Atmospheric Correction of Satellite Ocean-Color Imagery In the Presence of Sun Glint, Sea Ice, and Clouds

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References

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Steinmetz, F., P.-Y. Deschamps, and D. Ramon, 2008: Atmospheric correction in presence of sun glint: application to MERIS. 2nd MERIS (A)ATSR workshop 2008, 22-26 September, 2008. ESRIN, Frascati, Italy.

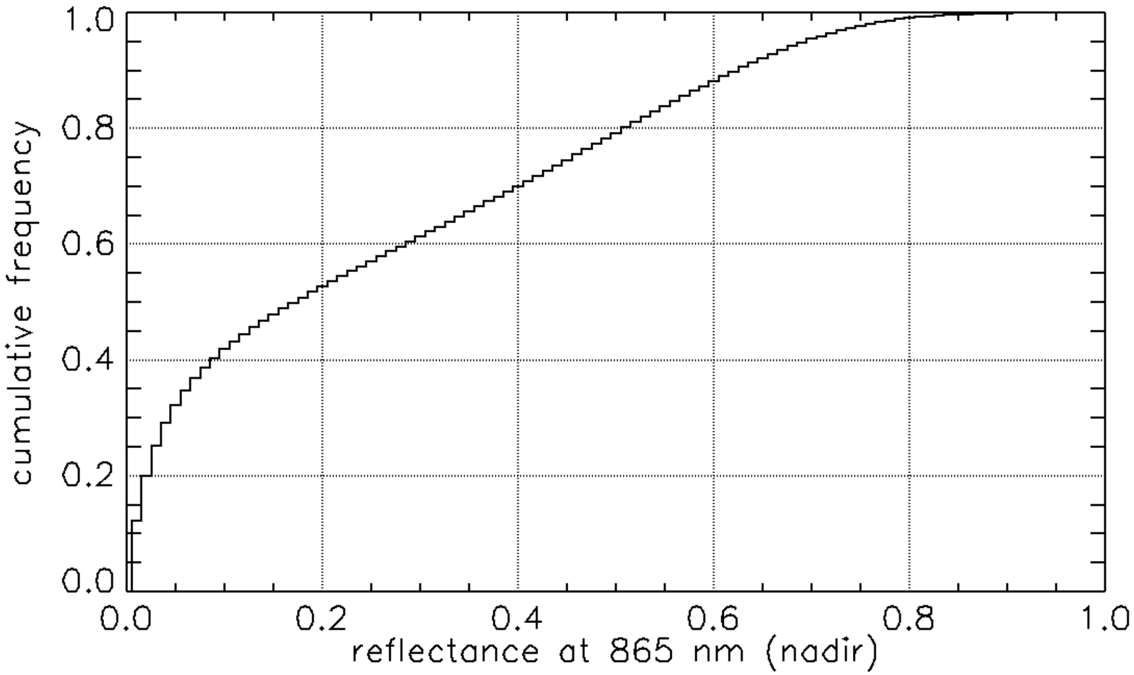
Introduction

-It is currently admitted that ocean color can be observed from space only over cloud-free and Sun glint-free areas.

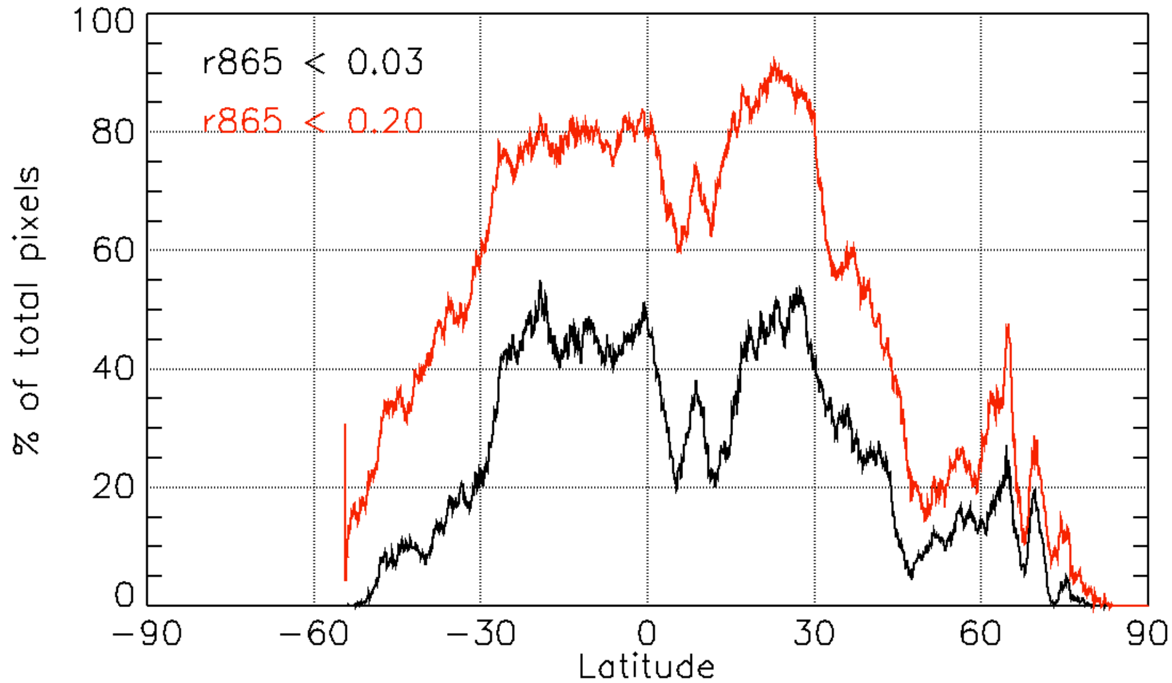
-In the state-of-the-art algorithms, the presence of a cloud or even a minimum amount of Sun glint definitely prevents utilization of the data.

-Consequently, the daily ocean coverage is typically 15-20%, and weekly products show no information in many areas.

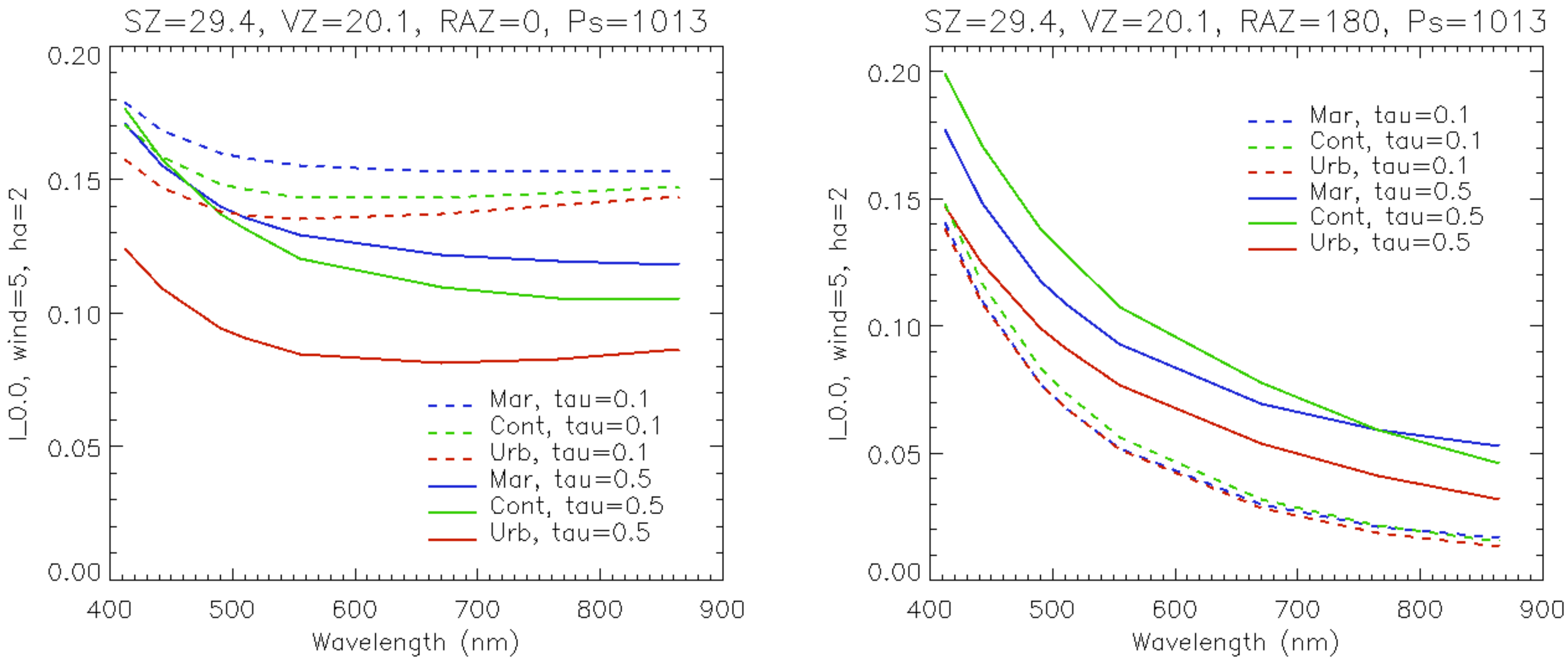
-This limits considerably the utility of satellite ocean color observations in oceanography. Global coverage is required every three to five days in the open ocean and at least every day in the coastal zone.



Cumulative histogram of the top-of-atmosphere reflectance at "nadir" observed by POLDER-2 over the global ocean on 02 July 2003. Here "nadir" refers to the direction of observation closest to nadir.



Percentage of POLDER-2 pixels (observations of 02 July 2003) selected by a threshold of 0.03 and 0.2 for the "nadir" reflectance at 865 nm.



Simulations, using a successive-orders-of-scattering code, of the top-of-atmosphere normalized radiance in the solar plane for several aerosol conditions. Water body is black. (Left) Forward scattering. (Right) Backscattering.

-Perturbing signal results from many processes and couplings, that may be difficult to model accurately.

Remark

-Perturbing signal is smooth spectrally.

-It can be represented by a polynomial or a linear combination of orthogonal components with a few terms or eigenvectors

$$\rho_p(\lambda_i) \approx \Sigma_j \, [a_j \lambda_i^{nj}]$$

$$\rho_p(\lambda_i) \approx \Sigma_j \, [c_j e_{ji}]$$

-Three n_j or e_j are usually sufficient.

-Representation is fairly general.

Methods

-Spectral Optimization (POLYMER)

-PCA-Based atmospheric correction

POLYMER Algorithm

-Originally developed to process MERIS data in glitter-affected areas (Steinmetz et al., 2008).

-Does not use a specific aerosol model, but fits the atmospheric reflectance by a polynomial with

(a) a non-spectral term that accounts for any non-spectral scattering (*clouds, aerosol coarse mode*) or reflection (*glitter, whitecaps, small ice surfaces*),

(b) a spectral term with a power law in λ^{-1} (*fine aerosol mode*), and

(c) a spectral term with a power law in λ^{-4} (*adjacency effects from clouds and white surfaces*).

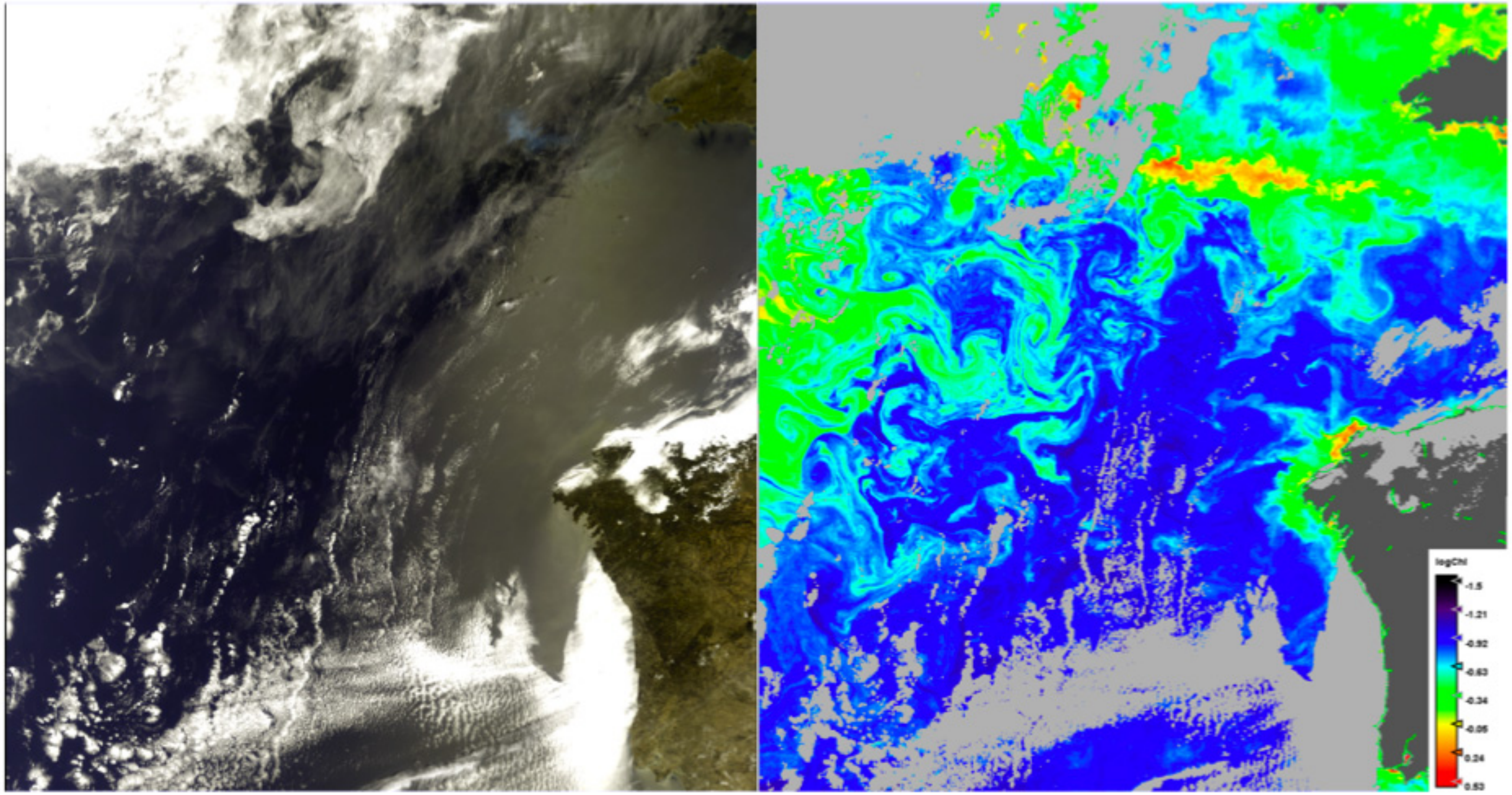
$$\rho_{gam} = \rho_p - \rho_m = C_0 + C_1 \lambda^{-1} + C_2 \lambda^{-4}$$

POLYMER Algorithm (cont.)

-Marine reflectance is parameterized as a function of the chlorophyll concentration, *Chl*, and a backscattering coefficient for non-phytoplankton particles, B_{bs}.

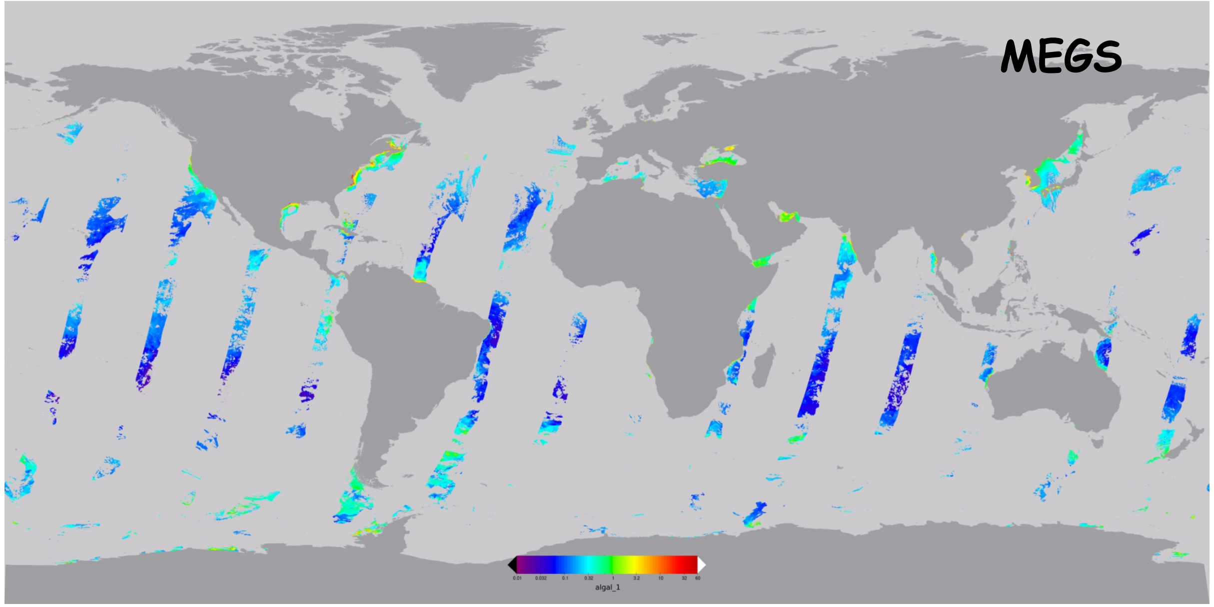
-The five parameters C_0, C_1, C_2, *Chl*, and B_{bs} are determined by minimizing the difference between observed and modeled reflectance.

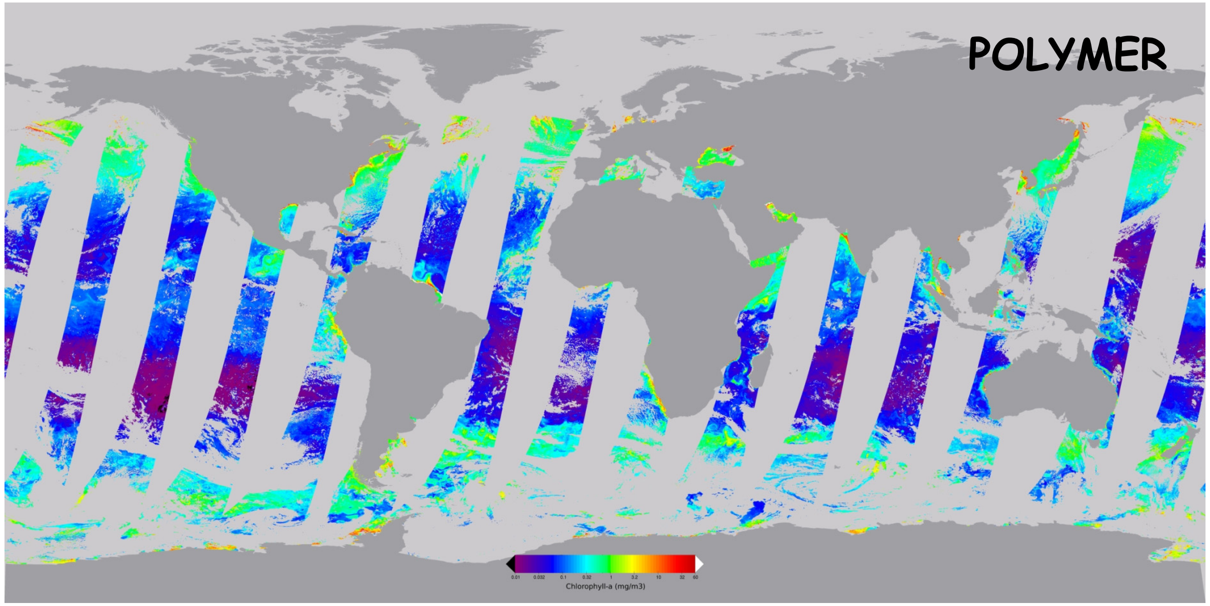
Example of MERIS data processing by the POLYMER algorithm



RGB composite of a MERIS scene off Portugal, 21 June 2005 (left) and chlorophyll concentration derived by the POLYMER algorithm (right). Chlorophyll concentration is retrieved in the presence of thin clouds and sun glint, and the chlorophyll patterns exhibit spatial continuity from cloud- and glint-free areas to adjacent cloud- and/or glint-contaminated areas.

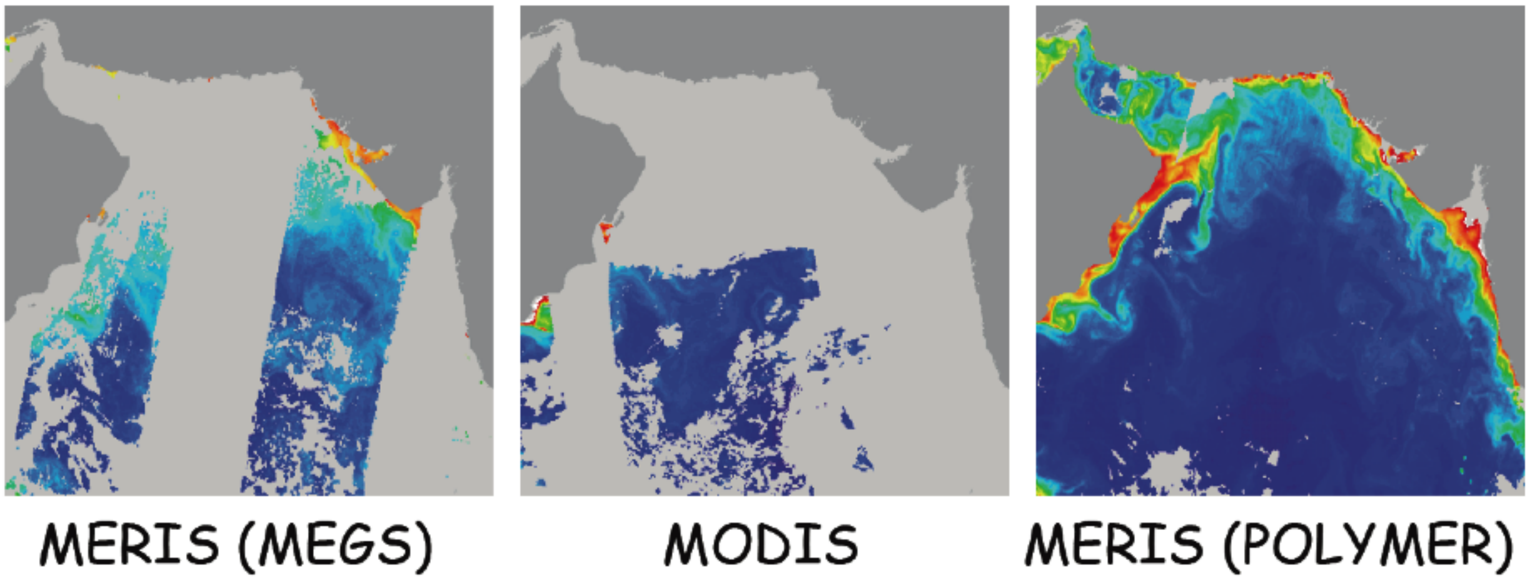
Increase in daily spatial coverage by the POLYMER algorithm



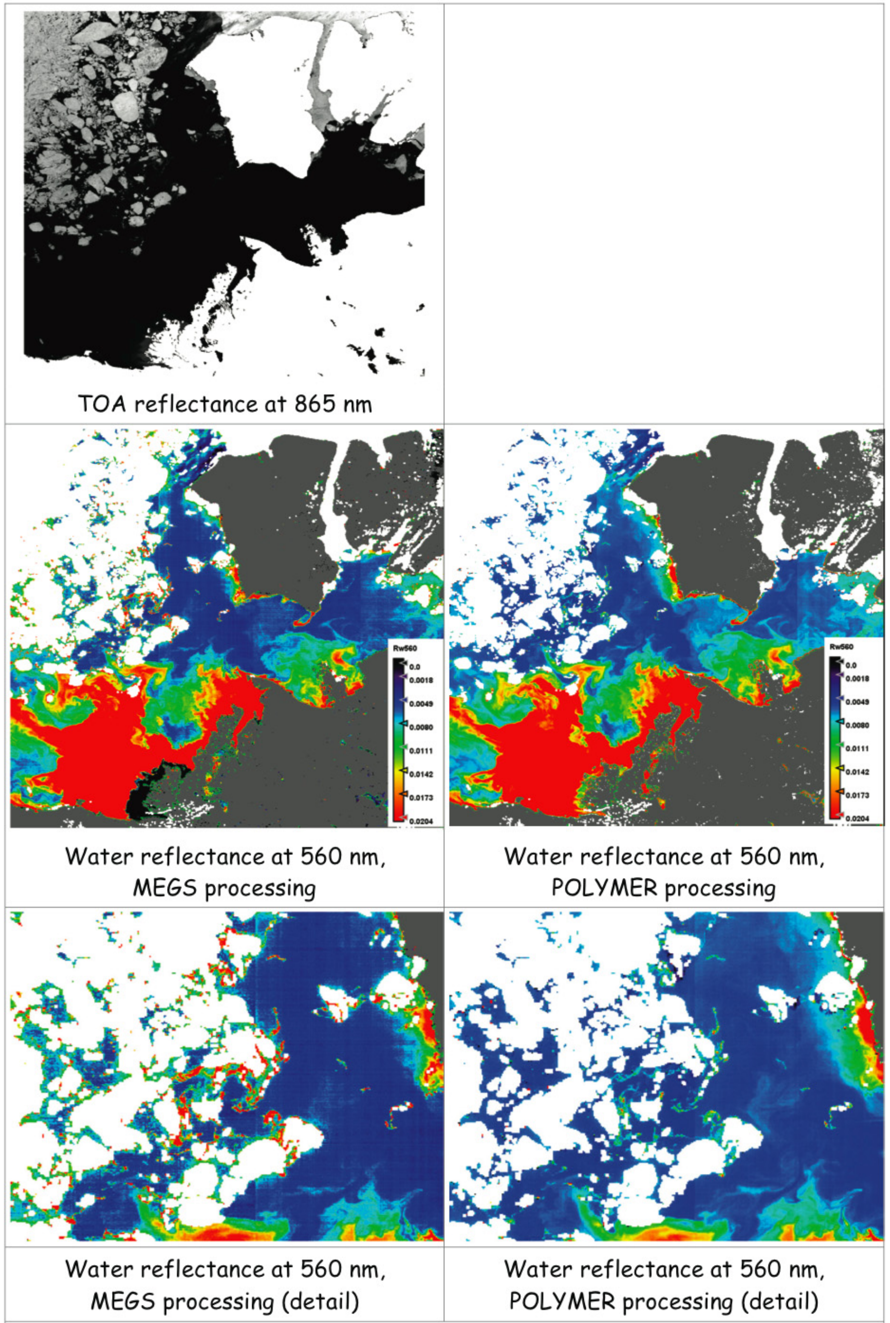


MERIS level 2 imagery of chlorophyll concentration, 21 December 2003.

Increase in spatial coverage by the POLYMER algorithm, 3-day composite



Level 3 composites of chlorophyll concentration, 3 to 5 June 2003, in the Arabian Sea, showing a dramatic increase in spatial coverage by the POLYMER algorithm.



TOA reflectance at 865 nm

Water reflectance at 560 nm, MEGS processing

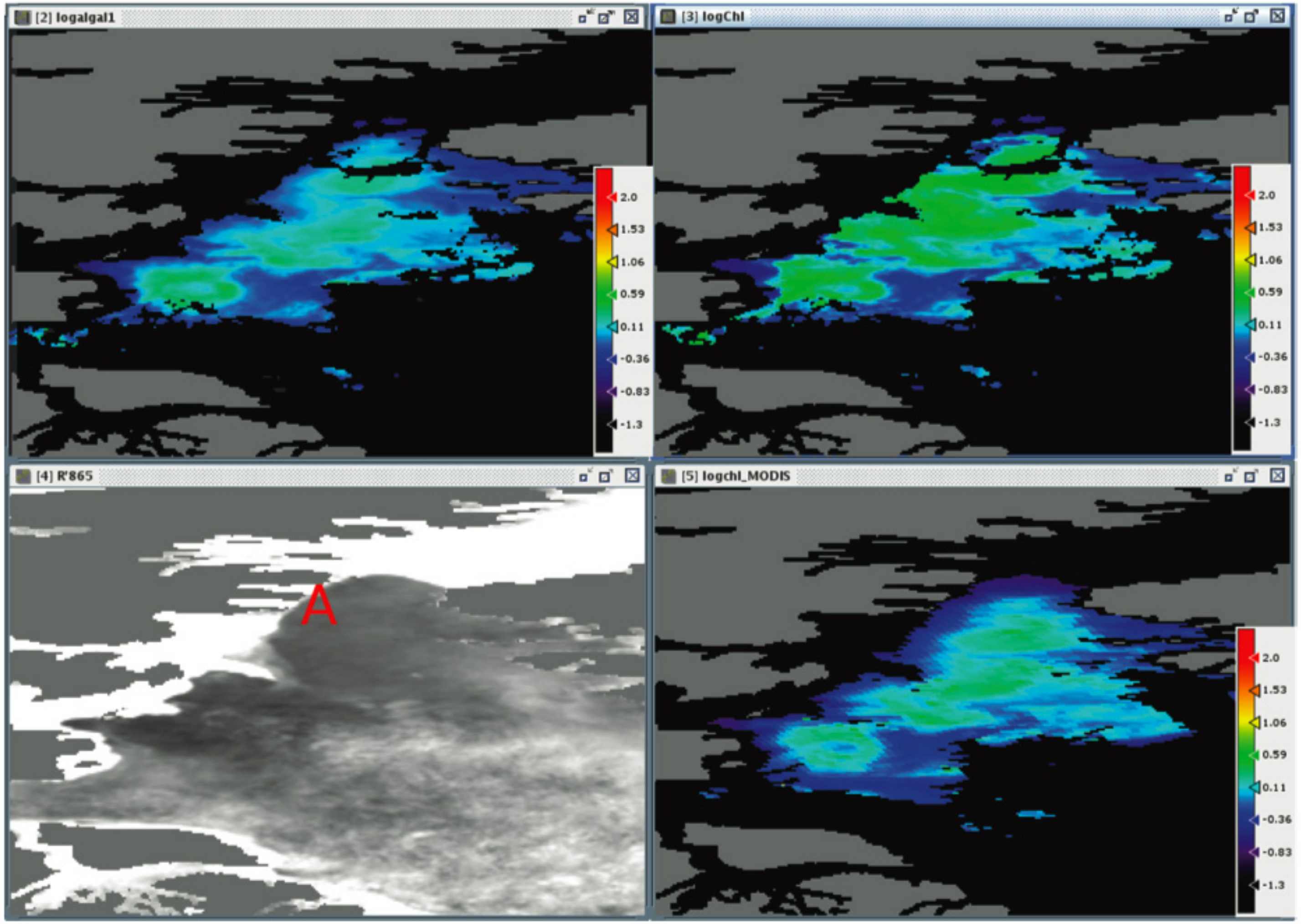
Water reflectance at 560 nm, POLYMER processing

Water reflectance at 560 nm, MEGS processing (detail)

Water reflectance at 560 nm, POLYMER processing (detail)

Beaufort Sea, 2008-07-04, MERIS

MERIS image of the Beaufort Sea, at the delta of the Mackenzie river, showing that the marine reflectance derived by the POLYMER algorithm is consistent over ice-free areas in the middle of the ice pack, while the MEGS processing is affected by the ice environment, leading to an anomalous increase of retrieved reflectance.



8-day level 3 composites of chlorophyll concentration in the bay of Baffin, from 2003-06-02 to 2003-06-09. The color scale unit is log10(chl). Top-left: Standard processing of MERIS data, top-right: POLYMER processing of MERIS data, bottom-left: observation at 865 nm, and bottom-right: MODIS level 3 processing. The MERIS standard processing and the MODIS processing show an anomalous decrease of chlorophyll concentration in the vicinity of the ice shelf (marked by "A"), but not the POLYMER processing.

PCA-Based Algorithm

-TOA reflectance (after correction for molecular scattering) is decomposed in principal components.

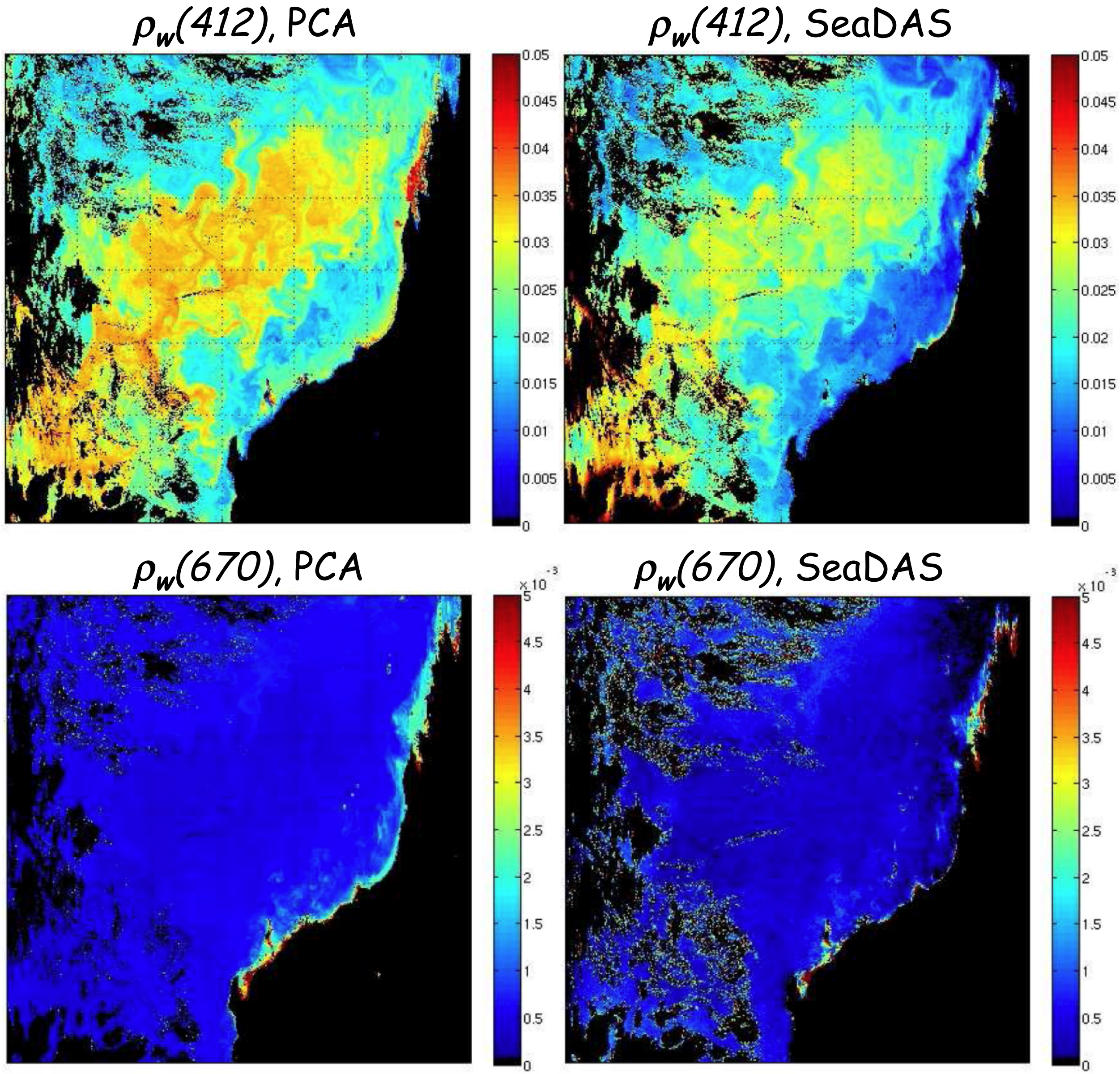
-Components sensitive to the ocean signal are combined to retrieve the principal components of marine reflectance, allowing reconstruction of the marine reflectance.

$$\rho = \rho_{TOA} - \rho_m = f(\rho_w)$$

$$\rho = \Sigma_i\, c_{pi}\, \mathbf{e}_{pi}$$

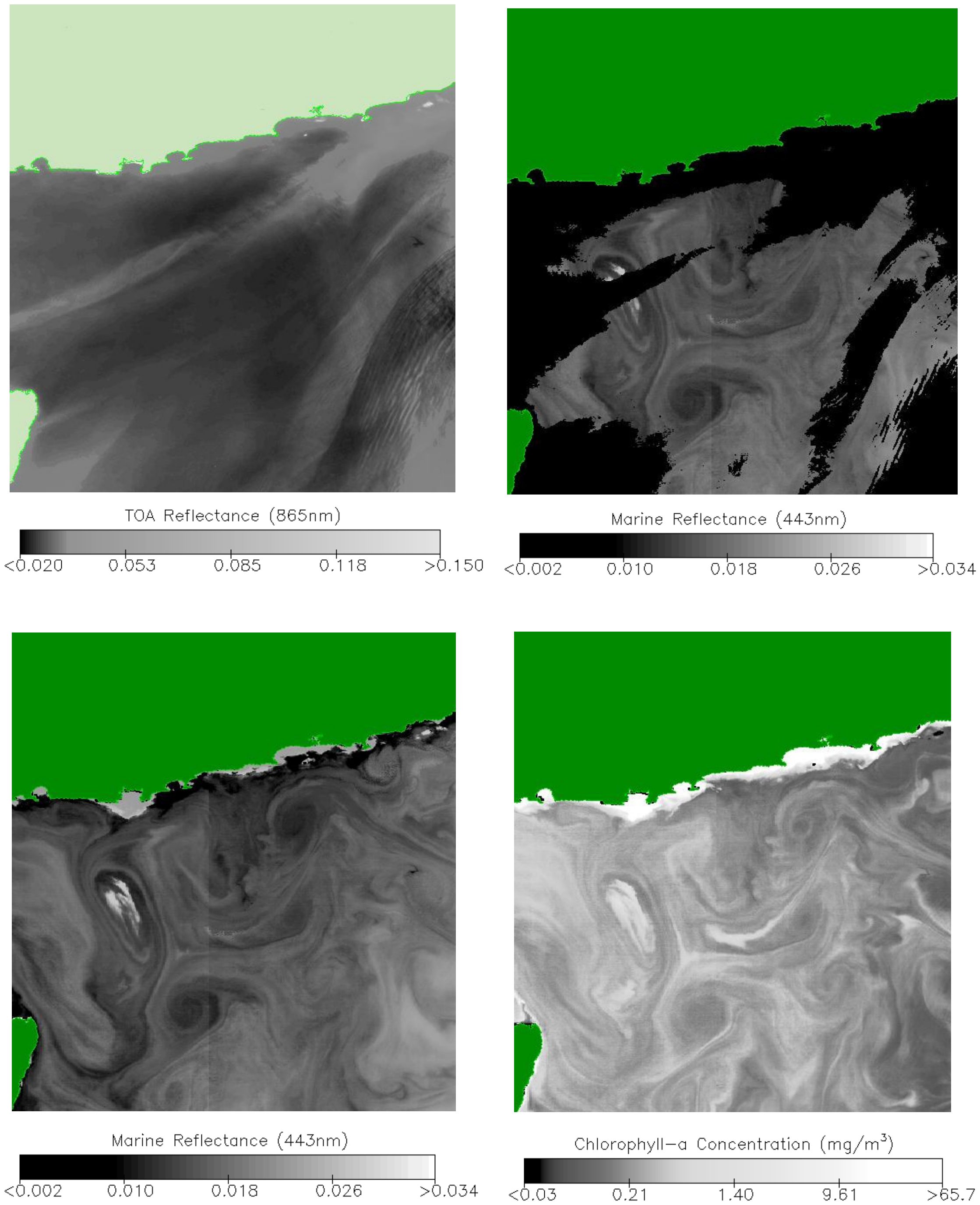
$$\rho_w = \Sigma_j\, c_{wj}\, \mathbf{e}_{wj}$$

$$c_{wj} = g(c_{pi}\text{'s})$$



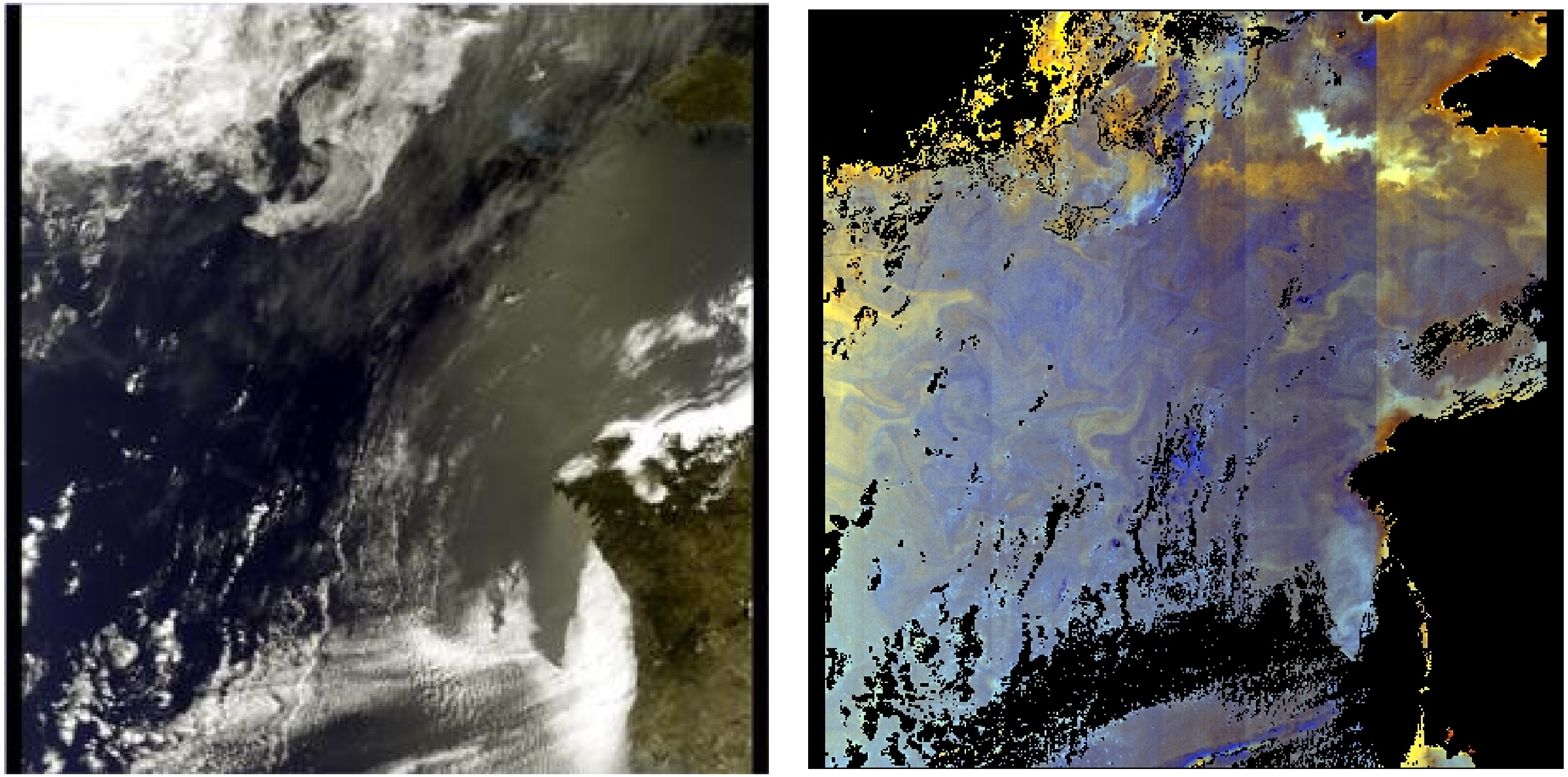
Marine reflectance retrieved from SeaWiFS data using the PCA method (left) and SeaDAS (right). PCA reflectance is slightly higher in the blue. PCA imagery is less noisy.

PCA-Based retrieval, Arabian Sea



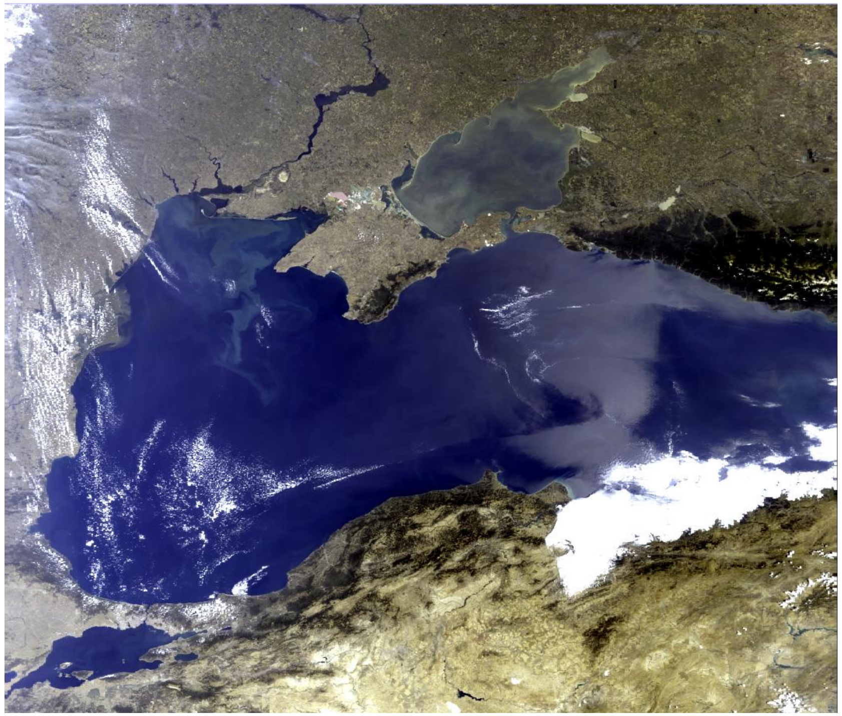
Imagery acquired by MERIS over the Arabian Sea on 09 November 2003. Top left: Reflectance at 865 nm showing thin clouds. Top right: Retrieved marine reflectance (PCA-based algorithm) with threshold of 0.03 at 865 nm. Bottom left: Same as upper right, but threshold of 0.2 at 865 nm. Bottom right: Retrieved chlorophyll-a concentration with threshold of 0.2 at 865 nm.

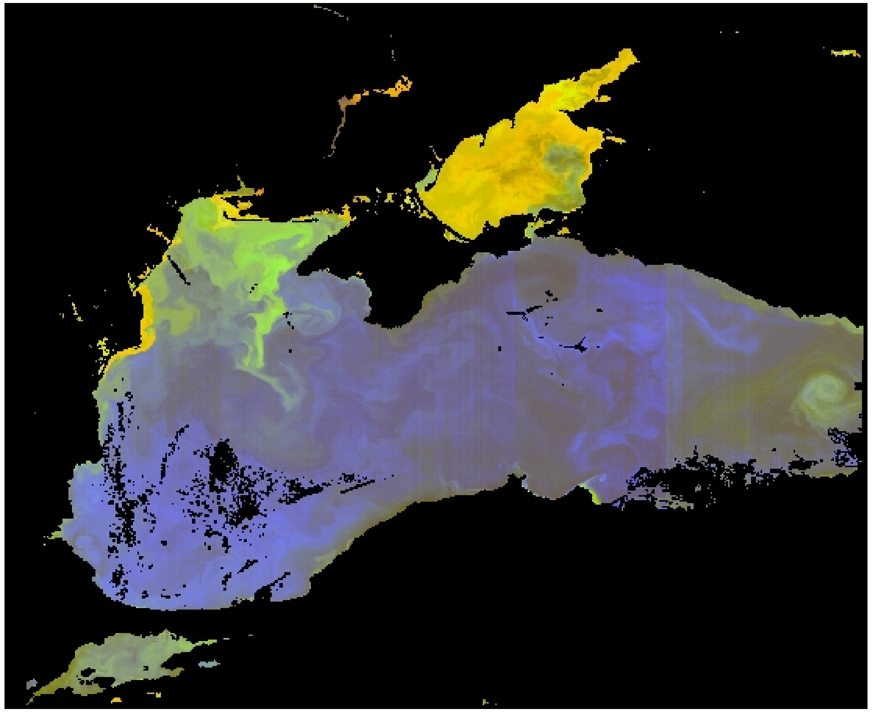
PCA-based retrieval, Northeast Atlantic



(Left) RGB composite of MERIS imagery off the coast of France and Portugal, 21 June 2005. (Right) RGB composite of marine reflectance retrieved by the PCA algorithm. Marine reflectance is retrieved in the presence of thin clouds and sun glint.

PCA-Based retrieval, Black Sea





(Left) RGB composite of MERIS imagery of the black Sea. (Right) RGB composite of marine reflectance retrieved by the PCA algorithm. Marine reflectance is retrieved in the presence of thin clouds and sun glint.

Conclusions

-Atmospheric correction of satellite ocean-color imagery can be performed through thin clouds and in the presence of Sun glint, and in the vicinity of clouds, sea ice, and land.

-The POLYMER and PCA-based algorithms yield imagery that is comparable with standard imagery. Spatial continuity is good from cloud- and glint-free areas to adjacent cloudy and/or glint-affected areas, and values are more realistic near sea ice.

-The daily ocean coverage, 15-20% with standard algorithms, is expected to increase substantially with the POLYMER and PCA-based algorithms (by up to 50%?).

-The gain in coverage will allow one to resolve better phytoplankton blooms in the open ocean and "events" linked to wind forcing in the coastal zone. This could lead to important new information about the temporal variability of biological processes.