International Coordination of Long-Term Ocean Biology Time Series Derived from Satellite Ocean Color Data

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Abstract

In this paper, we will describe plans to coordinate the initial development of long-term ocean biology time series derived from global ocean color observations acquired by the United States, Japan and Europe. Specifically, we have been commissioned by the International Ocean Color Coordinating Group (IOCCG) to coordinate the development of merged products derived from the OCTS, SeaWiFS, MODIS, MERIS and GLI imagers. Each of these missions will have been launched by the year 2002 and will have produced global ocean color data products. Our goal is to develop and document the procedures to be used by each space agency (NASA, NASDA, and ESA) to merge chlorophyll, primary productivity, and other products from these missions. This coordination is required to initiate the production of long-term ocean biology time series which will be continued operationally beyond 2002. The purpose of the time series is to monitor interannual to decadal-scale variability in oceanic primary productivity and to study the effects of environmental change on upper ocean biogeochemical processes.

Introduction

A multi-decadal time series of global ocean biological and biogeochemical measurements is needed to provide an observational basis for understanding and predicting the effects of environmental change on marine ecosystems. These observations will be relevant to both regional issues, such as land-ocean interactions and pollution, fisheries, and harmful algal blooms, as well as broader global issues, such as the global carbon cycle and whether marine primary productivity is changing in response to climate forcing. There are many practical benefits to be derived from such a time series, particularly if combined with time series of physical observations (ocean winds, temperature, sea surface height).

A major purpose of such observations is to provide input for global and regional ecosystem and biogeochemical models. The community of potential users of such data do not want to be concerned with the idiosyncracies of data sets generated by a particular space agency. They would prefer to have a single, self-consistent time series endorsed by all the agencies. There is merit in merging data from multiple mission to improve the space-time coverage of the global data products. This advantage accrues quickly over short time scales (fig. 1), but longer-term products (e.g., weekly or monthly means) derived from merged short-term products would also be improved (IOCCG Report 2).

Ocean color observations derived from satellite missions in the 1996-2002 period are largely experimental in nature. There are differences in atmospheric correction and bio-optical algorithms both within and between agencies. During this time period, we believe that each space agency will want to produce a suite of merged products compatible with its own products. Scientists can then compare different products created with the same data sets. There will likely be valuable information to be derived from systematic differences between products.

Our proposed approach will be to merge level-3 data. NASA and NASDA use different chlorophyll algorithms and also different level-3 binning (averaging) algorithms. These result in systematic differences between level-3 products produced by NASA and NASDA (figs. 2 and 3). ESA currently has no plans to produce level-3 products, and only limited plans for the production of level-2 products. They rely on the user community to develop and validate algorithms, but are willing to generate level-2 and level-3 products once the algorithms are developed and tested.

Importance of international coordination is clear. Thus, we propose to work together to develop and document the procedures to be used by each space agency to merge data products from international missions. Level-3 binned data products will be produced with the appropriate saved information to allow each agency to adjust the data furnished by the other two agencies to be compatible with its own algorithms and products.

Goals

Our long-term goal is to produce a time series of global-scale oceanic chlorophyll concentration and primary productivity, beginning with data from the ADEOS mission in 1996 and continuing indefinitely into the future, by merging global ocean-color satellite observations.

Our short-term goal is to coordinate the initial production of these time series by space agencies in the U.S., Japan and Europe. Specifically, we are proposing to develop and document procedures to be used operationally by NASA, NASDA, and ESA to create chlorophyll, primary productivity, and possibly other products by merging data from the OCTS, POLDER, SeaWiFS, MODIS, MERIS and GLI sensors.

Strategy

The three principal investigators will serve as team leaders within their respective communities, each identifying a team that will work toward developing the time series of merged products. The three team leaders will be responsible for coordinating the work within and between teams.

In the long-term, our strategy is to develop consensus algorithms, as well as consistent calibration and validation methods. In the short term we will share data to help understand differences and to begin creating merged products. Two types of data will be shared. There will be a diagnostic data set generated for selected sites containing all the information needed to process data from level 0 to level 2 (Table 1). These data will be generated during the routine processing of data by each space agency.

In addition, level 3 data will be shared. Our approach will be to merge level 3 (space and time binned) data. Each team will develop a methodology (merging algorithm) for the use of level-3 data from the different satellite missions. It is assumed that each space agency will want to produce a set of merged products that are consistent with its own products. As a minimum, there will be time series of global chlorophyll beginning with OCTS and POLDER data, and continuing with SeaWiFS, MODIS, MERIS, and GLI.

There are different chlorophyll algorithms being used and thus systematic differences between products (see comparison of OCTS and SeaWiFS, fig. 2). Also, there are different level-3 binning algorithms being used (fig. 3). For example, NASDA averages the logarithm of chlorophyll for level-3 OCTS data, whereas NASA's SeaWiFS Project averages chlorophyll. Differences between these methods were analyzed by Campbell et al. (1995) using CZCS data. They demonstrated that the average based on transforming the average logarithm is systematically less than the average chlorophyll.

We will investigate differences between algorithms and prescribe a way to derive chlorophyll from level-3 statistics saved by each sensor. This is likely to require that higher-order statistics be saved in the level-3 binning process. Each space agency will need to translate the "foreign" data to be compatible with its own products. The team for each community will define the input needed to produce its merged products. For example, to convert the average logarithm to a simple arithmetic average requires information on the variance of the logarithm (Campbell, 1995). Each space agency would agree to provide the data needed by the other agencies as a quid pro quo arrangement.

Table 1. Sites recommended for a Diagnostic Data Set to be generated by space agencies. All data within a two degree by two degree box surrounding each site will be saved and put into a separate file. These data will be used to compare algorithms and understand differences in data products generated by NASA, ESA, and NASDA.

MOBY (Hawaii), 20.8N, 157.2W
BATS/BTM (Bermuda), 32.0N, 64.5W
CALCOFI (California Current), 35N, 125W
Equatorial Pacific (EqPAC), 0N, 140W
Palmer LTER, 65S, 65W
LEO 15 (off New Jersey), 39N, 74W
Kashidoo (Maldives Islands), 5N, 73.5E
Lower Chesapeake Bay, 37N, 75.5W
NW African Upwelling, 21N, 17.5W
Ligurian Sea, 43.25 N, 7.05 E
North Adriatic ("Venice Tower"), 45.32N, 12.5E
Eastern Mediterranean, 33N, 32.5E
English Channel ("Plymbody"), 50.22 N, 4.08W
Helgoland/North Sea, 54N, 9E
Baltic Sea, 55N, 19.25E
East China Sea, 30N, 125E
Aline (Japan East Coast), 40N, 142E
KNOT (NW Pacific), 43N, 165E
Cariaco Basin, 11N, 65.1W
Gulf of Maine, 43N, 69W
Near Cape Town (St Helena Bay), 33S, 17.5E
Near Luderitz, Namibia 26S, 14.5E (World's strongest upwelling)
Philippine Sea, 17 N, 133 E
Cook Islands, 20 S, 163 W (World's deepest Secchi depth, 67m)

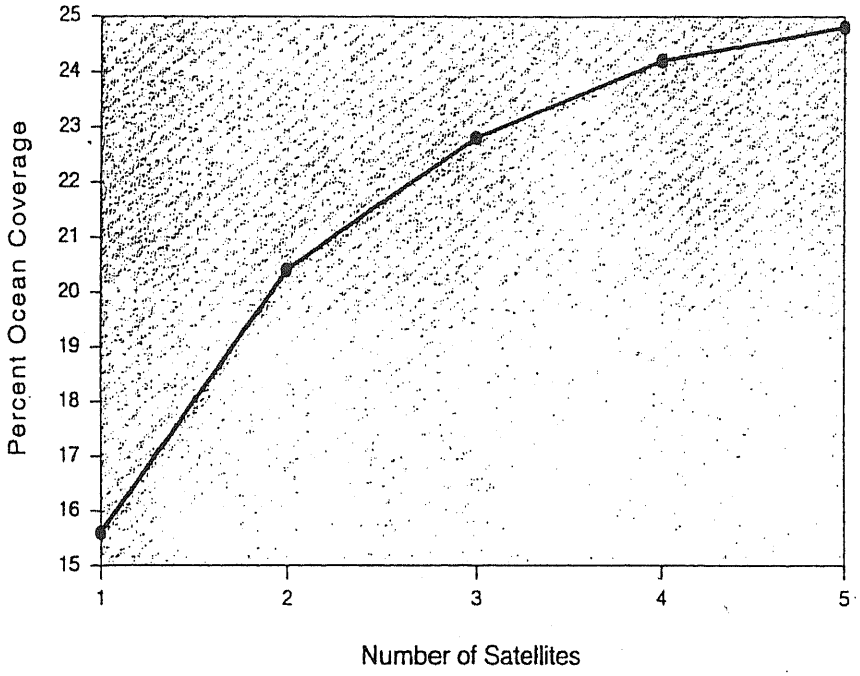

Figure 1. *Combined ocean coverage (in percent) by multiple satellites of the same design for one day. The satellite/sensor is SeaWiFS-type: noon descending node, 705 km altitude, scan width 45°, with a tilt capability. The satellite orbits differ only in the mean anomaly, which is set to produce average combined coverage. In this analysis, sun glint and clouds obscure observations of the ocean surface, producing the low estimates of ocean coverage. Sun glint is computed from climatological wind speeds as a function of viewing and solar geometry with respect to the satellite orbit. The sun-glint threshold is set to about four times the SeaWiFS Noise Equivalent Delta Radiance (NEΔL). This is an extreme estimate of sun glint contamination. However, sun glint can confuse the determination of aerosol characteristics, especially when the aerosol radiative characteristics are very different from those of sun glint, which may cause significant errors in chlorophyll retrieval. In the context of using data from multiple satellites, such possible errors need to be identified so they can be eliminated from the merged data set. Thus this estimate of sun glint supports the multi-mission application. Clouds are derived from global six-year climatology.*

From IOCCG, Report No. 2 entitled "Status and Plans for Satellite Ocean-Colour Missions: Considerations for Complementary Missions.

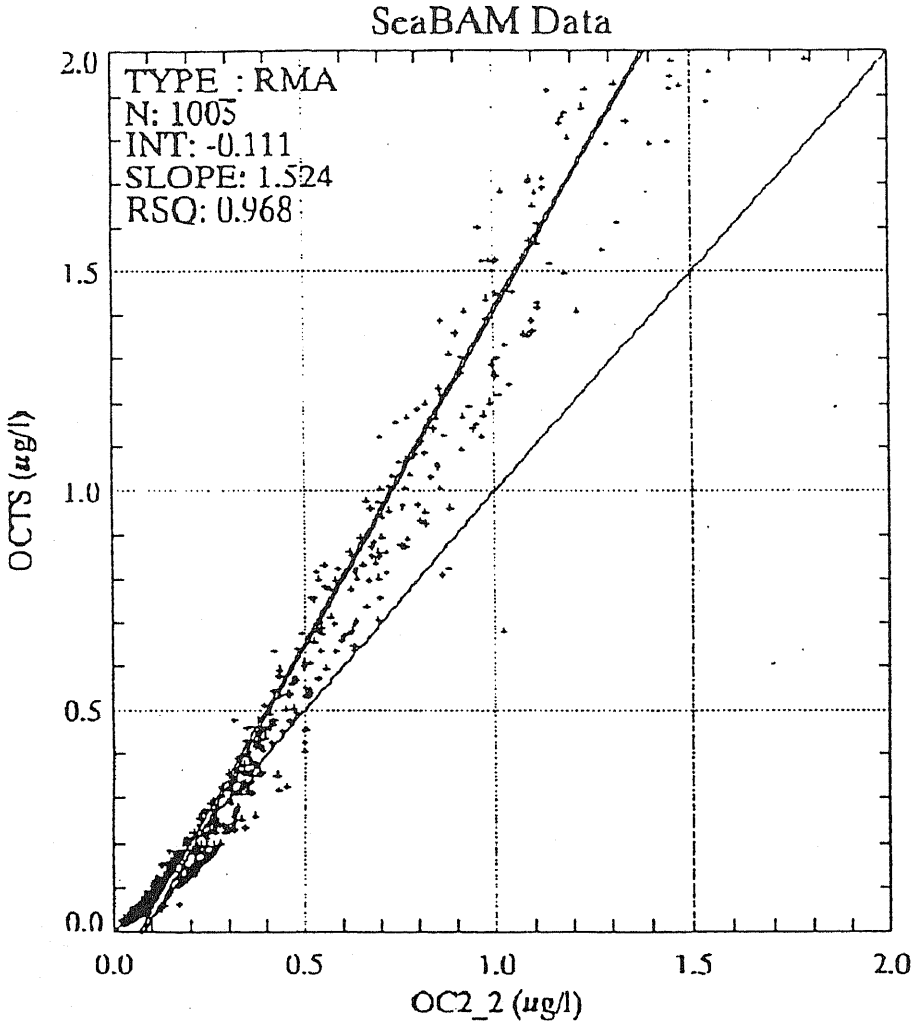

Figure. 2 Comparison of chlorophyll derived according to OCTS algorithm and chlorophyll derived according to SeaWiFS (OC2.V2) algorithm. Both algorithms were applied to the same data set (the SeaBAM data). Figure provided by John (Jay) O'Reilly and James (Jim) Yoder.

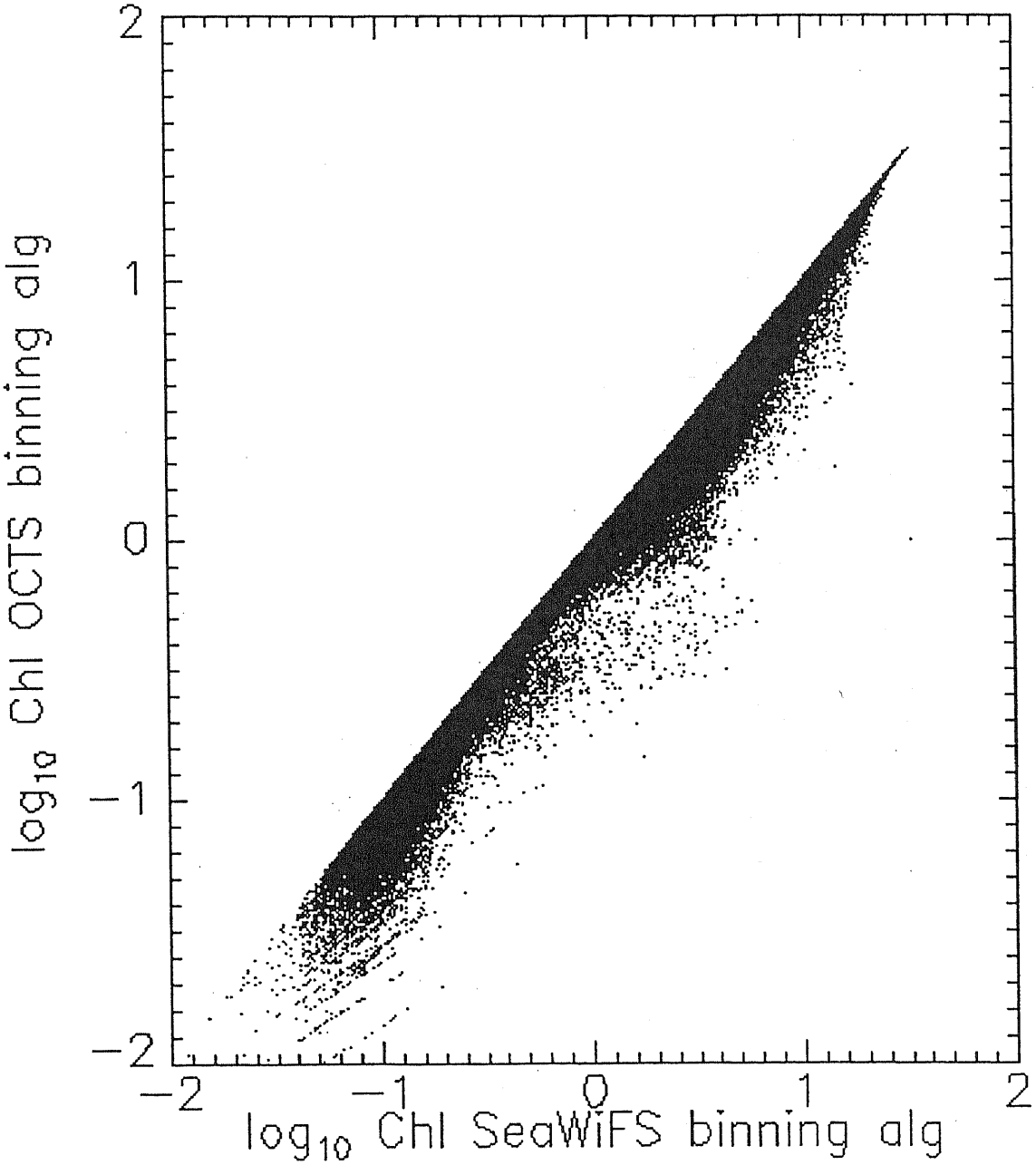

Figure. 3 Comparison of binning algorithms. The vertical axis is derived by transforming the average of the logarithm of chlorophyll. This is the binning algorithm used for OCTS data. The horizontal axis is the average of chlorophyll over the same set of images. This is the binning algorithm used by SeaWiFS. The data used were SeaWiFS data for Northwest Atlantic for the month of July 1998.