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Overflow '73 - Observations in a Small-Scale Overflow Event on the Iceland-Faroe Ridge

by

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Summary:

Some features of a small scale overflow 'event' observed during the international ICES expedition Overflow '73 on board R.V. 'Meteor' in the region shaded in fig. 1 are discussed. The overflow water with temperature $T \leqslant 2^{\circ}C$, and salinity $S \leqslant 35$ ‰ is well separated from the surrounding Atlantic water ($T \geqslant 5^{\circ}C$, $S \geqslant 35{,}05$ ‰) by sharp horizontal and vertical gradients in T and S as well as vertical velocity gradients. The current measurements indicate back flow (northwards) in the sill region and outflow (south- and westwards) on the south-west slope. RICHARDSON-numbers of 13 stations, calculated for the vertical temperature gradient layer are of order one.

1. The Data

The temperature section carried out along part of the crest of the Iceland-Faroe-Ridge (fig. 1) from 18th to 2oth August during the international ICES-expedition overflow '73, showed low temperatures ($T < 2^{\circ}C$) only in a cross channel within the region shaded in fig. 1. This cold water mass was an already mixed type of overflow water from the Norwegian Sea. In order to investigate its southward extension profiles were taken of temperature T, salinity S, light attenuation A as well as current speed v and direction φ using XBT's, the MULTIMEERESSONDE (MMS) described by KROEBEL (1973) and a profiling current meter (PCM), which was simply a m.dified (DÜING and JOHNSON, 1972) Aanderaa current meter switched to continnous recording (1 cycle per 32 sec). The two methods used to get profiles with the PCM are sketched in fig. 2:

In method A the groundweight is hold 3 m above the bottom and the PCM is then sinking freely from a stopper 1oo m above towards the bottom. A drift correction to the velocity data is necessary to get absolute values. But due to the unaccuracies in position finding this method will not give as good data as in method B: Here a short time mooring (for about 15 minutes) is established by attaching floats to the wire, lowering the groundweight onto the bottom and then paying out more wire from the drifting ship while the PCM is sinking as in method A.

Working from northeast to southwest and west, 'METEOR' took profiles at the stations shown in fig. 3. An example of such profiles with it's sharp vertical gradients between Atlantic and nearly vertical homogeneous overflow water is given in fig. 4. Note that all profiles show the 2°C level within this sharp gradients layer, so that the thickness of the homogeneous overflow layer, in this paper, maybe identified with the distance of the 2°C level from bottom, approximately. From the data of the profiles charts of currents in the bottom layer (fig. 5), of near bottom temperature and salinity (fig. 6a, b), and of bottom distances of special levels of T and S (fig. 7a, b, c) have been derived. They will be discussed in the following parts.

2. Currents

Fig. 5 shows the drift corrected and vertically averaged currents within the overflow layer ($T \leq 2°C$) measured with the PCM. The flow field looks rather irregular and one would expect tidal effects (STEELE, 1967) to be responsible for this. But at least in the western part (St. 118 - 158) tides seem to be not dominant, since the flow field here is regular although the stations are distributed uniformly in a time interval of 2.2 semi-diurnal tidal periods. In the sill region, too, tidal influence is at least not obvious. Thus the following rough model maybe explains the measured flow field: Consider several consecutive internal perturbations propagating from the Norwegian sea southwards to the ridge, piling up to the sill depth of the cross channel and thus resulting in a cold water spill-over. While the disturbance on the side of the Norwegian Sea decreases (backflow) till the next one has arrived, the overflow water on the southwest side becomes independent of the initial perturbation. Because of it's high density this water mass is driven by the slope-parallel component of gravity under the influence of CORIOLIS-force and friction westwards with a component downslope. In this model oscillations are expected only in the sill region, although the flow is initiated by oscillations in the Norwegian Sea. In a similar way overflow has been generated and observed qualitatively by one of the authors [1].

3. Hydrography and mixing

The bottom charts of T and S (fig. 6a, b) clearly show a tongue-like band of very cold ($T \leq 0.5^{o}C$) and low salinity ($S \leq 34.95$ ‰) water southwest of stations 96 - 99 a (fig. 3), henceforth called 'source'. It follows the isobaths westwards within the main branch of the cross channel that maybe defined by the 45o m depth contour. Separated from this larger band by an elevation of the bottom (closed 46o m depth contour in the center of the picture) a second smaller tongue with as low salinity ($S \leq 34,95$ ‰) but a little bit warmer ($T \leq 1^{o}C$) water occurs. The same features are obvious in the bottom distance chart of the $1^{o}C$-level (fig. 7a), whereas the second small tongue cannot be seen in the corresponding charts of the 34,95 ‰ (fig. 7 b) and 2^{o} C level (fig. 7 c). In case of the 34,95 ‰-level, it's distance from bottom is too low, because the water depth is only 465 m and, in the $2^{o}C$ - level, both tongues are no longer distinguishable.

The bottom distances of all these levels, i.e. including the thickness of the overflow layer, decrease with increasing distance from the 'source', while both, bottom temperature and salinity are increasing. At the same time the width of the tongue remains constant. Thus turbulent flux of heat and salt seems to take place from the Atlantic water into the overflow layer and vice versa, in order to increase temperature and salinity in the overflow layer and to decrease it's thickness. If so, one should expect increasing potential energy along

1) T.J. Müller, unpublished notes

the axis of the tongue. Looking at the corresponding σ_t -section (position see fig. 3) this effect is not found; but due to the large surrounding water mass it may simply be lost.

Because of the lack of stratification in the (vertical) homogeneous overflow layer, shear instability will cause fully turbulent flow, whereas in the 'gradient layer' between overflow and Atlantic water turbulence is damped by stratification, but not suppressed as the bottom charts of T and S indicate. An indication for this 'marginal' turbulence would be a RICHARDSON-number of order one. At 13 Stations (see table 1) such numbers $Ri_L = g\,\Delta\rho\,L/(\rho_B\,|\Delta \underset{\sim}{u}|^2)$ have been calculated. Here g, ρ_B, $\Delta\rho$ and $\Delta \underset{\sim}{u}$ denote gravity, density in the overflow layer, density difference and vector difference of velocity at the edges of an intervall L. L is choosen within the layer of maximum temperature gradient and is of order 5 m at each station.

<u>Table 1</u>

St.No.	112	118	143	144	145	146	15o	153	154	155	156	157	158
Ri_L	.7	.3	5.3	1.5	.6	1	1	1	1.7	.5	1.2	1.8	7

The distribution of the Ri_L is not Gaussian. Definition of Ri_L see text.

The Ri_L differ not much from 1, and the results are in good agreement with measurements of MOORE and LONG (1971) in tank experiments.

<u>Conclusions:</u>

Overflow in this region may occur as thin and narrow bands, spilling over the sills of cross channels. The flow is thus strongly influenced by small topographic effects. Both, sharp vertical and horizontal gradients in temperature and salinity separate overflow from Atlantic water. In these gradient layers RICHARDSON-numbers are of order one. More information from instruments moored in small scale distances, vertical as well as horizontal, are needed, to get more information about generation, tidal influences and mixing across the gradient layer.

References

DÜING, W. & D. JOHNSON, 1972: High resolution current profiling in the straits of Florida. Deep-Sea-Res. 19, 259-274

KROEBEL, W., 1973: Die Kieler Multi-Meeressonde. "METEOR"-Forsch. Ergebn. A, 12, 53-67

MOORE, M.J. & R.R. LONG, 1971: An experimental investigation of turbulent stratified shearing flow. J.Fl. Mech. 49, 635-655

STEELE, J.H. 1967: Current measurements on the Iceland-Faroe-Ridge. Deep-Sea-Res. 14, 469-473

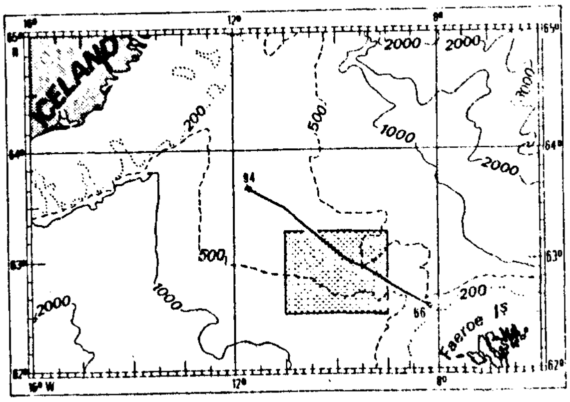


Fig. 1 Area of investigation (shaded) and location of the temperature section mentioned in the text. All depths in m.

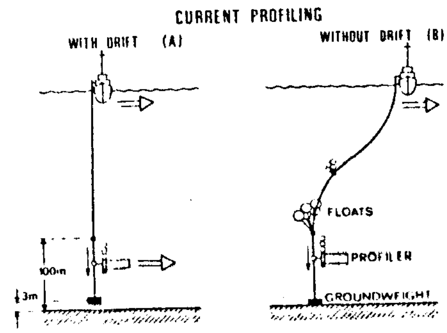


Fig. 2 Methods of taking profiles with the Profiling-Current-Meter (PCM).
A: PCM drifting with the ship
B: Short time mooring

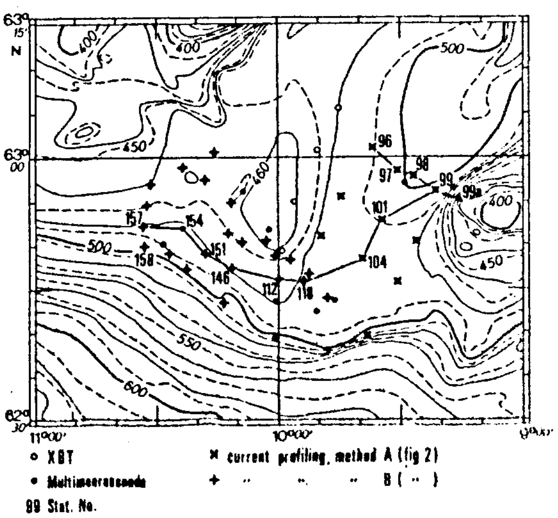


Fig. 3 Map showing the kind of measurements and σ_t-sections in the small-scale area, shaded in fig. 1.

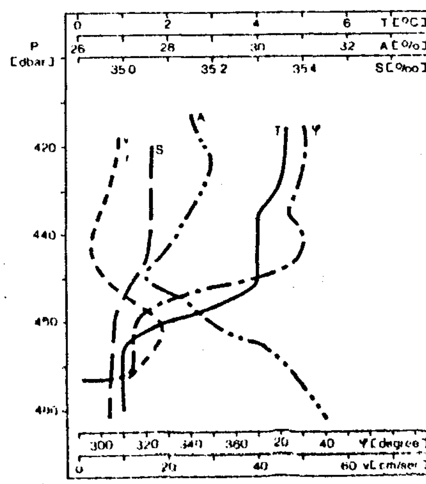


Fig. 4 Profiles of current speed and direction, v and ψ , temperature salinity S, and light attenuation A at station 154.

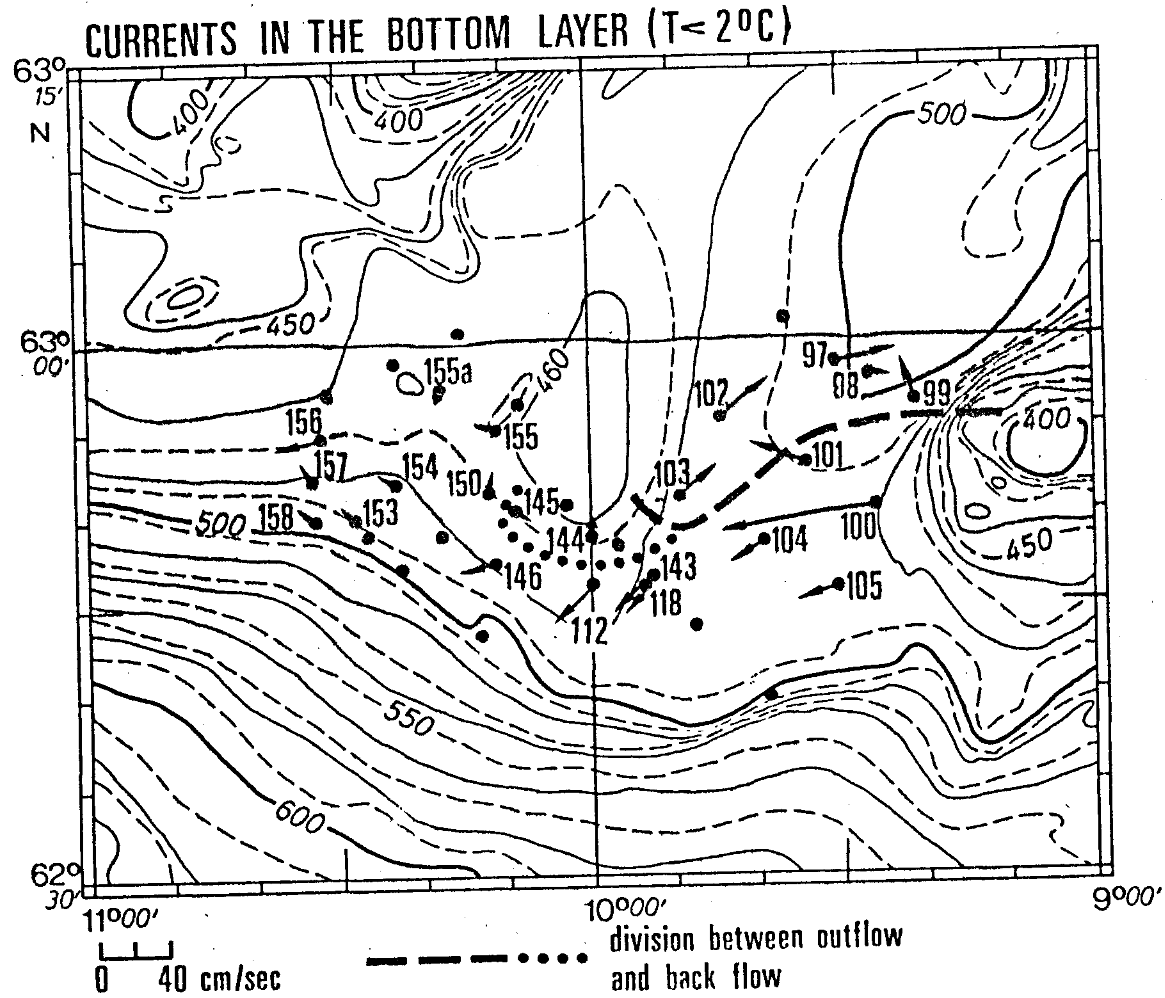


Fig. 5 Vertically averaged currents in the bottom-layer (T ≤ 2°C).

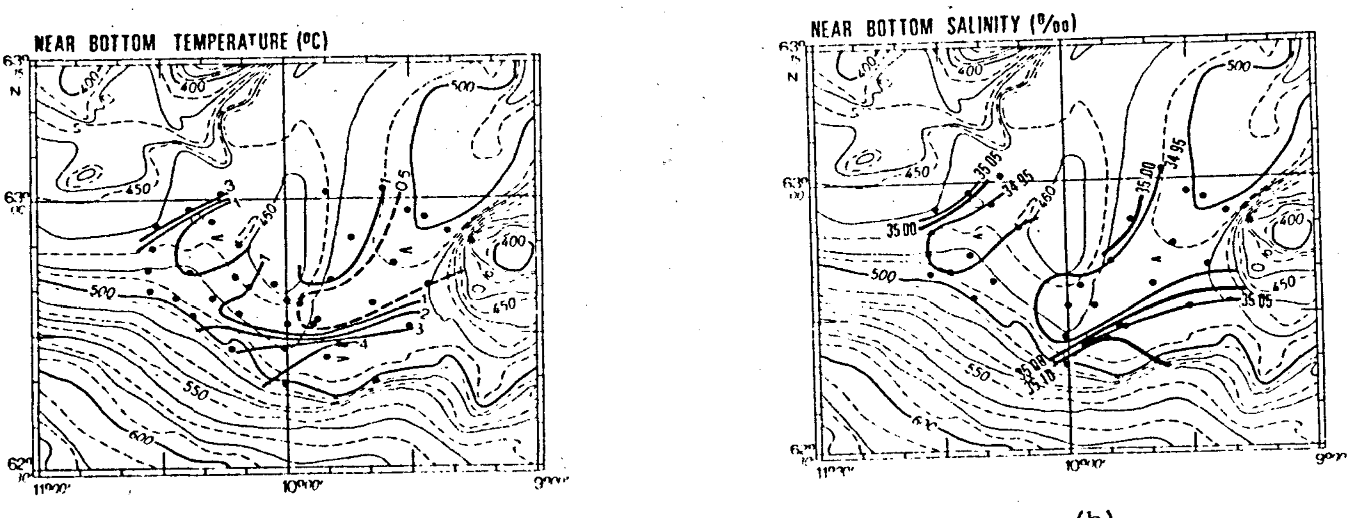
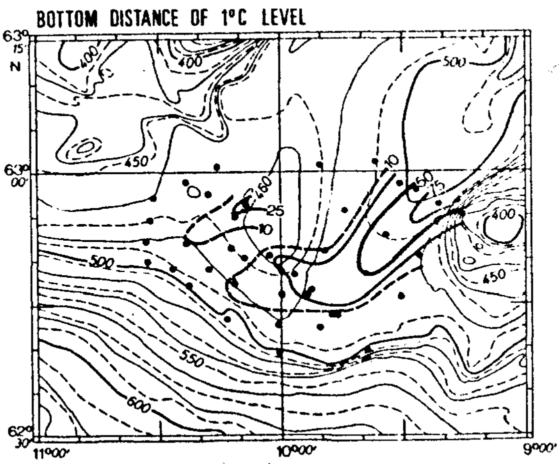
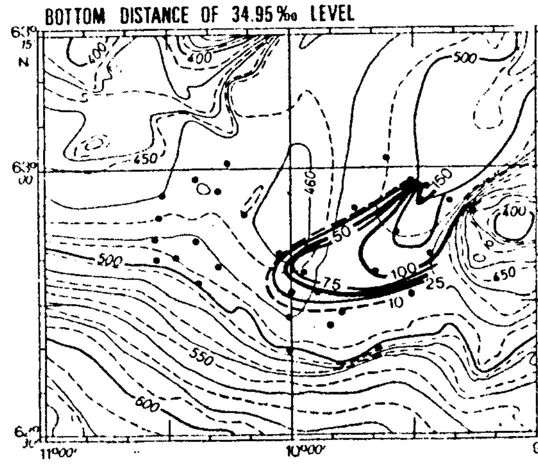


Fig. 6 Near bottom Temperature (a) and Salinity (b).

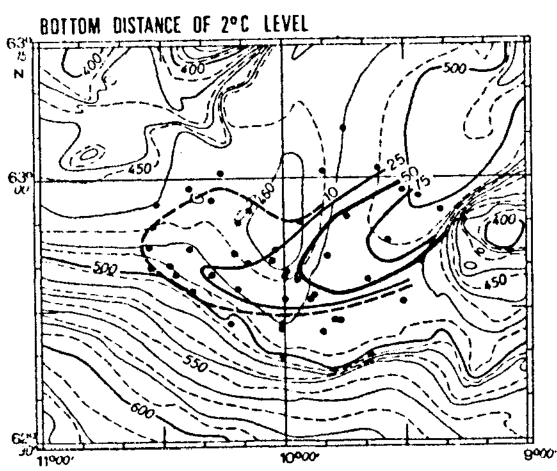


(a)



(b)

Fig.7 Bottom distances in m of 1^{O}C-level (a), 34.95 ‰-level (b) and 2^{O}C-level (c).



(c)