Performance of a dust-compensation algorithm for ocean color in SeaDAS: Initial results

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Introduction

A climate data record (CDR) is a time series of sufficient length, consistency and continuity to determine climate variability and change. Ocean color satellites are the source of global coverage data consisting of in-water leaving radiances and derived products such as chlorophyll a primary productivity. The collective data from past, present and future ocean color satellites will thus help evaluate if changes in ocean productivity are occurring.

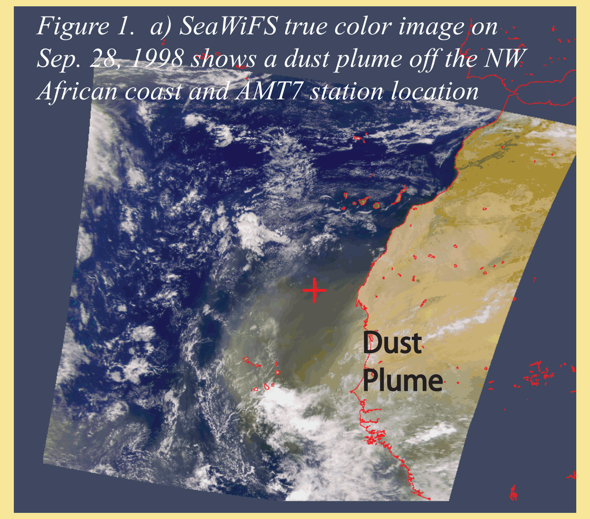


Figure 1. a) SeaWiFS true color image on Sep. 28, 1998 shows a dust plume off the NW African coast and AMT7 station location

Certain geographic locations are not well served by the ocean color dataset because of poor data retrieval caused by the presence of dust in the air (Fig. 1). The largest dust storms come off the African continent and propagate eastward over the Atlantic, or northward over the Mediterranean Sea.

The ability to retrieve in-water parameters from the raw satellite data depends to a large degree on the "atmospheric correction" (i.e., the removal of the effects of the intervening atmosphere). The most widespread aerosols are non- and weakly-absorbing types, and are well represented in the current atmospheric correction scheme. But over areas affected by absorbing aersols such as dust., the standard algorithms yield unrealistic values or fail completely.

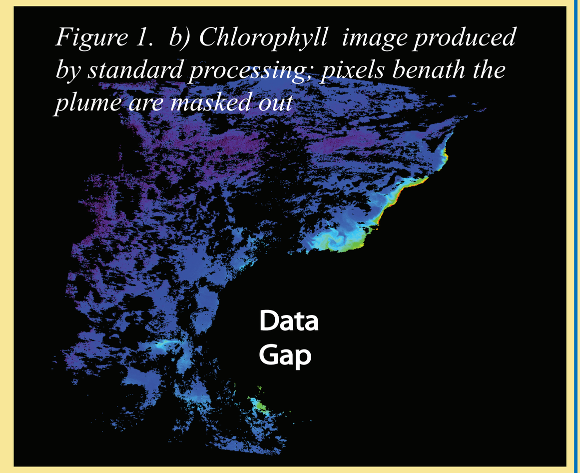


Figure 1. b) Chlorophyll image produced by standard processing; pixels benath the plume are masked out

What is SMA?

New algorithms, such as the spectral matching algorithm (SMA) used in this study, are being explored to recover data from dust-affected pixels in ocean color data. But before new methods can be adopted as part of the general processing scheme, they need to satisfy the requirements for accuracy in retrievals.

The spectral-matching algorithm or SMA (Gordon et al., 1997) compensates for the effects of dust aerosols by computing simultaneously in-water and aerosol properties, using information from all the ocean color bands. From a suite of 18 African dust models (3 sizes X 3 vertical heights X 2 absoprtion indices), it selects a single model that produces the least square error. Although it can also be run using scattering models only, mixing both scattering and dust models does not produce good results. In order to process the target pixels, all masks are turned off, since dust is highly reflective which triggers some masks, especially that for clouds. The current SMA version deals only with SeaWiFS bands. Applications to MODIS and future ocean color dataare possible, but not to CZCS due to insufficient band information.

Objective

Our objective was to embed SMA into SeaDAS, which is the current software environment widely used for ocean color processing, so that SMA results would be up-to-date in terms of calibration and other processing modifications. Previously, comparisons with in situ data and standard processing (STD) results had become difficult to evaluate. The preliminary results shown here provide the first look at the accuracy of SMA, and guidance on possible lines of improvement, so that SMA can eventually be useful in filling gaps in the long-term oceancolor dataset.

Northwest African Coast

Since SMA uses models with African dust properties, the N Atlantic is a good place to make initial tests. The example below on day 1998271 (Sep. 28, 1998) illustrates the differences between STD and SMA retrievals of in-water parameterwithin and outside a dust plume.

Beneath the plume, SMA processing yielded more realistic values (relative to clear-atmosphere images from previous days) for water-leaving radiances and the chlorophyll computed using the OC4V4 algorithm. The nLw_443 field is expected to be low over upwelling features rich in phytoplankton, while the nLw_555 is expected to be quites flat since chlorophyll absorption is minimal in this band.

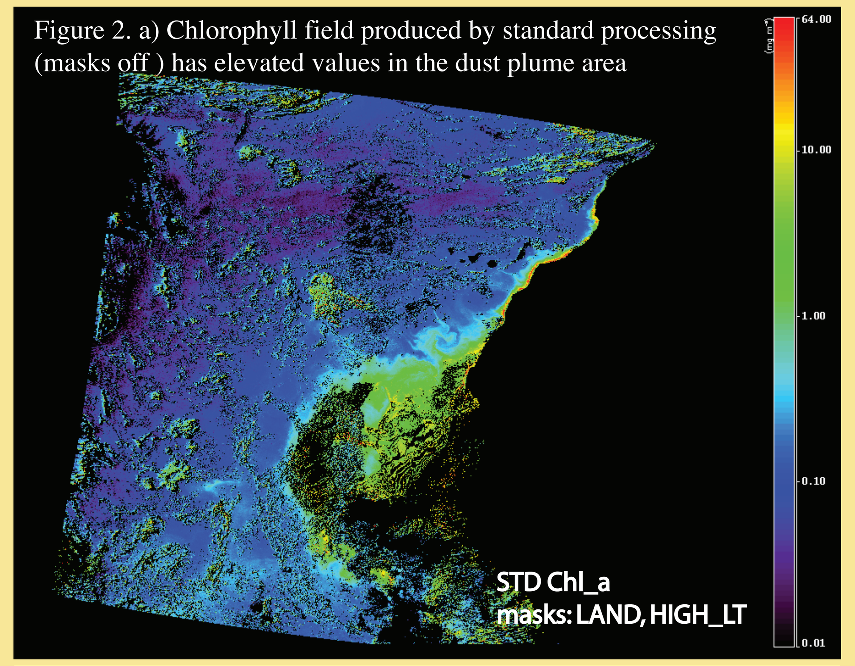


Figure 2. a) Chlorophyll field produced by standard processing (masks off) has elevated values in the dust plume area

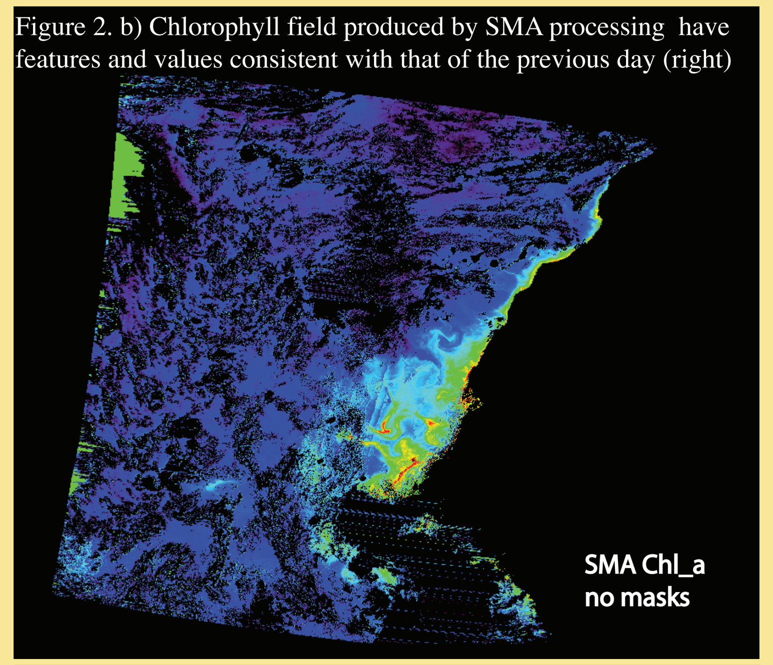


Figure 2. b) Chlorophyll field produced by SMA processing have features and values consistent with that of the previous day (right)

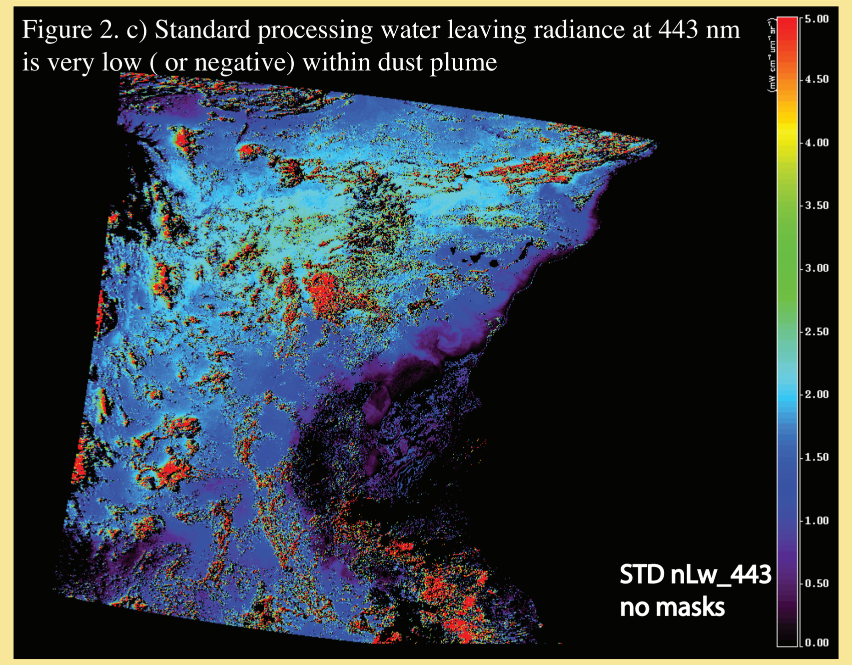


Figure 2. c) Standard processing water leaving radiance at 443 nm is very low (or negative) within dust plume

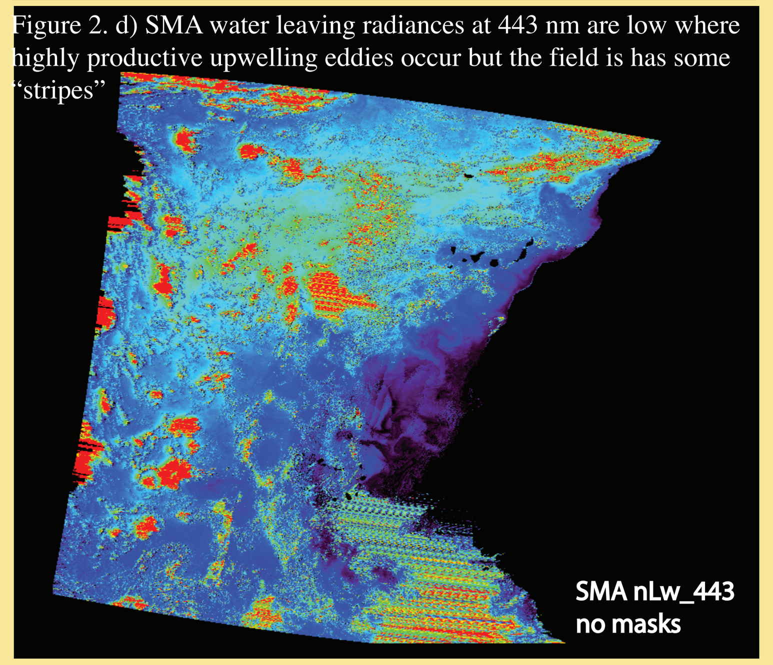


Figure 2. d) SMA water leaving radiances at 443 nm are low where highly productive upwelling eddies occur but the field is has some "stripes"

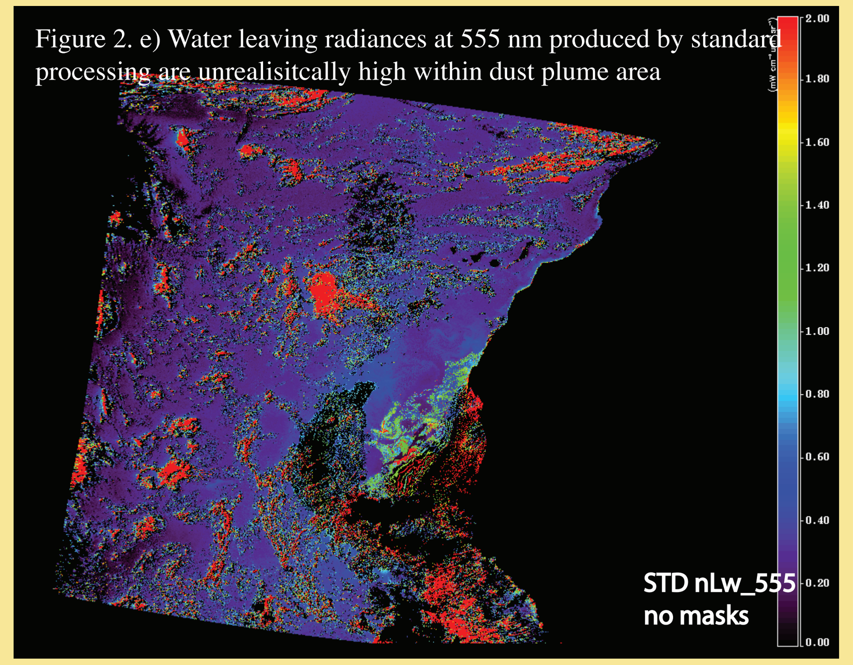


Figure 2. e) Water leaving radiances at 555 nm produced by standard processing are unrealisitcally high within dust plume area

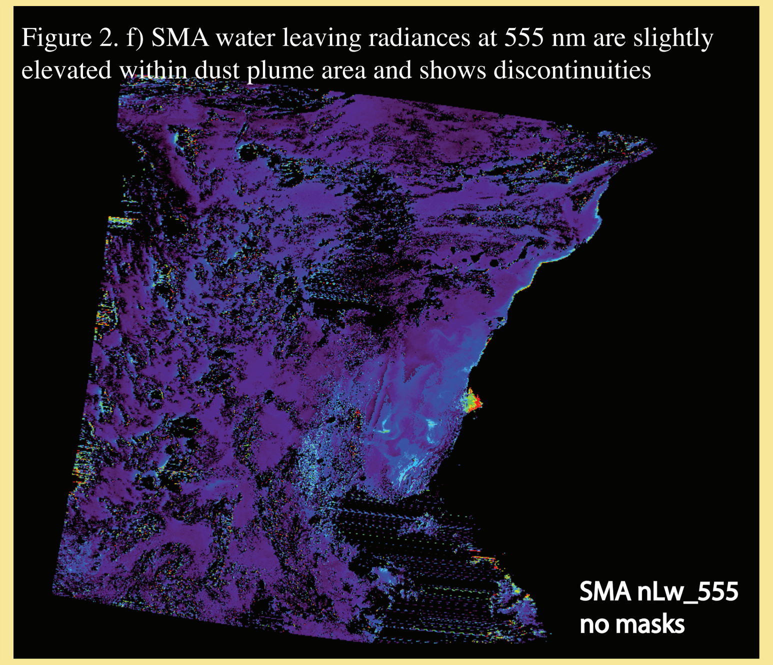


Figure 2. f) SMA water leaving radiances at 555 nm are slightly elevated within dust plume area and shows discontinuities

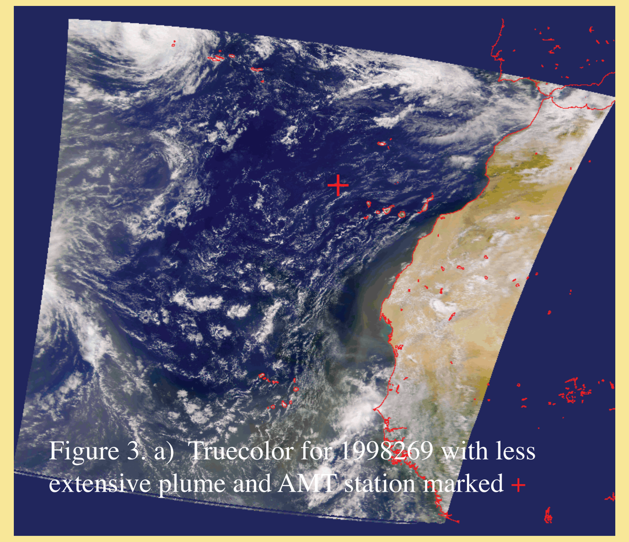


Figure 3. a) Truecolor for 1998269 with less extensive plume and AMT station marked +

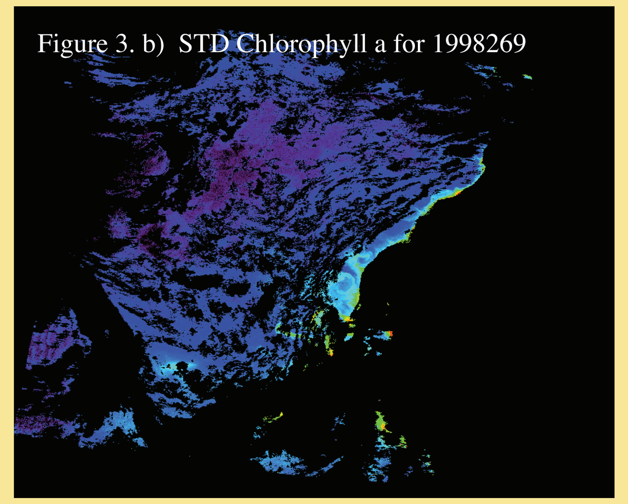


Figure 3. b) STD Chlorophyll a for 1998269

Comparison with in situ measurements at an AMT7 cruise station (see Acknowledgements; location shown in Figure 1. a) are summarized in the chart below. SMA results (red) were much closer to the in situ value (blue). The difference between the satellite and in situ values were as follows:

	SMA	STD
nLw_555	-7.2%	22.6%
nLw_443	-30.9%	-89.4%
Chlor_a	36.2%	690.1%

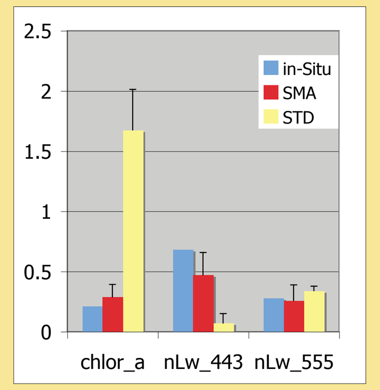


Chart 1. Retrieval comparisons for 1998271

A similar comparison was made for another station two days earlier using the corresponding image (Figure 3 a,b). The chart shows that in clear conditions, the standard method has better accuracy. The difference between satellite and in situ values were:

	SMA	STD
nLw_555	28.8%	10.4%
nLw_443	7.6%	-0.6%
Chlor_a	51.7%	27.6%

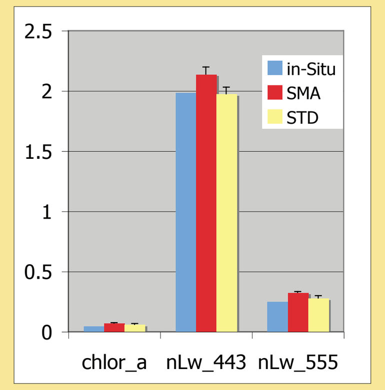


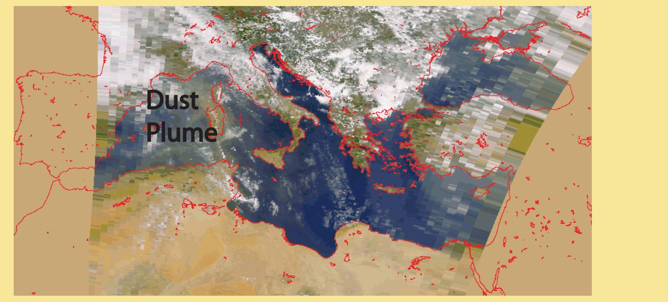
Chart 2. Retrieval comparisons for 1998269

STD and SMA have a slight overlap in the ability to deal with weakly absorbing aerosols, but with the magnitude of these error suggest it would be preferrable to avoid application of SMA to clear conditions. Thus a way to identify the target pixels is essential.

Mediterranean Sea

The Mediterranean Sea is generally oligotophic and waters are very clear. This area has been problematic for satellite data retrievals and many continue to investigate why satellite algorithms systematically underestimate water reflectance in the blue bands. Moreover, because of the very low chlorophyll levels, slight differences amount to a large %error between the measured and satellite values. Data from the AOPEX cruise in August 2004 was used to evaluate our test image. There was a dust plume over the ship station in the Tyrhennian sea (Fig. 4).. The results of SMA and STD processing are shown in Fig. 5 a-f.

Figure 4. Truecolor image for Aug 9, 2004



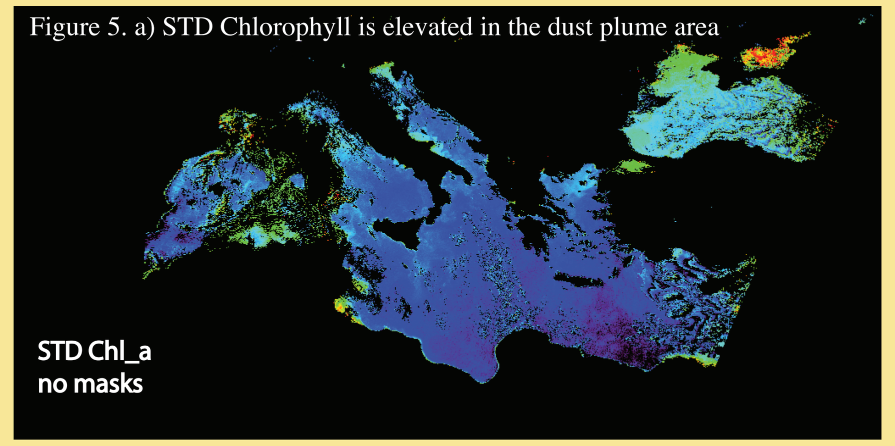


Figure 5. a) STD Chlorophyll is elevated in the dust plume area

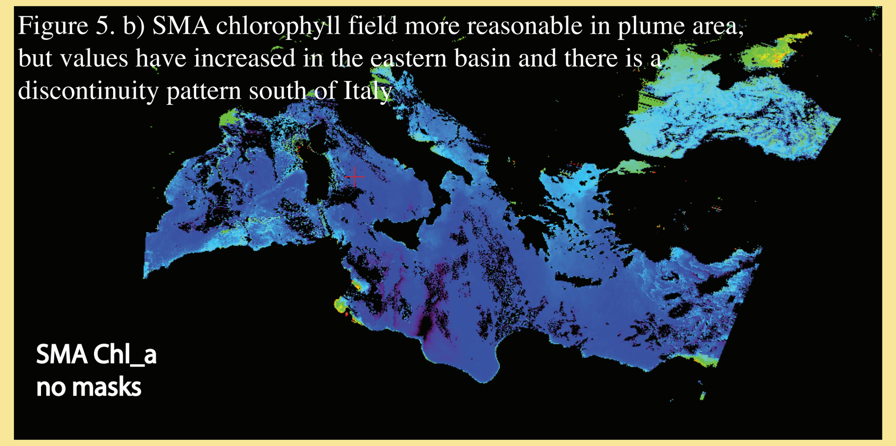


Figure 5. b) SMA chlorophyll field more reasonable in plume area, but values have increased in the eastern basin and there is a discontinuity pattern south of Italy

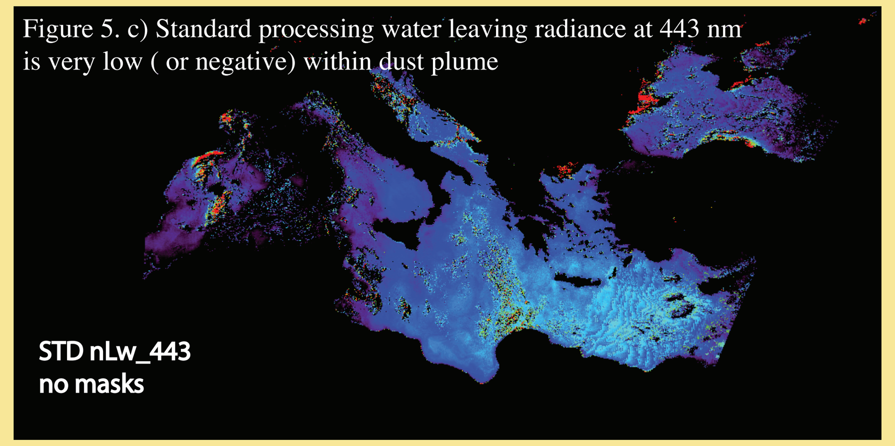


Figure 5. c) Standard processing water leaving radiance at 443 nm is very low (or negative) within dust plume

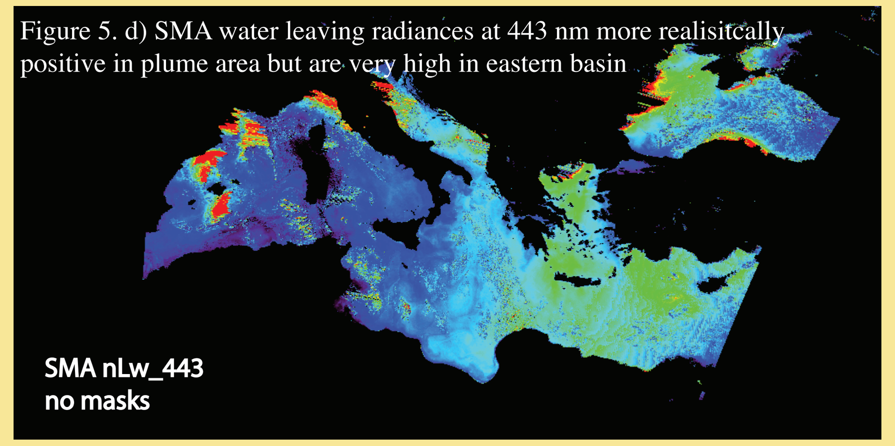


Figure 5. d) SMA water leaving radiances at 443 nm more realisitcally positive in plume area but are very high in eastern basin

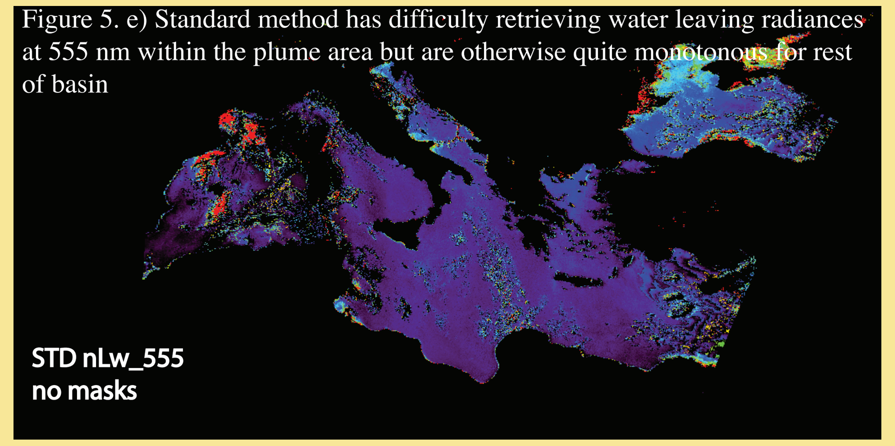


Figure 5. e) Standard method has difficulty retrieving water leaving radiances at 555 nm within the plume area but are otherwise quite monotonous for rest of basin

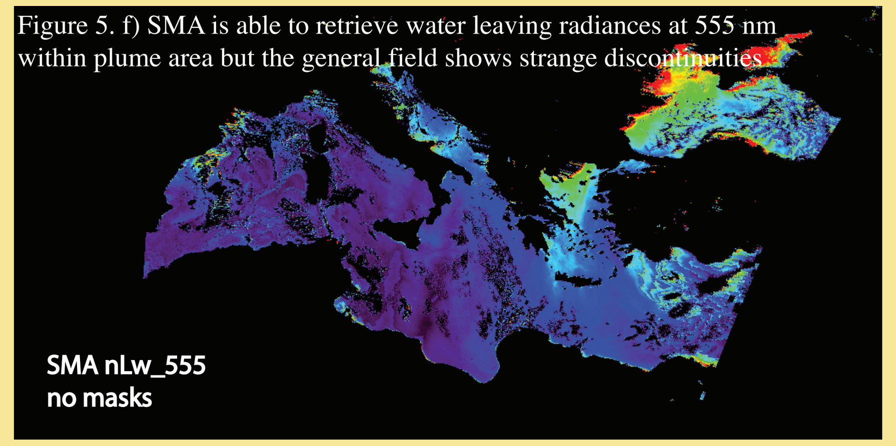


Figure 5. f) SMA is able to retrieve water leaving radiances at 555 nm within plume area but the general field shows strange discontinuities

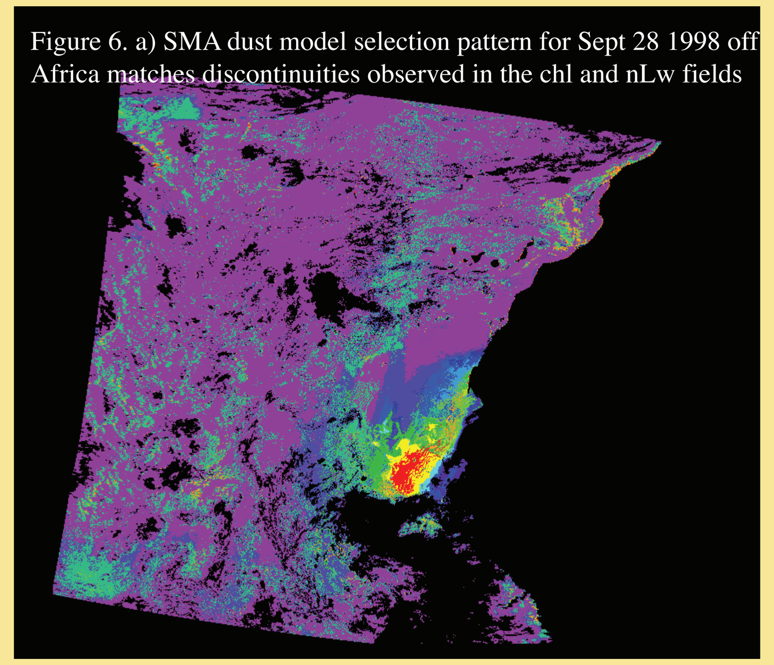


Figure 6. a) SMA dust model selection pattern for Sept 28 1998 off Africa matches discontinuities observed in the chl and nLw fields

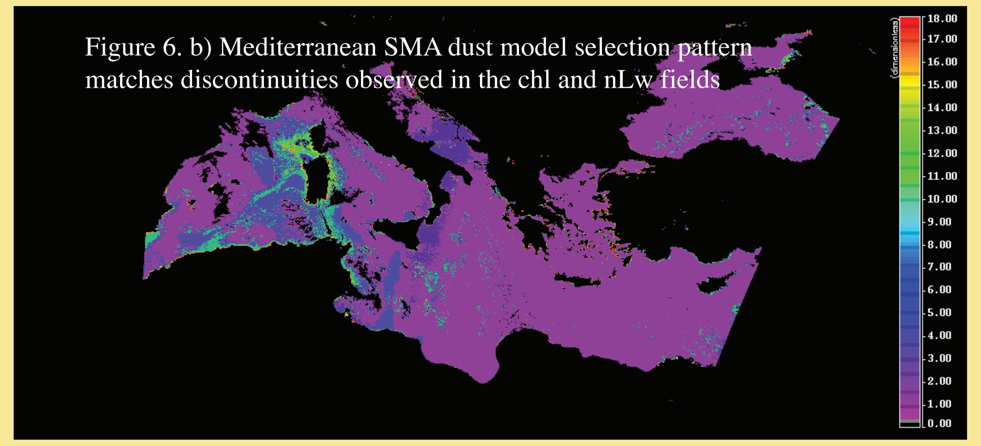


Figure 6. b) Mediterranean SMA dust model selection pattern matches discontinuities observed in the chl and nLw fields

Discontinuities in the model selection field occur in both SMA and standard processing (Fig. 6 a,b). But in standard atmospheric correction, two models are selected based on the near-IR data, and the actual amount of correction is interpolated between the two models. This helps create a smooth output field. In SMA, only one model is selected. Moreover the models are strongly absorbing and so the difference between models can be more noticeable. Thus, to avoid the discontinuities in SMA outputs, one could increase the number of dust models to select from, or mimic the standard procedure. That is, select two of the best models and interpolate.

Comparison of satellite retrievals to data from the AOPEX cruise station on August 9, 2004 (location shown in Figure 5b) is summarized in Chart 3 below. SMA results (red) were much closer to the in situ values (blue), than the standard processing (yellow). The % difference between the satellite and in situ values were as follows:

	SMA	STD
nLw_555	21.2%	45.9%
nLw_443	-7.8%	-35.2%
Chlor_a	97.3%	232.0%

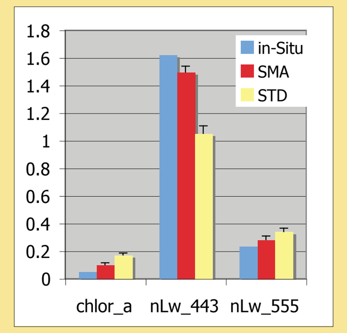


Chart 3. Retrieval comparisons for 2004222_TYR

SMA performed better than STD since this station was located in a dust-affected area. Outside the dust area, the SMA tends to overestimate in water radiances especially in the 443 band (not shown).

An additional issue in Mediterranean Sea is that the OC4V4 algorithm does not provide a good estimate of chlorophyll. Therefore, a more appropriate algorithm needs to be used to compute chlorophyll from the satellite nLw measurments. However, errors in those measurements are still too large to even explore the chlorophyll algorithm issue.

Conclusions

SMA has been successfully incorporated in the SeaDAS processing environment, yielding more realistic in-water values in dust-affected areas than the standard processing. This has made comparisons with in situ data possible. Initial results suggest that SMA retrieval accuracy is not yet sufficient to contemplate widespread use and implementation to improve the coverage of the long-term datasets. The water leaving radiances produced are not within 5% of the in situ values and the chlorophylls are not within 35%. Also, although SMA processing should be applied only to the target pixels because the greater retrieval error in clear atmospheric conditions. In general, the method appears to work better in the Atlantic waters than in the Mediterranean Sea.

Discontinuitites in the SMA-retrieved fields are related to shifts in model selection, since SMA selects only one model. These shifts occur in standard processing but is smoothed when the correction is interpolated between two models. Future work will need to explore using the two-model approach in SMA.

A more comprehensive match-up effort needs to be made. Because the masks are disabled in order to process the target pixels, a statistical study of the matchups will be needed to decide which how to flag the output pixels.

Acknowledgements

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