# Working with OLCI Level-2 data

Contents



# 1 Introduction

OLCI (https://sentinel.esa.int/web/sentinel/missions/sentinel-3/instrument-payload/olci) is ESA's advanced ocean and land color sensor on the Sentinel-3A satellite launched in 2016 and on Sentel-3B launched in 2018. OLCI has WRR (Water Reduced Resolution) data products at ~1000 m spatial resolution and WFR (Water Full Resolution) data products at ~300 m resolution. WFR data are especially useful in coastal zones but their disadvantage seems to be their higher uncertainty. OLCI Level-2 data can be ordered from EUMETSAT data archive https://archive.eumetsat.int/ or EO portal https://eoportal.eumetsat.int/. You need to register and open an accout before you can order any data.

# 2 Ordering and downloading OLCI level-2 data

There are several ways to order and download OLCI level-2 data. You can use the data store https://data.eumetsat.int/search?query= and type "OLCI level 2" after which you will see several available products (reprocessed and original). After selecting a product, you select the date range, the area of interest (e.g. -140,16,-100,45), timeliness (near real time NR or science quality NT), satellite (A or B), etc. After you click "Show Results" you will see the available datasets. You can then "Add Results to Cart". You need to log in to add products to your cart. You can download individual datasets by clicking on them but that is time consuming in case you need many datasets. You can download the whole cart (there is a limit on how many datasets you can can have in the cart) with a command line utility *aria2c* (you need to download and install it). The inconvenience of *aria2c* is that it needs a new API token every 15 minutes. The command line looks like that:

```
aria2c --header="Authorization: Bearer e3a82c2b-8d16-3415-82bf-07dd42c26320" -M cart-mkahru.xml
```

While the downloading is fast (it downloads several files concurrently), it is inconvenient to do this if you have many routine orders. A more convenient utility for ordering and downloading is *eumdac* (https://pypi.org/project/eumdac/ ). You need to install it, set the credentials, and after that it is easy to order and download data from the command line. Downloading with *eumdac* is

versatile but slow. You have many options. You need to specify the product type, e.g., the WFR (~300 m) as 0407 and the WRR (~1000 m) as 0408. A command like that:
eumdac download -c EO:EUM:DAT:0408 --bbox -140 16 -100 45 -s 2024-03-28T16:00:00 --timeliness NT
(all in 1 line) downloads WRR data for a box -140 16 -100 45 (Longitude -140 to -100, latitude 16 to 45) from date 2024-03-28 (time 16:00) to present and selects NT data (NR for the near real time data). You can specify the end date and time by adding something like "-e 2024-03-30T21:00:00". You can also select the satellite (A or B) by adding "--satellite Sentinel-3A" for Sentinel-3A or "--satellite Sentinel-3B" for Sentinel-3B. For example, for you can select all (both A and B) WFR (~300 m) data since 2024-03-28T16:00:00 :
eumdac download -c EO:EUM:DAT:0407 --bbox -128 30 -116 40 -s 2024-03-28T16:00:00 --timeliness NT
If you need all (both A and B) recent (both NT and NR) WFR (~300 m) data since 2024-04-18T16:00:00 :
eumdac download -c EO:EUM:DAT:0407 --bbox -128 30 -116 40 -s 2024-04-18T16:00:00

After you download your zipped OLCI Level-2 datasets, you have to extract the directories with files and place them in a directory structure that makes sense for data processing. Your ordered datasets are typically packaged in zip files with names like *S3?_OL_2_WRR*.zip* (for WRR data) or *S3?_OL_2_WFR*.zip* for WFR (~300 m) data. Here ? stands for either A or B (the satellite). I extract the directories from the zip files with *7z* with commands like:
*7z x S3?_OL_2_WRR*.zip* (WRR data) and *7z x S3?_OL_2_WFR*.zip* (WFR data). You need to type "a" after a prompt to overwrite some common files in each zip file. After extracting directories from zip files, you will have a set of directories netCDF files in each directory. You are ready to explore a particular dataset, e.g., *chl_oc4me.nc* with WIM (you need to select *geo_coordinates.nc* from the same directory).

As explained in the tutorial for processing NASA Level-2 data (https://www.wimsoft.com/Course/2/2_L2_batch_processing.pdf ) you need to follow a stringent directory structure for our batch files to work. OLCI-A and OLCI-B data would be just additional sensors in the general L2-processing framework and can be merged with respective products from NASA/NOAA and JAXA sensors. The recommended main directory structure is: AREA\YEAR\SENSORTYPE with no spaces in any of the directory names. For example, if we use AREA=*CAL* and YEAR=*2024*, we create a folder *E:\CAL\2024\OLCI* and move the downloaded **.zip* files to that folder or download them directly to that folder. Instead of *E:\CAL*, we can, of course, use another directory name without spaces.

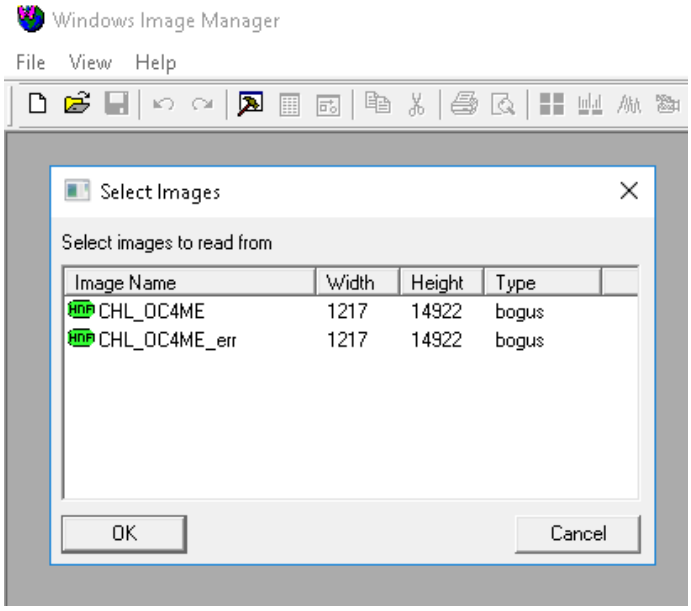
# 3 OLCI Level-2 data structure

While OLCI data are also in netCDF like NASA OBPG data, ESA has adopted a different structure for OLCI data. In contrast with NASA's OBPG data where many products are packed into a single netCDF file, OLCI Level-2 files have a single product and the names show only the name of the product (e.g., *chl_oc4me.nc*) while all the other information is in the long directory name, e.g.,
*S3A_OL_2_WRR____20240328T193132_20240328T201536_20240329T230317_2644_110_313_____MAR_O_NT_003.SEN3*

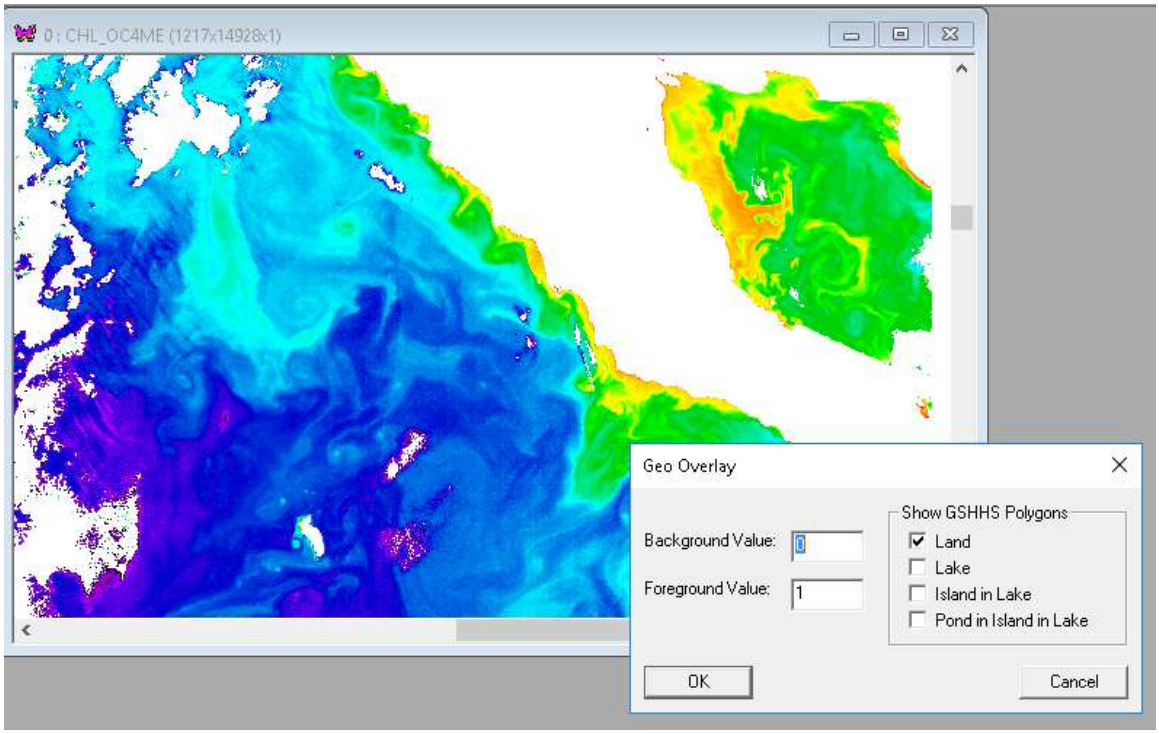
Each file has the data product and the corresponding error product, e.g. *CHL_OC4ME* (chlorophyll concentration of the OC4-MERIS algorithm) and *CHL_OC4ME_err*. The latitude and longitude arrays (LLA) are in a separate file *geo_coordinates.nc* in the same directory.

## *3.1 Evaluating OLCI Level-2 data with WIM*

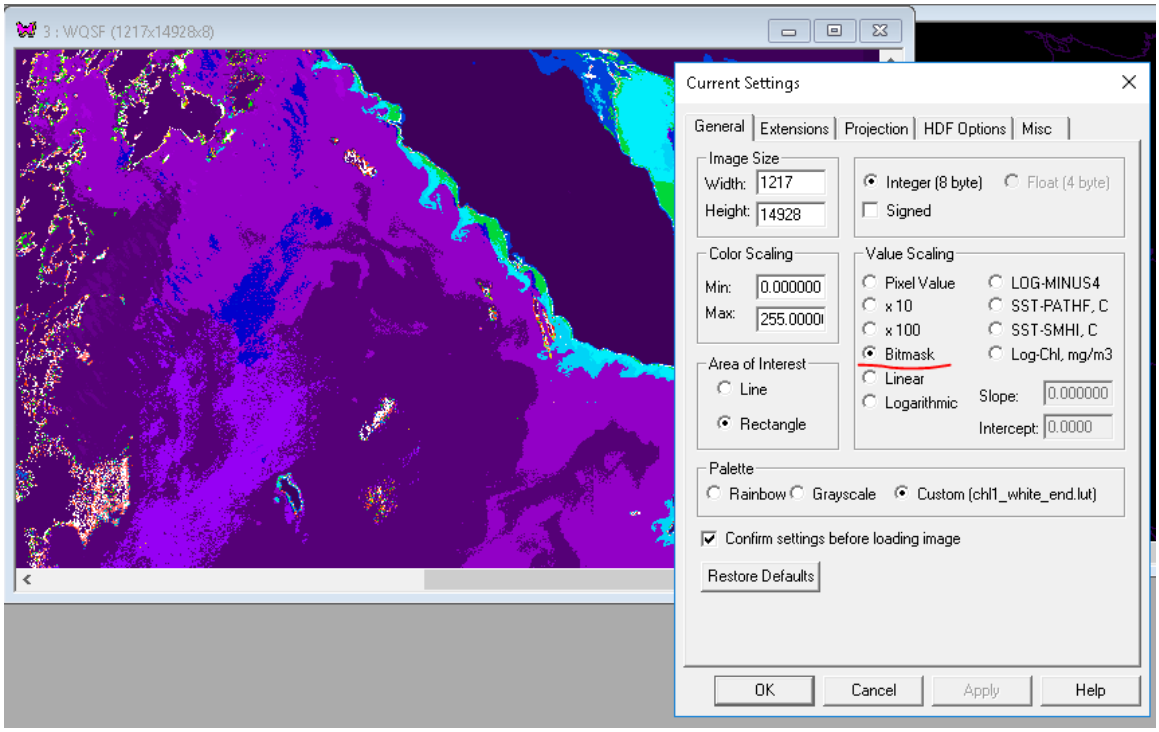
Find one of the directories with OLCI Level-2data, e.g. S3A_OL_2_WRR____20170217T175858_20170217T184245_20170218T230720_2626_014_255_____MAR_O_NT_002.SEN3. Click or double-click on *chl_oc4me.nc* and then load *CHL_OC4ME* (chlorophyll concentration of the OC4-MERIS algorithm).WIM will prompt for a file with coordinates – select the *geo_coordinates.nc* in the same directory.




You can scroll down and find an interesting area. You can check that the geo-coordinates are good by creating and overlaying coastlines. Use *Geo-Get Map Overlay-coast_full.b* and use background pixel value 0 and foreground pixel value 1 (black).




Now overlay the coastlines image on the Chla image. The coastlines should match the image. Now load the level-2 flags image from *wqsf.nc* (you have to select *geo_coordinates.nc* again in the same directory. Select the Hammer (Settings) icon on the Toolbar and set value scaling to Bitmask for the flags image.



When you right-click and move your mouse pointer around, you can see the various flags that are set for the selected pixels. For example, LAND flag is always set for land pixels.

***wam_remap_lladir*** is a WAM command line tool for processing OLCI (and MERIS) level-2 data. Open command window one level up from the directory with OLCI level-2 data and type the name of the command (*wam_remap_lladir*) to see all the options. Now type (copy and paste):

```
wam_remap_lladir  S3A_OL_2_WRR____20170221* chl_oc4me.nc   flags=no
```

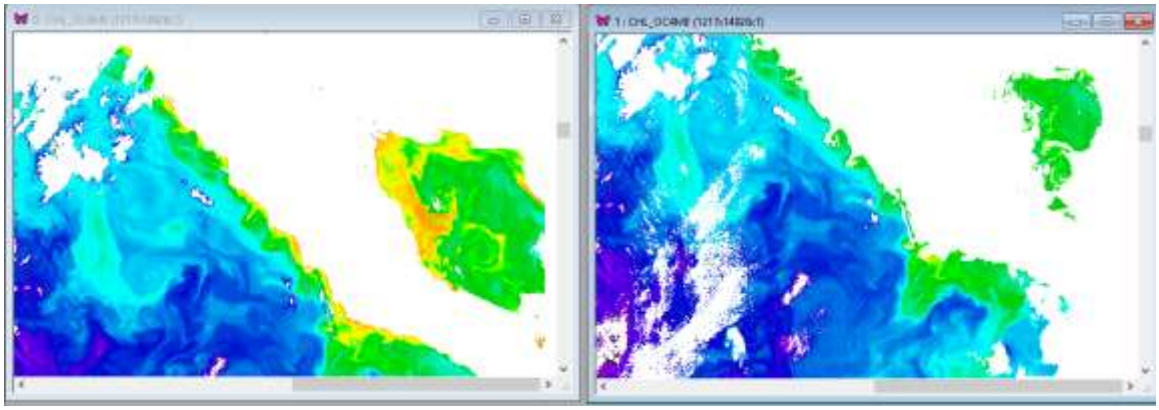
(we have added spaces in the above command line to make it better readable).

Of course, you will have to adapt the name of the directory to the ones that you have as the command above assumes that you have data from 20170221 (Feb 21, 2017). As you can see, we have shortened the directory name and use * after the date. The command loads data from file *chl_oc4me.nc* and uses option *flags=no*, i.e. not using flags. The output is the same Chla image saved in P2017052175445.L2_WRR_MAR_O_NT_002.SEN3_chl_oc4me.x.hdf.

Load the *CHL_OC4ME* image and confirm that it is the same (e.g. by *Multi-Difference*). Rename the just saved **chl_oc4me.x.hdf* file to **chl_oc4me.x_noflags.hdf*, i.e. noting that we did not use flags when creating this file. Now try the same command but replacing *flags=no* with *flags=CLALL* option:

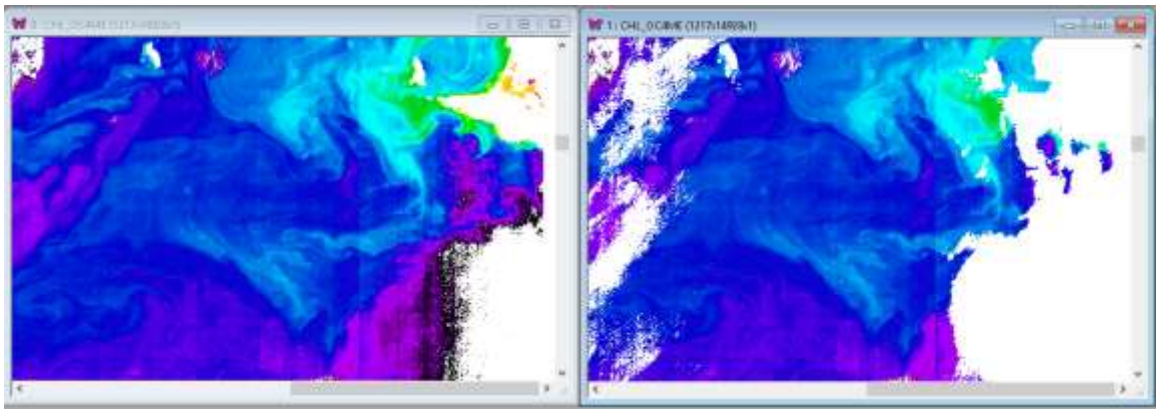
```
wam_remap_lladir  S3A_OL_2_WRR____20170221* chl_oc4me.nc flags=CLALL
```

…and compare both images.

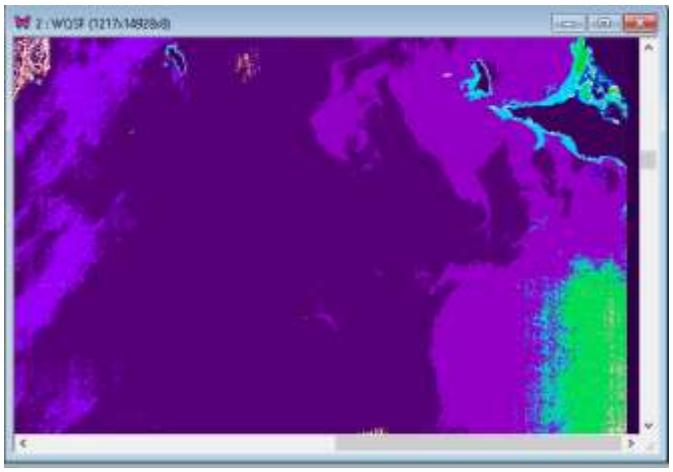


**Note: this example was run with previous version (2020) of OLCI data with *flags=L3* option. In the most recent version of OLCI data the flags have changed and we recommend the *flags=CLALL* option (using all cloud flags)!**

As you can see, the image processed with **flags=no** option (above left) has much more data compared to the image processed with the **flags=L3** option (above right). Many pixels in the above right image have been set to the invalid value (255, white). The L3 flags are more conservative and eliminate more pixels as suspect. Those flags are used to produce Level-3 data from Level-2 data. In this case the L3 flagging may seem excessive as the flagged data look good. However, when you scroll down and right in the unflagged image (below left) you see obviously bad areas (black) that have been correctly flagged image in the flagged image (below right). So, what is going on in these flagged areas?



Load the flags image from *wqsf.nc*.



Set value scaling to bitmap and right-click on the questionable areas. You can see that many flags are set in the flagged areas (e.g. the green area in the image to the left) but most importantly *HIGHGLINT*. Therefore, it seems that the flagged area is primarily due to high sun glint that prevents correctly deriving in-water properties.

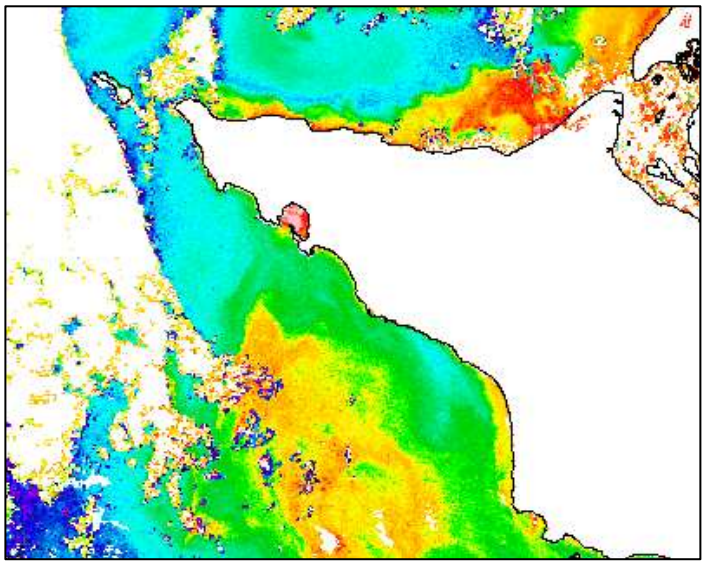
You can check the Attributes ( icon on the Toolbar)) to see the flag names under *flag_meanings*:
INVALID,WATER,LAND,CLOUD,TURBID_ATM,CLOUD_AMBIGUOUS,CLOUD_MARGIN,SNOW_ICE,INLAND_WATER,COASTLINE,TIDAL,COSMETIC,SUSPECT,HISOLZEN,SATURATED,MEGLINT,HIGHGLINT,WHITECAPS,ADJAC,WV_FAIL,PAR_FAIL,AC_FAIL,OC4ME_FAIL,OCNN_FAIL,KDM_FAIL,BPAC_ON,WHITE_SCATT,LOWRW,HIGHRW,IOP_LSD_FAIL,ANNOT_ANGSTROM,ANNOT_AERO_B,ANNOT_ABSO_D,ANNOT_ACLIM,ANNOT_ABSOA,ANNOT_MIXR1,ANNOT_DROUT,ANNOT_TAU06,RWNEG_O1,RWNEG_O2,RWNEG_O3,RWNEG_O4,RWNEG_O5,RWNEG_O6,RWNEG_O7,RWNEG_O8,RWNEG_O9,RWNEG_O10,RWNEG_O11,RWNEG_O12,RWNEG_O16,RWNEG_O17,RWNEG_O18,RWNEG_O21

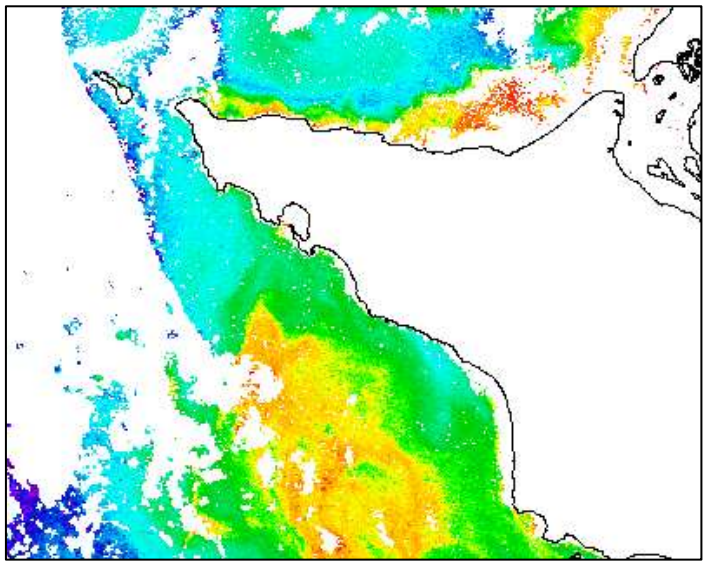
These are the 51 flags (originally there were 49 and since R004 processing CLOUD_AMBIGUOUS and CLOUD_MARGIN were added).

The following flags are recommended to make a pixel invalid in validation exercises:

INVALID, LAND, CLOUD, CLOUD_AMBIGUOUS, CLOUD_MARGIN, SNOW_ICE, SUSPECT, HISOLZEN, SATURATED, HIGHGLINT, WHITECAPS, AC_FAIL, OC4ME_FAIL, ANNOT_TAU06, RWNEG_O2, RWNEG_O3, RWNEG_O4, RWNEG_O5, RWNEG_O6, RWNEG_O7, RWNEG_O8

You can see the effect of flags filtering below: the left image has no pixels eliminated and the right image has eliminated all pixels according to the recommended flags. The left image has better coverage, especially in coastal areas but also erroneously low values along cloud edges. !!! Note that the flags have changed from the original processing and you need to be careful about the selection of flags! Currently I am recommending using *flags=ClAll dilate=0*. Here *ClAll* means to use all cloud flags and *dilate=0* means not dilating the cloud mask. If cloud edges still show out, then you can expand (dilate) the cloud mask by selecting *dilate=1* or even *dilate=2* (one or 2 times dilating) to exclude those edges. Of course, that may also eliminate "good" pixels. Note that you can select the individual flags that you want to use to invalidate pixels by using the following option:
flags=12345678901..... with 0 for the respective sequence number flag to be ignored and nonzero to use.
Here you can type a sequence of up to 64 zeroes or non-zeroes to either use or not use the flag with respecting sequence number. Numbers 1234… are used here to show the sequence number. For example, the "Cloud Only" option is equivalent to flags=10345000011000000890000, and the "Cloud ALL" option is equivalent to flag=10345000011000000890023. Here I am using some specific nonzero numbers as reminders of their sequence numbers.





## 3.2 Remapping with wam_remap_lladir

As you can realize, the L2 images are not mapped (i.e. they are in satellite-view). That's why they need the LLA (latitude-longitude arrays) for each set of images. With *wam_remap_lladir* you can not only extract images of your interest from the OLCI directories and save them with LLA in HDF4 files but also remap to your standard map projection. LLA wastes disk space and therefore it is better to map datasets to a common map. For example, like that:

```
wam_remap_lladir  S3A_OL_2_WRR*  chl_oc4me.nc  map= ..\Mymap.hdf
```

You can add more options to the command:

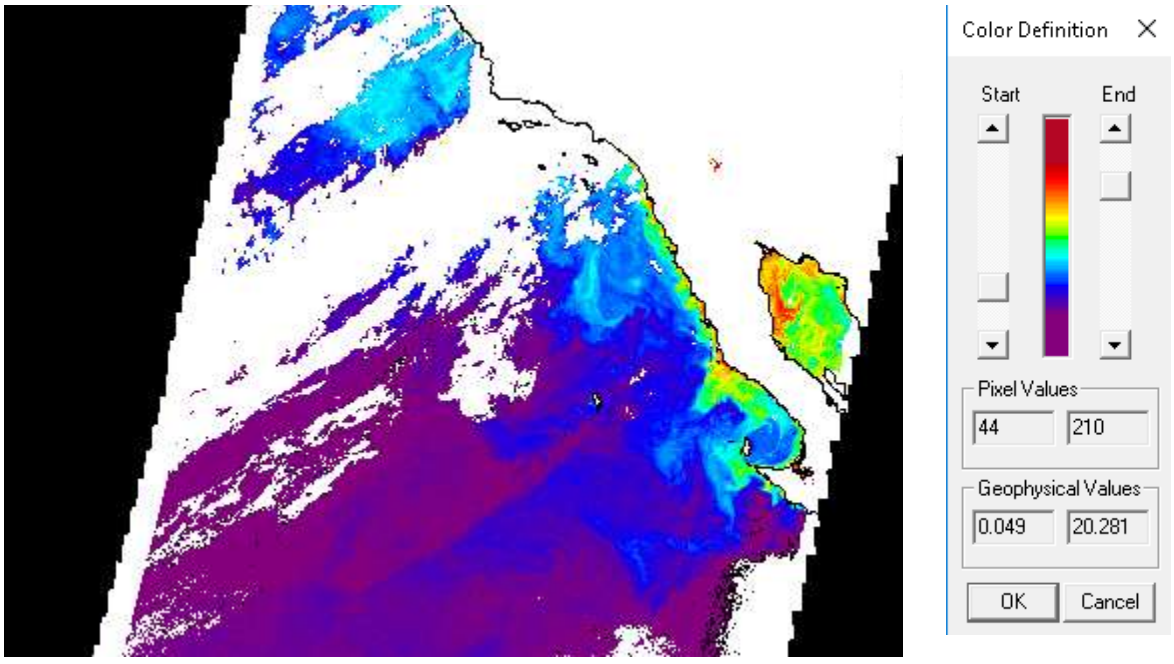
```
wam_remap_lladir S3A_OL_2_WRR____20170221* chl_oc4me.nc map=
California\cal_aco_3840.hdf  flags=ClAll colorMin=44 colorMax=210 overlay=Yes
```

The above command extracts the Chla image, remaps to a map specified with *map=Map* in the command line and saves as a mapped HDF4 image. It also stretches the colors from 44 to 210 and overlays the map image on top of the Chl image. This way you can add coastlines, color bar, etc. Annotations are added if their position is specified, e.g. with options *xPos=X* and *yPos=Y* where X is the x-coordinate from left and Y is the y-coordinate from top. Below is a subset of an unflagged Chla image, mapped to a standard Albers Conic Equal Area map (the image has been reduced by 4x). You can stretch the colors manually (see below right) or add them to the command line (with colorMin and colorMax).

You can run the same operation for many directories with a SINGLE command. For example,

```
wam_remap_lladir   S3A_OL_2_WRR* chl_oc4me.nc flags=ClAll
```

will go through all directories matching S3A_OL_2_WRR* and look for files like *chl_oc4me.nc*. It will read the 0-th dataset (*CHL_OC4ME*) from each file and the latitude-longitude arrays (LLA) from *geo_coordinates.nc* in each directory and save as HDF-LLA, i.e. with the latitude and longitude arrays in each file. Don't forget to add other options to the command line! The saved files will be given names like P2017052175445.L2_WRR_chl_oc4me.x.hdf where "P" is a letter identifying OLCI data on Sentinel A and R is the identifier for OLCI data on Sentinel 3B. Note that identifier S was taken by SeaWiFS, O by OCTS), 2017 is the year, 052 is the day of the year (February-21), 175445 is the time (17:54:45), L2 shows the processing level, WRR is the product and resolution (RR = reduced resolution), *chl_oc4me* is the product name.




For remapping we need a WIM file with a projection, e.g. ..\Mymap.hdf. The naming of the output file is similar with the ending of "*.mapped.hdf*" instead of just "*.hdf*". The mapped file is typically an order of magnitude smaller than the unmapped (HDF-LLA) file.
Similar commands can be applied for other product types, e.g. PAR and reflectance.

```
wam_remap_lladir   S3A_OL_2_WRR* par.nc   map= ..\Mymap.hdf
```

The command above will extract PAR, map to the specified projection and save as HDF4.

```
wam_remap_lladir S3A_OL_2_WRR*  *reflectance.nc   map= ..\Mymap.hdf
```

The command above will extract all *reflectance.nc files, map to the specified projection and save as HDF4. Note that while there was just one *chl_oc4me.nc* and one *par.nc* file in each directory, there are multiple **reflectance.nc* files and therefore all matching reflectance datasets will be mapped and saved.

We can also set the color in the command line. For example, color range from pixel value 44 to 210 that corresponds to Chla range approximately 0.05 to 20 mg $m^{-3}$ (see above right) can be set in command line with options colorMin=44 and colorMax=210.

# 4 Batch processing of OLCI Level-2 data

As with NASA level-2 data, we use batch commands to process OLCI level-2 data. In the OLCI folder, e.g. *E:\L2\Baltic\2020\OLCI* you should have a batch file *mapRR.bat* for processing RR data and *mapFR.bat* for processing FR data. Contents of a sample *mapRR.bat* that remaps ***chl_oc4me*** data and composites multiple datasets (if available!) into daily composites for OLCIA and OLCI-B is below. If your study AREA is small then you probably have no more than one pass of each sensor per day but larger areas can have multiple passes per day and therefore you need to composite these.
Before processing a big batch of OLCI Level-2 data, make some tests with various options. You can see all the options by typing the name of the command without any arguments:
wam_remap_lladir
Most important is to choose the flags option. For making nice looking images when the exact values are not so important you can use the *flags=no* option. For making long-term composites it is safer to use the *flags=L3* option. However, the *flags=L3* option eliminates too many good looking pixels. **NOTE: option *flags=L3* has not been adapted to the latest version of OLCI data!** The intermediate options are *flags=cloud* and *flags=ClAll* options. The *cloud* eliminates obvious clouds but the *ClAll* (Cloud All) option eliminates also pixels flagged as CLOUD_AMBIGUOUS and CLOUD_MARGIN. You can also use one of those flags options and add *Dilate=X* where X specifies how many times to dilate (expand) the bad pixels area. X is typically a small integer like 1 or 2. This way you can eliminate some cloud edge pixels. In the example below we are using the *flags=ClAll dilate=0* options, i.e. Clouds All and No dilate.

```
REM extracts ChlMe from OLCI WRR, remaps
@echo off
set YEAR=2020
set FROMDIR=tmp
set TMPDIR=tmp1
mkdir %TMPDIR%
set MAPPEDDIRA=WRRA_NT_mapped
mkdir %MAPPEDDIRA%
set COMPDIRA=..\P%YEAR%_chl_day
mkdir %COMPDIRA%
set MAPPEDDIRB=WRRB_NT_mapped
mkdir %MAPPEDDIRB%
set COMPDIRB=..\R%YEAR%_chl_day
mkdir %COMPDIRB%
set MAP0=..\..\..\..\Projections\Baltic\aco_balt_chl_48_220.hdf
set MAP4=..\..\..\..\Projections\Baltic\aco_balt_chl_48_220.hdf
```

```
set X4=950
set Y4=105
set LUT=chl1_white_end.lut
set START=45
set END=210
REM OLCI-A Chl
wam_remap_lladir %FROMDIR%\S3A_OL_2_WRR____%YEAR%* chl_oc4me.nc map=%MAP0%
savepng=yes flags=ClAll dilate=0
REM if not "%errorlevel%"=="0" goto err
move P%YEAR%*WRR_MAR_O_N*.* %TMPDIR%
REM 1-day Chl OLCI-A
wam_composite_2x %TMPDIR%\P%YEAR%*mapped.hdf 1 overlay=%MAP4% xpos=%X4%
ypos=%Y4% lut=%LUT% cmin=%START% cmax=%END%
move /Y %TMPDIR%\P*mapped.hdf %MAPPEDDIRA%
move /Y %TMPDIR%\P*mapped.png %MAPPEDDIRA%
move /Y P*comp*.hdf %COMPDIRA%
move /Y P*comp.png %COMPDIRA%
REM OLCI-B Chl
wam_remap_lladir %FROMDIR%\S3B_OL_2_WRR____* chl_oc4me.nc map=%MAP0%
savepng=no flags=ClAll dilate=0
REM if not "%errorlevel%"=="0" goto err
move R%YEAR%*WRR_MAR_O_N*.* %TMPDIR%
REM if not "%errorlevel%"=="0" goto err
REM 1-day Chl OLCI-B
wam_composite_2x %TMPDIR%\R%YEAR%%DAY%*mapped.hdf 1 overlay=%MAP4%
xpos=%X4% ypos=%Y4% lut=%LUT% cmin=%START% cmax=%END%
move /Y %TMPDIR%\R*mapped.hdf %MAPPEDDIRB%
move /Y %TMPDIR%\R*mapped.png %MAPPEDDIRB%
move /Y R*comp*.hdf %COMPDIRB%
move /Y R*comp.png %COMPDIRB%
:bye
echo ***** Done! *****
exit /b 0
:err
echo ***** FAILED! *****
exit /b 1
```