# AI4EO

## Beyond the Haze: Integrating Segment Anything Model with Traditional Algorithms for Advanced Satellite Dehazing


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# 1 Introduction

- Satellite imagery plays a crucial role in various applications, including environmental monitoring, urban planning, and disaster management.
- However, atmospheric haze significantly degrades the quality of satellite images, reducing visibility and making analysis challenging.
- This research explores image dehazing techniques, focusing on the Dark Channel Prior (DCP) and Retinex algorithm, along with **a novel region-aware dehazing approach using the Segment Anything Model (SAM)**.
- The study aims to improve image clarity by leveraging these techniques to enhance details and contrast in hazy satellite images.

# 2 Methodology

This section presents our novel region-aware image dehazing approach that combines the Segment Anything Model (SAM) with an enhanced Dark Channel Prior method to apply tailored dehazing parameters to different regions within the image. We first review the Dark Channel Prior (DCP) and Retinex algorithm as established dehazing solutions, then introduce our region-specific enhancement framework that addresses their limitations for complex scenes.

## 2.1 Dark Channel Prior (DCP)

Our implementation builds upon the traditional Dark Channel Prior algorithm with several steps:

1. Compute the dark channel of the image.
2. Estimate the atmospheric light.
3. Estimate the transmission map.
4. Refine the transmission map with a guided filter.
5. Recover the haze-free image.

## 2.2 Retinex Algorithm

The Retinex algorithm, originally developed to model human color perception under varying lighting conditions, has been effectively adapted for image dehazing. By enhancing the contrast and visibility of images, Retinex-based methods can mitigate the effects of haze.
Two variants were used:

- **SSR (Single Scale Retinex)**: uses a single Gaussian scale.
- **MSR (Multi Scale Retinex)**: combines several Gaussian scales.

## 2.3 Region-Aware Image Dehazing using Segment Anything Model

Our approach to image dehazing leverages semantic segmentation for region-specific processing. The key contribution is combining the Segment Anything Model (SAM) with an enhanced Dark Channel Prior method to apply tailored dehazing parameters to different regions within the image.

**Methodology Overview**

- **Semantic Segmentation Integration:** The approach utilizes the Segment Anything Model (SAM) to identify and classify different regions within hazy images, enabling region-specific dehazing treatments.
- **Enhanced Dark Channel Prior:** The traditional Dark Channel Prior algorithm is improved for more accurate atmospheric light estimation and transmission map calculation.
- **Region-Specific Parameter Optimization:** Different regions (sky, transportation objects, buildings/environment) receive customized dehazing parameters based on their semantic properties.

This methodology demonstrates how incorporating semantic information can significantly improve dehazing performance by acknowledging that different scene elements require different dehazing approaches, resulting in more natural and visually pleasing results compared to global dehazing methods.

## 2.4 Deep Learning-Based Dehazing Models

In addition to the approaches described above, we also explored some deep learning-based dehazing models to take advantage of their powerful feature extraction capabilities for satellite image dehazing. Specifically, we investigated two prominent transformer-based architectures: **DehazeFormer** and **MAXIM**.

### 2.4.1 DehazeFormer

DehazeFormer (Li et al., 2022) represents a significant advancement in image dehazing through its innovative use of transformer architecture. Unlike previous CNN-based methods that struggle with long-range dependencies, DehazeFormer uses a modified vision transformer to capture global context while maintaining computational efficiency.

**Implementation Challenges:**
Despite the potential of DehazeFormer, the implementation faced computational resource constraints that prevented full deployment. The high parameter count of the model and the memory requirements exceeded available GPU resources, highlighting the need for high-performance computing infrastructure when deploying transformer-based vision models for high-resolution satellite imagery.

#### 2.4.2 MAXIM

MAXIM (Tu et al., 2022) is Google's Multi-Axis MLP for Image Processing, which has demonstrated superior performance on multiple image restoration tasks including dehazing. We specifically targeted the MAXIM-S2 variant fine-tuned for the SOTS-outdoor dehazing.

**Implementation Challenges:**
Our attempt to implement MAXIM encountered compatibility issues with the Hugging Face model repository. Despite following standard implementation procedures, we encountered a critical error related to missing preprocessor configuration files, which prevented model initialization. This highlights the challenges of working with cutting-edge models that may have incomplete or evolving documentation.

#### 2.4.3 Significance of Deep Learning Approaches

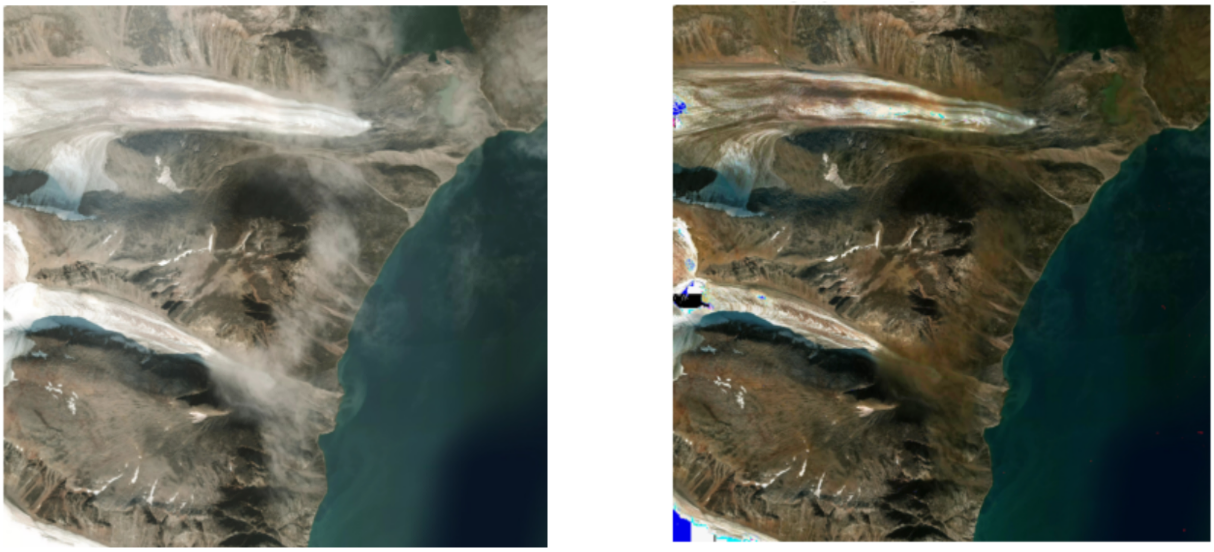
Although our attempts to implement these advanced models faced practical challenges, their exploration represents an important component of our comprehensive investigation into satellite image dehazing techniques.
The implementation challenges we encountered with these models reflect common obstacles in deploying state-of-the-art deep learning approaches in practical applications, particularly in resource-constrained environments. These experiences inform our future work direction, emphasizing the need for optimized implementations and potentially hybrid approaches that combine the computational efficiency of traditional methods with the powerful feature extraction capabilities of deep learning models.

# 3 Results

In this section, we present the experimental outcomes obtained from our dehazing and image enhancement techniques. The following subsections describe the performance of each method along with a result visualization.

## 3.1 DCP-based Image Dehazing

Figure 1 illustrates the application of the Dark Channel Prior (DCP) method for image dehazing. The left panel shows the original hazy image, while the right panel displays the dehazed output produced by the DCP algorithm. This method effectively reduces the haze, enhancing both the contrast and visibility of the image details.

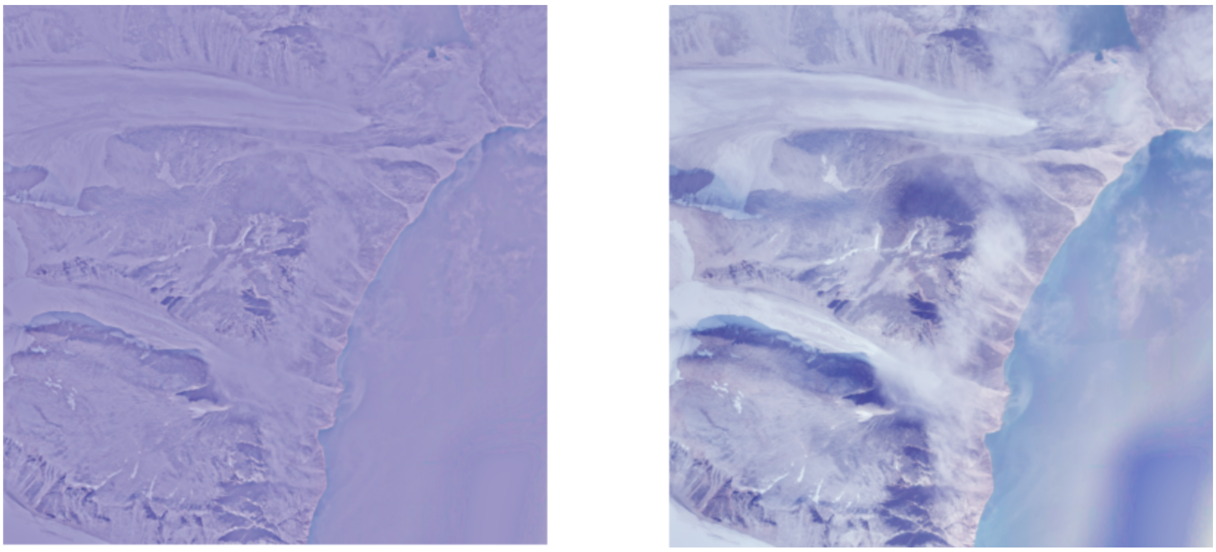


(a) Original Hazy Image (b) Dehazed Image via DCP

Figure 1: Comparison of the original image and the result after applying the DCP dehazing technique.

## 3.2 Retinex-based Image Enhancement

Figure 2 presents the outcomes achieved using the Retinex theory for image enhancement. Two approaches, Multi-Scale Retinex (MSR) and Single-Scale Retinex (SSR), are compared.



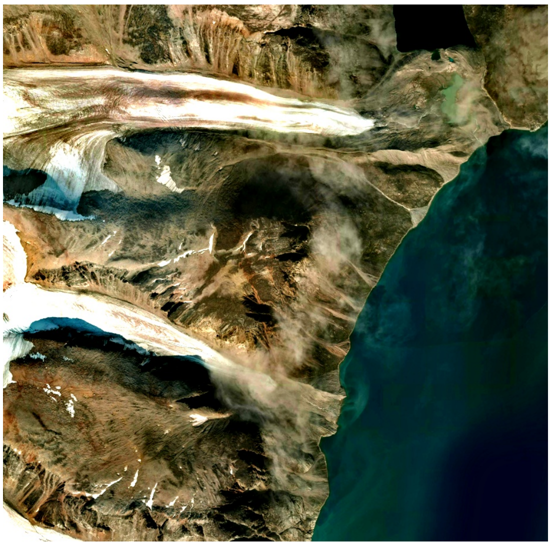
(a) MSR (b) SSR

Figure 2: Comparison between MSR and SSR approaches for image enhancement using Retinex theory.

## 3.3 Region-Aware Image Dehazing using SAM

Figure 3 showcases the results obtained from our proposed region-aware dehazing approach, which leverages the Segment Anything Model (SAM) to target and enhance specific image regions. The top set of figures compares a typical satellite image before and after dehazing.

(a) Original Hazy Image

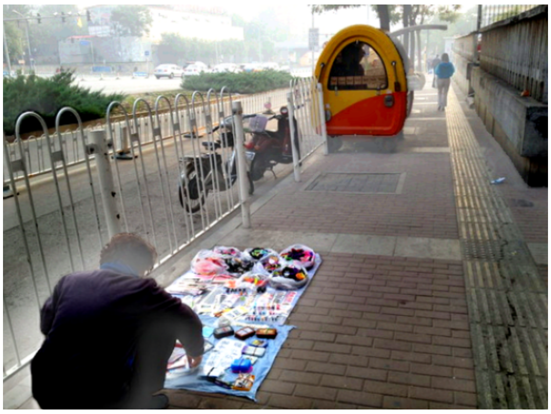


(b) Dehazed Result via SAM

Figure 3: Comparison between the original image and the SAM-based dehazing result.

Furthermore, Figure 4 provides an additional example demonstrating the performance of our SAM approach on non-satellite imagery.

(a) Original Image



(b) Dehazed Result via SAM

Figure 4: Additional comparison highlighting the effectiveness of the SAM-based dehazing.

Collectively, these results demonstrate that the combination of classical and novel image processing techniques can significantly improve the clarity and detail of degraded images.

# 4 Discussion

## 4.1 Achievements

- Successfully implemented and compared three different dehazing techniques: DCP, Retinex, and SAM-based approaches.
- Demonstrated that region-aware dehazing using SAM improves image clarity by adapting dehazing parameters to specific regions.

- Improved visibility and contrast in satellite images, enhancing their usability for various applications such as remote sensing and disaster management.
- Provided a comparative analysis showing the advantages and drawbacks of each method.
- Explored and attempted the implementation of advanced transformer-based deep learning models (DehazeFormer and MAXIM) for dehazing, demonstrating initiative in leveraging state-of-the-art AI approaches despite resource constraints and technical challenges.

### 4.2 Limitations

- **DCP Limitations:** The Dark Channel Prior method can lead to over-enhancement in certain regions, particularly in bright sky areas where it misestimates the haze levels.
- **Retinex Challenges:** Retinex-based approaches often introduce artifacts and unnatural color distortions when applied to highly degraded images.
- **SAM-Based Approach:** While the Segment Anything Model improves region-specific dehazing, its computational cost is higher compared to traditional methods, making it less suitable for real-time applications.
- **Deep Learning Implementation Barriers:** Despite their theoretical advantages, transformer-based models such as DehazeFormer and MAXIM presented significant practical challenges, including high computational resource requirements and dependency issues with model repositories, preventing their successful deployment for satellite image dehazing in our implementation environment.

### 4.3 Future Work

- Investigate deep learning-based dehazing approaches that integrate semantic segmentation for improved regional adaptability.
- Optimize computational efficiency to allow real-time processing of large-scale satellite images.
- Explore hybrid models combining classical and AI-driven approaches to balance accuracy and performance.
- Enhance Region-Aware Image Dehazing using SAM approach to assign region colors more efficiently.
- Overcome implementation barriers for transformer-based models by leveraging cloud computing resources and exploring model optimization techniques to successfully deploy DehazeFormer and MAXIM architectures for satellite image dehazing.

## 5 Conclusion

- This study demonstrated the effectiveness of DCP, Retinex, and SAM-based techniques for satellite image dehazing.

- While traditional methods like DCP and Retinex improve visibility, they have limitations in handling complex atmospheric conditions.
- The proposed region-aware approach using SAM shows promising results by adapting dehazing strategies to different image regions, leading to enhanced visual clarity.
- Future research will focus on integrating deep learning techniques and improving computational efficiency to advance real-world applications of satellite image dehazing while further optimizing the Region-Aware Image Dehazing approach using SAM.

# 6 Appendix: GitHub Source Code

**source code:** https://github.com/MOTARAKH/Dehazing-Satellite