Cloud Morphology --- Lake Effect Snow

Status: build passing dependencies out of date hits 169 version 0.2.0 License MIT status beta

1. Introduction

For this project, we aim to develop a simple classifier program which can identify existing lake-effect snow represented in the selected area. Moreover, the program is capable of giving suggestions on the type of specific cloud and the formation of the cloud.

1.1 What Is Lake-effect Snow

According to the definition,

> Lake-effect snow is produced during cooler atmospheric conditions when a cold air mass moves across long expanses of warmer lake water, warming the lower layer of air which picks up water vapor from the lake, rises up through the colder air above, freezes and is deposited on the leeward (downwind) shores.
> The areas affected by lake-effect snow are called snow-belts. These include areas east of the Great Lakes, the west coasts of northern Japan, the Kamchatka Peninsula in Russia, and areas near the Great Salt Lake, Black Sea, Caspian Sea, Baltic Sea, Adriatic Sea and parts of the northern Atlantic Ocean. --- ***Wikipedia Source***

The similar effect may also occur over other types of water bodies. As for our project, we are thoroughly concentrating on the lake-effect. We want to learn and predict the cause and the pattern of the weather phenomenon, which mostly bring not unpredictable damage to citizens around the lake area physically and economically. Hence, this project may benefit users from different perspectives.

1.2 Data Source Selection

As we try to identify lake-effect snow, the weather condition for the lake area is required. With the development of the Geostationary Operational Environmental Satellite (**GOES**) service thanks to National Oceanic and Atmospheric Administration (**NOAA**), we can obtain the accurate continental climate data for the past decade via public access.

In this case scenario, the program relies on the raw weather data image from **NOAA GOES Weather Toolkit**. The toolkit can provide background maps, animations and necessary filtering for selected bands.

Upon finishing the extraction of the toolkit, users are required to download data from **NOAA's FTP server**. The climate data is being collected by GOES weather satellite via several camera sensor sets. There are either 13 or 16 spectral bands available depending on the year of operation. These include two visible channels, four near-infrared channels, and ten infrared channels.

Here is a quick reference on all the available bands for selections.

ABI Band Number	Central Wavelength (µm)	Notation	Band Type	Available Year
1	0.47	Blue	Visible	2007
2	0.64	Red	Visible	2007
3	0.86	Veggie	Near-IR	2007
4	1.37	Cirrus	Near-IR	2007
5	1.6	Snow/Ice	Near-IR	2007
6	2.2	Cloud Particle	Near-IR	2007
7	3.9	Shortwave Window	IR	2007
8	6.2	Upper-Level Tropospheric Water Vapor	IR	2007
9	6.9	Mid-Level Tropospheric Water Vapor	IR	2007
10	7.3	Lower-level WaterVapor	IR	2007
11	8.4	Cloud-Top Phase	IR	2007
12	9.6	Ozone	IR	2007
13	10.3	"Clean" IR Longwave Window	IR	2013
14	11.2	IR Longwave Window	IR	2013
15	12.3	"Dirty" Longwave Window	IR	2013
16	13.3	"CO_2" longwave infrared	IR	2013

For our project, the program was developed thoroughly based on Band 1 sensor data. The choice was made based on previous academic analysis done by scholars from different Universities. Yet,

- Band 1

  With the lowest central wavelength, Band 1 sensor can capture continuous observations of components ranging from cloud to dust particles. As it covers the spectrum of all natural visible true colors -- Red, Green, and Blue, this band works extremely well during the daytime. The detailed guidance is accessible **here**.

Wavelength Micrometers	0.47
Band number	1
Baseline Products	
Aerosol Detection	√
Aerosol Optical Depth	√
Clear Sky Masks	
Cloud & Moisture Imagery	√
Cloud Optical Depth	
Cloud Particle Size Distribution	
Cloud Top Phase	
Cloud Top Height	
Cloud Top Pressure	
Cloud Top Temperature	
Hurricane Intensity	
Rainfall Rate/QPE	
Legacy Vertical Moisture Profile	
Legacy Vertical Temp Profile	
Derived Stability Indices	
Total Precipitable Water	
Downward Shortwave Radiation: Surface	√
Reflected Shortwave Radiation: TOA	√
Derived Motion Winds	
Fire Hot Spot Characterization	
Land Surface Temperature	
Snow Cover	√
Sea Surface Temperature	
Volcanic Ash: Detection/Height	
Radiances	√

- Band 5 ***[Experimental]***

```
Disclaim:
    This may not be integrated into the final product.
    Or may only exist as a special mode for the identifier.
```

Terminology:

In winter, icing surface and snow may co-exist at a particular geo-location. Base on Band 1 data, they may reflect light with similar visible wavelength, which makes it hard for the program to derive the cloud from the icing surface.

> The 1.6 μm band takes advantage of the relatively large difference between the refraction components of water and ice. This makes daytime water/ice cloud delineation possible. --- ***Band 5 Fact Sheet***

In addition, we are going to focus on two critical wavelengths centered at 1.6 μm and 2.2 μm

> One of the frustrations that meteorologists sometimes face with satellite imagery is discriminating land features from clouds. Using the 2.2 μm band, forecasters will find that snow, green grass, and certain white sands are all not particularly reflective, in contrast to water clouds. The challenge, however, is that ice cloud is also not very reflective in the 2.2 μm band, making it appear relatively dark in the imagery. Ice cloud is more reflective than what is evident using the 1.6 μm band, though. Outside of New Mexico (and shall we say, "Black Sands"), we anticipate that most forecasters will use the 1.6 μm band and its better spatial resolution in lieu of the 2.2 μm band. That does not suggest that the 2.2 μm band is not without specialized applications, particularly for certain cloud algorithms and "hot spot" detection when fires have an emission temperature of greater than 600 K. --- ***Band 5 Fact Sheet***

Therefore, Band 5 is capable to map out where the existing ice boundaries are. This can potentially help us to

- Band 6 ***[Experimental]***

```
Disclaim:
    This may not be integrated into the final product.
    Or may only exist as a special mode for the identifier.
```

When it comes to,

1.3 Data Formatting Selection

The software is designed to take patch input of color image files from any directories pointed by the users. As for now, only PNG image format is supported for the production run.

1.4 Production Server

When it comes to the production server, please make sure to install the following softwares:

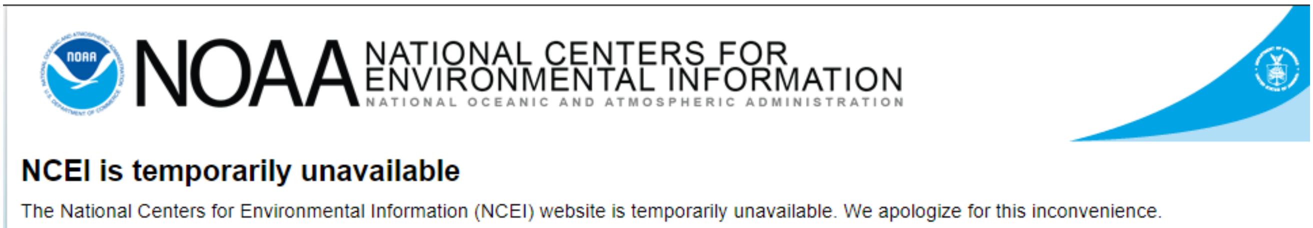
Package Name	Version	Why
MATLAB Base/Server	2015a or newer	Low-effort maintenance; cross-platform support; adopted by other on-going project at rsetserver, so play nice with existing server environment.
GNU Compiler Collection	GCC 5.5 or newer	For PNG utility tool support for image universal cropping

Package Name	Version	Why
MATLAB Parallel Processing Toolbox (Optional)	2015a or newer	To provide multi-threading support for the application. Rather than executing one image at a time, you could run as many threads as you desired. Only RAM is the limiting factor.
Weather Climate Toolkit	4.0.6 or newer	To extract and convert RAW band data into image format.
Google Earth	3.5 or newer	To provide backgroup mapping for the satellite images.

2. Raw Data Retriving

`Coming soon!`

GOES Server Status: website down Maintained? no



In this section, we will walk you though how to obtain the desired RAW band files from GOES FTP server and online tool.

3. Image Port in

3.1 Image Format

When it comes to the image format support, the NOAA's Weather and Climate Toolkit can export the data from raw band files to 7 different types of file formats. However, by comparison, the Portable Network Graphics, aka PNG format is more preferred for the following reasons:

1. Easy for visualization
2. Minimal output file size

When it comes to visualization, the PNG/TIFF format can be opened directly over most system embedded viewer programs, and also being widely supported by browser engines, which can be quickly rendered and integrated to online web tool.

As for the output files, currently, we do not need to include the real geolocation information into the cloud identifier. Therefore, the intensity of each pixel via the Red, Green, Blue channels are the only values required for the identification process.

In particular, the current batch processing settings lead the toolkit to export band images of the selected area to PNG format with lossless data compression to store the `uint8` format more efficiently. For each pixel of the output image, it contains intensity values for 3 different channels with the regard of the RGB color system. It uses the fundamental color set: red, green, blue. Moreover, as for each color, the data is assembled as `uint8` data type. The data type refers to an 8-bit binary value, which translates to 2^8 intensity levels. When we combine 3 different colors, we can yield 16,777,216 different colors.

When it comes to the identifier, we are utilizing `imread` from the MATLAB built-in Data Import and Analysis Toolbox. It is capable of importing the image into an array of integers.

For example, we have an input image of `sample.png`, which has a dimension of 1280 pixels in width, and 720 pixels in height. In order to import this target image, we

```
sample_input = imread('~/sample.png');
```

The imread will simply return a 1280-by-720-by-3 array, and store it into variable named `sample_input`. We can verify it by performing:

```
whos sample_output
```

This will return: (Redo this part)

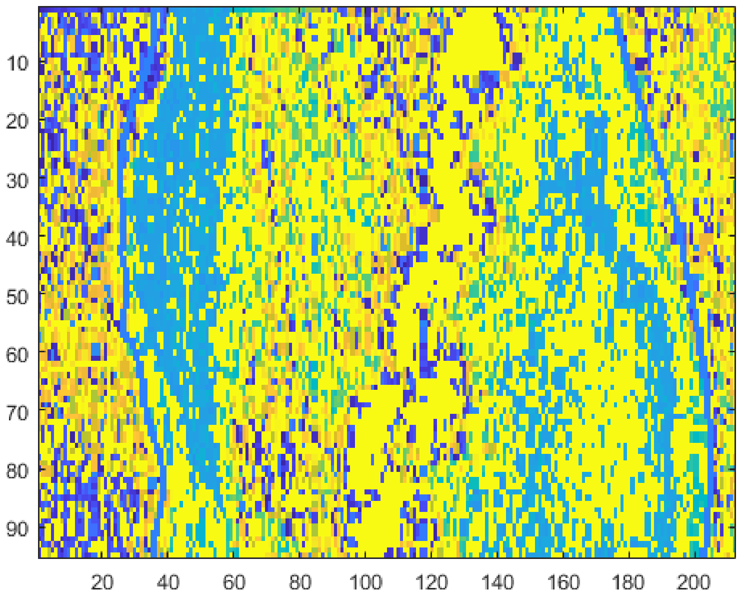
```
  Name           Size              Bytes  Class     Attributes

  sample        95x212             20140  uint8
```

Also, we will be able to visualize the image by performing:

```
image(sample_input)
```

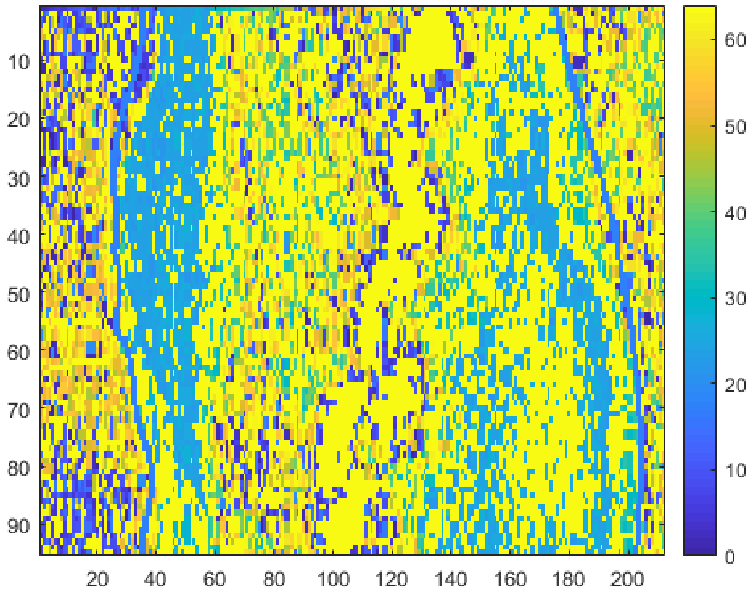
This will simply render the input image back to users.



And right after rendering the imported image, you may append the following command to see the single channel value of the imported target:

```
colorbar
```

This will add a slider to reveal the intensity variation to assist you on making decision of choosing the threshold of the cloud intensity. We will talk about that in the later sections.



And when it comes to the post-identification process, after the identifier is done with labeling the cloud area, it will simply return the output images. You may enable the selection to write the output images to your local disk directory.

4. Algorithms

In this section, we will walk you through the major procedures about how the program works as a whole.

4.1 Image Batch Extraction Configurator

We understand the frustration about the missing map configurator which NOAA used to have listed on their website. Starting on July 1, 2018, NOAA suspended the function for customizing the satellite images. We have reached out to NOAA for the reason and the estimated turn-around time for this functionality to come back online again. The response we received was

> Hi Noctis,
>
> We are currently updating the GOES web-tool. There is no plan on updating the web GUI ordering tool anytime soon since the process would push the limit of the GOES server. This can let down the FTP server opened for general public access.

> Hence, sorry for the inconveniences. Meanwhile, the full-disk images are still available via FTP servers.
>
> Thank you for the interests in GOES product. If you need further help, please email to the Helpdesk!

Therefore, if you have already obtained RAW band data from online ordering tool, please directly skip to Section 4.3.

Normally, the batch processing is done via command line terminals. Upon extracting the software into the directory, you may add the software to the global environment of your operating system. If not, please make sure you start the terminal and navigate to the root directory where the software resides at.

In general, the format of the command line which is needed for executing the toolkit should be:

```
wct-export <in> <out> <format> <config>
```

When it comes to each cell:

- = Input URL, filename or directory. If directory, then all supported files in directory are processed. A URL must be for a specific file, not a directory.
- = Output file or directory for processed files. If a directory, then the output files use the input filename. The directory must already exist or it will be treated as a file.
- = Output format (use one of the following abbreviations). shp=Shapefile, wkt=Well-Known Text, asc=Arc/Info ASCII Grid, flt=Arc/Info Binary Grid, nc=NetCDF, tif=8-bit grayscale GeoTIFF, tif32=32-bit real value GeoTIFF, csv=Comma-Separated Text File (Alphanumeric-Only), rnc=Raw NetCDF, json=GeoJSON
- = XML configuration file for export options. This may be a file or URL.

As we can see here

In addition, you may execute the software by using:

```
wct-export <listfile> <format>
```

Whereas:

- = Listfile with format of infile/dir/url,outfile/dir,config-xml-file/url. And here is an sample listfile configuration text.
- = Output format (use one of the following abbreviations). shp=Shapefile, wkt=Well-Known Text, asc=Arc/Info ASCII Grid, flt=Arc/Info Binary Grid, nc=NetCDF, tif=GeoTIFF, csv=Comma-Separated Text File (Alphanumeric-Only), rnc=Raw NetCDF, json=GeoJSON.

But we do not recommend you to process your batch output in this manner simply due to the effort on generating listfile can take long when you have over hundreds RAW files under the same directory.

And last, when it comes to the XML configuration, rather than listing all the variations here, we would like to introduce a sample XML configuration which contains all controllable variables and documentations.

7. References:

Reference links are hidden, please jump to the HTML edition of this documentation. (Or put your paws on the highlighted phrases and let Chrome to take you there.)