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# for
# Solar-Terrestrial Physics

## REPORT UAG - 50

## HIGH-LATITUDE SUPPLEMENT TO THE URSI HANDBOOK ON IONOGRAM INTERPRETATION AND REDUCTION

by

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## LISTING OF IONOGRAM FIGURES


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| USSR STATIONS | | | | | |
| Quiet and Disturbed Ionosphere -- Day: | | | | | |
| Vostok | Quiet, Summer | 1015 | 1970 Jan. 22 | 1.1 | 11 |
| Vostok | Disturbed, Summer | 1405 | 1970 Jan. 23 | 1.2 | 11 |
| Mirny | Quiet, Summer | 1300 | 1970 Jan. 25 | 1.3 | 11 |
| Mirny | Disturbed, Summer | 1500 | 1970 Jan. 24 | 1.4 | 11 |
| Heiss | Quiet, Summer | 1100 | 1970 July 7 | 1.5 | 11 |
| Heiss | Disturbed, Summer | 1230 | 1970 July 27 | 1.6 | 11 |
| Heiss | Quiet, Winter | 1055 | 1970 Jan. 4 | 1.13 | 13 |
| Heiss | Disturbed, Winter | 1215 | 1970 Jan. 2 | 1.14 | 13 |
| Dixon | Quiet, Summer | 1200 | 1970 July 7 | 1.15 | 13 |
| Dixon | Disturbed, Summer | 1315 | 1970 July 29 | 1.16 | 13 |
| Dixon | Quiet, Winter | 1505 | 1969 Jan. 3 | 1.17 | 13 |
| Dixon | Disturbed, Winter | 1430 | 1970 Jan. 2 | 1.18 | 13 |
| Quiet and Disturbed Ionosphere -- Night: | | | | | |
| Vostok | Quiet, Summer | 0400 | 1970 Jan. 11 | 1.7 | 12 |
| Vostok | Disturbed, Summer | 0355 | 1970 Jan. 13 | 1.8 | 12 |
| Mirny | Quiet, Summer | 0045 | 1970 Jan. 26 | 1.9 | 12 |
| Mirny | Disturbed, Summer | 0055 | 1970 Jan. 24 | 1.10 | 12 |
| Heiss | Quiet, Summer | 0200 | 1970 July 7 | 1.11 | 12 |
| Heiss | Disturbed, Summer | 0045 | 1970 July 27 | 1.12 | 12 |
| Heiss | Quiet, Winter | 1950 | 1970 Jan. 3 | 1.19 | 14 |
| Heiss | Disturbed, Winter | 2130 | 1970 Jan. 1 | 1.20 | 14 |
| Dixon | Quiet, Summer | 0100 | 1970 July 7 | 1.21 | 14 |
| Dixon | Disturbed, Summer | 0145 | 1970 July 13 | 1.22 | 14 |
| Dixon | Quiet, Winter | 0330 | 1969 Jan. 3 | 1.23 | 14 |
| Dixon | Disturbed, Winter | 0130 | 1969 Jan. 8 | 1.24 | 14 |
| Lacuna: | | | | | |
| Mirny | | 1105-1130 | 1970 Jan. 23 | 1.25a-c | 15 |
| Heiss | | 0530 | 1970 July 27 | 1.26 | 15 |
| Heiss | | 0550 | 1970 July 29 | 1.27 | 15 |
| Dixon | | 1655 | 1969 Jan. 25 | 1.28 | 15 |
| Development of Lacuna: | | | | | |
| Dixon | | 1530-1715 | 1970 July 9 | 1.29a-i | 16 |
| Sporadic E Type: | | | | | |
| Dixon | Es-a | 2055 | 1969 Jan. 7 | 1.30 | 17 |
| Dixon | Es-a | 0300 | 1970 July 10 | 1.31 | 17 |
| Dixon | Es-c,a | 2015 | 1970 Jan. 2 | 1.32 | 17 |
| Dixon | Es-a | 1715 | 1970 July 29 | 1.33 | 17 |
| Heiss | Es-a | 1700 | 1970 July 27 | 1.34 | 17 |
| Heiss | Es-r | 1715 | 1970 July 29 | 1.35 | 17 |
| Sporadic E type a and ASKAfilms: | | | | | |
| Tixie | | 1920 | 1958 Nov. 10 | 1.36 | 18 |
| Tixie | | 0000-0230 | 1958 Nov. 19 | 1.36a-d | 18 |
| Sporadic E Types: | | | | | |
| Tixie | Es-a | 1155 | 1958 Sept. 7 | 1.37 | 19 |
| Tixie | Es-a | 1200 | 1958 Sept. 5 | 1.38 | 19 |
| Tixie | Es-k | 0845 | 1958 Sept. 7 | 1.39 | 19 |
| Tixie | Es-r | 1600 | 1958 June 30 | 1.40 | 19 |
| Heiss | Es-k | 0545 | 1970 Jan. 4 | 1.41 | 20 |

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| Dixon | Es-k | 2005 | 1970 Jan. 3 | 1.42 | 20 |
| Heiss | Es-r | 1245 | 1970 Jan. 3 | 1.43 | 20 |
| Dixon | Es-r | 0345 | 1969 Jan. 9 | 1.44 | 20 |
| Mirny | Es-c | 1945 | 1970 Jan. 4 | 1.45 | 20 |
| Heiss | Es-ℓ | 2045 | 1970 July 29 | 1.46 | 20 |
| Ionogram Sequence With Es Type Changing in Time | | | | | |
| r,k; r; k; a,k; r; a,k; a,k; a,k: | | | | | |
| Dixon | | 1800-1930 | 1970 Jan. 2 | 1.47a-h | 21 |
| r; r; r-k; k; k; r; k; k; k; k: | | | | | |
| Dixon | | 0605-0755 | 1970 Jan. 1 | 1.48a-j | 22 |
| k; k; k; k; k; k; k;normal E: | | | | | |
| Dixon | | 0400-0530 | 1970 July 5 | 1.49a-h | 23 |
| Spread F Classifications: | | | | | |
| Vostok | P | 0915 | 1970 June 25 | 1.50 | 24 |
| Mirny | Q | 2345 | 1970 June 28 | 1.51 | 24 |
| Dixon | Q | 0445 | 1969 Jan. 9 | 1.52 | 24 |
| Mirny | F | 1215 | 1970 June 21 | 1.53 | 24 |
| Heiss | F | 1800 | 1970 July 28 | 1.54 | 24 |
| Heiss | F | 1845 | 1970 Jan. 2 | 1.55 | 24 |
| FLIZ Phenomenon, Winter - "Thick" F2-Layer, "Thin" F2-Layer: | | | | | |
| Vostok | | 0955 | 1970 June 28 | 1.56 | 25 |
| Vostok | | 1400 | 1970 June 23 | 1.57 | 25 |
| Mirny | | 1600 | 1970 June 24 | 1.58 | 25 |
| Mirny | | 1255 | 1970 June 29 | 1.59 | 25 |
| Mirny | | 2305 | 1970 Jan. 1 | 1.60 | 25 |
| Mirny | | 0155 | 1970 Jan 2 | 1.61 | 25 |
| Heiss | | 1845 | 1970 Jan. 16 | 1.62 | 26 |
| Heiss | | 2230 | 1970 Jan. 16 | 1.63 | 26 |
| Ionogram Sequence Showing FLIZ Phenomenon; Winter: | | | | | |
| Heiss | | 1915-2005 | 1970 Jan. 16 | 1.64a-e | 26 |
| Vostok | | 1905-2055 | 1970 June 27 | 1.65a-j | 27 |
| Ionogram Sequence Auroral Oval | | | | | |
| Magnetically Quiet Period, Night Sector: | | | | | |
| Dixon | | 0345-0645 | 1969 Jan. 4 | 1.66a-l | 28 |
| Magnetically Disturbed Period, Night Sector: | | | | | |
| Dixon | | 0530-0930 | 1969 Jan. 24 | 1.67a-l | 29 |
| Magnetically Quiet Period, Day Sector: | | | | | |
| Vostok | | 1905-2015 | 1970 Jan. 22 | 1.68a-f | 30 |
| Magnetically Disturbed Period, Day Sector: | | | | | |
| Vostok | | 1745-1830 | 1970 Jan. 24 | 1.69a-f | 31 |

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| SCANDINAVIAN STATIONS | | | | |
| KIRUNA | | | | |
| Quiet Summer Day | 1300 | 1970 Aug. 5 | 2.1 | 33 |
| Quiet Summer Day | 0100 | 1970 Aug. 6 | 2.1 | 33 |
| Quiet Winter Day | 1300 | 1971 Jan. 9 | 2.2 | 34 |
| Quiet Winter Night | 1900 | 1971 Jan. 9 | 2.2 | 34 |
| Quiet Winter Night | 0100,0600 | 1971 Jan. 10 | 2.3 | 35 |
| Es-a | 2100 | 1973 Aug. 13 | 2.4 | 36 |
| Es-a | 2030 | 1973 Oct. 27 | 2.4 | 36 |
| Es-k | 1900 | 1973 Oct. 22 | 2.5 | 37 |
| Es-k | 1730 | 1974 Apr. 18 | 2.5 | 37 |
| Es-a,f | 0330 | 1973 July 6 | 2.6 | 38 |
| Es-a,f | 2331 | 1971 Dec. 17 | 2.6 | 38 |
| Es-k,a | 2330 | 1974 Jan. 21 | 2.7 | 39 |
| Es-k,a | 2330 | 1973 Dec. 6 | 2.7 | 39 |
| Es-k,ℓ | 1000 | 1967 Dec. 24 | 2.8 | 40 |
| Es-k,ℓ | 0330 | 1974 July 2 | 2.8 | 40 |
| Gain Runs | 1600 | 1973 Oct. 19 | 2.9 | 41 |
| Equinox Day Showing TID | 1100 | 1960 Mar. 28 | 2.9 | 41 |
| Time Sequence In Disturbed Period | 1900-0100 | 1973 Apr. 14-15 | 2.10 | 42 |
| F2 and Es Change on Summer Day | 1300-1900 | 1973 June 7 | 2.11 | 44 |
| SODANKYLÄ | | | | |
| Sporadic E Layer | 2040 | 1973 June 20 | 2.12 | 49 |
| Gain Runs | 1046-1100 | 1973 Jan. 28 | 2.13 | 50 |
| Gain Runs | 1109-1123 | 1974 Jan. 28 | 2.14 | 51 |
| Gain Runs | 1340 | 1973 June 25 | 2.15 | 52 |
| Gain Runs | 1700 | 1973 July 6 | 2.16 | 53 |
| Gain Runs | 1830 | 1973 July 23 | 2.16 | 53 |
| Es-h | 0600 | 1974 Aug. 11 | 2.17 | 54 |
| Es-h | 0610 | 1974 Aug. 13 | 2.17 | 54 |
| Es-ℓ | 1710-1720 | 1974 Aug. 13 | 2.18 | 54 |
| Strong E-layer Scatter | 1730-2130 | 1974 July 21 | 2.19 | 55 |
| Strong E-layer Scatter | 1600-1700 | 1974 Aug. 27 | 2.20 | 56 |
| Spread E | 2230 | 1974 Aug. 1 | 2.21 | 57 |
| Particle E, with all three magneto-ionic components | 0130 | 1974 Aug. 27 | 2.22 | 58 |
| E-layer Microstructure | 1830-1900 | 1973 Aug. 5 | 2.23 | 59 |
| E-layer Microstructure | 0630-0700 | 1973 Sept.12 | 2.23 | 59 |
| Es-a | 1930-2230 | 1974 May 20 | 2.24 | 60 |
| Es-r,k | 0300 | 1973 Apr. 3 | 2.25 | 61 |
| Es-r,k | 0030 | 1973 Apr. 14 | 2.25 | 61 |
| Es-f, Es-f+Es-a | 0000-0030 | 1974 May 21 | 2.26 | 62 |
| LYCKSELE | | | | |
| Quiet Summer Day | 1400-1500 | 1973 May 12 | 2.27 | 64 |
| Quiet Winter Day | 1000-1200 | 1972 Jan. 7 | 2.28 | 65 |
| Quiet Winter Morning | 0400-0600 | 1974 Feb. 19 | 2.29 | 66 |
| Tilts and forking in the F Layer | 1000-1300 | 1974 Feb. 20 | 2.30 | 67 |
| Quiet Time Ionogram, Infinity Echo | 1600 | 1972 Jan. 5 | 2.31 | 68 |
| Es-r, Spread F | 1700-2000 | 1972 Nov. 16 | 2.32a | 69 |
| Es-c,r,f; Spread F | 2100-2200 | 1972 Nov. 16 | 2.32b | 70 |
| Es-k | 1700-1800 | 1973 Apr. 1 | 2.33a | 71 |
| Es-k,a | 1700-1900 | 1972 Nov. 1 | 2.33b | 72 |
| Spread F | 1900-2000 | 1974 Feb. 28 | 2.34 | 73 |
| Spread F; Es-r | 2000-2200 | 1973 Apr. 3 | 2.35 | 74 |
| Trough Sequence | 0000-0500 | 1972 Nov. 9 | 2.36 | 75 |
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| Spread Es-h | 1400-1600 | 1973 Apr. 14 | 2.38 | 77 |

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| Development of Lacuna | 1500-1600 | 1973 Apr. 1 | 2.41 | 81 |
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| THULE | | | | |
| Summer Night | 2329 | 1974 May 15 | 2.44 | 85 |
| Summer Day | 1429 | 1974 May 15 | 2.44 | 85 |
| Weak Lacuna with Slant Es and G Condition | 1130-1200 | 1974 May 15 | 2.45 | 86 |
| Lacuna Sequence; Weak Lacuna Combined with G Condition | 0830-1000 | 1974 May 15 | 2.46 | 87 |
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| Distinction Between Es-a and Polar Spur | 1344-1429 | 1974 Apr. 28 | 2.47 | 88 |
| Es-a, Es-k, Spread F Classifications P,F,Q | 0314-0355 | 1974 Apr. 28 | 2.48 | 89 |
| Lacuna Sequence | 0844-0959 | 1974 Apr. 28 | 2.49 | 90 |
| Distinction Between Spread F Classification P and Es-a | 0557-0559 | 1974 Apr. 28 | 2.50 | 92 |
| Very Weak Lacuna (Slant Es) | 0614-0629 | 1974 Apr. 28 | 2.51 | 92 |
| Polar Spur | 2114-2159 | 1974 Apr. 28 | 2.52 | 93 |
| NARSSARSSUAQ | | | | |
| Es-a | 1914 | 1974 May 15 | 2.53 | 94 |
| Es-a | 1329 | 1974 May 16 | 2.53 | 94 |
| Es-h | 1659 | 1974 May 15 | 2.54 | 95 |
| Es-d | 0557 | 1974 May 16 | 2.54 | 95 |
| Two Layer Sequence | 2144-2244 | 1974 May 14 | 2.55 | 96 |
| Es-a,k | 2257 | 1974 May 14 | 2.56 | 97 |
| Particle E (Es-k) | 0557 | 1974 May 16 | 2.57 | 98 |
| Particle E (Es-k) | 1629-1729 | 1974 May 16 | 2.57 | 98 |
| Es-f,ℓ with Es-a | 1959 | 1974 May 14 | 2.58 | 99 |
| Es-f with Es-a | 2057-2357 | 1974 May 16 | 2.58 | 99 |
| Es-c,a | 2057-2114 | 1974 May 14 | 2.59 | 100 |
| Auroral Es Distinction from Polar Spur | 1729-1759 | 1974 May 14 | 2.60 | 101 |
| Auroral Es Superposed on F Pattern | 1657-1659 | 1974 May 14 | 2.61 | 102 |
| Range Spread | 0957-1029 | 1974 May 14 | 2.62 | 103 |
| F-layer Tilt Sequence | 0630-0757 | 1974 May 14 | 2.63 | 104 |
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| CHURCHILL | | | | |
| TID Sequence | 1015-1045 | 1974 Feb. 9 | 3.1 | 107 |
| Es-r,k | 2315 | 1973 Dec. 13 | 3.2 | 109 |
| Particle E (Es-k) - Daytime | 2000 | 1973 Dec. 14 | 3.3 | 109 |
| Es-c,r,k | 2030 | 1974 May 30 | 3.4 | 110 |
| F1 Lacuna | 1645 | 1974 May 30 | 3.5 | 110 |
| Replacement Layer (Trough) Sequence | 1830-1900 | 1974 Apr. 22 | 3.6 | 111 |

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| Replacement Layer (Trough) Sequence | 1800-2245 | 1973 Dec. 24 | 3.8 | 115 |
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| Layer Tilt | 0858-0930 | 1974 Apr. 12 | 3.10 | 123 |
| Letter Y Severe Tilt | 0630 | 1974 Apr. 14 | 3.11 | 124 |
| Layer Tilt | 1059 | 1974 Jan. 11 | 3.12 | 124 |
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| Quiet Summer Day | 1159 | 1964 June 13 | 4.1 | 126 |
| Quiet Summer Night | 2359 | 1964 June 15 | 4.1 | 126 |
| Quiet Equinox Day | 1145 | 1964 Sept.11 | 4.1 | 126 |
| Quiet Equinox Night | 2259 | 1964 Sept.13 | 4.1 | 126 |
| Quiet Winter Day | 1159 | 1964 Dec. 15 | 4.1 | 126 |
| Quiet Winter Night | 0015 | 1964 Dec. 11 | 4.1 | 126 |
| Es-r,ℓ,s,a | 1000-1100 | 1964 Dec. 6 | 4.2 | 130 |
| Blanketing Es-r | 1000-1200 | 1964 Dec. 5 | 4.3 | 130 |
| Blanketing Es-r | 1000-1059 | 1964 Dec. 6 | 4.3 | 130 |
| Blanketing Es-r | 1059-1105 | 1964 Dec. 7 | 4.3 | 130 |
| Stratification Between E and F Layers | 1300-1700 | 1964 Dec. 5 | 4.4 | 132 |
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| Quiet Winter Day | 1200 | 1964 Dec. 2 | 4.5 | 134 |
| Quiet Winter Night | 0145 | 1964 Dec. 6 | 4.5 | 134 |
| Equinox Day | 1245 | 1964 Mar. 9 | 4.5 | 134 |
| Equinox Night | 0125 | 1964 Mar. 10 | 4.5 | 134 |
| Summer Day | 1200 | 1964 June 3 | 4.5 | 134 |
| Summer Night | 0000 | 1964 June 5 | 4.5 | 134 |
| Travelling Disturbance Sequence | 1425-1435 | 1973 July 5 | 4.6 | 136 |
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| Es-c and s | 1601 | 1973 Dec. 5 | 5.1 | 139 |
| Es-a | 0015 | 1973 June 19 | 5.2 | 140 |
| Es-a | 0901 | 1973 June 19 | 5.3 | 141 |
| Es-h | 1201 | 1973 Oct. 1 | 5.4 | 142 |
| Es-s | 1401 | 1973 Oct. 2 | 5.5 | 143 |
| Es-c | 1445 | 1973 Oct. 5 | 5.6 | 144 |
| Es-ℓ and r | 2000 | 1972 Jan. 6 | 5.7 | 145 |
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| z Traces | 0901 | 1972 Jan. 9 | 5.10 | 148 |
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| z Trace | 1201 | 1973 Dec. 3 | 5.13 | 151 |
| Use of DL for foF1 | 1545 | 1970 Apr. 12 | 5.14 | 152 |
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| Summer, No Spread | 2245 | 1973 Dec. 5 | 5.18 | 156 |
| Es-ℓ | 0845 | 1972 Dec. 13 | 5.19 | 157 |
| Replacement Letter "A" | 2200 | 1973 Dec. 6 | 5.20 | 158 |
| Small Tilts, Use of Descriptive Letter H | 1415 | 1973 Oct. 2 | 5.21 | 159 |
| Daytime Summer Ionogram , with Spread | 1701 | 1973 Dec. 3 | 5.22 | 160 |
| Winter Spread F | 1001 | 1973 June 19 | 5.23 | 161 |
| Winter Spread F | 1800 | 1973 June 18 | 5.24 | 162 |
| Es-a | 0101 | 1972 Mar. 21 | 5.25 | 163 |
| Lacuna | 1145-1301 | 1973 Oct. 2 | 5.26 | 164 |
| Use of Letter "G" for foF2 | 0830-0930 | 1973 Oct. 17 | 5.27 | 165 |
| TID of Particle E | 1401-1445 | 1973 Dec. 3 | 5.28 | 166 |
| **TERRE ADELIÈ (DUMONT D'URVILLE)** | | | | |
| Quiet Summer Day | 1101 | 1972 Jan. 3 | 6.1 | 169 |
| Quiet Summer Night | 0015 | 1971 Dec. 31 | 6.2 | 169 |
| Quiet Winter Day | 1215 | 1971 June 25 | 6.3 | 170 |
| Quiet Winter Night | 2315 | 1971 June 25 | 6.4 | 170 |
| Quiet Equinox Day | 1215 | 1971 Mar. 20 | 6.5 | 171 |
| Quiet Equinox Night | 2230 | 1971 Mar. 19 | 6.6 | 171 |
| **MAWSON STATION** | | | | |
| Quiet Summer Day | 1101 | 1972 Jan. 1 | 7.1 | 173 |
| Quiet Summer Night | 0230 | 1971 Dec. 29 | 7.2 | 174 |
| Quiet Summer Night | 2100 | 1971 Dec. 27 | 7.3 | 175 |
| Quiet Winter Day | 1301 | 1972 July 2 | 7.4 | 176 |
| Quiet Winter Night | 2201 | 1972 June 23 | 7.5 | 177 |
| Quiet Day | 1001 | 1971 Oct. 23 | 7.6 | 178 |
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| Es Sequence | 2300-0501 | 1966 Apr. 17-18 | 8.1 | 182 |
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| Frequency Spread | 2130 | 1972 Oct. 26 | 9.7 | 190 |
| Spread Es-a | 0045 | 1972 July 4 | 9.8 | 190 |
| Frequency Spread | 0515 | 9173 Jan. 3 | 9.9 | 191 |
| Frequency Spread | 1400 | 1972 July 11 | 9.10 | 191 |
| Es-r and Spread F | 0245 | 1973 Feb. 7 | 9.11 | 192 |
| Es-s | 1900 | 1972 Dec. 13 | 9.12 | 192 |
| Particle E and Spread F | 0200 | 1973 Feb. 7 | 9.13 | 193 |
| Particle E and Es-s | 2230 | 1972 Oct. 15 | 9.14 | 193 |
| Sequential Spread F | 1230-1615 | 1972 Oct. 29 | 9.15 | 194 |
| Sequential Spread F | 1300-1445 | 1971 Apr. 9 | 9.16 | 196 |

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| Rapid Evolution of Structure Followed by High Absorption | 1700-1845 | 1965 July 13 | 10.1 | 198 |
| Quiet Summer Day | 0830 | 1965 Nov. 17 | 10.2 | 199 |
| Distinction Between E2 and F 0.5 | 0515 | 1965 Nov. 17 | 10.3 | 200 |
| Es-h | 1500 | 1965 Nov. 16 | 10.4 | 201 |
| Use of Letter A | 0845 | 1965 Nov. 15 | 10.5 | 202 |
| Es-h or E2 | 1430 | 1965 Sept.12 | 10.6 | 203 |
| Stratified E Trace | 1400 | 1965 Sept 12 | 10.7 | 204 |
| Es-ℓ | 0900 | 1965 Sept.12 | 10.8 | 205 |
| Distinction Between a and f | 1345 | 1965 June 12 | 10.9 | 206 |
| Misuse of U | 1500 | 1965 May 10 | 10.10 | 207 |
| Es-f | 1215 | 1965 May 9 | 10.11 | 208 |
| Tilted Layer | 0145 | 1965 Mar. 17 | 10.12 | 209 |
| Es-h,c | 1315 | 1965 Mar. 15 | 10.13 | 210 |
| Es-f | 0030 | 1965 Mar. 15 | 10.14 | 211 |
| Misuse of DR | 0515 | 1965 Mar. 9 | 10.15 | 212 |
| Use of X on fxI | 0815 | 1965 Mar. 7 | 10.16 | 213 |
| Es-c | 0300 | 1965 Jan. 1 | 10.17 | 214 |
| Es-h | 0300 | 1965 Jan. 2 | 10.18 | 215 |
| Use of OR | 2100 | 1965 Jan. 2 | 10.19 | 216 |
| Es-c | 1300 | 1965 Jan. 3 | 10.20 | 217 |
| Es-ℓ | 1145 | 1965 Jan. 4 | 10.21 | 218 |
| Tilted Layer; Es-c | 0145 | 1965 Jan. 5 | 10.22 | 219 |
| HALLEY BAY STATION | | | | |
| Winter Day | 1145 | 1972 July 7 | 11.1 | 221 |
| Equinox Day | 0845 | 1972 Sept.26 | 11.2 | 221 |
| Summer Day | 0815 | 1972 Jan. 4 | 11.3 | 221 |
| Polar Spur | 0315 | 1972 Sept.26 | 11.4 | 222 |
| Range Spread due to Layer Tilt | 2015 | 1972 July 6 | 11.5 | 222 |
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| Gyro (infinity mode) Traces | 1015 | 1973 July 7 | 11.7 | 223 |
| Gyro; Es-f | 1445 | 1973 July 23 | 11.7 | 223 |
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# HIGH-LATITUDE SUPPLEMENT

to the

# URSI HANDBOOK ON IONOGRAM INTERPRETATION AND REDUCTION

by

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## INTRODUCTION

This Supplement to the Second Edition of the *URSI Handbook of Ionogram Interpretation and Reduction* [ W. R. Piggott and K. Rawer, *Report UAG-23*, World Data Center A (WDC-A) for Solar-Terrestrial Physics, November 1972] is intended to provide samples of actual ionograms to illustrate the line drawings given in the Handbook, to provide reference ionograms and ionogram sequences so as to aid future discussion and to clarify particular difficulties. This collection should also be useful to scientists who need to use ionospheric data but are not expert in the field of ionogram interpretation. Many of the phenomena shown occur at most latitudes. Typical examples of ionograms from all parts of the world will be found in the *Atlas of Ionograms* [A. H. Shapley, *Report UAG-10*, WDC-A for Solar-Terrestrial Physics, May 1970]

As there are many types of ionosondes in use and the characteristics of the ionosonde can change the appearance of the ionogram considerably, it has been thought best to keep ionograms from a given station or a given organization together. Comparison between different ionograms from a given station show clearly local effects due to interference, antenna characteristics, instrumental faults, degree of differentiation in use, etc.

Some organizations have provided a text commenting on their contribution which is most easily used when kept close to the ionograms discussed. The input has therefore been presented in two incompatible ways, with organization or network collections, but otherwise in order of descending geomagnetic latitude, first for the Northern Hemisphere and then for the Southern. There are also several discussions on particular phenomena, illustrated by special collections of ionograms.

To use the Supplement most effectively the Ionospheric Network Advisory Group (INAG) advises you to look first at the ionograms which are most nearly similar to those at your station and then to read the comments made on any given parameter from other stations. The figures, mainly ionograms, are listed by topic and station on pages ii to viii.

Some of our contributors have prepared their ionograms without having full access to the Second Edition or to the notes and comments in the INAG Bulletin and many have translation difficulties. After much thought, your Chairman decided that it would probably help all groups if their original reduction was shown with Editor's comments where they appeared not to agree with the best analysis. This means that these groups, and those who went to much trouble to pick out particularly difficult ionograms, will appear to need more correction than the remainder. INAG must stress that the presence of many comments and corrections does not imply that the analysis at the station was below standard -- samples of ionograms at the WDCs show that standards vary considerably from year-to-year and even the best stations have off-periods when their analysis is less than adequate. In selecting ionograms from the large number sent preference has been given to cases where a better analysis is possible or where a particular error is very widespread.

Some contributors have not provided full analyses of their ionograms and the work needed to do this was prohibitive for the Editor. There are, however, enough examples of full analyses to act as a guide, incompleteness in the remainder should not be regarded as permission to omit the missing parameters. Similarly height and frequency scales have been provided for a sample of the ionograms from each station. In some cases these had to be worked out by the Editor -- please remember to send scales when submitting ionograms for publication in the INAG Bulletin or for discussion by the INAG Chairman -- when the frequency scale is unusual or not steady, the deduction of the scale is difficult and often also not unique.

Owing to shortage of time, the majority of the comments have been made by your Editor without the advantage of discussion with other members of INAG. This implies that some of his comments may well be controversial. It is hoped that any reader disagreeing with the interpretation will inform INAG so that the problem can be publicly discussed in the INAG Bulletin and at INAG meetings. Your Editor apologizes for this which is entirely his fault.

The USSR contribution contains both examples of normal practice and examples to show special phenomena which deserve special treatment in the International Magnetosphere Study (IMS). Some of the proposals have not been discussed by INAG and are controversial. Further discussion will occur in the INAG Bulletin.

The Editor has freely amended contributions which appear incomplete where this is likely to be useful to the reader. Common cases include Es-r becoming Es-r and Es-k; Es-a becoming Es-a and Es-f or Es-a and Es-c with some examples of the use of numbers to indicate the number of multiple traces present. Most of the stations do this but some do not.

An attempt has been made to collect examples and sequences of ionograms to show abnormal F-layer structures as seen by as many types of ionosonde as possible. The monitoring of the major high latitude ridges and troughs by means of an ionosonde is an important contribution to the IMS. It is now clear that several important magnetospheric phenomena can be readily recognized by their effects on ionograms. Movements of the auroral oval can be monitored in this manner and there is a growing literature collating such observations with aircraft, satellite and rocket observations. These work both ways, establishing that the phenomena are correctly identified and then using the ionosonde data to show where particular magnetospheric boundaries were on occasions when detailed studies are being made.

At this time of writing, different groups are still using different words to describe the same phenomenon, e.g. ionogram patterns associated with the increased ionization on the poleward side of the plasmapause have been called 'replacement layer' phenomena by some groups, 'trough' phenomena by others and it is clear that at least part of the phenomena called FLIZ by the USSR refers to this condition.

There is also some difference in the words appropriate for the scientist and for those active in ionogram reduction. The former describes a complex phenomenon physically, the latter identifies each perturbation separately by its appearance on the ionogram and seldom has the training to make a physical interpretation. Thus Es-s (slant Es) can be generated by any mechanism which makes the E or Es layer sufficiently irregular to reflect signals back to the ionosonde over a considerable range of distances. The trace is highly characteristic and can thus be readily recognized and classified by an operator. Intense instability over a range of heights can cause the signal reflected to be weakened by many orders of magnitude -- the Lacuna phenomenon -- the trace suddenly disappears. A similar disappearance of the trace can be due to layer tilt (Handbook p. 78, 107). A scientist will note that, when intense instability is present, Es-s and weakened or missing traces are normal. He will make allowance for absorption weakening or hiding the Es-s or for weak traces to be visible rather than complete Lacuna and often gives the code name Slant Es Condition (SEC) or Lacuna to the combined phenomenon. SEC is the name adopted by J. K. Olesen who first described the phenomenon. For an operator, Lacuna means a missing trace, Es-s the presence of a slant-Es trace on the ionogram and his responsibility ends when he had adequately described what he saw on the ionogram. The name particle E has been widely adopted for the abnormal thick layer formed in the E region. While this is usually clearly associated with the particle activity, the definition (Handbook p. 17, 1.15 (Particle E-night E) is independent of the cause of the layer and does not imply that all particle E layers must be due to particle activity -- it is purely a question of whether the value of foE is abnormally large. A scientist would probably prefer the term Enhanced E to Particle E but the latter has been widely adopted, is more easily understood by operators and is appropriate for most, if not all, examples.

At the INAG meeting at Lima it was agreed that, for better clarity, Es types should be tabulated in capital letter form. This change has not been introduced in this Supplement. For tabulation purposes, Es-f, ℓ, c, h, a, r, k, s should become ES-F, L, C, H, A, R, K, S respectively as is the practice for computer-constructed tables. There appears to be no reason to change the more attractive lower case form for use in text, Es-a, etc. As more computers become available with both upper and lower case letters, it is likely that the original conventions foF2, foEs, etc, Es-a, etc., will again become popular except for manual tabulation of Es types where capitals have great advantages.

INAG at Lima decided to adopt spread-F typing with entry in the descriptive letter columns of fxI, foF2, h'F and recommends that this be used universally. With this convention the type letter takes precedence over the descriptive letter when doubt is present.

At Lima, F-layer nomenclature at high latitudes was discussed. It is desirable to keep clear three different phenomena:

(a) Trough-ridge phenomena characteristically changing in position,

(b) Polar cap enhancements characteristically changing in time,

(c) Exceptionally low F2-layer seen in solar minimum years.

It seems that some confusion has arisen because (a) and (b) can sometimes be superimposed and have then been discussed as if they were alternative forms of one phenomenon; some proposed names further confuse these distinctions.

For example the Irregular Zone identified by Pike in 1971 often contains the ridge (replacement layer) widely seen at night near the auroral zone and the F layer associated with this ridge is usually lower and thinner than the F layer adjoining it. Group retardation at the high-frequency end of the trace is not seen until the layer is overhead.

In its simplest form, phenomenon (b) is seen as a sudden replacement of the normal F layer in summer by a lower, thinner and denser structure which disappears as quickly as it appears leaving the normal F-layer traces relatively unaltered. A typical summer day ionogram is suddenly changed, the F1 trace, if present, disappears, and the F2 trace is low with a rapid change in retardation near foF2 corresponding to a remarkably thin layer sometimes only twice as thick as normal E. Particularly at the start and end considerable scatter and tilt can be present. Unlike phenomena (a), (b) can seldom be seen moving relative to the station and then only for a short time from when it is overhead. The jumps in foF2 reported have been large, usually several MHz.

In solar minimum years, h'F in the polar region often decreases slowly with time finally reaching E heights, e.g. about 110 km. Satellite ionograms confirm (at least for the few tests made) that there is no higher F structure present. The value of foF2 also varies slowly in time, the thickness of the layer is much greater than for particle E and decreases slowly as h'F decreases. This phenomenon is seen only in years of low solar activity.

INAG at Lima suggested that the name "Low F2-layer" should be confined to this phenomenon (c).

The characteristic feature of (b) is the enhancement of foF2 -- it is sometimes spread, sometimes not. For these reasons INAG proposed at Lima that phenomenon (b) be called Enhanced F. As there was not adequate representation of all high latitude groups at Lima, discussion on the name, definition and limits to be made for phenomenon (a) are left for further discussion in the INAG Bulletin. In the contributions to this UAG Report trough structure appears to be popular, with FLIZ (F2 layer of the Irregular Zone) a possible contender. When contrasted, thin and thick F-layer traces represent reflections from the ridge and trough when the trough is absent. The normal F layer and the denser thinner layer found at the boundary (see USSR and Olesen contributions and many individual examples) give similar patterns. Similarly some Es decisions have had to be left for further discussion.

The opportunity has been taken to update and collect the Handbook corrections as published in the INAG Bulletins so that they are readily available in one place. These are attached as an Appendix to this Supplement and include all decisions made at Lima. Where considerable changes have been made to the Handbook, replacement pages have been typed out which can be pasted onto the old page or, for those who have made it into a loose leaf book, used to replace obsolete pages. Any further changes will be announced in the INAG Bulletin.

Japanese, Russian and Spanish translations of this Supplement are planned to complement the corresponding translations of the Handbook. There does not appear to be sufficient demand to justify a French translation at present as French high latitude stations can use the English version without difficulty. Note that many of the changes in the English version of the Handbook have already been incorporated into its translations which were prepared after the Handbook had been widely circulated and discussed. Please make comments as soon as possible so that any changes needed in this Supplement can also be published quickly and incorporated into the translated versions.

A work of this nature can only be completed by unselfish work by many people. INAG wishes to thank all those who have helped to identify the problems of the station operators in interpreting ionograms either in discussions at INAG Meetings, in training symposia reported to INAG, by contributions to the INAG Bulletin or by letters to the INAG Chairman and Members. There are many problems for which suitable ionograms were not submitted. INAG asks you to select ionograms illustrating your difficulties for comment and publication in the INAG Bulletin and, in particular, asks those organizing training symposia to report on difficulties or problems where clarification is needed, preferably with illustrative ionograms. INAG wishes to make ionogram analysis problems a permanent regular feature of the INAG Bulletin and will use some of the ionograms not included in this UAG Report to start this feature.

Particular thanks are needed to those who have directly contributed to this Supplement. Wherever possible they have been identified in the introduction to their contribution -- people often do not read Introductions and Acknowledgements! Special mention must be made to Mr. Richard Smith of the Appleton Laboratory, Slough, Bucks, England, who examined all ionograms and comments included in this Report, identified a number of problems on particular ionograms which would interest operators and even on occasion successfully challenged an editorial comment. The INAG Secretary and Vice Chairman had the unenviable responsibility of translating the Editor's handwritten manuscript and notes into the form reproduced and the finished product would not have been possible without the large amount of detailed editing carried out by Helen E. Coffey and Raymond O. Conkright. The typing was done by Alice E. McRae and J. May Starr working from the Editor's manuscript as sorted and amended. This work was carried out at the World Data Center A for Solar-Terrestrial Physics and the Editor wishes to thank Mr. A. H. Shapley, Director, National Geophysical and Solar-Terrestrial Data Center, EDS, NOAA, for making this possible. Many users have expressed their appreciation of the Handbook and Atlas previously published through the good will of Mr. A. H. Shapley and the WDC-A and your Editor, acting as Chairman of INAG, feels that the operators and users of the World Vertical Sounding Network would wish him to convey these thanks to all concerned.

The Editor wishes to thank the Director of the British Antarctic Survey, Dr. R. Laws, for an allocation of time to be devoted to INAG problems and for his understanding and support in the special and large effort needed to produce this booklet.

On behalf of the Network, INAG wishes to thank its Members and Consultants who have contributed to this volume:

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SECTION 1. USSR STATIONS

Vostok, Mirny, Heiss, Dixon and Tixie

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General

This contribution has been prepared using data from the high-latitude network of vertical incidence sounding stations organized by the Arctic and Antarctic Research Institute (AARI) under the leadership of Dr. V. M. Driatsky. Geographic and geomagnetic positions of the stations with the indication of the type of ionosonde used are shown in Table 1. All times on the ionograms are local time. In accordance with the recommendation to add a special High Latitude Suppplement to the *URSI Handbook on Ionogram Interpretation and Reduction* the examples for this contribution were chosen with the aim:

1. To show the practice of ionogram reduction and interpretation, and

2. To show various types of ionograms for different latitudinal areas.

Table 1

LIST OF THE USSR STATIONS

| Station | Geographic Coordinates Lat. | E. Long. | Geomagnetic Coordinates Lat. | E. Long. | Invariant Latitude | Inclination or Dip | Time Zone | Ionosonde Type |
|---|---|---|---|---|---|---|---|---|
| Vostok | 76°26'S | 106°30'E | 89°.2S | 91°.4E | 84°.3S | 79°.5S | 105 E | AIS |
| Mirny | 66°33'S | 93°01'E | 77°.0S | 146°.8E | 76°.8S | 76°.7S | 90 E | AIS |
| Heiss | 80°37'N | 58°03'E | 71°.0N | 156°.0E | 73°.8N | 84°.3N | 45 E | AIS |
| Dixon | 73°30'N | 80°24'E | 63°.0N | 161°.4E | 67°.2N | 83°.5N | 105 E | AIS |
| Tixie | 71°34'N | 128°54'E | 60°.4N | 191°.0E | 65°.2N | 82°.6N | 135 E | C-3 |

Figures 1.1-1.24 are matched examples of quiet and disturbed ionosphere. The division into quiet and disturbed ionosphere is somewhat arbitrary for the high-latitude ionosphere and is mostly based on the magnetic activity. The quiet conditions cover periods with three-hourly Kp index not larger than 1. The ionograms show day and nighttime ionosphere effects. Table 2 gives the list of numerical values of the standard parameters taken from the ionograms of Figures 1.1-1.24.

It is interesting to note the appearance of Es type a in the near-pole area on the magnetically quiet day (Figure 1.7), low critical frequencies of F2-layer in the daytime at Heiss Island Station (Figure 1.13) and at night at Dixon Island Station (Figure 1.23) on a magnetically quiet day corresponding to the station position in the main trough [Muldrew, 1965], and the increase in scatter and the change from the normal structure in the ionosphere in magnetically disturbed periods: a) anomalous increase of critical frequencies under the conditions of dark ionosphere (Figures 1.14, 1.20, 1.24) (replacement layer -- Ed.); b) decrease of critical frequencies in the light periods (Figures 1.2, 1.4, 1.6); c) appearance of Lacuna in the daytime auroral zone (Figure 1.16), and d) disturbances of normal stratification of the ionosphere (tilts: Figures 1.2, 1.4, 1.6, 1.12; range-spread traces: Figure 1.10). The Lacuna Figures 1.25, 1.26, 1.27 and 1.28 may be compared with Figures 1.1, 1.11 and 1.17. Some examples of partial Lacuna are shown. A Lacuna sequence is shown in Figure 1.29. (More commonly the spread would disappear when the phenomenon disappeared. -- Ed.)

Figures 1.30, 1.32 and 1.34 are the examples of classical Es type a traces that completely correspond to the definition given in the Handbook.

Figures 1.34-1.38 are the examples of Es type a which are similar to other types of Es: Es-f and Es-r. That is why their interpretation is doubtful. (See Editor's Notes below.)

Table 2

LIST OF STANDARD PARAMETERS AVAILABLE FROM IONOGRAM FIGURES 1-24

| Name of station | Page No. | Fig. No. | fmin | | | F Region | | | | | | | | | | | | | | | E Region | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | fmin | qualif | descrip | foF2 | type spread | qualif | descrip | h'F2 | qualif | descrip | h'F | qualif | descrip | foF1 | qualif | descrip | foE | qualif | descrip | h'E | qualif | descrip | fbEs | foEs | qualif | descrip | h'Es | qualif | descrip | type Es | fxI | qualif | descrip |
| Vostok | 11 | 1.1 | 010 | | | 076 | F | | F | 370 | | | 220 | | | 460 | | | 320 | | H | 100 | | | G | | | G | | | G | | 090 | | |
| Vostok | 11 | 1.2 | 010 | | | | P | | F | 410 | U | F | 190 | | H | 470 | | H | 320 | | | 100 | | | G | | | G | | | G | | 070 | | |
| Mirny | 11 | 1.3 | 010 | | | 070 | X | | | 380 | | | 230 | | H | 490 | | H | 340 | U | R | 100 | | | G | | | G | | | G | | 078 | | X |
| Mirny | 11 | 1.4 | 010 | | | 056 | P | U | F | 460 | | F | 210 | | | 430 | | F | 320 | | | 100 | | | G | | | G | | | G | | 078 | | |
| Heiss | 11 | 1.5 | 010 | | | 060 | X | | | 390 | | | 210 | | H | 480 | | H | 320 | | | 100 | | | G | | | G | | | G | | 068 | | X |
| Heiss | 11 | 1.6 | 010 | | | 051 | P | U | F | 550 | | | 200 | | H | 420 | | H | 310 | | | 100 | | | G | | | G | | | G | | 075 | | |
| Vostok | 12 | 1.7 | 010 | | | 060 | X | | | 330 | | | 260 | | | 410 | | | | | A | | | A | 030 | 084 | J | X | 100 | | | a | 068 | | X |
| Vostok | 12 | 1.8 | 010 | | | | P | | N | | | N | | | N | | | N | 280 | E | A | | | A | G | 080 | J | X | 120 | | | ℓ,ℓ3 | 068 | | |
| Mirny | 12 | 1.9 | 010 | | | 060 | F | | F | | | | 270 | E | A | | | | | | A | | | A | 032 | 043 | J | X | 100 | | | ℓ4 | 070 | | |
| Mirny | 12 | 1.10 | 010 | | | | Q | | F | | | | 240 | | | | | | 120 | E | A | | | A | G | 092 | J | X | 110 | | | a | 060 | | |
| Heiss | 12 | 1.11 | 010 | | | 060 | M | U | F | 350 | | | 240 | | | 400 | | | 250 | | | 100 | | | G | | | G | | | G | | 072 | | |
| Heiss | 12 | 1.12 | 010 | | | 046 | P | | | 460 | | | 210 | | | 390 | | | 210 | | | 105 | | | G | | | G | | | G | | 065 | | |
| Heiss | 13 | 1.13 | 010 | | | 024 | F | U | F | | | | 250 | | | | | | | | | | | | E | | | E | | | E | | 036 | | |
| Heiss | 13 | 1.14 | 010 | | | | M | | F | | | | 240 | | | | | | 220 | | K | | | | 021 | 028 | J | X | 135 | | | r,k | 096 | | |
| Dixon | 13 | 1.15 | 010 | | | 052 | X | | | 440 | | | 220 | | | 400 | | | 330 | | R | 110 | | | G | | | G | | | G | | 070 | | X |
| Dixon | 13 | 1.16 | 010 | | | 062 | F | | F | 410 | | | | | Y | 390 | | Y | | | Y | 110 | | | G | | | G | | | G | | 075 | 0 | B |
| Dixon | 13 | 1.17 | 010 | | | 050 | X | | | | | | 240 | | Z | | | | | | E | | | E | E | | | E | | | E | | 058 | | X |
| Dixon | 13 | 1.18 | 013 | | | 059 | F | | F | | | | 240 | | | | | | 130 | E | B | | | | G | | | G | | | G | | 074 | | |
| Heiss | 14 | 1.19 | 010 | | | 029 | P | U | F | | | | 260 | E | A | | | | | | | | | | 017 | 025 | J | X | 100 | | | f3 | 052 | | |
| Heiss | 14 | 1.20 | 010 | | | 050 | P,F | | F | | | | 250 | | | | | | | | | | | | 019 | 040 | | | 100 | | | f3 | 105 | | |
| Dixon | 14 | 1.21 | 010 | | | 056 | F | | F | 350 | U | L | 330 | | | | | L | 270 | U | F | 130 | | | G | | | G | | | G | | 068 | 0 | B |
| Dixon | 14 | 1.22 | 010 | | | 046 | M | U | F | | | | 300 | | | | | | | | F | 110 | | | G | 044 | J | X | 120 | | | c | 062 | | |
| Dixon | 14 | 1.23 | 010 | | | 019 | F | | F | | | | 330 | E | E | | | | | | | | | | E | | | E | | | E | | 036 | 0 | B |
| Dixon | 14 | 1.24 | 010 | | | 046 | M | U | F | | | | 270 | | | | | | | | | | | | 016 | 030 | | | 120 | | | a | 062 | | |

Figures 1.31, 1.35, 1.36 and 1.38 are examples of Es similar to type r, but with increased scatter (Figures 1.31, 1.36, 1.38) or with a monotonic rise of the lower edge of the trace with the frequency increase (Figures 1.35, 1.36b).

Figures 1.36d and 1.37 are examples of Es-a similar to Es-f. This situation usually occurs with the increased absorption when scattered reflections typical of Es-a are absent.

Figure 1.48. Ionogram sequence is given illustrating assumed division of the sporadic ionization into particle E (Es-k) and Es-r depending on the rise at the lower frequency end of the F-layer trace. The classification is given in accordance with URSI Handbook recommendations (p. 69).

Figure 1.49. Figure 1.49h is defined as the regular E layer, since at this time critical frequencies of the E layer start to increase with the increase of the sun's altitude.

Figures 1.50-1.55 show different types of spread F traces according to the classification recommended by the URSI Handbook (section 12.34).

Editor's Notes: The following notes supplement those given by the authors and draw attention to some controversial points. Note that the reference quiet ionograms odd numbered Figures 1.1 to 1.23 can be used to match approximately to most of the other illustrative ionograms, Figure 1.25 onwards.

Clear z mode traces can be seen on Figures 1.1 and 1.2 (low frequency) and Figures 1.17 and 1.47 (high frequency end of F-trace).

Sporadic E gives much trouble. It is often overlooked that two types may be superimposed when a, k, r traces are present, e.g. a,f; c,k; r,k. When a or r types are superimposed on normal E or on particle E (Es-k), there is often a cusp at foE. This does not alter the ascription Es-a, Es-r. If however there is clear evidence of a normal type of Es (h,c,ℓ or f) superimposed on the a,r or k trace, its presence should be shown in the type table. Some examples: Figure 1.7 Es-a, f2; Figure 1.8 a, f3; Figure 1.9 f4; Figure 1.10 a; Figure 1.14 r,k with foE = 021UK; Figure 1.22 a,a (two distinct a structures); Figure 1.24 a; Figures 1.30, 1.32 and 1.33 show Es-a growing from a normal E trace (foE near 3.0 MHz).

Figure 1.32 has controversial features. The second order trace suggests this is an Es-c with Es-a superimposed but the intervals are not equal, showing tilt. I prefer Es-c with foEs about 083 and types c2,a. Figure 1.31 is a variant of Figure 4.29 (Handbook), center figure, f-min is low; there are no multiple traces so Es-a should be used. In Figure 1.33 Es-a characteristics dominate over r, thus a seems preferable. Figure 1.34 possibly Es-c present, but prefer just Es-a. Figure 1.35 is very difficult. There is a second order trace to about 6.0 MHz so this cannot be a pure Es-a. The first order trace is solid with weak scatter about it. I prefer Es type r,a (a for the blob near 4.0 MHz) with foEs from (ftEs) JA. Figure 1.36 shows multiple traces to above 6.0 MHz with weaker traces to 10 MHz. Prefer a,r2; r2 acceptable. Figure 1.37 trace tilted and shows some structure (Es type a). In the ionogram sequences retardation due to particle E can be seen so type k should be added. The presence of a z-mode trace in Figure 1.48b-e makes it fairly certain that the Es was really a particle E (Es-k) with the F-layer retardation missing because that layer was severely tilted. This is confirmed by lack of scatter near foEs. This sequence suggests INAG should alter rules so that when foEs = fbEs for an Es-r type trace, the trace is regarded as a particle E (Es-k) trace, even if retardation cannot be seen on the F trace.

Figure 1.48e shows enough retardation to justify Es-k according to existing rules. Note rapid changes of foF2 with time make it likely that the F layer is not horizontal. Figure 1.41 shows Es-k (particle E) confirmed by second order trace with little or no evidence of F-layer retardation.

f-plot conventions in Figures 1.57, 1.59, 1.61 and subsequent figures do not conform with rule 6.3g (p. 144 Handbook). This does not allow q-q to be used when a main trace is present, as in Figures 1.57, 1.61 or when it can confuse the representation of frequency spread, Figure 1.59. I do not see how this use could be accepted (see FLIZ below). Dots at fxI on sequence figures to identify fxI should be arrows (not at f-plot entry). There are also a number of cases where accurate values of foF2 are shown with a solid dot instead of an open circle and solid dots for satellite critical frequencies are not shown. The compilers wish to identify foF2 and fxI only, not to give a full f-plot interpretation in the Figure 1.64 illustrations.

Figure 1.65 d and e, the dashes below foF2 are not allowed as they confuse frequency spread interpretation. Presence of clear satellite traces should be shown by dots. (In practice if these appear only on one ionogram little is lost by omitting them but they often give a reasonable value for the critical frequency of an incipient replacement layer). Figure 1.65f,g,h is improper use of q-q according to rules, also Figure 1.68d,e. Note the proposal [INAG17, p. 6] to use P to denote polar spurs (Handbook type S) has been adopted in this contribution. This was confirmed at Lima.

## FLIZ Phenomenon

Editor's Notes: It is not clear at present whether the FLIZ phenomenon described below is identical with the "replacement" layer (trough and ridge phenomenon) or includes other phenomena also, e.g. Figures 1.57, 1.59, 1.61, 1.63 could be examples from trough sequences and Figure 1.65 is similar in form to a conventional trough-ridge sequence (e.g. Figure 1.66) but at a much earlier time than is usual. The characteristics given could apply directly to trough-ridge phenomena, e.g. Figures 3.39c,d in Handbook. However, pending clarification in the INAG Bulletin, the word FLIZ is used to identify the phenomenon described below. The text and figures have been included as proposed by the authors so as to start informed discussion and to make clear exactly what type of ionograms are under discussion. The problem was discussed at Lima and it was felt that further discussion was needed in the INAG Bulletin to produce an agreed consensus of opinion. This opinion was strongly supported by INAG at Lima.

Operators should not be asked to identify physical phenomena but only to describe ionograms as seen. I feel that the proposed use of q to identify FLIZ conditions on f-plots will not be practical -- it blurs the distinction between frequency spread and range spread on f-plots. When frequency spread is present it must have priority. This was strongly supported by INAG at Lima. For scientific purposes the simultaneous presence of range spread can be identified on an F-type table (letter Q) or by descriptive letter Q with the h'F entry. The proposed usage does not conform with Handbook rule 6.3g, p. 144 which most operators find simple and convenient. Note for scientific purposes this type of condition can be readily recognized in tabular data by the difference foF2 and fxI by the jump in values of foF2 and by the proper use of h'F-Q. I believe that a proper description of the morphology could be obtained using existing rules if all stations obeyed them carefully, in particular by recording fxI and using the q convention on f-plots according to rule 6.3g. It is very important that such phenomena are identified for purposes of the International Magnetosphere Study (IMS).

Figures 1.56-1.65. At a number of high latitude stations F-region traces are observed which cannot be interpreted as oblique traces but at the same time differ from the usual ones which correspond to a relatively thick F2 layer. Preliminary studies of such traces revealed their following characteristics [Whatman, 1949; Hill *et al.*, 1959; Besprozvannaya *et al.*, 1967; Wakai, 1960]:

a. They often lack a well-defined group retardation at the high frequency end of the trace.

b. They appear sporadically (on one day for several hours, on others they would not occur at all).

c. The top frequencies can vary with the gain.

d. The traces may be either blanketing or transparent.

e. Critical frequencies, as a rule, are much higher than those usually observed reflected from the F region for corresponding normal conditions.

In order to better understand the origin and spatial/temporal distribution of these traces it is necessary to interpret them similarly at all the stations of the high-latitude network. Figures 1.56-1.65 show the examples of ionograms with two different reflecting structures and the transitions from one to another. In accordance with the terminology proposed by Pike [1971], the reflections from a "thin" F2 layer with a poorly-defined group retardation were identified as F2 layer of the Irregular Zone (FLIZ). The AARI practice is that when FLIZ traces result from an overhead phenomenon and the traces from the normal "thick" F2 layer are absent, the foF2 parameter is not scaled, only descriptive letter Q is used (Figures 1.57, 1.59, 1.61, 1.63); parameter fxI with the entry spread F classification Q is used. When the diffusion is large, f-plot shows the whole range of FLIZ traces.

## Determination of Position of Plasma Trough Structures

Figures 1.66-1.69. The study of the morphology of the spatial distribution of ionization by satellite and ground-based data has shown that the synoptic F2-layer model can be expressed by a circumpolar zone of enhanced electronic density (plasma ring), bounded at the equator by a main "trough" and at the pole by a polar cavity [Thomas and Andrews model, 1969]. The equatorial boundary of the plasma ring crosses the night side depending on the magnetic activity at the corrected geomagnetic latitudes 65-69° and at the daytime side at 75-80° latitudes.

Figures 1.66 and 1.67 illustrate conditions in the nighttime ionosphere and Figures 1.68 and 1.69 in the daytime ionosphere.

Figure 1.66 shows the ionogram sequence from Dixon Station (invariant latitude = 67.2°N) on a magnetically quiet day (Kp does not exceed 0+). In this period the equatorial wall of the plasma ring passes northward of Dixon Station and the station is in the main trough with characteristic low critical frequencies of F2 layer (∿ 2MHz). Traces at h = 340-350 km are interpreted as oblique traces from the northern polar boundary of the trough. In this case we can calculate the position of the equatorial boundary of the plasma ring which appears to be located at a distance of 2° from Dixon Island.

Figure 1.67 shows the ionogram sequence corresponding to the conditions of moderate magnetic activity (K values = 2+), with the equatorial boundary of the plasma ring crossing to the south of Dixon Island. The zone of enhanced electron density of F2 layer moves over the station. The observed values of critical F2-layer frequencies are two to three times larger than foF2 on a magnetically quiet day.

Figures 1.68 and 1.69 demonstrate conditions in the high-latitude daytime ionosphere. The comparison of the airborne ionospheric soundings with those obtained by Alouette Satellite allowed Dr. Pike [1971] to conclude that the daytime position of the plasma ring coincides with the FLIZ zone.

Figure 1.68 shows ionogram sequence from Vostok Station, Antarctica about local geomagnetic noon (1900 LT). It is interesting to note the disappearance of the normal summer structure (separate F1 and F2 layers) at 1945 and 2000 LT when the station is located in the FLIZ zone. The ionogram sequence in Figure 1.69 is interesting, since at about that period only oblique traces from FLIZ zone were observed (polar spurs).

Bearing in mind the fact that the height of F2 layer in the irregular zone at vertical incidence is 250 km (See Figure 1.68d), we can estimate that during the period in question the FLIZ zone was at a distance of about 3° from Vostok Station. It seems that the boundary of the plasma ring was determined in this case.

(A further discussion of these phenomena will be found on page 111 and in the Introduction.)

## REFERENCES


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| BESPROZVANNAYA, A. S., G. N. GORBUSHINA, and T. I. SHCHUKA | 1967 | On the Practice of High-Latitude Ionogram Interpretation and Reduction, The Arctic and Antarctic Research Institute, Leningrad, USSR. |
| HILL, G. and R. PENNDORF | 1959 | Single Station and Synoptic Analysis of Ionosphere Data for the Arctic, *Sci. Rep. 3*, AVCO Corp., AD217316, PB143206. |
| MULDREW, D. B. | 1965 | F-layer Ionization Troughs Deduced from Alouette Data, *J. Geophys. Res., 70,* 2635-2650. |
| PIKE, C. P. | 1971 | A Latitudinal Survey of the Daytime Polar F Layer, *J. Geophys. Res., 76,* 7745-7753. |
| THOMAS, J. O. and M. K. ANDREWS | 1969 | The Trans-polar Exospheric Plasma, 3: A Unified Picture, *Planet. Space Sci., 17,* 433-446. |
| WAKAI, N. | 1960 | Seasonal Variation of foF2 and Abnormal Ionization in F Region at Syowa Base, Antarctica, *Antarctic Record, 11,* 195-199. |
| WHATMAN, A. B. | 1949 | Observations Made on the Ionosphere During Operation in Spitzbergen in 1942-43, *Proc. Phys. Soc. London, 62,* 307-320. |