(2)

Final Technical Report

Ocean Prediction Research: Regional Forecasting, Processes and Methodology

A Forecast Scheme for the Iceland-Faeroes Front in the GIUK Gap

ONR Contract N00014-88-K-6008

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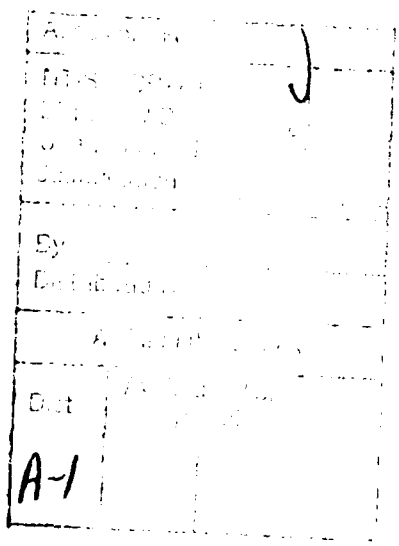
This was a project for research on the phenomenology, kinematics and dynamics of the East Iceland Polar front related to its mesoscale variability and for the development of a nowcast and forecast scheme for the frontal variability between Iceland and the Faeroe Islands. The lead scientist at Harvard and Co-Principal Investigator was Dr. Donald Denbo. An index of publications and reports is attached.

In order to investigate the time and space scales of variability, kinematics of mesoscale meandering, instabilities and eddies, and the feasibility of forecasting and the issues involved in the development of a forecast scheme a (quasi)connected synoptic time series of synoptic realizations of the frontal system was acquired. The data set consisted of 29 AXBT maps obtained between April and October 1987, 23 of which were dedicated flights carried out through the auspices of the Keflavik Naval Oceanographic Facility and 6 of which were obtained from NOARL (then NORDA). A typical AXBT survey is shown in Figure 1a. A 'Preliminary-Gap' version of the Harvard quasigeostrophic (QG) open ocean model was used to forecast and hindcast this data set. The data set, kinematic analysis

and Preliminary-Gap model runs are presented in report #(R4). Three real time exercises were carried out in the field with equipment easily ported from Harvard via P3 or commercial aircraft: at Keflavik, Iceland in May 1987 (R1), at Northwood, England in July 1987 (R2) and at Machrahanish, Scotland in April 1988 (R3). Nowcasts and 1 week forecasts were available three hours after data was acquired at the forecast center. At Northwood, in collaboration with the Johns Hopkins University Applied Physics Laboratory group, Geosat altimetric data was utilized in real time via a repeat track differencing method (Publication #P1).

Process studies and forecast experiments were carried out to determine dependencies on parameters including initial and boundary condition treatment, barotropic mode content, topographic interaction strength, computational resolutions and domain which are presented in R5. This formed the basis of the development of the Mark-I version of the QG forecast scheme involving: a flat bottom (top of the ridge) three level, 7.5 km, 1/16 day model with feature models for temperature data extension and for inlet condition variations. One week forecasts verify very well with adequate inflow and initialization data. Intermittent pulse events propagate with correct maintenance of structure. An improved QG scheme with six levels and topographic interactions was under development, and the Harvard Open Ocean Primitive Equation (PE) model with hybrid coordinates for accurate topographic representation had been set-up for benchmarking and intercomparisons when this project was suddenly terminated in mid-contract. Figure 1 presents and compares results from sample hindcasts with these models. Major features of the results are quite similar after one week. The dynamical models tighten realistically the thermal gradients which are not well enough resolved in the $\sim$ 50 km AXBT sampling (1b) as can be seen in both the day 6 maps (1e,h) and Section 1f. This effect occurs also in the Mark-I model. A paper (P2) conveying the scientific aspects of this work is in preparation now with 6.1 support (P3). Figure 2, although not supported by this contract is included for interest.

It shows acoustic propagation through the Iceland-Faeroe frontal fields generated from Harvard model output, as carried out by Lt. Jessie Carman as part of her Ph.D. thesis at Harvard (Oceanographic and Topographic Interactions in Underwater Acoustic Propagation, with Regional Applications, 1991). Twenty exact repeat path difference pairs of sea surface height estimates could be constructed nearly simultaneously from the 1987 AXBT and GEOSAT data. The frontal locations which compare well and the barotropic modes derived from the combined data set are presented in a submitted manuscript (P2, joint 6.1 support and JHU/APL collaboration).



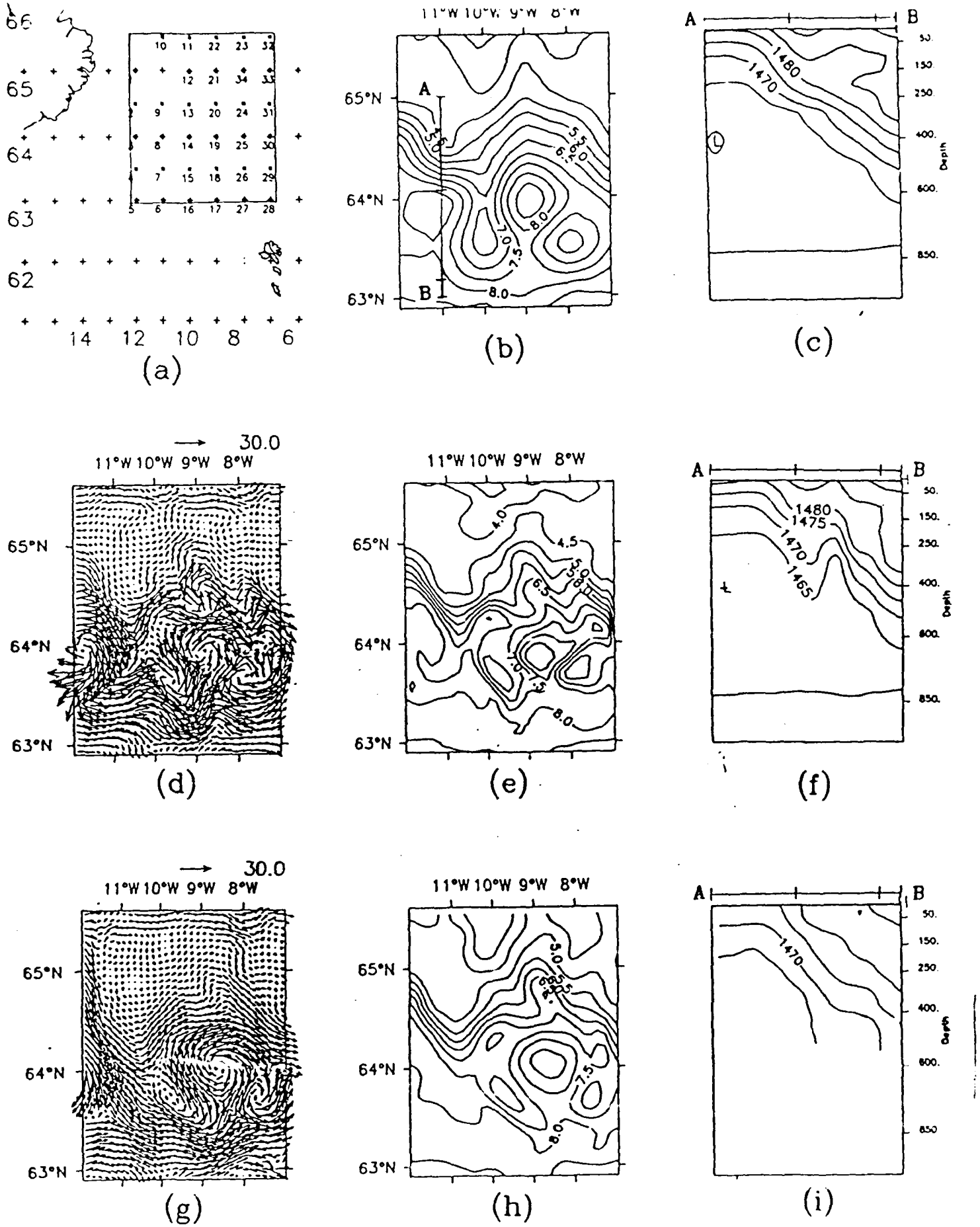


Figure 5

(from a chapter, in preparation)

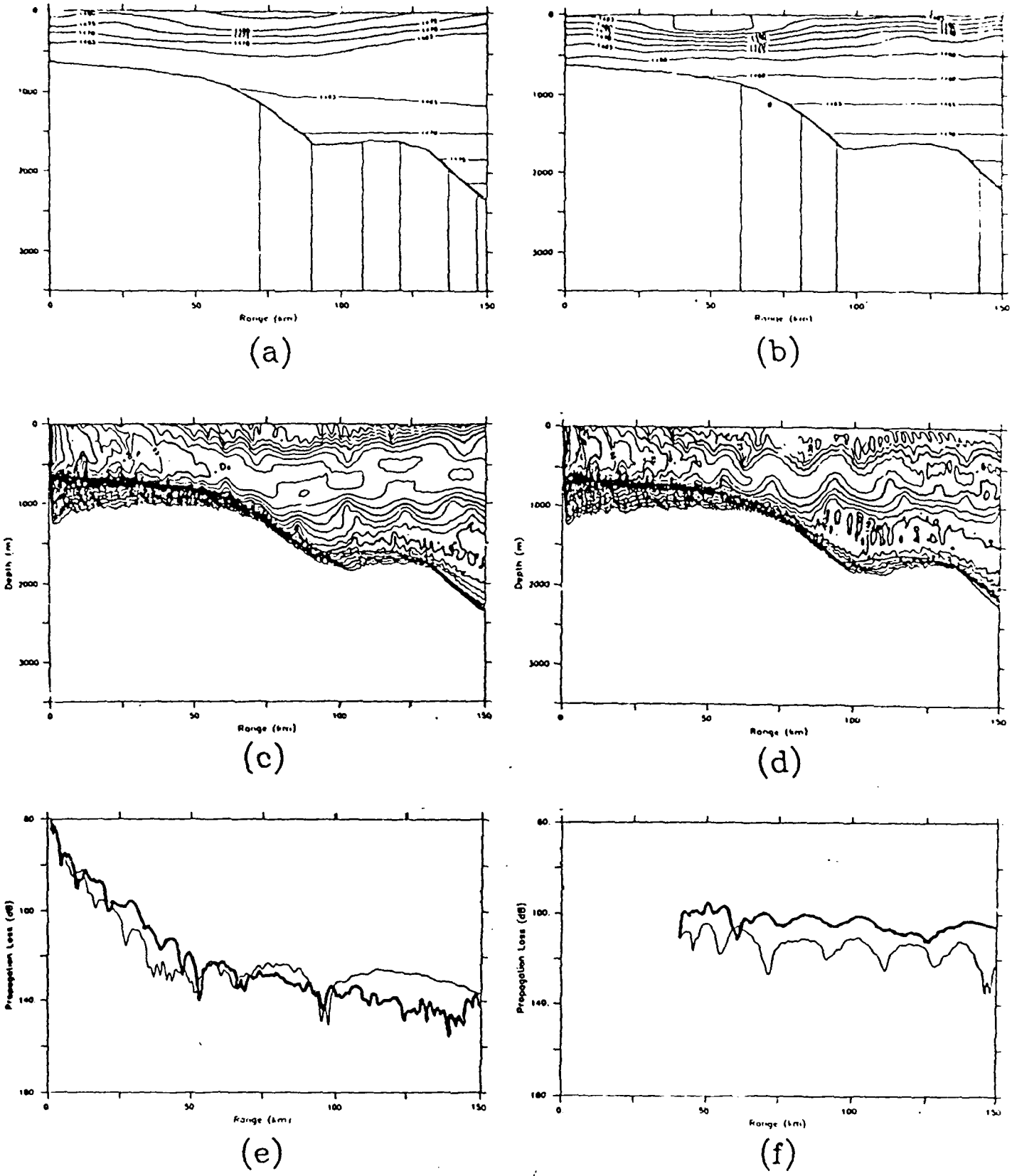


Figure 6
(from a chapter, in preparation)

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Publications

P 1. Robinson, A.R., L.J. Walstad, J. Calman, E.B. Dobson, D.W. Denbo, S.M. Glenn, D. Porter and J. Goldhirsh (1989) Frontal Signals East of Iceland from the GEOSAT Altimeter, *JGR Letters* 16(1), 77-80.

P 2. Robinson, A.R. and E.B. Dobson (1991) East Icelandic Frontal Meanders and Eddies from GEOSAT Altimetric Measurements, *Journal of Geophysical Research* (submitted).

P 3. Denbo, D.W. and A.R. Robinson, The Kinematics and Quasi-Geostrophic Dynamics of the East Iceland Polar Front Meandering (in preparation).

Reports

R 1. Robinson, A.R., D.W. Denbo, S.M. Glenn, M.A. Spall and L.J. Walstad (1987) Harvard Gapcasts: Dynamical Nowcasts and Forecasts of the East Iceland – Faeroe Front, Real Time Analyses, Keflavik, Iceland, 15 May – 25 May 1987. Harvard Open Ocean Model Reports **24**, *Reports in Meteorology and Oceanography*, Harvard University, Cambridge, MA.

R 2. Denbo, D.W., A.R. Robinson, S.M. Glenn, L.J. Walstad and C. Mooney (1987) Harvard Gapcasts: Dynamical Nowcasts and Forecasts of the East Iceland – Faeroe Front, 9 July – 15 July 1987; Real Time Analyses, Northwood, UK; Analyses, Cambridge, MA, 24 July – 29 July 1987. Harvard Open Ocean Model Reports **25**, *Reports in Meteorology and Oceanography*, Harvard University, Cambridge, MA.

R 3. Denbo, D.W., R.A. Schmalz and G.M. Gardner (1988) Harvard Gapcasts: Dynamical Nowcasts and Forecasts of the East Iceland – Faeroe Front, Real Time Analyses, Machrahanish, Scotland, 18 April – 23 April 1988; Analyses, Cambridge, MA, 28 April. Harvard Open Ocean Model Reports **30**, *Reports in Meteorology and Oceanography*, Harvard University, Cambridge, MA.

R 4. Denbo, D.W. and A.R. Robinson (1988) A Progress Report: Regional Forecasting, Processes and Methodology in the East Iceland – Faeroe Front. Part I: Data Forecast and Hindcast Experiments, Harvard Open Ocean Model Reports **32**, *Reports in Meteorology and Oceanography*, Harvard University, Cambridge, MA.

R 5. Denbo, D.W. and A.R. Robinson (1988) A Progress Report: Regional Forecasting, Processes and Methodology in the East Iceland – Faeroe Front. Part II: GFD and Process Experiments, Harvard Open Ocean Model Reports **33**, *Reports in Meteorology and Oceanography*, Harvard University, Cambridge, MA.