Time series of satellite data for SE Asia

Contents

1 Introduction

This document accompanies a lecture by Mati Kahru at EO-WPI Online Training on 25 May 2023 and provides details how the results shown in the lecture were created. The purpose of this document is to help participants to use the provided software and examples to run their own analyses using their own areas of interest and different datasets to create their own scientific results. However, for training, it is recommended to repeat the examples provided here with the same commands and the same datasets to confirm that the commands work and that you get the same result.

This tutorial is just a short summary, and more details on the WIM/WAM software and methods are provided in multiple tutorials elsewhere (https://www.wimsoft.com/course.htm).

2 Obtaining and installing the software

Download the setup file for WIM/WAM *wam64.msi* from *https://wimsoft.com/Course/wam64.msi*. Install by running (double-clicking) it, use option *Typical*. Run WIM, enter the license number – get it by emailing wim@wimsoft.com. The WIM.exe program is used to visualize the results, create the masks (regions of interest) while the command line commands are used to process the data. It is recommended that you create a similar directory structure like in the Google Drive *Sat*, i.e. *C:\Sat*. Of course, you can use a different drive letter but then you need to change the commands. In this document I will assume the *C:\Sat* is the directory where we will work and issue the commands. The folder where Wim/WAM was installed (e.g. *C:\Program Files (x86)\Wimsoft*) needs to be in your path in order to issue WAM commands in *C:\Sat* (it should be done automatically by setup). You can test that it works with the following commands:

```
C:

cd C:\Sat

wam_statist_mask
```

After that you should see the syntax of the command *wam_statist_mask* that we will use to calculate areal statistics of satellite data.

3 Downloading original data or prepared files from Google Drive

Although I will provide links to the original data by the original data providers, it is easier to start with the data that I have prepared. Downloading the original datasets is time consuming and can be tricky. Also, after downloading the original data in netCDF I normally extract only the required dataset ignoring the ancillary datasets and save as HDF4. That saves a lot of disk space as I don't keep what I don't use. Currently the downloading procedures at Physical Oceanography DAAC (PODAAC, source of SST and other datasets) are changing as they are moving from local hosting to AWS (Amazon Web Services). Therefore, my downloading scripts no longer work for several datasets. For your convenience, I have set up a Google drive share *Sat* that has the prepared (by me) datasets in HDF4 format that you can use in the examples. I will also provide some explanations on the procedures and commands that I have used in this pre-processing - in gray font! You don't need to use them unless you want to start from the original datasets or need to extend the datasets with new data that were not available when I compiled the prepared datasets. You can access my Google Drive *Sat* disk at https://drive.google.com/drive/folders/1i3R2GEsaMHqICbeeFQJZ0FyAD1In1jMx?usp=sharing

It is recommended that you copy the whole *Sat* share (about 900 MB) to your *C:* or another drive with sufficient space.

4 Creating areal statistics with *wam_statist_mask*

4.1 SST from AVHRR-OI

The source of the data at PODAAC was recently changed to AWS and the downloading procedure changed. The version 2.1 (2016 to present) data are available at https://podaac.jpl.nasa.gov/dataset/AVHRR_OI-NCEI-L4-GLOB-v2.1 and version 2.0 starting in 1981) are at https://podaac.jpl.nasa.gov/dataset/AVHRR_OI-NCEI-L4-GLOB-v2.0. You can download individual files by navigating with your browser to *Data Access* and then to *Browse Granule Listing* and then just clicking on the desired file. To download many files at once, you need to click on *Search Granules* and select the time interval, then create the script named *download.sh*. In order to run that script you need to use Linux or have *Cygwin64* installed (and in your path) in Windows. Then run:

```
chmod 777 download.sh
bash download.sh
```

Separate the netCDF files by year in your *tmp* folder, e.g. *tmp\2023*, *tmp\2022*, etc.

After that we extract the SST dataset and convert SST from Kelvin to Celsius:

```
set YEAR=2023
wam_convert_k2c %YEAR%\%YEAR%*.nc mirror=yes
```

Move **.hdf* files to new directory, e.g. *C:\Sat\AVHRR_OI\%YEAR%*. You can open a sample netCDF file in WIM.exe and look at the content. We can now delete the original netCDF files as we don't need them anymore.

Create monthly composites for year 2023:

```
set OUTDIR=..\AVHRR_OI_mo
mkdir %OUTDIR%
wam_composite_month %YEAR%\%YEAR%*.hdf
move *%YEAR%*comp.hdf %OUTDIR%
```

Create monthly anomalies:

```
set TODIR=AVHRR_OI_mo_anomaly
mkdir %TODIR%
wam_anomaly AVHRR_OI_mo\*.hdf 12 AnnotateX=2 AnnotateY=22 Show=yes Type=difference AnomalyMin=-7 AnomalyMax=7
mkdir Means
move *anomaly*.hdf %TODIR%
move *anomaly*.jpg %TODIR%
move _.hdf_Means.hdf Means\MeansSstMoAvhrrOI.hdf
```

```
move _.hdf_ValidCounts.hdf Means\ValidCountsSstMoAvhrrOI.hdf
```

Create time series of AVHRR-OI SST areal statistics:

```
C:
cd Sat
set FROM=AVHRR_OI_mo
set MASK=Masks\sea10sea1440x720.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK% validMin=10.0 validMax=34.95
move _statist_grid_sea10sea1440x720.csv avhrrOiMo_sea10sea1440x720.csv
```

Create time series of AVHRR-OI SST Anomaly areal statistics:

```
set FROM=AVHRR_OI_mo_anomaly
set MASK=Masks\sea10sea1440x720.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK%
move _statist_grid_sea10sea1440x720.csv avhrrOiMoAnom_sea10sea1440x720.csv
```

4.2 SST from CMC

4.2.1 Downloading and pre-processing

The link to this SST dataset from the Canadian Meteorological Center is:

https://podaac.jpl.nasa.gov/dataset/CMC0.1deg-CMC-L4-GLOB-v3.0

My example command to download the data file for 1-Jan-2023 is the following:

wget --user=XXX --password=YYY --keep-session-cookies --save-cookies C:\Users\ZZZ\.urs_cookies --auth-no-challenge=on --no-check-certificate https://archive.podaac.earthdata.nasa.gov/podaac-ops-cumulus-protected/CMC0.1deg-CMC-L4-GLOB-v3.0/%YEAR%0101120000-CMC-L4_GHRSST-SSTfnd-CMC0.1deg-GLOB-v02.0-fv03.0.nc

Here XXX is my username at NASA EarthData, YYY is my password at NASA EarthData, ZZZ is my username on the Windows computer that I am working at. %YEAR% is the year, e.g. 2023. All *.nc* files for a year are downloaded into a %YEAR% folder in *tmp* directory. The following command extracts the SST dataset, converts it from Kelvin to Celsius and saves as *.hdf*:

```
set YEAR=2023
mkdir ..\%YEAR%
wam_convert_k2c %YEAR%*.nc mirror=yes
move %YEAR%*.hdf ..\%YEAR%
echo Done %YEAR%
```

The following commands make monthly composites from daily files for year %YEAR% (e.g. 2023) and save into directory *mo*:

```
set TODIR=mo
mkdir %TODIR%
set YEAR=2023
wam_composite_month %YEAR%\*.hdf
move %YEAR%*_comp.hdf %TODIR%
```

The following commands make monthly anomalies from monthly files for year %YEAR% (e.g. 2023) and save into directory *mo_anomaly*:

```
set TODIR=mo_anomaly
mkdir %TODIR%
wam_anomaly mo\*.hdf 12 AnnotateX=2 AnnotateY=22 Show=yes Type=difference AnomalyMin=-7 AnomalyMax=7
mkdir Means
move *anomaly*.hdf %TODIR%
move *anomaly*.jpg %TODIR%
move _.hdf_Means.hdf Means\MeansSstMoAvhrrOI.hdf
move _.hdf_ValidCounts.hdf Means\ValidCountsSstMoAvhrrOI.hdf
```

4.2.2 Areal statistics of CMC SST

Create time series of CMC SST areal statistics:

```
set FROM=CMC0.1deg-CMC-L4-GLOB-v3.0\mo
set MASK=Masks\sea10sea3600x1801.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK% validMin=10.0 validMax=34.95
move _statist_grid_sea10sea3600x1801.csv cmcMo_sea10sea3600x1801.csv
```

Create time series of CMC SST Anomaly areal statistics:

```
set FROM=CMC0.1deg-CMC-L4-GLOB-v3.0\mo_anomaly
set MASK=Masks\sea10sea3600x1801.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK%
move _statist_grid_sea10sea3600x1801.csv cmcMoAnom_sea10sea3600x1801.csv
```

4.3 SST from SST data from global Multiscale Ultrahigh Resolution (MUR) L4 data

4.3.1 Downloading and preparing MUR SST data

Instructions on using *data-subscriber* and *data-downloader* are given at https://github.com/podaac/data-subscriber. Both subscriber and downloader require Python >= 3.7. When installing Python, make sure that you add python.exe to your PATH - check the respective checkbox! After installing Python, install the subscriber and downloader scripts:

```
pip install podaac-data-subscriber
```

You need to set up Earthdata login (name and password) if you don't have that already - See https://urs.earthdata.nasa.gov/. After that type

```
echo %HOMEDRIVE%%HOMEPATH%
```

to see where you need to have the *.netrc* file with the following:

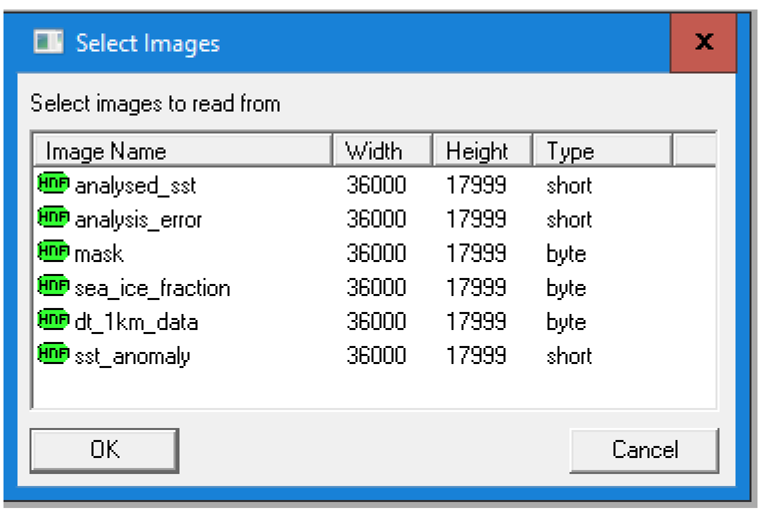
```
machine urs.earthdata.nasa.gov
   login <your username>
   password <your password>
```

Assuming that your current directory is *C:\Sat\MUR\tmp* (if you don't have it, create it and cd to it), you can now type:

```
podaac-data-downloader -c MUR-JPL-L4-GLOB-v4.1 -d ./ --start-date 2023-01-24T21:00:00Z --end-date 2023-01-24T21:00:00Z
```

This command downloads all netCDF files from 2023-01-24 to 2023-01-25.

The size of each file is about 730 MB with the following content:



We first change directory to one level up, extract only datasets *analysed_sst* and *sst_anomaly* and discard the rest, and convert temperature from Kelvin to Celsius:

```
cd ..
```

(we are now in the MUR folder)

```
set YEAR=2023
```

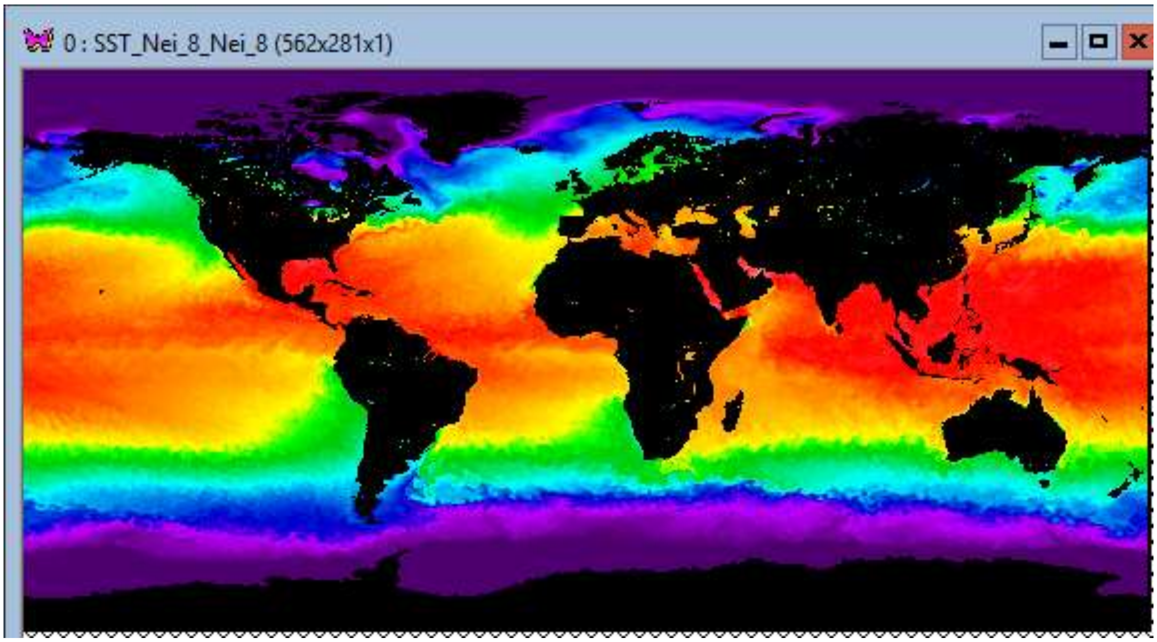
wam_convert_k2c tmp\%YEAR%*.nc mirror=yes anomaly=yes

This assumes that the downloaded files are in the *tmp* directory, we and we process all files of 2023. This produces 2 new files for each input file, e.g.:

20230124090000-JPL-L4_GHRSST-SSTfnd-MUR-GLOB-v02.0-fv04.1_anomaly.hdf

20220124090000-JPL-L4_GHRSST-SSTfnd-MUR-GLOB-v02.0-fv04.1_C.hdf

The anomaly and the SST files are about 10 times smaller than the input netCdf file. If we don't need the original input netCDF files, we can now delete those huge (700 MB) netCDF files. Example of a global SST image after 16x reduction in size is below:



4.3.2 Remapping global MUR SST and SST anomaly to a local map

We assume that you already have a target map that you want to remap the global SST and SST anomaly images. Instructions on how to create those target maps are given elsewhere in the tutorials (e.g. https://www.wimsoft.com/Course/2/Making_base_maps.pdf). In the batch file we declare the target maps like that:

(we are in the MUR folder)

set MAP=..\Masks\fst3km.hdf

wam_remap_and_overlay 2023\2023*_C.hdf %MAP% savepng=yes colorMin=202 colorMax=234

This maps the SST images. For mapping the anomaly images you need a different color LUT and different color scale. Try to manually find the best color range in WIM and then change the colorMin and colorMax values as used in the previous command. Note the file names end with **anomaly.hdf,* wam_remap_and_overlay 2023\2023*_anomaly.hdf %MAP% LUT=anomaly.lut savepng=yes colorMin=98 colorMax=158

You can also experiment with a label (and a color bar). We can specify the following parameters where the label is positioned and its color:

set XPOS=0

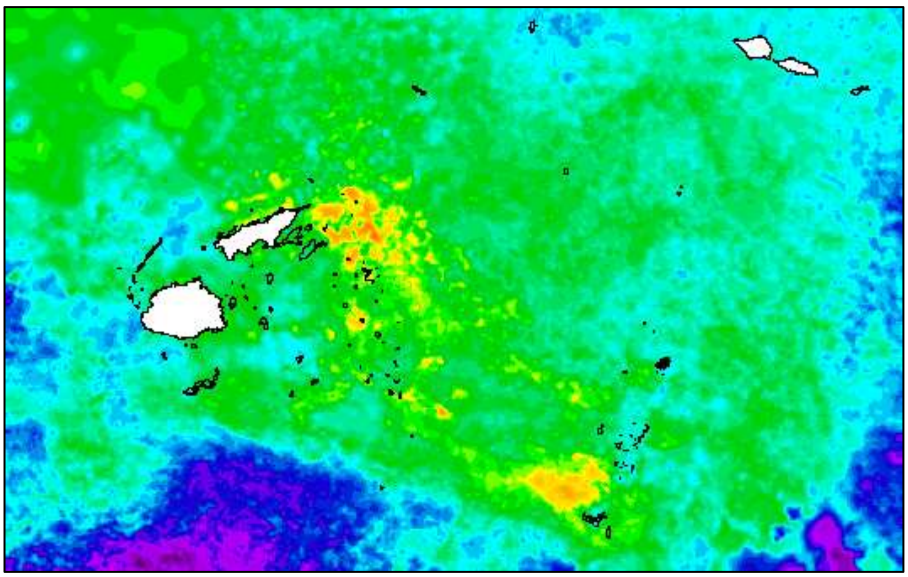
set YPOS=10

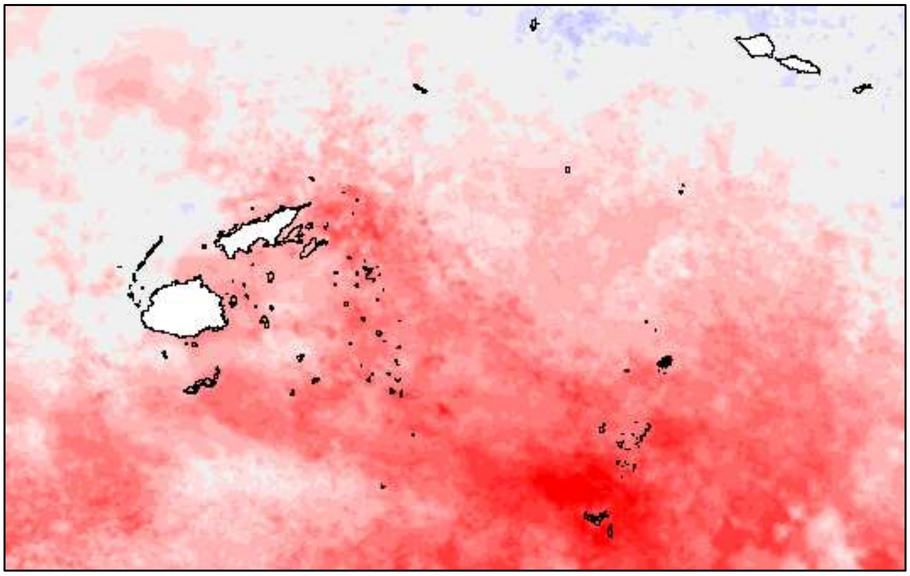
set LABELCOLORFRONT=-12.7

set LABELCOLORBACK=12.7

wam_remap_and_overlay 2023\2023*_anomaly.hdf %MAP% LUT=anomaly.lut savepng=yes colorMin=98 colorMax=158 xpos=0 ypos=10 labelcolorfront=-12.7 labelcolorback=12.7

The following images show examples of SST and SST anomaly for the Fiji region for 2023/01/24 when coral bleaching event was detected.





4.4 Chl from ESA-CCI

4.4.1 Downloading and preparing ESA-CCI data

Use an FTP client (e.g. Filezilla) to connect to ftp://oceancolour.org and navigate to */occci-v6.0/geographic/netcdf/monthly/chlor_a*. Download yearly data to a *tmp* folder. Extract *chlor_a*.

```
set NAME=chlor_a
mkdir %NAME%
set FROMDIR=tmp
set YEAR=2023
wam_extract_sds %FROMDIR%\%YEAR%\ESACCI*.nc %NAME%
move ESACCI*OCx-%YEAR%*.hdf %NAME%
REM del /Q %FROMDIR%\%YEAR%\*.nc
REM rmdir /Q %FROMDIR%\%YEAR%
echo Done %YEAR%
```

Remap global *chlor_a* monthly to SE Asia map:

```
set MAP=Maps\sea10.hdf
set OUTDIR=chlor_a_sea10
mkdir %OUTDIR%
wam_remap2 chlor_a\*.hdf %MAP% convert=logChl colorFrom=48 colorTo=220 medFilt=3
move *.hdf %OUTDIR%
```

Calculate *chlor_a* monthly anomaly for to SE Asia map:

```
set FROMDIR=chlor_a_sea10
set TODIR=%FROMDIR%_anom
wam_anomaly %FROMDIR%\*.hdf 12 type=ratio
mkdir %TODIR%
mkdir Means
move *_anomaly.??? %TODIR%
move  _.hdf_Means.hdf Means\Mean_%FROMDIR%.hdf
move  _.hdf_ValidCounts.hdf Means\ValidCounts_%FROMDIR%.hdf
```

4.4.2 Areal statistics of ESA-CCI chlor_a

Create time series of SE Asia *chlor_a* monthly areal statistics:

```
set FROM=chlor_a_sea10
set MASK=Masks\sea10_mask1-2.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK%
move _statist_grid_sea10_mask1-2.csv chlorMo_sea10_mask1-2.csv
sortmasks chlorMo_sea10_mask1-2.csv
REM make plots in Excel
```

Create time series of SE Asia *chlor_a* monthly Anomaly areal statistics:

```
set FROM=chlor_a_sea10_anom
set MASK=Masks\sea10_mask1-2.hdf
wam_statist_mask %FROM%\*.hdf mask=%MASK%
move _statist_grid_sea10_mask1-2.csv chlorMoAnom_sea10_mask1-2.csv
sortmasks chlorMoAnom_sea10_mask1-2.csv
REM make plots in Excel
```

5 Pixelwise trend with *wam_trend*

Calculate pixelwise trend for *chlor_a* monthly anomaly for SE Asia map, hide 1997-1998:

```
wam_trend chlor_a_sea10_anom\E*.hdf type=lin sig=90
move E__trend_lin_90.hdf chlorMoAnSea10_trend_lin_90_1999-2022.hdf
```

Calculate pixelwise trend for *SST AVHRR-OI* monthly anomaly for SE Asia map:

wam_trend AVHRR_OI_mo_anomaly\20*.hdf type=lin sig=90

move 20__trend_lin_90.hdf avhrrMo_trend_lin_90_2000-202303.hdf

REM add color scale -0.04,-0.02,0,0.02,0.04 C/y

6 Pixelwise correlation with *wam_correlation*

Calculate pixelwise trend for *chlor_a* monthly anomaly for SE Asia map, hide 1997-1998:

wam_correlation chlor_a_sea10_anom\E*.hdf mei2_2col.csv sig=90

move Corr_E_Meiv2.0_90.hdf chlorMoAnSea10_corr_Mei2_2col_90_1999-2022.hdf

7 Pixelwise correlation with *wam_correlation_series*

Calculate pixelwise trend for *chlor_a* monthly anomaly for SE Asia map, hide 1997-1998:

wam_correlation_series AVHRR_OI_mo_anomaly*.hdf chlor_a_1440x720_anom*.hdf signif=90

move ___Corr_90.hdf avhrrEsaChlorAnom_Corr_90.hdf

WORK IN PROGRESS! TO BE UPDATED!

Questions? Ask Mati at mkahru@ucsd.edu !