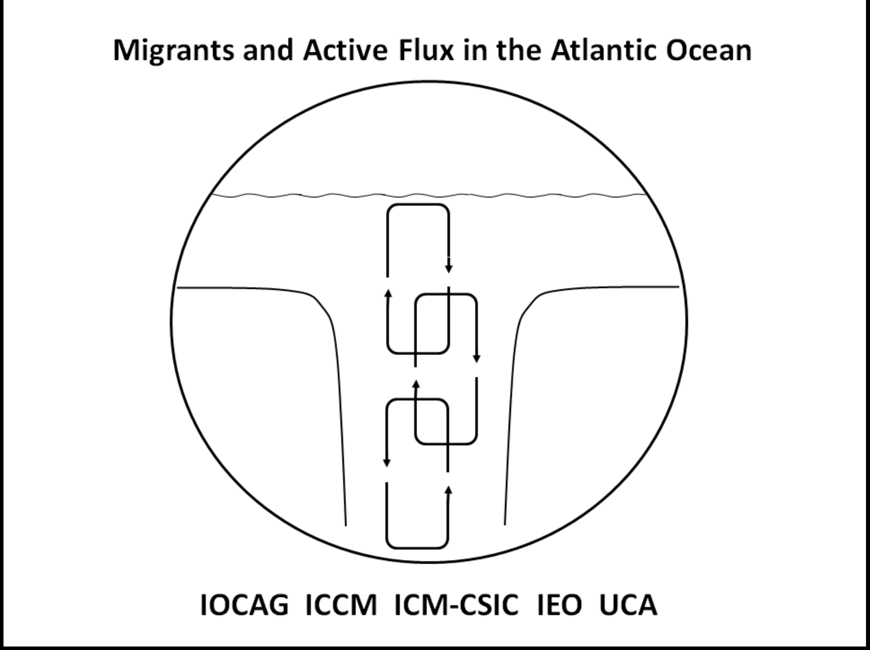
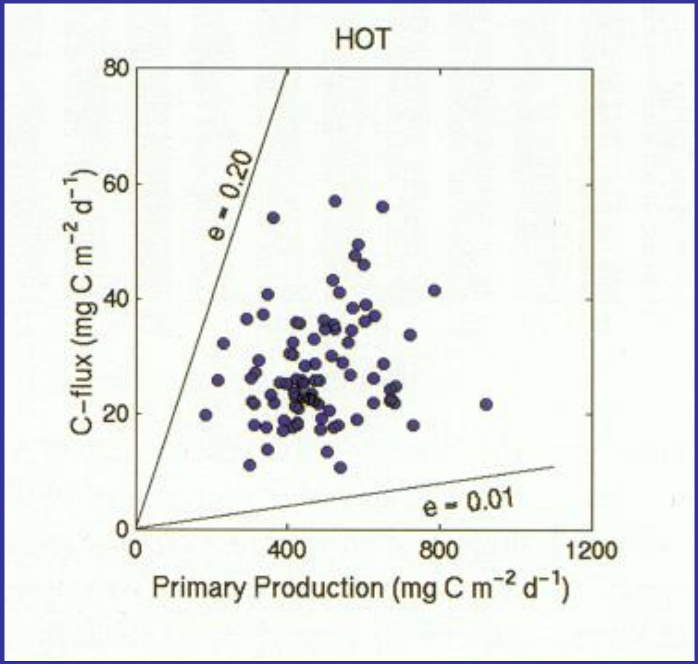
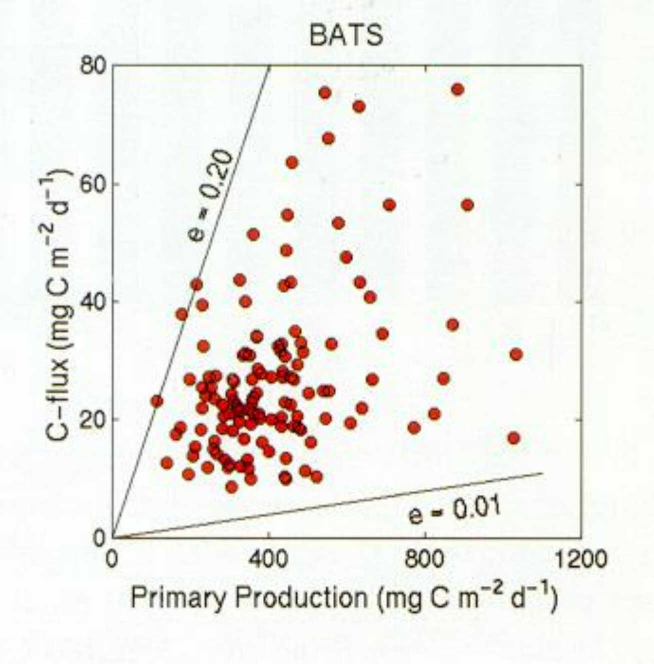
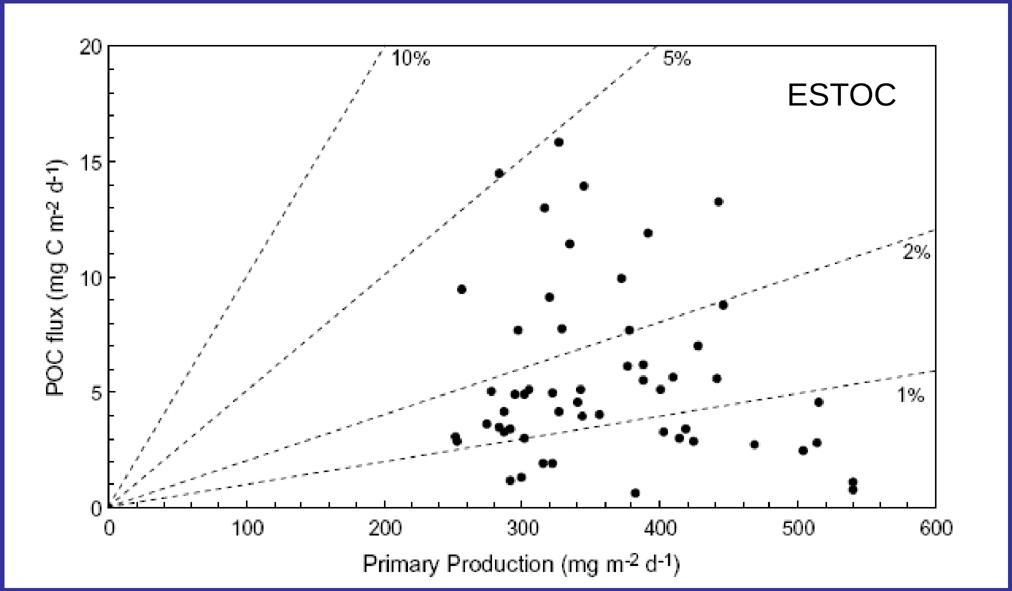
# The active flux by zonal migrants:
# Top-down control and the biological pump

Hernández-León, S., E. Fraile-Nuez, J. Gasol, S. Agustí, X. Irigoien, C. Duarte, et al.






Neuer et al. (2007)

## Equatorial Pacific

Export flux of carbon from $^{234}Th$ measurements

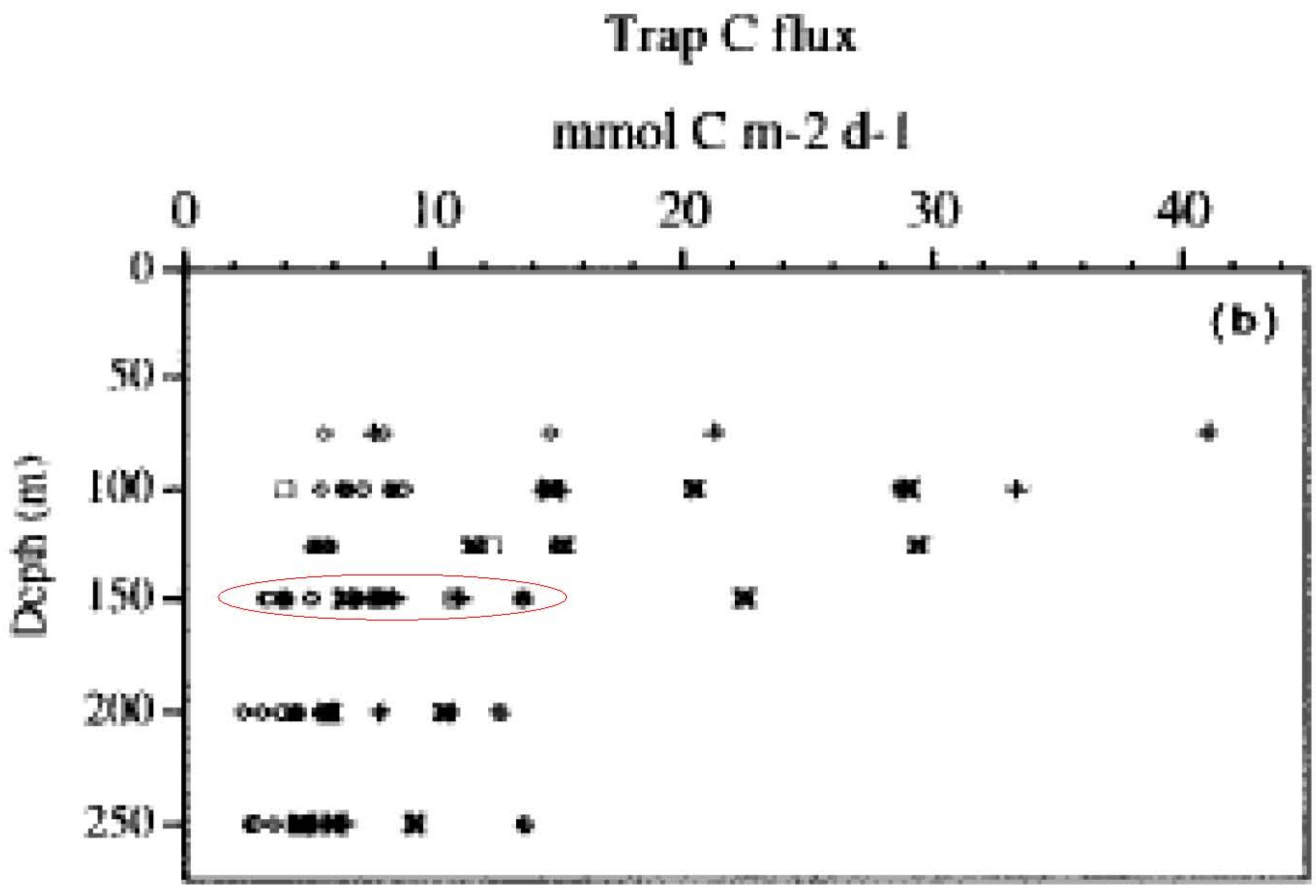
*Table 1. Total production, new production and export flux as sinking POC* (mmol C $m^{-2}$ $day^{-1}$)*

| | TS-I | TS-II |
|---|---|---|
| Total | 90 ± 10 | 129 ± 18 |
| New | 15 ± 7 | 22 ± 10 |
| Sinking flux | 1.9 ± 0.6 | 2.4 ± 0.9 |
| Sinking flux/ New | (13 ± 7)% | (11 ± 6)% |

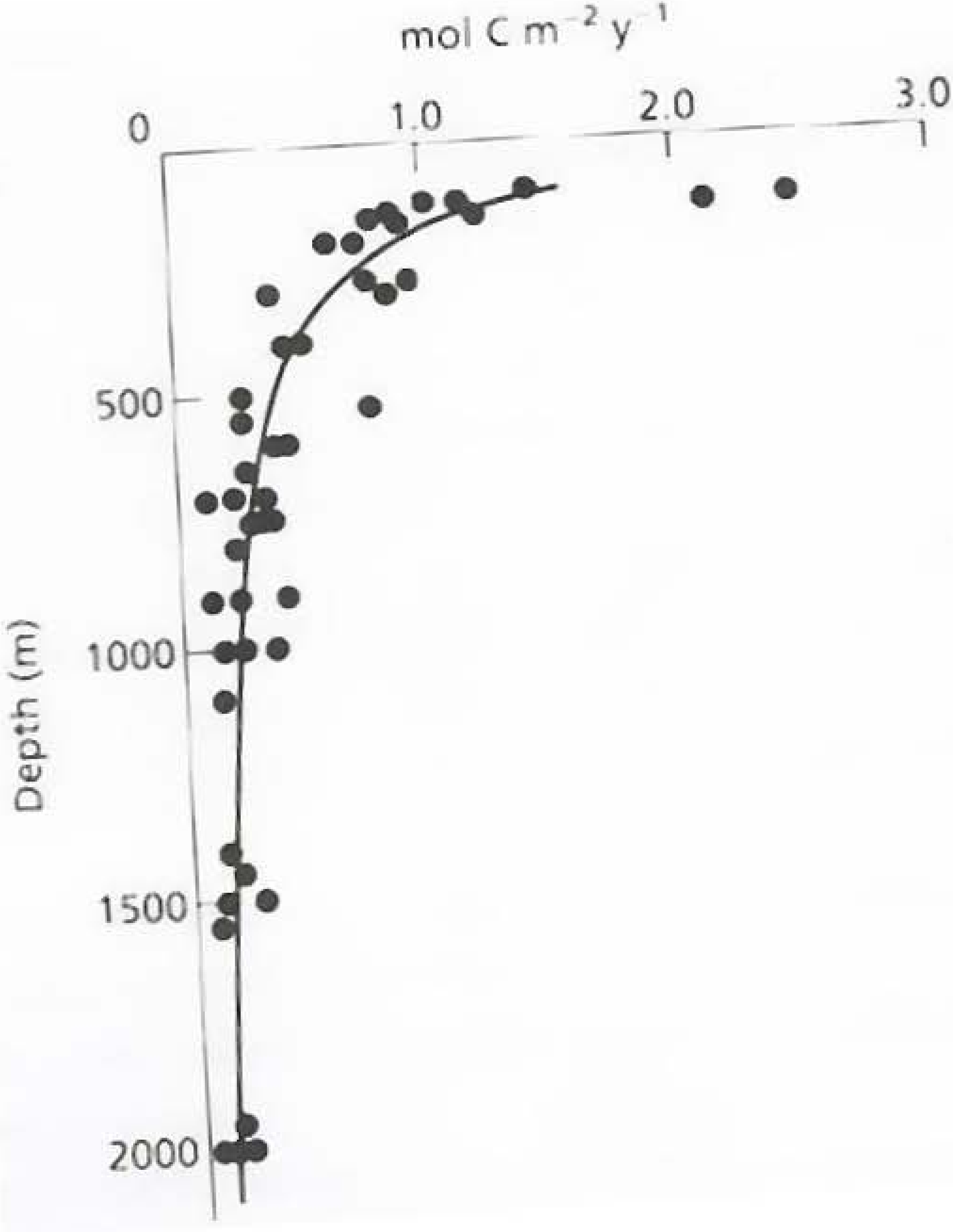
*Estimated uncertainties are twice the standard error of the mean based on replicate determinations. For sinking flux, each of the results computed from one of the individual profiles (Fig. 13) was taken as an independent determination. The greater variability during TS-II is due to the passage of a tropical instability wave.

Bacon *et al*. (1996)

# Equatorial Pacific

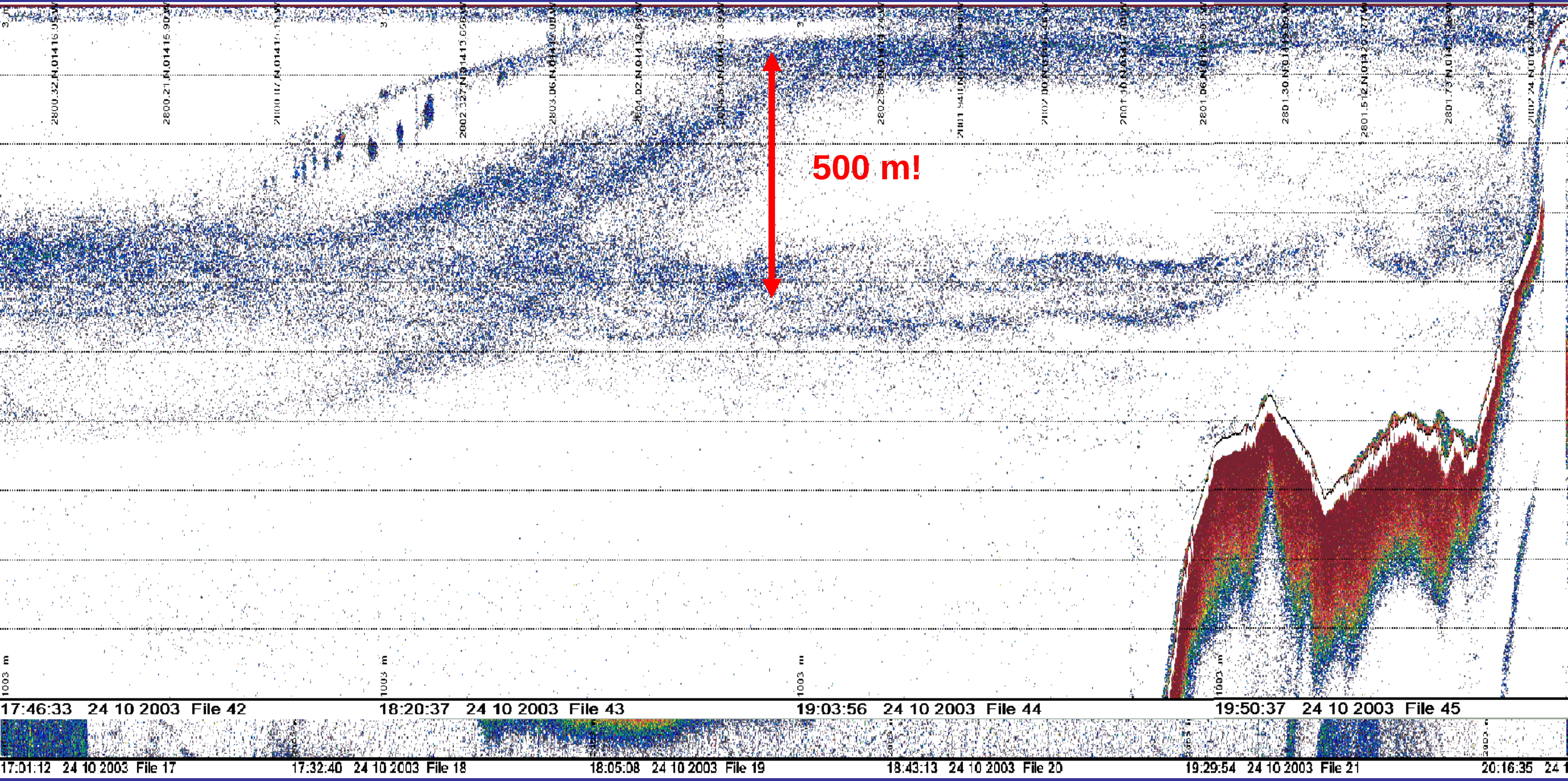



Murray *et al*. (1996)



mol C m⁻² y⁻¹
0
1.0
2.0
3.0
500
1000
1500
2000
Depth (m)

# Active Flux




Bordes et al. (2010)

Table 4.1. Zooplankton active flux estimated in different oceanic regions.

| Location | Time of year | Migrant biomass (mg $C \cdot m^{-2}$) | Respiratory flux (mg $C \cdot m^{-2} \cdot d^{-1}$) | Gut flux (mg $C \cdot m^{-2} \cdot d^{-1}$) | % of POC flux | References |
|---|---|---|---|---|---|---|
| Oligotrophic area | | | | | | |
| HOT | | 30.2 - 33.8 | 1.3-1.7 | - | 4[a] | Roman *et al.*, 2002 |
| Equator divergence | | 2.8 - 21.8 | 0.9-1.2 | - | <1-2[a] | Roman et al. (2002) |
| BATS | March/April | 192 (84–540) | 14.5 (6.2-40.8) | - | 34 (18-70)[a] | Dam *et al.* (1995) |
| BATS | year-round | 50 (0-123) | 2.0 (0-9.9) | - | 8 (0-39)[b] | Steinberg *et al.* (2000) |
| BATS | year-round | 83 (0.7-468) | - | 0.8 (0.007-4.5) | 4 (0.03-21)[c] | Schnetzer and Steinberg (2002) |
| Western Equator | October | 46.9 | 3 | - | 6 | Le Borgne and Rodier (1997) |
| North (Oceanic) | Oct-Nov | 30 ± 10 | 2.2 ± 0.3 | - | - | Isla and Anadón (2004) |
| Eastern Equator | March - April | 96 ± 25.2 | 4.2 ± 1.2 | - | 18[a] | Zhang and Dam (1997) |
| Eastern Equator | October | 154.8 ± 32.4 | 7.3 ± 1.4 | - | 25[a] | Zhang and Dam (1997) |
| ALOHA | Year-round | 162 (108-216) | 3.6 (2.6 - 19.1) | - | 15 (12-18)[a] | Al-Mutairi and Landry (2001) |
| ALOHA | June - July | 157.9 | 3.7 | - | 18[a] | Steinberg *et al.* (2008) |
| Eu- Meso-trophic area | | | | | | |
| Central Equator (HNLC) | October | 52.9 | 6 | - | 4[a] | Le Borgne and Rodier (1997) |
| North (coastal) | Oct-Nov | 360 ± 70 | 30.3 ± 1.9 | - | - | Isla and Anadón (2004) |
| North (poleward current) | Oct-Nov | 270 ± 210 | 10.4 ± 6.3 | - | - | Isla and Anadón (2004) |
| Western Equator | October | 46.9 | 3 | - | 6[a] | Le Borgne and Rodier (1997) |
| Western Equator | February | 367 (144 - 447) | 22.7 (7.3-19.1) | 4.8 (2.6-4.4) | 24 (13-35)[a] | Hidaka *et al.* (2001) |
| Canary Current | | | | | | |
| Canary Islands | March | 204 (108 - 341) | 0.8 (0.5-1.4) | 0.1 (0.05-0.18)[e] | 1.8 (1.1-2.7)[d] | Chapter 3.2 |
| Canary Islands | June | 580 - 1280 | 1.8 - 8.3 | 0.1 - 0-4[e] | 15-53[d] | Yebra *et al.* (2005) |
| Canary Islands | August | 247 - 125 | 4.2 - 1.9 | 0.3 - 2.4[e] | 20-45[d] | Hernández-León *et al.* (2001a) |
| 26ºN | Sept-Oct | 325 (106 - 486) | 0.6 (0.02 - 1.2) | 0.8 (0.01 - 3.0)[e] | 3.3 (0.1-9.0)[f] | Chapter 3.3 |
| | May-June | 314 (163.2 - 408) | 2.3 (1.7 - 3.4) | 0.2 (0.03 - 0.4)[e] | 47.8 (26.9-64.4)[f] | Chapter 3.4 |
| 21ºN | Sept-Oct | 857 (368 - 1601) | 6.5 (1.1 - 14.9) | 22.7 (1.3-96.1)[e] | 66.0 (0.1-149.5)[f] | Chapter 3.3 |
| | May-June | 314 (426.4 - 4480) | 2.3 (2.7 - 48.6) | 9.5 (0.05-28.0)[e] | 118.6 (29.1-273.7)[f] | Chapter 3.4 |

[a] %POC flux represents only respiratory flux. [b]Active flux includes DOC. [c]Active flux represents only gut flux. [d]Respiratory flux plus gut flux. [e]Gut flux assessed with GF.
[f]Potential ingestion assessed from respiration.

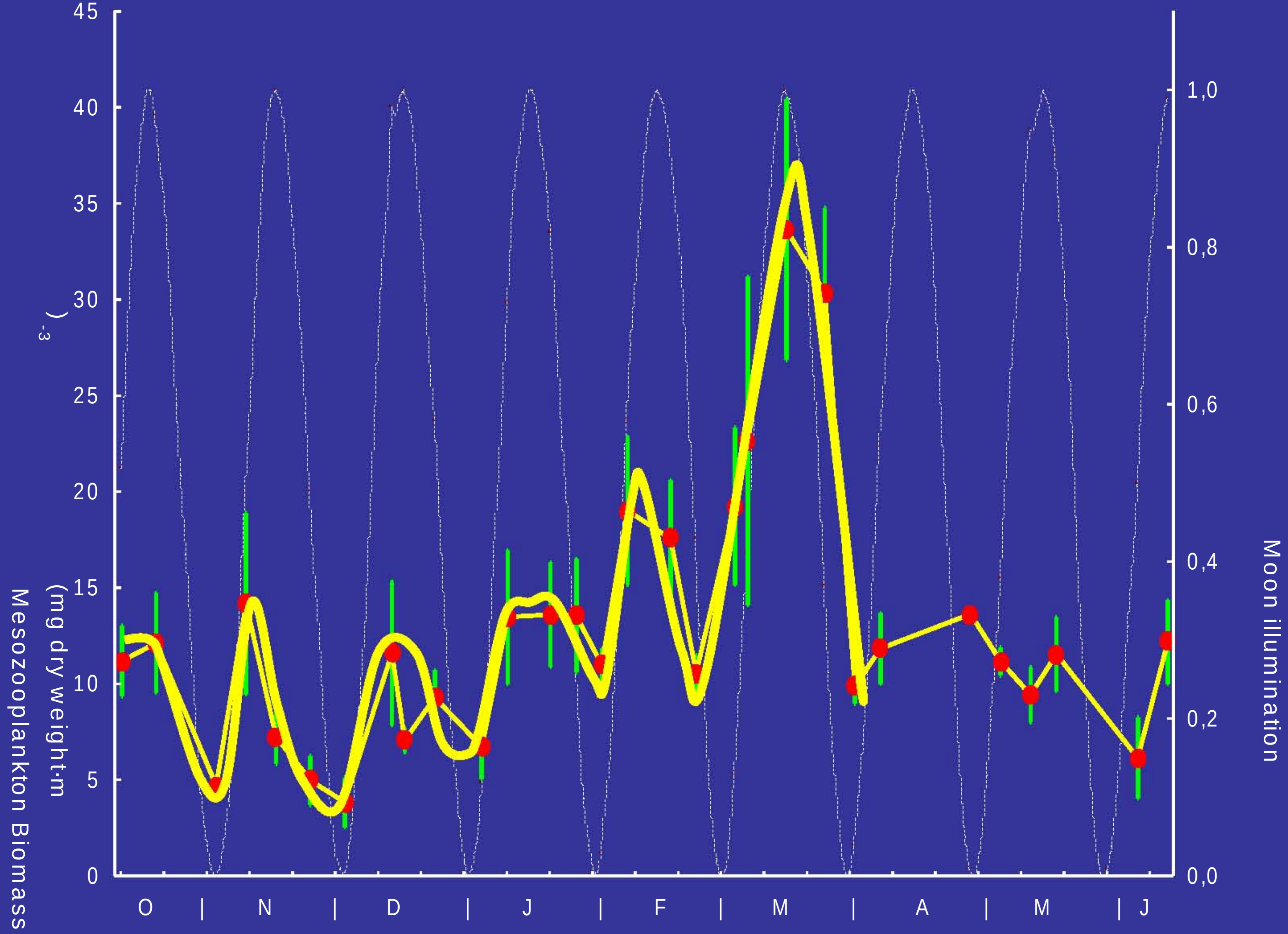
Putzeys (2013)

# But,

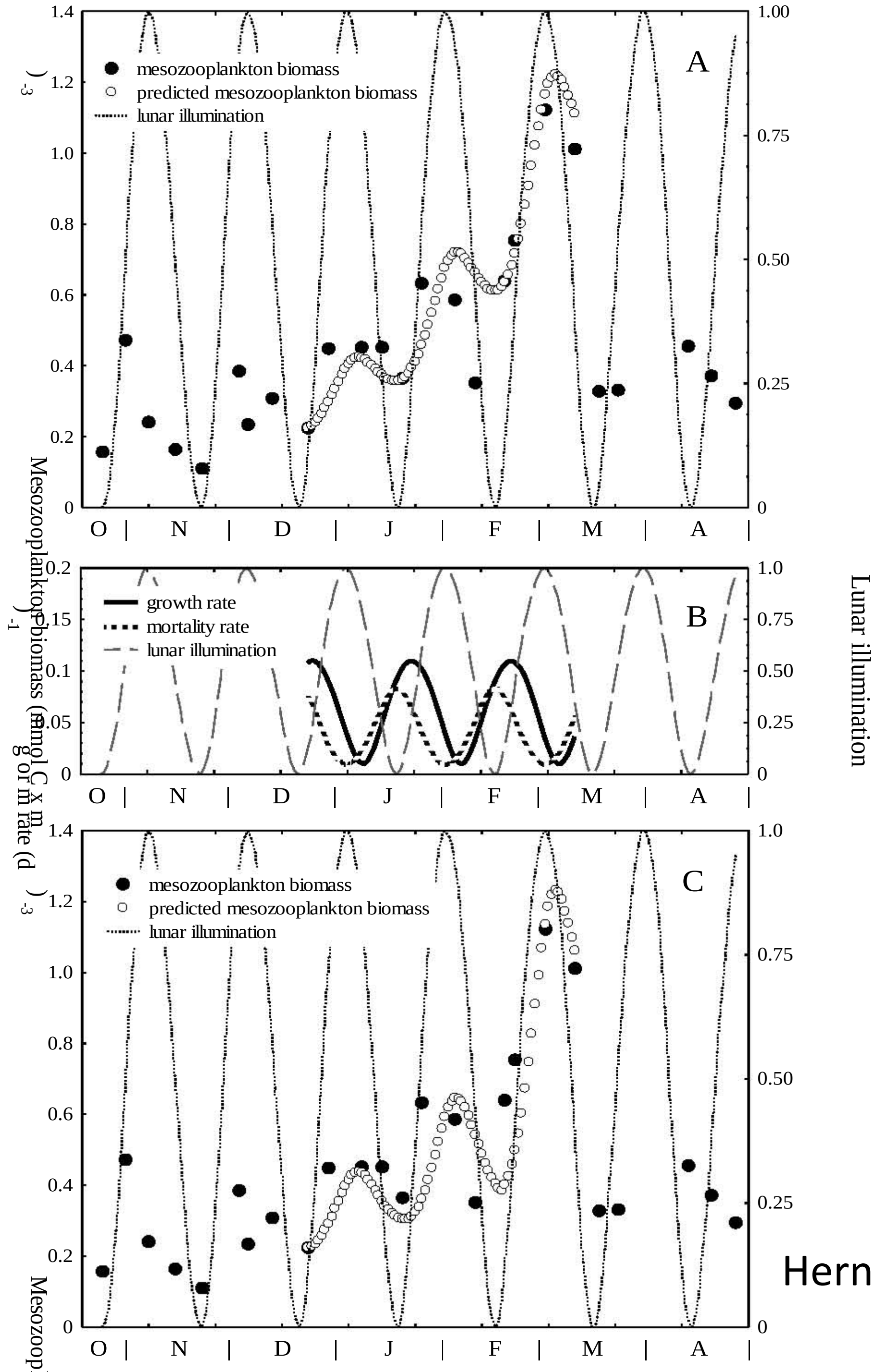
**Hidaka et al. (2001) showed that flux due to micronektonic organisms was 56-60% of total active flux.**

MOHT net
Oozeki et al. (2004)

# 2006




Hernández-León et al. (2010)




Hernández-León et al. (2010)

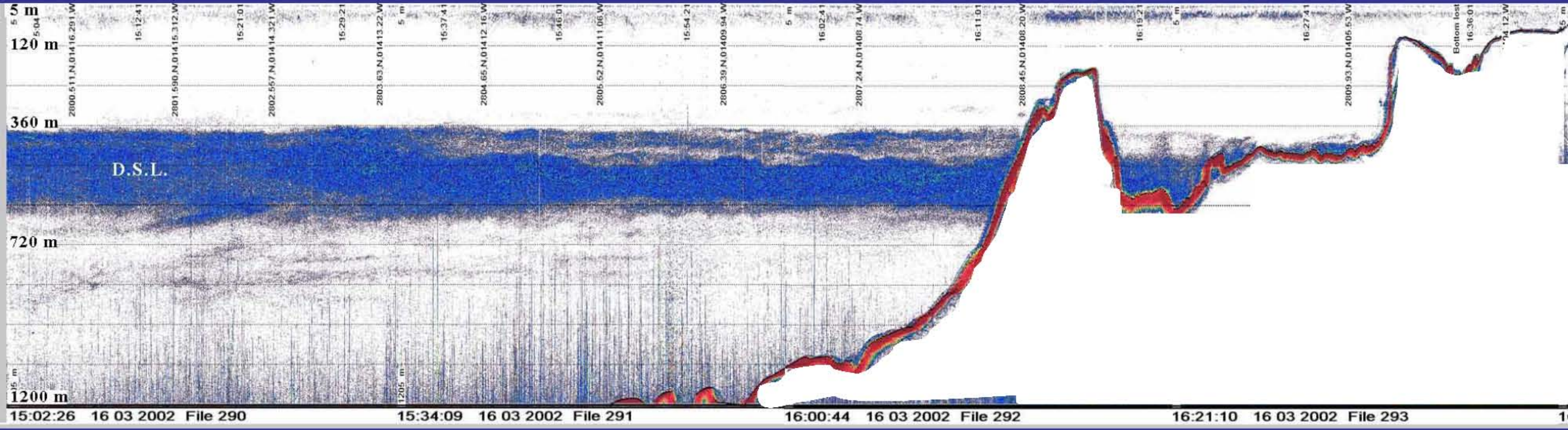
## Values of active flux:

| | | | | |
|---|---|---|---|---|
| No-bloom | May | 1999 | 1.9 | $mmolC \cdot m^{-2} \cdot d^{-1}$ |
| No-bloom | January | 2006 | 1.8-2.7 | " |
| Bloom | February-March | 2000 | 2.9 | " |
| Bloom | March-May | 2005 | 1.8-3.3 | " |
| Bloom | February-March | 2006 | 3.8-6.2 | " |
| Bloom | February-March | 2007 | 2.6-10.1 | " |

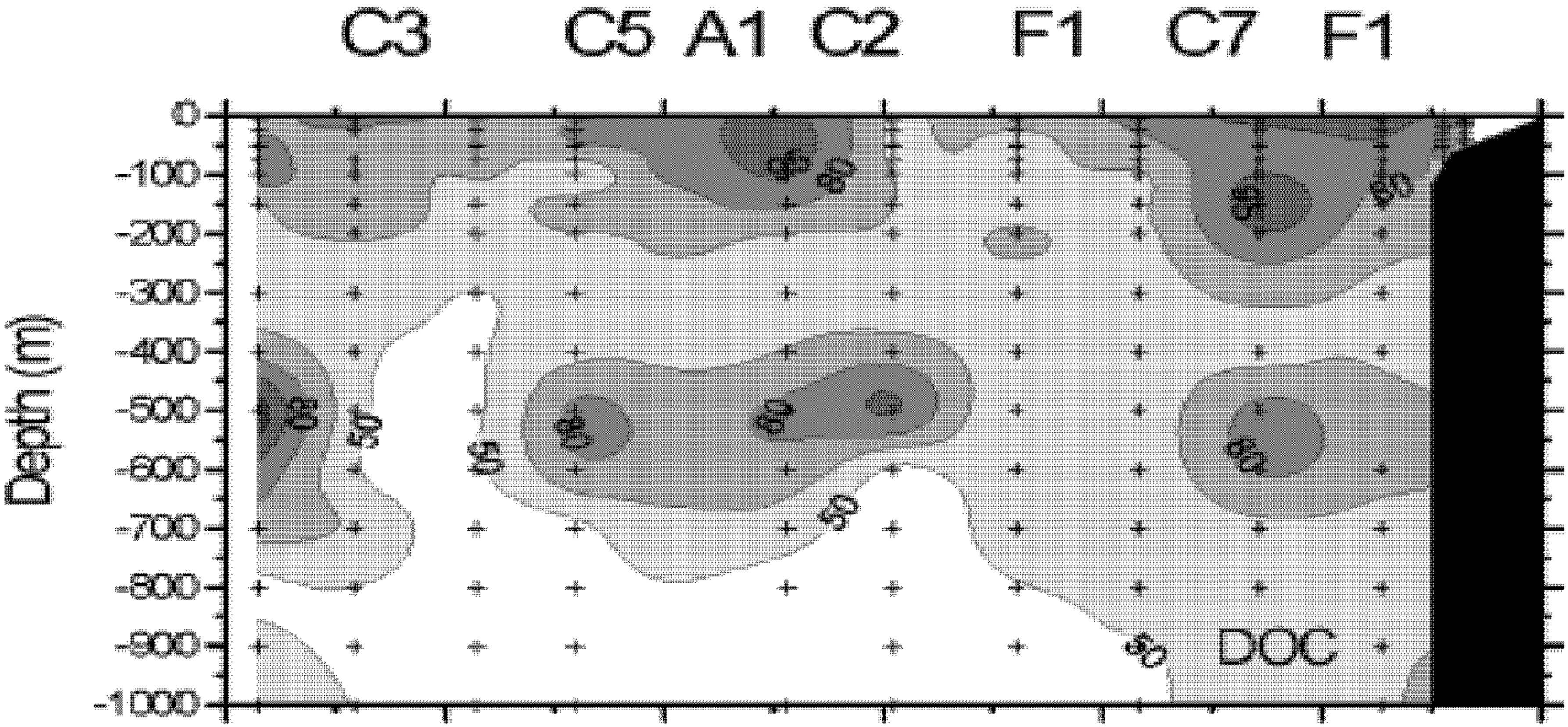
## Values of passive flux:

| | | | |
|---|---|---|---|
| Canary Cu | Neuer *et al.* (2007) | 0.1-1.3 | $mmolC \cdot m^{-2} \cdot d^{-1}$ |
| Canary Cu | Alonso-G. *et al*. (2009) | 5.8-9.7 | " |
| Canary Cu | Alonso-G. *et al*. (2010) | 0.1-2.0 | " |
| Canary Cu | Hernández-León *et al*. (unpubl.) | 0.5-2.2 | " |
| Hawaii | Karl *et al*. (2001) | 2.3-6.0 | " |
| Bermuda | Karl *et al*. (2001) | 2.4-6.0 | " |

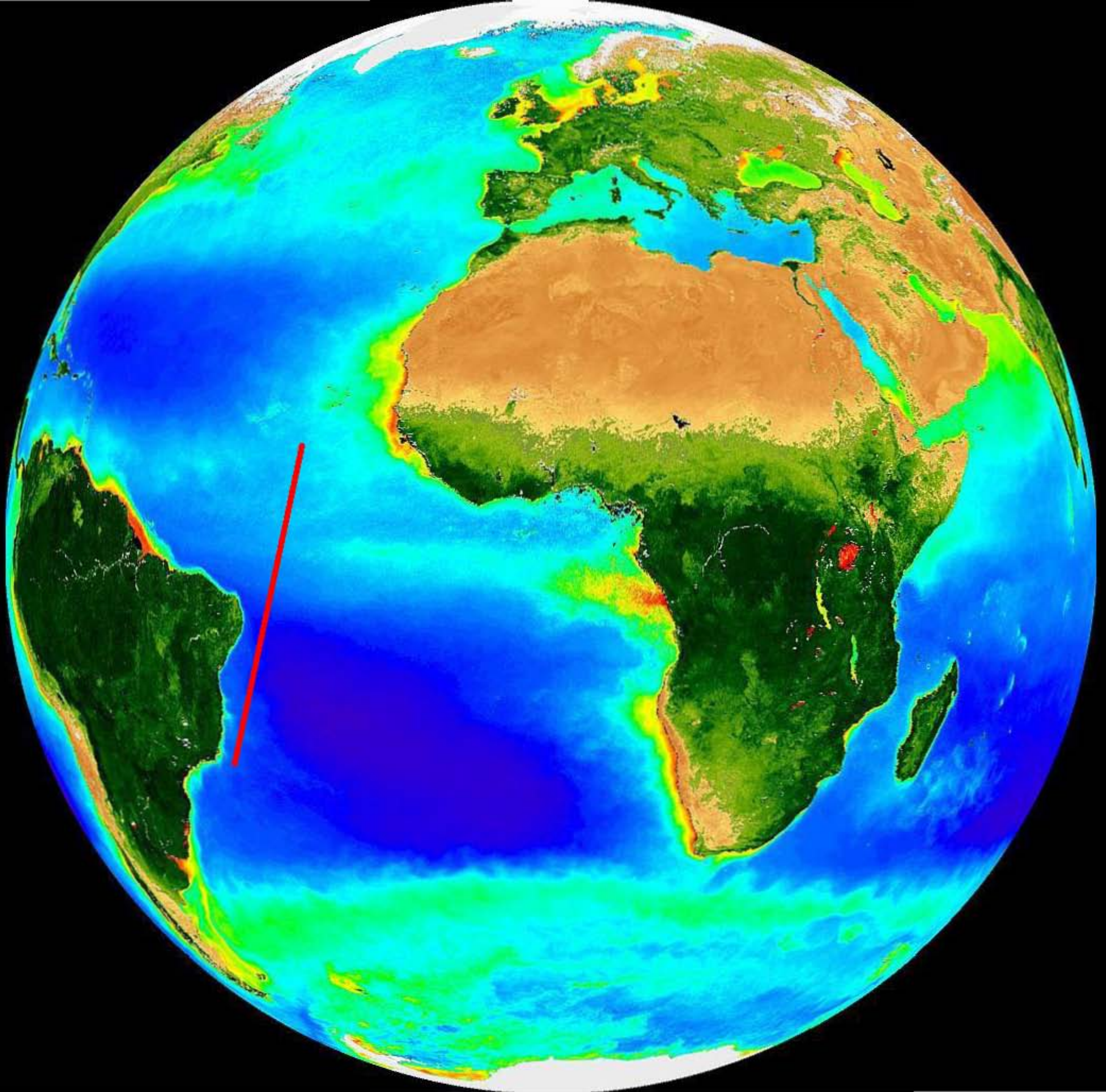
- Geochemical estimates
- of new production: 6.8-14.6 $mmolC \cdot m^{-2} \cdot d^{-1}$
- Gravitational flux: ~2-6 $mmolC \cdot m^{-2} \cdot d^{-1}$
- Active flux: ~2-6 "
- DOC: ?

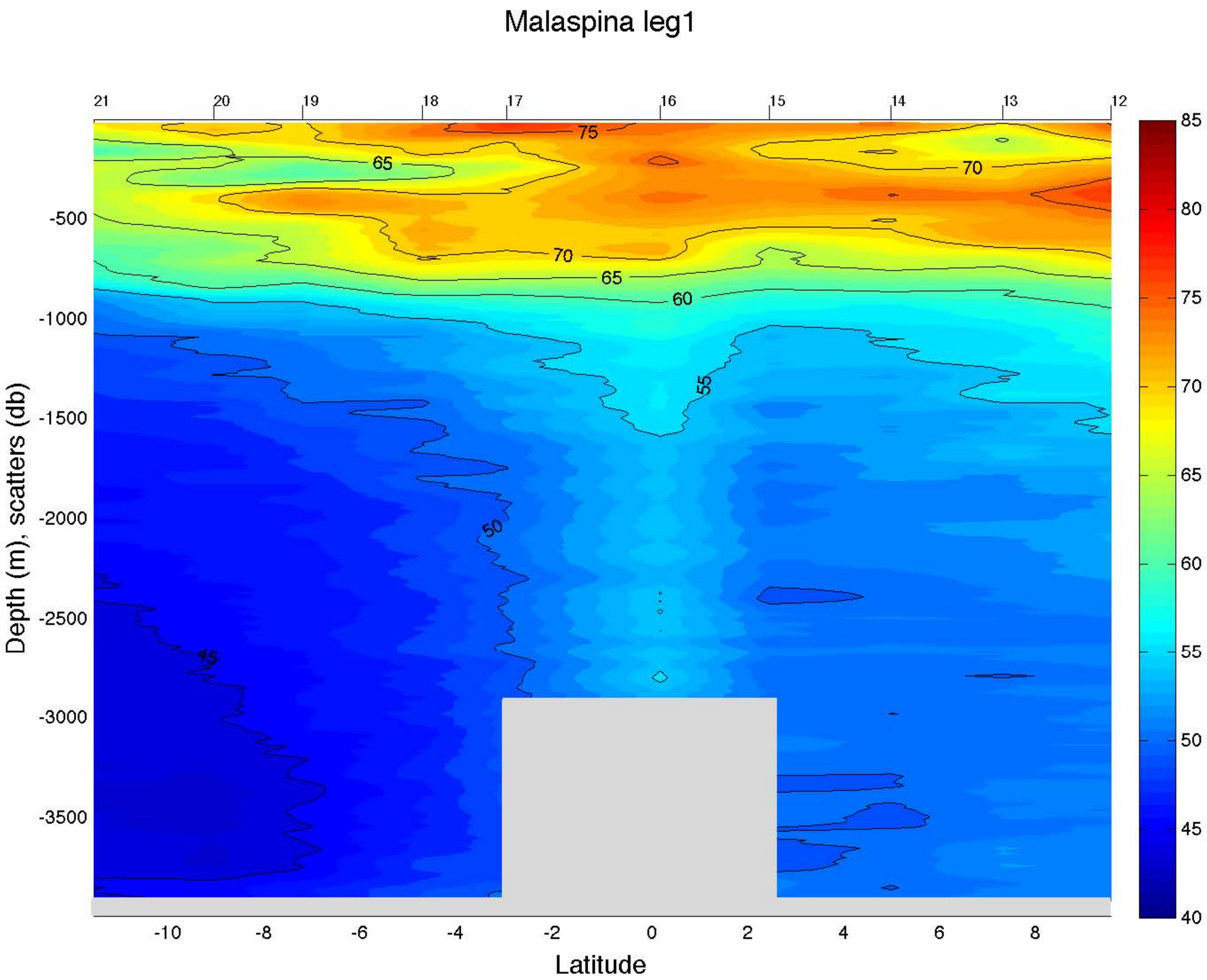



Bordes et al. (2010)

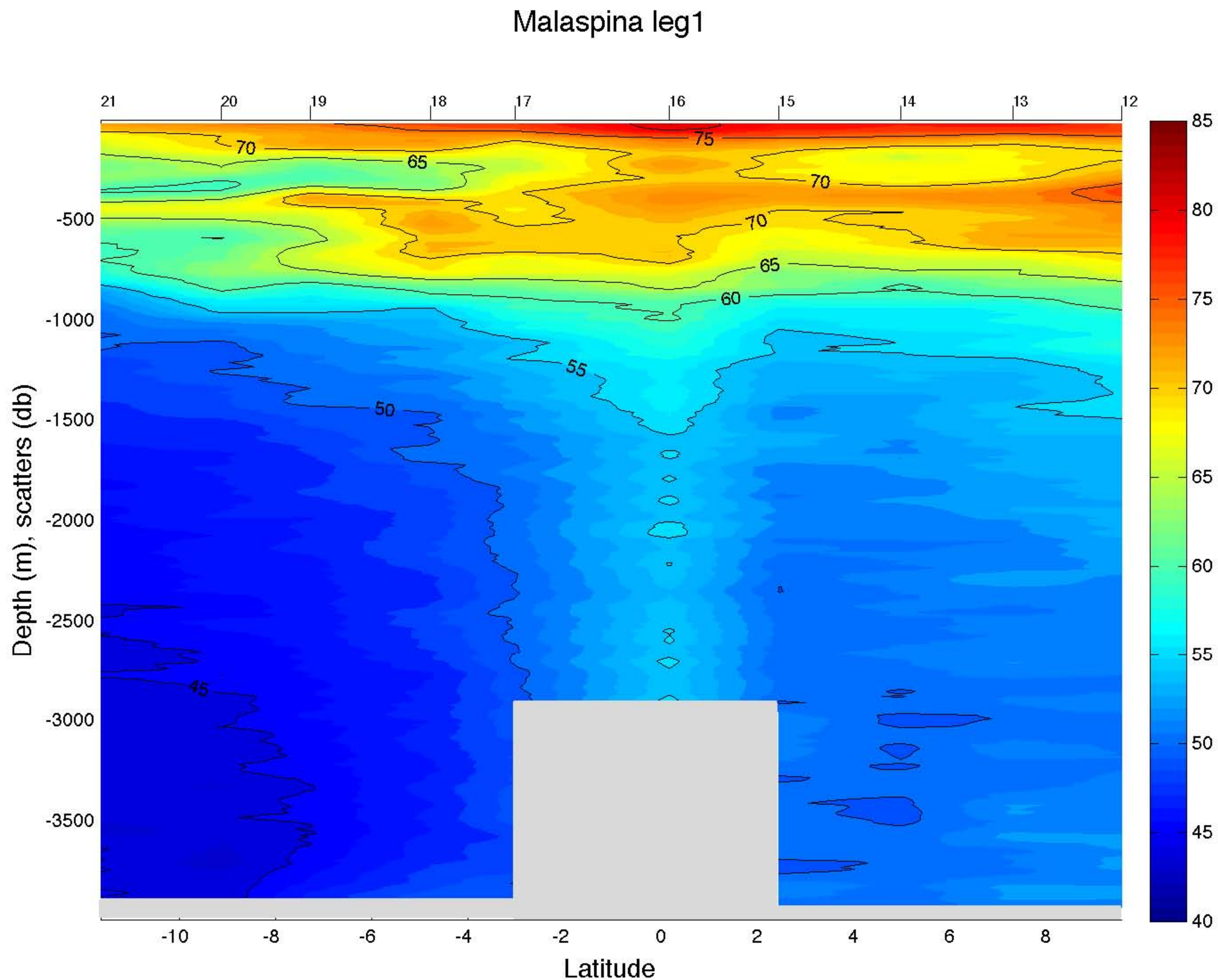



Arístegui et al. (2003)

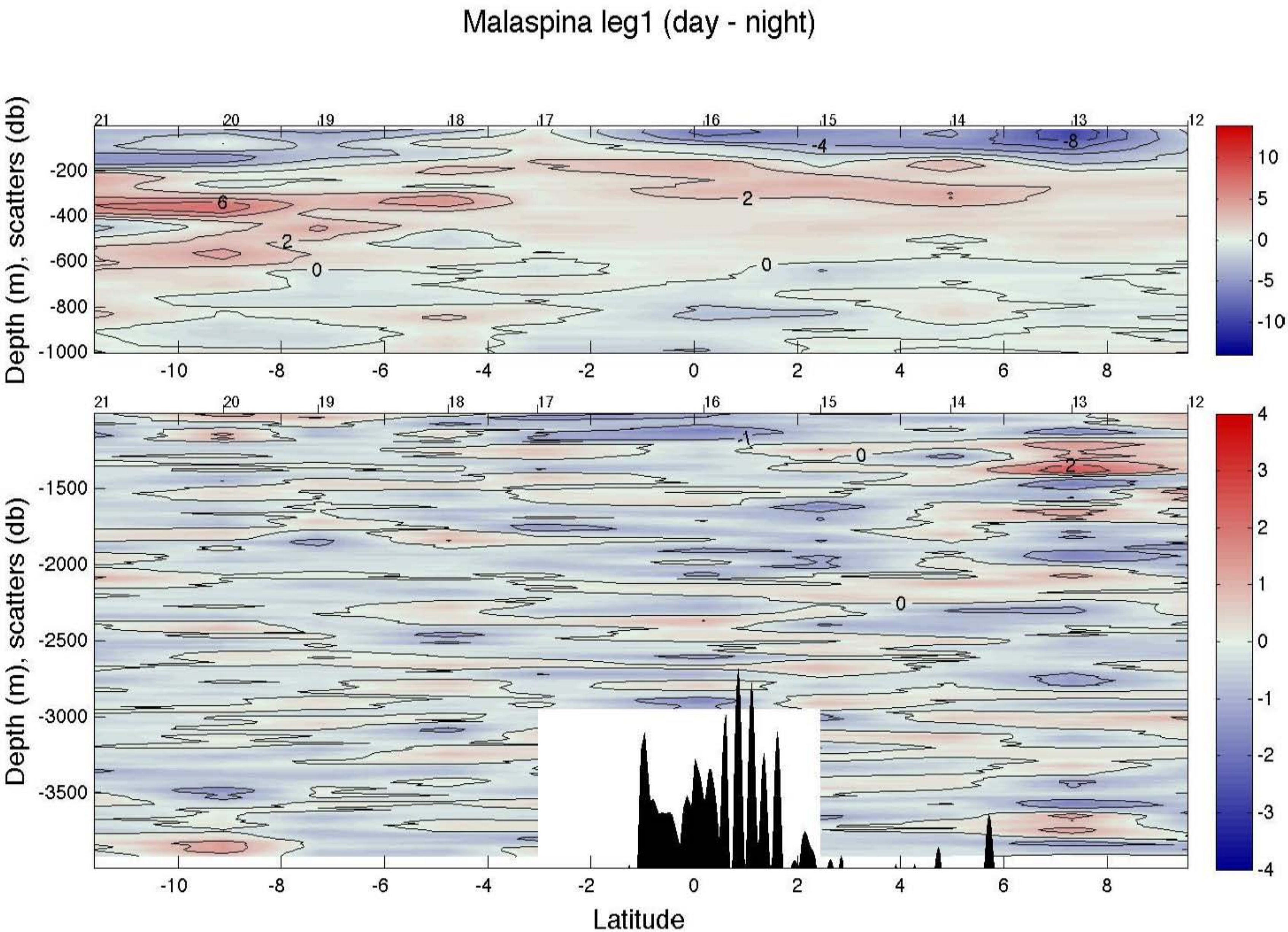




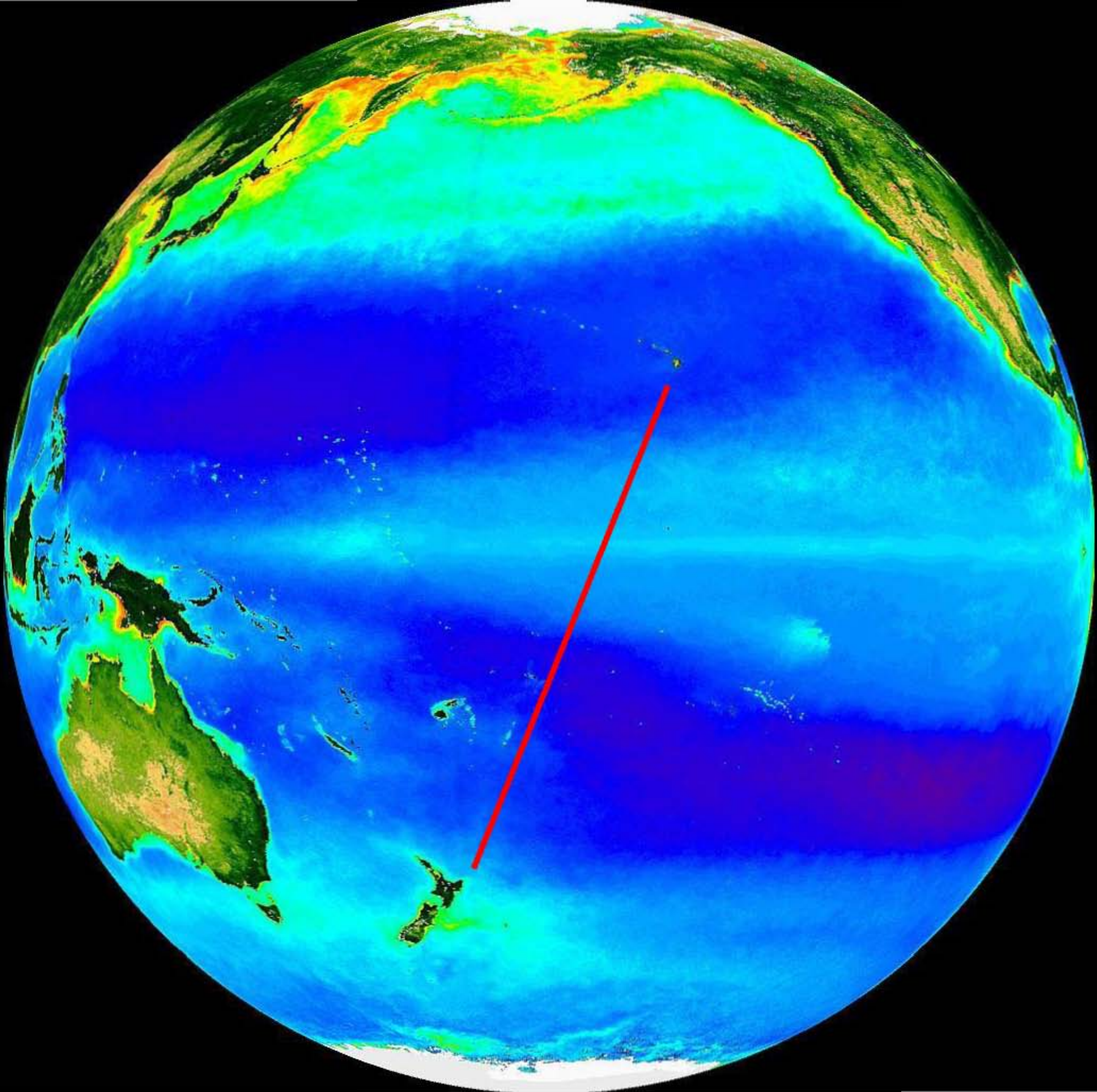
Malaspina leg1
21
20
19
18
17
16
15
14
13
12
75
65
70
70
65
60
55
50
45
-500
-1000
-1500
-2000
-2500
-3000
-3500
Depth (m), scatters (db)
-10
-8
-6
-4
-2
0
2
4
6
8
Latitude
85
80
75
70
65
60
55
50
45
40



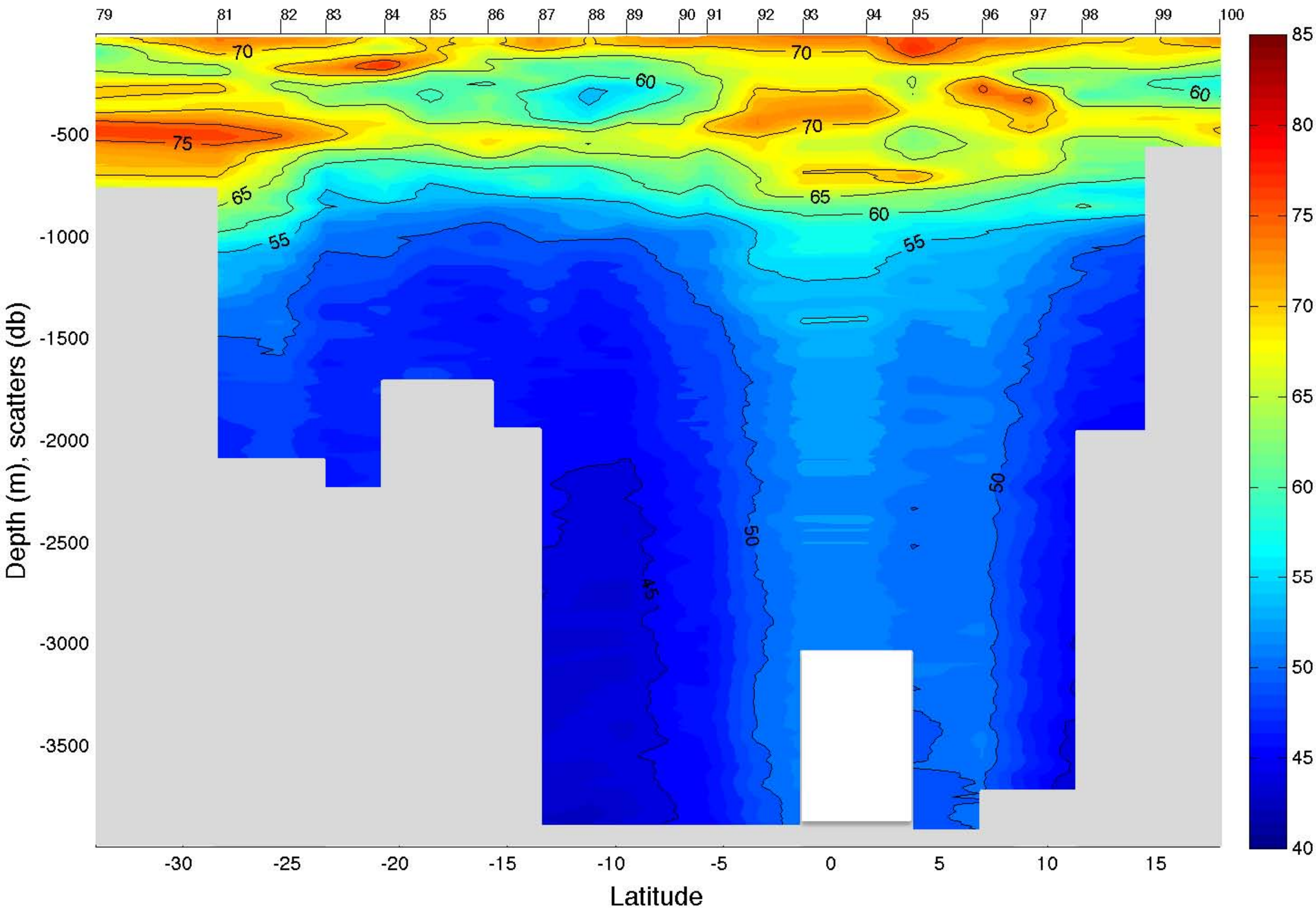
Malaspina leg1
21
20
19
18
17
16
15
14
13
12
70
65
75
70
70
65
60
55
50
45
Depth (m), scatters (db)
-500
-1000
-1500
-2000
-2500
-3000
-3500
-10
-8
-6
-4
-2
0
2
4
6
8
Latitude
85
80
75
70
65
60
55
50
45
40



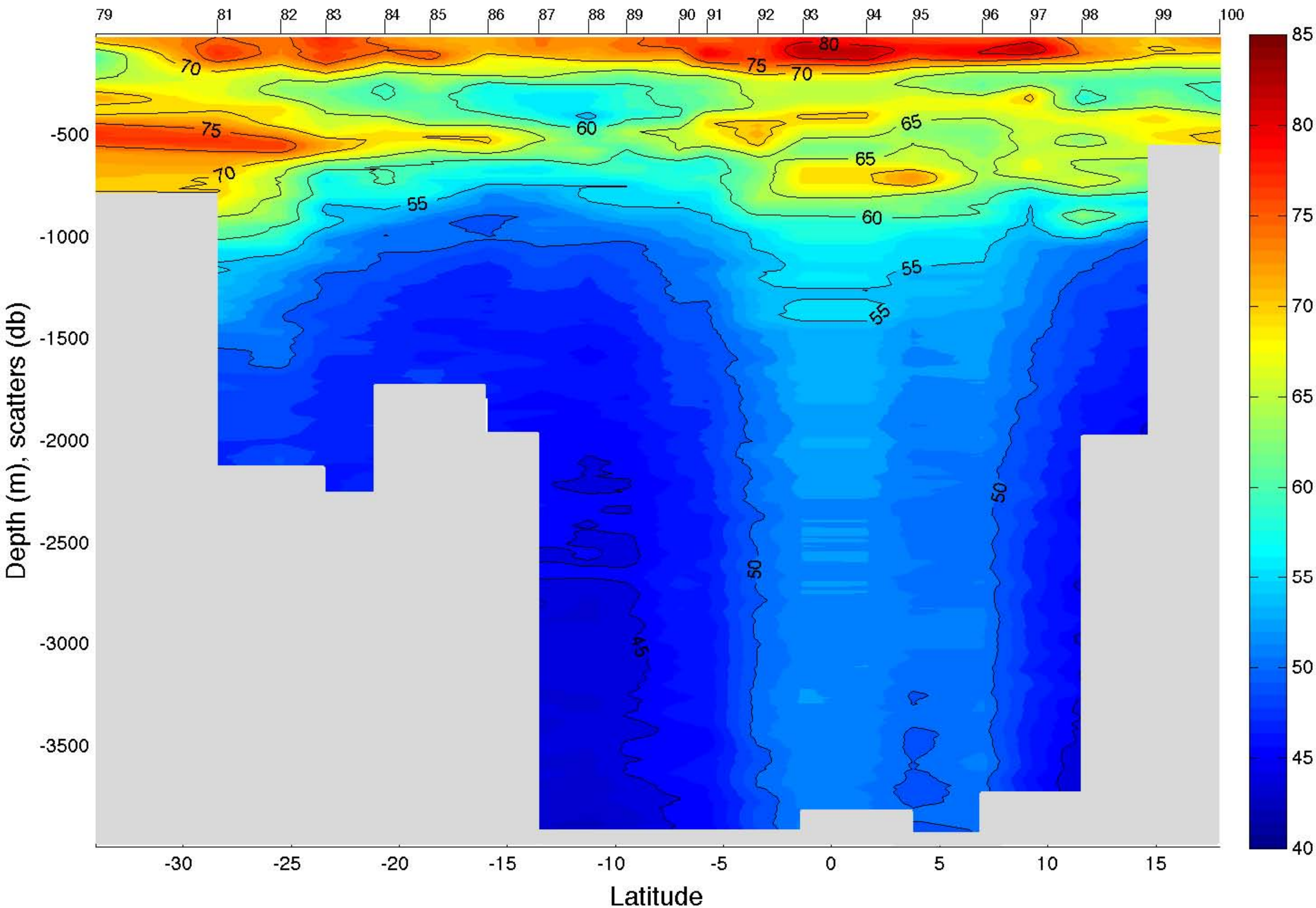
Malaspina leg1 (day - night)
Depth (m), scatters (db)
Latitude
21
20
19
18
17
16
15
14
13
12
-200
-400
-600
-800
-1000
-1500
-2000
-2500
-3000
-3500
-10
-8
-6
-4
-2
0
2
4
6
8
10
5
0
-5
-10
4
3
2
1
0
-1
-2
-3
-4



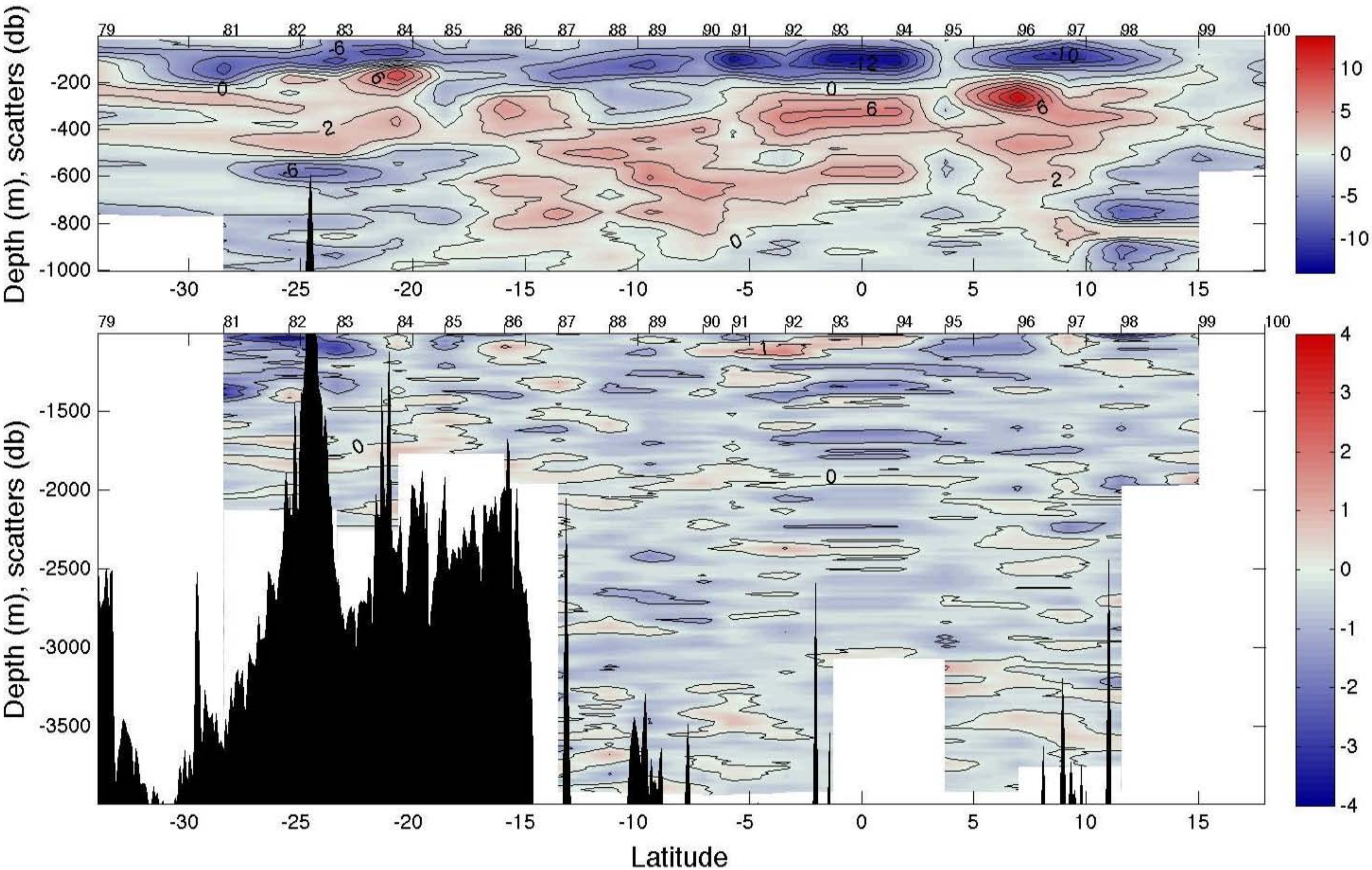
Malaspina leg5

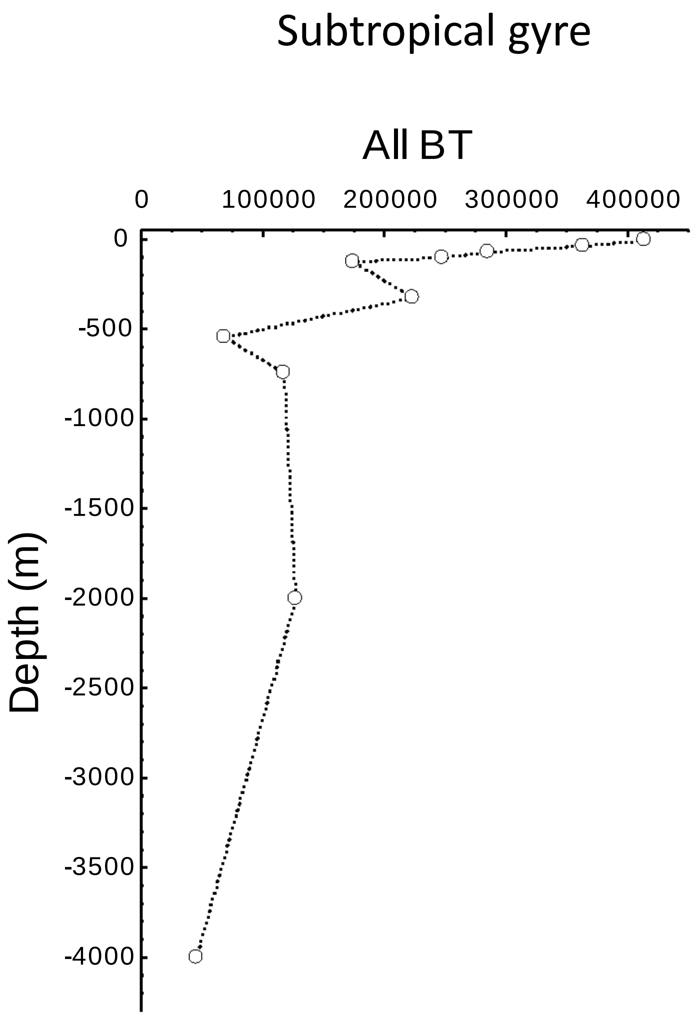


Malaspina leg5

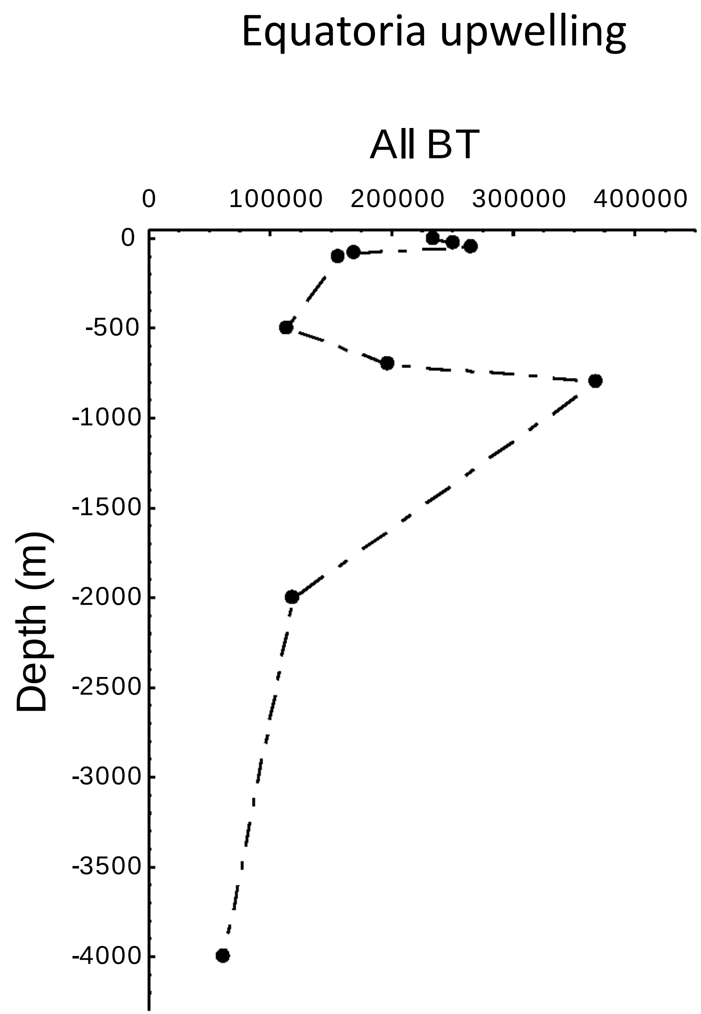


Malaspina leg5 (day - night)

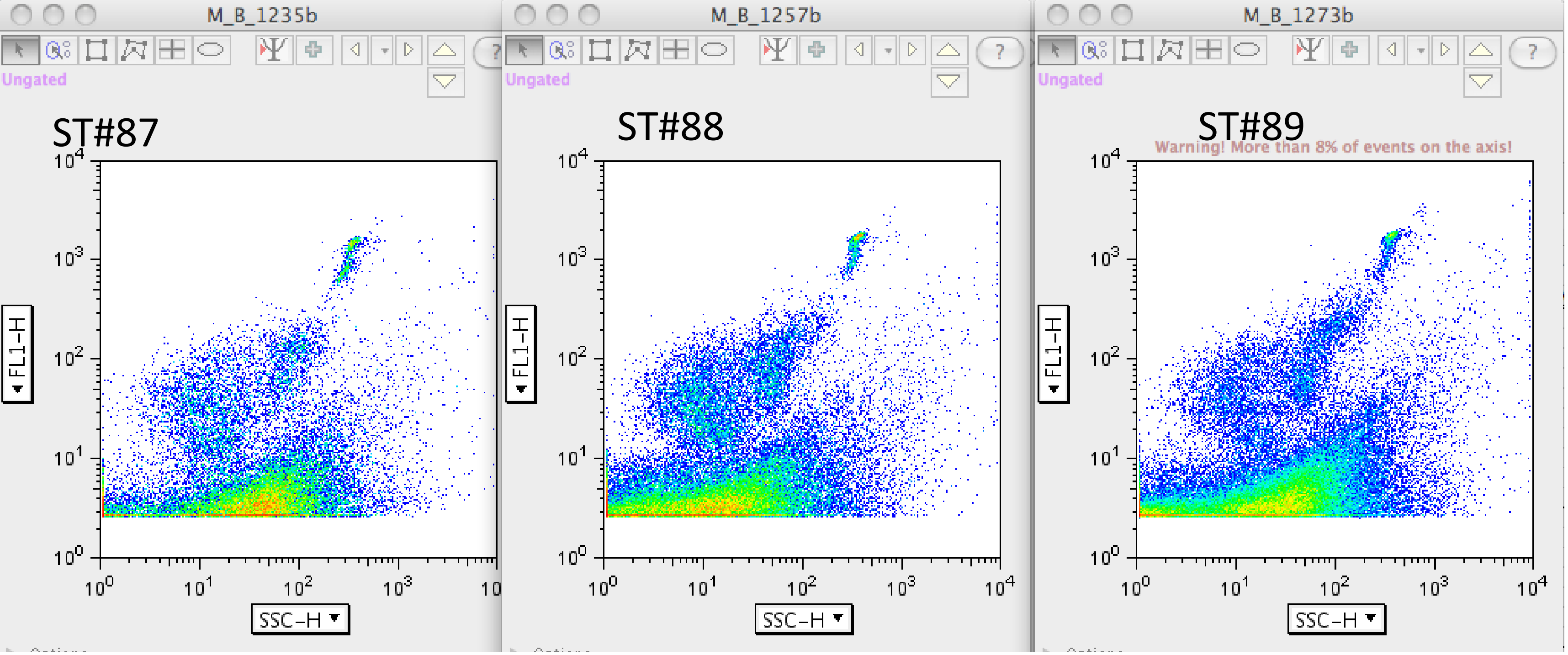


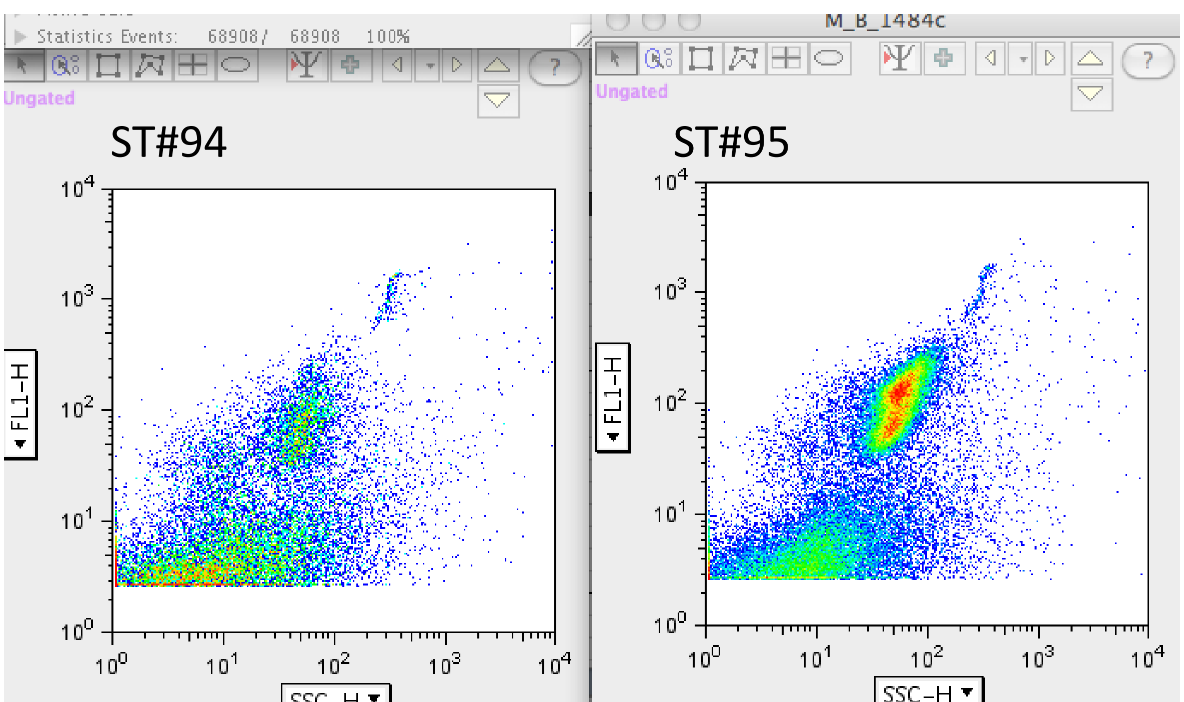


Subtropical gyre
All BT
0
100000
200000
300000
400000
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Depth (m)

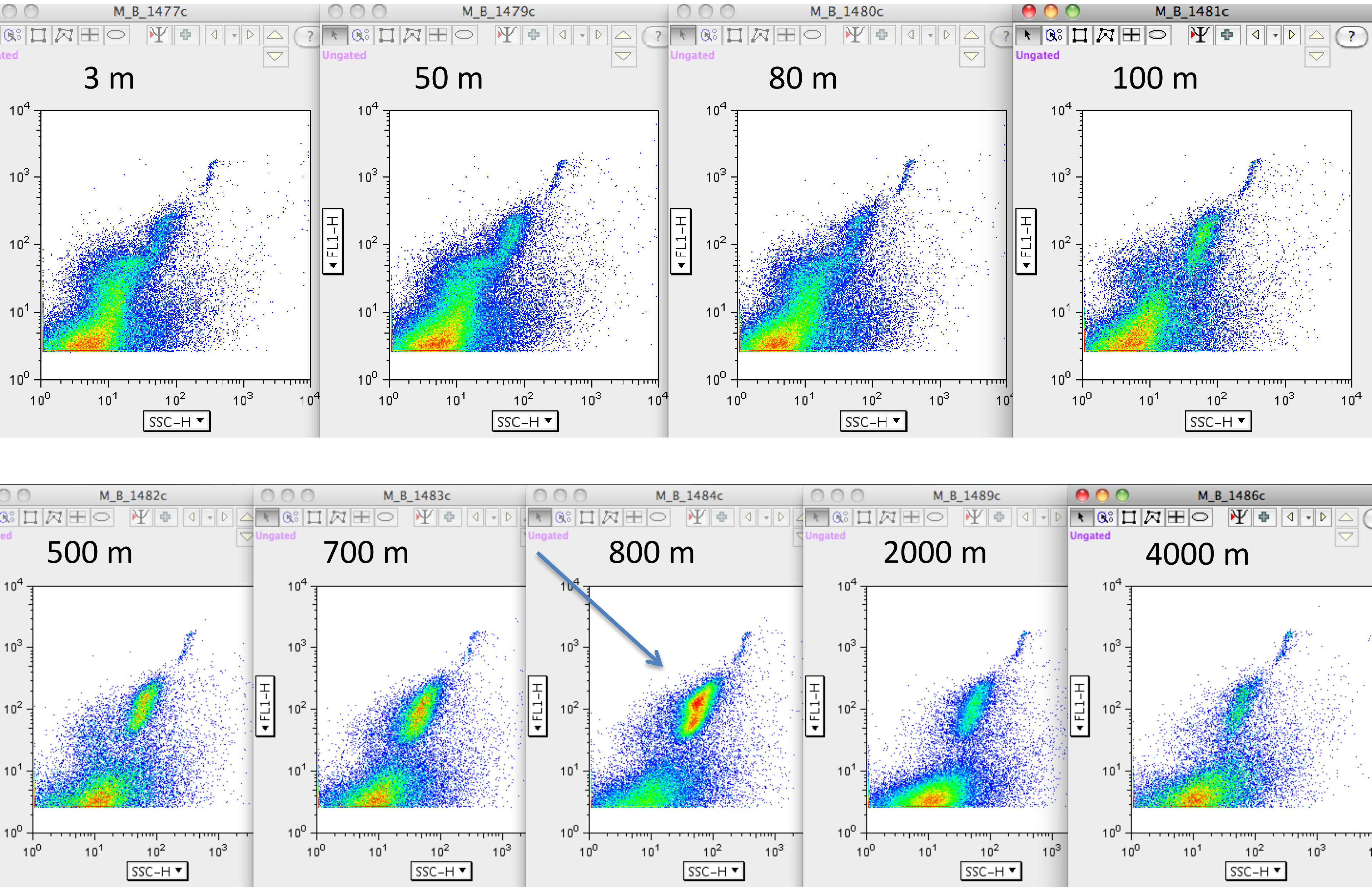
Equatoria upwelling
All BT
0
100000
200000
300000
400000
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Depth (m)

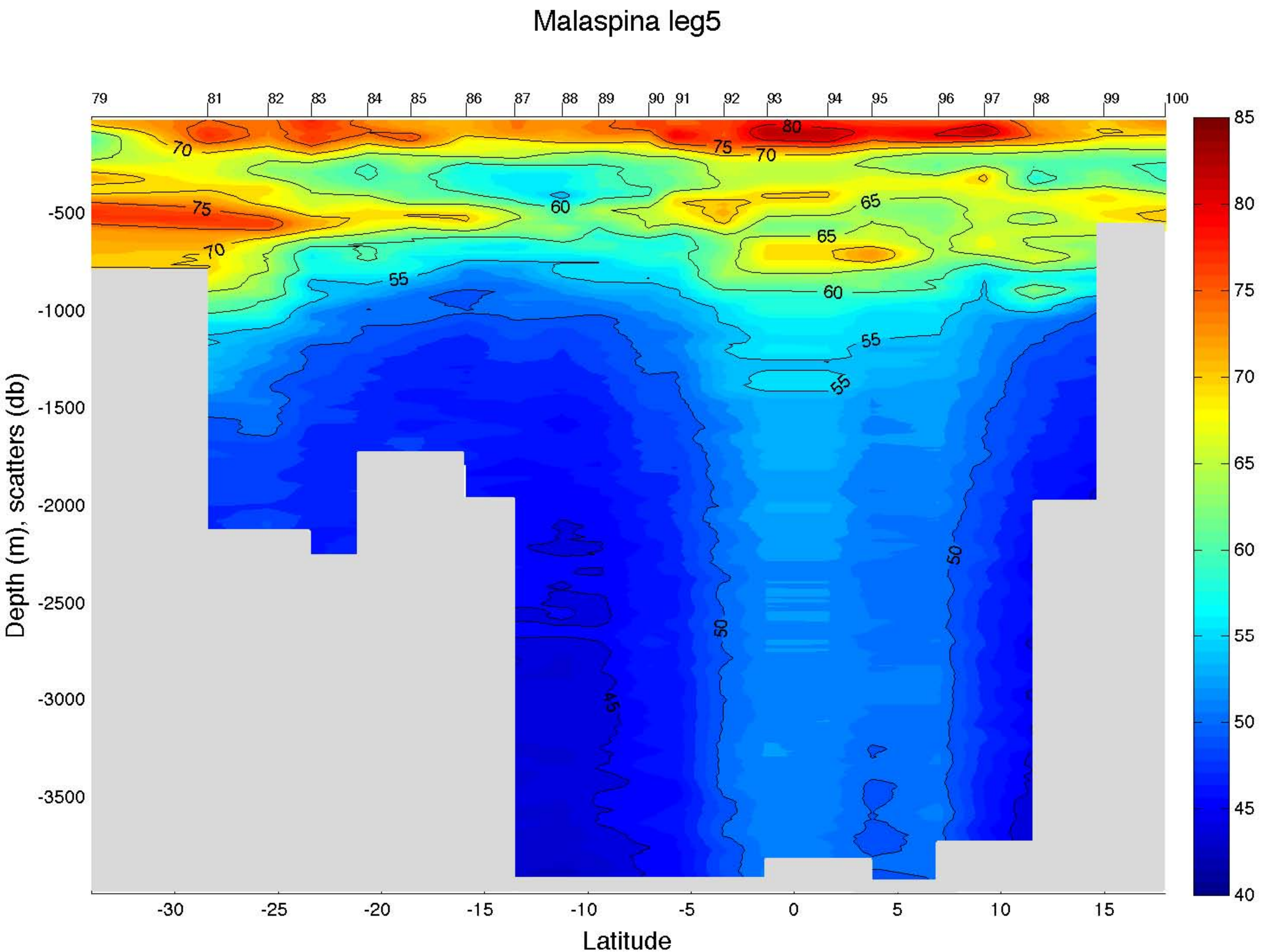

M_B_1235b
M_B_1257b
M_B_1273b
Ungated
ST#87
ST#88
ST#89
Warning! More than 8% of events on the axis!
FL1-H
SSC-H

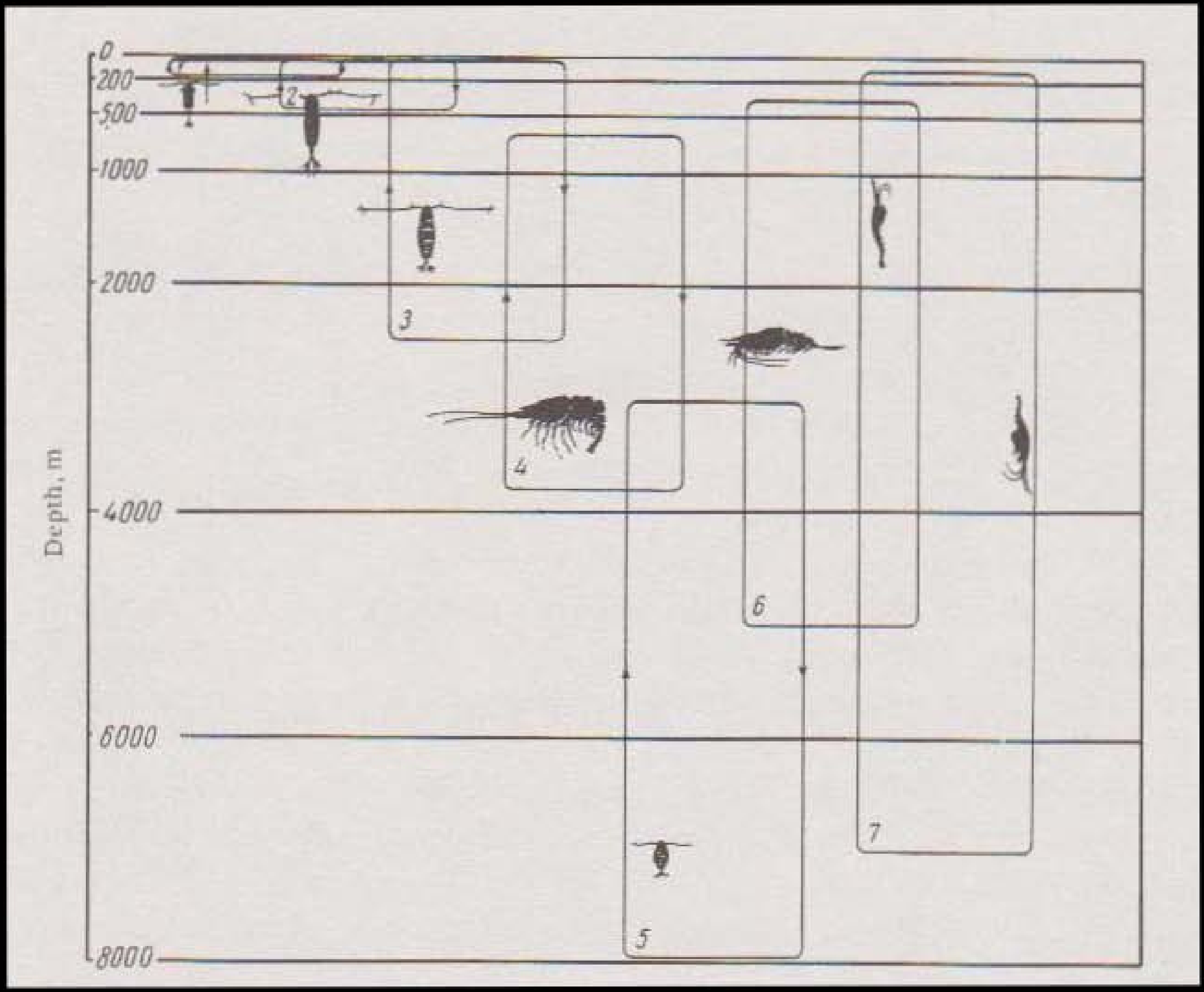

Statistics Events: 68908 / 68908 100%
M_B_1484c
Ungated
ST#94
ST#95
FL1-H
SSC-H

**700-800 m**

# Stn 95 in the Equatorial Upwelling




Malaspina leg5
79
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
Depth (m), scatters (db)
-500
-1000
-1500
-2000
-2500
-3000
-3500
Latitude
-30
-25
-20
-15
-10
-5
0
5
10
15
85
80
75
70
65
60
55
50
45
40



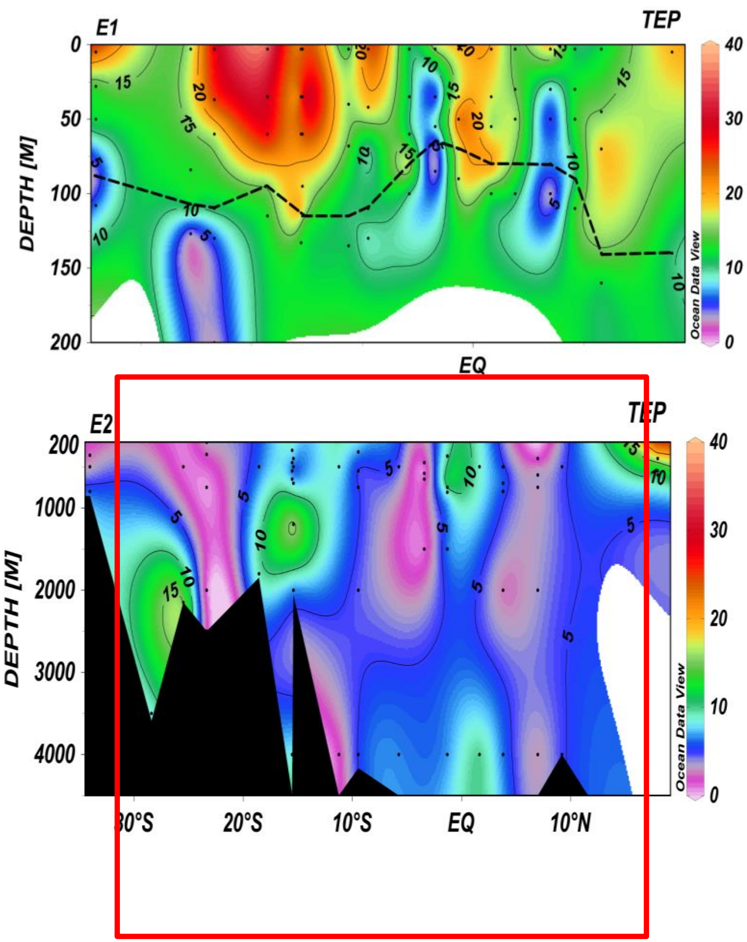

Vinogradov (1953)

# In summary,

- Mesozooplankton is shunt to the mesopelagic zone due to predation by DVMs
- Active flux seems similar to gravitational flux
- Clear gap in our knowledge of the biological pump
- The acoustic signal below the upwelling zone reached 4000 m depth
- Enhancement of the biological pump efficiency (true sequestration)
- Ladder of Migration

Gracias

## Equatorial Pacific




## Equatorial Atlantic