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Algal Bloom Information Service

by

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Abstract (100 words)

Increasing frequency of algal bloom that can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems is a major concern for the global scientific communities and demands continuous monitoring. The technical report presents setup of Automatic Satellite Data Processing Chain and various indicators used to provide "Algal Bloom Information Service". The operational implementation strategy is also provided in detail. The potential users of the service will be researchers, ecologist, environmentalist and policymakers. The information service will also complement the existing ecosystem based services like Potential Fishing Zone indicating safer zone for fishing.

1. Background

Algal blooms are environmental events resulting from quick multiplication of phytoplankton species over a short period of time. The algal blooms are regarded as harmful when exert deleterious effects on the flora and fauna as well on the environment (Anderson 1994; Hallegraeff 1995). The spatio-temporal occurrence of Algal Blooms is of major ecological concern of the present century. In general, the bloom events include the proliferation of algae in marine or brackish waters, which can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems in ways that humans perceive as harmful (Ferrante et al. 2013). In addition, massive algal bloom events result in dissolved oxygen concentration decline in the water column making inhabitable for different aquatic fauna (Glibert et al. 2005; Gowen et al. 2012). Anthropogenic impacts and multitude of natural phenomena are frequently triggering algal blooms in different coastal areas of the globe. Increasing frequency of algal bloom is being a major concern for the global scientific communities. In addition, introduction of non-native species to coastal waters through new algal species into inshore areas ballast water exchange, aquaculture, climatic changes and cultural eutrophication are also potential causes increase in frequency and extent of algal bloom events.

Categorically, there are five possible reasons for increase in frequency and geographical extent of algal bloom events (1) improved methods for detection and monitoring methods of blooms that would previously have gone unreported, (2) species dispersal through currents, storms or other natural mechanisms, (3) introduction of new algal species into inshore areas through ship ballast water exchange or aquaculture, (4) long-term climatic changes and (5) cultural eutrophication. Broadly, bloom species can be classified into three different groups: (1) those that produce harmless water discolourations, but the dense bloom on decomposition can cause anoxia and lead to indiscriminate mortality of marine life, (2) species that produce potent toxins causing a variety of gastrointestinal and neurological illness to humans and (3) species that are not toxic to humans but harmful to fish and invertebrates by damaging or clogging their fish gills.

Algal bloom events resulting deleterious effect on water quality have been reported in high numbers in Indian waters (D' Silva et al. 2012). Blooms of phytoplankton groups such as diatoms, dinoflagellates, cyanobacteria, raphidophytes and haptophytes have been reported from coastal waters of the Arabian Sea and Bay of Bengal. In general, Heterotrophic dinoflagellate *Noctiluca scintillans* and diazotrophic cyanobacteria *Trichodesmium* *erythraeum* were the most frequently occurring bloom species on the west coast of India. In addition to *N. scintillans* and *T. erythraeum*, recurring blooms diatomic species *Asterionellopsis glacialis* are regular algal bloom scenarios in coastal waters of western Bay of Bengal (D'Silva et al. 2012). In context of *N. scintillans*, the species exhibits two ecological forms red and green. Both ecological forms of *N. scintillans* deteriorates the ambient water quality in the waning phase. Blooms of red *N. scintillans* are recurrent phenomenon in coastal waters of the Bay of Bengal while green *N. scintillans* blooms reoccur in coastal as well open ocean waters of the Arabian Sea.

The advent of satellite remote sensing technology enables for synoptic imaging and monitoring of a wide range of oceanographic geophysical parameters. The time-variable critical oceanographic bio-physical process can discerned from ocean color sensors attributed to their high temporal and spatial resolution. Of late, in the 1970s, the first proof of ocean colour mission, CZCS provided important information on oceanic chlorophyll (proxy of phytoplankton biomass) and primary productivity (Antoine et al. 1995). Since then, several ocean color missions with improved instrumentation, and technical refinement based on the experiences earned from preceding missions have been conducted (IOCCG 2019). All these missions delivered a high volume of ocean color data covering the entire world ocean. The algal bloom events are widely occurring in global seas with frequent episodes. Several bio-optical algorithms have been developed and in use for remote detection of algal blooms in different pockets of world ocean. Based on the deleterious effects of algal blooms on the ambient water quality, it becomes necessary to understand the conducive factors, spreading mechanism and aftermath consequences. In context of Indian seas and adjoining water bodies, the algal bloom scenarios are of wide occurrence. In this backdrop, INCOIS has taken an initiative to start "Algal Bloom Information Service" for north Indian Ocean.

2. Stakeholders

The potential users of the service will be researchers, ecologist and environmentalist to study the impact of algal bloom on environment and subsequent to human health. Policymakers for sustainable ocean management and decision-making, to design marine protected areas and to conduct scientific research programs aimed to generate knowledge on source and sink of bloom. It will also complement the existing ecosystem based services like Potential Fishing Zone indicating safer zone for fishing.

3. Satellite indicators

Satellite remote sensing enables remote detection of oceanographic geophysical parameters attributed to their specific spectral signature. One of the most important optically active substances in the world ocean, the chlorophyll-*a* (proxy of phytoplankton biomass) is retrieved from ocean colour satellites and in use for environmental studies. In addition, based on the pattern and magnitude of remote sensing reflectance, different phytoplankton species/class/size can be detected from ocean colour satellite data through species/class/size specific bio-optical algorithms. In context of algal blooms, a multitude of satellite indicators are essential for their optical identification and monitoring (Table 3.1).

Table 3.1: Satellite indicators and their importance

Indicator	Remarks
Chlorophyll Concentration (OC3M Algorithm)	Open ocean chlorophyll concentration tends to < 1 $mg\text{-}m^3$ in normal condition and it cross way pass that value in case of a bloom condition
Chlorophyll Concentration (ABI Algorithm)	
Bloom Index	Lower bloom index (<-0.6) indicates no bloom condition where as a higher bloom index value corresponds to bloom condition
Phytoplankton Species/Class	Causative species of bloom.
Pico, Nano & Micro Phytoplankton Concentration	Phytoplankton size class biomass
Sea Surface Temperature	Indicator of upwelling and mixing
Chlorophyll Concentration Anomaly	Contrast in phytoplankton biomass production between bloom and non bloom conditions
Sea Surface Temperature Anomaly	Contrast in upwelling and mixing conducive for conceiving bloom

4. Operational Implementation

4.1. Automatic Data Processing Chain

The HAB information service processing script is integrated with existing Automatic Data Processing Chain (ADPC). ADPC download process and generates standard mapped data and image files for 12 geophysical variable from Ocean Color (OC) suit for 8 region of interest (ROI). The ROI are Entire Indian Ocean (EIO) (40°S-31°N & 35°E-103°E), IndiaSriLanka (0°-31°N & 35°E-103°E), Iran (23°N-31°N & 47°E-62°E), Oman (16°N-26°N & 52°E-62°E), Maldives (2°S-8°N & 71°E-75°E), Kenya (5°S-1°S & 38°E-45°E), Tanzania (11°S-4°S & 38°E-45°E) and Thailand (5.5°N-14°N & 95°E-103°E) as demarcated in Fig. 4.1.

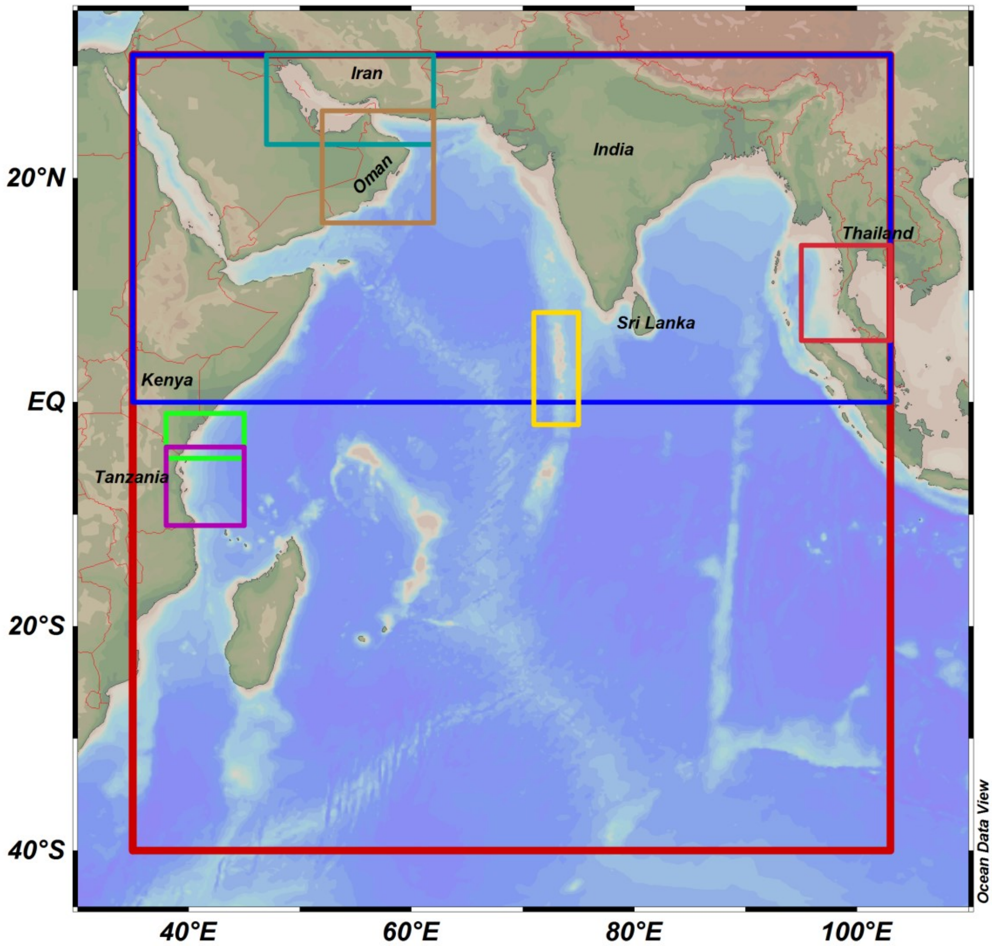


Fig. 4.1: Region of interest for Automatic Data Processing Chain

In addition four Radiance suit (EIO), one IOP suit (EIO), three value added products (IndiaSriLanka), Roll (IndiaSriLanka) and anomaly (IndiaSriLanka) products are also being generated. A brief account of output products are detailed in Table 4.1.

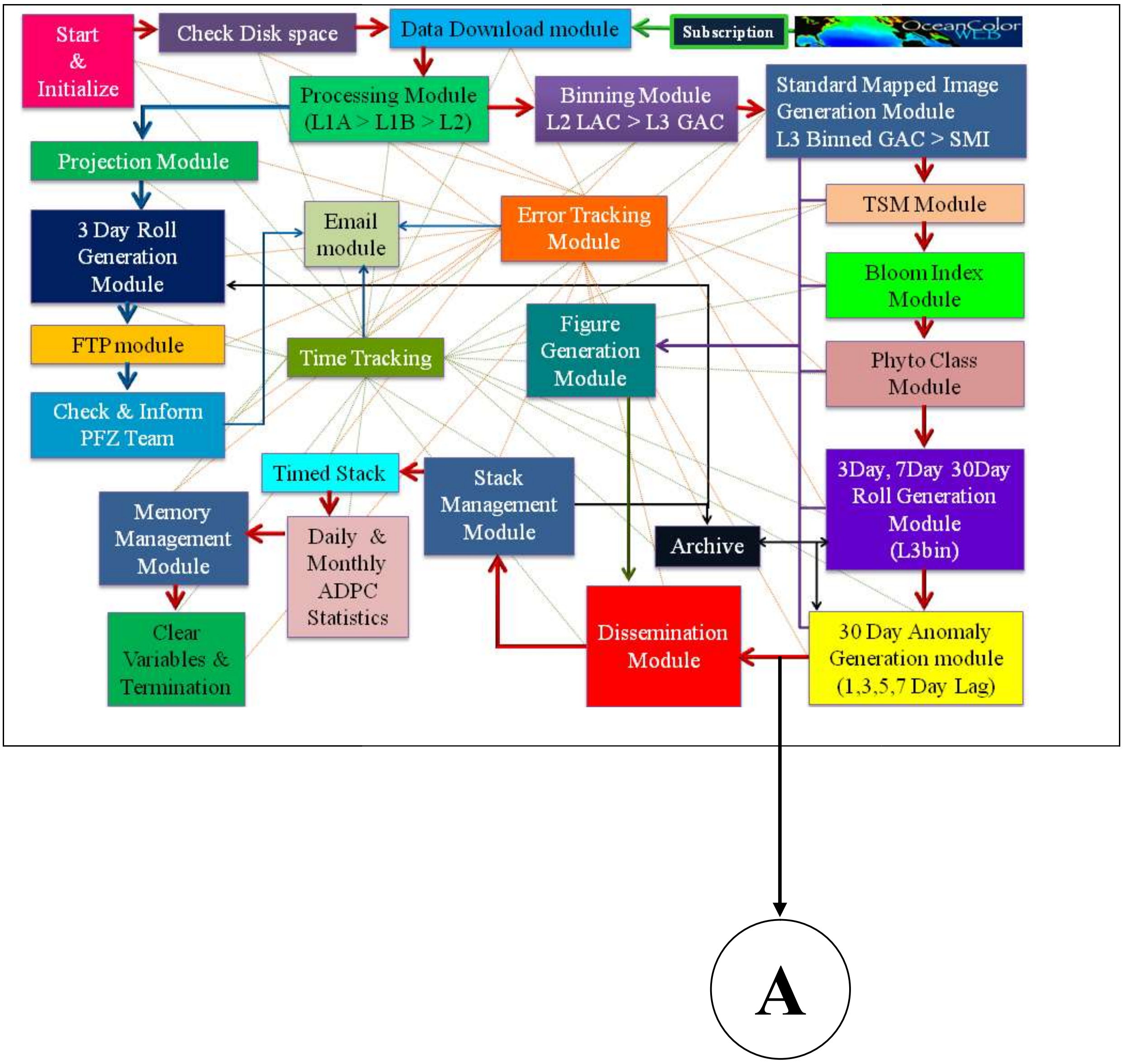
Table 4.1: Integrated ADPC products

S/N	Products	Region	Resolution
1	Quasi True Color Image	EIO	4km
2	sst, chlor_a, chl_abi, Kd_490, pic, poc, dom_index, nflh, aot_869, angstrom, par, ipar	EIO, IndiaSriLanka, Iran, Thailand, Maldives, Oman Tanzania and Kenya	1km, 4km
3	Lw_vvv, Lw_748, Lw_859, Lw_869	EIO	1km, 4km
4	nLw_vvv, nLw_748, nLw_859, nLw_869	EIO	1km, 4km
5	Rrs_vvv*,Rrs_748,Rrs_859,Rrs_869	EIO	1km, 4km
6	a_vvv_giop, adg_vvv_giop, aph_vvv_giop, bb_vvv_giop, bbp_vvv_giop	EIO	1km, 4km
7	Bloom Index, PhytoID, TSM	IndiaSriLanka	4km
8	Roll Products 3, 7 & 30 days	Oman, IndiaSriLanka	1km, 4km

	sst, chlor_a, chl_abi, Kd_490, pic, poc, cdom_index, nflh, aot_869, angstrom, par, ipar		
9	30 Day Anomaly with 0, 1, 3, 5 & 7 Day Lag chlor_a, chl_abi, sst	IndiaSriLanka	1km, 4km
10	Pico, Nano, Micro Plankton Concentration	IndiaSriLanka	4km
*_vvv corresponds to all visible wavelength from 400nm-700nm			

4.1.1. Level -1 to Level 2 processing

ADPC downloads subscription based level-1A data for Indian Ocean region (40°S-31°N, 35°E-103°E) from NASA Ocean Color Website. The Level-1A data files available to download are ocean-subsetted and compressed local area coverage files (5-minute granules comprising typically 200 swaths and encompass roughly 2330-km cross track and 2000-km along track) which contains only the ocean colour bands of MODIS-Aqua (Masuoka et al. 1998). After acquiring and decompressing the level-1 data, geolocation data for each granules is generated using *"modis_GEO.py"* (of SeaDAS OCSSW processor) keeping MODIS terrain elevation correction enabled. Once the geolocation files are prepared, L1B files for each local area coverage (LAC) are generated using L1A & GEO files by *"modis_L1B.py"*. The processing from L1B to L2 goes through atmospheric correction which requires ancillary data such as NO_2 concentration, O_3 concentration, sea ice status and information of other meteorological parameters. *"getanc.py"* is used to fetch such information from NASA-OBPG server and update local database with the optimal ancillary data files for Level-1 to Level-2 processing. The L1B and geolocation files along with the ancillary data are then processed to Level-2 and computed by L2Gen. The L2Gen program applies atmospheric correction algorithm to the L1B calibrated radiances and uses different bio-optical algorithms to retrieves various geophysical variables. The resolution of this L2 product is same as the resolution of the L1 product and the coverage is still local area coverage. L2Gen also introduce masks, a 6-byte set of flags, which indicates whether a pixel is cloudy or clear, over water or land, contains snow or ice, is in cloud shadow, or has sun glint. These are known as L2_Flags. Some of the flags are common for all products (ATMFAIL, LAND, HIGLINT, HILT, HISATZEN, COASTZ, STRAYLIGHT, PRODFAIL etc) where as some of the flags are product specific (such as BTRANGE, BTDIFF, SSTRANGE, SSTREFDIFF etc for SST). From each granules L2Gen produces 7 suite of L2 LAC files such as OC, Lw, nLw, Rrs, IOP, RHOS & SST. The OC suit contains chlor_a, chl_abi, $K_d(490)$, CDOM_index, PIC, POC, nFLH, AOT_869, angstrom, PAR, iPAR. Lw suit contains water leaving radiance for all visible ocean bands of MODIS-Aqua, similarly nLw & Rrs contains the visible ocean bands of normalized water leaving radiances and remote sensing reflectance. The IOP suit aggregates total absorption, absorption due to phytoplankton, absorption due to detritus, back scattering coefficients in all visible ocean bands of MODIA-Aqua instruments calculated using GIOP model. The ROHS suit has only three variable rhos_469, rhos_555 & rhos_645 and are enough to create quasi true color imagery.



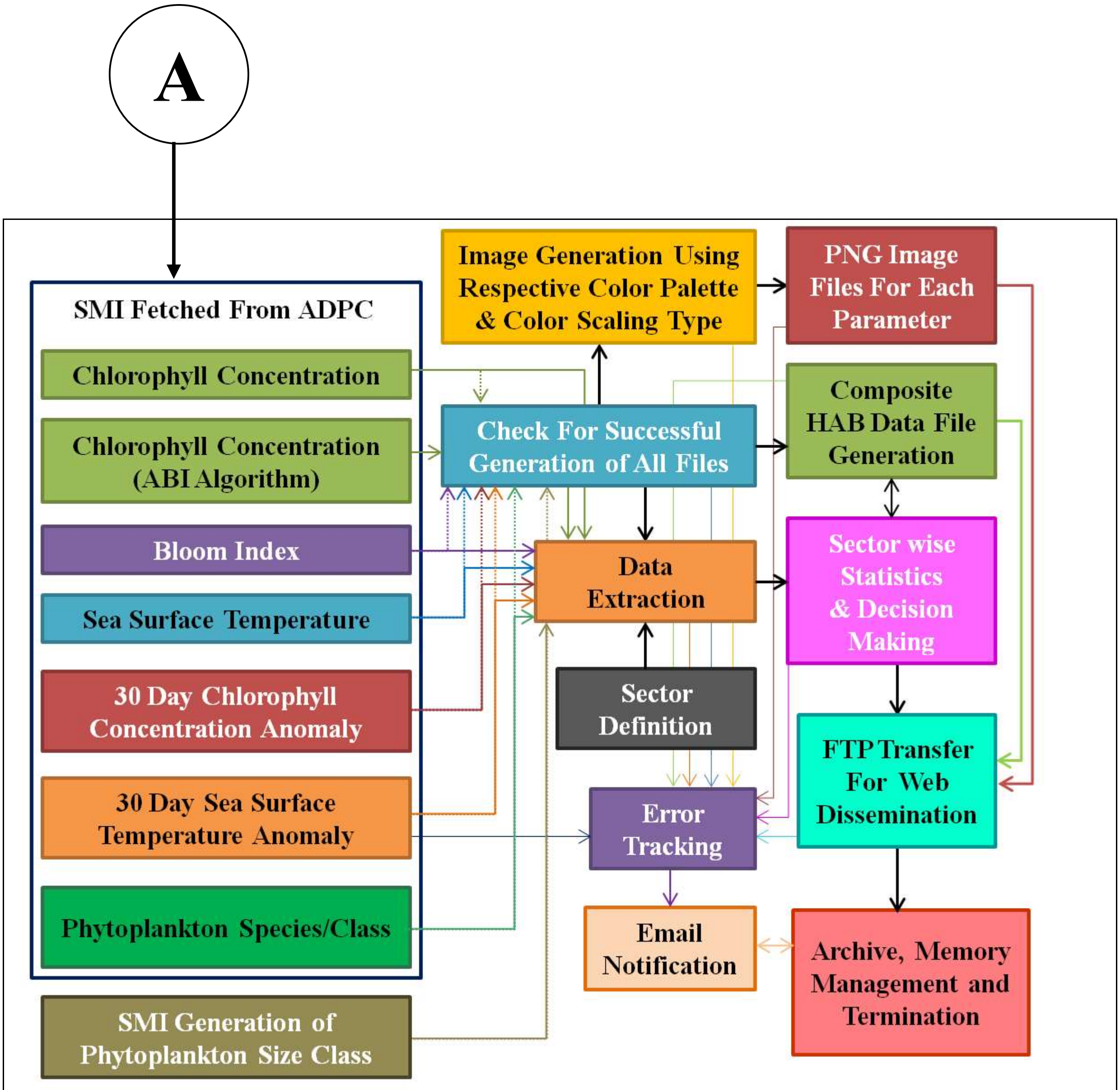


Fig. 4.2: Flowchart of integrated Automatic Data Processing Chain and Algal Bloom Information Service

The SST suit accommodate SST as well as additional variables such as bias_sst, flags_sst, qual_sst, sstref, stdv_sst. In addition to the described variables all the suit contains L2_Flags. These suits of L2 files are unprojected local area coverage files and needs to be stitched together and projected using suitable coordinate system to cover a large region of interest. To provide projected Chl, SST and K_d(490) data product to PFZ advisory service, L2 granules of OC suit are mosaiced in 1km & 4km resolution using Graph Processing Toolkit (GPT) of SeaDAS. However the above step is a bifurcation from the main flow chart of ADPC for faster delivery of projected Chl & SST products.

4.1.2. Level -3 processing

To generate 1km and 4km global area coverage level-3 bin files of each geophysical variables l2bin & l3bin are used in succession. l2bin performs spatial/temporal binning of L2 files to make level-3 binned files. For SST suit processing LAND, HISOLZEN flags are used, for PAR LAND, NAVFAIL, FILTER, HIGLINT flags are taken. For rest of the OC, Rrs, Lw, nLw and IOP products ATMFAIL, LAND, HILT, STRAYLIGHT, CLDICE, CHLWARN, CHLFAIL, NAVWARN, MAXAERITER, ATMWARN, NAVFAIL, FILTER, HIGLINT flags are set. However for RHOS suit flagging is not required as these band will be used only to create the quasi-true color imagery. In the next step l3bin program is used to performs spatial/temporal binning on the L3 GAC files. This step is necessary to prepare the data files which will be used for temporal binning during roll file generation. In l3bin longitudinal and latitudinal extent is required to set the area of interest. Level-3 standard mapped image is then produced applying l3mapgen tool on the L3 binned files prepared in the previous step. l3mapge applies projection to the L3 binned file and remove unrealistic values defined by user. Once the mapped files are generated WriteImage operator of GPT is used to produce png image files for each variable using respective color palette, color scaling type & data range. However, for RHOS suit after preparing the mapped NetCDF data file, l3mapgen also generates quasi true color image file (png) by setting use_rgb to 1 and oformat to png. Mapped NetCDF data files for 8 pre specified ROI having resolution 1 km and 4 km are being prepared and image files for the same region of interest (ROI) of 1km resolution is being generated and disseminated. In addition to the above mentioned standard, 3 values added products such as TSM (Tassan 1994), Bloom Indices (Ahn and Shanmugam 2006) and Phytoplankton Class/Species type (Dwivedi et al. 2015 and Baliarsingh et al. 2017) are also disseminated on a daily basis. The value added products are prepared using various standard products and different operators of GPT. 3day, 7day and 30 day roll products are also being generated using the L3 binned file which were kept aside in a folder to be used for this step. During L2 to L3 processing l3bin was used for spatial binning however, in this step it is being used for temporal binning of data files of last 3, 7 or 30 days to generate corresponding roll product. After the temporal binning is completed, l3mapgen is used to prepare mapped roll product followed by WriteImage tool for image generation. Once the roll products files are in place, 30day anomaly of CHL, SST & Kd(490) is prepared from 30 day roll products and daily products using SeaDAS GPT. As soon as ADPC finishes generation of all standard, value added, roll and anomaly products back up of the data is kept in another drive to avoid data loss in case of a event of a drive failure. All the intermediate and unnecessary files are removed and HAB information generation script is triggered.

4.2. Algal Bloom Information Services

INCOIS Algal Bloom Information service provides near real time information on presence of bloom over North Indian Ocean region (0°-31°N & 35°E - 103°E) illustrated in Fig. 4.2. Daily satellite derived standard mapped images of SST (Walton et al. 1998, Kilpatrick et al, 2015), Chl (Hu et al. 2012), Chl_abi (Shanmugam 2011), Bloom Index (Ahn and Shanmugam 2006), Chl Anomaly, SST anomaly, Phytoplankton class/species (Dwivedi et al. 2015 & Baliarsingh et al. 2017) & Phytoplankton size class (Sahay et al. 2017) for the above mentioned region is being disseminated for HAB information. Inside this full domain, four regions have been identified as bloom hotspots. The identified hotspots are a) North Eastern Arabian Sea (19°N - 23°N & 62°E - 67°E) b) Coastal waters of Kerala (8°N - 12°N & 73°E - 77°E) c) Gulf of Mannar (7°N - 11°N & 78°E - 81°E) d) Coastal waters of Gopalpur (17°N - 20°N & 84°E - 87°E). The four hotspot is demarcated in red in the location map.

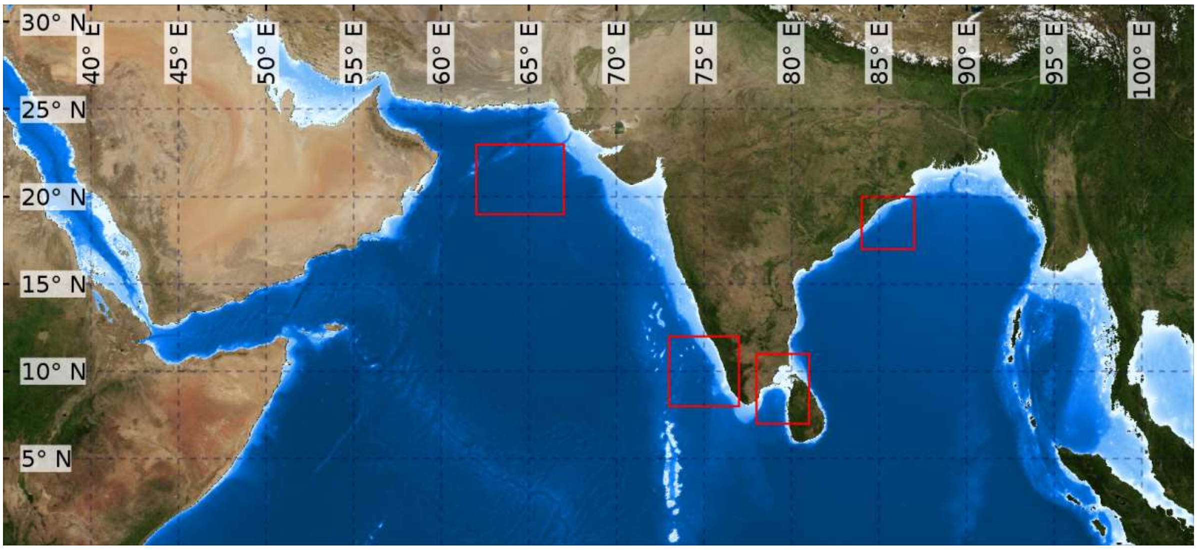


Fig. 4.2: Region of interest for the HAB information service and the demarcated hotspots.

4.2.1 Satellite based indices

Quantitative information of important parameters for these four hotspot are generated below and the parameters are tabulated below.

1. Average Biomass Concentration (mg/m3)
2. Standard Deviation of Biomass Concentration (mg/m3)

3. Average Sea Surface Temperature (°C)
4. Standard Deviation of Sea Surface Temperature (°C)
5. Average Bloom Index
6. Standard Deviation of Bloom Index
7. Average Biomass Concentration Anomaly (mg/m3)
8. Average Sea Surface Temperature Anomaly (°C)
9. Spread of Green Noctiluca (SqKm)
10. Spread of Red Noctiluca (Sq-Km)
11. Spread of Diatoms (Sq-Km)
12. Pico phytoplankton Abandance (%)
13. Nano phytoplankton Abandance (%)
14. Micro phytoplankton Abandance (%)
15. Status of the sector

4.2.2. Decision Making

A pixel is flagged as a bloom pixel, only if four of the following criteria are satisfied

- ✓ Chlorophyll concentration is more than 1 $mg\text{-}m^{-3}$
- ✓ SST does not exceeds 27.5°C
- ✓ Bloom Indices is more than -0.6
- ✓ The presence of green noctiluca or red noctiluca or diatom is confirmed.

After the flags are set, the conditions of each 4 sector are examined sequentially. A sector must have at least 50% data coverage to proceed otherwise the sector is marked as a sector with insufficient data. The possibility of error intrusion as the ROI of Kerala Coast, Gulf of Mannar and Gopalpur Coast unlike north-eastern Arabian sea contains land pixels has been removed as only the ocean pixels are taken in the consideration. Once a sector is proved to have sufficient valid pixels, depending upon the bloom and non bloom pixel counts a status identity is set from either one of the followings

- **Normal:** If the sector contains bloom pixels < 50%
- **Watch:** If the sector contains bloom pixels ≥ 50% and < 75%
- **Warning:** If the sector contains bloom pixels ≥ 75%

The status of each sector is displayed by color code (green for normal, yellow for watch & red for warning) during dissemination of the HAB information in the webpage. To other status *"No Data"* & *"Insufficient Data"* is also incorporated.

4.3. Technical details of automatic processing and web dissemination

4.3.1. Graph Processing Toolkit (GPT)

GPT is a intrigue part of both SeaDAS GUI and command line interface. The command line usage of GPT allows to construct directed, acyclic graphs (DAG) of processing nodes. GPT is comprised of 20 individual operators the can be used stand-alone or combined as node(s). The list of operators in GPT is listed in Table 4.3.1 with their short description taken (SeaDAS documentation).

Table 4.3.1: Available operators of GPT

Operator	Description
BandMaths	Create a product with one or more bands using mathematical expressions.
bathymetry	Operator creating a bathymetry band, elevation band, topography band and bathymetry mask
Binning	Performs spatial and temporal aggregation of pixel values into cells ('bins') of a planetary grid.
Collocate	Collocates two products based on their geo-codings.
EMClusterAnalysis	Performs an expectation-maximization (EM) cluster analysis.
KMeansClusterAnalysis	Performs a K-Means cluster analysis.
LandWaterMask	Operator creating a target product with a single band containing a land/water-mask, which is based on SRTM-shape files (between 60° north and 60° south) and the GlobCover world map (above 60° north) and therefore very accurate.
Merge	Allows copying raster data from any number of source products to a specified 'master' product.
Meris.N1Patcher	Copies an existing N1 file and replaces the data for the radiance bands
Mosaic	Creates a mosaic out of a set of source products.
PCA	Performs a Principle Component Analysis.
PixEx	Extracts pixels from given locations and source products.
Read	Reads a product from disk.
Reproject	Reprojection of a source product to a target Coordinate Reference System.
StatisticsOp	Computes statistics for an arbitrary number of source products.
Subset	Create a spatial and/or spectral subset of a data product.

TemporalPercentile	Computes percentiles over a given time period.
Unmix	Performs a linear spectral unmixing.
Write	Writes a data product to a file.
WriteImage	Creates a color image from a single source band.

A node in the graph refers to one of the above mentioned data processor or operator which gets raster inputs either from source files invoked or from the results of the previous node and either pass the output to the following node or writes in a file. When the graph is a collection of more than one nodes, each node pulls it's source node first in order to perform the algorithm it implements. This is known as pull-processing. A sample graph processing framework is illustrated in Fig. 4.3.1.

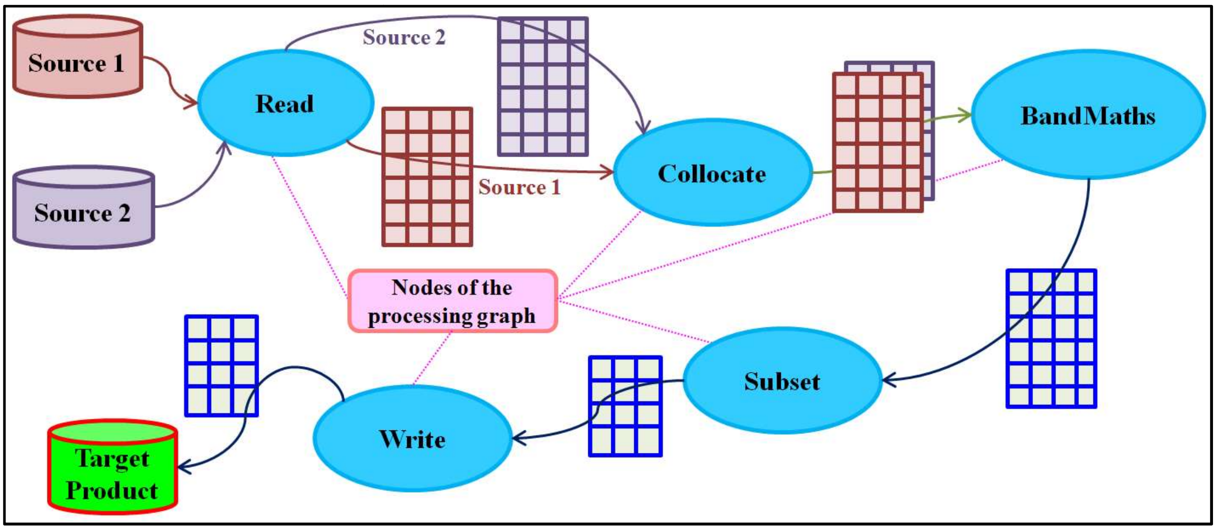


Fig. 4.3.1: A processing graph comprising five nodes. Graph pull-processing is triggered by the "Write" operation requesting raster data from its source node.

Processing graphs are represented using XML. Processing a graph using GPT can be invoked by the following command line usage.

```
gpt <graph-xml-file> [options] [<source-file-1> <source-file-2> ...]
```

A sample GPT Operator Configuration XML is given below. This xml is a operating xml files taken from the ADPC and it is used to produce subset for a particular ROI from the data file with maximum spatial extent.

```
<graph id="SubsetMODISA">
  <version>1.0</version>
  <node id="SubsetNode">
  <operator>Subset</operator>
    <sources>
      <source>${sourceFileName}</source>
    </sources>
    <parameters>
      <geoRegion>POLYGON((${West} ${South}, ${East} ${South},
${East} ${North}, ${West} ${North}, ${West} ${South}))</geoRegion>
```

```
      <bandNames>${variable}</bandNames>
      <copyMetadata>true</copyMetadata>
    </parameters>
  </node>
  <node id="writeNode">
    <operator>Write</operator>
    <sources>
      <source>SubsetNode</source>
    </sources>
    <parameters>
      <file>${outputSubsetFileName}</file>
      <formatName>NetCDF4-CF</formatName>
      <deleteOutputOnFailure>true</deleteOutputOnFailure>
    </parameters>
  </node>
</graph>
```

The above configuration is saved in a xml file named " SubsetForProjectionMODISA.xml" and the subset operation is being carried out by this command

gpt.sh -e SubsetForProjectionMODISA.xml -c 4G -SsourceFileName=A-Feb2019-d15-1KM-Entire-CHL.nc -PNorth=26.0 -PSouth=16.0 -PEast=62.0 -PWest=52 -Pvar=chlor_a -PoutputSubsetFileName=A-Feb2019-d15-1KM-Oman-CHL.nc

4.3.2. Folder Structure:

The processing scripts consists of several bash files, xml files, collor pallete definition files, and rgb profile definition files. The Main directory containing the files and folder is set as ScriptPat, in the main script. The directory structure required to be maintain as there are multiple access of this sub-scripts and supporting files in different processing levels. The output products are distributed in different directories for easy access and avoiding confusion. The script structure and the output product directory structure are shown in Fig. 4.3.2.

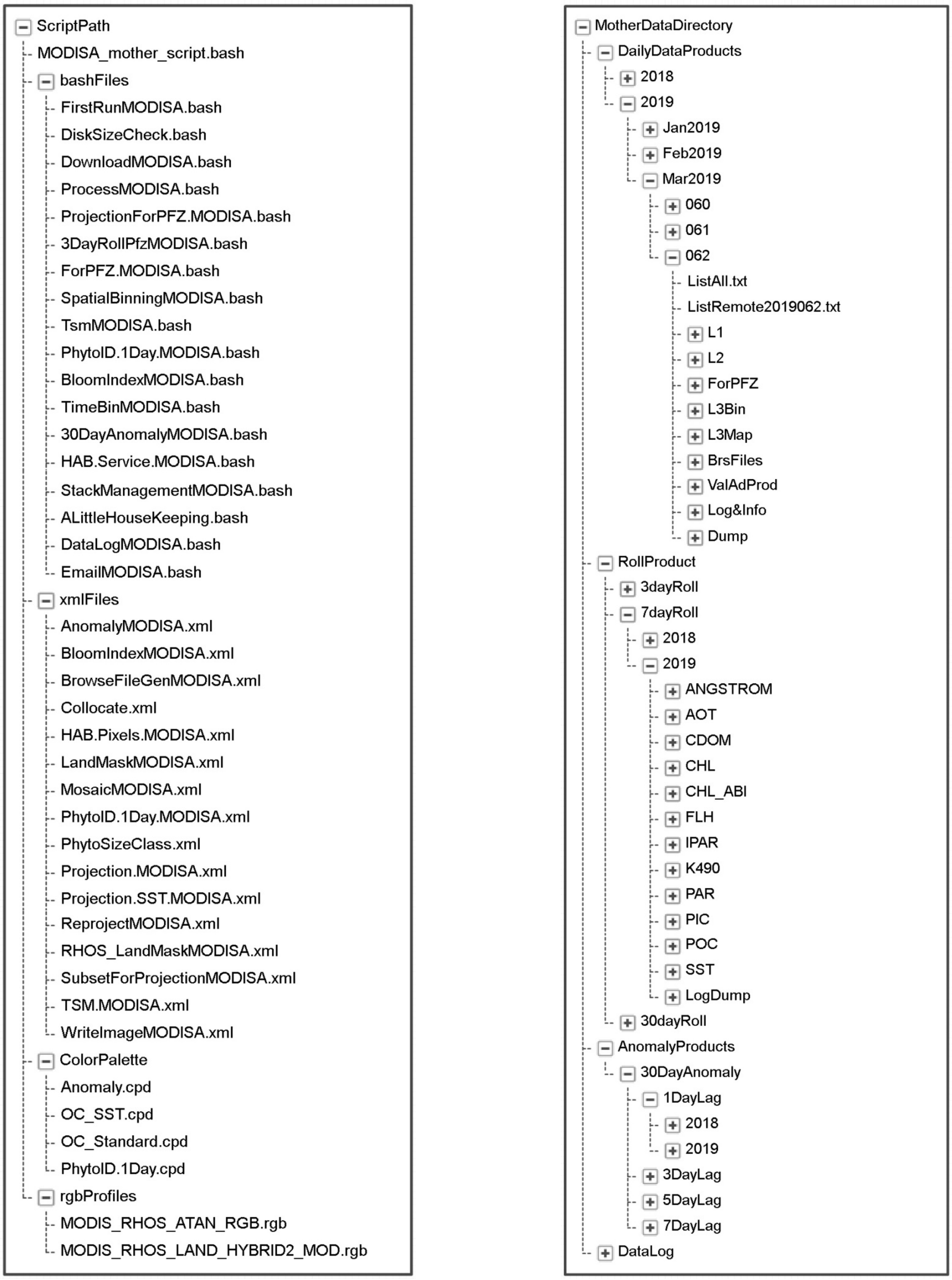


Fig. 4.3.2: Directory structure for the script running ADPC(left) and the directory structure of the processing output data directories(right)

4.3.3. Primary Dependencies:

SeaDAS	Primary data processing software.
java	To install & run SeaDAS v7.5.
wget & git	For Data Download, updating SeaDAS.
ferret	To handle NetCDF files as a complementary to SeaDAS, to extract data.
ssmtp	For email integration.

sshpass	For pushing password automatically to a ssh connection to push data to other server.
bzip2	Decompressing downloaded L1A files.
ncftp	To push data in ftp server.
nco	Handling various operation on NetCDF files.
cdo	Handling various operation on NetCDF files.

4.3.4 Automation, issues & fixes:

The main script is triggered every day at 06:30 Hrs IST using crontab. In crontab shell may have to be defined & user environment may have to be loaded for smooth trigger.

```
30 6 * * * /bin/bash -c 'source $HOME/.profile; source
/OceanColour/Scripts/MODISA/MODISA_mother_script.bash >& ProcessMODISA.log &'
```

Executable permission should be given to the script prior to first run by using chmod a+x.

Permission have to be set to run the script in non-interactively otherwise the script will be triggered by crontab but no processing will be done due to restriction imposed in the ~/.bashrc. The following commands in the ~/.bashrc are needed to be commented out for automation.

```
If not running interactively, don't do
anything
case $- in
   *i*) ;;
     *) return;;
Esac
```

To

```
# If not running interactively, don't do
anything
#case $- in
#    *i*) ;;
#      *) return;;
#esac
```

4.3.5. Cached Memory Managemen issue & fix:

To work properly, ADPC requires sufficient cached memory. So the maximum memory (heap space) parameter should be changed in these following files before first run.

1. $SeaDASPath/bin/gpt.sh
2. $SeaDASPath/bin/seadas.vmoptions

To set the maximum memory usage to 512 MB, -Xmx should be set as -Xmx512M in the above mentioned files. However, the maximum memory allocation is subjected to the available RAM of the system.

3. $HOME/.seadas/seadas-app/preferences.properties

To set the maximum memory usage to 512 MB, ‘jai.tileCache.memoryCapacity=’ should be set as ‘jai.tileCache.memoryCapacity=512’ in the preferences.properties file.

The above discussion is the solution for “Error: java heap space”, “Message: Cannot construct DataBuffer” issue.

4.3.6Others Notes

As 50m coastline is used for land masking during png image production in different sub scripts, 50m(SRTM_GC) coast line source data set must be installed in SeaDAS.

4.3.7. SeaDAS command line usage during main processing part:

- Preparation of GEO files

modis_GEO.py $L1AFile -o $GEOFile --verbose --enable-dem --threshold=95

- L1A to L1B

modis_L1B.py $ L1AFile $GEOFile -o $L1BFile --del-hkm --del-qkm

- Fetching ancillary data

getanc.py $L1BFile --no2 --verbose

- L1B to L2

```
/bin/bash -c "l2gen ifile=$L1BFile par=$L1BFile.anc geofile=$GEOFile \
ofile1=$L2OC l2prod1='chlor_a,chl_abi, Kd_490, cdom_index, pic, poc, nflh, aot_869,
angstrom, par, ipar, l2_flags' \
ofile2=$L2Lw l2prod2='Lw_vvv,Lw_748,Lw_859,Lw_869,l2_flags' \
ofile3=$L2nLw l2prod3='nLw_vvv,nLw_748,nLw_859,nLw_869,l2_flags' \
ofile4=$L2Rrs l2prod4='Rrs_vvv,Rrs_748,Rrs_859,Rrs_869,l2_flags'  \
ofile5=$L2IOP
l2prod5='a_vvv_giop,adg_vvv_giop,aph_vvv_giop,bb_vvv_giop,bbp_vvv_giop,l2_flags' \
ofile6=$L2RHOS l2prod6='rhos_469,rhos_555,rhos_645'" >$LogFile_OC
/bin/bash -c "l2gen ifile=$L1BFile par=$L1BFile.anc geofile=$GEOFile suite=SST \
ofile=$L2File7 l2prod='sst,bias_sst,flags_sst,qual_sst,sstref,stdv_sst,l2_flags'"
>$LogFile_SST
```

- L2 to L3bin

```
l2bin infile=$L2LacFileList ofile=$l2binFile.L3_GAC sday=$Year$JulianDay
eday=$Year$JulianDay resolve=$Resolution flaguse=ATMFAIL, LAND, HILT,
STRAYLIGHT, CLDICE, CHLWARN, CHLFAIL, NAVWARN, MAXAERITER,
ATMWARN, NAVFAIL, FILTER, HIGLINT l3bprod=$VariableName  prodtype='regional'
noext=1 oformat=L3_GAC verbose=1> $l2bin.log
```

- L3binning

```
l3bin in=$ l2binFile.L3_GAC out=$l3binFile.nc out_parm=$VariableName  loneast=$East
lonwest=$West latnorth=$North latsouth=$South oformat=netCDF4 noext=1 > $l3bin.log
```

- L3 binned to L3 mapped

```
l3mapgen ifile=$l3binFile.nc ofile=$OpMapFile.nc product=$ VariableName
projection=smi resolution=$Resolution north=$North south=$South east=$East west=$West
datamin=$minVal datamax=$maxVal oformat=netCDF4 > $l3map.log
```

- Quasi true-color image generation

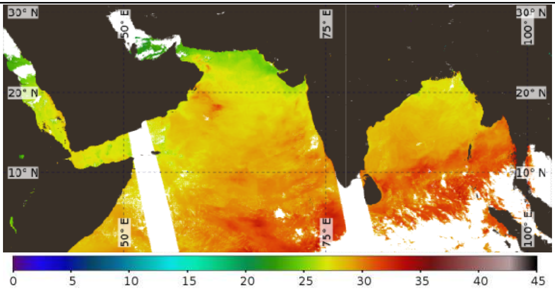
```
l3mapgen ifile=$OpMapFile.nc ofile=$OpPngFile.png projection=smi
resolution=$Resolution north=$North south=$South east=$East west=$West apply_pal=0
use_rgb=1 use_quality=0 product_rgb='rhos_645,rhos_555,rhos_469' oformat=png
```

- Roll Product

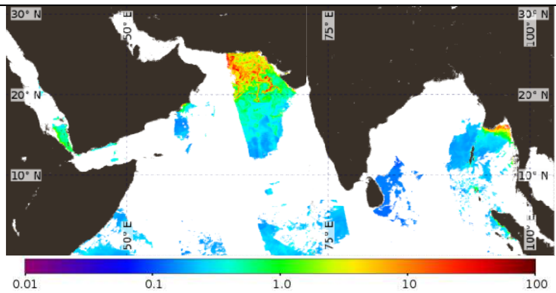
```
l3bin in=$ListOfInputL3BinFilesForRequiredDays out=$RollProductFileName.nc
out_parm=$VariableName loneast=$East lonwest=$West latnorth=$North latsouth=$South
noext=1 verbose=1
```

5. Case studies

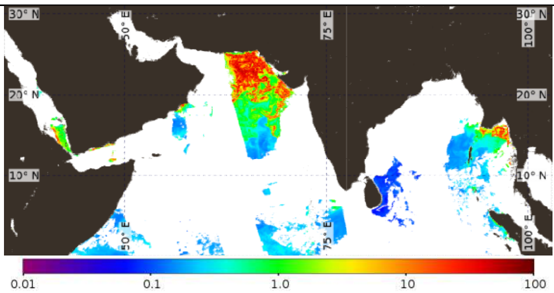
A case study for 31st March 2019 has been carried out to check performane of ADPC & Algal bloom information Service. All the output images, illustrated below, are fetched directly from integrated ADPC and algal bloom information services.



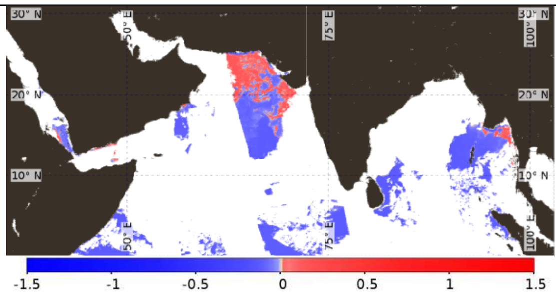
Sea Surface Temperature in °C



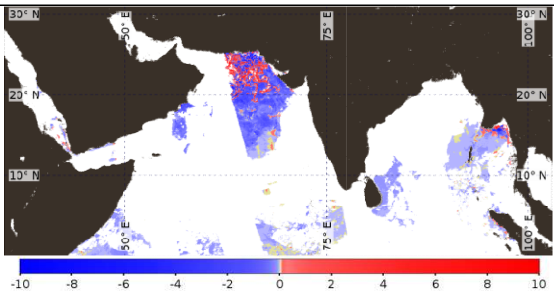
Chlorophyll-a Concentration in mg-m-3



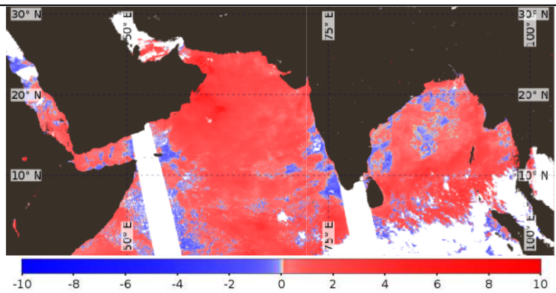
Chlorophyll-a Concentration (ABI) mg-m-3



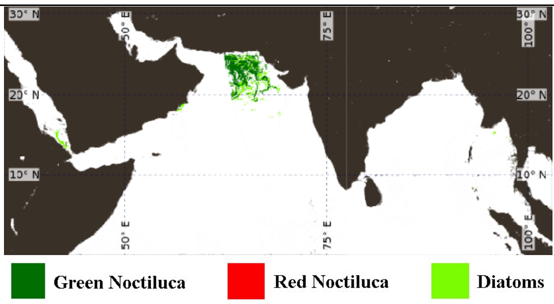
Bloom Index



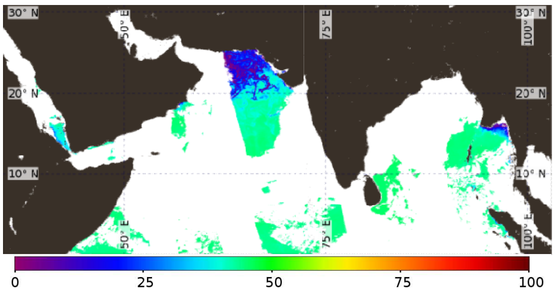
Chlorophyll-a Concentration anomaly in mg-m-3



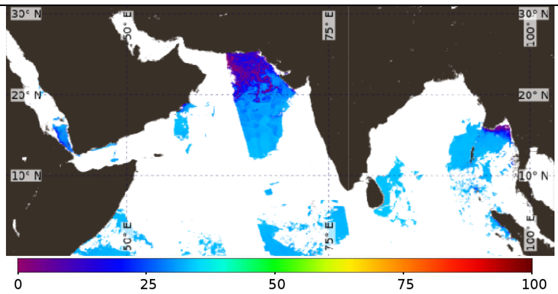
Sea Surface Temperature Anomaly in °C



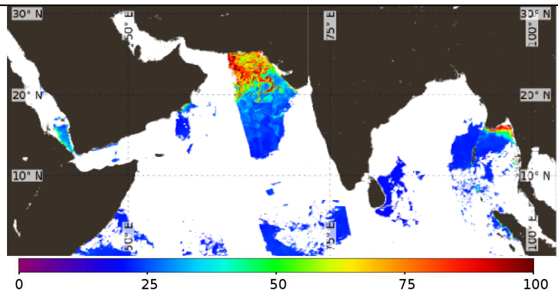
Phytoplankton Class/Species



Pico Plankton Abandance (%)



Nano Plankton Abandance (%)



Micro Plankton Abandance (%)

Daily quantitative information of important parameters for these four hotspots i.e. North Eastern Arabian Sea, Kerala Coast, Gulf of Mannar and Gopalpur Coast is tabulated in Table 5.1.

Table 5.1: Daily quantitative information of important parameters of four hotspot.

Parameter Description (& unit)	**North Eastern Arabian Sea**	**Kerala Coast**	**Gulf of Mannar**	**Gopalpur Coast**
Average Biomass Concentration (mg/m^3)	4.12	No Data	0.132	No Data
Standard Deviation of Biomass Concentration (mg/m^3)	5.516	No Data	0.007206	No Data
Average Sea Surface Temperature (°C)	26.85	29.64	30.03	27.96
Standard Deviation of Sea Surface Temperature (°C)	0.4617	0.5452	1.4	0.6856
Average Bloom Index	0.3717	No Data	-0.7149	No Data
Standard Deviation of Bloom Index	0.5469	No Data	0.01989	No Data
Average Biomass Concentration Anomaly(mg/m^3)	-0.102	No Data	-0.07214	No Data
Average Sea Surface Temperature Anomaly (°C)	1.711	0.0493	0.3045	0.2952
Spread of Green Noctiluca (Sq-Km)	44240	No Data	No Data	No Data
Spread of Red Noctiluca (Sq-Km)	No Data	No Data	No Data	No Data
Spread of Diatoms (Sq-Km)	25376	No Data	No Data	No Data
Pico phytoplankton Abundance	24.73 %	No Data %	45.81 %	No Data
Nano phytoplankton Abundance	18.07 %	No Data %	34.1 %	No Data
Micro phytoplankton Abundance	57.2 %	No Data %	20.09 %	No Data
Status				

	Normal		**Insufficient Data**
	Watch		**No Valid Data**
	Warning		

6. Future scope

The operational service has been planned to implemented in three phases as detailed in the table below

Phase	Service Type	Remarks
Phase-I	Information Service	• Based on Satellite data • Now-casting / Near real-time • Spatial and Temporal extent of the bloom
Phase-II	Advisory Service	• Based on Satellite data • Now-casting / Near real-time • Spatial and Temporal extent of the bloom • Probable impact on ecosystem (fisheries, water quality etc.)
Phase-III	Predictive Advisory Service	• Based on Satellite and Model data • Forecasting • Spatial and Temporal extent of the bloom • Probable impact on ecosystem (fisheries, water quality etc.)

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