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Introduction to 'The 1997–8 El Niño Atlas of oceanographic conditions along the west coast of North America (23°N–50°N)'

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Abstract

Hydrographic data collected along the West Coast of North America between January 1997 and January 1999 have been compiled into a web-based Atlas of the 1997–8 El Niño event. This paper discusses the organization of the Atlas, describes the data that were incorporated into the Atlas and explains how vertical and horizontal distributions for the different properties were constructed. Examples of figures from the Atlas are shown.

Contents

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1. Introduction

The effects of the 1997–8 El Niño along the West Coast of North America were extensively documented by a series of regional oceanographic programs ranging in their geographical coverage from Baja California to British Columbia. Analysis of the evolution of the event and its biogeochemical consequences for sub-regions have been the subjects of the previous manuscripts of this issue. The available shipboard hydrographic data have also been assembled into an Atlas. The sections and charts in the Atlas use a common scale, contour interval and shading and were constructed with a single contour package. The Atlas can be downloaded or viewed at http://www. mbari. org/bog/atlas/. A copy may also be obtained from the Defense Technical Information Center (Castro et al., 2002). It is hoped that the papers in this volume, combined with readily available data and charts from the Atlas, will stimulate additional studies of the 1997–8 El Niño, e.g. assimilation of hydrographic, nutrient and chlorophyll data into numerical ocean models.

The objective of this paper is to describe the preparation and organization of the Atlas, and to facilitate its use by on-line viewers. An outline of the Atlas is given. Sampling methods are described. The spatial and temporal coverage of hydrographic data is provided. Samples of vertical sections and horizontal charts from the Atlas are shown.

2. Organization of the Atlas

2.1. Observations and methods

The Atlas is based upon shipboard hydrographic data collected by the authors' institutions along the west coast of North America, from Baja California to British Columbia, between January 1997 and January 1999. The locations of the stations are shown in Fig. 1. Most stations fall along 25 coastal sections. Between 25°N and 37°N, these sections were along sampling lines established by the California Cooperative Fisheries Investigations (CalCOFI) in 1950. Off Oregon and British Columbia, the sampling sections are those that were begun by regional programs in the late 1950s and early 1960s. Those sections sampled with the highest frequency are referred to as cardinal lines and are shown as solid dots in Fig. 1. The cardinal lines include four CalCOFI lines, 120, 90, 80, 67, which range from Guerrero Negro (~28°N) to Monterey (~37°N). Additional cardinal lines are line Glf at the entrance to the Gulf of California, COC line off Eureka (~38°N), CR line off Crescent City (~42°N), NH line off Newport (~45°N) and line P off Vancouver Island (~49°N).

The dates when these sections were sampled are shown in Table 1. Line 90 and line P were sampled 13 times; line 67, 11 times; line 80 and NH line, nine times; and CR line off Crescent City four times. The section at the entrance to the Gulf of California and the section off Eureka were occupied only three times. The sampling methods for each institution have been described in individual manuscripts of this issue (Durazo & Baumgartner, 2002; Lynn & Bograd, 2002; Collins et al., 2002; Chavez et al., 2002; Huyer, Smith, & Fleischbein, 2002; Corwith & Wheeler, 2002; Whitney & Welch, 2002). Table 2 summarizes measurement and sampling protocols for the different subregions.

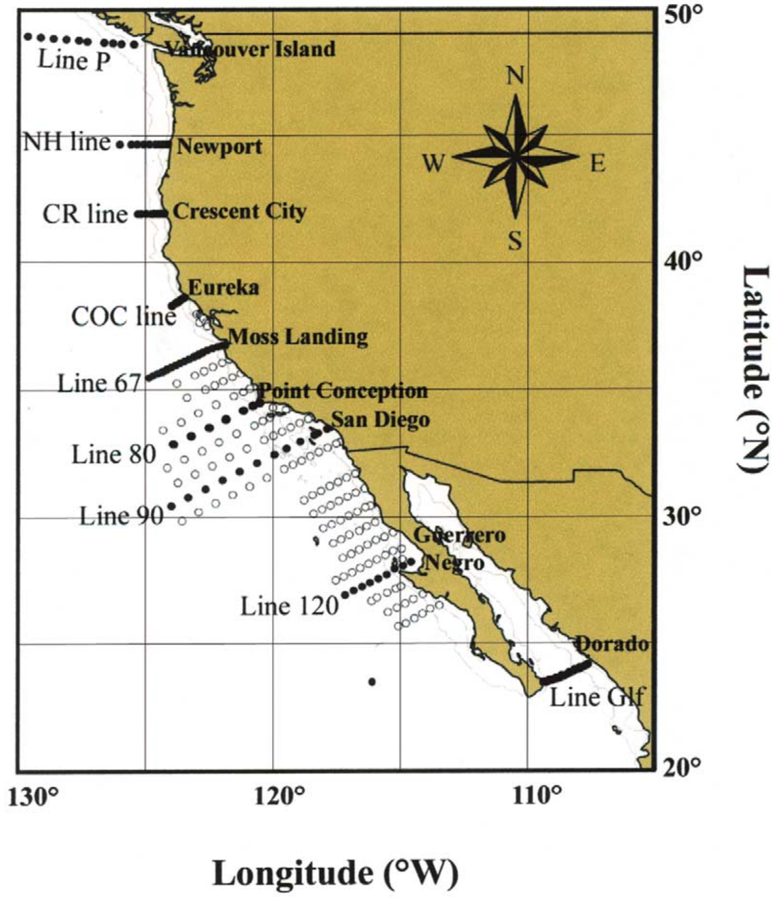

Fig. 1. Station positions. Cardinal lines are indicated by solid circles. Isobaths correspond to 100, and 1000 m.

2.2. Hydrographic data

All hydrographic data for the cardinal lines can be downloaded from the Atlas web site. The data are organized by sections (Fig. 1). For each section, there are two types of files, CTD and BOTTLE, which correspond to CTD profile and rosette bottle data for all stations along the section. The format for these data is tab delimited ASCII. The files are self-explanatory: one column is written for each parameter. Detailed explanations of the files can be found under 'CTD file format' and 'BOTTLE file format' in this section of the Atlas.

2.3. Vertical Distributions

Vertical distributions of temperature, salinity, density anomaly, nutrients and chlorophyll for the cardinal lines are presented. Sections of temperature, salinity, and density anomaly extend to 500 dbar pressure. For nutrients (nitrate, phosphate, silicate and nitrite) and chlorophyll, the sections extend to 150, 200 or 500 dbar depending upon the location of the section. The aspect ratio is the same for all sections. For this reason, the line P section extends only 700 km from shore (to station P15). Sections were contoured using the kriging option of Surface Mapping System® version 6.0.3 (Golden Software, 1995).

Table 1
Sampling dates for the most frequently sampled sections. Lines 120, 80, 90, 67, NH and P are the cardinal lines shown in Fig. 1. Line Glf is across the entrance to the Gulf of California, the COC line is about 38°N and the CR line is about 42°N

Date		Line Glf	Line 120	Line 80	Line 90	Line 67	COC Line	CR Line	NH Line	Line P
Feb	1997			02/10–02/11	02/02–02/05	02/23–02/24				02/13–02/19
										02/26–02/28
Mar	1997			03/14–03/15	03/14–03/15	03/06–03/07				
Apr	1997			04/15–04/17	04/06–04/09					
May	1997									
Jun	1997					06/02–06/05				06/05/–06/12
Jul	1997			07/13–07/14	07/05–07/08	07/26–07/28			07/28–07/30	
Aug	1997									08/21–09/02
Sep	1997				09/24–09/26	09/12–09/14			09/19–09/20	09/15–09/17
Oct	1997		10/01–10/02	10/02–10/04		10/11–10/13				10/24–10/27
Nov	1997	11/19–11/20				11/08–11/09	11/19–11/20	11/21	11/15–11/16	
Dec	1997				12/14–12/15					12/01–12/03
Jan	1998				01/27–01/29	01/21–01/23				01/19–01/21
Feb	1998		02/08–02/09	02/06–02/09					02/01–02/02	02/20–02/25
Mar	1998				03/12–03/14	03/21–03/23				03/04–03/05
Apr	1998			04/15–04/16	04/06–04/09	04/14–04/16	04/07–04/08	04/09–04/10	04/04–04/05	04/08–04/10
May	1998	05/28–05/30			05/17–05/19	05/09–05/12				
Jun	1998				06/18–06/20				06/03	06/04–06/10
Jul	1998		07/25–07/26	07/21–07/22	07/13–07/15	07/02–07/02				
Aug	1998	08/02–08/04			08/13–08/15	08/22–08/24	08/11	08/09	08/06–08/07	08/27–09/01
Sep	1998			09/25–09/26	09/17–09/19				09/24–09/25	09/08–09/18
Oct	1998		10/27–10/29		10/17–10/19					
Nov	1998				11/19–11/21	11/06–11/09		11/18–11/19	11/16–11/17	
Dec	1998				12/11–12/13					

Table 2
Sampling methods

Parameter	Sub-region	Sensor or Analytical procedure	Reference
Salinity-temperature-pressure	Line Glf	SeaBird 911 Plus™ CTD — rosette package	
	Line 120	SeaBird 911 Plus™ CTD — rosette package	
	Line 90 & 80	SeaBird 911 Plus™ CTD — rosette package	
	Line 67	SeaBird 911 Plus™ CTD — rosette package	
	COC, CR and NH lines	SeaBird 911 Plus™ CTD — rosette package	
	Line P	SeaBird CTD — rosette package	
Nutrients	Line 120	FIA[a] with a QuickChem 8000	Carranza, et al. (1999)
	Line 90 & 80	SFA[b] with a Technicon AA II autoanalyzer	Atlas, Hager, Gordon, & Park. (1971)
	Line 67	SFA with an Alpkem RFA-300	Sakamoto, Friederich and Codispoti (1990)
	COC, CR and NH lines	SFA with a Technicon AA II autoanalyzer (September 1997 and April 1998) SFA with an Alpkem RFA-300 (August 1998 and November 1998)	Gordon, Jennings, Ross and Krest (1995)
	Line P	SFA with a Technicon AA II autoanalyzer	Barwell-Clarke & Whitney (1996)
Chlorophyll a	Line 120	Extraction with 90% acetone and fluorometry with a Turner Designs™ 10	Venrick & Hayward (1984)
	Line 90 & 80	Extraction with 90% acetone and fluorometry with a Turner Designs™ 10	Venrick & Hayward, 1984
	Line 67	Extraction with 90% acetone and fluorometry with a Turner Designs™ 10	Venrick & Hayward (1984)
	COC, CR and NH lines	Extraction with 95% methanol and fluorometry with a Turner Designs™ 10	Parsons, Maita, & Lalli (1984)
	Line P	Extraction with 90% acetone and fluorometry with a Turner Designs™ 10	Strickland & Parsons (1968)

[a] Flow injection analysis
[b] Segmented flow analysis

Fig. 2 shows an example of the vertical distributions of temperature, nitrate and chlorophyll in January 1998 along CalCOFI line 67 (off Moss Landing, California). This corresponded to the extreme El Niño conditions observed for this section (Collins et al., 2002). Waters warmer than 14°C occupied the upper 80 dbar of the water column and between 250 km and 50 km isotherms tilted down toward the coast. Nitrate distributions were similar to the temperature distribution, with nitrate levels lower than 1 μmol/l in the upper 80 dbar along the entire section. Chlorophyll levels were also low with maximum values of 0. 5 mg/m^3.

2.4. Time-distance distributions

Temporal variation of hydrographic properties as a function of distance from shore are shown for three depths (0, 100, 300 m) and three isopycnals (25.8, 26.2, and 26.6 kg/m^3) between January 1997 and January 1999. These time–distance figures were completed for five sections: Lines 90, 80, 67, NH and P. Variables include temperature, salinity, density, nitrate, phosphate, silicate, nitrite, chlorophyll and pressure.

Fig. 3 is a sample of these time–distance figures, illustrating the temporal evolution of the pressure of

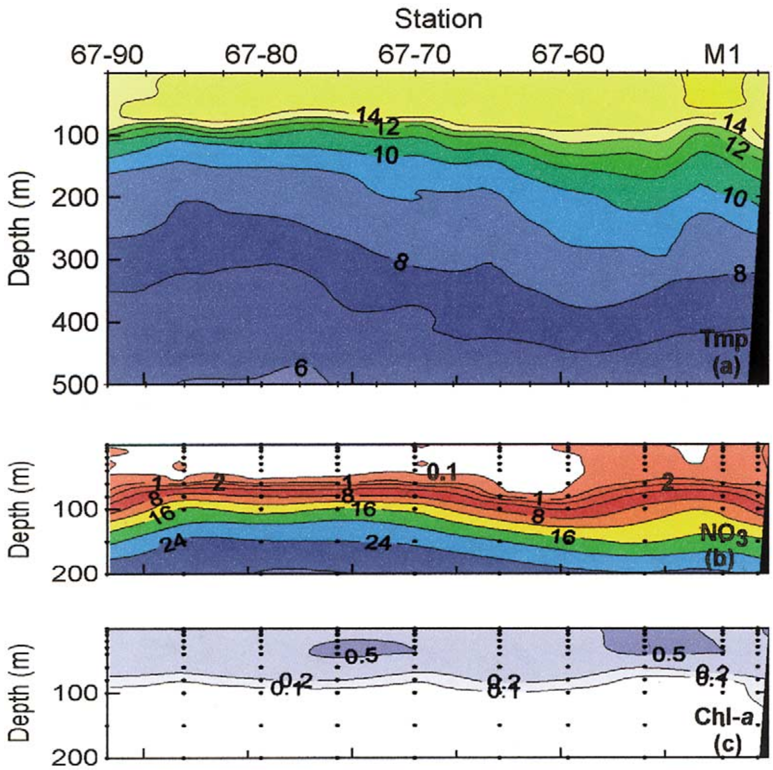

Fig. 2. Vertical sections off Moss Landing, California, for January, 1998. (a) Temperature, °C. (b) Nitrate, μmol/l (c) Chlorophyll, mg/m³.

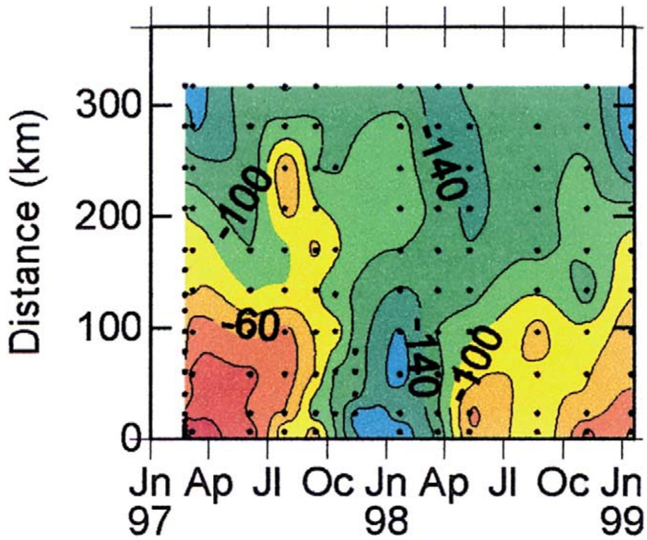

Fig. 3. Temporal variability of the pressure (dbar) of the 25. 8 kg/m³ isopycnal surface along CalCOFI line 67 off Moss Landing, California. Contour interval is 20 dbar.

the 25.8 kg/m^3 isopycnal along CalCOFI line 67 off Moss Landing, CA. Greatest variability occurred within the first 100 km from shore. In January 1997 and January 1999, the 25.8 kg/m^3 isopycnal shoaled toward the coast to a pressure of 20 to 60 dbar. During El Niño conditions in January 1998, the onshore slope reversed, and pressures of 180 dbar were observed at the coast.

2.5. Horizontal distributions

The final section of the Atlas contains charts of horizontal distributions for January, April, and July 1998. Temperature, salinity and nitrate charts at 50 dbar as well as the geopotential thickness of the upper 500 dbar are shown. The difference between the temperature, salinity, and nitrate fields and corresponding average conditions reported by the National Oceanographic Data Center (Antonov et al., 1998; Boyer et al., 1998; Conkright et al., 1998) are also shown. For temperature and salinity, monthly average mean fields were used; but for nitrate only a seasonal average was available. Both the monthly and seasonal climatologies were given on a one-degree grid. The 50 dbar level was chosen because it was the depth of maximum temperature difference between January 1998 and the mean January climatology.

A sample chart for January 1998 is shown in Fig. 4. In January 1998, waters were warmer than normal along the entire coast (Fig. 4a). Temperature anomalies at 50 dbar (Fig. 4b) were greater than those at the sea surface (not shown). The greatest warming occurred next to the coast, exceeding 4°C in the southern California bight. Poleward flow was observed along the eastern boundary of the North Pacific between October 1997 and February 1998 (Durazo & Baumgartner; Lynn & Bograd; Collins et al.; Huyer et al.; Kosro; all this issue). Isosteres (Fig. 4c) indicated a clearly defined northward geostrophic flow along the southern California Bight within 200 km from shore. Off Moss Landing (~37°N), the core of northward geostrophic flow was located further offshore between 100 and 250 km from the coast, while at the most

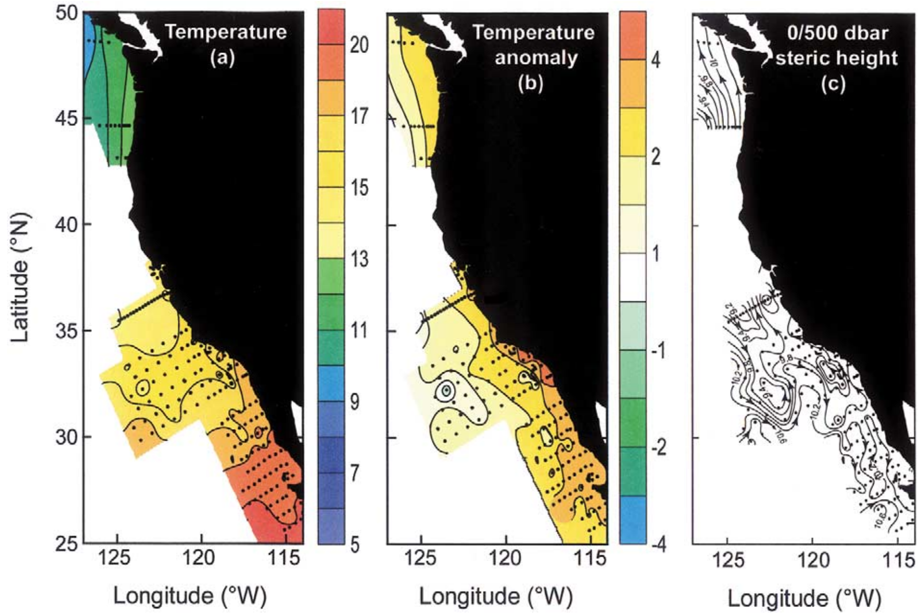

Fig. 4. January 1998 distributions of (a) 50 dbar temperature, °C, (b) 50 dbar temperature anomaly, °C, and (c) 0–500 dbar steric height, m^2/s^{-2}. Anomalies were calculated using monthly averages reported by the National Oceanographic Data Center (Antonov et al., 1998).

northern sections, northward currents dominated along the entire NH line and to more than 200 km offshore along line P.

3. Discussion

An Atlas has been assembled from available hydrographic data along the West Coast of North America to aid in the documentation of ocean conditions during the 1997–8 El Niño. Atlas fields show clearly that the region of largest El Niño variability was over the shelf-slope region, at depths normally occupied by the upper pycnocline, and extending along the entire coast. Charts of coastal anomalies were produced from a one-degree ocean climatology. The coastally trapped character of these anomalies would be better represented if a climatology with finer across shore resolution was available.

The Atlas also illustrates a number of sampling problems. There were significant spatial gaps in the horizontal distributions. For example, no sections were sampled off northern California in January 1998, and in April 1998 there were no data for Baja California. An offshore extension of hydrographic sampling in the region from central California to Oregon is needed to resolve variability within the core of the California Current. The first indication of El Niño along the eastern boundary was manifested as strong subsurface poleward flow between 200 and 500 dbar, and the chemistry of this feature was undersampled.

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