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Journal of Atmospheric Science Research
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ARTICLE

Identification of Black Dragon forest fire in Amur River Basin Using Satellite Borne NDVI Data and Its Impact on Long Range Transport of Pollutants: A Case Study

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ARTICLE INFO

Article history
Received: 5 September 2019
Accepted: 23 September 2019
Published Online: 30 November 2019

Keywords:
Black Dragon forest fire
NDVI
Ozone
Aerosol
Transport
HYSPLIT model

ABSTRACT

The Greater Hinggan Forest was the world's largest stand of evergreens, along the Black Dragon River (also known as Amur), which forms the border between Chinese Manchuria and Soviet Siberia. Black Dragon fire ranks as one of the worst environmental disasters of the 20th century and it burned about 18 million acres of conifer forest. In the 2nd week of May, 1987, we observe more than 10K rise in brightness temperature over a wide region in the China-Russia border. The weekly mean NDVI data shows the changes in greenness after the forest fire broke out. The NDVI value is positive with persistent greenness and vegetation in the Amur River valley, but from the 2nd week of May onwards the reddish patch appears to spread over the entire region, indicates the burned areas. In addition, we observe the impact of Black Dragon forest fire on tropospheric ozone concentration, aerosol index away from the location over North Pacific Ocean. A clear increase in atmospheric pollutants can be noticed after the forest fire event and the long range transports are confirmed with 72 hours NOAA HYSPLIT forward trajectory analysis.

1. Introduction

Forests, being the crucial ecological functions, regulate the climate and the water resources and serving the habitats for numerous plants and animals. Moreover, it provide a wide range of essential products for the humanity such as wood, food, fodder, medicines, fossil fuels etc. But in the recent decades, various anthropogenic factors accelerate the frequency and the intensity of the extreme natural disasters which also escalate the occurrences of the forest fires. Forest fires constitute a hazard that causes large damages, especially in arid and semi-arid regions. In many cases, this hazard contributes significantly to changes in the local and even global climate, soil erosion and leads to soil loss and desertification. The destruction of vegetation by forest fires can affect the land surface and the hydrologic cycle, by increasing the surface albedo, surface runoff, and decreasing the evapotranspiration [5]. Moreover, the biomass burning can contribute, with gases, to the greenhouse effect and cause destruction of the stratospheric

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  DOI: https://doi.org/10.30564/jasr.v2i3.1182

ozone layer or the production of tropospheric Ozone [4].

With the increasing number of satellite systems and on board efficient sensors, forest fires can be identified with extreme accuracy by implying various remote sensing techniques. Among them the NOAA/AVHRR and MODIS satellites are widely used by the scientific community. The meteorological satellite NOAA/AVHRR contributed to the operational and assessment of natural hazards [9]. Remotely sensed data and techniques have been used to detect active fires and extract the extent of the burned area during the fire [2]. The methods usually applied are based on the thermal signal generated by flaming and/or smouldering combustion [5] and the daily fire growth. The use of contextual algorithms [3] can improve the detection of active fires. Domenikiotis et al. [1] performed the case studies of the forest fire on21–24 July 1995 in Penteli Mountain near Athens (shown below), and the forest fire of 16 September 1994 in Pelion Mountain, Central Greece. He had used the Normalized Difference Vegetation Index (NDVI) and surface temperature (ST) derived from the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (NOAA/AVHRR) satellite data. The availability of data from NASA's Moderate Resolution Imaging Spectro radiometers (MODIS), which were launched in 2000 onboard the NASA Terra platform and 2002 onboard the Aqua platform, collect high-quality, continuous directional observations to support the long term monitoring of key biophysical variables. Products generated from MODIS data characterize global vegetation dynamics, the surface energy budget, land cover, fire and so on (Justice et al., 2002). Koji Nakau et al. detected the boreal forest fires in Alaska and Siberia using MODIS satellite imagery and compare the results with NOAA satellite imagery. Morisette et al. [6] validate the MODIS active fire detection products derived from two algorithms and Csiszar et al. (2006) and Giglio et al. (2003) validate the active fire detection by MODIS in Northern Eurasia.

In the present report we have focused on a case study of Black Dragon Forest Fire, which broke out in May 1987 along the Amur River, the boundary between eastern Siberia and Chinese Manchuria. Although, China is often not considered as a country in which large forest fires occur, Black Dragon fire rank as one of the worst environmental disasters of the 20th or any other century [8]. The fires were more than 10 times the size of the 1986 fires in Yellowstone National Park and it burned about 18 million acres of conifer forest [7]. The outline of the present report include the (a) identification of the Black Dragon fire from NOAA/AVHRR NDVI and Brightness temperature data, (b) changes in the greenness before and after the event, (c) enhancement in columnar Ozone and aerosol index after the event and (d) trajectory of the particles released from the event far away from the source location.

2. Data Used

Following are the data used for analysis:

(1) NOAA/AVHRR smoothed weekly means NDVI and Brightness temperature data with 16 km resolution.

(2) TOMS-Nimbus 7 data for columnar Ozone and aerosol index.

(3) NOAA HYSPLIT -Hybrid Single Particle Model Trajectories.

3. Results and Discussions: A case study

3.1 Black Dragon Fire in Russia and China

The Greater Hinggan Forest was the world's largest stand of evergreens, stretching like a green velvet sea approximately 500 miles long and 300 miles wide. It is bisected by the Heilongjiang, or Black Dragon River (known in the West by its Russian name, the Amur), which forms the border between Chinese Manchuria and Soviet Siberia. Before the fires, the Manchurian part of the forest accounted for one-third of China's timber reserves. In 1987, there had been a prolonged period of dry weather, and the danger of fire was high on both sides of the river in the spring. The Black Dragon Fire is perhaps an example that climate considerations need to be fully integrated into fire management.

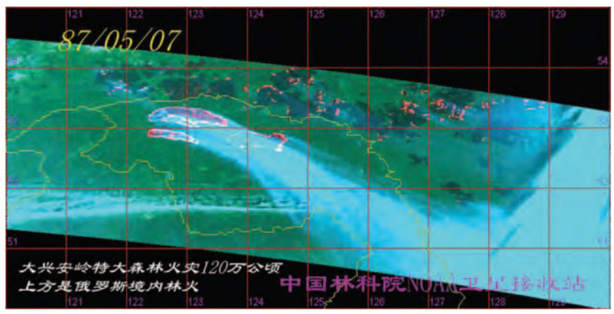

Figure 13.3. NOAA advanced very high-resolution radiometer (AVHRR) image of the black dragon fire taken on May 7, 1987.

Courtesy: Qu et al.[7], Developments in Environmental Science.

We have identified the Black Dragon Fire from the NOAA/AVHRR weekly mean brightness temperature data. It reveals the hot spots caused by the fire with temperature ranges from 300 to 335 K. A clear increase in brightness can be seen in the 2nd week of May, 1987, when the Black Dragon fire broke out severely. Figure 1 shows the weekly difference in brightness temperature before and after the event. More than 10K rise in brightness temperature has been recorded over a wide region in the China-Russia border. We have also plotted the weekly mean NDVI data to observe the changes in greenness after the

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forest fire broke out (Figure 2). The NDVI value is positive with persistent greenness and vegetation in the Amur River valley, but from the 2nd week of May onwards the reddish patch (negative NDVI) appears to spread over the entire region, indicates the burned areas. A wider swath of the region was affected by the Black Dragon fire with intense loss greenness and vegetation.

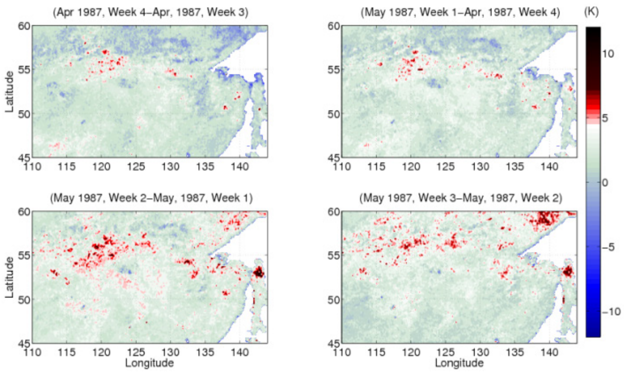

Figure 1. Weekly mean difference in NOAA/AVHRR, Brightness temperature, before and after the Black Dragon Fire event

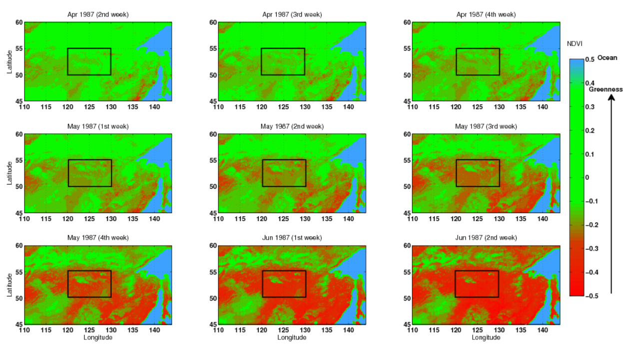

Figure 2. Weekly mean NOAA/AVHRR, NDVI data during the fire event. The green color indicate the greenness i.e. vegetation and the red indicates lack of vegetation

3.2 Impact of Black Dragon Fire on Atmospheric Pollution

Tropospheric Ozone has negative impact on the human health and ecosystems and the wildfires are one of the sources which have significant impact on the climate. Moreover, the forest fires emit pollutants and aerosols particles (pm 2.5) which persist in the atmosphere for long time and have significant impact on the radiation budget of the atmosphere. In this case study, we have observed a significant increase in the total columnar ozone over the North Pacific Ocean and aerosol index soon after the fire broke out. The top, middle and the lower panel shows the changes in tropospheric ozone before, during and after the Black Dragon forest fire broke out (Figure 3). In the second week of May the total columnar ozone increases by about 200 DU, which is possibly due to long range transport of ozone from the forest fire location.

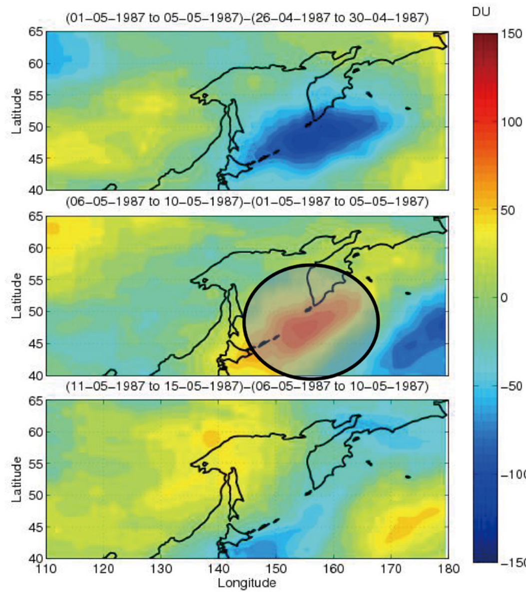

Figure 3. Pentad means difference in TOMS-Nimbus 7 columnar Ozone value before and after the fire event

In addition the aerosol index also increases by 8 units (Figure 4) after the Forest fire broke out. The particles species like PM 2.5 travel far away from the source and can be seen over the North Pacific Ocean in the second week of May within 72 hours of the massive forest fire broke out. To visualize this long distance transport by wind we have also plotted the trajectories of plumes and the particles after 72 hours of the onset of the fire event using NOAA HYSPLIT MODEL trajectories analysis.

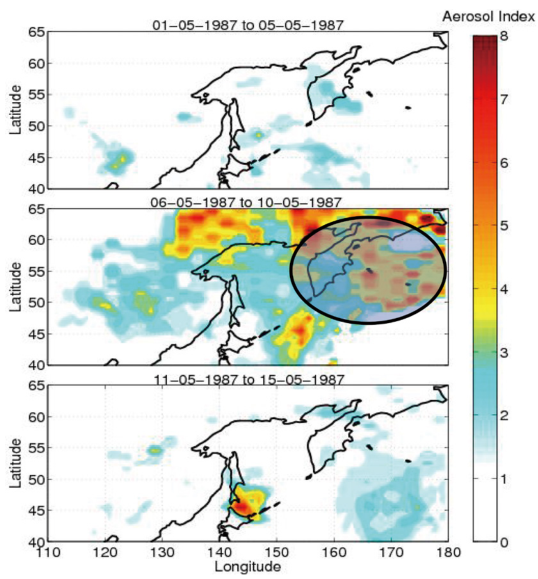

Figure 4. Pentad means difference in TOMS-Nimbus 7 Aerosol Index value before and after the fire event

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3.3 NOAA HYSPLIT Trajectories

The HYSPLIT model is a complete system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation and deposition simulations. HYSPLIT model is widely used to study the atmospheric transport and dispersions by simulating back and forward trajectories to determine the origin of air masses. It is used in variety of simulations to describe the atmospheric transport, dispersion, deposition of pollutants and hazardous materials. In this case study we used the 72 hours forward trajectories of the air masses from the location of the Black Dragon forest fire and reported long range transport of pollutants over North Pacific Ocean. The Figure 5 shows the 72 hours HYSPLIT MODEL forward trajectories for the plumes which contain minute aerosol particles like PM 2.5 from the Black Dragon fire location. After 72 hours, the PM 2.5 particle trajectories appear to advect over North Pacific Ocean and results are consistent with Figure 4. Similarly, Figure 6 shows the three dimensional propagation of particles from the ground level location of the forest fire to ~6 km over North Pacific Ocean.

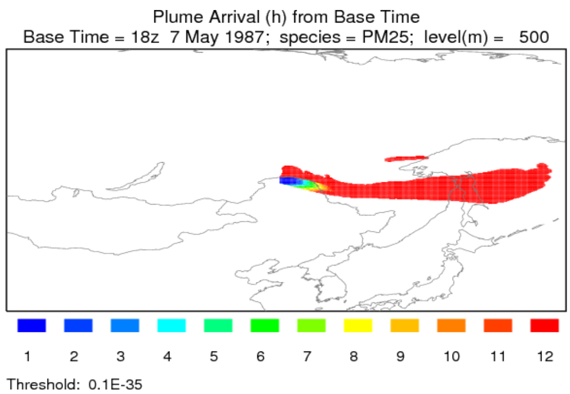

Figure 5. NOAA HYSPLIT MODEL trajectories for the plumes which contain minute aerosol particles like PM 2.5 after 72 hours of onset of the event

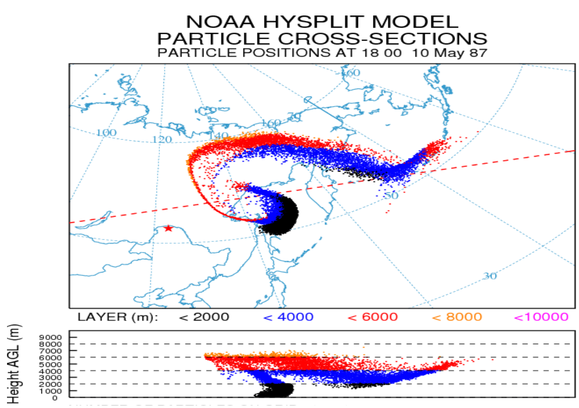

Figure 6. NOAA HYSPLIT MODEL, 3 dimensional trajectories for the particles which after 72 hours of onset of the event

4. Summary and Conclusions

The Greater Hinggan Forest was the world's largest stand of evergreens, along the Black Dragon River (also known as Amur), which forms the border between Chinese Manchuria and Soviet Siberia. In this study we have used the NOAA/AVHRR weekly mean NDVI and Brightness temperature data, TOMS-Nimbus 7 data for columnar Ozone and aerosol index and NOAA HYSPLIT -Hybrid Single Particle Model Trajectories for long range transport of the pollutants from the source region.

Black Dragon fire is one of the biggest forest fire and worst environmental disasters of the 20th century and it burned about 18 million acres of conifer forest. In the 2nd week of May, 1987, the brightness temperature increases more than 10K along the Amur River basin. The changes in greenness can be seen in the weekly mean NDVI data during and after the forest fire broke out. In the 2nd week of May the NDVI shifted from positive value i.e. greenness to negative and widespread burning can be seen along the Amur River basin. We observe the impact of Black Dragon forest fire on tropospheric ozone concentration and aerosol index, which increases sharply during and after the forest fire broke out, however, at locations far away from the origin. A clear increase in atmospheric pollutants can be noticed over the North Pacific Ocean, which is due to long range transports and the results are confirmed using 72 hours NOAA HYSPLIT forward trajectory analysis.

Acknowledgments

The authors acknowledge NOAA Atmospheric Research Laboratory for providing the HYSPLIT model trajectories. The research work is supported by National Natural Science Foundation of China International Cooperation and Exchange Program (4181101072).

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