Inter-comparison of MODIS AQUA and VIIRS I-Band Fire Products In An Agricultural Landscape – Implications for Air Pollution Research

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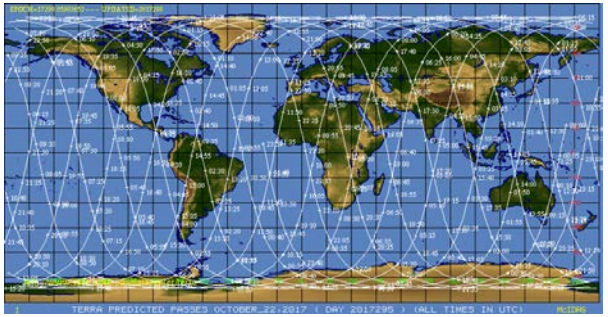
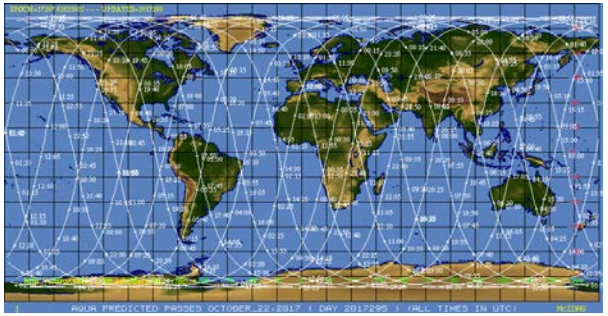
MODIS and VIIRS Data

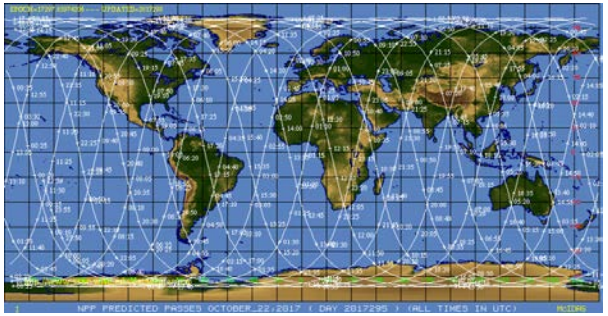
MODIS Terra satellite (EOS-AM):
-Started in December, 1999
-Overpass time: 10:30 + 22:30 solar local time



MODIS Aqua satellite (EOS-AM):
-Started in May, 2002
-Overpass time: 13:30 + 01:30 solar local time



NPP VIIRS (PM):
-Started in Oct, 2011
-Overpass time: 13:50 + 01:30 (20-mins ahead of AQUA)



NPP is a polar orbiting satellite with an orbit similar to Aqua, (VIIRS is on one satellite compared to MODIS which is on both Aqua and Terra)

VIIRS Active Fire Datasets (Schroeder et al., 2016)

- NOAA 750m product (**AVAFO ->AF_v1r0_npp**)
  - Original active fire data set (**AVAFO**) based on C4 MODIS fire algorithm
    - List of fire pixel lat/lon
    - Available through NOAA-CLASS online archive system (inconsistent record due to changes in input data)
    - Also available through IPOPP, CSPP direct readout data processing packages
    - To be discontinued soon
  - Revised product based on C6 MODIS fire algorithm (**AF_v1r0_npp - similar to VNP14**)
    - Mimics MOD/MYD14 data format/content
    - Running at NDE (≈3h latency), feeding NOAA-CLASS archive
- NASA 750m product (**VNP14**)
  - Based on C6 MODIS fire algorithm
    - Running at Land SIPS (≈12h latency), incomplete/inconsistent record due to changes in input data and data retention
    - Also available through IPOPP direct readout data processing package
- *NASA 375m product (**VNP14IMG**) – Used in the study*
  - *Builds on MODIS fire product, customized for VIIRS 375m data characteristics*
    - *Running at Land SIPS (≈12h latency), incomplete/inconsistent archive due to changes in input data and data retention*
    - *Running at LANCE, feeding FIRMS/Worldview since Dec 2015*
    - *Also available through through IPOPP direct readout data processing packages*
- Data reprocessing tasks being implemented at NASA and NOAA

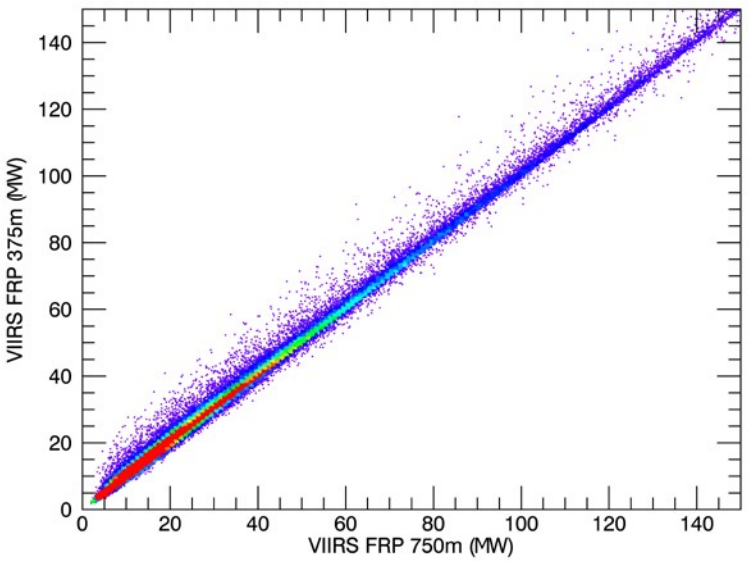
VIIRS FRP Retrievals

In the VIIRS 375m (VNP14IMG) product 375m mid-IR (I4) radiance data for FRP retrieval is not used due to frequent data saturation/folding; b). Quality flags (QF1) assigned during L1B onboard data aggregation won't indicate partial saturation

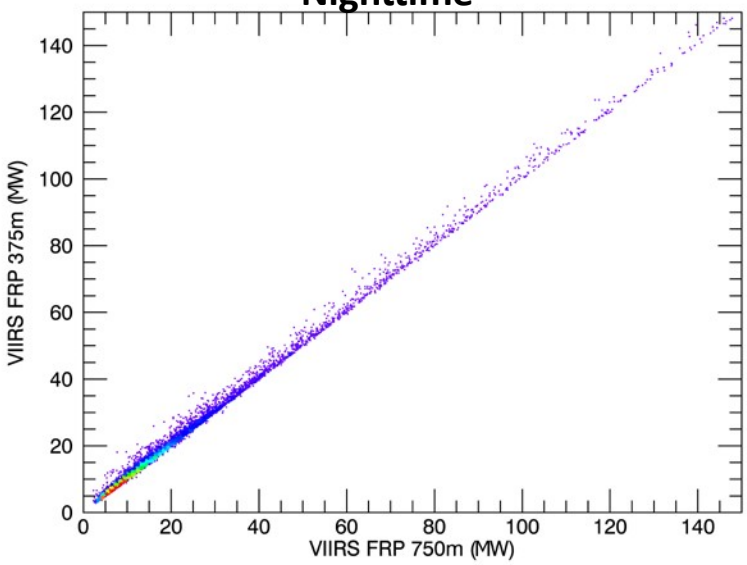
Instead

FRP is retrieved using co-located dual-gain mid-IR M13 channel (750m) for all fire pixels detected using 375m data and then divided by two to get 375m FRP (Schroeder et al., 2016).

Daytime



Nighttime

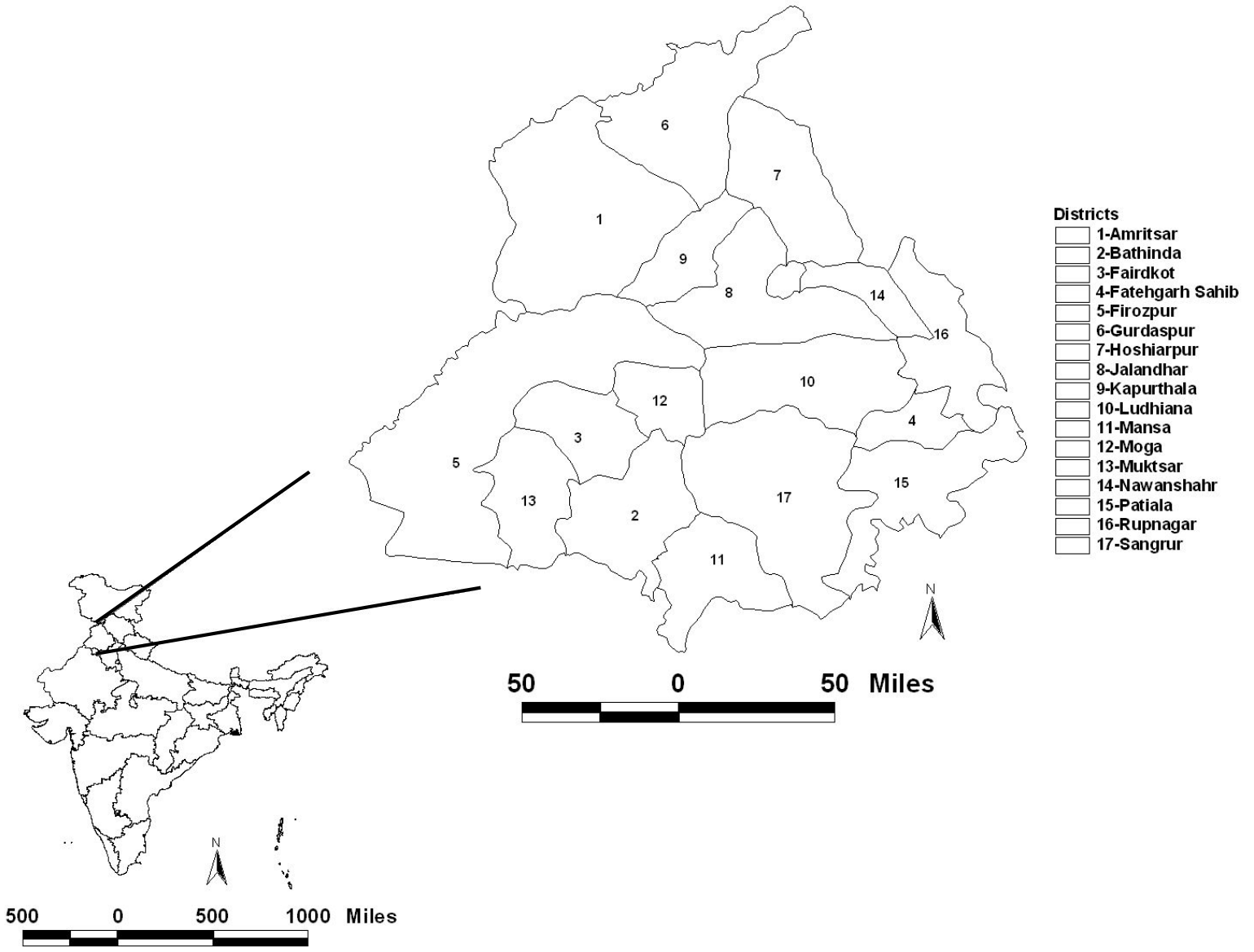


Questions Addressed

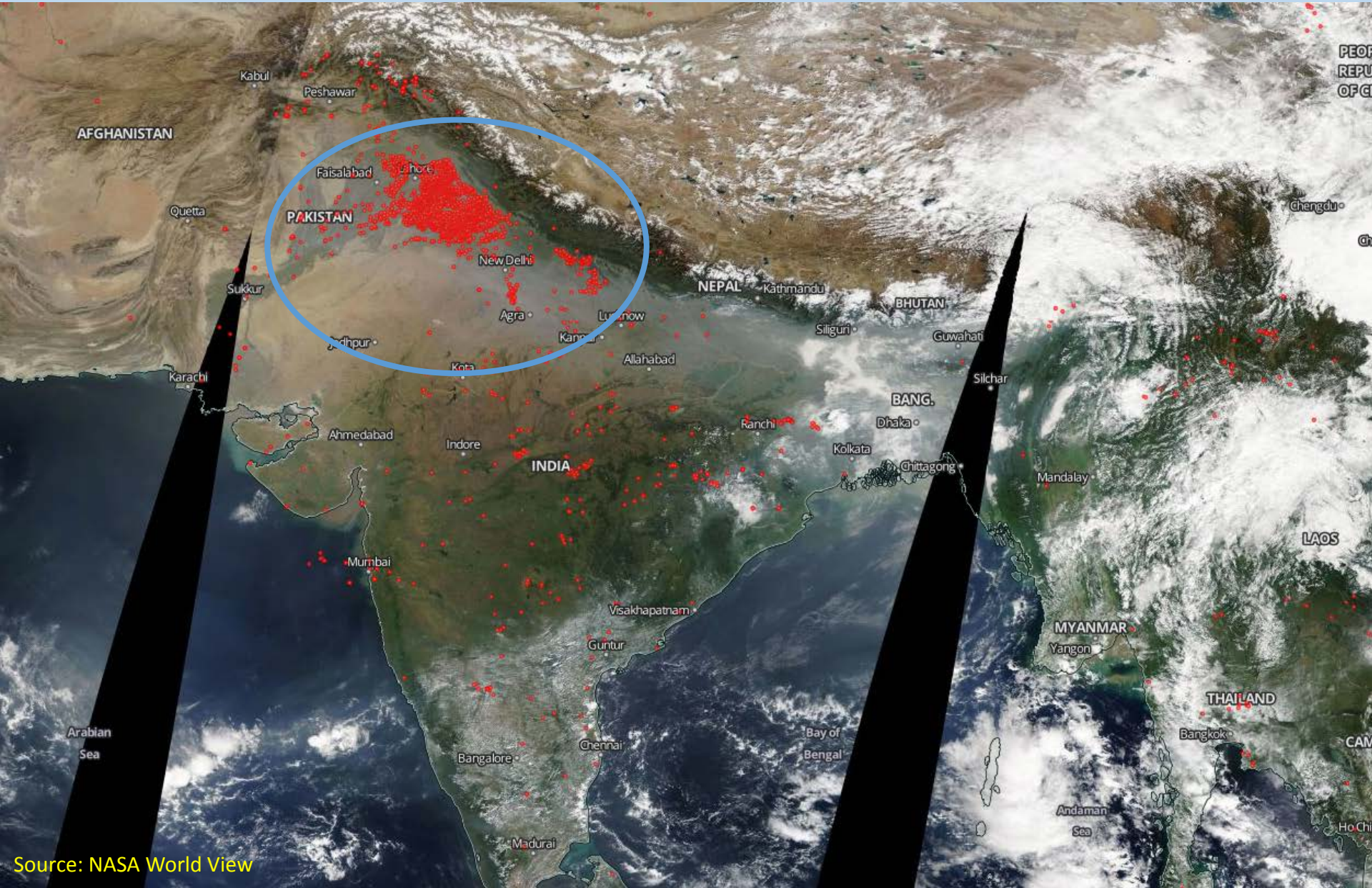
- How does MODIS (Aqua) compare with VIIRS (VNP14IMG) for monitoring agricultural fires?

- What are the implications of using MODIS versus VIIRS FRP data for emissions estimation?

Agricultural Fires in Punjab (NW India)

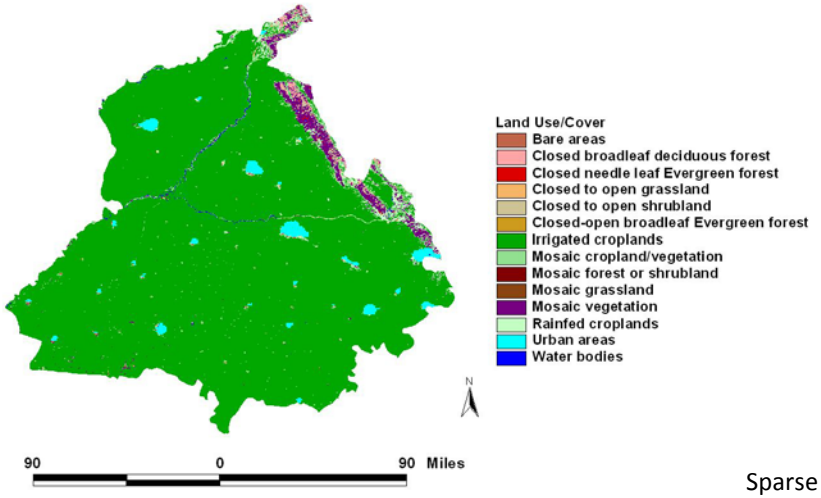


Agricultural Fires – Punjab (NW India)
Suomi NPP/VIIRS Thermal Anomalies (Oct-25, 2017)

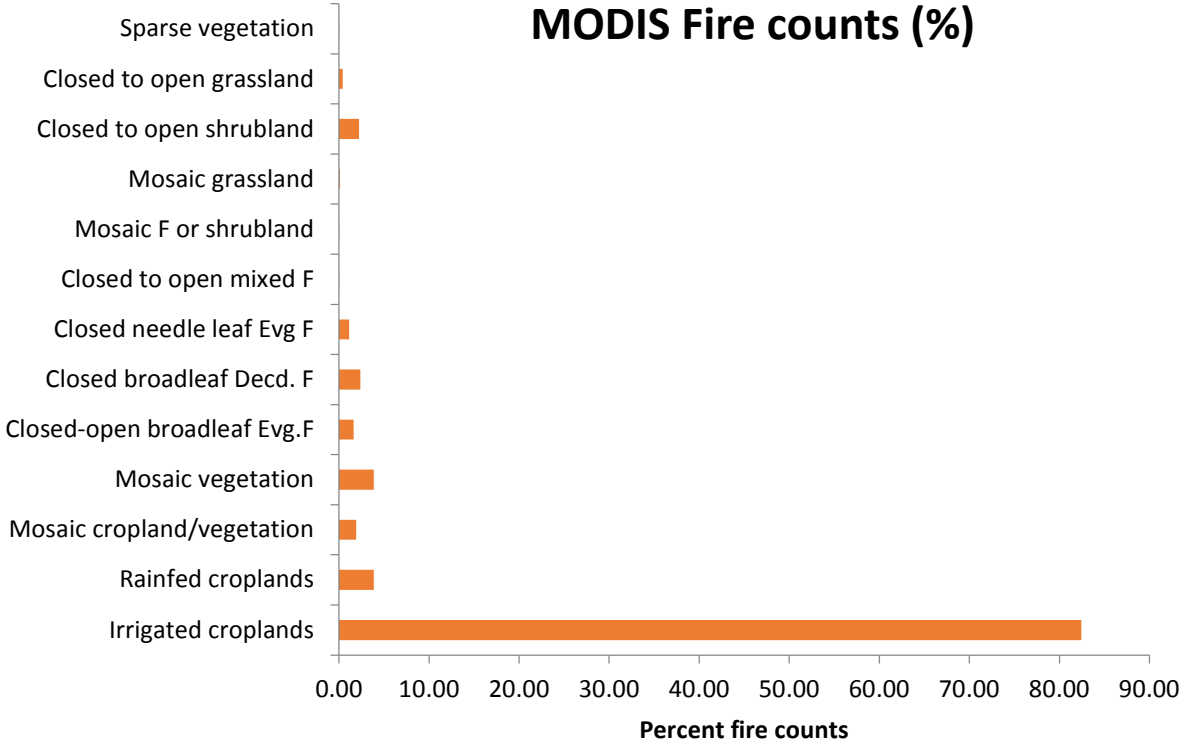


Source: NASA World View

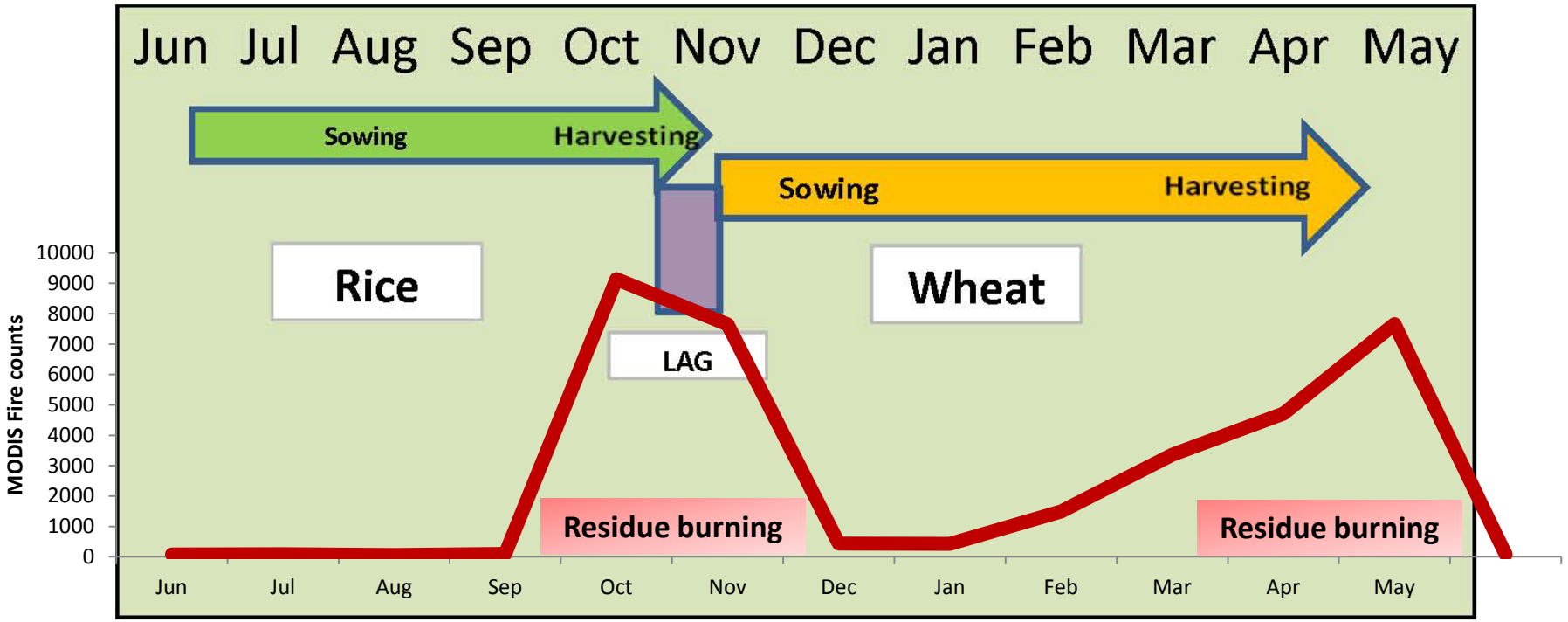
Agricultural Fires in Punjab (NW India)



MODIS fire counts aggregated based on land use / cover types. More than 80% of fires occurred in Irrigated Croplands mainly due to agricultural residue burning



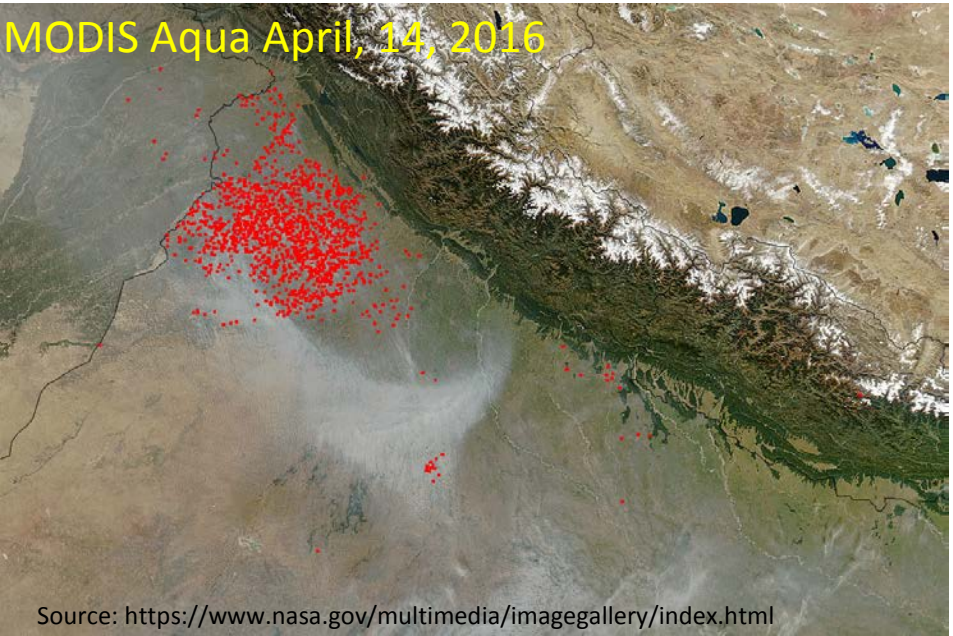
Agricultural Fires in Punjab (NW India)



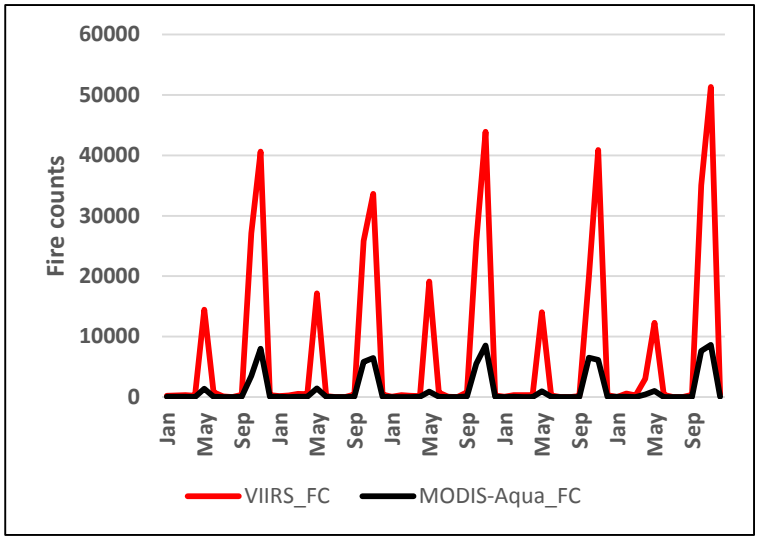
Bimodal trend in Fire activity corresponds to Rice-Wheat cropping system and residue burning. The sowing time of winter (Kharif) Rice is July-August and is harvested in October-November. Wheat is sown during November-December and harvested during April-May. High fire counts from MODIS correspond to the agricultural residue burning season.

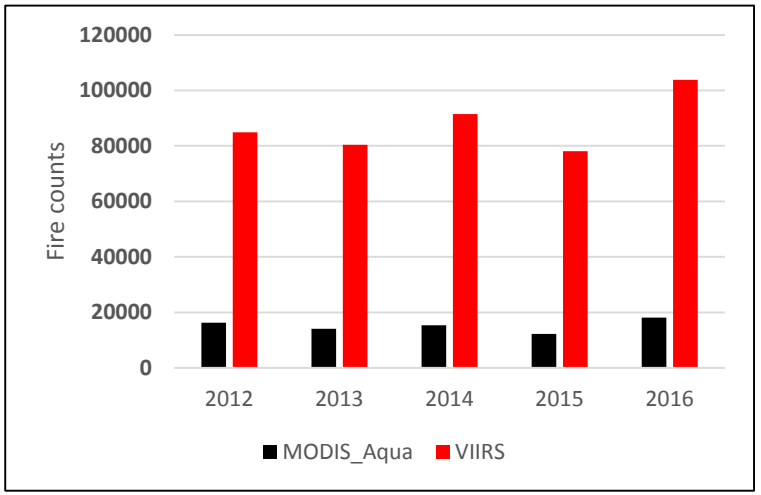
MODIS (Aqua) versus VIIRS Fire Counts

Tribune, October, 2016



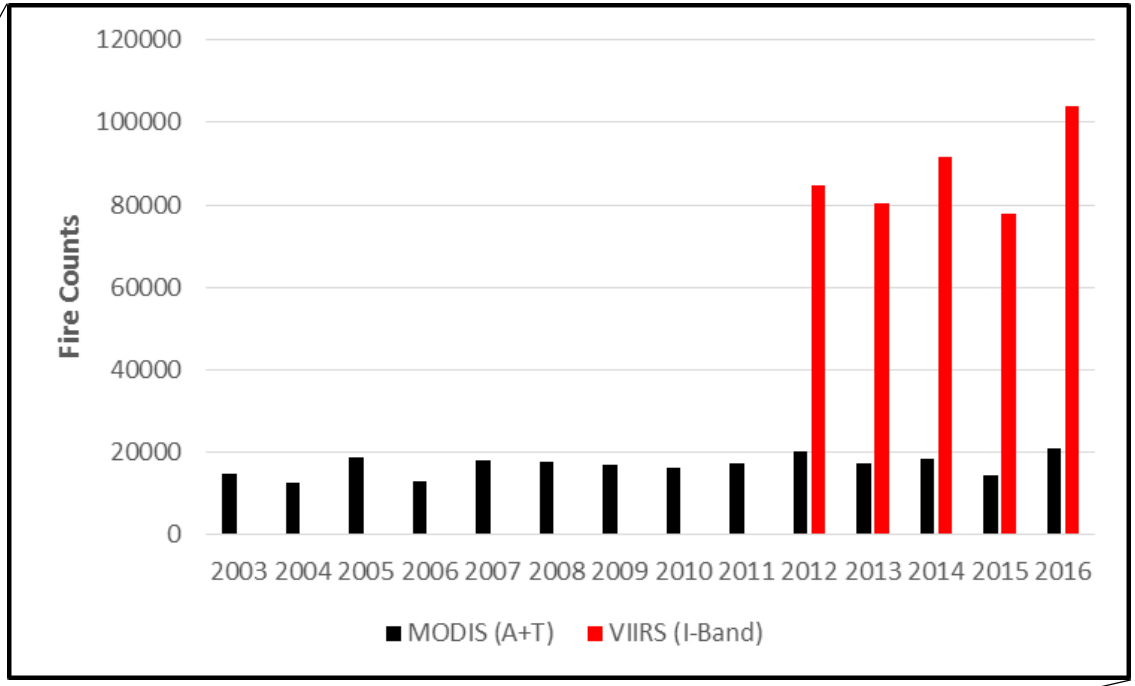
Source: https://www.nasa.gov/multimedia/imagegallery/index.html

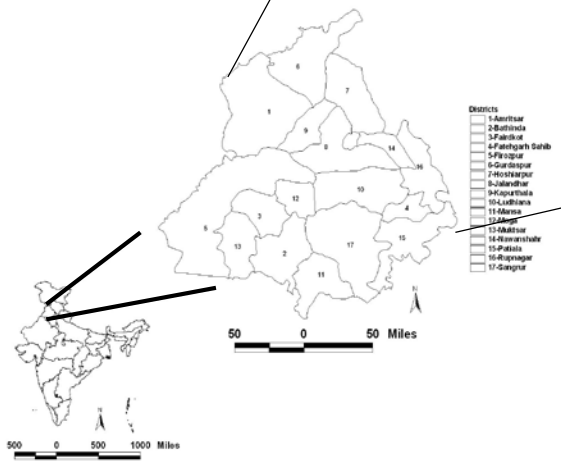




Averaged across five years, VIIRs detected fires were higher than MODIS by a factor of 5.7

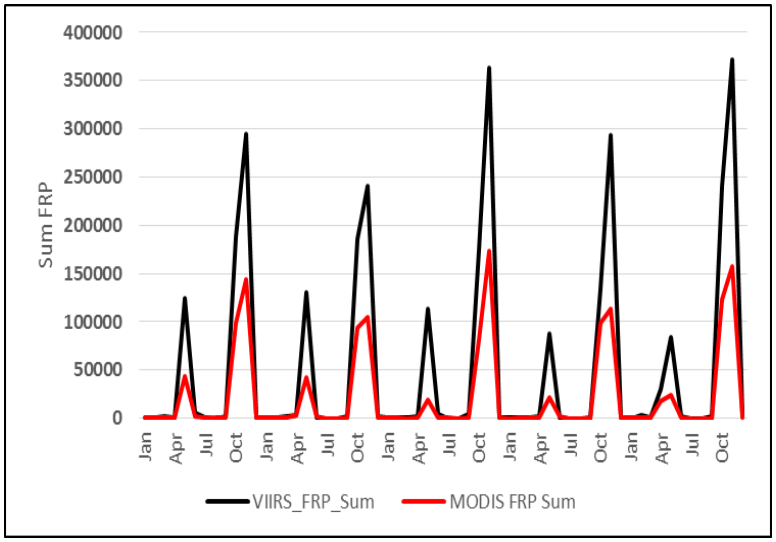
MODIS (Aqua+ Terra) versus VIIRS Fire Counts

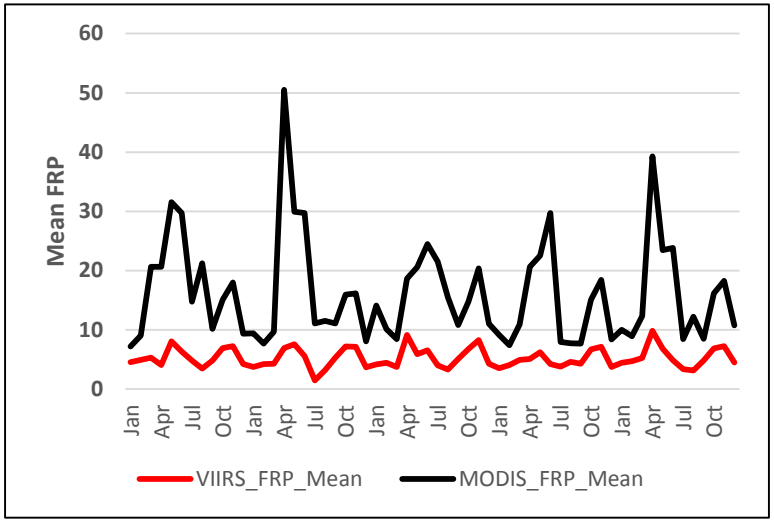


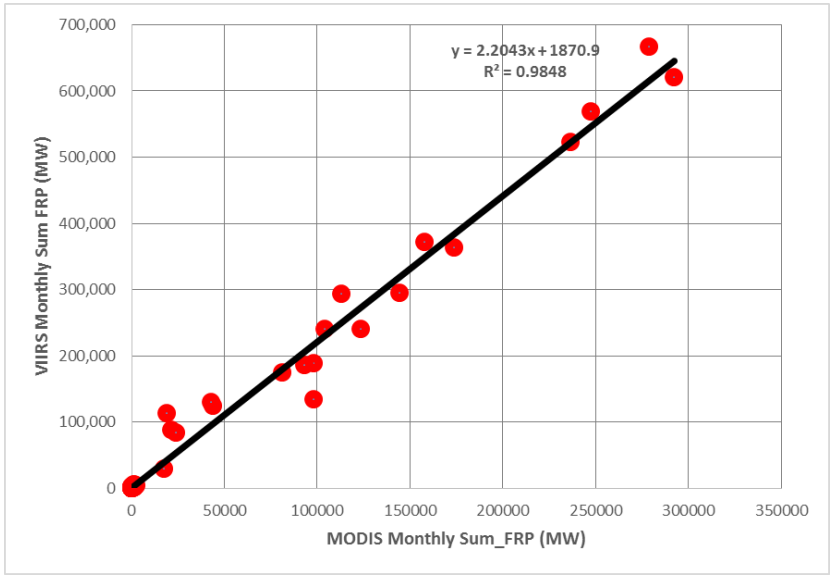


Averaged across five years, VIIRs detected fires were higher than MODIS (both Aqua + Terra combined) by a factor of 4.8

MODIS versus VIIRS FRP





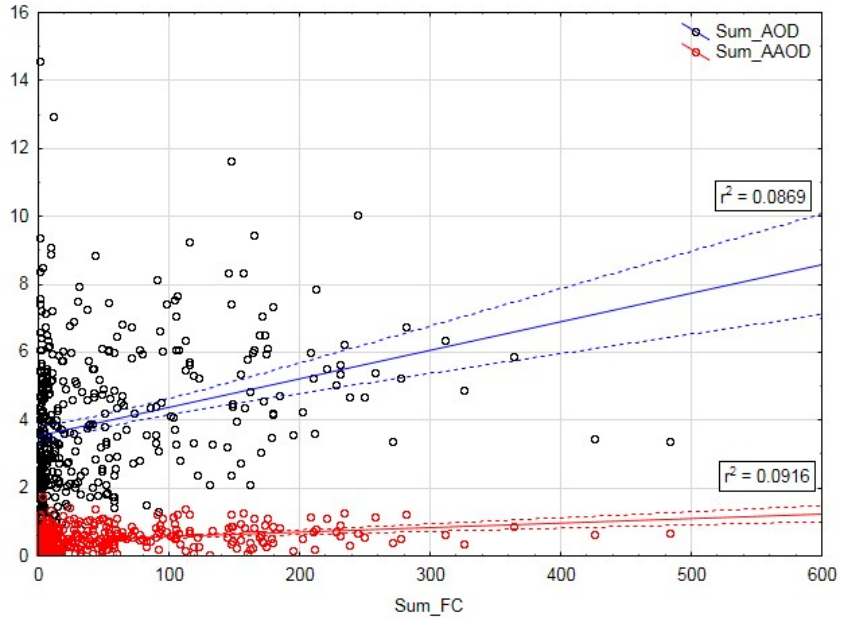


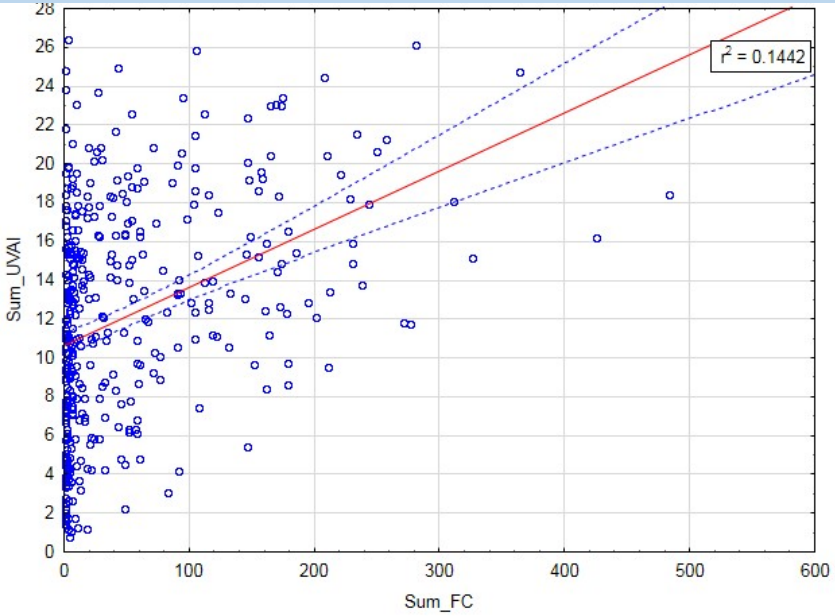
Note that the Mean for MODIS Aqua FRP is higher than the VIIRS FRP, whereas Sum of FRP is higher for VIIRS than MODIS (due to relatively large number of fires detected by VIIRS). Also note that MODIS and VIIRS (Sum of FRP) are highly correlated.

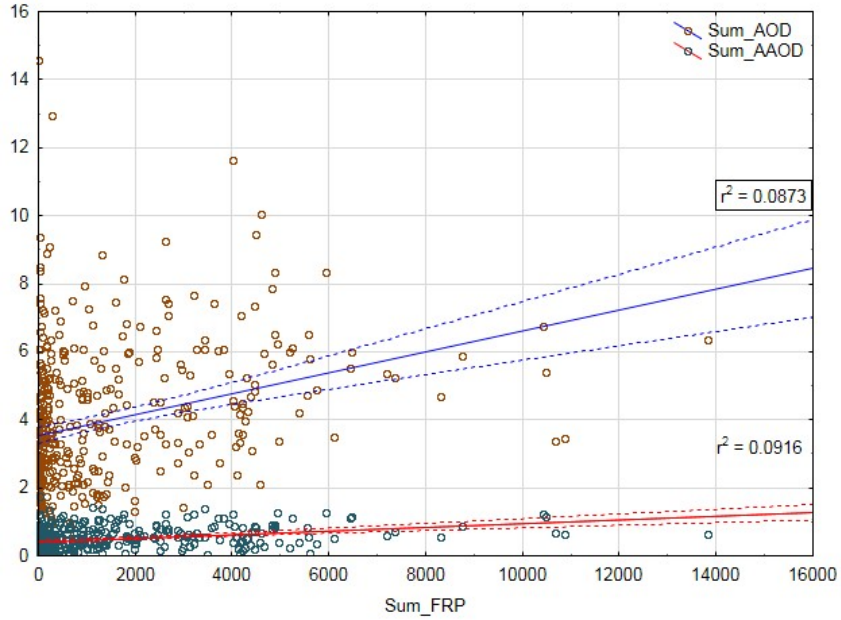
Caution!

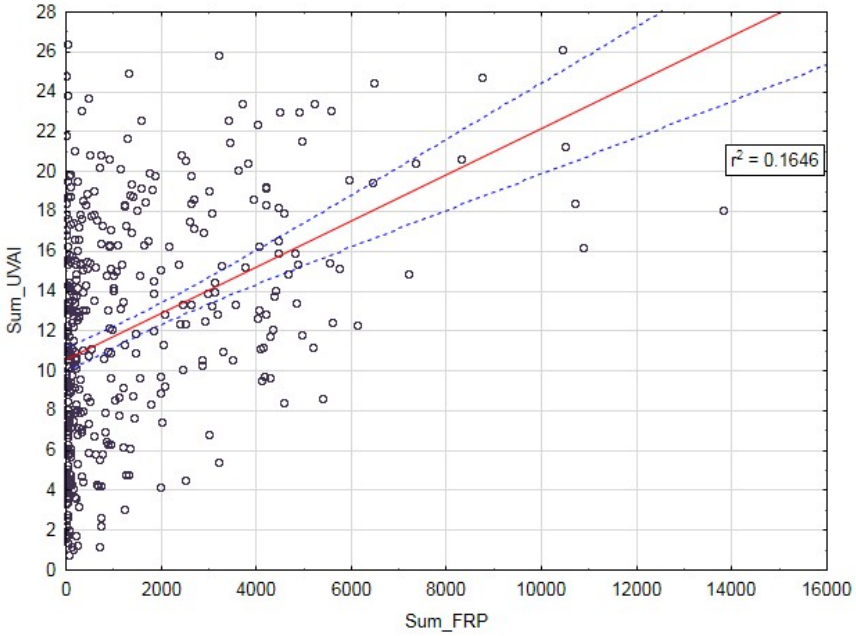
While assessing the question on "which fires burn more intensively using FRP products in different landscapes", MEAN versus SUM will give a different result !

MODIS FC/FRP and Aerosol products (Punjab Fires - Summer)

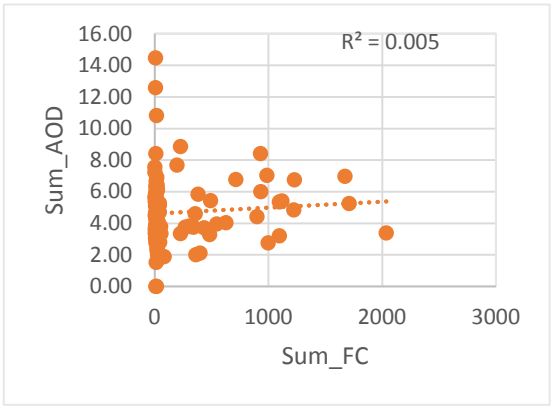


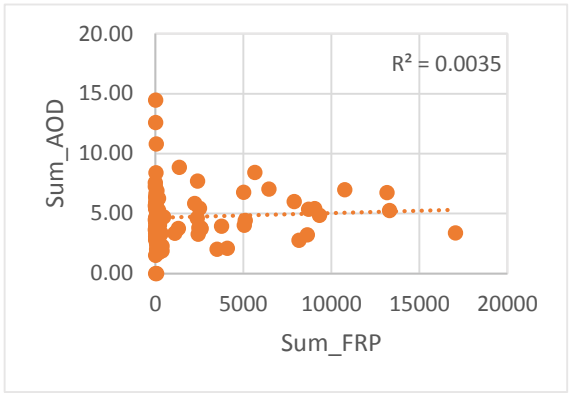


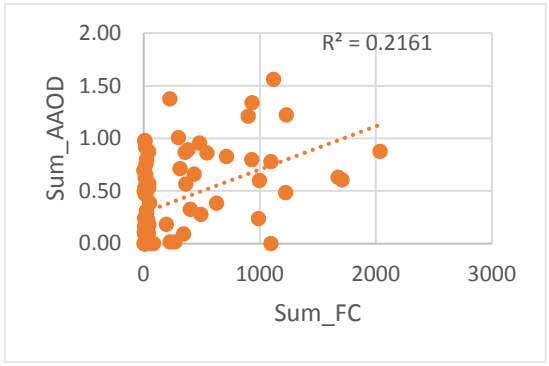


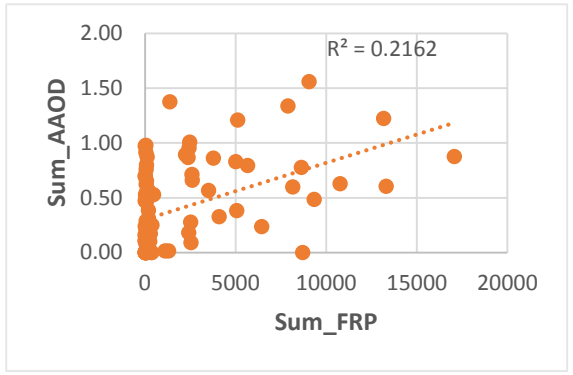


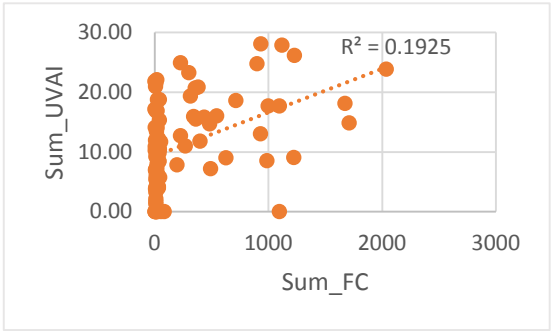
VIIRS FC/FRP and Aerosol products (Punjab Fires - Summer)

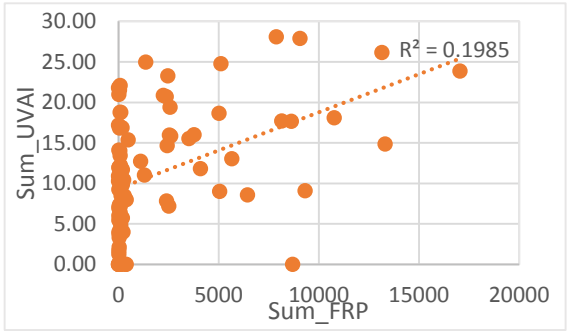












MODIS versus VIIRS FRP Smoke Emission Rates

- The mass of specific aerosols or greenhouse gases released from fires is directly proportional to the dry mass combusted (Seiler and Crutzen 1980; Andreae and Merlet 2001)

- Fire radiative energy (FRE), or the temporal integral of fire radiative power (FRP), is also directly proportional to the amount of dry biomass combusted (Wooster 2002; Roberts et al. 2005)

- Mass of smoke aerosol, can be linearly related to FRE (Ichoku et al. 2008; Freeborn et al. 2008)

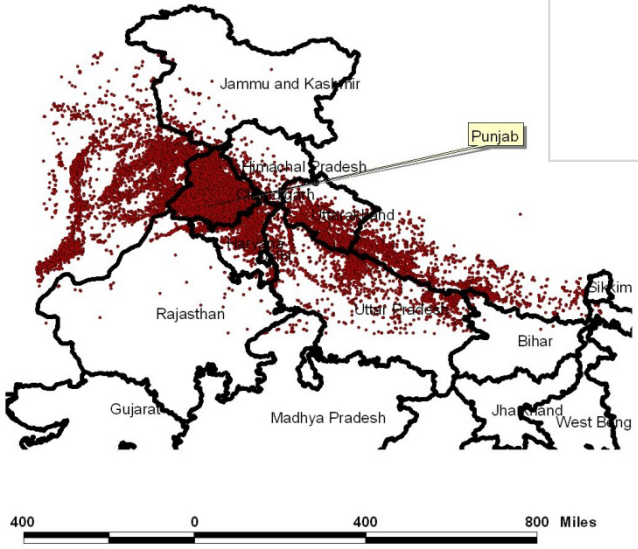
- The rate of aerosol emission (R_{sa} in kg/sec) can be related to that of FRP as (Ichoku et al. 2008)

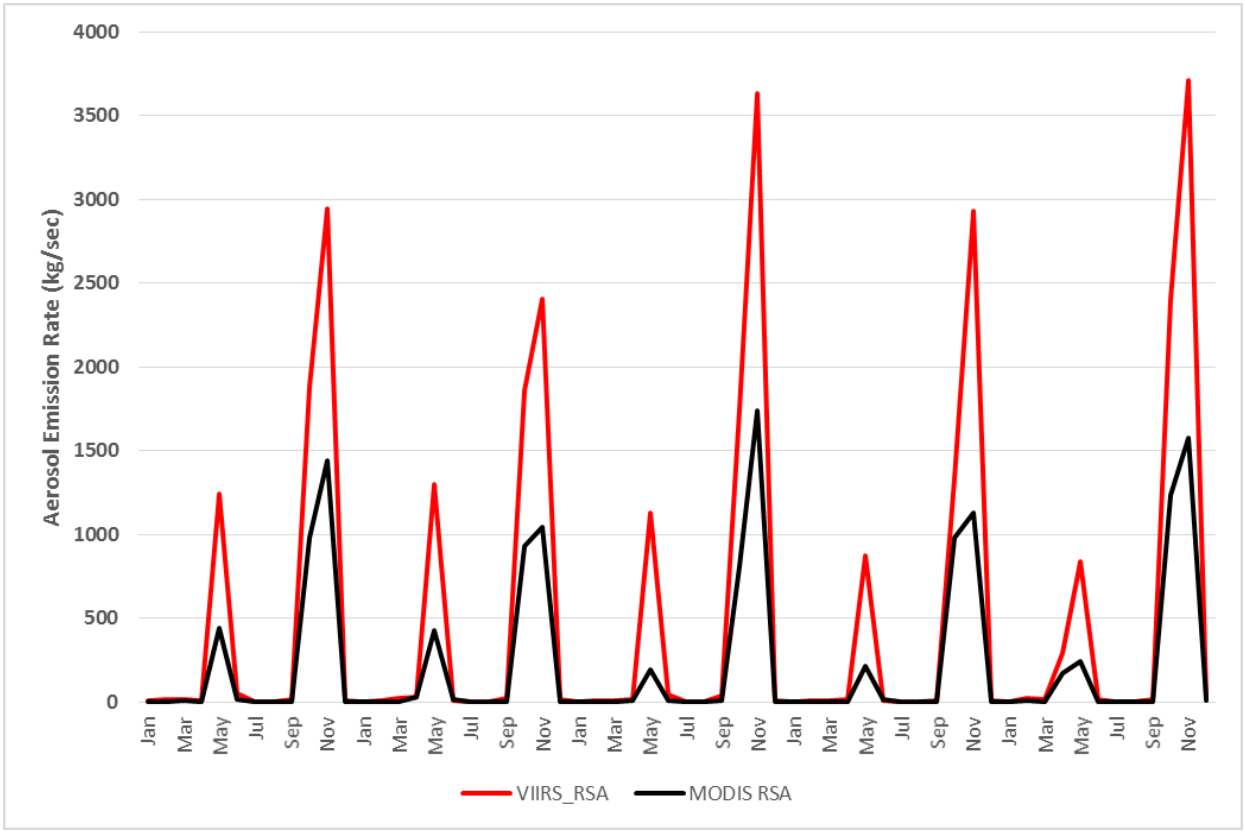
$$R_{sa} = C_e * FRP$$

Where C_e is the coefficient that directly relates radiative power from fire to its smoke aerosol emission rate (coefficients of emission in kg/MJ for particulate matter) and Mass of smoke aerosol emission (M_{sa}) is given as (Ichoku et al. 2008) :

$$M_{sa} = C_e * FRE$$

MODIS versus VIIRS FRP Aerosol Emission rates



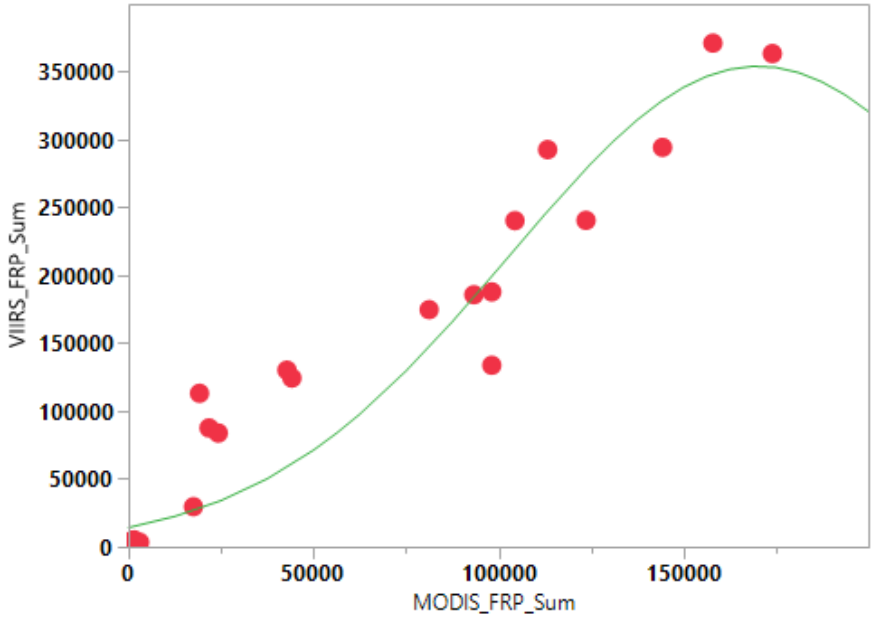


Using VIIRS FRP data suggests significantly higher emission rates than MODIS

Temporal VIIRS FRP Aerosol Emission rates

- VIIRS data was found to capture more fires with relatively higher FRP suggesting underestimation of MODIS based smoke emission rates.

- However, VIIRS data is available only from 2012 whereas MODIS Aqua from May 2002; thus, to account for the VIIRS temporal FRP based emissions, a prediction model with the peak Gaussian fit has been derived with MODIS Sum of FRP as independent (x) variable and VIIRS Sum of FRP as dependent (y) variable.



Prediction Model

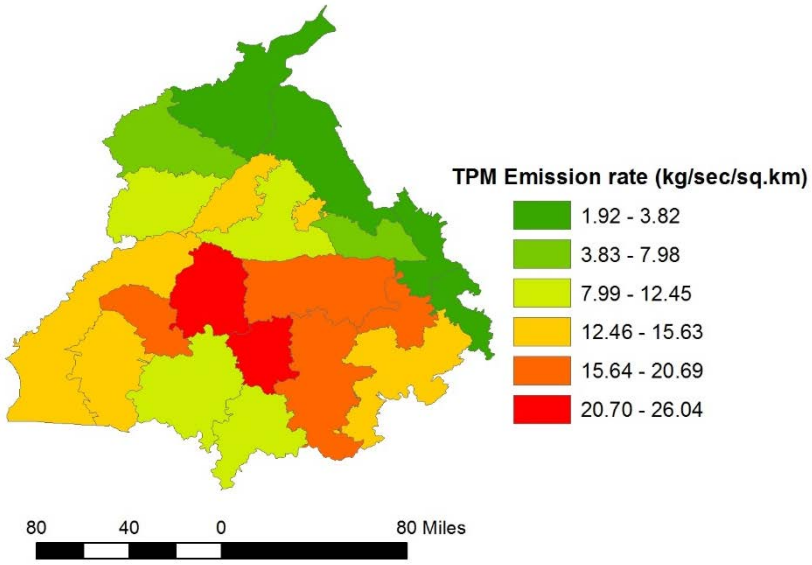
$$a \cdot \mathrm{Exp}\left(-\left(0.5 \cdot \left(\frac{\left(\mathrm{MODIS\_FRP\_Sum} - b\right)}{c}\right)^2\right)\right)$$

a = Peak Value

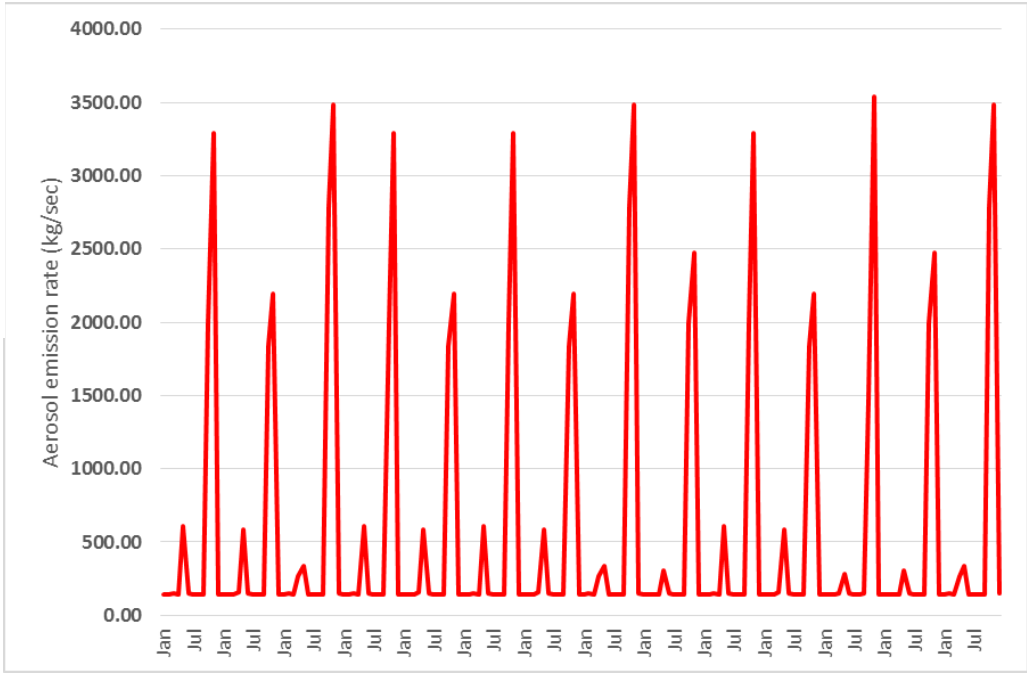
b = Critical Point

c = Growth Rate

Temporal VIIRS-MODIS (model fitted) FRP Aerosol Emission rates (2003-2016)



Districts of Moga and Burnala in central Punjab had the highest total particulate matter emission rates (as influenced by the highest SUM of FRP)



Aerosol emission rates (2003-2016) - Punjab

Summary

- In an agricultural landscape, averaged across five years, VIIRs detected fires were higher than MODIS Aqua by a factor of 5.7 and higher than Terra+Aqua combined by a factor of 4.8.

- MODIS and VIIRS (Sum of FRP) are highly correlated.

- Mean monthly MODIS Aqua FRP is higher than the VIIRS FRP, whereas Sum of FRP is higher for VIIRS than MODIS (due to relatively large number of fires detected by VIIRS). These results have implications for assessing fire intensities in different landscapes.

- For the raw data (without any transformations), in general, correlation between FRP products (both MODIS and VIIRS) in agricultural fires are weak. Relatively better correlations were observed when VIIRS products were used.

- To account for the temporal FRP-based particular matter emissions, a prediction model with peak Gaussian fitting combining VIIRS FRP and MODIS Aqua FRP data was useful (2003-2016).