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A Plotting Program for Producing Ashfall Prediction Maps from Output of the NOAA Forecast Trajectory Program: Application to and Examples from the 1980 Mount St. Helens Eruptions

By

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Abbreviations and Definitions

ARL	Air Resources Laboratories National Oceanic and Atmospheric Administration 8060 13th Street Silver Spring, MD 20910
baud	Data transmission rate in bits/s (characters/s ≈ 0.1 X baud rate)
CRT	Cathode ray tube
map time(M)	Time at which the wind data is updated (at either 00Z or 12Z)
mbar	millibar - unit of atmospheric pressure equal to 0.1 kPa
modem	Device for connecting a terminal to a computer via telephone lines
NOAA	National Oceanic and Atmospheric Administration, U.S. Department of Commerce
NWS	National Weather Service National Oceanic and Atmospheric Administration 8060 13th Street Silver Spring, MD 20910
start time	The time in hours after the map time at which a particle is injected into the atmosphere; a hypothetical "eruption time"
travel time	The time in hours after the start time at which the position of the particle is computed
USGS	U.S. Geological Survey
Z ("Zulu" or "Zebra")	Time zone designator for Greenwich

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INTRODUCTION

The recent eruptions of Mount St. Helens, Wash., have demonstrated the need for some system of predicting downwind areas likely to be affected by ashfall, for use by various agencies involved with emergency planning. This paper presents a program for plotting data obtained from the NOAA wind trajectory program. The overall system operates as follows:

1. Wind data and other weather observations are telemetered to the NOAA computer in Suitland, Md., twice daily.

2. A series of programs is executed automatically on the NOAA computer to produce a variety of weather forecast information. One of these programs generates data which is used as input to the forecast trajectory program.

3. The NOAA computer is accessed from a time-share terminal and the forecast trajectory program is executed. The program produces a table of latitudes and longitudes of expected particle positions. This table is recorded in the terminal memory or on an external device such as tape or disk.

4. The table of latitudes and longitudes is transferred to the USGS computer, again through the time-share terminal. The plotting program described in this report is executed from a graphics time-share terminal and a series of maps of the Northwestern States showing the forecast trajectories is generated on the terminal screen. Hard copies of the maps are made for use by interested persons.

ACKNOWLEDGMENTS

The U.S. Geological Survey wishes to thank the meteorologists at the Air Resources Laboratories, NOAA, Silver Spring, Md., especially Gus Telegadas, Roland Draxler, and Milt Smith, for their efforts in setting up and modifying the trajectory forecast model and in relaying data to us during the early days of the Mount St. Helens eruption. We would also like to thank the personnel of Tektronix, Inc., Beaverton, Oreg., for the emergency loan of graphics terminals and their help in interfacing the equipment to our computers.

THE NOAA FORECAST TRAJECTORY PROGRAM

ARL of NOAA has a forecast trajectory program initially developed for predicting the path of radioactive debris from a nuclear explosion. The program computes the path of a hypothetical particle injected into the atmosphere at a particular place, time, and elevation, based on the latest observed winds and the NWS computer forecasts extending 3-1/2 days beyond the latest weather observations. The wind data forecast is updated every 12

hours, at noon (12Z) and midnight (00Z) Greenwich time. The program output is in a standardized format which gives the latitude and longitude of the hypothetical particle at travel times of 3, 6, 12, 18, and 24 hours for different atmospheric-pressure levels. The levels used are 850, 700, 500, 400, 300, 200, and 100 mbar. These levels correspond approximately to the elevations shown in table 1. The program does not take into account settling of particles or dispersion about the trajectories.

Description of Data Files

The output files from the NOAA forecast trajectory program consist of sets of latitude and longitude with appropriate identifying headings and some interspersed system commands. These data become the input to the plotting program. The formats for the morning and afternoon data sets are slightly different because the morning set gives a slightly extended forecast in case of system malfunctions or communications problems later in the day. The morning set contains forecasts for start times of 18, 24, 30, 36, and 42 hours after map time. These correspond to 1000, 1600, 2200, 0400, and 1000 PST (Pacific Standard Time)[1]. The afternoon data set uses start times of 12, 18, 24, and 30 hours, corresponding to 1600, 2200, 0400, and 1000 PST. Thus, each data set gives forecasts at 6-hour intervals until 1000 PST on the following day. For each atmospheric pressure level, the position of the hypothetical particle is given for travel times of 3, 6, 12, 18, and 24 hours after start time. For the 300, 200, and 100 mbar levels and start time of M+18 hours, positions are also computed for the additional travel times of 30, 36, 42, and 48 hours. This additional upper-level information was requested by offices of the National Weather Service and is not used in the USGS ashfall plotting program. The morning data file contains 120 lines; the afternoon, 106 lines. These minor differences between the morning and afternoon data files account for the complex reading procedure in the plotting program. Examples of morning and afternoon data sets are shown in tables 2 and 3.

The naming convention used when transferring the data files to the USGS computer is to use the date and an indication of morning or afternoon data (for example, may18am).

OPERATIONAL SYSTEM

The output file from the forecast trajectory program on the NOAA computer is recorded at the terminal, either internally or on an external storage device, then read directly into the USGS computer. The plotting program on the USGS computer (program fallout_map, described in the next section) then uses this data file to create the plots of the trajectories on an outline map of the Northwestern States. The entire operation can be conducted from the field office.

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[1]Examples described in text are for Mount St. Helens, so all times are converted to Pacific Standard or Pacific Daylight Time for the convenience of users.

Table 1.--Correlation of atmospheric pressure levels and altitude

Pressure level	Approximate altitude	
(mbar)	(km)	(ft)
850	1.5	5,000
700	3	10,000
500	6	18,000
400	7	23,000
300	9	30,000
200	12	39,000
100	16	53,000

```
CFREE F(F00,F12,F24,F36,F48,F60,F72,F84)
CFREE F(FT06F001,FT05F001)
CFREE F(SYSUT1,SYSUT2,SYSUT3,SYSUT4)
ALLOC F(FT06F001) DA(*)
ALLOC F(FT05F001) DA('W.ERL.R32.RRD.T00Z.MSH1')
ALLOC F(F00) DA('NWS.NMC.PRUD.F00.T00Z.UPRNL')
ALLOC F(F12) DA('NWS.NMC.PRUD.F12.T00Z.UPRNL')
ALLOC F(F24) DA('NWS.NMC.PRUD.F24.T00Z.UPRNL')
ALLOC F(F36) DA('NWS.NMC.PRUD.F36.T00Z.UPRNL')
ALLOC F(F48) DA('NWS.NMC.PRUD.F48.T00Z.UPRNL')
ALLOC F(F60) DA('NWS.NMC.PRUD.F60.T00Z.UPRNL')
ALLOC F(F72) DA('NWS.NMC.PRUD.F72.T00Z.UPRNL')
ALLOC F(F84) DA('NWS.NMC.PRUD.F84.T00Z.UPRNL')
DUPGM MSHRUN LIB('W.ERL.R32.MS.MESSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 18 MAY 80  0Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           46.0 121.9  45.7 121.7  45.3 121.2  44.7 121.0  44.1 121.1
  700           46.4 121.7  46.8 121.2  47.6 120.1  48.3 119.0  49.0 117.9
  500           47.0 121.1  47.8 120.0  49.6 117.4  51.2 113.9  52.2 109.8
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           46.0 121.9  45.7 121.6  45.2 121.4  44.6 121.4  44.0 121.2
  700           46.6 121.7  47.0 121.2  47.6 120.3  48.2 119.5  48.8 118.5
  500           47.1 121.1  48.0 120.0  49.9 117.3  51.4 113.7  52.4 109.5
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           45.9 122.0  45.6 121.9  45.1 121.8  44.6 121.6  43.5 121.1
  700           46.5 121.7  46.8 121.4  47.3 120.8  47.8 120.0  48.7 118.6
  500           47.1 121.3  48.0 120.2  49.5 117.6  50.9 114.6  52.7 106.0
TRAJECTORIES STARTING AT  36HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           45.9 122.2  45.7 122.1  45.2 121.9  44.4 121.4  43.7 121.0
  700           46.4 121.9  46.6 121.6  47.0 121.0  47.9 119.9  49.1 118.8
  500           46.9 121.3  47.5 120.3  48.7 118.2  51.2 112.6  52.2 104.2
TRAJECTORIES STARTING AT  42HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           46.0 122.1  45.8 122.0  45.1 121.6  44.7 121.2  44.6 120.6
  700           46.4 121.9  46.5 121.6  47.4 120.6  48.6 119.6  50.2 118.9
  500           46.6 121.4  47.0 120.6  49.2 116.7  51.0 111.1  51.7 102.5
CFREE F(FT05F001)
ALLOC F(FT05F001) DA('W.ERL.R32.RRD.T00Z.MSH2')
DUPGM MSHRUN LIB('W.ERL.R32.MS.MESSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 18 MAY 80  0Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           47.1 120.7  47.9 119.2  49.4 116.0  50.7 112.3  51.4 108.1
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  300           47.1 120.2  47.7 118.2  48.3 114.5  48.5 111.0  48.6 108.5
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  300           48.3 105.7  46.8 101.7  44.8  99.9  42.5  99.2
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  200           46.9 119.7  47.2 117.2  46.8 112.7  45.5 109.4  43.7 106.7
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  200           41.8 104.3  39.2  98.9  38.9  92.8  41.2  86.3
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           47.2 120.8  46.3 119.3  50.3 115.8  51.8 111.5  52.6 106.2
  300           47.4 120.3  48.4 118.3  50.3 114.3  51.4 109.4  51.7 103.9
  200           47.2 119.7  47.9 117.4  48.9 112.8  48.6 108.5  47.7 105.3
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           47.2 121.0  48.2 119.6  50.0 116.5  51.6 112.4  52.8 101.2
  300           47.3 120.6  48.4 118.9  50.6 114.9  52.2 109.5  52.1  96.7
  200           47.2 120.2  48.2 117.9  49.6 113.2  50.2 108.4  49.7 100.0
TRAJECTORIES STARTING AT  36HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           46.9 121.1  47.6 119.9  48.9 117.4  51.5 109.9  52.3  98.5
  300           47.0 120.8  47.7 119.4  49.3 116.1  51.9 106.3  51.4  93.4
  200           47.0 120.2  47.5 118.4  48.8 114.4  50.4 104.7  49.4  96.2
TRAJECTORIES STARTING AT  42HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           46.6 121.2  47.0 120.2  49.2 115.3  51.3 107.6  51.7  95.5
  300           46.5 121.0  46.9 119.8  49.5 113.4  51.6 102.7  50.7  89.5
  200           46.3 120.8  46.7 119.4  49.3 112.1  50.2 102.4  49.2  93.0
CFREE F(FT05F001)
ALLOC F(FT05F001) DA('W.ERL.R32.RRD.T00Z.MSH3')
DUPGM MSHRUN LIB('W.ERL.R32.MS.MESSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 18 MAY 80  0Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.7 120.7  47.0 119.2  47.6 116.4  48.0 113.6  48.4 110.8
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           48.7 108.1  49.3 101.8  49.3  95.0  49.2  87.9
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.5 120.5  46.7 119.0  47.1 116.1  47.4 113.2  47.7 110.6
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.3 120.7  46.5 119.2  46.7 116.3  46.8 113.7  47.6 108.4
TRAJECTORIES STARTING AT  36HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.4 120.8  46.5 119.5  46.6 117.0  47.0 112.1  47.3 107.3
TRAJECTORIES STARTING AT  42HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.3 121.0  46.4 119.8  46.8 115.3  46.9 110.8  46.7 106.7
CFREE F(F00,F12,F24,F36,F48,F54,F60,F72,F84)
```

Table 2.--SAMPLE OUTPUT FILE FROM NOAA FORECAST TRAJECTORY PROGRAM, MORNING DATA

Table 3.--SAMPLE OUTPUT FILE FROM NOAA FORECAST TRAJECTORY PROGRAM, AFTERNOON DATA

```
CFREE F(F00,F12,F24,F36,F48,F60,F72,F84)
CFREE F(FT06F001,FT05F001)
CFREE F(SYSUT1,SYSUT2,SYSUT3,SYSUT4)
ALLOC F(FT06F001) DA(*)
ALLOC F(FT05F001) DA('W.FRL.R32.PRD.T12Z.SM1')
ALLOC F(F00) DA('RMS.RFC.PROD.F00.T12Z.UPRNL')
ALLOC F(F12) DA('RMS.RFC.PROD.F12.T12Z.UPRNL')
ALLOC F(F24) DA('RMS.RFC.PROD.F24.T12Z.UPRNL')
ALLOC F(F36) DA('RMS.RFC.PROD.F36.T12Z.UPRNL')
ALLOC F(F48) DA('RMS.RFC.PROD.F48.T12Z.UPRNL')
ALLOC F(F60) DA('RMS.RFC.PROD.F60.T12Z.UPRNL')
ALLOC F(F72) DA('RMS.RFC.PROD.F72.T12Z.UPRNL')
ALLOC F(F84) DA('RMS.RFC.PROD.F84.T12Z.UPRNL')
DUPGM MSHRUN LIB('W.FRL.R32.MS.RFSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 25 MAY 80 12Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  12HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           45.9 121.4  45.7 120.8  45.7 118.8  46.2 116.4  47.1 114.3
  700           45.5 121.7  44.7 121.0  43.4 119.4  42.8 117.3  42.9 114.7
  500           45.4 122.2  44.8 122.2  43.1 121.8  41.9 120.4  41.3 119.0
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           45.9 121.3  45.8 120.4  46.1 118.3  46.8 116.1  47.8 113.8
  700           45.4 121.5  44.7 120.7  43.8 118.8  43.5 116.0  43.0 112.6
  500           45.5 122.2  44.8 121.9  43.5 120.9  42.7 119.5  42.4 117.7
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           46.1 121.3  45.1 120.3  46.0 118.1  47.4 115.9  46.2 113.5
  700           45.5 121.4  45.0 120.3  44.3 117.8  44.2 114.4  44.2 110.8
  500           45.6 121.9  45.0 121.5  44.0 120.1  43.4 118.5  43.3 116.1
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  850           46.2 121.2  46.4 120.1  47.0 118.0  47.7 115.7  49.1 110.9
  700           45.7 121.1  45.3 119.8  44.9 118.7  44.7 112.8  44.8 108.1
  500           45.7 121.7  45.2 121.1  44.4 119.8  44.0 117.8  43.9 110.9
CFREE F(FT05F001)
ALLOC F(FT05F001) DA('W.FRL.R32.PRD.T12Z.MSH2')
DUPGM MSHRUN LIB('W.FRL.R32.MS.RFSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 25 MAY 80 12Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  12HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           45.6 122.7  45.0 123.0  43.9 123.1  42.9 122.7  42.3 122.1
  300           45.9 123.3  45.6 123.9  44.9 124.6  43.9 124.6  42.9 124.6
  200           45.9 123.4  45.3 124.4  44.3 125.7  43.0 126.1  41.3 126.0
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           45.7 122.8  45.2 122.7  44.2 122.4  43.7 121.9  43.4 121.2
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  300           45.9 122.9  45.5 123.5  44.8 124.2  44.3 124.3  43.7 124.5
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  300           43.1 124.8  41.8 124.2  40.1 122.7   0.0   0.0
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  200           45.8 123.3  45.4 124.2  44.2 125.2  42.9 125.5  41.5 125.4
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  200           40.3 125.0  38.7 124.3  39.8 119.1   0.0   0.0
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           45.8 122.3  45.2 122.2  44.5 121.7  44.0 120.9  43.8 119.9
  300           45.7 122.9  45.4 123.2  45.0 123.8  44.8 124.0  44.3 124.3
  200           45.7 123.2  45.3 123.8  44.4 124.7  43.3 125.1  42.2 125.2
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  400           45.8 122.1  45.4 121.9  44.8 121.2  44.4 120.2  43.9 117.8
  300           45.9 122.5  45.5 122.7  45.0 123.1  44.7 123.4  43.3 124.2
  200           45.8 122.9  45.4 123.5  44.8 124.4  43.8 124.9  41.3 125.1
CFREE F(FT05F001)
ALLOC F(FT05F001) DA('W.FRL.R32.PRD.T12Z.MSH3')
DUPGM MSHRUN LIB('W.FRL.R32.MS.RFSLD')
INITIAL POSITION: 46.20N  122.20W
DATA IS BASED ON THE 25 MAY 80 12Z FORECAST MAP TIME
TRAJECTORIES STARTING AT  12HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           46.1 123.4  45.8 124.7  44.9 127.1  43.8 128.8  42.4 130.1
TRAJECTORIES STARTING AT  18HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           45.8 123.8  45.4 124.8  44.3 126.8  42.9 128.1  41.4 129.0
TRAVEL TIME(HRS)   30          36          42          48
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           39.9 129.3  37.2 129.1  35.3 127.3   0.0   0.0
TRAJECTORIES STARTING AT  24HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           45.8 123.4  45.3 124.3  44.2 125.9  42.8 126.9  41.3 127.2
TRAJECTORIES STARTING AT  30HRS AFTER MAP TIME
TRAVEL TIME(HRS)   03          06          12          18          24
LEVEL(MB)        LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG   LAT  LONG
  100           45.8 123.1  45.4 124.0  44.3 125.3  43.1 125.8  40.7 126.1
CFREE F(F00,F12,F24,F36,F48,F60,F72,F84)
```

The essential items of equipment necessary to make the system function are:

1. A CRT graphics terminal with a hard-copy device--located at the field office site where the information is needed.

2. A terminal with internal memory or an external data-storage device capable of recording at least 121 80-character lines. This should also be located at the field office site, although in an emergency it can be located elsewhere. This may be the same terminal as described in 1 or it may be a separate terminal.

3. A modem capable of 110- or 300-baud transmission (300 baud preferred) for communication with the NOAA computer. Time-sharing baud rates greater than 300 are not available at NOAA.

4. A voice-grade telephone line.

5. A modem capable of 1200-baud transmission for communication with the USGS computer. This is highly desirable but not absolutely essential, since graphics work can be conducted at 300 or even 110 baud. For items 3 and 5, the best solution is a single modem with 300/1200 baud capability.

The overall system is shown graphically in figure 1.

THE PLOTTING PROGRAM

Description

The plotting program, fallout_map, is the program which reads the data file obtained from the NOAA computer and generates a series of plots of the trajectories on a map of the Northwestern States. The source program, fallout_map.fortran, is written in FORTRAN IV, card-image format, for the USGS Honeywell 60-80 computer and a Tektronix graphics terminal. The plotting routine uses Version 8.0 of DISSPLA, a graphics software package of Integrated Software Systems Corp. (ISSCO).

During execution, the program asks for three items to be entered from the terminal: the name of the input data file, the date, and whether the run is for morning (map time = 00Z) or afternoon (map time = 12Z) data. The program then generates one map for each start time, showing the trajectories at the various atmospheric levels, with symbols plotted at the 3-, 6-, 12-, 18-, and 24-hour travel-time points. Between plots the program waits for a carriage return from the terminal before proceeding. An explanation of the map symbols is shown in figure 2 and plots for wind data of 00Z, May 18, 1980, the date of the devastating eruption of Mount St. Helens, are shown in figures 3 through 7. Other plots for wind data of 12Z, May 24, 1980, showing a different wind pattern, is given in figures 8 through 11. An eruption on the morning of May 25 produced about 3 mm of ashfall at Portland, Oreg. (C. D. Miller, oral commun., 1980).

Detailed program documentation, including flow charts, a list of variables and definitions, and a compiled FORTRAN listing, is given in the appendix.

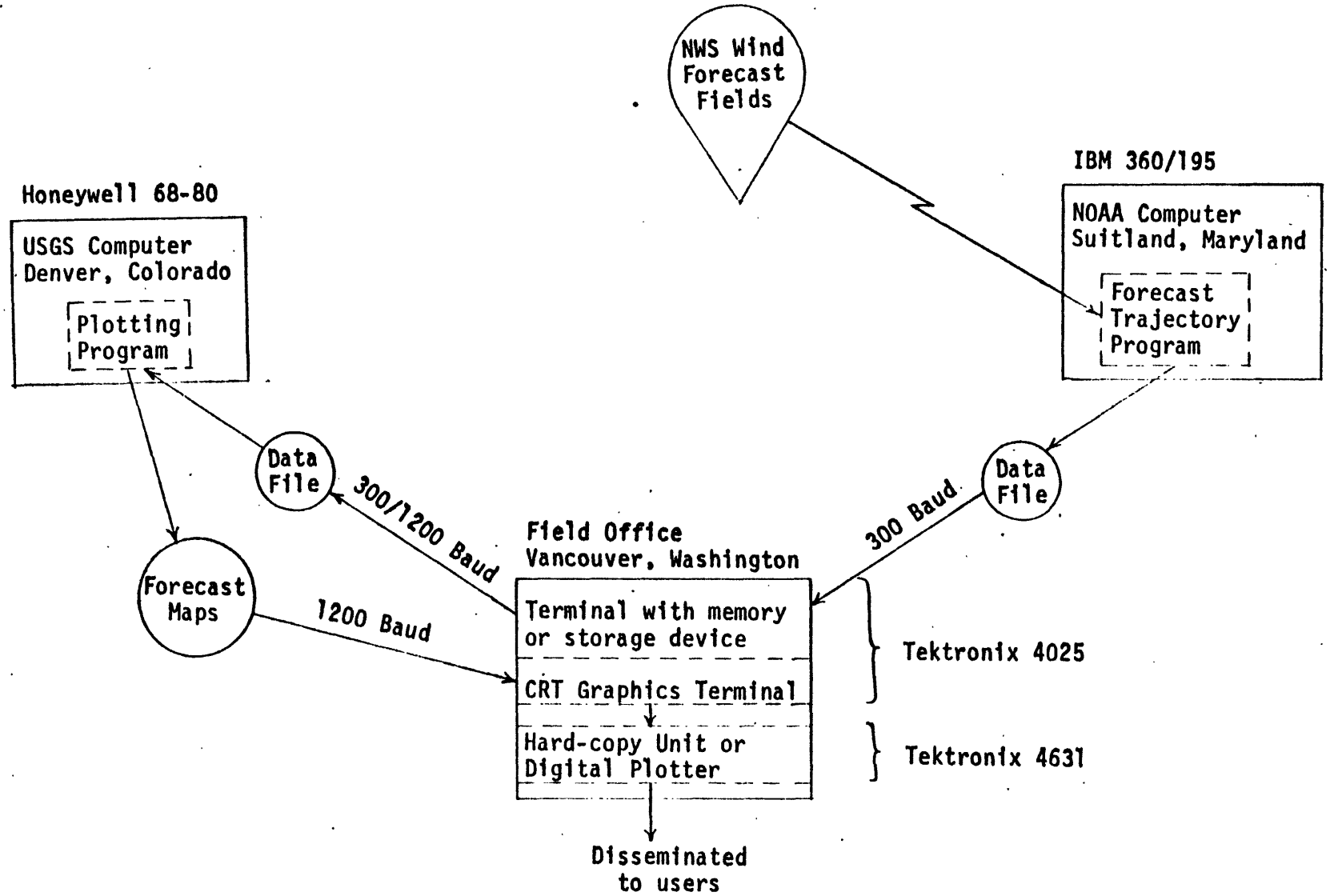

Figure 1.--Simplified flow chart of system for producing ashfall prediction maps.

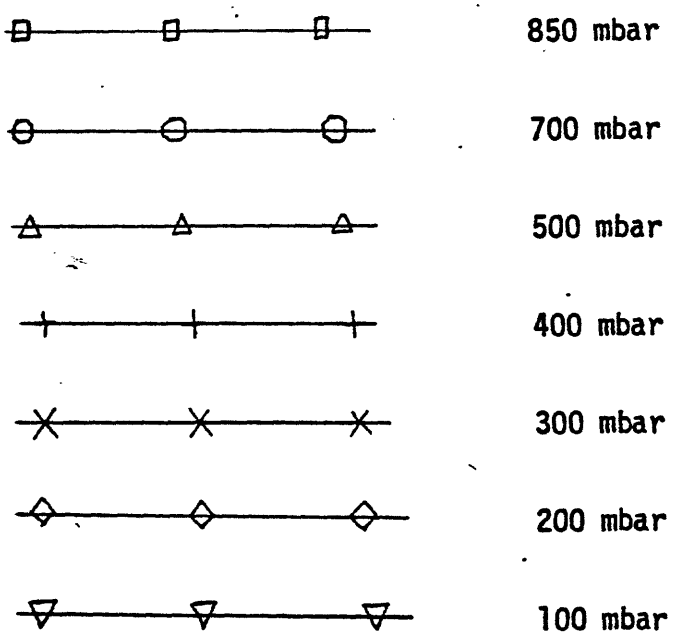

Figure 2.--Explanation for ashfall trajectory maps.

Comparison of Predicted and Observed Ashfall Patterns

Comparison of the forecast map for 1100 PDT, May 18, 1980 (fig. 3), the time nearest the eruption for which data is available, with an isochron map showing the extent of the ash plume determined from satellite images (Sarna-Wojicki and others, 1980, fig. 4) shows the same general pattern in the two types of maps, with the observed ashfall pattern being somewhat south of the predicted pattern. The observed rate of travel of the ash cloud is somewhat faster than predicted, however. The satellite images revealed that the ash plume extended to the vicinity of Missoula, Mont., in approximately 6 hours, while the forecast map indicates a travel time of about 10 hours. The southerly trajectory for the low-altitude winds (850 mbar, 1.5 km) is not reflected in the observed ashfall pattern because the ash was injected into the atmosphere above this level. Also, the 850 mbar trajectories are affected more by local surface topography than the higher-altitude trajectories.

The observed ashfall pattern from the May 25, 1980, eruption (Sarna-Wojicki, written commun., 1980) does not agree so well with the predicted pattern (figs. 9 and 10). The predicted wind pattern at the time was highly unusual, with the trajectories for the various levels fanned out over the southern half of the map. The observed ashfall deposits were mostly west and northwest of Mount St. Helens, with one lobe extending to the south and southwest.

More study is needed before the overall reliability of the predicted ashfall patterns can be properly assessed.

Program Modifications and Usage

One minor modification of the program needs to be made twice yearly, in April and October, to change the time conversion to Pacific time between Standard and Daylight Saving Time. The conversion from Greenwich (Z) time to Pacific Standard Time (PST) is -8 hours; to Pacific Daylight Time (PDT) it is -7 hours.

The area of map coverage can be altered by changing the latitude and longitude limits and increments in the call to subroutine mapgr (line 105) in subroutine pltmap(i). The default map projection used is cylindrical equidistant. When changing the area of map coverage care must be taken to scale the length of the axes to avoid distortion.

Changing the initial position on which the data file is based on the NOAA computer (in case of eruption of another volcano) can be accomplished by coordination with the ARL.

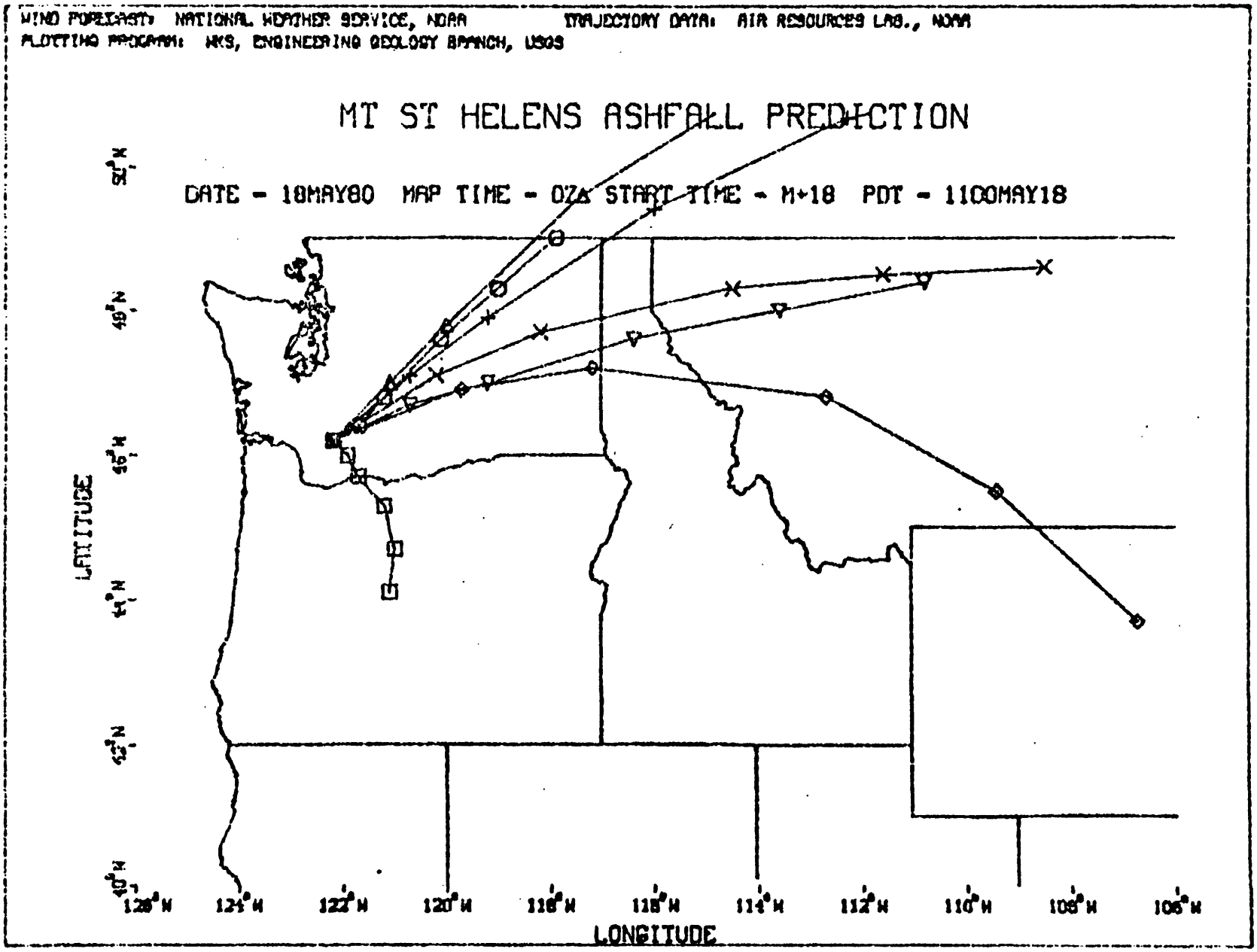

Figure 3.--Example trajectory plot from morning wind data, May 18, 1980, start time = M+18.

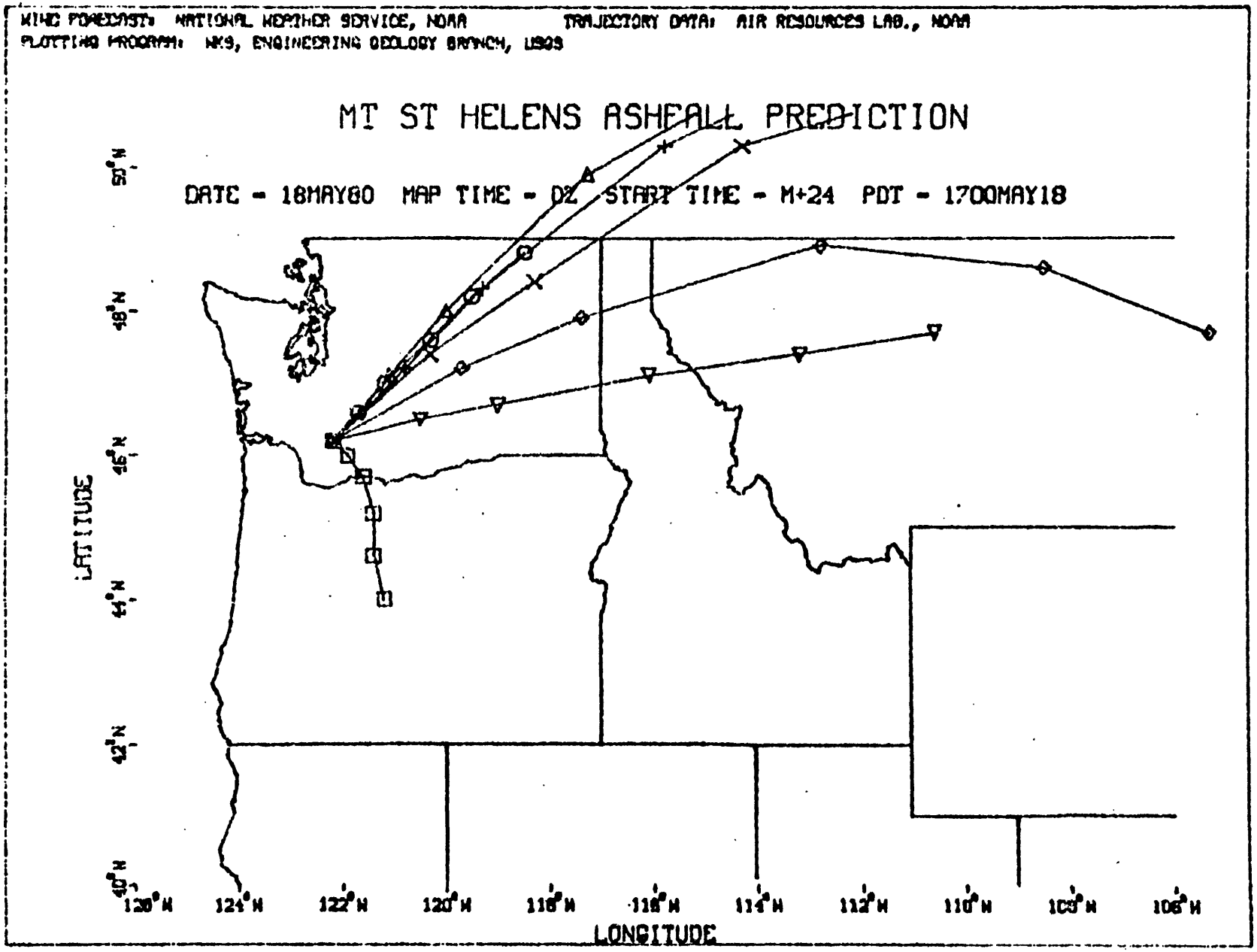

Figure 4.--Example trajectory plot from morning wind data, May 18, 1980, start time = M+24.

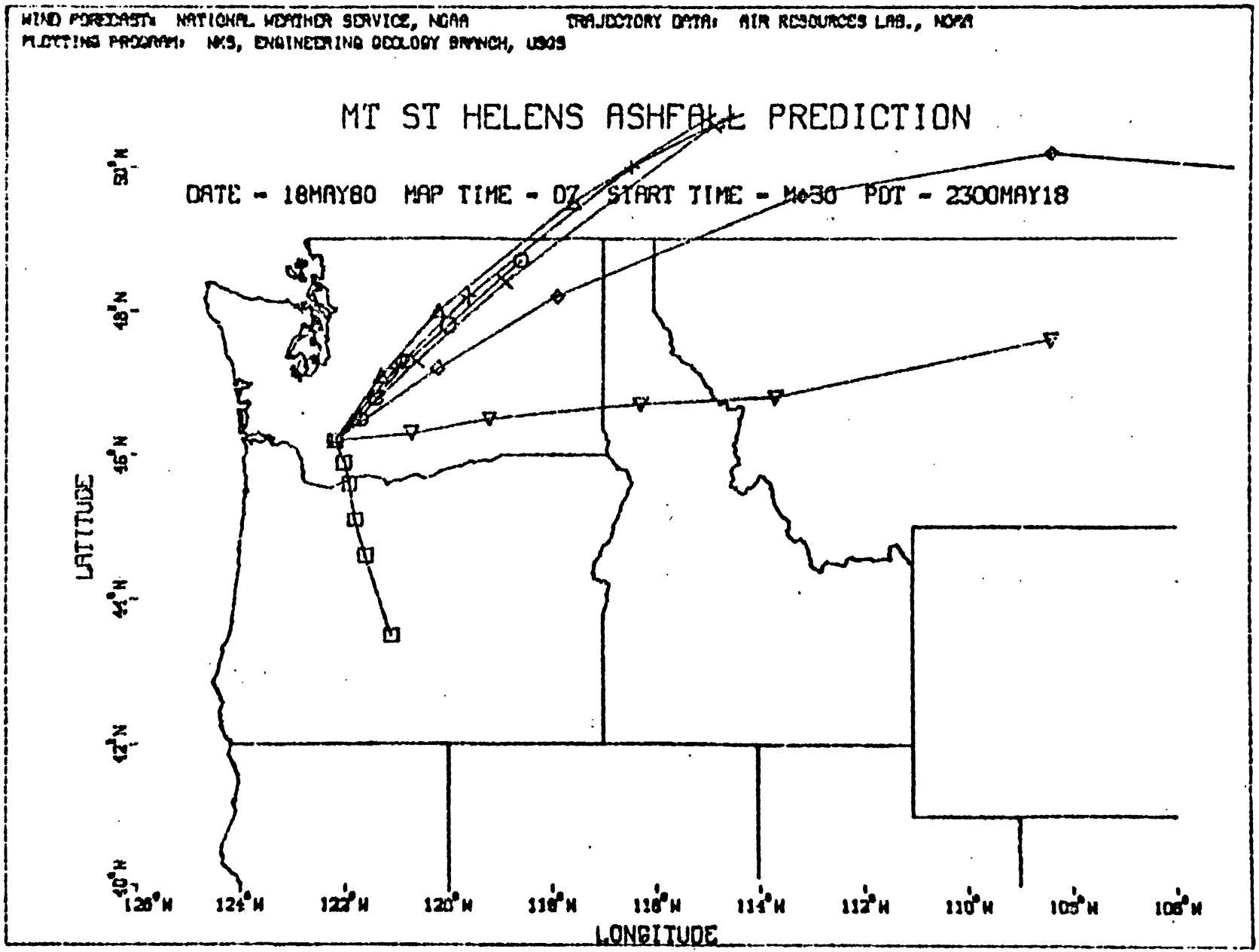

Figure 5.--Example trajectory plot from monrning wind data, May 18, 1980, start time = M+30.

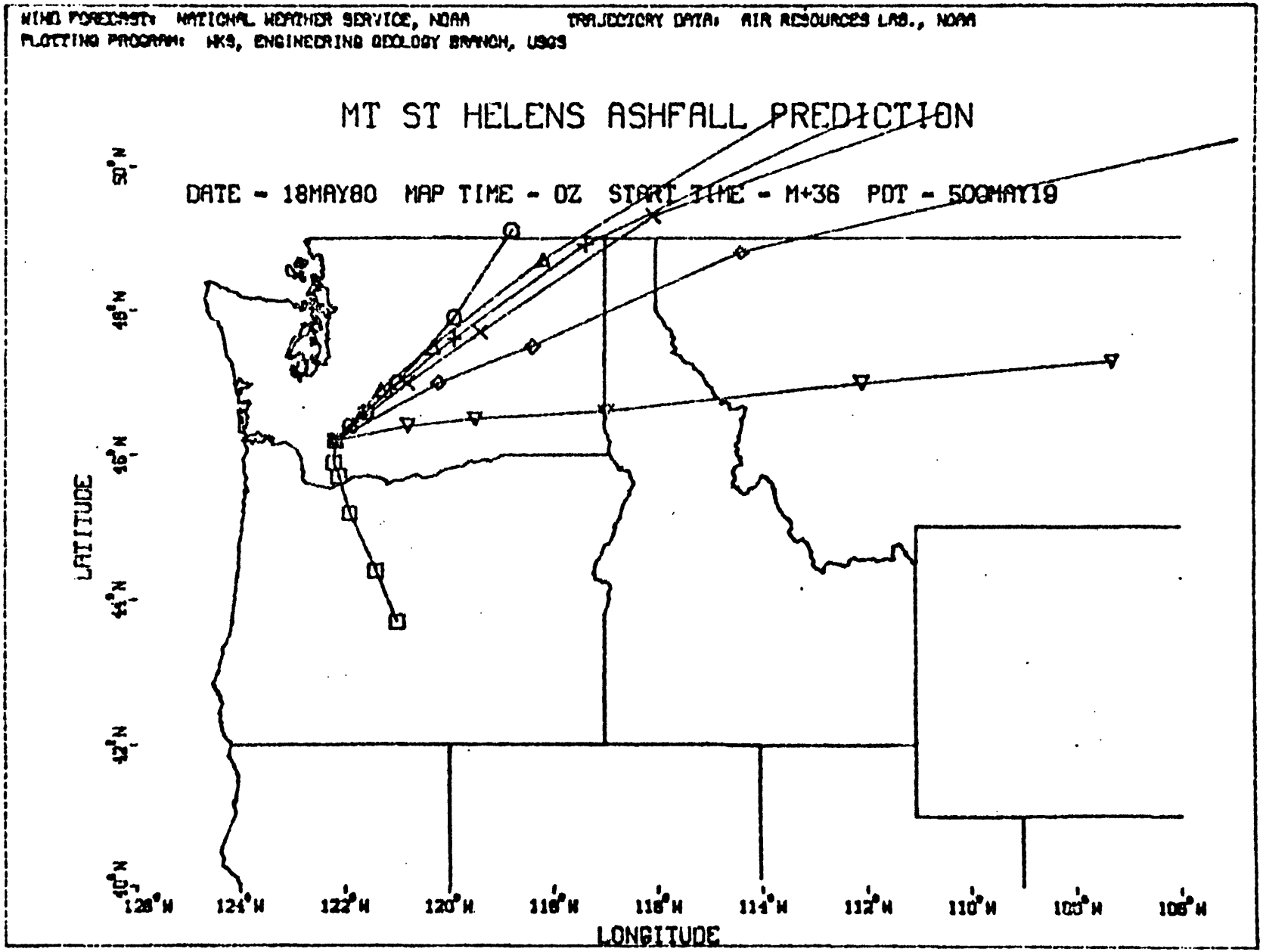

Figure 6.--Example trajectory plot from morning wind data, May 18, 1980, start time = M+36.

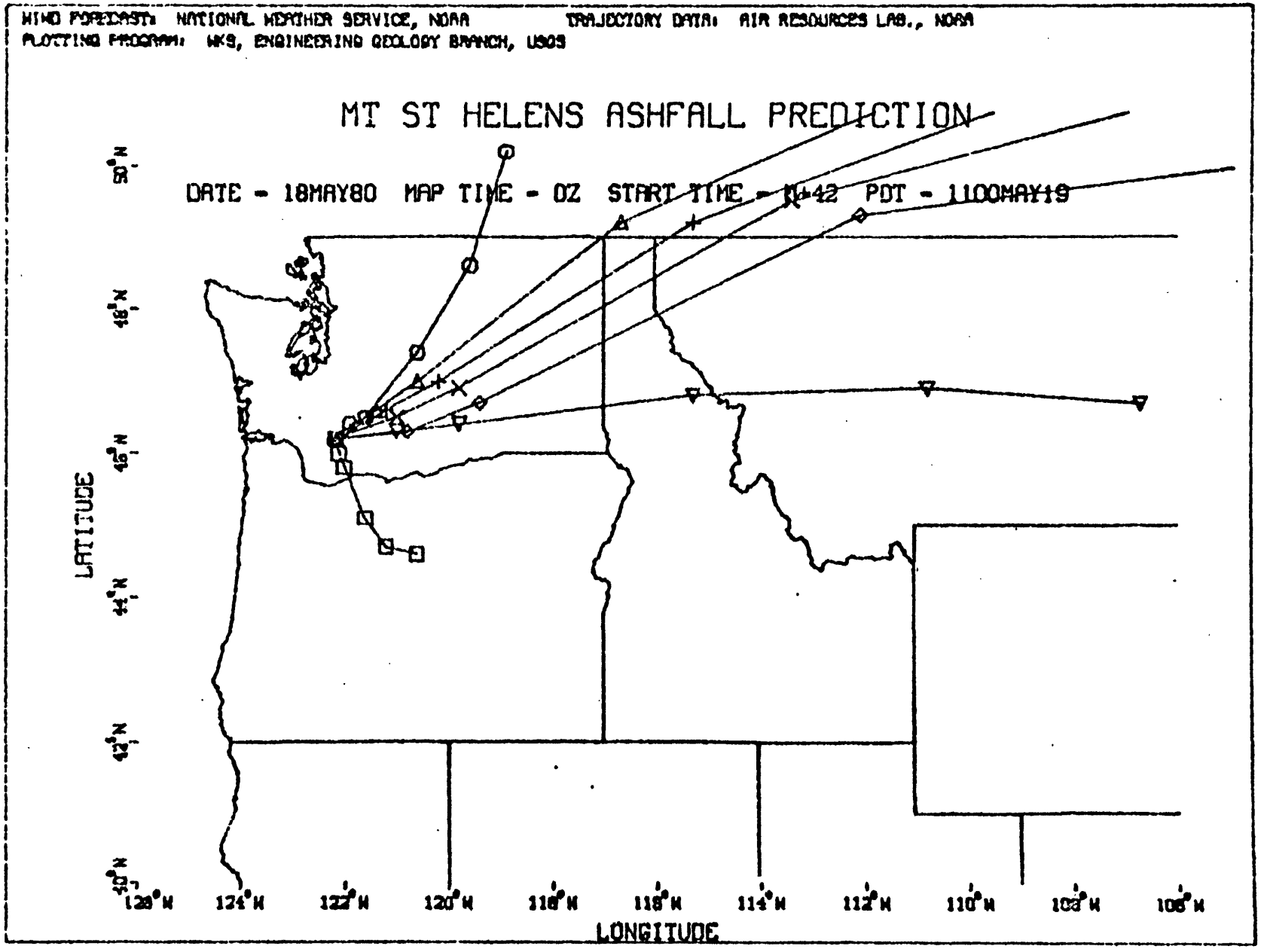

Figure 7.--Example trajectory plot from morning wind data, May 18, 1980, start time = M+42.

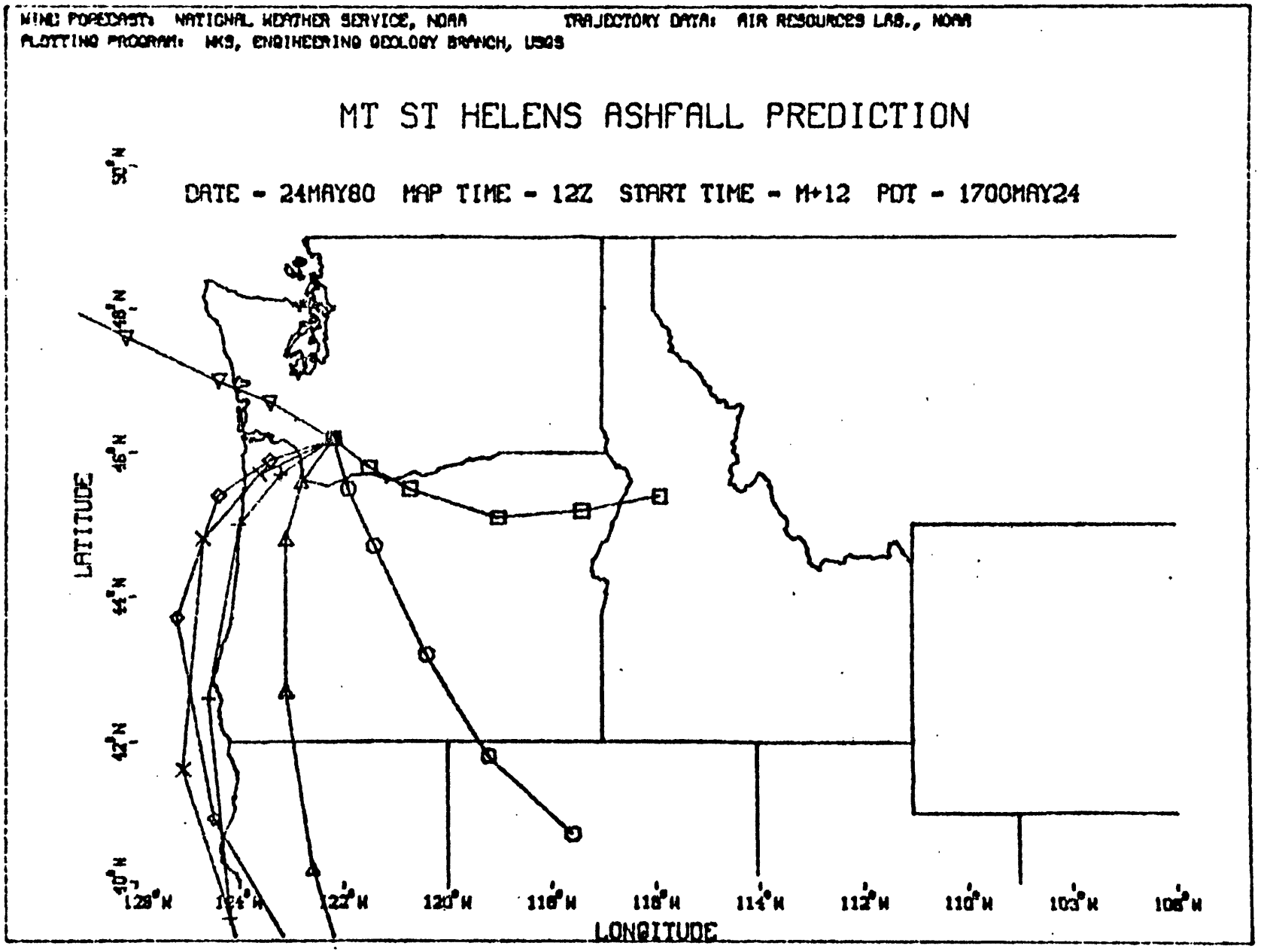

Figure 8.--Example trajectory plot from afternoon wind data, May 24, 1980, start time = M+12.

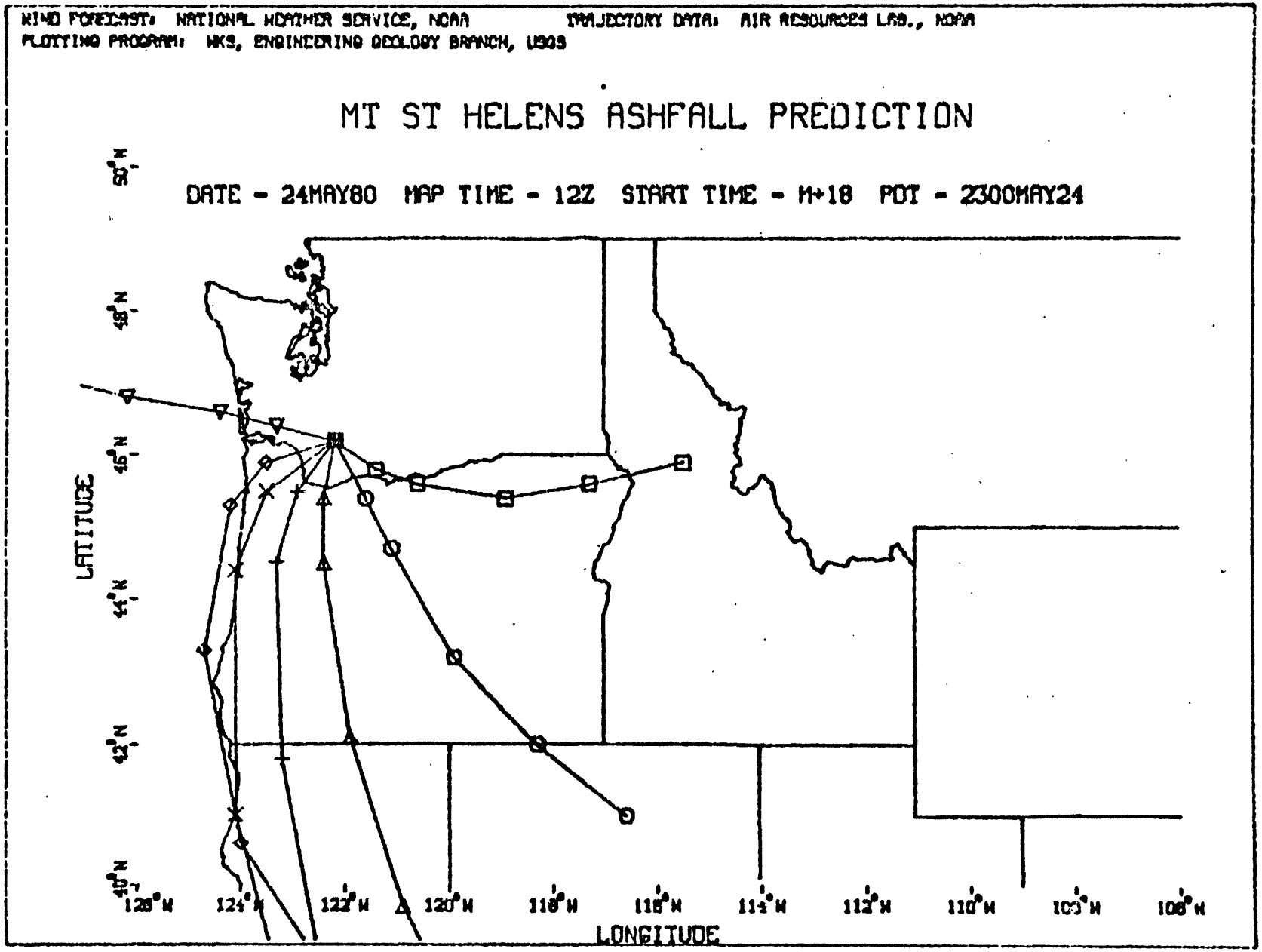

Figure 9.--Example trajectory plot from afternoon wind data, May 24, 1980, start time = M+18.

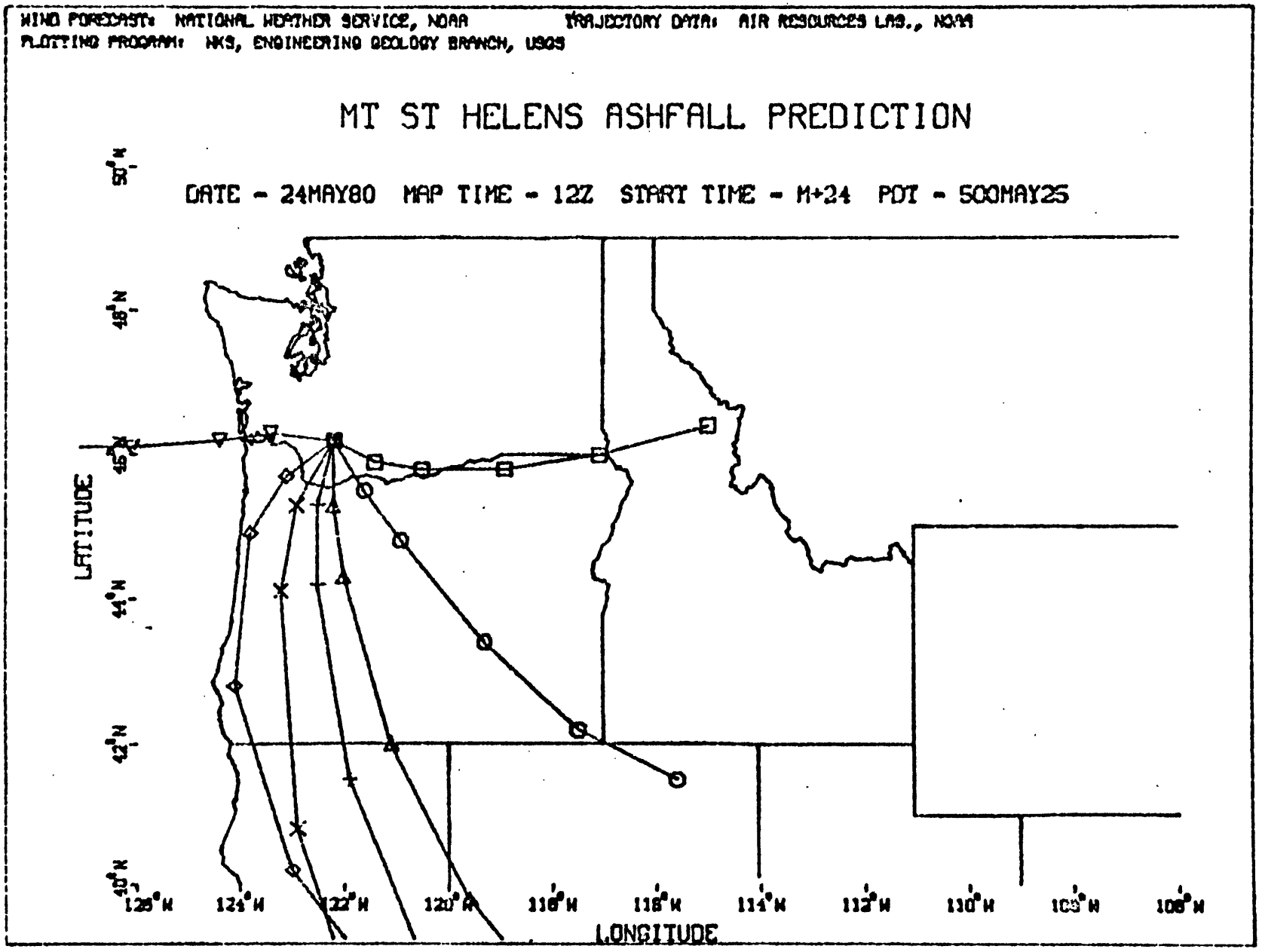

Figure 10.--Example trajectory plot from afternoon wind data, May 24, 1980, start time = M+24.

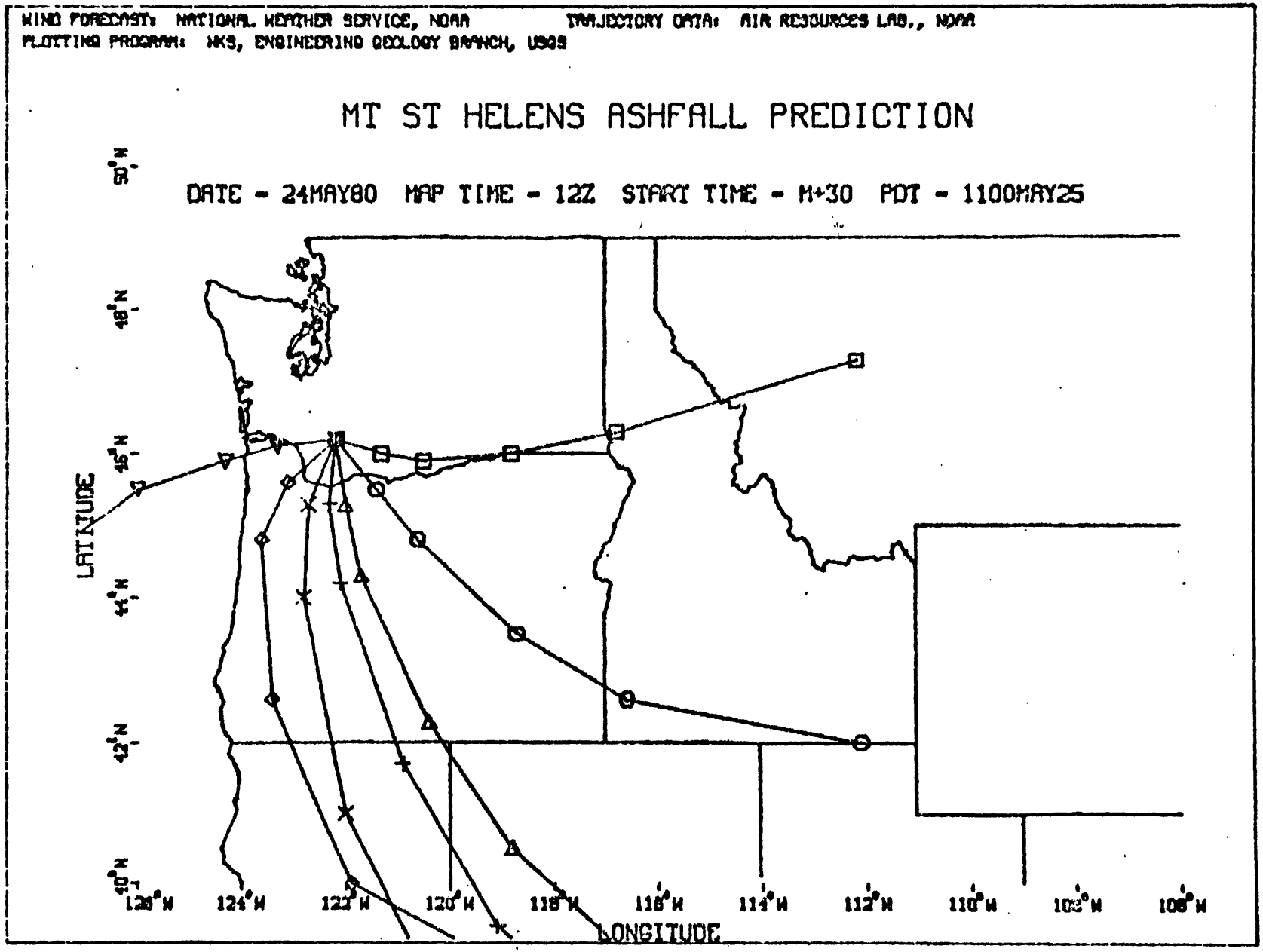

Figure 11.--Example trajectory plot from afternoon wind data, May 24, 1980, start time = M+30.

The most desirable improvement to the present system would be the ability to generate the plots on the NOAA computer, thus eliminating the need to transfer the data file to the USGS computer.

Interested users on the Denver USGS computer can generate plots with the following procedure:

```
add_search_rules >iml>disspla -after working_dir
setup_tektronix_tcs
change_wdir >udd>Egb00647>CDMiller
fallout_map
```

REFERENCE

Sarna-Wojicki, A. M., Shipley, Susan, Waitt, R. B., Dzurisin, Daniel, Hays, W. H., Davis, J. O., Wood, S. H., and Bateridge, Thomas, 1980, Areal distribution, thickness, and volume of downwind ash from the May 18, 1980 eruption of Mount St. Helens: U.S. Geological Survey Open-File Report 80-1078, 13 p.

APPENDIX--PLOTTING PROGRAM DOCUMENTATION

Flow Charts for Plotting Program

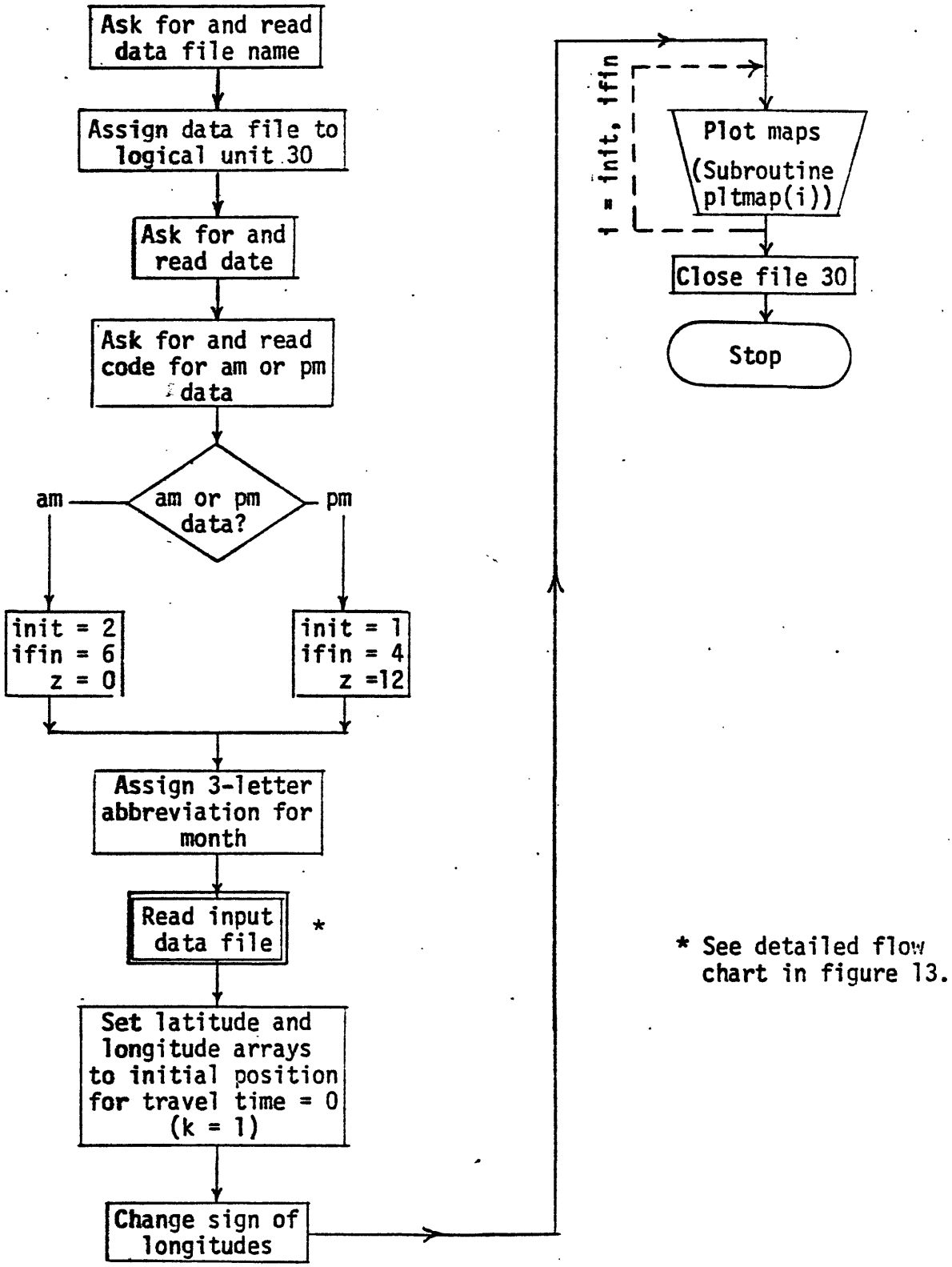

Figure 12. Generalized flow chart of program fallout_map.fortran.

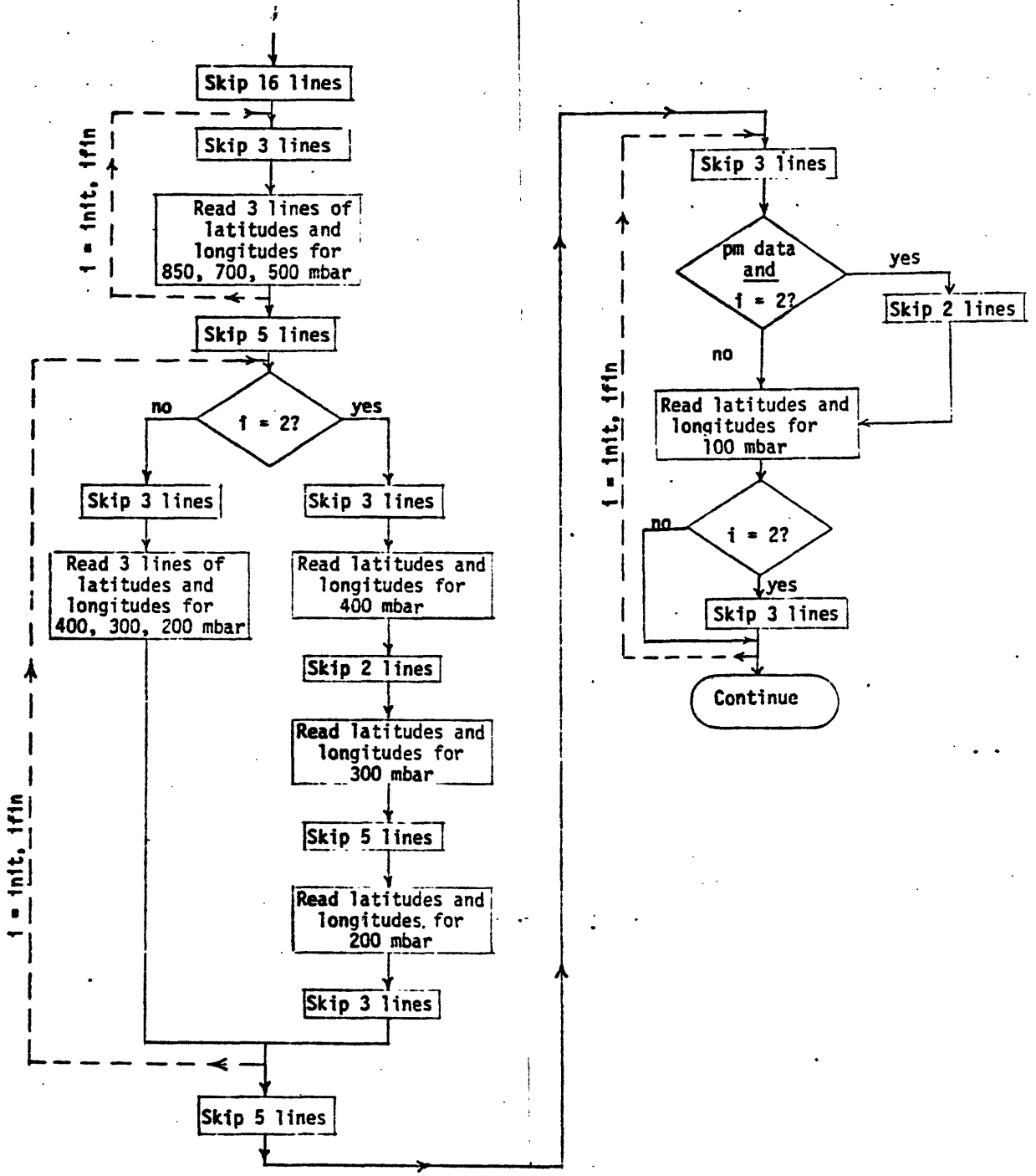

Figure 13. Detailed flow chart of data-reading procedure for fallout_map.fortran.

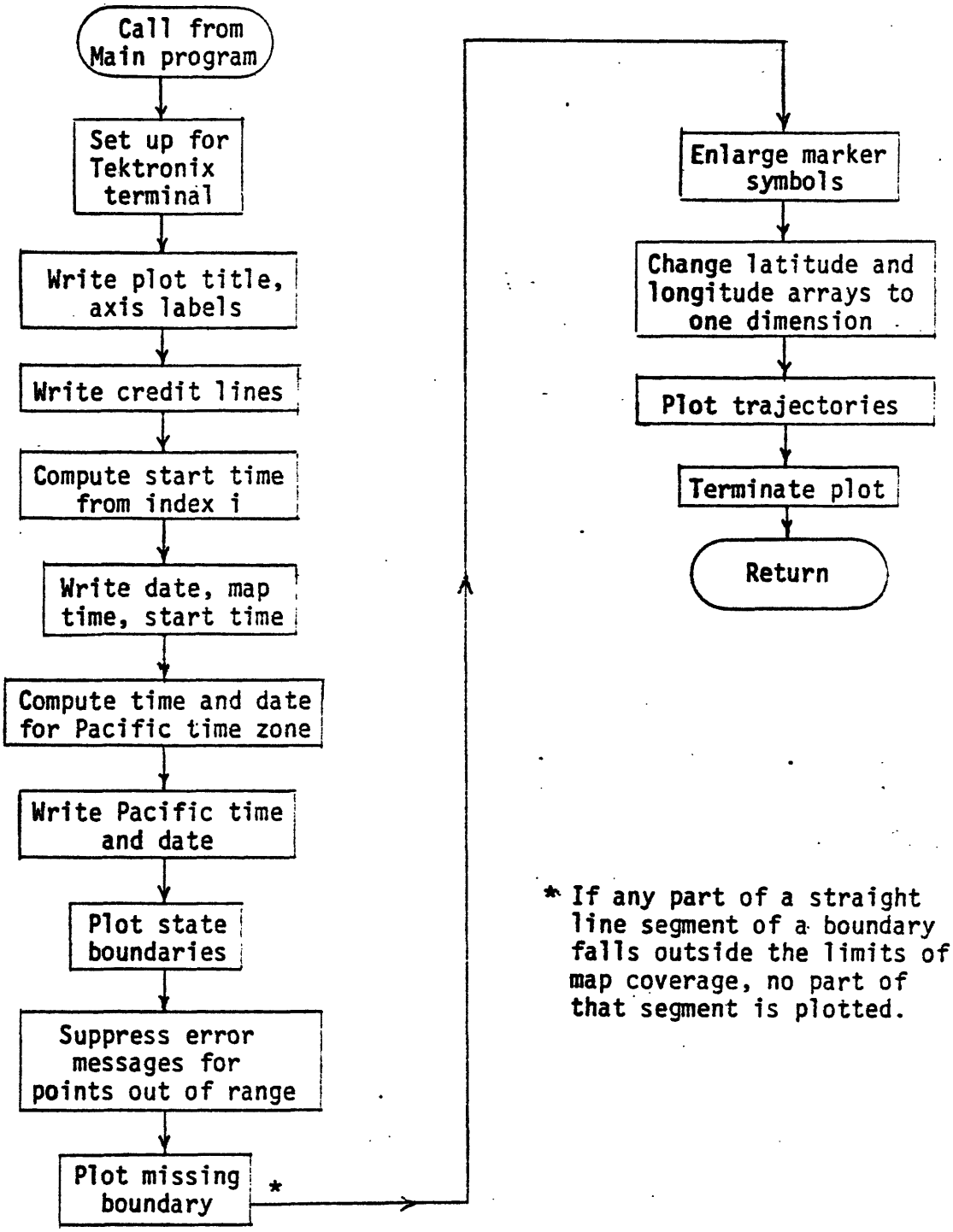

Figure 14.--Flow chart of subroutine pltmap(i).

Variable List and Definitions

Variable	Type and dimensions	Definition
ampm	integer	Code to identify morning or afternoon data sets: 1 = morning 2 = afternoon.
da	integer	Day of month for map time.
dal	integer	Day of month in Pacific time zone.
filein	character*32	Name of input data file.
i	integer	Index relating to start time: 1 = 12 h 2 = 18 h 3 = 24 h 4 = 30 h 5 = 36 h 6 = 42 h
ifin	integer	Ending value of index i.
imark	integer	Symbol code for plotting trajectories.
init	integer	Starting value of index i.
istart	integer	Start time in hours after map time.
j	integer	Index relating to pressure level: 1 = 850 mbar 2 = 700 mbar 3 = 500 mbar 4 = 400 mbar 5 = 300 mbar 6 = 200 mbar 7 = 100 mbar.
k	integer	Index relating to travel time: 1 = 0 (initial position) 2 = 3 h 3 = 6 h 4 = 12 h 5 = 18 h 6 = 24 h

Variable List and Definitions--Continued

Variable	Type and dimensions	Definition
lmo	character*4	Month name abbreviation.
mo	integer	Month (numeric).
pdt	integer	Pacific Daylight Time } 24-h clock, only one appears in program.
pst		Pacific Standard Time }
xlat(i,j,k)	real (6,7,6)	Latitude array.
xlong(i,j,k)	real (6,7,6)	Longitude array.
ylat(k)	real (6)	One-dimensional latitude array.
ylong(k)	real (6)	One-dimensional longitude array.
yr	integer	Year.
z	integer	Map time (either 0 or 12).

Notes: 1) Longitudes read from the data file are positive west; DISSPLA subroutine mapgr requires longitude to be positive east. This change is made by the program.

2) All subroutines called except pltmap(i) are DISSPLA 8.2 subroutines.

COMPILATION LISTING OF fallout_map (>user_dir_dir>Egb00647>CDMiller>fallout_map.fortran)

Compiled by: Multics New Fortran Compiler, Release 5a
Compiled on: 07/22/80 1254.9 mdt Tue
    Options: table card map

Main Program

```
1       external title(descriptors)
2       external rlmess(descriptors)
3       external messag(descriptors)
4       external intno(descriptors)
5       external mapfil(descriptors)
6       integer ampm, da, yr, z, pdt
7       common xlat(6,7,6),xlong(6,7,6),init,ifin,ampm,mo,lmo,da,yr,z
8       character*32 filein
9       character*4 lmo
10      write(0,1500)
11      read(0,1000) filein
12      open(30,file=filein,mode="in",form="formatted")
13      write(0,1505)
14      read(0,1000) mo, da, yr
15      write(0,1510)
16      read(0,1000) ampm
17      if(ampm .eq. 1) init=2
18      if(ampm .eq. 1) ifin=6
19      if(ampm .eq. 2) init=1
20      if(ampm .eq. 2) ifin=4
21      if (ampm.eq.1) z = 0
22      if (ampm.eq.2) z = 12
23      if(mo.eq.1) lmo = "JAN$"
24      if(mo.eq.2) lmo = "FEB$"
25      if(mo.eq.3) lmo = "MAR$"
26      if(mo.eq.4) lmo = "APR$"
27      if(mo.eq.5) lmo = "MAY$"
28      if(mo.eq.6) lmo = "JUN$"
29      if(mo.eq.7) lmo = "JUL$"
30      if(mo.eq.8) lmo = "AUG$"
31      if(mo.eq.9) lmo = "SEP$"
32      if(mo.eq.10) lmo = "OCT$"
33      if(mo.eq.11) lmo = "NOV$"
34      if(mo.eq.12) lmo = "DEC$"
35  c   Read Data File
36      read(30,2016)
37      do 100 i=init,ifin
38      read(30,2003)
39    100 read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=1,3)
40      read(30,2005)
41      do 200 i=init,ifin
42      if(i.ne.2) go to 150
43      read(30,2003)
```

```
      read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=4,4)
      read(30,2002)
      read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=5,5)
      read(30,2005)
      read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=6,6)
      read(30,2003)
      go to 200
  150 read(30,2003)
      read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=4,6)
  200 continue
      read(30,2005)
      do 300 i=init,ifin
      read(30,2003)
      if(ampm.eq.2.and.i.eq.2) read(30,2002)
      read(30,3000)((xlat(i,j,k),xlong(i,j,k),k=2,6),j=7,7)
      if(i.eq.2) read(30,2003)
  300 continue
c   Set Initial Position in Lat. and Long. Arrays
      do 350 i=init,ifin
      do 350 j=1,7
      xlat(i,j,1)=46.20
  350 xlong(i,j,1)=122.18
c   Change Sign of Longitudes
      do 375 i=init,ifin
      do 375 j=1,7
      do 375 k=1,6
  375 xlong(i,j,k)=-xlong(i,j,k)
      do 400 i=init,ifin
  400 call pltmap(i)
 1000 format(v)
 1500 format("ENTER NAME OF RAW DATA FILE")
 1505 format("ENTER DATE IN FORMAT 4 16 80 (CR)")
 1510 format("Enter 1 for am data; Enter 2 for pm data")
 2002 format(/)
 2003 format(//)
 2005 format(////)
 2016 format(/////////////////)
 3000 format(16x,f4.1,9f6.1)
      close(30)
      end
```

NAMES USED IN THIS PROGRAM UNIT

NAME	TYPE OF NAME	LOC	STORAGE	ATTRIBUTES AND REFERENCES
ampm		000772	//	integer ref 6 7 16 17 18 19 20 21 22 57
blnk*com	common block name			512 words ref 7
da		000775	//	integer ref 6 7 14
filein		000160	automatic	character(32) ref 8 11 12
i		000170	automatic	integer ref 37 39 39 41 42 44 44 46 46 48 48 52 52 55 57 58 58 59 62 64 65 67 70 70 71 72
ifin		000771	//	integer ref 7 18 20 37 41 55 62 67 71
init		000770	//	integer ref 7 17 19 37 41 55 62 67 71
j		000171	automatic	integer ref 39 39 39 44 44 44 46 46 46 48 48 48 52 52 52 58 58 58 63 64 65 68 70 70
k		000172	automatic	integer ref 39 39 39 44 44 44 46 46 46 48 48 48 52 52 52 58 58 58 69 70 70
lmo		000774	//	character(4) ref 7 9 23 24 25 26 27 28 29 30 31 32 33 34
main_	entry point	000134	constant	on line 1
mo		000773	//	integer ref 7 14 23 24 25 26 27 28 29 30 31 32 33 34
pltmap	internal subroutine		constant	ref 72
xlat		000000	//	real array(6,7,6) ref 7 39 44 46 48 52 58 64
xlong		000374	//	real array(6,7,6) ref 7 39 44 46 48 52 58 65 70 70
yr		000776	//	integer ref 6 7 14
z		000777	//	integer ref 6 7 21 22

NAMES DECLARED BUT NOT USED

intno	external	constant	with descriptors declared 4
mapfil	external	constant	with descriptors declared 5
messag	external	constant	with descriptors declared 3
pdt			integer declared 6
rlmess	external	constant	with descriptors declared 2
title	external	constant	with descriptors declared 1

LOC	LABEL	TYPE	LINE	REFERENCES
000533	100	executable	39	ref 37
001104	150	executable	51	used in transfer ref 42
001171	200	executable	53	used in transfer ref 41 50
001331	300	executable	60	ref 55
001353	350	executable	65	ref 62 63
001401	375	executable	70	ref 67 68 69
001440	400	executable	72	ref 71
	1000	format	73	ref 11 14 16
	1500	format	74	ref 10
	1505	format	75	ref 13
	1510	format	76	ref 15
	2002	format	77	ref 45 57
	2003	format	78	ref 38 43 49 51 56 59
	2005	format	79	ref 40 47 54
	2016	format	80	ref 36
	3000	format	81	ref 39 44 46 48 52 58

Subroutine pltmap

```
      subroutine pltmap(i)
      external title(descriptors)
      external rlmess(descriptors)
      external messag(descriptors)
      external intno(descriptors)
      external mapfil(descriptors)
      integer ampm, da, yr, z, pdt, dal
      common xlat(6,7,6),xlong(6,7,6),init,ifin,ampm,mo,lmo,da,yr,z
      character*4 lmo
      dimension ylat(6),ylong(6)
      call tektrn(120)
      call title("MT ST HELENS ASHFALL PREDICTIONS",-100,"LONGITUDES",
     1 100,"LATITUDES",100,9.2,6.5)
      call height(.10)
      call messag("WIND FORECAST: NATIONAL WEATHER SERVICE, NOAAS",
     1    100,-1.0,7.8)
      call messag("          TRAJECTORY DATA: AIR RESOURCES LAB., NOAAS
     1",100,"abut","abut")
      call messag("PLOTTING PROGRAM: WKS, ENGINEERING GEOLOGY BRANCH, U
     1SGSS",100,-1.0,7.6)
      call height(.14)
      call mapgr(-126.,2.,-106.,40.,2.,50.)
      istart = 6*i + 6
      call rlmess("date = $",100,-125.,49.5)
      call intno(da,"abut","abut")
      call messag(lmo,3,"abut","abut")
      call intno(yr,"abut","abut")
      call messag("  MAP TIME = $",100,"abut","abut")
      call intno(z,"abut","abut")
      call messag("Z  START TIME = M+$",100,"abut","abut")
      call intno(istart,"abut","abut")
      call messag("  PDT = $",100,"abut","abut")
      pdt = z + istart - 7
      dal = da
      if(pdt.ge.24) dal = da + 1
      if(pdt.ge.24) pdt = pdt - 24
      pdt = pdt*100
      call intno(pdt,"abut","abut")
      call messag(lmo,3,"abut","abut")
      call intno(dal,"abut","abut")
      call mapfil("usah")
      call nochek
c     Plot Missing State Boundaries
      call rlvec(-120.,42.,-120.,40.,0000)
      call rlvec(-109.,41.,-109.,40.,0000)
      call sclpic(1.5)
      imark=0
      do 200 j=1,7
      do 210 k=1,6
```

```
      ylat(k)=xlat(i,j,k)
  210  ylong(k)=xlong(i,j,k)
      call marker(imark)
      call curve(ylong,ylat,6,1)
      imark=imark+1
  200 continue
      call endpl(0)
      return
      end
```

NAMES USED IN THIS PROGRAM UNIT

NAME	TYPE OF NAME	LOC	STORAGE	ATTRIBUTES AND REFERENCES
blnk*com	common block name			512 words ref 91
curve	external subroutine	000152	constant	ref 136
da		000775	//	integer ref 90 91 108 117 118
dal		000175	automatic	integer ref 90 117 118 123
endpl	external subroutine	000154	constant	ref 139
height	external subroutine	000136	constant	ref 97 104
i			parameter	position 1 integer ref 84 106 133 134
imark		000213	automatic	integer ref 130 135 137 137
intno	external subroutine	000130	constant	with descriptors ref 88 108 110 112 114 121 123
istart		000212	automatic	integer ref 106 114 116
j		000214	automatic	integer ref 131 133 134
k		000215	automatic	integer ref 132 133 133 134 134
lmo		000774	//	character(4) ref 91 92 109 122
mapfil	external subroutine	000132	constant	with descriptors ref 89 124
mapgr	external subroutine	000140	constant	ref 105
marker	external subroutine	000150	constant	ref 135
messag	external subroutine	000126	constant	with descriptors ref 87 98 100 102 109 111 113 115 122
nochek	external subroutine	000142	constant	ref 125
pdt		000174	automatic	integer ref 90 116 118 119 119 119 120 120 121
pltmap	entry point	001465	constant	on line 84
rlmess	external subroutine	000124	constant	with descriptors ref 86 107
rlvec	external subroutine	000144	constant	ref 127 128
sclpic	external subroutine	000146	constant	ref 129
tektrn	external subroutine	000134	constant	ref 94
title	external subroutine	000122	constant	with descriptors ref 85 95
xlat		000000	//	real array(6,7,6) ref 91 133
xlong		000374	//	real array(6,7,6) ref 91 134
ylat		000176	automatic	real array(6) ref 93 133 136
ylong		000204	automatic	real array(6) ref 93 134 136
yr		000776	//	integer ref 90 91 110
z		000777	//	integer ref 90 91 112 116

NAMES DECLARED BUT NOT USED

ampm	000772	//	integer declared 90 91
iflin	000771	//	integer declared 91
init	000770	//	integer declared 91
mo	000773	//	integer declared 91

LOC	LABEL	TYPE	LINE	REFERENCES
002555	200	executable	138	ref 131
002511	210	executable	134	ref 132

Main program

LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC
0	000133	10	000150	11	000157	12	000176	13	000226	14	000235	15	000271
16	000300	17	000320	18	000326	19	000334	20	000342	21	000350	22	000356
23	000364	24	000373	25	000402	26	000411	27	000420	28	000427	29	000436
30	000445	31	000454	32	000463	33	000472	34	000501	36	000510	37	000517
38	000524	39	000533	40	000615	41	000624	42	000631	43	000635	44	000644
45	000722	46	000731	47	001007	48	001016	49	001074	50	001103	51	001104
52	001113	53	001171	54	001175	55	001204	56	001211	57	001220	58	001241
59	001317	60	001331	62	001335	63	001342	64	001344	65	001353	67	001371
68	001375	69	001377	70	001401	71	001434	72	001440	82	001447	83	001463

Subroutine pltmap(i)

LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC	LINE	LOC
84	001464	94	001504	95	001514	97	001564	98	001574	100	001625	102	001653
104	001704	105	001714	106	001744	107	001750	108	002001	109	002024	110	002053
111	002076	112	002124	113	002147	114	002175	115	002217	116	002245	117	002252
118	002254	119	002262	120	002270	121	002273	122	002315	123	002344	124	002366
125	002400	127	002406	128	002434	129	002462	130	002472	131	002474	132	002476
133	002500	134	002511	135	002524	136	002534	137	002552	138	002555	139	002561
140	002571												

```
OBJECT SEGMENT SUMMARY

STORAGE REQUIREMENTS FOR THIS PROGRAM

          Object    Text      Link      Symbol    Defs      Static
Start          0       0      2636        3172    3016        2666
Length      4676    2635       160        1470     153         110

Stack frame is 208 (decimal) words.

ENTRY POINT          LOC       ATTRIBUTES -

main_                000134    on line 1
pltmap               001465    on line 84 ref in main_ 72

EXTERNAL REFERENCE   LOC       ATTRIBUTES

curve                000152    in pltmap ref 136
endpl                000154    in pltmap ref 139
height               000136    in pltmap ref 97 104
intno                000130    in pltmap ref 88 108 110 112 114 121 123
mapfil               000132    in pltmap ref 89 124
mapgr                000140    in pltmap ref 105
marker               000150    in pltmap ref 135
messag               000126    in pltmap ref 87 98 100 102 109 111 113 115 122
nochek               000142    in pltmap ref 125
rlmess               000124    in pltmap ref 86 107
rlvec                000144    in pltmap ref 127 128
sclpic               000146    in pltmap ref 129
tektrn               000134    in pltmap ref 94
title                000122    in pltmap ref 85 95

COMMON BLOCK         LOC       LENGTH  REFERENCES

blnk*com             000120       512  declared 7
                                  512  declared 91
```