NOAA Technical Memorandum NOS CO-OPS 0021

TIDAL CURRENT ANALYSIS PROCEDURES AND ASSOCIATED COMPUTER PROGRAMS

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noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services
Products and Services Division

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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March 1999

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TABLE OF CONTENTS

1. TIDAL CURRENT ANALYSIS PROCEDURE

1.1. Introduction

The National Ocean Service (NOS) has been charged with producing tidal current tables for the coastal areas of the United States. Tidal currents are almost always the strongest current experienced by vessels operating offshore and for considerable distances inside of bays and river estuaries. Tidal currents are usually fastest where water level fluctuations on wide continental shelfs are amplified as they approach the coast and water is forced through a narrow constricted channel into a large bay or estuary.

Knowledge of the timing and strength of tidal currents is extremely important for safe navigation in coastal waters. Mariners are primarily interested in the timing and strength of four phases of the tidal current cycle which are printed in the NOS Tidal Current Tables. These phases are slack before flood (SBF), maximum flood current (MFC), slack before ebb (SBE), and maximum ebb current (MEC). Two other phases are also included in the NOS Tidal Current Tables. These are minimum currents between two successive maximum currents in the same direction and are known as slack flood current (SFC) and slack ebb current (SEC).

Although a standardized procedure has developed for analyzing water level data to obtain the parameters required to produce the NOS Tide Tables, there has not been such a procedure developed for tidal currents. This publication sets forth a suggested step-by-step procedure to follow for obtaining the parameters needed to produce the NOS Tidal Current Tables. This is followed by detailed explanations of each of the computer programs used. These sections are designed to be stand-alone user's guides for each of the programs, giving a complete explanation of how the calculations are carried out, options to be set by the user, and sample input and output files. Table A indicates the inputs and outputs for the major programs used in the analysis of tidal currents. All the programs are written in FORTRAN.

1.2. Comparison of Tidal and Tidal Current Analysis

Tides and tidal currents are driven by the gravitational forces of the sun and the moon acting on the earth's oceans. The rotation of the earth causes the cyclical rise and fall of the ocean levels on a daily (diurnal) and half-daily (semidiurnal) basis. Variations in the relative positions of the earth, moon, and sun cause fluctuations in the strength of the astronomical forcing. Tides and tidal currents are predictable far into the future due to the predictability of the astronomical forcing. These forces are expressed as the tidal potential which consists of a limited number of discrete frequencies whose amplitudes and phases are well known at any time. However, the tidal signal at any point in the world has been affected by the bathymetry of the oceans, seas, bays, and river estuaries as the tidal forces are transmitted and modified by fluid dynamic forces. The frequencies are unchanged but the amplitudes and phases of each frequency or tidal constituent has been changed by varying amounts.

TABLE A. TIDAL CURRENT ANALYSIS PROGRAMS		
Inputs	**Program**	**Outputs**
Current Speeds and Directions	PRCMP	Mean Current Principal Current Direction Major and Minor Axis Variance
Current Speeds and Directions Principal Current Direction	LSQHA	Tidal Constituents Mean Current
Current Speeds and Directions Principal Current Direction	HARM29 HARM15	Tidal Constituents Mean Current
Multiple Tidal Constituents Mean Currents	AVCONS	Averaged Tidal Constituents Averaged Mean Current
Tidal Constituents Mean Current (Observed Speeds and Directions)	PRED	Predicted Speeds and Directions (Detided Speeds and Directions)
Current Speeds and Directions Principal Current Direction	GI	Mean Greenwich Intervals, Speeds, and Directions of Floods, Ebbs, and Slacks
Tidal Constituents (major axis) Mean Current (major axis)	NCP2	Predicted Times and Speeds of Floods, Ebbs, and Slacks
Reference Station Predicted Floods, Ebbs, Slacks, and Greenwich Intervals Subordinate Station Current Speeds and Directions	REVRED	Subordinate Station Greenwich Intervals, Speeds, and Directions for Floods, Ebbs, and Slacks Mean Time Differences and Speed Ratios
Reference Station Predicted Floods, Ebbs, Slacks, and Greenwich Intervals Subordinate Station Current Speeds and Directions	ROTARY	Subordinate Station Mean Current, Greenwich Intervals, Speeds, and Directions for Floods, Ebbs, and Slacks, and Complete Mean Tidal Cycle
Station Name, Location, Depth, Tidal Constituents, Greenwich Intervals, Speeds, and Directions for Floods, Ebbs, and Slacks	CONVERT	Reformatted Station Name, Location, Depth, Tidal Constituents, Greenwich Intervals, Speeds, and Directions for Floods, Ebbs, and Slacks

To be able to accurately predict the tides or tidal currents at any point, the amplitudes and the phases of the strongest tidal constituents which have propagated to that point must be determined. This is done by recording the tidal signal at that point for a long enough period of time to be able to resolve the amplitudes and phases of the major tidal constituents. Two tidal constituents which are close together in frequency can be resolved by a period of observation greater than their synodic period, which is the length of time in which the higher frequency completes exactly one more cycle than the lower frequency. Once the tidal constituents are known, the tidal signal at that point can be predicted indefinitely into the future provided that there are no major changes to the bathymetry in the vicinity of that location.

The tidal analysis of currents differs in several ways from the tidal analysis of water levels. The main difference is that water level observations are a scalar time series whereas current observations are a vector time series. For water levels, only the height of the water is measured, whereas for currents, the speed and the direction of the current must be recorded. The directional aspect of a current time series can best be seen in a polar plot of the data (Figures 1 and 2). Individual data points are plotted on a (u,v) coordinate system with u as the eastward velocity and v as the northward velocity. The resulting scatter plot can take many different forms and is primarily controlled by the bathymetric features in the vicinity of the location where the measurements were made.

Tidal currents can be categorized as reversing or rotary. A reversing current flows primarily in two opposite directions (flood and ebb) with a slack period of near zero flow when the current direction reverses (Figures 1 and 3). A rotary current continually changes direction during the tidal cycle without a narrowly defined flood or ebb direction (Figures 2 and 4). Rotary currents are usually present offshore on the continental shelf or in the deep ocean. Reversing currents are usually present in bays or estuaries where bathymetry and boundary geometry restrict the direction of flow. Complicated shorelines can result in flood and ebb current directions not being 180° apart.

Another difference between water levels and currents is that currents have a natural zero level occurring when no current is flowing. Measured water levels must always be referenced to a datum, usually based on a long series of observations for a specified period, whereas the measured currents are the absolute current speed. A pure tidal current time series, which is a summation of sine waves, will eventually average to zero. However most measured current time series will have a nonzero mean current. If current predictions are to be made for another time period, it must be determined if the measured nonzero mean current is a "permanent" current (i.e. always present). The timing of slack periods and the strength of floods and ebbs are affected by the presence of a permanent current.

Observed mean currents can be due to different causes depending on the location of the instrument. In rivers, there is an overall current in the ebb direction. However, river flowrates can vary by an order of magnitude during the course of a year. In constricted channels or near manmade structures, the current pattern during flood and ebb periods may be very different leading to tidally-induced residual currents. Estuarine circulation, which involves the exchange of salty ocean water with fresh river water, can lead to a nontidal mean current into the estuary near the bottom and out of the estuary near the surface. Offshore on the continental shelf, ocean currents of various magnitudes and time scales can contribute to the measured mean current. Therefore, it is often uncertain if the measured mean current is a "permanent" current and, if it is, whether it is similar at nearby locations.

1.3. Calculation of Tidal Current Parameters

The first step in analyzing a tidal current is to determine whether the current is reversing or rotary. If the current is reversing, the principal current direction is obtained by the program **prcmp**. The current can then be separated into a major and a minor component with most of the current variance along the major or principal current direction. For a rotary current, the major component variance may not be much greater than the minor component variance or a strong nontidal signal can obscure the principal current direction of the tidal signal.

The tidal constituents are obtained from observed data by a process known as harmonic analysis. The tidal constituents consist of an amplitude and phase for each tidal frequency. Some of these constituents may be set to zero if the data is not sufficient to determine the constituents accurately. Two sets of tidal constituents will be obtained. The first will be along the major axis and the second along the minor axis. For a reversing current, the major axis will be the principal current direction. For a rotary current, the major axis is set to 0° (north). Different harmonic analysis programs are recommended depending on the length of the observed time series. If there are more than 180 days of data, the program **lsqha** should be used. If there are between 29 and 180 days of data, the program **harm29** can be used one or more times. If there are between 15 and 29 days of data, the program **harm15** is used. The program **avcons** is used to average multiple sets of tidal constituents. If there are less than 15 days of data, tidal constituents cannot be obtained by harmonic analysis.

The Greenwich intervals for SBF, MFC, SBE, and MEC are the mean time between the moon's transit over the Greenwich meridian at 0° longitude and the arrival of the tidal phase at the station. This is a standard way of comparing the timing of tidal phases between stations anywhere in the world. The mean speeds and directions for the tidal phases are also calculated. The recommended procedure is to use the program **pred** to predict the tidal current for an entire year and then use the program **gi** to obtain the mean Greenwich intervals, speeds, and directions. The program **convert** can then be used to combine all the relevant information calculated for each station into an easy-to-read tabular format.

1.4. Reference and Subordinate Stations

All tidal current stations are listed in the NOS Tidal Current Tables as either a reference station or a subordinate station. A yearly listing of the tables can only give the floods, ebbs, and slacks of a limited number of stations known as the reference stations. A reference station is usually located at the entrance to a major bay or river estuary and always has a reversing current. In the 1999 NOS Tidal Current Tables, there were 60 reference stations which are listed in the section known as Table 1. The times of the SBF, MFC, SBE, MEC, SFC, and SEC phases are given to the nearest minute and the velocities of the MFC, MEC, SFC, and SEC phases are given to the nearest tenth of a knot. If a maximum current speed is less than 0.25 knots, it is labeled in the tables as "current weak and variable" and the slack times before and after are not printed. Tidal constituents for a reference station should be obtained from at least 180 days of current data, although many of the older established reference station constituents were obtained from much shorter data sets. The program **ncp2** is used for the routine prediction of the daily floods, ebbs, and slacks of a reference station current.

If a station has a reversing current, is near a reference station, and has a similar tidal cycle, it is listed as a subordinate station in Table 2 of the NOS Tidal Current Tables. Table 2 is used to relate the printed times of SBF, MFC, SBE, and MEC and speeds of MFC and MEC of the reference station to those of the subordinate station. Table 2 lists the subordinate station time differences and speed ratios, along with station depth and position. It also gives the average speeds and directions of SBF, MFC, SBE, and MEC for the subordinate station. The Table 2 parameters for some older subordinate stations have been established from as little as one day of current measurements. If there are more than 15 days of observed data, tidal constituents can be obtained for the subordinate station and a whole year of predicted currents can be used to establish the Table 2 parameters. The program **revred** is used to relate a reversing current to a reference station.

If a station has a rotary current, is near a reference station, and has a similar tidal cycle, it is listed as a subordinate station in Table 5 of the NOS Tidal Current Tables. Table 5 is used to obtain the mean speed and direction of the subordinate station current for 0 to 12 hours after a specified tidal phase (usually flood) at the reference station. If there are more than 15 days of observed data, tidal constituents can be obtained for the subordinate station and a whole year of predicted currents can be used to establish the Table 5 parameters. The program **rotary** is used to relate a rotary current to a reference station.

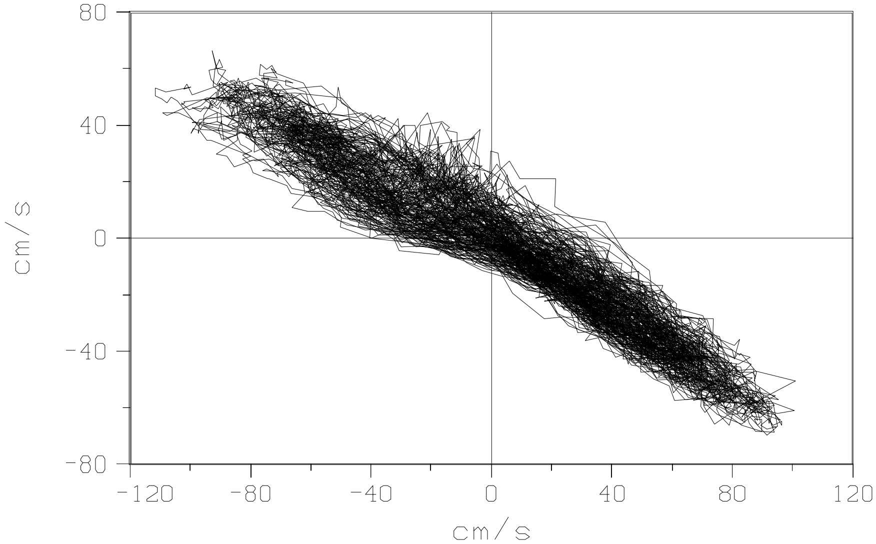


Figure 3. Plot of east-west and north-south current components for a typical reversing current over many tidal cycles.

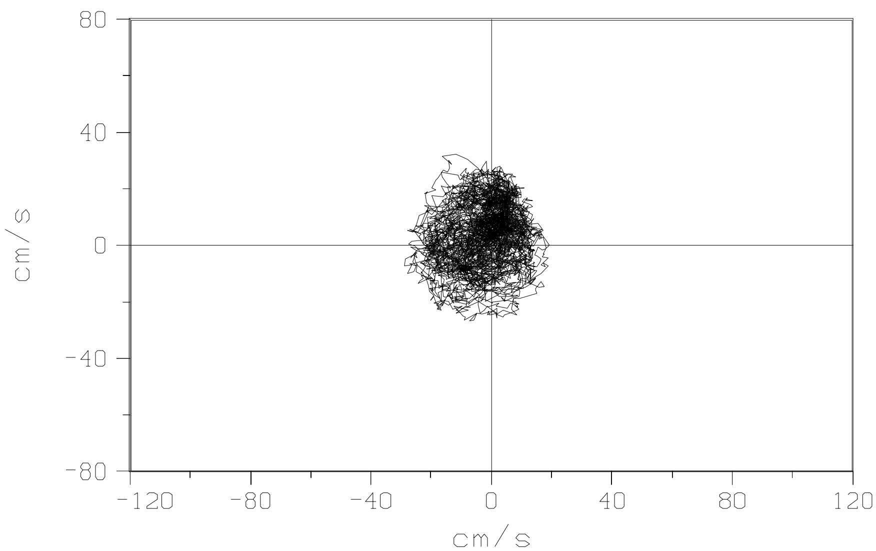


Figure 4. Plot of east-west and north-south current components for a typical rotary current over many tidal cycles.

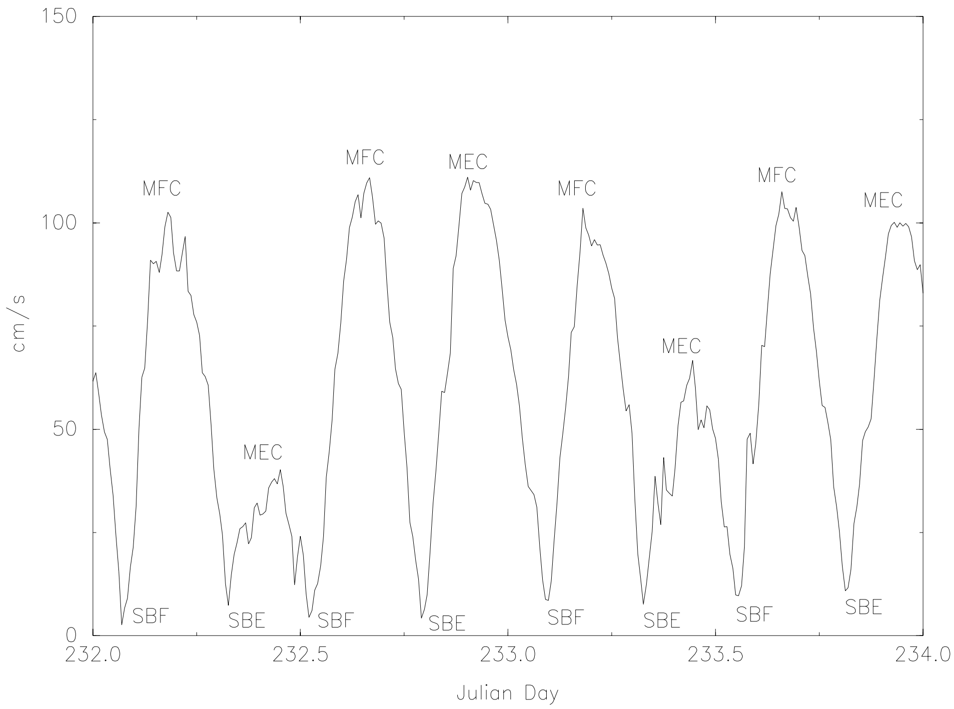


Figure 5. Current speed for a typical reversing current. MFC=Maximum Flood Current, MEC=Maximum Ebb Current, SBF=Slack Before Flood, SBE=Slack Before Ebb.

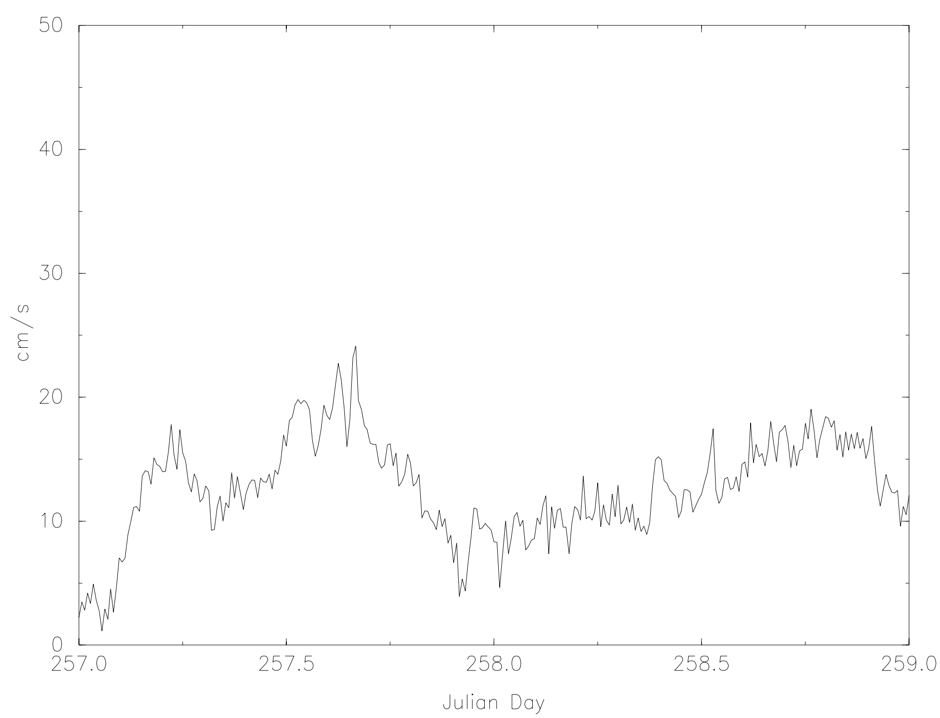


Figure 6. Current speed for a typical rotary current.

1.5. Tidal Current Analysis Procedure for All Stations

A1. Put the current data into a free-format three-column ASCII file as: Time, Current Speed, Current Direction. The time should be in Julian Days specified to the nearest minute (at least four decimal places) and should be the time for the middle of the sampling period.

A2. Plot the speed and direction versus time to check for bad data and delete all bad data. Carefully check the beginning and end of the time series, where the speeds may be within the normal range of the data, but the instrument may be out of the water.

A3. Determine the principal current direction by running the program **prcmp**. If the principal current direction is in the ebb direction, add or subtract 180° to put it in the flood direction.

If the minor axis variance is greater than 20%, the principal current direction is not well defined and the harmonic analysis to be carried out in step A6 should be along 0°.

For multiple deployments, run **prcmp** once for each deployment and average the individual principal current directions (in the flood direction). Small changes in instrument location can give differing principal current directions.

Prcmp will also print the mean current and indicate when the mean current is not significant (i.e. if both the 95% confidence intervals include zero).

A4. Find the first and last data point, the lengths of any gaps in the data, and the number of continuous data points by running the program **gap**. If there are several deployments, concatenate all the data together chronologically into one file before running **gap**. The output file *gaps* is useful in setting up the control files for harmonic analysis.

A5. Determine the type of harmonic analysis procedure to use based on the data set available.

If there are more than 180 days of data (continuous or with gaps), use the least squares harmonic analysis program **lsqha**. The continuous data option (INDATA=1) can be used if there are a limited number of blocks of continuous data (fewer than 20). If there are many small gaps, use the randomly-spaced data option (INDATA=2) which will take longer to run.

If there are between 29 and 180 days of data, use the 29-day Fourier harmonic analysis program **harm29** on one or more 29-day segments of continuous data.

If there are between 15 and 29 days of continuous data, use the 15-day harmonic analysis program **harm15**.

If there are less than 15 days of continuous data, the tidal constituents cannot be derived, but the station can be characterized as a subordinate station and related to a reference station by using the programs **revred** or **rotary** (see Section 1.6).

A6. Carry out the harmonic analysis procedure with **lsqha**, **harm29**, or **harm15** to obtain one or more sets of tidal constituents. For multiple deployments, perform the harmonic analyses along the individual principal current direction (flood direction) specified for each deployment. However, for poorly defined principal current directions (if **prcmp** gave minor axis variances greater than 20% in step A3), perform the harmonic analyses along 0°. If **lsqha** is used, do not solve for the long term constituents Mf, Msf, Mm, Ssa, and Sa. These constituents cannot be determined accurately from only a year of data. If the mean current was not significant (from **prcmp** results in step A3), set the mean current to zero in the tidal constituents output file *cons.out*.

A7. For multiple sets of tidal constituents at one station, concatenate all the *cons.out* files together and use **avcons** to average the constituents. If the mean currents were not significant (from **prcmp** results in step A3), set the mean current to zero in the average tidal constituents file.

A8. Detide the observed time series using the program **pred**. **Pred** will have to be run separately to detide data from different years. Plot the detided time series to check if the tidal constituents are good. This can turn up any time zone errors in the constituents. The end of the **pred** output file shows the root mean square, mean, and standard deviation of the observed, predicted, and residual time series.

A9. Predict tidal currents for a whole year using the program **pred**. Choose a year that is near one quarter or three quarters of the 18.6 year epoch corresponding to the variation in the obliquity of the moon's orbit. These years are determined by looking for nodal factors closest to 1.0 in Table 14 of the "Manual of Harmonic Analysis and Prediction of Tides" by Shureman (1976). Some good years to use are 1964, 1974, 1983, 1992, 2001, 2011, or 2020. The tidal amplitudes for these years are closest to the average amplitudes for an 18.6 year epoch. Other years will have higher or lower tidal amplitudes.

A10. Check if the principal current direction from predicted currents is close to the principal current direction obtained in step A3 from observed data by running **prcmp** again. If they are significantly different, strong nontidal currents could have shifted the principal current direction obtained in step A3. It may be desirable to redo steps A6, A7, A8, and A9 along the principal current direction derived from only predicted tidal currents.

A11. Make polar plots of the predicted tidal currents to observe any unusual features such as flood and ebb directions not 180 degrees apart, whether tidal currents have significant energy along a minor axis, rotary versus rectilinear character, etc.

A12. <u>Obtain Greenwich intervals from the predicted tidal currents for a whole year</u> using the program **gi**. Do not filter the predicted time series since it is already smooth. The Greenwich intervals and mean speeds and directions are at the end of the **.gi* output file.

Do not run **gi** for very weak tidal currents, since the program excludes maximum floods or ebbs with speeds less than 0.25 knots (12.86 cm/s). Do not run **gi** for a rotary tidal current, since the program tries to separate maximum and minimum speeds into floods, ebbs, and slacks.

A13. <u>Run the program **convert**</u> to convert the *cons.out* file, which will have tidal constituents in cm/s and modified local epochs (6’), into three output files with constituents in knots. There will be a file (**.kap*) with constituents in local epochs (6), a file (**.kpr*) with constituents in modified local epochs (6’), and an ellipse table file (**.elp*) in local epochs (6). These files are in the format requested for the routine prediction of tidal currents for Table 1 of the NOS Tidal Current Tables.

1.6. Tidal Current Analysis Procedure for Subordinate Stations

B1. Calculate the predicted reference station tidal currents along the principal current direction using **ncp2**. Use the tidal constituents in knots along the major axis. The year should be the year of the subordinate station predicted current from step A9 (or the year of the observed current if there were less that 15 days of data). The reference station should always have a rectilinear current and the current should not be weak since the **ncp2** output file gives speeds only to the nearest 0.1 knot (~5 cm/s). The reference station floods, ebbs, and slacks are printed in output file *13* in a standard max/min/slacks format. These are the times and speeds that would be printed in Table 1 of the NOS Tidal Current Tables. Save file *13* for use with the programs **revred** or **rotary**.

B2. Classify the subordinate station current as reversing or rotary by looking at a polar plot of predicted tidal currents for a whole year, previously obtained using the program **pred** (see step A9). (Use observed data if there were less than 15 days of continuous data and tidal constituents could not be obtained.) Check the results from the program **prcmp** in step A10. If the minor axis variance is greater than 20%, the current can be classified as rotary. A reversing subordinate station is listed in Table 2 of the NOS Tidal Current Tables while a rotary subordinate station is listed in Table 5.

B3. For a reversing subordinate station current with more than 15 days of continuous data, analyze the subordinate station current vectorially by running the program **revred** (set the parameters ITYAN = 1 and ITIDE = -1). Use the max/min/slacks file *13* created by **ncp2** for the floods, ebbs, and slacks of the reference station. Set the smoothing window length as short as possible (5 data points) since the subordinate station time series is a predicted tidal current.

Since **revred** can only analyze data from one year, remove any points in the subordinate station file that would be on December 31 of the previous year due to a shift from Greenwich to local time. Do not run **revred** with very weak subordinate station currents, since the program excludes maximum floods or ebbs with speeds less than 0.25 knots (12.86 cm/s).

The parameters needed for Table 2 of the NOS Tidal Current Tables are printed at the end of the **.tbl* output file. The printed standard deviations and extrema for these parameters in the **.tbl* file and the graphical output in the **.plt* file will show how closely the two time series are related. If the scatter is large, a better reference station should be found.

B4. If there are less than 15 days of continuous data at a subordinate station with a reversing current, the tidal constituents cannot be obtained and observed current data must be used in place of the predicted tidal current in step B3. Start with a smoothing window length of 1 hour and increase it if necessary. However, if there are strong nontidal currents during this time period, the results may be inaccurate.

A better method is available if there is observed data at the reference station during the deployment of the subordinate station. First, run **revred** with the parameters ITYAN = 2 and ITIDE = 0 to obtain a max/min/slacks file at the reference station from the observed data. Then, run **revred** again for the subordinate station (with ITYAN = 1 and ITIDE = -1) using the observed max/min/slacks file for the reference station.

B5. For a rotary current at a subordinate station with more than 15 days of continuous data, run the program **rotary** to obtain the mean tidal current cycle. Use the output file *13* created by **ncp2** for the reference station floods, ebbs, and slacks. The mean speeds and directions for the subordinate station current at 0 to 12 hours after maximum flood at the reference station are printed in the output file. The **rotary** program results can be used for Table 5 of the NOS Tidal Current Tables only if the reference station current is semidiurnal or mainly semidiurnal. (Set IEV1 = -1 for an hourly rotary analysis or set IEV1 = 0 for a half-hourly rotary analysis.) A rotary analysis using diurnal or mainly diurnal tidal cycles can be carried out by setting IEV1 = 26 and IEV2 = 0, but the times will run from 0 to the mean tidal cycle length and not fit the format of Table 5. Set the IEDIT parameter to 1 for weak rotary tidal currents.

Use the times in file *13* to choose an analysis period for the **rotary** control file consisting of an integral number of complete tidal cycles preferably beginning on reference station flood times. Choose the starting time after the beginning of the subordinate station predicted data and the ending time before the end of the subordinate station predicted data. This will trim off extra data so only complete tidal cycles will be in the analysis. Remember that while file *13* and the starting and ending times should all be local, subordinate station predicted data may be in Greenwich time.

B6. If there are less than 15 days of continuous data at a rotary subordinate station, the tidal constituents cannot be obtained and subordinate station observed data must be used in step B5. If there were large nontidal events during this period, the results may be inaccurate.

2. LSQHA: THE LEAST SQUARES HARMONIC ANALYSIS PROGRAM

2.1. Introduction

The least squares method of harmonic analysis is a method for deriving the tidal constituents from a water level or current time series. This is done by creating a matrix of covariance (or correlation coefficients) between each individual constituent time series and the observed time series (Harris, et al., 1963). The matrix is inverted to solve for the amplitudes and phases of the harmonic constituents. The constituent with the highest correlation is then subtracted from the observed time series and the matrix is recalculated with a residual time series in place of the observed. (An option exists for solving for the constituents in a specified order.) The least squares harmonic analysis program has the capability of solving for the 175 tidal constituents shown in Table B.

The number of constituents that can be determined depends on the amount of data available. In general, the time length of data needed to accurately distinguish the amplitudes and phases of two constituents is the synodic period. The synodic period is the length of time in which the higher frequency constituent completes exactly one more cycle than the lower frequency constituent.

NOS has traditionally analyzed water level data for 37 tidal constituents. For 15 days of data, the following 16 constituents can be resolved:

2Q(1), O(1), K(1), OO(1), 2N(2), M(2), S(2), 2SM(2),
2MK(3), MK(3), M(4), MS(4), S(4), M(6), S(6), M(8)

For 30 days of data, the following seven additional constituents can be resolved, for a total of 23:

Q(1), M(1), J(1), N(2), L(2), M(3), MN(4)

For 180 days of data, the following six additional constituents can be resolved, for a total of 29:

RHO(1), P(1), MU(2), NU(2), LAMBDA(2), K(2)

For 365 days of data, the following three additional constituents can be resolved, for a total of 32:

S(1), T(2), R(2)

Some of these tidal constituents, known as overtides and compound tides, can become increasingly important in shallow waters. The overtides are M(4), S(4), M(6), S(6), and M(8). The compound tides are 2MS(2), 2MK(3), MK(3), MS(4), and MN(4).

The last five constituents MF, MSF, MM, SSA, and SA are the fortnightly, monthly, semiannual, and annual constituents. Although synodic periods are not a problem, several years of data are usually necessary to determine these constituents with any degree of accuracy. These constituents are often dominated by nontidal meteorological influences which are highly variable from year to year (e.g. the steric effect on sea level or the density-driven flow effect on currents in estuaries). Although SSA and SA are usually important constituents for water level predictions, they are generally insignificant for current predictions.

In practice, constituents can often be accurately determined with less data than the synodic periods would indicate. The best plan is to start with the largest number of constituents and reduce the number if the results are unstable. Unstable results are indicated by unreasonably large constituent amplitudes for closely-spaced constituents. Be sure to check K(1), P(1), S(1), S(2), K(2), T(2), and R(2). P(1) should be smaller than K(1) and K(2) should be smaller than S(2). S(1), T(2), and R(2) should be very small.

The least squares program does not require the input data to be a continuous time series. There are three data input options: 1) an equally-spaced, continuous time series, 2) a limited number of blocks (up to 20) of equally-spaced, continuous data, or 3) equally-spaced data with numerous gaps or randomly-spaced data. For the third case, a time in Julian days must be read in for each data point. (If the data are from different years, separate blocks are needed to specify the data in each year.) The third case takes longer to run.

Some of the program parameters have been hard-wired. The program is dimensioned for 120000 records (NRECRD) which is equivalent to 1.37 years of 6 minute data. It is dimensioned to solve up to 175 constituents. Since MINTRM = 0 and MAXTRM = 0, no intermediate solutions are printed. The program can read up to 20 blocks of continuous data or it can read in randomly-spaced data with times in Julian days. The program will not analyze less than 29 days of data.

The following program options are available in the code, where 1 is chosen to implement the option and 0 is chosen not to implement the option. They have all been set to zero.

ICNTL=0,0,0,0,0,0,0,0,0,0

> ICNTL(1) is not used.
> ICNTL(2) is not used.
> ICNTL(3) is not used.
> ICNTL(4) is to print a table of means and standard deviations from subroutine CSTAT2.
> ICNTL(5) is to use the matrix of correlation coefficients instead of covariance to improve stability.
> ICNTL(6) is not used.
> ICNTL(7) is to display intermediate matrices from subroutines SCREEN and CSTAT2.
> ICNTL(8) is not used.
> ICNTL(9) is to continue through the list of all predictors requested instead of terminating calculations after finding the first predictor whose variance is below CUTOFF.
> ICNTL(10) is to calculate predictors in the order given instead of rearranging the matrix to choose predictors based on the largest reduction of variance.

The program is run in a UNIX environment using

```
lsqha < lsq.ctl > lsqout
```

where *lsq.ctl* is the control file and *lsqout* is the output file. A file named *cons.out* is also created with the constituents in standard predictions format.

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER

Number	Name	Speed (degrees/hour)
1	M(2)	28.9841042
2	S(2)	30.0000000
3	N(2)	28.4397295
4	K(1)	15.0410686
5	M(4)	57.9682084
6	O(1)	13.9430356
7	M(6)	86.9523127
8	MK(3)	44.0251729
9	S(4)	60.0000000
10	MN(4)	57.4238337
11	NU(2)	28.5125831
12	S(6)	90.0000000
13	MU(2)	27.9682084
14	2N(2)	27.8953548
15	OO(1)	16.1391017
16	LAMBDA(2)	29.4556253
17	S(1)	15.0000000
18	M(1)	14.4966939
19	J(1)	15.5854433
20	MM	0.5443747
21	SSA	0.0821373
22	SA	0.0410686
23	MSF	1.0158958
24	MF	1.0980331
25	RHO(1)	13.4715145
26	Q(1)	13.3986609
27	T(2)	29.9589333

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER		
Number	**Name**	**Speed (degrees/hour)**
28	R(2)	30.0410667
29	2Q(1)	12.8542862
30	P(1)	14.9589314
31	2SM(2)	31.0158958
32	M(3)	43.4761563
33	L(2)	29.5284789
34	2MK(3)	42.9271398
35	K(2)	30.0821373
36	M(8)	115.9364169
37	MS(4)	58.9841042
38	SIGMA(1)	12.9271398
39	MP(1)	14.0251729
40	CHI(1)	14.5695476
41	2PO(1)	15.9748272
42	SO(1)	16.0569644
43	MSN(2)	30.5443747
44	MNS(2)	27.4238337
45	OP(2)	28.9019669
46	MKS(2)	29.0662415
47	2NS(2)	26.8794590
48	MLN2S(2)	26.9523126
49	2ML2S(2)	27.4966873
50	SKM(2)	31.0980331
51	2MS2K(2)	27.8039338
52	MKL2S(2)	28.5947204
53	M2(KS)(2)	29.1483788
54	2SN(MK)(2)	29.3734880
55	2KM(SN)(2)	30.7086493
56	SO(3)	43.9430356
57	SK(3)	45.0410686
58	NO(3)	42.3827651
59	MK(4)	59.0662415
60	SN(4)	58.4397295

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER		
Number	**Name**	**Speed (degrees/hour)**
61	2MLS(4)	57.4966873
62	3MS(4)	56.9523127
63	ML(4)	58.5125831
64	N(4)	56.8794590
65	SL(4)	59.5284789
66	MNO(5)	71.3668693
67	2MO(5)	71.9112440
68	2MK(5)	73.0092770
69	MSK(5)	74.0251728
70	3KM(5)	74.1073100
71	2MP(5)	72.9271398
72	3MP(5)	71.9933813
73	MNK(5)	72.4649023
74	2SM(6)	88.9841042
75	2MN(6)	86.4079380
76	MSN(6)	87.4238337
77	2MS(6)	87.9682084
78	2NMLS(6)	85.3920421
79	2NM(6)	85.8635632
80	MSL(6)	88.5125831
81	2ML(6)	87.4966873
82	MSK(6)	89.0662415
83	2MLNS(6)	85.9364168
84	3MLS(6)	86.4807916
85	2MK(6)	88.0503457
86	2MNO(7)	100.3509735
87	2NMK(7)	100.9046318
88	2MSO(7)	101.9112440
89	MSKO(7)	103.0092771
90	2MSN(8)	116.4079380
91	3MS(8)	116.9523127
92	2(MS)(8)	117.9682084
93	2(MN)(8)	114.8476674

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER		
Number	**Name**	**Speed (degrees/hour)**
94	3MN(8)	115.3920422
95	2MSL(8)	117.4966873
96	4MLS(8)	115.4648958
97	3ML(8)	116.4807916
98	3MK(8)	117.0344500
99	2MSK(8)	118.0503457
100	2M2NK(9)	129.8887360
101	3MNK(9)	130.4331108
102	4MK(9)	130.9774855
103	3MSK(9)	131.9933813
104	4MN(10)	144.3761464
105	M(10)	144.9205211
106	3MNS(10)	145.3920422
107	4MS(10)	145.9364169
108	3MSL(10)	146.4807916
109	3M2S(10)	146.9523127
110	4MSK(11)	160.9774855
111	4MNS(12)	174.3761464
112	5MS(12)	174.9205211
113	4MSL(12)	175.4648958
114	4M2S(12)	175.9364169
115	TK(1)	14.9178647
116	RP(1)	15.0821353
117	KP(1)	15.1232059
118	THETA(1)	15.5125897
119	KJ(2)	30.6265119
120	OO(2)	27.3416965
121	MO(3)	42.9271397
122	SK(4)	60.0821373
123	2KO(1)	16.1391016
124	2OK(1)	12.8450026
125	2NK2S(2)	26.9615963
126	MNK2S(2)	27.5059710

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER		
Number	**Name**	**Speed (degrees/hour)**
127	2KN2S(2)	28.6040041
128	MNKS(4)	57.5059710
129	KN(4)	58.5218668
130	3NKS(6)	85.4013258
131	2NMKS(6)	85.9457005
132	2MNKS(6)	86.4900752
133	MKN(6)	87.5059710
134	NSK(6)	88.5218668
135	3MNKS(8)	115.4741794
136	2MNK(8)	116.4900752
137	MSNK(8)	117.5059710
138	2MNSK(10)	146.4900752
139	3MNKS(12)	175.4741794
140	2NP(3)	41.9205276
141	2KP(1)	15.1232058
142	2PK(1)	14.8767942
143	KP(2)	30.0000001
144	2SK(2)	29.9178627
145	2KS(2)	30.1642746
146	2TS(2)	29.9178666
147	ST(4)	59.9589333
148	3SK(4)	59.9178627
149	3KS(4)	60.2464119
150	3TS(4)	59.8767999
151	SO(2)	28.9430356
152	SO(0)	1.0569644
153	.5MF	0.5490165
154	.5MSF	0.5079479
155	ST(0)	0.0410667
156	3SA	0.1232059
157	4SA	0.1642746
158	6SA	0.2464118
159	8SA	0.3285841

TABLE B. TIDAL CONSTITUENTS IN STANDARD ORDER		
Number	**Name**	**Speed (degrees/hour)**
160	10SA	0.4106864
161	12SA	0.4928237
162	24SA	0.9856473
163	HS(3)	45.0000000
164	HS(5)	75.0000000
165	O(2)	27.8860712
166	SK(2)	30.0410686
167	NK(3)	43.4807981
168	SP(3)	44.9589314
169	K(3)	45.1232059
170	NO(4)	56.3258007
171	MO(4)	56.8701754
172	SO(4)	57.8860712
173	S(7)	105.0000000
174	S(8)	120.0000000
175	S(10)	150.0000000

2.2. Explanation of the Control File

The following is a sample of the **lsqha** control file which will be explained in detail in this section. The program uses free-format to read in the numbers.

```
tser1                                   ! Input data filename
 0.000001      1     66                 ! cutoff, nblk, njobx
 121.    9504   6    0.0  0.0   0.0     ! azi, n, nsph, cvar, umean, vmean
 1990.   8  19.  19.    0.  75.  82.76 ! xyer, month, day, stt, sttm, tm, gonl
 1    1   1.0     23    2               ! indata, kindat, vfac, ncon, itype
(9x,2f8.3)                              ! Format for input data
'2Q(1)','O(1)','K(1)','OO(1)','2N(2)','M(2)','S(2)','2SM(2)',
'2MK(3)','MK(3)','M(4)','MS(4)','S(4)','M(6)','S(6)','M(8)',
'Q(1)','M(1)','J(1)','N(2)','L(2)','M(3)','MN(4)',
'RHO(1)','P(1)','MU(2)','NU(2)','LAMBDA(2)','K(2)',
'S(1)','T(2)','R(2)','MF','MSF','MM','SSA','SA'
```

Line #1

The first line in the control file is the name of the input data file.

Line #2

CUTOFF is the variance cutoff for predictors. Calculations are terminated when the next constituent accounts for a fraction of the total variance less than CUTOFF.

NBLK is the number of blocks of data to be analyzed.

NJOBX is the total number of days (to the nearest integer) between the beginning and the end of the time series to be analyzed.

Line #3

AZI is the principal current direction for vector data. Pick the flood direction. (Not relevant for scalar input data, but must be given.)

N is the number of data points to analyze in a block.

NSPH is the number of samples per hour (e.g. 10 for 6 minute data, 1 for hourly data).

CVAR is the direction of magnetic north if it hasn't been corrected for in the data. Otherwise, is should be set to zero.

UMEAN is a mean current to the east or a mean water level.

VMEAN is a mean current to the north.

Usually set UMEAN and VMEAN to 0 unless the means are much larger than the data variance. UMEAN and VMEAN are subtracted from the time series before the analysis and added back to the results. This can make the variance matrix more stable and result in a more accurate solution.

Line #4

XYER is the starting year.

MONTH is the starting month.

DAY is the starting day.

STT is the starting hour which should be in <u>LOCAL</u> time to obtain modified local epochs (6') for the constituent phases. If STT is in Greenwich time, the Greenwich epochs (G) will be obtained.

STTM is the starting minute.

TM is the time meridian of the starting time STT (75 for Eastern Standard Time, 90 for Central Standard Time, 120 for Pacific Standard Time, or 0 for Greenwich Mean Time).

GONL is the longitude of the station in decimal degrees (positive for west longitude).

Line #5

INDATA is 1 for equally-spaced, continuous data or 2 for randomly-spaced data. (For INDATA=2, the first column of the input data file must contain time in decimal Julian days).

KINDAT is 1 for vector data (current speed and direction) or 2 for scalar data (water level).

VFAC is a scaling parameter in the denominator to give the user the option to change the units of the input time series (e.g., 51.444 to change cm/s to knots, 30.48 to change cm to feet).

NCON is the number of constituents to solve for.

ITYPE specifies how to read in the constituents to be solved for.

If ITYPE is 1, a list of NCON constituent speeds (in any order) are read in as

28.9841042, 28.4397295, 30.0000000,. . .

where up to 175 constituent speeds in degrees per hour can be given. (They must be given exactly as in Table B with 7 digits after the decimal point.)

If ITYPE is 2, a list of NCON constituent names (in any order) are read in as

'M(2)', 'N(2)', 'S(2)',. . .

The constituents must be specified as shown in Table B within single quote marks.

If ITYPE is 3, the NCON constituents solved for are in the standard order shown in Table B (e.g., if NCON = 37, the first 37 constituents in Table B are solved for).

Line #6

The sixth line of the control file is the FORTRAN format of the data in the input file. If INDATA=1 and KINDAT=1, a speed and a direction must be read in. If INDATA=1 and KINDAT=2, a scalar value must be read in. If INDATA=2 and KINDAT=1, a time in Julian days and a speed and direction must be read in. If INDATA=2 and KINDAT=2, a time in Julian days and a scalar value must be read in.

The last lines of the control file contain the list of constituents to be solved for if ITYPE = 1 or ITYPE = 2. That completes this control file.

2.3. Sample Control File for Multiple Deployments

The least squares program can be used for data collected over multiple deployments (up to 20) at a single station. The following is a sample control file for reading in a time series composed of four blocks of continuous data separated by three data gaps. The third, fourth, fifth, and sixth lines of the control file must be repeated for each block. The time used for STTM should be the middle of the first sampling period. Note that AZI, N, XYER, MONTH, DAY, STT, and STTM are different for each block. The number of samples per hour NSPH must be the same for all the blocks. If they are different, the random data option (INDATA = 2) must be used. The four input data block files were concatenated into the file *tser1*. Check the FORTRAN format for the input data to make sure it is correct.

```
tser1                                    ! Input data filename
 0.000001      4     262                 ! cutoff, nblk, njobx
 121.    9504   6   0.0  0.0   0.0       ! azi, n, nsph, cvar, umean, vmean
 1990.   8  19.  19.   0.  75.  82.76   ! xyer, month, day, stt, sttm, tm, gonl
 1    1   1.0    23    2                 ! indata, kindat, vfac, ncon, itype
(9x,2f8.3)                               ! FORTRAN format for input data
'2Q(1)','O(1)','K(1)','OO(1)','2N(2)','M(2)','S(2)','2SM(2)',
'2MK(3)','MK(3)','M(4)','MS(4)','S(4)','M(6)','S(6)','M(8)',
'Q(1)','M(1)','J(1)','N(2)','L(2)','M(3)','MN(4)',
'RHO(1)','P(1)','MU(2)','NU(2)','LAMBDA(2)','K(2)',
'S(1)','T(2)','R(2)','MF','MSF','MM','SSA','SA'
 122.    8784   6   0.0  0.0   0.0       ! azi, n, nsph, cvar, umean, vmean
 1990.  10  27.  19.   0.  75.  82.76   ! xyer, month, day, stt, sttm, tm, gonl
 1    1   1.0    23    2                 ! indata, kindat, vfac, ncon, itype
(9x,2f8.3)                               ! FORTRAN format for input data
 114.    8496   6   0.0  0.0   0.0       ! azi, n, nsph, cvar, umean, vmean
 1991.   1   2.  19.   0.  75.  82.76   ! xyer, month, day, stt, sttm, tm, gonl
 1    1   1.0    23    2                 ! indata, kindat, vfac, ncon, itype
(9x,2f8.3)                               ! FORTRAN format for input data
 123.   10944   6   0.0  0.0   0.0       ! azi, n, nsph, cvar, umean, vmean
 1991.   3  12.  19.   0.  75.  82.76   ! xyer, month, day, stt, sttm, tm, gonl
 1    1   1.0    23    2                 ! indata, kindat, vfac, ncon, itype
(9x,2f8.3)                               ! FORTRAN format for input data
```

2.4. Output Files

Two output files are produced by **lsqha**. An output file named *cons.out* is produced with the constituents in standard predictions format, which consists of a two line header, a line containing a mean value, and six lines containing the amplitudes and phases of 37 tidal constituents. This output file is the same as the file produced by the Fourier harmonic analysis programs **harm29** and **harm15** with modified local epochs (6'). The program **convert** can then be used to convert it into other forms (a standard predictions format file and an ellipse table file with amplitudes in knots and the local epochs 6).

Sample *cons.out* output file in standard predictions format:

```
Harmonic Analysis of Data in  tser1
Least Squares H.A.  Beginning  8-19-1990  at Hour 19.00     along 120 degrees
  2181
       153908338020877339 95113358307852470 2741 154271822477    0   0
       2 22412573 11522836  617 267    0   0  3052285    0   0  9442604
       3 13942823    0   0    0   0  7951051 11082566    0   0    0   0
       4    0   0    0   0    0   0    0   0 51002469    0   0    0   0
       5  5332214    0   0 18262551  7121204 25923435 22462718    0   0
       6  2433056 10503509
Harmonic Analysis of Data in  tser1
Least Squares H.A.  Beginning  8-19-1990  at Hour 19.00     along 210 degrees
   -95
       1 25622664 11672623  2722415 16151249  1263415 12251255  5663342
       2  526 767   912794  2862993    0   0  1901480    0   0  116 432
       3  116 933    0   0    0   0  3662205  3181901    0   0    0   0
       4    0   0    0   0    0   0    0   0  2411531    0   0    0   0
       5  2563269    0   0   791311  388 873  1842366  5541270    0   0
       6  1481916  2282407
```

If KINDAT = 1, the program first prints a solution for the major axis component and then for the minor axis component. Otherwise, if KINDAT = 2 (a scalar harmonic analysis) only one set of constitutents is printed.

The output file *lsqout* contains information about all the input parameters and the intermediate steps along with the solution. This output file has lines up to 132 characters long. The Unix command **lp -oc** can be used to print text in small letters.

Sample *lsqout* output file:

```
  azi =  121.0 n =  9504 nsph =  6
  cvar =  .0 umean =  .0 vmean =  .0
  xyer =  1990.0 month =  8 day =  19.0 stt =  19.0sttm =  .0
  tm =  75.0 gonl =  82.76
  indata =  1 kindat =  1 vfac =  1.0 ncon =  23 itype =  2

Harmonic Analysis of Data in  tser1
Least Squares H.A.  Beginning  8-19-1990  at Hour 19.00

          First data point of data set   1 is    61.70    292.
          Azimuth used =   121.00  degrees
            9504 data values to be analyzed

          Equally spaced data beginning Month  8 Day 19 Year 1990  Julian Day 231
          Number of Julian Days  to  beginning of series    230
          Number of Julian Days from beginning of series      0
          Start time of data set  1 from beginning of series is       .00  hours
          Average of data set    4.6469   1.0016     Data values   9504

 NCONST=  23 NYYYY= 1990 NDELTT=  6 CUTOFF= .10E-05 TZERO= .10E-05 MINTRM=  0 MAXTRM=  0 NCOL= 175 NROW= 175

 Harmonic Analysis considering  23 constituents.
 The time interval between observations is  .17 hours.  Predictors which account for less than  .0000010 of the variance
 of the input data series are dropped.  Harmonic constants are adjusted for the year 1990

 Binary control fields: 0 0 0 0 0 0 0 0 0 0

  azi =  122.0 n =  8784 nsph =  6
  cvar =  .0 umean =  .0 vmean =  .0
  xyer =  1990.0 month =  10 day =  27.0 stt =  19.0sttm =  .0
  tm =  75.0 gonl =  82.76
  indata =  1 kindat =  1 vfac =  1.0 ncon =  23 itype =  2

          First data point of data set   2 is    70.60    125.
          Azimuth used =   122.00  degrees
            8784 data values to be analyzed

          Equally spaced data beginning Month 10 Day 27 Year 1990  Julian Day 300
          Number of Julian Days  to  beginning of series    299
          Number of Julian Days from beginning of series     69
          Start time of data set  2 from beginning of series is   1656.00  hours
          Average of data set    3.2056   -.4167     Data values   8784

  azi =  114.0 n =  8496 nsph =  6
  cvar =  .0 umean =  .0 vmean =  .0
  xyer =  1991.0 month =  1 day =  2.0 stt =  19.0sttm =  .0
  tm =  75.0 gonl =  82.76
  indata =  1 kindat =  1 vfac =  1.0 ncon =  23 itype =  2

          First data point of data set   3 is    12.16    279.
          Azimuth used =   114.00  degrees
            8496 data values to be analyzed

          Equally spaced data beginning Month  1 Day  2 Year 1991  Julian Day   2
          Number of Julian Days  to  beginning of series    366
          Number of Julian Days from beginning of series    136
          Start time of data set  3 from beginning of series is   3264.00  hours
          Average of data set    -.2466   -.3408     Data values   8496

  azi =  123.0 n =  10944 nsph =  6
  cvar =  .0 umean =  .0 vmean =  .0
  xyer =  1991.0 month =  3 day =  12.0 stt =  19.0sttm =  .0
  tm =  75.0 gonl =  82.76
  indata =  1 kindat =  1 vfac =  1.0 ncon =  23 itype =  2

          First data point of data set   4 is    10.41    135.
          Azimuth used =   123.00  degrees
           10944 data values to be analyzed

      DAYB =  232.           DAYM =  372.
      GHBS =     .00           GRMS =   17.00
      Original T.M. =   75.00           Corrected T.M. =   75.00

      DAYB =    1.           DAYM =  183.
      GHBS =    5.00           GRMS =   17.00
      Original T.M. =   75.00           Corrected T.M. =   75.00

          Greenwich ( V(0)+U ) for the beginning of the series 1990
          Node factors are for the middle of the series
```

	2Q(1)	O(1)	K(1)	OO(1)	2N(2)	M(2)	S(2)	2SM(2)	2MK(3)	MK(3)
(V(0)+U)	289.84	70.60	169.12	92.83	101.55	242.31	210.00	177.69	315.51	51.44
Node	1.1056	1.1056	1.0656	1.4007	.9823	.9823	1.0000	.9823	1.0282	1.0467

	M(4)	MS(4)	S(4)	M(6)	S(6)	M(8)	Q(1)	M(1)	J(1)	N(2)
(V(0)+U)	124.63	92.31	60.01	6.94	270.00	249.26	.22	102.63	242.09	171.94
Node	.9648	.9823	1.0000	.9477	1.0000	.9309	1.1056	1.0384	1.1012	.9823

	L(2)	M(3)	MN(4)
(V(0)+U)	120.41	3.47	54.25
Node	1.3027	.9735	.9648

Equally spaced data beginning Month 3 Day 12 Year 1991 Julian Day 71
Number of Julian Days to beginning of series 435
Number of Julian Days from beginning of series 205
Start time of data set 4 from beginning of series is 4920.00 hours
Average of data set 1.1023 -.5977 Data values 10944

Data Block No. 1
From TRGSA: Gap in data between 9503.00000 and 9936.00000
Data Block No. 2
From TRGSA: Gap in data between 18719.00000 and 19584.00000
Data Block No. 3
From TRGSA: Gap in data between 28079.00000 and 29520.00000
Data Block No. 4
Data Block No. 1
From TRGSA: Gap in data between 9503.00000 and 9936.00000
Data Block No. 2
From TRGSA: Gap in data between 18719.00000 and 19584.00000
Data Block No. 3
From TRGSA: Gap in data between 28079.00000 and 29520.00000
Data Block No. 4
THE 23TH CONSTITUENT ACCOUNTS FOR ONLY .0000008 OF THE VARIANCE. CALCULATIONS FOR 22 CONSTITUENTS ARE GIVEN BELOW.
RESULTS OBTAINED LATER IN THE PROGRAM ARE OF DOUBTFUL VALUE.

(Major Axis)
Analysis based on 37728 observation points as indicated below

```
 9504 observations at intervals of  .17 hours   Year= 1990 Month=  8 Day= 19 Hour=19 Min=  0
 8784 observations at intervals of  .17 hours   Year= 1990 Month= 10 Day= 27 Hour=19 Min=  0
 8496 observations at intervals of  .17 hours   Year= 1991 Month=  1 Day=  2 Hour=19 Min=  0
10944 observations at intervals of  .17 hours   Year= 1991 Month=  3 Day= 12 Hour=19 Min=  0
```

(Major Axis)
Harmonic Analysis of Data in tser1
Least Squares H.A. Beginning 8-19-1990 at Hour 19.00 along 120 degrees

Observed Mean = 2.181 units Observed Variance = 2923.919 sq units Observed Standard Deviation = 54.073 units
Constant in regression = 2.181 units Residual Variance = 258.624 sq units Residual Standard Deviation = 16.082 units

Constituent		---- Adjusted for a standard year ----				*	Constituent	R**2 this	R**2 thru	Selec-	*	Unadjusted values	
		(H)	(K)	(K'- K)	(K')	*	Speed	constituent	this level	tion	*	(R)	(Z)
Num.	Label	(units)	(degrees)	(degrees)	(degrees)	*	(deg./hr.)	only (1)	screening(2)	Number	*	(units)	(degrees)
6	M(2)	53.9078	317.40	20.60	338.00	*	28.9841042	.484898	.484898	1	*	52.9518	95.69
3	K(1)	30.7849	239.46	7.55	247.02	*	15.0410686	.169686	.654584	2	*	32.8053	77.90
2	O(1)	27.1819	234.68	13.04	247.73	*	13.9430356	.153572	.808481	3	*	30.0523	177.12
7	S(2)	20.8767	324.34	15.52	339.86	*	30.0000000	.074957	.883449	4	*	20.8767	129.86
20	N(2)	9.5106	312.50	23.32	335.82	*	28.4397295	.015330	.898788	5	*	9.3419	163.88
17	Q(1)	5.1000	231.17	15.77	246.93	*	13.3986609	.005522	.904313	6	*	5.6385	246.71
21	L(2)	2.5924	325.66	17.88	343.53	*	29.5284789	.001928	.906251	7	*	3.3772	223.12
11	M(4)	2.7413	334.15	41.20	15.35	*	57.9682084	.001211	.907462	8	*	2.6450	250.72
10	MK(3)	2.2409	229.16	28.15	257.32	*	44.0251729	.000870	.908332	9	*	2.3456	205.88
9	2MK(3)	2.2464	238.18	33.64	271.82	*	42.9271398	.000896	.909229	10	*	2.3097	316.31
4	OO(1)	1.3936	280.20	2.06	282.26	*	16.1391017	.000612	.909843	11	*	1.9520	189.44
8	2SM(2)	1.8259	244.67	10.44	255.11	*	31.0158958	.000550	.910393	12	*	1.7935	77.42
19	J(1)	1.1079	251.77	4.83	256.60	*	15.5854433	.000262	.910655	13	*	1.2201	14.51
13	S(4)	1.1523	252.58	31.04	283.62	*	60.0000000	.000226	.910881	14	*	1.1523	223.61
12	MS(4)	1.0500	314.76	36.12	350.88	*	58.9841042	.000179	.911060	15	*	1.0313	258.57
5	2N(2)	.9435	234.34	26.04	260.39	*	27.8953548	.000145	.911206	16	*	.9268	158.84
18	M(1)	.7950	94.82	10.28	105.09	*	14.4966939	.000116	.911323	17	*	.8256	2.46
22	M(3)	.7122	89.50	30.90	120.40	*	43.4761563	.000082	.911404	18	*	.6933	116.92
23	MN(4)	.6169	342.75	43.92	26.67	*	57.4238337	.000061	.911465	19	*	.5952	332.42
1	2Q(1)	.5328	202.90	18.49	221.39	*	12.8542862	.000059	.911524	20	*	.5890	291.56
15	S(6)	.3049	181.90	46.56	228.46	*	90.0000000	.000016	.911540	21	*	.3049	318.46
16	M(8)	.2432	223.17	82.40	305.57	*	115.9364169	.000009	.911549	22	*	.2264	56.31

(1) R1 is the square of the multiple correlation coefficient between the tide and this constituent.
(2) RT is the square of the multiple correlation coefficient between the tide and all constituents thus far selected.
Each number is printed with at least one digit which is believed to be insignificant.

```
1111   1539083380208773399 95113358307852470 2741 154271822477    0    0 Major
1111   2 22412573 11522836  617 267    0    0  3052285    0    0  9442604 Major
1111   3 13942823    0    0    0    0  7951051 11082566    0    0    0    0 Major
1111   4    0    0    0    0    0    0    0    0 51002469    0    0    0    0 Major
1111   5  5332214    0    0 18262551  7121204 25923435 22462718    0    0 Major
1111   6  2433056 10503509    0    0    0    0    0    0    0    0    0    0 Major
1111   7    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111   8    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111   9    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  10    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  11    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  12    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  13    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  14    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  15    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  16    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  17    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  18    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  19    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  20    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  21    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  22    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  23    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  24    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
1111  25    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Major
```

THE FOLLOWING VARIABLES WERE REJECTED TO AVOID INSTABILITY

(Minor Axis)
Analysis based on 37728 observation points as indicated below

```
 9504 observations at intervals of  .17 hours   Year= 1990 Month=  8 Day= 19 Hour=19 Min=  0
 8784 observations at intervals of  .17 hours   Year= 1990 Month= 10 Day= 27 Hour=19 Min=  0
 8496 observations at intervals of  .17 hours   Year= 1991 Month=  1 Day=  2 Hour=19 Min=  0
10944 observations at intervals of  .17 hours   Year= 1991 Month=  3 Day= 12 Hour=19 Min=  0
```

(Minor Axis)
Harmonic Analysis of Data in tser1
Least Squares H.A. Beginning 8-19-1990 at Hour 19.00 along 210 degrees

Observed Mean = -.095 units Observed Variance = 39.824 sq units Observed Standard Deviation = 6.311 units
Constant in regression = -.095 units Residual Variance = 32.701 sq units Residual Standard Deviation = 5.718 units

Constituent		---- Adjusted for a standard year ----				*	Constituent	R**2 this	R**2 thru	Selec-	*	Unadjusted values	
Num.	Label	(H) (units)	(K) (degrees)	(K'- K) (degrees)	(K') (degrees)	*	Speed (deg./hr.)	constituent only (1)	this level screening(2)	tion Number	*	(R) (units)	(Z) (degrees)
6	M(2)	2.5618	245.78	20.60	266.38	*	28.9841042	.080571	.080571	1	*	2.5164	24.07
3	K(1)	1.6151	117.39	7.55	124.94	*	15.0410686	.034547	.115118	2	*	1.7211	315.82
2	O(1)	1.2245	112.41	13.04	125.46	*	13.9430356	.023457	.138623	3	*	1.3538	54.85
7	S(2)	1.1671	246.78	15.52	262.30	*	30.0000000	.017196	.155822	4	*	1.1671	52.30
9	2MK(3)	.5543	93.32	33.64	126.97	*	42.9271398	.003883	.159705	5	*	.5699	171.46
10	MK(3)	.5258	48.57	28.15	76.72	*	44.0251729	.003842	.163555	6	*	.5504	25.29
14	M(6)	.5664	272.39	61.80	334.19	*	86.9523127	.003597	.167152	7	*	.5368	327.25
22	M(3)	.3876	56.43	30.90	87.33	*	43.4761563	.001790	.168945	8	*	.3773	83.85
18	M(1)	.3665	210.18	10.28	220.45	*	14.4966939	.001655	.170602	9	*	.3806	117.82
19	J(1)	.3182	185.30	4.83	190.13	*	15.5854433	.001592	.172198	10	*	.3504	308.04
1	2Q(1)	.2557	308.42	18.49	326.91	*	12.8542862	.000971	.173171	11	*	.2827	37.07
23	MN(4)	.2863	255.37	43.92	299.29	*	57.4238337	.000962	.174133	12	*	.2762	245.04
20	N(2)	.2721	218.18	23.32	241.50	*	28.4397295	.000943	.175076	13	*	.2673	69.57
17	Q(1)	.2415	137.33	15.77	153.10	*	13.3986609	.000886	.175965	14	*	.2670	152.88
21	L(2)	.1843	218.74	17.88	236.61	*	29.5284789	.000709	.176678	15	*	.2400	116.20
12	MS(4)	.2283	204.59	36.12	240.71	*	58.9841042	.000633	.177311	16	*	.2242	148.40
15	S(6)	.1900	101.42	46.56	147.98	*	90.0000000	.000453	.177764	17	*	.1900	237.98
4	OO(1)	.1164	91.26	2.06	93.33	*	16.1391017	.000330	.178095	18	*	.1631	.50
16	M(8)	.1477	109.21	82.40	191.61	*	115.9364169	.000237	.178333	19	*	.1375	302.35
11	M(4)	.1257	300.27	41.20	341.47	*	57.9682084	.000183	.178516	20	*	.1212	216.84
5	2N(2)	.1160	17.15	26.04	43.19	*	27.8953548	.000161	.178677	21	*	.1140	301.64
13	S(4)	.0915	248.33	31.04	279.37	*	60.0000000	.000105	.178782	22	*	.0915	219.36
8	2SM(2)	.0793	120.62	10.44	131.06	*	31.0158958	.000076	.178858	23	*	.0778	313.37

(1) R1 is the square of the multiple correlation coefficient between the tide and this constituent.
(2) RT is the square of the multiple correlation coefficient between the tide and all constituents thus far selected.
Each number is printed with at least one digit which is believed to be insignificant.

```
2222   1 25622664 11672623  2722415 16151249  1263415 12251255  5663342 Minor
2222   2  526 767   912794  2862993    0    0  1901480    0    0  116 432 Minor
2222   3  116 933    0    0    0    0  3662205  3181901    0    0    0    0 Minor
2222   4    0    0    0    0    0    0    0    0  2411531    0    0    0    0 Minor
2222   5  2563269    0    0   791311  388 873  1842366  5541270    0    0 Minor
2222   6  1481916  2282407    0    0    0    0    0    0    0    0    0    0 Minor
2222   7    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222   8    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222   9    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  10    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  11    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  12    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  13    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  14    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  15    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  16    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  17    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  18    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  19    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  20    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  21    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  22    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  23    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  24    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
2222  25    0    0    0    0    0    0    0    0    0    0    0    0    0    0 Minor
```

THE FOLLOWING VARIABLES WERE REJECTED TO AVOID INSTABILITY

3. HARM29 AND HARM15: THE FOURIER HARMONIC ANALYSIS PROGRAMS

3.1. Introduction

The Fourier harmonic analysis method, described in Dennis and Long (1971), uses Fourier series summations to obtain the tidal constituents of water level or current data. This method has been programmed for data periods of either 15 or 29 days of continuous, evenly-spaced data. None of the long-term constituents (Mf, MSf, Mm, Sa, and Ssa) are solved for. Also none of the compound tidal constituents (MK_3, $2MK_3$, etc.), which can be important in shallow water areas, are solved for.

The program for 29 days of data (**harm29**) will solve for ten tidal constituents: M_2, S_2, N_2, O_1, K_1, and the overtides M_4, M_6, M_8, S_4, and S_6. Once preliminary values for the amplitude and phase of these ten constituents are obtained, fourteen other constituents are inferred using astronomically-determined amplitude ratios and phase shifts. (An option exists for using the constituents of a chosen reference station to derive the amplitude ratios and phase shifts.) The inferred constituents are: $2Q_1$, Q_1, k_1, M_1, P_1, J_1, OO_1, $2N_2$, $<_2$, 8_2, L_2, T_2, R_2, and K_2. Then, the elimination of perturbations between closely-spaced constituents is carried out. The program for 15 days of data (**harm15**) is similar to **harm29** except that the constituent N_2 cannot be resolved from M_2 without 29 days of data. Therefore, only nine constituents are determined directly and N_2 is inferred from M_2.

The program expects continuous, equally-spaced data in the input file with at least 29 days for **harm29** and at least 15 days for **harm15**. Multiple solutions can be obtained for different segments of a longer data set. The starting times for the segments and the number of points to skip to get to the start of the segments are read in from the control file not from the data input file. The program can read in 60000 data points which is equivalent to 208.3 days of 5-minute data. The harmonic analysis can be performed on either vector or scalar data and can be read in from a CDF format file or an ASCII file.

Harm29 is run in a Unix environment using

harm29 < harm.ctl > harmout

where *harm.ctl* is the control file and *harmout* is the output file. A file named *cons.out* is also created with the constituents in standard predictions format. **Harm15** is run the same way. The output file has lines up to 132 characters long. The Unix command **lp -oc** can be used to print text in small letters.

3.2. Explanation of the Control File

The following control file is used with either **harm29** or **harm15.** The program uses free format to read in the numbers.

```
FILEIN
NJ     IAND   NSPH   IREF   IIT
AZI    TM     GONL   CVAR   IEL
AQ
XYER   MONTH  DAY    STT    STTM   ISKIP9
XYER   MONTH  DAY    STT    STTM   ISKIP9
XYER   MONTH  DAY    STT    STTM   ISKIP9
XYER   MONTH  DAY    STT    STTM   ISKIP9
XYER   MONTH  DAY    STT    STTM   ISKIP9
              etc.
```

Line #1

FILEIN is the name of the input data file which can be up to 40 characters long.

Line #2

NJ is the number of harmonic analyses to perform on the data in FILEIN.

IAND indicates whether FILEIN is an ASCII file (IAND=0) or a CDF format file (IAND=1).

NSPH is the number of samples per hour.

IREF indicates whether to use the astronomically-determined amplitude ratios and phase shifts to infer the minor constituents (IREF=0) or to read in the constituents of a reference station to use in calculating the amplitude ratios and phase shifts (IREF=1). This option is not available for **harm15**.

IIT is the number of iterations to carry out to eliminate the perturbations between nearby constituents. In general, multiple iterations do not significantly change the results so one iteration should be enough. This option is not available for **harm15**.

Line #3

AZI is the azimuth of the major axis (in the flood direction) for vector data. The major axis will be analyzed first followed by the minor axis. This parameter is irrelevant for scalar data, but must be given.

TM is the time meridian (i.e. the time zone for the STT values to follow). Enter 0. for Greenwich time, 75. for Eastern Standard Time, 90. for Central Standard Time, or 120. for Pacific Standard Time. If TM is the local time zone, the constituent epochs will be the modified local epochs (6'). If TM is Greenwich time, the constituent epochs will be Greenwich epochs (G).

GONL is the longitude of the station in decimal degrees (positive for west longitude).

CVAR is the direction of magnetic north if it <u>hasn't</u> been corrected for in the data. Otherwise, it should be set to zero.

IEL indicates the type of data to be read in from FILEIN.
If FILEIN is an ASCII file (IAND=0),
IEL=-1 is for vector data in 24f3.2/24f3.0 format (hourly speeds followed by hourly directions), or
IEL=0 is for vector data in FORTRAN format AQ, or
IEL=1 is for scalar data in FORTRAN format AQ.
If FILEIN is a CDF format file (IAND=1),
IEL=0 is for vector data (speed and direction in fields 9 and 8), or
IEL is the field for scalar data (e.g. 3 for temperature, 4 for conductivity, 6 for pressure).

Line #4

AQ is the FORTRAN format for reading in an ASCII data input file. Not used for CDF format data input files, but a blank line must be entered anyway.

Line #5

XYER is the year for the first data point of the analysis period.

MONTH is the month for the first data point of the analysis period.

DAY is the day for the first data point of the analysis period.

STT is the hour for the first data point of the analysis period. (The time zone is indicated by TM.)

STTM is the minute for the first data point of the analysis period. The time used should be for the middle of the first sampling interval.

ISKIP9 is the number of points to skip from the beginning of FILEIN to reach the first data point of the analysis period.

The line beginning with XYER must be repeated NJ times (once for each 15 or 29 day analysis period requested).

3.3. Sample Control Files and Output Files

This sample control file is for vector data in an ASCII file.

```
02dspl                                  ! Input data filename
    1    0    6    0    0               ! nj iand nsph iref iit
 121.    75.    82.75139    0.    0     ! azi tm gonl cvar iel
(11x,2f8.3)                             ! FORTRAN format for reading in data
1990.    8   19   19    4.998  149      ! xyer month day stt sttm iskip9
```

To use the option (IREF=1) of deriving the amplitude ratios and phase shifts for inferring minor constituents from a reference station instead of astronomically, reference station constituents in standard predictions format must be inserted after the second line of the control file. This option is only available for **harm29**. A sample control file for multiple harmonic analyses of ASCII scalar data is shown here. The third through eighth lines are the tidal constituents of the reference station in standard predictions format. Twelve harmonical analyses of hourly data in *sp92.wat* will be carried out, one for the first 29 days of each month in 1992.

```
sp92.wat                                ! Input data filename
   12    0    1    1    1               ! nj iand nsph iref iit
       1  533 537  170 663   98 523  5313351   113200  4813291    61438
       2   132858    3 394    32829   27 426    1 243   302452   143584
       3   143464   10 891   52 677    91998   21   9     0   0   79 638
       4  2741479    0   0    0   0   263123   893222    5 627    9 236
       5   173052  1513373   103266    61942   22 842   112682   74 610
       6    31004    73278
 121.  75.   82.62    0.    1               ! azi tm gonl cvar iel
(10x,f10.5)                             ! FORTRAN format for reading in data
1992.    1   1.    0    0      0        ! xyer month day stt sttm iskip9
1992.    2   1.    0    0    744
1992.    3   1.    0    0   1440
1992.    4   1.    0    0   2184
1992.    5   1.    0    0   2904
1992.    6   1.    0    0   3648
1992.    7   1.    0    0   4368
1992.    8   1.    0    0   5112
1992.    9   1.    0    0   5856
1992.   10   1.    0    0   6576
1992.   11   1.    0    0   7320
1992.   12   1.    0    0   8040
```

The output file *cons.out* contains the tidal constituents in standard predictions format, which consists of a two line header, a line containing a mean value, and six lines containing the amplitudes and phases of 37 tidal constituents. For the analysis of vector data, constituents are given first along the major axis (AZI) followed by the minor axis (AZI + 90<). For the analysis of scalar data, only one set of constituents would be given. For multiple analyses, NJ or 2*NJ sets of constituents are printed depending on whether the data are scalar or vector. The program **avcons** can be used to average the multiple solutions for vector or scalar data. The program **convert** can then put the result into a useful form (a standard predictions formatted file and an ellipse table file with amplitudes in knots and local epochs 6).

```
Harmonic Analysis of Data in  02dspl
29-Day H.A.  Beginning  8-19-1990  at Hour 19.08  along 121 degrees
  3513
       158724335622115343112253324929832257 4 22933563277932453 11461920
       2    0   0 15243055    0   0 23773263  8812613    0   0 16303142
       3 11952695  4113391    0   0 19732514 21962634    0   0    0   0
       4    0   0    0   0    0   0 10562402 53922394 13053428  1773434
       5  7232334 98752565    0   0    0   0 17523194    0   0 60153437
       6  602  15    0   0
Harmonic Analysis of Data in  02dspl
29-Day H.A.  Beginning  8-19-1990  at Hour 19.08  along 211 degrees
  1921
       1 46312432 12802625 25572370 17721011  8993346 1813 836  9263248
       2    0   0  5323599    0   0  4962378  587 439    0   0  3402308
       3   781186   322521    0   0  129 923  1431098    0   0    0   0
       4    0   0    0   0    0   0   69 760  352 749   762617   102633
       5   47 662  586 998    0   0    0   0  3662315    0   0  3482641
       6  5851381    0   0
```

Sample Output File

```
       ********** 29 DAY HARMONIC ANALYSIS**********

   NJ IAND NSPH IREF  IIT
    1    0    6    0    0
   AZI   TM    GONL   CVAR  IEL
  121.00 75.00 82.75   .00   .00

 GONL =  82.75139 degrees west

Harmonic Analysis of Data in  02dspl
29-Day H.A.  Beginning  8-19-1990  at Hour 19.08

 Will skip  149 data points as requested
                          Begin at    Year  Mo Day Time
                                      1990.  8 19. 19.08

 First data point read in 208.96 243.
 Last data point read in   17.04 113.

 Data point No.  150 is   63.73 287.

 Data point No. 4325 is   45.93 279.

 Azimuth used =121.0

 Sum of series       14670.575
 Divisor                  4176
 Mean of series        3.51307

 Data demeaned before performing H. A.


 ***  Astronomical  Data  ***
    277.0256   334.3837    280.1895    281.2209    259.1560     1900.    .0    .5

     DAYB =  232.     DAYM =  246.
     GRBS =    .08     GRMS =  12.08

   135.334    62.192   148.077   282.779    63.807   305.454      .000      .000    26.749    -9.341
    -8.465    -6.598   -13.783    72.273   172.988   147.095      .000      .000      .000      .000
      .000      .000      .000      .000      .000      .000      .000      .000      .000      .000

              R          Q              U OF M(2)
            8.763       56.220             1.7506

      SMAC      PROD      ACCP    RESAM
     -2.23028   1.25938 -10.30771    .76107
     -4.3630    2.9589     .2449     .9753  -11.0819    -.2569


Harmonic Analysis of Data in  02dspl
29-Day H.A.  Beginning  8-19-1990  at Hour 19.08  along 121 degrees

                          M(2)       N(2)        S(2)        O(1)        K(1)
         Zeta(Prime)     91.761     142.708     135.010     171.155     100.818
          R(Prime)      57.609     11.779      27.169      30.856      23.788

                          M(4)       M(6)        M(8)        S(4)        S(6)
         Zeta(Prime)     226.634    177.565     102.198     240.515     343.755
          R(Prime)       2.196      1.074        .552       1.524        .881

                           1/F(K2)      RA        QA      H~O(1)
                            1.1894    .77437    .93615   27.5151

                    Equilibrium (V + U) and Elimination (F) Arguments

                          M(2)       N(2)        S(2)        O(1)        K(1)
            (V + U)      224.232    151.089     196.996      58.316     163.173
             F(A)       1.02187    1.02187     1.00000      .89174      .93014

                          K(2)       L(2)        (2N)        R(2)        T(2)
            (V + U)      146.933    108.611      77.947     242.294     331.699
             F(A)        .84079     .79130     1.02187     1.00000     1.00000

                         LAMBDA      MU(2)       NU(2)       J(1)        M(1)
            (V + U)      305.604    249.717     322.859     239.058      78.336
             F(A)       1.02187    1.02187     1.02187      .89741      .83480

                          OO(1)      P(1)        Q(1)        (2Q)       RHO(1)
            (V + U)       93.516     40.421     345.174     272.031     156.944
             F(A)        .67926    1.00000      .89174      .89174      .89174

                          M(4)       M(6)        M(8)        S(4)        S(6)
            (V + U)       88.464    312.695     176.927      33.992     230.989
             F(A)       1.04421    1.06705     1.09038     1.00000     1.00000

                                       Analysis and Inference

                          M(2)       N(2)        S(2)        O(1)        K(1)
               Kappa     315.992    293.797     329.776     229.471     253.683
               Zeta        91.8      142.7       132.8       171.2        90.5
               R(A)      57.6095    11.7795     21.5733     30.8556     31.2567
```

	K(2)	L(2)	(2N)	R(2)	T(2)
Kappa	330.892	338.188	271.602	330.327	329.225
Zeta	184.0	229.6	193.7	88.0	357.5
R(A)	6.9790	2.1753	1.5667	.1726	1.2728

	LAMBDA	MU(2)	NU(2)	J(1)	M(1)
Kappa	322.388	302.209	296.771	265.692	241.577
Zeta	16.8	52.5	333.9	26.6	163.2
R(A)	.4033	1.3826	2.2852	2.4222	2.3402

	OO(1)	P(1)	Q(1)	(2Q)	RHO(1)
Kappa	277.894	251.867	217.462	205.453	219.084
Zeta	184.4	211.4	232.3	293.4	62.1
R(A)	1.7418	9.6232	5.9860	.8022	1.1725

Elimination of Component Effects

	R(A)	Zeta	Kappa	H(A)
M(2)	57.46759	90.74	314.97	58.72424
N(2)	11.99106	150.46	301.55	12.25327
S(2)	22.11546	130.60	327.60	22.11546
O(1)	31.16687	173.99	232.31	27.79270
K(1)	32.07312	86.69	249.86	29.83246

Harmonic Constants (H) and Kappa

	J(1)	K(1)	K(2)	L(2)	M(1)
Kappa	258.56	249.86	328.62	301.55	241.08
H(A)	2.1956	29.8325	6.0154	1.7522	1.9733

	M(2)	M(4)	M(6)	M(8)	N(2)
Kappa	314.97	315.10	130.26	279.13	301.55
H(A)	58.7242	2.2927	1.1462	.6019	12.2533

	(2N)	O(1)	(OO)	P(1)	Q(1)
Kappa	288.13	232.31	267.41	248.54	223.60
H(A)	1.6297	27.7927	1.1951	9.8745	5.3918

	(2Q)	R(2)	S(2)	S(4)	S(6)
Kappa	214.90	328.10	327.60	274.51	214.74
H(A)	.7226	.1769	22.1155	1.5244	.8814

	T(2)	LAMBDA	NU(2)	RHO(1)
Kappa	327.09	320.83	303.35	224.78
H(A)	1.3048	.4111	2.3771	1.0561

Major Axis (121.)

Kappa Primes are for Time Meridian 75.

Harmonic Constants (H) and Kappa Prime

	J(1)	K(1)	K(2)	L(2)	M(1)
Kappa Prime	263.39	257.40	343.71	319.41	251.35
H(A)	2.1956	29.8325	6.0154	1.7522	1.9733

	M(2)	M(4)	M(6)	M(8)	N(2)
Kappa Prime	335.55	356.26	192.01	1.45	324.85
H(A)	58.7242	2.2927	1.1462	.6019	12.2533

	(2N)	O(1)	(OO)	P(1)	Q(1)
Kappa Prime	314.15	245.35	269.46	256.50	239.36
H(A)	1.6297	27.7927	1.1951	9.8745	5.3918

	(2Q)	R(2)	S(2)	S(4)	S(6)
Kappa Prime	233.38	343.40	343.10	305.51	261.25
H(A)	.7226	.1769	22.1155	1.5244	.8814

	T(2)	LAMBDA	NU(2)	RHO(1)
Kappa Prime	342.80	339.05	326.29	240.17
H(A)	1.3048	.4111	2.3771	1.0561

Sum of series	8023.262
Divisor	4176
Mean of series	1.92128

Data demeaned before performing H. A.

Harmonic Analysis of Data in 02dspl
29-Day H.A. Beginning 8-19-1990 at Hour 19.08 along 211 degrees

	M(2)	N(2)	S(2)	O(1)	K(1)
Zeta(Prime)	.589	61.148	54.999	9.586	305.110
R(Prime)	4.557	2.230	1.570	2.029	1.419

	M(4)	M(6)	M(8)	S(4)	S(6)
Zeta(Prime)	204.995	310.392	238.866	294.943	126.383
R(Prime)	.861	.868	.537	.532	.587

1/F(K2) RA QA H~O(1)

1.1894	.77437	.93615	1.8095

Equilibrium (V + U) and Elimination (F) Arguments

	M(2)	N(2)	S(2)	O(1)	K(1)
(V + U)	224.232	151.089	196.996	58.316	163.173
F(A)	1.02187	1.02187	1.00000	.89174	.93014

	K(2)	L(2)	(2N)	R(2)	T(2)
(V + U)	146.933	108.611	77.947	242.294	331.699
F(A)	.84079	.79130	1.02187	1.00000	1.00000

	LAMBDA	MU(2)	NU(2)	J(1)	M(1)
(V + U)	305.604	249.717	322.859	239.058	78.336
F(A)	1.02187	1.02187	1.02187	.89741	.83480

	OO(1)	P(1)	Q(1)	(2Q)	RHO(1)
(V + U)	93.516	40.421	345.174	272.031	156.944
F(A)	.67926	1.00000	.89174	.89174	.89174

	M(4)	M(6)	M(8)	S(4)	S(6)
(V + U)	88.464	312.695	176.927	33.992	230.989
F(A)	1.04421	1.06705	1.09038	1.00000	1.00000

Analysis and Inference

	M(2)	N(2)	S(2)	O(1)	K(1)
Kappa	224.821	212.237	249.765	67.902	97.975
Zeta	.6	61.1	52.8	9.6	294.8
R(A)	4.5568	2.2299	1.2463	2.0292	1.8648

	K(2)	L(2)	(2N)	R(2)	T(2)
Kappa	251.785	237.405	199.653	250.762	248.767
Zeta	104.9	128.8	121.7	8.5	277.1
R(A)	.4032	.4118	.2966	.0100	.0735

	LAMBDA	MU(2)	NU(2)	J(1)	M(1)
Kappa	236.395	199.878	213.924	112.891	82.938
Zeta	290.8	310.2	251.1	233.8	4.6
R(A)	.0319	.1094	.4326	.1593	.1539

	OO(1)	P(1)	Q(1)	(2Q)	RHO(1)
Kappa	128.048	95.719	52.985	38.069	55.000
Zeta	34.5	55.3	67.8	126.0	258.1
R(A)	.1146	.5741	.3937	.0528	.0771

Elimination of Component Effects

	R(A)	Zeta	Kappa	H(A)
M(2)	4.53215	358.35	222.58	4.63125
N(2)	2.50255	62.58	213.67	2.55727
S(2)	1.28011	49.99	246.99	1.28011
O(1)	2.03272	12.20	70.52	1.81266
K(1)	1.90486	290.36	93.53	1.77179

Harmonic Constants (H) and Kappa

	J(1)	K(1)	K(2)	L(2)	M(1)
Kappa	104.95	93.53	248.97	213.67	82.03
H(A)	.1432	1.7718	.3482	.3657	.1287

	M(2)	M(4)	M(6)	M(8)	N(2)
Kappa	222.58	293.46	263.09	55.79	213.67
H(A)	4.6313	.8987	.9264	.5852	2.5573

	(2N)	O(1)	(OO)	P(1)	Q(1)
Kappa	204.75	70.52	116.55	91.81	59.10
H(A)	.3401	1.8127	.0779	.5865	.3517

	(2Q)	R(2)	S(2)	S(4)	S(6)
Kappa	47.69	247.97	246.99	328.94	357.37
H(A)	.0471	.0102	1.2801	.5324	.5872

	T(2)	LAMBDA	NU(2)	RHO(1)
Kappa	246.01	233.91	214.86	60.64
H(A)	.0755	.0324	.4961	.0689

Minor Axis (211.)

Kappa Primes are for Time Meridian 75.
Mean Current
Speed Dir
4.00 150.

Harmonic Constants (H) and Kappa Prime

	J(1)	K(1)	K(2)	L(2)	M(1)
Kappa Prime	109.77	101.08	264.06	231.53	92.29
H(A)	.1432	1.7718	.3482	.3657	.1287

	M(2)	M(4)	M(6)	M(8)	N(2)
Kappa Prime	243.17	334.62	324.83	138.12	236.97

H(A)	4.6313	.8987	.9264	.5852	2.5573

	(2N)	O(1)	(OO)	P(1)	Q(1)
Kappa Prime	230.78	83.55	118.61	99.76	74.86
H(A)	.3401	1.8127	.0779	.5865	.3517

	(2Q)	R(2)	S(2)	S(4)	S(6)
Kappa Prime	66.17	263.26	262.49	359.94	43.88
H(A)	.0471	.0102	1.2801	.5324	.5872

	T(2)	LAMBDA	NU(2)	RHO(1)
Kappa Prime	261.72	252.13	237.80	76.04
H(A)	.0755	.0324	.4961	.0689

Harmonic Analysis of Data in 02dspl
29-Day H.A. Beginning 8-19-1990 at Hour 19.08

Ellipse Parameters (Right-Handed)

Time Meridian of results = 75.

	-----Major Ellipse Axis-----				-----Minor Ellipse Axis-----						121. Axis		211. Axis	
Constituent	Dir	Ampl	Phase	Hour	Dir	Ampl	Phase	Hour	Rot	Ecc	H(A)	Kappa Prime	H(A)	Kappa Prime
J(1)	297.7	2.199	83.5	5.36	27.7	.064	353.5	22.68	CCW	1.00	2.196	263.4	.143	109.8
K(1)	297.9	29.877	77.5	5.15	27.9	.710	347.5	23.10	CCW	1.00	29.832	257.4	1.772	101.1
K(2)	301.6	6.016	163.7	5.44	31.6	.343	73.7	2.45	CCW	1.00	6.015	343.7	.348	264.1
L(2)	301.5	1.752	139.3	4.72	31.5	.365	49.3	1.67	CCW	.98	1.752	319.4	.366	231.5
M(1)	297.5	1.977	71.4	4.93	27.5	.046	341.4	23.55	CCW	1.00	1.973	251.4	.129	92.3
M(2)	300.8	58.725	155.6	5.37	30.8	4.627	65.6	2.26	CCW	1.00	58.724	335.6	4.631	243.2
M(4)	321.4	2.443	173.6	2.99	51.4	.311	83.6	1.44	CCW	.99	2.293	356.3	.899	334.6
M(6)	84.8	1.358	174.8	2.01	174.8	.574	264.8	3.05	CW	-.91	1.146	192.0	.926	324.8
M(8)	257.1	.780	160.5	1.38	347.1	.310	250.5	2.16	CW	-.92	.602	1.5	.585	138.1
N(2)	301.5	12.254	144.8	5.09	31.5	2.555	54.8	1.93	CCW	.98	12.253	324.9	2.557	237.0
2N(2)	302.4	1.630	133.9	4.80	32.4	.338	43.9	1.57	CCW	.98	1.630	314.2	.340	230.8
O(1)	297.5	27.846	65.4	4.69	27.5	.565	335.4	24.06	CCW	1.00	27.793	245.3	1.813	83.6
OO(1)	297.7	1.197	89.6	5.55	27.7	.038	359.6	22.28	CCW	1.00	1.195	269.5	.078	118.6
P(1)	297.9	9.889	76.6	5.12	27.9	.231	346.6	23.17	CCW	1.00	9.875	256.5	.586	99.8
Q(1)	297.4	5.402	59.4	4.44	27.4	.094	329.4	24.59	CCW	1.00	5.392	239.4	.352	74.9
2Q(1)	297.4	.724	53.4	4.16	27.4	.010	323.4	25.16	CCW	1.00	.723	233.4	.047	66.2
R(2)	301.6	.177	163.4	5.44	31.6	.010	73.4	2.44	CCW	1.00	.177	343.4	.010	263.3
S(2)	301.5	22.116	163.1	5.44	31.5	1.263	73.1	2.44	CCW	1.00	22.115	343.1	1.280	262.5
S(4)	313.4	1.558	128.9	2.15	43.4	.424	218.9	3.65	CW	-.96	1.524	305.5	.532	359.9
S(6)	269.9	1.013	70.8	.79	359.9	.310	160.8	1.79	CW	-.95	.881	261.3	.587	43.9
T(2)	301.5	1.305	162.8	5.43	31.5	.075	72.8	2.43	CCW	1.00	1.305	342.8	.076	261.7
LAMBDA(2	301.2	.411	159.0	5.40	31.2	.032	69.0	2.34	CCW	1.00	.411	339.1	.032	252.1
NU(2)	301.3	2.377	146.2	5.13	31.3	.496	56.2	1.97	CCW	.98	2.377	326.3	.496	237.8
RHO(1)	297.4	1.058	60.2	4.47	27.4	.019	330.2	24.51	CCW	1.00	1.056	240.2	.069	76.0

NOTE --- Minor axis direction is considered as the major axis plus 90 degrees in all cases. If rotation is clockwise, phase will be major axis phase plus 90 degrees. If counter-clockwise, minus 90 degrees.

NOTE --- Direction of major axis is usually flood direction but may be ebb sometimes. If this occurs, to get the results for flood direction, add 180 degrees to all directions and phases, and (0.5 X constituent period) to all hour values.

NOTE --- Ecc = Eccentricity of ellipse (+ if CCW rotation)

Mean Current	
Speed	Dir
4.00	150.

4. PRED: THE TIDAL PREDICTION AND DETIDING PROGRAM

4.1. Introduction

The tidal constituents of a time series are derived using one of the Fourier harmonic analysis programs **harm29** or **harm15**, or the least squares harmonic analysis program **lsqha**. In order to predict tidal water levels or currents for any specified time period, the tidal prediction program **pred** is used (Harris, et al., 1965). **Pred** can also be used to detide a time series in order to obtain the nontidal (residual) water level or current. **Pred** can detide scalar or vector data in CDF or ASCII formats. The program reads in 37 tidal constituents in the standard predictions format from a control file. The program also accesses a file containing astronomical tidal parameters for each year from 1901 to 2025. Predictions can only be made for a chosen year (i.e., the time period cannot continue into the next year). The program is dimensioned for 90000 data points.

The program is run in a Unix environment as

pred < pred.ctl > predout

where *pred.ctl* is the control file and *predout* is the output file. There are two different types of control files depending on whether one is detiding a time series or only making a tidal prediction.
If **pred** is used to detide a time series, a table of statistics is printed at the end of the *predout* file. The table gives the root mean square, the mean, and the standard deviation of the observed, predicted, and residual time series. These statistics give a good idea of the proportions of tidal and nontidal energy in the observed time series. However, these proportions are variable, since the strength of the nontidal signal can depend on the season.

An alternate version of **pred** has been written to use all 175 tidal constituents in Table B to predict and/or detide a time series. It is called **pred175** and is run the same way as **pred** except that the control file has 25 lines of constituents in standard format (7 per line) instead of the 6 lines of constituents found in the *cons.out* files. The 25 lines of constituents can be found in the **lsqha** output file. The program **pred175** accesses a file which contains the astronomical tidal parameters for all 175 constituents for any year from 1901 to 2025.

4.2. Tidal Prediction

For predicting a scalar tidal series, the control file is in the following format:

NSTA IPREDK CONV TCONV IL2
FILEOUT
IEL MO NBDAY TIME MON NEDY TIMEL NOS1 IYEAR XMAJOR
HEADER1
HEADER2
DATUM
1 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
2 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
3 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
4 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
5 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
6 AMP EPOC AMP EPOC

For predicting a vector time series, the last nine lines are repeated for the minor axis.

The following is a description of the parameters in the control file for predicting a time series. The first line consists of the following parameters in free format:

NSTA is the number of jobs to be carried out. For multiple jobs (NSTA > 1), all the lines of the control file except the first line are repeated for each job.

IPREDK is for choosing whether to detide an ASCII data file (IPREDK=0), detide a CDF format data file (IPREDK=1), or to do a tidal prediction (IPREDK=2).

CONV is a multiplicative factor for converting the predicted time series to new units (e.g., CONV=30.48 to convert feet to centimeters or CONV=51.444 to convert knots to cm/s).

TCONV is a time shift in hours to change the time zone of the predictions. The constituent epochs obtained from a harmonic analysis program are usually the modified local epochs (6). (For predictions from constituents in Eastern Standard Time to be shifted to Greenwich time, TCONV=5. For no time shift, TCONV=0.)

IL2 is 0 for using the standard constituent L_2 or is 1 for using $2MN_2$ in place of L_2.

The following line is the name of the output file to contain the predicted time series (FILEOUT).

The next line depends on whether one is detiding (IPREDK is 0 or 1) or predicting (IPREDK is 2) a time series. For predicting a time series, the next line consists of the following parameters in free format:

> IEL is the type of prediction to make. IEL=0 for a vector prediction and IEL=1 for a scalar prediction. For a vector prediction, two sets of tidal constituents are needed.
>
> MO is the beginning month.
>
> NBDAY is the beginning day.
>
> TIME is the beginning time in decimal hours (e.g., 3:30 PM is 15.5).
>
> MON is the ending month.
>
> NEDY is the ending day.
>
> TIMEL is the ending time in decimal hours (e.g., 3:30 PM is 15.5).
>
> NOS1 is the number of samples per hour (greater than or equal to 1).
>
> IYEAR is the year of the predicted time series. The time series cannot continue into a second year.
>
> XMAJOR is the axis of the first set of tidal constituents. The second set of tidal constituents should be along XMAJOR+90/. For scalar predictions, the parameter XMAJOR is not relevant, but must be given.

The final nine (or eighteen) lines consist of the output from a harmonic analysis program (the *cons.out* file). There are two lines containing header information about the station analyzed (HEADER1 and HEADER2). This is followed by a line containing the mean water level or mean current (DATUM). The following six lines are the 37 tidal constituents in standard predictions format. For tidal current constituents, there are nine additional lines containing the headers, mean current, and tidal constituents for the minor axis.

The output in the file named FILEOUT will depend on the parameters IPREDK and IEL. If a scalar time series is predicted (IPREDK = 2 and IEL $ 1), the columns will be

TIME PREDICTED

If a vector time series is predicted (IPREDK = 2 and IEL = 0), the columns will be

	SPEED	DIRECTION	MAJOR	MINOR
TIME	PREDICTED	PREDICTED	PREDICTED	PREDICTED

The following is an example of a control file to predict a scalar time series. The tidal constituents are in feet and the predicted output will be in meters. There will be one sample per hour for the entire year of 1995 in local time.

```
1  2  .3048  0.  0                 ! nsta,ipredk,conv,tconv,il2
stp.prd                            ! Output time series file
1 1 1 0. 12 31 24. 1 1995 0.       ! iel,mo,nbday,time,mon,nedy,timel,nos1,iyear,xmajor
Tampa Bay Oceanography Project
8726520 St. Petersburg
  4512
       1  533 537  170 663   98 523  5313351   113200  4813291    61438
       2   132858    3 394    32829   27 426    1 243   302452   143584
       3   143464   10 891   52 677    91998   21   9    0   0   79 638
       4  2741479    0   0    0   0   263123   893222    5 627    9 236
       5   173052  1513373   103266    61942   22 842   112682   74 610
       6    31004    73278
```

The following is an example of a control file to predict a vector time series. The major axis of the constituents is 118/ and the entire year of 1992 will be predicted. The output time series will be hourly in local time.

```
1  2  1.  0.  0                    ! nsta,ipredk,conv,tconv,il2
egm.prd                            ! Output time series file
0 1 1 0. 12 31 23. 1 1992 118.     ! iel,mo,nbday,time,mon,nedy,time1,nos1,iyear,xmajor
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
  1801
       1533483360188803418101863288315872515 24703773267002446  1032059
       2    0    0 10292747    0    0 20073299  1031979    0    0 13383214
       3 11322585  3613384    0    0 19042481 21102549
       4    0    0    0    0    0    0 10292417 51452413 11323416  1553420
       5  6692378104442510    0    0    0    0 14413234    0    0 51453423
       6  2583064
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
   206
       1 27782797 11842790  4122606 14411412  5153293 11321244  5153226
       2    0    0  1032595    0    0  1032638  1551662    0    0   522534
       3   521609    12799    0    0  1031308  1031475
       4    0    0    0    0    0    0   521194  1551185   522787    12790
       5    11131  4631401    0    0    0    0   522551    0    0  3092796
       6  1551778
```

4.3. Detiding a Time Series

For detiding a scalar time series, the control file is in the following format:

NSTA IPREDK CONV TCONV IL2
FILEIN
FILEOUT
IEL ISKIP CONVD XMAXD IYEAR XMAJOR
HEADER1
HEADER2
DATUM
1 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
2 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
3 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
4 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
5 AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC AMP EPOC
6 AMP EPOC AMP EPOC

For detiding a vector time series, the last nine lines are repeated for the minor axis.

The following is a description of the parameters in the control file for detiding a time series. The first line consists of the following parameters in free format:

NSTA is the number of jobs to be carried out. For multiple jobs (NSTA > 1), all the lines of the control file except the first line are repeated for each job.

IPREDK is for choosing whether to detide an ASCII data file (IPREDK=0), detide a CDF format data file (IPREDK=1), or to do a tidal prediction (IPREDK=2).

CONV is a multiplicative factor for converting the predicted time series to new units (e.g., CONV=30.48 to convert feet to centimeters or CONV=51.444 to convert knots to cm/s).

TCONV is a time shift in hours to change the time zone of the predictions. The constituent epochs obtained from a harmonic analysis program are usually the modified local epochs (6). (For predictions from constituents in Eastern Standard Time to be shifted to Greenwich time, TCONV=5. For no time shift, TCONV=0.)

IL2 is 0 for using the standard constituent L_2 or is 1 for using $2MN_2$ in place of L_2.

If IPREDK is 0 or 1, the next line is the name of the file with the time series to be detided (FILEIN).

The following line is the name of the output file to contain the observed, predicted, and residual time series (FILEOUT).

The next line depends on whether one is detiding (IPREDK is 0 or 1) or predicting (IPREDK is 2) a time series. For detiding, the next line consists of the following parameters in free format:

> IEL indicates the type of the input data. IEL=0 for vector data or IEL>0 for scalar data. If the input data is scalar data in a CDF file (IPREDK=1), IEL should be the CDF field number of the values to be detided (e.g., IEL=3 for temperature, IEL=4 for conductivity, or IEL=6 for pressure).
>
> ISKIP is the number of data points to skip in the time series to be detided.
>
> CONVD is a multiplicative factor to convert the time series to be detided to new units (e.g., CONVD=30.48 to convert feet to centimeters or CONVD=51.444 to convert knots to cm/s).
>
> XMAXD is the maximum acceptable value in the input time series. For values higher than XMAXD, a 999 is output as the residual.
>
> IYEAR is the year of the input time series. The time series to be detided cannot continue into a second year.
>
> XMAJOR is the axis of the first set of tidal constituents. The second set of tidal constituents should be along XMAJOR+90/. For scalar data, the parameter XMAJOR is not relevant, but must be given.

The final nine (or eighteen) lines consist of the output from a harmonic analysis program (the *cons.out* file). There are two lines containing header information about the station analyzed (HEADER1 and HEADER2). This is followed by a line containing the mean water level or mean current (DATUM). The following six lines are the 37 tidal constituents in standard predictions format. For tidal current constituents, there are nine additional lines containing the headers, mean current, and tidal constituents for the minor axis.

The output in the file named FILEOUT will depend on the parameters IPREDK and IEL. If a scalar time series is detided (IPREDK # 1 and IEL $ 1), the columns will be

TIME OBSERVED PREDICTED RESIDUAL

If a vector time series is detided (IPREDK # 1 and IEL = 0), the columns will be

	MAJOR	MAJOR	MAJOR	MINOR	MINOR	MINOR
TIME	OBSERVED	PREDICTED	RESIDUAL	OBSERVED	PREDICTED	RESIDUAL

The following is an example of a control file to detide a scalar time series in a ASCII file. The constituents are in cm. The output time series will be in local time.

```
1   0    1.   0.   0                 ! nsta, ipredk, conv, tconv, il2
505.wll                              ! Name of file to be detided
505.det                              ! Output time series file
1    0    1.  200.  1995  0.         ! iel, iskip, convd, xmaxd, iyear, xmajor
Harmonic Analysis of Data in    505.wll
Least Squares H.A. Beginning   1- 1-1995  at Hour   .00
 77272
       1 5980 531 1272 446 1312 290115551040  399354611911 965   663256
       2  267 526   491796  2893279  1703329  1081361  2402955  5732653
       3 18141119  204 593  2002046 10651962  491 680 2108326711944 416
       4138301212 18921882  7293592  819 428 2314 660  215 936   401825
       5   982658 32311087  1541741  2182741  531 726  193 404 1234 591
       6   71 827  3473258
```

The following is an example of a control file to detide a vector time series in a CDF format file. The constituents are in cm/s and the major axis is 58/. The output time series will be shifted into Greenwich time.

```
1    1    1.   5.    0               ! nsta, ipredk, conv, tconv, il2
/dir6/cdf/PROJTAMPAB/tr1010/file11   ! Name of file to be detided
sunsky.det                           ! Output time series file
0    0    1.  150.  1990  58.        ! iel, iskip, convd, maxd, iyear, xmajor
Tampa Bay Oceanography Project
C-3   Sunshine Skyway   8/22/90 - 6/11/91
  5300
       148993339417443349 5 87413383272632514 17723242216492485  3231515
       2 32692436  6973085  3503050 22223317  1072916 19511818  7332404
       3  8122630 1044 354 39213171  6643341 10772714  787  73  4961477
       4  3632667  7433408  7831627 13742133 39692468  852  65  7253365
       5  5322311 78282489  9042320  5881348 27023397 29482579 77873471
       6  1632175  8153340
Tampa Bay Oceanography Project
C-3   Sunshine Skyway   8/22/90 - 6/11/91
  1820
       1  696 665  198 917  151 553  5222024  4953220  3392019   852959
       2  5092242   403134  2043338   543210   191338  1813160  158 974
       3  1222485   73 974  3682047   561333   65 126  5293595  5882001
       4  3541336  552 273  1131742   92 182  1231850  255 638  2781856
       5  1053223  2501914   682953   493041   30 807  5302373  1893287
       6   662142  4093365
```

The following is a sample output file:

```
 Minutes between samples is calculated to be   10.000
 Number of samples per hour is        6
 Start time for predictions is   234     8    22    14.91667    90
 Stop time for predictions is    365    12    31    24.00000
 NPTS =     18919

Tampa Bay Oceanography Project
C-3   Sunshine Skyway   8/22/90 - 6/11/91

 Values of the Epochs before   5.00 hour time shift

 Constituent           Kappa
                H(A)   Prime

 M(2)         48.993   339.40
 S(2)         17.443   349.50
 N(2)          8.741   338.30
 K(1)         27.263   251.40
 M(4)          1.772   324.20
 O(1)         21.649   248.50
 M(6)           .323   151.50
 MK(3)         3.269   243.60
 S(4)           .697   308.50
 MN(4)          .350   305.00
 NU(2)         2.222   331.70
 S(6)           .107   291.60
 MU(2)         1.951   181.80
 2N(2)          .733   240.40
 OO(1)          .812   263.00
 LAMBDA(2)     1.044    35.40
 S(1)          3.921   317.10
 M(1)           .664   334.10
 J(1)          1.077   271.40
 MM             .787     7.30
 SSA            .496   147.70
 SA             .363   266.70
 MSF            .743   340.80
 MF             .783   162.70
 RHO(1)        1.374   213.30
 Q(1)          3.969   246.80
 T(2)           .852     6.50
 R(2)           .725   336.50
 2Q(1)          .532   231.10
 P(1)          7.828   248.90
 2SM(2)         .904   232.00
 M(3)           .588   134.80
 L(2)          2.702   339.70
 2MK3(3)       2.948   257.90
 K(2)          7.787   347.10
 M(8)           .163   217.50
 MS(4)          .815   334.00



 Opening year card file 1990   0
       1990         0         1
      .977   259.400     1.000      .000       .977   324.300     1.080    16.600
      .954   158.800     1.128   240.100       .932    58.100     1.055   276.000
       1990         0         2
     1.000      .000      .954   223.700       .977    92.200     1.000      .000
      .977   157.100      .977    29.200     1.505   338.300      .977   246.600
       1990         0         3
     1.000   180.000     1.333    85.400     1.120   314.300      .918   295.100
     1.000   200.800     1.000   280.400      .977   100.600     1.303   319.100
```

```
   1990         0         4
  1.128    72.900     1.128   305.100     1.000     2.400     1.000   177.600
  1.128    10.000     1.000   349.600      .977   100.600      .966    29.100
   1990         0         5
  1.219     2.200     1.030   142.100     1.202   213.900      .911   317.500
   .977   259.400     1.273   130.700      .977   269.800     1.102   212.000
   1990         0         6
  1.128    99.100     1.128   119.900      .954   295.100      .954   223.700
  1.128   229.800     1.174   113.300      .954   288.600     1.164   225.900
   1990         0         7
  1.164   160.900     1.174   314.500     1.379    91.000     1.432   115.500
  1.412   327.200     1.147   211.000     1.379     2.900     1.128   240.100
   1990         0         8
  1.080    16.600     1.102   204.400     1.174   113.300      .977   324.300
  1.164   160.900      .932    58.100     1.191   261.600      .954   288.600
   1990         0         9
  1.219     2.200     1.077   103.800     1.077    38.900     1.030   175.400
  1.055   276.000     1.268   129.900      .954   148.400      .932    68.500
   1990         0        10
  1.030   240.300      .977   259.400      .932   123.100      .954   223.700
   .954   158.800     1.137   190.100      .932   188.000     1.191   261.600
   1990         0        11
  1.164   160.900     1.174   113.300     1.137   125.200     1.137    60.300
  1.147    12.700     1.052     3.200     1.007   204.600     1.077    38.900
   1990         0        12
  1.325   353.400      .932   123.100      .932    58.100      .954   158.800
   .911    87.300      .911    22.400     1.164   160.900     1.111   319.700
   1990         0        13
  1.137    60.300     1.121   272.000     1.147    12.700      .983   104.000
   .983    39.100      .983   334.200     1.007    74.800      .890   281.800
   1990         0        14
   .890   216.900      .911    22.400      .911   317.500     1.137    60.300
   .932    58.100      .983   334.200      .890   281.800      .890   216.900
   1990         0        15
  1.111   319.700      .911   317.500

Total number of prediction times =      18919
Year 1990  Datum  5.300  No. of Constituents   37    checksum   -.0268917

Harmonic Constants (Major Axis) ------


M(2)          48.993   124.32
S(2)          17.443   139.50
N(2)           8.741   120.50
K(1)          27.263   326.61
M(4)           1.772   254.04
O(1)          21.649   318.22
M(6)            .323   226.26
MK(3)          3.269   103.73
S(4)            .697   248.50
MN(4)           .350   232.12
NU(2)          2.222   114.26
S(6)            .107    21.60
MU(2)          1.951   321.64
2N(2)           .733    19.88
OO(1)           .812   343.70
LAMBDA(2)      1.044   182.68
S(1)           3.921    32.10
M(1)            .664    46.58
J(1)           1.077   349.33
MM              .787    10.02
SSA             .496   148.11
SA              .363   266.91
MSF             .743   345.88
MF              .783   168.19
RHO(1)         1.374   280.66
```

Q(1)	3.969	313.79
T(2)	.852	156.29
R(2)	.725	126.71
2Q(1)	.532	295.37
P(1)	7.828	323.69
2SM(2)	.904	27.08
M(3)	.588	352.18
L(2)	2.702	127.34
2MK3(3)	2.948	112.54
K(2)	7.787	137.51
M(8)	.163	77.18
MS(4)	.815	268.92

Tampa Bay Oceanography Project
C-3 Sunshine Skyway 8/22/90 - 6/11/91

Values of the Epochs before 5.00 hour time shift

Constituent	H(A)	Kappa Prime
M(2)	.696	66.50
S(2)	.198	91.70
N(2)	.151	55.30
K(1)	.522	202.40
M(4)	.495	322.00
O(1)	.339	201.90
M(6)	.085	295.90
MK(3)	.509	224.20
S(4)	.040	313.40
MN(4)	.204	333.80
NU(2)	.054	321.00
S(6)	.019	133.80
MU(2)	.181	316.00
2N(2)	.158	97.40
OO(1)	.122	248.50
LAMBDA(2)	.073	97.40
S(1)	.368	204.70
M(1)	.056	133.30
J(1)	.065	12.60
MM	.529	359.50
SSA	.588	200.10
SA	.354	133.60
MSF	.552	27.30
MF	.113	174.20
RHO(1)	.092	18.20
Q(1)	.123	185.00
T(2)	.255	63.80
R(2)	.278	185.60
2Q(1)	.105	322.30
P(1)	.250	191.40
2SM(2)	.068	295.30
M(3)	.049	304.10
L(2)	.030	80.70
2MK3(3)	.530	237.30
K(2)	.189	328.70
M(8)	.066	214.20
MS(4)	.409	336.50

Total number of prediction times = 18919
Year 1990 Datum 1.820 No. of Constituents 37 checksum .0000682

Harmonic Constants (Minor Axis) ------

M(2)	.696	211.42
S(2)	.198	241.70

N(2)	.151	197.50
K(1)	.522	277.61
M(4)	.495	251.84
O(1)	.339	271.62
M(6)	.085	10.66
MK(3)	.509	84.33
S(4)	.040	253.40
MN(4)	.204	260.92
NU(2)	.054	103.56
S(6)	.019	223.80
MU(2)	.181	95.84
2N(2)	.158	236.88
OO(1)	.122	329.20
LAMBDA(2)	.073	244.68
S(1)	.368	279.70
M(1)	.056	205.78
J(1)	.065	90.53
MM	.529	2.22
SSA	.588	200.51
SA	.354	133.81
MSF	.552	32.38
MF	.113	179.69
RHO(1)	.092	85.56
Q(1)	.123	251.99
T(2)	.255	213.59
R(2)	.278	335.81
2Q(1)	.105	26.57
P(1)	.250	266.19
2SM(2)	.068	90.38
M(3)	.049	161.48
L(2)	.030	228.34
2MK3(3)	.530	91.94
K(2)	.189	119.11
M(8)	.066	73.88
MS(4)	.409	271.42

Calculated time of first data point is 90. 234. 14. 55.

Calculated time of last data point is 90. 365. 23. 45.

Number of data points detided = 18918

	Major Axis			Minor Axis		
	Observed	Predicted	Residual	Observed	Predicted	Residual
RMS	48.136	46.071	10.352	3.394	2.097	2.588
Mean	5.523	5.557	-.033	1.863	1.719	.144
S.D.	47.820	45.736	10.352	2.837	1.200	2.584

5. GI AND GIPLOT: THE GREENWICH INTERVAL PROGRAMS

5.1. Introduction

Greenwich intervals are the periods between the moon's transit over the Greenwich meridian and the arrival of each tidal phase at a station. Comparing Greenwich intervals is a standard method of looking at the timing of tidal phases anywhere in the world. The program **gi** will calculate the mean Greenwich intervals for maximum flood currents (MFC), slack before ebb currents (SBE), maximum ebb currents (MEC), and slack before flood currents (SBF). It will also produce the mean current speed and direction for the four current phases. The program does not calculate Greenwich intervals for scalar data such as water levels. The input time series must be continuous since the data is interpolated to a 1-minute time interval using cubic splines. The program can be run individually for several continuous segments. The program is dimensioned for 105410 data points which is equivalent to 366 days of 5-minute data. There are three parts to the program.

The first part of **gi** reads in a time series of current data. A scaling factor and a time shift are requested in order to put the time series into cm/s and GMT. If a predicted tidal series is read in, no filtering is necessary. If the data are observed speeds and directions, the subroutine **filter** can be used to apply a Fourier filter to the data (see GI Examples 1 and 2). The purpose of filtering an observed time series is to remove high frequency noise and low frequency nontidal signals to produce a smooth time series which is mainly tidal. A good filter to use is a 3 to 36 hour band pass filter. High-pass or band-pass filters will remove the mean current (which can be added back in for the subsequent analysis). The u and v components of the mean current are printed along with a 95% confidence interval. If the mean current is significant (i.e. the confidence intervals do not include zero), the mean current should be added back to the time series. A output file (**.flt*) is created containing the filtered time series.

The second part of **gi** (the subroutine **calctcp**) picks the maximum and minimum currents in the time series, adds in the mean current if desired, sorts the maximum currents into flood or ebb currents (MFC or MEC), and labels the minimum currents as slack before flood (SBF), slack before ebb (SBE), slack between two floods (SFC), or slack between two ebbs (SEC). Any maximum flood or ebb current with a speed less than 0.25 knots (12.86 cm/s) is labeled SLC. The output file (**.tcp*) gives the time, speed, and direction of each pick. SFC, SEC, and SLC are not used in any subsequent calculations.

The third part of **gi** (the subroutine **gicalc**) reads in a Greenwich moon transits file (for 1985 to 2010) and subtracts the times in the **.tcp* file from the previous moon transit. Each moon transit is printed in an output file (**.gi*), followed by the tidal phases that occur before the next moon transit. The mean Greenwich intervals, current speeds, and current directions for MFC, SBE, MEC, and SBF are calculated and printed at the end of the **.gi* output file.

If there are several deployments at the same station, a **.tcp* file can be obtained for each deployment. Then, mean Greenwich intervals for the station can be determined by concatenating all the **.tcp* files together (in chronological order) and running **gi** using option 0. The first two parts of **gi** will be skipped and only the third part will be run (see GI Example 3).

5.2. Creating Plots

A second output file (**.plt*) is produced by **gi** with the Greenwich interval, current speed, and current direction of each individual pick in a format that can be used by a plotting program called **giplot**. **Giplot** uses commands from the DISSPLA graphics package. **Giplot** displays the changes to the means and the confidence intervals as each pick is added to the summation. **Giplot** will plot the Greenwich intervals and current velocities as capital letters (F and E) for MFC and MEC and small letters (f and e) for SBF and SBE. The Greenwich intervals can be plotted on a semidiurnal scale (see GIPLOT Example 1) or on a diurnal scale which distinguishes upper (U) and lower (L) moon transits (see GIPLOT Example 2). The current speeds can be plotted along any directional axis although the most meaningful choice would be the principal current direction (see GIPLOT Example 3).

GI Example 1

Interactive execution of the program. Gray shading indicates the input to be typed in by the user.

```
 If you:                                                    Enter
 already have a tidal current parameters file (*.tcp)   (0)
 want to read a CDF data file                           (1)
 want to read an ASCII data file (time,spd,dir)         (2)
1
 Enter the root for all the output filenames
t0218
 Enter 1 to filter input data or 0 not to filter input data
1
 Enter the name of the input data file
/dir6/cdf/PROJTAMPAB/t02010/file18
 Enter number of data points to skip and to read in
149   9500
 Enter number of sample(s) per hour for the input data
6
 Enter scaling factor and time shift (hrs) to put input data into cm/s and GMT
1.   0.
 Enter filtering option      (1) for low-pass filtering
                             (2) for high-pass filtering
                             (3) for band-pass filtering
3
 Enter cut-off periods in hours (shorter period, then longer period)
3   36
                        Mean       95% C.I.        S.D.
 U velocity (eastward)   3.47       2.56   4.37     45.09
 V velocity (northward) -3.25      -3.81  -2.70     27.70
 Filtering has removed the mean current
 Enter 1 to add it back or 0 not to add it back
1
 Enter the flood current direction ==>
118
```

Alternatively, the **gi** program can also be run with the following control file (*gi1.ctl*).

```
1                                      ! Type of analysis (0, 1, or 2)
t0219                                  ! Root for all output filenames
1                                      ! Filter the data ? (0=no, 1=yes)
/dir6/cdf/PROJTAMPAB/t02010/file18     ! Input data filename
149   9500                             ! Number of points to skip and read in
6                                      ! Number of samples per hour for input
1.  0.                                 ! Scaling factor and time shift for data
3                                      ! Filtering option (1=hi, 2=lo, 3=band)
3   36                                 ! Filtering cutoff period(s)
1                                      ! Add back mean currents ? (0=no, 1=yes)
118                                    ! Flood current direction
```

Filtered output file (*t0218.flt*):

```
232.00348   28.919  288.010  -27.502    8.942
```

```
232.01042   37.150  288.620  -35.205   11.862
232.01736   43.760  289.233  -41.318   14.415
232.02431   48.409  289.859  -45.530   16.445
232.03125   50.844  290.500  -47.624   17.806
232.03819   50.917  291.151  -47.487   18.372
232.04515   48.598  291.801  -45.123   18.049
232.05209   43.971  292.433  -40.644   16.779
232.05904   37.230  293.008  -34.268   14.552
232.06598   28.667  293.438  -26.302   11.403
```

Tidal current parameters output file (*t0218.tcp*):

```
 1990  8  20   0  50  MEC    51.18      290.82
 1990  8  20   2   2  SBF      .94      171.99
 1990  8  20   4   7  MFC    81.91      126.13
 1990  8  20   7  28  SBE    10.77       40.63
 1990  8  20  10  29  MEC    46.94      293.62
 1990  8  20  12  50  SBF     4.74      221.08
 1990  8  20  15  43  MFC    99.95      123.30
 1990  8  20  18  50  SBE     6.22       35.54
 1990  8  20  21  59  MEC   116.23      303.12
 1990  8  21   2   7  SBF     6.08      210.76
```

Greenwich intervals output file (*t0218.gi*):

```
 gtime =  231.4645 mtran = U iyear =  1990
 gtime =  231.9826 mtran = L iyear =  1990
MEC     1        13.67     51.18    290.82
SBF     1         2.45       .94    171.99
MFC     1         4.53     81.91    126.13
SBE     1         7.88     10.77     40.63
MEC     2        10.90     46.94    293.62
 gtime =  232.4992 mtran = U iyear =  1990
SBF     2          .85      4.74    221.08
MFC     2         3.73     99.95    123.30

                  etc.

 gtime =  296.6451 mtran = U iyear =  1990
SBF   102         1.27      7.75    201.22
MFC   131         4.58     61.03    125.04
 gtime =  297.1632 mtran = L iyear =  1990
MFC   132         1.25     58.70    113.45
SBE   102         5.43      1.22     24.80
MEC   106         8.10     71.73    295.91
 gtime =  297.6798 mtran = U iyear =  1990
SBF   103         1.77      1.02     38.60
MFC   133         5.08     54.43    110.69
SBE   103         6.62       .24    160.90


      Greenwich       95% Conf        Standard         Mean  Speed        Mean
      Interval        Interval        Deviation      (cm/s)   (knots)   Direction

MFC      4.11       3.86      4.35       1.45          74.38     1.446        123.
SBE      7.04       6.83      7.25       1.07           5.68      .110         30.
```

```
MEC     10.13       9.93    10.32       1.00         69.06    1.342        301.
SBF      1.37       1.19     1.56        .95          3.59     .070        206.
```

Greenwich intervals plotting file (*t0218.plt*):

```
232.916 MECU 10.0 11.5 16.1  6.9 -97.3 -62.7   9.7-135.2  63.5  33.5  96.1
-29.1
233.088 SBFL  1.7  1.7  3.6  -.3  -3.1  -2.0   2.5  -6.5  -5.2  -3.2   2.0
-8.5
233.206 MFCL  4.6  4.3  5.4  3.1  82.2  77.3 100.6  54.0 -59.8 -54.3 -40.4
-68.2
233.333 SBEL  7.6  7.4  8.7  6.2   4.9   5.2   9.3   1.1  12.3   8.5  17.3
-.3
233.453 MECL 10.5 11.3 13.9  8.7 -45.7 -58.5 -17.4 -99.5  26.9  31.9  65.8
-2.1
233.542 SBFU   .3  1.3  2.9  -.2  -2.8  -2.2    .3  -4.7  -3.6  -3.3   -.5
-6.2
233.673 MFCU  3.4  4.1  5.0  3.1  90.5  80.6  96.9  64.4 -59.6 -55.6 -47.1
-64.2
233.817 SBEU  6.8  7.3  8.1  6.5   6.9   5.6   8.2   3.0   9.9   8.9  13.7
4.0
233.944 MECU  9.9 11.0 12.9  9.1 -82.0 -63.2 -32.4 -94.0  52.4  36.0  61.7
10.3
234.112 SBFL  1.5  1.4  2.4   .3   -.8  -1.9   -.1  -3.8  -3.1  -3.3  -1.4
-5.2
```

GI Example 2

ASCII input data file (*c2.sd*):

```
  232.00002  61.699 291.669
  232.00697  63.734 286.594
  232.01392  58.706 281.763
  232.02086  53.519 281.877
  232.02780  49.371 284.210
  232.03474  47.539 282.534
  232.04169  40.620 281.848
  232.04865  34.065 280.665
  232.05559  24.223 284.680
  232.06253  15.575 289.734
```

Interactive execution of the program. Gray shading indicates the input to be typed in by the user.

```
 If you:                                               Enter
 already have a tidal current parameters file (*.tcp)  (0)
 want to read a CDF data file                          (1)
 want to read an ASCII data file (time,spd,dir)        (2)
2
 Enter the root for all the output filenames
c0218
 Enter 1 to filter input data or 0 not to filter input data
1
 Enter the name of the input data file
c2.sd
 Enter year of first data point (e.g. 1990)
```

```
1990
 Enter number of sample(s) per hour for the input data
6
 Enter scaling factor and time shift (hrs) to put input data into cm/s and GMT
1.   0.
 Enter filtering option      (1) for low-pass filtering
                             (2) for high-pass filtering
                             (3) for band-pass filtering
3
 Enter cut-off periods in hours (shorter period, then longer period)
3   36
                         Mean        95% C.I.        S.D.
 U velocity (eastward)    3.46      2.55   4.36     45.09
 V velocity (northward) -3.25     -3.81  -2.69     27.70
 Filtering has removed the mean current
 Enter 1 to add it back or 0 not to add it back
1
 Enter the flood current direction ==>
118
```

Alternatively, the **gi** program can also be run with the following control file (*gi2.ctl*).

```
2                                      ! Type of analysis (0, 1, or 2)
c0219                                  ! Root for all output filenames
1                                      ! Filter the data ? (0=no, 1=yes)
c2.sd                                  ! Input data filename
1990                                   ! Year of first data point
6                                      ! Number of samples per hour for input
1.  0.                                 ! Scaling factor and time shift for data
3                                      ! Filtering option (1=hi, 2=lo, 3=band)
3   36                                 ! Filtering cutoff period(s)
1                                      ! Add back mean currents ? (0=no, 1=yes)
118                                    ! Flood current direction
```

Filtered output file (*c0218.flt*):

```
232.00002   28.491  288.560  -27.009    9.069
232.00697   37.753  288.751  -35.749   12.136
232.01392   45.457  289.087  -42.958   14.865
232.02086   51.226  289.516  -48.283   17.113
232.02780   54.773  290.012  -51.466   18.744
232.03474   55.916  290.561  -52.354   19.638
232.04169   54.591  291.152  -50.913   19.699
232.04865   50.851  291.773  -47.224   18.862
232.05559   44.865  292.407  -41.478   17.102
232.06253   36.902  293.024  -33.963   14.433
```

Tidal current parameters output file (*c0218.tcp*):

```
 1990  8  20   0  50  MEC    55.92      290.56
 1990  8  20   2   4  SBF      .53      229.11
 1990  8  20   4  17  MFC    81.73      126.20
 1990  8  20   7  33  SBE    10.85       41.75
 1990  8  20  10  31  MEC    46.84      293.69
 1990  8  20  12  55  SBF     4.70      219.95
 1990  8  20  15  47  MFC   100.06      123.28
 1990  8  20  18  55  SBE     6.21       35.36
 1990  8  20  22   5  MEC   116.37      303.11
```

```
 1990  8  21   2  13  SBF     6.10     205.76
```

Greenwich intervals output file (*c0218.gi*):

```
 gtime =  231.4645 mtran = U iyear =  1990
 gtime =  231.9826 mtran = L iyear =  1990
MEC     1        13.67     55.92    290.56
SBF     1         2.48       .53    229.11
MFC     1         4.70     81.73    126.20
SBE     1         7.97     10.85     41.75
MEC     2        10.93     46.84    293.69
 gtime =  232.4992 mtran = U iyear =  1990
SBF     2          .93      4.70    219.95
MFC     2         3.80    100.06    123.28

                  etc.

 gtime =  296.6451 mtran = U iyear =  1990
SBF   102         1.35      7.75    201.94
MFC   131         4.65     60.91    125.17
 gtime =  297.1632 mtran = L iyear =  1990
MFC   132         1.33     58.92    113.44
SBE   102         5.52      1.22     29.01
MEC   106         8.22     71.17    296.06
 gtime =  297.6798 mtran = U iyear =  1990
SBF   103         1.78      1.13     27.65
MFC   133         5.08     56.78    111.40
SBE   103         6.58       .54    331.05


      Greenwich      95% Conf       Standard        Mean Speed         Mean
      Interval       Interval       Deviation     (cm/s)  (knots)   Direction

MFC      4.19      3.94      4.44      1.45         74.39    1.446        123.
SBE      7.13      6.92      7.33      1.07          5.68     .110         30.
MEC     10.21     10.02     10.40      1.00         69.11    1.343        301.
SBF      1.46      1.27      1.64       .95          3.58     .070        206.
```

Greenwich intervals plotting file (*c0218.plt*):

```
232.920 MECU 10.1 11.6 16.1  7.1 -97.5 -64.2   6.0-134.5  63.6  34.0  95.7
-27.6
233.092 SBFL  1.8  1.8  3.6  -.1  -2.7  -2.0   1.4  -5.4  -5.5  -3.1   3.1
-9.4
233.210 MFCL  4.6  4.4  5.6  3.2  82.0  77.2 100.7  53.7 -59.7 -54.3 -40.4
-68.2
233.336 SBEL  7.7  7.5  8.8  6.2   4.8   5.2   9.7    .7  12.4   8.5  17.4
-.4
233.457 MECL 10.6 11.3 13.9  8.8 -45.8 -59.6 -19.3-100.0  26.9  32.2  65.7
-1.2
233.546 SBFU   .3  1.4  2.9  -.1  -2.8  -2.2   -.3  -4.1  -3.6  -3.3    .1
-6.7
233.676 MFCU  3.5  4.2  5.1  3.2  90.6  80.5  97.0  64.1 -59.6 -55.6 -47.1
-64.2
233.821 SBEU  6.9  7.4  8.2  6.5   7.0   5.6   8.4   2.9   9.9   8.9  13.7
4.0
233.948 MECU 10.0 11.1 12.9  9.2 -81.9 -64.1 -34.1 -94.1  52.4  36.3  61.6
10.9
```

234.115 SBFL 1.6 1.4 2.5   .4 -1.4 -2.1   -.7 -3.4 -2.8 -3.2   -.9
-5.5

GI Example 3

Tidal current parameters input file (*all.tcp*):

```
 1992  1   1   0  47  MFC    53.52     119.00
 1992  1   1   3  38  SBE     2.74      32.25
 1992  1   1   7  50  MEC   102.49     298.23
 1992  1   1  12   4  SBF     5.32     208.25
 1992  1   1  15  12  MFC    69.54     119.61
 1992  1   1  20  38  SFC    12.10     106.13
 1992  1   2   1  38  MFC    55.52     119.20
 1992  1   2   4  21  SBE     3.05      35.57
 1992  1   2   8  32  MEC   108.24     298.31
 1992  1   2  12  44  SBF     5.41     208.70
```

Interactive execution of the program. Gray shading indicates the input to be typed in by the user.

```
 If you:                                                 Enter
 already have a tidal current parameters file (*.tcp)  (0)
 want to read a CDF data file                          (1)
 want to read an ASCII data file (time,spd,dir)        (2)
0
 Enter the root for the *.tcp file
all
```

Greenwich intervals output file (*all.gi*):

```
 gtime =  365.3472 mtran = U iyear =  1991
 gtime =  365.8652 mtran = L iyear =  1991
MFC     1         4.02     53.52    119.00
SBE     1         6.87      2.74     32.25
MEC     1        11.07    102.49    298.23
 gtime =  366.3819 mtran = U iyear =  1992
SBF     1         2.90      5.32    208.25
MFC     2         6.03     69.54    119.61
 gtime =  1.9 mtran = L iyear =  1992
MFC     3         4.03     55.52    119.20

                  etc.

 gtime =  365.7006 mtran = U iyear =  1992
SBF   516          .25      2.84    208.80
MFC   706         4.08     54.89    119.82
SBE   517         7.38      3.03     26.36
MEC   517         9.80     31.78    299.50
 gtime =  366.2159 mtran = L iyear =  1992
SBF   517         1.03      1.45    208.35
MFC   707         4.05     24.47    121.89
SBE   518         6.37       .76     22.93
MEC   518         9.18     33.35    297.98
SBF   518         -.25      1.42    210.80


      Greenwich      95% Conf      Standard      Mean  Speed      Mean
      Interval       Interval      Deviation    (cm/s)  (knots)   Direction
```

```
MFC      4.23       4.16      4.30         .97          62.93    1.223         120.
SBE      6.92       6.84      7.01         .99           2.77     .054          29.
MEC     10.19      10.14     10.24         .61          74.68    1.452         299.
SBF      1.29       1.21      1.37         .96           3.31     .064         208.
```

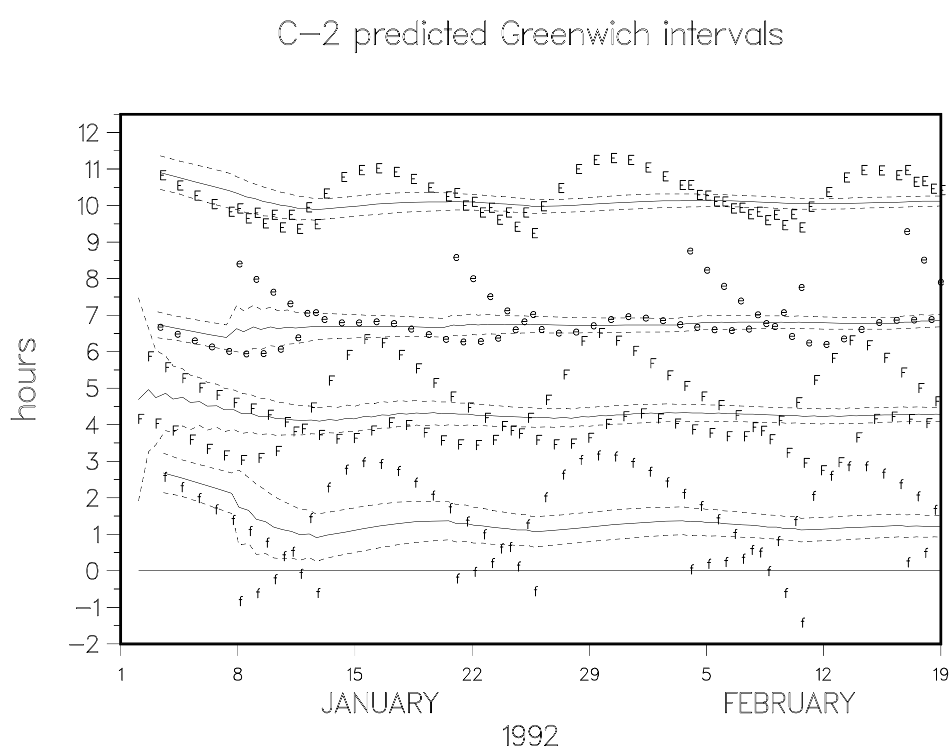
Greenwich intervals plotting file (*all.plt*):

```
  2.068 MFCL  4.0  4.7  7.5  1.9  48.5  51.9  69.9  34.0 -27.1 -29.1 -18.1
-40.1
  2.657 MFCU  5.7  5.0  6.7  3.2  65.1  55.2  69.4  41.0 -37.3 -31.2 -22.4
-39.9
  3.098 MFCL  3.9  4.7  6.0  3.4  51.2  54.4  64.3  44.5 -28.9 -30.7 -24.6
-36.8
  3.210 SBEL  6.6  6.7  7.1  6.4   1.7   1.7   2.1   1.2   2.7   2.5   3.0
2.0
  3.381 MECL 10.7 10.9 11.3 10.5 -98.3 -94.6 -84.9-104.4  53.1  51.0  56.5
45.4
  3.555 SBFU  2.4  2.7  3.2  2.1  -3.0  -2.7  -2.1  -3.3  -4.6  -4.7  -4.4
-4.9
  3.680 MFCU  5.4  4.9  5.9  3.8  67.3  56.5  65.8  47.3 -38.8 -32.1 -26.3
-37.8
  4.125 MFCL  3.7  4.7  5.6  3.8  53.6  56.1  63.7  48.6 -30.3 -31.8 -27.1
-36.5
  4.237 SBEL  6.4  6.7  7.0  6.3   1.8   1.7   1.9   1.5   2.7   2.6   2.9
2.2
  4.405 MECL 10.4 10.8 11.2 10.3 -99.8 -95.9 -89.3-102.5  53.8  51.7  55.4
47.9
```

GIPLOT Example 1

```
 To make a *.pgl plot type 1, otherwise type 0
1
 GI Plot File?
all.plt
 Plot Greenwich Intervals (1) or Velocity (2)?
1
 Plot G. I. to contrast upper and lower moon transits  (y for yes)?
n
 Input last two digits of year
92
 Range of time is  2.068 to  366.722
 Range of Y is  -1.55 to  11.67
 For time axis, input TMIN,TSTEP,TMAX
1 7 50
 For Y axis, input YMIN,YSTEP,YMAX
-2 1 12.5
 Plot title ---
C-2 predicted Greenwich intervals
```

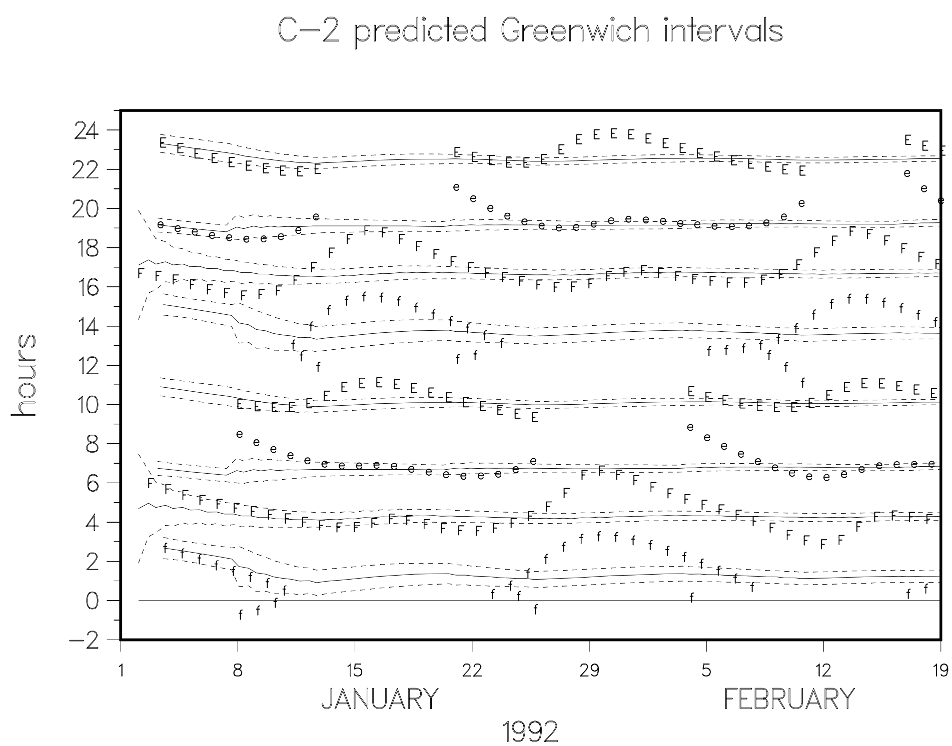
Sample plot of Greenwich intervals (12.42 hour range):



GIPLOT Example 2

```
 To make a *.pgl plot type 1, otherwise type 0
1
 GI Plot File?
all.plt
 Plot Greenwich Intervals (1) or Velocity (2)?
1
 Plot G. I. to contrast upper and lower moon transits  (y for yes)?
y
 Input last two digits of year
92
 Range of time is  2.068 to  366.722
 Range of Y is  -1.55 to  23.67
 For time axis, input TMIN,TSTEP,TMAX
1 7 50
 For Y axis, input YMIN,YSTEP,YMAX
-2 2 25
 Plot title ---
C-2 predicted Greenwich intervals
```

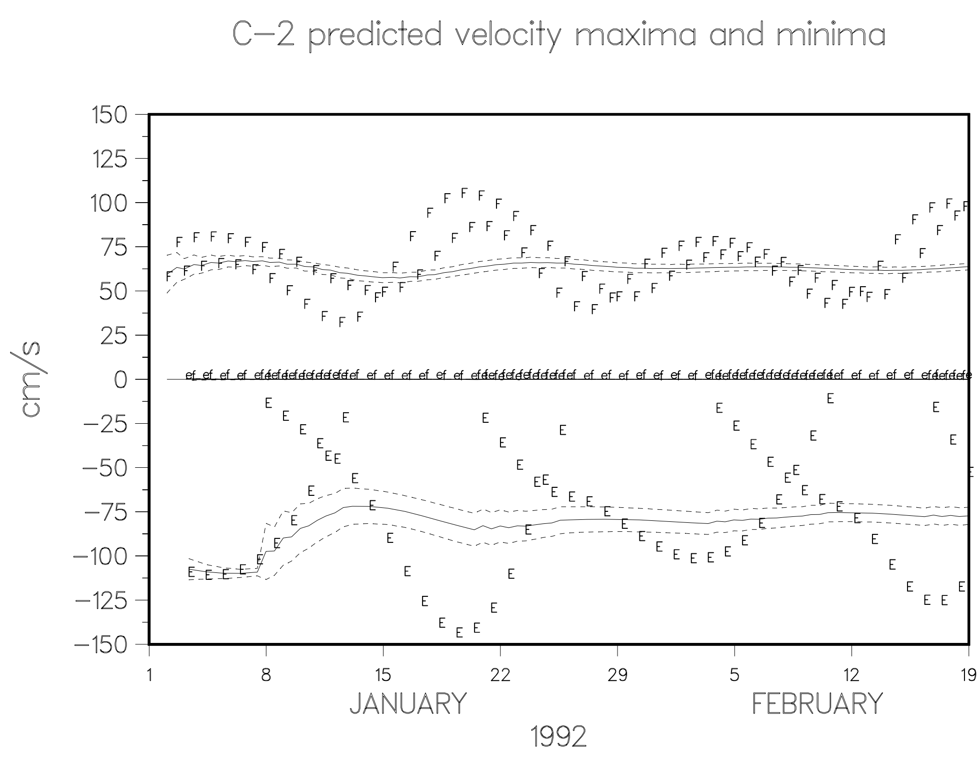
Sample plot of Greenwich intervals (24.84 hour range):



GIPLOT Example 3

```
 To make a *.pgl plot type 1, otherwise type 0
1
 GI Plot File?
all.plt
 Plot Greenwich Intervals (1) or Velocity (2)?
2
 Plot velocity along which axis (clockwise from N)?
118
 Input last two digits of year
92
 Range of time is  2.068 to  366.722
 Range of Y is  -146.03 to  102.801
 For time axis, input TMIN,TSTEP,TMAX
1 7 50
 For Y axis, input YMIN,YSTEP,YMAX
-150 25 150
 Plot title ---
C-2 predicted velocity maxima and minima
```

Sample plot of velocities:



6. REVRED: THE REVERSING REDUCTION PROGRAM

6.1. Introduction

Time differences and speed ratios are provided in Table 2 of the Tidal Current Tables to relate tidal currents at a reference station to tidal currents at a subordinate station. The reversing reduction program **revred** calculates the time differences and speed ratios between tidal currents at two stations or between tidal predictions and observed data at the same station. Current data can be analyzed vectorially or can be projected along a chosen flood direction for scalar analysis.

First, the predicted currents at the reference station must be calculated from the major axis tidal constituents by the program **ncp2** and output in standard max/min/slacks format. Then, **revred** calculates the time differences for slack before flood (SBF), maximum flood current (MFC), slack before ebb (SBE), and maximum ebb current (MEC). These values can then be used to obtain Greenwich intervals for the subordinate station if Greenwich intervals for the reference station are known. Speed ratios are also calculated for MFC and MEC.

The program also has the option of doing a tide-by-tide analysis of water level data. First, predicted water levels at the reference station must be calculated from tidal constituents by the program **ntp4** and output in standard max/mins format. Then, **revred** calculates the time differences for high water and low water. These values can then be used to obtain Greenwich intervals for the subordinate station if Greenwich intervals for the reference station are known. Height ratios or height differences are also calculated.

6.2. Input Parameters and Program Algorithm

Revred can be run as an interactive program or with a control file. The first parameters requested by **revred** are NJOBS, ITYAN, XMXDIF, ITIDE, and IYRC.

NJOBS indicates the number of reversing reduction analyses to be done. All subsequent input lines are repeated for each analysis.

ITYAN is an index for the type of analysis to be done.

If ITYAN=1, subordinate station data is read in and smoothed. Max/min/(slacks) are picked and matched with predicted max/min/(slacks) at the reference station. Time differences and speed ratios (or height ratios or height differences) are calculated.

If ITYAN=2, data is read in and smoothed. Max/min/(slacks) are picked and then the program stops.

If ITYAN=3, a max/min/(slacks) file from a subordinate station is read in and matched with predicted max/min/(slacks) at the reference station. Time differences and speed ratios (or height ratios or height differences) are calculated.

XMXDIF is the maximum allowable time difference between corresponding phases at the two stations (defaults to 6.21 hours when XMXDIF = 0.0).

ITIDE is an index for the option of analyzing current or water level stations.

ITIDE=-1 for tidal currents (max/min/slacks) with data analyzed vectorially. Slacks are minimum currents. Speed ratios are obtained.

ITIDE=0 for tidal currents (max/min/slacks) with data projected along the principal current direction (flood). Slacks are zero crossings. Speed ratios are obtained.

ITIDE=1 for tides (max/min) relative to chart datums. Height differences are obtained.

ITIDE=2 for tides (max/min) relative to mean sea level. Height differences are obtained.

ITIDE=3 for tides (max/min) relative to chart datums. Height ratios relative to mean sea level are obtained.

ITIDE=4 for tides (max/min) relative to mean sea level. Height ratios relative to mean sea level are obtained.

ITIDE=5 for tides (max/min) relative to chart datums. Height ratios relative to chart datum are obtained.

ITIDE=6 for tides (max/min) relative to mean sea level. Height ratios relative to chart datum are obtained.

IYRC is the year of the analysis (format i4). Only one year can be analyzed at a time.

Next, **revred** asks for headers identifying the reference and subordinate stations followed by the name of the max/min/(slacks) file for the reference station (unless ITYAN=2). Then, **revred** asks for the name of the max/min/(slacks) file for the subordinate station. If ITYAN=1 or ITYAN=2, provide an output file name; if ITYAN=3, provide the input file name.

If ITYAN=1 or ITYAN=2, the subroutine **maxmin** is entered. (If ITYAN=3, the program skips ahead to the subroutine **difrat**.) **Maxmin** finds the max/min/(slacks) from a time series and saves the results in a standard format and in a long format in a file with the extension *.*lst*. The parameters required are ITYIN, NSKIP, NOBS, SPH, FLDIR, and TMCHR.

ITYIN is an index for choosing the type of the subordinate station input data file. Results will be in knots or in feet.

ITYIN=-1 for ASCII free format vector data (time, speed, and direction) in knots.

ITYIN=0 for ASCII free format vector data (time, speed, and direction) in cm/s.

ITYIN=1 for vector data in CDF format (cm/s).

ITYIN=2 for vector data in 24f3.0 format (hourly and cm/s).

ITYIN=3 for one component of current data (along FLDIR) or tide data in 12f5.2 format (hourly and knots or feet).

ITYIN=4 for ASCII free format scalar data (time and water level).

NSKIP is the number of data points to skip at the beginning.

NOBS is the number of data points to use in the analysis (Enter 0 for all points except first NSKIP).

SPH is the number of data points per hour.

FLDIR is the principal current direction (flood) for the <u>subordinate</u> station data (when ITIDE = -1 or 0) and is the component of the current to analyze when ITIDE = 0. Not relevant for water level analysis (ITIDE > 0) but must be given.

TMCHR is the time meridian correction in hours to subtract from the data if it is not in the same time as the reference station max/min/(slacks). (**ncp2** and **ntp4** output is usually in local time if the constituents were modified local epochs 6'.) For example, if the subordinate station data is in GMT, TMCHR is 5 for EST, 6 for CST, or 8 for PST to shift to the local time zone.

Then, **maxmin** asks for the name of the subordinate station data file, reads in the data, and smooths it with a running average filter. The program asks for the window length in hours and checks that it is at least 5 data points long (required by the algorithm). If 0.0 is input as the window length, it defaults to 6.21 hours (half a semidiurnal period). When the slope of the smoothed time series changes sign, a 3-point parabolic fit is used to find the time and speed of MFC or MEC or the time and height of HW or LW. When ITIDE = -1, the minumum current times are the SBF or SBE time. When ITIDE = 0 and the smoothed time series crosses zero, the crossing time is the SBF or SBE time. Warnings are printed when there are more than 5 max/mins on any one day. If there are many warnings, consider using a longer window length. If the warnings cannot be eliminated, the max/min/(slacks) file for the subordinate station must be edited by the user so that there is only one line per day (i.e. a total of five floods and ebbs). Then **revred** is run again with ITYAN=3.

The subroutine **difrat** reads the max/min/(slacks) at the reference and subordinate stations, matches max/min/(slacks) at the reference and subordinate stations which are within XMXDIF hours, and calculates time differences, speed ratios (or height ratios or height differences), and statistics which are printed in an output file. If ITIDE = -1 or 0, any flood or ebb speed less than 0.25 knots is considered to be a "weak and variable current" as labeled in the Tidal Current Tables and is not included in the statistical summations. If ITIDE $ 1 (i.e. the stations are tide stations), the program asks for the datum of each station.

The program also asks for the Greenwich intervals at the reference station and, if ITIDE = -1 or ITIDE = 0, the mean maximum flood and mean maximum ebb speeds at the reference station. If ITIDE > 0, the program asks for the mean tidal range at the reference station. If these values are given, the Greenwich intervals are calculated at the subordinate station and a correction factor for the mean flood and ebb currents or the mean high and low waters at the subordinate station is obtained. The correction factor accounts for any difference between the mean range at the reference station during the analysis period and the "long term" mean range at the reference station (obtained by some other method such as the program **gi**). If the values are unknown for the reference station, zeros should be entered. Then, Greenwich intervals and/or the correction factor will not be calculated for the subordinate station.

The output files have extensions **.tbl* and **.plt* (and **.lst* if ITYAN=1 or ITYAN=2). The output files have lines that are 132 characters long. (The Unix command **lp -oc** can be used to print text in small letters.) The **.tbl* file tabulates the daily time differences and speed ratios (or height ratios or height differences) and the output statistics. The **.plt* file plots out the time differences and speed ratios (or height ratios or height differences).

REVRED Example 1 (ITIDE = -1)

Input predictions file for the reference station, created by **ncp2** (*02pred*):

```
 0   0 1 1909999 101  1.0 356 740 -1.911261454  1.418322023 -0.522389999 99.9  1
 0   0 2 1909999 212  0.8 456 823 -1.511551531  1.318532118 -0.899999999 99.9  2
 0   0 3 190  28 338  0.7 612 912 -1.012191607  1.219212226 -1.199999999 99.9  3
 0   0 4 190 219 512  0.7 8031013 -0.412331647  1.219562335 -1.599999999 99.9  4
 0   0 5 190 352 646  0.999991136  0.099991734  1.120399999 99.999999999 99.9  5
 0   0 6 1909999  43 -1.8 506 820  1.299991312  0.399991833  1.121319999 99.9  6
 0   0 7 1909999 143 -2.2 609 929  1.599991435  0.499991936  1.122269999 99.9  7
 0   0 8 1909999 243 -2.5 7041018  1.799991540  0.499992036  1.223219999 99.9  8
 0   0 9 1909999 336 -2.7 7531103  1.999991632  0.399992131  1.399999999 99.9  9
```

Input data file for the subordinate station (*c2.sd*):

```
 156.60434  40.171  21.720
 156.61128  40.717  26.255
 156.61823  39.706  27.636
 156.62517  41.118  25.381
 156.63213  38.247  21.111
 156.63907  30.213  23.525
 156.64601  32.717  25.624
 156.65295  37.518  27.512
 156.65990  36.185  26.634
 156.66684  33.132  23.836
```

Interactive execution of the program. Gray shading indicates the input to be typed in by the user. In this case, subordinate station current data is analyzed vectorially (ITIDE=-1).

```
 Enter njobs,ityan,xmxdif,itide,iyrc
1  1  0  -1  1990
 Header for Reference Station
C-2   Inner Egmont Channel
 Header for Subordinate Station
C-5   Old Port Tampa
 Input file with Max/Min/(Slacks) for Reference Station
02pred
 Output file with Max/Min/(Slacks) for Subordinate Station
c5obs
 Enter ityin,nskip,nobs,sph,fldir,tmchr
0  0  0  6  28  5
 Input ASCII data file in free format (Time Speed Dir)
c5.sd
 Enter Smoothing Window Length in hours (0 defaults to 6.21 hours)
 Possible Range is  .8333333 TO  10.83333 hours
0
 Smoothing Window is   37 data points long

 Enter Reference Station Greenwich Intervals for SBF,MFC,SBE,MEC , IHM
 IHM=0 for decimal hours    or   IHM=1 for HH.MM  (All zeros if unknown)
1.28  4.25  7.19  10.20  0
 Input Mean Max Flood and Mean Max Ebb in knots for Reference Station
 (Both zeros if unknown)
1.306  1.339
```

Alternatively, the program **revred** can also be run with the following control file (*revred.ctl*).

```
1   1   0   -1   1990                    ! Enter njobs,ityan,xmxdif,itide,iyrc
C-2   Inner Egmont Channel
C-5   Old Port Tampa
02pred                                   ! Reference Station Max/Min/(Slacks)
c5obs                                    ! Subordinate Station Max/Min/(Slacks)
0   0    0    6   28   5                 ! Enter ityin,nskip,nobs,sph,fldir,tmchr
c5.sd                                    ! Subordinate Station Data File
0                                        ! Smoothing Window Length (0 = 6.21 hrs)
1.28   4.25   7.19   10.20   0           ! Ref. Station Greenwich Ints & hr frmt
1.306   1.339                            ! Ref. Station MFC and MEC
```

Output max/min/slacks file for the subordinate station (*c5obs*). There are two lines per day. The first line gives times and speeds; the second line gives directions.

```
5 69099991642 -1.121029999 99.999999999 99.999999999 99.999999999 99.9  1
5 690        203.6        999.9        999.9        999.9        999.9  1
6 6909999  23  0.9 420 525 -0.5 6331026  0.812471659 -1.321479999 99.9  2
6 690         20.5        210.6         23.8        203.7        999.9  2
7 6909999 118  0.79999 548  0.099991051  0.913211810 -1.122419999 99.9  3
7 690         20.7        287.2         22.7        203.8        999.9  3
8 6909999 155  1.09999 648  0.199991118  0.813471841 -1.123099999 99.9  4
8 690         20.9         13.7         24.0        203.1        999.9  4
9 6909999 214  1.0 608 640 -0.5 7071144  1.014291909 -1.223419999 99.9  5
9 690         19.5        250.8         22.4        203.7        999.9  5
```

Output **.lst* file for the subordinate station (*c5obs.lst*):

```
 Minimum at:  6/ 5/1990 16.70 hours, Value =   -1.124  Dir = 204
 S.B.Max at:  6/ 5/1990 21.04 hours, Value =     .000  Dir =   0
 Maximum at:  6/ 6/1990   .38 hours, Value =     .882  Dir =  21
 S.B.Min at:  6/ 6/1990  4.34 hours, Value =     .000  Dir =   0
 Minimum at:  6/ 6/1990  5.41 hours, Value =    -.480  Dir = 211
 S.B.Max at:  6/ 6/1990  6.56 hours, Value =     .000  Dir =   0
 Maximum at:  6/ 6/1990 10.43 hours, Value =     .848  Dir =  24
 S.B.Min at:  6/ 6/1990 12.78 hours, Value =     .000  Dir =   0
 Minimum at:  6/ 6/1990 16.99 hours, Value =   -1.288  Dir = 204
 S.B.Max at:  6/ 6/1990 21.78 hours, Value =     .000  Dir =   0
 Maximum at:  6/ 7/1990  1.30 hours, Value =     .738  Dir =  21
 Minimum at:  6/ 7/1990  5.80 hours, Value =     .017  Dir = 287  Double Flood
 Maximum at:  6/ 7/1990 10.84 hours, Value =     .857  Dir =  23
 S.B.Min at:  6/ 7/1990 13.34 hours, Value =     .000  Dir =   0
 Minimum at:  6/ 7/1990 18.17 hours, Value =   -1.116  Dir = 204
 S.B.Max at:  6/ 7/1990 22.69 hours, Value =     .000  Dir =   0
 Maximum at:  6/ 8/1990  1.92 hours, Value =    1.015  Dir =  21
 Minimum at:  6/ 8/1990  6.79 hours, Value =     .143  Dir =  14  Double Flood
 Maximum at:  6/ 8/1990 11.31 hours, Value =     .821  Dir =  24
 S.B.Min at:  6/ 8/1990 13.79 hours, Value =     .000  Dir =   0
```

Note that a double flood is labeled when the ebb was "weak and variable" (less than 0.25 knots). S.B.Min and S.B.Max were not picked before and after the Minimum.

REVRED Example 2 (ITIDE = 0)

Input predictions file for the reference station, created by **ncp2** (*02pred*):

```
 0   0 1 1909999 101  1.0 356 740 -1.911261454  1.418322023 -0.522389999 99.9  1
 0   0 2 1909999 212  0.8 456 823 -1.511551531  1.318532118 -0.899999999 99.9  2
 0   0 3 190  28 338  0.7 612 912 -1.012191607  1.219212226 -1.199999999 99.9  3
 0   0 4 190 219 512  0.7 8031013 -0.412331647  1.219562335 -1.599999999 99.9  4
 0   0 5 190 352 646  0.999991136  0.099991734  1.120399999 99.999999999 99.9  5
 0   0 6 1909999  43 -1.8 506 820  1.299991312  0.399991833  1.121319999 99.9  6
 0   0 7 1909999 143 -2.2 609 929  1.599991435  0.499991936  1.122269999 99.9  7
 0   0 8 1909999 243 -2.5 7041018  1.799991540  0.499992036  1.223219999 99.9  8
 0   0 9 1909999 336 -2.7 7531103  1.999991632  0.399992131  1.399999999 99.9  9
```

Interactive execution of the program. Gray shading indicates the input to be typed in by the user. In this case, one component (along 28/) of the subordinate station current data is analyzed (ITIDE=0).

```
 Enter njobs,ityan,xmxdif,itide,iyrc
1  1  0  0  1990
 Header for Reference Station
C-2   Inner Egmont Channel
 Header for Subordinate Station
C-5   Old Port Tampa
 Input file with Max/Min/(Slacks) for Reference Station
02pred
 Output file with Max/Min/(Slacks) for Subordinate Station
05obs
 Enter ityin,nskip,nobs,sph,fldir,tmchr
1  10  8121  6  28  5
 Input CDF file
/dir6/cdf/PROJTAMPAB/t05010/file6
 Enter Smoothing Window Length in hours (0 defaults to 6.21 hours)
 Possible Range is  .8333333 TO  10.83333 hours
0
 Smoothing Window is   37 data points long

 Enter Reference Station Greenwich Intervals for SBF,MFC,SBE,MEC , IHM
 IHM=0 for decimal hours   or   IHM=1 for HH.MM  (All zeros if unknown)
1.28  4.25  7.19  10.20  0
 Input Mean Max Flood and Mean Max Ebb in knots for Reference Station
 (Both zeros if unknown)
1.306  1.339
```

Alternatively, the program **revred** can also be run with the following control file (*revred1.ctl*).

```
1   1   0    0   1990                 ! Enter njobs,ityan,xmxdif,itide,iyrc
C-2   Inner Egmont Channel
C-5   Old Port Tampa
02pred                                ! Reference Station Max/Min/(Slacks)
05obs                                 ! Subordinate Station Max/Min/(Slacks)
1  10   8121   6   28   5             ! Enter ityin,nskip,nobs,sph,fldir,tmchr
/dir6/cdf/PROJTAMPAB/t05010/file6     ! Subordinate Station Data File
0                                     ! Smoothing Window Length (0 = 6.21 hrs)
1.28   4.25   7.19   10.20   0        ! Ref. Station Greenwich Ints & hr frmt
1.306   1.339                         ! Ref. Station MFC and MEC
```

Output max/min/slacks file for the subordinate station (*05obs*):

```
  5 69099991637 -1.120589999 99.999999999 99.999999999 99.999999999 99.9  1
  6 6909999  18  0.9 414 520 -0.5 6311021  0.812411654 -1.321419999 99.9  2
  7 6909999 113  0.7 533 544 -0.6 5571046  0.913161805 -1.122379999 99.9  3
  8 6909999 150  1.09999 643 -0.199991114  0.813421836 -1.123049999 99.9  4
  9 6909999 208  1.0 559 633 -0.5 7061138  1.014231904 -1.223369999 99.9  5
 10 6909999 249  1.09999 718 -0.499991216  1.014521944 -1.399999999 99.9  6
 11 690   9 318  1.0 712 754 -0.5 8401257  1.015382015 -1.399999999 99.9  7
 12 690  38 345  1.0 735 847 -0.410101358  1.016322059 -1.299999999 99.9  8
 13 690 126 459  0.99999 933 -0.199991401  0.816522150 -1.299999999 99.9  9
 14 690 211 532  0.9 9201107 -0.613061609  0.818242232 -1.199999999 99.9 10
```

Output **.lst* file for the subordinate station (*05obs.lst*):

```
Minimum at:  6/ 5/1990 16.62 hours, Value =   -1.121  Dir =  28
S.B.Max at:  6/ 5/1990 20.97 hours, Value =     .000  Dir =  28
Maximum at:  6/ 6/1990   .30 hours, Value =     .874  Dir =  28
S.B.Min at:  6/ 6/1990  4.24 hours, Value =     .000  Dir =  28
Minimum at:  6/ 6/1990  5.33 hours, Value =    -.479  Dir =  28
S.B.Max at:  6/ 6/1990  6.52 hours, Value =     .000  Dir =  28
Maximum at:  6/ 6/1990 10.34 hours, Value =     .847  Dir =  28
S.B.Min at:  6/ 6/1990 12.69 hours, Value =     .000  Dir =  28
Minimum at:  6/ 6/1990 16.90 hours, Value =   -1.284  Dir =  28
S.B.Max at:  6/ 6/1990 21.69 hours, Value =     .000  Dir =  28
Maximum at:  6/ 7/1990  1.22 hours, Value =     .733  Dir =  28
S.B.Min at:  6/ 7/1990  5.55 hours, Value =     .000  Dir =  28
Minimum at:  6/ 7/1990  5.73 hours, Value =    -.581  Dir =  28
S.B.Max at:  6/ 7/1990  5.94 hours, Value =     .000  Dir =  28
Maximum at:  6/ 7/1990 10.77 hours, Value =     .853  Dir =  28
S.B.Min at:  6/ 7/1990 13.26 hours, Value =     .000  Dir =  28
Minimum at:  6/ 7/1990 18.08 hours, Value =   -1.115  Dir =  28
S.B.Max at:  6/ 7/1990 22.61 hours, Value =     .000  Dir =  28
Maximum at:  6/ 8/1990  1.84 hours, Value =    1.007  Dir =  28
Minimum at:  6/ 8/1990  6.72 hours, Value =     .138  Dir =  28  Double Flood
Maximum at:  6/ 8/1990 11.23 hours, Value =     .818  Dir =  28
S.B.Min at:  6/ 8/1990 13.71 hours, Value =     .000  Dir =  28
Minimum at:  6/ 8/1990 18.60 hours, Value =   -1.141  Dir =  28
```

Note that a double flood is labeled when the ebb was "weak and variable" (less than 0.25 knots). S.B.Min and S.B.Max were not picked before and after the Minimum.

REVRED Example 3 (ITIDE $ 1)

Input predictions file for the reference station, created by **ntp4** (*cbpred*):

```
90    0  1  190  102  4.4  820  1.6 1458  3.8 2020  2.6 9999 99.9             1
90    0  2  190  159  4.1  855  1.9 1532  3.9 2126  2.4 9999 99.9             2
90    0  3  190  312  3.7  927  2.2 1605  4.1 2248  2.2 9999 99.9             3
90    0  4  190  439  3.4 1003  2.6 1647  4.2 9999 99.9 9999 99.9             4
91    0  5  190   18  1.9  635  3.2 1051  2.9 1737  4.4 9999 99.9             5
91    0  6  190  134  1.6  901  3.2 1207  3.1 1837  4.5 9999 99.9             6
91    0  7  190  243  1.3 1030  3.4 1331  3.2 1943  4.6 9999 99.9             7
91    0  8  190  341  1.0 1115  3.5 1443  3.2 2048  4.8 9999 99.9             8
91    0  9  190  431   .8 1154  3.5 1539  3.1 2140  4.9 9999 99.9             9
91    0 10  190  516   .8 1221  3.5 1627  3.0 2229  4.9 9999 99.9            10
```

Input data file for the subordinate station (*sp*):

```
87265201990 1 11075W  497  533  562  581  577  553  522  479  436  393  354
329
87265201990 1 12075W  310  325  349  360  370  379  364  353  339  317  299
291
87265201990 1 21075W  293  306  323  341  359  365  361  339  310  281  253
235
87265201990 1 22075W  247  275  304  344  384  414  434  437  419  393  369
345
87265201990 1 31075W  334  347  364  385  409  429  437  430  415  386  350
323
87265201990 1 32075W  306  319  343  373  411  444  465  475  465  441  412
382
87265201990 1 41075W  356  343  347  365  384  410  434  447  447  436  418
397
87265201990 1 42075W  380  375  389  413  446  477  502  519  513  493  464
428
87265201990 1 51075W  387  351  325  310  313  333  352  373  397  408  409
407
87265201990 1 52075W  402  398  397  415  438  464  493  520  527  521  500
468
```

Interactive execution of the program. Gray shading indicates the input to be typed in by the user. In this case, subordinate station water level data is analyzed (ITIDE$1).

```
 Enter njobs,ityan,xmxdif,itide,iyrc
1  1  0  1  1990
 Header for Reference Station
E-724   Clearwater Beach
 Header for Subordinate Station
E-520   St. Petersburg
 Input file with Max/Min/(Slacks) for Reference Station
cbpred
 Output file with Max/Min/(Slacks) for Subordinate Station
spobs
 Enter ityin,nskip,nobs,sph,fldir,tmchr
3  0  2400  1  0  0
 Input data file in tide format
sp
 Enter Smoothing Window Length in hours (0 defaults to 6.21 hours)
 Possible Range is  5.0 TO  65.0 hours
0
 Smoothing Window is    5 data points long
```

```
 Input Datum(reference), Datum(subordinate)
3.363  4.512
 Enter Reference Station Greenwich Intervals for HW,LW and IHM
 IHM=0 for decimal hours   or   IHM=1 for HH.MM  (All zeros if unknown)
4.246  10.527  0
 Input Mean Tidal Range for Reference Station (Zero if unknown)
1.8
```

Alternatively, the program **revred** can also be run with the following control file (*revredwl.ctl*).

```
1   1    0   1   1990                     ! Enter njobs,ityan,xmxdif,itide,iyrc
E-724   Clearwater Beach
E-520   St Petersburg
cbpred                                    ! Reference Station Max/Min/(Slacks)
spobs                                     ! Subordinate Station Max/Min/(Slacks)
3   0   2400   1    0    0                ! Enter ityin,nskip,nobs,sph,fldir,tmchr
sp                                        ! Subordinate Station Data File
0                                         ! Smoothing Window Length (0 = 6.21 hrs)
3.363   4.512                             ! Datum (Reference), Datum (Subordinate)
4.246   10.527   0                        ! Ref. Station Greenwich Ints & hr frmt
1.8                                       ! Ref. Station Mean Tidal Range
```

Output max/mins file for the subordinate station (*spobs*):

```
 1  190   320   5.8 1223   3.2 1640   3.7 2321   2.9 9999 99.9            1
 2  190   450   3.7 1106   2.4 1840   4.3 9999 99.9 9999 99.9            2
 3  190     9   3.4  604   4.4 1209   3.1 1859   4.7 9999 99.9            3
 4  190   128   3.4  741   4.5 1236   3.8 1917   5.2 9999 99.9            4
 5  190   329   3.1 1035   4.1 1209   4.0 2005   5.3 9999 99.9            5
 6  190   433   3.0 2045   5.3 9999 99.9 9999 99.9 9999 99.9            6
 7  190   534   2.7 2139   5.7 9999 99.9 9999 99.9 9999 99.9            7
 8  190   657   2.8 2224   5.5 9999 99.9 9999 99.9 9999 99.9            8
 9  190   750   2.4 2345   5.6 9999 99.9 9999 99.9 9999 99.9            9
10  190   835   2.5 9999 99.9 9999 99.9 9999 99.9 9999 99.9           10
```

Output *.lst* file for the subordinate station (*spobs.lst*):

```
 Maximum at:  1/ 1/1990  3.34 hours, Value =    5.787  Dir =   0
 Minimum at:  1/ 1/1990 12.38 hours, Value =    3.175  Dir =   0
 Maximum at:  1/ 1/1990 16.66 hours, Value =    3.730  Dir =   0
 Minimum at:  1/ 1/1990 23.35 hours, Value =    2.914  Dir =   0
 Maximum at:  1/ 2/1990  4.84 hours, Value =    3.650  Dir =   0
 Minimum at:  1/ 2/1990 11.10 hours, Value =    2.413  Dir =   0
 Maximum at:  1/ 2/1990 18.67 hours, Value =    4.343  Dir =   0
 Minimum at:  1/ 3/1990   .14 hours, Value =    3.390  Dir =   0
 Maximum at:  1/ 3/1990  6.07 hours, Value =    4.357  Dir =   0
 Minimum at:  1/ 3/1990 12.15 hours, Value =    3.117  Dir =   0
 Maximum at:  1/ 3/1990 18.98 hours, Value =    4.726  Dir =   0
 Minimum at:  1/ 4/1990  1.46 hours, Value =    3.445  Dir =   0
 Maximum at:  1/ 4/1990  7.68 hours, Value =    4.469  Dir =   0
 Minimum at:  1/ 4/1990 12.59 hours, Value =    3.770  Dir =   0
 Maximum at:  1/ 4/1990 19.28 hours, Value =    5.159  Dir =   0
 Minimum at:  1/ 5/1990  3.48 hours, Value =    3.113  Dir =   0
 Maximum at:  1/ 5/1990 10.58 hours, Value =    4.070  Dir =   0
 Minimum at:  1/ 5/1990 12.15 hours, Value =    4.012  Dir =   0
 Maximum at:  1/ 5/1990 20.09 hours, Value =    5.269  Dir =   0
 Minimum at:  1/ 6/1990  4.55 hours, Value =    3.005  Dir =   0
```

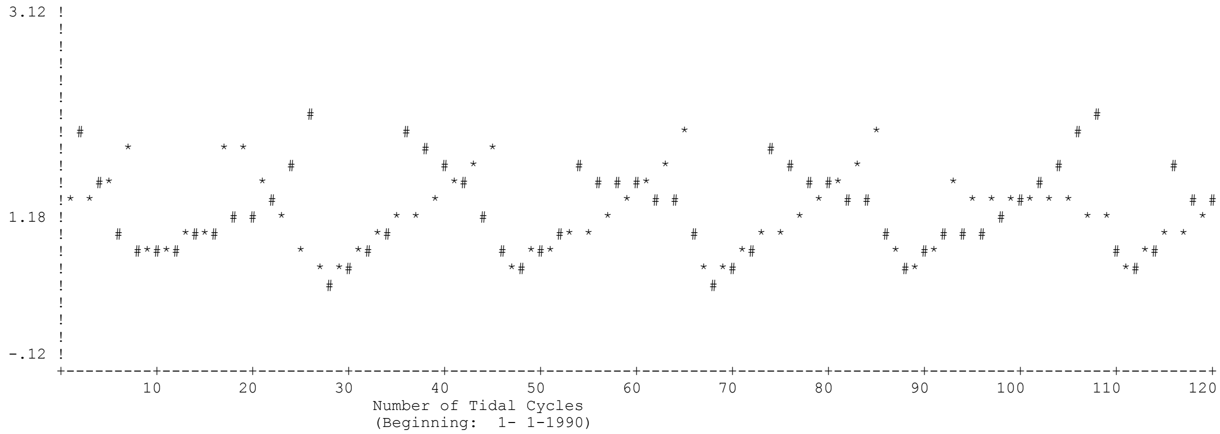
Sample **.tbl* output file:

```
                                R E V E R S I N G    R E D U C T I O N
                                -----------------    -----------------


 Subordinate Station: C-5   Old Port Tampa

 Reference Station: C-2   Inner Egmont Channel

+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Year   !          S U B O R D I N A T E          !      R E F E R E N C E         !!     (SUB - REF)           (SUB / REF) !
! 1990   !                                         !                                !!         Time                Speed   !
!        !  ----T i m e s-----                     !  ----T i m e s-----     Speeds !!  -----Differences------      Ratios  !
! Date   !  SBF  MFC  SBE  MEC    Spd Dir    Spd Dir !  SBF  MFC  SBE  MEC  MFC    MEC !!   SBF   MFC   SBE   MEC     MFC   MEC !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  1 ! ****  2.4  5.1  8.8   .9  *** -1.4  *** ! 11.4  1.0  3.9  7.7  1.0  -1.9 !! *****  1.37  1.13  1.13 !   .90   .74 !
!        ! 12.7 15.6 19.1 21.6  1.1  ***  -.6  *** ! 22.6 14.9 18.5 20.4  1.4   -.5 !!  1.28   .68   .60  1.25 !   .79  1.20 !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  2 !   .6  3.4  6.0  9.6   .8  *** -1.2  *** ! 11.9  2.2  4.9  8.4   .8  -1.5 !!  1.92  1.20  1.10  1.23 !  1.00   .80 !
!        ! 13.3 16.2 19.6 22.5  1.0  ***  -.7  *** ! **** 15.5 18.9 21.3  1.3   -.8 !!  1.37   .68   .72  1.15 !   .77   .88 !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  3 !  1.9  4.5  7.2 10.4   .7  ***  -.8  *** !   .5  3.6  6.2  9.2   .7  -1.0 !!  1.43   .85  1.02  1.23 !  1.00   .80 !
!        ! 13.9 17.0 20.1 23.5  1.0  ***  -.9  *** ! 12.3 16.1 19.4 22.4  1.2  -1.1 !!  1.53   .83   .78  1.07 !   .83   .82 !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  4 !  3.3  5.8  8.8 11.4   .6  ***  -.5  *** !  2.3  5.2  8.1 10.2   .7   -.4 !!  1.02   .55   .77  1.17 !   .86  1.25 !
!        ! 14.4 17.7 20.8 ****   .9  *** ****  *** ! 12.6 16.8 19.9 23.6  1.2  -1.5 !!  1.83   .92   .83 ***** !   .75 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  5 !  4.7  7.3 ****   .6   .6  *** -1.1  *** !  3.9  6.8 **** ****   .9  **** !!   .83   .52 *****  1.05 !   .67   .73 !
!        ! **** 18.5 21.5 ****   .8  *** ****  *** ! **** 17.6 20.6 ****  1.1  **** !! *****   .98   .85 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  6 !  5.9  8.8 ****  1.9   .8  *** -1.3  *** !  5.1  8.3 ****   .7  1.2  -1.8 !!   .82   .45 *****  1.20 !   .67   .72 !
!        ! **** 19.5 22.4 ****   .8  *** ****  *** ! **** 18.5 21.5 ****  1.1  **** !! *****   .93   .87 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Jan  7 !  7.0 10.2 ****  3.0   .9  *** -1.6  *** !  6.2  9.5 ****  1.7  1.5  -2.2 !!   .83   .68 *****  1.30 !   .60   .73 !
!        ! **** 20.5 23.4 ****   .8  *** ****  *** ! **** 19.6 22.4 ****  1.1  **** !! *****   .85   .92 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+

                                                       etc.

+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 25 !  3.8  6.2  9.1 11.8   .5  ***  -.5  *** !  2.8  5.6  8.3 10.7   .6   -.5 !!  1.03   .60   .75  1.12 !   .83  1.00 !
!        ! 14.9 18.2 21.3 ****   .8  *** ****  *** ! 13.1 17.3 20.5 ****  1.1  **** !!  1.78   .97   .78 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 26 !  5.1  7.6 ****  1.1   .6  *** -1.0  *** !  4.2  7.1 ****   .1   .8  -1.3 !!   .92   .53 *****  1.05 !   .75   .77 !
!        ! **** 19.0 22.0 ****   .8  *** ****  *** ! **** 18.0 21.1 ****  1.1  **** !! *****  1.07   .85 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 27 !  6.2  9.0 ****  2.2   .8  *** -1.3  *** !  5.3  8.5 ****  1.0  1.2  -1.8 !!   .88   .52 *****  1.13 !   .67   .72 !
!        ! **** 20.0 22.8 ****   .8  *** ****  *** ! **** 18.9 21.9 ****  1.1  **** !! *****  1.10   .90 ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 28 !  7.2 10.3 ****  3.2  1.0  *** -1.6  *** !  6.3  9.6 ****  1.9  1.6  -2.2 !!   .90   .68 *****  1.25 !   .63   .73 !
!        ! **** 20.8 23.6 ****   .8  *** ****  *** ! **** 19.9 22.7 ****  1.2  **** !! *****   .92   .97 ***** !   .67 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 29 !  8.1 11.3 ****  4.1  1.2  *** -1.8  *** !  7.2 10.4 ****  2.8  1.8  -2.6 !!   .92   .83 *****  1.33 !   .67   .69 !
!        ! **** 21.8 **** ****   .9  *** ****  *** ! **** 20.8 23.5 ****  1.3  **** !! *****   .93 ***** ***** !   .69 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 30 !  8.9 12.1   .6  5.0  1.3  *** -2.0  *** !  8.0 11.2 ****  3.7  2.0  -2.9 !!   .93   .97  1.05  1.32 !   .65   .69 !
!        ! **** 22.7 **** ****  1.0  *** ****  *** ! **** 21.6 **** ****  1.4  **** !! *****  1.03 ***** ***** !   .71 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Dec 31 !  9.8 12.9  1.5  5.8  1.4  *** -2.1  *** !  8.8 11.9   .4  4.5  2.0  -3.0 !!   .98   .92  1.12  1.32 !   .70   .70 !
!        ! **** 23.6 **** ****  1.1  *** ****  *** ! **** 22.5 **** ****  1.5  **** !! *****  1.13 ***** ***** !   .73 ***** !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+


+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
! Year   !          S U B O R D I N A T E          !      R E F E R E N C E         !!     (SUB - REF)           (SUB / REF) !
! 1990   !                                         !                                !!         Time                Speed   !
!        !  ----T i m e s-----                     !  ----T i m e s-----     Speeds !!  -----Differences------      Ratios  !
! Date   !  SBF  MFC  SBE  MEC    Spd Dir    Spd Dir !  SBF  MFC  SBE  MEC  MFC    MEC !!   SBF   MFC   SBE   MEC     MFC   MEC !
+--------+--------------------+--------------------+--------------------+-----------++-------------------------+------------+
                  No. of Obs. !   706 706   552 552!        No. of Obs. !  706   498 !!   498   706   498   498 !   706   498 !
                              +--------------------+                    +-----------++-------------------------+------------+
                         Mean !   .88 *** -1.08 ***!               Mean ! 1.22 -1.51 !!  1.18   .89   .93  1.25 !   .73   .82 !
                              +--------------------+                    +-----------++-------------------------+------------+
                   Stand.Dev. !   .24 ***   .47 ***!         Stand.Dev. !  .34   .67 !!   .33   .39   .16   .13 !   .09   .16 !
                              +--------------------+                    +-----------++-------------------------+------------+
                      Maximum !  1.50 ***  -.30 ***!            Maximum ! 2.10  -.30 !!  2.22  3.12  1.18  1.60 !  1.00  1.67 !
                              +--------------------+                    +-----------++-------------------------+------------+
                      Minimum !   .40 *** -2.20 ***!            Minimum !  .40 -3.10 !!   .58  -.12   .37   .75 !   .54   .67 !
                              +--------------------+                    +-----------++-------------------------+------------+
                                                                              Speed Ratio from Means !   .72   .71 !
                              +--------------------+                    +-----------++-------------------------+------------+
               Corrected Mean !   .85     -1.05    !    ( Correction Factor = ( 1.31 + 1.34)/( 1.22 + 1.51) =  .97 )
                              +--------------------+                                 ++-------------------------+
                                        Reference Station Greenwich Intervals !!  1.28  4.25  7.19 10.20 !
                                                                               ++-------------------------+
                                      Subordinate Station Greenwich Intervals !!  2.46  5.14  8.12 11.45 !
                                                                               ++-------------------------+
```

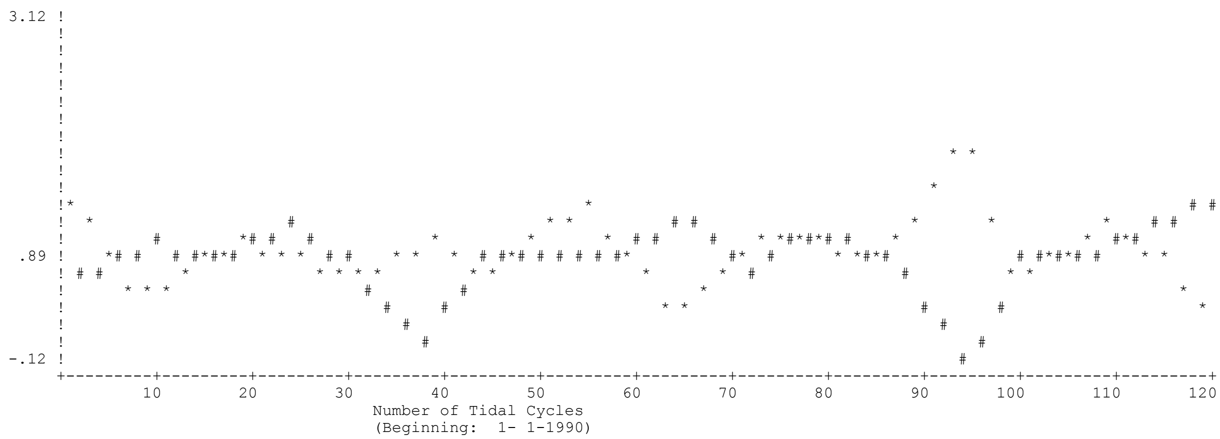
Sample *.*plt* output file:

```
                                  R E V E R S I N G    R E D U C T I O N
                                  -----------------    -----------------

 Subordinate Station: C-5   Old Port Tampa

 Reference Station: C-2   Inner Egmont Channel
```

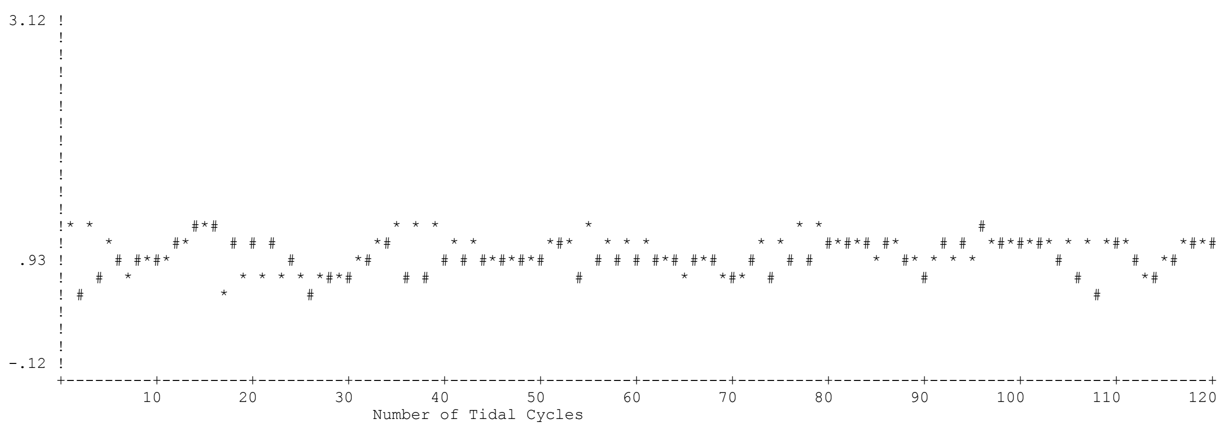
Slack B Flood Time Differences   (hours)



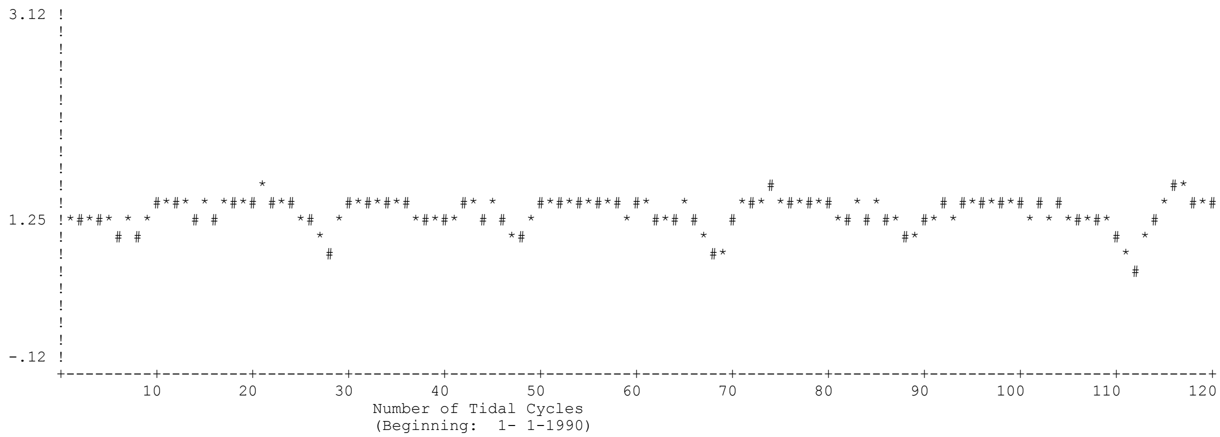
Maximum Flood Time Differences   (hours)



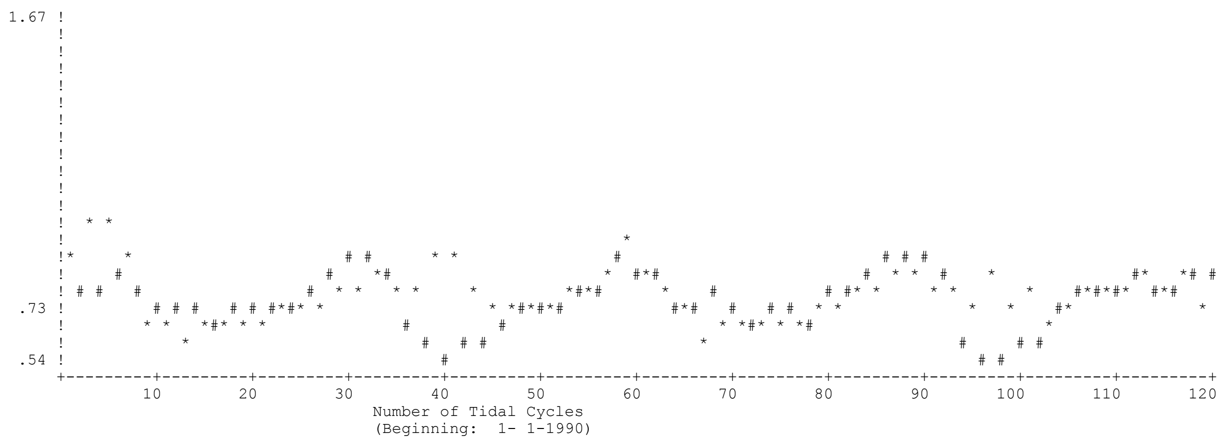
Slack B Ebb Time Differences   (hours)



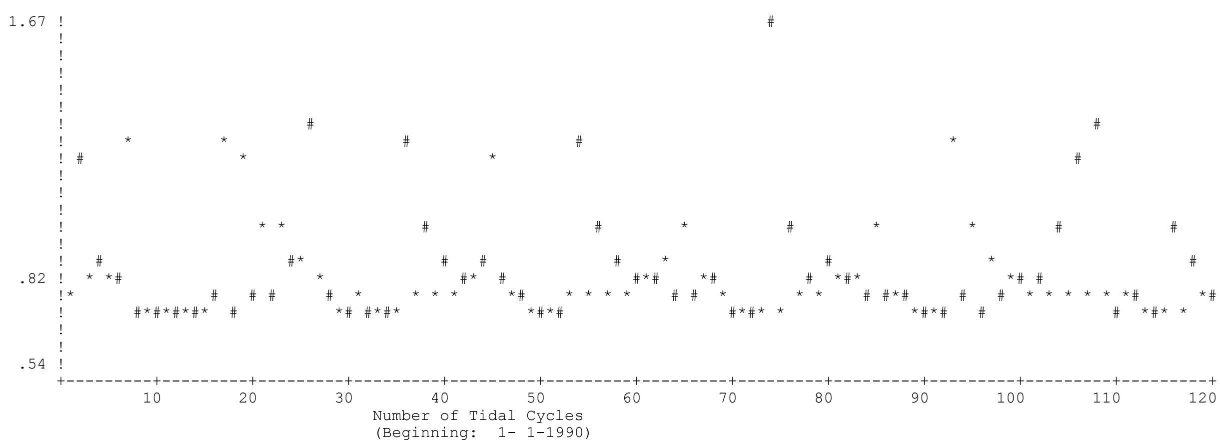
Maximum Ebb Time Differences (hours)



Maximum Flood Speed Ratios



Maximum Ebb Speed Ratios



7. ROTARY: THE ROTARY REDUCTION PROGRAM

7.1. Introduction

The rotary program relates tidal current vectors at a subordinate station to one component of the tidal current at a reference station. The data at the subordinate station are divided into periods corresponding to the reference station tidal cycles and sorted into time intervals after a designated phase (e.g. flood) at the reference station. The result is a series of mean current vectors showing the changing speeds and directions at the subordinate station during a complete tidal cycle.

The rotary program is dimensioned to analyze one year of data but all the data must be in the same year. The subordinate station data can be in the CDF file format or in a free format ASCII file (as decimal Julian day, speed, direction). The Julian day should be given to at least four decimal places to define the time to the nearest minute.

The reference station phase (SBF, MFC, SBE, or MEC) at the beginning of the tidal cycles must be chosen. To get accurate results for short time series, an integral number of tidal cycles should be used. This can be done by picking starting and ending dates and times from the reference station input file which is created by the program **ncp2**. If there is a significant diurnal inequality, an even number of tidal cycles should be analyzed, preferably starting and ending with the stronger flood or ebb.

7.2. Program Algorithm

The subordinate station data can be sorted into time intervals in one of four different ways depending on the parameters IEV1 and IEV2.

> If IEV1 is negative, an hourly rotary analysis is carried out in which the subordinate station data are placed in one of 13 different time periods from 0 to 12 hours after a specified tidal phase (e.g. flood) at the reference station. For tidal cycles longer than 13 hours, the data points after 13 hours are evenly divided between the last interval of one tidal cycle and the first interval of the next tidal cycle. This option works well only for semidiurnal or mainly semidiurnal tidal currents. (The results can be used in Table 5 of the Tidal Current Tables.)
>
> If IEV1 is 0, a half hourly rotary analysis is carried out in which the subordinate station data are placed in one of 26 different time periods from 0 to 12.5 hours after a specified tidal phase (e.g. flood) at the reference station. For tidal cycles longer than 13 hours, the data points after 13 hours are evenly divided between the last interval of one tidal cycle and the first interval of the next tidal cycle. This option works well only for semidiurnal or mainly semidiurnal tidal currents. (The results can be used in Table 5 of the Tidal Current Tables.)

If IEV1 is positive and IEV2 is 0, every tidal cycle at the reference station is divided into IEV1 intervals and the subordinate station data are placed in the appropriate time interval. IEV1 must be an even number less than or equal to 26. This option works for semidiurnal, mixed, or diurnal tidal currents.

If IEV1 is positive and IEV2 is positive, every tidal cycle at the reference station is divided into two half cycles (e.g. by SBF and SBE) which are in turn subdivided into IEV1 intervals and IEV2 intervals. The subordinate station data are placed in the appropriate time interval. IEV1 and IEV2 must both be even numbers whose total is less than or equal to 26. This option works for semidiurnal, mixed, or diurnal tidal currents.

The mean current vector at the subordinate station is calculated for each time interval. The mean current vectors are averaged to obtain the mean nontidal current. Then, for the half hour interval analysis only (IEV1=0), because 12.5 hours is beyond the 12.42-hour semidiurnal M_2 period, the data for 12.5 hours are combined with the data for 12 hours.

Next, an editing procedure is carried out to suppress the effects of noise on the results. IEDIT=0 is for strong tidal currents and IEDIT=1 is for weak tidal currents.

If the parameter IEDIT is set to 0, the high signal-to-noise editing procedure is performed. The first step is to remove speed outliers greater than two standard deviations from the mean speeds for each interval. Then, direction outliers are removed in a 3-step process narrowing the range of acceptable directions from 90° to 60° to 45°, recalculating the mean current vectors at each step. If less than 80% of the original data in an interval remains after the direction-editing step, the mean current vector after the speed-editing step is retained and is printed with a question mark. For a rectilinear tidal current, mean current vectors near slack times are small and likely to be labeled questionable.

If IEDIT is set to 1, the low signal-to-noise editing procedure is performed. Velocity outliers are removed vectorially in a 2-step process in which outliers greater than (1) the magnitude or (2) half the magnitude of the mean current vectors (or 25 cm/s whichever is greater) are removed, recalculating the mean current vectors at each step.

After editing is completed, the mean nontidal current is recalculated and is subtracted from each mean current vector to give the tidal components (north and east) and the tidal current vector for each time interval. A velocity correction factor is calculated by dividing the average of the mean maximum flood and ebb speeds at the reference station by the average of all the flood and ebb speeds at the reference station during the analysis period. The velocity correction factor is applied to the subordinate station tidal current vectors and the mean nontidal current is added back to get the total current vectors. The speeds and directions of the total current are plotted out versus time interval and as a polar plot.

Next, the maximum and minimum current time intervals are determined. A range of intervals (up to 4 before and up to 4 after the maximum current) is chosen where the speeds are within 5 cm/s of the maximum current. If the number of intervals is greater than three and the speeds do not uniformly decrease both before and after the maximum, the time of the maximum current is considered to be the midpoint of the range. Otherwise, a 3-point parabolic fit is applied to the maximum speed and the two adjacent speeds to more accurately obtain the time and the maximum speed. The direction of the maximum current is always obtained by taking the average of the maximum current direction with the two adjacent directions.

A secondary velocity maximum is found from the current vectors more than five intervals from the first and greater than 90° in direction from the first. The above process is repeated with the secondary maximum.

Next, the velocity minimum interval and the two intervals before and the two intervals after the minimum are considered. The minimum current vector is found by determining the shortest vector to one of the four line segments connecting the five points.

A secondary velocity minimum is found from the current vectors more than five intervals from the first. The above process is repeated for the secondary minimum.

A warning is printed if either minimum direction is closer than 45° to either maximum direction. Always check the choices for maximum and minimum currents on the speed and direction plots and on the polar plot to see if they make sense.

The program is run in a Unix environment as

rotary < rotary.ctl > rotout

where *rotary.ctl* is the control file and *rotout* is the output file. The output file *rotout* has to be formatted for printing by the Unix command **asa** as follows:

asa rotout > rotary.out

The file *rotary.out* has lines up to 132 characters long. The Unix command **lp -oc** can be used to print text in small letters.

7.3. Explanation of the Control File

The **rotary** control file is in the following format:

PPRED
JOBXXX IIN ITW2 NSPH ITYPE IEDIT IOUT NT
PPATH
IEV1 IEV2
JYR MBG IDBG TBG ITFMT
JYR MEND IDEND TEND ITFMT
TITEL
RTIM(1) RTIM(2) RTIM(3) RTIM(4) IHM IRTIM
REFVELF REFVELE

The numerical parameters are read in by **rotary** in free format.

Line #1

PPRED	Full pathname of input file containing reference station predictions created by the program **ncp2**. Times should be in local time. Speeds are in knots.

Line #2

JOBXXX	Number of jobs (lines 3 through 9 must be repeated for each job).
IIN = 0	For subordinate station input data in CDF format.
IIN = 1	For subordinate station input data in ASCII format (decimal Julian day, speed, and direction).
ITW2	Number of hours to add to reference station times to adjust them to subordinate station times. For example, if reference times are for 75° W and data are for 0° (GMT), then set ITW2 to 5. ITW2 will represent the difference in time meridians divided by 15° (the number of degrees in one time meridian).
NSPH	Number of samples per hour for subordinate station input data.
ITYPE= 1	For subordinate station input data in knots, results in knots.
ITYPE= 2	For subordinate station input data in cm/s, results in knots.
ITYPE= 3	For subordinate station input data in knots, results in cm/s.
ITYPE= 4	For subordinate station input data in cm/s, results in cm/s.
IEDIT = 0	Use editing procedure for strong tidal currents (first edit velocities, then edit directions).

IEDIT = 1	Use editing procedure for weak tidal currents (edit vectorially).
IOUT = 0	Only the first and last subordinate station input data points are printed.
IOUT = 1	All the input data points are printed.
IOUT = 2	All the input data points will be printed with four additional terms indicating which interval of which tidal cycle the data point is in.
NT = 0	No approximate running mean flow.
NT = 1	Gives approximate running mean flow (estimates nontidal current during each tidal cycle).

Line #3

PPATH	Full pathname of input file containing subordinate station observed data in CDF or ASCII format.

Line #4

IEV1 < 0	One reference time per tidal cycle and hourly intervals.
IEV1 = 0	One reference time per tidal cycle and half hourly intervals.
IEV1 > 0 and IEV2 = 0	One reference time per cycle and a selected number of even intervals # 26 (IEV1 = the number of intervals).
IEV1 > 0 and IEV2 > 0	Two reference times per cycle (i.e. Slack before Flood and Slack before Ebb) and an even number of intervals in each phase with the total number of intervals less than or equal to 26 (IEV1 = the number of intervals in the first phase, IEV2 = the number of intervals in the second phase).

Line #5

JYR	Year of the first data point to be analyzed (4 digits).
MBG	Month of the first data point to be analyzed.
IDBG	Calendar day of the first data point to be analyzed.
TBG	Time (local) of the first data point to be analyzed.
ITFMT ... 1	Time in decimal hours.
ITFMT = 1	Time in hours and minutes (HH.MM).

To ensure that only complete tidal cycles will be included in the analysis, choose the beginning time (e. g. a flood time) from the file PPRED such that it is after the first data point in PPATH. PPRED times should be local while PPATH times may be local or GMT.

Line #6

JYR — Year of the last data point to be analyzed (4 digits). Must be same as the starting year.

MEND — Month of the last data point to be analyzed.

IDEND — Calendar day of the last data point to be analyzed.

TEND — Time (local) of the last data point to be analyzed.

ITFMT ... 1 — Time in decimal hours.
ITFMT = 1 — Time in hours and minutes (HH.MM).

To ensure that only complete tidal cycles are included in the analysis, choose the end time (e. g. a flood time) from the file PPRED such that it is before the last data point in PPATH. PPRED times should be local while PPATH times may be local or GMT.

Line #7

TITEL — 80 character header for output file.

Line #8 — RTIM(1), RTIM(2), RTIM(3), RTIM(4), IHM, IRTIM

RTIM(1) — Reference station Greenwich interval for slack before flood (SBF).
RTIM(2) — Reference station Greenwich interval for flood (MFC).
RTIM(3) — Reference station Greenwich interval for slack before ebb (SBE).
RTIM(4) — Reference station Greenwich interval for ebb (MEC).

IHM = 0 — Time in decimal hours.
IHM = 1 — Time in hours and minutes (HH.MM).

IRTIM — Number corresponding to requested phase at begining of the tidal cycles. Pick 1 for tidal cycles to start at SBF, 2 for tidal cycles to start at MFC, 3 for tidal cycles to start at SBE, or 4 for tidal cycles to start at MEC.

If reference station Greenwich intervals are unknown, enter zeros for RTIM. Greenwich intervals will not be calculated for the subordinate station. However, the phase at the beginning of the tidal cycles (IRTIM) must still be specified.

Line #9

REFVELF — The reference station mean maximum flood current (MFC).

REFVELE — The reference station mean maximum ebb current (MEC).

Enter zeros if mean maximum flood and ebb currents are unknown. No correction factor will be applied.

7.4. Sample Input and Output Files

Sample reference station predictions file created by the program **ncp2** (*c2pred92*).

```
 0   0 1 1929999 251 -2.0 7051012  1.499991534  0.299992039  1.123229999 99.9  1
 0   0 2 1929999 332 -2.1 7451049  1.599991615  0.299992121  1.199999999 99.9  2
 0   0 3 192   3 409 -2.2 8201124  1.599991646  0.199992201  1.299999999 99.9  3
 0   0 4 192  42 444 -2.2 8531151  1.599991717  0.099992232  1.299999999 99.9  4
 0   0 5 192 120 516 -2.2 9221225  1.599991745 -0.199992307  1.299999999 99.9  5
 0   0 6 192 157 547 -2.1 9501257  1.599991815 -0.299992341  1.299999999 99.9  6
 0   0 7 192 234 620 -2.010151332  1.417181847 -0.320289999 99.999999999 99.9  7
 0   0 8 1929999  16  1.1 313 651 -1.910391401  1.317351923 -0.521239999 99.9  8
 0   0 9 1929999  59  0.9 355 726 -1.611011430  1.217552000 -0.622279999 99.9  9
 0   010 1929999 152  0.8 443 801 -1.311211500  1.118182043 -0.823499999 99.9 10
```

Sample control file (*rotary.ctl*).

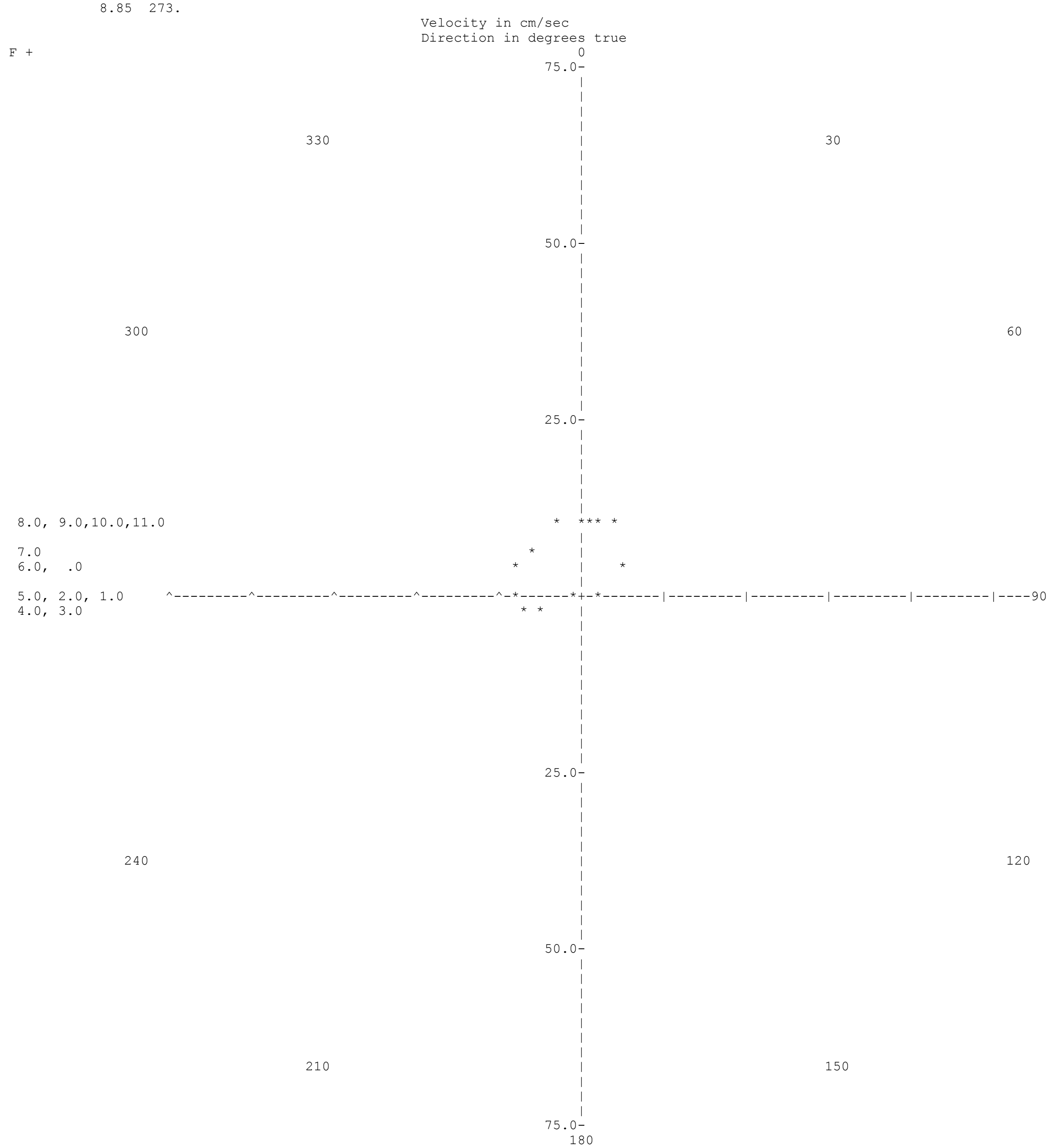
```
c2pred92                               ! Reference station predictions file
   1   1   0   6   4   0   0   0       ! Subordinate station data parameters
c1spdr                                 ! Subordinate station data file
   -1    0                             ! Sorting parameters IEV1 and IEV2
1992   11   30 16.17     1             ! First point for analysis & hour format
1992   12   29  1.49     1             ! Last point for analysis & hour format
Referenced to Maximum Flood Current at Inner Egmont Channel
   1.28   4.25   7.19  10.20   0   2   ! Greenwich Ints, hr frmt, & begin cycle
   1.30  1.34                          ! Reference station MFC and MEC
```

Sample output file (*rotary.out*).

```
 jobs=    1 iin =    1 itape =    1 itw2 =    0 nsph =    6 itype =    4 isave=    0
iedit =    0 zzmax =9999.00000 iout=    0 nt=    0 iev1 =    0 iev2 =    0

Begin  1992   11   30 16.28
End    1992   12   29  1.82

Referenced to Maximum Flood Current at Inner Egmont Channel
Reference Station Greenwich Intervals
 1.28    4.25*   7.19   10.20

Mean Max Flood and Ebb Speeds at Reference Station =  1.30 1.34

itwdy =   56, ivels=   98

F Times
1617.  331. 1701.  458. 1747.  621. 1827.  741. 1909.  847. 1951.  939. 2032. 1020. 2105. 1057.
2139. 1139. 2212. 1221. 2251. 1307. 2328. 1352.   15. 1440.  124. 1525.  249. 1611.  417. 1654.
 548. 1741.  719. 1827.  841. 1921.  939. 2010. 1027. 2101. 1106. 2143. 1143. 2223. 1220. 2256.
1257. 2333. 1329.   10. 1406.   53. 1443.  149.

F Times
 16.3  3.5 17.0  5.0 17.8  6.3 18.5  7.7 19.1  8.8 19.9  9.6 20.5 10.3 21.1 10.9
 21.6 11.6 22.2 12.4 22.9 13.1 23.5 13.9   .3 14.7  1.4 15.4  2.8 16.2  4.3 16.9
  5.8 17.7  7.3 18.5  8.7 19.4  9.6 20.2 10.4 21.0 11.1 21.7 11.7 22.4 12.3 22.9
 12.9 23.5 13.5   .2 14.1   .9 14.7  1.8

Flood and Ebb Speeds
  1.1   .1   .5  1.1  1.0   .3   .4   .7  1.0   .6   .5   .5  1.0  1.0   .7   .3
  1.0  1.3  1.0   .2  1.0  1.7  1.3   .1  1.0  2.0  1.5  1.1  2.3  1.7  1.2  2.5
  1.8  1.3  2.6  1.8  1.3  2.7  1.8  1.3  2.6  1.7   .1  1.2  2.4  1.6   .2  1.0
  2.0  1.5   .4   .8  1.5  1.4   .7   .7  1.0  1.3  1.0   .7   .5  1.3  1.4   .9
   .2  1.2  1.8  1.2  1.2  2.1  1.5  1.2  2.3  1.6  1.2  2.5  1.7  1.3  2.5  1.7

  1.3  2.4  1.7  1.3  2.4  1.6  1.2  2.2  1.5   .1  1.1  2.0  1.4   .2   .9  1.7
  1.3   .4


nskip =48194

   Date              Speed   Components
Da Mo Year Hour  Dir (cm/sec)   N     E

30 11 1992 16.33  54   5.02   2.95   4.06    First data point


29 12 1992  1.83  31   3.58   3.07   1.85    Last data point       4090

Mean Components
      Hour      N      E       Vel  Dir      X    Component Velocities in cm/sec
 F +   .00    3.66    5.59      6.68   57.    400
 F +  1.00    -.24    2.40      2.42   96.    331
 F +  2.00   -2.53   -1.59      2.99  212.    330
 F +  3.00   -3.38   -5.67      6.60  239.    330
 F +  4.00   -2.47   -8.78      9.12  254.    330
 F +  5.00     .07  -10.23     10.23  270.    330
 F +  6.00    3.63   -9.71     10.36  291.    330
 F +  7.00    7.20   -7.30     10.25  315.    330
 F +  8.00    9.64   -3.79     10.36  339.    330
 F +  9.00   10.30    -.40     10.31  358.    330
 F + 10.00   10.02    1.36     10.11    8.    294
 F + 11.00   11.03    2.26     11.26   12.    199  X = Number of data points in the
 F + 12.00    9.78    5.57     11.26   30.    226      respective time interval.
                                                 Nontidal Components  Nontidal Current
                                                         N     E          Vel    Dir
                                                      4.36  -2.33       4.95    332.
Eliminated data  -  Velocities
Eliminated data  -  Directions

With bad data eliminated
Mean Components                                Directions    Velocities
                N      E       Vel  Dir      X Percent    X  Percent
 F +   .00    3.58    6.04      7.02   59.    353  88.     386   96.
 F +  1.00    -.36    2.24      2.27   99.?   196  59.     316   95.
 F +  2.00   -2.26   -1.34      2.63  211.?   179  54.     315   95.
 F +  3.00   -3.49   -5.85      6.81  239.    271  82.     325   98.
 F +  4.00   -2.47   -8.78      9.12  254.?   247  74.     330  100.
 F +  5.00     .07  -10.23     10.23  270.?   196  59.     330  100.
 F +  6.00    3.63   -9.71     10.36  291.?   180  54.     330  100.
 F +  7.00    7.20   -7.30     10.25  315.?   171  51.     330  100.
 F +  8.00    9.65   -3.68     10.33  339.?   168  50.     328   99.
 F +  9.00   10.29    -.36     10.30  358.?   177  53.     329   99.
 F + 10.00   10.03    1.36     10.13    8.?   208  70.     293   99.
 F + 11.00   11.62    2.18     11.82   11.    189  94.     195   97.
 F + 12.00   10.14    5.88     11.72   30.    218  96.     218   96.
                                                 Nontidal Components  Nontidal Current
                                                         N     E          Vel    Dir
                                                      4.43  -2.27       4.98    333.
```

```
Tidal Components
      Hour      N      E
 F +   .00    -.86   8.31
 F +  1.00   -4.79   4.51
 F +  2.00   -6.70    .93
 F +  3.00   -7.92  -3.58
 F +  4.00   -6.90  -6.50
 F +  5.00   -4.36  -7.95
 F +  6.00    -.80  -7.43
 F +  7.00    2.77  -5.03
 F +  8.00    5.22  -1.41
 F +  9.00    5.86   1.91
 F + 10.00    5.60   3.64
 F + 11.00    7.19   4.45
 F + 12.00    5.71   8.15

Tidal Current
                                                                                                    Velocity in cm/sec
                                                                                                    Direction in degrees true

      Hour  Vel  Dir
 F +   .00  8.36  96.
 F +  1.00  6.58 137.
 F +  2.00  6.76 172.
 F +  3.00  8.69 204.
 F +  4.00  9.48 223.
 F +  5.00  9.07 241.
 F +  6.00  7.48 264.
 F +  7.00  5.74 299.
 F +  8.00  5.40 345.
 F +  9.00  6.16  18.
 F + 10.00  6.68  33.
 F + 11.00  8.45  32.
 F + 12.00  9.95  55.
                                          Velocity Correction Factor
                                          1.32/1.37 =  .97

Tidal Current
Corrected Velocities
                                                Velocity                                               Direction
                               25        50        75       100          0        100       200        300   360
      Hour  Vel  Dir __________^_________^_________^_________^_________ __________^_________^_________^_____^
 F +   .00  8.08  96.|  +                                                |         *
 F +  1.00  6.36 137.| +                                                 |             *
 F +  2.00  6.53 172.| +                                                 |                *
 F +  3.00  8.40 204.|  +                                                |                   *
 F +  4.00  9.17 223.|  +                                                |                     *
 F +  5.00  8.77 241.|  +                                                |                       *
 F +  6.00  7.23 264.| +                                                 |                         *
 F +  7.00  5.55 299.| +                                                 |                             *
 F +  8.00  5.22 345.| +                                                 |                                 *
 F +  9.00  5.96  18.| +                                                 | *
 F + 10.00  6.45  33.| +                                                 |  *
 F + 11.00  8.17  32.|  +                                                |  *
 F + 12.00  9.62  55.|  +                                                |     *

Referenced to Maximum Flood Current at Inner Egmont Channel
Ref. Station Greenwich Intervals --   SBF    MFC    SBE    MEC
                                      1.28   4.25*  7.19  10.20
                                    ( * Indicates G.I. of first ref.time read in)
                                                                                                    Velocity in cm/sec
                                                                                                    Direction in degrees true
Total Current
                                                Velocity                                               Direction
                               25        50        75       100          0        100       200        300   360
      Hour Vel  Dir  __________^_________^_________^_________^_________ __________^_________^_________^_____^
 F +   .00  6.80  58.| +                                                 |     *
 F +  1.00  2.10  95.|+                                                  |         *
 F +  2.00  2.46 214.|+                                                  |                    *
 F +  3.00  6.58 241.| +                                                 |                       *
 F +  4.00  8.85 255.|  +                                                |                         *
 F +  5.00  9.96 271.|  +                                                |                          *
 F +  6.00 10.14 291.|   +                                               |                            *
 F +  7.00 10.07 315.|   +                                               |                              *
 F +  8.00 10.15 339.|   +                                               |                                 *
 F +  9.00 10.11 358.|   +                                               |                                   *
 F + 10.00  9.93   7.|  +                                                |*
 F + 11.00 11.56  10.|   +                                               |*
 F + 12.00 11.42  29.|   +                                               |  *

                                          Maximum Observed Current
                                                Vel   Dir
                                              25.98   258                     Nontidal Current
                                                                                 Vel    Dir
                                                                                4.98   333.
```

```
Maximum at  F +  9.71 ( G.I. = 1.54 )
  Vel  Dir
11.56    5.

Maximum at  F +  5.50 ( G.I. = 9.75 )
  Vel  Dir
 8.85  273.
```




```
Minimum at  F +  1.45 ( G.I. = 5.70 )
  Vel  Dir
 1.15  152.

Minimum at  F +  7.46 ( G.I. =11.71 )
  Vel  Dir
 9.89  326.
CHECK MINIMUM BY HAND.
```

8. UTILITY PROGRAMS

8.1. Calculation of the Principal Current Direction

Before the harmonic analysis of current data can be carried out, the principal current direction must be determined. Tidal constituents can then be determined for components parallel and perpendicular to the principal current direction. Currents in restricted bodies of water such as bays and estuaries are generally rectilinear; the current is directed toward one of two opposite directions (flood and ebb), except during slack periods when the current is near zero. Such currents are also called reversing, although the flood and ebb directions for a reversing current do not have to be 180° apart.

In large bodies of water, strong currents can flow unrestricted in any direction and a polar plot may not show a clear directionality. Tidal currents in the oceans are generally rotary; that is, they rotate clockwise or counter-clockwise passing through two maxima and two minima in approximately opposite directions. It may be difficult to estimate the principal current direction with precision unless the major current axes of each of the tidal constituents are aligned with each other and the minor current axes are significantly smaller than the major current axes. Furthermore, when tidal currents are weak, nontidal currents can be as large as the tidal currents and can flow in any direction. If the nontidal currents tend to flow in different directions than the tidal current, the calculated principal current direction may be strongly affected by the nontidal current.

The east (u) and north (v) velocity components of a current make up a bivariate data set. The principal angle for a bivariate data set can be calculated as described by Preisendorfer (1988). Given the following variances and covariance calculated for the data

$$s_{uu} = \frac{1}{n-1} \sum_{i=1}^{n} [u_i - \bar{u}]^2 \qquad \textbf{(1)}$$

$$s_{vv} = \frac{1}{n-1} \sum_{i=1}^{n} [v_i - \bar{v}]^2 \qquad \textbf{(2)}$$

$$s_{uv} = \frac{1}{n-1} \sum_{i=1}^{n} [u_i - \bar{u}][v_i - \bar{v}] \qquad \textbf{(3)}$$

where the mean currents are

$$\bar{u} = \frac{1}{n} \sum_{i=1}^{n} u_i \quad \text{and} \quad \bar{v} = \frac{1}{n} \sum_{i=1}^{n} v_i \ , \qquad \textbf{(4)}$$

the principal angle 2 (counter-clockwise from east) is obtained from

$$\tan 2\theta = \frac{2s_{uv}}{s_{uu} - s_{vv}} \quad . \qquad \textbf{(5)}$$

The correlation coefficient r_{uv}, a measure of the directionality of the current, is

$$r_{uv} = \frac{s_{uv}}{s_{uu}^{1/2} s_{vv}^{1/2}} \quad . \qquad \textbf{(6)}$$

If a new set of basis vectors are set up parallel and perpendicular to the principal angle, the two principal variances are

$$s_{11} = \frac{1}{2}[(s_{uu} + s_{vv}) + [(s_{uu} - s_{vv})^2 + 4s_{uv}^2]^{\frac{1}{2}}] \qquad \textbf{(7)}$$

$$s_{22} = \frac{1}{2}[(s_{uu} + s_{vv}) - [(s_{uu} - s_{vv})^2 + 4s_{uv}^2]^{\frac{1}{2}}] \qquad \textbf{(8)}$$

and the principal covariance is

$$s_{12} = 0 \quad . \qquad \textbf{(9)}$$

The principal current direction program is called **prcmp**. The program is dimensioned for 120000 points which are read in from a free format ASCII file. The columns of the input file are either (time in decimal Julian days, speed, direction) or (time in decimal Julian days, u component, v component).

The program is run interactively as follows, with gray shading indicating user input:

```
 Input filename --->
c2.sd
 Is data (speed,direction) (1) or (u,v) (2) ?
1

 Mean velocity --- Speed   4.7455 Direction 133.24

 Correlation coefficient =  -.955792
 Principal current direction =  121.0393 degrees (true)

 Major axis variance =  2751.4961      98.2492 %
 Minor axis variance =    49.0328       1.7508 %

 Major axis standard deviation =    52.4547
 Minor axis standard deviation =     7.0023
```

The output is also printed in a file named *vel.lst* as shown below.

```
Number of data points =  9500

U-compoment mean velocity & 95% confidence interval  3.4572  2.5504  4.3640
V-component mean velocity & 95% confidence interval -3.2508 -3.8080 -2.6936

Mean velocity --- Speed   4.7455 Direction 133.24

Correlation coefficient =  -.955792
Principal current direction =  121.0393 degrees (true)

Major axis variance =  2751.4961      98.2492 %
Minor axis variance =    49.0328       1.7508 %

Major axis standard deviation =    52.4547
Minor axis standard deviation =     7.0023
```

The mean u and v velocities are printed with 95% confidence intervals. If both of the confidence intervals include zero, a warning will be printed indicating that the mean current is not significantly different than zero. The principal current direction is in degrees clockwise from north. It may be either the flood or the ebb direction. If it is in the ebb direction, add or subtract 180° to give it the flood direction.

The correlation coefficient and the major and minor axis variances indicate the directionality of the current. If the minor axis variance is less than 20%, the current can be characterized as rectilinear. Harmonic analysis should be carried out parallel and perpendicular to the principal current direction. If the minor axis variance is greater than 20%, there are significant currents perpendicular to the principal current direction. The current may be rotary or it may be reversing with flood and ebb directions not close to 180° apart. Given the imprecision of the principal current direction, harmonic analysis should be done along 0° and 90° (north and east).

8.2. Finding Gaps in a Time Series

To find all the gaps greater than a specified time period in a time series, run the program **gap**. The first column in the input file should be the time in decimal Julian days. The program is run interactively as follows, where gray shading indicates user input.

```
 Input filename
c2.det
 Enter year of first data point
1990
 Search for gaps greater than ? (in hours)
.25
```

The output is printed in a file named *gaps* as shown below. This output is useful for setting up the control file for a least squares harmonic analysis using **lsqha**.

```
Gaps in  c2.det

First point         1990   231  8/19 13:30

                                                    9585 continuous
points
298 10/25  2:50      to     300 10/27 17:20       62.501 hour gap
                                                    8840 continuous
points
362 12/28  2:30      to       2  1/ 2 13:13      130.717 hour gap
                                                    8917 continuous
points
 64  3/ 5 11:13      to      71  3/12 18: 0      174.782 hour gap
                                                   11067 continuous
points
148  5/28 14:20      to     148  5/28 16:20        2.001 hour gap
                                                    6031 continuous
points

Last  point         1991   190  7/ 9 13:20
```

8.3. Averaging Multiple Sets of Tidal Constituents

The Fourier harmonic analysis programs **harm29** or **harm15** may have been used to analyze several 29 or 15 day periods during a single or multiple deployments of an instrument. Multiple sets of tidal constituents can be vectorially averaged by using the program **avcons**.

The input file can consist of up to 30 sets of tidal constituents in standard predictions format. For a scalar variable such as water levels, each set has nine lines consisting of a two line header, a line containing the mean value and six lines containing amplitudes and phases of 37 tidal constituents. For a vector variable such as currents, each set consists of two such groups (the first for the major axis and the second for the minor axis). The following is an input file for tidal current constituents created by concatenating 12 sets of tidal current constituents.

```
ADCP STATION  Inner Egmont AT    18 ABOVE BOT.
29-DAY H.A. BEGINNING   1- 3-91  AT HOUR   .13
  -395
       152820331718335346411938324533970245 4 2488 592300282519  436 459
       2    0   0 21023336    0   0 23163255  5212650    0   0 15883173
       3 12912388  3703386    0   0 21322486 23722421    0   0    0   0
       4    0   0    0   0    0   0 11412548 58252552 10823459  1473470
       5  7812585112442459    0   0    0   0 17073191    0   0 49873476
       6  4633152    0   0
ADCP STATION  Inner Egmont AT    18 ABOVE BOT.
29-DAY H.A. BEGINNING   1- 3-91  AT HOUR   .13
  -452
       1  6702425  8073024  359 335 15491239  257 902 15971608  3993314
       2    0   0  3152143    0   0   70 133  2191372    0   0   481845
       3   69 871    52703    0   0  1131424  1261057    0   0    0   0
       4    0   0    0   0    0   0   611766  3101791   483000    63048
       5   421974  5131267    0   0    0   0   51 281    0   0  2203073
       6  1682654    0   0
ADCP STATION  Inner Egmont AT    18 ABOVE BOT.
29-DAY H.A. BEGINNING   2- 2-91  AT HOUR   .13
    -4
       154061333521437343910664321537350245 2 1946 653303722474  7151506
       2    0   0 25083205    0   0 20693231  2041598    0   0 14183096
       3 13062430  3783383    0   0 21562463 23992441    0   0    0   0
       4    0   0    0   0    0   0 11542483 58922485 12653435  1713443
       5  7902495123632454    0   0    0   0 15253161    0   0 58313447
       6  2012218    0   0
ADCP STATION  Inner Egmont AT    18 ABOVE BOT.
29-DAY H.A. BEGINNING   2- 2-91  AT HOUR   .13
  -233
       1 12863184  3432875  846 666 17891151  6251581  7581431  550 587
       2    0   0  1361392    0   0  164 521  1832058    0   0  1131747
       3   33 872    93041    0   0   541291   601013    0   0    0   0
       4    0   0    0   0    0   0   291551  1471569   202887    32862
       5   201708  5921172    0   0    0   0  121 611    0   0   932850
       6  144 604    0   0
```

etc.

The program is run interactively as follows, where gray shading indicates user input.

```
 Enter the Input constituents file
c2cons
 Enter the averaged output constituents file
c2cons.avg
 type 1 for scalar constituents (water levels) or 2 for
 vector constituents (major axis and minor axis currents)
2
 Major axis (flood direction)?
118
```

The following is a sample output file for tidal current constituents.

```
Average of 12 sets of harmonic analysis constituents
Major axis component (along 118 degrees)
  1803
       1535253359189063417102123287316512514 2480 176267482446  1172146
       2    0    0 10122748    0    0 19843297   991893    0    0 13333214
       3 11232585  3743384    0    0 19062481 20952549    0    0    0    0
       4    0    0    0    0    0    0 10082417 51402412 11163415  1513419
       5  6782378104852509    0    0    0    0 14603233    0    0 51353422
       6  2663049    0    0
Average of 12 sets of harmonic analysis constituents
Minor axis component (along 208 degrees)
   101
       1 25082640  9432652  4152418 16771249  4103216 13641104  4793204
       2    0    0   962871    0    0   902472  1641617    0    0   382241
       3   441395   172654    0    0  1051178  1031317    0    0    0    0
       4    0    0    0    0    0    0   451029  2201014   572651    72648
       5   22 891  5601240    0    0    0    0   592364    0    0  2442655
       6  1571800    0    0
```

8.4. NCP2: The Reversing Current Predictions Program

ncp2 predicts the timing and speed of tidal current phases using constituents along the major axis for Table 1 of the NOS Tidal Current Tables. The original program has been documented in greater detail by Pore and Cummings (1967). The program accesses an ASCII file which contains astronomical tidal parameters for each year from 1901 to 2025. To run **ncp2** in a Unix environment:

ncp2 - < inputfile

Sample inputfile:

```
 C-2    INNER EGMONT CHANNEL   8/20/90 - 9/22/91
    35 1 3 1
       1 10373360  3673418  1983288  6142515   48 173  5192446    22059
       2    0   0   202747    0   0   393299    21979    0   0   263214
       3   222585    73384    0   0   372481   412549    0   0    0   0
       4    0   0    0   0    0   0   202417  1002413   223416    33420
       5   132378  2032510    0   0    0   0   283234    0   0  1003423
       6    53064    0   0
1994

   0   0   0
```

The first line gives station identifying information. The second line begins with the mean current (knots) in the format f6.3, followed by three parameters (format 3i2) set to 1 3 1. The next six lines contain the constituents in standard predictions format (knots and kappa prime) obtained from a harmonic analysis program. The next line contains the year for which predictions are to be made (format i4). The next line is blank if the whole year is to be predicted. The last line is three zeros in the format 3i4. Output will be in a file named *13*. Output times are in local time and velocities are in knots. Times of 9999 and velocities of 99.9 are used as filler. The program will indicate if there are any "trouble days". This occurs when there are more than five floods and ebbs in a day. The user must decide which phase(s) to edit out to reduce the number of floods and ebbs to five for that day.

Sample output file *13*:

```
 0   0 1 1949999  34  1.1 330 713 -2.110551421  1.617561948 -0.622059999 99.9  1
 0   0 2 1949999 139  1.0 424 748 -1.811281459  1.518262041 -0.823359999 99.9  2
 0   0 3 1949999 254  0.8 529 837 -1.312011544  1.419002139 -1.099999999 99.9  3
 0   0 4 194 121 419  0.7 652 934 -0.812301629  1.319392255 -1.299999999 99.9  4
 0   0 5 194 302 548  0.8 8541048 -0.312541720  1.220269999 99.999999999 99.9  5
 0   0 6 1949999  12 -1.6 426 718  0.999991219  0.099991814  1.221189999 99.9  6
 0   0 7 1949999 118 -1.9 533 839  1.299991341  0.199991918  1.222129999 99.9  7
 0   0 8 1949999 215 -2.2 630 938  1.599991455  0.199992020  1.223049999 99.9  8
 0   0 9 1949999 308 -2.4 7201026  1.799991556  0.199992111  1.323549999 99.9  9
 0   010 1949999 355 -2.5 8031105  1.899991639  0.099992158  1.499999999 99.9 10
```

8.5. NTP4: The Tide Predictions Program

ntp4 predicts the timing and height of the tides for Table 1 of the NOS Tide Tables. The original program has been documented in greater detail by Pore and Cummings (1967). The program accesses an ASCII file which contains astronomical tidal parameters for each year from 1901 to 2025. To run **ntp4** in a Unix environment:

ntp4 - inputfile

Sample inputfile:

```
 CLEARWATER BEACH   E724
  3363 1 3 1 1
       1  7983386  3063516  1553363  5132967   291515  4822942    6 304
       2   101342    82817   111361   353247    12201    73308   373312
       3   212909    5 531   47 186   232877   313023    0   0   92 627
       4  2811474    0   0    0   0   252737  1002853   153221    72810
       5    72536  1702949   102784   12 773   143550   17 887   853446
       6    12006   201671
1990

   0   0   0
```

The first line gives station identifying information. The second line begins with the datum (mean sea level - mean lower low water in feet) in the format f6.3, followed by four parameters (format 4i2) set to 1 3 1 1. The next six lines contain the constituents in standard predictions format (feet and kappa prime) obtained from a harmonic analysis program. The next line contains the year for which predictions are to be made (format i4). The next line is blank if the whole year is to be predicted. The last line is three zeros in the format 3i4. Output will be in a file named *13*. Output times are in local time and water levels are in feet. Times of 9999 and water levels of 99.9 are used as filler. The program will indicate if there are any "trouble days". This occurs when there are more than five high and low waters in a day. The user must decide which phase(s) to edit out to reduce the number of high and low waters to five for that day.

Sample output file *13*:

```
90    0  1  190  102  4.4  820  1.6 1458  3.8 2020  2.6 9999 99.9            1
90    0  2  190  159  4.1  855  1.9 1532  3.9 2126  2.4 9999 99.9            2
90    0  3  190  312  3.7  927  2.2 1605  4.1 2248  2.2 9999 99.9            3
90    0  4  190  439  3.4 1003  2.6 1647  4.2 9999 99.9 9999 99.9            4
91    0  5  190   18  1.9  635  3.2 1051  2.9 1737  4.4 9999 99.9            5
91    0  6  190  134  1.6  901  3.2 1207  3.1 1837  4.5 9999 99.9            6
91    0  7  190  243  1.3 1030  3.4 1331  3.2 1943  4.6 9999 99.9            7
91    0  8  190  341  1.0 1115  3.5 1443  3.2 2048  4.8 9999 99.9            8
91    0  9  190  431   .8 1154  3.5 1539  3.1 2140  4.9 9999 99.9            9
91    0 10  190  516   .8 1221  3.5 1627  3.0 2229  4.9 9999 99.9           10
```

8.6. Converting the Format of Tidal Current Constituents

Convert is an program designed to produce output files in the format required by the Products and Services Division. The harmonic analysis programs **harm29**, **harm15**, and **lsqha** produce output files with tidal constituents in standard predictions format parallel and perpendicular to the principal current direction. However, the constituent amplitudes may be in cm/s and the phases will be modified local epochs (6'). PSD requires that the constituents be delivered with the amplitudes in knots and the phases as local epochs (6).

The input file for **convert** consists of the *cons.out* file created by the harmonic analysis programs with tidal current constituents parallel and perpendicular to the principal current direction. Three output files are created by **convert** distinguished by the extensions **.kap*, **.kpr*, and **.elp*.

The first output file (**.kap*) contains the constituents in standard predictions format in knots and local epochs (6). The second output file (**.kpr*) contains the constituents in standard predictions format in knots and modified local epochs (6'). This file is useful for running the tidal current prediction program **ncp2**.

The third output file (**.elp*) contains the constituents in an easy-to-read tabular format in knots and local epochs (6) parallel and perpendicular to the principal current direction and parallel and perpendicular to the major axis of each constituent's tidal ellipse. It also contains the name of the project, the station number and name, the station location, the bottom depth and analysis depth, the principal current direction, the speed and direction of the permanent current, and a table of Greenwich intervals.

The following pages show sample input and output files and how to run the program interactively. It is important that the longitude of the station, the time meridian of the station, and the principal current direction be correct when running **convert** for the local epochs (6) to be calculated accurately. The other information requested by **convert** can be filled in with any numbers if unknown and changed later by editing the **.elp* file.

Interactive execution of the program is shown below. Gray shading indicates user input.

```
 Enter the Input constituents file
02cons
 Enter the averaged output constituents file
egmont
 Enter the name of the project
Tampa Bay Oceanography Project
 Enter the station number, name, and time period
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
 Enter station location as -- latitude degrees, decimal
 minutes, (west) longitude degrees, decimal minutes
27 36.26 82 45.62
 Enter time meridian (75 for EST, 90 for CST, 120 for PST)
75
 Enter the bottom depth and depth of station below mllw (feet)
82.9 15
```

```
 Enter the principal current direction (no decimal)
118
 Are input tidal constituents already in knots (y or n)?
n
 Enter the computed Greenwich Intervals (hours) in this order:
 Slack before flood, flood, slack before ebb, ebb
1.28 4.25 7.19 10.20
 Enter the mean speeds (cm/s) in the same order
1.492 67.186 3.550 68.884
 Enter the mean directions (degrees) in the same order
203 120 32 298
```

Alternatively, the program **convert** can also be run with the following control file.

```
02cons                                    ! Input constituents file
egmont                                    ! Averaged output constituents file
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
27 36.26   82 45.62                       ! Station location: Lat, Long (deg, min)
75                                        ! Time meridian (75 for EST,120 for PST)
82.9   15.                                ! Bottom depth and analysis depth
118                                       ! Principal current direction
n                                         ! Tidal cons. already in knots (y,n)?
1.28   4.25   7.19   10.20                ! Greenwich intervals (SBF,MFC,SBE,MEC)
1.492   67.186   3.550   68.884           ! Mean speeds in cm/s (SBF,MFC,SBE,MEC)
203   120   32   298                      ! Mean directions (SBF,MFC,SBE,MEC)
```

Sample *.*kap* output file (*egmont.kap*):

```
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
    35
       1 10403153  3683262  1993054  6152439   483364  5202316    21528
       2    0    0   202437    0    0   393067    21428    0    0   262954
       3   222564    73202    0    0   372378   412501    0    0    0    0
       4    0    0    0    0    0    0   202263  1002254   223258    33266
       5   132193  2042429    0    0    0    0   283054    0    0  1003271
       6    52225    0    0
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
     2
       1   492434   182497    82185   331173    82804   27 973    92586
       2    0    0    22560    0    0    22242    31152    0    0    11980
       3    11375    0    0    0    0    21075    21269    0    0    0    0
       4    0    0    0    0    0    0    1 875    4 857    12494    0    0
       5    0    0   111161    0    0    0    0    12185    0    0    52504
       6    3 976    0    0
```

SAMPLE **.KPR* OUTPUT FILE (*EGMONT.KPR*):

```
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
    35
       1 10403359  3683417  1993287  6152514   48 176  5202446    22146
       2    0   0   202748    0   0   393297    21893    0   0   263214
       3   222585    73384    0   0   372481   412549    0   0    0   0
       4    0   0    0   0    0   0   202417  1002412   223415    33419
       5   132378  2042509    0   0    0   0   283233    0   0  1003422
       6    53049    0   0
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
     2
       1   492640   182652    82418   331249    83216   271104    93204
       2    0   0    22871    0   0    22472    31617    0   0    12241
       3    11395    0   0    0   0    21178    21317    0   0    0   0
       4    0   0    0   0    0   0    11029    41014    12651    0   0
       5    0   0   111240    0   0    0   0    12364    0   0    52655
       6    31800    0   0
```

Sample **.elp* output file (*egmont.elp*):

```
Tampa Bay Oceanography Project
C-2   Inner Egmont Channel   8/20/90 - 9/22/91
Location:   27 36.26 N   82 45.62 W
Bottom Depth = 82.9 feet below MLLW             Analysis for 15.0 feet below MLLW
Principal Current Direction = 118 degrees(true)
Permanent Current =  .035 knots at 121 degrees(true)

              Major Ellipse Axis        Minor Ellipse Axis       118 Axis      208 Axis
Constituent  Dir   Amp(kts)  Phase     Dir   Amp(kts)  Phase    H(A)  Kappa   H(A)  Kappa

M(2)        118.8  1.041     315.3     208.8  .046     225.3   1.040   315.3  .049   243.4
S(2)        118.7   .368     326.2     208.7  .018     236.2    .368   326.2  .018   249.7
N(2)        118.1   .199     305.4     208.1  .008     215.4    .199   305.4  .008   218.5
K(1)        116.2   .616     243.9     206.2  .026     153.9    .615   243.9  .033   117.3
M(4)        123.4   .048     335.7     213.4  .007     245.7    .048   336.4  .008   280.4
O(1)        116.0   .520     231.6     206.0  .019     141.6    .520   231.6  .027    97.3
M(6)         32.0   .009      79.5     122.0  .002     169.5    .002   152.8  .009   258.6
S(4)        123.3   .020     243.8     213.3  .000     333.8    .020   243.7  .002   256.0
Nu(2)       118.3   .039     306.7     208.3  .002     216.7    .039   306.7  .002   224.2
S(6)        178.2   .004     122.2     268.2  .001      32.2    .002   142.8  .003   115.2
2N(2)       117.8   .026     295.4     207.8  .001     205.4    .026   295.4  .001   198.0
OO(1)       116.9   .022     256.4     206.9  .001     166.4    .022   256.4  .001   137.5
Lambda(2)   118.8   .007     320.1     208.8  .000     230.1    .007   320.2  .000   247.1
M(1)        116.0   .037     237.9     206.0  .002     147.9    .037   237.8  .002   107.5
J(1)        116.5   .041     250.2     206.5  .002     160.2    .041   250.1  .002   126.9
Rho(1)      116.1   .020     226.3     206.1  .001     136.3    .020   226.3  .001    87.5
Q(1)        116.1   .100     225.5     206.1  .003     135.5    .100   225.4  .004    85.7
T(2)        118.7   .022     325.8     208.7  .001     235.8    .022   325.8  .001   249.4
R(2)        118.6   .003     326.6     208.6  .000     236.6    .003   326.6  .000   249.5
2Q(1)       116.4   .013     219.3     206.4  .000     129.3    .013   219.3  .000    70.6
P(1)        116.2   .204     243.0     206.2  .009     153.0    .204   242.9  .011   116.1
L(2)        118.1   .028     305.4     208.1  .001     215.4    .028   305.4  .001   218.5
K(2)        118.6   .100     327.0     208.6  .005     237.0    .100   327.1  .005   250.4
M(8)         95.1   .006     232.7     185.1  .002     142.7    .005   222.5  .003    97.6

                   Greenwich Interval (hours)     Mean Speed (knots)       Mean Direction
Slack Before Flood            1.28                        .029                  203
Flood                         4.25                       1.306                  120
Slack Before Ebb              7.19                        .069                   32
Ebb                          10.20                       1.339                  298
```

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The following table gives the names of the original authors of the computer programs described in this document and those who have revised the programs over the years.

Program	**Original Author(s)**	**Revisions**
LSQHA	D. Harris, N. Pore, R. Cummings	E. Long, J. Fancher, B. Parker, L. Hickman, G. French, C. Zervas
HARM29 and HARM15	R. Dennis, E. Long	B. Parker, L. Hickman, C. Zervas
PRED	N. Pore, R. Cummings	B. Parker, G. French, L. Hickman, T. Bethem, C. Zervas
GI	C. Sun, C. Zervas	
GIPLOT	C. Zervas	
REVRED	B. Parker	C. Zervas
ROTARY	B. Parker	S. Hahn, C. Zervas
PRCMP	W. Wilmot	C. Zervas
GAP	C. Zervas	
AVCONS	C. Zervas	
NCP2	N. Pore, R. Cummings	G. French, L. Hickman
NTP4	N. Pore, R. Cummings	G. French, L. Hickman
CONVERT	C. Zervas	

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