Dense overflows: theory, tank experiments, numerical simulations and in-situ observations

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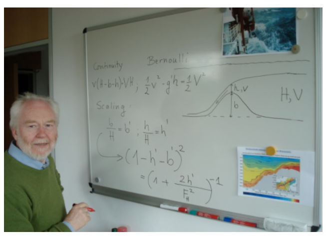
ABSTRACT

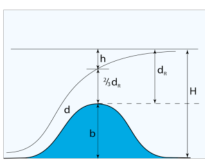
As part of the curriculum in marine sciences at the University of Hamburg we offer a course on oceanic processes, such as internal waves, instabilities and eddy formation, convection and dense overflows. Processes are first explored theoretically, using mostly classical text books. Based on this, the students design laboratory experiments in either a rotating or non-rotating frame. For the rotating experiments we use a small (diameter 0.6 m) turntable. In parallel, numerical experiments are set up in models such as MITgcm and ROMS/TOMS, simulating the tank experiments realistically and with certain features (hydrostatic, non-hydrostatic, friction) turned off or on. Finally, whenever data sets are available, the results are compared with in-situ observations.

In this poster we demonstrate this teaching approach for the process of dense overflows through the narrow straits in the Greenland-Scotland Ridge.

I. THEORY

Students are given textbooks or review articles to make themselves familiar with the basic theoretical background of the process to be explored. Here, for the overflow, we used Jack Whitehead's 1998 *Rev. Geophys.* paper.



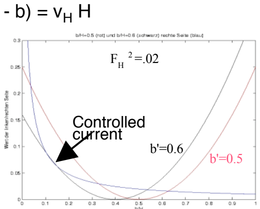


For the non-rotating case the hydraulic state
e exchange through narrow straits, with
ater on one side and lighter water on
de, can be described by two

Bernoulli $\frac{1}{2} v^2 - g'h = \frac{1}{2} v_H^2$ and

Continuity $v (H - h - b) = v_H H$

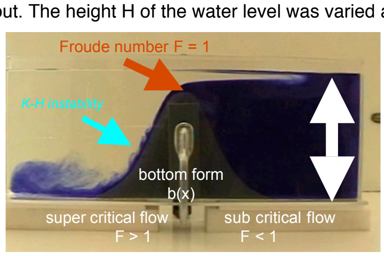
Scaling with H gives $h' = h/H$ and $b' = b/H$ with the Froude number in the dense reservoir $F_H^2 = v_H^2/g'H$. Combination of the two equations and applying the scaling leads to $(1 - h' - b')^2 = (1 + (2h'/F_H^2)^{-1}$ which can be solved graphically. Where both curves (r.h.s. and l.h.s.) have a common tangent, the Froude number is $F_H = 1$ and the flow is critically controlled. The flux is then given by



$$Q_{crit} = 2\ v\ h = g'^{1/2}\ (2/3\ d_R)^{3/2}$$

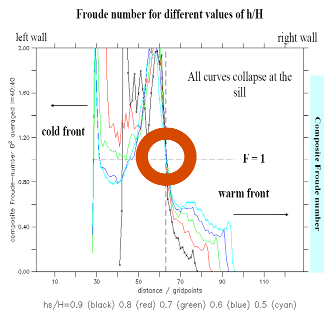
II. TANK EXPERIMENTS

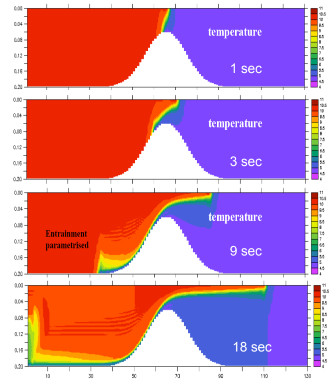
To test the Froude scaling, non-rotating lock exchange experiments with a narrow tank that had a sill separating the light and dense water were carried out. The height H of the water level was varied and the dependence of h on the horizontal distance from the sill was observed. Direct observation of the volume flux was not feasible. Students analysed the graphical output, e.g. frontal movement.



III. NUMERICAL SIMULATIONS

The lock exchange experiments were repeated using the terrain following ocean model TOMS-2.0 The effect of instability is parameterized via a mixing scheme.

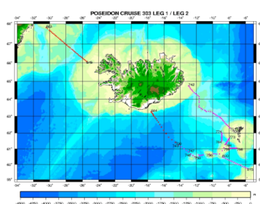


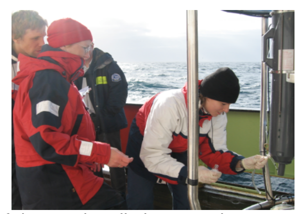


We ran the model for 5 different normalized bottom heights b' = [0.5 … 0.9]. In all cases Froude numbers collapse to 1 at the sill.

IV. IN-SITU OBSERVATIONS

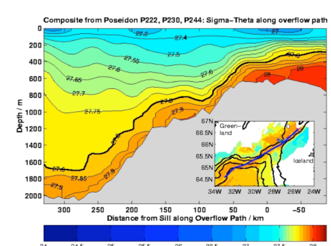
Annual student excursions linked to 'real' research cruises provide the opportunity to study the processes in-situ. Several of the cruises have been carried out on and south of the Greenland-Scotland Ridge, focussing on the exchanges through Denmark Strait and through the Faroe Bank Channel.





ollection of data and preliminary analyses, that are then summarized in cruise websites available to all students at the university.

An example of the density section along the Denmark Strait overflow Macrander et. al, 2005) reveals the typical asymmetric distribution of the dense water layer.



References

Macrander, A., Send, U., Valdimarsson, H., Jónsson, S. & Käse, R. (2005). Geophys. Res. Let., 32, L06606.

Whitehead, J.A. (1998) Rev. Geophys., 36, 423-440.