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SATELLITE VIEWED DUSTSTORMS – AN OVERVIEW

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ABSTRACT

Mainly two types Duststorms in India (i) pressure gradient and (ii) convective type is responsible for, hazard to aviation, road and rail services. Their intensity and frequency of occurrence is affected by the increase of year –to –year in aerosol concentration due to natural and man- made activities. Present paper presents an overview of the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor onboard EOS – Terra polar orbiting satellite viewed two cases (June 9, 2003 and June 10, 2005) of duststorms along with climatological aspects. The effect of aerosol distribution on cloud and transport services is also highlighted.

Key Words: *Duststorm, Andhi, Convective, Pressure Gradient And MODIS*

INTRODUCTION

Satellite is very powerful source in providing the spatial extent of the duststorms and helpful in tracing out the origin of the duststorm. Band (1-7) in MODIS sensor is sensitive to aerosol and their relative spectral properties. Generally, pressure gradient type of duststorm occurs in association with a well- marked low pressure area or western depression passing through Pakistan and adjoining northwest India, developing steep to very steep pressure gradient to the south of low, of the order of 1 to 2 hPa per degree latitude. Under the influence of very strong winds ranging between 30 -50 knots generated due to strong pressure gradient, enormous amount of dust is raised in the atmosphere reducing horizontal visibility below one kilometer. This type of duststorms occurs frequently over Rajasthan in May and June. The dust particles in the air remain suspended for a long time even after the cessation of the strong wind. The latter type of duststorm develops in association with the downdraft of cumulonimbus cloud (Fig. 2). For this type of duststorm, the atmosphere should be convectively unstable, adequate supply of moisture be available in the lower part of the atmosphere and there should be a dynamical mechanism to release the instability present in the air mass. Presence of large amplitude westerly troughs and sub-tropical jet streams in the mid- and upper troposphere is additional favourable synoptic situations to provide low level convergence and high level divergence. The pressure gradient type of duststorms lasts for longer periods (several hours to few days) whereas convective type lasts for a few minutes to a few hours. This weather phenomenon in northwest India is called ‘Andhi’ because of very low visibility which prevents human being to see earthly objects beyond 100 meters or so. In case of severe duststorms in which visibility is of the order of tens of meters, it is impossible to see objects inside the houses without the aid of lamps during day time; even vehicles do not ply on the road without headlights on. Duststorms are major hazards to aviation, rail and road services because of very poor visibility, horizontal and vertical extent and their duration. They create the hazard to human and animal health in arid and semi-arid regions of Indo-Gangetic Plains (Fig 1). The sand and dusts are normally large particles blown by the wind. The size of the dust varies between 10 µm to 100 µm, while size of the sand is more than 100 µm. The sands and dusts are normally trapped in the nose and throat and cause sour throat. However, dust particles smaller than 10 µm can settle in the bronchi and lungs and cause serious health problems.

- Duststorms are essentially thunderstorms in dry region. They are local instability phenomena exactly like thunderstorms and are associated with the growth of large cumulus or cumulonimbus clouds. Duststorms like thunderstorms are attended by powerful squalls of short duration ranging from a few minutes to half an hour or so, in which individual gusts may attain in exceptional cases velocity as high as

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140 to 150 kilometers per hour. Because of the comparatively dry conditions associated with the genesis of duststorms and the high degree of turbulence produced by the powerful descending currents associated with the passage of squalls, large quantities of dust are raised in the air to a considerable height. The walls of the dust advancing with the squalls reduce the visibility to a very low value. At times, the squalls may be so turbulent and air so loaded with dust that the darkness produced could be matched only by that blackest night, making it practically impossible to do anything inside a house without the aid of lamps or some other artificial lights. This is why duststorms are called “Andhi” in India. Joseph et al, (1980) classified the Andhi into four types and this convective type of events can be as large as 30 kilometers. Joseph, (1982) proposed the downdraft model for Andhi which assumes that the Andhi ‘head’ moves forward more slowly at night, when the ambient air density is higher and visibility improvement is slower as compared to type 1st of duststorms. The criteria of moderate duststorm based on wind and horizontal surface visibility is wind speed between 39 to 74 kmph and horizontal visibility less than 1000m up to 500 m and for severe case wind speed \geq 75 kmph and horizontal visibility less than 500m up to 50 m.

MATERIALS AND METHODS

The imagery data is taken from the global MODIS data web site (modis.gsfc.nasa.gov) and the 500 hPa wind data is taken from NCEP reanalysis data (www.esrl.noaa.gov/psd/data/reanalysis/). The climatological data used is taken from the India Meteorological Department (IMD) climatological tables.

RESULTS AND DISCUSSION

Modis View

Two cases of widespread duststorms have been observed by MODIS (Moderate Resolution Imaging Spectroradiometer) sensor onboard EOS – Terra polar orbiting satellite on June 9, 2003 and June 10, 2005 respectively. Both the duststorms, observed in the visible imagery, have their origins in Pakistan. Under the influence of strong winds and consequent turbulence, huge amount of dust is seen to be raised over the area upto mid- troposphere (about 6 Km) and spread in the northwestern parts of Indo-Gangetic plains. On 9th June 2003, the dust was confined to the major parts of Punjab, Haryana and north Rajasthan due to the presence of an anticyclone over South Pakistan and adjoining north Arabian sea at 00 UTC in the mid –troposphere, which turned the orientation of dust flow from north to south. However, thin layers of dust could also be seen over some parts of Uttar Pradesh under the influence of prevailing winds in lower and mid – troposphere (fig 4). Extremely bright plumes of dust having smooth texture in visible imagery indicates that western parts of Punjab and north Rajasthan has thick layer of dust up to mid-troposphere. A shallow layer of dust is seen to cover western Himalayas, which may perhaps have great bearing on the behaviour of glaciers in the long run. The dust layers deposited on the glaciers may reduce their albedo and enhance the process of melting due to increased rate of absorption, thereby reducing the life of the glacier.

A widespread duststorm is also seen to originate from Pakistan at a little lower latitude as compared to previous one in the MODIS picture of EOS – Terra satellite on June 10, 2005. A thick dust layer is seen to be transported to north Rajasthan, Haryana, east Rajasthan, southwest Uttar Pradesh and adjoining northwest Madhya Pradesh. The patterns of blowing dust seen in the satellite imageries in both the cases of duststorms are in conformity with the wind flow patterns prevailing in the middle troposphere over the areas mentioned above (fig 5). Prasad et al (2004) has showed the variability of aerosol optical depth over Indian subcontinent using MODIS data.

Climatology of Duststorms

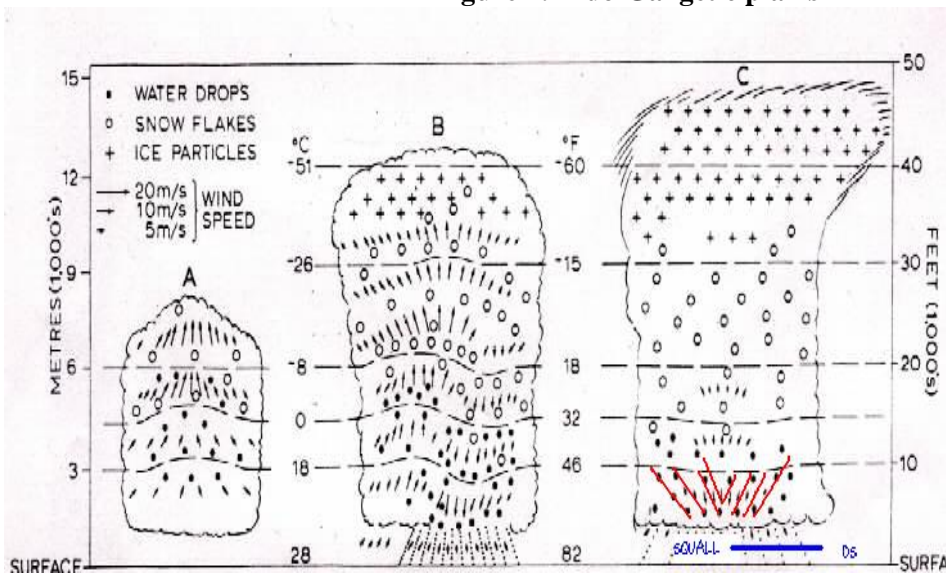
Climatology of duststorms has been discussed in detail using data from I.M.D. Climatological Tables, 1951 to 1980, published in July 1999 and also from the maps produced by Middleton (1986) for the duststorms of Southwest Asia including Pakistan and India (Table 1-6). It is seen that duststorms in

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Pakistan have higher annual mean frequencies than those in India. Pakistan has two regions of high frequency, one across upper Indus plains to the north of Thar Desert (20-25), and another over Sind and



Figure 1: Indo-Gangetic plains



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Figure 2: Pressure gradient type of duststorms (downdrafts of cumulonimbus clouds)

adjoining parts of southwest Pakistan bordering Afghanistan (≥ 30). In India, higher annual mean frequencies are observed over Rajasthan, Punjab, Haryana and Delhi as compared to other parts of Indo-Gangetic plains e.g. Jalore 13, Amritsar and Ferozpur 11, Delhi, Jaipur, Phalodi, Bikaner and Hissar 10 each, Pathankot 9, Rohtak 5 etc. Bihar and West Bengal have lowered annual frequencies e.g. Jamshedpur 3.4, Patna 3.0, Bhagalpur 2.8, Purulia 2.4, Krishnanagar and Gaya 2.0 each etc. These lower frequencies are due to wet climate of this region. The distribution of thunderstorms over Indo-gangetic plains and neighbored is shown in the fig. 3. This information is useful to know the possible transport of aerosols of different types which play an important role in modify the climate and quality of life.

Aerosol distribution

Aerosols are minute solid particles suspended in the atmosphere. Aerosol particles come in many different forms, such as dust, fume, mist, smoke, fog and others. Many of the aerosols are from natural sources, such as soil dust, marine aerosols and biogenic, volcanic and other particles as well as anthropogenic particles such as sulphates, fly ash from power plant emissions and automobile emissions, which are present in urban and remote areas. These aerosols affect human health and quality of life as well as visibility, radiation balance, climate, cloud formation, ecosystem health and many other key aspects of the global earth system. The major air pollutants of concern are identified as sulphur dioxide, nitrogen dioxide, ozone and particulate matter. Thermal power plants and transport sector is the biggest contributor of air pollution in the country. Central Pollution Control Board (CPCB) already showed pollutants levels above the threshold around the industrial sources and metropolitan cities.

These aerosols have two effects on the climate system. One direct effect of most aerosols is to reflect some solar radiation back into space and so act to cool the affected area, although some particulates such as soot are dark in colour and have the opposite effect, causing local warming. The magnitude of cooling or warming depends on the nature of the aerosols and their distribution in the atmosphere. There is also an important indirect effect of tropospheric aerosols. They act as additional cloud condensation nuclei to cause more, smaller, drops to form in clouds, increasing the reflectivity of clouds, further cooling the planet. Aerosols reduce the vital water resources in densely populated regions by suppressing precipitation (Givati and Rosenfeld, 2004). The sand and dust are normally large particles blown by the wind. The size of the dust varies between $10\ \mu\text{m}$ to $100\ \mu\text{m}$, while size of the sand is more than $100\ \mu\text{m}$. The sands and dusts are normally trapped in the nose and throat and cause sour throat. Dust particles smaller than $10\ \mu\text{m}$ can settle in the bronchi and lungs and cause health problems.

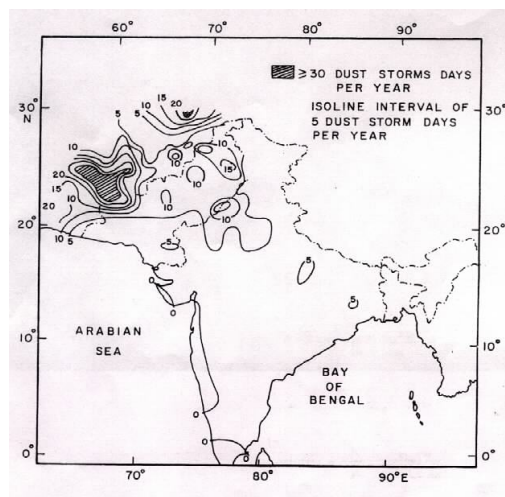
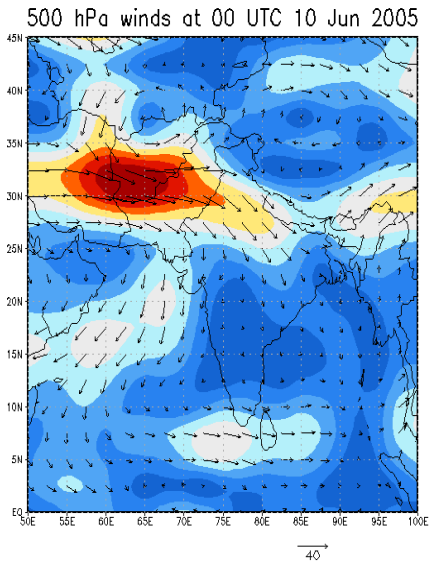
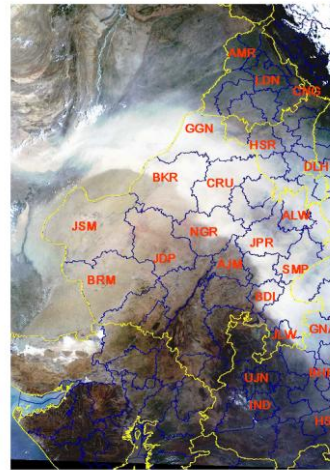


Fig 3: Distribution of Duststorms

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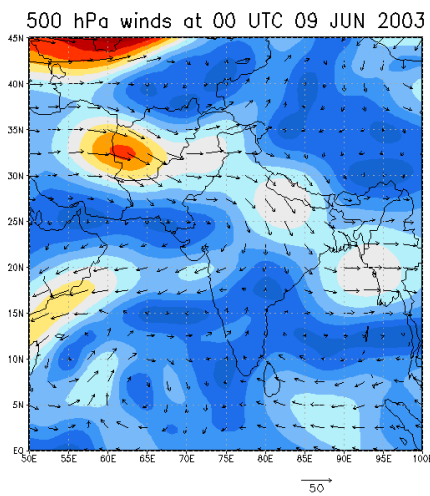
(a) Model reanalysis data



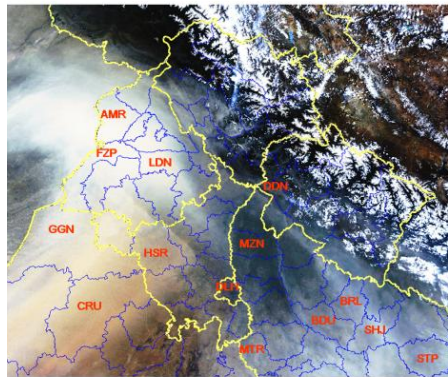
Dust storm over India as observed by MODIS sensor onboard EOS-TERRA satellite on June 10, 2005.

(b) MODIS image areal coverage of dust

Figure 4: 10 June 2005 (a,b)



(a) Model reanalysis data



Dust storm over India as observed by MODIS sensor onboard EOS-TERRA satellite on June 9, 2003.

(b) MODIS image areal coverage of dust

Figure 5: 09 June 2003 (a,b)

Table 1: Annual mean of frequency of duststorms at some stations over Pakistan Area *

Station	Annual mean
Quetta	5.6
Peshawar	13.5
Banu	25.5
Dalbandin	28.6

(*Source: Y.P Rao, 1981, Climate of the Indian Subcontinent in: World Survey of Climatology, vol. 9, Climate of Southern and western Asia: Editors: K. Takahasi and H. Arakawa)

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Table 2: Annual mean of Climatological frequencies (No. of days) of Duststorms/ Squall (DS/SQ) over Indo – Gangetic plains*

Station	Annual mean (DS/SQ)
Amritsar	11.9/8.9
New Delhi (SFD)	8.3/18.5
New Delhi (PLM)	10.3/4.7
Lucknow	7.0/7.7
Allahabad	6.4/4.6
Kanpur	4.9/0.3
Varanasi	2.3/0.0
Patna	2.9/0.2
Gorakhpur	0.9/0.0
Chapra	1.2/0.0
Gaya	2.0/10.5
Bhagalpur	2.8/1.2
Midnapur	0.9/0.1
Kolkata	0.1/19.9
Kolkata (Dum Dum)	0.2/6.6

(* Source: I.M.D. Climatological Tables, 1951 -1980, published in July 1999)

Table 3: Annual mean of Climatological frequencies (No. of days) of Duststorms/ Squall (DS/SQ) over Indo – Gangetic plains (Rajasthan)*

Station	Annual mean (DS/SQ)
Barmer	3.9/0.0
Bikaner	10.0/0.0
Sriganganagar	6.9/0.0
Jaisalmer	2.1/0.0
Phalodi	9.5/0.0
Jaipur	10.3/4.4
Pilani	7.6/0.0
Churu	8.2/0.0
Alwar	2.2/0.1
Bhilwara	2.6/0.0
Dholpur	6.1/0.0
Jalore	12.7/0.0
Kota	6.1/0.3
Nagpur	7.8/0.0

(* Source: I.M.D. Climatological Tables, 1951 -1980, published in July 1999)

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Table 4: Annual mean of Climatological frequencies (No. of days) of Duststorms (DS) over Indo – Gangetic plains (Punjab & Haryana)*

Station	Annual mean (DS)
Bhatinda	3.8
Chandigarh	1.7
Ferozpur	10.8
Ludhiana	3.5
Pathankot	8.8
Patiala	3.1
Ambala	1.3
Gurgaon	0.2
Hissar	9.6
Narnaul	1.9
Rohtak	5.1
Karnal	2.7

(* Source: I.M.D. Climatological Tables, 1951 -1980, published in July 1999)

Table 5: Annual mean of Climatological frequencies (No. of days) of Duststorms (DS) over Indo – Gangetic plains (Uttar Pradesh & Uttranchal)*

Station	Annual mean (DS)
Agra	4.6
Aligarh	4.2
Bareilly	3.4
Mainpuri	2.8
Meerut	0.1
Roorkee	2.5
Dehradun	1.6
Hardoi	2.3
Jhansi	2.4
Banda	1.5
Sultanpur	0.6
Gonda	0.7
Bahraich	2.3
Faridabad	2.5
Fatehpur	2.0
Kheri-Lakhimpur	8.3
Azamgarh	0.4
Ballia	0.8

(* Source: I.M.D. Climatological Tables, 1951 -1980, published in July 1999)

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Table 6: Annual mean of Climatological frequencies (No. of days) of Duststorms (DS) over Indo – Gangetic plains (Bihar, Jharkhand and West Bengal)*

Station	Annual mean (DS)
Darbhanga	0.9
Daltongang	0.7
Dehri	0.3
Motihari	0.2
Muzaffarpur	0.5
Raxaul	0.2
Dhanbad	1.4
Dumka	0.5
Jamshedpur	3.4
Bankura	0.1
Berhampur	0.6
Purulia	2.4
Balurghat	0.5
Cooch Behar	0.1
Krishnanagar	2.0
Malda	0.8

(* Source: I.M.D. Climatological Tables, 1951 -1980, published in July 1999)

Duststorms hazard to aviation, road and rail services

The only sources of dust which need concern to meteorologist are the sandy deserts of the world and the semi-desert regions in the dry season. Dust or sand is raised from the ground by the wind and carried upwards to a height depending on the meteorological conditions and the size of the particles. Whenever the deterioration in visibility is serious, the phenomenon is generally known as duststorm or sandstorm. The terminology is not everywhere the same and the meteorological conditions associated with a 'duststorm' vary widely from place to place. It is therefore necessary that the pilot flying in the regions subject to such storms should make him familiar with local types and special name applied to them. Visibility is reduced to a few hundred meters or even to tens of meters and the vertical extent may be a few thousand feet. They are common during day time but less frequent during night. They constitute a serious hazard to flying on account of their vertical and horizontal extent and their duration.

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