Discrepancies between Satellite-based and Ground-based Fire Detection: Implication for Wildfire Emissions in Alaska

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Introduction

Wildfire events are getting more frequent in Alaska due to climate change. (Woo et al., 2020)

Wildfire detection in Alaska rely on MODIS/VIIRS satellites. Among 155 wildfires in Alaska in 2016, MODIS missed 70 and VIIRS missed 55 (Waigl et al., 2017), yet more thorough evaluation needs to be done. Large discrepancies among emission inventories also exist in boreal America (BONA, Carter et al., 2020).

Synthetic Aperture Radar (SAR) , operating at microwave wavelength (1 cm – 100 cm), can penetrate through clouds and observe the surface changes. It has been used in wildfire burned scars detection research (Ban et al., 2020).

Goals

Evaluations on the performance of satellite-based fire detection wildfire products and inventories in Alaska.
How many fires were missed? Can we use SAR data to detect these missed fires?

Data and Tools

Ground-based fire reports

AICC Fire Reports (2012-2023)
Alaska Interagency Coordination Center (AICC) will report all fire incidents in Alaska, including small local fires.
The report has start date, end date, central location and estimated burned area.

Satellite-based fire products and emission inventories

- **VIIRS NPP Active Fire Products**
- **(VNP14IMGTDL_NRT)**

Time Period: 04/01-08/31, 2012-2023

- **QFED (FRP-based)**
- **GFED4s (Burned-area based)**

Time Period: 04/01-08/31, 2012-2023

- **OPERA-Sentinel 1 SAR C-band VV backscatters**

Time Period: 2016-now

Data are processed and analyzed using ArcGIS Pro software.

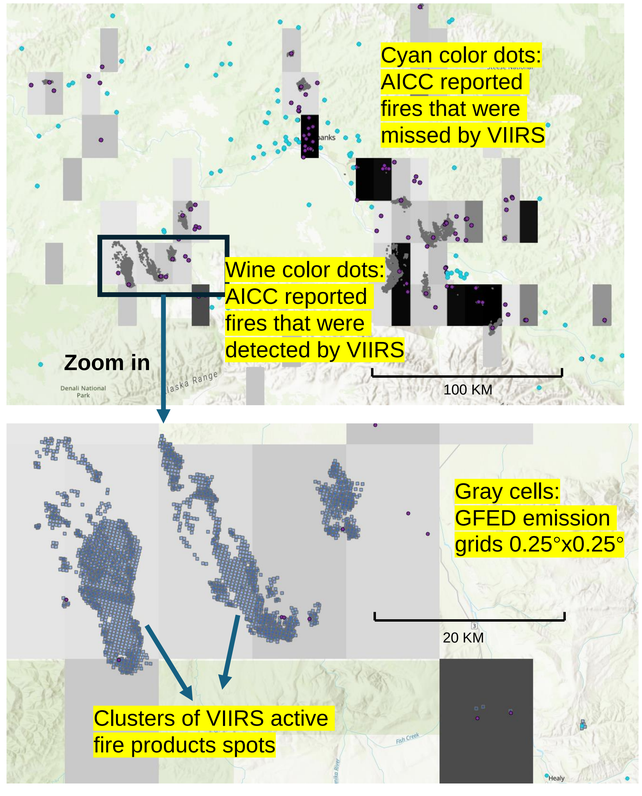


Fig.1 (a) AICC reported fires (blue and red spots), VIIRS active fire products (blue square clusters), GFED4s emission grids (grey cells) in central Alaska in 2023. (b) Zoomed-in area.

Results

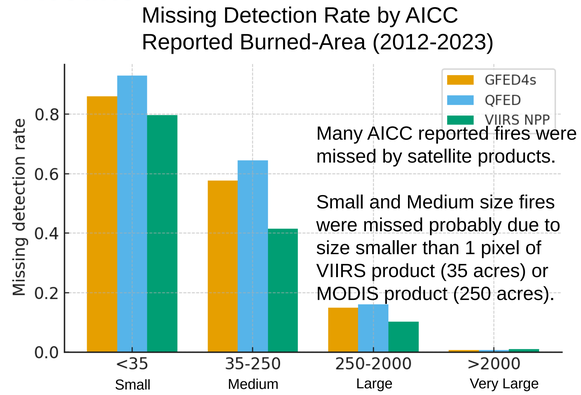


Fig.2 Missing detection rates of GFED4s, QFED, and VIIRS NPP active fire products relative to AICC-reported burned areas (2012–2023). Units: acres.

Each year, the absolutely missed fires account for only 1-2% of the AICC reported burned area.

Year	AICC Burned Area (acres)	GFED Missed BA	GFED Percent %	QFED Missed BA	QFED Percent %	VIIRS NPP Missed BA	VIIRS NPP Percent %
2012	273186.5	11041.5	4.04	5493.7	2.01	7397.9	2.71
2013	1326744.3	9201.9	0.69	11898.7	0.90	2821.6	0.21
2014	293100.7	9498.1	3.24	4300.7	1.47	2124.1	0.72
2015	5150447.7	17339.5	0.34	20183.6	0.39	5144.1	0.10
2016	527794.4	6826.7	1.29	8159.2	1.55	8948.5	1.70
2017	728587	8862.8	1.22	10514.3	1.44	23759.1	3.26
2018	447907	4821.4	1.08	5688	1.27	5326.4	1.19
2019	2673149.6	4785.8	0.18	9140.9	0.34	5030.5	0.19
2020	255195	6464.4	2.53	7669.8	3.01	4810.7	1.89
2021	300196	5036.6	1.68	2343.3	0.78	1779.4	0.59
2022	3182533.5	4039.3	0.13	5348.4	0.17	3819.7	0.12
2023	342327.7	2327.5	0.68	2766.2	0.81	3272.4	0.96

Table.1 Missing burned areas of GFED4s, QFED, and VIIRS NPP active fire products relative to AICC-reported burned areas (2012–2023). Units: acres.

VIIRS missed 69 large fires (250-2000 acres) between 2012 and 2023, most due to clouds.

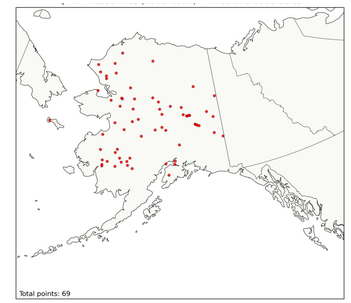
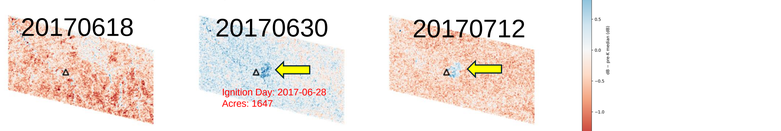


Fig.3 Locations of the 69 large size fires (250-2000 acres) from 2012 to 2023 in Alaska.

Can SAR detect these missed large fires despite cloud coverage?

Example 1: Omikmuktusuk Fire, 2017, 1647 acres

Sentinel-1 SAR provides repeat observations of the same location every 12 days.



Example 2: Tagagawik River Fire, 2020, 1006 acres

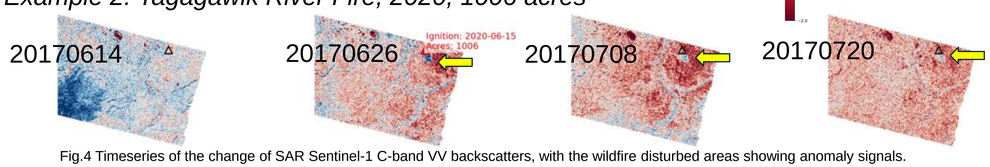


Fig.4 Timeseries of the change of SAR Sentinel-1 C-band VV backscatters, with the wildfire disturbed areas showing anomaly signals.

Summary of SAR Detection

Fire Name	Area	Detected By SAR
2016_39289_Marie_Creek	402	No
2016_39324_Copper_Creek	376	Yes
2016_39342_Alder_Creek	485	Yes
2016_39366_McHugh	778	Yes
2017_39750_Paimiut	354	Yes
2017_39762_Fossil	501	No
2017_39812_Omikmuktusuk	1647	Yes
2018_40124_Sec_29	323	No
2018_40216_Snohomish	311	No
2018_40223_William_Slough	278	No
2018_69553_Ipewik	690	Yes
2020_66760_Tagagawik_River	1006	Yes
2020_66761_Tagagawik_River_2	505	Yes
2020_69554_Thamnolia	351	Yes
2021_68029_Hickel	366	No
2022_68967_Tom_Cook	326	Yes
2022_69054_Tagagawik_2	620	Yes

Table.2 The large size fires that have SAR data coverage, and the detection rate by SAR.

•VIIRS Satellite Detection Overall Performance

- **Small fires (<35 acres)** are largely **missed** by all satellite products.
- **Medium fires (35–250 acres)** show ~**50%** missing rate, while **large fires (250-2000 acres)** are missed by ~**15%**.
- The **missed burned area accounts for only 1–2%** of total annual burned area, meaning **most wildfire activities in Alaska were successfully captured** by current satellite products.
- **69 large fires (250-2000 acres)** were not detected by VIIRS from 2012 to 2023.

•Implications on Emission Inventories

- **Some fires detected by VIIRS active fire spots** are **not included** in MODIS based emission products like **QFED** and **GFED4s**, suggesting algorithmic thresholds remove certain valid detections. MODIS active fire products evaluation will be added.
- **GFED4s (burned-area-based)** shows **lower omission rates** than **QFED (FRP-based)**, suggesting burned area products is slightly better than FRP-based emission products.
- The main source of uncertainty in BONA is not from missing detection. The main driver should be dry matter indicated by previous study (Carter et al., 2020).

Conclusion

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•Synthetic Aperture Radar (SAR)

- SAR data available after 2016. Among **17** undetected large fires that have SAR coverage, SAR **detected 11 of them** using a simple change of VV scatter method.
- Smaller fires may require additional SAR algorithms to recognize them from noisy backscatters.
- **Synthetic Aperture Radar (SAR)** offers a **promising complementary tool**, improving mid-size wildfire detection in high-latitude regions and improving forecasts during cloudy days, with higher temporal resolution data.

Acknowledgement

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Citation

1.Woo, S. H. L., Liu, J. C., Yue, X., Mickley, L. J., & Bell, M. L. (2020). Air pollution from wildfires and human health vulnerability in Alaskan communities under climate change. *Environmental Research Letters*, *15*(9), 094019.
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4.Ban, Y., Zhang, P., Nascetti, A., Bevington, A. R., & Wulder, M. A. (2020). Near real-time wildfire progression monitoring with Sentinel-1 SAR time series and deep learning. *Scientific reports*, *10*(1), 1322.