Application of Machine Learning to Characterization of GPS L1 Ionospheric Amplitude Scintillation

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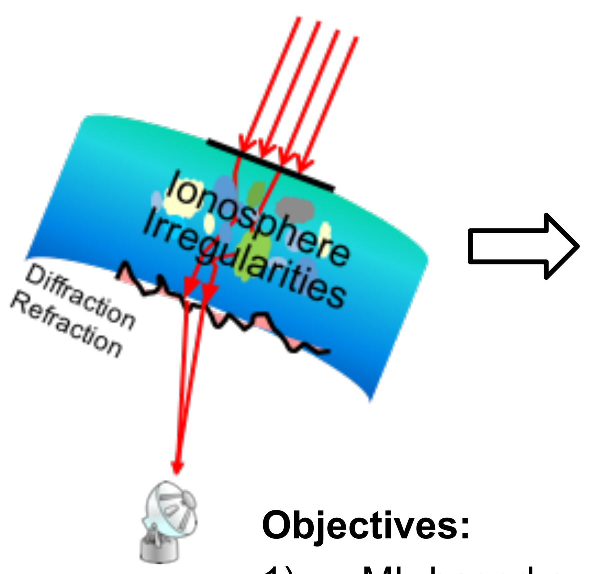
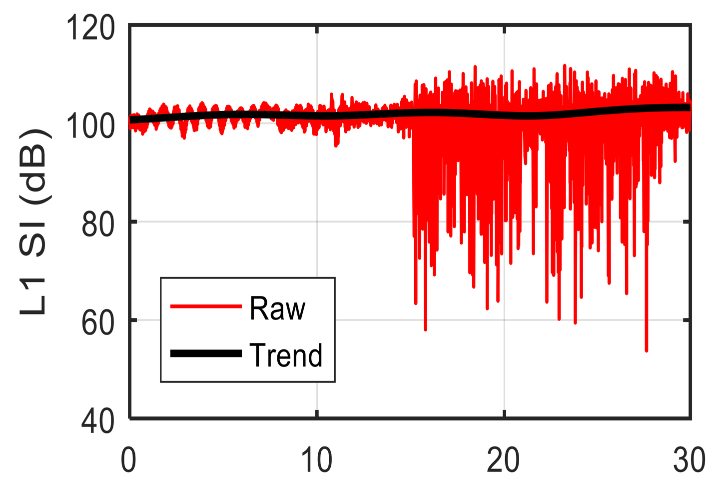
Summary: Ionospheric scintillation refers to the rapid fluctuation of the amplitude and phase of radio-frequency signals, such as GNSS (Global Navigation Satellite System) signals, propagating through the ionosphere. The rapid fluctuation can severely impact signal acquisition and tracking in a GNSS receiver, resulting in a performance degradation in accuracy and continuity. Therefore, a comprehensive characterization of ionospheric scintillation effects on GNSS signals has drawn lots of attention. In previous studies, scintillation events are usually identified manually by human experts, who process the received signals and identify the scintillation events via S4 (for amplitude scintillation) based on their experience. This tedious work is very time consuming, which hampers the possibility of a large-scale batch data processing. In this poster, we first implement a machine learning algorithm called support vector machine to automatically detect scintillation events. The detection accuracy is 96%, which is sufficient for the purpose of the characterization of scintillation events. Then the proposed support vector machine is applied to detect amplitude scintillation events in a large database of data collected in both equatorial (Ascension Island, Jicamarca, Peru, Hong Kong, Singapore) and high latitude areas (Poker, Alaska, Greenland). Finally, the statistical characterization of amplitude scintillation is obtained. The comparison studies between different locations are also discussed.

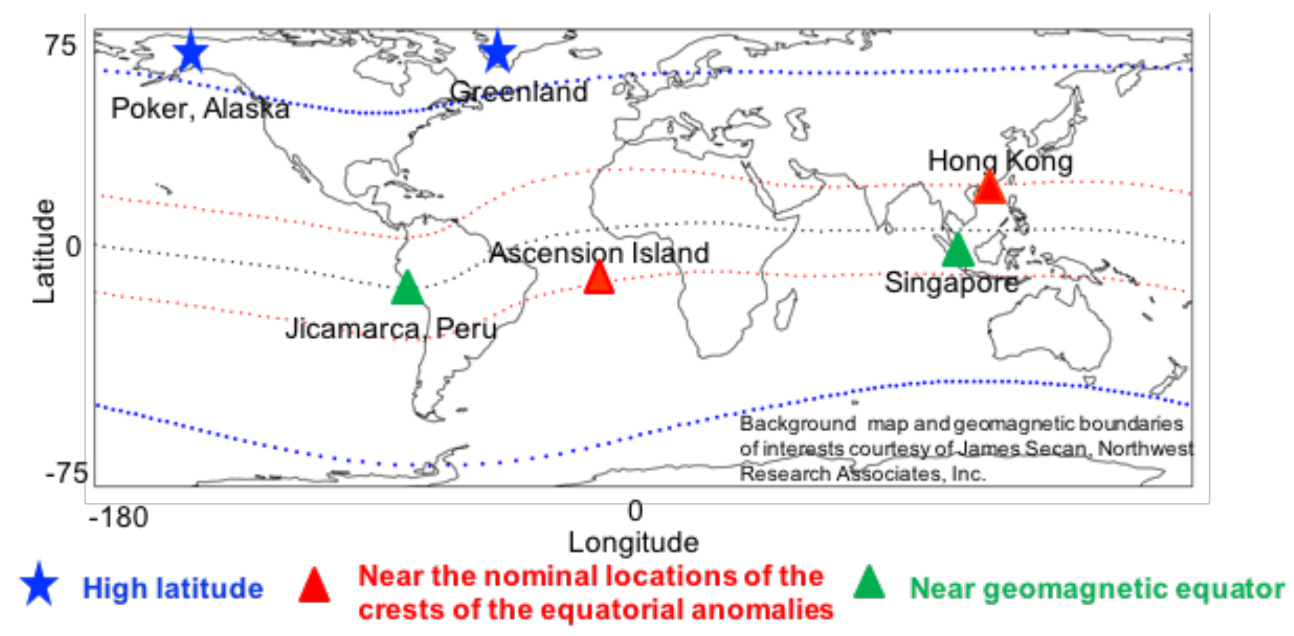
❑ Motivation & Objectives





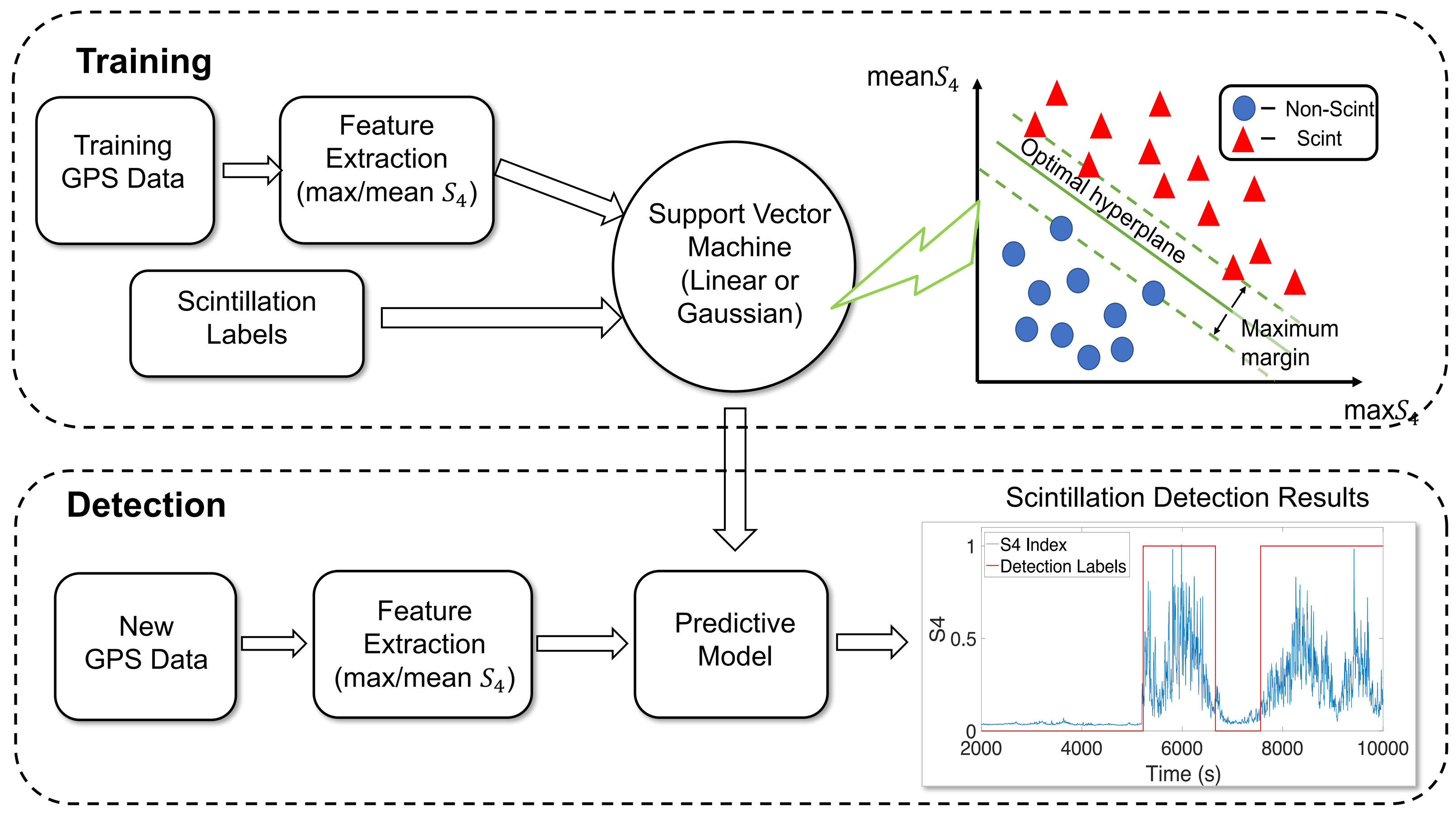
Objectives:
1) ML-based automatic scintillation detection
2) Characterization of the scintillation events at multiple locations

❑ Data Collection System



Location	Start Date	End Date	No. of Days Available	Perc. of Days Available
Alaska	2014/7/1	2016/6/30	530	72.5%
Greenland	2015/7/1	2016/6/30	353	96.7%
Peru	2013/1/1	2016/6/30	959	71.2%
Singapore	2014/7/1	2015/9/30	196	42.9%
Hong Kong	2012/4/1	2016/3/30	1138	89.1%
Ascension	2013/3/1	2013/3/11	11	100%

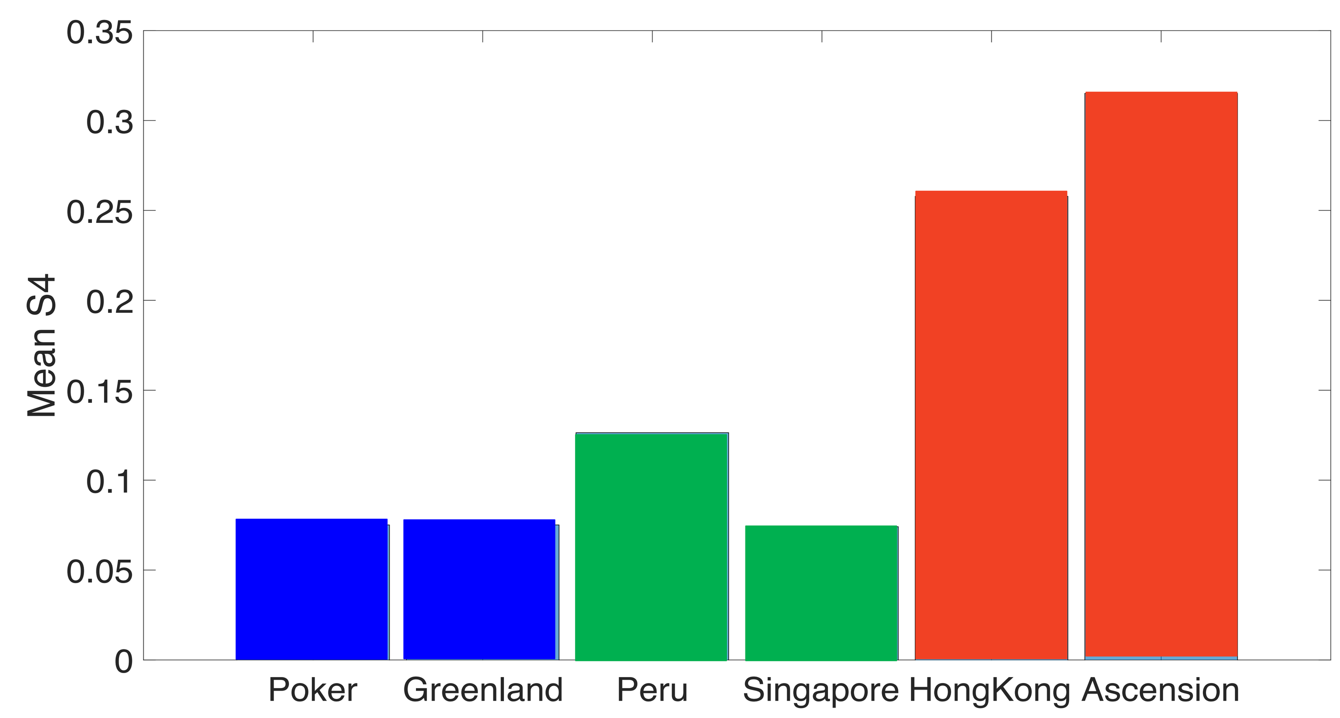
❑ ML-based Scintillation Detection



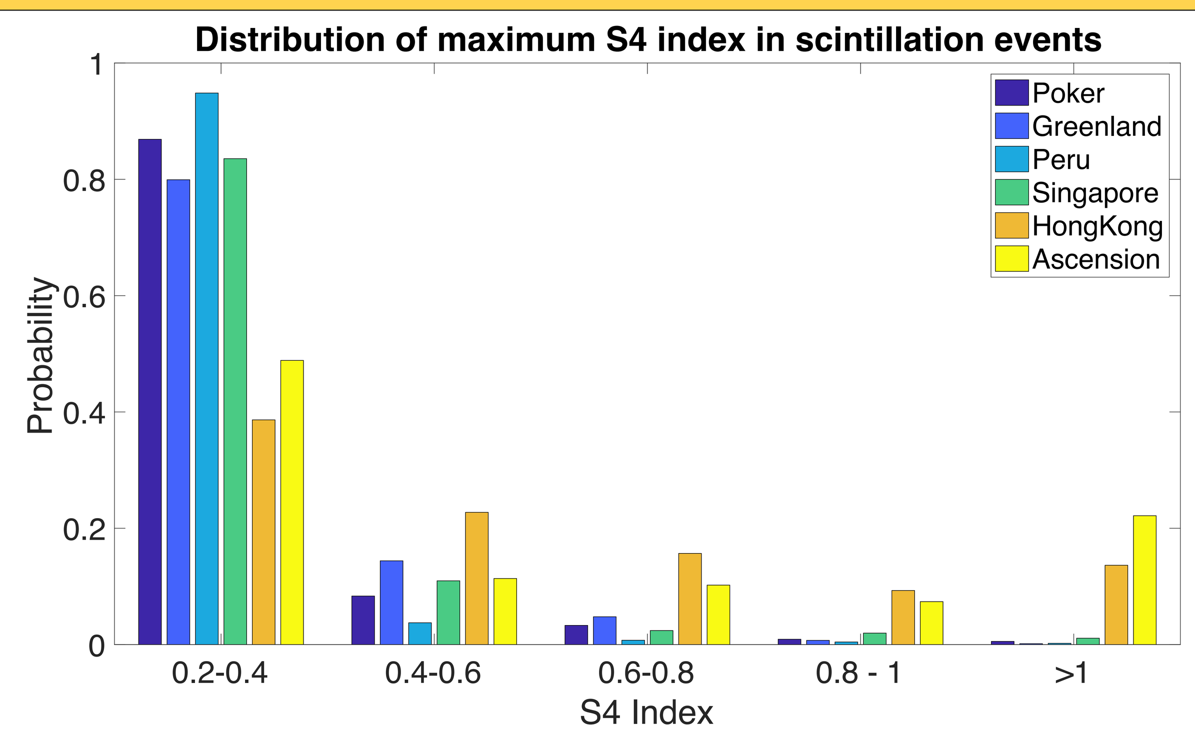
Dataset Size	2590
Scintillation	760
Non-scintillation	1830
Training Data	70%
Testing Data	30%
Detection Accuracy	96%

Conclusion: 96% detection accuracy is sufficient for a large-batch automatic detection.

❑ Scintillation Characterization

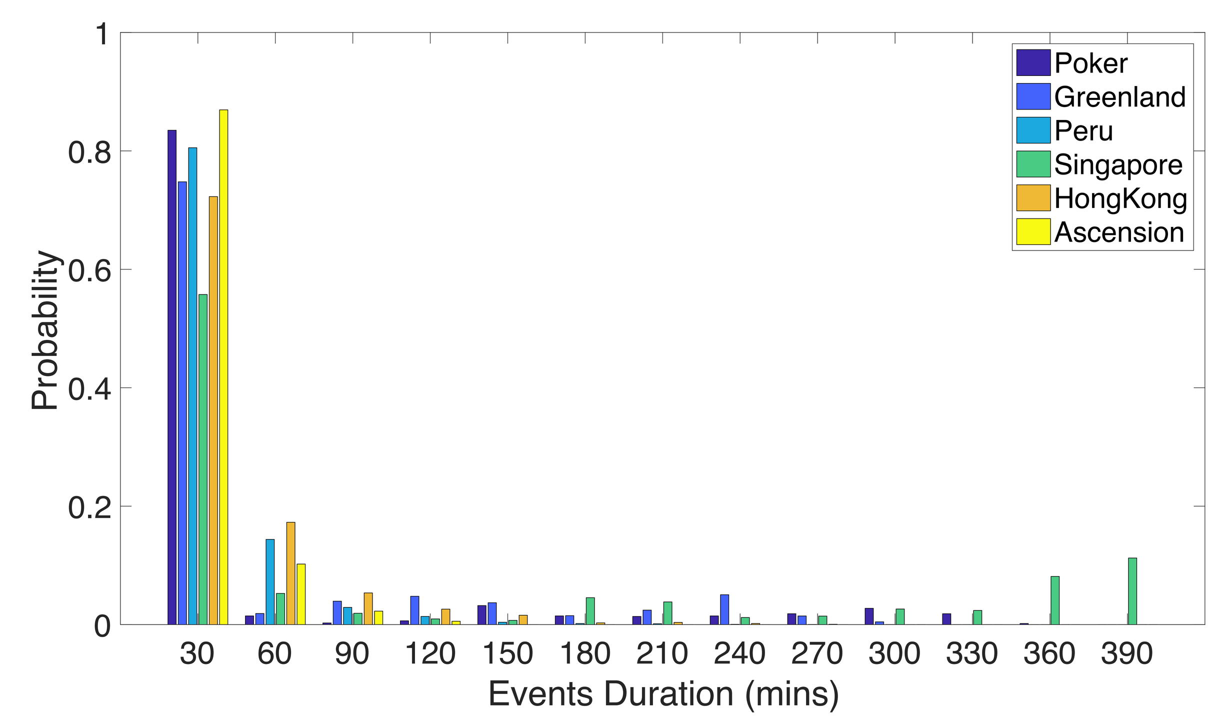


Conclusion: Strong scintillation happens near the nominal locations of the crests of the equatorial anomalies.



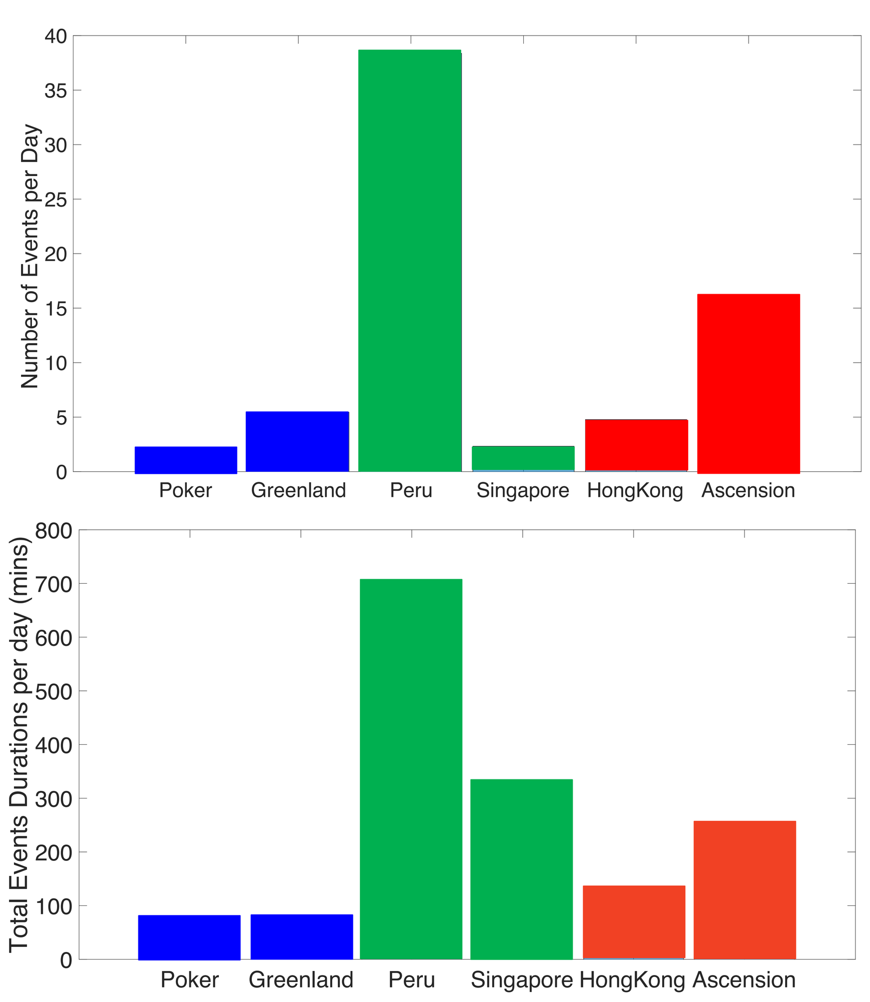
Location	$P(S_4 > 0.4)$
Alaska	0.13
Greenland	0.2
Peru	0.05
Singapore	0.16
Hong Kong	**0.61**
Ascension Island	**0.51**

Conclusion: Strong scintillation happens near the nominal locations of the crests of the equatorial anomalies.

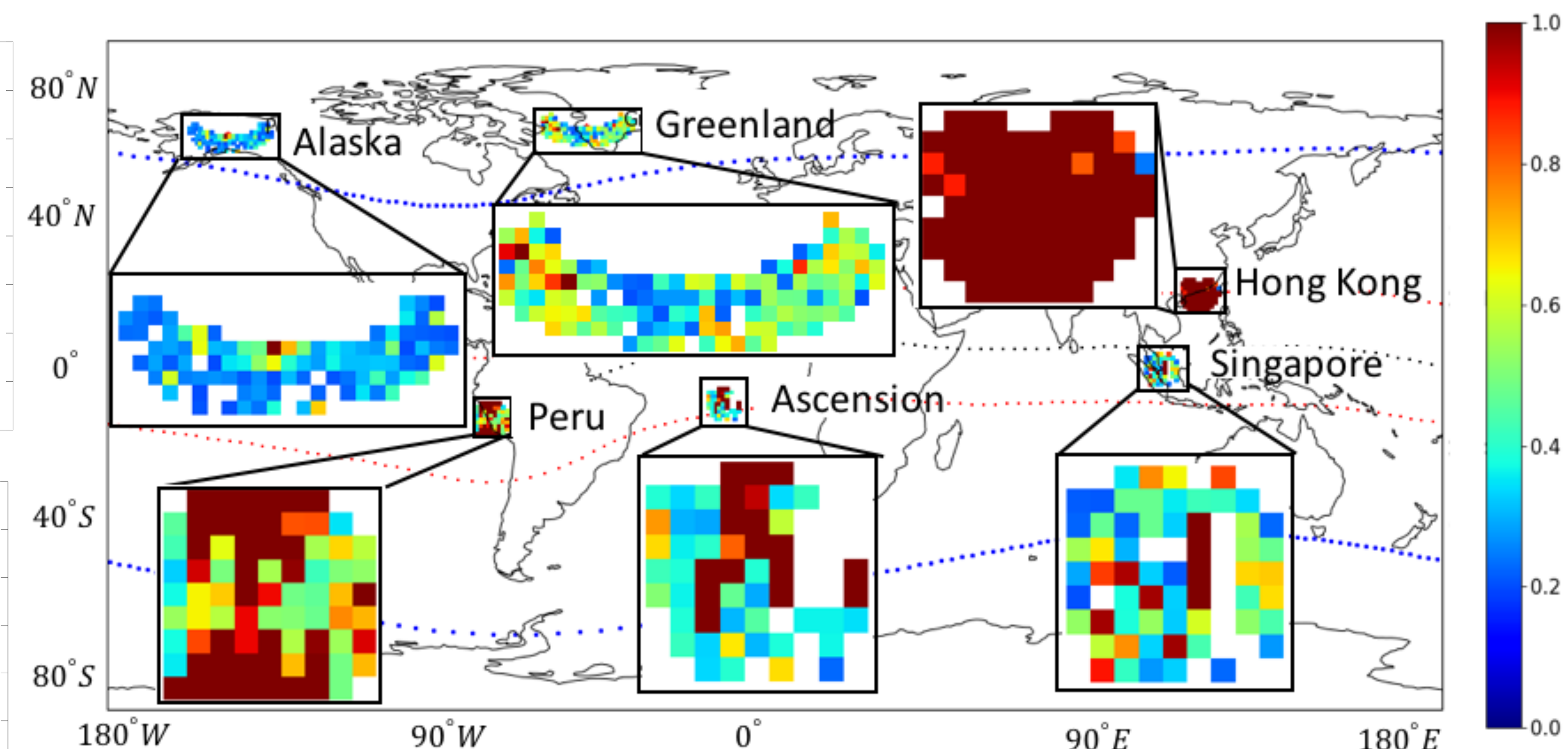


Location	Mean Duration (mins)
Alaska	39
Greenland	42
Peru	18
Singapore	**142**
Hong Kong	27
Ascension Island	16

Conclusion: Scintillation events last longer in Singapore.



Conclusion: More frequent in Peru.



Conclusion:
1.Equatorial regions tend to have stronger scintillation events
2.Strongest scintillation events happen near the nominal locations of crests of the equatorial anomalies
3.At Peru, strong scintillation happens at the locations that are towards to the anomalies.

❑ Conclusion

- Automatic scintillation detection
  - The proposed machine learning algorithm, SVM, presents a detection accuracy of 96%.
  - The high accuracy enables the possibilities of a large-batch data processing.
- Scintillation characterization
  - >3000 days of data are processed
  - >10000 hours of scintillation events are detected
  - Equatorial regions tend to have stronger scintillation events
  - Strongest scintillations observed in the areas around nominal location of the crests of the equatorial anomalies.
  - At Peru, strong scintillation events happen at the locations that are towards to the anomalies.

Acknowledgement

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