Practical Exercises with WIM and WAM:

Emphasis on ocean color and SST

August, 2007

Contents

1 Purpose and Requirements

The exercises with WIM (=Windows Image Manager) and WAM (=WIM Automation Module) are designed for students who want to gain practical experience in using digital satellite imagery. While all the examples are using the WIM and WAM software, they should be useful for learning how to use satellite data in general.

It is assumed that WIM and WAM have been installed. Instructions and tips for installing WIM and WAM are given in the end of this document.

2 WIM/WAM exercises at a glance

2.1 Exercises with WIM

Exercise Name	Details, requirements
Loading files	*File-Open* dialog is **NOT** the preferred method. Better use Click (or double click) on the file name. Reading multiple images at once. Associate WIM with data files. Samples: *composite.hdf, S2000*.hdf* in *Images\SeaWiFS\baja_2000_april*.
Right-click and left-	Looking up pixel details (pixel value, scaled value, coordinates).

click	Selecting areas of interest.
Basic operations	*Geo – Get Map Overlay; Multi –Overlay Image; List of Images; Current Settings; Examine-Statistics*, Valid data range; *Examine-Profiles*, *Examine-Histogram*.
Changing colors	Palettes, LUTs, *View-Set Colors*
Compositing images	*Multi-Composite* with *S2000*.hdf* images in *Images\SeaWiFS\baja_2000_april*.
Bathymetry image and depth contours	*Geo-Bathy Image* with *world_bathy_2min.dat*
Creating 3-component RGB images	SeaWiFS image *sw_l1a_mapped_byte.hdf* in *Images\SeaWiFS*
SeaWiFS Level-3 (SMI) images	All files in *Images\SeaWiFS\L3*
Calculating primary production from a set of 3 images (CHLO, PAR, SST)	Use *Multi-Primary production* with *S20000612000091.L3m_MO_CHLO_9* and S20000612000091.L3m_MO_PAR_9 in *Images\SeaWiFS\L3* and SST image *200003.s04m3pfv50-sst-16b.screened.hdf* in *Images\SST*
Tracking in situ measurements on images	Using *composite.hdf* in *Images\SeaWiFS\baja_2000_april*, point file *ime9801.pnt*. *Vector objects* table. *Geo – Distance.*
Utility for converting between dates and Julian days	julian YYYYMMDD julian YYYY JDAY
Remapping and overlaying images	Using SeaWiFS Level 3 chlorophyll with Polar Stereo projection from *Images\SSMI\S3ACOAST.HDF*.
Screen Level-3 images for best quality	Use the quality value is *l3m_qual* to screen SST data in *l3m_data* in file *A20060602006090.L3m_MO_SST_4*, use operation *Multi-Mask w. Image*
Edge Detection in Sea-Surface Temperature Images	Find edges (fronts) in SST images using various methods, e.g. *Transf-Gradients-Sobel, Edge-Shade Edge, Edge-SIED*.
Compare MODIS and SeaWiFS chlorophyll products	Compare the SeaWiFS, Aqua and merged SeaWiFS-Aqua L3 CHLO products.
SeaWiFS Level-2 data: "Black waters" of Florida	Red tide detection off Florida: *S2001265175156.L2_HUSF.sub.map.hdf* of 22-Sep-2001 in *Images\SeaWiFS\L2; Transf-Binarize*.
Using MODIS-Aqua Level-2 images	Download from http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am

Combining RGB images with pseudo-color images	Combine RGB land (as a RGB overlay) with pseudo-color Chl-a or SST images converted from Level-2 data
QuikScat Level-2 products	Examine and composite wind speed data
Opening image files the hard way	Open NGSST raw binary file, manually set size, header, value scaling, projection and geo-location coefficients.

2.2 Exercises with WAM GUI applications

Exercise Name	Details, requirements
wam_series	Allows the user to selectively apply a number of operations to a series of images. Includes options for input and output formats, sub-area, filtering, overlays, converting, remapping, statistics, color stretch, etc.
wam_match	Finding match-ups between in-situ data and satellite images. Creates a CSV text file with match-up statistics of a DX x DY window image statistics corresponding to in situ measurements.
wam_statist	Use a series of masks (areas of interest) and a list of images to create time series of statistics for a series of images.

2.3 Exercises with WAM command-line applications

Exercise Name	Details, requirements
wam_composite	Reads a list of files, calculates mean composite and a count image from all valid pixels, saves as HDF. Tries to create attributes so that the start and end periods correspond to the first and last images, respectively.
wam_anomaly	Reads all matching files, calculates monthly means or annual means, creates monthly or annual anomalies.
wam_pp and run_pp	A batch process for creating primary production images from a list of component files (CHLO, PAR, SST).
wam_statist_sta	Calculates statistics for 3x3 pixel windows of images from a list of images and a list of points (stations).
wam_screen	Batch process to screen images, i.e. excluding low quality pixels
wam_rgb_modis	Batch process to create true-color RGB images from MODIS bands 1, 4, 3, at resolutions 1 km, 500 m and 250 m.
wam_turbidity	Batch process to calculate turbidity images from MODIS bands 1 and 2 at 250 m resolution.
Merging Level-2 Chl-	Batch process Level-2 files from multiple sensors (Aqua, Terra,

a and SST data	SeaWiFS) into merged daily, 5-day, 15-day and monthly composites of Chl-a and SST.

3 WIM exercises

The exercises use sample images from the *Images* folder. It is recommended that you copy the *Images* folder from the CD to the Wimsoft folder on your hard disk (e.g. to *C:\Program Files\WimSoft*) for faster access. In languages other than English the default folder names may be different (e.g. *C:\Archivos de programa\Wimsoft* in the Spanish version of Windows). When using command line WAM programs it is **not** convenient to use long folder names with spaces like "*Program Files*". Therefore, when working with real satellite data (not just sample data), use folders like *C:\sat*, *C:\sat\SeaWiFS\L3*, *C:\sat\Aqua\L3\month\CHLO*,sorted by sensor name and product level (e.g. L3, L4)

3.1 Loading files

- You can load an image with the standard [icon] *File-Open...* dialog in WIM (an icon on the toolbar) but a much faster way to find and navigate between the necessary image files is with the *Windows Explorer,* and then loading them by clicking (or double-clicking, depending on your Windows setup) on the filename. To be able to do that you need to associate WIM with the particular filename extension. Click (or double-click) on any HDF image file (e.g. *composite.hdf* in *Images\SeaWiFS\baja_2000_april*) and select *Wim.exe* (typically in *C:\Program Files\WimSoft*) as the program to open it with. You have to repeat that for HDF files with a different extension (e.g. SeaWiFS global Level-3 files like *S20000612000091.L3m_MO_CHLO_9* in *Images\SeaWiFS\L3\Month*) or Aqua Level-2 files *A*.L2_LAC*. **Please note**: after selecting WIM to handle these files, you have to select "***read as HDF***" for this file type in WIM. If you choose a wrong file type then the file will not be correctly loaded (You can correct your error with *View – Settings - Restore Defaults* – that will clear the previously set "*read as*" file types.).

- If you load images with the *Open* icon on the toolbar (menu *File – Open...*) you need to pay attention to the type of images that you are trying to read. WIM can read and write many types of images but you have to select the correct **Files of type** in the dialog. The next time you are trying to read or write an image the type used last time is already selected as default for you. In each folder you will be shown **only** the files with the extension that has been selected to correspond to the selected file type. This may create a problem for a beginner WIM user. For example, the folder *Images\SeaWiFS\L3\Month* has five HDF files but not all of them have the extension **.hdf*. In fact, most HDF files distributes by the NASA Ocean Color website do not have the **.hdf* extension. If you try to load the 9-km Level 3 chlorophyll file *S20060322006059.L3m_MO_CHLO_9* then it does not show up in the Open dialog box. You can see all the files by typing *.* in the *File name* box and then all files will show up. If you are regularly trying to open files that are not shown then you can add your extensions to the default extensions in *View - Settings – Extensions*. However, it

is better **not** to use the *File-Open* dialog at all and open files just by clicking or double-clicking on them in Windows Explorer.

- The only advantage of using the *File – Open...* dialog is that you can read multiple images at once by clicking on the *Open* icon on the toolbar (menu *File – Open...*) and selecting multiple files. For example, you can read all the HDF files from *Images\SeaWiFS\baja_2000_april* in one step.

- Each file can contain multiple images of its own. For example, you can load 3 SeaWiFS Level-1A images from *sw_l1a_mapped_byte.hdf* in folder *Images\SeaWiFS*.

3.2 Right-click and left-click

- To look up pixel values hold down the **right button** of your mouse and move the mouse on the image. In the top part of the image window frame you will see values in the format *X;Y (Lon; Lat)=PV (SV)* where *X* and *Y* are image coordinates (*X* = distance in pixels from the leftmost column, *Y* = distance in pixels from the top row), *Lon* and *Lat* are the corresponding longitude and latitude (note the order!), the pixel value (*PV*) and the scaled value (*SV* in geophysical units). If the image has no projection then the corresponding *Lat* and *Lon* are not shown.

- Select an area of interest (e.g. a rectangle) by moving the mouse with the **left button** down. Assuming that you have successfully opened *composite.hdf*, select an area of interest and apply the *Histogram* function (*Histogram* icon on the toolbar or menu *Examine – Histogram - Calculate*). Many functions (*Histogram, Statistics, Profiles,* etc.) operate on the selected area of interest (either a rectangle or a line).

3.3 Basic operations

- To create a coastline overlay for an image use the *Map Overlay* tool in the Toolbar or select menu *Geo – Get Map Overlay*. Then pick a map file with global coastlines, e.g. **coast_inter.b** or *coast_crude.b*. When you do it for the first time you have to locate the map file (e.g. in *C:\Program Files\WimSoft\Maps*). WIM memorizes the locations and the parameters so that when you do it the next time you will be directed to that folder at once). When creating an overlay make sure that the background pixel value is 0 and the foreground pixel value is either 255 (white) or 1 (black).

- Create multiple coastline overlays (*Geo-Get Map Overlay*) using different coastline files (*coast_crude.b*, *coast_low.b*, *coast_inter.b*, *coast_high.b*) compare the resolutions, overlay them on the sample image. The recommended coastline file is the 1-km coastlines file *coast_inter.b*.

- To overlay coastlines or other features on an image, click on the image in WIM, then on the *Overlay* icon on the toolbar (or *Multi –Overlay Image* in the menu). Make sure the image number to be overlaid is correct. The current image is assumed

when looking up values or performing operations (e.g. *Histogram*, *Statistics*). You can make an image current by either **left clicking** on it or **double clicking** on it in the List of Images box. Question to you: When should you use foreground pixel value 255 (white) or 1 (black)? Which one to use for SeaWiFS Level 3 files? Which one to use for files in the *Images\SeaWiFS\baja_2000_april* folder?

- The basic information about an image is shown in the List of Images box but more detailed image attributes are shown when clicking on the ▦ *Attributes* icon on the toolbar (*View –Attributes* in the menu).

- Scaling and other settings of an image are shown in the in the 🗟 *Current Settings* box (*Settings* icon on the toolbar or *View – Settings* in the menu). For example, check that the scaling for the *chlor_a* image in file *composite.hdf* is *Logarithmic* with *Slope* = 0.015 and *Intercept* = -2.0 (equivalent to the *Chl* scaling) and the projection is *Linear*.

- Get statistics for an area of your choice (select a rectangle with the mouse) by using *Examine-Statistics*, report Min, Max, Mean, St.Dev, Median, N-in-range, N-out-range. Note and select a proper valid data range. Note how the **valid data range** influences the results.

- 🗟 Select an area of interest by dragging the left mouse button (e.g. using file *composite.hdf*). Draw profiles in the horizontal and vertical direction.

- 🗟 Select an area of interest, calculate and plot Histogram (*Examine - Histogram*). Check out the *Values*, explain what the numbers mean.

- 🗟 Familiarize yourself with various options of the Settings panels (*View - Settings*), check and if necessary, edit the *Extensions* box for your files.

3.4 Changing colors

There are 3 ways to change color in WIM.

- Change colors by linear stretch with 🗟 - this uses the same palette of 256 colors but stretches them differently to correspond to pixel values from 0 to 255. By changing the *Start* and *End* values in *Color Definition* you set pixel values less than *Start* to black (the first color) and pixel values larger than End to the last color of the palette (e.g. white or pink, depending on the palette).

- Switch between one of the 3 types of palettes: *Rainbow*, *Grayscale*, *Custom*. The *Grayscale* and *Rainbow* are built in. The *Custom* is loaded with when loading the file or loaded with *File - Lookup Table - Load LUT* or that is set in *Settings – Special – Default LUT*. Switch between *Rainbow, Grayscale*, *Custom*, palettes. HDF files can include their own palettes. If a palette is included in the HDF file then WIM can either use that one or use the default palette depending if you have checked or unchecked *Settings – Special – Override LUT in HDF*.

- Set a suitable default palette (LUT) in *Settings – Special – Default LUT*, e.g. *LUT\chl1_white_end.lut.*

3.5 Compositing images

- Read all the *S2000*.hdf* images in *Images\SeaWiFS\baja_2000_april* at once by clicking on the *Open* icon on the toolbar (menu *File – Open…*) and selecting multiple files. Or read them one by one by clicking (double-clicking) on the filename.

- Create a composite with *Multi-Composite*. Pay attention to the *Valid Range* values. Try different options. The recommended values are 0.015 to 64 using the *Geophysical Values*. Explain the **pixel** and **geophysical values** in the resulting **two** new images.

- Compare your results with the existing composited image file *composite.hdf*. Observe the differences with *Multi - Difference*. The difference image should look mostly black (i.e. 0). However, there are some "dots" in the image. Observe their values with *Right-Click*. It is obvious that there are minor differences with the image in *composite.hdf* but the differences are minor. What could cause the differences? If your course covers also WAM exercises, you can do the same task later using the command line WAM program *wam_composite*.

3.6 Bathymetry image and depth contours

- Read *composite.hdf* or any other image with a projection. The projection is important – without it you cannot create a corresponding bathymetry image. Why? Use *Geo-Bathy Image*, select *world_bathy_5min.dat* (in the *Maps* folder) as the bathymetry data file. Now try the same with the 2-min bathymetry data (*world_bathy_2min.dat*). Observe and explain the differences between them.

- Create depth contours with *Examine - Contour Lines*. Select depth isobaths from 1000 m to 5000 m with a step of 1000 m and pixel value of 255. The depth contours show as white. Overlay the depth contours on the bathymetry image: the contours are not white, why? They are white on *composite.hdf*. Why? How to make them white on the bathymetry image?

- Convert the (2-byte) int16 bathymetry image to byte in *Logarithmic* scaling using ⊕ *Transf – Convert – BYTE - Logrithmic-Slope = 0.015, Intercept = 0*. Check out the differences between pixel values and scaled (geo-physical) values between the int16 and byte images. What are the differences?

- Overlay the depth contours and possible coastlines on the scaled byte bathymetry image.

3.7 Creating 3-component RGB images

- Read 3 image bands from a sample mapped SeaWiFS Level-1A image *sw_l1a_mapped_byte.hdf* in *Images\SeaWiFS*.

- Use *Examine – RGB Image* to create a RGB composite of the 3 bands; experiment with various settings.

- To create a natural looking "true color" image use the red band (670 nm) for the Red, green band (555 nm) for the Green and blue band (412 nm) for the Blue component of the RGB composite.

- Try the following combination: Red = 100-255, Green = 40-255, Blue = 44-255. Note that the smaller number must be on the lower scrollbar and the higher number on the higher scrollbar

- Save as JPEG, GIF or 24-bit Bitmap (BMP), confirm that the colors of the saved file are OK using another program (e.g. *Windows Picture and Fax Viewer*), and compare the color quality of the different formats.

- Please note that the more complex procedures of creating "true-color" RGB images with MODIS data using *wam_rgb_modis* is described in a separate document (*Exercises_modis_250m.pdf*).

3.8 SeaWiFS Level-3 (SMI) images

- Global SeaWiFS Level-3 images are usually referred to as Standard Mapped Images (SMI). With the nominal resolution of 9 km at the equator the image size is 4320 x 2160 pixels (4096 x 2048 in older versions). MODIS Aqua and other datasets are also distributed at 4 km nominal resolution. SMI images are usually composited for daily, 8-day, monthly and annual time periods. Check out all files in *Images\SeaWiFS\L3*. Keep in mind that these files are in HDF format but the extensions are different. The extension depends on the period and resolution type, e.g. **.L3m_MO_CHLO_9* for monthly 9-km Chl data and **.L3m_MO_PAR_9* for monthly 9-km PAR data. Set up the association between WIM and these files by clicking (double-clicking) on the file and then selecting WIM as the application (see exercise 3.1 *Loading Files*). Check out the attributes with 🔲 and find the units and the time compositing time period (start year and day, end year and day). What month is that?

- What is the purpose of making composites with over time? Compare the coverage of daily, 8-day, monthly and annual CHLO files. Explain the difference. Explain the patterns of missing data in the daily CHLO image. Calculate the number of missing pixels for selected daily, 8-day, monthly and annual CHLO images in 1998 using the *Histogram* tool (📊). Present these numbers in a table. What do they show? Do you get the numbers of missing data pixels as 8,562,051; 6,011,440; 4,583,810; 3,858,275 for, respectively, the daily, 8-day, monthly and annual CHLO images? Calculate the change in ocean coverage (i.e. % of ocean pixels with valid CHLO values) from daily to annual composites. Tip: subtract the land and coastline pixels that you can get from *land_4320x2160.hdf* in *Images\SeaWiFS\L3*. Create a table (see below) with pixel counts and percentages for the daily, 3-day, monthly and annual images. Explain the changes.

	Number of Missing Pixels	Number of Valid Pixels	Valid of Total%	Valid % of Ocean	Number of Total Pixels	
Daily					Land	
8-day					Coast	
Month					Land + Coast	
Annual					Total Ocean	

- Cut out rectangular subsets in your area of interest, create coastlines for them with *Geo - Get Map Overlay* with *coast_inter.b*. Which pixel value is best to use for coastlines? Why? Use [icon] to stretch the colors to best visualize the spatial structure in the ocean.

3.9 Calculating primary production from a set of 3 images (CHLO, PAR, SST)

- Load a set of 3 monthly images: SeaWiFS chlorophyll image *S20000612000091.L3m_MO_CHLO_9* and SeaWiFS PAR image *S20000612000091.L3m_MO_PAR_9 in Images\SeaWiFS\L3\month and* Pathfinder SST image *200003.s04m3pfv50-sst-16b.screened.hdf* in *Images\SST.* Note that they all represent monthly data from March, 2000. Confirm that all images represent the same time period. Check the Attributes (*View-Attributes*, [icon] icon on toolbar) of the images. Confirm each image's scaling.

- Use *Multi - Primary Production* (with default settings) to create a PP image. Make sure that you have selected the right image numbers for the CHLO, PAR and SST images, respectively.

- Check the Pixel type and the size of the PP image from the *List of Images*, compare the attributes using the *Attributes* icon on the Toolbar. What are the units? How can we get primary production per month?

- You can convert the (2-byte) int16 PP image to byte in *Logarithmic* scaling using [icon] *Transf – Convert – BYTE – Logrithmic – Slope = 0.015, Intercept = 0.*

- To calculate PP for a set of many image triplets it is better to use a WAM command-line program *wam_pp* - see the section on WAM command-line exercises.

3.10 Tracking in situ measurements on images

- Load the composited SeaWiFS Chl image of the Baja California area *composite.hdf* in *Images\SeaWiFS\baja_2000_april*. Load a sample point file *ime9801.pnt* in

Images\SeaWiFS\baja_2000_april with *Geo-Get Vector Objects-Point* (Bitmap Only, Geographic Lon, Lat, Float Lon Lat). These are actual stations from a Mexican cruise IMECOCAL 9801.

- Select a point in the *Vector objects* table and see which one is blinking. Select *Statistics* for the selected point. The statistics is calculated for a 3 x 3 pixel window centered at the point. Note the **Nin** (= number of pixels in valid range) and **Nout** (= number of pixels out of valid range) values.

- You can select one or more (or all) the points and save all the statistics at once into a new file, e.g. *test.pnt* with the *Save Lat,Lon,Value* button. Note that the valid data range is not available for changing in this operation and is assumed to be set previously. You can change the valid data range in *Examine - Statistics*. Now load the saved file into a text editor, e.g. *Notepad*, or MS *Excel* and verify the file format. Do not use the *Save* button that saves in an HDF file (it is not an image file that WIM can read). Select all the points in the *Vector objects* table and delete them all. You can also try to load the points from the saved point file *test.pnt* again.

- Familiarize yourself with the various vector object types (*Point, Transect, Rectangle, Drifter Track, Vector*), Coordinate (X-Y vs. Lon-Lat), drawing (bitmap vs. image buffer) options and with the *Vector Objects* table;

- Use *Geo- Get Vector Objects – Drifter Track* and select *drifter_track_test.pnt* that represents an imaginary drifter track file. Note the start (circle) and end of the drifter track.

- Load more point objects and display with a different symbol (select other than *Standard* when reading the points). You can make the points with pixel value 255 (white) and then load and overlay the same points with a different symbol and different color (e.g. 220, red). This improves the combined symbol's visibility. Load an image from *2nd_ovl.hdf* in the *Program Files\Wimsoft* folder and reproduce it!

- Create some sample *Transect* objects with *Geo – Distance – Save – Close*. Save as a **.trk* file. Load the saved **.trk* file using *Geo – Tracking – Transect*. Select individual Transect objects, show their profiles, calculate statistics along the transect.

- For more automated finding of matches between many points and many images you can use the graphical WAM utility *wam_match* (see the exercise on *wam_match*). For automated point statistics use *wam_statist* or *wam_statist_sta*.

3.11 Utility for converting between dates and Julian days

Many image file names use the day of the year (Julian day of the year) instead of the date. A simple command line utility *julian.exe* converts between a date and a Julian day.


```
Syntax: julian YYYYMMDD => converts to date to Julian day
    or: julian YYYY JDAY => converts julian day to date
```

For example:

```
julian 20011123
YYYYMMDD=20011123 => Julian Day=327
```

shows that November 23 of 2001 is Julian Day 327. Try the reverse calculation:

```
julian 200 327
Julian Day=327 => Year=0200 Month=11 Day=22
```

3.12 Remapping and overlaying images

- Load any Level-3 standard mapped image (SMI, e.g. in *Images\SeaWiFS\L3\Month*) and another image from *composite.hdf* in *Images\SeaWiFS\baja_2000_april*. Using *Geo-Remap Projection* remap the SMI image to the projection of *composite.hdf* using *Forward* mapping. Then do the opposite, remap the local image in *composite.hdf* to the projection of the SMI image. Try to find it by scrolling the big black image up and down and left to right. Now create a coastline overlay for it with *Geo-Get Map Overlay* with *coast_inter.b*, pixel value 255, overlay it on top of the last remapped image. Repeat the previous remapping operations using *Inverse* mapping.

- Try to create an image that looks like the following image. Note that the coastlines are black; latitude-longitude grid is white. Try to reproduce it as close as possible.

  Hints: Projection is *Polar Stereo (S3A)* of the SSMI products (*Images\SSMI\S3ACOAST.HDF*), the data is SeaWiFS Level-3 chlorophyll.

© Mati Kahru, WimSoft
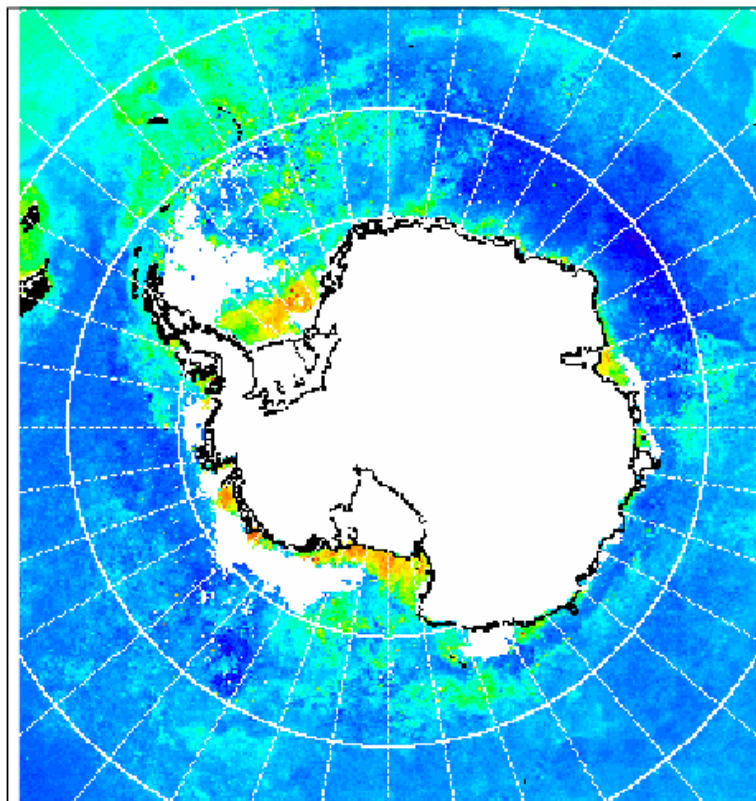
3.13 Screen Level-3 images for best quality

- Many MODIS and AVHRR Pathfinder version 5 global Level-3 SST datasets are distributed at various quality levels. A separate image specifies the quality index of the data. Before using these SST data you should evaluate the quality pixels first. Typically the lower-quality pixels are believed to be contaminated by clouds and should be eliminated. Sub-pixel, thin or otherwise undetected clouds usually cause cold anomalies as clouds are almost always colder than the sea surface. However, sometimes obvious "false positives" are assigned, i.e. pixels suspected to be contaminated by clouds are actually from sharp SST fronts. In most cases pixels with lower quality should be excluded. They are frequent in certain areas, e.g. in the Pacific Ocean off South America. The purpose of the screening operation is to exclude the low-quality or questionable data by setting those pixels to zero pixel value.
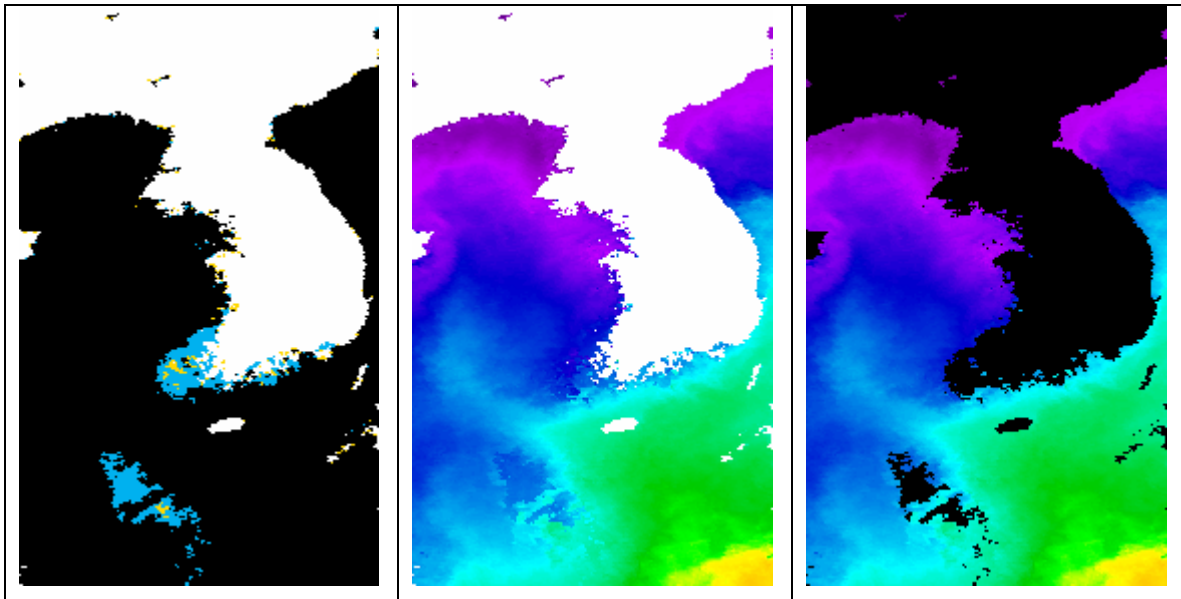
- MODIS-Aqua SST data processed by the OCPG include both the SST data and the quality data in the same file as separate datasets (SDS). The MODIS-Aqua monthly 4-km SST data can be downloaded from ftp://oceans.gsfc.nasa.gov/MODISA/Mapped/Monthly/4/SST/. Load a sample monthly data from *A20060602006090.L3m_MO_SST_4* in *Images\MODIS-Aqua\L3\Month\SST_4*. First note that the file has two datasets (SDS): the SST data are in the *l3m_data* and the quality index in the *l3m_qual*. Load them both into WIM. Select the quality image. Note that the scaling of the quality image is *Linear* with *Slope* = 0.000717 and *Intercept* = -2.0, i.e. the same as for the *l3m_data*. This is **not**

correct as the *l3m_qual* has erroneously the *Slope* and *Intercept* arguments. Fix that manually by selecting *Settings - Value Scaling - Pixel Value*. Stretch the colors of the quality image so that you can better see the low range pixels (e.g. set the *End* pixel value at 3 in *Color Definition*). Navigate to an area with nonzero quality pixels, e.g. south-west from the Korean peninsula (see the left panel in the figure above). Find the corresponding area in the SST image. Notice the strange SST pattern that is obviously contaminated (see the middle panel in the figure above). The purpose of the following operation is to eliminate those questionable pixels by setting their pixel value to zero. That should eliminate those pixels from any calculations, e.g. for statistics. To do that make the SST image the current image and use *Multi - Mask w. Image*, selecting the quality image as the mask image with mask value = 0, and click "Yes" to accept pixels with mask smaller or equal than 0. This will keep only those SST pixels that have high quality (quality = 0) and mask all others with pixel value 0 (see the right panel in the figure above). To better visualize the SST data and save disk space, you can also convert the 2-byte integer image to a byte image with *SST-Pathfinder* scaling. To do that use *Transf – Convert – BYTE - SST-Pathfinder*. Now compare the screened SST image that you just created with *A20060602006090.L3m_MO_SST_4_screened.hdf* in the same folder where you loaded the source images. Evaluate the difference with *Multi - Difference*. The resulting difference pixels should all have value 0.

- For screening many images at once (in batch mode) you can use command line WAM programs: *wam_screen_sst_ocpg* for MODIS-Aqua and MODIS-Terra SST, *wam_screen_pf* for AVHRR Pathfinder version 5 data, *wam_screen_modis* for old-style MODIS files.

3.14   Edge detection in sea-surface temperature images

- More details on edge (front) detection with WIM and WAM are provided in *Exercises_WAM_Edge_Detection.pdf*. Here we test several edge detection methods with WIM.

- Load a MODIS-Aqua SST 4-km monthly data screened with WIM *A20060602006090.L3m_MO_SST_4_screened.hdf* in *Images\MODIS-Aqua\L3\Month\SST_4*.

- Navigate to area around Japan, or the Gulf of Mexico/Florida, or another area with strong and large-scale SST gradients. The Gulf Stream and Kuroshio currents are well visible in these areas, respectively. Cut out a rectangular area with the Cut (✂) tool. Apply the following edge detection methods:

- *Transf-Gradients-Sobel*

- *Edge-Shade Edge* (select *Min pixel value to use* 1 or higher to eliminate edges with land).

- *Edge-SIED* (try first the variable window and then a fixed window of size, e.g., 20).

- Evaluate the histogram in some well-defined frontal regions by selecting a rectangular area and then applying the *Histogram* tool (). Confirm that the histogram has two or more peaks that define the existence of a front in the SIED method.
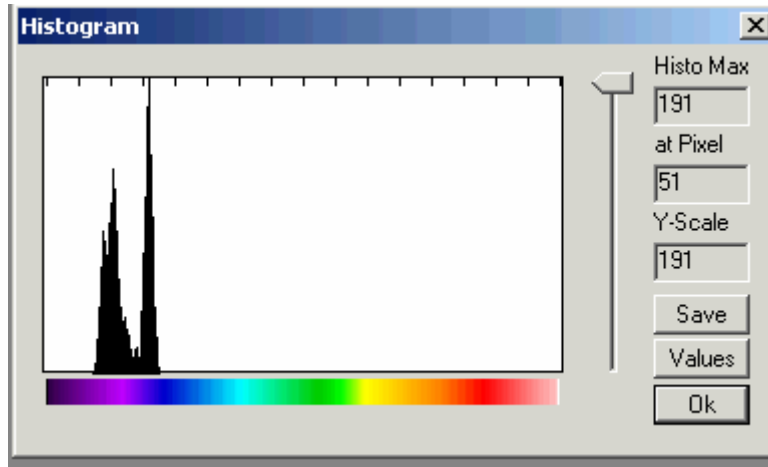
- Overlay the detected edges onto the Cut image with the Overlay () tool.
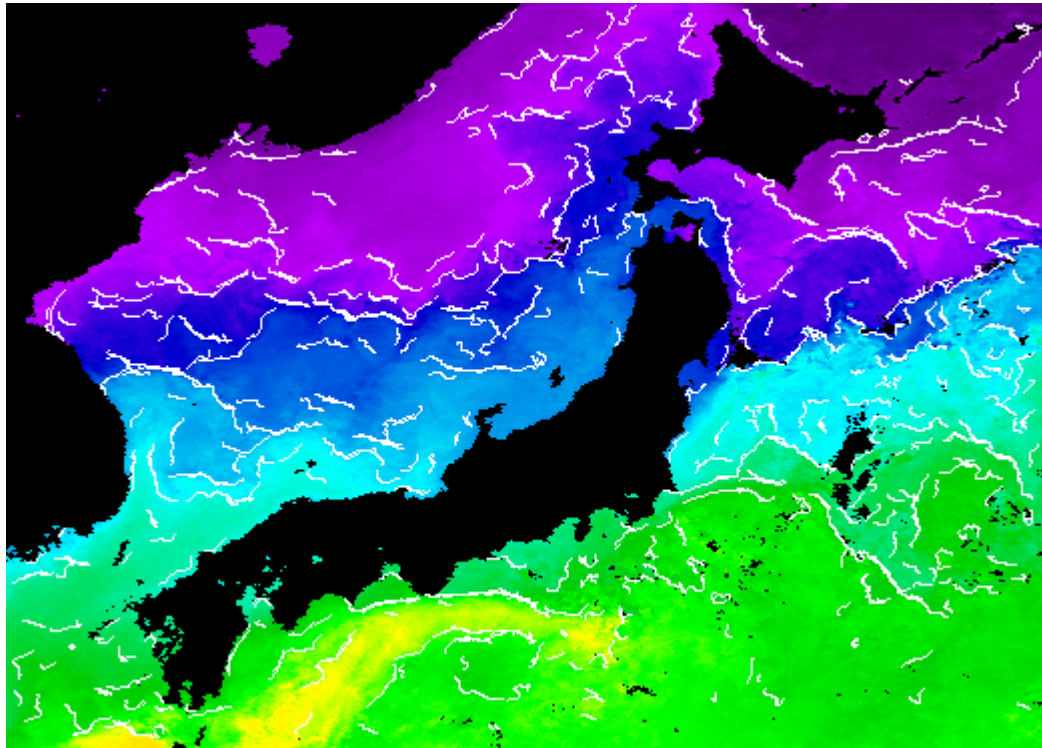
- You can automate edge detection and compositing on many images with *wam_edge* and *wam_edge_accumulate* (see *Exercises_WAM_Edge_Detection.pdf*).

3.15   Compare MODIS and SeaWiFS chlorophyll products

- Several satellite sensors (e.g. SeaWiFS and MODIS-Aqua) can produce similar products, e.g. Chlorophyll-*a*. Also, a number of different algorithms can be used to produce different versions of the same product from the same sensor. In addition, data from different sensors can be merged to produce merged, multi-sensor products. As clouds tend to move in between the different overpass times of different sensors, these merged products have the potential to provide more data in case of variable cloudiness.

- Compare three monthly, 9-km Chl-a composites from February, 2006:

    - *S20060322006059.L3m_MO_CHLO_9* in *Images\SeaWiFS\L3\Month* (SeaWiFS)

    - *A20060322006059.L3m_MO_CHLO_9* in *Images\MODIS-Aqua\L3\Month\CHLO_9* (MODIS-Aqua)

    - *A20060322006059.L3m_MO_XS_CHLO_9* in *Images\SeaWiFS-Aqua\Month\CHLO_9* (merged SeaWiFS-Aqua)

- Examine the spatial coverage, i.e. the number of missing or bad data. You can calculate pixel distribution with the *Histogram* tool ( ), click on *Value* to see the number of pixels in each histogram class. The merged product has 2 bytes per pixel. Histogram calculation in WIM is implemented for Byte images that can have pixel values from 0 to 255. Convert the 2-byte per pixel product to byte with the Conversion tool ( ) using *Log-Chl* scaling. Calculate the total number of pixels in the highest pixel value class (255 or 253, i.e. the invalid pixel value). Which product has the best coverage, i.e. least number of invalid pixels? Rank the products in terms of coverage. Do you get numbers like those below? Explain the values.

    4,815,743

    4,644,353

    4,409,064

- Calculate the percentage improvement of the merged product compared to the two individual products. Note that this is a monthly product and therefore the improvement in coverage is not dramatic. For 8-day and especially daily products the improvement is much better. Explain why.

- Examine how well the values correspond to each other in different products. Select a sub-area, do *Examine – X-Y Scatter*, experiment with different ranges. Evaluate the differences. Calculate statistics for some sub-area with *Examine-Statistics*. Which is higher, on average?

- Find the differences between images with *Multi-Difference* and *Multi-Subtract Image*. The calculated image is Float32 and needs adjustment for better visualization. Make the *Max* value in *Color Scaling* in *Settings* ( ) smaller, e.g. 1.

- Calculate the ratio with *Multi – Divide w. Img* (use Pixel Value scaling on both images).

3.16 SeaWiFS Level-2 data: "Black waters" of Florida

- More details on SeaWiFS Level-2 data are provided in a separate document *Exercises_detecting_habs.pdf*.

- Load SeaWiFS Level-2 data from *S2001265175156.L2_HUSF.sub.map.hdf* of 22-Sep-2001 in *Images\SeaWiFS\L2*, select *nLw_555*, *chlor_a*. Convert *chlor_a* to Byte with ⇐-$ *Transf – Convert* – BYTE - Log-Chl.

- Use *Transf - Binarize* to find areas (pixel) that have LOW reflectance at 555 nm and at the same time HIGH chlor_a. For example, use the following conditions:
  0 <= nLw_555 < 0.5,   4 <= chlor_a < 66.
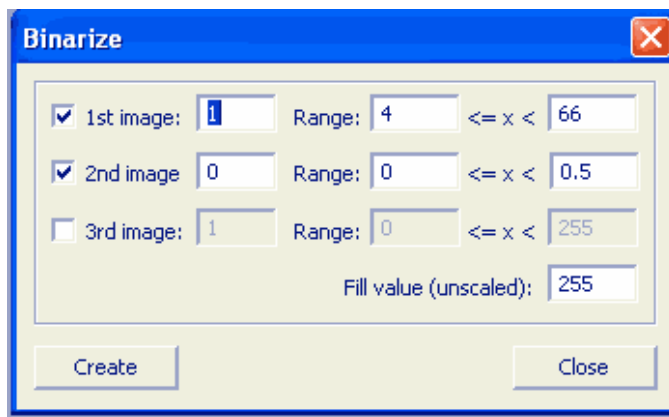
- Create coastlines with *Geo - Get Map Overlay* with *coast_inter.b*, coastlines value 1. Why 1? Overlay coastlines on the masked image, explain the distribution.

3.17 Using MODIS-Aqua Level-2 images

- More detailed instructions and examples on working with Level-2 ocean color data are provided in a separate document *Exercises_SeaWiFS_Aqua_Level2.pdf* and *Exercises_SeaWiFS_Aqua_Level2_Appendix_Your_area.pdf*.

- You can select order and download various Level-2 (i.e. unmapped) ocean color data on the NASA ocean color website http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am. You need to select the sensor (e.g. MODIS-Aqua), time and space range. You can immediately download a full granule. It is better to order a whole set of subset (i.e. cut to the selected spatial range) datasets. A granule is a swath dataset collected in 5 minutes.

- Download a suitable Level-2 data file by clicking on it. Note that it is compressed using the BZip2 compression scheme; you need a program to uncompress it. Included with WIM is a command line utility *bzip2.exe*. You can open a command window and

type *bzip2 –d *.bz2* to unzip all **.bz2* files in the directory. Alternatively, you can you use *Power Archiver* (http://www.powerarchiver.com), and right-click on the downloaded file, and use *Extract Here*. You can also get sample Aqua L2 data from the WIM CD in *Images\MODIS-Aqua\L2*.

- Load the *chlor_a* dataset from both of the **.L2_LAC* files in the *Images\MODIS-Aqua\L2* folder. (The easiest way to do that is just to click (double-click) on the file. When you do it the first time you have to select WIM as the application to load the data file, then select read as HDF.) Resize the windows so that you can see both images at the same time and navigate both to the Gulf of California area. Why is the Gulf of California bigger on one and smaller on the other image? This is the reason why we have to remap the images to a standard projection. You can also convert the *chlor_a* images from the float32 format to the scaled byte format by using *Transf-Convert* ((€-$ icon on the toolbar) - *Log-Chl* scaling.

- If you have internet connection then you can display the map of the Level-2 swath in *Google – Maps* (, *Geo - View in Google Maps*) or overlay the image in *Google Earth* (, *Geo – View in Google Earth*), see the two examples below.

(27.586184, -117.893539)
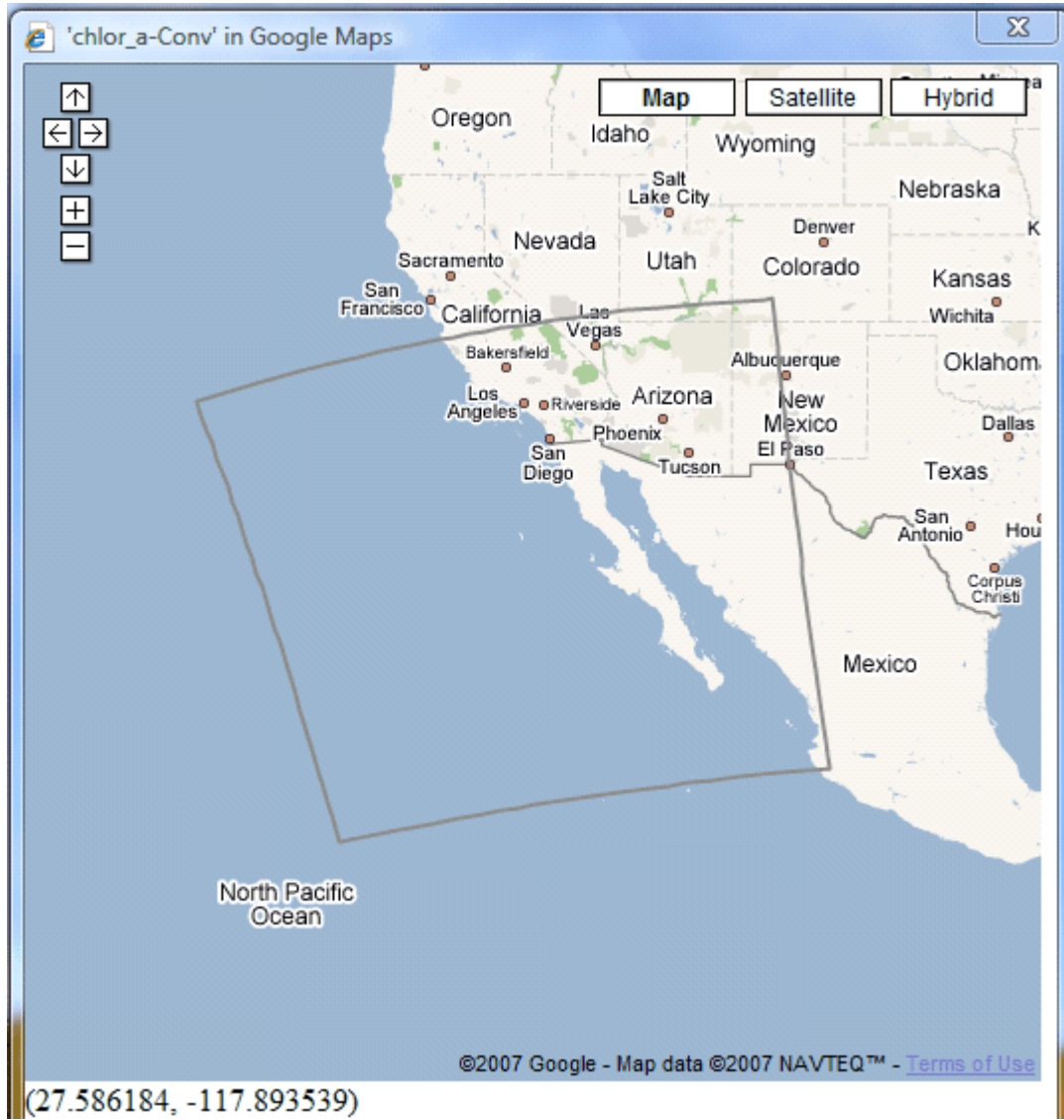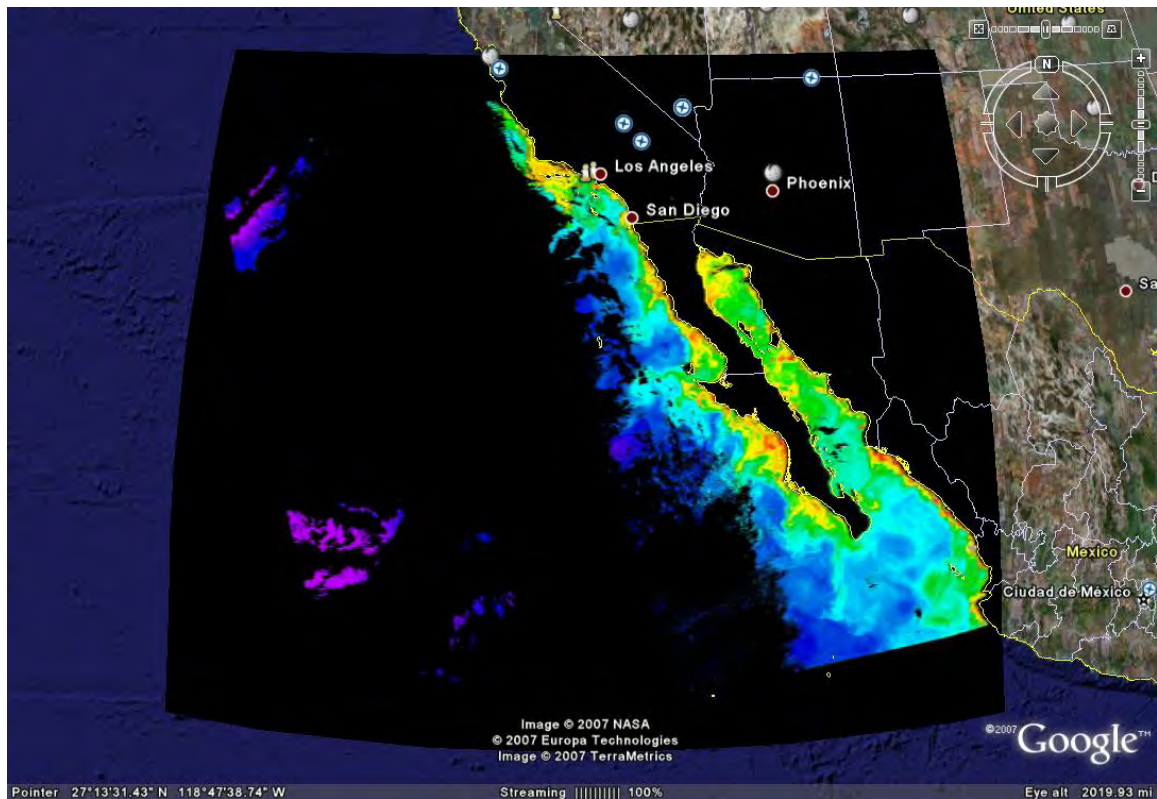
- In order to have a consistent projection of the images we need to remap them to some "standard" projection using *Geo - Remap Projection*. You need to spend some time to find the best target projection for your area of interest. The easiest projection is *Linear*. Check out the target projections (and overlay files at the same time) in *Images\MODIS-Aqua\L2_processing*. The 512 x 512 pixel images were created using the HDF images in the *Images\SeaWiFS\baja_2000_april* folder. Try to reproduce these or similar overlay images. You can create a new *Linear* projection with *File - New* and selecting the target image size and latitude-longitude range. Consider the pixel size in the target image: if the source image has 1 km pixel size then you may want to make the pixel size of the target image close to that. Measure the distance across the image with *Geo - Distance*, calculate the average pixel size using the distance and the number of pixels along the picked transect. You can also draw and open square of size 100 x 100 pixels near the center of the image with *Edit – Draw* and measure the horizontal and vertical distance. The pixel size is now easy to calculate by dividing the distance with 100. Note that the 512 x 512 pixel images have the pixel size of approximately 2.7 x 3.7 km in the center of the image. In order to make the pixel approximately square we can expend the height of the image. The 512 x 700 pixel overlay image has approximately square pixels.

- When you have decided on the target projection and image size you can add some standard features to the target image that you use as an overlay to create a series of annotated mapped images. For example, put coastlines, latitude-longitude grid, maybe some stations (e.g. use small filled red circles to designate stations) and the color

scale to the target image. Most of this has been covered in previous exercises. To get the appropriate color scale set the scaling of the target image to *Log-Chl*, scroll the *Start* and *End* of color scaling to your preferred range. For example, to consistently display all the chlor_a images with the color range 0.05-10 mg m^{-3} use *Start* and *End* of 48 and 200, respectively. After that select a rectangular area somewhere on the image (where it does not cover the main features of interest) and use *View - Annotate*. You may have to experiment a few times to get what you are satisfied with. Do the same for SST; i.e. make a new overlay image, set the value scaling to SST, Pathfinder, set the Start and End pixel values to 120 and 255 (corresponding to SST of 15.0 and 35.25, respectively). There is a sample SST overlay file in *Images\MODIS-Aqua\L2_processing*. Now you can use that target image not only as the standard projection to remap to but also as a standard overlay for the remapped images. The process of converting, remapping, annotating and overlaying images can be automated with a WAM program *wam_series* (see below in this document). Even more advanced results can be achieved with a WAM command line program *wam_l2_map*.

- Open the command window and navigate to the *Images\MODIS-Aqua\L2 folder*. Move or copy your target and overlay files to the same folder (e.g. from *Images\MODIS-Aqua\L2_processing*). Type a command

     wam_l2_map A2006*LAC cal_chl_48_200.hdf 215 17

- Here the first argument is a set of matching *LAC files, then comes the target projection/overlay file, then the *X* and *Y* coordinates of the annotation. More details on this are in the separate documents *Exercises_SeaWiFS_Aqua_Level2.pdf* and *Exercises_SeaWiFS_Aqua_Level2_Appendix_Your_area.pdf*. If the command finished successfully, you should have 3 chl-a files per matching file: a mapped HDF file, a mapped and annotated HDF file and a PNG file. Sample chl-a PNG file is shown below.

-
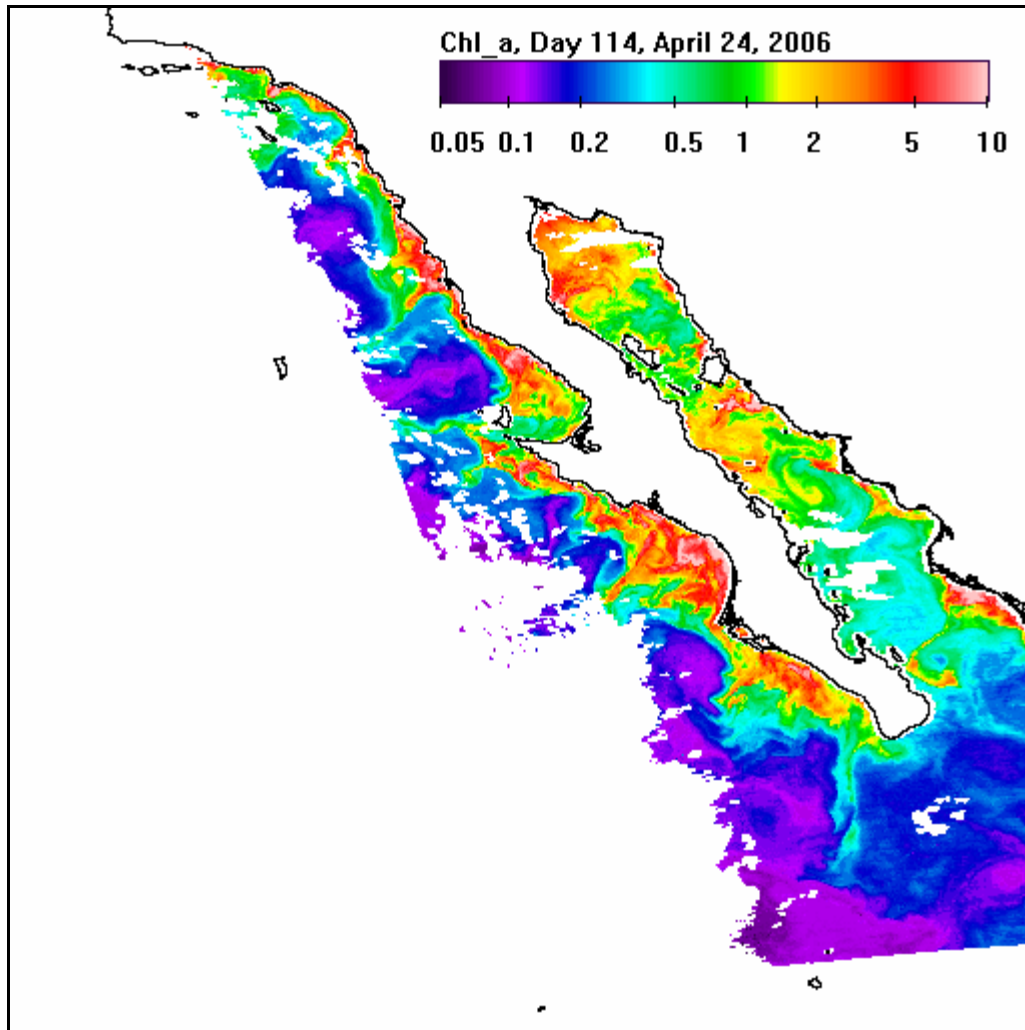
- Note that the *LAC file have also the SST data but no SST quality data. To produce a quality-checked ST file you have to run another command with the *SST files:

  wam_l2_map A2006*LAC_SST cal_sst_120_255.hdf 215 17

- If the command finished successfully, you should have 3 SST files per matching SST file: a mapped HDF file, a mapped and annotated HDF file and a PNG file. The PNG file is shown below.
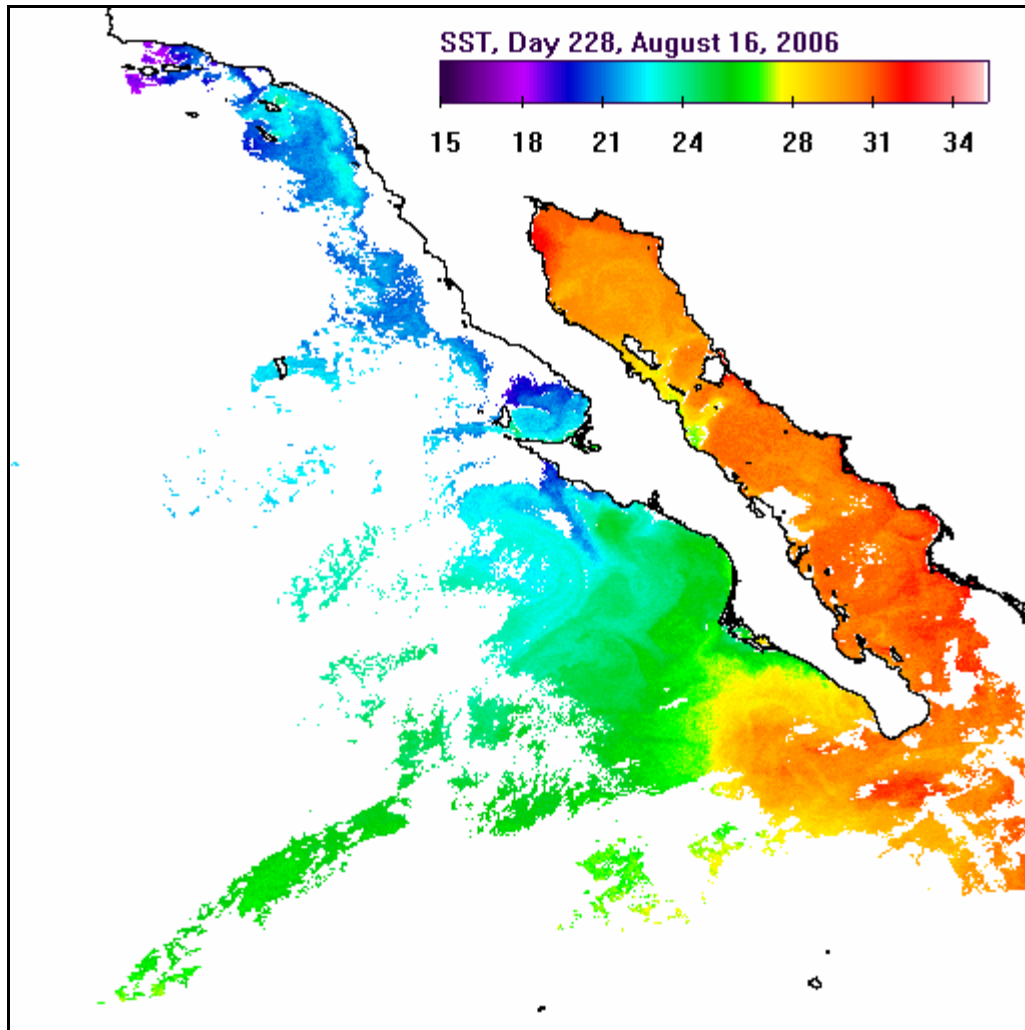
3.18 Combining RGB images with pseudo-color images

- The color images created in the previous exercise are called "pseudo-color" images as the colors are assigned using a rather arbitrary palette or lookup table (LUT). If we have a pseudo-color chlorophyll-a or SST image of the ocean then it is often appealing to cover land and or clouds with "true-color" like colors. In this exercise we will combine Level-2 ocean color images like those used in the previous exercise with a quasi-true-color image created from MODIS Level-1B data (see separate exercises in *Exercises_modis_250m.pdf*).

- Load a sample RGB image from *Images\MODIS-Aqua\L1B*. This is a Aqua-MODIS RGB image from julian day 123 of 2004, mapped to a 500 m Albers conic projection.

- Load a sample Level-2 Chlor-a image, e.g. from *A2004123212000.L2_LAC* in *Images\MODIS-Aqua\L2*, convert to *Log-Chl* scaling with *Transf-Convert*.

- Remap to the 500 m Albers conic projection of the RGB image.

- Stretch the colors to 48-220 (Chl-a concentration of 0.05-20 mg m^{-3}).

- Convert pixel value 0 (black) to 255 (white): first set *Value Scaling* in *Settings* to *Pixel Value*, then use *Transf – Replace Values* from 0-0 to 255).

- Create coastlines with *Geo – Get Map Overlay* with Foreground value of 1 and background value of 0 using coastlines file *coast_full.b*. Fill the ocean area with pixel value 1 using *Edit - Draw – Fill* and Convert to RGB using *Transf – Convert to 24bbp (RGB)* .

- Overlay this on top of the original RGB image using *Multi – Overlay Image*.

- Fill the ocean area with a RGB color of black (0-0-0) using *Edit - Draw – Fill*. Save this last image in HDF format to be used as a standard overlay file (in case you want to use it later for other images). We will call this image a "RGB overlay".

- Convert the Chl-a (with white missing values) to RGB using *Transf – Convert to 24bbp (RGB)* and overlay the "RGB overlay" on top of it using *Multi – Overlay Image*.

- The coastlines will be "washed out" (not visble) as we used pixel value 255 for the coastlines and there is no ocean color data next to the coastlines (white). We can create separate coastlines with pixel value 1, make them look dark blue (or any other dark color), transfer to RGB and overlay on top of our "RGB overlay" and use the new image with dark coastlines as the "RGB overlay".

- The final image should have pseudo-color Chl-a data over the ocean, white pixels for clouds and quasi-true color pixels for land. Some of the intermediate and the final images are shown in the table below. Try to reproduce these images yourself!

- You can also add color bar, etc. to your "RGB overlay". Try to create a similar RGB image for SST by combining the SST data from the same file (in pseudo-color) with true-color land. Use the color bar from *sf_sb_aco_500m_sst_80_120.hdf* in *Images\MODIS-Aqua\L2_processing*.

- As you see, the process of creating nice-looking RGB images with RGB land and pseudo-color ocean takes a number of steps and quite a bit of time. You can easily automate the process if you want to apply the same RGB overlay on many images. A WAM application wam_series can be used for that – please see a separate section on wam_series. Sample log-files of wam_series for processing Level-2 Chl-a and SST data with RGB overlays (*log_chl_15day_RGB.txt* and *log_sst_15day_RGB.txt*) are in *Images\MODIS-Aqua\L2_processing*. You will need to modify them for your file locations.

•
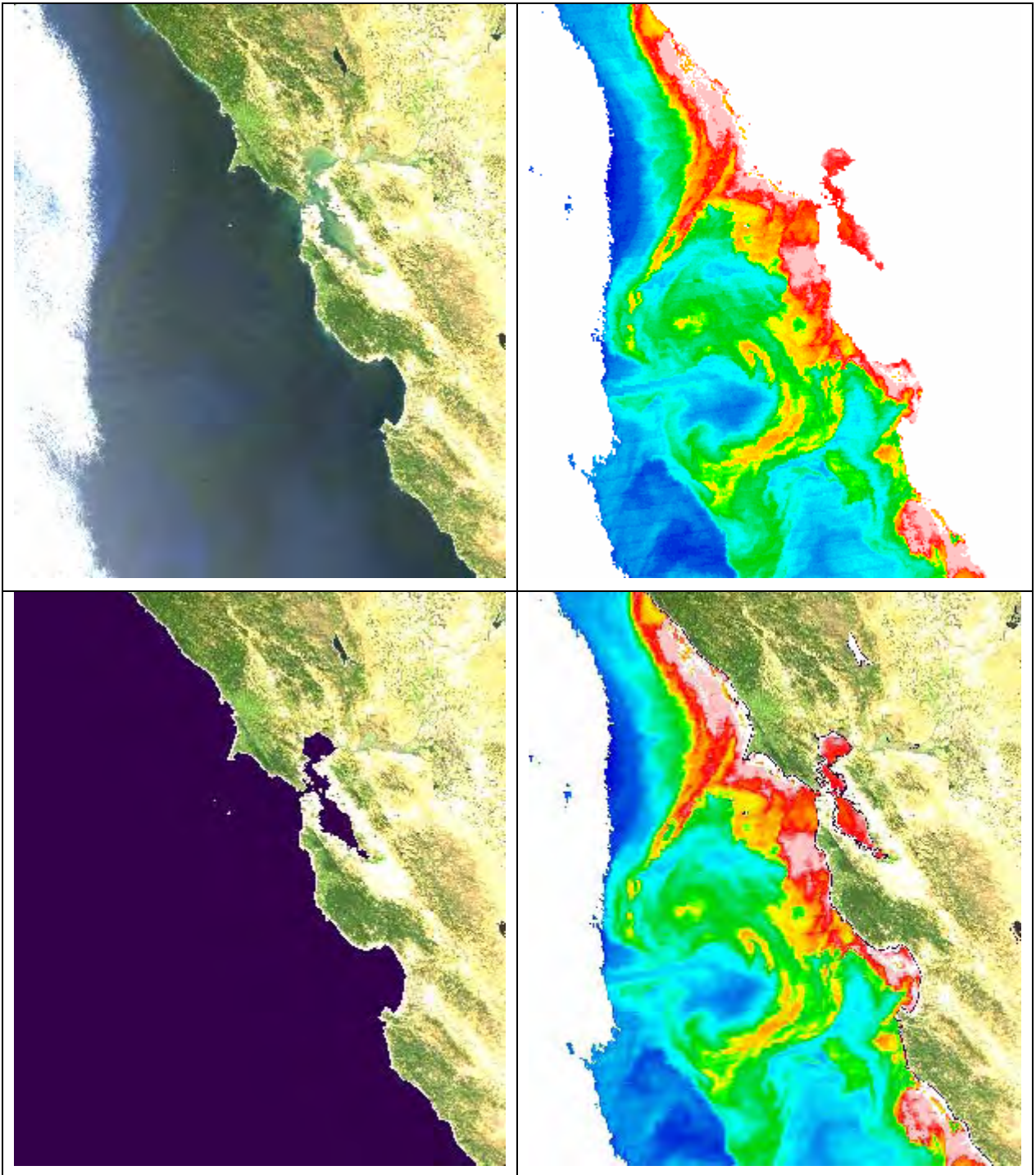
3.19 QuikSCAT Level-3 products

• Global ocean wind data can be obtained from the SeaWinds scatterometer (a specialized radar) on the QuikSCAT satellite (see http://podaac.jpl.nasa.gov/ftp/). The data can be downloaded from ftp://podaac.jpl.nasa.gov/pub/ocean_wind/quikscat/ .

- Open and examine a sample QuikSCAT file
  *QS_XWGRD3_2003230.20032311346.*hdf in *Images\QuikSCAT* that has the Level 3-
  derived multi-algorithm surface wind stress products. You may need to extract
  (unzip) the file first. The file has many datasets (SDS).

- Load the ascending and descending average wind speed images, *asc_avg_wind_speed*
  and *des_avg_wind_speed* (the first 2 SDS-s). Check their HDF attributes. If the image
  appears upside down, mirror it (*Transf-Mirror*) over the horizontal axis.

- Create a composite (average of valid values from ascending and descending passes)
  with *Multi-Composite* using reasonable (make your guess!) valid data range. Check
  out the Count image, do *Examine-Histogram-Values*. Explain the results: 0: 563750
  pixels, 1: 222070 pixels, 2: 250980 pixels. The following figure shows the Count
  image. What do the patterns indicate?
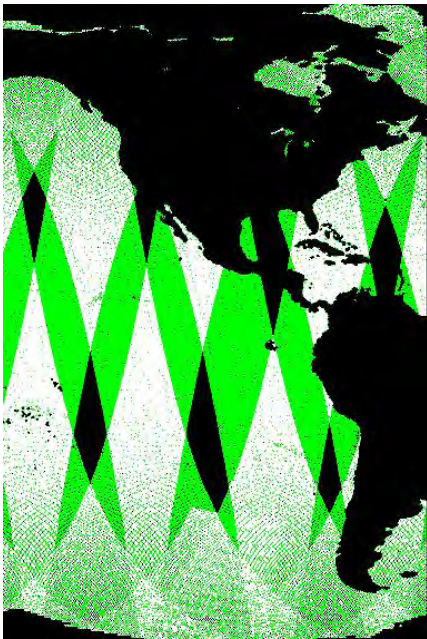
3.20 Opening image files the hard way

- Opening HDF files is easy as everything is set for you if the reading software (e.g.
  WIM) understands correctly the HDF attributes. We expect that the image size, the
  value scaling, the color scaling and the geo-location are all set when we click on the
  file. To understand what the reading software is actually doing, we read an image file
  the "hard way".

- The New Generation Sea Surface Temperature (NGSST) for Open Ocean
  (http://www.ocean.caos.tohoku.ac.jp/~merge/sstbinary/actvalbm.cgi?eng=1) is a
  merged SST product for the ocean around Japan that is being assembled from various
  sources by the Kawamura Lab in the Tohoku University, Japan. The main advantage
  compared to other traditional satellite products is that by merging data from different

sources and modeling achieves high spatial resolution at high temporal frequency. The data format is a simple raster binary (Image in WIM terminology) with a header of 200 bytes. Try to read a sample NGSST binary file *msst2006121012.raw* (December 10, 2006) from *Images\SST\NGSST\raw*. However, this format is not a modern format like HDF and therefore reading it is not so easy. First, you have to know that the size of the image is 1000 x 1000 pixels with 1 byte per pixel. Try to open the file with the *File – Open* dialog as *Files of Type: Image* (type *.* to see the file). Set the *Width* and *Height* to 1000. Before finishing that dialog, click on the *Special* tab and set *Image Header* to 200 bytes. Of course, you have to know that the header is 200 bytes. If you don't know the image *Width* and *Height* and the *Header Length*, the image will not be read correctly. Assuming that you read the image correctly, you will notice that the image is upside down. To fix that use *Transf – Mirror – Horiz. Axis*. Try to guess the pixel coordinates or the temperature? You will notice that they are not set. For scaling, set *Settings –Value Scaling* to *SST-Pathinder*, C. Why are some areas white? Could it be ice? Setting the geo-location is harder: in *Settings - Projection - WIM native projections* set the projection to *Linear*, the *Longitude coefficients* to 116 and 0.05 and the *Latitude coefficients* to 63 and -0.05. **Explain what is the meaning of these numbers?** Now check that you get the coastlines that are correct (with *Geo – Get Map Overlay*).

- Hopefully you managed to do all these operations correctly and have the SST image in WIM memory. Now open the corresponding HDF file is the *Images\SST\NGSST* folder by clicking on it. Check the difference between the two images with *Multi – Difference*. You must receive a black (= 0) image. Check the HDF attributes of the both images. Why are they different? The attributes (e.g. *Start Year*, *Start Day*, etc) are essential when performing time series analysis.

- You probably realized how much work it is to read a simple binary file compared to an HDF file. A WAM program *wam_convert_ngsst* converts all raw binary NGSST files to HDF files including all attributes with a single command.

4 WAM exercises with Graphical User Interface

The following exercises are with the WAM programs that use GUI (graphical user interface) in the form of Windows Forms. These programs are powerful utilities that incorporate many functions in a single Windows program. You have more control over the individual components in the command-line WAM utilities (next section). Using WAM programs assumes that you have installed the .NET Framework (see section 6.3).

4.1 wam_series

A common scenario for WIM users is that they have a series of image files that need the same kind of kind of transformations. You can easily do that with WIM on a single image but doing it on many images is tedious and error prone. For example, you may have a

large batch of images that cover a large area and you want to cut out a small sub-area or map it to another projection, overlay coastlines and/or station locations, convert to byte, stretch the color scale, annotate with year and date, and save in a number of different formats (GIF, JPEG, PNG, HDF, Lat/Lon/Value). This is where *wam_series* is used.

Detailed information on *wam_series* is provided in the WAM manual (*WAM.pdf*). Start *wam_series*. You should begin with a few simple functions and proceed to more complex examples. As a start, run *wam_series* with the default settings. If you have copied the *Images* folder on the WIM/WAM CD to *C:\Program Files\Wimsoft* then you can just click *Start* and check out the resulting JPEG files in the *C:\Temp* folder. The default option is to use the sample SeaWiFS Level-3 images, cut out a subset in the California region, overlay coastlines with pixel value 1, annotate with date, and stretch the colors from 20 to 220 and save the JPEGs of the output in *C:\Temp*. If you have sample files in a different location then you need to modify the *From dir* text box.

You can now start experimenting with *wam_series*. Let's pick the source files from *Images\SeaWiFS\L3\Month*. Open any file from there with WIM (by clicking or double-clicking on the filename) and select your area of interest. To be used in an animated GIF the area cannot be very large (images of about 400 x 400 pixels are OK.). Note the latitude and longitude ranges. You should now type the latitude and longitude range into *wam_series* to the right of the *Cut subimage* check box. The north latitude goes to the top box, south latitude to the bottom box, west longitude to the left box, east longitude to the right box. Pick a folder where you are going to store the results, e.g. *C:\Sat\out* (create it if it does not exist). For temporary tests you can save the output to *C:\Temp* folder but for more useful results you can create a new folder, e.g. *C:\Sat\out*.

Wam_series has a number of inputs that specify the sources, outputs and operations. All selected options are stored in the registry just before processing starts, so even if you close the *wam_series* application or turn off the PC, the next run of *wam_series* will start with your last options selected.

If you want to save the settings of more than one set of parameters you can save these in separate log files and load these another time. In this way you will have a record of what you did; and you can repeat the same operations or modify them at a later time.

 The following are the main options:

    "**From dir**"specifies where your source images are. In the test you can use *C:\Program files\Wimsoft\Images\SeaWiFS\L3\Month* but for a more useful exercise get a longer dataset, e.g. all the monthly OCTS and SeaWiFS chlorophyll datasets from DVD *Sat-Data*, folder *OceanColor/SeaWiFS/CHLO* and copy these to *C:\Sat\SeaWiFS*. It is convenient to navigate to the folder where your files are with Windows Explorer and copy and paste the folder name in the Address bar into the text box in *wam_series*.

    "**File pattern**" is how you pick (match) the files in the input directory. For example, you can use S*CHLO* - that would match all SeaWiFS CHLO files. Be careful not to match too many images as it may take a long time to process!

"**To dir**" is the folder name where your output files will be written, e.g. *C:\Temp* or *C:\Sat\out*.

"**Input type**" as **HDF**, **SDS** as 0. With HDF files containing multiple images (scientific datasets = SDS) you can specify the sequence number of the image in the file. With single image HDF files this should be "0". Note that the numbering starts at 0 and not 1.

"**Save as**" is the output file type, e.g. JPEG or HDF.

"**Cut subimage?**" – check this and select your area of interest by the range: North (top box), South (bottom box), East (right box) and West (left box). Remember to use negative longitude for West longitudes and negative latitude for south latitudes. All values are in decimal degrees, e.g. latitude of 0.5 means 0 degrees and 30.0 minutes north. When *Statistics* is checked, no sub-image is produced and instead, the statistics is calculated. Uncheck all the other check-boxes and click **Start**.

When everything worked out as expected, start experimenting with more options. You can try **Median filter** with the window **size** (typically 3 or 5 pixels) to smooth the output image with a median filter of a specified size. Overlay coastlines by checking "**Coastlines**" with **Overlay Pixel Value** with *C:\Program Files\Wimsoft\Maps\coast_inter.b* and the pixel value of the coastline. Typically, you may want to use 255 (white) for the coastlines to be visible on black background or 1 (purple or black) on white background. Use 1 for the SeaWiFS Level-3 SMI images. Experiment with "**Color stretch**" to find the best "**Start**" and "**End**" values corresponding to the *View-Set Colors* (color definition) type of color stretch operation in WIM.

"**Overlay**" lets you use an overlay file that you have to generate WIM before running *wam_serie*s. For example, you may want to put a specific latitude, longitude grid with station locations, color bar or anything else on top of the images. Even bathymetry contours may be used in the overlay image. Remember that the overlay needs to be of the same size as the output files and the background (transparent on the overlay image) needs to have pixel value of 0. If you are using the specified overlay file you should not use *Coastlines* overlay.

Create an overlay file using one of your output files saved as HDF as the starting point. When you are done, saved as HDF, then specify that filename in the **Overlay** text box of *wam_series*.

"**Annotate**" with selectable **X** and **Y** values lets you specify where an annotation consisting of the year and start day of the image will be put. X means the distance in pixels from the left and Y means the distance in pixels from the top. If you use a negative values, e.g. "-1" for any of these, the default values corresponding to the top right corner will be used. The date annotation will be correct only if *wam_series* can find date (e.g. the *Start Year* and *Start Day* from the image attributes or name). This works for most common images.

"**Statistics**" with "**Valid Min, Max**" selects to calculate statistics for either the whole image or a sub-area specified by the "*Cut subimage*" values. The resulting output file of statistics for the whole series of images is saved in a text file *statistics.txt* in the current folder. The Min and Max values for the valid data range need to be specified as invalid values should be excluded from the statistics calculations. For example, in case of typical chlorophyll-a values the Min and Max should be 0.015 and 64.0, respectively.

 "**Convert to byte?**" lets you convert multi-byte (e.g. Int16 and Float) images to simple scaled byte images that are easier to manipulate and visualize. The selectable scalings are "**Chlor_a, Logarithmic**", "**SST-Pathfinder**", "**Linear**"and "**Logarithmic**" that correspond to the available scaling types in WIM.

"**Remap to**" lets you remap the image to a selected image in a specific projection (and size). You can also change the mapping options (*Forward*, *Forward* with *Fill gaps* or *Inverse*) in *wam_series*.

One application of *wam_series* is to create a sequences of images that can be viewed as an animation (movie loop). With Windows XP you can easily navigate through the images with the *Windows Picture and Fax Viewer* and have the appearance of an animation. Animated GIFs can be easily created with some simple software tools. These GIFs can be viewed by dragging the file to Internet Explorer. Ask the instructor for a sample program to create animated GIFs. Make your own animated GIF, set the time interval (e.g. to 1 second).

4.2   wam_match

The need to understand the relationships between satellite data and ground measurements is fundamental in any application of satellite measurements. The problem is that satellites never measure **exactly** the same variables as ground measurements and need validation. There is no one-to-one relationship between the remote and ground methods. An important source of discrepancy is the huge difference in the measurement footprint. Let's say you have a set of measurements that you want to compare with satellite images. You can just move the mouse pointer and by right-clicking in WIM see the geophysical values at a certain location of longitude and latitude. This can be done if you have only a few points and a single image. However, usually we have a whole time series of images and a set of points. The number of all possible pairs of comparisons gets overwhelming.

The purpose of *wam_match* is to generate coincident datasets between satellite and *in situ* data. You can get more information on *wam_match* in the WAM manual (*WAM.pdf*).

An important restriction is the validity of the satellite data. Invalid or missing data within an image is caused, e.g. by clouds, and is usually flagged or masked with invalid pixel values. There are two ways of separating valid values from invalid values: using a valid range or a separate image of flags.

Valid range with Min and Max is the easiest way of defining valid pixels. The problem is that the valid range may not obvious and may change for different scalings. Also, when doing match-ups with multiple images in the same file (e.g. *chlor_a*, *nLw412*, *nLw443*, *nLw490*,…) the valid range may be different for the individual images. Also, in some cases we may need to have more details in the classification of pixels based on their quality. Use 0.015 and 64 as the typical valid range for Chl-a data.

Using **flags** allows a more detailed characterization of the "quality" of match-ups. For each pixel a set of flags is generated in the Level-2 processing. Each flag indicates if a certain condition has been met. For example, SeaWiFS Level-2 images have 32 flags each of which can be on or off.

Before starting matching satellite images with **your** data you need to gain experience by reproducing the screenshot in the WAM manual.

- Select "*C:\Program Files\Wimsoft\list_mapped_C.txt*" as the *List of Images*, and "*C:\Program Files\Wimsoft\match.pnt*" as the *List of Point* data (point file), uncheck the *Use flags* checkbox, use "*Time lag, hr*" of 28, "*Window, DX x DY*" of 3 x 3 and 5 for "*Min Valid Pixels*" (minimum number of valid pixels considered acceptable). Also select Band 0 to be used (the files in the selected list have only 1 SDS). Note that if you are using the Spanish version of Windows and have installed WIM in *C:\Archivos de programa* instead of *C:\Program files* then you need to pick "*C:\Program Files\Wimsoft\list_mapped_spanish.txt*" as your *List of Images.* This assumes that you have copied the *Images* folder from the WIM CD to the *Wimsoft* folder on your hard disk.

- The sample list file expects the image files to be in *D:\Images\SeaWiFS\baja_2000_april.* If you have the images in a different path then you need to edit the list file.

- After you click *Start* and the program finishes you should get 35 matches. Examine the output log by scrolling it up. Try to understand the output results.

- If any match-ups are found they are put into a *data-grid* and into the graph. You can select variables to be plotted from the point dataset (X-axis) versus variables from the satellite data (Y-axis) as well as the point's "Label" variable using respective up-down controls. The point's "Label" is shown in the "**Point Label**" text box. A "label" is actually any field in the point table (e.g. longitude, latitude, date, time, etc.) and can be selected in the "**Select Point Label**" domain up-down control. When moving the mouse cursor to a particular point you can see the point label in the "Point label" text box. Also, in the data-grid the corresponding row is selected. Vice versa, when a row is selected in the data-grid by selecting it with a mouse click, the corresponding point in the plot will be surrounded by a blue diamond frame. The value is used to represent **missing values** in both the point and satellite data can be chosen. Typical values are 0 or -9.

- You mark outliers for elimination and eliminate them from the plot. As the plot ranges are picked by the min and max, eliminating outliers will likely create a more

focused plot. Try to save the results as a CSV file and as figures (PNG, EMF). The *Save as XML* option is not fully implemented yet. Examine the saved CSV file with MS *Excel*. Observe that the eliminated matches have been moved to a separate section.

You can experiment with *wam_match* by observing the effects of changing some parameters. For example, reduce the *Time lag*; note the changes to the number of matches. Explain. Check up the figure in *WAM.pdf* explaining the *Time lag*.

- If you want to create match-ups for your own data and images, you have to create your own List and Point files. Note that you need to have the full path name of image files, e.g. *C:\Sat\SeaWiFS\L3\ S20062742006304.L3m_MO_CHLO_9* for each image file. The image list is easily generated by a command like this:

    dir/b S*.hdf > list.txt.

    You can then edit the text file with *Notepad* and add the full path to the files.

- Please note that with some image files (e.g. MODIS-Terra Level-2, GLI Level-2) having the latitude-longitude arrays (LLA) in a separate file, the list file format is slightly different. You need to add the name of the geo-referencing file after a comma and without the full path. It is assumed that the geo-referencing file is in the same folder as the data file.

- Create your own "**List of Point data**", i.e. a WIM point file. The point file format has tab or comma separated columns of *longitude*, *latitude*, *date* and *time* followed by *station* and whatever measurements you have. See the sample file *match.pnt*. The point file is best generated in *Excel* worksheet and saved as tab or comma separated text file. In WIM point files have extension **.pnt*. The first line in a point file is a header and is not used for data.

4.3 wam_statist

Wam_statist calculates statistics for masked areas for a series of images. More information is provided in the WAM manual (*WAM.pdf*). You can start with a simple example and proceed to more complex exercises. *Wam_statist* uses masks of any shape to select areas of interest. For example, if you can create a time series of statistics and integrated primary production values for a certain masked area. You can have up to 255 different areas of interest that you are calculating statistics for. Of course, in a typical case the number of areas of interest is much smaller. *Wam_statist* calculates statistics for each masked area and, in addition, the sum of each pixel's value multiplied by the pixel area. The integral is calculated only for the commonly used *Global Equal Angle* projection where the pixel area is a simple function of latitude. Pixel area of an image in other projections is more complicated and has not been implemented. The standard mapped images (SMI) of SeaWiFS, MODIS, AVHRR Pathfinder and MCSST are all in *Global Equal Angle* projection. In order to calculate meaningful statistics the program needs the range of valid values. Note that there are no options to manually specify the

valid data range. It is assumed that *wam_statist* can correctly estimate the valid range for the set of images. This works for most common images but may need to be updated at the source code level for new types of images. The *fMin* and *fMax* values that *wam_statist* is using are reported. If these values are not correct for your images, please report to WimSoft with a sample image and we will update *wam_statist*. For example, for the Log-Chl (byte) scaling the valid chlorophyll-a values are between 0.015 and 65. All values outside this range are considered invalid and are not used in the statistics. As an output *wam_statist* saves a text file (CSV file) that can be importing into a spreadsheet program like MS Excel. It reports the following: *Image* (file name), *SYear* (start year), *EYear* (end year), *SDay* (start day), *EDay* (end day), *Mask* (mask number), *Nin* (number of valid pixels in the mask), *Nout* (number of invalid pixels in the mask), *Min*, *Max*, *Mean*, *StDev*, *Median*, *Total* (integral over the mask).

Wam_statist uses a mask image to define areas of interest. A mask image defines areas of interest with pixel values from 1 to 255 whereas pixel value 0 specifies an area not to be used. Mask images can be created with a number of different ways, e.g. drawing with the WIM functions *Edit-Draw*, *Transf-Binarize*, filling coastline contours, shifting coastline contours with *Multi-Shift Image* and then overlaying with the original coastlines, etc.

A sample mask image before cleaning looks like this:

The mask numbers (pixel values) are shown only for demonstration here. Please note that the mask image has to be of the same size and projection as the images that are being used. You can create the mask image by creating a coastline image for one of your data images. The mask image shown above was created by cutting the Mediterranean area from the global SMI image. The mask image should be saved either in HDF (preferred) or *compressed (RLE)* format. Before using the mask in *wam_statist* the sample mask image above needs cleaning, i.e. coastlines, grids, etc that have pixel value of 255 (white) have to be cleared (converted to pixel value 0). Otherwise those pixels will also be considered as another area of interest and used in calculating statistics (for mask area 255). This is probably not what you intended to do. You can use *Transf - Replace Values - Replace range from* 255 *until* 255 with value 0. Remember that *Value scaling* should be *Pixel value* before running *Transf - Replace Values* (otherwise the scaled values will be used).

You also need a list of images that you are going to use.

A few lines from a sample image list look like this:

C:\sat\Projects\Medit\CHLO\O19963061996335.L3m_MO_CHLO.cut.hdf

C:\sat\Projects\Medit\CHLO\O19963361996366.L3m_MO_CHLO.cut.hdf

C:\sat\Projects\Medit\CHLO\O19970011997031.L3m_MO_CHLO.cut.hdf

You can easily create lists of images with a DOS command, e.g. *dir/b *.hdf > list.txt*. This command lists all *.hdf* files in the current folder. You need to precede each file name with its path (e.g. `C:\sat\SeaWiFS\Month\CHLO\`).

The output file is in the CSV (comma separated values) format. It is currently assumed that comma is a separator between numbers and not a decimal comma (point). If your Windows is set up to use comma as a decimal comma then you need to change it in *Control Panel – Regional and Language Options*. We will try to make next versions of *wam_statist* independent of regional settings.

The output format is effective to produce but cumbersome in using simple plotting routines, e.g. in MS *Excel*. You can sort the output file by mask numbers in Excel or use a utility *sortmasks*. The syntax is

```
sortmasks input_file
```

Sortmasks converts the input file into a sorted file **_sorted.csv*. The sorted file is ready to be imported to a spreadsheet like MS *Excel*. A time series of chlorophyll concentration (the *Median* is plotted here) using monthly composites of OCTS and SeaWiFS is shown below. As you can see, with a few simple operations we were able to generate Chl time series for a set of different regions.
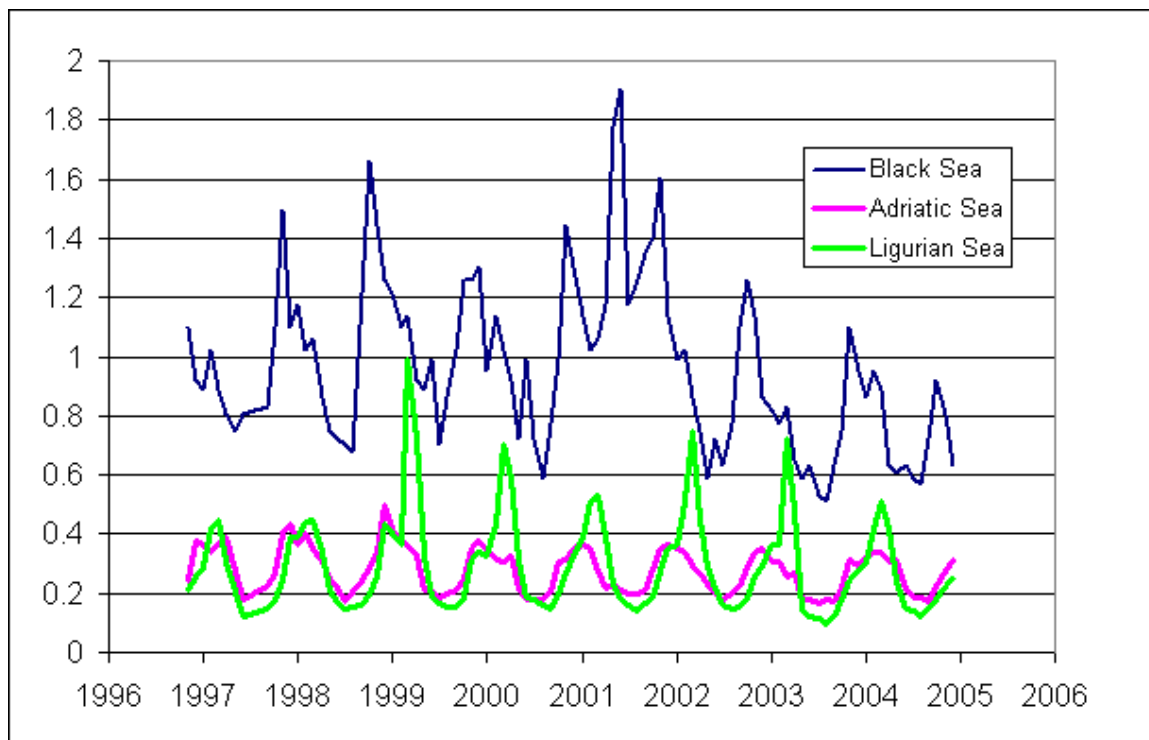
5 WAM exercises with command-line applications

The following are simple examples of WAM programs that in spite of their simplicity can be a big help for a WIM user who tries to automate WIM operations. The source codes of all the examples are included. Most of the WAM examples are command line programs, i.e. they are executed by typing the command with arguments in the Windows command window.

The executable programs of the command-line utilities are provided but you can also modify the source code and recompile. The source codes are in the C# language and are in the WAM folder on the WIM/WAM CD. The command-line C# compiler is part of the .NET Framework and is available for free. When compiling your own WAM programs you can have the source code in any folder but the executable should be built or copied into the Wimsoft folder.

5.1 wam_composite

wam_composite is a useful utility for creating composites from various file types. You may want to make a composite Chl image of a certain 10-day period using available daily images but the official products are daily and 8-day images. Or may-be you want to make composite of all October SeaWiFS images from 1997 to 2003. You can make the composites interactively with WIM but it is much more convenient to use

© Mati Kahru, WimSoft

wam_composite. All you need to do is make a list of the image files names that you want to composite. Having a list gives the additional benefit of having a record of files used in the composite. You can create the list by simply doing *dir/b* on your image files and piping that to a list file. You can, for example, change directory (*cd*) to *C:\Program Files\Wimsoft\Images\SeaWiFS\L3\Month* and type

```
dir/b S199*CHLO* > list.txt
```

That creates a list file called *list.txt* and dumps all the matching SeaWiFS filenames into it. You can skip files from being used in the compositing by preceding the file name with the # character. That allows you to keep the file name in the list in case you want to use it another time. Run *wam_composite* with:

```
wam_composite list.txt composite.hdf count.hdf
```

That creates two HDF files: a composite file and the corresponding count file. Explain the contents of the *count.hdf* image Check out the attributes of the resulting images. Do they make sense? If you wan to use the composited image in a time series analysis then you need to make sure that the attributes are correct.

Create a January (or pick any other month) composite of all the SeaWiFS monthly images of a certain variable (e.g. CHLO) of that month: get the data from the separate DVD *Sat-Data*, create the list file, run *wam_composite*.

5.2 wam_anomaly

wam_anomaly is a powerful WAM utility for creating mean and anomaly images from a series of images. It is a complex process with many options. In the process of learning how to use *wam_anomaly* we will use some of the tools that we learned to use earlier (image editing with WIM, *wam_series* and *wam_composite*). Please also see a separate document *Exercises_WAM_EOF.doc*.

1) Locate the SeaWiFS monthly chlorophyll data on the sample CD or DVD or ask the instructor. We can use all available monthly images from SeaWiFS. We prefer to use not the originals but the slightly modified version of them. The file names have a pattern of *SYYYDDDYYYYDDD.L3m_MO_CHLO_9* where S means SeaWiFS(O as the first letter means OCTS), YYYY are the start or end year, respectively, *DDD* are the start and end julian days of the year, respectively. The "_9" string in the end means the 9-km nominal resolution. Aqua-MODIS data have both 9 and 4 km resolution mapped global data.

2) Create a work area for this project on the disk, e.g. *C:\sat\Projects\Medit*. Under it make a folder CHLO for subsets of the standard chlor_a.

3) Using *wam_series* extract subsets covering the Mediterranean area and save as HDF. You can also save the JPEGs but that is not essential. The cut area could be, e.g. between latitudes 30 and 50 and longitudes -11 and 42.5.

4) Create a mask image for your subsets. Load any of the HDF cut images and create the coastlines (*Geo-Get Map Overlay* with *coast_inter.b*). We would like to fill land with a pixel value of 128 because in the anomaly images the pixel value 128 would mean no change. Use *Edit-Draw* with *Outline* and *Fill* values 128. To save your time against a "spill of color" outside the land areas, make a copy of your image with *File-Copy Image*. It is better first to find possible leak areas near the image edges and fill them with the Paintbrush tool. It's all much easier than it sounds! Now, fill the land with the Paint can tool. Take care of the islands in the same way. Save the resulting image as HDF in your work area (e.g. *C:\sat\Projects\Medit*) as *mask_medit.hdf*.

5) Now create monthly means and monthly anomalies with the *wam_anomaly* utility. Open a command window and navigate to your work area. *Wam_anomaly* has 2 modes: *Monthly* and *Interannual*. in the monthly mode it creates monthly means for each of the 12 months available and monthly anomalies relative to the monthly mean. In case of chlorophyll the anomalies are calculated as ratio to the mean. The full scale of the anomalies is for the from 0.1 to 10 of the ratio, i.e. from 10 times below and 10 times above the mean. Below average values are blue, above average values are red. The intensity of the color shows the intensity of the anomaly (ratio value). In the command window type the following

> *wam_anomaly 12 CHLO\S1997*.hdf mask_medit.hdf*

The number 12 here means that we are using the Monthly mode (12 months). The *S1997*_9* is just for a test. For the real run replace *S1997*_9* with *S*_9*. This will now match all the SeaWiFS images. You will now have new files *S_Means.hdf* and *S_ValidCounts.hdf*. Evaluate these files. Do you understand what these data represent? Make sure you do! Now evaluate the many anomaly images. Look at both the HDF and the JPEG files. You can make an animated GIF from the JPEGs.

6) The next task is to study *interannual* variability at annual scale. For that we need to create annual composites that are representative for the year. You can make a composite of all the 12 months of each year or pick a certain season. For example, for the southern ocean near Antarctica, the productive season spans the New Year and it makes sense to use, for example, months from December to February. You can use WIM interactively to make the annual composites and save in a separate folder; however, a better way is to use *wam_composite*. This way you will have a record of what files were used in the compositing. To use the *wam_composite* utility make list files (see previous exercise on *wam_composite*). For example, a list file for 1998 could be named *list_S1998.txt* would have the following contents:

```
CHLO\S19980011998031.L3m_MO_CHLO_9.cut.hdf
CHLO\S19980321998059.L3m_MO_CHLO_9.cut.hdf
CHLO\S19980601998090.L3m_MO_CHLO_9.cut.hdf
CHLO\S19980911998120.L3m_MO_CHLO_9.cut.hdf
CHLO\S19981211998151.L3m_MO_CHLO_9.cut.hdf
CHLO\S19981521998181.L3m_MO_CHLO_9.cut.hdf
CHLO\S19981821998212.L3m_MO_CHLO_9.cut.hdf
CHLO\S19982131998243.L3m_MO_CHLO_9.cut.hdf
CHLO\S19982441998273.L3m_MO_CHLO_9.cut.hdf
```

```
CHLO\S19982741998304.L3m_MO_CHLO_9.cut.hdf
CHLO\S19983051998334.L3m_MO_CHLO_9.cut.hdf
CHLO\S19983351998365.L3m_MO_CHLO_9.cut.hdf
```

Please note that the filenames here do not use the full path (*E:\sat\Projects\Medit\CHLO*) and are accessible only from the work folder. It is better to have the full path as you could then use the list file from any location. Make list files for all the years. If using the whole year then you may need to exclude 1997 as it only has months from September to December.

7) Create annual composites using *wam_composite* and the list files created earlier. You can name the annual composites something like chlo_med)1998.hdf and so on. The command are like that:

> *wam_composite list_S1998.txt chlo_med_1998.hdf count.hdf*

Note that the count image will be overwritten if using the same command pattern for other years.

8) For clarity move the anomaly images to a new folder *CHLO_anomalies* and the annual images to a new folder *CHLO_annual* (both under your work folder).

9) Now make the interannual anomalies (and interannual mean) by issuing the following command:

> *wam_anomaly 1 CHLO_annual\chlo_*.hdf mask_medit.hdf*

The number 1 here means that we are using the Interannual mode (there is just one interannual mean instead of the 12 monthly means). The *chlo_*.hdf* is a pattern that matches the newly generated annual images. You will now have new files *chlo_Means.hdf* and *chlo_ValidCounts.hdf*. Evaluate these files. Do you understand what these data represent? Make sure you do! Now evaluate the annual anomaly images. Look at both the HDF and the JPEG files. You can make an animated GIF from the JPEGs.

5.3 wam_pp

wam_pp is a command line program for creating primary production images in batch mode. The input files, their paths and options are read from a list file. A sample list file (*list_calc_npp.txt*) is provided. Before you can run the test example you have to uncheck the *Read-only* property of the file *list_calc_pp.txt* (right-click on the file in *C:\Program Files\Wimsoft*, select *Properties*, uncheck *Read-only*). The format of the list file is the following:

```
 C:\Program Files\WimSoft\Images\SeaWiFS\L3\Month\
 C:\Program Files\WimSoft\Images\SeaWiFS\L3\Month\
 C:\Program Files\WimSoft\Images\SST\
 #
 S20000612000091.L3m_MO_CHLO_9,
      S20000612000091.L3m_MO_PAR_9,
```

© Mati Kahru, WimSoft

```
        200003.s04m3pfv50-sst-16b.screened.hdf,289,1,1,1
```

Please note that the 3 filenames have to be in one line. The triplet of file names of sample images: *S20000612000091.L3m_MO_CHLO_9* and *S20000612000091.L3m_MO_PAR_9* in *Images\SeaWiFS\L3\month* and *200003.s04m3pfv50-sst-16b.screened.hdf* in *Images\SST* (see example on calculating PP using WIM). You need to modify the list file. Copy *list_calc_npp.txt* and rename it, then modify by using your paths and file names. Each line should have the filenames of the CHL, PAR, and SST data, followed by the Julian day of the middle of the period, and optionally the three option parameters (see the WIM manual *Wim.pdf* for an explanation). The lines that start with the "#" character are skipped in reading the image names but not the path names. That is a convenient way to mark sets of images that you do not want to use in the current run but would like to keep in the list. For each line a new primary production image of type int16 created. The name of the resulting primary production image is derived from the CHL image. If any of the strings "CHLO", "CHL3" or "CHL" is found, it is replaced with "PP", otherwise "_PP.hdf" is appended to the CHL filename.

To run it with the provided list file, type:

```
    run_pp list_calc_npp.txt
```

The int16 (16-bit integer) pixel value that represents primary production in mg $C/m^2/month$ is assumed with a simple linear scaling (intercept=0.0, slope=1.0). You can visualize the primary production image by loading it into WIM.

The function that calculates primary production has 3 optional parameters that follow the list of image names. The default values are *1,1,1*, i.e. each line is followed by three values of one. The first parameter specifies photoinhibition (2=no photoinhibition, 1 and anything else = photoinhibition). The second parameter specifies PBopt functions (see WIM manual). The third parameter specifies euphotic zone depth calculation (2=Morel and Maritorena, 2001 model; 3=SPG Southern Ocean formulation; 1 and anything else=Morel and Berthon, 1988).

5.4 wam_statist_sta

wam_statist_sta is another image statistics program. Please note it is probably easier to use the GUI program *wam_statist* instead of this command line program. It uses a list of points (stations) given by their longitude, latitude and name, and a list of images, to calculate statistics for 3 x 3 pixel areas centered at the stations for all the images.

You can modify the source code and recompile by typing:

```
    c wam_statist_sta
```

To run it, type:

```
    wam_statist_sta  sta_list   img_list  output
```

where *sta_list* is a text file with longitudes, latitudes and station names (in that order), img_list is a list of filenames to be used, output is the name of the output file.

You may have to modify the validMin and validMax variables specifying the valid data range in the source code to comply with your images. The correct minimum and maximum values are difficult to determine programmatically for all potential images.

A sample station list file looks like this:

```
Longitude    Latitude    Station
-117.3050    32.9567     Sta1
-117.3950    32.9133     Sta2
```

A sample image list file looks like this:

```
D:\sat\S19972441997273.L3m_MO_CHLO
#D:\sat\S19972741997304.L3m_MO_CHLO
```

Symbol # in the beginning of the line is used to exclude the marked line from the calculation. The output file is in the CSV (comma separated values) format and has the following header:

```
Image,SYear,EYear,SDay,EDay,Station,Nin,Nout,Min,Max,Mean,StDev,M
edian,Pixelvalue
```

Here SYear and EYear specify, respectively, the start and end year of the image, SDay and EDay, the start and end day of the image, Nin and Nout are the number of pixels within the valid range and outside the valid range, respectively. The last column is the pixel value in the nearest pixel that is the center of the 3 x 3 pixel area where statistics is calculated.

Note that the output is sorted first by image and then by station. If you want to sort first by station, for example, for easy plotting of time series for each station, you can use another WAM utility *sortstas*. The syntax is

```
sortstas input_file
```

Sortstas converts the input file into a sorted by station file named *sorted.csv*. To compile *sortstas*, don't use *c.bat* as MWIM.dll is not used here. The command of building *sortstas* is:

```
csc /out:%WAMPATH%\sortstas.exe sortstas.cs
```

5.5 wam_screen

Some Level-3 Mapped images have both the data of various quality and a corresponding quality flag. It is often necessary to eliminate or screen out pixels of lower quality. The best quality flag is sometimes 0 (MODIS) or 7 (AVHRR Pathfinder 5). Versions of this program operate on SST Pathfinder data (*wam_screen_pf*), old type MODIS data (*wam_screen_modis*), and new MODIS SST data by the Ocean Color Processing Group ((*wam_screen_sst_ocpg*). While quality flag image for the old MODIS and SST

Pathfinder data is in a separate file, for the new OCPG SST data it is in the same file in a separate dataset.

As a result of screening, pixels with the corresponding best quality flag will retain their value while pixels with lower quality flags will be masked with invalid data value. Different options may exist. See the WAM manual (*WAM.pdf*) for more details.

Find some MODIS Level-3 SST files and try something like the following command:

```
wam_screen_sst_ocog S2006*.L3m_MO_SST_4
```

5.6 wam_rgb_modis

See a separate document *Exercises_modis_250m.pdf*.

5.7 wam_turbidity

See a separate document *Exercises_modis_250m.pdf*.

5.8 Merging Level-2 Chl-a and SST data

See a separate document Exercises_Merging_L2_Chl_and_SST.pdf.

6 Installing WIM and WAM

6.1 Install WIM/WAM

Installing WIM and WAM is straightforward: installation should start after inserting the WIM/WAM CD. You can also run either the *wim.msi* or the *wam.msi* installer files. Choose all the default, i.e. **Typical** setup options. When you run WIM for the first time you need the license number from the cover of the WIM CD case.

6.2 Install the Microsoft .NET Framework

WAM is based on the Microsoft .NET Framework. Windows Vista and other later versions of Windows come with the .NET Framework installed. In Windows XP the .NET Framework may already be installed by another software package. If the .NET Framework is not installed on your computer then syou need to install it. The easiest is just to **click** (double-click) on the executable file *dotnetfx.exe* included in the *WAM_samples* directory of the WIM/WAM CD and follow the prompts with default options.

   Alternative ways of installing the .NET Framework are:

- Windows update site http://v4.windowsupdate.microsoft.com/en/default.asp

- Microsoft website http://microsoft.com/downloads/details.aspx?FamilyId=262D25E3-F589-4842-8157-034D1E7CF3A3&displaylang=en

The default *Wimsoft* folder path (*C:\Program Files\Wimsoft*) is automatically added to your path when installing WIM. If you have WIM installed in a different folder then you need to add its location manually to the path if you want to run the WAM command line programs. The best way to do it is to create an environment variable WAMPATH and add it to the PATH system variable. To do that right-click on *My Computer*, select *Properties*, *Advanced - Environment Variables,* select *New* in the *System variables* and create a new variable WAMPATH with the path of your WIM executables, typically *C:\Program Files\Wimsoft*. Then edit the PATH system variable in the same dialog and add %WAMPTH% to it after a semicolon. Don't forget the % characters! To check if the paths are properly defined, open the command window by running *cmd.exe*, and type *echo %WAMPATH%.* You should see the location of your Wimsoft folder. To see the full PATH variable type *echo %PATH%.* You should see the location of your Wimsoft folder listed in the path.

6.3 Copy the Images folder

For the purpose of running these exercises it is recommended that you copy the *Images* folder in the WIM/WAM CD to your Wimsoft folder (e.g. *C:\Program Files\Wimsoft*). Most examples assume that the sample data files have been copied to the default Wimsoft folder.

7 Answers

7.1 Exercise 3.8

	Number of Missing Pixels	Number of Valid Pixels	Valid of Total%	Valid % of Ocean	Number of Total Pixels	9331200
Daily	8562051	769149	8.24	12.67	Land	3109142
8-day	6011440	3319760	35.58	54.67	Coast	149373
Month	4583810	4747390	50.88	78.18	Land + Coast	3258515
Annual	3858275	5472925	58.65	90.12	Total Ocean	6072685