

Comparison of Level-3 aggregations methods

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Introduction

In order to assess the differences between level-2 to level-3 aggregation methods one month of MODIS level-2 data have been collected and used to derive level-3 monthly products of Cloud Top Pressure, Cloud Optical Thickness and Cloud Particle Size taking 4 different aggregation methods. The aggregation methods compared are the official MODIS method, the GEWEX Cloud Assessment method, the University of Wisconsin method, and the EUMETSAT prototype method. In the presentation the differences between the methods will be presented. In addition, we will show the effect of using different filtering rules, and different temporal and spatial resolutions.

The results reveal that level-3 products differ considerably, even when the input level-2 products are identical. The differences can be assigned to filtering rules (number of pixels required, cloud screening, quality flag handling, etc), to manner of accounting for the products frequency distributions (Gaussian, bimodal, logarithmic, etc), to the re-sampling method (grid snapping, grid averaging, etc). It will be shown that differences are a function of the spatial location.

Study Setup

This study aims to assess differences in level-3 products due to using different aggregation methods. We applied three different aggregation methods to derive monthly level-3 products using the same Level-2 products. The monthly level-3 cloud parameter products were derived for Cloud Top Pressure (CTP), Cloud Top Temperature (CTT), Cloud Effective Radius (CER), and Cloud Optical Thickness (COT) for the month September 2012. As level-2 cloud parameter products the MODIS L2 products (collection 5.1) were used. We restricted our comparison to products that were aggregated on a 1 degree rectangular grid. The three Level-3 products evaluated are:

1. MODIS EUM: The level-3 products aggregated at EUMETSAT using a classical averaging approach
2. MODIS LAADS: The level-3 products of the MODIS LAADS team
3. MODIS GEWEX-CA: The Level-3 product generated with the aggregation methods prepared of GEWEX-CA.

The comparison statistics are provided for three segments (sea/ocean, land and coastal area), as well as all three combined. To distinguish the coastal area, a distance of 150 km over sea/ocean to the nearest shore line has been used. The number of observations for the MODIS EUM products has been derived by counting the number of individual scans per grid box. No threshold value to the number of observations has been used. Note that the number of observations is not included in the MODIS LAADS products for CER and COT. A schematic representation of our evaluation procedure is presented in **Fig 1**, which compares the traditional evaluation approach to the one used in our study.

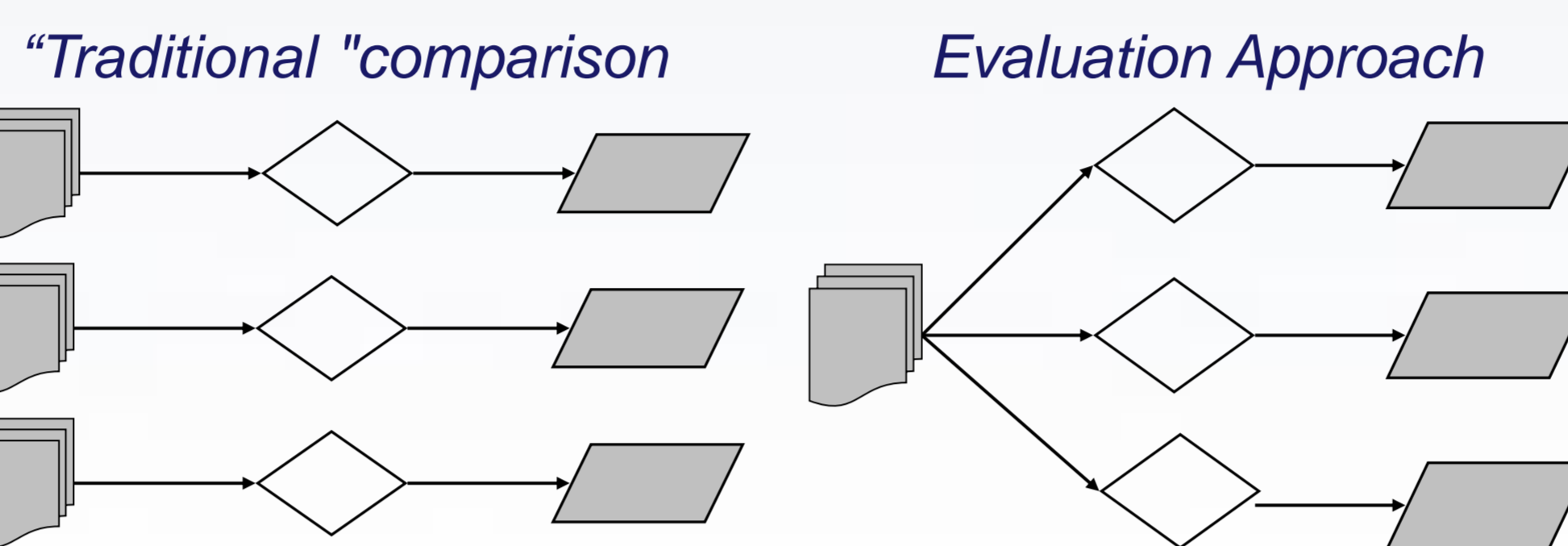


Fig 1: Schematic representation Level-2 to Level-3 error assessment. Traditional comparison (left) versus the Evaluation Approach used in our study (right).

Results

Fig 2 shows the comparison of the monthly CTP products from the three aggregation methods. The lower two panels of this figure reveal that the MODIS EUM produces lower cloud top pressures than the MODIS LAADS and MODIS GEWEX product. The MODIS GEWEX CTP product shows the highest cloud top pressures, which are ~35 hPa higher. In regions of low clouds over ocean (> 800 hPa) the MODIS EUM product shows higher cloud top pressures than the other two products, whereas these cloud top pressures are lower in regions with high clouds (< 600 hPa).

Fig 3 shows that the monthly COTs from MODIS EUM are smaller than those from MODIS LAADS, i.e., about 2 optical thicknesses over land and 4 optical thicknesses over ocean. The COT values of MODIS GEWEX are about 5 optical thicknesses smaller than those from MODIS EUM. Remarkably the differences are similar over ocean and land. The larger difference with the MODIS GEWEX products may be attributed to differences in the method of averaging the COT values: MODIS EUM used linear averaging while MODIS GEWEX used logarithmic.

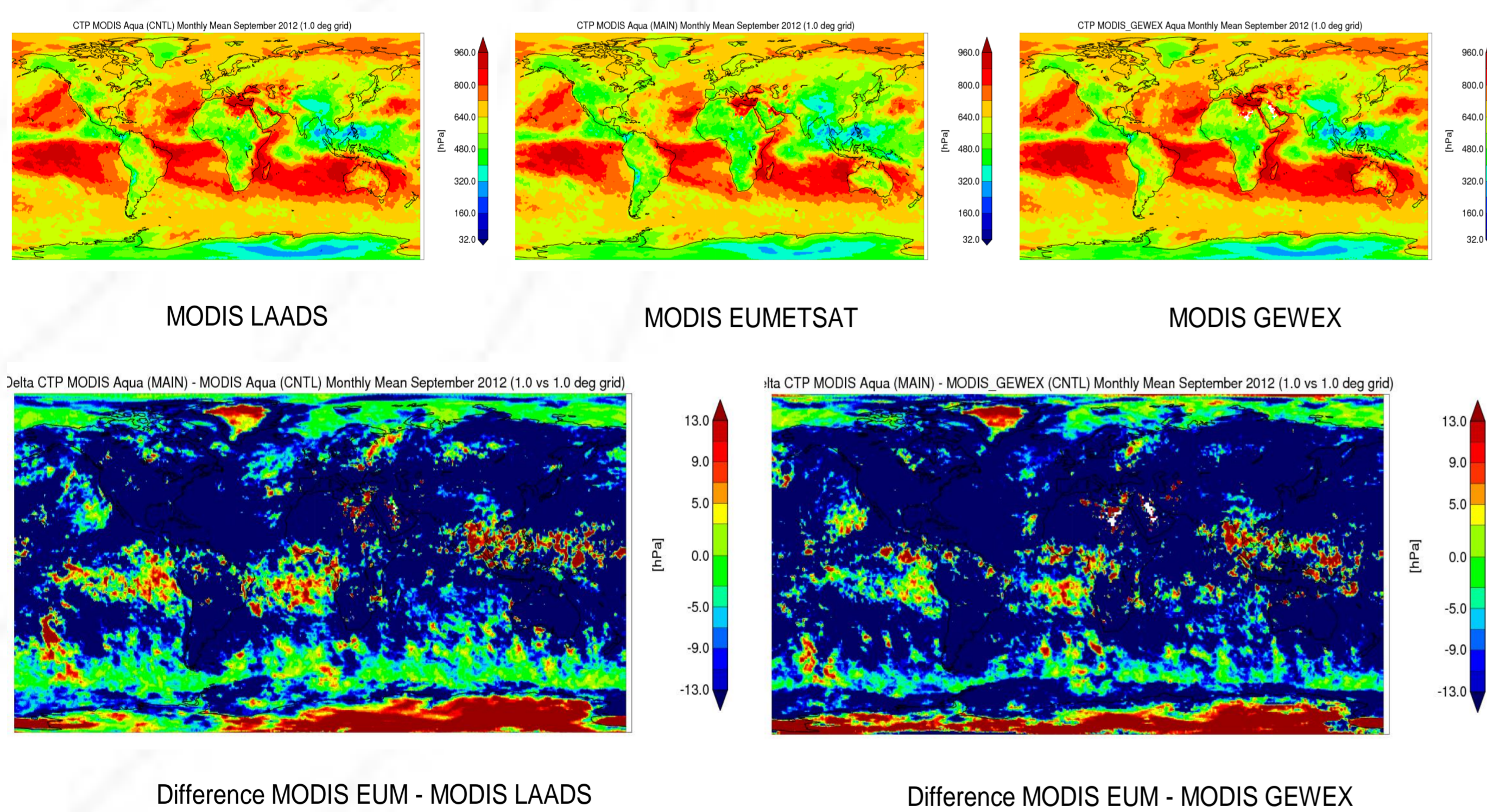


Fig 2: Monthly mean CTP from MODIS LAADS (left), MODIS EUM (middle), and MODIS GEWEX (right). The lower images show the difference MODIS EUM - MODIS LAADS (left) and MODIS EUM - MODIS GEWEX (right).

Table 1: Inter-comparison results of CTP for MODIS CREW vs MODIS LAADS, September 2012 monthly mean.

	Min (hPa)	Max (hPa)	Mean (hPa)	Std Dev (hPa)	Mean N_obs	Bias (hPa)	RMSE (hPa)	Valid Grids (%)
Sea/Ocean								
EUM	265.1	971.6	680.1	100.9	12,314	-	-	-
LAADS	260.5	967.9	695.1	100.3	12,355	-15.0	24.7	58
GEWEX	265.9	972.3	699.7	100.2	12,355	-19.6	29.8	58
Coast								
EUM	261.6	966.7	616.7	107.6	12,031	-	-	-
LAADS	254.8	959.6	644.2	108.8	12,074	-27.4	42.4	17
GEWEX	257.2	957.0	650.3	109.3	12,075	-33.6	48.6	17
Land								
EUM	242.4	924.8	517.6	103.0	7,897	-	-	-
LAADS	237.8	930.4	537.9	119.6	7,940	-20.4	46.7	25
GEWEX	247.3	922.5	543.0	120.4	8,270	-23.7	50.0	24
All								
EUM	242.4	971.6	628.9	123.2	11,167	-	-	-
LAADS	237.8	967.9	647.4	125.4	11,209	-18.4	34.7	100
GEWEX	247.3	972.3	653.5	125.1	11,323	-23.0	39.1	99

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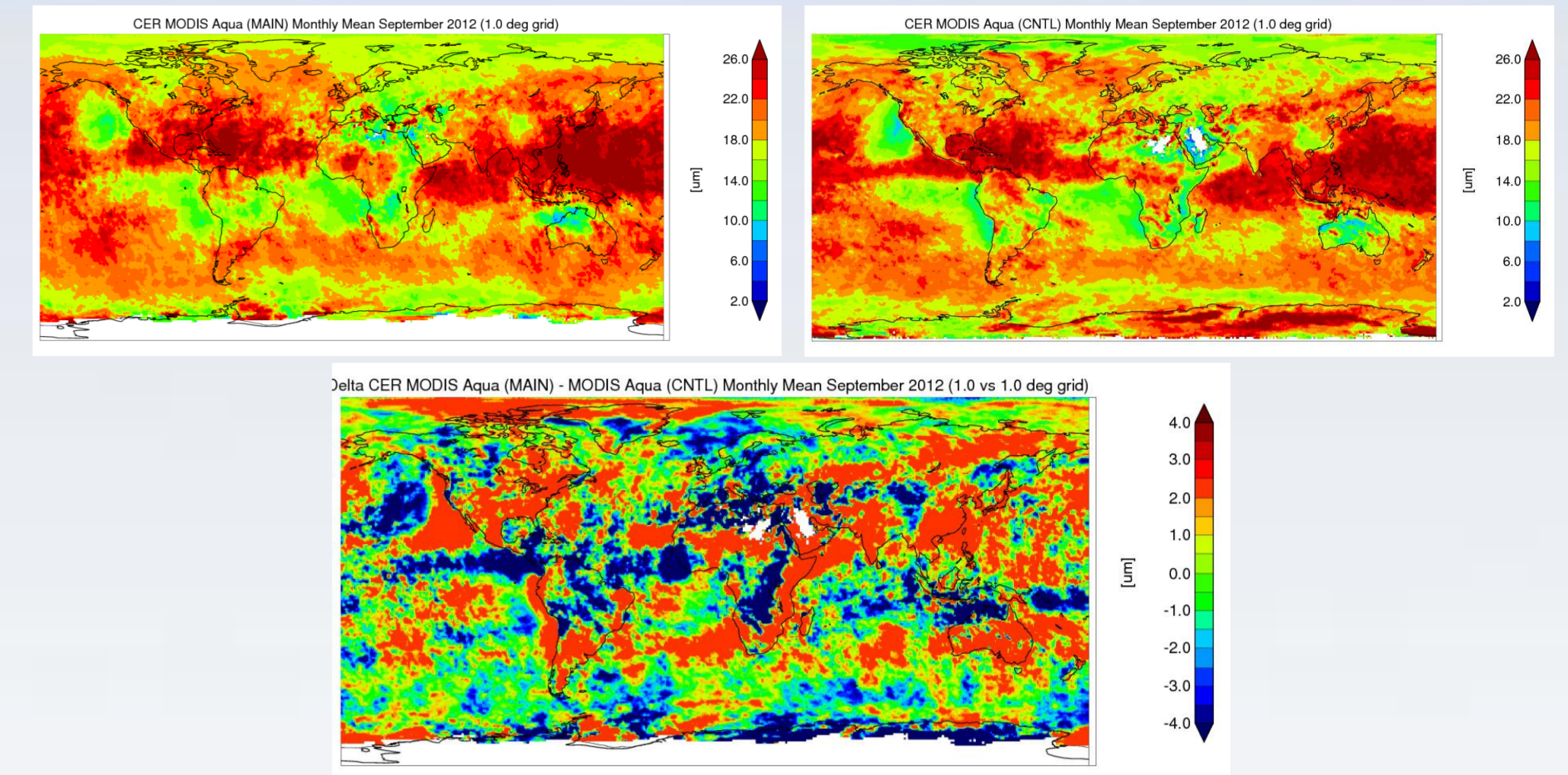


Fig 3: Monthly mean CER from MODIS EUM (left), MODIS LAADS (right), and the difference MODIS EUM - MODIS LAADS (lower).

Table 3: Inter-comparison results of CER for MODIS CREW vs MODIS LAADS, September 2012 monthly mean.

	Min (μm)	Max (μm)	Mean (μm)	Std Dev (μm)	Mean N_obs	Bias (μm)	RMSE (μm)	Val grd (%)
Sea/Ocean								
EUM	7.51	43.63	19.67	3.62	/	+0.14	2.87	58
LAADS	4.60	34.53	19.53	3.53	/	-	-	-
Coast								
EUM	7.20	40.08	19.22	3.43	/	+0.48	3.63	16
LAADS	7.10	37.31	18.74	3.36	/	-	-	-
Land								
EUM	5.86	40.27	18.55	3.34	/	+0.40	4.81	17
LAADS	4.08	37.67	18.14	3.83	/	-	-	-
All								
EUM	5.86	19.38	3.56	2.77	/	+0.25	3.45	91
LAADS	4.08	19.13	3.60	2.79	/	-	-	-

Fig 4 shows the comparison of the monthly CER products from two aggregation methods, i.e., MODIS EUM and MODIS LAADS. The summary in **Table 3** shows that the differences between both products are acceptable, with are globally smaller than 0.5 μm. At regional scales the differences increase to more than 4 μm, with MODIS EUM having larger particles than MODIS LAADS. Although there are patterns in the difference fields, there are no systematic land sea differences as apparent in the CTP and COT products.

Conclusions

- Differences are not negligible, and reveal that more research is needed to reach consensus.
- The MODIS LAADS and MODIS GEWEX products seem to differ less than the MODIS EUM product.
- Differences are systematic and reveal typical behaviour over different climate regions and/or surface conditions (e.g. land versus ocean).
- The climate community would benefit from a more coordination on aggregation methods.

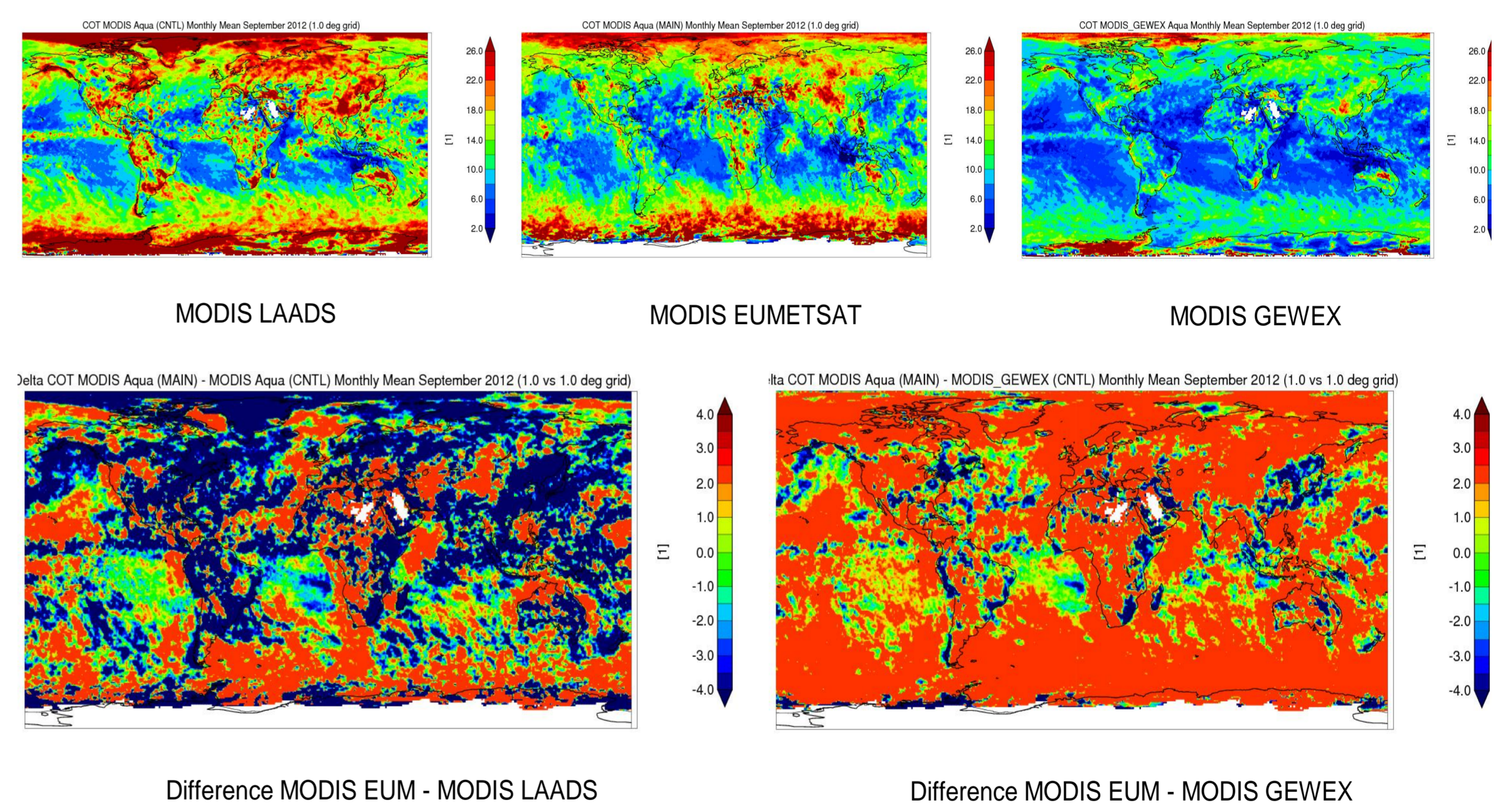


Fig 3: Monthly mean COT from MODIS LAADS (left), MODIS EUM (middle), and MODIS GEWEX (right). The lower images show the difference MODIS EUM - MODIS LAADS (left) and MODIS EUM - MODIS GEWEX (right).

Table 2: Inter-comparison results of COT for MODIS CREW vs MODIS LAADS, September 2012 monthly mean.

	Min (-)	Max (-)	Mean (-)	Std Dev (-)	Mean N_obs	Bias (-)	RMSE (-)	Valid Grids (%)
Sea/Ocean								
EUM	0.72	100.00	14.13	7.36	/	-	-	-
LAADS	0.77	100.00	15.19	8.72	/	-1.07	7.72	58
GEWEX	0.77	100.00	9.24	5.42	/	+4.89	8.35	58
Coast								
EUM	0.50	100.00	14.66	6.63	/	-	-	-
LAADS	1.38	65.75	18.49	7.94	/	-3.83	9.11	16
GEWEX	1.29	40.27	10.85	4.28	/	+3.81	7.67	16
Land								
EUM	0.05	100.00	15.71	9.73	/	-	-	-
LAADS	0.94	66.48	18.77	7.76	/	-3.06	11.76	17
GEWEX	0.94	45.39	10.84	4.34	/	+4.86	11.59	17
All								
EUM	0.05	100.00	14.52	7.76	/	-	-	-
LAADS	0.77	100.00	16.45	8.57	/	-1.93	8.86	91
GEWEX	0.77	100.00	9.83	5.10	/	+4.69	8.93	91