

Analysis of Atmospheric Aerosol and NO₂ during the Stubble Burning Period Using Satellite Data over Haryana and Punjab States, India

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Abstract

This study evaluate the spatio-temporal occurrence of agricultural residues burning impact on aerosols during one rice crop harvesting season (September to December 2018) over Haryana and Punjab State, India. OMI (Ozone monitoring instrument) AOD_{342.5µm} daily aerosol product and daily active fire data from The impact of stubble burning on the aerosol distribution was found to be significant and it was observed more for residue burnt sites. Increase in concentration of aerosols during the paddy harvesting period especially when the fire counts were highest was observed due to increase in dust particle and precursor pollutants. The increased number of fire counts (with the help of Terra and Aqua MODIS data) is associated with severe aerosol-loading atmospheres (AOD_{342.5 nm} > 1.5) over the Haryana and Punjab region, high values of high Aerosol Optical depth (~1.5) and NO₂ concentrations (~8 × 10¹⁵ mol/cm²), indicating the dominance of smoke aerosols from agricultural crop residue burning. The aerosol and NO₂ was very high during burning period compared to that in pre burning and post burning period indicating that burning of rice residue is having significant role in aerosol loading. The increase in aerosol shows its potential effect on air quality, climate and risk on human health. The spatial distribution of aerosols was also analyzed in GIS.

Introduction

The burning of crop residues in fields is almost key component of global biomass burning (excluding biofuels; Streets et al., 2003), and contributes substantially to air pollution. After harvesting, the rice straw is frequently burned in the open field in northern part of the India due to insufficient time for next cropping. This is also saving money and labor required to remove and dispose of rice straw. Another expected reason for rice straw burning is the applications of mechanized combined harvesting technologies in RWS (Rice Wheat System) of India. Almost 90-95% of Paddy area in Punjab, Haryana and Western UP is under intensive Rice-Wheat-System (RWS) Ladha, et al., 2000). Every year during the post monsoon season (October–November), extensive agricultural (rice) crop residue burning takes place in this region (Sarkar et al., 2013). It has significant impact on greenhouse gas emissions and aerosol loading (Badarinath et al., 2009). In addition to aerosol particles, biomass burning due to crop residue burning are considered a major source of carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), volatile organic compounds (VOC), nitrogen oxides (NO_x) and halogen compounds (Guyon et al., 2005; Andreae and Merlet, 2001). These gases may lead to a regional increase in the levels of pollution which causes perturbation in atmospheric chemistry and hazards to the local inhabitants (Wang and Christopher, 2003).

The possible solution suggested for the management of rice straw in a more controlled manner is using it as fuel for furnace or closed burning, vermin composting, alternate to plastic plates etc. (Calvo et al., 2011). However, following these suggestions at ground level is still not realistic and farmers see stubble burning as easy alternate to clear the fields for next cropping which causes pollution problem in northern India.

Delhi NCR is highly affected from pollution problem since last few years due to rice straw burning during the winter season and attracted world towards this complicated issue. High concentration of aerosols with temperature inversion condition makes dense smoke in this region which related with rice straw burning. It is reported by various researchers that the aerosol get increased during the burning period. Last few years the problem has attracted worldwide attractive and complicated issues.

Satellite remote sensing is a well-established tool for monitoring burned areas, and evaluating agriculture biomass-burning based aerosols. The MODIS (Moderate Resolution Imaging Spectroradiometer (MODIS) sensor satellite) sensor 1000 m active fire products (<http://rapidfire.sci.gsfc.nasa.gov/>) has provide usefull in the such study. Anu Rani Sharma examined the influence of rice crop stubble burning practices on the atmospheric aerosol properties using ground based measurements and satellite dataset during October 2006 and 2007 over the Patiala city, Punjab state, India (Anu rani et al 2010). Kaskaoutis also examine the effects of extensive crop residue burning during the post monsoon season of 2012 of them aerosol properties over northern India using the ground-based (Sun photometer measurements at six locations over the IGP) and satellite observations (MODIS, Ozone Monitoring Instrument (OMI), and CALIPSO) was utilized (Kaskaoutis 2014) In recent years, several techniques have been developed for satellite monitoring of stubble burning associated with air pollution and their impact from local-to-regional scales.

In the present study, we had examined the influence of rice crop stubble burning practices on the atmospheric aerosol AURA-OMI derived Aerosol Optical Depth (AOD) and Nitrogen dioxide (NO₂) using satellite dataset during Oct to Nov 2018 over the Haryana Punjab state, India.

2 Study area

Haryana and Punjab State are located at centre of the agrarian region of north-west India, close to Shivalik Hills in the east and Thar Desert in the southwest. Punjab and Haryana state also called "Bread Basket". These States suffers from harsh fog, haze and smog during winter period due to anthropogenic activities, rice stubble burning, and climatic conditions. These states become the chamber of smog during the post monsoon period. There wheat residual used for animal feed and due to high amount of silica in rice stubble it reduce the digestive capacity of the cattle. So, paddy residue is burnt in open field which releases large quantity of GHG and aerosol. Climate of the Haryana and Punjab state is very hot in the summer and very cold in the winter. This region is generally dry and hot with maxi temperature of 43.1 °C during May. The monsoon season last for three months with an annual rainfall of 688 mm. January is the coldest month with mean monthly minimum temperature of 2.1 °C.

3. Data and Methodology

Satellite observations from Suomi National Polar-orbiting Partnership (SUOMI- NPP), related to the active fire locations, Ozone Monitoring Instrument (OMI) based Aerosol Optical Depth (AOD_{342.5µm}) and NO₂ were utilized. Initially, temporal and spatial evolution of the fire counts and aerosol emissions is studied over the Haryana and Punjab during September to December 2018. Crop stubble burning in open fields in these states, is a major pollution source during October-November each year. Therefore, the season was divided into four sub-categories based on burning practices supported by the number of fire counts.

1. Pre burning (20 Sept-15 Oct)
2. Early Burning (16-30 October)
3. During Burning (1 Nov-30 November)
4. After Burning (After 1 December to 30 December)

3.1 Real Time Active Fire Data

Active Fire Data (MODIS)

Data are Collection from Aqua (MYD14A1) and Terra (MOD14A1) products available (<https://firms.modaps.eosdis.nasa.gov/>) with 1000M resolution. These fire observations satellite are performed four times a day from the Terra (10:30 and 22:30) and Aqua (13:30 and 01:30) platforms. MODIS active fire locations composited for the period of 25 Sep to 5 Dec 2018 were used. These observations were quantified for spatiotemporal dynamics of fires across the Haryana and Punjab State, India.

3.2 Aerosol optical depth Ozone Monitoring Instrument (OMI)

Aura OMI daily aerosol products of Aerosol Optical Depth AOD_{342.5µm} used over the Haryana and Punjab during October to November 2018. The data set is Level-2G, version 1.4.2, generated by binning the original pixels from the Level-3 (15 orbits per day 13×24 km spatial resolution) into a 0.25°×0.25 grid. (<https://giovanni.gsfc.nasa.gov/giovanni/>) Detailed descriptions of the algorithm for the standard OMI NO₂ data product are given in (Boersma et al., 2002; Bucsele et al., 2006; Celarier et al 2008).

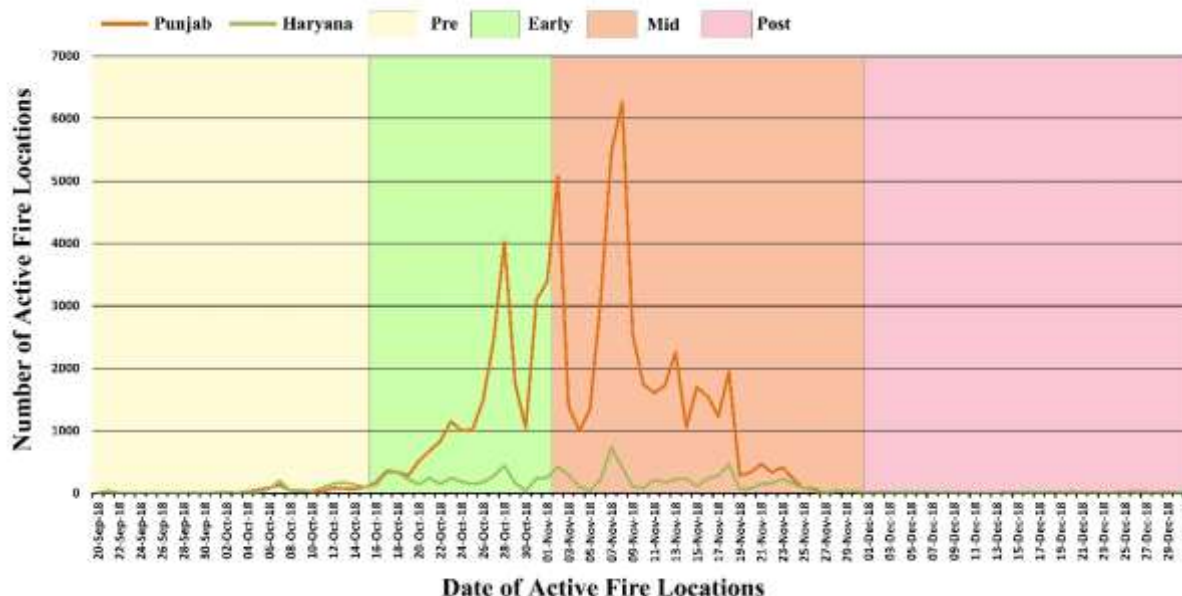
OMI tropospheric NO₂

Giovanni provide Level-3 daily global gridded (0.25x0.25 degree) Nitrogen Dioxide Product (OMNO2d). OMNO2d data product is a Level-3 Gridded Product where pixel level data of good quality are binned and "averaged" into 0.25x0.25 degree global grids. OMI Level 3 daily global products are produced by using best pixel data over small equal angle grids (0.25 degree × 0.25 degree). This product contains total column NO₂ and total tropospheric column NO₂, for all atmospheric conditions, and for sky conditions where cloud fraction is less than 30 percent. Detailed descriptions of the algorithm for the standard OMI NO₂ data product are given in Boersma et al., 2002; Bucsele et al., 2006; Celarier et al., 2008.

4. Results and Discussion

4.1 Trend of the Agriculture Fire associated with Aerosol concentration and NO₂

The analysis of fire events helps in the understanding the source region of burnt area along with its, spatial and temporal distribution. The fire product shows large spatial and temporal variation during the stubble burning period. The fire events were predominantly located in the Punjab district and lesser fire event were observed in south-west Haryana. During the rice harvesting season total fire events detected were 82245 (including non-agricultural areas. Haryana and Punjab state. The Most fire events detected in the month of October to November Mid October showed the highest fire events in the Punjab and Haryana. The result showed that the rapid increase in fire events over Punjab from 986 to 20815 in just a few days, indicating that Punjab is leading contributor to the burning in comparison to Haryana. Increasing values of AOD_{342.5µm} and NO₂ similar to the fire events, suggested that the aerosol loading over the Haryana-Punjab region is associated mainly with stubble burning.



4.1.1 Active fire and Aerosol during the pre burning period (20 September-15 October):-

During the pre harvesting the total 2245 fire events were detected in Haryana and Punjab, in which 986 active fires observed in Panjab and 1259 in Haryana. Maximum number of (403) and (396) active fire points were recorded in Amritsar district (Punjab) and Karnal district (Haryana) during 2018 respectively, followed by Kurukshetra (281),Kaithal (736) in Haryana and Tarn Tarn (146) in Punjab. The number of fire points in these states started increasing from the 7 October and increased at maximum. This analysis indicated that the burning of paddy stubble takes place in northern districts namely Kaithal, Karnal, Kurukshetra of Haryana and Amritsar, Tarn Tarn, and Patiala district of Punjab during second week of October (Fig.1a). Similar trend was observed for AOD and NO_2 .

During the period moderate to high $\text{AOD}_{342.5\mu\text{m}}$ Values (<0.2 to >0.4) and NO_2 ($\sim 2 \times 10^{15}$ mol/cm²) were observed in the eastern Haryana However, for Punjab region the area with high active fire events had not showed increase in AOD (Fig.2 b).

4.2. Active fire and aerosol during the early burning period :-(16 October to 30 October):-

During the early burning period active fire events increased rapidly in Punjab state compared to the Haryana (Figure 2 a). In this period,a total of 20818 active fireswere observed in Punjab state where as only 3404 in Haryana. Maximum number of active fire were counted in Firozpur (2897) district followed by Patiala (2223), Muktsar (2105), Tarn tarn (2006) and Sangrur (1889).

Figure.2 (b) During the early burning period more $\text{AOD}_{342.5\mu\text{m}}$ (< 1.0) wasrecorded over the Mansa district of Punjaband moderate $\text{AOD}_{342.5\mu\text{m}}$ recoded over Fatehabad (Haryana), Batinda, Sangrur and Barnala districts of Punjab (Figure 2 b). The temporal pattern of the average $\text{AOD}_{342.5\mu\text{m}}$ over the Haryana and Punjab provide the evidence that active fire counts play very important role in the variation of atmospheric aerosol. Higher values for aerosol associated with higher active fires. Figure 2 (b)shows that during the early burning period moderate to high $\text{AOD}_{342.5\mu\text{m}}$ (<0.2 to >0.4) condition prevails in the western and central part of the study.

4.3. Active fire and Aerosolduring the afterburning period :-(1 November to 30 November)

During the burning period total fire events were counts as 54577 in Haryana and Punjab state, in which 48643 active fire detected in Punjab and 5919 in Haryana (Figure 3 a). Thus, Punjab alone contributes a total of 78.27 per cent more active fire point. More active fire points were recorded inSangsur(7009), Batinda (5801), Muktsar(4904), and Moga (4058)district followed by Firojpur (4041) and Barnala(3374) district.

Noticeable impact of high number of active fire events on $\text{AOD}_{342.5\mu\text{m}}$ distribution and its concentration was visible over Sangsur, Batinda, Muktsar, Moga, Firojpur, Barnala districts of Punjab and Karnal, Kaithal, Kurukshetra districts of Haryana. (Fegure3b). In these districts very high $\text{AOD}_{342.5\mu\text{m}}$ along with high number of fire events indicated that the stubble burring has significant role in aerosol loading over this region. Minimum active fire recorded in south-west part of Haryana. It also indicate that in these districts with minimum to moderate $\text{AOD}_{342.5\mu\text{m}}$ (<0.2 to >0.4

Figure 1 C shows the OMI derived monthly mean tropospheric columnar NO_2 during mid burning period over Punjab and Haryana State. Figure suggests relatively higher values of NO_2 in the range of minimum ~ 4 to a maximum of ~ 9 (10^{15} molec cm⁻²) during mid burning period, compared to Early Burning.

4.4 Active fire and Aerosol after burning period :-(1 December to 31 December)

During the after burning period only 1004 fire event were observed in both the states, in which 469 event counts in Punjab and 535 in Haryana state (Fig.4 (a)). In this period the trend of fire events decreases and the pattern of $\text{AOD}_{342.5\mu\text{m}}$ were low (Fig.4 (b)). The fire events were very sparsely and very random appearance

Conclusion

Present study is an effort to examine the spatial extent and trend of active fire events followed by its association with the distribution of atmospheric aerosol and associated gases including NO₂ and CO contents over the Punjab and Haryana state. Haryana and Punjab cover high densely populated plain of north India and stubble burning in this region coincides winter season that creates lot of problem in NCR region. Fire events and aerosol content was found to be in close association. It was concluded that the stubble is a major contributory factor in the high aerosol contents

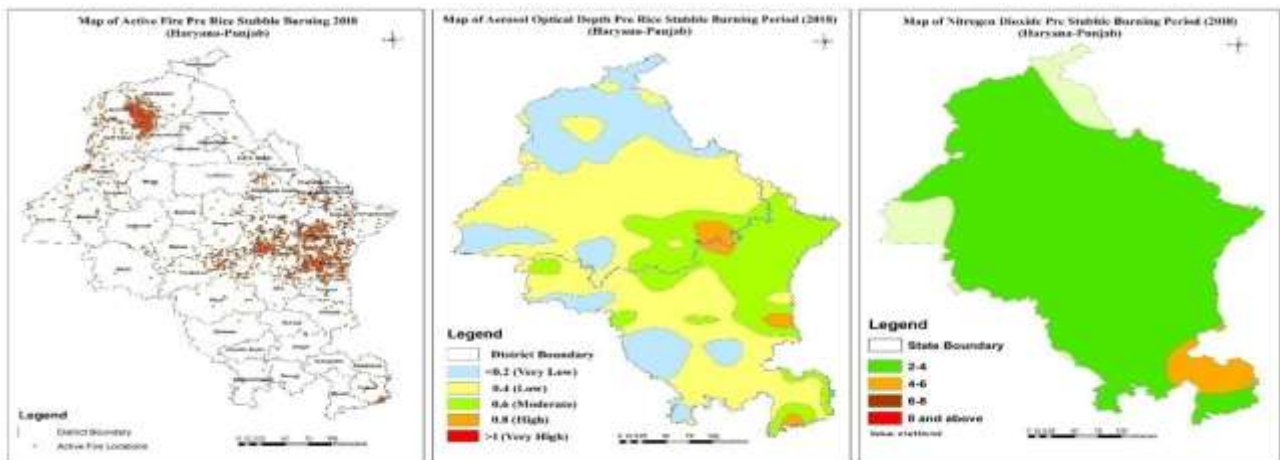


Fig.1. (a) Aerosol Optical Depth the during pre rice stubble burning period (b) Active Fire during the pre rice stubble burning period

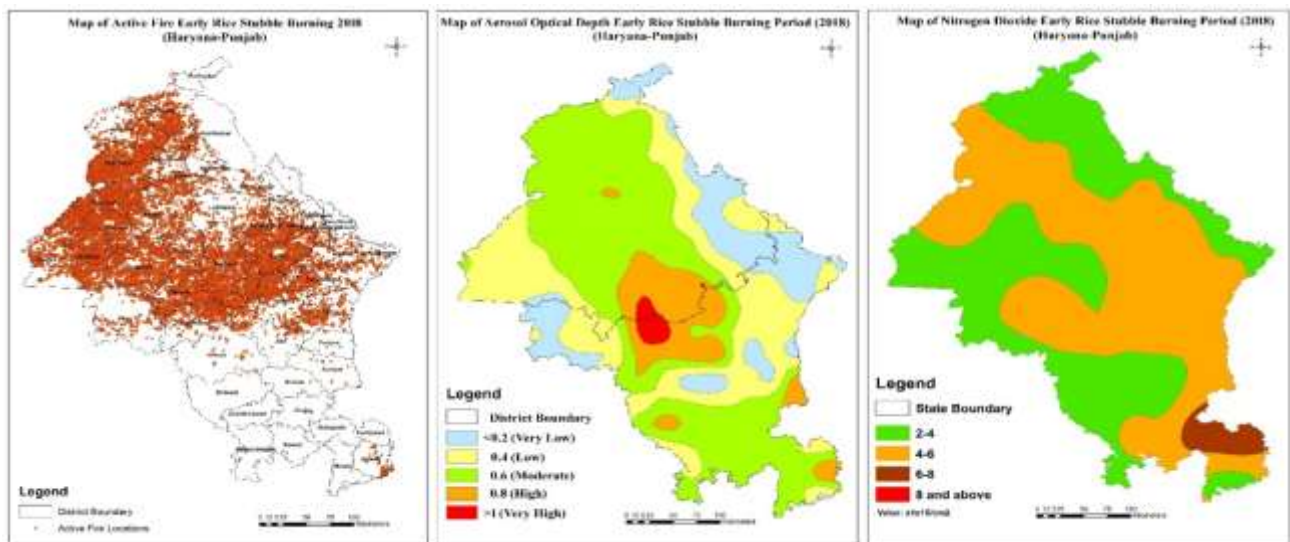


Fig.2 (a) Aerosol Optical Depth during Early rice stubble burning period (b) Active Fire during the early rice stubble burning period

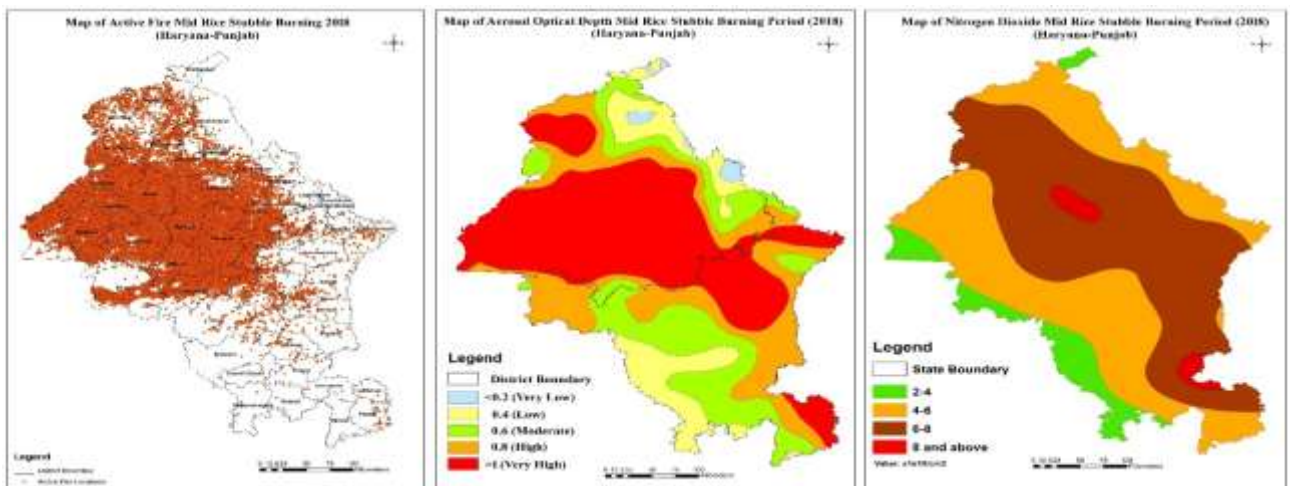


Fig.3 (a) Aerosol Optical Depth during late rice stubble burning period (b) Active Fire during the late rice stubble burning (C)NO₂ during the late rice stubble burning period

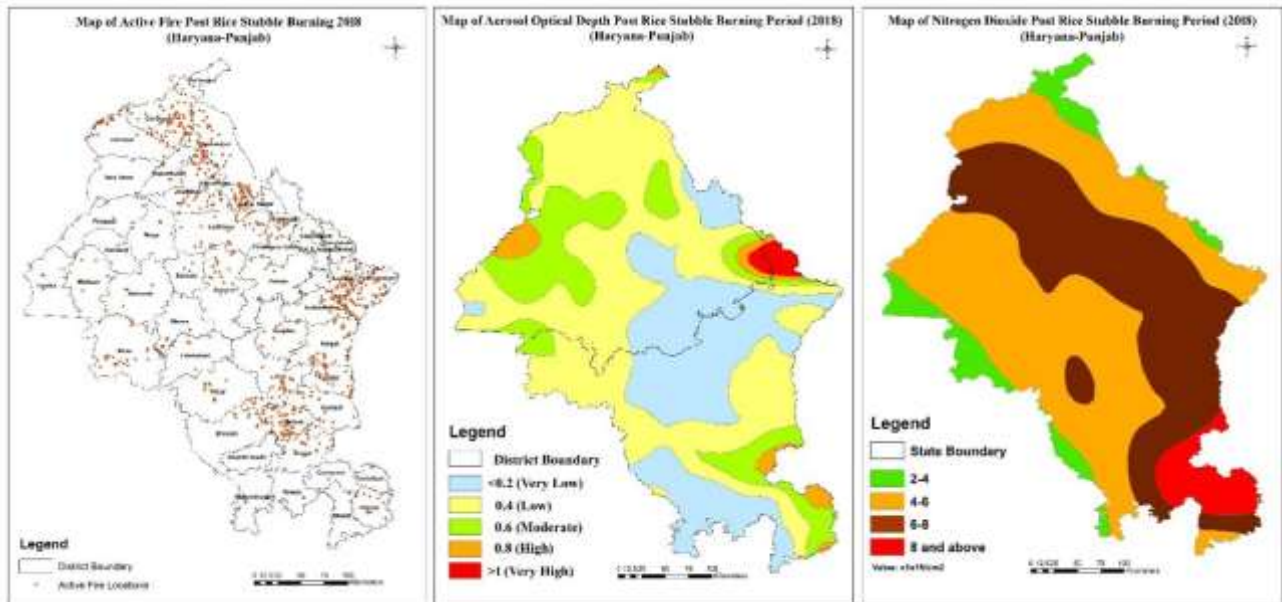


Fig.3 (a) Aerosol Optical Depth After rice stubble burning period (b) Active Fire After the rice stubble burning period

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