Report

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Project report
(BSCC3151)

On

INSAT 3D/3DR derived wind indices analysis over India for weather forecasting

Submitted in partial fulfilment of the Requirement for the degree of B.Sc. (Hons.) Chemistry

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Uttar Pradesh
May 2022

GALGOTIAS UNIVERSITY
(Established under Galgotias University Uttar Pradesh Act No. 14 of 2011)
School of Basic and Applied Science

CERTIFICATE

This is to Certify that **Ms. Shruti Mishra** has carried out her project work entitled "INSAT 3D/3DR derived wind indices analysis over India for weather forecasting" under my supervision. This work is fit for submission for the award of Bachelor Degree (Hons) in Chemistry.

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CERTIFICATE

This is to certify that Ms. Shruti Mishra has carried out her major project work entitled "INSAT-3D/3R derived Wind Index analysis over India for weather forecasting" under my supervision from 13th January to 31st May-2022. This work is fit for submission for the award of Bachelor's Degree in Chemistry.

I wish her all the best for her upcoming career.

R.K. Giri

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CANDIDATE DECLARATION

I hereby declare that the dissertation entitled "**INSAT 3D/3DR derived wind indices analysis over India for weather forecasting**" submitted by me in partial fulfillment for the degree of B.Sc. (Hons) Chemistry to the Division of Chemistry, Department of Basic Sciences, School of Basic and Applied Science, Galgotias University, Greater Noida, Uttar Pradesh, India is my original work. It has not been submitted in part or full to this University or any other Universities for the award of diploma or degree.

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(Signature)

SHRUTI MISHRA

ABSTRACT

Changing climate is global concern nowadays and many organizations are working together to discuss, analyze and interpret the information in more meaningful way. The conventional information are limited and data sparse regions are mainly depending on the remote sensing (satellite or radar) observations. This remote sensing information's are associated with errors and needs to validate. In this present study IR sounder data onboard on INSAT-3DR satellite has been validated with in situ ground-based Radiosonde data. It is found that the results are agrees fairly well with negative bias of satellite data. Further this analysis is found to be very useful in diagnosing the thunderstorm or dust storm events in more meaningful way at the time of wind gusts etc. Therefore, satellite derived index is very useful in aviation forecasting especially for short duration or helicopter operations. The values of horizontal wind speed and WINDEX during the winter months of January and February are plotted for Delhi, Lucknow, Dehradun, and Varanasi. For disaster managers and decision makers, a study using more data sets from different seasons will be extremely beneficial in estimating the probable damage from the season's predominant weather.

Key words: Windex, Satellite, INSAT-3DR, Algorithm, Remote Sensing

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NOTATIONS

WI: WINDEX

INSAT-3D: Indian National Satellite

INSAT-3DR: Indian National Satellite 3D

METAR: Meteorological Terminal Aviation Routine Weather Report

IMD: Indian Meteorological Department

VIS: Visible

SWIR: Short Wave Infrared

MIR: Middle Infra-Red

TIR: Thermal Infra-Red

SATMET: Satellite Meteorological

UTC: Universal Time Coordinated

CHAPTER – 1

INTRODUCTION

INTRODUCTION

INSAT-3DR has the same configuration as INSAT-3D. INSAT-3D/3DR Sounders' atmospheric vertical profiles of temperature and humidity have created a new dimension to the observational capability for monitoring and predicting quickly emerging weather systems. INSAT-3D and INSAT-3DR work together to give multi-spectral images of the earth and atmosphere every 15 minutes from the Imager and every 30 minutes from the Sounder, ensuring more accurate and fast detection of meteorological parameters over the Indian subcontinent. INSAT-3D/3DR Imagers' enhanced spatial and temporal resolutions have cleared the path for more precise estimates of AMV winds, resulting in better weather forecast. Sounder sensors give 3-dimensional thermodynamic structure of the atmosphere over Indian landmass, helping forecasters to anticipate potential severe weather situations such as thunderstorms ahead of time. Windex is a sounder-derived parameter.

Windex is a useful tool that meteorologists can use to predict the possibility of microbursts. Windex is more accurate at predicting microbursts than traditional statistics indexes such as the lifted index, which measures updraft potential. It is physically significant because it is based on studies of microburst production (McCann DW 1994

Microbursts are outcome of convective downbursts and one of the potential hazardous phenomena that impacts social sectors like aviation community, public utilities and agriculture. Microbursts and outflow boundaries in mountain terrain pose a significant risk to firefighters' safety, as microbursts and outflow barriers can quickly spread a fire to previously safe areas (Luchetti N). Further, dry and wet microburst be categorized on the basis of surface rainfall rate during a microburst (Wakimoto 1985). A wet microburst is associated with powerful thunderstorm precipitation shafts and is associated with substantial rainfall between the begin and finish of the heavy winds. A hybrid microburst is a hybrid of a wet and a dry microburst that is generally linked with thunderstorms with a strong base (Ellord 2002). Wakimoto's (1985) sounding characteristics of a dry microburst environment were taken into account by Windex.

Since pre-monsoon season in India commonly associated with thunderstorm and dust storm activities. Its effects or damaging potential depends on the vertical development and growth the weather system and brings middle tropospheric air down to the surface. Sudden downburst is generally hazardous in nature and its impact depends on the size & area of occurrence, demography, population density etc. These events during pre-monsoon or even monsoon are very common over hilly areas where sudden downpour in a very short time can effect, he society. WINDEX or wind index is the potential of air mass available over the area at a particular instant of time which can cause sudden downpour or microburst. Therefore, its prediction is very difficult and important especially in tropical regions. In tropical region the characteristics of the air masses changes frequently with time and heterogeneous in nature. Their sudden development, vertical growth and sudden downpour over a small area depends so many other processes occur in the atmosphere. As we know there should be sufficient instability present in the atmosphere and environment should be conducive for vertical growth of moisture. In a changing climate scenario this problem is most relevant and concern to understand of such sudden growth and damaging effects. This type of events is more vulnerable when flash flood type of situations occurs and damages multi-fold if strong winds also associated with it & it main becomes intense geo meteorological hazards. Its prediction accuracy will further help to the forecaster's knowledge enhancement, stakeholder's awareness and advance planning, disaster manager's alertness and policy makers can take preventive measure for these vulnerable areas. Therefore, to study such a burning issue is very right and judicial steps. This thermodynamic index (described in detail in data & methodology part) along with other remote sensing derived products or imageries of satellite and radar along with Numerical Model Guidance can help the forecasters to judge the event more meaningful and effective way. The multiplication of 5 in WINDEX equation was done to make it compatible with surface flux. This will further help to decide main geo-hazard regions. It also supports the Government to take preventive and effective measures for these vulnerable geo-meteorological hazard regions. WINDEX is associated is sensitive to lapse rate and lower-level moisture (Caracena and Maier, 1987, Curran et al., 1977, McCann, 1994). There is no universal standard for defining averaging intervals for persistent or gusty winds. The averaging time varies by country, and it varies within countries based on usage. The normal synoptic wind observation in the United States is a 2-minute average. The sustained wind in the United States for a tropical cyclone report or forecast is a 1-minute average.ϒ Most other countries use a 10-minute average for tropical cyclone sustained winds, and some even use a 3-minute average. Anemometer can measure sustained wind speed of three-minute average and usually used to measure the strength like intense thunderstorms/dust storms or tropical storms. Wind gust, on the other hand, is described as a brief (seconds) maximum in the variable wind speed. Traditionally, gusts are monitored and wind forecasts are produced using a gust time tg = 3 s and a sample length T = 10 minute in meteorological applications (WMO, 2014).

Wind speed and direction averaged over the last 10 minutes of each hour are routine observations that are distributed globally via SYNOP and SHIP bulletins. Meteorologists utilise this information, together with other data, to provide a holistic picture of the weather situation. Wind extremes are typically documented in strong wind oases and are only exchanged on a regional scale. Long-term, continuous, representative wind gust observations either surface observations or through remote sensing measurements is the basis for risk assessments and wind gust forecasting.

CHAPTER – 2

LITERATURE REVIEW

LITERATURE REVIEW

The wind index is a new measure created specifically to forecast microburst potential. It is physically significant because it is based on studies of microburst production (McCann DW 1994). Microbursts are the result of convective downbursts and are one of the potentially hazardous phenomena that affect societal sectors such as aviation. Because of their enormous destructive potential, meteorologists are paying closer attention to microbursts. There is enough microburst evolution knowledge in the literature that can be applied on the mesoscale to give some warning to the public and aviation.

According to Fujita and Wakimoto (1983), a downburst is strong downdraft that causes an outflow of damaging winds at or near the surface. According to research by Roberts and Wilson (1989) and Hermes et al (1993), high resolution Doppler radar can detect some microbursts and show precursors that may help accurately locate microbursts. Fujita (1985) classified downburst on the basis of size into two categories. Downbursts with outflow diameters of 4km or greater and damaging winds between 5 and 20 minutes is macroburst whereas microburst is with outburst diameter of less than 4km and a peak wind duration of 2 to 5 minutes. Downburst is localized high wind occurrence caused by convective storms that can be particularly dangerous for aeroplanes during take-off and landing (Ellrod 2000). They are most common during the spring and summer months over the western and southern tier of states, as they are exclusively a by-product of convective processes (Ladd 1989).

Further, dry and wet microburst be categorized on the basis of surface rainfall rate during a microburst (Wakimoto 1985). Whenever there is little or no rain at the begin and finish of strong gusts a dry microburst occurs and it is frequently associated with the time from thunderclouds with a high base. Dry microbursts form when precipitation evaporates, melts, and sublimates, creating intense and turbulent ground-level winds that spread as outflow boundaries radially out from the microburst. They are mostly found in arid and semi-arid locations like the United States intermountain west (Fujita and Wakimoto 1983; Wilson et al. 1984; Fujita 1985). Since outflow boundaries associated with intense dry microbursts are typically associated with high cloud bases and precipitation that evaporates before reaching the ground, they are difficult to predict and observe (Monastersky 1987; Haines 1988; Wakimoto et al. 1994; Potter and Hernandez 2017).

When powerful thunderstorm precipitation shafts and is associated with substantial rains between the begin and finish of the strong winds then wet microburst occur. Other scientists have recognized the classification of microbursts into two types. Rodi et al. (1983)

presented findings from a case study of a dry microburst with blown dust at the surface. Wolfson (1983) uses the terms dry microburst and wet microburst, claiming that the former is caused by innocuous seeming cumulus clouds and the latter is caused by thunderstorms. Caracena et al. (1983) uses the terms dry and wet microburst in the same way that Wolfsen does. Wilson et al. (1984) claims that there are two types of microbursts: dry microbursts and wet microbursts, each with its own forcing mechanism. Hybrid of a wet and a dry microburst which has been commonly associated with thunderstorms with a strong base is known as hybrid microburst (Ellrod 2002).

Previous studies have shown that sub-cloud evaporation of precipitation is a significant factor in downdraft acceleration (Atkins and Wakimoto, 1991; Wakimoto 1985; Kenneth Pyror, 2007). Studies by Roberts and Wilson, 1989; Hermes et al 1993 suggest that High resolution Doppler radar can detect some microbursts and show precursors that may help accurately locate microbursts.

Several important commercial aeroplane accidents, such as the one that happened on June 24, 1975, at New York's Kennedy Airport, were attributed by Fujita (1976, 1985) to the effects of microbursts on aircraft lift. According to the National Transportation Safety Board, twenty-one such fatal accidents were caused by microburst "wind shear" from 1975 to 1994 (Wolfson et al. 1990). Hermes et al 1993 suggest that gust front is a zone of quick wind increase or shear near the front edge of a thunderstorm's cold air outflow. He also stated that wind shear and turbulence at the gust front can be dangerous for landing or taking off aircraft. Forecasters now have useful tools to give the public and aviation a 1–2-hour lead time of microburst potential on relatively small scales by combining the Windex with boundary interpretation in satellite and radar imaginaries.

Other than meteorology, wind gust information is useful in many other applications, such as wind energy, aviation, timber damage assessment, design codes for buildings, bridges, and electrical transmission lines, and resuspension models for deposited radioactive particles (Manasseh and Middleton 1999; Jung et al. 2016; Paulsen and Schroeder 2005; Giess et al. 1997; Pryor et al. 2014; Greenway 1979; Suomi et al. 2013; Wong and Miller 2010). Meteorological elements like as stability and turbulence have a significant impact, but gusts and wind speed are also influenced by nonatmospheric parameters known as metadata (Powell et al. 1996). Furthermore, we have concentrated our report on Windex.

OBJECTIVE

- Calculating Windex using Radiosonde data
- Satellite data is taken as standard to compare values obtain from radiosonde data
- Wind speed data taken from METAR and compare it with Windex from Satellite data
- Utilising the above data to predict the weather

CHAPTER – 3

METHODOLOGY

METHOD AND METHODOLOGY

Wind Index (WINDEX) data from INSAT-3DR, Infrared Sounder over land region (~20 hourly passes) every day is taken from India Meteorological Department (IMD) Lodi Road, New Delhi. This study is focused initially, for Indian airport (New Delhi, Patiala, Dehradun. Lucknow and Varanasi) regions. The actual wind data recorded of the 5 mentioned airports also collected for comparison with satellite derived wind index data. Wind Index calculated from radiosonde observations also competed with INSAT-3DR and found fairly well with radiosonde. Although the collocated data sets with radiosonde data were limited due to frequency of radiosonde data. The methodology adopted for calculation of WINDEX is given below. The Wind Index (WINDEX) is one of the sounder-derived parameters utilized for this purpose, and it estimates the maximum wind gusts. The Wind Index (WINDEX) is a measure created by McCann (1994) [2] that shows the highest probable convective wind gusts in thunderstorms. The following equation represents the WINDEX:

$$WI = 5[H_M R_Q (G^2 - 30 + Q_L - 2Q_M)]^{0.5}$$

where H_M is the melting level's height in kilometers above ground; $R_Q = Q_L/12$ but not more than one; G denotes the lapse rate in degrees Celsius per kilometre from the surface to the melting point; Q_L denotes the mixing ratio in the first 1 km above the surface, while Q_M denotes the mixing ratio at the melting level. Step wise procedure flow diagram is given below

STEP 1: $WI = 5[H_M R_Q (G^2 - 30 + Q_L - 2Q_M)]^{0.5}$ …… (1)

↓

STEP 2: Calculating Height (H_M) i.e., Melting level's height in kilometers above ground. Refer section 1.1**

↓

STEP 3:

Lapse rate(Γ) = Surface level (temp)/ H. After finding lapse rate put it in step 1 formula

STEP 4:

Q_L= Average height of 1000m

Q_L+ 50 and Q_L-50. If there is only one value between the range of height then take the corresponding mixing ratio value else there are multiple value between range of height then take the average of values and find its corresponding mixing ratio then put the value of Q_L in step 1 formula

STEP 5:

Qm = Mixing ratio at melting point

temp 0 +1 degree and temp 0 – 1 degree. If there is only one value between the range of temperature then take that mixing ratio and find corresponding mixing ratio value else there are multiple value between range then take average and find its corresponding mixing ratio value then put the value of Q_M in step 1 formula

STEP 6:

R_Q = Q_L/12, If Q_L<12, then R_Q=Q_L/12

For Q_L>12, take R_Q =1, then put the value of R_Q in step 1 formula

OUTPUT:

Calculated Windex

Section 1.1:** First in Temperature column it will search 0 value, if it will get 0 value take it directly value of corresponding height and convert it into kilometer else took upper 0 value and lower 0 value temperatures and pressure. Upper 0 value(hpa) – lower 0 value (hpa) =X, Upper 0 value(temp) – lower 0 value (temp) =Y, 1 degree Celsius = X/Y = A, A*upper 0 value (temp) = Z, Upper 0 value (hpa) – Z = B. If there is only one value between the range then take that pressure value and find its corresponding height that is B`else if there are multiple value between the range then take B+10 AND B -10. Take all value in between and take average of pressure value and find its corresponding height. Convert this height into kilometre then put in step 1 formula

CHAPTER - 4

RESULT AND DISCUSSIONS

Results and discussions

The specifications of INSAT-3DR 19 channel sounder is given in:

Detector	Ch. No.	λ_c(mm)	ν_c (cm-1)	NEΔT @300K	Principal absorbing gas	Purpose
Long wave	1	14.67	682	0.17	CO2	Stratosphere temperature
	2	14.32	699	0.16	CO2	Tropopause temperature
	3	14.04	712	0.15	CO2	Upper-level temperature
	4	13.64	733	0.12	CO2	Mid-level temperature
	5	13.32	751	0.12	CO2	Low-level temperature
	6	12.62	793	0.07	Water vapour	Total perceptible water
	7	11.99	834	0.05	Water vapour	Surface temp., moisture
Mid wave	8	11.04	906	0.05	Window	Surface temperature
	9	9.72	1029	0.10	Ozone	Total ozone
	10	7.44	1344	0.05	water vapour	Low-level moisture
	11	7.03	1422	0.05	Water vapour	Mid-level moisture
	12	6.53	1531	0.10	Water vapour	Upper-level moisture
Short wave	13	4.58	2184	0.05	N2O	Low-level temperature
	14	4.53	2209	0.05	N2O	Mid-level temperature
	15	4.46	2241	0.05	CO2	Upper-level temperature
	16	4.13	2420	0.05	CO2	Boundary-level temp.
	17	3.98	2510	0.05	Window	Surface temperature
	18	3.76	2658	0.05	Window	Surface temp., moisture

Visible	19	0.695	14367	-	Visible	Cloud

Table 1: Every 100ms, the Sounder monitors brightness in 18 IR and 1 visible channel concurrently over a 10km40km region at nadir. This footprint can be positioned anywhere in the FOR [24°(E-W) 19°(N-S)] using a two-axes gimballed scan mirror. A scan programme mode enables the sequential sounding of a specific area with periodic space and calibration looks. A 'frame' consisting of numerous 'blocks' of the size 640km640km can be sounded in this mode. The INSAT 3D Sounder has reached the end of its useful life, and a new scan method for the INSAT-3D Sounder payload will be introduced on September 23, 2020. INSAT-3D's sounder payload is programmed to cover the Indian land area sector data twenty times and the Indian Ocean region data once. Source:https://www.isro.gov.in/insat-3d/geo-physical-parameters-gpr-derived-insat-3d-imager-and-sounder

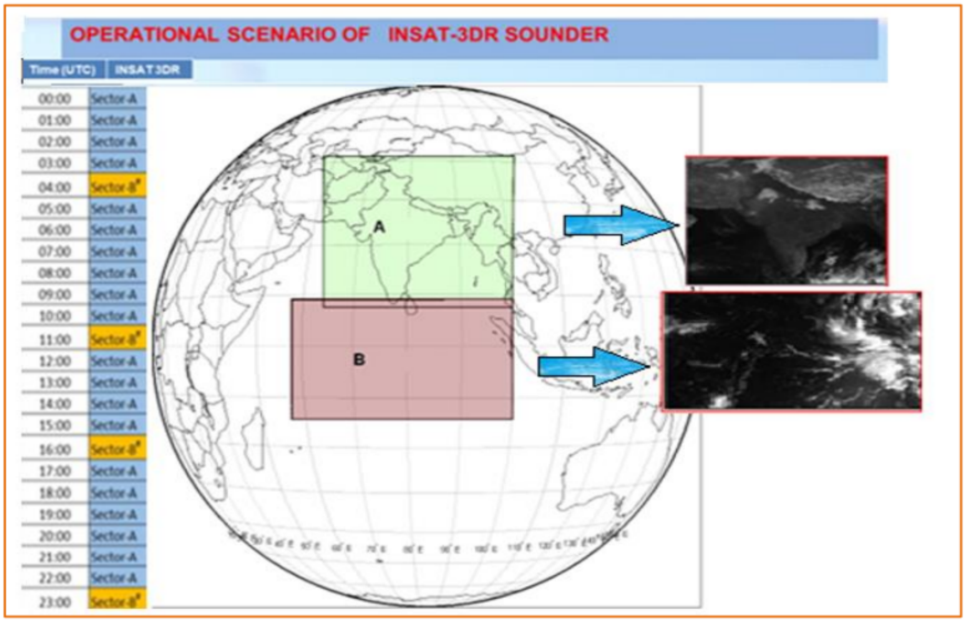
Spectral Band	Wave length (µm)	Ground Resolution
VIS	0.55 – 0.75	1km
SWIR	1.55 – 1.70	1 km
MIR	3.80 – 4.00	1 km
WV	6.50 – 7.10	8 km
TIR-1	10.3 – 11.3	4 km
TIR-2	11.5 – 12.5	4 km

Table 2: Channel Wavelength

There are many applications in meteorology for WINDEX (kt) derived from INSAT-3DR sounder data.

a) Use in convective development of weather system

Sounder-derived parameter Wind Index (WINDEX) from INSAT-3DR satellite scans hourly 20 passes over land and 4 passes over Oceanic region every day.



Scheme 1: Scanning Strategy. Source:https://www.isro.gov.in/insat-3d/geo-physical-parameters-gpr-derived-insat-3d-imager-and-sounder

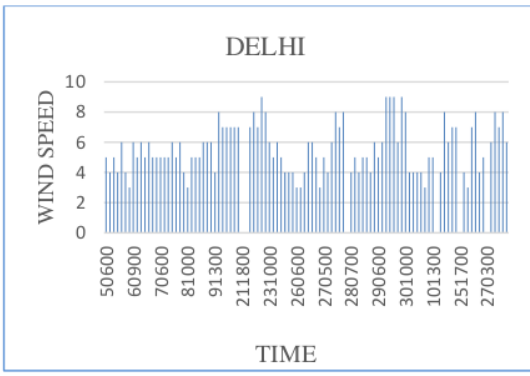
WINDEX (kt) is utilized for estimating the maximum wind gusts and useful for the development of convection, however, the proper understanding requires other environmental factors as well for prediction of weather prediction.

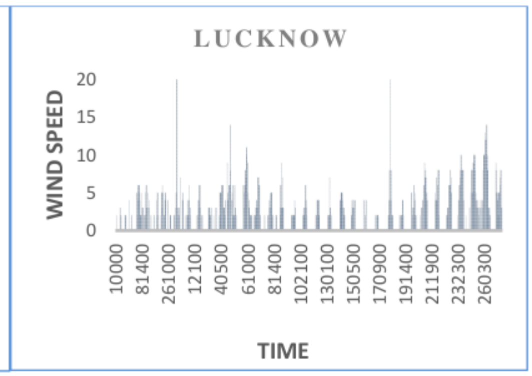
b) Validation with Radiosonde data

WINDEX derived from traditional or in-situ observations by radiosonde observations agrees fairly well with clear sky sounder observations. The sounder instrument from INSAT-3DR measurement temperature profiles at 41 vertical levels of the atmosphere. Satellite processed sounder data hourly and each hourly profile calculates a single value of WINDEX based on the formula given above in the methodology. As the in-situ observations are limited 0000 UTC only and satellite also have its own limitation of clear sky retrievals. Therefore, collocations matchup data set points are very less. During COVID -19 period the radiosonde observations were limited. Therefore, due to limited match-up points we have not present the results for this limited data sets study. We are working on larger data sets to get more matchup points and then results will be updated in graphical format accordingly.

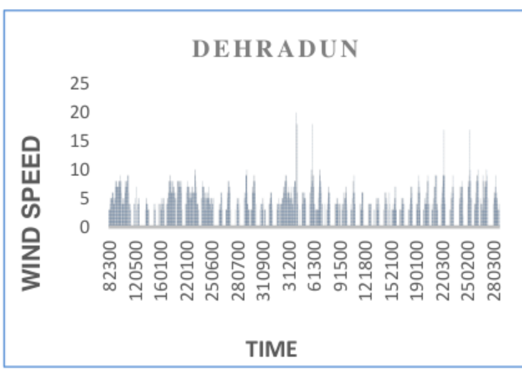
c) Comparison WINDEX (knots) with actual surface observation data

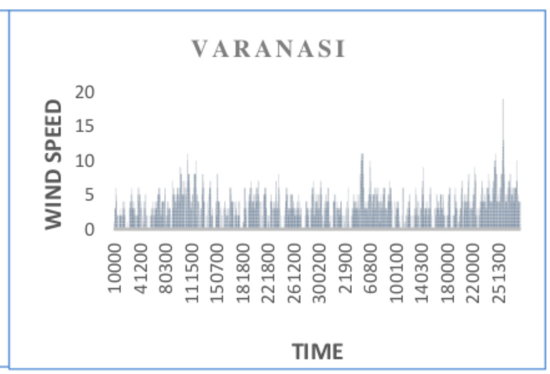
Surface wind data is measured with the help of wind vane and anemometer and have its own importance in meteorology. Beaufort designed a scale based on the surface wind speed intensity and its expected damage associated with the speed. The wind blowing over the earth's surface I exceeds from certain threshold becomes turbulent, and is characterized by random fluctuations of speed and direction. These fluctuations are the main cause of damages. WINDEX derived from satellite sounder in cloud free areas is the vertical representation of temperature & moisture association confined mainly up lifted condensation level LCL) or convective condensation level (CCL). The instability in the atmosphere regulates or decides the moisture up liftment potential over the station area. Therefore, WINDEX also called wind gust potential which is associated with the convective instability of the atmosphere. Greater will be the convection and vertical mixing or instability in the atmosphere more vertical growth will be noticed. On the other hand, surface wind speed in general not directly associated with the WINDEX derived from satellite or radiosonde data. However, lower layer horizontal winds can trigger the transport of moisture horizontally far away and if vertical growth of clouds are high or deep convection is associated with it then WINDEX also will be high and we expect bad weather conditions with more damage. This translation of horizontal wind speed and WINDEX information is further value added by the forecasters or weather scientists before transmit it to public domain.





(a) (b)





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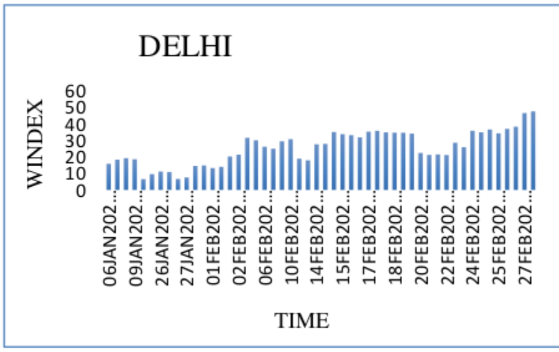

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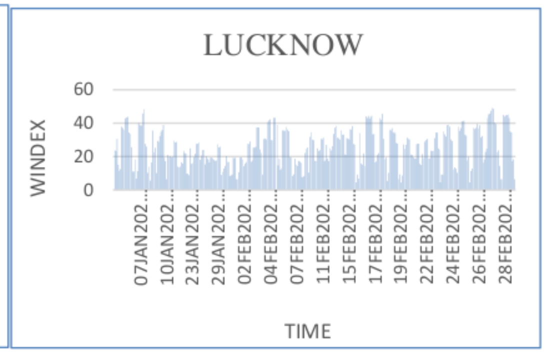

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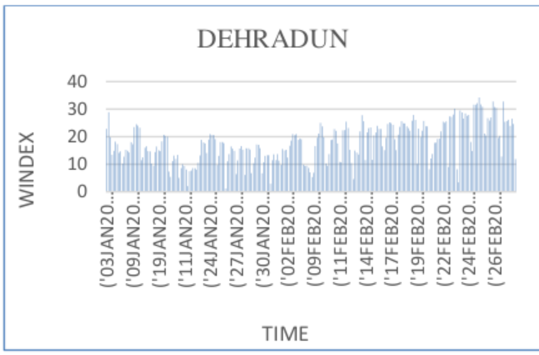
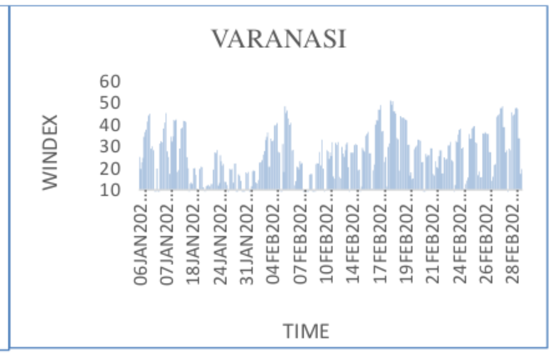
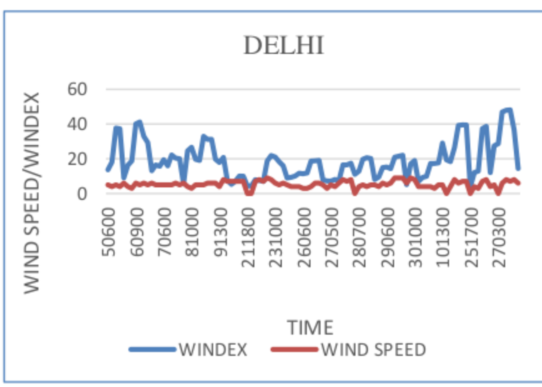


(g)

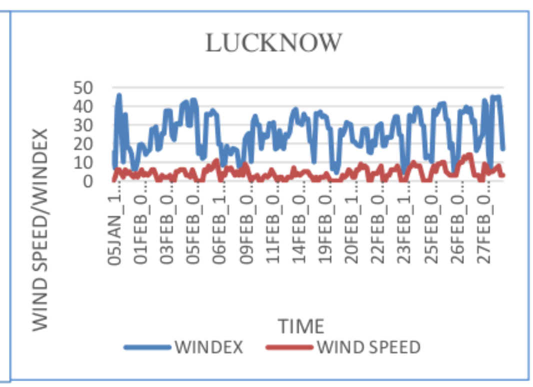


(h)

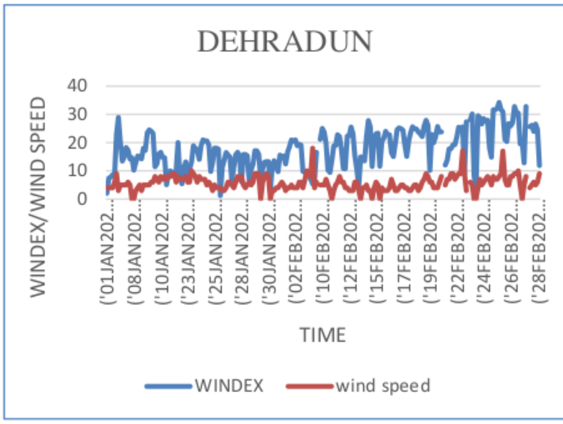
Figure 2: Graphical representation of different stations showing Windex vs Time in the months of January and February 2021 of stations as follow: (e)Delhi, (f)Lucknow, (g)Dehradun and (h)Varanasi



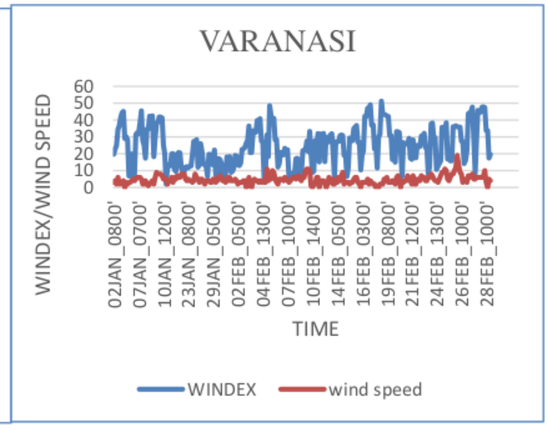
(i)



(j)



(k)



(J)

Figure 3: Graphical representation of different stations showing Windex/Wind speed vs Time in the months of January and February 2021 of stations as follow: (i)Delhi, (j)Lucknow, (k)Dehradun and (l)Varanasi

Therefore, the knowledge of the horizontal wind speed and WINDEX together can be better customized to know the expected area of impact or location specific expected damage information. Keeping in mind this fact both the values horizontal wind speed and WINDEX are plotted for Delhi, Lucknow, Dehradun and Varanasi for the months of January and February winter seasons. Study with more data sets of different seasons will be really useful for disaster managers and decision makers to estimate the expected damage of the prevalent weather of that season.

CASE STUDY

In the case of thunder with rain observed around Delhi during 17 May 2022 to 23 May 2022.We saw wind index graph last 5 to 6 days of May and observed when thunderstorm cell formation started Windex values are respectively Higher Wind Index have high wind guard potential and on high Windex day many trees are uprooted and caused damage same wind speed observer in METAR report also so in future wind index become one of the important phenomenon while thunderstorm event occurs it may be very helpful for forecaster to predict such phenonemenon with the help of these index also.

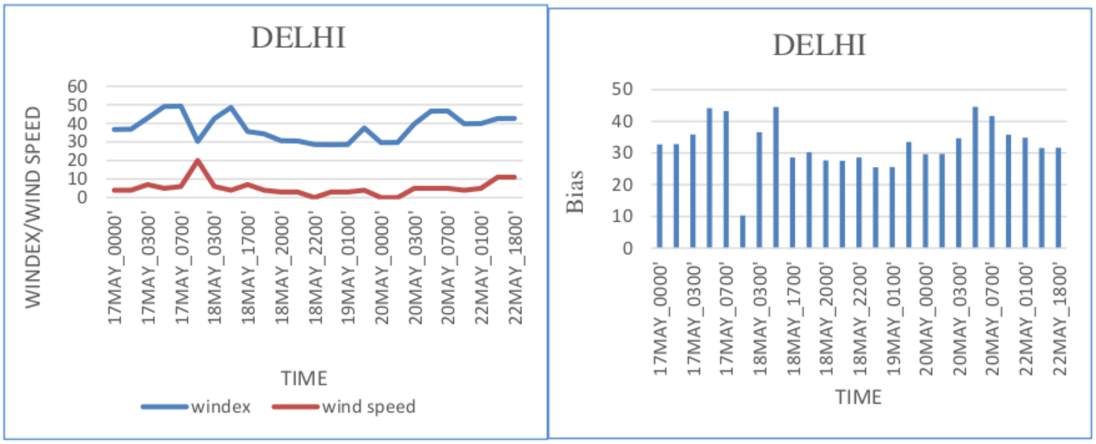
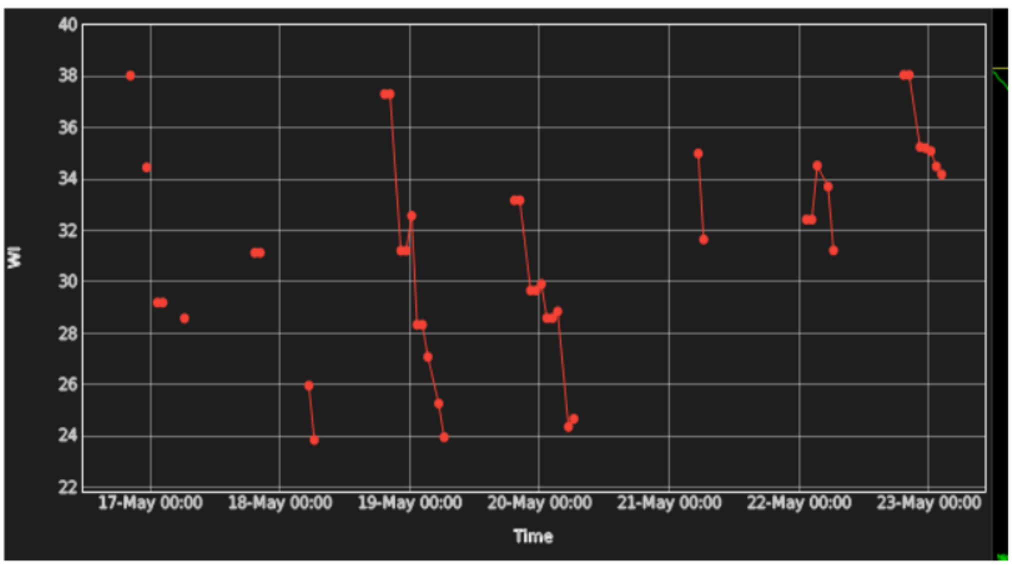


Figure 4: Graphical representation of Delhi stations in the months of May 2022 showing (m) Windex/Wind speed vs Time and (n) Bias vs Time of the same time span.



Scheme 2: Graph has taken from satellite rapid website rapid.imd.gov.in in that thunderstorm days wind index value are supporting to thunderstorm event

Hence, this information is useful for public to provide warning. So, its proper monitoring can save life and property. This is generated with Rapid visualization tool of INSAT-3R.

CHAPTER - 5

CONCLUSION

CONCLUSION

Wind gust potential accompanied with thunderstorm is sometimes hazardous for mankind. Microburst activities well find out by wind index so many thermodynamic indices are available to study different phenomenon here Wind index is very useful for finding convection. Its role in aviation services is also very important during windy situation especially low-level flight or helicopter operations. This index along with other indices can be utilized for thunderstorm forecasting also. In future this wind index sounding feature will help in combining radiosonde-based wind index with different satellite and Radar imaginary to animate finding location of occurrence of microburst phenomenon.

The combined customized information of the horizontal wind speed and WINDEX together can help to demarcate the expected area of impact or location specific expected damage. We know that high value of WINDEX support the high vertical convective development and can cause more damage over the area. At the same time if we have high values of horizontal wind speed measured with anemometer then the moisture can advect over large area and it can affect more population over the area. Therefore, damages and losses will be more in densely populated areas as compared to less dense area. At the same time it will also depends how intense the weather system was and season in which the weather event occurred or occurring.

Keeping in mind this fact both the values horizontal wind speed and WINDEX are plotted for Delhi, Lucknow, Dehradun and Varanasi for the months of January and February winter seasons. Study with more data sets of different season will be really useful for disaster managers and decision makers to estimate the expected damage of the prevalent weather of that season.

CHAPTER – 6

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