

Apéndice I: descripción del formato RINEX

El presente apéndice contiene la descripción de los ficheros de formato RINEX de observables GPS y de efemérides de los satélites. Las descripciones se basan en los ficheros de información proporcionados por el Jet Propulsion Laboratory (JPL), Pasadena, y son accesibles vía Internet a través de la dirección

`/gps/gipsy_r2/gipsy-oasis/file_formats`

para los ficheros de observables GPS y

`/gps/gipsy_r2/gipsy-oasis/sta_info`

para los ficheros de efemérides.

Estos ficheros se obtienen a partir del mensaje transmitido por los satélites GPS a las estaciones de tierra. Las estaciones separan la información en ficheros RINEX de observables (código y fase de la portadora) y en ficheros RINEX de efemérides de cada satélite.

Los nombres de ambos tipos de ficheros contienen la fecha de observación así como el identificativo de la estación receptora expresado mediante la fórmula `yyymmdd` seguida del identificador de la estación. El año viene dado por `yy` (year), `mm` (month) indica el mes, `dd` el día de observación y, por ejemplo, la palabra `madr` identificaría a la estación receptora "Madrid". Finalmente, el nombre del fichero lleva la extensión `*.rnx` o `*.eph` según si contiene los observables GPS o las efemérides de navegación.

Esta estructura puede ser más larga por otros motivos. Por ejemplo, la extensión `r0` indicaría que el receptor está provisto de una antena tipo ROGUE. En este caso, los nombres finales serían `93nov18madr__r0.rnx` o bien `93nov18madr__r0.eph`.

Ficheros rinex de observables GPS (*.rnx)

La tabla siguiente muestra la estructura de la cabecera de los ficheros RINEX y es válida tanto para ficheros de observables `*.rnx` como para ficheros de efemérides `*.eph`. El símbolo `**` colocado en algunos márgenes indica información opcional.

OBSERVATION DATA FILE - HEADER DESCRIPTION		
HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2) - File type ('0' Observation Data) - Satellite System: blank or 'G': GPS 'R': GLONASS 'T': NNSS Transit 'M': Mixed	I6,14X, A1,19X, A1,19X
PGM / RUN BY / DATE	- Name of program creating current file - Name of agency creating current file - Date of file creation	A20, A20, A20
COMMENT	Comment line(s)	A60 **
MARKER NAME	Name of antenna marker	A60
MARKER NUMBER	Number of antenna marker	A20 **
OBSERVER / AGENCY	Name of observer / agency	A20,A40
REC # / TYPE / VERS	Receiver number, type, and version (Version: e.g., Internal Software Version)	3A20
ANT # / TYPE	Antenna number and type	2A20
APPROX POSITION XYZ	Approximate marker position (WGS84)	3F14.4
ANTENNA: DELTA H/E/N	- Antenna height: Height of bottom surface of antenna above marker - Eccentricities of antenna center relative to marker to the east and north (all units in meters)	3F14.4
WAVELENGTH FACT L1/2	- Wavelength factors for L1 and L2 1: Full cycle ambiguities 2: Half cycle ambiguities (squaring) 0 (in L2): Single frequency instrument - Number of satellites to follow in list 0: Default wavelength factors Max 7. If more than 7 satellites: Repeat record.	2I6, I6,

	- List of PRNs (satellite numbers)	7(3X,A1,I2)
#/TYPES OF OBSERV.	- Number of different observation types stored in the file	I6,
	- Observation types	9(4X,A2)
<p>The following observation types are defined in RINEX Version 2:</p> <p>L1, L2: Phase measurements on L1 and L2 C1 : Pseudorange using C/A-Code on L1 C2 : Pseudorange using C/A-Code on L1 and P2-P1 code P1, P2: Pseudorange using P-Code on L1, L2 D1, D2: Doppler frequency on L1 and L2 T1, T2: Transit integrated doppler on 150 (T1) and 400 MHz (T2)</p> <p>Units: Phase : full cycles Pseudorange : meters Doppler : Hz Transit : cycles</p> <p>The sequence of the types in this record has to correspond to the sequence of the observations in the observation records</p>		
INTERVAL	Observation interval in seconds	I6 **
TIME OF FIRST OBS	Time of first observation record year (4 digits), month,day,hour,min,sec	5I6,F12.6
TIME OF LAST OBS	Time of last observation record year (4 digits), month,day,hour,min,sec	5I6,F12.6 **
# OF SATELLITES	Number of satellites, for which observations are stored in the file	I6 **
PRN / #OF OBS	PRN (sat.number), number of observations for each observation type indicated in the R# / TYPES OF OBSERVS - record. This record is repeated for each satellite present in the data file.	3X,A1,I2,9I6 **
END OF HEADER	Last record in the header section.	60X

A continuación se muestra la estructura de los registros de observables GPS:

OBSERVATION DATA FILE - DATA RECORD DESCRIPTION		
OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / SAT or EVENT FLAG	- Epoch: year (2 digits), month,day,hour,min,sec	5I3,F11.7,
	- Epoch flag 0: OK 1: power failure between previous and current epoch >1: Event flag	I3,
	- Number of satellites in current epoch	I3,
	- List of PRNs (sat. numbers) in current epoch If more than 12 satellites: continued in next line with n(A1,I2)	12(A1,I2)
	- Receiver clock offset (seconds, optional) (GPS time = receiver time - offset)	F12.9
	If EVENT FLAG record (epoch flag > 1):	
	- Event flag: 2: start moving antenna 3: new site occupation (end of kinem. data) (at least MARKER NAME record follows) 4: header information follows 5: external event (epoch is significant) 6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as OBSERVATIONS records; slip instead of observation; LLI and signal strength blank)	
	- "Number of satellites" contains member of records to follow	
OBSERVATIONS	- Observation rep. within record for - LLI each obs. type (same seq - Signal strength as given in header)	m(F14.3, I1, I1)
	This record is repeated for each satellite given in EPOCH/SAT - record If more than 5 observation types (=80 char): Continue observations in next record.	
	Observations: Phase : Units in whole cycles of carrier Code : Units in meters	

Missing observations are written as 0.0 or blanks

Loss of lock indicator (LLI, important for phase only)

- 0 or blank: OK or not known
- 1 (=bit 0): lost lock between previous and current observation: cycle slip possible
- 2 (=bit) : Inverse wavelength factor to default (does NOT change default)
- 3 (=bits 0,1): lost lock, inverse w/fact

Signal strength projected into interval 1-9:

- 1: minimum possible signal strength
 - 5: threshold for good S/N ratio
 - 9: maximum possible signal strength
 - 0 or blank: not known, don't care
-

Ficheros RINEX de efemérides de navegación (*.eph)

Los ficheros rinex de efemérides tienen una cabecera que se ajusta a la descripción vista en el apartado anterior, por lo tanto, sólo describiremos el formato de las efemérides de navegación:

```

-----
NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION
-----
HEADER LABEL                DESCRIPTION                FORMAT
-----
PRN / EPOCH / SV CLK - Satellite PRN number                I2,5I3,
                                                                F5.1,3D19.12
    - Epoch: TOC - Time of clock
      year (2 digits)
      month
      day
      hour
      minute
      second
    - SV clock bias (seconds)
    - SV clock drift (sec/sec)
    - SV clock drift rate (sec/sec2)
-----
BROADCAST ORBIT - 1 - AODE (age of data ephemeris, sec)    3X,4D19.12
    - Crs (meters)
    - Delta n (radians/sec)
    - Mo (radians)
-----
BROADCAST ORBIT - 2 - Cuc (radians)                        3X,4D19.12
    - Eccentricity
    - Cus (radians)
    - A1/2 (meter1/2)
-----
BROADCAST ORBIT - 3 - TOE Time of Ephemeris                3X,4D19.12
    (seconds into GPS week)
    - Cic (radians)
    - Omega (radians)
    - Cis (radians)
-----
BROADCAST ORBIT - 4 - io (radians)                         3X,4D19.12
    - Crc (meters)
    - omega (radians)
    - omega dot (radians/sec)
-----

```

BROADCAST ORBIT - 5 - IDOT (radians/sec) 3X,4D19.12
- Codes on L2 channel
- GPS Week # (to go with TOE)
- L2 P data flag

BROADCAST ORBIT - 6 - SV accuracy 3X,4D19.12
- SV health (MSB only)
- TGD (seconds)
- AODC (seconds)

BROADCAST ORBIT - 7 - Transmission time of message 3X,4D19.12
(seconds into GPS week, derived e.g.
from Z-count in Hand Over Word [HOW])
- spare
- spare
- spare

Apéndice II: listados de Programas

Programas FORTRAN

A continuación se presentan los listados de algunos de los programas FORTRAN que se utilizan en las prácticas del libro. Estos programas utilizan subrutinas para inversión y producto de matrices, ejemplos de las cuales pueden encontrarse en el libro *Numerical Recipes*.

- **Programa cart2esf:**

Realiza el cambio de coordenadas de cartesianas a esféricas.

```

c2345678901234567
      implicit double precision (a-h,o-z)
c -----
c          (x,y,z) ---->|cart2esf| ---> (r, alfa, delta)
c                                     en grados
c
c   Ejemplo:
c          Ejecutar: echo "1 0 0"|cart2esf
c
c   @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----
      pi=datan2(1.d0,1.d0)*4
      do i=1,1000000
      read (*,*,end=100) x,y,z
      x=x*1.d0
      y=y*1.d0
      z=z*1.d0
      r=dsqrt(x**2+y**2+z**2)
      alfa=datan2(y,x)
      if (alfa.lt.0.d0) alfa=alfa+2.d0*pi
      delta=datan2(z,dsqrt(x**2+y**2))
      print *, r, alfa*180/pi, delta*180/pi
      enddo
100    continue
      end

```

- Programa `esf2cart`:

Realiza el cambio de coordenadas de esféricas a cartesianas.

```

c234567
      implicit double precision (a-h,o-z)

c -----
c
c      (r, alfa, delta) ---->|esf2cart| ---> (x,y,z)
c      en grados
c      Ejemplo:
c      Ejecutar: echo "1 90 90"|esf2cart
c
c      @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

      pi=datan2(1.d0,1.d0)*4

      do i=1,1000000

      read (*,*,end=100) r,a,d

      r=r*1.d0
      a=a*pi/180.d0
      d=d*pi/180.d0

      x=r*dcos(a)*dcos(d)
      y=r*dsin(a)*dcos(d)
      z=r*dsin(d)
      write(*, '(f16.9,1x,f16.9,1x,f16.9)') x,y,z
      enddo

100    continue
end

```

- Programa ymdUT2sid:

Cálculo del día juliano y del tiempo sidéreo a partir del año, mes, día, hora.

```

c234567890
      implicit double precision (a-h,o-z)
      double precision jd
c
c -----
c   Calcula el DIA JULIANO y el tiempo SIDEREO MEDIO
c   para una fecha y una hora determinadas (es decir, el
c   angulo horario del punto Aries):
c
c   anyo mes dia hora(UT)-->|ymdUT2sid|--> jd sid(hh.hh)
c
c   Ejecutar:
c   echo "1978 11 13 0"| ymdUT2sid
c   resultado:
c           2443825.5    3.45038611041    3  27  1.39000
c
c   @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----
      read(*,*) xy,xm,xd,xt
      if (xm.le.2.) then
         xy=xy-1.d0
         xm=xm+12.d0
      endif
      jd=int(365.25d0*xy)+int(30.6001d0*(xm+1.d0))+xd
*      +xt/24.d0+1720981.5d0
      tt=(jd-2451545.d0)/36525.d0
      sid1=24110.54841d0+8640184.812866d0*tt
*      +0.093104d0*tt**2-(6.2d-6)*(tt**3)
      sid1=(sid1/3600.d0+xt)
      sid1=dmod(sid1,24.d0)
      if (sid1.lt.0.d0) sid1=sid1+24.d0
      ih=int(sid1)
      xmm=(sid1-ih*1.d0)*60.d0
      mm=int(xmm)
      xss=(xmm-mm*1.d0)*60.d0
      write(*,'(f10.1,1x,f16.11,1x,i3,1x,i3,1x,f8.5)')
*      jd, sid1, ih,mm,xss
      end

```

- Programa wgs2eq.f:

Realiza el cambio de coordenadas terrestres (WGS84) a coordenadas ecuatoriales.

```

c234567
      implicit double precision (a-h,o-z)
      dimension r(3), rp(3)

c -----
c
c      (t_sid,x,y,z) ---->|wgs2eq| ----> (x,y,z)
c              WGS84                      coordenadas ecuat.
c      x => Greenwich                      x => Aries
c      z => Polo Norte                      z => Polo Norte
c
c      Ejemplo:
c              echo "3.460 16336.506 7596.636 -19390.923"|wgs2eq
c
c      @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

      pi=datan2(1.d0,1.d0)*4

      read (*,*) ts,r
      ts=ts*pi/12.d0
      call rot3(-ts,r,rp)

      write(*, '(f12.5,1x,f12.5,1x,f12.5)') rp

      end

c -----

      subroutine rot3(ang,r,rp)
      implicit double precision (a-h,o-z)
      dimension r(3),rp(3)

      rp(1)=cos(ang)*r(1)+sin(ang)*r(2)
      rp(2)=-sin(ang)*r(1)+cos(ang)*r(2)
      rp(3)=r(3)
      end

c -----

```

- Programa eq2wgs:

Realiza el cambio de coordenadas de ecuatoriales a coordenadas terrestres.

```

c234567
      implicit double precision (a-h,o-z)
      dimension r(3), rp(3)

c -----
c
c      (t_sid,x,y,z)  -----> |eq2wgs| -----> (x,y,z)
c      coordenadas ecuatoriales                WGS84
c      x => Aries                                x => Greenwich
c      z => Polo Norte                          z => Polo Norte
c
c  Ejemplo:
c  echo "3.460 4099.155 17543.866 -19390.923"|eq2wgs
c
c  @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

      pi=datan2(1.d0,1.d0)*4

      read (*,*) ts,r
      ts=ts*pi/12.d0
      call rot3(ts,r,rp)

      write(*, '(f12.5,1x,f12.5,1x,f12.5)') rp

      end

c -----

      subroutine rot3(ang,r,rp)
      implicit double precision (a-h,o-z)
      dimension r(3),rp(3)

      rp(1)=cos(ang)*r(1)+sin(ang)*r(2)
      rp(2)=-sin(ang)*r(1)+cos(ang)*r(2)
      rp(3)=r(3)
      end

c -----

```

- Programa wgs2eq_ts:

Lo mismo que wgs2eq, pero el tiempo sidéreo lo calcula el propio programa.

```

c234567
      implicit double precision (a-h,o-z)
      dimension r(3), rp(3)

c -----
c
c      (yy mm dd UT,x,y,z) ---->|wgs2eq_ts| ---> (x,y,z)
c      WGS84                                coordenadas ecuat.
c      x => Greenwich                        x => Aries
c      z => Polo Norte                        z => Polo Norte
c
c Ejemplo:
c echo "1998 11 13 0 16336.5 7596.6 -19390.9 "|wgs2eq_ts
c
c @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

      pi=datan2(1.d0,1.d0)*4

      read (*,*) ay,am,ad,ah,r

c      Calculo del tiempo sidereo
      call sid0TU(ay,am,ad,ts)
      ts=ts+1.00273790934d0*ah
      ts=dmod(ts,24)
c      print *, ay,am,ad,ah,ts
      ts=ts*pi/12.d0

c      Transformacion de coordenadas
      call rot3(-ts,r,rp)

      write(*, '(f12.5,1x,f12.5,1x,f12.5)') rp

      end

```

```

c -----
      subroutine rot3(ang,r,rp)
      implicit double precision (a-h,o-z)
      dimension r(3),rp(3)

      rp(1)=dcos(ang)*r(1)+dsin(ang)*r(2)
      rp(2)=-dsin(ang)*r(1)+dcos(ang)*r(2)
      rp(3)=r(3)
      end

c -----

      subroutine sid0TU(xy,xm,xd,sid)
      implicit double precision (a-h,o-z)
      double precision jd

c -----
c      anyo mes dia -->|sid0TU|--> sid(hh.hh)
c -----

      if (xm.le.2.) then
          xy=xy-1.d0
          xm=xm+12.d0
      endif

c      dia juliano (jd)
      jd=int(365.25d0*xy)+int(30.6001d0*(xm+1.d0))+xd+
* +1720981.5d0

c      Calculo del tiempo sidereo a 0h TU(sid)
      tt=(jd-2451545.d0)/36525.d0

      sid=24110.54841d0+8640184.812866d0*tt
*      +0.093104d0*tt**2-(6.2d-6)*(tt**3)
      sid=sid/3600.d0
      sid=dmod(sid,24.d0)
      if (sid.lt.0.d0) sid=sid+24.d0

      end

c -----

```

- Programa eq2wgs_ts:

Lo mismo que eq2wgs, pero el tiempo sidéreo lo calcula el propio programa.

```

c234567
      implicit double precision (a-h,o-z)
      dimension r(3), rp(3)

c -----
c
c   (yy,mm,dd,hh,x,y,z)  -----> |eq2wgs_ts| -----> (x,y,z)
c   coordenadas ecuatoriales                                WGS84
c       x => Aries                                           x => Greenwich
c       z => Polo Norte                                       z => Polo Norte
c
c Ejemplo:
c   echo "1998 11 13 0 4099.15 17543.86 -19390.92"|eq2wgs_ts
c
c   @gAGE (grupo de Astronomia y Geodesia Espacial. UPC)
c -----

      pi=datan2(1.d0,1.d0)*4
      do i=1,1000000
      read(*,*,end=100) ay,am,ad,ah,r

c   Calculo del tiempo sidereo
c   call sid0TU(ay,am,ad,ts)
c   ts=ts+(365.2422d0/364.2422d0)*ah
c   ts=ts+1.00273790934d0*ah
c   ts=dmod(ts,24)

c   print *, ay,am,ad,ah,ts
c   ts=ts*pi/12.d0
c   Transformacion de coordenadas
c   call rot3(ts,r,rp)
c   print *, ts
c   write(*,'(f12.5,1x,f12.5,1x,f12.5)') rp
c   enddo

100   continue
      end

```

```

c -----
  subroutine rot3(ang,r,rp)
  implicit double precision (a-h,o-z)
  dimension r(3),rp(3)

  rp(1)=dcos(ang)*r(1)+dsin(ang)*r(2)
  rp(2)=-dsin(ang)*r(1)+dcos(ang)*r(2)
  rp(3)=r(3)

  end

c -----
  subroutine sid0TU(xy,xm,xd,sid)
  implicit double precision (a-h,o-z)
  double precision jd

c   Calculo del tiempo sidereo a 0h TU

c   -----
c   anyo mes dia -->|sid0TU|--> sid(hh.hh)
c   -----

  if (xm.le.2.) then
    xy=xy-1.d0
    xm=xm+12.d0
  endif

c   dia juliano (jd)
  jd=int(365.25d0*xy)+int(30.6001d0*(xm+1.d0))+xd
* +1720981.5d0

c   print *,xy,xm,xd,jd
c   Calculo tiempo sidereo a 0h TU (sid)
  tt=(jd-2451545.d0)/36525.d0

  sid=24110.54841d0+8640184.812866d0*tt
*   +0.093104d0*tt**2-(6.2d-6)*(tt**3)
  sid=sid/3600.d0
  sid=dmod(sid,24.d0)
  if (sid.lt.0.d0) sid=sid+24.d0
  end

c -----

```

- Programa orb2xyz:

Calcula las coordenadas (x, y, z) a partir de los elementos orbitales.

```

cx234567
  implicit double precision (a-h,o-z)
  dimension p(6),r0(3),r(3),rot1(9),rot2(9),
  * rot3(9),

c .....
c
c
c sat,dia,seg,[a,e,i,OMEGA,omega,Mo]-->|orb2xyz|-->isat,idia,
c                                     time,
c                                     r_sat_topo
c
c  NOTA:
c  z => Polo Norte
c  Si W (long. nodo asc.) referida a Aries => x hacia Aries
c  Si W (long. nodo asc.) referida a Green. => x hacia Green.
c
c      Nota: en los ficheros *eph y los *b
c            se toma W referida a Greenwich
c
c      @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----
c      Nota: Mo=n(to-T) con n=dsqrt(gm/a**3); T=tiempo de paso
c                                     por el perigeo
c .....

      c=299792458.

c      Lectura de los elementos orbitales
c      do i=1,100000
c      read (*,*,end=100) isat,id,t,p
c      call kepler(p(6),p(2),ex)
c      print *,p
c      r0(1)=p(1)*(1-p(2)*dcos(ex))
c      xv=datan2(dsqrt(1-p(2)**2)*dsin(ex),dcos(ex)-p(2))

```

```
c      print *,p(6),ex,xv
      call rotate(3,-p(5)-xv,rot3)
      call rotate(1,-p(3),rot1)
call g_axb(rot1,3,3,0,'N',rot3,3,3,0,'N',
*          rot2,nr,nc,0,ier)
      call rotate(3,-p(4),rot3)
call g_axb(rot3,3,3,0,'N',rot2,3,3,0,'N',
*          rot1,nr,nc,0,ier)
      call g_axb(rot1,3,3,0,'N',r0,3,1,0,'N',r,nr,nc,0,ier)

      write(*,*) isat,id,t,r
      enddo

100    end
```

```
c -----
      subroutine kepler(xm,e,ex)
      implicit double precision (a-h,o-z)

      eps=1.d-12
      ex=xm

1000  dex=xm-(ex-e*dsin(ex))
      ex=ex+dex
      if (dex .gt. eps) goto 1000
      return
      end
c -----
```

- Programa `ele_orb2rv`:

Cálculo de la posición y la velocidad a partir de los elementos orbitales.

```

cx234567
  implicit double precision (a-h,o-z)
  dimension p(6),r0(3),r(3),v(3),rot1(9),rot2(9),
* rot3(9), rot(9)

c .....
c
c
c
c [a,e,i,OMEGA,omega,M] ---> |ele_orb2rv| ----> [r,v]
c                                     (ecuatoriales)
c                                     x => Aries
c                                     z => Polo Norte
c (unidades: km y rad)                (unidades: km y km/s)
c
c  NOTA: !! Coordenadas TERRESTRES!!: -----
c Si W (long. nodo asc.) referida a Aries => x hacia Aries
c Si W (long. nodo asc.) referida a Green. => x hacia Green.
c  WARNING: en este ultimo caso la velocidad corresponderia
c           a un sistema inercial rotado un angulo=t_sider.
c           alrededor del eje z.
c
c  Nota: en los ficheros *eph y los *b
c        se toma W referida a Greenwich
c
c -----
c  Nota: M=n(t-T) con n=dsqrt(gm/a**3)
c .....
c
c Ejemplo1:
c echo "26549. 0.014 0.946 -1.246 -2.476 0.781" |ele_orb2rv
c
c Resultado:
c      -15366.34 -2287.86 -21205.69 .99 -3.77 -.36
c
c
c @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

```

```

gm=398600.44d0
c=299792458.
do i=1,10000
read (*,*,end=100) p
call kepler(p(6),p(2),ex)
rr=p(1)*(1-p(2)*dcos(ex))
xv=datan2(dsqrt(1-p(2)**2)*dsin(ex),dcos(ex)-p(2))
call rotate(3,-p(5),rot3)
call rotate(1,-p(3),rot1)
call g_axb(rot1,3,3,0,'N',rot3,3,3,0,'N',
*       rot2,nr,nc,0,ier)
call rotate(3,-p(4),rot3)
call g_axb(rot3,3,3,0,'N',rot2,3,3,0,'N',
*       rot,nr,nc,0,ier)
c   calculo de la posicion r:
r0(1)=rr*dcos(xv)
r0(2)=rr*dsin(xv)
r0(3)=0.d0
call g_axb(rot,3,3,0,'N',r0,3,1,0,'N',r,nr,nc,0,ier)
c   calculo de la velocidad v:
xna=dsqrt(gm/p(1))
b=p(1)*dsqrt(1-p(2)**2)
v(1)=xna/rr*(rot(4)*b*dcos(ex)-rot(1)*p(1)*dsin(ex))
v(2)=xna/rr*(rot(5)*b*dcos(ex)-rot(2)*p(1)*dsin(ex))
v(3)=xna/rr*(rot(6)*b*dcos(ex)-rot(3)*p(1)*dsin(ex))
write(*,*) r,v
enddo
100  end
c -----
subroutine kepler(xm,e,ex)
implicit double precision (a-h,o-z)
eps=1.d-12
ex=xm
1000 dex=xm-(ex-e*dsin(ex))
ex=ex+dex
if (dex .gt. eps) goto 1000
return
end
c -----

```

- Programa `rv2ele_orb2`:

Calculo de los elementos orbitales a partir de la posición y la velocidad del satélite.

```

cx234567
  implicit double precision (a-h,o-z)
  dimension r(3),v(3),c(3),ve(3)

c .....
c
c
c [r,v] -----> |rv2ele_orb| --> [a,e,i,OMEGA,omega,M]
c (ecuatoriales)
c x => Aries
c z => Polo Norte
c (unidades: km y km/s)          (unidades: km y rad)
c
c -----
c Nota: M=n(t-T) con n=dsqrt(gm/a**3)
c .....
c
c
c Ejemplo1:
c echo "-15334. -2312. -21208. .994 -3.770 -.359" |rv2ele_orb
c
c Resultado:
c      26549.521 .015 .947 -1.247 -2.477 .782
c
c
c @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c -----

```

```

pi=datan2(1.d0,1.d0)*4
gm=398600.44d0

```

```

do i=1,1000000

read (*,*,end=100) r,v

rr=dsqrt(r(1)**2+r(2)**2+r(3)**2)
vv=dsqrt(v(1)**2+v(2)**2+v(3)**2)

c(1)=r(2)*v(3)-r(3)*v(2)
c(2)=r(3)*v(1)-r(1)*v(3)
c(3)=r(1)*v(2)-r(2)*v(1)
cc=dsqrt(c(1)**2+c(2)**2+c(3)**2)

ve(1)=(-c(2)*v(3)+c(3)*v(2))/gm-r(1)/rr
ve(2)=(-c(3)*v(1)+c(1)*v(3))/gm-r(2)/rr
ve(3)=(-c(1)*v(2)+c(2)*v(1))/gm-r(3)/rr

ex=dsqrt(ve(1)**2+ve(2)**2+ve(3)**2)
a=1/(2/rr-vv**2/gm)
Wg=datan2(c(1),-c(2))
xi=dacos(c(3)/cc)
wp=datan2(ve(3)/dsin(xi),(ve(1)+dsin(Wg)*ve(3)*
* dcos(xi)/dsin(xi))/dcos(Wg))
E=dacos((1-rr/a)/ex)
control=r(1)*v(1)+r(2)*v(2)+r(3)*v(3)
if (control.lt.0.d0) E=-E
xn=dsqrt(gm/a**3)
xM=E-ex*dsin(E)

c      TT=t-xM/xn
c      if (TT.lt.0.d0) TT=TT+2*pi/xn

write(*,'(f16.9,1x,f16.9,1x,f16.9,1x,f16.9,1x,
* f16.9,1x,f16.9)') a,ex,xi,Wg,wp,xM

enddo

100    continue

end

```



```
c      print *,p(6),ex,xv
      call rotate(3,-p(5)-xv,rot3)
      call rotate(1,-p(3),rot1)
      call g_axb(rot1,3,3,0,'N',rot3,3,3,0,'N',rot2,nr,nc,
*          0,ier)
      call rotate(3,-p(4),rot3)
      call g_axb(rot3,3,3,0,'N',rot2,3,3,0,'N',rot1,nr,nc,
*          0,ier)
      call g_axb(rot1,3,3,0,'N',r0,3,1,0,'N',r,nr,nc,0,ier)
      write(*,*) isat,id,t,r
      enddo

100    end
c -----

      subroutine kepler(xm,e,ex)
      implicit double precision (a-h,o-z)

      eps=1.d-12
      ex=xm

1000  dex=xm-(ex-e*dsin(ex))
      ex=ex+dex
      if (dex .gt. eps) goto 1000
      return
      end
c -----
```

- Programa lms:

Resolución de un sistema de ecuaciones sobredimensionado por el método de mínimos cuadrados con pesos.

c234567890

```

program lms

implicit double precision (a-h,o-z)
parameter (nmc=100)
dimension a(nmc),ay(nmc),aa((nmc**2+nmc)/2),x(nmc)

c -----
c      Dado el sistema  $Y=AX$  con covarianzas (ruido de datos)
c               $P=\text{diag}(\text{sig}(Y_1)**2,\dots,\text{sig}(Y_k)**2)$ 
c      calcula la solucion de varianza minima:
c               $X^{\wedge}=\text{inv}[A^{\wedge}*\text{inv}(P)*A]*[A^{\wedge}*\text{inv}(P)*Y]$ 
c .....
c
c
c      El fichero de datos debe tener el siguiente formato:
c
c
c      n      <----- numero de componentes del vector X
c      a(1,1).....a(1,n) y(1) sig_y(1)  <---- error standar
c      :           :           :           :
c      :           :           :           :
c      a(k,1).....a(k,n) y(k) sig_y(k)
c      :           :           :           :
c
c                                     <----- el numero de filas
c                                     puede ser cualquiera
c
c      @gAGE (grupo de Astronomia y Geodesia Espacial). UPC
c .....
c
c      Ejecutar:  cat fichero | lms
c
c -----

```

```
read(*,*) n

do 30 k=1,100000
read(*,*,end=100) (a(i),i=1,n),y,sig

do 10 i=1,n
ay(i)=ay(i)+a(i)*y/(sig**2)
aa(i*(i+1)/2)=aa(i*(i+1)/2)+a(i)*a(i)/(sig**2)
do 20 j=i+1,n
aa(j*(j-1)/2+i)=aa(j*(j-1)/2+i)+a(i)*a(j)/(sig**2)
20 continue
10 continue

30 continue
100 continue

call invsp(aa,n,ier)
if (ier.eq.1) print *, "Warning: sigular matrix"
call g_axb(aa,n,n,1,'N',ay,n,1,0,'N',x,nf,nc,0,ier)

write(*,*) (x(i),i=1,n)

end
```

Programas awk

- Programa `matrix_pos_casa.awk`:

Este programa genera la matriz del sistema lineal $Y = AX$ para el posicionamiento GPS de la estación `casa`. Se estiman las coordenadas de la estación y el *offset* de su reloj. No se tiene en cuenta la troposfera.

```
# Ejecutar  cat 95oct18obs_casa | head -12 |
#                                     matrix_pos_casa.awk | lms

BEGIN {x0=-2444430.1722;y0= -4428687.9961;z0= 3875747.4100;
       f1=1575.42; f2=1227.6};
{dx=(x0-$10);dy=(y0-$11);dz=(z0-$12);r=sqrt(dx^2+dy^2+dz^2);
  pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13};

#Numero de parametros a estimar
{if (NR==1) print 4};

# Matriz ampliada:
{print dx/r,dy/r,dz/r,1,pc-r+cdt,10};
```

- Programa `matrix_pos_trop_casa.awk`:

Este programa genera la matriz del sistema lineal $Y = AX$ para el posicionamiento GPS de la estación `casa`. Se estiman las coordenadas de la estación y el *offset* de su reloj. Se supone un retardo de 2.1 m para la troposfera.

```
# Ejecutar:
#  cat 95oct18obs_casa | awk -f matrix_pos_trop_casa.awk | lms

BEGIN {x0=-2444430.1722;y0= -4428687.9961;z0= 3875747.4100;
       f1=1575.42; f2=1227.6};
{dx=(x0-$10);dy=(y0-$11);dz=(z0-$12);r=sqrt(dx^2+dy^2+dz^2);
  pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13;
  sinelev=-(dx*x0+dy*y0+dz*z0)/(r*sqrt(x0^2+y0^2+z0^2))};

#Numero de parametros a estimar:
{if (NR==1) print 4};

# Matriz ampliada:
{print dx/r,dy/r,dz/r,1,pc-r+cdt-2.1/sinelev,10};
```

- Programa `matrix_pos_esttrop_jplt.awk`:

Este programa genera la matriz del sistema lineal $Y = AX$ para el posicionamiento GPS de la estación *casa*. Se estiman las coordenadas de la estación, el *offset* de su reloj y el retardo troposférico.

```
# Ejecutar:
# cat 95oct18obs_casa |awk -f matrix_pos_esttrop_casa.awk| lms

#Coordenadas de casa:
BEGIN {x0=-2444430.1722;y0= -4428687.9961;z0= 3875747.4100
      f1=1575.42; f2=1227.6};

{dx=(x0-$10);dy=(y0-$11);dz=(z0-$12);r=sqrt(dx^2+dy^2+dz^2);
 pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13;
 sinelev=-(dx*x0+dy*y0+dz*z0)/(r*sqrt(x0^2+y0^2+z0^2))};

#Numero de parametros a estimar:
{if (NR==1) print 5};

# Matriz ampliada:
{print dx/r,dy/r,dz/r,1,1/sinelev,pc-r+cdt-2.1/sinelev,10};

# Ligadura troposfera:

END {
 print 0, 0, 0, 0, 1, 0, 1e-1}
```

- Programa `matrix_pos_sat_casa.awk`:

Este programa genera la matriz del sistema lineal $Y = AX$ para el posicionamiento GPS de la estación `casa`. Se estiman las coordenadas de la estación y el *offset* de los relojes de los satélites (se supone conocido el del receptor). Se supone retardo troposférico de 2.1 m.

```
# Ejecutar: cat 95oct18obs_casa | head -12|
#                               awk -f matrix_pos_sat_casa.awk |lms

BEGIN {x0=-2444430.1722;y0= -4428687.9961;z0= 3875747.4100;
      re=sqrt(x0^2+y0^2+z0^2);f1=1575.42; f2=1227.6};
{
# Numero de parametros a estimar:
if (NR==1) print 10;
{
  dx=x0-$10;dy=y0-$11;dz=z0-$12; r=sqrt(dx^2+dy^2+dz^2);
  pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13;
  sinel=-(dx*x0+dy*y0+dz*z0)/(r*re);

if ($4== 4) print dx/r,dy/r,dz/r,1,-1, 0, 0, 0, 0, 0, pc-r+cdt-2.1/sinel,10;
if ($4==18) print dx/r,dy/r,dz/r,1, 0,-1, 0, 0, 0, 0, pc-r+cdt-2.1/sinel,10;
if ($4==19) print dx/r,dy/r,dz/r,1, 0, 0,-1, 0, 0, 0, pc-r+cdt-2.1/sinel,10;
if ($4==22) print dx/r,dy/r,dz/r,1, 0, 0, 0,-1, 0, 0, pc-r+cdt-2.1/sinel,10;
if ($4==28) print dx/r,dy/r,dz/r,1, 0, 0, 0, 0,-1, 0, pc-r+cdt-2.1/sinel,10;
if ($4==29) print dx/r,dy/r,dz/r,1, 0, 0, 0, 0, 0,-1, pc-r+cdt-2.1/sinel,10;
      };
}
# Ligaduras: Fijamos el reloj del receptor
END {
      print 0, 0 ,0 ,1, 0, 0, 0, 0, 0, 0, 0, 1e-6;
};
```

- Programa `formato_matrix.awk` :

Este programa se emplea para dar un formato más legible a los resultados del programa `matrix_pos_casa.awk`.

```
# Ejecutar: cat 95oct18obs_casa |awk -f matrix_pos_casa.awk
#                               | awk -f formato_matrix.awk
{if (NR==1) print $0}
{if (NR>1) printf "%.2f %.2f %.2f %s \t %.2f \t %.2f \n",
                  $1,$2,$3,$4,$5,$6}
```

- Programa `dgps_uclp_jplm.awk`:

Este programa genera la matriz del sistema lineal $Y = AX$ para el posicionamiento GPS diferencial de la estación `jplm`, respecto de `uclp`, que se toma como *fiducial*. Se estiman las coordenadas de la estación y los *offsets* del reloj de `jplm` y de los relojes de los satélites. Se suponen conocidas las coordenadas y el *offset* del reloj de `uclp`. Se supone retardo troposférico de 2.1 m.

```
# Ejecutar: cat 95oct18obs_uclp 95oct18obs_jplm |
#
#                               awk -f dgps_uclp_jplm.awk | lms
#
BEGIN {x01=-2519007.9690;y01=-4650674.9267;z01=3552863.1807;
      r1=sqrt(x01^2+y01^2+z01^2);
      x02=-2493304.0136;y02=-4655215.5989;z02=3565497.3229;
      r2=sqrt(x02^2+y02^2+z02^2);f1=1575.42; f2=1227.6};
{
# Numero de parametros a estimar:
if (NR==1) print 13;

# Estacion uclp:
if ($1=="uclp") {
  dx=x01-$10;dy=y01-$11;dz=z01-$12; r=sqrt(dx^2+dy^2+dz^2);
  pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13;
  sinel=-(dx*x01+dy*y01+dz*z01)/(r*r1);

if ($4== 2) print dx/r,dy/r,dz/r,1,0,0,0,0,-1,0,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==19) print dx/r,dy/r,dz/r,1,0,0,0,0,0,-1,0,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==27) print dx/r,dy/r,dz/r,1,0,0,0,0,0,0,-1,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==28) print dx/r,dy/r,dz/r,1,0,0,0,0,0,0,0,-1,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==31) print dx/r,dy/r,dz/r,1,0,0,0,0,0,0,0,0,-1,pc-r+cdt-2.1/sinel,10;
  };

# Estacion jplm:
if ($1=="jplm") {
  dx=x02-$10;dy=y02-$11;dz=z02-$12;r=sqrt(dx^2+dy^2+dz^2);
  pc=((f1^2)*$7-(f2^2)*$8)/((f1^2)-(f2^2)); cdt=$13;
  sinel=-(dx*x02+dy*y02+dz*z02)/(r*r2);

if ($4== 2) print 0,0,0,0,dx/r,dy/r,dz/r,1,-1,0,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==19) print 0,0,0,0,dx/r,dy/r,dz/r,1,0,-1,0,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==27) print 0,0,0,0,dx/r,dy/r,dz/r,1,0,0,-1,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==28) print 0,0,0,0,dx/r,dy/r,dz/r,1,0,0,0,-1,0,0,0,pc-r+cdt-2.1/sinel,10;
if ($4==31) print 0,0,0,0,dx/r,dy/r,dz/r,1,0,0,0,0,-1,pc-r+cdt-2.1/sinel,10;
}
```

```

        };
    }
    # Ligaduras:
    END {
        print 1,0,0,0, 0, 0, 0, 0,0,0,0,0,0, 0, 1e-3;
        print 0,1,0,0, 0, 0, 0, 0,0,0,0,0,0, 0, 1e-3;
        print 0,0,1,0, 0, 0, 0, 0,0,0,0,0,0, 0, 1e-3;
        print 0,0,0,1, 0, 0, 0, 0,0,0,0,0,0, 0, 1e-6;
    };

```

- Programa `formato_dgps.awk`:

Este programa se emplea para dar un formato más legible a los resultados del programa `dgps_uclp_jplm.awk`.

```

# Ejecutar: cat 95oct18obs_uclp 95oct18obs_jplm |
#           awk -f dgps_uclp_jplm.awk |awk -f formato.awk

{if (NR==1) print $0}
{if (NR>1) printf "%.2f %.2f %.2f %s \t %.2f %.2f %.2f %s \t
                 %s %s %s %s %s \t %.1f %s \n", $1, $2, $3,
                 $4,$5,$6,$7,$8,$9,$10,$11,$12,$13,$14,$15}

```

- Programa `media.awk`:

Este programa se utiliza para calcular la media de dos vectores de datos.

```

# Ejecutar cat datos1 datos2 | gawk -f media.awk|tail -1

{if (NR==1) {a=$1;e=$2;i=$3;omg=$4;omp=$5;m=$6}};
{printf "%2.9f \t %2.9f \t%2.9f \t%2.9f \t%2.9f \t %2.9f \n",
        ($1+a)/2, ($2+e)/2, ($3+i)/2, ($4+omg)/2, ($5+omp)/2,
        ($6+m)/2};

```

- Programa `elev_sta_sat`:

Este programa permite calcular la elevación de un satélite visto desde una estación determinada.

```
#!/usr/bin/awk -f

# Este script calcula la elevacion de un satelite de
# coordenadas ($1,$2,$3) en un sistema WGS respecto
# del horizonte de una estacion de coordenadas (x,y,z)
# en el mismo sistema WGS.
#
# -----
#
# Ejecutar: cat coor_esta coor_sat | elev_sta_sat
#
# -----

{if (NR == 1) {x=$1;y=$2;z=$3}}

{if (NR>1) { s=((($1-x)*x+($2-y)*y+($3-z)*z)/sqrt(((($1-x)**2+
($2-y)**2+($3-z)**2)*(x**2+y**2+z**2)));

        print atan2(s,sqrt(1-s**2))}
}
```

Apéndice III: algunos ficheros de datos

Fichero 95oct18casa____r0.rnx

2	OBSERVATION DATA				GPS	RINEX VERSION / TYPE		
srx/v1.8.1.4	BAI				95/10/19 03:18:22	PGM / RUN BY / DATE		
CASA						MARKER NAME		
4087-S						MARKER NUMBER		
gn2	jpl					OBSERVER / AGENCY		
138	ROGUE SNR-8000				95.03.08	REC # / TYPE / VERS		
	DORNE MARGOLIN T					ANT # / TYPE		
-2444431.2031	-4428688.6270	3875750.1442				APPROX POSITION XYZ		
0.163000	0.0000	0.0000				ANTENNA: DELTA H/E/N		
30					INTERVAL			
1	1	0		WAVELENGTH FACT L1/2				
4	L1	L2	P1	P2	# / TYPES OF OBSERV			
SNR is mapped to signal strength [0,1,4-9]								
SNR:	>500	>100	>50	>10	>5	>0	bad	n/a
sig:	9	8	7	6	5	4	1	0
1995	10	18	00	00	00.000000			
1995	10	18	23	59	30.000000			
24					# OF SATELLITES			
01	783	783	783	783	PRN / # OF OBS			
02	878	878	878	878	PRN / # OF OBS			
04	925	925	925	925	PRN / # OF OBS			
05	746	746	746	746	PRN / # OF OBS			
06	762	762	762	762	PRN / # OF OBS			
07	793	793	793	793	PRN / # OF OBS			
09	907	907	907	907	PRN / # OF OBS			
14	739	739	739	739	PRN / # OF OBS			
15	973	973	973	973	PRN / # OF OBS			
16	936	936	936	936	PRN / # OF OBS			
17	848	848	848	848	PRN / # OF OBS			
18	740	740	740	740	PRN / # OF OBS			
19	883	883	883	883	PRN / # OF OBS			
20	876	876	876	876	PRN / # OF OBS			
21	871	871	871	871	PRN / # OF OBS			
22	891	891	891	891	PRN / # OF OBS			
23	835	835	835	835	PRN / # OF OBS			
24	737	737	737	737	PRN / # OF OBS			
25	874	874	874	874	PRN / # OF OBS			

PRN	#	OF	OBS
26	1046	1046	1046
27	843	843	843
28	956	956	956
29	836	836	836
31	1041	1041	1041

PRN / # OF OBS
PRN / # OF OBS
PRN / # OF OBS
PRN / # OF OBS
PRN / # OF OBS
END OF HEADER

```

95 10 18 00 00 00.0000000 0 6 14 15 18 22 25 29
-20141789.28908 -15694892.26208 20764791.10308 20764791.88908
-10156688.05308 -7914296.97108 23025606.13308 23025608.42008
-1005974.21907 -783874.88007 24656587.15107 24656589.16307
-12846588.72508 -10010318.02408 22508513.35408 22508514.93708
-15501368.59408 -12078973.35808 22258999.20508 22258999.63208
-8778399.37908 -6840304.85208 22409115.47708 22409115.63508
95 10 18 00 00 30.0000000 0 6 14 15 18 22 25 29
-20180843.59808 -15725324.18808 20757359.26608 20757360.16208
-10059627.94808 -7838665.76408 23044076.11208 23044078.37308
-1089522.05507 -848977.05707 24640688.39407 24640690.63507
-12918063.69808 -10066012.75108 22494912.01508 22494913.64808
-15427158.70008 -12021147.48308 22273121.01508 22273121.20808
-8834322.07108 -6883880.95608 22398473.85408 22398474.05408
95 10 18 00 01 00.0000000 0 6 14 15 18 22 25 29
-20219463.08808 -15755417.29708 20750010.06208 20750010.98808
-9962343.71908 -7762859.92208 23062588.65308 23062591.02308
-1173023.79007 -914043.30307 24624798.01507 24624800.80007
-12989135.97508 -10121393.69808 22481387.45608 22481388.93408
-15352642.34508 -11963082.79508 22287301.00108 22287301.34708
-8890128.47608 -6927366.45408 22387854.08208 22387854.42908
95 10 18 00 01 30.0000000 0 6 14 15 18 22 25 29
-20257638.92508 -15785164.69808 20742745.40308 20742746.30108
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-8945816.58908 -6970759.77208 22377257.01008 22377257.22508
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-1339857.31807 -1044043.36207 24593050.72507 24593053.16807
-13130100.61608 -10231236.17508 22454562.75208 22454564.08708
-15202710.66308 -11846252.93808 22315832.09408 22315832.42008
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Fichero 95oct18casa____r0.eph

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                                          COMMENT
                                          END OF HEADER
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  9.636381916043D-01 2.153437500000D+02 3.056960010495D+00-8.030691653399D-09
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  3.200000000000D+01 0.000000000000D+00 1.396983861923D-09 1.730000000000D+02
  2.592180000000D+05 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00
18 95 10 18 00 51 44.0-3.725290298462D-06-2.273736754432D-13 0.000000000000D+00
  2.120000000000D+02 2.618750000000D+01 4.973421448680D-09-5.133230702863D-01
  1.206994056702D-06 6.170925335027D-03 9.013339877129D-06 5.153748090744D+03
  2.623040000000D+05-1.303851604462D-07 2.681992356113D+00 4.842877388000D-08
  9.431056887089D-01 1.989062500000D+02 1.455299735875D+00-8.303560162325D-09
  2.064371703653D-10 1.000000000000D+00 8.230000000000D+02 0.000000000000D+00
  3.200000000000D+01 0.000000000000D+00-1.862645149231D-09 2.120000000000D+02
  2.642280000000D+05 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00
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  2.654280000000D+05 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00
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  2.180000000000D+02 2.471875000000D+01 4.634478758928D-09-3.024837471822D+00
  1.160427927971D-06 4.891381249763D-03 9.119510650635D-06 5.153622446060D+03
  2.623040000000D+05 4.656612873077D-08 2.687151563471D+00 1.676380634308D-08
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  2.664000000000D+05 1.490116119385D-08 6.257514816552D-01 3.911554813385D-08
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Fichero 95oct18casa.a

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casa 291	0 22	-2444624.551	-2444621.901	22508513.354	22508514.937	1
casa 291	0 25	-2949812.363	-2949808.662	22258999.205	22258999.632	1
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casa 291	30 18	-207329.153	-207328.868	24640688.394	24640690.635	1
casa 291	30 22	-2458225.787	-2458223.122	22494912.015	22494913.648	1
casa 291	30 25	-2935690.690	-2935686.992	22273121.015	22273121.208	1
casa 291	30 29	-1681115.594	-1681114.037	22398473.854	22398474.054	1
casa 291	60 14	-3847635.893	-3847633.821	20750010.062	20750010.988	1
casa 291	60 15	-1895770.976	-1895769.678	23062588.653	23062591.023	1
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casa 291	60 22	-2471750.391	-2471747.715	22481387.456	22481388.934	1
casa 291	60 25	-2921510.699	-2921507.003	22287301.001	22287301.347	1
casa 291	60 29	-1691735.199	-1691733.640	22387854.082	22387854.429	1
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casa 291	120 18	-254966.370	-254966.052	24593050.725	24593053.168	1
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casa 291	120 25	-2892979.649	-2892975.958	22315832.094	22315832.420	1
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casa 291	150 14	-3869175.843	-3869173.768	20728470.119	20728470.864	1
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Fichero 95oct18.b

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01 291 75104 26560733.497989449 3.317848895D-03 9.545894551D-01 -21.647705449028965 -1.353219885D+00 2.569409848D+00
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Fichero 95oct18.clocks

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Fichero 97jan09coco____r0.rnx

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Australian Regional GPS Network (ARGN) - COCOS ISLAND  COMMENT
BIT 2 OF LLI(+4) FLAGS DATA COLLECTED UNDER "AS" CONDITION COMMENT
      -0.000000000103          HARDWARE CALIBRATION (S)  COMMENT
      -0.000000054663          CLOCK OFFSET (S)         COMMENT
COCO                                MARKER NAME
AU18                                MARKER NUMBER
mrh                                auslig              OBSERVER / AGENCY
126                                ROGUE SNR-8100   93.05.25 / 2.8.33.2 REC # / TYPE / VERS
327                                DORNE MARGOLIN T ANT # / TYPE
      -741950.3241  6190961.9624 -1337769.9813  APPROX POSITION XYZ
              0.0040          0.0000          0.0000  ANTENNA: DELTA H/E/N
              1          1                                WAVELENGTH FACT L1/2
              5          C1          L1          L2          P2          P1          # / TYPES OF OBSERV
              30                                INTERVAL
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1997          1          9          23         59          30.000000  TIME OF LAST OBS
                                END OF HEADER

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22594902.367  -12949753.825  7  -10090708.53945  22594903.7394
22731128.796  -11621184.951  7  -9055464.16945  22731130.0094
24610920.702  -924108.174  6  -720085.67045  24610920.0404
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22655271.274  -11599563.608  7  -9038621.81245  22655271.4994
22612558.689  -12856969.398  7  -10018409.02845  22612559.6234
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24604536.459  -957654.791  6  -746225.94245  24604534.7294
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24598097.384  -991492.176  6  -772592.83444  24598100.2324
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Fichero 1995-10-18.eci

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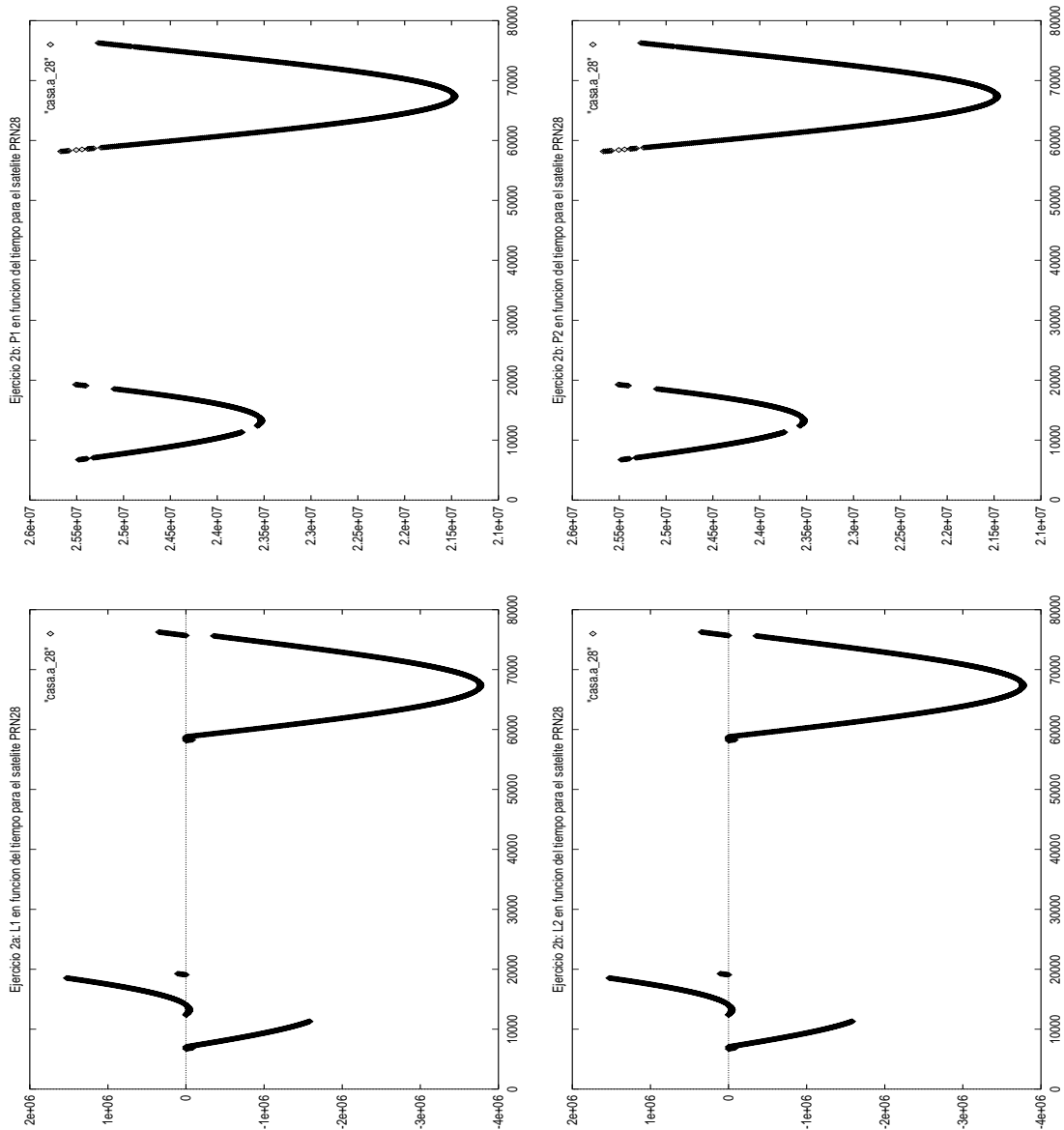
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10 1995 10 17 16 59 50.00 -1604.91090-25860.40172 3531.76545 1.88091096 .33901976 3.43871688 0
10 1995 10 17 17 14 50.00 97.28443-25323.19163 6585.48190 1.89605185 .85282690 3.33714327 0
10 1995 10 17 17 29 50.00 1797.74176-24330.26159 9520.68224 1.87708037 1.35015382 3.17580594 0
10 1995 10 17 17 44 50.00 3465.94881-22900.62882 12284.99177 1.82453030 1.82178812 2.95803585 0
10 1995 10 17 17 59 50.00 5072.17706-21061.33515 14829.53493 1.73960365 2.25914209 2.68825859 0
10 1995 10 17 18 14 50.00 6588.06462-18846.80158 17109.86454 1.62412670 2.65443288 2.37186634 -1
10 1995 10 17 18 29 50.00 7987.15251-16298.03436 19086.76631 1.48049086 3.00083151 2.01506919 -1
10 1995 10 17 18 44 50.00 9245.36193-13461.71203 20726.92236 1.31158136 3.29257802 1.62473248 -1
10 1995 10 17 18 59 50.00 10341.40344-10389.18488 22003.42517 1.12069781 3.52506128 1.20820762 -1
10 1995 10 17 19 14 50.00 11257.11227 -7135.41784 22896.13851 .91147002 3.69486457 .77316262 -1
10 1995 10 17 19 29 50.00 11977.70696 -3757.90718 23391.90817 .68777251 3.79977931 .32741851 -1
10 1995 10 17 19 44 50.00 12491.97165 -315.59775 23484.62963 .45364057 3.83879043 -.12120431 -1
10 1995 10 17 19 59 50.00 12792.36449 3132.17550 23175.18337 .21319046 3.81203791 -.56502617 -1
10 1995 10 17 20 14 50.00 12875.05649 6526.70234 22471.25091 -.02945500 3.72075910 -.99663264 -1
10 1995 10 17 20 29 50.00 12739.90672 9810.85330 21387.02618 -.27023373 3.56721646-1.40898282 -1
10 1995 10 17 20 44 50.00 12390.37990 12929.96577 19942.83688 -.50520455 3.35461499-1.79550097 -1
10 1995 10 17 20 59 50.00 11833.41338 15832.65263 18164.69040 -.73059985 3.08701340-2.15015272 -1
10 1995 10 17 21 14 50.00 11079.24001 18471.52918 16083.75775 -.94287097 2.76923174-2.46750705 -1
10 1995 10 17 21 29 50.00 10141.17301 20803.85646 13735.80739-1.13872723 2.40675827-2.74278554 -1
10 1995 10 17 21 44 50.00 9035.35855 22792.10089 11160.59986-1.31516896 2.00565703-2.97190111 -1
10 1995 10 17 21 59 50.00 7780.50085 24404.41158 8401.25153-1.46951558 1.57247723-3.15148768 -1
10 1995 10 17 22 14 50.00 6397.56390 25615.01701 5503.57511-1.59942963 1.11416481-3.27892274 -1
10 1995 10 17 22 29 50.00 4909.45323 26404.54312 2515.40245-1.70293732 .63797619-3.35234411 -1
10 1995 10 17 22 44 50.00 3340.68028 26760.25448 -514.10547-1.77844646 .15139338-3.37066210 -1
10 1995 10 17 22 59 50.00 1717.01172 26676.21948 -3535.15778-1.82476230 -.33795994-3.33356778 -1
10 1995 10 17 23 14 50.00 65.10540 26153.40000 -6498.03893-1.84110144 -.82240282-3.24153789 -1

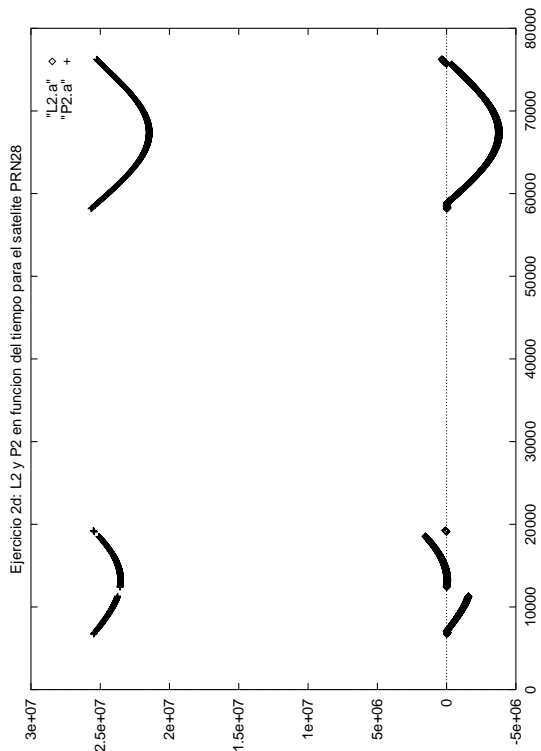
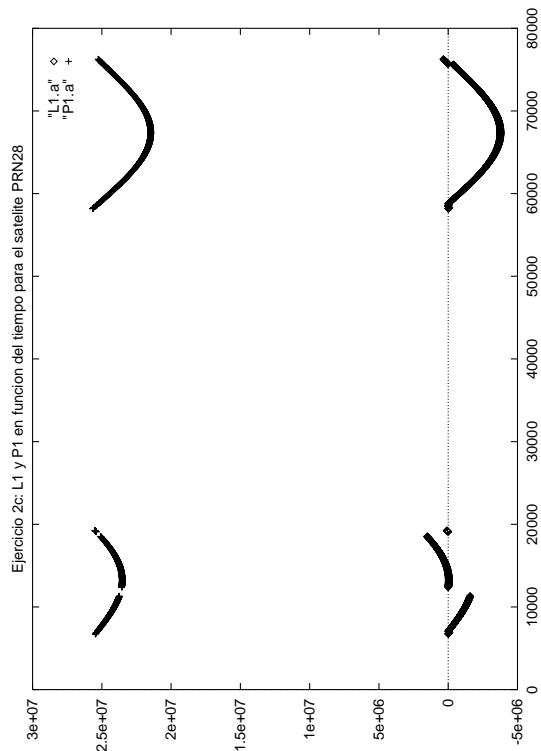
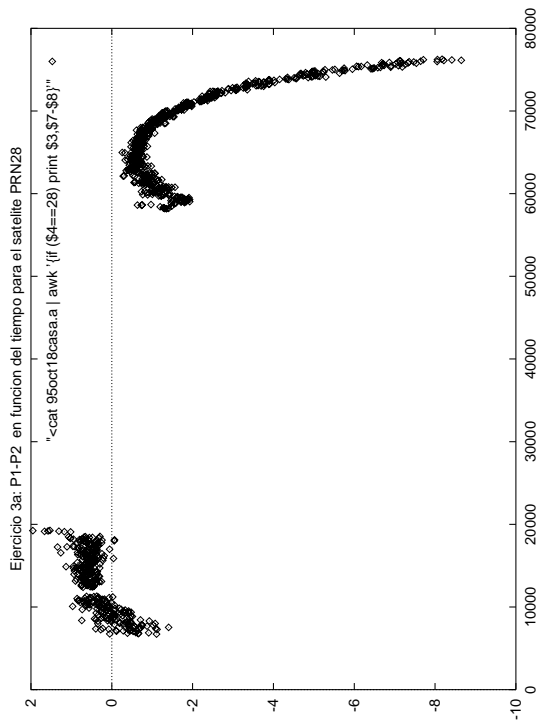
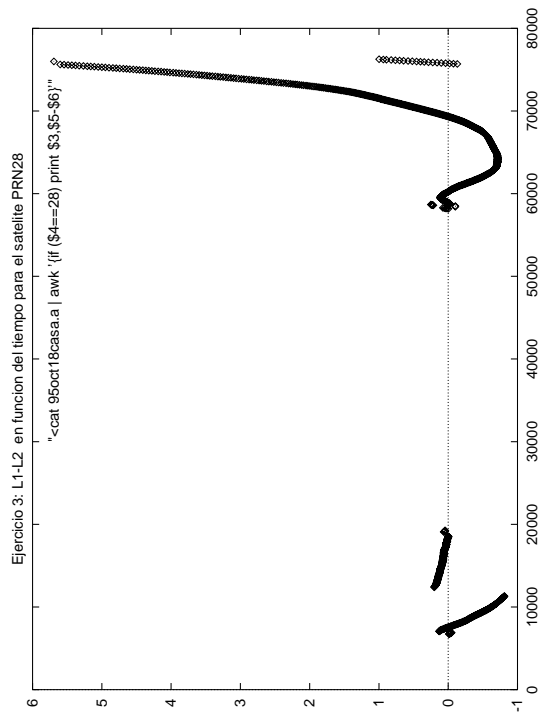
```

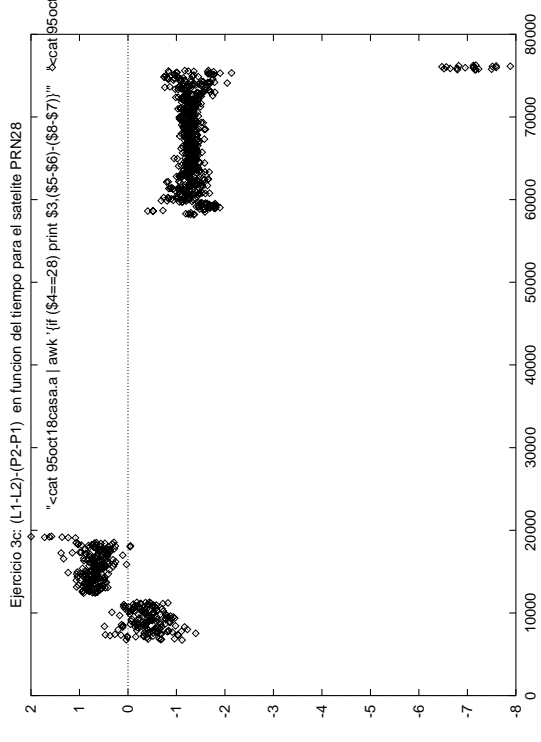
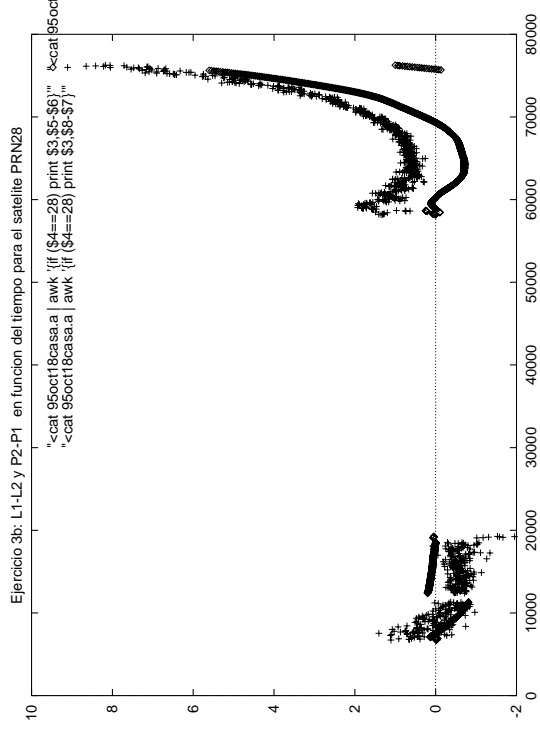
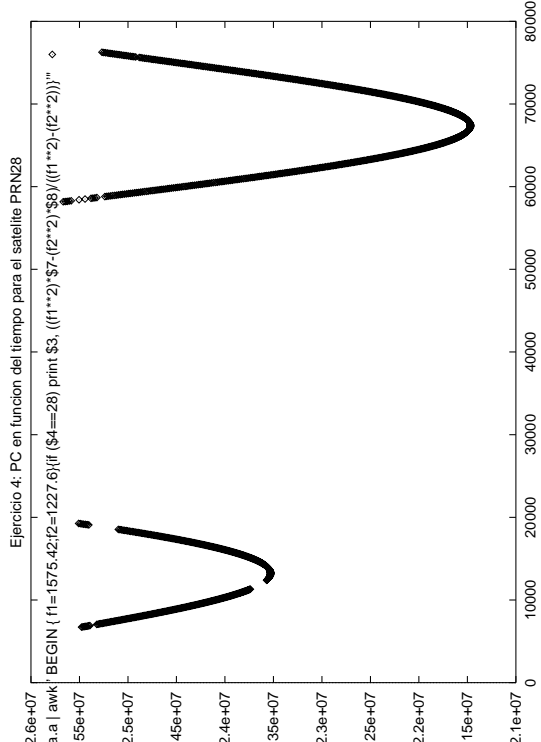
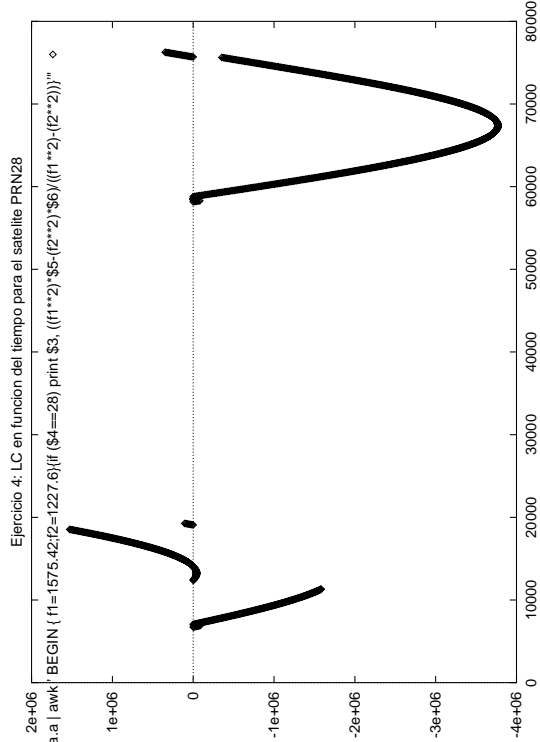
Apéndice IV: gráficas de los ejercicios

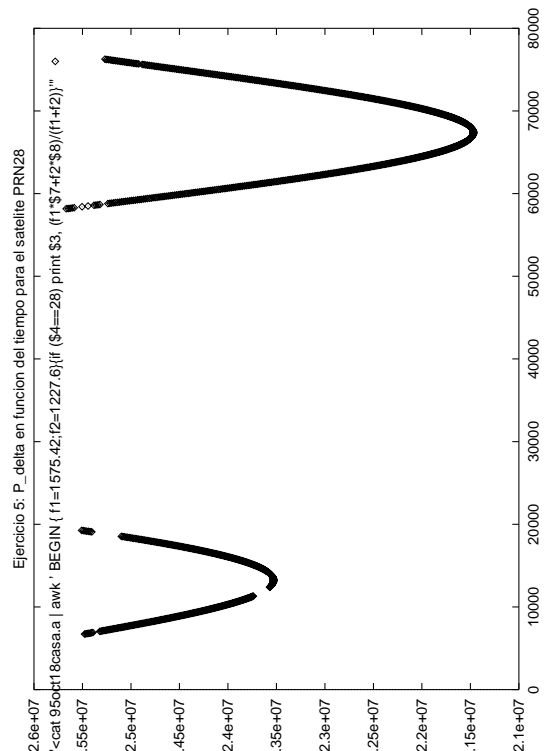
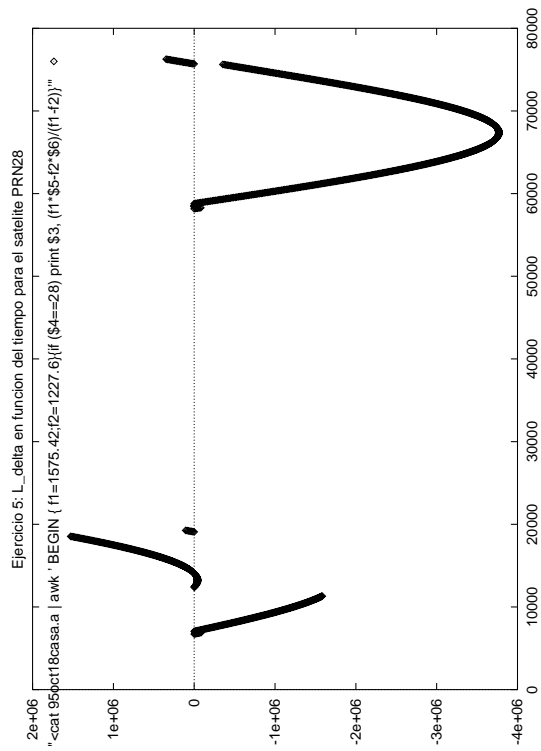
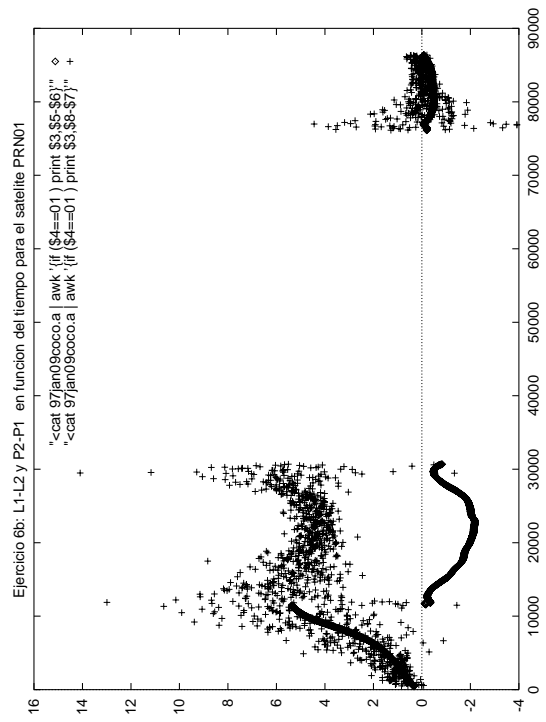
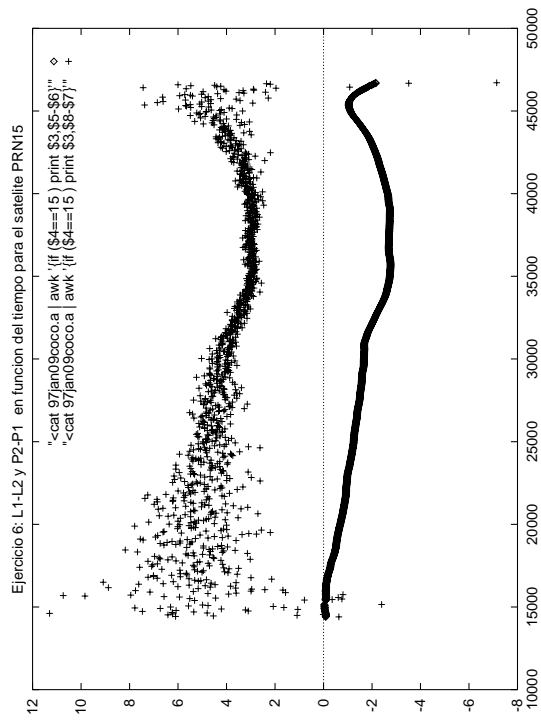
Gráficas de la práctica 3

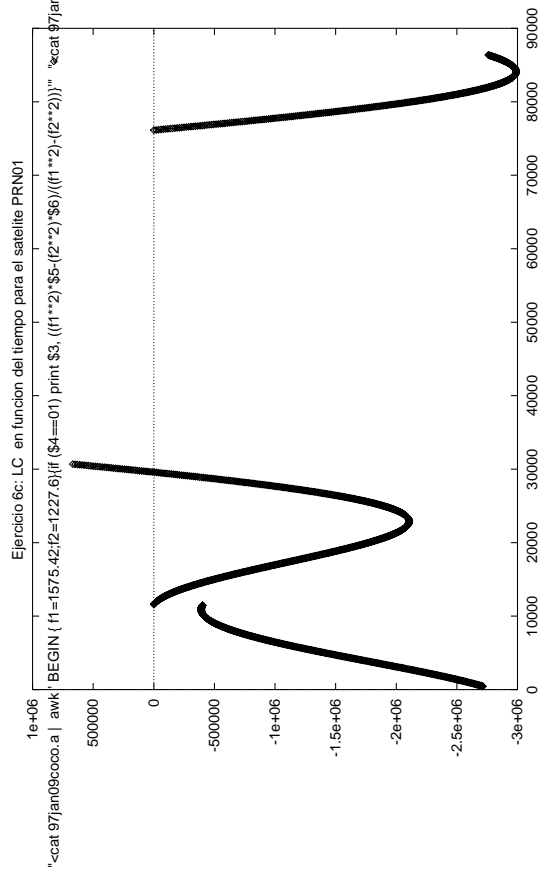
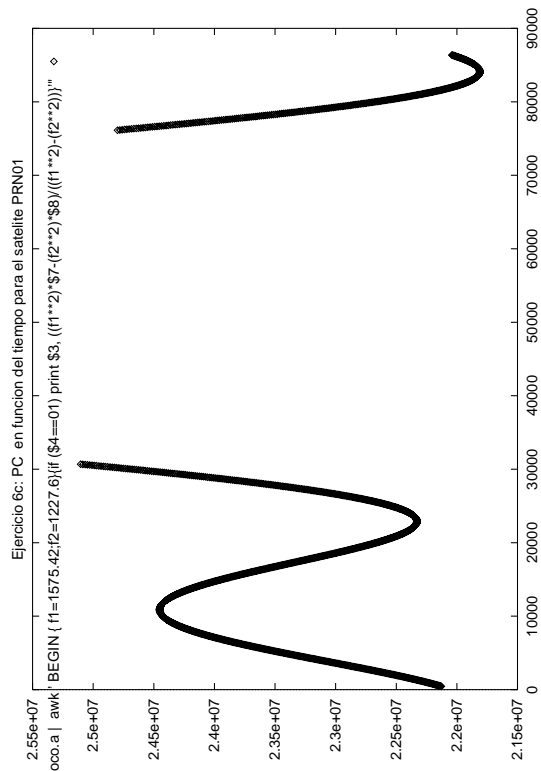
Observables GPS: L1, L2, P1, P2 y sus combinaciones





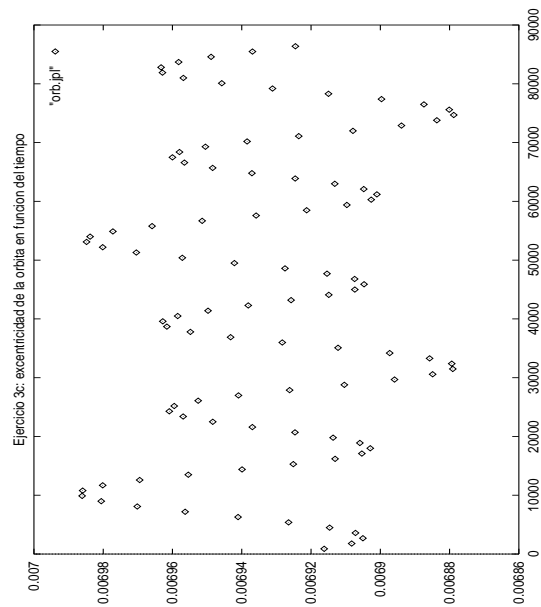
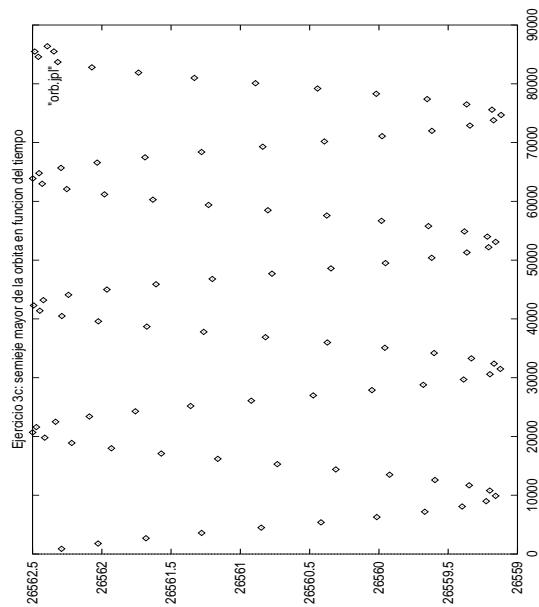
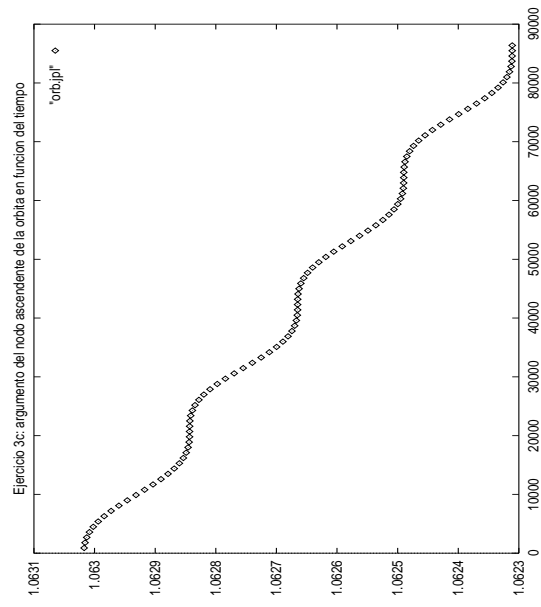
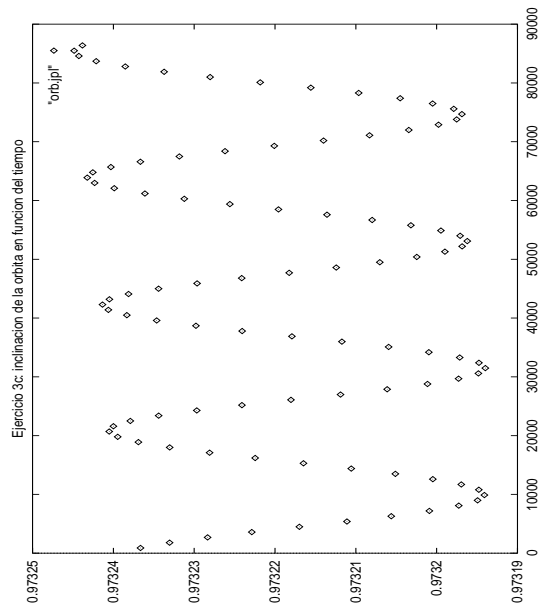


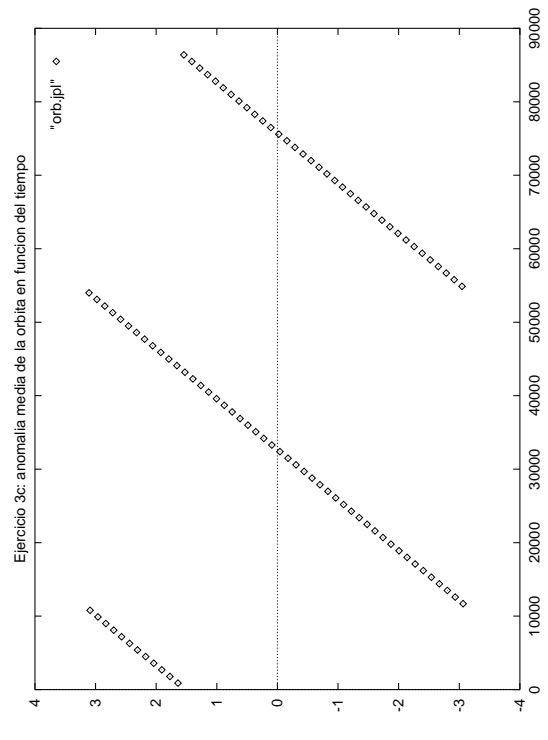
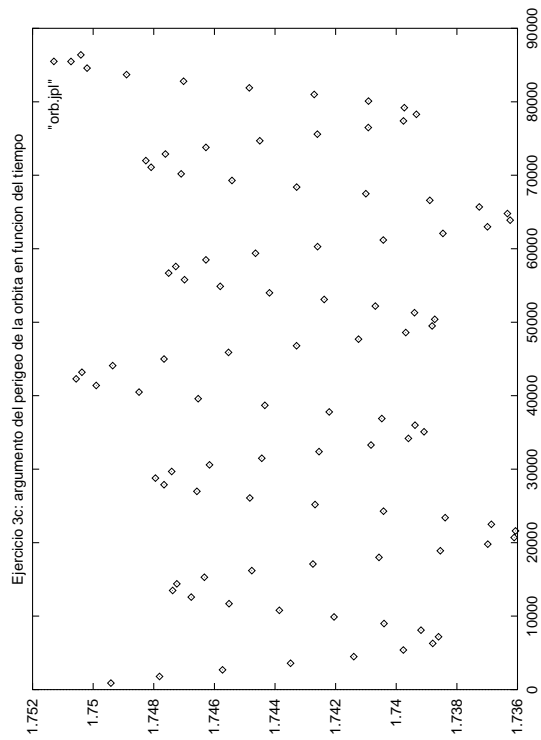
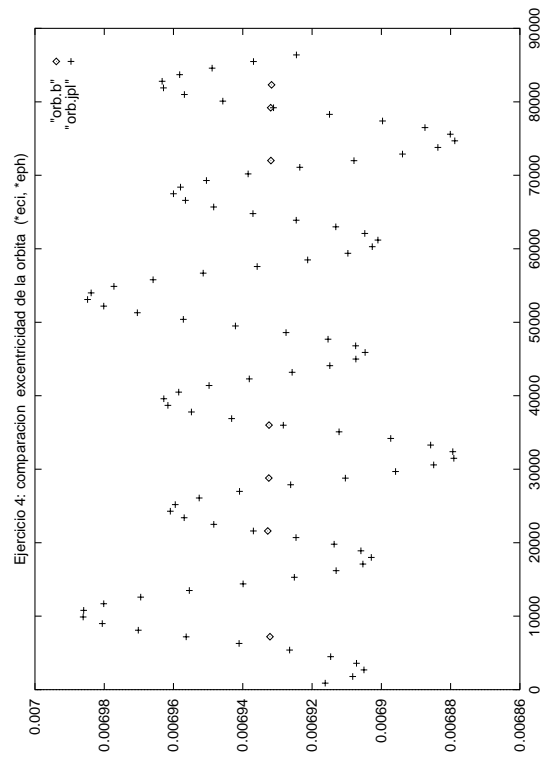
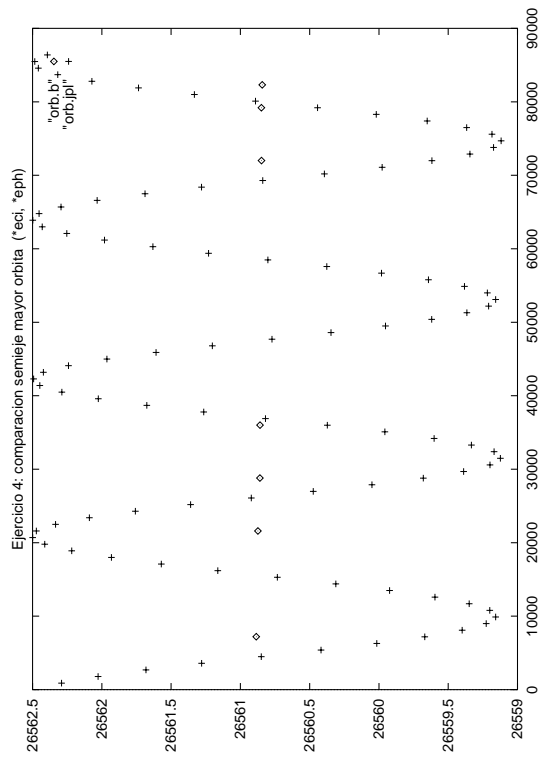


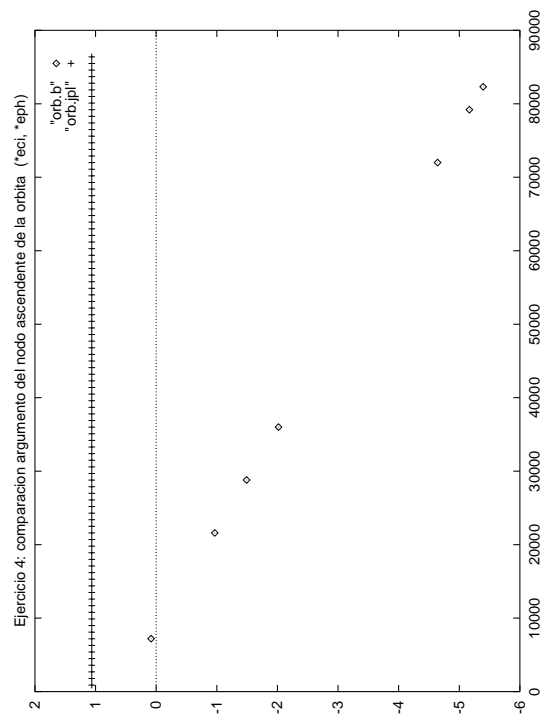
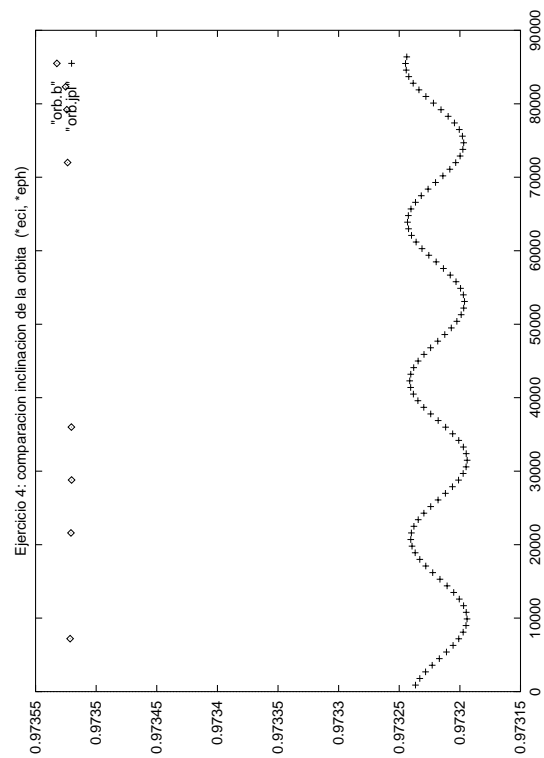
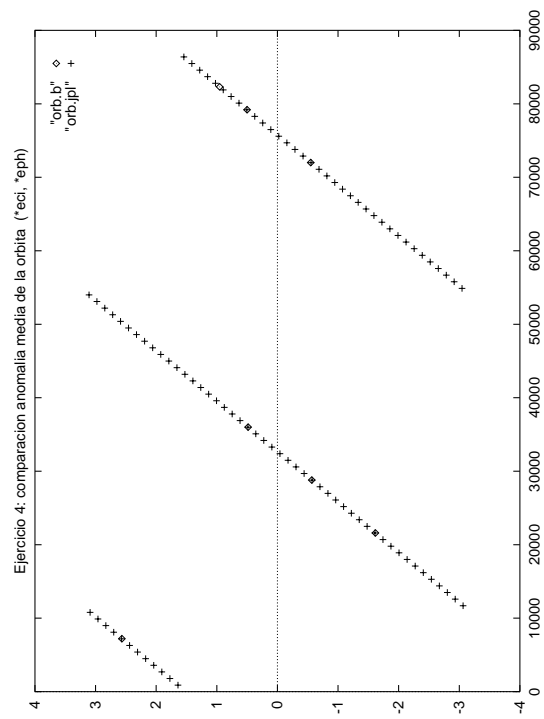
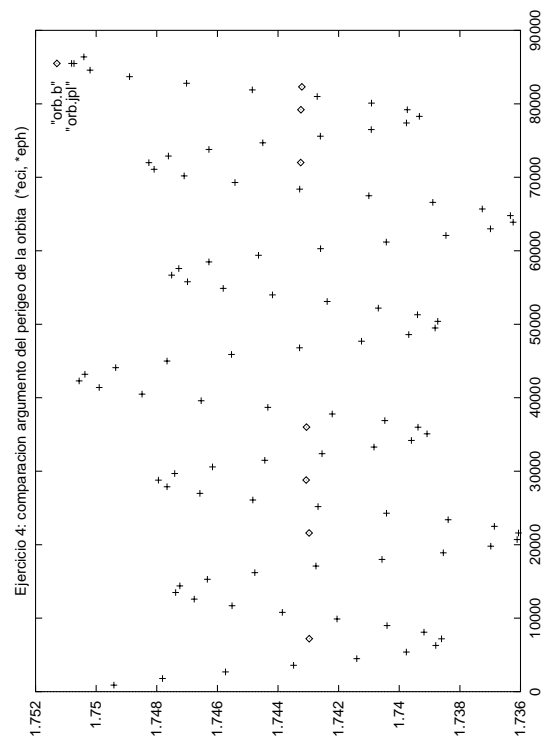


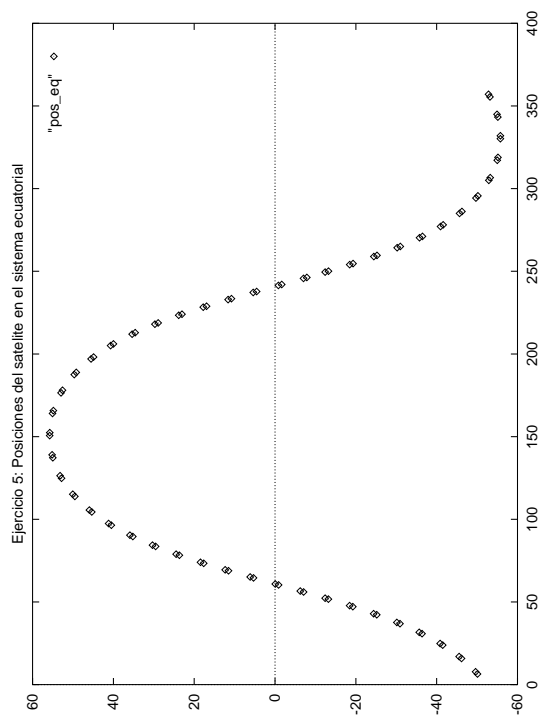
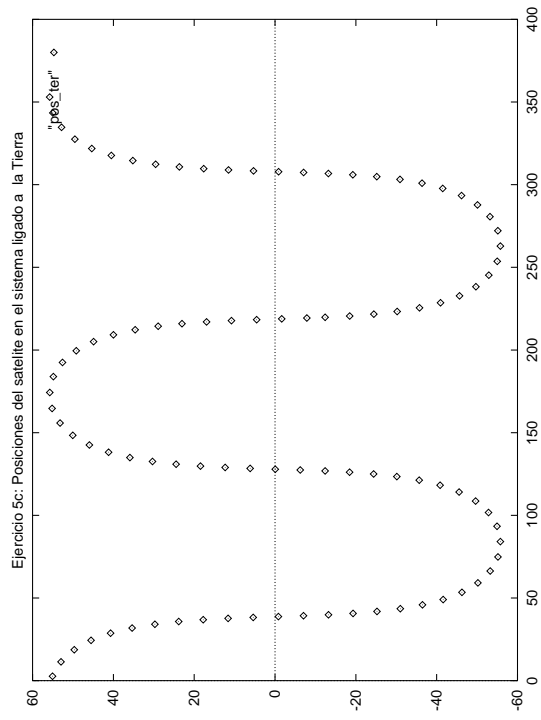
Gráficas de la práctica 4

Elementos orbitales y sistemas de referencia



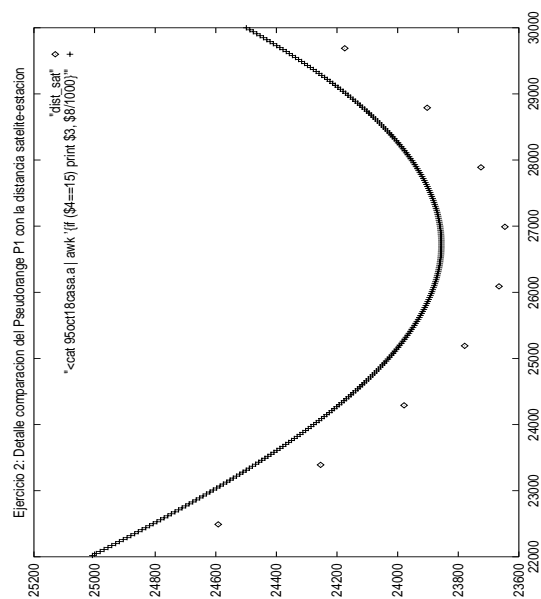
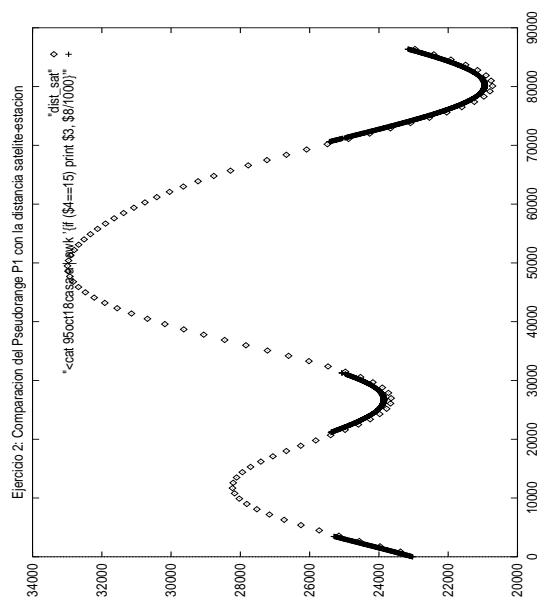
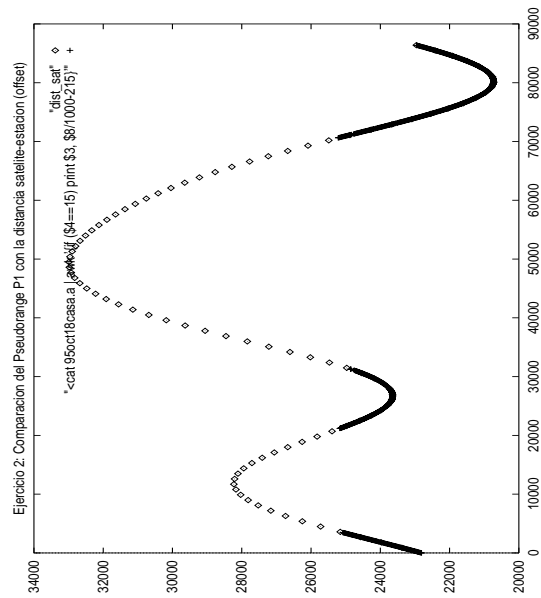
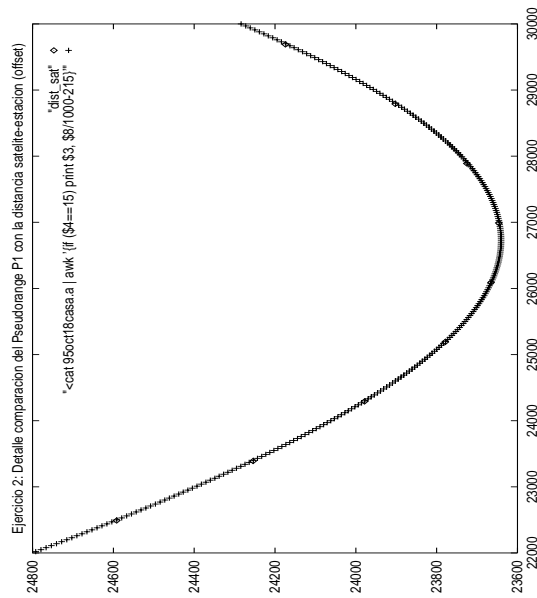


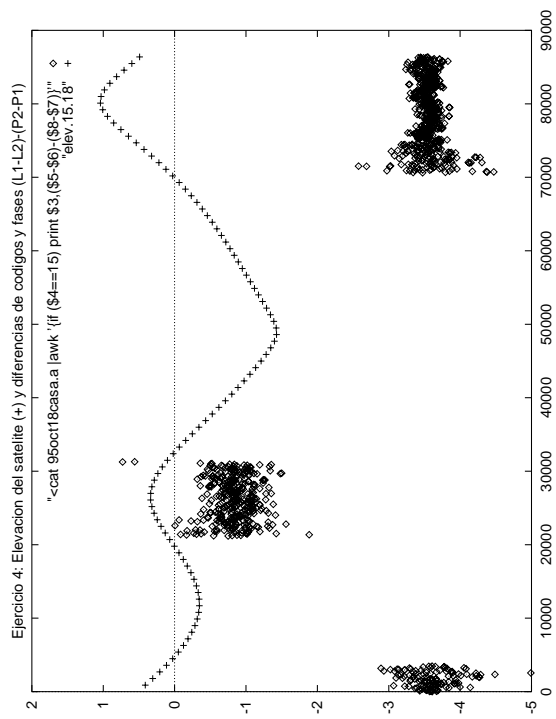




Gráficas de la práctica 5

Miscelánea: observables y elementos orbitales





Apéndice V: algunos resultados numéricos sobre los ejercicios

Práctica 4

Ejercicio 6}

b)

```
cat 95oct18obs_casa_44520 | awk '{print $4,$7,  
    sqrt(($10+2444430)^2+($11+4428687)^2+($12-3875747)^2),$13}'
```

```
05 20529743.426 2.02407e+07 1271.23064  
06 23739868.997 2.34499e+07 407.07404  
09 24258890.767 2.39647e+07 -3830.98208  
16 22821096.182 2.24913e+07 -39433.90144  
20 21508557.927 2.12273e+07 9136.46149  
24 21093984.684 2.08876e+07 83914.95171
```

c)

```
cat 95oct18obs_casa_44520 | awk '{print $4,  
$7-sqrt(($10+2444430)^2+($11+4428687)^2+($12-3875747)^2)+$13}'
```

```
05 290356  
06 290344  
09 290323  
16 290401  
20 290403  
24 290336
```

El valor aproximado del offset del reloj de la estación "casa"
es de 290360 m

d)

```
cat 95oct18obs_casa_44520 | awk '{print $4,
    $7-sqrt(($10+2444430)^2+($11+4428687)^2+($12-3875747)^2)+
    $13-290360}'
```

```
05 -4.12725
06 -15.865
09 -36.991
16 41.4633
20 43.4153
24 -23.5625
```

Práctica 5

Ejercicio 5}

a)

```
cat 1995-10-18.eci | awk '{if ($1==13 && $4==18) print
    $8,$9,$10,$11,$12,$13}' | head -3 > pv
```

```
head -1 pv >datos1
tail -1 pv > datos2
```

```
cat datos1 datos2 |gawk -f media.awk| tail -1
-17078.6218 3240.5697 -19308.4229 0.7462 -3.5886 -1.3010
```

b)

```
cat 1995-10-18.eci | awk '{if ($1==13 && $4==18) print
    $8,$9,$10,$11,$12,$13}' |rv2ele_orb | head -3 > orb
```

```
cat orb
```

```
echo " 26559.596847628 .014829899 .948871736 -1.108509701
    -2.501434355 .500251212 "|ele_orb2rv
-17228.455 3249.2126 -19490.1987 .7556 -3.6215 -1.3098
```

c)

```
cat 1995-10-18.eci | awk '{if ($1==13 && $4==18) print
    $8,$9,$10,$11,$12,$13}' | rv2ele_orb | head -3 > orb
```

```
head -1 orb >datos1
tail -1 orb > datos2
```

```
cat datos1 datos2 | gawk -f media.awk | tail -1|ele_orb2rv
-17232.7342  3269.7639  -19482.7563  .7534  -3.6211  -1.3122
```

d)

```
cat 1995-10-18.eci | awk '{if ($1==13 && $4==18) print
    $8,$9,$10,$11,$12,$13}' | rv2ele_orb | head -2 > orb
```

```
cat orb|tail -1 |ele_orb2rv
-17232.7737  3269.83299  -19482.7277  .7534  -3.6211  -1.3122
```

Práctica 6

Ejercicio 3

a)

```
cat 95oct18obs_casa| head -12| awk -f matrix_pos_casa.awk| lms
 19.6596647  1.97188452  28.7368612  287991.166
```

```
d=[19.6596647  1.97188452  28.7368612]
distancia= norm(d,2)=34.87
```

b)

```
cat 95oct18obs_casa | head -6| awk -f matrix_pos_casa.awk| lms
 25.2352793  11.3254027  31.1648576  287988.287
```

```
cat 95oct18obs_casa | head -6| awk -f matrix_pos_casa.awk| dop
```

```
COFACTOR Matrix Q=inv(A'*A)
  1.58596202  2.02039196  .313441102 -.803753317
  2.02039196  3.6069392  .381262017 -1.31012379
  .313441102  .381262017  1.21988545  .345783579
 -1.803753317 -1.31012379  .345783579  .86893548
GDOD=  2.69846663
PDOD=  2.53234806
TDOD=  .932167088
```

Ejercicio 4:

```
cat 95oct18obs_casa_2|tail -4|gawk -f matrix_pos_casa.awk| lms
-462.329146 -555.07416 -565.085894 291629.857
cat 95oct18obs_casa_2| tail -4|gawk -f matrix_pos_casa.awk|dop
```

```
COFACTOR Matrix Q=inv(A'*A)
  9.95477686  13.4138569 -7.97033263 -14.2706
  13.4138569  21.1076108 -12.0352763 -21.2988276
 -7.97033263 -12.0352763  21.0310827  21.4609161
 -14.2706 -21.2988276  21.4609161  28.0605096
GDOD=  8.95287551
PDOD=  7.21758064
TDOD=  5.29721715
```

Ejercicio 5:

a)
i)

```
cat 95oct18obs_casa | head -12 |
      gawk -f matrix_pos_esttrop_casa.awk | lms
```

```
25.6472037  10.2266357  19.9694467  287977.685 -.0354844806
```

octave:

```
d=[25.6472037  10.2266357  19.9694467]
distancia= norm(d,2)= 34.076
```

ii)

```
cat 95oct18obs_casa | head -6 |  
    gawk -f matrix_pos_esttrop_casa.awk | lms  
  
    31.8835182  20.6032793  22.3253402  287974.21  -.0198996977  
octave:  
d=[31.8835182  20.6032793  22.3253402]  
distancia= norm(d,2)= 44.039
```

b)

i)

```
cat 95oct18obs_casa | head -12 |  
    gawk -f matrix_pos_esttrop_casa.awk | lms  
  
    -16.9476377 -49.1099035  84.5150731  288075.761 -14.8018422  
  
d=[-16.9476377 -49.1099035  84.5150731]  
distancia= norm(d,2)= 99.206
```

ii)

```
cat 95oct18obs_casa | head -6 |  
    gawk -f matrix_pos_esttrop_casa.awk | lms  
  
    -15.8085354 -45.3142281  94.4755227  288083.579 -16.4403059  
  
d=[-15.8085354 -45.3142281  94.4755227]  
distancia= norm(d,2)= 105.97
```

Ejercicio 6:

```
cat 95oct18obs_casa | head -12 |  
    gawk -f matrix_pos_sat_casa.awk | lms  
  
    835.637696  691.675912  326.393104 -2.29418026E-24  
    -287676.935 -287703.778 -287203.456 -288206.299  
    -287919.633 -287639.166
```

Ejercicio 7:

a)

```
-----gps.nml-----
```

```
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d-6
trop=0.
is_data=4
out_res='sta'
coord='xyz'
corr='n'
$end
```

```
-----
cat 95oct18obs_casa | head -12 | p_posc
```

```
casa  2.01   19.6986   1.9424   28.8600   287991.3098
```

b)

```
-----gps.nml-----
```

```
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d-6
trop=2.1
is_data=4
out_res='sta'
coord='xyz'
corr='n'
$end
```

```
-----
cat 95oct18obs_casa | head -12 | p_posc
```

```
casa  2.01   25.7562   10.3810   19.6807   287977.3619
```

c)

i)

-----gps.nml-----

```
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d-6
trop=0.
is_data=4
out_res='sta'
coor='enu'
corr='n'
$end
```

cat 95oct18obs_casa | head -12 | p_posc

```
casa 2.01 16.3073 29.7325 8.6464 287991.3098 .0000
```

ii)

-----gps.nml-----

```
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d-6
trop=2.1
is_data=4
out_res='sta'
coor='enu'
corr='n'
$end
```

cat 95oct18obs_casa | head -12 | p_posc

```
casa 2.01 17.5330 28.7195 -5.1245 287977.3619 .0000
```

Notar que la mayor variación --entre los casos i) y ii)-- se da en la coordenada vertical (8.6464 ---> -5.1245)

Ejercicio 8:

a)

```
-----gps.nml-----
```

```
$aprioris
```

```
  itype=3
```

```
  sigdat=1.d1
```

```
    ap_var(1)='sat 0000 '
```

```
    apsigma(1)=1.d-6
```

```
    ap_var(2)='tro casa'
```

```
    apsigma(2)=2.d-1
```

```
  trop=2.1
```

```
  is_data=5
```

```
  out_res='sta'
```

```
  coor='xyz'
```

```
  corr='n'
```

```
$end
```

```
-----
```

```
  cat 95oct18obs_casa | head -12 | p_posc
```

casa	2.01	25.6537	10.2382	19.8360	287977.5979	-.0355
------	------	---------	---------	---------	-------------	--------

b)

```
-----gps.nml-----
```

```
:
```

```
:
```

```
  apsigma(2)=1.d+6
```

```
:
```

```
:
```

```
-----
```

```
  cat 95oct18obs_casa | head -12 | p_posc
```

casa	2.01	-17.0116	-49.1965	84.4883	288075.8364	-14.8263
------	------	----------	----------	---------	-------------	----------

c)

i)

-----gps.nml-----

\$aprioris

itype=3

sigdat=1.d1

ap_var(1)='sat 0000 '

ap_var(2)='tro casa'

apsigma(1)=1.d-6

apsigma(2)=2.d-1

trop=2.1

is_data=5

out_res='sta'

coor='enu'

corr='n'

\$end

cat 95oct18obs_casa | head -12 | p_posc

casa 2.01 17.5122 28.7367 -4.8914 287977.5979 -.0355

ii)

-----gps.nml-----

:

:

apsigma(2)=1.d+6

:

:

cat 95oct18obs_casa | head -12 | p_posc

casa 2.01 8.8798 35.8710 92.0999 288075.8364 -14.8263

Ejercicio 9:

a)

```
-----gps.nml-----
$aprioris
  itype=3
  sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d+6
  ap_var(2)='tim casa'
  apsigma(2)=1.d-6
  trop=2.1
  is_data=4
  out_res='all'
  coor='xyz'
  corr='n'
$end
```

```
-----
cat 95oct18obs_casa | head -12 | p_posc
```

```
casa  2.01  983.5363  843.2097  220.6006   .0000
  4    2.01                .1461E+05      -.2876E+06
 18    2.01                -.1118E+04      -.2875E+06
 19    2.01                .1476E+04      -.2870E+06
 22    2.01                .7663E+05      -.2881E+06
 28    2.01                .1269E+05      -.2879E+06
 29    2.01                .5651E+03      -.2874E+06
```

Práctica 7

Ejercicio 2:

```
cat 95oct18obs_jplm 95oct18obs_uclp |sort -n +2 |head -10 |
      awk -f dgps_uclp_jplm.awk | lms
```

```
1.87520371E-13  5.32416161E-13  8.76712643E-13  5.37214277E-27
-.38751712  -1.01777417  .137551278  1465.05209  -50.1019359
-27.0790615  32.7581856  -5.83325543  -14.4100128
```

(ver el fichero "dgps_uclp_jplm.awk" para identificar los diferentes campos de esta estimacion)

g)

octave:

```
uclp_0= [-2519007.9690 -4650674.9267 3552863.1807]
jplm_0= [-2493304.0136 -4655215.5989 3565497.3229]
```

```
- Distancia de referencia (inicial) uclp-jplm:
  distancia_u0_j0=norm(uclp_0-jplm_0,2)= 28998.84
```

```
  d_jplm=[-.38751712  -1.01777417  .137551278]
```

```
- Posicion estimada para jplm:
  jplm= jplm_0+d_jplm= [-2493304.4 -4655216.6 3565497.5]
  uclp=uclp_0
```

```
- Distancia_estimada uclp-jplm:
  distancia_u_j=norm(uclp-jplm,2)= 28998.71
```

```
- Diferencia de distancias:
```

```
diferencia= 28998.84 - 28998.71 = 0.13 m
```

Ejercicio 3:

```
-----gps.nml-----
```

```
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  ap_var(2)='sta uclp '
  ap_var(3)='tim uclp '
  apsigma(1)=1.d+6
  apsigma(2)=1.d-6
  apsigma(3)=1.d-6
trop=2.1
is_data=4
out_res='all'
coor='xyz'
corr='n'
$end
```

```
-----
cat 95oct18obs_jplm 95oct18obs_uclp | sort -n +2 |
                                     head -10 |p_posc
jplm  4.03  -.3853    -1.0169   .1370   1465.0500
uclp  4.03   .0000     .0000    .0000     .0000
  2    4.03          -.6026E+05   -.5010E+02
 19    4.03          .1589E+04   -.2708E+02
 27    4.03          .1927E+04    .3276E+02
 28    4.03          .1270E+05   -.5833E+01
 31    4.03          .1971E+06   -.1441E+02
```

Ejercicio 4:

```
-----gps.nml-----
$aprioris
itype=3
  sigdat=1.d1
ap_var(1)='sat 0000 '
  ap_var(2)='sta uclp '
  ap_var(3)='tim uclp '
  apsigma(1)=1.d+6
  apsigma(2)=1.d-6
  apsigma(3)=1.d-6
trop=2.1
is_data=4
out_res='all'
coor='enu'
corr='n'
$end
-----
```

```
cat 95oct18obs_uclp 95oct18obs_jplm | sort -n +2 |
                                         head -10 | p_posc

jplm  4.03      .1404      -.4898      .9704  1465.0500      .0000
uclp  4.03      .0000      .0000      .0000      .0000      .0000
  2    4.03              -.6026E+05      -.5010E+02
 19    4.03              .1589E+04      -.2708E+02
 27    4.03              .1927E+04      .3276E+02
 28    4.03              .1270E+05      -.5833E+01
 31    4.03              .1971E+06      -.1441E+02
```

Ejercicio 5:

a)

```
-----gps.nml-----
$aprioris
itype=3
sigdat=1.d1
  ap_var(1)='sat 0000 '
  ap_var(2)='sta usc1 '
  ap_var(3)='tim usc1 '
  apsigma(1)=1.d+6
  apsigma(2)=1.d-6
  apsigma(3)=1.d-6
trop=2.1
is_data=4
out_res='all'
coor='xyz'
corr='n'
$end
-----
```

```
cat 95oct18obs_jplm 95oct18obs_usc1 | sort -n +2 |
                                     head -10 | p_posc
jplm  4.03   -1.4373   -.9109   .3338   1428.2902
usc1  4.03    .0000    .0000   .0000    .0000
  2    4.03           -.6026E+05   -.8768E+02
 19    4.03           .1589E+04   -.6429E+02
 27    4.03           .1927E+04   -.5071E+01
 28    4.03           .1270E+05   -.4192E+02
 31    4.03           .1971E+06   -.5078E+02
```

b)

octave:

```
usc1_0=[-2507565.9786 -4659956.2882 3548661.9105]
jplm_0=[-2493304.0136 -4655215.5989 3565497.3229]
```

```

distancia_usc1_0_jplm_0=norm(usc1_0-jplm_0,2)= 22567.87
d_jplm=[-1.4373  -.9109  .3338]
    
```

```

Posicion estimada jplm:
jplm=jplm_0+d_jplm= [-2493305.5  -4655216.5  3565497.7 ]
usc1=usc1_0
    
```

```

Distancia_estimada_usc1_jplm=norm(usc1-jplm,2)= 22567.02
Diferencia= 22567.87 - 22567.02 = 0.85 metros
    
```

d)

```

cat 95oct18obs_jplm 95oct18obs_usc1 | sort -n +2 |
                                     head -10 | p_posc
    
```

```

jplm  4.03  -.8369  -.5523  1.4147  1428.2902
usc1  4.03  .0000  .0000  .0000  .0000
      .0000
  2   4.03          -.6026E+05          -.8768E+02
 19   4.03          .1589E+04          -.6429E+02
 27   4.03          .1927E+04          -.5071E+01
 28   4.03          .1270E+05          -.4192E+02
 31   4.03          .1971E+06          -.5078E+02
    
```

Ejercicio 6:

a)

```

-----gps.nml-----
$aprioris
  itype=3
  sigdat=1.d1
  ap_var(1)='sat 0000 '
  apsigma(1)=1.d-6
  trop=2.1
  is_data=4
  out_res='sta'
  coor='xyz'
  corr='n'
$end
-----
    
```

```
cat 95oct18obs_jplm 95oct18obs_usc1 | sort -n +2 |  
                                         head -10 | p_posc
```

```
jplm 4.03  16.8438  52.7577  23.6381  1464.1384  
usc1 4.03  18.2945  53.7165  23.2791   35.8525
```

b)

octave:

```
usc1_0=[ -2507565.9786 -4659956.2882 3548661.9105]  
jplm_0=[ -2493304.0136 -4655215.5989 3565497.3229]
```

```
distancia_usc1_0_jplm_0=norm(usc1_0-jplm_0,2)= 22567.87
```

```
d_jplm=[16.8438  52.7577  23.6381]  
d_usc1=[18.2945  53.7165  23.2791]
```

Posicion estimada jplm:

```
jplm=jplm_0+d_jplm=[-2493287.2  -4655162.8  3565521.0]
```

Posicion estimada aoa1:

```
usc1=usc1_0+d_usc1=[-2507547.7  -4659902.6  3548685.2]
```

```
Distancia_estimada_aoa1_jplm=norm(usc1-jplm,2)= 22567.02
```

Diferencia= 22567.87 - 22567.02 = 0.85 metros

c)

```
cat 95oct18obs_jplm | head -5 | p_posc  
jplm 4.03  16.8438  52.7577  23.6381  1464.1384
```

```
cat 95oct18obs_usc1 | head -5 | p_posc  
usc1 4.03  18.2945  53.7165  23.2791   35.8525
```

Lecturas recomendadas

A continuación presentamos tres títulos de libros de GPS que recomendamos al lector (a pesar de que somos conscientes de que en esta selección podrían estar otros títulos tan meritorios como los que relacionamos):

- B. Hofmann-Wellenhof et al. *GPS, Theory and Practice*. Springer-Verlag. Wien, New York
- G. Seeber. *Satellite Geodesy*. Walter de Gruyter. New York
- D. Wells. *Guide to GPS Positioning*. Canadian GPS Associates

Instrucciones para la instalación del software

El disquete que se distribuye juntamente con este libro contiene todos los ficheros y el código fuente de los programas que se utilizan en las diferentes prácticas (`readme` y `program.tgz`).

Este software está preparado para ser instalado de forma "casi automática" en una máquina con sistema operativo LINUX (o, con muy ligeras variaciones, sobre cualquier plataforma UNIX).

En el fichero `readme` se dan las instrucciones para:

1. copiar el fichero `program.tgz` (se trata de un "*tar-comprimido*") de la disquetera al disco duro del ordenador en el que se vaya a realizar la instalación
2. descomprimir e instalar el fichero `program.tgz`

Una vez instalado el fichero `program.tgz`, se habrá creado un directorio llamado `practicas` que contendrá el fichero `README_config` (con las instrucciones necesarias para compilar las subrutinas y programas FORTRAN) y los subdirectorios `ficheros`, `programas` y `subroutines` que contienen los ficheros de datos y el código fuente de las subrutinas y programas.

Requisitos mínimos para la instalación del software

- Disponer de un PC (486 o superior, con 8Mb de memoria RAM y al menos 5Mb libres de memoria en el disco duro), provisto del sistema operativo LINUX y que pueda trabajar en modo gráfico –Xwindows–. Naturalmente, puesto que se facilita el código fuente, la instalación puede hacerse sobre cualquier otra plataforma UNIX.
- Tener instalados:
 - el compilador de FORTRAN `f77` (si se utiliza el compilador `g77` deberán modificarse el fichero `config` del directorio `subroutines` y el

Makefile del directorio `programas` –basta con sustituir la palabra `f77` por `g77`–)³

- los lenguajes: `awk` o `gawk` y `perl`
- el entorno de representación gráfica `gnuplot`

Tanto el compilador de FORTRAN, como los lenguajes de programación o el programa `gnuplot`, forman parte de cualquier distribución estándar de LINUX y, generalmente, suelen instalarse por defecto.

³Por otra parte, algunos compiladores de FORTRAN no reconocen las instrucciones `dsin`, `dcos`, `datan2`, `etc.`, específicas para trabajar en doble precisión. Si se da este caso, bastará sustituir dichas funciones por sus correspondientes `sin`, `cos`, `atan2`, `etc.` en el código fuente de los programas.