Satellite observations of mineral dust in the Sistan region

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About the Sistan region

Sistan (Figure 1) :

- Is located in the **southeastern Iran**, along the Afghanistan and Pakistan borders, and belongs to the «desert dust belt» that extends in the Northern Hemisphere from the west coast of North Africa, over the Middle East, Central and South Asia, to China [Prospero et al., 2002]
- Is considered as one of the most active dust source regions in southwest Asia as highlighted in several recent studies [Rashki et al., 2014, 2015; Kaskaoutis et al., 2014]
- Meteorological and visibility records are available at Zabol (Iran), the most polluted city in the world in terms of $PM_{2.5}$ and PM_{10} according to 2016 WHO report (http://timesofindia.indiatimes.com/city/delhi/Delhi-no-more-the-most-polluted-city-in-the-world-says-WHO-report/articleshow/52232427.cms)

Figure 1. Left, topographic map of the Sistan region - **Right**, position of Hamoun Lakes in Iran and Afghanistan with location of Zabol indicated by the white circle (31° 02'N, 61° 50'E). From Rashki et al. [2013].

General objective :

- Investigate dust emission and transport in Sistan with special interest on the role of synoptic/local atmospheric dynamics

Approach:

- Climatological analysis of desert dust satellite retrievals in the Sistan region, especially MODIS/Aqua Dark Target Deep blue combined $AOD_{550\ nm}$ [Levy et al., 2013]*
- Identification of specific dust events (case studies) that will be analysed by combining multiple ground-based/satellite obs. and numerical simulations of dust (RAMS regional meteorological model and CHIMERE-CTM model)

* MODIS data (Collection 6, 1° x 1° spatial resolution) are extracted from NASA/GIOVANNI web site (MYD08_D3 v6)

Analysis of MODIS Combined Dark Target and Deep Blue AOD derived from MODIS/Aqua

Time series over the Sistan region (30-31°N, 61-62°E) – Period 2003 - 2016

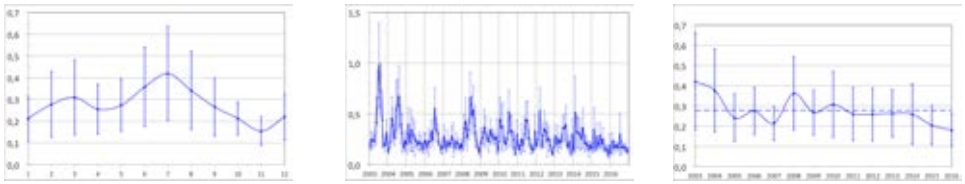

Figure 2. Left, Averaged seasonal cycle of MODIS DT-DB $AOD_{550\ nm}$ (mean values and associated standard deviations) – **Middle**, Monthly means of MODIS DT-DB $AOD_{550\ nm}$ and associated standard deviations - **Right**, Annual means of MODIS DT-DB $AOD_{550\ nm}$ with associated standard deviations. The dashed line indicates the annual mean over the whole period (2003-2016).

- Sesonal cycle shows a summer maximum (June - **July** - August) and minimum in autumn & winter (Oct. – **Nov** – Dec – Jan) in agreement with previous aerosol satellite analysis over the region [Rashki et al., 2014]
- Monthly means time series highlight high inter-annual and intra-annual variability, with monthly AOD from 0.98 (July 2003) to 0.10 (Nov. 2015)
- Annual mean values of AOD range between 0.42 (2003) and 0.18 (2016) suggesting a possible decreasing of dust loads over the Sistan in the recent years

Summer dust events over the Sistan region (30-31°N, 61-62°E) as detected by MODIS

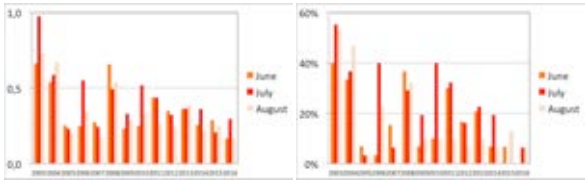

Figure 3. Left, Monthly means of MODIS DT-DB $AOD_{550\ nm}$ for the summer months – **Right,** Frequency of MODIS DT-DB $AOD_{550\ nm}$ daily values above 0.5 for the summer months over the period 2003-2016.

- Summer monthly averages of MODIS AOD show high variability, from 0.98 (July 2003) to 0.17 (June & Aug., 2016)
- Monthly frequency of occurrence of MODIS AOD > 0.5 show pronounced differences between months and years, from 55% (in July 2003 to 0% (Aug. 2007, July 2015, June 2016)
- Such a high interannual variability of summer dust events is illustrated on MODIS AOD daily time series and averaged spatial distribution (Figure 4)
- Our results are consistent with the analysis of visibility records at Zabol reported by Rashki et al. [2015] over the period 2001-2012, that highlighted:
  - High frequency and severity of dust storms over the period 2001-2004 due to an extensive dry period that caused desiccation of the Hamoun lakes
  - Low dust activity during the summer seasons of 2005 and 2007 due to water coverage in the Hamoun lakes and the growth vegetation in the basin
- MODIS AOD suggest moderate to low summer dust activity over the Sistan in the recent years (2015-2016)

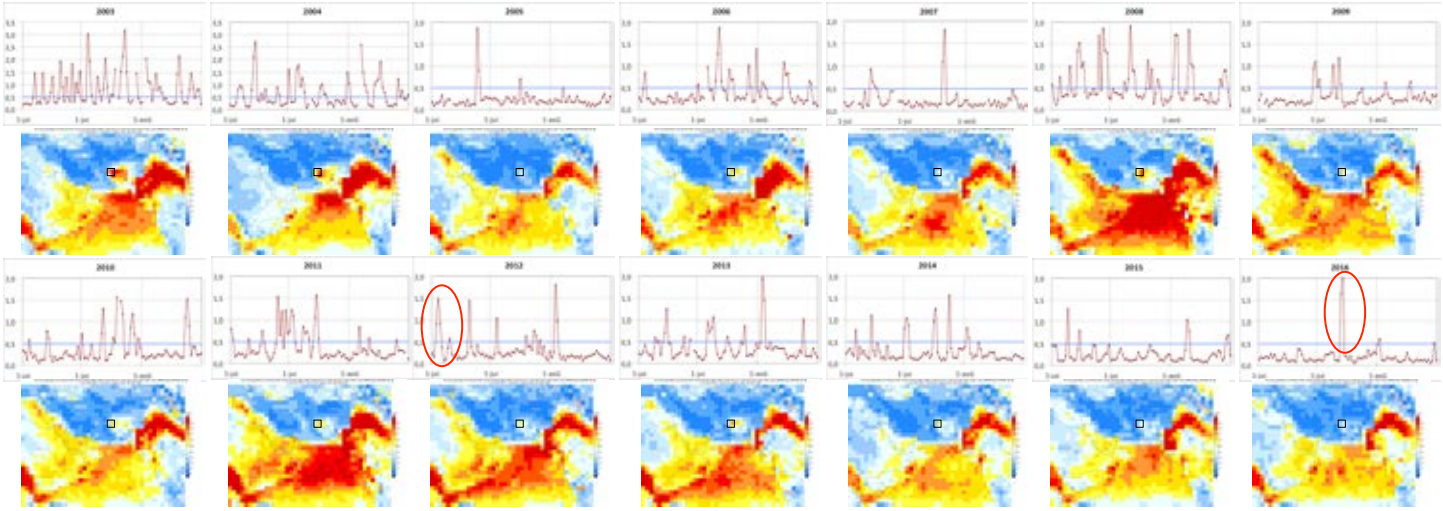

Figure 4. Top, Daily evolutions of MODIS DT-DB $AOD_{550\ nm}$ for the summer months (June-July-August) 2003 to 2016, the blue line indicating the threshold AOD value of 0.5 - **Bottom** Associated averaged geographical distribution of MODIS DT-DB $AOD_{550\ nm}$ for the summer months (June-July-August) 2003 to 2016.The black square indicates the Sistan source.

Case Studies

June 3-5 2012

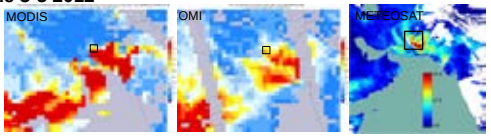

Figure 5. Left, MODIS DT-DB $AOD_{550\ nm}$, OMI AI, and METEOSAT IDDI dust retrievals for June 5 2012. **Right**, Meteorological measurements at Zabol in June 2012.

- MODIS DT-DB $AOD_{550\ nm}$ reaches values up to 1.5 over Sistan
- Zabol meteorological measurements highlight coincident low visibility and high wind speed
- Dust is also observed by METEOSAT IDDI and OMI AI over the Sistan region

July 13-14 2016

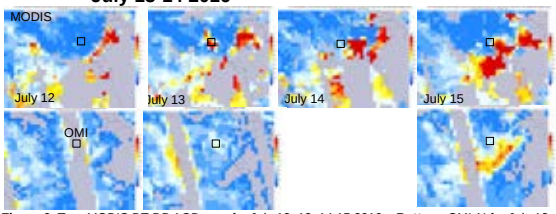

Figure 6. Top, MODIS DT-DB $AOD_{550\ nm}$ for July 12, 13, 14,15 2016 – **Bottom**, OMI AI for July 12, 13, 14,15 2016.

MODIS DT-DB $AOD_{550\ nm}$ reaches values up to 2 over Sistan

The dust event is nicely detected by MODIS but appears of moderate intensity on OMI AI images (July 14 image is missing)

Fig 7. Daily PM_{10} (red line) & visibility (blue line) recorded in Zabol in July 2016.

Conclusions

1. Dust temporal and spatial variability over the Sistan are investigated through analysis of 14 years of MODIS/Aqua aerosol retrievals (2003-2016).
2. Our analysis confirms the seasonal cycle and highlight high interrannual variability of summer dust events
3. Case studies (June 2012 – July 2016) will be further investigated by combining regional modeling and multiple observations

References. **Kaskaoutis et al. (2014)**, Extremely high aerosol loading over Arabian Sea during June 2008: The specific role of the atmospheric dynamics and Sistan dust storms *Atm. Environm.* - **Levy et al. (2013)**, The collection 6 MODIS aerosol products over land and ocean *Atmos. Meas. Tech.* - **Prospero et al. (2002)**, Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone Mapping Spectrometer Absorbing Aerosol product *Rev. Geophys.* - **Rashki et al. (2014)**, Spatio-temporal variability of dust aerosols over the Sistan region in Iran based on satellite observations *Nat. Hazards*. 2014 - **Rashki et al. (2015)**, Dust-storm dynamics over Sistan region, Iran: Seasonality, transport characteristics and affected areas *Aeol. Res.*

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