ICEBEAR: Recent Results from a Bistatic Coded Continuous-Wave E-region Coherent Scatter Radar EGU 2020, Online

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ICEBEAR Motivation

- ICEBEAR is a recently commissioned VHF coherent scatter radar that makes measurements of the auroral E-region ionosphere
- The radar signal scatters from plasma density irregularities that are aligned with the geomagnetic field
- These field-aligned irregularities at E-region altitudes (≈110 km) are typically generated from the Farley-Buneman, or two-stream, instability (Farley, 1963; Buneman, 1963) in auroral regions
- The Farley-Buneman instability occurs during periods of enhanced electric fields in the ionosphere that cause electrons to have a velocity greater than the ions by at least the ion-acoustic speed
- What do measurements of these plasma density irregularities with coherent scatter radars look like?



ICEBEAR Motivation

- Spectra measurements of plasma density irregularities generated by Farley-Buneman instability
- Previous coherent scatter studies characterized 4 different types of auroral E-region coherent scatter
- Type I
 - narrow spectral width
 - Doppler velocity around ion-acoustic speed (C_s)
- Type II
 - broad spectral width
 - Doppler velocity around 0
- Type III
 - narrow spectral width
 - Doppler velocity around half ion-acoustic speed
- Type IV
 - narrow spectral width
 - Doppler velocity around double ion-acoustic speed





ICEBEAR Initial Operations

The Ionospheric Continuous-wave E-region Bistatic Experimental Auroral Radar (ICEBEAR)

- Coherent scatter radar measuring the E-region
- CW pseudo random phase modulated signal
- Bistatic setup
- Fully digital
- Center frequency of 49.5 MHz with a 100 kHz bandwidth
- 10 antenna linear array with wavelength spacing
- 5 X300 Ettus research transceivers per site
- Temporal resolution: 1.0 s
- Range resolution: 1.5 km
- Range/Doppler/SNR/Azimuthal angle of arrival able to be determined
- Campaign basis operations due to substantial data footprint for continuous operation



ICEBEAR TX Site



ICEBEAR Initial Results

- Measurement of E-region coherent scatter using ICEBEAR for a 5 second average (shown below)
- Can observe all four different types of previously labelled E-region coherent scatter simultaneously
- Measurement was taken with linear receiving array, allowing the determination of the azimuth angle of arrival
- Data can be mapped to the field of view



(Huyghebaert et al., 2019)



ICEBEAR Initial Results





ICEBEAR-3D Motivations

Decision was made to reconfigure the receiver array. Why?

- Resolve azimuth aliasing
 - $\bullet\,$ ICEBEAR azimuth aliasing ambiguous outside \pm 30° w/ linear array
- Improve azimuth angle-of-arrival resolution
 - Determine scale of coherent scatter volumes
 - Widen azimuth field-of-view
 - Obtain higher resolution angle-of-arrival
- Obtain elevation angle-of-arrival measurements
 - Elevation angles can be used to determine altitude values
 - Altitude information is required for more accurate determination of aspect angle of scattering region
 - Altitude dependencies of E-region scatter can be studied



Receiver Antenna Array Reconfiguration

ICEBEAR-3D Receiver Array Design

- Restricted area for antenna placement
- Maximum of 10 antenna available
- All unique baselines (N=45) to maximize spatial frequency sampling
- Jacobs-Ralston minimized phase error baseline selection process (Jacobs et. al, 1981)
- Elastic-net based antenna position optimization to maximize spatial frequency sampling distribution
- Shortest East-West baseline 1.5 λ
- Longest East-West baseline 16.0 λ
- Shortest North-South baseline 4.5 λ
- Longest North-south baseline 34.0 λ





Benefits of Reconfiguration

- 3D signal angle-of-arrival possible
- Aperture synthesis imaging methods possible for determination of both elevation and azimuth
- Phase error tolerant for imaging
 - Tested through simulation
 - Tolerant of $\pm~15^\circ$ phase error
 - $\bullet\,$ Tolerant of \pm 25 cm antenna position
- Phase self-calibration possible (future work)





ICEBEAR 3D Initial Results

- Multiple scans included in the scatter plot from full field of view
- Results show expected trend of decreasing elevation with increasing range
- Elevations mapped to altitude are higher than expected investigations underway
- Data from measurements taken on Dec. 19, 2019





ICEBEAR Video (1 s res. 10x speed, 6 dB SNR cutoff)

https://www.youtube.com/watch?v=BcMNTPYJ7mk



Summary

- ICEBEAR 3D Operational
 - Successful reconfiguration of ICEBEAR receiver
 - High resolution measurements of E-region plasma density irregularities during active ionospheric periods
 - Promising preliminary results
- Altitude information attainable from array design
 - Validating results and verifying calibration
- ICEBEAR resolution
 - 1.5 km range
 - 1 s temporal (depends on suppression of noise that is satisfactory)
 - 10 Hz Doppler
 - From Rayleigh Criterion:
 - \bullet 4.4° Azimuth
 - 2.1° Elevation
 - Note: These angle of arrival resolutions can be improved upon by assuming characteristics of the scattering region during imaging



Thank You

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- Graduate and summer students
- Administration staff





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