Scilab case study project on

Simulating and Removing Cloud Cover in Satellite Imagery

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Image Processing

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Abstract

This project explores a simulation-based method for removing cloud cover from satellite imagery to reveal obscured terrain. Given that cloud cover affects about 40% of the Earth's surface, it significantly hinders satellite image clarity. The approach involves simulating cloud noise and applying optimal filtering techniques that consider cloud thickness, sunlight illumination, and attenuation. By transforming the noise into an additive form, the methodology effectively reduces cloud interference in multispectral images. The study includes the design of a low-pass filter and the recovery of clearer images through inverse transformation. The results demonstrate successful cloud removal, enhancing image quality without losing important details.

1. Introduction

Satellite imagery plays a crucial role in various applications, including environmental monitoring, urban planning, and disaster management. However, one of the persistent challenges in remote sensing is the presence of cloud cover, which obscures the view of the Earth's surface and hinders accurate image analysis. Approximately 40% of the Earth's surface is covered by clouds at any given time, making it imperative to develop techniques to mitigate this issue.

Cloud cover introduces complex noise into satellite images, which is neither purely additive nor multiplicative but a combination of both. This noise varies with cloud thickness, sunlight illumination, and atmospheric conditions, making its removal a challenging task. The ability to effectively remove or reduce cloud cover from satellite imagery is essential for improving the quality and reliability of the data captured by remote sensing technologies.

This project focuses on simulating cloud cover in satellite images and developing a method to remove it, thereby enhancing the visibility of the underlying terrain. The approach leverages the characteristics of multispectral images, where certain wavelengths can partially penetrate clouds, and applies advanced filtering techniques to separate the cloud noise from the true signal. By modeling the cloud distortion process and transforming the noise into an additive form, the proposed method enables effective cloud removal, improving the overall quality of the satellite imagery.

The study utilizes Scilab, an open-source software platform, to design and implement the filtering techniques. Through the simulation of different cloud cover scenarios and the application of low-pass filtering, this project demonstrates a practical approach to reducing cloud interference, thereby enhancing the clarity and usefulness of satellite images for various applications.

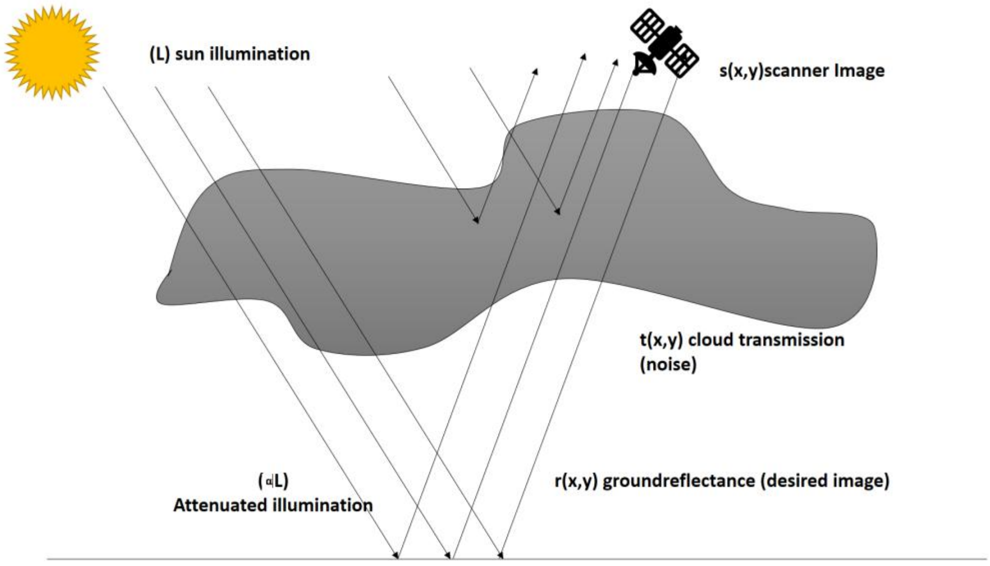
2. Problem Statement

Cloud noise in satellite imagery is a complex challenge, as it is not strictly additive or multiplicative but rather a combination of both. To address this, the project aims to simulate cloud cover and develop a method for its removal using optimum filtering techniques.
The key objectives include:

- Developing a model of the cloud distortion process.
- Introducing a transformation that makes the signal and noise additive.
- Designing a filter for the effective removal of cloud cover.
- Enhancing the noise-suppressed image through histogram equalization.
- Applying the technique to RGB images to achieve output in a colored format.

The task is to suppress cloud noise as much as possible without attenuating the essential details of the scanned images, using various image processing techniques.

3. Basic concepts related to the topic



(Satellite scanner image formation)

I. Scanner Image formation Equation

The scanner image formation is based on the various natural parameters which are mentioned in the depicted picture and is mainly governed by the equation,

$$s(x,y) = \phi[Lr(x,y)] = \alpha * Lr(x,y)t(x,y) + L[1 - t(x,y)] <= L$$

Parameters:-

s(x,y) is the scanner image

r(x,y) is the ground Reflectance (desired Image)

t(x,y) is the attenuation due to cloud(Noise to be removed)

L is the sun illumination

α is the sunlght attenuation (due to thickness of the cloud)

Ranges of the values :

r(x,y) [0,1]

t(x,y) [0,1]

L = max(s(x,y))

α = [0,1]

Transformation Noise removal:

Rearranging the below equation leads to another step for making noise uncorrelated from the signal

$$s(x,y) = \phi[Lr(x,y)] = \alpha * Lr(x,y)t(x,y) + L[1 - t(x,y)]$$

$$Log[L - s(x,y)] = Log[t(x,y)] + Log[L - \alpha * Lr(x,y)]$$

After transformation of the scanned images the noise is un correlated from the actual signal. Since the thin clouds have low spatial-frequency content compared to the signal;we can get the Log[t(x,y)] by using lowpass filtering and then exponentiating the filter output.

Retriveing the desired Image:

$$Lr(x,y) = \phi^{-1}[s(x,y)] = L/\alpha - [L - s(x,y)]/\alpha t(x,y)$$

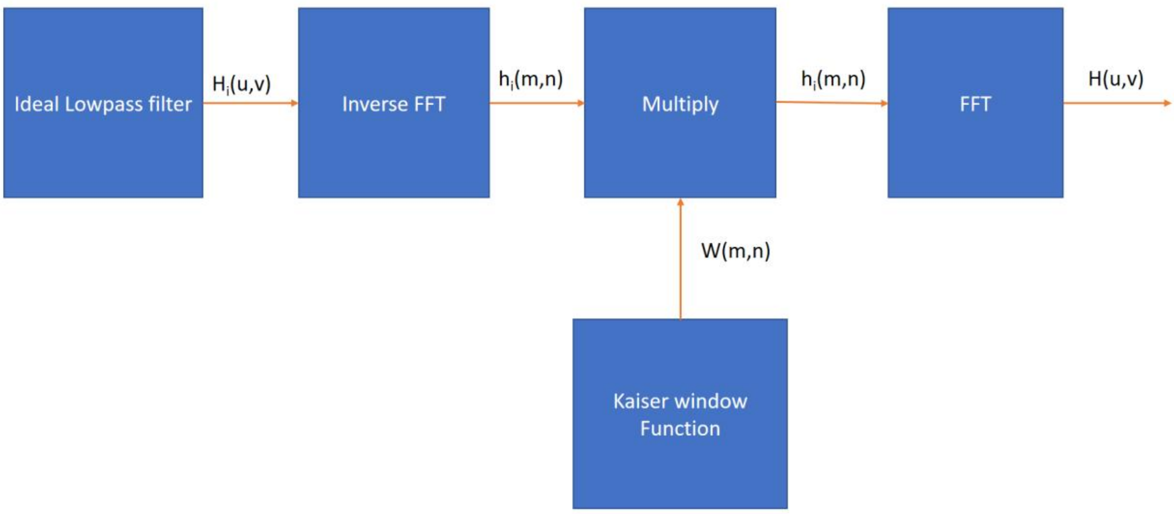
II. Computer Simulation steps

(a) We design a FIR digital lowpass filter by using a Kaiser window function.

(b) Taking the two-dimensional inverse FFT of H,(p, v), we obtain the impulse response of the ideal lowpass filter h,(m, n). We multiply hi(m, n) and w(m, n) and have h(m, n) = hi(m, n) . w(M, n).

(c) After taking the FFT of h(m, n), we obtain the transfer function of the desired FIR digital lowpass filter H(p, v).

Note: Here w(m,n) is the output of the kaiser window function

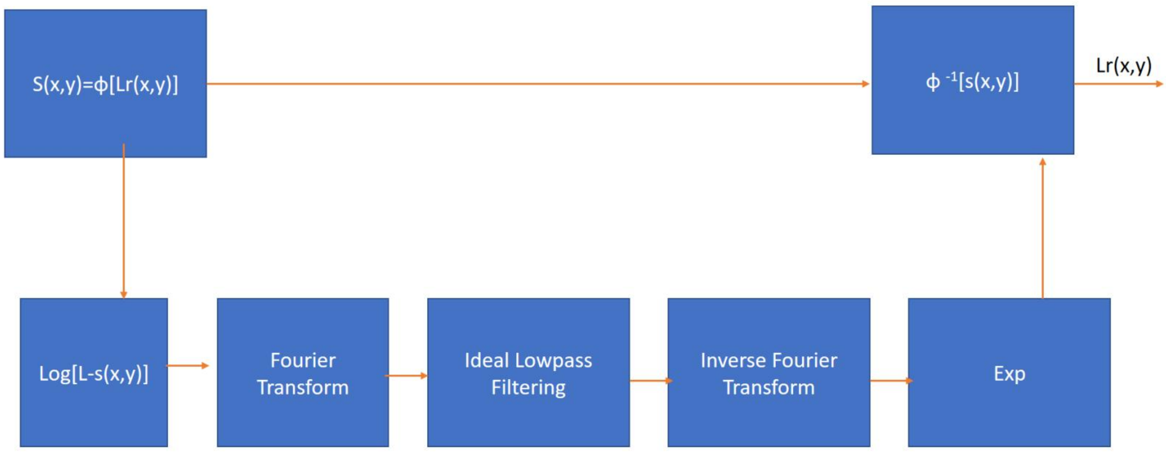


(d) We simulate a low spatial-frequency noise image r(x, y). Using a RANDOM FUNCTION, we can obtain a noisy image which is uniformly distributed between 0.02 and 1.0. After filtering by using the lowpass filter which we have obtained in step (a), we have a low spatial-frequency cloud noise image t(x, y).

(e) Taking the IFFT of the output of the filter and the exponentiang it for 3 getting the nose t obtained(x,y) separated from the signal.
(f) Plugging the value t obtained(x,y) value to the desired image equation and the retriving the filtered image back.

$$Lr(x,y) = \phi^{-1}[s(x,y)] = L/\alpha - [L - s(x,y)]/\alpha * t\_obtained(x,y)$$

4. Flowchart



5. Software/Hardware used

a. Windows 10 OS
b. Scilab 6.1.1
c. Image Processing and Computer Vision Toolbox

6. Procedure of execution

A. Go to the Applications menu and click on ATOMS.
In the ATOMS window:

- Select the **Image Processing** module from the left-side panel.
- Locate the toolbox named Image Processing and Computer Vision Toolbox.
- Click on Install on the right side to install the toolbox.

B. After the installation is complete, restart Scilab to ensure the toolbox loads successfully.
C. Change the current working directory to the folder containing the code
D. Execute main.sce file and then follow the instruction seen on console.

NOTE: Three version will be executed:

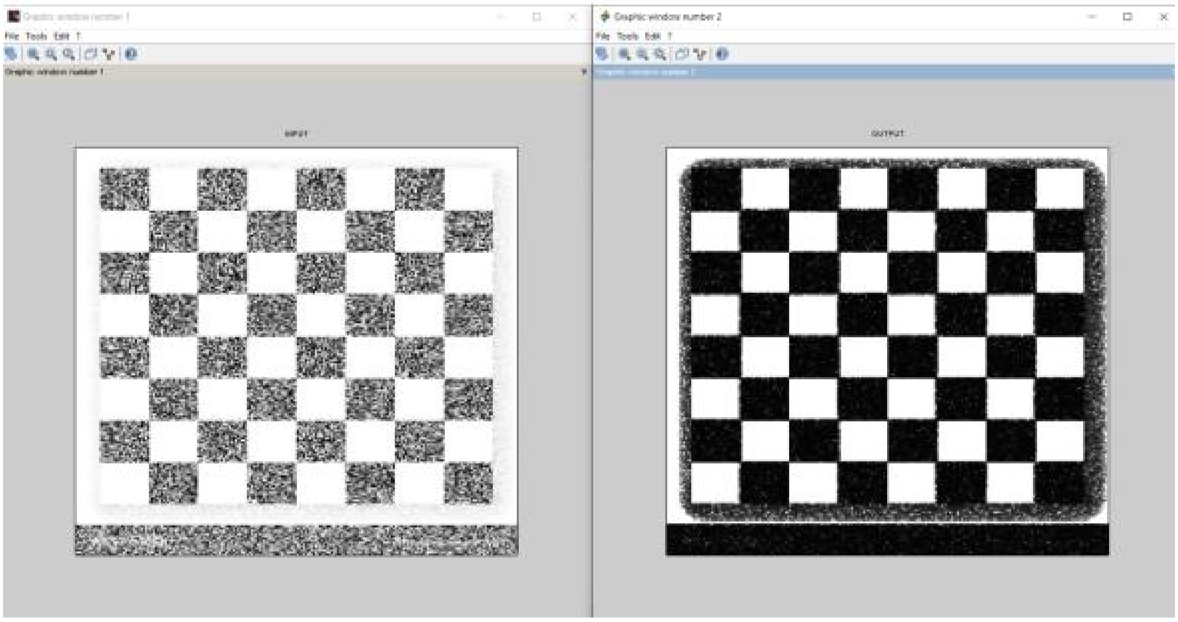
1st version[Random Noise]

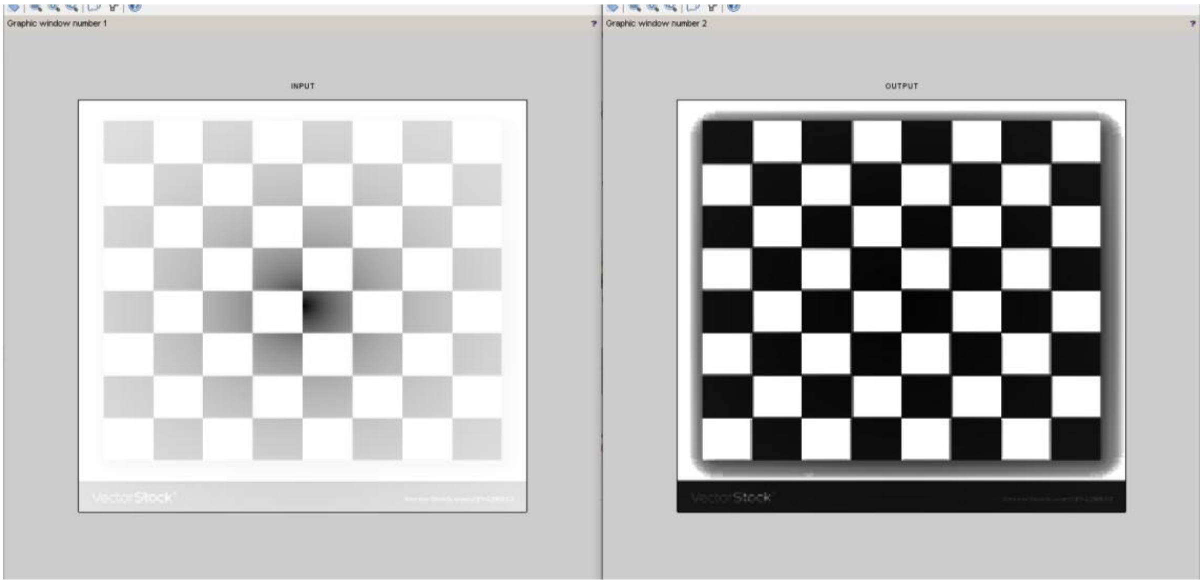
2nd Version [Cloudy noise]

3rd version [RGB version]

Sr No	Files	Purpose
1	main.sce	Main executable file
2	*.sci [cloud.sci, cloud noise.sci, cloudy version3.sci, fftshow.sci, ideal lpf, ifft2.sci, ifftshow.sci, RGB splitter.sci, RGB recombiner.sci, ifftshow2.sci, run cloud.sci, window2.sci]	Dependant executable files
3	chessboardgrascale.png	Model Output
4	skyscrapper.jpg	Model Output
5	scilabcloud.jpg	Noise for version 3

7. Result

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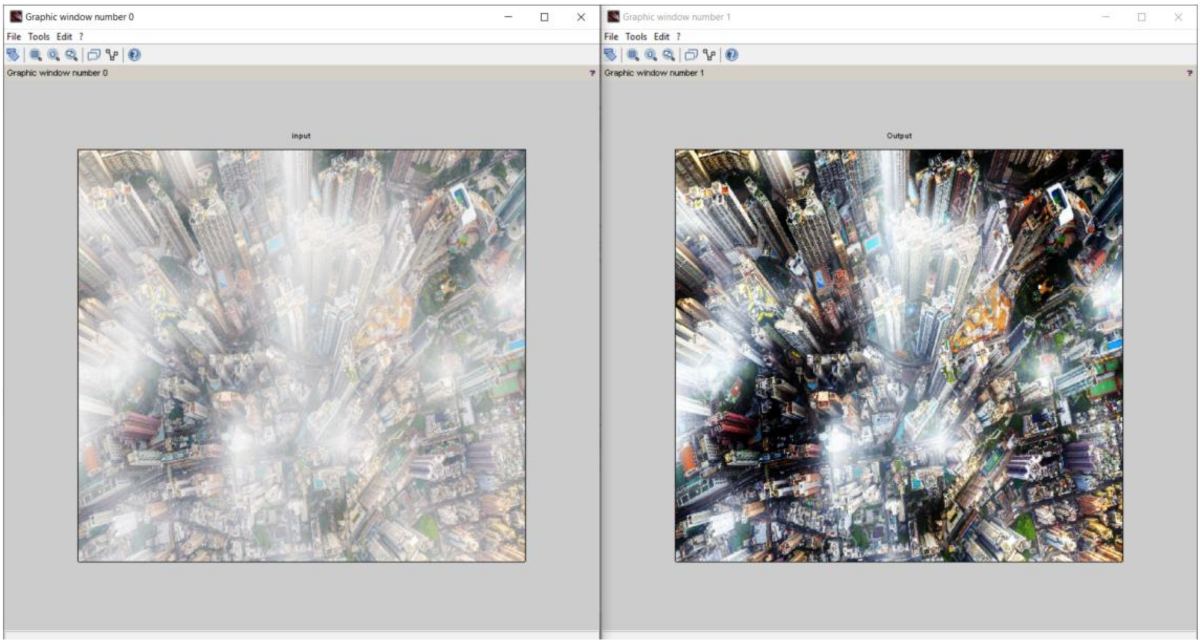
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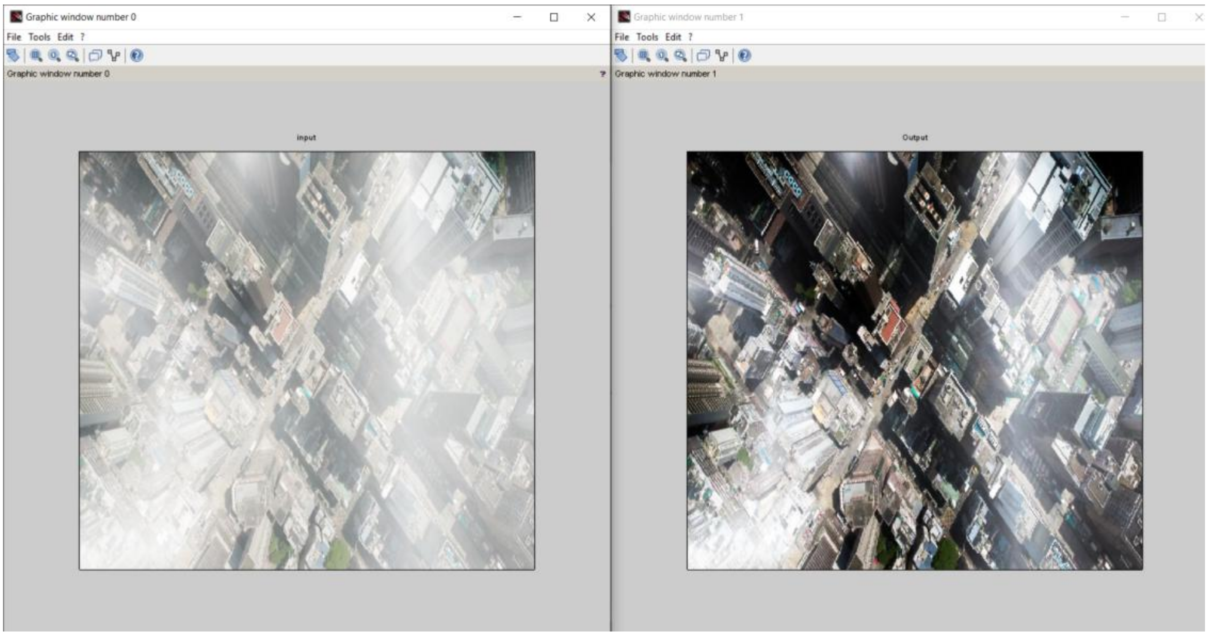
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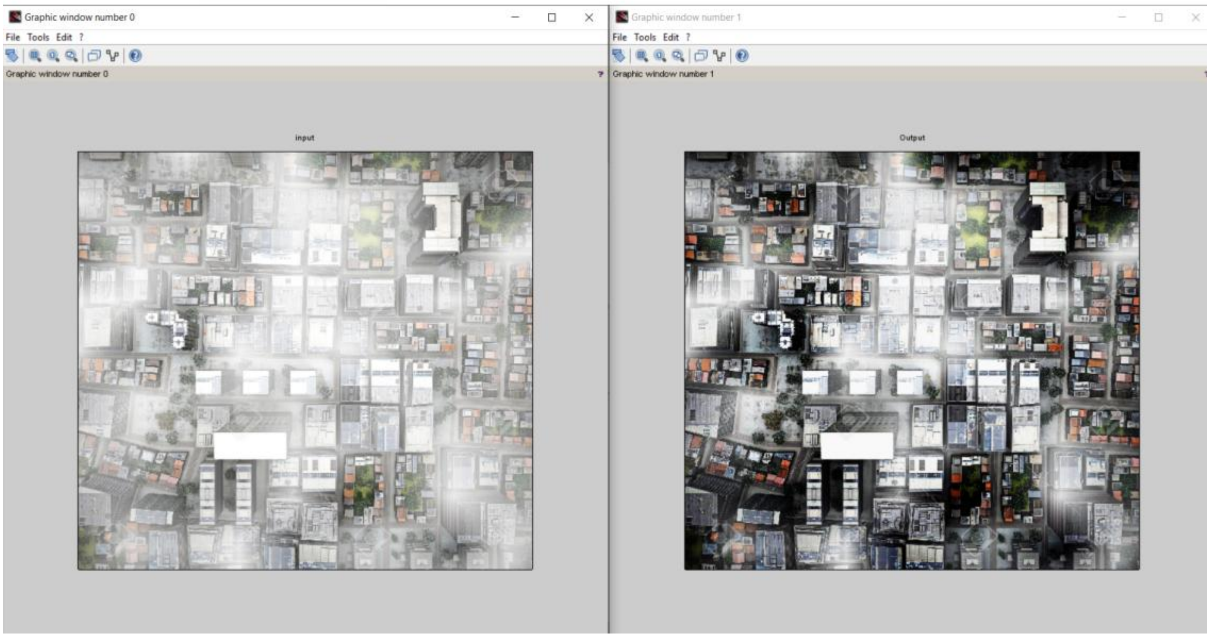
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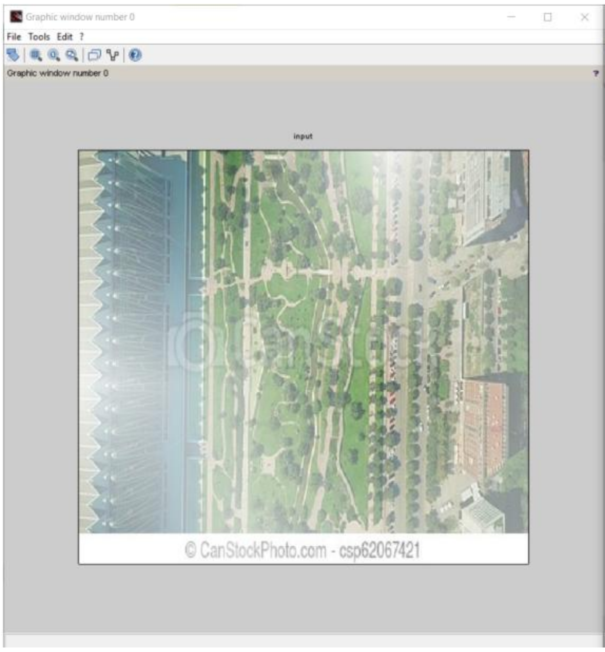
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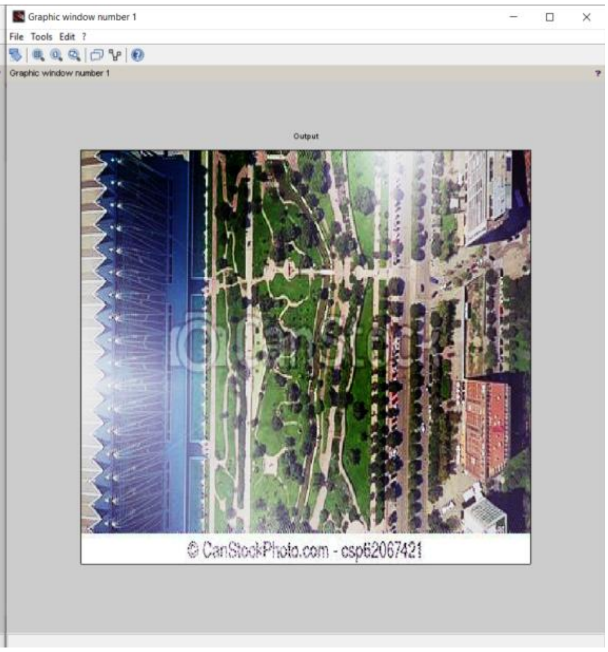
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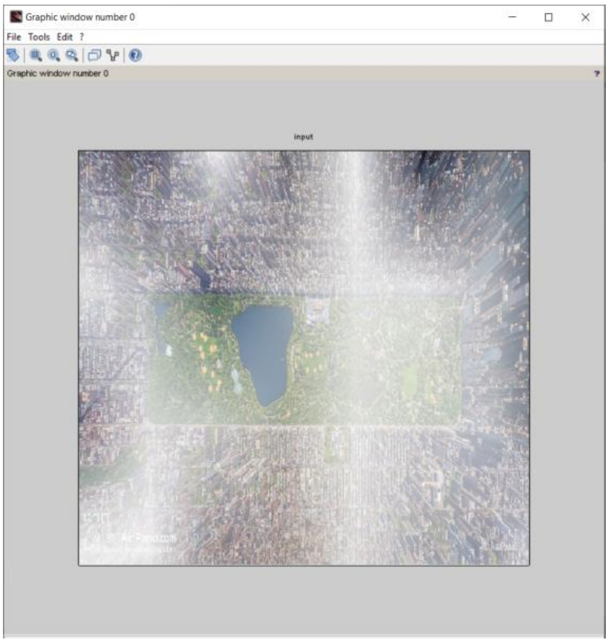
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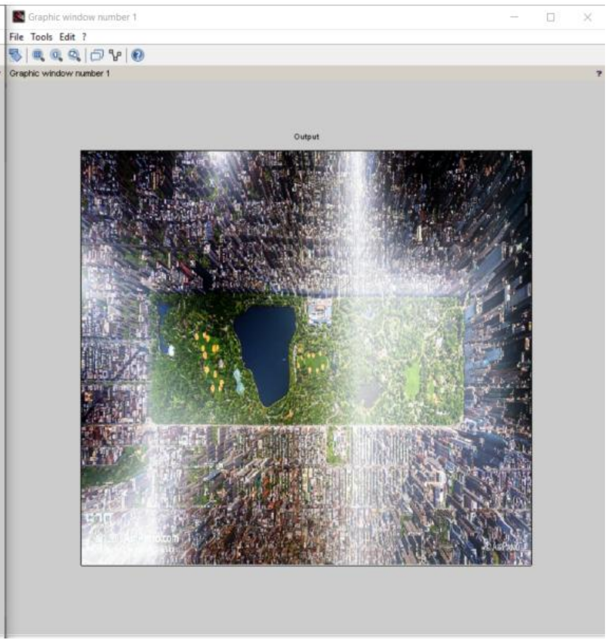
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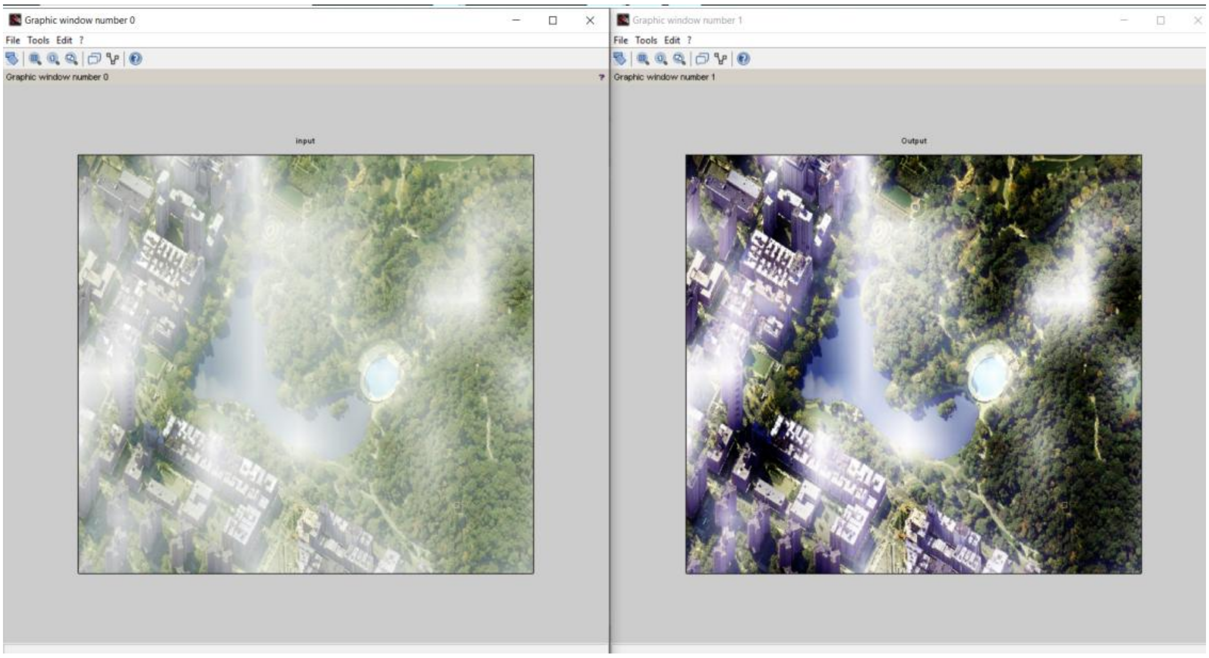

To change the parameter of cloud thickness, make change in the main.sce file as shown below:

8. References

[1] A new approach to removing cloud cover from satellite imagery Z.KLiu B.RHunt

[2] R. Mitchell, B. J. Delp, and P. L. Chen, Filtering to remove cloud cover in satellite imagery, IEEE Trans. Geusci. Electron. GE15, 1977, 137-141.