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Auroral Infrasonic Waves and Poleward Expansions of Auroral Substorms at Inuvik, N.W.T., Canada

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Summary

Observations at Inuvik (70·4° dipole latitude) have shown that supersonic motions of auroral arcs that sweep across the zenith from south to north during poleward expansions of auroral substorms do not generate observable auroral infrasonic waves. This is in contrast to the fact that equatorward supersonic motions of similar auroral arcs do produce large amplitude infrasonic bow waves. These results imply an asymmetry in the basic generation mechanism of infrasound within the auroral electrojet arcs.

The morphology of auroral infrasonic wave (AIW) substorms has been determined from auroral zone observations at College, Alaska (64·6° dipole latitude) by comparison of all sky camera (ASC) photographs, surface magnetometer observations and riometer records of auroral cosmic noise absorption events (Wilson 1969a, b, c, 1970). Supersonic motion of large-scale auroral forms in a direction transverse to the long axis of the auroral arcs was found to be a necessary condition for the production of AIW by an auroral arc (Wilson & Nichparenko 1967). This led to the development of a ' shock wave ' model to explain the directional and amplification properties of the radiation of infrasonic waves by auroral arcs in supersonic translation (Wilson 1967). It was shown that if a pressure pulse is produced within the auroral arc by an unspecified mechanism that is of constant amplitude and phase in the frame of reference of the moving arc, then a ' shock wave ' would be produced by constructive interference of the wavefronts as the source moved across the sky. It has been pointed out that ' bow wave ' is a better name for this phenomenon (Chimonas & Peltier 1970). Shock conditions may prevail in the E region of the aurora; however, by the time the infrasound reaches the ground the wave amplitude is only a few dyn/cm^{-2}.

Magnetometer records have been used to relate the translational speeds of auroral electrojet arcs to the generation of AIW (Wilson 1969b). The AIW was found to arrive at the surface from six to eight minutes after zenith passage of an auroral electrojet arc in supersonic translation. The horizontal trace velocity V_h of the AIW was shown to have the same direction and speed as the auroral sources motion (Wilson 1967). Further evidence for the association of AIW with supersonic auroral motion that develops along the auroral oval (Feldstein & Starkov 1967) during the expansion phase of the average auroral substorm (Akasofu 1968) was found by a comparison of auroral sudden-onset cosmic noise absorption events and AIW (Wilson 1970).

An infrasonic observatory was set up at Inuvik, N.W.T. in Canada at dipole latitude 70·4° (geographic co-ordinates 68°35′N, 133°W) with an array of four microphones (see Cook & Young 1962, for equipment description), a three-component magnetometer, an all-sky auroral camera and a riometer for measuring cosmic noise

absorption. During the winter of 1969–70 many examples of poleward expansions (Akasofu, Kimball & Meng 1966) of auroral substorms took place with auroral arcs moving with supersonic speeds from south to north across the Inuvik zenith. The magnetic records showed large negative bays in H and plus-to-minus changes in Z, the vertical component of the magnetic perturbation associated with the poleward expanding arcs, indicating that strong westward electrojets were flowing in the arcs. The riometer records at Inuvik showed ' F ' type (Parthasarathy & Berkey 1965) sudden-onset cosmic noise absorption events in association with the zenith passage of the poleward expansions. An analysis of the ASC photographs was made to determine the direction and speed of the supersonic poleward expansions. In this manner the poleward expansions at Inuvik were shown to have all the proper characteristics of supersonic electrojet arcs that do produce strong AIW at College or Inuvik when the direction of motion of the arcs is equatorward or parallel to the auroral oval (Wilson 1969c).

On 1970 January 30 during exceptionally quiet infrasonic noise level conditions of $\pm\frac{1}{2}$ μbar at Inuvik, two successive poleward expansions crossed the zenith at Inuvik at 0621 and 1000 U.T. without producing any associated AIW. The poleward expansions, as shown in the Inuvik ASC in Fig. 1, had velocities of 1160 ms at 0620 travelling from an azimuth $\phi = 200°$ and 900 ms at 1000 with $\phi = 205°$ as calculated from the ASC data at Inuvik. The magnetic bays and sudden-onset ' F ' type auroral absorption associated with these two poleward expansions at 0620 and 1000 are shown in Fig. 2 by the H and D magnetometer records and the 30 MHz riometer trace. The negative bay in H of -400γ and plus-to-minus change in Z at 0620, and the bay in H of -340γ and similar change in Z at 1000, indicate that westward electrojets were flowing in the poleward moving acts during both of these events. The infrasonic records shown at the bottom of Fig. 1 from 0605 to 0637 and from 0954 to 1015 show that no AIW were observed to the radiated by either of these two supersonic poleward expansions. The rather poor AIW at 1016 and 1021 are from directions $\phi = 20°$ and $\phi = 31°$ respectively. These signals can probably be associated with the supersonic *equatorward* motion of the arc shown in the bottom row of ASC photographs in Fig. 1. At 1012 this arc moves from $\phi = 40°$ toward the south with a speed of 1170 ms.

If there had been AIW radiated by the poleward expansions at 0621 and 1000, then the infrasonic bow waves would have arrived around 0627 to 0630 from $\phi = 200°$

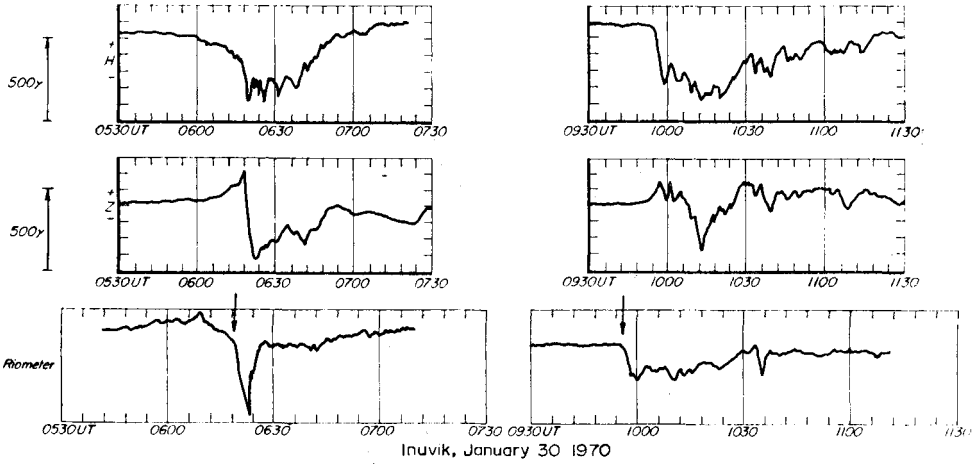

FIG. 2. Inuvik magnetometer and riometer for two poleward expansion events on 1970 January 30 at 0621 and 1000 showing ' F ' type riometer absorption and negative bays in H.

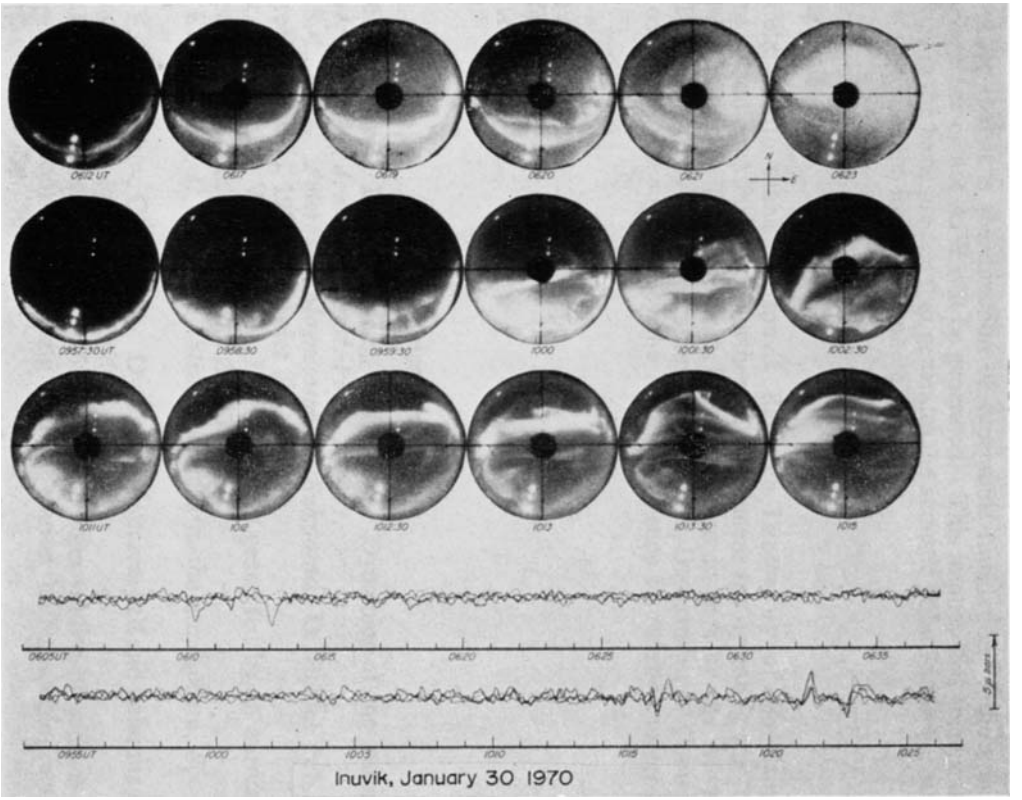

FIG. 1. Inuvik ASC and infrasonic records for two poleward expansions at 0621 and 1000 on 1970 January 30. An equatorward motion is shown at 1012–1013.

and around 1006 to 1008 from $\phi = 205°$ respectively. The only AIW observed were coming from the opposite direction, and thus could not possibly be bow waves from the poleward expansions shown in Fig. 1.

Many similar observations of poleward expansions at Inuvik have been made. No AIW were observed at Inuvik that were moving in the same directions and could be associated in delay time with the poleward moving arcs. It was found that if a reversal in the direction of the arc took place, then a north-to-south supersonic motion would produce an AIW travelling equatorward parallel to the motion of its source arc.

Thus we see that it is the direction of supersonic translation of the arcs that determines whether or not AIW will be generated. This implies that there must be an asymmetry in the basic process that generates the acoustic pulse within the auroral arc in the E region of the lower ionosphere.

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