Global Patterns of Pigment Concentration, Cloud Cover, and Sun Glint: Application to the OSMI Data Collection Planning

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Abstract

To establish a monthly data collection planning for the Ocean Scanning Multispectral Imager (OSMI), we have examined the global patterns of three impacting factors: pigment concentration, cloud cover, and sun glint. Other than satellite mission constraints (e.g., duty cycle), these three factors are considered critical for the OSMI data collection. The Nimbus-7 Coastal Zone Color Scanner (CZCS) monthly mean products and the International Satellite Cloud Climatology Project (ISCCP) monthly mean products (C2) were used for the analysis of pigment concentration and cloud cover distributions, respectively. And the monthly simulated patterns of sun glint were produced by performing the OSMI orbit prediction and the calculation of sun glint radiances at the top-of-atmosphere (TOA). Using monthly statistics (mean and/or standard deviation) of each factor in the above for a given 10° latitude by 10° longitude grid, we generated the priority map for each month. The priority maps of three factors for each month were subsequently superimposed to visualize the impact of three factors in all. The initial results illustrated that a large part of oceans in the summer hemisphere was classified into the low priority regions because of seasonal changes of clouds and sun illumination. Sensitivity tests were performed to see how cloud cover and sun glint affect the priority determined by pigment concentration distributions, and consequently to minimize their seasonal effects upon the data collection planning.

1. Introduction

The ocean scanning multispectral imager (OSMI) is designed to observe the global ocean color in support of biological oceanography. The OSMI collects data in the six visible spectral bands with the nominal selection centered at 412, 443, 490, 555, 765, and 865 nm. However, data collection capabilities of the OSMI are significantly limited by its 20% duty cycle per orbit because most of the sunlit globe can be covered with a 40% duty cycle. In addition to the limited duty cycle, there are other factors such as sun glint and clouds to be considered in the OSMI data collection planning. The OSMI will be saturated when observing regions of sun glint and clouds because of high reflectivity. Data from those regions are no use for ocean color. It is therefore very important to develop a data collection plan for the OSMI mission considering the above impacting factors.

In this study we focus on the development of a monthly data collection plan and provide a rationale behind it. We have examined the global patterns of pigment concentration, cloud cover, and sun glint. The Nimbus-7 Coastal Zone Color Scanner (CZCS) monthly mean products and the International Satellite Cloud Climatology Project (ISCCP) monthly mean products (C2) were used for the analysis of pigment concentration and cloud cover distributions, respectively. Since pigment concentration is closely linked to the ocean color, its mean and variations would be suitable to characterize global oceans for the ocean color monitoring. Unlike the patterns of pigment concentration and cloud cover, the monthly patterns of sun glint were simulated by performing the OSMI orbit prediction and the calculation of sun glint radiances at the top-of-atmosphere (TOA).

2. Data

The Nimbus-7 CZCS monthly mean pigment concentration data are used to calculate the multi-year averages and intra-annual variations for the period of January 1982 to December 1985. The CZCS monthly mean products of a 1° latitude by 1° longitude grid were obtained from the Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center. The CZCS data spans from 1978 to 1986 but the twelve month data in a year are available for the above period. The International Satellite Cloud Climatology Project (ISCCP) monthly mean products (C2) of a 2.5° latitude by 2.5° longitude grid were downloaded from the web site (http://isccp.giss.nasa.gov). And the eight year mean (July 1983 through June 1991) cloud cover data are used for this analysis. As for sun glint data, we incorporate the monthly simulated patterns as described in the following section.

3. Methods

We first calculate the multi-year monthly statistics, such as mean and standard deviation (intra-annual variations), for the CZCS data. The cloud cover data are the eight year mean monthly product obtained from the ISCCP data. The monthly patterns of sun glint are produced by performing the OSMI orbit prediction and the calculation of sun glint radiances at the top-of- atmosphere (TOA) (Lim et al., 1998). These monthly statistics are subsequently binned into given grid boxes of 10° latitude by 10° longitude while calculating mean values. Based on the grid mean value, each grid box can be classified into a specific region of priority.

3.1. Monthly Statistics

Global patterns of pigment concentration, cloud cover, and sun glint are shown in Fig. 1. It is evident that the high mean pigment concentrations occur near coast areas and low values are seen over open oceans.

Distributions of intra-annual variations also show the similar features over coast and open ocean areas. Note that log-transformation has been applied to the pigment concentration data to enhance the patterns of open oceans. Distributions of clouds over oceans exhibit the maximum amounts in the mid-latitude storm tracks while showing the lowest amounts in the sub-tropical regions. Sun glint patterns illustrate that a large portion of the satellite pass on the right of sub-satellite point is contaminated by sun glint.

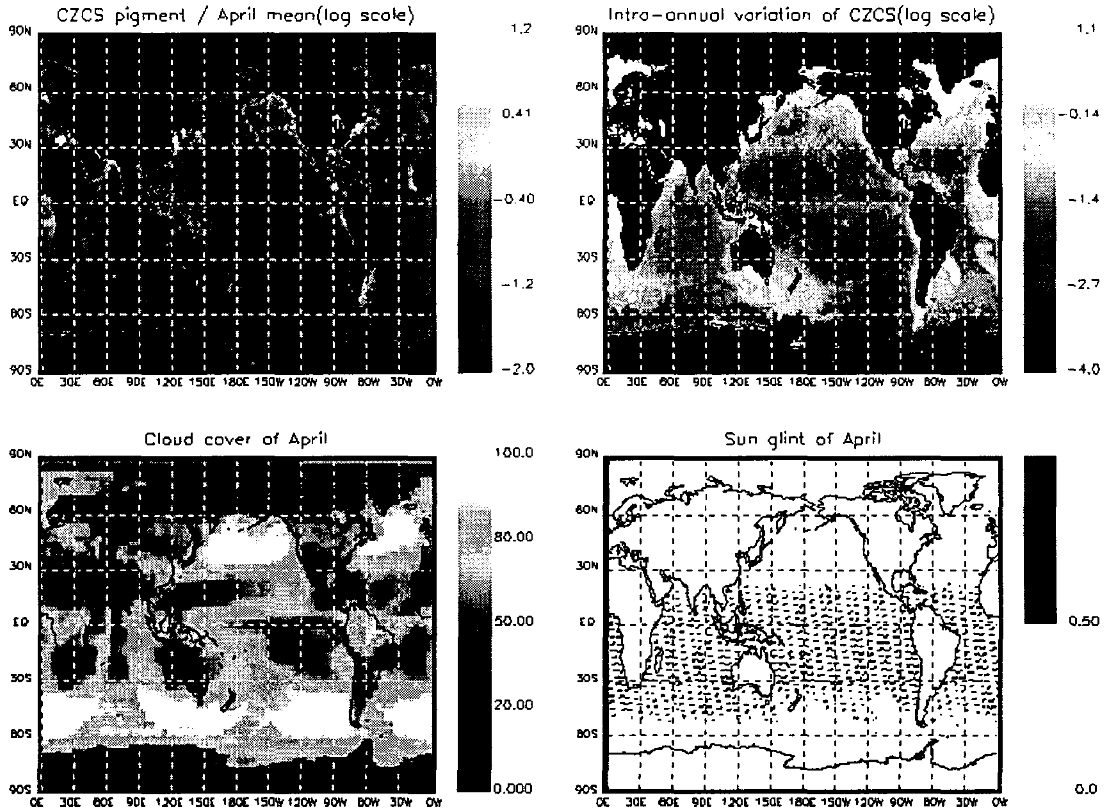

Fig. 1. Global patterns of mean pigment concentration (top-left), cloud cover (bottom-left), and sun glint (bottom-right) for the month of April. Intra-annual variations of pigment concentration for the period of January 1982 to December 1985 are shown in the top-right panel. Units are referred to Table 1.

3.2. Classification

Using monthly statistics of pigment concentration, cloud cover, and sun glint, we generate the monthly bin products. Binning is performed for a 10° latitude by 10° longitude grid. Each grid value is then used to classify a given grid into a certain region of priority based on the threshold values in Table 1. It is noted that threshold values for pigment concentration include three types of water: eutrophic, 1.0 < mean; mesotrophic, 0.3<mean≤ 1.0; oligotropic, mean<0.3 (units in mg/m^3). The highest priority (class 1) corresponds to the highest mean and standard deviation for pigment concentration, the lowest cloud cover, and the sun glint radiance of 865 nm band less than 0.5 mW/cm^2/sr/μm. The threshold value for a sun glint radiance is based on the SeaWiFS algorithms (McClain et al., 1995).

4. Results and Discussion

The monthly bin products of pigment concentration, cloud cover, and sun glint are finally superimposed to examine the impact of three factors in all. Priority classes have been normalized for superimposition.

Table 1. Classification based on monthly statistics of pigment concentration, cloud cover, and sun glint

Priority	Pigment Concentration (mg/m^3)		Cloud Cover (%)	Sun Glint (mW/cm^2/sr/μm)
	Mean (M)	Standard Dev. (σ)	CC	I_{glint}
1	$1.0 < M$	$5.0 < \sigma$	$0 < CC \leq 20$	$I_{glint} < 0.5$
2		$2.5 < \sigma \leq 5.0$	$20 < CC \leq 50$	$0.5 \leq I_{glint}$
3		$0.0 \leq \sigma \leq 2.5$	$50 < CC \leq 80$	
4	$0.3 < M \leq 1.0$	$5.0 < \sigma$	$80 < CC \leq 100$	
5		$2.5 < \sigma \leq 5.0$		
6		$0.0 \leq \sigma \leq 2.5$		
7	$0.14 < M \leq 0.3$	$5.0 < \sigma$		
8		$2.5 < \sigma \leq 5.0$		
9		$0.0 \leq \sigma \leq 2.5$		
10	$M \leq 0.14$	$5.0 < \sigma$		
11		$2.5 < \sigma \leq 5.0$		
12		$0.0 \leq \sigma \leq 2.5$		

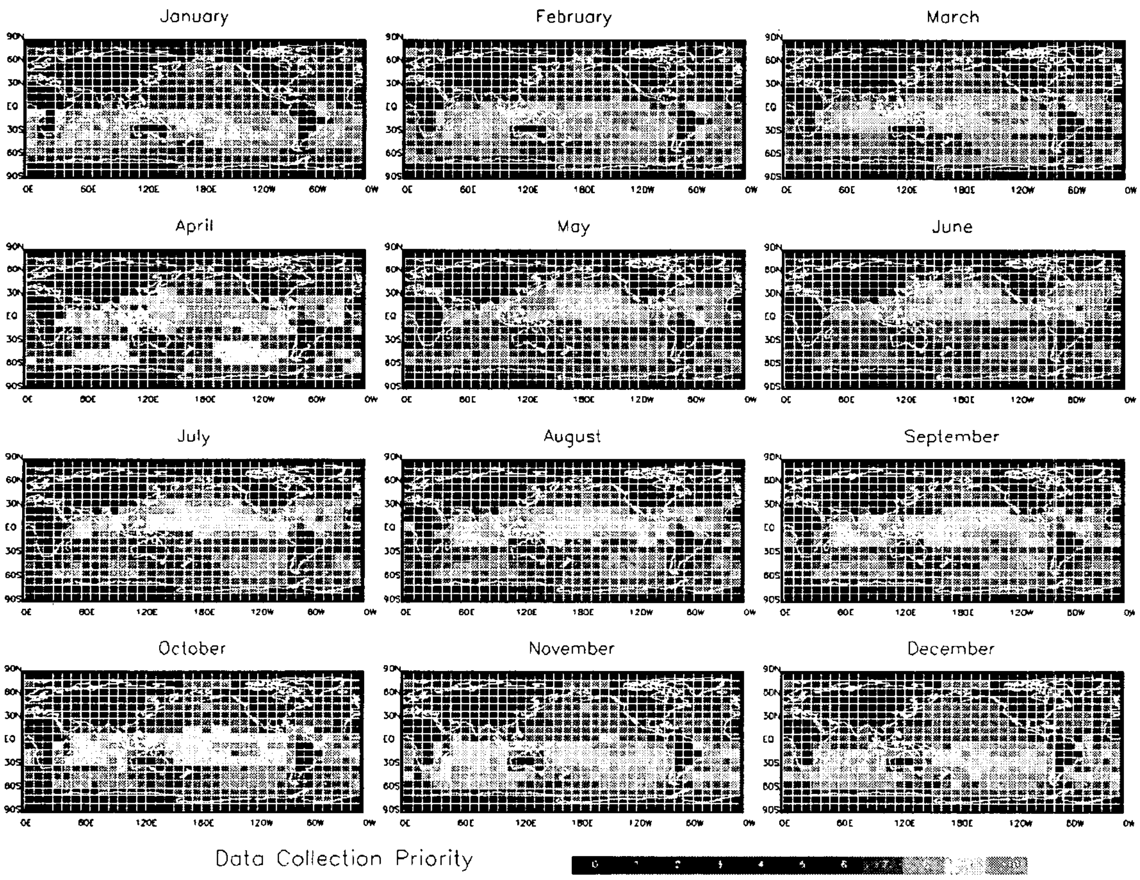

Fig. 2. Monthly priority maps (preliminary) for the OSMI data collection.

The results are shown in Fig. 2. It appears that a large part of oceans in the summer hemisphere is classified into the low priority regions (hereinafter called seasonal belt) because of seasonal changes of clouds and sun illumination. However, most of coast areas exhibit the relatively high priority values. This is encouraging in that coast areas need to be monitored in any case due to the high variability of pigment concentration. Concerning the results shown in Fig. 2, it would be appropriate to examine the frequency distributions of priority. We plot three cases for each month as shown in Fig. 3 to demonstrate how clouds and sun glint affect the priority determined by pigment concentration distributions. Overall results (thick solid line) reveal the bimodal distributions in 11 of 12 month cases. Bimodal features may be useful when grouping the regions of interest for the purpose of data collection. By this, however, we should not imply that the current ramification point (priority 6) is ideally suitable for the OSMI data collection. Of particular interest is to note that the addition of clouds and sun glint to the priority distribution of pigment concentration results in a rise of priority rank. This is mainly caused by averaging in which significant compensation occurs in open oceans with low priority.

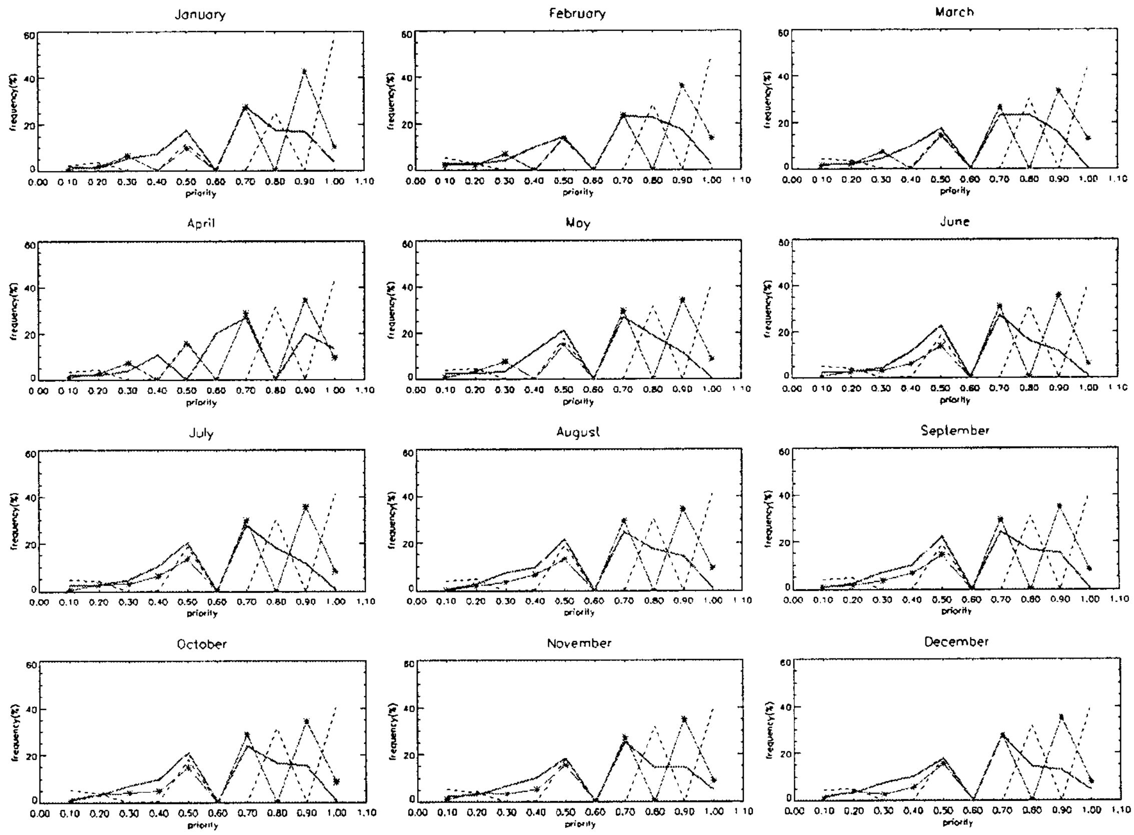

Fig. 3. Effects of cloud cover and sun glint on the priority distribution of pigment concentration. Dashed line denotes the histogram of CZCS pigment concentration alone. Solid line with asterisk denotes the histogram of CZCS pigment concentration and cloud cover. Thick solid line represents the histogram of three factors together. Priority values of X-axis must be multiplied by a scale factor of ten.

Although the classification of cloud cover and sun glint given in Table 1 appears to be reasonable, it is necessary to perform the sensitivity test that employs the different sets of classification. Two test sets are supplemented for this analysis: Case 1 - two priority classes for both clouds and sun glint, and Case 2 - four priority classes for both clouds and sun glint. Preliminary results indicate that the aforementioned seasonal belts are present in both cases (figures not shown). Compared to the current classification, the priority of seasonal belt in Case 1 is lowered while that of Case 2 remains to be nearly the same. A notable rise of priority out of seasonal belt is also seen in Case 2. It seems that the extent of seasonal belt would be relatively insensitive to varying the classification of clouds and sun glint.

References

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