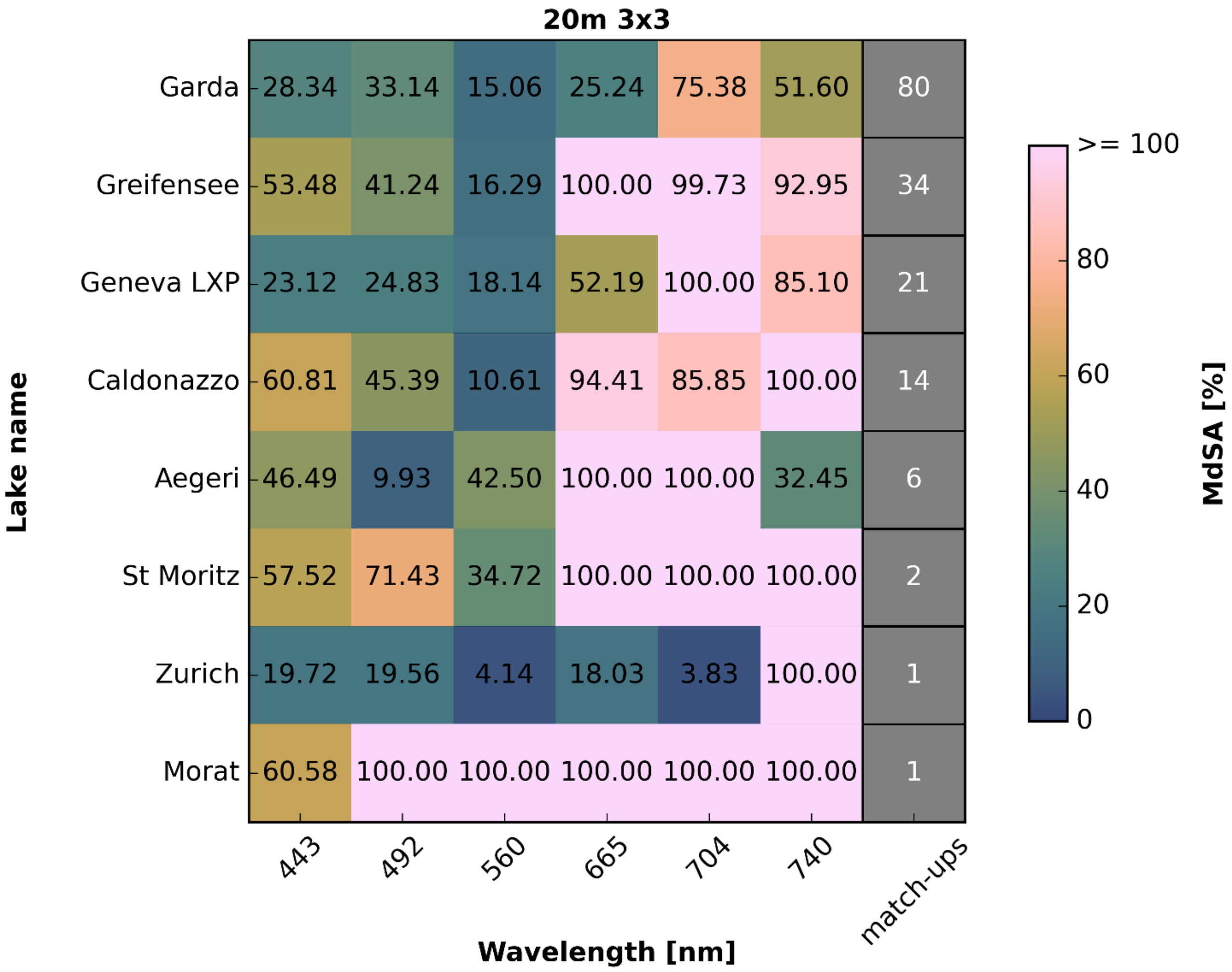
Lake name	443	492	560	665	704	740
Garda	C	A	C	P	C	P
Greifensee	C	A	A	A	A	P
Geneva LXP	P	P	P	P	A	P

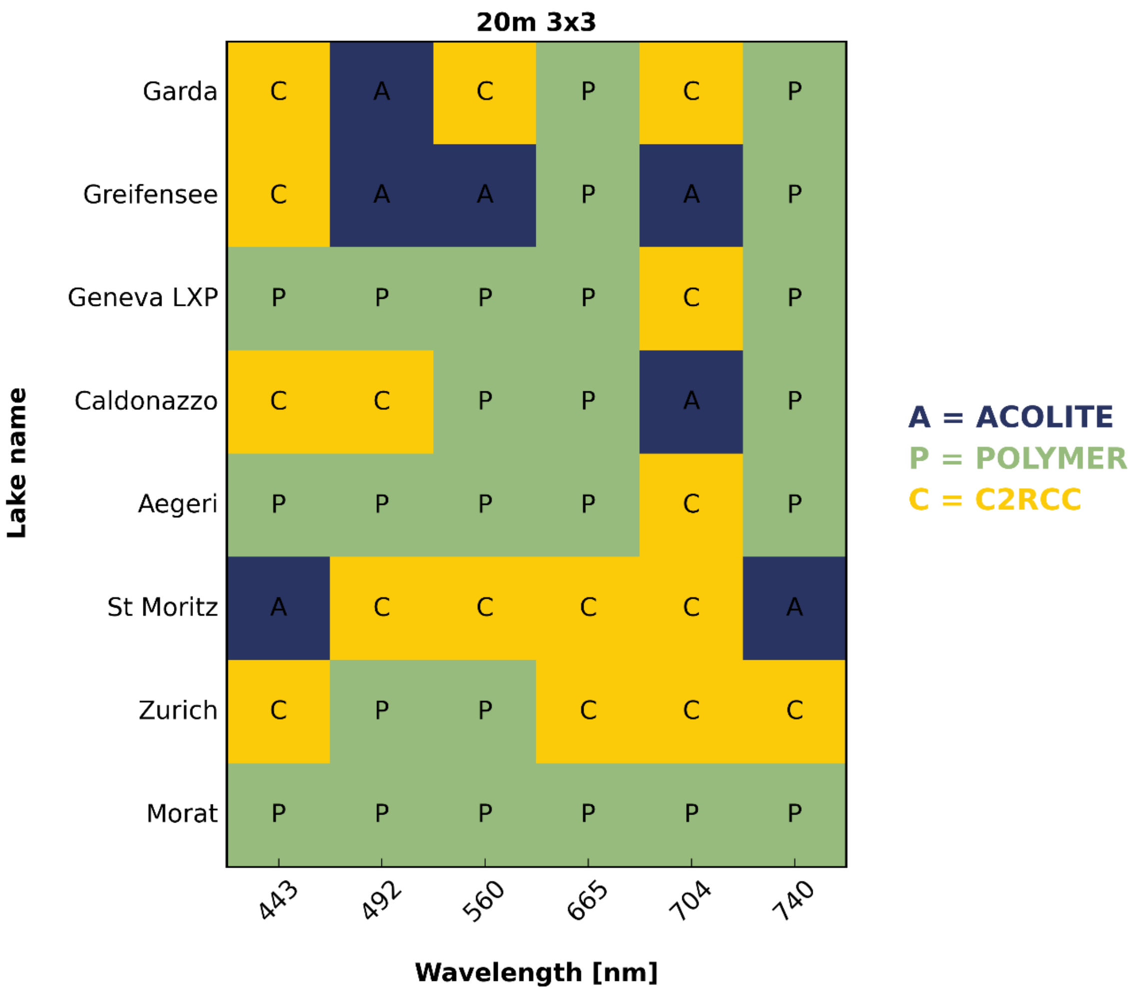
60m 3x3

Lake name	443	492	560	665	704	740
Garda	C	A	C	P	C	P
Greifensee	C	A	A	A	A	P
Geneva LXP	P	C	P	P	A	P

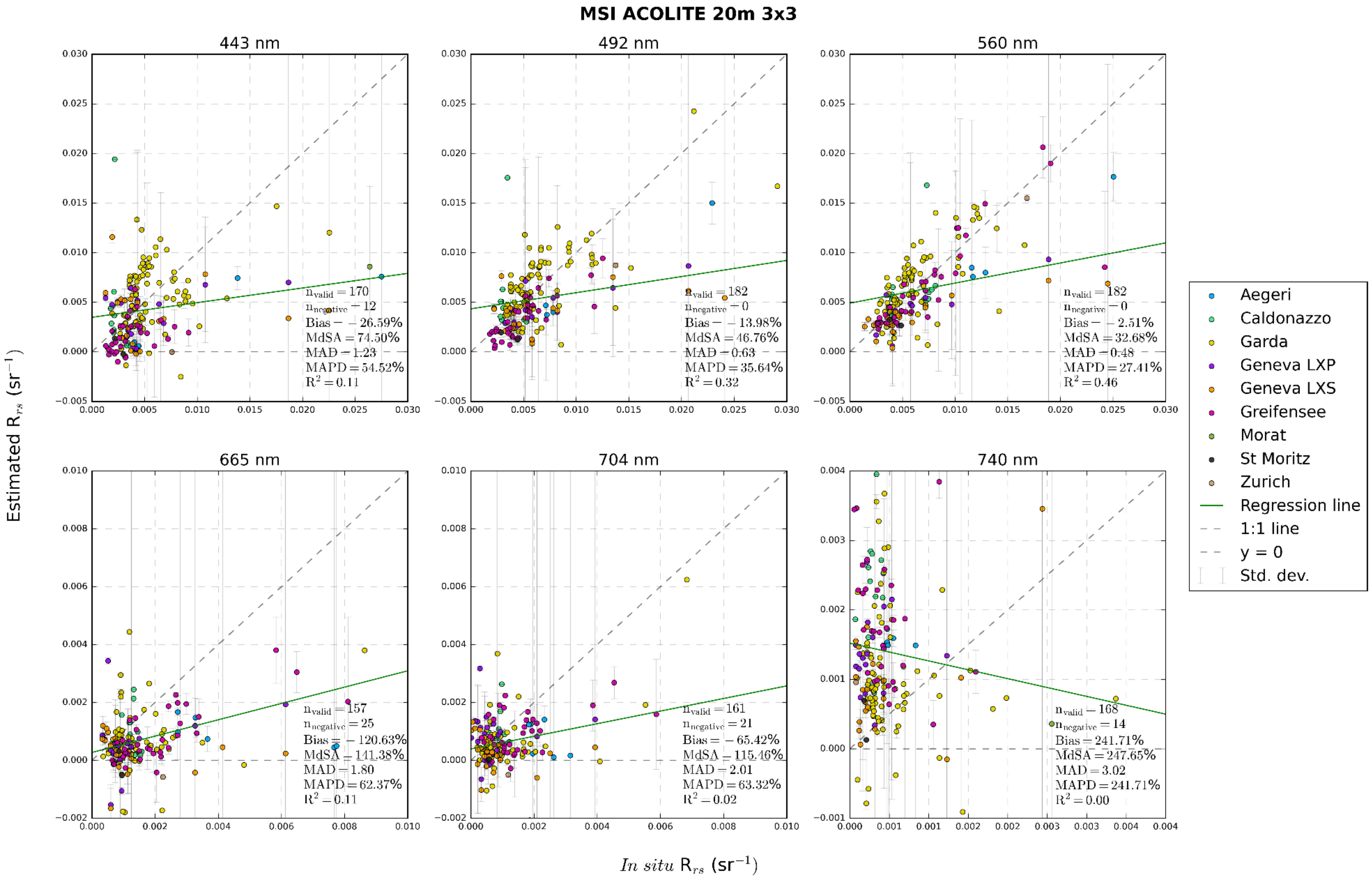
A = ACOLITE
C = C2RCC
P = POLYMER

MdSA and AC for all sites

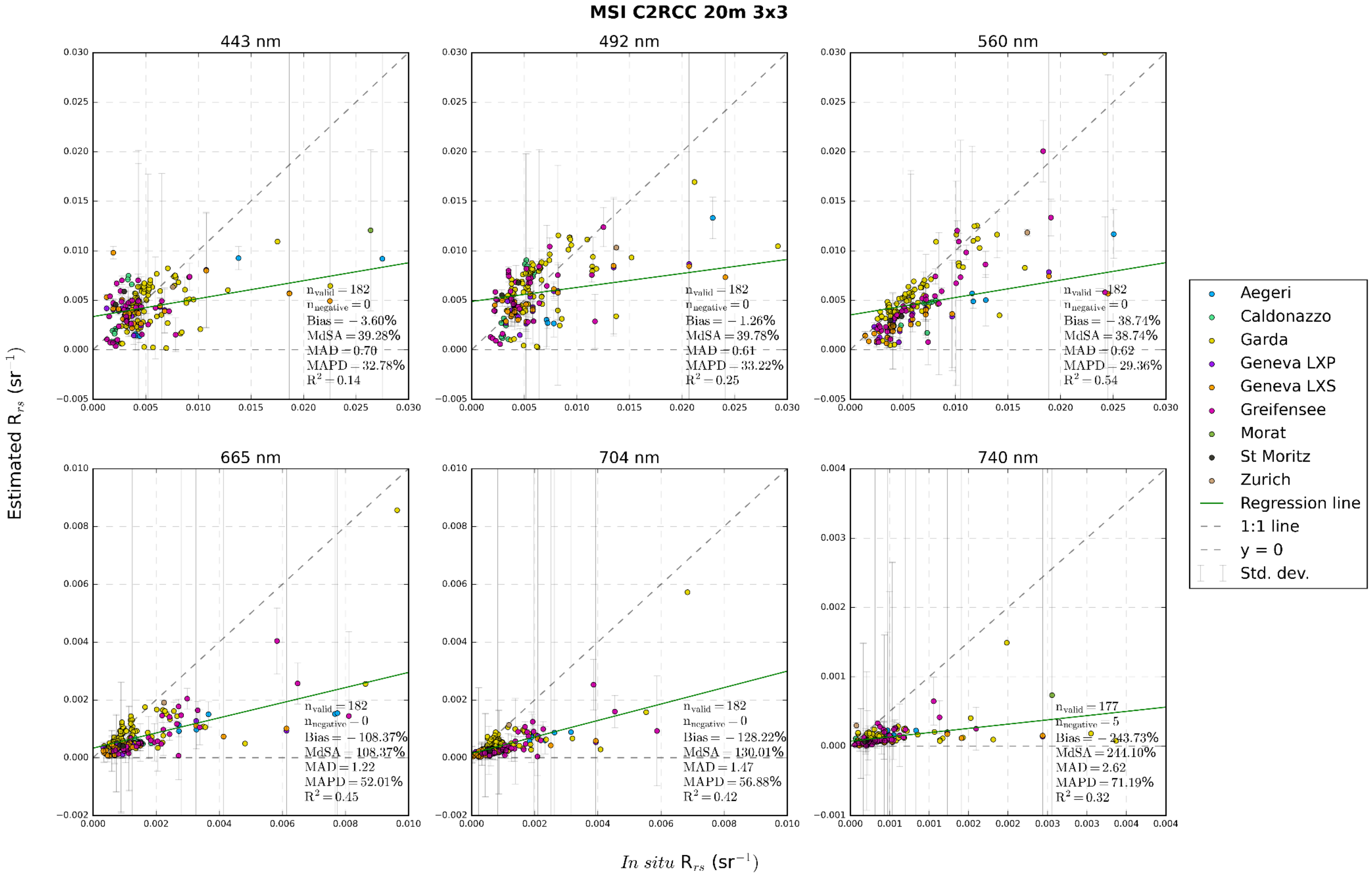




ACOLITE MSI 20m 3x3



C2RCC MSI 20m 3x3

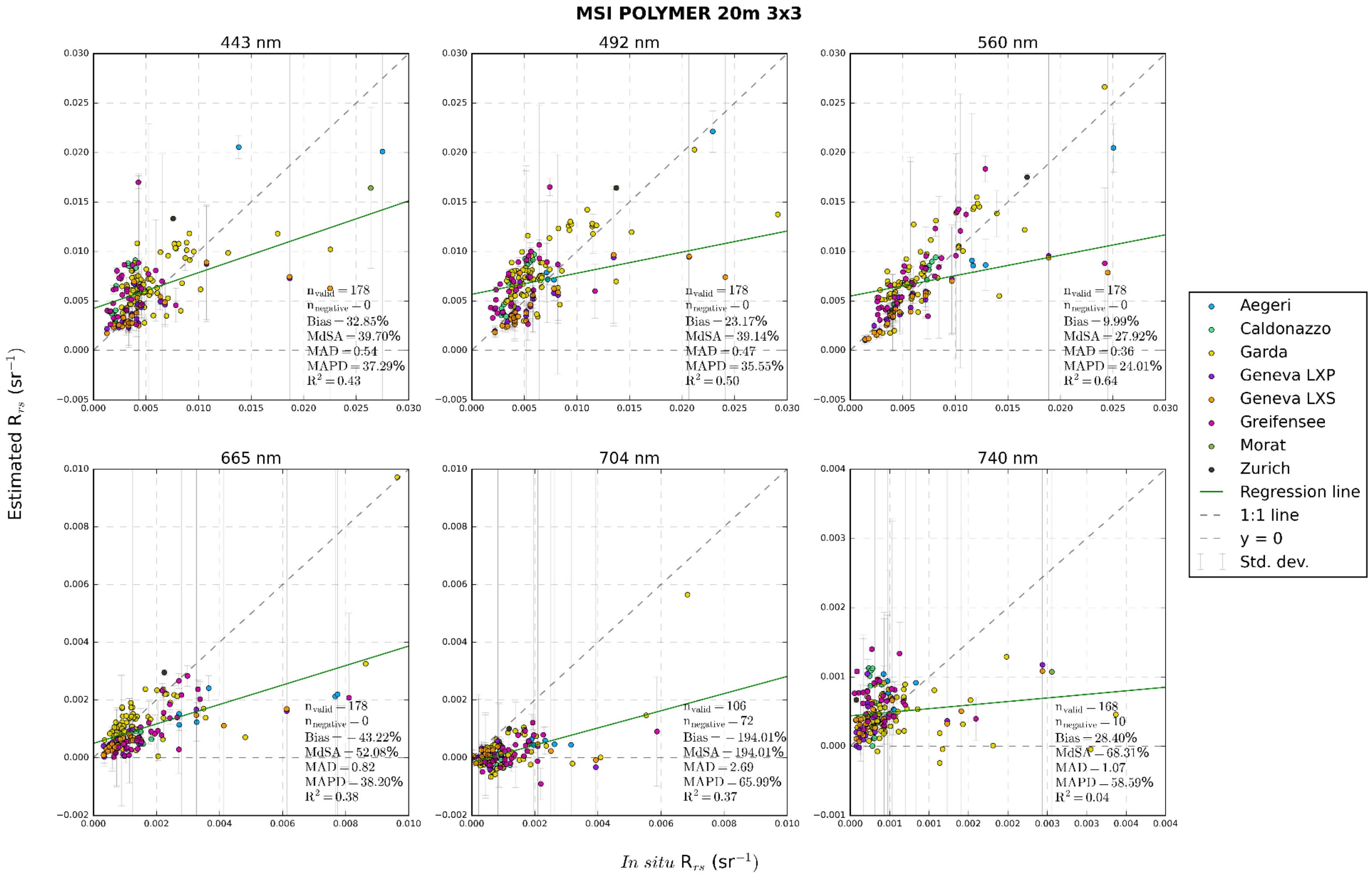


POLYMER MSI 20m 3x3

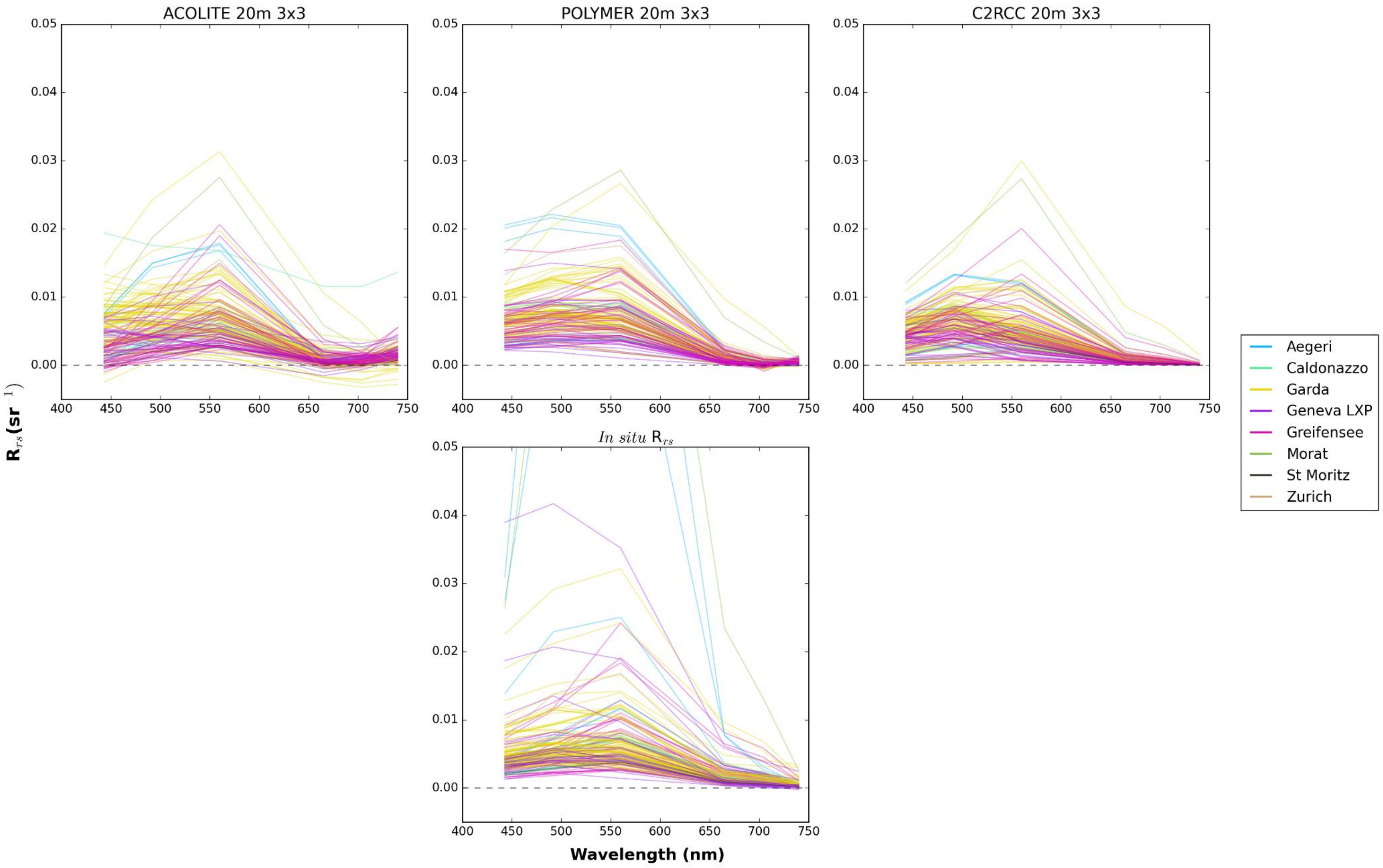
PROGRAMME OF THE EUROPEAN UNION

copernicus Europe's eyes on Earth

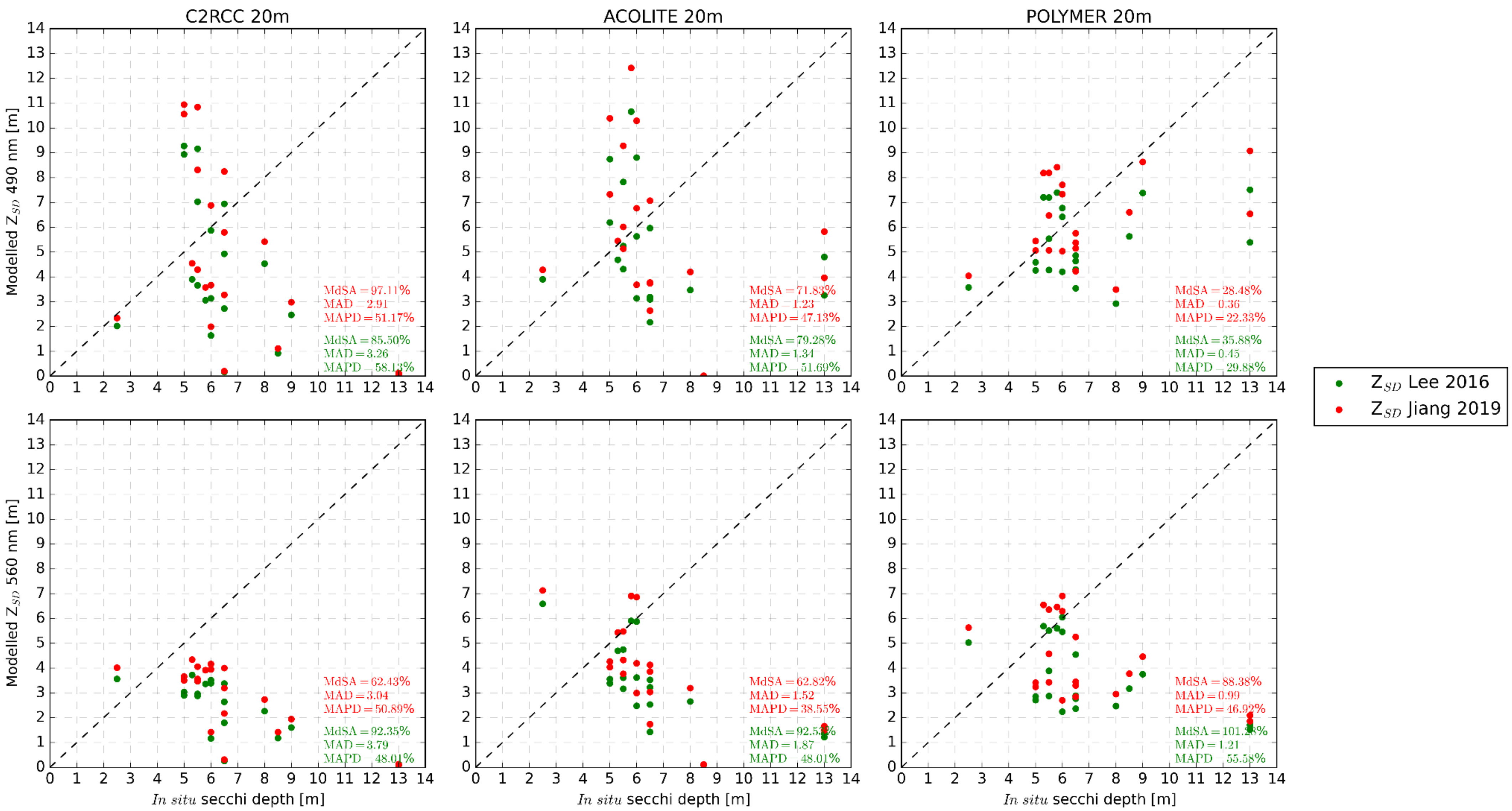
co-funded with esa



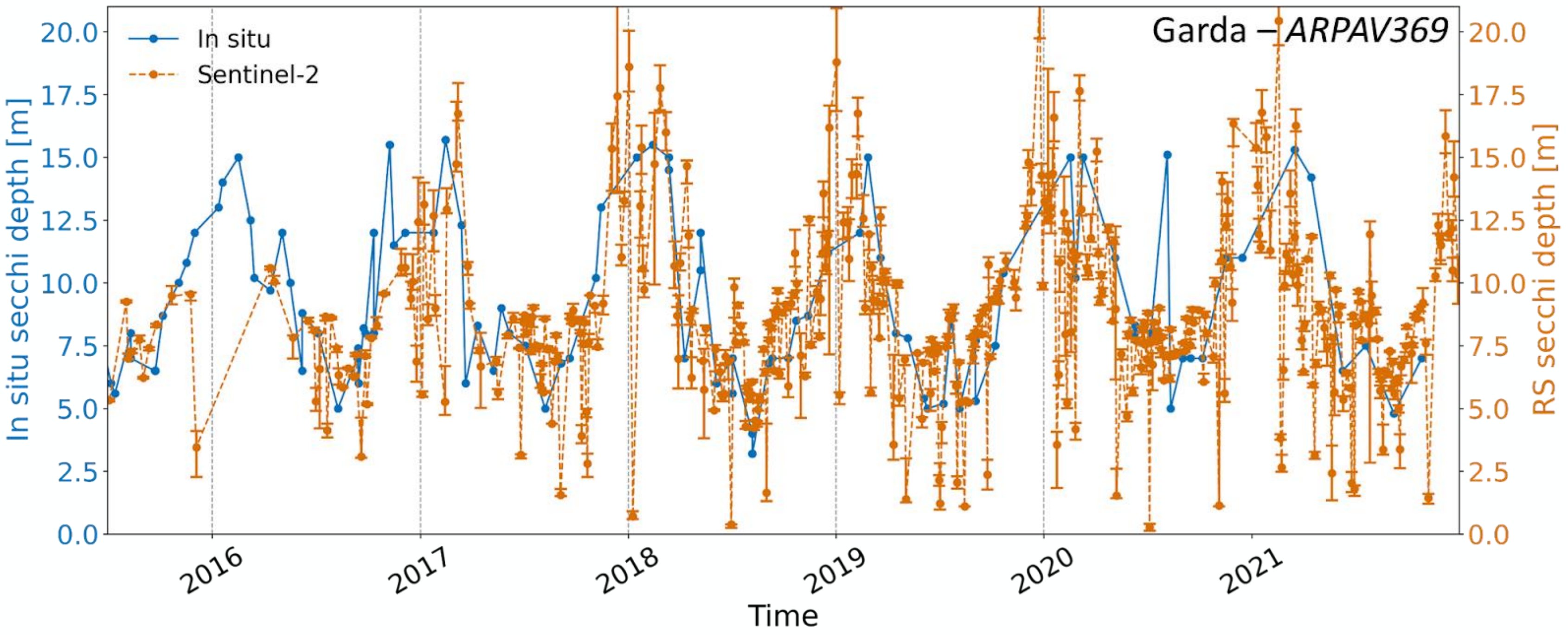
Match-up R_{rs}

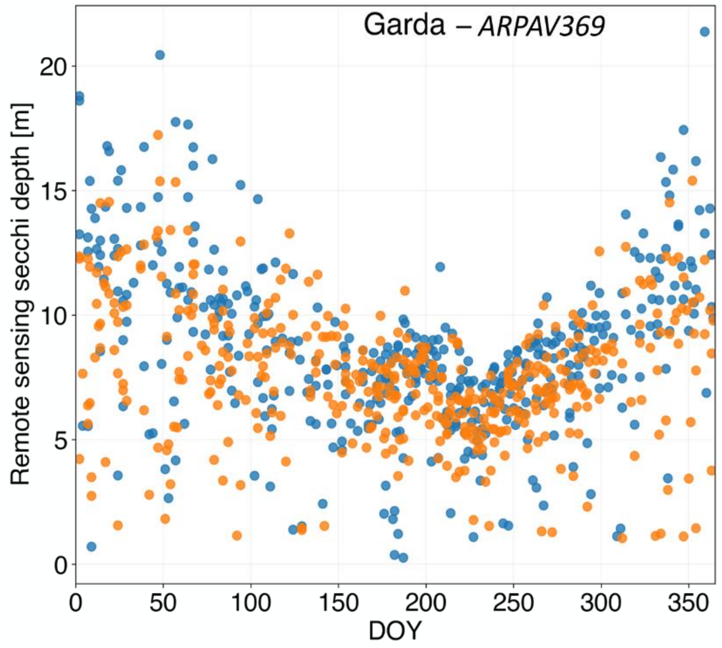

ACOLITE 20m 3x3
POLYMER 20m 3x3
C2RCC 20m 3x3
In situ R_{rs}
R_{rs} (sr^{-1})
Wavelength (nm)
0.00
0.01
0.02
0.03
0.04
0.05
400
450
500
550
600
650
700
750
Aegeri
Caldonazzo
Garda
Geneva LXP
Greifensee
Morat
St Moritz
Zurich

Secchi depth (Z_{SD}) retrievals: Lake Garda match-ups



Time series Secchi - Lake Garda





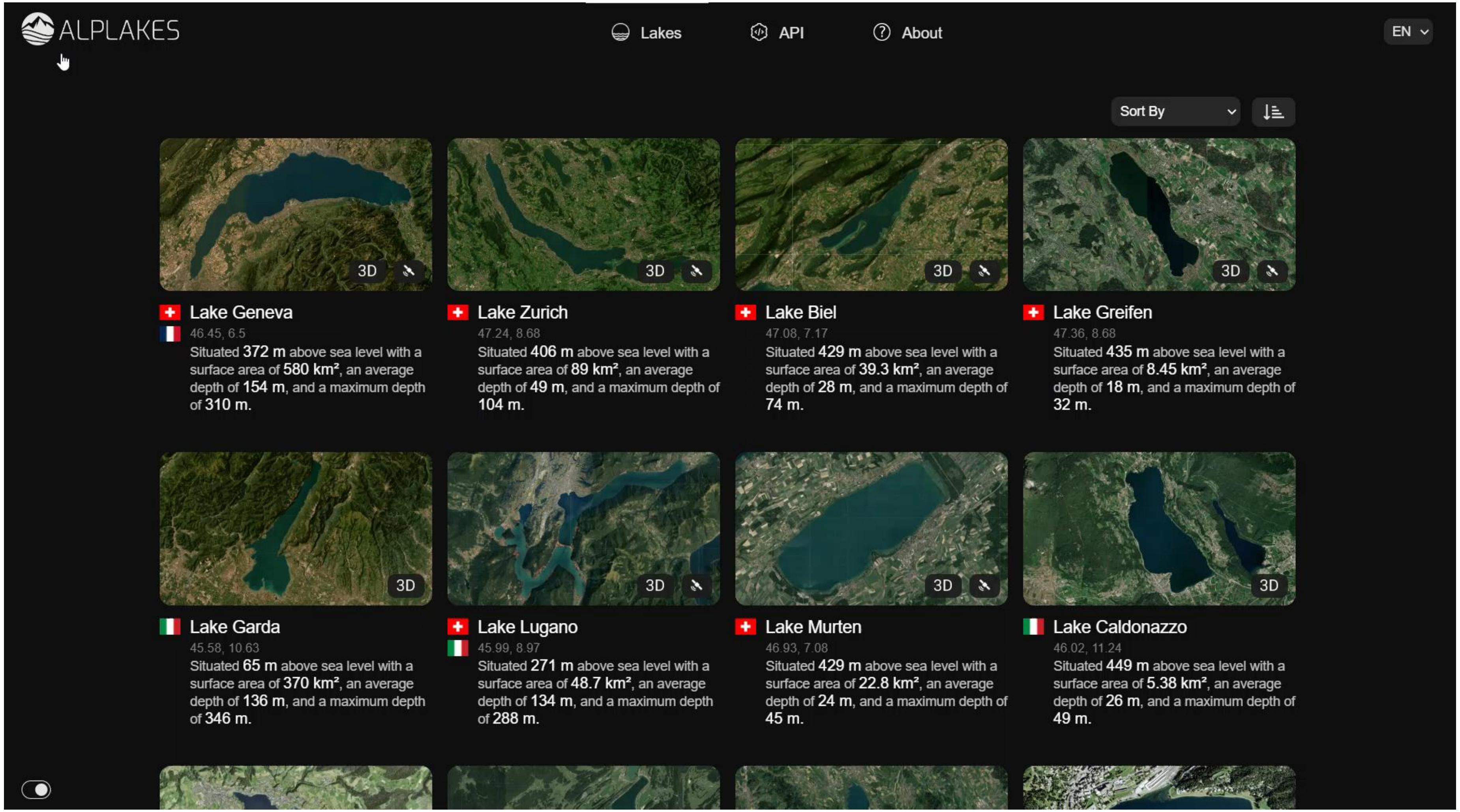
Jiang, D., Matsushita, B., Setiawan, F., Vundo, A., 2019. An improved algorithm for estimating the Secchi disk depth from remote sensing data based on the new underwater visibility theory. ISPRS Journal of Photogrammetry and Remote Sensing 152, 13–23.

Conclusions

1. 20m resolution outperforms 60m: Lower error, more match-ups, higher spatial detail
2. 1x1 vs 3x3: Single center pixel leads to increased error
3. Algorithm comparison: POLYMER 20m 3x3 is most consistent across evaluations, followed by C2RCC and ACOLITE for the dataset under study
4. Lake-specific AC: Necessity for switching depending on downstream algorithm retrieval
5. Regional tuning: Accurate downstream retrieval [MdSA < 30%] of Z_{SD} and TSM possible when coefficients are adjusted
6. Inaccuracies: Noticeable in red/NIR bands across sensors and lakes, hinting at possible signal to noise ratio limitations or the need for additional glint correction
7. Outstanding issue: Lack of uncertainty provision in current algorithms for TSM and Z_{SD}

Thank you for listening!

PROGRAMME OF THE EUROPEAN UNION
copernicus
co-funded with
esa



Available online:
www.alplakes.eawag.ch
www.datalakes-eawag.ch

Mortimer.Werther
@eawag.ch