Compositing Satellite Data

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1 Introduction

Monthly or annual images of Chl-a may give a wrong impression that ocean color data is available for all the time and for any area. In fact, many areas are cloudy most of the time and these nice images are based on a few clear pixels that have been combined over a long time period. The operation of combining valid data over a longer time period is called *compositing*. Different compositing methods can be used. The most common method of temporal compositing means averaging all valid pixels over a time period (e.g. 1 day, 8-day, month). However, determining the valid pixels is not always an easy task. For example, SST pixels are often contaminated by undetected clouds and therefore a popular method for compositing SST has been to use the warmest pixel over a time period as clouds and cloud-contaminated pixels are almost always colder than the true sea surface. Of course, this method will also bias the true SST in case of temporal variability.

Fig. 1 shows that in any day, most of our area of interest has no data either due to clouds or limitations of the viewing geometry (satellite orbit, sensor swath and possible sun glint). California is known for its sunshine but even off California the chances are high that our area is cloudy during our time of interest. Other areas can be much worse. In fact, in some areas the expected number of valid pixels during some months of the year is less than 1, e.g. see http://spg.ucsd.edu/Satellite_Projects/EffectsOfCloudsOnOceanColor/EffectsOfCloudsOnOceanColor.htm. That means that during some months you cannot expect even a single valid data point in certain areas. Therefore, in order to get meaningful data, some form of compositing is almost unavoidable.

In this tutorial we will explore different methods of temporal compositing of satellite images.
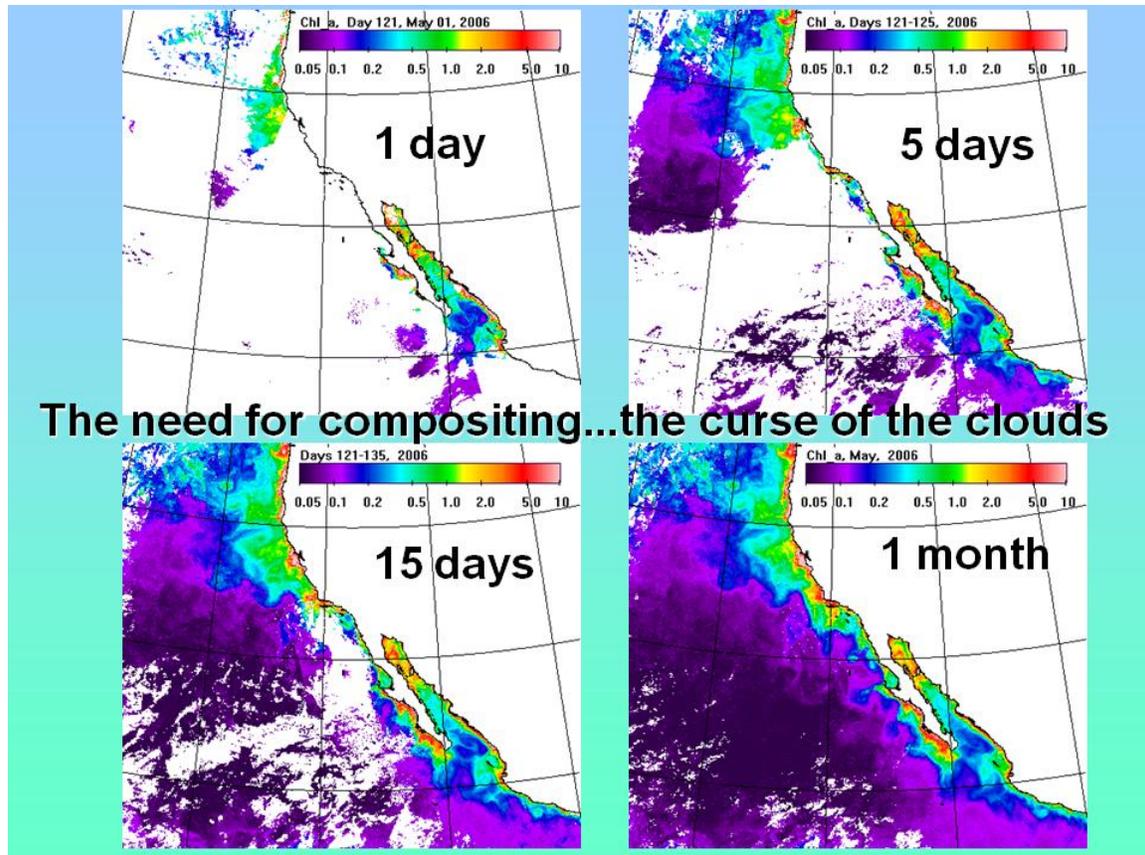
Fig. 1. Examples of compositing Chl-a data in the California Current: 1 day, 5 days, 15 days and 1 month in May 2006.

2 Interactive compositing with WIM

Exercise 3.5 in Practical Exercises with WIM and WAM gives an example how to perform interactive compositing with WIM. While interactive processing is useful in exploratory analysis, it is too time consuming and error prone in routine processing of many images.

3 Compositing with WAM command line utilities

3.1   *Number of valid data pixels in daily Level-3 images*

In this exercise we will try to partly reproduce the analysis presented in http://spg.ucsd.edu/Satellite_Projects/EffectsOfCloudsOnOceanColor/EffectsOfCloudsOnOceanColor.htm). Our main purpose here is to evaluate the number of daily pixels available in different areas and in different months. As a by-product, we will generate monthly composites of Chl-a but we will not really need them. Monthly composites are available for downloading from NASA but for creating composites of other periods you can use the tools described here.

We assume that you are familiar with WIM and how to use the command line programs. If not, please check out the WIM and WAM manuals. We also assume that you have a set of images that you can use. In our example we use standard mapped (9 km) daily chlorophyll-a (CHLO_9) images that are merged from SeaWiFS and MODIS-Aqua by NASA. In order to save disk space, these *Int16* images have been converted to *Byte* format using *wam_series*. These datasets are on the WIM DVD under \Sat\Merged\L3\Daily\CHLO_9. If you have enough disk space then you should copy these data to your hard disk, e.g. to C:\Sat\Merged\L3\Daily\CHLO_9. You can also keep the data on DVD but keep in mind that output is generated to the current directory where you are issuing commands. As you cannot add files to the DVD then you have to issue the commands from a location where you can save files.

- Open the command prompt and *cd* to the directory where you will store the output files, e.g. C:\Sat\Merged\L3\Daily.

- In the command window run the following command:

    wam_composite_month

- This will show the command options. Now run the following command:

    wam_composite_month CHLO_9\A2007*9.hdf count

- This will create the following output files:

    A2007001_A2007031_chl_comp.hdf
    A2007001_A2007031_chl_count.hdf
    A2007032_A2007059_chl_comp.hdf
    A2007032_A2007059_chl_count.hdf
    A2007060_A2007090_chl_comp.hdf
    A2007060_A2007090_chl_count.hdf
    ……….

- As you can see, it created one composite (*comp.hdf) and one count (*count.hdf) image per each of the 12 months. Open one of these and familiarize yourself with the content of the image. Compare one of the composited images with the monthly composite on the DVD (\Sat\Merged\L3\month\CHLO_9). Create a new folder *Month_new* and move your newly created files to that folder. We want to keep these separate from the *Month* folder with the standard data from the DVD.

- We had only one year (2007) of daily Chl images on the DVD. If you had more than one year then you could make another set of a composite and a count of the monthly datasets of different years, e.g. Januaries of all years, Februaries of all years, etc.

- We now want now to create 2 views of the number of valid pixels (counts): a spatial view of our area of interest and a temporal view of the annual cycle in the number of valid pixels (counts).

- Create a target map of your area of interest. You can use *File-New* in WIM with a range of latitudes and longitudes or another sample image as your area of interest.

I just cut out a rectangular section of south-east Asia with WIM, create coastlines with pixel value 1 and fill land with pixel value 255 (Fig. 2).
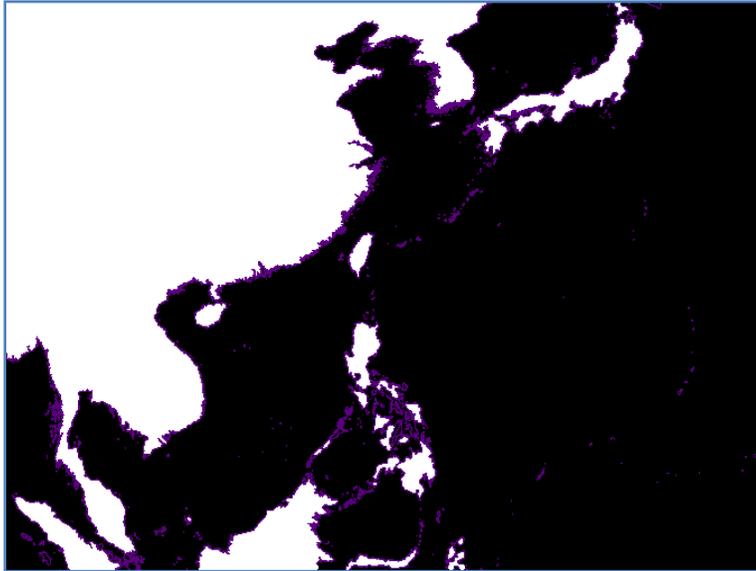

Fig. 2. Target map of area of interest.

I then create masks for small areas where I will generate time series. I pick 6 masks or small areas of interest (Fig. 3). Each mask is specified by its pixel value. The coastlines and all other details have to be deleted (made 0) before running statistics. We should only have pixel values different from 0 that correspond to masks.
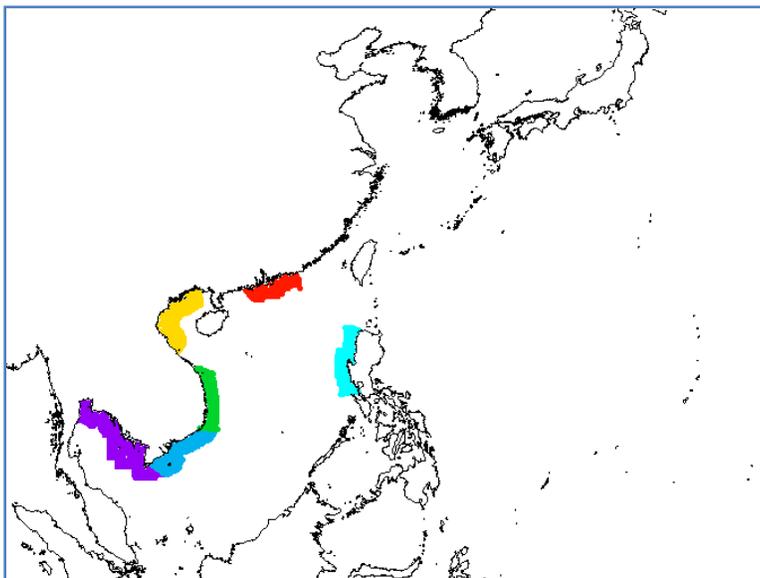

Fig. 3. Masks for time series: off Hong Kong, North Vietnam, Central Vietnam, South Vietnam, Eastern Gulf of Thailand, and west of Luzon Island.

More examples on creating masks and creating time series of statistics can be found in section 4.3 on *wam_series* in Practical Exercises with WIM and WAM.

We need:

-   The mask image. Its size has to be the same as the data images; if it is not then it should be remapped to the data image size. I use *se-asia_land.hdf* to create the masks image *se-asia_masks_6.hdf*. Before I can use it in *wam_statist* I have to remap it into the size of the images to be used (*se-asia_masks_6_9km.hdf*).

-   You can also make images of your area of interest by remapping any of the monthly count images to the target image (*se-asia_land.hdf*) and then overlaying it on the remapped count image. The result for January should be something like that on Fig. 4. Bear in mind that Fig. 4 is the average of 2002 to 2007 while here we use only one year (2007).

-    A list of images to be used. This can be created with a command like that:

dir/b /s Month_new *count.hdf > list_count.txt

-   Now run *wam_statist* with the mask and list files specified above. Save the output to *counts_merged_mo.csv*.

-   If you use more than 1 mask, sort the data in *ts_counts_merged_mo.csv* with sortmasks ts_counts_merged_mo.csv

-   Load the CSV file into Excel and create plots like on Fig. 5. The plots on Fig. 5 are averages for 1998-2007 of SeaWiFS and 2002-2007 of the merged SeaWiFS-Aqua datasets. If you are using only 1 year of data (2007) then the plot will look somewhat different even if you have the same mask.

Fig. 5 shows that for the ocean west of Luzon Island we can expect 16-17 cloud-free pixels per month during the months of January-March using the merged SeaWiFS and Aqua data. However, in August the expected number of cloud-free days drops to only 2. This makes a big difference in the availability and quality of ocean color data in this region.
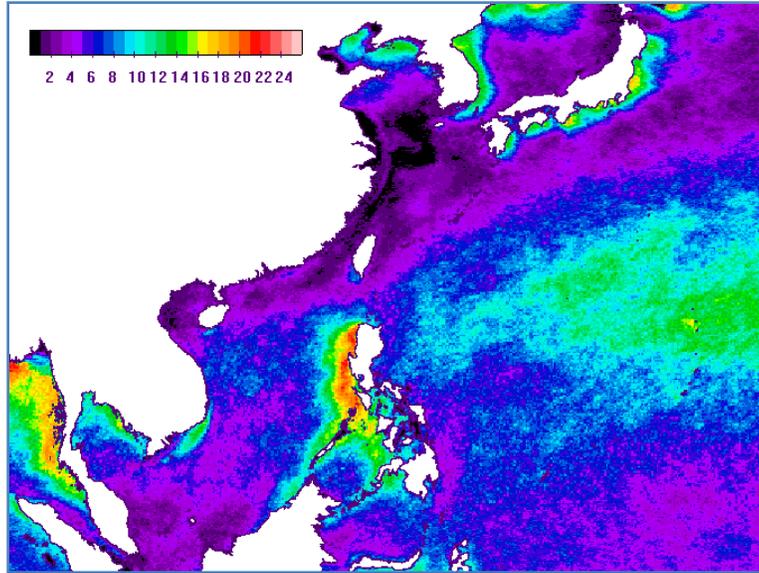
Fig. 4. Average number of valid pixels per month of the merged SeaWiFS-Aqua data.
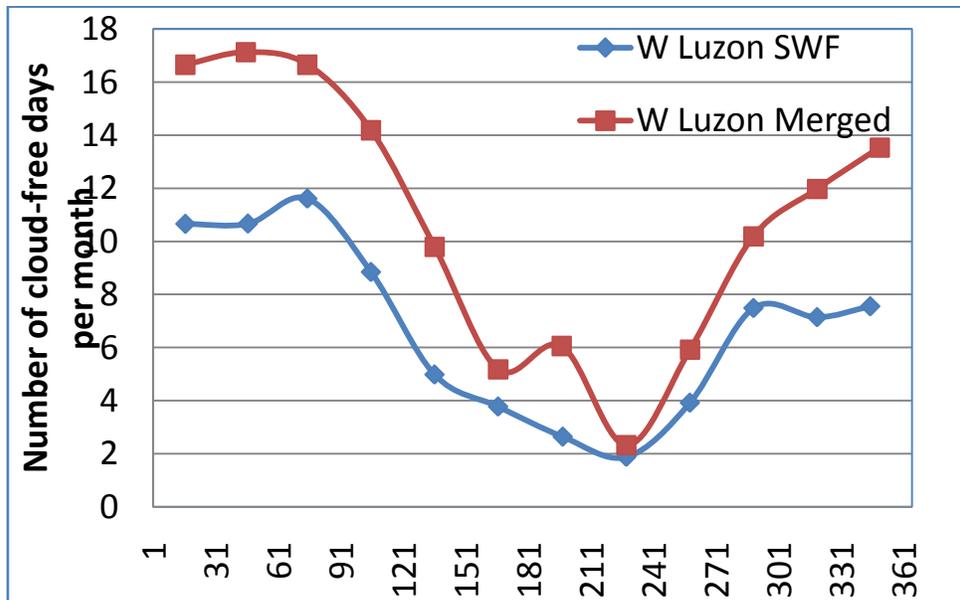

Fig. 5. Time series of the average number of valid pixels per month corresponding to SeaWiFS (SWF) and the merged SeaWiFS-Aqua (Merged) data for a mask west of Luzon Island. The horizontal axis shows the day of the year.

3.2   Compositing Level-2 satellite data

Compositing Level-2 Chl-a and SST data is a separate topic and is covered in detail in the following documents in the *Course\2* folder of the WIM/WAM DVD:

- *2_Exercises_time_series_L2_commands.ppt*
- *2_Exercises_time_series_L2.ppt*
- *Exercises_Merging_L2_Chl_and_SST.pdf*
- *Exercises_SeaWiFS_Aqua_Level2_Appendix_CalCOFI.pdf*
- *Exercises_SeaWiFS_Aqua_Level2_Appendix_Your_area.pdf*
- *Exercises_SeaWiFS_Aqua_Level2_Appendix_South_China_Sea.pdf*

The following commands are used:
- wam_l2_map - for creating daily composites from multiple L2 datasets
- wam_composite_2x - for creating N day composites using daily composites
- wam_composite_month - for creating monthly composites using daily composites
- wam_composite_last - for creating N day composites using daily composites and the last valid data for each pixel
- wam_composite_list - for creating composites using a list of daily composites
- wam_composite_running   - for creating N day running composites using daily composites. For example, for a 5-day running composites each daily image and the 2 daily images before and the 2 daily images after that are composited.