

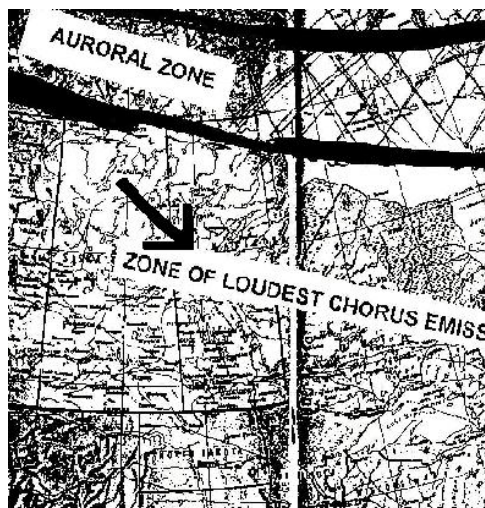
**SOLAR-MINIMUM NATURAL VLF RADIO RECORDING & AURORA OBSERVING EXPEDITION TO MANITOBA, CANADA, and NEVADA, U.S.A.**

**REPORT OF NATURAL VLF RADIO RECORDING RESULTS, DESCRIPTIONS OF AURORAL DISPLAYS, GEO-MAGNETIC INDICES, PHOTOGRAPHS, VLF SOUND FILES, AND OTHER RELEVANT INFORMATION.**

by Stephen P. McGreevy

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**GRASS RIVER PROVINCIAL PARK, MANITOBA, 22 August - 05 September 1996**



Geographic coordinates: 54 degrees 40 minutes North latitude / 101 degrees 10 minutes West longitude, located 2 miles north of Simonhouse Lake and 1/3 mile south of Provincial Hwy. 39 (was 391), 5.5 miles (8.8 km) east of the junction of Highway 10 and 39. Geo-magnetic latitude: approximately 64 degrees north - a prime location for making superb field-recordings of an amazing variety of auroral-zone natural VLF radio phenomena and aurora observation in August and early September.

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**[Manitoba SOLAR-MINIMUM VLF EXPEDITION MP3-file VLF audio recordings and associated spectrograms.](#)**

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Other VLF listening/camping stops on my way south from Manitoba: Southeastern UTAH (Canyonlands National Park), and three northeastern to northwestern NEVADA LOCATIONS, 12 - 22 September 1996 as follows:

Canyonlands National Park, southeastern UTAH: 12-13 September

Great Basin National Park, eastern Nevada, upper Lehman Campground: 13-16 September

Angel Creek NFG, northeastern Nevada (7 miles s.w. of Wells, NV): 16-18 September

Black Rock Desert, northwestern Nevada: 19-22 September

VLF receivers used were McGreevy WR-4B e-field receiver with 3 meter (10-foot) whip antenna attached to rear door of my van, and also a hand-held WR-3E portable VLF receiver with 85 cm (33-inch) whip antenna. For LF-HF observations, I used a Kenwood R-1000 and Yaesu FRT-7700 tuner with homebrew pre-amplifier, a 100 foot wire at 10-20 feet for HF reception observations, and a 600 foot wire up 1-3 feet above the ground pointed to the north-east for LF and MF observation. Additionally, I made MF and HF propagation observations using a Sangean ATS-808 portable receiver.

All times and dates UTC (GMT/z), and Central Daylight Time (CDT) These are Natural Radio recordings sessions and also relevant notes about the visible auroral displays and other radio propagation notes.

Thursday, 22 August 1996, 1922 UTC/2:30 p.m. CDT - approximately 40 miles/60 km south of The Pas, Manitoba, at a turn-off of Hwy. 10 to Springwater Picnic Area.

VLF: Loud auroral hiss-band, occasional parallel discrete tones and 'whines' audible in the fairly loud hissband. Occasional 'ringing/chiming' sounds also heard (most unusual!) 20 min. of excellent tape made, cassette MBVLF-1, side A and B. WWV indices: SF 70 A7 Boulder - K2 1800 UTC 22 Aug. Planetary K = 2.

Geo-magnetic indices for Thursday 22 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 1 1 1 1 2 2 2. Quiet to unsettled levels. Solar-flux = 73, SSN = 012, GT 2 MeV Electron fluence = 2.1+07E (moderate). No proton events. X-ray background: A4.3

Friday, 23 August 1996, 0006 UTC/7:06 p.m. CDT Thursday 22 August 96 CDT: arrival at the "VLF Camp" listening site in Grass River Provincial Park, where I would spend the next 12 nights.

(Quite strong reception of Norway on 1314 mediumwave at 0230 UT, also weak Talk Radio UK on 1053 in the bad splatter from 1050 Mexico and Cuba.)

VLF: 0355 UTC/10:55 p.m. Thursday 22 August local date, Planetary & Boulder K index = 2: Weak hissband, a few risers (chorus), tweeks, light/moderate static, occasional weak whistler.

Aurora viewing:

IBC (International Brightness Coefficient) is a general measurement of the brightness of aurora in four (logarithmic) levels. I will attempt to provide the IBC levels as accurately as possible in the following report:

IBC I Aurora that has brightness equal to that of the Milky Way.

IBC II Aurora has the brightness of thin moonlit cirrus clouds (about 10 times brighter than IBC I).

IBC III Aurora has the brightness of moonlit cumulus clouds (about 100 times brighter than IBC I).

IBC IV Aurora is so bright as to provide total illumination on the ground equivalent to the full moon.

0420 UT/11:25 p.m. CDT: Auroral "arch" (arc) to visible from north-west horizon to north-east horizon and about 20 degrees above the northern horizon at maximum altitude and averages between IBC I and II. The auroral arch is developing brightenings and rayed striations in the north-eastern quadrant at IBC II-plus levels.

Note: This auroral "arch" or "arc" - not unlike a flattened green rainbow - is actually the visible part of the auroral oval which crosses almost directly overhead over Lynn Lake and Churchill, Manitoba most nights. As I was about 200-300 miles south of this "average" auroral oval location (it does move north and southward depending on magnetic activity), this auroral arch/oval was usually visible anywhere from 10 - 30 degrees above the northern horizon (at max. height/alt.) soon after evening twilight faded in the west. The very faint (IBC I) "hydrogen-arc" was also often visible to the south of the main auroral oval arch. Later on each night, the arch would start to form discrete auroral displays and forms usually by 10:30 - 11 p.m. local time (CDT) and usually starting in the north-eastern section of it (typical pattern, as locations eastward usually start to see the discrete auroral forms begin first, and they soon move westward as the auroral-oval undergoes substorms.-



This is a typical "quiescent auroral arc/arch" which was often visible to the north before it became more active. Photo by S. P. McGreevy 25 August 1996

Generally by 11:30 p.m. to 12:45 am local Manitoba time (near the local midnight meridian), the aurora would form lovely discrete forms - rays, striations, pillars, parallel bands, swirls, curtains, and so forth. Usually, these beautiful auroral forms would move southward and overhead. At times such as these, there would be an auroral "corona" overhead, indicating end of sub-storm and the peak of the auroral "break-up." Soon afterward, the aurora would fade to more quiescent levels for a while.

On three nights, the aurora was covering the entire sky by midnight. Most nights, however, the active display would remain in the northern half of the sky (Churchill and Lynn Lake, MB would be enjoying the aurora directly overhead at those times).

One problem for me was that a full moon occurred on the night of Wednesday 28-29 August, making each night before that full moon increasingly washed out by moon twilight. However, as I shall describe further on in this report, the night of the full moon also had auroral displays which were trying "their best" to outshine the full-moon, reaching IBC IV levels of brightness - the maximum. I could go outside and read a book easily in the eerie bright light of the combined bright aurora and the

full moon!

[View U. AK graph of K-indices for the period of this report](#)

Onward with the report...

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Friday, 23 August 1996, starting at 0355 UTC/10:55 p.m. CDT Thursday 22 August:

VLF: Weak hissband, occasional discrete tones, risers (chorus), tweeks.

Aurora viewing: Moderately bright auroral "arch" over the northern horizon and about 20 degrees above horizon as well. Surprisingly little VLF sounds to be heard despite the active auroral display in progress.

VLF: 0450 UT/11:50 p.m. CDT, Rising tonal bands, hiss, moderate lightning static levels. The same at 0508 UTC upon re-check. Tape: MBVLF-2, side B.

Aurora viewing: At 0508 UTC, the "primary" auroral band/arch has greatly brightened to between IBC II and III levels, and has "slipped" southward to about 35-40 degrees above northern horizon at its highest point. Faint second parallel band below it. You can walk outside to their light, and they seem to be getting even brighter. A few minutes later, a third band appeared almost overhead.

VLF: Only weak tones and hissband, not much else at 0515 UTC. Tape: MBVLF-2, side B.

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Friday, 23 August 0530 UTC/12:30 a.m. CDT:

Aurora viewing: The auroral arch is straight overhead and curls all over the sky with curtains, striations, etc. A brightening auroral "corona" is now overhead - essentially, I see 3/4 sky full of auroral displays - so beautiful! Brightness exceeds IBC III to almost IBC IV. By 0540 UTC, the aurora is dazzling and FULL-SKY. I get busy photographing it for about 30 minutes with my Pentax ME-Super and 35 mm lens., and these photos turn out to be some of the best I've ever taken of the aurora and show some colors other than the usual greenish (color Type C) aurora (such as some reddish purple in the photos indicative of color Type A aurora).



VLF: Despite the nearly full-sky aurora, VLF seems quite "dead" except for auroral hiss and a few tonal "ringing" sounds now and then, all rather weak. It seems quite apparent that active, discrete auroral displays generate relatively little VLF radio waves--at least this night. The aurora is all over the sky: shimmering, curtains, swirls, pillars, and yet, only weak hiss and ringing tones rising and falling in volume with the auroral activity. The loud and infinite variety of dawn chorus and "roar" hiss to follow each morning is being generated in the magnetosphere's "bow-shock" region, where the solar wind is impinging on it. The ensuing radio emissions follow lines-of-force in the "whistler-mode" whence they are heard at my ground-based location. Tape: MBVLF-2, side B.



Geo-magnetic indices for 23 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 2 4 5 4 3 1 2 2. Quiet to major storm levels. Solar-flux = 74, SSN = 024, GT 2 MeV Electron fluence = 1.4E+06 (low). No proton events. X-ray background: B2.9

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Friday, 23 August, starting at 0836 UTC / 3:30 a.m. CDT:

VLF: Chorus has begun: low and high "chirps and squawks, hiss - still not too strong or impressive. 2 min. tape made, MBVLF-2, side B.

Upon a re-check at 0840 UT, there has already been an upsurge in the chorus and louder low-pitched riser "squawks." Occasional weak pure-tone whistlers descending to about 2 kHz. 10 minute recording made, tape MBVLF-2, to end of side B. By 0905 UT, there are a rapidly increasing number of "nose" whistlers occurring--these unusual sounding whistlers are unique to higher latitudes such as this location, and are not too common south of 40 degrees north (geographic lat.) in North America. The chorus is also getting louder--quite noticeably by 0915 UT. More nice tape made: MBVLF-3, side A.

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Friday, 23 August, starting at 1108 UTC / 6:08 a.m. CDT through 2135 UT (4:35 p.m. CDT):

VLF: After catching some sleep, I resumed VLF monitoring. The chorus and hiss both are fairly loud now and are also undulating louder and softer--evidence of geo-magnetic field micropulsations occurring. Hiss and low-pitched chorus whoops and barks. Not much lightning static. Quite nice sounding stuff happening! Tape: MBVLF-3, side A.

By 1125 UTC, gorgeous sounding echoing chorus trains occurring -- very distinct and intriguing! Tape: MBVLF-3, last 10 min. of tape.

At 1230 UT (7:30 am CDT local), just hiss occurring (the chorus will start up in a bit...)

At 1356 UT/ 8:56 am CDT, the chorus has developed into nice, low whoops along with semi-pure whistlers. Some of the chorus whoops are very low in frequency (less than 400 Hz) many of the chorus whoops are not the usual "risers but are 'fallers, sounding like "dweeeooop! They are occurring in clusters along with individual risers every 2-3 seconds- eerie! This is a great tape segment. Tape: MBVLF-3, beginning to end of side B.

1444 UTC / 9:44 a.m. CDT Just started a new cassette: MBVLF-4, side A. The chorus is incredibly beautiful sounding - just like last year in Alaska by the Chatanika River. Awesome and very loud chorus trains and parallel whooping, squawking risers. Not very loud hiss and light static. I made 25-30 minutes of unmarred, uninterrupted recording. Very pleasant weather outside: clear, sunny, about 75 degrees. F/24 degrees. C.

1531 UT: I flipped tape MBVLF-4 over to side B and resumed after a 1531 UTC WWV time check. The chorus is very dense and beautiful; undulating with geo-magnetic field micro-pulsations - sounding better than the Alaska recordings of Sept. 6, 1995 on the "Electric Enigma" CD set. I just let tape roll until it ended side B at approximately 1615 UTC. So far, what I've heard this morning is making the long drive up here very WORTH IT!

After starting a new tape, MBVLF-5, side A, beginning at 1622 UT, the chorus was still sounding fabulous--like the central Alaska (Chatanika River) chorus recorded during the major magnetic storm of 06 September 1995. Non-stop 45 minute tape made (entire side A) ending at approximately 1705 UT.

Flipping over tape 5 to side B, I continued recording starting at 1751 UT. Excellent chorus, hiss, intriguing "cricket" sounds were mixed in with low squawking sounds. In addition, this is being accompanied by occasional, slowly rising in pitch sounds similar to reverse whistlers (which usually fall in pitch from high to low).

Stopping the tape after about 10 minutes recording of this natural radio activity, I resumed recording at 1914 UT: similar sounding VLF activity to the 1751 - 1800 UT period except for an increase in the frequency of the auroral hiss and "main" frequency band of the chorus.

At 2059 UT, the excellent chorus was still going on, and by 2106, there were gorgeous slow risers and then nose whistlers (with rising and falling components) by 2135 UT. This segment of tape is another CD quality recording. Tape ends at 2223 UT

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Friday, 23 August, starting at 2227 UTC / 5:27 p.m. CDT

VLF: Late afternoon. Usually a very "dead" time of the day for natural radio listening at lower latitudes, but the chorus keeps on going on and on: activity has increased in the past few hours - sure evidence of the magnetic storm that is ongoing after a night of fabulous full-sky auroral displays. Loud hiss, very diffuse, slow-falling whistlers, a multitude of overlapping riser trains - very beautiful. Also, there are occasional slow risers similar to the ones recorded in the Peace River region of Alberta on 02 June 1996. Tape: MBVLF-6, side A.

By 2314 UT, The hiss has greatly declined in strength and there are nice "nose" -type falling whistlers happening (unique to these higher latitudes) and which are fairly diffuse (not pure-tone).



Daytime view of listening site and van amongst the northern boreal forest

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Saturday, 24 August, starting at 0535 UTC / 12:35 a.m. CDT

Geo-magnetic indices for Saturday 24 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 2 2 3 2 1 2 2 3. Quiet to unsettled levels. Solar-flux = 75, SSN = 022, GT 2 MeV Electron fluence = 1.5E+06 (low). No proton events. X-ray background: B1.2

Aurora viewing: The moon is gibbous. The auroral arch is bright (between IBC II to III) in the northern sky and about 20 - 25 degrees above the horizon at its highest point (about 10 degrees. east of true north). The auroral arch is also rapidly developing rays and striations.

VLF: As usual for this time of evening/night (0537 UT), only tweeks, weak power-line hum, faint hiss and weak tonal whistles and whines - no chorus and little else except for strange 'ricochet' sounding fast whistlers occurring within 50-100 milliseconds following a few very strong lightning static bursts--I've only heard this phenomenon at high latitudes such as Alberta in June 1996.

I did another "VLF check" at 1006 UT/5:06 a.m. CDT and noted weak chorus squawks and occasional nice sounding chorus trains centered on about 2 kHz. Ran MBVLF-6 cassette tape to end of side B.

Aurora viewing: Still aurora in form of the "arch" and faint pulsating auroral forms at 1012 UT, IBC I to II.

VLF: By 1039 UT, low hissband has begun and moderate strength chorus "squawks" (risers) are occurring. Recorded this activity to end of side A of MBVLF-7 cassette. Flipped tape over. At 1257 UT (7:57 a.m.), I noted the low pitched hissband "roar" and chorus.

1346 UT: Loud and sustained chorus "whoops" Incredible sounding! Made nice tape segment on MBVLF-7, side B. I saw a beautiful "V" formation of Canada Geese heading southward--autumn coming for sure...

At 1442 UT/9:42 a.m. CDT, There is a nice variety of low, whooping chorus. Also, there are what I'm calling "ghostly tones" for lack of a better scientific description. Some of the tones are going "woooo wheee..." and are reaching about 300 Hz at their lowest pitches! Recorded an entire side (A) of tape MBVLF-8 ending at 1538 UT.

At 1530 UT, continued recording onto side B of MBVLF-8. Just INCREDIBLE sounding chorus of rare low-frequencies (characteristic of "polar chorus").

Saturday, 24 August, starting at 1601 UTC / 11:46 a.m. CDT to 0100 UT Sunday 25 August 1996

VLF: Low pitched hissband, bursts of loud chorus trains - very DIFFERENT than 1/2 hour earlier! Gorgeous! Loud risers and roaring hiss... at this point, I decided to set-up video camera and tape the set-up with audio from the VLF receiver patched into the camcorder's audio input jack. As time progressed, static crashes of lightning storms about 400 miles to the south were increasing in strength and numbers - normally annoying - but the chorus trains were "responding" to each strong static crash with loud bursts of 2-5 seconds in duration approximately 2-3 seconds after each of the loud static bursts, particularly after 1700 UT. Activity taped to the end of side B of MBVLF-8 and also side A of tape cassette MBVLF-9A.

At 1801 UT, the chorus activity has further increased to very vigorous density and volume levels. Spectacular tape, especially the last 5-10 minutes of side A of tape MBVLF-9A.

At 1937 UT and now recording this very impressive natural radio activity onto side B of MBVLF-9A, there are truly beautiful chorus risers happening.

Activity rapidly died down by 2100 UT, leaving "just static and tweeks" by 0100 UT, Sunday 25 August UT date.

Sunday 25 August 1996 starting at 0400 UT (11:00 p.m. CDT Sat. 24 Aug. CDT) to 0515 UT (12:15 am CDT)

Geo-magnetic indices for Sunday 25 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 4 3 4 4 3 3 2 2. Quiet to active levels. Solar-flux = 75, SSN = 014, GT 2 MeV Electron fluence = 5.9E+06 (low). No proton events. X-ray background: B1.1

Aurora viewing: Commentary directly from the tape: "Oh my goodness, the auroral arc is very bright (IBC II to III) at the moment! Even with the moon gibbous and brighter than last night! It's clearing off (clouds). The (auroral) arc is slightly lower in the northern sky than last night (indicating northward retreat of auroral oval) but I can clearly see it is part of a large circle. There are some bright stars shining through it - oh, I love that - so beautiful! It's like a flattened green rainbow, rising out of the northeastern horizon and arcs across the northern sky at about 15 degrees above the magnetic north horizon at its highest point, then drops down to the northwestern horizon. It's soooo beautiful!"



Within a few minutes of this taped verbal description, the auroral arc (arch) rose to about 25 degrees above the northern horizon and the north-eastern quadrant developed rayed striations and some discrete auroral forms with IBC of II average-0415 UT.

VLF: At 0425 - 0515 UT, very faint hissband, static and tweeking sferics, weak power-line hum from the big powerlines 4.2 miles to the west. "Dead." The auroral arch is really showing rayed striations in its north-eastern section.

Aurora viewing: By 0510 UT, the auroral arc looks quiescent (IBC I to II) and by 0547 UT, has lowered to only 10 degrees or so above the northern horizon, indicating sub-storm an hour or so earlier has ended, with no active/discrete auroral forms observed during the periods throughout the night I was awake to observe the auroral arc.

Sunday 25 August 1996 from 0635 UT (1:35 a.m. CDT) to 1254 UT (7:54 a.m. CDT)

Aurora viewing: By 0635 UT, the main auroral arc has retreated far enough northward to be only 5 degrees above the northern horizon and not easily visible through the Spruce and Aspen trees The fainter (IBC I) Hydrogen Arc is visible at about 45 degrees at its highest point above the magnetic-north horizon. This location has very dark skies, but the increasingly bright moon is creating increasing lunar twilight in the sky.

VLF: Tweeking lightning static (sferics) and weak power-line hum is all that is audible. No auroral hiss stronger than my relatively low receiver noise floor is audible.

However, by 0810 UT (3:10 a.m. CDT), there is the beginnings of chorus but quite weak. This chorus increases in average strength by about 6 dB louder by 1025 UT and another few dB by 1150 UT. This rather unremarkable "plain" and homogeneous sounding chorus continues to gradually increase in strength by 1254 UT. End of side B of tape cassette MBVLF-9B.

Sunday 25 August 1996 from 1353 UT (8:53 a.m. CDT) to 2015 UT (3:15 p.m. CDT):

VLF: Now things are starting to sound interesting (as expected for this time of day): The chorus has risen to quite loud levels but is rather homogeneous and "plain" sounding - as has been the case for the past few hours. Low pitched 'roaring' hissband has risen up to good levels too. There are some nice louder outbursts of chorus trains centred on about 2 kHz accompanied by "auroral sizzle." Now 1/3 way through side A of tape cassette MBVLF-10.

At 1439 UT VLF check, it essentially sounds similar to 1353 UT, but by 1508 UT, there are occasional pure-tone whistlers of weak to moderate strength accompanying the chorus. Not as "wild" sounding as the chorus of Saturday 24 August (yesterday) at this same time.

By 1544 UT (10:44 a.m. CDT) the chorus is quite loud but homogeneous and without interesting-sounding outbursts. This is to change by 1646 UT, when there start to be interesting sounding outbursts again.

1658 UT (11:58 a.m. CDT), nice loud chorus outbursts - really interesting now - it is going to be a nice segment! Recording tape to end of side A and first part of side B of tape MBVLF-10.

By 1734 UT, essentially similar sounding natural VLF radio activity but with slightly less amounts of riser bursts and a few more weak whistlers. At 1805 UT, again, quite similar to 1734 UT but now some "cricket" sounding chorus of higher pitch than the lower-pitched barking and chirping chorus.

Chorus activity declined by 1825 UT, but dramatically increased to spectacular sounding riser outbursts at a 1932 UT check and continued through 2015 UT (3:15 p.m. CDT) This increased activity probably due to another auroral substorm, since the Kp-index was generally declining. Taped onto cassette tape MBVLF-10, from 1/2 way to last 1/4 of side B.

Monday 26 August 1996 from 0233 UT (9:25 p.m. Sun. 25 August CDT) to 0539 UT (12:39 a.m. CDT 26 Aug.):

Geo-magnetic indices for Monday 26 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 3 4 4 3 1 1 3 2. Quiet to active levels. Solar-flux = 74, SSN = 016, GT 2 MeV Electron fluence = 2.0E + 08 (moderate - high - a rapid rise upward from yesterday). No proton events. X-ray background: A6.6

VLF: at 0233 UT, Rapid "chirping" risers and some slow risers, some auroral hissband and fairly high lightning static levels. At an 0318 UT check, the chorus had weakened and the lightning sferics were quite loud, and by 0345 UT the chorus completely vanished, leaving only weak auroral hiss and tonal bands.

Auroral viewing: (From tape commentary): "At 10:18 p.m. CDT, as evening twilight has faded in the west/north-western skies and the moon is gibbous in the south-eastern sky, I can see the auroral arch is already there in northern sky (IBC I to II), but it already has 'kinks' and 'sags' in it, and the north-eastern segment of it has developed rays and striations. It is either going to contract and disappear like last night, or it is going to do like Friday night the 22nd, and expand like crazy all over the sky with gorgeous auroral forms by 11 p.m.. We'll see... There's (westward moving) waves of brightness (IBC II to III) moving through it right now."



At 0345 UT, the auroral arc lies about 15 degrees above the magnetic-north horizon (it highest point) and has developed striations and rays as well as multiple bands and a couple swirls. After this substorm ended, the aurora faded back to just a dim quiescent auroral arch (IBC I - II).

I fell asleep for an hour or so, and looked out the van's north-facing window at 0523 UT to see discrete auroral forms had returned 'with a vengeance': the auroral arc has widened up again and parts of it have rays/striations and bright vertical "pillars" (IBC II - III). As this new substorm progressed, by 0539 UT, there was corona (aurora at magnetic zenith) overhead once again at IBC II - III! As night progressed, the aurora retreated northward (typical) but was visible especially from 25

to 30 degrees above northern horizon until morning twilight lightened up the sky

VLF: 0539 UT: Loud lightning sferics but little else - 'dead.'

Other radio propagation notes: WWV on 5.000 MHz has substantial auroral flutter fading on their signal at 0540 UT. Relatively weak European mediumwave (AM broadcast) reception earlier during the 0300-0500 time period. The usually strongest 1314 Norway signal was about 10 dB below average levels throughout this period - highly indicative of auroral D-layer absorption.

Monday 26 August 1996 from 0800 UT (3:00 a.m. CDT) to 2158 UT (4:58 p.m. CDT):

VLF: Weak chorus(probably stronger at locations eastward like Labrador and Greenland) and a few diffuse and weak whistlers in the 10 minute period I listened.

At 1044 UT (5:44 a.m. CDT), the chorus has strengthened and sounds aesthetically nice. Very similar to my eastern Alberta recording made during this same time back on 26 September 1993. Recording made to end of side A of cassette tape MBVLF-11.

Interestingly, the chorus was gone at a 1221 UT (7:21 a.m. CDT) time check, probably due to rapid drop in Kp index (from 4 down to 1 within 9 hours) and similar reduction in local K-index. However, Mother Nature never is predictable, and by 1317 UT, the chorus came back to strong levels - a very pleasing (aesthetically) mix of different sounding risers (squawks, chirps, etc.) By 1342 UT, this chorus is very loud, lower pitched than at 1317 UT, and very vigorous.

As morning progressed, the chorus increasingly took on fantastic characteristics. The following is transcribed verbatim from my hand-written notes:

"1352 UT, continuous 1 kHz squawks (cool!) and a bit unusual sounding low-pitched stuff. Quite nice. Not really that many low 'whoops' happening yet."

"1610 UT (11:10 a.m. CDT) Blue sky with high cirrus clouds. Perfect daytime weather. Ultra-low pitched chorus now - loud 'whoops' that are fairly loud and also some higher pitched (around 1.5 kHz centre freq.) 1614 - 1619 UT, a period with a large amount of whooping chorus trains - superb!"

At 1745 UT, low 'roar' hiss increased in strength, more higher pitched chirping chorus but less whooping chorus. Nice sounding chorus riser clusters noted at 1825 UT. By 2001 UT (3:01 p.m. CDT), there were 'slow' risers and loud, low-pitched 'roaring' hiss.

By 2158 UT (4:58 p.m. CDT), there were only isolated/individual chorus risers in the fairly loud levels of lightning storm static.

(The last several hours' VLF radio events, from 1221 to 2158 UT, were recorded onto side B of tape MBVLF-11. A great taping session, particularly the 1353 to 2015 UT period).

Tuesday 27 August 1996 from 0140 UT (8:40 p.m. 26 Aug. CDT) to 2239 UT (5:39 p.m. CDT):

Geo-magnetic indices for Tuesday 27 August (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT:3 3 4 3 2 3 3 3. Quiet to unsettled levels with a single active interval at high latitudes. Solar-flux = 74, SSN = 013, GT 2 MeV Electron fluence = 1.3E + 08 (moderate - high). No proton events. X-ray background: A6.7

Misc. radio propagation notes: BBC 198 longwave from the U.K., and also Atlantic 252 from Ireland were both fairly strong at 0145-0150 UT despite loud lightning static levels and remained fairly strong on fade-up peaks past 0241 UT.

VLF: 0140 UT, just static and tweeks and weak power-line hum - nothing else at all yet.

Auroral viewing: "No Virginia, it's NOT moonlit clouds--the auroral oval (arc) is already fairly bright (IBC II+) and showing little 'off-shoots' The arc is fluctuating from dim to bright (IBC I+ to IBC III) - really quite nice to watch! At 10:01 p.m. Central Time (0301 UT), there are two bright sections in the arc to the north and north-east showing rayed structures. Churchill, Manitoba must be under or on the other side of that auroral ring (arc), as tonight, it lies 15 degrees above my magnetic northern horizon. I wonder if the people in the Japanese auroral viewing tour groups to Yellowknife, NWT are enjoying this aurora..."

At 10:31 p.m. CDT (0331 UT), the main auroral arc/oval has 'split' into two parallel bands to the north, and a third band has appeared to the west which is about 70 degrees above the horizon and 'almost overhead'. A new sub-storm has begun...The aurora, like the dawn and daytime VLF radio chorus, has never been the same each night! This is why I've looked forward to each day's VLF radio and auroral events - anyone who has said 'if you've seen one auroral display, you've seen them all' is sadly mistaken. The same goes for natural radio...

By 10:40 p.m. CDT (0340 UT), the 'top' arch to the north has formed curls and rays in its north-eastern section. Somewhere, about 200 miles to the north, this display is overhead and viewers there are enjoying an auroral corona. At 10:45 p.m. CDT, five parallel striated/rayed bands completely fill the sky to the north and almost to overhead! So beautiful!

VLF: 1208 UT (7:08 a.m. CDT) Loud, vigorous chorus, low pitched hissband - quite nice sounding already! Individual risers began to be discernible at 1213 UT.

At 1328 UT (8:28 a.m. CDT), the chorus is loud and quite homogeneous, i.e., dense but unvarying intermixed chorus risers and loud, low-pitched 'roaring' hiss. Between 1411 to 1457 UT, this activity began decreasing in volume but still sounded identical to the 1328 UT.

Interestingly, low 'whoops' started to intersperse themselves amongst the higher-pitched homogeneous chorus. This activity gained in volume and remained through 1525 UT (10:25 a.m. CDT). Tape: MBVLF-12, side B

By 1545 UT, the chorus nearly 'died out' (leaving low hissband and a few weak low pitched 'whooping' risers), but was back LOUDLY with very loud whooping risers within 30 minutes UT.

1715 UT, the chorus attained very loud levels and was quite fabulous: barking and whooping. A fine recording made of this on tape MBVLF-13, side A.

Once again, the chorus faded out to minimal levels at 1810 UT, but 'roared' back to loud levels by 1905 UT (2:05 p.m. CDT) and continued through 1957 UT, to begin fading down to lower levels at 2030 UT.. Began taping this activity onto side B of tape MBVLF-13.

By 2055 UT, a few 'hooks' began to be heard and alternated with low whooping chorus risers. Another great recording - CD quality for sure! This wonderful sounding VLF activity continued along with great 'roaring' hissband all the way past 2239 UT (5:39 p.m. CDT) - an all day chorus event once again!



View of WR-4B VLF receiver with filled cassette tapes atop it, and the Marantz PMD-212 recorder inside van at bedside. (The book in the photo next to the tape recorder is " The Aurora Watchers Handbook " by Neil Davis, U. of Alaska Press, 1992)

Wednesday 28 August 1996 from 0319 UT (10:19 p.m. 27 Aug. CDT) to 2347 UT (6:47 p.m. 28 Aug. CDT):

Geo-magnetic indices for Wednesday 28 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT:3 3 3 3 3 4 3. unsettled to active at all latitudes. Solar-flux = 74, SSN = 013, GT 2 MeV Electron fluence =  $1.9E + 08$  (moderate - high). No proton events. X-ray background: A6.9

VLF: At 0319 UT After watching a beautiful sunset, I switched on the WR-4B VLF receiver and noted weak, high-pitched hissband, very faint chorus/riser type emissions, and very loud lightning sferics, some of it tweaking. Also, an occasional diffuse (non-pure-tone) whistler every few minutes. Little else and not too useful for data or for aesthetic recordings (as my notes state: 'wait 8 hours and there'll be awesome chorus').

At 0458 UT, the weak chorus slightly increased in strength but remained weak for the ensuing hour. During active display of aurora to north and west at 0528 UT, only weak hiss, a few discrete musical tones, and faint chorus noted (see Aurora section below).

At 0715 UT, there were frequent, diffuse whistlers occurring with weak hiss. no chorus yet. & minutes later, the auroral arc became massively bright (IBC III+), spawning frying/sizzling hiss sounds. Another auroral substorm is beginning, perhaps caused by a big upsurge in plasma from the Sun.

Interestingly, soon after this sudden brightening of the auroral arch and onset of auroral hiss at 0722 UT, low 'whooping' chorus emissions began, centered on about 1 kHz. These soon became a dense barrage by 0732 UT with a rapid build-up in their volume level. Also, the diffuse whistlers reached very high levels - as much as 20-30 per minute, some of them pure-tone (non-diffuse)! An incredible sounding segment of tape: MBVLF-14 side A.

Auroral viewing: An auroral sub-storm is already underway at 0500 UT (Midnight CDT): an 'outbreak' of pillars and rayed curtains is visible to the WEST, and the diffuse auroral arc lies about 45 degrees above the magnetic northern horizon. The north-eastern segment of the auroral arc looks quiescent and diffuse, i.e. only a dim band of IBC I to II.

At 0527 UT, there are 'dancing pillars' (bright rayed curtain segments) to the west and north, some of them nearly overhead! Only weak hiss, a few discrete musical tones, and faint chorus at this same time, indicating, once again, that active auroral displays do not always generate loud VLF emissions, and most chorus events are generated at Earth's equatorial plane several Earth radii out in space on the sunward side.

I went to sleep for a bit, to wake up and view a now quiescent auroral arch at 0710. Occasionally stealing glances out the north-facing window of the van, I'm surprised to see sudden brightening of the arch at 0722 UT to IBC III+ levels of brightness, accompanied by sudden upsurge in VLF emissions (see above).

VLF: The auroral arc settled down into quiescent levels again, and I fell asleep. At 0908 UT, the chorus sounds "average" and not very exciting yet--its characteristics are the usual "start-up" sounding and not really interesting at this time.

By 1211 UT (7:11 a.m. CDT), the (dawn) chorus risers are high pitched (2-3 kHz) and there are high-pitched musical tonal bands. Interestingly, there are sudden onsets of lower-pitched chorus trains which are beginning to sound quite interesting...

Nice, low 'whooping' chorus was in full swing by 1335 UT. This low pitched chorus was centered on about 1 kHz or even lower with sudden commencement of chorus trains! Gorgeous recording made on tape MBVLF-14, side B. Also a boon to this recording is the lack of strong lightning static - in fact, the static was rather minimal. Continuous recording made to 1353 UT - great tape segment.

At 1436, the chorus became more "standard" sounding - homogeneous and not the rarer low-pitched chorus riser bursts/trains.

Another long recording began at 1541 UT - the chorus was extremely LOUD along with the roaring hissband. By 1637 UT, with the tape still rolling, the roar-hiss increased to extremely strong levels and resembled a jet airplane in sound characteristics - quite incredible! From this peak of chorus activity at approximately 1700 UT (Noon CDT), it gradually faded to weaker levels as each hour past local noon went on. By 2347 UT (6:47 p.m. CDT), the chorus was subtle but still nice sounding, with far louder lightning sferics (static) though.

Thursday 29 August 1996 from 0319 UT (10:19 p.m. 28 Aug. CDT) to 0000 UT 30 Aug. (7 p.m. 29 Aug. CDT):

Geo-magnetic indices for Thursday 29 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT:4 6 6 5 4 3 3 4. unsettled to minor storm at middle latitudes, unsettled to major storm at high latitudes. Solar-flux = 74, SSN = 020, GT 2 MeV Electron fluence =  $5.6E + 07$  (moderate). No proton events. X-ray background: A4.7



Auroral viewing: 0230 UT (9:30 p.m. CDT) Not yet aware that a major geo-magnetic storm was brewing, I did my usual "thing" and looked out the north-facing van windows to see NOTHING - no auroral arc in its usual place to the north. I first thought that it had retreated far enough northward to be too low in the northern horizon to be visible. This would mean quiet geo-magnetic conditions and no auroral sub-storm in progress.

But, it occurred to me to open up the van's back doors and look southward, and was I startled (pleasantly) to see a fairly bright (IBC II - III) auroral arch already with rays and striations "hanging" all across the southern skies at about 30 degrees above the southern and south-western horizon. At this time, this would put the main/brightest part of the auroral arc approximately over the south-central part of Lake Winnipeg; over Duck Mountain, Manitoba; over Prince Albert or Saskatoon, Saskatchewan, and so forth. Certainly, this afforded aurora watchers in north-eastern Montana and northern North Dakota views of the aurora (otherwise not easily visible to them on more quiescent nights when the auroral arc lies a few-hundred miles farther northward). At this time, the planetary K-index was about 6 (minor-major storm).

The following is a direct transcription of audio commentary made on cassette tape MBVLF-15, side B and which repeats information in previous paragraph: "Then I opened up rear van doors and looked to the south - the southern sky has the brightest auroral arc in the sky - there are fainter parallel arcs/bands in the sky, but there is this really BRIGHT one in the sky about 30 degrees high (above southern horizon). There are also faint bands above it, dancing and shimmering to the north. Despite the brightness of the full moon tonight, there are these bright curtains pouring down right below the full moon east to west. It's like a fluorescent bulb with the bright patches sweeping back and forth along the bright arc. Gorgeous!" (Time is about 0320 UT/10:20 p.m. CDT and is the start of a major auroral sub-storm and subsequent break-up which spawned full-sky auroral displays within 15 minutes).

(At 0330 UT): "There is a gigantic bright green swirl almost above me but slightly to the south. It is just incredible and so bright (IBC IV)! - it's trying to outshine the full moon (5 min later): There's corona overhead (rayed/striated aurora at magnetic zenith). I can see the faint hydrogen arc to the south - it's to the south instead of normally to the north. Amazing!" (This is visible evidence of southward expansion of auroral oval during the major magnetic storm conditions occurring with the Kp of 6).

At a 0538 UT (12:38 a.m. CDT) check of the skies and also the VLF receiver, only dim, pulsating aurora was visible and there were no discrete auroral forms including curtains. The rest of the night (again, what I observed while awake) lacked any bright auroral enhancements/substorms, only dim and diffuse pulsating aurora over much of the sky.

VLF: During the height of the bright auroral displays at 0330 UT, weak frying auroral hiss was audible. By 0538 UT (12:38 a.m. CDT): "This is as close to a whistler 'shower' as we've gotten..." strong lightning static, frequent, pure-tone or near pure-tone (non diffuse) whistlers. No auroral hissband or chorus audible at the moment. (The auroral sub-storm so bright earlier at 0330 UT ended a while back, leaving just dim, pulsating aurora - nothing bright and no discrete auroral forms including curtains.").

Noting no interesting auroral outbreaks, I fell asleep for a while and awoke to make a VLF check at 0845 UT (3:45 a.m. CDT), noting weak hissband and faint background low-pitched chorus, plus whistlers or near pure-tone every 15 seconds or so. Dim, diffuse pulsating aurora also visible outside in the sky.

1032 UT (5:32 a.m. CDT): Every 5 seconds there is a pure-tone whistler. The chorus riser chirps and squawking is louder now. Hissband weaker than at 0845 UT.

1148 UT: (6:48 a.m. CDT): "Swishy" sounding chorus; riser "squawks" more dense and vigorous - fairly homogeneous sounding chorus but not all that strong yet. The pure-tone whistlers continue at same levels: 1 every 5 to 10 seconds.

1302 UT (8:02 a.m. CDT): Homogeneous "pond of frogs" sounding chorus. Light hissband.

1322 UT: Hissband continues to decline in strength. The chorus sounds the same as at 1302 UT.

1421 UT (9:21 a.m. CDT): Very loud, less dense "frog croak" chorus. Hissband is weaker recorded to end of side B of tape MBVLF-15.

1544 UT (10:44 a.m. CDT): The hissband has risen to very loud "roaring" levels again. Moderately active chorus of bird-like chirps (continuous, 2-3 kHz centered riser trains). Recorded onto tape MBVLF-16, beginning of side A.

1622 UT: Similar sounding chorus as 1544 UT but less hissband.

1703 UT (12:03 p.m. CDT): LOUD hissband - ROARING! Magnificent sounding bursts of risers - low-pitched squawks. Isolated bursts of chorus trains sounding very nice. Nice bit of tape! Continued at same characteristics past 1845 UT, but the hissband gradually declined to lower levels by that time.

2051 UT (3:51 p.m. CDT): The static from lightning (over the Plains, etc.) is quite loud and the hissband and chorus have both declined in strength from an hour earlier. But, there are numerous "falling" tones similar to whistlers but not true whistlers. These are the so-called "pseudo-whistlers" and are in the chorus/discrete-emissions category of VLF emissions. In addition to these emissions, there are sudden bursts of semi-diffuse chorus riser trains - quite unusual! I have not anything like these emissions so far on this expedition!

At 2053 UT, a DRAMATIC AND ABRUPT rise in hissband occurred, with the sound levels reaching 10-15 dB higher than just a few minutes before. By 2055 UT, the hiss is extremely LOUD and roaring. And in just a few more minutes at approximately 2058 UT, there has also been an abrupt increase in the volume levels of the chirping chorus. The general (center) frequency of the loud hissband is also rising. This event indicates a sudden impulse has occurred - i.e., a strong "wave" of particles in the Solar Wind has impacted Earth's magnetosphere, resulting in the abrupt rise in the chorus and hiss levels. At this time (approximately 2100 UT), the Kp-index is 4, up from 3 at 1800 UT. This dramatic VLF event recorded onto tape MBVLF-16 about 2/3rds way into side A. (Comments on my notes say "Wierd!" and "Wow!"). Spectacular run of taping sessions between about 1703 - 2115 UT.

At 2158 UT, there was mainly hissband, and this would subtly rise and fall in strength over a minute period or so.

By 0005 UT (30 August), "just static."

Other radio propagation notes (MF, HF, VHF): At 0330 UT 29 August, a quick check of the car radio and a scan across the FM broadcast dial revealed greatly enhanced reception of several high-powered 50 - 100 kW stations approximately 150 - 300 miles away in southern MB, SK and the Dakotas due to auroral reflection/scattering. All the FM stations enhanced by the aurora had flutter/rumble (doppler-shifted frequency modulation) superimposed on their audio, and this effect became very enhanced at 0330 UT. The region of maximum auroral display lay about halfway between my location and the enhanced FM stations.

HF signals in the 4-8 MHz from all points south of my location suffered dramatic attenuation and severe auroral flutter-fading in the 0230 - 0400 UTC period of observation. However, European HF signals in the same frequency range are actually enhanced and more fade-free than has been the usual situation since I arrived in north/central Manitoba.

Likewise, at approximately 0230 UT on mediumwave, Norway 1314 kHz was very strong with excellent audio - so strong as to put heavy audio "splash" on 1310 and 1320 North American frequencies; Holland 1395 was quite listenable as was 1134 Sweden, 1053 "Talk Radio U.K" and 1215 "Virgin", U.K., indicating enhanced MF reception through the auroral zone from north-western Europe and Britain.

Similar to HF reception southward, most MF (AM BCB) signals from the south-east to the south-west were about 10-20 dB down from usual levels, indicating auroral absorption.

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Friday 30 August 1996 from 0005 UT (7:05 p.m. 29 Aug. CDT) to : 2303 UT (6:03 p.m. 30 August CDT)

Geo-magnetic indices for Friday 30 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT:5 3 4 1 1 2 2 3. quiet to minor storm ,0000-0600 UT was most disturbed period. Solar-flux = 73, SSN = 016, GT 2 MeV Electron fluence =  $4.1E + 08$  (moderate - high). No proton events. X-ray background: A5.7

VLF: At 0005 UT 30th August (7:05 p.m. 29 August CDT) Only lightning static/sferics audible at this time. By 0132 UT (8:32 p.m. CDT), Low-pitched "roaring" hissband has started and is unusually strong for this period of the evening (the sun has just set). No chorus yet. The loud hissband indicates enhanced influx of solar-wind plasma and auroral primaries into the magnetosphere.

0220 UT (9:20 p.m. CDT), low-pitched hissband and a few weak "beeping/ringing" musical emissions then some high-pitched chorus trains of weak strength.

0323 UT: Nothing, just static again , but at 0354 UT, weak hiss is audible again, along with the occasional weak individual riser. By 0434 UT, There was no VLF activity heard except for the ubiquitous and incessant lightning static. Recorded to end of side B, tape MBVLF-16.

Catching a few hours of sleep, I made another VLF check at 0846 ut (3:46 a.m. CDT) and noted occasional very weak chorus trains sounding like typical "start-up" chorus quite typical for this time and magnetic indices.

0933 UT (4:33 a.m. CDT): High-pitched hissband, occasional chorus riser "barks" of low-pitch, and fairly diffuse (non pure-tone) whistlers were audible, and many of these whistlers had extended echo trains. Tape: MBVLF-17, side A.

0955 UT, similar VLF activity to 0933 UT, however, wavering-tone emissions are now audible and the chorus chirps/barking has increased in strength. The wavering-tone emissions - quite interesting sounding - are increasing in numbers as time progresses. 10 minute recording made onto tape MBVLF-17, side A.

Catching still more sleep, I made another VLF check at 1204 UT, noting very weak chorus including low 'whooping' chorus, and weak diffuse whistlers with echo trains. As usual, the chorus is probably stronger farther eastward (such as Labrador or Greenland) and will increase as the mid-day time (noon standard time) period sweeps westward to my location. In fact, by 1220 UT, the chorus already has increased in amplitude, particularly the low pitched whooping chorus centred around 800 to 1500 Hz. Already quite interesting sounding! Light static from lightning storms.

At 1246 UT (7:46 a.m. CDT), the chorus has declined in strength, but by 1320 UT it has "roared" back with nice, low-pitched whooping chorus emissions, diffuse echoing whistlers, and still light static levels, making for a fine recording on tape MBVLF-17, side A. My notes also have "hooting owls!" scribbled amongst the other notes above.

At 1358 UT (8:58 a.m. CDT), the mid-frequency has shifted slightly higher, and the "hooting" of chorus emissions has become quite loud. Another nice bit of tape made.

1432 UT (9:32 a.m. CDT): (from written notes) "Now this is wierd...low hoots, squawks, and some of the hooting (chorus) emissions are about 1 second in duration! everything has shifted lower in frequency again, rather like a slow-motion tape. Spooky low pitched chorus and there are elongated 1 kHz tones preceeding each riser!" (page 36 of notes)

1554 UT: The low-pitched whooping chorus emission continue along with higher-pitched squawking and chirping chorus. Diffuse whistler trains following some of the stronger lightning sferic impulses. Parallel "hook" emissions (tone falls than abruptly rises - named for spectrogram traces similarity to a hook).

1603 UT (11:03 p.m. CDT) Similar to 1554 UT but slightly louder in volume. Low-pitched hissband in background undergoing subtle rises and falls in intensity. Occasional diffuse whistlers.

1652 UT 30th August: "Busier" activity still: Activity similar to 1603 but now a higher-pitched band of chorus is occurring. The echoing whistler trains have greatly increased in strength and there are echoing chorus trains. "Incredible!" And by 1700 UT, these echoing chorus trains are repeatedly increasing in pitch/frequency band over a 5 second period. Making for a spectacular recording, this activity continued past 1800 UT (1:00 p.m. CDT).

1841 UT 30 August 1996: similar to 1800 UT activity but less low-pitched hissband.

1941 UT: Less of the upward-rising chorus trains and the hissband has shifted upward.

2211 UT (5:11 p.m. CDT) Medium-high pitched hissband and lower-pitched (and weaker) clusters of chorus risers; weak diffuse "hook" emissions

2303 UT 30th August: Just hissband, no discrete emissions of any kind.

Auroral viewing: At 0330 UT (10:30 p.m. CDT), the auroral "arc" (arch) is in its usual NORTHERLY spot, hanging in the sky about 15 degrees above the horizon with some wide and brightened sections in it. It's not in the southern skies like last night.

At 0425 UT another auroral sub-storm has begun, with a now very bright auroral arch with kinks and contortions along it now. By 0430, it has spread across the sky closer to me with striations, rays and pillars - Very beautiful! Active auroral activity soon ended, with a quiescent and dim arc by 0440 UT.



Other radio propagation notes (MF, HF): At 0240 UT 30 August, Virgin 1215 from the UK has a very strong and very listenable signal for about 10 minutes with concert information on tel. # 0976 100 500 then into Don Henley song. By far the best European/British mediumwave reception of the my entire stay! Other huge signals from the UK/Europe were 882 BBC R. Wales, 1053 & 1089 Talk R. U.K., 1314 Norway (gigantic signal again)

Like last night, HF signals exhibited auroral flutter-fading and marked attenuation, such as Cuba 5.025, 5.000 WWV-Colorado, Peru 4.915, WEWN Alabama 7.425; various Marine stations on the West Coast of North America such as KPH 4247 kHz CW, etc., between 0200-0430 UT. (to be cont'd)

Saturday 31 August 1996 from 0236 UTC (9:36 p.m. 30th August CDT) to 24 hours later:

Geo-magnetic indices for Saturday 31 August (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 3 3 4 4 3 2 2 2. unsettled to active, 0600-0900 UT was most active period. Solar-flux = 76, SSN = 026, GT 2 MeV Electron fluence =  $4.4E + 08$  (moderate - high). No proton events. X-ray background: A5.2

VLF: 0236 UT (9:36 p.m. CDT 30th Aug.): Weak undulating/echoing hissband or very diffuse emissions, occasional diffuse (non pure-tone) whistlers with echo-trains (probably contributing to the hiss), heavy lightning static. There is still evening twilight.

AT 0444 UT: No hiss, moderate static, nothing else noted, but when the auroral display became more active, brighter and beautiful at 0535 UT, weak hissband and 1 weak, truncated diffuse whistler was noted during a 2 minute listening period.

0912 UT (5:12 a.m. CDT): Weak chorus of low-pitch. By 1136 UT, the chorus is about 3-4 dB louder punctuated by occasional higher-pitched trains - sounds like "typical" dawn chorus and not really spectacular and such.

At 1300 UT 8:00 a.m. CDT): The chorus is similar to at 1136 UT, but now there is low-pitched hissband and stronger lightning static. The fact that the lightning static is getting louder when normally it weakens during the night told me that the lightning storms were already brewing up and probably moving my way...in 18 hours...

1336 UT: barking chorus, low-pitched hissband, low squawking chorus, strong lightning static. Occasional outbreaks of high-pitched chorus trains.

1501 UT: similar sounding emissions to the 1336 UT listening check. By 1538 UT (10:38 p.m. CDT), however, there has been a large increase in "whooping" risers, and the lightning static steadily increases in strength...

1704 UT (12:04 p.m. CDT): Gorgeous whooping chorus emissions and LOUD now - very dense. Long-duration whooping risers of 500 ms to 1 second in duration, with sudden outbursts every 5-7 seconds or so. Wonderful span of tape on MBVLF-18, side A.

1728 UT: Similar emissions to 1704 UT, but slightly more and stronger 1.7 to 2 kHz frequency-centred risers.

1918 UT: The chorus has generally shifted to lower frequency bands and there is vigorous whooping emissions. The lightning static steadily increases... (End of side A, tape MBVLF-18)

2030 UT (3:30 p.m. CDT): Strong outbursts of low pitched whooping chorus risers sounding very different than a hour earlier.

By 2232 UT, the low-pitched whooping chorus has dramatically decreased in strength to almost nil, except for occasional high-pitched "chirping" and "cricket" sounds. This was a temporary decline in low-frequency emissions, and the low-pitched "whoops" are back occasionally. High-pitched chorus dominates with clusters of chorus trains.

At 0132 01 September UT (8:32 p.m. 31 August CDT): There is no VLF activity audible except for LOUD static. The weather outside is very warm and balmy - almost oppressive.

By 10:00 p.m. 31 August CDT (0200 UT 01 Sept). Off to the distant west and south-west, I can see faint flashes of lightning lighting up the sky, but no lightning is visible, yet...

Auroral viewing: 0445 UT: Discrete, rayed but dim (IBC I - II) auroral bands OVERHEAD and to the west and north-west. The Kp index = 3 at this time - perhaps more locally. The rayed forms overhead are gently moving. Despite the overhead aurora, there are no VLF emissions noted whatsoever.

At 0535 UT (12:35 a.m. CDT): Beautiful Rayed curtains in the sky overhead and much brighter (IBC III) than 50 minutes earlier at 0445 UT.

0912 UT (4:12 a.m. CDT): The auroral arc is still visible in the northern sky about 15 degrees above the northern horizon at its highest point at magnetic north. There are brighter sections visible in its northwestern segment.

Sunday 01 September 1996 from 0238 UTC (10:38 p.m. 30th August CDT) to 1900 UT:

Geo-magnetic indices for Sunday 01 September (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 2 1 1 3 1 1 1 1. quiet to slightly unsettled. 0900 UT was most unsettled period. Solar-flux = 74, SSN = 011, GT 2 MeV Electron fluence =  $7.0E + 08$  (moderate -high). No proton events. X-ray background: A8.5

Auroral viewing: At 10:38 p.m. 31 August CDT (0238 UT 01 Sept). I can see the auroral arc is 10-15 degrees above the northern horizon. Moonrise (gibbous and waning) was not long ago and it sits low in the south-western sky between the spruce trees. It has finally cooled off a bit, but ominous lightning flashes from an approaching cold front fill the western skies...

VLF and a lightning storm experience: At about midnight. CDT, I wrote in the notes: The lightning is closing in about 15 miles away from here - I've taken down the WR-4B VLF receiver's antenna and stowed it in inside the van. Lightning is flashing all along the entire western horizon from north to south - scary and awesome! It is a strange, warm balmy night. I think the main band of thunder cells is nigh. They're approaching me rapidly and the wind is now blowing like crazy. No rain yet, and I'm holding the WR-3E receiver out the van's back doors and listening to and tape-recording interesting 'hook' emissions following the really LOUD lightning pops and crashes of static. I've also disconnected the wire antennas to the other radios and moved them away from the van. I'm feeling a bit worried about this storm. These woods are awfully dry and I hope some of these ground strikes are not going to set off a forest fire or strike near or at me."

At 12:45 a.m. now early on Monday morning 01 Sept. (0545 UT), Blindingly bright, forked lightning is arching across the sky just to the west and south about 30-45 seconds' duration between the lightning flashes and the following thunder boom and rumble - I'd estimate about 6 to 10 miles away at most.

At 1:30 a.m., the storm has arrived at my location in all its fury - intense driving rain for brief moments, gusts of wind loudly roaring in the surrounding spruce trees, and terribly bright lightning in spectacular forked displays arcing half-way across the sky followed by big booms of thunder. I'm getting considerably scared at this point and decide to temporarily leave the camp and drive out onto Highway 39 to get away from the storm and out of the sandy area in which I'm parked lest it rain hard and cause me to be stuck in mud. Well...stuck I was anyway, because the van WOULD NOT START but only gave a pathetic chattering of its solenoid relay, due to me running down the battery for the past 10 days without checking its voltage or if it would start earlier in the week. Really stupid!

"Well, I guess I just need to sit in here calmly and wait out the storm." I decide to try and enjoy the surrounding fury of the storm, and make a very good 15-20 minute tape of the thunder and the wind blowing, all the while being blinded by such intensely bright lightning flashes which never came within a couple miles from me, judging from the duration between lightning and thunder.

For the next hour, I watched the storm front pass and carry along its wolf pack of lightning storm clouds off to the east and north-east, and fell asleep at around 3 a.m. early Sunday morning 01 September. September arrives with a fury...or did August go out with a bang?

1551 UT (10:55 a.m. CDT): Low-pitched whooping chorus is back again this morning - not very strong but sounds quite nice anyway. Occasional diffuse whistlers every 10-15 seconds. moderate strength, low density lightning static.

1710 UT: The lightning static is getting strong again, but it does not storm near me for the remaining duration of my stay. Similar chorus to 1555 UT.

1828 UT: Unremarkable and weaker chorus than earlier, static is still louder, so I do not listen or record for long.

Strong static and weak VLF emissions did not induce me to record anything for the remainder of this day. This was the least interesting day of VLF activity since my arrival on 22 August. At 6 p.m. , after a mostly sunny day, my 8-watt solar panel sufficiently re-charged my van's battery to allow me to start it and run it for about half an hour - enough to ensure I could drive off in a few days without another "surprise."

Monday, 02 September 1996 beginning 0150 UT (8:50 p.m. 01 Sept. CDT) to 2115 UT (4:15 p.m. CDT)

Geo-magnetic indices for Monday 02 September (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 1 2 2 2 2 1 1. generally quiet. Solar-flux = 72, SSN = 013, GT 2 MeV Electron fluence =  $9.0E + 08$  (very high). No proton events. X-ray background: A5.5

Auroral viewing: The auroral arc is visible very low (less than 10 degrees) above the northern horizon at 0301 UT (10:01 p.m. CDT) There is a brightening of the auroral arc to the north-west, and within 1 minute, there is a rapid brightening of the northwestern part of the arc to fairly bright levels (IBC III). Soon after that, the north-eastern segment also undergoes brightening - quite spectacular to watch! The auroral arc is very beautiful at this moment.

At 0451 UT, the auroral arc is "still there in its usual place in the northern sky and has returned to a dim, quiescent state." Every once on a while over the ensuing half-hour, it undergoes periodic brightenings in one part or another and these brighter sections also develop rays and striations.

VLF: 0451 UT, weak hissband and nothing else - no discrete emissions or chorus.

At 1215 UT (7:15 a.m. CDT), gorgeous loud chorus is in full swing and is multi-banded in frequency. weak hissband. Spoke taped notes: "The current boulder K-index announced on WWV was 1 at 1200 UT, and had I heard this if farther south such as in California, Nevada or Oregon, I probably would not have tried to listen much, but - this is the NORTH, and things ARE different up here!" The chorus at this time sounds nice - not dense and homogeneous, but it does have strong surges in volume levels which sound spectacular!

1247 UT: Hiss has greatly increased in strength and is about 2 kHz in general middle-band pitch. Chorus is much weaker. There are very diffuse slowly rising (in frequency) emissions in an echo mode occurring every 1.5 seconds or so - Nice!

1328 UT: Low whooping chorus undulating in strength and mid-pitched chorus chirps. Light static levels and occasional weak whistlers. This activity increased in strength by 1400 UT (9:00 a.m. CDT). Nice series of taping sessions this morning on tape MBVLF-19, side B.

1430 UT: Low whooping chorus of coalesced chorus "whoops" - hard to tell at this point, but the emissions have considerably different sound characteristics than at 1400 UT. The lightning static seems to be DECREASING in intensity and density.

1518 UT (10:18 a.m. CDT): Strong whooping and squawking chorus risers - another spectacular sounding bit of tape made (MBVLF-19, side B). By 1530, strange "ringing" musical tones occasionally are audible.

1650 UT (11:50 a.m. CDT): Chorus activity has weakened somewhat and shifted upward in frequency band, but the hissband remains at the same low pitch as in the previous hour.

1802 UT: (1:02 p.m. CDT): Louder hissband now and some louder risers of fairly long (500 mS) duration. At 1802, similar sounding emissions as at 1802 UT but louder. A brief rain shower caused rain static on the e-field antenna, so no VLF checks were made until it ended at around 2100 UT.

2102 UT: "Weird" weak and generally subtle emissions - low pitched ("roar") hissband, long-duration risers, some of them fairly strong.

At 2115 UT, I connected my 600 foot-north-east pointing wire onto a "long-wire front-end" circuit and connected this front-end to the main WR-4B control box. Strong hum was picked from the large power-lines 4.2 miles to the west. This proves the superior immunity of a short e-field whip antenna in reducing hum from AC wires compared to a longer wire antenna close to the ground. In short order, I re-connected the 3-metre whip antenna unit.

Tuesday, 03 September 1996 beginning 0151 UT (8:51 p.m. 02 Sept. CDT) to 1900 UT (2:00 p.m. CDT):

Geo-magnetic indices for Tuesday 03 September (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 1 2 1 2 1 1 2. generally quiet. Solar-flux = 71, SSN = 011, GT 2 MeV Electron fluence =  $8.3E + 08$  (high). No proton events. X-ray background: A4.7

Aurora Viewing: 0505 UT: Tall rays and "pillars" bright to the north at about 5-10 degrees above northern horizon.

At 0525 UT (12:25 a.m. CDT), rayed bands with vertical, magnetic-field striations and bright pillars to the west and north-west. Very beautiful auroral display now and getting "super bright" (IBC IV), rapidly filling up half the sky in multiple bands. Another (brief) auroral substorm surge is underway, but by 0535, the auroral display faded down to a quiescent arc and became faint.

Other radio propagation notes: 0202 UT (02 September UT): Not even fully dark yet - fairly light still to the west and north-west, but there are several fairly strong European/British mediumwave signals audible, especially 1215 Virgin synchro-transmitters from the U.K., strong Norway 1314, 1134 Sweden, 171 Germany and France 162 LWBC stations, and several other carriers on MW from Europe above 1000 kHz. Greece 7448 very strong (unusually so).

VLF: 0151 UT: Tweaking lightning sferics, some low "whooping" risers in the background but quite overwhelmed by the static. Within a few minutes, the hissband became loud during the increase in auroral display brightness, then faded down to low levels again by 0507 UT.

0504 UT: Weak, low-pitched hiss, weak. . Within a few minutes, the hissband became loud during the increase in auroral display brightness, then faded down to low levels again by 0507 UT. Occasional weak, pure-tone whistler.

0512: tweeks, occasional triggered emission sounds, faint hissband despite bright aurora low in the northern skies.

Somewhat tired from so many days and also due to a resumption in the rain, I next listened to VLF at 1218 UT after sleeping most of the night away.

1218 UT (7:18 a.m. CDT): weak whooping emissions, increasing to slightly louder volume by 1317 UT.

1341 UT: Low pitched hissband and whooping risers , some weak higher-pitched "chirping" chorus emissions, frequent, weak lightly diffuse whistlers - subtle but nice to listen to. (tape MBVLF-20, first 1/3 of side B).

1433 UT: similar to 1341 UT but about 3 dB louder overall.

1503 UT: increased low-pitched hissband, low pitched risers of approximately 0.5 - 1 second in duration, occasional diffuse whistlers every 30 seconds or so.

1600 UT (11:00 a.m. CDT): Low pitched hissband, far fewer risers but occasional, quite pronounced low-pitched risers of long duration. The whistlers are purer in tone now from before, though still quite weak. Some high-pitched wavering-tone emissions in the background - all making for a subtle but interesting mix of natural radio sounds!

By 1629 UT, all the above emissions EXCEPT for the low whooping risers have declined in volume - the low-pitched risers continue to ever-so-slightly increase in strength.

1700 UT Low-pitched hissband and very-high-pitched "twittering" chorus emissions at 5-6 kHz frequency range. Occasional low-pitched "whoop" riser. Activity declined by 1800 UT but still a bit.


1900 UT: Slight increase in the natural radio activity over 1800 UT. The static is fairly low right now.

Wednesday, 04 September 1996 beginning 0248 UT (9:48 p.m. 03 Sept. CDT) to 2234 UT (5:34 p.m. CDT):

Geo-magnetic indices for Wednesday 04 September (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 1 1 1 2 2 4 2 4. quiet to active. Solar-flux = 71, SSN = 011, GT 2 MeV Electron fluence =  $4.9E + 08$  (moderate). No proton events. X-ray background: A5.5

September 4, 1996 - LAST FULL UTC DAY AT THIS LOCATION: "I'm tired of being here and need a change in scenery. Wanderlust has struck again. I'm low on supplies, decent food, and need a REAL shower - I miss the mountains, the high-desert, the rolling hills and open farm-lands and Prairie of the Plains - it's a bit too flat at this location and I'm beginning to feel a bit hemmed in by the trees...But, I've truly enjoyed watching the nightly auroral displays, the stay in the beautiful Spruce forests watching the autumn colors increase in intensity, the migrating flocks of Canada Geese, the pretty lakes of this region, and the best VLF listening in my 7 years of recording Natural Radio" I've also greatly enjoyed many of the sunsets...

View of van and VLF receiver antenna against red sunset

At this point, I decided to pack up after staying exactly "a fortnight" here and head southward to explore the canyonlands of southern Utah, and meander back toward eastern and northern Nevada to do more VLF recording at a more southern geo-magnetic latitude, with hopes to catch a 27-day (one solar rotation) recurrence of the geo-magnetic storm of 22/23 August. Indeed, I was in the Black Rock Desert of n. w. Nevada between 19-22 September when it DID recur, and I recorded another 5 hours of wonderful chorus...

Auroral Viewing: 0306 UT (10:06 p.m. CDT): The auroral arc is not visible at all at this time - it must have retreated far enough north not to be visible at this time.

0316 UT: Just 10 minutes after the above report, the auroral arc has appeared low in the northern horizon - just 3-5 degrees above the horizon and barely above the distant Spruce trees. The quiet geo-magnetic conditions mean the auroral oval has again retreated northward away from my location - most likely it is over the 60th parallel - at the Manitoba/Northwest Territories Border.

VLF: 1212 UT (7:10 a.m. CDT): weak hissband and weak, diffuse slow-falling whistlers with echo trains. Some overlapping whistler echo trains are contributing to the background "hissband."

1305 UT (8:05 a.m. CDT): Similar emissions to 1212 UT, but the hissband has shifted to a lower frequency band.

1353 UT: Still the low-pitched hiss and diffuse whistler echo-trains. The some whistlers are fairly strong now. No chorus yet. All activity above weakened by 1418 UT, and this is the first morning I've not heard any chorus at this time.

1646 UT (11:46 p.m. CDT): Subtle but quite nice sounding chorus now, and unusual, slow-falling and very low-pitched PURE whistlers! Weird... Another "first heard" mixture of VLF emissions not noted before during this expedition. (recorded onto first 10 minutes of side B, tape MBVLF-21).

1902 UT (2:02 p.m. CDT): weak hissband, some weak, low-pitched emissions and also nose-type whistlers of semi-diffuse character following some of the stronger static bursts. This activity would increase dramatically in a couple hours.

2011 UT: the hissband has shifted up to a higher frequency band. Musical ringing emissions and diffuse whistler echo trains which are slow-falling in pitch. Weak whooping risers in the background. At 2031 UT, the hissband dramatically increased in strength for a few minutes along with a slight increase in the strength of the low-pitched "whooping" risers.

2102 UT: Similar activity to 2100 UT.

2144 UT (4:44 p.m. CDT): Strong static bursts initiating BEAUTIFUL, slow-falling diffuse whistlers with echo-trains. Many of these whistlers are of the "multi-path nose type" and sound gorgeous! The diffuse whistler echo-trains are coalescing into a band of hiss. Recording now 2/3rds into side B of MBVLF-21.

The lightning static is very high at this time, though not especially dense, and the CBC is reporting high-winds accompanied by lightning and heavy rain, and a tornado was spotted in the northern suburbs and outlying areas of Winnipeg, about 300 miles/400 km south-southeast of my location.

By 2234, much of the very interesting-sounding VLF activity occurring at 2144 UT has died away. Only a few weak whistlers are audible now.

Other radio propagation notes: 0248 UT: Another excellent night for MF and LF broadcast signal propagation from Europe and the British Isles. 1314 Norway has excellent audio with Norwegian music, audio from unID European on 972, carriers on 1188, 1089, 1053 Talk radio U.K. (weak audio), audio from Virgin U.K. on 1215, and many other weaker carriers detectable on the 9 kHz-spaced channels. LWBC station "Atlantic 252" from Ireland also reached fair audio levels at 0310 UT, despite beacon interference from 250 kHz "FO" in Flin Flon, MB.

Thursday, 05 September 1996 beginning 0200 UT (9:00 p.m. 04 Sept. PDT) one check only:

Geo-magnetic indices for Thursday 05 September (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 2 2 2 1 1 2 2 2. quiet to unsettled. Solar-flux = 70, SSN = 000, GT 2 MeV Electron fluence = 1.3E + 07 (low). No proton events. X-ray background: A3.2

VLF: 0200 UT (9:00 p.m. 04 September UT): weak, low-pitched whooping chorus. (end side B, tape MBVLF-21).

No more VLF listening was done Thursday, and the skies were cloudy so I was not able to observe any auroral displays.

I departed the Grass River Provincial Park "VLF Camp" listening site at approximately 10:00 a.m. local time on the 5th under partly-sunny skies, and headed back westward on Highway 39, then southward back down Manitoba Provincial Highway 10.

Arriving in The Pas, Manitoba, I re-stocked my depleted food storage bins and headed toward Hudson Bay, Saskatchewan (nowhere near the Bay of the same name) and stayed in the Hotel Desrochers Hotel, an old hotel in the style of a European Inn, where I enjoyed a LONG bath to the sound of pouring rain outside. Sleep, however, came with difficulty due to the noise of traffic right below my window--I had become accustomed to the pure-silence back at the Manitoba VLF Camp.

Under cloudy skies the following morning and very glad to be on the road again, I headed southward and made a beeline toward the U.S. border - not that I was anxious to depart Canada, but I wanted to cover many miles and drive out of the depressing cold-fronts and heavy rain now plaguing northern Manitoba and Saskatchewan. I was also anxious to make it back into mountainous country again.

Driving into the night (now under clear skies), I finally wound up in Terry, Montana (eastern side of the state) near the Yellowstone River, where I spent the next 3 nights at the Terry RV Park, run by a truly WONDERFUL couple named Carm and Jim Berg. Several RV'ers (Caravaners) were in rock-hunting expeditions into the Yellowstone River badlands searching for Montana Moss Agate, and I joined one rock hound, Ted Hill, on a warm Sunday morning (08 Sept.) hike along Cottonwood Creek, a tributary of the Yellowstone, in search of the elusive stones with feathery mineral deposits. I brought along my WR-3E hand-held VLF receiver but did not hear any VLF emissions at all the entire day except for the ubiquitous lightning static.

Monday morning on the 9th of September saw me back on the road, heading westward on I-94 toward Miles City, Montana and ultimately, I-25 southward into Wyoming, where I stopped to sleep at Glendo State Park near Wheatland. I could not listen for any natural VLF radio sounds due to being about 100 yards from large, 100kV or greater AC power-lines.

By noon the next day, I was at radio station WWV/WWVB just to the north of Fort Collins, Colorado, run by the U.S. National Bureau of Standards. Snapping a quick roll of film, I rolled southward again on Interstate 25 into the maw of Denver, barely missing their afternoon "rush-hour" traffic.

In western Colorado, the beauty of the gorges and red rock formations of western Colorado soothed my road weariness, and I was also glad to be back in more arid surroundings again. Again, no ELF-VLF monitoring was done on the night of September 10th and morning of the 11th due to local power-lines next to the campsite feeding the Visitor Center of the Colorado National Monument.

Canyonlands National Park in south-eastern Utah near Moab was, in one word, incredible! And to make things even nicer, most of this National Park lacks any powerlines except for a small set feeding the Visitor Center from an unknown source (probably from Moab). As such, all of the drive-in and hike-in campsites are "VLF-quiet" and totally lack any hum, and the views of the surrounding canyons and gorges, including the Green River, are spectacular.

Arriving in Canyonlands in the mid-morning, as it was fairly close to the Colorado N. M., I was able to quickly get the van ready for the night, eat some lunch, then hike toward nearby buttes, where I watched the Green River flow in the near distance and far below me. As afternoon monsoonal and convective thunderstorms built up over the mountains to the southeast, I enjoyed watching ground strikes hit some distant cliffs. VLF lightning static was fierce and too strong to enjoy. None of that lightning came too close, but I enjoyed still another display and reminder of Mother Nature's majestic power at work.

Thursday, 12 September 1996 beginning 1015 UT (4:15 a.m. PDT):

### CANYONLANDS NATIONAL PARK, southeastern UTAH

#### ISLAND-IN-THE-SKY

Location coordinates: 109 degrees 50 minutes west longitude/38 degrees 25 minutes north latitude.

Geo-magnetic indices for Thursday 12 September: (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are unavailable.

VLF: 1015 UT (4:15 a.m. MDT): Weak whistlers and strong tweeks. Not many of the very weak whistlers audible.

1130 UT: Vy. faint high-pitched chorus "twittering" sounds. Weak whistlers.

1210 UT (6:15 a.m. MDT): Nothing noted besides lightning static.

1310 UT: Slightly increased background hissband, and by 1325 UT, the hissband got even louder (by 3 dB or so) and very weak wavering tones are just audible in the hissband.

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Friday 13 September 1996 beginning 0330 UT (8:30 p.m. Thursday 12 Sept. PDT):

### GREAT BASIN NATIONAL PARK, Upper Lehman Camp, eastern NEVADA

Location coordinates: 114 degrees 17 minutes west longitude/39 degrees 01 minutes north latitude.

VLF: At 0330 UT, huge lightning cloud formations to the east over western Utah are generating long-duration ground strikes which pummel the distant mountain tops to the east about 50-100 miles away - truly incredible sight! BIG lightning sferics generating faint, hissy (diffuse) whistlers. Hand-held listening with WR-3E VLF receiver.

No other listening or recording for the rest of this night.

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Saturday 14 September 1996 beginning 0330 UT again (8:30 p.m. Friday 13 Sept. PDT):

VLF: 0331 UT: Intense tweeking sferics. Faint weak, fuzzy whistlers now and then. Nothing else of interest.

0611 UT: Deep. ringy tweeks! Nicer than a few hours earlier. A great tweek recording made on tape UTENV-1 side B.

At 0730 UT (12:30 a.m. PDT 14 Sept.) similar deep ringy tweeks occurring as at 0611 UT.

1105 UT (4:05 a.m.) strong lightning sferics without much tweeking going on. A couple of weak but pure-tone whistlers "swooping" to low pitches below 1 kHz occurred after some of the sferics.

1342 UT: Rather dead sounding - nothing of interest.

1403 UT: Weak, hissy (diffuse) whistlers occurring after some of the stronger lightning static pops (about 10 to 20 per-minute, with stronger ones 2 or 3 per minute).

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Sunday 15 September 1996 beginning at 0003 UT (5:03 p.m. Sat. 14 Sept. PDT):

Geo-magnetic indices for Sunday 15 September (via: [gopher://proton.sel.noaa.gov](http://gopher://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 2 2 3 3 4 2 4 4. unsettled to active. Solar-flux = 66, SSN = 000, GT 2 MeV Electron fluence =  $9.8E + 08$  (high). No proton events. X-ray background: A1.0

VLF: At 0003 UT, weak, hissy/diffuse whistlers every 5 to 10 seconds.

0158 UT: Dense tweeking lightning sferics.

0625 UT: Very deep, ringy tweeks - harmonic rich and of long duration and high dispersion.

1025 UT (3:25 a.m. PDT): The intense tweeks continued. A few weak, hissy whistlers occurred after some of the tweeks. The whistlers sound similar to ones that occurred 10 hours earlier.

1504 UT (8:04 a.m. PDT): weak power-line hum (actually in background all the time at Great Basin NP) and perhaps faint hissband. No whistlers heard during a few minutes listening time. end side B, tape UTENV-1.

No VLF observations were made on Monday, 16 September due to rain and snow.

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Tuesday, 17 September 1996, from 0538 UT to 1548 UT:

**HUMBOLDT NATIONAL FOREST - Angel Creek USFS campsite**

Location coordinates: 115 degrees 02 minutes west longitude/41 degrees 02 minutes north latitude

Geo-magnetic indices for Tuesday 17 September: (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 3 2 0 2 1 2 1 2. quiet to unsettled. Solar-flux = 69, SSN = 000, GT 2 MeV Electron fluence = 5.4E+08 (moderate - high). No proton events. X-ray background: A1.3

VLF: At 0538 UT, there were some fairly loud, very diffuse, non-pure-tone "hissy" whistlers with 4 hop echoes following them. Weak hissband too.

1300 UT: Nothing of interest noted.

1405 UT (7:05 a.m. PDT): Very faint "whooping" emissions noted in light static. Probably much louder farther north...

1548 UT: "Tiny" whistlers

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Wednesday, 18 September 1996 beginning 0438 UT (9:38 p.m. 18 Sept. PDT) to:

Geo-magnetic indices for Wednesday 18 September (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are unavailable

VLF: 0438 UT: Heavy amounts of lightning static - some of it tweaking. At least a four-fold increase in amount of lightning sferics compared to the previous night at or near the same time!

0710 UT: Heavy static, nothing else noted in the "mess."

1200 UT: Still heavy static and little else

1420 UT (7:20 a.m. PDT): Dawn Chorus! Weak, low-pitched "squawking" chorus with occasional very weak whistlers. Much lighter static levels at this time.

1547 UT: Just a trace of the dawn chorus now. Probably louder in Canada...

I left Angel Creek and the Humboldt National Forest at mid-morning on Wednesday the 18th, and headed toward Elko, Nevada to visit Judy Langley, former Camp Host of the Angel Creek campground and a fine lady whose company I enjoyed long talks with into the night during several stays on my way to or from Nevada on the many trips I took that summer of 1996 in June, July and August. Judy had burned out from the long stay alone at the campsite in charge of generally amiable campers who came and went, but it was the occasional "not-so-nice" campers and the need to keep up a constant vigil, particularly as her husband, Jerry, was on the road trucking several rock groups' instruments into Quebec and other eastern locations. Thus, she had left Angel Creek just one day prior to my arrival, and I left to locate her in the Elko area.

While in Elko, I developed most of my print film at Inkley's Photo Shop and Studio on East Idaho Street (next door to the Ford Auto/Truck dealership where my van was under drive-train inspection). Several of the gals working there loved my aurora photos, and 2 of my best aurora photographs were scanned into a computer and printed out as 12 x 18 inch photos, which both are now up on their studio wall next to many other photos. Quite an honor to me, and what a NICE establishment too!

Colder than normal, winter-like weather in Utah and Eastern Nevada was slowly moving eastward, but I was anxious to re-experience summer weather once again (winter would come soon enough anyway), and so at mid-morning on Thursday the 19th, I departed Elko after a brief farewell visit with Judy at her workplace, and drove westbound on the Interstate 80 freeway, went north on U.S. 95 from Winnemucca then turned westward on Hwy. 140 and thence southward into the northern section of the Black Rock Desert to a favorite VLF listening spot 12 miles from the nearest AC powerlines. It was at this same location where Gail West and I heard our first "Nevada whistlers" back in 1989 and where we met friends Laura and Bill Bostic in July 1989. I love this location about 5 miles distant from the granite-cliffed summit of King Lear Peak.

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Friday, 20 September 1996 beginning 0430 UT (9:30 p.m. 19 Sept. PDT) to:

**BLACK ROCK DESERT, northwestern NEVADA****KING LEAR PEAK AREA VLF CAMP**

Location coordinates: 118 degrees 38 minutes west longitude/41 degrees 11 minutes north latitude.



Geo-magnetic indices for Friday 20 September: (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 4 4 5 5 4 3 2 4. unsettled to minor storm. Solar-flux = 69, SSN = 000, GT 2 MeV Electron fluence =  $1.3E + 08$  (moderate). No proton events. X-ray background: A1.5

VLF: 0430 UT (9:30 p.m. Thursday 19 Sept. PDT): Moderate lightning static, some of it tweaking, but nothing else of interest.

1301 UT (6:01 a.m. Friday 20 Sept. PDT): weak low-pitched hiss, fairly strong chirping and squawking (dawn) chorus trains and pure whistlers with weak echoes at an average rate of 5 - 10/minute.

1340 UT: The lower-pitched dawn chorus has further increased in strength but is also less "dense." The pure-tone whistlers are increasing in strength and numbers-per-minute.

1418 UT: The chorus is stronger but less dense again.

1520 UT: The whistlers continue to gain in numbers and strength, and by 1545 UT, are very loud and pure-tone - very nice! The chorus is fading away to nil. (end side B, tape ACBRDNV-1)

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Saturday, 21 September 1996 beginning at 0435 UT (9:35 p.m. 20 Sept. PDT):

Geo-magnetic indices for Saturday 21 September (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 5 5 4 4 3 4 3 3. unsettled to minor storm. Solar-flux = 70, SSN = 000, GT 2 MeV Electron fluence =  $6.0E + 08$  (moderate-high). No proton events. X-ray background: A1.7

VLF: 0435 UT: "Bunch o' tweaks."

0735 UT: Weak, high-pitched hissband is audible

1100 UT: The high-pitched hissband has diminished, and low-pitched whistlers are being triggered after some of the louder static bursts.

1227 UT (5:27 a.m. PDT): Dawn chorus now audible! Chirping and squawking. Less tweaking sferics. Some whistlers in there too! Beginning to sound nice.

1310 UT (6:10 a.m. PDT): Weak, high-pitched chorus, hardly any chorus at this point. Some weak sustained whistler echo-trains.

1350 UT: Similar activity to 1310 UT, except the whistlers are getting more interesting sounding; I call them "spraying" type of whistlers, as they start out fairly pure in tone at high frequencies then swoop down into more of a "whizzer" sound as they descend in pitch. There are 10 - 20 per-minute at this time. Occasional weak chorus train "outbursts" indicating increasing chorus activity will probably ensue.

1405 UT (7:05 a.m. PDT): Lots of "little" whistlers, and there is low-pitched squawking chorus in the background.

1424 UT: The low-pitched chorus of 20 minutes earlier has changed into a high-pitched "hissy" (diffuse) form of chorus, and the multitude of weak whistlers continue as before.

1450 UT: Increased low-pitched whooping chorus again. Less hissy/diffuse whistler activity now.

1630 UT (9:30 a.m. PDT): Faint background "woofie-dog" whooping/barking chorus (longer duration risers) which are just barely audible above the WR-4B receiver's fairly low- noise floor.

By 1800 UT: "Just sferics."

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Sunday, 22 September 1996 beginning at 0355 UT (8:55 p.m. 21 Sept. PDT):

Geo-magnetic indices for Sunday 22 September (via: [gopher://proton.sel.noaa.gov](http://proton.sel.noaa.gov)) are as follows:

3-hourly planetary-K index 0000-2100 UT: 4 3 5 3 4 4 2 2. quiet to active. Solar-flux = 69, SSN = 000, GT 2 MeV Electron fluence =  $1.1E + 09$  (high). No proton events. X-ray background: A1.8

VLF: 0355 UT: Tweaking lightning static (sferics), weak high-pitched hissband.

0500 UT (9 p.m. PDT): The hissband has gotten quite loud now and also occasional low-pitched whooping emissions are audible - this sounds like being farther north! In fact, even up in Manitoba, it was rare that the hissband was this loud at this time of the night. Occasional diffuse (hissy) whistlers with echo trains. A few wavering tone emissions of weak strength also noted - possibly related to the low-pitched whooping emissions. Moderate static levels.

At 0525 UT, the whistler rate vastly increased and they have echo-trains characteristic of geo-magnetic storm-time conditions. The high-pitched hissband remains at same levels as 25 minutes earlier.

0555 UT: Still increasing levels of whistlers of generally hissy type, though some of them sound fairly pure-tone at their highest frequencies of audibility. Occasional "hook" emissions (fall then rise in tonal pitch) and quite spectacular sounding. I'm very excited at hearing VLF sounds similar to up in Manitoba thanks to the magnetic storm.

Auroral Viewing: I didn't think I would need to put this entry here, as Nevada does not have frequent auroral displays being located well to the south of the main auroral oval. However, after 0720 UT (12:20 a.m. PDT), the sky to the north brightened considerably and a diffuse, weak green GLOW was visible in this extremely dark-sky location in the desert. A strong and probably spectacular auroral display must be underway in Alberta, British Columbia (and across most of central and northwestern Canada for that matter)!

VLF: 1211 UT (5:12 a.m. PDT Sunday morning) Wavering-tone emissions and nice, loud "hooking" whistlers are occurring - sounds really great! Running tape, ACBRDNV-2, side B. Very beautiful mixture of natural radio sounds. I LOVE this place...

1300 UT: Moderate dawn chorus and whistlers, now lacking echo-trains. Activity continues at same level past 1320 UT.

2/6/2019

## Summer 1996 Manitoba Solar-Minimum Natural VLF Radio Expedition Report

1425 UT (7:25 a.m. PDT): Vigorous and "fabulous" chorus now - low squawks combined with higher-pitched chirping and tweeting sounds. Frequent, fast and high-pitched pure-tone whistlers also in the mixture. I haven't heard chorus this LOUD in the Nevada desert in over 4 years! Magnetic-field micro-pulsations are quite evident as a gentle rising and falling in volume of the background hissband and in the rhythmic repeating of the chorus trains.

1458 UT: The chorus is starting to decline in strength and activity, but RESUMES its fury by 1519 UT. Nice!

It is extremely loud and rivals the best chorus I've ever taped at this geo-graphic (and geo-magnetic) latitude! Occasional fast, near-pure whistlers every 10 seconds or so, too.

It is about 27-28 days (one solar rotation) after the big magnetic storm of 22-23 August when I saw spectacular full-sky aurora in Manitoba, Canada and recorded loud chorus all day up there.

1545 UT: Similar vigorous activity as 1458 UT. Taped to end of tape ACBRDNV-3, side A.

Black Rock Desert at sunset on September 21, 1996 - view of Jackson Mountains and the dry lakebed playa.

Soon after finishing the one side of the tape cassette, I packed away the equipment and drove out of the Black Rock Desert and headed toward Lakeview, Oregon on Highway 140 westbound, passing through the beautiful Sheldon P. National Antelope Refuge in far north-western Nevada, then into Oregon.

The second to the last night was in the desert near Plush, Oregon (about 20 miles east of Lakeview), but too close to the HUGE Boneville Power Authority 1 Megavolt powerlines, and too much hum was received on my WR-3E.

The final night of the trip was on 24-25 September at the Lassen National Park in northern California, where I enjoyed a respite from radio and enjoyed a 4 mile evening hike up to a lookout with nice views of this still-active volcanic mountain.

Stephen P. McGreevy, 16 December 1996

All photographs taken by Stephen P. McGreevy

\*\*\* END SUMMER 1996 SOLAR-MINIMUM VLF EXPEDITION REPORT \*\*\*

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