Static thermal anomalies and their contribution to global thermal activity

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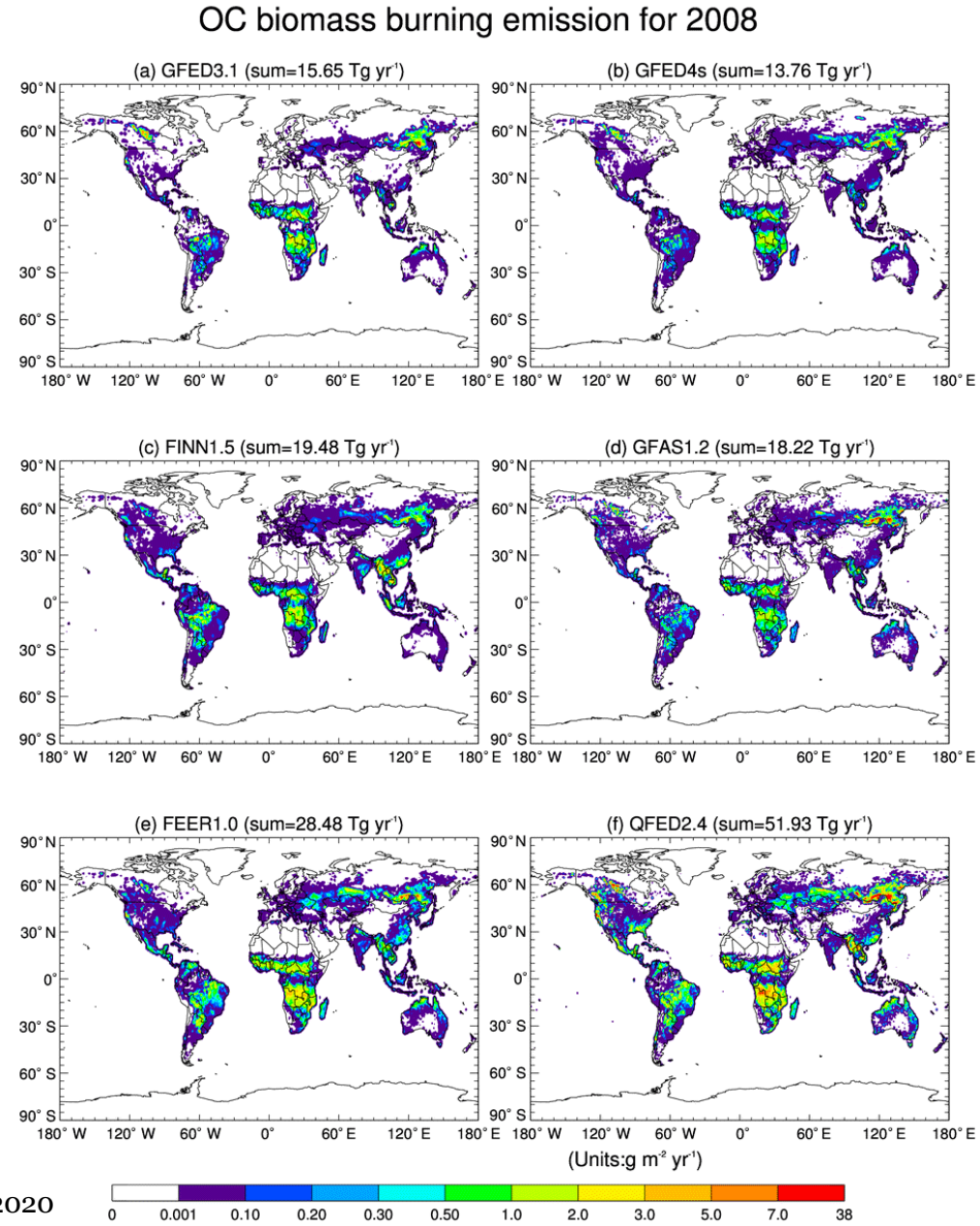
Thermal Anomalies Products

- Earth Observation (EO) Thermal Anomalies products detect thermal emissions from all sources (e.g. biomass burning, volcano's, anthropogenic activity)
- Largest use of these products is the detection of landscape fires
- Some products identity the type of thermal anomaly (e.g. MODIS, VIIRS, SLSTR)
- However, thermal classification can omit some anthropogenic sources
  - impacting validation activates (Forghani et al., 2021)
  - leading to errors in biomass burning emissions inventories (Pan et al., 2020)



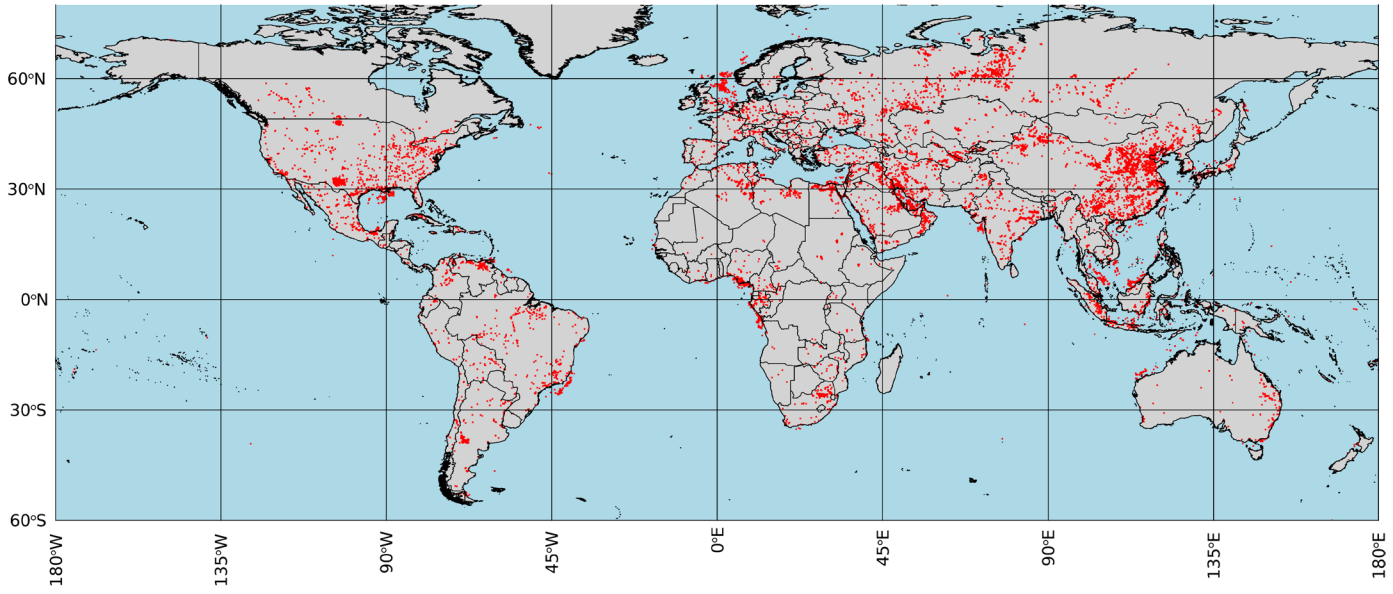
Source : Pan et al., 2020

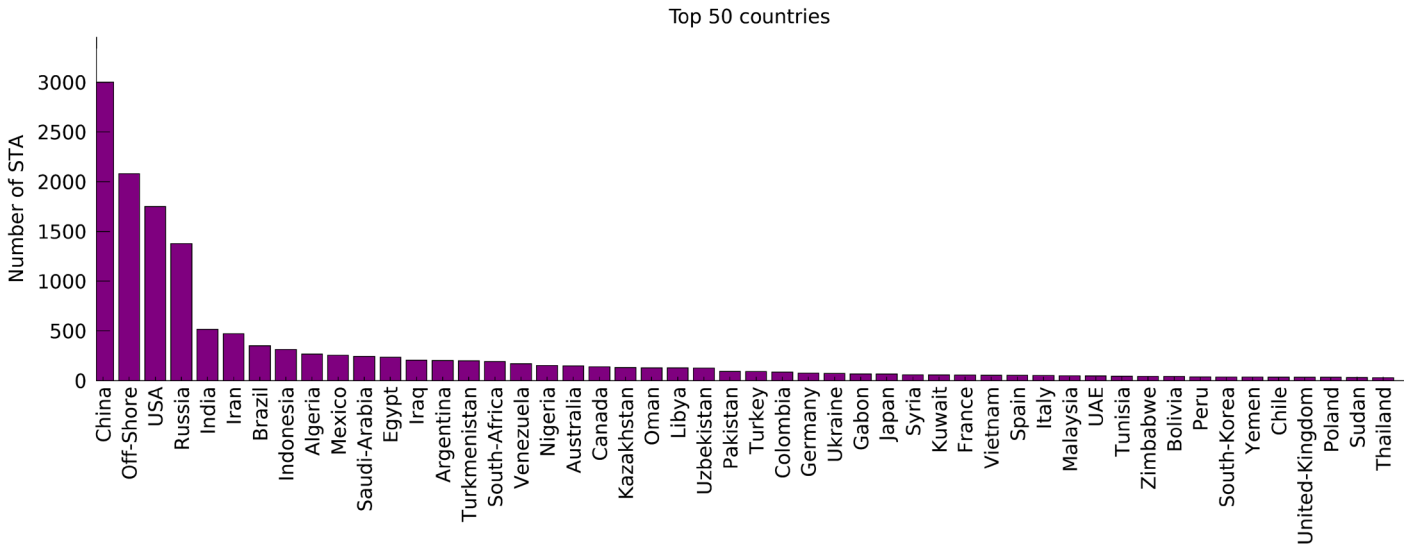
Detection of Static Thermal Anomalies (STA)

- A static thermal anomalies dataset developed using :
  - VIIRS 375 m thermal anomalies product (VNP14IMG, Schroeder et al., 2014)
    - accumulated between 2012-2021 and remapped to 500 m spatial resolution
  - Ancillary datasets to constrain detections :
    - MODIS burned area product (MCD64, Giglio et al., 2016)
    - ESA CCI water bodies dataset (Lamarche et al., 2017)
    - Copernicus crop fractional cover and ESA 10 m human settlement dataset (Pesaresi and Panagiotis, 2023)
    - Smithsonian volcano database
- Static thermal anomalies (STA) identified using a series of temporal and occurrence metrics & constrained by ancillary datasets
  - e.g. number of nighttime detections, average number of annual detections, number of months of active detections etc

VIIRS Static Thermal Anomalies (STA) : Global Distribution

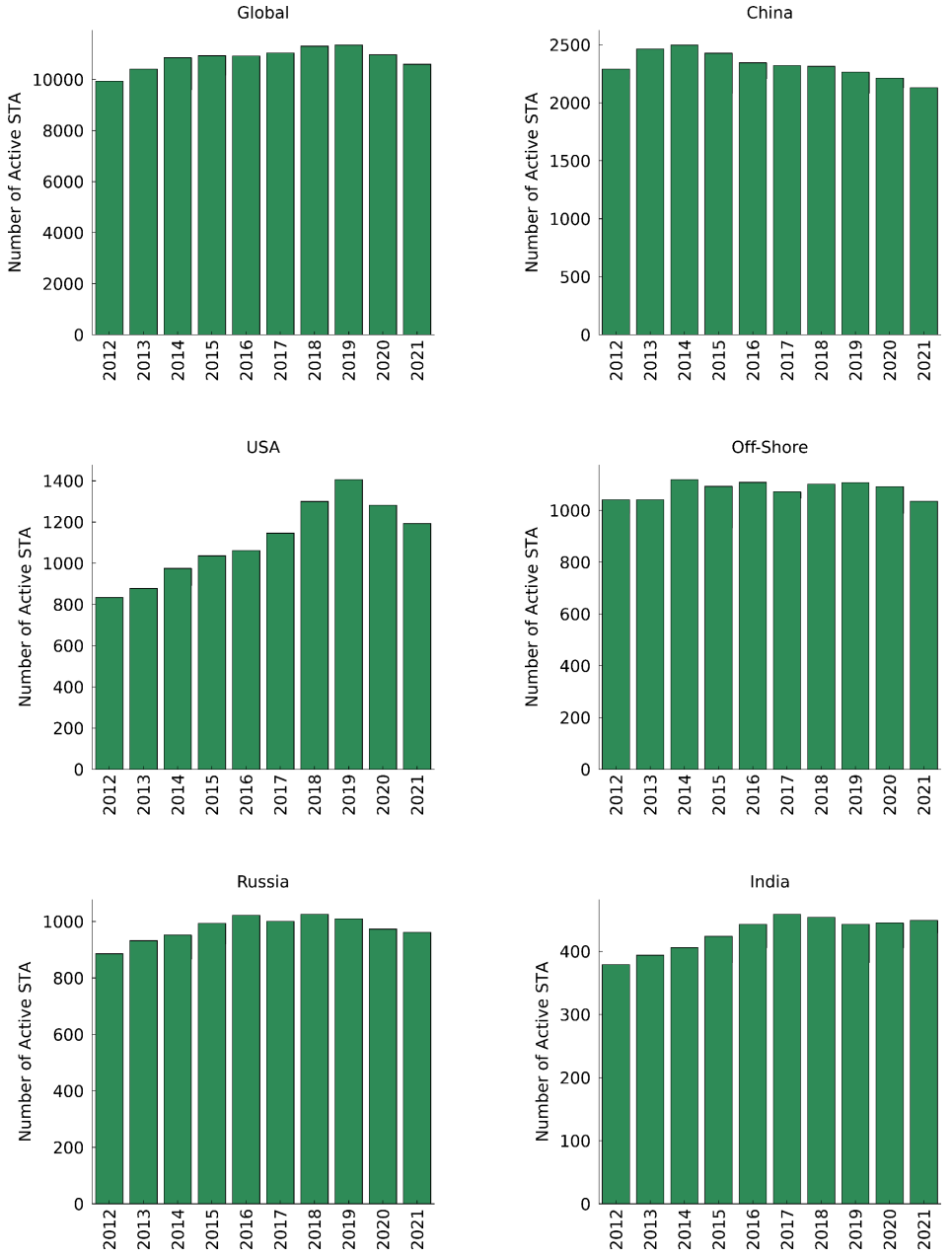
- Globally, 14,892 static thermal anomalies are detected over 10 years
  - STAs defined as contiguous clusters of pixels (54,444 500 m pixels)
  - includes (e.g.) petrochemical and cement production, gas flaring, mining operations, wood processing factories and refuse sites
- China, USA, Russia and India have the greatest number
  - combined 44% of global STAs
  - off-shore sites account for 14% of global total





VIIRS Static Thermal Anomalies (STA) : Annual Dynamics

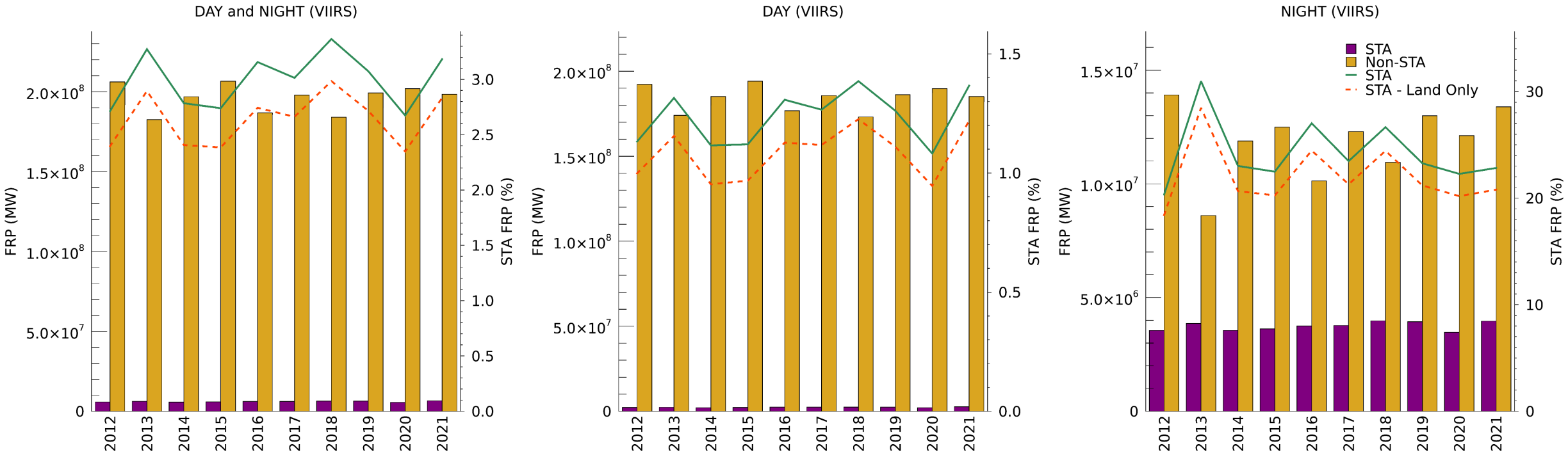
- Annual variation in the number of STAs detected as being ‘active’
  - STAs where a thermal anomaly is detected
  - peaks at 11,350 sites globally in 2019
- Dynamics in USA driven by thermal activity due to gas flaring *
  - sites increased by 300 % between 2012 and 2017
- Dynamics in China result from slight reduction in STA in most sources except gas flaring *
  - largest reduction in coal mining emissions sources (~40%)



* Identified using the Oil and Gas Infrastructure Mapping (OGIM) database (Omara et al., 2023) which maps emissions sources into 11 classes (e.g. cement production, solid wate disposal, oil and gas production etc).

STA contribution to global FRP : VIIRS

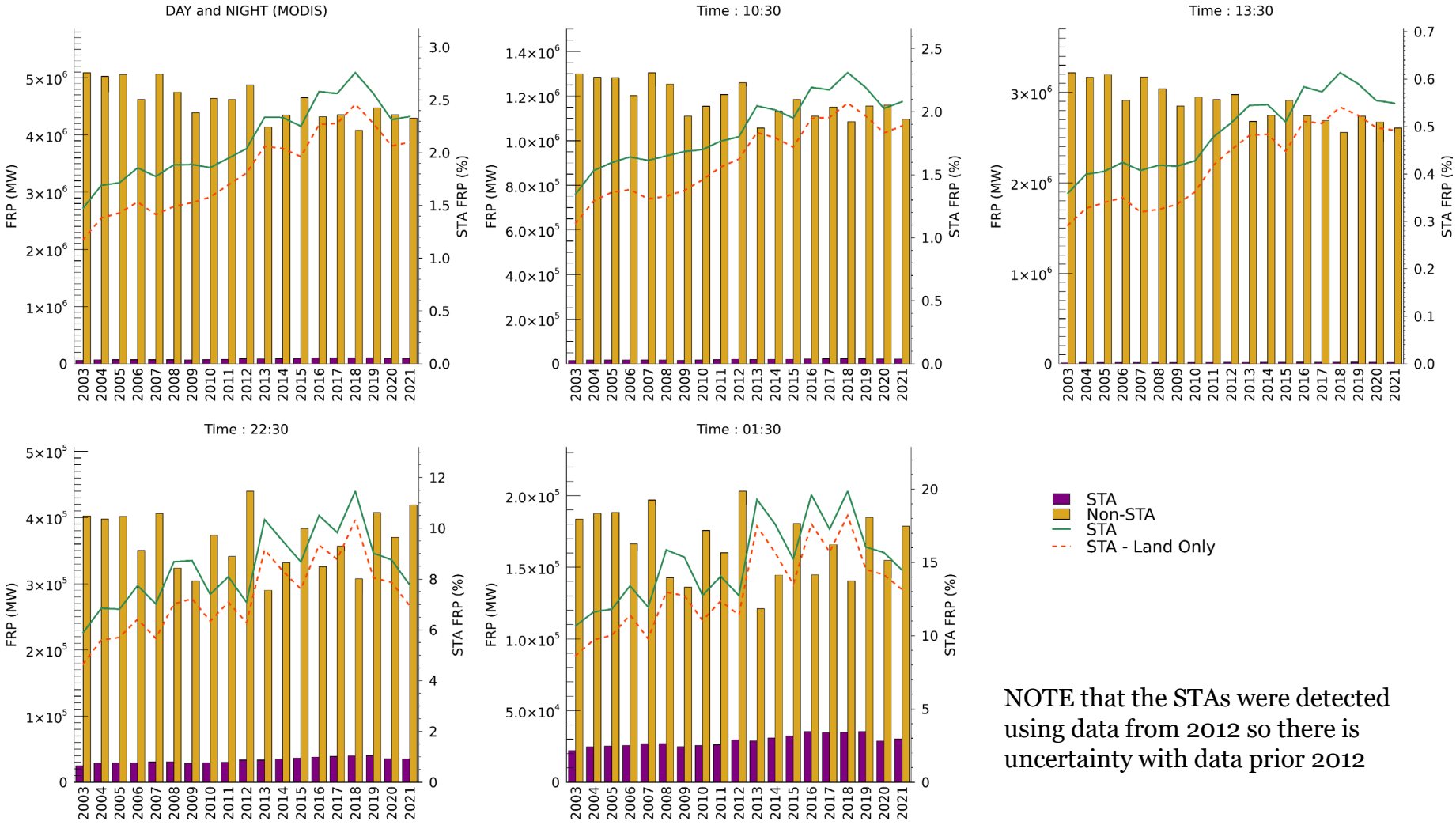
- Results indicate :
  - 2 – 3% of global VIIRS FRP originates from STAs
  - STAs account for 20 - 30% of nighttime FRP
    - low level landscape fire activity and increased detection of STAs



STA Contribution to global FRP : MODIS

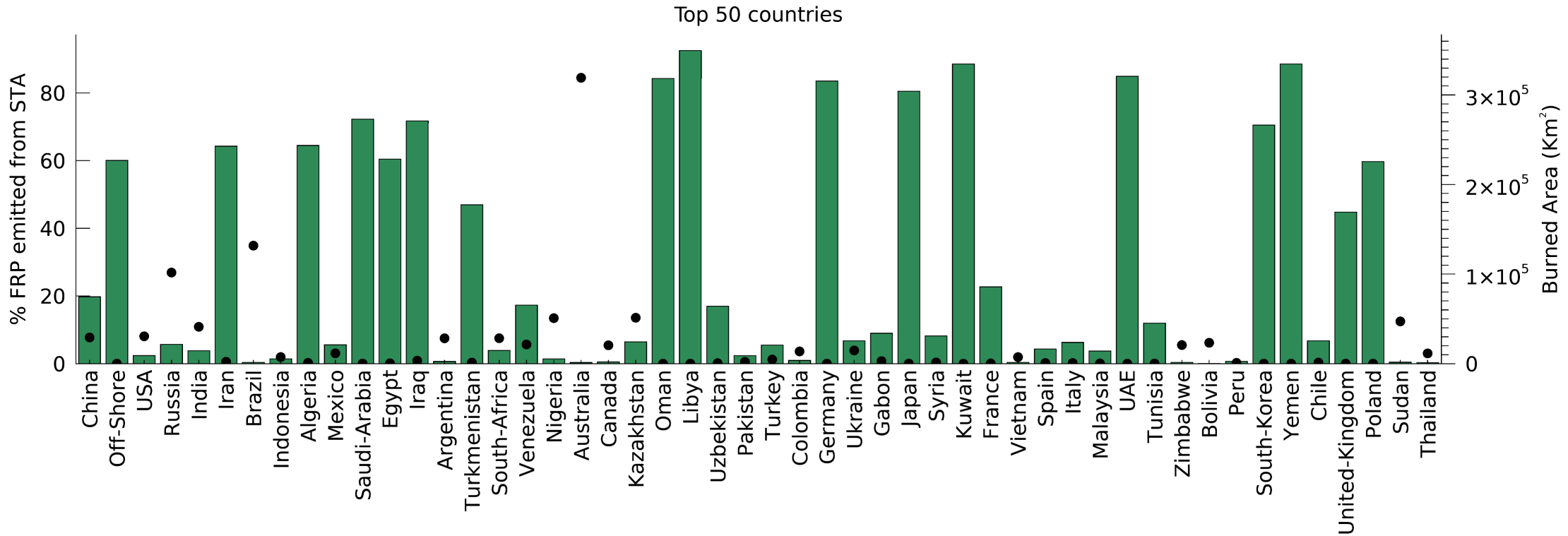
- Lower % of FRP originates from STAs than VIIRS
  - VIIRS capacity to detect lower FRP signals (particularly at night)

- Daytime FRP from STAs 0.3 - 2% of global total
- 6 – 18% FRP contribution during the night
- Diurnal variation due to improved STA detection
  - 10% higher at night (22:30 & 01:30)
  - lowest at 13:30
- Need to account for non-BB sources if nighttime fire activity of interest



NOTE that the STAs were detected using data from 2012 so there is uncertainty with data prior 2012

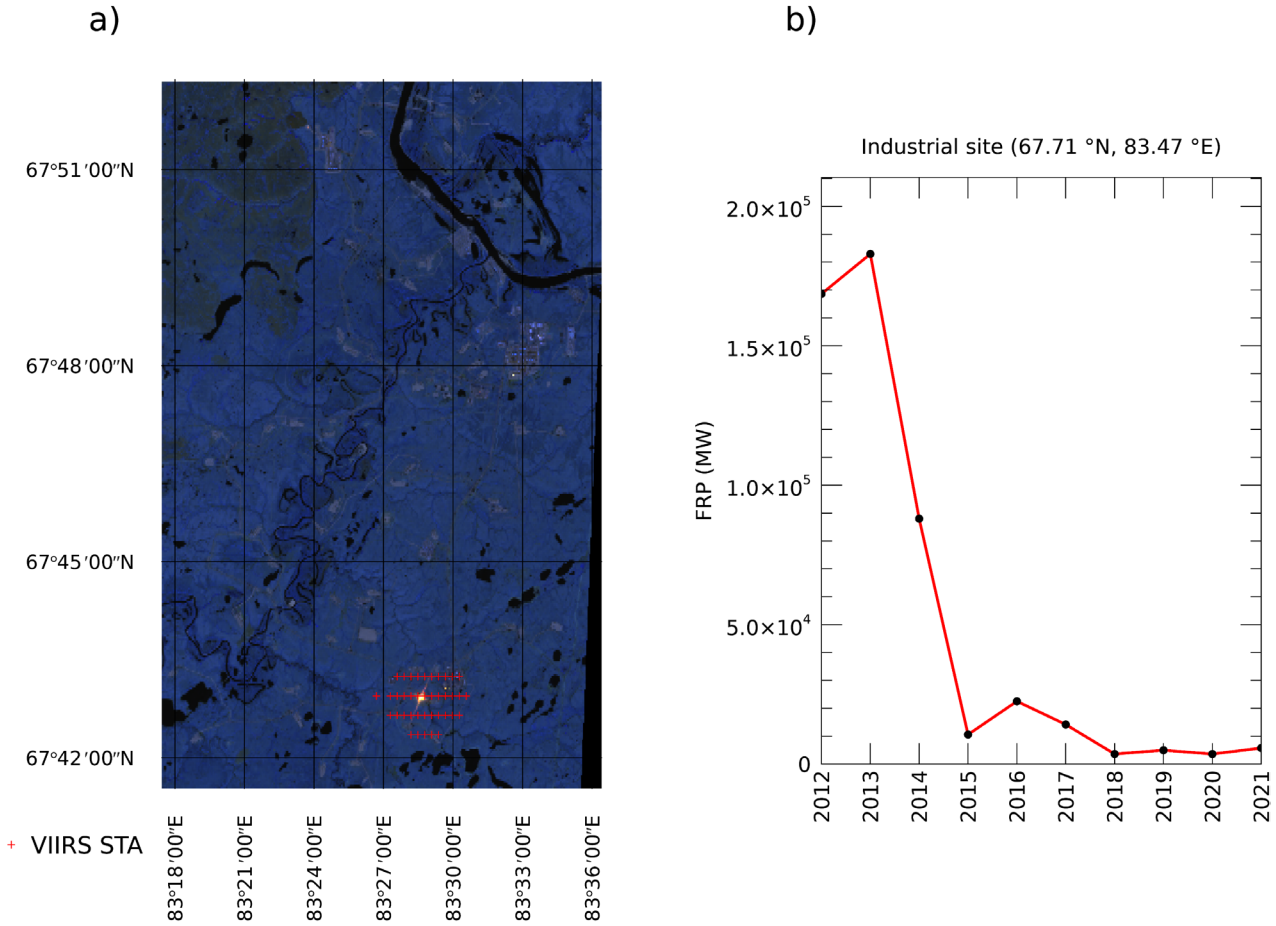
STA contribution to national-level FRP



- Countries with greatest percentage of FRP from STAs :
  - arid regions with no/low burned area
- Countries of moderate burned area include
  - China (20% of national scale FRP from STAs)
  - Russia (6%)
  - Venezuela (17%)
  - potentially large regional errors in FRP-based emissions inventories

Local Scale FRP from static thermal anomalies

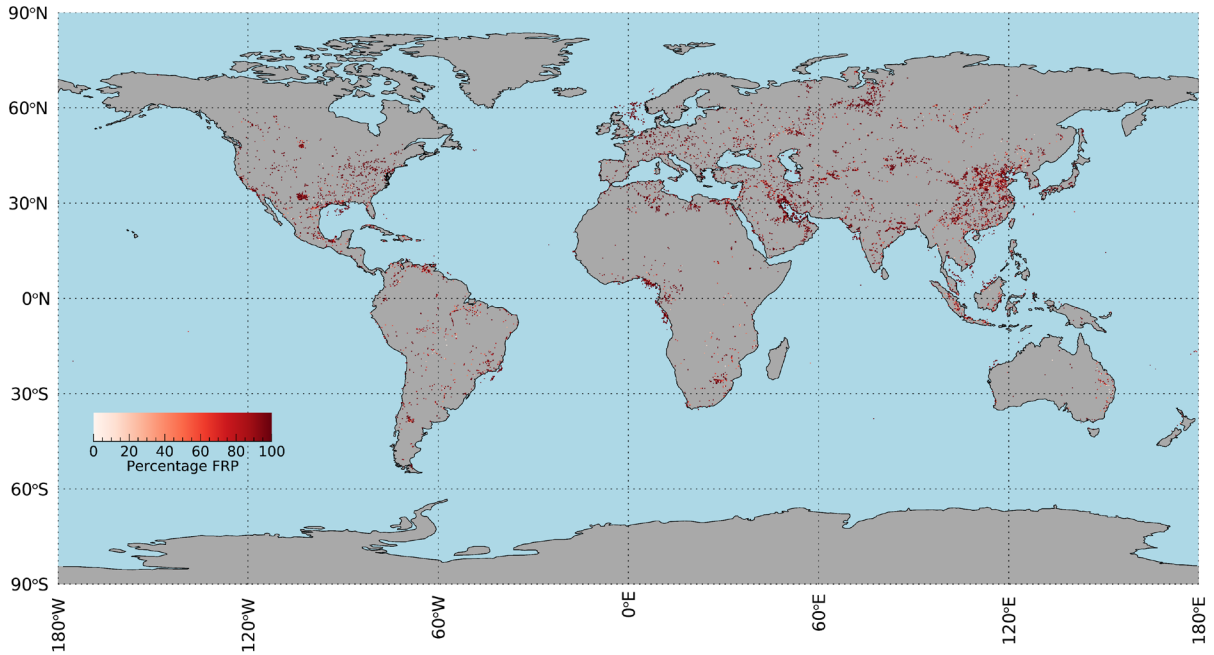
- Individual STAs can have high annual FRP totals
  - Site in Russia has an annual FRP of 182,000 MW
    - North Complex fire (2020) burned 316,000 acres and FRP total 190,000 MW
    - Red Salmon Complex fire (2020) burned 147,000 acres and FRP total 173,000 MW



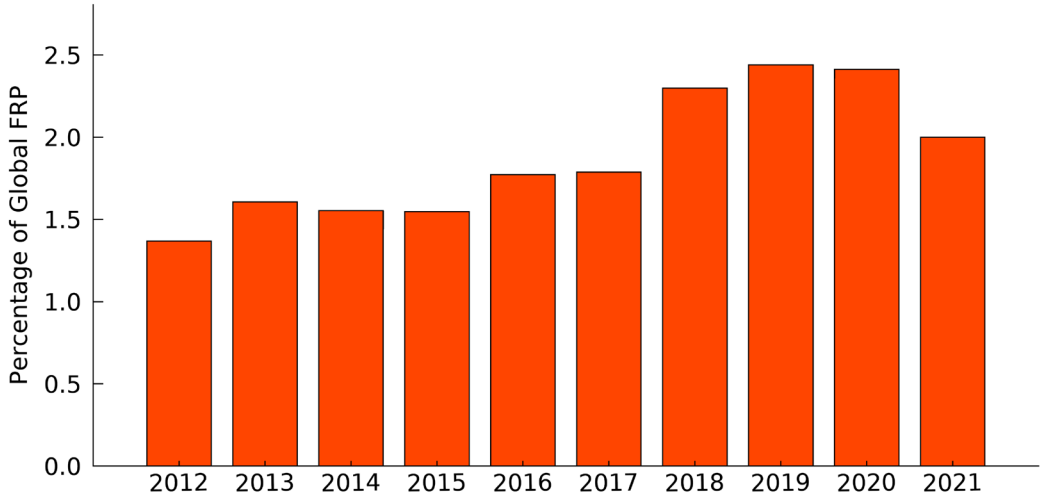
Annual FRP of 182,000 MW in 2013. Also evident is the large variation in thermal activity

VIIRS STA : Global Fire Assimilation System

- GFAS (Kaiser et al., 2012) utilises MODIS FRP to estimate landscape fire emissions
  - acknowledges inclusion of non-BB FRP sources
- Non-biomass burning GFAS FRP accounts for
  - 1.5 – 2.5% of annual FRP
- 10,510 0.1° grid cells contain STAs :
  - 76% of these where >90% of FRP is from STAs
- Global FRP impact minimal but
  - local, regional and potentially national scale emissions impacts greater
  - diurnal and seasonal emissions impact



GFAS grid cells containing STAs showing the percentage of FRP from STAs



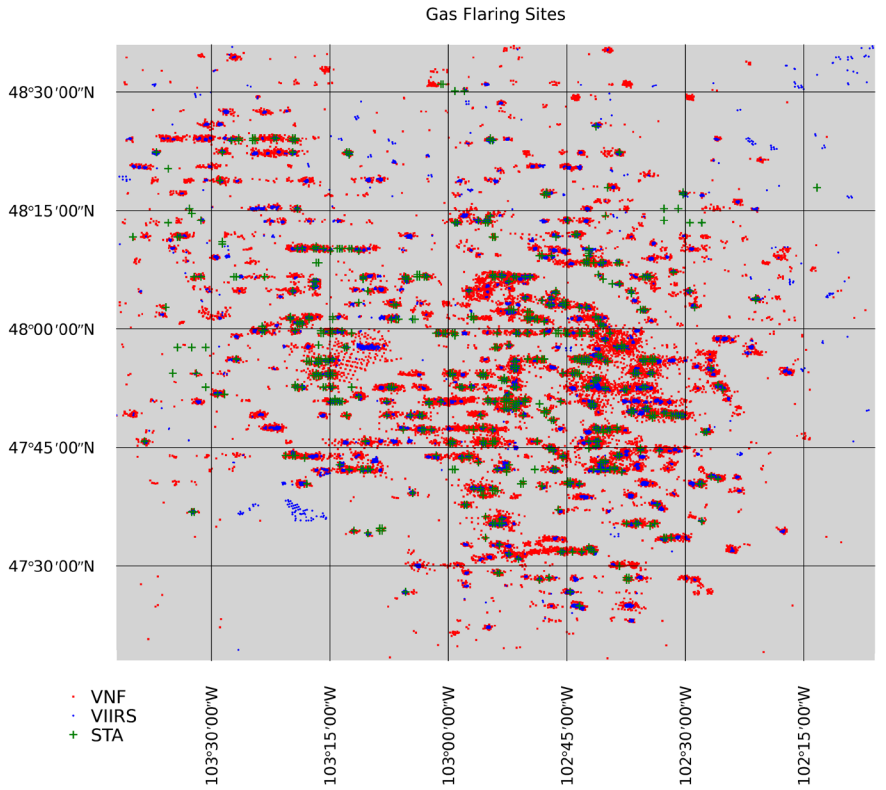
VIIRS STA : VIIRS NightFire Intercomparison

- Intercompare the STAs dataset with those from a VIIRS NightFire dataset (VNF; Lui et al., 2018)
  - identifies thermals anomalies between 2012-2016 using object-orientated clustering
  - sources classified (e.g. cement, coal, gas production) based on temperature distribution

- Results indicate :
  - 58% agreement (8,220 VIIRS STAs match 14,281 VNF sites)
  - 7,316 unique to VNF dataset
  - 4,841 unique to VIIRS STA dataset
  - of the 12,691 VIIRS STAs active between 2012 - 2016
    - 8,220 (65%) agree and 4,471 (42%) are unique

  - VIIRS STA dataset underestimates gas flaring activity on land
    - less 'persistent' on monthly and annual time scales

  - VNF dataset underestimates thermal activity associated with (e.g.) steel production, solid waste disposal and electricity generation

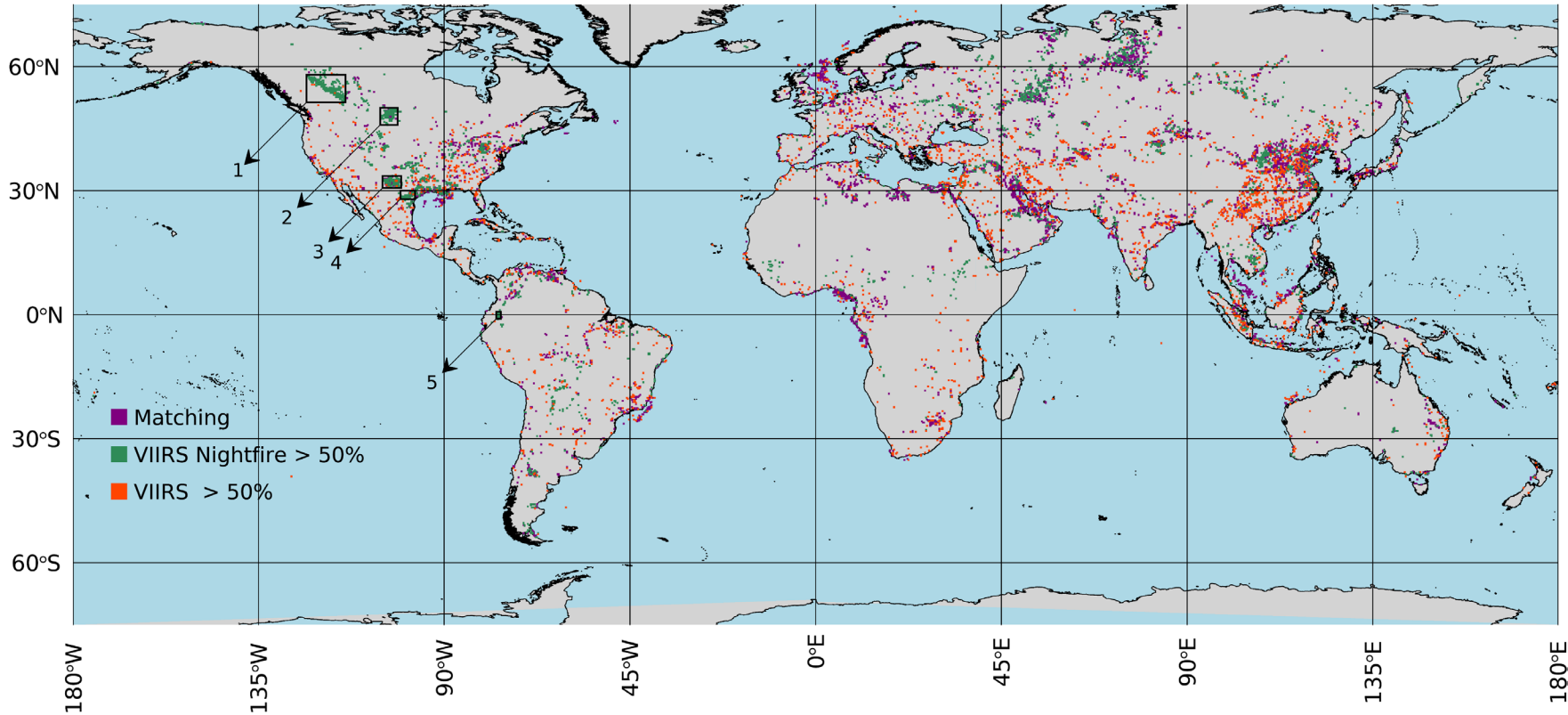


North Dakota Flaring Site : VIIRS and VNF detections (2019-21)

VIIRS STA : VIIRS NightFire Intercomparison

- 0.25° grid cells where ≥50 % of the STAs match or are unique to either dataset

- Difference in global FRP due to false detection of deforestation fires
  - VNF : 68% of pixels have < 4500 m² deforestation; 14% have >300,000 m² deforestation
  - VIIRS STA : 89% of pixels have < 4500 m² deforestation; 0.44% have >300,000 m² deforestation



Region	Matching FRP	FRP Unique to VNF	FRP Unique to VIIRS
Global	54.7 GW (91 %)	3.7 GW (6%)	1.7 GW (3%)
ROI 1	3378 MW (19%)	13,138 MW (74%)	1,265 MW (7%)
ROI 2	44,215 MW (70%)	17,332 MW (27%)	1,854 MW (3%)
ROI 3	86,024 MW (74%)	17,596 MW (15%)	12,957 MW (11%)
ROI 4	26,343 MW (77%)	7,383 MW (22%)	336 MW (1%)
ROI 5	3,979 MW (94%)	243 MW (6%)	0

- >90% of VIIRS thermal anomalies in flaring regions [ROIs 1-5] are detected < 20 times annually on average

Conclusion

- Thermal emissions from static thermal anomalies :
  - minor (1 - 3%) contribution during the day BUT
  - 10 - 20% of FRP at night from non-BB sources
    - much lower FRP at night but potentially impactful in climate\fire research

- FRP-derived emissions databases may erroneously include anthropogenic sources
  - local and national-scale impacts can be large
    - (e.g.) large disparities between inventories in Middle East (Pan et al., 2020)

- VIIRS STA dataset has high omission rate over gas flaring regions
  - 6 – 74 % FRP omission (28% on average over five sites)
    - FRP contribution appears low in these regions
      - approach designed to detect more persistent (months & years) STAs and to limit false detections