GPS Phase Scintillation and HF Radar Backscatter Occurrence at High Latitudes

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Outline

• Canadian High Arctic Ionospheric Network (CHAIN)
• Scintillation in auroral arcs, cusp and polar cap patches
• Climatology of phase scintillation and HF radar backscatter
  – MLT and magnetic latitude dependence
  – Geomagnetic activity dependence & Seasonal variation
• Future plans: CHAIN expansion & CASSIOPE/ePOP mission
Basic measurements and data products

- CADI **ionograms** 1-5min
- **convection** at 30-s res.
- GPS $\sigma_\phi$ and $S_4$ from 50-Hz data over 1 min intervals
- slant and vertical TEC
- 3D tomographic TEC maps
GPS TEC and scintillation data from Cambridge Bay elevation > 30°

\[ \sigma_\phi = \sqrt{\Phi^2 - <\Phi>^2} \]

\[ S_4 = \sqrt{<I^2> - <I>^2} / <I>^2 \]

Cambridge Bay based on 1-minute definitive data January 8, 2008

Cambridge Bay

NOAA/POES 2008 Jan 08

Cambridge Bay TEC

00:00 12:00 MLT
CHAIN: Cambridge Bay

σΦ

Cycle slips

05:00  05:20  05:40  06:00
CHAIN: Example of scintillation in the cusp

Taloyoak

SuperDARN Rankin Radar beam2
CHAIN: Example of scintillation in the cusp

SuperDARN Saskatoon Radar beam5

\[ \sigma_\phi = \sqrt{\langle \phi^2 \rangle} - \langle \phi \rangle^2 \]
Polar cap patches observed by ionosondes in Resolute Bay and Eureka.

\[ \sigma_\phi = \sqrt{\langle \Phi^2 \rangle} - \langle \Phi \rangle^2 \]
Polar cap patches observed by ionosondes and SuperDARN Rankin Inlet radar beam 8
Vertical TEC maps without & with CHAIN
Climatology of scintillation and HF radar backscatter

Constructed maps of percentage occurrence of

**Phase scintillation:**
\[ N(\sigma_\varphi > 0.1 \text{ radians}) / N_{\text{total number of IPPs}} \]
(elevation > 30°, IPPs (at 350 km) binned on a grid 1 hour MLT \times 2.5° CGM latitude)

**Ionospheric backscatter:**
\[ N(|V_{los}| > 100 \text{ m/s}) / N_{\text{total number of range gates}} \]
(Beam 8 range gates binned on a grid 1 hour MLT \times 1.5° CGM latitude)
CHAIN & SuperDARN

Canadian High-Arctic Ionospheric Network (CHAIN)
Mean TEC and phase scintillation occurrence 2008-2010
Phase scintillation occurrence in 2008-2010 for quiet & moderately disturbed days

CHAIN 2008–2010: SIGMA PHI >0.1 OCCURRENCE

QUIET DAYS n=970
less than 60% Kp/2

IQ=2

DISTURBED DAYS n=126
more than 60% Kp/2

IQ=4

(a) (b)
HF backscatter $|V_{LoS}| > 100$ m/s

Phase scintillation $\sigma_\phi > 0.1$
HF backscatter $|V_{LoS}| > 100$ m/s

Phase scintillation $\sigma_\Phi > 0.1$
2008-2009 SuperDARN/Sask: Ionospheric backscatter

(a) autumn equinox
(b) winter solstice
(c) spring equinox
(d) summer solstice
2008-2009 CHAIN: Phase scintillation $\sigma_\phi > 0.1$

(a) autumn equinox

(b) winter solstice

(c) spring equinox

(d) summer solstice
Phase scintillation climatology 2008-2010

CHAIN 2008–2010: SIGMA PHI > 0.1 OCCURRENCE
Seasonal variations of occurrence in the cusp and in the nightside auroral oval

Phase scintillation $\sigma_\phi > 0.1$
Seasonal variations of occurrence in the cusp and in the nightside auroral oval

Phase scintillation $\sigma_{\phi} > 0.1$

Ionospheric HF backscatter $|V_{LoS}| > 100$ m/s
SUMMARY

• 2008-2010: Maps as a function of CGM latitude and MLT of phase scintillation and HF backscatter
  – GPS phase scintillation strongest in the cusp and pre-midnight auroral oval
  – Statistically, scintillation collocated with HF backscatter
  – Geomagnetic activity dependence
  – Seasonal variation

• Nightside auroral phase scintillation (E region)
  – Intermittent (bursty) - collocated with auroral arc brightenings and substorms
  – Semiannual variation of occurrence: Maxima in equinoxes

• Cusp/cleft phase scintillation (F region)
  – Continuous, often lasting for several hours
  – Annual variation of occurrence: Maximum in late autumn/winter
Future plans

• CHAIN expansion
  Interhemispheric scintillation studies between Arctic and Antarctic

• CASSIOPE/ePOP mission
  New perspective on ionospheric irregularities
  In-situ plasma measurements for scintillation climatology modeling
**Enhanced Polar Outflow Probe (e-POP)**

**Science**

Plasma outflow: Micro-scale ion acceleration; wave particle interaction; auroral connection

Wave propagation: 3D structure of ionospheric irregularities; GPS radio occultation

Neutral escape: Neutral heating, non-thermal atmospheric escape

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**Mission Concept**

High-resolution in-situ measurements
Radio wave propagation 3D studies
Fast imaging of meso-scale aurora

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**Mission Design**

Polar orbit: $325 \times 1500$ km; $80^\circ$ incl.
Agile, 3-axis stabilized platform
8-instrument plasma & field payload
Large onboard data storage (terabyte)
Fast telemetry downlink ($>300$Mbps)
New CHAIN proposal
CHAIN + European GISTMs

“Conjugate” GPS receivers in Antarctica
GPS receivers in Antarctica

Conjugate CHAIN + European GISTMs + SuperDARN
GPS receivers in Antarctica

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