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On Aerosol Properties during Uttarakhand Forest Fires 2016 – A Remote Sensing Approach

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Abstract—*In 2016 a large amount of smoke was dispersed into the atmosphere from forest fires in the state of Uttarakhand thereby affecting the air quality in the surrounding regions. The detection of smoke aerosols has been carried out by using data from Moderate Resolution Imaging Spectrometer (MODIS) & Ozone Monitoring Instrument (OMI). The smoke transport has been shown using Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model from National Oceanic and Atmospheric Administration(NOAA). The sink area was found out to be mid-Nepal, Tibet and upper parts of Uttar Pradesh.*

1. INTRODUCTION

Forest fires affect the climate, and air quality in and around the forest areas under study by affecting the aerosol density in the atmosphere. This paper aims to develop a relation between forest fire in Uttarakhand and smoke aerosol in the potential sink regions. Starting from the last week of April to the first week of May 2016, forest fires took place in numerous places across the state of Uttarakhand and affected more than 4500 hectares of land [1]. These forest fires in the sub-Himalayan region, produced thick clouds of smoke in the affected region. We have used data from Moderate Resolution Imaging Spectrometer (MODIS) from Terra satellite & Ozone Monitoring Instrument (OMI) for spatial identification of smoke aerosol at the fire points identified from MODIS Fire/Thermal Anomaly Product. National Oceanic and Atmospheric (NOAA)'s Hybrid Single Particle (HYSPLIT) forward trajectory model has been used then to show that smoke aerosol from Uttarakhand has been transported to Nepal.

2. STUDY AREA

In Uttarakhand forest region accidental and intentional wildfires is a common phenomenon during dry summer months every year [1,3]. Figure 2 depicts the area under study (lat. 28.58° to 31.89° N; long. 77.52° to 80.93° E). Dehradun, Haridwar, Tehri Garhwal, Garhwal, Almora and Nainital were the worst hit during the 2016 Uttarakhand fire incident. But for a wider study of the aerosol distribution after the fire, we have taken the whole of Uttarakhand as the study area.

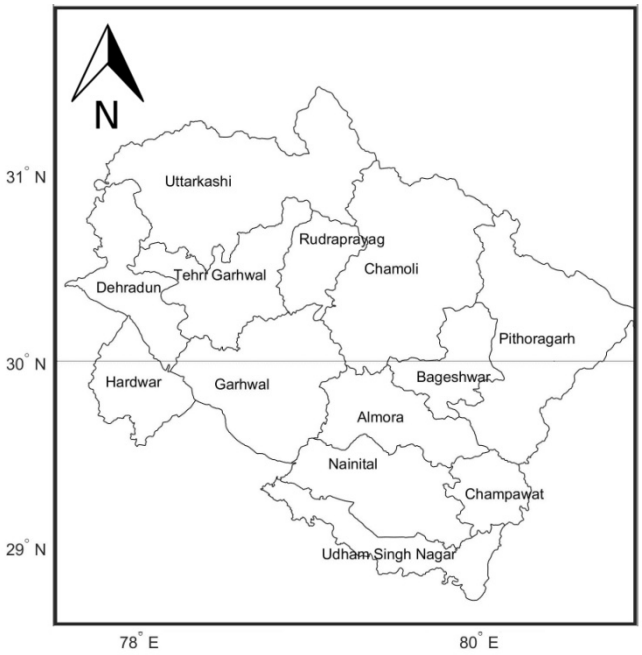

Figure 1: Source Area - Indian State of Uttarakhand

3. DATA SOURCES

The data sources used in this study include MODIS Aerosol, MODIS Fire, OMI Aerosol. The usages of these datasets in the study are described in details as follows:

3.1 MODIS Aerosol Level 2 AOD Data

The MODIS Aerosol L2 product retrieves AOD over cloud-free snow/ice-free land and ocean surfaces at 10 km resolution. Data calculated using two different algorithms are provided over land, known as Deep Blue and Dark Target

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Land [3,10]. Here we have used data from MODIS – Terra only.

3.2 OMI Aerosol Level 2 Data

The OMI Level 2 Aerosol Product contains georeferenced aerosol column amount information. It uses multi wavelength UV-VIS algorithm consisting of 14 different wavelengths in the range of 331-500 nm to calculate the aerosol optical thickness and discriminate between various types of aerosols [4]. OMI Aerosol Level 2 products contain data at 13 x 24 km2 spatial resolution.

3.3 MODIS Thermal Anomalies/Fire Level 2 Data

This product is primarily derived from MODIS 4 & 11 µm radiances. The fire detection strategy is based on absolute detection of a fire, and on detection relative to its background. This data is acquired at a spatial resolution of 1 km [5,9]. Here we have used data from MODIS – Terra only.

In table I we have listed the data availability for various satellite data sets used in our study in the extended study period in the source area starting from 22nd April 2016 to 5th May 2016.

4. METHODOLOGY

4.1 Studying the source area – Uttarakhand

4.1.1 MODIS AOD against MODIS Fire/Thermal Anomalies. We have first identified the areas affected by forest fire using Level 2 MODIS Fire/Thermal Anomaly where the confidence flag is greater than 50 and then we have plotted AOD calculated using Deep Blue algorithm over the study area [9,10]. In Figure 2 the result has been plotted over the study area using data from MODIS – Terra. The variation in spatial mean for the data from MODIS – Terra for the period starting from 22nd April to 5th May has been graphically represented in Figure 2.

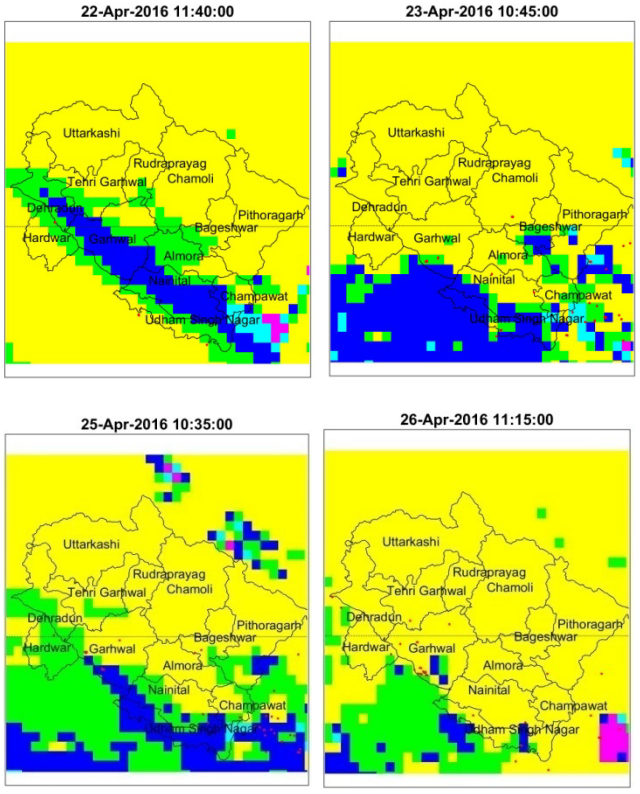
Table 1: Data Availability

Dates	MODIS Aerosol Level 2	MODIS Fire/Thermal Anomalies Level 2	OMI Aerosol Level 2
22/04/2016	Yes	Yes	Yes
23/04/2016	Yes	Yes	No
24/04/2016	No	No	No
25/04/2016	Yes	Yes	No
26/04/2016	Yes	Yes	Yes
27/04/2016	Yes	Yes	No
28/04/2016	Yes	Yes	Yes
29/04/2016	No	No	Yes
30/04/2016	Yes	Yes	No
01/05/2016	Yes	Yes	No
02/05/2016	Yes	Yes	No
03/05/2016	Yes	Yes	Yes
04/05/2016	Yes	Yes	No
05/05/2016	Yes	Yes	Yes

4.1.2 OMI AI against MODIS Fire/Thermal Anomalies. We have identified the areas affected by forest fire using Level 2 MODIS Fire/Thermal Anomaly and plotted the fire points accordingly [9]. Then we have plotted AI taken by the UV spectrum from OMI over the study area [11]. In Figure 3. the derived result has been plotted over the state of Uttarakhand. The variation in spatial mean of AI at the source starting from 22nd April 2016 to 5th May 2016 has been shown graphically in Figure 3.

4.2 Using NOAA's HYSPLIT model to find the potential sink areas

The forward air mass trajectory analysis HYSPLIT model reveals the potential sink of aerosols transported from the fire source [7,8]. The HYSPLIT model of Air Resources Laboratory(ARL), NOAA, is a complete system for computing sample air parcel trajectories to complex dispersion and deposition simulations. The model requires meteorological REANALYSIS files available online.



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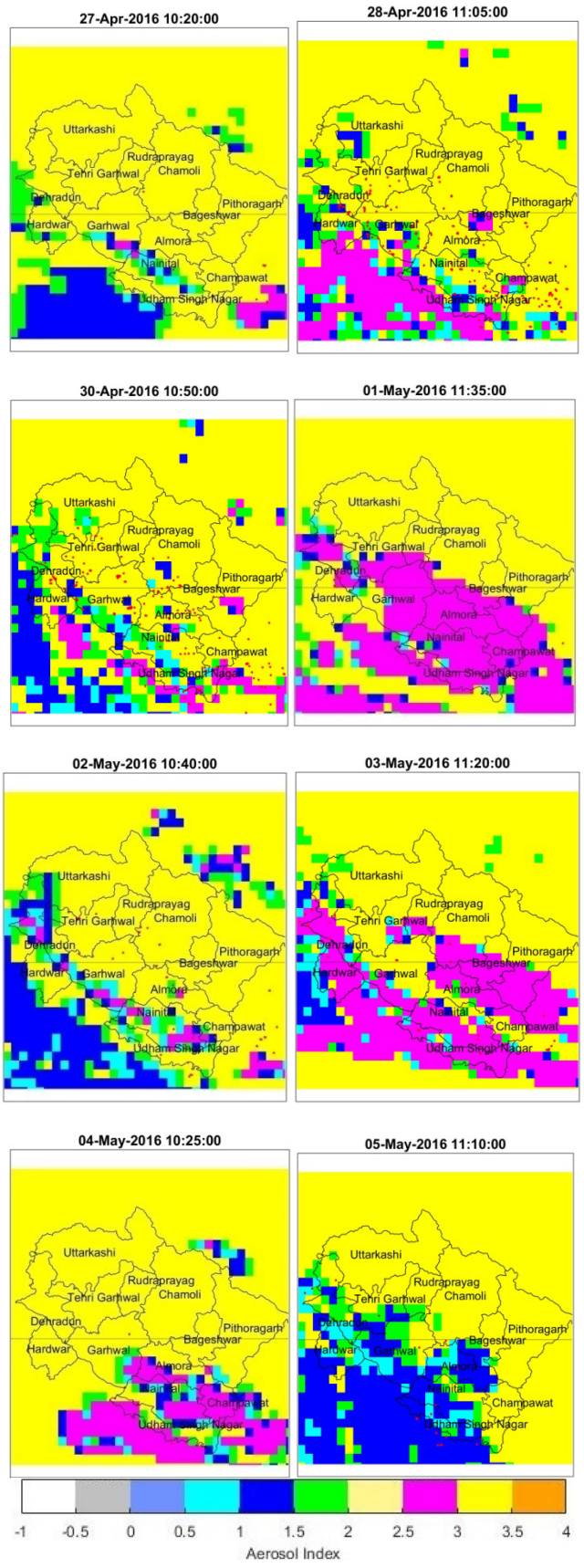


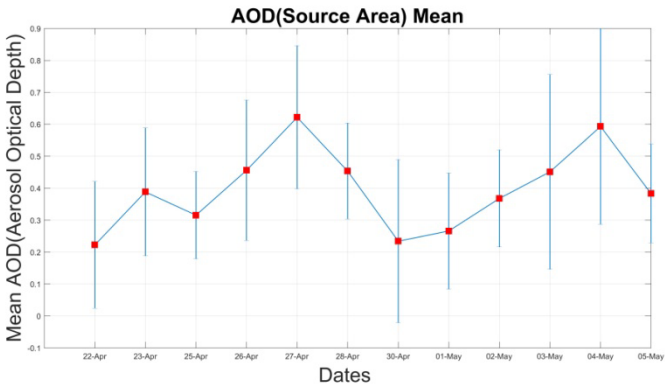
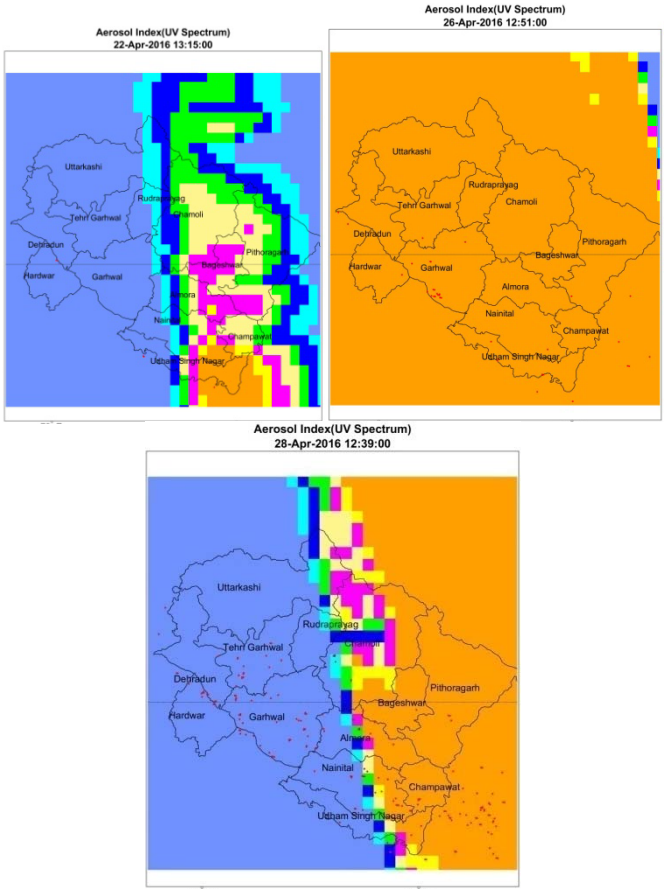


Figure 2: MODIS – Terra AOD against MODIS Fire/Thermal anomalies



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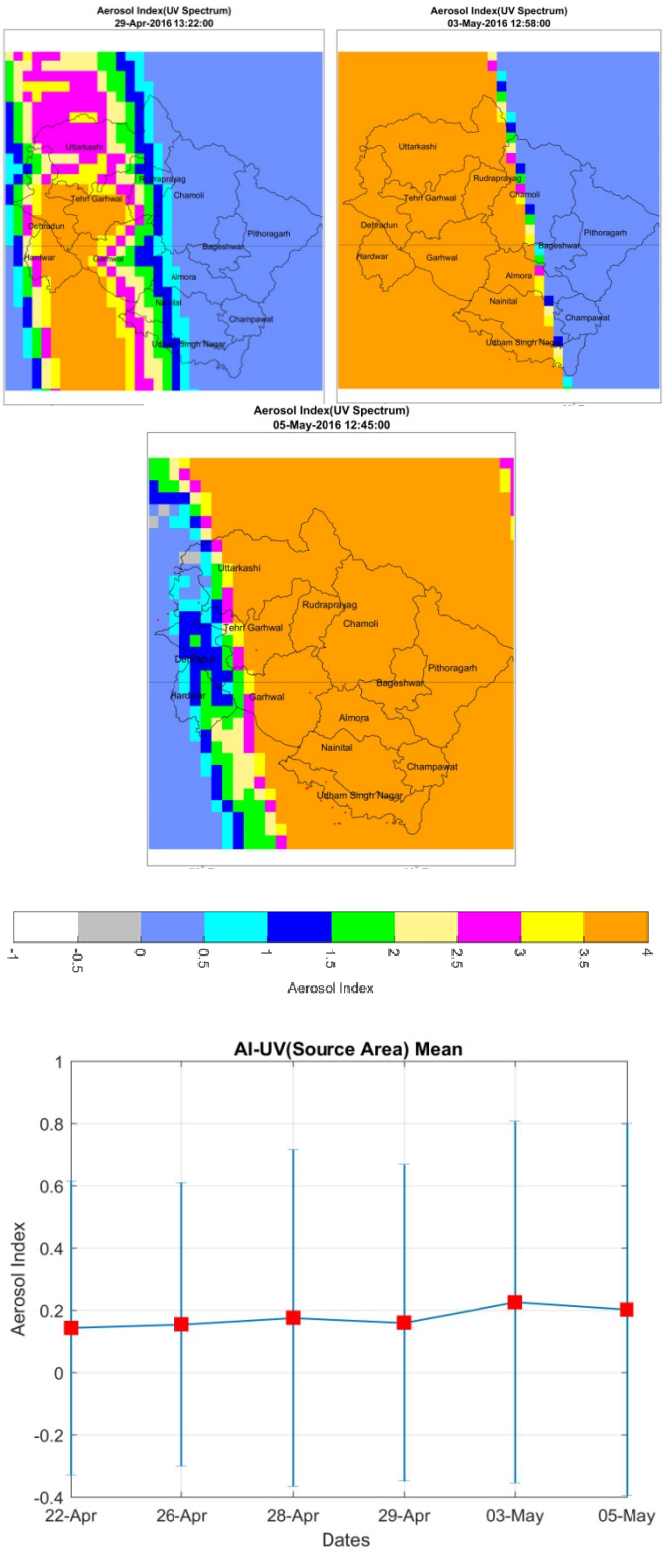
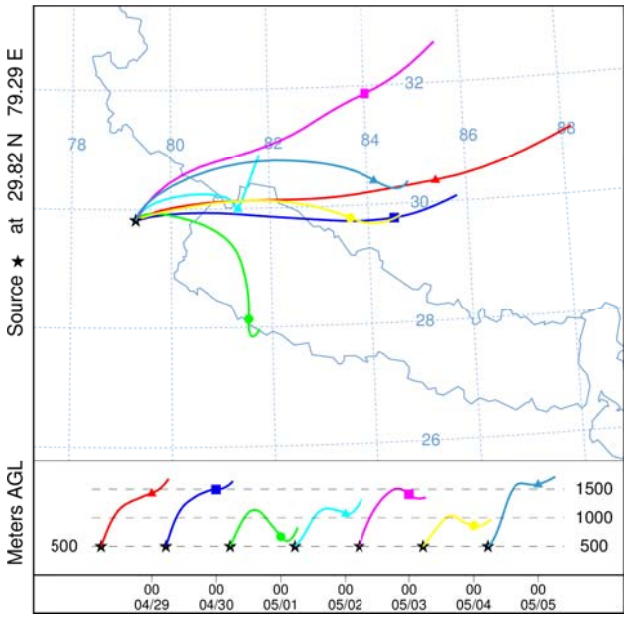
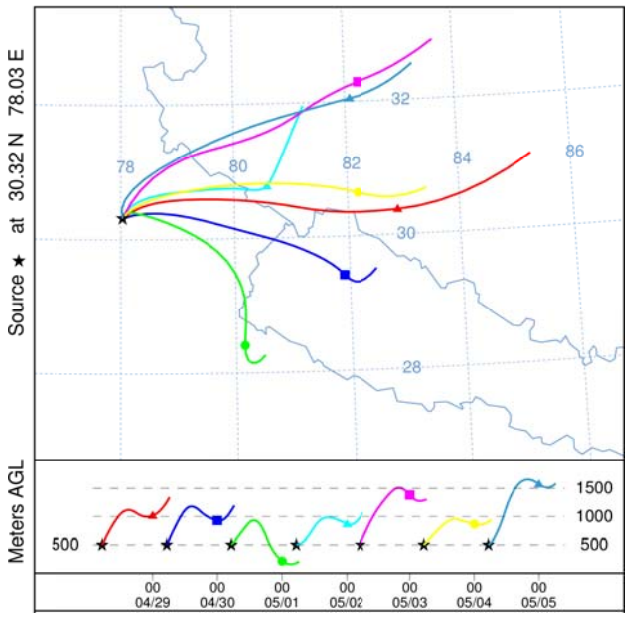


Figure 3: OMI AI-UV against MODIS Fire/Thermal Anomalies at Source Area (Indian State of Uttarakhand)



(a) Almora



(b) Dehradun

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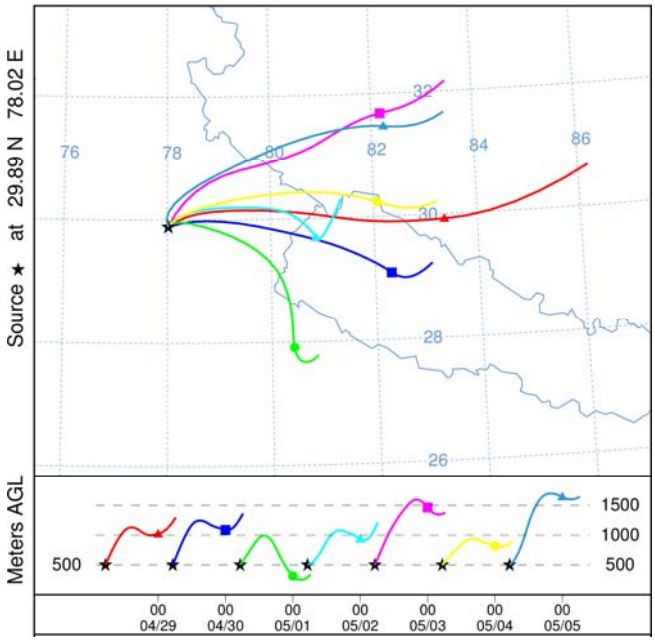
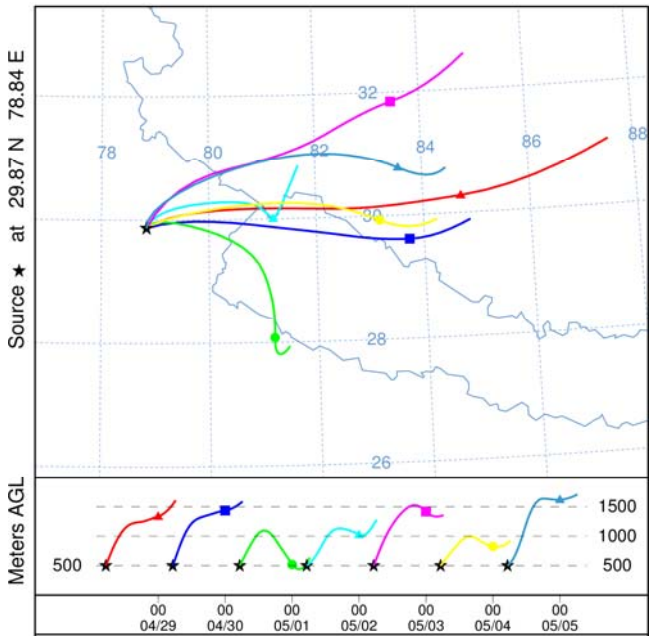
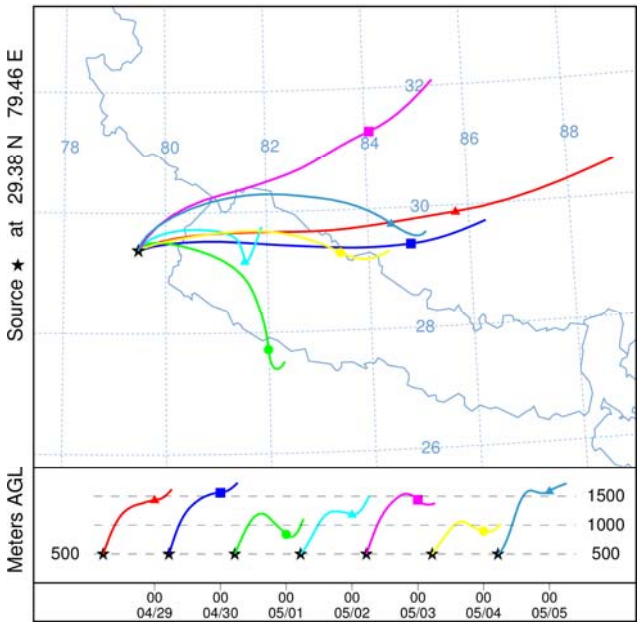


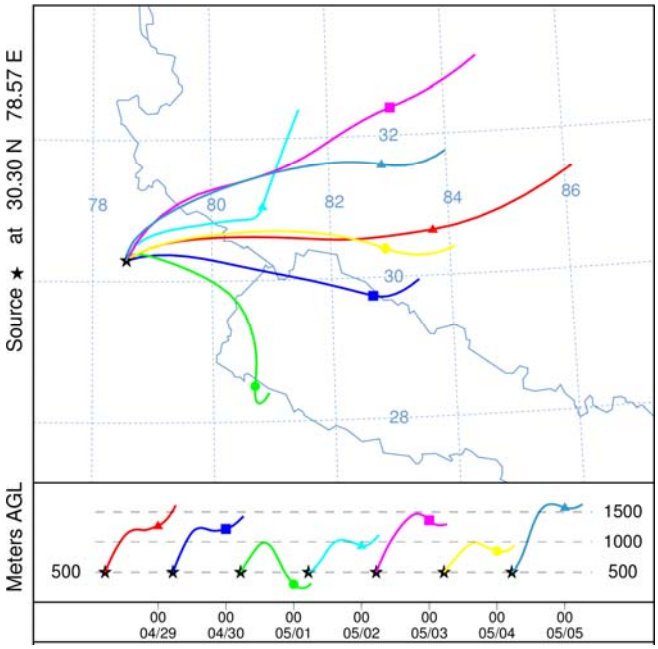
(c) Haridwar



(e) Pauri Garhwal



(d) Nainital



(f) Tehri Garhwal

Figure 4. NOAA HYSPLIT forward trajectories for 28th April 2016 showing air transport from source to sink

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Almora, Dehradun, Haridwar, Nainital, Garhwal, & Tehri Garhwal has been taken as the source points for the air trajectory model. As we have already discussed that these regions were the worst hit by the fire incident. Figure 4, depicts the forward air mass trajectories derived at 500 m AGL for 28th April to 4th May using the HYSPLIT model [6]. 28th April has been considered to be the starting date for the HYSPLIT model, as from Figure 4 the fire we can say it was most intense on 28th April 2016 from density of MODIS fire points. Three altitude level, 1500 m 1000 m & 500 m AGL has been considered at the sink site. From the results of NOAA's HYSPLIT forward trajectories model as shown in Figure 6, we have considered a rough sink area from 27° N to 32° N & 82° E to 86° E, consisting Nepal, parts of Tibet, Indian states of Uttar Pradesh & Bihar as shown in Figure 5 can be taken as the potential sink regions.

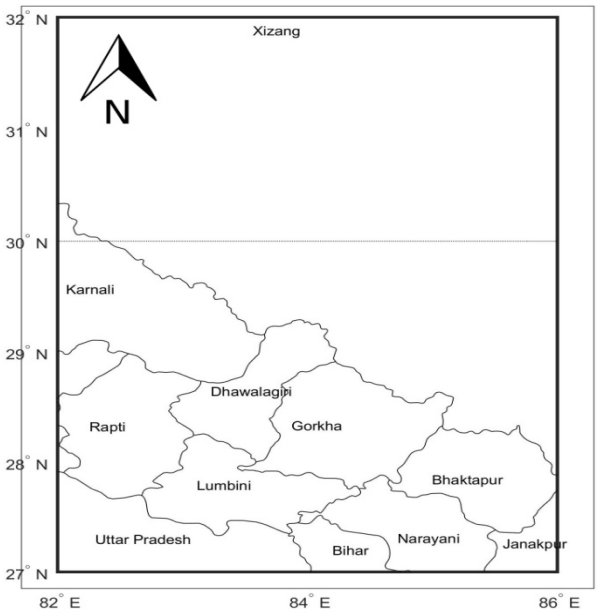

Figure 5: Sink Area - Nepal and Tibet

5. CONCLUSION

Forest-fire in Uttarakhand occurred during the early summer of 2016. The forest-fire smoke was transported in the atmosphere in two major routes of northeastern and eastern directions. The forest-fire smoke might have a potential impact on the atmospheres of the neighboring Indian provinces and even in the neighboring countries. The potential sink areas of the smoke generated from the forest-fires were mainly scattered over, North of Indian province of Uttar Pradesh, southern parts of Tibet, and Northern parts of Nepal. This study does not exclude any other source for these aerosols near the potential sink regions. Study of vertical aerosol profile are yet to be explored to ascertain the smoke plume height during the fire incident and vertical aerosol properties. Future works are required to establish annual atmospheric and climatic change in the potential sink areas due to the forest fires, as this is quite a regular phenomenon.

6. ACKNOWLEDGEMENTS

We are most grateful to MODIS team and OMI team for providing us access to MODIS – Aerosol, MODIS – Fire and OMI. In particular we are indebted to National Oceanic Atmospheric Administration (NOAA)'s Air Resources Laboratory (ARL), for providing access to Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model for forward and backward air-mass trajectories. Thanks, are also due to the Director, IIRS, Dehradun for his constant support and encouragement.

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