IDENTIFICATION OF PERSISTENT INFRARED EMITTERS IN ASIA WITH VIIRS NIGHTFIRE DATA: 2012-2020

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ABSTRACT: The Visible Infrared Imaging Radiometer Suite (VIIRS) collects nightly global data in near infrared (NIR), shortwave infrared (SWIR) and midwave infrared (MWIR) spectral bands, providing a unique capability to observe and characterize infrared emitters at night. The VIIRS nightfire (VNF) algorithm identifies infrared (IR) emitters in multiple spectral bands and calculates temperature, source area and radiant heat via Planck curve fitting. VNF data are produced nightly and extend from 2012 to present. The most common infrared emitter across Asia is biomass burning. Industrial IR emitters are hidden amongst the vast numbers of biomass burning detections. Here we present a survey of persistent IR emitters in Asia. Having a catalog of known IR emitter sites make it possible to monitor the sites for use in economic forecasting and greenhouse gas emission inventories.

1. INTRODUCTION

Anthropogenic climate change is driving the nations of the world to collectively commit to reducing greenhouse gas emissions associated with the consumption of fossil fuels. The challenge to avert the worst consequences of global warming is immense and monitoring is key to confirming the progress made. Satellite sensors offer some advantages in monitoring greenhouse gas emitters because of their ability to collect frequent global data, provide long temporal records, and the ability locate and characterize infrared (IR) emitters. The VIIRS nightfire (VNF) algorithm detects IR emitters at night using spectral bands spanning NIR, SWIR and MWIR (Elvidge *et al*., 2013 and 2016). With sunlight eliminated - the NIR and SWIR band data are particularly valuable because the emitters can be clearly detected against the sensor's noise floor and the observed radiances can be fully attributed to the IR emitter. VNF uses Planck curve fitting to calculate temperature, source area and radiant heat. VNF detects are several types of IR emitters, including biomass burning, volcanoes, industrial sites and natural gas flares. Biomass burning is the most common type of IR emitter detected by VNF. Distinguishing biomass burning from industrial IR emitters involves filtering based on persistence. Biomass burning is ephemeral, concentrated primarily in the dry months, and it may take multiple years for the vegetation to regrow and burn again. In contrast, industrial emitters and gas flares are fixed locations and can have multiple detections every year.

The keys to the monitoring of greenhouse gas emission point sources is to know where to look and to have an effective means to repeatedly observe the radiant emissions at each identified sites. In this paper we present results from a survey of persistent IR emitters in Asia based on the nightly record of VNF detections from 2012 through 2020.

2. METHODS

Our method for identifying persistent infrared emitters involve the compositing of all cloud-free local maxima VNF detection spanning 2012 through 2020. The output grids are at 15 arc second resolution, The key grids include average temperature and percent frequency of detection. Temperature and % frequency samples are taken from prominent zones of biomass burning and atmospheric glow surrounding natural gas flares. From these sample we set persistence thresholds indexed to temperature. For temperatures under 1300 K sites are rated as persistent if they are present at least 2% of the time. For temperatures above 1300 K the persistence threshold drops to 1%.

3. RESULTS

3.1 IR Emitter Totals by Country

The total number of VIIRS persistent IR emitters worldwide is 18,788. The total found in Asia is 4493 (Table 1) or 23.9%. China stands out for its large number of persistent IR emitter tally of 2167, nearly half of all Asian IR emitters.

Table 1. Persistent IR Emitter Tallies by Country

Country	Onshore	Offshore	Total
China	2077	90	2167
Indonesia	369	54	423
India	365	20	385
Iran	331	40	371
Kazakhstan	229	1	230
Iraq	219	0	219
Malaysia	27	87	114
Vietnam	76	30	106
Turkmenistan	88	11	99
Uzbekistan	97	0	97
Pakistan	84	0	84
Thailand	46	18	64
Azerbaijan	19	9	28
Japan	25	2	27
South Korea	16	0	16
Bangladesh	13	0	13
Papua New Guinea	10	0	10
China-Taipei	5	4	9
Myanmar	3	4	7
Philippines	4	2	6
Cambodia	4	0	4
Mongolia	3	0	3
North Korea	3	0	3
Kyrgyzstan	2	0	2
Singapore	1	1	2
Sri Lanka	2	0	2
Timor Leste	0	2	2

3.2 Assembling VNF Detections for Emitter Sites

Once the persistent IR emitter locations are defined – we run through the VNF database to find detections in close proximity to the centroid. This results in clusters of detections the can be used to refine the outlines of the emitter features. The outline is then used to assign the incoming VNF detections to the correct emitter feature. Figure 1 shows the emitter cluster for the YK Steelmill in Busan, Korea.

3.3 Temporal Profiles

Nightly temporal profiles are being assembled for each of the IR emitter sites. These reveal the activity patterns and temperature ranges of the sites. Figure 2 shows the temporal profile of the steelmill shown in Figure 1. The emitter profiles for non-flaring sites include three charts: 1) The SWIR M10 radiance. 2) Temperature. And 3) Radiant heat. The clear sky observations are marked in blue and cloudy observations are red. Note that activity levels have been stable through the entire record back to 2012. The temperature variance is high – perhaps indicating that several types of IR emitters are present at the site.

For gas flares the site profiles include the M10 radiance, temperature, and flared gas volumes in methane equivalents. Figure 3 shows the temporal profile for a gas flare located off the coast of Vietnam. This flare first appeared in mid-2014 and was highly active until early 2016. Then the flaring activity was reduced for about two years. In 2018 flaring activity stepped up. The flaring activity stepped up again in late 2020 to present. The temperature of the flare has averaged 1753 K and has been stable through the changes in activity levels recorded with the SWIR.

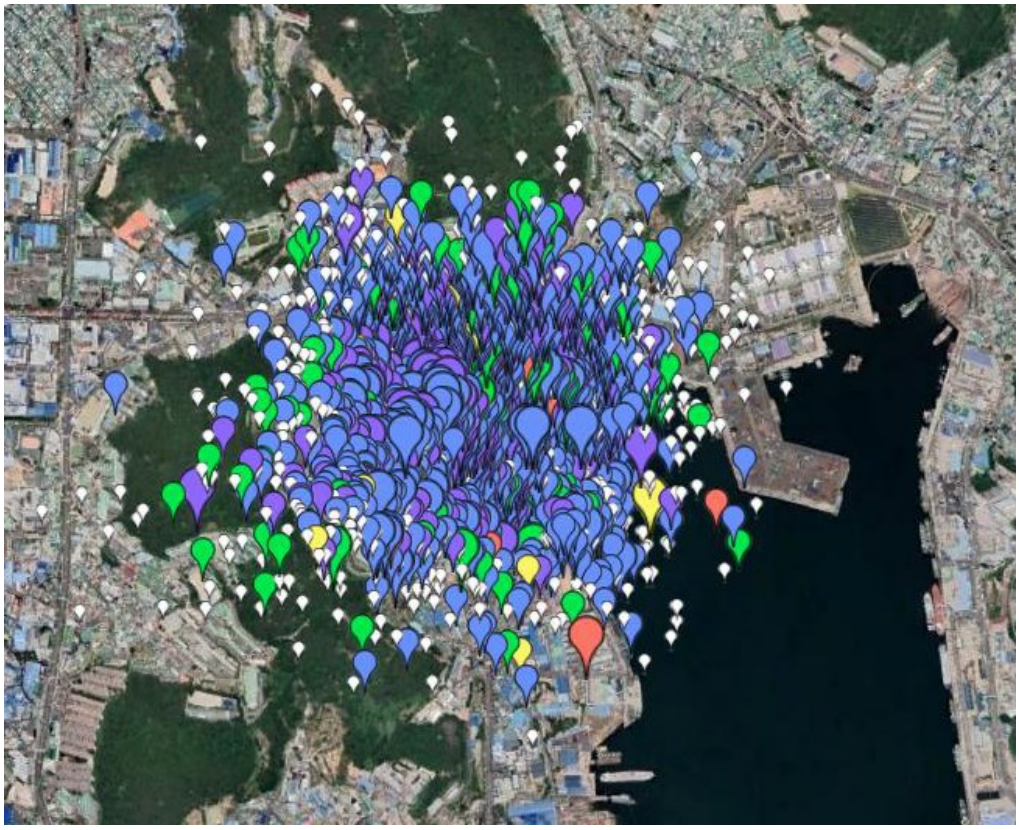

Figure 1. Cumulative detections from the YK Steel Corporation steelmill in Busan, Korea.

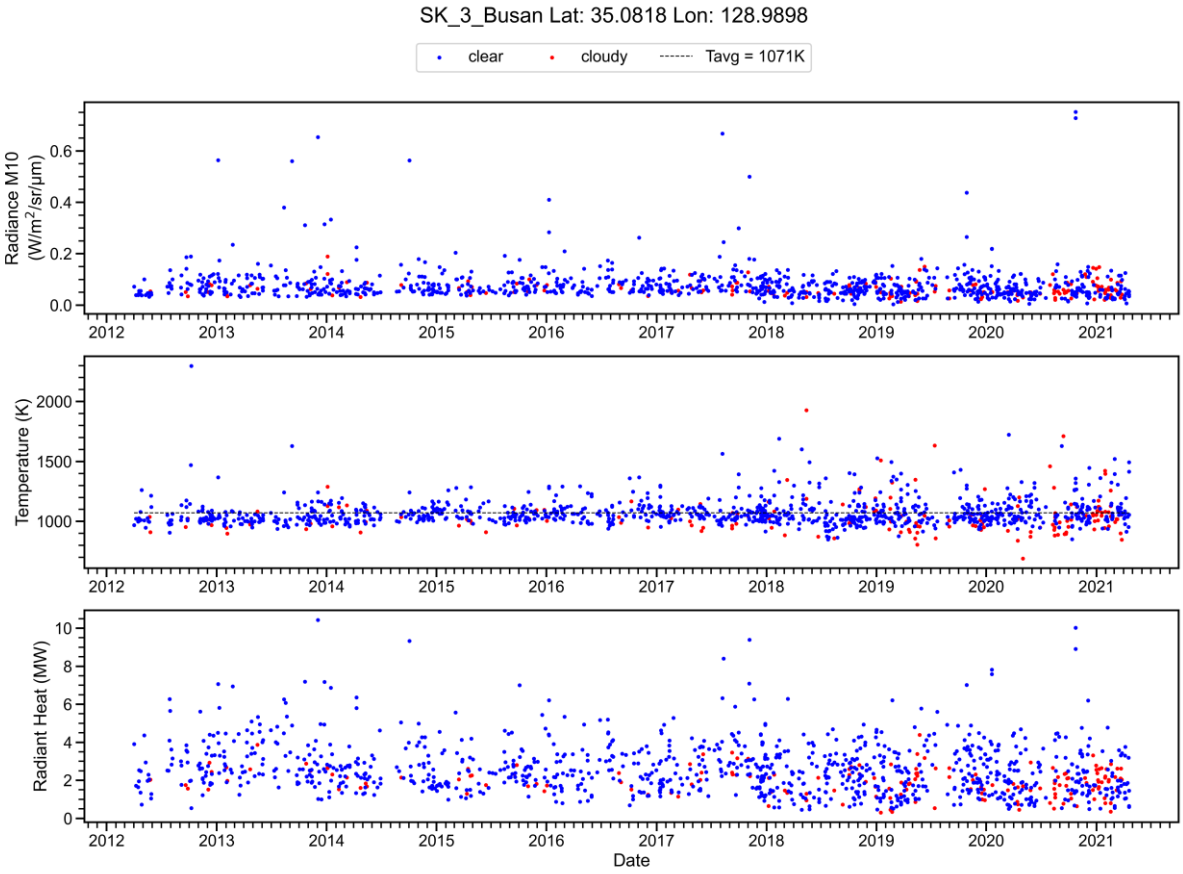

Figure 2. VNF temporal profile of the YK Steel Corporation's steelmill in Busan, Korea.

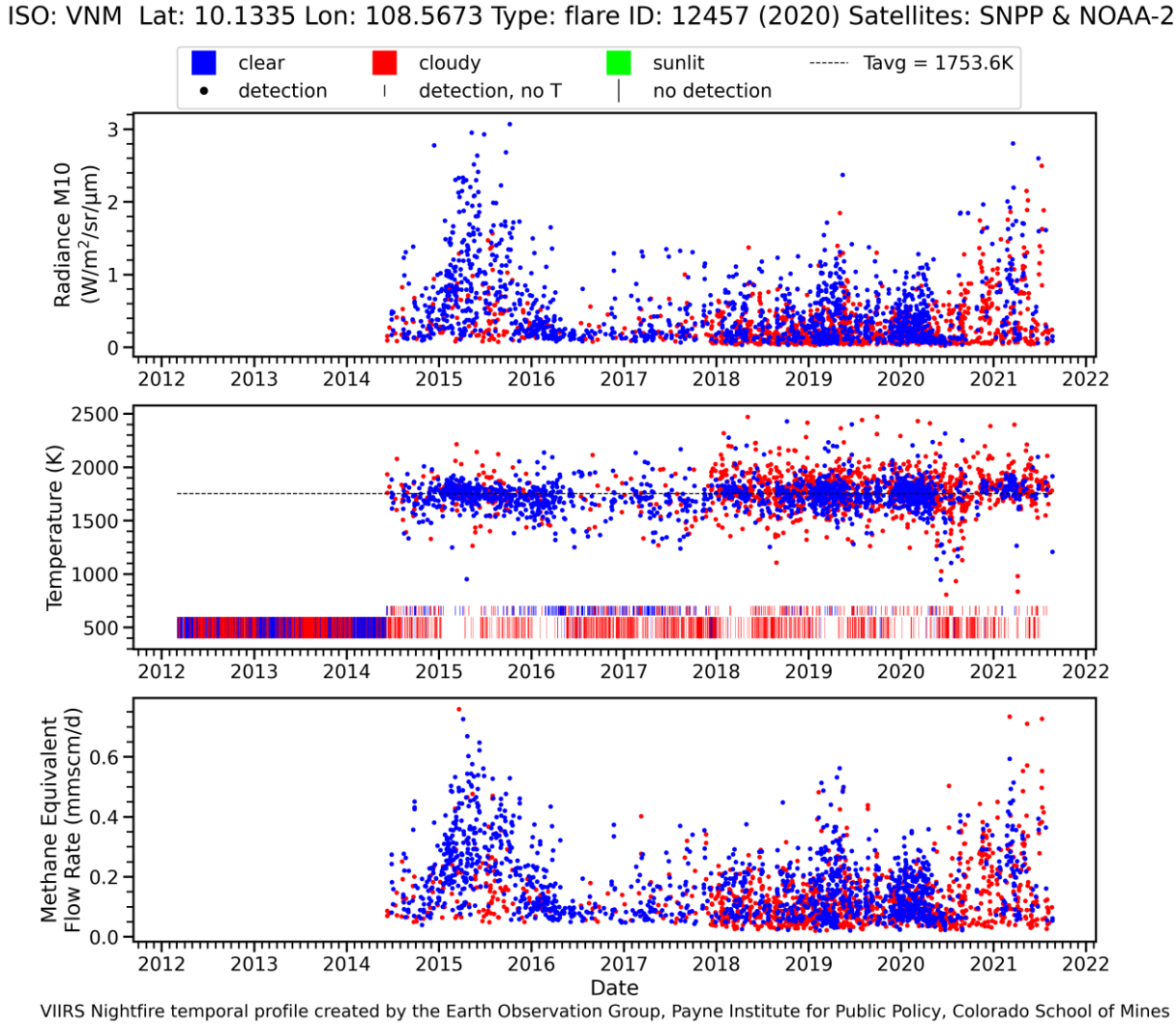

Figure 3. Temporal profile of a natural gas flare located offshore from Vietnam.

3.4 National Temperature Profiles

Countries vary in their temperature profiles – reflecting the diversity of the IR emitter types. Figure 4 shows the temperature profiles for IR emitters from China and Iran. The China profile has a peak in IR emitter numbers from 900 to 1200 K, typical of manufacturing sites. In contrast, Iran's temperature profile is skewed toward higher temperatures – indicating the predominance of gas flares in the population of IR emitters in Iran.

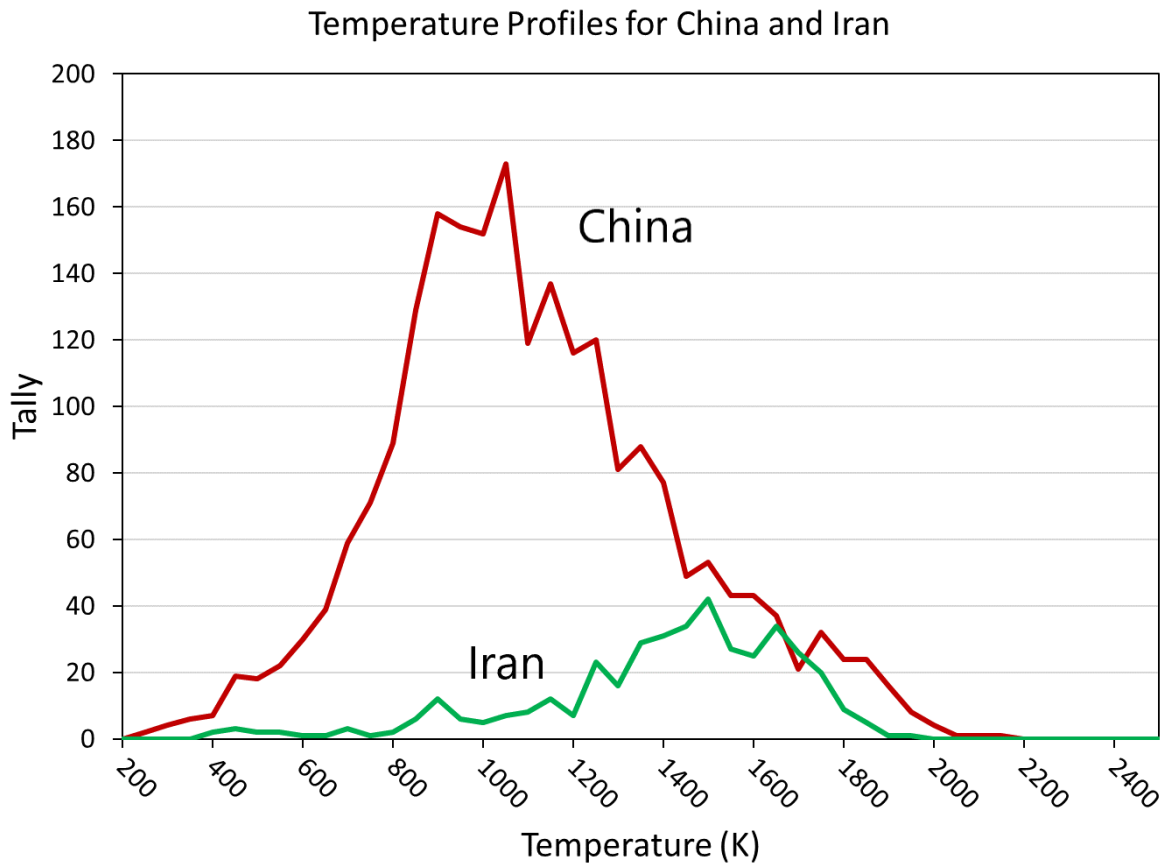

Figure 4. Temperature profile of persistent IR emitters in China and Iran.

4. Conclusion

We have produced a global inventory of persistent IR emitters using VIIRS nightfire (VNF) data. Biomass burning is the most common type of IR emitter detected by VIIRS. The major challenge in identifying infrared emitters from industrial sites and gas flares is the filtering of biomass burning. This can be done by applying a test for persistence. For sites having temperatures below 1300 K a persistence threshold of 2% effectively filters out biomass burning. Sites above 1300 K are gas flares, which in some cases are surrounded by a dim glow from atmospheric scatter. Here the persistence threshold can be dropped to 1%. The multiyear VNF IR emitter catalog includes 18,788 sites and 24% of these are in Asia. EOG is assembling VNF temporal profiles for each of the sites. The profiles reveal temporal changes in activity levels. Some sites are quite steady in their activity levels while others show the start up or termination of the IR emissions, plus changes in activity levels or temperatures over time. EOG plans to keep the temporal profiles updated as new data arrives. The temporal profiles should be useful in monitoring efforts to reduce natural gas flaring and improving the efficiency of industrial processes.

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