

# CONTENTS

Preface.....	xiii
--------------	------

## **Chapter 1. Circulation, variability and near-equatorial meridional flow in the central tropical Atlantic**

<i>L. Stramma, J. Fischer, P. Brandt and F. Schott</i> .....	1
--	---

1. Introduction.....	1
2. Methods and data.....	3
3. The water masses.....	6
4. Results.....	8
4.1. Mean circulation.....	8
4.2. Variability.....	11
4.3. Near-equatorial meridional flow.....	11
5. Discussion.....	19

## **Chapter 2. Comparison of hydrographic and altimeter based estimates of sea level height variability in the Atlantic Ocean**

<i>D. Mayer, M. Baringer and G. Goni</i> .....	23
--	----

1. Introduction.....	24
2. Data and methods.....	27
2.1. Hydrographic data.....	27
2.2. Altimeter data.....	27
3. Analysis.....	28
3.1. Background states and climatology.....	28
3.2. Regression between SHA and TA and DHA.....	33
3.3. Correlations.....	33
3.4. Variance explained.....	38
3.5. Panulirus data and reference levels.....	39
3.6. Inferred salinity vs. <i>in situ</i> salinity.....	41
3.7. Barotropic component.....	42
4. Discussion.....	43
5. Summary.....	45

## **Chapter 3. Estimation of the tropical Atlantic circulation from altimetry data using a reduced-rank stationary Kalman filter**

<i>M. Buehner, P. Malanotte-Rizzoli, A. Busalacchi and T. Inui</i> .....	49
--	----

1. Introduction.....	50
2. Model of the tropical Atlantic.....	52
3. Approach for assimilating SHA.....	57
3.1. The reduced-rank Kalman filter.....	57
3.2. TOPEX/Poseidon altimetry data.....	59

3.3.	Specification of $Q_r$ and $R$ .....	61
3.4.	Diagnostics of the stationary forecast error covariance.....	63
4.	Identical twin assimilation experiment.....	68
4.1.	Configuration of the experiment.....	68
4.2.	Results from assimilating simulated SHA observations.....	69
5.	Assimilation of the TOPEX/Poseidon SHA.....	72
5.1.	Configuration of the experiment.....	74
5.2.	Results from assimilating TOPEX/Poseidon SHA.....	75
6.	Summary and conclusions.....	82
	Appendix: Derivation of reduced-rank Kalman filter.....	87

## **Chapter 4. A synthetic float analysis of upper-limb meridional overturning circulation interior ocean pathways in the tropical/subtropical Atlantic**

	<i>G. Halliwell, R. Weisberg and D. Mayer</i> .....	93
1.	Introduction.....	94
2.	Background and goals.....	96
3.	Analysis procedures.....	98
3.1.	The numerical model.....	98
3.2.	Float/drifter analysis in HYCOM.....	101
3.3.	Vorticity balance analysis.....	102
4.	Eulerian Analysis.....	104
4.1.	Model fields.....	104
4.2.	The seasonal internal energy storage and release mechanism.....	105
5.	Lagrangian analysis.....	106
5.1.	Design of the southern hemisphere float release experiment.....	106
5.2.	Overview of simulated upper-limb pathways.....	108
5.3.	Co-existence of the upper-limb MOC flow and subtropical cells.....	111
5.4.	Importance of using particle-following floats to track upper-limb pathways.....	112
5.5.	Float census.....	114
6.	Case study and mechanisms.....	114
6.1.	Float 1 approaches the equator and retroflects into the EUC.....	118
6.2.	Float 1 transits across the basin along the equator.....	120
6.3.	Float 1 departs from the equator and enters into the NECC.....	120
6.4.	Float 1 moves northward in the interior North Atlantic.....	123
6.5.	Float 1 moves southwestward after subduction in the subtropical gyre.....	123
6.6.	Float 1 travels along the western boundary.....	126
7.	Discussion.....	127
	Appendix 1: Diagnosis of vertical velocity.....	129
	Appendix 2: Spatial interpolation of model variables to floats.....	132
	Appendix 3: Float advection.....	133

## **Chapter 5. A seasonal and interannual study of the western equatorial Atlantic upper thermocline circulation variability**

<i>M. Vianna and V. Menezes</i> .....	137
1. Introduction.....	138
2. Estimates of current velocity from SSH slopes and curvatures.....	140
3. Data.....	143
3.1. Altimeter data.....	143
3.2. <i>In situ</i> data.....	143
4. Data processing.....	144
4.1. Circulation fields from SSH data.....	144
4.2. Computation of transport fields.....	146
4.3. Comparison of <i>in situ</i> data and altimeter-derived fields.....	146
5. Comparison of <i>in situ</i> data and altimeter-derived fields.....	146
5.1. SSHA time series and dynamic heights from PIRATA moorings.....	146
5.2. SSH and dynamic height from the CTD Etambot cruises.....	147
5.3. Current velocities and measurements of SADCPC and CTD-derived velocities.....	148
6. Analysis of the circulation fields.....	151
6.1. The mean currents.....	152
6.2. The seasonal cycle.....	155
6.3. Standing trapped annual equatorial waves and meandering.....	158
6.4. Interannual variability.....	162
7. Inter-hemispheric transports and transport pathways.....	165
8. Summary and conclusions.....	167
Appendix: Preparation of band-limited circulation and transport fields.....	169

## **Chapter 6. Fate of the equatorial undercurrent in the Atlantic**

<i>W. Hazeleger and P. de Vries</i> .....	175
1. Introduction.....	175
2. Model and data handling.....	176
3. Results.....	178
3.1. Upwelling sites and pathways.....	179
4. Summary and conclusions.....	189

## **Chapter 7. The flow of AAIW along the equator**

<i>M. Jochum and P. Malanotte-Rizzoli</i> .....	193
1. Introduction.....	193
2. The model configuration.....	194
3. Synthesis of theory and observations.....	199
4. Summary.....	210

**Chapter 8. Planetary equatorial trapped waves in the Atlantic Ocean from TOPEX/Poseidon altimetry**

*C. França, I. Wainer, A. Mesquita and G. Goni*.....213

1.	Introduction.....	213
2.	Sea height and sea surface temperature data.....	215
3.	Equatorially trapped modes.....	219
4.	Results.....	221
5.	Discussion.....	226
6.	Summary and conclusions.....	229

**Chapter 9. Pathways and variability at intermediate depths in the tropical Atlantic**

*C. Schmid, Z. Garraffo, E. Johns and S. Garzoli*.....233

1.	Introduction.....	233
2.	Data and methods.....	237
3.	Large scale flow patterns.....	239
3.1.	Vertical and horizontal structure.....	239
3.2.	Interior pathways.....	244
3.3.	Western boundary pathways.....	247
3.4.	Semi-annual means of the velocity at intermediate depth.....	249
4.	Temporal and spatial variability between 5°S and 7°S.....	251
4.1.	Observations.....	251
4.2.	Comparison with MICOM.....	252
4.3.	Characteristic length scales.....	256
4.4.	Characteristic time scales.....	256
4.5.	Kinematic analysis.....	259
5.	Discussion and conclusions.....	263

**Chapter 10. A comparison of kinematic evidence for tropical cells in the Atlantic and Pacific oceans**

*R. Molinari, S. Bauer, D. Snowden, G. Johnson, B. Bourles, Y. Gouriou and H. Mercier*.....269

1.	Introduction.....	269
2.	Data and analyses.....	271
3.	Results.....	274
4.	Discussion.....	280

**Chapter 11. Subtropical cells in the Atlantic Ocean: An observational summary**

*D. Snowden and R. Molinari*.....287

1.	Introduction.....	287
2.	Subduction.....	291
	2.1. Water masses and sources regions.....	291
	2.2. Formation rates.....	294
3.	Pathways between the subduction regions and the upwelling regions.....	295
	3.1. Western boundary pathways.....	295
	3.2. Interior pathways.....	298
	3.3. Interior entrainment into the Equatorial Undercurrent.....	299
4.	Upwelling in the tropical Atlantic.....	300
	4.1. Equatorial upwelling.....	300
	4.2. Off equatorial upwelling.....	303
5.	Near surface return flow to the subduction areas.....	305
6.	Summary and remaining questions.....	306

**Chapter 12. Spectral, formal, and nonlinear stability in a layered quasigeostrophic model with application to the Atlantic North Equatorial Current**

*F. Beron-Vera and J. Olascoaga*..... 313

1.	Introduction.....	313
2.	Theory.....	315
	2.1. Model.....	315
	2.2. Stability Analysis.....	317
	2.2.1. Formal and nonlinear stability.....	318
	2.2.2. Spectral stability.....	320
	2.2.3. Elementary modes resonance.....	320
3.	Data.....	321
	3.1. Basic flow.....	322
	3.2. Stability properties.....	323
	3.3. Comparison with <i>in situ</i> observations and earlier works.....	327
4.	Summary and conclusions.....	329
	Appendix A: Energy and Casimir matrices.....	330
	Appendix B: Dispersion relation.....	331
	Appendix C: Eigenvalue problem in $\psi$ coordinates.....	331

**Chapter 13. Synoptic study of warm rings in the North Brazil Current retroflection region using satellite altimetry**

*G. Goni and W. Johns*..... 335

1.	Introduction.....	335
2.	Region of study.....	338
3.	Data.....	338
	3.1. Altimeter data.....	338
	3.2. Climatological data.....	341
4.	Two-layer model approximation.....	343
5.	Results and discussion.....	345
	5.1. Upper layer thickness fields.....	345

5.2.	Ring shedding.....	347
5.3.	Ring trajectories.....	347
5.4.	Ring parameters.....	350
5.5.	Interannual variability.....	352
6.	Summary.....	354

**Chapter 14. North Brazil Current rings and the variability in the latitude of the retroflection**

*S. Garzoli, A. Field and Q. Yao*..... 357

1.	Introduction.....	357
2.	Methodology.....	360
3.	Dynamic height field.....	362
4.	Latitude of penetration and number of rings shed.....	366
5.	Rings volume and temperature transport.....	367
6.	Summary.....	370

**Chapter 15. North Brazil Current rings and transport of southern waters in a high resolution numerical simulation of the North Atlantic**

*Z. Garraffo, W. Johns, E. Chassignet and G. Goni*..... 375

1.	Introduction.....	375
2.	Model configuration.....	378
3.	The North Brazil Current system from the model and observations: The seasonal circulation.....	379
4.	The North Brazil rings, sea surface height variability and effect on transports through the Lesser Antilles passages.....	383
4.1.	Sea surface height space-time diagrams.....	383
4.2.	Surface height variability from the model and observations.....	385
4.3.	Ring types, associated sea height anomaly, and trajectories.....	387
4.4.	Effect of NBC rings in the transports through the Lesser Antilles passages.....	393
5.	Transport of southern Atlantic waters by rings.....	393
5.1.	Transport from criteria on radius and vertical extent.....	395
5.2.	Transport from water mass analysis.....	395
5.3.	Comparison of kinematic and water mass methods.....	401
6.	Discussion and conclusions.....	403

**Chapter 16. Cross-gyre transport by North Brazil Current rings**

*W. Johns, R. Zantopp and G. Goni*..... 411

1.	Introduction.....	412
2.	Data and Methods.....	413
2.1.	Shipboard surveys.....	413
2.2.	Moored time series observations.....	413

2.3.	Water mass identification.....	416
3.	Results.....	420
3.1.	Surveyed rings.....	420
3.2.	Rings identified by moorings.....	423
3.3.	Cross-gyre transport by NBC rings.....	432
3.4.	Ring “watermass” vs. “geometric” volumes.....	434
4.	Discussion and conclusions.....	436

**Chapter 17. Impact of North Brazil Current rings on the local circulation and coral reef fish recruitment to Barbados, West Indies**

*R. Cowen, S. Sponaugle, C. Paris, J. Fortuna, K. Lwiza and S. Dorsey.....* 443

1.	Introduction.....	444
2.	Methods.....	445
2.1.	Bio-physical sampling.....	445
2.2.	Flow field calculations.....	447
2.3.	Biological measurements.....	448
3.	Results.....	449
3.1.	Surface salinity and transport.....	449
3.2.	Chlorophyll $\alpha$ and larval fish vertical distribution.....	451
3.3.	Fish settlement intensity.....	454
3.4.	Otolith growth and larval duration.....	454
4.	Discussion.....	455

**Chapter 18. Wind bursts and enhanced evaporation in the tropical and subtropical Atlantic Ocean**

*K. Katsaros, A. Mestas-Nuñez, A. Bentamy and E. Forde.....* 463

1.	Introduction and background.....	464
2.	Results.....	466
2.1.	Mean values and standard deviations.....	466
2.2.	Wind bursts and associated latent heat flux.....	468
3.	Concluding remarks.....	472

**Chapter 19. Spatial-temporal evolution of the low frequency climate variability in the tropical Atlantic**

*L. Ayina and J. Servain.....* 475

1.	Introduction.....	475
2.	Data and processing.....	479
2.1.	Data.....	479
2.2.	Processing.....	480
3.	Results.....	481

3.1.	The 5-year oscillation.....	482
3.2	The 1.5-year oscillation.....	485
4.	Conclusions.....	492
	Index.....	497