Cloud vector mapping using MODIS 09 Climate Modeling Grid (CMG) for the year 2010 and 2011

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Abstract. An alternate use for MODIS images was sought by mapping cloud movement directions and dissipation time during the 2010 and 2011 floods. MODIS Level-02 daily CMG (Climate Modelling Grid) land-cover images were downloaded and subsequently rectified and clipped to the study area. These images were then put together to observe the direction of cloud movement and vectorize the observed paths. Initial findings suggest that usually cloud does not have a prolonged coverage period over the northern humid region of the country and dissipates within less than 24-hours. Additionally, this led to the development of a robust methodology for cloud motion analysis using FOSS and market leading GIS utilities.

Keywords: Satellite Remote Sensing, Cloud mapping, Climate Modelling Grid, Pakistan, Floods

1. Introduction
Pakistan is situated in a region with a sub-season in summer called the monsoon. The monsoon of 2010 and 2011 were special due to the fact that they caused widespread devastation across wide swaths of land in the country. In the floods of 2010 more than 20% of the territory was inundated alone [1] and similarly the 2011 floods caused havoc in Southeastern Sindh province.

During the monsoon overcast conditions prevails in various parts of the country. An analysis of these conditions and their correlation with atmospheric pollutions, the urban heat island phenomena and rainfall distribution is expected to deliver interesting scientific knowledge. In this regard a mapping exercise using the MODIS, MOD09 CMG product (see figure 1) was sought using Open Source GDAL (Geospatial Data Abstraction Library) and ArcGIS. A series of images were downloaded for the monsoon season in 2010 and 2011 from the NASA LAADSWEB data portal. These images were then clipped and converted to RGB using band 1, 4 and 3 and subsequently used for mapping cloud movement and dissipation durations.
2. Data and methods
A selected set of MOD09 CMG (Level-2 climate modelling grid) product tiles were downloaded from the NASA LAADS web data portal for the months of July and Aug for the years 2010 and 2011. These images were stored on a dedicated cluster meant for MODIS low to high resolution imagery processing due to the immense data size.

```python
import arcpy
from arcpy import env
arcpy.env.workspace = "G:/files"
arcpy.env.overwriteOutput = True
files = arcpy.ListFiles("*.tif")
# Provide the total number of files in the folder
totalFiles = XX
# Give total bands per scene
totalBands = X
i=0
outFile=1
while i+2 < totalFiles:
    # Change the order of the three files as per RGB
```
print("Band Composite Processing " + files[i] + " + " + files[i+1] + " + " + files[i+2])
#output file will be numbered in ascending order, you can also prefix an identifier in the output name
arcpy.CompositeBands_management(files[i]+ ";"); +files[i+1]+ ";" + files[i+2],G:/out/"+str(outFile)+".tif"

Scrip t 1: Python script used in ArcGIS for band composite generation

The MODIS CMG product tiles bear a coarse resolution of 0.05° and cover the entire globe on a regular basis. For this exercise the choice was that of the former due to limited processing capacity and significantly high data size of ~130 GB. The MODIS (MOD09 CMG) data is distributed in HDF-4 format and hence contains a set of 7 surface reflectance sub-dataset bands of which band 1, 4 and 3 are suitable for RGB generation, in respective order [2].

A custom bash script was written to spectrally and spatially subset these files which were 116 in number and convert these bands to TIFF format. Once this was done these images were imported using another bash script in GRASS-GIS [3] and clipped to the political boundaries of Pakistan. RGBs were developed for our vectorization needs wherever required using a custom python script in ArcGIS (see script 1), and clouds and their direction of advance was mapped accordingly (see figure 2 and figure 3).

3. Results and findings
This cloud mapping exercise was critical to our understanding of the horizontal spread of clouds across Pakistan, their development and dissipation rates and forms over different parts of the country. With such clouds maps we plan to further incorporate precipitation records from the TRMM (Tropical Rainfall Measurement Mission) and develop cross-tabulation maps for cloud types and precipitation variability over the entire territory.

4. Conclusion
The cloud distribution maps helped us observe an extended residence period of two days over the northern parts of the country. This forms a humid belt of high rainfall in the Hindu-Kush, Karakoram and Himalayan piedmont. Moreover, such persistent cloud cover was rare and mostly the cloud would dissipate in less than 24 hours. FOSS-GIS coupled with ArcGIS is a handy utility for mapping decadal time-series variations in cloud cover as this work proves and their shift in any seasonal variations.
5. References
[1] Robotka, B. Pakistani Floods 2010: An analysis of its impact on the country and its people, 2011.

[2] E. Vermote and J. Ray. MODIS surface reflectance user’s guide, 2011.

[3] Neteler M., Bowman M.H., et.al. GRASS GIS: A multi-purpose Open-Source GIS. Environmental Modelling & Software, 2012.

6. Acknowledgements
We would like to thank the NUST IGIS faculty and Mr. Kamran Aslam for their kind support and guidance.