# MESOSCALE ASSESSMENTS OF CLOUD AND RAINFALL

# OVER THE BRITISH ISLES

ERTS Follow-on Programme Study No. 2962A



Quarterly Report

by

Eric C. Barrett
M.Sc., Ph.D., F.R.G.S., F.R.Met.S.. F.B.I.S.,

and

Colin K. Grant
B.Sc.

2962A

Supported by the U.K. Department of Industry,
Monsanto House, 10-18, Victoria Street, London, SW1H 0NQ



December, 1975.

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## I. INTRODUCTION

This investigation began as a proposal for studies of cloud and associated rainfall over south-western England and the western sea approaches within the limits defined by latitudes 49° and 55°N and longitudes 0° and 20°W, associated with other proposals from the University of Bristol related to the Sabrina Project. This is an inter-disciplinary study of the estuary of the River Severn and its environs, considering many aspects of its natural science independent of, and affected by, the activities of man. Since the related proposals dealt with terrestrial and marine phenomena and their distributions through space and time, a complementary programme of work was designed to examine atmospheric variables which might have a bearing upon them.

In the event, the related proposals were not accepted by N.A.S.A., leaving the proposed study of cloud and rainfall to stand alone as an independent investigation. Modifications were clearly necessary to the study plan. Of these, the most fundamental was the re-drawing of the area involved. Cut free from the need to focus attention on south-western England, it was decided to include the whole of the British Isles in the revised investigation so that results of more general significance to the United Kingdom of Great Britain and Northern Ireland and the Irish Republic might be obtained. This had less of an effect upon the required photo-coverage than at first it might be thought likely to have had. In the original plan a rainfall forecasting component was included, for which data coverage well beyond the coastline of south-western England would have been required (cf. the rainfall forecasting method described by Barrett (1973) based on weather satellite data). Negotiations with N.A.S.A. on new limits for the revised study region resulted in the allotment of the co-ordinates listed in Table 1.

TABLE 1

Effective co-ordinates for the revised study plan (clockwise order)

| Corner | Latitude | Longitude |
|---|---|---|
| North-west | 60°00'N | 12°30'W |
| North-east | 60°00'N | 2°30'E |
| South-east | 49°00'N | 2°30'E |
| South-west | 49°00'N | 12°30'W |

This conclusion is advantageous from the point of view of the cloud analyses planned for the revised study, but very disadvantageous from that of examining cloud/rainfall/river flow relationships, excepting possibly on a rather local basis.

One further type of problem must be outlined owing to its considerable - and continuing - influence on the study plan. No suggestion was made before Landsat 2 went into operation that the data coverage for the region indicated by the co-ordinates in Table 1 would be other than that described by N.A.S.A. in its Data Profile (Attachment B) to the Principal Investigator, namely from March 1975 - February 1976 for up to and including 100% cloud cover. Although it was appreciated that the "best efforts to provide the Principal Investigator with the ERTS data described in the data profile" (N.A.S.A.,1974) recognised that some short-fall might occur, especially if technical problems were encountered, so far reality has proved to be unexpectedly disappointing. By the time of writing (December 8th, 1975) a total of 180 frames have been received, covering the period from the launching of Landsat 2 on 22 January, 1975 to the end of July. This compares poorly with the anticipated maximum number of frames which might have been expected had there been a full and complete coverage in space and time, which we estimate to be about 560. This actual coverage does not compare well with that in some other regions (e.g. U.S.A. and southern Canada; the Middle East; eastern Siberia and China), and has had implications for the structuring of our programme of work, especially insofar as the order of work to be done, the acquisition of in situ ("ground truth") data, and the identification of realistic goals are concerned. Some discussion of these points is inherent in the sections that follow.

## II. TECHNIQUES

For the present, attention is being focussed on the first of the detailed objectives outlined in the Statement of Work (Attachment A, N.A.S.A., 1974). This seeks:

> "To develop a unifying paradigm of cloud statistics from Landsat, Noaa and conventional sources for encyclopaedic purposes, and for use in the planning of future programmes of Earth Resources studies from aircraft and satellites".

Given that some time elapses before weather satellite image data are available from the U.S.A. in a form suitable for easy use (as computer-rectified, brightness-normalized products) our immediate concern is with the acquisition of appropriate conventional weather observations, and the development of means of comparison between them and the Landsat images. Table 2 lists the frames received by early December. Fig.1(a - g) illustrates their coverage by individual Landsat cycles. It is clear that this is both fragmentary and variable from cycle to cycle. Although this is not necessarily a significant problem so far as the compilation of worthwhile populations of cloud statistics on a non-location specific basis is concerned, the broken coverage through space and time may limit the possibility of other than case studies for specific areas.

Table 2 also indicates the time of Landsat imagery for each frame. The range of times across the rather large expanse of the study region is from 10.00 - 11.30 G.M.T. Fig. 2 illustrates the detailed distribution of the imagery through time. In view of the large area involved, and the uncertainty of obtaining Landsat cover on specified dates, the collection of ground truth information has been based on existing and operational data sources. The Meteorological Office of the United Kingdom maintains 98 weather observing stations in the British Isles (with a further 12 in the Republic of Ireland) of which weather records are compiled on an hourly basis and their geographic distribution is illustrated by Fig. 3. It is from these that our basic ground truth file is being compiled. It is recognised that some time difference will occur usually between the local time of Landsat imaging and the time of weather observation. This difference ranges from about $\pm$ 50 mins. when the 1100 G.M.T. conventional observations are invoked.

The Meteorological Office was consulted on the possibility of their Observers making additional observations of the more significant parameters (cloud type and amount, visibility and rainfall) or rearranging their observing schedules on pre-determined days to afford a better coincidence with the time of Landsat imagery. Such possibilities were ruled out by the Meteorological Office

TABLE 2

LANDSAT 2 COVERAGE OF THE BRITISH ISLES
TABULATION OF INDIVIDUAL FRAMES

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT. No. | FRAME Nos 4 | FRAME Nos 5 | FRAME Nos 6 | FRAME Nos 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|---|---|
| 2068 | 31 MARCH | 0944 | 010 | 031 | 052 | 073 | 10:49:10 | N60:07 | W003:20 |
| " | " | " | 011 | 032 | 053 | 074 | 10:49:40 | N58:44 | W004:19 |
| " | " | " | 012 | 033 | 054 | 075 | 10:50:00 | N57:21 | W005:14 |
| " | " | " | 013 | 034 | 055 | 076 | 10:50:30 | N55:57 | W006:06 |
| " | " | " | 014 | 035 | 056 | 077 | 10:50:50 | N54:33 | W006:55 |
| " | " | " | 015 | 036 | 057 | 078 | 10:51:20 | N53:09 | W007:41 |
| " | " | " | 016 | 037 | 058 | 079 | 10:51:40 | N51:44 | W008:24 |
| " | " | " | 017 | 038 | 059 | 080 | 10:52:10 | N50:20 | W009:05 |
| " | " | " | 018 | 039 | 060 | 081 | 10:52:30 | N48:55 | W009:44 |
| 2069 | 1 APRIL | 0958 | 165 | 180 | 195 | 210 | 10:55:00 | N60:09 | W004:46 |
| | | | 166 | 181 | 196 | 211 | 10:55:20 | N58:46 | W005:45 |
| | | | 167 | 182 | 197 | 212 | 10:55:50 | N57:23 | W006:40 |
| | | | 168 | 183 | 198 | 213 | 10:56:10 | N55:59 | W007:32 |
| | | | 169 | 184 | 199 | 214 | 10:56:40 | N54:35 | W008:20 |
| | | | 170 | 185 | 200 | 215 | 10:57:00 | N53:11 | W009:06 |
| | | | 171 | 186 | 201 | 216 | 10:57:30 | N51:46 | W009:49 |
| | | | 173 | 198 | 223 | 248 | 10:57:50 | N50:22 | W010:30 |
| | | | 174 | 199 | 224 | 249 | 10:58:20 | N48:57 | W011:09 |
| 2070 | 2 APRIL | 0972 | 062 | 082 | 102 | 122 | 11:00:40 | N60:07 | W006:13 |
| | | | 063 | 083 | 103 | 123 | 11:01:10 | N58:45 | W007:12 |
| | | | 064 | 084 | 104 | 124 | 11:01:30 | N57:21 | W008:07 |
| | | | 065 | 085 | 105 | 125 | 11:02:00 | N55:57 | W008:59 |
| | | | 066 | 086 | 106 | 126 | 11:02:20 | N54:34 | W009:47 |
| | | | 067 | 087 | 107 | 127 | 11:02:50 | N53:09 | W010:33 |
| | | | 068 | 088 | 108 | 128 | 11:03:10 | N51:45 | W011:16 |
| | | | 145 | 176 | 207 | 238 | 11:03:40 | N50:20 | W011:57 |
| | | | 146 | 177 | 208 | 239 | 11:04:00 | N48:55 | W012:36 |

| DAY SINCE LAUNCH | DATE (1975) | ORBIT No. | FRAME Nos. 4 / 6 | FRAME Nos. 5 / 7 | TIME H: M: S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2121 | 23 MAY | 1682 | 018 / 066 | 042 / 090 | 10:45:40 | N51:31 | W007:10 |
| " | " | " | 019 / 067 | 043 / 091 | 10:46:10 | N50:07 | W007:50 |
| " | " | " | 020 / 068 | 044 / 092 | 10:46:30 | N48:43 | W008:28 |
| 2122 | 24 MAY | 1697 | 134 / 158 | 146 / 170 | 10:49:20 | N58:29 | W004:36 |
| " | " | " | 135 / 159 | 147 / 171 | 10:49:50 | N57:06 | W005:30 |
| " | " | " | 136 / 160 | 148 / 172 | 10:50:10 | N55:43 | W006:20 |
| " | " | " | 137 / 161 | 149 / 173 | 10:50:40 | N54:19 | W007:08 |
| " | " | " | 138 / 162 | 150 / 174 | 10:51:00 | N52:55 | W007:53 |
| " | " | " | 139 / 163 | 151 / 175 | 10:51:30 | N51:30 | W008:36 |
| " | " | " | 140 / 164 | 152 / 176 | 10:51:50 | N50:06 | W009:16 |
| " | " | " | 141 / 165 | 153 / 177 | 10:52:20 | N48:41 | W009:55 |
| 2126 | 28 MAY | 1753 | 138 / 196 | 167 / 225 | 11:12:00 | N59:48 | W009:27 |
| " | " | " | 139 / 197 | 168 / 226 | 11:12:30 | N58:26 | W010:25 |
| " | " | " | 140 / 198 | 169 / 227 | 11:12:50 | N57:02 | W011:18 |
| " | " | " | 141 / 199 | 170 / 228 | 11:13:20 | N55:40 | W012:09 |
| " | " | " | 142 / 200 | 171 / 229 | 11:13:40 | N54:17 | W012:56 |
| " | " | " | 143 / 201 | 172 / 230 | 11:14:10 | N52:52 | W013:41 |
| 2128 | 30 MAY | 1781 | 051 / 131 | 091 / 171 | 11:23:30 | N59:45 | W012:23 |
| | | | 052 / 132 | 092 / 172 | 11:24:00 | N58:22 | W013:20 |
| 2131 | 2 JUNE | 1822 | 009 / 055 | 032 / 078 | 10:00:30 | N49:57 | E003:28 |
| " | " | " | 010 / 056 | 033 / 079 | 10:00:50 | N48:33 | E002:50 |
| 2132 | 3 JUNE | 1836 | 195 / 241 | 218 / 264 | 10:05:00 | N54:07 | E004:08 |
| " | " | " | 196 / 242 | 219 / 265 | 10:05:20 | N52:43 | E003:24 |
| " | " | " | 197 / 243 | 220 / 266 | 10:05:50 | N51:19 | E002:42 |

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | Frame Nos. 4 / 6 | Frame Nos. 5 / 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2140 | 11 JUNE | 1948 | 004 / 038 | 021 / 055 | 10:51:20 | N52:53 | W008:01 |
| " | " | " | 005 / 039 | 022 / 056 | 10:51:50 | N51:29 | W008:43 |
| " | " | " | 006 / 040 | 023 / 057 | 10:52:10 | N50:05 | W009:23 |
| " | " | " | 007 / 041 | 024 / 058 | 10:52:40 | N48:40 | W010:01 |
| 2142 | 13 JUNE | 1976 | 065 / 099 | 082 / 116 | 11:02:30 | N54:15 | W010:12 |
| " | " | " | 066 / 100 | 083 / 117 | 11:02:50 | N52:51 | W010:57 |
| " | " | " | 067 / 101 | 084 / 118 | 11:03:20 | N51:27 | W011:39 |
| " | " | " | 068 / 102 | 085 / 119 | 11:03:40 | N50:03 | W012:19 |
| " | " | " | 069 / 103 | 086 / 120 | 11:04:10 | N48:38 | W012:57 |
| 2145 | 16 JUNE | 2018 | 056 / 080 | 068 / 092 | 11:18:00 | N59:45 | W011:03 |
| | " | " | 057 / 081 | 069 / 093 | 11:18:30 | N58:23 | W012:00 |
| | " | " | 058 / 082 | 070 / 094 | 11:18:50 | N57:00 | W012:54 |
| | " | " | 059 / 083 | 071 / 095 | 11:19:20 | N55:37 | W013:44 |
| 2150 | 21 JUNE | 2087 | 103 / 153 | 128 / 178 | 11:05:30 | N52:54 | E003:27 |
| " | " | " | 104 / 154 | 129 / 179 | 11:06:00 | N51:30 | E002:45 |
| 2151 | 22 JUNE | 2101 | 012 / 044 | 028 / 060 | 10:12:10 | N50:06 | E000:37 |
| 2152 | 23 JUNE | 2115 | 005 / 075 | 040 / 110 | 10:15:20 | N58:26 | E003:49 |
| " | " | " | 006 / 076 | 041 / 111 | 10:15:50 | N57:03 | E002:55 |
| " | " | " | 007 / 077 | 042 / 112 | 10:16:10 | N55:40 | E002:05 |
| " | " | " | 008 / 078 | 043 / 113 | 10:16:40 | N54:16 | E001:18 |
| " | " | " | 009 / 079 | 044 / 114 | 10:17:00 | N52:52 | E000:33 |
| " | " | " | 011 / 081 | 046 / 116 | 10:17:50 | N50:04 | W000:50 |
| " | " | " | 012 / 082 | 047 / 117 | 10:18:20 | N48:39 | W001:28 |

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | FRAME Nos. 4 / 6 | FRAME Nos. 5 / 7 | TIME H:M:S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2173 | 14 JULY | 2408 | 157 / 195 | 176 / 214 | 10:32:50 | N57:19 | W001:13 |
| " | " | " | 158 / 196 | 177 / 215 | 10:33:10 | N55:55 | W002:04 |
| " | " | " | 159 / 197 | 178 / 216 | 10:33:40 | N54:32 | W002:52 |
| " | " | " | 160 / 198 | 179 / 217 | 10:34:00 | N53:07 | W003:37 |
| " | " | " | 161 / 199 | 180 / 218 | 10:34:30 | N51:43 | W004:20 |
| " | " | " | 162 / 200 | 181 / 219 | 10:34:50 | N50:19 | W005:01 |
| " | " | " | 163 / 201 | 182 / 220 | 10:35:20 | N48:54 | W005:40 |
| 2174 | 15 JULY | 2422 | 096 / 134 | 115 / 153 | 10:37:40 | N60:03 | W000:46 |
| " | " | " | 097 / 135 | 116 / 154 | 10:38:00 | N58:41 | W001:44 |
| " | " | " | 098 / 136 | 117 / 155 | 10:38:30 | N57:17 | W002:39 |
| " | " | " | 099 / 137 | 118 / 156 | 10:38:50 | N55:54 | W003:30 |
| " | " | " | 101 / 139 | 120 / 158 | 10:39:40 | N53:06 | W005:03 |
| " | " | " | 102 / 140 | 121 / 159 | 10:40:10 | N51:41 | W005:46 |
| " | " | " | 103 / 141 | 122 / 160 | 10:40:30 | N50:17 | W006:27 |
| " | " | " | 104 / 142 | 123 / 161 | 10:41:00 | N48:52 | W007:06 |
| 2175 | 16 JULY | 2436 | 011 / 063 | 037 / 089 | 10:43:20 | N60:07 | W002:11 |
| " | " | " | 012 / 064 | 038 / 090 | 10:43:50 | N58:45 | W003:10 |
| " | " | " | 013 / 065 | 039 / 091 | 10:44:10 | N57:21 | W004:05 |
| " | " | " | 014 / 066 | 040 / 092 | 10:44:40 | N55:57 | W004:56 |
| " | " | " | 015 / 067 | 041 / 093 | 10:45:00 | N54:34 | W005:44 |
| " | " | " | 016 / 068 | 042 / 094 | 10:45:30 | N53:10 | W006:29 |
| " | " | " | 057 / 111 | 084 / 138 | 10:46:20 | N50:21 | W007:52 |
| 2176 | 17 JULY | 2450 | 013 / 071 | 042 / 100 | 10:49:10 | N60:05 | W003:37 |
| " | " | " | 014 / 072 | 043 / 101 | 10:49:30 | N58:43 | W004:36 |
| " | " | " | 015 / 073 | 044 / 102 | 10:50:00 | N57:19 | W005:30 |
| " | " | " | 016 / 074 | 045 / 103 | 10:50:20 | N55:55 | W006:22 |

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | FRAME Nos 4 / 6 | FRAME Nos 5 / 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2071 | 3 APRIL | 0986 | 053 / 081 | 067 / 095 | 11 : 09 : 20 | N 50 : 19 | W 013 : 25 |
| 2075 | 7 APRIL | 1042 | 115 / 145 | 130 / 160 | 11 : 29 : 20 | N 60 : 06 | W 013 : 33 |
| 2078 | 10 APRIL | 1083 | 001 / 031 | 016 / 046 | 10 : 05 : 50 | N 51 : 35 | E 002 : 50 |
| " | " | " | 002 / 032 | 017 / 047 | 10 : 06 : 20 | N 50 : 10 | E 002 : 09 |
| " | " | " | 003 / 033 | 018 / 048 | 10 : 06 : 40 | N 48 : 46 | E 001 : 31 |
| 2081 | 13 APRIL | 1125 | 009 / 049 | 029 / 069 | 10 : 20 : 40 | N 59 : 52 | E 003 : 28 |
| " | " | " | 010 / 050 | 030 / 070 | 10 : 21 : 00 | N 58 : 29 | E 002 : 30 |
| " | " | " | 011 / 051 | 031 / 071 | 10 : 21 : 30 | N 57 : 06 | E 001 : 36 |
| " | " | " | 012 / 052 | 032 / 072 | 10 : 21 : 50 | N 55 : 42 | E 000 : 45 |
| " | " | " | 013 / 053 | 033 / 073 | 10 : 22 : 20 | N 54 : 18 | W 000 : 03 |
| " | " | " | 014 / 054 | 034 / 074 | 10 : 22 : 40 | N 52 : 53 | W 000 : 49 |
| " | " | " | 015 / 055 | 035 / 075 | 10 : 23 : 10 | N 51 : 29 | W 001 : 31 |
| 2120 | 22 MAY | 1669 | 137 / 173 | 155 / 191 | 10 : 37 : 20 | N 60 : 10 | W 008 : 32 |
| " | " | " | 138 / 174 | 156 / 192 | 10 : 37 : 50 | N 58 : 48 | W 001 : 31 |
| " | " | " | 139 / 175 | 157 / 193 | 10 : 38 : 10 | N 57 : 25 | W 002 : 26 |
| " | " | " | 140 / 176 | 158 / 194 | 10 : 38 : 40 | N 56 : 01 | W 003 : 18 |
| " | " | " | 141 / 177 | 159 / 195 | 10 : 39 : 00 | N 54 : 37 | W 004 : 06 |
| " | " | " | 142 / 178 | 160 / 196 | 10 : 39 : 30 | N 53 : 13 | W 004 : 51 |
| " | " | " | 143 / 179 | 161 / 197 | 10 : 39 : 50 | N 51 : 48 | W 005 : 34 |
| " | " | " | 144 / 180 | 162 / 198 | 10 : 40 : 20 | N 50 : 25 | W 006 : 14 |
| " | " | " | 145 / 181 | 163 / 199 | 10 : 40 : 40 | N 49 : 01 | W 006 : 53 |
| 2121 | 23 MAY | 1682 | 015 / 063 | 039 / 087 | 10 : 44 : 30 | N 55 : 43 | W 004 : 55 |
| " | " | " | 016 / 064 | 040 / 088 | 10 : 44 : 50 | N 54 : 19 | W 005 : 42 |
| " | " | " | 017 / 065 | 041 / 089 | 10 : 45 : 20 | N 52 : 55 | W 006 : 27 |

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| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | FRAME Nos 4 / 6 | FRAME Nos 5 / 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2132 | 3 JUNE | 1836 | 198 / 244 | 221 / 267 | 10:06:10 | N49:55 | E002:02 |
| " | " | " | 199 / 245 | 222 / 268 | 10:06:40 | N48:30 | E001:23 |
| 2133 | 4 JUNE | 1850 | 011 / 045 | 028 / 062 | 10:11:30 | N51:19 | E001:16 |
| " | " | " | 012 / 046 | 029 / 063 | 10:12:00 | N49:55 | E000:37 |
| " | " | " | 013 / 047 | 030 / 064 | 10:12:20 | N48:31 | W000:02 |
| 2135 | 6 JUNE | 1878 | 011 / 063 | 037 / 089 | 10:23:30 | N49:59 | W002:15 |
| " | " | " | 012 / 064 | 038 / 090 | 10:23:50 | N48:34 | W002:53 |
| 2137 | 8 JUNE | 1906 | 001 / 055 | 028 / 082 | 10:34:10 | N52:47 | W003:44 |
| " | " | " | 002 / 056 | 029 / 083 | 10:34:30 | N51:23 | W004:26 |
| " | " | " | 003 / 057 | 030 / 084 | 10:35:00 | N49:59 | W005:07 |
| " | " | " | 004 / 058 | 031 / 085 | 10:35:20 | N48:34 | W005:45 |
| " | " | " | 013 / 067 | 040 / 094 | 10:32:50 | N56:58 | W001:23 |
| " | " | " | 014 / 068 | 041 / 095 | 10:33:20 | N55:34 | W002:13 |
| " | " | " | 015 / 069 | 042 / 096 | 10:33:40 | N54:11 | W003:0[illegible] |
| 2139 | 10 JUNE | 1934 | 149 / 193 | 171 / 215 | 10:43:30 | N59:40 | W002:30 |
| " | " | " | 150 / 194 | 172 / 216 | 10:44:00 | N58:17 | W003:27 |
| " | " | " | 151 / 195 | 173 / 217 | 10:44:?? | ? ? | ? ? |
| " | " | " | 152 / 196 | 174 / 218 | 10:44:50 | N55:30 | W005:09 |
| " | " | " | 153 / 197 | 175 / 219 | 10:45:10 | N54:07 | W005:55 |
| " | " | " | 155 / 199 | 177 / 221 | 10:46:30 | N49:54 | W008:01 |
| " | " | " | 156 / 200 | 178 / 222 | 10:46:50 | N48:30 | W008:39 |
| 2140 | 11 JUNE | 1948 | 001 / 035 | 018 / 052 | 10:50:10 | N57:04 | W005:38 |
| " | " | " | 002 / 036 | 019 / 053 | 10:50:30 | N55:40 | W006:29 |
| " | " | " | 003 / 037 | 020 / 054 | 10:51:10 | N54:17 | W007:16 |

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | FRAME Nos. 4 / 6 | FRAME Nos. 5 / 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2155 | 26 JUNE | 2157 | 103 / 135 | 119 / 151 | 10:32:10 | N59:54 | E000:31 |
| " | " | " | 104 / 136 | 120 / 152 | 10:32:30 | N58:32 | W000:26 |
| 2157 | 28 JUNE | 2185 | 166 / 202 | 184 / 220 | 10:44:00 | N58:33 | W003:19 |
| 2160 | 1 JULY | 2227 | 178 / 240 | 209 / 271 | 11:00:50 | N59:53 | W006:38 |
| " | " | " | 179 / 241 | 210 / 272 | 11:01:10 | N58:31 | W007:36 |
| " | " | " | 182 / 244 | 213 / 275 | 11:02:50 | N52:56 | W010:53 |
| 2161 | 2 JULY | 2241 | 001 / 041 | 021 / 061 | 11:09:30 | N50:11 | W013:40 |
| 2163 | 4 JULY | 2269 | 200 / 242 | 221 / 263 | 11:18:00 | N59:57 | W010:53 |
| " | " | " | 201 / 243 | 222 / 264 | 11:18:20 | N58:34 | W011:51 |
| " | " | " | 202 / 244 | 223 / 265 | 11:18:50 | N57:10 | W012:46 |
| 2164 | 5 JULY | 2283 | 214 / 238 | 226 / 250 | 11:23:40 | N59:56 | W012:22 |
| " | " | " | 215 / 239 | 227 / 251 | 11:24:10 | N58:33 | W013:20 |
| 2172 | 13 JULY | 2394 | 012 / 050 | 031 / 069 | 10:26:10 | N60:04 | E002:05 |
| " | " | " | 013 / 051 | 032 / 070 | 10:26:40 | N58:41 | E001:07 |
| " | " | " | 014 / 052 | 033 / 071 | 10:27:00 | N57:18 | E000:12 |
| " | " | " | 015 / 053 | 034 / 073 | 10:27:30 | N55:54 | W000:39 |
| " | " | " | 016 / 054 | 035 / 074 | 10:27:50 | N54:30 | W001:27 |
| " | " | " | 017 / 055 | 036 / 075 | 10:28:20 | N53:06 | W002:13 |
| " | " | " | 018 / 056 | 037 / 076 | 10:28:40 | N51:42 | W002:56 |
| " | " | " | 019 / 057 | 038 / 077 | 10:29:10 | N50:17 | W003:36 |
| 2173 | 14 JULY | 2408 | 155 / 193 | 174 / 212 | 10:32:00 | N60:05 | E000:40 |
| " | " | " | 156 / 194 | 175 / 213 | 10:32:20 | N58:42 | W000:19 |

| DAY (SINCE LAUNCH) | DATE (1975) | ORBIT No. | FRAME Nos. 4 / 6 | FRAME Nos. 5 / 7 | TIME H : M : S | CO-ORDS OF CENTRE LATITUDE | CO-ORDS OF CENTRE LONGITUDE |
|---|---|---|---|---|---|---|---|
| 2176 | 17 JULY | 2450 | 017<br>075 | 046<br>104 | 10:50:50 | N54:32 | W007:10 |
| " | " | " | 018<br>076 | 047<br>105 | 10:51:10 | N53:08 | W007:55 |
| " | " | " | 019<br>077 | 048<br>106 | 10:51:40 | N51:43 | W008:38 |
| " | " | " | 020<br>078 | 049<br>107 | 10:52:00 | N50:19 | W009:18 |
| " | " | " | 021<br>079 | 050<br>108 | 10:52:30 | N48:54 | W009:57 |
| 2179 | 20 JULY | 2492 | 002<br>068 | 035<br>101 | 11:06:40 | N58:46 | W008:50 |
| " | " | " | 003<br>069 | 036<br>102 | 11:07:00 | N57:23 | W009:45 |
| " | " | " | 004<br>070 | 037<br>103 | 11:07:30 | N55:59 | W010:36 |
| 2182 | 23 JULY | 2534 | 136<br>170 | 153<br>187 | 11:23:20 | N60:10 | W012:08 |
| " | " | " | 137<br>171 | 154<br>188 | 11:23:50 | N58:47 | W013:07 |
| 2185 | 26 JULY | 2575 | 001 | | 10:00:40 | N48:57 | E003:01 |
| 2187 | 28 JULY | 2603 | 063<br>135 | 099<br>— | 10:11:10 | N51:45 | E001:28 |
| " | " | " | 064<br>136 | 100<br>172 | 10:11:40 | N50:21 | E000:47 |
| " | " | " | 065<br>137 | 101<br>173 | 10:12:00 | N48:55 | E000:09 |

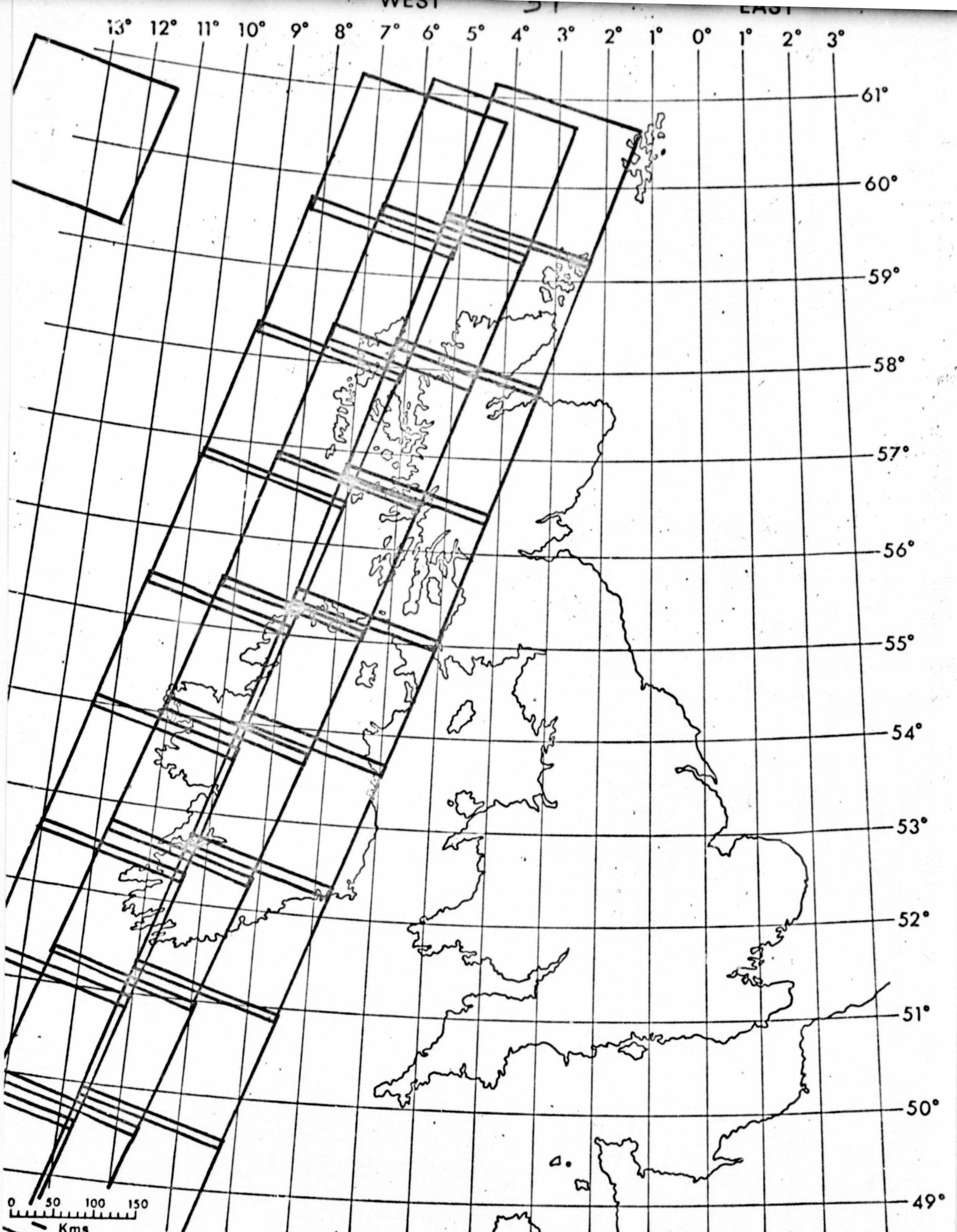


Fig. 1 (a): Landsat coverage of the British Isles, Cycle 3, 22 March - 8 April, 1975.

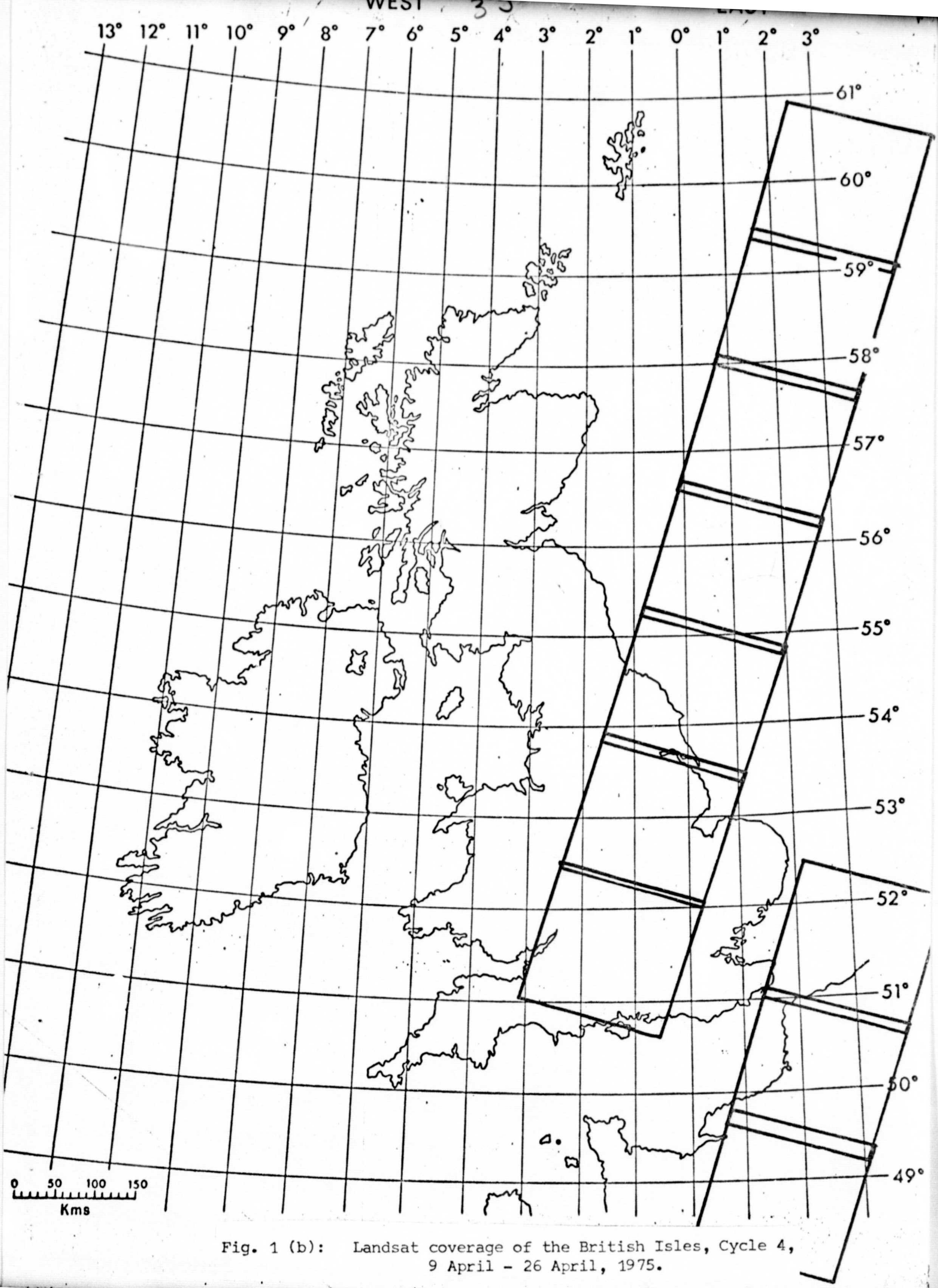


Fig. 1 (b): Landsat coverage of the British Isles, Cycle 4, 9 April - 26 April, 1975.

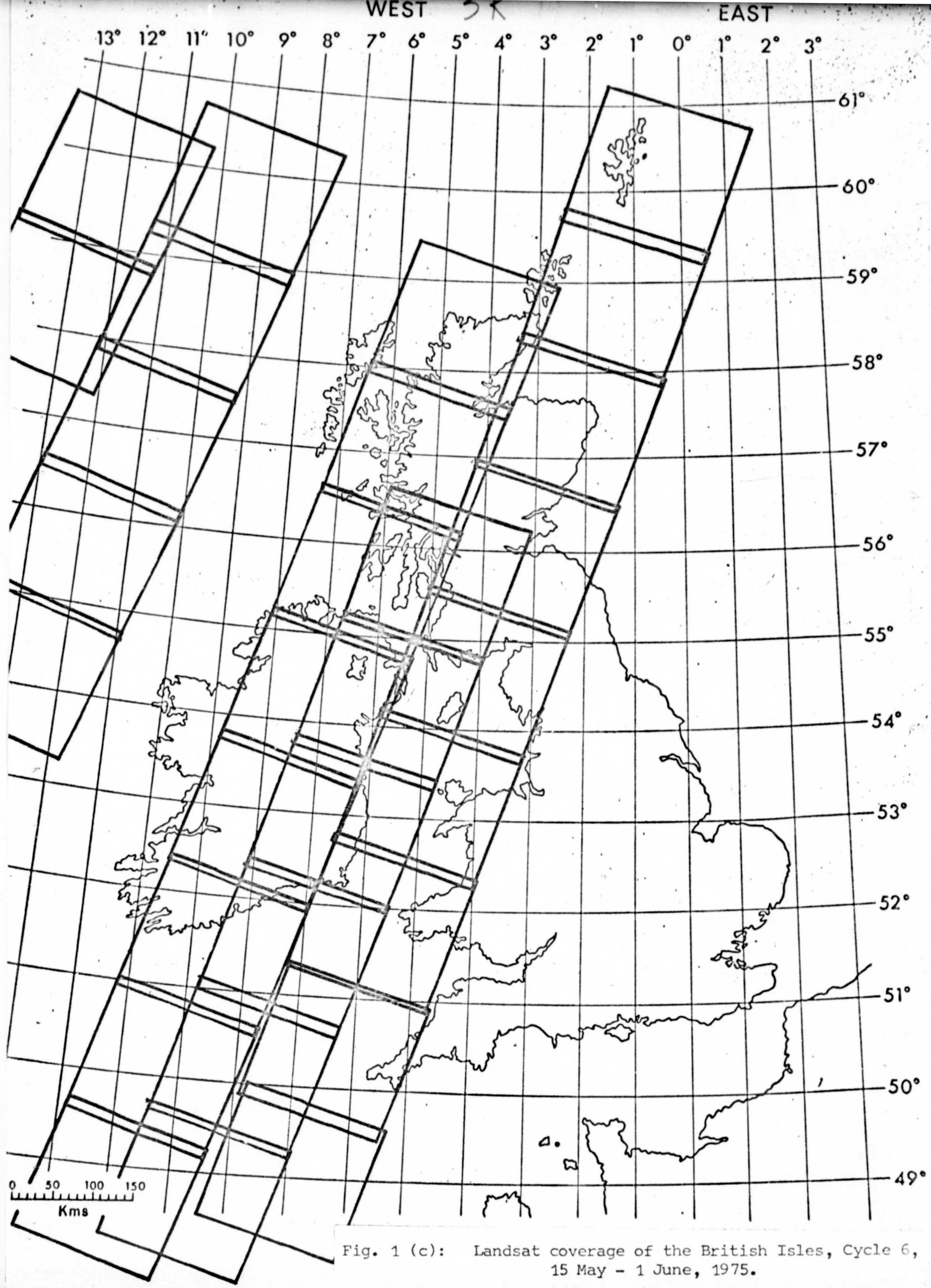


Fig. 1 (c): Landsat coverage of the British Isles, Cycle 6, 15 May - 1 June, 1975.

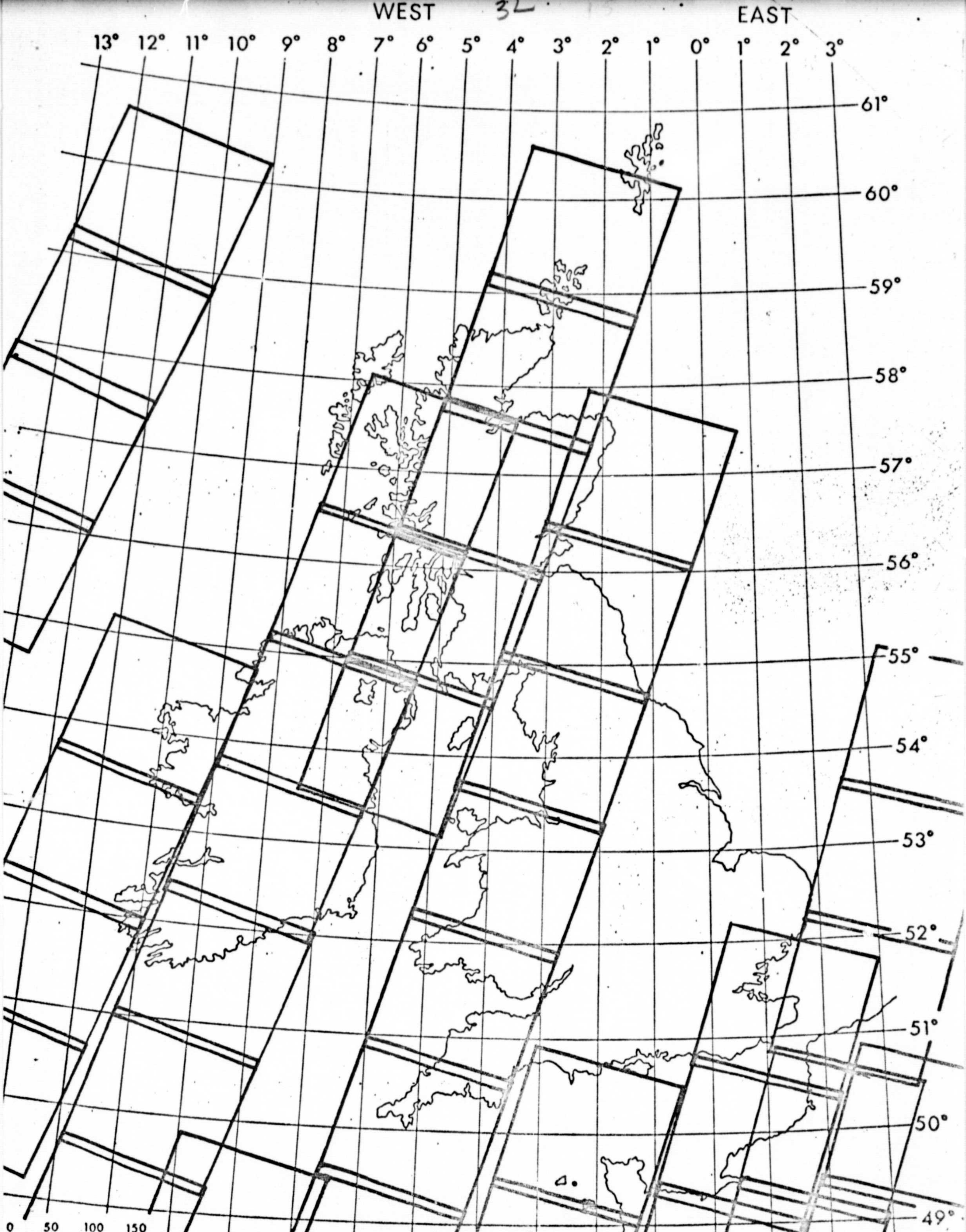


Fig. 1 (d): Landsat coverage of the British Isles, Cycle 7, 1 June - 19 June, 1975.

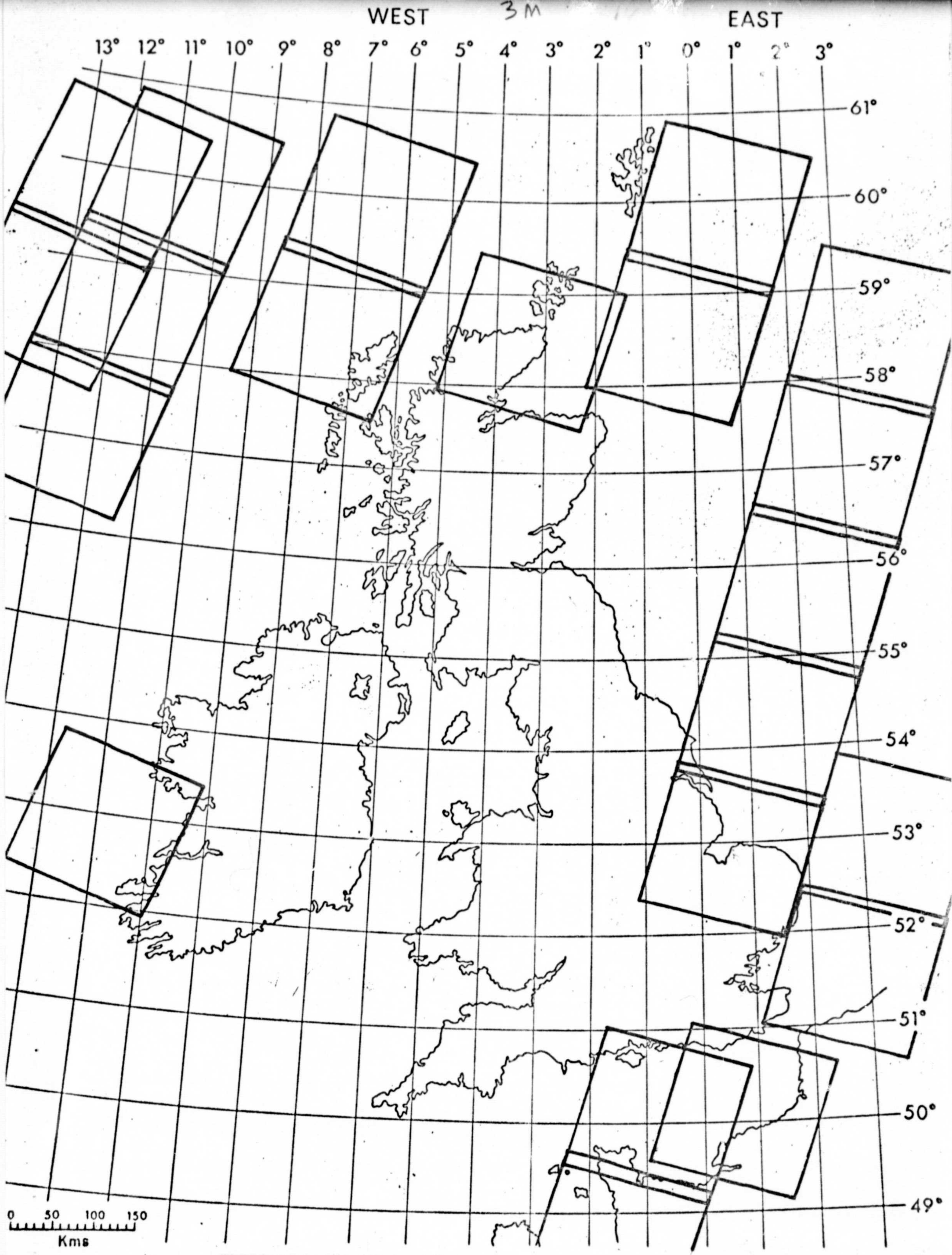


Fig. 1 (e) Landsat coverage of the British Isles, Cycle 8, 20 June - 7 July, 1975.

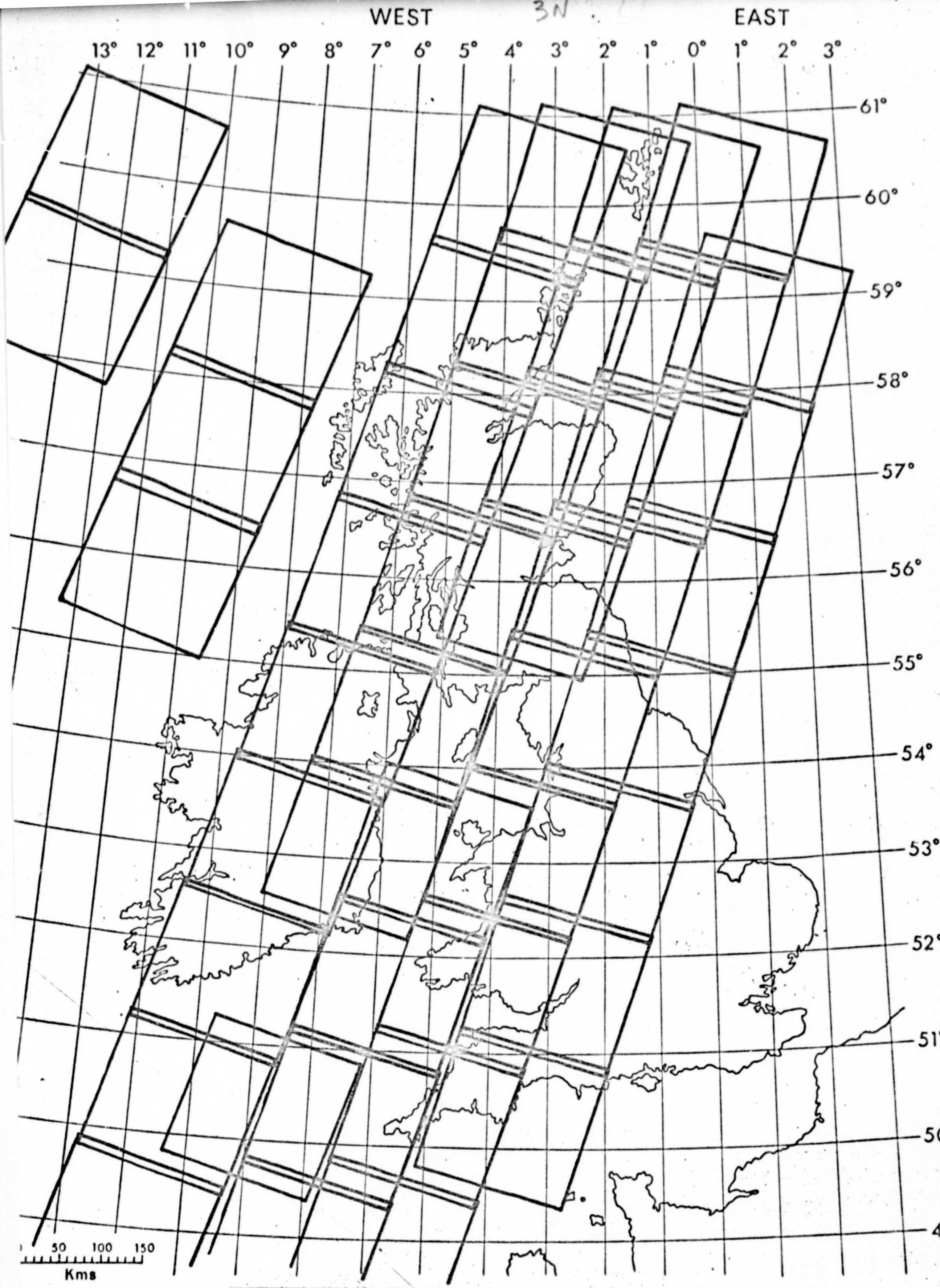


Fig. 1 (f): Landsat coverage of the British Isles, Cycle 9, 8 July - 25 July, 1975.

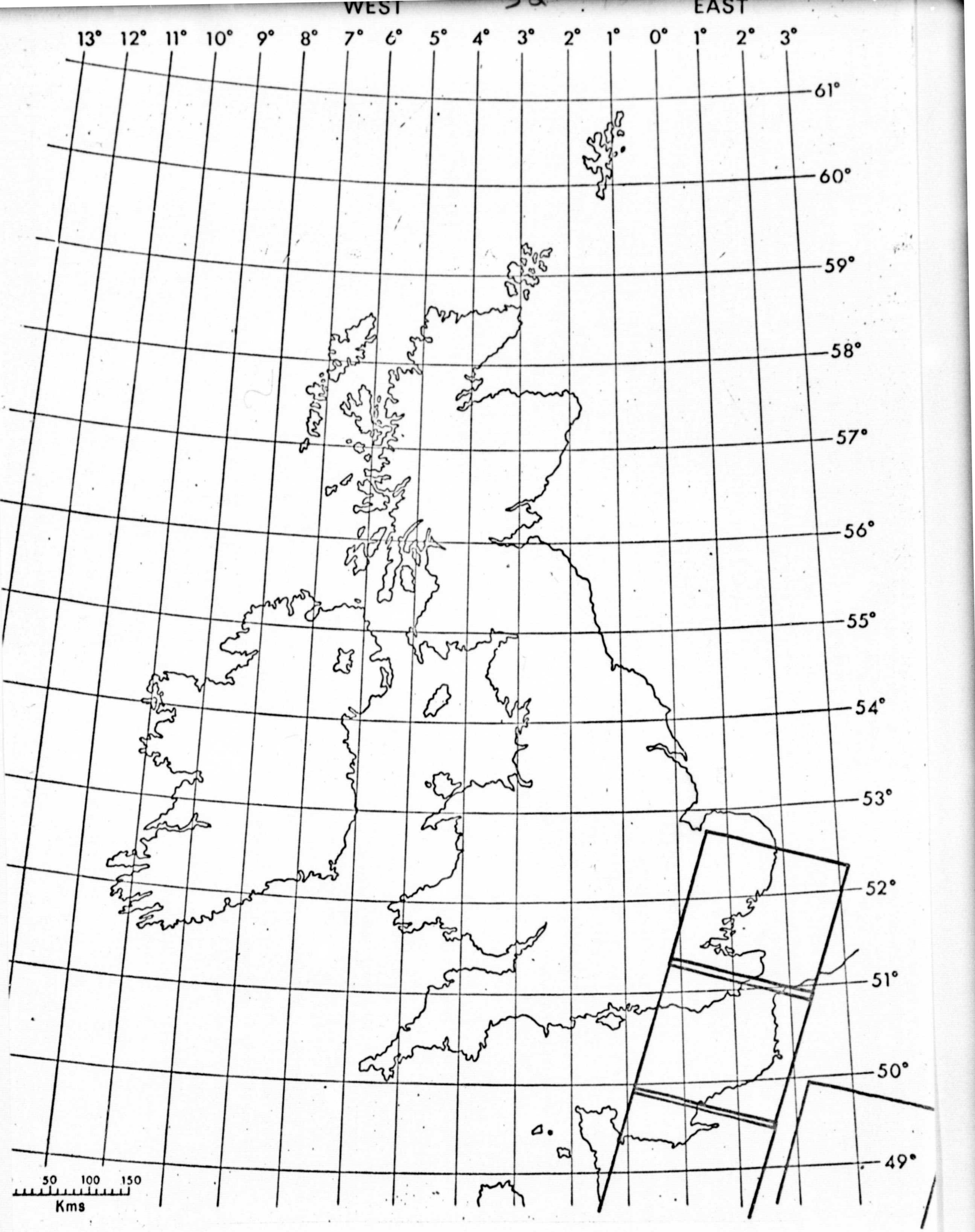


Fig. 1 (g): Landsat coverage of the British Isles, Cycle 10, 26 July - 12 August, 1975.

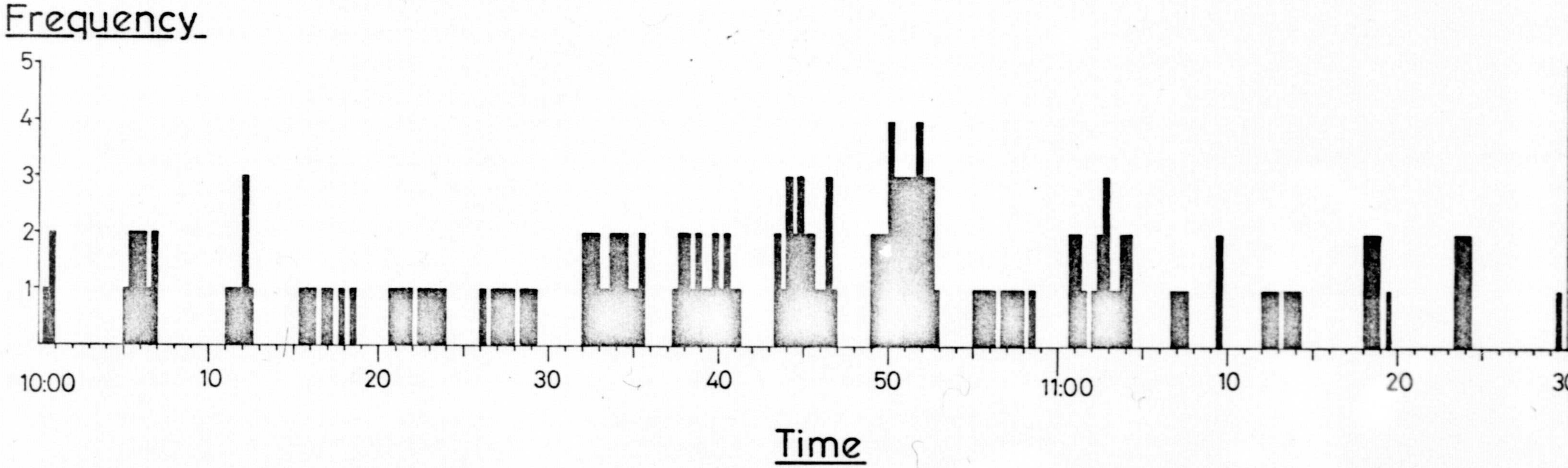


Fig.2 Distribution of the imagery through time

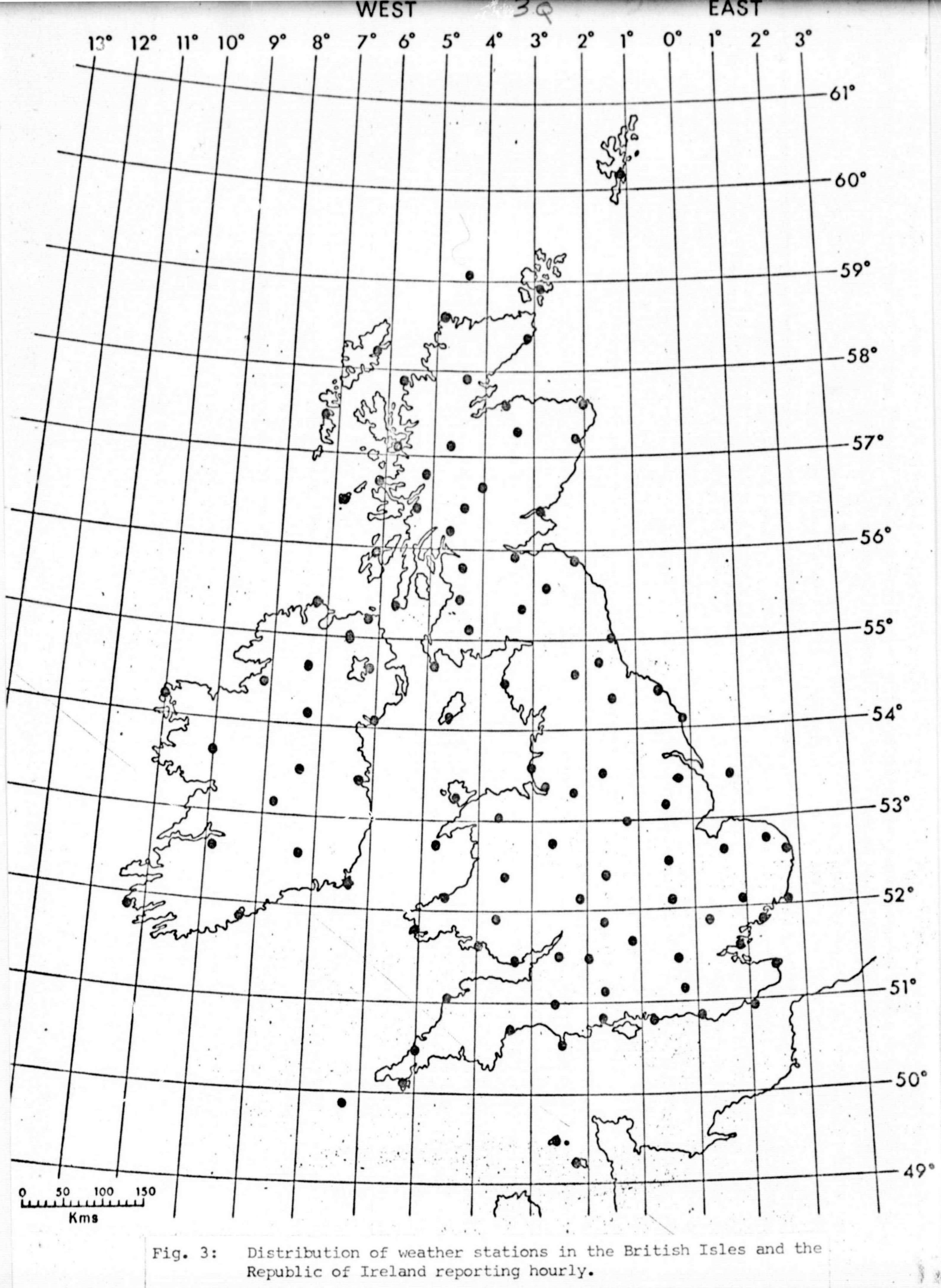


Fig. 3: Distribution of weather stations in the British Isles and the Republic of Ireland reporting hourly.

on the reasonable grounds that the Observer's lot is already a busy one, and that sporadic rearrangement of a schedule would be a source of confusion which might lead to loss of efficiency.

In fact, we are not unduly worried by the time differentials separating the two data gathering approaches. Cloud is usually rather slow to develop and/or change, and, in reasonable populations of comparative statistics we might expect that the effects of observing non-contemporaneously by satellite and on the ground would be distributed about the mean-relationship. Possibly significant cloud character contrasts resulting from the relatively rapid operation of meteorological processes in knife-edge situations will be disallowed from our statistical comparisons by means to be decided in view of the scale of the problem when it is apparent. One suitable means might be the construction of envelope curves of bivariate scattergrams of satellite and conventional cloud estimates to indicate the more seriously affected relationships. The kinds of synoptic situations in which these might occur range from highly mobile weather systems bringing frontal cloud quickly across areas which were previously covered by little or no cloud, to static situations in which, for example, overnight radiation fog may be rapidly dispersed. Examples of such situations will be sought and illustrated in later reports.

Whilst our file of Landsat frames is being extended, we are giving detailed thought to the design of our techniques for image analysis, with particular reference to cloud type and area, and for the correlation of the results with conventional cloud observations. Since conventional methods of observing cloud characteristics are non-instrumental, there is a greater chance of observational variation from day to day, from observer to observer, and from place to place than with most meteorological parameters. The more important sources of variation associated with the methodology for observing clouds include the following:

(1) The location of the observing station in relation to surrounding relief features, buildings, trees, etc., which may affect the extent and shape of the visible bowl of the sky.

(2) The variation of the radius of the cloud area assessed in conjunction with differences in the height of the cloud base.

(3) The effect of special influences upon cloud type and cloud cover locally, e.g., hill ranges enhancing cloud by day and water bodies suppressing cloud growth in the morning.

(4) The subjective judgement of the observer in the periodic assessment of cloud type, and cover, across a field of view in which perspective changes continuously from the vertical line of sight to the horizons.

(5) The advice given to the observer in his training programme. The British observer is advised to "give equal weight to the areas around the zenith and those at a lower angular elevation" (H.M.S.O. 1969). It is not easy to decide what such advice means in terms of relative areas; in practice, greater weight is almost certainly given to that (comparatively small) area overhead in which the relations between cloud elements and breaks in the cloud are most obvious.

It is to (1) and (2) above that we intend to address our attention in particular, believing that the other three would be difficult to investigate in any objective way. The first may be elucidated by circularising the reporting stations with a line-of-sight diagram to be completed in silhouette to indicate the distribution through 360$^{\circ}$ of skyline forms which result in angles of elevation or declination from the observing position. The second will entail inferences drawn from Table 3, which shows that the radius of the visible bowl of the sky (insofar as this may be defined in terms of the base of the clouds) is much wider for high clouds than for low.

The first routine analytical tasks which will be undertaken, therefore, involve the following comparisons:

(1) Conventional cloud observations and Landsat cloud estimates based on circular areas of a standard size centred on the

TABLE 3

Radius (r) and Area (A) of visible cloud areas seen from viewing positions on the Earth's surface, for different angles of elevation of view ($\alpha$) and different heights of clouds (kms.)

| $\alpha$ | | 0.1 | 0.3 | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1° | r | 5·7 | 17·2 | 28·6 | 57·3 | 114·6 | 171·9 | 229·2 | 286·5 | 343·7 | 458·3 | 572·9 | 687·5 |
| | A | 103 | 928 | 2,578 | 10,311 | 41,245 | 92,000 | 164,978 | 257,779 | 371,201 | 659,913 | 1,031,115 | 1,484,805 |
| 2° | r | 2·9 | 8·6 | 14·3 | 28·6 | 57·3 | 85·9 | 114·5 | 143·2 | 171·8 | 229·1 | 286·4 | 343·6 |
| | A | 25·8 | 232 | 644 | 2,576 | 10,305 | 23,186 | 41,219 | 64,405 | 92,744 | 164,878 | 257,622 | 370,975 |
| 3° | r | 1·9 | 5·7 | 9·5 | 19·1 | 38·2 | 57·2 | 76·3 | 95·4 | 114·5 | 152·6 | 190·8 | 229 |
| | A | 11·4 | 103 | 286 | 1,144 | 4,575 | 10,294 | 18,301 | 28,596 | 41,173 | 73,205 | 114,382 | 164,710 |
| 4° | r | 1·4 | 4·3 | 7·2 | 14·3 | 28·6 | 42·9 | 57·2 | 71·5 | 85·8 | 114·4 | 143·0 | 171·6 |
| | A | 6·4 | 58 | 161 | 642 | 2,570 | 5,782 | 10,280 | 16,062 | 23,129 | 41,119 | 64,248 | 92,518 |
| 5° | r | 1·1 | 3·4 | 5·7 | 11·4 | 22·9 | 34·3 | 45·7 | 57·2 | 68·6 | 91·4 | 114·3 | 137·2 |
| | A | 4·1 | 37 | 103 | 410 | 1,642 | 3,694 | 6,567 | 10,261 | 14,776 | 26,268 | 41,044 | 59,103 |
| 10° | r | 0·6 | 1·7 | 2·8 | 5·7 | 11·3 | 17·0 | 22·7 | 28·4 | 34·0 | 45·4 | 56·7 | 68·1 |
| | A | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

station positions.

(2) Conventional cloud observations and Landsat cloud estimates based on circular areas of different sizes depending on the height of the dominant cloud; and, if information about obstruction silhouettes is adequate and our results seem to warrant it, comparisons between.

(3) Conventional cloud observations and Landsat cloud estimates based on station-specific sky areas of appropriate shapes.

## III ACCOMPLISHMENTS

There is little to report under this heading owing to the preliminary nature of our work to date. Although the first Landsat imagery were received early in August 1975, it was not possible to commence work upon the data until the beginning of October, which has left little time for progress to be made. However, it is clear that Landsat has already provided cloud information for the British Isles with certain very distinctive and potentially valuable characteristics. These include:

(1) Breadth of cover. Conventional cloud observations from the British meteorological station network ar very largely overland observations. Landsat has provided some data for coastal waters which could not have been obtained from the surface. Additionally, of course, the Landsat views are spatially complete as distinct from the isolated point-sampling-views obtained from conventional meteorological stations on the ground.

(2) Detail of cover. The highest resolution meteorological satellite data for the British Isles are within the range from c. 0.6 - 4.0 km. depending on waveband, time of day, and the operation of DMSP and Noaa satellites and associated reception facilities. Although the Landsat coverage is more restricted temporally, it is much more detailed in terms of resolution, bettering the meteorological satellite data by one or two orders of magnitude.

## IV. PROBLEMS

In the Introduction, reference was made to some of the difficulties which have impeded the progress of the investigation to this point in time, especially those which have necessitated some reappraising of the original study plan.

A related problem of a continuing nature is the uncertainty that Landsat will image any given area of the study region during a particular cycle. To date, the "on-off" pattern of behaviour has appeared essentially random. Coupled with the rather low frequency of coverage which has been achieved for most sub-regions rather serious difficulties have arisen with tasks we would have liked to have planned, but which are either labour or cost-intensive. For example, time-synchronised cloud photography from the ground at a number of locations might have provided a useful further check on comparisons between satellite and conventional surface cloud observation, and the use of instrumented aircraft from the Meteorological Flight and/or the time-synchronisation of weather radar observations organised by the Royal Radar Establishment could have yielded very valuable supporting information; those who would have been involved in such programmes needed a suitable assurance that their services would not have been provided in vain. Whether the advent of the Telespazio station in Italy will improve matters during the remaining weeks of the data gathering exercise (ending February 29th, 1976) remains to be seen. Some indication of the likelihood that this might be so would be appreciated.

Lastly, it may be repeated that, for in-house reasons, the study was not begin until early October 1975, coincidental with the opening of a new university session in Bristol.

## V. DATA QUALITY AND DELIVERY

The quality of the data received has been dominantly fair or good, with the exception of a small proportion of transparencies which were heavily finger-marked.

Their timeliness has been poorer than expected. There has been a consistent delay of about four months from the date of imaging to the receipt of the imagery.

This is considerably longer than the delay experienced by clients with standing orders for images, a fact which has caused some embarrassment to the present Principal Investigator when questioned on Landsat data availability by scientific bodies and the media.

## VI. RECOMMENDATIONS AND CONCLUSIONS

The fragmentary nature of the Landsat coverage of the British Isles to data, coupled with the considerable uncertainty in advance that coverage might be obtained in specified areas during selected Landsat cycles, has seriously affected our hopes of achieving certain agreed goals and additional targets. If a full coverage through space and time, within the limits approved by N.A.S.A. is not possible, a planned coverage whose details would be known in advance, would be much more helpful than past experience. In large measure, our project in its final form will be dictated by the data we have received. For this reason, the feasibility of some tasks may only be clear when the last consignment of images has arrived. Clearly, this is scientifically unfortunate. Although we are hopeful that useful and interesting results will still emerge from our study, we regret that its original design and its final execution may have rather little in common.

## VII. REFERENCES

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