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A multi-dimensional criteria algorithm for cloud detection in the circumsolar area

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Presentation Structure

- Introduction
- Equipment
- Methodology
- Conclusion

Solar Irradiance

- Computational models for modelling Solar Irradiance
  - Simple empirical models
  - Complicated, integrating various parameters
- Cloudiness
  - Most profound parameter
  - Presence of clouds obscuring the sun
  - Cloud types – Correlation to irradiance attenuation
  - Possible enhancement of Solar Irradiance due to clouds
- Cloud Coverage
  - Additional parameter for cloudy models

Introduction

AIM

- Direct Normal Irradiance
  - Circumsolar area around 2.5^{o} around the sun
  - Influenced by clouds only inside this area
  - Cloud coverage not always a representative parameter

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Equipment

Laboratory

- Meteorological Station
  - Direct, Diffuse, Global Radiation
  - Wind, temperature, humidity
  - EKO sensors
- DeltaT BF-5 Sunshine sensor
  - Diffuse and Global irradiance
- Photovoltaics
  - 150kWp, Several 3kWp
- Cameras
  - Orion All Sky II
  - CMS CloudCam II
  - Go Pro cameras

Equipment

Measurements

- Site
  - Larnaka, Cyprus (34.92^{o}N, 33.63^{o}E)
  - Urban Environment
- CMS CloudCam II
  - 1600x1200 pixel (~2MP)
  - 180^{o} FOV
  - 1 image every 24 sec
  - Colour digital camera, JPEG mages
  - Sunscreen for protection from thermal heating effects
  - Pictures with standard exposure and under exposure time

Equipment

Images - Exposure

Normal Exposure

Under Exposure

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Methodology

Pre-Processing

- Invert images
  - East-West direction
- Sun Position
  - Based on location and time/date
- Zenith angle
  - Limited to 66^{o} → Field Of View = 134^{o}
- Fisheye Projection
  - Pixel per pixel – Fisheye lens pixel to image plane
  - Dependent of zenith angle
- Horizon
  - Remove nearby buildings

Methodology

Pre-processed images

Methodology

RGB space – HSV space

- NE and UE Images are split to RGB components
  - Red – Green – Blue
- NE and UE Images are split to HSV space
  - Hue: degree of similarity of a color compared to the unique spectrum colors
  - Saturation: the color purity (the colorfulness of a color relative to its own brightness)
  - Value: the value of brightness (black is zero)
- Values of each component are used for further calculations

Image Calculator

- Pixel to Pixel calculations for NE and UE images

$$RB_{i,j} = Red_{i,j} - Blue_{i,j}$$

$$GB_{i,j} = Green_{i,j} - Blue_{i,j}$$

$$RBRB_{i,j} = \frac{Red_{i,j} - Blue_{i,j}}{Red_{i,j} + Blue_{i,j}}$$

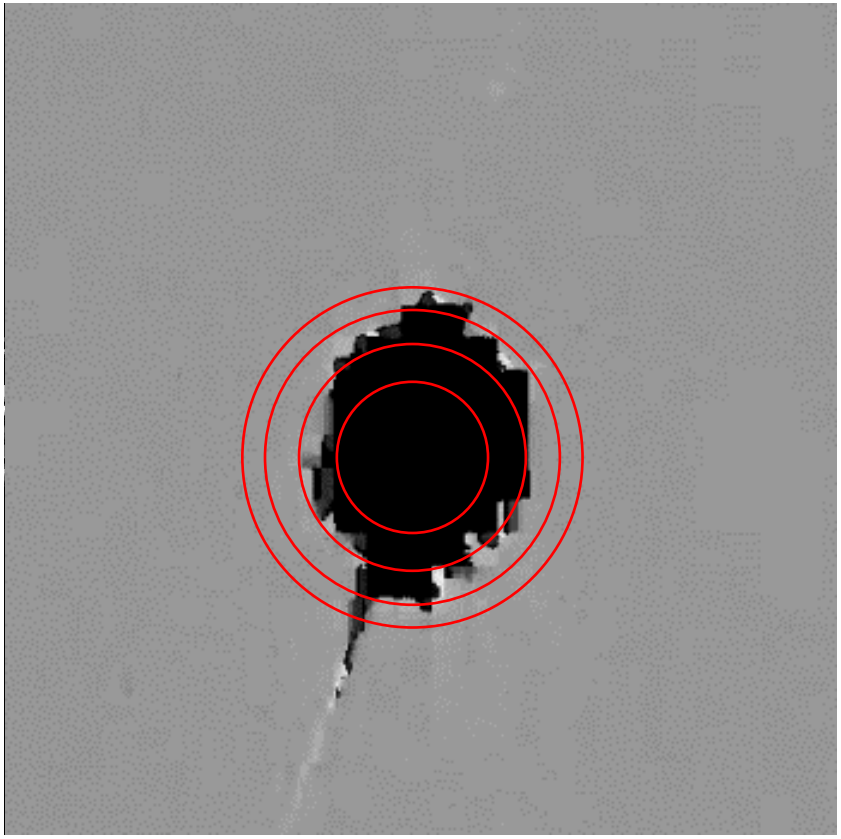
$$RBV_{i,j} = \frac{Red_{i,j} - Blue_{i,j}}{Value_{i,j}}$$

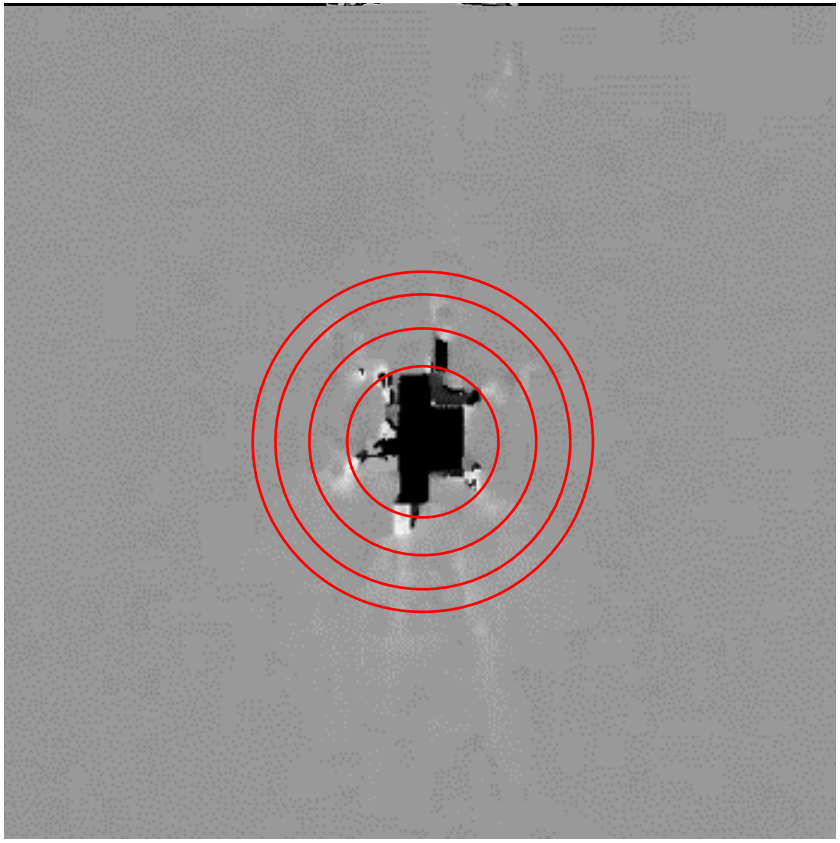
Image Regions

Image is separated into two regions

1. Around the sun
   - Four concentric circles defining the circumsolar area
     - Outer circle covers the blur of the Hue component in NE image
     - Inner circle covers the blur of the Hue component in UE image
     - Two additional intermediate sub regions. Required due to varied brightness around the sun
   - Centre of image is the centre of the sun
2. Away from the sun
   - The rest of the image
   - Horizon

Image Regions





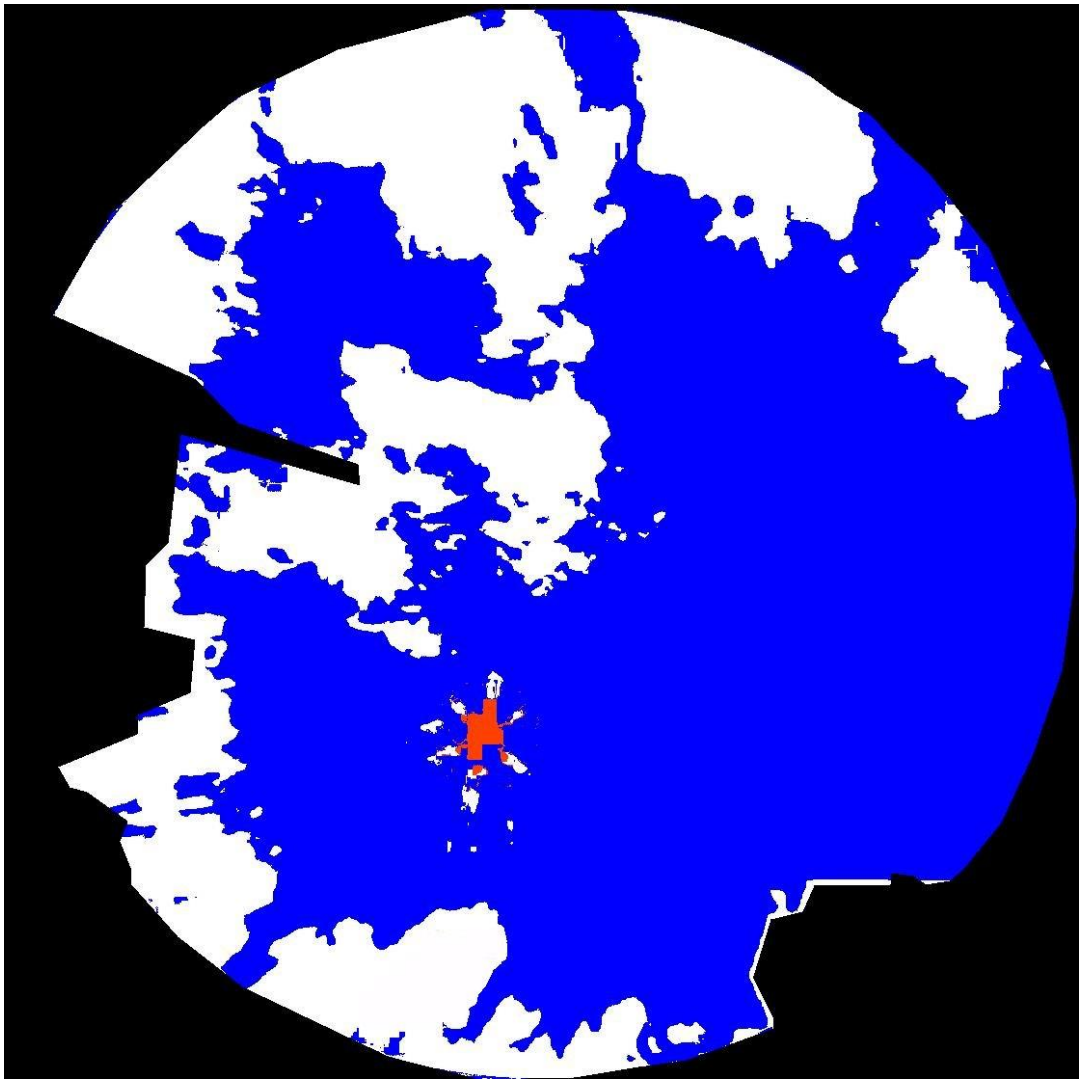
Methodology

Threshold based decision

- Pixels are categorised
  - Sun – Cloud – Sky – Horizon
- Different thresholds for each region
  - Sun
    - Hue UE
    - Hue NE
    - RBV UE
  - Sky
    - Hue UE
    - Hue NE
    - RBRB UE
    - RBV UE
    - RB NE
    - RB UE
    - GB NE
  - Cloud
    - Hue UE
    - Hue NE
    - RBRB UE
    - RBV UE
    - RB NE
    - RB UE
    - GB NE

Methodology

Processed Image



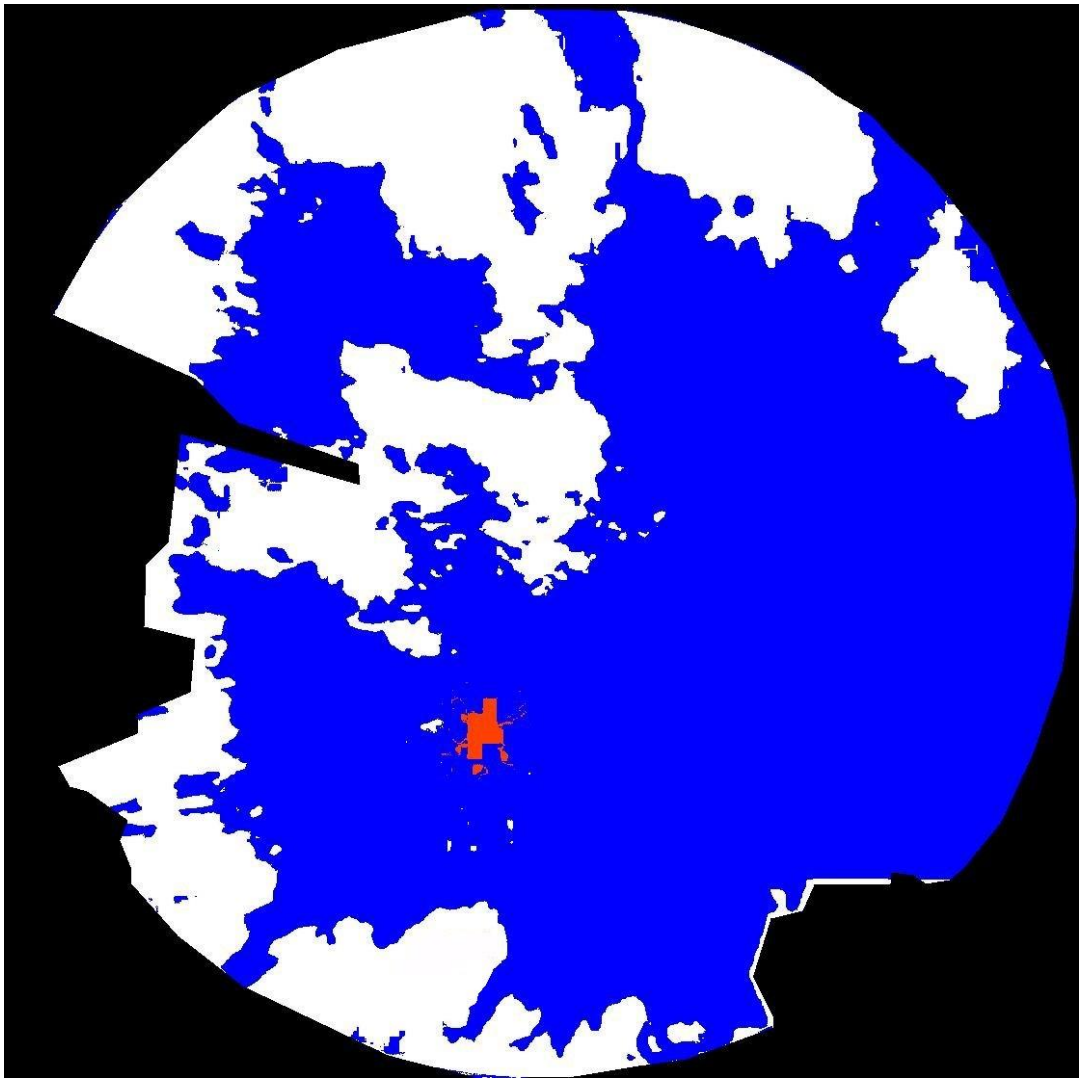
Methodology

Further Processing

- Star shaped saturated region inside the circles
  - Cloudy pixels in ROI
  - Cloudy pixels in rotated ROI
  - Comparison of two numbers
- Implementation of Gaussian convolution filter
  - Filter on processed image
  - State of neighbouring pixels
  - Comparison of filtered and non-filtered processed image
  - Eliminate errors
  - Especially for individual pixels incorrectly identified as sun

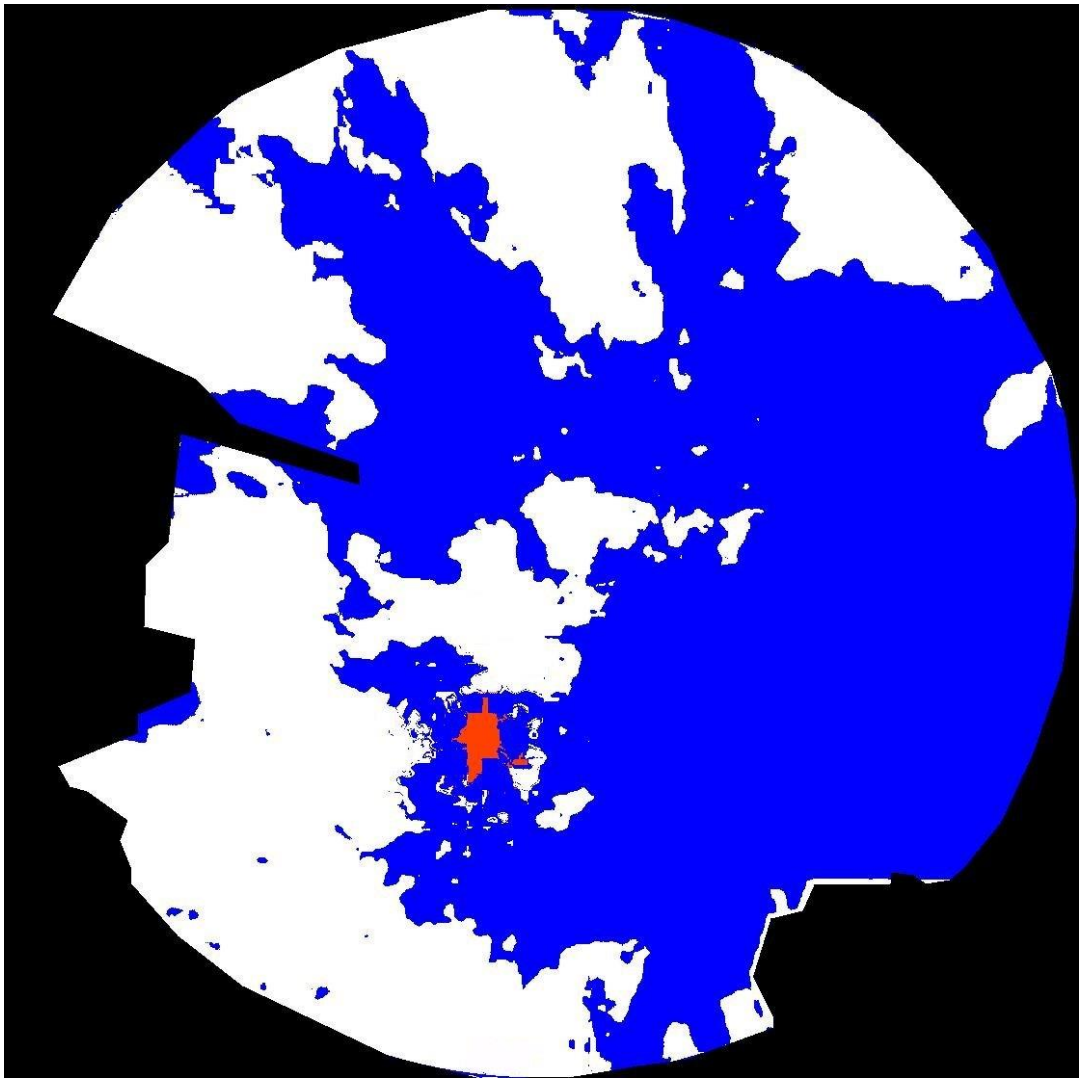
Methodology

Processed Image



Methodology

Processed Image



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Conclusions

- Outcomes of the study
  - A methodology for the classification of pixels inside the circumsolar area
  - Normal Exposed and Under Exposed images were used
  - Variable threshold based on distance from the sun
- Future Work
  - Variable image brightness
  - Correlation to solar irradiance
  - Cloud motion vectors

Acknowledgement

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End of Presentation

THANK YOU FOR YOUR ATTENTION

Questions?