A New Blended Near-infrared Ocean Reflectance Correction Algorithm for Satellite Ocean Color Data Processing in Coastal and Inland Waters

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Abstract

A new approach that combines advantages of various existing near-infrared (NIR) ocean reflectance correction algorithms for satellite ocean color data processing, including Bailey et al. (2010) algorithm, Ruddick et al. (2000) "MUMM" algorithm, and Wang et al. (2012) algorithm, has bee developed. The new algorithm is named BMW after Bailey, MUMM, and Wang. The results from the BMW algorithm are evaluated against those from the shortwave infrared (SWIR)-based atmospheric correction algorithm and also compared with results from various existing NIR ocean reflectance correction algorithms using data from **MODIS-Aqua** and **VIIRS-SNPP**, with emphasis on the performance in various coastal and inland turbid waters in the world. The new BMW algorithm provides improved satellite ocean color results compared with various existing NIR algorithms and can be incorporated into the official VIIRS ocean color data processing system, which does not have the NIR radiance correction algorithm that is required for the data processing in coastal and inland waters. Some detailed algorithm evaluations and discussions are provided.

Three different methods for estimation of ocean reflectance at the NIR bands

B: The bio-optical model described by Bailey et al. (2010) is used in the current NASA MODIS atmospheric correction algorithm, which is an improved version of the Stumpf et al. (2003) model. It exploits the relationships in the intrinsic optical properties (IOP) of the NIR and red/green bands. However, the disadvantage is that it cannot be applied to extremely turbid waters because the IOP relationship stops to work in those areas.

M: The MUMM algorithm described by Ruddick et al. (2000) is originally proposed for SeaWiFS. Its advantage is that it does not use any bio-optical model and it simultaneously solves for water-leaving reflectance and aerosol reflectance at the two NIR bands. However, it requires knowing ***a priori*** the reflectance ratios between the two NIR bands for both water (α) and aerosol (ε) contributions obtained from a scatter plot of the entire scene, which limits its operational usage.

W: Wang et al. (2012) proposed a regional, iterative method for estimation of water reflectance at the NIR from diffuse attenuation coefficient $K_d(490)$, to be used in the atmospheric correction algorithm for the Korean geostationary ocean color sensor – the Geostationary Ocean Color Imager (GOCI). The NIR model (radiance relationship between two NIR bands) was derived from MODIS data using the SWIR approach. Its field of view include one of the most turbid areas in the world where the current MODIS algorithm will not work. GOCI does not have SWIR bands that can be used for atmospheric correction purpose.

BMW - the new blended algorithm

Simply speaking, the proposed blended algorithm uses **B** algorithm to identify and process clear water pixels and **M** algorithm to process the remaining turbid water pixels, and for the turbid water pixel processing **M** algorithm uses the NIR water reflectance relationship established by **W** algorithm and NIR aerosol reflectance ratio (ε) derived from nearby clear water pixels. In detail, the BMW algorithm works as follows:

1. Use **B** algorithm to perform a preliminary atmospheric correction, identify clear water pixels and save their corresponding NIR aerosol reflectance ratio ε (If a valid pixel is not a clear water pixel, it is regarded as a turbid water pixel).
2. For each turbid water pixel not yet assigned an ε value, assign it an ε value using the mean of the ε values of all clear or turbid water pixels (that have already been assigned an ε value) within the 101 pixels by 101 pixels box centered at this turbid water pixel. If no clear water pixel is found within the box, this turbid water pixel will wait for assignment of ε value in the next iteration.
3. Repeat Step 2 until no more turbid water pixels can find clear water pixels or turbid water pixels that has been assigned an ε value. The remaining turbid water pixels are assigned the mean ε value of all clear pixels in the image.
4. Use **M** algorithm incorporated with **W** algorithm's NIR water reflectance relationship to process all the turbid water pixels using their assigned ε values.

Results: case studies

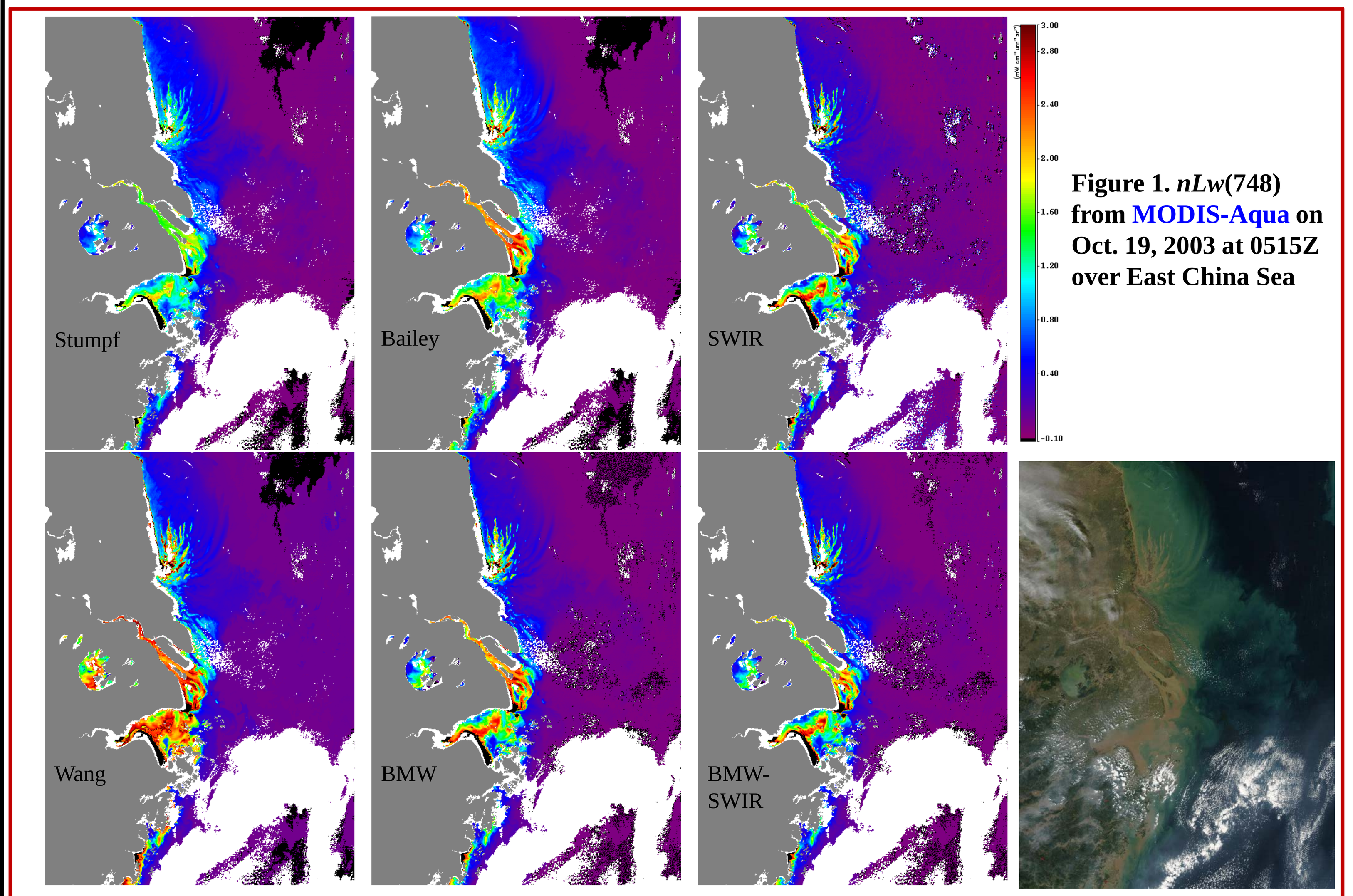

Figure 1. $nLw(748)$ **from MODIS-Aqua on Oct. 19, 2003 at 0515Z over East China Sea**

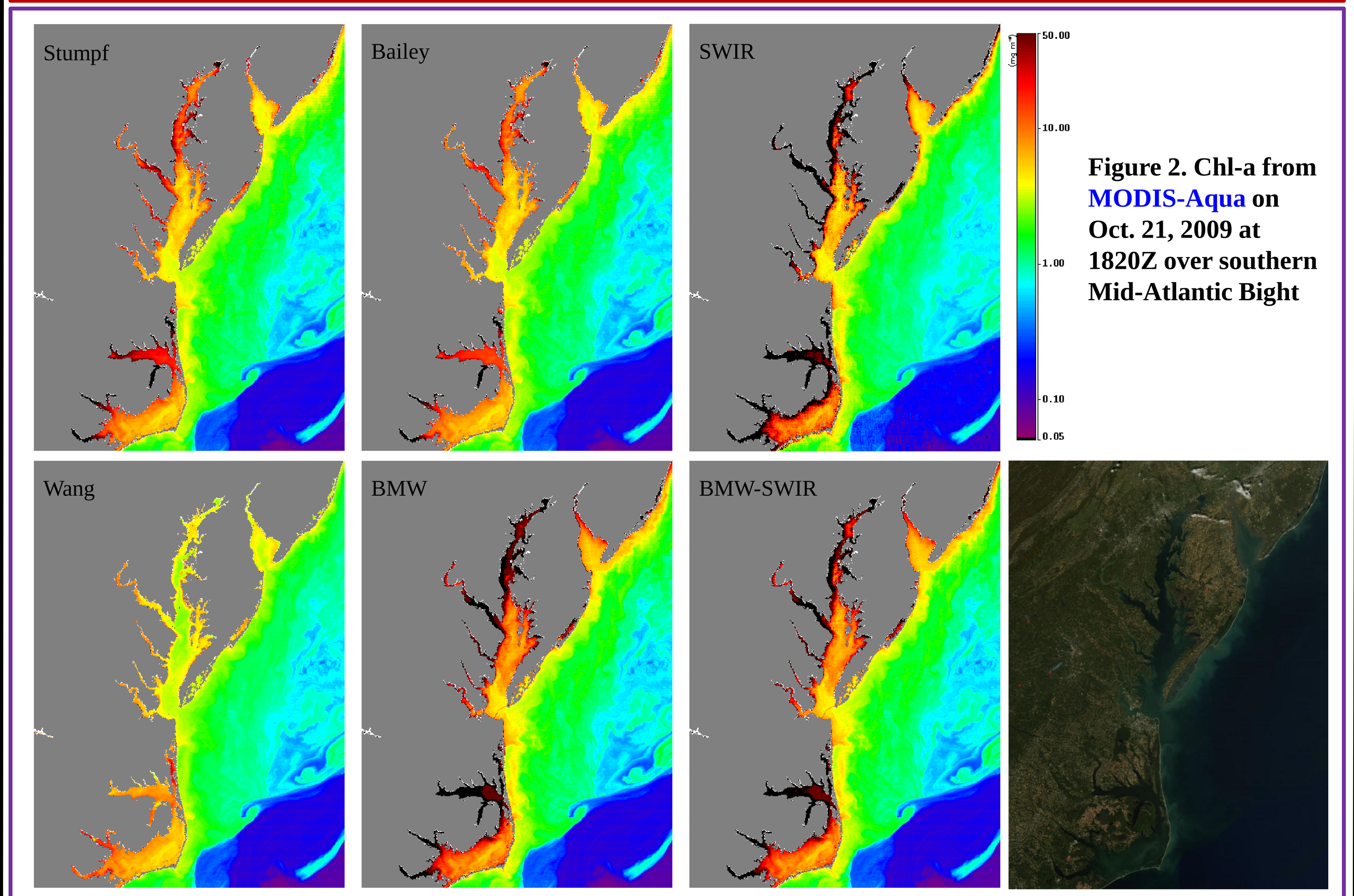

Figure 2. Chl-a from MODIS-Aqua on Oct. 21, 2009 at 1820Z over southern Mid-Atlantic Bight

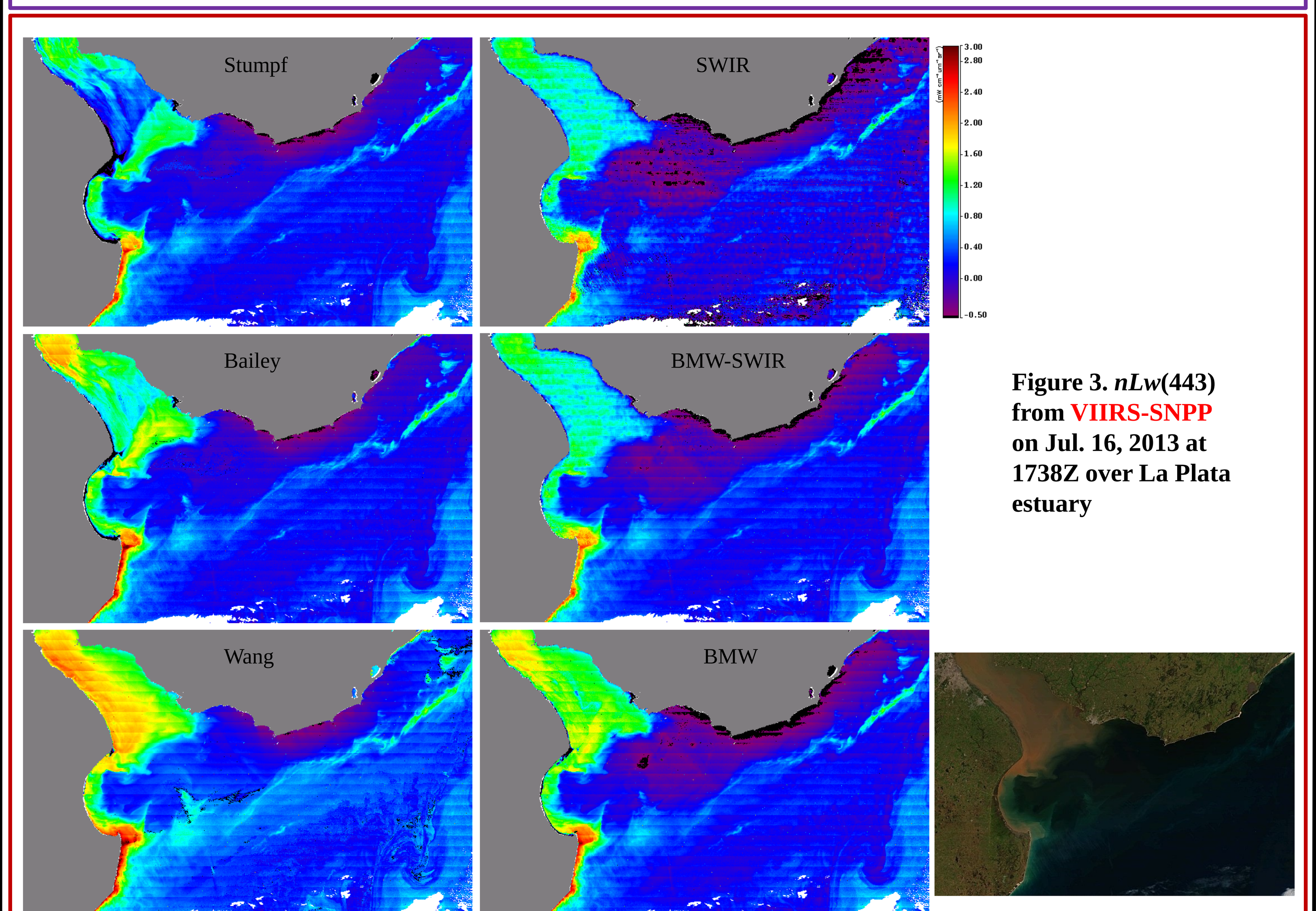

Figure 3. $nLw(443)$ **from VIIRS-SNPP on Jul. 16, 2013 at 1738Z over La Plata estuary**

The NIR-SWIR processing using BMW

Although the BMW algorithm works reasonably well in very turbid waters, there are circumstances where the SWIR algorithm is necessary. For example, in MODIS-Aqua images, 746 and 869 nm often get saturated in extremely turbid waters, such as in the La Plata estuary (Fig. 4), which will prevent the applicability of any NIR algorithm. Also, for highly turbid waters the NIR model is not accurate. Therefore, a NIR-SWIR processing algorithm using BMW as NIR component was developed to solve this problem. The BMW is first used to process all pixels, which is also used to identify turbid pixels with water-leaving radiances at ~865 nm band larger than a threshold (~0.2). For those turbid waters the SWIR algorithm is used, but there is a buffer zone 0.2-0.4 where the BMW and SWIR results are blended to create a smooth transition between the two algorithms.

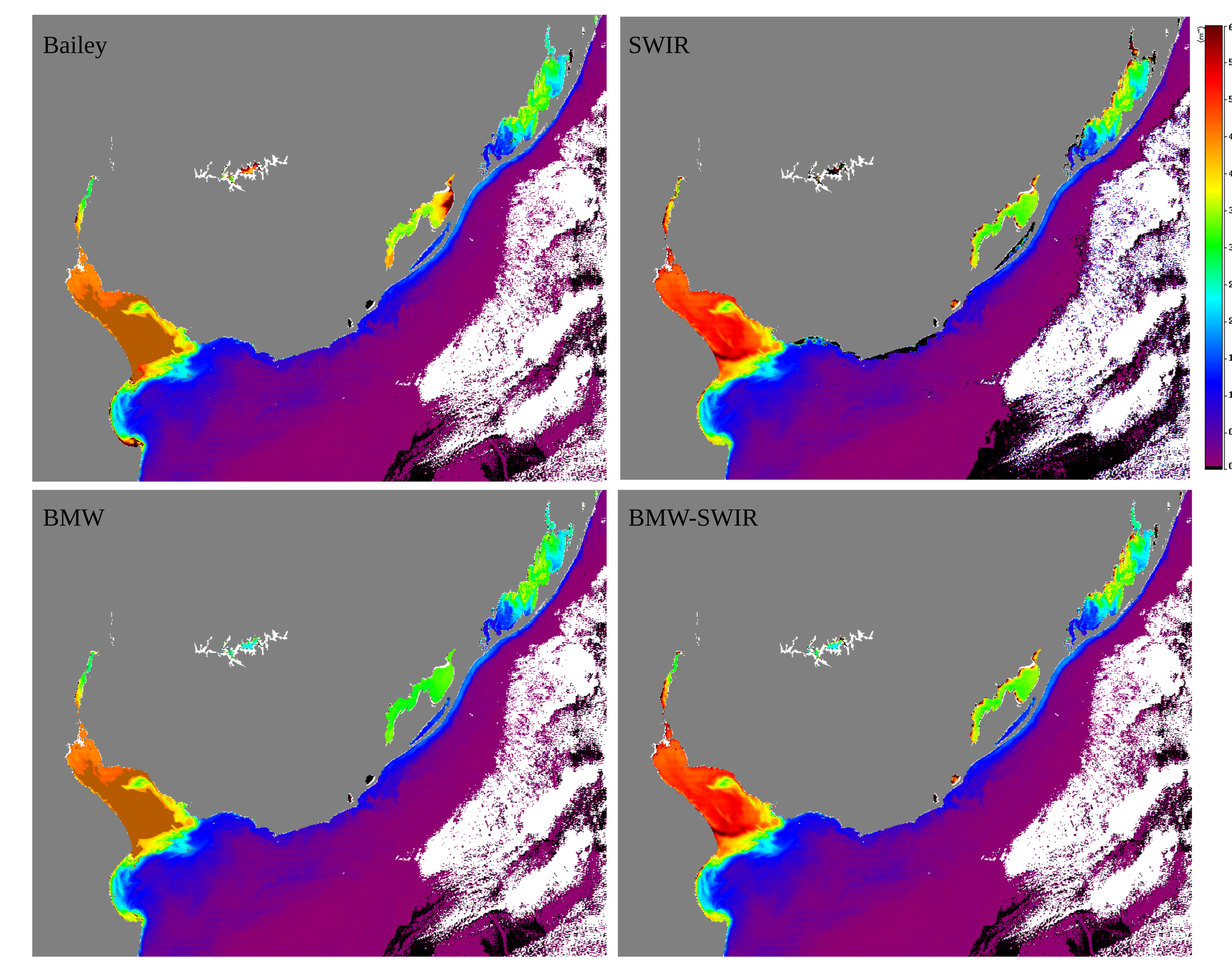

Figure 4. Kd(490) from MODIS-Aqua on Mar. 30, 2006 at 1735Z over La Plata estuary

Results: match-ups

MOBY match-ups	NASA-NIR (Bailey) 794 match-ups		NOAA-NIR (BMW) 982 match-ups		
Product	**Mean Ratio**	**STD**	**Mean Ratio**	**Median Ratio**	**STD**
$nL_w(410)$	1.0428	0.120	1.0253	1.0147	0.149
$nL_w(443)$	1.0299	0.111	1.0170	1.0046	0.136
$nL_w(488)$	1.0143	0.098	1.0012	0.9967	0.120
$nL_w(551)$	0.9988	0.182	1.0045	0.9931	0.196
$nL_w(667)$	1.4125	0.559	0.9049	0.9392	1.050
Chlorophyll-a	0.9348	0.238	0.9712	0.9699	0.214

SeaBASS match-ups	NASA-NIR (Bailey)			NOAA-NIR (BMW)		
Product	**Mean Ratio**	**STD**	**match-ups**	**Mean Ratio**	**STD**	**match-ups**
$nL_w(410)$	0.9330	0.318	373	0.8173	0.359	369
$nL_w(443)$	1.0119	0.300	825	0.9445	0.309	863
$nL_w(488)$	0.9207	0.181	875	0.9440	0.193	931
$nL_w(551)$	0.8945	0.201	441	0.9485	0.209	487
$nL_w(667)$	0.7573	0.756	516	1.0498	0.823	560

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Acknowledgments: This research was supported by NOAA funding. The MODIS L1B data were obtained from NASA/GSFC MODAPS Services website, and the in situ data were obtained from NASA SeaBASS and NOAA MOBY website.