

Kinematics and Heat Budget of the Leeuwin Current

by

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Contents

List of figures	v
List of tables	xiii
Abstract	xiv
Declaration	xv
Acknowledgements	xvi
List of supporting publications	xvii
Chapter 1 Introduction	1–1
Chapter 2 Regional background	2–3
2.1 <i>Shelves and basins</i>	2–3
2.2 <i>Winds</i>	2–3
2.3 <i>Major current systems</i>	2–4
2.4 <i>Source regions of the Leeuwin Current</i>	2–6
2.5 <i>The Leeuwin Current System</i>	2–7
2.6 <i>Cooling of the Leeuwin Current</i>	2–10
Chapter 3 WOCE observations of the Leeuwin Current System at 22°S	3–12
3.1 <i>Introduction</i>	3–12
3.2 <i>Data description</i>	3–12

3.2.1	ICM6	3–12
3.2.1.1	Moored observations	3–13
3.2.1.2	Synoptic observations	3–17
3.2.2	Complementary observations	3–17
3.2.2.1	CSIRO Atlas of Regional Seas	3–17
3.2.2.2	Altimetry	3–17
3.2.2.3	JADE and WOCE hydrographic lines	3–19
3.2.2.4	Sea Surface Temperature imagery	3–19
3.2.2.5	Southern Oscillation Index	3–19
3.3	<i>Results</i>	3–19
3.3.1	Direct current observations	3–19
3.3.1.1	Structure of the mean currents	3–21
3.3.1.2	Current and temperature variability	3–27
3.3.1.3	Volume transports	3–32
3.3.1.3.1	Leeuwin Current	3–32
3.3.1.3.2	Leeuwin Undercurrent	3–34
3.3.2	Shipboard ADCP currents	3–36
3.3.3	Water properties	3–42
3.3.3.1	Variability between cruise surveys	3–43
3.3.4	Source water inferences	3–52
3.3.4.1	Tropical Water	3–52
3.3.4.2	Subtropical Water and South Indian Central Water	3–53
3.3.4.3	Antarctic Intermediate Water	3–54
3.3.4.4	Mixed Intermediate Water	3–54
3.4	<i>Summary and discussion</i>	3–60
3.5	<i>Conclusions</i>	3–63
Chapter 4 POP online particle tracking of the Leeuwin Current System		4–65
4.1	<i>Introduction</i>	4–65
4.2	<i>Particle tracking and selection criteria</i>	4–65
4.3	<i>Trajectories</i>	4–67
4.3.1	Leeuwin Current	4–71
4.3.1.1	Tropical source	4–71
4.3.1.2	Subtropical source	4–72
4.3.1.3	Fate of the Leeuwin Current's waters	4–73
4.3.2	Eastern Gyral Current	4–79
4.3.3	Leeuwin Undercurrent and Subtropical Gyre	4–80

4.4	<i>Conclusions</i>	4–84
Chapter 5 Anatomy of the mean and seasonal Leeuwin Current		5–86
5.1	<i>Introduction</i>	5–86
5.2	<i>Method</i>	5–86
5.3	<i>Mean</i>	5–87
5.3.1	Current structure and property distributions	5–87
5.3.2	Volume transport and transport-weighted properties	5–88
5.4	<i>Seasonal cycle</i>	5–92
5.4.1	Current structure and property distributions	5–92
5.4.2	Volume transport and transport-weighted properties	5–93
5.5	<i>How realistic are the model results?</i>	5–102
5.6	<i>Conclusions</i>	5–105
Chapter 6 Heat budgets of the Leeuwin Current System		6–108
6.1	<i>Introduction</i>	6–108
6.2	<i>Box method</i>	6–108
6.3	<i>Heat budgets</i>	6–110
6.3.1	Coastal and offshore boxes	6–111
6.3.2	Regional overview	6–113
6.3.3	Westward eddy heat flux	6–114
6.4	<i>Conclusions</i>	6–120
Chapter 7 Conclusion		7–121
7.1	<i>Summary and discussion</i>	7–121
7.2	<i>Conclusions</i>	7–126
7.2.1	Source regions of the Leeuwin Current	7–127
7.2.2	Mean flow and seasonality of the Leeuwin Current	7–128
7.2.3	Cooling mechanism of the Leeuwin Current	7–129

Appendix A ICM6 variance preserving spectra	130
Appendix B ICM6 geostrophic current shears	136
Appendix C Parallel Ocean Program model description	140
<i>C.1 Parallel Ocean Program</i>	<i>140</i>
C.1.1 Formulation and developments	140
C.1.2 POP11B 1993/97	142
C.1.2.1 Geographical domain, grid structure and bottom topography	143
C.1.2.2 Initialisation	143
C.1.2.3 Surface forcing	143
C.1.2.4 Deep restoring	144
C.1.2.5 Subgridscale parameterisation	144
C.1.2.6 Eulerian outputs	145
Appendix D Regional heat balance	147
References	150
Abbreviations	156

List of figures

- Figure 1.1.** High resolution map of sea surface temperature and current off Western Australia. The Leeuwin Current is the warm boundary flow from which an anticyclonic (warm core) mesoscale eddy detaches at $\sim 28^\circ\text{S}$. Courtesy of David Griffin and CSIRO Marine Research, Hobart, Australia [<http://www.marine.csiro.au/remotesensing/oceancurrents/>]. 1–2
- Figure 2.1.** Southeast Indian Ocean. Shelves, basins, topographic features and upper ocean current schematic. The small green arrows on the west Australian shelf represent the Ningaloo Current near North West Cape (22°S) and the Capes Current near Cape Leeuwin (34°S). See text for details. 2–4
- Figure 2.2.** Seasonal European Centre for Medium–range Weather Forecasts (ECMWF) wind stress [every sixth vector plotted as in POP11B 1993/97 output, see **Appendix C**]. 2–5
- Figure 2.3.** Annual average steric height relative to 1300 db: at 0 db (a), 100 db (b), 200 db (c), 300 db (d), 450 db (e) and 700 db (f) [from Godfrey and Ridgway, 1985]. 2–6
- Figure 2.4.** Three–year time series from Rottnest Island. Mid shelf station (full line) and continental slope stations at 32°S , $114^\circ 40'$ (dashed) and 20°S , 114°E (dotted) for surface salinity (top) and surface temperature (bottom) [from Cresswell and Golding, 1980]. 2–9
- Figure 2.5.** Alongshore momentum balance averaged between 22.5°S and 32.5°S . Negative of the pressure gradient term along the continental shelf edge (dashed line). Longshore component of the wind stress averaged (dotted line) along the same track (positive is poleward). Sum of the two terms (bold line) [from Godfrey and Ridgway, 1985]. 2–10
- Figure 2.6.** Annual mean heat flux. Contours are 25 W m^{-2} . Ocean heat loss is in blue [from Doney et al., 1998]. [Doney et al., 1998] 2–11
- Figure 3.1.** ICM6 array location (top) and current meter distribution (bottom). Gray symbols denote instruments that were not recovered on mooring 4. 3–14
- Figure 3.2.** ICM6 array configuration. Identification numbers and depth positions are respectively on the right and below each instrument. Water depths are given at the base of each mooring line.

ACR (acoustic release). SF and SS (surface floats). ADCP (acoustic current Doppler profiler). RCM (mechanical recording current meter). ACM2 (acoustic current meter).	3–15
Figure 3.3. ICM6 CTD and underway SADCP sampling.....	3–18
Figure 3.4. ICM6 mean current structure and water masses schematic. STW (Subtropical Water). SICW (South Indian Central Water). AAIW (Antarctic Intermediate Water). IDW (Indian Deep Water). M (mooring). The mean meridional current values were averaged from 30/08/94 to the date indicated on the top of each instrument.	3–20
Figure 3.5. ICM6 mean velocity cross–shelf sections (+N,+E). (a) 363–day mean; (b) 463–day mean; and 640–day mean. Circles denote current meters, white (recovered) and gray (not recovered). See text for explanation on the different averaged periods.	3–23
Figure 3.6. ICM6 standard deviation velocity cross–shelf sections (+N,+E). (a) 363–day std; (b) 463–day std; and 640–day std. Circles denote current meters, white (recovered) and gray (not recovered). See text for explanation on the different averaged periods.	3–24
Figure 3.7. ICM6 progressive vector diagrams. Start positions are offset from origin (0,0) in many cases. Start date is 30 August 1994. End dates, moorings and current meter depths are indicated. The gray shade transition marks 30 August 1995 (initial 363 days). White circles indicate a 2–month time step starting from October 1994.	3–25
Figure 3.8. ICM6 velocity vectors (+N,+E) and temperature time series.	3–28
Figure 3.9. ICM6 normalised temperature anomaly Hovmoller at ~200–300 m depth. The monthly averaged SOI is represented by a double thin line and its linear trend over the period by the dashed line. The temperature normalisation was carried out for each instrument to allow intercomparison. Positive anomalies are in red and negative in blue. The anomalies have been smoothed by a 45–day running mean filter. Gray lines outline every 0.5 contour above or below zero.	3–32
Figure 3.10. ICM6 volume transport time series (+N,+E). Leeuwin Current (top) and Leeuwin Undercurrent (bottom). Low frequency variability is in gray. Its darker segment includes linearly regressed data on mooring 3. The thick black lines are monthly averaged transports while double thin lines are monthly averaged SOI. Cruise dates are marked by arrows and some calendar dates are outlined by vertical dashed lines. Tropical cyclones dates (x) are indicated on top of the timeline axis. The long term means and their error estimates are indicated (bottom left).	3–35
Figure 3.11. SADCP upper ocean velocity (+N,+E) sections for individual cruise surveys across the ICM6 array, as indicated. Circles denote current meters, white (recovered) and gray (not recovered).	3–37
Figure 3.12. ICM6 SADCP 20–m vectors overlain in TP+ERS maps of sea level anomaly for individual cruise surveys across the ICM6 array, as indicated. Map dates are as close as possible to ICM6 cruise dates [Table 3.2]. Circles denote current meters, white (recovered) and gray (not recovered). The white line is the 4000 m isobath. A large scale version of these maps (15° to 35°S) are shown in Figure 3.13	3–39

- Figure 3.13.** TP+ERS maps of sea level anomaly in a large scale version. Circles denote ICM6 moorings, the smaller rectangle (dashed line) is the area shown in **Figure 3.12** and the larger rectangle (solid line) is the area shown in **Figure 3.14**. Isobaths (gray lines) are 1000 and 4000 m.3-40
- Figure 3.14.** Sea surface temperature images. Circles denote ICM6 moorings and the dashed rectangle is the area shown in **Figure 3.13**. Image dates are as close as possible to the ICM6 cruise dates [**Table 3.2**]. Isobaths (gray lines) are 200, 1000, 3000 and 4000 m. Gray shades over ocean are clouds.3-41
- Figure 3.15.** ICM6 Hydrographic sections during voyage FR 08/94. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-44
- Figure 3.16.** ICM6 Hydrographic sections during voyage FR 03/95. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-45
- Figure 3.17.** ICM6 Hydrographic sections during voyage KN 145/8. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-46
- Figure 3.18.** ICM6 Hydrographic sections during voyage FR 05/96. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-47
- Figure 3.19.** ICM6 Hydrographic sections during voyage FR 06/96 leg1. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-48
- Figure 3.20.** ICM6 Hydrographic sections during voyage FR 06/96 leg2. The section is split in upper (1) and deeper (2) ocean. Circles denote current meters, white (recovered) and gray (not recovered). CTD stations are indicated by downward pointing arrows.3-49
- Figure 3.21.** ICM6 θ -S diagrams (left) and zoom (right). (a) August 1994; (b) April 1995; and (c) May/June 1996. Black symbols are associated with the title of each diagram (cruise in discussion) while gray symbols are plotted only for reference and are associated with the other ICM6 cruises as indicated in the bottom of each diagram. TW (Tropical Water). STW (Subtropical Water). SICW (South Indian Central Water). AAIW (Antarctic Intermediate Water). MIW (Mixed Intermediate Water). IDW (Indian Deep Water).3-50
- Figure 3.22.** CARS seasonal θ -S diagrams at 20°S. Variation in colour of the symbols represent variation of the longitudinal location, from 103° to 120°E, as indicated by the colorbar on the top right. The continuous θ -S line is at 112°E.3-51
- Figure 3.23.** August 1994 θ -S diagrams comparisons. Black symbols are ICM6 data while coloured symbols are JADE or WOCE, as indicated and identified by station location (left). Gray symbols are JADE or WOCE observations only used for reference. Right panels are zoom at depth.3-55

- Figure 3.24.** April 1995 θ -S diagrams comparisons. Black symbols are ICM6 data while coloured symbols are JADE or WOCE, as indicated and identified by station location (left). Gray symbols are JADE or WOCE observations only used for reference. Right panels are zoom at depth.....3-56
- Figure 3.25.** May/June θ -S diagrams comparisons. Black symbols are ICM6 data while coloured symbols are JADE or WOCE, as indicated and identified by station location (left). Gray symbols are JADE or WOCE observations only used for reference. Right panels are zoom at depth.....3-57
- Figure 3.26.** CARS sea surface salinity 35.9 (left) and 35.8 (right) psu contours for wintertime in the southeastern Indian Ocean. Isobaths are 1000 and 4000 m. ICM6 current meter location is represented by the red/black cross near 22°S.....3-57
- Figure 3.27.** θ -S diagram comparison. Black symbols are ICM6 data in the eastern boundary (22°S) while coloured symbols are part of the WOCE I4 line in the western boundary (25°S), as indicated and identified by station location (left). Right panel is zoom at depth.3-59
- Figure 3.28.** Schematic diagram for flow patterns, from surface to intermediate depths.....3-59
- Figure 4.1.** Global POP11B Lagrangian grid (gray and red circles). The shaded (blue) area denotes the selection area off Western Australia used as a criterion to separate the numerical particles for this study and the red circles are their associated start points.....4-66
- Figure 4.2.** Numerical particle trajectories traversing the selected area (rectangle) off Western Australia from start points at depths ≤ 600 m. Trajectories associated with the Leeuwin Current (panel a). Trajectories associated with the Leeuwin Undercurrent and Subtropical Gyre (panel b). Colour represents salinity variation. Isobaths are 1000 and 3000 m (gray lines).....4-69
- Figure 4.3.** Schematic diagram of the circulation based on the numerical particle trajectories in **Figure 4.2**. Top panel: source regions of the Leeuwin Current. The “C” and “S” (via southern part of the North West Shelf) routes are exemplified by the red highlight (see text for details). Bottom panel: source regions of the Leeuwin Undercurrent. The alongstream deepening of the zonal jets in the Subtropical Indian (eastward near surface jets and deeper westward jets) are represented by the black to gray shading of the arrows.4-70
- Figure 4.4.** Numerical particle trajectories from tropical source regions of the Leeuwin Current [**Table 4.1**]. “S” route via North West Shelf. “C” route otherwise. Colour represents salinity variation. Isobath is 1000 m (gray line).....4-74
- Figure 4.5.** Cross-shelf section at 22°S (upper 400 m). Top panel indicates the depth distribution of the numerical trajectories associated with the Leeuwin Current [**Table 4.1**] on top of the salinity distribution. The middle panel is meridional velocity (+N) and σ_θ and the bottom panel is zonal velocity (+E) and θ . All distributions are averaged for 1993/97.....4-75
- Figure 4.6.** Cross-shelf section at 26°S (upper 400 m). Top panel indicates the depth distribution of the numerical trajectories associated with the Leeuwin Current [**Table 4.1**] on top of the salinity

distribution. The middle panel is meridional velocity (+N) and σ_θ and the bottom panel is zonal velocity (+E) and θ . All distributions are averaged for 1993/97.....4-76

Figure 4.7. Cross-shelf section at 32°S (upper 400 m). Top panel indicates the depth distribution of the numerical trajectories associated with the Leeuwin Current [**Table 4.1**] on top of the salinity distribution. The middle panel is meridional velocity (+N) and σ_θ and the bottom panel is zonal velocity (+E) and θ . All distributions are averaged for 1993/97.....4-77

Figure 4.8. θ -S diagrams from source regions of the Leeuwin Current [**Table 1**]. Colour represents different latitude bands along the ocean off the west Australian coast.....4-78

Figure 4.9. Numerical particle trajectories from the Eastern Gyral Current which are not a source for the Leeuwin Current [**Table 4.2**]. Colour represents depth variation. Isobath is 1000 m (gray line).....4-80

Figure 4.10. Numerical particle trajectories from source regions of the Leeuwin Undercurrent and Subtropical Gyre [**Table 4.2**]. Colour represents depth variation. Isobath is 1000 m.....4-82

Figure 4.11. Along-shore section at 110°E (upper 1000 m). Top two panels indicate the depth distribution of the numerical trajectories listed in **Table 4.2** on top of salinity distribution. The middle panel is meridional velocity (+N) and σ_θ and the bottom panel is zonal velocity (+E) and θ . All distributions are averaged for 1993/97.....4-83

Figure 5.1. Mean horizontal maps at 37.5 m depth. Velocity vectors (left), salinity (middle) and θ (right). Velocity vectors are superimposed on the absolute speed (**V**) multiplied by the sign of the meridional velocity (+N). SSH contours are indicated in green and isobaths in white. Vectors in black are part of the “mask” (see text).5-88

Figure 5.2. Vertical sections of the zonally-averaged mean Leeuwin Current. Salinity and meridional velocity (top). θ and zonal velocity (middle). σ_θ and vertical velocity (bottom). The bold green contour is the meridional velocity zero line on all plates. Note that these properties are volume averaged and not transported averaged.5-90

Figure 5.3. Mean volume transport, transport-weighted velocity and area (top panel). SSH, cross-shore SSH gradient, bottom depth along the Leeuwin Current axis (middle panel). Transport-weighted θ , salinity and σ_θ (bottom panel). From 22°S to 34°S, the Leeuwin Current became cooler (-5.5°C), saltier (0.6 psu) and denser (2 kg m^{-3}).....5-91

Figure 5.4. Seasonal velocity vectors at 37.5 m. Velocity vectors are superimposed on the absolute speed (**V**) multiplied by the sign of the meridional velocity (+N). SSH contours are indicated in green and isobaths in white. Vectors in black are part of the “mask” (see text).5-94

Figure 5.5. Seasonal salinity at 37.5 m depth. SSH contours are indicated in green and isobaths in white.5-95

Figure 5.6. Seasonal θ at 37.5 m depth. SSH contours are indicated in green and isobaths in white.5-96

Figure 5.7. Seasonal SSH anomaly (zero line in bold black). The 1000 m isobath is the green line.5-97

Figure 5.8. January vertical section. Salinity and meridional velocity (top). θ and zonal velocity (middle). σ_θ and vertical velocity (bottom). The bold green contour is the meridional velocity zero line on all plates.5-98

Figure 5.9. April vertical section. Salinity and meridional velocity (top). θ and zonal velocity (middle). σ_θ and vertical velocity (bottom). The bold green contour is the meridional velocity zero line on all plates.5-99

Figure 5.10. July vertical section. Salinity and meridional velocity (top). θ and zonal velocity (middle). σ_θ and vertical velocity (bottom). The bold green contour is the meridional velocity zero line on all plates.5-100

Figure 5.11. October vertical section. Salinity and meridional velocity (top). θ and zonal velocity (middle). σ_θ and vertical velocity (bottom). The bold green contour is the meridional velocity zero line on all plates.5-101

Figure 5.12. Seasonal volume transport of the Leeuwin Current jet off Western Australia. SSH is contoured in black.5-103

Figure 5.13. Seasonal transport-weighted salinity (top) and θ (bottom) of the Leeuwin Current jet off Western Australia. SSH is contoured in black.5-103

Figure 5.14. Seasonal anomalies of the Leeuwin Current jet averaged over 22°–34°S. Volume transport (top left). Transport-weighted salinity (top right). SSH (bottom left). Transport-weighted θ (left axis) and σ_θ (right axis) (bottom right).5-104

Figure 5.15. Schematic of the mean Leeuwin Current jet transport and its transport-weighted properties from 22°S to 34°S.5-106

Figure 6.1. Net surface heat fluxes and potential temperature (θ) in the southeast Indian Ocean over a 5-year mean period between 1993/97. Ocean heat loss is negative. The dotted lines define the coastal and the offshore boxes used in the heat budget calculations.6-110

Figure 6.2. Total, mean and eddy heat divergence per model z-level in the upper 400 m, for the coastal box (top panel) and offshore box (bottom panel), both depicted in **Figure 6.1**. The model z-level thicknesses are detailed in **Appendix C**.6-112

Figure 6.3. Net surface heat fluxes over 1° x 1° grid boxes. Ocean heat loss is negative (blue). The thin black line is the 3000 m isobath. The gray line defines the model coastline.6-116

Figure 6.4. Total ocean heat divergence over 1° x 1° grid boxes. Ocean heat gain is positive (red). The thin black line is the 3000 m isobath. The gray line defines the model coastline.6-116

Figure 6.5. Mean ocean heat divergence over 1° x 1° grid boxes. Ocean heat gain is positive (red). The thin black line is the 3000 m isobath. The gray line defines the model coastline.6-117

Figure 6.6. Eddy ocean heat divergence over $1^\circ \times 1^\circ$ grid boxes. Ocean heat gain is positive (red). The thin black line is the 3000 m isobath. The gray line defines the model coastline.	6–117
Figure 6.7. Mean ocean heat fluxes (every second vector plotted) and potential temperature (θ) in the upper 185 m of the southeast Indian Ocean averaged over a 5–year period between 1993/97. The colour indicates the absolute mean heat flux with the sign of the meridional component (N+).	6–118
Figure 6.8. The same as in Figure 6.7 but for the eddy ocean heat fluxes.	6–118
Figure 6.9. Schematic diagrams for the mean and eddy heat fluxes in the coastal and offshore boxes [Figure 6.1], above and below 185 m depth.	6–119
Figure A.1. Kinetic energy (left) and temperature (right) variance preserving spectra from ICM6 mooring 1.	131
Figure A.2. Kinetic energy (left) and temperature (right) variance preserving spectra from ICM6 mooring 2.	132
Figure A.3. Kinetic energy (left) and temperature (right) variance preserving spectra from ICM6 mooring 3.	133
Figure A.4. Kinetic energy (left) and temperature (right) variance preserving spectra from ICM6 mooring 5.	134
Figure A.5. Kinetic energy (left) and temperature (right) variance preserving spectra from ICM6 mooring 6.	135
Figure B.1. Example of high frequency temperature oscillations (gray) on ICM6 moorings 1, 2 and 3 at ~ 250 m depth. Black line is low passed time series. Vertical lines indicate cruise dates.	138
Figure B.2. Best match between geostrophic velocity shears (red crosses) and direct velocity (black dots). Horizontal gray bars indicate their differences (geostrophy minus direct). Current meter dates are listed on Table B.1	139
Figure C.1. POP11B horizontal and vertical B–grid cell discretisation.	141
Figure C.2. POP11B global grid in Mercator projection. The study area in the southeast Indian Ocean is highlighted in gray [Eulerian diagnostics used in Chapters 5 and 6]. Also indicated are the locations of the start points for the numerical particle tracking [online Lagrangian diagnostics in Chapter 4], the ICM6 current meter array, the JADE and WOCE hydrographic lines, and the IX–1 and IX–22 XBT lines [Chapter 3].	146
Figure C.3. POP11B initialisation schematic diagram.	146

Figure D.1. Storage+diffusion over $1^\circ \times 1^\circ$ boxes off Western Australia. The gray bold line is the model coastline whereas the thin gray line is the model 3000 m isobath. Dashed lines are the coastal and offshore boxes used in a previous calculation of the heat balance in those areas [see **Chapter 6** for details]. Positive values indicate heat storage in the ocean. Note that the estimates for the 5-year period (1993/97) are quite small and so the model is in a dynamical steady state.

..... 148

Figure D.2. Same as above but for net volume (mass) flux. Positive values indicate mass flux into the boxes. Note, however, that the estimates in each of the $1^\circ \times 1^\circ$ boxes are ~ 0 Sv ($\equiv 10^{-6} \text{ m}^3 \text{ s}^{-1}$), hence there is virtually no net mass flux (thus mass balance is closed).

148

Figure D.3. Depth-integrated ocean heat transport (mean and eddy) in each of the faces of the coastal and offshore boxes, as indicated by colour and symbols. The heat transport values at ~ 1000 m are equivalent to the full depth integration (0–5200 m)

149

List of tables

Table 3.1. ICM6 data return time series. Speed gaps are indicated in days.	3–16
Table 3.2. ICM6 cruise surveys.	3–18
Table 3.3. Statistics of selected ICM6 current meters. Velocity (+N,+E). Note that the number of decimal places is the result of averaging and do not indicate precision.	3–26
Table 3.4. Mean and standard deviation of the Leeuwin Current’s volume transport (+N,+E), with and without surface extrapolation (no vertical shear) in the top 50 m to provide an upper and lower bound to the estimates.	3–34
Table 4.1. Distribution of the particle trajectories in start groups, start depths and pathways. Contribution to the Leeuwin Current.	4–68
Table 4.2. Distribution of the particle trajectories in start groups and start depths. Contribution to the Leeuwin Undercurrent and Subtropical Gyre.	4–68
Table 6.1. Heat balance in the coastal and offshore boxes defined in Figure 6.1	6–111
Table B.1. Corresponding current meter dates for the shear matching in Figure B.2	138

Abstract

This study investigates the upper ocean circulation along the west Australian coast, based on recent observations (WOCE ICM6, 1994/96) and numerical output from the $\frac{1}{6}^\circ$ Parallel Ocean Program model (POP11B 1993/97). Particularly, we identify the source regions of the Leeuwin Current, quantify its mean and seasonal variability in terms of volume, heat and salt transports, and examine its heat balance (cooling mechanism). This also leads to further understanding of the regional circulation associated with the Leeuwin Undercurrent, the Eastern Gyral Current and the southeast Indian Subtropical Gyre.

The tropical and subtropical sources of the Leeuwin Current are understood from an online numerical particle tracking. Some of the new findings are the Tropical Indian Ocean source of the Leeuwin Current (in addition to the Indonesian Throughflow/Pacific); the Eastern Gyral Current as a recirculation of the South Equatorial Current; the subtropical source of the Leeuwin Current fed by relatively narrow subsurface-intensified eastward jets in the Subtropical Gyre, which are also a major source for the Subtropical Water (salinity maximum) as observed in the Leeuwin Undercurrent along the ICM6 section at 22°S.

The ICM6 current meter array reveals a rich vertical current structure near North West Cape (22°S). The coastal part of the Leeuwin Current has dominant synoptic variability and occasionally contains large spikes in its transport time series arising from the passage of tropical cyclones. On the mean, it is weaker and shallower compared to further downstream, and it only transports Tropical Water, of a variable content. The Leeuwin Undercurrent carries Subtropical Water, South Indian Central Water and Antarctic Intermediate Water equatorward between 150/250 to 500/750 m. There is a poleward flow just below the undercurrent which advects a mixed Intermediate Water, partially associated with outflows from the Red Sea and Persian Gulf. Narrow bottom-intensified currents are also observed.

The 5-year mean model Leeuwin Current is a year-round poleward flow between 22°S and 34°S. It progressively deepens, from 150 to 300 m depth. Latitudinal variations in its volume transport are a response to lateral inflows/outflows. It has double the transport at 34°S (−2.2 Sv) compared to at 22°S (−1.2 Sv). These model estimates, however, may underestimate the transport of the Leeuwin Current by 50%. Along its path, the current becomes cooler (6°C), saltier (0.6 psu) and denser (2 kg m⁻³). At seasonal scales, a stronger poleward flow in May–June advects the warmest and freshest waters along the west Australian coast. This advection is apparently spun up by the arrival of a poleward Kelvin wave in April, and reinforced by a minimum in the equatorward wind stress during July.

In the model heat balance, the Leeuwin Current is significantly cooled by the eddy heat flux divergence (4°C out of 6°C), associated with mechanisms operating at submonthly time scales. However, exactly which mechanisms it is not yet clear. Air–sea fluxes only account for ~30% of the cooling and seasonal rectification is negligible. The eddy heat divergence, originating over a narrow region along the outer edge of the Leeuwin Current, is responsible for a considerable warming of a vast area of the adjacent ocean interior, which is then associated with strong heat losses to the atmosphere. The model westward eddy heat flux estimates are considerably larger than those associated with long lived warm core eddies detaching from the Leeuwin Current and moving offshore. This suggests that these mesoscale features are not the main mechanism responsible for the cooling of the Leeuwin Current. We suspect instead that short lived warm core eddies might play an important role.

Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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List of supporting publications

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