Atmospheric Conditions Conducive to Forest Fire Events in the Greater Himalayan Region

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ABSTRACT

During the last decade, there has been a dramatic rise in Forest Fire incidents over the Indian Himalayan region, leading to a considerable loss of life and property. To mitigate and manage the impact of forest fires through a Forest Fire Early Warning System, a better understanding of both small and large-scale atmospheric processes conducive to the spread of forest fires is required. Although significant progress has been made in disseminating forest fire danger information, most of the operational methodologies in the Indian sub-continent still do not consider real-time weather forecasts from atmospheric numerical models as input to the fire module. The objective of this work is to systematically analyze the meteorological conditions during two major forest fire events that occurred over the Uttarakhand region in 2016 and 2020. Forest fire events in 2016 and 2020 coincide with El Nino, La-Nina and cycles of Indian Ocean Dipole (IOD). A detailed analysis of the 2016 and 2020 fire events shows an increased frequency of fire events and burnt areas in 2016, whereas the area burnt was considerably low in the 2020 event. A typical year without significant influences from ENSO and IOD shows relatively low spread of fires and burnt areas. Such an impenetrable correlation between atmospheric oscillations and fire events results in vast damage over the Indian Himalayan region. The inculcation of real-time weather forecasts with numerical weather prediction models could tackle this existing gap in the Forest Fire Early Warning System and possibly mitigate the further casualties caused by the increased acceleration of fire spread induced by atmospheric oscillation over the Indian Himalayan region.

MOTIVATION

1. The impact of short-term climatic variability is often underestimated while generating the output for Forest Fire Early Warning System(FFEWS) in the Indian context.
2. The current FFEWS in India does not consider inputs from Numerical Weather Prediction Models and other Atmospheric oscillations, which is in fact, the most important factor in understanding fire propagation and spread and may lead to more fire spread and associated casualties.
3. Such uncontrolled wildfire leads to a reduction in forest cover affecting the ecosystem imbalance and associated pollution (Lazaridis et al., 2008) in the Indian Himalayan region.
4. Emissions of aerosol from the incomplete combustion leading to emission of more greenhouse gases to the atmosphere enhancing global warming (Kostrykin et al., 2021).
5. Emissions of carbon particles that deposit on the glacial surfaces, leading to a decrease in albedo and further enhancement of global warming.
6. Forest fires make the burnt area easily vulnerable to landslides (Rengers et al., 2020).
7. Alteration produces severe impacts on soils leading to their loss and erosion after fire occurrence, along with greenhouse gas emissions, change of climate patterns, and loss of ecosystem values and environmental services.

BACKGROUND

1. In India 54.40% of forests are exposed to occasional fires, 7.49% to moderately frequent fires and 2.40% to high incidence levels while 35.71% of India's forests have not yet been exposed to fires of any real significance.
2. Nearly 4 % of the India's forest cover is extremely prone to fire, whereas 6% of forest cover is found to be very highly fire prone.
3. A number of 52,785 forest fires were detected using MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor and 3,45,989 forest fires were detected using SNPP-VIIRS (Suomi-National Polar-orbiting Partnership - Visible Infrared Imaging Radiometer Suite)in forest fire season from Nov 2020 to June 2021.
4. Over 4500 forest fires are recorded in Uttarakhand, burning over 0.6 million hectares of forest annually (Babu et al., 2017).
5. Most of the forest fires in Uttarakhand are man-made and more than 50% of mountain forests in Uttarakhand are prone to high incidence of fire during the months of March to June every year (Barghali et al., 2022).
6. The Chir-dominated pine forest promote the forest fires and increased population of Chir pine which makes the forest extremely vulnerable to fires (Fule et al., 2021).
7. Years 2015/16 experience strong El nino conditions with the burned area over the Uttarakhand region much higher compared to the normal ENSO conditions with strong negative Indian Ocean Dipole(IOD) which lead to low rainfall conditions in the Indian Subcontinent.
8. Our work contributes to understand the impact of ENSO and IOD in regulating the fire spread and burned area.

OBJECTIVES

- Investigate the impact of El Nino Southern Oscillation on major forest fire events in 2015/16 and 2020.
- Analyse the impact of Indian Ocean Dipole in the 2016 and 2020 fire events.
- Understand the teleconnection between ENSO and IOD and their combined effect in enhancing fire spread and propagation in meteorological Perspective.

STUDY AREA

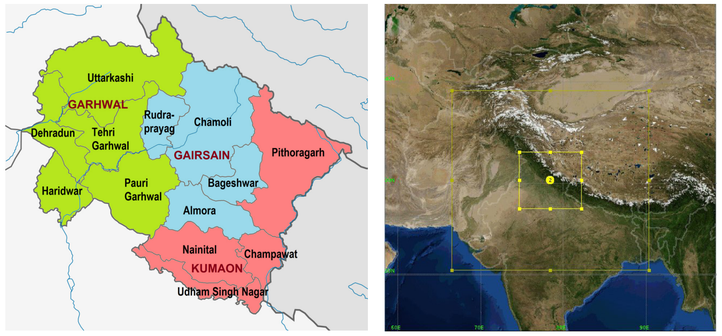

Figure 1 : Study area - Uttarakhand (30.0668° N, 79.0193° E), India

METHODOLOGY

- Surface temperature, moisture and availability of oxygen play a crucial role in fire initiation and propagation.
- Low moisture with high surface temperature further promotes fire propagation.
- For our studies we analysed temperature, precipitation and Surface moisture over a 1o x 1o grid for the entire duration of the study on daily basis.
- Trend analysis of temperature at 1000 hPa is carried out to understand how the temperature enhanced fire in the year 2015, 2016 and 2020.
- Trend analysis of surface moisture has been carried out to understand how surface moisture content variation played its role in fire propagation in correlation with the surface temperature.
- Similar to the fire event in 2016, 2011 also experienced the same meteorological conditions with the La Nina event.
- The correlation between moisture content and surface temperature are taken into account to understand how El-Nino's teleconnection with the IOD impacts the fire propagation and burned area.

DATA ANALYSIS

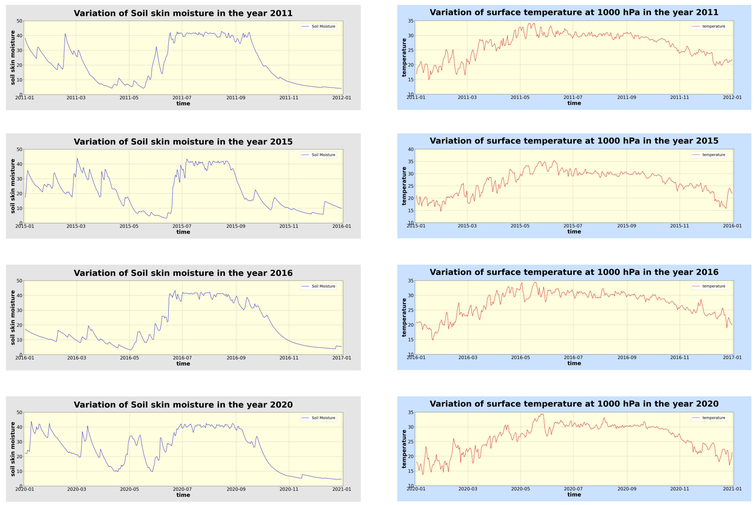

Figure 2 : Variation of '***Soil Skin Moisture***' and '***Surface Temperature at 1000 hPa***' in the years 2011, 2015, 2016 and 2020

Fire event	Burned area (in ha)	Casualties	ENSO	IOD Condition
2011	72	2	La Nina	nIOD
2016	1320	16	El Nino	nIOD
2020	71	2	La Nina	pIOD

Table 1 : Fire events in 2016 and 2020 and associated casualties and burned area

OBSERVATIONS

1. In the year 2015, the surface temperature shows an increasing trend with low rainfall conditions and declining trend in soil skin moisture with correlation coefficient of 0.08 which resulted in dry conditions and subsequently more fires in 2016.
2. In the year 2020, surface temperature and moisture gives a correlation coefficient value 0.20 which indicates the increase in moisture content and hence the decline in the fire spread area.
3. The analysis between 2011 and 2016 showed that surface temperature and soil moisture had correlation coefficients 0.19 and 0.08 which indicate that El nino event in 2016 which enhance temperature condition and low moisture condition which further enhance fire spread and burned area in 2016.
4. La Nina along with Positive Indian Ocean Dipole in 2020 shows a correlation value of 0.18 with skin temperature and soil skin moisture content indicating more rainfall due to La Nina and low burned area.
5. El Nino along with Negative Indian Ocean Dipole in the 2015/16 season with correlation coefficient 0.08 between skin temperature and surface temperature enhanced the fire propagation due to drought like situation and more burned area.
6. The year 2011 had enough nIOD condition for fire propagation but the presence of La Nina suppressed the fire spread. Hence the impact of ENSO on fire spread is strong compared to the Indian Ocean Dipole.

SUMMARY

- Analysis of 2015/16 and 2020 fire events depict the need to understand meteorological factors conducive to fire events in the Indian Himalayan region.
- The teleconnection between IOD and ENSO result in more fire burned area in 2015/16 fire events compared to the 2020 La Nina conditions.
- Further we need to understand the impact of individual events to disseminate the impacts of climate variability on fire spread.

ACKNOWLEDGEMENT

REFERENCES

1. India State of Forest Report 2017, 2019 & 2021
2. Lazaridis, M., Latos, M., Aleksandropoulou, V., Hov, O., Papayannis, A., & Tørseth, K. (2008). Contribution of forest fire emissions to atmospheric pollution in Greece. Air Quality, Atmosphere and Health, 1(3), 143–158. https://doi.org/10.1007/s11869-008-0020-0
3. Kostrykin, S., Revokatova, A., Chernenkov, A., Ginzburg, V., Polumieva, P., & Zelenova, M. (2021). Black carbon emissions from the siberian fires 2019: Modelling of the atmospheric transport and possible impact on the radiation balance in the arctic region. Atmosphere, 12(7). https://doi.org/10.3390/atmos12070814
4. Rengers, F. K., McGuire, L. A., Oakley, N. S., Kean, J. W., Staley, D. M., & Tang, H. (2020). Landslides after wildfire: initiation, magnitude, and mobility. Landslides, 17(11), 2631–2641. https://doi.org/10.1007/s10346-020-01506-3
5. Bargali, H., Calderon, L. P. P., Sundriyal, R. C., & Bhatt, D. (2022). Impact of forest fire frequency on floristic diversity in the forests of Uttarakhand, western Himalaya. Trees, Forests and People, 9, 100300. https://doi.org/10.1016/J.TFP.2022.100300

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