Title	**SIMEC-ICOL-ODESA processing MERIS (ISECA-A2)**
Version	0.1
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Executive summary:

This report describes the validation exercise conducted on MERIS thanks to the MUMM data base. Two codes for the correction of the adjacency effect were used: SIMEC from VITO and ICOL from ADRINORD. The evaluation of these two codes is performed by comparison to in situ measurements collected off shore of Oostende. The results confirm the sensitivity of the MERIS L2 to the adjacency effect at least for the traditional scheme. The second algorithm based on a neural network which analyses all the reflectance spectrum appears to be robust to the adjacency effect and, at least on the 8 matchups were analyzed, quite accurate in the retrieval of the water reflectance.

ADRINORD	Association pour le Developpement de la Recherche et de l'Innovation dans le NORD
AERONET	Aerosol RObotic NETwork (http://aeronet.gsfc.nasa.gov/)
AOT	Aerosol Optical Thickness
BEAM	Basic ERS and Envisat (A)ATSR and MERIS Toolbox
C2R	Case 2 Regionall
Chl	Chlorophyll pigment content
ESA	European Space Agency (*www.**esa**.int)*
FR	Full Resolution
ICOL	Improve Contrast between Ocean and Land
IS	In Situ
ISECA	Information System on the Eutrophication of our Coastal Areas
L1	Level 1=satellite sensor radiometry
L2	Level 2=satellite sensor geophysical values
LUT	Look Up Table
MODTRAN	MODerate resolution atmospheric TRANsmission)
MEGS	MERIS Ground Segment
MERIS	Medium Resolution Imaging Spectrometer (ESA Envisat)
MERMAID	MEris MAtchup In-situ Database
MUMM	Management Unit of the North Sea Mathematical Models
NIR	Near Infra Red
ODESA	Optical Data processor of the European Space Agency
RGB	Red Green Blue
RR	Reduced Resolution
TOA	Top Of Atmosphere
VITO	Vlaamse instelling voor technologisch onderzoek

1. Introduction

This document describes the different steps applied to the MERIS data for the SIMEC-ICOL intercomparison as part of Action 2 of the ISECA project. Furthermore an overview is given of the used data in section 2. Section 3 described the data process to generate L2 with the correction of the adjacency effects. The analysis is provided in section 4.

2. Data

Table 1 lists the MERIS FR and RR images used in the study.

MERIS FR images	MERIS RR images
MER_FR__1PNUPA20030423_100741_000000982015_00423_05988_3720.N1	MER_RR__1PRBCC20030423_100642_000001862015_00423_05988_RAD.N1
MER_FR__1PNUPA20030616_101038_000000982017_00194_06761_3719.N1	MER_RR__1PRBCC20030616_101045_000001862017_00194_06761_RAD.N1
MER_FR__1PNUPA20030806_100754_000000982018_00423_07491_3718.N1	MER_RR__1PRBCC20030806_100547_000001942018_00423_07491_RAD.N1
MER_FR__1PNUPA20060713_101627_000000982049_00237_22836_3723.N1	MER_RR__1PNBCC20060713_101518_000001912049_00237_22836_RAD.N1
MER_FR__1PNUPA20090616_101905_000000982080_00008_38138_3722.N1	MER_RR__1PRBCC20090616_101839_000001912080_00008_38138_RAD.N1

Table 1. List of MERIS data

In Table 2 the time and coordinates of the in-situ validation data are given. These are situated in the Belgian coastal waters of the North Sea and the lower Scheldt estuary.

	LAT	LON	IMAGE	LAT	LON	Time of sampling
1	51.271	2.903	20030423_100741	51.272	2.905	8:24
2	51.311	2.844	20030423_100741b	51.31	2.845	10:02
3	51.273	2.903	20030616_101038	51.272	2.905	12:05
4	51.28	2.892	20030806_100754	51.28	2.892	9:40
5	51.308	2.849	20030806_100754b	51.308	2.849	10:10
6	51.271	2.903	20060713_101627	51.271	2.902	10:14
7	51.372	3.732	20090616_101905	51.371	3.732	12:44
8	51.418	3.252	20090616_101905b	51.418	3.252	10:06

Table 2 Match-up points: number of the sequence, center of the MERIS FR window in lat-lon, date (year_month_day) and time(hour_min_sec), lat and lon of the in situ measurement, time of sampling (hour:min)

We used Google map in figure 1 to locate all the in situ points. Clearly points 1, 3, 4 and 6 are in the range of the adjacency effects for the aerosols which is about 10 km. Point 7 is challenging as inland water.

Qualitatively, it will impact the satellite signal in the NIR where the land is much brighter than the ocean. In the visible, the Rayleigh scattering dominates and the larger range of about 30 km may influence the observations for all the IS points.

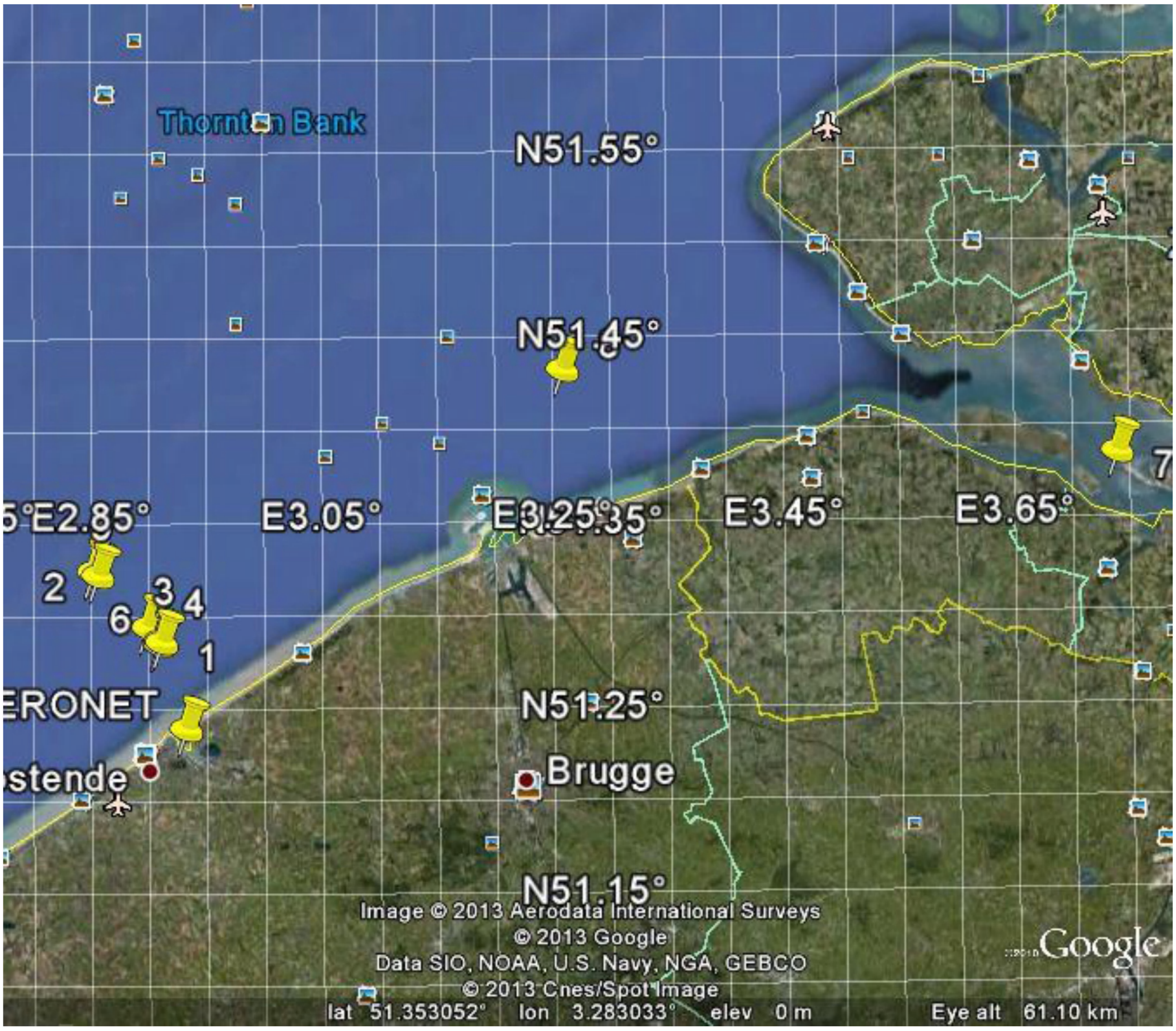
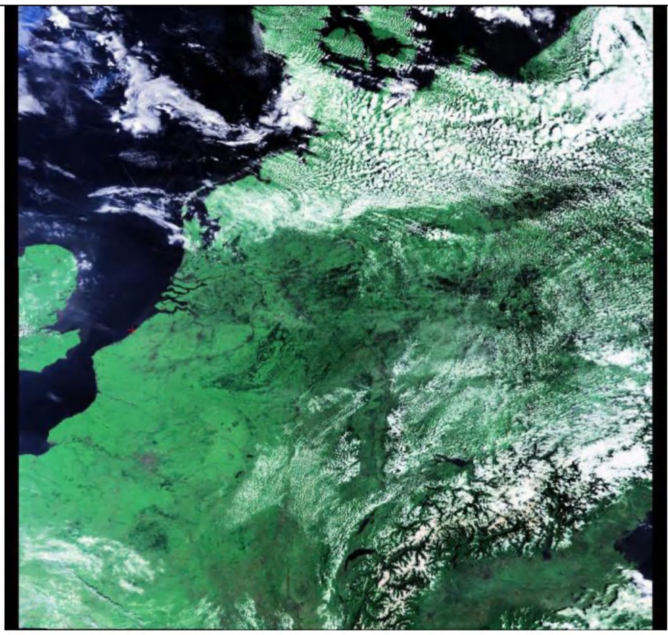


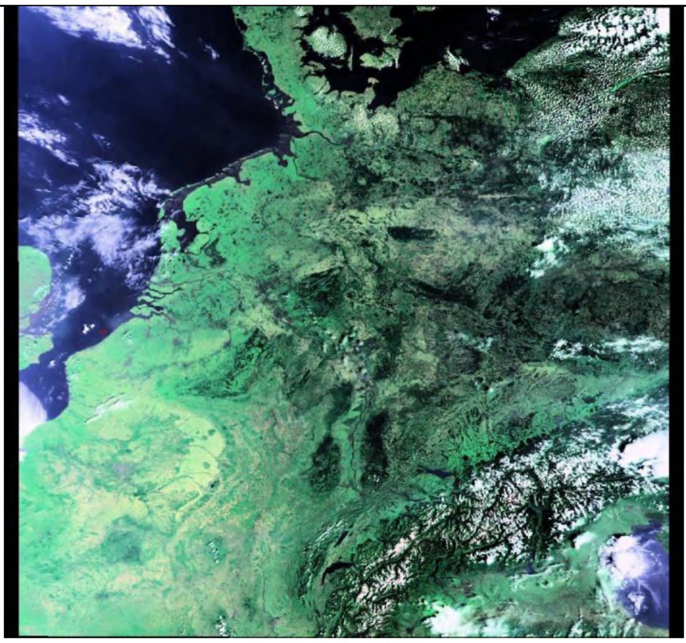
Figure 1: Location of the in situ points, labeled with numbering of table 2 and date; plus the location of the Oostende AERONET (Holben et al, 1998) station.

One important piece of information is also provided by the RGB quick looks as reported in figure 2. Most of the time, the North Sea off shore of Oostende appears clear with a noticeable exception on June 16, 2009 with contamination by cirrus clouds and cumulus clouds. The clouds are mostly over land which should deeply affect the MERIS data for sequence 7.

2003/04/23



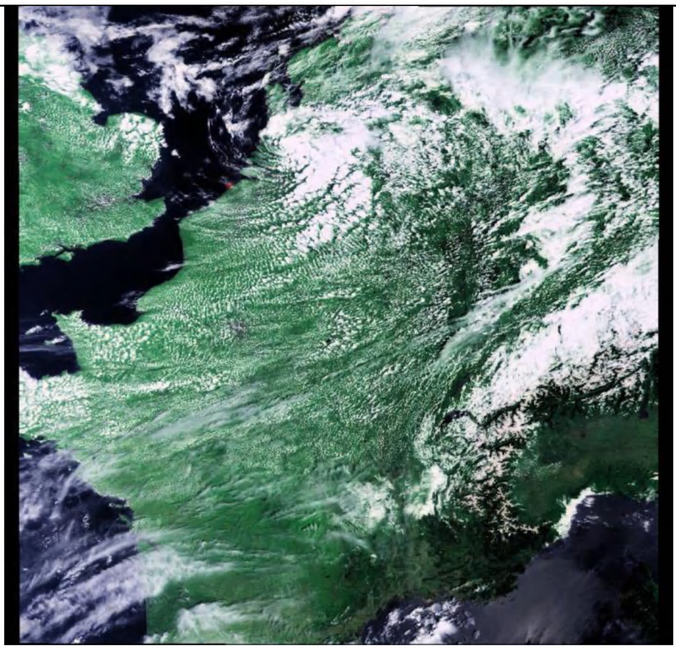
2003/06/16



2003/08/06

Figure 2: MERIS RGB images

2006/07/13



2009/06/16

3. Processing

a. *SIMEC processing*

SIMEC background

The SIMEC (SIMilarity Environment Correction) method was first proposed by Sterckx et al. (2010) for the correction of high resolution airborne imaging spectroscopy data. The SIMEC correction algorithm estimates the contribution of the background radiance based on the correspondence with the NIR similarity spectrum (Ruddick et al, 2006). In this approach SIMEC corrects the TOA radiance (L_{target}^{TOA}) for the environment effects by first performing an atmospheric correction assuming an invariant shape of the water reflectance. The adjacency corrected water reflectance is converted back to L1 TOA radiance ($L_{\text{target}}^{TOA,c}$). $L_{\text{target}}^{TOA,c}$ is corrected for the adjacency effects and can further be processed using an user selected atmospheric correction method (eg. ODESA-MEGS).

MERIS – SIMEC processing

SIMEC is applied to a 3 by 3 pixel region around the in-situ match-up point however with considering image pixels up to 30 km from the target pixel for the environment correction. SIMEC consists of a C++ routine for Radiative Transfer Calculations and LUT interpolation and an ENVI/IDL script for the image application. As there is no direct interface within the BEAM MERIS toolbox ((*www.brockmann-consult.de/cms/web/**beam**/*) some pre-processing has to be performed on the MERIS imagery before SIMEC can be applied.

The MERIS FR/RR *.N1 images are first orthorectified in BEAM (in order to locate the in-situ match-up point). The orthorectified radiance images and all required ancillary layers (eg. Sun-View geometry, Meteo data etc.) are saved in DIMAP format and imported in SIMEC.

Next SIMEC is applied to the orthorectified MERIS data for the 3 by 3 pixel region around the in-situ location. Essential for the application of SIMEC is that aerosol is not retrieved by a standard pixel wise 'water-based' aerosol retrieval approach, but instead either taken from sunphotometer readings or through a land based aerosol retrieval approach. In this case the AOT given in Table 3 was used together with a standard rural MODTRAN aerosol.

	CIMEL - AERONET	
image date	angstrom	AOT_550
20030423	1.69	0.29
20030616	1.64	0.35
20030806	1.13	0.38
20060713	1.67	0.23
20090616	1.52	0.09

Table 3 Aerosol data

For the 3 by 3 pixel windows around the in-situ validation points the original TOA radiance and the SIMEC adjacency corrected radiance together with the required ancillary information were written to an ODESA compatible *.csv input file for application of the MERIS Ground Segment Processing (MEGS-v8.1).

b. *ICOL processing*

ICOL background

ICOL (Improve Contrast between Ocean and Land) includes in it formalism the classical adjacency effect (influence of the land albedo) but also (i) the reduction of the coupling between photons reflected by the sea surface and then scattered toward the sensor and (ii) a simplified formalism of the influence of bright clouds. ICOL retrieves the aerosol model over water even turbid waters. ICOL returns a L1 radiance after correction of the adjacency effects. ICOL is available in BEAM to process MERIS images.

MERIS-ICOL Processing

The ICOL MERIS processing is performed in the BEAM toolbox using the ICOL processor. ICOL is applied to the *N1 data listed in Table 1. ICOL was applied in two different ways: 1) with the option 'over water compute the aerosol type by adjacency effect algorithm' selected and 2) with this option deselected and with the aerosol data as given in Table 3 as input.

The ICOL corrected radiance images were next orthorectified in BEAM. The orthorectified data were saved in DIMAP format. Finally, using an ENVI/IDL routine the ICOL corrected radiance together with the required ancillary information data, for the 3 by 3 pixel windows around the in-situ validation points, were written to an ODESA compatible *.csv input.

c. ODESA-MEGS processing

Finally the *.csv files with the original radiances, the SIMEC and ICOL corrected radiances for the 3 by 3 pixel windows around the in-situ match-up points (together with the required ancillary information data) were imported in ODESA for the application of the MERIS Ground Segment Processing (MEGS-v8.1) in order to retrieve the water reflectance and to compare with in-situ measured water reflectance. This process (for SIMEC) is illustrated in Figure .

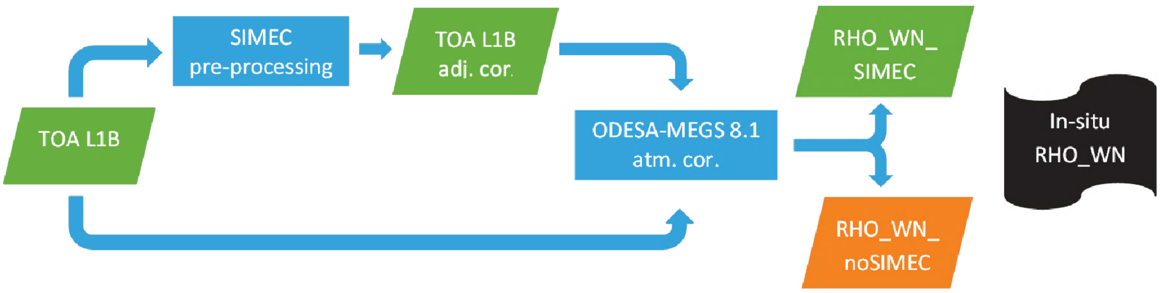


Figure 3: SIMEC – ODESA flowchart

4. RESULTS

a. L1

The adjacency effects directly impact on the satellite signal, i.e. at level 1. The effects are generally small and a direct comparison between the initial values, the values return by SIMEC and by ICOL (using the CIMEL aerosol model or remote sense this aerosol model by itself) does not allow to really see the small discrepancies. What we then did is to ratio the SIMEC and ICOL values of the TOA radiance by the original ones.

The results are reported in figure 4 for the FR. Sequences 1, 3, 4 and 6 are the most favorable to understand the impact of the adjacency effects. For ICOL in 1 and 3, there is a significant correction in the NIR in removing the photons coming from the bright land with is cover by dense vegetation during the spring. In the blue, the correction by ICOL is small because the contrast between land and water is weak. For ICOL in 4, we have the same tend but weaker in the NIR because the land becomes less bright in summer. There is a numerical problem with ICOL at sequence 6 when using MERIS FR. Therefore this sequence was processed by ICOL on MERIS RR as reported in figure 5. The correction by ICOL outputs what we expect to see. Sequences 2, 5, and 8 are more off shore and therefore the adjacency effects are vanished mainly in the NIR where the impact of the aerosol disappeared. For sequences 7 and 8, on June 16, 2009, we know that the image is contaminated by cirrus and cumulus clouds and ICOL does not account for the cirrus and may be not accurately of the cumulus clouds.

For sequences 4, 5, 6, 7 and 8 a strong correction in the NIR by SIMEC can be seen. This is, as expected, largest for the sequence 7, which is located in the Scheldt estuary very close to land. For this sequence also a strong correction in the shorter wavelengths is observed. For sequence 8, although situated offshore at a distance of about 6 km from the coastline, a relatively strong correction by SIMEC is observed. This is probably due to the presence of clouds relatively close to the sampling location. For sequence 1,2 and 3 differences with and without SIMEC pre-processing is minimal. For sequence 2 this is as expected as this station is located at a distance of about 9 km from the coastline and without clouds.

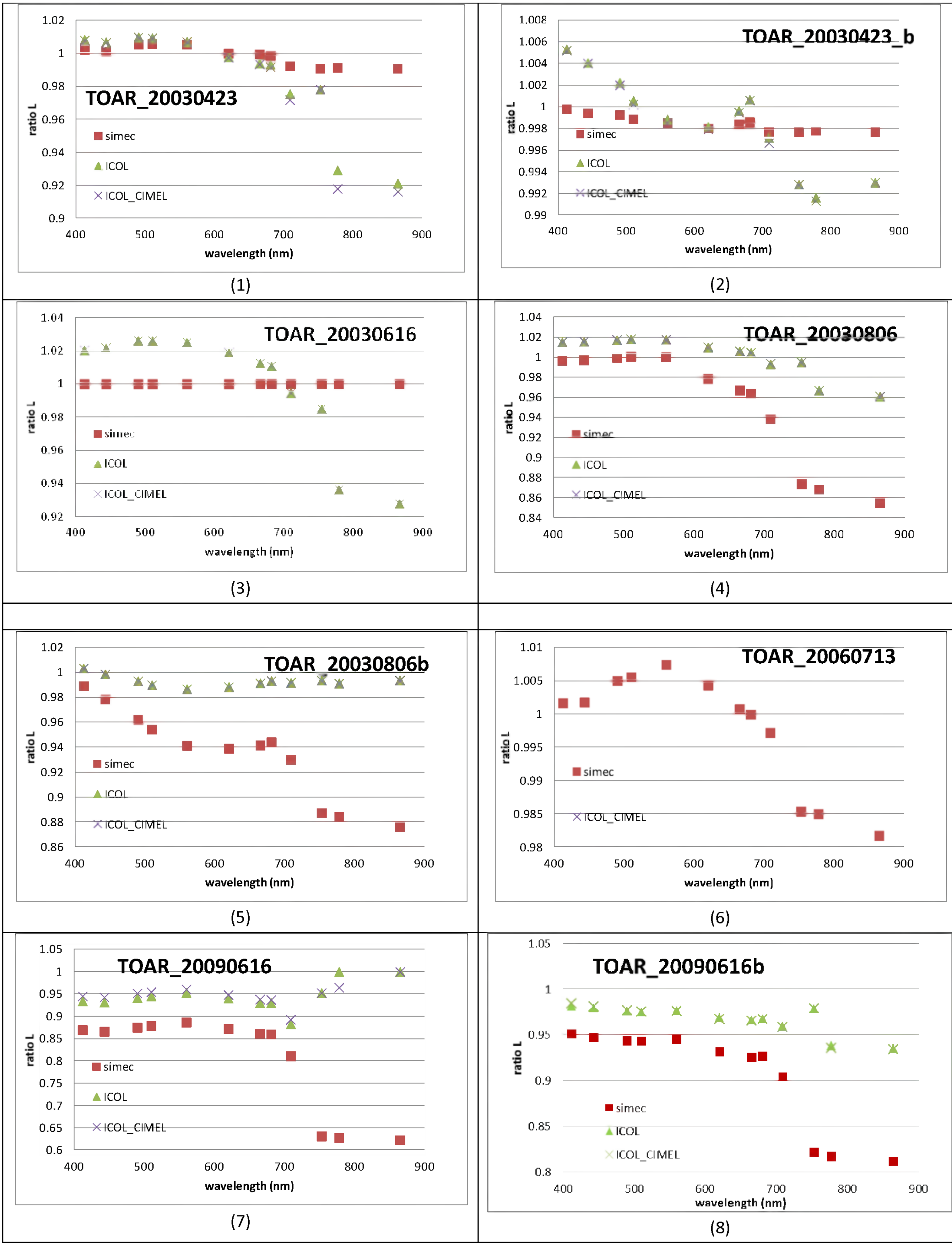


Figure 4: Ratio of TOA radiance in FR as returned by ICOL (using it own aerosol model (triangle) and using the CIMEL AERONET AOT (cross)or SIMEC(square) divided by original L1 values versus the wavelength

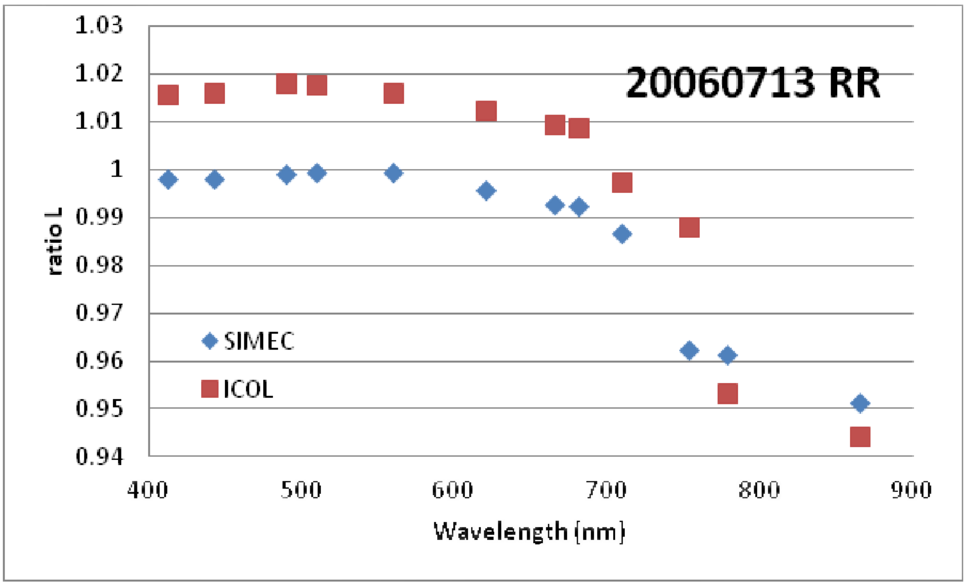


Figure 5: Ratio of TOA radiance on July 17, 2006 in FR as returned by ICOL using it own aerosol model (square) and SIMEC(diamond) divided by original L1 values versus the wavelenght

B Aerosol product

The MERIS aerosol product result here from what we call the standard atmospheric correction which combines the correction in the NIR of the residual water reflectance (T and the traditional aerosol remote sensing (Antoine and Morel,)able 4 gives the MEGS L2 Angstroem coefficient α for the 4 processing. For ICOL, the interpretation impact is provided by figure 4. For sequences 1, 3, 4 and 6, because the correction is stronger at 865 nm compared to 778 nm, α is less than the original value. Similar effects are observed for SIMEC for sequences 4,5,6,7 and 8.

	ALPHA	20030423	20030423b	20030616	20030806	20030806b	20060713	20090616	20090616b
original	mean	1.58	1.45	1.84	1.25	1.22	2.27	1.35	0.97
	stdev	0.15	0.10	0.30	0.07	0.05	0.10	0.16	0.34
SIMEC	mean	1.59	1.45	1.84	1.06	1.09	2.23	0.13	0.22
	stdev	0.17	0.11	0.30	0.16	0.12	0.17	0.17	0.19
ICOL_noinput	mean	1.32	1.38	1.54	1.21	1.18	999	1.61	0.70
	stdev	0.11	0.11	0.34	0.10	0.07	999	0.62	0.26
ICOL_input	mean	1.07	1.38	1.49	1.21	1.18	999	1.75	1.50
	stdev	0.18	0.11	0.35	0.10	0.07	999	0.25	0.05

Table 4: the L2 α from ODESA as a mean on the 3*3 FR window and below the r.m.s. on the same window. The results are provided for the 8 sequences. On July 13, 2006 when ICOL failed on FR

Table 5 gives the MEGS L2 AOT for the 4 processing. The interpretation of the AOT is not straightforward, less than on α actually, the adjacency effect correction brings first on the TOA reflectance and then, after Rayleigh correction, on the aerosol reflectance. The AOT is proportional to the aerosol reflectance but also on the phase function which depends on α. As see above, α is impacted by ICOL and therefore the interpretation on the AOT is complex when the two effects (decrease of the aerosol reflectance and of α) are opposite. For ICOL sequences 1, 3, 4, we see this expected small decrease of the AOT. We report for sequence the AOT for ICOL RR but it iss hazardeous to compare FR and RR when seeing that the spatial dispersion is not the same. On June 16, 2009, the dispersion of the AOT is important resulting from the atmospheric correction. If following the MERMAID recommendations for validation, this matchup is not qualified.

For SIMEC a decrease in the AOT is observed for sequences 4,5,6,7 and 8 where we had the largest correction by SIMEC.

	original	SIMEC	ICOL noinput	ICOL_input
20030423	0.192	0.190	0.178	0.149
	0.021	0.023	0.017	0.014
2003042b	0.198	0.196	0.196	0.196
	0.010	0.011	0.011	0.011
20030616	0.208	0.208	0.214	0.199
	0.039	0.039	0.039	0.034
20030806	0.328	0.223	0.297	0.298
	0.023	0.022	0.026	0.027
20030806b	0.306	0.225	0.292	0.292
	0.014	0.023	0.017	0.017
20060713	0.102	0.100	0.123	
	0.006	0.012	0.022	
20090616	0.357	0.151	0.316	0.323
	0.134	0.080	0.135	0.153
20090616b	0.268	0.228	0.218	0.225
	0.177	0.186	0.159	0.163

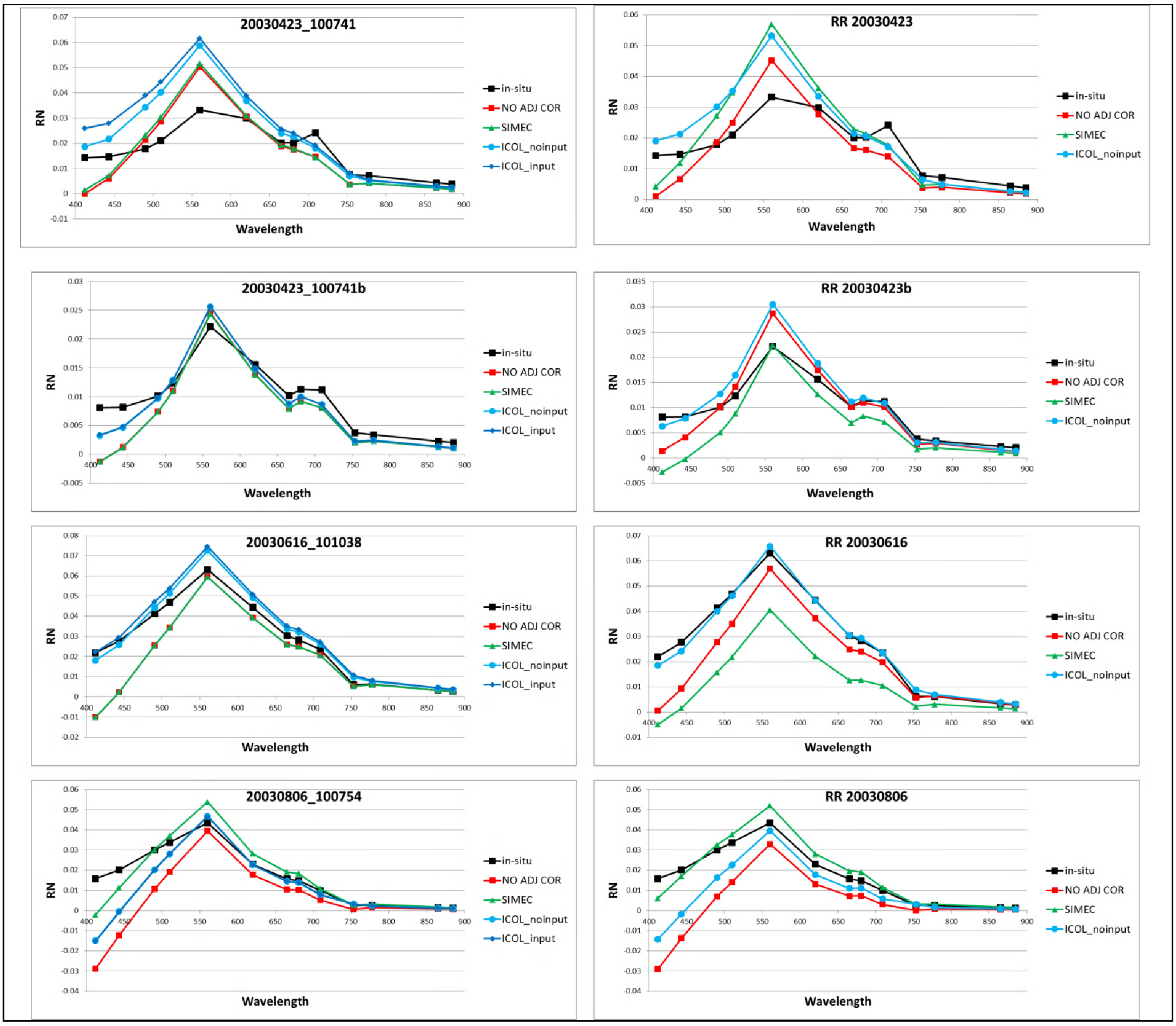
Table 5: the L2 AOT from ODESA as a mean on the 3*3 FR window and below the r.m.s. on the same window. The results are provided for the 8 sequences. On July 13, 2006 when ICOL failed on FR, we provide in red the result for ICOL in RR.

C Water reflectance from the standard atmospheric correction algorithm

The 4 sets of new MERIS L1, both in RR and FR, are processed. Nominally, we have four sets of MERIS water reflectance values to be compared to the MUMM in situ measurements. In annex, we did compare the MUM measurements with another simultaneous measurements provide by another radiometer, SIMBADA. Of course, the quality of the water reflectance retrieval depends on the L1 TOA reflectance (corrected or not of the AE) but also on the performance of the MERIS standard atmospheric correction. What we know in general is that the standard atmospheric correction over corrects (Zibordi et al, 2013) in the blue bands. We also need to believe on the intrinsic quality of the in situ measurements as well as on their spatio temporal representativeness

The comparison is done in Figure 6 both for FR and RR. We see the over correction of the standard algorithm in the blue. No firm conclusion can be drawn on the impact of the adjacency effect correction with this data set.

Because the results are clearly linked to the atmospheric correction algorithm, we have to interpret the comparison with the IS measurements not in absolute values but relatively with as concern: how the adjacency effect correction improves the comparison. It is what we did with no real recommendation to make between the 4 processing.


20030423_100741
RR 20030423
20030423_100741b
RR 20030423b
20030616_101038
RR 20030616
20030806_100754
RR 20030806
RN
Wavelength
in-situ
NO ADJ COR
SIMEC
ICOL_noinput
ICOL_input

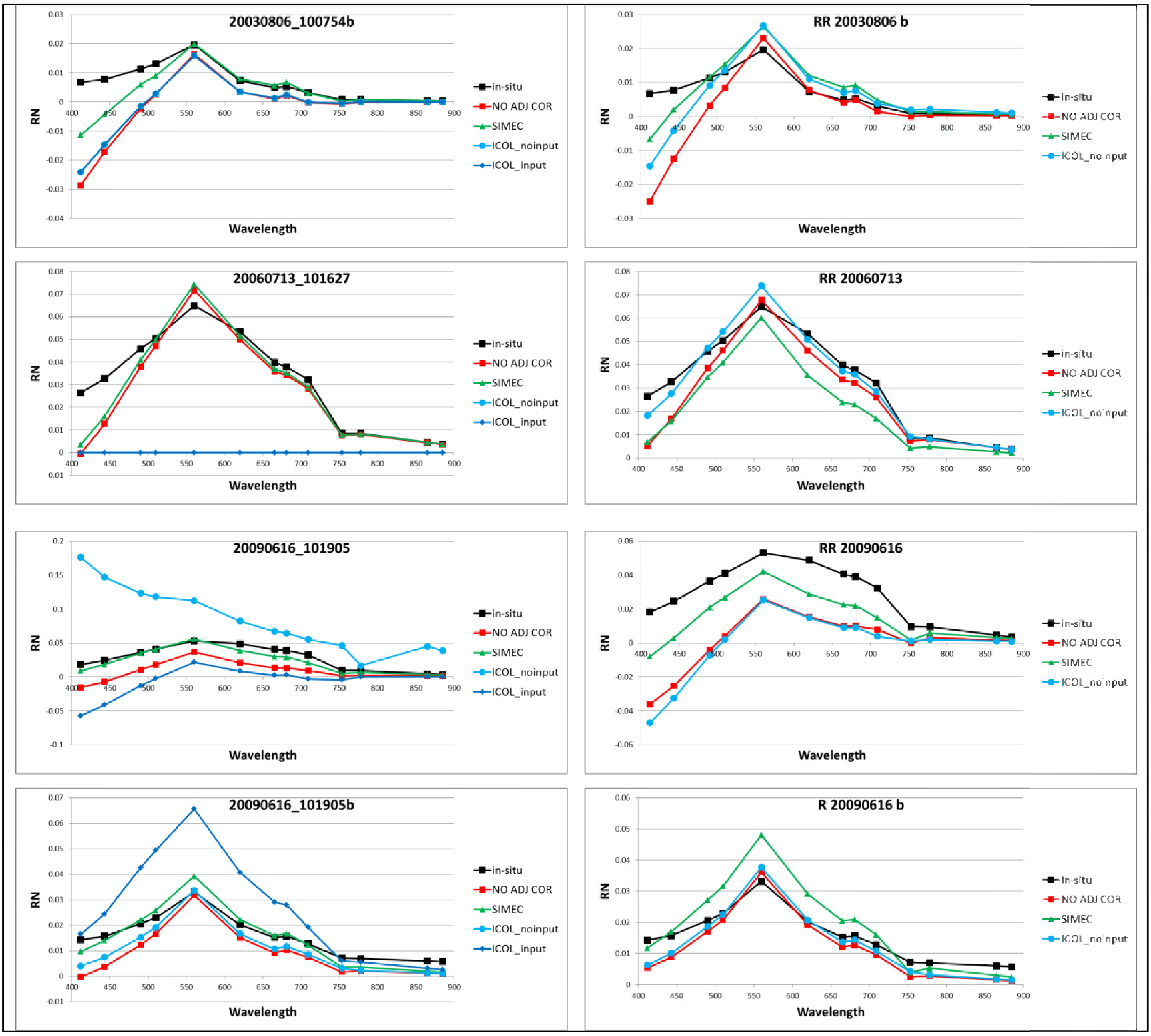


Figure 6: ODESA standard water reflectance from MERIS FR(right) and MERIS RR (left) with different adjacency effect corrections and the standard atmospheric correction

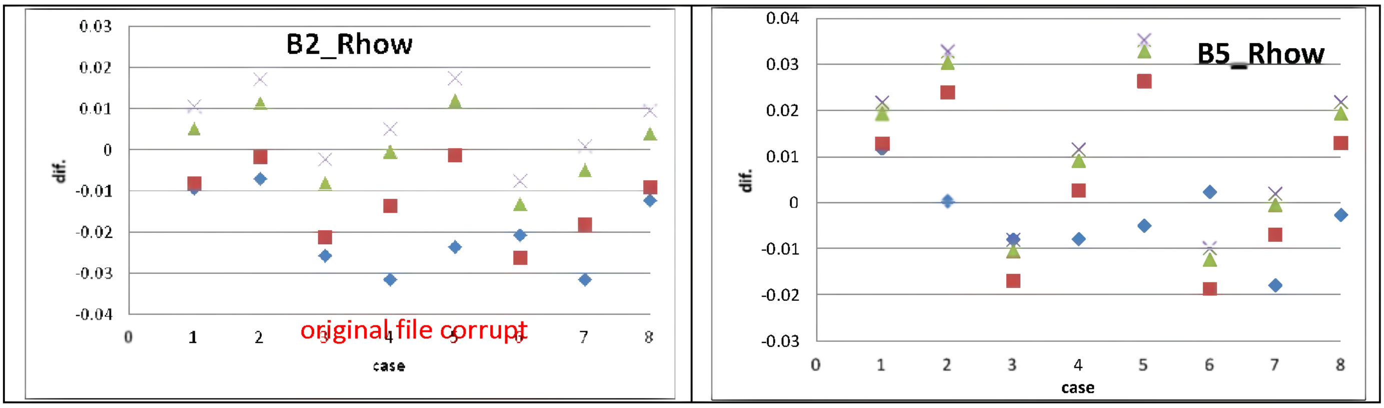


Figure 7: Difference in water reflectance between ODESA, with the 4 adjacency effect corrections, in FR and in situ: original (diamond), SIMEC(square), ICOL(triangle) and ICOL_CIMEL(cross)

Water reflectance from the Neural Network

The C2R (Doerffer and Shiller, 2007) also returns the water reflectance for the 4 adjacency effect corrections. Figure 8 compares the C2R water reflectance values with the IS. First, the adjacency effect has a little impact on the C2R results. The standard atmospheric correction relies on the use of the NIR where the AEs are significant. Conversely, the atmospheric correction for the neural network deeply relies on the visible spectrum for which the adjacency effects are marginal…except may be for case 7. Second, it is amazing how the C2R well retrieve the IS water reflectance.

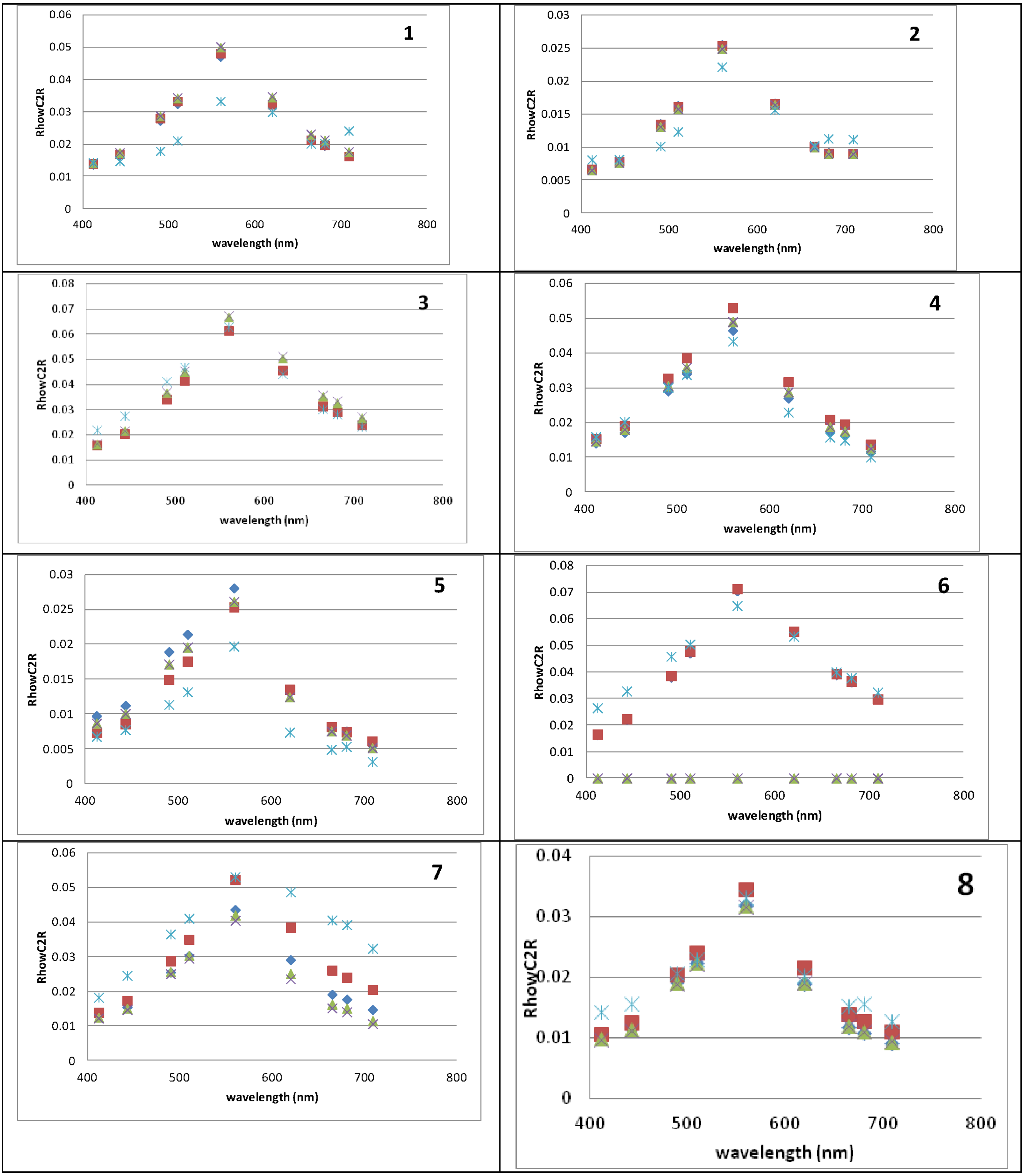


Figure 8:The C2R water reflectance in FR using the 4 L1: original (diamond), SIMEC(square), ICOL(triangle) and ICOL_CIMEL(cross) for the 8 matchups. Comparison with the IS measurements.

d. *Chlorophyll a*

They are 2 values of the Chla. The first one, Chl1, uses the water reflectance from the standard atmospheric correction and then derives the Chla on a two bands ratio algorithm. The second one is for the C2R algorithm based on a NN. The results in table 6 first illustrate the sensitivity of the first algorithm to the AE. For the second, because the water reflectance retrieval does not depend on the AE, then the Chl2 values are also independent.

		20030423		20030423b		20030616		20030806	
		CHL1	CHL2	CHL1	CHL2	CHL1	CHL2	CHL1	CHL2
mean	original	29.63	10.80	7.51	16.80	28.10	9.95	999.00	6.73
stdev		0.74	0.57	15.00	3.38	2.36	1.97	999.00	0.26
mean	SIMEC	29.33	10.23	7.51	16.89	28.10	9.95	16.21	5.98
stdev		0.84	1.05	15.00	3.44	2.36	1.97	3.17	0.60
mean	ICOL_noinput	16.75	10.52	10.01	17.56	14.47	9.27	24.40	6.42
stdev		3.50	0.64	15.00	4.34	3.28	1.98	5.21	0.39
mean	ICOL_input	13.03	10.47	9.98	17.60	12.88	9.27	24.75	6.41
stdev		2.37	0.66	14.95	4.37	2.49	2.00	5.47	0.38

		20030806b		20060713		20090616		20090616b	
		CHL1	CHL2	CHL1	CHL2	CHL1	CHL2	CHL1	CHL2
mean	original	999.00	6.55	20.44	9.42	25.88	10.68	22.50	10.48
stdev		999.00	0.37	3.05	1.61	5.83	0.73	13.88	0.85
mean	SIMEC	999.00	10.10	18.19	9.11	11.36	11.44	16.17	11.30
stdev		999.00	0.46	2.85	1.91	0.93	0.58	6.57	1.05
mean	ICOL_noinput	999.00	7.06	999.00	999.00	5.80	7.95	25.42	10.81
stdev		999.00	0.47	999.00	999.00	999.00	0.80	10.53	0.92
mean	ICOL_input	999.00	7.06	999.00	999.00	999.00	7.75	10.35	7.08
stdev		999.00	0.48	999.00	999.00	999.00	0.54	0.28	0.76

Table 6: determination of and Chl2 using the 4 adjacency effect corrections associated to the Chla1 algorithm and to the ChL2 neural network algorithm

5. CONCLUSIONS

ICOL correct the adjacency effects at L1 as expected. A clear effect of SIMEC at both the L1 and water reflectance level is observed.

The standard MERIS atmospheric correction is sensitive to the adjacency effect correction. But, the retrieve water reflectance values are not compatible with the IS measurements.

The neural network is not sensitive to the adjacency effect and gives a nice retrieval for our IS data set of the water reflectance.

A first straightforward recommendation is to use the neural network water reflectance and then applied a “regional” inversion as suggested by PML (Tilstone, 2013).

ACKNOWLEDGMENTS

We first thank the INTERREG 2 Seas program for supporting the ISECA project. We thank Kevin Ruddick for the in situ measurements, as well as Pierre Yves Deschamps for the SIMBADA measurements in the annex, and the MERMAID team to make them available with the MERIS matchups.

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Annex: Comparison TRIOS –SIMBADA on the Belgica

Site	Lat_IS	Lon_IS	TIME_IS
MUMMTriOS-Bel	51.431	2.807	20030422T124100Z
SIMBADA-Belgica	51.431	2.807	20030422T124210Z
MUMMTriOS-Bel	51.308	2.847	20030422T105300Z
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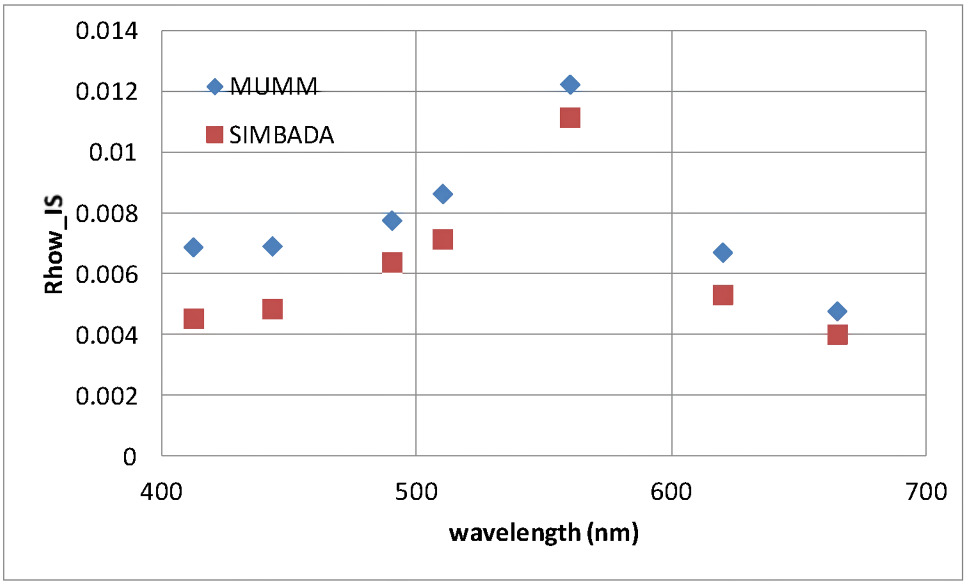

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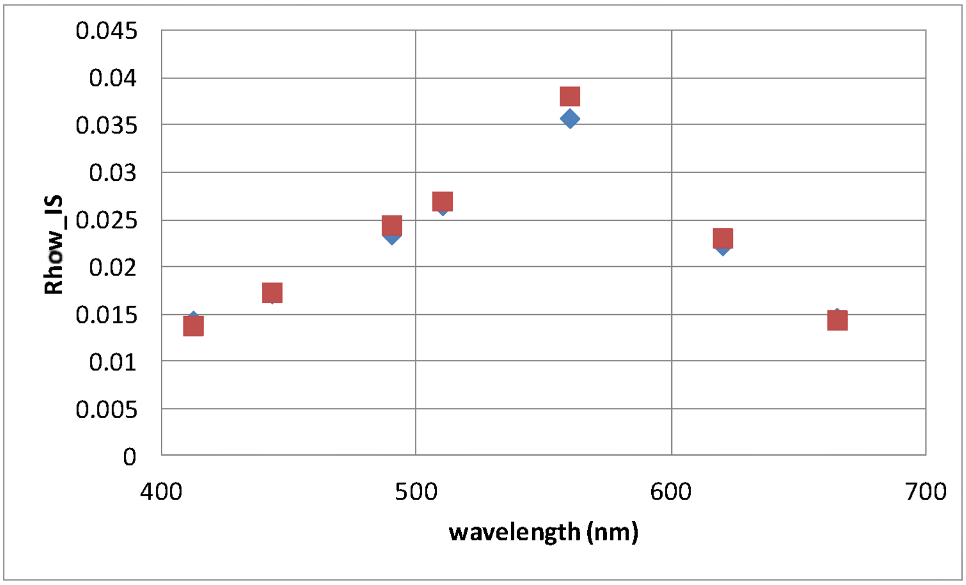

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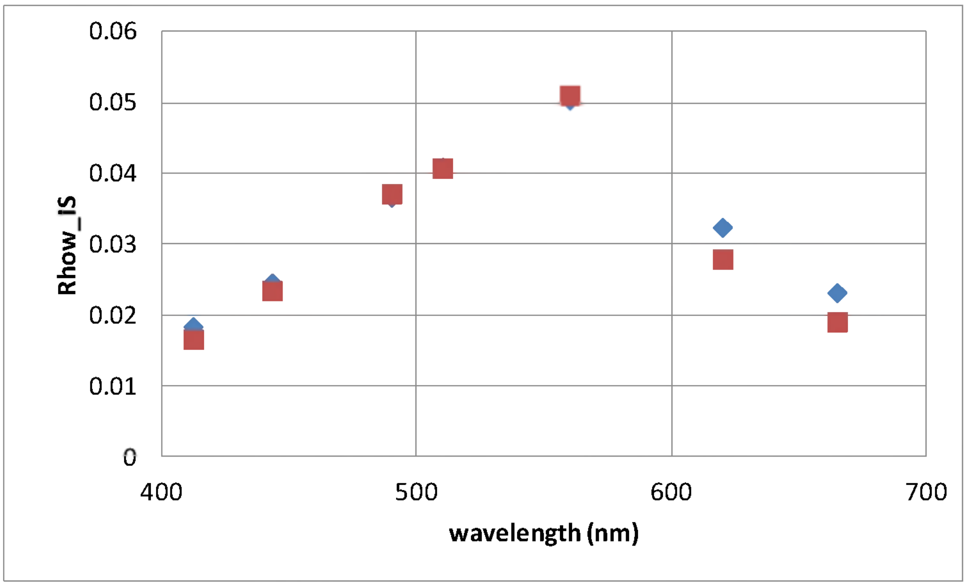

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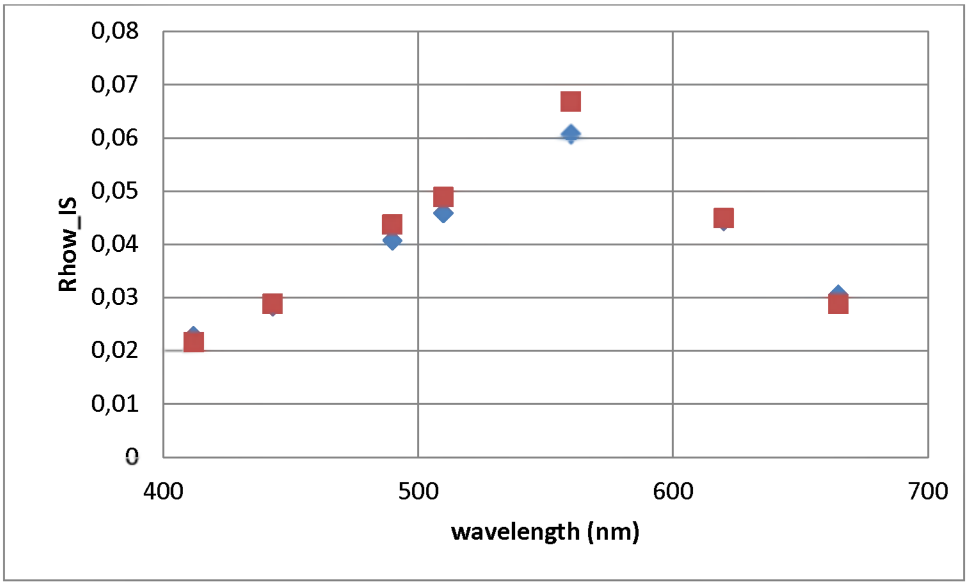

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