Development of forecast model for ionospheric scintillation in Canadian high latitudes

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INTRODUCTION

- Ionospheric scintillation caused by space weather has impacts on the accuracy and availability of GNSS performance, and is considered a natural hazard for aviation and other GNSS users. The development of operational services to mitigate the risks to users requires the development of a forecast model for ionosphere scintillation.
- Phase scintillation activity (σ_φ) is often observed in high latitude ionosphere; special location of Canada provides opportunity to monitor scintillation in high latitudes. Monitoring is based on the analysis of data from the Canadian High Arctic Ionosphere Network (CHAIN, http://chain.physics.unb.ca/chain)
- Natural Resources Canada (NRCan) develops a forecast model of scintillation activity over high latitudes across Canada. This presentation provides new results from the development of a probabilistic model to forecast intensity and duration of scintillation activity.
- Scintillation activity in high latitudes is strongly related to geomagnetic disturbances; CHAIN scintillation data were analyzed together with geomagnetic activity recorded at co-located Canadian geomagnetic observatories operated by NRCan to develop a regression model between duration of scintillation events for σ_φ > 0.1 rad, σ_φ > 0.4 rad and σ_φ > 0.7 rad and geomagnetic activity.
- The regression model between duration of scintillation activity and its intensity vs geomagnetic activity was studied for the auroral zone across Canada. Dependence on local time, during both geomagnetic quiet conditions and intense space weather events was examined.
- Probabilistic model of duration of scintillation event for σ_φ > 0.1 rad, > 0.4 rad and > 0.7 rad (in minutes per hour) is developed in addition to the regression model

Scintillation in high latitudes and Service for Aviation
WAAS performance over Canada on November 7, 2022

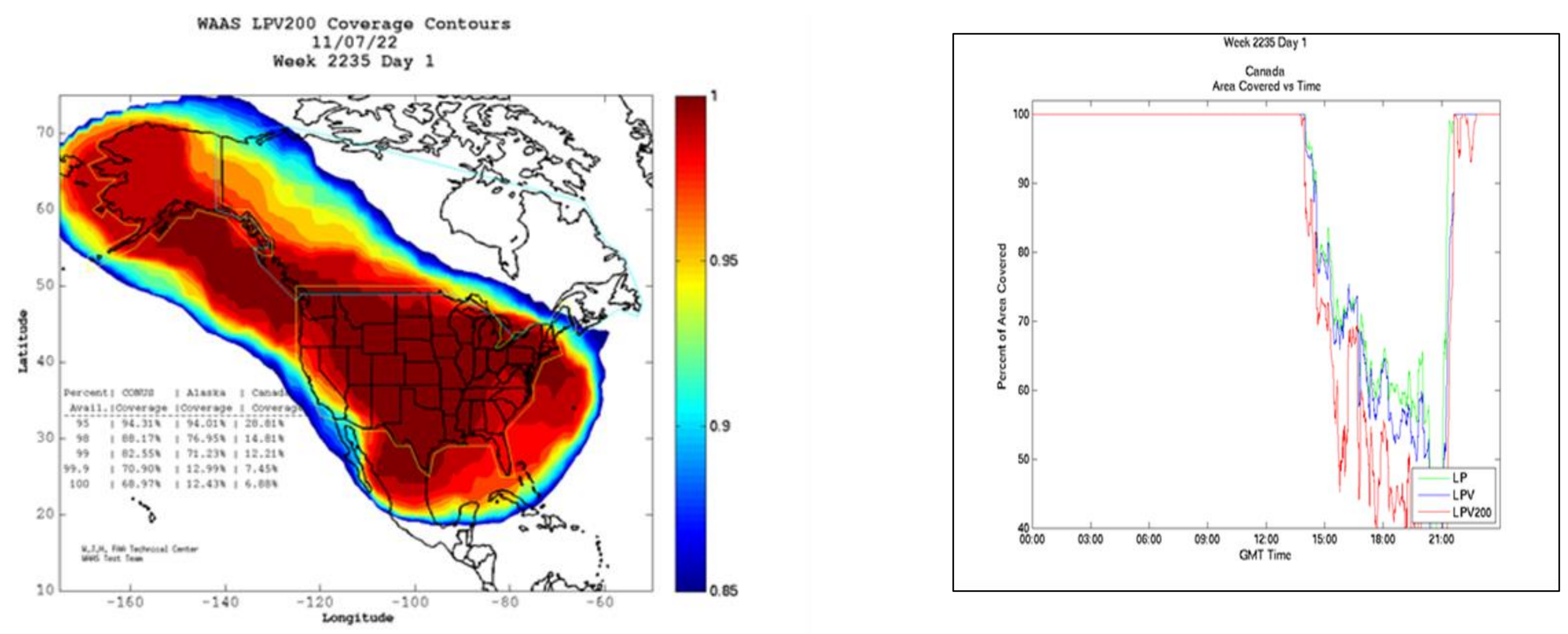

Figure 1. WAAS performance on November 7, 2022. https://www.nstb.tc.faa.gov/nstbarchive.html?dir=/24HOURPLOTS/

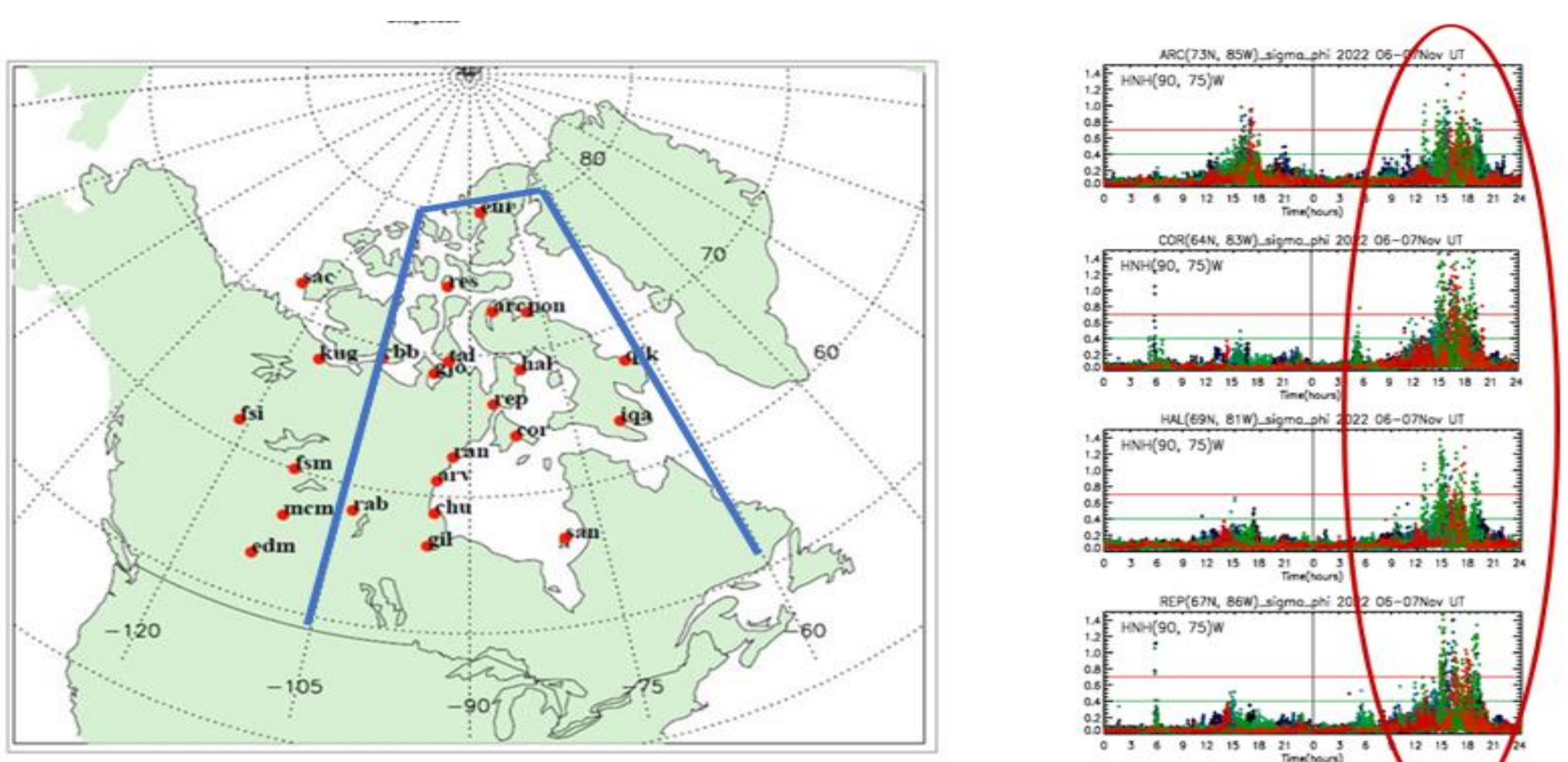

Figure 2. Phase scintillation from CHAIN receivers on November 7, 20222. http://chain.physics.unb.ca/chain/

Networks of NRCan geomagnetic observatories and CHAIN scintillation stations

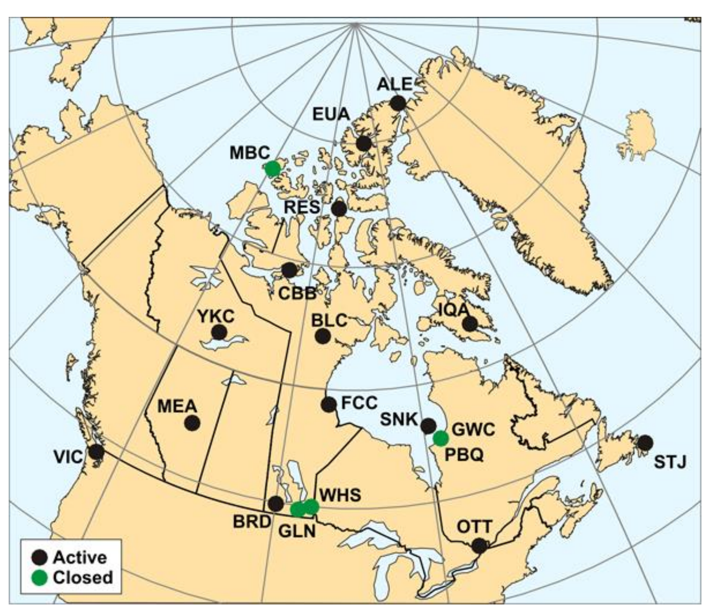

Figure 3: Map of NRCan geomagnetic observatories. https://www.geomag.nrcan.gc.ca/

CHAIN Station Name	Geographic Latitude	Geographic Longitude	Magnetic Latitude	NRCan Geomagnetic Observatory	Geographic Latitude	Geographic Longitude	Magnetic Latitude
Churchill (chu)	58.8° N	265.9° E	67.3° N	Fort Churchill (FCC)	58.8° N	265.9° E	67.3° N
Fort Simpson (fsi)	61.8° N	238.8° E	66.8° N	Yellowknife (YKC)	62.5° N	245.5° E	68.6° N
Fort Smith (fsm)	60.0° N	248.1° E	66.6° N	Meanook (MEA)	54.6° N	246.7° E	61.2° N
Iqaluit (iqa)	63.7° N	291.5° E	73.0° N	Iqaluit (IQA)	63.8° N	295.1° E	73.0° N
Cambridge Bay (cbb)	69.1° N	254.9° E	76.1° N	Cambridge Bay (cbb)	69.1° N	255.0° E	76.1° N
Resolute (res)	74.7° N	265.0° E	82.5° N	Resolute (RES)	74.7° N	265.1° E	82.5° N

- For assessment of geomagnetic activity, the hourly range of the horizontal magnetic field has been used by NRCan geomagnetic monitoring and forecast
- HR= Max $_{per\_hour}$-Min $_{per\_hour}$ (nT);
- Geomagnetic data from NRCan geomagnetic observatories were analysed together with the scintillation data from co-located CHAIN stations to develop a model of scintillation activity related to geomagnetic activity;
- Natural Resources Canada provides forecast of the hourly indices of geomagnetic activity for the next 48 hours. The developed model can be used to provide scintillation forecast based on the existing geomagnetic forecast.

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Statistical analysis of intensity and duration of phase scintillation

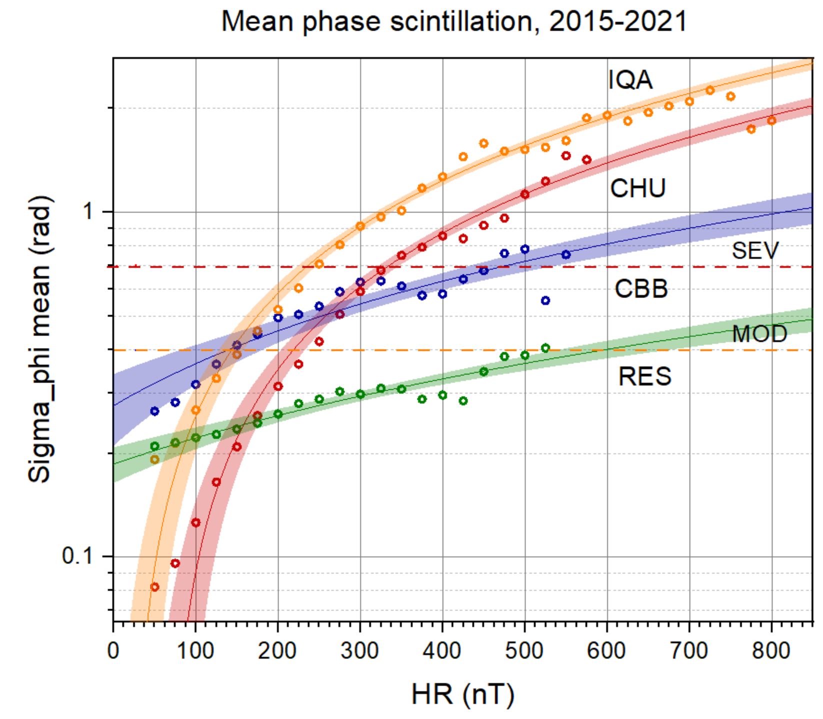

Figure 4: The mean phase scintillation vs geomagnetic activity. Local day. Data from Iqaluit, Fort Churchill, Cambridge Bay and Resolute.

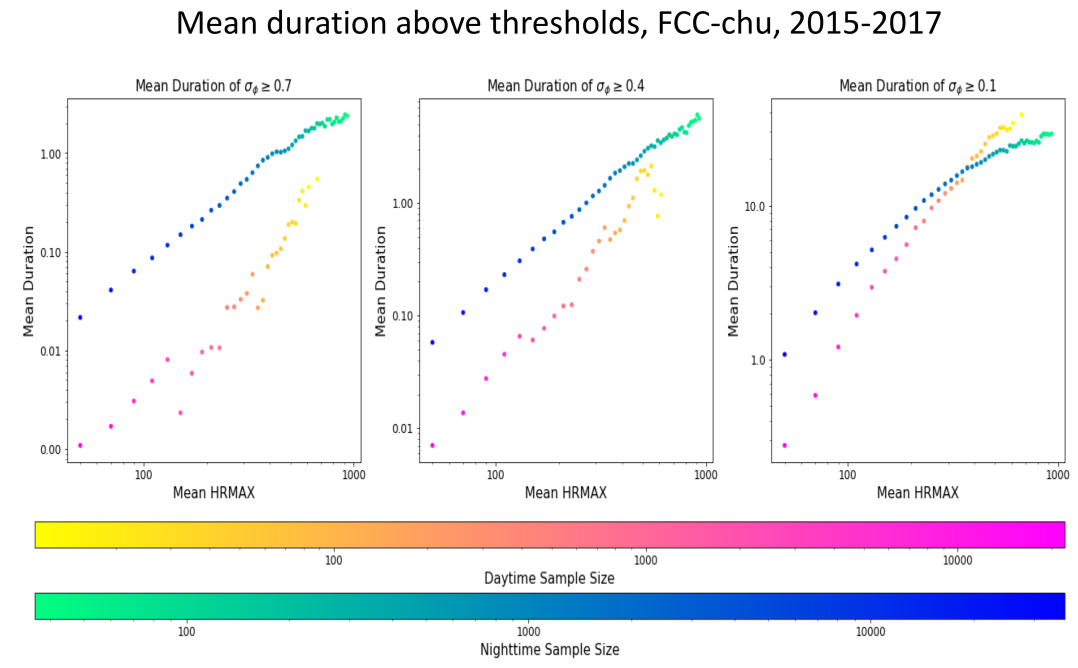

Figure 5 Average duration of scintillation event, min/hour

Probabilistic model of duration of scintillation event

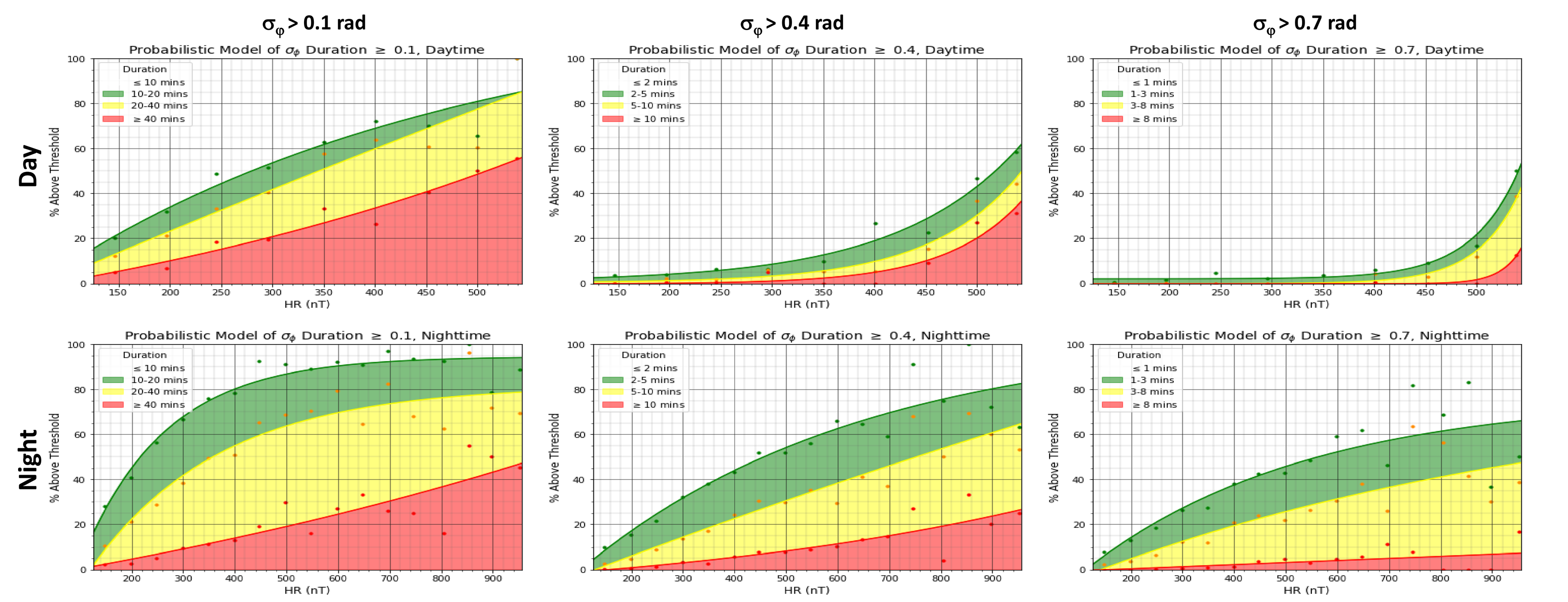

Figure 6: Probabilistic model of scintillation duration versus the hourly range of geomagnetic activity HR for day-time (top row) and night-time (bottom row), for σ_ϕ greater than, from left to right, σ_ϕ > 0.1 rad, σ_ϕ > 0.4 rad and σ_ϕ > 0.7 rad. Data is grouped by HR into bins of 50 nT width, and the percentage of data within three duration intervals are provided by different colors: green for the shortest duration, yellow – for a longer duration, and red – for the longest scintillation duration. The duration intervals are provided in the upper left corner of each panel. Daytime corresponds to 14h00 to 0h00 UT or 8am to 6pm local time, whereas nighttime corresponds to all other hours. Data is taken from observatories in Fort Churchill (UTC - 6:00) from 2015 to 2017.

Model and observed phase scintillation

4-11 September 2017, FCC | **3-4 November 2021, FCC**

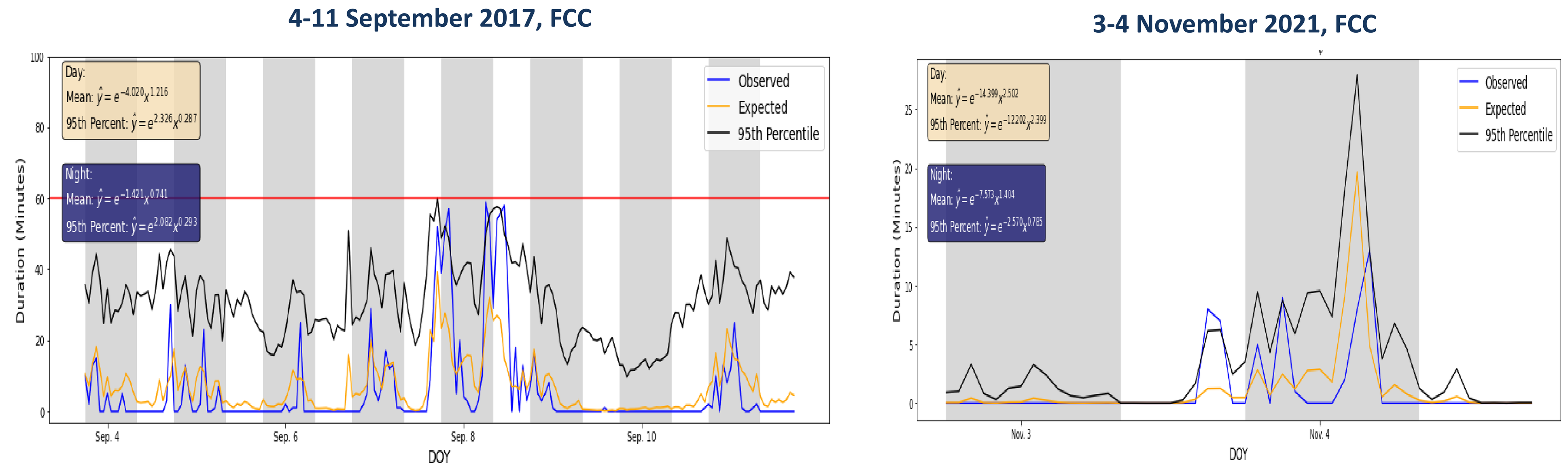

Figure 7: comparison of the observed duration of scintillation events and the values modeled with use of geomagnetic activity. Left panel for event 4-7 September 2017, σ_ϕ > 0.1 rad. Right panel for 3-4 November 2021, σ_ϕ > 0.4 rad. For both events the observed duration (blue curve) of scintillation event usually follows the modeled mean value (yellow curve) and is inside the modeled 95th percentile (black curve). Grey areas denote local nights.

CONCLUSIONS

- Scintillation activity over Canadian high latitudes has been analysed together with the geomagnetic activity recorded by Canadian geomagnetic observatories;
- Intensity of scintillation activity and duration of scintillation scintillation events when σ_ϕ > 0.1 rad, σ_ϕ > 0.4 rad and σ_ϕ > 0.7 rad has been analysed together with geomagnetic data from co-located magnetic observatories;
- The developed model was supported by development of a probabilistic model, which generates probability for scintillation duration for a given geomagnetic activity. This analysis has been done separately for day and night time.
- Comparison of the observed data and the modeled values for a space weather event demonstrates a good agreement.
- Increasing of number of scintillation with increase of solar activity (Figure 8) motivates the further development of the forecast model

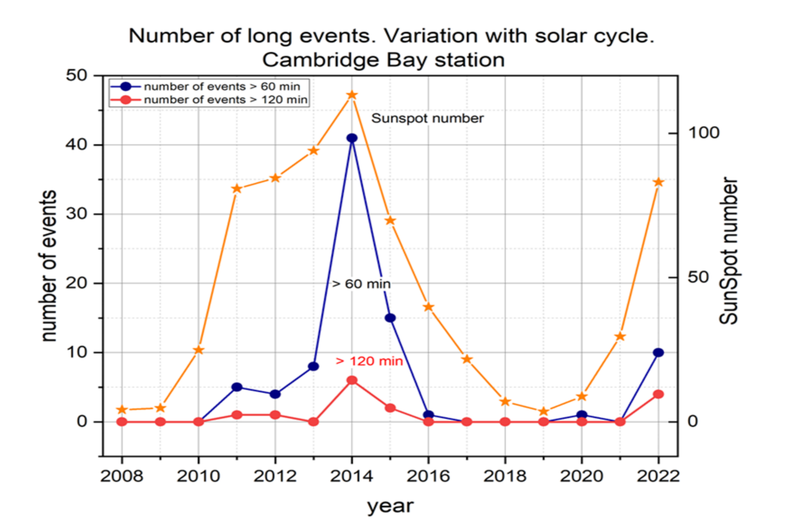

Figure 8 Number of long events at CBB. Variation with solar cycle.

ACKNOWLEDGEMENTS

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