Department of Geography and Environmental Science

High resolution mapping of dust sources in Central Asia using MODIS imagery

Mohamad Nobakht* | Maria Shahgedanova | Kevin White

Introduction

Central Asia is a region where large deserts are located in close proximity to the mountains whose extensive glaciers and snow packs provide runoff supporting agriculture in the densely populated foothills. Deposition of mineral dust significantly affects glaciers of Tien Shan Mountains in Central Asia, including both their snow pack and glacier ice (Wake et al., 1994). In this research, spatial distribution and seasonal variations of dust sources in surrounding regions of Tien Shan Mountains are investigated using MODIS Deep Blue Aerosol Optical Depth data obtained between January 2003 and January 2015. An adapted dust enhancement algorithm was also used for high resolution mapping of dust point sources, leading to better understanding of land surface characteristics at dust sources.

Data & Method

This project aims to characterize sources regions and pathway of mineral dust from the deserts of Central Asia to the glaciated environments of Tien Shan Mountains, through employing remote sensing imagery and GIS tools, as well as atmospheric trajectory modelling and station observations. For this purpose, daily satellite images acquired by Moderate Resolution Imaging Spectrometer (MODIS) over a time period of 12 years were analyzed in order to obtain an updated map of dust sources in Central Asia. Second generation Deep Blue Aerosol Optical Depth (DB AOD), provided in MODIS/Aqua Collection 6 Atmosphere Level 2 products with spatial resolution of 10 km, were used to investigate the distribution of dust hotspots. MODIS DB products used in this study were as follows:

- DB AOD at 550 nm over land (Quality Assurance 2 & 3 only)
- DB Angstrom Exponent Over Land
- DB Single Scattering Albedo Over Land at 412 and 650 nm

MODIS Level 1B images were also processed using a dust enhancement algorithm, adapted from Miller (2003), to produce MODIS Dust Enhancement Products (DEP) in 1km resolution.

Methodology

A database of daily dust optical depth (DOD) was generated by imposing two criteria to DB AOD observations (τ):

i. Angstrom Exponent less than 0.5 ($\alpha < 0.5$)
ii. Decreasing absorption with wavelengths ($\omega_{650} - \omega_{412} > 0$)

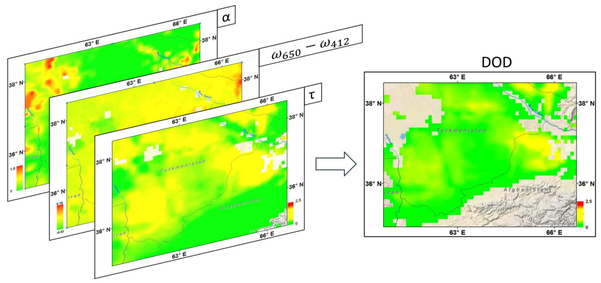

Figure 1. An example of DOD over deserts of Turkmenistan, obtained by imposing two screening criteria to MODIS DB AOD (τ)

MODIS DEP

MODIS DEP was obtained by combining near and far infrared measurements with color information from visible channels (Figure 2). The result is a false color RGB image in which MODIS bands 4 and 3 log-scaled reflectances are loaded into the green and blue color guns and the red gun is replaced by:

$$D_{lnd} = L_1 + L_3 + L_4 + (1 - L_2)$$

where:

$L_1 = B_{32} - B_{31}$ Normalized over [-2 , 2]

$L_2 = B_{31}$ Normalized over [0 , 1]

$L_3 = 2B_1 - B_3 - B_4 - L_2$ Normalized over [-1.5 , 0.25]

$L_4 = if\ (B_{26} > 0.03\ OR\ B_7 < 0.1) \Rightarrow 0\ , otherwise\ 1$

Results

In order to localize dust sources, Frequency of Occurrence (FO) was analyzed (Figure 2). FO was calculated as the number of days in each season that DOD is greater than 0.2. The units of FO are percentage of days with DOD > 0.2 by total number of days with non-missing DB AOD data per season.

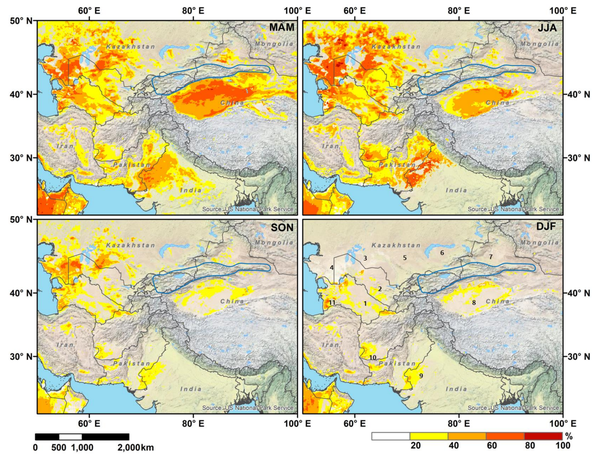

Figure 2. Seasonal variation of FO distribution for DOD > 0.2 in Central Asia, averaged from 2003 to 2015. Location of the Tien Shan Mountains is indicated by blue polygon and numbered areas in DJF map indicate the deserts, including Kara Kum (1), Kyzyl Kum (2), Aral Kum (3), Ustyurt Plateau (4), Betpaqdala (5), Saryyesik Atyrau (6), Gurbantunggut (7), Taklimakan (8), Thar Desert (9), Rigestan (10) and Atrek Delta (11).

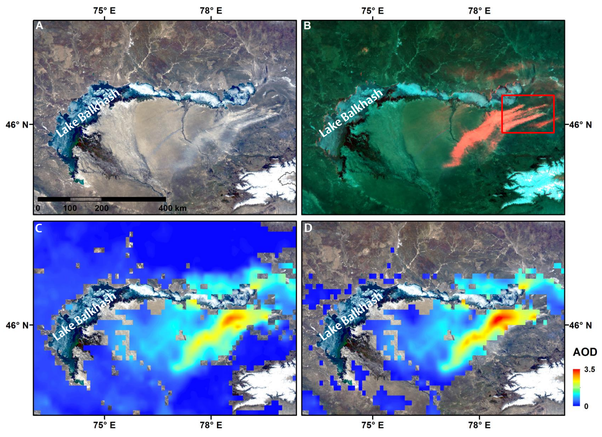

Figure 3. Visual comparison between (A) MODIS true color, (B) DEP, (C) DB AOD and (D) DOD for a dust event on 30th March 2008 at Balkhash-Alakol basin. Location of dust sources at the head of the dust plume is depicted by a red rectangle in DEP image.

Conclusions & Further Work

The most recent map of dust sources in Central Asia was generated, for the first time, using MODIS second generation DB AOD products introduced in MODIS Collection 6. Analysis of FO distribution revealed that sources in east and southern sides of Tien Shan, e.g. Taklimakan, are the most active sources in spring, while deserts in western side of Tien Shan are the dominant dust sources in summer. High resolution MODIS DEP images provided an exceptional ability to identify eroding point sources within the dust source areas in order

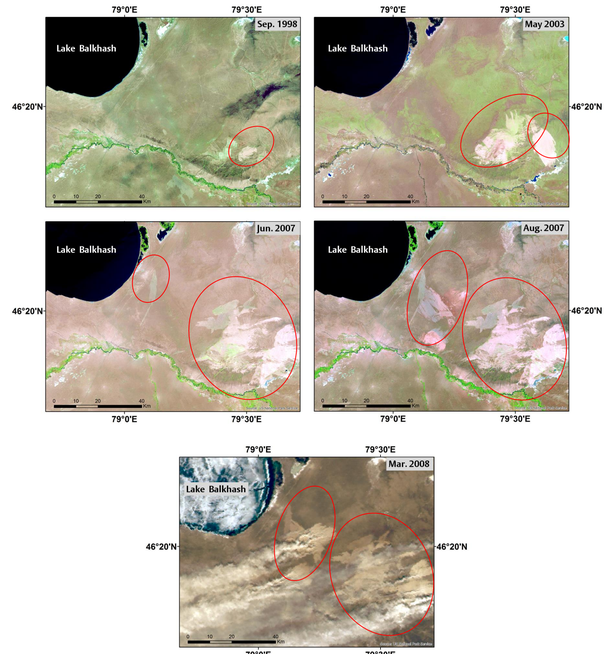

Figure 4. True color Landsat-5 TM images showing the formation of fire-scars in Balkhash-Alakol basin from 1998 to 2007 (top four images), and true color MODIS image of a dust storm in March 2008 originated from this region (bottom). Red rectangle in Figure 3-B shows the area of the image.

to obtain a detailed inventory of dust erodible surfaces in this region. Investigation of land surface characteristics of dust source regions revealed several active sources associated with post-fire dust emission (e.g. eastern part of Balkhash-Alakol basin, shown in figure 4). It was also shown that dried bottom of Aral Sea has been a very active source of dust during the last decade. In further research, pathway of dust originated from these sources will be studied using atmospheric trajectory modelling and NCEP/NCAR reanalyses data. Finally, assessments of dust deposition on Tien Shan glaciers will be made from observations of change in surface albedo of glaciers obtained by MODIS imagery.

*** Contact information**

- Department of Geography and Environmental Science, The University of Reading, Whiteknights, RG6 6DW, Reading, United Kingdom.
- Email: **m.nobakht@pgr.reading.ac.uk**

References

1. Wake, C., Mayewski, P., Li, Z., Han, J. & Qin, D. 1994. Modern eolian dust deposition in central Asia. Tellus B, 220-233.
2. Miller, S. 2003. A consolidated technique for enhancing desert dust storms with MODIS. Geophysical Research Letters, 30.