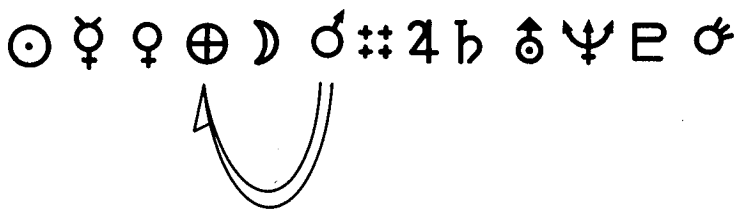
JPL PUBLICATION 82-43

Interplanetary Mission Design Handbook, Volume I, Part 5

Mars-to-Earth Ballistic Mission Opportunities, 1992–2007

Andrey B. Sergeyevsky
Ross A. Cunniff



December 1, 1987

NASA
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Abstract

This document contains graphical data necessary for the preliminary design of ballistic missions returning from Mars. Contours of Mars-departure energy requirements, as well as many other launch and Earth-arrival parameters, are presented in arrival-date/launch-date space for all departure opportunities from 1992 through 2007. In addition, an extensive companion document (Part 2 of this volume) is available; it contains Earth-to-Mars graphical data and explains mission design methods, from launch-window development to Mars probe and orbiter arrival design, using the graphical data as well as numerous equations relating various parameters. This document is one of a planned series of mission design handbooks.

Preface

This publication is one of a series of volumes devoted to interplanetary trajectories of different types. Volume I deals with ballistic trajectories. The present publication is Part 5 and describes ballistic Mars-to-Earth return trajectories. Part 3, which was published in 1982, treated ballistic trajectories to Jupiter. Part 4, which was published in 1983, described ballistic trajectories to Saturn. Parts 1 and 2, which were also published in 1983, treated ballistic trajectories to Venus and Mars, respectively.

Contents

I. Introduction

The purpose of this series of Mission Design Handbooks is to provide trajectory designers and mission planners with graphical trajectory information sufficient for preliminary interplanetary mission design and evaluation. In most respects the series is a continuation of the previous three volumes of the Mission Design Data, TM 33-736 (Ref. 1) and its predecessors (e.g., Ref. 2); it extends their coverage to Earth departures through the year 2005 A.D.

The entire series is planned as two volumes, each describing a distinct mission mode as follows:

Volume I: Ballistic (i.e., unpowered) transfers between Earth and a planet, consisting of one-leg trajectory arcs. For Venus and Mars missions, the planet-to-Earth return trajectory data will also be provided.

Volume II: Gravity-Assist (G/A) trajectory transfers, comprising from two to four ballistic interplanetary legs, connected by successive planetary swingbys (in planning stage only).

Each volume consists of several parts, describing trajectory opportunities for missions toward specific target or swingby bodies.

Volume I, Part 2, of the series was devoted to ballistic transfers between Earth and Mars (Ref. 3). It described trajectories taking from 100 to 500 days of flight time for the eight successive mission opportunities that depart Earth in the following years: 1990, 1992, 1994, 1996/7, 1998/9, 2000/1, 2002/3, and 2005.

This Part 5 of Volume I is a sequel to Part 2 of the series. It is devoted to ballistic Mars-to-Earth return transfers of similar duration, departing Mars in 1992, 1994, 1996, 1998, 2000/1, 2002/3, 2004/5, and 2006/7. The two parts are intended to be used together.

Individual variables presented herein are described in detail in Section II. Suffice it to say here that all the data are presented in sets of 10 contour plots each, displayed on the arrival-date/launch-date space for each opportunity. Required departure energy C_3, departure asymptote declination and right ascension, arrival V_∞ and its equatorial directions, as well as Sun and Earth direction angles with respect to the arrival/departure asymptotes, are presented.

A separate series of volumes (Ref. 4) has been published concurrently to provide purely geometrical (i.e., trajectory-independent) data on planetary positions and viewing/orientation angles, experienced by a spacecraft in the vicinity of each planetary body. The data cover the time span through 2020 A.D. to allow sufficient mission duration time for all Earth departures up to 2005 A.D.

II. Description of Trajectory Characteristics Data

A. General

The data in this handbook represent trajectory performance information plotted in the Earth-arrival date vs Mars-departure date space. The mission space thus defined contains all possible direct Type I and Type II ballistic transfer trajectories between the two bodies within the time span considered for each opportunity. Eleven individual parameters are contour-plotted. The first, C_3L, is plotted bold on a time-of-flight (TFL) background; the remaining nine variables are plotted with bold contouring on a faint C_3L background. Ten plots are presented for each of eight mission opportunities between 1992 and 2007.

The individual plots are labeled in the upper outer corner by bold logos displaying an acronym of the variable plotted, the mission's departure year, and symbols of the departure and arrival planets. These permit a quick and fail-safe location and transmittal of copies of desired information.

For the years 2000 to 2007, the contoured variables are presented on two-page spreads labeled "EARLY" and "LATE" in the corner for more efficient reference.

A more detailed description and graphical representation of the presented variables can be found in the companion Volume I, Part 2, handbook.

B. Definition of Departure Variables

C_3L: Mars departure energy (km^2/s^2); same as the square of departure hyperbolic excess velocity:

$$V_\infty^2 = C_3L = V_I^2 - 2\mu_P/R_I$$

where

V_I = conic injection velocity (km/s)

R_I = $R_S + h_I$; i.e., injection radius (km), sum of surface radius $R_{S_{PLANET}}$ and injection altitude h_I, where $R_{S_{PLANET}}$ refers to Mars' surface radius (for value of which, see Section IV on constants).

μ_P = gravitational constant times mass of the

departure body (for values of which, see Section IV on constants).

C_3L must be equal to, or exceeded by, the Mars-departure-vehicle capabilities.

DLA: δ_{∞_L}, planetocentric declination (vs mean Mars equator of date) of the departure V_∞ vector. May impose launch constraints (deg).

RLA: α_{∞_L}, planetocentric right ascension (vs mean Mars equator and equinox of date) of the departure V_∞ vector. RLA is measured counterclockwise in the planet's equator plane from the ascending node of the planet's mean orbit plane on the planetary equator. Can be used with C_3L and DLA to compute a heliocentric initial state for trajectory analysis (deg).

ZALS: Angle between departure V_∞ vector and Sun-Mars vector. Equivalent to Mars-spacecraft-Sun angle several days out (deg).

ZALE: Angle between departure V_∞ vector and the Earth-to-Mars vector. Equivalent to Mars-spacecraft-Earth angle several days out.

C. Definition of Arrival Variables

VHP: V_{∞_A}, geocentric arrival hyperbolic excess velocity or V-infinity (km/s), the magnitude of the vector obtained by vectorial subtraction of the heliocentric Earth velocity from the spacecraft heliocentric velocity at arrival. It represents Earth-relative velocity at great distance from Earth at the beginning of far encounter. Can be used to compute spacecraft velocity at any point r of flyby, including C/A (periapse) distance r_p:

$$V = \sqrt{V_\infty^2 + \frac{2\mu_E}{r}}, \text{ km/s}$$

where

μ_E = gravitational parameter GM of the arrival planet–Earth (for values of which, see Section IV on constants).

DAP: δ_{∞_A}, geocentric declination (vs mean Earth equator of 1950.0) of arrival V_∞ vector. Defines lowest possible flyby/orbiter equatorial inclination achievable without plane change (deg).

RAP: α_{∞_A}, geocentric right ascension (vs mean Earth equator and equinox of 1950.0). Can be used together with VHP and DAP to compute an initial flyby trajectory state, but requires B-plane arrival aim-point information, e.g., B and θ (deg).

ZAPS: Angle between arrival V_∞ vector and the arrival planet-to-Sun vector. Equivalent to planet-spacecraft-Sun angle at far encounter; for subsolar impact would be equal to 180 deg. Can be used with ETSP, VHP, DAP, and θ to determine solar phase angle at such points as periapse or entry (deg).

ETSP: Angle in arrival B-plane, measured from T-axis* clockwise to projection of Sun-to-Earth (arrival planet) vector. Equivalent to solar occultation region centerline direction in B-plane, θ_S (deg).

III. Use of the Trajectory Data

A. Mission Space

Each arrival-date/departure-date point on the mission space contour plot represents a unique conic transfer trajectory between the two specified planets, provided the transfer angle is less than one revolution (Fig. 1).

Both legs of a Mars stopover mission can be adequately designed with the aid of the respective Earth-outbound or Earth-inbound data plots (Parts 2 and 5 of Volume I of this handbook series, respectively). Optimization issues such as minimum departure energy vs minimum arrival ΔV (a function of arrival V_∞ and periapse radius), mission duration or arrival date planning, and satisfaction of declination or solar lighting constraints can all be addressed using the information presented.

Departure window analysis, especially for two or more launches, is also adequately presented on the single-leg mission space chart.

Stay time for round-trip missions, on the other hand, requires simultaneous viewing of both Earth-outbound and Earth-inbound chart sets.

For convenience, the contours of the trajectory characteristics are plotted in this handbook (Mars-to-Earth Return, Part 5) with the departure and arrival axes interchanged with respect to their usual orientation. This enables alignment of the Mars dates at arrival and departure along the same Y-axis direction, which in turn allows direct comparison of the two plot groups, taken from Part 2 and Part 5, respectively (Fig. 2). Note that Type I and Type II regions have changed places on the Mars-to-Earth mission space.

*ETSP plot is based on T-axis defined as parallel to ecliptic plane (see the Part 2 handbook for explanation).

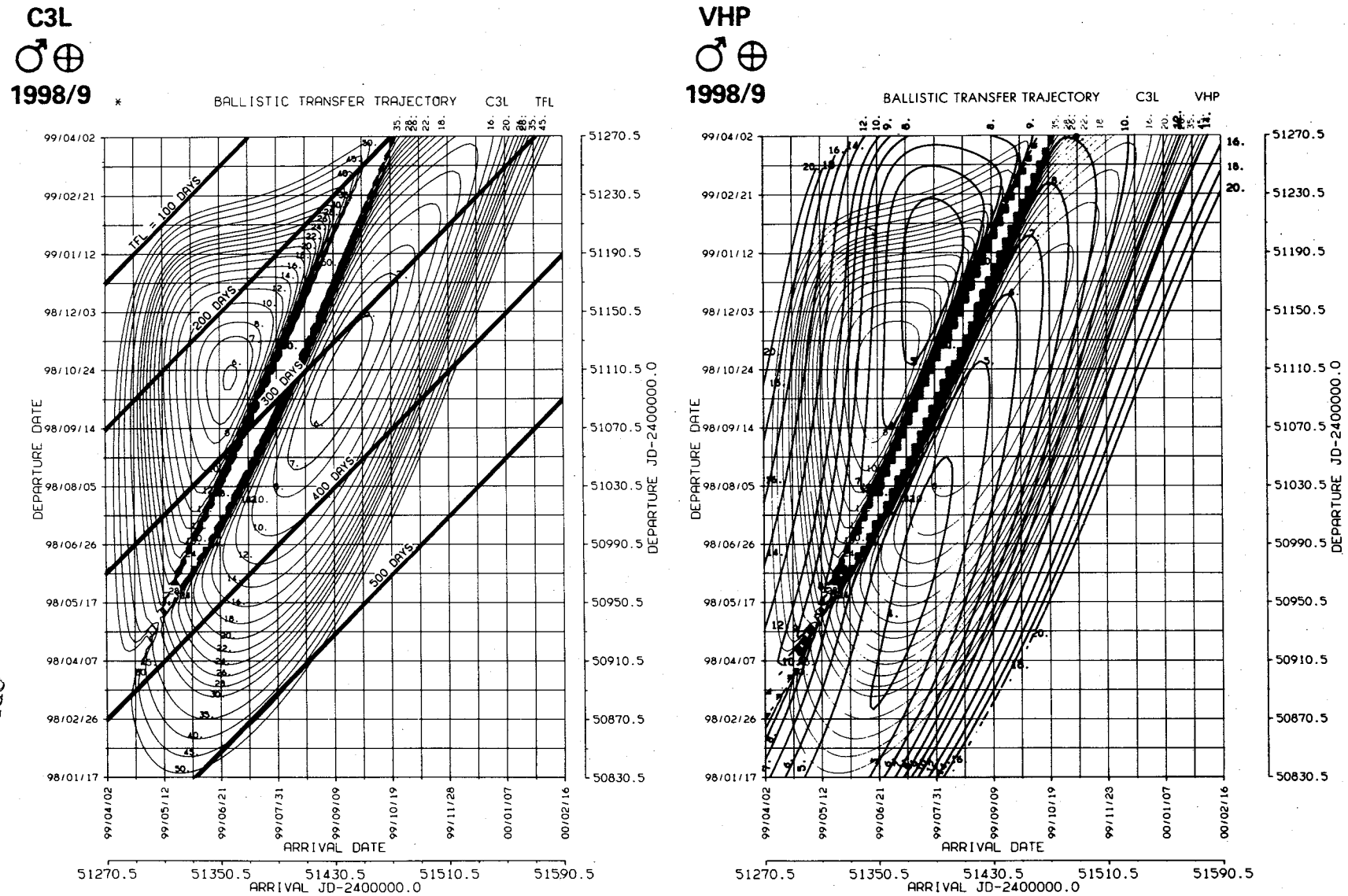


Fig. 1. Mars-to-Earth return mission space: C_3L and VHP (note reversal of arrival/departure axes)

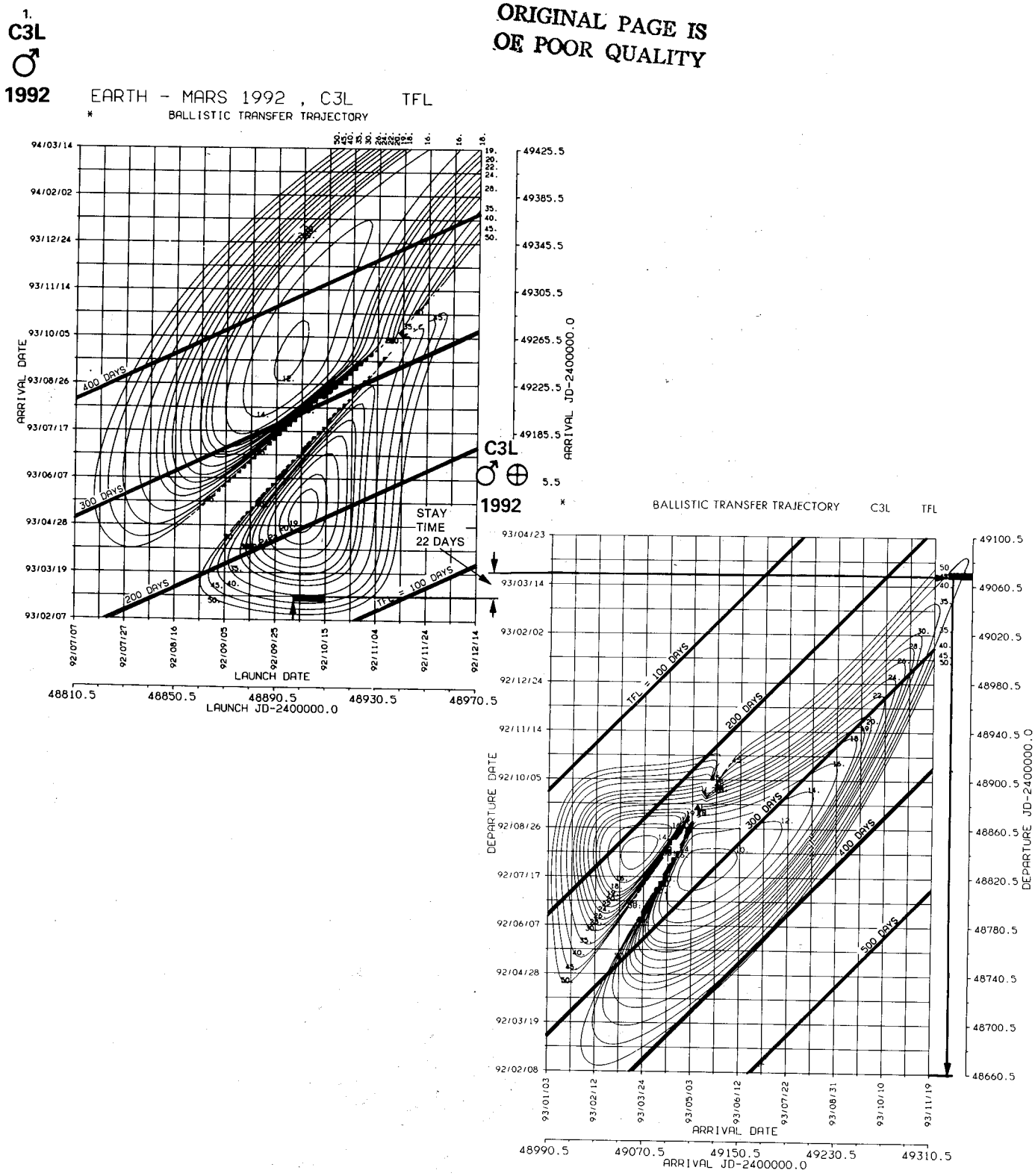


Fig. 2. Typical Mars short-stopover mission space ("opposition class," ballistic)

B. Stay-Time Analysis

As can readily be observed, reasonably optimal Mars arrivals are too late and regularly *miss* the dates of good Mars-to-Earth departure opportunities. To salvage these short stay-time missions, unreasonably high arrival or departure energies are imperative; these eccentric round-trip missions are frequently categorized as "opposition class" missions (Fig. 2). A variant of the missions of this class uses Venus gravity assist, either on the Earth-outbound or on the Earth-inbound leg, to allow missions with short (10- to 60-day) stay times on Mars. Such typically manned missions have been the subject matter of Ref. 5, and may be covered in a future volume of this series.

If long stay times (over 1 year) are found to be acceptable in Mars' vicinity, then waiting for the *next* homebound departure opportunity is feasible. These missions are frequently of Type II (transfer angles over 180 degrees) often on both legs and would require stay times of about 300 to 600 days. Such missions are frequently, though somewhat misleadingly, categorized as "conjunction class" cases (Fig. 3). An Earth-Sun-spacecraft conjunction event is bound to occur somewhere on such missions during the long transfer-flight and stay-time phases.

The combined set of Earth-outbound/inbound charts of trajectory characteristics provides a good insight into options available in the design of round-trip flyby and stopover missions to Mars.

IV. Table of Constants

Constants used to generate the information presented are summarized in this section.

A. Sun

$$\mu = GM = 132{,}712{,}439{,}935 \text{ km}^3/\text{s}^2$$

$$R_{SURFACE} = 696{,}000 \text{ km}$$

B. Earth/Moon System

$$\mu_E = GM_{SYSTEM} = 403,503.253 \text{ km}^3/\text{s}^2$$

$$GM_{EARTH} = 398{,}600.448\,073 \text{ km}^3/\text{s}^2$$

$$J_2 = 0.00108263$$

$$R_{EARTH\ SURFACE} = 6378.140 \text{ km}$$

C. Mars System

$$\mu_P = GM_{SYSTEM} = 42{,}828.287 \text{ km}^3/\text{s}^2$$

$$J_{2_{MARS}} = 0.001965$$

Direction of the Martian planetary equatorial north pole (in Earth Mean Equator of 1950.0 coordinates):

$$\alpha_P = 317.342 \text{ deg}, \qquad \delta_P = 52.711 \text{ deg}$$

Planet and Satellites	μ_{P_i} (GM), km^3/s^2	R_{S_i} Surface Radius, km	Mean Orbit Radius,* km	Sidereal Period, hours
Mars (alone)	42,828.286	3397.5	–	24.6229621
Phobos	0.00066	13.5 × 10.7 × 9.6	9374	7.6538444
Deimos	0.00013	7.5 × 6.0 × 5.5	23457	30.2985774

*Computed from period and Mars GM, rounded.

D. Sources

The constants represent the DE-118 planetary ephemeris (Ref. 6) and Mariner 9/Viking trajectory reconstruction data. Definition of the Earth's equator (EME50.0) is consistent with Refs. 7 and 8, but would require minor adjustments for the new equator and equinox, epoch of J2000.0 (Ref. 9).

Acknowledgments

The contributions, reviews, and suggestions by members of the Handbook Advisory Committee, especially those of S. J. Kerridge, J. H. Kwok, R. E. Diehl, K. T. Nock, P. A. Penzo, G. C. Snyder, W. I. McLaughlin, W. E. Bollman, R. A. Wallace, D. F. Bender, D. V. Byrnes, L. A. D'Amario, and T. H. Sweetser, graphic assistance by Nanette Yin, as well as the computational and plotting algorithm development effort by R. S. Schlaifer are acknowledged and greatly appreciated. The authors would like to thank Mary Fran Buehler, Paulette Cali, Douglas Maple, David Fulton, and Michael Farquhar for their editorial contributions to this series.

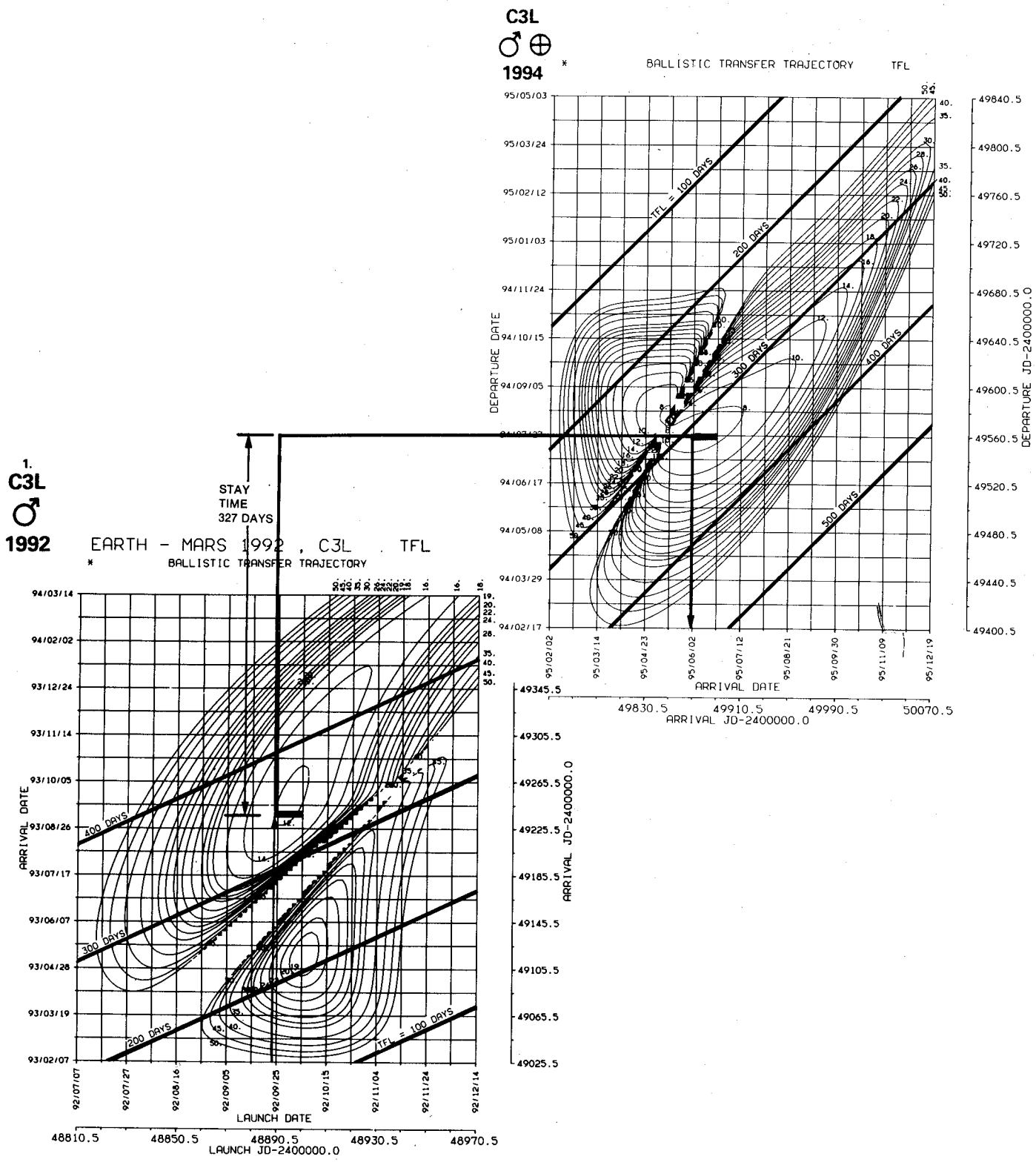


Fig. 3. Typical Mars long-stopover mission space ("conjunction class")

References

1. Sergeyevsky, A. B., *Mission Design Data for Venus, Mars, and Jupiter Through 1990*, Technical Memorandum 33-736, Vols. I, II, III, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1975.

2. Clarke, V. C., Jr., Bollman, W. E., Feitis, P. H., Roth, R. Y., *Design Parameters for Ballistic Interplanetary Trajectories, Part II: One-way Transfers to Mercury and Jupiter*, Technical Report 32-77, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 1966.

3. Sergeyevsky, A. B., Snyder, G. C., Cunniff, R. A., *Interplanetary Mission Design Handbook, Volume I, Part 2: Earth to Mars Ballistic Mission Opportunities, 1990–2005*, Publication 82-43, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1983.

4. Sergeyevsky, A. B., Snyder, G. C., Paulson, B. L., *Planetary Geometry Handbook*, Publication 82-44, Volumes II through V, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1983.

5. Deerwester, J., *Planetary Flight Handbook*, NASA SP-35, Vol. III, Part 6, Aug. 1967.

6. Newhall, XX, Standish, E. M., and Williams, J. G., "DE-102: A Numerically Integrated Ephemeris of the Moon and Planets, Spanning 44 Centuries," *Astronomy and Astrophysics*, 1983 (in press).

7. *Explanatory Supplement to the Ephemeris*, Her Majesty's Stationery Office, London, 1961.

8. Sturms, F. M., *Polynomial Expressions for Planetary Equators and Orbit Elements With Respect to the Mean 1950.0 Coordinate System*, Technical Report 32-1508, pp. 6–9, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 15, 1971.

9. Davies, M. E., et al., "Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 1982," *Celestial Mechanics*, Vol. 29, No. 4, pp. 309–321, April 1983. (Follow-on report for 1985, *Celestial Mechanics*, Vol. 39, No. 2, pp. 103–113, Feb. 1986.)

Mission Design Data
Contour Plots

Mars-to-Earth Ballistic
Mission Opportunities 1992–2007

Mars to Earth

1992

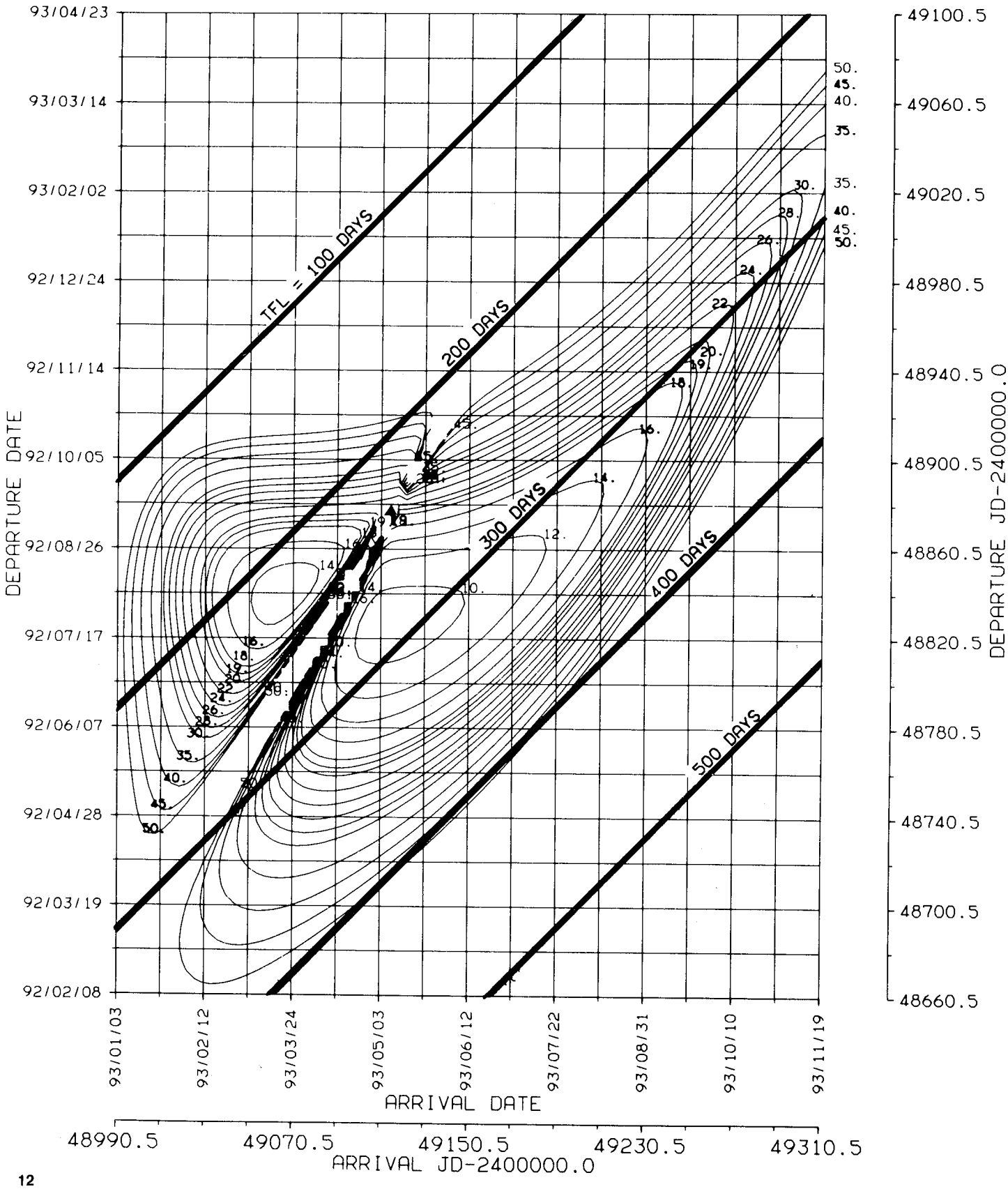
Opportunity

ENERGY MINIMA

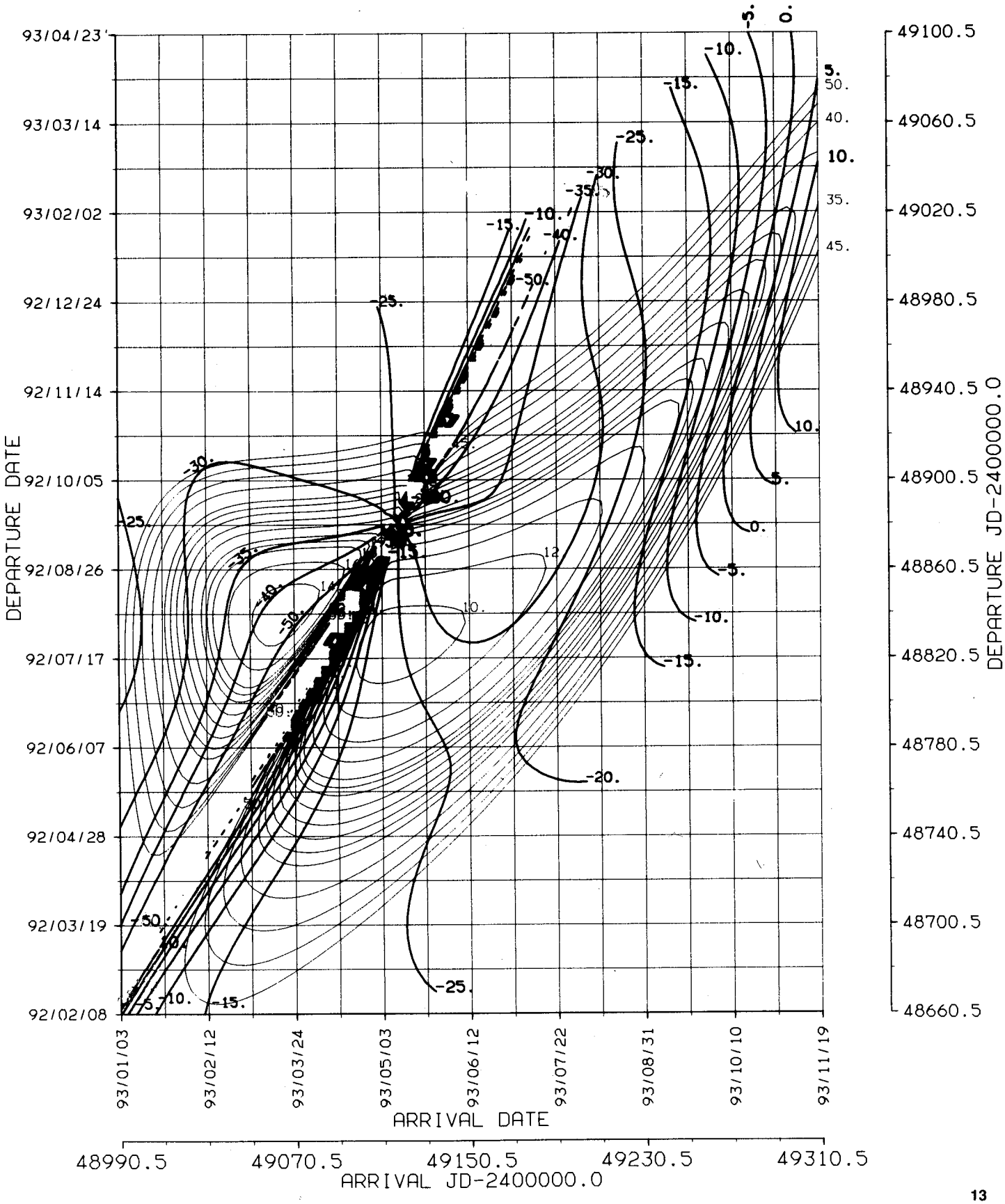
	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	12.981	I	1992/08/06	1993/03/20
C_3L	9.138	II	1992/07/23	1993/05/07
VHP	2.794	I	1992/09/10	1993/04/27
VHP	2.818	II	1992/07/20	1993/05/06

C3L ♂ ⊕ 1992

* BALLISTIC TRANSFER TRAJECTORY C3L TFL



BALLISTIC TRANSFER TRAJECTORY C3L DLA

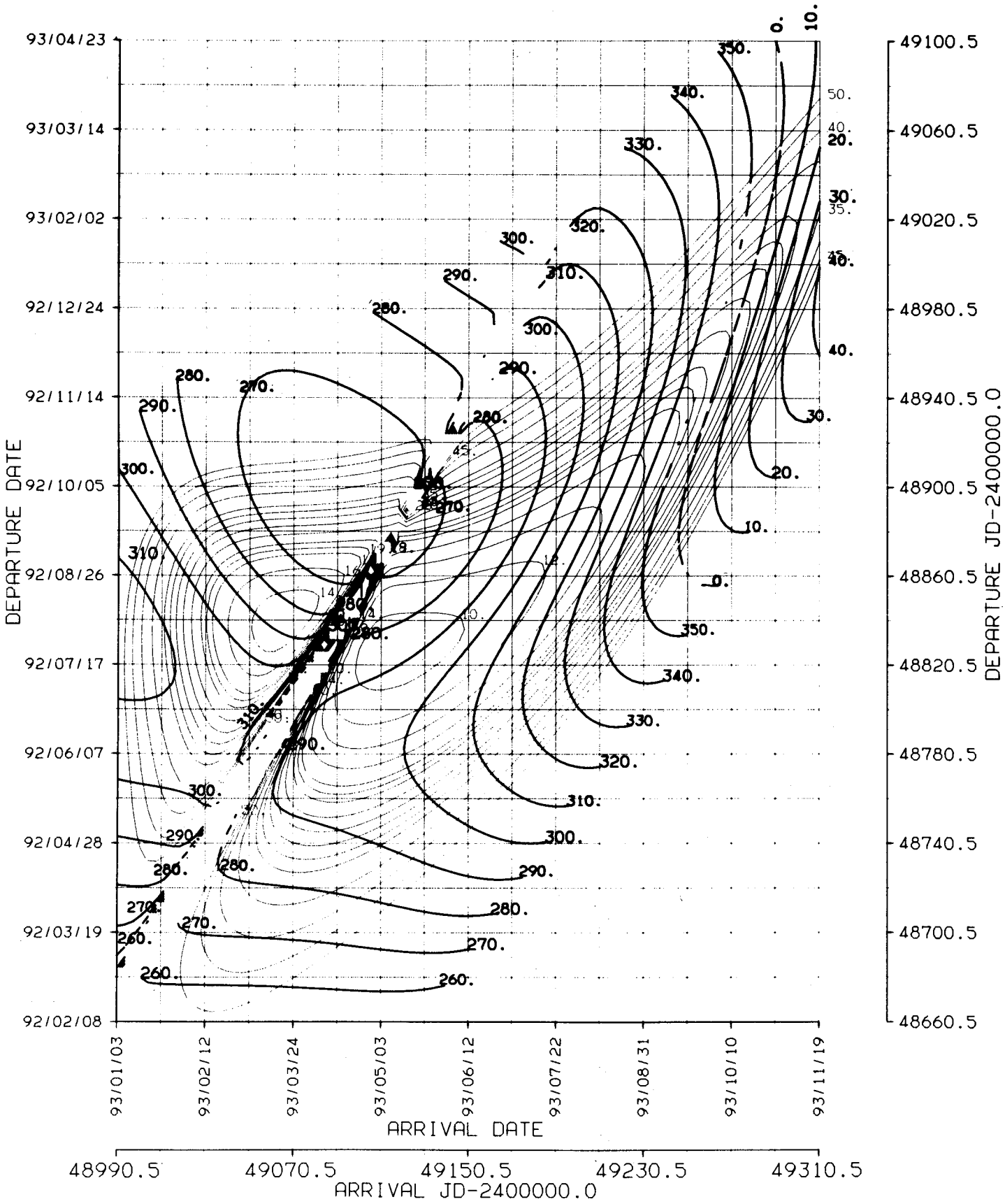


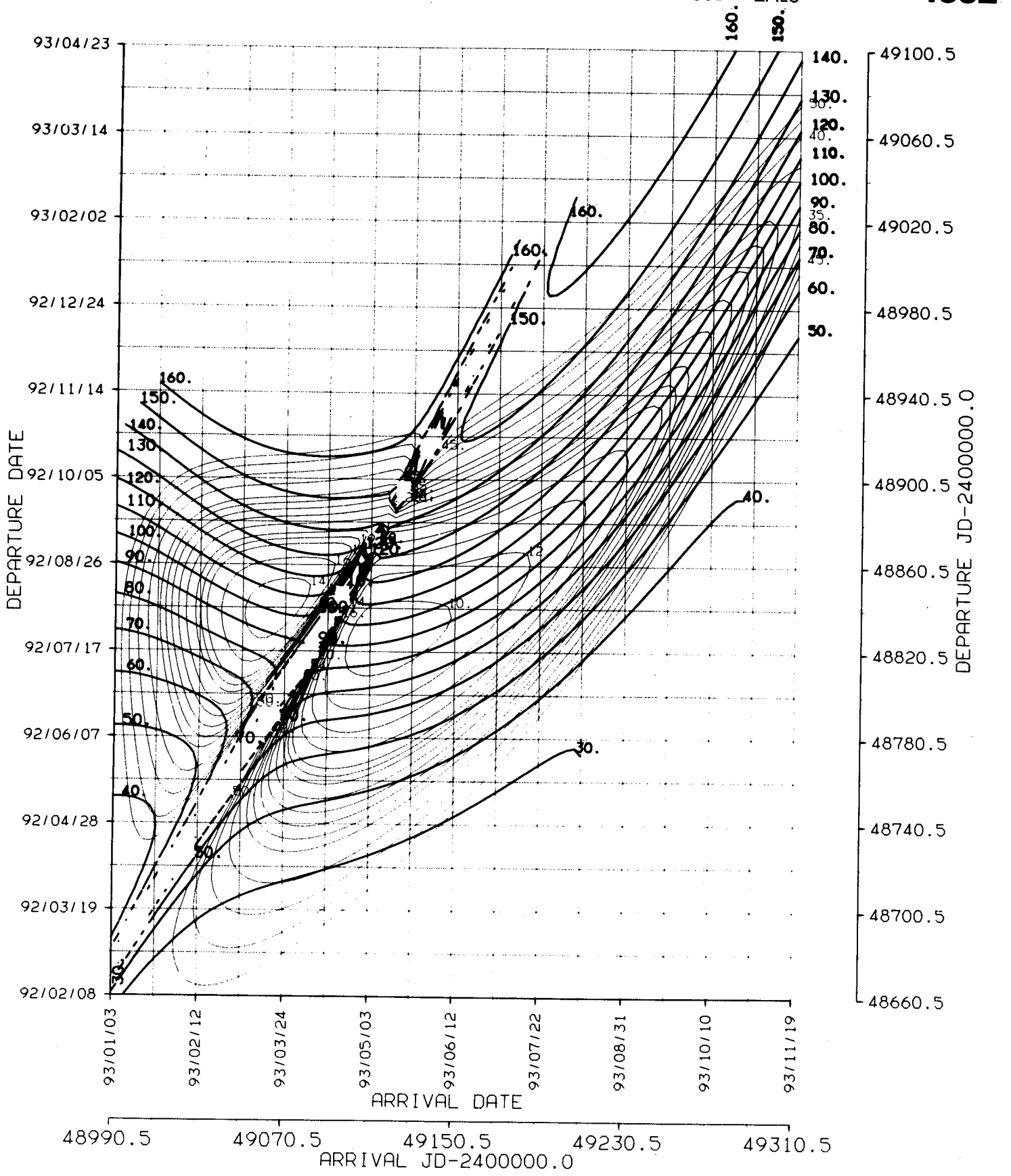
RLA

♂ ⊕

1992

* BALLISTIC TRANSFER TRAJECTORY C3L RLA




* BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
93/04/23
93/03/14
93/02/02
92/12/24
92/11/14
92/10/05
92/08/26
92/07/17
92/06/07
92/04/28
92/03/19
92/02/08
DEPARTURE JD-2400000.0
49100.5
49060.5
49020.5
48980.5
48940.5
48900.5
48860.5
48820.5
48780.5
48740.5
48700.5
48660.5
93/01/03
93/02/12
93/03/24
93/05/03
93/06/12
93/07/22
93/08/31
93/10/10
93/11/19
ARRIVAL DATE
48990.5
49070.5
49150.5
49230.5
49310.5
ARRIVAL JD-2400000.0

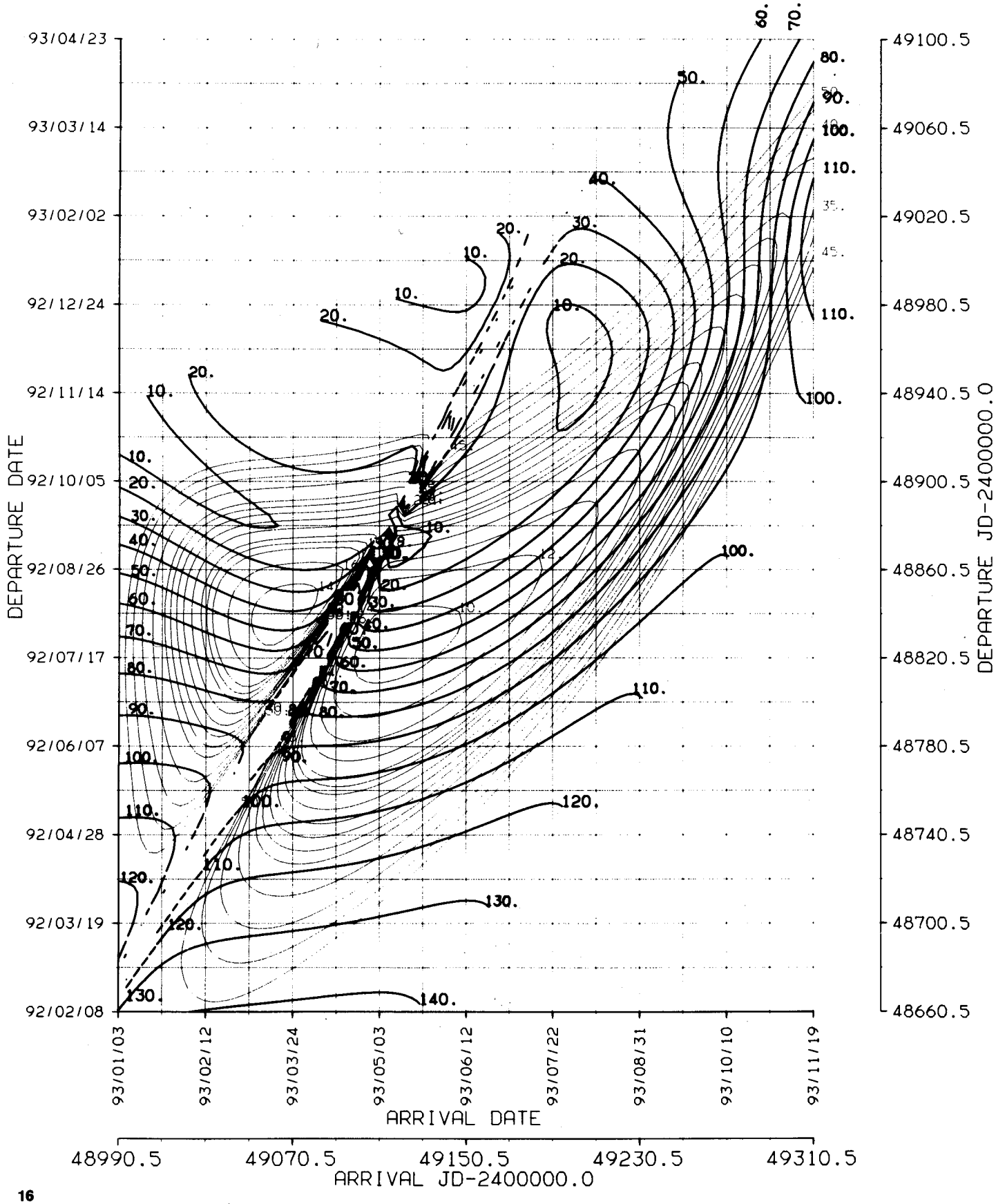
ZALE

♂ ⊕

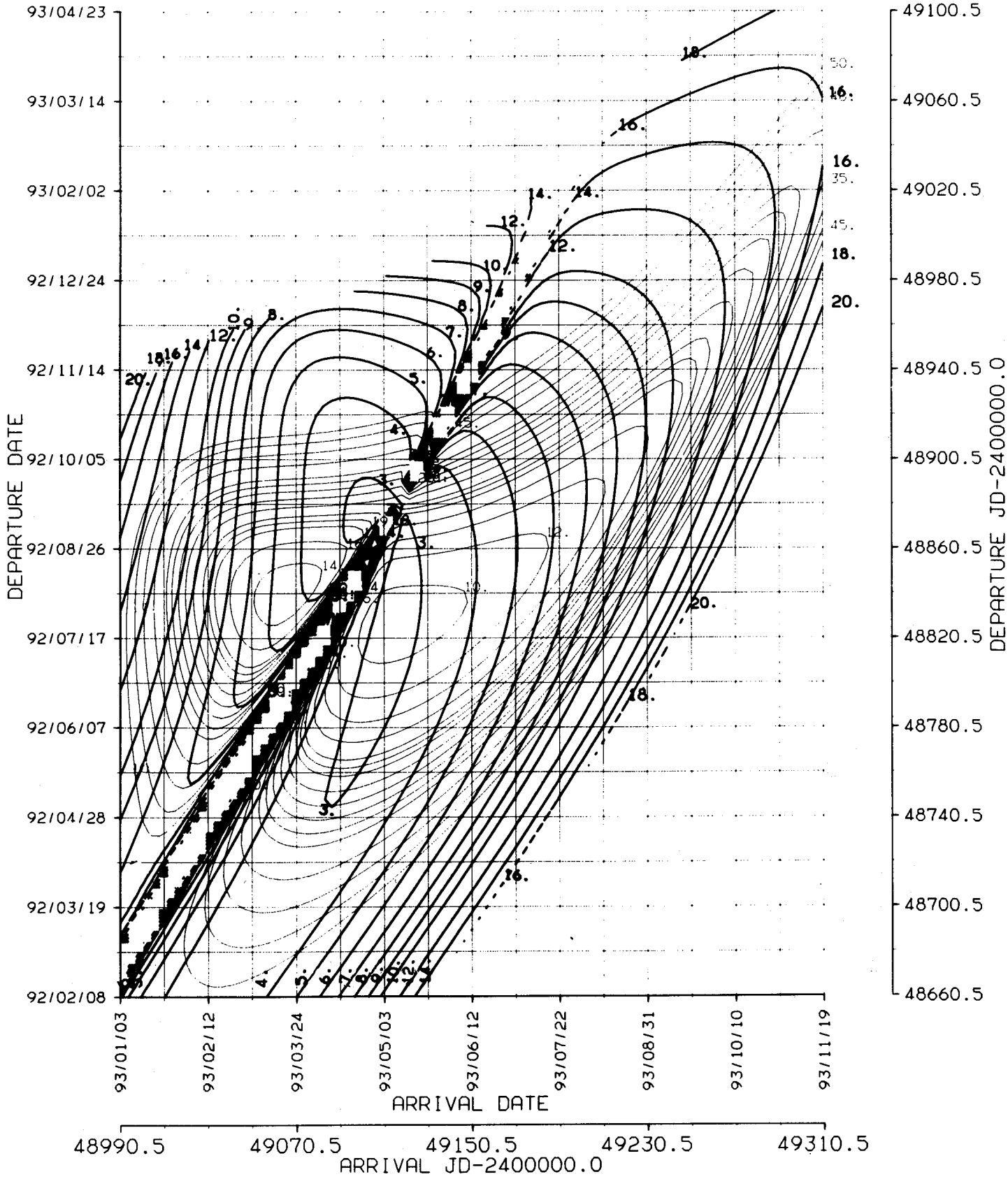
1992

*

BALLISTIC TRANSFER TRAJECTORY C3L ZALE



* BALLISTIC TRANSFER TRAJECTORY C3L VHP

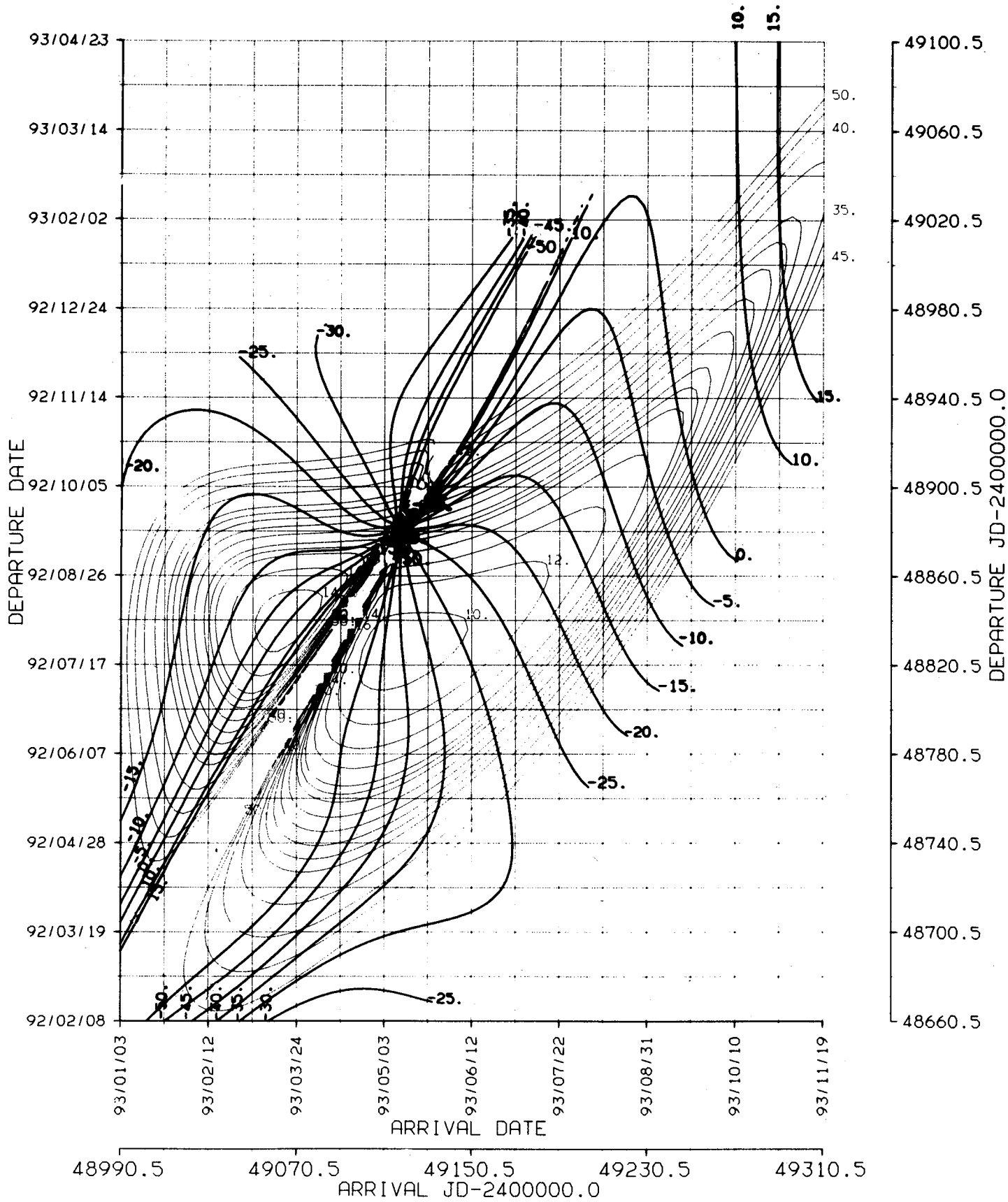


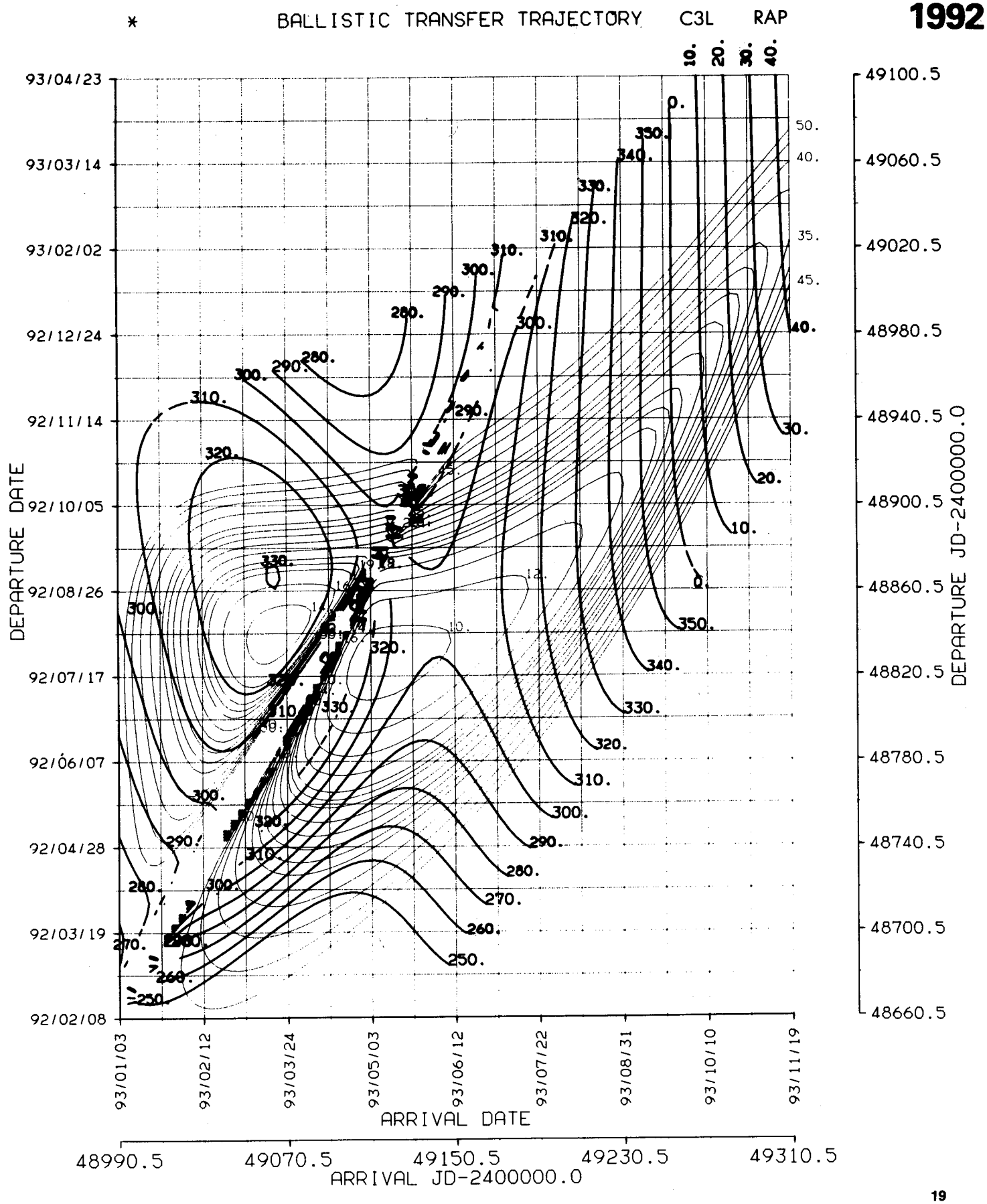
DAP

1992

*

BALLISTIC TRANSFER TRAJECTORY C3L DAP




* BALLISTIC TRANSFER TRAJECTORY C3L RAP
DEPARTURE DATE
93/04/23
93/03/14
93/02/02
92/12/24
92/11/14
92/10/05
92/08/26
92/07/17
92/06/07
92/04/28
92/03/19
92/02/08
DEPARTURE JD-2400000.0
49100.5
49060.5
49020.5
48980.5
48940.5
48900.5
48860.5
48820.5
48780.5
48740.5
48700.5
48660.5
ARRIVAL DATE
93/01/03
93/02/12
93/03/24
93/05/03
93/06/12
93/07/22
93/08/31
93/10/10
93/11/19
ARRIVAL JD-2400000.0
48990.5
49070.5
49150.5
49230.5
49310.5

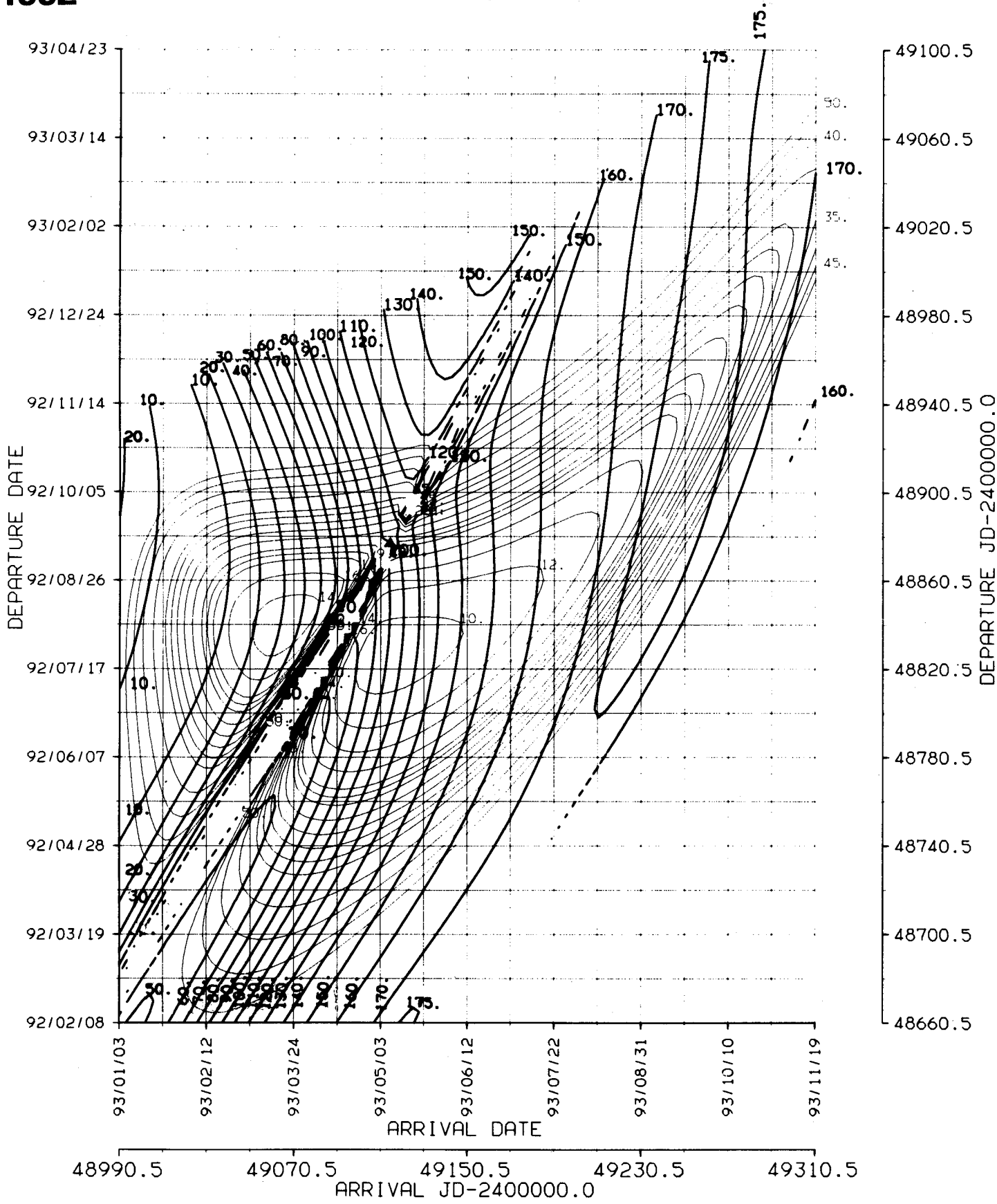
ZAPS

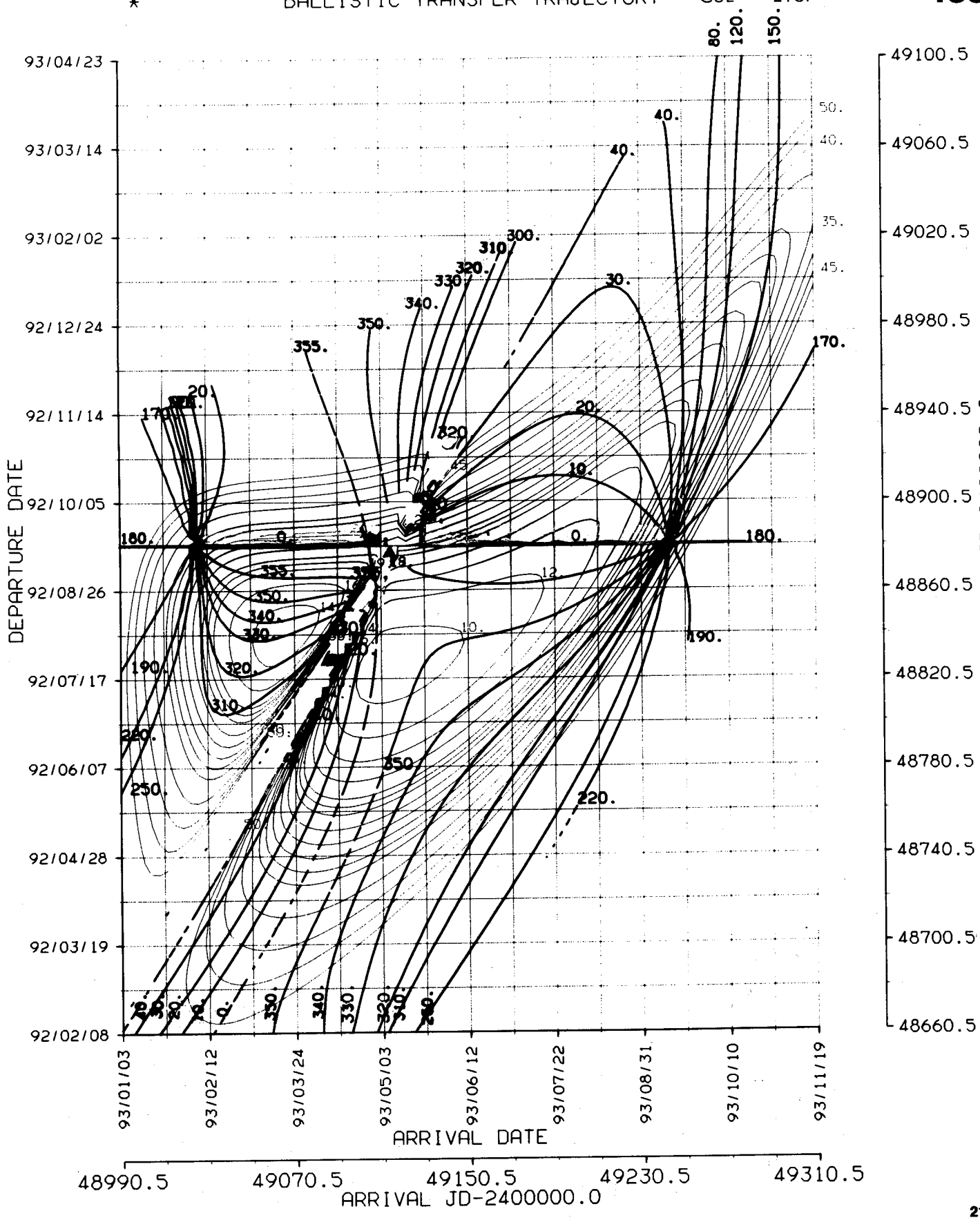
♂ ⊕

1992

*

BALLISTIC TRANSFER TRAJECTORY C3L ZAPS




* BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
93/04/23
93/03/14
93/02/02
92/12/24
92/11/14
92/10/05
92/08/26
92/07/17
92/06/07
92/04/28
92/03/19
92/02/08
DEPARTURE JD-2400000.0
49100.5
49060.5
49020.5
48980.5
48940.5
48900.5
48860.5
48820.5
48780.5
48740.5
48700.5
48660.5
93/01/03
93/02/12
93/03/24
93/05/03
93/06/12
93/07/22
93/08/31
93/10/10
93/11/19
ARRIVAL DATE
48990.5
49070.5
49150.5
49230.5
49310.5
ARRIVAL JD-2400000.0

Mars to Earth

1994

Opportunity

ENERGY MINIMA

	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	7.433	I	1994/08/05	1995/05/10
C_3L	7.370	II	1994/07/30	1995/06/04
VHP	3.701	I	1994/10/07	1995/05/23
VHP	2.938	II	1994/07/31	1995/06/05

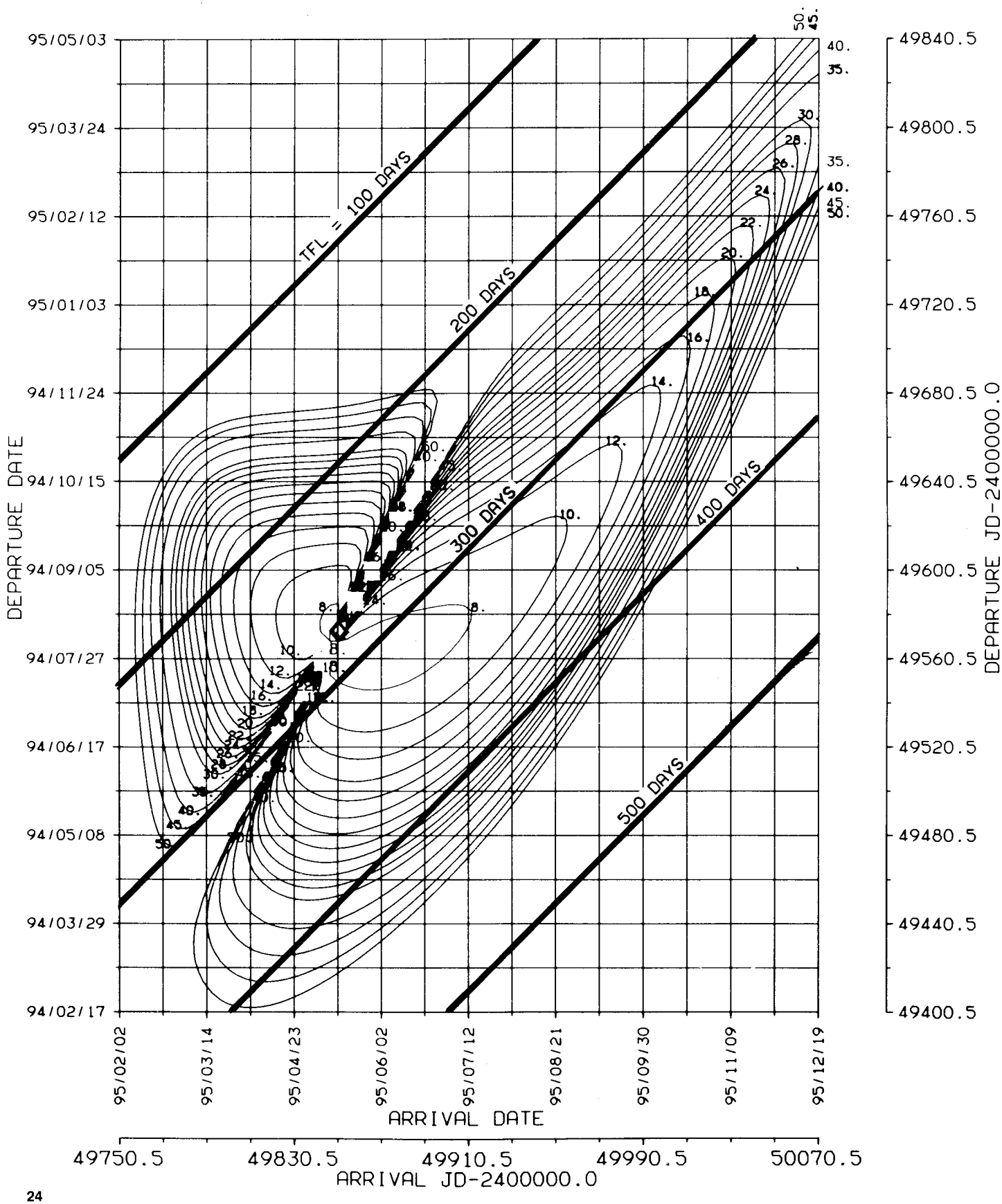
C3L

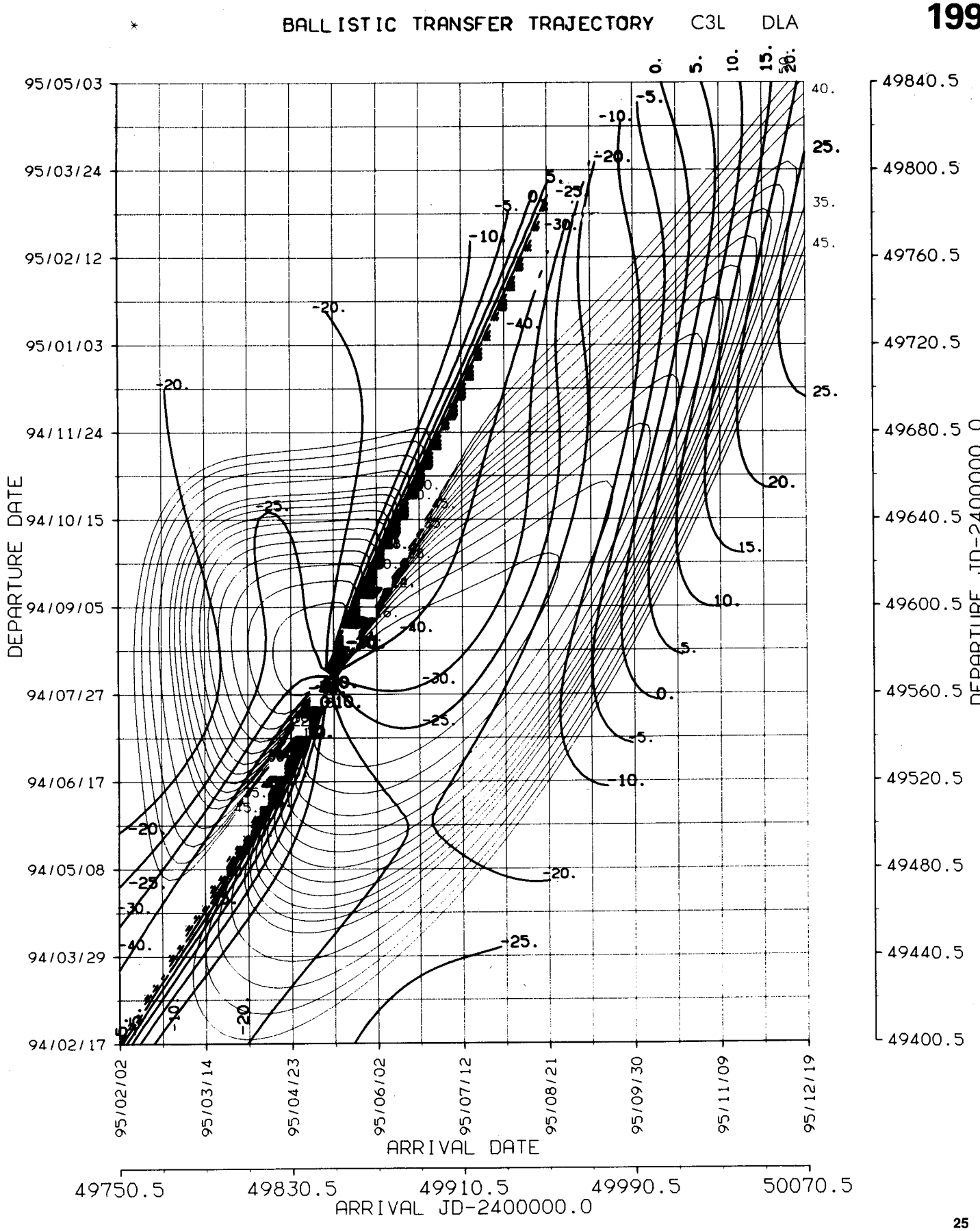
♂ ⊕

1994

*

BALLISTIC TRANSFER TRAJECTORY C3L TFL

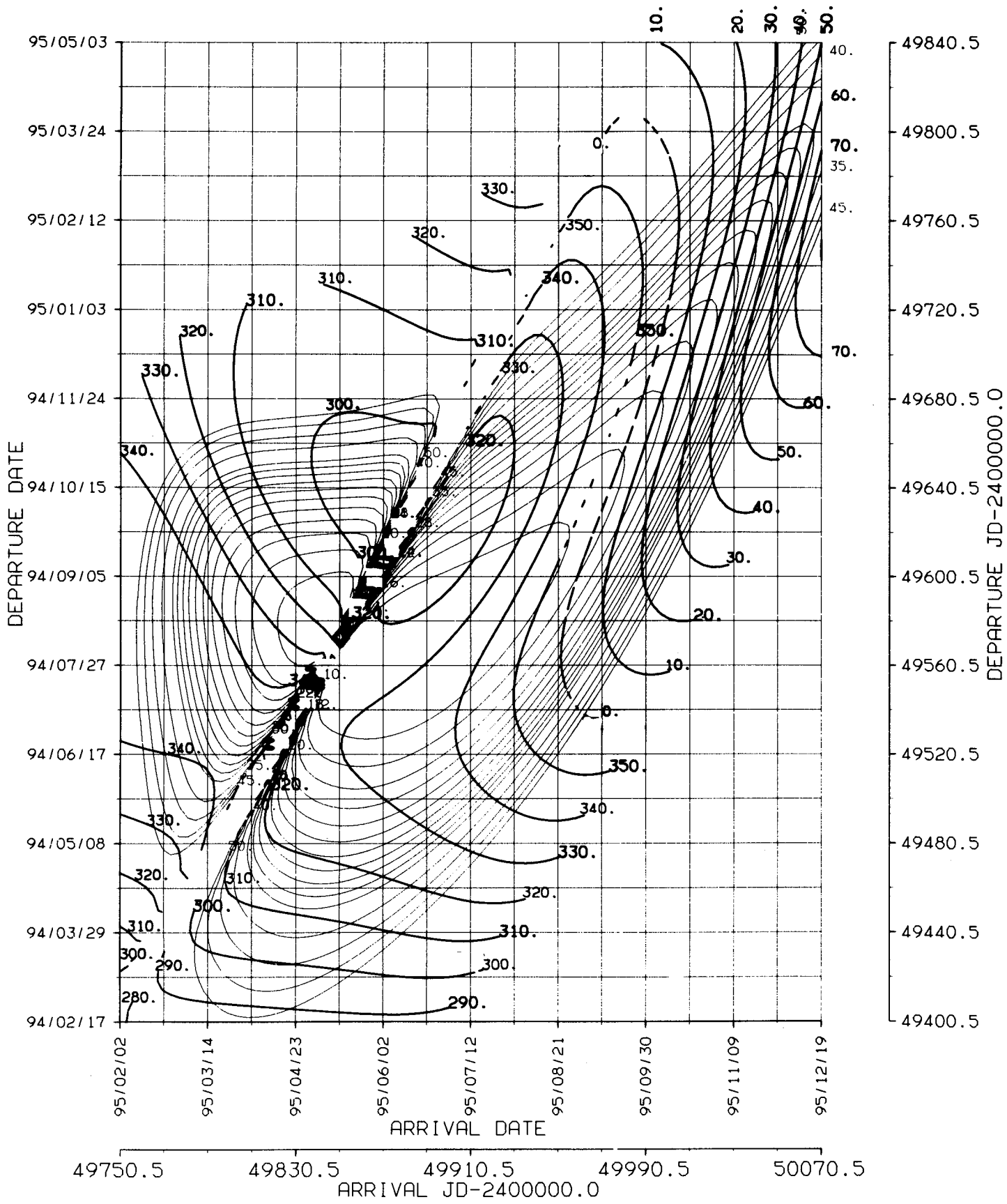


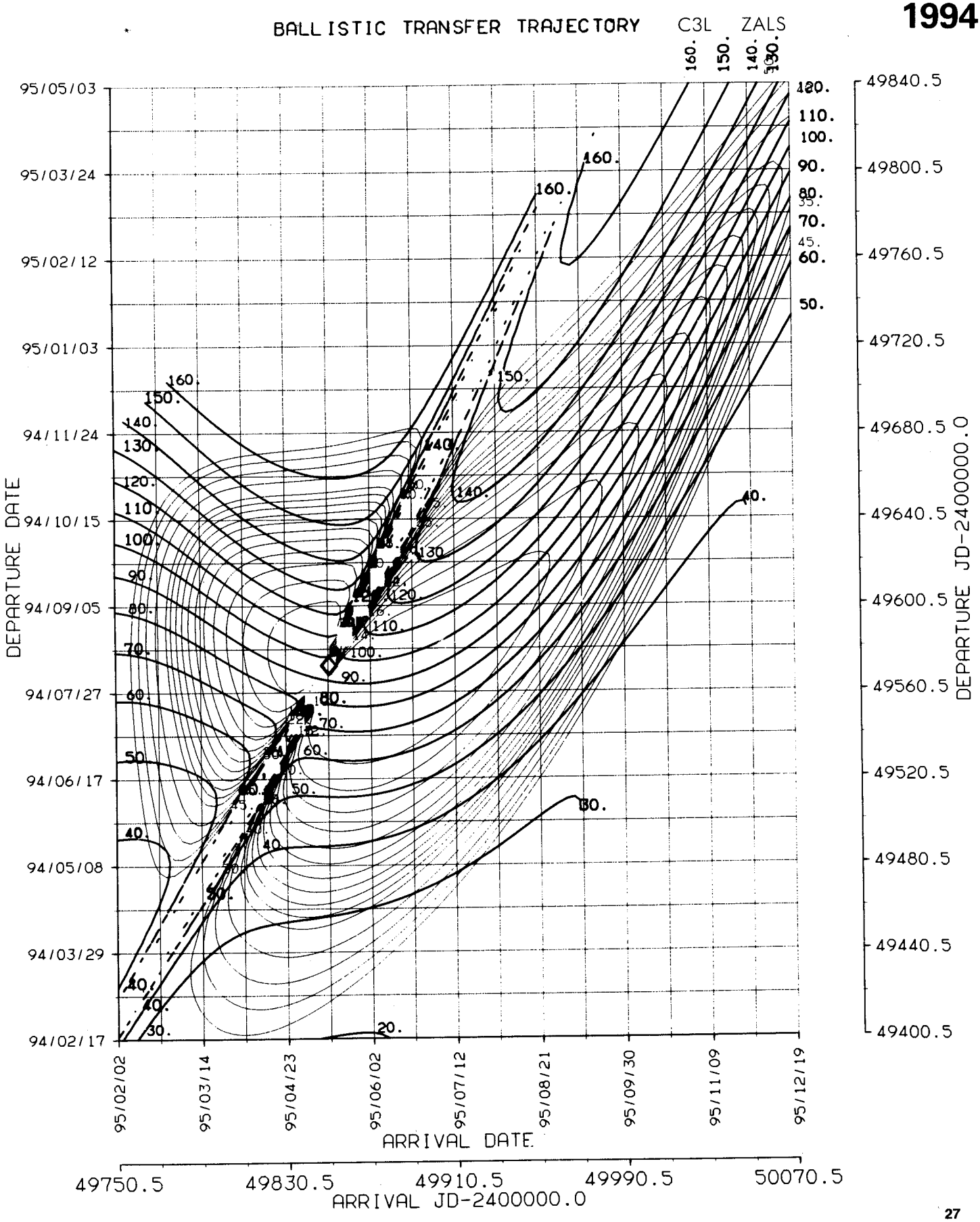

BALLISTIC TRANSFER TRAJECTORY C3L DLA
DEPARTURE DATE
95/05/03
95/03/24
95/02/12
95/01/03
94/11/24
94/10/15
94/09/05
94/07/27
94/06/17
94/05/08
94/03/29
94/02/17
DEPARTURE JD-2400000.0
49840.5
49800.5
49760.5
49720.5
49680.5
49640.5
49600.5
49560.5
49520.5
49480.5
49440.5
49400.5
ARRIVAL DATE
95/02/02
95/03/14
95/04/23
95/06/02
95/07/12
95/08/21
95/09/30
95/11/09
95/12/19
ARRIVAL JD-2400000.0
49750.5
49830.5
49910.5
49990.5
50070.5

RLA

1994

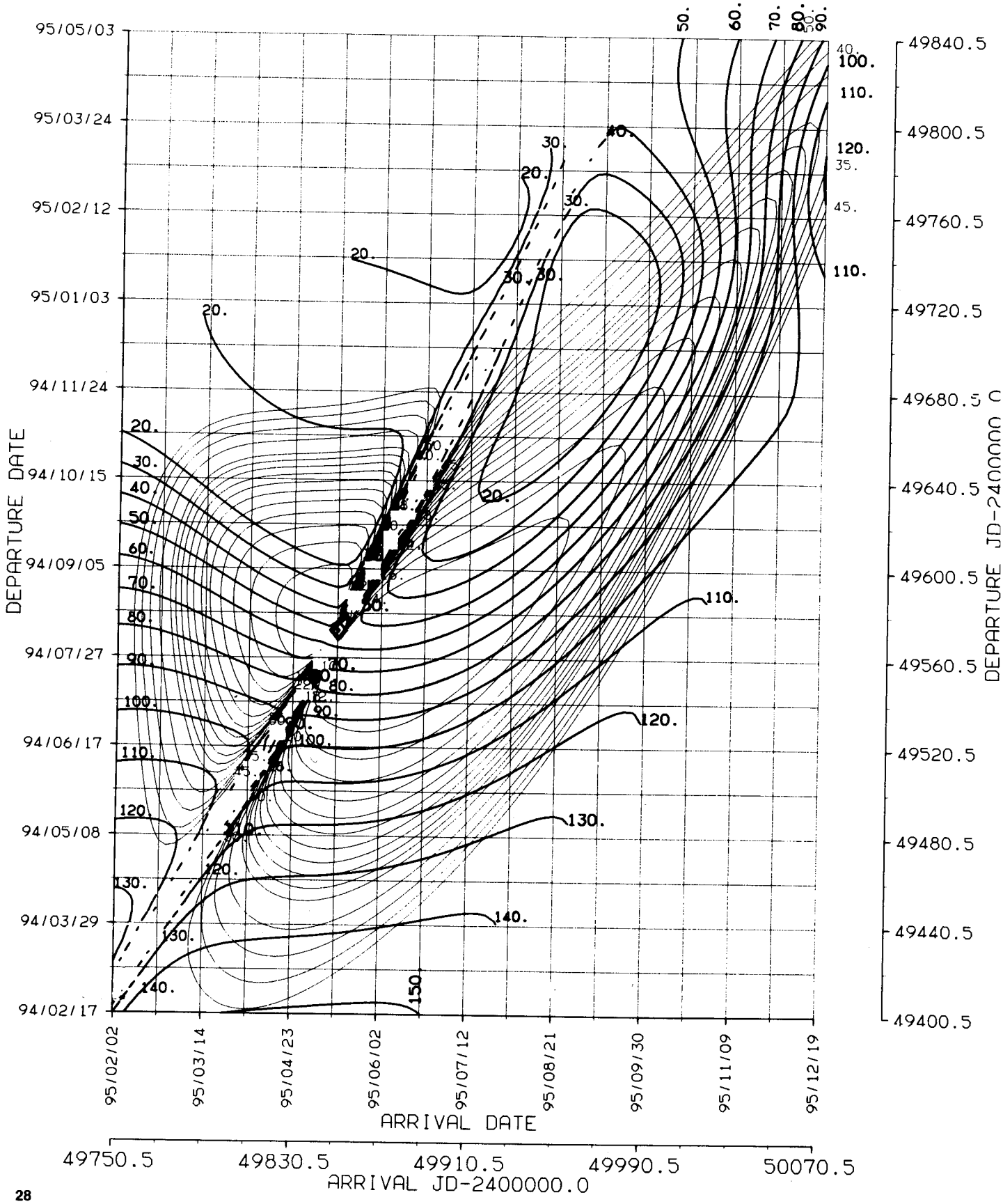
BALLISTIC TRANSFER TRAJECTORY C3L RLA



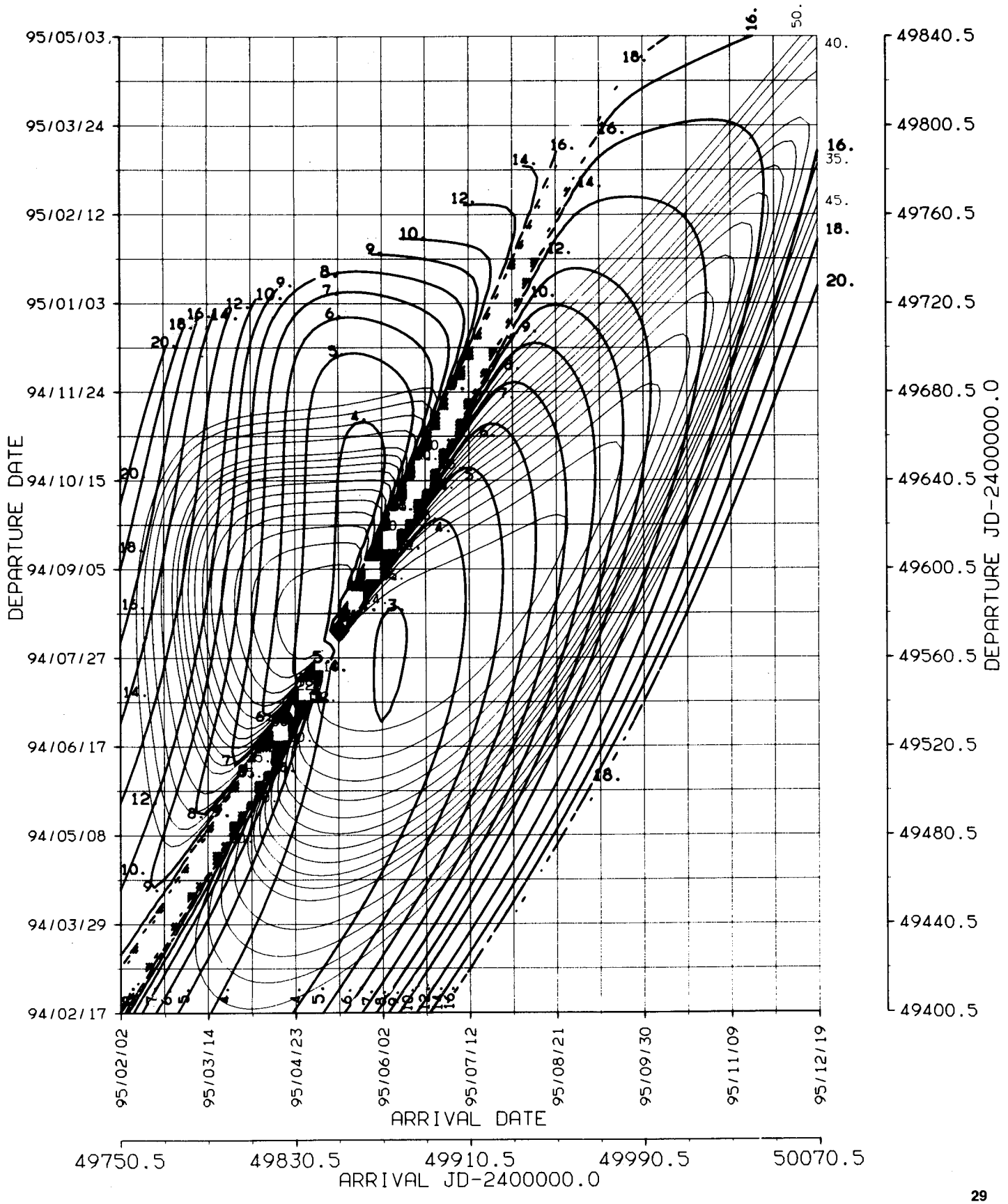

BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
95/05/03
95/03/24
95/02/12
95/01/03
94/11/24
94/10/15
94/09/05
94/07/27
94/06/17
94/05/08
94/03/29
94/02/17
DEPARTURE JD-2400000.0
49840.5
49800.5
49760.5
49720.5
49680.5
49640.5
49600.5
49560.5
49520.5
49480.5
49440.5
49400.5
ARRIVAL DATE
95/02/02
95/03/14
95/04/23
95/06/02
95/07/12
95/08/21
95/09/30
95/11/09
95/12/19
ARRIVAL JD-2400000.0
49750.5
49830.5
49910.5
49990.5
50070.5

ZALE
♂⊕
1994

BALLISTIC TRANSFER TRAJECTORY C3L ZALE



BALLISTIC TRANSFER TRAJECTORY C3L VHP



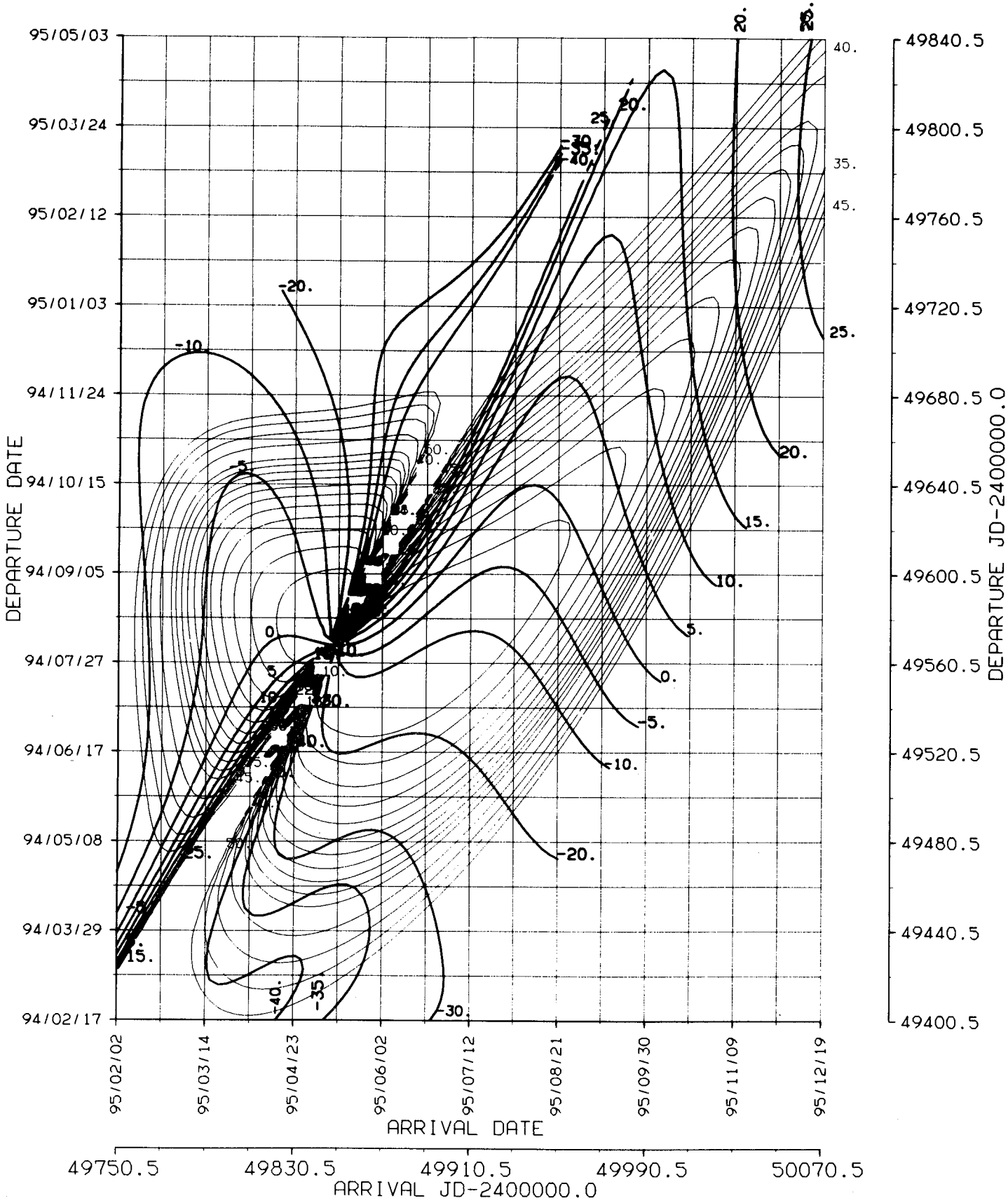
DAP

♂ ⊕

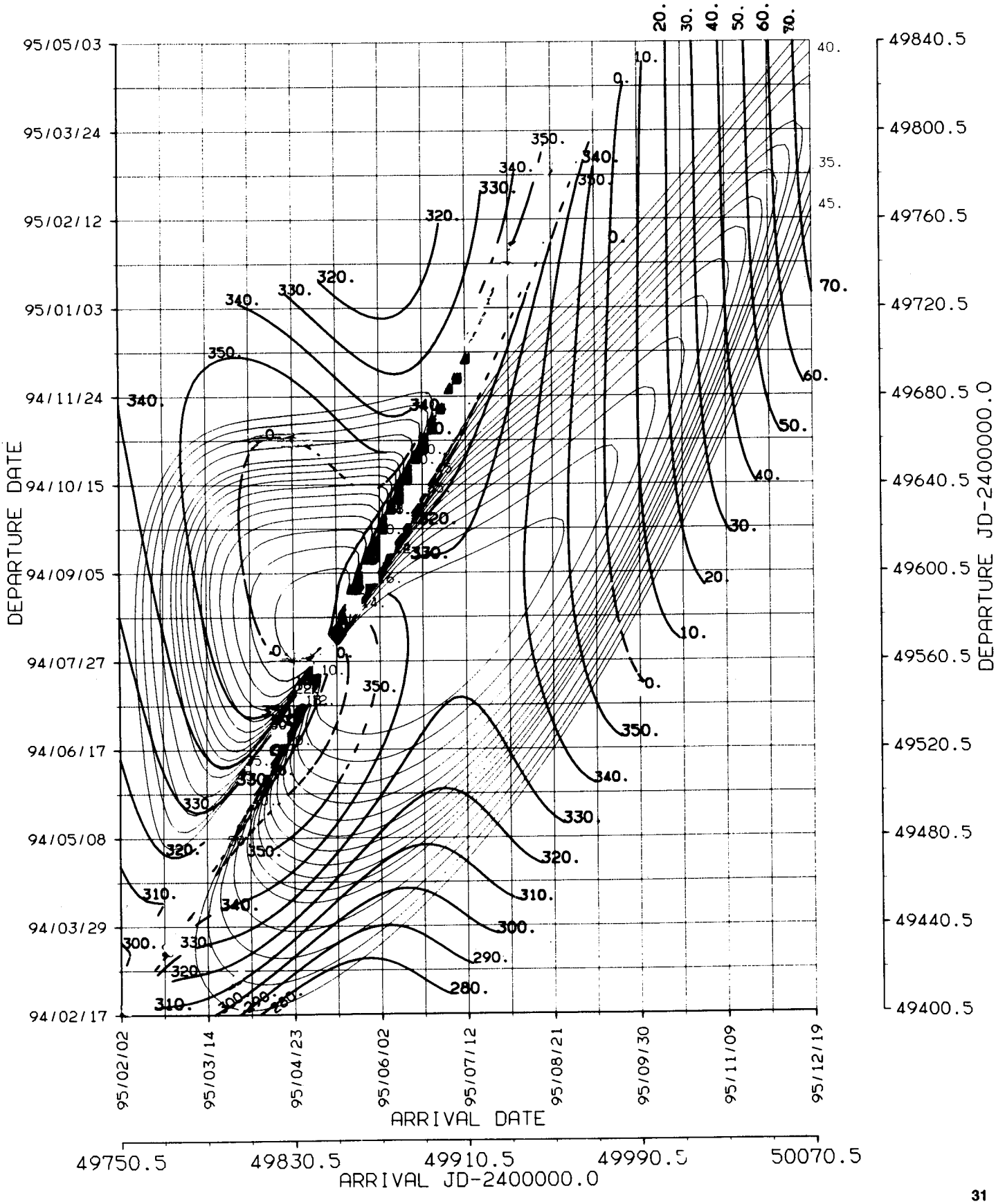
1994

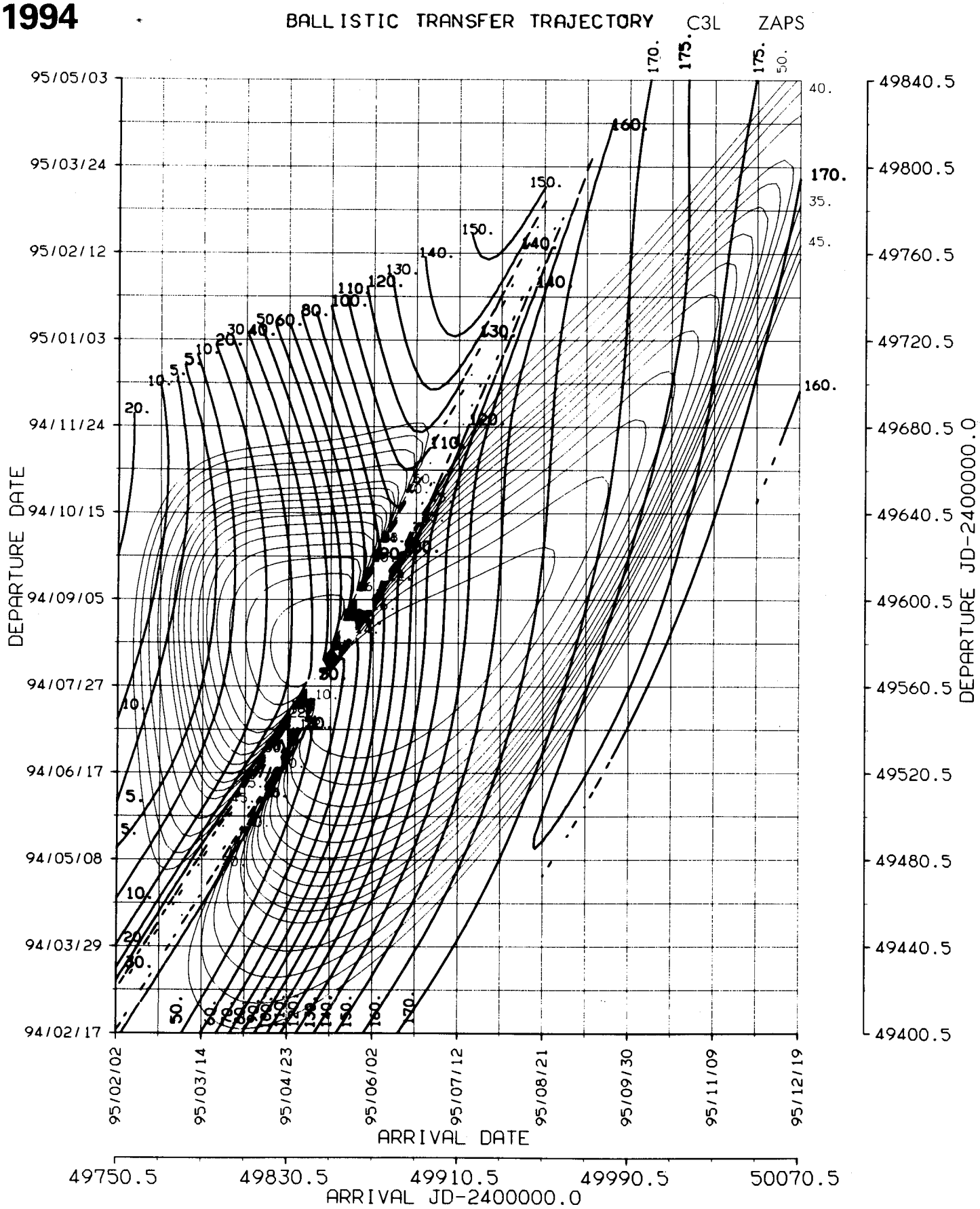
*

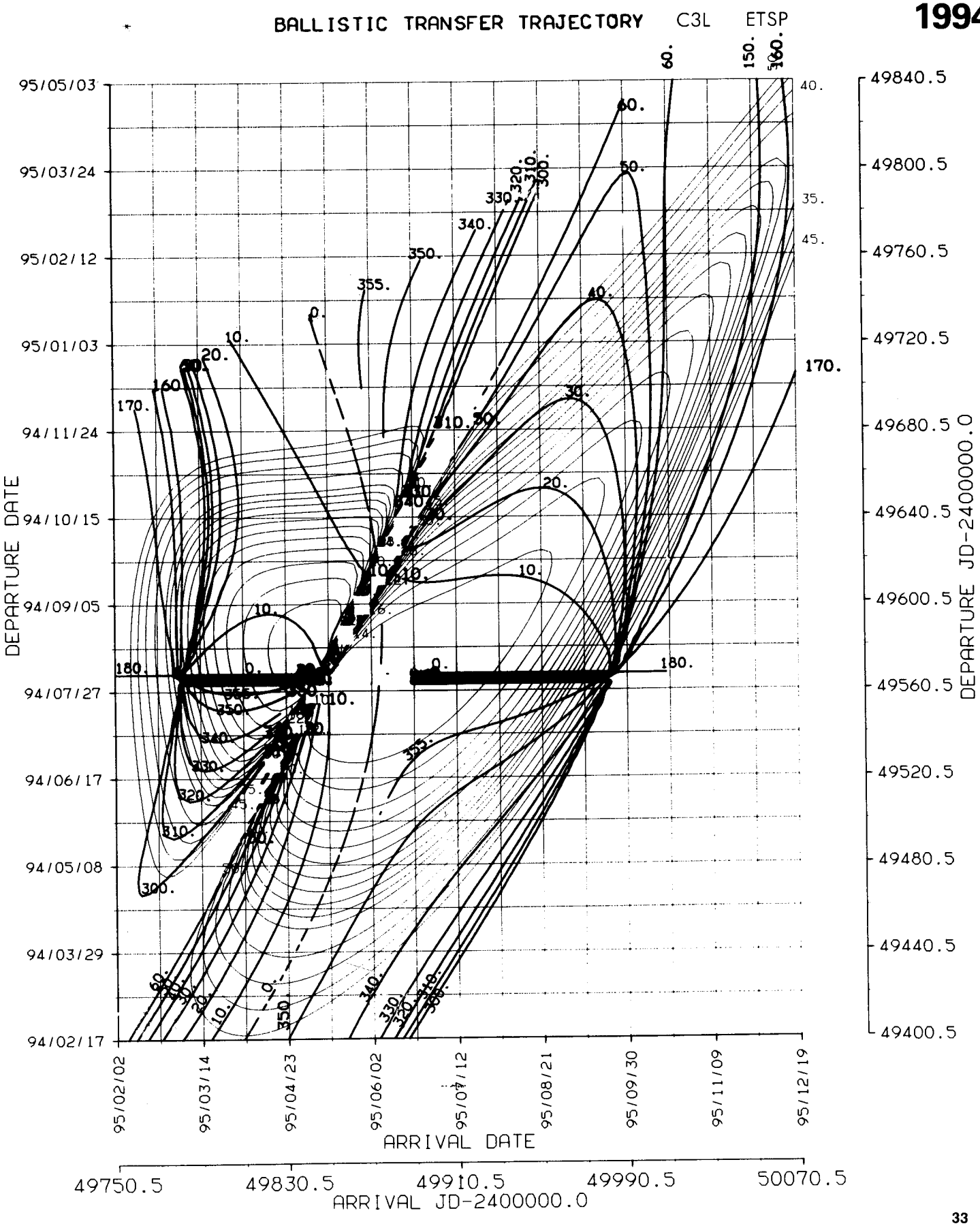
BALLISTIC TRANSFER TRAJECTORY C3L DAP



BALLISTIC TRANSFER TRAJECTORY C3L RAP




BALLISTIC TRANSFER TRAJECTORY C3L ZAPS
DEPARTURE DATE
95/05/03
95/03/24
95/02/12
95/01/03
94/11/24
94/10/15
94/09/05
94/07/27
94/06/17
94/05/08
94/03/29
94/02/17
DEPARTURE JD-2400000.0
49840.5
49800.5
49760.5
49720.5
49680.5
49640.5
49600.5
49560.5
49520.5
49480.5
49440.5
49400.5
95/02/02
95/03/14
95/04/23
95/06/02
95/07/12
95/08/21
95/09/30
95/11/09
95/12/19
ARRIVAL DATE
49750.5
49830.5
49910.5
49990.5
50070.5
ARRIVAL JD-2400000.0


BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
95/05/03
95/03/24
95/02/12
95/01/03
94/11/24
94/10/15
94/09/05
94/07/27
94/06/17
94/05/08
94/03/29
94/02/17
DEPARTURE JD-2400000.0
49840.5
49800.5
49760.5
49720.5
49680.5
49640.5
49600.5
49560.5
49520.5
49480.5
49440.5
49400.5
ARRIVAL DATE
95/02/02
95/03/14
95/04/23
95/06/02
95/07/12
95/08/21
95/09/30
95/11/09
95/12/19
ARRIVAL JD-2400000.0
49750.5
49830.5
49910.5
49990.5
50070.5

Mars to Earth

1996

Opportunity

ENERGY MINIMA

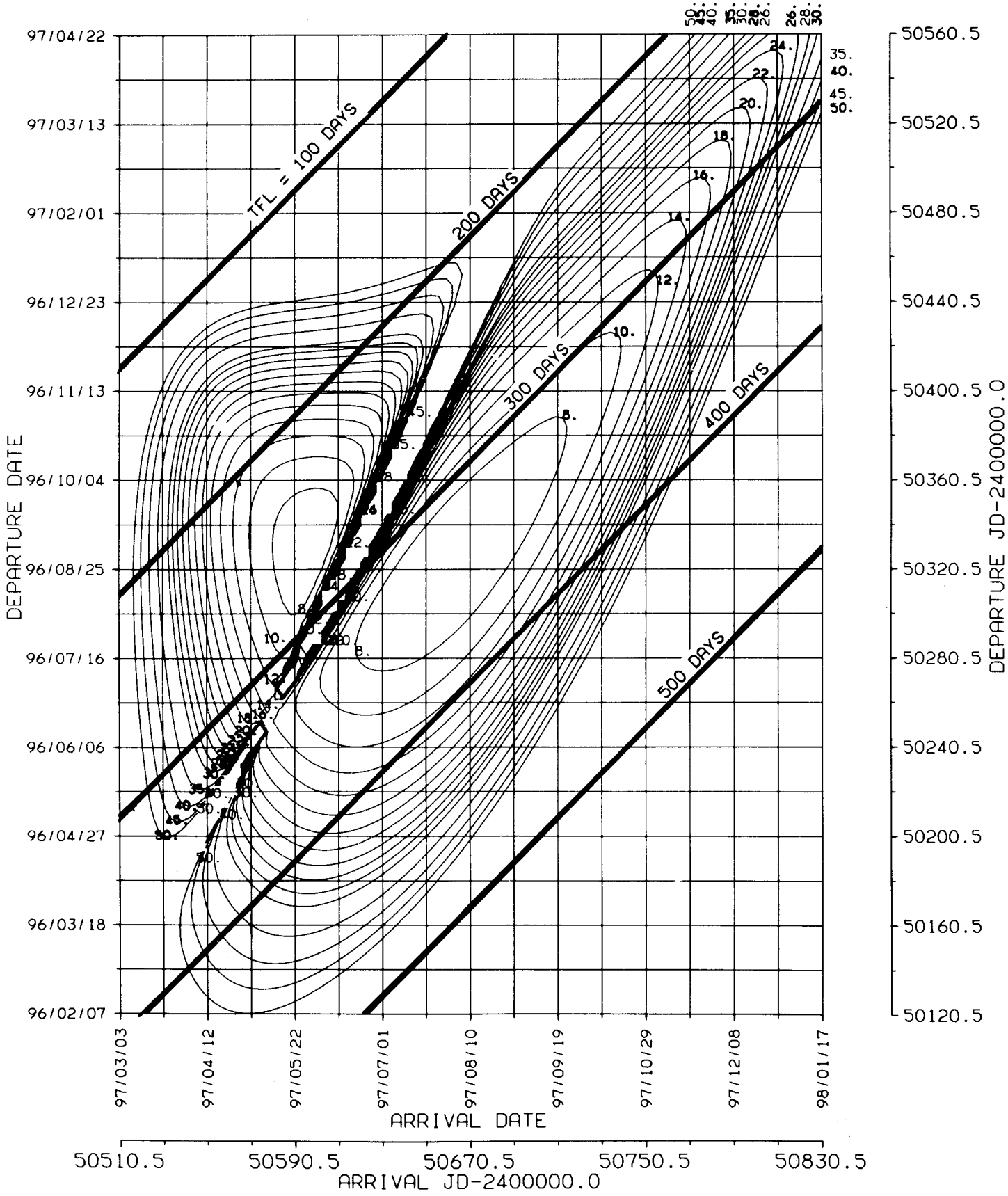
	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	6.621	I	1996/09/03	1997/05/28
C_3L	6.373	II	1996/08/26	1997/07/30
VHP	4.229	I	1996/11/17	1997/06/23
VHP	3.329	II	1996/07/07	1997/06/29

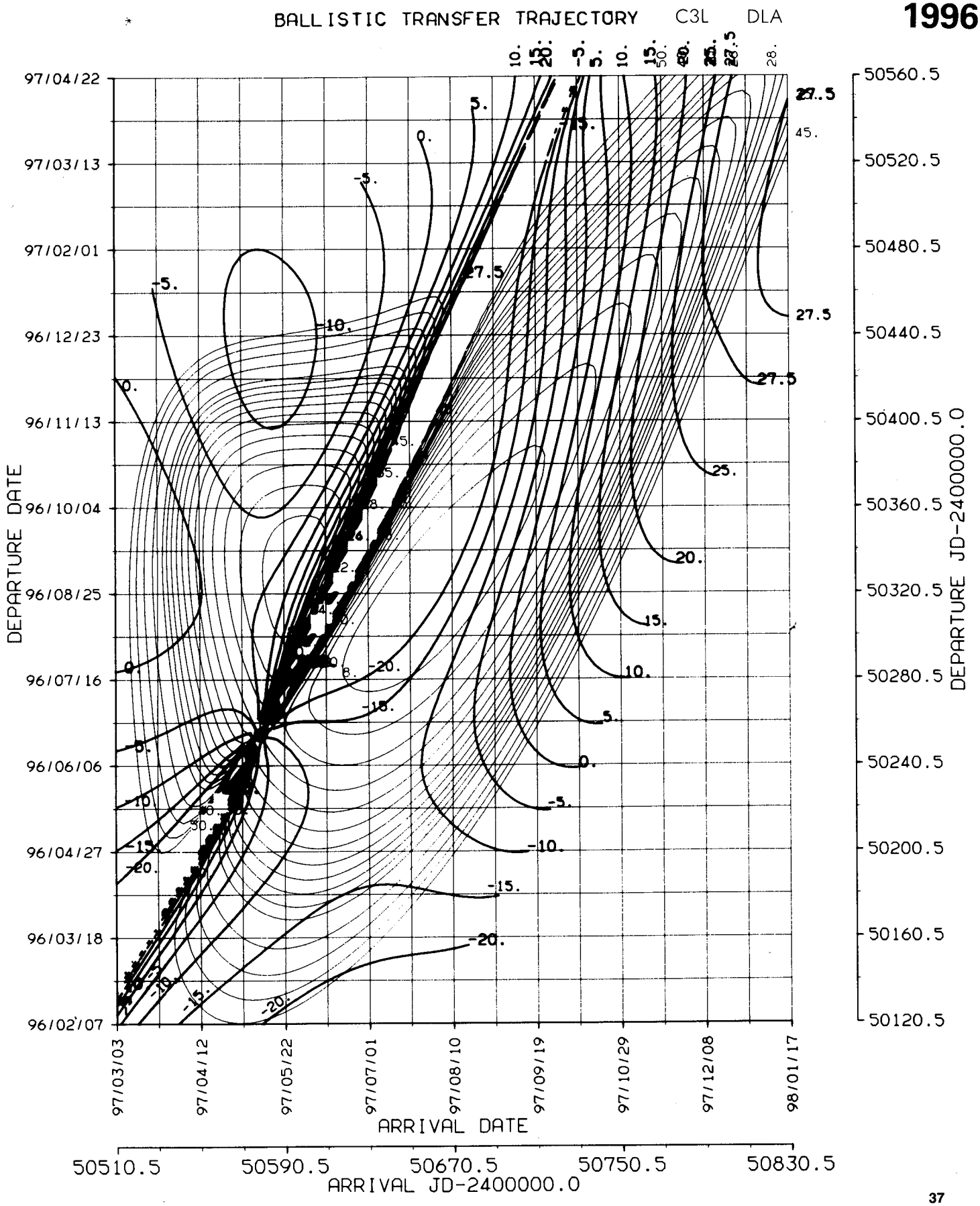
C3L

♂ ⊕

1996

* BALLISTIC TRANSFER TRAJECTORY C3L TFL



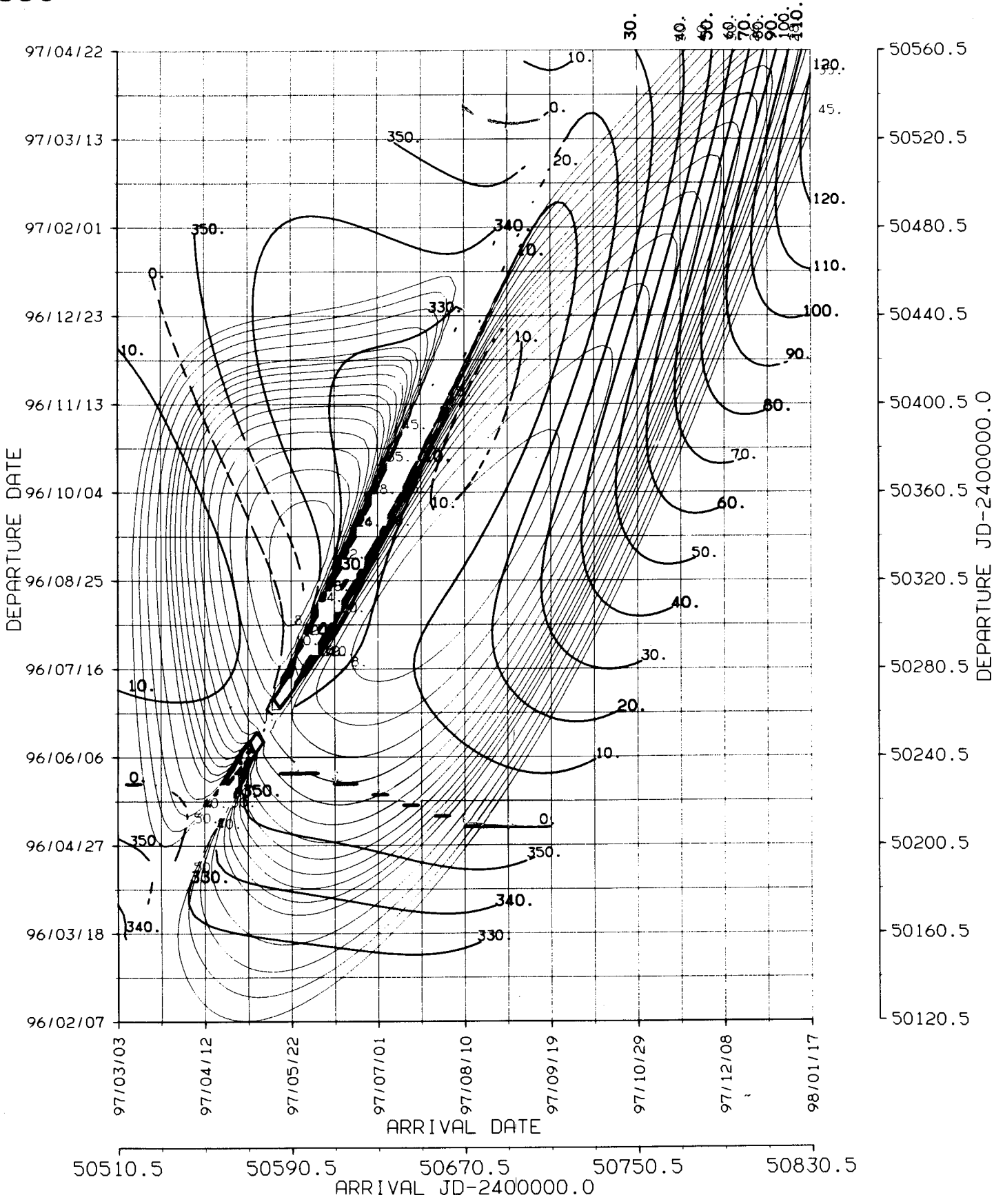

BALLISTIC TRANSFER TRAJECTORY C3L DLA
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL DATE
50510.5
50590.5
50670.5
50750.5
50830.5
ARRIVAL JD-2400000.0

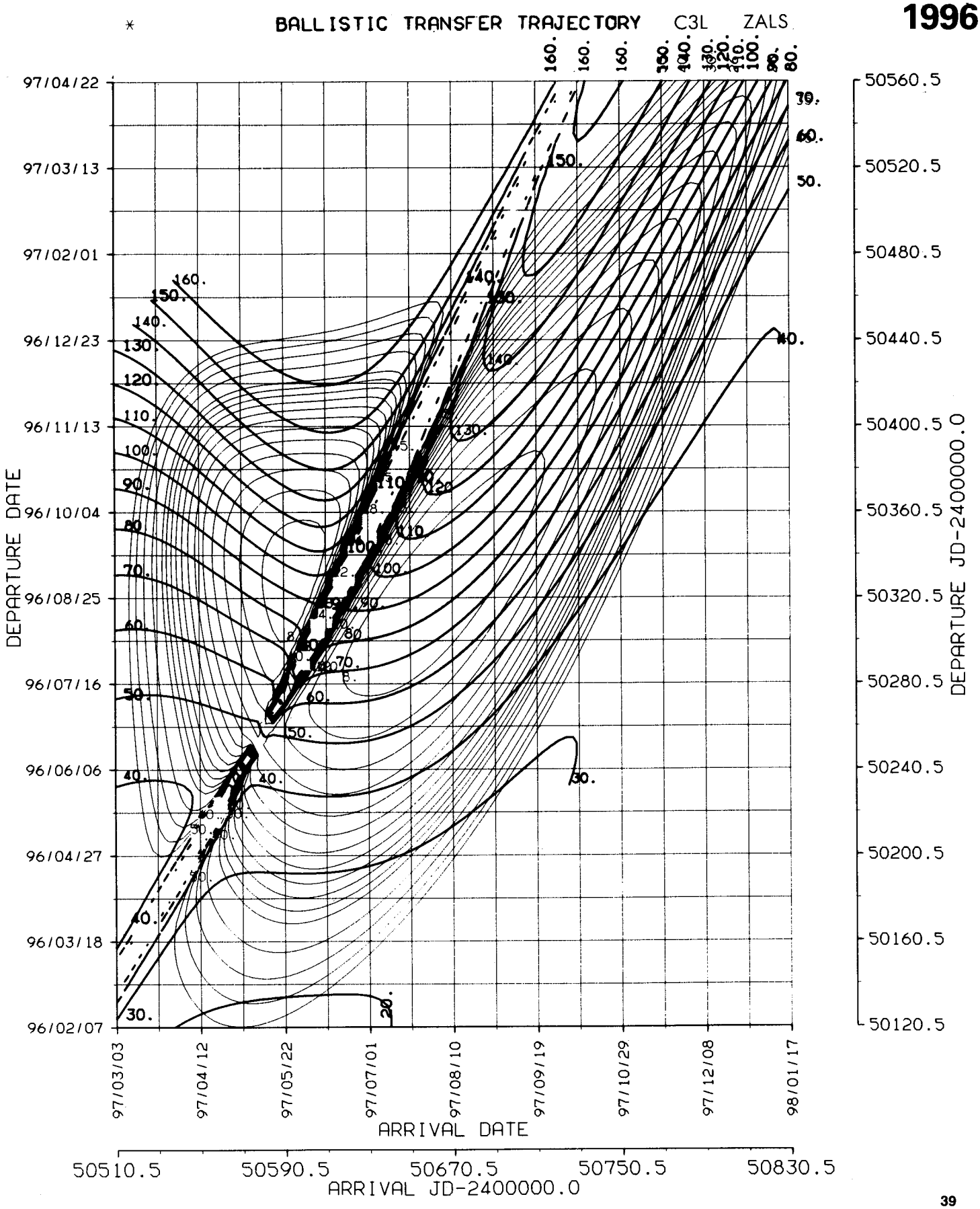
RLA

♂ ⊕

1996

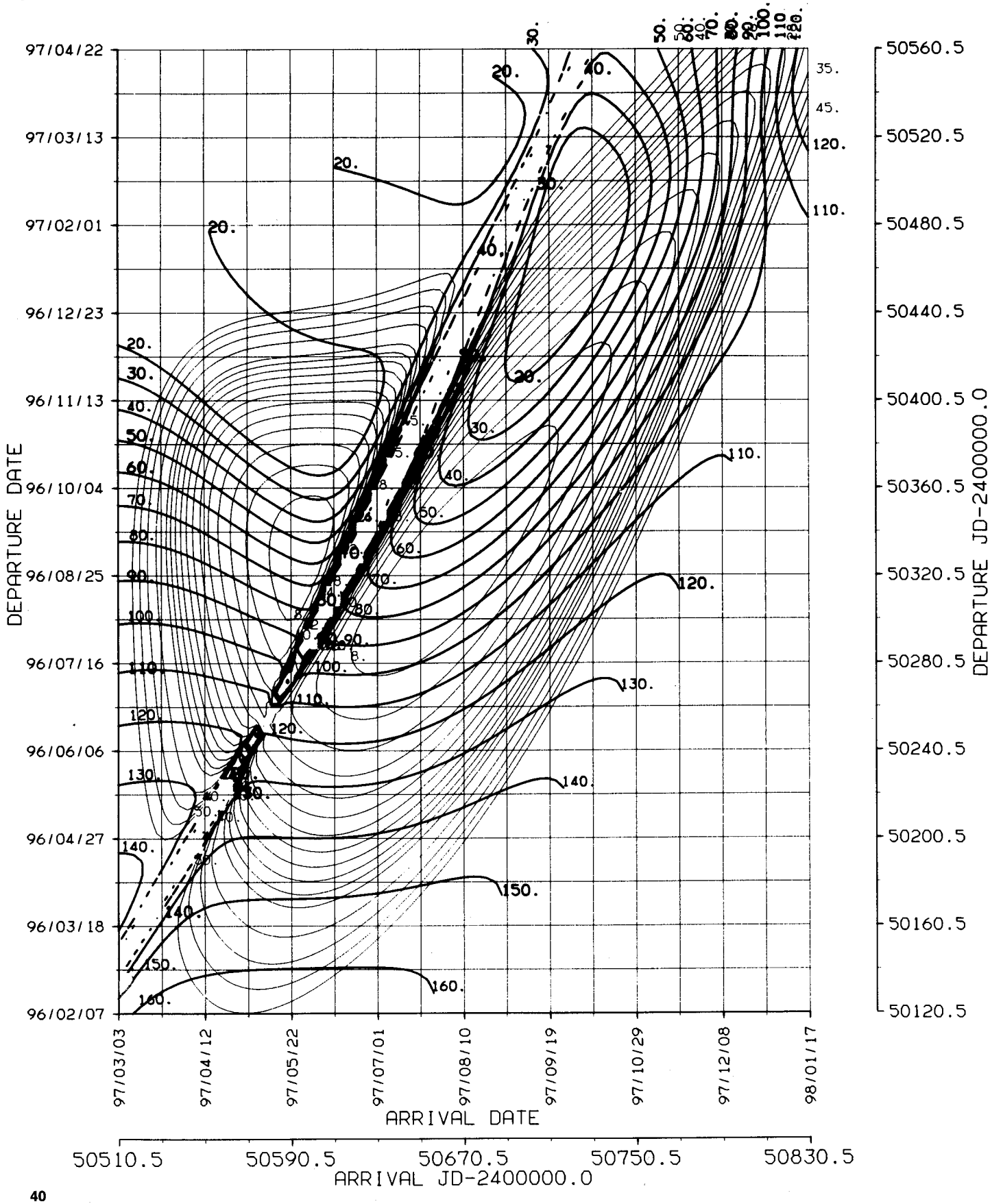
BALLISTIC TRANSFER TRAJECTORY C3L RLA

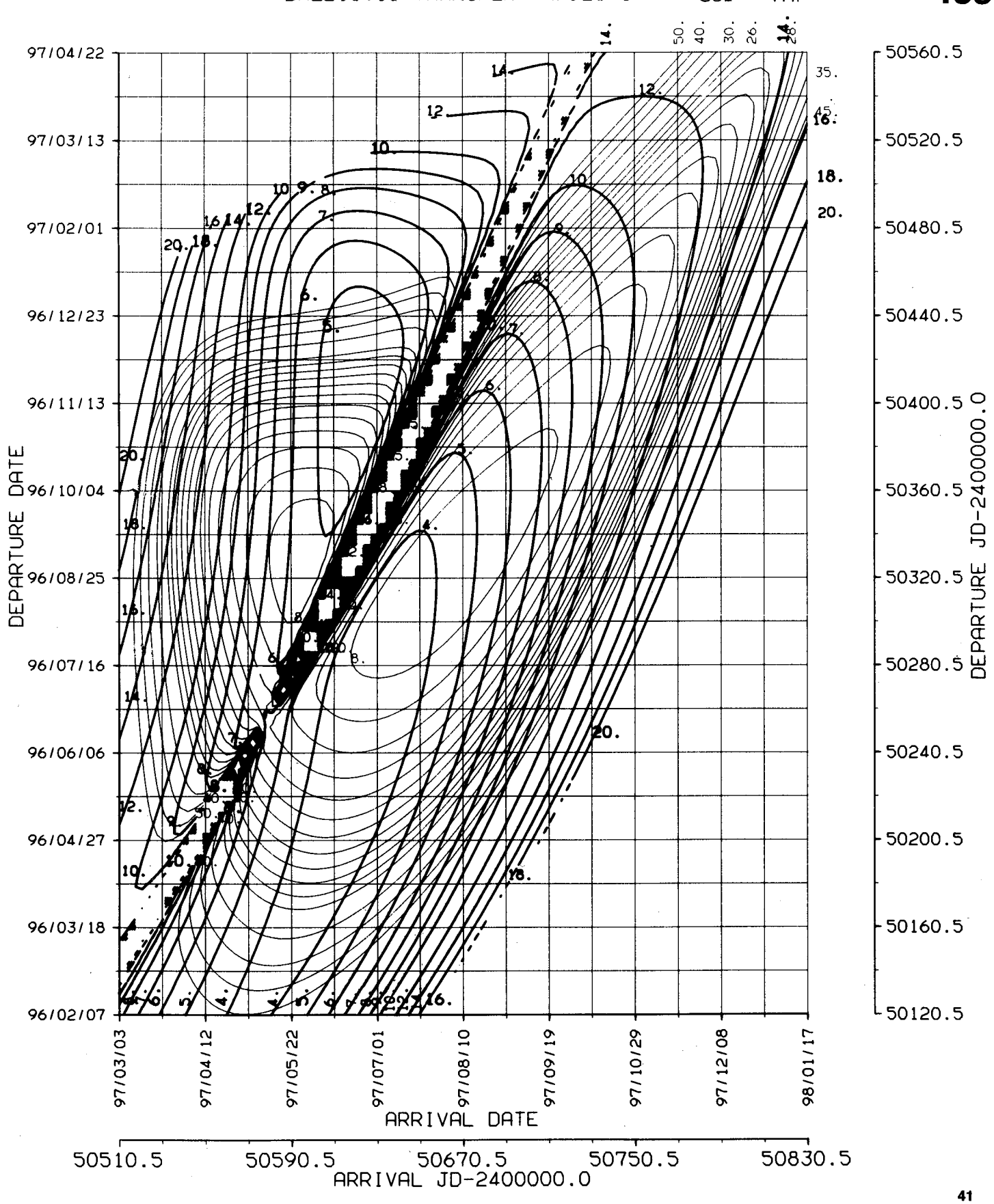



BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL DATE
50510.5
50590.5
50670.5
50750.5
50830.5
ARRIVAL JD-2400000.0

ZALE ♂⊕ 1996

BALLISTIC TRANSFER TRAJECTORY C3L ZALE



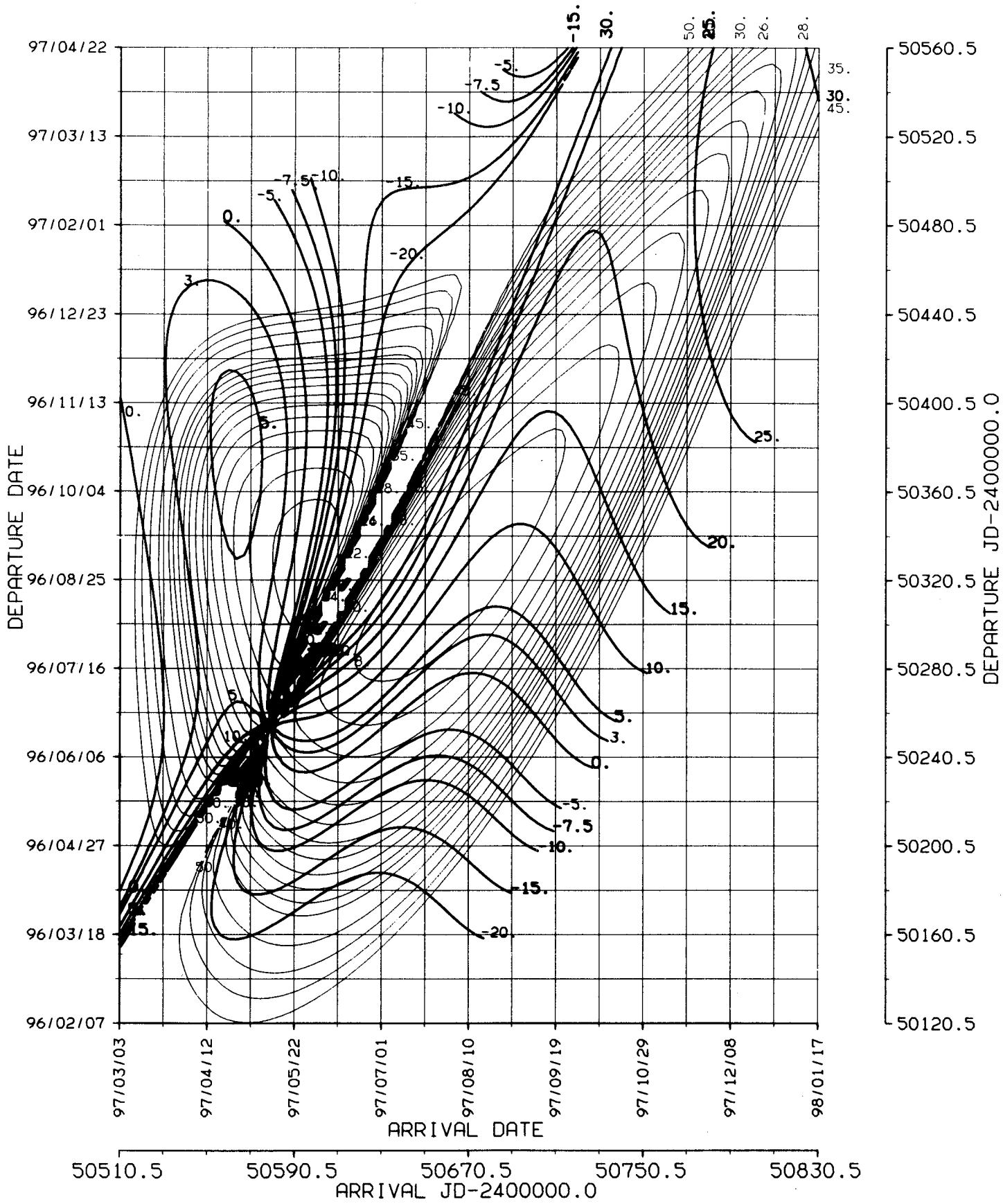

BALLISTIC TRANSFER TRAJECTORY C3L VHP
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL DATE
50510.5
50590.5
50670.5
50750.5
50830.5
ARRIVAL JD-2400000.0

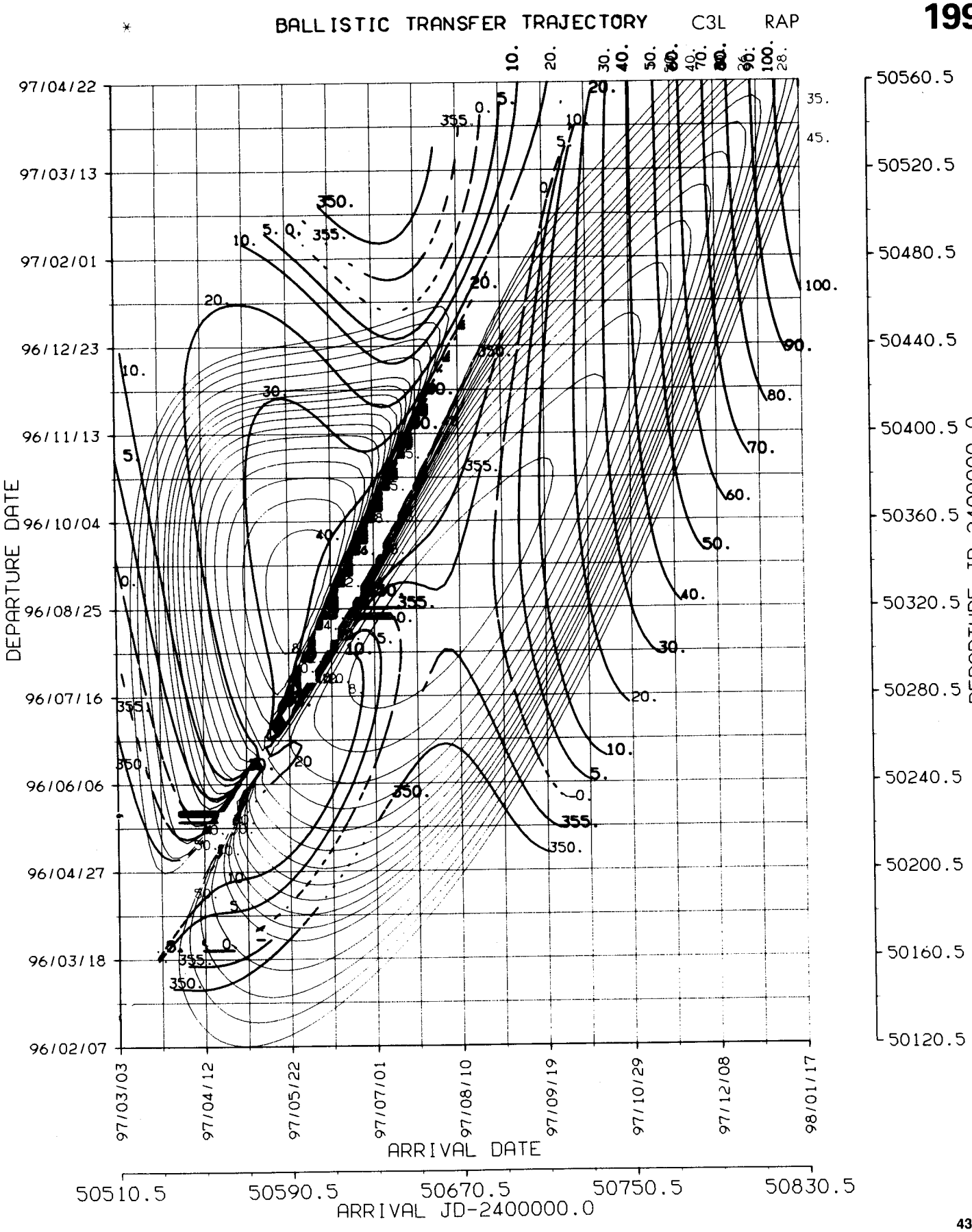
DAP

♂ ⊕

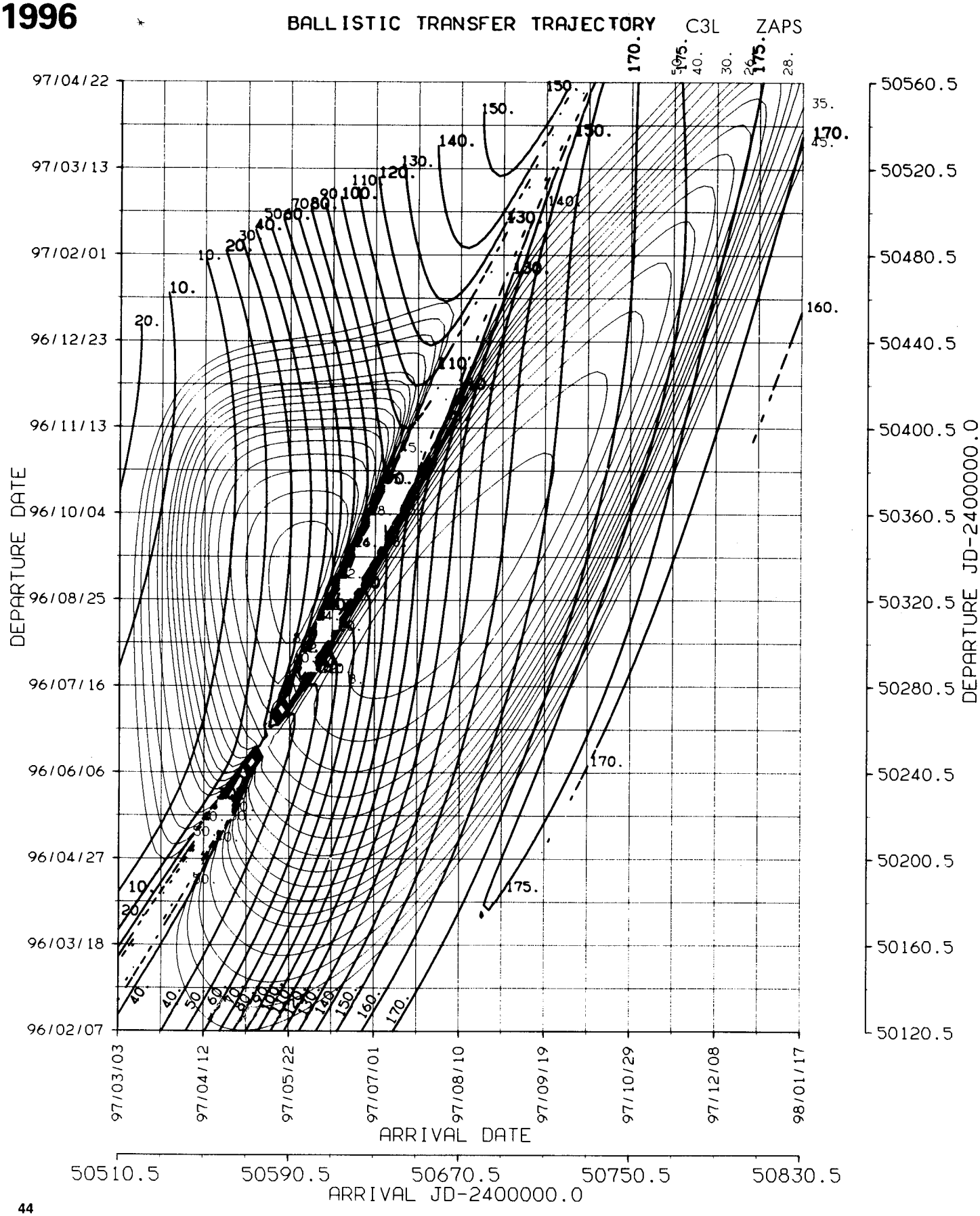
1996

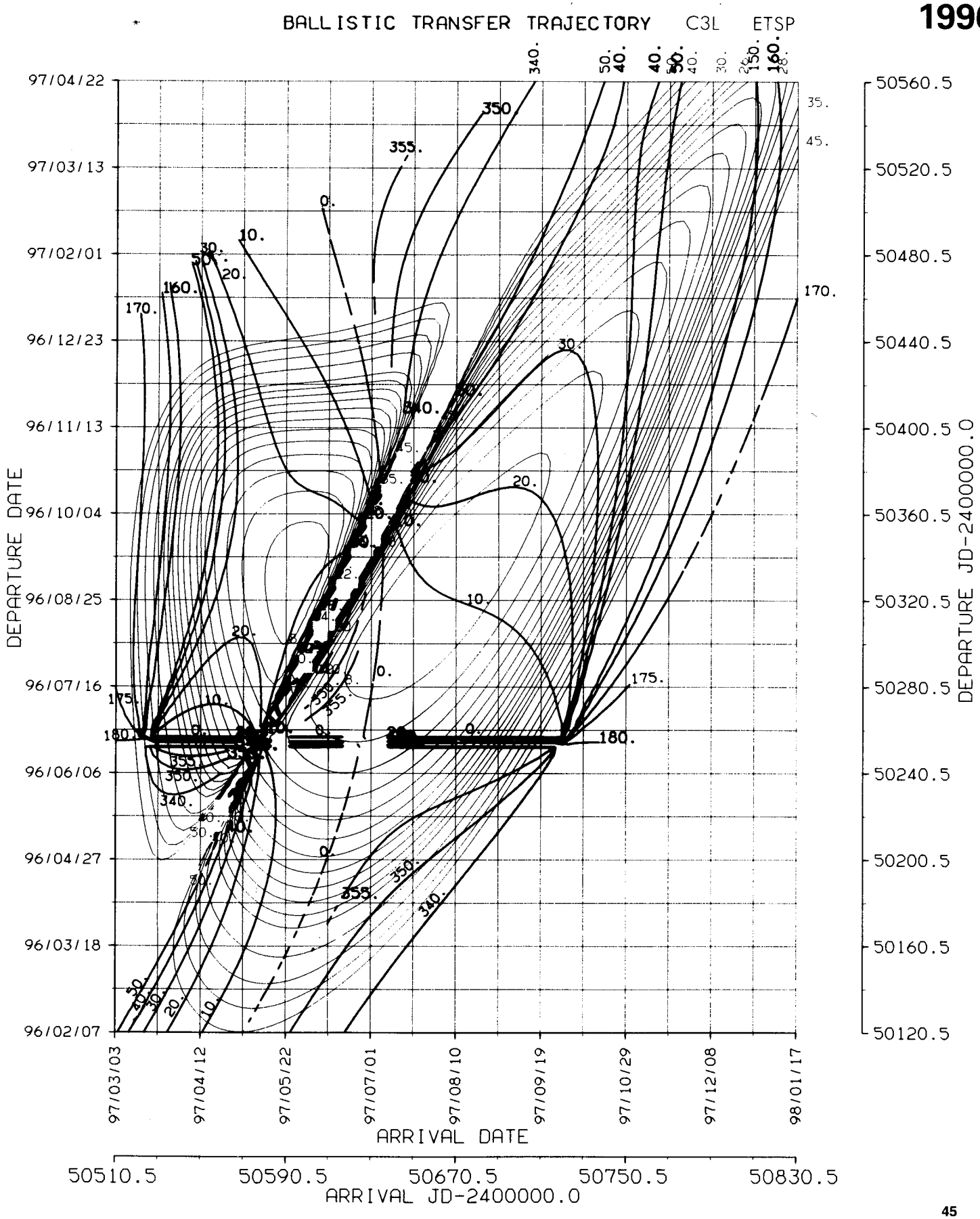
BALLISTIC TRANSFER TRAJECTORY C3L DAP




BALLISTIC TRANSFER TRAJECTORY C3L RAP
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
ARRIVAL DATE
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL JD-2400000.0
50510.5
50590.5
50670.5
50750.5
50830.5

ZAPS
♂⊕
1996


BALLISTIC TRANSFER TRAJECTORY C3L ZAPS
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL DATE
50510.5
50590.5
50670.5
50750.5
50830.5
ARRIVAL JD-2400000.0


BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
97/04/22
97/03/13
97/02/01
96/12/23
96/11/13
96/10/04
96/08/25
96/07/16
96/06/06
96/04/27
96/03/18
96/02/07
DEPARTURE JD-2400000.0
50560.5
50520.5
50480.5
50440.5
50400.5
50360.5
50320.5
50280.5
50240.5
50200.5
50160.5
50120.5
ARRIVAL DATE
97/03/03
97/04/12
97/05/22
97/07/01
97/08/10
97/09/19
97/10/29
97/12/08
98/01/17
ARRIVAL JD-2400000.0
50510.5
50590.5
50670.5
50750.5
50830.5

Mars to Earth

1998

Opportunity

ENERGY MINIMA

	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	5.895	I	1998/10/18	1999/06/28
C_3L	5.531	II	1998/10/23	1999/09/14
VHP	4.240	I	1998/12/28	1999/07/29
VHP	3.724	II	1998/06/19	1999/07/20

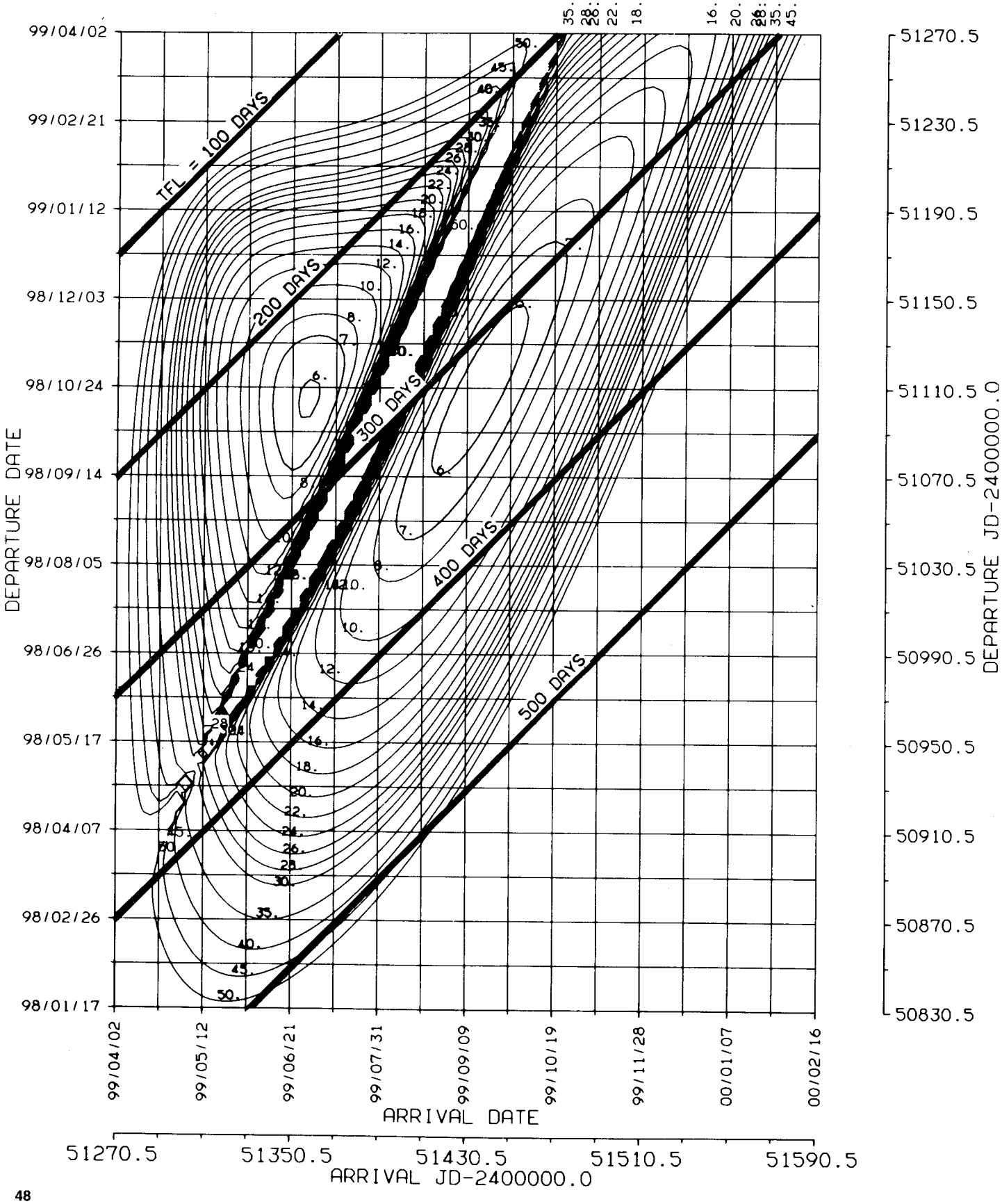
C3L

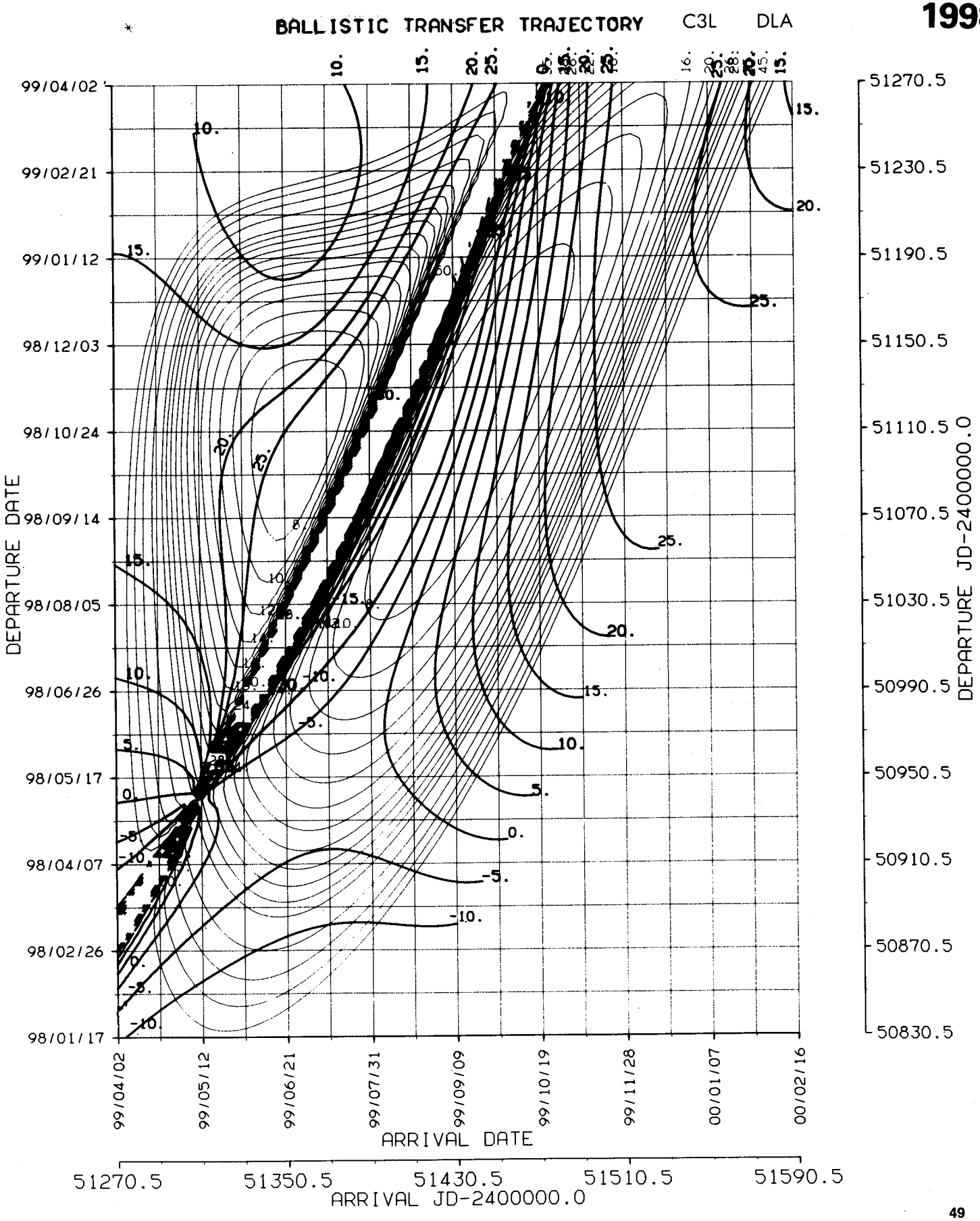
♂ ⊕

1998

*

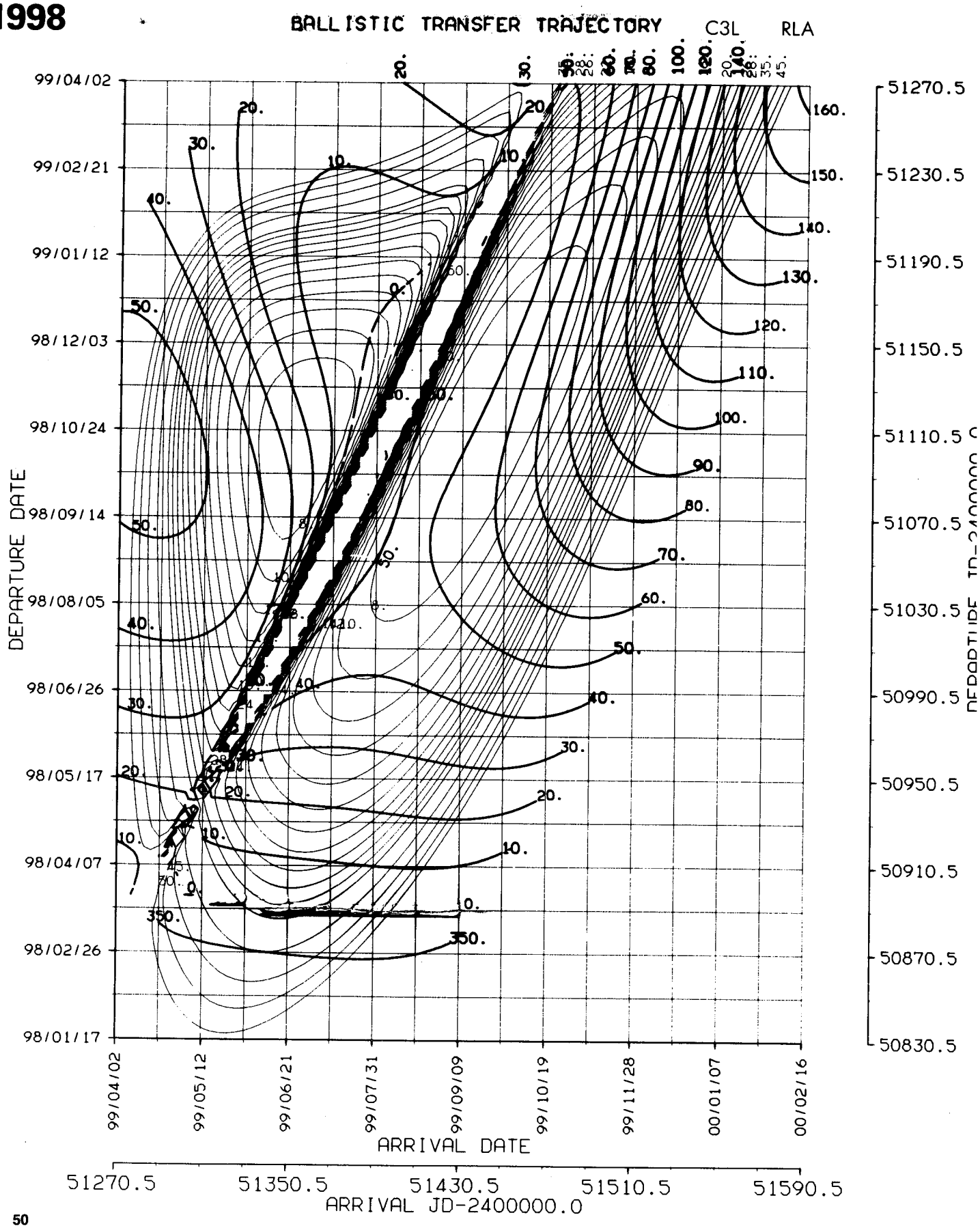
BALLISTIC TRANSFER TRAJECTORY C3L TFL

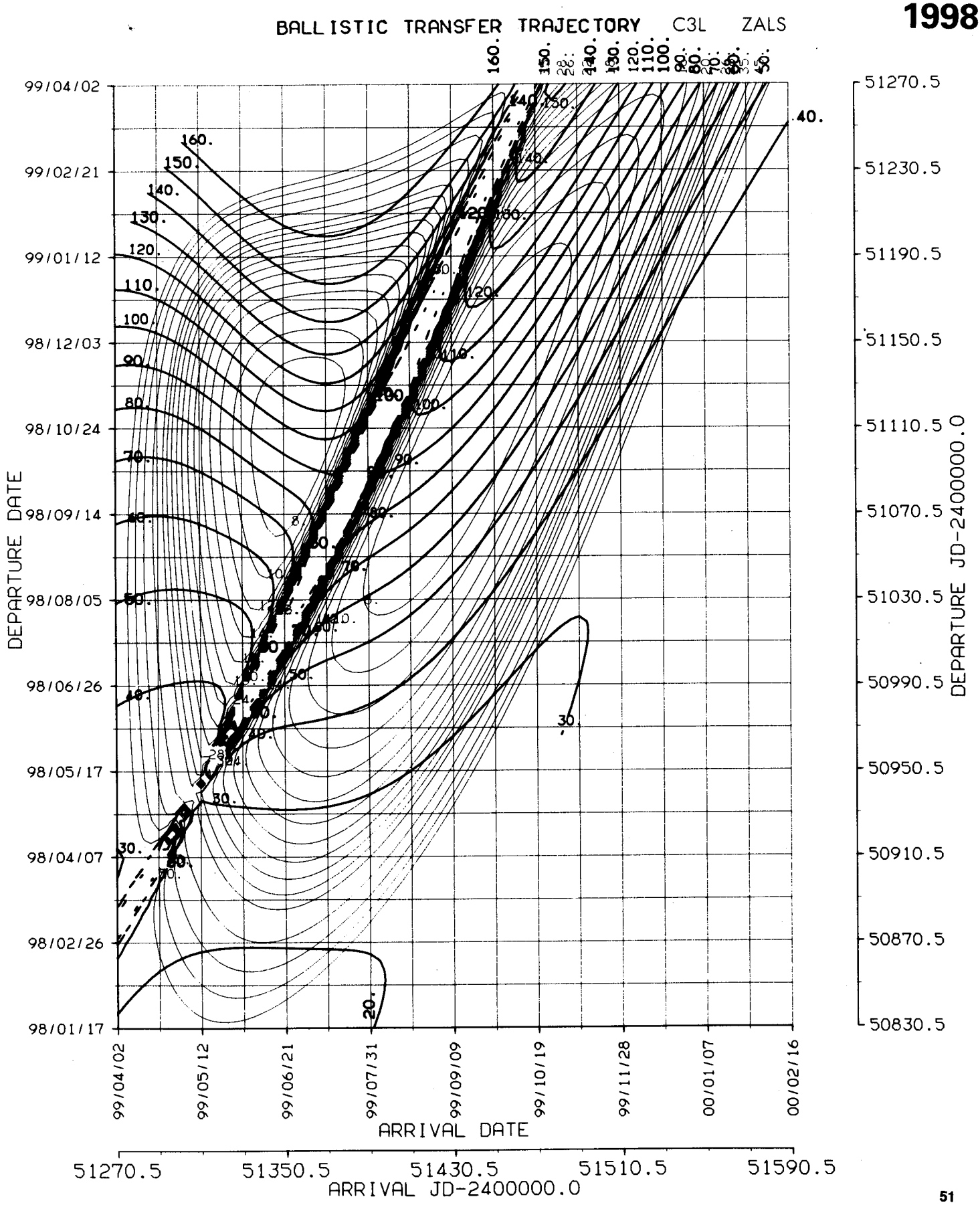



BALLISTIC TRANSFER TRAJECTORY C3L DLA
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

RLA

1998

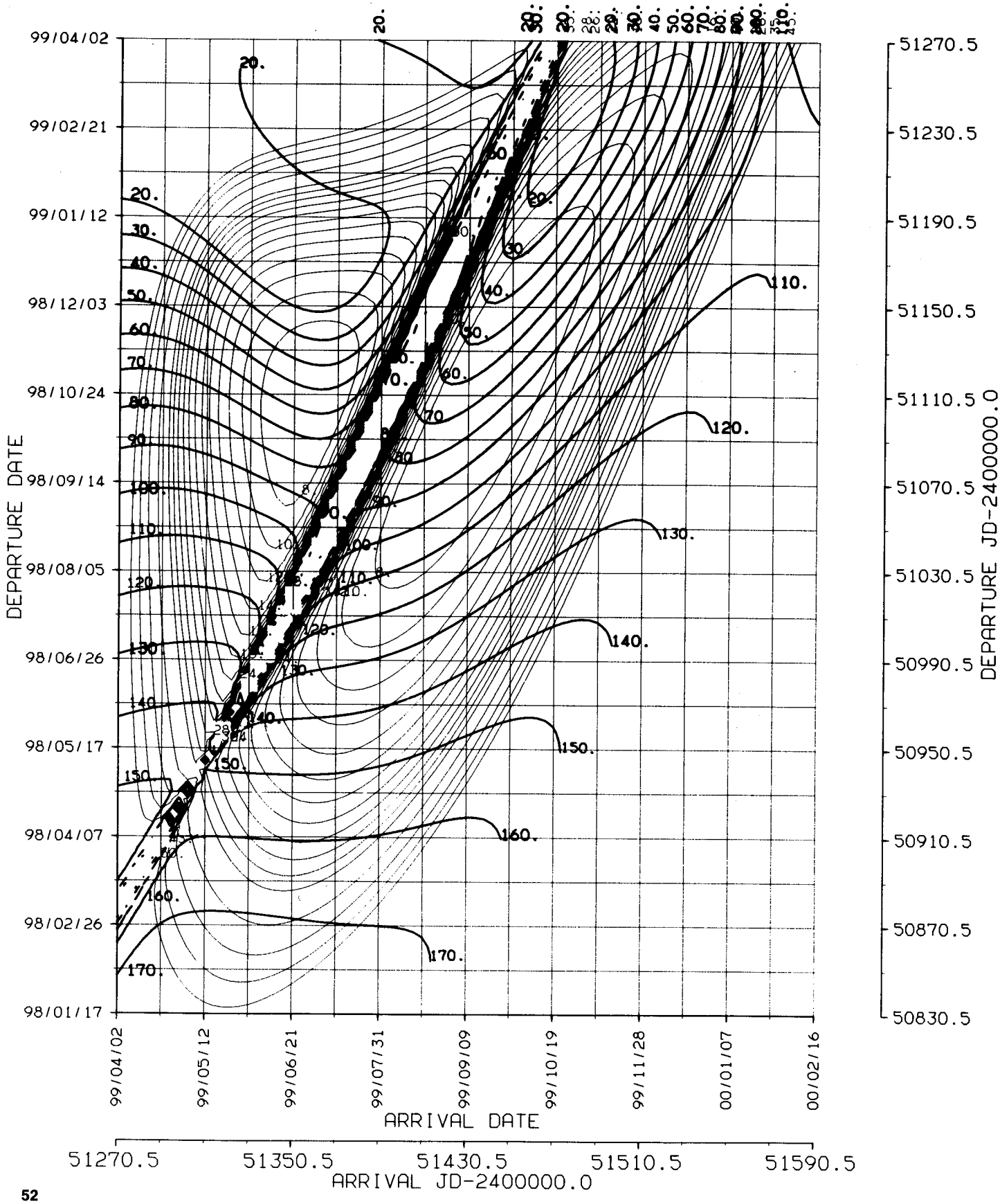

BALLISTIC TRANSFER TRAJECTORY C3L RLA
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

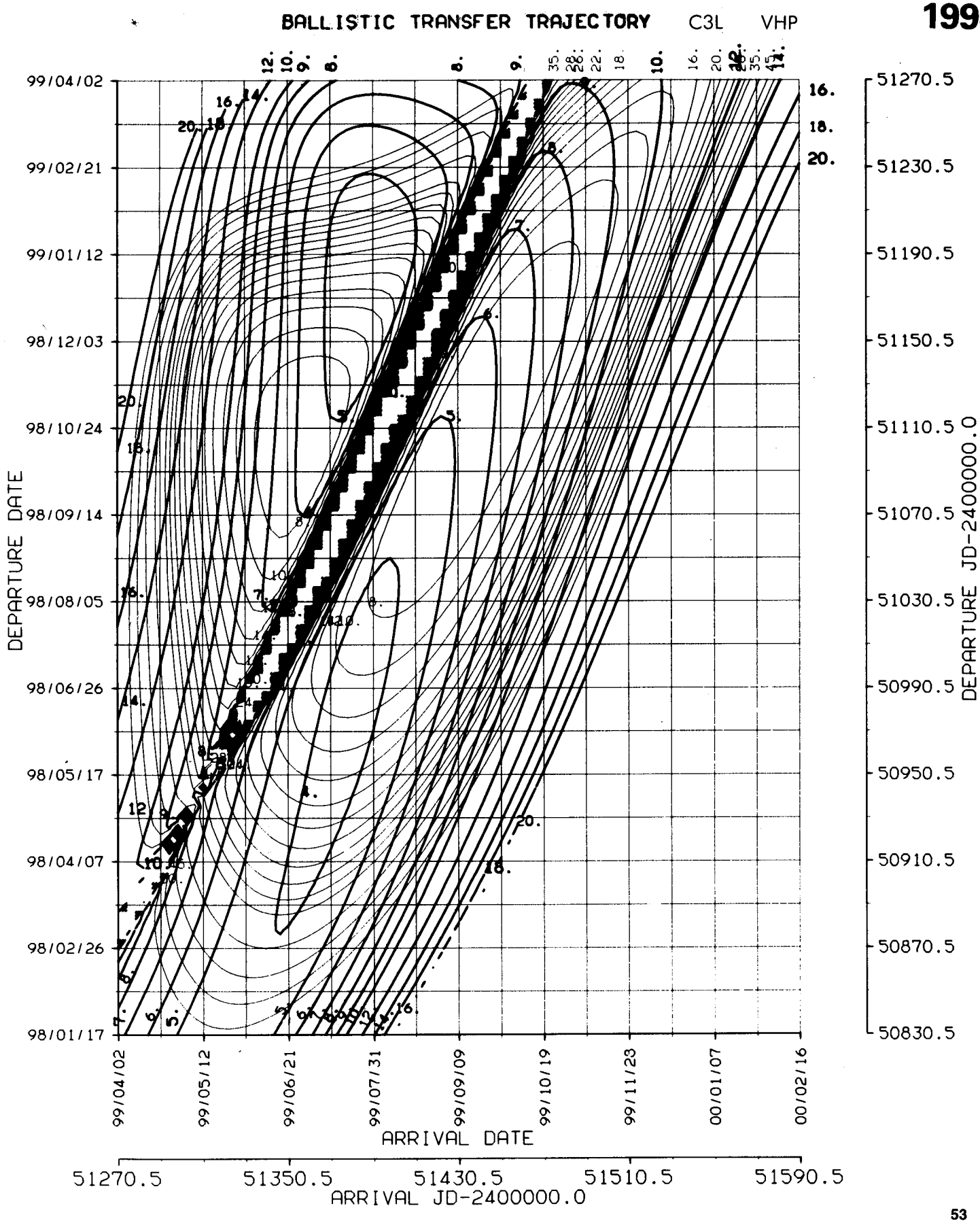

BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

ZALE

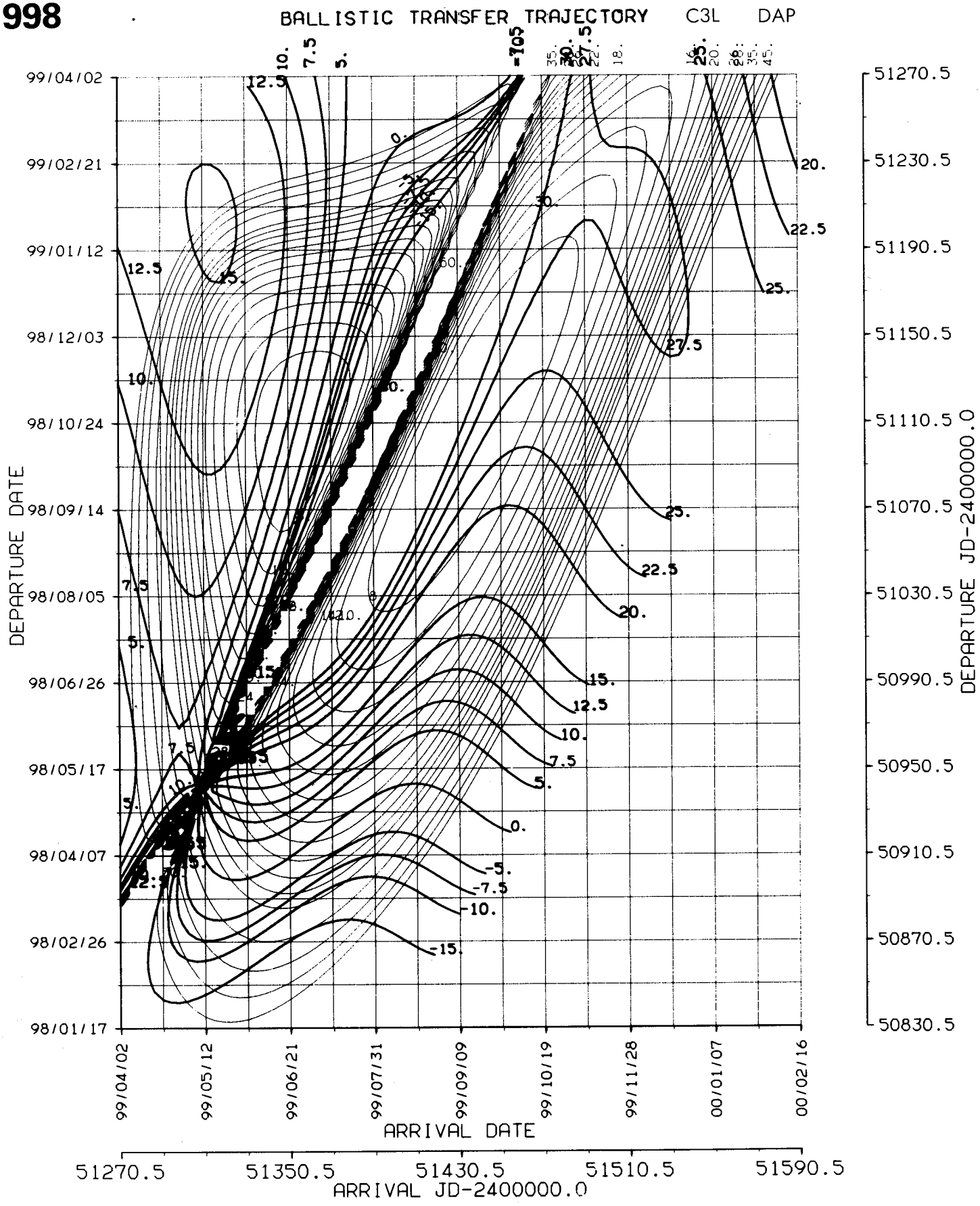
1998

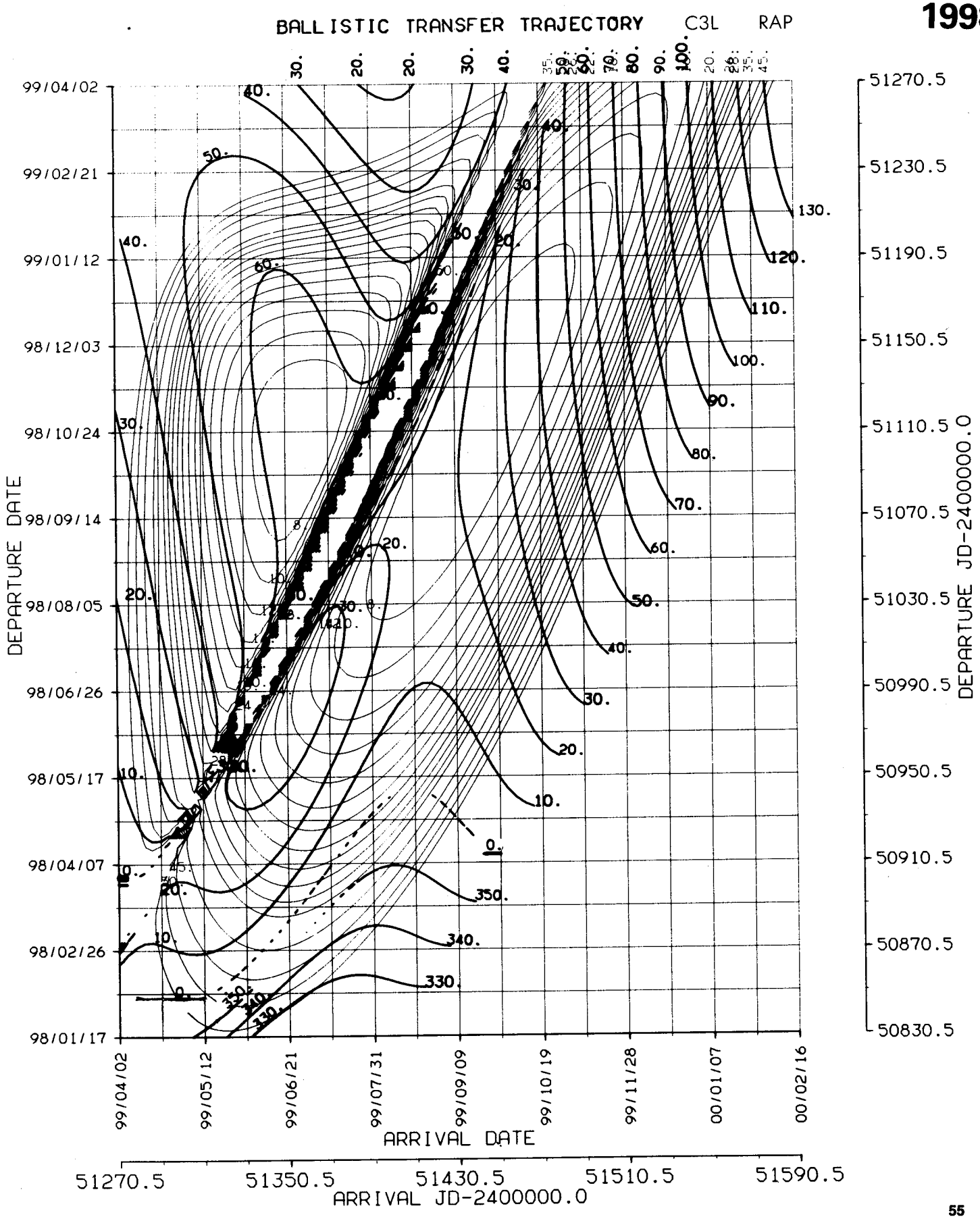
BALLISTIC TRANSFER TRAJECTORY C3L ZALE



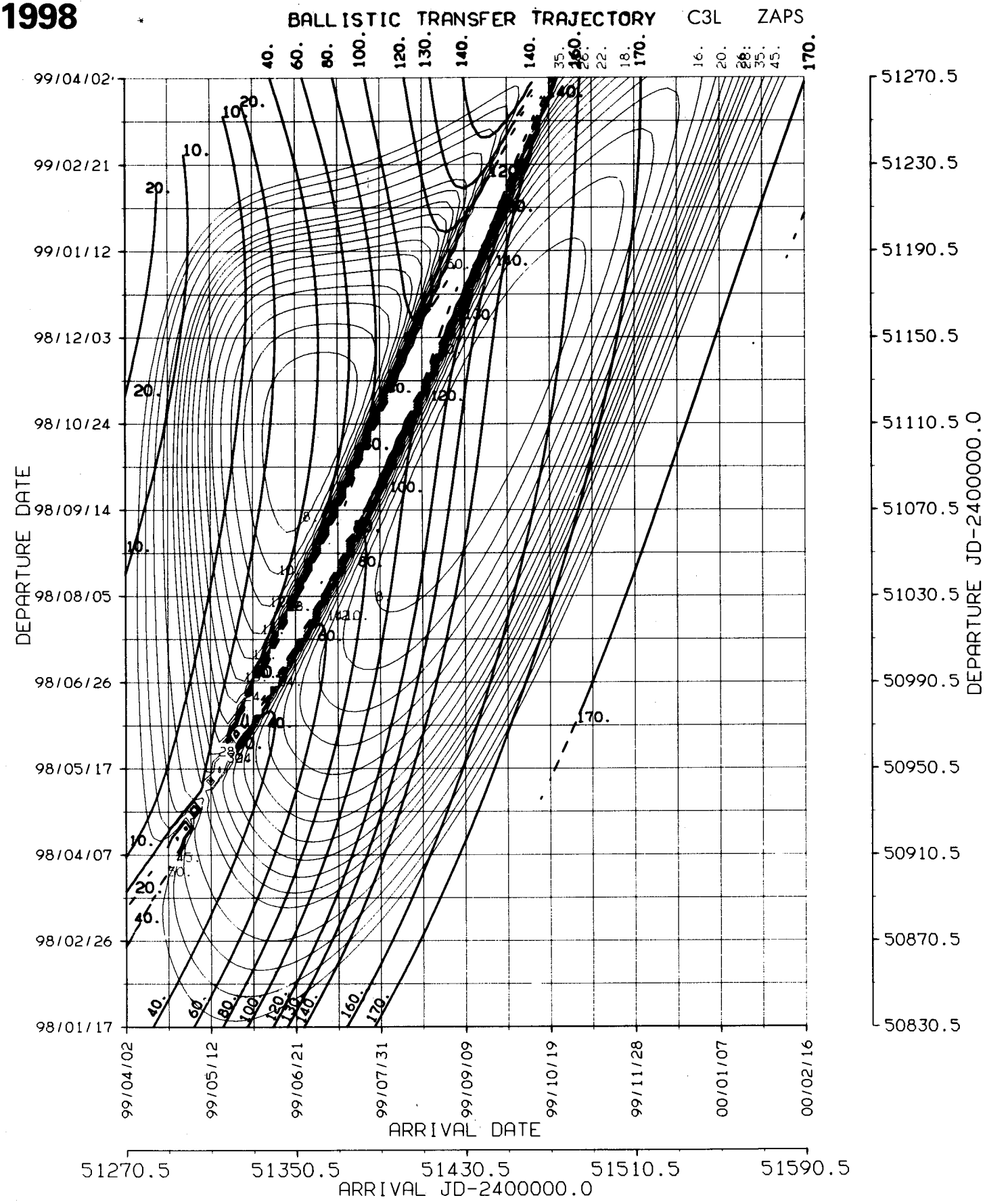

BALLISTIC TRANSFER TRAJECTORY C3L VHP
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/23
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

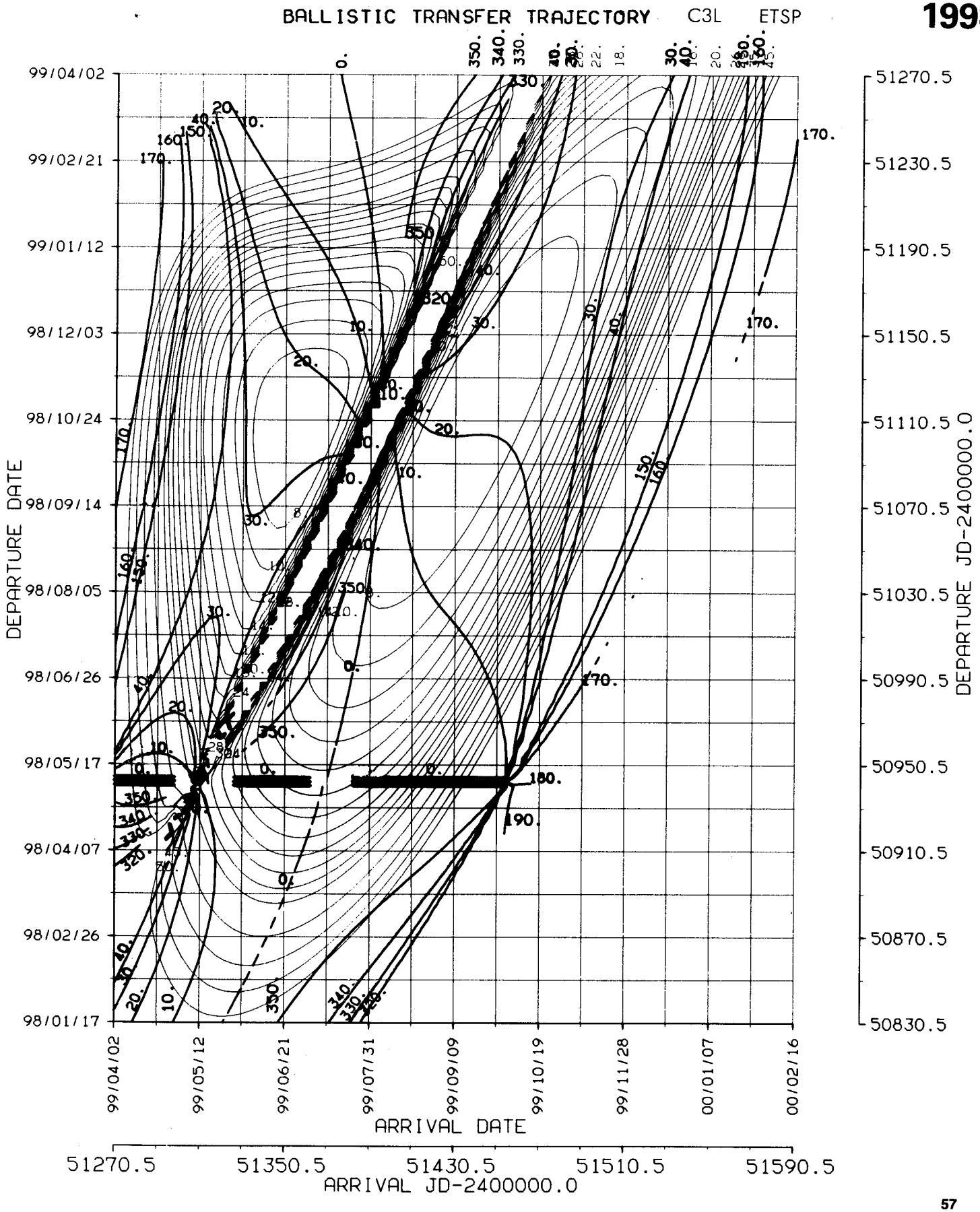
DAP
♂ ⊕
1998


BALLISTIC TRANSFER TRAJECTORY C3L DAP
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
ARRIVAL DATE
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL JD-2400000.0
51270.5
51350.5
51430.5
51510.5
51590.5


BALLISTIC TRANSFER TRAJECTORY C3L RAP
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

ZAPS
♂⊕
1998


BALLISTIC TRANSFER TRAJECTORY C3L ZAPS
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0


BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
99/04/02
99/02/21
99/01/12
98/12/03
98/10/24
98/09/14
98/08/05
98/06/26
98/05/17
98/04/07
98/02/26
98/01/17
DEPARTURE JD-2400000.0
51270.5
51230.5
51190.5
51150.5
51110.5
51070.5
51030.5
50990.5
50950.5
50910.5
50870.5
50830.5
99/04/02
99/05/12
99/06/21
99/07/31
99/09/09
99/10/19
99/11/28
00/01/07
00/02/16
ARRIVAL DATE
51270.5
51350.5
51430.5
51510.5
51590.5
ARRIVAL JD-2400000.0

Mars to Earth

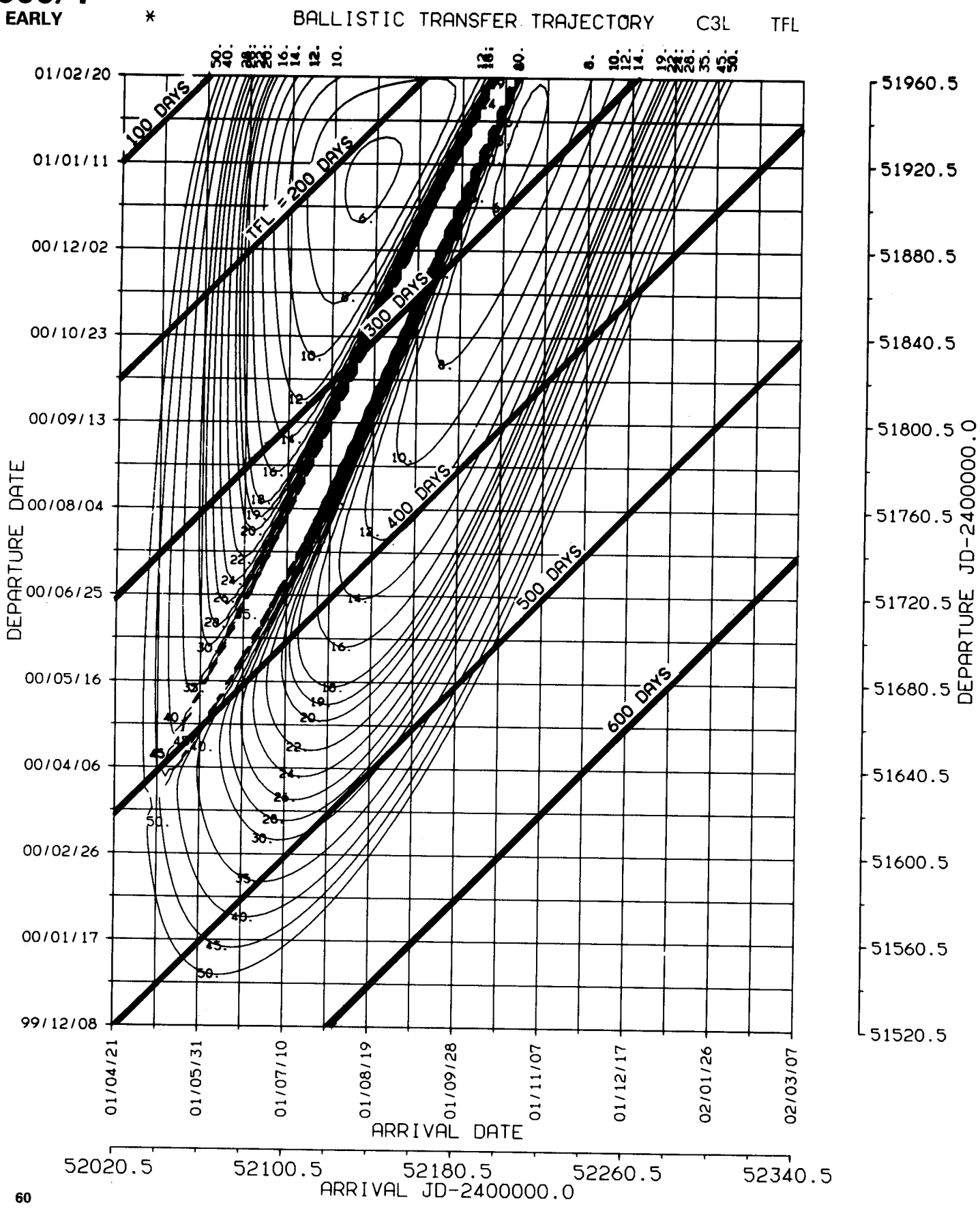
2000/1

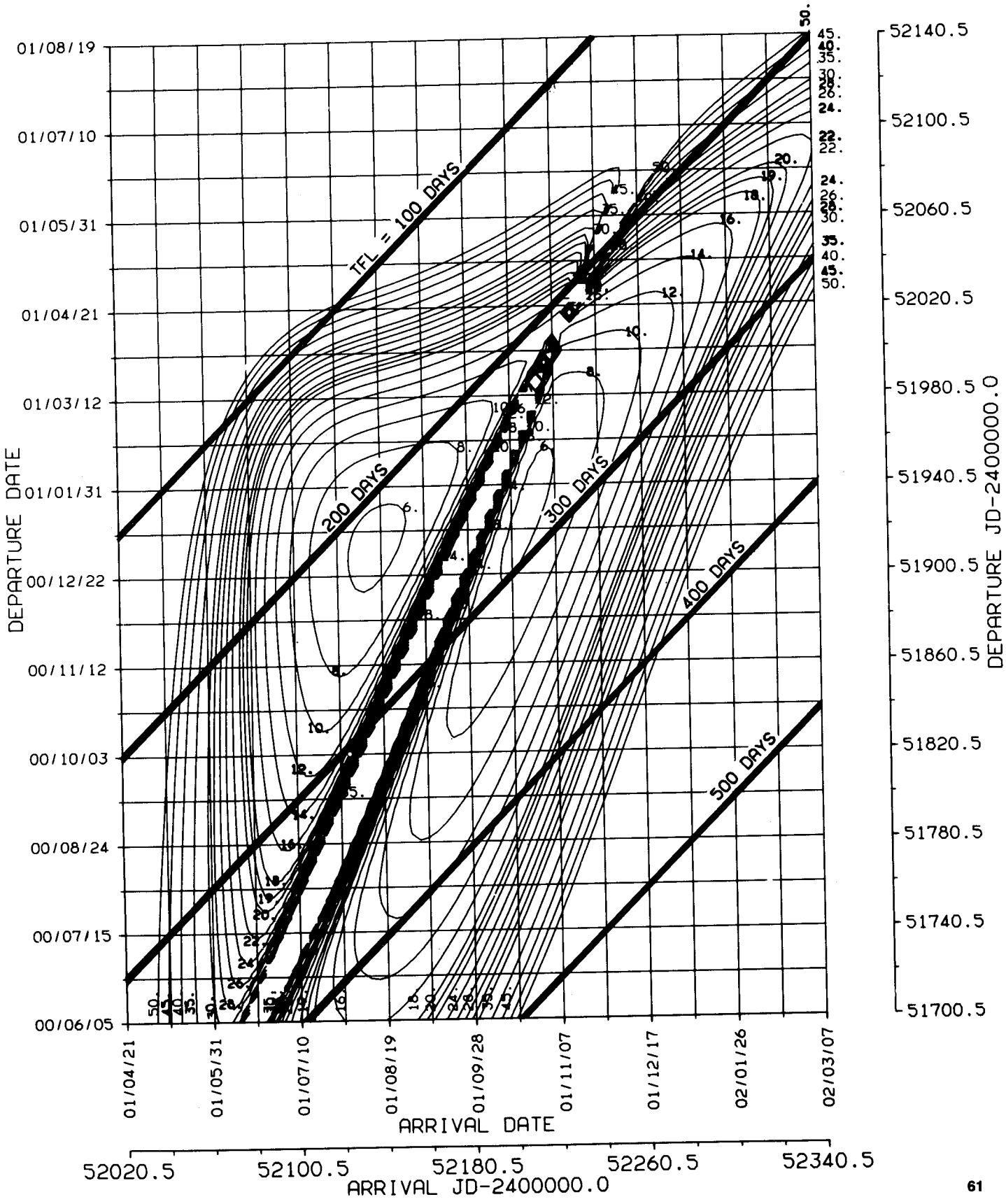
Opportunity

ENERGY MINIMA

	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	5.643	I	2001/01/04	2001/08/16
C_3L	5.626	II	2001/01/20	2001/10/25
VHP	3.705	I	2001/02/16	2001/09/11
VHP	4.085	II	2000/06/08	2001/08/08

C3L
♂⊕
2000/1
EARLY



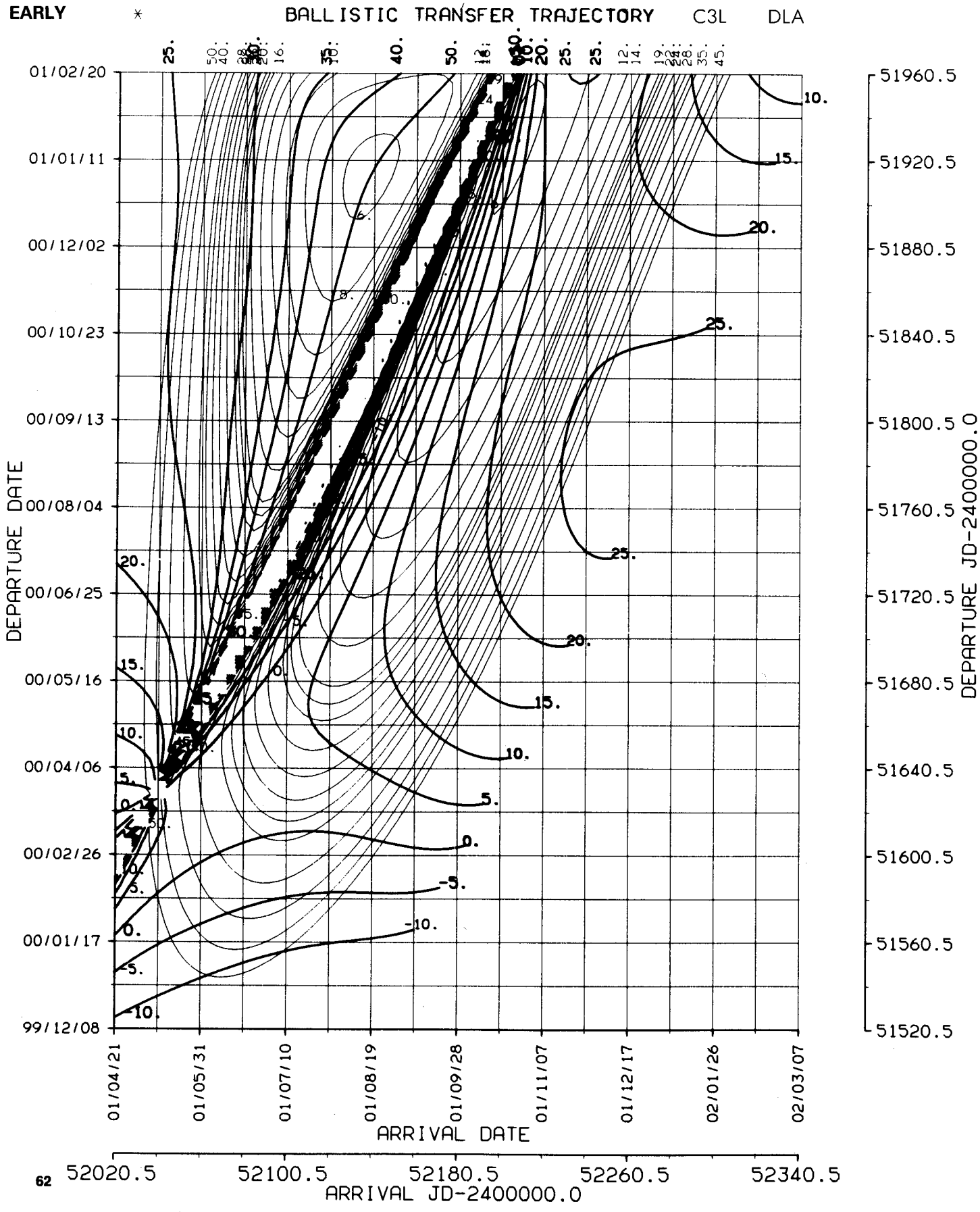

* BALLISTIC TRANSFER TRAJECTORY C3L TFL
TFL = 100 DAYS
200 DAYS
300 DAYS
400 DAYS
500 DAYS
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL DATE
52020.5
52100.5
52180.5
52260.5
52340.5
ARRIVAL JD-2400000.0

DLA

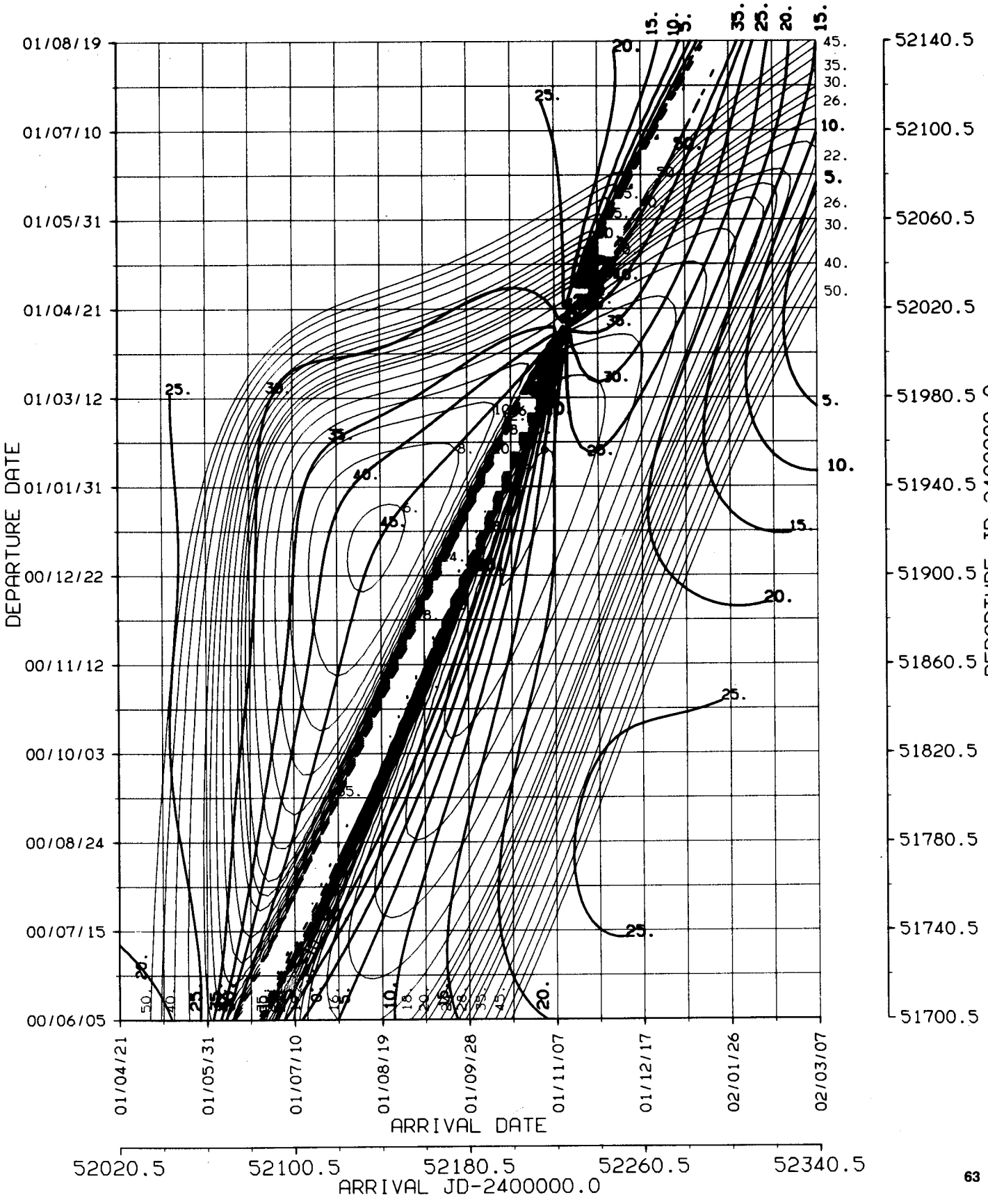
♂ ⊕

2000/1

EARLY



BALLISTIC TRANSFER TRAJECTORY C3L DLA

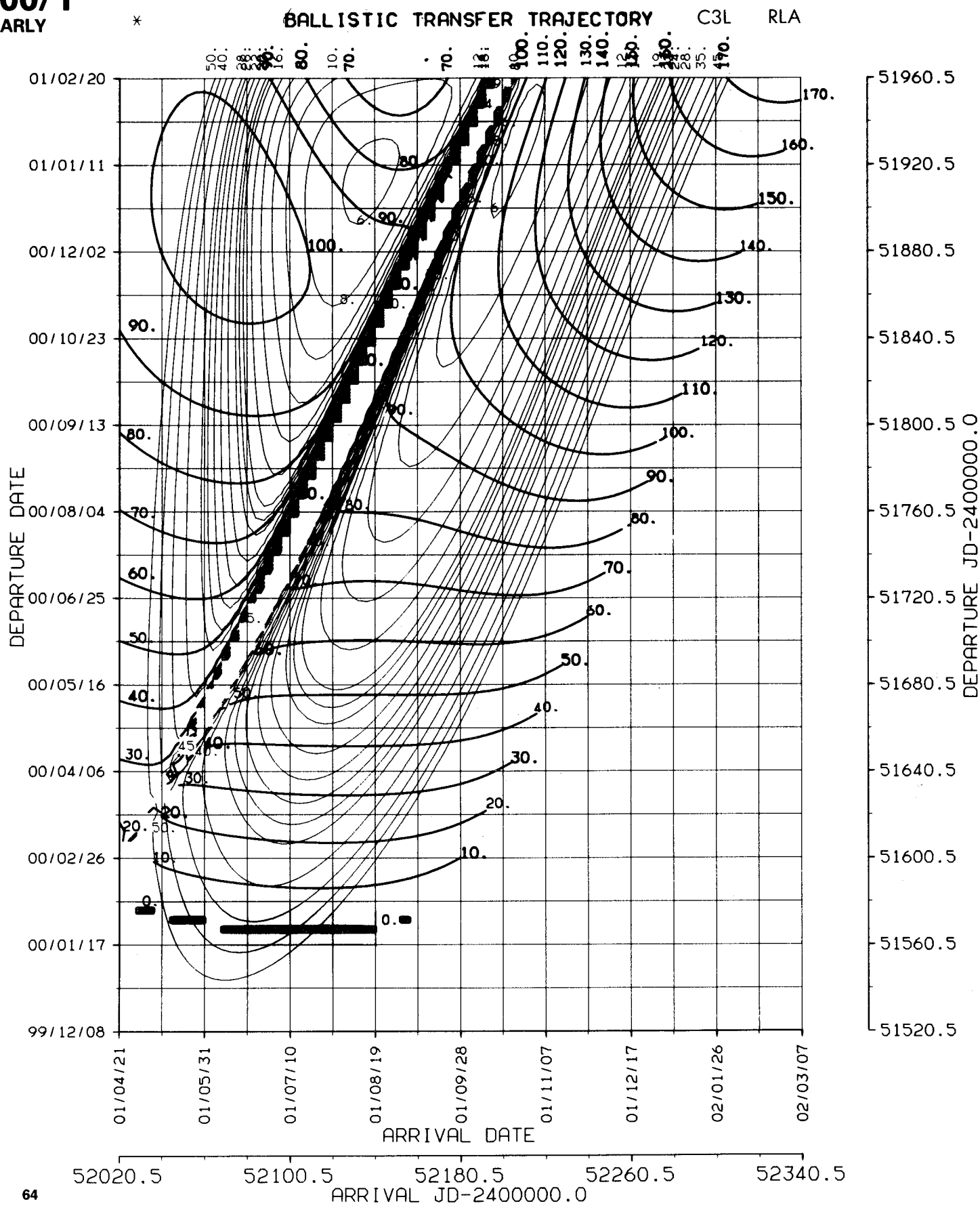


RLA

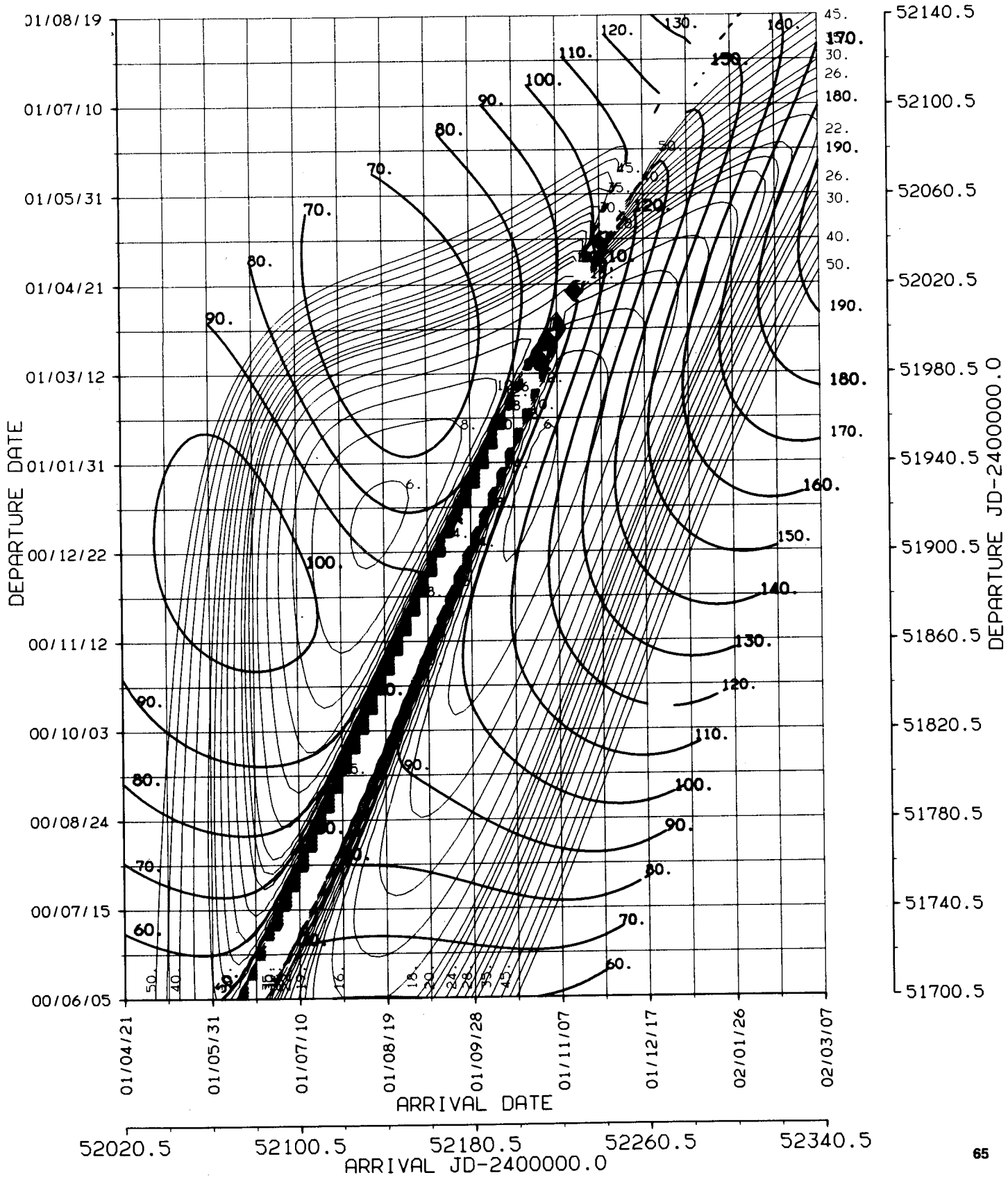
♂ ⊕

2000/1

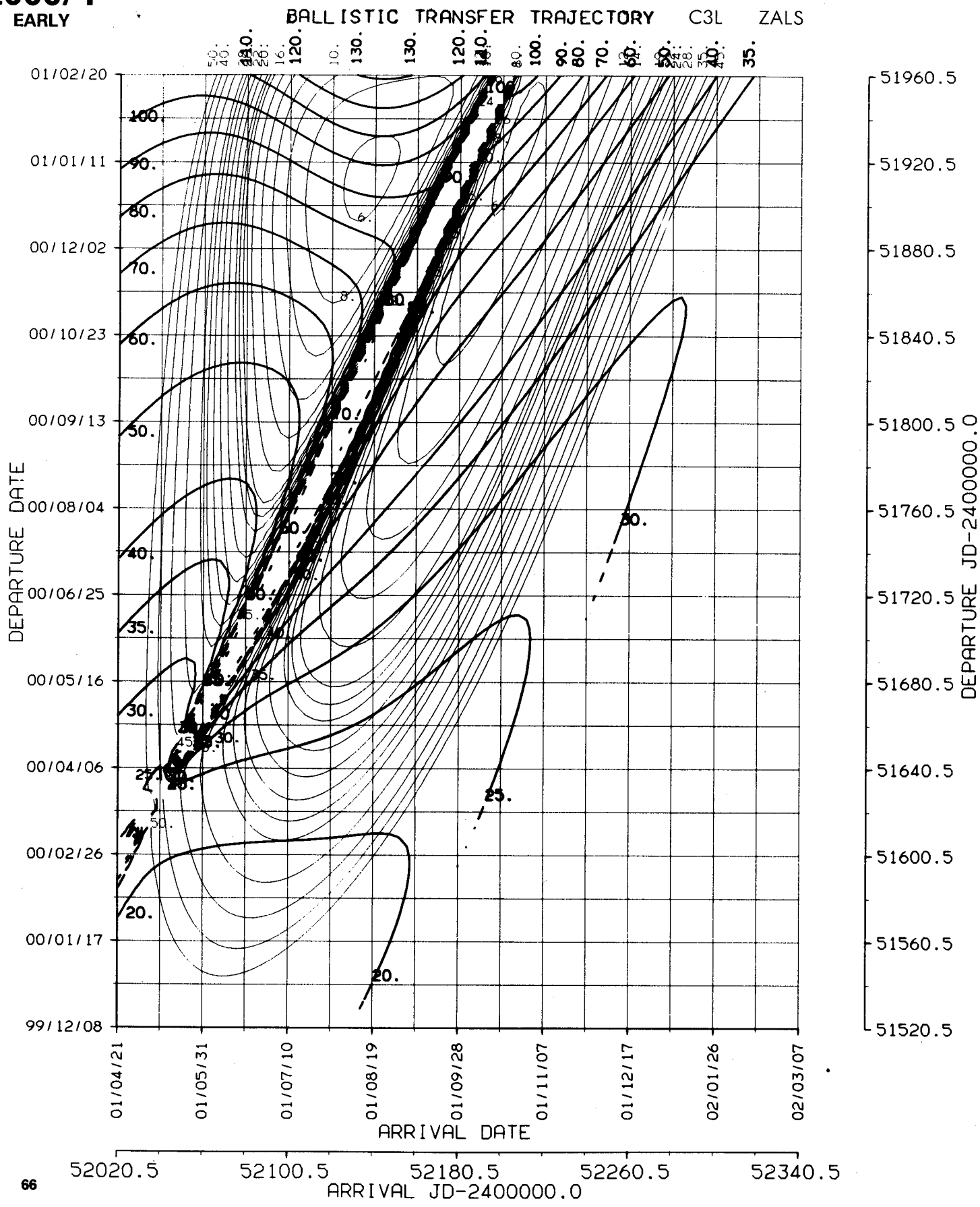
EARLY

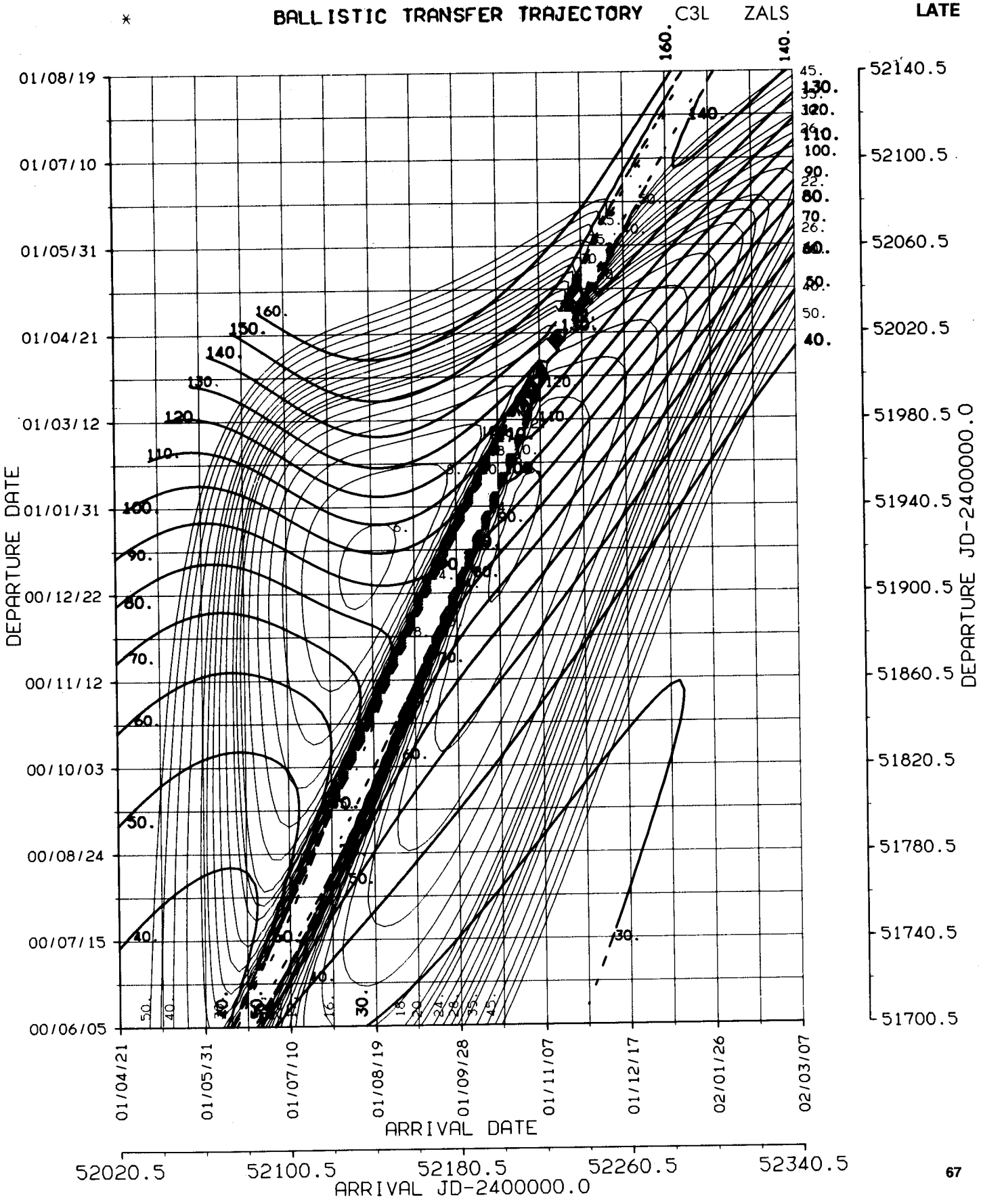


BALLISTIC TRANSFER TRAJECTORY C3L RLA



ZALS
♂⊕
2000/1
EARLY



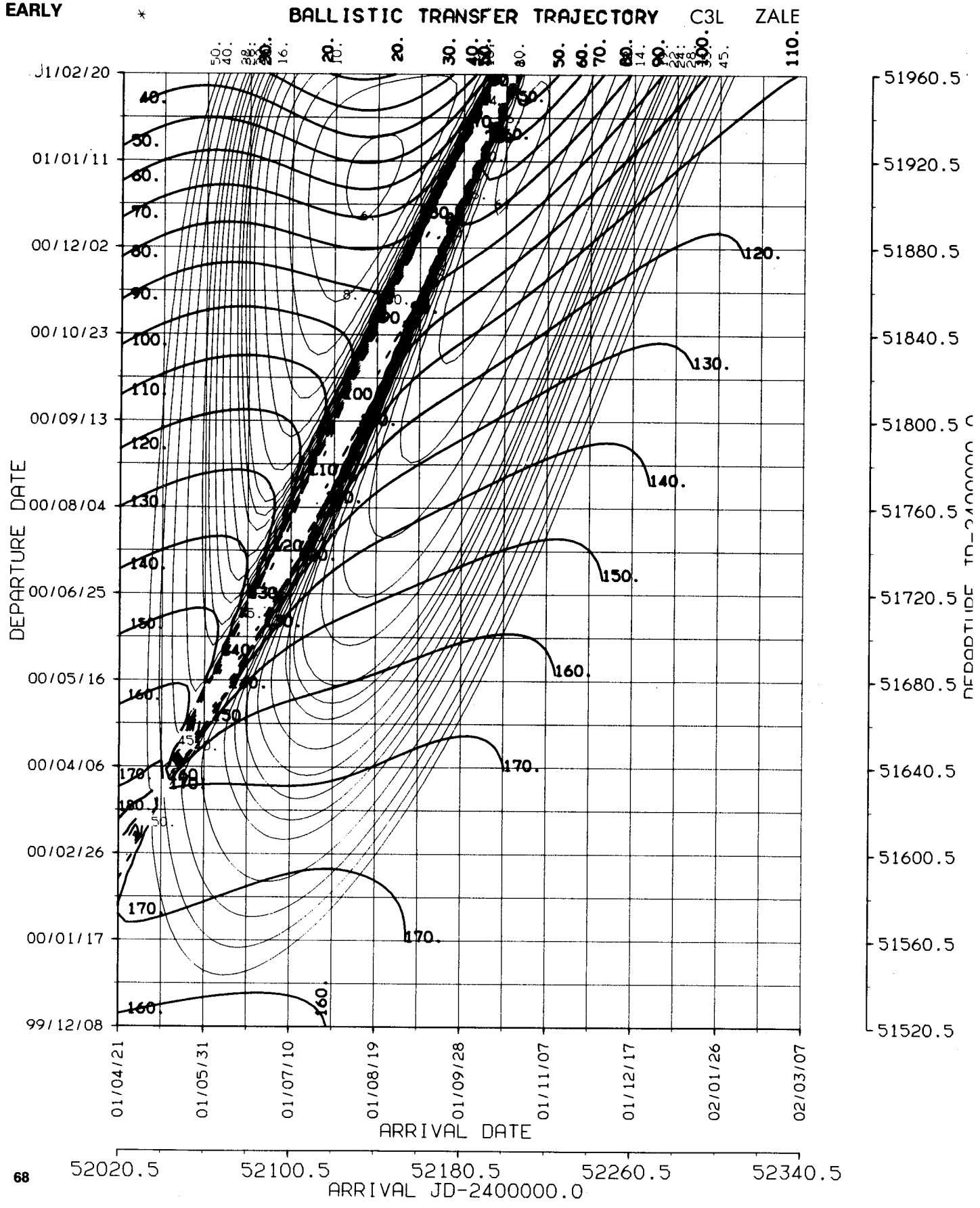

BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL DATE
52020.5
52100.5
52180.5
52260.5
52340.5
ARRIVAL JD-2400000.0

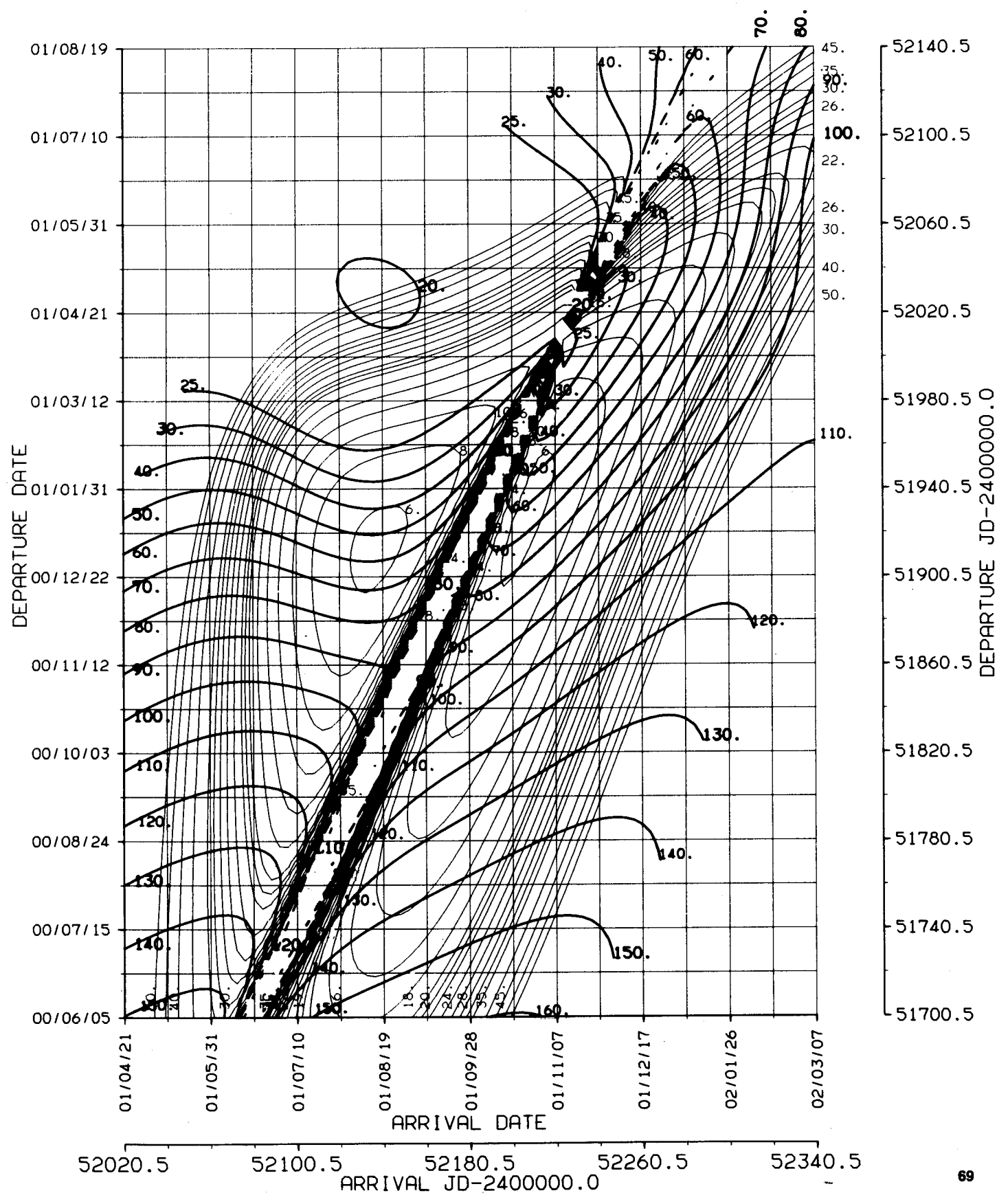
ZALE

♂ ⊕

2000/1

EARLY



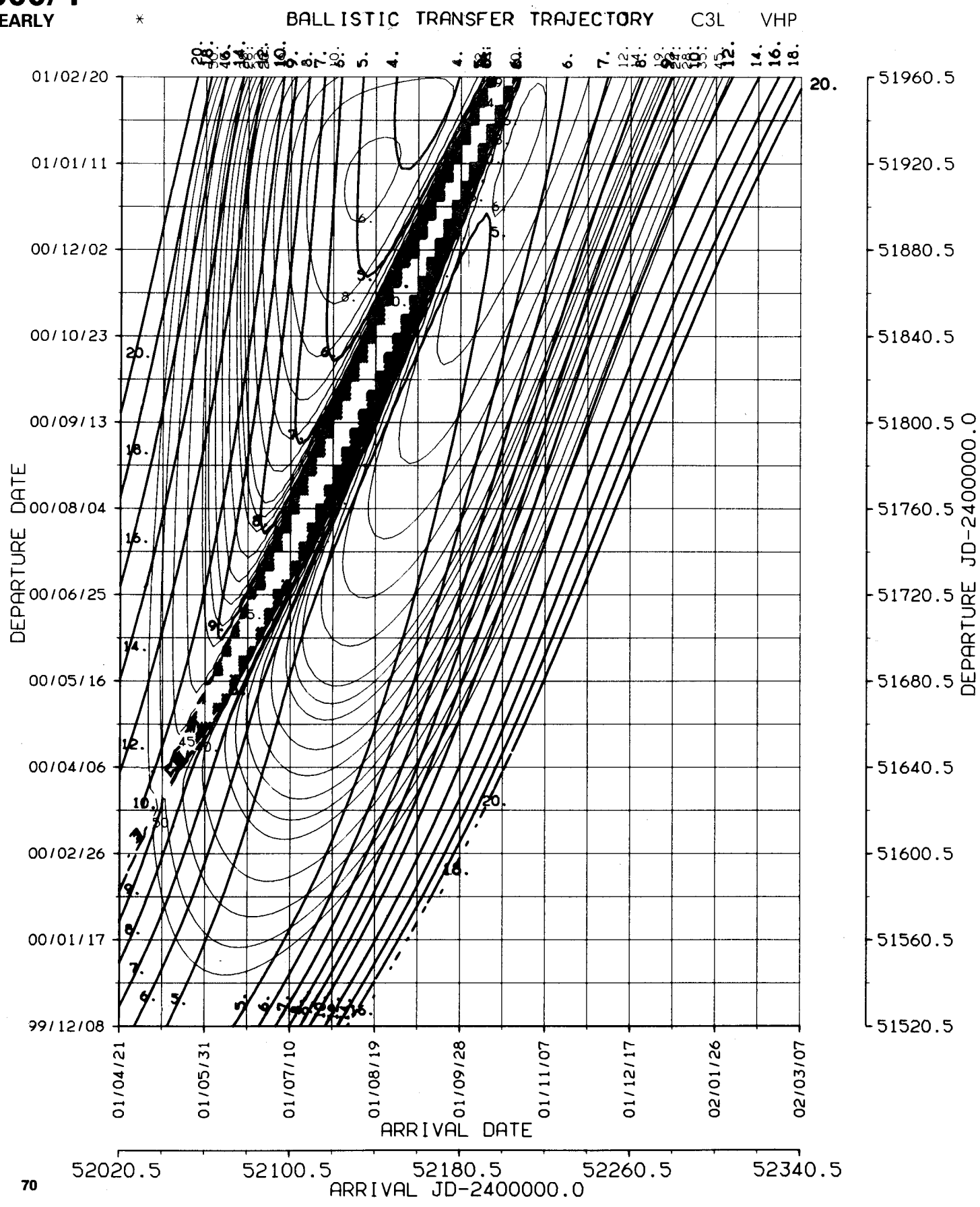

BALLISTIC TRANSFER TRAJECTORY C3L ZALE
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL DATE
52020.5
52100.5
52180.5
52260.5
52340.5
ARRIVAL JD-2400000.0

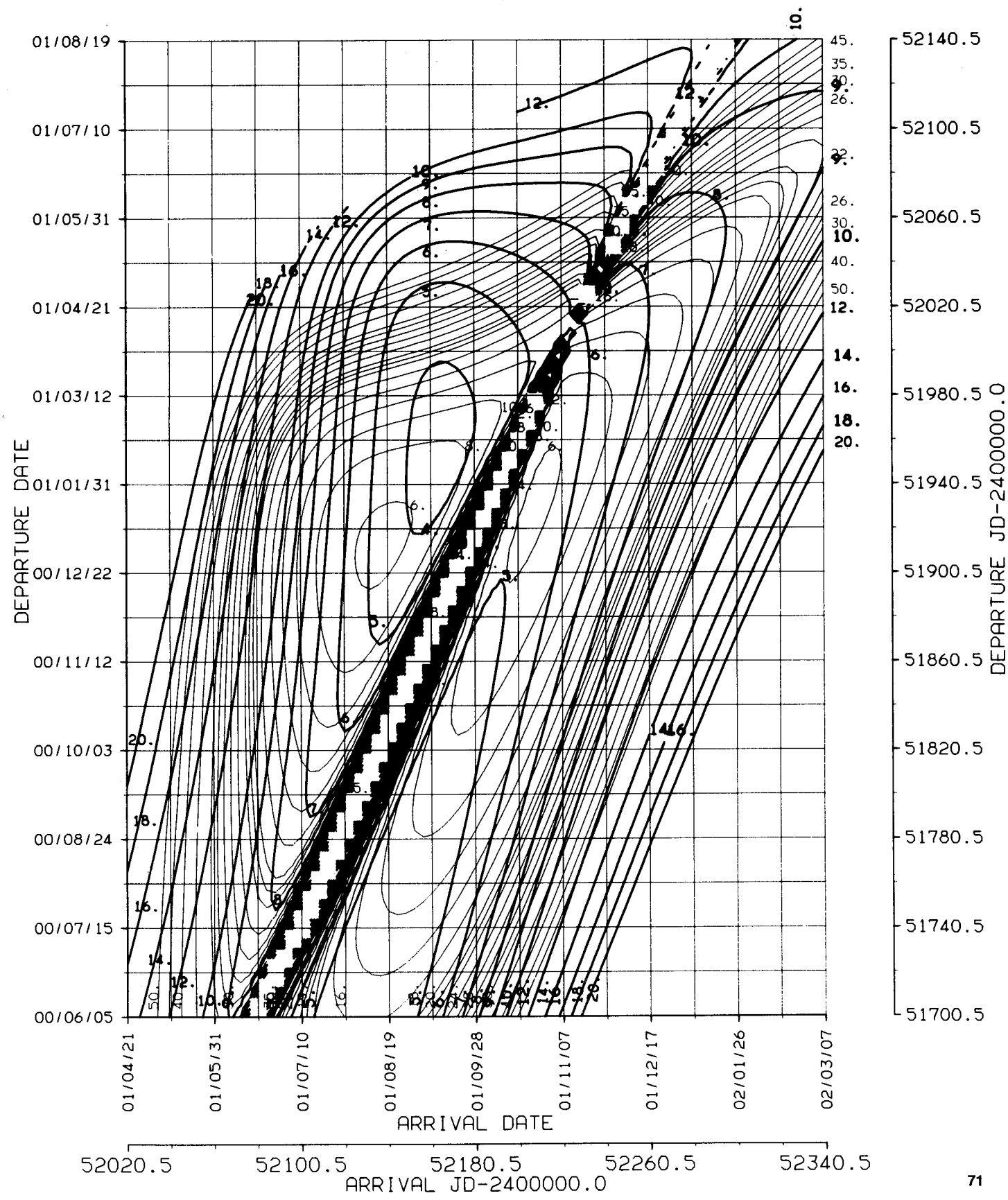
VHP

♂ ⊕

2000/1

EARLY



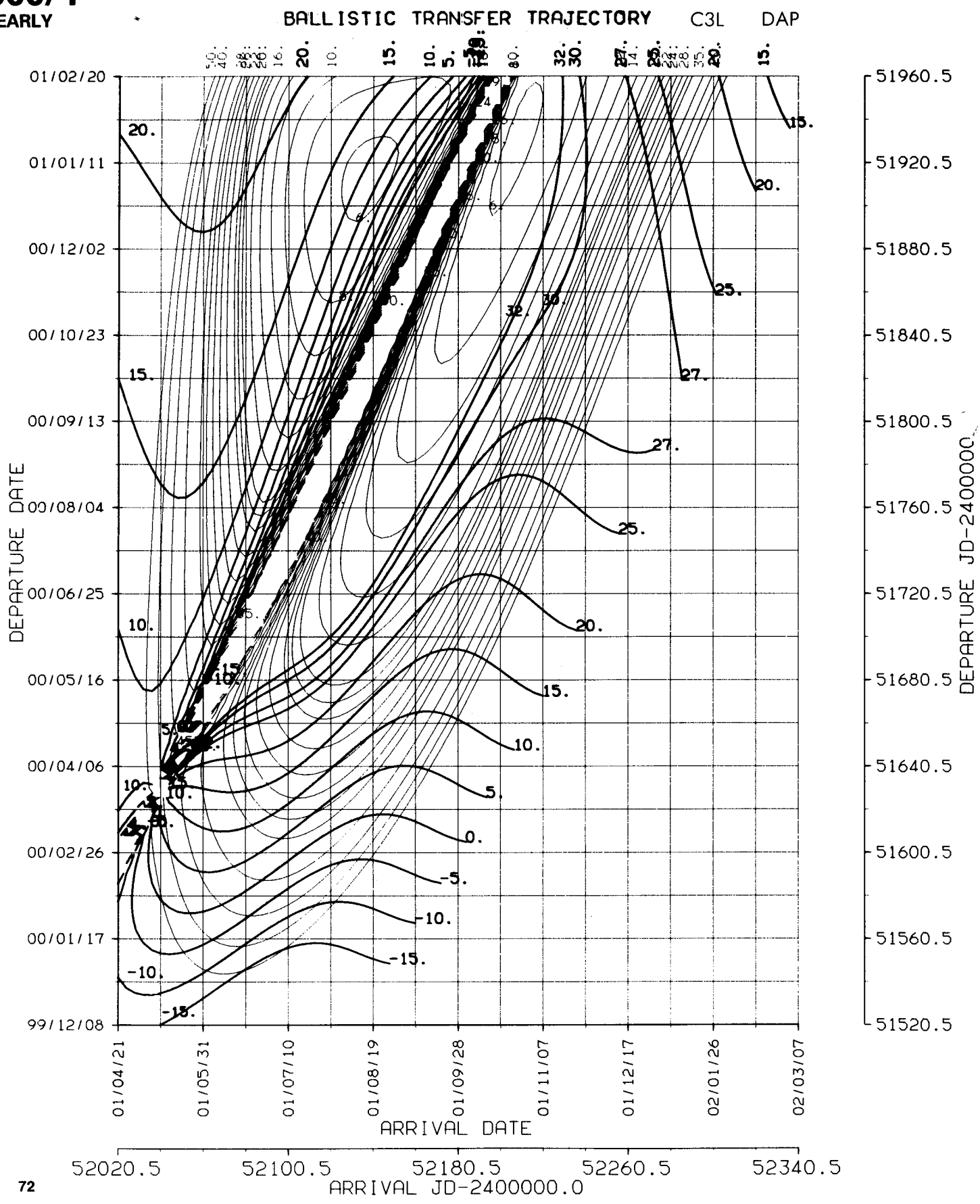

* BALLISTIC TRANSFER TRAJECTORY C3L VHP
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL DATE
52020.5
52100.5
52180.5
52260.5
52340.5
ARRIVAL JD-2400000.0

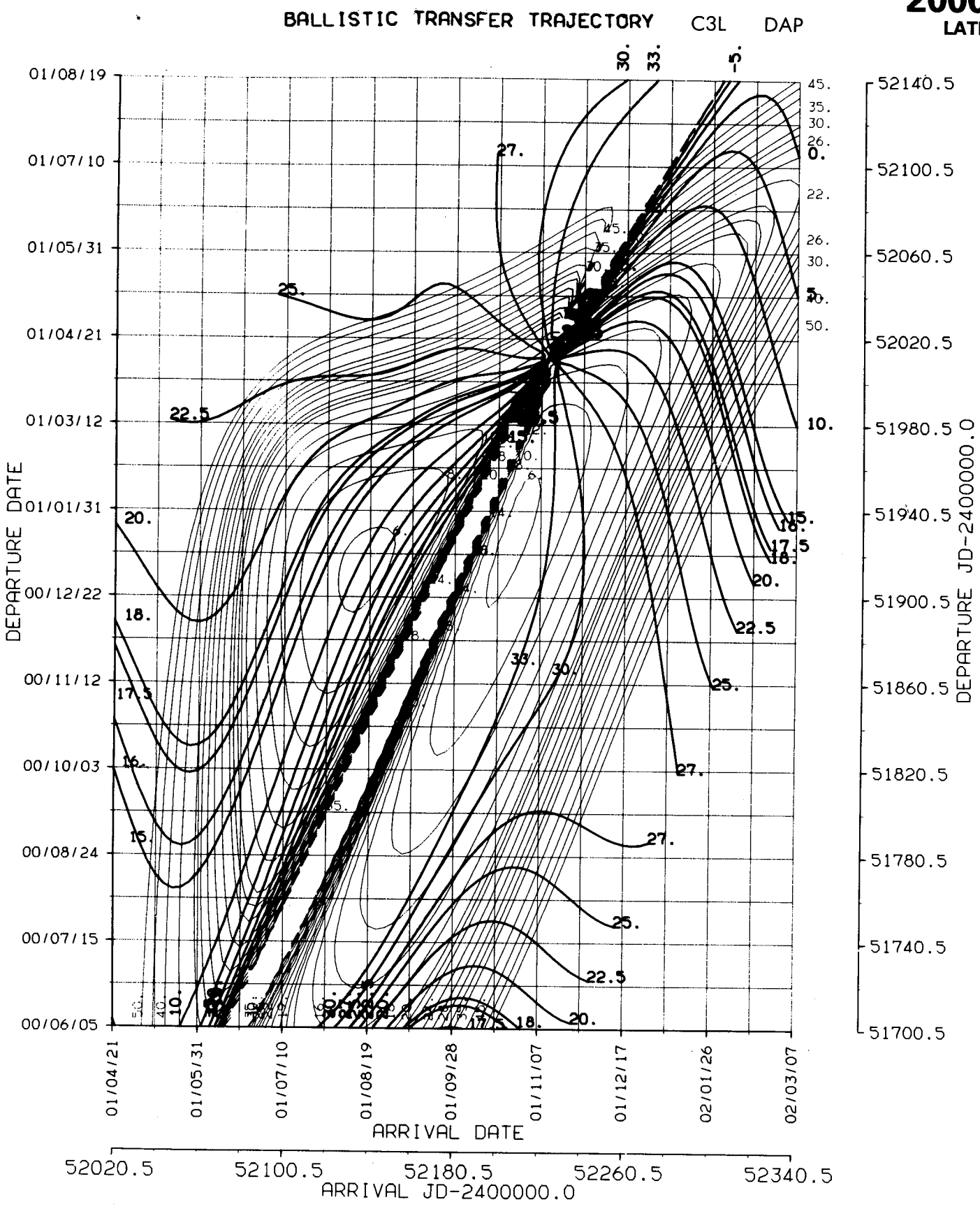
DAP

♂ ⊕

2000/1

EARLY



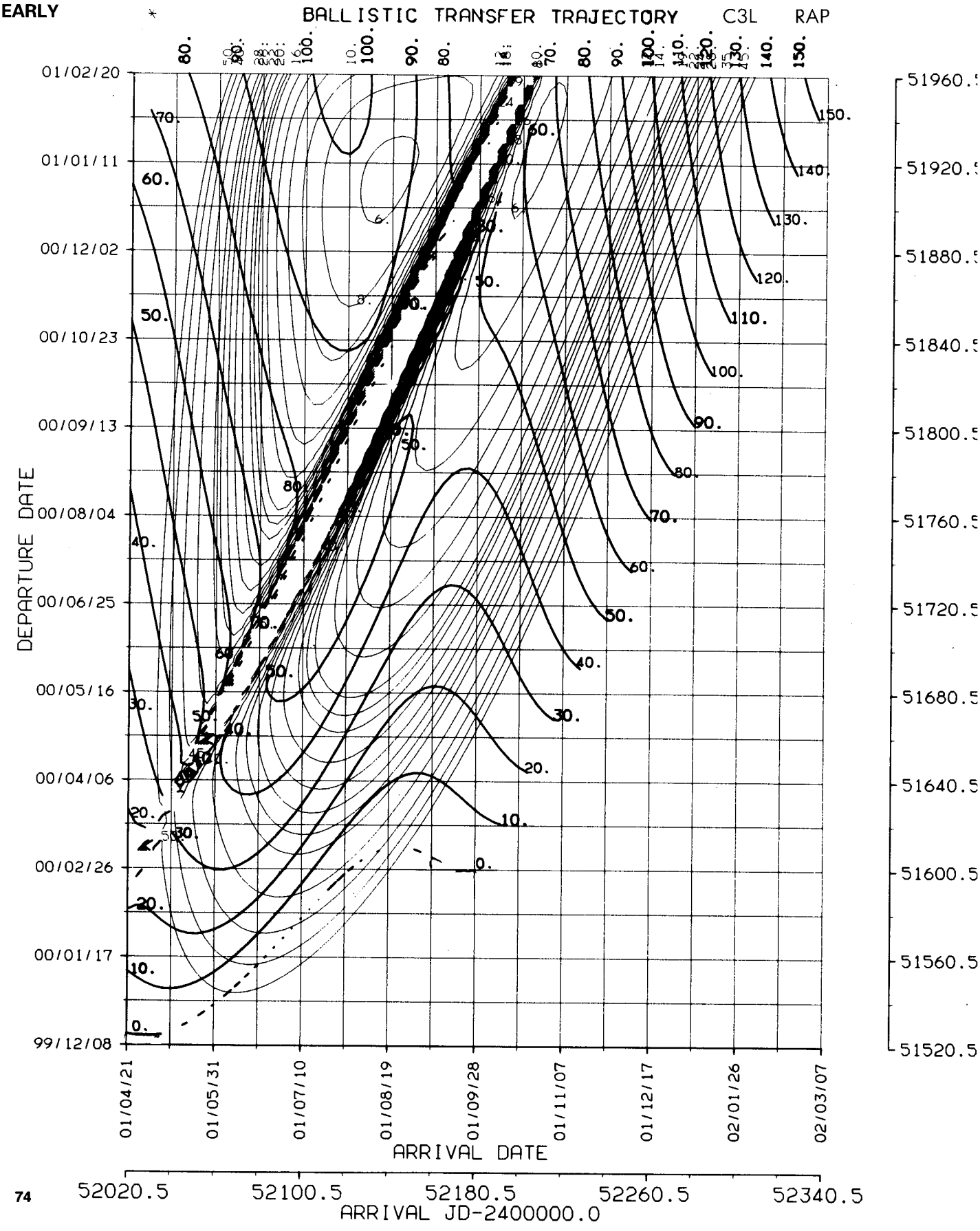

BALLISTIC TRANSFER TRAJECTORY C3L DAP
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
ARRIVAL DATE
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL JD-2400000.0
52020.5
52100.5
52180.5
52260.5
52340.5

RAP

♂ ⊕

2000/1

EARLY

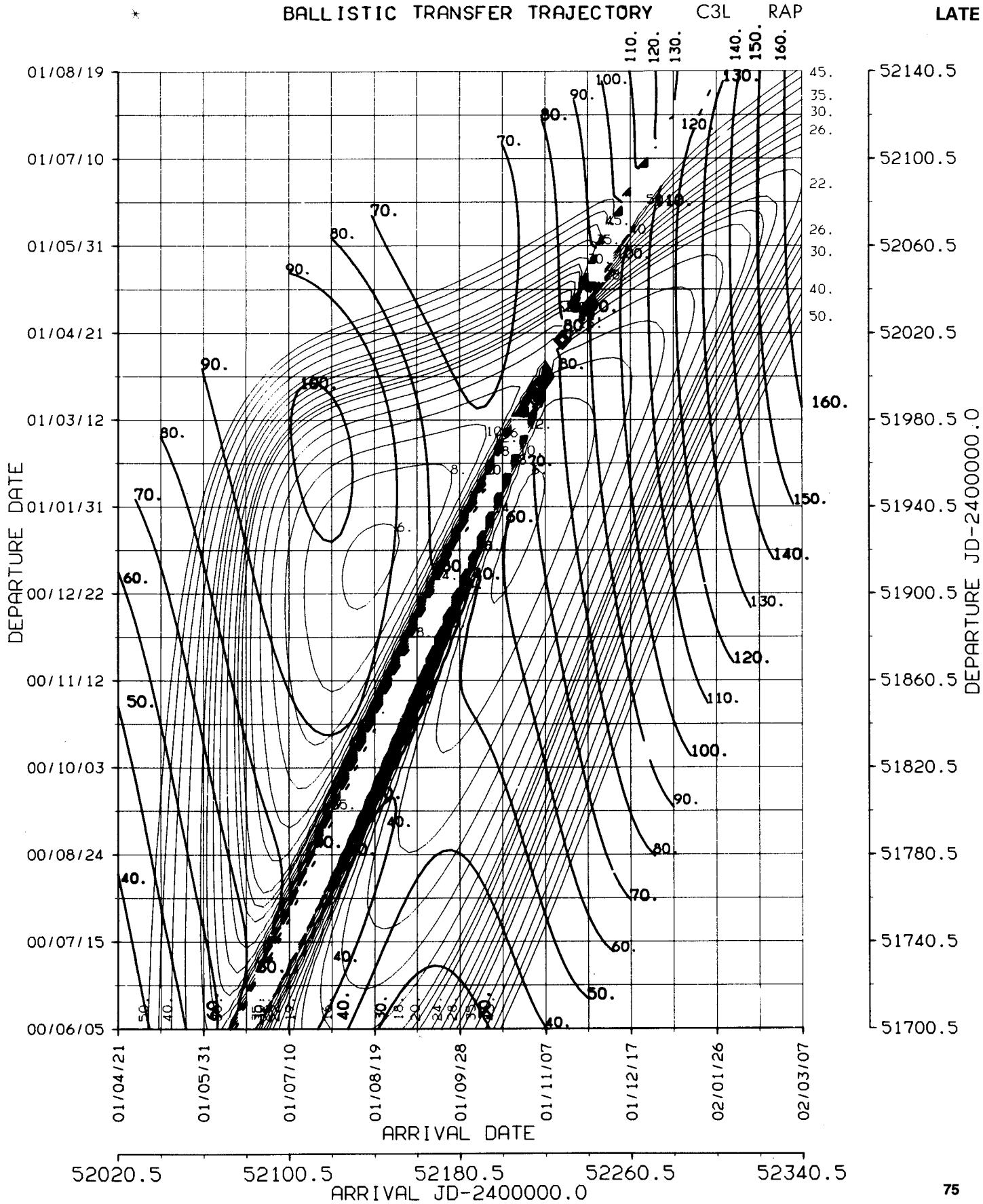


RAP

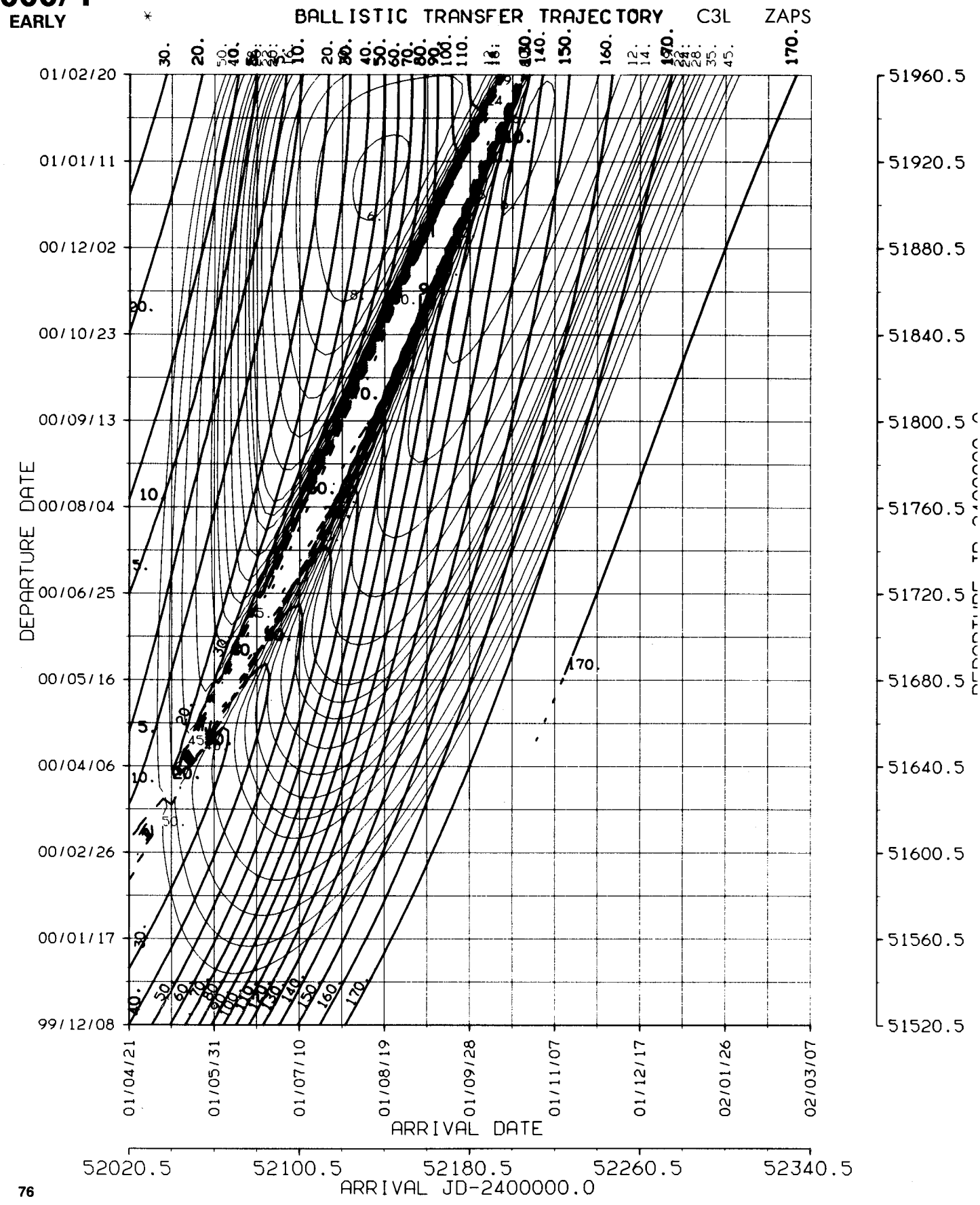
♂ ⊕

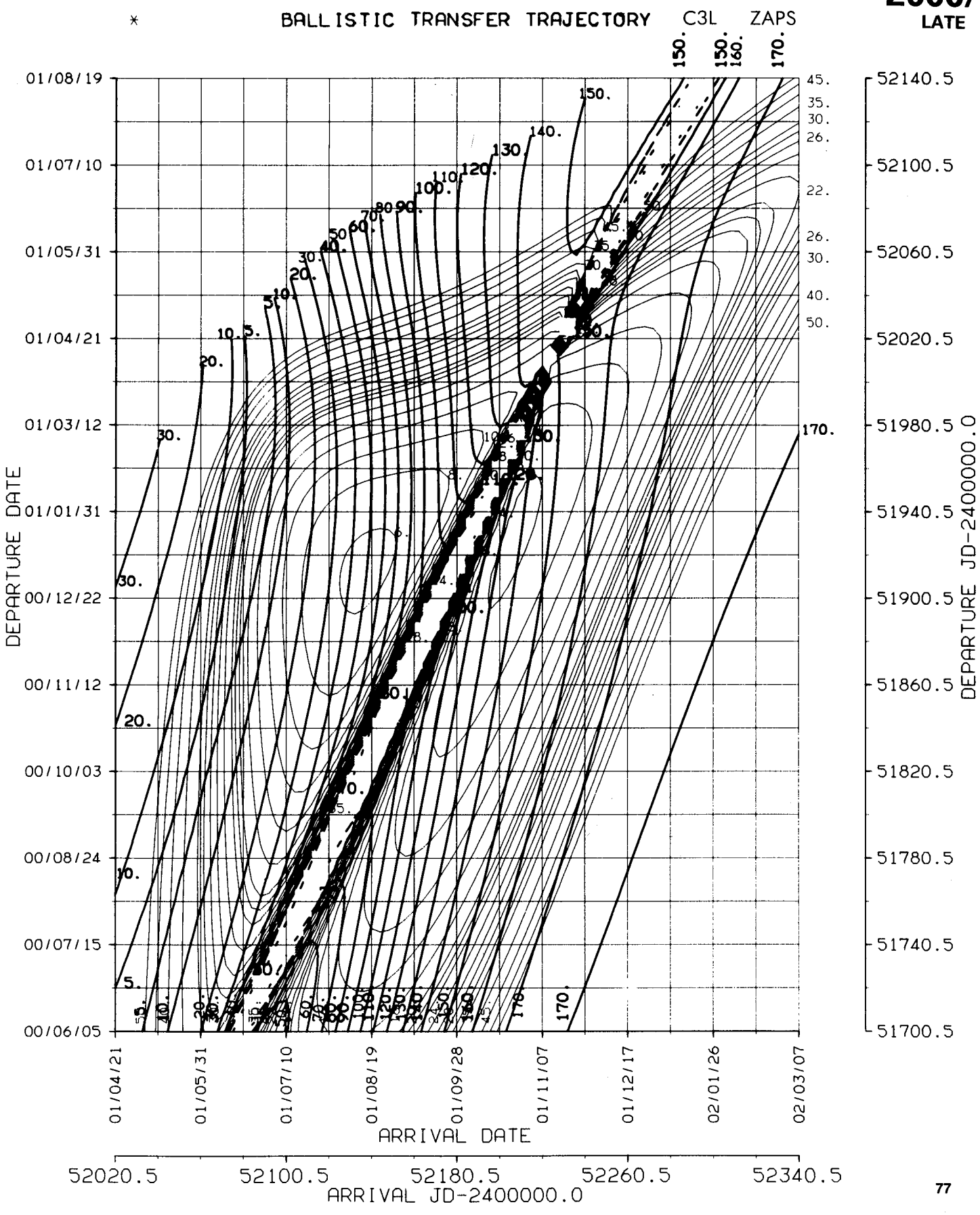
2000/1

LATE



ZAPS ♂ ⊕ 2000/1 EARLY



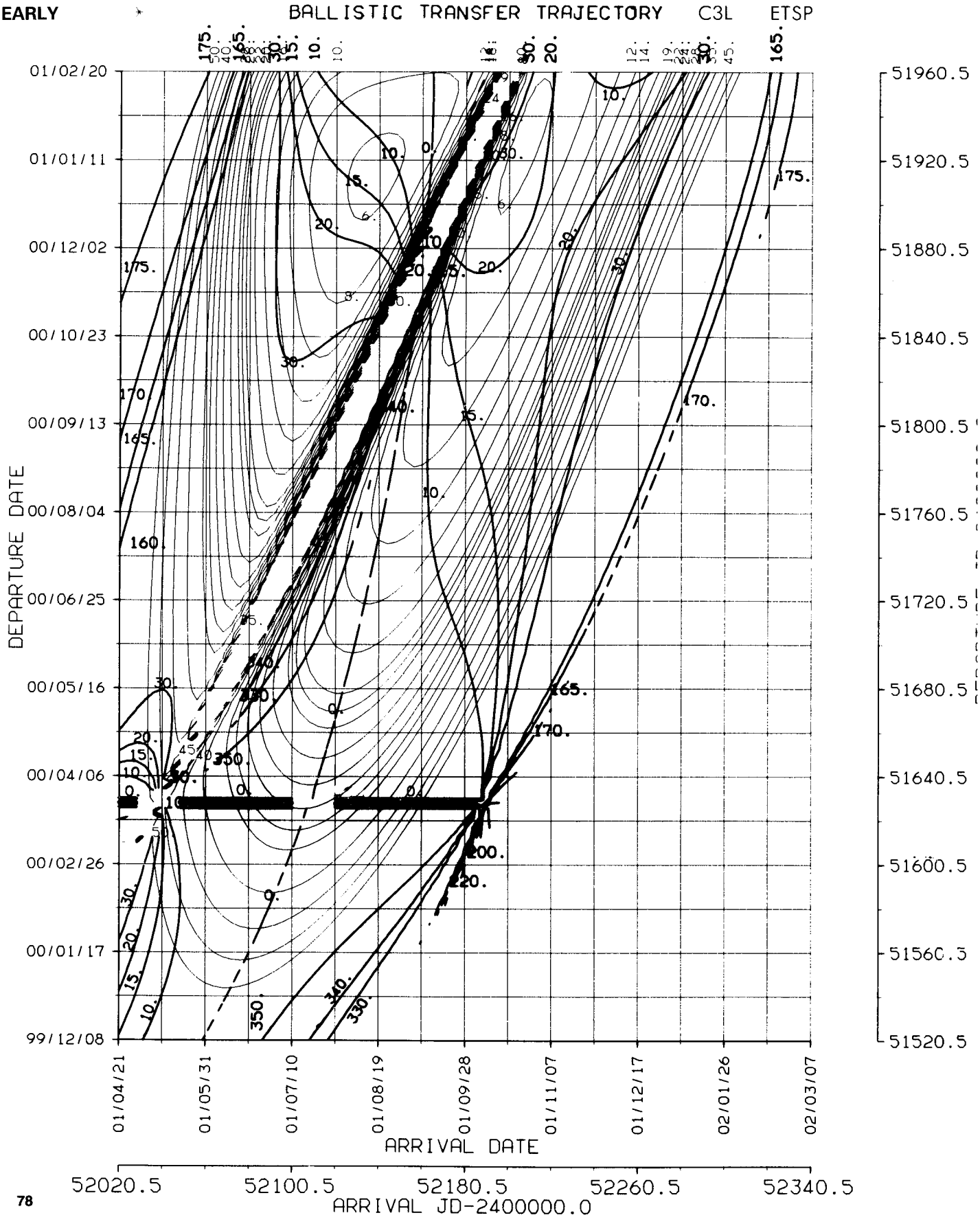

BALLISTIC TRANSFER TRAJECTORY C3L ZAPS
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
ARRIVAL DATE
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL JD-2400000.0
52020.5
52100.5
52180.5
52260.5
52340.5

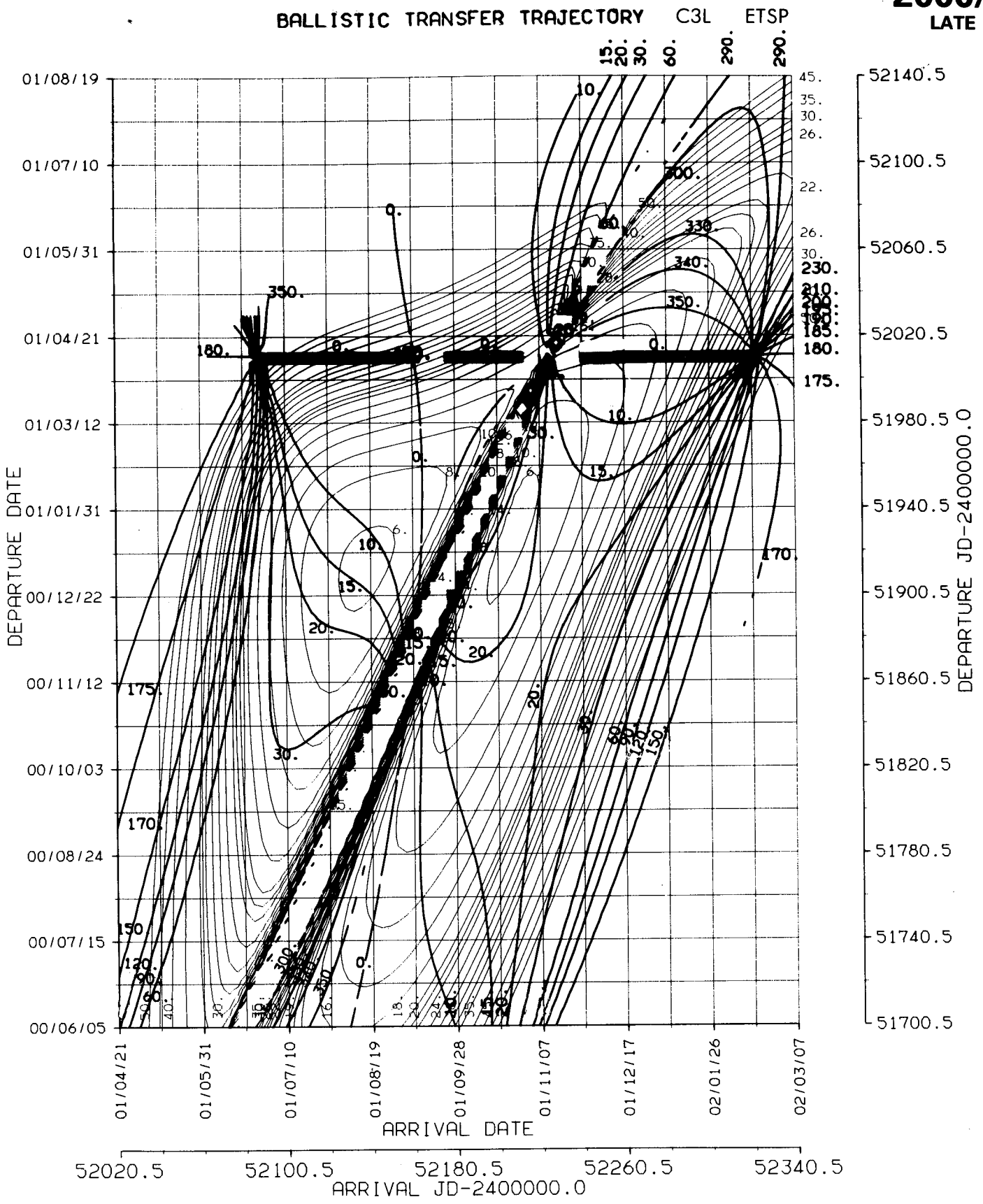
ETSP

♂ ⊕

2000/1

EARLY




BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
01/08/19
01/07/10
01/05/31
01/04/21
01/03/12
01/01/31
00/12/22
00/11/12
00/10/03
00/08/24
00/07/15
00/06/05
DEPARTURE JD-2400000.0
52140.5
52100.5
52060.5
52020.5
51980.5
51940.5
51900.5
51860.5
51820.5
51780.5
51740.5
51700.5
01/04/21
01/05/31
01/07/10
01/08/19
01/09/28
01/11/07
01/12/17
02/01/26
02/03/07
ARRIVAL DATE
52020.5
52100.5
52180.5
52260.5
52340.5
ARRIVAL JD-2400000.0

Mars to Earth

2002/3

Opportunity

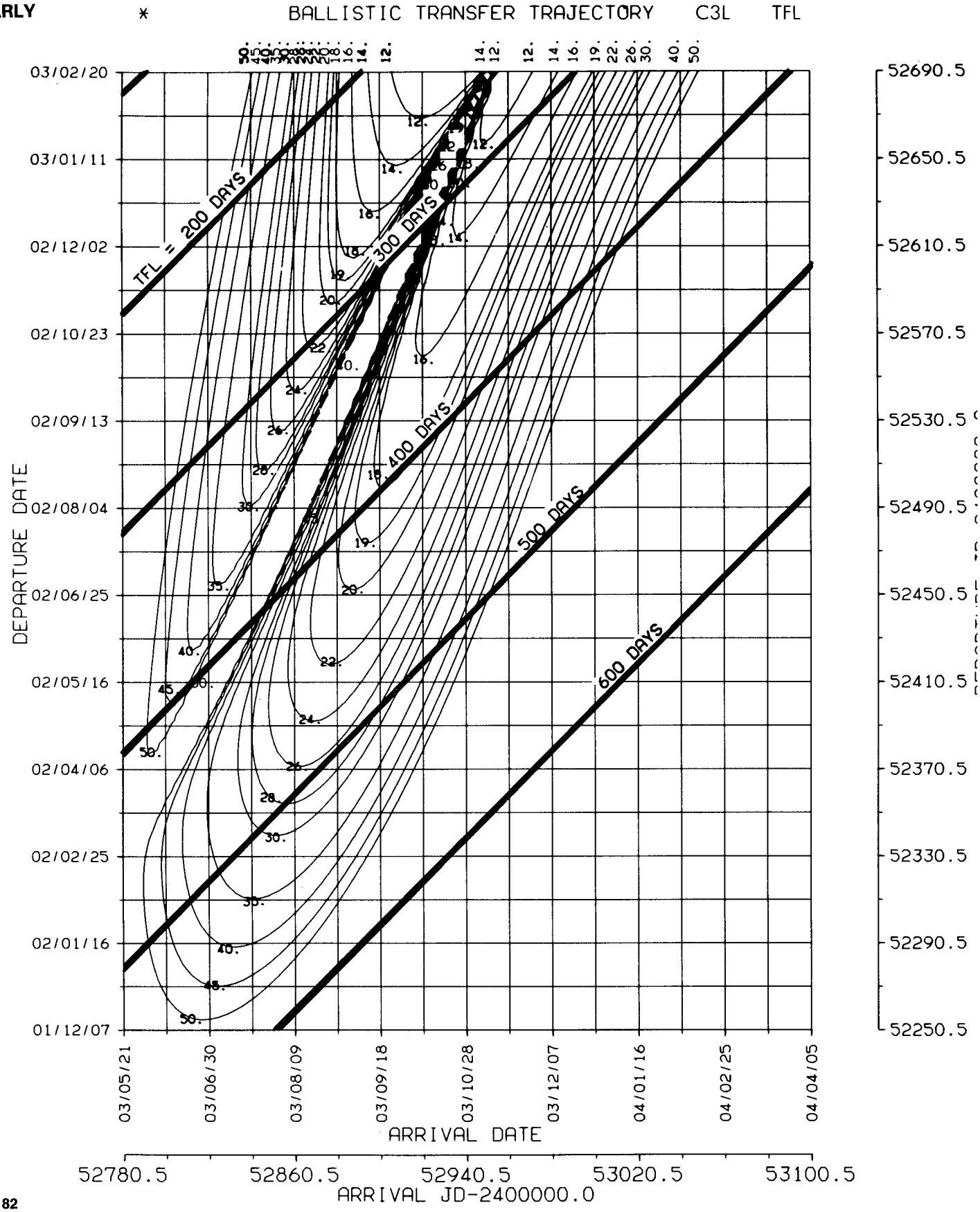
ENERGY MINIMA

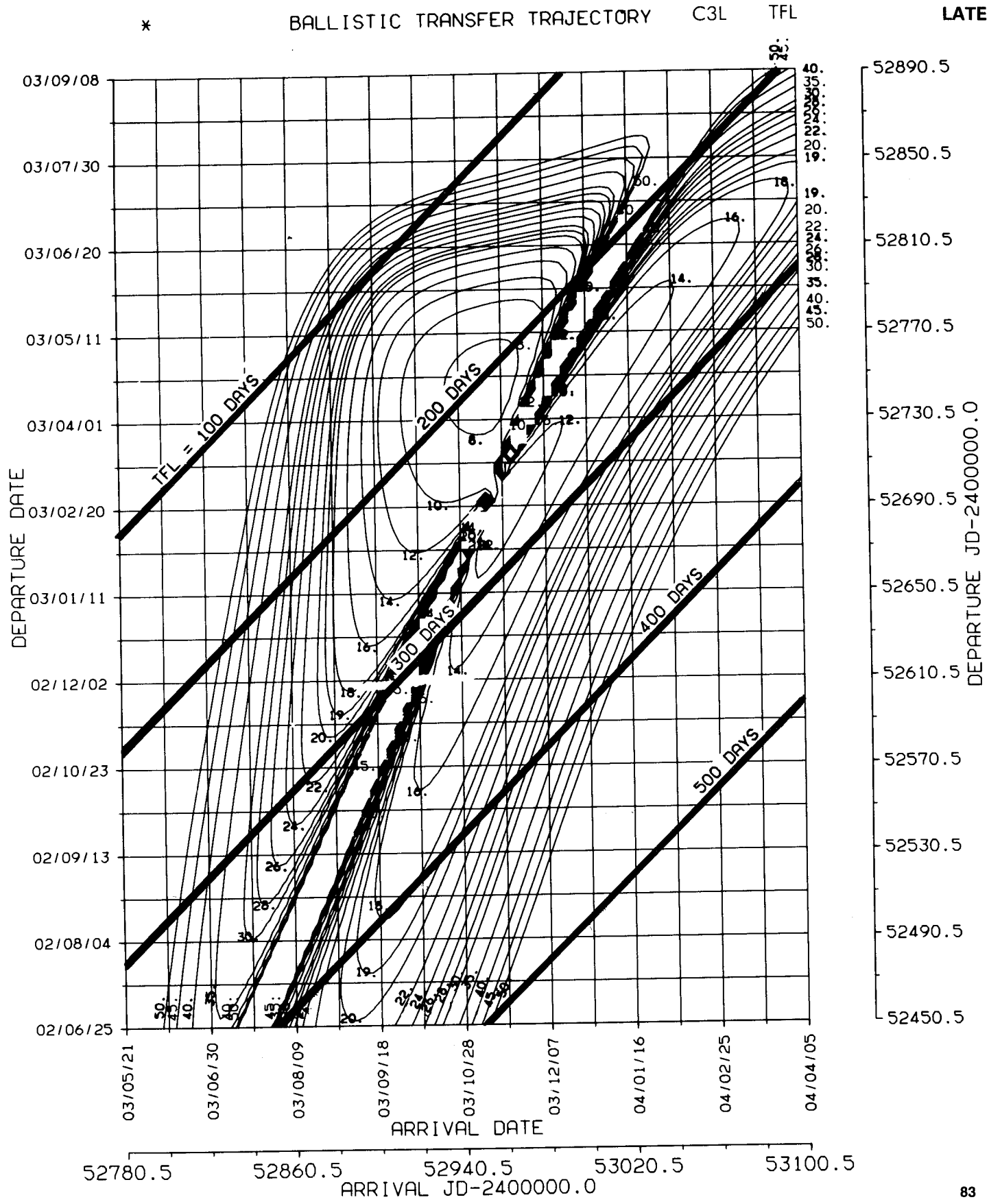
	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	7.426	I	2003/04/18	2003/11/10
C_3L	9.525	II	2003/02/27	2003/11/12
VHP	2.990	I	2003/04/06	2003/11/07
VHP	3.014	II	2003/02/27	2003/11/04

C3L

2002/3

EARLY




BALLISTIC TRANSFER TRAJECTORY C3L TFL
TFL = 100 DAYS
200 DAYS
300 DAYS
400 DAYS
500 DAYS
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
ARRIVAL DATE
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL JD-2400000.0
52780.5
52860.5
52940.5
53020.5
53100.5

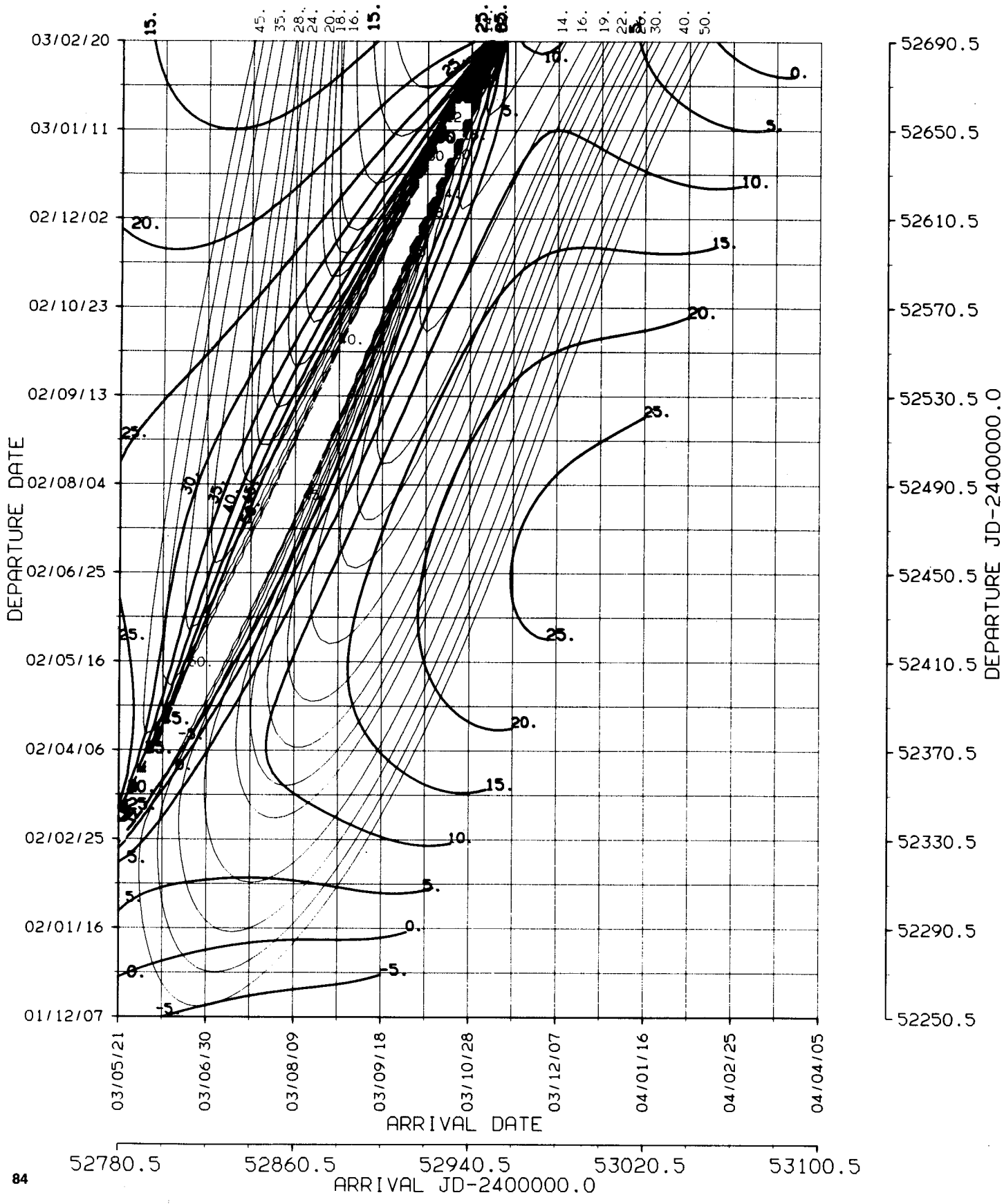
DLA

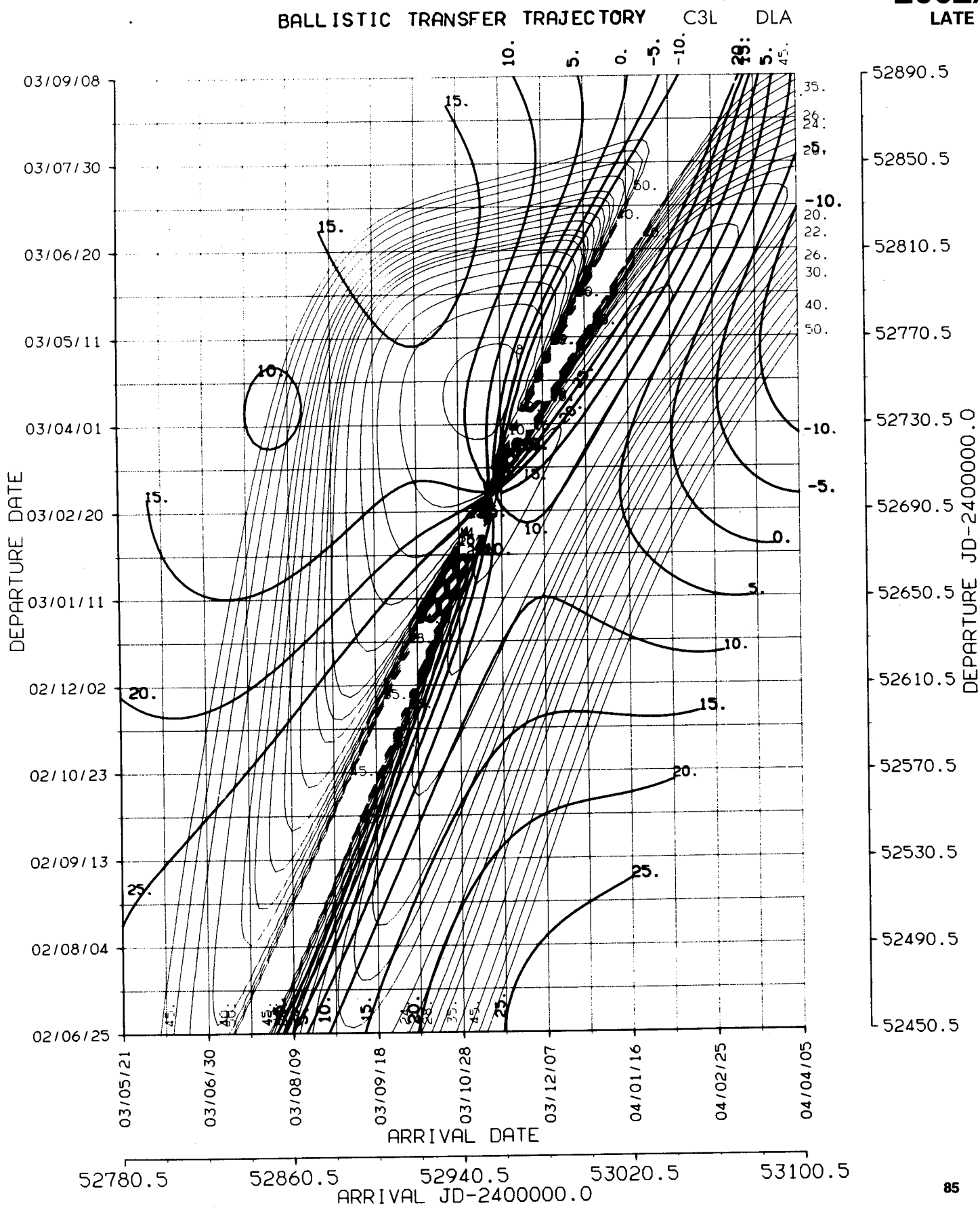
♂ ⊕

2002/3

EARLY

BALLISTIC TRANSFER TRAJECTORY C3L DLA



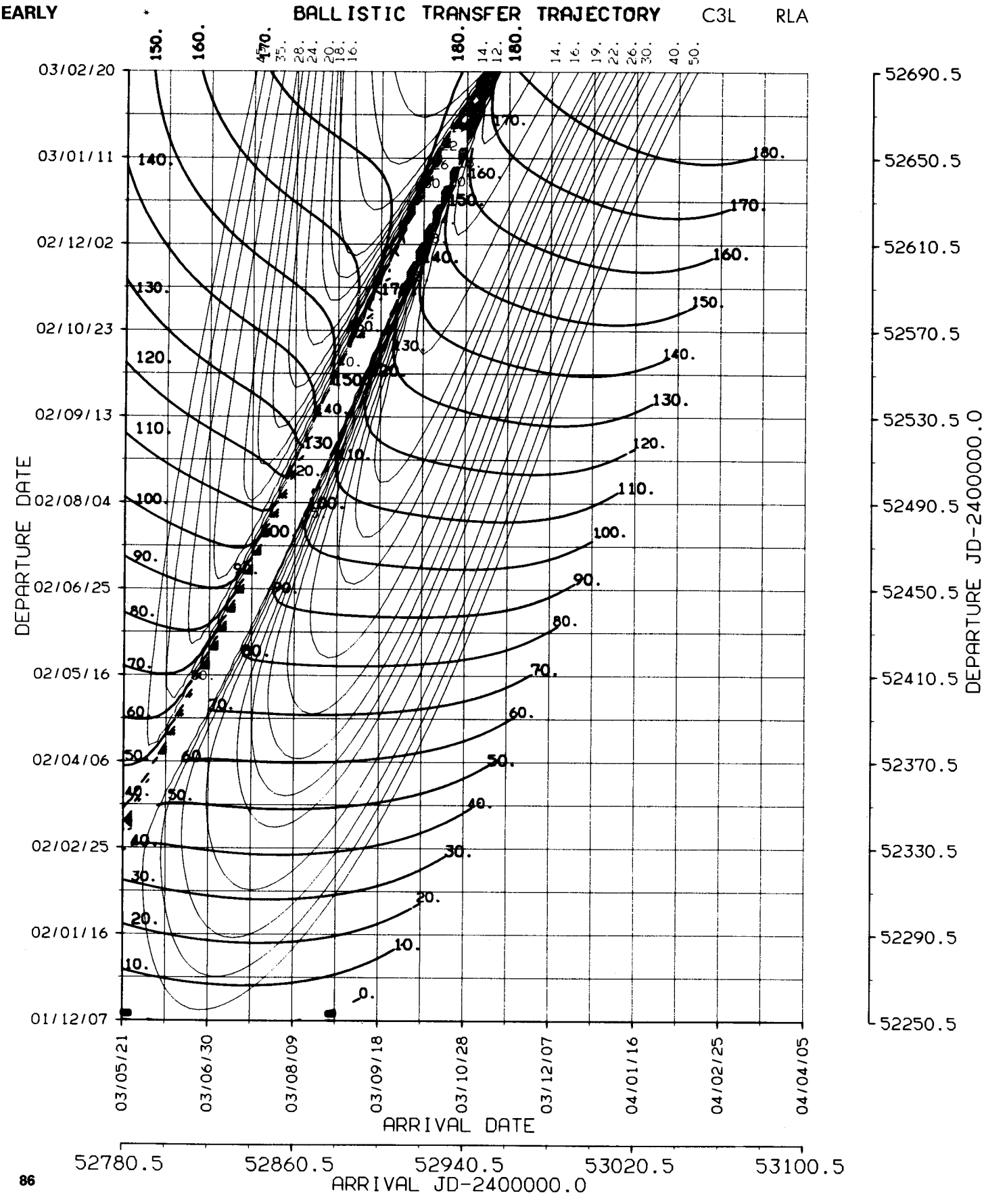

BALLISTIC TRANSFER TRAJECTORY C3L DLA
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
ARRIVAL DATE
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL JD-2400000.0
52780.5
52860.5
52940.5
53020.5
53100.5

RLA

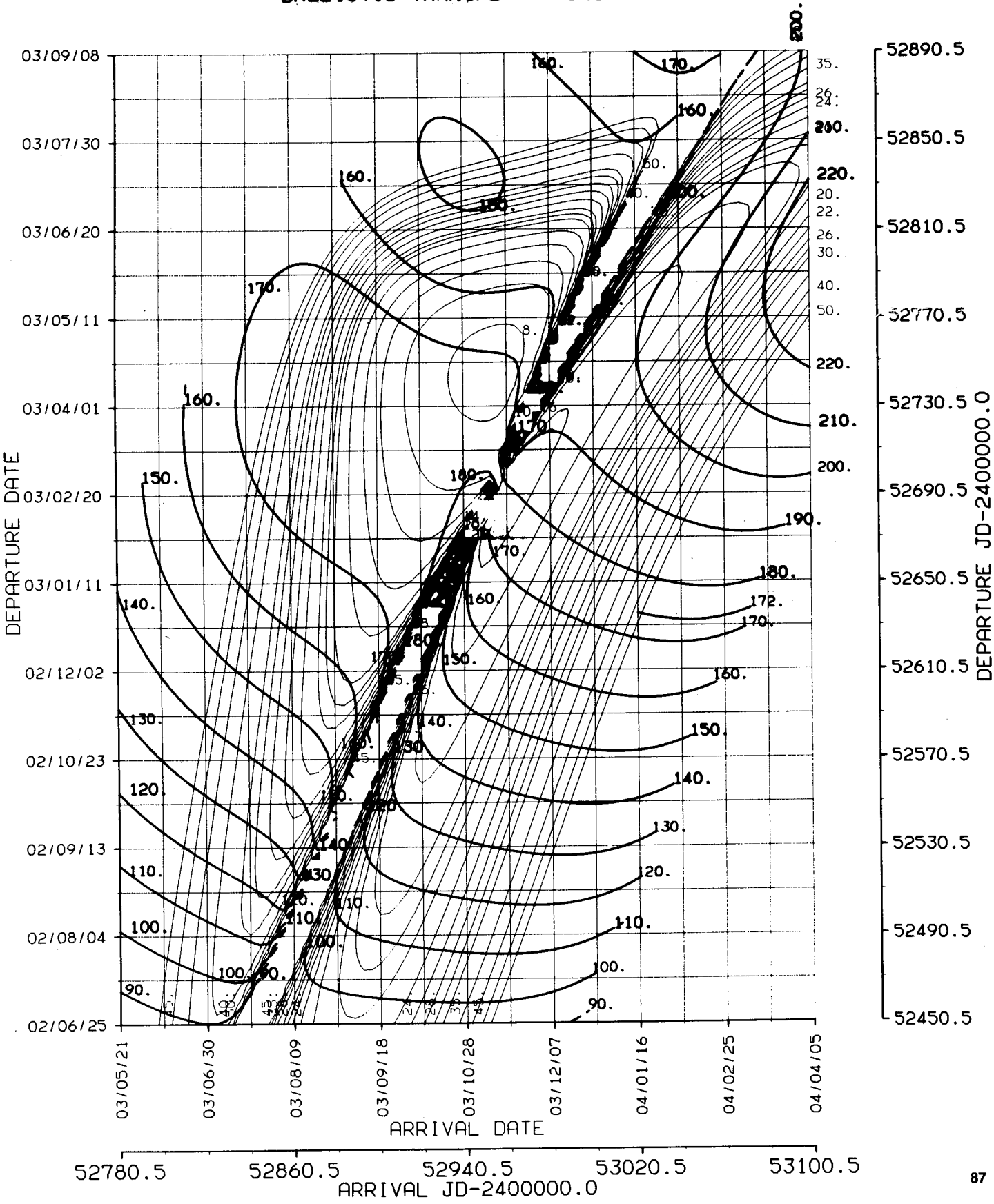
♂ ⊕

2002/3

EARLY

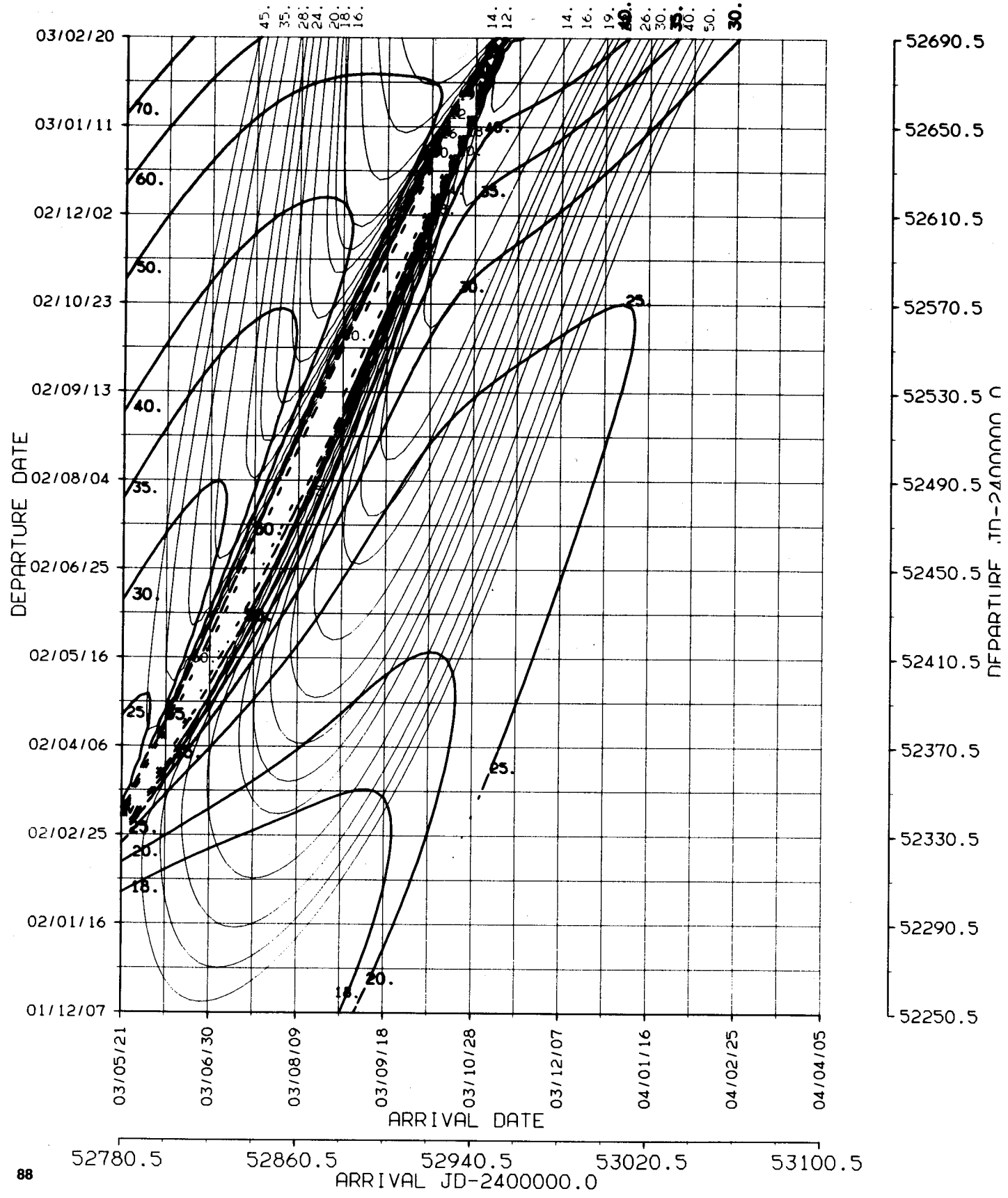


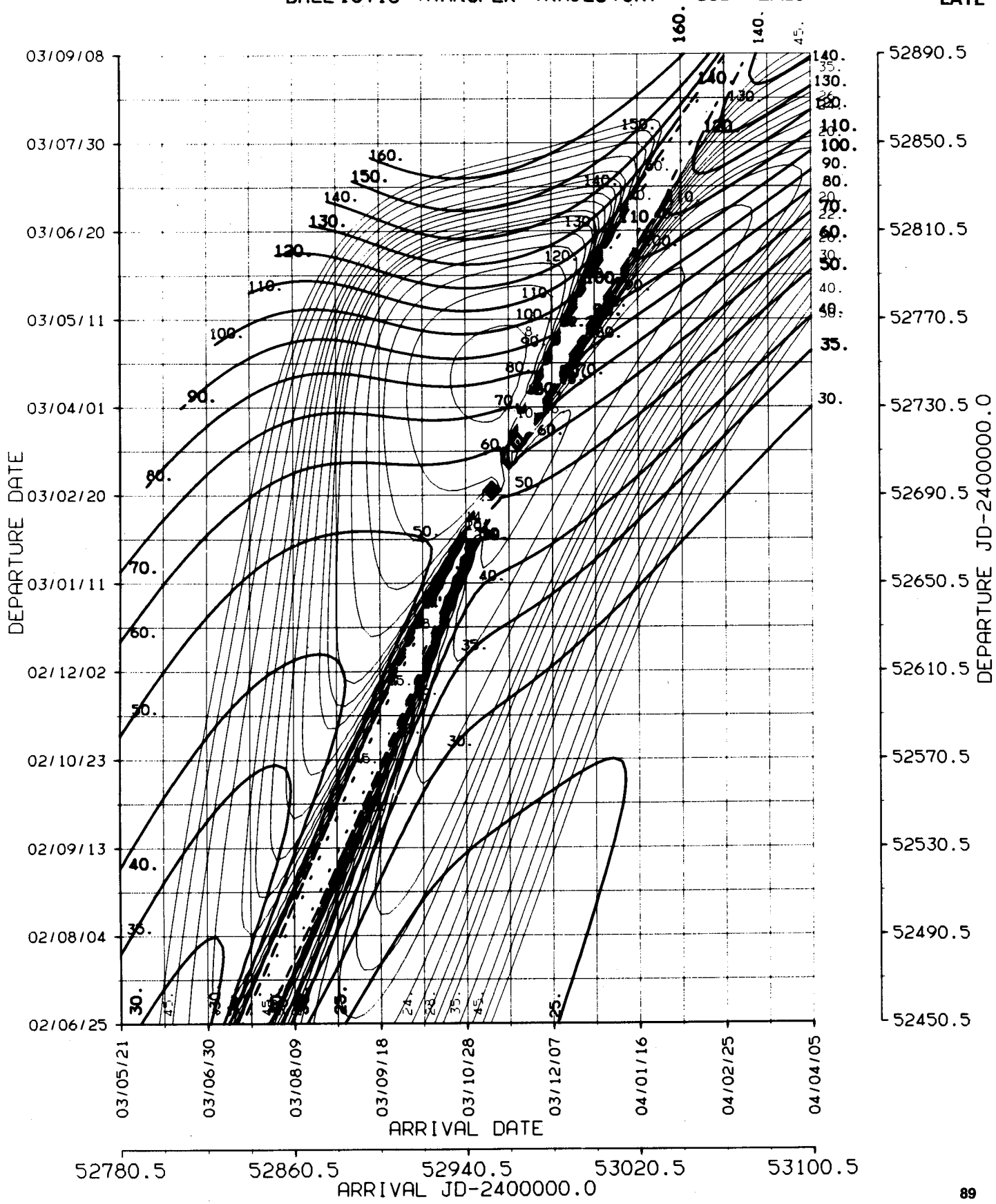
BALLISTIC TRANSFER TRAJECTORY C3L RLA



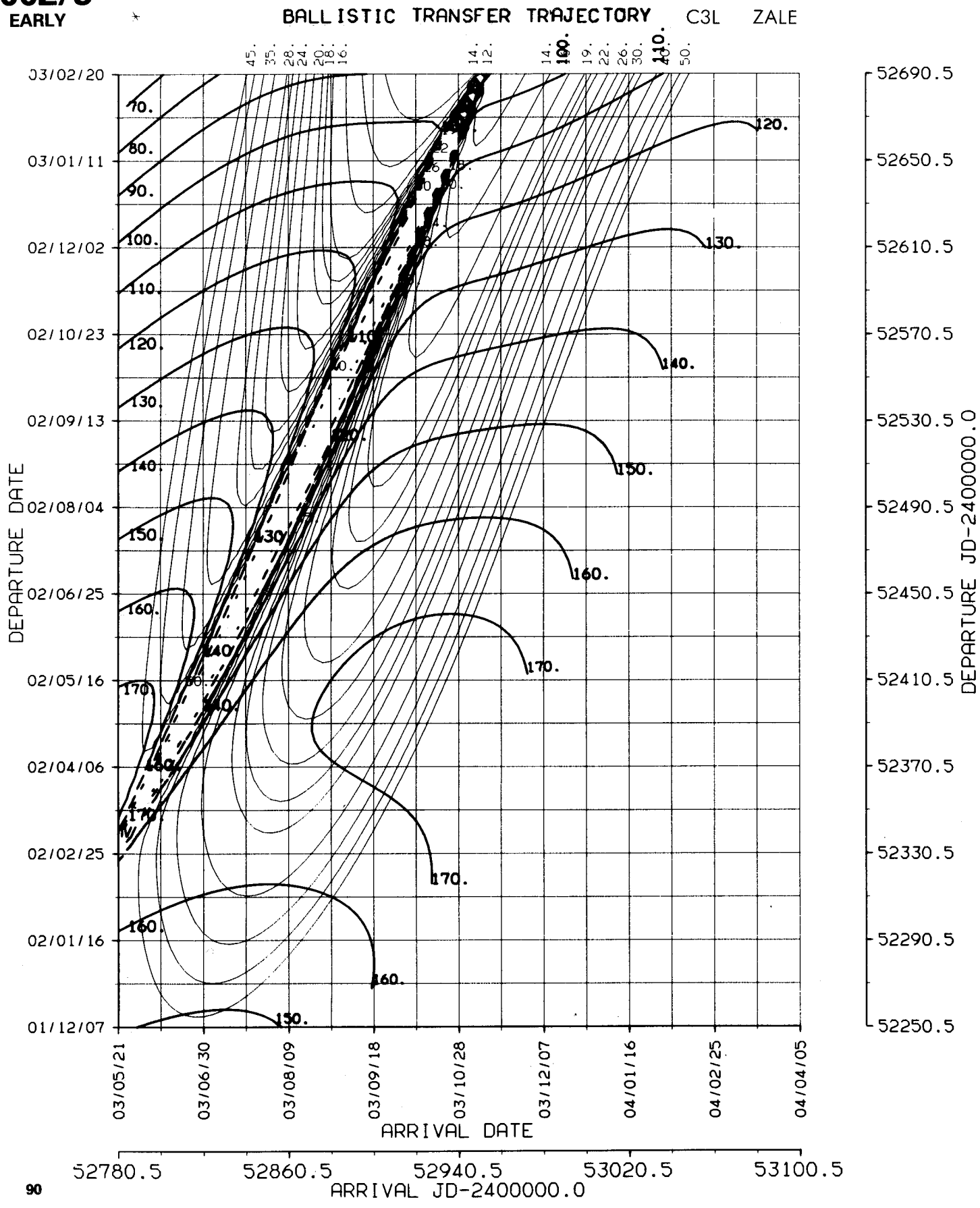
ZALS
♂⊕
2002/3
EARLY

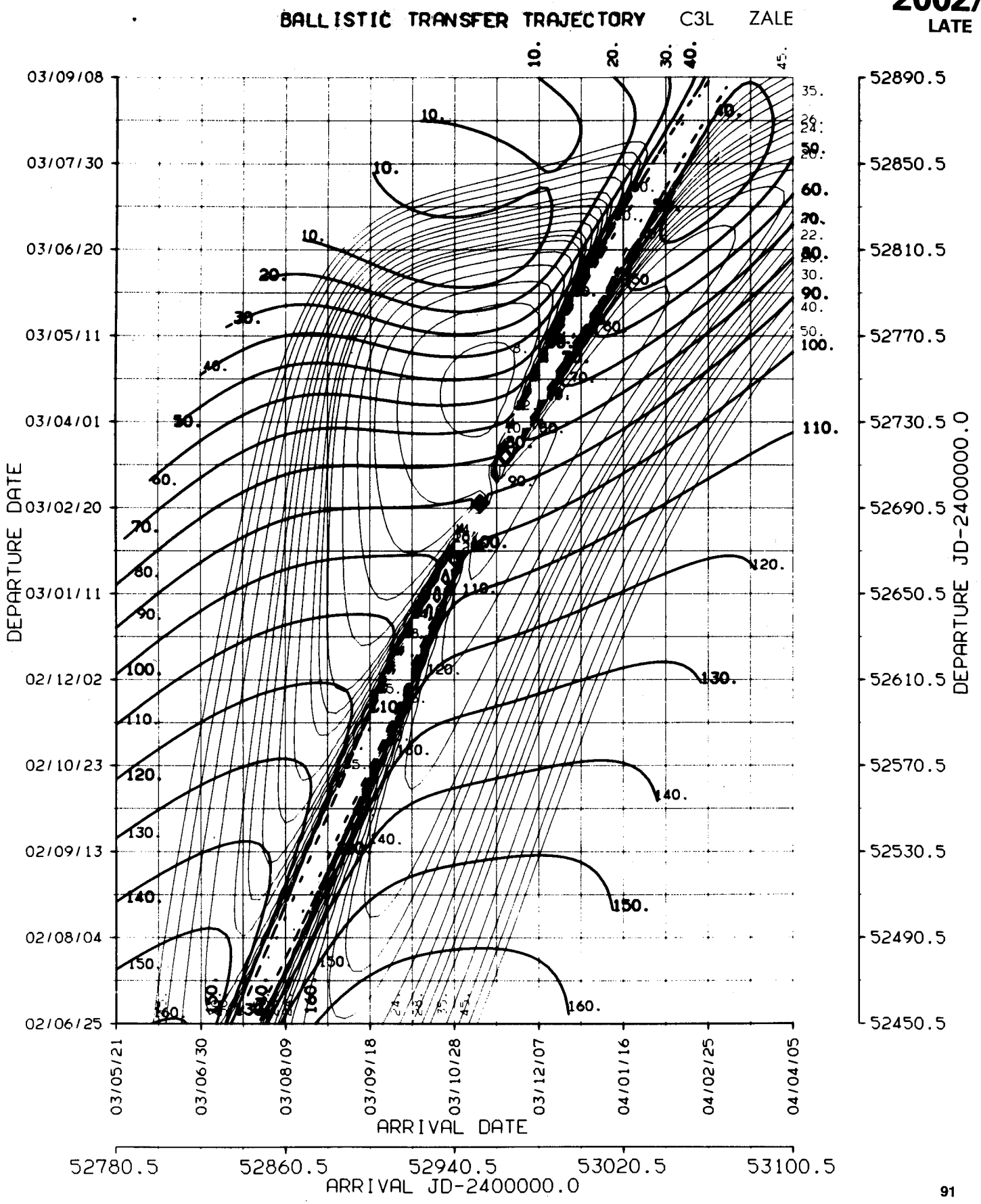
BALLISTIC TRANSFER TRAJECTORY C3L ZALS



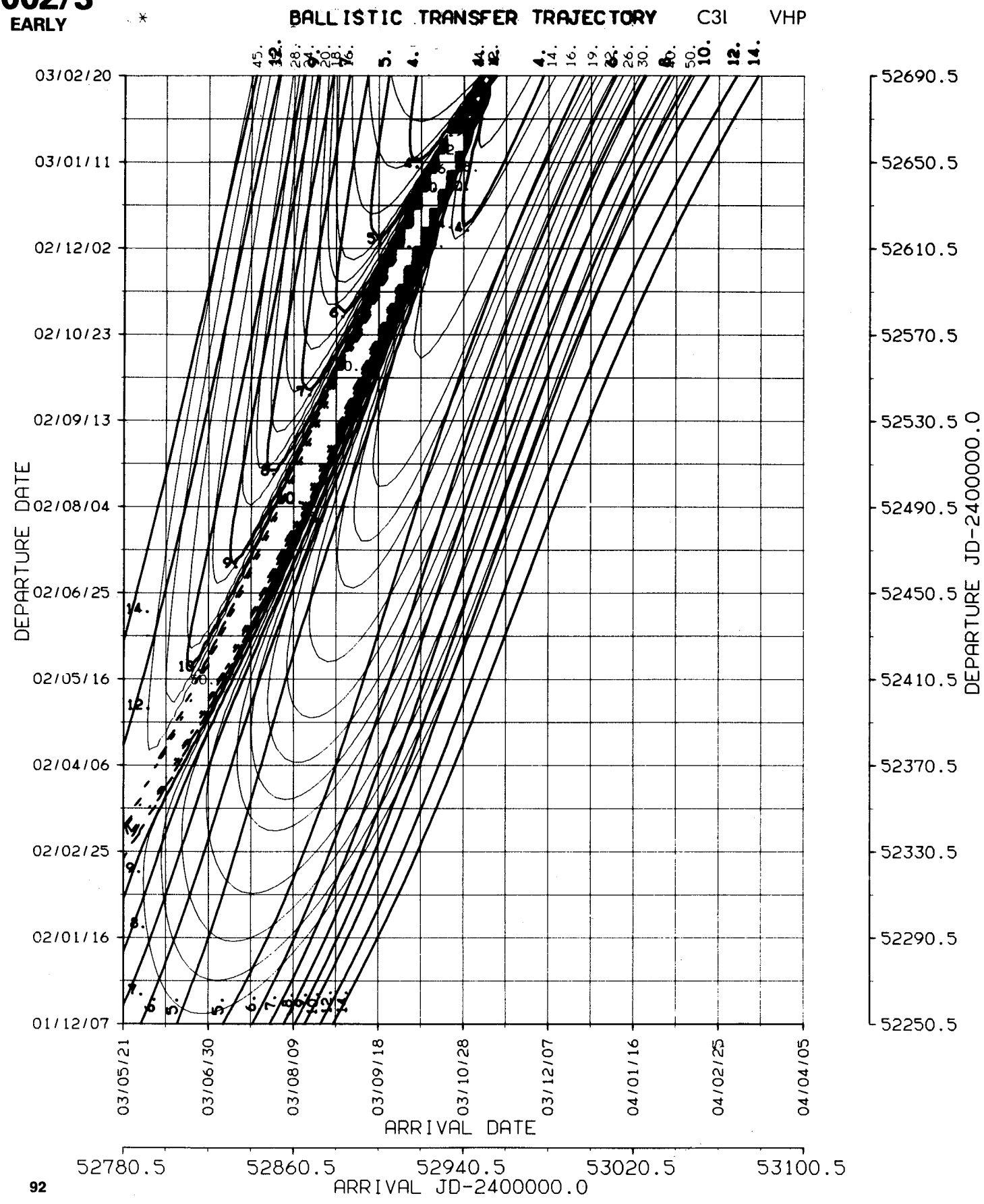

BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL DATE
52780.5
52860.5
52940.5
53020.5
53100.5
ARRIVAL JD-2400000.0

ZALE
♂⊕
2002/3
EARLY




BALLISTIC TRANSFER TRAJECTORY C3L ZALE
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL DATE
52780.5
52860.5
52940.5
53020.5
53100.5
ARRIVAL JD-2400000.0

VHP
♂ ⊕
2002/3
EARLY



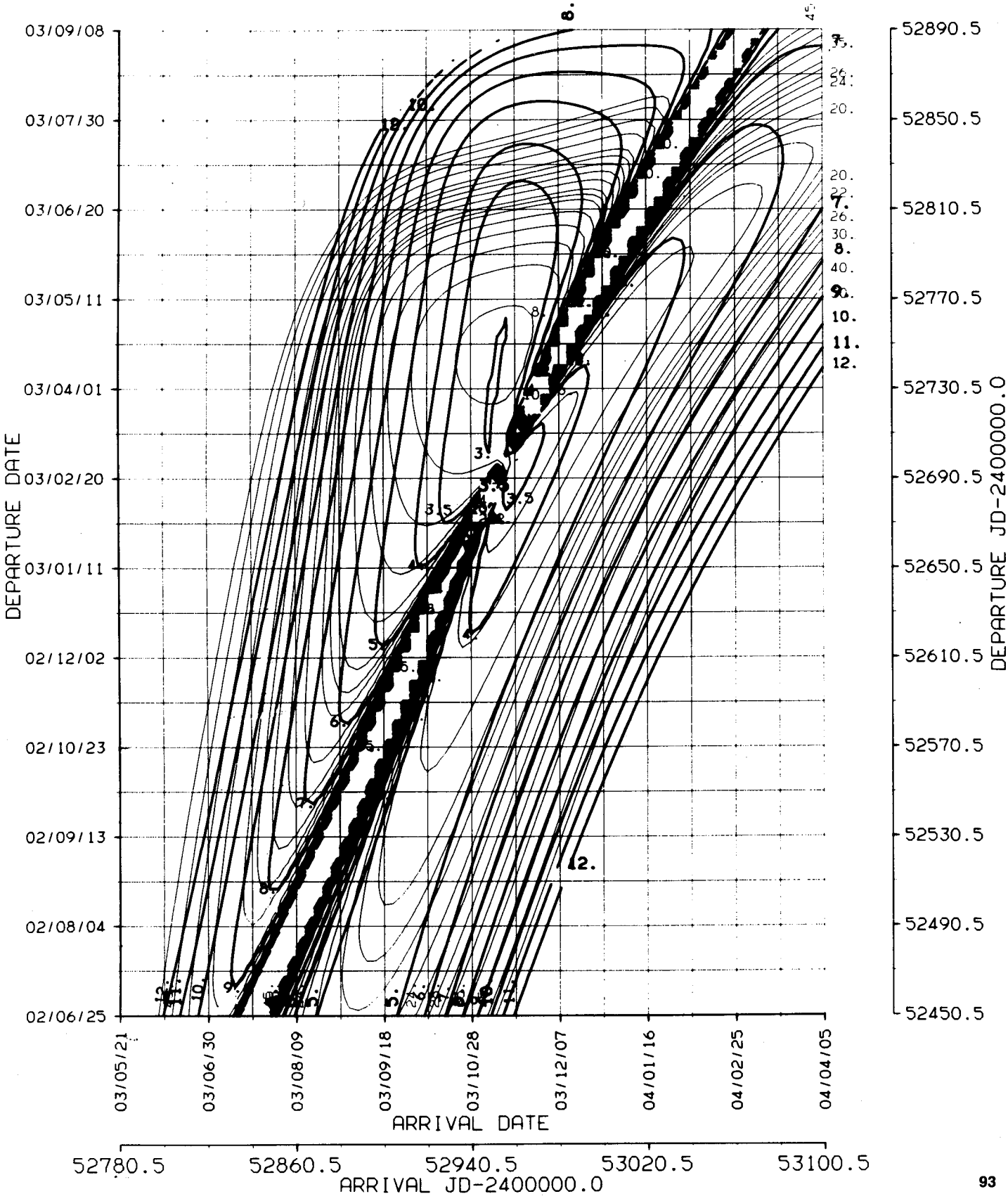
VHP

♂ ⊕

2002/3

LATE

BALLISTIC TRANSFER TRAJECTORY C3L VHP

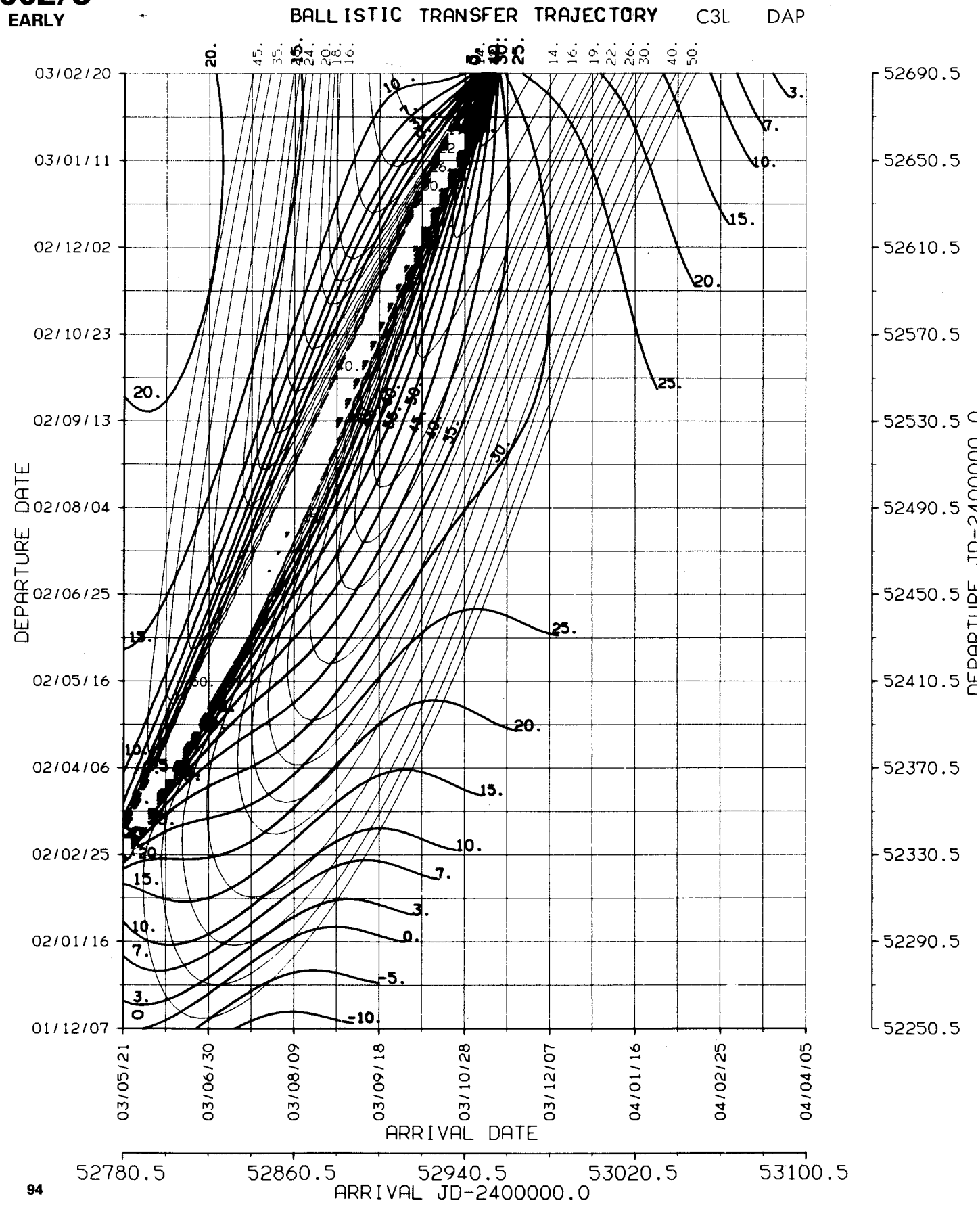


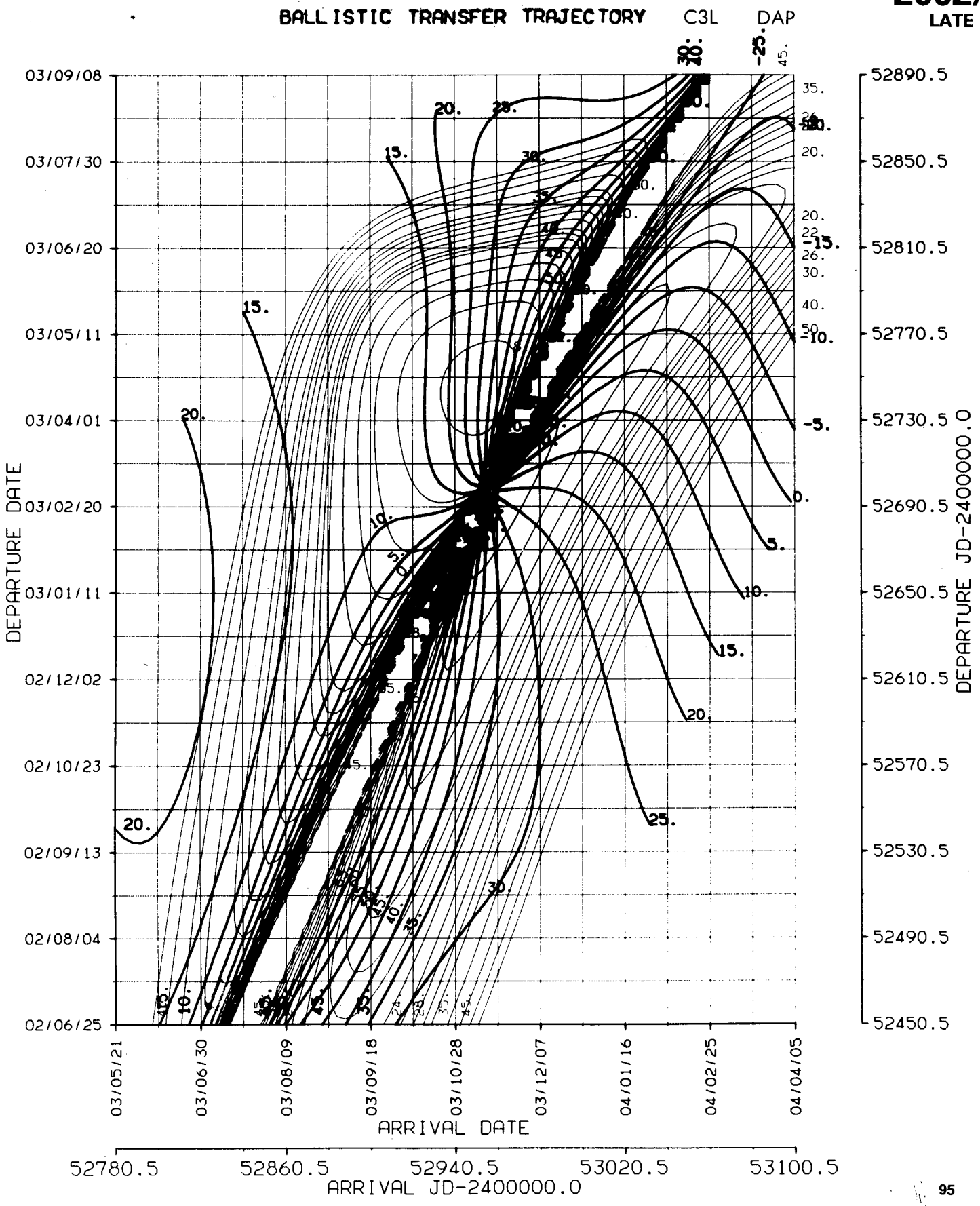
DAP

♂ ⊕

2002/3

EARLY



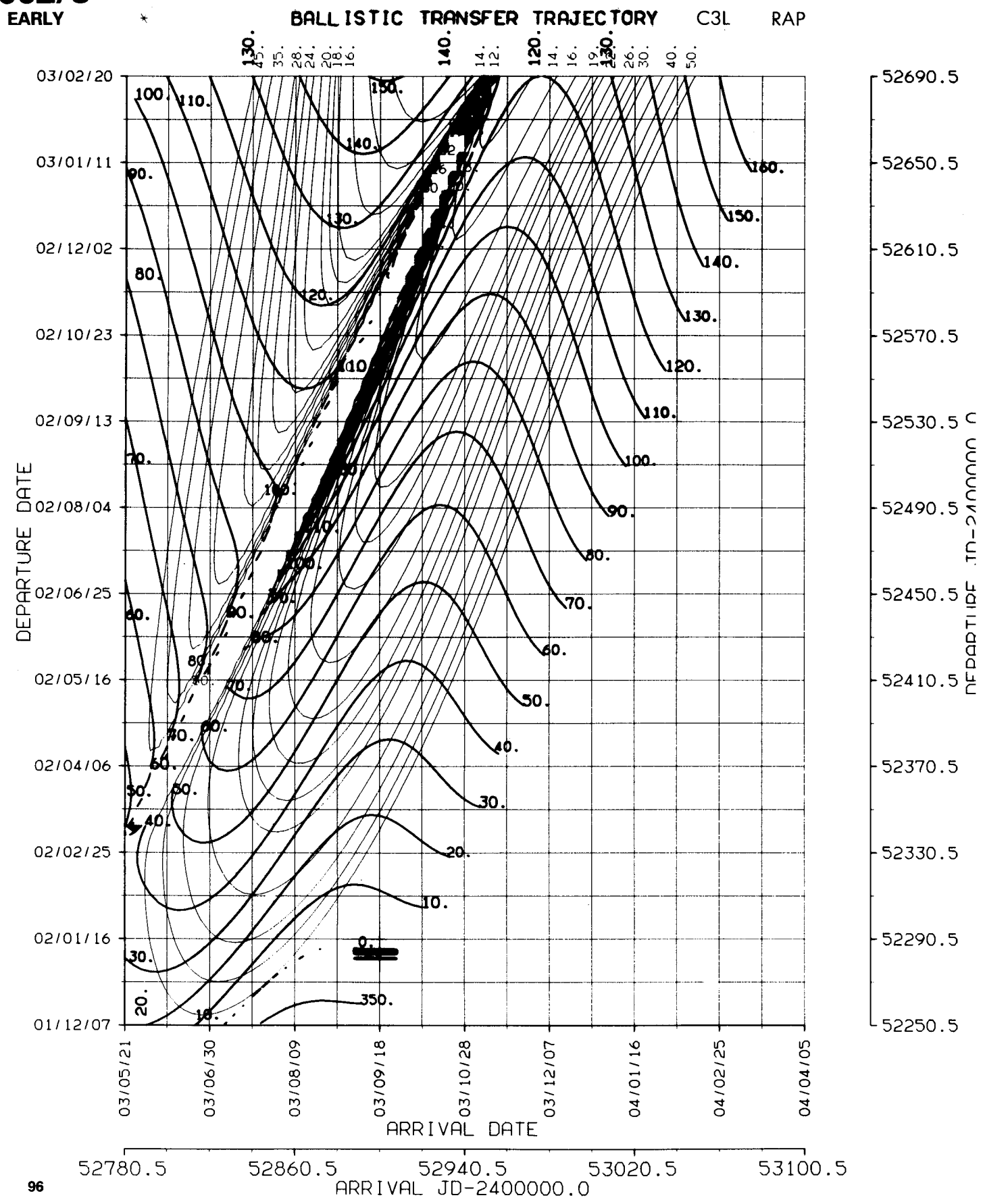

BALLISTIC TRANSFER TRAJECTORY C3L DAP
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL DATE
52780.5
52860.5
52940.5
53020.5
53100.5
ARRIVAL JD-2400000.0

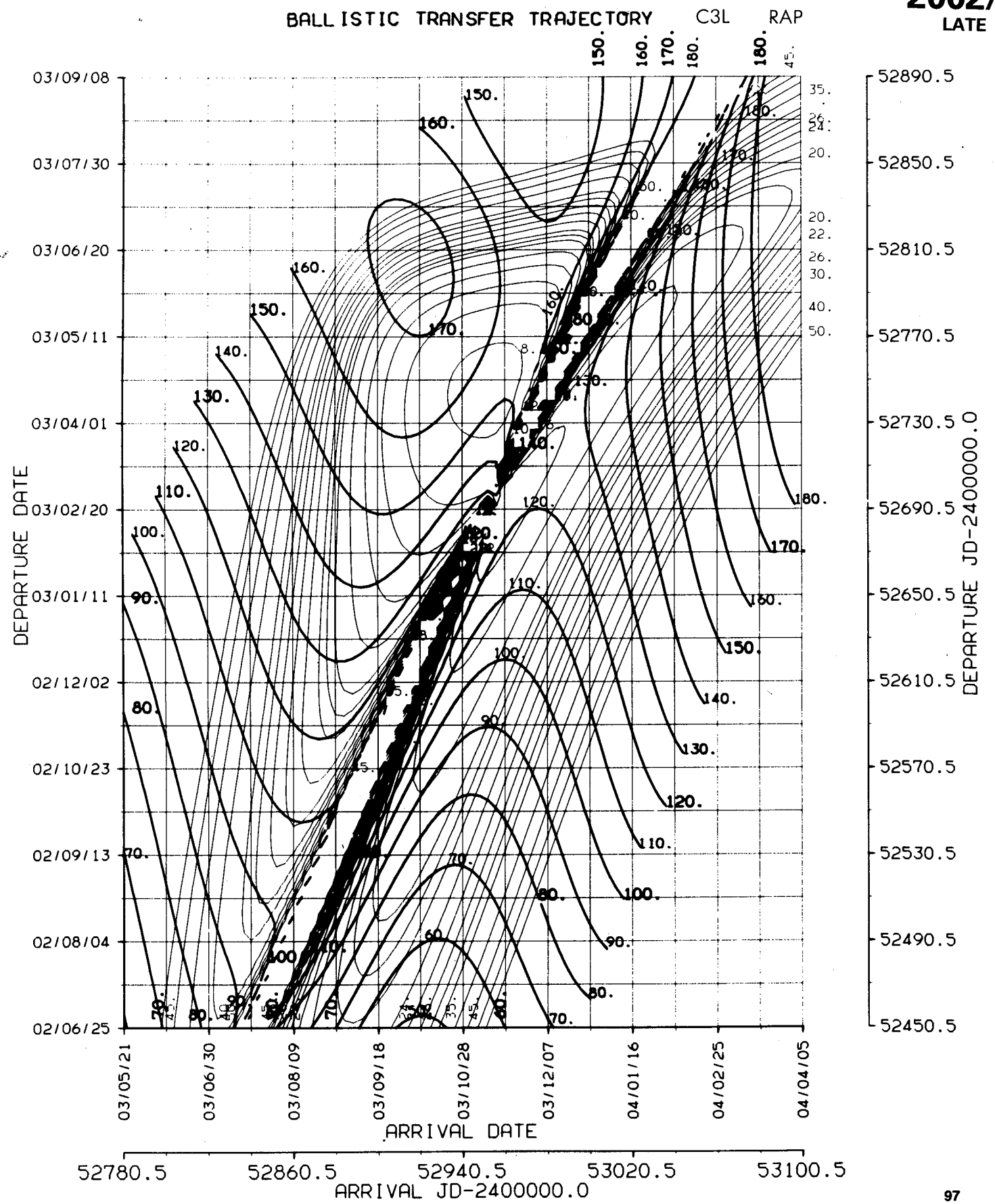
RAP

♂ ⊕

2002/3

EARLY



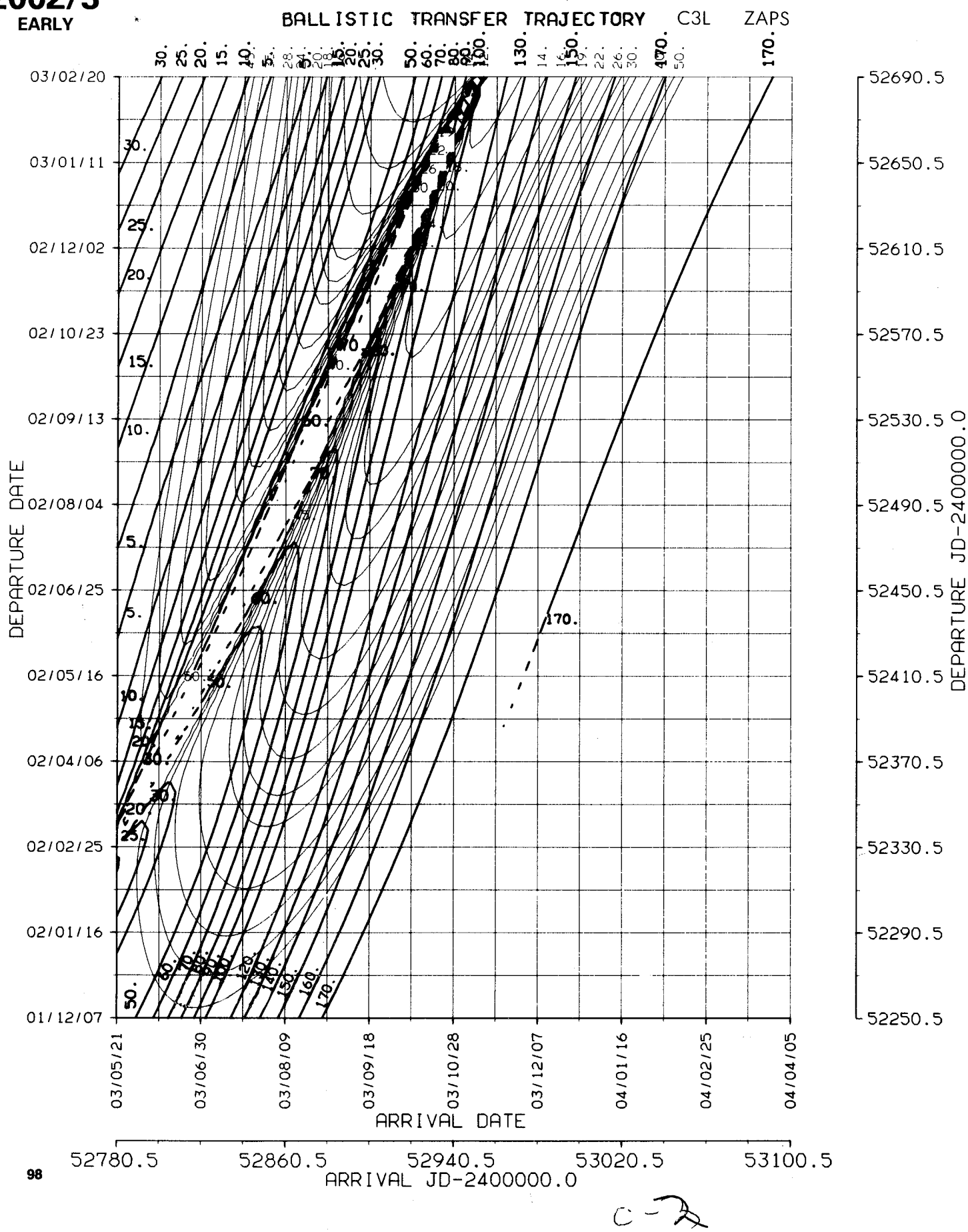

BALLISTIC TRANSFER TRAJECTORY C3L RAP
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL DATE
52780.5
52860.5
52940.5
53020.5
53100.5
ARRIVAL JD-2400000.0

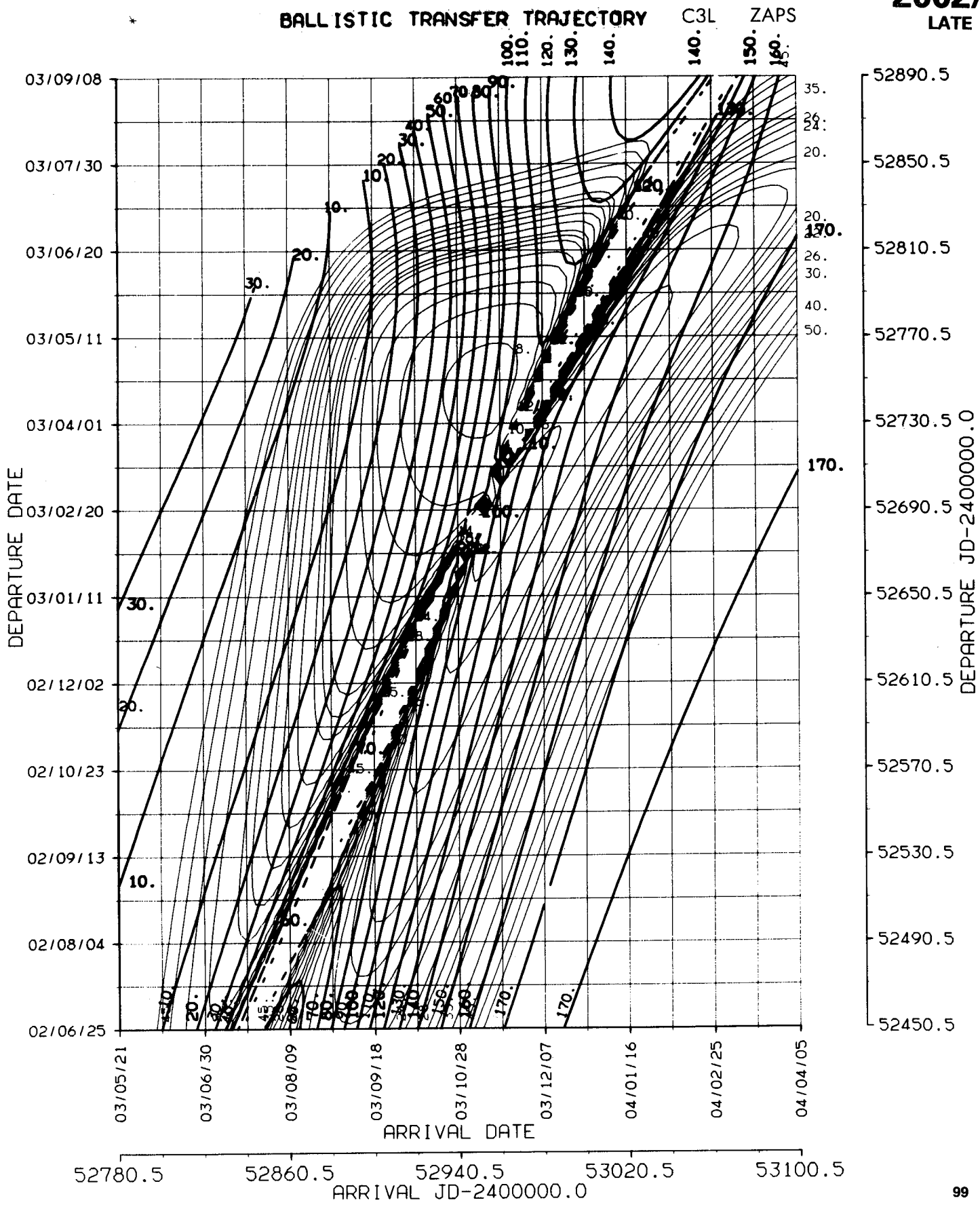
ZAPS

♂ ⊕

2002/3

EARLY




BALLISTIC TRANSFER TRAJECTORY
C3L
ZAPS
DEPARTURE DATE
03/09/08
03/07/30
03/06/20
03/05/11
03/04/01
03/02/20
03/01/11
02/12/02
02/10/23
02/09/13
02/08/04
02/06/25
DEPARTURE JD-2400000.0
52890.5
52850.5
52810.5
52770.5
52730.5
52690.5
52650.5
52610.5
52570.5
52530.5
52490.5
52450.5
03/05/21
03/06/30
03/08/09
03/09/18
03/10/28
03/12/07
04/01/16
04/02/25
04/04/05
ARRIVAL DATE
52780.5
52860.5
52940.5
53020.5
53100.5
ARRIVAL JD-2400000.0

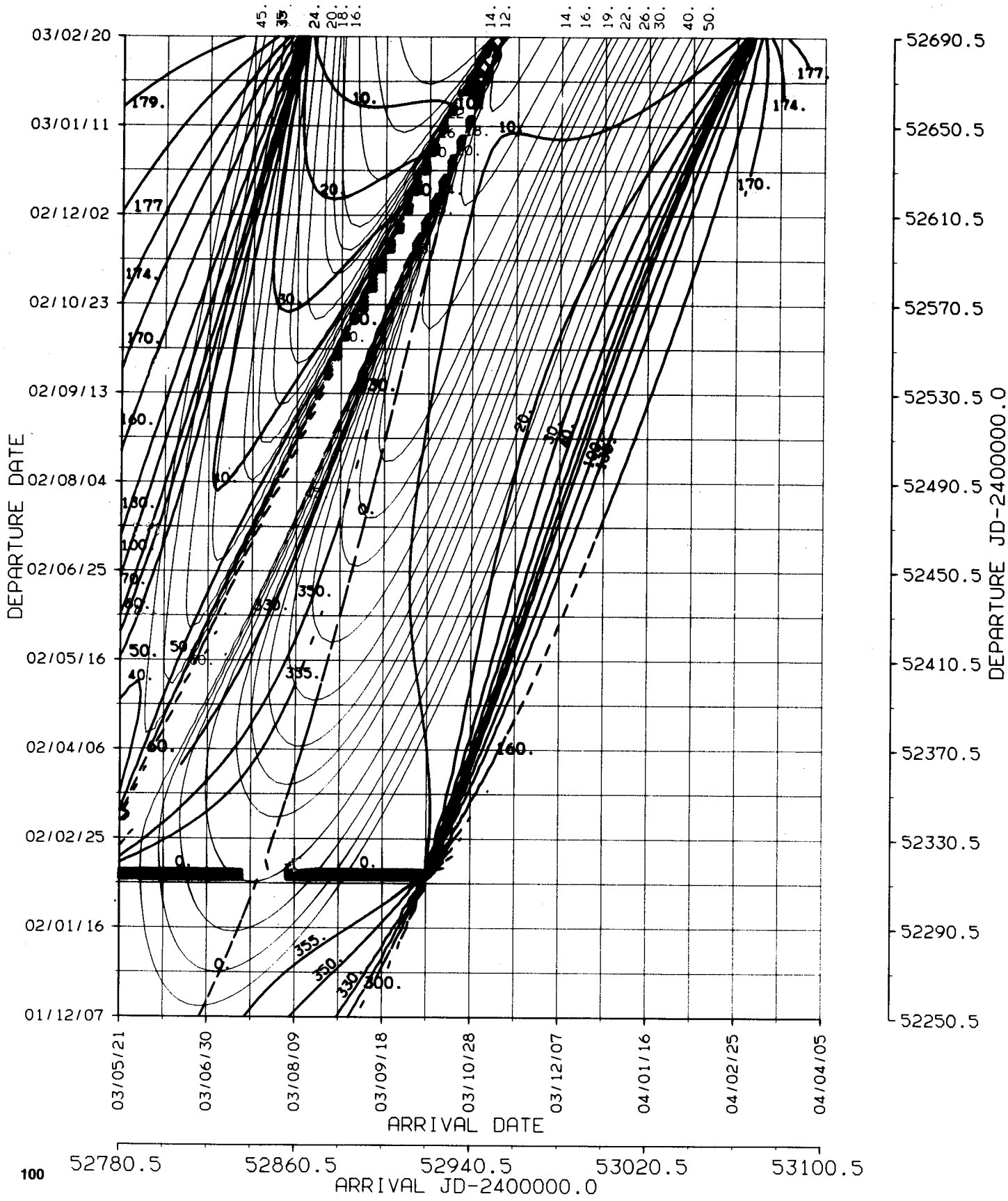
ETSP

♂ ⊕

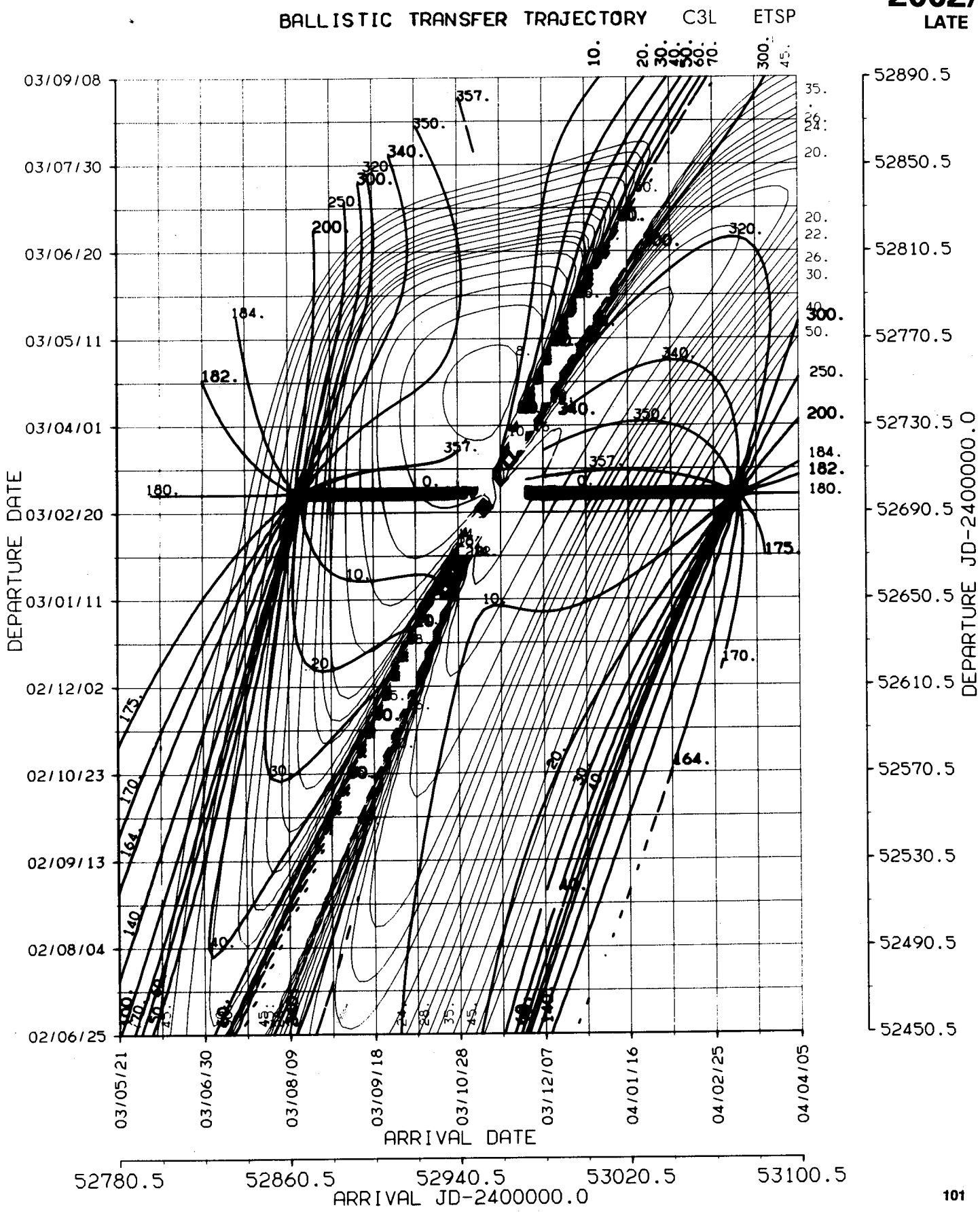
2002/3

EARLY *

BALLISTIC TRANSFER TRAJECTORY C3L ETSP



ETSP
♂ ⊕
2002/3
LATE



Mars to Earth

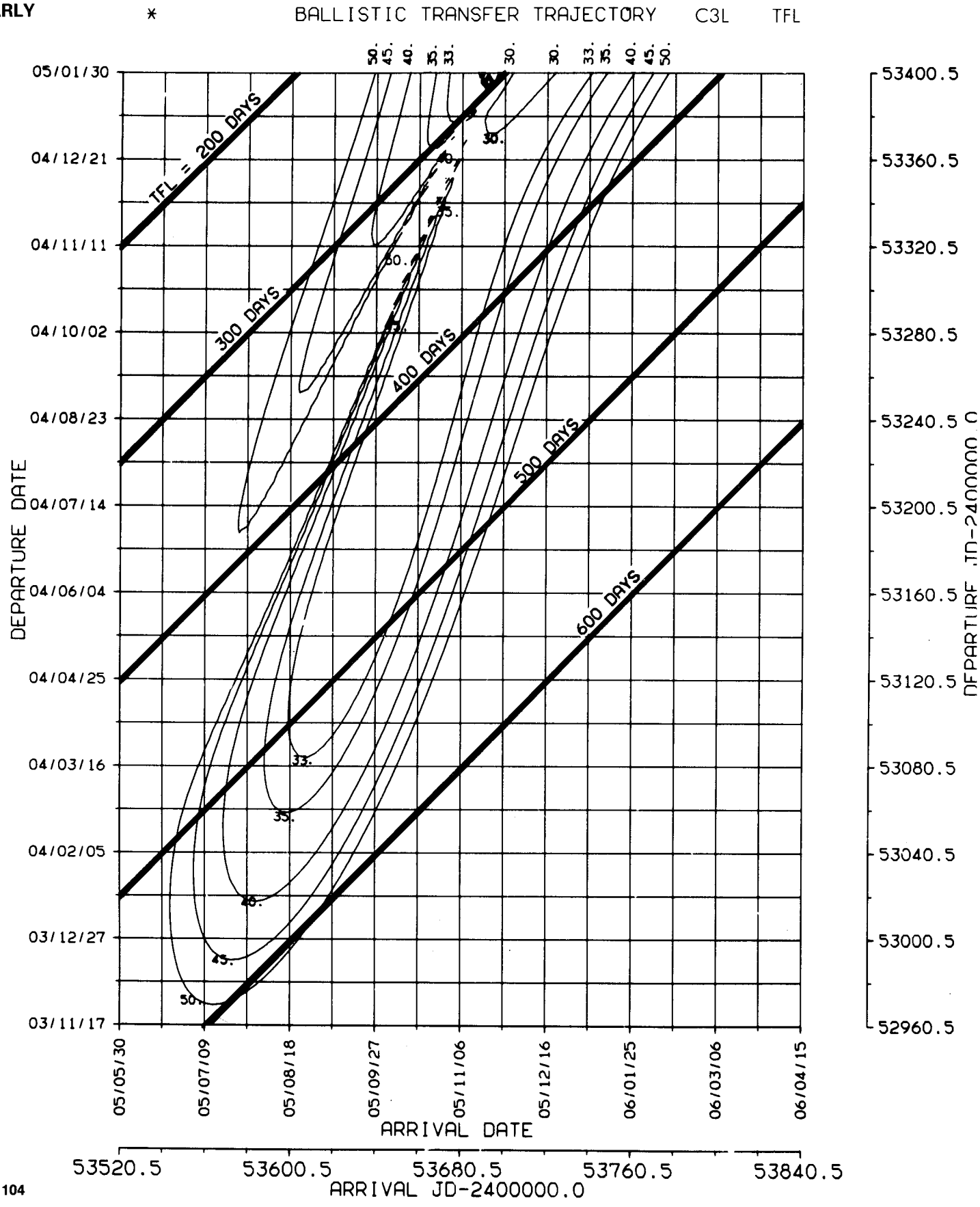
2004/5

Opportunity

ENERGY MINIMA

	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	13.558	I	2005/06/28	2006/01/06
C_3L	13.197	II	2005/07/08	2006/06/30
VHP	2.899	I	2005/08/14	2006/02/03
VHP	3.007	II	2005/02/23	2005/12/26

C3L
♂ ⊕
2004/5
EARLY

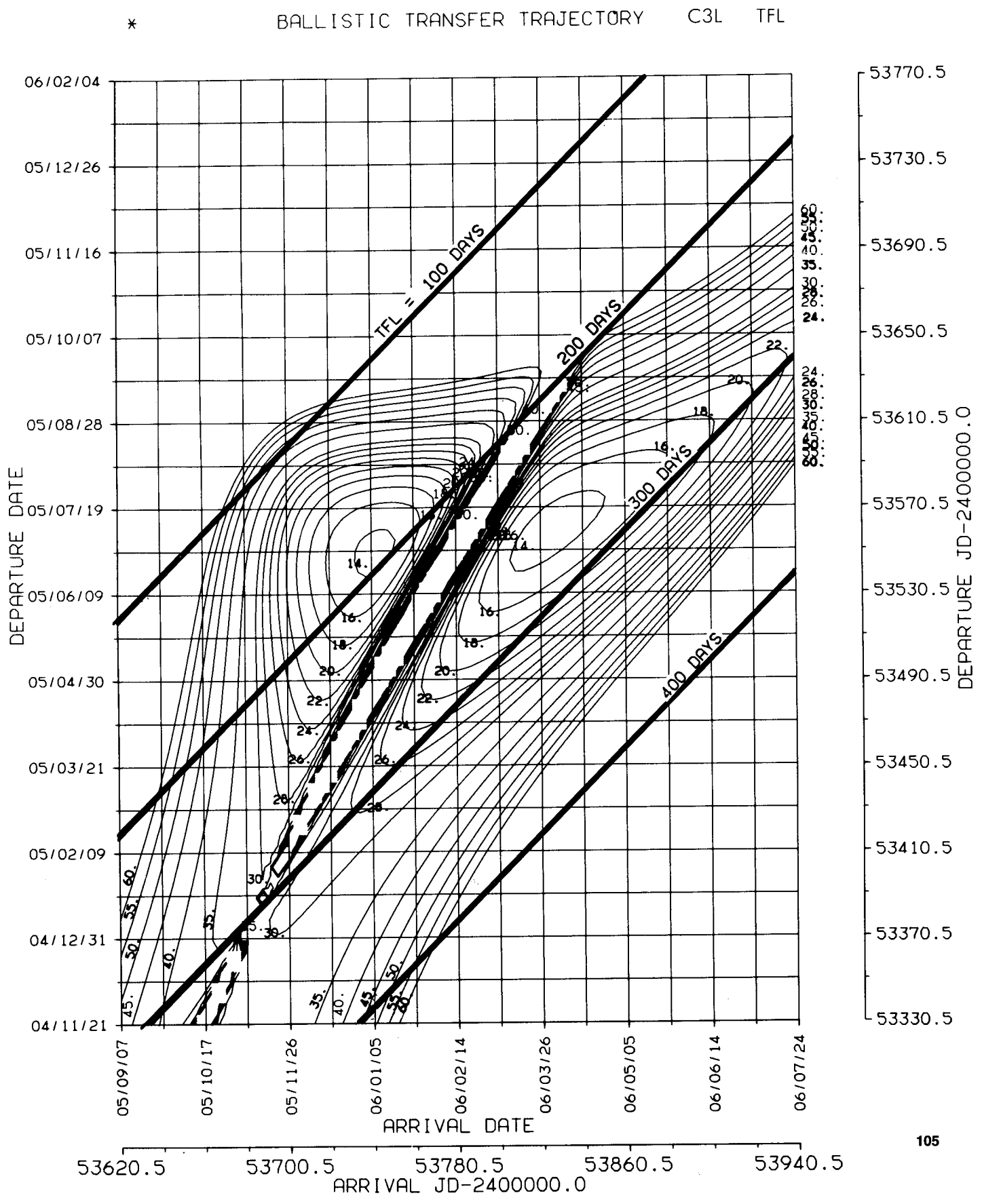


C3L

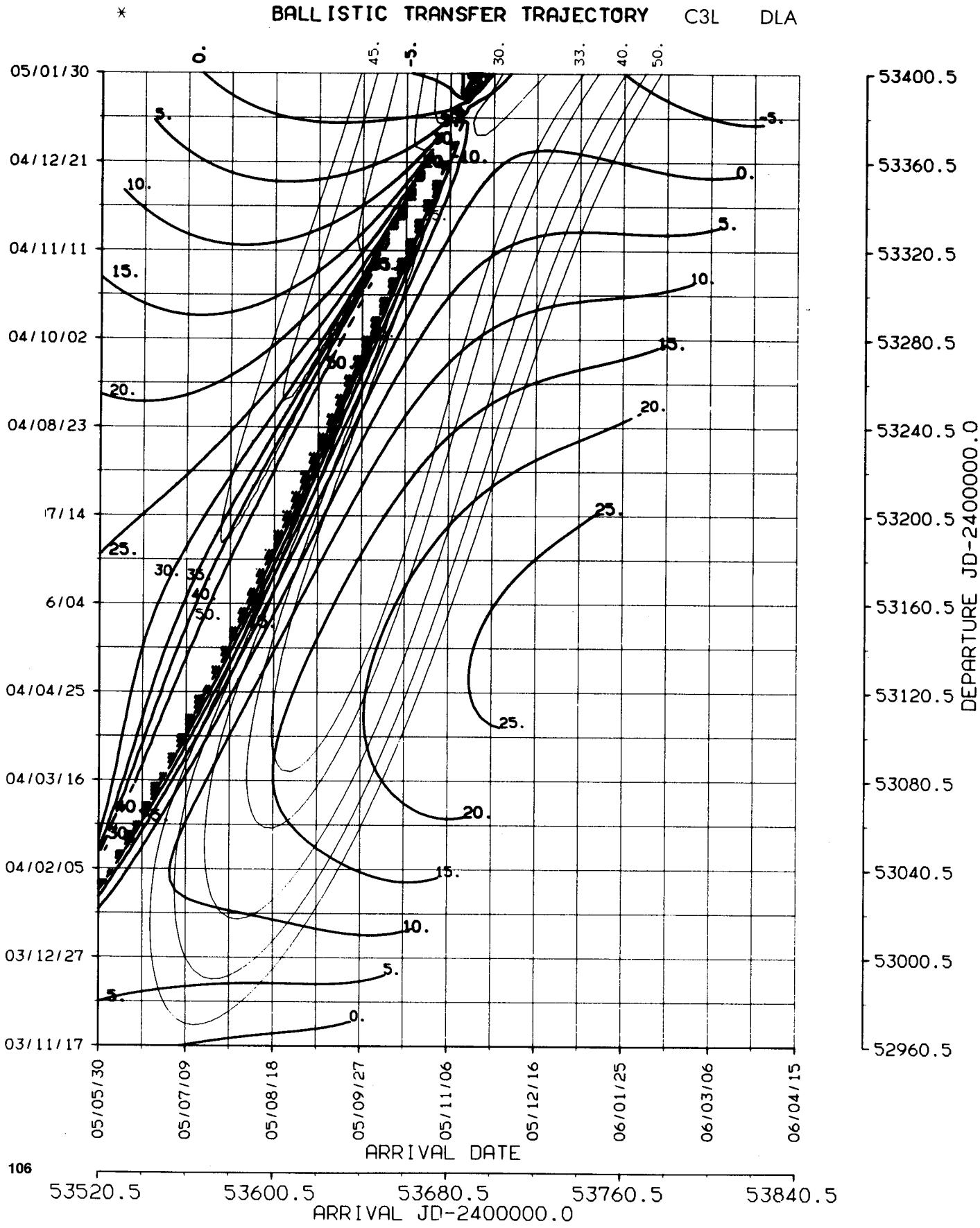
♂ ⊕

2004/5

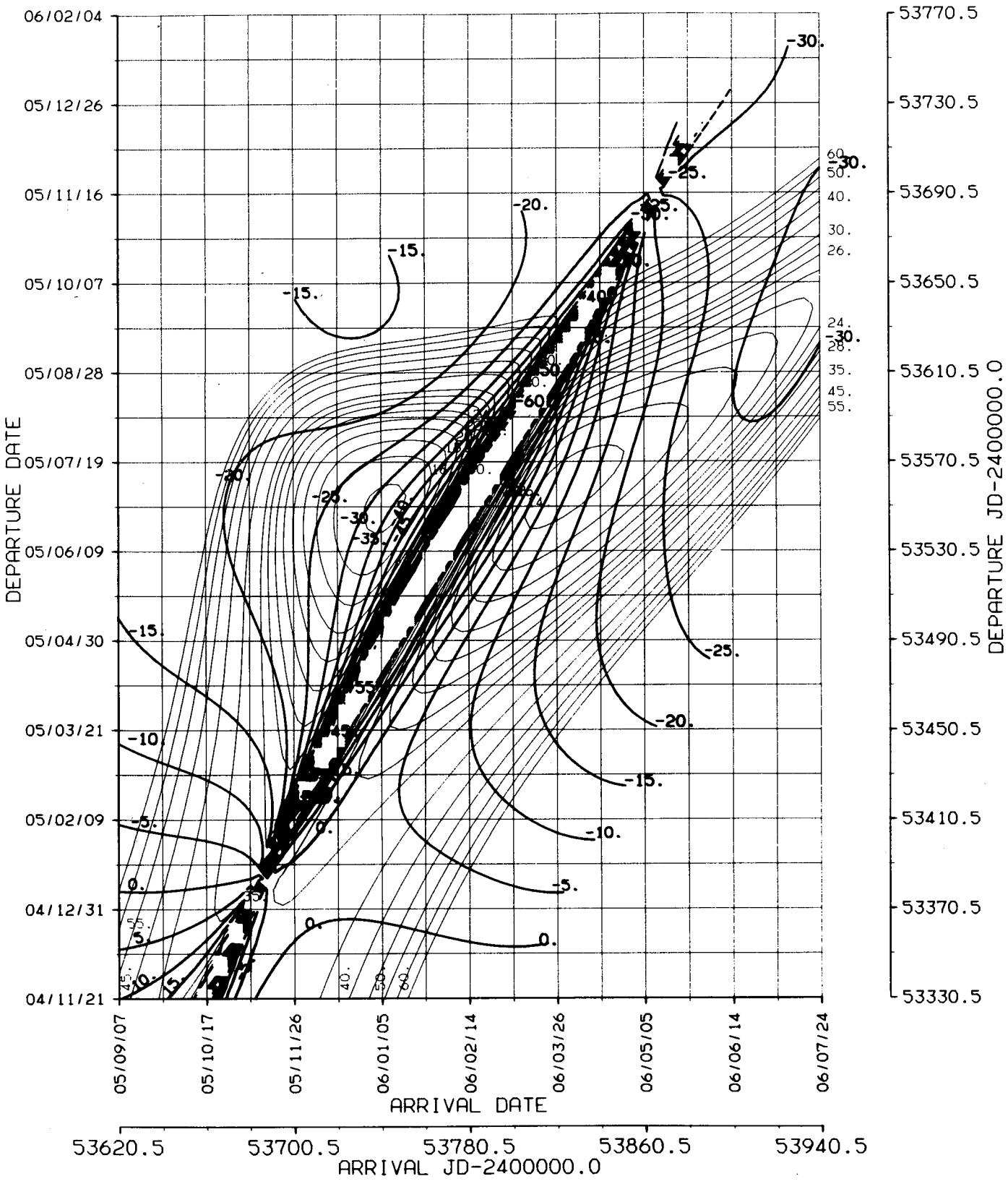
LATE



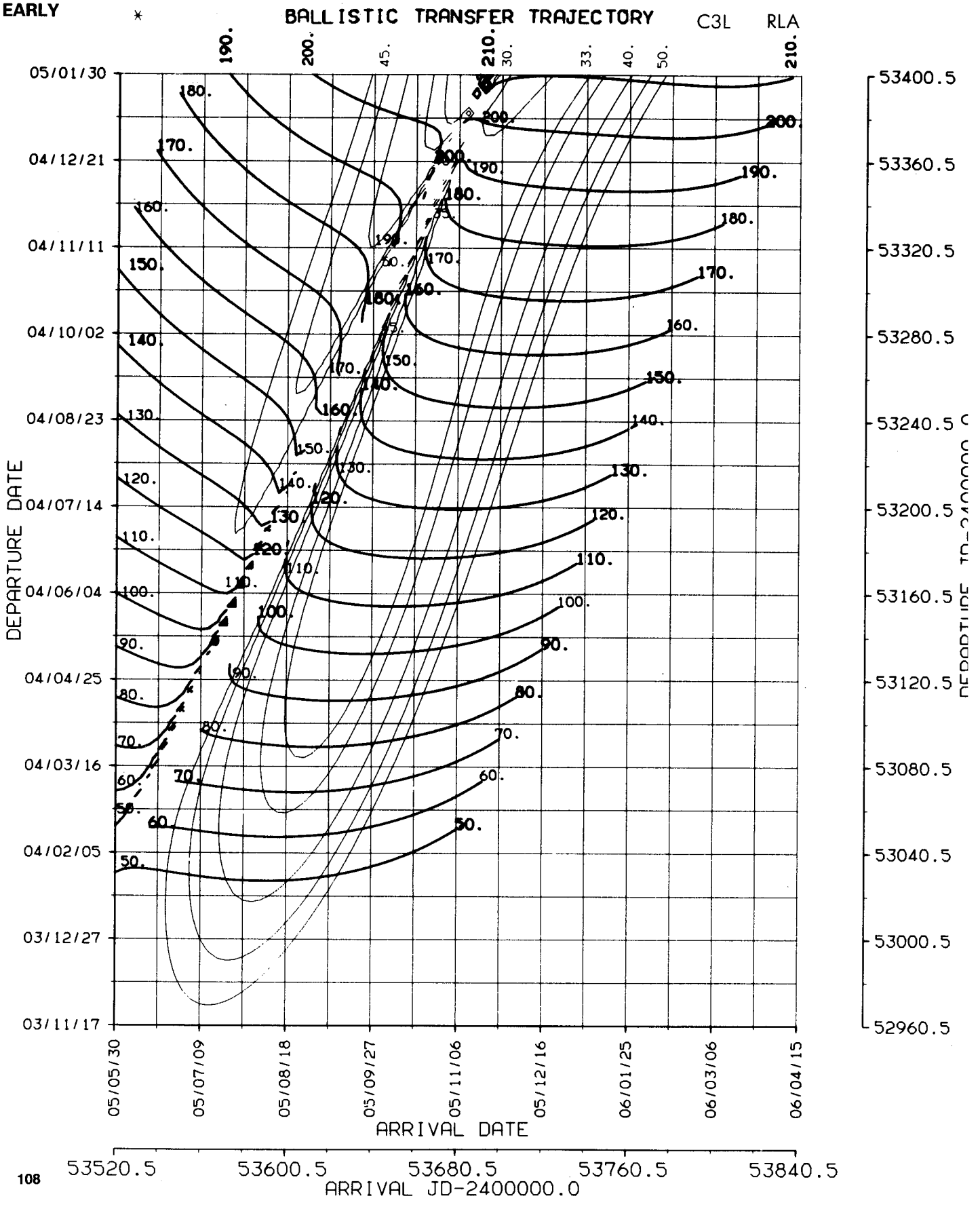
DLA ♂⊕ 2004/5 EARLY



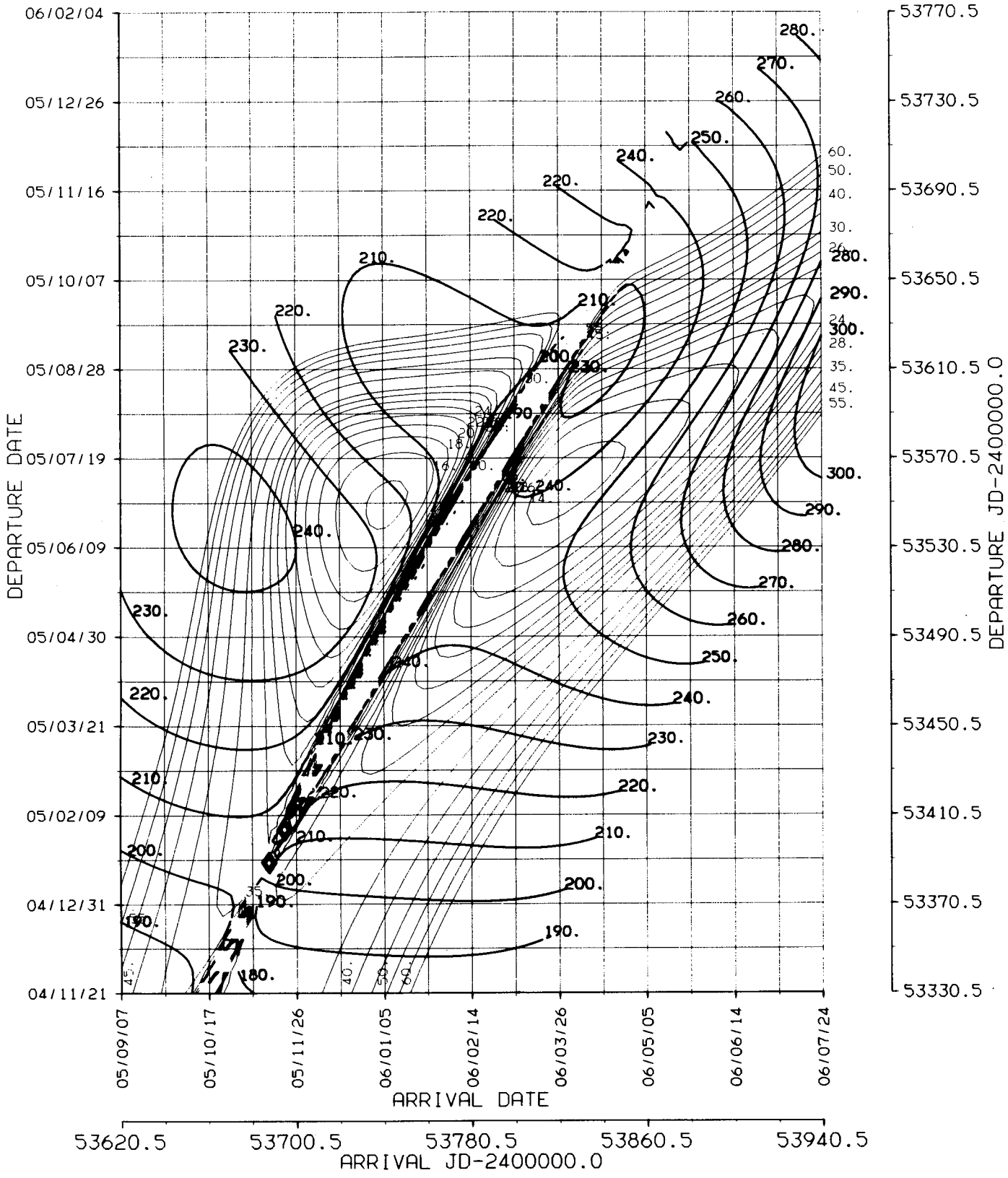
BALLISTIC TRANSFER TRAJECTORY C3L DLA



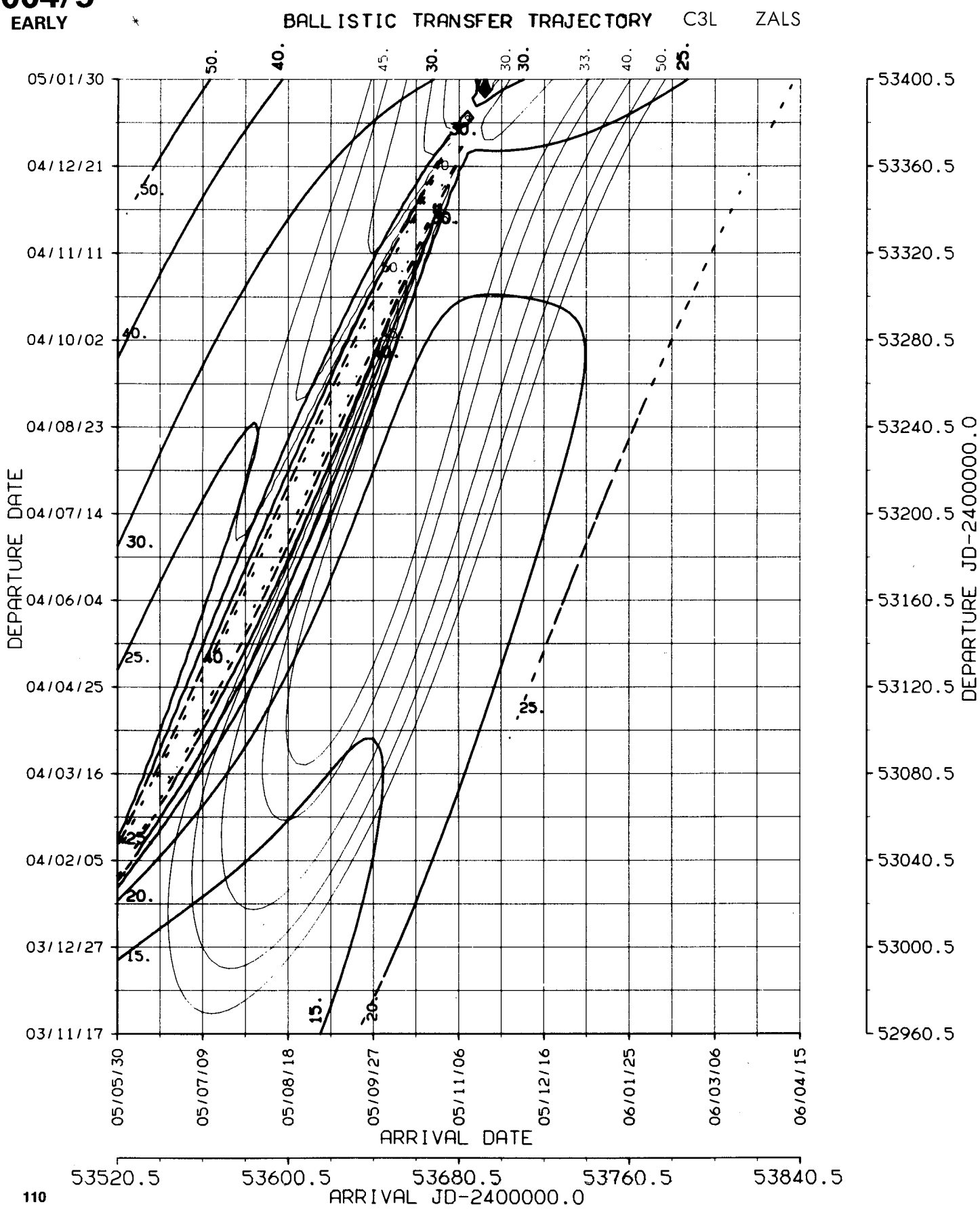
RLA ♂ ⊕ 2004/5 EARLY



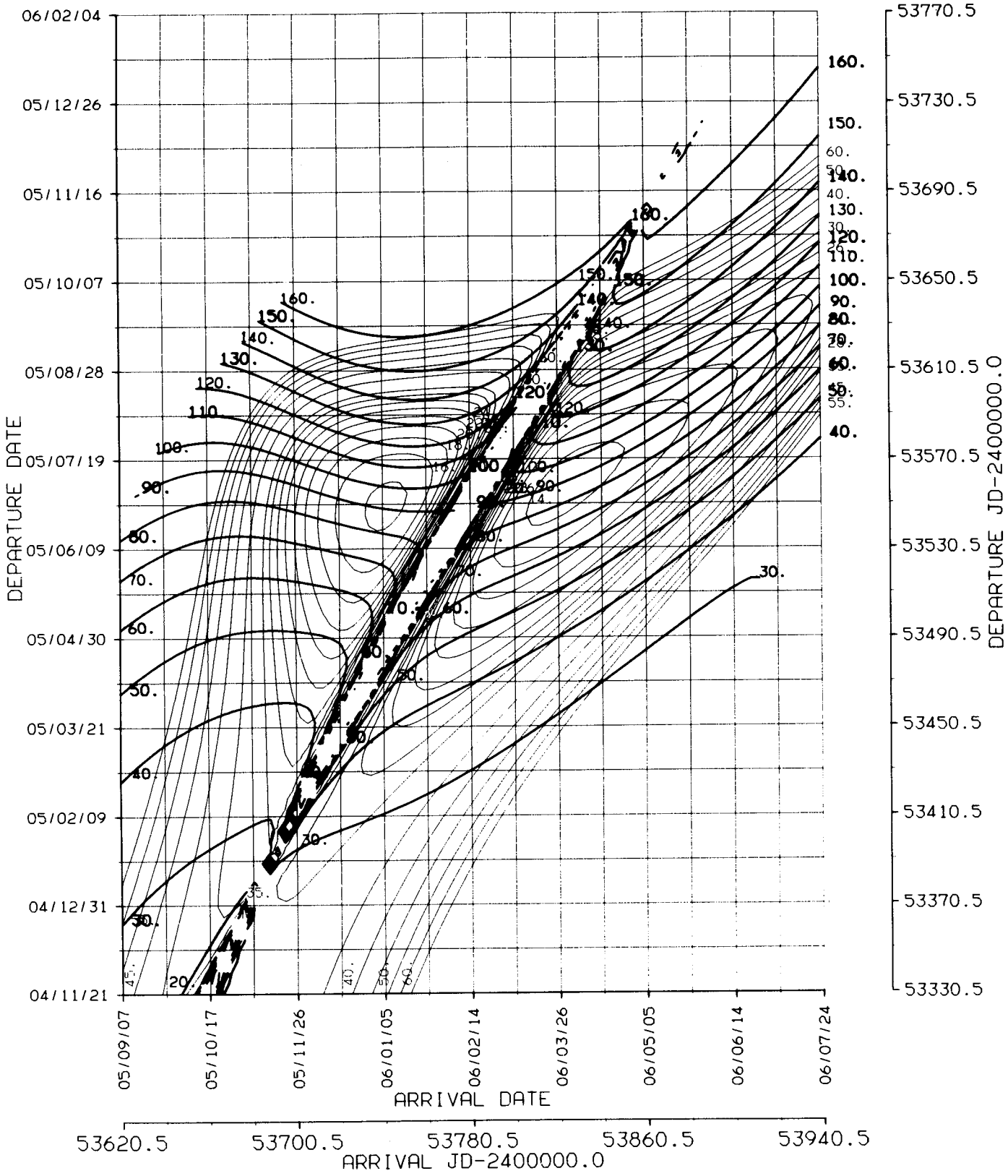
BALLISTIC TRANSFER TRAJECTORY C3L RLA



ZALS ♂⊕ 2004/5 EARLY



BALLISTIC TRANSFER TRAJECTORY C3L ZALS

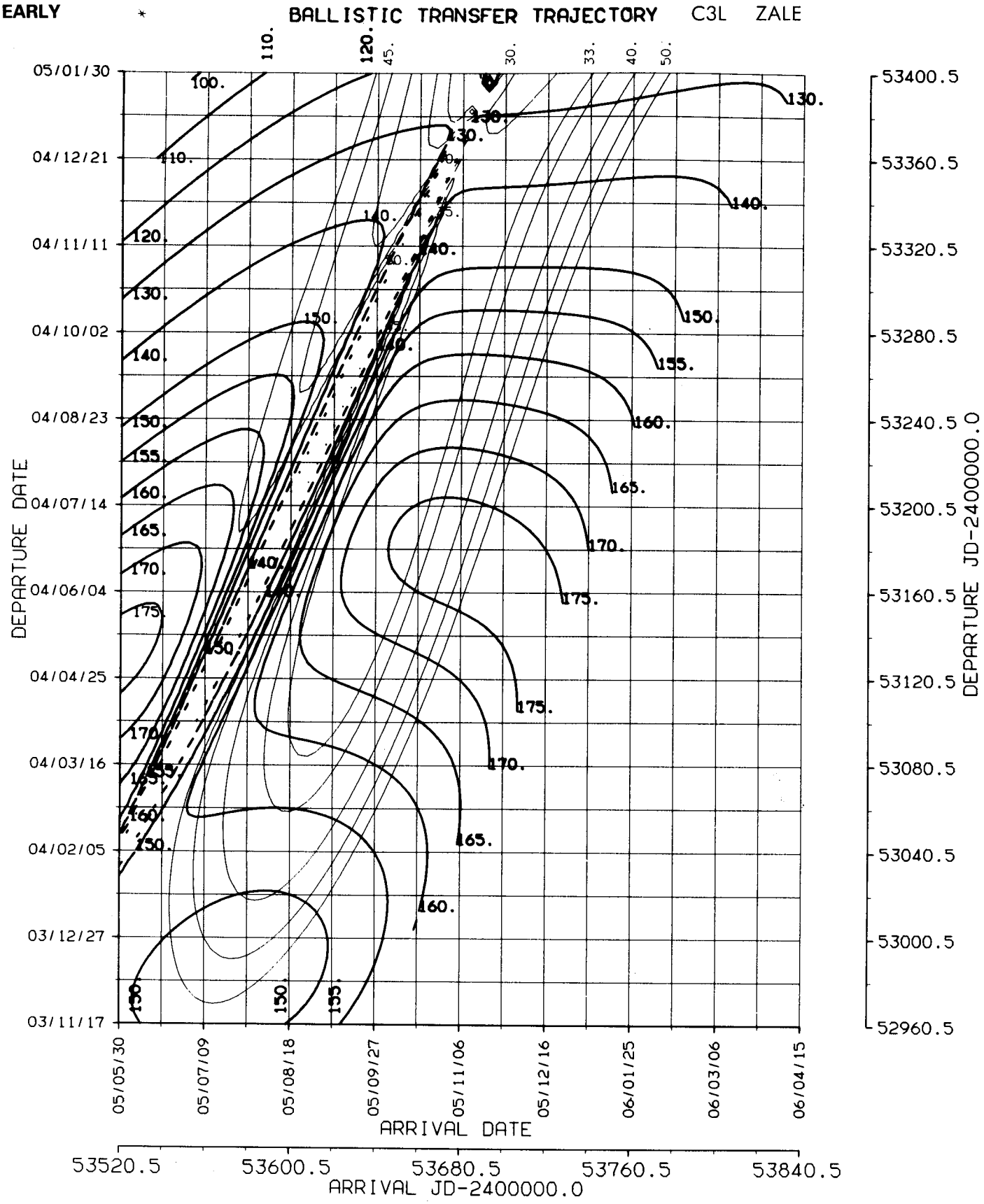


ZALE

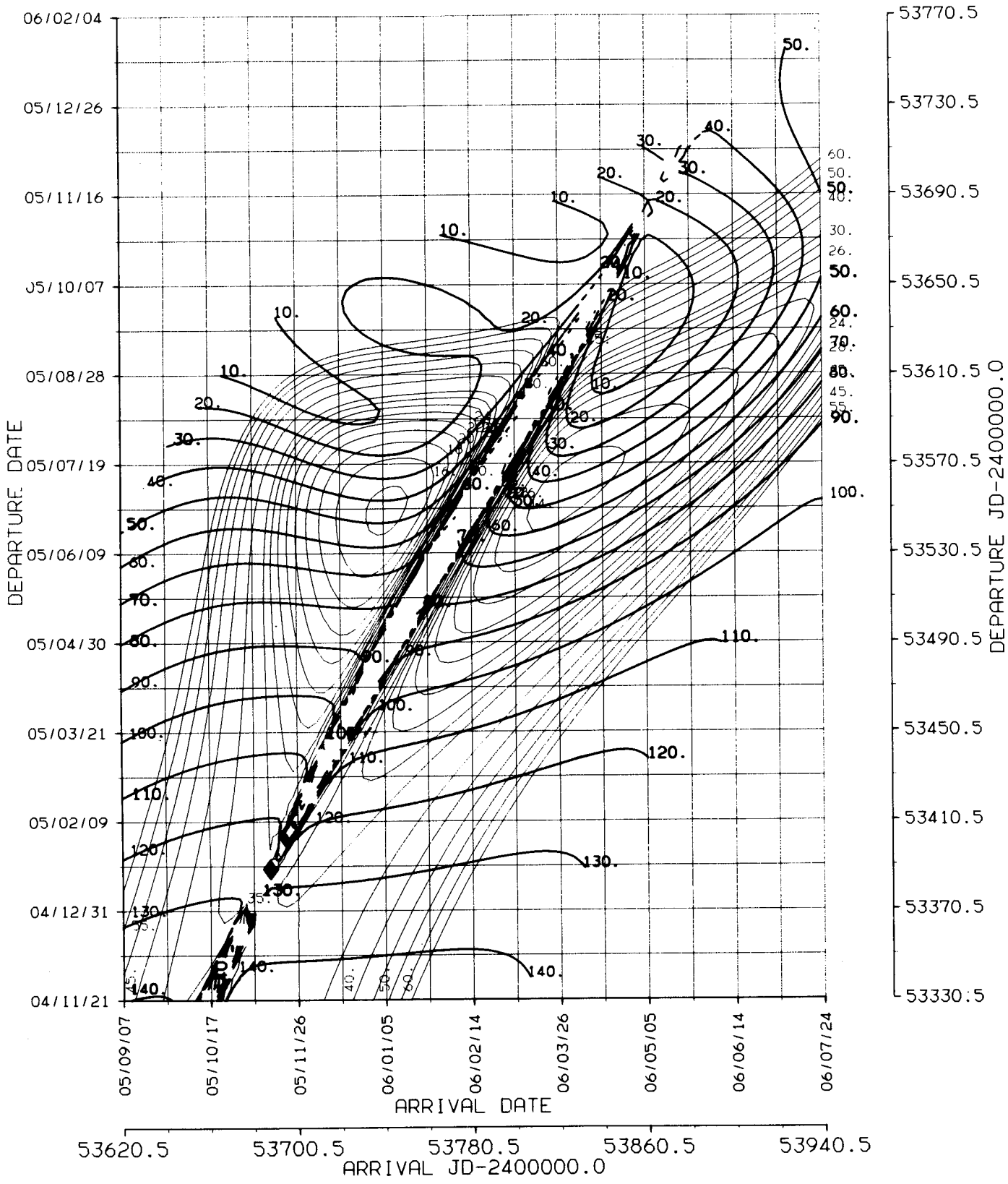
♂ ⊕

2004/5

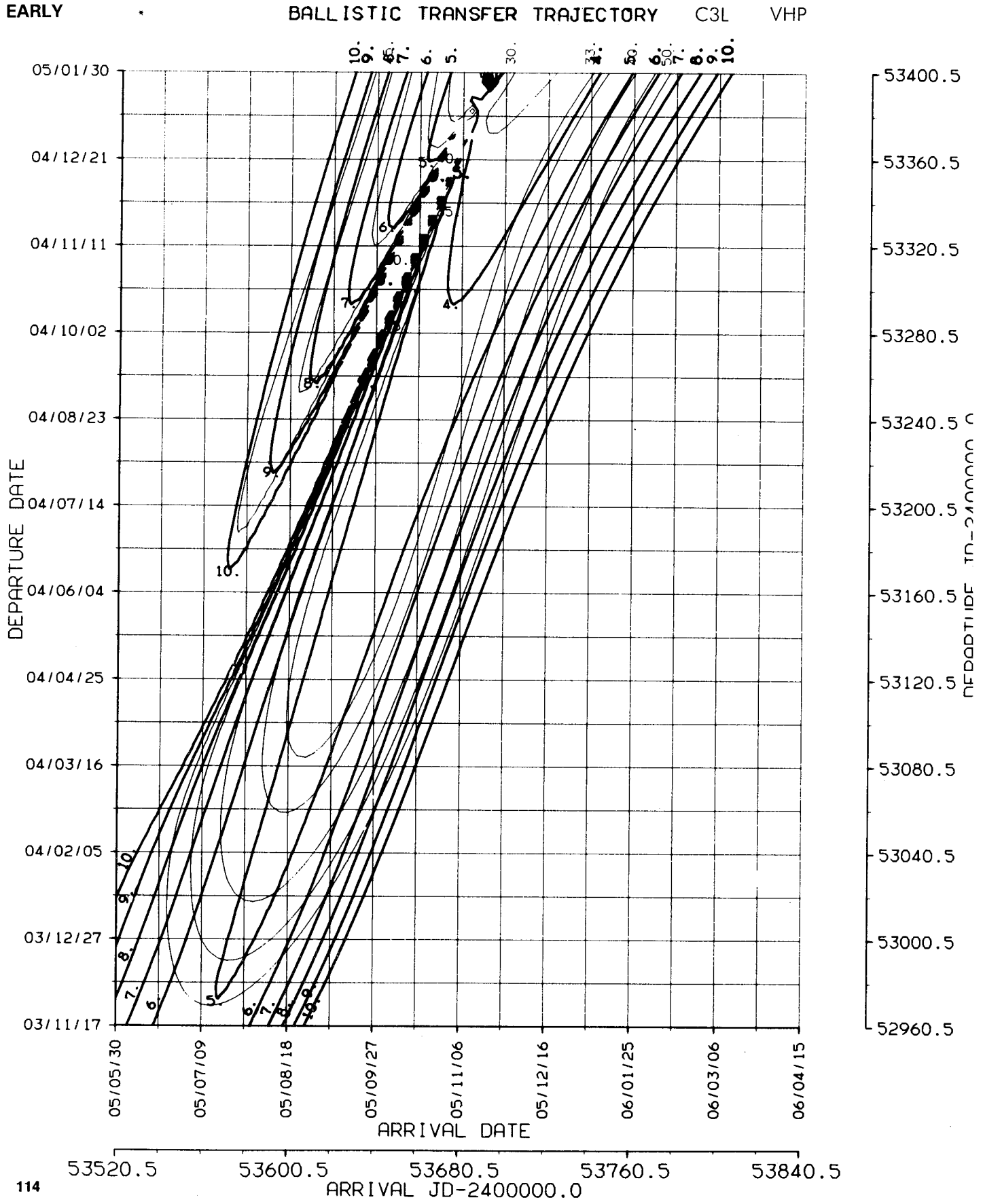
EARLY



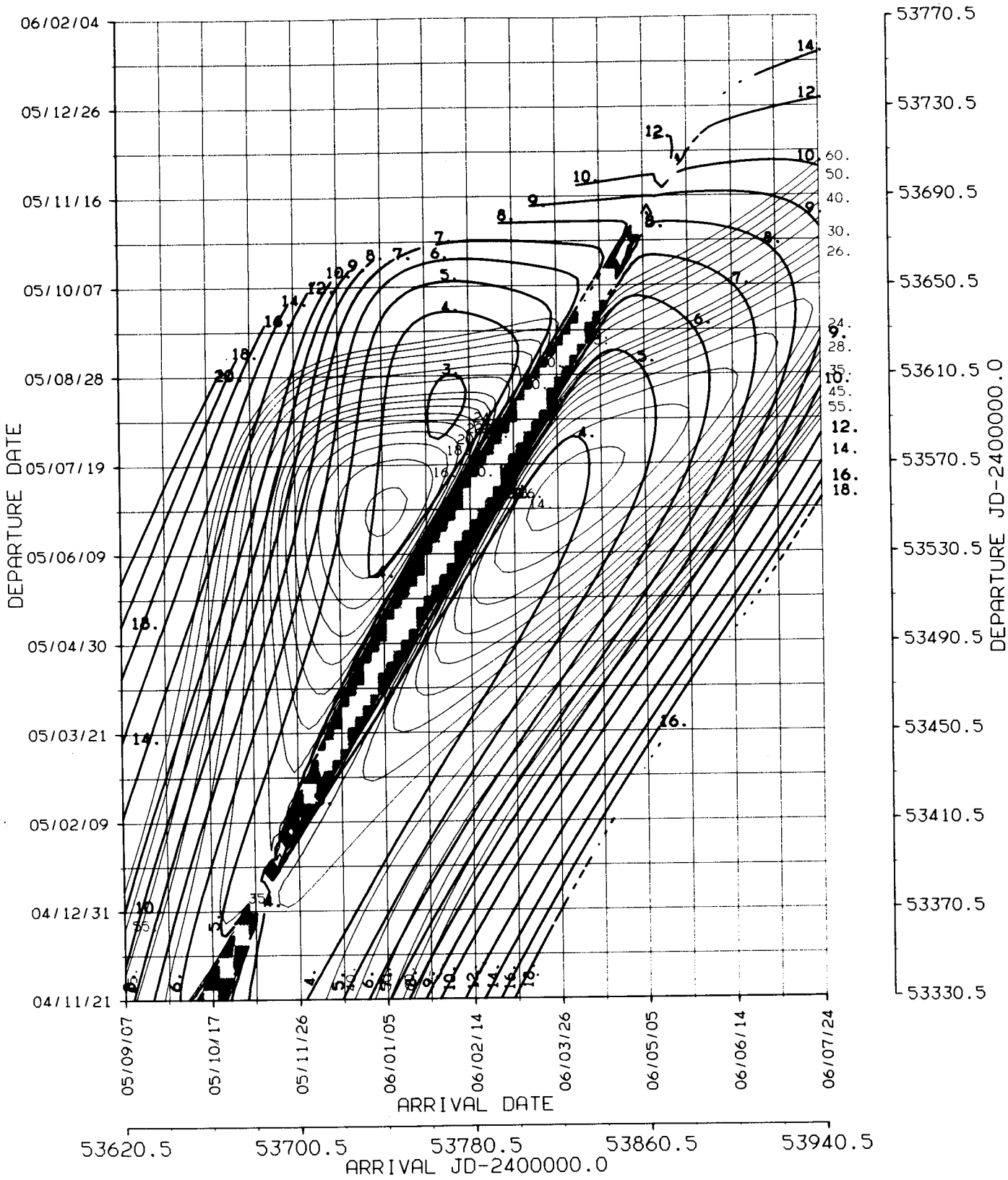
BALLISTIC TRANSFER TRAJECTORY C3L ZALE



VHP ♂ ⊕ 2004/5 EARLY



BALLISTIC TRANSFER TRAJECTORY C3L VHP

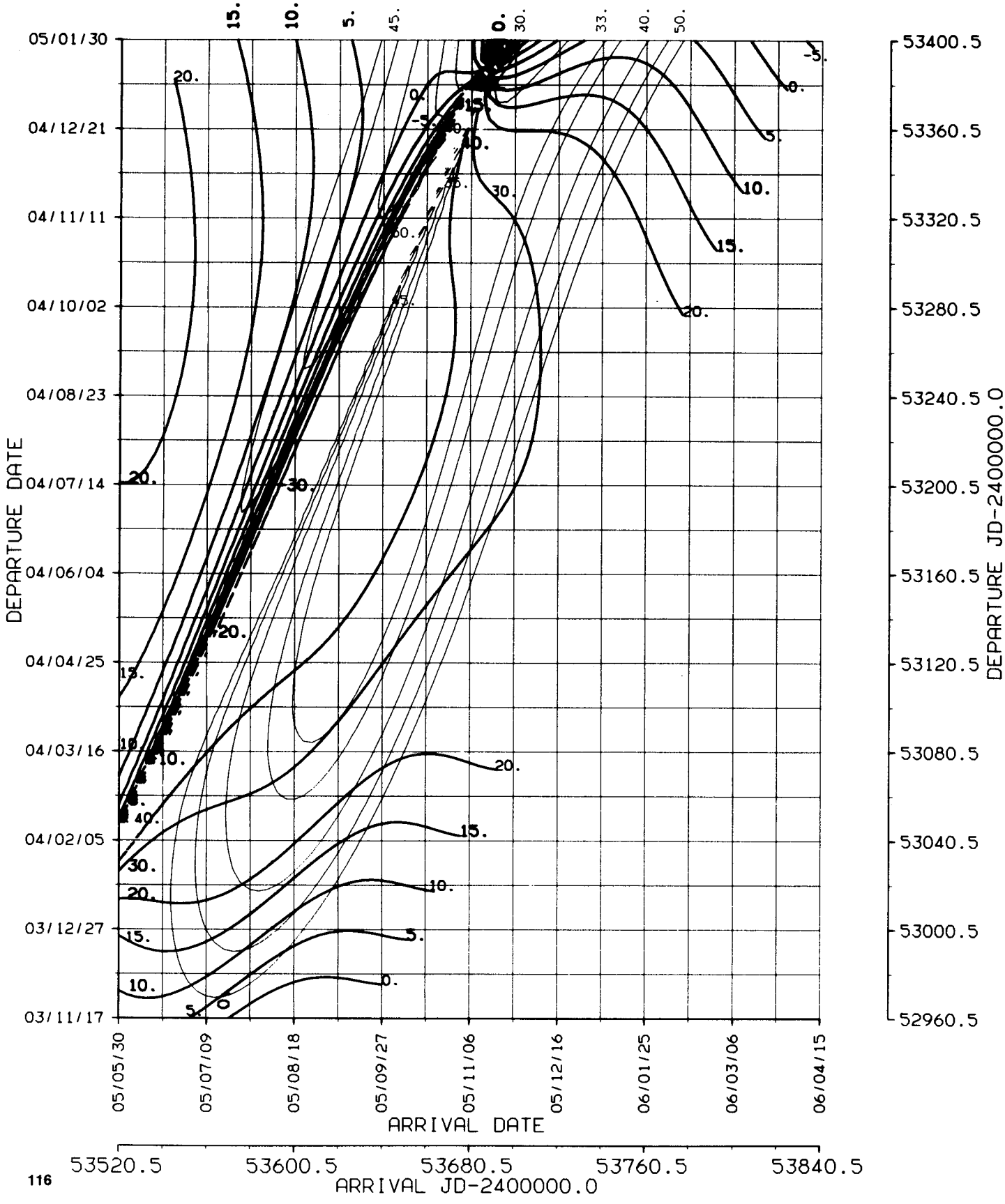


DAP

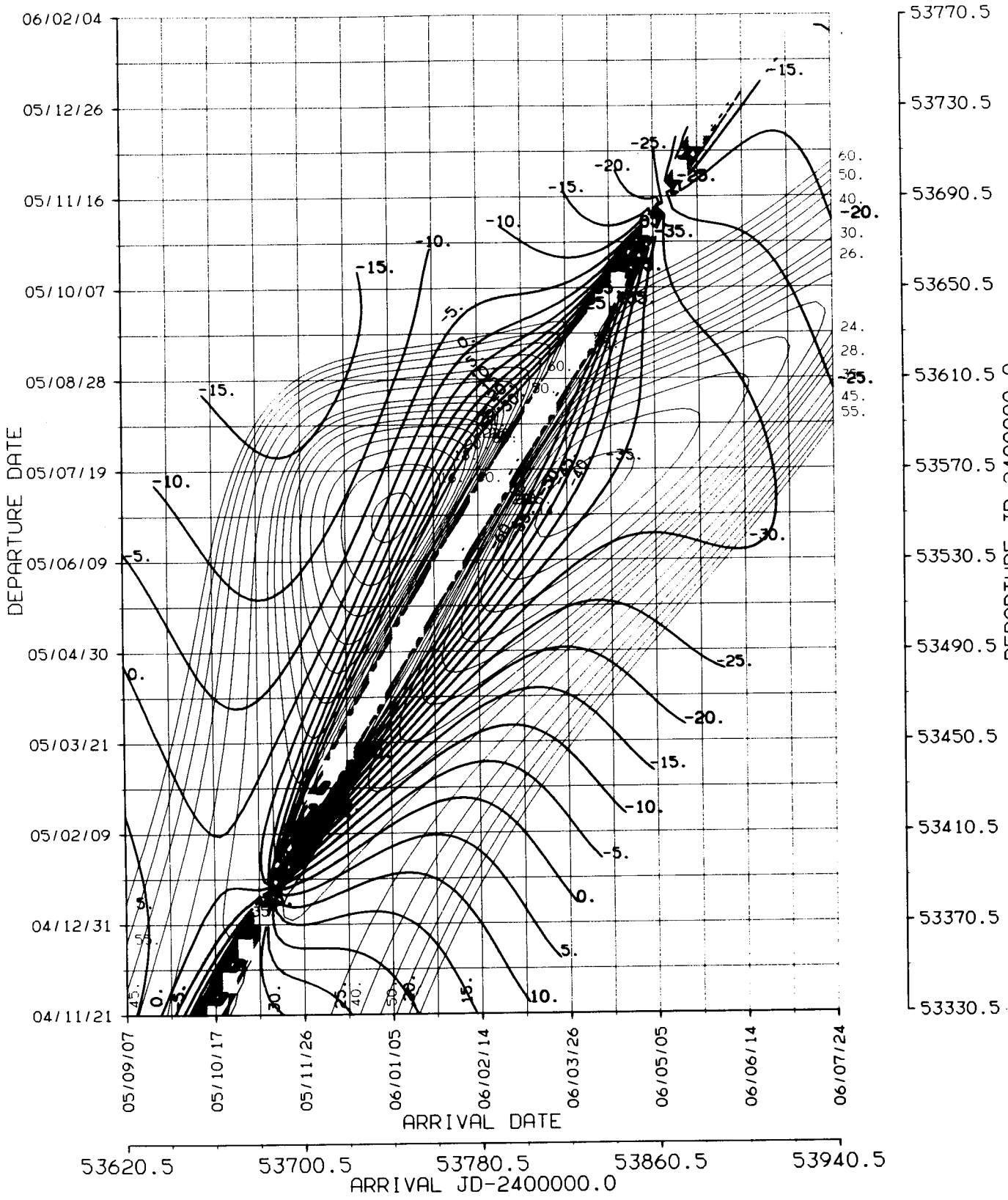
2004/5

EARLY

BALLISTIC TRANSFER TRAJECTORY C3L DAP



BALLISTIC TRANSFER TRAJECTORY C3L DAP

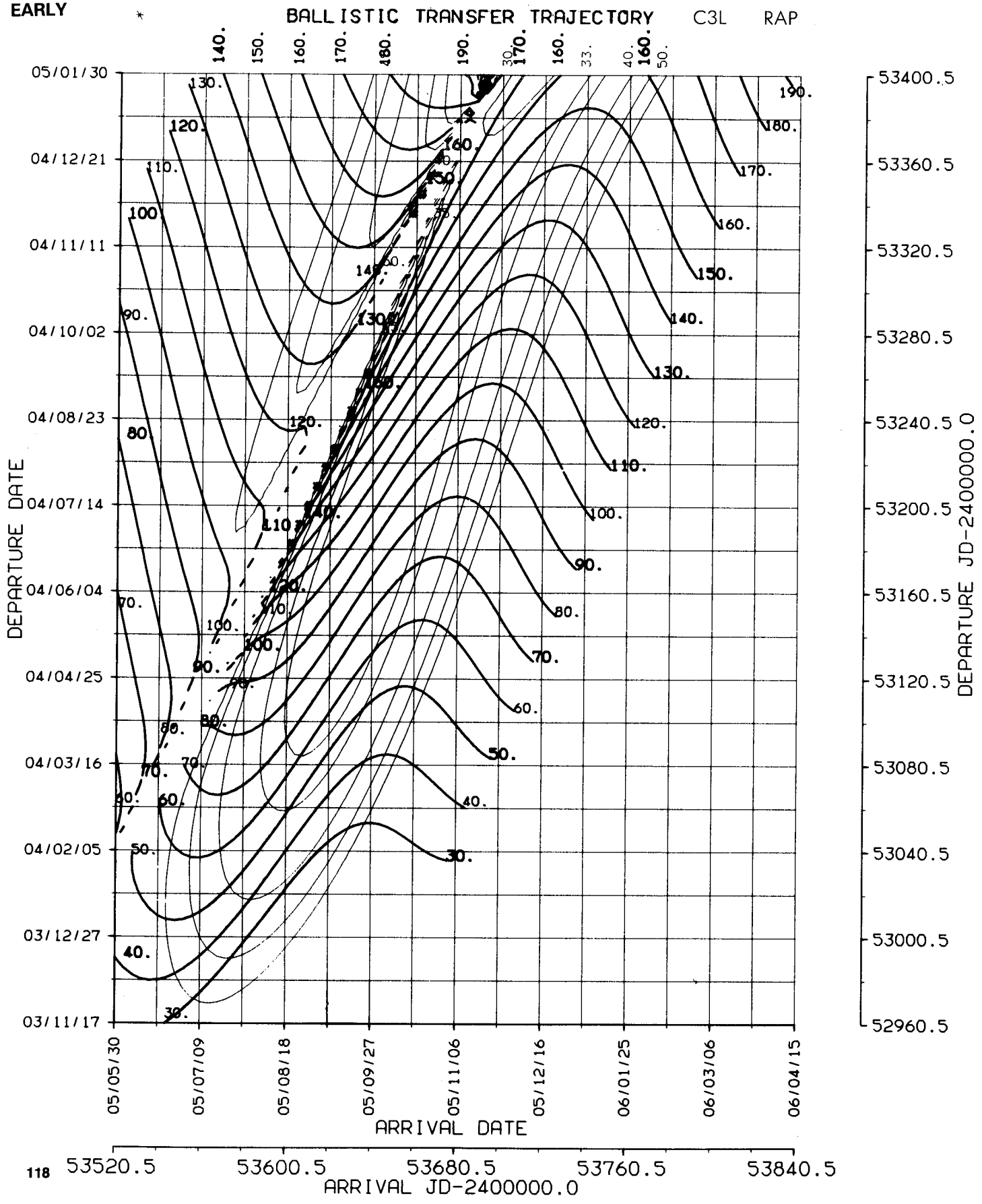


RAP

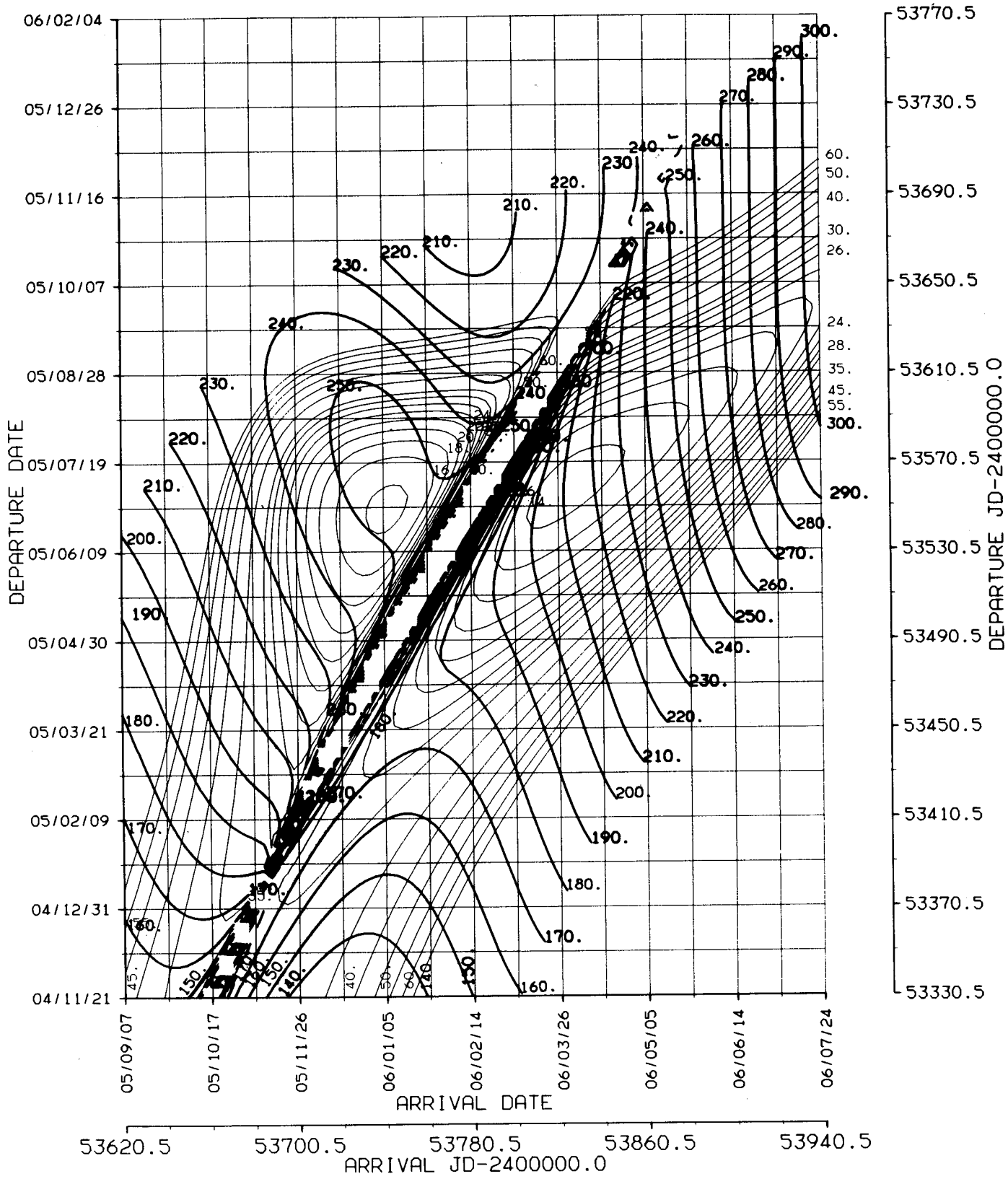
♂⊕

2004/5

EARLY



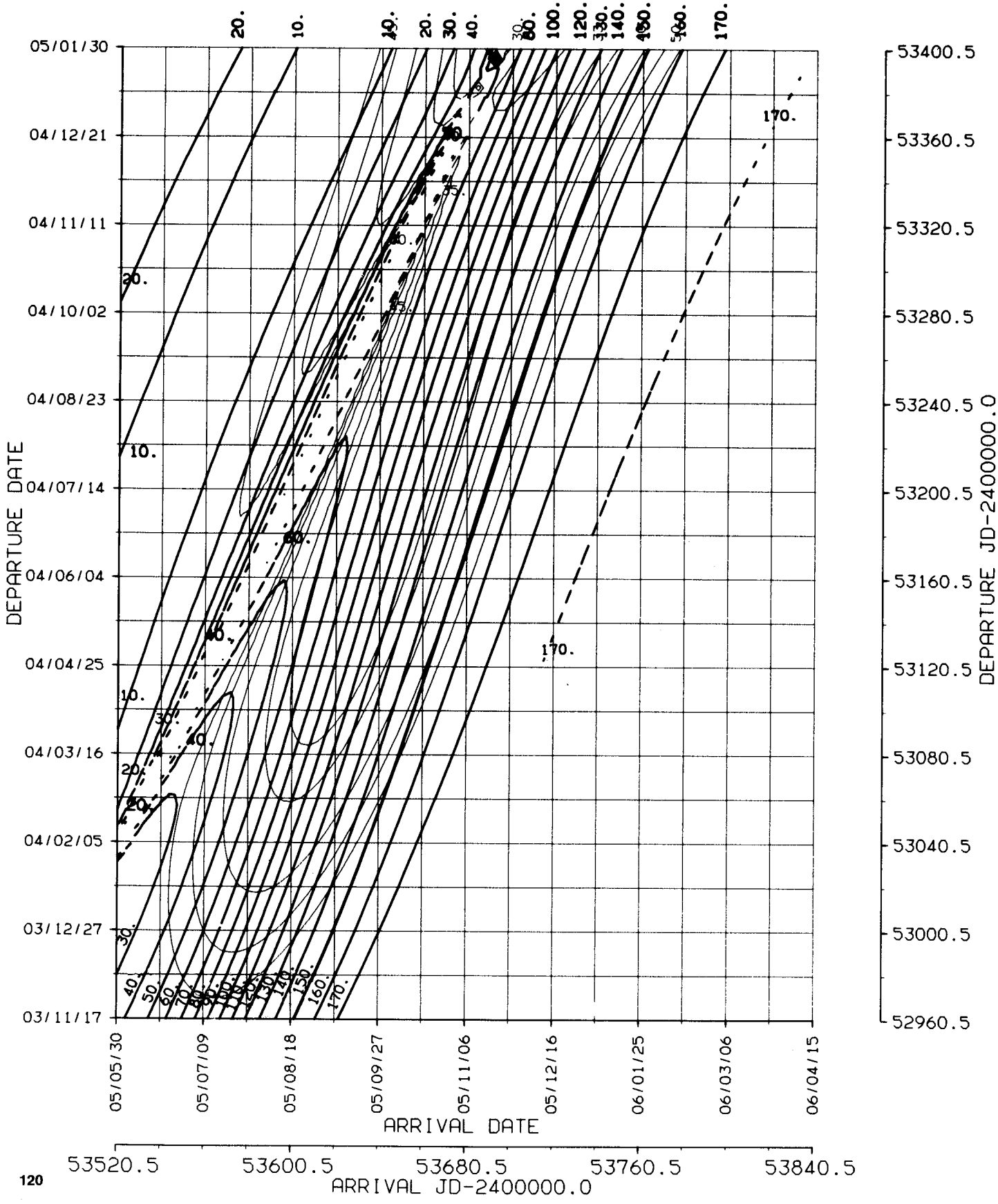
BALLISTIC TRANSFER TRAJECTORY C3L RAP



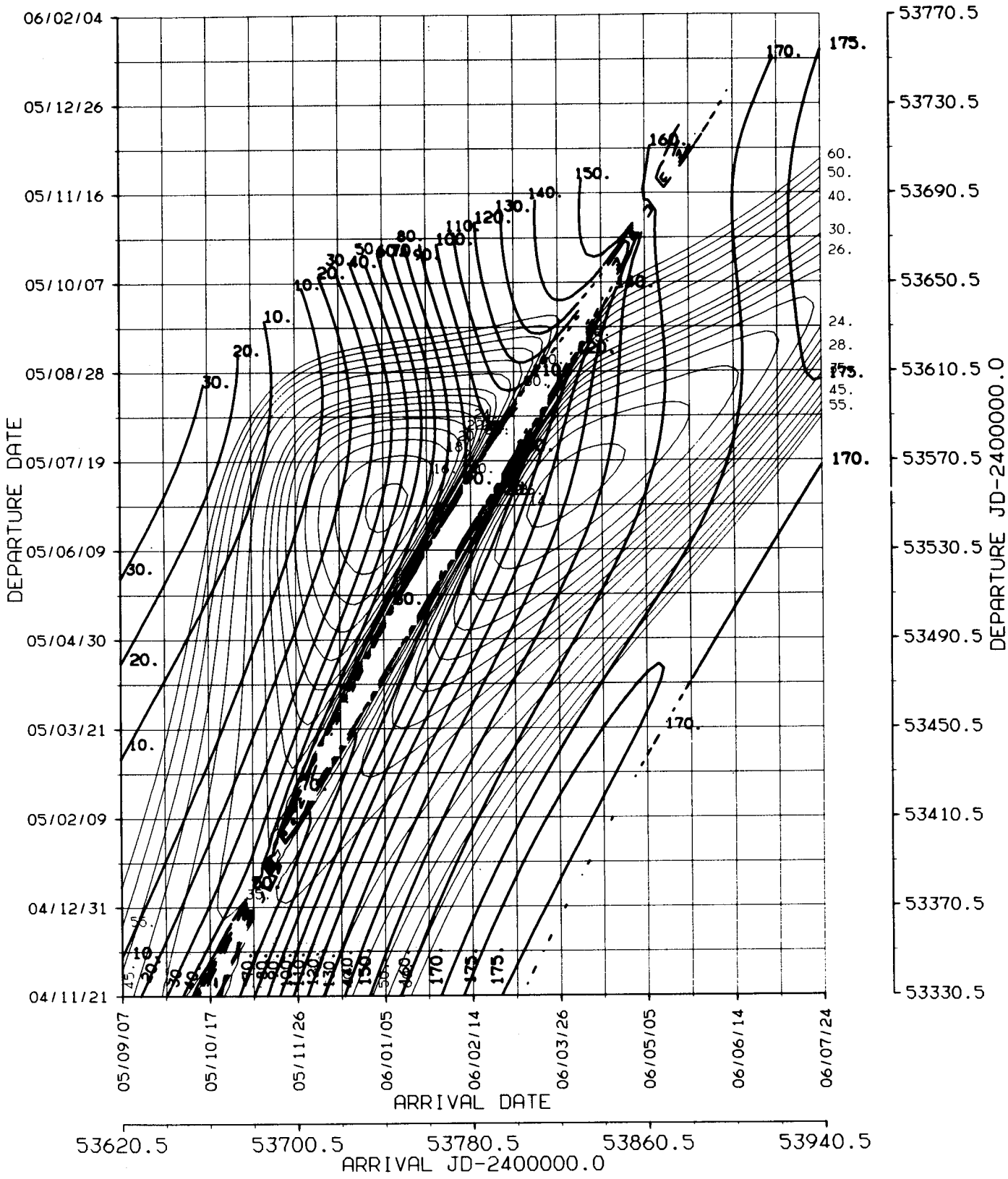
ZAPS ♂ ⊕ 2004/5

EARLY *

BALLISTIC TRANSFER TRAJECTORY C3L ZAPS



BALLISTIC TRANSFER TRAJECTORY C3L ZAPS

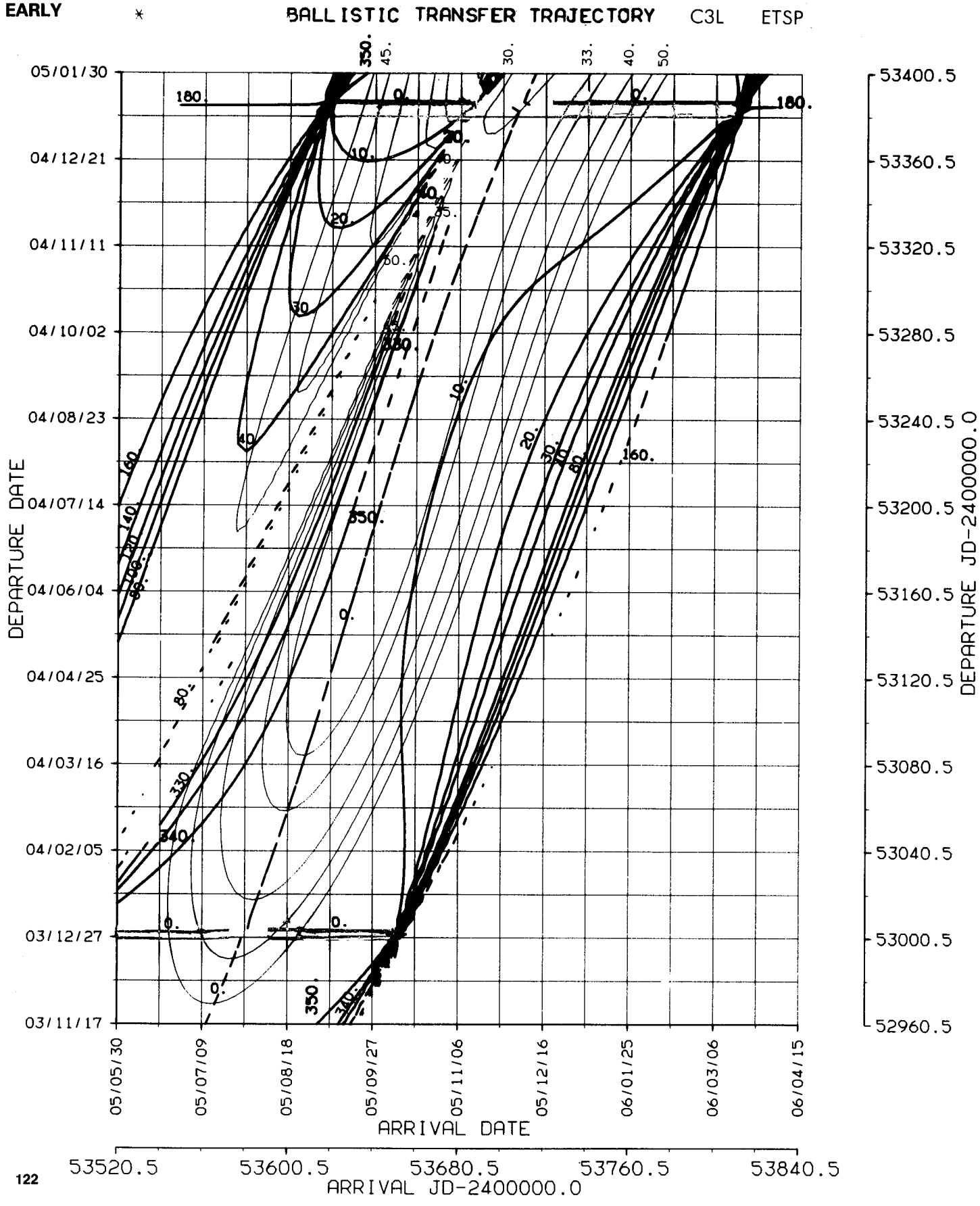


ETSP

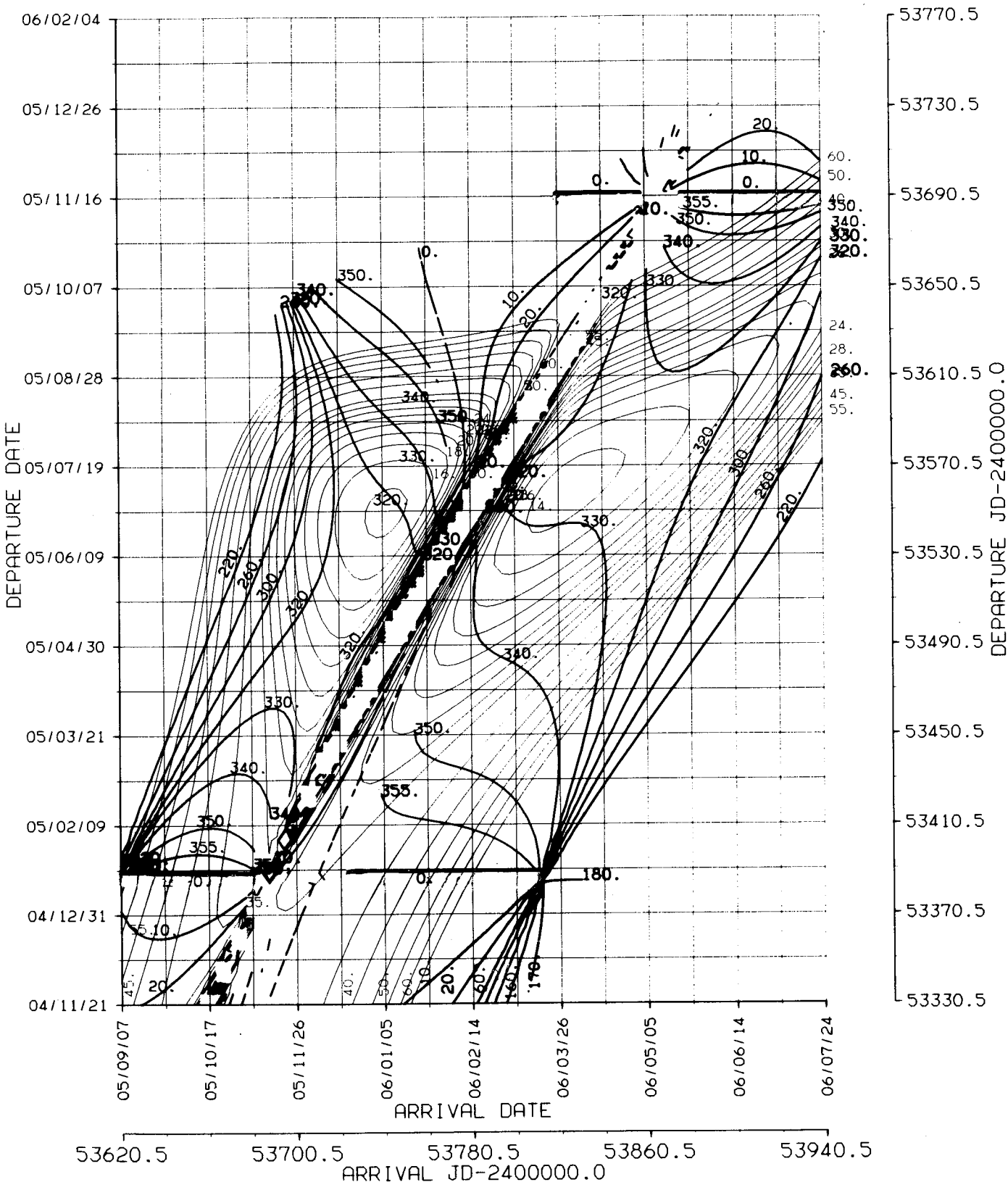
♂ ⊕

2004/5

EARLY



BALLISTIC TRANSFER TRAJECTORY C3L ETSP



Mars to Earth

2006/7

Opportunity

ENERGY MINIMA

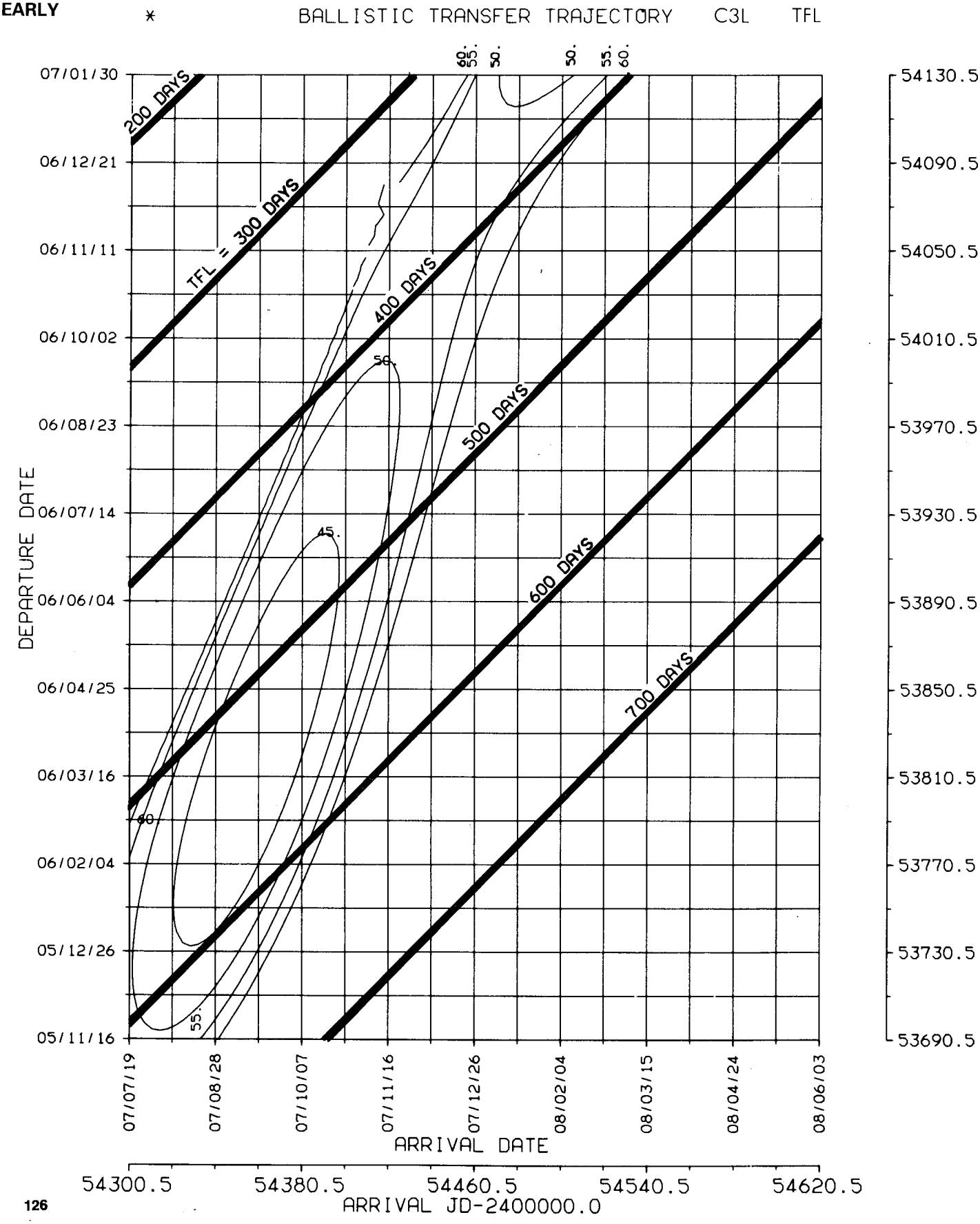
	VALUE	TYPE	DEPARTURE (YEAR/MONTH/DAY)	ARRIVAL (YEAR/MONTH/DAY)
C_3L	14.230	I	2007/07/30	2008/02/29
C_3L	10.196	II	2007/07/21	2008/04/29
VHP	2.809	I	2007/09/10	2008/04/06
VHP	2.881	II	2007/06/24	2008/04/16

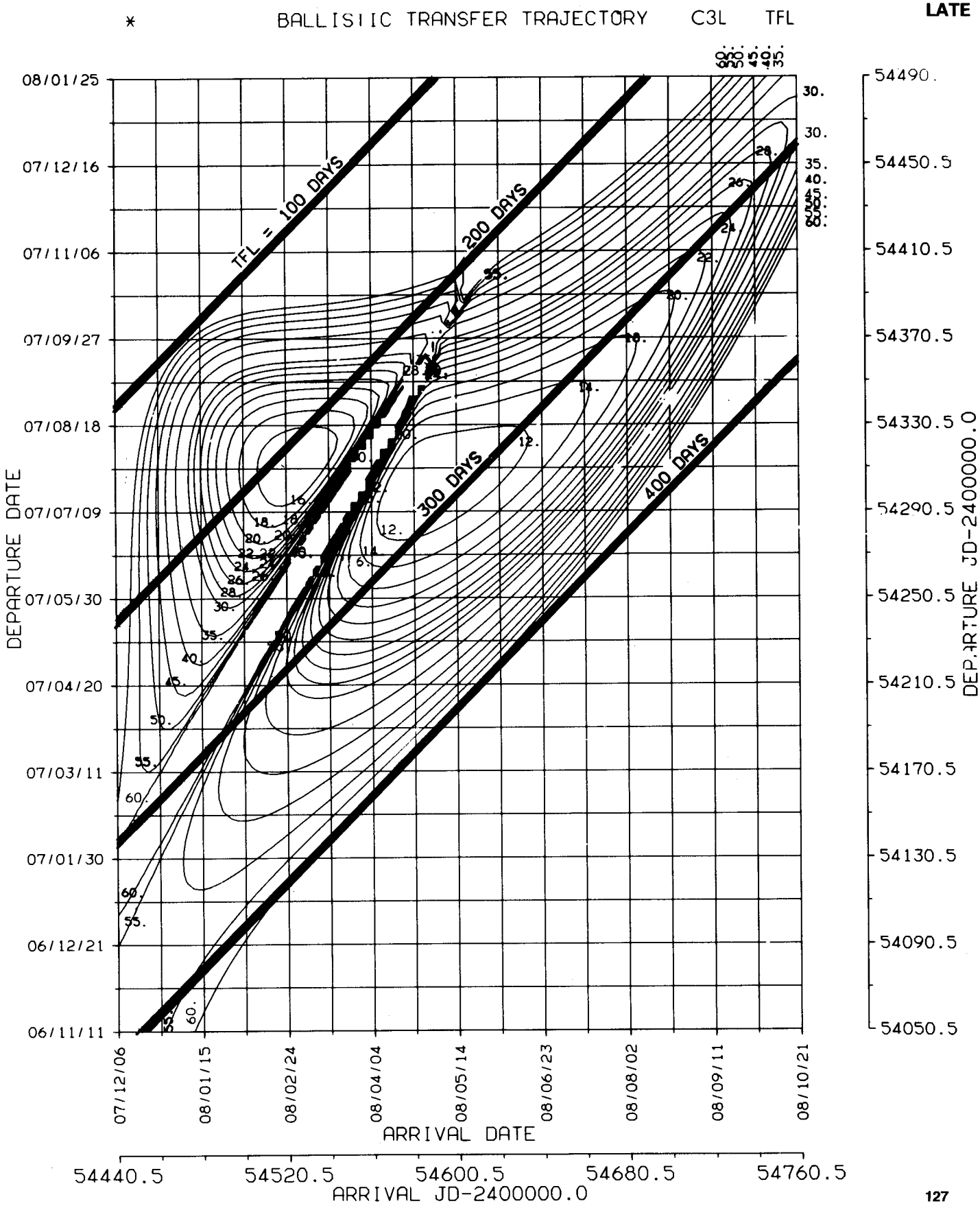
C3L

♂ ⊕

2006/7

EARLY



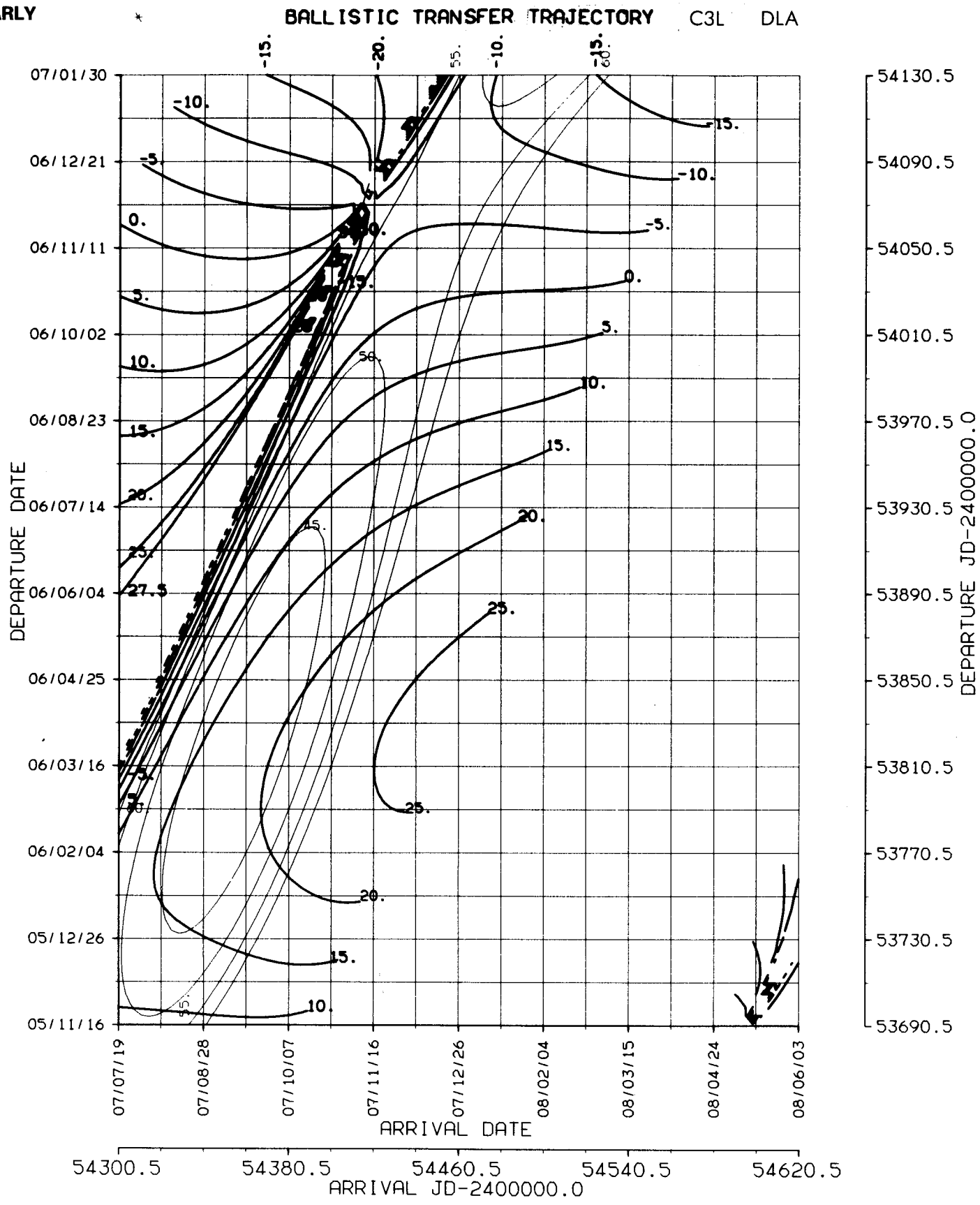

* BALLISTIC TRANSFER TRAJECTORY C3L TFL
TFL = 100 DAYS
200 DAYS
300 DAYS
400 DAYS
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

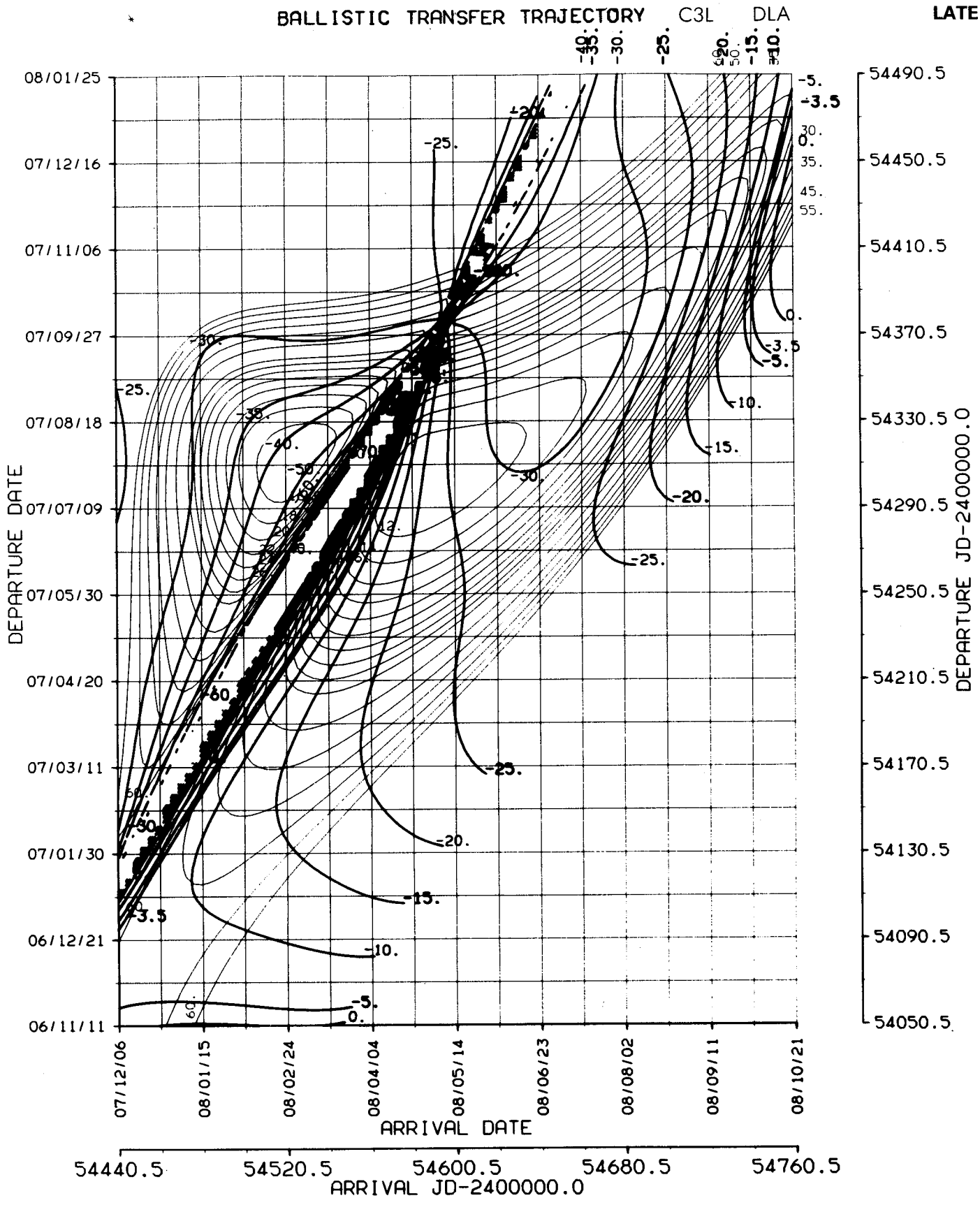
DLA

♂ ⊕

2006/7

EARLY



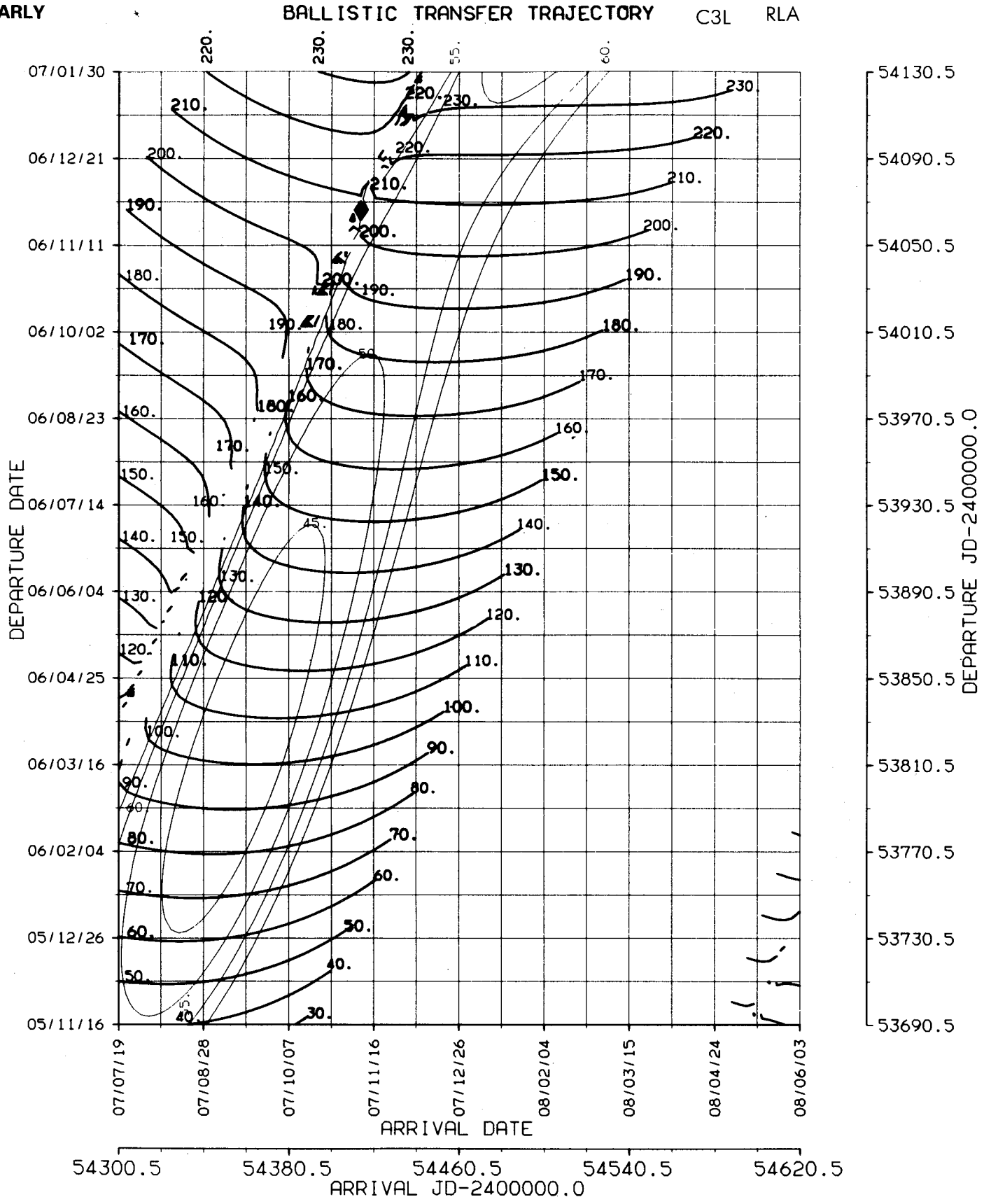

BALLISTIC TRANSFER TRAJECTORY C3L DLA
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
ARRIVAL DATE
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL JD-2400000.0
54440.5
54520.5
54600.5
54680.5
54760.5

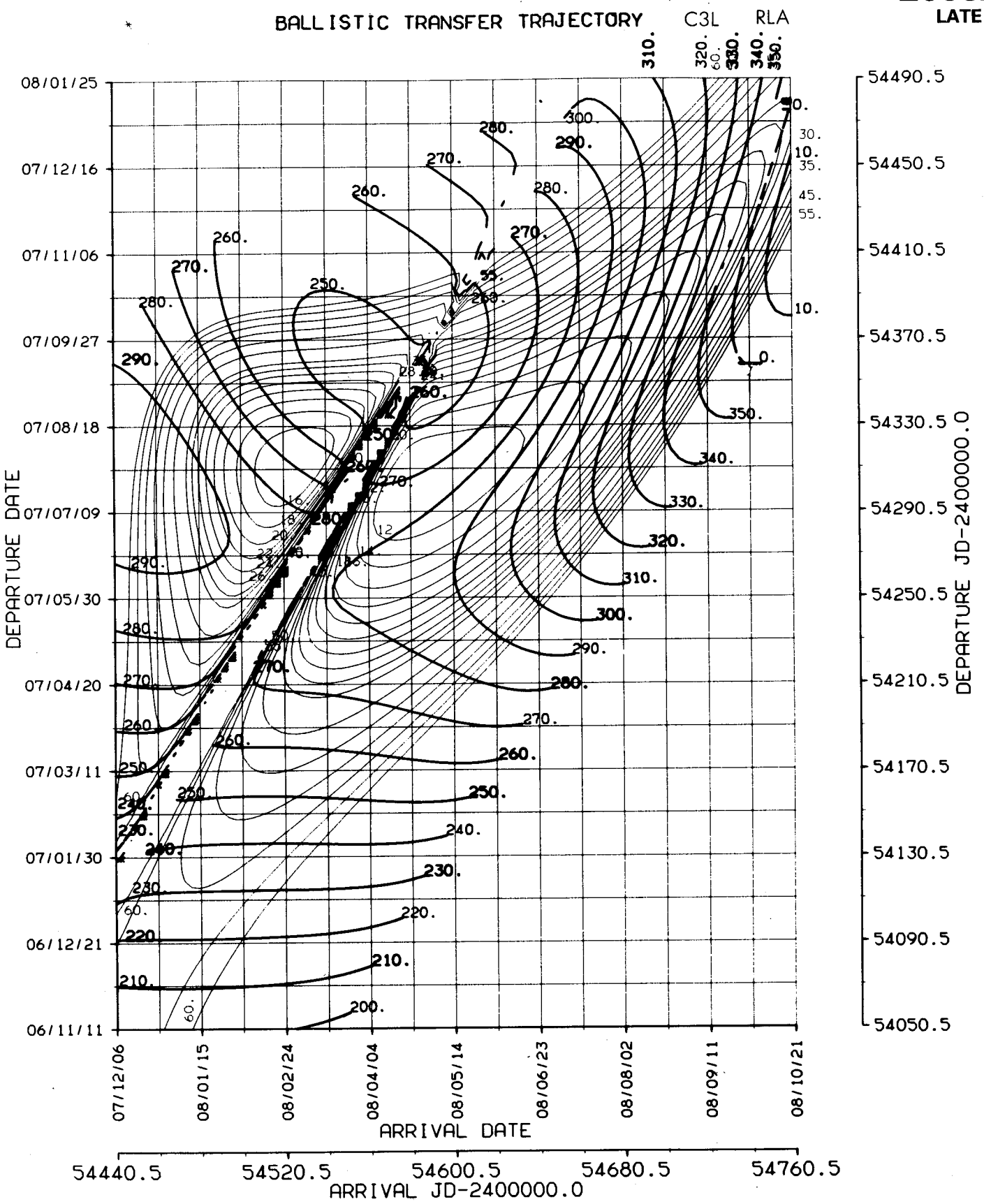
RLA

♂⊕

2006/7

EARLY




BALLISTIC TRANSFER TRAJECTORY C3L RLA
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

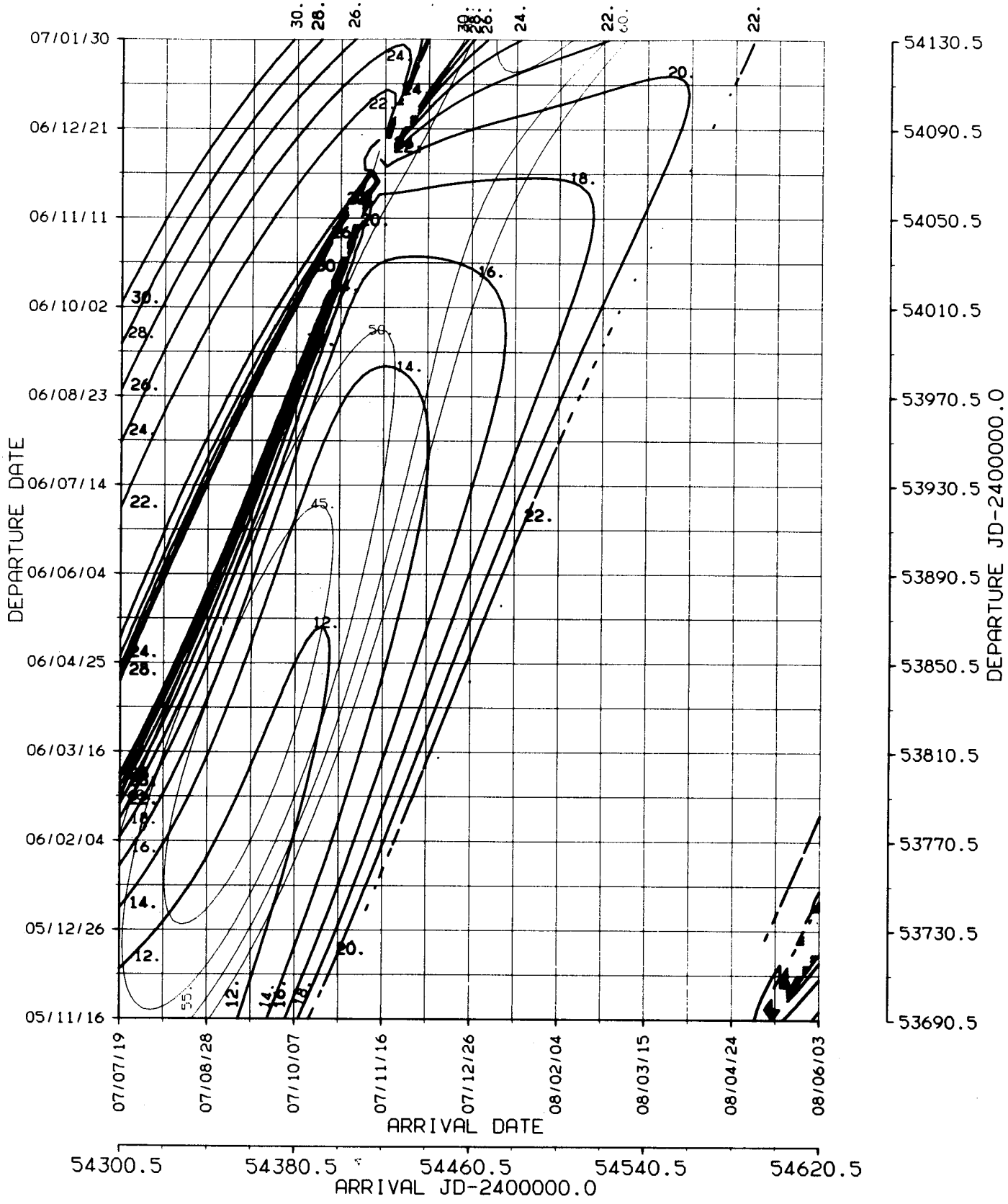
ZALS

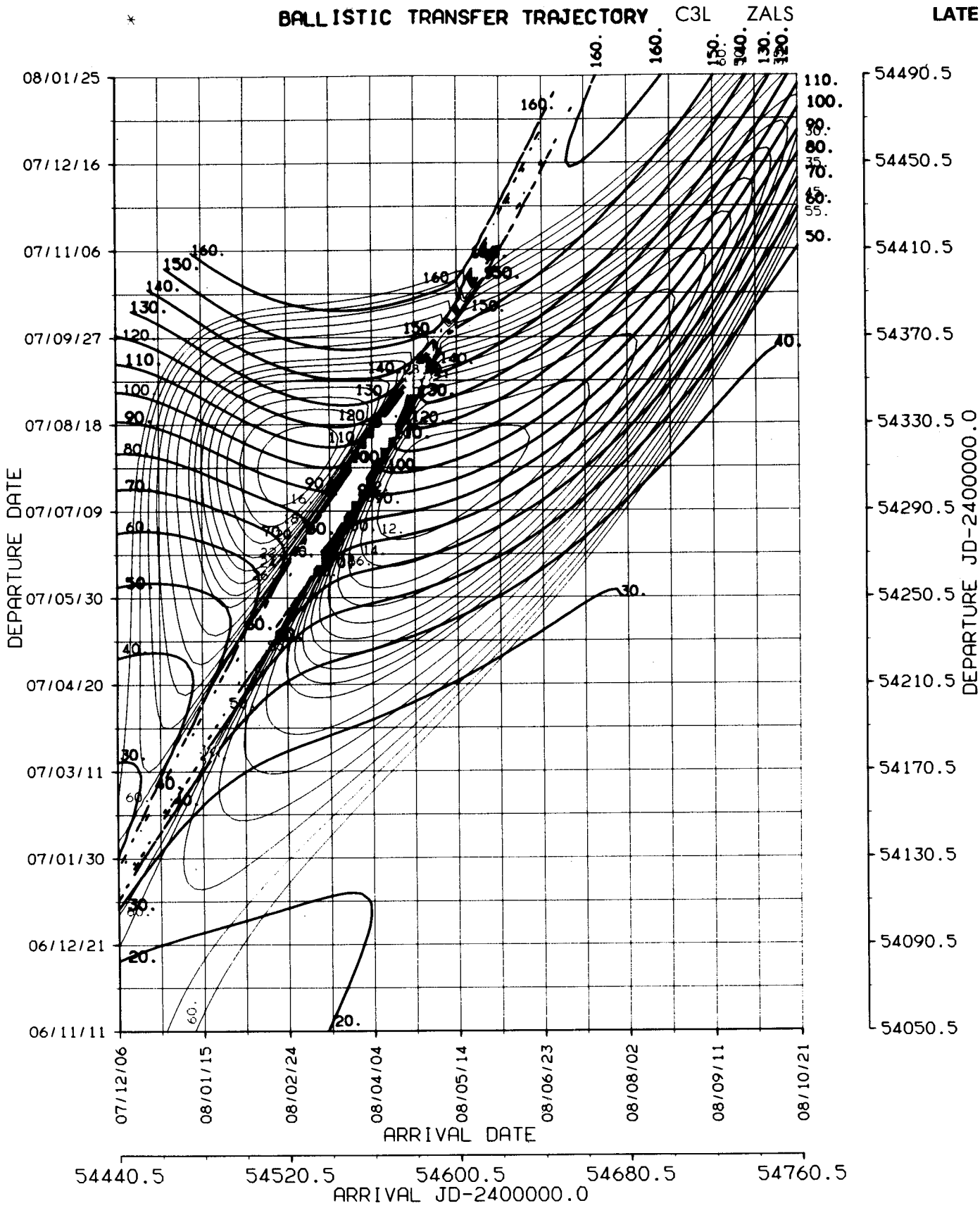
♂ ⊕

2006/7

EARLY

BALLISTIC TRANSFER TRAJECTORY C3L ZALS




BALLISTIC TRANSFER TRAJECTORY C3L ZALS
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

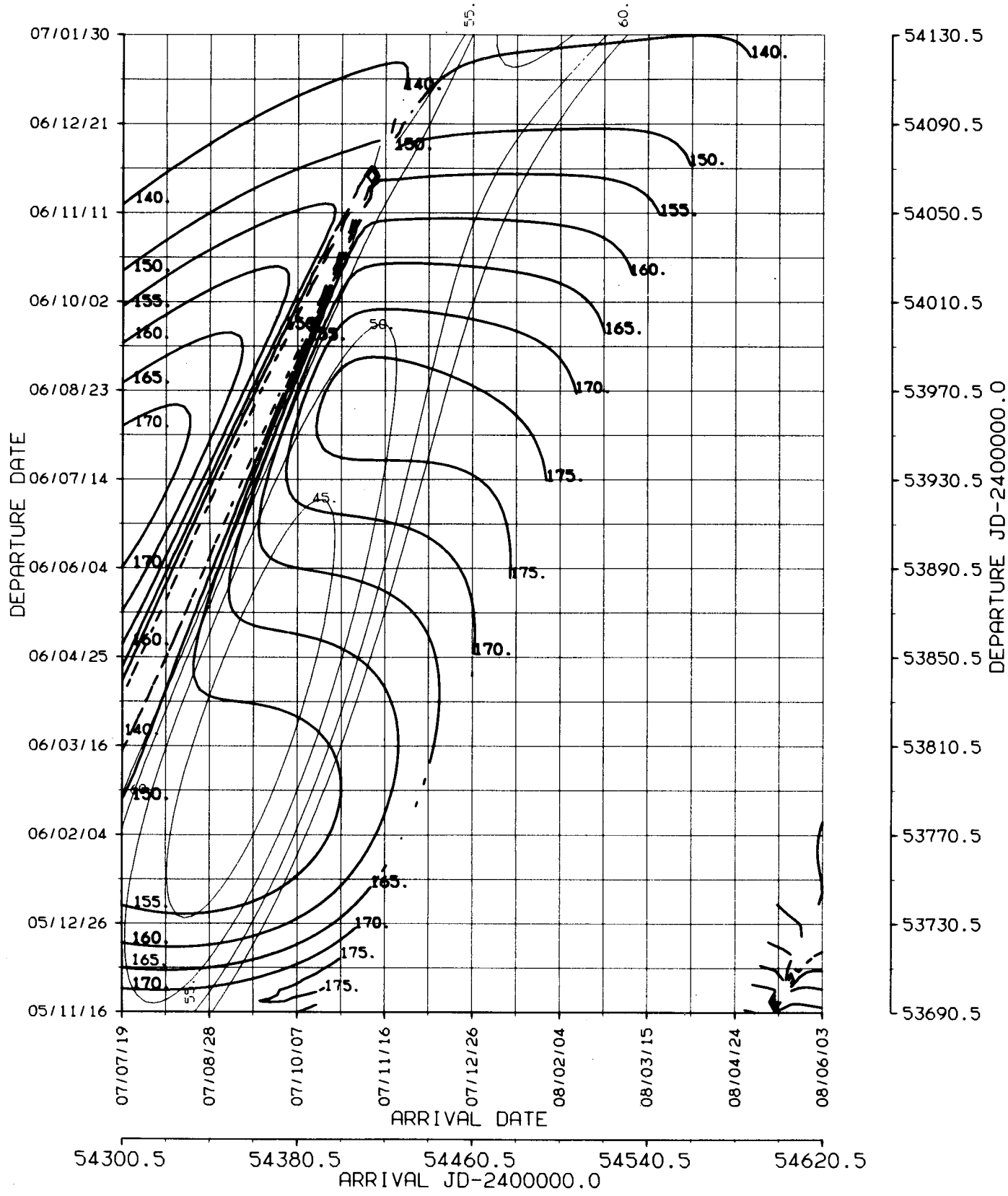
ZALE

♂ ⊕

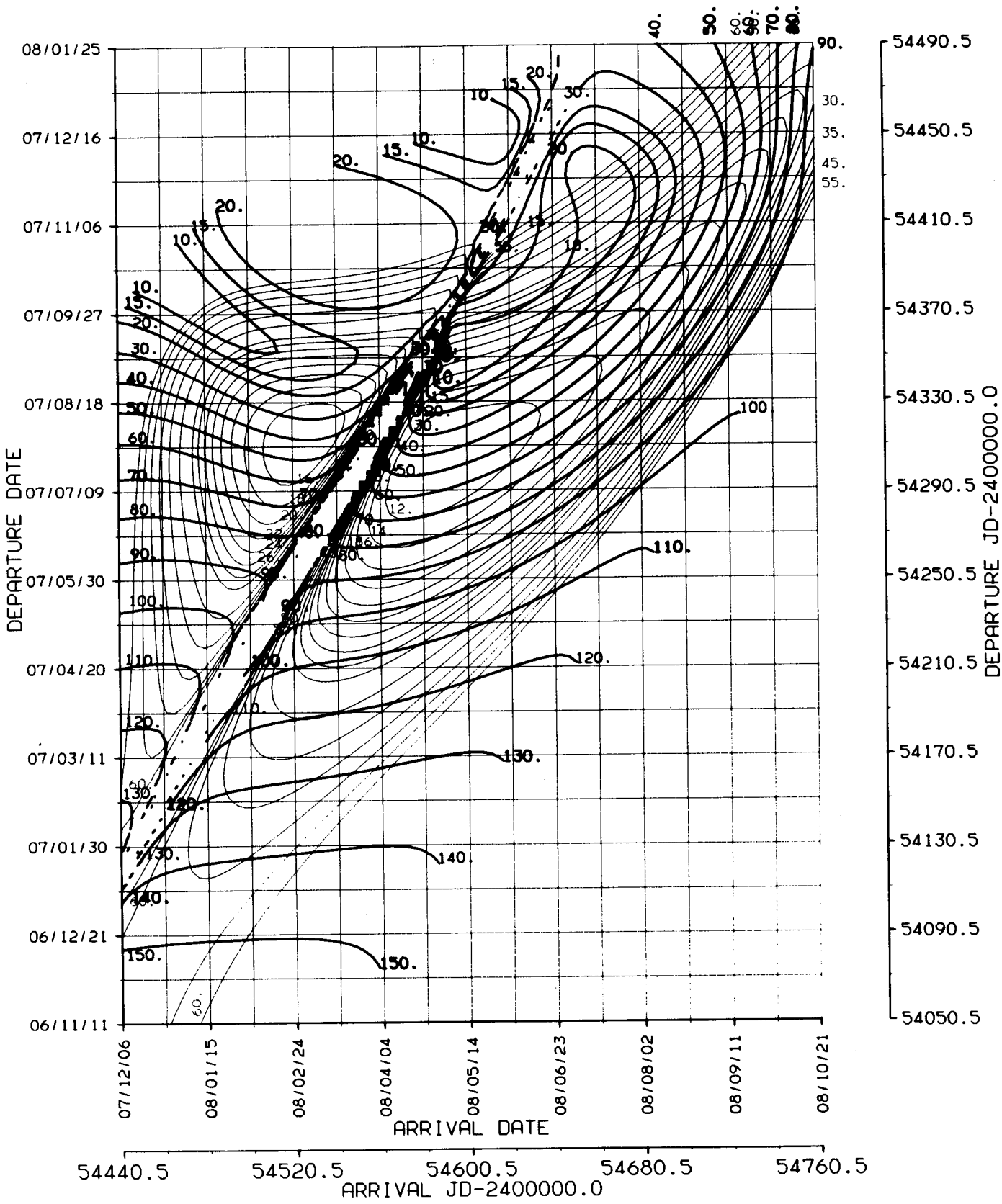
2006/7

EARLY

BALLISTIC TRANSFER TRAJECTORY C3L ZALE



BALLISTIC TRANSFER TRAJECTORY C3L ZALE

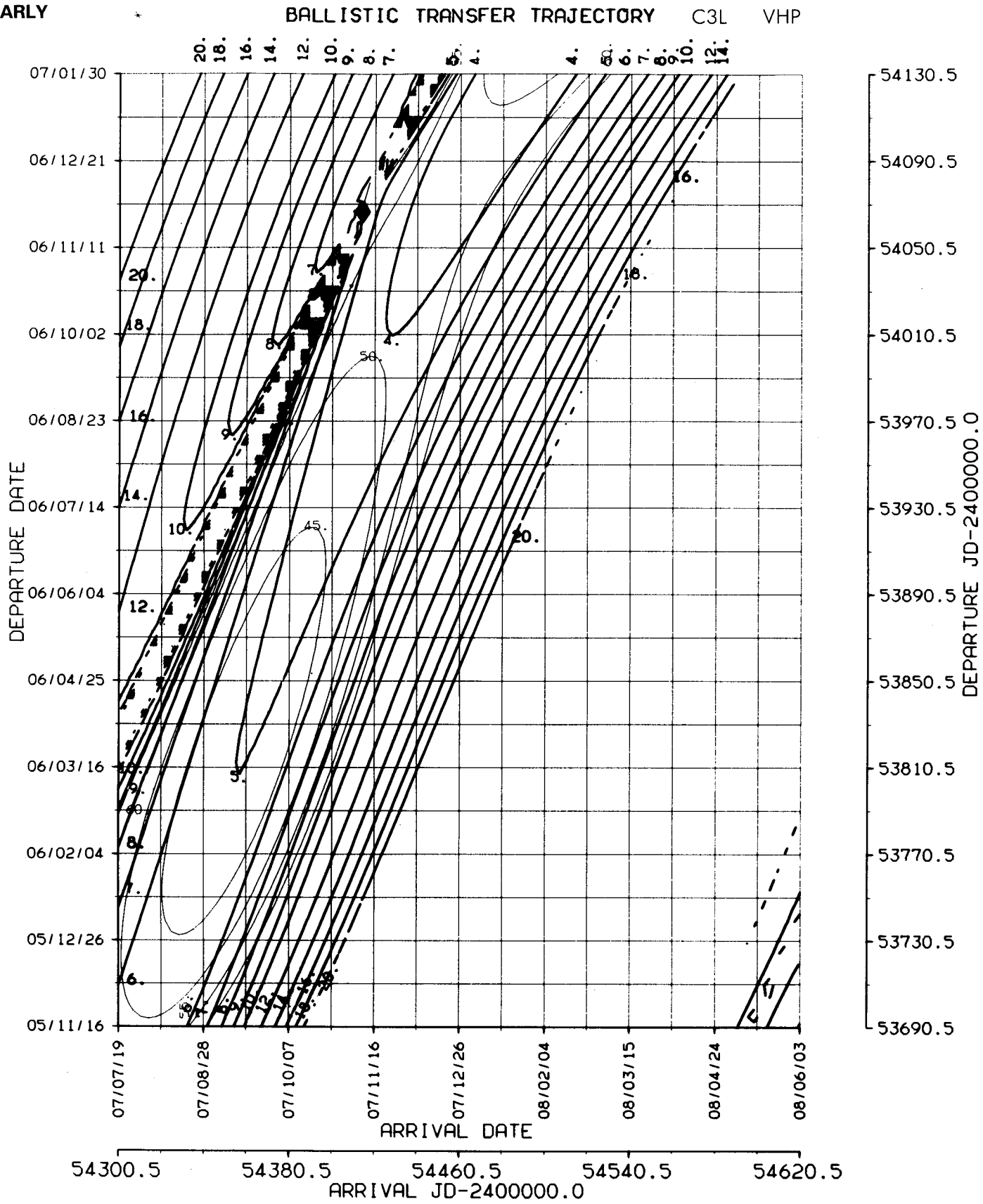


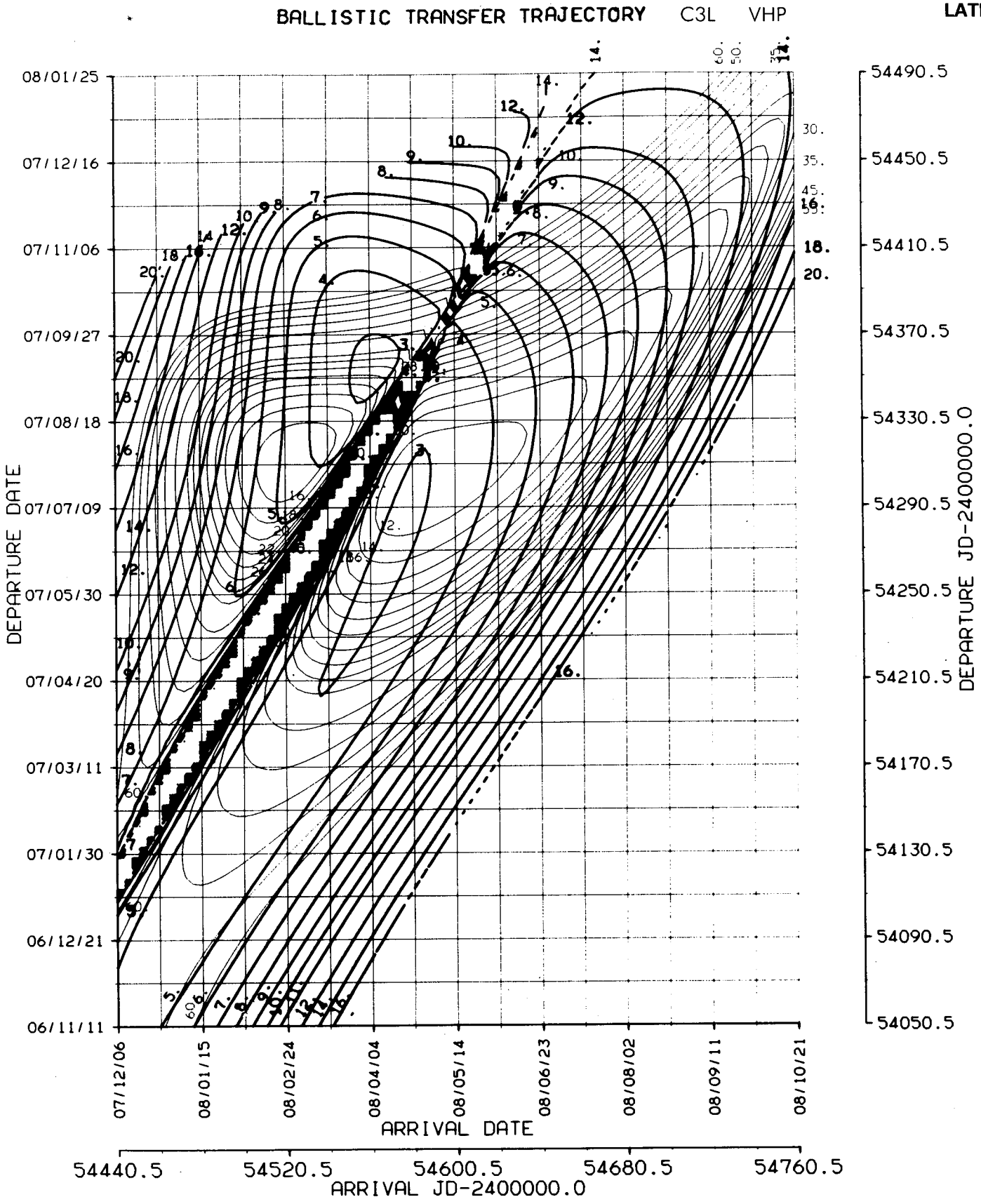
VHP

♂ ⊕

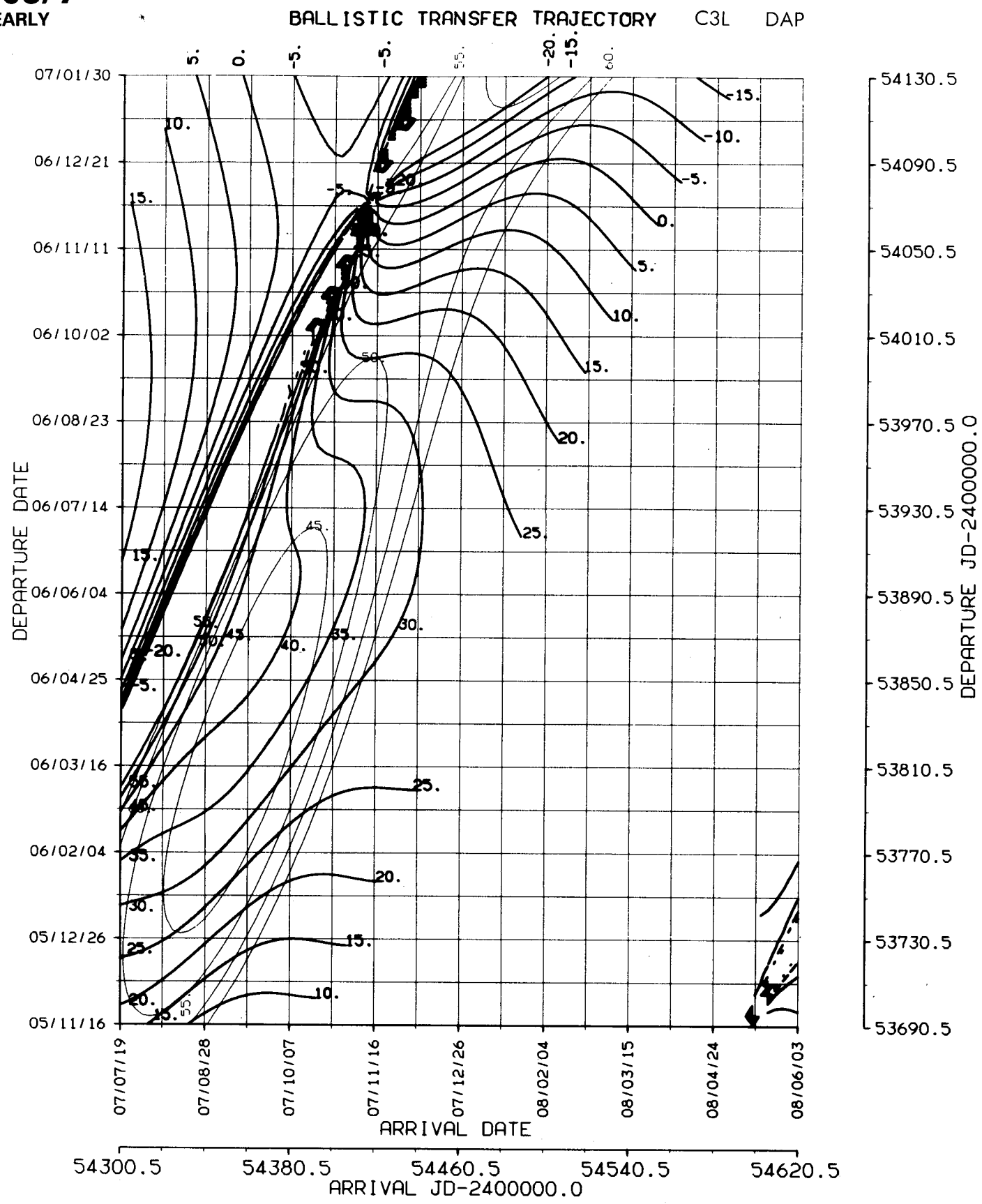
2006/7

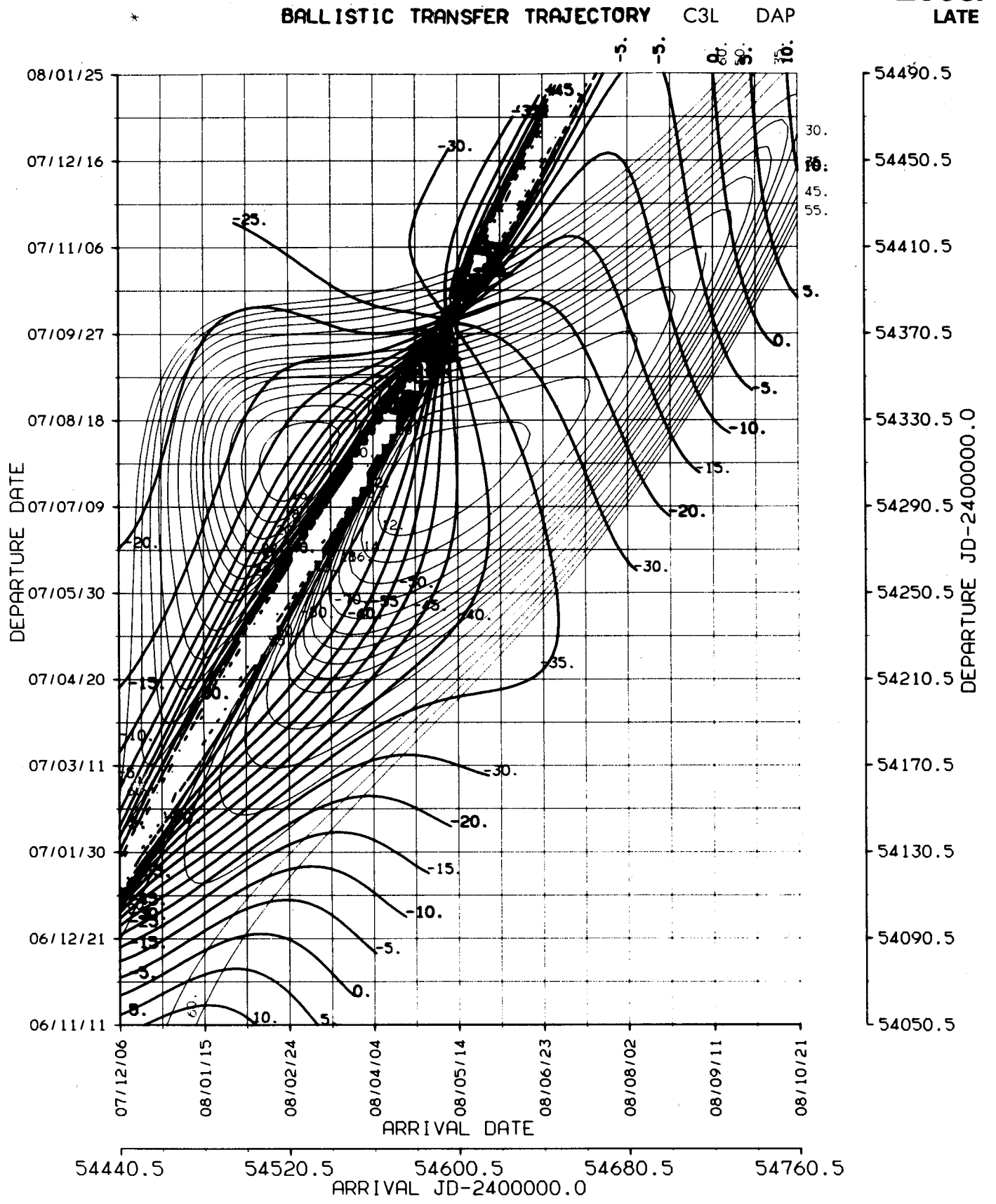
EARLY




BALLISTIC TRANSFER TRAJECTORY C3L VHP
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

DAP ♂ ⊕ 2006/7 EARLY



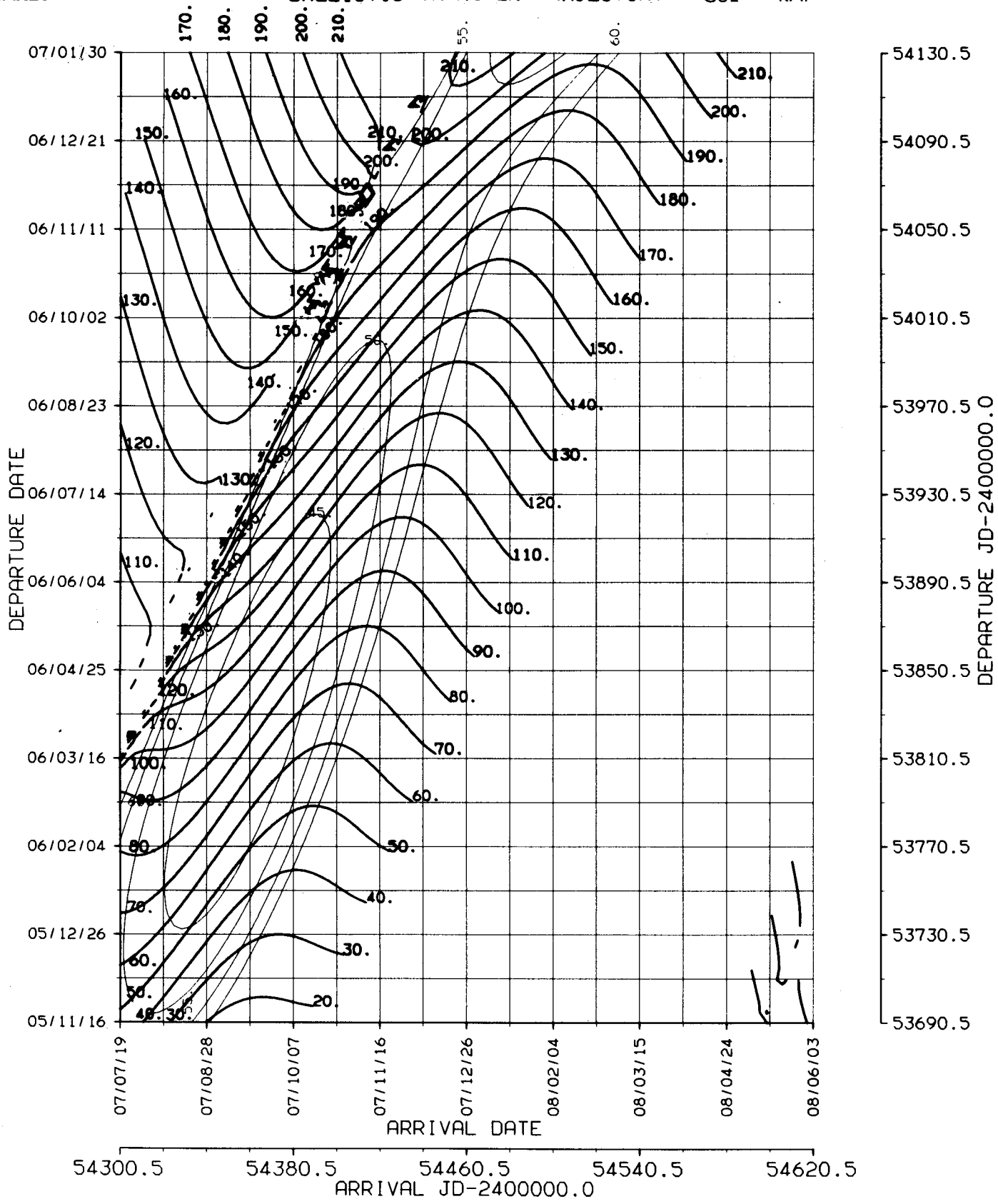

BALLISTIC TRANSFER TRAJECTORY C3L DAP
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

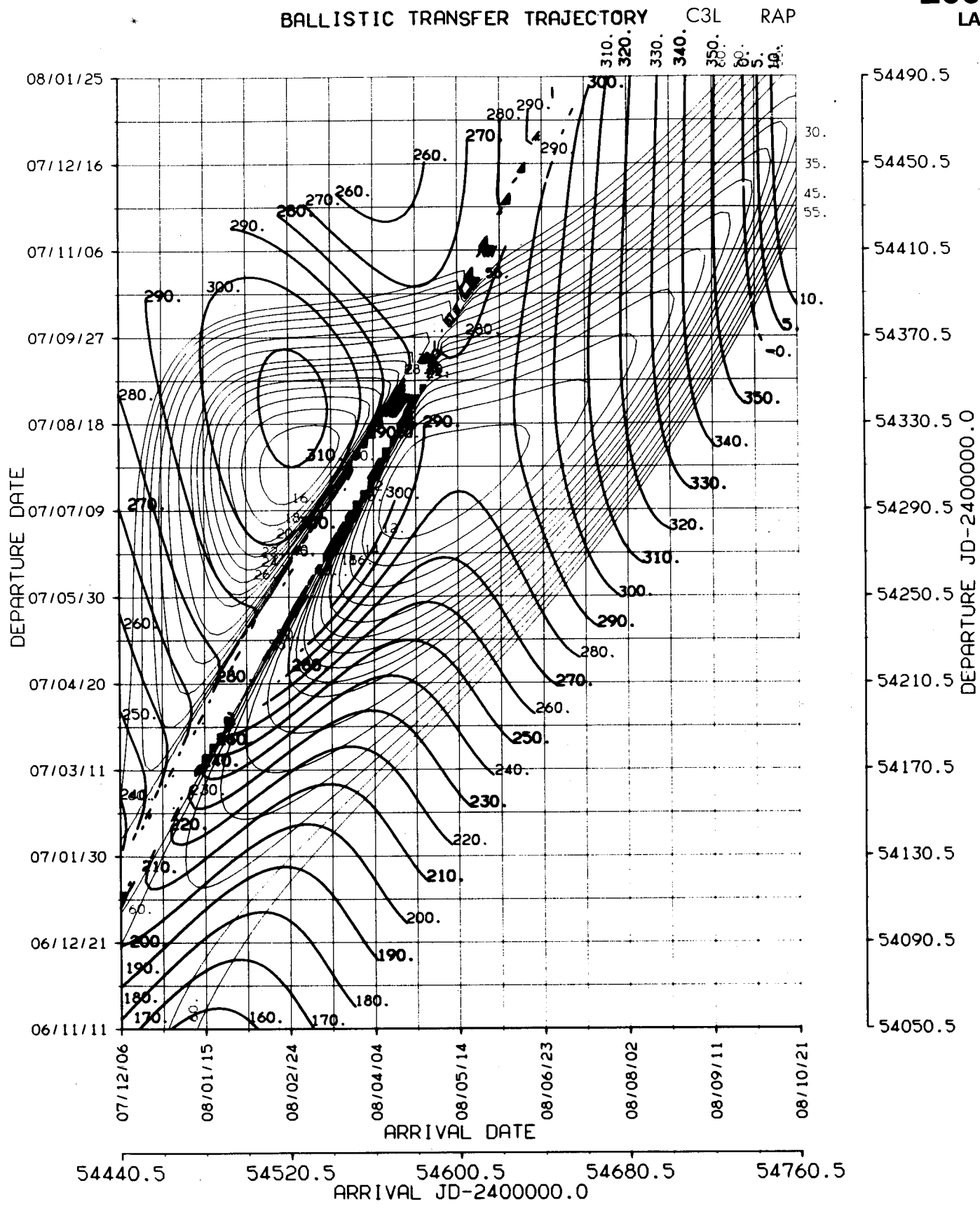
RAP

2006/7

EARLY

BALLISTIC TRANSFER TRAJECTORY C3L RAP



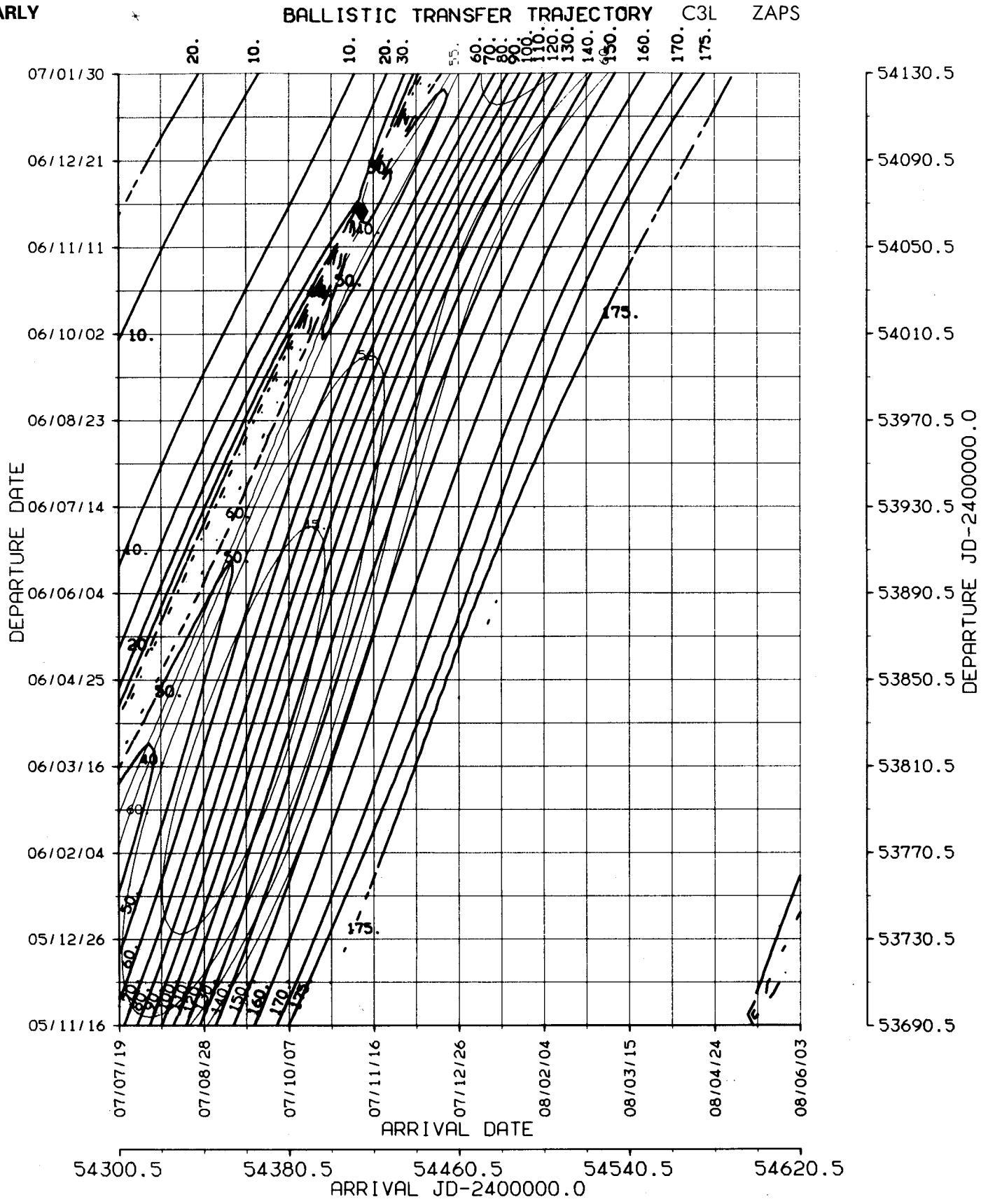

BALLISTIC TRANSFER TRAJECTORY C3L RAP
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

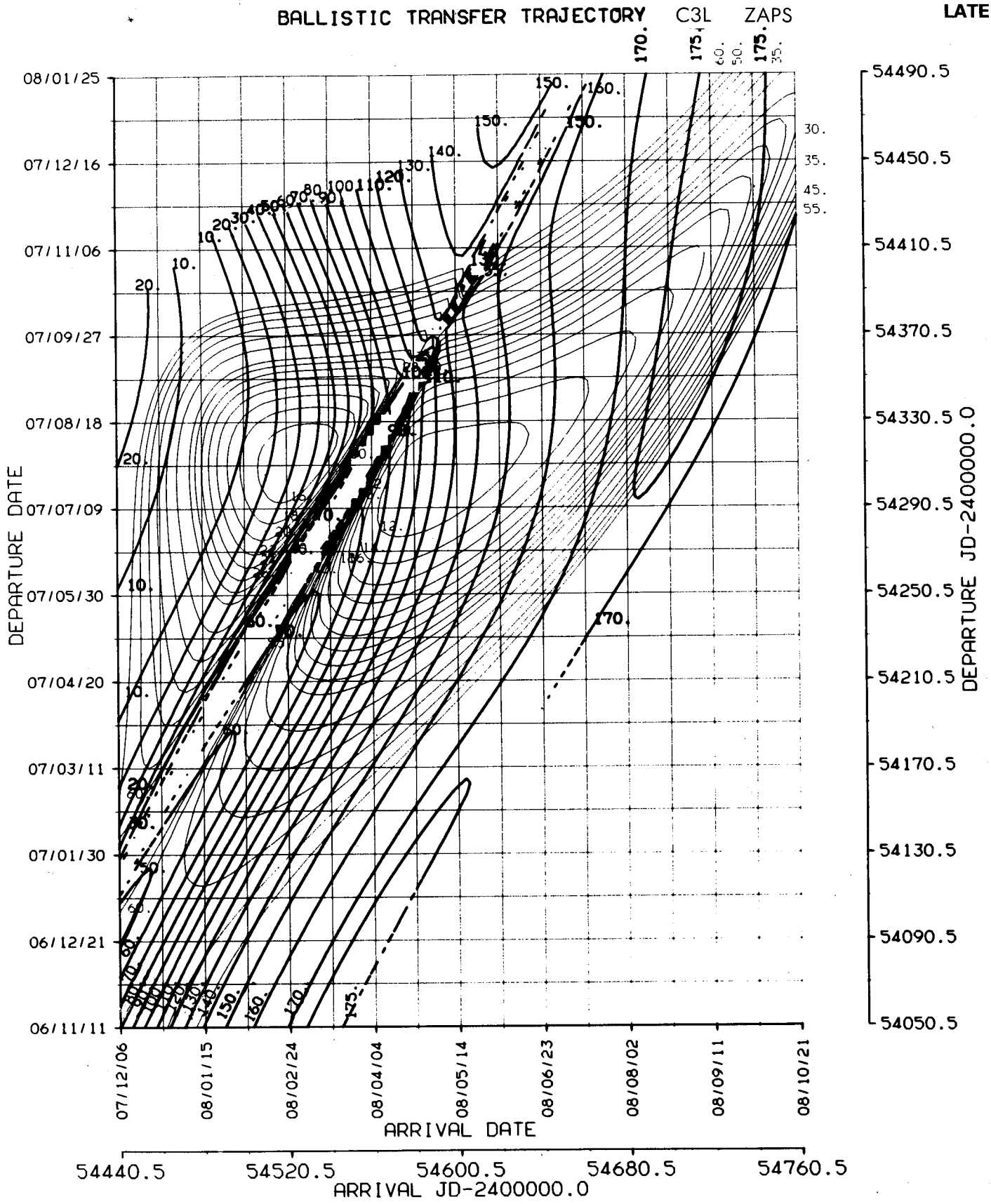
ZAPS

♂ ⊕

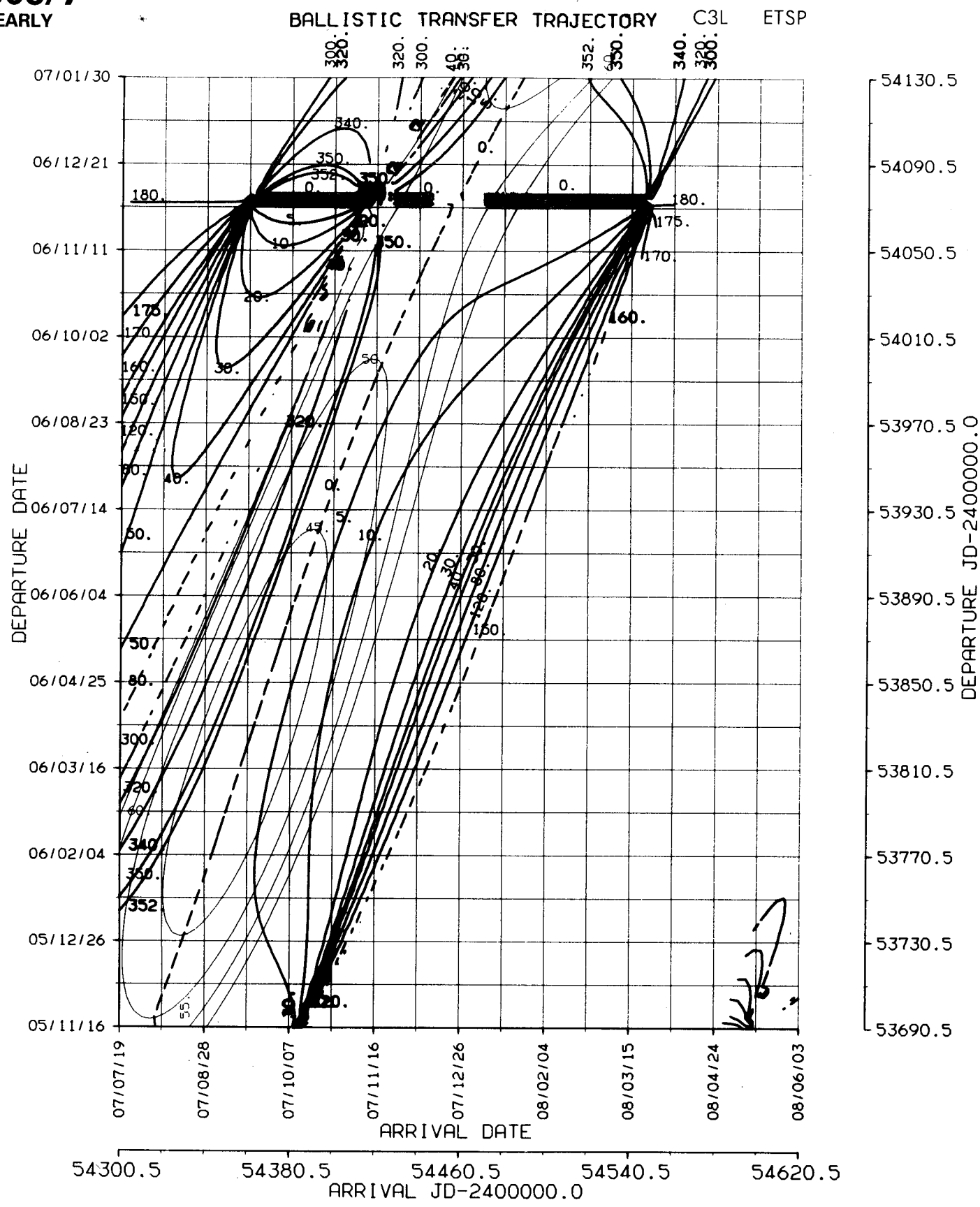
2006/7

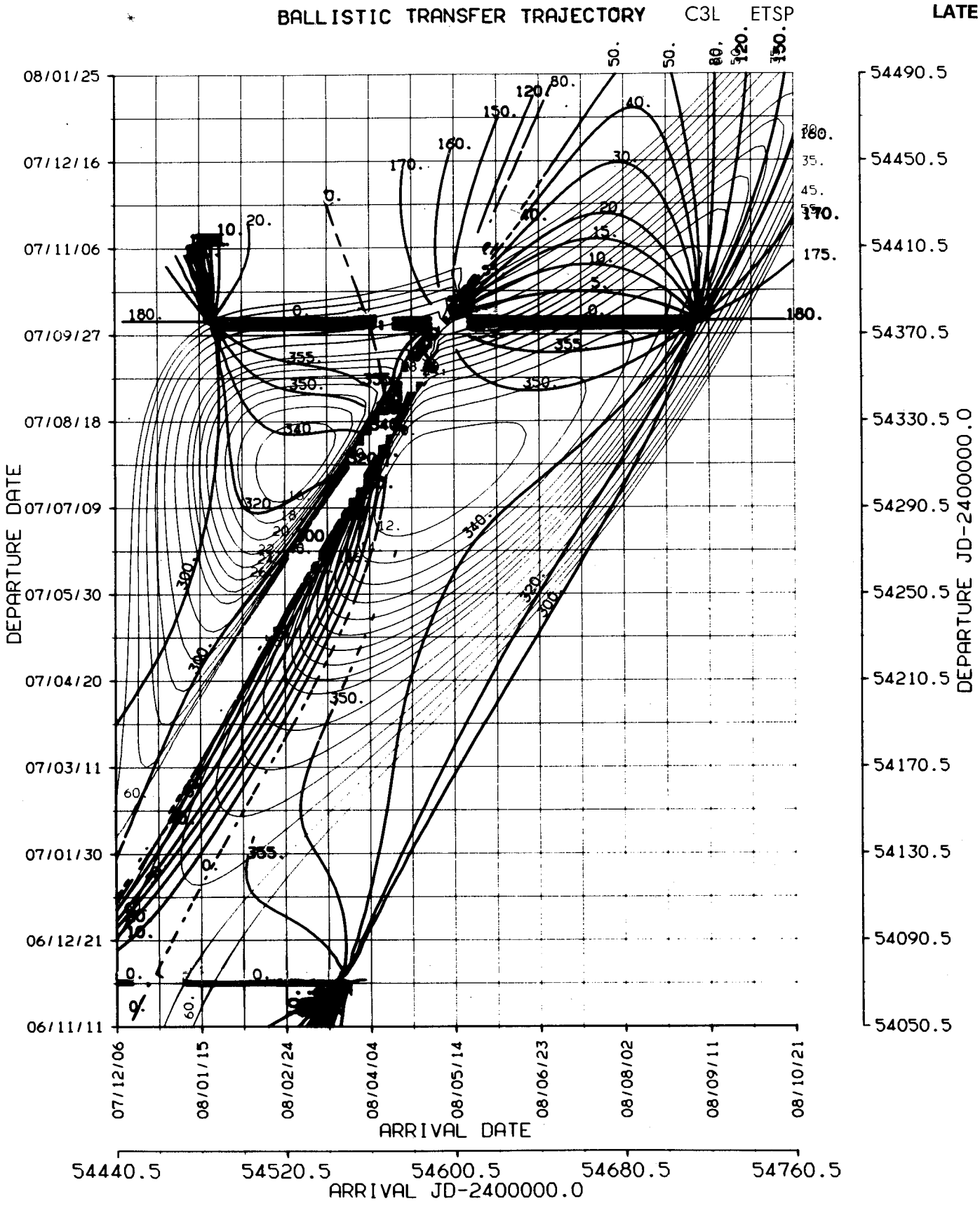
EARLY




BALLISTIC TRANSFER TRAJECTORY C3L ZAPS
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0

ETSP
♂ ⊕
2006/7
EARLY




BALLISTIC TRANSFER TRAJECTORY C3L ETSP
DEPARTURE DATE
08/01/25
07/12/16
07/11/06
07/09/27
07/08/18
07/07/09
07/05/30
07/04/20
07/03/11
07/01/30
06/12/21
06/11/11
DEPARTURE JD-2400000.0
54490.5
54450.5
54410.5
54370.5
54330.5
54290.5
54250.5
54210.5
54170.5
54130.5
54090.5
54050.5
07/12/06
08/01/15
08/02/24
08/04/04
08/05/14
08/06/23
08/08/02
08/09/11
08/10/21
ARRIVAL DATE
54440.5
54520.5
54600.5
54680.5
54760.5
ARRIVAL JD-2400000.0