

Comparison of the Results of two West Pacific Oceanographic Expeditions FOC (1971) and WEPOCS (1985-86)

Jean René DONGUY⁽¹⁾, Gary MEYERS⁽²⁾ and Eric LINDSTROM⁽²⁾

⁽¹⁾ *Centre ORSTOM de Brest, IFREMER
BP 70, 26263 Plouzane - France*

⁽²⁾ *CSIRO Division of Oceanography, GPO Box 1538
Hobart, Tasmania 7001 - Australia*

1. Introduction

After study of the 1982-83 ENSO, oceanographic research has focused on phenomena occurring in western equatorial Pacific. Consequently, the Western Equatorial Pacific ocean Circulation Study (WEPOCS) was launched in order to study problems located in this area such as the circulation, heat storage and water properties.

Two expeditions were conducted (June-August 1985, WEPOCS1; January-February 1986, WEPOCS2) by Australian and US scientists, in the region north and east of Papua New Guinea (PNG) (Fig. 1) (Lindstrom et al. 1987).

Fifteen years before, a similar series of cruises occurred in the same area (Fig. 1) and at the same season (January-February 1971, FOC1; June-July 1971, FOC2) conducted by French scientists from centre ORSTOM de Nouméa (Anonyme, 1980).

The methods of investigation present large differences as a result of technological advancements. During FOC cruises, hydrographic casts with Niskin bottles provided discrete measurements of temperature, salinity, oxygen and nutrient. Current measurements were obtained with HYTECH currentmeters used as profilers from the surface to 600 meters depth. Similar data were provided by WEPOCS cruises but using CTD stations (including discrete sampling for oxygen and nutrients) and a ship board Acoustic Doppler current Profiler (ADCP).

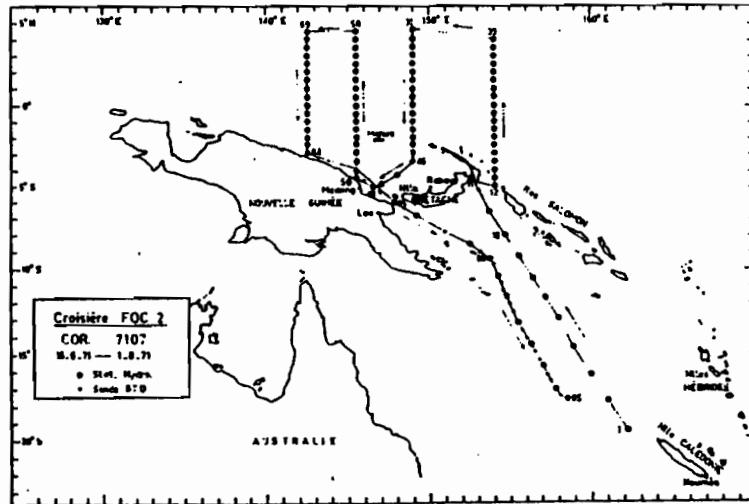
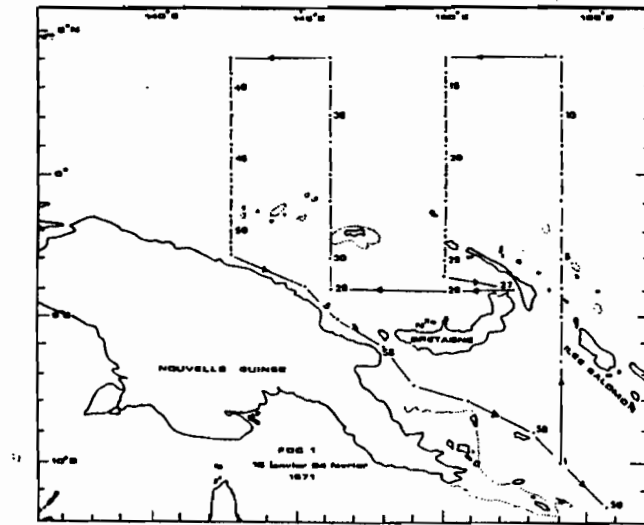
Both of these cruise series point out interesting results concerning the New Guinea Coastal Undercurrent (NGCU) the source of the Equatorial Undercurrent, the Pacific Equatorial Monsoon jet and upper ocean heat storage.

2. New Guinea Coastal Undercurrent

Northwest of Vitiaz strait, along the coast of Papua New-Guinea, a subsurface northward flow was found during the four cruises. The velocity maximum is usually centred at 200 meter depth. As the measurements of the four cruises stopped at 142°E, it is not certain now much of the transport of the undercurrent was caught by the eastward Equatorial Undercurrent and how much continues to the west.

The reverse of the monsoon has no effect on the direction of the NGCU : figure 2 shows during FOC2 (June-July 1971) at 142°30'E a westward core of 40 cm.s⁻¹ and during WEPOCS2 (January-February 1986) at 143°E a westward core of 50 cm.s⁻¹. This velocity core is associated with a spreading of the 15°C-25°C isotherms against the shore. This spreading may be easily explained during WEPOCS2 when the NGCU is covered by a surface eastward current due to the N-W monsoon.





WEPOCS 1-CTD STATIONS

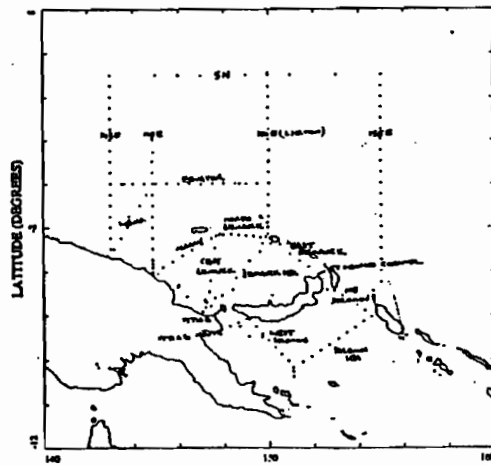


FIG.1. FOC1 (up), FOC2 (middle) and WEPOCS1 (down) cruises. Note that WEPOCS2 (not shown here) has the same design as WEPOCS1.

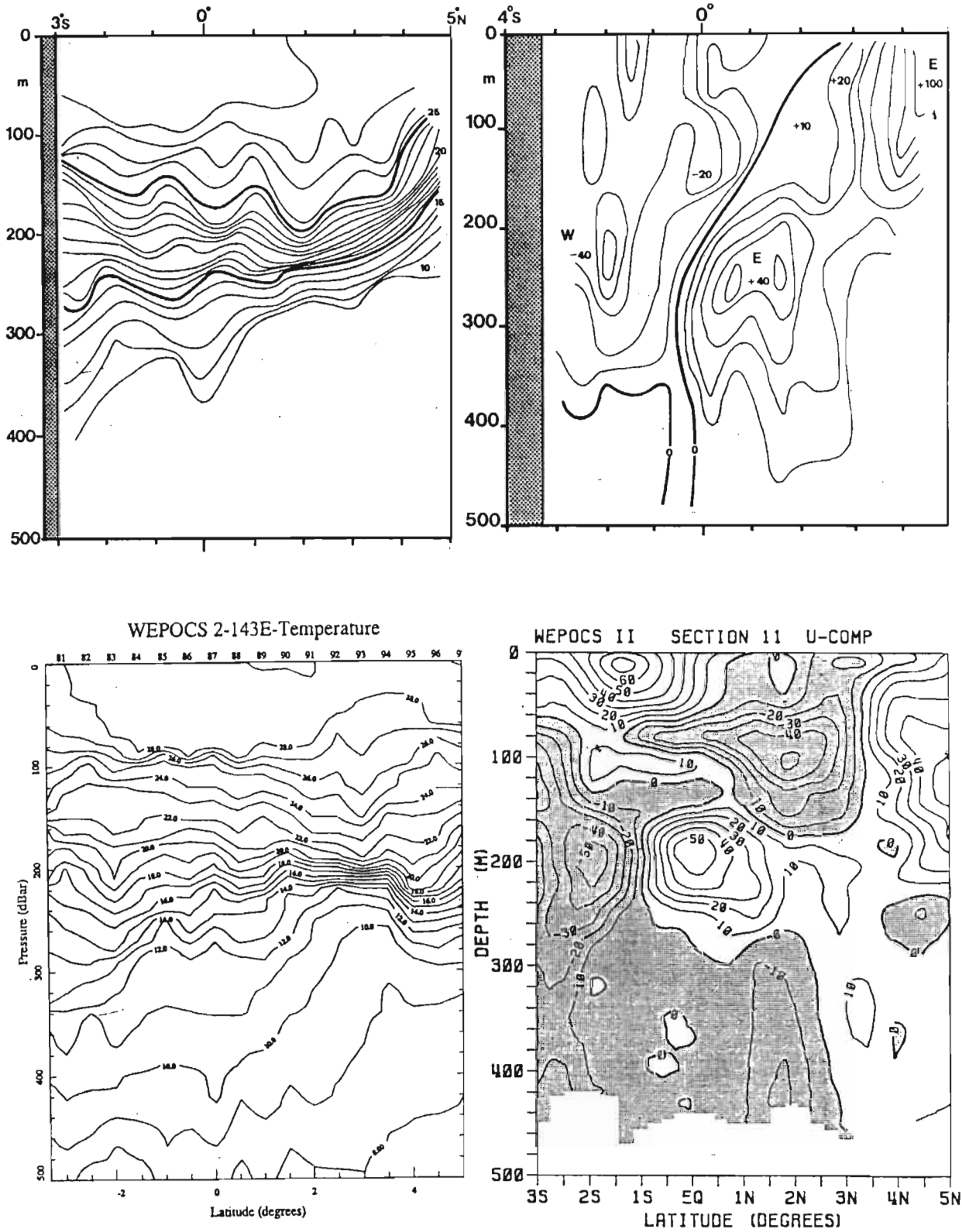


FIG.2. Sections of temperature and zonal velocity (cm s^{-1}), in June-July 1971 at $142^{\circ}30'E$ during FOC2 (upward panel) and in Jan.-Feb. 1986 at $143^{\circ}E$ during WEPOCS2. Shaded areas and negative values indicate westward flows.

3. Source of the Equatorial Undercurrent

Isopycnal analysis for WEPOCS by Tsuchiya et al. (1989) provides interesting informations concerning the source of the Equatorial Undercurrent. A comparison with FOC cruises is added in this analysis.

At 300 cl/t (fig. 3), corresponding to 150-220 meter depth, salinities exceeding 35.6 extend to 146°E during the two series of cruises FOC and WEPOCS and have a westward extension. During the WEPOCS cruises, the high salinity tongue extends mainly through the Vitiaz Strait and along the coast of New Guinea, carried by the NGCU. A secondary source takes place north of New Ireland.

During the FOC cruises, the main source of the high salinity may occur north of New Ireland and the salinities exceeding 35.6 extends to 146°E during FOC1 and 143°E during FOC2, instead 150°E during WEPOCS. In the FOC data the secondary source is Vitiaz Strait (Colin et al., 1973), however the resolution of WEPOCS data in the Vitiaz Strait region is much greater.

At 200 cl/t, corresponding to 200-250 meters depth, there are two sources of water extending westward, one characterized by low oxygen content flowing north of New Ireland, other characterized by high oxygen content flowing through Vitiaz Strait along the coast of New Guinea (Fig. 4).

According to Tsuchiya (1968), low oxygen water is carried westward by the South Equatorial Current from the eastern Pacific. The values are increasing from the east to the west. High oxygen water comes from the Coral Sea and the values are decreasing westward away from the PNG coast. It seems that the convergence and the mixing of these two kinds of water lead to a water containing 3.4 ml/l of oxygen. This water is feeding the EUC in the vicinity of 140°E (Rougerie, 1969).

This feature is corroborated by oxygen content at 160 cl/t (220-300 meter depth) (Fig. 5). During the four cruises, high values are found from Coral Sea to the coast of New Guinea, whereas low values (less than 3.2) occur north of New Ireland reaching 145°E during WEPOCS cruises and only 153°E during FOC cruises.

4. Equatorial Monsoon Jet

During the N-W monsoon (January-February), westerlies are prevailing in the equatorial zone. At this time, the westward South Equatorial Current is replaced by an eastward current distinct from the Equatorial Undercurrent. Subsurface remnants of Westward flow are embedded between the surface eastward current and the eastward undercurrent. The surface eastward current is named Pacific Equatorial Monsoon Jet (Lindstrom et al., 1987).

This feature occurred in January-February during the cruises FOC1 and WEPOCS2. At 154°E and 155°E (Fig. 6), the Pacific Equatorial Monsoon Jet is exactly located on the equator, whereas at 142°30E and 143°E (fig. 7) it has shifted to the south.

Some occurrences of eastward flow at the surface are observed in the June-July cruises and may be the results of unseasonable transient wind forcing. The current system observed at 143°E and 155°E (Fig.9) in June-July 1985, is not noticeable at 165°E at the same period (Delcroix et al., 1987; Fig.4d). This observation is in favor of an explanation involving the transient influence of a wind change as already suggested by Hisard et al. (1970).

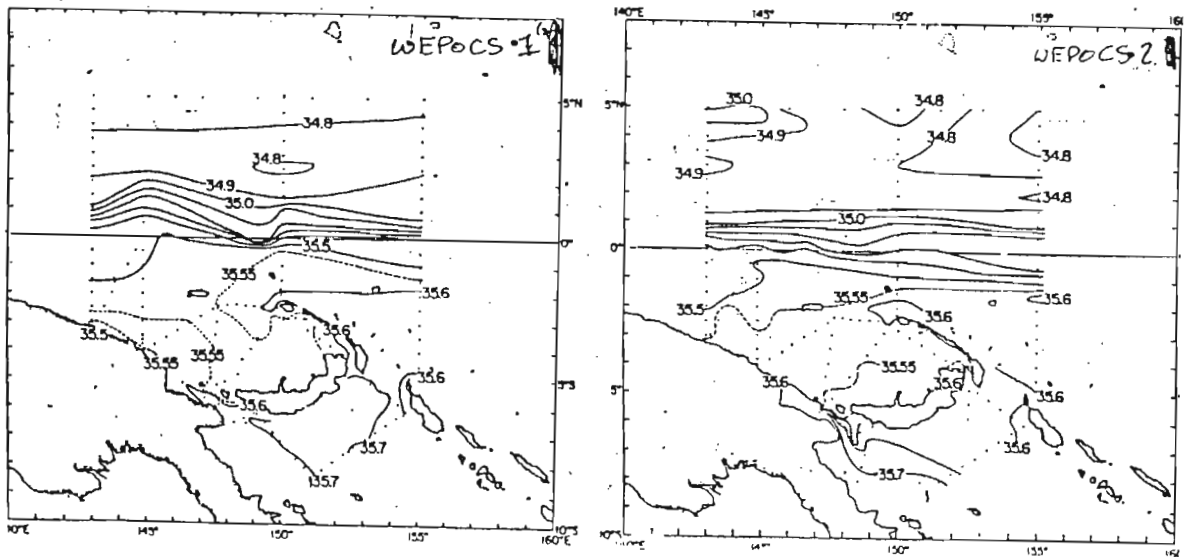
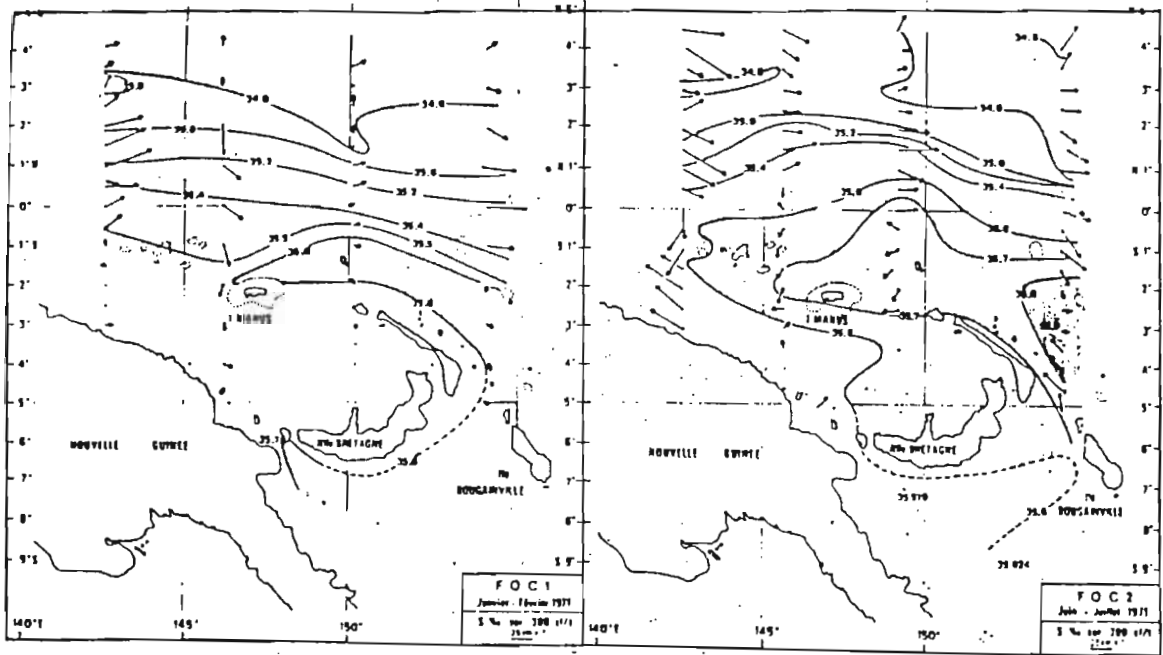


FIG.3. Salinity on surface 300 c.l.t.⁻¹, during FOC1 (upper left), FOC2 (upper right), WEPOCS1 (lower left) and WEPOCS2 (lower right).

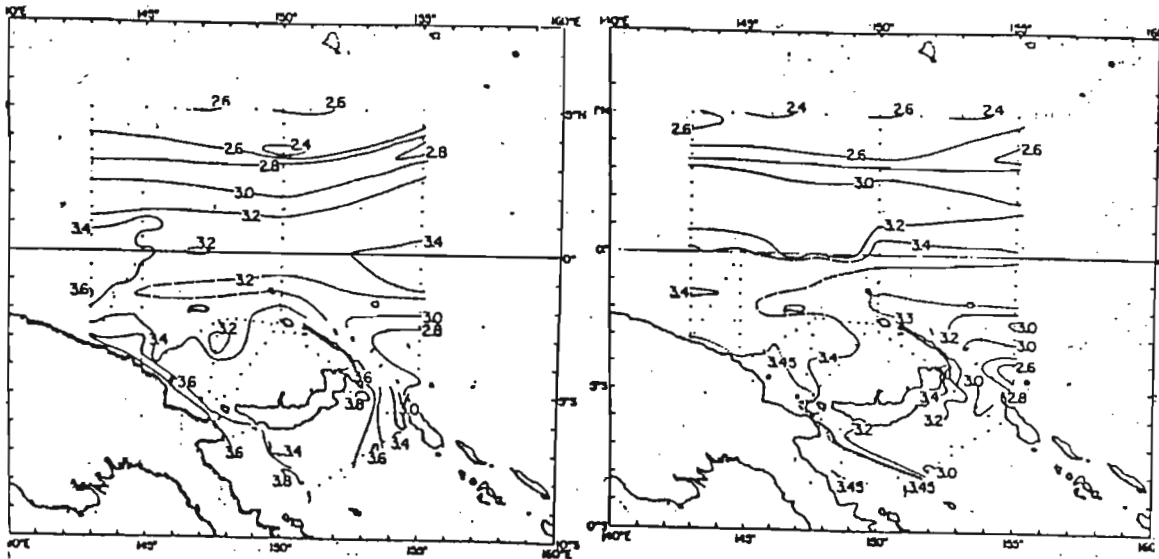
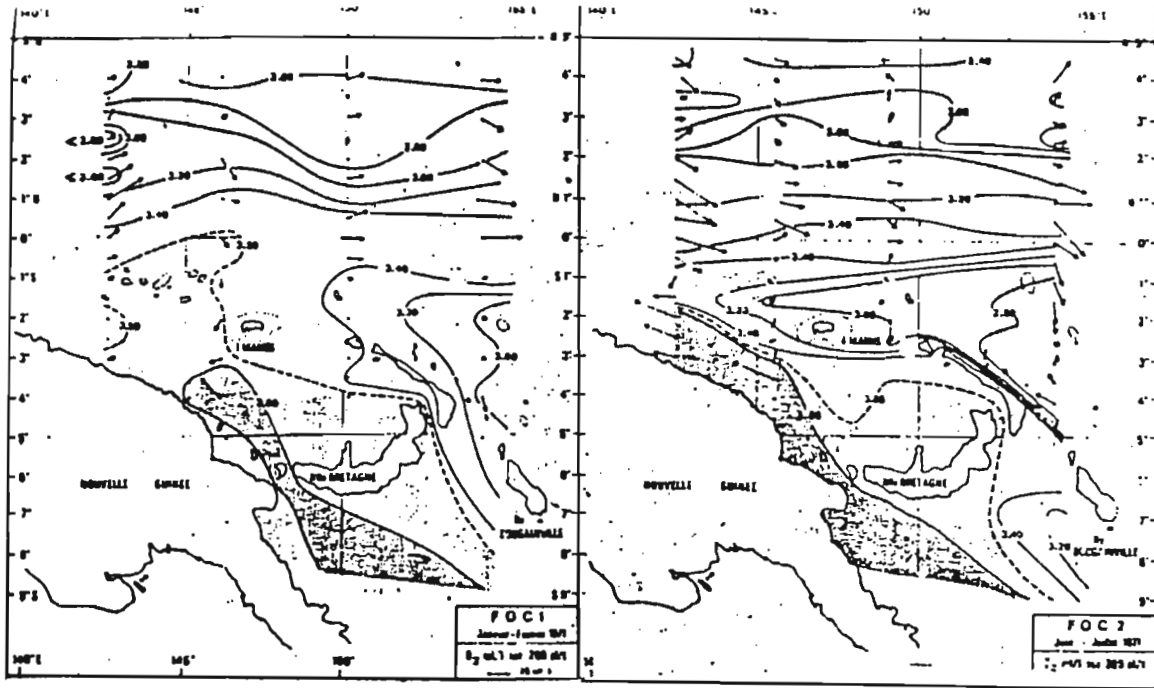


FIG.4. Oxygen (ml.l⁻¹) on surface 200 cl.t⁻¹, during FOC1 (upper left), FOC2 (upper right), WEPOCS1 (lower left) and WEPOCS2 (lower right).

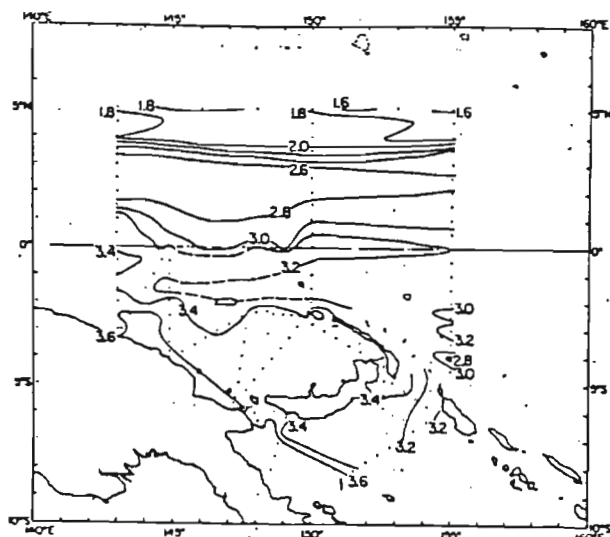
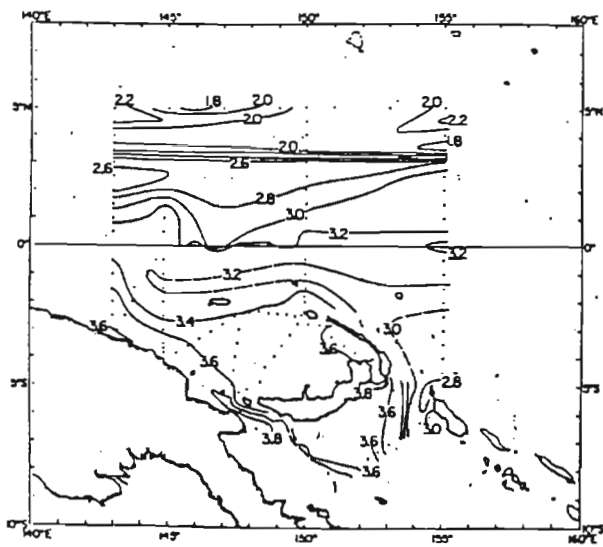
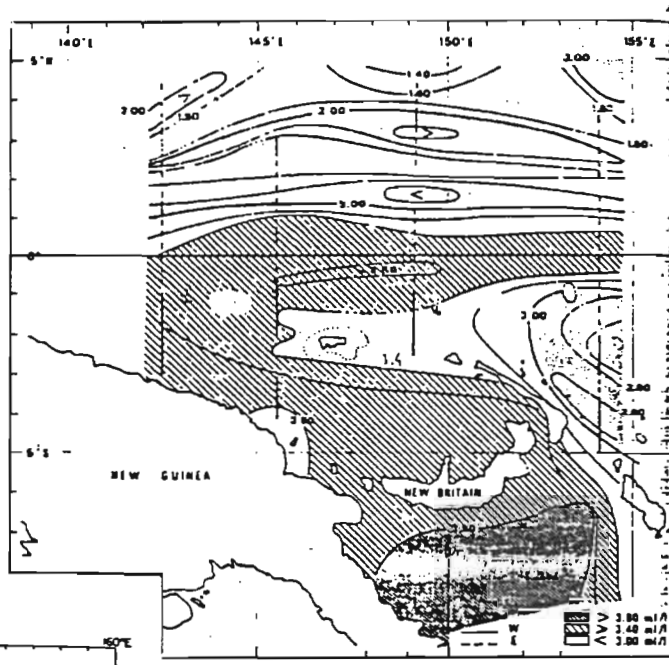
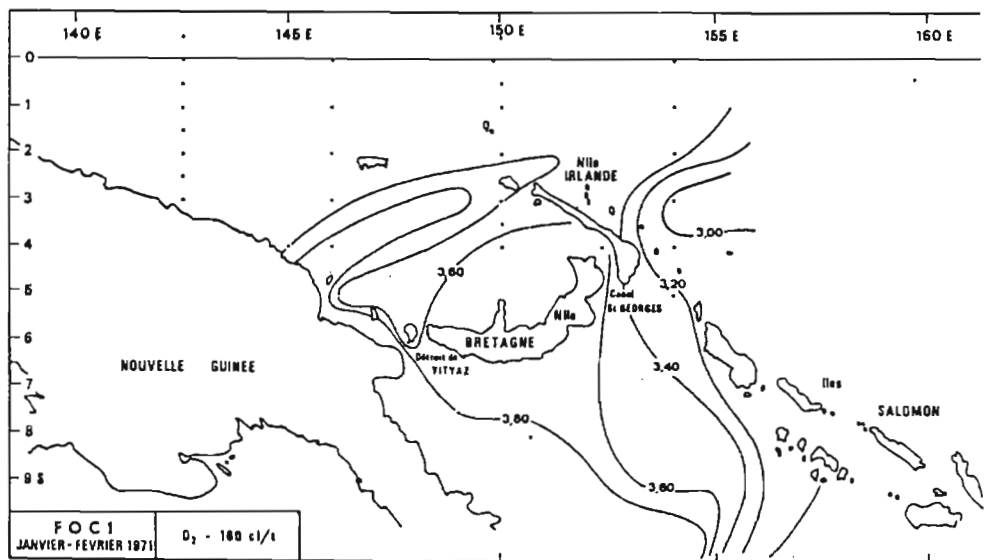


FIG.5. Oxygen (ml.l^{-1}) on surface 160 cl.t^{-1} , during FOC1 (upper left), FOC2 (upper right), WEPOCS1 (lower left) and WEPOCS2 (lower right).

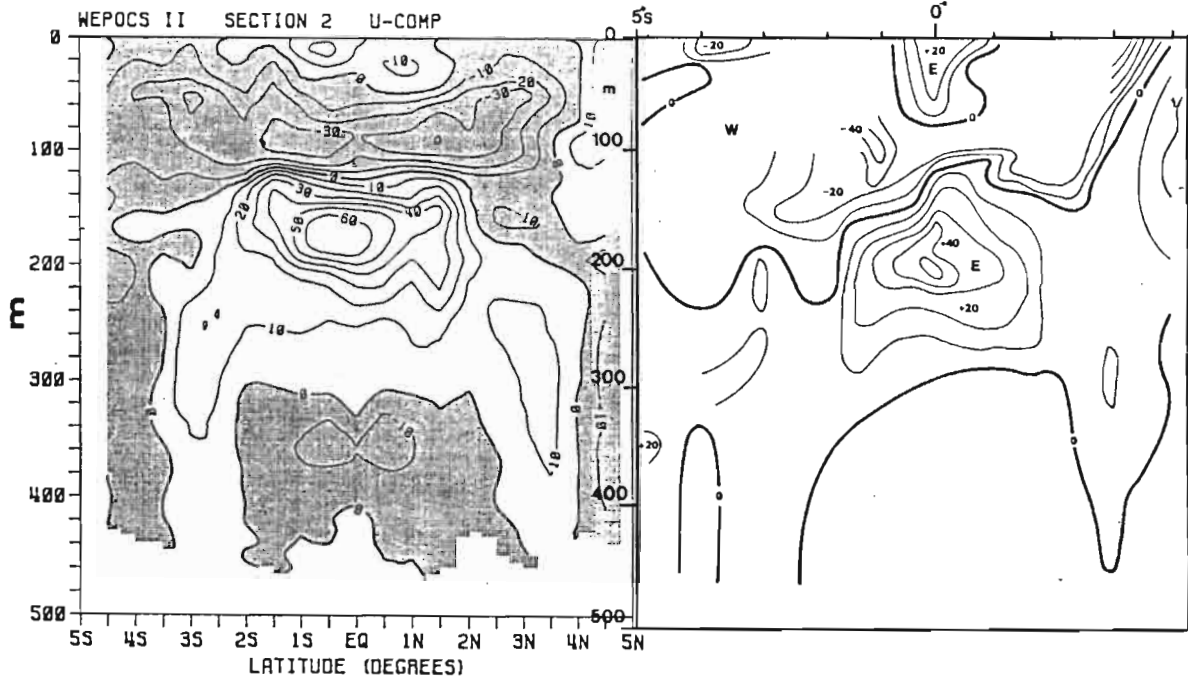


FIG.6. Section of zonal velocity ($\text{cm}\cdot\text{s}^{-1}$) during FOC1 (right) at 154°E and WEPOCS2 (left) at 155°E . Shaded areas and negative values indicate westward flows.

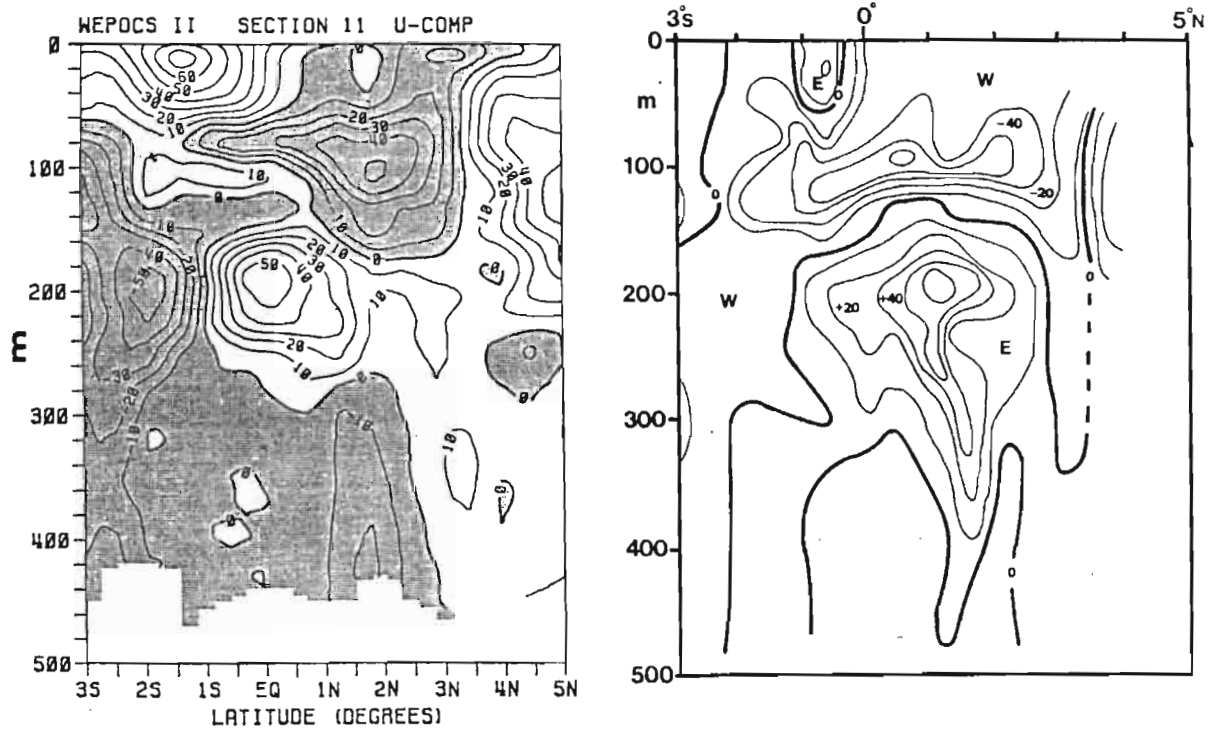


FIG.7. Section of zonal velocity ($\text{cm}\cdot\text{s}^{-1}$) during FOC1 (right) at $142^\circ30'\text{E}$ and WEPOCS2 (left) at 143° . Shaded areas and negative values indicate westward flows.

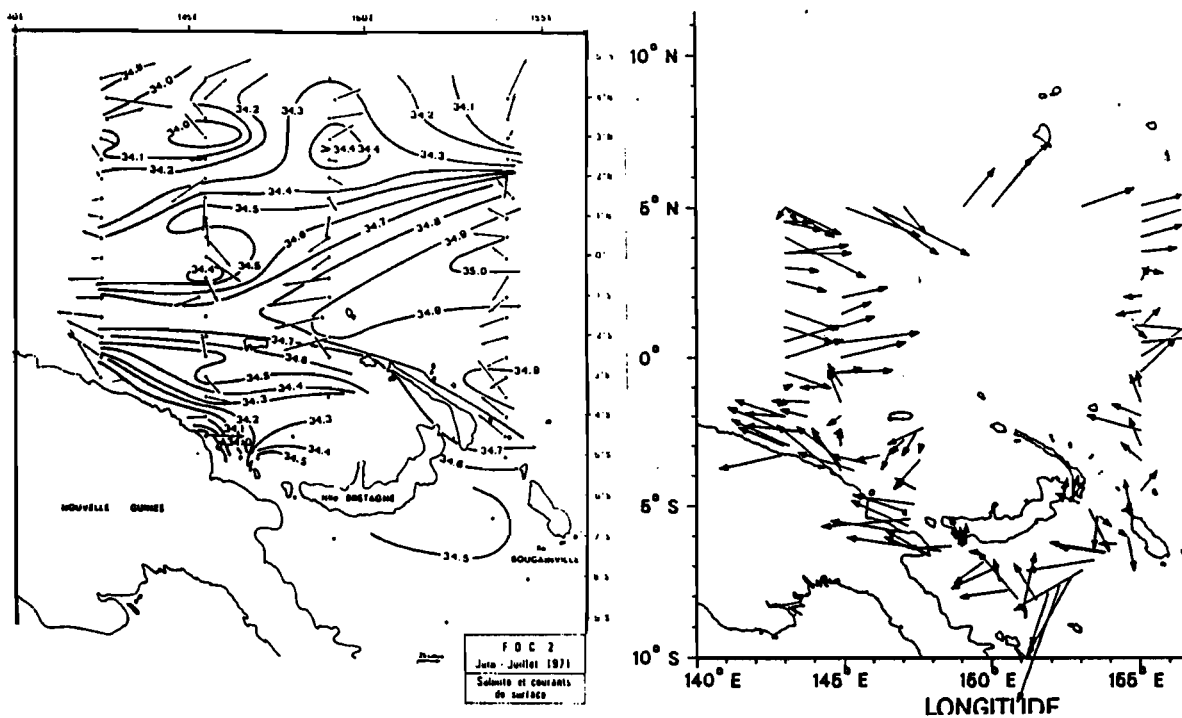


FIG.8. Surface circulation during FOC2 (left) and WEPOCS1 (right).

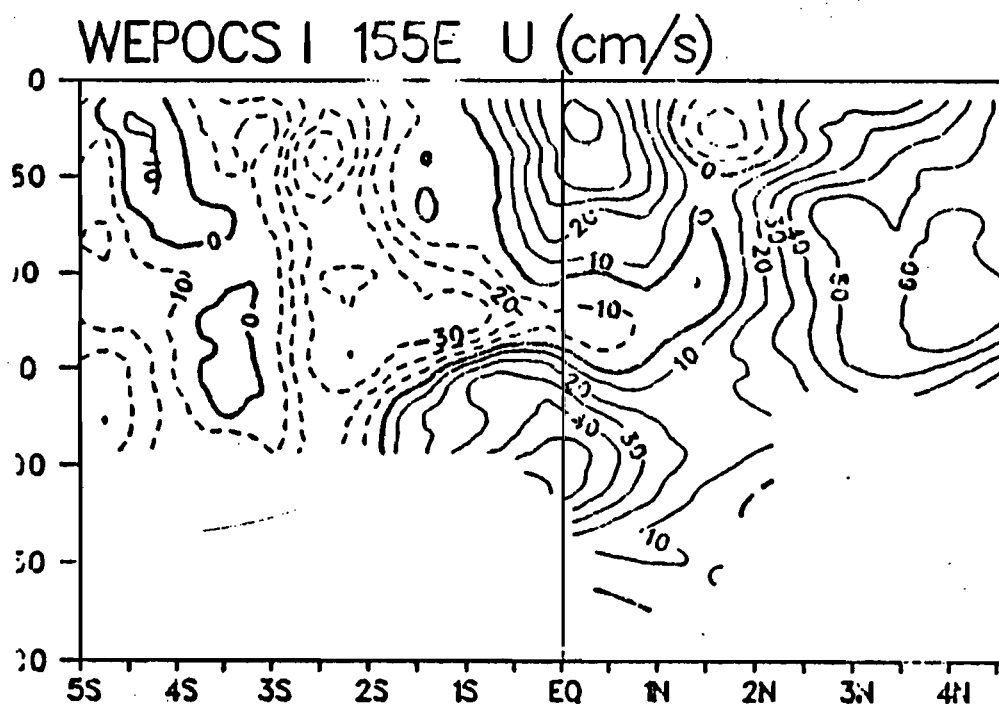


FIG.9. Section of zonal velocity ($\text{cm}\cdot\text{s}^{-1}$) during WEPOCS1 (June-July 1985) at 155°E. Positive values indicate eastward flow.

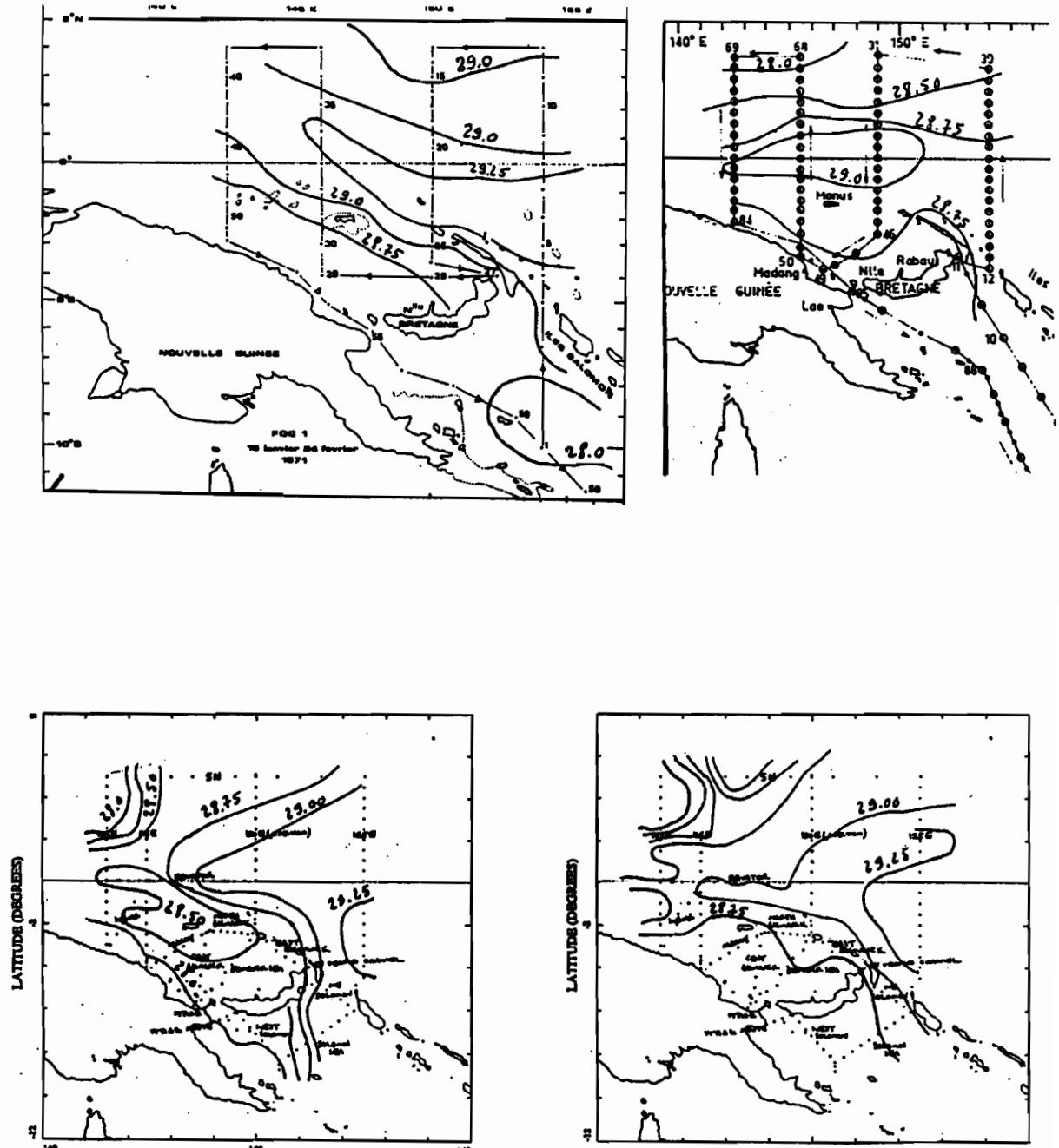


FIG.10. Mean temperature of the 0-100 meter-depth layer (°C). Up : FOC1 and FOC2 cruises. Down : WEPOCS2 and WEPOCS1 cruises.

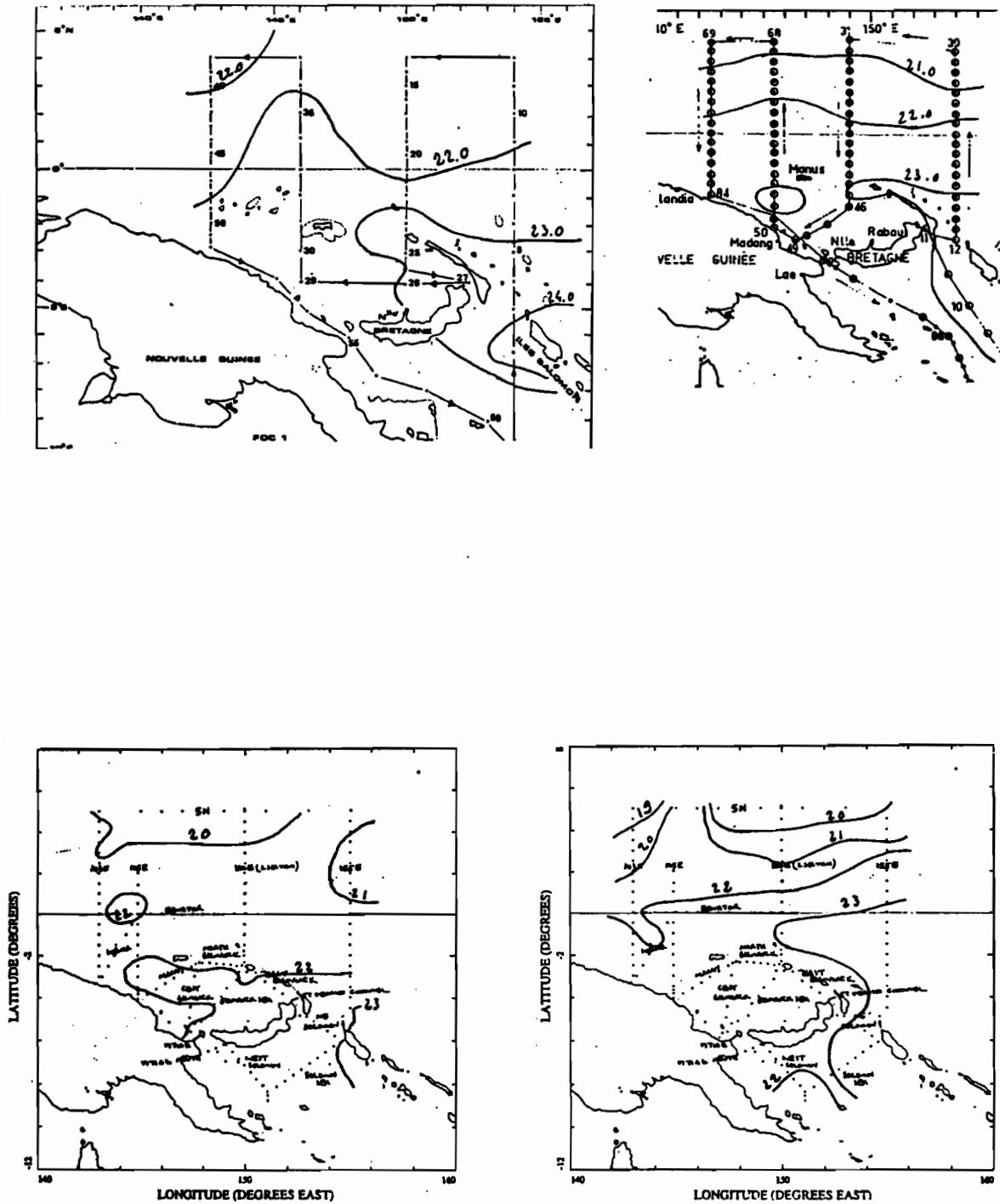


FIG.11. Mean temperature of the 0-300 meter-depth layer (°C). Up : FOC1 and FOC2 cruises : Down : WEPOCS2 and WEPOCS1 cruises.

5. Heat storage

Heat storage is considered during the FOC and WEPOCS cruises under the form of the mean temperature from the surface to 100 meters depth, and the mean temperature from the surface to 300 meters.

0-100 m mean temperature (Fig. 10) is very similar during the four cruises whatever the season : a maximum more than 29°C is located in the vicinity of the equator. West and north of this maximum, heat storage is decreasing.

0-300 m mean temperature (Fig. 11) is homogeneous for three cruises (FOC1, FOC2 and WEPOCS1) : a maximum more than 23°C is found south of the equator and heat storage is decreasing northward. The pattern is different during WEPOCS2 (January-February, 1986) : the mean temperature is 1° less than during the three other cruises. This low heat storage is connected to the appearance of the 1986-87 El Nino : it is likely that a part of the heat content stored in the equatorial western Pacific was already transported to the eastern Pacific through the North Equatorial Countercurrent (Meyers and Donguy, 1984).

6. Conclusion

These four cruises carried out at the same seasons but 15 years apart display very similar features. It seems that the patterns of the equatorial current system (eastward-westward-eastward and westward-eastward from the surface to 300 m depth), which has been observed are worthy of further investigation as to their relationship with the wind forcing. It would be interesting to ascertain how heat storage decrease in the western Pacific could be considered as a precursor of El Nino.

REFERENCES

- Anonyme, 1980: Résultats des croisières équatoriales du centre ORSTOM de Nouméa (1971). *Rapports Scientifiques et Techniques*, 13, Centre ORSTOM de Nouméa, New Caledonia.
- Colin, C., J.R. Donguy, C. Hénin, C. Oudot, B. Wauthy, 1973: Upper waters north of New Guinea in 1971. *The KUROSHIO 3*. Proceeding of the third C.S.K. Symposium, Bangkok, Thailand.
- Delcroix, T., G. Eldin, C. Hénin, 1987: Upper Ocean water masses and transports in the Western Tropical Pacific (165°E). *J. Phys. Oceanogr.*, 17, 2248-2261.
- Hisard, P., J. Merle, B. Voituriez, 1970: The equatorial Undercurrent at 170°E in March and April 1967. *J. Mar. Res.*, 28, 281-303.
- Lindstrom, E., R. Lukas, R. Fine, E. Firing, S. Godfrey, G. Meyers, M. Tsuchiya, 1987: The Western Equatorial Pacific ocean Circulation Study. *Nature*, 330, 6148, 533-537.
- Meyers, G., J.R. Donguy, 1984: The North Equatorial Countercurrent and heat storage in the western Pacific Ocean during 1982-83. *Nature*, 312, 5991, 258-260.
- Rougerie, F., 1969: Sur un noyau à forte teneur en oxygène dans la partie inférieure du courant de Cromwell. *Cah. ORSTOM, sér. Océanogr.*, 7, n° 3, 21-28.
- Tsuchiya, M., 1968: Upper water in the intertropical Pacific Ocean. *The John Hopkins oceanogr. studies*, 4, 50 pp.
- Tsuchiya, M., R. Lukas, E. Firing, R. Fine, E. Lindstrom - Source waters of the Equatorial Undercurrent, *Submitted to progress in Oceanography*.

**WESTERN PACIFIC INTERNATIONAL MEETING
AND WORKSHOP ON TOGA COARE**

Nouméa, New Caledonia

May 24-30, 1989

PROCEEDINGS

edited by

Joël Picaut *

Roger Lukas **

Thierry Delcroix *

* ORSTOM, Nouméa, New Caledonia

** JIMAR, University of Hawaii, U.S.A.

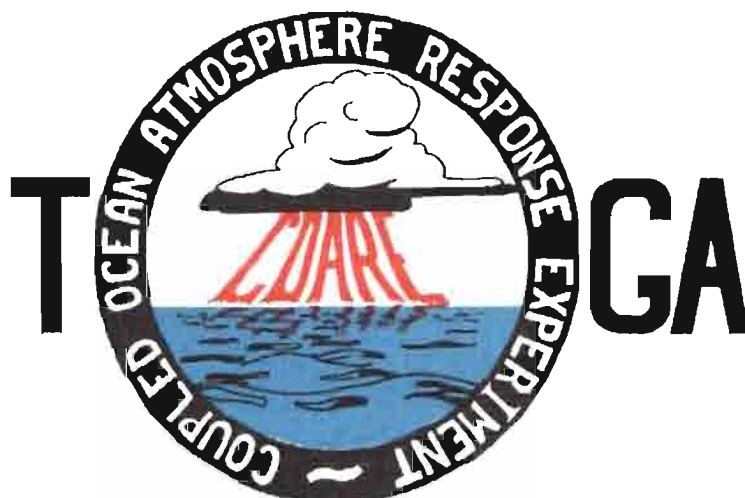


TABLE OF CONTENTS

ABSTRACT	i
RESUME	iii
ACKNOWLEDGMENTS	vi
INTRODUCTION	
1. Motivation	1
2. Structure	2
LIST OF PARTICIPANTS	5
AGENDA	7
WORKSHOP REPORT	
1. Introduction	19
2. Working group discussions, recommendations, and plans	20
a. Air-Sea Fluxes and Boundary Layer Processes	20
b. Regional Scale Atmospheric Circulation and Waves	24
c. Regional Scale Oceanic Circulation and Waves	30
3. Related programs	35
a. NASA Ocean Processes and Satellite Missions	35
b. Tropical Rainfall Measuring Mission	37
c. Typhoon Motion Program	39
d. World Ocean Circulation Experiment	39
4. Presentations on related technology	40
5. National reports	40
6. Meeting of the International Ad Hoc Committee on TOGA COARE	40
APPENDIX: WORKSHOP RELATED PAPERS	
Robert A. Weller and David S. Hosom: Improved Meteorological Measurements from Buoys and Ships for the World Ocean Circulation Experiment	45
Peter H. Hildebrand: Flux Measurement using Aircraft and Radars	57
Walter F. Dabberdt, Hale Cole, K. Gage, W. Ecklund and W.L. Smith: Determination of Boundary-Layer Fluxes with an Integrated Sounding System	81

MEETING COLLECTED PAPERS

WATER MASSES, SEA SURFACE TOPOGRAPHY, AND CIRCULATION

Klaus Wyrtki: Some Thoughts about the West Pacific Warm Pool	99
Jean René Donguy, Gary Meyers, and Eric Lindstrom: Comparison of the Results of two West Pacific Oceanographic Expeditions FOC (1971) and WEPOCS (1985-86)	111
Dunxin Hu, and Maochang Cui: The Western Boundary Current in the Far Western Pacific Ocean	123
Peter Hacker, Eric Firing, Roger Lukas, Philipp L. Richardson, and Curtis A. Collins: Observations of the Low-latitude Western Boundary Circulation in the Pacific during WEPOCS III	135
Stephen P. Murray, John Kindle, Dharma Arief, and Harley Hurlburt: Comparison of Observations and Numerical Model Results in the Indonesian Throughflow Region	145
Christian Henin: Thermohaline Structure Variability along 165°E in the Western Tropical Pacific Ocean (January 1984 - January 1989)	155
David J. Webb, and Brian A. King: Preliminary Results from Charles Darwin Cruise 34A in the Western Equatorial Pacific	165
Warren B. White, Nicholas Graham, and Chang-Kou Tai: Reflection of Annual Rossby Waves at The Maritime Western Boundary of the Tropical Pacific	173
William S. Kessler: Observations of Long Rossby Waves in the Northern Tropical Pacific	185
Eric Firing, and Jiang Songnian: Variable Currents in the Western Pacific Measured During the US/PRC Bilateral Air-Sea Interaction Program and WEPOCS	205
John S. Godfrey, and A. Weaver: Why are there Such Strong Steric Height Gradients off Western Australia ?	215
John M. Toole, R.C. Millard, Z. Wang, and S. Pu: Observations of the Pacific North Equatorial Current Bifurcation at the Philippine Coast	223

EL NINO/SOUTHERN OSCILLATION 1986-87

Gary Meyers, Rick Bailey, Eric Lindstrom, and Helen Phillips: Air/Sea Interaction in the Western Tropical Pacific Ocean during 1982/83 and 1986/87	229
Laury Miller, and Robert Cheney: GEOSAT Observations of Sea Level in the Tropical Pacific and Indian Oceans during the 1986-87 El Nino Event	247
Thierry Delcroix, Gérard Eldin, and Joël Picaut: GEOSAT Sea Level Anomalies in the Western Equatorial Pacific during the 1986-87 El Nino, Elucidated as Equatorial Kelvin and Rossby Waves	259
Gérard Eldin, and Thierry Delcroix: Vertical Thermal Structure Variability along 165°E during the 1986-87 ENSO Event	269
Michael J. McPhaden: On the Relationship between Winds and Upper Ocean Temperature Variability in the Western Equatorial Pacific	283

John S. Godfrey, K. Ridgway, Gary Meyers, and Rick Bailey: Sea Level and Thermal Response to the 1986-87 ENSO Event in the Far Western Pacific	291
Joël Picaut, Bruno Camusat, Thierry Delcroix, Michael J. McPhaden, and Antonio J. Busalacchi: Surface Equatorial Flow Anomalies in the Pacific Ocean during the 1986-87 ENSO using GEOSAT Altimeter Data	301

THEORETICAL AND MODELING STUDIES OF ENSO AND RELATED PROCESSES

Julian P. McCreary, Jr.: An Overview of Coupled Ocean-Atmosphere Models of El Nino and the Southern Oscillation	313
Kensuke Takeuchi: On Warm Rossby Waves and their Relations to ENSO Events	329
Yves du Penhoat, and Mark A. Cane: Effect of Low Latitude Western Boundary Gaps on the Reflection of Equatorial Motions	335
Harley Hurlburt, John Kindle, E. Joseph Metzger, and Alan Wallcraft: Results from a Global Ocean Model in the Western Tropical Pacific	343
John C. Kindle, Harley E. Hurlburt, and E. Joseph Metzger: On the Seasonal and Interannual Variability of the Pacific to Indian Ocean Throughflow	355
Antonio J. Busalacchi, Michael J. McPhaden, Joël Picaut, and Scott Springer: Uncertainties in Tropical Pacific Ocean Simulations: The Seasonal and Interannual Sea Level Response to Three Analyses of the Surface Wind Field	367
Stephen E. Zebiak: Intraseasonal Variability - A Critical Component of ENSO ?	379
Akimasa Sumi: Behavior of Convective Activity over the "Jovian-type" Aqua-Planet Experiments	389
Ka-Ming Lau: Dynamics of Multi-Scale Interactions Relevant to ENSO	397
Pecheng C. Chu and Roland W. Garwood, Jr.: Hydrological Effects on the Air-Ocean Coupled System	407
Sam F. Iacobellis, and Richard C.J. Somerville: A one Dimensional Coupled Air-Sea Model for Diagnostic Studies during TOGA-COARE	419
Allan J. Clarke: On the Reflection and Transmission of Low Frequency Energy at the Irregular Western Pacific Ocean Boundary - a Preliminary Report	423
Roland W. Garwood, Jr., Pecheng C. Chu, Peter Muller, and Niklas Schneider: Equatorial Entrainment Zone : the Diurnal Cycle	435
Peter R. Gent: A New Ocean GCM for Tropical Ocean and ENSO Studies	445
Wasito Hadi, and Nuraini: The Steady State Response of Indonesian Sea to a Steady Wind Field	451
Pedro Ripa: Instability Conditions and Energetics in the Equatorial Pacific	457
Lewis M. Rothstein: Mixed Layer Modelling in the Western Equatorial Pacific Ocean	465
Neville R. Smith: An Oceanic Subsurface Thermal Analysis Scheme with Objective Quality Control	475
Duane E. Stevens, Qi Hu, Graeme Stephens, and David Randall: The hydrological Cycle of the Intraseasonal Oscillation	485
Peter J. Webster, Hai-Ru Chang, and Chidong Zhang: Transmission Characteristics of the Dynamic Response to Episodic Forcing in the Warm Pool Regions of the Tropical Oceans	493

MOMENTUM, HEAT, AND MOISTURE FLUXES BETWEEN ATMOSPHERE AND OCEAN

W. Timothy Liu: An Overview of Bulk Parametrization and Remote Sensing of Latent Heat Flux in the Tropical Ocean	513
E. Frank Bradley, Peter A. Coppin, and John S. Godfrey: Measurements of Heat and Moisture Fluxes from the Western Tropical Pacific Ocean	523
Richard W. Reynolds, and Ants Leetmaa: Evaluation of NMC's Operational Surface Fluxes in the Tropical Pacific	535
Stanley P. Hayes, Michael J. McPhaden, John M. Wallace, and Joël Picaut: The Influence of Sea-Surface Temperature on Surface Wind in the Equatorial Pacific Ocean	543
T.D. Keenan, and Richard E. Carbone: A Preliminary Morphology of Precipitation Systems In Tropical Northern Australia	549
Phillip A. Arkin: Estimation of Large-Scale Oceanic Rainfall for TOGA	561
Catherine Gautier, and Robert Frouin: Surface Radiation Processes in the Tropical Pacific	571
Thierry Delcroix, and Christian Henin: Mechanisms of Subsurface Thermal Structure and Sea Surface Thermo-Haline Variabilities in the South Western Tropical Pacific during 1979-85 - A Preliminary Report	581
Greg. J. Holland, T.D. Keenan, and M.J. Manton: Observations from the Maritime Continent : Darwin, Australia	591
Roger Lukas: Observations of Air-Sea Interactions in the Western Pacific Warm Pool during WEPOCS	599
M. Nunez, and K. Michael: Satellite Derivation of Ocean-Atmosphere Heat Fluxes in a Tropical Environment	611

EMPIRICAL STUDIES OF ENSO AND SHORT-TERM CLIMATE VARIABILITY

Klaus M. Weickmann: Convection and Circulation Anomalies over the Oceanic Warm Pool during 1981-1982	623
Claire Perigaud: Instability Waves in the Tropical Pacific Observed with GEOSAT	637
Ryuichi Kawamura: Intraseasonal and Interannual Modes of Atmosphere-Ocean System Over the Tropical Western Pacific	649
David Gutzler, and Tamara M. Wood: Observed Structure of Convective Anomalies	659
Siri Jodha Khalsa: Remote Sensing of Atmospheric Thermodynamics in the Tropics	665
Bingrong Xu: Some Features of the Western Tropical Pacific: Surface Wind Field and its Influence on the Upper Ocean Thermal Structure	677
Bret A. Mullan: Influence of Southern Oscillation on New Zealand Weather	687
Kenneth S. Gage, Ben Basley, Warner Ecklund, D.A. Carter, and John R. McAfee: Wind Profiler Related Research in the Tropical Pacific	699
John Joseph Bates: Signature of a West Wind Convective Event in SSM/I Data	711
David S. Gutzler: Seasonal and Interannual Variability of the Madden-Julian Oscillation	723
Marie-Hélène Radenac: Fine Structure Variability in the Equatorial Western Pacific Ocean	735
George C. Reid, Kenneth S. Gage, and John R. McAfee: The Climatology of the Western Tropical Pacific: Analysis of the Radiosonde Data Base	741

Chung-Hsiung Sui, and Ka-Ming Lau: Multi-Scale Processes in the Equatorial Western Pacific	747
Stephen E. Zebiak: Diagnostic Studies of Pacific Surface Winds	757

MISCELLANEOUS

Rick J. Bailey, Helene E. Phillips, and Gary Meyers: Relevance to TOGA of Systematic XBT Errors	775
Jean Blanchot, Robert Le Borgne, Aubert Le Bouteiller, and Martine Rodier: ENSO Events and Consequences on Nutrient, Planktonic Biomass, and Production in the Western Tropical Pacific Ocean	785
Yves Dandonneau: Abnormal Bloom of Phytoplankton around 10°N in the Western Pacific during the 1982-83 ENSO	791
Cécile Dupouy: Sea Surface Chlorophyll Concentration in the South Western Tropical Pacific, as seen from NIMBUS Coastal Zone Color Scanner from 1979 to 1984 (New Caledonia and Vanuatu)	803
Michael Szabados, and Darren Wright: Field Evaluation of Real-Time XBT Systems	811
Pierre Rual: For a Better XBT Bathy-Message: Onboard Quality Control, plus a New Data Reduction Method	823