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The effect of auroral absorption events on HF propagation links over Canada

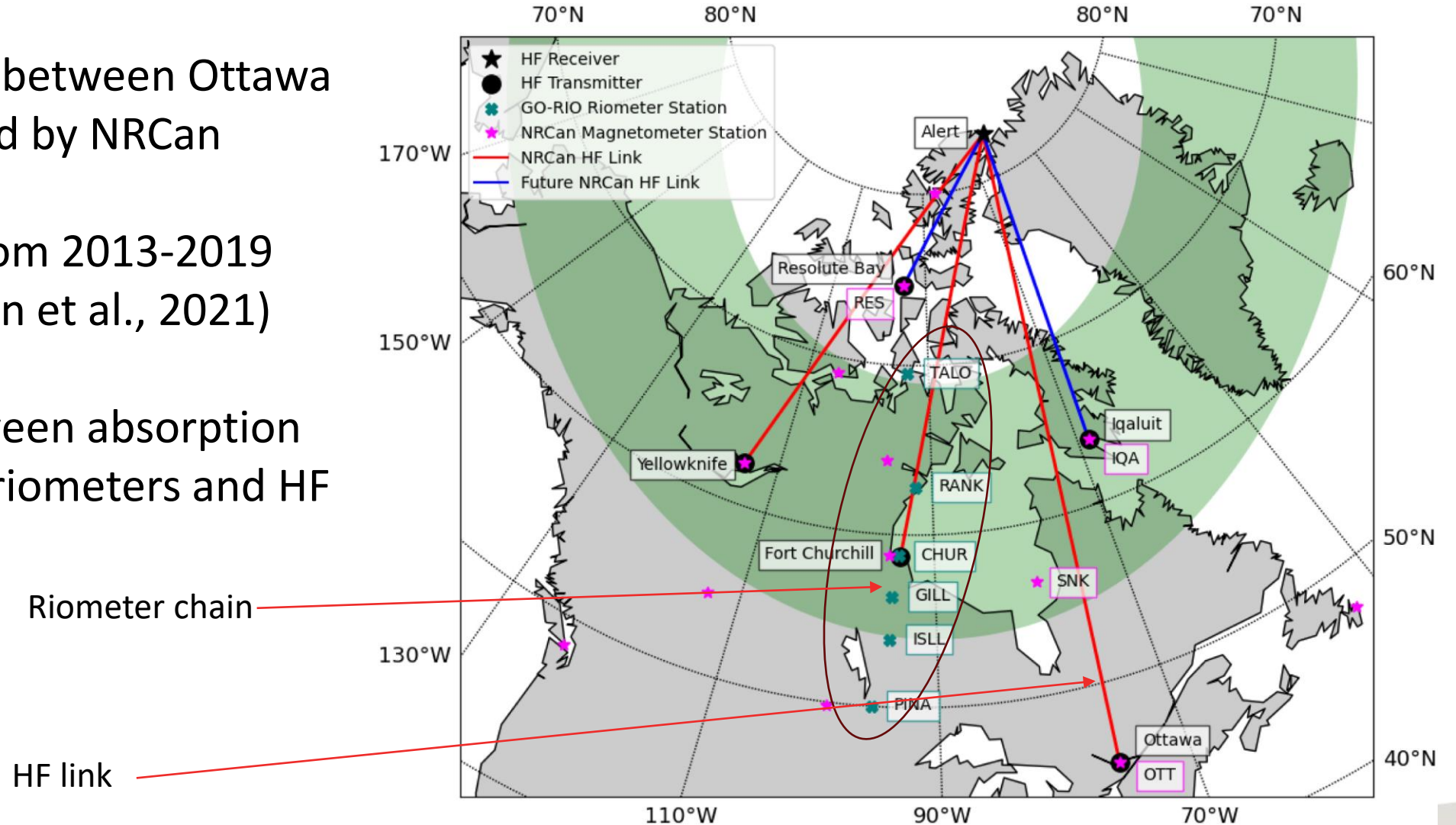
R. G. Gillies, E. Spanswick, F. Ghaly, T. Cameron, R. Fiori, and S. Skone

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NRCan Ottawa-Alert HF link

- Dedicated HF link between Ottawa and Alert operated by NRCan
- Reception data from 2013-2019 available (Cameron et al., 2021)
- Relationship between absorption from GO-Canada riometers and HF link examined



Cameron et al., 2021, Fig 1

Absorption as a function of radio wave frequency

$$A \propto \frac{N_e v}{\omega^2 + v^2}$$

- A : absorption/distance (dB/km)
- N_e : electron density
- v : collision frequency
- ω : wave frequency
- Typically, $v \ll \omega$, so, absorption follows $1/\omega^2$
 - HF wave propagating from Ottawa to Alert (5-14 MHz in this case) experiences much more absorption than a 30 MHz wave would
 - Further, riometer measures one vertical path, HF link has multiple low elevation ($\sim 10^\circ$) passes through D-region
 - E.g., **1 dB @ 30 MHz** -> more than **100 dB @ 10 MHz**

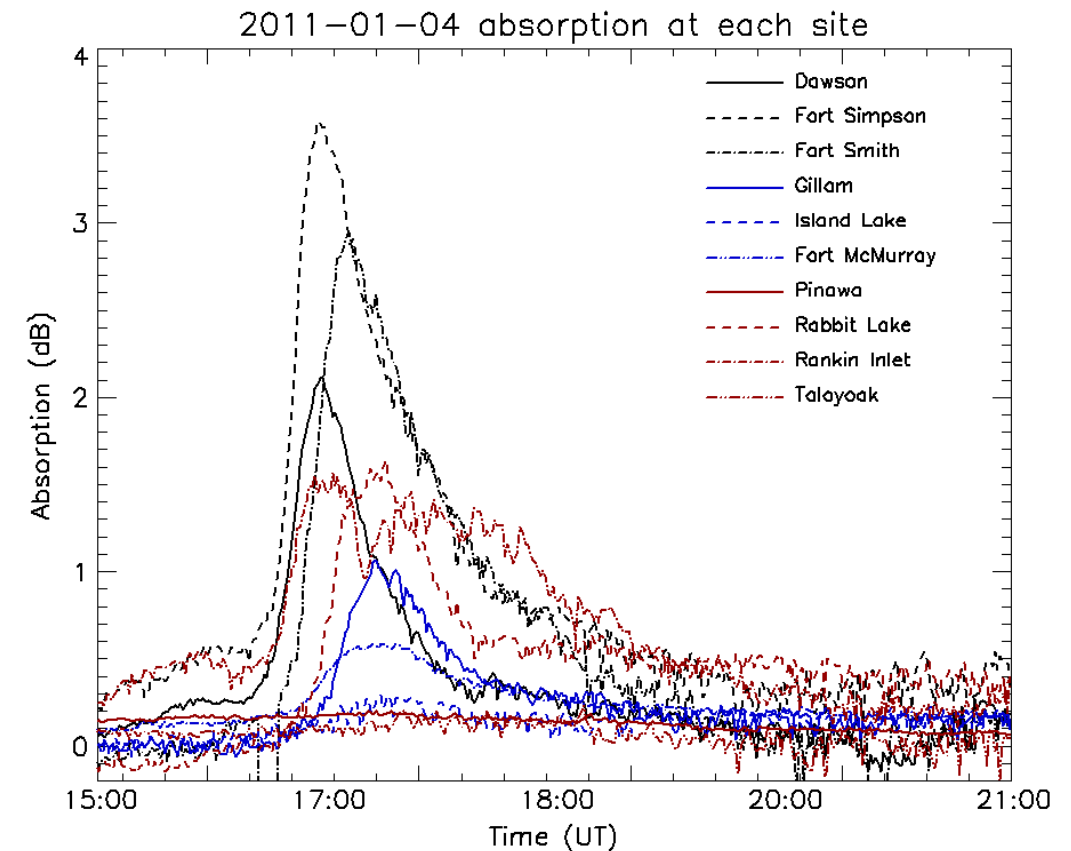
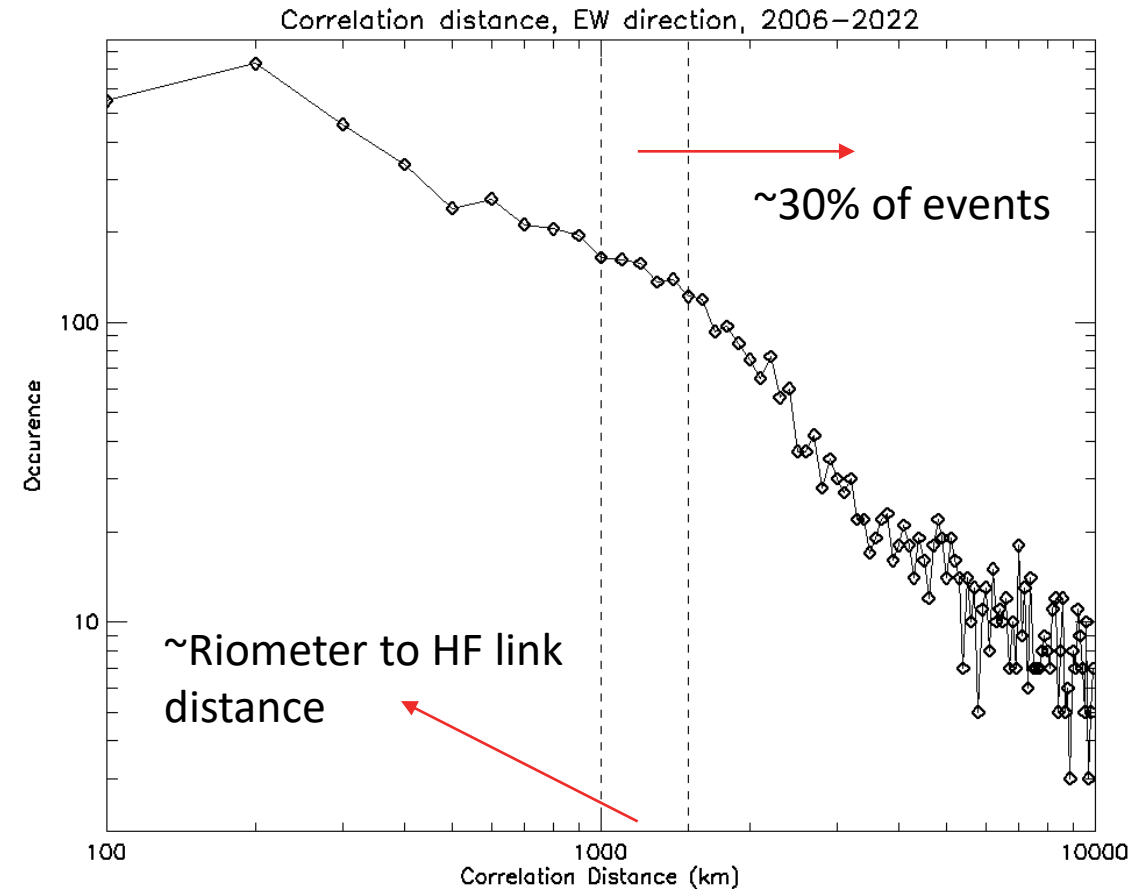


Figure 2: Gillies et al., 2024



Riometers

- GO-Canada sites examined: Rabbit, Gillam, Churchill, and Rankin (from farthest to closest)
 - Distance from riometers to HF link ~1000-2000 km
- *Gillies et al., 2024* examined typical auroral absorption region sizes
 - 0.5 dB threshold used in that study
 - Roughly **30%** of events have scale sizes larger than ~1000 km
 - **Most absorption events measured at riometer sites are not expected to affect HF link**



Gillies et al., 2024; absorption region scale size occurrence (magnetic East-West direction)



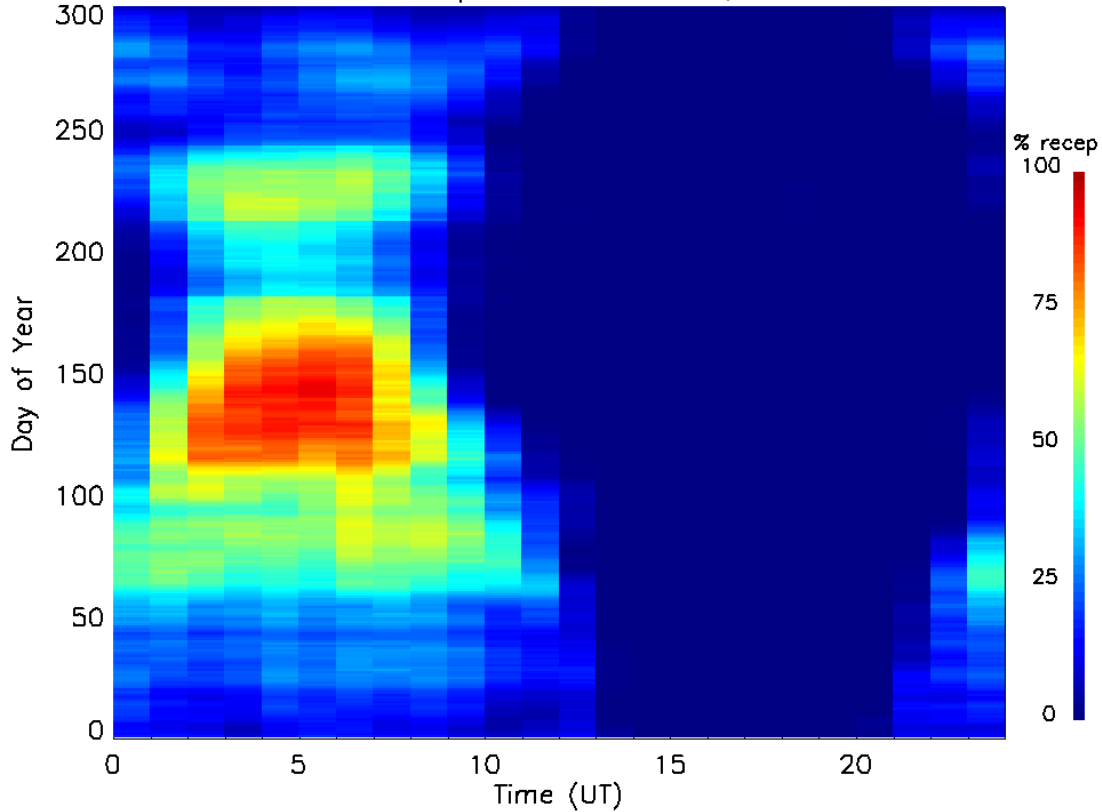
NRCan HF link

- HF pulses (CW and Barker code) transmitted from Ottawa and received at Alert
- 5.4, 6.9, 8.1, 10.4, 11.1, 14.4 MHz transmitted (4 - 24 pulses/hour for each frequency)
- Parameters measured for each pulse (if received/decoded) included:
 - Received SNR
 - Angle-of-arrival
 - Doppler shift
 - Time delay
- Signal propagation depends on ionospheric electron density profile:
 - F-region -> controls maximum usable frequency (MUF) -> allows sufficient refraction
 - D-region -> controls lowest usable frequency (LUF) -> allows minimal absorption

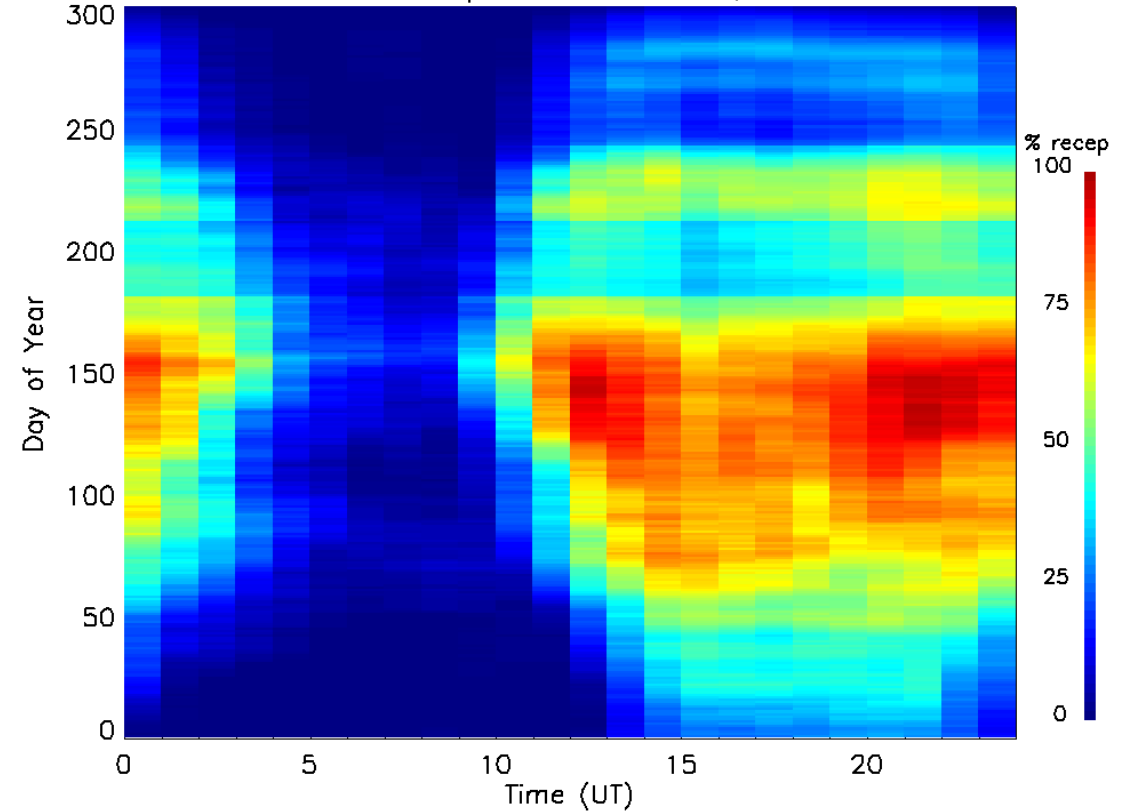


NRCan reception occurrences

NRCan reception occurrence, 5MHz



NRCan reception occurrence, 14MHz



- 5 MHz reception occurrence probability
 - Lower absorption during night -> more receptions

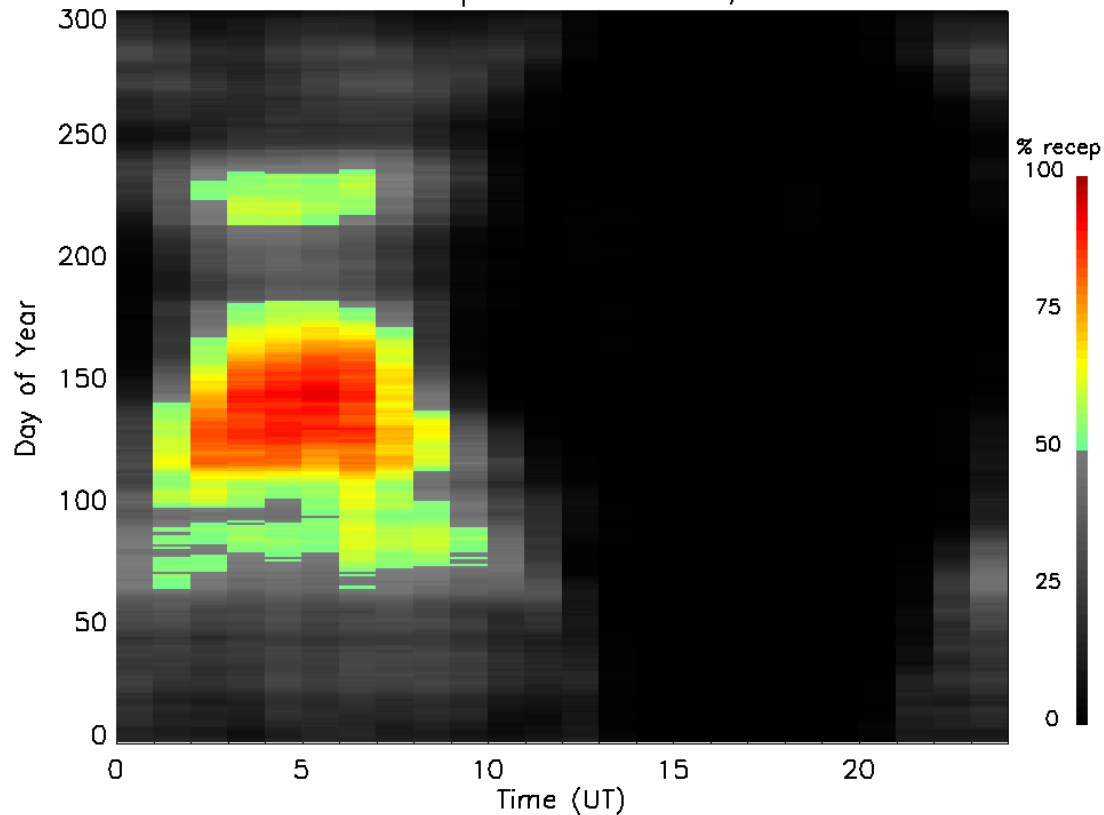
- 14 MHz reception occurrence probability
 - Higher density during day -> more receptions

NRCan data selection

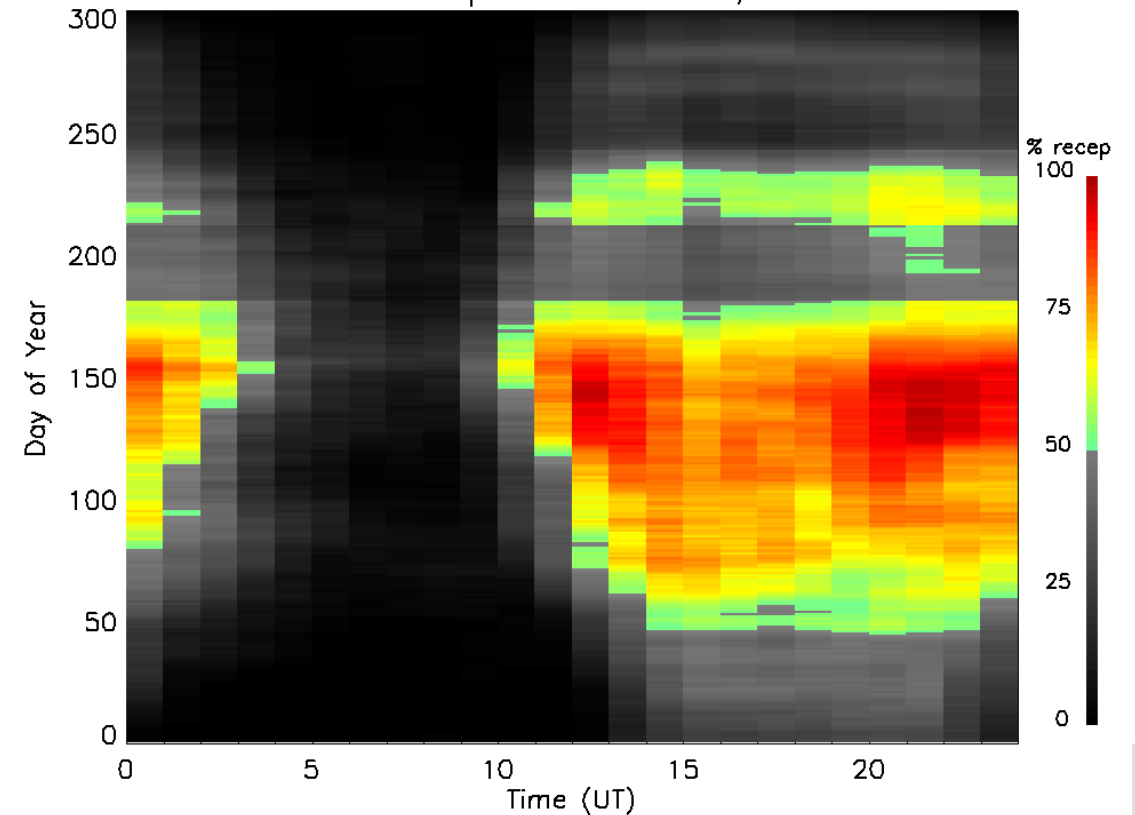


- Large-scale variation of HF propagation conditions generally predictable
 - Local time, season, and solar cycle variation of F-layer
- Interested in more sporadic deviations from this occurrence when reception otherwise expected
- Consider hour/days when 20-day running average of reception is $>50\%$

NRCan reception occurrence, 5MHz

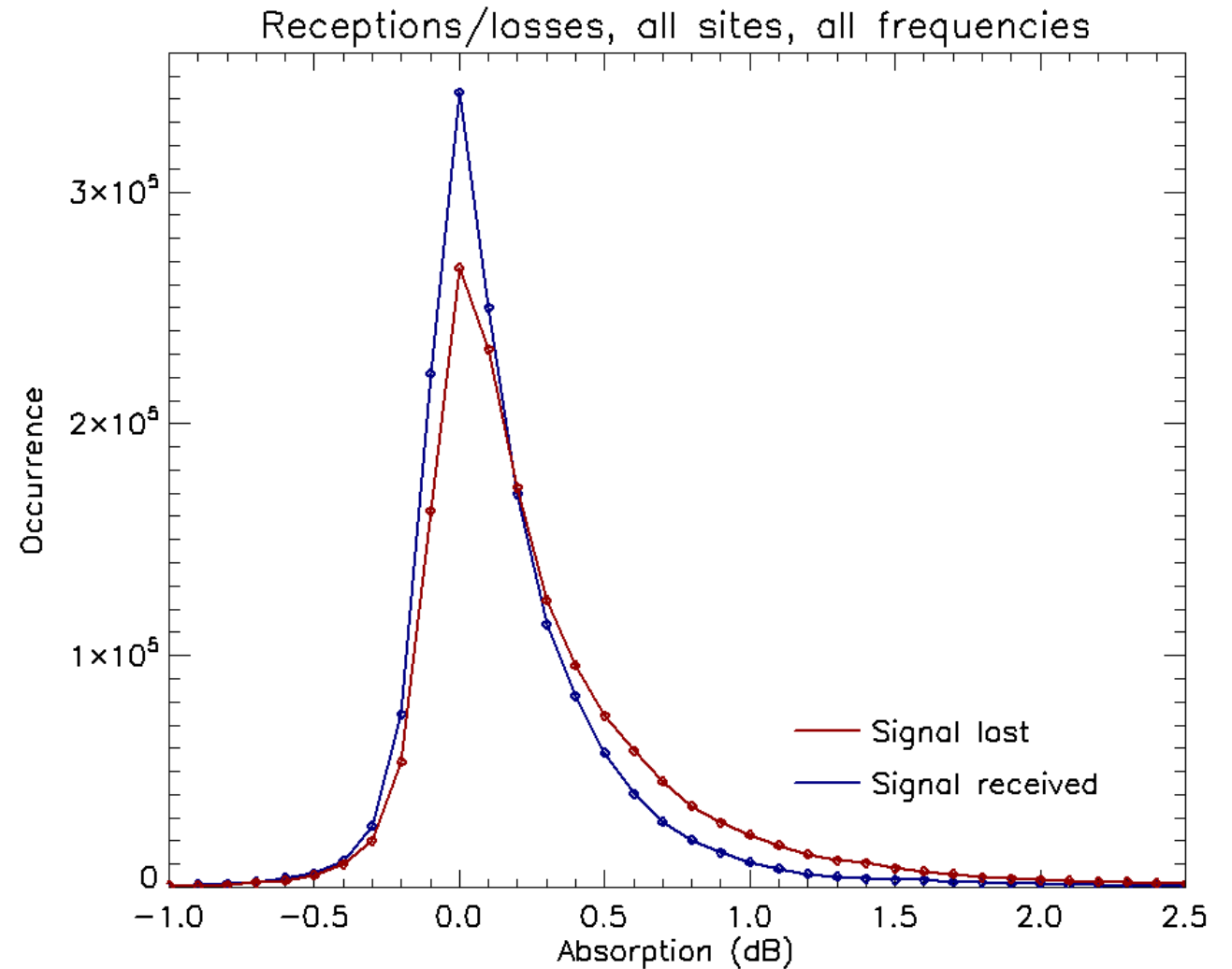


NRCan reception occurrence, 14MHz



Absorption when signal received vs not

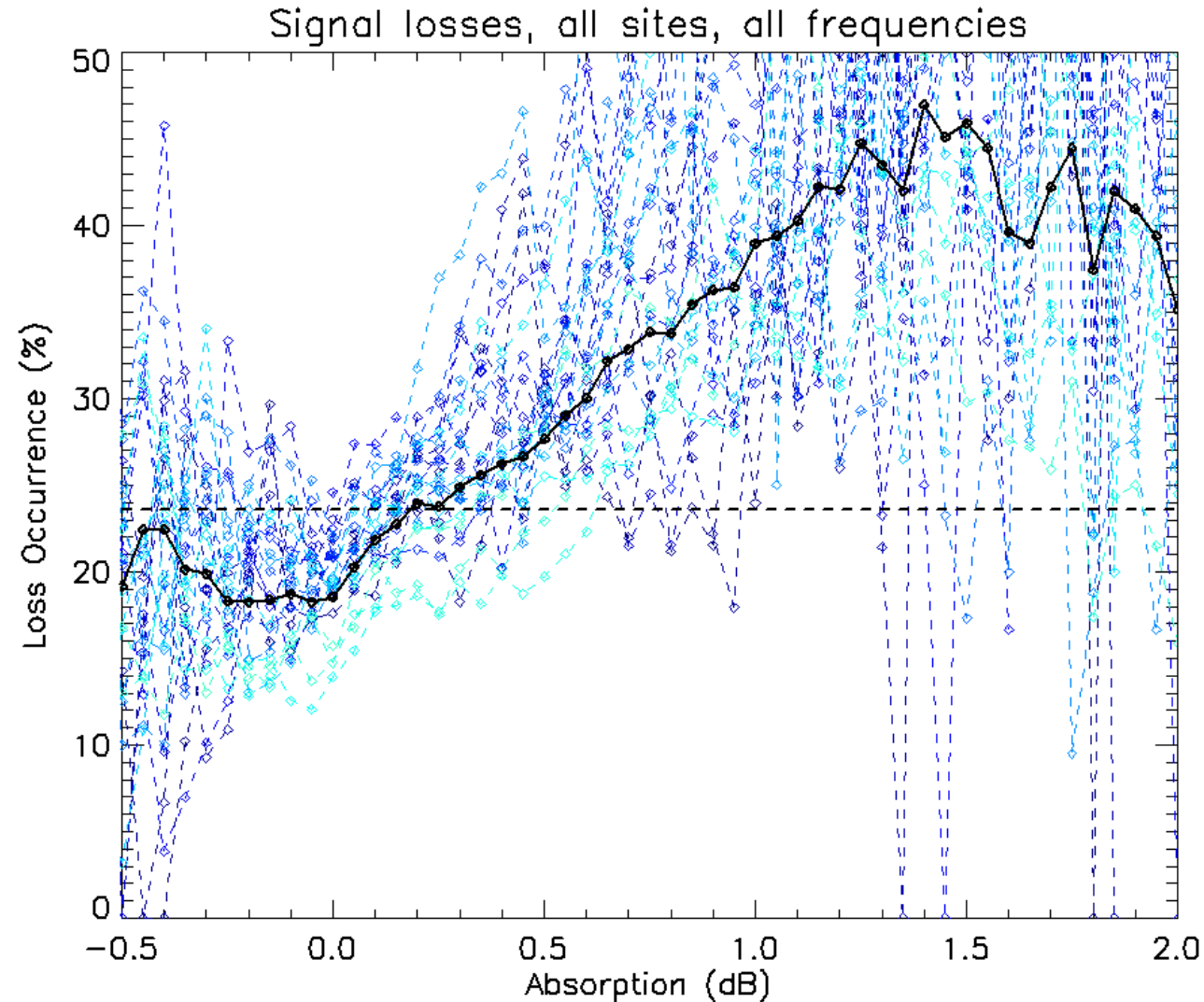
- **Blue curve:** total receptions vs absorption
- **Red curve:** signal losses (signal should be received but was not)
- Red curve normalized to area of blue curve
- At low absorption (<0.5 dB), signal is received more than lost
- At higher absorptions, signal is lost more than received





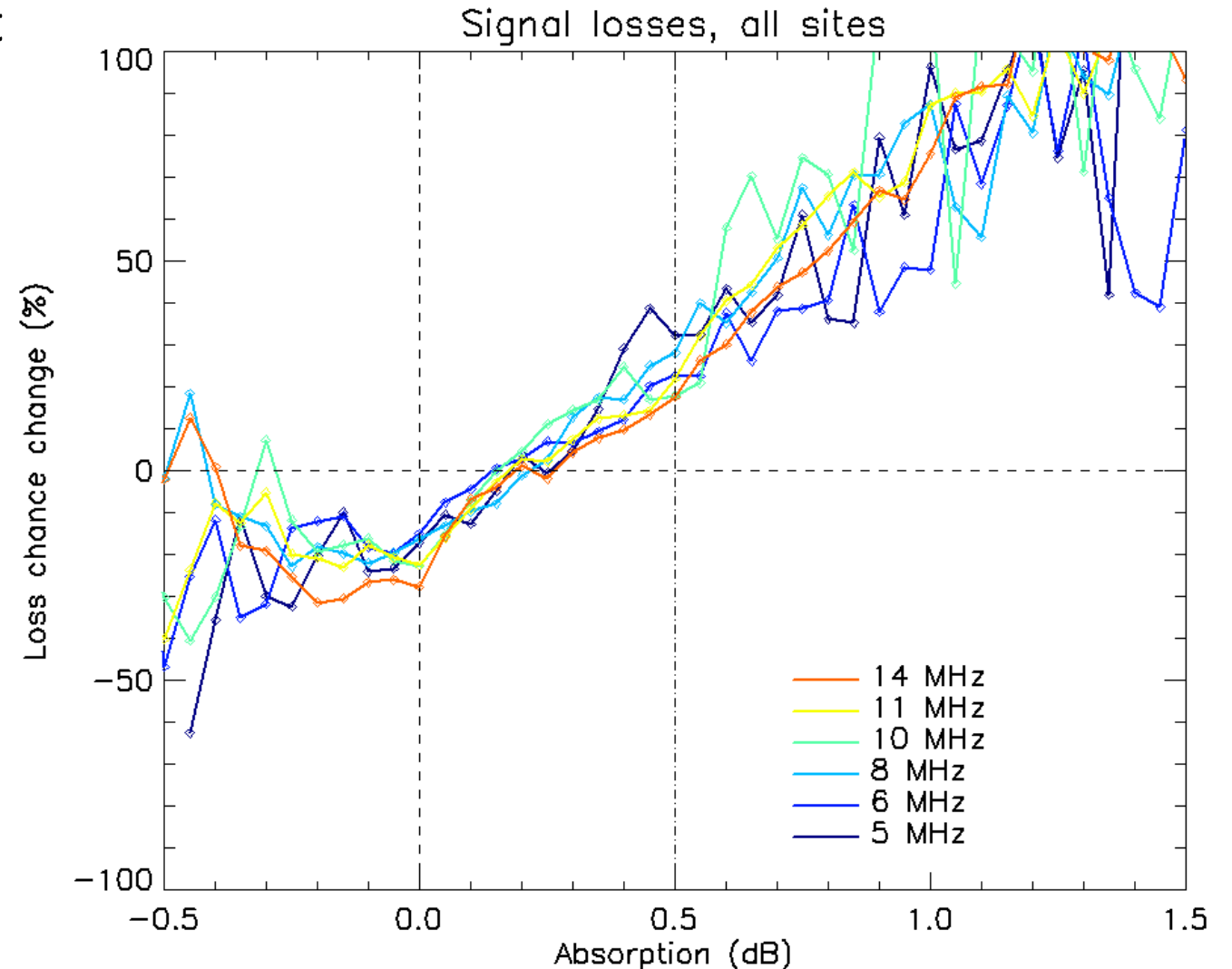
Signal loss vs measured absorption

- Number of missed pulses/total expected
- Dashed line is overall missed/expected
 - Above dashed line: more losses
 - Below dashed line: more receptions
- Blue curves: separate frequencies/sites
- Black curve: overall average (all sites and frequencies)
- **Overall, higher measured absorption corresponds to more signals being lost**



Signal loss vs absorption at different frequencies

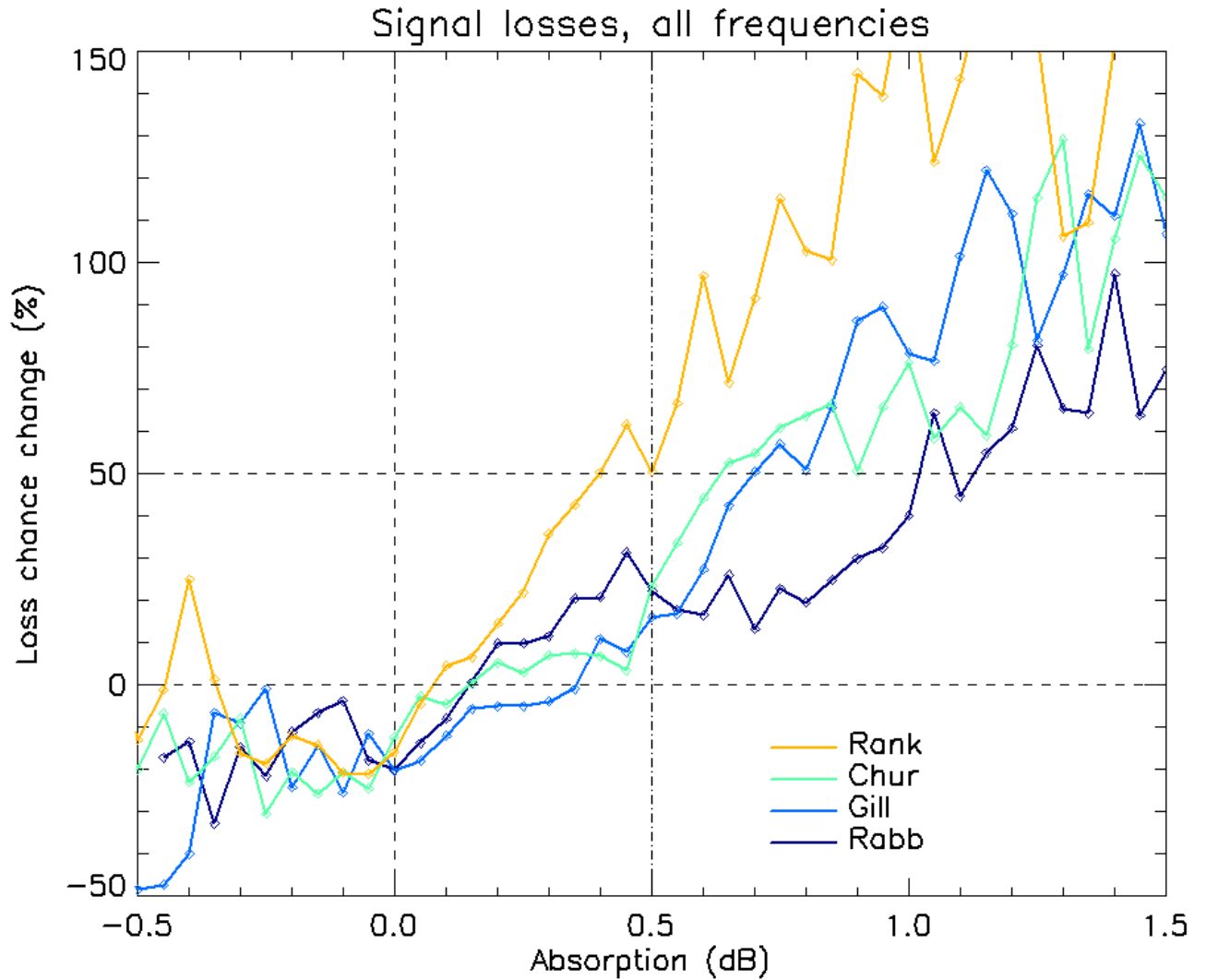
- Increase of signal losses vs absorption at different frequencies
- Little frequency dependence:
 - Any absorption (~ 0.1 - 0.2 dB) at 30 MHz corresponds to a total blackout at frequencies below 14 MHz
- Therefore, signal along the HF link is only lost if measured absorption region is large enough to be detected above both the riometer site and the HF link





Signal loss vs absorption at different sites

- Increase of signal losses vs absorption at different riometer sites
- Rankin Inlet (closest site to link) shows most loss vs absorption
 - Overall, at 0.5 dB threshold (*Gillies et al., 2024*), ~20-50% increase in signal losses (broadly in agreement with ~30% of absorption events having appropriate sizes)
- **Proximity of riometer to HF link/path is very important for predicting useability of link with absorption measurement**



Summary

- HF link between Ottawa and Alert examined with respect to ionospheric absorption
- Signal tends to be lost more often as measured absorption increases
- From 5 to 14 MHz, a given level of absorption tends to result in same probability of signal loss
 - Any amount of absorption measured at 30-MHz results in total signal loss regardless of frequency **if** region above riometers is representative of the D-region at the pierce points of HF signal
- Sites closer to HF link path correlate better with HF signal losses
- Future studies may consider other HF links/transmitters (e.g., SuperDARN) and/or other riometers closer to predicted HF path and D-region intersections



References

- Gillies, R. G., Spanswick, E., and Skone, S. (2024). A statistical examination of the spatial correlations of HF ionospheric absorption signatures using the GO-Canada riometer network. *Journal of Geophysical Research: Space Physics*, 129, e2023JA032082. <https://doi.org/10.1029/2023JA032082>
- Cameron, T. G., R. A. D. Fiori, E. M. Warrington, A. J. Stocker, T. Thayaparan, & D. W. Danskin (2021). Characterization of high latitude radio wave propagation over Canada, *Journal of Atmospheric and Solar-Terrestrial Physics*, Volume 219, 2021, 105666, <https://doi.org/10.1016/j.jastp.2021.105666>