Auroral absorption, or Cosmic Noise Absorption (CNA) is caused by energetic (30-300 keV) electrons, generated during substorms & scattered/accelerated by VLF waves
Registered by riometers (Little & Leinbach, *Proc. IRE, 47*, 315, 1959)

Example of substorm-related CNA at different MLTs →
Introduction

Energetic electron fluxes and CNA affect **HF communication on the ground, in aviation and space** (e.g. Knipp et al., Space Weather, 2016.), as well as **ozone concentration and polar climate** (Rozanov et al., Surv. in Geophys., 2012, Seppala et al., Geophys. Res. Lett., 2015) and thus exert influence on **Space Weather** ⇒ importance of their modeling.

Morphology of substorm-induced CNA is known since 1960-1970s


However existing models:

Cresswell-Moorcock et al., JGR., 2013; Beharrell et al., JGR, 2015, You et al., GRL, 2018....

are incapable to describe the reaction of energetic electron fluxes/CNA on substorms of different shape, intensity and location.

The main difficulty -how to parametrize the problem
Our Approach
(Physical grounds)

Assumptions:
- CNA value ($A$) ~ injection strength
- Betatron acceleration – primary acceleration mechanism
- Injection strength ~ dipolarization amplitude
- Dipolarization amplitude ~ $\Delta T$, where $\Delta T \equiv \Delta (MPB)^{1/2}$

$MPB(nT^2) = \Delta X^2 + \Delta Y^2$

$\Delta$ relative to quiet level

Credit from McPherron et al., 1973
Method

- CNA response is presented as linear superposition of dipolarization $\Delta T$ effects during 4 h after onset $t_0$ & 1 h before. **Negative $\Delta T$ prescribed zero.**

- Linear prediction filter (LPF, e.g. Bargatze et al., J. Geophys. Res., V. 90, 6387, 1985) technique used separately for each MLT bin.

\[
T(t) = MPB^{1/2}(t+1) - MPB^{1/2}(t) \\
T_{1k}, k=1,60 = T(i), i=1,60 \\
T_{2k}, k=1,60 = T(i), i=2,61 \\
\vdots \\
T_{60k}, k=1,60 = T(i), i=541,600
\]

\[
A_i = \sum_{k=1}^{60} F_k T_{ik} ; \quad i=1,60
\]

$A=TF$  
F-response function
Data

- 5 Canadian riometers at \(\sim 67^\circ\) CGMLat (E-W chain) (only azimuthal dynamics is considered).
- Isolated substorms identified in AL and MPB index (>3-4h quiet before);
- \(~240\) substorms selected in 2007-2012;
- Data on CNA and differences \(\Delta T\) of MPB\(^{1/2}\) (only \(\Delta T>0\) considered) at 5min resolution.

Data of different stations in the same MLT sector are consistent and thus taken together.
Response functions for different MLT sectors

LPFs constructed for combined set of Canadian riometers:

• LPFs reasonably agree with median/quartile responses

• LPFs are narrower and have larger & earlier peak

• Large dawn/dusk asymmetry (long known since 1960th)

• Data/model correlation is 0.6-0.7 where the response is large
Precipitation response to a unit-scale injection at 67°

LPF evolution during CNA eastward drift as seen (top) from the plot of their half-width parameter and (bottom) from their summary plot. **The propagation velocity** 12h MLT/56 min corresponds to ~50keV electrons drift at L ~ 7.5.

- Narrow intense precipitation at 22-02 MLT – an injection image!
- Long morning CNA peak (max at 7-8 h MLT)
- CNA void of e-precipitation near dusk (both are mostly an effect of convection E-field)
Validation of LPF results

- LPFs have similar shapes for stations with same latitude and MLT;
- Application of Canadian-based LPFs to Finnish riometer data provides a similar level prediction in CC (worse in PE).
- Application of isolated substorm-based LPFs for disturbed period with 60 non-isolated substorms →
Conclusions

• We propose a method to monitor the substorm-caused CNA dynamics in the center of auroral zone based on SCW effects (MPB index).

• The method is observationally confirmed, supporting that our understanding of injection physics is realistic. The observed dynamical features of injections (initial injection size (~4h MLT) and location, CNA eastward drift and dawn-dusk asymmetry) are consistent with drift model and agree with previous results.

• Such approach is perspective for application purposes, to address different Space Weather problems (monitoring/short term prediction of HF communication on the ground, in aviation and space; ozone variations, climate dynamics).

Work in progress: non-isolated substorms, latitudinal dynamics, study of electron spectra, LPF application to ionospheric electron density...
Most useful would be to find a predictor based on continuous observations within the magnetotail, as the immediate source of the substorm; such do not, however, seem very likely at present. An indicator, by satellite observation or otherwise, of substorm onset in the midnight sector may be more feasible as an early warning of activity in other sectors.


MPB index is such a predictor