NOAA Data Report ERL PMEL-67

TOGA-TAO Shipboard ADCP Data Report, 1991–1995

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1. Introduction

Since 1979 the variability of the tropical Pacific Ocean has been studied using arrays of moored instruments. The several equatorial moorings of the Equatorial Pacific Ocean Climate Studies (EPOCS) program grew into a tropical array during the Tropical Ocean Global Atmosphere (TOGA) program, and most recently into the larger Tropical Atmosphere Ocean (TAO) array of the El Niño/Southern Oscillation (ENSO) observing System. The present array, consisting of nearly 70 moorings spanning the width of the Pacific from 8°N to 8°S, is designed to provide atmospheric data and oceanic temperature and current velocity data which resolve the large-scale variability of the tropical climate system, both as a means of increasing our understanding of the physics involved and to enable successful modeling and prediction of the interannual variability related to ENSO. While the array itself cannot resolve smaller-scale processes, some of which (e.g., tropical instability waves) contribute significantly to the larger-scale physics, it nevertheless provides the background against which more detailed investigations can be undertaken. In addition, the TAO array is periodically maintained by ship, and these repeat cruises form an ideal vehicle for collecting ancillary data sets such as the acoustic Doppler current profiler (ADCP) data discussed in this report. The shipboard ADCP data provide a direct measure of the velocity field over a significant portion of the basin. Moreover, the fine vertical and horizontal scales of the ADCP velocity profiles provide a powerful tool for investigating smaller-scale phenomena.

Briefly, the ADCP instrument uses acoustic pulses to measure the horizontal velocity of the water below the hull of a ship as a function of depth. Since the instrument functions continuously with very little oversight, it inexpensively collects a large amount of data covering all spatial scales as the ship transits from mooring to mooring. The ADCP velocities are measured relative to the ship itself rather than to the earth; thus for the ADCP velocities to be useful, additional data must be collected from which the ship's velocity can be determined and then subtracted from the ADCP relative velocities to give absolute velocities. A fuller treatment of ADCP data preparation can be found in Luther and Johnson (1990).

The present data consist of approximately twice-yearly cruises by the NOAA ship *Discoverer* along each of the instrumented longitudes in the tropical Pacific, generally from 8°S to 8°N, together with transit legs to and from various ports (Figure 1a–f). The first usable data were collected in 1991 along a few longitudes, with the number of sampled longitudes grow-

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ing through the years along with the TAO array (e.g., McPhaden *et al.*, 1998). Depth coverage extends from 19 m down to around 300 m, depending on acoustic conditions. Navigation data consist of Global Positioning System (GPS) fixes and gyrocompass headings. The ADCP installation on the *Discover* was plagued by interference from bubbles entrained in the ship's boundary layer at higher speeds. Installation of a fairing to divert the boundary layer around the transducer reduced the problem to an intermittent nuisance.

2. Data Preparation

Preparation of the PMEL data consists of three stages: the timing adjustment, the navigation of the data, and the calibration of the ADCP. Each 1-minute ADCP ensemble is recorded with a GMT timing mark, but these times are derived from the recording computer's internal clock, which is subject to a constant drift and to operator resets. The ADCP time marks are corrected to true GMT using the integrally recorded GPS navigational fixes that include accurate GMT time. At the same time the measured relative velocities are corrected for the true speed of sound at the transducer, determined using the water temperature as measured by the instrument's thermistor and an assumed salinity of 35 psu. In situations where the thermistor was not working the speed-of-sound correction cannot be carried out, but its cruise-averaged value and the broadest scales of its spatial variability are necessarily incorporated in the time-dependent instrument calibration detailed below.

After the ADCP time marks are corrected the ship's velocity is determined using the ancillary GPS fixes. The resulting ship's velocities are subtracted from the ADCP relative velocities to give absolute water velocities in a deep reference layer (139–195 m), chosen to minimize the expected spatial variability of currents without severely taxing the instrument's depth range. Both computer and hand editing of the resulting velocities are used to eliminate obviously bad fixes, whereupon the data is renavigated until results are satisfactory.

The resulting reference layer velocities are used to calibrate the ADCP instrument for heading offsets and gain errors. The data are searched by computer for hour-long intervals containing large variations in ship's velocity. These intervals are used to estimate the heading bias and gain error of the instrument as in Joyce (1989). The calibrations are edited for obvious outliers, filtered heavily in time to remove time scales shorter than 1.6 days, and fed back into a final, clean navigation of the data.

Routine navigational noise is then further reduced by time filtering the clean reference velocities to eliminate periods shorter than 2 hours (time scales shorter than 20 minutes), corresponding to space scales shorter than 8 km when the ship is underway at 12 knots. Note that this filtering cannot be done at any earlier stage of data preparation since the ADCP relative velocities and ship velocities contain large, rapidly varying signals associated with ship maneuvers. Filtering such maneuvers would aliase differences in sampling rate and coverage between the ADCP and the GPS data into spurious velocities, as well as eliminating the possibility of instrument calibration. Once the filtered reference level velocity is determined the velocities at other depths are built up using the observed shears in each profile; the results are the ADCP absolute velocities.

Some cleaning of the data takes place during the navigational process: data that cannot produce reasonable reference layer velocities are flagged as unnavigable. However, additional sources of noise and error, such as the bubbles while underway and lowered instruments while on station, are present in the data. Users must be aware of such potential limitations and test for those that might affect their particular analysis. The data are archived in original depth bins rather than re-gridded, so depths are not corrected for the small (~2%) difference between nominal and local speed of sound. Velocity, AGC, and percent good are recorded at all depths: the shallowest bin is centered at 19 m depth, with each succeeding bin located 8 m deeper. The combination of 8 m bin width and 8 m pulse length results in a triangular response function spanning 16 m depth. Thus the response functions of the successive depth bins overlap by 50%.

Roughly meridional sections of velocity data are shown in Figure 2. Sections are presented in chronological order; each comprises about a week of data (Table 1).

3. Conclusion

The collection and processing of shipboard ADCP data from equatorial cruises by the NOAA ship *Discoverer* have produced 41 meridional sections of absolute velocities for zonal and meridional currents. The sections were along eight different longitudes in the Pacific Ocean between 95°W and 165°E during the period from 1991 to 1995. The sections have been incorporated into the NODC data base of shipboard ADCP measurements located at the University of Hawaii.

4. Acknowledgments

We would like to thank the Pacific Marine Center engineers who installed and maintained the ADCP on the NOAA ship *Discoverer*. We also appreciate the diligent work of the *Discoverer*'s officers and survey technicians, who oversaw the ADCP operation during the cruises. This work was supported by NASA grant NAGW-5035 and by the TAO Project Office.

5. References

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Luther, D.S., and E.S. Johnson (1990): Eddy energetics in the upper equatorial Pacific during the Hawaii-to-Tahiti Shuttle Experiment. *J. Phys. Oceanogr., 20,* 913–944.

McPhaden, M.J., A.J. Busalacchi, R. Cheney, J.R. Donguy, K.S. Gage, D. Halpern, M. Ji, P. Julian, G. Meyers, G.T. Mitchum, P.P. Niiler, J. Picaut, R.W. Reynolds, N. Smith, and K. Takeuchi (1998): The Tropical Ocean Global Atmosphere observing system: a decade of progress. *J. Geophys. Res., 103*(C7), 14,169–14,240.

FIGURES AND TABLES

Table 1: The dates (day-month-year) of the southernmost, equatorial, and northernmost data included in each plotted section.

Cruise and Latitude	Southern	Equatorial	Northern
TOGA91 155°W	22-07-91	19-07-91	14-07-91
TOGA91 160°W	22-07-91	24-07-91	26-07-91
EP391 110°W	31-10-91	28-10-91	22-10-91
EP491 140°W	28-11-91	26-11-91	20-11-91
EP491 125°W	03-12-91	03-12-91	09-12-91
TOGA92 155°W	13-03-92	06-03-92	01-03-92
TOGA92 170°W	14-03-92	16-03-92	20-03-92
TOGA292 155°W	16-08-92	14-08-92	08-08-92
TOGA292 170°W	20-08-92	22-08-92	27-08-92
EP592 140°W	18-09-92	14-09-92	08-09-92
EP592 125°W	21-09-92	26-09-92	04-10-92
EP692 110°W	09-11-92	05-11-92	30-10-92
EP792 95°W	28-11-92	01-12-92	04-12-92
TG193 155°W	04-03-93	02-03-93	27-02-93
TG193 170°W	14-03-93	10-03-93	09-03-93
TG293 180°W	22-03-93	25-03-93	28-03-93
TG293 170°W	02-04-93	02-04-93	06-04-93
EP393 95°W	04-09-93	01-09-93	27-08-93
EP393 110°W	07-09-93	09-09-93	15-09-93
EP493 125°W	06-10-93	02-10-93	29-09-93
EP493 140°W	10-10-93	12-10-93	19-10-93
EP593 155°W	04-11-93	31-10-93	27-10-93
EP593 170°W	14-11-93	11-11-93	09-11-93
EP693 180°W	21-11-93	25-11-93	01-12-93
TG194 155°W	26-05-94	22-05-94	17-05-94
TG194 180°W	04-06-94	07-06-94	10-06-94
TG194 170°W	02-06-94	30-05-94	17-06-94
TG294 140°W	13-10-94	11-10-94	07-10-94
TG294 155°W	17-10-94	20-10-94	25-10-94
TG394 170°W	10-11-94	06-11-94	02-11-94
TG394 180°W	14-11-94	16-11-94	22-11-94
GP195 95°W	18-02-95	15-02-95	09-02-95
GP195 110°W	22-02-95	24-02-95	27-02-95
GP295 125°W	17-03-95	14-03-95	10-03-95
GP295 140°W	18-03-95	21-03-95	26-03-95
GP395 155°W	11-04-95	09-04-95	05-04-95
GP395 170°W	12-04-95	15-04-95	20-04-95
GP495 195°W	06-05-95	30-04-95	25-04-95
GP495 180°W	06-05-95	08-05-95	13-05-95
GS95 125°W	06-09-95	03-09-95	29-08-95
GS95 140°W	06-09-95	10-09-95	15-09-95

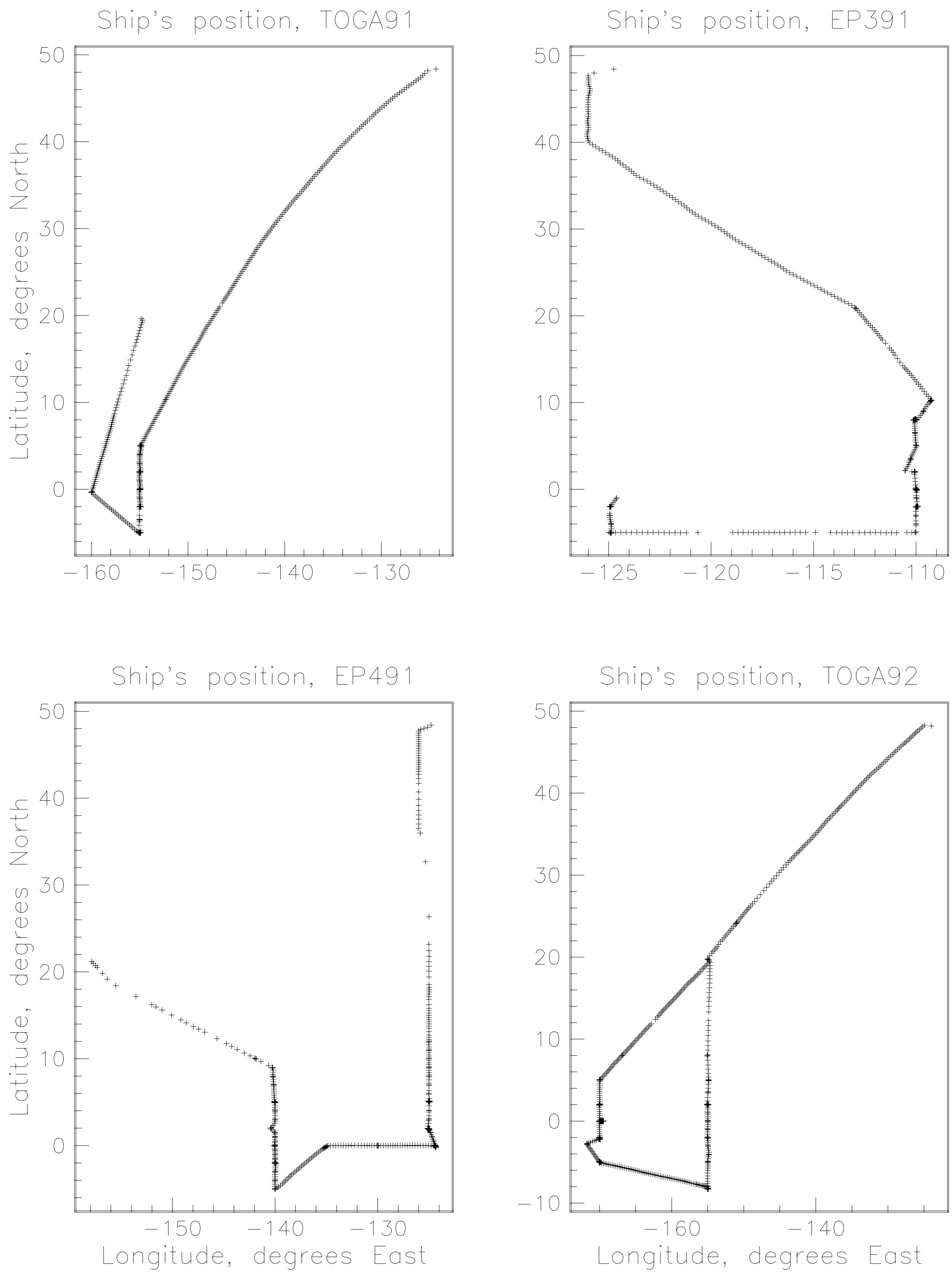


Figure 1a: Figures 1a–f show the locations of fully navigated ADCP data for each cruise by latitude and longitude: each cross represents one hour of data. Regions of sparser coverage were generally due to data loss through bubble interference.

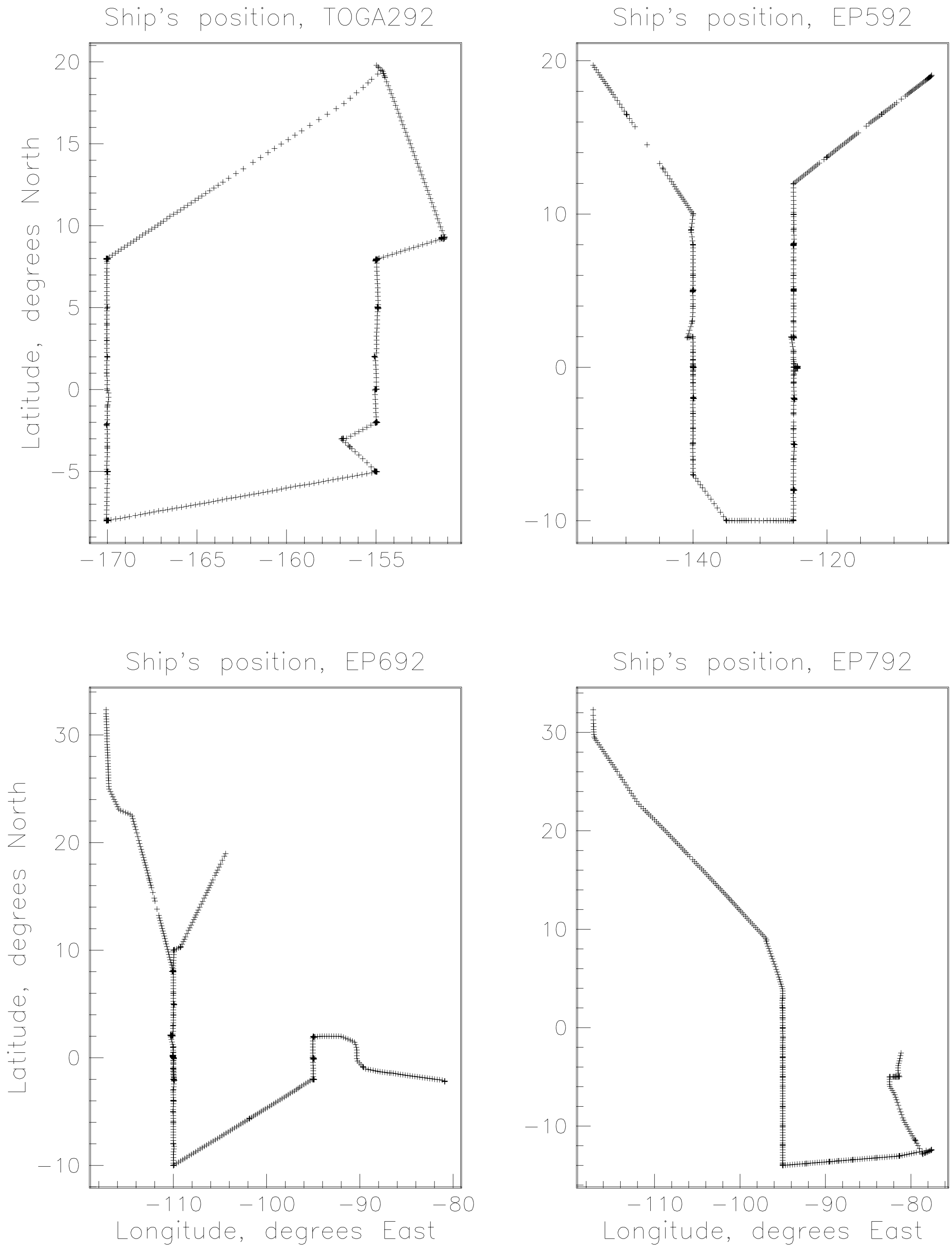


Figure 1b: Same as Figure 1a.

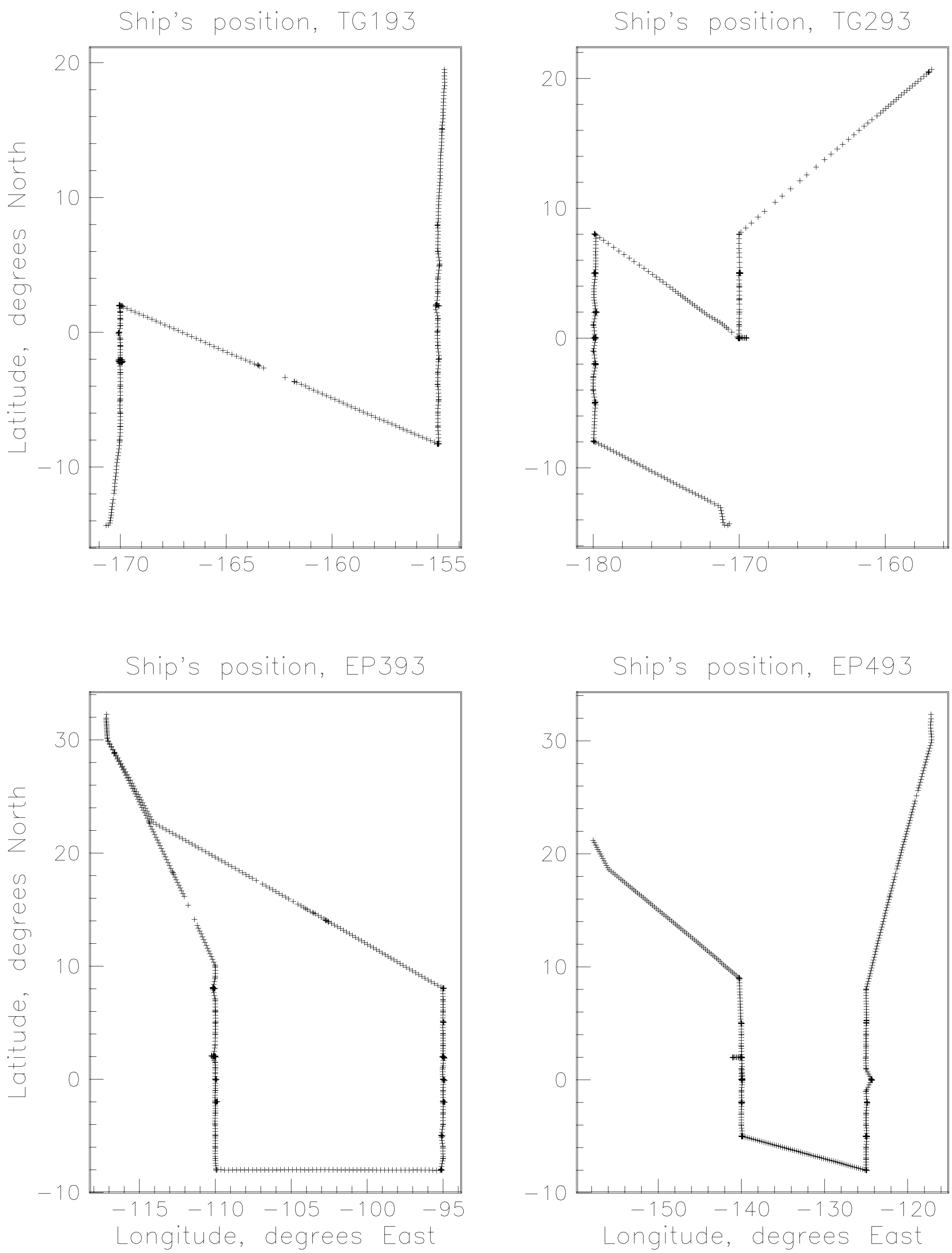


Figure 1c: Same as Figure 1a.

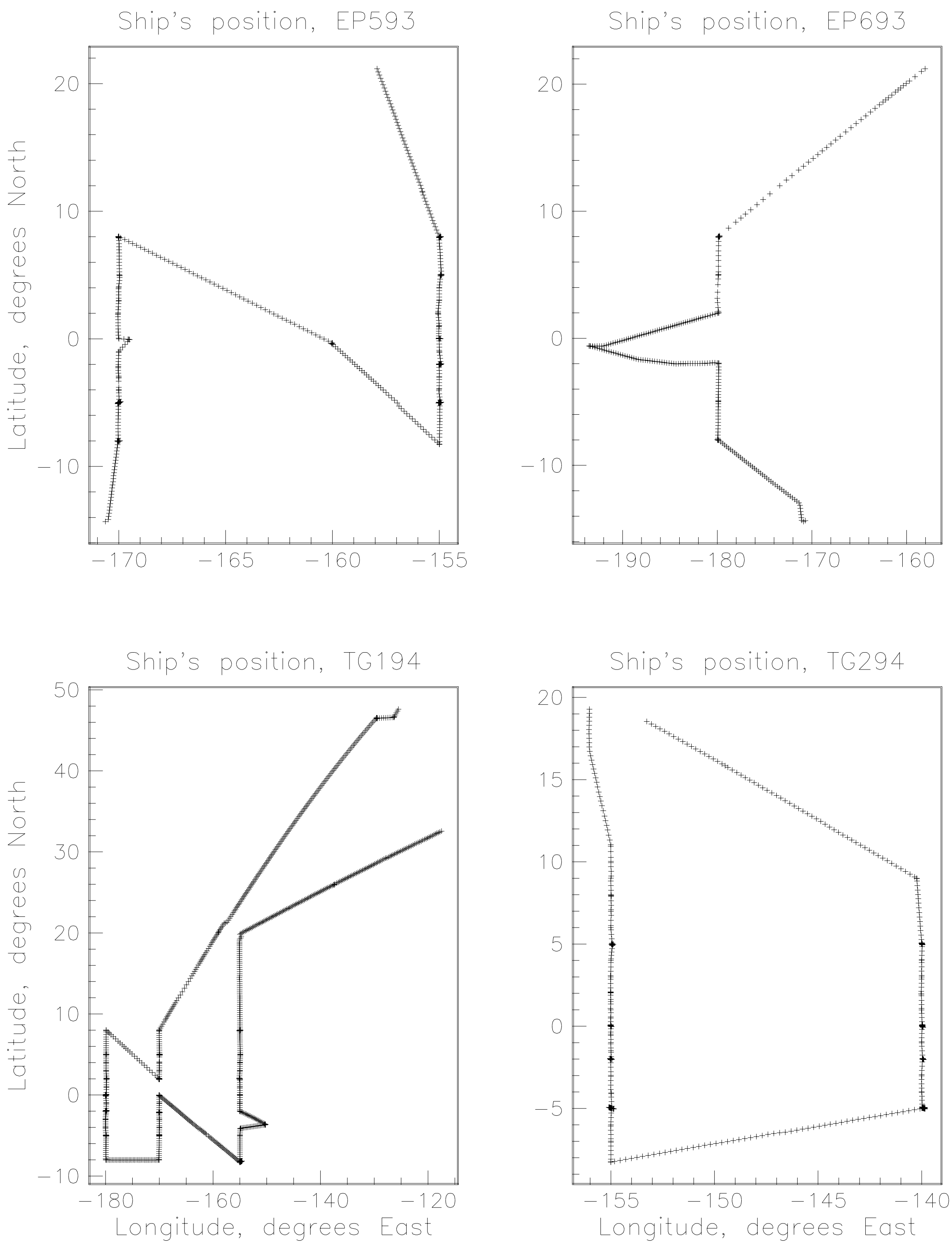


Figure 1d: Same as Figure 1a.

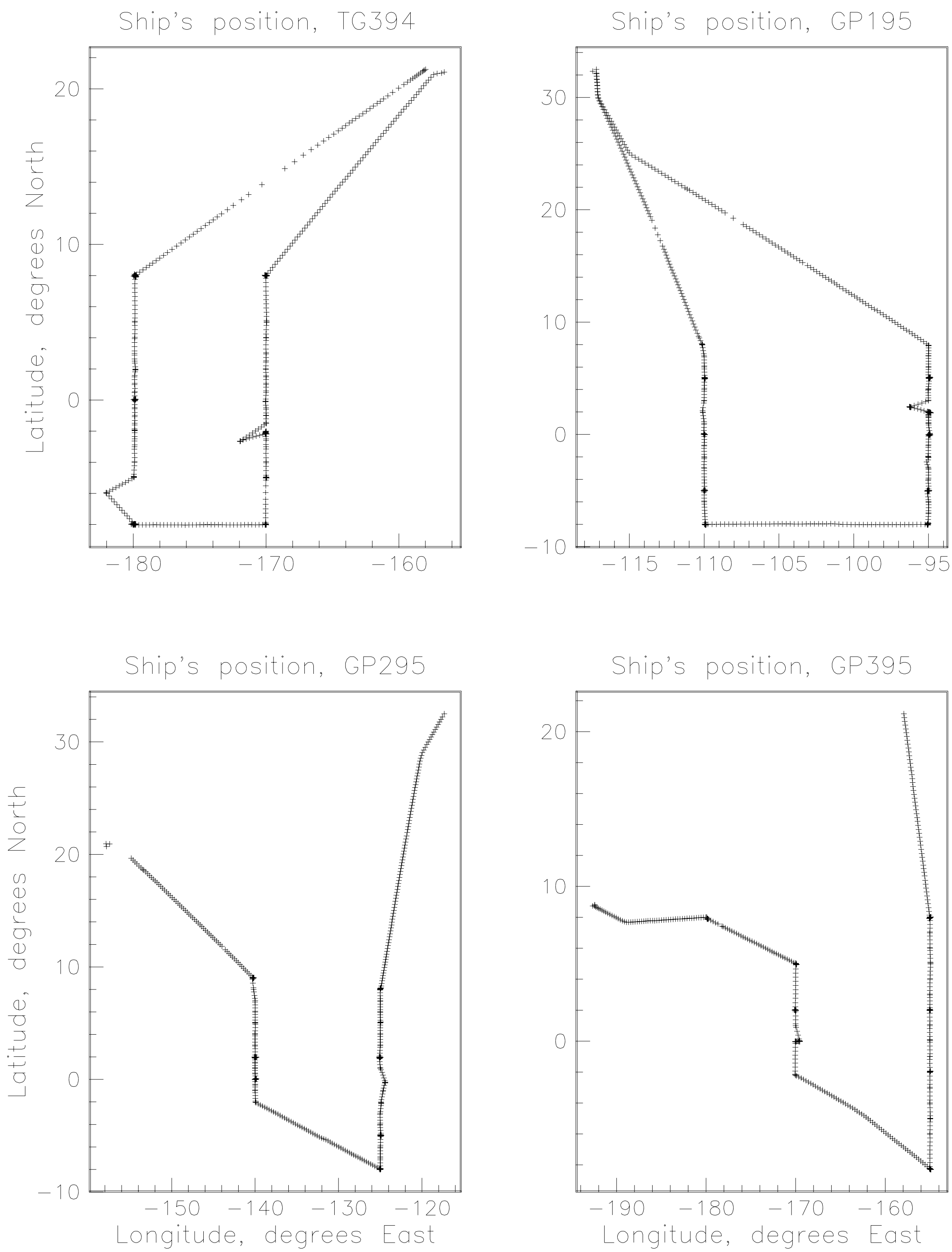


Figure 1e: Same as Figure 1a.

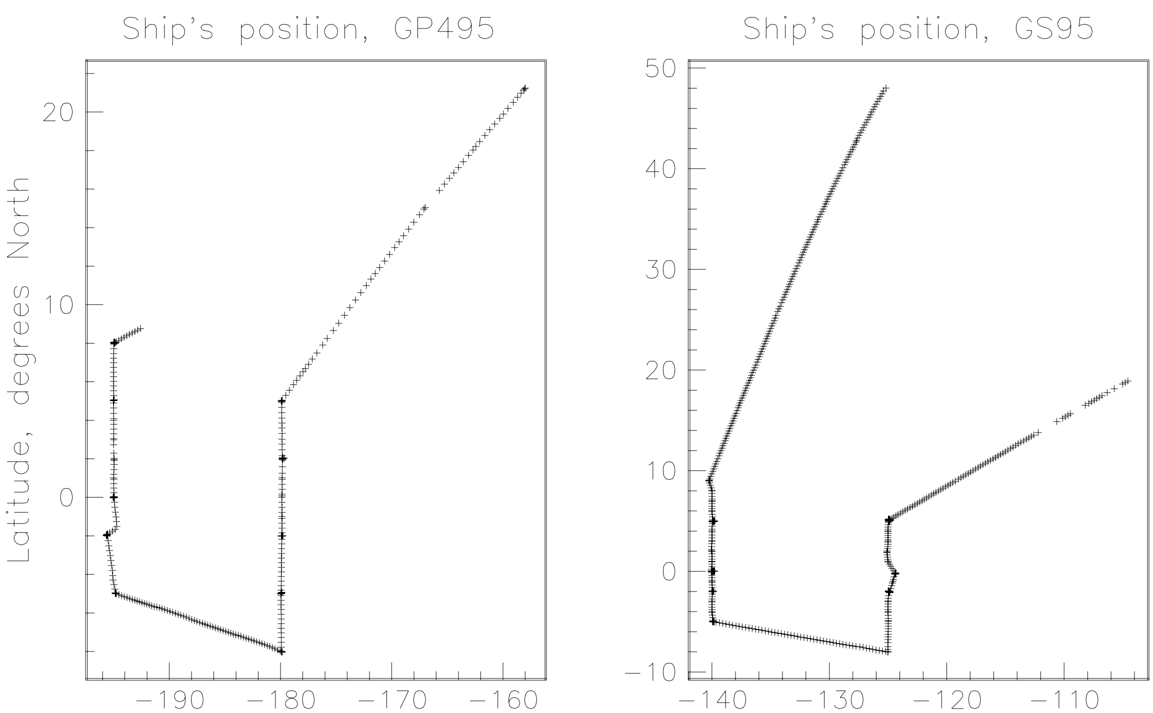


Figure 1f: Same as Figure 1a.

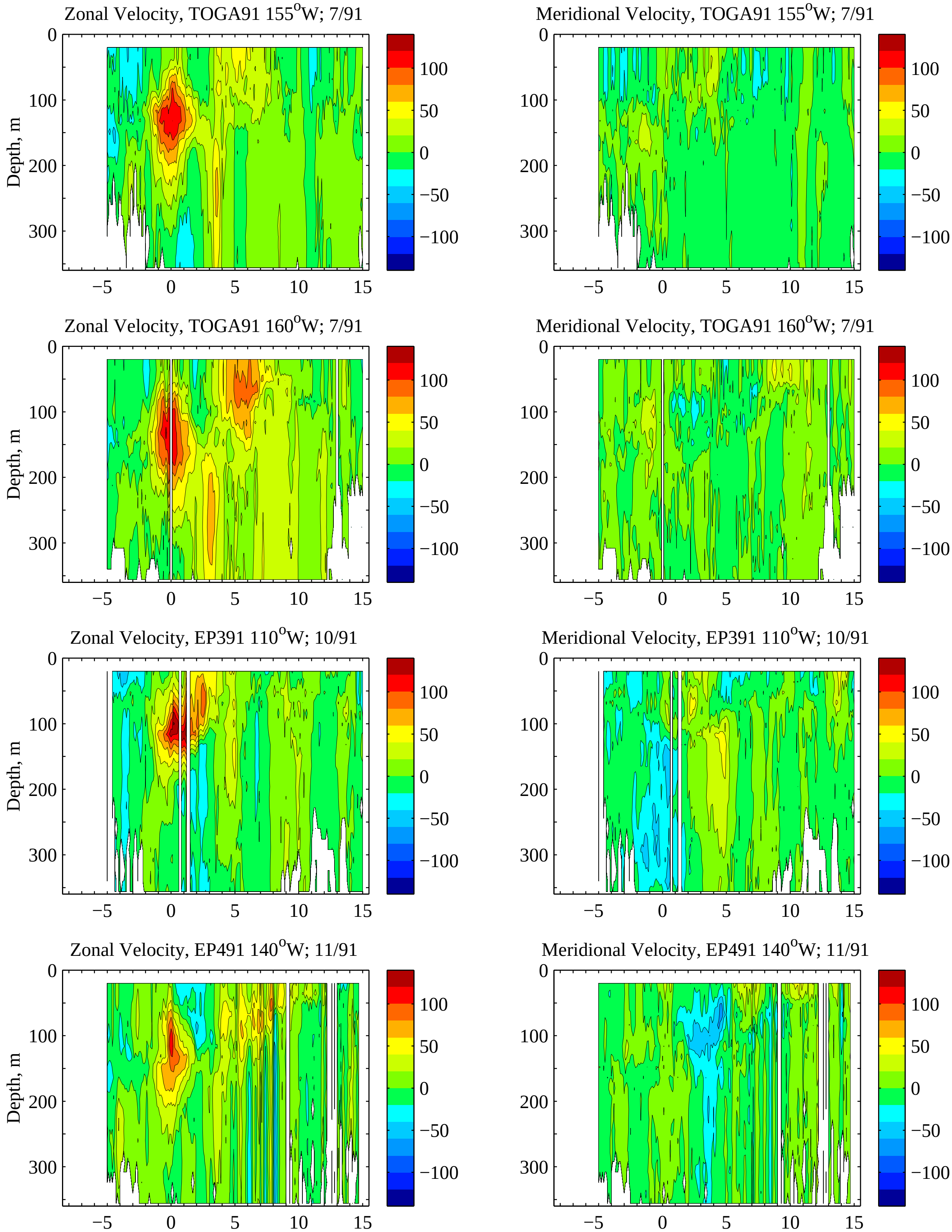


Figure 2a: Figures 2a-k show sections of zonal and meridional velocity from each roughly meridional section of cruise track. The original ADCP data were averaged into bins of 0.1° latitude and 16 m depth, and plotted with interpolated (10 cm/s banded) shading.

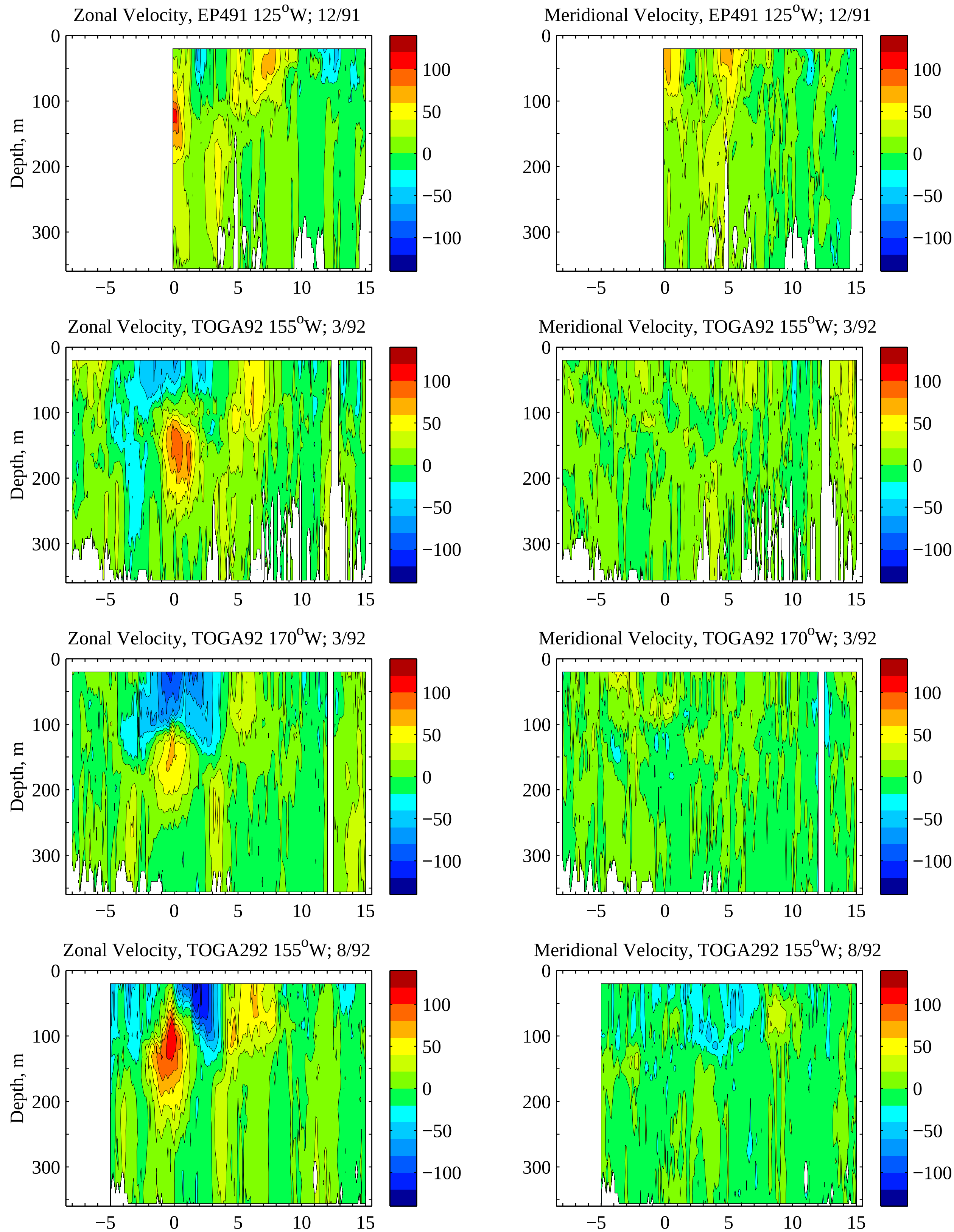


Figure 2b: Same as Figure 2a.

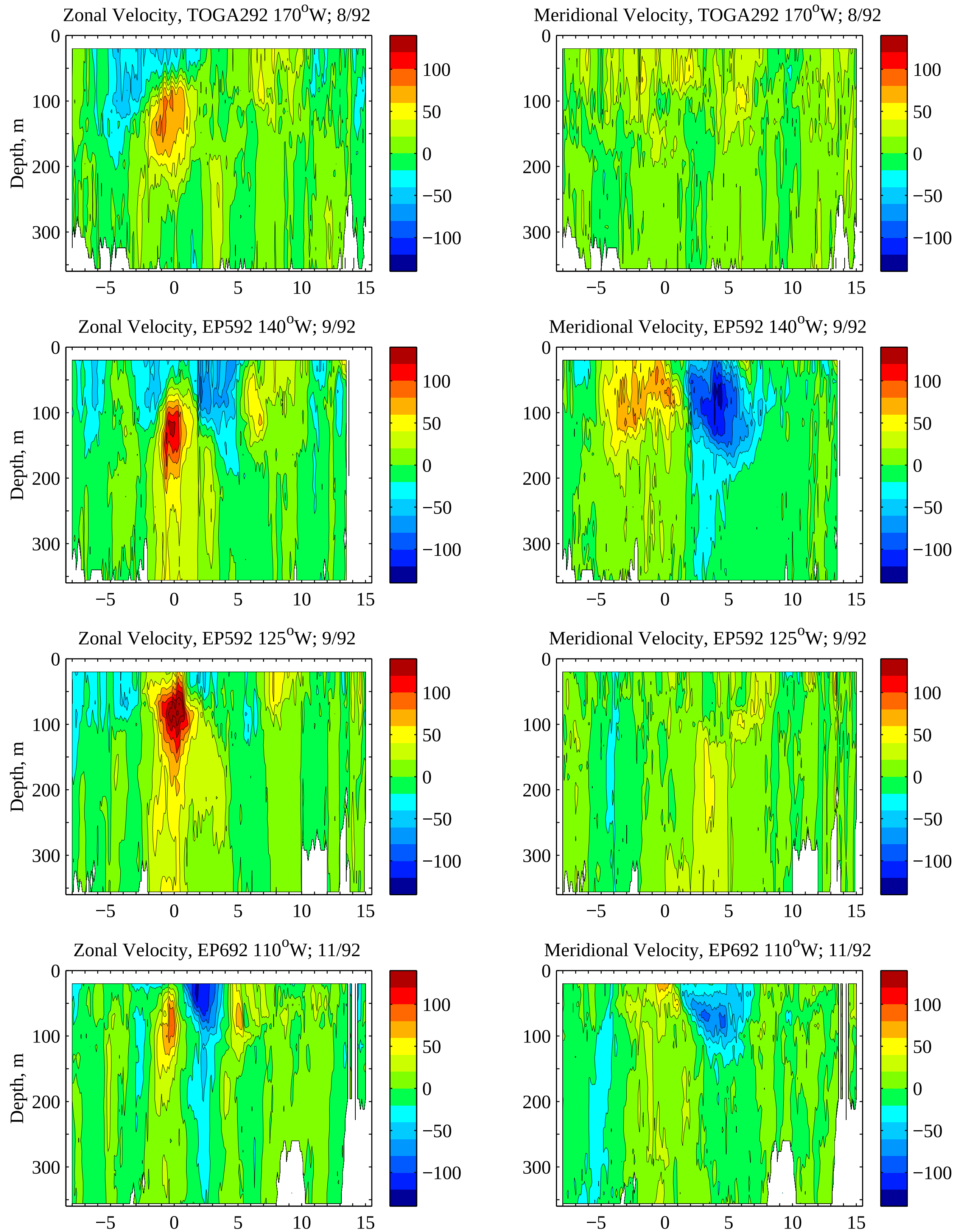


Figure 2c: Same as Figure 2a.

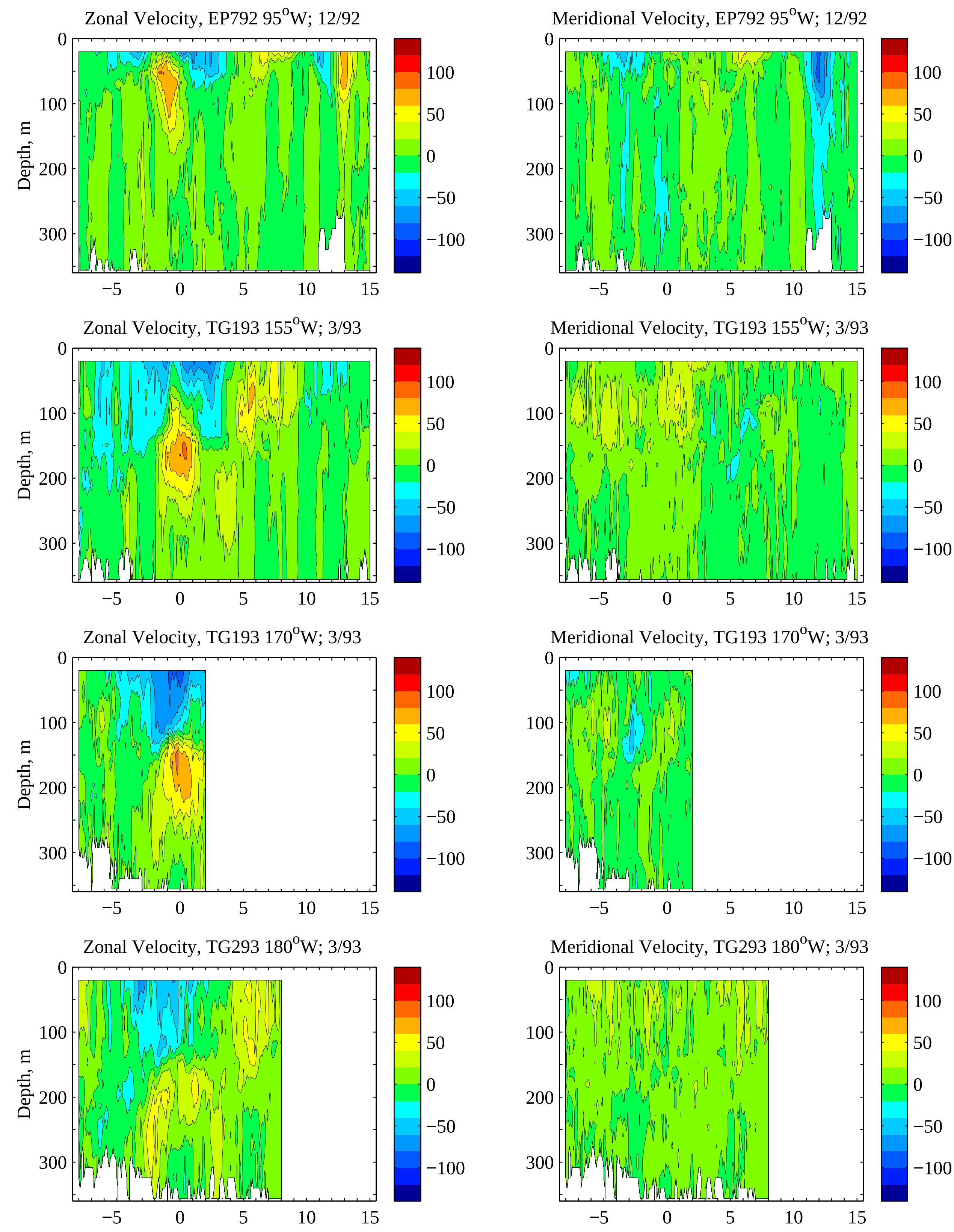


Figure 2d: Same as Figure 2a.

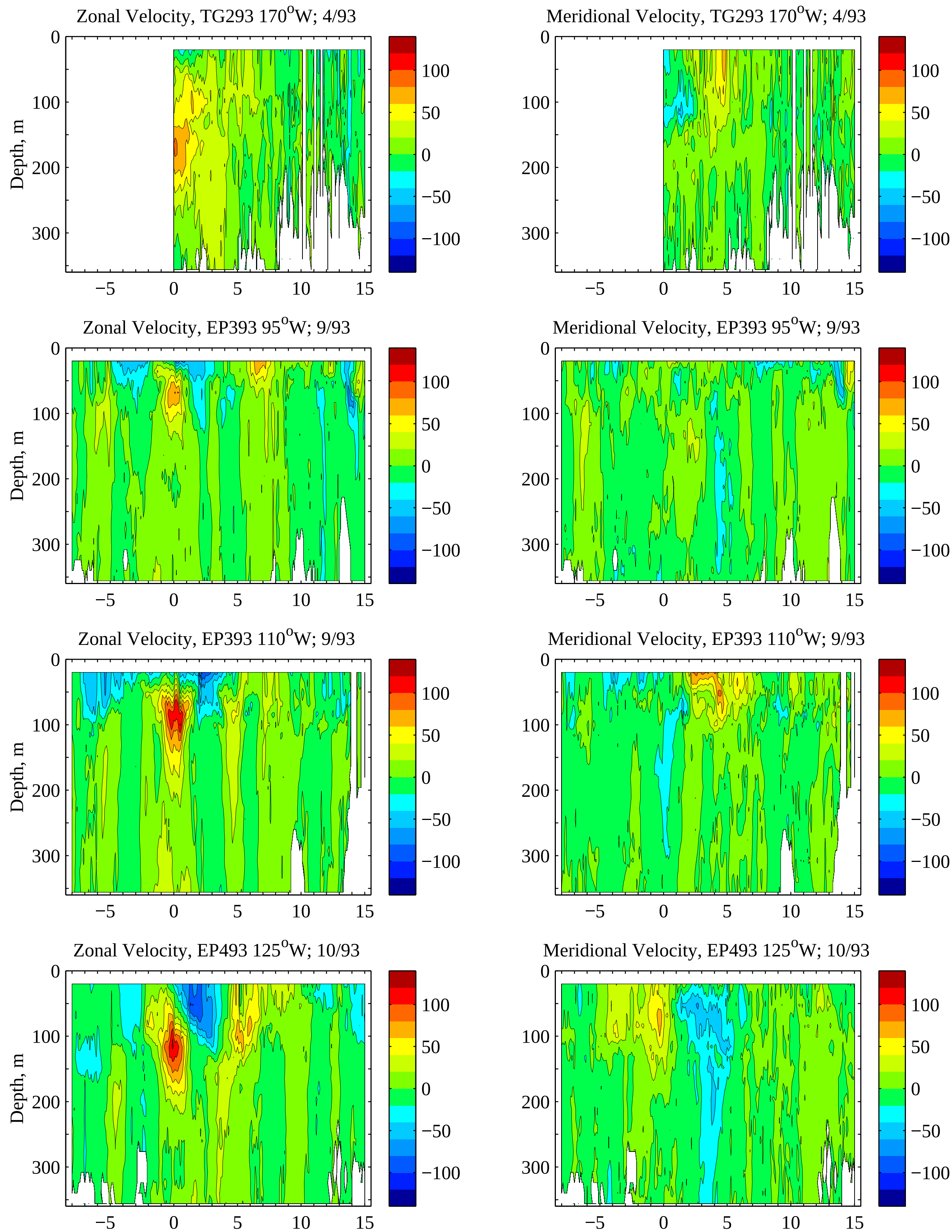
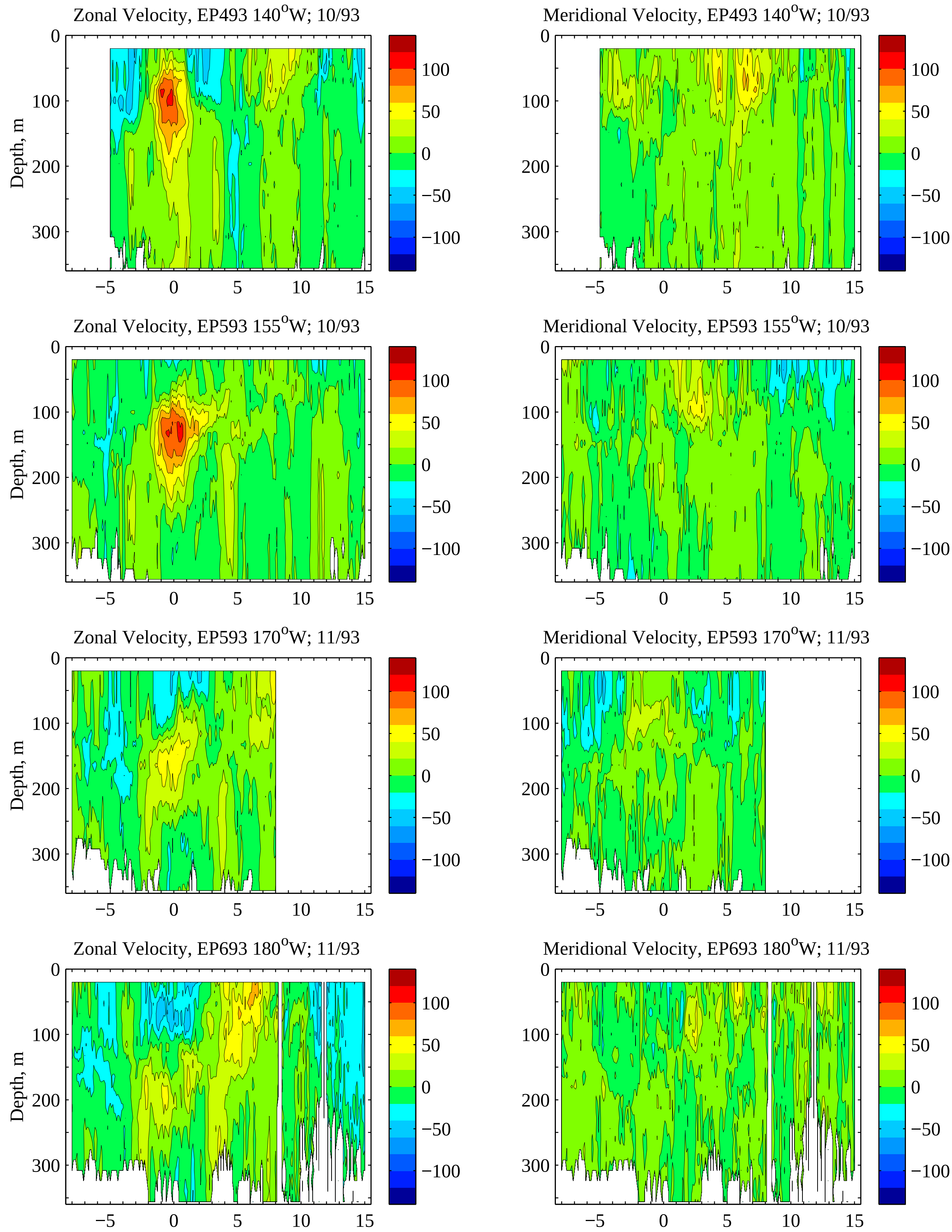


Figure 2e: Same as Figure 2a.



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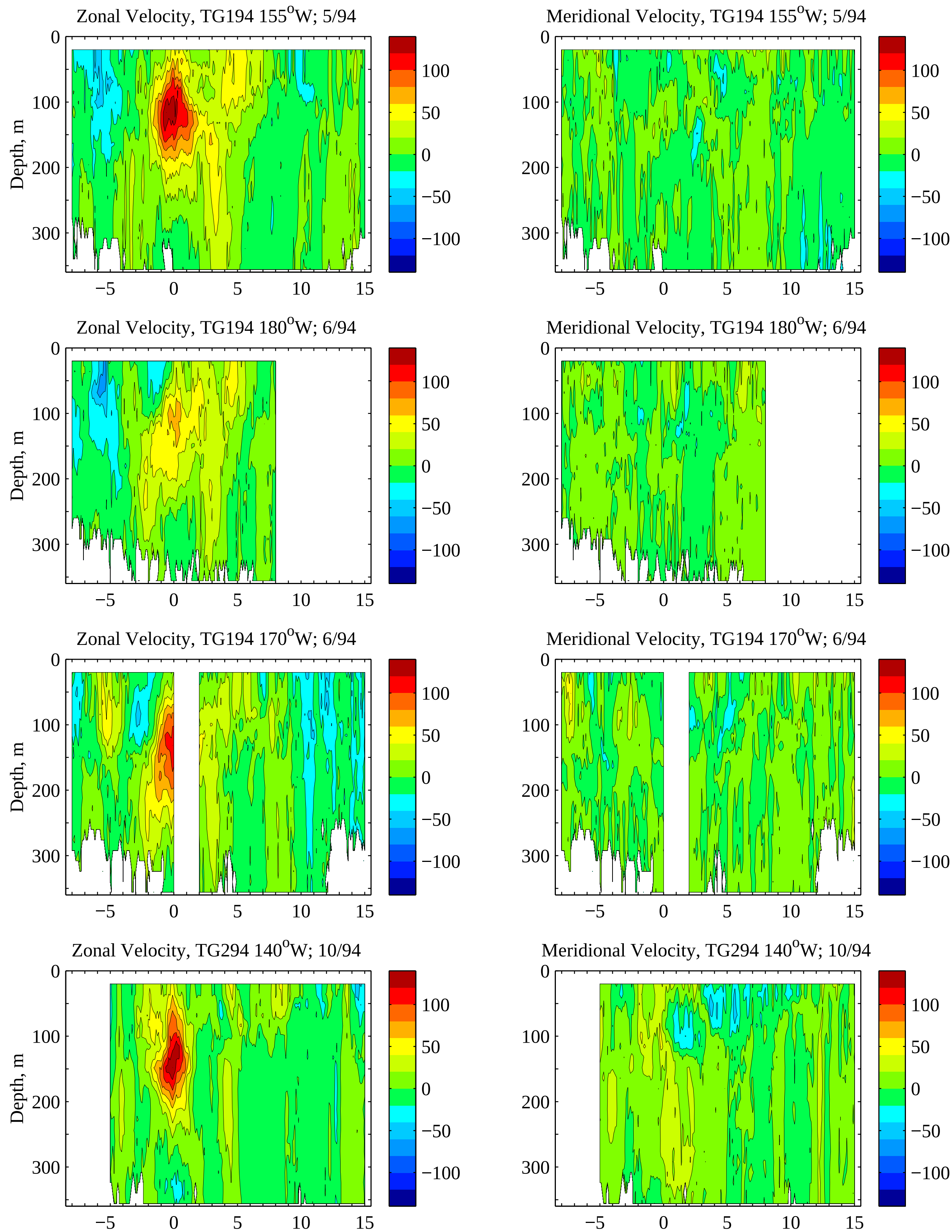

Figure 2g: Same as Figure 2a.

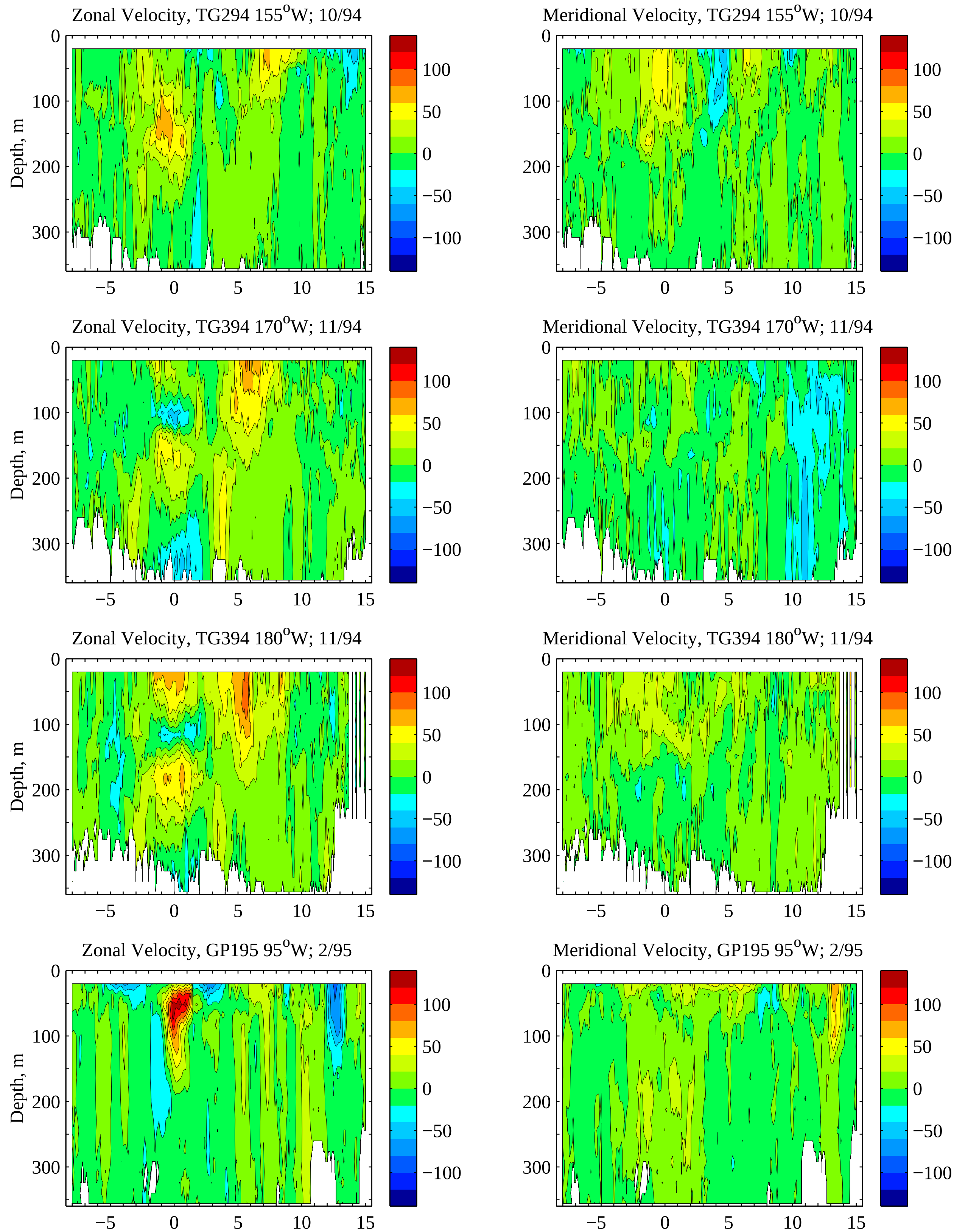

Figure 2h: Same as Figure 2a.

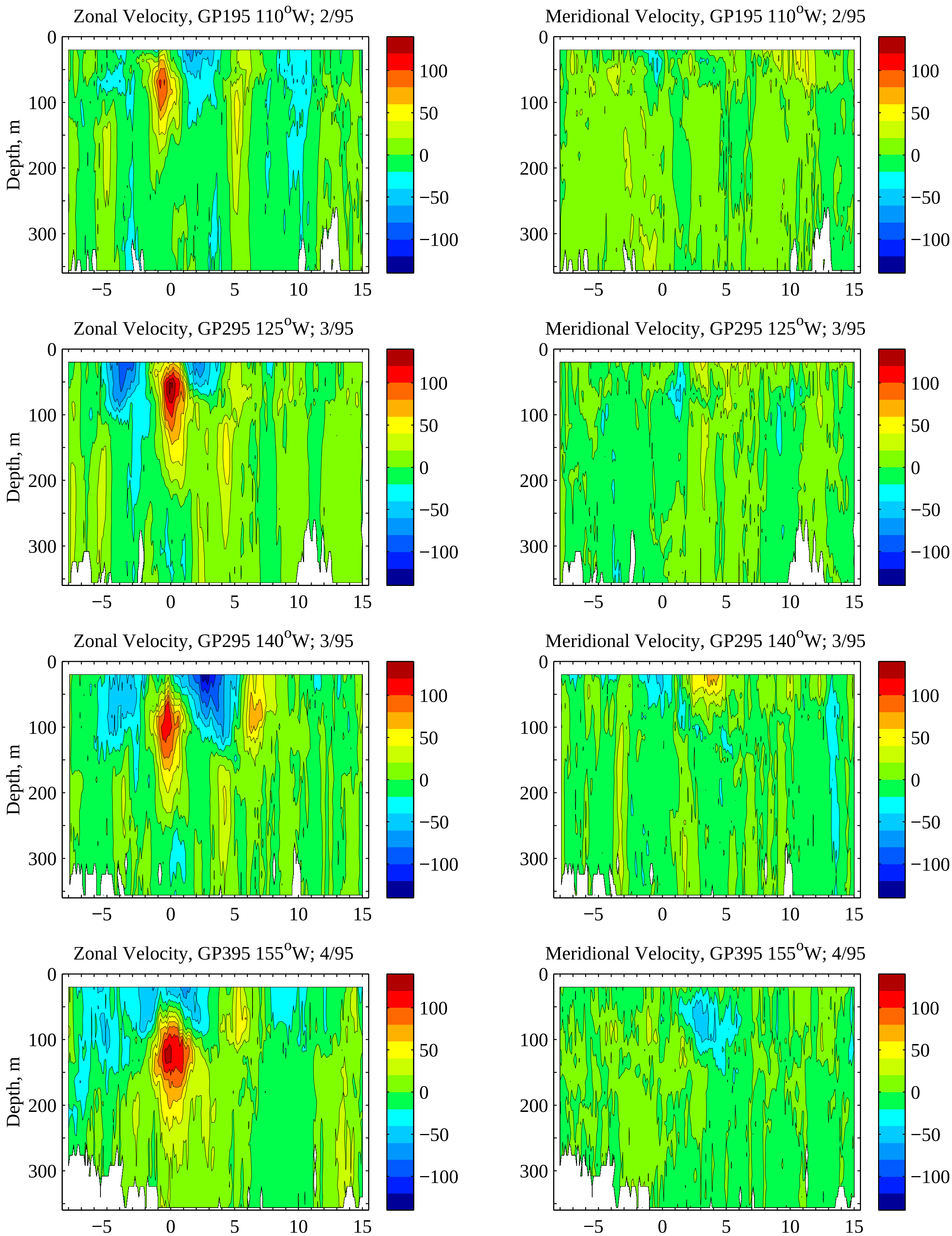

Figure 2i: Same as Figure 2a.

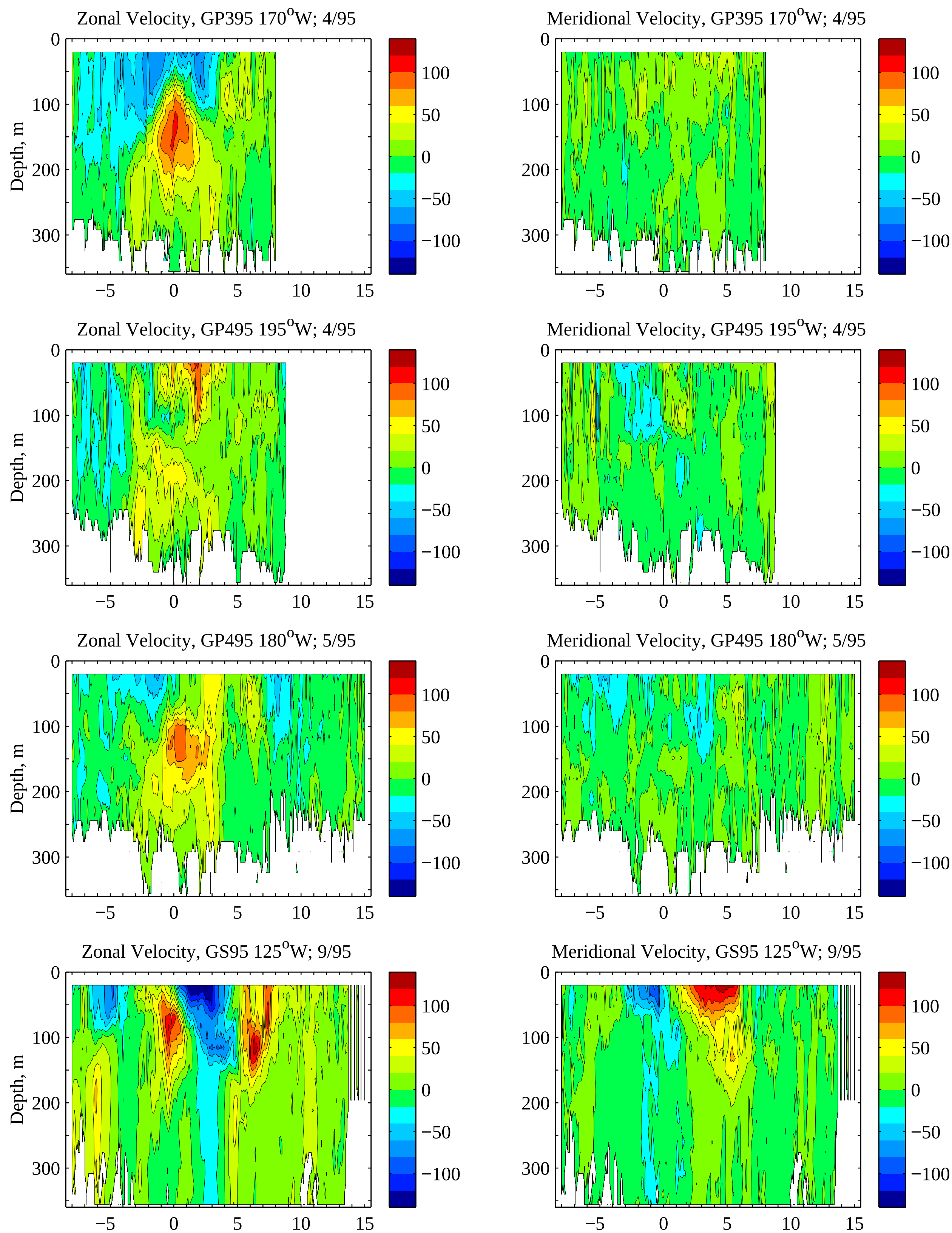

Figure 2j: Same as Figure 2a.

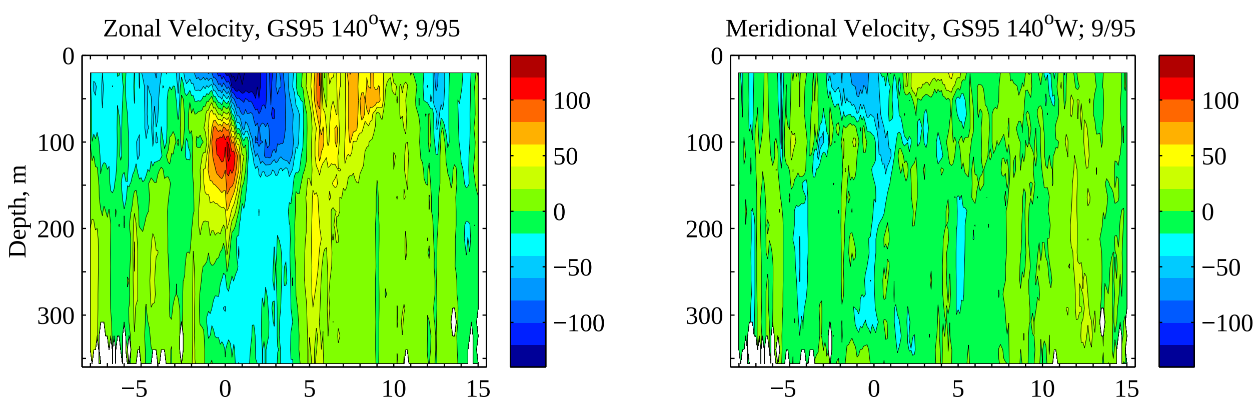

Figure 2k: Same as Figure 2a.