Formulation and Application of Metrics for Ocean Modeling

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LONG-TERM GOALS

The overall goal is to aid the performance and evaluation of ocean models used for nowcasting and forecasting by the Navy. More specific goals are the evaluation of global ocean models coupled to the atmosphere and to regional forecast models.

OBJECTIVES

The primary objective of this effort is the preparation and evaluation of metrics to evaluate the physcial soundness and forecast accuracy of ocean forecast models. A corollary objective is the preparation of hydrographic data employed in metrics applications for validating model output, and the climatological fields used in model initialization, surface restoration and open boundary forcing.

APPROACH

Our approach has focussed on three tasks this fiscal year: (1) completion of the hydrographic data base in the GIN (Greenland-Iceland-Norwegain) Sea for model and climatology evaluation; (2) formulation and application of metrics suitable for synoptic forecast verification (such as in operational centers), and (3) formulation and application of metrics to monitor correct model behavior (generally, but not exclusively, in an R&D mode for longer simulation times).

WORK COMPLETED

We have completed the building of the GIN Sea hydrographic data base, including CTDs and AXBTs, covering the period 1986-1993, for model and climatology evaluation.

We have continued to evaluate the MODPOL climatology, a blend in the Arctic/Nordic Seas region of global MODAS (NRL/NAVO, ref. 1) and PHC2 (Univ. of Washington's Polar Science Center, ref. 2). We have made improvements in terms of smoothing some discontinuities in the North Sea and in the Southern Oceans.

We have applied the chosen metrics to evaluate in the GIN Sea the output of a 1/3^o global POP model run by the Navy Postgraduate School and the Los Alamos Scientific Laboratory [ref. 3].

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14. ABSTRACT
The overall goal is to aid the performance and evaluation of ocean models used for nowcasting and forecasting by the Navy. More specific goals are the evaluation of global ocean models coupled to the atmosphere and to regional forecast models.

15. SUBJECT TERMS

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RESULTS

We have completed the building of the GIN Sea hydrographic data base, including 760 near-to-bottom CTD casts spanning the 1986-89 period [ref. 4,5; Fig. 1], hundreds of NODC casts for the period 1986-1993 with smaller cast/ bottom depth ratios [ref. 6], and thousands of 400m and 700m AXBT casts for the 1987-1993 period, obtained by Navy flights from Iceland [ref. 7, Fig. 2]. The SACLANT Center data can be found on the web page of the ICES center in Denmark [ref. 8]

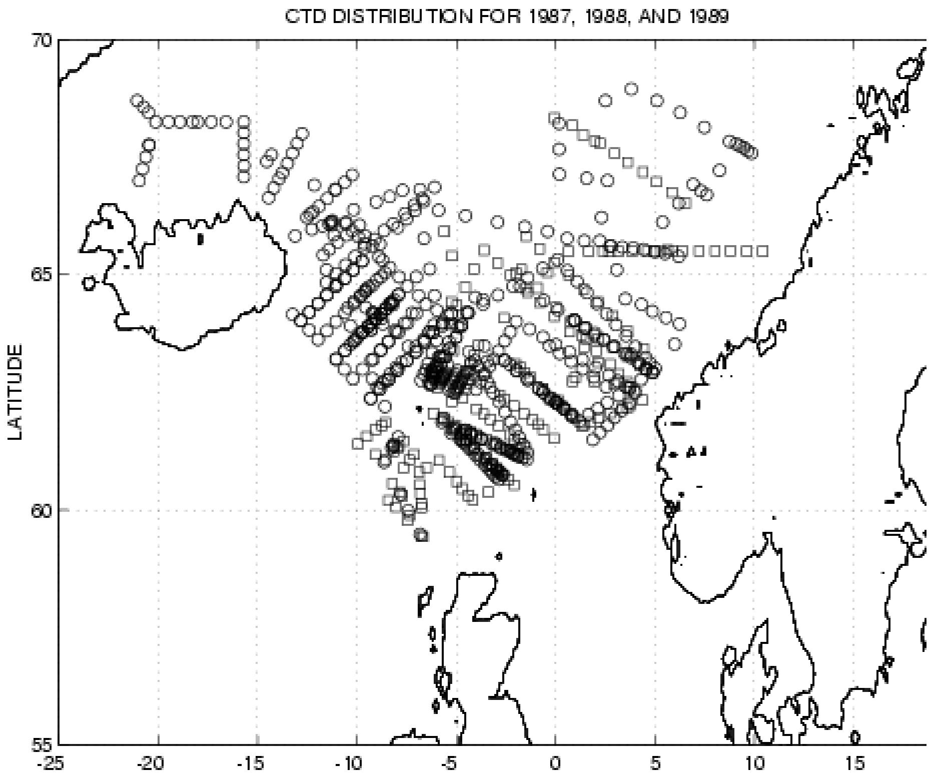

Fig. 1. Distribution of the SACLANT Center CTD casts for the period 1986-1989 in the GIN (Greenland-Iceland-Norwegian) Sea. The spring months May and June contain 460 casts, and the autumn months (September, October, November) 266 casts. The 6 surveys cover the region 60N-70N, 10W-10E, with the densest coverage over the Iceland-Faroe front.

These large in-situ data sets were organized and prepared for comparisons by space-time grid interpolation , to match the output of the 1/3^{o} global POP simulations [ref. 3] and the climatologies MODAS [ref. 1] and WOA98 [ref. 9]. In addition to the hydrography, also 113 near-surface drifters [ref 10] were tracked over the 1991-1994 period and their motions analyzed.

We have evaluated the POP output, as well as several climatologies, via ‘synoptic’ and ‘seasonal’ metrics. In the synoptic comparisons, the model and climatological fields were interpolated to the CTD locations and times, and the RMS deviations were computed as a function of depth. This was done both for individual CTD cruises with over 100 casts, and for the cumulative multi-year set. In the seasonal comparisons, we have calculated the watermass census to examine the correct seasonal behavior of the model and the climatologies.

Fig. 3 displays the results of a 'synoptic' comparison, with the RMS errors of both model output and the WOA98 climatology vs. CTD data as function of depth. The model performs better than climatology by almost a factor of 2 in the top 500m. This is probably achieved by the correct magnitude and application of the daily surface fluxes that forced the model. Between 500m and 1000m, the model is closer to the climatology that initialized it. Below 1000m, climatology and the CTDs exhibit close agreement, but the model displays growing errors with depth. This part of the model's behavior is probably due to the accelerated time-stepping for T and S in the spin-up stages, which [see Table 1] tends to destroy the watermass census.

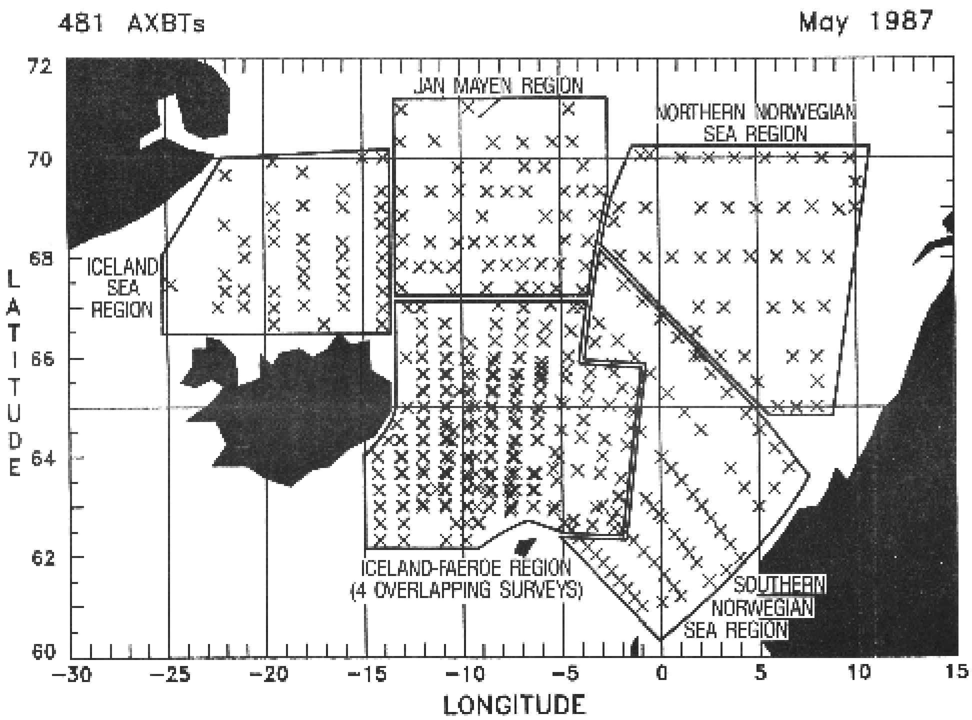

Fig. 2. Distribution of the Navy/NRL AXBT casts during the May 1987 surveys (481 casts). The 5 flights cover the region 60N-70N, 25W-10E, with 2 overlapping flights providing dense coverage over the Iceland-Faroe frontal region [from Boyd, 1988; ref. 7].

Tabel 1 gives an overview of the watermass census by volume of the 3 most important water masses in the GIN Sea, namely Atlantic water (AW), Lower Arctic Intermediate Water (LAIW), and Deep Water (DW). Here DW represents only the sum of the principal components of the DW, the Norwegian Sea Deep Water and Greenland Sea Deep Water. For the definition of watermass classes in the GIN Sea sea Fig. 4; for a breakdown of DW into various sub-classes the reader is referred to Fig. 1 of ref. 11. The census is performed for the cumulative SACLANT spring and fall cruise CTD data, the WOA98 and MODAS spring and fall climatologies, and the POP model results for 1997 May and September. The left columns are the spring data, and the right columns are for the fall. The AW and LAIW show at most a 10% variation with season, but the DW shows a large range: 27% for the CTDs, ~20% for the climatology, and almost a factor of 2 for the POP results. The most significant fact concerning the model census is the enormous amount of LAIW not seen in either the climatologies or the CTD data.

By noting that in general, the sum of LAIW and DW tend to be close, as well as the sum of PW and AW, and inspecting the adjacent masses in Fig. 4, we obtain a clue as to the origin of the model disagreements. Excessive cooling of the surface waters, or mixing of cooler waters from below 500m shifted AW into the LAIW range; similarly, excessive mixing of warmer waters from above 800m or so into the deeper layers could be responsible for a shifting of DW into LAIW. Evidently the class of LAIW plays an important role in GIN Sea thermodynamics.

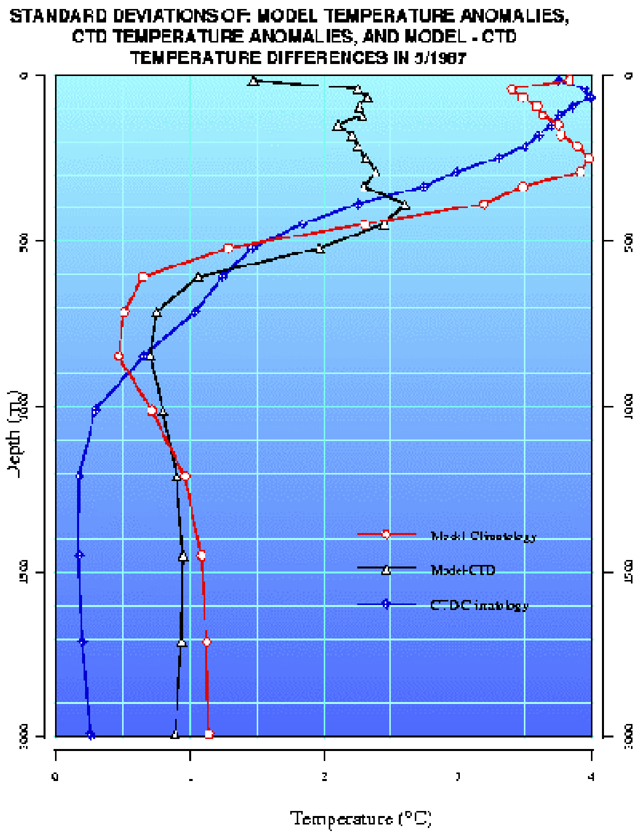

Fig 3. The depth variation of the RMS error profiles for the 1987 May POP model output and the May WOA98 climatology. Red: (model-climatology); Black: (model-CTDs); Blue: CTD-Climatology). The depth range examined is 2000m. Model errors increase from ~ 1.5° C near the surface to ~ 2.0° C at 400m, and thereafter decrease to about .8° C.

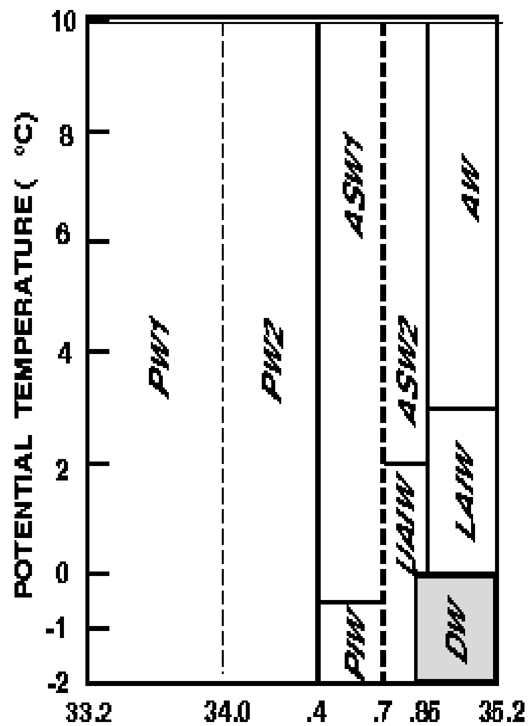

Fig 4. The major watermass classes in the T-S diagram of the GIN Sea. Horizontal axis is salinity. For annotation see bottom of Table 1. DW ranges from –2 to 0° C, 34.85 to 35.2 psu, LAIW from 0 to 3 °C, 34.90 to 35.2 psu, and AW with T > 3.0 °C and S > 34.90 psu [from ref.11]

TABLE 1

Watermass Census: CTDs vs. Climatologies and POP Model
[The results are volume percentages]

Wmass	CTD	WOA98	MODAS	POP
PW	0.9 / 0.6	2.5 / 0.0	6.5 / 0.2	24.4 / 27.8
AW	30.1 / 33.2	26.5 / 26.7	26.1 / 29.8	16.0 / 17.7
LAIW	11.3 / 11.5	18.5 / 20.2	16.2 / 16.2	47.0 / 45.0
DW	27.0 / 37.1	37.9 / 32.9	33.6 / 25.9	13.7 / 7.6

Notation: AW - Atlantic Water
LAIW - Lower Arctic Intermediate Water
GSDW - Greenland Sea Deep Water
NSDW - Norwegian Sea Deep Water
PW - Polar Water

IMPACT/APPLICATION

The high resolution climatology will improve the spinup of the global model, particularly in the deeper waters. It will also aid in the simulation of the surface salinity field which undergoes a weak restoring to climatology. The demonstration of watermass destruction in the deep waters by accelerated time-stepping in the spinup process has led to the elimination of this procedure in current and future global simulations. The demonstration of success of the POP model in long-term simulations of the top 500m in the GIN Sea gives validity to the surface fluxes employed and the method of their application.

TRANSITIONS

An improved 1/8 degree global MODPOL climatology was transitioned to NAVO to initialize and selectively restore fields of the global NCOM model.

RELATED PROJECTS

1. The development and testing of the global POP model in the Navy's coupled air-sea model (J.McClean, Naval Postgraduate School; M.Maltrud, Los Alamos National Laboratory). We have developed the MODPOL climatology for model initialization and surface restoring, as a first guess field in data assimilation, and the GIN Sea hydrographic data base for model verification.

2. The development of global climatologies and synoptic oceanic analyzed fields within the MODAS (Modular Ocean Data Assimilation System) framework [C.Barron, NRL Code 7320, M.Carnes, Naval Oceanograpohic Office]. We use their products for blending into hybrid climatologies, and adapt their analyzed fields to the POP model setup.

3. The development of the POLES climatology [M.Steele, Polar Science Center, University of Washington]. We have used the POLES climatology to form the Nordic component of the MODPOL global climatology, and have performed

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