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Satellite Wind shear and fog dispersal

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Abstract:

Winter season (December –February) time over North-West India is badly affected by low visibility Phenomena (Fog /Mist /Haze) every year. Mostly radiation fog generated in clear sky, calm wind and humid (~90 %) conditions or after passing the westward moving synoptic scale weather systems prevails over the area. The day to day activities related to traffic (land, sea, air) and related economic growth of the country severely affected. Timely forecasting of fog is very difficult task for meteorologists. Satellite wind derived products, like shear and shear tendency play an eminent role in the dispersal of fog /stratus over the area. Proper discrimination of fog /stratus in the present Indian scenario is extremely difficult. In near future with the help of technological advancement of INSAT Imager and sounder the discrimination of fog /stratus can be done. In the present work the role of wind shear and shear tendency derived from Meteosat -7 satellites available on Cooperative Institute of Meteorological Satellite studies (CIMSS) global website link is highlighted with reference of Patna airport of Bihar district.

Key Words: Wind shear, shear tendency, fog and stratus.

Introduction:

Indian region enjoys tropical climate in four types of meteorological defined seasons. Winter seasons comes after post monsoon season (sensitive for tropical cyclones) after establishing north –south temperature gradient. Low temperature prevails over Northern India and high temperature over Southern India. The behavior of atmosphere is entirely different from post monsoon season during winter season. Westward moving system known as western disturbance (WD) is the main synoptic system in winter season and main carrier of moisture and rain over Northern part of India. Moisture availability in boundary layers in clear and calm nights generates low visibility conditions over most of the North-West India. These low visibility phenomena is known as fog, mist or haze depending on the visibility. If the visibility is less than 1 km then we call it fog and the visibility range 1-2 km is mist or haze under 5 km visibility range. Hence, the main ingredients of radiation fog are calm wind, ~90 % humidity clear sky and visibility will be less than 1 km. Fog persistency in hours or day made the day to day activities almost paralyzed. It badly affects the economy of the country with loss in terms of traffic (land, air or sea) hazard. WD's affects India throughout the year but during winter there frequencies are more (4-5 in each winter months) and affects especially J & K, North West India. These systems generate induced circulations at lower latitudes and produces rain and low visibility conditions. After passing the WD's the atmosphere have plenty of moisture and temperature also very low, clear and calm night support the fog formation over the region. Meteorological observations based on the surface instruments (temperature, humidity, dew point etc) have inherent limitations and only able to tell the current situations. Real time forecasting of fog is a burning topic for meteorologists. Various attempts have been made in recent past to forecasting the low visibility phenomena's using the numerical weather prediction (NWP) model derived

outputs. NWP output based forecasting of fog success in some cases but unable to capture the sudden change of the atmospheric state. In spite of NWP models have their inherent limitations and the physics of the fog is not correctly parameterized or understood. Active remote sensing by Radar is unable to properly discriminate the reflectivity of fog. Passive remote sensing by satellite (INSAT) is able to capture the areal extent of fog during day time by Visible images (0.55-0.75 um) by the difference of reflectivity's over the fog area. But this will not provide any clue of forecasting of fog. Night time fog can be discriminated by applying the channel differencing techniques in 3 um and 11 um channels. Negative difference denotes the low visibility phenomena pixels and areal extent of night time fog can be estimated. But it will not provide certainty of fog persistency. Technological advancement of INSAT Imager and sounder can provide the channel discrimination of night time fog and inversion layer height by the temperature profiles generated by the sounder. Because the radiation fog is normally lies in inversion layers of the atmosphere. Geo-satellite provides continuous coverage and hourly profiles of temperature. By knowing the inversion layer depth from temperature profiles we can estimate the vertical extent of the fog. Simultaneously observing the moisture profiles of the Geo-satellite we can generate analogues trend of the vertical extents of the fog layers and can generate probabilistic forecasting of fog. This methodology in under progress and will be implemented in future. To know the temporal or spatial range of fog or how much time or area, the fog will persist its dispersal mechanism should be properly understood. This will supports the forecasting of fog dispersal. Prevailing winds and moisture advection systems (anticyclone, trough etc) play an eminent role in this process. Satellite derived wind shear or its tendency provides an idea of dispersal of fog /mist or haze. This paper highlights the use of these products in some of the fog events.

Data and methodology:

Satellite derived wind and shear tendency data utilized in this work has been taken from the global website: http://tropic.ssec.wisc.edu/real-time/ at three hourly intervals. The fog generation mechanism during winter season is normally affected by WDs weather systems which can easily be monitored by the wind shear and its tendency products. Fog dispersal rate is induced by the movement of WDs. Movement of WDs is coupled with atmospheric motion at different layers of the atmosphere and decided by the rate of wind shear or its tendency. By seeing the gradient of winds at various layers the movement of clouds over the area is decided. If shear tendency is increasing and of the orders of 20 to 30 knots, clouds will be disorganize faster and weather will be almost clear and free from fog.

Results and discussions:

Fig (1) shows the mechanism of the radiation fog formation over the area. Moist air close to surface starts lifting up by turbulent mixing till the inversion layer of the atmosphere. Table (1) below shows the visibility condition of Jai Prakash Narayan Airport (JPNI) of Patna (25.6 N & 85.14 E). Fig3 (a, b) below shows the deep layer shear tendency derived from Meteosat -7 satellite wind products. Decreasing shear tendency of the order of 10-20 knot is favorable for fog formation and increasing shear tendency of the order of 10 -20 knot will support the dissipation of fog. This product is available every three hourly on global web –site. In support of the deep layer wind shear tendency sun shine hours also helps dissipation of fog by breaking the inversion in above layers. Bennetts et al (1986) showed physical and dynamical aspects of stratocumulus cloud formation and dissipation and highlighting the role of radiation and turbulence mixing of clouds. Similar concept of turbulence mixing and radiation is used in stratus cloud or fog formation and dissipation.

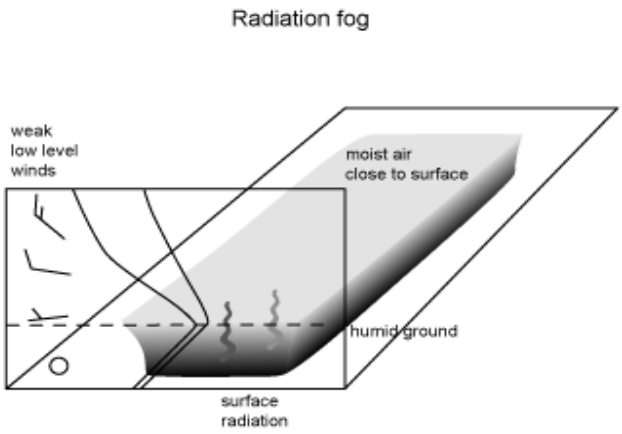

Fig 1: Mechanism of radiation fog

Source:(http://www.zamg.ac.at/docu/Manual/SatManu/main.htm?/docu/Manual/SatManu/CMs/FgStr/backgr.htm)

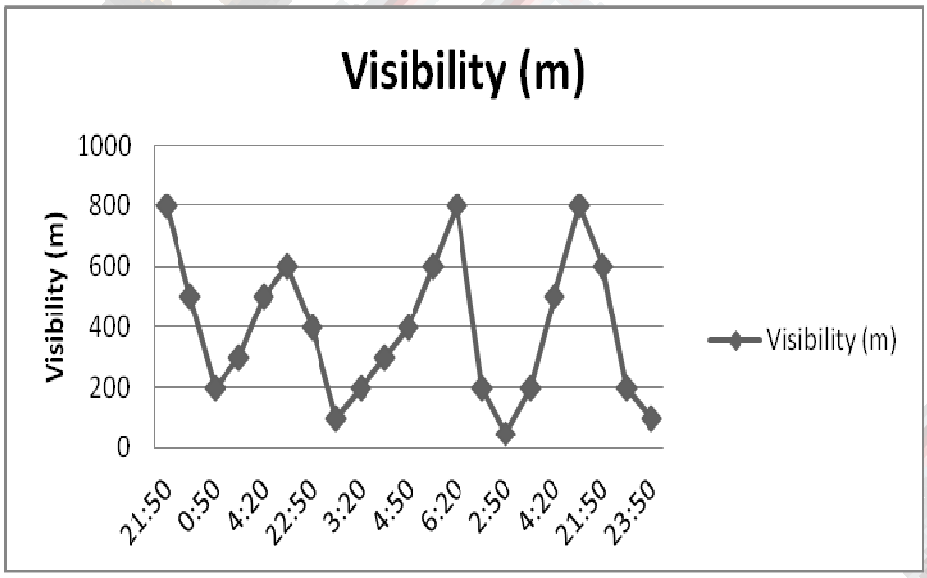

Fig 2: Visibility on 11, 12, 13 and 16 January-2014 at JPNI airport Patna

Table 1: Visibility at JPNI airport Patna

Date	Time (GMT)	Visibility (m)
11-01-2014	21:50	800
	22:50	500
12-01-2014	0:50	200
	3:50	300
	4:20	500
	4:50	600
	22:50	400
	23:50	100
13-01-2014	3:20	200
	3:50	300
	4:50	400
	5:50	600
	6:20	800
16-01-2014	0:50	200
	2:50	50
	3:20	200
	4:20	500
	4:50	800
	21:50	600
	22:50	200
	23:50	100

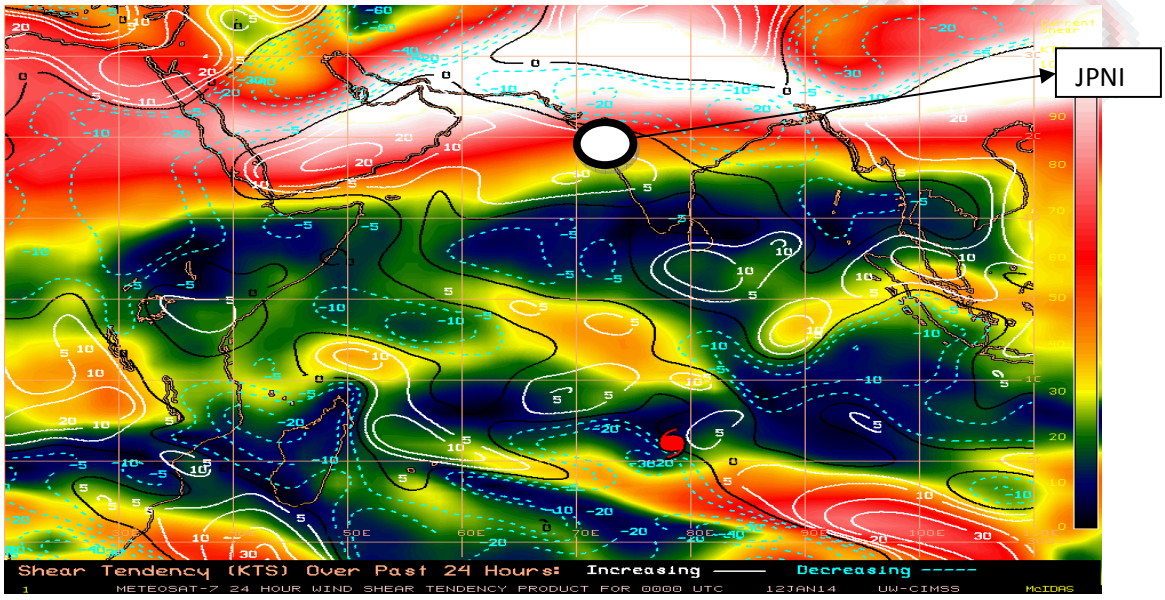

Fig 3 (a): Shear tendency 12 January-2014 at 0000 UTC

{Decreasing shear tendency (10 to 20 knots) over Patna Area (25.6 N & 85.14 E)}

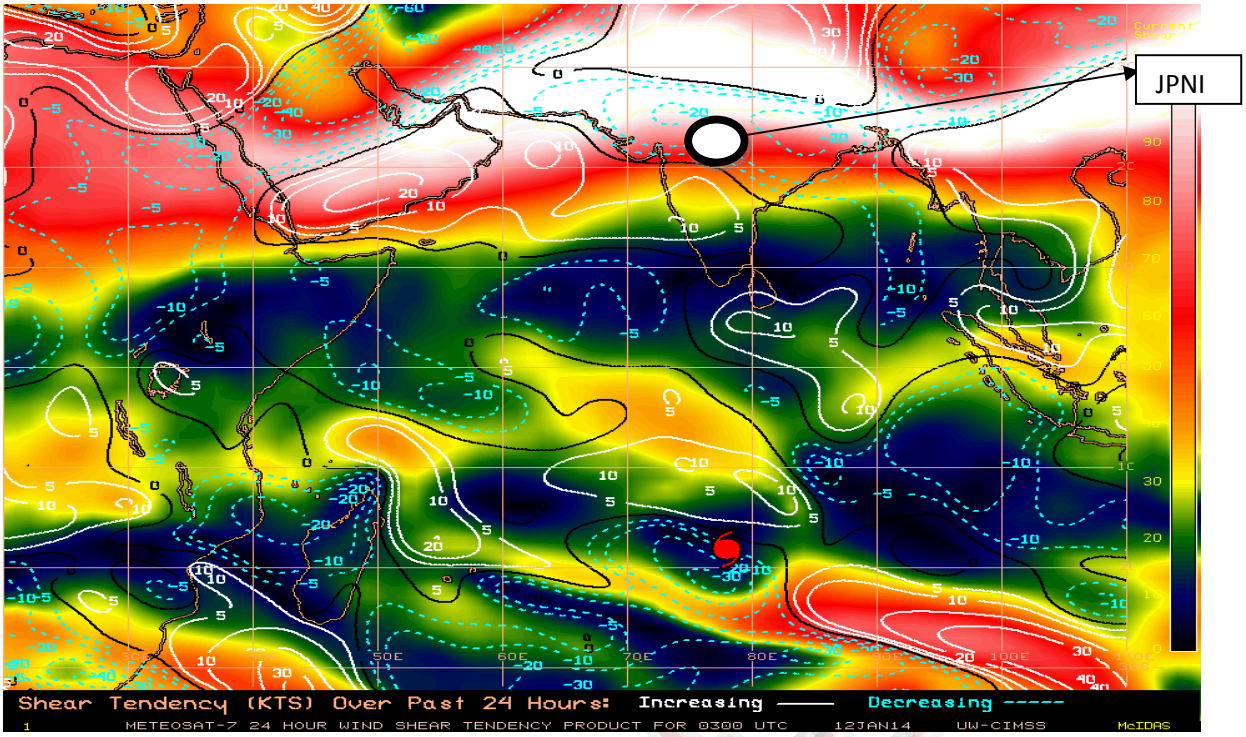

Fig 3 (b): Shear tendency 12 January-2014 at 0300 UTC

{Decreasing shear tendency (10 to 20 knots) over Patna Area (25.6 N & 85.14 E)}

Fog persistence and dispersion:

As shown in the figure 4 below the fog dispersal mainly take place due to heating of cold air layer , entrainment of dry air and disturbance in the inversion layer).On the contrary, the persistency of fog event depends vertical extent of cold air layer below the inversion, tilting of inversion layer and becomes less marked(Ahrens, C,Donalds , 2008). Earlier studies by Hoy, (1973) shows the fog clearance can be forecast by the temperature alone .When the surface temperature exceeded a certain threshold. The work of Eyre et al, 1984 explains satellite based night time fog detection techniques. Kawamoto, K. et al (2001) explains the idea of cloud droplets and water content behavior in understanding the fog persistency and dispersion. Key & Schweiger, (1998) suggests a methodology of radiative transfer in boundary layers and fog dispersal techniques.

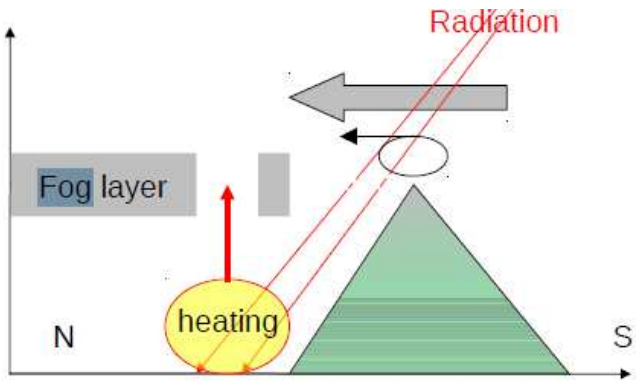

Fig4: Fog dispersal mechani (Source: http://www.iac.ethz.ch/edu/courses/master/lab_fiel_work/weather_discussion/fog)

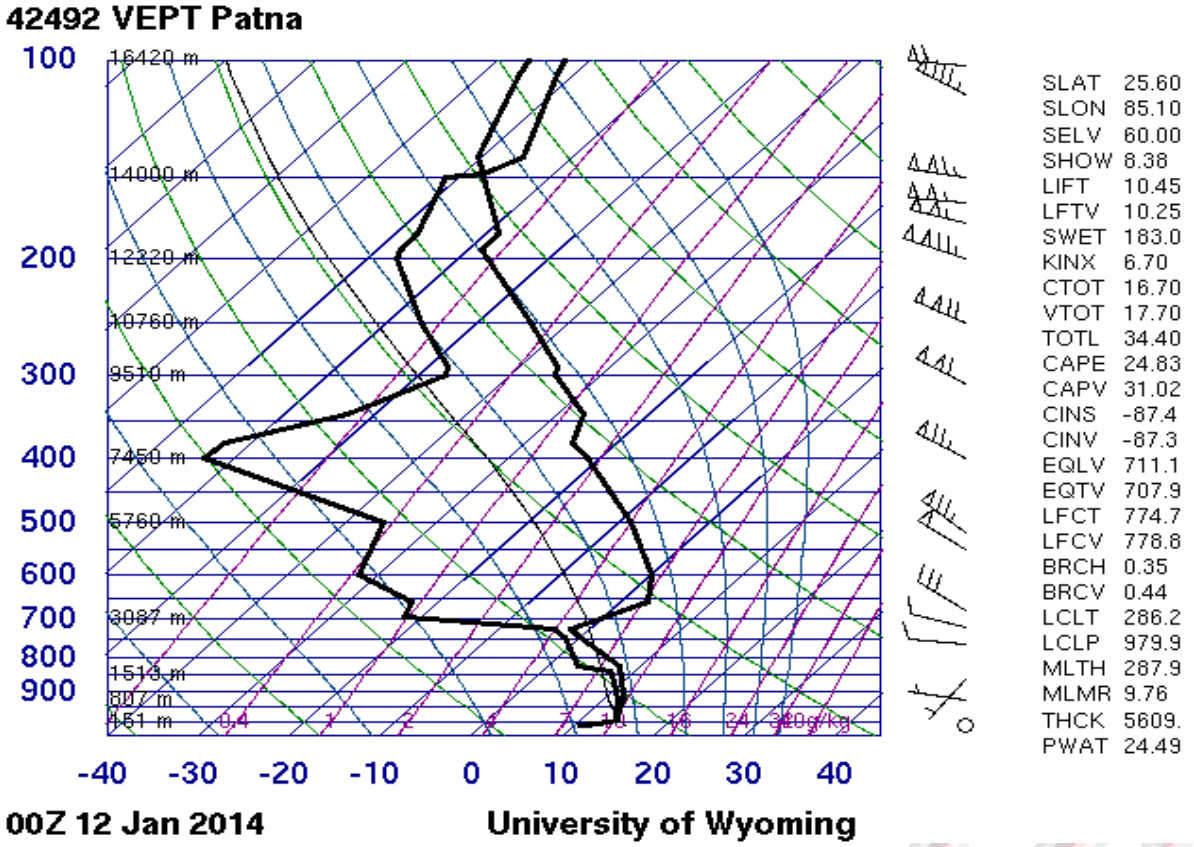

Figure 5: Skew –T diagram of Patna (42492) on 00 GMT of 12 Jan 2014.

Conclusion:

Satellite wind shear plays an eminent role in fog dispersal. If the deep layer wind shear tendency is of the order of 10 -20 knot then it favors the fog dispersal and on the contrary decreasing tendency of almost the same order as increasing one then it favors the fog formation over the area. The topography and local geography of the area modulates the flow and also the wind shear and tendency. Therefore its value differs area to area. Sun light also favors to dispose of the inversion above and in turn fog dispersal. As the product is available globally free for all so we can use it for monitor the low visibilities phenomena's. In the similar way inversion play an important in fog persistency or dispersal. Figure 5 above shows 12th January 2014,0000 UTC radiosonde data plot indicating the well marked inversion over the area. The same is clear from the ground observations of visibility recorded in Table 1.

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