CHAPTER 8 SITE DISPLACEMENT DUE TO OCEAN AND ATMOSPHERIC LOADING

OCEAN LOADING

In the past decade, displacements due to ocean loading have been computed by several authors (Goad, 1980; Agnew, 1983; Scherneck, 1983; Pagiatakis, et al., 1984; Sato and Hanada, 1985), most of them using methods similar to that described by Farrell (1972) and based on global representations of the ocean tides like those by Schwiderski (1980).

In all of these models, the locally referenced displacement vector $\vec{E}$ in the vertical (radial), N-S and E-W local coordinate system at time t can be computed as a sum of the contributions of n individual ocean tides

$$\vec{E}(t) = \sum_{i=1}^{n} \left\{ \begin{array}{l} A_i^r \cdot \cos(\omega_i t + \phi_i - \delta_i^r) \\ A_i^{NS} \cdot \cos(\omega_i t + \phi_i - \delta_i^{NS}) \\ A_i^{EW} \cdot \cos(\omega_i t + \phi_i - \delta_i^{EW}) \end{array} \right.$$

where ω_i is the frequency of the tidal constituents and ϕ_i the corresponding astronomical argument. The amplitudes A_i^r, A_i^{NS}, A_i^{EW}, and the Greenwich phase lags δ_i^r, δ_i^{NS}, δ_i^{EW} of each tidal component are determined by the particular model assumed for the deformation of the Earth.

The site displacements resulting from the ocean tides have been compiled by Clyde Goad. Tidal loading radial (height) displacement amplitude and phase values for laser and VLBI station locations have been computed for the M_2, S_2, K_2, N_2, O_1, K_1, P_1, Q_1, M_f, M_m, and S_{sa} ocean tides using models generated by Schwiderski (1978). The technique of Goad (1980) which uses integrated Green's Functions was employed. The load deformation coefficients used in generating the Green's function integrals were taken from Farrell (1972).

Table 8.1 gives the amplitude and phase values for the eleven main tides. The phase convention of Schwiderski has been preserved. His phases for the diurnal tides are different by ± 90° with the standard Doodson definition. This chapter also contains a FORTRAN subroutine which will return the proper angular argument to be used with the Schwiderski phases. The height displacement, in centimeters, can be found for a given constituent i as follows:

$$h(i) = amp(i) \times \cos\ (\ arg(i,\ t) - phase\ (i)\ ),$$

where arg(i,t) is generated by the subroutine ARG below. The total tidal displacement is found by summing over all 9 constituents. A negative h(i) means that the surface at the predicted point has been lowered.

ATMOSPHERIC LOADING

The procedure described below is taken from the publication of Sovers and Fanselow (1987). A time varying atmospheric pressure distribution can induce crustal deformation. Rabbel and Schuh (1986) estimate the effects of atmospheric loading on VLBI baseline determinations, and conclude that they may amount to many millimeters of seasonal variation. In contrast to ocean tidal effects, analysis of the situation in the atmospheric case does not benefit from the presence of a well-understood periodic driving force. Otherwise, estimation of atmospheric loading via Green's function techniques is analogous to methods used to calculate ocean loading effects. Rabbel and Schuh recommend a simplified form of the dependence of the vertical crustal displacement on pressure distribution. It involves only the instantaneous pressure at the site in question, and an average pressure over a circular region C with a 2000 km radius surrounding the site. The expression for the vertical displacement (mm) is

$$\Delta r = -0.35p - 0.55\bar{p}, \qquad (1)$$

where p is the local pressure anomaly, and $\bar{p}$ the pressure anomaly within 2000 km circular region mentioned above (both quantites are in mbar). Note that the reference point for this displacement is the site location at standard pressure (1013 mbar).

An additional mechanism for characterizing $\bar{p}$ may be applied. The two-dimensional surface pressure distribution surrounding a site is described by

$$p(x,y) = A_0 + A_1x + A_2y + A_3x^2 + A_4xy + A_5y^2, \qquad (2)$$

where x and y are the local East and North distances of the point in question from the VLBI site. The pressure anamoly $\bar{p}$ may be evaluated by the simple integration

$$\bar{p} = \iint_C dx\, dy\, p(x,y) \;/\; \iint_C dx\, dy \qquad (3)$$

giving

$$\bar{p} = A_0 + (A_3 + A_5)R^2/4, \qquad (4)$$

where $R^2=(x^2 + y^2)$.

It remains the task of the data analyst to perform a quadratic fit to the available weather data to determine the coefficients A_{0-5}. Future advances in understanding the atmosphere-crust elastic interaction can probably be accomodated by adjusting the coefficients in Eq. (1). Furthermore, expansion of eq. (1) might be required for stations close to the coast.

REFERENCES

Agnew, D. C., 1983, "Conservation of mass in tidal loading computations," Geophys. J. Roy. Astron. Soc., **72**, pp. 321-325.

Goad, C. C., 1980, "Gravimetric Tidal Loading Computed from Integrated Green's Functions," J. Geophys. Res., **85**, pp. 2679-2683.

Farrell, W. E., 1972, "Deformation of the Earth by Surface Loads," Rev. Geophys. Space Phys., **10**, pp. 761-797.

Pagiatakis, S. D., Langley, R. B., and Vanicek, P., 1984, "Ocean Tide Loading: A Global Model for the analysis of VLBI Observations," Proc. of the 3rd International Symposium on the Use of Artificial Satellites for Geodesy and Geodynamics, Ermioni, Greece, Sept. 1982, ed. by G. Veis, Publication of the National Techn. Univ. Athens, pp. 328-340.

Rabbel, W. and Schuh, H., 1986, "The Influence of Atmospheric Loading on VLBI Experiments," J. Geophysics, **59**, pp.164-170.

Sato, T., and Hanada, H., 1985, "A Program for the Computation of Ocean Tidal Loading Effects 'GOTIC'," Proc. of the International Conference on Earth Rotation and the Terrestrial Reference Frame, Columbus, 1985, Dept. of Geodetic Science and Surveying, Ohio State Univ. Columbus, Ohio 43210-1247, **2**, pp. 742-748.

Scherneck, H. G., 1983, Crustal Loading Affecting VLBI Sites, University of Uppsala, Institute of Geophysics, Dept. of Geodesy, Report No. 20, Uppsala, Sweden.

Schwiderski, E. W., 1978, Global Ocean Tides, Part 1, A Detailed Hydrodynamical Model, Rep TR-3866, U.S. Nav. Surface Weapons Center, Dahlgren, Va.

Schwiderski, E. W., 1980, "On Charting Global Ocean Tides," Rev. Geophys. Space Phys., **18**, pp. 243-268.

Sovers, O. J., Fanselow, J. L., 1987, "Observation Model and Parameter Partials for the JPL VLBI Parameter Software 'MASTERFIT'-1987," JPL Publication 83-39, Rev. 3.

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C    SUBROUTINE ARG(IYEAR,DAY,ANGLE)
C
C  COMPUTES THE ANGULAR ARGUMENT WHICH DEPENDS ON TIME FOR 11
C  TIDAL ARGUMENT CALCULATIONS
C
C
C    ORDER OF THE 11 ANGULAR QUANTITIES IN VECTOR ANGLE
C
C  01-$M_2$
C  02-$S_2$
C  03-$N_2$
C  04-$K_2$
C  05-$K_1$
C  06-$O_1$
C  07-$P_1$
C  08-$Q_1$
C  09-$M_f$
C  10-$M_m$
C  11-$S_{sa}$
C
C  TAKEN FROM 'TABLE 1 CONSTANTS OF MAJOR TIDAL MODES'
C       WHICH DR. SCHWIDERSKI SENDS ALONG WITH HIS TAPE OF TIDAL
C       AMPLITUDES AND PHASES
C
C
C  INPUT--
C
C     IYEAR - EX. 79 FOR 1979
C     DAY - DAY OF YEAR GREENWICH TIME
C                      EXAMPLE 32.5 FOR FEB 1   12 NOON
C                              1.25 FOR JAN 1    6 AM
C
C  OUTPUT--
C
C     ANGLE - ANGULAR ARGUMENT FOR SCHWIDERSKI COMPUTATION
C
C***********************************************************
C
C
C              C A U T I O N
C
C  SCHWIDERSKI MODIFIES THE ANGULAR ARGUMENTS OF THE DIURNAL
C  TERMS BY ± 90 DEGREES.  THEREFORE HIS DIURNAL PHASES
C  CANNOT BE USED WITH THE STANDARD DOODSON OR CARTWRIGHT
C  CONVENTIONS
C
C  THIS SUBROUTINE IS VALID ONLY FOR DATES AFTER 1973.
C
C***********************************************************
C
C
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      SUBROUTINE ARG(IYEAR,DAY,ANGLE)
      IMPLICIT DOUBLE PRECISION (A-H,0-Z)
      REAL ANGFAC(4,11)
      DIMENSION ANGLE(11),SPEED(11)
C
C  SPEED OF ALL TERMS IN RADIANS PER SEC
C
      EQUIVALENCE (SPEED(1),SIGM2),(SPEED(2),SIGS2),(SPEED(3),SIGN2)
      EQUIVALENCE (SPEED(4),SIGK2),(SPEED(5),SIGK1),(SPEED(6),SIGO1)
      EQUIVALENCE (SPEED(7),SIGP1),(SPEED(8),SIGQ1),(SPEED(9),SIGMF)
      EQUIVALENCE (SPEED(10),SIGMM),(SPEED(11),SIGSSA)
      DATA SIGM2/1.40519D-4/
      DATA SIGS2/1.45444D-4/
      DATA SIGN2/1.37880D-4/
      DATA SIGK2/1.45842D-4/
      DATA SIGK1/.72921D-4/
      DATA SIGO1/.67598D-4/
      DATA SIGP1/.72523D-4/
      DATA SIGQ1/.64959D-4/
      DATA SIGMF/.053234D-4/
      DATA SIGMM/.026392D-4/
      DATA SIGSSA/.003982D-4/
      DATA ANGFAC/2.E0,-2.E0,0.E0,0.E0,4*0.E0,
     .            2.E0,-3.E0,1.E0,0.E0,2.E0,3*0.E0,
     .            1.E0,2*0.E0,.25E0,1.E0,-2.E0,0.E0,-.25E0,
     .            -1.E0,2*0.E0,-.25E0,1.E0,-3.E0,1.E0,-.25E0,
     .            0.E0,2.E0,2*0.E0,0.E0,1.E0,-1.E0,0.E0,
     .            2.E0,3*0.E0/
      DATA TWOPI/6.28318530718D0/
      DATA DTR/.174532925199D-1/
C
C  DAY OF YEAR
C
      ID=DAY
C
C  FRACTIONAL PART OF DAY IN SECONDS
C
      FDAY=(DAY-ID)*86400.D0
      ICAPD=ID+365*(IYEAR-75)+((IYEAR-73)/4)
      CAPT=(27392.500528D0+1.000000035D0*ICAPD)/36525.D0
C
C MEAN LONGITUDE OF SUN AT BEGINNING OF DAY
C
      H0=(279.69668D0+(36000.768930485D0+3.03D-4*CAPT)*CAPT)*DTR
C
C MEAN LONGITUDE OF MOON AT BEGINNING OF DAY
C
      S0=(((1.9D-6*CAPT-.001133D0)*CAPT+481267.88314137D0)*CAPT
     .  +270.434358D0)*DTR
C
C MEAN LONGITUDE OF LUNAR PERIGEE AT BEGINNING OF DAY
```

```
C
      P0=(((-1.2D-5*CAPT-.010325D0)*CAPT+4069.0340329577D0)*CAPT
     .  +334.329653D0)*DTR
      DO 500 K=1,11
      ANGLE(K)=SPEED(K)*FDAY+ANGFAC(1,K)*H0+ANGFAC(2,K)*S0
     .  +ANGFAC(3,K)*P0+ANGFAC(4,K)*TWOPI
      ANGLE(K)=DMOD(ANGLE(K),TWOPI)
      IF(ANGLE(K).LT.0.D0)ANGLE(K)=ANGLE(K)+TWOPI
  500 CONTINUE
      RETURN
      END
```

Table 8.1. Displacement due to ocean loading (cm in amplitude and degree in phase).

	M_2		S_2		K_1		O_1		N_2		P_1		K_2		Q_1		M_f		M_m		S_{sa}	
	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS
Chlboltn	1.37	-46.1	.47	-11.1	.31	-58.5	.10	-127.5	.31	-63.7	.10	-58.9	.12	-5.4	.01	106.4	.09	-4.2	.03	-26.8	.04	-27.5
Madrid64	1.37	-86.4	.46	-61.4	.23	-70.0	.03	-151.3	.29	-106.3	.07	-69.4	.12	-63.8	.02	48.1	.04	-25.5	.02	-98.1	.01	-102.4
Robled32	1.37	-86.4	.46	-61.5	.23	-70.0	.03	-151.0	.29	-106.3	.07	-69.4	.12	-63.8	.02	48.0	.04	-25.5	.02	-98.1	.01	-102.5
Cebrer26	1.37	-87.0	.45	-62.0	.23	-70.0	.03	-149.7	.28	-106.6	.07	-69.5	.12	-64.6	.02	48.1	.04	-25.2	.02	-97.8	.01	-102.8
Haystack	.96	-176.8	.26	-154.8	.39	-5.4	.26	-4.8	.21	165.2	.12	-3.2	.07	-161.6	.05	-1.7	.04	10.5	.02	59.2	.04	-96.0
Westford	.96	-176.9	.26	-154.8	.39	-5.4	.26	-4.8	.21	165.2	.12	-3.2	.07	-161.6	.05	-1.7	.04	10.5	.02	59.2	.04	-96.1
Marpoint	.95	158.7	.24	-170.4	.33	-1.9	.22	-1.6	.16	141.7	.11	.7	.06	-175.0	.05	2.3	.02	17.7	.01	74.3	.05	-117.3
NRAO 140	.68	152.1	.20	-173.2	.29	.6	.20	-.9	.11	133.7	.10	3.6	.05	-177.1	.04	2.9	.01	20.5	.00	66.4	.04	-121.8
Richmond	.82	165.9	.24	-162.3	.18	15.2	.12	25.1	.14	146.6	.06	13.1	.06	-169.7	.03	35.0	.05	154.8	.02	160.5	.18	-122.2
HRAS 085	.08	-168.8	.15	-128.1	.47	32.5	.32	17.1	.05	-69.3	.15	30.8	.04	-109.1	.07	10.0	.02	-167.7	.01	157.3	.01	137.3
Plattvil	.22	111.6	.13	-168.3	.47	39.5	.31	25.2	.02	-11.2	.15	38.7	.03	-151.3	.06	17.8	.01	6.5	.01	49.2	.02	92.7
VLA	.04	169.6	.14	-131.9	.57	38.0	.37	22.8	.06	-67.0	.18	36.8	.04	-108.8	.08	14.6	.01	-138.3	.01	123.5	.02	90.2
Vernal	.22	96.5	.13	-170.8	.58	44.5	.37	29.9	.03	-18.3	.18	43.6	.02	-148.3	.07	21.5	.01	-1.9	.01	49.3	.03	83.0
Flagstaf	.01	-2.8	.14	-129.2	.69	41.6	.44	26.3	.07	-63.9	.22	40.5	.04	-103.0	.09	17.6	.01	-88.3	.01	105.0	.03	79.9
Yuma	.26	-57.2	.21	-98.3	.90	40.1	.57	24.8	.13	-70.8	.28	38.9	.07	-83.7	.11	15.9	.01	-117.4	.01	145.2	.05	73.7
Ely	.24	70.2	.12	-168.2	.76	47.4	.48	32.8	.06	-27.1	.24	46.6	.02	-132.5	.09	23.9	.01	-16.7	.01	55.0	.04	77.6
BlkButte	.28	-42.4	.19	-99.9	.96	41.5	.61	26.3	.13	-65.6	.30	40.6	.07	-82.7	.12	17.4	.01	-100.7	.01	137.7	.05	72.9
Ocotillo	.42	-49.5	.26	-86.6	1.06	39.6	.67	24.3	.17	-67.8	.33	38.4	.09	-76.2	.13	15.6	.01	-110.5	.01	154.8	.06	71.6
DeadManL	.28	-34.2	.18	-99.2	1.00	42.1	.63	27.0	.13	-62.5	.31	41.2	.07	-81.2	.12	18.1	.01	-89.6	.01	130.4	.06	73.4
Mon Peak	.51	-45.7	.27	-83.1	1.12	39.7	.71	24.5	.19	-66.2	.35	38.7	.10	-73.6	.13	15.7	.01	-106.4	.01	157.0	.06	71.4
PinFlats	.38	-39.5	.22	-89.7	1.07	41.0	.68	25.9	.16	-63.5	.33	40.1	.08	-76.2	.13	17.1	.01	-96.2	.01	143.1	.06	72.6
GoldVenu	.22	-13.4	.15	-108.7	.98	43.6	.62	28.6	.12	-56.7	.31	42.8	.05	-84.0	.12	19.7	.01	-69.8	.01	109.4	.06	73.8
Mojave12	.22	-11.3	.15	-107.5	.99	43.6	.62	28.7	.12	-55.3	.31	42.9	.05	-82.5	.12	19.8	.01	-67.2	.01	107.7	.06	73.9
GoldEcho	.22	-11.7	.15	-108.6	.98	43.6	.62	28.7	.12	-56.5	.31	42.8	.05	-83.7	.12	19.8	.01	-68.8	.01	108.5	.06	73.9
Otay	.70	-45.0	.35	-74.0	1.29	38.2	.81	23.1	.24	-64.7	.40	37.1	.12	-68.2	.15	14.6	.02	-104.4	.01	167.0	.07	71.1
GoldPion	.22	-10.3	.14	-108.6	.99	43.7	.62	28.8	.12	-55.0	.31	42.9	.05	-82.8	.12	19.9	.01	-66.1	.01	106.3	.06	74.1
GoldMars	.23	-8.5	.14	-109.7	.99	43.8	.62	28.9	.12	-54.3	.31	43.1	.05	-83.1	.12	20.0	.01	-64.4	.01	104.9	.06	74.2
LaJolla	.84	-41.1	.36	-71.8	1.36	38.4	.85	23.3	.25	-63.2	.43	37.3	.13	-66.3	.16	14.8	.02	-99.4	.01	167.6	.08	71.3
PBlossom	.40	-23.8	.19	-89.1	1.15	42.3	.72	27.3	.17	-57.4	.36	41.5	.07	-73.4	.14	18.5	.01	-77.2	.01	131.3	.07	72.6
JPL MV3	.51	-27.0	.21	-84.7	1.21	41.9	.76	26.9	.18	-57.9	.38	41.2	.08	-71.1	.14	18.1	.01	-81.2	.01	141.3	.07	71.9
JPL MV1	.51	-27.0	.21	-84.7	1.21	41.9	.76	26.9	.18	-57.9	.38	41.2	.08	-71.1	.14	18.1	.01	-81.2	.01	141.3	.07	71.9
JPL MV2	.51	-27.0	.21	-84.7	1.21	41.9	.76	26.9	.18	-57.9	.38	41.2	.08	-71.1	.14	18.1	.01	-81.2	.01	141.3	.07	71.9
OVRO 130	.28	32.6	.10	-140.6	1.01	46.8	.63	32.1	.10	-37.6	.31	46.3	.03	-91.4	.12	23.2	.01	-38.4	.01	73.4	.06	74.4
OVRO 90	.28	32.7	.10	-140.6	1.01	46.8	.63	32.1	.10	-37.7	.31	46.3	.03	-91.5	.12	23.2	.01	-38.5	.01	73.5	.06	74.4
PVerdes	.80	-31.7	.32	-69.9	1.42	39.9	.90	24.9	.25	-58.3	.45	39.0	.12	-63.4	.17	16.2	.02	-84.2	.01	165.3	.08	71.9
Malibu	.64	-27.1	.27	-72.8	1.37	40.8	.86	25.8	.23	-56.5	.43	40.1	.10	-64.2	.16	17.0	.02	-80.4	.01	158.0	.08	71.7
SaddlePk	.64	-26.4	.27	-73.5	1.36	40.9	.86	25.9	.23	-56.5	.43	40.2	.10	-64.5	.16	17.1	.02	-80.3	.01	157.1	.08	71.7
Gorman	.45	-13.3	.18	-84.6	1.25	43.0	.78	28.1	.18	-51.4	.39	42.6	.07	-68.2	.14	19.3	.01	-67.9	.01	128.7	.07	72.3
MammothL	.35	39.7	.09	-155.2	1.02	47.8	.64	33.2	.10	-30.5	.32	47.3	.02	-95.6	.12	24.3	.02	-33.5	.01	65.9	.06	74.2
SanPaula	.59	-20.6	.24	-73.3	1.38	41.6	.86	26.7	.22	-53.4	.43	41.1	.09	-63.2	.16	17.9	.02	-74.2	.01	150.7	.08	72.1
Vandenbg	.92	-11.2	.27	-59.1	1.65	42.0	1.03	27.2	.28	-45.7	.51	42.1	.11	-52.4	.19	18.3	.02	-64.6	.01	162.9	.10	71.8
Vndnberg	.97	-11.3	.26	-58.7	1.67	42.0	1.04	27.3	.28	-45.0	.52	42.3	.11	-51.6	.19	18.2	.02	-64.3	.01	164.9	.10	71.6
Quincy	.62	56.2	.13	150.3	1.11	51.5	.69	37.4	.12	-2.5	.34	51.1	.01	138.9	.13	28.6	.03	-20.1	.02	49.4	.07	74.2
HatCreek	.74	59.8	.16	138.8	1.15	52.7	.71	38.7	.14	5.5	.35	52.1	.02	115.6	.13	29.9	.03	-17.3	.02	45.8	.07	74.1
Fort Ord	.89	20.3	.04	-53.4	1.55	46.4	.96	31.9	.23	-25.1	.47	46.8	.05	-34.1	.18	23.1	.03	-41.2	.01	92.8	.09	73.1
Vacavill	.74	42.0	.07	133.3	1.37	49.2	.85	35.1	.18	-10.8	.42	49.4	.02	1.4	.16	26.3	.03	-30.1	.01	62.6	.08	73.9
SanFranc	1.04	33.8	.05	105.5	1.53	48.4	.95	34.2	.22	-12.9	.47	48.8	.03	-4.1	.18	25.4	.03	-33.6	.01	71.1	.09	73.8
Presidio	1.04	33.8	.05	105.5	1.53	48.4	.95	34.2	.22	-12.9	.47	48.8	.03	-4.1	.18	25.4	.03	-33.6	.01	71.1	.09	73.8
Pt Reyes	1.19	36.4	.10	81.4	1.69	48.6	1.05	34.5	.27	-8.7	.51	49.1	.04	16.7	.19	25.6	.04	-32.5	.02	66.3	.10	73.9
Yakataga	2.49	100.7	.89	137.4	1.32	87.4	.83	75.0	.43	78.1	.43	85.7	.23	133.1	.15	66.9	.10	4.7	.09	32.1	.13	59.6
GilCreek	.78	100.7	.32	140.1	.51	96.3	.35	88.1	.10	87.5	.16	95.3	.08	134.7	.06	79.4	.09	16.7	.06	23.1	.10	71.7
Kodiak	2.82	113.1	1.07	147.3	1.61	98.0	1.05	85.7	.51	94.5	.52	96.9	.27	144.7	.19	79.7	.12	.8	.10	38.8	.15	56.6
Kauai	.95	-111.3	.38	-130.0	1.15	61.9	.66	56.2	.21	-132.3	.33	61.9	.12	-138.7	.10	58.4	.05	-140.1	.03	-170.8	.06	112.5
SndPoint	1.94	127.6	.80	150.9	1.45	112.9	1.06	104.1	.33	122.2	.49	115.6	.21	151.1	.19	102.8	.13	-4.7	.09	56.9	.15	63.6
Kwajal26	3.03	-46.7	1.60	-28.1	.95	-125.9	.66	-151.2	.48	-45.2	.31	-127.2	.39	-30.3	.13	-165.3	.10	-162.3	.04	179.4	.11	-161.9
Tidbin64	.91	125.1	.12	175.5	.26	116.5	.27	65.2	.19	95.2	.10	108.8	.03	160.7	.08	50.5	.01	-18.0	.00	-26.6	.03	-126.8
Kashima	.87	51.5	.46	75.4	1.14	-138.3	.89	-157.6	.13	64.7	.35	-138.5	.13	78.7	.18	-163.0	.02	-12.2	.05	42.9	.10	105.6

Table 8.1 (continued)

	M_2		S_2		K_1		O_1		N_2		P_1		K_2		Q_1		M_f		M_m		S_{sa}	
	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS	AMP	PHAS
Johani26	1.63	-127.4	.74	-102.4	.09	128.3	.14	116.8	.33	-135.6	.03	127.6	.20	-101.8	.03	101.6	.02	-171.6	.03	112.6	.07	146.0
Wettzell	.52	-64.4	.14	-36.6	.18	-57.9	.08	-97.7	.11	-88.3	.05	-54.1	.04	-32.7	.01	-40.5	.05	6.1	.03	11.9	.05	75.4
Onsala60	.39	-62.3	.10	-29.2	.22	-50.4	.11	-103.3	.08	-84.2	.07	-47.7	.02	-12.6	.00	-130.0	.08	13.2	.05	23.1	.06	51.5
Onsala85	.39	-62.3	.10	-29.5	.22	-50.2	.11	-103.2	.08	-84.3	.07	-47.6	.02	-12.7	.00	-129.6	.08	13.2	.05	23.0	.06	51.5
Werthovn	.66	-59.7	.19	-28.6	.20	-58.0	.09	-92.5	.14	-81.1	.06	-55.4	.04	-25.5	.01	-35.4	.06	3.3	.04	6.5	.03	52.0
Eflsberg	.64	-60.7	.18	-31.5	.21	-58.2	.09	-93.0	.14	-82.2	.06	-55.8	.04	-30.2	.01	-36.9	.06	2.7	.04	5.9	.03	50.6
Orroral	.91	125.6	.13	174.3	.28	116.5	.28	66.1	.20	97.0	.11	109.1	.03	160.0	.08	51.6	.01	-16.3	.00	-24.0	.03	-120.6
Yaragade	.37	168.9	.13	-105.4	.81	13.5	.64	6.5	.07	94.7	.26	13.4	.02	-95.0	.13	-2.6	.01	-129.5	.04	-131.7	.08	-63.8
Graz	.53	-65.1	.14	-37.6	.16	-60.3	.07	-99.0	.11	-89.1	.05	-55.6	.04	-32.9	.01	-42.7	.04	6.1	.03	13.5	.05	82.0
Plana	.42	-63.9	.11	-39.9	.10	-71.8	.06	-104.4	.09	-90.3	.03	-64.2	.03	-34.3	.01	-51.7	.03	7.8	.03	20.2	.06	91.0
Kralov	.52	-65.1	.14	-37.5	.17	-58.1	.08	-98.3	.11	-89.0	.05	-54.1	.03	-32.8	.01	-46.0	.05	6.8	.03	13.2	.05	76.7
Ondrejov	.50	-65.1	.14	-33.6	.17	-57.8	.08	-98.9	.11	-87.2	.05	-53.6	.04	-27.8	.01	-55.5	.05	8.0	.03	13.6	.05	75.7
Helwan	.37	-67.0	.11	-52.3	.08	-170.9	.05	-150.5	.09	-93.4	.02	-174.8	.03	-48.1	.00	-124.4	.00	-42.3	.02	30.7	.07	99.6
Wettzell	.53	-63.8	.14	-36.6	.18	-57.8	.08	-97.5	.11	-88.2	.05	-54.0	.04	-32.7	.01	-39.9	.05	6.1	.03	12.0	.05	75.4
Metsahov	.28	-59.8	.07	-23.3	.17	-52.2	.11	-102.9	.06	-89.2	.05	-48.4	.02	-1.4	.01	-110.3	.07	19.8	.05	16.8	.07	74.8
Grasse	.73	-71.4	.21	-45.7	.18	-62.0	.06	-97.9	.15	-93.3	.05	-58.3	.05	-44.8	.01	5.5	.04	-4.5	.02	-2.0	.03	83.2
Huahine	.46	-107.5	.23	167.4	.04	142.9	.10	-82.2	.10	-122.5	.01	132.1	.07	174.6	.03	-99.4	.08	-158.2	.04	-151.5	.05	-141.4
Potsdam	.51	-63.3	.13	-31.3	.19	-55.5	.09	-98.4	.10	-84.2	.06	-52.3	.03	-24.4	.01	-62.3	.06	9.0	.04	14.9	.05	67.4
Dionysos	.42	-65.3	.11	-44.0	.07	-85.5	.05	-109.1	.09	-91.3	.02	-76.9	.03	-39.7	.01	-46.6	.02	3.6	.02	22.8	.06	95.1
Matera	.49	-65.9	.13	-39.4	.15	-60.4	.07	-98.5	.11	-90.2	.04	-55.2	.03	-34.8	.01	-42.3	.04	6.6	.03	14.7	.05	83.5
Dodair	.72	65.1	.37	84.4	.97	-135.2	.76	-154.4	.12	81.8	.30	-135.4	.11	88.3	.15	-159.9	.01	-10.1	.04	46.0	.09	110.9
Simosato	1.25	87.6	.57	107.0	1.11	-126.5	.86	-145.5	.25	95.7	.34	-126.6	.17	108.9	.17	-153.0	.01	-32.2	.05	43.7	.11	113.0
Mazatlan	.74	-89.2	.53	-88.2	.81	20.0	.56	5.2	.22	-81.6	.25	15.5	.16	-85.0	.12	-2.6	.05	-158.7	.03	-171.5	.06	48.5
Kootwijk	.60	-36.6	.19	-7.1	.20	-63.1	.10	-69.5	.15	-63.1	.06	-62.3	.04	-1.6	.02	-38.0	.08	1.3	.05	15.0	.04	12.0
Shanghai	.58	169.9	.14	-178.2	.62	-97.8	.51	-113.2	.17	163.6	.19	-92.8	.04	172.2	.10	-115.7	.01	105.3	.03	95.7	.09	146.8
Arequipa	.37	124.2	.10	95.2	.50	-140.1	.26	-160.2	.13	96.5	.15	-141.7	.04	99.4	.04	-177.2	.04	-176.8	.01	126.8	.03	105.0
Borowiec	.44	-61.4	.12	-28.8	.17	-56.1	.09	-99.9	.09	-85.2	.05	-52.0	.03	-19.7	.01	-73.1	.05	11.2	.04	15.5	.06	74.9
San Fern	2.29	-105.7	.77	-84.4	.24	-89.5	.07	141.5	.48	-128.4	.07	-90.9	.21	-86.0	.04	53.0	.03	-47.7	.03	-124.5	.03	-108.1
Zimmerwa	.68	-68.9	.21	-41.4	.20	-59.2	.07	-99.9	.15	-90.7	.06	-56.3	.05	-40.0	.01	-1.9	.05	-.2	.02	2.5	.03	71.9
Herstmon	.44	-88.0	.11	-74.6	.30	-60.2	.10	-111.6	.06	-4.4	.08	-61.8	.03	-132.9	.01	-141.7	.09	1.0	.05	-18.7	.03	-25.3
Ft. Davi	.08	-164.8	.15	-127.2	.48	32.5	.32	17.2	.05	-70.3	.15	30.8	.04	-108.3	.07	10.0	.02	-167.9	.01	157.8	.01	135.4
Mojave	.22	-10.7	.15	-107.6	.99	43.6	.62	28.7	.12	-55.2	.31	42.9	.05	-82.5	.12	19.9	.01	-67.1	.01	107.7	.06	73.9
Greenbel	.94	159.1	.25	-169.9	.34	-2.3	.23	-1.9	.17	143.6	.11	.1	.07	-174.4	.05	2.0	.02	19.5	.01	68.9	.05	-115.5
Maui, HI	1.18	-117.1	.48	-134.4	1.28	57.7	.73	49.2	.28	-138.7	.37	57.5	.15	-135.1	.11	47.2	.06	-143.7	.03	-169.1	.05	109.5
Monument	.51	-45.7	.27	-83.5	1.12	39.8	.71	24.5	.18	-66.2	.35	38.7	.10	-73.8	.13	15.8	.01	-106.4	.01	156.7	.06	71.4
Plattevi	.23	111.4	.13	-168.1	.47	39.5	.31	25.2	.02	-11.7	.15	38.7	.03	-151.0	.06	17.8	.01	6.3	.01	49.2	.02	92.7
Quincy	.62	56.3	.13	150.8	1.11	51.5	.69	37.4	.12	-2.6	.34	51.0	.01	140.8	.13	28.6	.03	-20.1	.02	49.3	.07	74.2
Simeiz	.34	-55.1	.09	-27.6	.07	-86.3	.07	-112.4	.08	-87.0	.02	-77.0	.02	-19.4	.01	-85.5	.03	16.1	.03	22.2	.07	91.0
Zvenigor	.28	-53.1	.07	-16.7	.12	-64.1	.09	-105.2	.06	-87.6	.04	-57.9	.02	-2.1	.01	-94.4	.05	21.4	.05	19.7	.08	85.5