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Reply to "Comment on 'A parametric model for the Yellow Sea thermal variability' by P. C. Chu et al."

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1. Introduction

In the paper by *Chu et al.* [1997a] (hereinafter referred to as CETAL) we developed a thermal parametric model that was capable of estimating physical parameters from historical profile data. The output parameters included sea surface temperature (SST), mixed-layer depth (MLD), thermocline depth (THD), thermocline temperature difference (TTD), and deep layer stratification. On the basis of the U.S. Navy's Master Oceanographic Observation Data Set (MOODS) that was taken in the Yellow Sea (YS) from 1950 to 1988, we computed the thermal structure functions and spatial decorrelation scales of the water properties in the Yellow Sea [*Chu et al.*, 1997b]. The results shown in our papers were derived from ~35,658 profiles, which have provided us with the statistical seasonal variations of the thermal structure in this region. To our knowledge, these issues have not been addressed in previous observational and modeling studies in the Yellow Sea.

We appreciate *Lie*'s [1999] (hereinafter referred to as L99) comments on our two papers. The points he raised, to a certain extent, resulted from an unclear explanation of some aspects of our analysis and from a limitation on access to Asian (especially Korean and Chinese) journals. We were unaware of previous studies on the YS thermal features reported in the Asian literature, such as *Kang* [1985], *Lie* [1984], *Lie et al.* [1986], *Nakao* [1977], *Seung et al.* [1990], and *Zhao* [1989]. On the other hand, most previous work was based on individual hydrographic surveys. Those studies did provide some insights into the seasonal pattern of the thermal structure in the YS for particular years, but they lacked statistical meaning. MOODS has included more than 39 years of observational data in the YS, and our study was the first to provide a statistical pattern of the seasonal variation of the thermal structure in this region. Detailed responses and explanations to L99's comments are given as follows.

2. Bohai Sea Issue

MOODS does not cover the Bohai Sea. The isolines in this region (see CETAL Figures 5, 7, and 8) were caused by the excessive extrapolation of the contour plot in our plotting program. This is why we did not discuss any features in the Bohai Sea in CETAL. We apologize that this led to a misunderstanding by *Lie* [1999]. Again, we would like to point out here that all of our discussion and results applied only to the YS, with no inclusion of the Bohai Sea.

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3. Synoptic and Climatological Thermal Structures

There are two major approaches to investigating the YS thermal structure: synoptic and climatic. The first approach was conducted based on analysis of individual cruise data sets. Good examples of this approach are given by *Lie* [1984], *Zhao* [1989], and *Chen et al.* [1994]. The temporal and spatial data distributions of *Lie* [1984] and *Zhao* [1989] are illustrated in Figures 1a and 1b, respectively. This method, however, provides only a snapshot of the thermal structure at the time during measurement, which lacked statistical meaning. The second approach is carried out based on the statistical analysis of a long-term historical data set. This method provides a climatological pattern of the thermal structure, which is statistically meaningful. Using this approach, we analyzed 39 years of MOODS hydrographic data (Figure 1c). The seasonal pattern of the thermal structure found in our analysis should represent a climatological pattern of the vertical thermal structure in the YS. We appreciated seeing that this seasonal pattern was also found in previous synoptic studies, as pointed by L99. This probably suggested that the interannual variation of the vertical thermal structure in the YS was not significant.

4. Intercomparison Among Different Data Sets

It is good that L99 noted the discrepancy between the MOODS and Chinese/Korean data. We also noted this difference during our studies. For example, the SST in the northern YS reported by the *Editorial Board for Marine Atlas* (*EBMA*) [1992] showed a cooler water mass than that shown in MOODS; in addition, the MOODS data did not show ice formation, as pointed out by *EBMA* [1992]. That the thermal pattern depicted in CETAL somewhat differed from *Lie* [1985], *Zhao* [1989], and *Seung et al.* [1990] was probably due to different samplings and calibrations. This raises an important issue of intercomparison between the data sets, including sampling density, quality control, and process methods. Therefore one should be careful in making an intercomparison between data sets that were calibrated and sampled with different standards. It would be a good idea to make an intercomparison among Chinese, Korean, and MOODS data. However, it was beyond the scope of the study presented in CETAL.

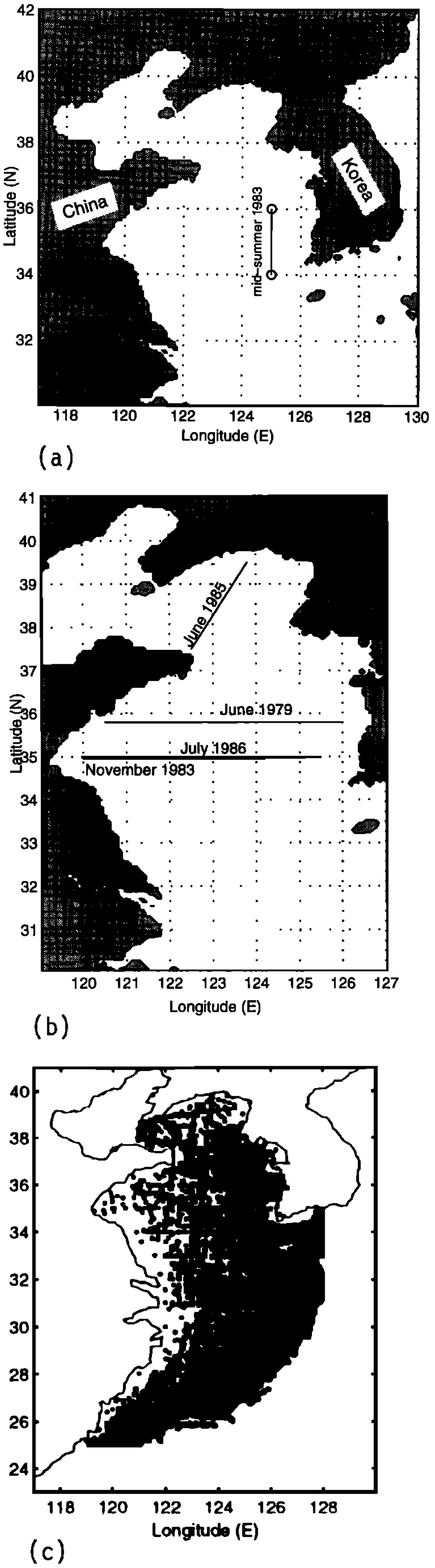

Figure 1. Observational stations reported by (a) *Lie* [1984], (b) *Zhao* [1989], and (c) *Chu et al.* [1997a, b].

5. Irregular Distribution of the MOODS Data

L99 pointed out that the MOODS data were collected with a significant odd/even month unevenness, so that some of the results found in CETAL might not be statistically meaningful. To address this question, let us first look at Figure 2, which shows the monthly numbers of the MOODS profiles in the YS during 1929–1991. There is no significant evidence of odd/even month unevenness in the MOODS data as pointed out by L99. We also found that temporal and spatial distributions of the MOODS significantly differed from the Korean data collected during 1961–1988. It was beyond our scope to find out if the MOODS originally came from the Korean data set mentioned by L99, but, at least, his concerns here were not the case in the MOODS.

6. SST Seasonal Variability

Statistical characteristics (such as SST seasonal variability) obtained from data are estimates of the population features and largely depend on data sampling strategy. The seasonal variation characterized by maximum (minimum) SST in August (February) was found by *Kang* [1985] and *Lie et al.* [1986] from the Korean data set, whose temporal and spatial distributions are indicated in Figures 1 and 2 of L99 with odd/even month unevenness, and by *Zhao* [1989] from the Chinese data set, whose temporal and spatial distributions are indicated in Figure 1b. The seasonal variation characterized by maximum (minimum) SST in late July and early August (March) for the central YS was found by CETAL from the MOODS data, whose temporal and spatial distributions are indicated in Figures 2 and 1c. Again, this discrepancy can be resolved only by the comparison of the MOODS data with Chinese/Korean data, which may lead to an ocean data set intercomparison program between us and our Chinese/Korean colleagues.

7. Mechanism for a Shallow Summer Mixed Layer Near the Chinese Coast

It is well known that the mixed-layer structure depends on buoyancy flux, wind forcing, and tidal mixing. In the inner shelf region the mixed layer could form owing to wintertime cooling, wind, and tidal mixing. The freshwater discharge tends to enhance the vertical stratification around the coastal region, particularly in the summer season [*Chen et al.*, 1994]. CETAL show that the monthly mean winds in July are much weaker (around 50%) than in January. *Kang et al.* [1998] show that the tidal current was ~50% smaller near the Chinese coast in the YS than near the Korean coast. Tidal currents were not strong enough to mix the water during summer, as river discharge becomes larger. The minimum thickness of the mixed layer found in July near the Chinese coast was mainly due to the increasing river discharge.

8. Reliability and Validity of Statistical Analysis

We agree with L99 that reliability and validity of any statistical analysis depend absolutely upon the amount of data and their spatial and temporal distributions, especially in the shallow seas at midlatitudes, where the hydrographic structures are highly variable in time and space. It is very important to investigate the statistical structure functions or the decorrelation

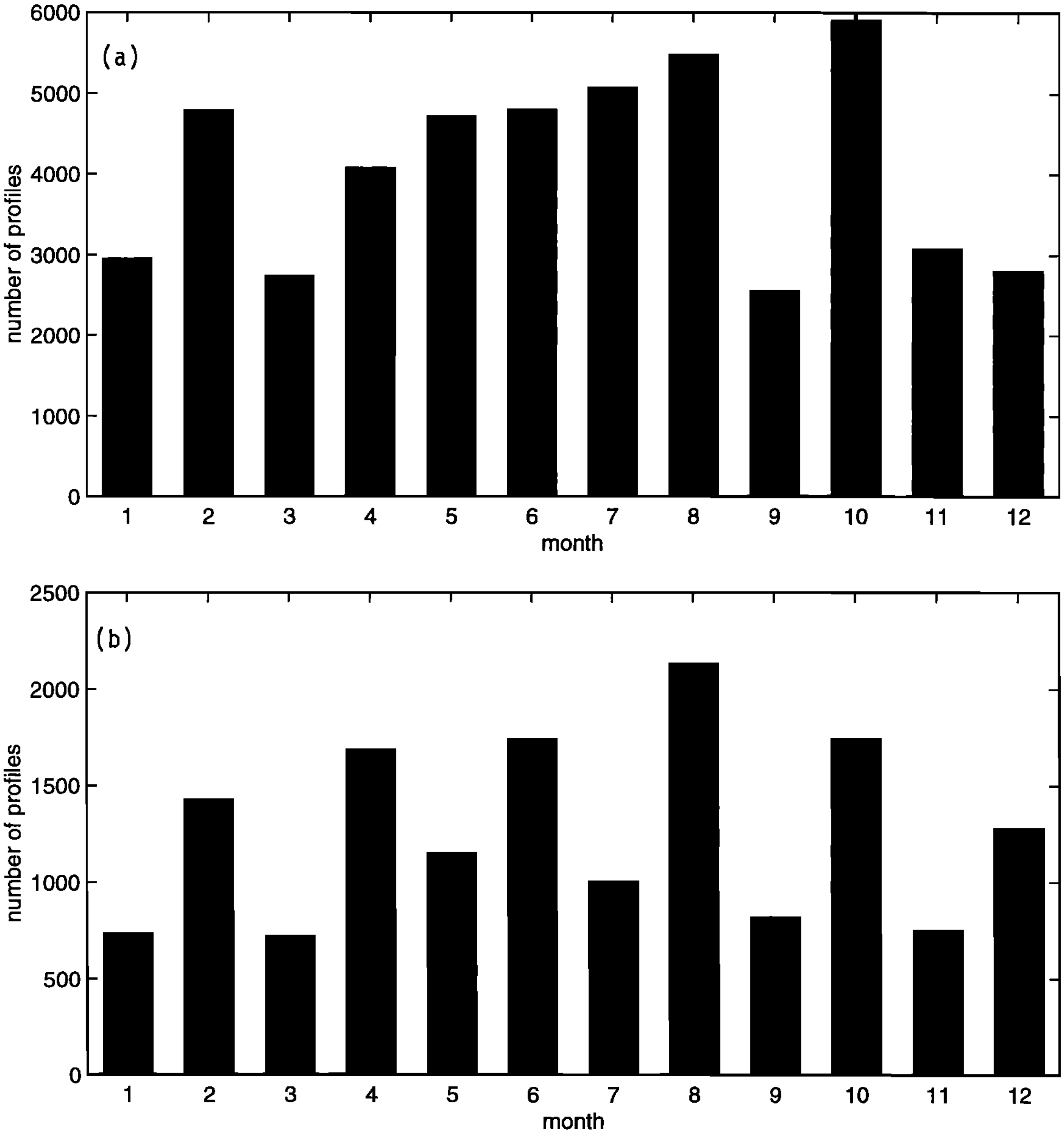

Figure 2. (a) Monthly data number distribution of the MOODS temperature profiles for the Yellow Sea during 1929–1991. These data were used to compute the statistical structure functions and decorrelation scales [*Chu et al.*, 1997b]. (b) Monthly data number distribution of the MOODS temperature profiles for the Yellow Sea during 1950–1988. These data were used to display the thermal parameters [*Chu et al.*, 1997a].

scales from the data. Without knowledge of the coherence structure, any mapping of data is probably meaningless. Figure 1c shows unevenness of MOODS data distribution. The climatological features of data-sparse regions (such as the Chinese coastal region) were not as reliable as data-dense regions. Reconstructing the Yellow/East China Sea databases to provide a more realistic field for the data-sparse regions is one of our ongoing projects.

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