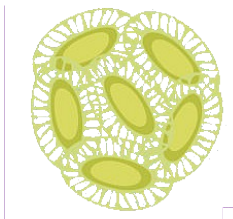
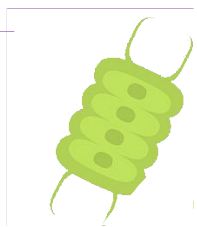
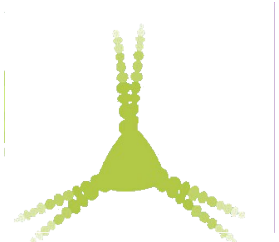
# Satellite derived chlorophyll: A remote sensing perspective







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PhD Candidate, IMAS
3rd July 2019

Some content from Dr. Rob Johnson, BoM
Introduction to Remote Sensing (QMS515)

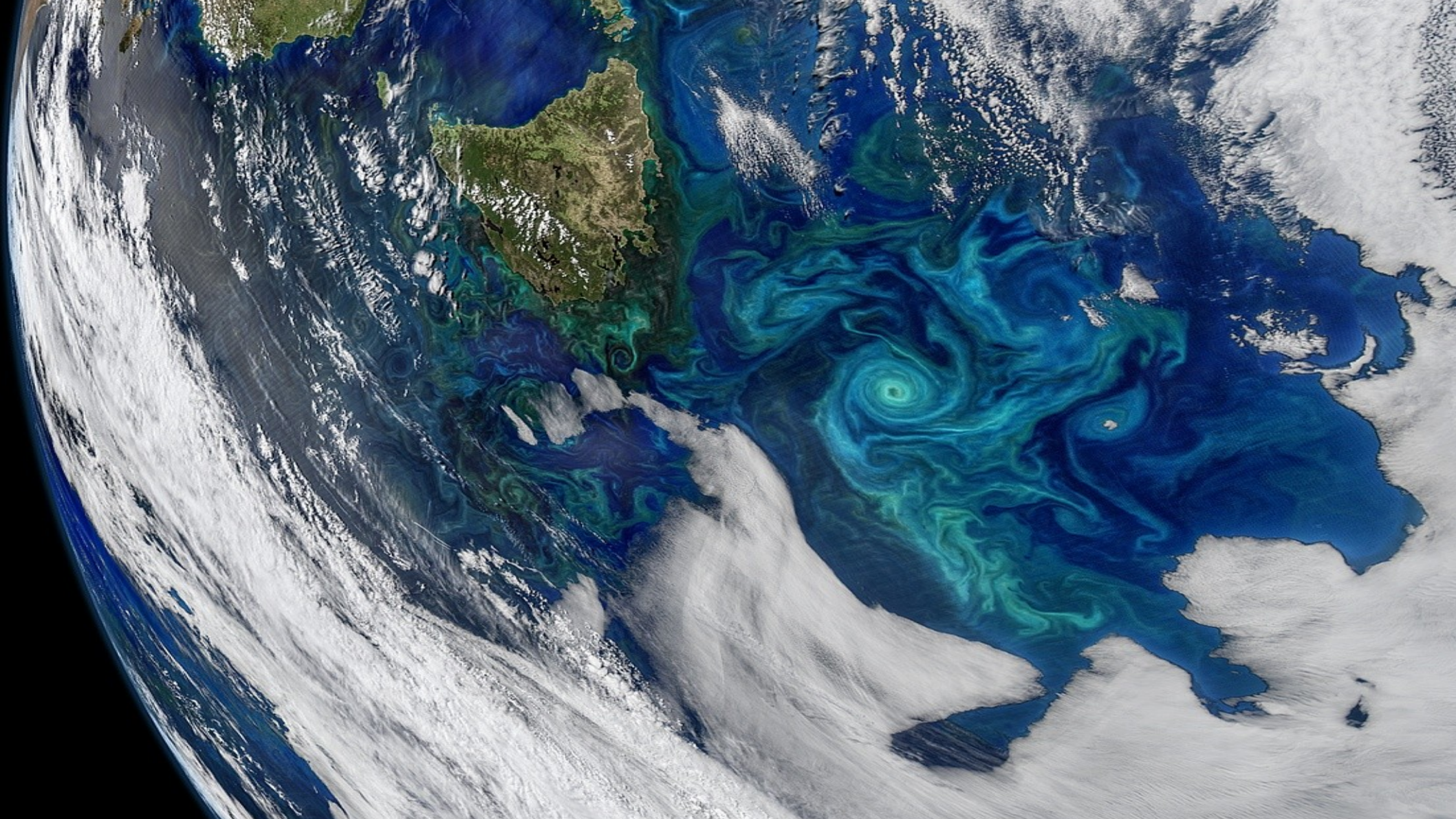
IMAS
INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

climate extremes
ARC centre of excellence

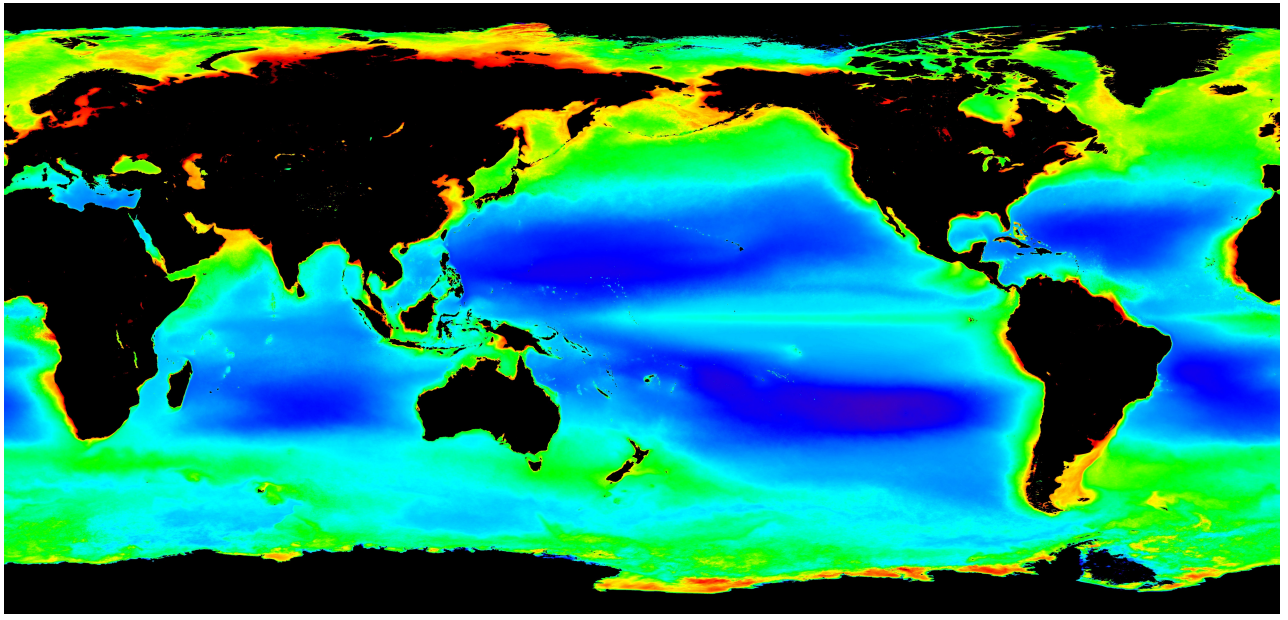
Australian Government
Australian Research Council

CSIRO

UNIVERSITY of TASMANIA



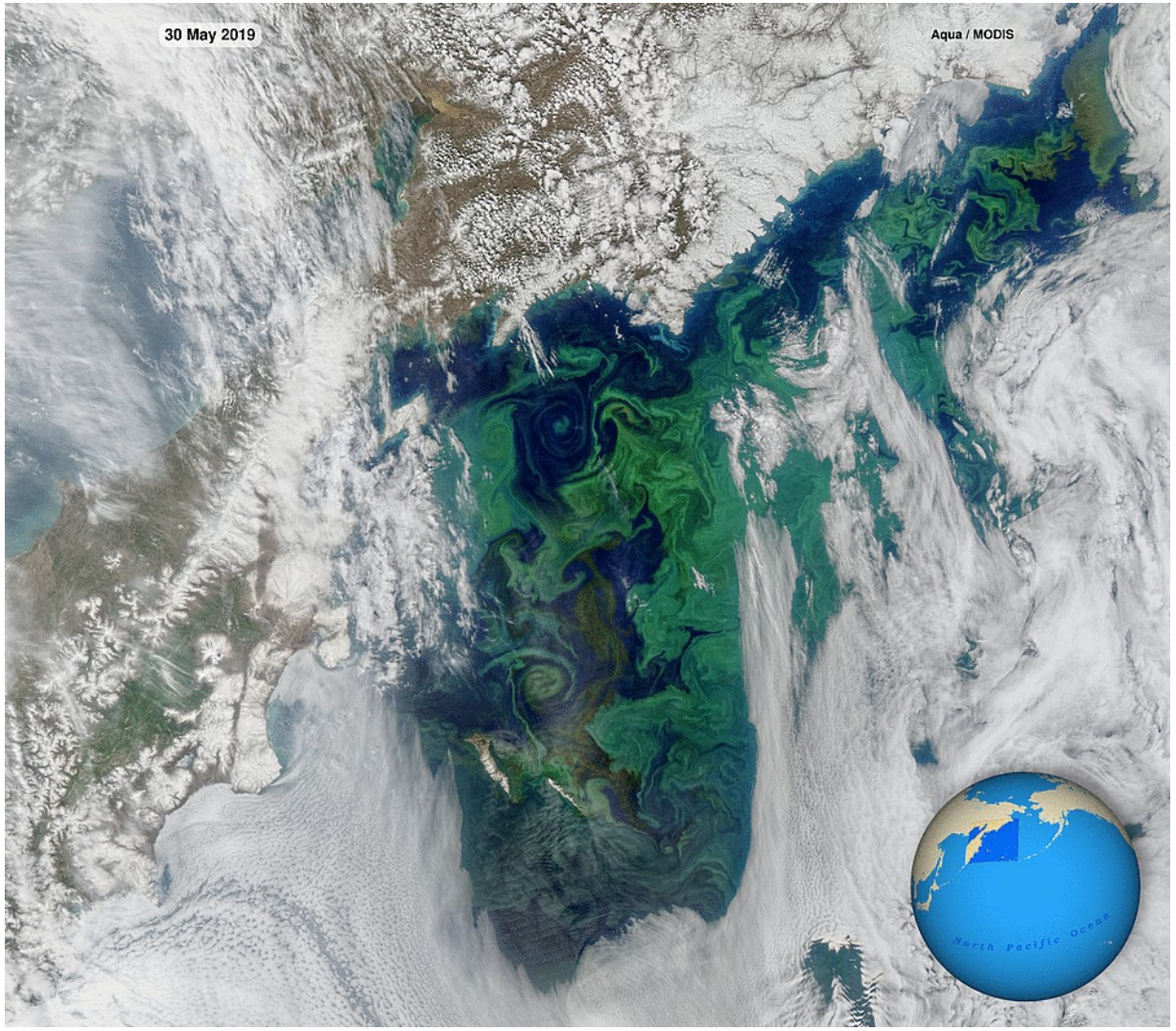
# Global ocean color




MODIS-Aqua Chlorophyll concentration

4 Jul 2002 - 31 Mar 2019 (Entire Mission Composite)

L3 – Mapped – 9km - https://oceancolor.gsfc.nasa.gov/l3/




Clouds cleared over the western Bering Sea at the end of May 2019 to reveal phytoplankton assemblages stirred by ocean currents. Variations in species composition, depth distribution, and even the physiological state of the phytoplankton all contribute to subtle changes in water color as measured by the orbiting radiometer.

# Inherent Optical Properties (IOPs)

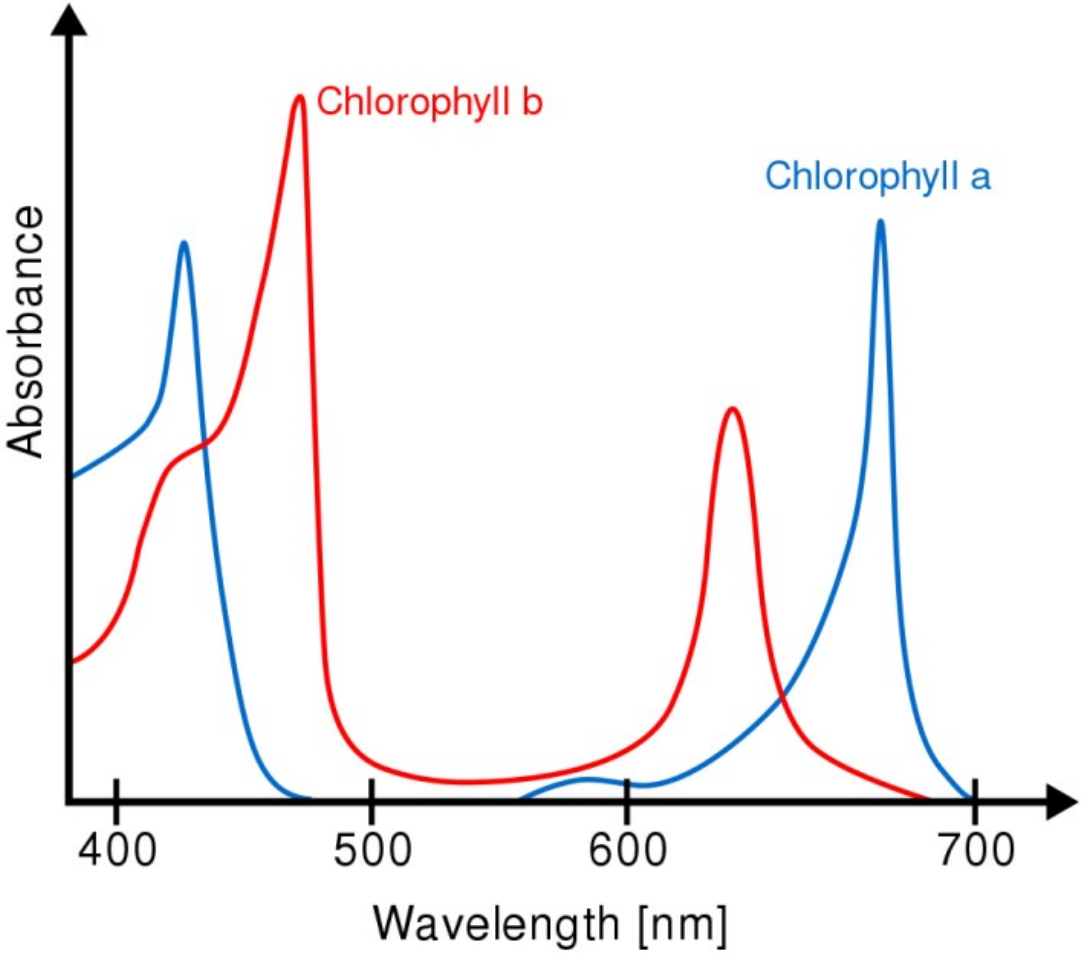
## Things that absorb

- Chlorophyll in Phytoplankton!
- Seawater
- Particles (dirt)
- Detritus
- Coloured Dissolved Organic Matter (CDOM)
- +++

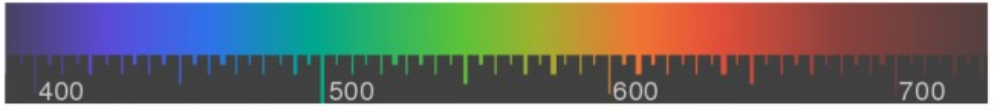
## Things that reflect

- Seawater
- Detritus
- Phytoplankton
- Bubbles and turbulence
- Sea floor
- +++

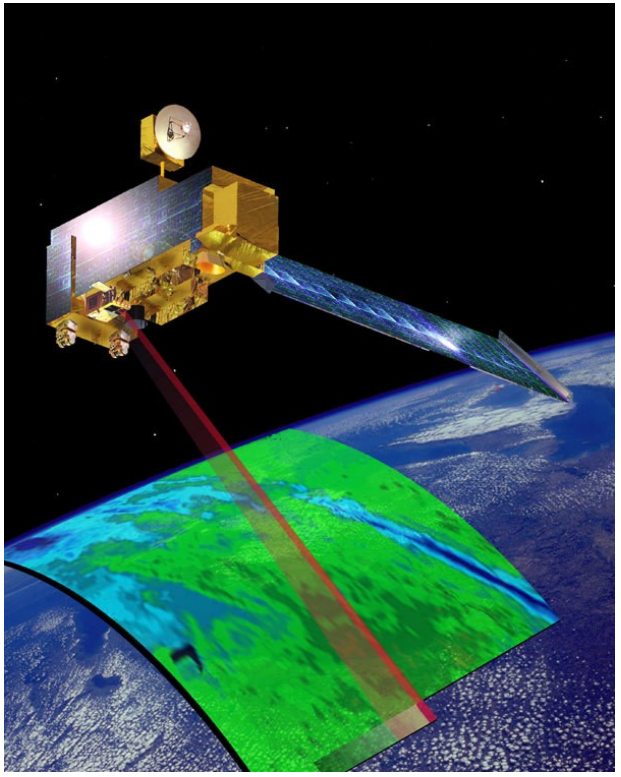
| Primary Use | Band | Bandwidth[1] | Spectral Radiance[2] | Required SNR[3] |
|---|---|---|---|---|
| Land/Cloud/Aerosols Boundaries | 1 | 620 - 670 | 21.8 | 128 |
| | 2 | 841 - 876 | 24.7 | 201 |
| Land/Cloud/Aerosols Properties | 3 | 459 - 479 | 35.3 | 243 |
| | 4 | 545 - 565 | 29.0 | 228 |
| | 5 | 1230 - 1250 | 5.4 | 74 |
| | 6 | 1628 - 1652 | 7.3 | 275 |
| | 7 | 2105 - 2155 | 1.0 | 110 |
| Ocean Color/ Phytoplankton/ Biogeochemistry | 8 | 405 - 420 | 44.9 | 880 |
| | 9 | 438 - 448 | 41.9 | 838 |
| | 10 | 483 - 493 | 32.1 | 802 |
| | 11 | 526 - 536 | 27.9 | 754 |
| | 12 | 546 - 556 | 21.0 | 750 |
| | 13 | 662 - 672 | 9.5 | 910 |
| | 14 | 673 - 683 | 8.7 | 1087 |
| | 15 | 743 - 753 | 10.2 | 586 |
| | 16 | 862 - 877 | 6.2 | 516 |
| Atmospheric Water Vapor | 17 | 890 - 920 | 10.0 | 167 |
| | 18 | 931 - 941 | 3.6 | 57 |
| | 19 | 915 - 965 | 15.0 | 250 |



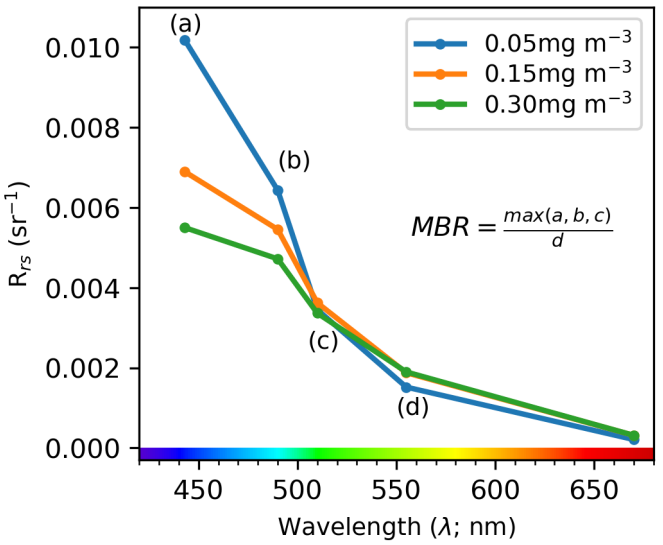

https://modis.gsfc.nasa.gov/about/specifications.php



# Satellite Chlorophyll Algorithms

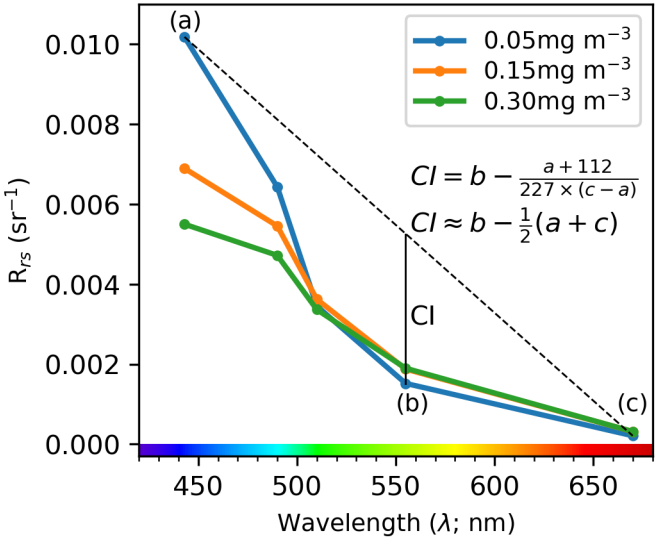


## Max Band Ratio




O'Reilly et al., (1998) Algorithm

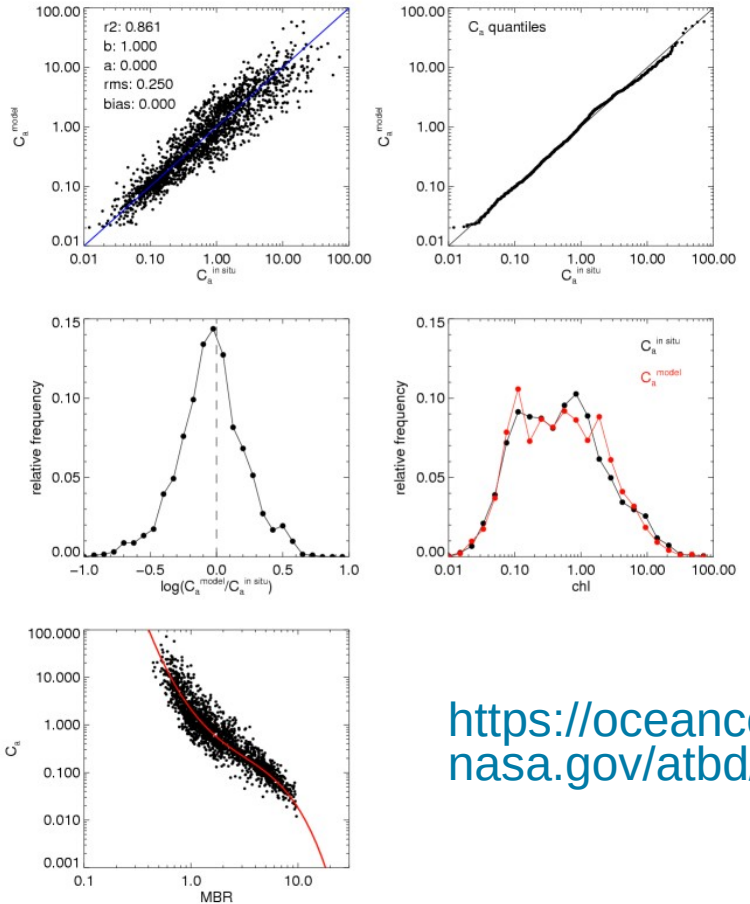
## Colour Index



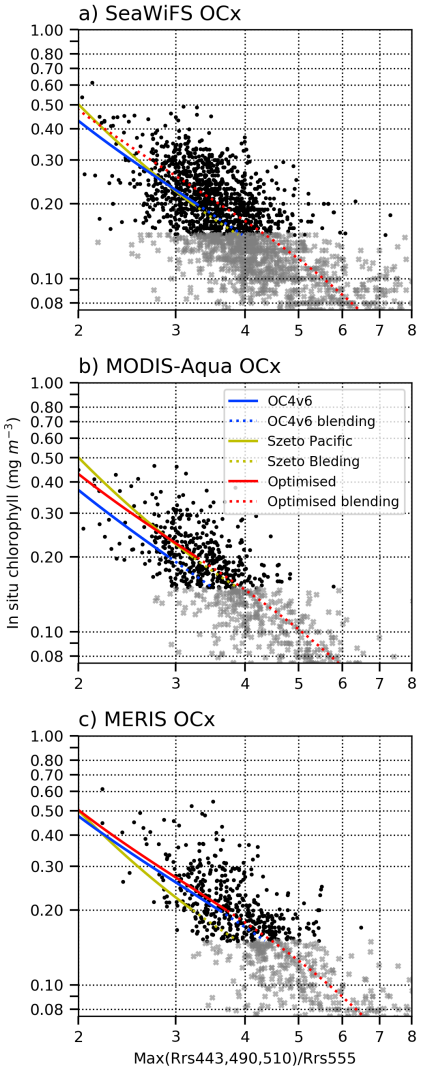

Hu et al., (2012) Algorithm

Cassardo et al., (2014); https://modis.gsfc.nasa.gov

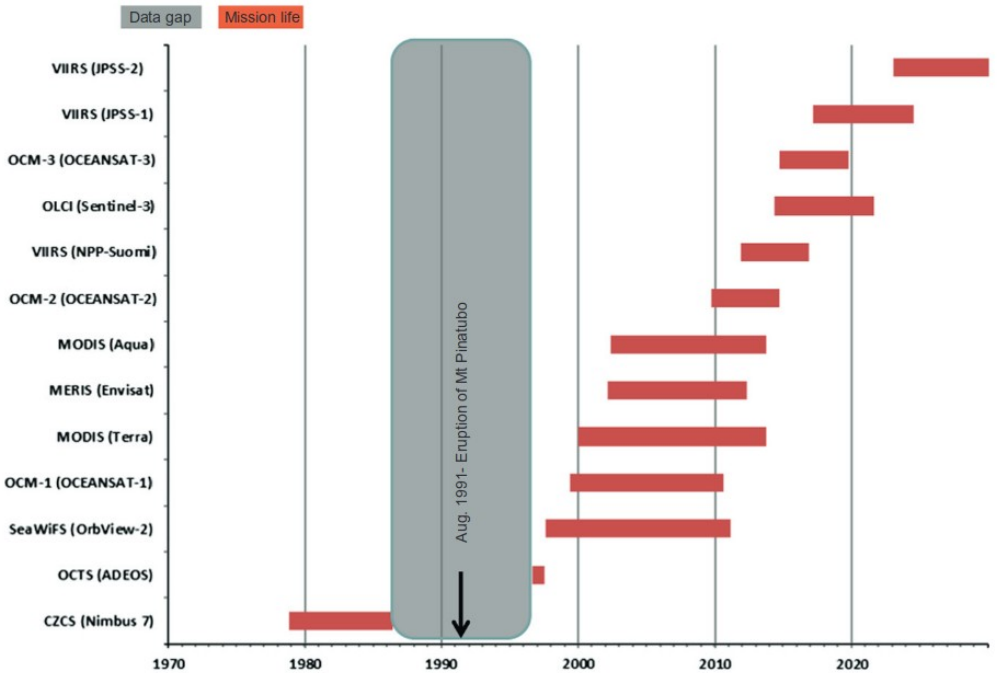
# Global Algorithm Polynomials

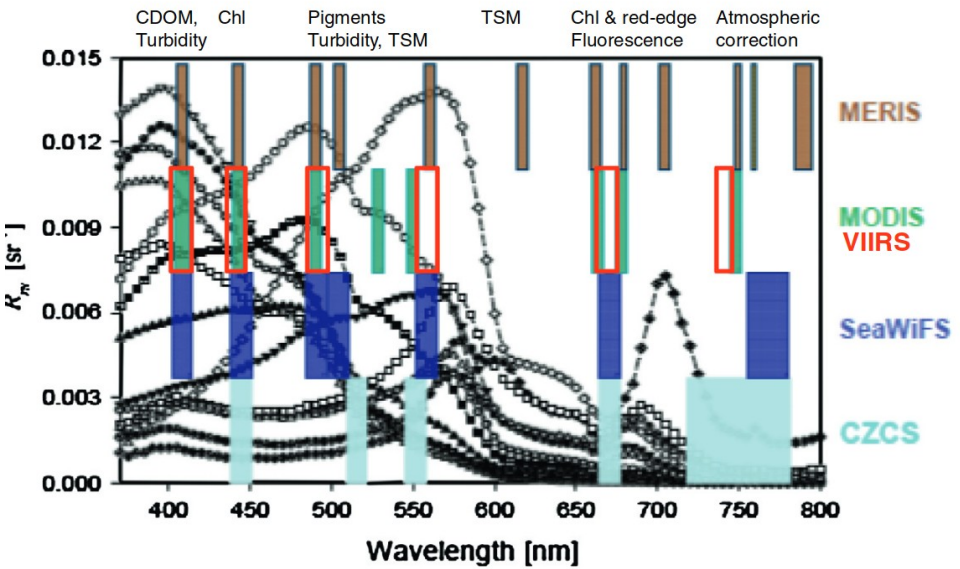


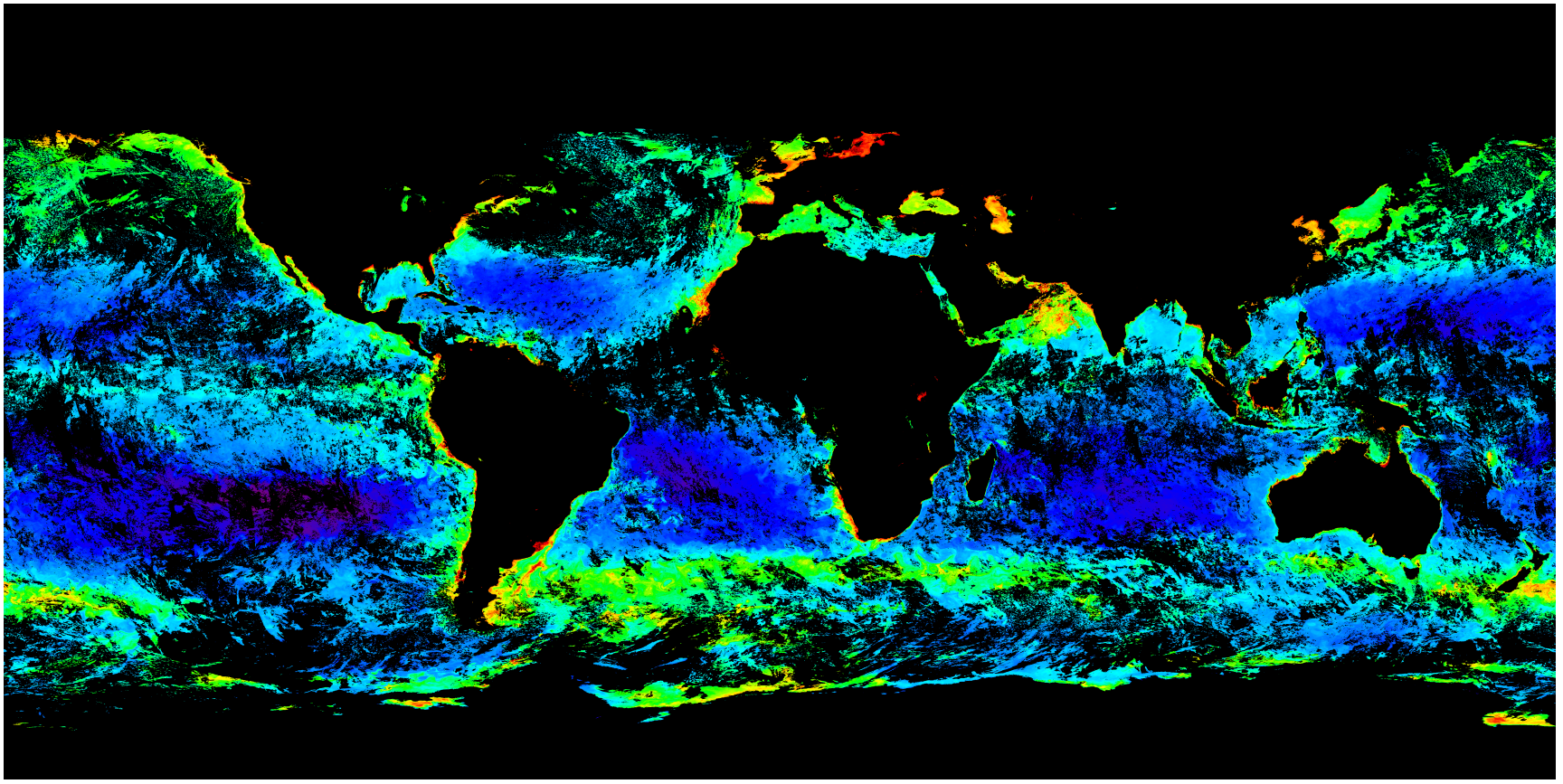

https://oceancolor.gsfc.nasa.gov/atbd/chlor_a/




Pittman et al.
In prep (2019)


Data gap
Mission life
VIIRS (JPSS-2)
VIIRS (JPSS-1)
OCM-3 (OCEANSAT-3)
OLCI (Sentinel-3)
VIIRS (NPP-Suomi)
OCM-2 (OCEANSAT-2)
MODIS (Aqua)
MERIS (Envisat)
MODIS (Terra)
OCM-1 (OCEANSAT-1)
SeaWiFS (OrbView-2)
OCTS (ADEOS)
CZCS (Nimbus 7)
Aug. 1991- Eruption of Mt Pinatubo
1970
1980
1990
2000
2010
2020

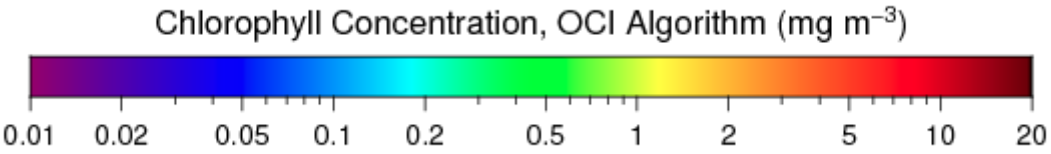

CDOM, Turbidity
Chl
Pigments Turbidity, TSM
TSM
Chl & red-edge Fluorescence
Atmospheric correction
0.015
0.012
0.009
0.006
0.003
0.000
$K_m$ [sr$^{-1}$]
400
450
500
550
600
650
700
750
800
Wavelength [nm]
MERIS
MODIS
VIIRS
SeaWiFS
CZCS



MODIS-Aqua Chlorophyll concentration **Chlor_a (OCI)**

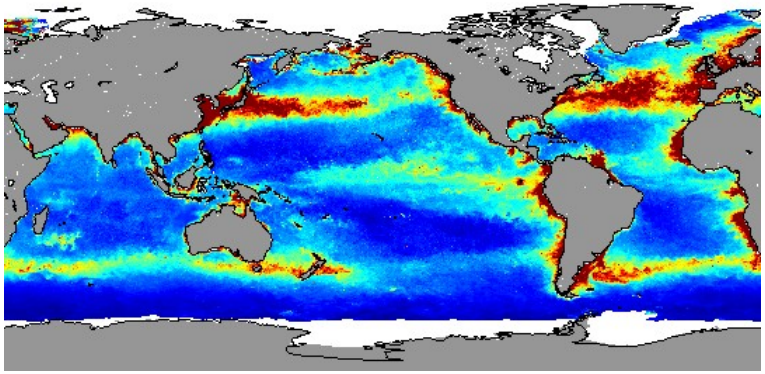
18 Feb - 25 Feb 2019 (8-day)

L3 – Mapped – 4km - https://oceancolor.gsfc.nasa.gov/l3/

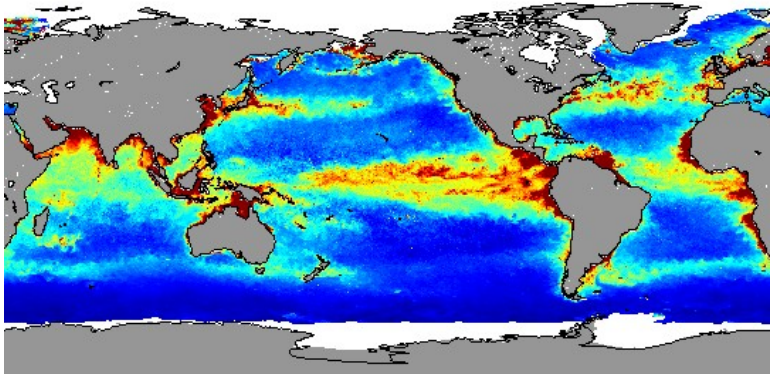


# Data levels

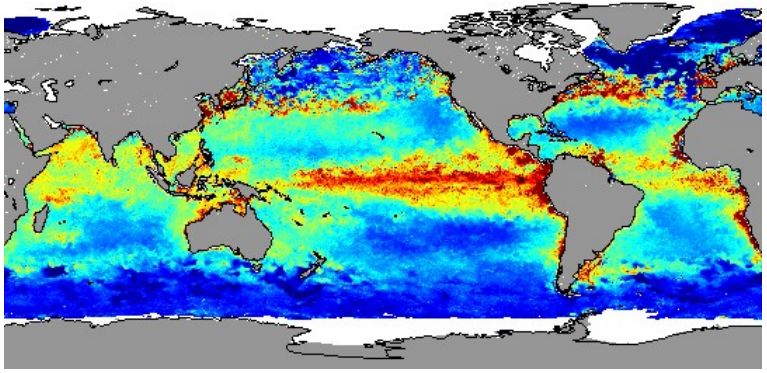
- Level 0 – Full resolution raw satellite data
- Level 1a – reconstructed and georeferenced raw data
- Level 1b – calibrated, needs reprocessing every update
- Level 2 – geophysical variables
- Level 3 – Gridded / Mapped quality controlled products
- Level 4 – Processed outputs (primary productivity models)



Standard VGPM: Vertically Generalized Production Model



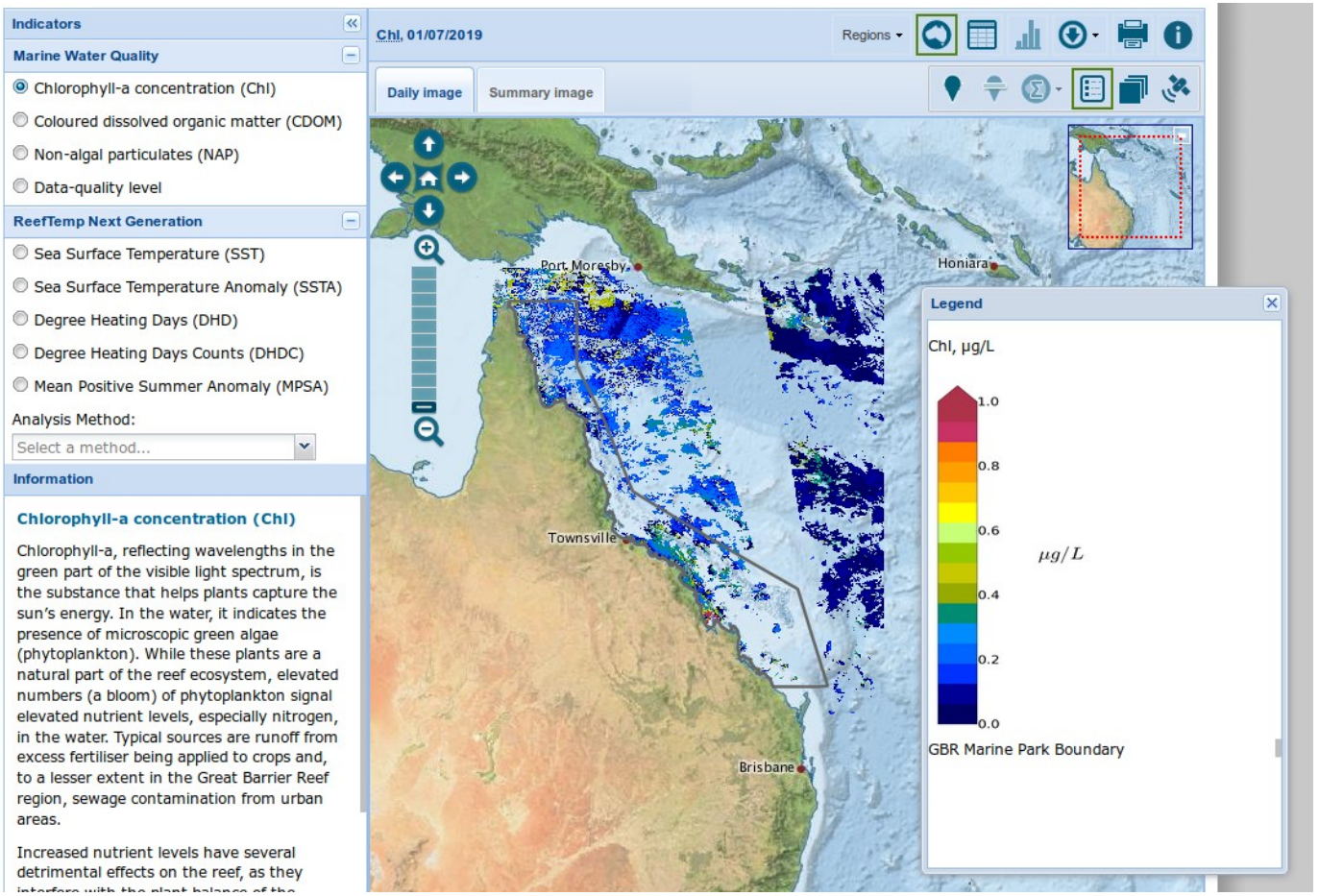
Eppley-VGPM



Updated CbPM: Carbon-based Production Model

http://www.science.oregonstate.edu/ocean.productivity/

# eReefs Marine Water Quality Dashboard




http://www.bom.gov.au/marinewaterquality/

# Data

Downloads:

- https://oceancolor.gsfc.nasa.gov/
- https://oceandata.sci.gsfc.nasa.gov/opendap/
- http://www.science.oregonstate.edu/ocean.productivity/

Plotting:

- https://oceancolor.gsfc.nasa.gov/l3/
- https://giovanni.gsfc.nasa.gov/giovanni/
- http://www.bom.gov.au/marinewaterquality/
- https://oceancolor.gsfc.nasa.gov/cgi/l3bts
- https://seabass.gsfc.nasa.gov/search#val

# Example download script

download_modis.sh — Raw

```
#Download MODIS

myURL=https://oceandata.sci.gsfc.nasa.gov/MODIS-Aqua/Mapped/8-Day/9km/chlor_a

for year in $(curl $myURL?format=txt |cut -d "," -f 1); do
    echo $year
    for ncfile in $(curl $myURL/$year?format=txt |cut -d "," -f 1); do
            echo $ncfile
            curl -L -O https://oceandata.sci.gsfc.nasa.gov/cgi/getfile/$ncfile;
    done;
done;

```

https://gist.github.com/nicpittman/677fab70eb4e05ef658b67f62ceb7845

OpenDAP via python:
xr.open_dataset('https://oceandata.sci.gsfc.nasa.gov:443/opendap/MODISA/L3SMI/2008/001/A2008001.L3m_DAY_CHL_chl_ocx_4km.nc')

```
#----------------------------

from bs4 import BeautifulSoup
import requests
import multiprocessing
import xarray as xr
import sys
import os


def multi_downloader(urls):
    '''
    Multiprocessing downloader
    Need to add the saveloc functionality, at the moment it just saves to working dir.
    '''
    flocs=[]
    s = requests.Session()
    for url in urls:
        print('Preping for Download: '+url)

        #Download the wavelengths for each day
        saveloc=url.split('/')[3]
        if urls[1].split('/')[5][0] =='S':
            saveloc='SeaWiFS'
        else:
            saveloc='MODIS-Aqua'

        while True:
            try:
                r = s.get(url,timeout=10)
            except:
                pass
            fileloc=saveloc+'/'+url.split('/')[-1]
            if os.path.isfile(fileloc)==True:
                try:
                    xr.open_dataset(fileloc)
                    print('File Downloaded / Exists: '+ fileloc)
                    flocs.append(fileloc)
                    break
                except:
                    #If file doesn't exist
                    #DownLoad the file
                    with open(fileloc, 'wb') as f:
                        f.write(r.content)
            else:
                with open(fileloc, 'wb') as f:
                    f.write(r.content)

    #Now the days files are downloaded
    #We need to cut, process, calculate tpca_chl
    return flocs
```

# Summary

- Use chlor_a  (OCI)
- Multiple scales and products for multiple purposes
- Reasonably accurate
- Come to coffee, cupcakes and code 12 – 2pm Friday in the IMAS FLEX space.