Design, Operation and Performance of an Expendable Temperature and Velocity Profiler (XTVP)

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**ABSTRACT**

This report presents system design and implementation information for the Expendable Temperature and Velocity Profiler (XTVP). The topics include discussions of the probe, acquisition equipment, analysis software, probe calibration, launch procedures, and error analysis.
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I. Introduction

The concept of measuring ocean currents from the motionally induced electric fields is an old one, having been first enunciated by Michael Faraday (1832). Numerous electric measurements have been made over submarine cables (Hemust-Higgins, 1949) and between electrodes towed behind a vessel (von Arx, 1950) More recently a profiling instrument called the Electro Magnetic Velocity Profiler (EMVP) has been developed by Sanford, Drever and Dunlap (1978). Experience with the EMVP suggested that a smaller, expendable version could be developed. This report describes this development and performance results.

The development of the expendable profiler began in 1976 under support from ONR Code 481 (now 422). A device was needed to sense voltages between two electrodes, effectively spaced 5 cm apart, to within $50 \times 10^{-9}$ V rms over a 1 Hz bandwidth. The sensitivity results from the necessity to measure the expected signal to the equivalent of about 1 cm/s rms. To be operable from a ship under way, the device must not only be expendable but also able to transmit data to the vessel. For reasons of cost and convenience, body parts and wire spools from a T-7 XBT (Expendable Bathy-Thermograph, Sippican Corp., Marion, MA) were utilized, providing a suitable vehicle and the means for transmitting the data back to the vessel over the wire link.

Development activity proceeded into 1977 with the design of several electronics circuits and the performance of sea trials. The results were not encouraging; a persistent electronic instability arose within each probe.

During 1977, Code 500 of the Naval Oceanographic Research and Development Activity (NORDA) at Bay St. Louis, MS, took over program support. After the unsuccessful sea trials in 1977, efforts were concentrated on laboratory testing and theoretical evaluations to discover the cause of the electronic instability. Ultimately this problem was found to be due to feedback from the turns on the probe wire spool into the low-level electrode amplifiers.

By spring 1978, the instability had been isolated and new circuits designed to eliminate the problem. About two dozen probes were taken to sea on Oceanus Cruise 42 in April 1978. These probes were successful and revealed stable profile-to-profile repeatability.

In June 1978, a complement of over 50 probes was taken on Cruise 47 of the R.V. Oceanus as part of the Local Dynamics Experiment of the U.S./U.S.S.R. POLYMODE program. These probes, which we call XTVP's for Expendable Temperature and Velocity Profiler, were used simultaneously with our recoverable profiler (the Absolute Velocity Profiler, successor to the EMVP) and alone to study upper-ocean velocity features such as internal waves and fronts.
With the support of the Applied Physics Laboratory of the Johns Hopkins University, a series of performance tests was conducted in May 1978 at the U.S. Navy's AUTEC (Atlantic Underwater Test and Evaluation Center). A free-fall, acoustically tracked profiler was operated by Wenstrand (1979) as the standard against which the XTVP's were compared. These tests, reported by Sanford, Dunlap and Drever (1981), showed that the probes were accurate to within about 1 cm/s rms. The XTVP's do not measure the vertically averaged flow but reveal only the depth dependent part. Hence, the two profilers can only be compared with an unknown velocity offset. The 1 cm/s rms performance reflects the expected differences when the XTVP profile has been offset to match the acoustic profile's vertical average.

At the AUTEC trials, XTVP's manufactured by the Sippican Corporation according to a slightly different design were also tested. These did not perform quite as well as those built by APL-UW, and the changes incorporated were not included in subsequent units.

Several hundreds of Sippican-produced probes were deployed in experiments in the fall and winter of 1979-80. These probes performed well, with a failure rate of about 1 in 4.

During 1979, a new digital receiver was designed and built. This device determines the amplitudes and phases of the electric field and compass signals, from which the velocity estimates result. These quantities are derived from direct frequency evaluation of the FM signals, eliminating the analog stages (frequency to voltage and analog synchronous demodulation) of the original profile processor. The digital receiver was interfaced to an HP 9845T desk-top computer. Raw data were acquired in real time, but a processed profile requires too much computation to be produced in real time.

The recent emphasis of the program has been on using the probes, assisting others in probe deployment and processing, and completion of a digital receiver, especially a means for internal digital storage.

To many readers it may seem unconscionable to expend such sophisticated probes. But when used to this maximum advantage, these devices provide invaluable results and save considerable personnel and operational costs. Operation of an equivalent recoverable instrument is very expensive in terms of capital equipment (support equipment, the profiler, spares, etc.), highly trained personnel (engineers, technicians, programmers) and ship time for launch, search and recovery. Clearly, there is some point at which the scientific and operational requirements argue strongly for the advantages of operational speed, real-time data presentation, logistical convenience and routine operation by minimally trained personnel.
II. Principles of Motional Induction

As seawater moves through the earth's magnetic field, electric fields, currents and magnetic fields arise. The physics is identical to that demonstrated as a wire connected to a voltmeter is moved between the poles of a magnet. The voltmeter registers an emf as the wire enters and exits the pole area. A similar experiment can be performed with the wire loop just in the presence of the geomagnetic field. If the loop were to change its area or be rotated, an emf would be induced. Note that the loop area projected onto the geomagnetic field must change. Motion of the loop and voltmeter in any rectilinear direction will not result in an induced emf. There seems to be a contradiction here in that we assert that velocity can be detected by the XTVP, but not in the above example. The resolution is that in the rigidly translating loop and voltmeter all circuit elements move together with no relative velocity. If the loop were elastic with a section moving away from the voltmeter, then an emf would arise proportional to the rate of change of magnetic flux through the loop area. If the voltmeter were also moving, then the emf may be proportional to the velocity of the loop section minus (or relative to) that of the voltmeter. The general point is that the emf is related to the motion of all circuit or loop elements. The same principle applies to the ocean; namely, the emf induced by the velocity at some depth will be relative to the velocities in the surrounding seawater. It is this fact that restricts the XTVP velocity measurements to be relative to an unknown, spatially averaged velocity. This restriction is indeed unfortunate, but there is one important consolation: the unknown is not depth dependent, so it represents only an offset having no vertical structure. In most, if not all, geophysical flows, the vertical scale of the motion is small compared with the horizontal length scale. This low aspect ratio leads to the assertion that the offset is not depth dependent. A more rigorous analysis of motional induction is presented by Sanford (1971), and Sanford et al. (1978) discuss induction using a discrete circuit analog.

In addition to the obvious problem of nanovolt measurement in the severe pressure and temperature environment of a profile, there are other special considerations. The fall rate of 4-5 m/s (8-10 knots) means that there will be an extremely large signal generated by this motion through the horizontal magnetic field. This voltage will be about 5 µV. The extraction of voltage due to horizontal velocities (~50 nV) in the presence of a 40 dB larger one is difficult. A scheme is employed using the compass coil to cancel the bulk of the fall induced voltage. Another consideration is that electrodes have enormous (>1 mV) drifts and offsets and have broadband noise. To extract 50 nV signals, it is necessary to limit the bandwidth of the desired signal. This is achieved with a rapid probe rotation rate, which modulates the
ocean's emf and allows the separation of the induced signal from broadband noise and the lower frequency drift of the electrodes. Finally, the transmission of the data to the vessel must be carefully executed to avoid feedback from the high-level output into the low-level input.

III. Method of Operation of the Expendable Profiler

The method of operation of the expendable temperature and velocity profiler has been developed based on our experience with a free-fall electromagnetic velocity profiler (EMVP; Sanford et al., 1978). The XTVP shown in Fig. 1 is made from standard expendable bathythermograph (XBT, Sippican Corp.) parts with the addition of a 29.5 cm center section of active electronics. As the probe falls and spins through the water column, it modulates the motionally induced electric field at its spin frequency. These weak signals are amplified and converted to an FM signal that is transmitted over a pair of #39 wires to the ship.

The signal Δφ from a falling, rotating electrode line pointing in the direction θ, measured clockwise from geomagnetic north, in the presence of the motionally induced electric currents in the sea is

\[ Δφ = F_L(u-u_1)(1+C_1) \cos θ - [F_L(v-v_1)(1+C_1) - F_HW(1+C_2)] \sin θ, \]  

where

- \( F_H \) and \( F_z \) = horizontal and vertical components of the geomagnetic field, taken here as 1/4 and -1/2 x 10⁻⁴ tesla,
- \( L \) = length of electrode line = 5 x 10⁻² m,
- \( u-u_1 \) and \( v-v_1 \) = east and north horizontal velocity components minus a vertically-averaged contribution,
- \( C_1 \) and \( C_2 \) = scale factors depending on the shape of the probe = 1 and 0,
- \( W \) = vertical component of velocity (negative value for falling probe) = 4 m/s.
Figure 1. Expendable Temperature and Velocity Profiler (XTVP)
The magnitudes of the terms are found for $u-u$ and $v-v = 1 \text{ cm/s}$ using

$$F_z L(u-u)(1+C_1) = F_z L(v-v)(1+C_1) = -50 \times 10^{-9} \text{ V},$$  \hspace{1cm} (2)$$

and

$$F_H L W(1+C_2) = 5 \times 10^{-6} \text{ V}. \hspace{1cm} (3)$$

The very low signal levels place stringent requirements on the expendable electronics. The desired signal of 0.05 $\mu$V represents 1.0% of the 5 $\mu$V signal induced by fall speed. To resolve the desired signal to an uncertainty of 1 cm/s requires that the gain of the amplifiers be stable within 1.0%, that the phase of the signal relative to the electrode line orientation be determined to 0.6°, and that the fall speed be known to about 1.0%.

The 0.6° is a specification that is very hard to meet in an expendable probe. The phase error tolerance can be improved by mixing a portion of the coil signal with the electric field. The amplitude of the coil signal is given by $F_\omega \omega n A$, where $\omega$ is the rotation rate and $n A$ is the effective area times the number of turns. Consequently, the electric field signal plus the coil contribution would be

$$\text{in-phase} = -F_z L(v-v)(1+C_1) = F_H L W(1+C_2) - F_H \omega n A C_3,$$  \hspace{1cm} (4)$$

where $C_3$ is the fraction of the coil signal added. The value of $C_3$ is chosen such that for average fall rates and rotation frequencies ($W$ and $\omega$) the two terms nearly cancel. That is, we find that $\omega = 50 \text{ s}^{-1}$ and $nA = 10^3 \text{ cm}^2$, hence

$$C_3 = \frac{L W(1+C_2)}{\omega n A} \approx \frac{1}{25}. \hspace{1cm} (5)$$
The principal benefit of this procedure is to reduce by about 90% the magnitude of the in-phase signal, making the in-phase and quadrature signals of comparable strength. In this case, phase shift uncertainties in the probe and deck equipment can be as large as ±6° without degrading the ±1 cm/s performance goal.

The low-noise preamplifiers used in the probes have a noise voltage of about $10 \times 10^{-9}$ V/√Hz in the 5 Hz to 1000 Hz band referred to input. This noise level corresponds to an ~1/4 cm/s rms uncertainty in velocity.

The discussion of the hardware is divided into topics related to the probe construction and electronics and the receivers, both analog and digital versions.

A. PROBE

1. Package and Construction

The mechanical design of the probe is shown in Fig. 1. The probe is 52 cm long, 5 cm in diameter, and weighs in air approximately 1470 grams. In seawater the probe weighs about 800 grams. The three main parts of the probe are the afterbody, electronics section and nose weight.

The afterbody contains a spool of approximately 900 m of two-conductor, #39 wire used to send data to the surface. A shroud in the form of a right cylindrical shell has been mounted on the afterbody to stabilize the fall of the probe. The fins of the afterbody make the probe rotate at about 450 rpm.

The electronics section contains two printed-circuit boards, batteries, electrodes, compass coil and thermistor flushing tubes, all potted inside a thin-walled PVC tube. The potting is a soft compound which allows the components to be at pressure equilibrium with the surrounding seawater. The electric field sensor is made up of two silver-silver chloride electrodes in tubes filled with agar to form a salt bridge for making electrical connection to the seawater at the outer skin of the probe. The compass coil is a coil of wire wound coaxially over the electrode tubes.

The nose weight is made of zinc, weighs about 500 grams in seawater and supplies the main driving force causing the probe to fall. A thermistor is mounted in the hole in the center of the nose weight. The thermistor is flushed by water passing through the nose cone and then through the flushing tubes which are potted in the electronics section.
2. Electronics

The electronics are made up of sensor preamplifiers, three voltage-to-frequency converters (V/F), a battery pack, voltage reference, mixer and line driver. Figure 2 is a block diagram of the probe electronics.

The electric field, as sensed by the electrodes, is amplified by a low noise preamplifier. The signal generated by the rotation of the compass coil in the earth's magnetic field is also amplified. The compass coil and the electrodes have been wired so that the output of the compass amplifier will be 180° out of phase with the part of the electric field amplifier output that is due to the fall rate term, $F_{LW}(1+C_2)$, of Eq. (1). As described in Eq. (4), a small amount of the compass coil amplifier signal is added to the electric field amplifier signal to cancel most of the fall rate term. The output of the electric field post-amplifier is ac coupled into a V/F converter. The reference voltage is used to offset the V/F to operate at the center frequency of its designated channel. The output of the V/F is divided by two to eliminate the even harmonics. The signal is then filtered to reduce the third harmonic and to give a 10 dB boost to the higher-frequency portion of the channel over the lower-frequency end. The compass signal is also ac coupled into a V/F, and the output of the V/F is divided by two to remove the even harmonics.

The thermistor is used with the reference voltage to modulate a third V/F. The output of the temperature V/F is divided by two to remove the even harmonics. The signal is then filtered to reduce the odd harmonics.

The three FM channels are amplified to compensate for the different signal attenuation on each channel (caused by the wire link to the shipboard processing system), mixed and impressed on the wire link. Design signal levels and the actual signal levels out of a wire link for a couple of drops are shown in Fig. 3. There are curves showing the signal levels at the start and end of a drop. The attenuation of signal on the wire can be as much as 120 dB at 5 kHz with all the wire in the water. Figure 4 shows the frequency spectra of signals out of the digital receiver preamplifier at three different times for drop #67. The broadband energy centered at 2500 Hz in the top spectrum is caused by the electric field amplifier in the probe being open-circuited while in air in the deck launcher. The figure shows that even when the signals are greatly affected by the wire links they still stand out well above the noise.
Figure 2. Diagram of probe electronics.
Figure 3. Typical signal spectra at probe, receiver input and after preamplifier at various times into a drop.

Figure 4. Signal spectra 10 seconds before and after probe launch, and near the end of a drop.
B. ANALOG RECEIVING SYSTEM

The analog receiving system, Fig. 5, consists of the XTVP receiver, two custom-designed plug-in units for a Tektronix TM 500 module, and standard laboratory instrumentation.

The three channels of FM data are transmitted to the ship by way of the expendable wire link. The signals are transformer coupled, amplified and filtered into the three separate frequency bands. These three FM signals are recorded on an HP 3960 tape recorder so the data can be replayed after the drop. The period of the temperature frequency is measured in a counter and converted to a voltage $V_T$ which can be displayed on the XY plotter. The electric field and compass frequencies are converted to voltages, $V_E$ and $V_C$, respectively, that are a linear representation of the voltages sensed by the probe.

The compass voltage $V_C$ is used as a reference signal for the two-phase, lock-in amplifier (PAR, Inc., Model 129). The lock-in amplifier synchronously demodulates the electric field voltage into in-phase (north-south) and quadrature (east-west) components with respect to the compass signal. These signals are recorded in the two-pen XY recorder as a function of time (depth) in real time as the probe is falling. Thus, the velocity data are available for immediate examination and analysis in analog form.

The processing system also measures and plots the in-phase and quadrature components of the compass signal and the period of the compass signal.

The velocity profiles produced by the analog system contain errors and lack corrections for known systematic effects. To compute corrected profiles, it is necessary to digitize the analog plots. To accomplish this we have used an HP 9874A digitizer and an HP 9845 desk-top computer. The analog receiver has now been replaced by a digital version; the analog receiver now serves as a backup to the digital receiver and provides real-time information.
Figure 5. Analog or digital-backup XTVP shipboard processing system.
C. DIGITAL RECEIVER

The XTVP digital receiver is a one-box unit that takes the composite FM signals from the wire link and processes them into digital data that are recorded on an internal magnetic cartridge tape recorder. In this way, the receiver is capable of being used without an on-line computer. With an $X, Y_1, Y_2$ plotter, as shown in Fig. 6, the receiver can be used to obtain real-time plots of $u$ and $v$ with $X$ equal to the product of time and a constant fall rate similar to those produced by the analog receiver. It is recommended that a backup magnetic tape recording be made of the FM signals. The data must be further processed by a computer to get completely processed profiles.

1. Preamplifier, Filters and Carrier Detector

The preamplifier and filters take the signal from the output of the wire link, amplify, and separate the FM signal into the three channels. The signals from the wire link are coupled into the launcher and fed to the input of the receiver by a shielded, four-wire cable. At the input to the receiver, the signal is passed through an isolation transformer followed by the preamp which has frequency-dependent gain. The compass channel has a gain of approximately 40 dB. The electric field channel is boosted approximately 25 dB, and the temperature channel has a gain of approximately 10 dB. The effect of the nonuniform gain appears in Fig. 4 as the difference between the two curves showing drop #67 signal levels into the receiver and out of the preamp. The signal then goes through three bandpass filters that separate and further amplify the signals. The outputs of the filters are recorded on a magnetic tape recorder and applied to the inputs of the carrier detectors. When the carrier voltage of each channel goes above a preset value, the FM signal will be gated into the phase lock loops. The carrier detector circuit serves to keep the phase lock loop squelched until a carrier is present. The carrier detector generates 3 bits of the status data word which is used by the processing computer to determine that all carriers are present during the drop.

2. Phase Lock Loops

The phase lock loops perform the three functions of frequency multiplication, frequency-to-voltage conversion and signal-to-noise improvement at low carrier levels.

The most important function of the phase lock loops (PLL) is to multiply the carrier frequency such that a zero crossing counter will have sufficient resolution for making the velocity determinations. The electric field carrier frequency has a transfer function from the input of the electrodes of the probe to the PLL input of 2.5 Hz per 0.1 μV peak to peak. An ocean flow having a horizontal speed of 1 cm/s in a
Figure 6. Processing section of XTVP digital receiver (control and I/O sections shown in Fig. 8).
vertical geomagnetic field of $1/2 \times 10^{-4}$ tesla will induce a signal of 0.1 $\mu$V peak to peak at the probe electrodes. The electric field carrier frequency is multiplied by 40, increasing the transfer function to 100 Hz per 0.1 $\mu$V peak to peak. The counters are used in an up/down count mode over one period of probe rotation. Because the up/down counter accumulates over one period, and the modulation of the carrier is a sine wave at the period of rotation, it can be shown that

$$TC = \frac{2F \cdot N}{P} \cdot P,$$

where

- $TC =$ total counts in up/down counter,
- $F_p =$ deviation of carrier frequency per $\mu$V,
- $P =$ period of rotation in seconds,
- $N =$ multiplication factor of PLL.

For $P = 0.125 \text{ s}$, $F_p = 25 \text{ Hz/}$per $\mu$V and $N = 40$, $TC = 125 \text{ counts/}$per $\mu$V $= 12.5 \text{ counts/cm/s}.$

The second function that the PLL's perform is frequency-to-voltage (analog) conversion of the electric field and compass FM signals. The compass analog voltage signal is used by the reference generator to produce reference signals for the phase-sensitive demodulation of the FM signals. The electric field and compass analog signals can also be used with a two-phase lock-in amplifier as was done in the original analog receiver described previously.

A third function of the PLL is to achieve an improvement in signal-to-noise ratio at small carrier-to-noise ratios. The output signal-to-noise ratio of an FM signal is (Schwartz, 1966)

$$\frac{S_o}{N_o} = 3\beta^2 \frac{S_c}{N_c},$$

where

- $\frac{S_c}{N_c} =$ FM carrier-to-noise ratio (must be greater than 10),
- $\beta \equiv \frac{\Delta f}{f_m} =$ modulation index,
- $f_m =$ frequency of the modulation in radians/s,
- $\Delta f =$ deviation of the carrier frequency from zero modulation frequency of the carrier.

For $\Delta f = 500 \text{ Hz}$, $f_m = 8 \text{ Hz}$ and $S_c/N_c = 10$, $S_o/N_o = 39,000$ or 46 dB.
Below the $S_c/N_c = 10$ threshold, Eq. (7) is not valid, and $S_o/N_o$ declines about 30 dB by the point where $S_c/N_c = 1$. Schwartz (1966) shows that a PLL can be used to move the threshold down to about 0 dB giving a threshold improvement of 10 dB.

3. Reference Generator and Up/Down Counter

The reference generator and the up/down counters perform the function of phase-sensitive demodulation of the FM signals into two orthogonal components. The reference generator generates two reference signals, CQR and CIR, with the former lagging the latter by 90°. These signals are used to control the up and down counting times of the up/down counters. Figure 7 shows the important signals that are used to generate the reference signals for controlling the up/down counters. $V_C$ is the ac coupled demodulated analog signal out of the compass PLL. The signal CR is generated by detecting the zero crossings of $V_C$. The period of CR is measured by a digital counter for every rotation of the probe with a resolution of 10 μs. The period measurement is stored on the tape recorder and in a temporary buffer. The data in this temporary buffer are used to preset a down counter which counts at a rate four times faster than the period up counter. This down count is repeated to generate the signal $S_1$, which is a series of pulses that roughly divides the time period into four equal parts. The $S_1$ signal is used to generate the $S_2$ signal. $S_2$ is generated by a one-stage flip-flop that is reset at $t_0$ and $t_4$ and stepped at $t_1$, $t_2$ and $t_3$. The positive-going edge of $S_2$ is used to clock the state of CR into a 1 bit data register. The output of the data register is the Compass Quadrature Reference signal (CQR). The Compass In-Phase Reference (CIR) is generated by clocking a one into a data register at $t_0$ to $t_4$ and a zero in at $t_2$. There are small errors in the generation of CQR and CIR, which are corrected when the data are processed in the computer. CIR is used rather than CR because if there is any baseline wandering of $V_C$ it will appear as noise in the timing of the negative-going edge of CR. But since the time of the negative-going edge of CR is not measured, a correction cannot be implemented.

The four up/down counters shown in Fig. 6 are controlled by CQR and CIR. These counters up/down count the PLL frequencies, $N_{F_2}$ and $N_{F_3}$. At the end of a count period, the counters have measured the in-phase and quadrature components of the electric field and compass signals. The two components of the compass signal are used to correct for the phase shift error caused by the receiver between CQR and the FM modulated signal from which $V_C$ is derived. The compass components are also used to eliminate the fall velocity component. The up/down counters average
the baseline carrier frequencies of the FM signals. These are counters that just count up, making a measurement of the baseline carrier frequencies of electric field, compass coil and temperature signals. There is also a counter that measures elapsed time to the nearest 10 ms.

Figure 7. Timing diagram for in-phase and quad-phase counters.
4. **Pre-Drop and Start of Drop Controls**

The start of a drop is detected by sensing when the compass analog signal $V_C$ goes above a preset threshold. Going above the threshold sets a flag called PF (probe falling) and, as long as the threshold is reached at least once every 600 ms, the flag will stay true.

The threshold is set so that when a probe starts falling and rotating the PF flag will turn on within 1 s. The threshold setting is dependent on the earth's horizontal magnetic field. The threshold can be increased near the magnetic equator to reduce false triggers. At high latitudes the threshold must be reduced. Note that when the horizontal magnetic field is nearly zero the system cannot develop an accurate CD signal and thus velocity information is compromised.

The PF flag is used by the receiver to switch CR between an 8-Hz square wave generated by the time base and CD. $V_C$ is used to generate CD by passing it through the zero-crossing detector. The 8 Hz square wave is used as a default signal by the receiver to collect data before and after a drop. Without it there would be no timing signals for the counters.

5. **Controller**

The controller shown in Fig. 8 regulates the collection and processing of digital data in the receiver. The heart of the controller is an MCA 1802 microprocessor with 6K (K=1024) bytes (8 bits) of EPROM (erasable, programmable read-only memory) and 16K bytes of RAM (read and write memory). Data are collected by the controller, stored on internal magnetic tape and sent to the HP 9845 computer. The flow of data is controlled by a seven-level priority code for interrupts and DMA (direct memory access) transfers.

The receiver's operator enters data and commands through a 16-pad numeric keyboard, a 20-digit alphanumeric display and control switches on the front panel. The operator is able to enter into the receiver the data to be recorded on the magnetic tape along with the profile data collected during an actual drop. The data recorded and the storage format will be discussed later in the tape recorder section.

The controller also has the capability of performing a small amount of data processing to provide a quick look at the profiles in real time on an external XYZ plotter. The counter values from a single rotation are normalized by the rotation period and averaged over a number of rotations. These processed data are sent to the three, digital to analog converters.
Figure 8. Control and I/O sections of XTVP digital receiver.
Data from the signal processing section buffers are collected once every rotation of the probe and stored in RAM until a 2K byte buffer is filled. The controller then sends the 2K data buffer to the tape recorder and HP 9845. Besides storing data, the controller can also find the digital data for a particular drop on the digital tape recorder and play it back for quick-look processing or pass it on to the HP 9845.

6. Digital Tape Recorder

The tape recorder is Digital Electronic's Model 3447 cartridge magnetic tape drive with four tracks and erase, write and read heads. We use 3M DC300A 1/4-inch tape cartridges with a storage capacity of approximately 10 million bytes of unformatted data. Data are recorded serially at 6400 bits per inch.

The data capacity is much greater than is needed by the receiver, but it was cost effective to use a design shared with another program. One cartridge can store more than 50 drops, but because of the high probe cost relative to tape cost it is recommended that not more than 10 drops be put on a cartridge.

The tape drive reads immediately after writing and performs a CRC (cycle redundancy check) on the data read. In the event of an error, the data block is recorded again (without backspacing and erasing the first). The controller will try three times to write the data block, and then move on to record the next block of data.

Data are recorded in 2K-byte-long records. There are only three types of records: data records, end-of-file records and end-of-information records. The end-of-information record indicates where recording can begin without writing over previous data; it is always added to the tape at the completion of a drop. Because the amount of data storage is not a problem, all records have 128 byte headers. The header is made up of words that are 2 bytes each (16 bits). Table 1 is a list of the words and their position in the header.

The preamble is used by the tape recorder electronics to find a record during a tape read. When the recorder is searching for data, it looks for at least 39 zeros followed by a one before it will put its DAD (data detected) line true.

The controller will write an end-of-file record and an end-of-information (EOI) record at the end of each drop when the operator sets the end-of-drop switch on the front panel. When a new drop is to be recorded on tape, the controller looks for the EOI record and positions the tape write head in the inter-record gap before the EOI record. At the start of writing the new drop, the EOI record will be erased.
Table 1.

<table>
<thead>
<tr>
<th>Word #</th>
<th>Name</th>
<th>Data (HEX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preamble</td>
<td>0000</td>
</tr>
<tr>
<td>2</td>
<td>Preamble</td>
<td>0000</td>
</tr>
<tr>
<td>3</td>
<td>Preamble</td>
<td>0001</td>
</tr>
<tr>
<td>4</td>
<td>Keyword (record type)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Data record</td>
<td>AAAA</td>
</tr>
<tr>
<td></td>
<td>End-of-file record</td>
<td>AAAB</td>
</tr>
<tr>
<td></td>
<td>End-of-information record</td>
<td>AAAC</td>
</tr>
<tr>
<td>5</td>
<td>Record #</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Number of times the record has been recorded on tape</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Version # of receiver program</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Number of data words per scan</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Tape # (cartridge #)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Track #</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cruise #</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Drop #</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Version # of drop</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Number of files on tape, including this drop</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Real time year</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Real time day of year</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Real time hours (24)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Real time minutes</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Real time seconds</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Number of previous scans in this file</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Number of previous scans in this record</td>
<td></td>
</tr>
<tr>
<td>22-64</td>
<td>These are spares that are filled with all F's.</td>
<td></td>
</tr>
</tbody>
</table>

Each record has one record header and 64 scans of data. One scan of data contains all the data collected during one rotation of the probe. The makeup of the scan is given in Table 2.
Table 2.

<table>
<thead>
<tr>
<th>Channel #</th>
<th>Name</th>
<th>No. of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sync. word (7777HEX)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Status</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Bit # (true state = 1)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>temperature carrier present</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>E field carrier present</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Compass carrier present</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Probe falling (PF)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Compass channel F3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8 Hz default OFF</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manual XY start</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Real time mode</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>CTLO (HP 9845 control line 0)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>CTLI (HP 9845 control line 1)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Spare</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>End of drop</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Temperature baseline (B_T)</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Period of rotation (T)</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Compass in-phase (I_C)</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>E field in-phase (I_E)</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Compass baseline (B_C)</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>E field baseline (B_E)</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Compass quadrature (Q_C)</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>E field quadrature (Q_E)</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Rotation counter</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Elapsed time counter</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Real time hours (24/day)</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Real time minutes</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Real time seconds</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
</tr>
</tbody>
</table>

For a rotation rate of 8 Hz, it takes about 8 seconds to fill the 2K byte buffer of data.
7. Computer Interface

The HP 9845T computer is connected to the receiver by a 16 bit parallel I/O interface. The computer can send control words to the receiver to initialize a transfer of data. The receiver is designed to allow the HP 9845 to read and write anywhere in the RAM memory space of the receiver. The HP 9845 can also read from the EPROM memory space to check the EPROM in case of a problem that is caused by the receiver program. Data are transferred through the interface by DMA. The maximum rate of data transfer is limited by the receiver to about 64K bytes per second, not including the transfer setup time of the 9845. It takes about 32 ms plus setup time to transfer a 2K byte block of data.

During a probe drop, the 9845 can be locked out from writing into the memory of the receiver. With the computer lock-out switch on, only the data blocks will be transmitted to the 9845.

8. Analog and FM Outputs

The receiver has analog and FM outputs that are used for a quick look and for backup data storage. There are two means for getting a quick look at the analog profile. The analog voltages of electric field and compass coil are available on BNC connectors on the front panel. These signals can be fed into a two-phase lock-in amplifier that will demodulate the electric field into two components using the compass coil voltage as a reference signal. The components are displayed on an $X,Y_1,Y_2$ plotter as a function of time. Also, as mentioned in the controller section, there are D to A outputs on the front panel that can be used to drive an $X,Y_1,Y_2$ plotter.

The receiver has available on the front panel FM carriers for temperature, electric field and compass to be recorded on an HP 3960 or similar instrumentation recorder for backup. The FM signals can be played back through the front panel connectors to reprocess a drop any time it is needed.

D. SOFTWARE

HP 9845T BASIC language programs are described here. DXGET is for acquisition, DXPRO for processing, SPLOT for series plotting, CROSS for cross-correlation, structure-function, and coherence. Listings and sample runs are found in Appendix A.
1. **Acquisition**--**DXGET**

DXGET accepts a user-specified number of data scans (one repetition of all variables) from the digital receiver. The computer's real-time clock is sampled just before starting the single DMA ENTER statement into the integer data array, Din(*). Because ENTER must run to completion, the 8 Hz default in the receiver must be on. The program was kept very simple so as not to risk data loss.

After the data are ENTER'd, the user enters comments and the file name. The data are then written to mass-storage, either floppy disc or tape cartridge.

2. **XTVP Signal and Data Processing Description**

The XTVP probe and digital receiver transfer functions are described to provide a basis for the application of a signal model. Careful attention to gains, phases and timing is required to determine oceanic water velocity profiles accurately.

The probe input stages shown in Fig. 2 can be described with three transfer functions for electric field, fall speed correction and compass coil:

\[
G_{EF2} = \frac{E_7}{E_E},
\]

\[
G_{COR2} = \frac{E_7}{E_C},
\]

\[
G_{CC2} = \frac{E_0}{E_C}.
\]

Estimated gains and phases are functions of frequency and typically are represented as phasors, \( G = |G| e^{j\phi_G} \), where \(|G|\) is the magnitude of \( G \) and \( \phi_G \) is the phase of \( G \).

Voltage to frequency (V/F) converter factors in the probe are
Solving for the probe inputs as a function of outputs yields

\[ E_E = \frac{F_E}{G_{EFV} G_{EF2}} - E_C G_{COR2}, \]
\[ E_C = \frac{F_C}{G_{CCV} G_{CC2}}, \]

where all quantities are complex because both amplitude and phase are needed.

Gain amplitudes for each probe are measured during manufacture; phases are estimated from a transfer function analysis using nominal component values. The analog gains measured at 7 Hz are

\[ G_{EF} = E_7/E_E, \]
\[ G_{COR} = E_7/E_C, \]
\[ G_{CC} = E_8/E_C. \]

These choices of output measurement points introduce some loading effects because \( E_7 \) and \( E_9 \) are rather high impedance. The loading is estimated from nominal component values.

The voltage-to-frequency converters are calibrated statically. Our analysis shows a negligible phase angle.
The digital receiver response to input is described in terms of a timing diagram (Fig. 7). The counter start, stop and up-to-down times ($t_0, \ldots, t_5$) are developed from the zero-crossing detector output CR and the rotation periods $T_{n-1}$ and $T_n$.

The in-phase ($I$), quadrature ($Q$) and baseline ($B$) counter outputs (Fig. 6) are signed summations of the number of cycles of the phase lock loop (PLL) output that are counted during the counter reference signals CIR and CQR. Approximating the summations by integrals simplifies analysis. The following generation formulae are for the $n^{th}$ rotation, where $N$ is the appropriate PLL frequency multiplier and $F(t)$ is the frequency input to the PLL:

$$I_n = N \int_{t_0}^{t_2} F(t) \, dt - N \int_{t_2}^{t_4} F(t) \, dt,$$

$$Q_n = N \int_{t_1}^{t_3} F(t) \, dt - N \int_{t_3}^{t_5} F(t) \, dt,$$

$$B_n = N \int_{t_0}^{t_4} F(t) \, dt.$$  \hfill (12)

The times when the counter reference timing generator changes the states of CIR and CQR are

$$t_0 = 0,$$

$$t_1 = \frac{1}{4} T_{n-1},$$

$$t_2 = \frac{1}{2} T_{n-1},$$

$$t_3 = \frac{3}{4} T_{n-1},$$

$$t_4 = T_n,$$

$$t_5 = \frac{5}{4} T_n.$$  \hfill (13)
Note that there is a significant phase shift between $V_C$ and CR. Thus $Q_n$ of the coil signal is nonzero.

The present processing models probe carrier frequencies for electric field and compass coil channels as follows:

$$F(t) = A \cos (\omega t + \phi) + C + D t + E t^2 + \text{noise},$$

where $A$ and $\phi$ are the amplitude and phase of the probe carrier frequency modulation and $\omega$ is the probe's radian rotation frequency. $C$, $D$ and $E$ allow for the exponential impulse response of the probe filters $\tau_1$, $\tau_2$, $\tau_3$ (Fig. 2).

Expanding $I$, $Q$ and $B$ according to $F(t)$ we have

$$I_n = 2N[\frac{A}{\omega} \sin(\omega t_2 + \phi) + C t_2 + \frac{1}{2} D t_2^2 + \frac{1}{3} E t_2^3]$$

$$-N[\frac{A}{\omega} \sin(\omega t_0 + \phi) + C t_0 + \frac{1}{2} D t_0^2 + \frac{1}{3} E t_0^3]$$

$$-N[\frac{A}{\omega} \sin(\omega t_4 + \phi) + C t_4 + \frac{1}{2} D t_4^2 + \frac{1}{3} E t_4^3],$$

$$Q_n = 2N[\frac{A}{\omega} \sin(\omega t_3 + \phi) + C t_3 + \frac{1}{2} D t_3^2 + \frac{1}{3} E t_3^3]$$

$$-N[\frac{A}{\omega} \sin(\omega t_1 + \phi) + C t_1 + \frac{1}{2} D t_1^2 + \frac{1}{3} E t_1^3]$$

$$-N[\frac{A}{\omega} \sin(\omega t_5 + \phi) + C t_5 + \frac{1}{2} D t_5^2 + \frac{1}{3} E t_5^3],$$

$$B_n = N[\frac{A}{\omega} \sin(\omega t_4 + \phi) + C t_4 + \frac{1}{2} D t_4^2 + \frac{1}{3} E t_4^3]$$

$$-N[\frac{A}{\omega} \sin(\omega t_0 + \phi) + C t_0 + \frac{1}{2} D t_0^2 + \frac{1}{3} E t_0^3].$$

Time variations in $\omega$ significantly influence the counter outputs.

In general, one must use the exact time intervals when processing.
time intervals for $I_n$ and $B_n$ are the same ($t_0$, $t_2$, $t_4$), while those for $Q$ are 1/4 cycle later ($t_1$, $t_3$, $t_5$). Normalization of counter outputs thus requires separate $T_{In}$ and $T_{Qn}$.

$$T_{In} = T_n$$
$$T_{Qn} = 5/4 T_n - 1/4 T_{n-1}$$
$$T_{Bn} = T_n$$

(15)

However, $\omega$ in the sinusoidal arguments is approximated by $\omega = 2\pi/T_n$, with a further approximation of $T_n/T_{n-1} = 1$ which results in

$$\omega t_i = \frac{\pi}{2} i, \quad i = 1, \ldots, 5$$

(16)

The measured rms deviations of $T_n/T_{n-1}$ appear to be bounded by 0.5% which roughly corresponds to 0.5% rms noise in $I$ and $Q$. This seems acceptable at present.

In any case, this noise is included in the velocity error estimated from $I'$ and $Q'$ noise (see Eq. 19). Thus we can write, using $\omega = 2\pi/T$:

$$\frac{I_n}{N} = -\frac{4A}{2\pi} T_{In} \sin\phi + C(T_{n-1} - T_n)$$
$$+ D(1/2 T_{n-1}^2 - T_n^2)/2 + E(1/4 T_{n-1}^3 - T_n^3)/3$$

(17)

$$\frac{Q_n}{N} = -\frac{4A}{2\pi} T_{Qn} \cos\phi + C(T_{n-1} - T_n)5/4$$
$$+ D(17 T_{n-1}^2 - 25 T_n^2)/32$$
$$+ E(53 T_{n-1}^3 - 125 T_n^3)/192$$

$$\frac{B_n}{N} = C T_n + 1/2 D T_n^2 + 1/3 E T_n^3$$

To solve for $A$ and $\phi$ we find $C$, $D$ and $E$ from $B_{n-1}$, $B_n$, and $B_{n+1}$ by solving a linear 3x3 matrix equation. The other values of $B$ are:

28 APL-UW 8110
\[
\frac{B_{n-1}}{N} = C T_{n-1} - \frac{1}{2} D T_{n-1}^2 + \frac{1}{3} E T_{n-1}^3,
\]

\[
\frac{B_{n+1}}{N} = C T_{n+1} + D (T_n T_{n+1} + \frac{1}{2} T_{n+1}^2)
+ \frac{1}{3} E [(T_n + T_{n+1})^3 - T_n^3].
\]

The corrected in-phase and quadrature results can then be determined:

\[
I_{n}' = -\frac{4 A N T_{In}}{2 \pi} \sin \phi,
\]

\[
Q_{n}' = -\frac{4 A N T_{Qn}}{2 \pi} \cos \phi.
\]

To obtain averaged FM amplitude and phase, we convert to rectangular coordinates:

\[
F_I = -A \sin \phi = \frac{2 \pi}{4 N T_{In}} I_{n}',
\]

\[
F_Q = -A \cos \phi = \frac{2 \pi}{4 N T_{Qn}} Q_{n}'.
\]

Then we filter using a Bartlet (i.e., triangular) window with weights \(w_n\):

\[
\overline{F}_I = \frac{2 \pi}{4 N} \sum_{n=1}^{N} w_n I_{n}' / T_{In},
\]

\[
\overline{F}_Q = \frac{2 \pi}{4 N} \sum_{n=1}^{N} w_n B_n / T_{Bn}.
\]
Baseline carrier frequencies are computed similarly:

$$\bar{F}_B = \frac{1}{N} \sum_{n=1}^{N} \omega_n B_n / B_n .$$

(22)

Averaged amplitude \(F_a\) and phase \(F_p\) are found from \(\bar{F}_I\) and \(\bar{F}_Q\) by converting to polar coordinates using a four-quadrant arctangent function:

$$F_a = (F_I^2 + F_Q^2)^{1/2},$$

$$F_p = \tan^{-1} \frac{F_I}{F_Q} .$$

(23)

Thus an input signal of \(\cos(\omega t + \phi)\) will result in \(F_p = \phi\). When \(\phi>0\), the input signal leads \(\cos(\omega t)\). The reference is the zero-crossing-detector output CR.

Using phasor notation we write the complex frequency deviation in terms of amplitude and phase for both the electric field and compass coil.

$$F_E = \frac{F_{Ea}}{F_{Ep}},$$

$$F_C = \frac{F_{Ca}}{F_{Ep}} .$$

(24)

Using (10) we compute the complex voltages at the probe input:

$$E_E = \frac{E_{Ea}}{E_{Ep}},$$

$$E_C = \frac{E_{Ca}}{E_{Cp}} .$$

(25)
The east and north velocities are found as

\[ u = \frac{E_E}{F_Z(1+C_1)} \cos \psi, \]

\[ v = -\frac{E_E}{F_Z(1+C_1)} \sin \psi + W \frac{E_H(1+C_1)}{F_Z(1+C_1)}, \]

where

\[ \psi = \beta_E - \beta_C + \pi/2 + \alpha, \]

\[ \beta_E = -E_{EP}, \]

\[ \beta_C = -E_{CP}, \]

\[ \alpha = \pi. \]

W is the estimated fall rate, \( dz/dt \), of the probe computed from a depth versus time polynomial.

Depth versus time was measured using five special probes with pressure transducers instead of thermistors. An average quadratic was fit to these measurements for use in determining \( Z \) and \( W \) versus time during processing.

\[ P = -Z = 3.1 + 4.544t - 0.0006749t^2. \]

A "tilt" correction (discussed in section V.C.) is applied to the north velocity component to remove effects caused by north-south probe tilt. The "area" \( A \) of the coil is computed assuming no probe tilt:

\[ A = \frac{E_T}{2\pi H}. \]
where $T$ is the rotation period, $E_c$ is the coil signal, and $F_H$ is the earth's horizontal magnetic field.

Individual corrected estimates of the north velocity component are found by using

$$V = -\frac{E_E}{F_L(1+C_1)} \sin \psi + W \frac{F_H(1+C_0)}{F_L(1+C_1)} A,$$

(30)

where $\bar{A}$ is the vertical mean of $A$.

3. Plotting and Analysis Programs

a. SPLOT

SPLOT is used to obtain more insight into the profiles. It plots a series of $U$, $V$ profiles with various processing applied. Generally a quadratic fit is performed on the profile to obtain the residuals. These can be rotated to a given time by specifying the inertial period and the time of each profile. Cartesian or polar displays are available. One can also plot the fits.

b. CROSS

CROSS will compute cross-correlations, structure functions, or coherences between $U$ and $V$ profiles. Input is set up in advance, and then processing continues unattended. Many sets and combinations of files can be processed in a single run.

E. PROBE CALIBRATIONS

1. Sippican's Calibration

The XTVP gains $G_{EF} = E_7/E_5$, $G_{COR} = E_7/E_6$, $G_{CC} = E_8/E_6$, $G_{EFVP} = E_E/E_7$, and $G_{CCVP} = F_C/E_8$ are measured during manufacture before potting. Figure 9 shows the test setup to obtain $G_{EF}$, $G_{COR'}$ and $G_{CC}$. The operator adjusts the quadrature potentiometer $F = R_7/(R_6 + R_7)$ and the resistance box $R_2$ to obtain a null reading on both the $I$ and $Q$ meters of the PAR 129.

This forces

$$G_{ATTEN} * G_{PROBE} = \frac{1}{\phi_{PAR}},$$

(31)
where $\phi_{\text{PAR}}$ is the phase offset of the PAR 129. The Sippican calibration estimates $G_{\text{PROBE}} = R_2 + 100$, which is a result of considering only the resistive part of the attenuator. Further analysis of the attenuator transfer function shows that this estimate is about 3% too large for $G_{\text{EF}}$ and $G_{\text{COR}}$ because approximately 15° phase angles exist at 7 Hz. The exact error depends on $\phi_{\text{PAR}}$. Table 3 shows results of the analysis where $P$ and $R_2$ were adjusted to obtain analytic probe gains and phases.

Table 3.

<table>
<thead>
<tr>
<th></th>
<th>$P = \frac{R_7}{(R_6 + R_7)}$</th>
<th>$R_2$</th>
<th>$\frac{1}{G_{\text{ATTEN}}}$</th>
<th>$-\phi_{\text{ATTEN}}$</th>
<th>% error of $\frac{R_2 + 100}{G_{\text{PROBE}}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{\text{EF}}$</td>
<td>0.0244</td>
<td>25278</td>
<td>24495</td>
<td>15.2°</td>
<td>3.5%</td>
</tr>
<tr>
<td>$G_{\text{COR}}$</td>
<td>0.525</td>
<td>1036</td>
<td>1097</td>
<td>15.3°</td>
<td>3.5%</td>
</tr>
<tr>
<td>$G_{\text{CC}}$</td>
<td>0.011</td>
<td>3598</td>
<td>3698</td>
<td>1.0°</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Figure 9. Standard setup used by Sippican for probe calibrations.
These estimates assume $\phi_{\text{PAR}} = 0$. Our PAR 129 indicates $-3^\circ$ to $-5^\circ$ with dials set to $0^\circ$. Sippican's PAR 5204 indicates a value closer to $0^\circ$. For correct results, the PAR dials should be set so that the Q meter indicates zero for the signal equal to the reference.

Obtaining the correct $G_{\text{PROBE}}$ requires knowledge of the quadrature adjust potentiometer $P$, which is not recorded. However, if $\phi_{\text{PAR}}$ is zero, we can estimate $\phi_{\text{ATTEN}}$ from a $\phi_{\text{PROBE}}$ obtained from a transfer function analysis of a typical probe.

From the computer analysis of the attenuator gain we find that $1/(R_2 + 100)$ approximates the real part of $G_{\text{ATTEN}}$ quite closely. Thus a better estimate for the gain magnitude of the probe is

$$|G_{\text{PROBE}}| = (R_2 + 100) \cos(\phi_{\text{PROBE}}).$$

(32)

$G_{\text{EFVF}}$ and $G_{\text{GCCVF}}$ are found statically by applying $+0.5$ V and then $-0.5$ V to both $E_7$ and $E_8$ while recording the voltage-to-frequency converter output frequencies $F_E$ and $F_C$. The change in frequency divided by the change in voltage provides the estimate for $G_{\text{EFVF}}$ and $G_{\text{GCCVF}}$.

Early calibrations had a 1K resistor in series with the $\pm 0.5$ V source. Thus the early Sippican $G_{\text{EFVF}}$ and $G_{\text{GCCVF}}$ estimates were low by 3.3% and 1.7%, respectively. In May 1980 the 1K resistor was removed from the setup.

2. APL-UW's Calibrations

The calibrations described in the previous section are time consuming. A simplified calibration procedure is used by Sippican Corp. in the manufacture of XCP's. We wanted to verify their calibrations to eliminate uncertainties in the velocity determination. We also wanted to be able to correct old calibrations by finding any systematic differences. Therefore, ten unpotted, Sippican-calibrated probes were purchased for our measurements.

Our calibrations (Fig. 10) were done with both channels of the probe having nominal signal amplitudes at all times rather than setting one channel to zero input while measuring the other as Sippican did. Our input signals were exactly in phase however, due to lack of test equipment. (We would have liked to check for cross-talk and non-linearity.)
To check the Sippican calibrations, we wanted to measure the probe at the same points. However, this meant loading E7 and E8 (Fig. 2) and thus changing the overall transfer functions. We therefore measured at E5 and E6, and estimated the transfer functions to E7 and E8.

Note that in the future these intermediate points need not be measured; only the three overall transfer functions, $G_E$, $G_{EFVF}$, $G_{COR}G_{EFVF}$, and $G_{CC}G_{CCVF}$ will be needed.

Because only single-ended test signals with a common reference were available, the drive signal should go to the “plus” (noninverting) inputs of $E_E$ and $E_C$. This procedure reduces drive signal loading and tests all the components.
The measurement points EFCAL and CCCAL are needed since there is significant interaction between the two attenuator-adjust switches. The attenuations from EFCAL and CCCAL to EFOUT and CCOUT are estimated stagewise using a dc source and a digital voltmeter.

The ac coupling to channels 3 and 4 of the HP 59313A digitizer isolates its input bias current from the probe. These transfer functions are allowed for in the analysis.

The HP 59313A digitizer multiplexes the analog to digital converter between four input channels. The time differences between channels are corrected by adjusting the phase angles of the sinusoidal fits during analysis.

The digital receiver is used in the real-time mode. The acquisition program sets up a direct memory access from the receiver. This runs concurrently with input from the digitizer. Each channel’s sample rate is limited to 5 Hz by the speed of the HP 9845 desk-top computer.

Operation is not fully automatic due to lack of equipment: the operator is required to change the attenuator settings manually for each "set" in a "run." Typically, four linearly independent sets of attenuator settings are used per calibration run, although the program can handle nine sets.

Following acquisition, the processing runs unattended for several minutes to compute gain estimates for that run. We made from 5 to 15 runs per probe to observe the variability of the method and obtain reliable results.

To obtain amplitudes and phases of the digitizer channels, they are least-squares fit to

\[ a_1 + a_2 \cos \omega t + a_3 \sin \omega t + a_4 (t - \bar{t}) \],

where \( \omega \) is the radian frequency, \( \bar{t} \) is the mean \( t \) and \( a_1, \ldots, a_4 \) are the coefficients determined by the "set." \( \omega \) is found by iterative adjustment to obtain phase continuity between successive blocks of the CC-CAL channel. The procedure is identical to that described by Sanford et al. (1978). The amplitude \( A \) and phase \( \phi \) are...
\( a = (a_2^2 + a_3^2)^{1/2} \),

\( \phi = -\tan^{-1} \frac{a_3}{a_2} \).

The amplitude and phase angle of each sinusoidal fit and the average I and Q from the receiver were then least-squares fit to a linear model of complex probe gains:

\[
\begin{align*}
E_7 &= G_E F_E + G_{COR} E_C, \\
E_8 &= G_{CC} E_C, \\
F_E &= G_{EFVF} E_7, \\
F_C &= G_{CCVF} E_8, \\
F_E &= (G_{EFVF} G_E) E_E + (G_{COR} G_{EFVF}) E_C, \\
F_C &= (G_{CC} G_{CCVF}) E_C.
\end{align*}
\]

The first four expressions are to be compared with Sippican's, while the last two are used to find the overall transfer functions of the probe.

The receiver counters average over each revolution, so the measured \( F_E \) and \( F_C \) are quieter than \( E_7 \) and \( E_8 \) which are only sampled once per 200 ms. Thus, the overall transfer functions can be determined more accurately and with less effort than the individual transfer functions.

The circuit gains (e.g., \( G_{EFVF} \)) are complex coefficients \( a_j \) in models of the form

\[
y = \sum_{j=1}^{m} a_j x_j,
\]

where \( y \) is the output and the \( x_j \)'s are the inputs.
To solve for the $a_{ij}$'s, several linearly-independent "sets" of $y$ versus $x_j$ are required. Each measured output $y_i$ is related to the inputs $x_{ij}$ as follows:

$$y_i = \sum_{j=1}^{m} a_{ij} x_j + r_i, \quad \text{for } i = 1, \ldots, n \quad (37)$$

where $n$ is the number of sets and the $r_i$ are the residuals. The complex gains $a_{ij}$ are found by least-squares fitting in a manner similar to the sinusoidal fitting.

For each probe, the gains were averaged over a number of runs. These averages include only those runs with low fit noise and low receiver noise.

Multiple short runs enabled elimination of bad sections of data instead of repeating an entire long run. Multiple runs also allowed an estimation of the reliability of the method. The sinusoidal fits are less sensitive to the rotation frequency estimate when the fits are shorter.

Our measurements indicate that the complex gains from probe to probe are quite similar, within 0.4% in magnitude and 0.4° in phase, as summarized in the standard deviations in Table 4.

**Table 4.**

<table>
<thead>
<tr>
<th>Amplitude Deviation from Analytic (%)</th>
<th>Phase Deviation from Analytic (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_EF$</td>
<td>0.2</td>
</tr>
<tr>
<td>$G_{COR}$</td>
<td>-1.6</td>
</tr>
<tr>
<td>$G_{CC}$</td>
<td>-1.8</td>
</tr>
</tbody>
</table>

Note, however, that the averages for $G_{COR}$ and $G_{CC}$ amplitudes differ significantly from the analytic estimates.

Our measurements deviate from Sippican's using $|G_{PROBE}| = (R_2 + 100) \cos(\phi_{PROBE})$ as summarized in Table 5.
Table 5.

Amplitude Deviation from Sippican's (%)

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{EF}$</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>$G_{COR}$</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td>$G_{CC}$</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The $G_{EF}$ and $G_{COR}$ errors are significant and would be smaller if the Sippican PAR phase error were $1^\circ$ as summarized in the following table.

Table 6.

Amplitude Deviation (%) from Sippican's Assuming $1^\circ$ PAR Error

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{EF}$</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>$G_{COR}$</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>$G_{CC}$</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Our estimates of $G_{EFVF}$ and $G_{CCVF}$ show relatively small variability from probe to probe compared with Sippican's measurements for the same nine probes. The following table summarizes.

Table 7.

Sippican's V/F Estimates Our V/F Estimates Allowing for $1K$ Resistor Deviations of Our Estimates From Sippican's

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{EFVF}$</td>
<td>994</td>
<td>0.2</td>
<td>1000</td>
<td>1.0</td>
<td>-0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$G_{CCVF}$</td>
<td>1001</td>
<td>0.1</td>
<td>1000</td>
<td>0.6</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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The general conclusion about the calibration problem is that future designs should eliminate the need for calibration, or, if needed, make it automatic with frequent verification of the test setup.

We have not attempted to answer the question of how the calibrations change with potting or depth. There is some reason to believe potting may affect the V/F converter calibration. We have not determined why the measured gains differ from the analytic estimates.

F. SENSITIVITY ANALYSIS OF PROBE

Sensitivity analysis of the XTVP probe is performed using the analytic transfer functions for the probe while varying the component values. We have not shown sensitivities for individual components; rather we have computed the variability of the probe transfer functions as a function of component tolerances. We have not shown statistics for the V/F converters.

The component tolerances are used to choose random component values. Uniform distributions were used for simplicity. Typically 20 realizations of the transfer function with independent random component values are used.

The maximum, minimum, average and standard deviation for the amplitude and phase of each transfer function are computed given the rotation frequency and component tolerances using a computer program.

Table 8 shows deviations at 7 Hz using standard component tolerances of 0.1% resistors and 10% capacitors.

<table>
<thead>
<tr>
<th></th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>rms(%)</td>
</tr>
<tr>
<td>GEF</td>
<td>24333</td>
<td>0.13</td>
</tr>
<tr>
<td>GCOR</td>
<td>1096</td>
<td>0.15</td>
</tr>
<tr>
<td>GCC</td>
<td>3696</td>
<td>0.13</td>
</tr>
</tbody>
</table>

If 1% resistors and 10% capacitors are used, the amplitude deviations increase while the phase deviations remain the same, as can be seen in the following table.
Table 9.

<table>
<thead>
<tr>
<th></th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>rms(%)</td>
</tr>
<tr>
<td>$G_E$</td>
<td>24568</td>
<td>1.1</td>
</tr>
<tr>
<td>$G_{COR}$</td>
<td>1094</td>
<td>1.7</td>
</tr>
<tr>
<td>$G_{CC}$</td>
<td>3682</td>
<td>1.2</td>
</tr>
</tbody>
</table>

An attempt to determine the pressure variability uses 0.5% capacitor deviations and no resistor deviations (Table 10).

Table 10.

<table>
<thead>
<tr>
<th></th>
<th>Amplitude</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>rms(%)</td>
</tr>
<tr>
<td>$G_E$</td>
<td>24494</td>
<td>0.00</td>
</tr>
<tr>
<td>$G_{COR}$</td>
<td>1097</td>
<td>0.00</td>
</tr>
<tr>
<td>$G_{CC}$</td>
<td>3697</td>
<td>0.00</td>
</tr>
</tbody>
</table>
IV. Operations

A. EQUIPMENT INVENTORY

Table 11 lists the equipment that was shipped to support the deployment of about 50 XTVP's from the USNS Kane.

Table 11.

<table>
<thead>
<tr>
<th>Box #</th>
<th>Contents</th>
<th>Function</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>a) PAR Lock-in Amplifier</td>
<td>Resolves analog U and V velocity components</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) HP 3960 Analog Tape Recorder</td>
<td>Records FM signals during drop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Sippican Digital Receiver</td>
<td>Determines digital U and V velocity components; sends data to 9845 computer</td>
<td>291</td>
</tr>
<tr>
<td>2.</td>
<td>a) Tektronix TM506 Mainframe 1) PS 503A Power Supply incl. 2) FG 501 Function Generator 3) DC 503 Counter/Timer 4) DM 501 Multimeter 5) SC 502 Oscilloscope</td>
<td>Repair and calibration equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) HP 3964 Analog Tape Recorder</td>
<td>Spare recorder for FM signal storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) APL-UW Digital Receiver</td>
<td>Spare receiver to Sippican made unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) HP 7046A XYY Plotter</td>
<td>Analog plotter for real time display</td>
<td>305 (total)</td>
</tr>
<tr>
<td>3.</td>
<td>a) HP 9845T Computer (CRT)</td>
<td>Digital acquisition and processing</td>
<td>50</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Box #</th>
<th>Contents</th>
<th>Function</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. a)</td>
<td>HP 9845T Computer (CPU)</td>
<td>Digital acquisition and processing</td>
<td>101</td>
</tr>
<tr>
<td>5. a)</td>
<td>HP 9872A Plotter</td>
<td>Plots digital U,V profiles</td>
<td>94</td>
</tr>
<tr>
<td>6. a)</td>
<td>HP 9885M Disk Drive</td>
<td>Digital storage for raw and processed profiles</td>
<td>128</td>
</tr>
<tr>
<td>7. a)</td>
<td>HP 98034A HP-IB Interface</td>
<td>9845T computer peripheral and interface cards</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>HP 98035A Opt. 100 Real Time Clock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>HP 98032A 16-bit I/O APL-UW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>HP 98032A 16-bit I/O Sipp. DR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>Fluke 8024A Multimeter</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td>HP 32E Calculator</td>
<td>Hand calculator</td>
<td></td>
</tr>
<tr>
<td>g)</td>
<td>Misc. Electronic Spares</td>
<td>Repair</td>
<td>75</td>
</tr>
<tr>
<td>8-10. a)</td>
<td>Floats (Ethofoam) (3 boxes used because of bulk)</td>
<td>For XTVP surface flotation (Total 3 boxes)</td>
<td>50</td>
</tr>
<tr>
<td>11. a)</td>
<td>Misc. Support Equipment</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>12. a)</td>
<td>10 Mag. Tapes for Analog Recording</td>
<td>Supplies</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>50 Cassettes for Digital Recording</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>4 boxes Graph Paper for Analog Plots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>1 box Xerox Paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. a)</td>
<td>10 Mag. Tapes for Analog Recording</td>
<td>Supplies</td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>25 Diskettes (8 1/2&quot; IBM) for Digital Recording</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>4 boxes Graph Paper for Digital Plots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>1 box Xerox Paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>1 Tool Box - Misc. Hand Tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f)</td>
<td>1 XTVP Log Book</td>
<td></td>
<td>84</td>
</tr>
<tr>
<td>Box #</td>
<td>Contents</td>
<td>Function</td>
<td>Weight (lb)</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>14.</td>
<td>a) Tektronix 7603R Oscilloscope</td>
<td>FM data display</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) 7A22 Plug-In Amplifier</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) 7A26 Plug-In Amplifier</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) 7B23 Plug-In Time Base</td>
<td>&quot;</td>
<td>85</td>
</tr>
<tr>
<td>15.</td>
<td>a) Launcher Tube Ends</td>
<td>For launching tube assembly</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>b) Adaptor Tubes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Metal Hose Clamps and Hardware</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>a) 2 Sippican Hand Launchers</td>
<td>XTVP launcher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Deck Cable</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Misc. Cables</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) Scope Probes</td>
<td>&quot;</td>
<td>89</td>
</tr>
<tr>
<td>17.</td>
<td>a) 1 Garbage Can</td>
<td>For on-deck check</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Anti-hypothermia Suits</td>
<td>Personnel protection</td>
<td>24</td>
</tr>
<tr>
<td>18.</td>
<td>a) 5 LEXAN Tubes, 2 1/2&quot; x 9'</td>
<td>For deck launcher</td>
<td>10</td>
</tr>
<tr>
<td>19.</td>
<td>a) Box Misc. Stores</td>
<td></td>
<td>57</td>
</tr>
<tr>
<td>20.</td>
<td>a) Probes (12/box)</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>21.</td>
<td>a) Probes</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>22.</td>
<td>a) Probes</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>23.</td>
<td>a) Probes</td>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>

TOTAL SHIPPING WEIGHT 1,925

This equipment comprises both analog and digital processing instrumentation including spare data receivers, analog tape recorders and launch hardware.
B. INSTALLATION OF XTVP SHIPBOARD LAUNCH AND RECEIVING SYSTEM

1. Deck Setup
   
a. Determine exact weather deck location where probes will be launched. Some (but not all) of the factors that will fix this position are:

   1) Concurrence of Chief Scientist and Chief Bos'n (or equivalents)
   2) Consideration of other scientific projects on same cruise
   3) Distance from assigned laboratory space
   4) Type of ship
   5) Wind/weather expected, and its influence on launching operations
   6) Sufficient space aft of launcher loading position to swing launcher tube inboard in order to load probes and attach flotation collars.

b. Assemble LEXAN launcher tube (usually two 9' sections are enough, unless ship's rail is >10' above waterline). Attach launcher loading end to ship's rail (Pos. A) so outer end can be swung inboard for loading and outboard for launching. Attach all necessary support and securing lines. Prepare a release line and leave coiled at point where launcher end is brought inboard (Pos. B). Secure a 30 gal. plastic garbage can at ship's rail at (Pos. A). Fill to ~16" with clean seawater.

c. The Sippican hand launcher and intercom (currently Radio Shack # 43-221) are needed at Pos. A.

   1) The hand launcher is usually hung on a bulkhead hook or equivalent, to protect it when not used in the launching tube, with about 10' of slack cable to enable probes to be tested in the plastic bucket.

   2) The intercom is secured in a suitable location at about head height, using a convenient stanchion or bulkhead. Note that this unit is not waterproof. During inclement weather or high sea states it should be stored in the lab when not being used; thus a "shock cord" (quick release) type of attachment should be used.

d. The launcher and intercom wires must be routed to the lab operating area. Considerable care must be taken to avoid hazards that may injure the wires. If possible, an overhead or bulkhead route is preferable to a deck route.
2. Laboratory Setup

a. Determine from Chief Scientist the maximum available bench and deck space.

b. Set up communications link to bridge (mandatory), and radio room and chartroom if possible.

c. Bench space allocation should be:

1) HP 9845T computer ~20" wide
2) HP 9872A digital plotter and HP 9885M disc drive are mounted together vertically ~20" wide
3) HP 7046B analog plotter (if used) ~19" wide
4) Approximately 30" of bench area for writing
5) If more bench space available, some of the following items listed as rack mounted may be used in 36" high racks which can usually be mounted on top of the bench.

d. Rack space. The following is a "top-to-bottom" guide.

1) HP 3964 analog tape recorder - must be accessible to load and unload tapes.
2) PAR 129A lock-in amplifier - occasional changes in control settings will be made on this unit.
3) Tektronix TM 506 mainframe scope - check to ensure electric field and compass signals are present.
4) XTVP digital receiver - once connected, usually no changes need be made to this unit.

e. If additional rack space is available, the backup HP 3960 analog tape recorder and XTVP-DR should be mounted so as to allow a quick switch if the primary units malfunction.

f. Boxes of expendable supplies (probes, magnetic tape, plotting paper, etc.) should be stored in the lab area if possible for easy access during the cruise. Boxes of spare parts or seldom used items may be stored in a hold or other nonlab area.

g. Before sailing, all items must be properly secured in accordance with good seamanlike practice. The Chief Boatswain (or equivalent) can advise and assist, and may be able to suggest improvements, etc.

h. Try to do a dummy drop, testing a probe in a bucket, etc. and communicating with bridge, radio room, engine room, etc. before the cruise begins. All installations, rigging and testing are more easily done alongside the dock.
C. SUMMARY OF XTVP LAUNCH AND OPERATIONS

1. General Instructions to Bridge

   a. Establish communications channels.

   b. Emphasize radio silence for bridge and radio room.

   c. Emphasize speed requirements (must be less than 8 knots). In high winds, head into wind/seas to prevent paying out too much wire.

   d. Provide the bridge with written instructions and a copy of this summary if possible.

2. Pre-Launch Procedure

   a. Operator gives bridge desired position for next drop and asks for 5 minute warning.

   b. Launch person picks out a probe, writes serial number in the drop log, puts probe in hand launcher, removes magnet (turns on), puts probe into bucket of seawater and waves magnet in the vicinity of the electrodes (not to turn on and off, but to induce a signal in the coil channel). Lab confirms presence of FM carriers, and that $V_1$ and $V_2$ deviates with magnet. Launch person replaces magnet (turns off).

   c. When ready for launch, lab person comes to the deck to help put probe in launcher (a second person is needed to catch the probe as it falls down launch tube). Fuse and float are attached to the probe (see Appendix B), and then complete unit is secured in launcher. Lab person returns to the lab.

   d. Lab person puts voice header onto the analog magnetic tape (e.g., STREX '80, drop number, probe number), and loads acquisition program into HP 9845 computer.

   e. Bridge informs lab that the ship is on or approaching station.

   f. Lab acknowledges and requests radio silence for bridge and radio room.

   g. Lab informs deck to launch when ready.
3. Launch Operations
   a. Deck operator informs lab that it's 10 seconds to launch, lights fuse, and hollers into intercom. Lab operator starts analog tape recorder, 9845 acquisition program, and elapsed time counter (model DC 503 timer-counter).
   b. Fuse burns at 120 seconds per yard; 27 inches (about 80 to 90 seconds) was used during STREX.
   c. The end of the fuse is bent at 90 degrees and thrust into the Ethafoam float to prevent the fuse from rotating. See Appendix B for construction details.
   d. Launcher is lowered down toward the waves.
   e. Operator waits for a high wave so that the probe will only drop 1 to 2 feet from the launcher into the water.

4. Data Acquisition and Processing
   a. Turn on HP 9845 with AUTOST key locked down and the system cartridge in T15 (right-hand cartridge slot).
   b. Press special function key "k_o" to load and start DXGET, the acquisition program. Press CONT again when probe is launched.
   c. After the drop is completed, type the file name for the disk file to store data and add comments to the real time when DXGET was started.
   d. Earth's magnetic field can be found using the PADOC program. PADOC requires the date and position as input.
   e. To process the disk file, press special function key "k_1" to load and start DXPRO, the processing program. Answer the prompts with the appropriate file names and probe numbers. Add the drop and earth's magnetic field to the calibration data found on the XCAL file. Processing will take about 20 minutes to obtain a completed plot.

5. Post-Launch Procedure
   a. Lab advises bridge that the probe has been dropped, and the time is entered in the bridge log.
   b. Operator writes the time which appears on the 9845 CRT display.
c. Ship continues for 2 min at the same course and speed, after which it is told to come into the wind and sea and essentially maintain direction.

d. At the end of the drop, the wire breaks at the hand launcher so that no wire is left in the tube.

e. The XBT wire canister stays on launcher until next drop to protect launcher contacts.

f. The operator writes down the elapsed time from when the fuse was lit to the time the wire broke.

h. Operator notifies bridge that drop has been completed and that there is no need for further radio silence.
V. Error Analysis

A. Contamination of XTVP Profiles from Vessel's EM Fields

Contamination of XTVP velocity measurements is severe in the near vicinity of large research vessels. Based on the simple dipole character of vessel fields, our rule of thumb has been to release a probe 1-2 ship lengths away. This section describes some recent analyses to assess the amount of contamination found during two recent experiments.

Separation of vessel-caused disturbances from the desired motionally induced field is possible only because the former can be so large. Near the ship we frequently find electric currents that are interpreted as due to a velocity in excess of $10^3$ cm/s. Since there are no ocean flows of this speed, we can assume this velocity is due to the vessel and compare it with a model.

The model used is a horizontally oriented current dipole at the sea surface aligned with the vessel. The idea here is that electric currents exist around the vessel because of corrosion and cathodic protection. The latter cause probably will be dipole-like and of rather small scale. The horizontal and vertical electric current density in the area would be

$$J_x = \frac{2p}{4\pi} \frac{2}{(2x^2-z^2)/(x^2+z^2)^5/2}$$

$$J_z = \frac{6p x z/(x^2+z^2)^{5/2}}{4\pi}$$

where $p$ is the dipole strength in ampere meters. These expressions are twice those found for a dipole in an infinite medium because the current is confined to only the lower half domain.

For a ship speed of 5 knots and a fall speed of 4.5 m/s (say 10 knots), the horizontal position of the probe will increase at a rate of 0.5 W or $x = a + 0.5 z$, where $a$ is the distance of release from the center of the dipole.

The XTVP measures the horizontal component of the electric current as
where $\sigma$ is the electrical conductivity and $\xi = z/a$. The electric current is connected to velocity by the relation

$$v_y = \frac{J_x/\sigma}{x/z} = \frac{p(1+\xi^2/4)}{a \pi \sigma (1+5\xi^2/4)^{5/2}} \text{ m/s}.$$  

One aspect of this expression to note is that $J_x/\sigma = 0$ at a depth of $z = 2a(1+\sqrt{2}) = 4.8 \, a$. A near-surface notch, or low-signal zone, is frequently observed in the Kane and other near-vessel dropped profiles. This is because the electric current lines are curved and must become vertical as they converge toward the source and sink. A probe will experience this zone of zero horizontal electric currents at a depth of $z = 4.8 \, a$. Thus we would expect it to be seen at deeper depths for large release separations. Note also that the sign of $J_x$ changes at $z = 4.8 \, a$.

Figures 11 and 12 show two drops from the September 1979 Kane experiment. An example is shown for the SE-NW leg and for the NE-SW leg, two different orientations of the ship with respect to the earth's magnetic field. The absolute values of east ($u$: dashed), north ($v$: dash-dot) and speed $\sqrt{(u^2 + v^2)/2}$ (solid) are plotted versus depth. The near-ship notch is seen in both figures, and a signal decay of about $z^{-3}$ is observed as expected. At a depth of 30 m and deeper, the ocean-induced signal seems to dominate.

Figures 13 and 14 show two other drops, one from the remote launcher and another from the towed rubber boat. Neither of these profiles shows the vessel signature. They quickly converge on a signal level of 20-30 cm/s, which is the ocean contribution.

In Fig. 15, a comparison of the data of Fig. 11 is made with a fit [i.e., the absolute value of (41)] of the model for $p/\pi F \sigma = 4.9 \times 10^4$ which corresponds to $p = 30.8$ A-m, and for $a = 1$ m. A current dipole moment of this amount is typical for ships of this size. The model and data agree reasonably well until the ocean field takes over at 20 m. It should be emphasized that the model predicts $>1$ cm/s error until a depth of $\sim 100$ m.
Curves are of east (dashed), north (dash-dot) and speed (solid).

Figure 11. Drop 281 USNS Kane, deck launched. Dipole-like decay is shown as $z^{-3}$.

Figure 12. Drop 274 USNS Kane, deck launched. Dipole-like decay is shown as $z^{-3}$.

Figure 13. Drop 276 USNS Kane, remote launched.

Figure 14. Drop 290 USNS Kane, rubber boat launched.

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The model can be used to predict interference from the ship as a function of $a$, the distance of the release point from the ship. Figure 16 presents these results for $a = 1, 5, 10, 50$ and $100$ m for $p = 30.8$ A-m. As expected, the level of interference and the depth of the notch change as $a$ is increased. These calculations show that, even for $a = 100$ m, the interference is about 3-5 cm/s until a depth of 60-70 m. In order to limit the errors to <1 cm/s it seems that $a \approx 170$ m is needed. Caution should be used in interpreting these results, since the model is rather crude and is based on only one calibration. On the other hand, $p$ is reasonable in its strength, and the results are comparable to our rule of thumb.

Two examples, Figs. 17 and 18, of data and model fits are shown for drops launched from the starboard rail of the NOAA Oceanographer. In this case, a current dipole of 30.8 A-m was again used, but $a = 2.5$ m. Again the fit is reasonably good, and a predicted interference exceeds 1 cm/s until a depth of ~150 m. The larger depth scale for the Oceanographer versus the Kane is in the sense of their lengths, but this result may only be fortuitous, since vessel length does not enter the model.
Finally, the influence of the magnetic distortion of the Kane was examined. In Fig. 19, the magnitude of the coil area is shown for a sampling of differently launched profiles. The coil area is used as a measure of magnetic disturbance. It is also sensitive to tilt, which makes the interpretation of this signal somewhat ambiguous. Nonetheless, if the ship distorts the earth's magnetic field, then we expect the coil output to change with depth. The coil area is the variable to look at, since variations due to changing rotation frequency are removed. In Fig. 19 the profiles seem to converge to a similar value at about 30 m. Above this depth the area seems to be influenced by the vessel.

The final two figures, 20 and 21, show examples of simultaneous profiles from deck and remote launchers aboard the Kane. Here we see clear cases of the convergence of the area variable below 30 m. Since the compass signal does enter the electric field channel, it is important to avoid magnetic contamination.
Figure 19.
Coil area profiles for variously launched probes from USNS Kane.

Figure 20. Simultaneous deck and remote launched profiles of coil area from USNS Kane.

Figure 21. Simultaneous deck and remote launched profiles of coil area from USNS Kane.
The Kane profiles show a tendency for the coil area to be low around the vessel compared with that farther away. This suggests that near the ship the magnetic field is less.

On the basis of this analysis, it is recommended that probes be released 1-2 vessel lengths (100-200 m, depending on the ship) behind the vessel to reduce electric and magnetic influences to less than 1 cm/s. The analysis is subject to considerable error, since it is based on an extrapolation of near-ship observations. More profiles should be taken at distances of 1-50 m from the ships, or more detailed electric and magnetic measurements should be made. The latter does not require expenditure of XTVP probes. Also there may be a significant improvement achieved in the reduction of the electric influence if active cathodic protection (if used) is suspended during profiles. That is, p may be due to electric currents deliberately circulated to protect the propeller and shafts from corrosion. Suspension of this activity for brief periods would be beneficial to the data quality and not too detrimental to corrosion control.

The numerical calculations were carried out by John Litherland.

B. INFLUENCES OF SPATIAL AND TEMPORAL VARIATIONS OF THE GEOMAGNETIC FIELD

Spatial and temporal variations of the geomagnetic field can strongly influence the operation of the XTVP and interpretation of the measurements. The elements of the main, steady geomagnetic field determine the generation of the motionally induced electric currents. Regions of large and small geomagnetic components are shown in Fig. 22. Errors in the knowledge of these elements lead to errors in the interpretation of the measurements. An error in $F_H$ tends to contribute an error to the north flow component, while $F_Z$ errors lead to scaling errors for both flow components. Variations of $F$ in space and time lead to the generation of $\mathbf{j}^*$ electric currents.

Errors in estimating the magnetic field components arise mainly from magnetic anomalies of spatial scales smaller than detailed in the world charts (DMAGN magnetic field charts, #33 and 36). The magnitude of temporal variations is generally less than 1% of the steady field. However, these time variations generate induced electric currents which can be quite large compared with the motionally induced signals.

The main field, approximately that of a magnetic dipole aligned along the axis of rotation, has components
Figure 2. Locations of zones of small $F_n$ (magnetic equator) and small $F_n$ (magnetic poles).
\[ F_H = \frac{M \cos \theta}{r^3} \]

and

\[ F_z = -\frac{2M \sin \theta}{r^3} \]

where \( M = 8 \times 10^{15} \text{ tesla-m}^3 \), \( \theta \) is the latitude (positive to north) and \( r \) the geocentric radius.

The variations with depth are small: \( (1 \gamma = 10^{-9} \text{ teslas}) \)

\[ \frac{\partial F_H}{\partial z} = -1.4 \times 10^{-11} \cos \theta \text{ tesla/m} \]

\[ = -1.4 \cos \theta \gamma/100 \text{ m} \, , \quad (43) \]

\[ \frac{\partial F_z}{\partial z} = 2.8 \sin \theta \lambda/100 \text{ m} \, . \]

Within a 5 km deep ocean, the percentage changes to \( F_H \) and \( F_z \) are:

\[ \frac{\Delta F_H}{F_H} = \frac{\Delta F_z}{F_z} = 0.25\% \, . \quad (44) \]

The horizontal variations are

\[ \frac{1}{r} \frac{\partial F_H}{\partial \theta} = \frac{1}{2} \frac{F_z}{r} \gamma = 4\gamma/\text{km} \, , \]

\[ \quad \frac{1}{r} \frac{\partial F_z}{\partial \theta} = -2 \frac{F_H}{r} \gamma = 8\gamma/\text{km} \, . \quad (45) \]

An uncertainty in latitude, \( \Delta \theta \), leads to
\[
\frac{\Delta F}{F_H} = -\Delta \theta \tan \theta ,
\]
\[
\frac{\Delta F}{F_Z} = \Delta \theta \cot \theta .
\] (46)

At mid-latitudes ($\theta = 40^\circ$), the errors are ~1-2% per degree of latitude. The world charts (#33 and 36) are contoured every 1000 $\gamma$ for $F_H$ and 2000 $\gamma$ for $F_Z$, and can be scaled to at least 100 $\gamma$. If the charts were accurate to 100 $\gamma$, then $2F_H/F_H = 0.5\%$ and $\Delta F_Z/F_Z = 0.25\%$. However, it is known that the world chart is not accurate to this extent everywhere.

Small-scale magnetic anomalies exist over many topographic features such as seamounts, islands and submarine ridges. For instance, a fine-scale aeromagnetic survey of Plantagenet Bank, 25 n.mi. SW of Bermuda (Young and Kantis, 1964), reveals that the undisturbed field is 4-6% different from the world chart. Over the Bank itself, the errors reach 10-15%. Vertical and horizontal field gradients are 100 times larger than over an undisturbed area.

The magnetic field generated by the motionally induced electric currents has components no larger than 0.25% of the main geomagnetic field.

Temporal variations of the geomagnetic field generate electric fields and currents in the ocean. These magnetotelluric fields depend on the frequency and structure of the source magnetic field and on the depth and electrical conductivity of the ocean crust and mantle.

Magnetotelluric currents represent one of the largest sources of error in the EM profiling method. These effects are generally not independently measured or easily inferred from land-based magnetic measurements.

Cox, Filloux and Larsen (1971) and Fonarev (1968) have provided estimates of the electric fields generated by geomagnetic variations. The magnetic variations are described by Chapman and Bartels (1940). Variations having periods longer than one day generate only weak electric fields ($<1 \mu$V/m). Shorter period variations are responsible for significant electric induction. The major categories for the high-frequency variations are the solar-diurnal variations, bay-like disturbances, magnetic storms and short-period variations.
Solar-diurnal variations are always present, even on magnetically quiet days. These variations result in electric fields of the order of $3 \times 10^{-2} \mu V/m/\gamma$ in the open ocean. The maximum influence of these variations is given in Table 12 [Fonarev (1968)].

Bay-like disturbances derive their name from their appearance as bays or gulfs on magnetograms. These events provide mainly horizontal magnetic fields which decrease away from the auroral zone ($70^\circ$). Frequencies from tens of minutes to a few hours are present. Bay disturbances occur 10 to 40 times per year with an amplitude of 40-100 $\gamma$. An estimate of the resulting induction can be derived for a plane wave impinging on the sea surface. Such a wave will be attenuated as it propagates into the sea due to the generation of electric currents with opposing magnetic fields. At any depth, the magnetic field is

$$B(z) = B_0 e^{z/\delta}, \quad (47)$$

where $B_0$ is the surface value and $\delta$ is the skin depth. The skin depth is defined as

$$\delta = \left(\frac{2}{\mu \omega}\right)^{1/2}, \quad (48)$$

where the permeability $\mu = 4\pi \times 10^{-7} \ H/m$, $\sigma$ is the electrical conductivity and $\omega$ is the radian frequency of the wave.

The electric currents can be computed from Ampere's law:

$$\nabla \times B = \mu J, \quad (49)$$

The electric field due to the current density $J$ is $J/\sigma$. Hence

$$E = \frac{B_0}{\mu \sigma} e^{z/\delta}. \quad (50)$$
Table 12. Magnetotelluric effects [after Fonarev (1968)]:
For solar-diurnal variations

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Activity</th>
<th>$B_{L}/Y$</th>
<th>$E_{v}/\mu V/m$</th>
<th>$V_{cm/s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30°</td>
<td>Quiet</td>
<td>30-80</td>
<td>0.9-2.4</td>
<td>4.5-12</td>
</tr>
<tr>
<td></td>
<td>Disturbed</td>
<td>60-100</td>
<td>1.8-3.0</td>
<td>9.0-15</td>
</tr>
<tr>
<td>30-60</td>
<td>Quiet</td>
<td>15-60</td>
<td>0.45-1.8</td>
<td>1.1-4.2</td>
</tr>
<tr>
<td></td>
<td>Disturbed</td>
<td>25-110</td>
<td>0.75-3.3</td>
<td>1.9-8.2</td>
</tr>
<tr>
<td>&gt;60°</td>
<td>Quiet</td>
<td>90-400</td>
<td>2.7-12</td>
<td>4.6-20</td>
</tr>
<tr>
<td></td>
<td>Disturbed</td>
<td>50-460</td>
<td>1.5-14</td>
<td>2.5-22</td>
</tr>
</tbody>
</table>

For magnetic storm variations

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Activity</th>
<th>$B_{L}/Y$</th>
<th>$E_{v}/\mu V/m$</th>
<th>$V_{cm/s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30°</td>
<td>Weak</td>
<td>0-30</td>
<td>0-2</td>
<td>0-9</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>15-60</td>
<td>1-4</td>
<td>4-18</td>
</tr>
<tr>
<td></td>
<td>Strong</td>
<td>30-90</td>
<td>2-5</td>
<td>9-26</td>
</tr>
<tr>
<td>30-60</td>
<td>Weak</td>
<td>40-120</td>
<td>2-7</td>
<td>6-17</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>70-300</td>
<td>4-16</td>
<td>10-44</td>
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<tr>
<td></td>
<td>Strong</td>
<td>150-700</td>
<td>9-41</td>
<td>22-103</td>
</tr>
<tr>
<td>&gt;60°</td>
<td>Weak</td>
<td>70-600</td>
<td>4-32</td>
<td>7-60</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>150-900</td>
<td>9-52</td>
<td>15-88</td>
</tr>
<tr>
<td></td>
<td>Strong</td>
<td>900-1500</td>
<td>52-88</td>
<td>88-150</td>
</tr>
</tbody>
</table>

For water depth of 5 km and $\sigma = 2.7$ S/m.
This expression is appropriate for an infinitely deep ocean or when \( \delta < H \). The latter condition occurs for wave periods of 5 min or less. For longer periods, a more appropriate expression is:

\[
E(\mu V/m) = \frac{\sqrt{5\rho_a} B(\gamma)}{\sqrt{T}},
\]

(51)

where \( \rho_a \) is the apparent resistivity (combination of ocean and mantle resistivities) in ohm-m and \( T \) is the wave period in seconds. According to Poehls and von Herzen (1976), \( \rho_a \) in the NW Atlantic is about 20 ohm-m. Hence,

\[
E \sim \frac{10 B(\gamma)}{\sqrt{T}},
\]

(52)

For a bay-like disturbance of 40 \( \gamma \) over a period of 3 hours,

\[
E = 3.8 \mu V/m,
\]

(53)

leading to a velocity error of about 5 cm/s. Since the bay-like disturbances are of very large scale, it is possible to estimate the errors, perhaps even to correct the measurements, using land-based magnetic records.

Magnetic storms are more irregular than bay disturbances, often having rapid changes at the commencement over a few hours followed by a gradual recovery over tens of hours. The E/B ratios are the same as for the bay but the amplitude of B can be much larger, particularly in the auroral zone. According to Fonarev (1968), magnetic storms are as frequent as 20-50 times per year during years of maximum solar activity while 3-5 times fewer in years of minimum activity. The peak-to-peak variations and the expected electric induction and velocity errors are listed in Table 12.

Except for the most rapid components of magnetic storms, bays and diurnal disturbances produce little depth-dependent electric variations. That is, the energetic, long-period disturbances induce mainly depth-uniform electric currents, and these do not contribute errors to XTVP
profiles. Short-period variations (periods less than 10 minutes) are weak and contribute little induced electric field except in polar regions.

According to Fig. 16 of Cox et al. (1971), the electric field has a variance of about 0.1 (μV/m)^2 in the frequency band from 0.1 to 12 c/h. Thus we might expect deviations between profiles spaced several hours apart of about 0.6 cm/s due to changes in the ambient electric field. Over a small frequency interval, say, 1 to 12 c/h, the variance is about 10^{-2} (μV/m)^2 yielding a standard deviation of 0.2 cm/s.

C. TILT EFFECTS IN XTVP DATA

The XTVP is designed to measure electric currents present in the sea induced by the motion of seawater through the earth's magnetic field. Drever and Sanford (1980) and Sanford et al. (1978) discuss the calculation of oceanic velocities from these electrical measurements, assuming that the instrument remains vertical. Small instrumental tilts, however, are produced by vertical shear. In this report the effect of these tilts on the computed velocity profile is investigated and an algorithm to correct for these effects is developed and tested.

1. Model of Tilt Effects

The XTVP measures the electric potential between a pair of electrodes on opposite sides of a rotating cylinder falling through the ocean. The measured potential is the sum of a potential Δφ due to induced electric currents J and a potential Δφ due to the motion of the probe through the water. Both potentials are modified by the presence of the insulating probe within the conducting seawater.

The oceanic electric current density J is assumed to be entirely horizontal, due to the large aspect ratio of oceanic currents. Let

$$\frac{\mathbf{J}}{\sigma} = F_z (\mathbf{v} \hat{x} - u \hat{y})$$

where $$\hat{x}, \hat{y}, \hat{z}$$ are unit vectors in an earth fixed coordinate system (Fig. 23). Fz is the vertical component of the earth's magnetic field and u,v are the components of the purely horizontal current relative to the unknown electrical offsets u*,v* (Sanford, 1971). This electrical current results in a potential drop
Figure 23. Coordinate systems used in the analysis. \((\hat{z}, \hat{y}, \hat{x})\) is an earth fixed system, with \(\hat{y}\) pointing north (magnetic). The magnetic field has no east component, and the oceanic velocities have no \(z\) component. \((\hat{x}', \hat{y}', \hat{z}')\) is a coordinate system fixed with the probe, but not rotating, and is rotated by angles \(\alpha\) and \(\beta\) with respect to \((\hat{x}, \hat{y}, \hat{z})\). \((\hat{x}'', \hat{y}'', \hat{z}'')\) is fixed with the probe and rotating with it so that \(\hat{y}''\) is along the electrode/coil line. Table 13 gives the rotation matrices between these systems.
Table 13. Rotation matrices.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Matrix</th>
</tr>
</thead>
</table>
| y axis rotation by $\alpha$ (ccw) | \[
\begin{bmatrix}
\cos \alpha & 0 & \sin \alpha \\
0 & 1 & 0 \\
-sin \alpha & 0 & \cos \alpha
\end{bmatrix}
\] |
| x axis rotation by $\beta$ (ccw) | \[
\begin{bmatrix}
1 & 0 & 0 \\
0 & \cos \beta & \sin \beta \\
0 & -\sin \beta & \cos \beta
\end{bmatrix}
\] |
| z axis rotation by $\omega$ (cw) | \[
\begin{bmatrix}
\cos \omega & -\sin \omega & 0 \\
\sin \omega & \cos \omega & 0 \\
0 & 0 & 1
\end{bmatrix}
\] |

**Probe coordinates:**

<table>
<thead>
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<th>Axis</th>
<th>Probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{x}'$</td>
<td>$x$</td>
</tr>
<tr>
<td>$\hat{y}'$</td>
<td>$R_\beta R_\alpha y$</td>
</tr>
<tr>
<td>$\hat{z}'$</td>
<td>$z$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Matrix</th>
</tr>
</thead>
</table>
| $R_\beta R_\alpha$ | \[
\begin{bmatrix}
\cos \alpha & 0 & \sin \alpha \\
-sin \alpha \sin \beta & \cos \beta & \cos \alpha \sin \beta \\
-sin \alpha \cos \beta & -\sin \beta & \cos \alpha \cos \beta
\end{bmatrix}
\] |

<table>
<thead>
<tr>
<th>Rotating probe coordinates:</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{x}''$</td>
<td>$x$</td>
</tr>
<tr>
<td>$\hat{y}''$</td>
<td>$R_\omega R_\beta R_\alpha y$</td>
</tr>
<tr>
<td>$\hat{z}''$</td>
<td>$z$</td>
</tr>
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<tr>
<th>Rotation</th>
<th>Matrix</th>
</tr>
</thead>
</table>
| $R_\omega R_\beta R_\alpha$ | \[
\begin{bmatrix}
\cos \alpha \cos \omega & -\cos \beta \sin \omega & \sin \alpha \cos \omega \\
+\sin \alpha \sin \beta \sin \omega & \cos \beta \cos \omega & \sin \alpha \sin \beta \cos \omega \\
-sin \alpha \cos \beta \cos \omega & -\sin \beta & \cos \alpha \cos \beta
\end{bmatrix}
\] |
\[
\Delta \phi_V = -(1 + C_1) \hat{z} \wedge \mathbf{J} / \sigma
\]  
(55)

across the probe electrodes, where \(l\) is the electrode separation, \(\hat{y}'\) is the orientation of the electrode line, and \(C_1 = 0.9\) gives the magnification of the potential difference due to the presence of the probe. Because the electric current density must increase as the current is diverted by the probe, the voltage drop increases by the factor \(1 + C_1\).

The potential \(\Delta \phi_I\) induced by the probe motion relative to the water is best calculated in a nonrotating coordinate system oriented with the probe. Let \(z'\) be along the probe axis. The fixed system \(\hat{x}', \hat{y}', \hat{z}'\) can be transformed into the probe system \(\hat{x}', \hat{y}', \hat{z}'\) by a rotation of \(\alpha\) about \(\hat{y}\) followed by an \(x\)-axis rotation of \(\beta\) (Table 13, Fig. 23). In this coordinate system the induced potential is given by (Sanford et al., 1978, Equation A12)

\[
\Delta \phi_I = (1 + C_2) \hat{z} \wedge ((F_y \hat{y}' - F_x \hat{x}') \mathbf{W}') + (1 + C_3) \hat{z} \wedge ((U' \hat{y}' - V' \hat{x}') \mathbf{F}_Z'),
\]  
(56)

where \(W', U',\) and \(V'\) are the probe velocities relative to the water in the nonrotating probe coordinate system, and \(\hat{y}'\) is the orientation of the electrode line. Motion of the probe relative to the surrounding water results in two signals: induction by the relative motion of the probe itself and by the perturbation flow around the probe. These two signals may nearly cancel; the estimated values of \(C_2\) and \(C_3\) are \(-0.1\) and \(-0.8\) respectively.

The east and north components of velocity are determined relative to the voltage induced in a coil (the compass coil) coaxial with the electrode line. For technical reasons, a fraction \(c\) of the coil signal is also added to the measured electrode signal. Assuming the coil to have a total area \(A_c\), the potential induced in the coil by the probe's rotation is

\[
\Delta \phi_c = d \left( F \cdot A_c \hat{y}' \right) = \omega A_c F \cdot \hat{y}'
\]  
(57)

assuming

\[
\begin{align*}
\frac{da}{dt} & \approx \frac{dp}{dt} < \omega.
\end{align*}
\]
Using the rotation operators shown in Table 13 and Eqs. (55), (56) and (57), the following expressions can be derived to lowest order in \(a\) and \(B\):

\[
\begin{align*}
\Delta \phi_v &= (1+C_1)WF_z [u \cos \omega t - v \sin \omega t], \\
\Delta \phi_i &= (1+C_2)W' [(F_z + BF_y) \sin \omega t - aF_z \cos \omega t] \\
&\quad + (1+C_3)(F - BF_y)[U' \cos \omega t - V' \sin \omega t], \\
\Delta \phi_c &= -F \omega A_0 [(1+\frac{2}{F_y})\beta \sin \omega t - a \frac{2}{F_y} \cos \omega t].
\end{align*}
\]

The XTVP electrode signal transmitted up the wire is

\[
\Delta \phi = \Delta \phi_v + \Delta \phi_i + C\Delta \phi_c.
\]

This is then demodulated with the coil signal to produce in-phase (north) and quadrature (east) signals. If \(a = \beta = U' = V' = 0\), the coil signal is proportional to \(I = \sin \omega t\), and is in quadrature with \(Q = \cos \omega t\). The demodulation yields

**north:**

\[
\bar{\Delta \phi}_n = \bar{\Delta \phi} = -v(1+C_1)WF_z + [(1+C_2)W' + \omega A_0]F_y,
\]

**east:**

\[
\bar{\Delta \phi}_e = \bar{\Delta \phi} = u(1+C_1)WF_z,
\]

where the overbar denotes a time average. Equation (62) is identical to Eq. (4) of Drever and Sanford (1980). If \(W'\) is known, the oceanic velocities \(u\) and \(v\) can be determined.
The direction of north is defined by the phase of the coil signal. For a vertical probe, the coil signal passes through zero when the coil \( \frac{F}{y} \) points north. If the probe is not vertical, an east-west tilt results in a phase shift of the coil signal so that this zero crossing no longer gives the same direction. The demodulation signals using (60) are now

\[
I = \sin\omega t - \alpha \frac{F_z}{y} \cos\omega t ,
\]

(64)

\[
Q = \cos\omega t + \alpha \frac{F_z}{y} \sin\omega t ,
\]

(65)

and the demodulated signals are

north:

\[
\Delta\phi_n = - (1+C_1)IF_z (v + \alpha \frac{F_z}{y} u)
\]

\[
+ F_y (1+\beta F_z/F_y) [(1+C_2)IF' - cuA_o ]
\]

\[
- (1+C_3)IF_z (1-\beta F_z/F_y) (v' + \alpha \frac{F_z}{y} U' ) ,
\]

(66)

east:

\[
\Delta\phi_e = (1+C_1)IF_z [u - \alpha \frac{F_z}{y} v]
\]

\[
+ (1+C_3)IF_z (1-\beta F_z/F_y) (U' - \alpha \frac{F_z}{y} V' ) .
\]

(67)

Equations (66) and (67) give the demodulated potential difference for a tipped probe with velocities \( U' \), \( V' \) and \( W' \) relative to the water.
Since the probe is a stable streamlined body, it will be assumed to fall along its length, so that $U' = V' = 0$. There is no direct verification of this assumption. However, since $(1+C_3)/(1+C_4) = 0.1$, the measured potentials are much more sensitive to oceanic velocities $(u,v)$ than probe velocities $(U',V')$.

The probe tilt is seen to have two major effects. An east-west tilt ($\alpha \neq 0$) changes the measured phase of the coil signal and therefore mixes east and north contributions. This is seen in the first and last terms of (66) and (67). If $\alpha$ is small, this effect is small. A north-south tilt changes the magnitude of the magnetic field parallel to the probe $(F_x')$, leading to a change in both the coil and $W'$ induced signals. This can be seen in the second term of (66).

The effect of these tilts is seen in a different way if the calculation is done entirely in the fixed coordinate frame. Suppose the probe is falling with velocity components $U$, $V$ and $W$ in a stationary ocean (i.e., $J = 0$); the induced potential is given by

$$F = E_y W' + F_z (U' - v)\hat{x},$$

where we take $C_1 = C_2 = C_3 = 0$ for simplicity. Since the probe is tilted and falling along its length, $U = \alpha W$ and $V = \beta W$. Neglecting, for the moment, the small phase shift caused by $\alpha$,

$$\hat{\chi}'' = \hat{x} \sin\omega t + \hat{y} \cos\omega t,$$

and the measured signals are

north:

$$\Delta \phi_n = \beta WF_z + WF_y = F_y (1 + \beta F_z/F_y)W,$$

east:

$$\Delta \phi_e = - \alpha WF_z.$$
The tilt causes the probe to move horizontally relative to the water; the probe measures an induced potential resulting from this motion. The resulting in-phase signal $\beta WF_z$ in (70) is clearly present in the second term of (66). The corresponding quadrature signal $-\alpha WF_z$, however, is not present in (67). It is canceled by the east-west tip term neglected in (70) and (71). As discussed above, an east-west tip $\alpha$ results in a phase shift in the coil signal. This mixes the east and north potentials. The north potential is dominated not by the north velocity potential, but by induced potential due to $W$. The primary effect of the coil phase shift is thus to mix some of this $W$ induced potential into the east potential. The additional east potential is of magnitude $\alpha WF_z$ and exactly cancels the $\alpha$ induced potential in (71).

Switching to probe coordinates, this clearly must be true, since the signal induced by $W'$ is in phase with the coil, and cannot appear in the east signal. Thus, except for the small amount of east-north mixing, there is no effect of tilt in the east velocity component, to first order, if the probe falls along its length.

2. Processing Changes

The present XTVP processing computes a north velocity $\tilde{v}$ using

$$\tilde{v} = -[\Delta \phi_n - (1+C_2)\gamma \Delta \phi_c]/(1+C_1)\ell F_z,$$  \hspace{1cm} (72)

where $W_e$ is the estimated fall rate and $\Delta \phi$ is calculated from the probe rotation rate. Using (60), (64) and (66) with $U' = V' = 0$, the computed velocity will be

$$\tilde{v} = (v + \alpha \frac{\ell}{\gamma} u) + \frac{\ell}{\gamma} \frac{(1+C_2)}{(1+C_1)} (W - W') \beta \frac{(1+C_2)}{(1+C_1)} W'. \hspace{1cm} (73)$$

The computed north velocity contains three errors: a mixing of $u$ with $v$ due to east-west tip ($\alpha$), an error due to the incorrect estimation of $W_e$, and an error due to north-south tilt ($\beta$). Since $W' = 450 \text{ cm/s} > u$, the last term is dominant. A north-south tip of 1° will lead to an error of 4 cm/s.

It is possible to correct for the $\beta$ tilt. Using (60), the magnitude of the coil signal is
The effective area of the coil is

$$A = \frac{\Delta \phi_C}{\omega F_y} = A_0 (1 + \frac{F_z}{F_y} \beta) \tag{75}$$

which to first order in $\alpha$ and $\beta$ is a function only of the north-south tilt. The third term in (73) can be estimated using

$$\frac{(1 + C_2)}{(1 + C_1)} W' = - \left( \frac{A}{A_0} - 1 \right) \frac{F_z}{F_y} \frac{(1 + C_2)}{(1 + C_1)} W_e \tag{76}$$

and removed from the estimate of $v$ using

$$\vartheta = -\left[ \Delta \phi_n - \frac{A}{A_0} (1 + C_2) F_y W_e - c \Delta \phi_c \right] / (1 + C_1) F_z \tag{77}$$

In practice, $A_0$ is estimated from the vertical mean of $A$, since the fluctuations in $A$ occur on a relatively short vertical scale.

3. **Comparison of Tilt-Corrected and Uncorrected Profiles**

Figure 24 shows a typical XTVP profile of east and north velocity and area as defined by (75). Interpreting the area fluctuations as tilt fluctuations, the probe is seen to tilt only a few degrees, north-south. These small tilts are sufficient, however, to significantly affect the computed north velocity. Notice the difference between the velocity computed using (72) (light line) and (77) (heavy line, tilt corrected). The north velocity is most affected on the 10-50 m scale, where the area, or tilt, fluctuations are concentrated. Note that the corrected profile shows less correlation with the area than the uncorrected profile, and that the tilt correction primarily affects the amplitude, not the phase, of the computed profile.

The effect of the tilt correction on different vertical scales is more clearly seen in Fig. 25. The average autospectra of east and north...
Figure 24. A low noise XTVP profile (AUTEQ 176) of east and north relative velocity, and effective coil area (75). North is computed both by (72) (uncorrected, light line) and by (77) (corrected, heavy line). Area is also interpreted as north-south tilt.

from 64 XTVP profiles are shown with the north velocity computed using both (72) (light line) and (77) (heavy line). The uncorrected data show more energy in north than east at scales smaller than 300 m, while the tilt corrected data show the same energy in east and north.
Figure 25. Average autospectra from 64 XTVP profiles taken during the USNS Kane cruise. Both tilt-corrected by (7?) and uncorrected by (72) north spectra are shown. The 95% confidence interval was computed using 64 EDOF. The wavenumber bin is 1/640 cpm.

4. Comparison with Other Measurements

The differences between the corrected and uncorrected profiles occur primarily on vertical scales where internal wave fluctuations are dominant. Current meter measurements in the open ocean usually show an isotropic internal wave field with the same amount of energy in east and north (Wunsch, 1976). The corrected XTVP profiles, which show equal energy in east and north, agree with these current meter data, while the uncorrected data profiles do not.
Simultaneous velocity profiles using two different profilers are an excellent test of both instruments. Two such comparisons are discussed below, an XTVP comparison with TOPS (Hayes, 1981; data courtesy of Dr. S. Hayes NOAA/PMEL), a profiler expected to be most accurate at 1-50 m scales, and a comparison with acoustically tracked floats (Wenstrand, 1979; data courtesy of Dr. D. Wenstrand APL/JHU), which are expected to be most accurate at scales greater than 50 m.

Figure 26 compares the data obtained from nearly simultaneous drops of an XTVP and TOPS, a free-fall velocity profiler that measures its own velocity, relative to the ocean, using a nose mounted acoustic current meter. A model of the body dynamics is used to compute the large scale velocity profile from these measurements. Figure 26 compares the autospectra from the uncorrected XTVP data and TOPS. The east spectra are

![Figure 26. Autospectra from TOPS/XTVP intercomparison. XTVP data are not tilt corrected. (Figure courtesy Dr. S. Hayes, NOAA/PMEL)](image-url)
quite similar. The north spectra, however, show more energy in the XTVP profile at scales smaller than 100 m, just as in Fig. 25. This again suggests that the XTVP north velocity must be corrected for north-south tilt. Figure 27 compares the TOPS and XTVP profiles. If a slowly increasing depth offset in one of the profiles is recognized, the correspondence between the two profiles, especially on a feature for feature basis, is excellent, even with the uncorrected XTVP data.

Figure 28 shows a comparison between simultaneous XTVP and acoustically tracked dropsonde data. Sanford et al. (1981) discuss this intercomparison in more detail. Figure 28 compares a typical acoustic profile with an exceptionally quiet (for this data set) XTVP, processed both by (72) (uncorrected) and (77) (corrected). All three profiles have zero vertical mean; no other adjustments have been made. The correspondence between the acoustic and the corrected XTVP profiles is excellent. The uncorrected XTVP north profile fits the acoustic profile much less accurately than the corrected profile.

![Figure 27. Velocity profiles from TOPS/XTVP intercomparison. (Figure courtesy of Dr. S. Hayes NOAA/PMEL)](image-url)
Figure 28. Comparison of nearly simultaneous XTVP (176) and acoustic tracked float (#7) velocity profiles. Both tilt-corrected by (77) and uncorrected (72) north XTVP profiles are shown. All profiles have zero vertical mean; otherwise not adjusted.

5. XTVP Error Analysis

The results of the acoustic dropsonde/XTVP intercomparison will be used to estimate the errors in the XTVP measurement. Each intercomparison set consists of an acoustic up and down profile, and several XTVP profiles taken during the acoustic profile. Three intercomparison sets are used below. In addition, simultaneous acoustic profiles using two different floats were taken.

Table 14 lists the rms differences between the various profiles averaged over all intercomparisons. Each profile is divided into two, 100-m sections (150-250 m, 250-350 m) and each pair of profiles is shifted vertically up to ±8 m so that a maximum correlation occurs. This allows for some depth error in the XTVP.
Table 14. The rms difference between adjusted profiles (cm/s).

<table>
<thead>
<tr>
<th>Simultaneous acoustic profiles$^1$</th>
<th>East</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.77</td>
<td>0.61</td>
</tr>
<tr>
<td>Acoustic up/down pairs$^2$</td>
<td>1.23</td>
<td>1.48</td>
</tr>
<tr>
<td>XTVP nearly simultaneous$^3$</td>
<td>1.33</td>
<td>1.65</td>
</tr>
<tr>
<td>XTVP pairs within intercomparison$^4$</td>
<td>1.33</td>
<td>1.55</td>
</tr>
<tr>
<td>XTVP/acoustic pairs$^5$</td>
<td>1.19</td>
<td>1.38</td>
</tr>
</tbody>
</table>

$^1$ AUTEC profiles 8 and 9, 10 and 11, down profiles only. Time differences less than 5 minutes.

$^2$ AUTEC profiles 8, 9, 10, 11.

$^3$ All next neighbor pairs in sets (160-163), (165-169). Time differences less than 10 minutes.

$^4$ All pairs in sets (160-163), (165-169), (176, 179)

$^5$ All XTVP/acoustic pairs in sets (#4, 160-163), (#5, 165-169), (#7, 176, 179), where #4, #5, and #7 are AUTEC acoustic profiles.

For either acoustic velocity component $A$, let

$$A = O_A + \epsilon_A,$$

(78)

where $O_A$ is the oceanic velocity field measured by a noiseless acoustic profiler and $\epsilon_A$ is a random error. From simultaneous profiles, $\epsilon_A$ can be estimated with

$$\overline{(A_1 - A_2)^2} = 2\epsilon_A^2.$$  

(79)
Using the statistics shown in Table 14, $\varepsilon_A = 0.6$ to 0.7 cm/s. The difference between the up and down acoustic profiles can be used to estimate the change in the oceanic velocity field during the profile:

$$(A_U - A_D)^2 = (O_{AU} - O_{AD})^2 + 2\varepsilon_A^2.$$  \hspace{1cm} (80)

A value of 0.5 cm/s is estimated.

Similarly, if either XTVP velocity component is given by

$$X = O_X + \varepsilon_X,$$  \hspace{1cm} (81)

simultaneous XTVP profiles can be used to estimate $\varepsilon_X$,

$$(X_i - X_{i+1})^2 = 2\varepsilon_X^2,$$  \hspace{1cm} (82)

and the entire set of XTVP intercomparison profiles gives an estimate of the oceanic change during the experiment:

$$(X_1 - X_2)^2 = (O_{X_1} - O_{X_2})^2 + 2\varepsilon_X^2.$$  \hspace{1cm} (83)

Sufficient XTVP profiles simultaneous with the acoustic drops do not exist. The acoustic and XTVP error estimates have thus been made using data taken at different times on the same day. Table 14 shows no significant difference between the XTVP rms errors computed for nearly simultaneous profiles as in (82) or using all the profiles in each intercomparison set.

$$(O_{X_1} - O_{X_2})^2$$
will thus be taken as zero. Some oceanic change is certainly present, but for the small number of profiles used here, it cannot be resolved.

Systematic differences may exist between the acoustic and XTVP velocity profiles. These can be computed from the XTVP/acoustic statistics:

\[
(X - A)^2 = (O_X - O_A)^2 + \varepsilon_X^2 + \varepsilon_A^2.
\] (84)

Assuming that there is no temporal change in the ocean during the intercomparison, an upper limit for

\[
\sqrt{(O_X - O_A)^2}
\]

of 0.5 cm/s for the east or tilt corrected north is computed. Notice that the uncorrected north velocity shows a much larger systematic error of 1.6 cm/s. If some oceanic change is allowed, the calculated systematic error becomes smaller.

The XTVP errors are summarized in Table 15. The systematic velocity errors are significantly less than 1 cm/s, and the random velocity errors are about 1 cm/s. The XTVP's used in this intercomparison were early models, and showed a considerably higher noise level than more recently manufactured probes. The value of \(\varepsilon_X\) computed here certainly overestimates the random noise in more recent probes, probably by a factor of 2 or more.

6. Conclusions

The above analysis clearly shows the significance of small north-south tilts in affecting the measured XTVP north velocities. The velocity errors due to these tilts can be removed if the XTVP is assumed to fall along its length when tilted. An analysis of the AUTEC XTVP intercomparison with acoustically tracked floats shows that the tilt errors can be removed and an accurate velocity profile constructed.

This analysis reveals systematic differences of approximately 0.5 cm/s rms between the acoustic and XTVP profiles. The XTVP random error is estimated at 1 cm/s rms for this set of probes. The more recently manufactured probes have less random error.
Table 15. Error analysis results (cm/s).

<table>
<thead>
<tr>
<th></th>
<th>East</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic random error εₐ</td>
<td>0.54</td>
<td>0.43</td>
</tr>
<tr>
<td>Acoustically measured oceanic change during up/down profiles</td>
<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td>(OₐU - OₐAD)²/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XTVP random error εₓ</td>
<td>0.94</td>
<td>1.1</td>
</tr>
<tr>
<td>XTVP/acoustic systematic error (Oₓ - OₓA)²/2 upper bound</td>
<td>0.49</td>
<td>0.51</td>
</tr>
</tbody>
</table>

D. Surface Wave Interference

Surface waves produce strong surface enhanced velocities and electric currents. Typical particle velocities are about 100 cm/s, a large value compared with typical low frequency flows. Moreover, since the frequency is large, about 1 s⁻¹, the probe will see a time varying signal as it falls. The wave signal will appear as a vertical shear of wavelength equal to the probe's fall speed times the wave period. For a 6 s wave and a 4.5 m/s fall rate, the wavelength is 27 m.

The vertical attenuation of a surface wave depends on its horizontal wavenumber (k) which is ω²/g, where ω is its frequency and g is gravity. For a 6 s period wave the wavelength is about 60 m. The velocity decreases as eᵏz, which is e⁻²π or 0.002 at z = -60 m. Thus, caution must be exercised in the interpretation of velocity shear in the upper 50 m under typical ocean surface wave conditions.

E. Sensitivity Analysis

The rms error of the velocity estimates U' and V' is determined numerically using randomly determined probe tilts α and β, probe gains and probe component values. The digital receiver outputs I and Q are generated given U and V using deviated gains. U' and V' are then estimated from I and Q using nominal gains and component values.

The square root of the average variance of the velocity errors for 25 U and V combinations is found for 20 pseudoprobes. This is listed in Table 16 as the U and V rms error.
Table 16.

$U, V$ rms error as a function of gain tolerances

<table>
<thead>
<tr>
<th>$U, V$ velocity range (±cm/s)</th>
<th>$\alpha, \beta$ tilt range (°)</th>
<th>Probe gain tolerances (°)</th>
<th>Probe phase tolerances (°)</th>
<th>V/F converter tolerances (°)</th>
<th>$U, V$ rms error (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

$U, V$ rms error as a function of component tolerances

<table>
<thead>
<tr>
<th>$U, V$ velocity range (±cm/s)</th>
<th>$\alpha, \beta$ tilt range (°)</th>
<th>Resistor tolerances (±%)</th>
<th>Resistor tolerances (±%)</th>
<th>V/F converter tolerances (°)</th>
<th>$U, V$ rms error (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1</td>
<td>0.1</td>
<td>10</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>0.1</td>
<td>10</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>1.3</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>2.0</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>5</td>
<td>20</td>
<td>10</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Typical ranges of $U, V$ and tilt were used. The rms error scales linearly with $U, V$ ranges and also increases with tilt. As the velocity range increases one would expect larger tilts and thus a more than proportional increase in error. Even with a perfectly known probe calibration, one should expect a 1.1 cm/s rms error over ±40 cm/s range with ±2° tilts.

Present resistor tolerances are 0.1%, but 1% would be sufficient (except for common mode rejection). The voltage to frequency (V/F) converters should be within 5% for less than 1.5 cm/s rms error.
VI. References


APPENDIX A
Program Listings and Sample Runs
Listing of Program DXGET

DXGET accepts data from the XTVP receiver via the 16-bit parallel I/O card (HP 98032A). One single HP 9845 ENTER statement is used with an integer array of 28800 words. We use DMA and NOFORMAT to ensure that no data are lost. The XTVP receiver outputs are two's complement 16-bit binary integers to match the HP 9845 integer word format. The keyboard is locked out during the ENTER to prevent loss of data.

After the HP 9845 data array is full, the array is written onto magnetic storage media for later processing by DXPRO. We elected not to collect and process simultaneously, for data integrity reasons and because the acquisition only takes 5 minutes. A more complicated program would be more prone to failure during data acquisition.

10 Progrlev$="DXGETG"
20 ! DXGET .. JAN 16 80. GET DIGITAL RCVR XTVP DATA.
30 ! DXGETG .. SEPT 16 80. OPERATOR INPUTS THE NUMBER OF SCANS TO READ.
40
50 OPTION BASE 1
60 SERIAL
80
90 PRINT "";
100 PRINT Progrlev$;" TAKES XTVP DATA FROM THE DIGITAL RECEIVER FOR THE SPECIF IED";
110 PRINT "NUMBER OF DATA CYCLES. A DATA CYCLE IS ONE REPEITION OF EACH OF ";
120 PRINT "THE TEN VARIABLES.";
130
140 PRINT "THE USER CAN ENTER THE NUMBER OF DATA CYCLES WISHED OR CAN LEAVE";
150 PRINT "THAT PARAMETER (Ncyc) AT IT'S DEFAULT";
160
170 PRINT "THERE IS ONE DATA CYCLE PER XTVP REVOLUTION. ";
180
190 PRINT "FOR REAL TIME DATA USE NCYC=2880 TO ALLOW FOR PRE-DROP TIME";
200 PRINT "FOR PLAYBACK USE NCYC=1800 IF COMPUTER IS STARTED A FEW SECONDS PR IOR TO DROP";
210 PRINT LIN(I)
220
230 Ncyc=2880
240 DISP "ENTER THE NO. DATA CYCLES TO TAKE FROM THE DIG RCVR. THE DEFAULT I S";Ncyc;
250 INPUT "",Ncyc
260 Nword=Ncyc*10
270 PRINT "THE NUMBER OF DATA CYCLES WILL BE ";Ncyc;" FOR THIS RUN";
271 PRINT "THIS WILL TAKE ";Ncyc/8;" SECONDS AT 8 HZ ROTATION FREQ.";
290 !
300 INTEGER Din(32000)
310 !
320 REDIM Din(Nword)
330 !
340 !
350 DISP "PUSH CONT TO START RECORDING FROM DIGITAL RECEIVER"
360 !
370 !

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380 ! OUTPUT 9; "R" ! GET REAL TIME
390 ENTER 9; Comment$
400 !
410 DISP Comment$; "GETTING DATA FROM DIGITAL RECEIVER NOW. "
420 SYSTEM TIMEOUT OFF
430 SUSPEND INTERACTIVE
440 ENTER 11 WDMA Nword NOFORMAT; Din(*)
450 RESUME INTERACTIVE
460 SYSTEM TIMEOUT ON
470 BEEP
480 ! STORE JUST-READ-IN DATA
490 EDIT "OUTPUT FILE NAME ?", File$
500 ASSIGN #2 TO File$, Ret
510 IF Ret<>0 THEN 510
520 DISP "FILE NAME "; File$; " EXISTS. USE ANOTHER FILE NAME. ";
530 GOTO 500
540 IF LEN.File$)=0 THEN 480
550 EDIT "COMMENTS ?", Comment$
560 ASSIGN #2 TO File$, Ret
570 IF Ret<>1 THEN 500
580 GOTO 640
590 DISP ERRMS; " WHILE CREATING "; File$; ". PUSH CONT USING ANOTHER DISC"
600 ON ERROR GOTO 600
610 PAUSE
620 GOTO 500
630 !
640 CREATE File$, Nword*4/256+5
650 OFF ERROR
660 !
670 ASSIGN #2 TO File$
680 READ #2, 1
690 PRINT #2; Comment$
700 PRINT #2; Din(*)
710 ASSIGN #2 TO *
720 !
730 DISP Progrev$; " FINISHED"
740 BEEP
750 END
Program PADOC, Sample Run

PADOC is a program that computes the magnetic field components needed for data processing by DXPRO. The operator enters the date and position, and the program evaluates a spherical polynomial model. The program was modified by Jagit Hayre to run on the HP 9845 in BASIC. The original FORTRAN program was purchased from NOAA EDIS/NGSDC (D62), 325 Broadway, Boulder, Colorado 80303, (303) 497-6478. The model currently used is USWC75, but more refined models will soon be available.

The following page shows operator input and program output for 40°30'N and 150°55'W on 30 March 1981. The results for horizontal and vertical intensity in Gauss (10⁻⁴ tesla) are 0.2408963 and -0.3883425. Note that the vertical intensity is taken to be <0 in the northern hemisphere. This is the opposite of some conventions.

```
PADDock 02...........CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL
AND VERTICAL INTENSITY FOR A GIVEN DATE AND
POSITION........

ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN POSITION?
(GEOETIC/GEOCENTRIC)
GEODETIC
GEODETIC VALUES WILL BE CALCULATED FOR A GIVEN DATE AND POSITION
IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)
YES
THERE ARE PRESENT 1 MODELS WHOSE NAMES ARE:
1 USWC75

MODEL 1 (USWC75) IS THE ONLY AVAILABLE MODEL--- USED BY DEFAULT
INPUT DATE: DAY, MONTH, YEAR
30,3,81

GIVEN DATE: 30/ 3/ 1981
WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH? (N/S)
N
WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST? (E/W)
W

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<th>VERTICAL INTENSITY</th>
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<td>DEG MIN N</td>
<td>DEG MIN W</td>
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<td>(GAUSS)</td>
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INPUT POSITION: LATITUDE (DEG,MIN), LONGITUDE (DEG,MIN)
40°30'00" 150°55'00"
1.2408963 -0.3883425

INPUT POSITION: LATITUDE (DEG,MIN), LONGITUDE (DEG,MIN)
40°30'00" 150°55'00"

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**Listing of Program PADOC**

10 !******************************************************************************
20 ! PROGRAM PADDOCK-- CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL AND VERTICAL INTENSITY FOR A GIVEN DATE AND POSITION USING VARIOUS MODELS STORED IN DATA STATEMENTS
30 !
40 ! This program is a modification of a FORTRAN program of spherical harmonic models for the earth's magnetic field, model AWC75, from U.S. Dept. of Commerce, NOAA, NGSDC (D62), Environmental Data Service, Boulder, Colorado, 80302.
50 !
60 ! INPUT REQUIRED FOR THIS PROGRAM IS:
70 ! 1) ARE THE GEODETIC OR GEOCENTRIC VALUES TO BE CALCULATED FOR THE GIVEN DATE AND POSITION?
80 ! 2) IS A LIST OF THE AVAILABLE MODELS DESIRED?
90 ! 3) IF THE # OF AVAILABLE MODELS<>0 THEN ENTER THE MODEL # OF THE DESIRED MODEL TO BE USED FOR THE CALCULATION
100 ! 4) ENTER THE DATE: DAY, MONTH, YEAR.
110 ! 5) WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH?
120 ! 6) WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST?
130 ! 7) ENTER POSITION: DEG MIN (<LAT>) DEG MIN (<LONG>)
140 ! 8) REPEAT STEP (7) AS DESIRED...
150 !
160 !
170 !
180 ! PADDOCK 01...... ORIGINAL FORTRAN PROGRAM
190 ! PADDOCK 02...... FORTRAN PROGRAM CONVERTED TO RUN ON THE HP 9845B
200 !
210 ! PRINT "PADDOCK 02........ CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL AND VERTICAL INTENSITY FOR A GIVEN DATE AND POSITION....."
220 !
230 !
240 !
250 !
260 !
270 !******************************************************************************
THIS PROGRAM DEMONSTRATES THE USE OF FUNCTIONS NGDXYZ AND NGCXYZ TO COMPUTE VALUES OF THE GEOMAGNETIC ELEMENTS, AS DEFINED BY A SPECIFIED MODEL OF SPHERICAL HARMONIC COEFFICIENTS, FOR A GIVEN TIME AND FOR A GIVEN GEODETIC OR GEOCENTRIC POSITION. THE SHC'S OF THE AVAILABLE MODELS ARE CONTAINED IN DATA STATEMENTS IN FUNCTION NGDXYZ.

SAMPLE CALLS

N = NGDXYZ( YEAR, GDLAT, ELONG, GDALT, MODEL, ENTRY )

YEAR.......THE DATE IN YEARS
GDLAT.......GEODETIC NORTH LATITUDE, IN DEGREES
ELONG.......EAST LONGITUDE, IN DEGREES
GDALT.......ALTITUDE ABOVE THE GEOID, IN KILOMETERS
MODEL.......ORDINAL OF MODEL THAT IS TO BE USED
ENTRY.......=0 FOR SIMPLE CALL TO NGDXYZ ( NO ENTRY PT )
WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE INTERNATIONAL ELLIPSOID OF 1961. THIS IS THE ENTRY THAT WOULD NORMALLY BE USED.

N = NGDXYZ( YEAR, GCLAT, ELONG, GCALT, MODEL, ENTRY )

GCLAT......GEOCENTRIC NORTH LATITUDE, IN DEGREES
GCALT......ALTITUDE ABOVE THE SPHERE OF RADIUS 6371.2KM, IN KM
ENTRY.......=1 FOR CALL TO ENTRY POINT NGCXYZ IN FUNCTION NGDXYZ

WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE SPHERICAL EARTH WHOSE RADIUS IS 6371.2KM.

RAD
OPTION BASE 1
COM X,Y,Z,Xdot,Ydot,Zdot,Models,Name$<20,Ymn<900),Ymn<900),Zmn<900

FUNCTION NGDXYZ RETURNS THE MAGNETIC ELEMENTS X(NORTHWARD INTENSITY), Y(EASTWARD INTENSITY), AND Z(DOWNWARD INTENSITY), AND THEIR ANNUAL RATES, VIA COMMON. THE UNITS ARE GAMMAS (NANOTESLAS) AND GAMMAS/YEAR (NANOTESLAS/YEAR). THESE VALUES APPLY TO THE DATE AND POSITION USED IN THE CALL STATEMENT.

DETERMINE IF GEODETIC OR GEOCENTRIC VALUES ARE DESIRED

INPUT "ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN POSITION? (GEODETIC/GEOCENTRIC)","Geotype$

IF (Geotype$="GEOCENTRIC") OR (Geotype$="GEODETIC") THEN 880
BEEP
DISP "MISSPELLED DESIRED TYPE--- ",Geotype$
GOTO 750

APL-UW 8110 AS
FIRST WE MAKE A DUMMY CALL TO NGDXYZ. THIS FIRST CALL WILL SIMPLY
READ THE SHC MODEL HEADER CARDS, PLACE IN MODELS THE NUMBER OF SHC
MODELS, AND PLACE IN NAMES THE INDIVIDUAL MODEL NAMES. THIS DUMMY
CALL IS NORMALLY UNNECESSARY, IT IS NEEDED HERE ONLY BECAUSE WE WIS
H TO PRINT THE NUMBER OF MODELS AND THEIR NAMES BEFORE MAKING AN ACTU
AL CALL TO NGDXYZ.
PRINT USING "K";Geotype$," VALUES WILL BE CALCULATED FOR A GIVEN DA
TE AND POSITION"
N=FNNGdxyz(1999,0,0,0,0,0)
INPUT "IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)",Response$
IF Response$="NO" THEN 990
OUTPUT THE LIST OF AVAILABLE MODELS
PRINT USING "/3(K)";"THERE ARE PRESENT ",Model!, " MODELS WHOSE NAME
S ARE:"
FOR I=1 TO Models
PRINT USING "/X,DD,2X,K/;I,Name$(I) ! OUTPUT AVAILABLE MODEL NAM
ES
NEXT I
Model=1
IF Models<>1 THEN 1060
PRINT USING "K";"MODEL 1 (",Name$,") IS THE ONLY AVAILABLE MODEL
--- USED BY DEFAULT"
GOTO 1110
INPUT THE DESIRED MODEL NUMBER
INPUT "ENTER THE NUMBER OF THE DESIRED MODEL",Model
IF (Model<>1) OR (Model>Models) THEN 1110
BEEP
DISP "MODEL NUMBER ",Model!, "OUT OF RANGE ---- MAX MODEL NUMBER IS 
,Models
GOTO 1060
IF Models>1 THEN PRINT USING "/3(K)";"MODEL ",Model!, ",Name$(Model
1),") IS BEING USED FOR THIS RUN"
Rod=.017453293 ! RAD/DEGREE CONVERSION FACTOR
Rod=Rod+SIN(180.0*Rod)/180.0
Rod=Rod+SIN(180.0*Rod)/-180.0
Rom2=2*Rod/60.0
READ IN THE DATE AND POSITION DIRECTION
INPUT "INPUT DATE: DAY, MONTH, YEAR",Day,Month,Year
IF Year<1900 THEN Year=Year+1900
Date=Year+Month/12+Day/365
INPUT "WILL THE GIVEN POSITION's LATITUDE BE NORTH OR SOUTH? (N/S)"

DIM$=

IF (Dirns$="N") OR (Dirns$="S") THEN 1290

BEEP

DISP "DIRECTION MUST BE N OR S ---- ",Dirns$," IS ILLEGAL "

GOTO 1240

INPUT "WILL THE GIVEN POSITION's LONGITUDE BE EAST OR WEST? (E/W)"

Direw$=

IF (Direw$="E") OR (Direw$="W") THEN 1370

BEEP

DISP "DIRECTION MUST BE E OR W ---- ",Direw$," IS ILLEGAL "

GOTO 1290

PRINT TABLE HEADINGS

PRINT " POSITION HORIZONTAL VERTICAL"

PRINT " LATITUDE LONGITUDE INTENSITY INTENSITY"

PRINT USING "2(K,1A),K/";"DEG MIN ",Dirns$," DEG MIN ",Direw$"

READ IN THE POSITION (ACTUAL LOOPING OCCURS HERE)

Input: INPUT "INPUT POSITION: LATITUDE (DEG,MIN), LONGITUDE (DEG,MIN)"

Alt=Alat+Alatmin/60.0

Elon=Elondeg+Elonmin/60.0

IF Dirns$="S" THEN Alt=-Alt

IF Direw$="W" THEN Elon=-Elon

Alt=0

IF Geotype$="GEOCENTRIC" THEN 1640

GEOCENTRIC POSITION AT THE GIVEN GEODETIC POSITION.

N=FNNGdxyz(Date,Alat,Elon,Alt,Model,0)

WE NOW HAVE VALUES AND RATES FOR MAGNETIC ELEMENTS X, Y, AND Z.

VALUES FOR THE OTHER GEOMAGNETIC ELEMENTS, IF NEEDED, MUST BE COMPUTED.

HORIZONTAL INTENSITY

H=SQR(X^2+Y^2)

Hdot=(SQR((X+Xdot)^2+(Y+Ydot)^2)-SQR((X-Xdot)^2+(Y-Ydot)^2))/2

TOTAL INTENSITY

F=SQR(X^2+Y^2+Z^2)

Fdot=(SQR((X+Xdot)^2+(Y+Ydot)^2+(Z+Zdot)^2)-SQR((X-Xdot)^2+(Y-Ydot)^2+(Z-Zdot)^2))/2
DECLINATION

\[ D = \frac{\text{FNAtan2}(Y, X)}{\text{Rod}} \]

\[ D_{\text{dot}} = \frac{\text{FNAtan2}(Y + Y_{\text{dot}}, X + X_{\text{dot}}) - \text{FNAtan2}(Y - Y_{\text{dot}}, X - X_{\text{dot}})}{\text{Rom}^2} \]

INCLINATION

\[ \text{Dip} = \frac{\text{FNAtan2}(Z, H)}{\text{Rod}} \]

\[ \text{Dip}_{\text{dot}} = \frac{\text{FNAtan2}(Z + Z_{\text{dot}}, H + H_{\text{dot}}) - \text{FNAtan2}(Z - Z_{\text{dot}}, H - H_{\text{dot}})}{\text{Rom}^2} \]

IF Geotype$ = $"GEODETIC" THEN M9

OBTAIN GEOCENTRIC VALUES FOR THE GIVEN GEOCENTRIC POSITION

\[ N = \text{FNNgdxzy}(\text{Date, Alat, Elon, Alt, Model, 1}) \]

1970 PRINT USING "2(3D,1X,3D.DD,2X,1IX),2(3.DDDDDDD,2X)"; Alatdeg, Alatmin, Elondeg, Elomin, H, Z

GOTO Input

END

DEF FNNgdxzy(Yr, Alat, Elon, Alt, Kthmod, Entry)

OPTION BASE 1

COM X, Y, Z, Dx, Dy, Dz, Models, Model$$(20), Xmn(900), Ymn(900), Zmn(900)

FOR THE GIVEN YEAR, GEODETIC POSITION, ALTITUDE, AND MODEL, THIS FUNCTION COMPUTES THE MAGNETIC ELEMENTS X, Y, Z, XDOT, YDOT, ZDOT, AND RETURNS THEM IN COMMON.

AT THE FIRST ENTRY, THIS FUNCTION READS A DECK OF 1 TO 20 MODELS.

THIS DECK IS TERMINATED BY A CARD WITH 9999 IN CC 1-4.

PARAMETERS

\[ YR.............\text{DATE IN YEARS / 1975.0} \]

\[ ALAT...........\text{NORTH LATITUDE IN DEGREES / 40.0} \]

\[ ELON...........\text{EAST LONGITUDE, IN DEGREES / -103.0} \]

\[ ALT............\text{HEIGHT ABOVE THE GEOID IN KILOMETERS / 100.0} \]

\[ KTHMOD........\text{EITHER...THE ORDINAL OF THE MODEL, IE, 3 WILL CAUSE THE 3RD MODEL TO BE USED} \]

\[ ENTRY...........=0 \text{ IMPLIES SIMPLE FUNCTION NGDXYZ CALL} \]

\[ =1 \text{ IMPLIES ENTRY NGCXYZ CALL.} \]

ON RETURN, THE VALUE OF NGDXYZ WILL INDICATE WHAT ERROR, IF ANY, OCCURRED.

\[ NGDXYZ = 0.....\text{NO ERROR} \]

\[ =-1.....\text{ERROR IN MODEL DATA RECORD. FATAL} \]

\[ =-2.....\text{ARRAY G (WHEREIN THE SHC S OF THE MODELS ARE STORED)} \]

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IS
2310  C NOT LARGE ENOUGH. (THE SIZE OF G IS GIVEN BY MAXGS). FATAL.
2320  C = -3.....MODEL SPECIFIED BY KTHMOD NOT FOUND. FATAL.
2330
2340  C = I.....yr outside date limits set by model header card
2350  C = 2.....alt outside height limits set by header card
2360  C = 3.....both yr and alt outside limits
2370  C
2380  C
2390  C
2400  DIM IJS(20,3),MAX(20,3),Epoch(20),Yrmin(20),Yrmax(20),Altmax(20),Altmin(20),G(6080)
2410  C THE SIZE OF ARRAY G IS PROBABLY UNREASONABLY LARGE FOR MOST USERS.
2420  C IF ITS SIZE IS CHANGED, THEN THE VALUE OF MAXGS, AS SET IN THE
2430  C FIRST DATA STATEMENT, MUST ALSO BE CHANGED.
2440
2450
2460  IF Entry=1 THEN Lngcxyz  ! ENTRY NGCXYZ SIMULATION
2470  C ENTRY NGCXYZ SIMULATION
2480  Ngdgc=0
2490  R1: READ Maxgs,Models
2500  DATA 600, 0
2510  READ Maxmod,Maxxyz
2520  DATA 20, 30
2530  IF Kthmod=0 THEN A2
2540  MAT IJS=(0)
2550  MAT Yrmax=(2000)
2560  MAT Yrmin=(0)
2570  MAT Altmax=(-1.0E11)
2580  MAT Altmin=(-1.0E11)
2590  READ Nthold,Killer
2600  DATA -1, 1
2610
2620  ! ******************* MODEL "USWC75" *******************
2630
2640  DATA 0,0,"USWC75", 1975.0, 12.8, 0, 1967.0, 1980.0, -1.0, 100.0
2650  DATA 0.1,-30055.7, 0, 24.39, 0, 0
2660  DATA 1,1,-2017.0, 5670.5, 9.94, -10.29, 0
2670  DATA 0,1,-1932.0, 0, -24.85, 0, 0
2680  DATA 1,2, 3001.3,-2044.4, 1.19, -3.30, 0
2690  DATA 2,2, 1619.7, -69.2, 3.10, -18.98, 0
2700  DATA 0,3, 1267.1, -3.74, 0, 0
2710  DATA 1,3,-2127.2, -343.5, -10.42, 6.68, 0
2720  DATA 2,3, 1259.4, 263.2, -3.41, 2.13, 0
2730  DATA 3,3, 818.0, -206.5, -3.70, -3.53, 0
2740  DATA 0,4, 953.8, 0, .46, 0, 0
2750  DATA 1,4, 786.1, 196.7, -1.78, 4.65, 0
2760  DATA 2,4, 437.8, -257.0, -3.69, .96, 0
2770  DATA 3,4, -412.6, 20.1, -2.06, .87, 0
2780  DATA 4,4, 232.3, -287.5, -1.60, -1.37, 0
2790  DATA 0,5, -214.2, 0, .31, 0, 0
2800  DATA 1,5, 357.4, 31.4, -.34, 1.45, 0
2810  DATA 2,5, 256.1, 150.7, .96, 2.04, 0
2820  DATA 3,5, -42.8, -137.4, -1.16, -1.27, 0
2830  DATA 4,5, -166.7, -81.9, -.37, 1.34, 0
2840  DATA 5,5, -58.9, 86.2, .63, 1.04, 0

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3420 DATA 0,12, -.7, 0 , 0 , 0, 0, 0
3430 DATA 1,12, 0.0, 1.3, 0 , 0, 0, 0
3440 DATA 2,12, 1.6, -1.8, 0 , 0, 0, 0
3450 DATA 3,12, .4, .9, 0 , 0, 0, 0
3460 DATA 4,12, -1.5, .1, 0 , 0, 0, 0
3470 DATA 5,12, -1.2, -1.8, 0 , 0, 0, 0
3480 DATA 6,12, -1.4, 1.4, 0 , 0, 0, 0
3490 DATA 7,12, -3.6, -1.1, 0 , 0, 0, 0
3500 DATA 8,12, .6, .1, 0 , 0, 0, 0
3510 DATA 9,12, .8, 1.9, 0 , 0, 0, 0
3520 DATA 10,12, -.3, -3.3, 0 , 0, 0, 0
3530 DATA 11,12, 1.3, .6, 0 , 0, 0, 0
3540 DATA 12,12, .7, 1.5, 0 , 0, 0, 0
3550 ! ********************************************
3560 ! TERMINATION DATA HEADER CARD ***************
3570 ! ********************************************
3580 DATA 99,99,"END", 0 , 0, 0, 0, 0, 0, 0
3590 ! ********************************************
3600 ! ********************************************
3610 ! ********************************************
3620 !
3630 !
3640 !
3650 ! Ngdxyz=0
3660 ! IF Models>0 THEN A10
3670 ! Ijnext=0
3680 ! A2: I=Models+1
3690 ! IF I>Maxmod THEN A8
3700 ! C
3710 ! C
3720 ! IF I=1 THEN RESTORE 2640 ! SELECT THE DATA FOR THE 1th MODEL
3730 ! IF I=2 THEN RESTORE 3600 ! TERMINATION DATA HEADER CARD IS
3740 ! REQUIRED
3750 ! C
3760 ! SELECT THE DATA FOR THE 1th MODEL
3770 ! IF P=99 THEN A9 ! TERMINATION MODEL HEADER CARD
3780 ! IF Kthmod<>0 THEN A3
3790 ! THIS LOOP SIMPLY COUNTS THE NUMBER OF MODELS AVAILABLE (BY THE DUMMY CALL TO NGDXYZ FROM THE MAIN PROGRAM)
3800 ! Models=Models+1
3810 ! GOTO A2
3820 ! IF <M<0 OR <N<0 THEN A81
3830 ! IF Altmnin<>0 THEN Altmnin=Altmnin
3840 ! IF Altmxii<>0 THEN Altmxii=Altmxii
3850 ! IF Yrmnin<>0 THEN Yrmnin=Yrmnin
3860 ! FOR J=1 TO 3
3870 ! IF Max(I,J)=0 THEN A4
3880 ! Max(I,J)=Max(I,J)+1
3890 ! Ijs(I,J)=Ijnext
3900 ! Ijnext=Ijnext+Max(I,J)^2
3910 ! NEXT J
3920 ! A4: IF Ijnext>=Maxgs THEN A82
3930 ! Models=1

APL-UW 8110 A11
CALCULATE THE NUMBER OF DATA STATEMENTS TO BE READ FOR THE DESIRED MODEL

3940 3950 3960 3970 3980
Ncards=Max(I,1)*Max(I,1)+1/2
Maxg=Max(I,1)
Maxdg=Max(I,1,2)
Max2g=Max(I,3)

3990
ij10=Ijs(I,1)
ij20=Ijs(I,2)
ij30=Ijs(I,3)

4000 FOR Ij=1 TO Ijnext
4010 G(Ij)=0
4020 NEXT Ij
4030 FOR Nc=2 TO Ncards
4040 C
4050 C
4060 C
4070 C
4080 C
4090 C
4100 C
4110 C
4120 C
4130 C
4140 C
4150 C
4160 IF Dgmn<>0 THEN G(Ij2)=Dgmn
4170 IF D2gmn<>0 THEN G(Ij3)=D2gmn
4180 IF M=0 THEN A6
4190 J1=Ij10+N*Maxg+M+1
4200 J2=Ij20+N*Maxdg+M+1
4210 J3=Ij30+N*Max2g+M+1
4220 C(Ij1)=Hmn
4230 IF Dhmn<>0 THEN G(Ij2)=Dhmn
4240 IF D2hmn<>0 THEN G(Ij3)=D2hmn
4250 A6: NEXT Nc
4260 CALL Smigau(G(*),Ij10+Maxg,Maxg)
4270 IF Maxdg<>0 THEN CALL Smigau(G(*),Ij20+Maxdg,Maxdg)
4280 IF Max2g<>0 THEN CALL Smigau(G(*),Ij30+Max2g,Max2g)
4290 GOTO A2
4300 A8: IF M>99 THEN A81
4310 A9: IF Models=0 THEN A81
4320 IF Kthmod=0 THEN RETURN Ngdxyz
4330 A10: IF Kthmod=Nthold THEN A20
4340 A11: IF ABS(Kthmod)=Maxmod THEN A12
4350 FOR I=1 TO Models
4360 IF Kthmod<>Model(I) THEN A11
4370 Nthmod=I
4380 GOTO A13
4390 A11: NEXT I
4400 GOTO A83
4410 A12: IF (Kthmod<1) OR (Kthmod>Models) THEN A83
4420 Nthmod=Kthmod
4430 A13: Nthold=Kthmod
4440 Maxg=Max(Nthmod,1)
4450 Maxdg=Max(Nthmod,2)
4460 Max2g=Max(Nthmod,3)
4470 Ij10=Ijs(Nthmod,1)
4480 Ij20=Ijs(Nthmod,2)
4490 Ij30=Ijs(Nthmod,3)

A12 APL-UW 8110
CALL Vecxyz(Alat,Elon,Alt,Maxg,Ngdgc)

TEST FOR NON-FATAL ERRORS

IF (Yr<Yrmin(Nthmod)) OR (Yr>Yrmax(Nthmod)) THEN Ngdxyz=1
IF (Alt<Altmin(Nthmod)) OR (Alt>Altmax(Nthmod)) THEN Ngdxyz=Ngdxyz+2

X=0
Y=0
Z=0
Ij=Ij+j0
Ji=Ji+0
FOR I=1 TO Maxg
Ji=Ji+0
Ji=Ji+0
Gmij=G(Ij)
X=X+Xmn(Ji)*Gmij
Y=Y+Ymn(Ji)*Gmij
Z=Z+Zmn(Ji)*Gmij
NEXT J
NEXT I
Dx=0
Dy=0
Dz=0
IF Maxdg<=0 THEN RETURN Ngdxyz
Ij=Ij+j20
Ji=Ji+0
FOR I=1 TO Maxdg
Ji=Ji+0
Ji=Ji+0
Dgmnij=G(Ij)
Dx=Dx+Xmn(Ji)*Dgmnij
Dy=Dy+Ymn(Ji)*Dgmnij
Dz=Dz+Zmn(Ji)*Dgmnij
NEXT J
NEXT I
De1=Yr-Epoch(Nthmod)
IF Maxd2g>0 THEN A30
X=X+De1*Dx
Y=Y+De1*Dy
Z=Z+De1*Dz
RETURN Ngdxyz
Dx=0
Dy=0
Dz=0
Ij=Ij+j30
Ji=Ji+0
FOR I=1 TO Maxd2g
Ji=Ji+0
Ji=Ji+0
NEXT J
NEXT I
A30:
A24:
A23:
A21:
A22:
A20:


```apl
Ij=Ij+1
Ji=Ji+1
Dgmni j=G(Ij)
D2x=D2x+Xmn(Ji)*Dgmni j
D2y=D2y+Ymn(Ji)*Dgmni j
D2z=D2z+Zmn(Ji)*Dgmni j
NEXT J
NEXT I
Del2=Del*Del
X=X+Del*Dx+Del2*D2x
Y=Y+Del*Dy+Del2*D2y
Z=Z+Del*Dz+Del2*D2z
Del2=2*Del
Dx=Dx+Del2*D2x
Dy=Dy+Del2*D2y
Dz=Dz+Del2*D2z
RETURN Ngdxyz
ENTRY NGCXYZ
C * ( YR, ALAT, ELON, ALT, NTHMOD ) C
OUT
THIS ENTRY IS USED WHEN POSITION AND ALTITUDE ARE GEOCENTRIC. THE
RETURNED MAGNETIC ELEMENTS ARE GEOCENTRIC.

C

Ngcxyz;Ngdc=1
GOTO A1
ERROR RETURNS
GOTO A82:
Mistek=2
PRINT "MISTEK=2 AT A82 --- ARRAY G INADEQUATELY DIMENSIONED"
GOTO A89
MODEL SPECIFIED BY KTHMOD NOT FOUND
AS9:
Ngdxyz=-Mistek/Killer
RETURN Ngdxyz
FNEND

A14 APL-UW 8110
```
SUB Vecxyz(Alat, Elon, Alt, Maxnew, Nyceno)

OPTION BASE 1
RAD

DIM X(900), Y(900), Z(900), Xmn(900), Ymn(900), Zmn(900)

READ Rod, Oldth, Oldam, Oldlat, Oldalt, Oldr
DATA 0.017453293, 9999., 9999., 9999., 9999., -99.

READ Maxi, New, Radius, Max, Nyceno
DATA 30, 1, 6371.2, -1, -1

IF Max = Maxnew THEN GOTO B2
Nyceno = -1
Max = Maxnew
IF New = 0 THEN GOTO B2
New = 0
Max = Max + 1
Max = Max + 2

SET UP CONSTANTS IN LOWER TRIANGULAR OF P
FOR J = 1 TO Maxi
    Ji = J - Maxi
    A = (J - 2) * (J - 2)
    B = (2 * J - 3) * (2 * J - 5)
FOR I = 1 TO J
    Ji = Ji + Maxi
    NEXT I

Am = Elon * Rod

IF Nycen = Nyceno THEN GOTO B3
Nycen = Nycen
Oldlat = 9999
Oldth = 9999
Oldr = -1

IF Nycen <> 0 THEN B9

POSITIONS ARE GEODETIC
XMN, YMN, ZMN WILL BE GEODETIC

Vlat = Alat
Valt = Alt
IF (Vlat = Oldlat) AND (Valt = Oldalt) THEN B10
Oldlat = Vlat
Oldalt = Vlat

Gg = Vlat ^ 2
Rs = 6378.160 + Gg * (-.0064601509 + Gg * (6.39897239E-7 + Gg * (-2.3568098E-11 + Gg * 3.44645500E-16)))

Del = Vlat * (1.16781720E-4 + Gg * (-2.34129534E-8 + Gg * (1.34088770E-12 - Gg * 2.84450572E-17)))

Hrs = Valt + Rs
Beta = Rs / Hrs
Th = (90.0 - Vlat) * Rod + Beta
R = (Hrs - Beta * Valt * Del * .5) / Radius
BBeta = Beta * 2
Beta = Beta + (1 + BBeta * (-1 / 6.0 + BBeta / 120.0))
IF ABS(Beta) < 1 THEN B8

AML-UW 8110 A15
SIMULATION OF FORTRAN "SIGN(A,B)" FUNCTION

IF Beta>0 THEN Beta=1
IF Beta<0 THEN Beta=-1

Cbeta=0
GOTO B10

IF Beta<O THEN Beta=1

Cbeta=SQR(1-Beta^2)
GOTO B10

POSITIONS ARE GEOCENTRIC
XMN, YMN, ZMN WILL BE GEOCENTRIC

R=1+Alt/Radius
Th=(90.0-Alat)*Rod
Beta=0

IF Th=Oldth THEN B20

IF V=0 THEN V=1.0E-20
P(I)=1
D(I)=0
I=1
FOR I=2 TO Max

I1i=I
I1i=I1i+1
I1i=I1i-1
P(I)=V*P(I1i)
D(I)=U*P(I1i)+V*D(I1i)
 FOR J=1 TO Max

I2j=I1i
J2i=I1i+1
I1i=I1i+1
J2i=I1i-1
FOR J=1 TO Max

I2j2=I2j1
I2j1=I2j
I2j=I2j+Maxi
J2j2=J2j+1
P(I2j)=U*P(I2j1)-P(J1i)*P(I2j2)
D(I2j)=U*D(I2j1)-P(J1i)*D(I2j2)-V*P(I2j1)

NEXT J

NEXT I

I=1
FOR I=3 TO Max

I2j1=I1i
J2i=I1i+1
I1i=I1i+1
J2i=I1i-1
FOR J=1 TO Max

I2j2=I2j1
I2j1=I2j
I2j=I2j+Maxi
J2j2=J2j+1
P(I2j)=U*P(I2j1)-P(J1i)*P(I2j2)
D(I2j)=U*D(I2j1)-P(J1i)*D(I2j2)-V*P(I2j1)

NEXT J

NEXT I

STORE SINES AND COSINES OF LONGITUDE

IF Am=Oldam THEN B30

Oldam=Am
Cm(2)=COS(Am)
Sm(2)=SIN(Am)
Cm(1)=1
Sm(1)=0
FOR I=3 TO Max
Sm(I)=Sm(I-1)*Cm(2)+Cm(I-1)*Sm(2)
Cm(I)=Cm(I-1)*Cm(2)-Sm(I-1)*Sm(2)
NEXT I

STORE POWERS OF R

IF R=Oldr THEN B40
Oldr=R
Rxy(1)=1/R/R
Rz(1)=-Rxy(1)
FOR I=2 TO Max
Rxy(I)=Rxy(I-1)/R
Rz(I)=-1*Rxy(I)
NEXT I

COMPUTE XMN, YMN, ZMN ARRAYS

J1=1
FOR J=2 TO Max
Xmn(J1)=Rxy(J)*D(J1)
NEXT J

J1=0
FOR I=2 TO Max
Cmi=Cm(I)
Smi=Sm(I)
Ij=Ii+1
Ji=li
Ii=Ii+Maxi1
FOR J=1 TO Max
Ij=Ij+Maxi
Ji=Ji+1
Rxyj=Rxy(J)
Rdij=Rxyj*D(Ij)
Xmn(Ij)=Cmi*Rdij
Ymn(Ij)=-Epr*Smi
Ymn(J1)=Em+V1
NEXT J

NEXT I

IF Beta=0 THEN B50
J1=0
FOR I=1 TO Max
Ij=J1
NEXT I

IF Beta=0 THEN B50
J1=0
FOR I=1 TO Max
Ij=J1
NEXT I
FOR J = 1 TO Max
Ij = Ij + 1
IF Ij = 1 THEN B48
Xij = Xmn(Ij)
Zij = Zmn(Ij)
Xmn(Ij) = Cbeta * Xij + Beta * Zij
Zmn(Ij) = Cbeta * Zij - Beta * Xij
B48: NEXT J
B49: NEXT I
B50: SUBEND

SUB Smigau(G(*), Pointer, Maxg, Maxi)
OPTION BASE 1
RAD
Root = Pointer - 1
G(*) AND POINTER ARE USED HERE TO SIMULATE THE PASSING OF ARRAYS
AS PARAMETERS IN FORTRAN
DIM P(30,30)
THIS ROUTINE CONVERTS A (MAX,G,MAXG) ARRAY OF SPHERICAL HARMONIC
COEFFICIENTS, STORED IN AN ARRAY DIMENSIONED (MAXI,MAXI),
FROM SCHMIDT-NORMALIZED TO GAUSS-NORMALIZED (MAIN ENTRY), OR
FROM GAUSS-NORMALIZED TO SCHMIDT-NORMALIZED (GAUSMI ENTRY).
READ New, Max
DATA 0, 30
Next = 1
DI: IF New < 0 THEN D10
New = 1
P(1,1) = 0
P(1,2) = 1
P(2,2) = 1
FOR I = 3 TO Max
H = I - 1
P(I,1) = P(I-1,1)*SQR(1-.5/H)
P(I,1) = P(I-1,1)*(2-1/H)
H = H - 1
Hh = H^2
FOR J = I TO Max
F = J - 1
P(I-1,J) = P(I-1,J-1)*(F+F-1)/SQR(F+F-Hh)
D3: NEXT J
NEXT I
FOR I = 2 TO Max
FOR J = 1 TO Max
P(J, I-1) = P(I, J)
NEXT J
NEXT I
IF Next = 2 THEN D21
FOR J = 1 TO Maxg
K = (J-1)*Maxi + Root
FOR I = 1 TO Maxg
G(I+K) = G(I+K) * P(I, J)
NEXT I
NEXT J
D10: NEXT I
D11: FOR J = 1 TO Maxg
K = (J-1)*Maxi + Root
FOR I = 1 TO Maxg
G(I+K) = G(I+K) * P(I, J)
NEXT I
NEXT J
D12: NEXT I
NEXT J
A18 APL-UW 8110
SUBEXIT
D21: FOR J=1 TO Maxg
    K=(J-1)*Maxi+Root
    FOR I=1 TO Maxg
        Pij=P(I,J)
        IF Pij=0 THEN D22
        G(I+K)=G(I+K)/Pij
    NEXT I
    NEXT J
SUBEXIT
ENTRY GAUSMI
C * ( G, MAXG, MAXI )
GOTO D1
SUBEND

DEF FNAtan2(Y,X)
EQUIVALENT OF THE ATAN2 FUNCTION IN FORTRAN
RAD
IF X=0 THEN Vert
Ang=ATN(Y/X)
IF X>0 THEN RETURN Ang
IF Y<0 THEN Q3
Ang=Ang+PI
RETURN Ang
QU:< Ang=Ang-PI
RETURN Ang
Vert: IF Y<0 THEN Down
Ang=PI/2
RETURN Ang
Down: Ang=-PI/2
RETURN Ang
FNEND
Program DXPRO, Sample Run

DXPRO is the program that takes DXGET files of raw data and produces velocity profiles on files and as plots. The algorithms are described in Section III.B.2.

DXPRO is usually run with 10 probe revolutions per average and with 5 revolutions between each average. The probe calibrations are usually pre-stored in the XCAL:T15 file but can be entered by hand. DXPRO can search the XCAL:T15 file by probe number or drop number. The earth's magnetic field components must be entered with the calibration.

DXPRO will use the HP 9845T internal graphics option or an HP 9872A or HP 9872S plotter.

The following pages show the operator input and program output.

The program listing follows.

```
DXPROZ 81:04:07:18:18:47
INPUT FILE NO. 1 ? (CLEAR TO TERMINATE)
620RD
EDIT COMMENTS
11:10:04:27:40 INTENSIVE SURVEY HEADING 270
NUMBER OF SCANS IN EACH AVERAGING WINDOW?
10
STEPPING INCREMENT?
5
EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)
XCAL :T15
XTVP SERIAL NO.? (ZERO TO SEARCH BY DROP NO.)
871
READING XCAL :T15
EDIT: Probe Mod Gcc Gcor Gef Evco Cuco Drop Fh Fz
500 871 6 3628 1838 25230 1001 1000 620 .204-.490
OUTPUT FILE NAME?
620P
INPUT FILE NO. 2 ? (CLEAR TO TERMINATE)

PLOTTER? (0=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)
3
LOOKING FOR PF ON
LAUNCH-TIME= 11:10:04:27:52 12.2378
DOWN-TIME= 11:10:04:29:06 96.24273
ISCAN= 98
ISCAN= 673
PROCESSING FILE 1. IFILE=620RD, OFILE=620P
2 Temp U V W Rotf Area Uw Vc0a Zcdp Ve0a Ve0p Fefb Fccb Ver
-7 10.18 33.5 12.4 -454 5.23 682 94 59 -7.6 4.36 118.3 2453 450329.9
-11 10.18 28.4 -1 -454 6.27 798 94 64 -8.3 4.85 113.9 2438 4505 9.0
-15 10.18 44.0 -12.3 -454 6.60 771 94 65 -6.8 5.69 118.1 2477 4505 1.3
-19 10.18 39.8 -18.4 -454 6.75 767 94 66 -6.5 5.90 114.9 2465 4504 1.1
-21 10.18 32.9 -22.5 -454 6.83 767 94 67 -6.3 5.98 111.1 2485 4504 1.0
-24 10.18 26.2 -22.0 -454 6.90 763 94 67 -6.5 5.88 108.2 2498 4504 1.1
```

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<th>V</th>
<th>W Rot' Area</th>
<th>Uw</th>
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Z Temp U V W Rot' Area Uw VeOa Zcdp VeOa VeOp Fefb Fccb Ver.
| Z Temp | U | V | W | Rotf | Area | Uv | VcbA | Zcdp | VeB | Ve0p | Fefb | Fccb | Ver |
|--------|---|---|---|------|------|---|-----|------|-----|-----|------|------|------|-----|
| -266  | 5.24| 4.3 | .4 | -448 | 6.71 | 737 | 93  | 63  | -5.9 | 4.58 | 97.4 | 2505 | 4502 | .3  |
| -289  | 5.22| 4.5 | -1.1 | -448 | 6.71 | 740 | 93  | 64  | -6.0 | 4.65 | 97.7 | 2505 | 4502 | .3  |
| -213  | 5.17| 5.9 | -3.1 | -448 | 6.74 | 744 | 93  | 64  | -5.9 | 4.75 | 98.4 | 2504 | 4502 | .3  |
| -216  | 5.11| 6.9 | -1.9 | -448 | 6.73 | 743 | 93  | 64  | -5.7 | 4.69 | 98.8 | 2505 | 4502 | .3  |
| -219  | 5.05| 7.6 | -2.9 | -448 | 6.70 | 745 | 93  | 64  | -5.7 | 4.74 | 99.2 | 2504 | 4502 | .4  |
| -223  | 5.02| 7.9 | -4.9 | -448 | 6.69 | 747 | 93  | 64  | -5.9 | 4.84 | 99.4 | 2504 | 4502 | .3  |
| -226  | 5.01| 8.3 | -4.1 | -448 | 6.71 | 745 | 93  | 64  | -6.0 | 4.80 | 99.8 | 2505 | 4502 | .4  |
| -229  | 4.99| 9.2 | -2.5 | -448 | 6.72 | 738 | 93  | 64  | -5.9 | 4.73 | 100.3 | 2505 | 4502 | .3  |
| -233  | 4.97| 9.0 | -2.4 | -448 | 6.70 | 736 | 93  | 63  | -5.8 | 4.72 | 100.1 | 2505 | 4502 | .4  |
| -236  | 4.93| 10.1 | -3.3 | -448 | 6.68 | 739 | 93  | 63  | -6.0 | 4.77 | 100.9 | 2505 | 4502 | .4  |
| -239  | 4.89| 11.8 | -4.6 | -447 | 6.70 | 739 | 93  | 63  | -6.0 | 4.84 | 101.8 | 2505 | 4502 | .4  |
| -243  | 4.86| 13.3 | -3.4 | -447 | 6.71 | 735 | 93  | 63  | -5.8 | 4.79 | 102.6 | 2504 | 4502 | .5  |
| -246  | 4.84| 13.8 | -1.6 | -447 | 6.69 | 728 | 93  | 62  | -5.7 | 4.71 | 103.0 | 2505 | 4502 | .4  |
| -249  | 4.82| 14.0 | -1.7 | -447 | 6.67 | 727 | 93  | 62  | -5.9 | 4.71 | 103.2 | 2505 | 4502 | .4  |
| -253  | 4.81| 14.4 | -3.9 | -447 | 6.68 | 735 | 93  | 63  | -5.9 | 4.82 | 103.3 | 2505 | 4502 | .3  |
| -256  | 4.79| 13.9 | -4.4 | -447 | 6.69 | 739 | 93  | 63  | -5.9 | 4.84 | 103.0 | 2505 | 4502 | .3  |
| -260  | 4.76| 14.1 | -3.9 | -447 | 6.69 | 739 | 93  | 63  | -5.8 | 4.81 | 103.0 | 2505 | 4502 | .3  |
| -263  | 4.73| 14.3 | -3.7 | -447 | 6.65 | 738 | 92  | 63  | -5.6 | 4.81 | 103.0 | 2505 | 4502 | .4  |
| -266  | 4.78| 14.2 | -2.3 | -447 | 6.64 | 736 | 92  | 63  | -5.9 | 4.79 | 103.3 | 2504 | 4502 | .4  |
| -270  | 4.68| 14.5 | -2.4 | -446 | 6.67 | 737 | 92  | 63  | -6.1 | 4.74 | 103.7 | 2504 | 4502 | .3  |

Z Temp U V W Rotf Area Uv VcbA Zcdp VeB Ve0p Fefb Fccb Ver
<table>
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<th>V</th>
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<th>Uv</th>
<th>Vc0A</th>
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<td>.4</td>
</tr>
</tbody>
</table>

APL-UW 8110  A23
| Z | Temp | U | V | W | Rotf | Area | Uu | Vc0a | Zdcp | Ve0a | Veop | Fe0p | Fccb | Ver |
|---|------|---|---|---|------|------|---|------|------|------|------|------|------|------|-----|
| -672 | 3.79 | 5.9 | -9.2 | -437 | 6.49 | 746 | 91 | 62 | -5.6 | 4.94 | 97.8 | 2504 | 4502  | .3  |
| -676 | 3.78 | 5.5 | -9.4 | -437 | 6.47 | 750 | 91 | 62 | -5.6 | 4.95 | 97.5 | 2504 | 4501  | .3  |
| -679 | 3.77 | 4.9 | -9.6 | -437 | 6.47 | 751 | 90 | 62 | -5.7 | 4.95 | 96.8 | 2504 | 4502  | .3  |
| -682 | 3.76 | 3.4 | -9.9 | -437 | 6.48 | 751 | 90 | 62 | -5.7 | 4.96 | 96.5 | 2504 | 4502  | .3  |
| -686 | 3.76 | 2.8 | -9.3 | -437 | 6.49 | 752 | 90 | 63 | -5.6 | 4.93 | 96.1 | 2504 | 4502  | .4  |
| -689 | 3.75 | 3.9 | -9.8 | -437 | 6.47 | 750 | 90 | 62 | -5.6 | 4.96 | 96.6 | 2504 | 4501  | .4  |
| -692 | 3.74 | 4.3 | -9.6 | -437 | 6.46 | 747 | 90 | 62 | -5.8 | 4.95 | 97.1 | 2504 | 4501  | .4  |
| -696 | 3.74 | 3.7 | -8.9 | -436 | 6.48 | 745 | 90 | 62 | -5.8 | 4.91 | 96.8 | 2504 | 4501  | .3  |
| -699 | 3.72 | 4.8 | -8.6 | -436 | 6.48 | 743 | 90 | 62 | -5.5 | 4.96 | 97.1 | 2504 | 4501  | .4  |
| -703 | 3.71 | 5.1 | -8.9 | -436 | 6.46 | 743 | 90 | 62 | -5.5 | 4.91 | 97.3 | 2504 | 4501  | .4  |
| -706 | 3.71 | 4.9 | -8.5 | -436 | 6.46 | 741 | 90 | 61 | -5.6 | 4.89 | 97.3 | 2504 | 4501  | .4  |
| Z | Temp | U | V | W | Rotf | Area | Uu | Vc0a | Zdcp | Ve0a | Veop | Fe0p | Fccb | Ver |
|---|------|---|---|---|------|------|---|------|------|------|------|------|------|------|-----|
| -699 | 3.70 | 4.5 | -7.4 | -436 | 6.47 | 739 | 90 | 61 | -5.7 | 4.63 | 97.2 | 2504 | 4501  | .4  |
| -613 | 3.69 | 5.3 | -8.1 | -436 | 6.47 | 741 | 90 | 61 | -5.6 | 4.87 | 97.6 | 2504 | 4501  | .3  |
| -616 | 3.68 | 4.9 | -9.2 | -436 | 6.46 | 745 | 90 | 62 | -5.4 | 4.92 | 97.1 | 2504 | 4501  | .4  |
| -619 | 3.67 | 4.1 | -9.8 | -436 | 6.44 | 747 | 90 | 62 | -5.6 | 4.95 | 96.7 | 2504 | 4501  | .5  |
| -623 | 3.66 | 3.2 | -8.7 | -436 | 6.46 | 747 | 90 | 62 | -5.7 | 4.89 | 96.5 | 2504 | 4501  | .4  |
| -626 | 3.66 | 2.6 | -8.0 | -435 | 6.45 | 745 | 90 | 62 | -5.5 | 4.86 | 95.9 | 2504 | 4501  | .4  |
| -630 | 3.65 | 2.2 | -8.2 | -435 | 6.45 | 746 | 90 | 62 | -5.5 | 4.87 | 95.7 | 2504 | 4501  | .2  |
| -633 | 3.64 | 1.8 | -8.3 | -435 | 6.44 | 746 | 90 | 62 | -5.6 | 4.86 | 95.5 | 2504 | 4501  | .2  |
| -636 | 3.64 | 2.3 | -8.1 | -435 | 6.45 | 745 | 90 | 62 | -5.8 | 4.86 | 96.0 | 2504 | 4501  | .3  |
| -640 | 3.63 | 1.8 | -7.6 | -435 | 6.47 | 744 | 90 | 62 | -5.6 | 4.83 | 95.5 | 2504 | 4501  | .3  |
| -643 | 3.62 | 1.4 | -6.7 | -435 | 6.45 | 744 | 90 | 62 | -5.5 | 4.78 | 95.2 | 2504 | 4501  | .3  |
| -646 | 3.61 | 0.9 | -7.6 | -435 | 6.44 | 747 | 90 | 62 | -5.6 | 4.83 | 95.0 | 2504 | 4501  | .3  |
| -650 | 3.61 | 0.4 | -6.6 | -435 | 6.45 | 745 | 90 | 62 | -5.7 | 4.77 | 94.8 | 2504 | 4501  | .3  |
| -653 | 3.60 | 0.7 | -5.5 | -435 | 6.45 | 746 | 90 | 62 | -5.7 | 4.72 | 94.9 | 2504 | 4501  | .3  |
| -657 | 3.59 | 1.3 | -5.6 | -435 | 6.45 | 742 | 90 | 61 | -5.5 | 4.73 | 95.2 | 2504 | 4501  | .3  |
| -660 | 3.59 | 1.1 | -6.4 | -434 | 6.44 | 742 | 90 | 61 | -5.6 | 4.77 | 95.1 | 2504 | 4502  | .3  |
| -663 | 3.59 | 1.4 | -5.5 | -434 | 6.45 | 745 | 90 | 62 | -5.6 | 4.72 | 95.3 | 2504 | 4501  | .3  |
| -667 | 3.58 | 1.4 | -4.8 | -434 | 6.45 | 745 | 90 | 62 | -5.6 | 4.68 | 95.3 | 2504 | 4501  | .2  |
| -670 | 3.58 | 1.0 | -3.8 | -434 | 6.43 | 739 | 90 | 61 | -5.6 | 4.63 | 95.1 | 2504 | 4501  | .2  |
| -673 | 3.57 | 1.6 | -5.3 | -434 | 6.44 | 741 | 90 | 61 | -5.7 | 4.71 | 95.5 | 2504 | 4501  | .3  |
| Z     | Temp | U   | V   | W ROTF | AREA | Uw | Vc0a | Zcdp | VeOa | VeOp | Fefb | Fccb | Ver |
|-------|------|-----|-----|--------|------|----|------|------|------|------|------|------|------|-----|
| -758  | 3.43 | 1.8 | -1.8 | -431   | 6.39 | 741| 89   | 61   | -5.6 | 4.51 | 95.6 | 2504 | 4502 | .5  |
| -761  | 3.42 | .9  | -2.1 | -431   | 6.39 | 742| 89   | 61   | -5.5 | 4.52 | 94.9 | 2504 | 4501 | .5  |
| -764  | 3.42 | .9  | -3.5 | -431   | 6.37 | 745| 89   | 61   | -5.5 | 4.59 | 94.9 | 2504 | 4501 | .4  |
| -768  | 3.41 | .8  | -3.2 | -431   | 6.37 | 745| 89   | 61   | -5.5 | 4.57 | 94.8 | 2504 | 4502 | .4  |
| -771  | 3.41 | .3  | -1.8 | -431   | 6.39 | 741| 89   | 61   | -5.5 | 4.50 | 94.5 | 2504 | 4502 | .3  |
| -775  | 3.41 | .4  | -1.8 | -431   | 6.38 | 736| 89   | 60   | -5.6 | 4.45 | 94.7 | 2504 | 4502 | .2  |
| -778  | 3.40 | .9  | -7   | -431   | 6.37 | 745| 89   | 60   | -5.5 | 4.49 | 95.0 | 2504 | 4502 | .3  |
| -781  | 3.39 | 1.2  | -1.3 | -431  | 6.37 | 739| 89   | 60   | -5.5 | 4.47 | 95.1 | 2504 | 4502 | .3  |
| -785  | 3.38 | 1.7  | -1.7 | -431  | 6.36 | 742| 89   | 60   | -5.4 | 4.49 | 95.3 | 2504 | 4502 | .3  |
| -788  | 3.37 | 1.8  | -1.4 | -430  | 6.35 | 740| 89   | 60   | -5.5 | 4.48 | 95.5 | 2504 | 4502 | .3  |
| -792  | 3.37 | 1.6  | -1.9 | -430  | 6.36 | 740| 89   | 60   | -5.5 | 4.50 | 95.4 | 2504 | 4502 | .3  |
| -795  | 3.36 | 1.4  | -1.2 | -430  | 6.35 | 740| 89   | 60   | -5.5 | 4.46 | 95.0 | 2504 | 4502 | .3  |
| -798  | 3.35 | 1.2  | -5   | -430  | 6.36 | 740| 89   | 60   | -5.5 | 4.43 | 95.1 | 2505 | 4502 | .5  |
| -802  | 3.34 | -1.1 | -3   | -430  | 6.36 | 739| 89   | 60   | -5.5 | 4.42 | 94.2 | 2504 | 4502 | .5  |
| -805  | 3.34 | -1.2 | -3   | -430  | 6.35 | 741| 89   | 60   | -5.4 | 4.42 | 93.5 | 2504 | 4502 | .4  |
| -808  | 3.33 | -1.7 | -4   | -430  | 6.34 | 743| 89   | 60   | -5.6 | 4.42 | 93.3 | 2504 | 4502 | .3  |

Z Temp U V W Rotf Area Uw Vc0a Zcdp VeOa VeOp Fefb Fccb Ver

-812 3.33 -2.0 -.3 -430 6.35 744| 89 | 61 | -5.6 | 4.41 | 93.1 | 2504 | 4502 | .3  |
-815 3.33 -1.9 -1.3 -430 6.33 746| 89 | 61 | -5.3 | 4.46 | 93.0 | 2504 | 4502 | .3  |
-819 3.32 -3.0 -.9 -429 6.33 746| 89 | 60 | -5.5 | 4.44 | 92.4 | 2504 | 4502 | .3  |
-822 3.32 -3.0 .4 -429 6.33 743| 89 | 60 | -5.7 | 4.38 | 92.5 | 2504 | 4502 | .3  |
-825 3.31 -2.7 .1 -429 6.32 743| 89 | 60 | -5.5 | 4.39 | 92.6 | 2504 | 4502 | .3  |
-829 3.31 -4.1 .0 -429 6.32 743| 89 | 60 | -5.6 | 4.40 | 91.7 | 2504 | 4502 | .4  |
-832 3.30 -3.9 1.1 -429 6.32 744| 89 | 60 | -5.4 | 4.34 | 91.7 | 2504 | 4502 | .4  |
-836 3.29 -3.7 .1 -429 6.31 746| 89 | 60 | -5.4 | 4.39 | 91.6 | 2505 | 4502 | .4  |
-839 3.28 -3.9 -.4 -429 6.32 749| 89 | 61 | -5.5 | 4.42 | 91.8 | 2504 | 4502 | .3  |
-842 3.28 -5.4 -.8 -429 6.31 749| 89 | 61 | -5.4 | 4.44 | 90.8 | 2504 | 4502 | .3  |
-846 3.27 -6.1 -1.5 -429 6.30 751| 89 | 61 | -5.4 | 4.47 | 90.4 | 2504 | 4502 | .3  |
-849 3.27 -6.9 -1.7 -429 6.30 751| 89 | 61 | -5.5 | 4.49 | 90.0 | 2504 | 4502 | .3  |
-853 3.27 -7.4 -2.0 -428 6.38 753| 89 | 61 | -5.4 | 4.50 | 89.6 | 2504 | 4502 | .4  |
-856 3.26 -7.5 -2.7 -428 6.29 753| 89 | 61 | -5.5 | 4.53 | 89.6 | 2505 | 4502 | .4  |
-859 1.78 77.2 -3.9 -428 6.23 1612| 89 | 129 | 72.9 | 5.96 | 55.7 | 2450 | 4507 | 1.32 |

282.997415541 2D.D

-862 -1.98 347.2 -259.3 -428 7.1610727| 89 | 985 |
-219.81372993 3D.D
24.29 -6.2 2450 4484
425.722796875 2D.D

MEAN AREA= 745 cm^-2
Z-1000 0
ENTER NEW PLOT LIMITS: PLO, PHI
Listing of DXPRO

10 Progrev$="DXPROZ"  ! PROGRAM REVISION
20 Year=81
30
40 ! DXPRO .. DEC 19 79. DIGITAL XTVP RCVR PROCESSING (see outline below)
50 ! DXPROB .. DEC 21 79. BARTLETT WINDOWS; INSTANTANEOUS NORMALIZATION.
60 ! DXPROC .. JAN 13 80. CORRECTED I & Q OF EF & CC FOR DIFF UP & DOWN COUNT TIMES
70 ! DXPROD .. JAN 14 80. ALLOW FOR FCVR HICCUPS AND DE-GLITCH I&Q
80 ! DXPROE .. JAN 15 80. FORCE TIME TO INCREASE AFTER PF COMES ON FOR 5 TURNS
90 ! DXPROF .. JAN 16 80. PROCESS ONLY. TO GET DATA USE DXGET.
100 ! DXPROG .. JAN 17 80. INTERPOLATE TO EQUALLY SPACED DEPTH AND OUTPUT FILE
110 ! DXPROH .. JAN 18 80. PLOT EF&CC BL.
120 ! DXPROI .. JAN 19 80. MORE TESTS.
130 ! DXPROJ .. JAN 20 80. PLOT BL AVG'S AND STD DEV
140 ! DXPROK .. JAN 21 80. PLOT RMSERR
150 ! DXPROL .. JAN 22 80. RMSERR SHOWS DIFF BETWEEN ERRCOR=3 AND ERRCOR=1
160 ! DXPROM .. JAN 23 80. MODIFIED TO OUTPUT NEW FILE FORMAT AND USE GRAPHICS
170 ! DXPON .. JAN 24 80. CHANGED RMSERR TO VELERR=RMSERR/SQR(NAV)
180 ! DXPON .. JAN 25 80. ADDED "BATCH" CAPABILITY.
190 ! DXPON .. JAN 26 80. ADDED 9872S LOGIC FOR BATCH.
200 ! DXPON .. JAN 27 80. REMOVED PAUSE BEFORE PLOTTING ON 9872A.
210 ! DXPON .. JAN 28 80. CHANGED CAL FILE TO BE ON :T15
220 ! DXPON .. JAN 29 80. FIXED PROBLEMS WITH COMPENSATION
230 ! DXPON .. JAN 30 80. THE PROBE PHASE VS FREQ COEFFICIENTS ARE ALSO ADDED.
240 ! OUTLINE ..........................................................
250 ! Initialization
260 ! - print program name, revision and run time
270 ! - dimension arrays
280 ! - read in processing parameters for up to 100 drops; terminate when
290 ! an input file name is blank.
300 ! - get parameter file name with probe gain calibrations.
310 ! - must add the earth's magnetic field if not in file
320 ! - calibration string can be edited.
330 ! - the plotter choice allows the 9872A only when one file is processed
340 ! Drop loop: repeats once per drop
350 ! - some constants are preset to reduce run time.
360 ! Main Processing Loop.
370 ! - repeats once each NAV-long averaging window.
380 ! - for NAV=10, NSTEP=5 this loop repeats about 300 times.
390 ! - read raw input data keeping in sync with the sync word (7777 hex)
400 ! - look for beginning of drop by examining status word:
410 ! 1. received carriers
420 ! 2. probe falling bit (PF)
430 ! - probe depth is based on the time from the PF bit turns on.

APL-UW 8110   A27
- for each new raw data scan the baseline error correction is
  applied to I and Q and the scan is appended to the Dbuf(*) array.
- old scans are pushed off end of Dbuf(*) array
- form Dav(*) array with weighted averages of Dbuf(*).
- in-phase and quadrature-phase probe carrier frequencies are computed
- real and imaginary input voltages to probe are computed.
- U and V velocity component estimates are computed, tilt correction
  is done in next loop as mean area is needed.
- each output scan is stored in Dout(*) array.
- Correct the north component for North-South tilt errors
- need mean area
- fix the Dout(*) array
- Write Data in Dout(*) to File.
- standard format with labels
- Plot Data on 9872A, 9872S, or GRAPHICS screen.
- the 9872S handles multiple plots
- keep to 8.5 by 11 inch plots
- all graphs on one sheet in multiple colors
- Repeat drop loop

Printer=0
PRINTER IS Printer
OUTPUT 9;"R" ! SETUP TO GET REAL-TIME FROM CLOCK
ENTER 9;Runtime$ ! GET IT
Runtime$=VAL$(Year)&":"&Runtime$
PRINT Progrev$,Runtime$

OPTION BASE 1 ! STARTS ARRAYS AT 1 INSTEAD OF DEFAULT 0
OVERLAP ! RUN HP-9845 PROCESSORS SO I/O OVERLAPS CPU
DEG ! TRIG FUNCTIONS USE DEGREES INSTEAD OF RADIANS

DIM CommentStr[160] ! COMMENTS FROM/TO FILES
DIM Var$(9) ! OUTPUT FILE VARIABLE NAMES
DIM String$t[160] ! USED TO READ PARAMETER FILE

SHORT Din(2:11) ! INPUT DATA BUFFER READS 10 VALUES PER READ
SHORT Dbuf(52,2:10) ! PUSH-DOWN INPUT BUFFER WITH EXTRA SCAN AT EACH END
SHORT Wt(50) ! BARTLETT FILTER WEIGHTS APPLIED TO INPUT DATA
SHORT Dav(2:10) ! FOR DOT PRODUCT OF DBUF AND WT
SHORT Phi(9) ! PLOTTER HIGH LIMITS
SHORT Plo(9) ! PLOTTER LOW LIMITS
SHORT Dout(1000,9) ! DATA OUTPUT ARRAY (GETS REDIMENSIONED LATER)

DIM B3(3),B2(3) ! BASELINE FREQUENCIES FOR F2(EF) AND F3(CC)
DIM T(3,3) ! COEFFICIENTS OF C, D & E IN B(n-1), B(n), B(n+1)
DIM Tinv(3,3) ! INVERSE OF T ABOVE TO SOLVE FOR C, D & E.
DIM C2(3),C3(3) ! C2(1)=C, C2(2)=D, C2(3)=E FOR F2(EF); C3(*) FOR F3.
DIM Tei(3),Teq(3) ! COEFFICIENTS OF C, D & E IN I(n) AND Q(n)

Nvar=10 ! NUMBER OF INPUT VARIABLES
Mav=50 ! MAXIMUM AVERAGING SPAN <NAV>. MUST AGREE WITH DIM
Msout=1000 ! MAXIMUM SCANS OUT. MUST AGREE WITH DIM OF DOUT.
1100 Nvout=9 ! MAXIMUM VARIABLES OUT. MUST AGREE WITH DIM OF DOUT,
1110  PHI,PLO,VAR$ ! PH,PLO,VAR$ AGREE
1120  Bad=0 ! FLAG USED FOR BAD DATA OUT
1130  ! SETUP FOR MULTIPLE INPUT FILE PROCESSING.
1140  !
1150  DIM Iile$(100) ! INPUT FILE NAMES
1160  DIM Ofile$(100) ! OUTPUT FILE NAMES
1170  DIM Nav(100) ! NUMBER OF SCANS TO AVERAGE
1180  DIM Nstep(100) ! NUMBER OF SCANS TO STEP THE AVERAGES BY; USUALLY
1190  ! AVERAGES ARE OVERLAPPED 50% OR SO
1200  DIM String$[100][80] ! CALIBRATION CONSTANTS FROM THE XCAL FILE FOR EACH
1210  ! FILE
1220  DIM Comment$(100)[160] ! COMMENTS FROM EACH INPUT FILE.
1230  !
1240  FOR File=1 TO 100
1250  DISP "INPUT FILE NO. ";File;"? (CLEAR TO TERMINATE)";
1260  EDIT ",",Iile$(File)
1270  Iile$=Iile$(File)
1280  IF LEN(Iile$)=0 THEN 2070
1290  !
1300  ASSIGN #1 TO Iile$,Ret
1310  IF Ret=0 THEN 1350
1320  DISP "FILE NOT ON PRESENT DISC. ";
1330  GOTO 1260
1340  !
1350  READ #1;Comment$(File)
1360  EDIT "EDIT COMMENTS",Comment$(File)
1370  !
1380  INPUT "NUMBER OF SCANS IN EACH AVERAGING WINDOW ?",Nav(File)
1390  !
1400  IF NAV>Nav THEN 1400 ! RESTRICT NAV TO MAV
1410  !
1420  INPUT "STEPPING INCREMENT?",Nstep(File)
1430  !
1440  IF LEN(Pfile$)=0 THEN Pfile$="XCAL :T15"
1450  EDIT "EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)",Pfile$
1460  IF LEN(Pfile$)=0 THEN 1720
1470  !
1480  INPUT "XTVP SERIAL NO. ? (ZERO TO SEARCH BY DROP NO.)",Serial
1490  !
1500  IF Serial=0 THEN INPUT "Drop ID. ?",Dropid$
1510  !
1520  ASSIGN #3 TO Pfile$,Ret ! ASSIGN UNIT NUMBER TO PARAMETER FILE NAME
1530  IF Ret<>0 THEN 1400 ! Ret SHOULD BE 0 IF FILE IS THERE
1540  !
1550  READ #3,1 ! REWIND FILE
1560  ON END #3 GOTO 1890 ! SET UP END OF FILE TRAP
1570  !
1580  DISP "READING ";Pfile$
1590  !
1600  !
1610  !
1620  !
1630  !
1640  !
1650  IF LEN(String$)<58 THEN String$=String$&RPT" ",58-LEN(String$))
IF (Serial<>0) AND (VAL(String$[8,12]=Serial)) THEN 1720
IF (Serial=0) AND (TRIM$(String$[44,48]=TRIM$(Dropid$)) THEN 1720
GOTO 1640
1700 EDIT ENTER THE CALIBRATION STRING. THERE MUST BE A VALUE IN EACH FIELD
1720 EDIT "EDIT: Probe Mod Gcc Gcor Gef Euco Ccvo Drop Fh Fz",St ring$
GOTO 1830
1750 IF ERRN=159 THEN 1870
1760 DISP ERRM$
PAUSE
GOTO 1860
1790 GOTO 1840
1800 ENTER String$ USING 1850;Probe,Mod,Gcc,Gcor,Gef,Euf,Ccuf,Drop,Fh,Fz
1850 IMAGE #,7X,4<5N>,6N,2<5N>,5A,2<5N>
1860 OFF ERROR
GOTO 1940
1890 BEEP
1900 DISP "CANNOT FIND THE CALIBRATION STRING."
WAIT 3000
GOTO 1230
1940 ASSIGNED #3 TO * UNASSIGNED UNIT 3; PFILE$ IS NOT Assigned.
1950 String$=(File)=String$
1960 EDIT "OUTPUT FILE NAME?",Ofile$=(File)
1980 Ofile$=Ofile$=(File)
1990 IF LEN(Ofile$)=0 THEN 1940
2000 ASSIGN #2 TO Ofile$,Ret ! CHECK TO SEE IF OUTPUT FILE ALREADY EXISTS;
2020 IF Ret=1 THEN 2050 ! FORCE USER TO USE ANOTHER NAME IF IT DOES.
2030 DISP "ALREADY EXISTS -- CHOOSE ANOTHER NAME";
2040 GOTO 1970
2050 NEXT File ! END OF PARAMETER INPUT ****************************
2070 IF Nfile=File-1 ! NUMBER OF INPUT FILES TO PROCESS
2100 ! CANNOT USE THE 9872A PLOTTER WITH MULTIPLE FILE PROCESSING BECAUSE
2110 ! THERE IS NO AUTOMATIC PAPER FEED.
2120 IF Nfile>1 THEN "PLOTTER ? (O=NONE, 1=GRAPHICS, 3=9872S)" Plotter
2140 IF Nfile=1 THEN "PLOTTER ? (O=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)" Plotter
2150 IF (Plotter<0) OR (Plotter>3) THEN 2130
2160 IF (Nfile)<1 AND (Plotter=2) THEN 2130
2170 ACTUAL PROCESSING STARTS HERE AND REQUIRES NO MORE OPERATOR RESPONSES.
FOR File=1 TO Nfile
  String$=String$(File)
  ENTER String$ USING 1858;Probe,Mod,Gcc,Gcor,Gef,Efuf,Ccvf,Drop$,Fh,Fz
  Ifile$=Ifile$(File)
  Ofile$=Ofile$(File)
  Nav=Nav$(File)
  Nstep=Nstep$(File)
  ASSIGNED #1 TO Ifile$ ! ASSUMES IFILE$ IS PRESENT BECAUSE CHECKED BEFORE
  READ #1,1
  READ #1;Comments ! INPUT DATA IS ONE COMMENT$ STRING FOLLOWED BY
  REDIM Dout(Mout,9) ! DIGITAL RECEIVER DATA NUMERIC VALUES.
  ON Mod-3 GOTO 2430,2480,2530
  ! PROBE PHASE FROM CIRCUIT ANALYSIS DEPENDS ON MODEL NUMBER.
  ! SIPPICAN MANUFACTURED MOD 5 ONLY FOR TOM SANFORD AT W.H.O.I. IN
  ! MAY 1979.
  ! SIPPICAN MANUFACTURED MOD 6 AFTER JULY 1979.
  !
  Gefp=15.2 ! XTVP MOD 4 (WHOI/BARTLETT-MADE)
  Gcorp=-145.1
  Gccp=-179.0
  GOTO 2680
  !
  Gefp=10.9 ! XTVP MOD 5 (SIPPICAN-MADE FOR AUTEC WORK ONLY)
  Gcorp=-169.3
  Gccp=-177.7
  GOTO 2680
  !
  Gefp=15.2 ! XTVP MOD 6 (SIPPICAN-MADE AFTER JULY 1979)
  Gcorp=-165.1
  Gccp=-179.0
  !
  Gefp0=45.77142872 ! QUADRATIC FITS VS ROTATION FREQUENCY
  Gefp1=-6.29750005 ! DETERMINED ANALYTICALLY FOR MOD 6 PROBES
  Gefp2=2.76785719
  Gcorp0=-133.4857151
  Gcorp1=-6.5403571
  Gcorp2=2.9107141
  !
  Gccp0=-176.0285726
  Gccp1=-5.978569
  Gccp2=0.02499997
  !
  ! CONVERT TO NEW LINGO
  Gcor=Gcor
  Gcc=Gcc
  Gef=Gef
  Efuf=Efuf
  Ccvf=Ccvf
  Gefp=Gefp
  Gccp=Gccp
  ApL-UW 8110 A31
Esep=5.12 ! cm ! PROBE PHYSICAL PARAMETERS
C1=.97
C2=-.02

DATA .00129299,.00023488,.980557E-7 ! CAL FOR SIPPICAN THERMISTOR
RESTORE 2810
READ Tecala,Tecalb,TecalC ! PUT ABOVE DATA IN TECALA,B,C

DATA -11336.3,7302.0 ! TEMP RESISTANCE VS MS
RESTORE 2850
READ Teres0,Teres1 ! PUT ABOVE DATA IN TERES0,1

DATA 3.1,4.544,-.0006749 ! PRESSURE VS TIME CAL
RESTORE 2890
REnD Pcal0,Pcal1,Pcal2 ! PUT ABOVE DATA IN PCAL0,1,2

RC:VR SCALE FACTORS FOR EACH FREQUENCY CHANNEL:
S1=1/200 ! S1,S2,S3 ARE INVERSE OF PHASE LOCK LOOP
S2=1/40 ! MULTIPLICATION FACTORS.
S3=1/20

Sff2=2+PI/4*S2 ! SFF2,3 ARE SCALE FACTORS TO CONVERT I & O
Sff3=2+PI/4*S3 ! TO THE AMPLITUDE OF THE FREQUENCY DEVIATIONS.

Sffe=Sff2 ! FOR MOD 5 PROBES F3 WAS EF AND F2 WAS CC
IF Mod=5 THEN Sffe=Sff3 ! FOR ALL OTHERS F3=CC AND F2=EF

Sfu=100/Fz/Esep/(1+C1) ! SCALE FACTOR OF VELOCITY FROM EF
Sfw=Fh/Fz/(1+C2)/(1+C1) ! SCALE FACTOR OF Uw FROM W
Sfa=100/2/PI/Fh ! SCALE FACTOR FOR AREA FROM VCO/FREQ

REDim Wt(Nav) BARTLETT WINDOW FOR FILTERING
FOR I=1 TO (Nav+1) DIV 2 ! TRIANGULAR WINDOW, SUM NORMALIZED TO 1.0
Wt(I)=Wt(Nav+1-I)
NEXT I
MAT Wt=Wt/(SUM(Wt))

Snc=30583 ! SYNC WORD EXPECTED FROM DIGITAL RECEIVER

Mastertime#=Comment$[1,18] ! REAL-TIME WHEN DXGET WAS RUN
Oscan=Iscan=Nhave=Fall=Time=Mastertime=Launchtime=0
Nwant=Nav+2 ! WANT THE INPUT BUFFER TO OVERLAP A VALUE ON EACH END
MAT Dout=(Bad) INITIALIZ THE OUTPUT DATA ARRAY
MAT "LOOKING FOR PF ON"

MAINLOOP
Npush=Nstep
Col$=""

PUSHDOWN DBUF(*) BY NSTEP SCANS

A32 APL-UW 1.10
REDIM Dbuf(1:Nwant,2:Nvar)
IF Npush<Nhave THEN 3360
Nhave=O
GOTO Getmore
FOR I=Npush+1 TO Nhave
J=I-Npush
FOR L=2 TO Nvar
Dbuf(J,L)=Dbuf(I,L)
NEXT L
NEXT I
Nhave=Nhave-Npush

Getmore: GETMORE KEEPING IN SYNC.
EARLY VERSIONS OF THE DIGITAL RECEIVER WOULD GIVE DATA
TOO FAST FOR DXGET AND THUS WOULD GET OUT OF SYNC
READ #1;Din(*) ! READ ONE INPUT SCAN AT A TIME UNLESS LOSE SYNC
IF (Din(2)<<Sync) AND (Din(11)=Sync) THEN 3590
IF Iscan>0 THEN PRINT "LOST SYNC BEFORE ISCAN=";Iscan
Din0=Din(2)
FOR I=2 TO Nvar
Din(I)=Din(I+1)
NEXT I
READ #1;Din(Nvar+1)
IF Din0<>Sync THEN 3510
GOTO 3490
Iscan=Iscan+1
Mastertime=Mastertime+Din(4)*1E-5
PRINT USING "11(7D)";Iscan,Din(*); I ! DEBUGGING PRINT
TEST STATUS WORD
Status=Din(2)
THE NUMBER OF WORDS TAKEN IN THE LAST SCAN IS ENCODED IN BITS 11-8
IF (SHIFT(Status,8)<<Nvar) AND (Iscan>1) THEN PRINT "MISSING SCAN:" FROM
DR AT ISCAN=";Iscan
BITS 2-0 INDICATE IF THE CARRIERS ARE PRESENT LIKE THE LIGHTS ON PANEL.
WHEN THE PROBE IS LAUNCHED THE CARRIERS SHOULD ALL COME ON
IF Launctime OR NOT BIT(Status,"111") THEN 3740
Launctime=Mastertime
CALL Addtime(Mastertime$,Launctime$,Launctime)
PRINT "LAUNCH-TIME=";Launctime$,Launctime,"ISCAN=";Iscan
BIT 3 OF STATUS SHOWS THE PF LIGHT ON PANEL, IT IS ON WHEN THE CC
CHANNEL DEVIATES MORE THAN A PRE-SET THRESHOLD.
IF NOT Falling AND (BIT(Status,3)=0) THEN Getmore
TRANSFER FROM DIN TO DUF
Nhave=Nhave+1
FOR L=2 TO Nvar
Dbuf(Nhave,L)=Din(L)
NEXT L
IF Nhave<Nwant THEN Getmore
REDIM Dbuf(0:Nwant-1,2:Nvar)
USE PROBE FALLING (PF) BIT TO START AND STOP PROCESSING:
Npf=0 ! WANT NPF=NAV TO START PROCESSING
FOR I=1 TO Nav ! ALLOW NPF<NAV TO STOP PROCESSING WHEN TIME>200 SEC
Npf=Npf+BIT(Dbuf(I,2),3)
3870 NEXT I
3880 IF Falling OR (Npf=Nav) THEN 3910
3890 Npush=1
3900 GOTO Pushdown
3910 IF (Time>200) AND (Npf<Nav) THEN Endloop
3920 IF Npf=0 THEN Endloop
3930 IF Falling THEN 4000
3940 Falling=1
3950 Downtime=Mastertime
3960 CALL Addtime(Mastertime$, Downtime$, Downtime$)
3970 PRINT "DOWN-TIME="$, Downtime$, Downtime$, "ISCAN="; Iscan-Nwant+1
3980 DISP "PROCESSING FILE "; File; "; IFILE="; Ifile; "; OFILE="; Ofile$
3990 ! COMPUTE THE ERROR TERMS IN I AND O THEN CORRECT DBUF FOR NEW SCANS
4000 ! (THE OLD SCANS WERE CORRECTED ALREADY BECAUSE DBUF WAS PUSHED DOWN)
4010 !
4020 !
4030 J1=Nhave-Npush-1
4040 IF Oscan>0 THEN 4160
4050 J1=1
4060 ! T1 = T(n-1) in report
4070 ! T2 = T(n)
4080 ! T3 = T(n+1)
4090 T11=Dbuf(J1-1,4)*1E-5 ! T11 IS T1
4100 T12=T11*T11 ! T12 IS T1 SQUARED
4110 T13=T12*T11 ! T13 IS T1 CUBED
4120 T21=Dbuf(J1,4)*1E-5
4130 T22=T21*T21
4140 T23=T22*T21
4150 D3=1/3
4160 J2=Nav
4170 FOR J=J1 TO J2
4180 I=J-1
4190 K=J+1
4200 T31=Dbuf(K,4)*1E-5
4210 T32=T31*T31
4220 T33=T32*T31
4230 T(1,1)=T11 ! SET UP T(*) TO SOLVE FOR C, D, E GIVEN B1, B2, B3.
4240 T(1,2)=-.5*T12 ! C, D, E ARE COMPUTED IN C2(*) AND C3(*) FOR
4250 T(1,3)=D3*T13 ! EF AND C3 RESPECTIVELY.
4260 T(2,1)=T21
4270 T(2,2)=.5*T22
4280 T(2,3)=D3*T23
4290 T(3,1)=T31
4300 T(3,2)=T2*T31+.5*T32
4310 T(3,3)=T2*T31+T21*T32+D3*T33
4320 MAT Tinv=INV(T)
4330 B3(1)=Dbuf(I,7)
4340 B2(1)=Dbuf(I,8)
4350 B3(2)=Dbuf(J,7)
4360 B2(2)=Dbuf(J,8)
4370 B3(3)=Dbuf(K,7)
4380 B2(3)=Dbuf(K,8)
4390 MAT C3=Tinv*B3 ! C3(*)=C, D, E FOR COIL CHANNEL
4400 MAT C2=Tinv*B2 ! C2(*)=C, D, E FOR EF CHANNEL
4410 Te(1)=T11-T21
4420 Te(2)=-.25*T12-.5*T22
\begin{verbatim}
        Tel(3) = T13/12 - T23/3
        Tel(1) = 1.25*(T11 - T21)
        Tel(2) = (17*T12 - 25*T22)/32
        Tel(3) = (53*T13 - 125*T23)/192
        Eq1 = DOT(Tel, C3)
        Eq2 = DOT(Teq, C2)
        Eq3 = DOT(Teq, C3)

        Ei3 = DOT(Tei, C3)
        IC0M0RTE
        I AND 0
        ERP0RS FOR
        EF AND CC

        Ei2 = DOT(Tei, C2)
        Eq1 = DOT(Teq, C3)
        Eq2 = DOT(Teq, C2)

        ! debugging printout
        IF NOT Debugging THEN 4580
        IF J = J1 THEN PRINT LIN(1); "ISCAN STATU5 TEMP PERIOD Icc I
        ef BLcc BLe5 Qcc Qef"

        PRINT USING 4550; Iscan-Huant+J, Dbuf(J, 2), Dbuf(J, 3), Dbuf(J, 4), Dbuf(J, 5), Dbuf(J, 6), Dbuf(J, 7), Dbuf(J, 8), Dbuf(J, 9), Dbuf(J, 10)
        IMAGE 6D,9(7D)

        PRINT USING 4570; I, Ei3, Eq1, Eq2
        IMAGE 14X, "I & Q ERRORS:", 7D, 7D, 14X, 7D, 7D

        Dbuf(J, 5) = Dbuf(J, 5) - Ei3 ! SUBTRACT ERRORS FROM DBUF
        Dbuf(J, 6) = Dbuf(J, 6) - Ei2
        Dbuf(J, 9) = Dbuf(J, 9) - Eq3
        Dbuf(J, 10) = Dbuf(J, 10) - Eq2

        IF NOT Debugging THEN 4650
        PRINT USING 4640; Dbuf(J, 5), Dbuf(J, 6), Dbuf(J, 9), Dbuf(J, 10)
        IMAGE 13X, "I & Q RESULTS:", 7D, 7D, 14X, 7D, 7D

        T11 = T21 ! PUSH DOWN SOME STUFF TO SPEED PROCESSING
        T12 = T22 ! INSTEAD OF RECOMPUTING

        T13 = T23
        T14 = T21
        T22 = T22
        T23 = T23
        NEXT J

        IF NOT Debugging THEN 4650

        MAT Dav=ZERO
        Ei5=Eiss=Eqs=Eqss=0

        FOR J = J1 TO Nav
            Wt = Wt(J)
            T1 = Dbuf(J-1, 4) * 1E-5
            T2 = Dbuf(J, 4) * 1E-5
            D1 = Dbuf(J, 4) - Dbuf(J-1, 4)
            Rfi = 1/T2
            Rf1 = 1/(1.25*T2 - .25*T1)

            Wtri = Wt * Rfi
            Wtrq = Wt * Rf1
            Dag(3) = Dav(3) + Dbuf(J, 3) * Wtri
            Dav(4) = Dav(4) + Dbuf(J, 4) * Wt
            Dav(7) = Dav(7) + Dbuf(J, 7) * Wtri
            Dav(8) = Dav(8) + Dbuf(J, 8) * Wtri
            Dav(5) = Dav(5) + Dbuf(J, 5) * Wtri
            Dav(6) = Dav(6) + Dbuf(J, 6) * Wtri
            Dav(9) = Dav(9) + Dbuf(J, 9) * Wtrq
            Dav(10) = Dav(10) + Dbuf(J, 10) * Wtrq

            SUMS AND SUMS OF SQUARES TO COMPUTE RMS ERR
\end{verbatim}
IF Mod=5 THEN 5050
Ei=Dbuf(J,6)*Rfi
Eq=Dbuf(J,10)*Rfq
Eis=Eis+Ei
Eiss=Eiss+Ei^2
Eqs=Eqs+Eq
Eqss=Eqss+Eq^2
GOTO 5110
Ei=Dbuf(J,5)*Rfi
Eq=Dbuf(J,9)*Rfq
Eis=Eis+Ei
Eiss=Eiss+Ei^2
Eqs=Eqs+Eq
Eqss=Eqss+Eq^2
GOTO 5110
NEXT J

Rotp=Dav(4)*1E-5
Rotf=1/Rotp

TIME IS COMPUTED BY SUMMING ALL THE PERIODS SINCE THE PROBE STARTED DOWN
IF Oscan=0 THEN Time=Rotp*(Nav/2-Nstep)
Time=Time+Nstep*Rotp

PROBE CARRIER FREQUENCIES
F1b=Dav(3)*S1
F2i=Dav(6)*Sff2
F2q=Dav(10)*Sff2
F2b=Dav(8)*S2
F3i=Dav(5)*Sff3
F3q=Dav(9)*Sff3
F3b=Dav(7)*S3
F3b=Dav(7)*S3

IF Mod=5 THEN 5360
Fcci=F3i
Fccq=F3q
Fccb=F3b
Fefi=F2i
Fefq=F2q
Fefb=F2b
GOTO 5420

TEMPERATURE
Tems=1000/F1b
Teres=Teres0+Teres1*Tems
IF Teres>0 THEN 5480
Temp=Bad
GOTO 5560
Ln=LOG(Teres)
Temp=1/(Tecala+Tecalb*Ln+Tecalc*Ln^3)-273.15
DEGREES C

PROBE PHASES VS ROTATION FREQ USING QUADRATIC ESTIMATES
R1=Rotf
R2=Rotf^2
5530 Gefp=Gefp0+Gefp1*R1+Gefp2*R2
5540 Gcorp=Gcorp0+Gcorp1*R1+Gcorp2*R2
5550 Gccp=Gccp0+Gccp1*R1+Gccp2*R2
5560 ! COIL MICROVOLTS
5570 CALL Polar(-Fccq,-Fcci,Fcca,Fccp)
5580 VcOa=Fcca/Gcvfa/Gcca*1E6 ! Eca in report
5590 VcOp=Fccp/Gcvfp-Gccp ! Ecp in report
5600 ! ELECTRODE MICROVOLTS
5610 CALL Polar(-Fefq,-Fefi,Fefa,Fefp)
5620 Ve0a1=Fefa/Gevfa/Gefa*1E6
5630 Ve0p1=Fep-Gevfp-Gefp
5640 CALL Rect(Ve0a1,Ve0p1,Ve0q1,Ve0i1)
5650 Ve0a2=Fcca/Gcufa/Gcca*Gcora/Gefa*1E6
5660 Ve0p2=Fccp-Gcufp-Gcorp-Gefp
5670 CALL Rect(Ve0a2,Ve0p2,Ve0q2,Ve0i2)
5680 Ve0q=Ve0q1-Ve0q2
5690 Ve0i=Ve0i1-Ve0i2
5700 CALL Polar(Ve0q,Ve0i,Ve0a,Ve0p) ! Ve0a is Eea in report
5710 ! Ve0p is Eep in report
5720 ! FALL RATE, PRESSURE, Z=-PRESSURE
5730 W=-100*(Pcal1+2*Pcal2*Time) ! empirically determined pressure vs time
5740 P=Pcal0+Time*KPcal1+Time*Pcal2)
5750 Z=-P
5760 ! AREA OF COIL TIMES TURNS (cm2) PHASE OF ZERO CROSSING DETECTOR circuit
5770 VeOa2=Fc ca/Cc vfa*Gc ca*Gc ora/Cefa* 1 6
5780 VeOp2=Fccp-Gcvfp-Gccp+Gcorp-Gefp
5790 ! CALL Rect(VeOa2,VeOp2,VeOq2,VeOi2)
5800 ! VELOCITY COMPENSATION
5810 Uw=W*Sf
5820 Betae=Ve0p ! Ve0p and Ve0p phases have signs so if the signal leads
5830 Betac=Ve0p the phases are positive. Betae and Betac are opposite.
5840 Alpha=180 ! angle from electrode to coil
5850 Psi=Betae-Betac+90+Alpha ! see EMVP report
5860 U=Ve0a*Sf+COS(Psi)
5870 V=-Ve0a+Sf*SIN(Psi)+Uw
5880 ! Sfe=1E6/Gefa/Gefa*
5890 Rserr=SOR(.5*(Eis/Nau-(Eis/Nau)^2+Eqss/Nau-(Eqss/Nau)^2)+ABS(Sfe+Sfe *Sfu)
5900 Velerr=Rserr/SOR(Nau)! normalize rmserr
5910 ! PRINT
5920 IF Debugging OR (Oscan MOD 20=0) THEN PRINT USING 5940
5930 PRINT USING 5940;Z,Temp,U,V,WRotf,Area,Uw,VcOa,Zcdp,VeOa,Ve0p,
5940 Fefb,Fccb
5950 PRINT USING 5960;Z,Temp,U,V,WRotf,Area,Uw,VcOa,Zcdp,VeOa,Ve0p,Fefb,Fccb,
5960 IMAGE 4D,3D,2D,2 (4D,D),5D,2D,2D,3(5D),3D,D,3D,2D,4D,D,2(5D),2D
5970 ! Oscan=Oscan+1
5980 ! STORE IN OUTPUT ARRAYS
5990 Dout(Oscan,1)=Z
6000 Dout(Oscan,2)=Temp
6010 Dout(Oscan,3)=U
6020 Dout(Oscan,4)=V
6030 Dout(Oscan,5)=Area
6040 Dout(Oscan,6)=Rotf
6050 Dout(Oscan,7)=Fefb

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Dout(Oscan,8)=Fccb
Dout(Oscan,9)=Velerr
!
IF Oscan<Mout THEN Mainloop
!
Endloop:
!
Nsout=Oscan-3
REDIM Dout(Nsout,Nvout)
!
CORRECT FOR NORTH-SOUTH TILTS A LA D'ASARO
Velerrmax=4
Na=0
Amean=0
!
FOR Oscan=1 TO Nsout
Velerr=Dout(Oscan,9)
IF Velerr>Velerrmax THEN
Area=Dout(Oscan,5)
Amean=Amean+Area
Na=Na+1
NEXT Oscan
!
Amean=Amean/Na
PRINT USING "K,,K,"MEAN AREA="Amean," cm^{-2}
!
FOR Oscan=1 TO Nsout
Rotf=Dout(Oscan,6)
Rotp=1/Rotf
IF Oscan=1 THEN Time=Rotp*(Nav/2-Nstep)
Time=Time+Nstep*Rotp
W=-100*(Pcall+2*Pcal2+Time)
Area=Dout(Oscan,5)
W=W*Sf*(Area/Amean-1)
V=Dout(Oscan,4)
V=V+W*Vcor
!
Dout(Oscan,4)=V
!
PRINT USING "K,,K,,K,DDD.D,"VCOR="Vcor,"V=";V
!
NEXT Oscan
!
DATA "Z","T","U","V","AREA","FREQ","EF BL","CC BL","VELERR"
RESTORE
!
CREATE Ofile$,Nrec ! standard txtup data format
ASSIGN Ofile$ TO *2
PRINT *2;Drop$,Downtime$,Lat$,Long$,Comment$,Progres$,Ifile$,Runtime$
6630 PRINT #2; Nvout, Nsout, Bad, 11
6640 PRINT #2; Nav, Nstep, Probe, Mod, Gcc, Gcor, Gef, Efuf, Ccuf, Fh, Fz
6650 PRINT #2; Var$(*) , Dout(*)
6660 PRINT #2; END
6670 ASSIGN #2 TO *
6680 DATA -1000, 0, 30, 30, 600, 6, 2000, 4000, 0 ! plotting scales
6690 DATA 0, 28, 40, 40, 1300, 9.5, 3000, 5000, 70
6700 DATA -1000, 0, 30, 30, 700, 6, 4000, 2000, 0
6710 DATA 0, 28, 40, 40, 1400, 9.5, 5000, 3000, 70
6720 IF Mod <> 5 THEN RESTORE 6690
6730 IF Mod = 5 THEN RESTORE 6710
6740 READ Plo(*), Phi(*)
6750 IF File = 1 THEN PLOTTER IS "9872R"
6760 IF File = 1 THEN PLOTTER IS "9872A"
6770 SETUP PLOTTER FOR 7 WIDE BY 10 HIGH
6780 ON Plotter + 1 GOTO 8340, 6790, 6840, 6890
6790 IF Plotter = 1 THEN PLOTTER IS "9872A"
6800 LIMIT 600 40, 7730 40, 280 40, 10440 40
6810 FRAME
6820 SETUP 9872A
6830 IF File = 1 THEN PLOTTER IS "9872A"
6840 LIMIT 600 40, 7730 40, 1060 40, 11220 40
6850 FRAME
6860 Nhalf = 1
6870 IF Plotter = 1 THEN Nhalf = 2
6880 FOR Half = 1 TO Nhalf
6890 IF (Plotter = 1) AND (Half = 1) THEN 7310
6900 LINE TYPE 1
6910 PEN 1
6920 SETGU
6930 Xgdumax = 100 * MAX(1, RATIO)
6940 MOVE Xgdumax - 25, 60
6950 IF Plotter = 1 THEN MOVE Xgdumax - 45, 97
6960 CSIZE 3
6970 IF Plotter = 1 THEN CSIZE 3.89
6980 LABEL USING "K"; "PROG"; Progrev$
6990 LABEL USING "K"; "IFILE"; Ifile$
7000 LABEL USING "K"; "OFILE"; Ofile$
7010 LABEL USING "K"; "Runtime"$
7020 LABEL USING "K"; "NAV"; Nav
7030 LABEL USING "K"; "NSTEP"; Nstep
7040 LABEL USING "K"; "XTVP S/N"; Probe
7050 LABEL USING "K"; "XTVP MOD"; Mod
7060 LABEL USING "K"; "GCC"; Gcc
7070 LABEL USING "K"; "GCO"; Gcor
7080 LABEL USING "K"; "GEF"; Gef
7090 CSIZE 2
7100 IF Plotter = 1 THEN CSIZE 3.89
7110 IF Plotter = 1 THEN CSIZE 3.89
7120 LABEL USING "K"; Runtime$
7130 LABEL USING "K"; "NAV"; Nav
7140 LABEL USING "K"; "NSTEP"; Nstep
7150 LABEL USING "K"; "XTVP S/N"; Probe
7160 LABEL USING "K"; "XTVP MOD"; Mod
7170 LABEL USING "K"; "GCC"; Gcc
7180 LABEL USING "K"; "GCO"; Gcor
7190 LABEL USING "K"; "GEF"; Gef

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LABEL USING "K"; "EVCO"; Ef	
LABEL USING "K"; "CVCO"; Cc	
LABEL USING "K"; "FH"; Fh	
LABEL USING "K"; "FZ"; Fz

PLOT EACH VARIABLE

Csize = 2
IF Plotter = 1 THEN Csize = 3.89
CSIZE Csize

FOR Var = 2 TO Nvout
Pen = MIN(Var - 1, 4)
IF Var = 9 THEN Pen = 1
IF NOT Pub THEN PEN Pen 1
IF Pub THEN PEN 1
IF (Plotter = 1) AND (Half = 1) THEN 7440
LINE TYPE 1
SETGU
MOVE Xlab, Ylab
LABEL USING "5A,2(5D.D)"; Var$(Var), Plo$(Var), Phi$(Var)
WHERE Xlab, Ylab
LINE TYPE 1
IF NOT Pub THEN
PEN I
IF Var = 2 THEN LINE TYPE 4, 4
IF Var = 3 THEN LINE TYPE 4, 1
IF Var = 4 THEN LINE TYPE 4, 2
IF Var = 5 THEN LINE TYPE 7, 2
IF Var = 6 THEN LINE TYPE 5, 2
IF Var = 7 THEN LINE TYPE 7, 4
IF Var = 8 THEN LINE TYPE 8, 4
IF Var = 9 THEN LINE TYPE 1
GOTO 7610
IF (Plotter = 1) AND (Var = 4) THEN LINE TYPE 3
IF Var = 6 THEN LINE TYPE 5, 1
IF Var = 7 THEN LINE TYPE 5, 2
IF Var = 8 THEN LINE TYPE 5, 3
MOVE Xlab, Ylab + .8 * Csize
DRAW Xlab + 11 * Csize, Ylab + .8 * Csize
Ylab = Ylab - .2 * Csize
SCALE Plo$(Var), Phi$(Var), Plo$(1), Phi$(1)
IF (Plotter = 1) AND (Half = 1) THEN SCALE Plo$(Var), Phi$(Var), Plo$(1)/2, Phi$(1)
IF (Plotter = 1) AND (Half = 2) THEN SCALE Plo$(Var), Phi$(Var), Plo$(1), Plo$(1)/2
GOTO 7610
P=-2
FOR I = 1 TO Nsout
D=Dout(I, Var)
IF D<>Bad THEN 7770
7750   P=-2
7760   GOTO 7810
7770   !
7780   Z=Dout(l,l)
7790   PLOT D,Z,P
7800   P=-1
7810   NEXT I
7820   SETGU
7830   MOVE 130,0
7840   NEXT Var
7850   IF Plotter<>1 THEN 8070
7860   PEN 1
7870   SCALE 0,1,0,1
7880   IF Half<>1 THEN 7930
7890   MOVE 0,0   ! PARTIAL FRAMES
7900   DRAW 0,1
7910   DRAW 1,1
7920   DRAW 1,0
7930   IF Half<>2 THEN 8030
7940   MOVE 0,1
7950   DRAW 0,0
7960   DRAW 1,0
7970   DRAW 1,1
7980   !
7990   SETGU
8000   MOVE 1,1
8010   PEN 1
8020   LABEL USING "K":Comment$
8030   !
8040   SCALE 0,1,0,1
8050   DUMP GRAPHICS 0,1
8060   GCLEAR
8070   NEXT Half
8080   !
8090   CSIZE Csize
8100   IF Plotter=1 THEN 8150
8110   SETGU
8120   MOVE 1,1
8130   PEN 1
8140   LABEL USING "K":Comment$
8150   !
8160   MOVE 100,0
8170   PEN 0
8180   !
8190   IF Plotter<>1 THEN 8240
8200   EXIT GRAPHICS
8210   PRINTER IS 0
8220   PRINT PAGE;   ! TOP OF FORM ON PRINTER
8230   PRINTER IS Printer
8240   IF Plotter<>3 THEN 8270
8250   OUTPUT 795:"EC"   ! enable cutter on 9872S
8260   OUTPUT 795:"AH"   ! advance half page on 9872S
8270   IF Nfile<>1 THEN 8340
8280   ! ONLY EXECUTE THE FOLLOWING CODE IF NFILE=1
8290   FOR V=1 TO Nvout  ! allow different plot scales
8300   DISP Var$(V);Plo(V);Phi(V);
8310   INPUT "ENTER NEW PLOT LIMITS: PLO, PHI",Plo(V),Phi(V)

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8320 NEXT V
8330 GOTO 6770
8340 NEXT File
8350 DISP "FINISHED"
8360 STOP
8370 !
8380 !*************************************************************************
8390 DEF FN~tan2(Y,X)
     ! FN ATAN2(Y,X) four quadrant arc-tangent
8400 DEG
8410 IF X=0 THEN Vert
8420 Ang=ATN(Y/X)
8430 IF X>0 THEN RETURN Ang
8440 IF Y>0 THEN Q3
8450 Ang=Ang+180
8460 RETURN Ang
8470 Q3: Ang=Ang-180
8480 RETURN Ang
8490 Vert: IF Y<0 THEN Down
8500 Ang=90
8510 RETURN Ang
8520 Down: Ang=-90
8530 RETURN Ang
8540 FNEND
8550 !*************************************************************************
8560 SUB Interp(Nin,Nout,BadDzout,SHORT Pin(*),Dir(*),Dou(*))
8570 SUBEND
8580 !*************************************************************************
8590 SUB Addtime(Mastertime$,Addtime$,Rddsecs)
8600 ENTER Mastertime$ USING "# 4(NN, X),NN"; Mo,Da,Hr,Mn,Sc
8610 Sc=Sc+Addsecs
8620 Mn=Mn+Sc DIV 60
8630 Sc=Sc MOD 60
8640 Hr=Hr+Mn DIV 60
8650 Mn=Mn MOD 60
8660 Da=Da+Hr DIV 24
8670 Hr=Hr MOD 24
8680 OUTPUT Addtime$ USING 8690; Mo,Da,Hr,Mn,Sc
8690 IMAGE #.4(ZZ,";"),ZZ
8700 SUBEND
8710 !*************************************************************************
8720 SUB Polar(X,Y,Amp,Ang) ! rectangular to polar conversion
8730 DEG
8740 Amp=SQR(X^2+Y^2)
8750 IF X>0 THEN Ang=ATN(Y/X)
8760 IF (X<0) AND (Y<0) THEN Ang=Ang-180
8770 IF (X<0) AND (Y>0) THEN Ang=Ang+180
8780 IF (X=0) AND (Y>0) THEN Ang=90
8790 IF (X=0) AND (Y<0) THEN Ang=-90
8800 SUBEND
8810 !*************************************************************************
8820 SUB Rect(Amp,Ang,X,Y) ! polar to rectangular conversion
8830 DEG
8840 X=Amp*COS(Ang)
8850 Y=Amp*SIN(Ang)
8860 SUBEND
8870 !*************************************************************************

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Program SPLOT, Sample Run

SPLOT produces a series of plots of XTVP profiles. Many features are available. One can fit each profile to a polynomial and rotate the profile based on its time and inertial period. One can plot the fit or the profile minus the fit.

The following example shows the program prompts, operator entries and program responses for a typical run of plotting, in Cartesian coordinates, the rotated residues of quadratic fits to each of four profiles.

VARIABLE NAMES USED ARE U,V
VELOCITY ERROR LIMIT= 2
DATA FITTED TO A POLYNOMIAL OF DEGREE 2
PLOT THE RESIDUE
PLOTS ARE CARTESIAN
THE RESIDUE PROFILES WERE ROTATED BASED ON REF. TIME OF 0 hr 0 min
FOR A ROTATION PERIOD OF 13.4088046171
ROTATED TO 00:00
A PLOT OF THE RESIDUE WAS MADE USING PEN #1
PLOT IS LABELLED.
INPUT DATA IS PROCESSED.
TIC SIZE = 17.78 mm
PLOT WILL BE 266.7 mm 10.5 in WIDE AND 177.8 mm 7 in HIGH
FILE NO. FILE NAME TIME HR MIN U,V OFFSETS (TICS)
1 539P 00:32 4.0 4.0
2 542P 01:29 4.0 4.0
3 543P 01:56 4.0 4.0
4 544P 02:23 4.0 4.0
TOP 0 m OF PROFILES ZAPPED
PLOT MADE 81:04:09:22:58:59
1 FILE NAME=539P
539 12:02:02:35:50
12:02:02:35:42 XTVP 539 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 539R, ON 80:12:04:17:39:41
AVERAGE FIT. NBLOCKS= 30 A= -1.1841562398 -.28223036716 4.9702050700E-04
AVERAGE FIT. NBLOCKS= 30 A=-9.6595643077 -.06076936895 2.26920819670E-04
INPUT FILE, VARIABLE, NO. OF GOOD PTS, STD. DEV. BASED ON GOOD PTS
539F U COMP 295 .143 3.921
539F V COMP 295 .072 3.788
2 FILE NAME=542P
542 12:02:18:42:02
12:02:18:41:56 XTVP 542 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 542R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 23.6964354786 -.22053932126 3.60916726720E-04
AVERAGE FIT. NBLOCKS= 30 A=9.0635253676 -.05074011791 2.38360183380E-04
542P U COMP 279 .162 3.243
542P V COMP 279 .041 4.564
3 FILE NAME=543P
543 12:02:18:49:36
12:02:18:49:31 XTVP 543 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 543R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A=21.7290392777 -.218441083637 4.3213723550E-04
AVERAGE FIT. NBLOCKS= 30 A=-14.0893444811 .06392939153 -1.48637570870E-04

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AVERAGE FIT. NBLOCKS= 30 A= 31.332172827 -.34130695143 7.04315634480E-04
AVERAGE FIT. NBLOCKS= 30 A= -20.1443709546 .1250602827 -3.00207053690E-04

543P U COMP 280 .035 1.613
543P V COMP 280 .142 3.508

FILE NAME=544P
Program Listing of SPLIT

10 Progrev$="SPLIT0"
20 Year=81
30 SPLIT: SERIES PLOT BY TOM SANFORD MODIFICATIONS BY JOHN DUNLAP
40 THIS PROGRAM ALLOWS FILES TO BE REQUESTED WHICH ARE ON
50 SEPARATE DISKS AND PLOTTED WITH OFFSETS FOR U(V) AND V(Y).
60 SPLITC ALLOWS POLYNOMIAL FIT AND RESIDUES TO BE PLOTTED.
70 SPLITC ALLOWS THE PROFILES TO BE ROTATED CCW
80 SPLITC ALLOWS THE RESIDUE PROFILES TO BE PLOTTED IN POLAR FORM
90 SPLITC ALLOWS FOR VARIOUS VARIABLE POSITIONS IN FILE. SEARCHES NVUS(*).
100 SPLTOPRINTS FOR VARIOUS VARIABLE POSITIONS IN FILE. SEARCHES NVUS(*).
110 SPLITG CRT OR HP-9872A. QUICKER POLYNOMIAL PLOTTING. JHD.
120 SPLITH JAN 23 80. SPECIAL NSCAN=500 TO ALLOW FOR ERROR IN FRONTS DXPROG
130 SPLITI MAY 7 80. FOR NEW XTVP FORMAT... NOT RIGHT YET. JHD.
140 SPLITJ ... ERIC KUNZE FIXED FROM SPLITI.
150 SPLITK ... ALSO ROTATES THE FITS. RECEIVED FROM ERIC KUNZE AS FITPRO.
160 SPLITL ... MODIFIED TO MAKE VIEW GRAPHS OF WENSTRANDS 8 WITH OUR 191,...
170 SPLITM ... APR 8 81, FIXED INPUT STATEMENTS TO CHECK PARAMETERS.
180
190
200
210
220
230 SPLIT accepts standard-format processed XTVP files for some specialized
240 processing and then plotting to assist scientific analysis. It will plot
250 several profiles with the same processing on the same page for easy
260 comparison.
270 Usually the profiles are fit to a low-degree polynomial
280 to remove the low wave-number components. The fits or residuals
290 are then plotted instead.
300 The residuals can be rotated to a common time according to the
310 local inertial period (12 hours divided by the sine of the latitude).
320 This allows one to attempt to view a time series or section as if it
330 had occured instantaneously.
340 Cartesian or polar plots are available as are various plotters.
350
360 One specifies the following parameters with defaults in ()
370 . variable names (U,V) for processing.
380 . velocity error limit (2 cm/s) for use in eliminating noisy data.
390 . degree of polynomial fit (0).
400 . plot residuals or fits (R).
410 . cartesian or polar plots (C).
420 . whether or not to rotate the plots (N).
430 . pen number to use (0).
440 . whether to label the plot (Y). Don't label overlays of fits on data.
450 . tic size (25.4mm). the plots are 10 cm/s/tic and 200m/tic. The
460 default tic size is for 15 by 10 inch paper. To use the 10 by 7
470 inch paper use a tic size of 25.4*7/10=17.78. When using the GRAPHICS
480 plotter the tic size is adjusted to fit exactly.
490 . size of paper in tics. (15,15).
500 . size of paper in inches - user can choose three types. Position
510 view graphs up from the bottom somewhat.
520 . file names until a blank name.
530 . if rotating then input the time of the profile.
540 . offsets for each component (4,4 tics). This is in addition to the

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normal incrementing of tics to the right for each profile. Use
the default value of 4, 4 the first time through and refine it later.
specify the amount at the top of all profiles to zap in meters.
now the program should continue by itself and print each drop header as
they are read from mass storage. If a file cannot be found then the
program will prompt for another disc or tape. Plots are drawn as the
data is processed.

PRINTER IS 0
OPTION BASE 1
OVERLAP
STANDARD

PRINT PAGE
MAT W=CON
OUTPUT 9; "R"
Enter 9; R$
R$=VALS(Year)&:":&R$
PRINT Progrev$, "RUN DATE/TIME="; R$

DIM Var$(3:4)
IF LEN(Var$(3)=0 THEN Var$(3)="U"
IF LEN(Var$(4)=0 THEN Var$(4)="V"
DISP "VARIABLE NAMES (DEFAULT= ";Var$(3);",";Var$(4);")"
INPUT Var$(3), Var$(4)
PRINT "VARIABLE NAMES USED ARE "; Var$(3);","; Var$(4)
IF Veler=0 THEN Veler=2
DISP "VELOCITY ERROR LIMIT (DEFAULT= ";Veler;")"
INPUT Veler
IF Veler<=0 THEN 940
PRINT "VELOCITY ERROR LIMIT= "; Veler
Rmslabel$="VELOCITY ERROR LIMIT= "; VALS(Veler)
IF LEN(Fit$)=0 THEN Fit$="Y"
DISP "IS DATA TO BE FITTED TO POLYNOMIAL (Y OR N; DEFAULT= ";Fit$;")"
INPUT Fit$
IF (Fit$<"Y") AND (Fit$<"N") THEN 1020
IF Fit$="Y" THEN Fit$
DISP "DATA NOT FITTED TO POLYNOMIAL.
Rtos="N" !NO FIT THEN NO ROTATION
Polar$="C" !NO ROTATION THEN USE CARTISIAN COORD.
1110 ' Fit!
1120 DISP "DEGREE OF POLYNOMIAL FIT (0=CONST,1=LIN,2=QUAD,3=CUBIC; DEFAULT=";Degree;");
1130 INPUT Degree
1140 IF (Degree<8) OR (Degree>3) THEN 1130
1150 !
1160 PRINT "DATA FITTED TO A POLYNOMIAL OF DEGREE ";Degree
1170 Order=Degree+1
1180 ' Fitlabel$="FIT TO DEGREE ";VAL$(Degree)
1190 !
1200 IF LEN(Plot$)=0 THEN Plot$="R"
1210 DISP "PLOT FIT OR RESIDUE (F OR R; DEFAULT=";Plot$;" )";
1220 INPUT Plots
1230 IF (Plots<"F") AND (Plots<"R") THEN 1220
1240 !
1250 IF Plots="F" THEN Plttyp$="FIT"
1260 IF Plots="R" THEN Plttyp$="RESIDUE"
1270 PRINT "PLOT THE ";Plttyp$
1280 !
1290 IF LEN(Polar$)=0 THEN Polar$="C"
1300 DISP "CARTESIAN OR POLAR PLOTS (C OR P; DEFAULT=";Polar$;" )";
1310 INPUT Polar$
1320 IF (Polar$<"C") AND (Polar$<"P") THEN 1310
1330 IF Polar$="C" THEN PRINT "PLOTS ARE CARTESIAN"
1340 IF Polar$="P" THEN PRINT "PLOTS ARE POLAR"
1350 !
1360 IF LEN(Rot$)=0 THEN Rot$="N"
1370 DISP "ARE PROFILES TO BE ROTATED (Y OR N; DEFAULT=";Rot$;" )";
1380 INPUT Rot$
1390 IF (Rot$<"Y") AND (Rot$<"N") THEN 1380
1400 IF Rot$="Y" THEN 
1410 !
1420 IF Rot$="Y" THEN 1460
1430 GOTO 1650
1440 !
1450 PRINT "PROFILES ARE NOT ROTATED"
1460 GOTO 1650
1470 !
1480 INPUT T0hr,Tomin
1490 !
1500 DISP "ENTER REFERENCE TIME (hr,min; DEFAULT=";T0hr;Tomin;" )";
1510 INPUT Rotper
1520 IF Rotper=0 THEN 1500
1530 !
1540 Blankhr$=Blankmin$=""
1550 IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(Tomin))=1) THEN Blankhr$=Blankmin$="0"
1560 IF (LEN(VAL$(T0hr))>1) AND (LEN(VAL$(Tomin))=1) THEN Blankmin$="0"
1570 IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(Tomin))>1) THEN Blankhr$="0"
1580 Rotlabel$="ROTATED TO ";Blankhr$&VAL$(T0hr)&":"&Blankmin$&VAL$(Tomin)
1590 !
1600 PRINT "THE RESIDUE PROFILES WERE ROTATED BASED ON REF. TIME OF ";T0hr;hr ";Tomin;" min "
1610 PRINT " FOR A ROTATION PERIOD OF ";Rotper
1620 PRINT Rotlabel$
1640 Pen=VAL(Pen$)
1650 DISP "PEN NUMBER TO BE USED (1, 2, 3 OR 4; 0 FOR ALL; DEFAULT=", Pen");"
1660 INPUT Pen
1670 IF (Pen<0) OR (Pen>4) THEN 1650
1680 Pen$=VAL$(Pen)
1690 !
1700 PRINT "A PLOT OF THE ", Pttyp$;" WAS MADE USING PEN ", Pen$"
1710 !
1720 IF LEN(Label$)=0 THEN Label$="Y"
1730 DISP "LABEL PLOT (Y OR N; DEFAULT=";Label$; ")");"
1740 INPUT Label$
1750 IF (Label$<="Y") AND (Label$>="N"") THEN 1730
1760 !
1770 IF Label$="Y" THEN PRINT "PLOT IS NOT LABELLED."
1780 IF Label$="Y" THEN PRINT "PLOT IS LABELLED."
1790 !
1800 Ans$="P"
1810 !
1820 IF Ans$="R" THEN Dataty;p$="RAW"
1830 IF Ans$="P" THEN Dataty;p$="PROCESSED"
1840 !
1850 PRINT "INPUT DATA IS ", Dataty;p$;"."
2170 Change$="N"
2180 INPUT "DO YOU WANT TO CHANGE THE SPECS? (Y/N) ", Change$
2190 IF Change$="Y" THEN 2020
2200 !
2210 ON Plotter GOTO Graphics,Hp9872a,Hp9872s
2220 !
2230 Hp9872s: !
2240 Hp9872a: !
2250 !
2260 IF Paper=0 THEN Paper=3
2270 IF NOT Film THEN DISP "PAPER TYPE: 1=7W,10H. 2=15W,10H. 3=10W,7H,HOLES U P; DEFAULT=";Paper;"");
2280 IF NOT Film THEN INPUT Paper
2290 !
2300 IF Paper=1 THEN OUTPUT 705 USING "K";"IP600,260,7730,10420"
2310 IF Paper=2 THEN OUTPUT 705 USING "K";"IP600,260,15876,10401"
2320 IF Paper=3 THEN OUTPUT 705 USING "K";"IP77,269,10252,7377"
2330 !
2340 PLOTTER IS "9872A"
2350 !
2360 IF Film THEN OUTPUT 705;"VS10;" LIMIT PEN VELOCITY TO 10 CM/S WHEN FIL M IS USED
2370 IF Pen$<>"0" THEN PEN VAL(Pen$)
2380 IF Label$="Y" THEN FRAME
2390 PEN 0
2400 GOTO 2530
2410 !
2420 Graphics: PLOTTER IS "GRAPHICS"
2430 GRAPHICS
2440 Tic=MIN(184.47,XTics,149.82,YYtics)
2450 PRINT "GRAPHICS TIC SIZE CHANGED TO";Tic;"mm TO FIT SCREEN"
2460 LIMIT 0,XTics*Tic,0,YYtics*Tic
2470 MScale Tic,Tic
2480 LINE TYPE 3
2490 GRAY Tic,Tic
2500 LINE TYPE 1
2510 FRAME
2520 EXIT GRAPHICS
2530 !
2540 IF Ans$="R" THEN Raw
2550 IF Ans$="P" THEN Proc
2560 !
2570 Zsc=Tic/50 ! 50 SEC PER TIC
2580 Dsc=Tic/(1.25*1016) ! ABOUT 10 CM/S PER TIC
2590 Plotscx$=VAL$(Tic/20/(2.5*1016)/Dsc)" cm/s"
2600 Plotscy$=VAL$(Tic/Zsc)" sec"
2610 GOTO 2700
2620 !
2630 Proc:!
2640 Zsc=Tic/200 ! 200 M PER TIC
2650 Dsc=Tic/10 ! 10 CM/S PER TIC
2660 Plotscx$=VAL$(Tic/Dsc)" cm/s"
2670 Plotscy$=VAL$(Tic/Zsc)" m"
2680 !
2690 SETUP FILE NAMES AND PARAMETERS
2700 PRINT "FILE NO. FILE NAME TIME HR MIN U,V OFFSETS (TICS)"
2708 FOR File=1 TO 16

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DISP "FILE NAME FOR FILE NUMBER=";File;
EDIT File$(File)
IF LEN(File$(File))=0 THEN 3060 ! BLANK INDICATES END OF INPUT LIST
File$=File$(File)
IF POS(File$,",") THEN
ASSIGN #1 TO File$(File),Ret
IF Ret=0 THEN 2860
BEEP
DISP "THIS FILE NOT ON THIS DISC. ";
GOTO 2720
DISP "IMPROPER FILE NAME. ";
GOTO 2720
IF Rot$="N" THEN 2950
!
DISP "ENTER DROP TIME (hr, min; DEFAULT=";Thr(File);Tmin(File);")";
INPUT Thr(File),Tmin(File)
IF (Thr(File)<-1000) OR (Thr(File)>=1000) THEN 2890
IF (Tmin(File)<0) OR (Tmin(File)>=60) THEN 2890
!
IMAGE #,4D,6X,15A,3X,2Z,"":"",22
PRINT USING #1;File$UFile;Thr(File);Tmin(File)
IF Offqu(File)=0 THEN Offqu(File)=4
IF Offiv(File)=0 THEN Offiv(File)=4
DISP "U, V OFFSET (tics; DEFAULT=";Offqu(File);",";Offiv(File);")";
INPUT Offqu(File),Offiv(File)
PRINT USING 3020;Offqu(File);Offiv(File)
IMAGE 8X,3D,D, 3D.D
!
NEXT File
IF Nfile=File-I THEN 3050
!
DISP "ZAP TOP OF PROFILES (meters; DEFAULT=";Zzap;")";
INPUT Zzap
Zzap=-ABS(Zzap)
IF Zzap>1000 THEN 3080
PRINT "TOP";RBS(Zzap);"m OF PROFILES ZAPPED"
!
OUTPUT 9;"R"
ENTER 9;Now$&NOW$
PRINT USING "K";"PLOT MADE ";Now$
IF Plotter=1 THEN GRAPHICS
!
FOR File=1 TO Nfile
Penuse=VAL(Pen$)
IF Pen$="0" THEN Penuse=(File-1) MOD 4+1
PRINT File;"FILE NAME=";File$(File)
!
ASSIGN #1 TO File$(File), Ret
IF Ret=0 THEN 3320
BEEP
EDIT "THIS FILE NOT FOUND ON THIS DISC", File$(File)
GOTO 3270
READ #1,1
READ #1; Drop$, Downtime$, Lat$, Long$
PRINT Drop$, Downtime$, Lat$, Long$
READ #1; Comments
PRINT Comments
READ #1; Oldprog$, Oldfile$, Created$
PRINT USING 3410; Oldprog$, Oldfile$, Created$
IMAGE "CREATED BY ", K, " FROM FILE ", K, " ON ", K
READ #1; Nvar, Nscan, Bad, Nparam
REDim Param(Nparam), Nuvs(Nvar), D(Nscan, Nvar)
READ #1; Param(*), Nuvs(*), D(*)
FOR I=1 TO Nscan
IF D(I,9)< Vel B THEN 3510
D(I,3)= Bad
D(I,4)= Bad
NEXT I
FOR V=3 TO 4
SEARCH FOR VARIABLES BY NAME
FOR L=1 TO Nvar
IF Nuvs$L>[I;LEN(Var$(V))]= Var$(V) THEN 3650
NEXT L
BEEP
EXIT GRAPHICS
PRINTER IS 16
PRINT Nuvs$(*)
PRINTER IS 0
EDIT "CAN'T FIND VARIABLE BELOW. CHOOSE NAME FROM ABOVE LIST", Var$(V)
GRAPHICS
GOTO 3540
Var$(V)= L
NEXT V
DIM Var$(9)
IF Ans$="R" THEN Dz=-.5
FOR V=3 TO 4
FOR I=1 TO Nscan
IF D(I,1)< Zzap THEN 3750
D(I,V)= Bad
NEXT I
NEXT V
LINE TYPE 1
CSIZE 2
IF Plotter=1 THEN CSIZE 2.8
LONG 9
LDIR 0
3820 MScale 0,0
3830 IF Label$="N" THEN 3970
3840 IF File>1 THEN 3970
3850 PEN 1
3860 SETGU
3870 Xgdamax=100*MAX(1,RATIO)
3880 Ygdamax=100*MAX(1,1/RATIO)
3890 MOVE .99*Xgdamax,.99*Ygdamax
3900 IMAGE 3<2Z,X>,2<2Z,"":),2Z
3910 LABEL USING "K";Now$
3920 LABEL USING "K";Fitlabel$
3930 LABEL USING "K";Rmstlabel$
3940 IF Rot$="N" THEN 3960
3950 LABEL USING "K";Rotlabel$
3960 SETUU
3970 Xoff=2*Tic*(1+File)-1.5*Tic
3980 MScale Xoff,0 PLOT IN mm
3990 MOVE 0,2
4000 LORG 4
4010 PEN Penuse
4020 IF Label$="Y" THEN LABEL USING "K";File$(File
4030 PEN 0
4040 ! START OF Var LOOP #1
4050 IF Fit$="N" THEN 4700 ! SKIP OVER FITTING PORTION
4060 !
4070 FOR I=1 TO Nscan ! SET UP FITTING FUNCTIONS
4080 F(I,1)=1
4090 F(2,1)=I
4100 F(3,1)=I^2
4110 F(4,1)=I^3
4120 NEXT I
4130 ! AVERAGE FITTING FUNCTIONS
4140 Nblocks=30
4150 REDIM Fav(4,Nblocks),Wav(Nblocks),Dav(Nblocks,4)
4160 Blocksize=Nscan DIV Nblocks
4170 FOR J=1 TO Nblocks
4180 FOR V=1 TO Order
4190 Fav=0
4200 FOR L=1 TO Blocksize
4210 I=(J-1)*Blocksize+L
4220 Fav=Fav+F(I,V-1)
4230 NEXT L
4240 Fav(V,J)=Fav/Blocksize
4250 NEXT V
4260 NEXT J
4270 ! AVERAGE WEIGHTING FUNCTION W TO WAV
4280 FOR J=1 TO Nblocks
4290 Wav=0
4300 FOR K=1 TO Blocksize
4310 I=(J-1)*Blocksize+K
4320 Wav=Wav+W(I)
4330 NEXT K
4340 Wav(J)=Wav/Blocksize
4350 NEXT J
4360 ! AVERAGE DATA D TO Dav
4370 MAT Dav=(Bad)

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4380 FOR V=3 TO 4
4390 Var=Var(V)
4400 FOR J=1 TO Nblocks
4410 Dav=0
4420 Nav=0
4430 FOR K=1 TO Blocksize
4440 I=(J-1)*Blocksize+K
4450 D=D(I,Var)
4460 IF D=Bad THEN 4490
4470 Dav=Dav+D
4480 Nav=Nav+1
4490 NEXT K
4500 IF Nav THEN Dav(J,V)=Dav/Nav
4510 NEXT J
4520 NEXT V

4530 !
4540 FOR V=3 TO 4
4550 Var=Var(V)
4560 CALL Lsqw2(A(*),V,Nblocks,Order,Bad,Ngood,1,Dav(*),Nav(*),Fav(*))
4570 PRINT "AVERAGE FIT. NBLOCKS=";Nblocks;
4580 PRINT USING "K,X";"A=";A(&)
4590 !
4600 !
4610 FOR I=1 TO Nscan
4620 IF D(I,Var)=Bad THEN 4680
4630 FOR J=1 TO Order I FORM FIT
4640 Fit=Fit+F(J,I)*A(J)
4650 NEXT J
4660 IF Plot$="F" THEN D(I,Var)=Fit
4670 IF Plot$="R" THEN D(I,Var)=D(I,Var)-Fit
4680 NEXT I
4690 NEXT V

4700 !
4710 !
4720 PEN Penuse
4730 FOR V=3 TO 4
4740 Var=Var(V)
4750 V3=Var(3)
4760 V4=Var(4)
4770 Yoffs=Tic*5*(5-V) ! PUT U ABOVE V, EACH 5 TICS HIGH
4780 Offset=Offquu(File)*Tic !OFFSET 0<U
4790 IF V=4 THEN Offset=Offuu(File)*Tic !OFFSET I<V
4800 LONG 3
4810 MSSCALE 0,Yoffs
4820 LINE TYPE 1
4830 IF File>1 THEN 5080
4840 IF Label$="H" THEN 5080
4850 MOVE 2,-2
4860 LTIR 0
4870 IF Polar$="C" THEN 4910
4880 Nuu$(V3)="SPEED"
4890 Nuu$(V4)="PHASE"
4900 IF V=4 THEN Plotscx$="200 deg"
4910 LABEL USING "K";Nuu$(Var)
4920 MOVE Tic/10,-3*Tic/10
4930 DRAW Tic/10,-4*Tic/10

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```
DRAW 11*Tic/10, -4*Tic/10
DRAW 11*Tic/10, -3*Tic/10
MOVE 6*Tic/10, -5*Tic/10
LOR 6
LDIR 0
LABEL USING "K"; Plotsct$
MOVE 2*Tic/10, -2*Tic
DRAW Tic/10, -2*Tic
DRAW Tic/10, -3*Tic
DRAW 2*Tic/10, -3*Tic
MOVE 3*Tic/10, -2.5*Tic
LOR 6
LDIR 90
LABEL USING "K"; Plotsry$
IF Pen$="O" THEN 5110
IF File MOD 2=1 THEN LINE TYPE 1
IF File MOD 2=0 THEN LINE TYPE 5, 1
P=-2
MSCAL Xoff, Yoff
510 ! PLOT THE DATA
5150 Slide=4*Tic
5160 Ngood=Sr=Ssr=Sru=Srw=0
5170 IF Rot$="N" THEN 5230
5180 ! Angle=(Thr(File)-Thrmin(File)-Thrmin/F)*360/Rotper
5200 IF Ans$="R" THEN Angle=-1*Angle ! FOR RAW DATA QUAD-PHASE CORRESP
DS TO EAST, HENCE THE NEED TO CHANGE ANGLE
5210 Cos=COS(Angle)
5220 Sin=SIN(Angle)
5230 FOR Scan=1 TO Nscan
5240 D=D(Scan,Var)
5250 D3=D(Scan,Var)
5260 D4=D(Scan,Var)
5270 IF (D3<Bad) AND (D4<Bad) THEN 5310
5280 D=D=Bad
5290 P=-2
5300 GOTO 5610
5310 Y=D(Scan,1)*Zsc
5320 IF (Rot$="N") OR (V=4) THEN 5380
5330 Drot(3)=D3*Cos-D4*Sin
5340 Drot(4)=D3*Sin+D4*Cos
5350 D=Drot(Var)
5360 D3=Drot(3)
5370 D4=Drot(4)
5380 IF Polar$="C" THEN 5510
5390 IF Ans$="R" THEN D3=-D3
5400 D=SQR(D3^2+D4^2)
5410 IF V=3 THEN 5510
5420 D=ATN(D3/D4)
5430 IF (D3<0) AND (D4>0) THEN D=D+180
5440 IF (D3<0) AND (D4<0) THEN D=D-180
5450 X=D*Tic/200 ! 200 DEG PER TIC FOR PHASE
5460 IF ABS(D-Dlast)<200 THEN 5520
5470 Dlast=D
5480 P=-2
```
5490    GOTO 5610
5500    X=D*Sc-Slide+Offset  ! OFFSET TO LEFT BY 4 TICS PLUS DESIRED OFFSET
5510
5520    Dlast=D
5530    Ngood=Ngood+1
5540    Sr=Sr+D
5550    Ssr=Ssr+D^2
5560    Xw=D*W(Scan)
5570    Srw=Srw+Xw
5580    Ssrw=Ssrw+Xw^2
5590
5600    P=-1
5610    D(Scan,3)=D3
5620    D(Scan,4)=D4
5630    NEXT Scan
5640
5650    Avg=Sr/Ngood
5660    Sig=SQR(Ssr/Ngood-Avg^2)
5670    Avgw=Srw/Ngood
5680    Sigw=SQR(Ssrw/Ngood-Avgw^2)
5690    IF Ans$="P" THEN 5740
5700    Comtyp$="QUAD-PHASE"
5710    IF V=4 THEN Comtyp$="IN-PHASE"
5720    GOTO 5800
5730    Comtyp$="U COMP"
5740    IF V=4 THEN Comtyp$="V COMP"
5750    IF File>1 THEN 5800    !PRINT HEADING ONCE
5760    IF V>3 THEN 5800
5770    PRINT "INPUT FILE,VARIABLE,NO. OF GOOD PTS,AVER.,STD. DEV. BASED ON GOOD PTS"
5780    IMAGE 4x,6A,4X,10A,4X,DDD,DDDD,DDD,4X,DDD.DDD
5790    PRINT USING 5790;File$(File),Comtyp.$,Ngood,Rvgw,Sigw
5800    NEXT V
5810    PEN 0
5820    NEXT File
5830    PEN 0
5840    BEEP
5850    IF Plotter=1 THEN PRINT PAGE
5860    IF Plotter=1 THEN DUMP GRAPHICS
5870    IF Plotter=1 THEN PRINT PAGE
5880    IF Plotter=1 THEN EXIT GRAPHICS
5890    DISP Progrtv$;
5900    INPUT "FINISHED. 0 TO STOP, 1 TO CHANGE OFFSETS AND REPRO",Control
5910    ON Control+1 GOTO 5930,Plotter_setup
5920    STOP
5930
5940    !
5950    END
5960    !***********************************************************************************
5970    SUB Lsqw2(A(*),Var,Nscan,Order,Bad,Ngood,I1,SHORT D(*),W(*),F(*))
5980    OPTION BASE 1
5990    DIM C(Order,Order),C1(Order,Order),B(Order)
6000    Ngood=0
6010    FOR I=1 TO Nscan
6020    D=D(I+I1-1,Var)

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6030 IF D=Bad THEN 6120
6040 Ngood=Ngood+1
6050 FOR J=1 TO Order
6060 Fw=F(J,I)+W(I)
6070 B(J)=B(J)+Fw*D
6080 FOR K=1 TO J
6090 C(J,K)=C(J,K)+Fw*F(K,I)
6100 NEXT K
6110 NEXT J
6120 NEXT I
6130 FOR J=1 TO Order
6140 FOR K=1 TO J
6150 C(K,J)=C(J,K)
6160 NEXT K
6170 NEXT J
6180 MAT Ci=INV(C)
6190 MAT A=Ci*B
6200 SUBEND
6210 END
Program CROSS, Sample Run

CROSS is a program that computes cross correlation, structure functions and coherences between pairs of profiles. The operator can select the number of profiles, number of variables in each profile, plotter to use, depth interval and depth interpolation interval.

The operator sets up the program in advance for many operations; the computer can then be left unattended. This program can be very time consuming, depending on the options selected.

The following is an example of computing structure functions of seven profiles for both east and north components.

PRINTER ? (0=THERMAL, 16=CRT) 0  
CROSSE SEPT 24 80  RUN DATE AND TIME = 81:04:08:23:41:27  
NUMBER OF VARIABLES ? 2  
NUMBER OF VARIABLES = 2  
NUMBER OF FILES ? 7  
NUMBER OF FILES = 7  
PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A) 0  
PLOTTERS=NONE  
PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=COHERANCE) 2  
PROCESSING OPTION=STRUCTURE  
FIRST, LAST DEPTH TO PROCESS ? 200,800  
FIRST, LAST DEPTH TO PROCESS =-200 -800  
NUMBER OF POINTS PER PIECE ? 50  
NUMBER OF POINTS PER PIECE = 50  
NUMBER OF PIECES? 2  
NUMBER OF PIECES= 2  
TOTAL NUMBER OF POINTS USED= 100  
DEPTH INCREMENT=-6.06060606061  
DEPTH PER PIECE=-296.96969697  
MAX DEPTH LAG ? 20  
MAX DEPTH LAG = 20  
MAXIMUM RMSERR ALLOWED FOR XTVP DATA? 3  
MAXIMUM RMSERR ALLOWED FOR XTVP DATA= 3  
TYPE FILE NAME FOR FILE No. 1 82P  
WHICH 2 VARIABLE No.s TO PROCESS?

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3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 1 FILENAME=82P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 2

83P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 2 FILENAME=83P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 3

84P
WHICH 2 VARIABLE No.s TO PROCESS?
U, V
WHICH 2 VARIABLE No.s TO PROCESS?
U, V
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 3 FILENAME=84P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 4

85P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 4 FILENAME=85P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 5

86P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 5 FILENAME=86P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 6

87P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No. = 6 FILENAME=87P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 7
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 7  FILENAME=88P  VARIABLES=U, V, VELERR.
NUMBER OF SETS OF COMBINATIONS ?
3
NUMBER OF SETS OF COMBINATIONS = 3
No. FILES IN SET No. 1 ?

3
WHICH 3 FILE No.s FOR SET No. 1 ?

1,2,3
SET= 1 HAS FILE No.s: 1 , 2 , 3 .
No. FILES IN SET No. 2 ?

4
WHICH 4 FILE No.s FOR SET No. 2 ?

3,4,5,6
SET= 2 HAS FILE No.s: 3 , 4 , 5 , 6 .
No. FILES IN SET No. 3 ?

3
WHICH 3 FILE No.s FOR SET No. 3 ?

1,2,7
SET= 3 HAS FILE No.s: 1 , 2 , 7 .

SET FILENO FILENAME VARIABLE
1 1 82P U
2 83P U
DEPTH RANGE AV1 AV2 ZLAG AVDIF RMSDIF RMSMIN OK1 OK2 RMS1 RMS2
(meters) (m) fraction
INTERPOLATING
PROCESSING STRUCTURE
-200 -497 -9.23 -9.77 -18 -.14 1.65 1.65 1.00 1.00 1.7 1.4
INTERPOLATING
PROCESSING STRUCTURE
-497 -794 -6.48 -5.22 6 .12 2.12 2.12 1.00 1.00 3.5 4.4
SET FILENO FILENAME VARIABLE
1 1 82P V
2 83P V
DEPTH RANGE AV1 AV2 ZLAG AVDIF RMSDIF RMSMIN OK1 OK2 RMS1 RMS2
(meters) (m) fraction
INTERPOLATING

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<table>
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<tr>
<td>-200 -497 -2.92 4.78 -18 .40 2.51 2.51 1.00 1.00 3.5 1.7</td>
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<tr>
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**Set File Number, File Name, Variable**

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**Depth Range, AV1, AV2, Zlag, AVDIF, RMSDIFF, RMSMIN, OK1, OK2, RMS1, RMS2**

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<th>AV1</th>
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<th>Zlag</th>
<th>AVDIF</th>
<th>RMSDIFF</th>
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<th>OK1</th>
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**Depth Range, AV1, AV2, Zlag, AVDIF, RMSDIFF, RMSMIN, OK1, OK2, RMS1, RMS2**

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<th>Zlag</th>
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<th>RMSDIFF</th>
<th>RMSMIN</th>
<th>OK1</th>
<th>OK2</th>
<th>RMS1</th>
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**Depth Range, AV1, AV2, Zlag, AVDIF, RMSDIFF, RMSMIN, OK1, OK2, RMS1, RMS2**

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**APL-UW 8110 A61**
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<td>3 84P V</td>
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**DEPTH RANGE**

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<th>OK1</th>
<th>OK2</th>
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<tr>
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<td>6.72</td>
<td>18</td>
<td>-.10</td>
<td>1.84</td>
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<td>-497 -794</td>
<td>.18</td>
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**INTERPOLATING PROCESSING STRUCTURE**

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**DEPTH RANGE**

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<tr>
<td>-200 -497</td>
<td>-9.77</td>
<td>-15.91</td>
<td>18</td>
<td>.45</td>
<td>2.49</td>
<td>2.49</td>
<td>1.00</td>
<td>1.00</td>
<td>1.4</td>
<td>2.9</td>
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<tr>
<td>-497 -794</td>
<td>-5.22</td>
<td>-4.92</td>
<td>18</td>
<td>.18</td>
<td>4.24</td>
<td>4.24</td>
<td>1.00</td>
<td>1.00</td>
<td>4.4</td>
<td>2.0</td>
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SET FILENO FILENAME VARIABLE
3 2 83P V
7 88P V

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<th>DEPTH RANGE</th>
<th>AV1</th>
<th>AV2</th>
<th>ZLAG</th>
<th>AVDIF</th>
<th>RMSDIF</th>
<th>RMSMIN</th>
<th>OK1</th>
<th>OK2</th>
<th>RMS1</th>
<th>RMS2</th>
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<td>(meters)</td>
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<tr>
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<td>.41</td>
<td>4.43</td>
<td>4.43</td>
<td>1.00</td>
<td>1.00</td>
<td>1.7</td>
<td>3.6</td>
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<tr>
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<td>.18</td>
<td>-9.48</td>
<td>-12</td>
<td>.00</td>
<td>3.44</td>
<td>3.44</td>
<td>1.00</td>
<td>1.00</td>
<td>2.1</td>
<td>3.8</td>
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A64 APL-UW 8110
Listing of Program CROSS

10 ! CROSS CORRELATION, STRUCTURE FUNCTION OR COHERANCE BETWEEN TWO PROFILES.
20 ! SPECIALLY MODIFIED TO ZAP U,V OF XTVP PROFILES WHEN RMSERR>MAXERR.
30 ! J. DUNLAP
40 ! SEPT 17 1980. CROSSD HAS COHERANCE ADDED.
50 ! SEPT 24 1980. CROSSSE HAS COHERANCE WORKING AFTER A FASHION.
60 !
70 Progrev$="CROSSE SEPT 24 80"
80 Year=80
90 !
100 NORMAL
110 STANDARD
120 OVERLAP
130 OPTION BASE 1
140 INPUT "PRINTER? (0=THERMAL, 16=CRT)",Printer
150 PRINT "PRINTER IS";Printer
160!
170 OUTPUT 9;"R"
180 ENTER 9;Runtime$
190 Runtime$=VAL$(Year)&"":"&Runtime$
200!
210 DIM Comment$[160],Param(100),Nvu$(9)
220!
230 DIM Comment1$[160],Param1(100),Nvu1$(9)
240 SHORT D1(500,9)
250!
260 DIM Param2(100),Nvu2$(9),Comment2$[160]
270 SHORT D2(500,9)
280!
290 DIM Y1(2000),Y2(2000),R12(100)
300!
310 PRINT Progrev$,"RUN DATE AND TIME = ";Runtime$
320!
330 IF "NUMBER OF VARIABLES?",Npair
340 PRINT "NUMBER OF VARIABLES = ";Npair
350!
360 INPUT "NUMBER OF FILES?",Nfile
370 PRINT "NUMBER OF FILES = ";Nfile
380!
390 DIM L1p(50,3),Lupp(3),File$(50),Luprms(50)
400 REDIM L1p(Nfile,Npair),Lupp(Npair),File$(Nfile),Luprms(Nfile)
410!
420 INPUT "PLOTTER? (0=NONE, 1=GRAPHICS, 2=9872A)",Plotter
430 IF Plotter=0 THEN Plotter$="NONE"
440 IF Plotter=1 THEN Plotter$="GRAPHICS"
450 IF Plotter=2 THEN Plotter$="9872A"
460 PRINT "PLOTTER IS";Plotter$
470!
480 INPUT "PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=COHERANCE)",Process
490 IF (Process<1) OR (Process>3) THEN 480
500 IF Process=1 THEN Process$="CROSSCOR"
510 IF Process=2 THEN Process$="STRUCTURE"
520 IF Process=3 THEN Process$="COHERANCE"
530 PRINT "PROCESSING OPTION IS";Process$
INPUT "FIRST, LAST DEPTH TO PROCESS?", Z1, Z2
Z1 = ABS(Z1)
Z2 = ABS(Z2)
PRINT "FIRST, LAST DEPTH TO PROCESS = "; Z1; Z2

INPUT "NUMBER OF POINTS PER PIECE?", Npp
Npp = ROUND(Npp, 0)
PRINT "NUMBER OF POINTS PER PIECE = "; Npp

INPUT "NUMBER OF PIECES?", Npie
Npie = ROUND(Npie, 0)
PRINT "NUMBER OF PIECES = "; Npie

Nuse = Npie * Npp
Dz = ABS((Z2 - Z1) / (Nuse - 1))
Zpp = ABS((Npp - 1) * Dz)
PRINT "TOTAL NUMBER OF POINTS USED = "; Nuse
PRINT "DEPTH INCREMENT = "; Dz
PRINT "DEPTH PER PIECE = "; Zpp

IF Process$ <> "CROSSCOR" AND Process$ <> "STRUCTURE" THEN
INPUT "MAX DEPTH LAG?", Zlagmax
PRINT "MAX DEPTH LAG = " ; Zlagmax
Nlagmax = ABS(Zlagmax + 1 * Dz) DIV Dz

IF Process$ <> "COHERANCE" THEN
INPUT "NO. FREQ. BANDS TO AVERAGE?", Nband
PRINT "NO. FREQ. BANDS TO AVERAGE = " ; Nband
Nfft = Npp
PRINT "NUMBER OF POINTS IN FFT = NUMBER OF POINTS PER PIECE = " ; Nfft
REDIM R12(-Nlagmax: Nlagmax), Y1(Npp), Y2(Npp)
INPUT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA?", Rmsmaxallowed
PRINT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA = " ; Rmsmaxallowed

*************** GET FILE NAMES AND VARIABLES FOR EACH FILE
FOR File = 1 TO Nfile
DISP "TYPE FILE NAME FOR FILE No.; File;"
EDIT " ", File$(File)
ASSIGN File$(File) TO #1, Ret
IF Ret = 0 THEN 1040
BEEP
DISP "CANNOT FIND THE FOLLOWING FILE. PLEASE EDIT OR TRY ANOTHER TAB DISC.";
GOTO 960
FOR File = 1 TO Nfile
DISP "TYPE FILE NAME FOR FILE No.; File;"
EDIT " ", File$(File)
ASSIGN File$(File) TO #1, Ret
IF Ret = 0 THEN 1040
BEEP
DISP "CANNOT FIND THE FOLLOWING FILE. PLEASE EDIT OR TRY ANOTHER TAB DISC.";
GOTO 960
READ #1, Nvar, Nscan, Bad, Nparam
READ #1, Nuu$(Nvar), Param(Nparam)
READ #1;Param(*),Nvu$(*)

PRINTER IS 16
PRINT "FILE";File$(File)
PRINT "VARIABLE No.","VARIABLE NAME"
FOR L=1 TO Nvar
 PRINT L,Nvu$(L)
NEXT L
PRINTER IS Printer

FOR Pair=1 TO Npair
 Lupp(Pair)=Lup(File,Pair)
NEXT Pair

DISP "WHICH";Npair;"VARIABLE No.s TO PROCESS?";
INPUT """,Lupp(*)

FOR Pair=1 TO Npair
 IF (Lupp(Pair)<1) OR (Lupp(Pair)>Nvar) THEN 1220
 Lupp(File,Pair)=Lupp(Pair)
NEXT Pair

INPUT "VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)";Luprms(File)
IF (Luprms(File)<0) OR (Luprms(File)>Nvar) THEN 1300

PRINT "FILE No.=";File;" FILENAME=";File$(File);" VARIABLES=";
FOR Pair=1 TO Npair
 PRINT Nvu$(Lup(File,Pair));", ";
NEXT Pair

IF Luprms(File) THEN PRINT Nvu$(Luprms(File));"
IF NOT Luprms(File) THEN PRINT "."
NEXT File

! DETERMINE THE SET BOUNDRIES
! IN ONE SET ALL THE COMBINATIONS WILL BE USED
!  
! INPUT "NUMBER OF SETS OF COMBINATIONS ?",Nset
PRINT "NUMBER OF SETS OF COMBINATIONS =";Nset

DIM Fileno(50,20),Nfile(20)
REDIM Fileno(Nfile,Nset),Nfile(Nset)

FOR Set=1 TO Nset
 DISP "No. FILES IN SET No.";Set;"?"
 INPUT ";",Nfile(Set)
 IF (Nfile(Set)<2) OR (Nfile(Set)>Nfile) THEN 1520
 DIM Filen(20)
 REDIM Filen(Nfile(Set))
 FOR F=1 TO Nfile(Set)
 Filen(F)=Fileno(F,Set)
 NEXT F
 DISP "WHICH";Nfile(Set);"FILE No.s FOR SET No.";Set;"?";
1640 INPUT "", Filen(*)
1650 ! CHECK FILE No.s
1660 FOR F=1 TO Nfile(Set)
1670 IF (Filen(F)<1) OR (Filen(F)>Nfile) THEN 1630
1680 Fileno(F,Set)=Filen(F)
1690 NEXT F
1700 !
1710 PRINT "SET=", Set; "HAS FILE No.s:"
1720 FOR F=1 TO Nfile(Set)-1
1730 PRINT Fileno(F,Set);",";
1740 NEXT F
1750 PRINT Fileno(Nfile(Set),Set);"."
1760 !
1770 NEXT Set
1780 !
1790 ! *************** READ DATA FROM ALL PAIRS OF FILES FROM EACH SET !
1800 !
1810 FOR Set=1 TO Nset
1820 FOR File1=1 TO Nfile(Set)-1
1830 ! INPUT FILE 1
1840 File1no=Fileno(File1,Set)
1850 File1#=File#(File1no)
1860 ASSIGN File1# TO #1, Ret
1870 IF Ret=0 THEN 1930
1880 DISP "CANNOT FIND FILE = "; File$(File1);", TRY ANOTHER DISC TAPE THEN PUSH CONT"
1890 !
1900 !
1910 DISP ""
1920 GOTO 1860
1930 READ #1,1
1940 READ #1; Drop1$, Datetime1$, Lat$, Long1$
1950 READ #1; Comment1$, Fromprogl$, Fromfile1$, Created1$
1960 READ #1; Nvar1, Nscan1, Bad1, Nparam1
1970 REDIM Nvul$(Nvar1>, Dl(Nscan1,Nvar1), Paraami(Nparam1)
1980 READ #1; Param1(*), Nvul$(*)
1990 !
2000 ! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
2010 ! JUST FOR VARIABLES USED
2020 !
2030 Luprms=Luprms(File1)
2040 IF Luprms=0 THEN 2130
2050 ! FOR I=1 TO Nscan1
2060 Rms=Dl(I,Luprms)
2070 IF Rms<Rmsmaxallowed THEN 2120
2080 ! FOR Var=1 TO Npair
2090 ! Lup=Lup(File1,Var)
2100 ! Dl(I,Lup)=Bad1
2110 ! NEXT Var
2120 ! NEXT I
2130 !
2140 FOR File2=File1+1 TO Nfile(Set)
2150 ! INPUT FILE 2
2160 File2no=Fileno(File2,Set)
2170 File2#=File#(File2no)
2180 ASSIGN File2# TO #2, Ret
IF Ret=0 THEN 2250
BEEP
DISP "CANNOT FIND FILE = ";File$(File2);". TRY ANOTHER TAPE/DISC THEN PUSH CONT"
PAUSE
DISP ""
GOTO 2180
READ #2,1
READ #2;Drop2$;DateTime2$;Lat2$;Long2$
READ #2;Comment2$;FromProg2$;FromFile2$;Created2$
READ #2;Nvar2;Nscan2;Bad2;Nparam2
REDIM Nvu2$(Nvar2);D2(Nscan2,Nvar2);Param2(Nparam2)
READ #2;Param2(*),Nvu2$(*),D2(*)
!
! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
JUST FOR VARIABLES USED
!
Luprms=Luprms(File2)
IF Luprms=0 THEN 2450
FOR I=1 TO Nscan2
    Rms=D2(I,Luprms)
    IF Rms<Rmsmaxallowed THEN 2440
    FOR Var=1 TO Npair
        Lup=Lup(File2,Var)
        D2(I,Lup)=Bad2
    NEXT Var
    NEXT I
IF Plotter$="NONE" THEN 2500
PLOTTER IS Plotter$
Xgdu=100*MAX(1,RATIO)
Ygdu=100*MAX(1,1/RATIO)
!
FOR Pair=1 TO Npair
    Lup1=Lup(File1,Pair)
    Lup2=Lup(File2,Pair)
    PRINT USING 2560;SetFile1no,File1$,Nvu1$(Lup1),File2no,File2$,Nvu2$(Lup2)
    IMAGE /,"SET FILENO FILENAME VARIABLE",/3D,X,3D,4X,18A,18R,/,4X,3D,4X,18A,18A
!
IF Process$="CROSSCOR" THEN 2620
PRINT "DEPTH RANGE AV1 AV2 R12MAX ZLAG AVDIFF RMSDIFF 0"
!
PRINT " (meters)"
GOTO 2660
!
IF Process$="STRUCTURE" THEN 2660
PRINT "DEPTH RANGE AV1 AV2 R12MAX ZLAG AVDIFF RMSDIFF RMSMIN 0"
!
PRINT " (meters)"
GOTO 2660
!
IF (Process$="STRUCTURE") AND (Process$="CROSSCOR") THEN 3770
FOR Pie=1 TO Npie
  Zp1=Z1+(Pie-1)*Zpp
  Zp2=Zp1+Zpp
  INTERPOLATE D1(*),D2(*) INTO Y1(*),Y2(*)
  DISP "INTERPOLATING"
  CALL Interp(D1(*),Nscan1,I,Lup1,Zp1,Dz,Npp,Bad1,Y1(*))
  CALL Interp(D2(*),Nscan2,I,Lup2,Zp1,Dz,Npp,Bad2,Y2(*))
  DISP ""
  S1=S1=0
  Ss1=Ss1=0
  Nok1=Nok2=0
  FOR I=1 TO Npp
    Y1=V1(I)
    Y2=Y2(I)
    IF Y1=Bad1 THEN 2880
    Nok1=Nok1+1
    S1=S1+Y1
    Ss1=Ss1+Y1^2
    IF Y2=Bad2 THEN 2920
    Nok2=Nok2+1
    S2=S2+Y2
    Ss2=Ss2+Y2^2
  NEXT I
  Av1=Av2=0
  Std1=Std2=0
  IF Nok1 THEN Av1=S1/Nok1
  IF Nok1 THEN Std1=SQR(Ss1/Nok1-Av1^2)
  IF Nok2 THEN Av2=S2/Nok2
  IF Nok2 THEN Std2=SQR(Ss2/Nok2-Av2^2)
  NEXT I
  DISP "PROCESSING ";Process$
  IF Process$="CROSSCOR" THEN CALL Crosscor(Y1(*),Y2(*),Npp,-Nlagmax,R12(*),S11,S22,Bad1,Bad2,Ok1,Ok2)
  IF Process$="STRUCTURE" THEN CALL Structure(Y1(*),Y2(*),Npp,-Nlagmax,R12(*),Bad1,Bad2,Ok1,Ok2)
  DISP ""
  IF Process$<>"CROSSCOR" THEN 3210
  CROSS CORRELATION: FIND LAG WITH MAX CORRELATION
  R12max=-1
  FOR Lag=-Nlagmax TO Nlagmax
    IF R12max>R12(Lag) THEN 3170
    R12max=R12(Lag)
    Mlag=Lag
  NEXT Lag
  IF Process$<>"STRUCTURE" THEN 3320
  STRUCTURE FUNCTION: FIND LAG WITH RMS MINIMUM
  Z1ag=0
  IF R12max<>0 THEN Z1ag=Mlag*Dz
  NEXT I
  IF Process$<>"STRUCTURE" THEN 3320
  STRUCTURE FUNCTION: FIND LAG WITH RMS MINIMUM
Rmsmin = R12(0)
Mlag = 0
FOR Lag = -Nlagmax TO Nlagmax
   IF Rmsmin < R12(Lag) THEN 3290
      Rmsmin = R12(Lag)
      Mlag = Lag
   NEXT Lag
Zlag = 0
IF Rmsmin > 0 THEN Zlag = Mlag + Dz
Nd = Sd = Sdd = 0
GET AVG AND RMS OF DIFFERENCE AT MLAG
FOR I = MAX(1, 1 - Mlag) TO MIN(Npp, Npp - Mlag)
   Y1(I) = Y1(I)
   Y2(I + Mlag) = Y2(I + Mlag)
   IF (Y1 = Bad1) OR (Y2 = Bad2) THEN 3420
   Dif = Y1 - Y2
   Nd = Nd + 1
   Sd = Sd + Dif
   Sdd = Sdd + Dif
   Sd = Sd + Dif
   NEXT I
Avdif = Rnsdif = 0
IF Nd = 0 THEN
   Avdif = Sd / Nd
   Rnsdif = SQR(Sdd / Nd - Avdif ^ 2)
   IF Process$ = "CROSSCOR" THEN 3530
   PRINT FOR CROSS CORRELATION
   PRINT USING 3520; Zp1, Zp2, Av1, Av2, R12max, Zlag, Avdif, Rmsdif, 0k1, 0k2, Std1, Std2
   IMAGE 2(5D), 2(5D.DD), 4D, 3D, 5D, 2(5D.DD), 2(2D.2D), 2(5D.D)
   IF Process$ = "STRUCTURE" THEN 3580
   PRINT FOR STRUCTURE FUNCTION
   PRINT USING 3560; Zp1, Zp2, Av1, Av2, Zlag, Avdif, Rmsdif, Rmsmin, 0k1, 0k2, Std1, Std2
   PRINT USING 3570; Zp1, Zp2, Av1, Av2, Zlag, Avdif, Rmsdif, Rmsmin, 0k1, 0k2
   IMAGE 2(5D), 2(5D.DD), 5D, 3(5D.DD), 2(2D.2D), 2(5D.D)
   IF Plotter$ = "NONE" THEN 3760
   IF Plotter$ = "GRAPHICS" THEN GRAPHICS
   FOR Lag = -Nlagmax TO Nlagmax
      PLOT Lag, R12(Lag), P
   NEXT Lag
   IF Plotter$ = "9872A" THEN PENV
   NEXT P
   NEXT N
IF Process$<>"COHERANCE" THEN 3880
Nppp=Npp*Npp
REDIM Y1(Nppp),Y2(Nppp)
DISP "INTERPOLATING"
Lup1=Lup(File1,Pair)
Lup2=Lup(File2,Pair)
CALL Interp(D1(*),Nscan1,1,Lup1,1,Dz,Nppp,Bad1,Y1(*))
CALL Interp(D2(*),Nscan2,1,Lup2,1,Dz,Nppp,Bad2,Y2(*))
!
CALL Coher(Y1(*),Y2(*),Nppp,Nfft,Nband,Idif,Dz,Nu1$(Lup1),Nu2$(Lup2))
!
NEXT Pair
!
IF Plotter$="GRAPHICS" THEN 4050
GRAPHICS
PRINT PAGE
PRINT "PROGRAM=";Progrev$;"RUN DATE&TIME";RunTime$
PRINT "PROCESS=";Process$
IF Printer<0 THEN 4000
DUMP GRAPHICS
PRINT PAGE
!
EXIT GRAPHICS
GCLEAR
!
IF Plotter$="9872A" THEN 4060
9872A
PEN 0
!
NEXT File2
NEXT File1
NEXT Set
!
DISP "FINISHED"
STOP
!
**************************************************************************************************
SUB Junk
SUBEND
!* **************************************************************************************************
SUB Crosscor(X(*),Y(*),N,L1,L2,Rxy(*),Sxx,Syy,Badx,Bady,Okx,Oky)
Sxx=Syy=Okx=Oky=0
FOR I=1 TO N
X=X(I)
IF X=Badx THEN 4250
Nokx=Nokx+1
Sxx=Sxx+X^2
Y=Y(I)
IF Y=Bady THEN 4290
Noky=Noky+1
Syy=Syy+Y^2
NEXT I
Okx=Nokx/N
Oky=Noky/N
!
MAT Rxy=ZER

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4340 IF (Sxx=0) OR (Syy=0) THEN SUBEXIT
4350 !
4360 FOR L=L1 TO L2
4370  Sxy=0
4380  FOR I=MAX(1,1-L) TO MIN(N,N-L)
4390    J=I+L
4400    X=X(I)
4410    IF X=Badx THEN 4460
4420    Y=Y(J)
4430    IF Y=Bady THEN 4460
4440    Sxy=Sxy+X*Y
4450    Nokxy=Nokxy+1
4460    NEXT I
4470    RxY(L)=Sxy/SQR(Sxx*Syy)
4480    NEXT L
4490 SUBEND
4500 ! *************************************************************************
4510 SUB Junk
4520 SUBEND
4530 ! *************************************************************************
4540 SUB Structure(X(*), Y(*), N, L1, L2, Rmslag(*), Badx, Bady, Okx, Oky)
4550 Nokx=Nokx+0
4560 FOR I=1 TO N
4570  IF X(I)<Badx THEN Nokx=Nokx+1
4580  IF Y(I)<Bady THEN Noky=Noky+1
4590 NEXT I
4600 Okx=Nokx/N
4610 Oky=Noky/N
4620 !
4630 FOR Lag=L1 TO L2
4640  Nc=Nd=Sdd=0
4650  FOR I=MAX(1,1-Lag) TO MIN(N,N-Lag)
4660    X=X(I)
4670    Y=Y(I+Lag)
4680    IF (X=Badx) OR (Y=Bady) THEN 4730
4690    Nd=Nd+1
4700    Dif=X-Y
4710    Sd=Sd+Dif
4720    Sdd=Sdd+Dif^2
4730    NEXT I
4740    Av=Rms=0
4750    IF Nd=0 THEN 4780
4760    Av=Sd/Nd
4770    Rms=SQR(Sdd/Nd-Av^2)
4780    Rmslag(Lag)=Rms
4790 NEXT Lag
4800 SUBEND
4810 END
4820 ! *************************************************************************
4830 SUB Interp(SHOPT Din(*), REAL Min, Zvar, Dvar, Z1, Dz, Nout, Bad, Dout(*))
4840 ! JUL 8,80 JHD. MODIFIED TO WORK WITH 2 DIM ARRAY INPUT, 1 DIM OUT
4850 OPTION BASE 1
4860 Dp=ABS(Dz)
4870 P1=ABS(Z1)
4880 MAT Dout=(Bad)
4890 J=2
4900 FOR Iout=1 TO Nout

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Pout=Pl+(lout-i)*Dp
FOR S=J TO Nin
  FIND PIN(J)
  JUST GREATER THAN POUT
Pj=ABS(Din(J,2var))
Dj=Din(J,Dvar)
IF (Pj>Pout) AND (Dj<>Bad) THEN 4980
NEXT J
SUBEXIT
IF Pj<Pout THEN 5010 ! SPECIAL SPEED-UP IF PJ=POUT
Dout(Iout)=Dj
GOTO 5070
SUBEND
! **************
SUB Coher(X(*),Y(*),Nin,Nfft,Nband,Idif,Delz,Labx$,Laby$)
OPTION BASE 1
SHORT Xx,Nfft,Nfft,Yy,Nfft
Deg=180/PI
Rad=1/Deg
Delz=ABS(Delz)
Npie=Nin DIV Nfft
Nh=Nfft/2
Do=Nd>Nfft*2
IF Do>1 THEN 5240
GOTO 5260
T95=1.96+2.38/Do+2.64/Do*2+2.56/Do*3
C95=SQR(1-(1-.95)*(1/(Do-1)))
PRINT "COHERANCE BETWEEN ";Labx$;" AND ";Laby$
PRINT "NPIE=",Npie,"C95=",C95,"DOF=",Do
PRINT "I EST 2 WNO WLEN AXX AYY CXY QXY RXY PXD"
IMAGE 2(3D),5D.D,4D.2D,4<X MD.2DE),2D.2D,2<5D)
IF Idif=0 THEN S7
FOR I=1 TO Nin-1
  X(I)=X(I+1)-X(I)
  Y(I)=Y(I+1)-Y(I)
NEXT I
X(Nin)=X(Nin-1)
Y(Nin)=Y(Nin-1)
S7: ! FFT
FOR L=1 TO Npie
  L0=(L-1)*Nfft
  FOR I=1 TO Nfft
    Xx(I)=X(L0+I)
    Yy(I)=Y(L0+I)
  NEXT I
NEXT L

CALL Fork(Xx(*),Yy(*),Nfft,1)

Sc=SQR(2)/Nfft
FOR I=1 TO Nfft
X(L0+I)=Xx(I)*Sc
Y(L0+I)=Yy(I)*Sc
NEXT I
NEXT L

FOR V=0 TO 4
Kk=0
FOR K=1 TO Nh-1 STEP Nband
Ax=Ayy=Cxy=Qxy=Nav=0
FOR L=1 TO Npie
I=I+1
J=J+1
Xc=X(I)+X(J)
Xs=Y(I)-Y(J)
Yc=Y(I)+Y(J)
Ys=Y(J)-X(I)
Cxy=Cxy+.5*(Xc*Yc+Xs*Ys)
Qxy=Qxy+.5*(Yc*Xs-Xc*Ys)
Axx=Axx+.5*(Xc^2+Xs^2)
Ayy=Ayy+.5*(Yc^2+Ys^2)
Nav=Nav+1
NEXT M
NEXT L

IF Idif<>1 THEN S22
Recolor=4*SIN(PI+(K+.5*(Nband-1))/Nfft)*2
Cxy=Cxy/Recolor
Qxy=Qxy/Recolor
Axx=Axx/Recolor
Ayy=Ayy/Recolor

S22: Kk=Kk+1
Axx=Axx/Nav
Ayy=Ayy/Nav
Cxy=Cxy/Nav
Qxy=Qxy/Nav
Rx=SQR((Cxy^2+Qxy^2)/(Axx*Ayy))
Pxy=FRtan(Qxy,Cxy)*Deg

Est1=(Kk-1)*Nba: i+1
Est2=Kk*Nband
Est=(Est1+Est2)/2
Dph=T95*SQR(1/Rxy^2-1)/Dof
IF Dph<>1 THEN Dph=90
IF Dph<1 THEN Dph=ASIN(Dph)*Deg
Wno=Est/Nfft/Delz*1E3
Wlen=1E3/Wno

IF V>0 THEN 6190
6040 PRINT USING 5310;Est1,Est2,Wno,Wlen,Axx,Ayy,Cxy,Qxy,Rxy,Pxy,Dph
6050 !
6060 IF Kk>1 THEN 6110
6070 Axxmax=Axxmin=Axx
6080 Ayymax=Ayymin=Ayy
6090 Wnmax=Wnomin=Wno
6100 !
6110 Axxmax=MAX(Axxmax,Axx)
6120 Ayymax=MAX(Ayymax,Ayy)
6130 Axxmin=MIN(Axxmin,Axx)
6140 Ayymin=MIN(Ayymin,Ayy)
6150 Wnmax=MAX(Wnmax,Wno)
6160 Wnomin=MIN(Wnomin,Wno)
6170 !
6180 GOTO 6860
6190 !
6200 ON V GOTO Autoxx,Autoyy,Coher,Phase
6210 !
6220 Autoxx: !
6230 A=Axx
6240 IF Kk>1 THEN 6300
6250 PLOTTER IS "GRAPHICS"
6260 GRAPHICS
6270 LOCATE 0,50,50,100
6280 Lgtamin=LGT(Axxmin)
6290 Lgtamax=LGT(Axxmax)
6300 GOTO 6380
6310 !
6320 Autoyy: !
6330 A=Ayy
6340 IF Kk>1 THEN 6380
6350 LOCATE 0,50,0,50
6360 Lgtamin=LGT(Ayymin)
6370 Lgtamax=LGT(Ayymax)
6380 !
6390 IF Kk>1 THEN 6550
6400 Lgtwmin=LGT(Wnomin)
6410 Lgtwmax=LGT(Wnmax)
6420 ilgtwmin=INT(Lgtwmin)
6430 ilgtwmax=INT(Lgtwmax+.999)
6440 !
6450 ilgtamin=INT(Lgtamin)
6460 ilgtamax=INT(Lgtamax+.999)
6470 !
6480 SCALE ilgtwmin,ilgtwmax,ilgtamin,ilgtamax
6490 LINE TYPE 3,1
6500 GRID 1,1
6510 LINE TYPE 1
6520 FRAME
6530 MOVE LGT(Wno),LGT(A)
6540 GOTO 6860
6550 !
6560 DRAW LGT(Wno),LGT(A)
6570 GOTO 6860
6580 !
6590 Coher: !
6600 !

A76 APL-UW 8110
6610   IF Kk>1 THEN 6690
6620   LOCATE 50,100,0,50
6630   SCALE Ilgtumin,Ilgtumax,0,1
6640   LINE TYPE 3,1
6650   GRID 1,-2
6660   LINE TYPE 1
6670   FRAME
6680   MOVE LGT(Wno),Rxy
6690   DRAW LGT(Wno),Rxy
6700   GOTO 6860
6710
6720  Phase: !
6730 !
6740   IF Kk>1 THEN 6830
6750   LOCATE 50,100,50,100
6760   SCALE Ilgtumin,Ilgtumax,-100,100
6770   LINE TYPE 3,1
6780   GRID 1,90
6790   LINE TYPE 1
6800   FRAME
6810   MOVE LGT(Wno),Pxy
6820   DRAW LGT(Wno),Pxy
6830 !
6840   DRAW LGT(Wno),Pxy
6850 !
6860   NEXT K
6870   NEXT V
6880 !
6890   DUMP GRAPHICS
6900   PRINT PAGE
6910   EXIT GRAPHICS
6920   SUBEND
6930 !
6940 ! ************************************************************
6950 !
6960   SUB Fork(SHORT X(*),Y(*),REAL Lx,Signi) MODIFIED FROM DENHAM'S PASY FFT
6970   J=1
6980   FOR I=1 TO Lx ! SORT IN TIME DOMAIN
6990   IF I>J THEN S10
7000   Rtemp=X(J)
7010   Itemp=Y(J)
7020   X(J)=X(I)
7030   Y(J)=Y(I)
7040   X(I)=Rtemp
7050   Y(I)=Itemp
7060 S10: M=Lx/2
7070 S20: IF J=M THEN S30
7080   J=J-M
7090   M=M/2
7100   IF M>=1 THEN S20
7110 S30: J=J+M
7120   NEXT I
7130   L=1
7140 S40: Istep=2*L ! FOLD IN FREQ DOMAIN
7150   FOR M=1 TO L
7160   Iarg=PI*Signi*(M-1)/L
7170   Rw=COS(Iarg)
7180  Iw=SIN(Iarg)
7190  FOR I=M TO Lx STEP Istep
7200   Ipl=I+L
7210   Rtemp=Rw*X(Ipl)-Iw*Y(Ipl)
7220   Itemp=Rw*Y(Ipl)+Iw*X(Ipl)
7230   X(Ipl)=X(I)-Rtemp
7240   Y(Ipl)=Y(I)-Itemp
7250   X(I)=X(I)+Rtemp
7260   Y(I)=Y(I)+Itemp
7270   NEXT I
7280   NEXT M
7290   L=Istep
7300   IF L<Lx THEN S40
7310   SUBEND
7320 ! ************************************************************
7330 DEF FNAtan(Y,X)
7340  IF X=0 THEN Vert
7350  Ang=ATN(Y/X)
7360  IF X>0 THEN RETURN Ang
7370  IF Y<0 THEN Q3
7380  Ang=Ang+PI
7390  RETURN Ang
7400  Q3: Ang=Ang-PI
7410  RETURN Ang
7420  Vert: IF Y<0 THEN Down
7430  Ang=PI/2
7440  RETURN Ang
7450  Down: Ang=-PI/2
7460  FNEND
7470 ! **************************************************************
7480  END
APPENDIX B
Flotation and Fuse Assembly
I. Materials

A. Knife
B. Velux 10 lb nylon monofilament fishing leader
C. Rubber bands, about 3\" x 1/4\"
D. Orange wax safety fuse
E. Flotation collars (Fig. B1)
F. Pull-wire igniters and instructions

II. Assembly

A. Loop two rubber bands together (Fig. B2).
B. Thread an 8\" piece of leader material through both rubber bands, and tie end with surgeon's knot (Fig. B2).

Figure B1. XTVP expendable float, side view cross section.
C. Slip rubberband/line assembly over the foam float as shown in Fig. B3.

D. Prepare fuse by measuring amount needed for desired delay time (orange wax safety fuse burns at 120 sec/yard) plus 5", and cut ends square. Scrape ignitor end to expose powder for reliable ignition.

E. At the measured point, make a single straight cut in the safety fuse to 1/2 diameter so that knife cut extends into channel filled with fuse burning material, as shown in Fig. B3.

F. Use a pencil to punch hole into Ethafoam float in longitudinal line with fishline as shown in Fig. B3.

Figure B3. Foam float with rubber band assembly; fuse cut to half the diameter and attached with cut under nylon leader.
G. Insert fuse into float
   1. with end of fuse in hole of float
   2. with fishline inserted into cut in fuse so that when fuse
      burns down it will melt the nylon and release the float
      halves.

H. Install assembly in launcher and secure in place.

I. When ready to deploy, pull wire fuse igniter according to
   instructions on igniter box, being careful that igniter is pushed
   well down onto the fuse and that it is not pulled off when the
   wire is pulled.

J. The operator should test the method several times to ensure good
   technique. (Use XBT's to economize.)