THE UNIVERSITY OF ARIZONA

BE/BAT 485/585

Remote Sensing Data and Methods

Lab 12

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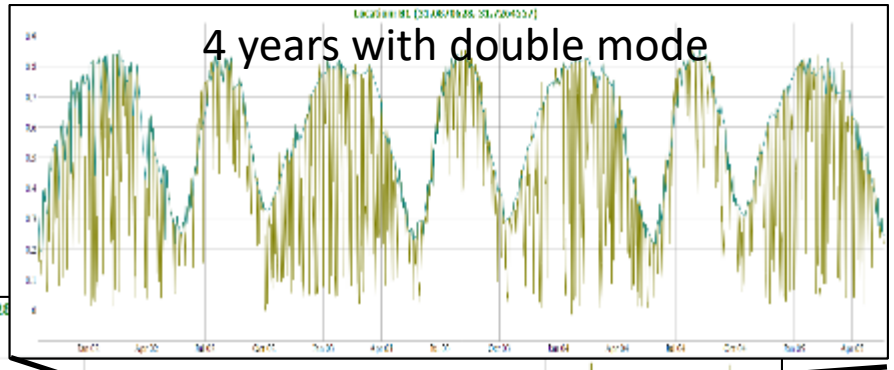
Lab. Objectives

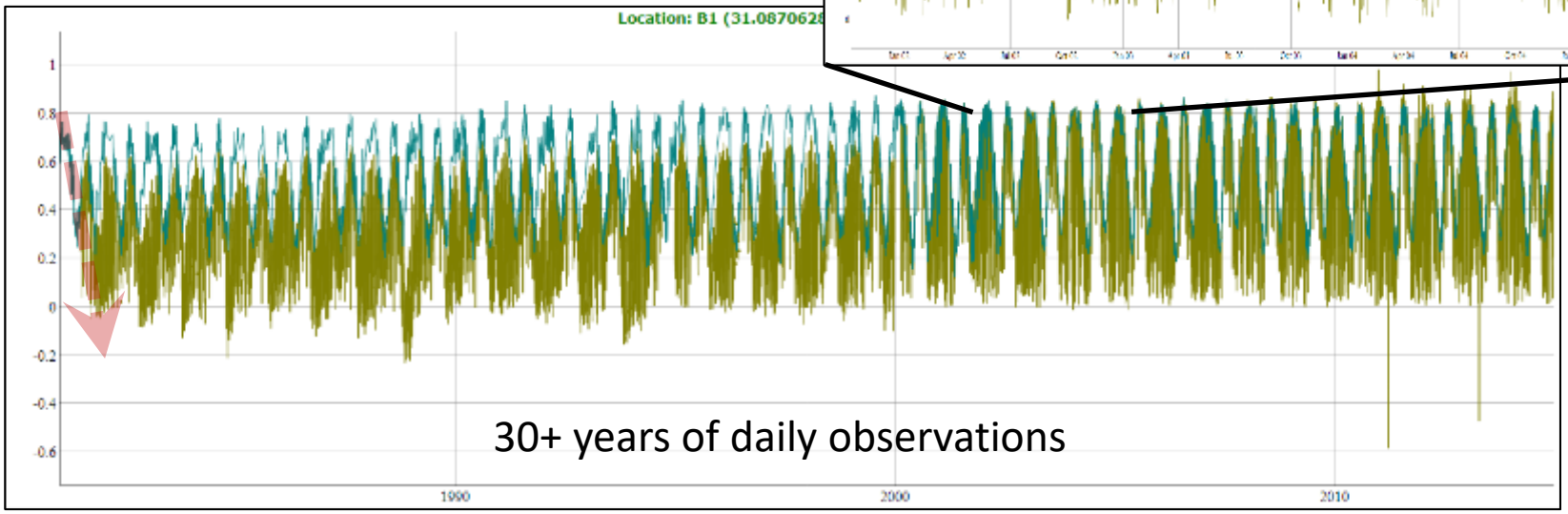
- Learn about the Normalized Difference Vegetation Index (**NDVI**) **time-series** data record
  - How to work with the MODIS Data record
- How to deal with poor quality data
  - Compositing
  - QA Filtering/Analysis
  - Statistical Analysis
  - Using Ancillary info to filter

What is a Time Series (NDVI)

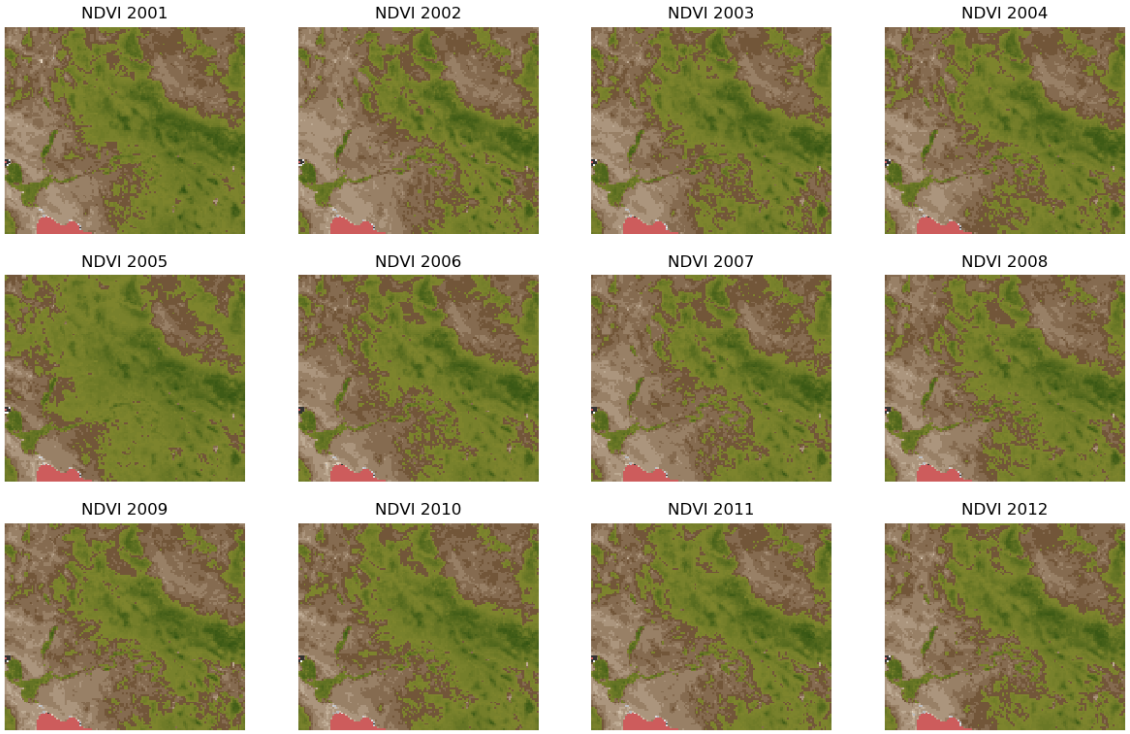
- Normalized Difference Vegetation Index (**NDVI**) **time-series** data are important for many regional and global ecological and environmental applications.
- Unfortunately, residual noise, discontinuity, and other issues greatly hinder their applications, requiring advanced preprocessing:
  - QA Filtering/Analysis
  - Statistical Analysis
  - Using Ancillary info to filter

Egypt – Nile Delta

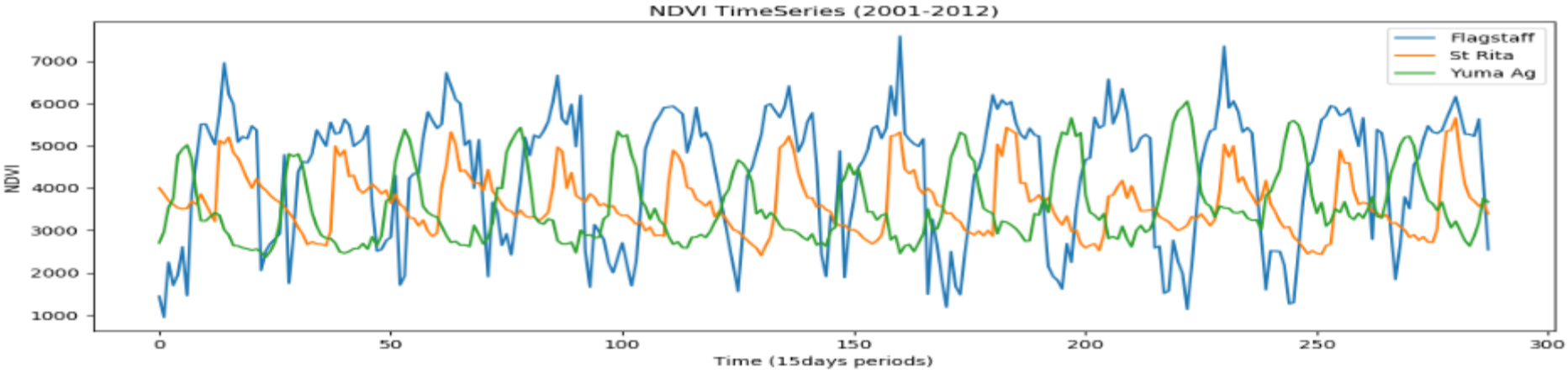




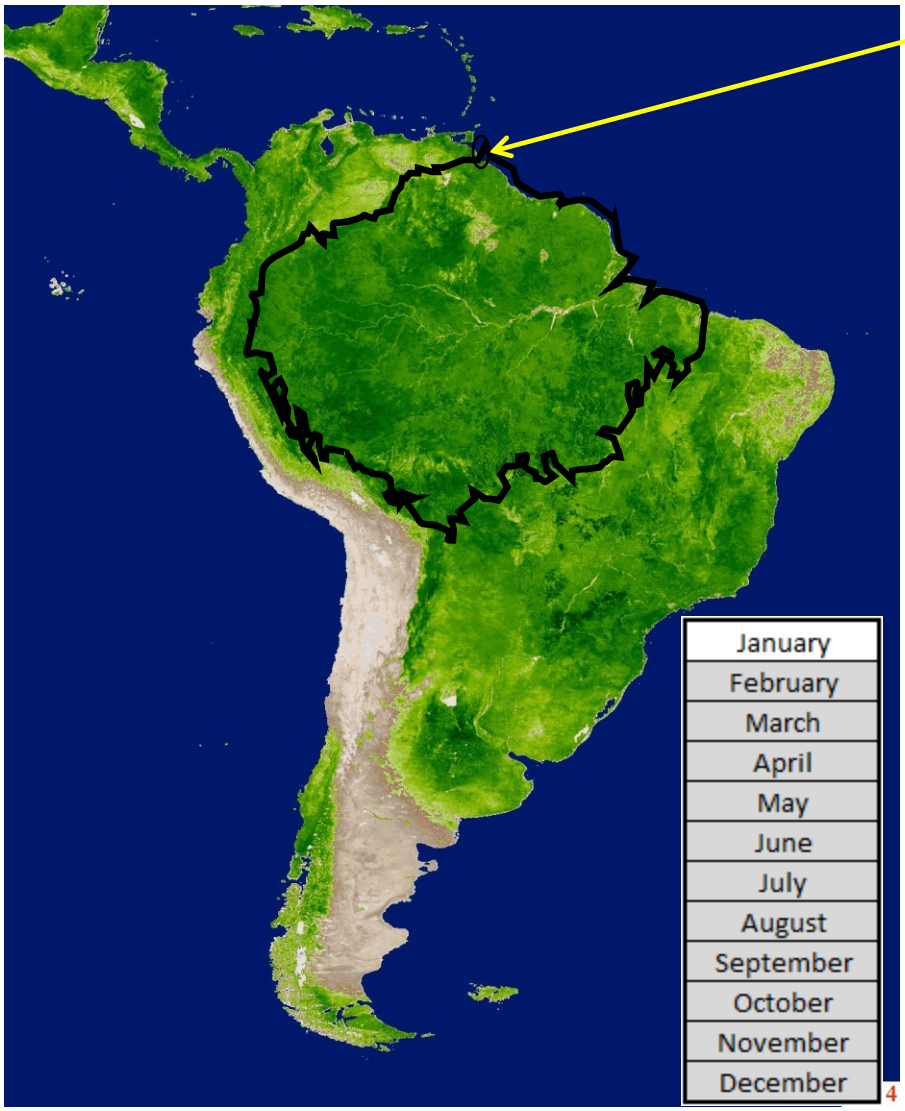
Typical - VI Time Series

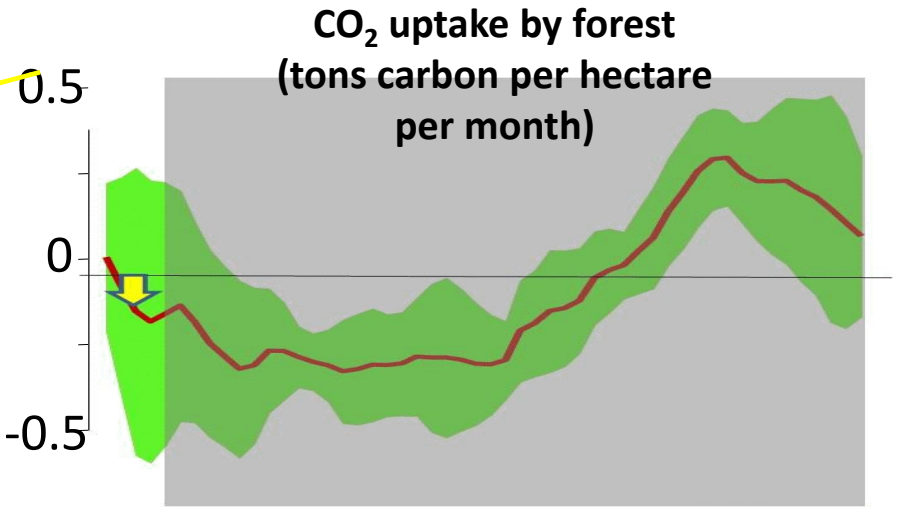


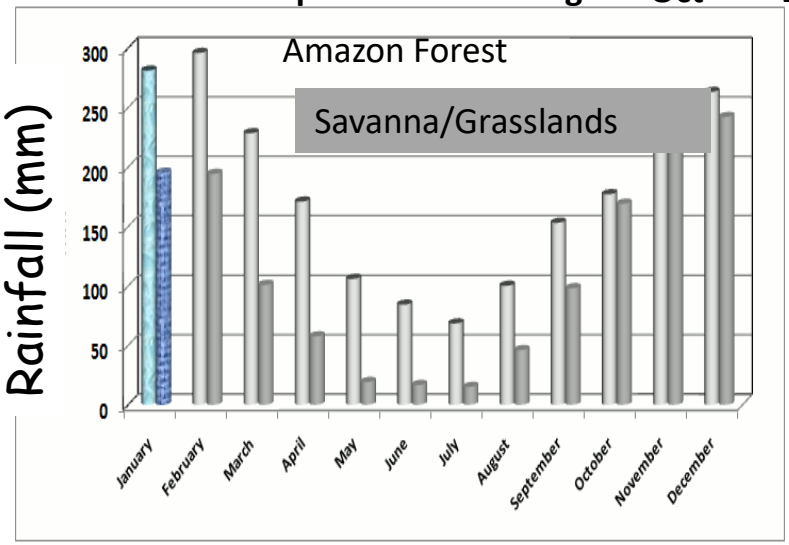
Yearly NDVI
Computed from 15days files



Visual Time Series (NDVI & Precip) – Amazon Dry season







MODIS VI data

The MODIS VI products (MOD13 series) contain Reflectance, Vegetation Index, View geometry and Quality Information data within the same hdf file (BSQ – HDF).

i.e. MOD13A2.A2020065.h08v05.006.2020082012602.hdf

```
 0) INT16 [1200x1200] 1 km 16 days NDVI
 1) INT16 [1200x1200] 1 km 16 days EVI
 2) UINT16 [1200x1200] 1 km 16 days VI Quality
 3) INT16 [1200x1200] 1 km 16 days red reflectance
 4) INT16 [1200x1200] 1 km 16 days NIR reflectance
 5) INT16 [1200x1200] 1 km 16 days blue reflectance
 6) INT16 [1200x1200] 1 km 16 days MIR reflectance
 7) INT16 [1200x1200] 1 km 16 days view zenith angle
 8) INT16 [1200x1200] 1 km 16 days sun zenith angle
 9) INT16 [1200x1200] 1 km 16 days relative azimuth angle
10) INT16 [1200x1200] 1 km 16 days composite day of the year
11) INT8 [1200x1200] 1 km 16 days pixel reliability
```

Vegetation Indices

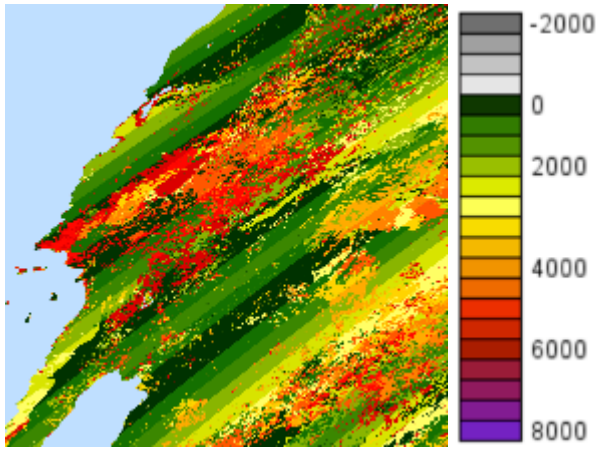
QA

Reflectance

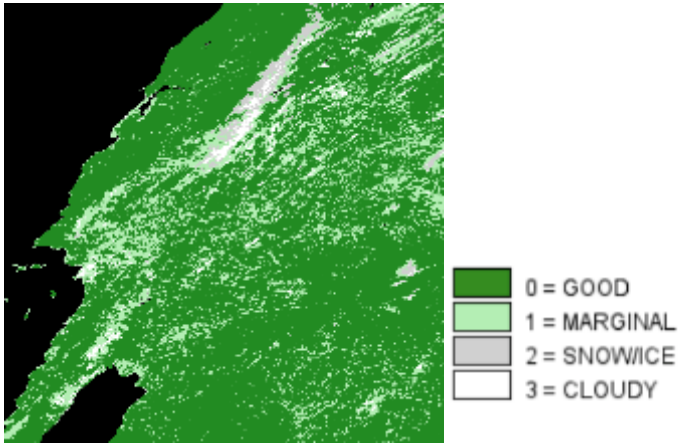
Geometry

QA (Rank)

NDVI



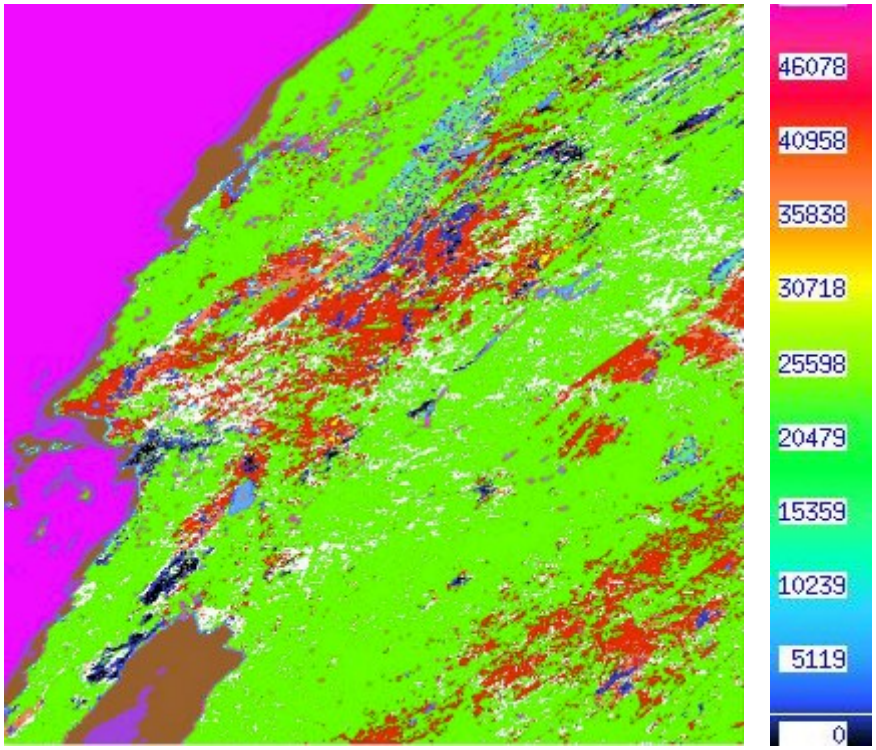
View Zenith Angle



RANK

MODIS QA

- Most modern Remote Sensing Data will have some sort of Quality (QA).
- This QA could be complex and elaborate (describes many aspects of the data). The information is stored in BIT format to reduce disk volume.
- MODIS for example uses 16bit **unsigned integers** to store QA. This means each 16bit is organized into BIT fields/flags to store different QA flags all at once.



QA

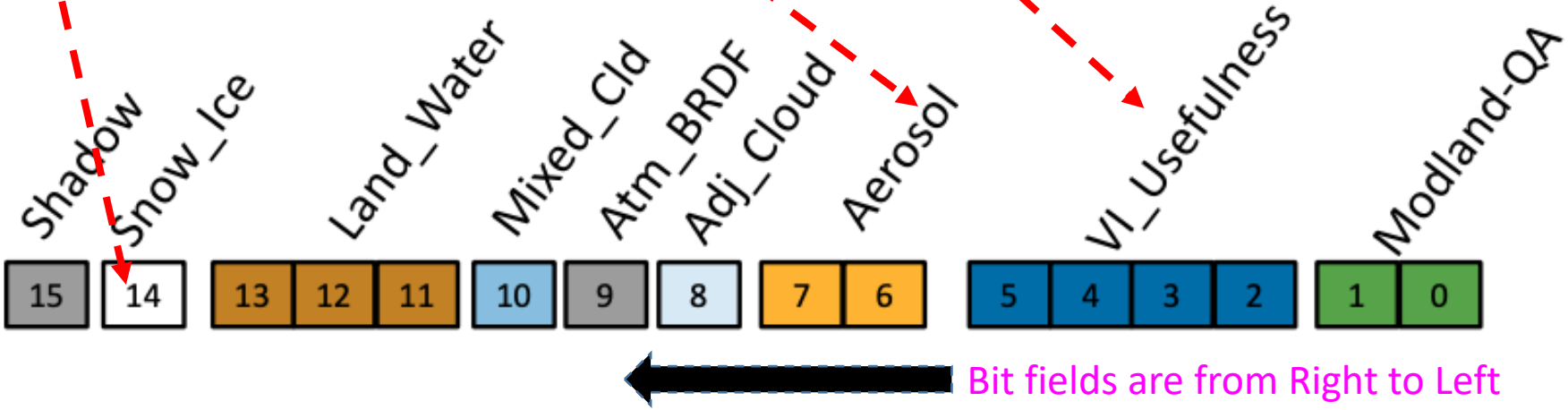
```
Set no 2: Rank: 2, 1200 x 1200
        Data set name: '1 km 16 days VI Quality'
        Data type: 16-bit unsigned integer

SDS attributes
        Number of attributes: 5
                long_name:      1 km 16 days VI Quality
                units:  bit field
                valid_range:    0,  65534
                _FillValue:     65535
                Legend:
         Bit Fields Description (Right to Left):
        [0-1] : MODLAND_QA [2 bit range]
                 00: VI produced, good quality
                 01: VI produced, but check other QA
                 10: Pixel produced, but most probably cloudy
                 11: Pixel not produced due to other reasons than clouds
        [2-5] : VI usefulness [4 bit range]
                 0000: Highest quality
                 0001: Lower quality
                 0010..1010: Decreasing quality
                 1100: Lowest quality
                 1101: Quality so low that it is not useful
                 1110: L1B data faulty
                 1111: Not useful for any other reason/not processed
        [6-7] : Aerosol quantity [2 bit range]
                 00: Climatology
                 01: Low
                 10: Average
                 11: High (11)
        [8] : Adjacent cloud detected: [1 bit range]
                 1: Yes
                 0: No
        [9] : Atmosphere BRDF correction performed [1 bit range]
                 1: Yes
                 0: No
        [10] : Mixed clouds  [1 bit range]
                 1: Yes
                 0: No
        [11-13] : Land/Water Flag [3 bit range]
                 000: Shallow ocean
                 001: Land (Nothing else but land)
                 010: Ocean coastlines and lake shorelines
                 011: Shallow inland water
                 100: Ephemeral water
                 101: Deep inland water
                 110: Moderate or continental ocean
                 111: Deep ocean
        [14] : Possible snow/ice [1 bit range]
                 1: Yes
                 0: No
        [15] : Possible shadow [1 bit range]
                 1: Yes
                 0: No
```

Understanding QA bits

```
[14] : Possible snow/ice [1 bit range]
       1: Yes
       0: No
```

```
[6-7] : Aerosol quantity [2 bit range]
        00: Climatology
        01: Low
        10: Average
        11: High (11)
```

```
[2-5] : VI usefulness [4 bit range]
        0000: Highest quality
        0001: Lower quality
        0010..1010: Decreasing quality
        1100: Lowest quality
        1101: Quality so low that it is not useful
        1110: L1B data faulty
        1111: Not useful for any other reason/not processed
```



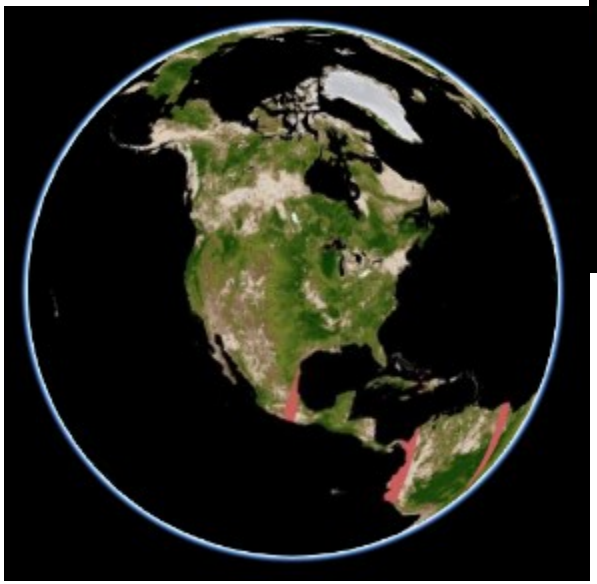
Bit fields are from Right to Left

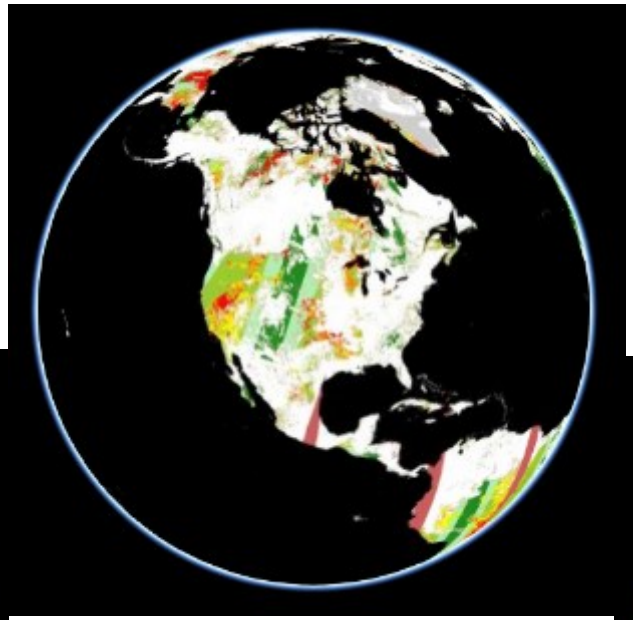
```
 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
  1  1  0  0  1  0  0  1  0  0  0  1  1  0  0  1  = [51481]

- MODLAND_QA = 1 [VI produced, but check other QA]
- VI usefulness = 6 [Decreasing quality]
- aerosol quantity = 0 [climatology]
- adjacent cloud detected?   Yes
- atmosphere BRDF correction performed?   No
- mixed clouds?   No
- land water flag = 1 [land]
- possible snow/ice?   Yes
- possible shadow?   Yes
```

```
 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
  0  0  0  0  1  0  0  0  0  1  0  0  0  1  0  0  = [2116]

- MODLAND_QA = 0 [VI produced, good quality]
- VI usefulness = 1 [Lower quality]
- aerosol quantity = 1 [low]
- adjacent cloud detected?   No
- atmosphere BRDF correction performed?   No
- mixed clouds?   No
- land water flag = 1 [land]
- possible snow/ice?   No
- possible shadow?   No
```

Data and QA - Filtering

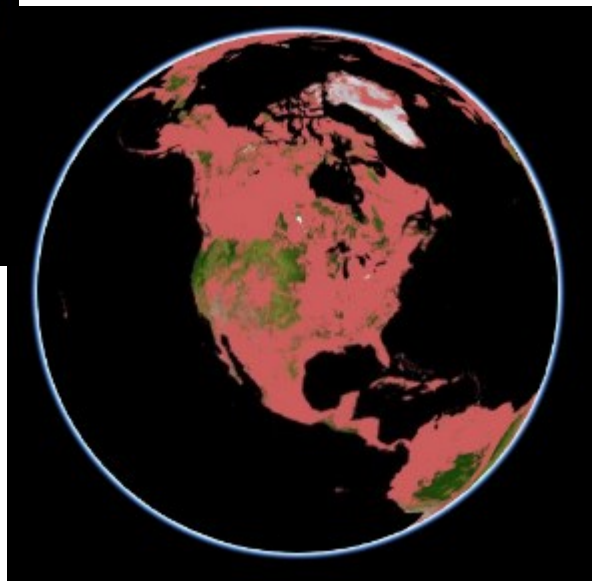
Original Raw Data





QA Data/Flags

Filtered Data



What is left for science!

Exercise #1: QA flags (Quality Assurance)

- **Read a QA layer and create layers from bits**
  - MODLAND QA flag
  - AEROSOL QA flag
  - MIXEDCLOUDS QA flag
  - LANDWATER QA flag
- Display each QA flag using a color LUT
- Mask NDVI using QA flags and compute average values
- **Homework:**
  - Extract Possible shadow, possible snow/ice and adjacent cloud
  - Create a LUT color MODLAND QA Layer
  - Mask NDVI by MODLAND QA classes
  - Mask NDVI with AEROSOL=Low or Average
  - NOTE: Masking here means filtering out certain data

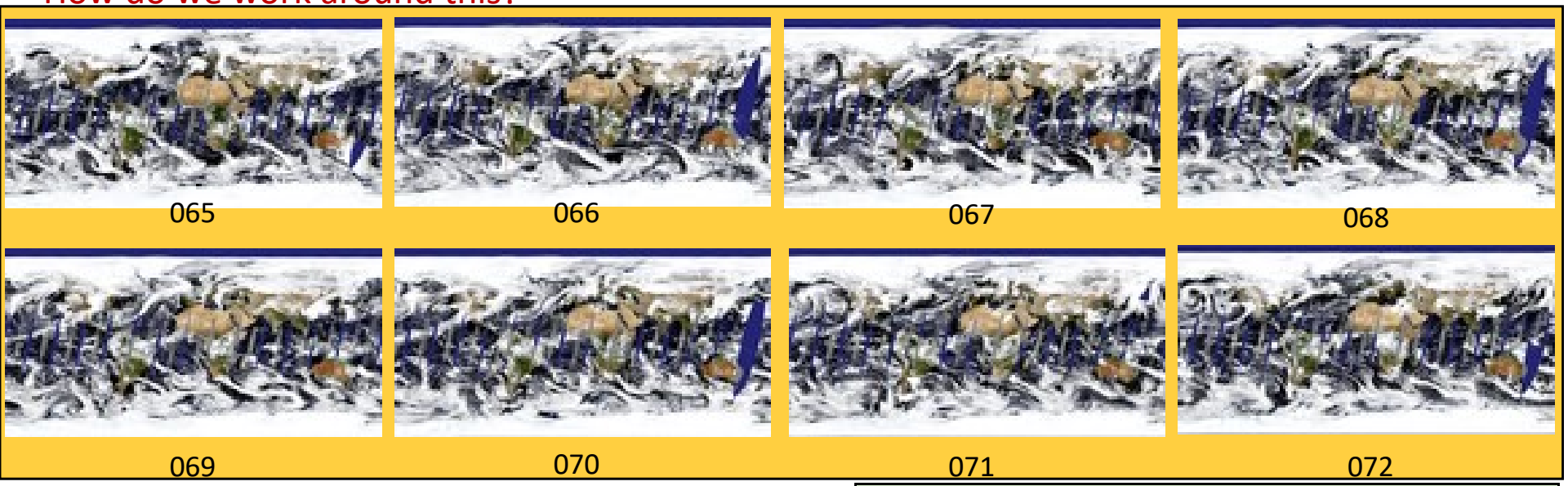
Instructions:

- Download files:
  - MOD13A2.A2020064.006.hdf
  - Library: viplab_lib5.py
  - Python script: BE485_Lab12_Ex1.ipynb

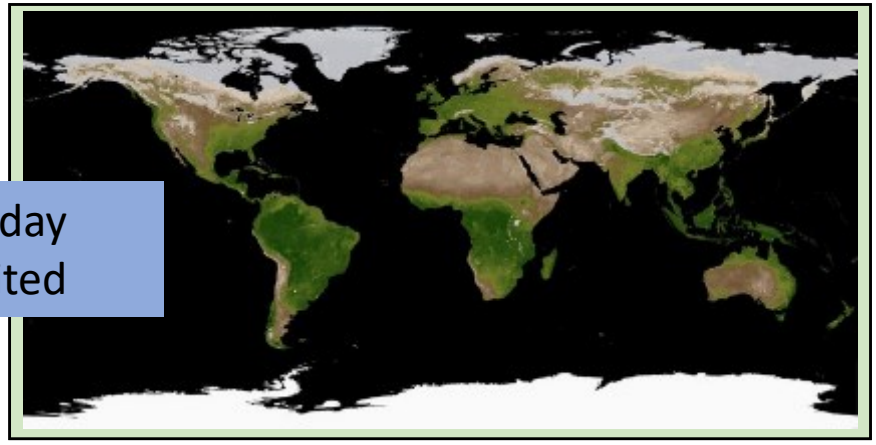
VI Compositing

Synoptic Remote sensing observations suffer from excessive clouds that render the observations of little use if any (~65% of the planet is covered by clouds every day).

How do we work around this?



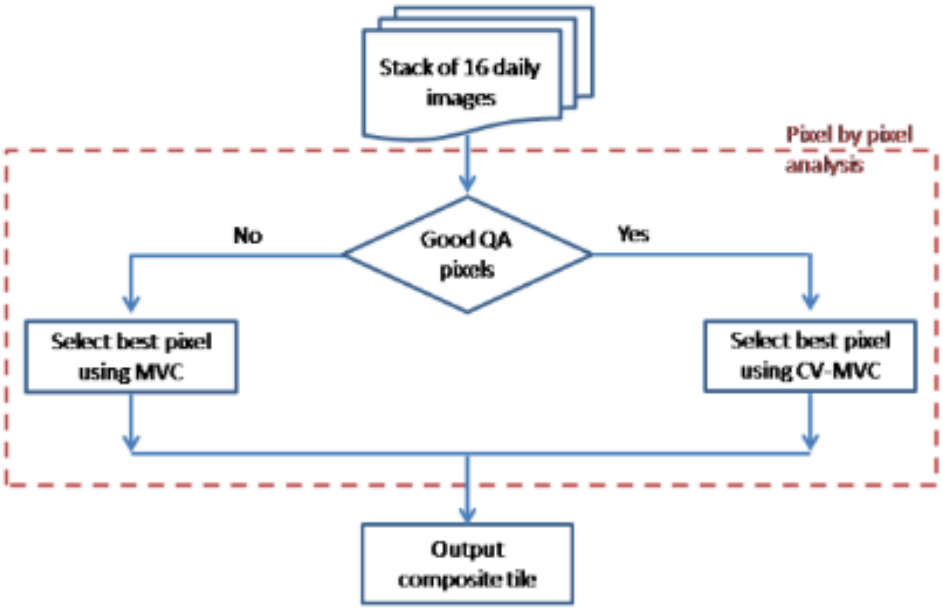
Compositing is a process of accumulating daily images for a long period of time then selecting the "best" pixels to represent the full period (Holben 1986, Huete & Didan, et al. 2002)

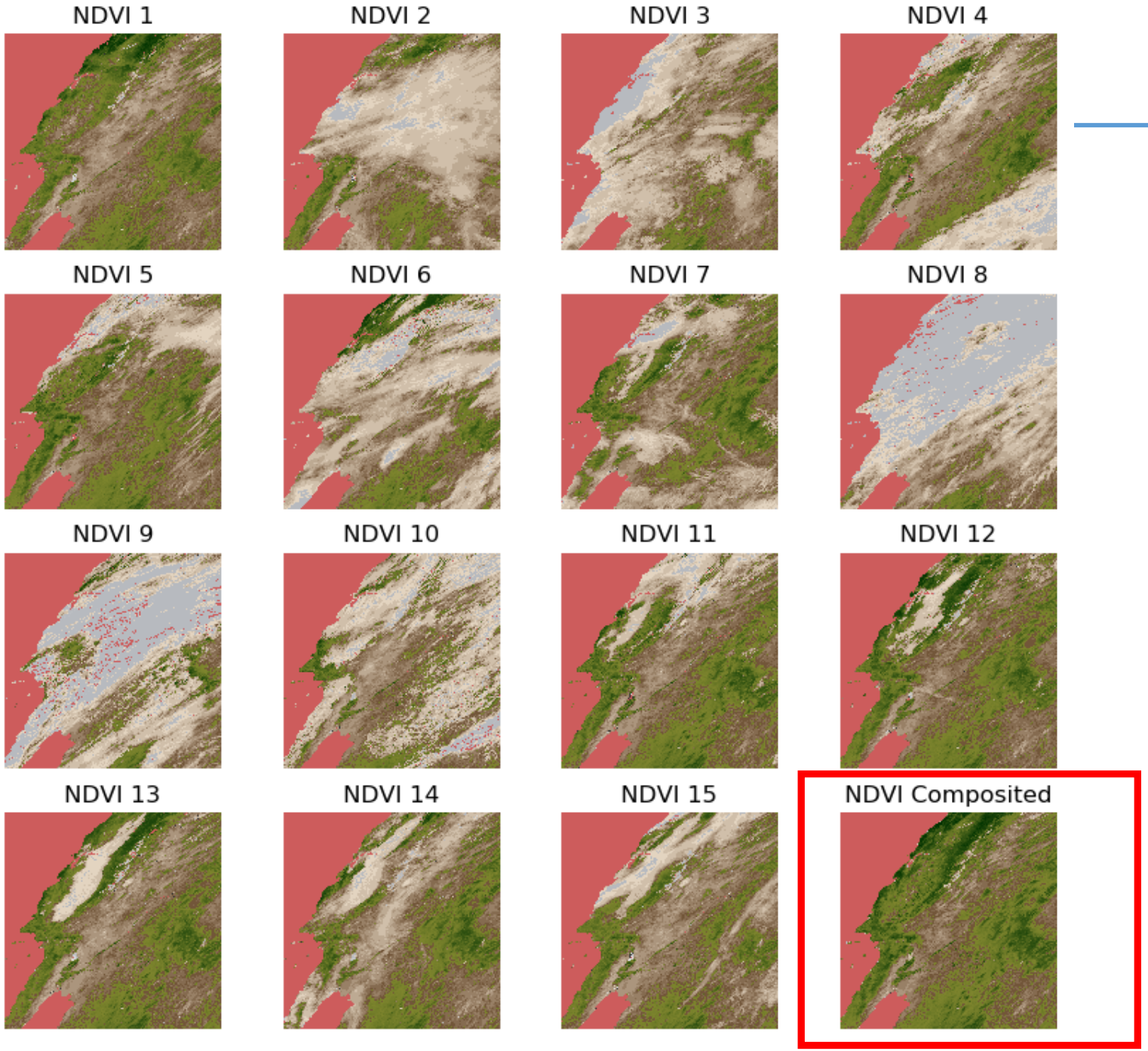


NDVI 16day composited

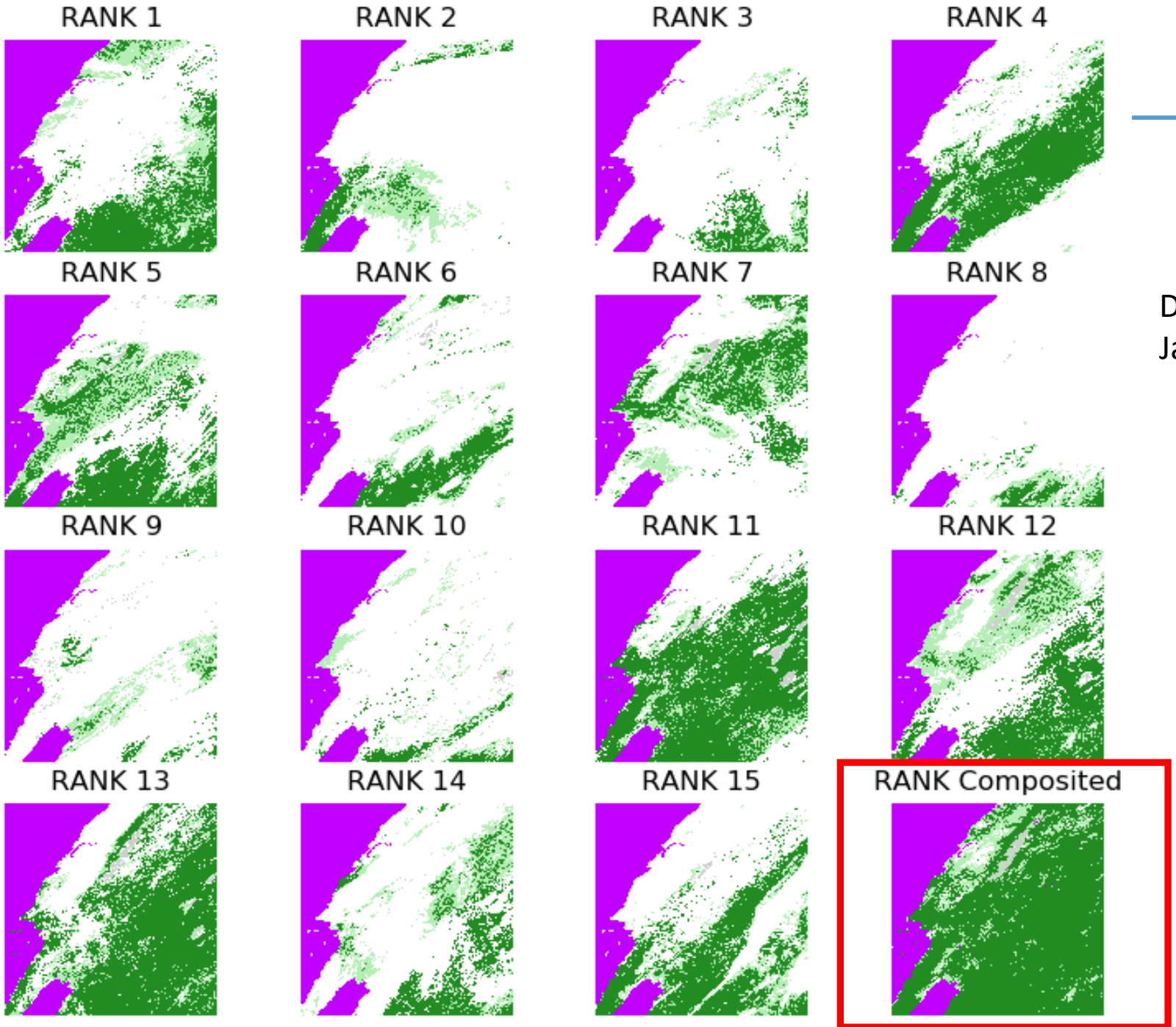
VI Compositing

- Compositing science Algorithms operate on a per-pixel basis and requires multiple observations (days) to generate a clear/clean/high fidelity composited VI value. The algorithm uses complex data processing strategies:
- Applies a filter to the data based on quality, cloud and viewing geometry.
- Cloud contaminated pixels and extreme off-nadir sensor views are considered lower quality.
- Maximum value Composite (MVC).
- A **cloud-free**, **nadir** view pixel with **no residual atmospheric contamination** represents the **best quality**.
- The goal of the compositing methodology is to extract a single value for the pixel (location) from all the retained filtered observations.
- The VI compositing technique is based on the Constrained View Angle - Maximum Value Composite (CV-MVC) or simply the Maximum value Composite (MVC).





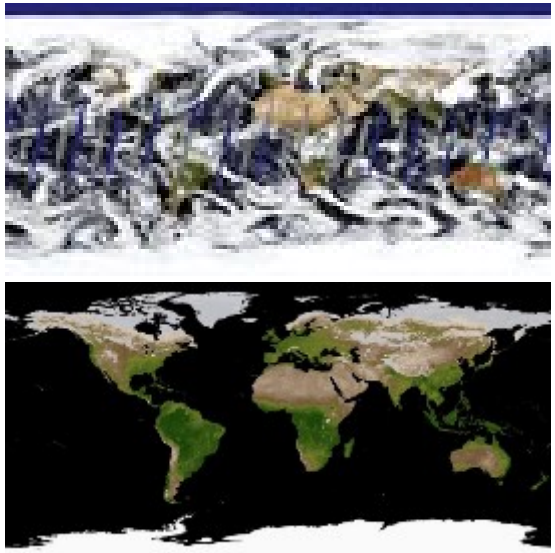
DAILY NDVI,
Jan 1-15 2018



DAILY NDVI,
Jan 1-15 2018

Exercise #2: 16 day VI Compositing

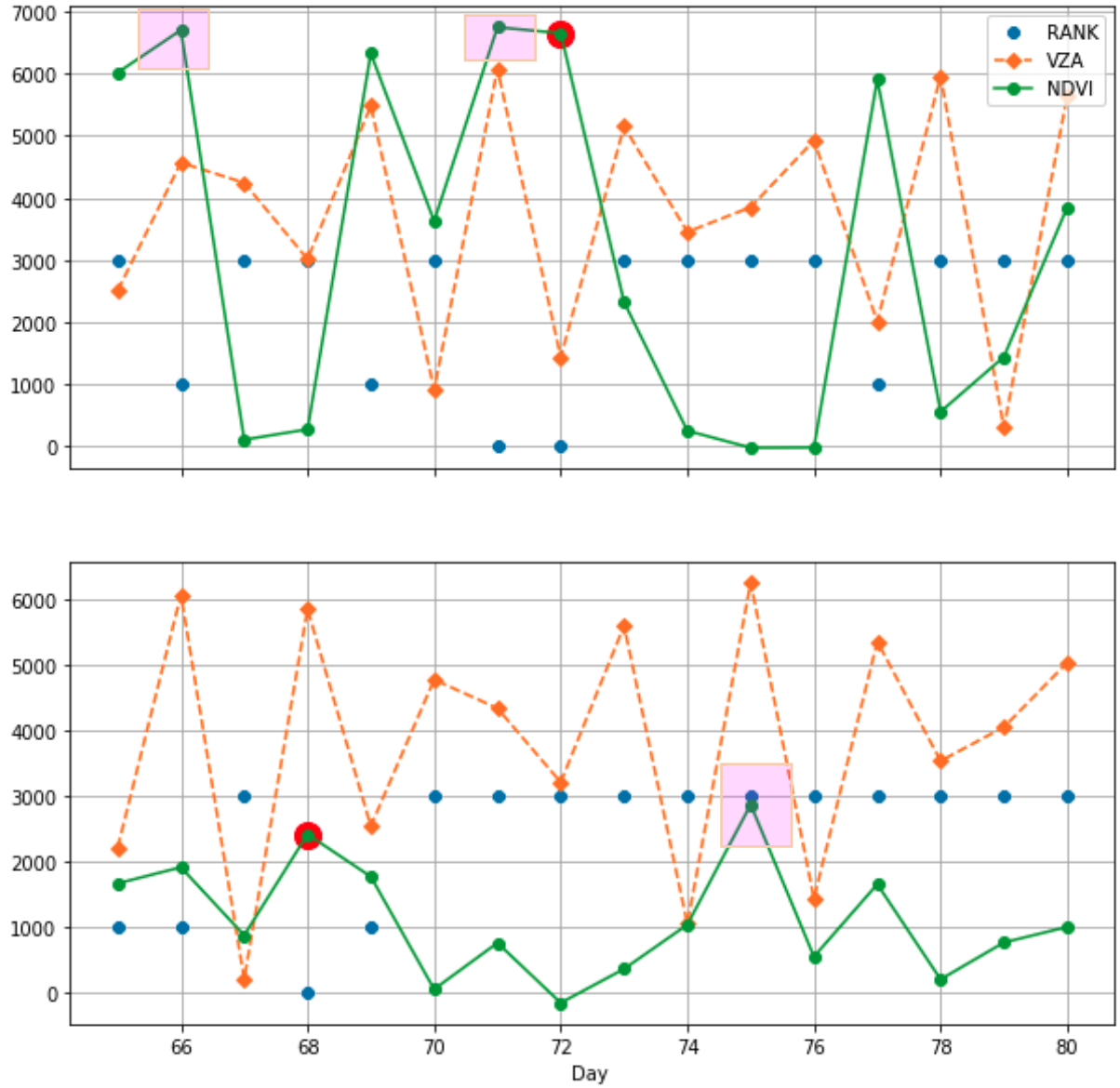
- Read multiple daily surface reflectance (observations) files
  - MOD09GA Daily 1KM: March 05 to March 21, 2020
- Compute Daily Vegetation Indices
- VI Compositing
  - MVC: Maximum Value Composite
  - CV-MVC: Constrained View angle – Maximum VC
- Display Composited NDVI, Rank, VZA and CDAY
- Save the Composited data as **hdf** file
- **Homework**
  - Extract Daily values for a pixel and from the Composited 16Day product
    - Plot, analyze compositing process and comment on its performance
  - Display daily NDVI and RANK images
  - **Can you think of (and maybe design your own compositing algorithm)?**



Instructions:

- Download files:
  - Data files: [Daily reflectances, data_daily.zip
    - The ZIP file will decompress into a DIR ./data_daily
  - Library: viplab_lib5.py
  - Script: BE485_Lab12_Ex2.ipynb

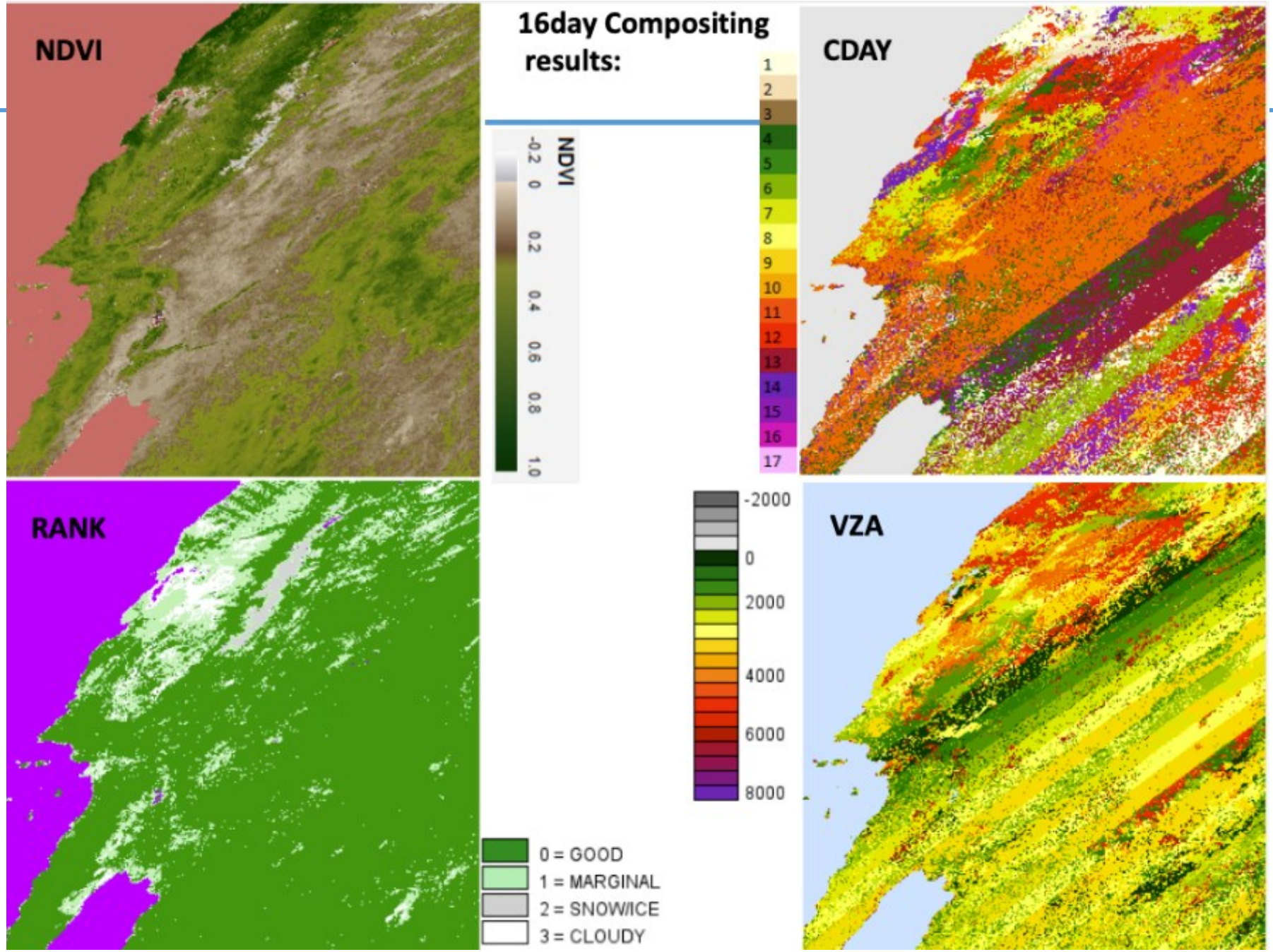
Understanding Compositing



Why not these values?

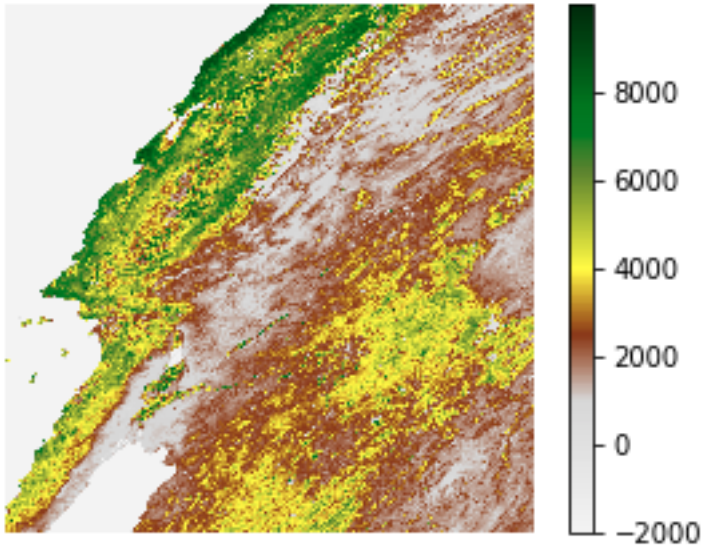
Note:

- Rank was multiplied by 10000
- VZA *100

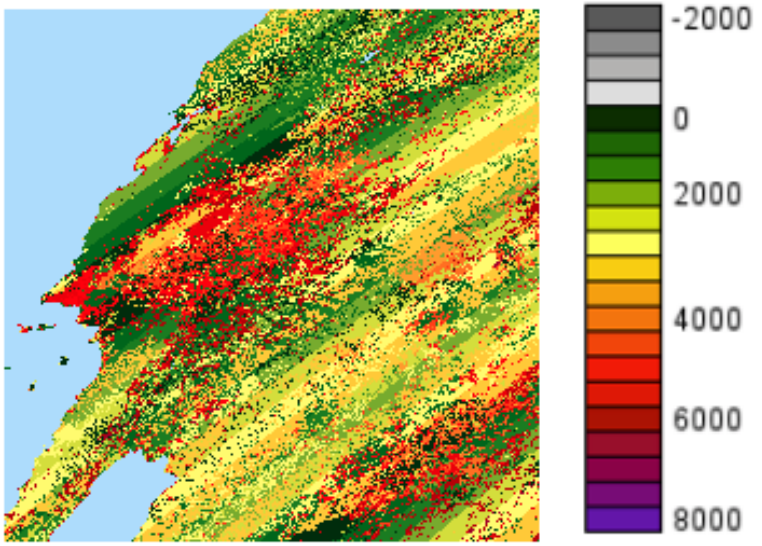

NDVI
16day Compositing results:
NDVI
-0.2
0
0.2
0.4
0.6
0.8
1.0
CDAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
RANK
0 = GOOD
1 = MARGINAL
2 = SNOW/ICE
3 = CLOUDY
-2000
0
2000
4000
6000
8000
VZA

Result Ex2

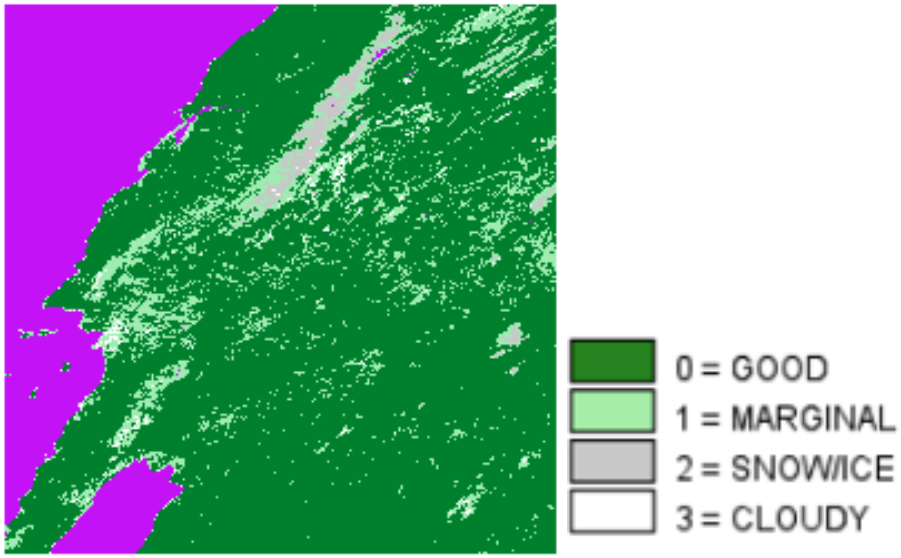
NDVI 16days



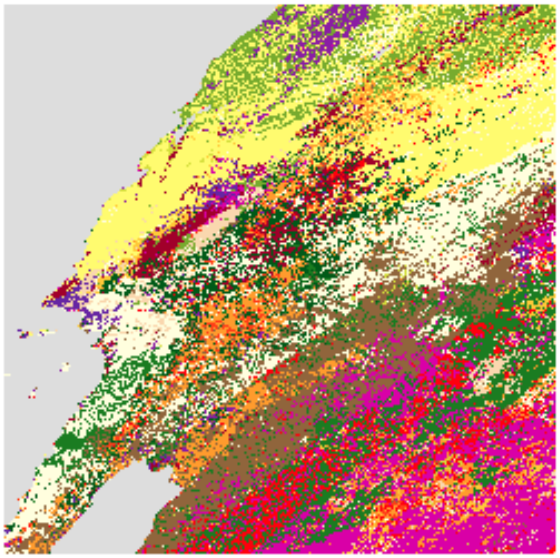
VZA



RANK



CDAY



If you did not already – Install pyHDF Library

- This lab requires a library to handle HDF files (pyHDF)
  - Install using: *conda install -c conda-forge pyhdf*

- If for whatever reasons the pyHDF library does not install or work, you can use the standard **BSQ** files instead