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Current Measurement by a Telemetering System in the Helsinki Sea Area

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The Water Conservation Laboratory of the Helsinki City Engineer´s Office needs information about water currents in the Gulf of Finland and especially those near the shores of Helsinki because of the city´s waste water problems. The laboratory is provided with a current metering system constructed for local conditions i.e. a long winter, shallow sea water and low current velocities. Until the summer of 1969 the use of the system was experimental. Since that time, however, detailed information about water currents, especially in the bays of Helsinki, has been logged.

Telemetering

The central or logger station for the measuring system is at the Water Conservation Laboratory in Rajasaari. Seven measuring stations are located at distances of 2 to 12 kilometres from the recording station. Radio VHF freqvencies provide communication between the recording and measuring stations. At each measuring station there are ten information channels for various meters. If necessary, the number of channels may be increased to twenty. By a selector switch in the central station all stations may be operated at intervals of 120, 60, 30, 20, 10, 8 and 4 minutes. In the central station all information from the measuring stations is stored on a punch tape. Later on, the information is processed in a computer.

Each measuring station consists of an 8 metres high aerial mast, a wooden shed, 1.2 x 0.7 x 0.6 metres where the telemetering equipment is housed, the meters and cables. At all seven stations there are current meters and at most stations water level and temperature meters. The length of cable connecting a current meter with the other equipment is usually from 100 to 500 metres although at one station it is 1500 metres.

Figure 1 depicts the system´s radio connections with lines and the locations of current meters with small circles. Figure 2 is a schematic depiction of a telemetering station and of the system´s logger station.

Current meter

The current meter used is constructed in the Water Conservation Laboratory. When constructing it two aims were foremost in mind, the need for continous measurement for long periods and for a measurement range including very low velocities.

The principle of oporation is roughly to measure the equilibrium position of a neutrally buoyant rod connected to a buoyant sensor on which the water current acts. The information about the position of the sensor rod is then transferred by cable as an electrical signal to the logger station.

Figure 3 represents a current meter in operation. The current sensor is joined by a thin line to the neutrally buoyant rod. The sensor rod is connected to two potentiometers which convert the mechanical information of the position of the sensor rod to electrical signals. If we assume that the water current is merely horizontal the tilting angle of the sensor rod determines the current velocity and the horizontal projection of the tilting direction indicates the current direction.

The current sensor is shaped like a kite. The tilting of the sensor rod is determined by the resultant of the horizontal and vertical forces on the sensor. Because of the buoyancy of the sensor there is a principal force acting vertically on the sensor. The horizontal current of cource causes a horizontal force on the sensor, and in addition a vertical force due to the kite-like shape of the sensor. At small current velocities (0 to 3 cm/s, smaller sensor) the calibration curve is gently sloping. At medium velocities (5 to 25 cm/s) the curve is steep and at high velocities (30 to 60 cm/s) the curve is gently sloping again. Even above the measuring range (e.g. at 1 m/s, smaller sensor) the tilting angle of the sensor line and rod remains at about 45 degrees because of the shape of the sensor.

The buoyancy of a sensor ought to be always constant, 130 ponds. Because of changes in water salinity and temperature there are changes in the sensor buoyancy. Table 1 indicates quantitatively differences of buoyancy of a sensor from that in +4^{o}C temperature and 0 %o salinity.

Table 1. Difference of buoyancy of current sensor in ponds from that in +4^{o}C temperature and 0 %o salinity.

	0^{o}C	4^{o}C	10^{o}C	20^{o}C	
0 %o	-0.5	-	-1.3	-7.3	bigger sensor
0 %o	-1.0	-	-0.2	-1.1	smaller sensor
5 %o	16.3	16.5	14.8	8.5	bigger sensor
5 %o	2.4	2.4	2.2	1.2	smaller sensor
10 %o	32.8	32.8	30.8	24.0	bigger sensor
10 %o	4.8	4.8	4.5	3.5	smaller sensor

The probable salinity at the outermost measuring station is 6.0 to 6.5 %o and at the stations in the bays of Helsinki 3 to 5 %o. For half the year the temperature stays between +4.0 and -0.5^{o}C. In summer changes between +4 and +20^{o}C are to be expected.

Another significant error source is the fouling of the current sensor. To prohibit it the sensors are coated with an antifouling paint and changed 1 to 3 times a year. The most common or troublesome animals to distort sensors are *Balanus improvisus* and *Ephydatia fluviatilis*.

Sensors of two different sizes have been used. Each one has a buoyancy of 130 ponds. The bigger one is more sensitive to small current velocities and to density change and fouling distortion as well. Table 2 indicates the calibration relations for both sensors used in calculations when processing current velocities from measuring signals.

Table 2. Relation between current velocity and the filting angle of sensor rod.

Bigger sensor		Smaller sensor	
angle degrees	velocity cm/s	angle degrees	velocity cm/s
0	0	0	0
0.3	0.8	0.3	1.0
1.2	1.7	1.2	3.0
2.1	2.7	3.7	6.0
4.8	4.1	9.0	10.0
9.6	6.1	22.0	18.0
26.0	12.3	30.7	25.0
34.0	18.0	35.8	31.0
39.0	26.0	39.3	40.0
42.0	36.0	43.5	60.0

Because of the lack of a test channel where the velocity, temperature and salinity of water could be altered and the complexity of a theorefical analysis the accuracy of this meansuring method has remained unanalyzed. According to my own rough and unreliable evaluation an accuracy of $\pm$ 1 cm/s (bigger sensor) or $\pm$ 2 cm/s (Smaller sensor) $\pm$ 5 % of the actual velocity can be achieved when the tilting angle of the sensor rod is less than 35 degrees. At tilting angles near 45 degrees the meter only provides the magnitude of the velocity.

Current investigations

Information on currents has been logged simultaneously from several stations at intervals of 10 minutes. Means, standard deviations, distributions, correlation matrices and spectral functions have been calculated from the material.

In the current direction and velocity distribution patterns for each measuring station the geomorphology of the area is apparent, most of all in the narrow sounds in the bay area (compare fig:s 2 and 4).

The mutual correlations of currents in the sounds of the bay area are high (0.8 to 0.9) on the basis of means for both hour and day. The correlations between currents and wind are very irregular and seldom above 0.8. On the basis of some of the material, correlations between daily means of current and daily sea level changes have been computed. These correlations are found to be rather high (0.7 to 0.8) for stations in the bay area and not higher than 0.4 at the other stations.

To analyze the periodicity of currents, the power spectrum of the autocorrelation function was calculated from some parts of the material. In order to obtain information on periods lasting at least three hours observation periods covering one and a half hours were combined. All the power spectra drawn on the basis of these one and a half hour averages show tidal motions of 12 and 24 hours with very clear peaks. There are also other clear periods, but none of these appear in all spectra.

Without combining observations power spectra were calculated to analyze oscillation periods from 20 minutes to 3 hours. Periods longer than 30 minutes and appearing simultaneously at the stations in the bay area are usually also found at the most southwestern station. This indicates that oscillations in the bay area might be common to the whole Helsinki maritime area. The non-exponential shape of the power spectra may indicate that energy is introduced into the water movements with these 30 minute to 3 hour oscillations.

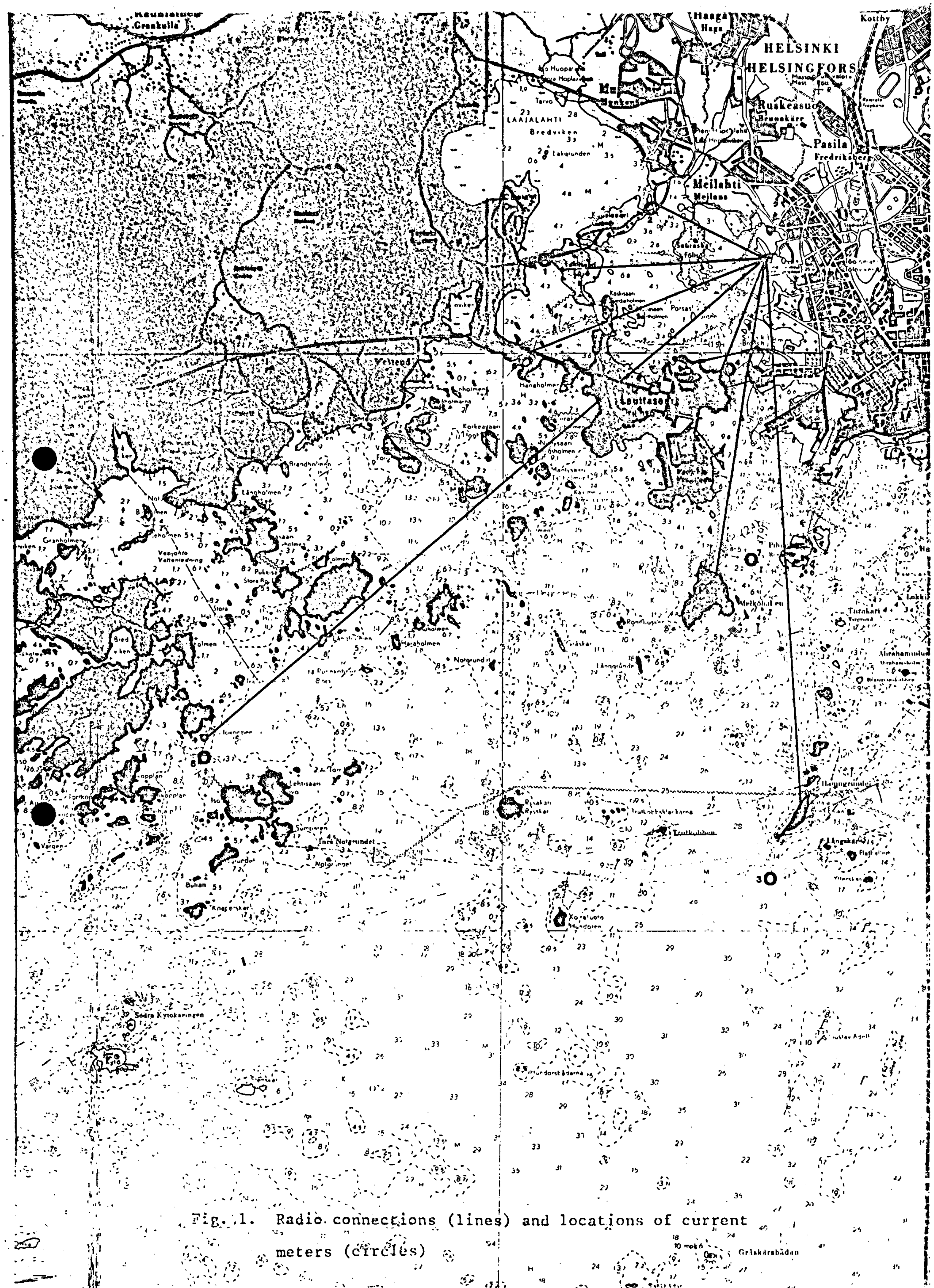

Fig. 1. Radio connections (lines) and locations of current meters (circles)

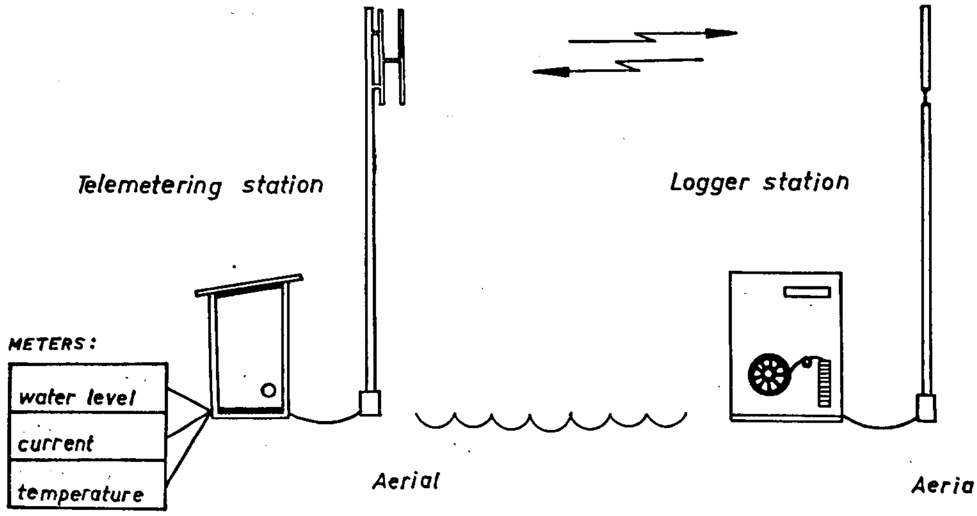

Fig. 2. Telemetering station and logger station schematically

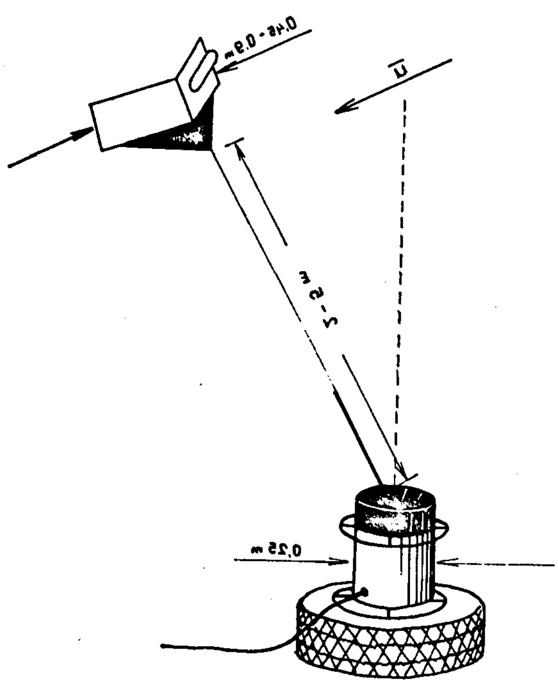

Fig. 3. Current meter

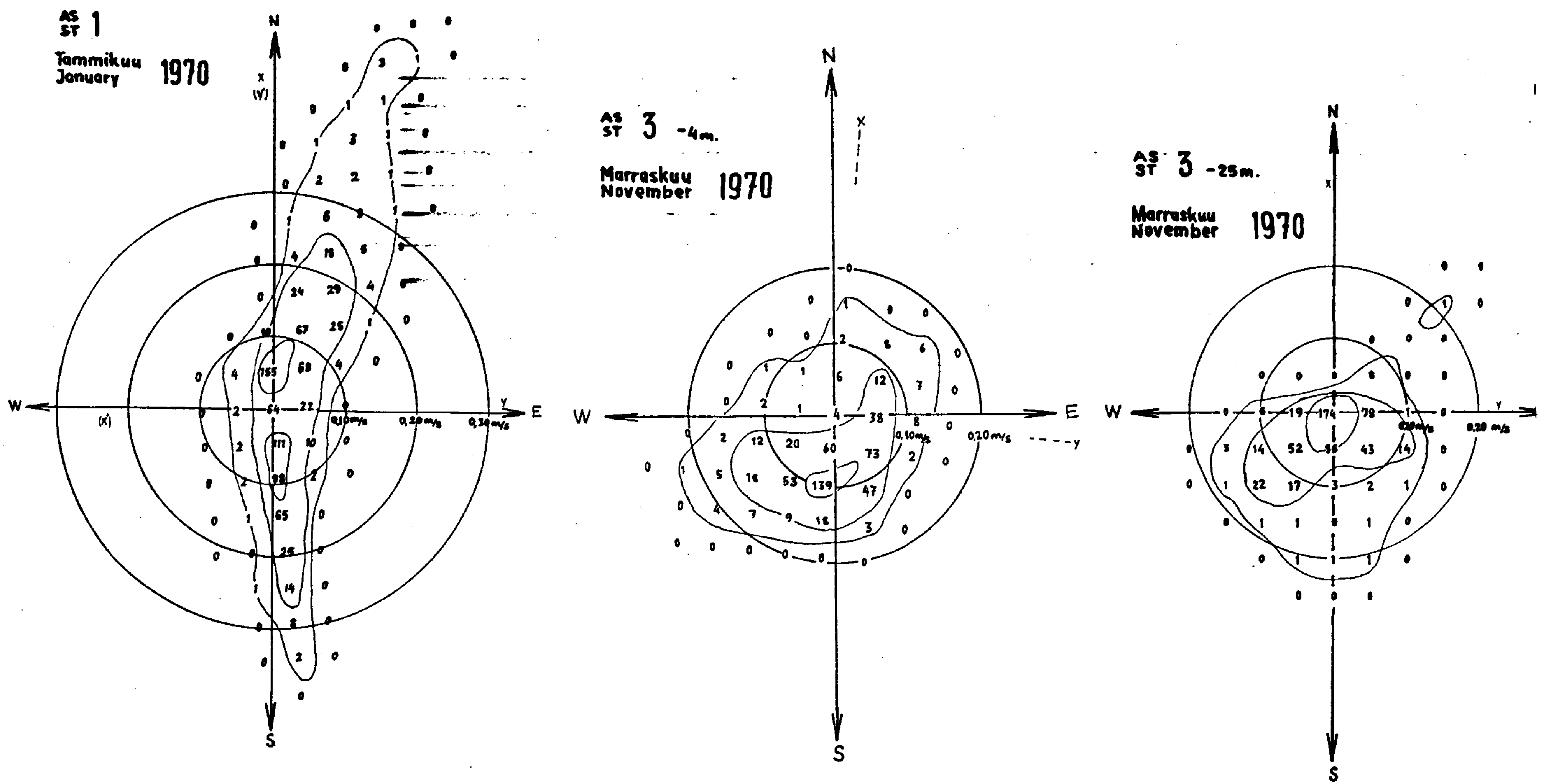

Fig. 4. Distribution of current velocities and directions at stations 1and 3.