Study of long-term Trend in Dust Distribution over Persian Gulf:
Satellite Imagery Application and Weather Charts interpretation

M.Dadizadeh[1], H.Malakooti[2] , A.Gheiby[2], Z.Alizadeh[3]

[1] *Remote Sensing & GIS M.Sc Student, Hormozgan University, Bandarabbass ,Iran.*

[2] *Faculty member of Hormozgan University, Bandarabbass, Iran.*

[3] *Meteorology M.Sc Student, University of Tehran, Tehran, Iran .*

Name of the Presenter: Marziyeh Dadizadeh

m_dadizadeh@yahoo.com

Abstract

Landuse change, loss of soil moisture and special dynamic and thermodynamic conditions can caused intense soil erosion and dust storms. Emission of dust on land surface is a function of wind shear and surface properties. According to marginal basin properties of Persian Gulf, this area suffers from high level mineral dust concentration during the year. As first step, annual mean aerosol concentrations were studied using satellite data from SeaWiFS sensor over Persian Gulf during 1997-2010. It was observed that in this area is experienced high level of concentrations in 2005. Then, the inter-annual variability of mineral dust concentration was studied and it has usually shown monthly peak of concentration in June-July, but in 2005 it was occurred in April with strong positive anomaly**.** Thereafter, in order to determine the weather conditions during April 2005, actual weather charts were interpreted in surface and standard synoptical levels. It is observed that five synoptical scale cyclones, originated from the east of Mediterranean Sea have crossed this region during April 2005. These systems were associated with significant dynamical baroclinicity in low level troposphere and perfect surface wind shear over known dust emission sources over marginal basin of Persian Gulf.

Key words: Dust, Persian Gulf, Satellite Imagery, SeaWiFS, Soil erosion

1. Introduction

Dust storms are one of the most notable natural hazards in Middle East and cause a great variety of environmental impacts. Atmospheric dust particles originating in the arid and semi arid regions of the world are known to be principal sources of mineral dust. The frequency and magnitude of dust input is influenced by season, source area, climate, human land disturbance, local and regional scale weather and global atmospheric circulation (Bonnet et al., 2005). Dust also has an impact on the nutrient dynamics and biogeochemical cycling of ecosystems, and it has a major influence on soil characteristics, oceanic productivity, and air chemistry. Moreover, because of the thousands of kilometers over which dust is transported, it has an influence at large distances from its sources (Goudie and Middleton 2001; Middleton and Goudie 2001, Myhre et al., 2005). In most areas, we can classify dust storms by the broad meteorological conditions that cause them. Middle Eastern dust storms generally formed by prefrontal and postfrontal winds during the winter, and summer Shamal during hot and dry season. Other dust storms in this region generate and influence by mesoscale forcings such as downslope wind regimes, strong sea breeze regimes, gap flows, and convection cells.

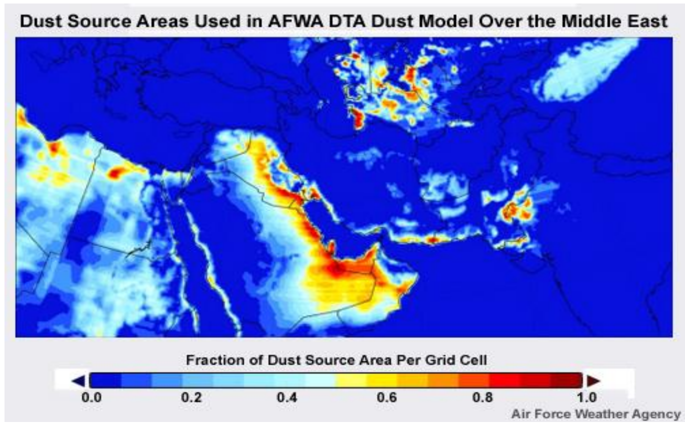

Fig. 1: dust sources used in the Air Force Weather Dust Transport Application (DTA) model (http://www.goes-r.gov/users/comet/mesoprim/dust/)

In Middle East, the averaged maximum dust storm occurs in the summer during which for more than 30% of the time are present due to blowing dust. However, during winter, the percentage reduces to about 5% (Kutiel and furman, 2003). Effective sources in this region classify as river flood plains (alluvial plains), dry lake beds, agricultural areas, coastal areas and many other point sources of dust. Among this active sources Tigris and Euphrates basin in Iraq as well as Syria to the west, Arabian Peninsula to the south and southwest, Turkmenistan basin to the north and Iran (e.g. Kavir and Lut desert and Hamoun Jaz-Mourian Lake) to the east can be named. It means that more than 65% of the Middle East land surface has the potential of dust emission (Prospro et al. 2002; Leon & Legrand, 2003). Persian Gulf is located in middle of the several important source of dust storm in this region and it is so important to study its condition. High dust deposition has a great effect on its ecosystem. Aerosol concentration can be obtained by the satellite-mapped product, aerosol optical thickness (AOT), which quantifies atmospheric suspended particles and the degree to which they prevent the transmission of light. In this study, it is investigated a long term dust storm event over Persian Gulf by using satellite data and also is analyzed meteorological conditions from weather charts during April 2005 anomaly event that was detected for 1997–2010 period.

2. Data and Material

A 14 years databases of satellite and ground based meteorological data from 1997–2010 have been considered to study long term fluctuations of dust storm over Persian Gulf. For satellite data, Level 3 monthly averaged images were included Aerosol Optical Thickness (AOT), derived from infrared measurements at 865 nm which are taken by SeaWiFS sensor. The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) was launched on the SeaStar spacecraft in August 1, 1997 with the purpose of providing quantitative data on global ocean bio-optical properties. SeaWiFS measures atmospheric radiance in eight narrow spectral bands. The bands span from the visible to the near infra-red parts of the spectrum centered on 412, 443, 490, 510, 555, 670, 765 and 865 nm, with a spectral resolution of 20 nm for wavelengths smaller than 700 nm and 40 nm for wavelengths larger than 700 nm. In order to diagnose the weather conditions during formation, transportation and dispersion of dust plums over Persian Gulf, Atmospheric Research reanalysis project (NCEP_NCAR) meteorological database from the National Center for Environmental Prediction–National Center on a 2.5°×2.5° grid was applied for this purpose, each 6 hours during selected episodes.

3. Research Methodology

In this research, by aerosol optical thickness (AOT) through SeaWiFS is studied monthly and annual long-term trends of mineral dust concentrations during our statistical period. Thereafter, it is focused on the years that were experienced highest level of mineral dust concentrations. For this purpose, inter-annual monthly time-series of mineral dust variability were compared with long-term monthly series. According to this analysis, it was found one month with high positive anomaly of mineral dust concentrations over Persian Gulf. In order to investigate the weather conditions those were caused formation and evolution of dust plums over Persian Gulf, the actual weather charts were interpreted in surface and standard synoptical levels for each 6 hours by meteorological data from NCEP–NCAR reanalysis project.

4. Results and Analysis

Annual long-term aerosol optical thickness analysis through SeaWiFS showed high level aerosol presence over Persian Gulf during 1997–2010 periods. This time-series of AOT is represented aerosol concentration variability with two anomaly occurrences (1999 and 2005) in this region. Second aerosol concentration anomaly that it was seems stronger, was occurred in 2005 (Fig. 2-Left).

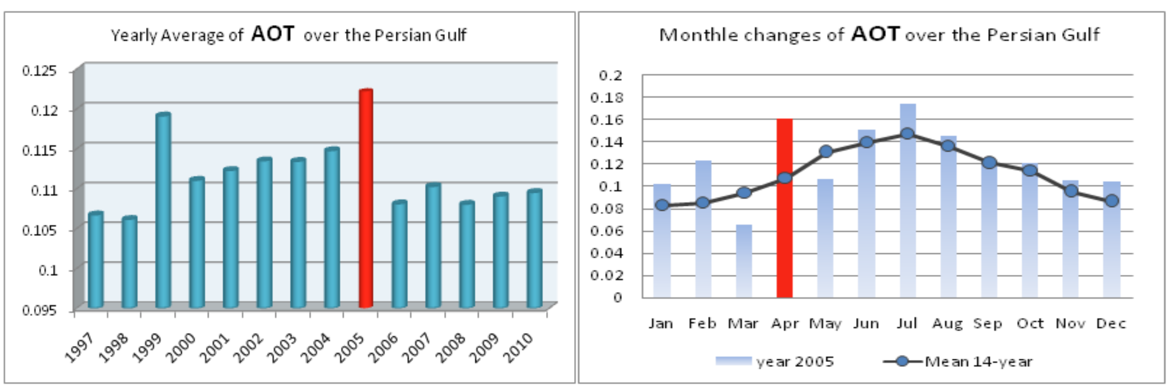

Fig. 2: Time series of mean annual AOT over Persian Gulf during 1997-2010 (Left) and average inter-annual variations of monthly mean during 1997-2010 in solid line and during 2005 in histogram format (Right).

In order to understand the situations during 2005, it is analyzed inter-annual monthly time-series of AOT. Annual mean monthly time-series of AOT showed maximum values during summer period (Jun, July and August) over Persian Gulf. During this statistical period, monthly time-series of AOT during 2005 was showed different variability in comparison with long-term inter-annual monthly series. According to this comparison, it is observed that during 10 month in 2005, Persian Gulf was affected by dust more than mean monthly observational profile during 1997 to 2010. Among these months, April 2005 is showed maximum positive anomaly with two negative anomalies on both sides in March and May (Fig. 2-Right).

In order to figure out how April 2005 anomaly is occurred, it is investigated the weather conditions from March 20 to May 10. For this purpose, the actual weather charts were interpreted in surface and standard synoptical levels (850, 700, 500 and 300 hPa) for each 6 hours by meteorological data from NCEP–NCAR reanalysis project during this period.

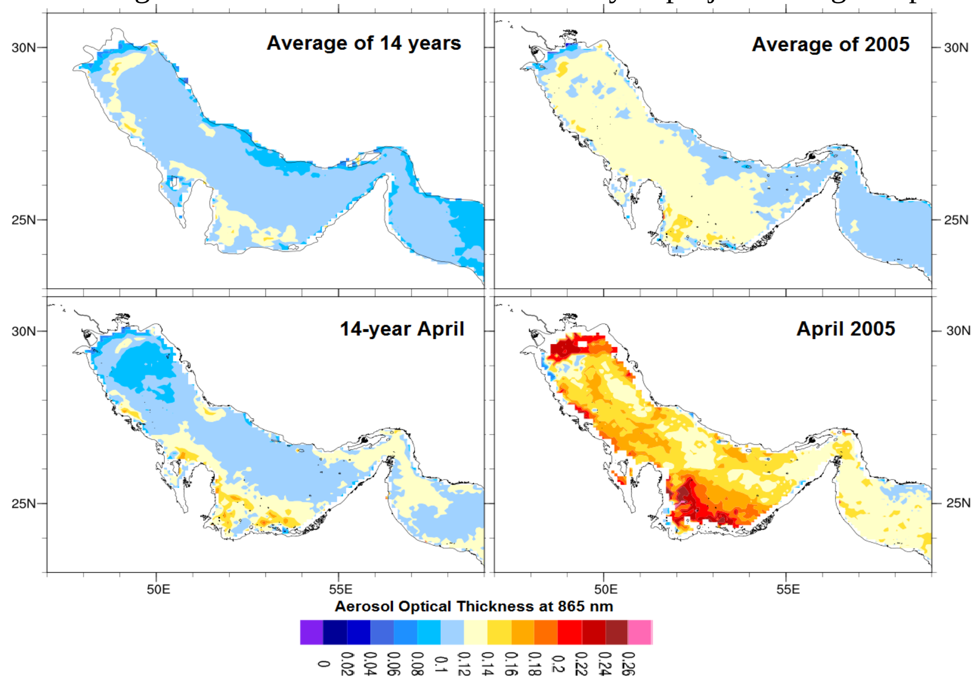

Fig. 3: AOT distribution over Persian Gulf during 1997-2010 [top left panel], during 2005 [top right panel], mean April during 14 years [bottom left panel] and April 2005 [bottom right panel].

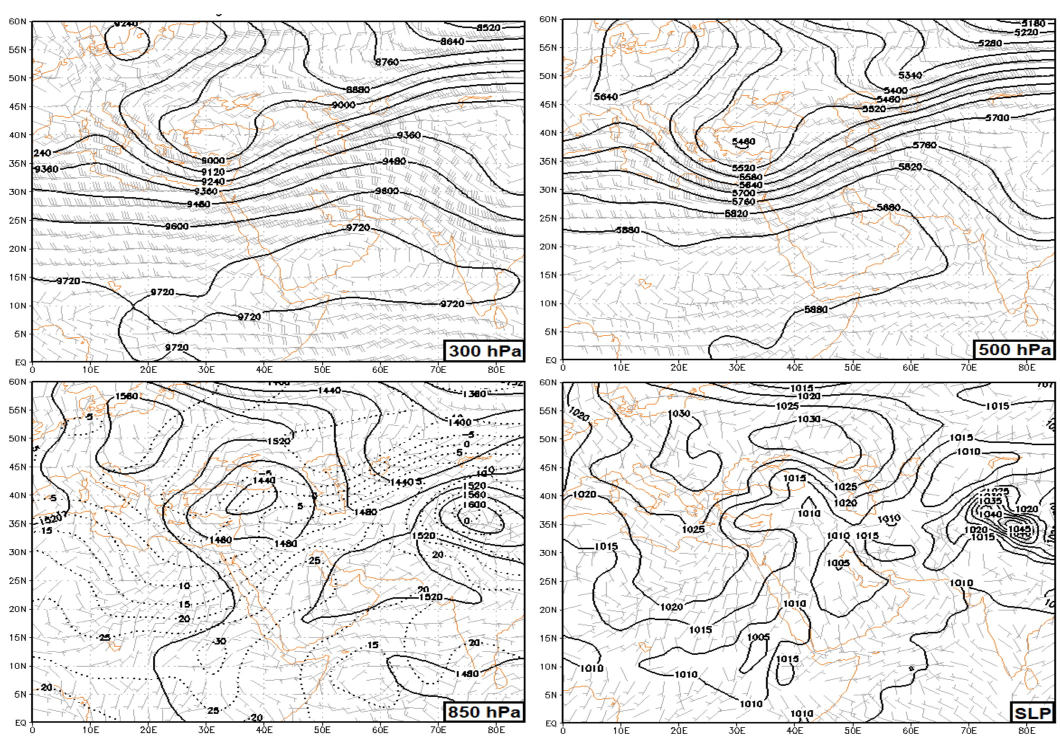

Fig 4. Weather charts in different levels at 00z 8 April 2005. Solid lines are geopotential and mean sea level pressure (in surface chart) contours and dotted line is temperature contours.

According to synoptical analyses of weather charts, it was clearly observed that East Mediterranean cyclogenesis was activated during this period. Initial interpretation of weather chart was showed that five frontal cyclones have crossed Persian Gulf on 2-4, 8-10, 15-17, 19-21 and 26-28 April 2005 with significant baroclinicity and upper level forcing. The presure, temrature, and wind time series of meteorological observation network around this area were clearly showed passage of these synoptical cyclones. It means that the main rasone of positive anomaly of aerosol optical thickness during April 2005 should be synoptically-forced dust storms around Persian Gulf.

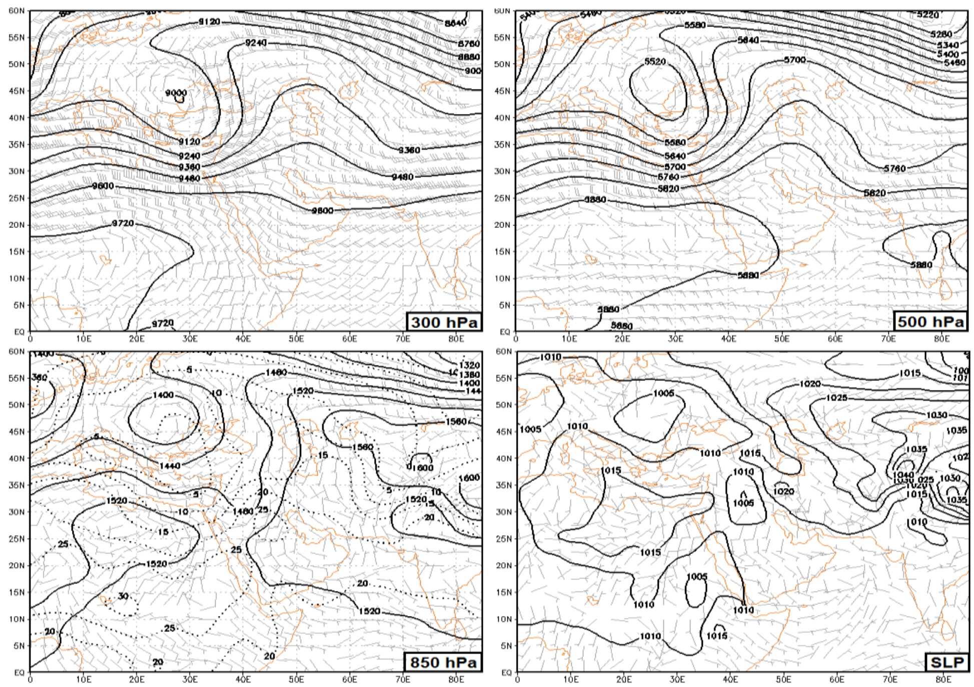

Fig 5. As shown in Fig. 3 but at 00z 15 April 2005.

For sample, Fig. 4 and Fig. 5 represent synoptical conditions in the biginig of two frontal systems entrance to Persian Gulf regin at 00 Z 8 April and 00 Z 15 April. As can be seen in these figures, in both cases, upper and middle levels (300 and 500 hPa charts) situation show deep tillted trough with significat divergence in their fronts. In lower and surfce charts (850 and surface charts), it clearly recognizable the presence of baroclinicities, frontal areas and sea level low pressures.

According to mean spatial distribution of AOT over Persian Gulf during April 2005 (Fig. 3) and wind field in surface charts, it is concluded that dust sources in south of Persian Gulf have been active during southly high near surface wind in worm sector (front of cold frontal zone) and sources in north east of Persian Gulf have been active during north easterly (winter shamal regime) high near surface wind in back of cold frontal zone. It means this area was affected by pre-frontal dust plum from south (especially from United Arab Emirate deserts and coastal area) and post-frontal dusts from north east (from Mesopotamia region).

5. Conclusions

According to the long-term AOT analysis, it is found that the Persian Gulf suffers by significant mineral dust concentration during the year, especially in summer period. This condition can be due to low soil humidity, high temperature and presence of mechanisms for formation of dust storms over known sources such as summer Shamal with during late May to early July over Mesopotamia basin. Heavy dust concentration over Persian Gulf region can make different environmental problems such as high dust deposition that it can cause great effects on local ecosystems. It show that this phenomena need to be research and control before occurrence of strange critical environmental conditions. In anomaly cases, heavy dusty conditions can occur during spring too, when this region affects by deep frontal cyclones with low humidity. During the spring when the frontal Mediterranean cyclone penetrate to lower latitude, it can cause strong wind shear in south of Persian Gulf and after passing cold front, Shamal wind can cause blowing dust from north east. It means that seasonal mechanisms for formation dust storm are different. In order to diagnose the formation and evolution of dust storm during the studied episode, it will conduct dust simulations with different Scenarios for better recognition.

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