Invalidation of the MEGS 8.0 chlorophyll product in turbid waters.

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Abstract

The MERIS chlorophyll product for turbid waters (algal_2) has been used for various applications, such as algal bloom detection and eutrophication monitoring. This product was updated with the third reprocessing of the MERIS data. The new version of algal_2 is clearly correlated with the signal from suspended matter. This results in the retrieval of unnatural spatial and temporal patterns of chlorophyll concentration in turbid waters (corresponding to suspended matter variability). The algal_2 dataset from MEGS 8.0 is not usable in turbid waters, and users should revert to using data from MEGS 7.5.

Introduction

The MERIS 'Case 2' chlorophyll product (algal_2, [1]) from the MEGS 7.5 processor has been successfully used in turbid waters for the detection and timing of algal blooms [2], for the validation of an ecosystem model [3], and the determination of CO_2 dissolved in seawater [4]. Some quality issues were associated with the MEGS 7.5 algal_2 product, especially in the low concentrations [5,6], where significant spatial noise and indications of a detection limit were found. In general a reasonable correspondence was found in comparison with in situ measurements, especially regarding relative changes, but there is a lack of a significant number of matchups [7,8].

A new version of this algorithm was introduced with the third reprocessing of the MERIS reduced resolution dataset in 2011 [9]. The outputs from the new algorithm seemed to perform well over a wide range of chlorophyll concentrations [10], but turbidity ranges are not mentioned.

In this paper, the performance of the new reprocessing in turbid waters is analysed: long time-series and multi-temporal composites reveal an unnatural trend in the chlorophyll concentration and a clear correlation is found with suspended matter.

Results

The Southern North Sea (48.5°N – 52.5°N, 4.0°W – 5.0° E) is a shallow sea, with high suspended matter (SPM) concentrations near the coast. Typically, SPM values are higher in winter than in summer, due to an increase in resuspension of bottom sediments by winds [11]. A chlorophyll peak is expected in spring as a result of the phytoplankton bloom in response to increasing light levels [12]. During winter, low chlorophyll values are expected (3 mg/m^3 and less).

MERIS reduced resolution L2 data (algal_2 and total_susp datasets) from both MEGS 7.5 and 8.0 were collected for the full mission duration and have been screened using the appropriate PCD flags (PCD_17 and PCD_16 respectively). MODIS L2 data was collected up to and including September 2012 and uses the R2012.0 reprocessing (http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20120MA.html). The standard chlor_a product was used (and will give erroneous results in turbid waters) and SPM was calculated using the 667 nm band using the algorithm from [13], and was quality checked using the level 2 flags [14]. All satellite data was collocated on a common one kilometre grid [14], which facilitates composite generation, time-series extraction and sensor intercomparisons.

Long time-series for two points in Belgian (W04) and English (WARP) coastal waters from MODIS (R2012.0) and MERIS (MEGS7.5 and MEGS8.0) are given in Fig. 1. Spring blooms are visible in the MEGS 7.5 algal_2 time-series, and the SPM time-series shows a clear seasonal cycle with highest concentrations reached in winter, as is expected for this region. When comparing algal_2 from MEGS7.5 and 8.0, there is a considerable increase in autumn and winter values. There still seems to be a small signal from some spring phytoplankton blooms - where MEGS 7.5 and MODIS retrieve a high concentration. The MEGS 8.0 chlorophyll values quite clearly follow the trend found in the SPM time-series, showing unrealistic winter 'blooms' of phytoplankton.

Multi-temporal composites of February 2007, a low phytoplankton biomass winter month, and April 2007, a high biomass bloom spring month are given in Fig. 2. There is a huge difference between MEGS 8.0 in comparison with both MODIS and MEGS 7.5. MEGS 8.0 gives an unrealistic image of the chlorophyll values in February with high chlorophyll patches corresponding to high SPM retrievals in all three datasets. This effect is most clear in the Bristol Channel (51.5°N, 3°W), the Thames estuary (51.5°N, 1°E) and in Belgian coastal waters (51.5°N, 3°E), see arrows in Fig. 2. The chlorophyll values from MEGS

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8.0 are unnaturally high (10-30 mg/m^3) for winter conditions.

In April the chlorophyll concentrations in the Bristol Channel and the Thames estuary are low in MEGS 7.5 and MODIS, and high in MEGS 8.0. The April SPM values in the Bristol channel and the Thames are high in all three datasets, and the extent of the turbid zone in Belgian coastal waters has been strongly reduced (in fact, this drop in SPM causes an increase in light availability and is one of the triggers of the spring algal bloom).

Scatterplots comparing all scenes from February and April 2007 are given in Fig. 3 and 4 (regression statistics are omitted for clarity but available on request). A good correspondence is found between the total_susp datasets from MEGS 7.5 and 8.0 (Fig. 3a-b). A significant difference is found when comparing the algal_2 datasets from MEGS 8.0 and MEGS 7.5 (Fig. 3c-d). These products even seem to be unrelated. Overall, in MEGS 8.0 a clear correlation between SPM and algal_2 is found (Fig. 4c-d) that is absent in MEGS 7.5 (Fig. 4a-b). There are natural systems where SPM and algal_2 are highly correlated - obviously for Case 1 waters, by definition, where all optical constituents, and hence SPM, are correlated to CHL. However, for these turbid waters most of the SPM is non-algal and SPM dynamics are controlled mainly by vertical resuspension and horizontal advection processes rather than by the local growth and mortality processes that are important for phytoplankton.

The checkerboard pattern in the scatterplots (Fig. 3-6) is caused by the 1-byte discretization of the derived products stored in the N1 file format (technical description of the N1 format in [15]). This 1-byte discretization limits the number of different values to 256. For example, the algal_1, algal_2 and total_susp datasets are log-scaled to the range 0.01 to 100 (parameter units), with 64 values for each step in magnitude. This adds a 3.5% uncertainty to each of those products. Apart from the reflectance datasets (stored using 2-bytes precision), other MERIS products in the N1 format use the same 1-byte precision and will be similarly affected, but are scaled to different intervals.

A new masking scheme is adopted in MEGS 8.1, that eliminates data from the most turbid regions, but this does not solve the problem reported here, as only minor differences are found due to small bug corrections (Fig. 5). The straight cut-offs at SPM of 7 g/m^3 and CHL of 11 mg/m^3, indicate the threshold values used in the MEGS 8.1 flagging. Similarly, a masking of MEGS 8.0 algal_2 data is suggested by the MERIS QWG [10], in essence for SPM > 20 g/m^3, (the main contributor to the mask, other checks are made for the medium and high glint flags and whether the case2_s flag is not set). This masking is, however, not sufficient (Fig. 6) and also provides no solution for the underlying problem that the algal_2 product is almost everywhere strongly correlated with SPM.

MEGS 8.0 algal_2 data for other turbid regions is similarly affected by this strong relationship with turbidity, some example are posted online: http://www.odesa-info.eu/forum/viewtopic.php?t=111.

In addition to the fact that MEGS 8.0 algal_2 product is plainly invalid in turbid waters, the differences between the product over two subsequent reprocessing versions is extreme and this will cause compatibility issues. For users of the MEGS 7.5 product (e.g. in an algal bloom detection scheme or ecosystem model validation), a transition to MEGS 8.0 will deliver unexpected and unexplainable results.

Conclusion

A clear relationship between suspended matter and chlorophyll concentrations is found in the MEGS 8.0 algal_2 product. In turbid waters this will give an unnatural pattern of chlorophyll concentration, with high biomass blooms occurring in periods with high SPM concentrations. For the Southern North Sea this gives erroneous algal blooms in the middle of winter.

Users of the algal_2 chlorophyll a concentration product are strongly suggested to revert to using MEGS 7.5, as the MEGS 8.0 data clearly delivers wrong results. Additional input to this discussion is welcomed online (http://www.odesa-info.eu/forum/viewtopic.php?t=111). On this forum an alternative - but computationally intensive - way is shown to avoid this problem, by reprocessing the L1B data and using the MEGS 8.0 reflectance data with the MEGS 7.5 water processor.

Acknowledgment

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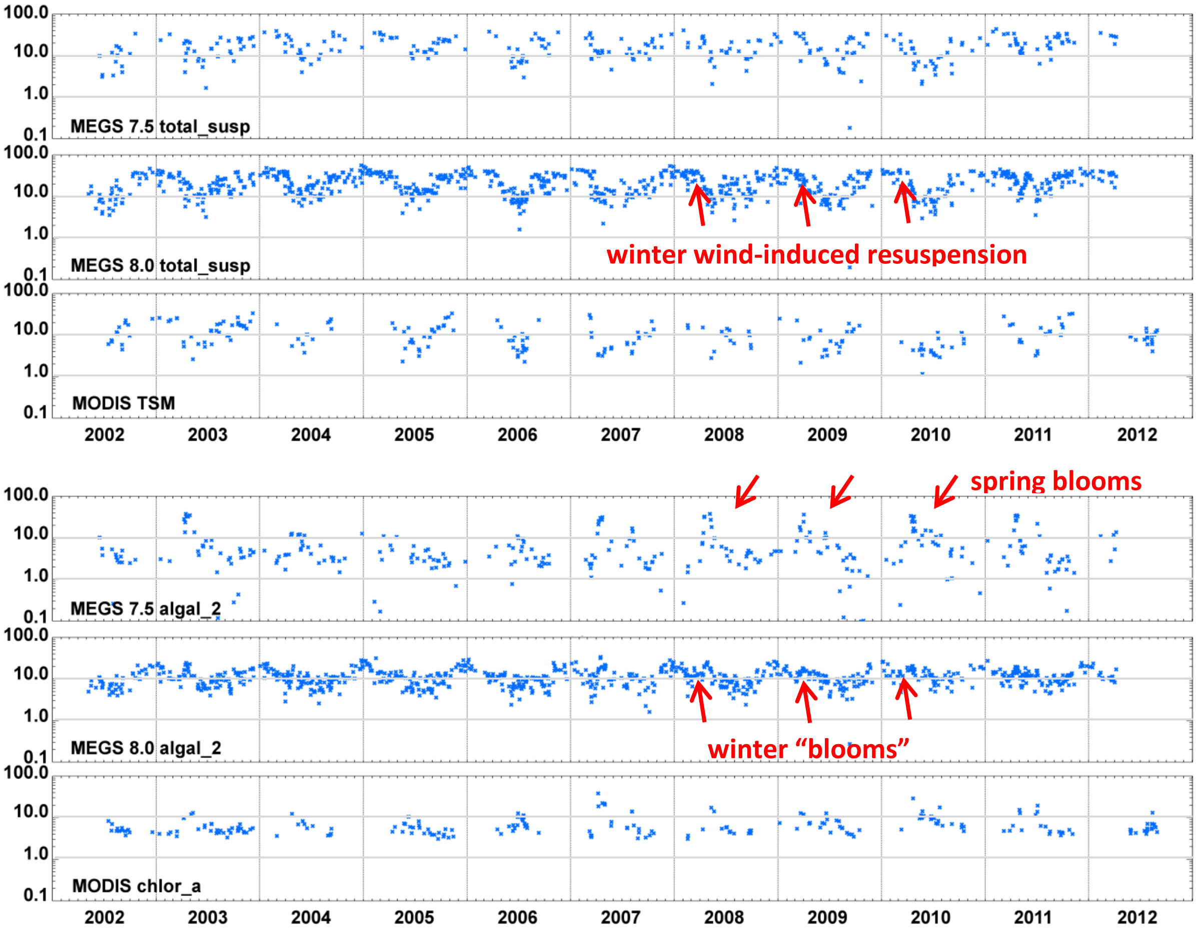

Figure 1. Time-series of SPM (g/m^3, top three plots) and chlorophyll a (mg/m^3, bottom three plots) at W04 (51.42° N, 3.25° E), from 2002 to 2012.

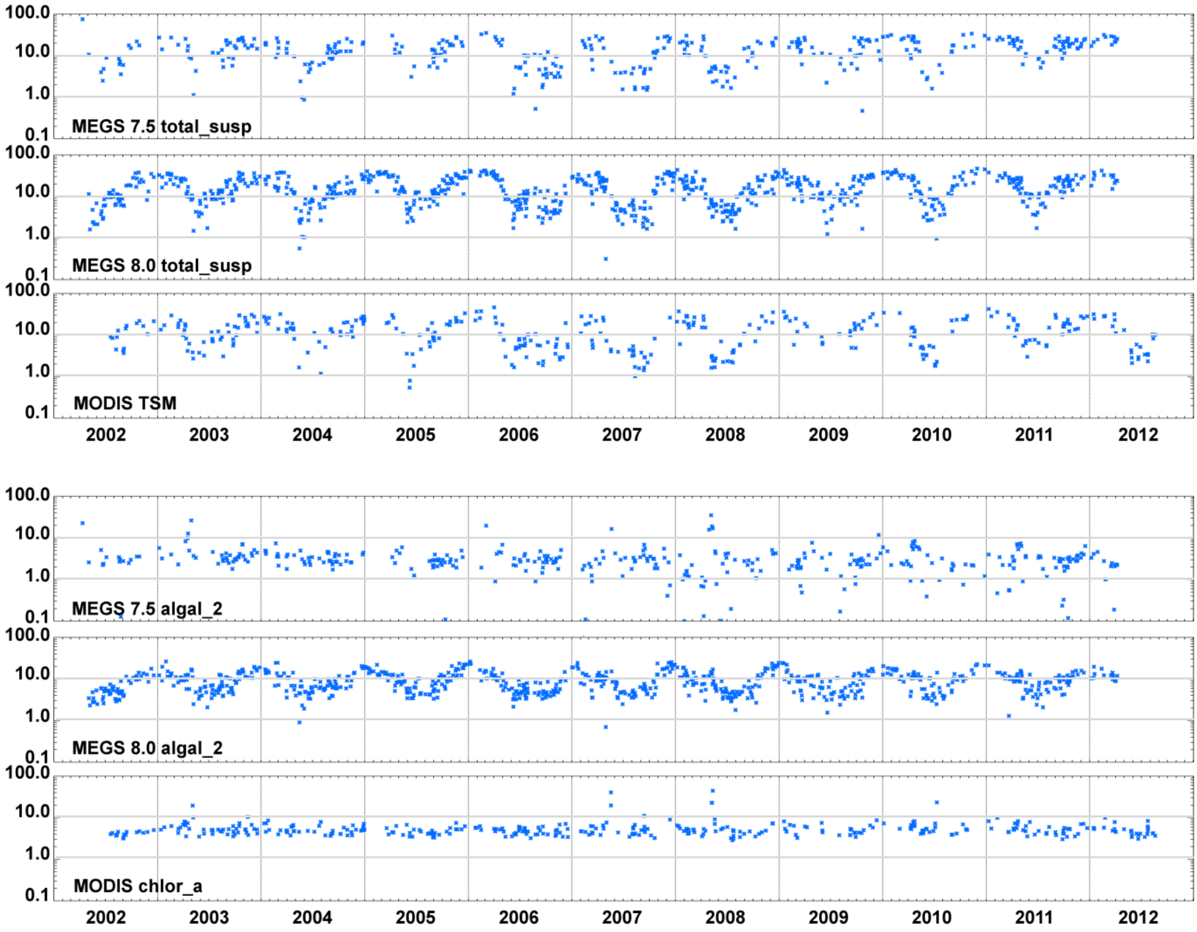

Figure 1 (continued). Time-series of SPM (g/m^3, top three plots) and chlorophyll a (mg/m^3, bottom three plots) at WARP (51.53° N, 1.03° E), from 2002 to 2012.

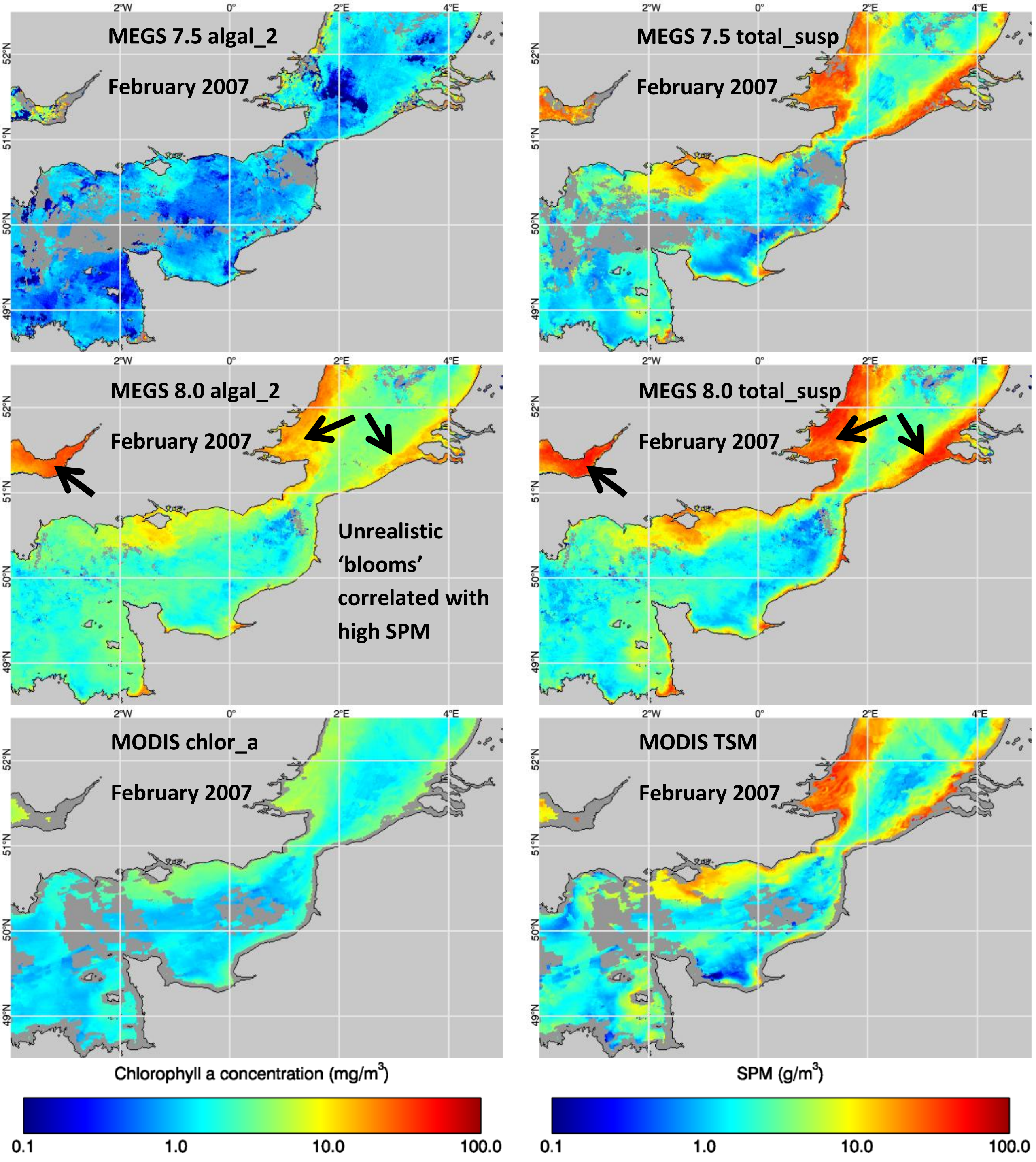

Figure 2. Monthly composites for February 2007, left column: chlorophyll a concentration, right column: suspended matter concentration. Top to bottom row: MEGS7.5, MEGS8.0, and MODIS R2012.0.

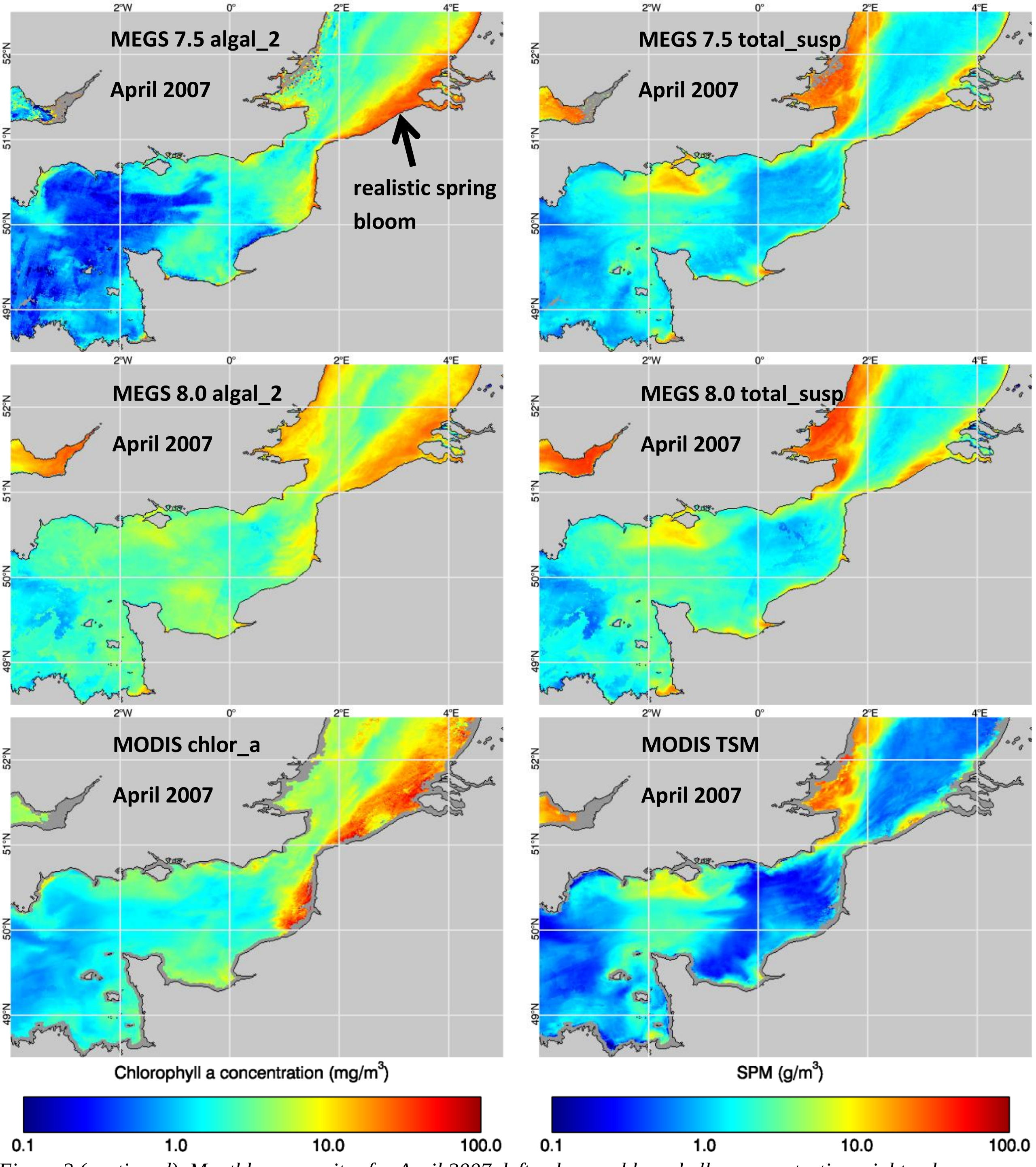

Figure 2 (continued). Monthly composites for April 2007, left column: chlorophyll a concentration, right column: suspended matter concentration. Top to bottom row: MEGS7.5, MEGS8.0, and MODIS R2012.0.

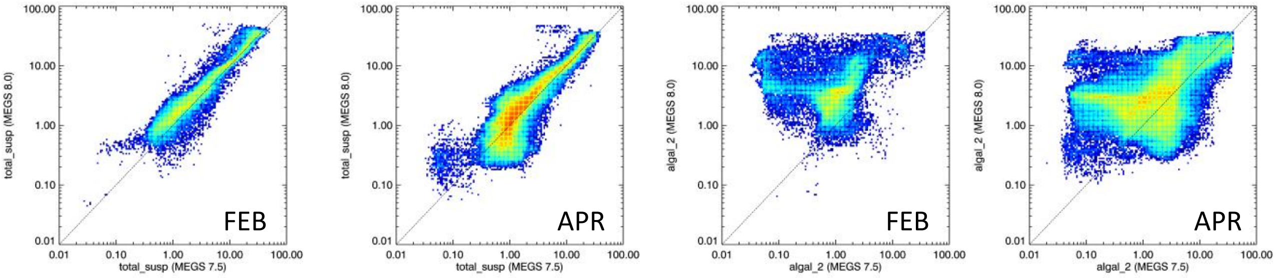

Figure 3. Scatterplots of MEGS 8.0 total_susp (g/m^3) as function of MEGS 7.5 total_susp (g/m^3) for February 2007 (a) and April 2007 (b) and MEGS 8.0 algal_2 (mg/m^3) as function of MEGS 7.5 algal_2 (mg/m^3) for February 2007 (c) and April 2007 (d).

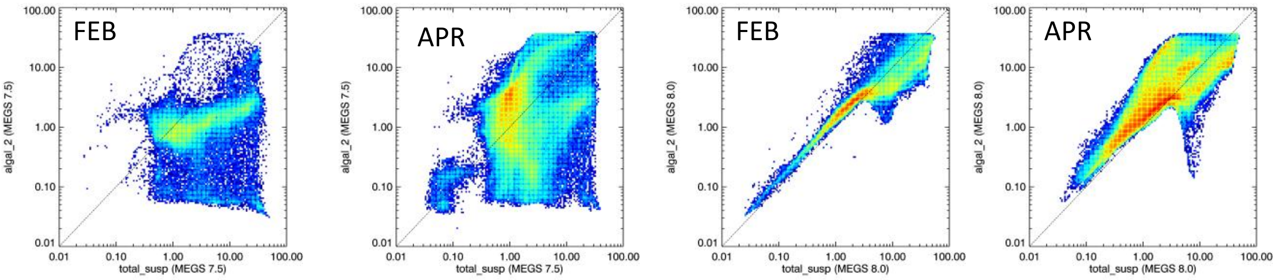

Figure 4. Scatterplots of MEGS 7.5 algal_2 (mg/m^3) as function of MEGS 7.5 total_susp (g/m^3) for February 2007 (a) and April 2007 (b) and MEGS 8.0 algal_2 (mg/m^3) as function of MEGS 8.0 total_susp (g/m^3) for February 2007 (c) and April 2007 (d).

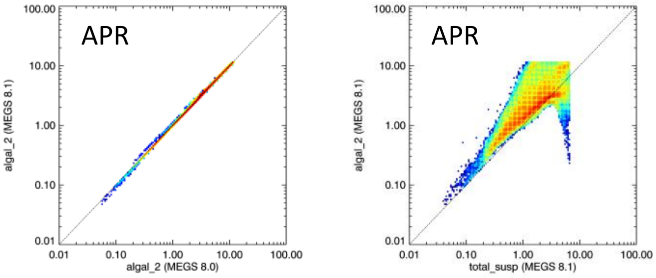

Figure 5. Left: comparison of MEGS 8.0 and MEGS 8.1 algal_2 (mg/m^3). Right: scatterplot of MEGS 8.1 algal_2 (mg/m^3) as function of MEGS 8.1 total_susp (g/m^3). Data from April 2007. The straight cut-offs at the high end of SPM and CHL indicate the threshold values used in the MEGS 8.1 flagging.

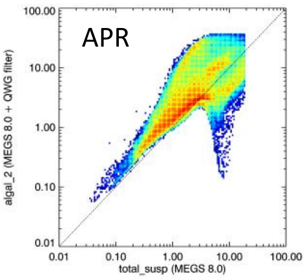

Figure 6. Scatterplot of MEGS 8.0 algal_2 (mg/m^3), after the masking suggested by the MERIS QWG, as function of MEGS 8.0 total_susp (g/m^3). Data from April 2007. Note the vertical cut-off at SPM of 20 g/m^3.