CONTEMPORARY PLATE MOTIONS FROM LAGEOS: A DECADE LATER

BY

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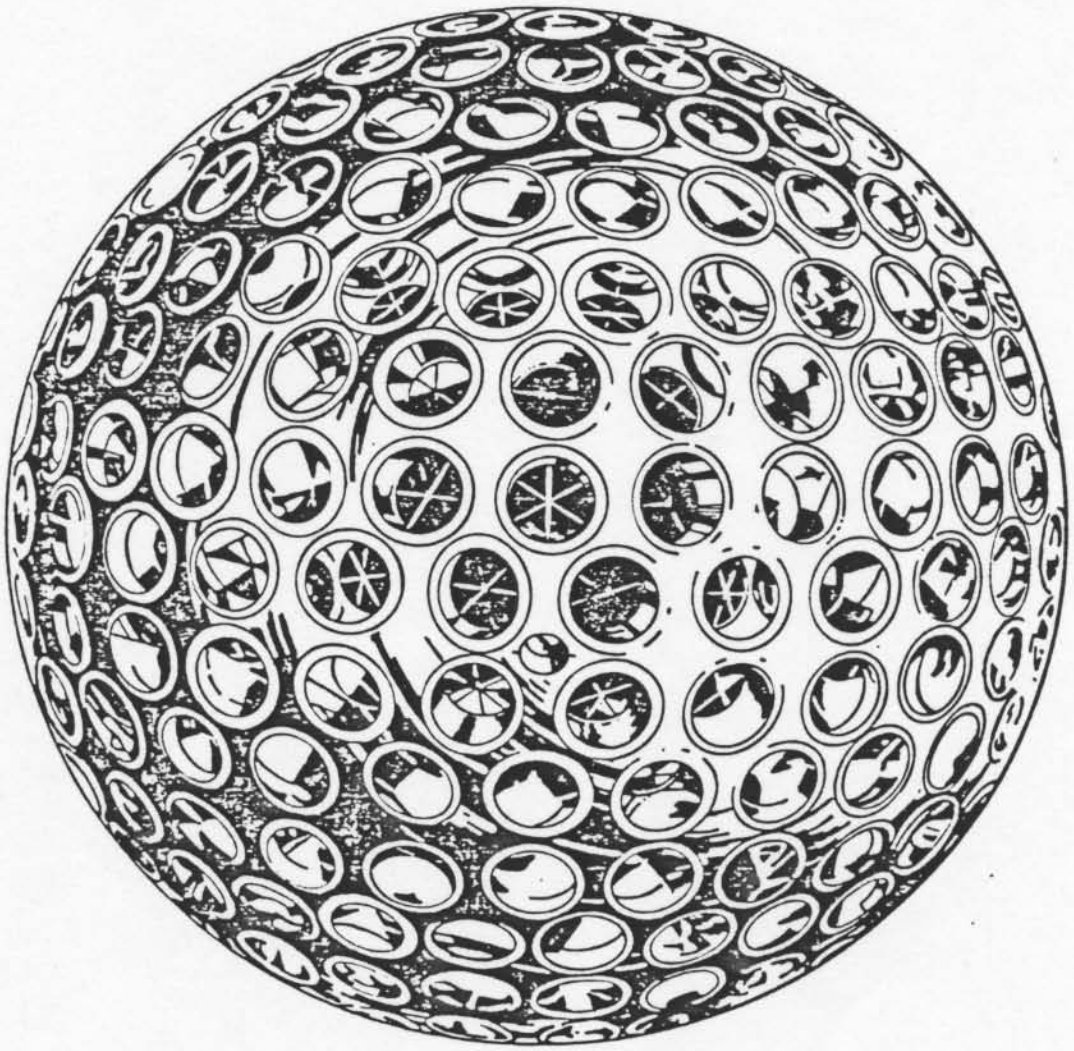
SCIENTIFIC OBJECTIVES

RESEARCH IN EARTH SCIENCES MADE POSSIBLE THROUGH VERY PRECISE SATELLITE GEODESY WITH PARTICULAR EMPHASIS ON FURTHERING OUR UNDERSTANDING OF:

- GLOBAL PLATE TECTONICS
- REGIONAL CRUSTAL DEFORMATIONS
- GEODETIC REFERENCE DATUM AND EARTH ORIENTATION
- GEOPOTENTIAL MODELING
- EARTH AND OCEAN TIDES



LAGEOS

(LASER GEODYNAMICS SATELLITE)

LAUNCH: MAY 4, 1976

SPACECRAFT: SPHERICAL, 60 CM DIAMETER
406.965 KG
426 LASER RETRO-REFLECTORS, 3.8 CM DIAMETER

ORBIT:		
	SEMIMAJOR AXIS	12265 KM
	INCLINATION	109.8 DEGREES
	ECCENTRICITY	0.004
	PERIGEE HEIGHT	5858 KM
	APOGEE HEIGHT	5958 KM
	NODE RATE	+0.343 DEG/DAY
	PERIGEE RATE	-0.214 DEG/DAY
	SEMIMAJOR AXIS RATE	-1.1 MM/DAY

LAGEOS MISSION OBJECTIVES:

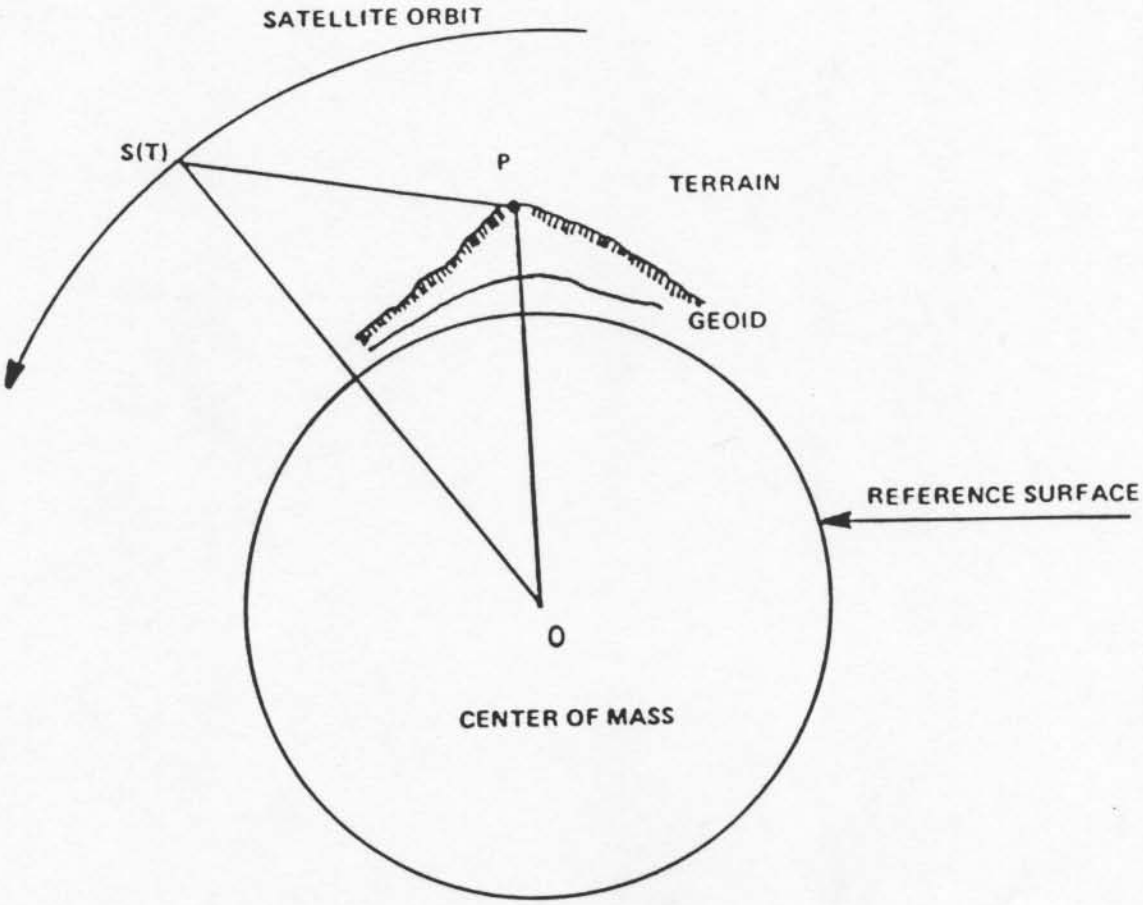
.... o "RELATIVE TECTONIC PLATE MOTION ON A GLOBAL SCALE TO WITHIN 1.0 CM/YEAR AVERAGED OVER FOUR YEARS;

o MOTIONS ACROSS SELECTED FAULTS TO WITHIN 0.5 CM/YEAR AVERAGED OVER TWO YEARS;

o RELATIVE VERTICAL MOTIONS BETWEEN LOCAL SITES TO WITHIN 2.0 CM/YEAR AVERAGED OVER FOUR YEARS; (and)

o STATION LOCATIONS TO WITHIN 10 CM;" ....

Project Plan
for
Lageos Earth Dynamics
August 1975



DYNAMIC SATELLITE GEODESY

OBSERVABLES: RANGE (PS) (GIVEN SPEED OF LIGHT) AND EPOCH OF MEASUREMENT (T).

RECOVERABLES: ORBIT (OS); STATION POSITIONS (OP); PARAMETERS DEFINING THE FORCE FIELD (INCLUDING GM), EARTH ORIENTATION, ETC.

METHOD: NUMERCAL INTEGRATION OF EQUATIONS OF MOTION OF SATELLITE IN AN INERTIAL COORDINATE SYSTEM.

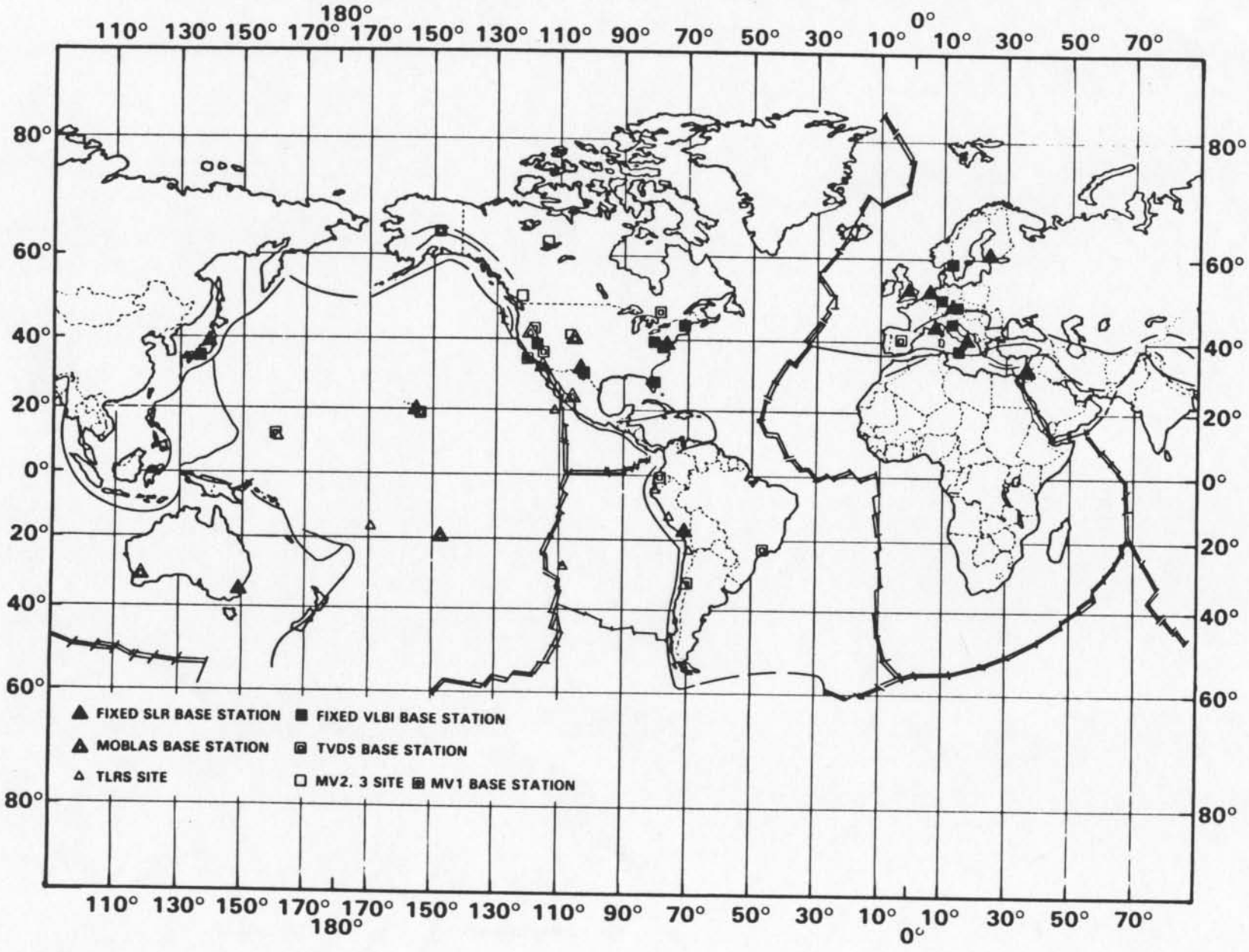
RESEARCH OBJECTIVES

- Measurement of tectonic plate kinematics through the use of satellite geodesy.

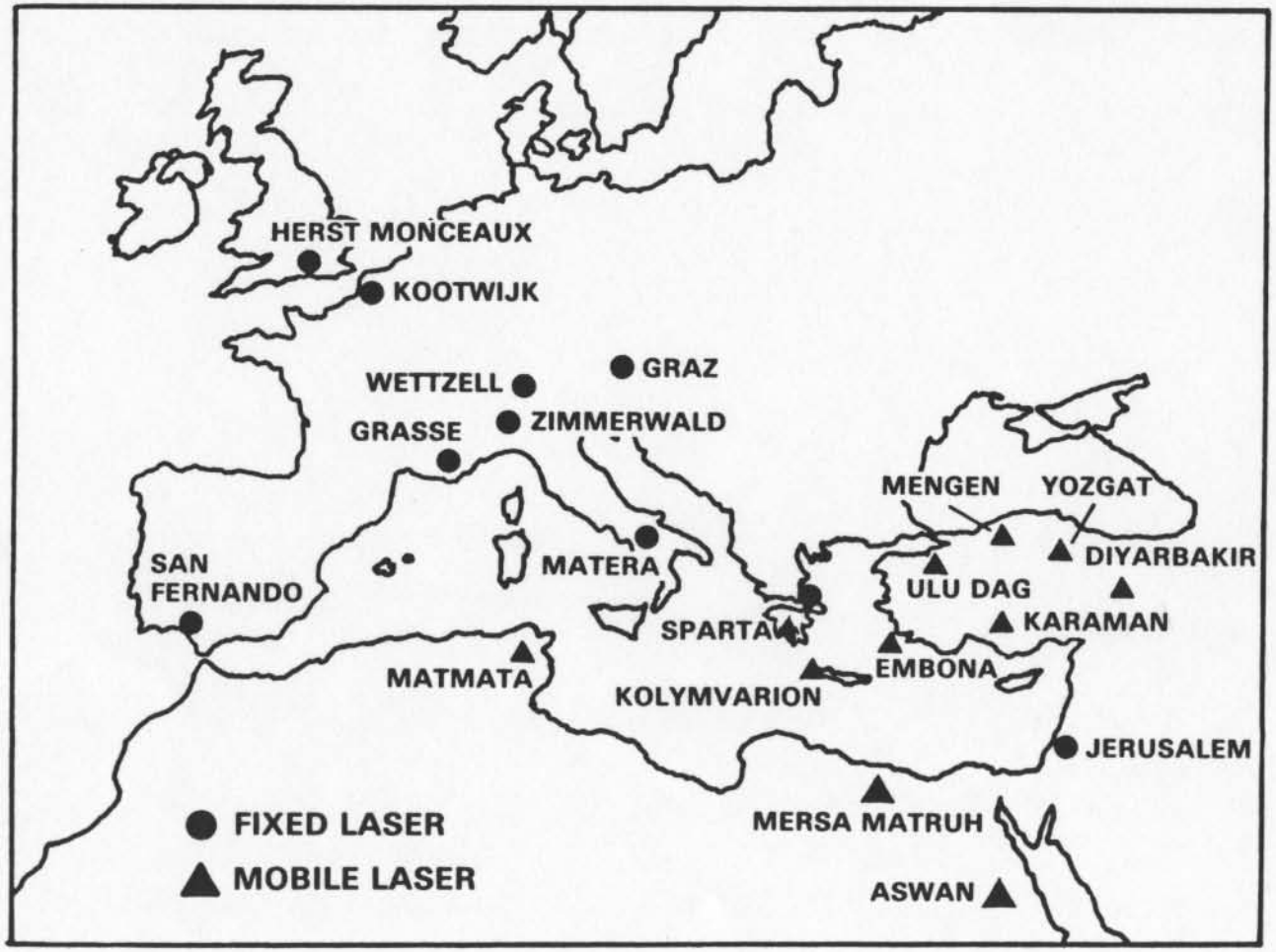
- Comparison of observed contemporary plate motions with million-year averaged motions predicted from geologic models.

- Assessment of the contribution of space geodesy to the further understanding of global and regional tectonic activity.

GLOBAL CRUSTAL DYNAMICS PROJECT SITES

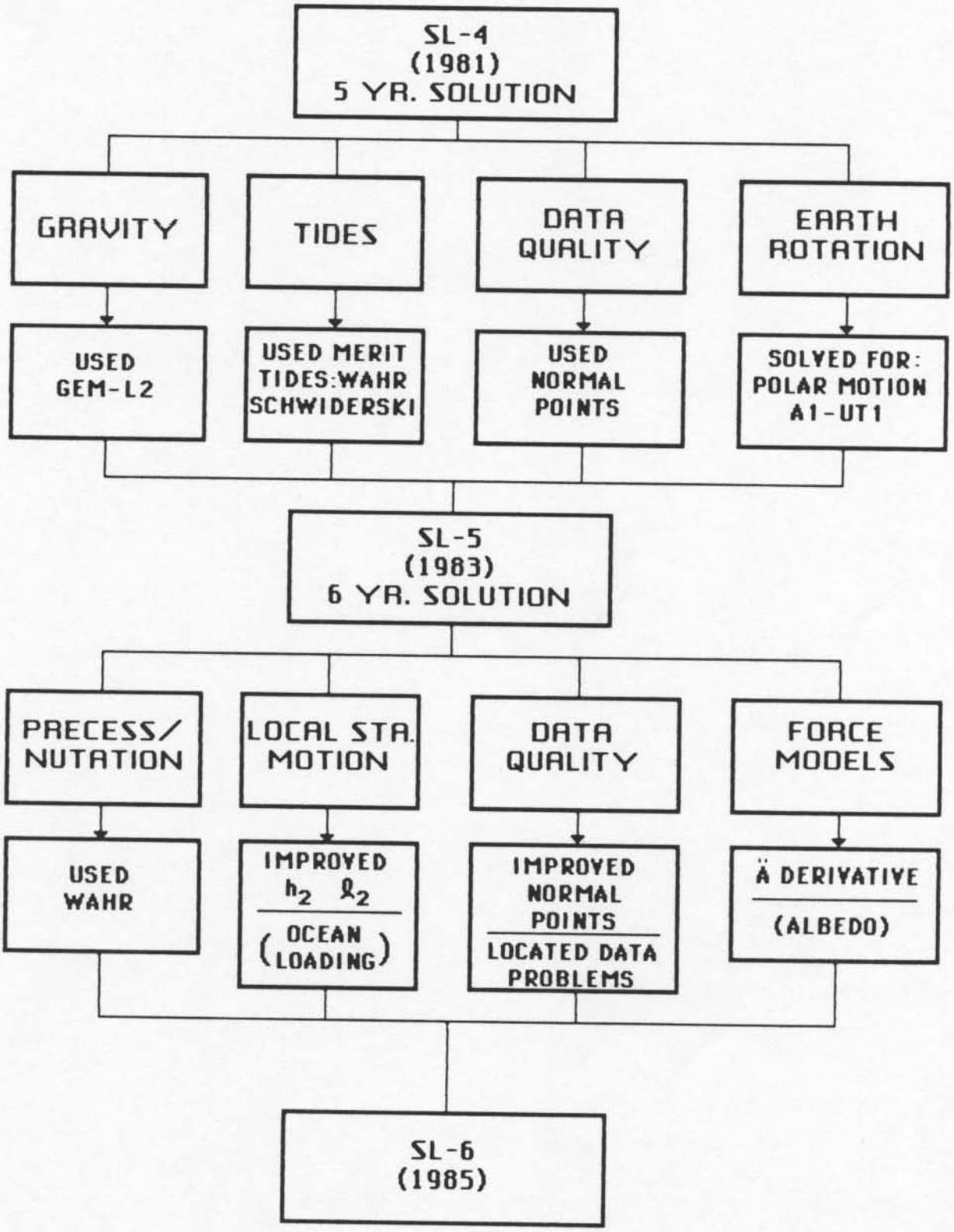


MEDITERREAN SITES

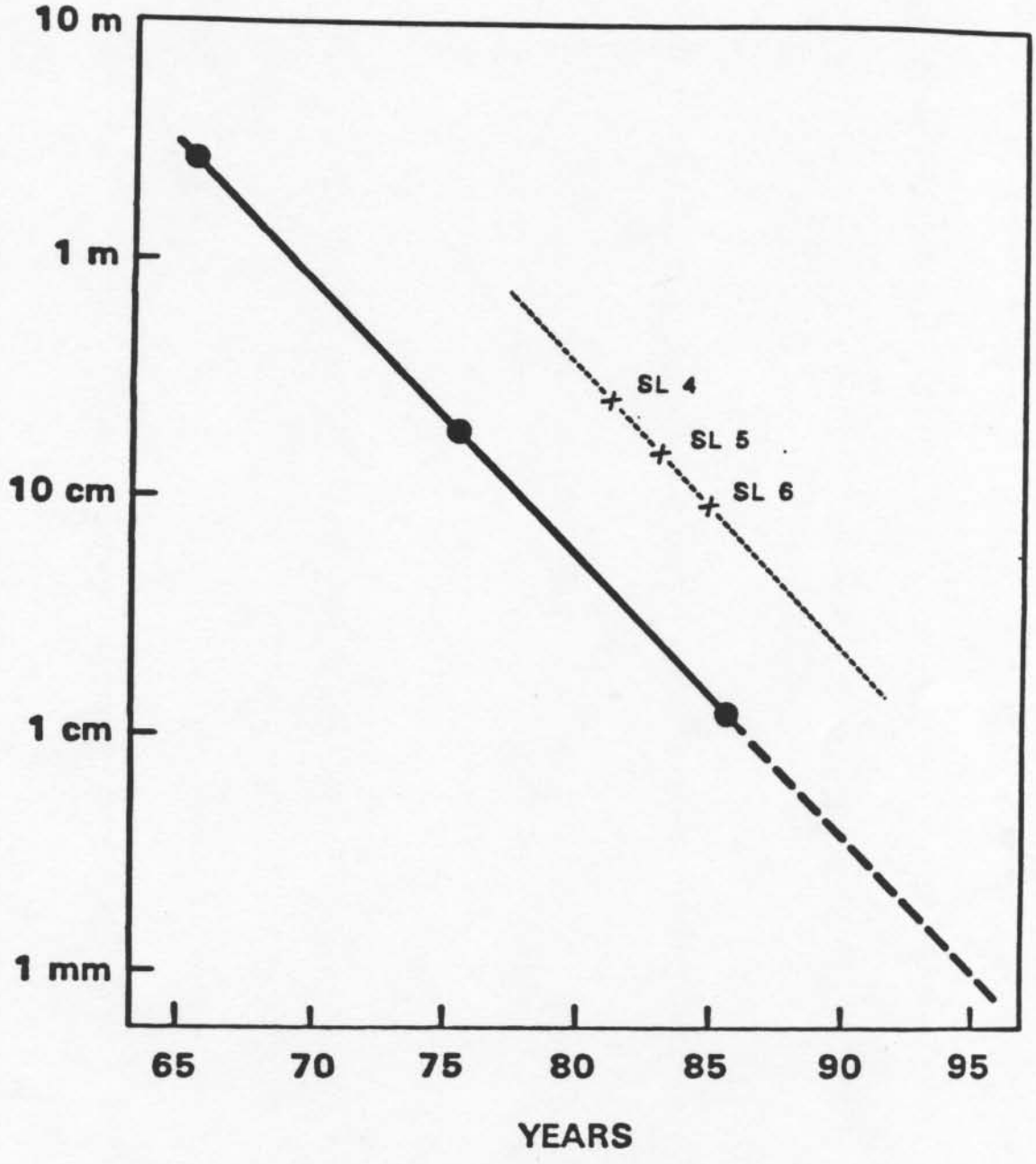


NASA HQ EE84-1776(1)
7-6-84

EVOLUTION OF THE GFSC SL-6 SOLUTION



GEODETIC SYSTEM ACCURACY



SYSTEM ACCURACY GOAL FOR 1995: 1 mm

GSFC SL-6 GEODETIC SOLUTION

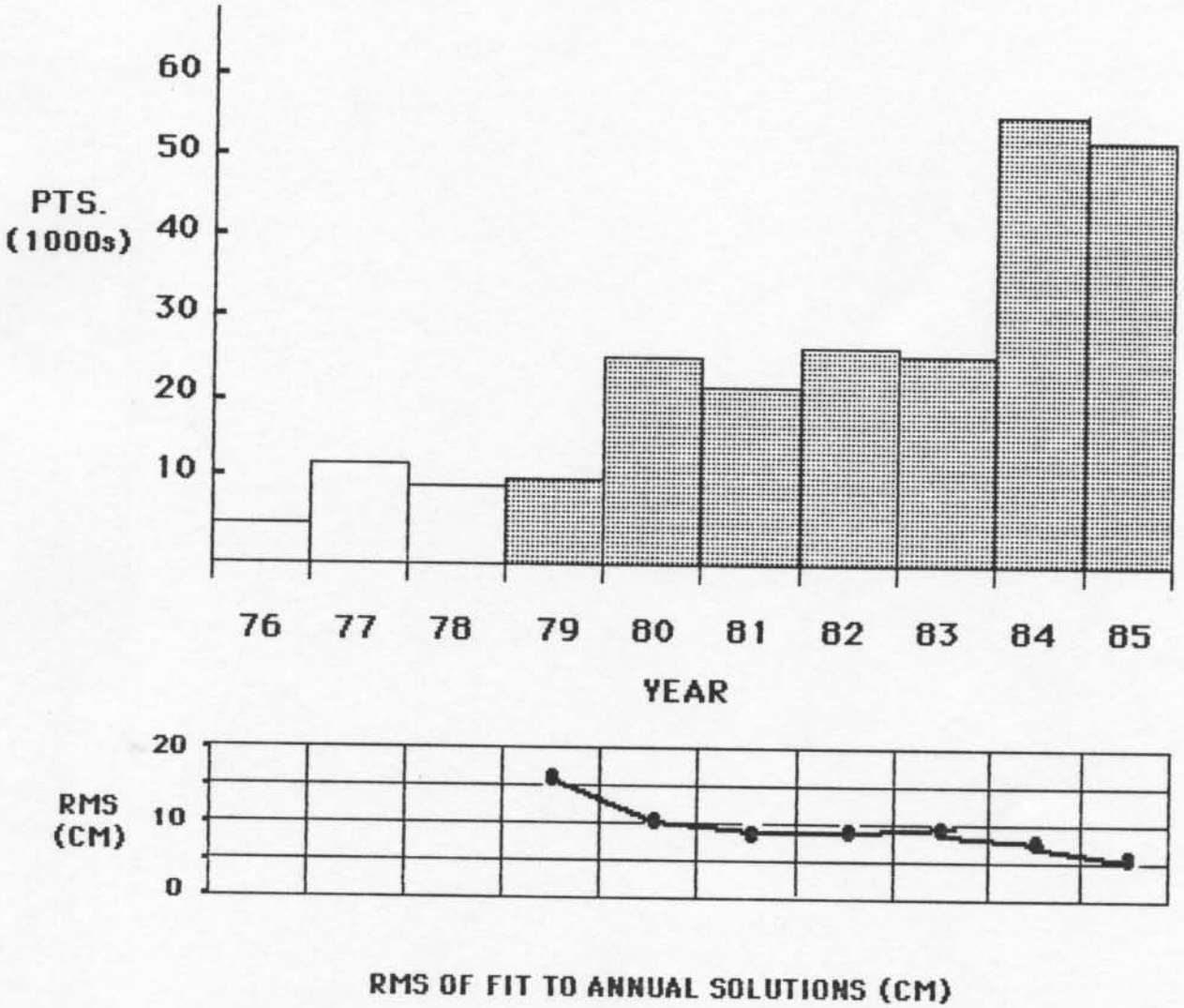
- REFERENCE FRAME
  - SL6 TRACKING STATION LOCATIONS
  - LAGEOS EARTH ROTATION AND ORIENTATION (EVERY 5 DAYS)
  - WAHR'S NUTATION SERIES
  - JPL DE-718 PLANETARY EPHEMERIDES: FK4 REFERENCE SYSTEM

- FORCE MODEL
  - PGS-1680 GRAVITY FIELD (COMPLETE TO DEGREE AND ORDER 20)
  - LUNI-SOLAR AND PLANETARY GRAVITATIONAL PERTURBATIONS (VENUS THROUGH SATURN)
  - LAGEOS DERIVED GM = 398600.436 km^3/s^2
  - WAHR'S SOLID EARTH TIDES (O_1, P_1, RES_2, K_1, RES_1, ψ_1, M_2, S_2, K_2)
  - SCHWIDERSKI OCEAN TIDES. DEGREES 2-3 ADJUSTED, 4-6 FIXED
  - DIRECT SOLAR RADIATION PRESSURE
  - ALONG TRACK ACCELERATION
  - GENERAL AND SPECIAL RELATIVISTIC EFFECTS ARE NOT APPLIED

- MEASUREMENTS
  - MARINI-MURRAY TROPOSPHERIC REFRACTION MODEL WITH EXCLUSIVELY SURFACE METEOROLOGICAL MEASUREMENTS
  - VELOCITY OF LIGHT (299792458 M/S)
  - VERTICAL AND HORIZONTAL TIDE DISPLACEMENT (h_2 = 0.60, ℓ_2 = 0.075)
  - NORMAL POINTS (2 MINUTE BINS)

- DATA SPAN
  - JANUARY 1979 TO DECEMBER 1984

LAGEOS NORMAL POINT DISTRIBUTION

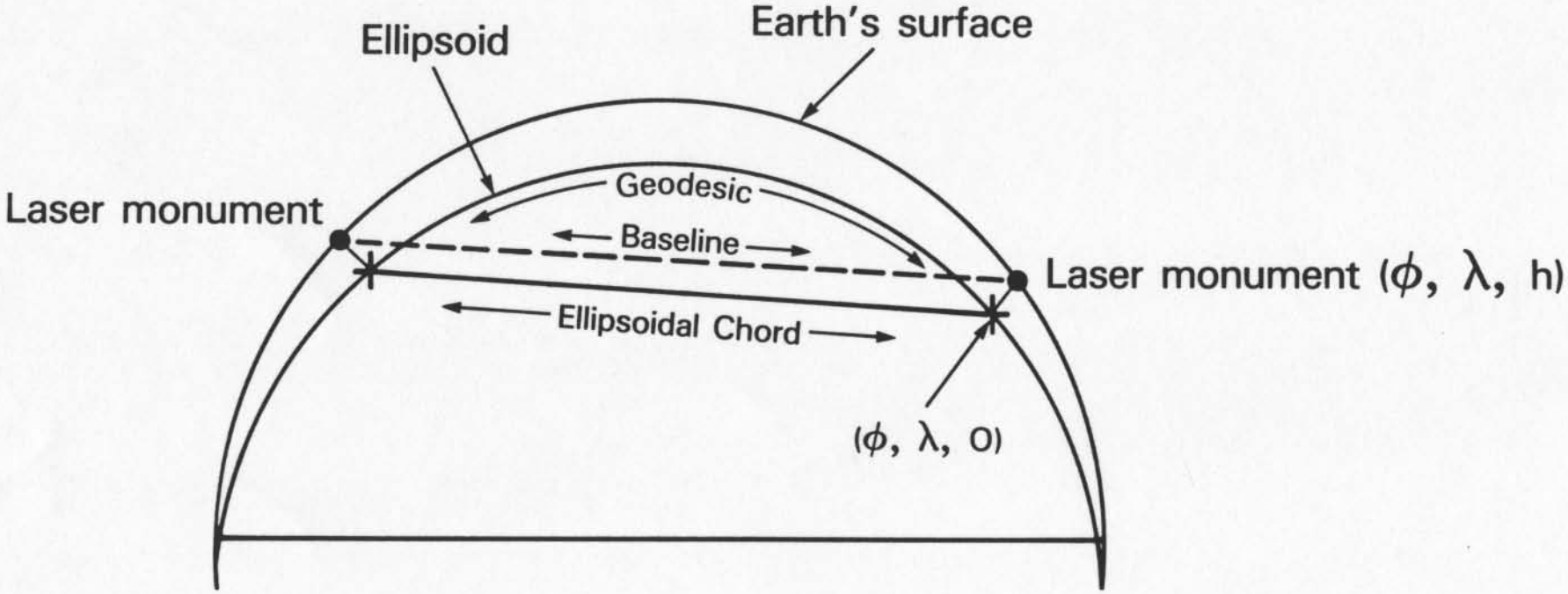


RMS OF FIT TO ANNUAL SOLUTIONS (CM)

GLOBAL GEODETIC STATION POSITIONS FOR A LASER REFERENCE FRAME

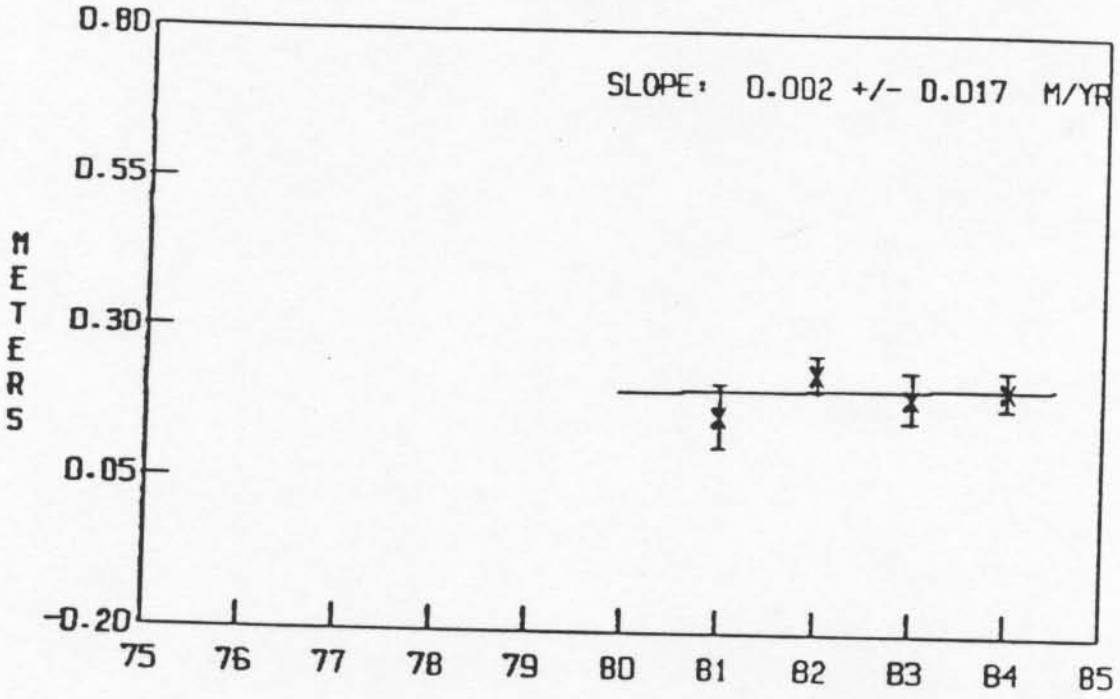
TEMPORAL RESOLUTION	ESTIMATED PRECISION VERTICAL	HORIZONTAL
MULTI–YEAR SOLUTION	± 1 cm	± 2 cm
ANNUAL SOLUTION	± 2 cm	± 3 cm
MONTHLY SOLUTIONS	± 6 cm	± 6 cm

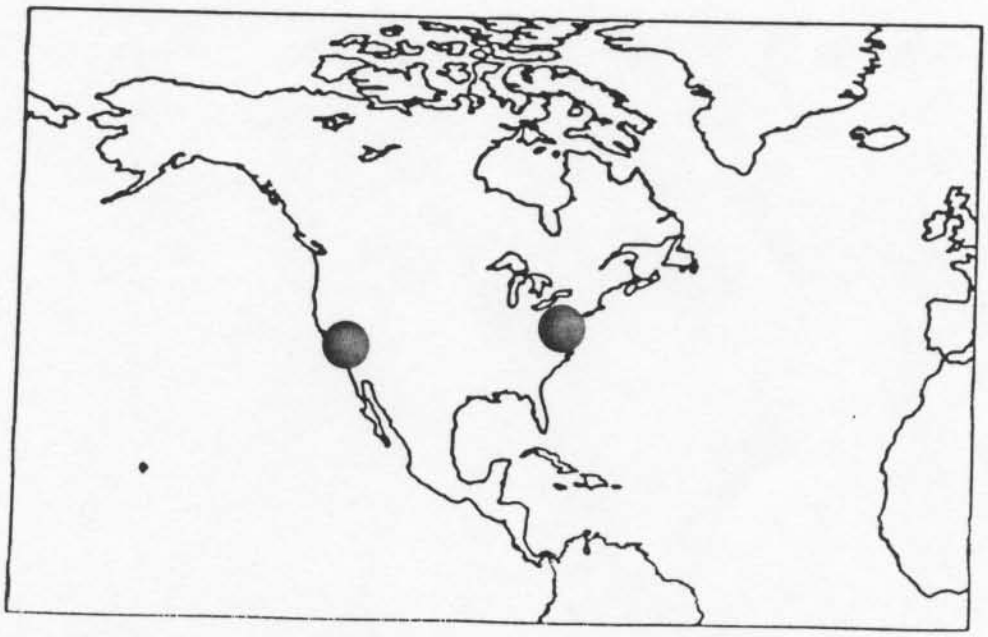
BASELINE, ELLIPSOIDAL CHORD, GEODESIC



GREENBELT, MD TO MONUMENT PEAK, CA

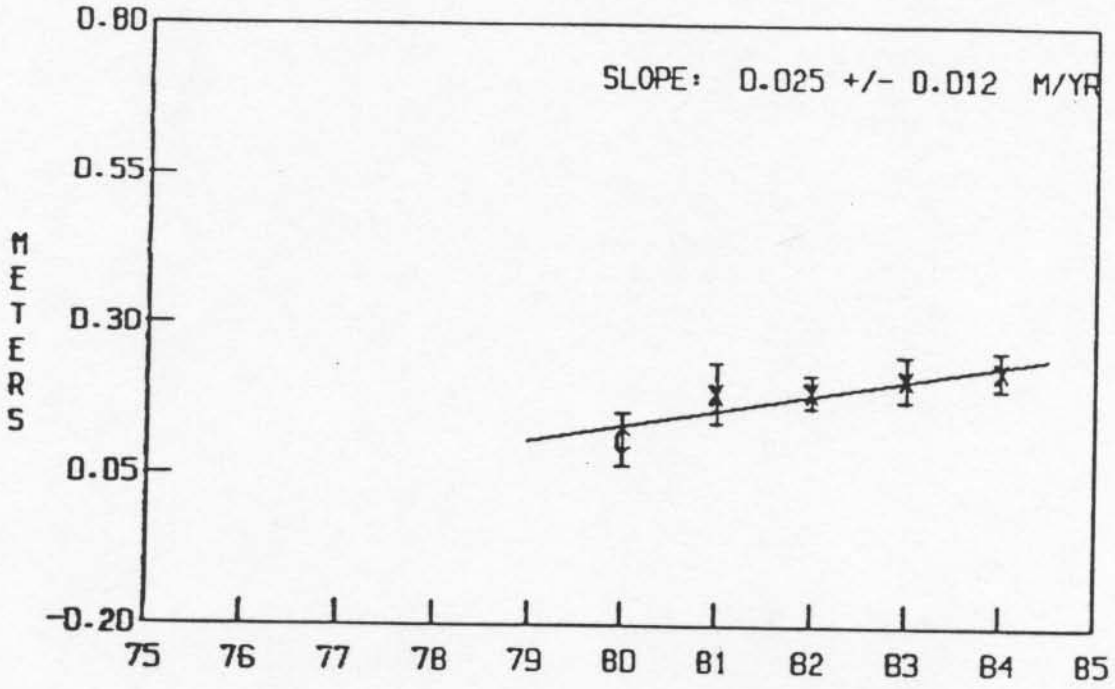
GEODESIC CHORD 3607003 + M M-J RATE: 0.016 M/YR

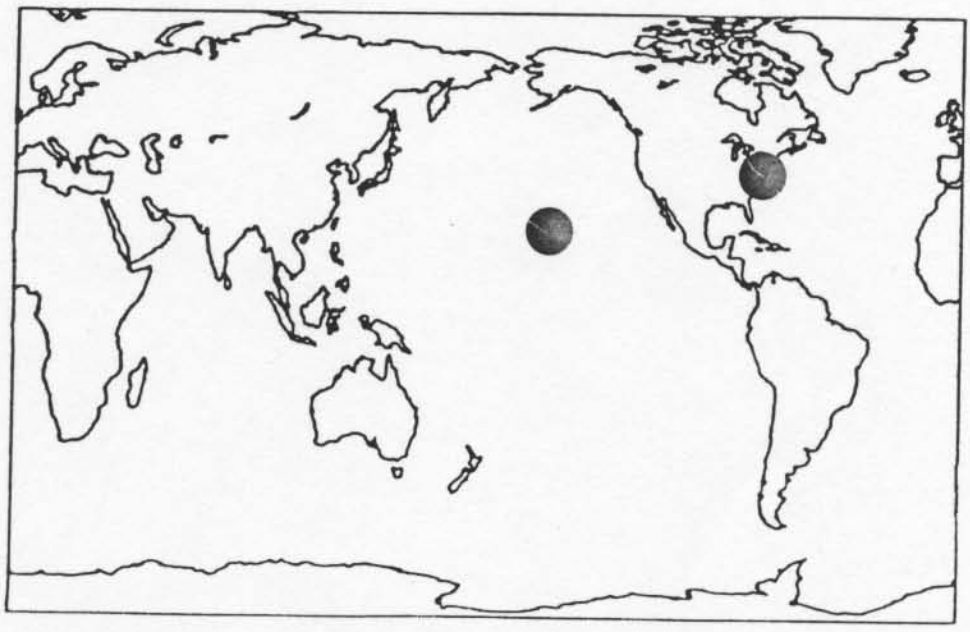




GREENBELT, MD TO HAWAII

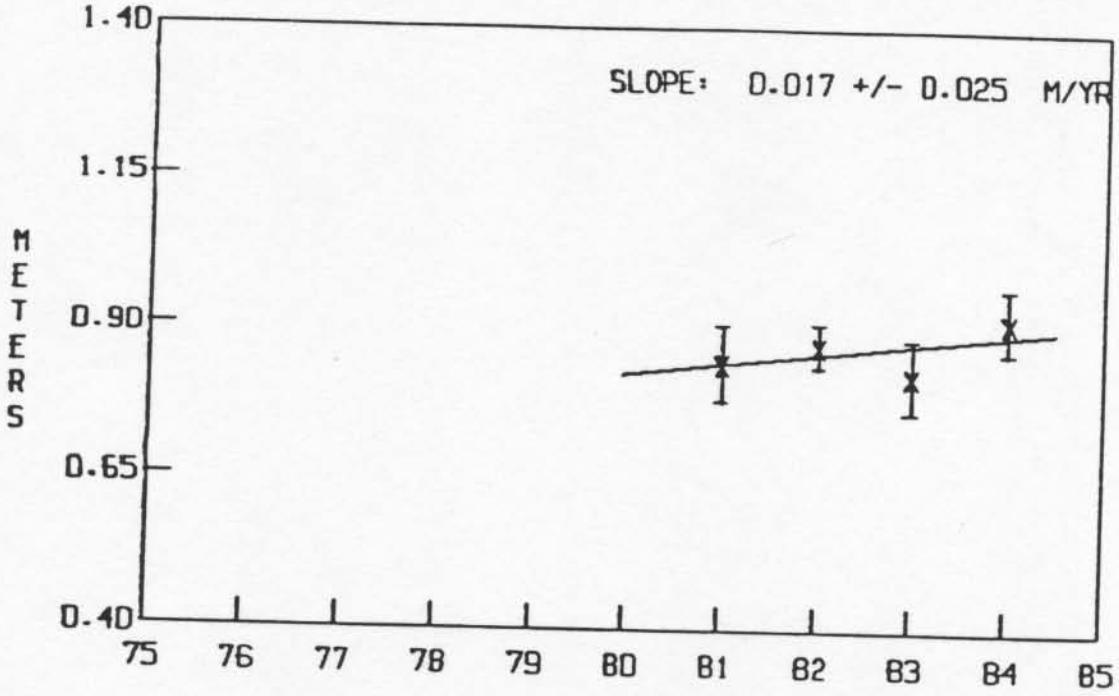
GEODESIC CHORD 7701094 + M M-J RATE: 0.017 M/YR

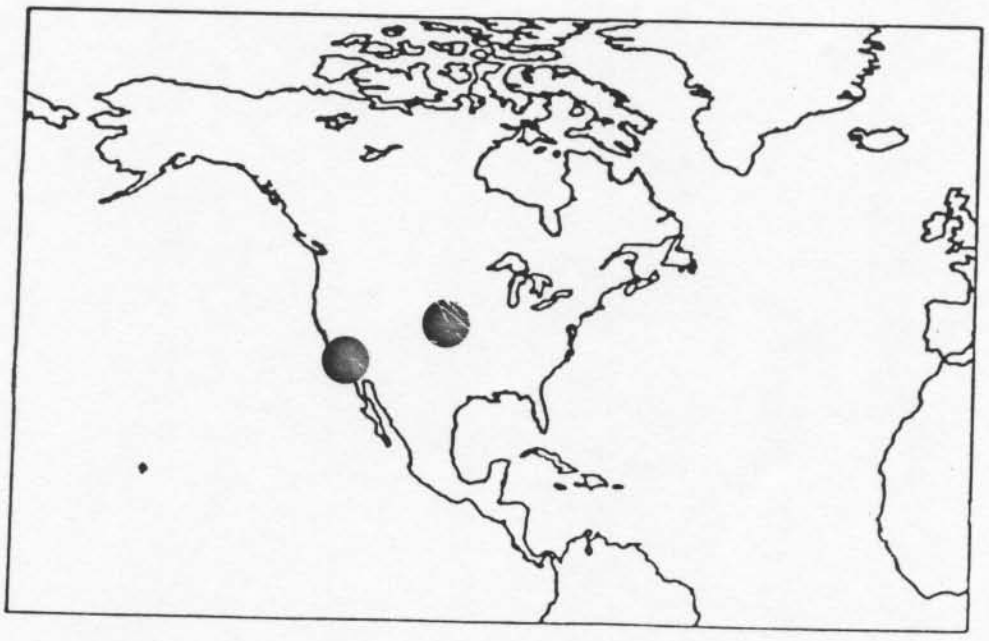




PLATTEVILLE, CO TO MONUMENT PEAK, CA

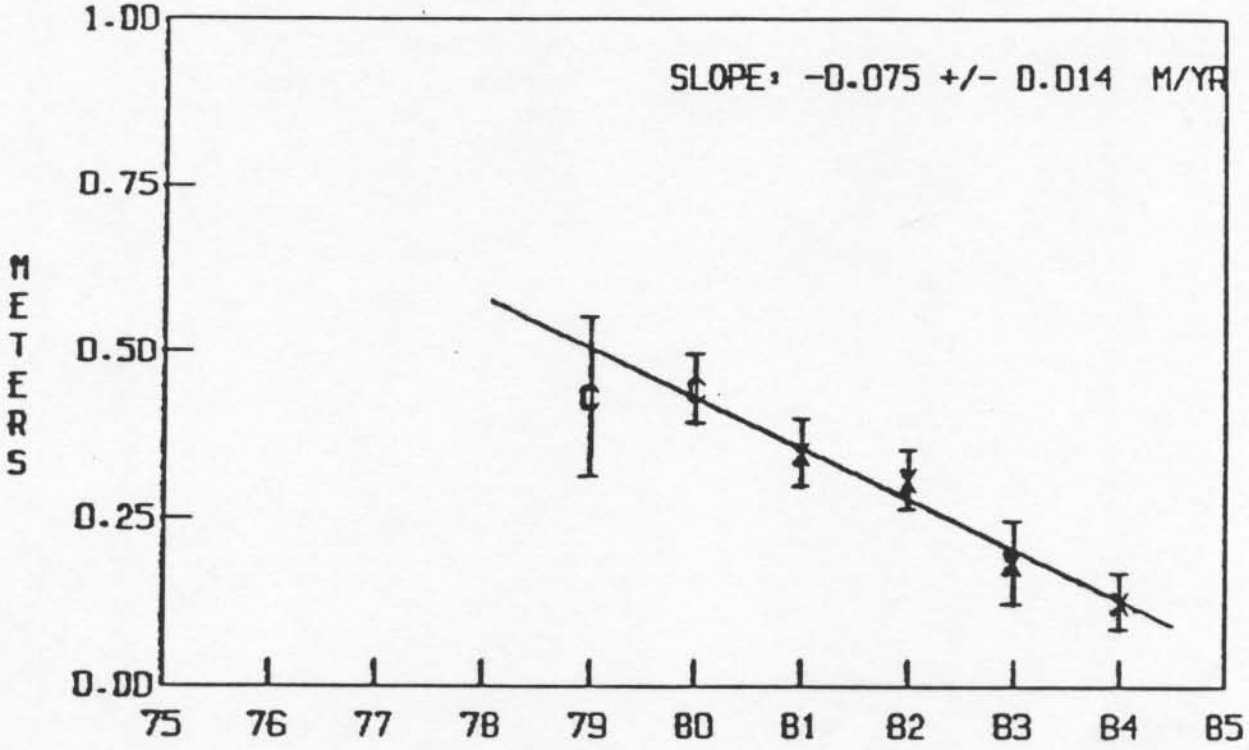
GEODESIC CHORD 1321521 + M M-J RATE: -0.001 M/YR

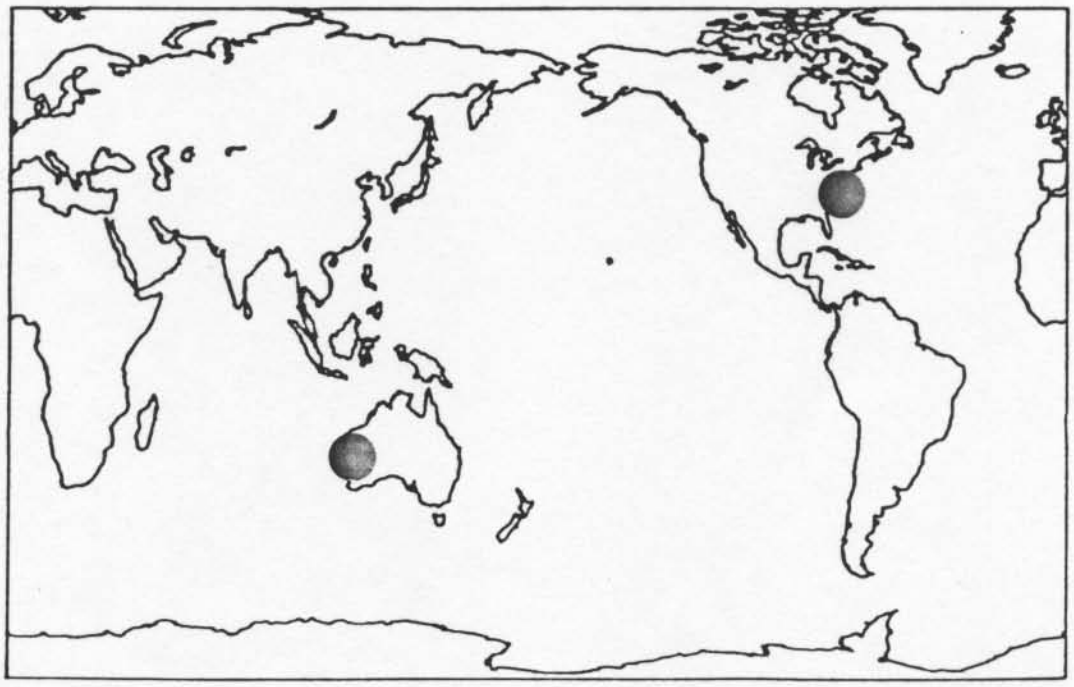




YARAGADEE, AUSTRALIA TO GREENBELT, MD

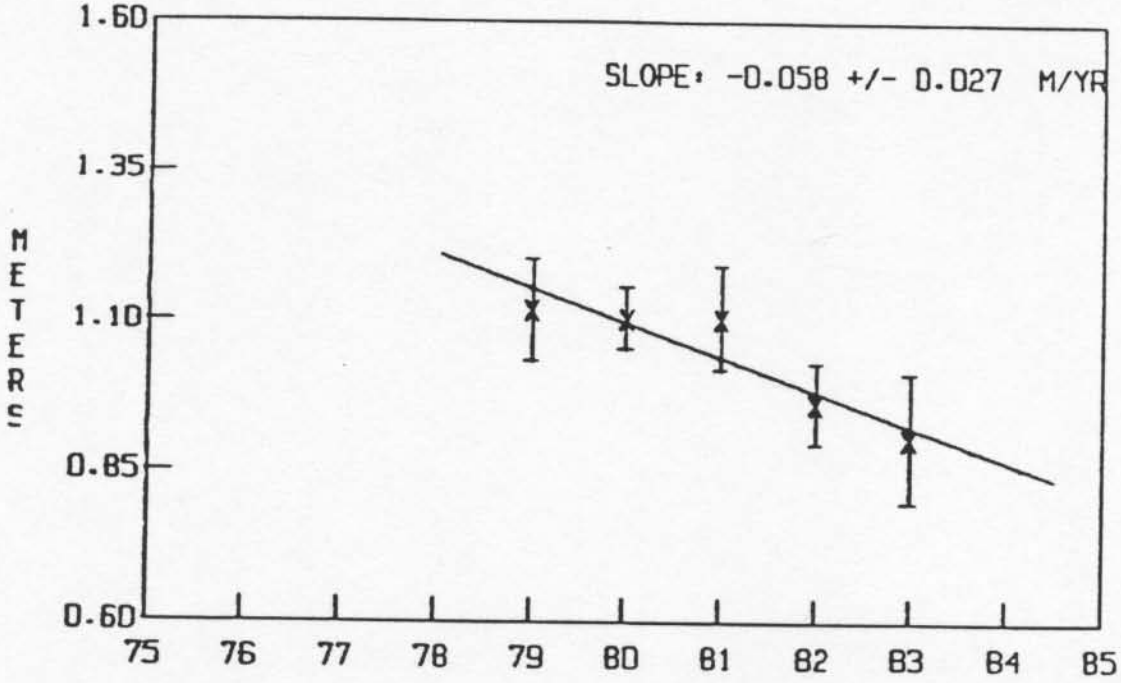
GEODESIC CHORD 18440885 M M-J RATE: -0.089 M/YR

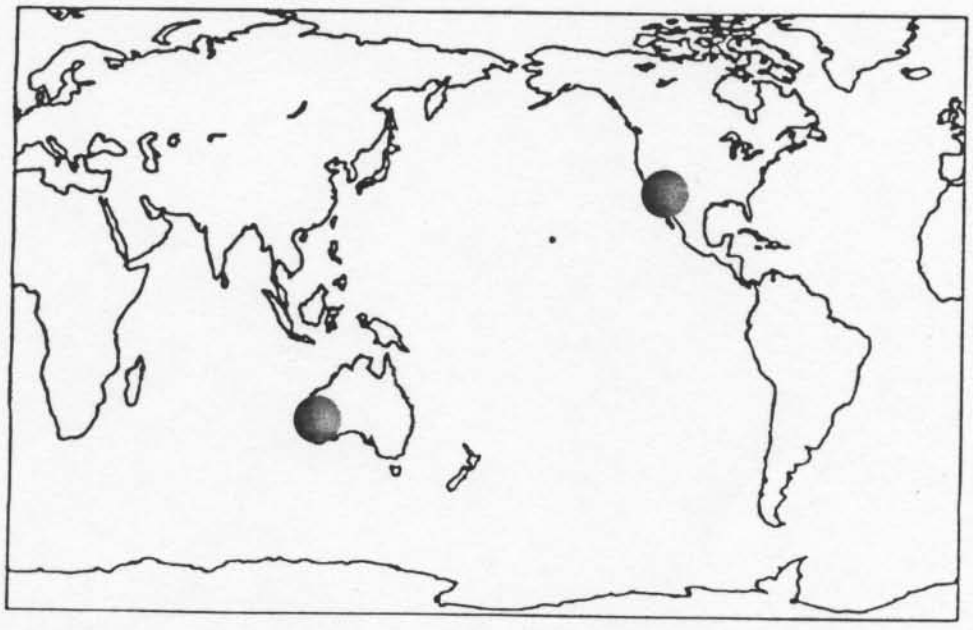




YARAGADEE, AUSTRALIA TO OWENS VALLEY, CA

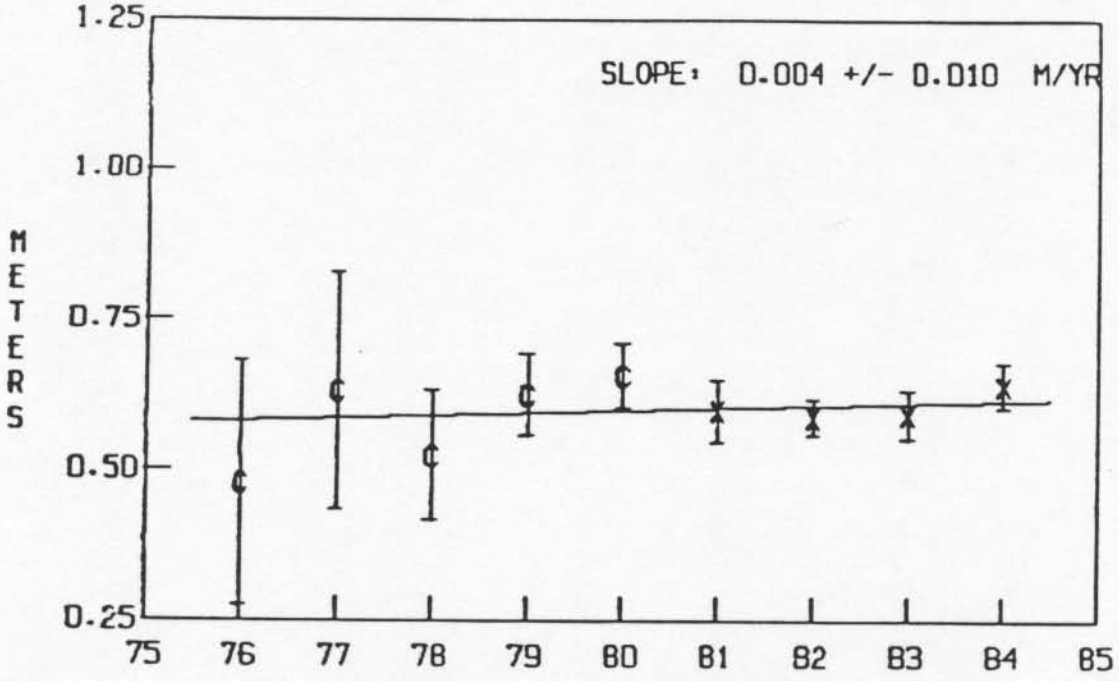
GEODESIC CHORD 15005222 + M M-J RATE: -0.080 M/YR

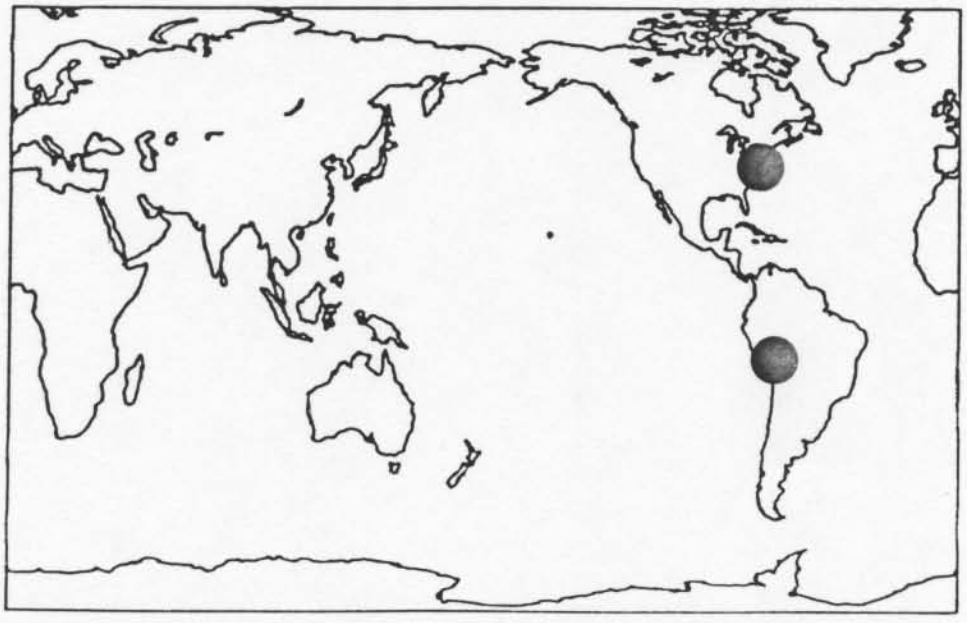




GREENBELT, MD TO AREQUIPA, PERU

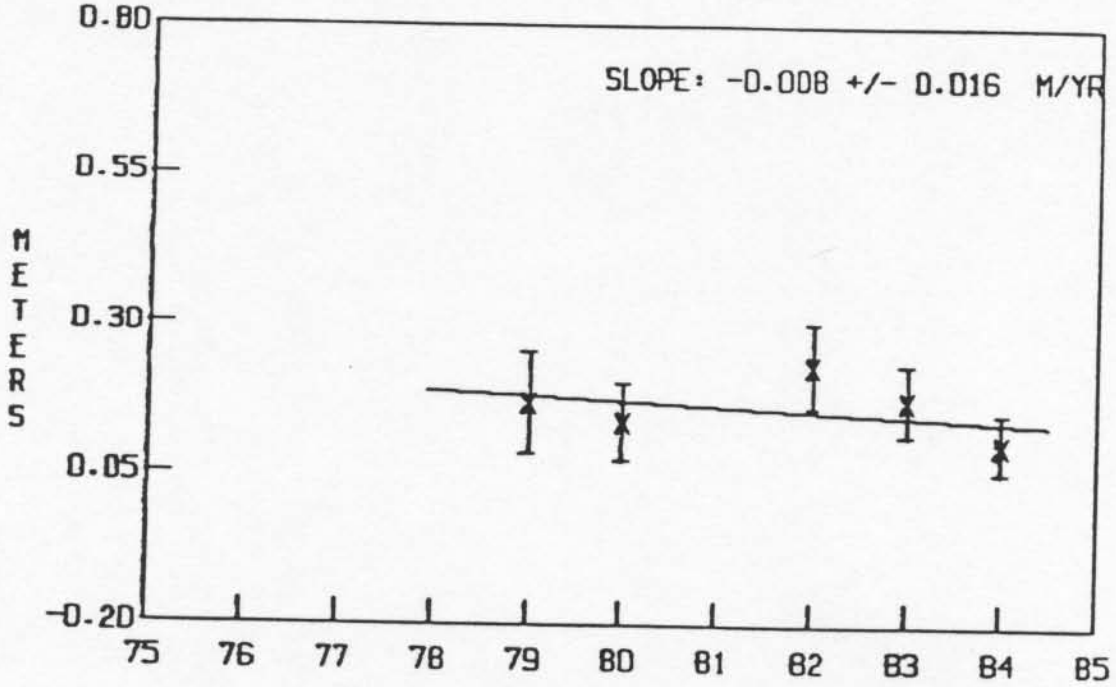
GEODESIC CHORD 6167083 + M M-J RATE: -0.006 M/YR

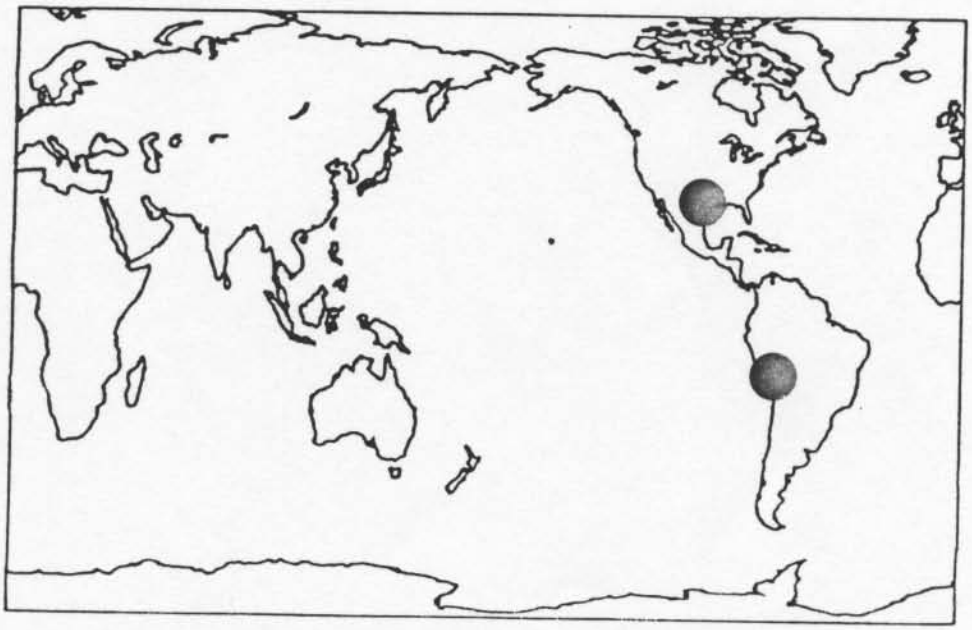




AREQUIPA, PERU TO FORT DAVIS, TX

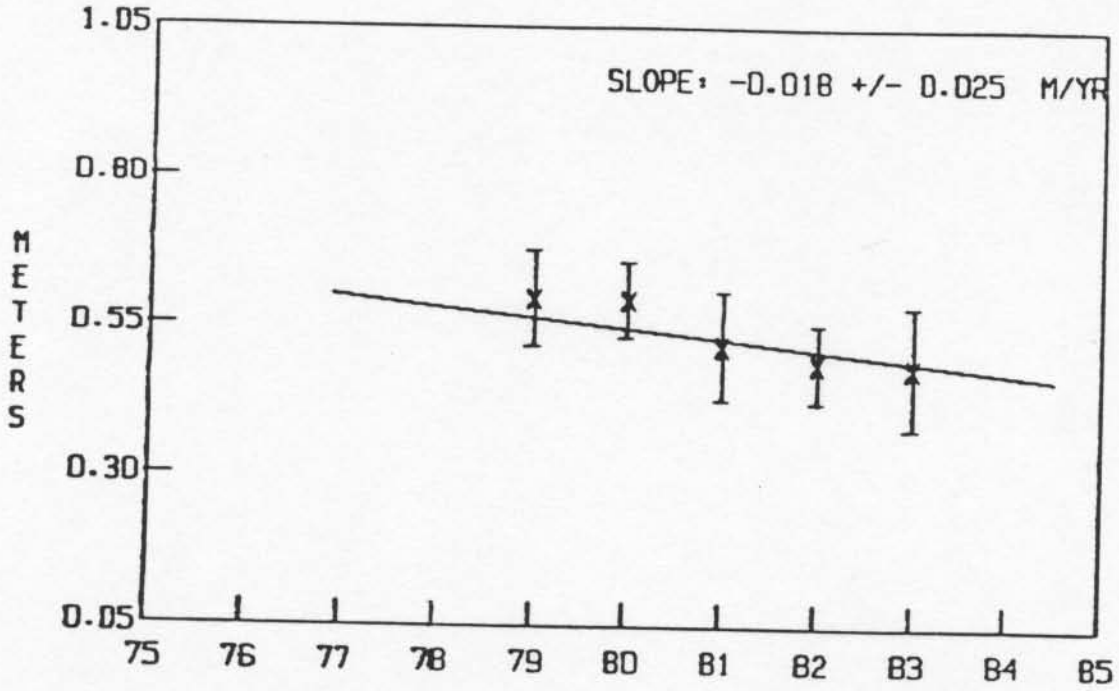
GEODESIC CHORD 6272179 + M M-J RATE: -0.011 M/YR

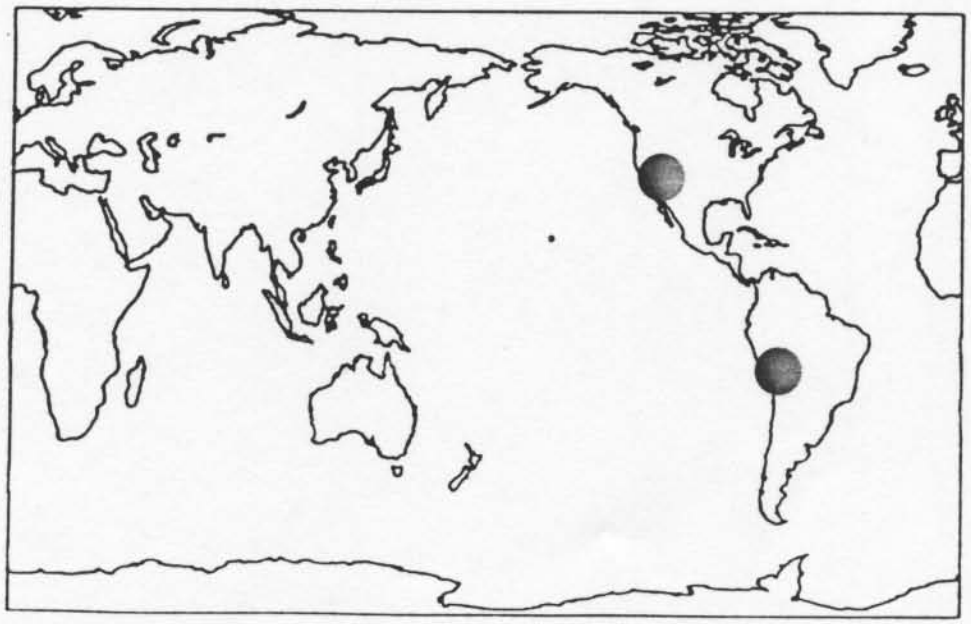




AREQUIPA, PERU TO OWENS VALLEY, CA

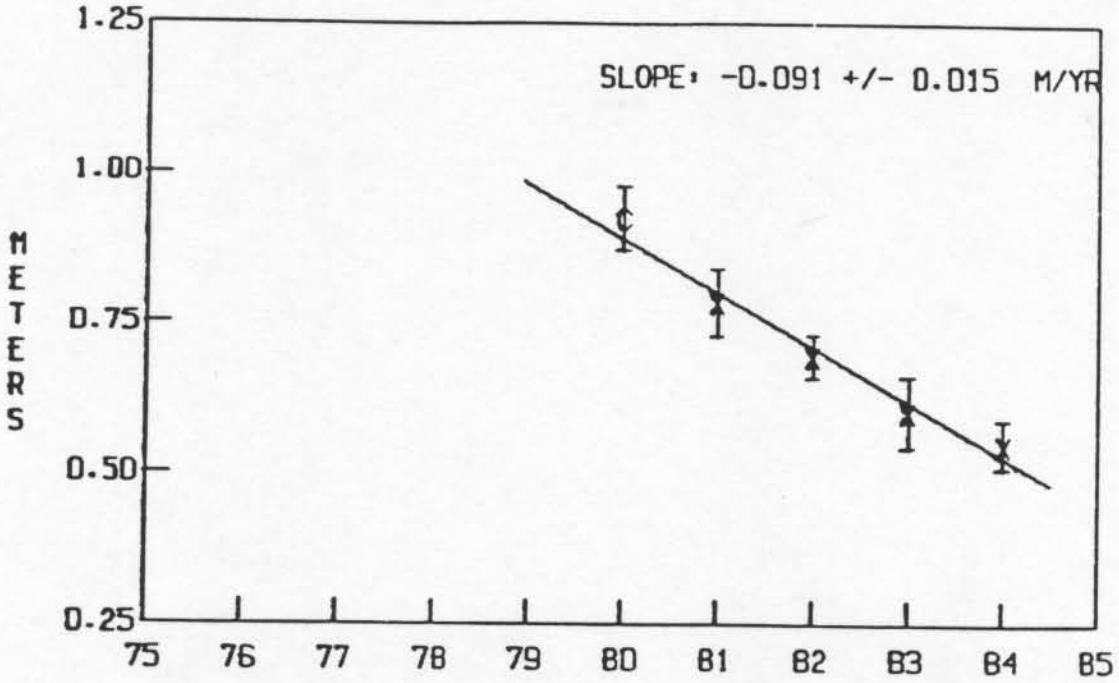
GEODESIC CHORD 7704701 + M M-J RATE: -0.012 M/YR

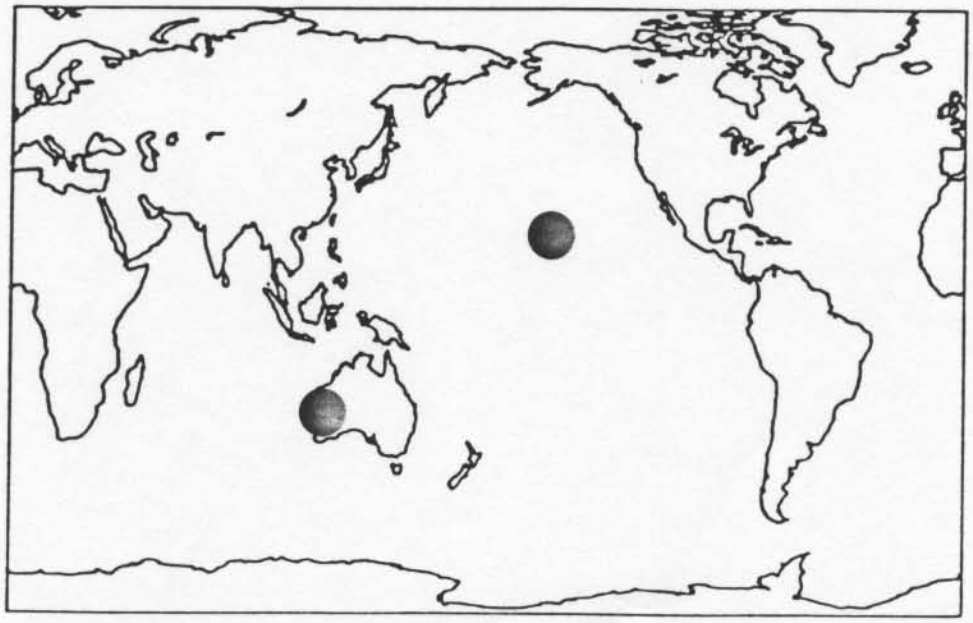




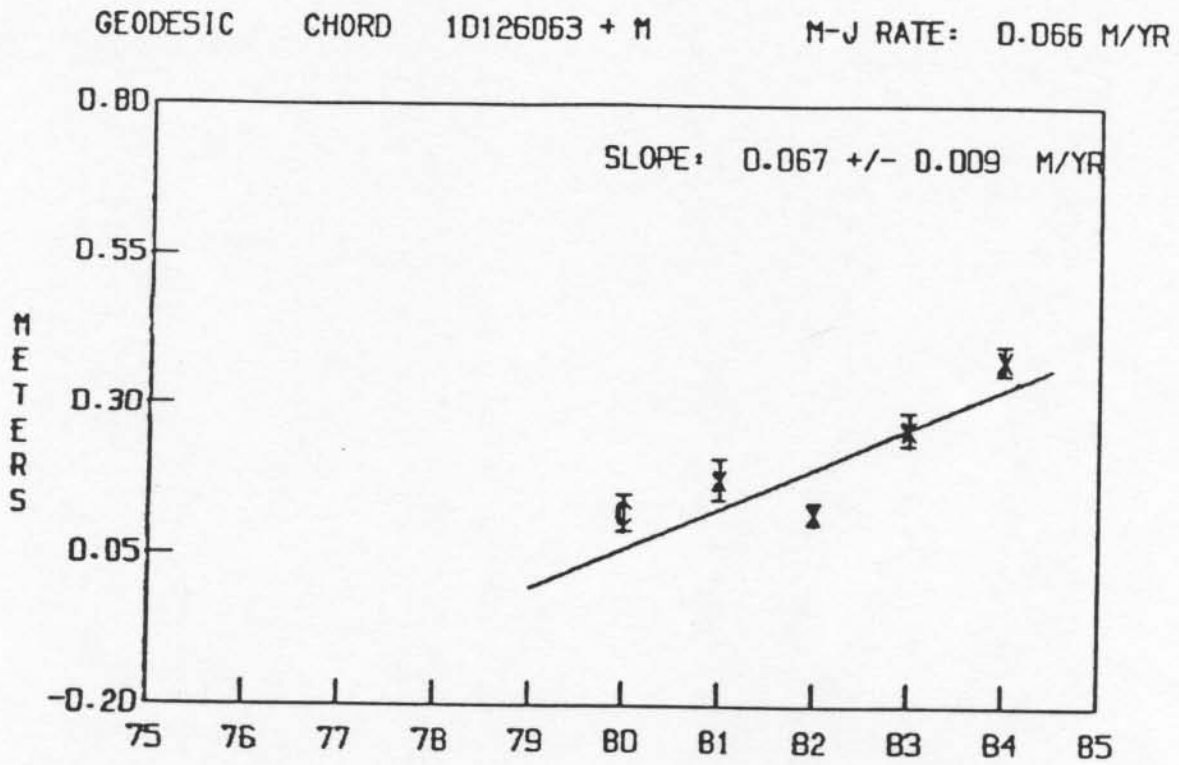
YARAGADEE, AUSTRALIA TO HAWAII

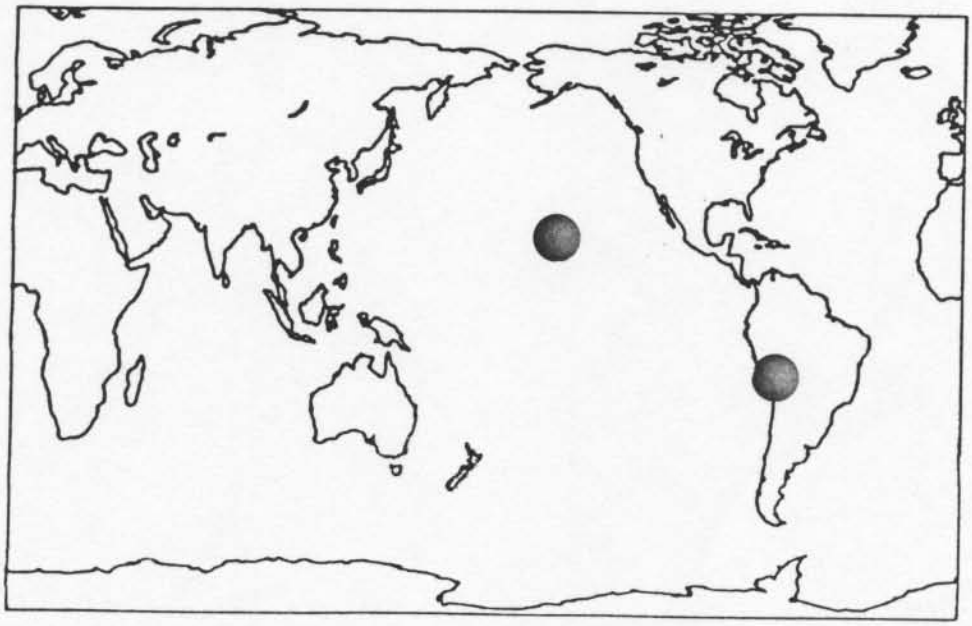
GEODESIC CHORD 10956242 + M M-J RATE: -0.103 M/YR





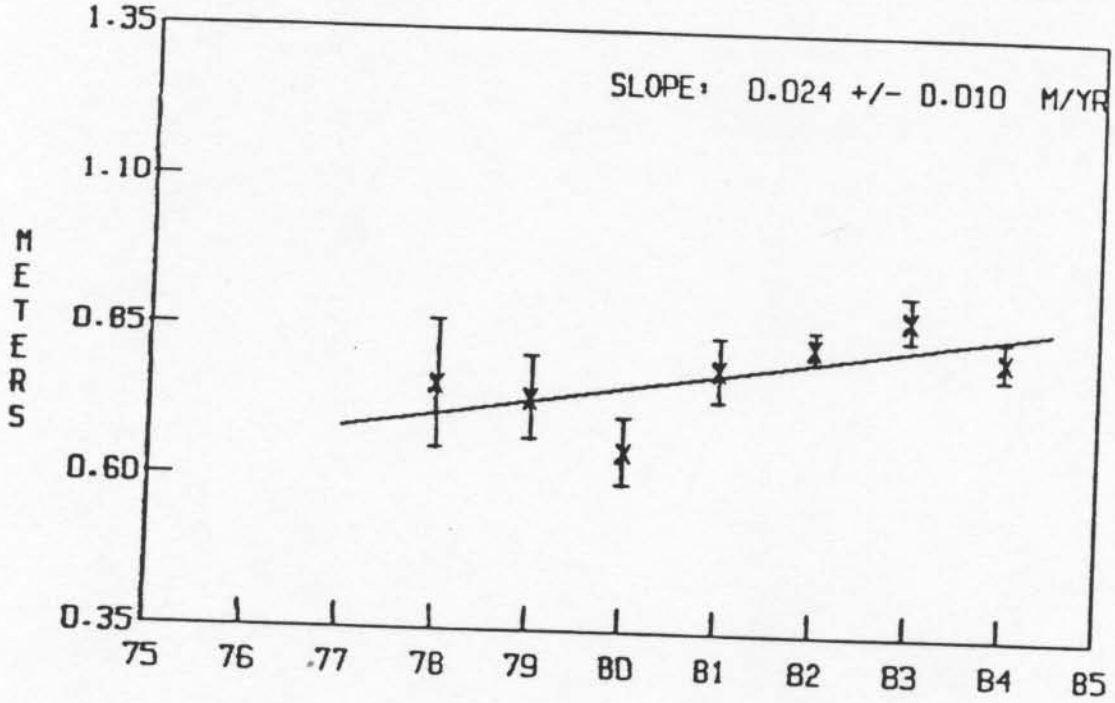
AREQUIPA, PERU TO HAWAII

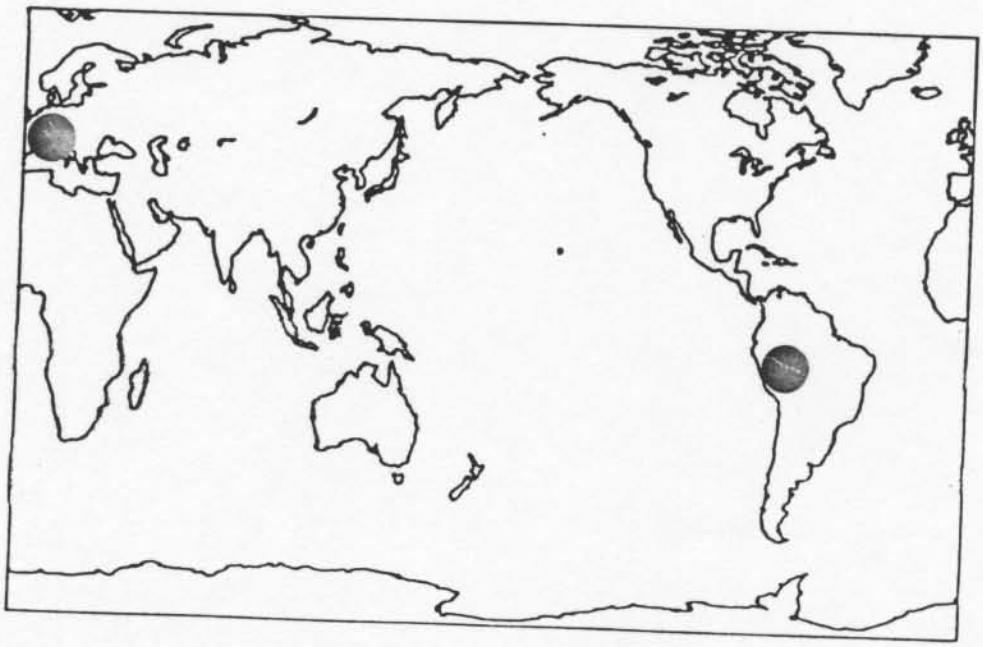




AREQUIPA, PERU TO WETTZELL, W. GERMANY

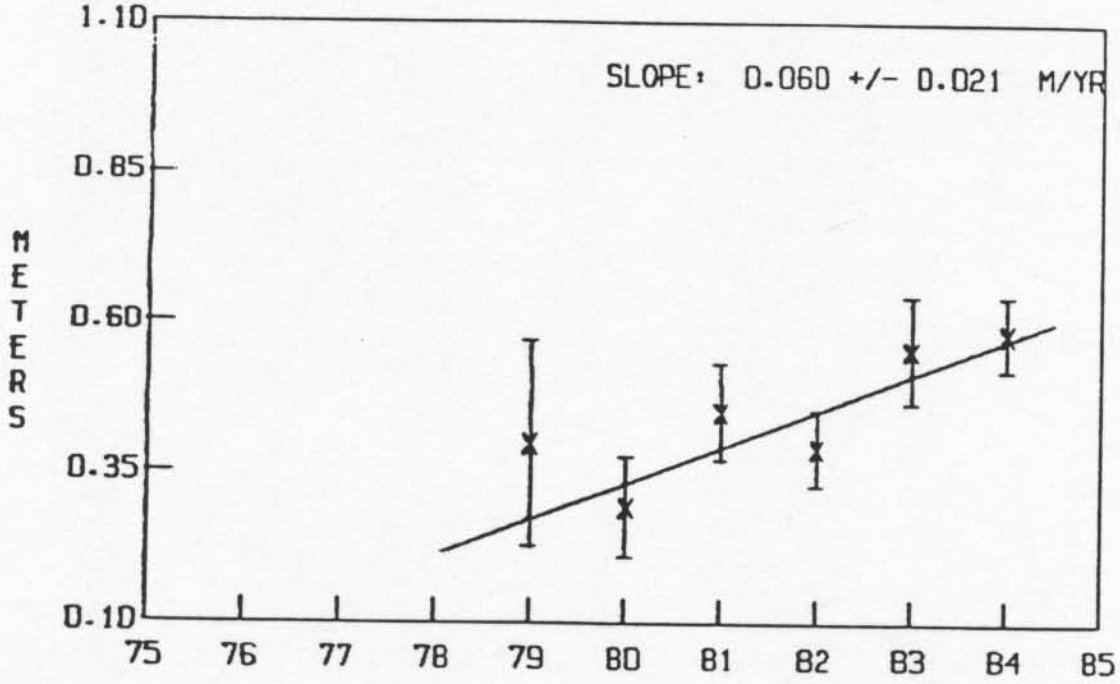
GEODESIC CHORD 10975838 + M M-J RATE: 0.021 M/YR

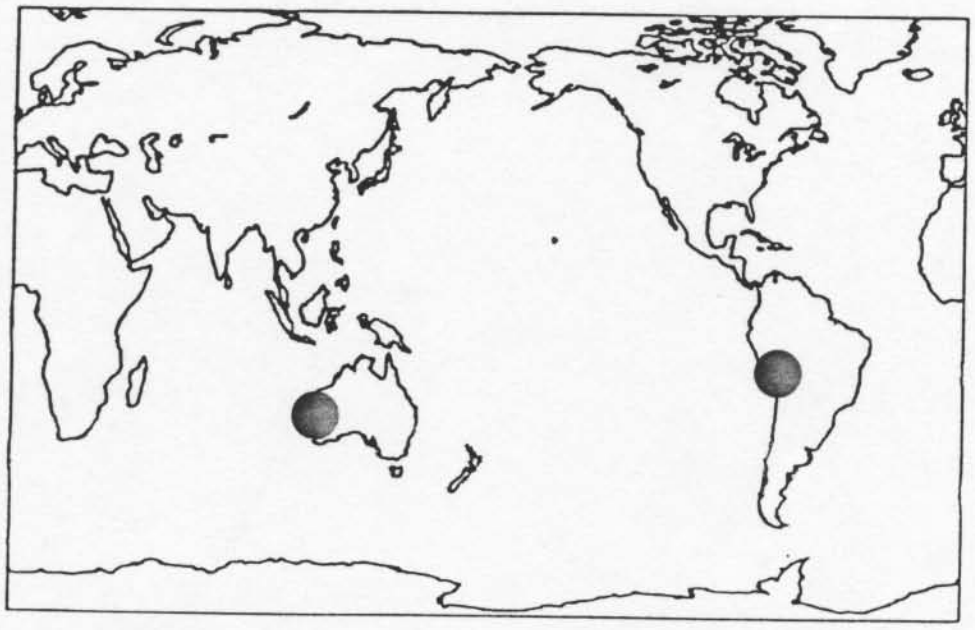




YARAGADEE, AUSTRALIA TO AREQUIPA, PERU

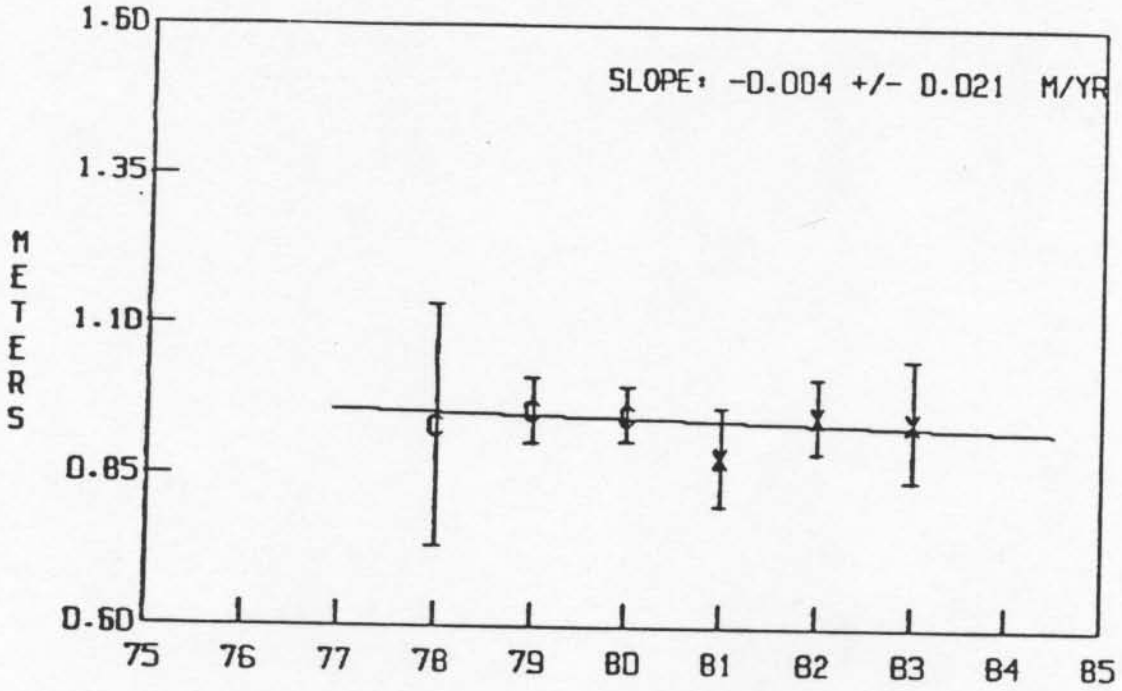
GEODESIC CHORD 14915516 + M M-J RATE: 0.061 M/YR

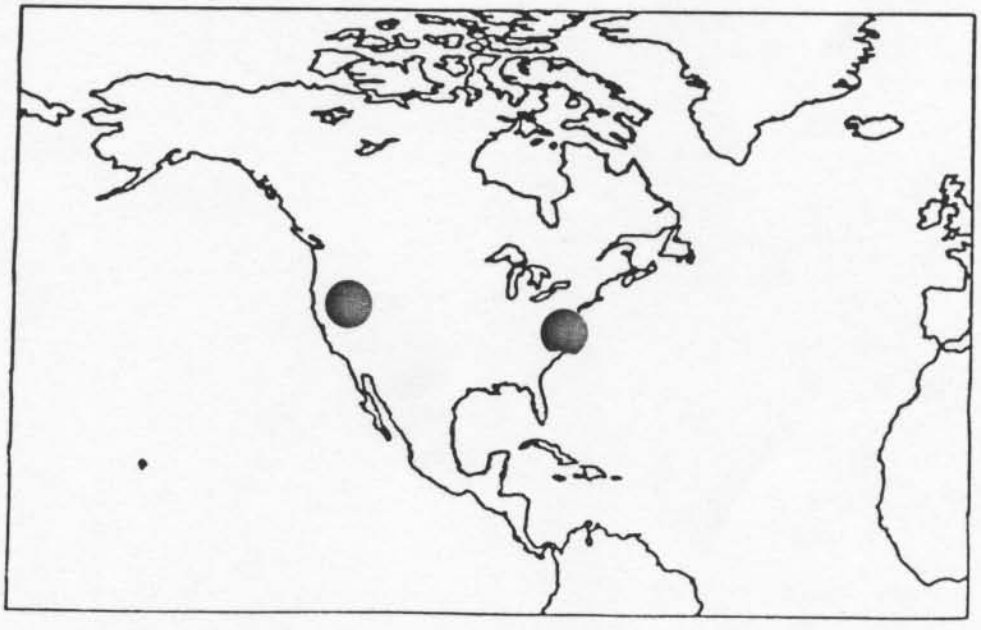




GREENBELT, MD TO OWENS VALLEY, CA

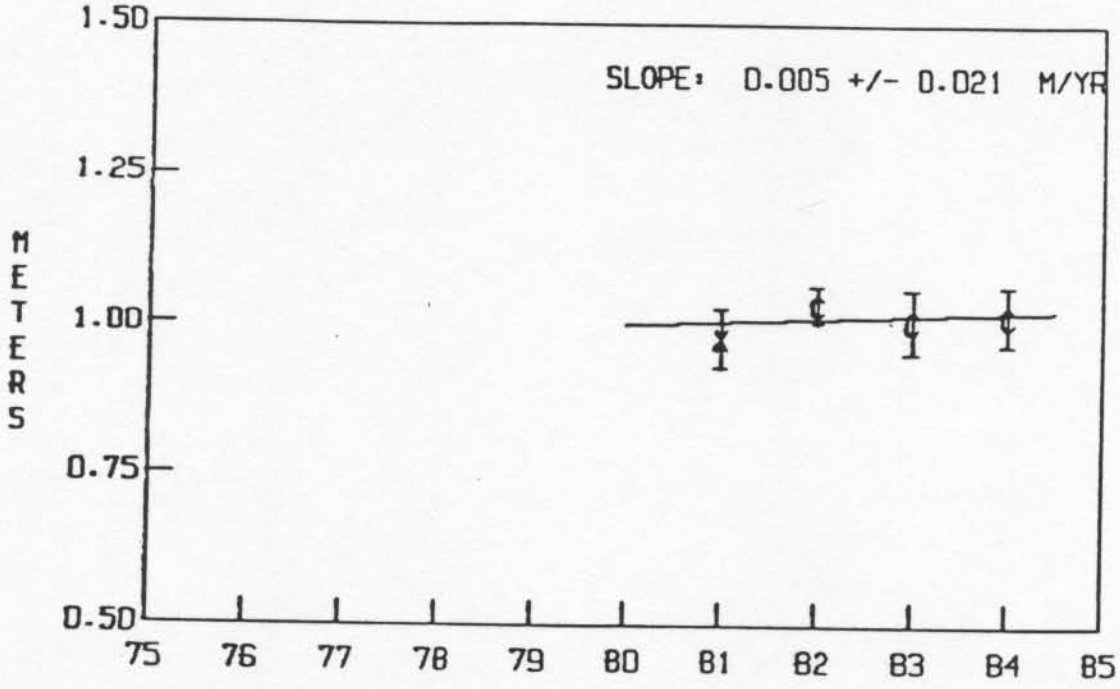
GEODESIC CHORD 3609664 + M M-J RATE: 0.000 M/YR

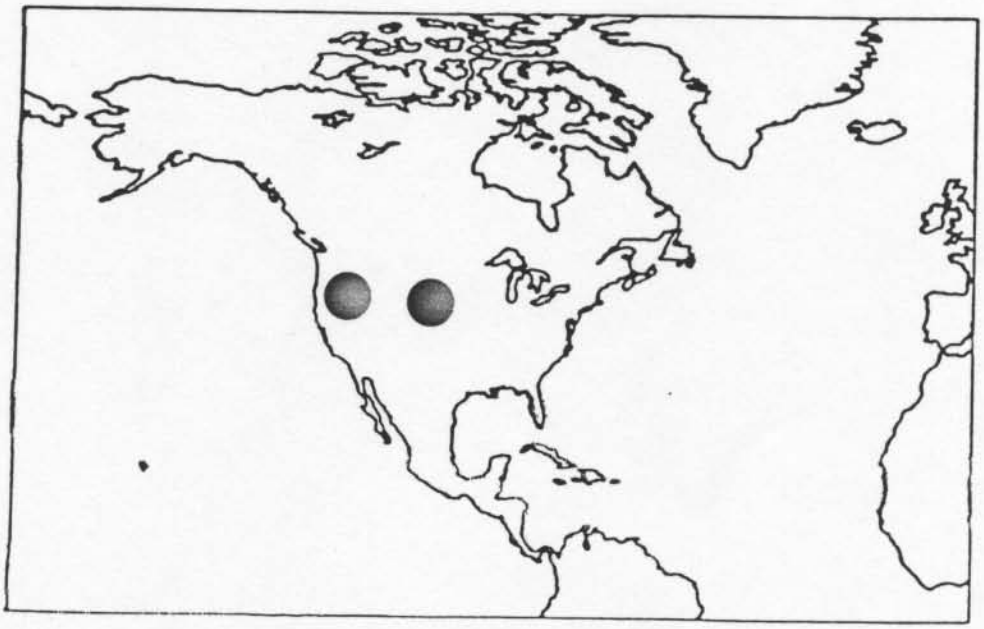




PLATTEVILLE, CO TO QUINCY, CA

GEODESIC CHORD 1381231 + M M-J RATE: 0.000 M/YR

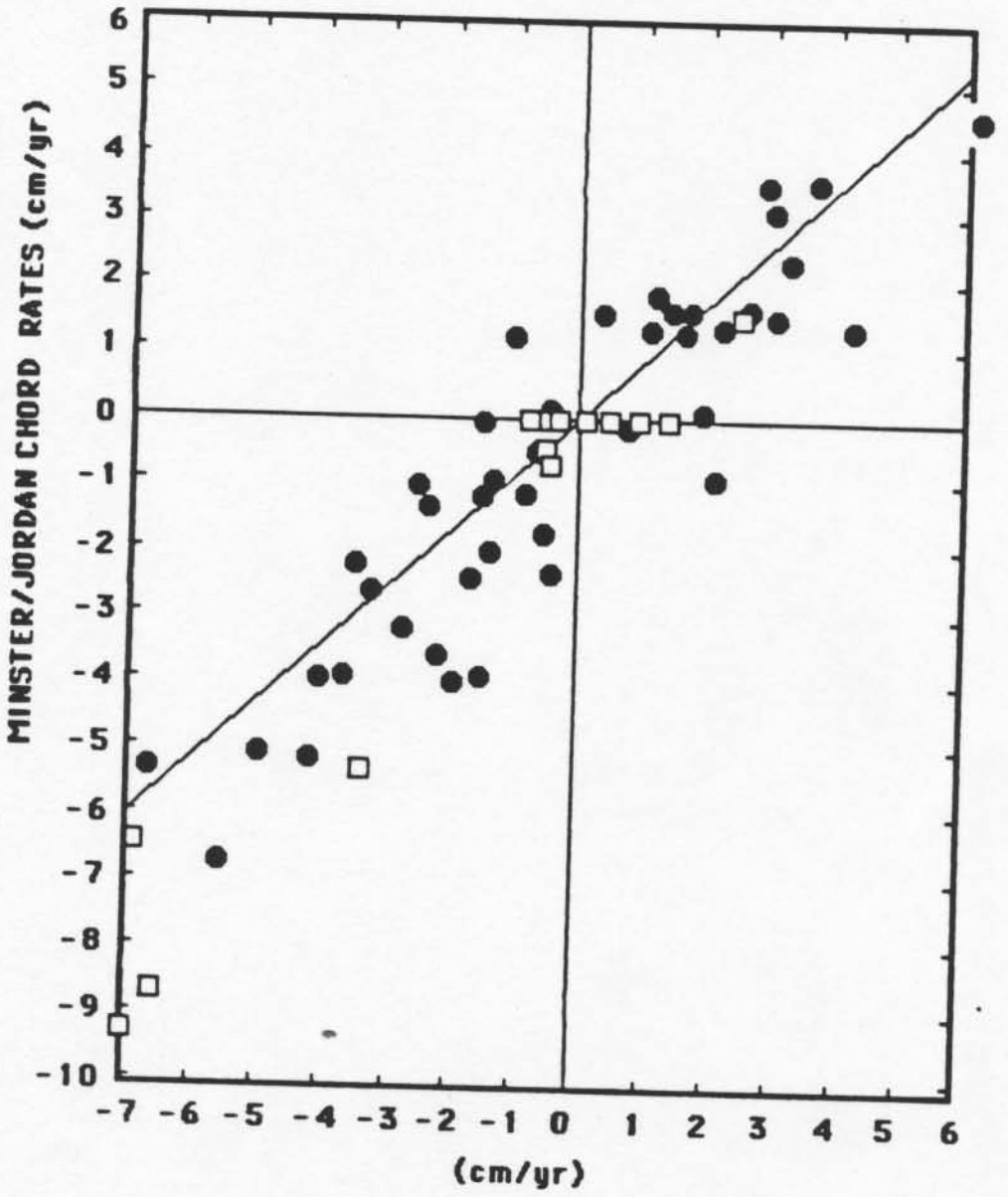




COMPARISON OF OBSERVED SLR GLOBAL CHORD RATES WITH THOSE OF MINSTER/JORDAN

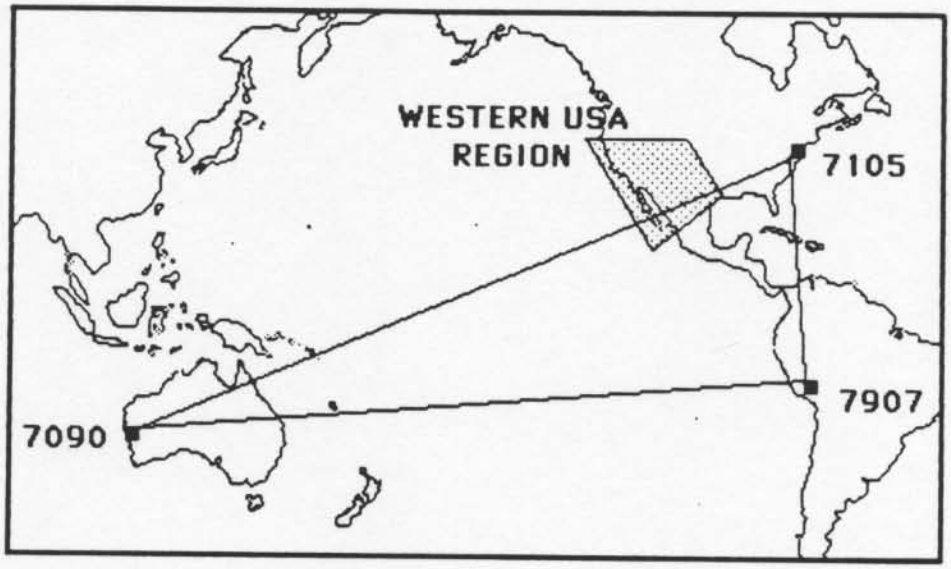
1979 to 1984

	CM/YEAR SL6	CM/YEAR M/J	CM/YEAR AVERAGE SL6	CM/YEAR AVERAGE M/J
NORTH AMERICAN TO –				
PACIFIC				
GSFC–MON PK	0.3	1.6		
OTAY	2.7	1.6		
HAW	2.1	1.4		
FORT DAV–HAW	3.0	3.2	0.2	0.1
OWENS–MON PK	–4.1	–5.1		
OTAY	–5.0	–5.0		
HAW	3.0	1.6		
PLATT–MON PK	0.7	–0.1		
OTAY	–1.5	–0.1		
HAW	1.1	1.4		
EURASIAN				
GSFC–WETZ	1.2	1.8		
FORT DAV–WETZ	1.6	1.6	1.5	1.6
OWEN–WETZ	1.6	1.4		
PLATT–WETZ	1.4	1.6		
AUSTRALIAN				
GSFC–YARG	–0.9	–1.1		
ORRL	–0.6	–1.7		
FORT DAV–YARG	–1.4	–2.0	–2.0	–2.3
ORRL	–3.3	–2.6		
OWEN–YARG	–2.7	–3.1		
ORRL	–2.2	–3.5		
PLATT–YARG	–1.7	–2.4		
ORRL	–3.5	–2.2		
SOUTH AMERICAN				
GSFC–AREQ	–0.7	–0.5		
FORT DAV–AREQ	–1.4	–1.0	–0.6	–0.9
OWEN–AREQ	–2.5	–1.0		
PLATT–AREQ	2.1	–0.9		
PACIFIC TO –				
EURASIAN				
MON PK–WETZ	1.8	0.1		
OTAY–WETZ	–0.5	0.1	0.3	–0.7
HAW–WETZ	–0.5	–2.3		
AUSTRALIAN				
MON PK–YARG	–2.0	–3.9		
ORRL	–1.6	–3.9		
OTAY–YARG	–3.7	–3.9	–4.0	–4.6
ORRL	–4.0	–3.9		
HAW–YARG	–5.6	–6.7		
ORRL	–6.8	–5.3		
SOUTH AMERICAN				
MON PK–AREQ	3.7	3.6		
OTAY–AREQ	2.9	3.6	4.3	3.9
HAW–AREQ	6.2	4.6		
EURASIAN TO –				
AUSTRALIAN				
WETZ–YARG	–2.4	–1.3	–1.9	–1.2
ORRL	–1.5	–1.1		
SOUTH AMERICAN				
WETZ–AREQ	–1.1	1.3	–1.1	1.3
AUSTRALIAN TO –				
SOUTH AMERICAN				
YARG–AREQ	3.3	2.4	3.7	1.9
ORRL–AREQ	4.2	1.4		

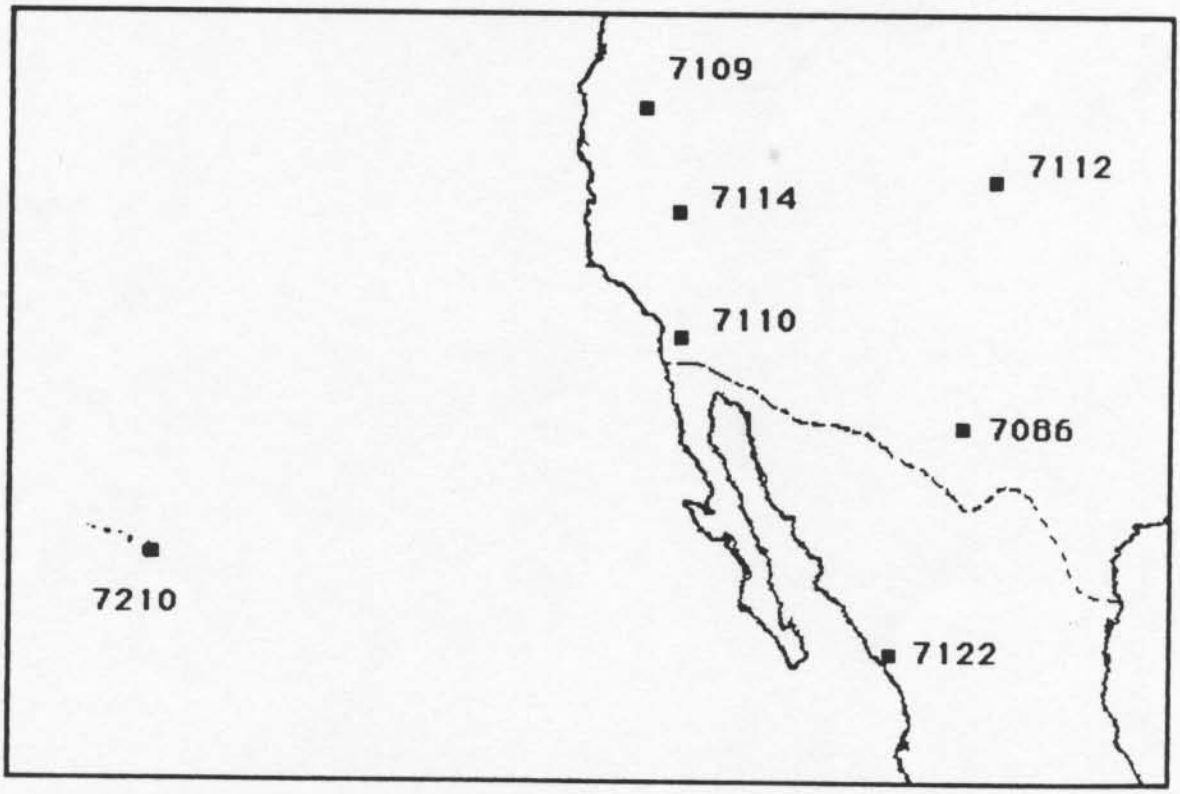


● SL6 LASER CHORD RATES
SLOPE = 0.86, CORRELATION COEFFICIENT = 0.91

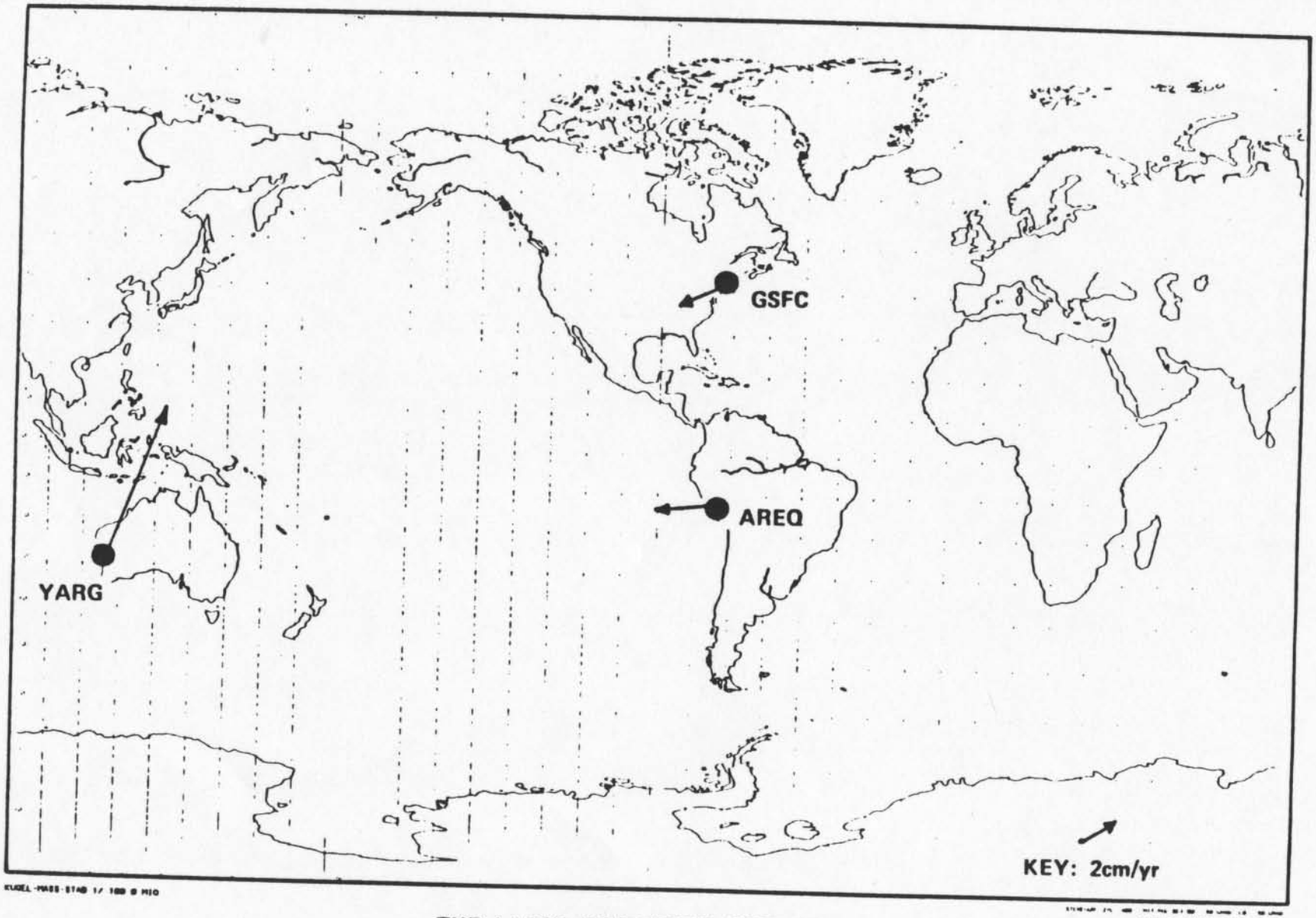
□ VLBI CHORD RATES



"EXTERNAL" SLR NETWORK



"INTERNAL" SLR NETWORK



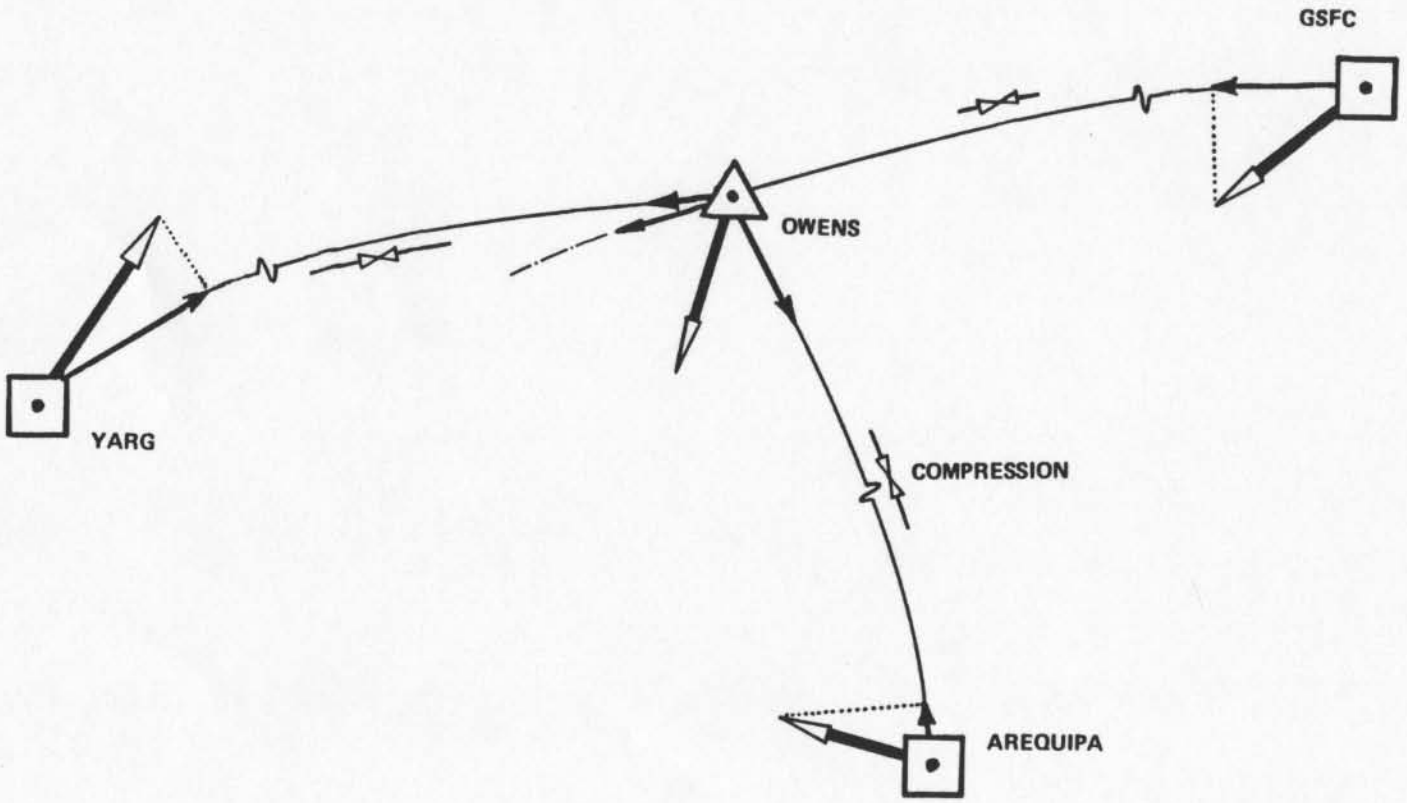
THE LASER REFERENCE NETWORK

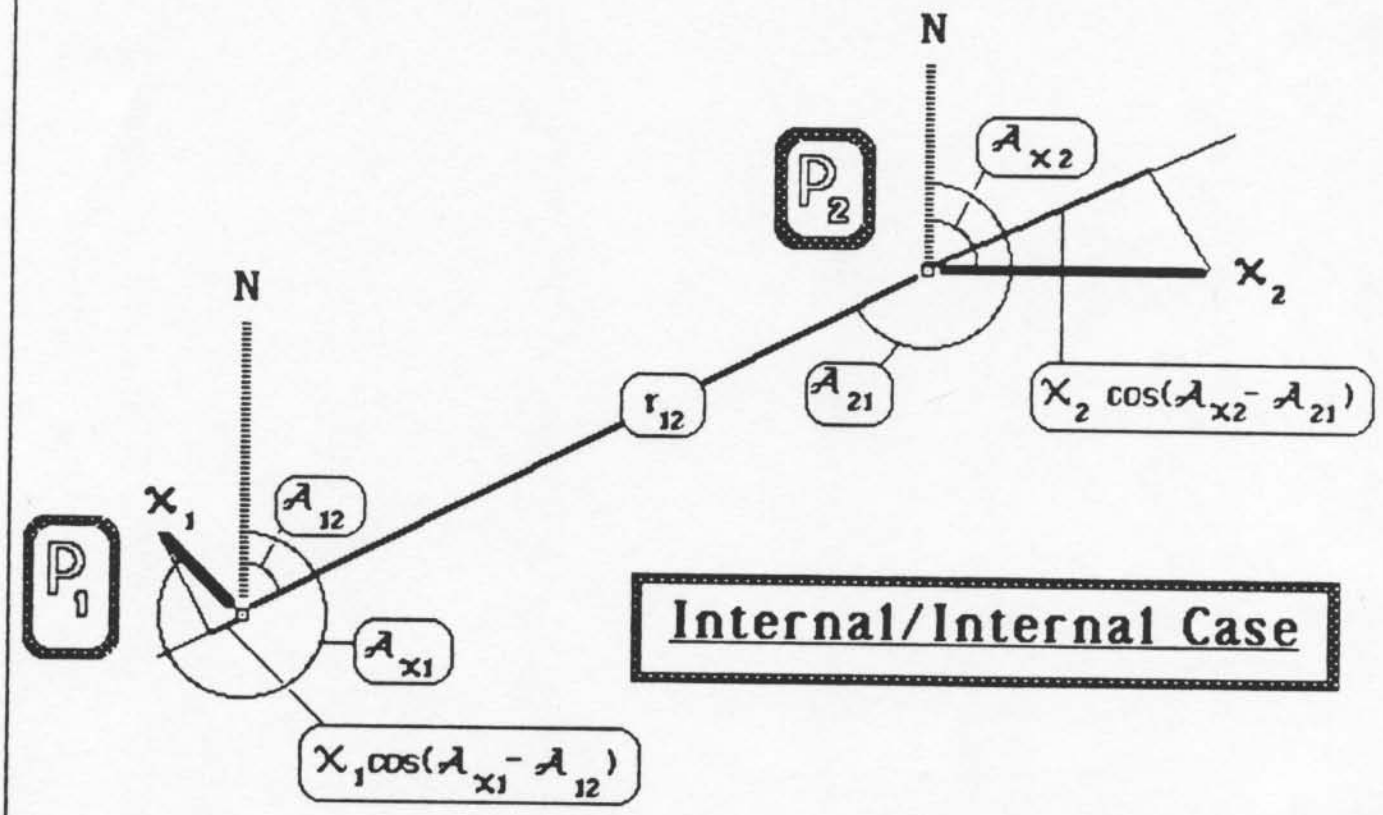
ABSOLUTE MOTIONS FROM MINSTER / JORDAN AM1 - 2 MODEL

COMPARISON OF GEODESIC RATES FOR EXTERNAL NETWORK STATIONS

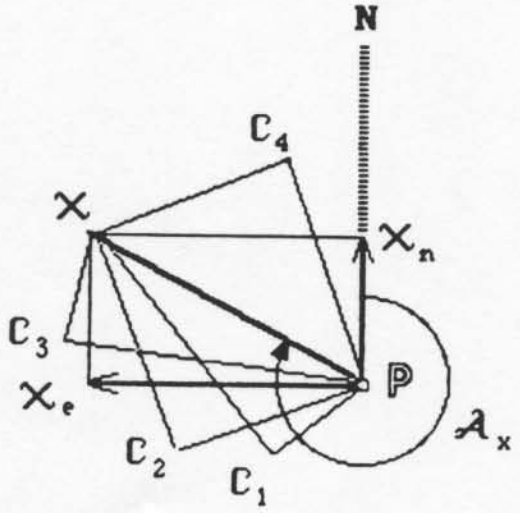
FROM	TO	SL-6 OBSERVED RATE(cm/yr)	SIGMA (cm/yr)	MINSTER/JORDAN RATE (cm/yr)
GSFC (NA)	AREQ (SA)	-0.9	±0.4	-0.6
GSFC (NA)	YARG (AUS)	-8.4	±0.4	-8.8
AREQ (SA)	YARG (AUS)	6.4	±0.4	6.2

ABSOLUTE MOTIONS





Internal/Internal Case



External/Internal Case

The C_i represent the component of the Internal station's absolute motion in the direction of External station **i**.

COMPARISON OF ABSOLUTE STATION MOTIONS

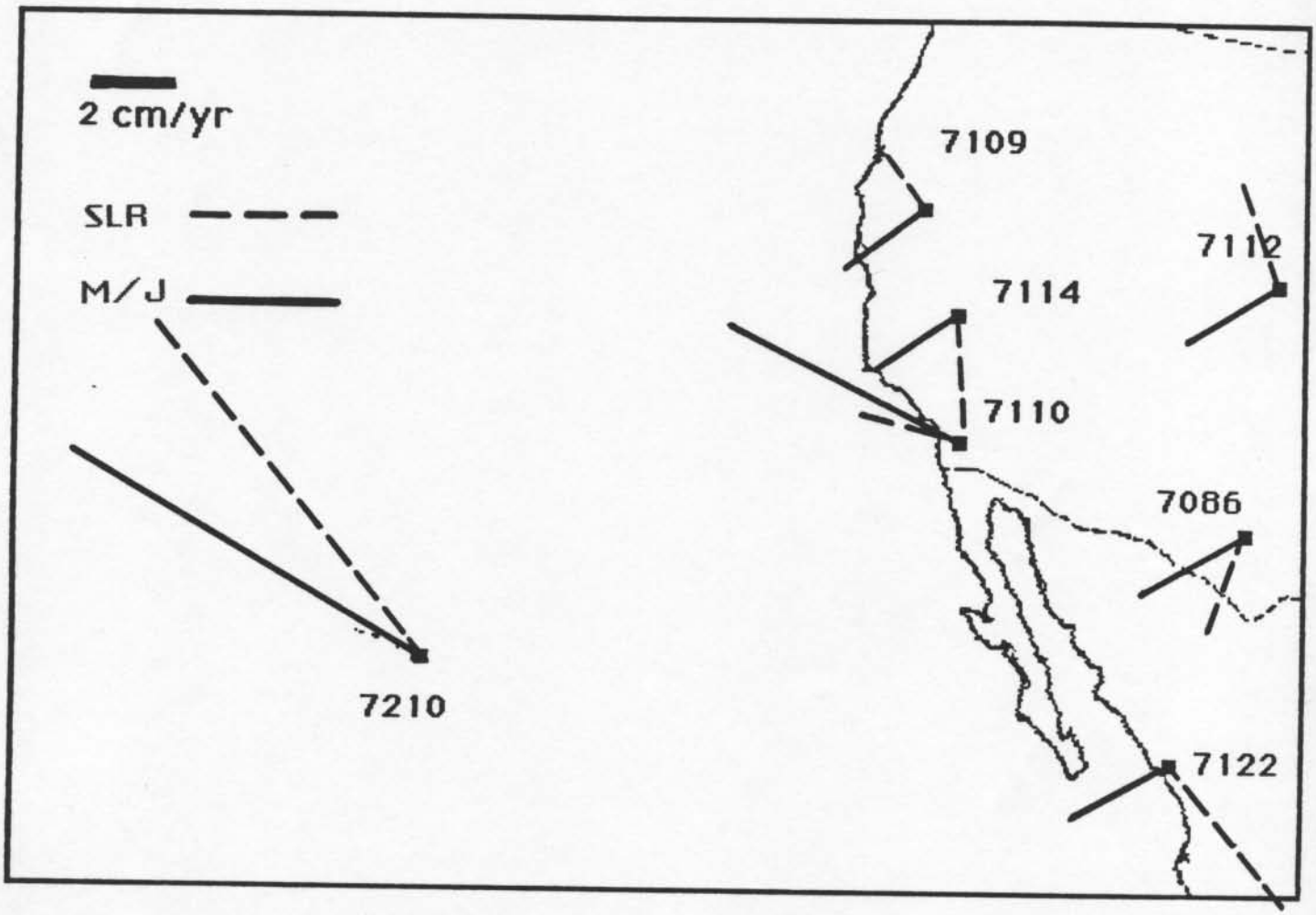
STATION (yrs of obs.)		MINSTER/ JORDAN		SL - 6	
	PLATE	RATE	AZIMUTH	RATE	AZIMUTH
QUINCY (5)	NA	2.4	234	1.6	323
MON. PK. (5)	PAC	6.3	297	2.5	295
FT. DAVIS (4)	NA	2.9	240	2.6	199
PLATVL. (5)	NA	2.6	239	2.6	340
HAWAII (7)	PAC	9.7	300	10.3	321
OWENS (3)	NA	2.5	236	4.5	175 (w)
MAZAT. (3)	NA	2.7	241	4.7	140

KEY:

: WELL DETERMINED STATION DIFFERING FROM M/J PREDICTION.

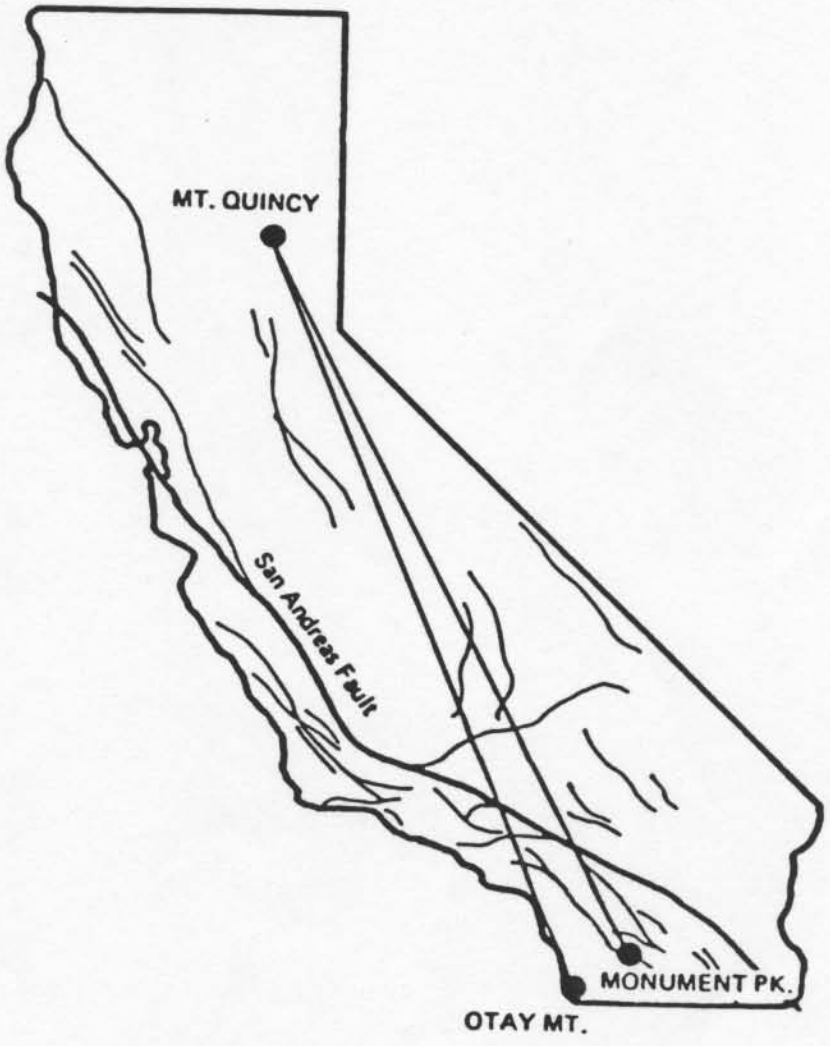
: MODERATELY WELL DETERMINED STATION DIFFERING FROM M/J.

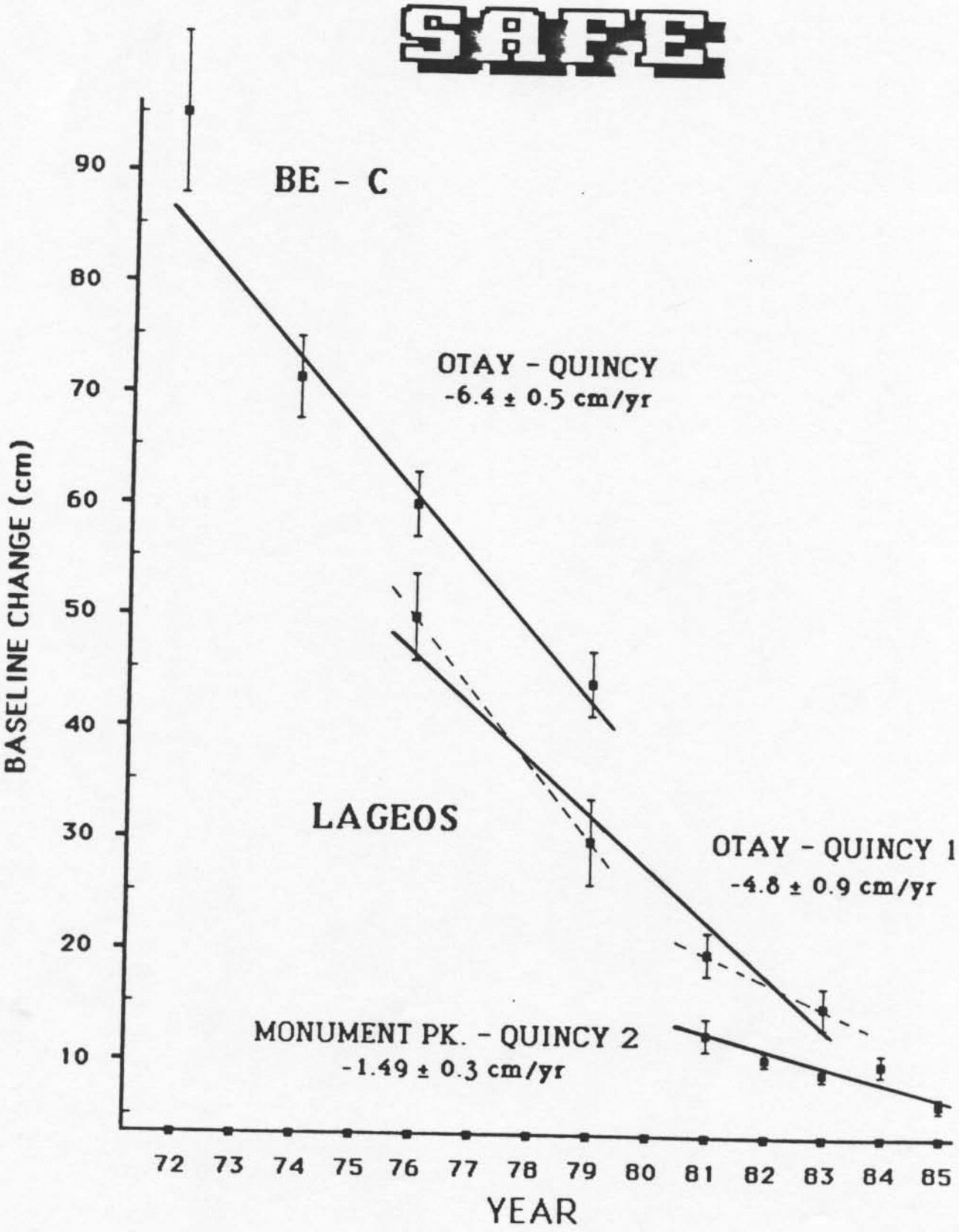
(w) : WEAKLY DETERMINED STATION.



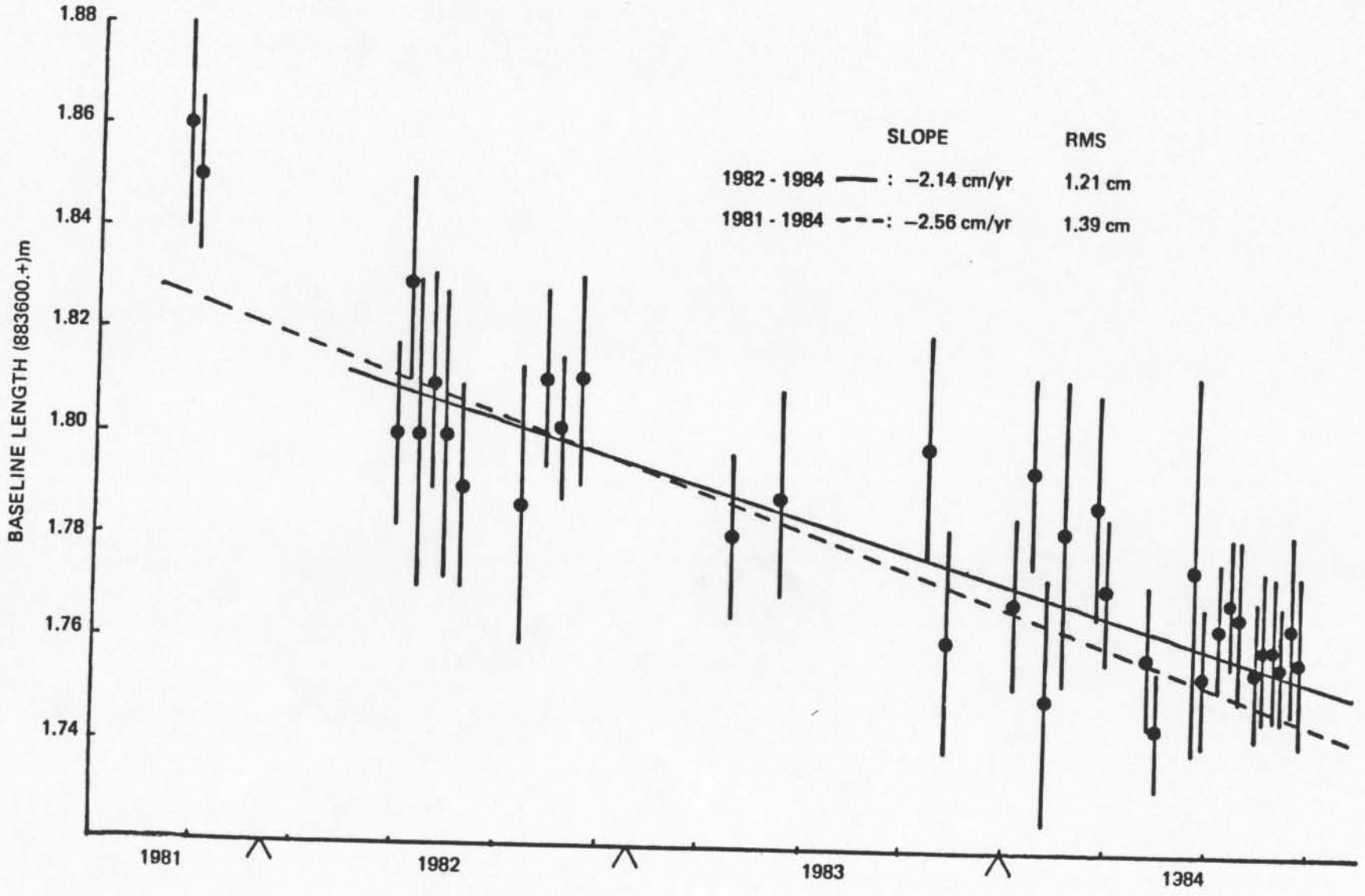
"INTERNAL" SLR NETWORK

"ABSOLUTE" VELOCITY VECTORS (cm/yr)

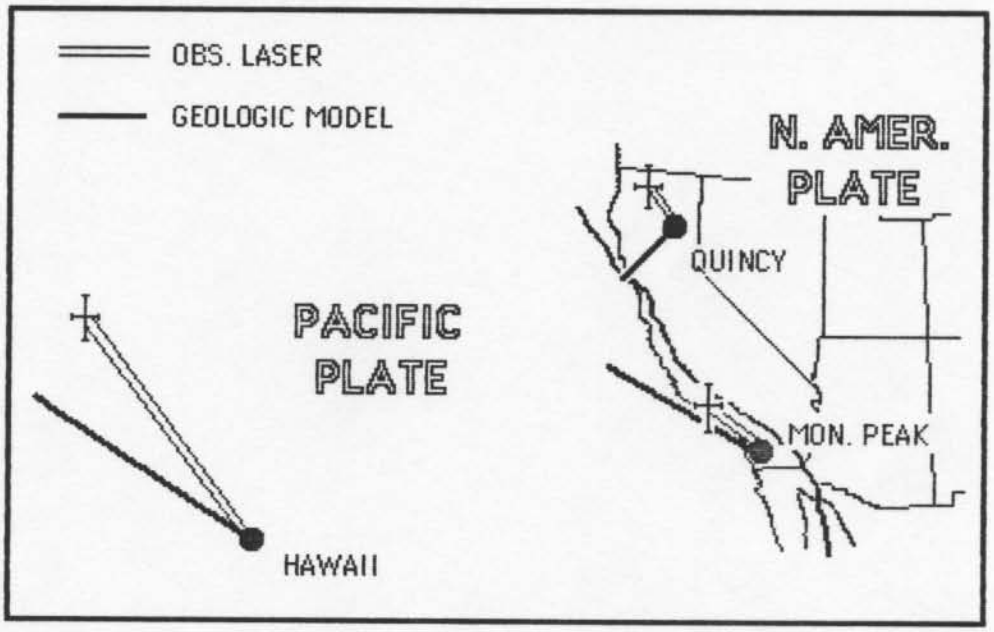

MT. QUINCY
San Andreas Fault
MONUMENT PK.
OTAY MT.


SAFE
BE - C
OTAY - QUINCY
-6.4 ± 0.5 cm/yr
LAGEOS
OTAY - QUINCY 1
-4.8 ± 0.9 cm/yr
MONUMENT PK. - QUINCY 2
-1.49 ± 0.3 cm/yr
BASELINE CHANGE (cm)
90
80
70
60
50
40
30
20
10
72 73 74 75 76 77 78 79 80 81 82 83 84 85
YEAR

SAFE: MONUMENT PEAK TO QUINCY, 1981 to 1984 USING SHORT ARC TECHNIQUE



OBSERVED ABSOLUTE MOTIONS
FOR N. AMER./ PACIFIC SITES



LASER SL - 6 SOLUTION VS. MINSTER/JORDAN AM1-2

LAGEOS-I OBSERVATIONS HAVE BEEN OBTAINED
AND ANALYSED FOR TEN YEARS

CURRENT SCIENTIFIC ACCOMPLISHMENTS

- GLOBAL TECTONIC MOTIONS HAVE BEEN OBSERVED.
- REGIONAL MOTIONS LIKE THOSE FOUND ALONG THE SAN ANDREAS FAULT IN CALIFORNIA HAVE BEEN EXTENSIVELY MONITORED.
- POLAR MOTION ACCURATE TO 1-2 masec AND LOD ACCURATE TO 0.1 msec ARE BEING MEASURED.
- FORCE MODEL IMPROVEMENTS HAVE BEEN ACHIEVED.

SLR IN THE 1990's

GLOBAL DISTRIBUTION

- Permanent Occupations
- Regular Re–occupations
- Local Networks

SYSTEM IMPROVEMENTS

- Improved Systems Accuracy
- Improved Models

} 5 mm.

- Compact Systems
- Full Automation
- Cost Reduction

LASER SATELLITES

- LAGEOS II
- POPSAT
- EGP (JAPAN)

SLR PRODUCTS IN THE 1990's

Positioning	o	Altimetric Missions
	o	Global Datums
	o	Tectonic Motion
	o	Plate Deformation
Earth Orientation	o	Polar Motion Frequency Structure
P. Motion <0.6 msec	o	Polar Wander
LOD <0.03 msec	o	Earthquake Excitation
	o	Atmospheric Excitation
Geopotential	o	Rheology – Post Glacial Response
	o	Mantle Convection
	o	Polar Wander
	o	Ice Loading
	o	Mission Support (Altimetry, Navigation)
	o	Gravitational Constant
Surface Forces	o	Albedo
	o	Drag
Earth and Ocean Tides	o	Tidal Dissipation
	o	Earth Moon Separation
	o	Zonal Tides and Departure from Equilibrium
	o	Improved Length of Day
	o	18.6 yr. Tide for Q at Intermediate Frequencies
	o	Core–Mantle Resonances (K_1 Tide)
	o	Love Numbers of Load Tides