Western Pacific Warm Pool (WP2) Cruise:
A study of the physical, chemical and biological features of a unique marine environment

Cruise Report

3 January – 10 February 2007

Honolulu Hawaii USA to
Noumea, New Caledonia to
Brisbane, Australia

R/V Kilo-Moana

Zackary Johnson (University of Hawaii)
Erik Zinser (University of Tennessee)

Major Funding by the US National Science Foundation

vOct2008

Abstract

In most tropical and subtropical ecosystems, the prokaryotic cyanobacteria *Prochlorococcus* plays a critical role in ecosystem structure and biogeochemistry because it is the numerically dominant photoautotrophic picoplankter. Although the worldwide distributions of *Prochlorococcus* are generally understood, the precise reasons for its overwhelming ecological success have remained elusive. This picture has recently become complicated by the discovery that *Prochlorococcus* is not monophyletic and that different genetic clades of *Prochlorococcus* have remarkably different distributions with depth and over oceanic basins. Thus, our understanding of factors that structure *Prochlorococcus* populations in the natural environment, and our ability to predict how this structure might respond to environmental changes, are limited. The PIs are addressing this question by focusing on naturally occurring populations in the Western Pacific Warm Pool, an area where *Prochlorococcus* is known to dominate, but where there are no data on clade abundances. In addition to being a large region of the Pacific Ocean with significance to the global carbon cycle, the Western Pacific Warm Pool (WPWP) is of particular interest because it is typically highly stratified, with surface waters having extreme temperatures and light levels compared to those at depth. Populations of *Prochlorococcus* at the surface and at depth experience different environmental pressures, and may belong to different clades and have different adaptive physiologies. The PIs tested this hypothesis on a cruise aboard the R/V Kilo-Moana from Hawaii to Brisbane, Australia through the stratified WPWP during January – February 2007. Samples from this transect will be used to quantify (using quantitative PCR) the six known clades of *Prochlorococcus* and to search for new clades (using clone libraries and isolates) and their abundances. The ultimate goal is to relate clade abundances to temperature, light, nutrient concentrations and other measured biological, chemical and physical variables. Collaborators aboard the cruise included biologists studying the grazing of *Prochlorococcus*, viral community composition and dynamics, nitrogen fixation rates and composition. Collaborators also included chemists measuring the macronutrient (phosphate, nitrate, silicate) concentrations and micronutrient concentrations (copper, iron, zinc). Meteorological and hydrographic data was collected along the transect as well.

Table of Contents

Participants

Cruise Participants

Name	Institution	Lab	contact
Zackary Johnson	UH	Johnson	zij@hawaii.edu
Anna Ritchie	UH	Johnson	ritchiea@hawaii.edu
Erik Zinser	UTK	Zinser	ezinser@utk.edu
Jeff Morris	UTK	Zinser	jmorri40@utk.edu
Jeremy Chandler	UTK	Zinser	zaskarle@gmail.com
Gary LeCleir	UTK	Wilhelm	glecleir@utk.edu
Janet Rowe	UTK	Wilhelm	jrowe2@utk.edu
Audrey Cupp	UTK	Wilhelm	acupp1@utk.edu
Sue Brown	UH	Brown	sbrown@soest.hawaii.edu
Karen Selph	UH	Selph	selph@hawaii.edu
Robert Bidigare III	UH	Johnson	Robtheexplorer@aol.com
Ryan Lau	UH	Johnson	ryan@mediumfits.com
James Moffet	USC	Moffett	jmoffett@whoi.edu
Dreux Chappell	USC	Moffett	dreux@whoi.edu
Daniel Ohnemus	USC	Moffett	dohnemus@whoi.edu
Andrew Rose	USC	Moffett	anrose@whoi.edu
Tyler Goepfert	USC	Moffett	tgoepfert@whoi.edu
Eric Webb	USC	Webb	eawebb@usc.edu
Annette Hynes	USC	Webb	ahynes@whoi.edu
Whitney Krey	USC	Webb	wkrey@whoi.edu
Allison Buchan	UTK	Buchan	abuchan@utk.edu
Leo Poorvin	UTK	Wilhelm	lpoorvin@gmail.com
Veronica Lance	Duke	Barber	vplance@duke.edu

Non-cruise Participants

Eric Firing	UH	Firing	efiring@hawaii.edu
Jules Hummon	UH	Firing	jules@soest.hawaii.edu
Elizabeth Steffen	PMEL	Steffen/Johnson	Elizabeth.Steffen@noaa.gov
Greg Johnson	PMEL	Steffen/Johnson	gregory.c.johnson@noaa.gov
Guangyi Wang	UH	Wang	guangyi@hawaii.edu
Carli Bober	UH	Johnson	carliannb@aim.com
Steve Wilhelm	UTK	Wilhelm	wilhelm@utk.edu
Robert (Bob) Bidigare	UH	Bidigare	bidigare@hawaii.edu

Group Photos from Leg 1 (Hawaii to Noumea, New Caledonia) and Leg 2 (Noumea, New Caledonia to Brisbane, Australia)

Johnson Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Zinser Lab
University of Tennessee
Dept. of Microbiology, SERF640
M409 WLS
Knoxville, TN 37996

Wilhelm Lab
University of Tennessee
Dept. of Microbiology
M409 WLS
Knoxville, TN 37996

Brown Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Selph Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Moffett Lab
Department of Biological Sciences
Marine and Environmental Biology Section
University of Southern California, AHF 107
3616 Trousdale Parkway
Los Angeles, CA 90089-0371

Webb Lab
Department of Biological Sciences
Marine and Environmental Biology Section
University of Southern California, AHF 301
3616 Trousdale Parkway
Los Angeles, CA 90089-0371

Buchan Lab
University of Tennessee
Dept. of Microbiology
M409 WLS
Knoxville, TN 37996

Barber Lab
Duke University
Nicholas School of Environment and Earth Sciences
135 Marine Lab Rd
Beaufort, NC 28516

Firing Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Wang Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Bidigare Lab
University of Hawaii
1000 Pope Rd.
Honolulu, HI 96822 USA

Research Objectives

Johnson Lab

Our research objectives are to characterize the phytoplankton standing stock using flow cytometry to enumerate individual cell populations. In addition, we will characterize the photophysiology of phytoplankton in general and cyanobacteria in particular using short-term C-14 incubations (photosynthesis-irradiance curves) as well as using fluorescence induction and relaxation techniques (FIRe). Specific attention will be paid to *Prochlorococcus* and those populations that may be iron and or light limited, such as the deep chlorophyll maximum. We will also be assaying abundances of bacteriochlorophyll containing microbes.

Zinser Lab

Our research objectives are to characterize the diversity and molecular ecology of *Prochlorococcus*. We will be using qPCR and clone libraries to assess the breadth and patterns of diversity over basin scales. We will also be assessing the potential of oxidative stress to impact populations of microbes.

Wilhelm Lab

Our research group will be undertaking research to support two ongoing National Science Foundation projects:

Diversity and production of marine viruses:
Doctoral students Janet Rowe and Audrey Cupp collected samples to determine virus production rates in surface waters at all 36 stations. They will also collect samples to determine burst sizes for infection in surface waters. Virus abundance will be determined at 5, 50, DCM and 200 m in the water column. They will also determine size fractionated chlorophyll (n = 2 for each of >0.2, >2.0 and >20 μm size classes).

Development of bioreporters for Fe availability:
Drs. Gary LeCleir and Leo Poorvin will be working to collect samples for analysis by our bioreporter assays. They will be responsible for the deployment and management of the trace metal clean pumping system, measurements of total Fe and Fe 2+ (total and 0.2 μm filterable), collection of DOM for analysis of impacts on Fe bioavailability, collection of 0.2 μm filtered water for Fe bioavailability determinations and estimate bacterial production rates (^{3}H-leucine) at 5 m and in the DCM.

Brown/Selph / Bidigare Lab

Our primary science objective is to measure grazing related processes along the transect. This is done using classic grazer dilution experiments as well as using grazer abundance techniques. Our group, in collaboration with Robert Bidigare at UH, is also measuring phytoplankton pigment concentrations to estimate the contributions of major taxonomic groups to phytoplankton standing stocks and rates.

Moffett Lab
Our science objective is to characterize the trace metal concentrations along the Pacific Ocean transect. In particular, our group will be measuring both iron and copper concentrations sampled from a trace metal clean rosette.

Webb Lab
Our science objective is to measure the contribution of cyanobacteria, in particular nitrogen fixers, to the total phytoplankton standing stock. We will also be measuring nitrogen fixation rates, focusing on Trichodesmium as the major nitrogen fixer in the region.

Buchan Lab
Our primary science objective is to characterize the diversity, abundance and distribution of members of the Roseobacter clade of marine heterotrophic bacteria in coastal to near off-shore transects. Bacterioplankton were collected on filters at nine stations for future nucleic acid extraction and molecular analysis. Samples were also collected along a depth profile at each station so that vertical distributions can be assessed for this group of bacteria.

Barber Lab
Our laboratory focuses on primary production and the processes regulating it. During the WP2 cruise our objective is to measure primary production (photosynthesis) using the C-14 method for several different size classes of phytoplankton. We will also measure particulate absorption to assess how light is absorbed by phytoplankton.

Firing Lab
Our primary science objective is to measure and characterize the oceanic currents along the transect in the Pacific Ocean. In particular, we are interested in processes leading to the formation and maintenance of the equatorial undercurrent, a prominent feature located near the equator.

Wang Lab
Our primary science objective is the characterize the diversity of eukaryotic microbes along the transect in the Pacific Ocean. In particular, we are focusing on marine fungal taxonomy and systematics. We are interested in using the information to further our understanding of the ecology of microbes in the ocean and also assess their potential for biotechnological applications.

Data

Station Locations / Times

CTD #	Station	Latitude	Longitude	Year Day	UTC
1	1	20.9143	-158.3312	4	05:27
2	2	19.4942	-160.0367	4	18:13
3	2	19.5287	-159.9021	4	23:04
4	3	17.3794	-162.4426	5	18:17
5	3	17.3836	-162.4029	5	22:16
6	4	14.9630	-165.0515	6	18:01
7	4	14.9829	-165.0327	6	22:15
8	5	12.4348	-167.7297	7	19:00
9	5	12.4745	-167.6912	7	23:17
10	6	10.0808	-170.1366	8	19:08
11	6	10.1024	-170.1215	8	23:15
12	7	7.8845	-172.3385	9	19:05
13	7	7.9386	-172.4000	9	23:15
14	8	5.6491	-174.5349	10	19:22
15	8	5.6878	-174.4646	10	23:20
16	9	3.2368	-176.8836	10	19:05
17	9	3.2653	-176.8587	11	23:21
18	10	0.3653	-179.6440	12	20:10
19	10	0.3912	-179.6362	13	00:08
20	11	-2.3007	177.4370	13	20:01
21	11	-2.3126	177.3427	14	00:11
22	12	-4.7209	174.7345	14	20:01
23	12	-4.7261	174.7001	15	00:13
24	13	-7.0696	172.3052	15	20:15
25	13	-7.0672	172.2640	16	00:15
26	14	-9.2503	169.9996	16	20:01
27	14	-9.2430	169.9608	17	00:20
28	14	-9.2500	170.0001	17	07:30
29	14	-9.2467	170.0004	17	16:00
30	14	-9.2503	169.9997	17	18:00
31	14	-9.2502	169.9999	17	20:00
32	14	-9.2500	170.0000	17	22:00
33	14	-9.2490	170.0000	18	23:58
34	14	-9.2502	169.9996	18	01:59
35	14	-9.2506	169.9999	18	04:00
36	14	-9.2500	170.0000	18	06:00
37	14	-9.2500	170.0001	18	08:00
38	14	-9.2501	170.0000	18	10:00
39	14	-9.2499	169.9996	18	12:00
40	14	-9.2499	169.9990	18	13:58
41	14	-9.2510	170.0004	18	16:00
42	14	-9.2501	170.0000	18	18:33
43	14	-9.2504	170.0000	18	21:17
44	14	-9.2501	170.0000	18	23:45
45	15	-12.5758	169.8590	19	21:05
46	15	-12.5752	169.8587	20	01:15

47	16	-15.8937	169.7160	20	21:10
48	16	-15.9101	169.7416	21	01:07
49	17	-19.2322	169.5775	21	22:35
50	18	-19.4970	170.2146	22	04:25
51	19	-21.6237	168.6583	22	21:02
52	19	-21.6234	168.6575	23	00:15
53	20	-25.6717	165.4164	25	21:26
54	20	-25.6583	165.4538	26	01:16
55	21	-29.0405	164.3379	26	21:13
56	21	-29.0289	164.3304	27	01:16
57	22	-31.9220	163.3611	27	21:22
58	22	-31.9080	163.3469	28	01:07
59	23	-34.1580	162.5514	28	21:07
60	23	-34.1569	162.5390	29	01:12
61	24	-36.1654	161.7915	29	21:27
62	24	-36.1648	161.7660	30	01:18
63	24	-36.1606	161.7709	30	17:05
64	24	-36.1596	161.7710	30	19:00
65	24	-36.1588	161.7719	30	21:04
66	24	-36.1584	161.7726	30	22:58
67	24	-36.1576	161.7736	31	01:01
68	24	-36.1572	161.7745	31	02:58
69	24	-36.1565	161.7753	31	05:03
70	24	-36.1559	161.7759	31	07:00
71	24	-36.1551	161.7765	31	09:02
72	24	-36.1546	161.7774	31	11:05
73	24	-36.1539	161.7748	31	13:01
74	24	-36.1532	161.7787	31	15:04
75	24	-36.1526	161.7800	31	17:03
76	24	-36.1519	161.7805	31	18:54
77	24	-36.1514	161.7814	31	21:00
78	24	-36.1508	161.7822	32	00:00
79	25	-34.2348	160.3546	32	21:20
80	25	-34.2349	160.3542	33	01:04
81	26	-32.4212	159.0889	33	21:03
82	26	-32.4215	159.0888	34	01:20
83	26	-32.4221	159.0893	34	05:03
84	26	-32.4230	159.0894	34	13:02
85	26	-32.4215	159.0889	34	17:00
86	26	-32.4216	159.0889	34	21:03
87	26	-32.4218	159.0896	35	01:10
88	26	-32.4216	159.0890	35	05:00
89	26	-32.4242	159.0922	35	13:08
90	26	-32.0382	159.0891	35	21:07
91	26	-32.4216	159.0890	36	05:00
92	26	-32.4217	159.0892	36	12:58
93	27	-30.7152	157.9413	37	13:04
94	28	-30.2585	157.3032	37	23:01
95	29	-29.7603	156.6248	38	23:01
96	30	-28.7630	155.3701	39	23:05

ARGO deployment

Float #	WMO ID#	Latitude	Longitude	Deployment Year Day	Deployment UTC
3023	5901419	17.3838	-162.3821	5	23:50
3022	5901418	14.9846	-165.0243	7	00:02
3082	5901414	13.6012	-166.5189	7	10:14
3014	5901408	12.4775	-167.6815	7	23:37
3083	5901415	11.0078	-169.1962	8	12:07
3015	5901409	10.1135	-170.0963	9	02:23
3016	5901410	5.6914	-174.4831	10	01:11
3085	5901417	4.4569	-175.6976	11	10:17
3017	5901411	3.2790	-176.8372	12	01:43
2989	5901394	0.3970	-179.6296	13	00:59
2988	5901393	-7.0693	172.2357	16	02:43
2891	5901386	-9.2681	169.9945	18	00:29
3020	5901413	-36.1467	161.7737	31	00:35

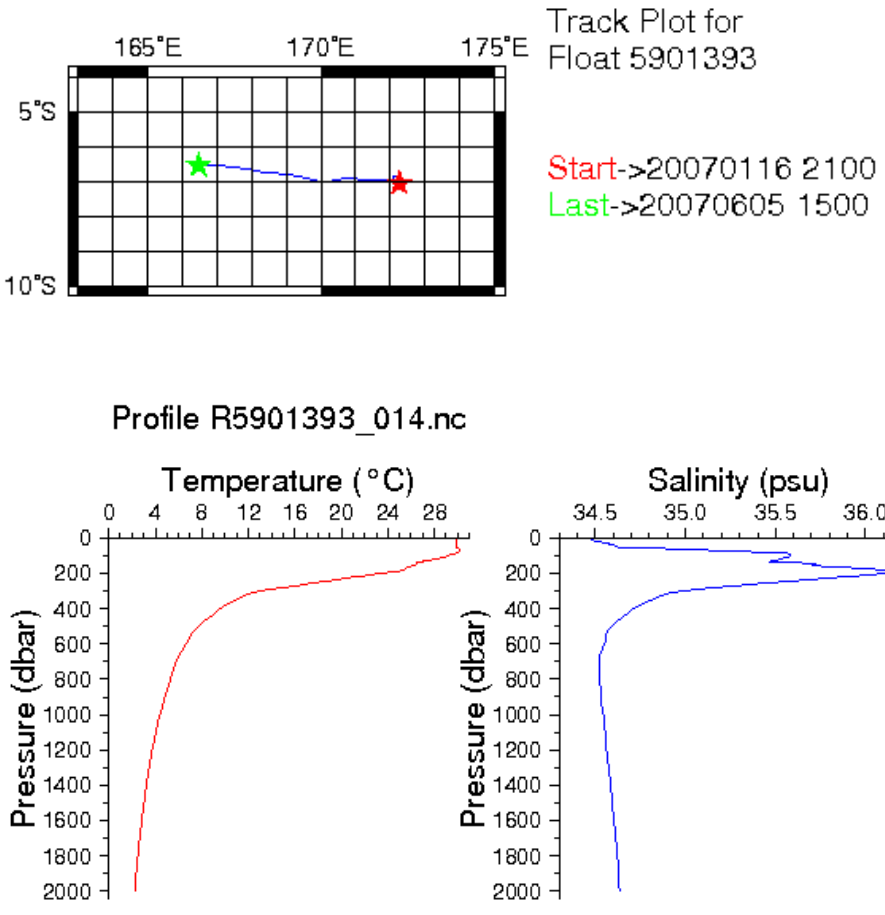


Figure: Sample profile (20070605) and trajectory for ARGO float (#2988)

Maps

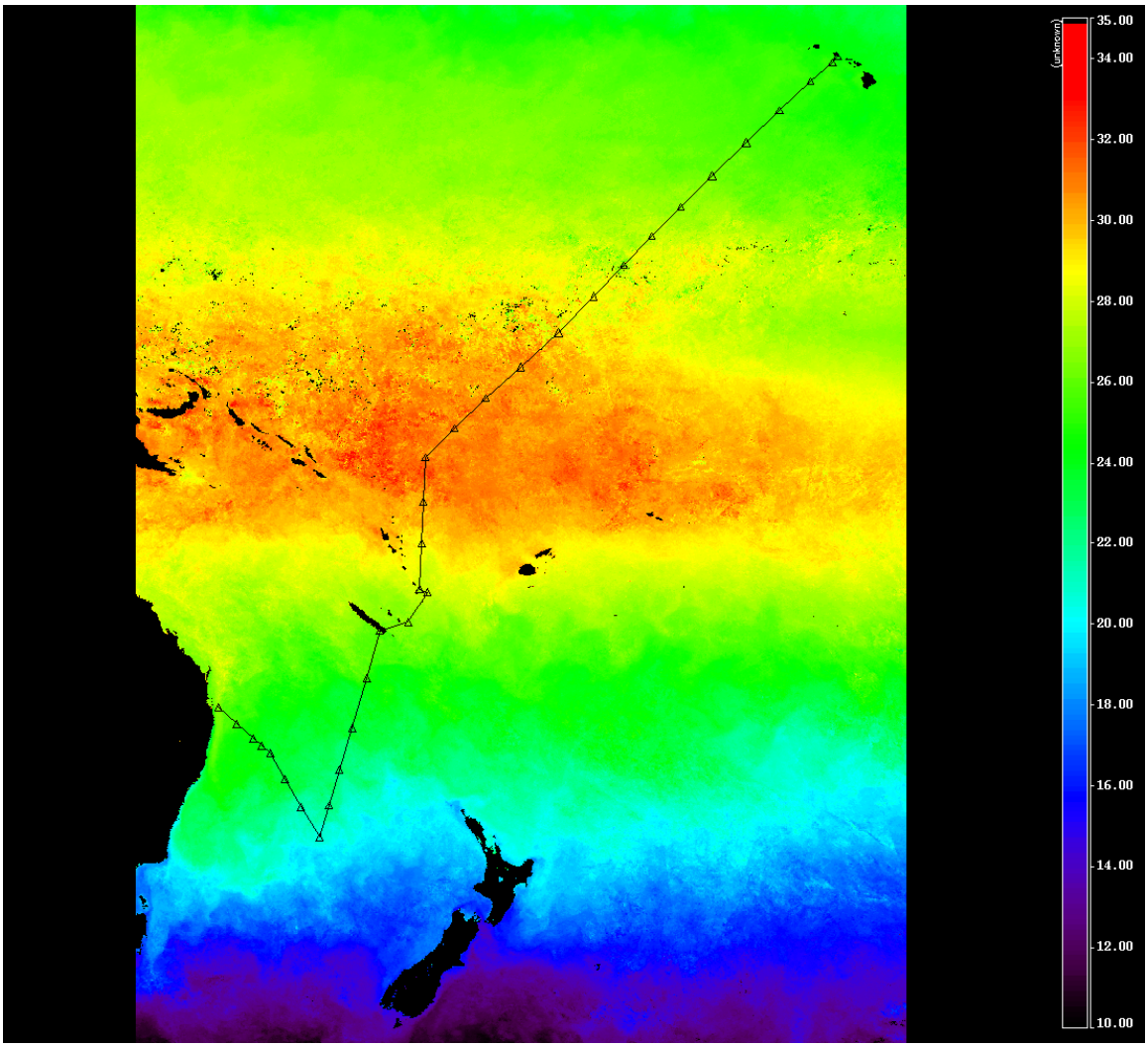


Figure 1: Station locations (triangles) on false color image of sea surface temperature averaged over the month of January 2007 as measured by the MODIS satellite. Black pixels indicate areas of cloud cover.

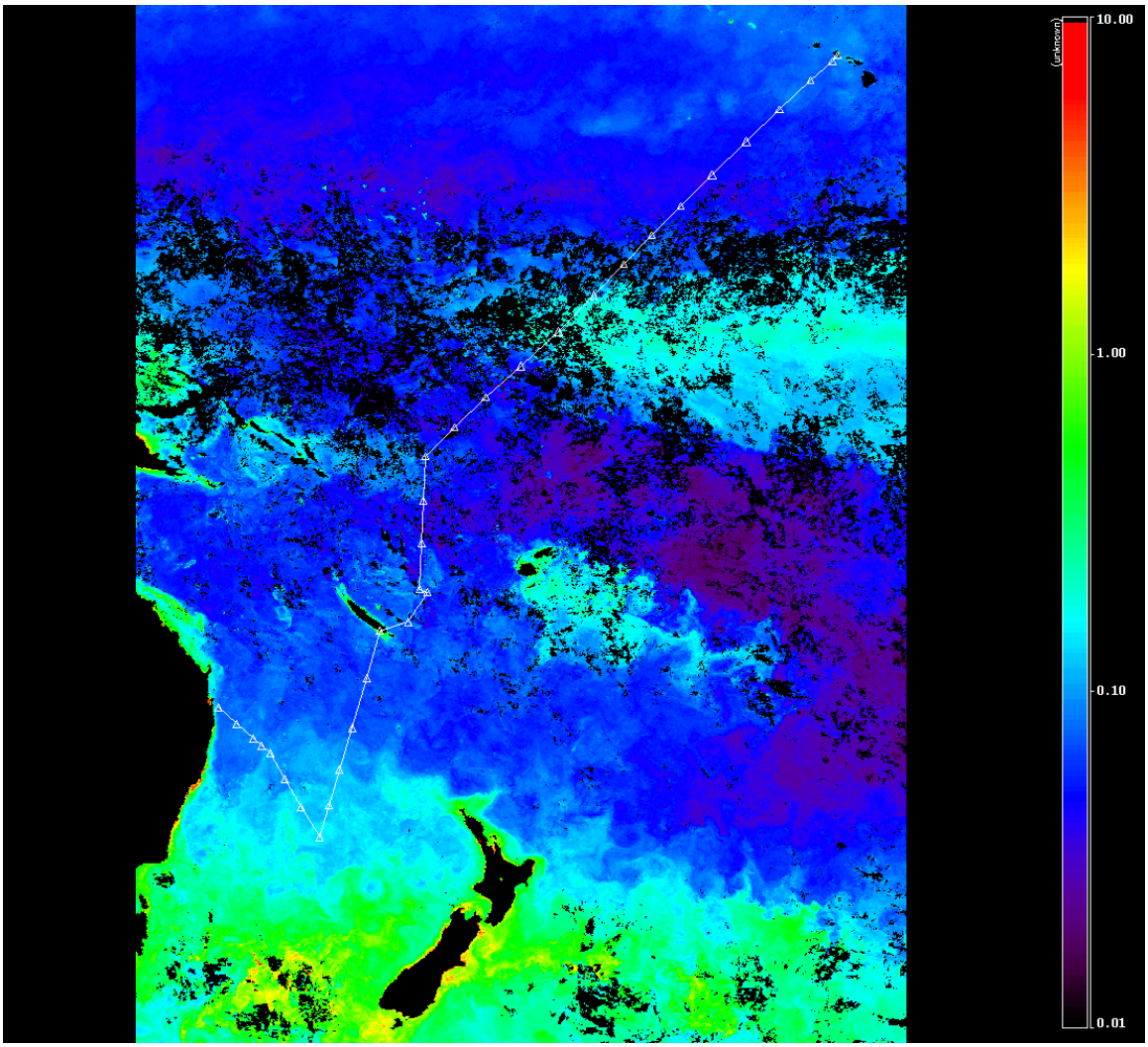


Figure 2: Station locations (triangles) on false color image of sea surface chlorophyll pigment averaged over the month of January 2007 as measured by the MODIS satellite. Black pixels indicate areas of cloud cover.

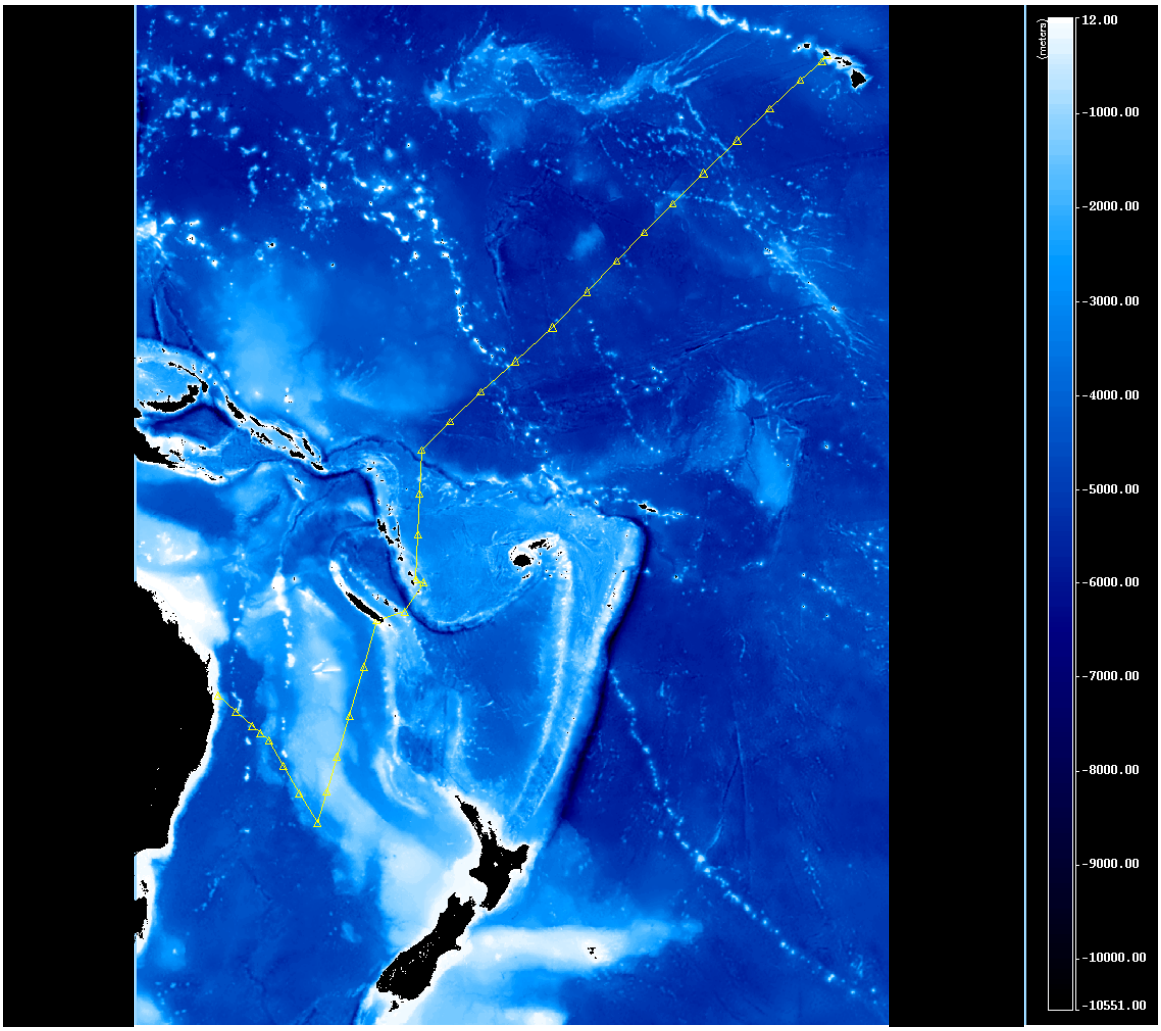
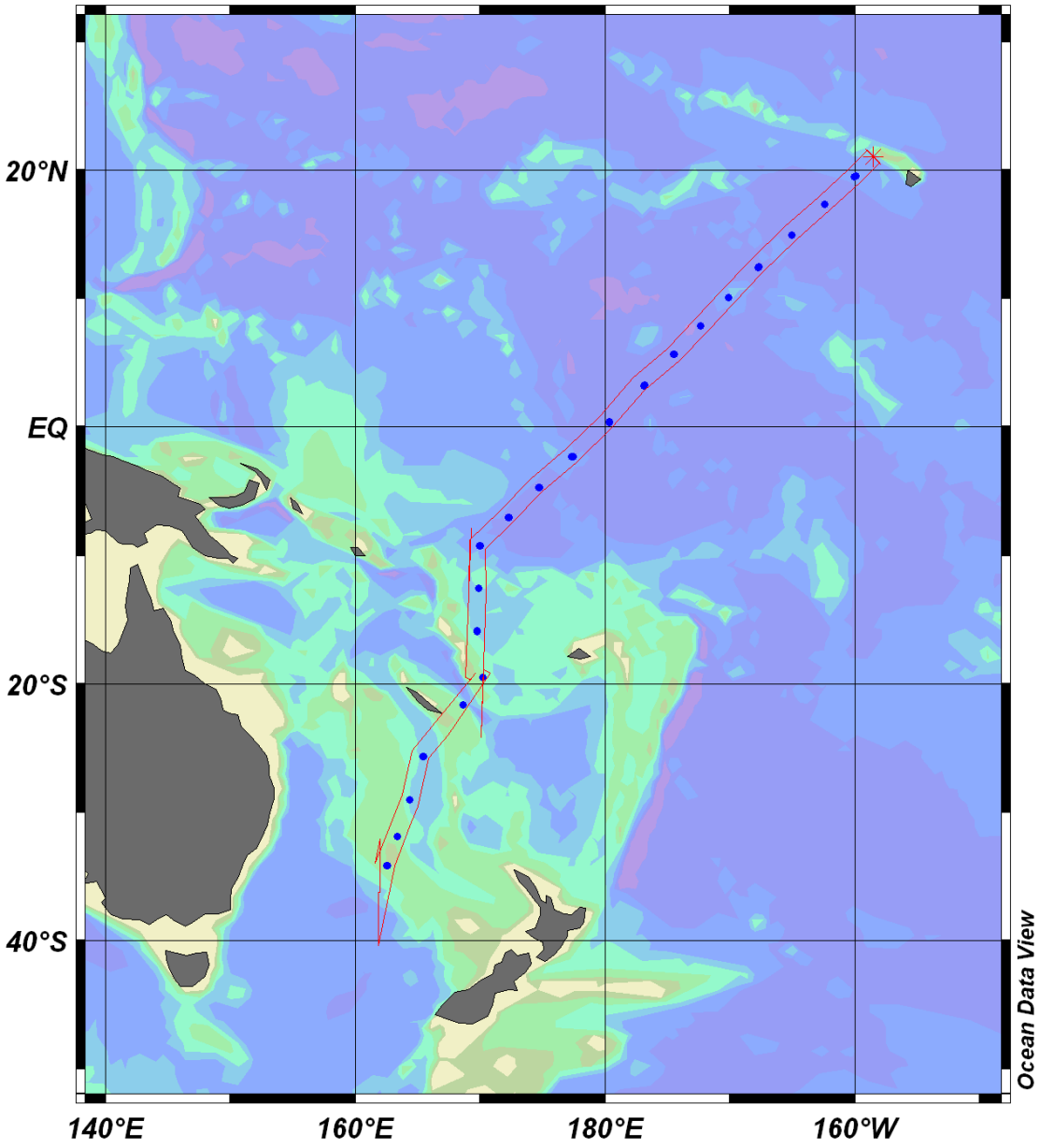
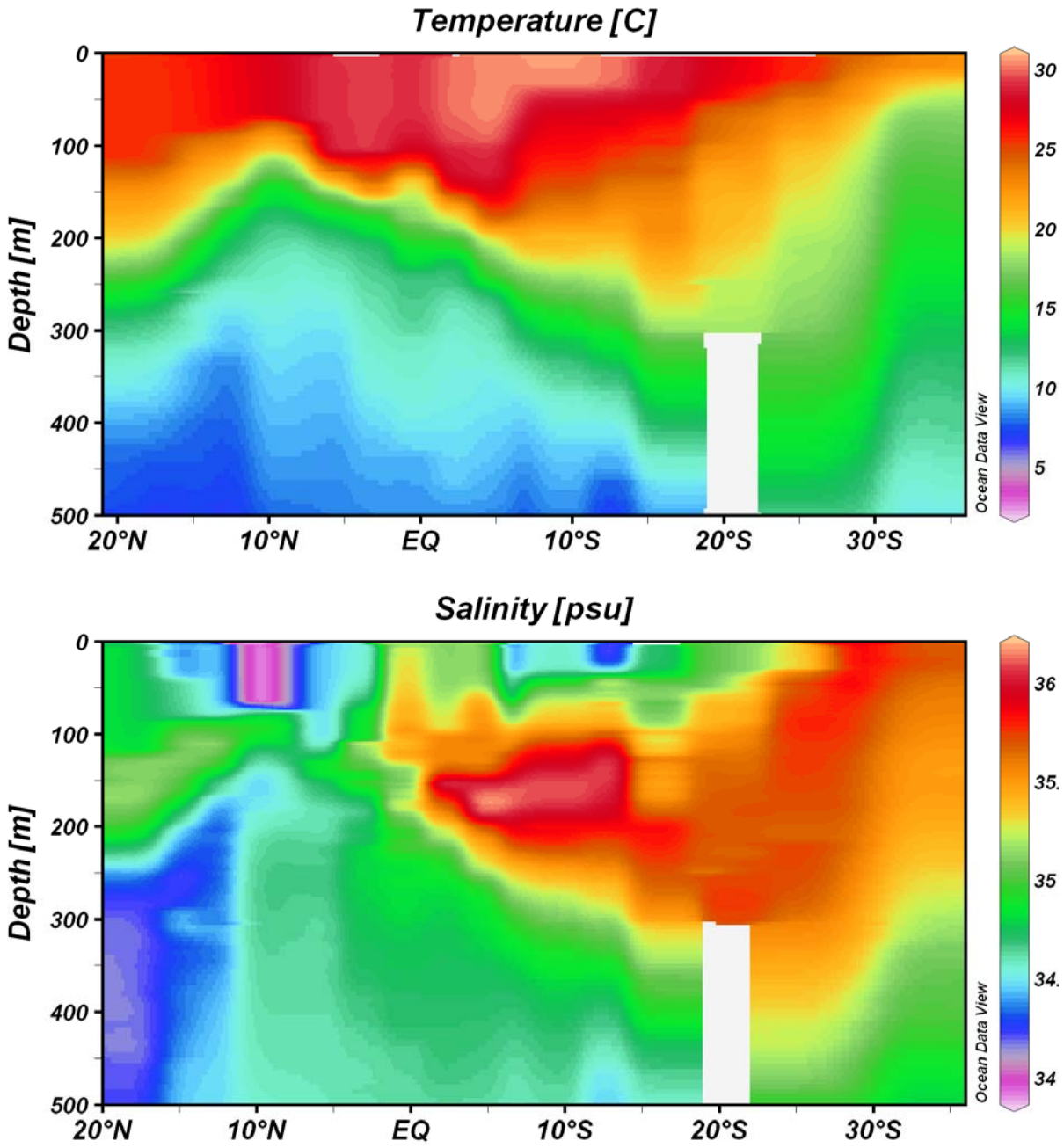


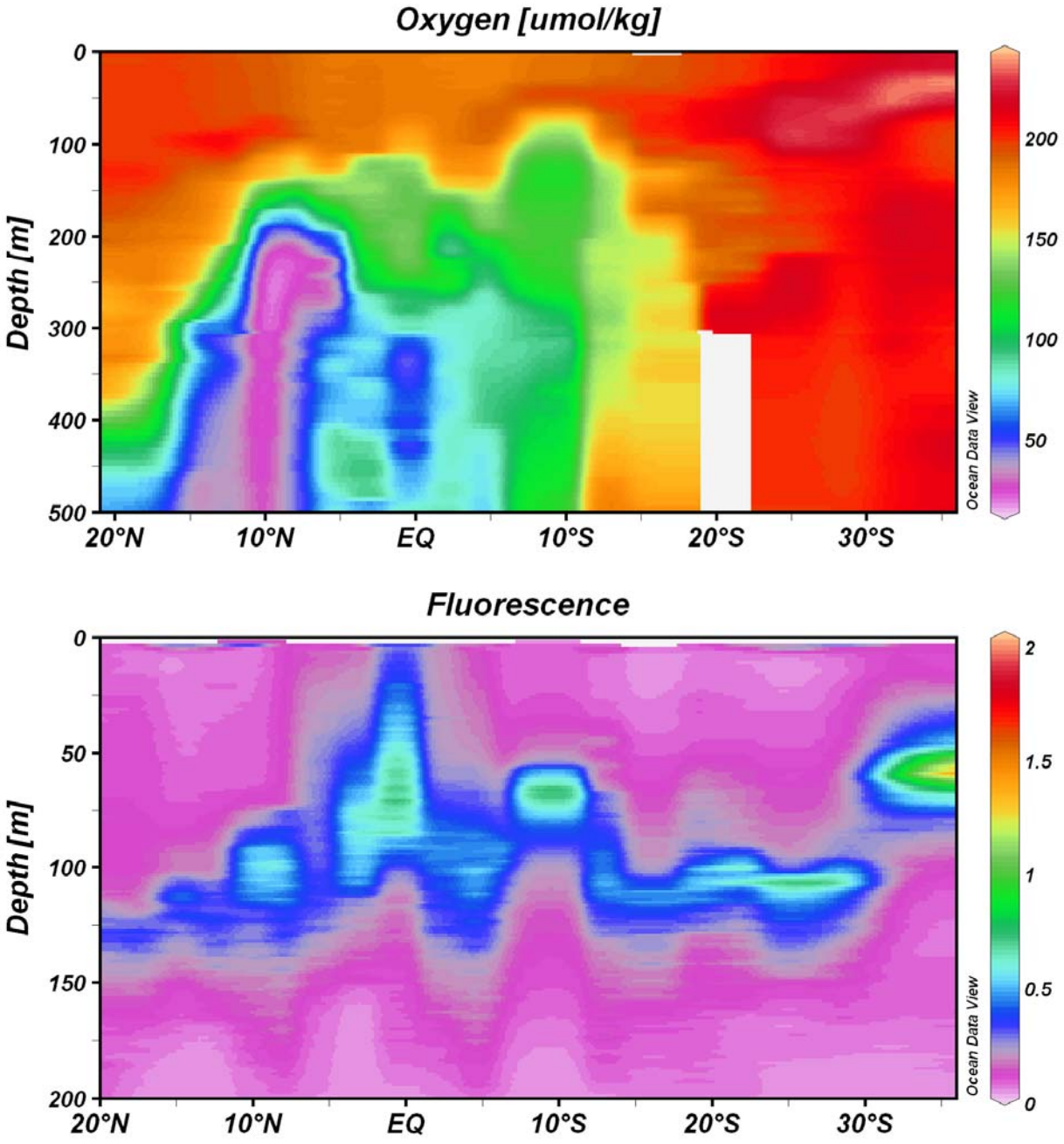
Figure 3: Station locations (triangles) on false color image of bathymetry.

Hydrography: Sectional Data

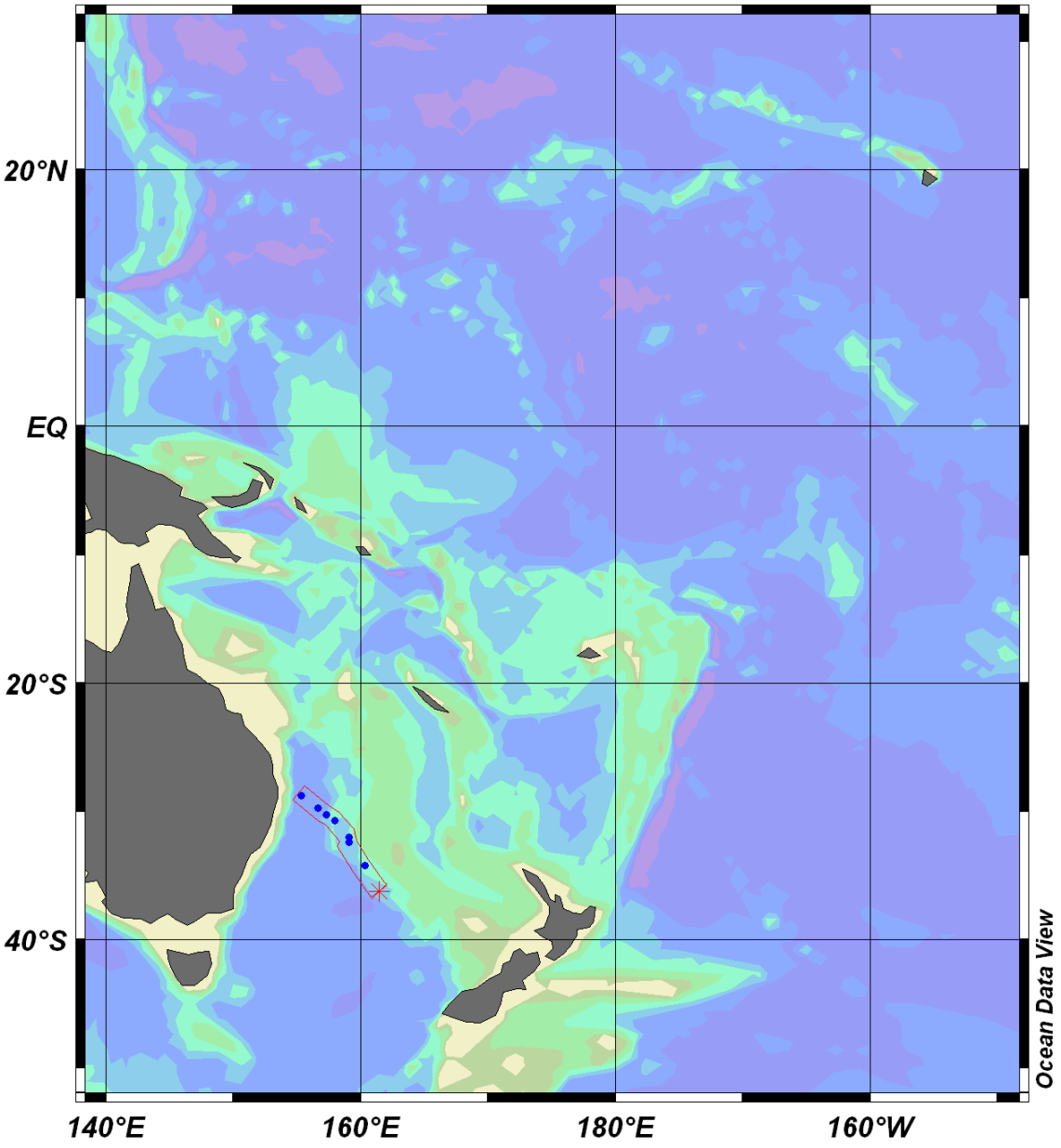
Section 1

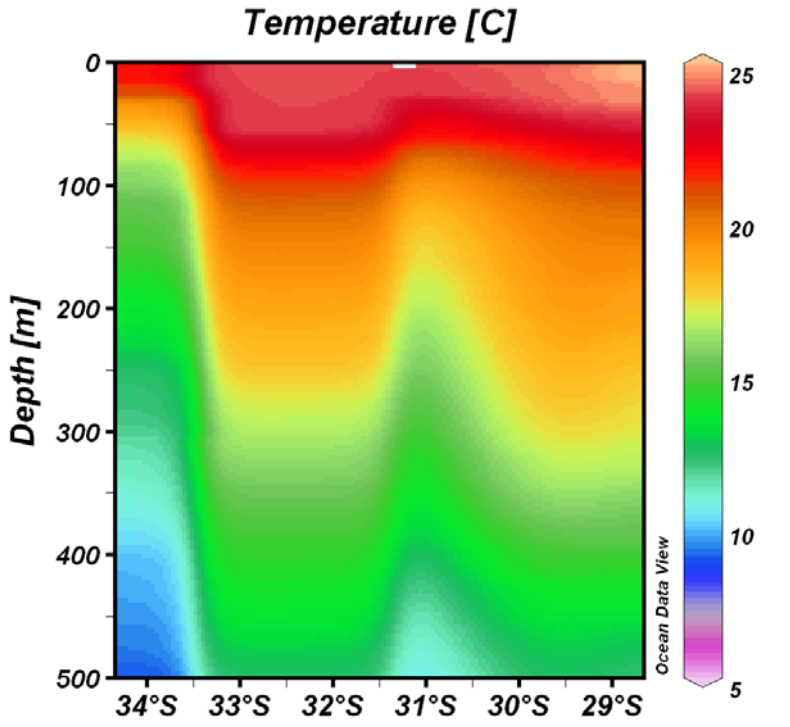


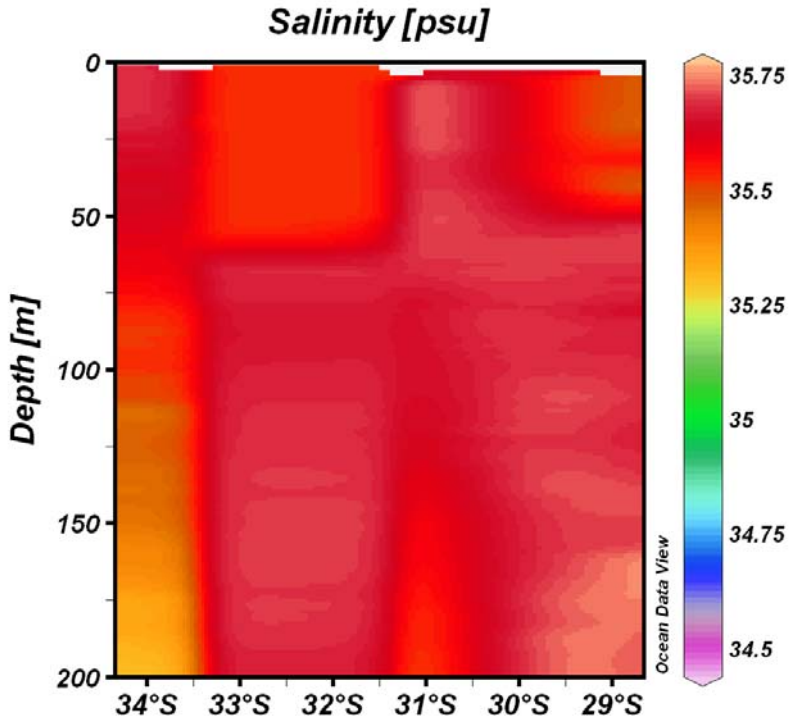

Temperature [C]
Depth [m]
0
100
200
300
400
500
20°N
10°N
EQ
10°S
20°S
30°S
30
25
20
15
10
5
Ocean Data View
Salinity [psu]
Depth [m]
0
100
200
300
400
500
20°N
10°N
EQ
10°S
20°S
30°S
36
35.
35
34.
34
Ocean Data View

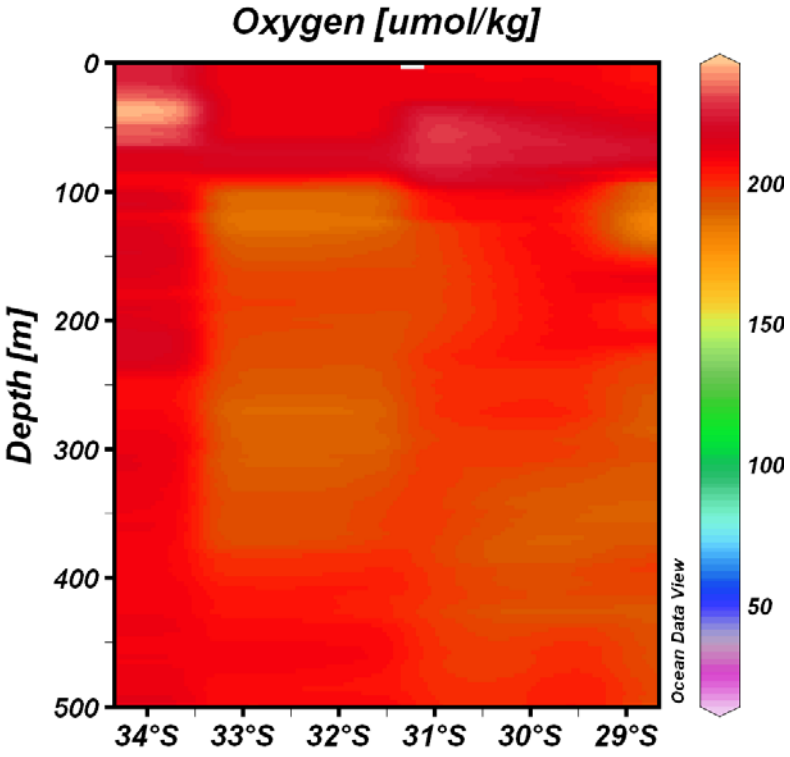

Oxygen [umol/kg]
Depth [m]
0
100
200
300
400
500
20°N
10°N
EQ
10°S
20°S
30°S
200
150
100
50
Ocean Data View
Fluorescence
Depth [m]
0
50
100
150
200
20°N
10°N
EQ
10°S
20°S
30°S
2
1.5
1
0.5
0
Ocean Data View

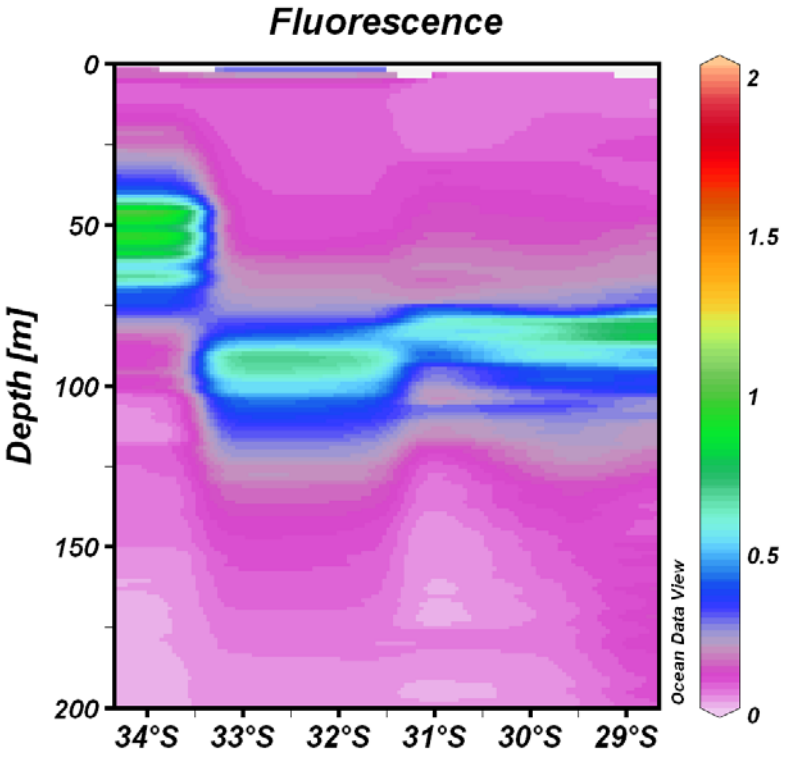
Section 2




Temperature [C]
Depth [m]
0
100
200
300
400
500
34°S
33°S
32°S
31°S
30°S
29°S
25
20
15
10
5
Ocean Data View


Salinity [psu]
Depth [m]
0
50
100
150
200
34°S
33°S
32°S
31°S
30°S
29°S
35.75
35.5
35.25
35
34.75
34.5
Ocean Data View

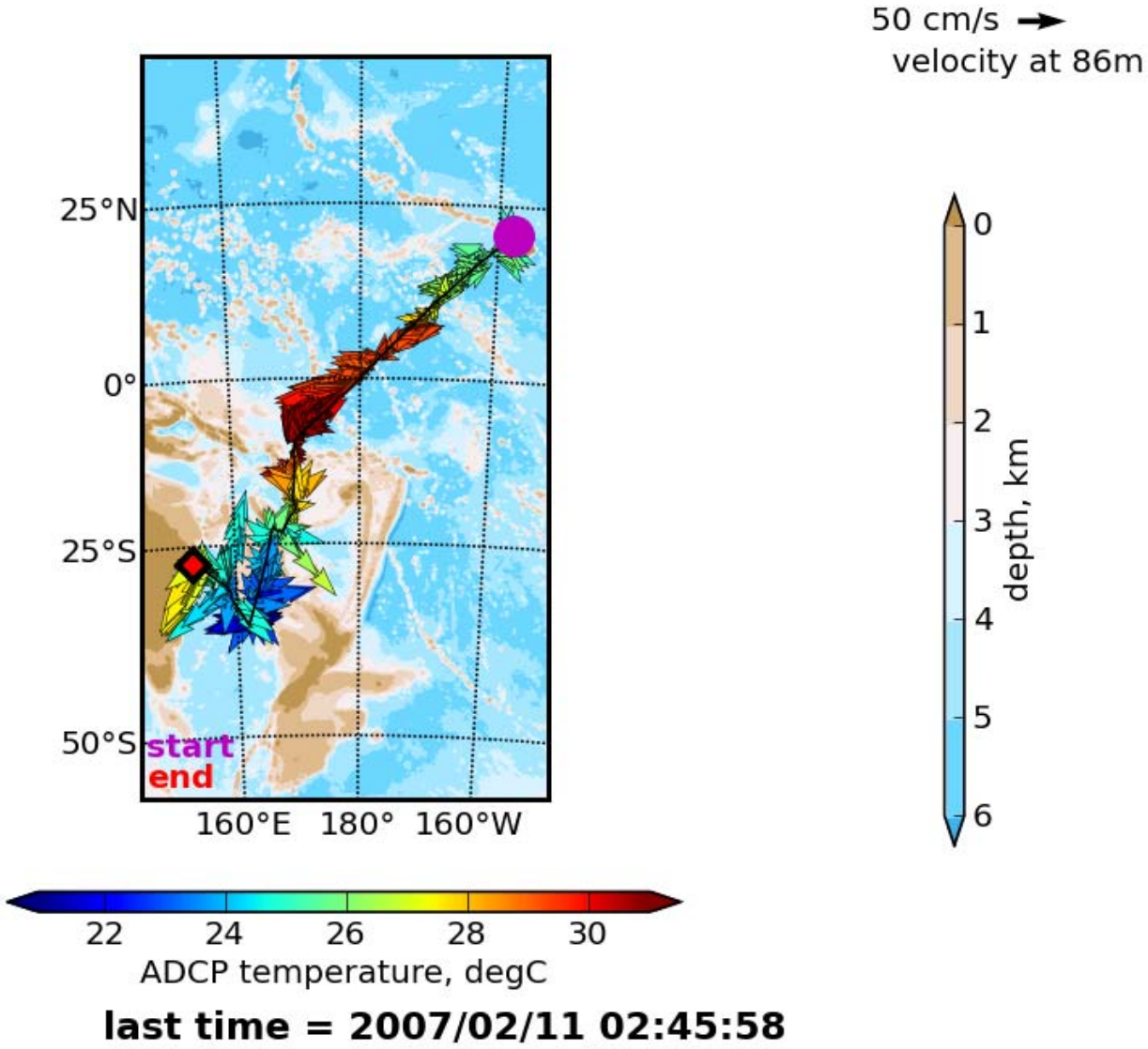

Oxygen [umol/kg]
Depth [m]
0
100
200
300
400
500
34°S
33°S
32°S
31°S
30°S
29°S
200
150
100
50
Ocean Data View

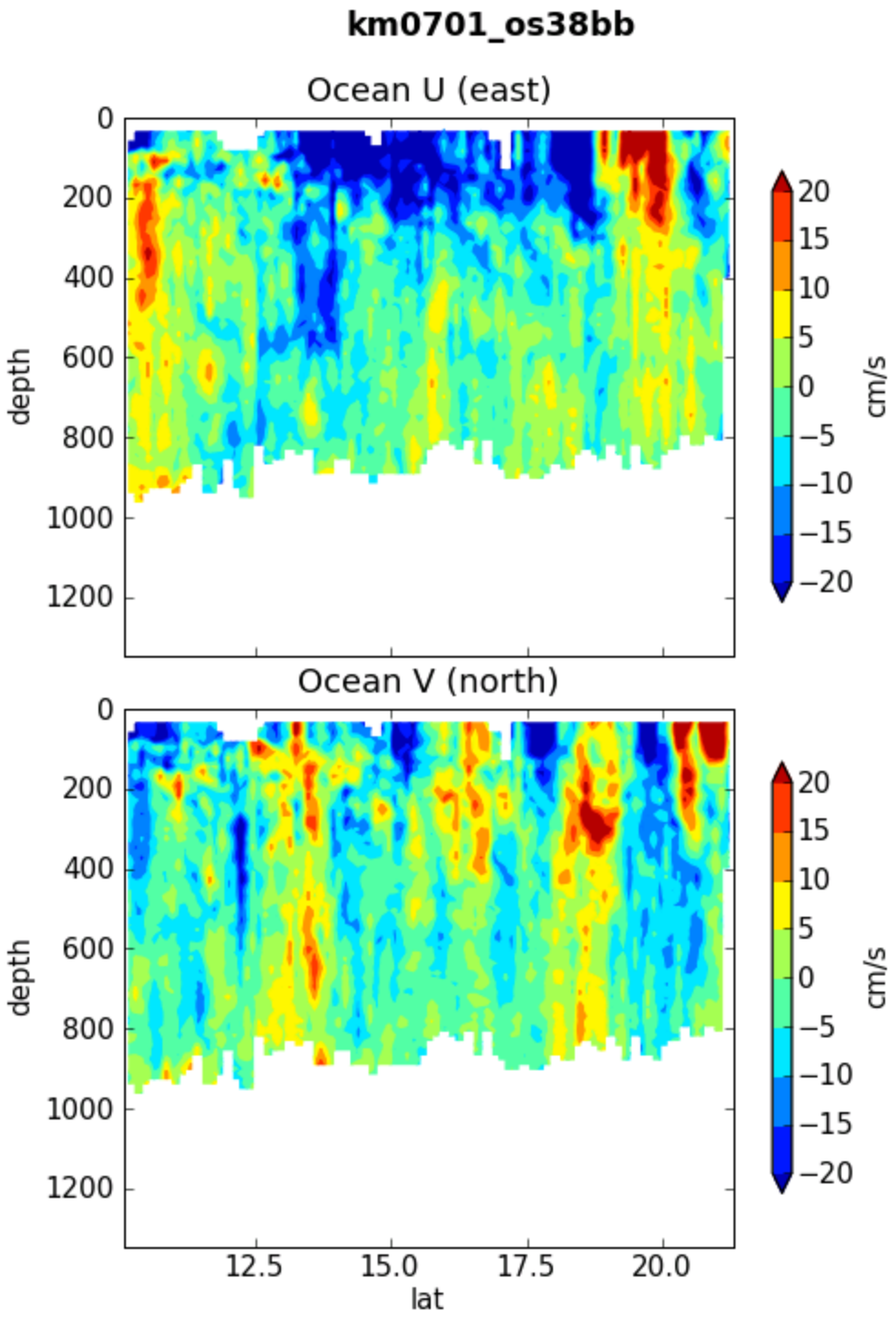

Fluorescence
Depth [m]
0
50
100
150
200
34°S
33°S
32°S
31°S
30°S
29°S
2
1.5
1
0.5
0
Ocean Data View

Hydrography: vertical station plots

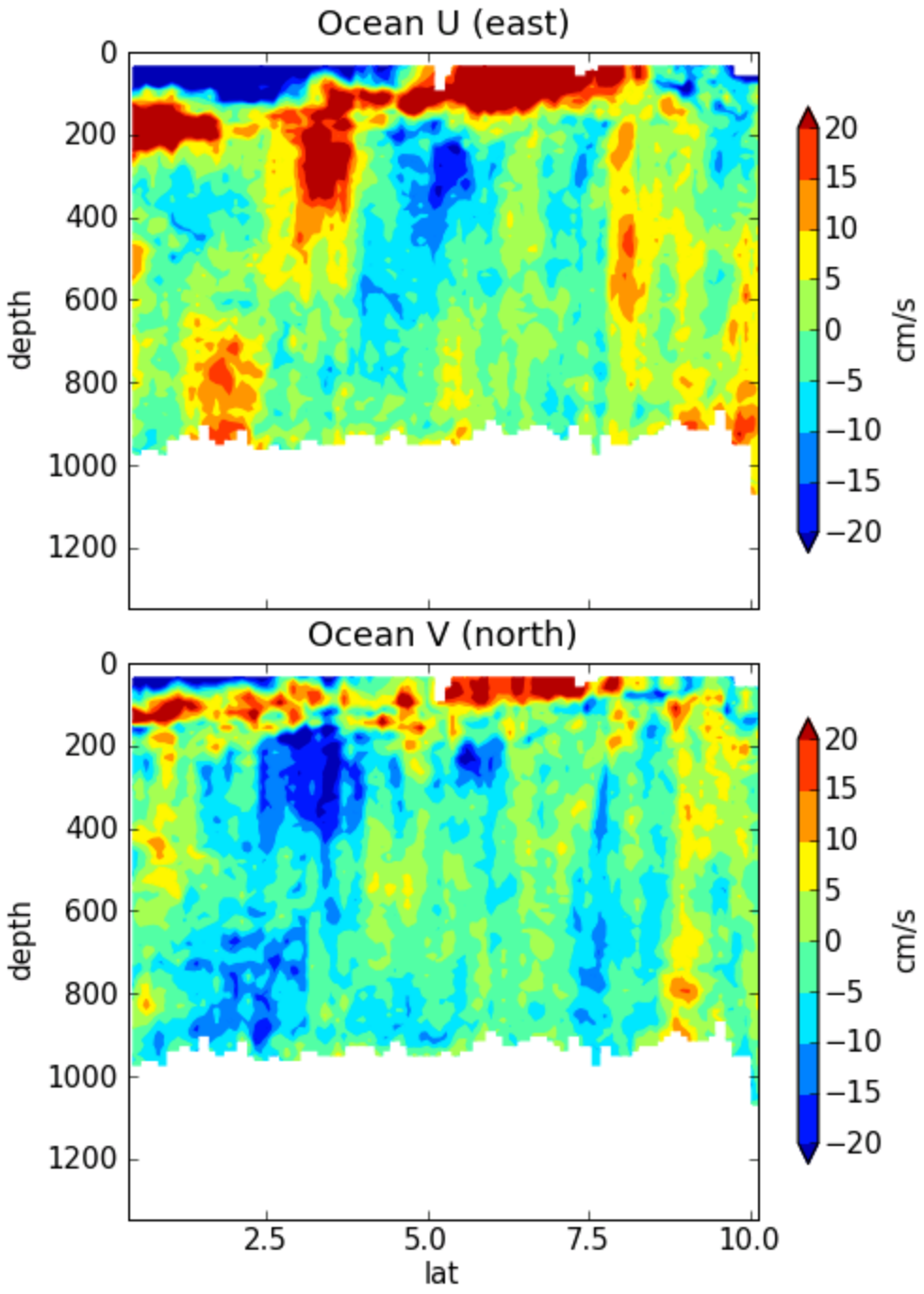
MET: PAR plots

ADCP (OS38BB):

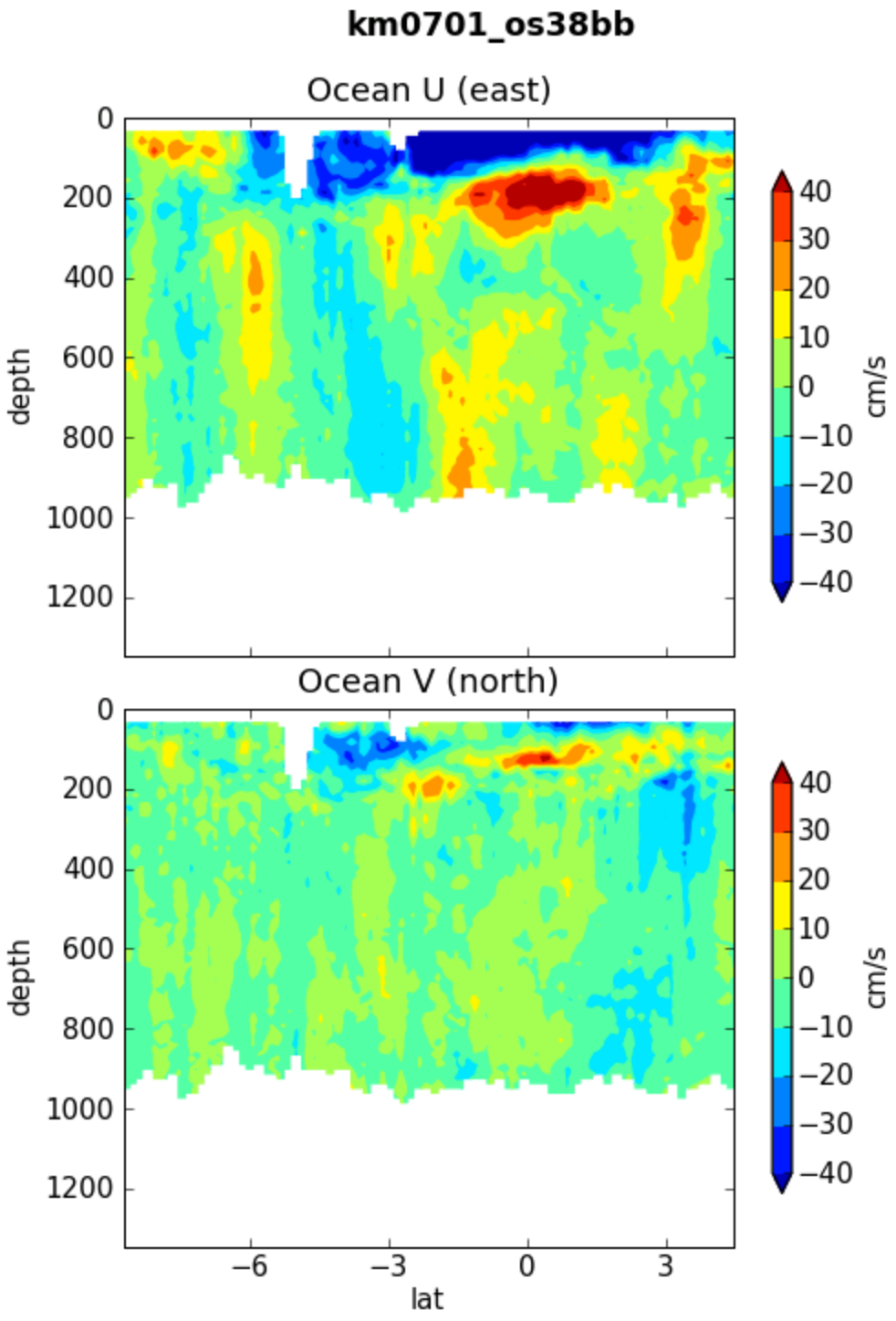

50 cm/s
velocity at 86m
25°N
0°
25°S
50°S
start
end
160°E
180°
160°W
0
1
2
3
4
5
6
depth, km
22
24
26
28
30
ADCP temperature, degC
last time = 2007/02/11 02:45:58

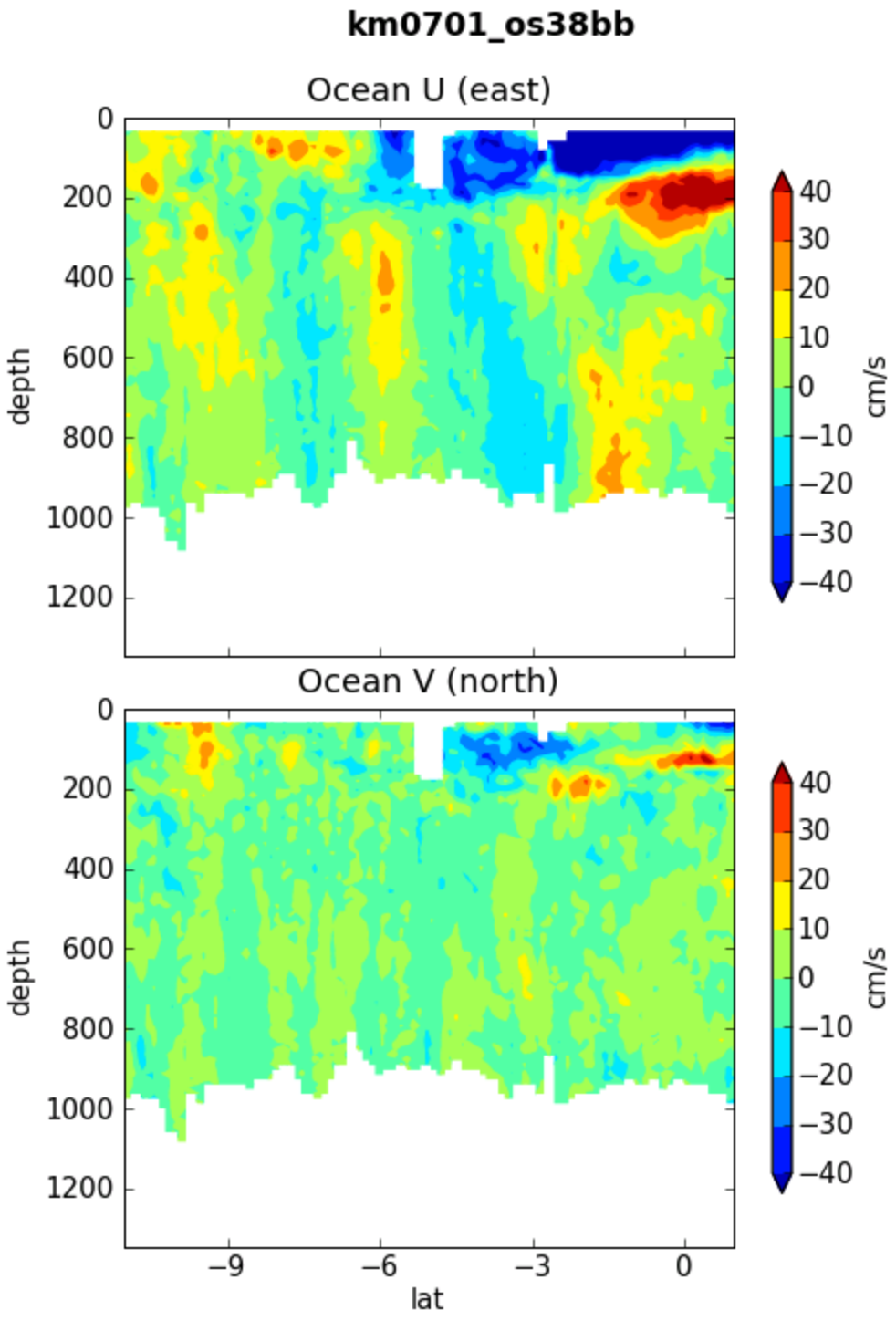

km0701_os38bb
Ocean U (east)
Ocean V (north)
depth
lat
cm/s
0
200
400
600
800
1000
1200
12.5
15.0
17.5
20.0
20
15
10
5
0
−5
−10
−15
−20
os38bb: last time = 2007/01/08 19:31:02

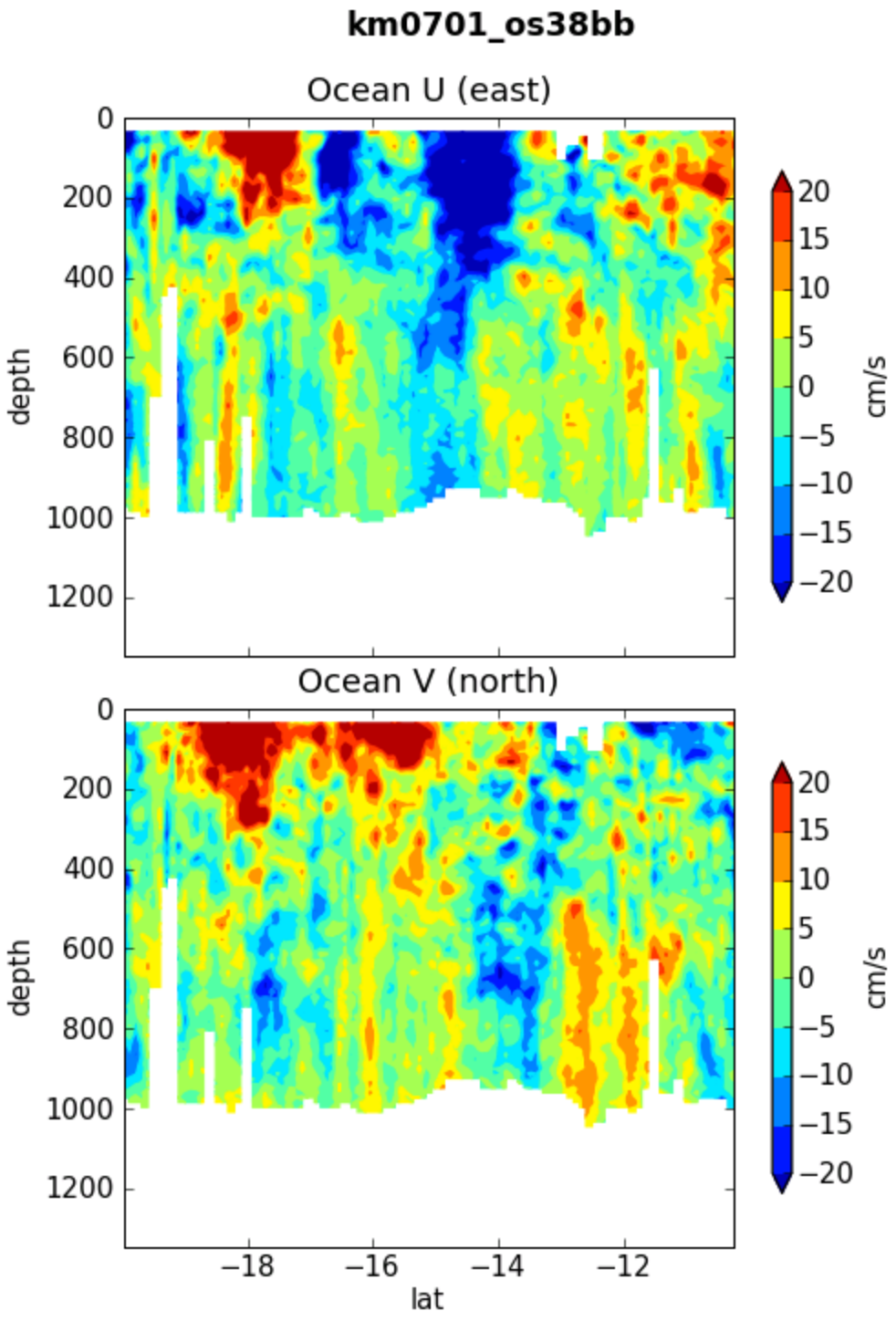
km0701_os38bb

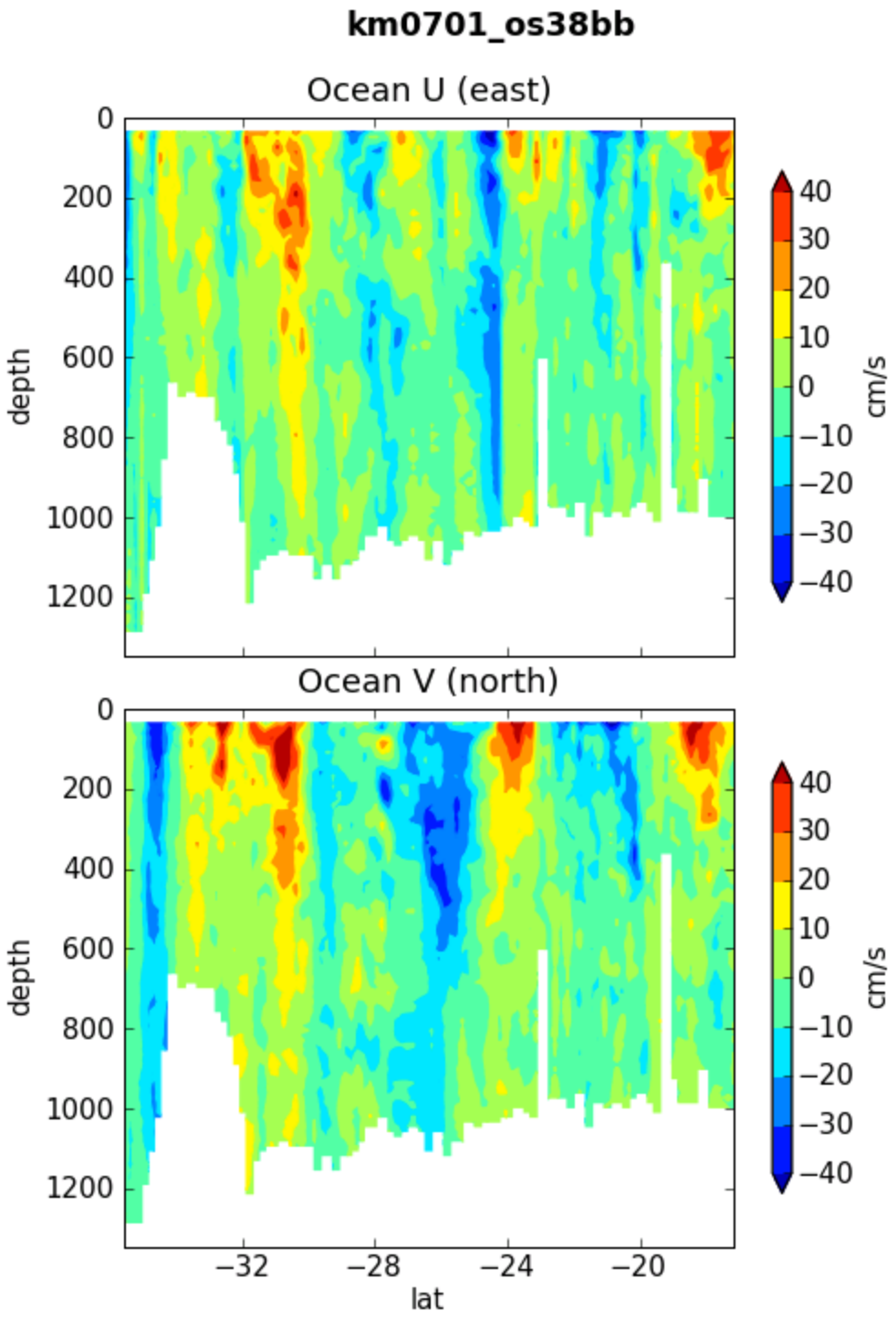


os38bb: last time = 2007/01/12 21:11:03

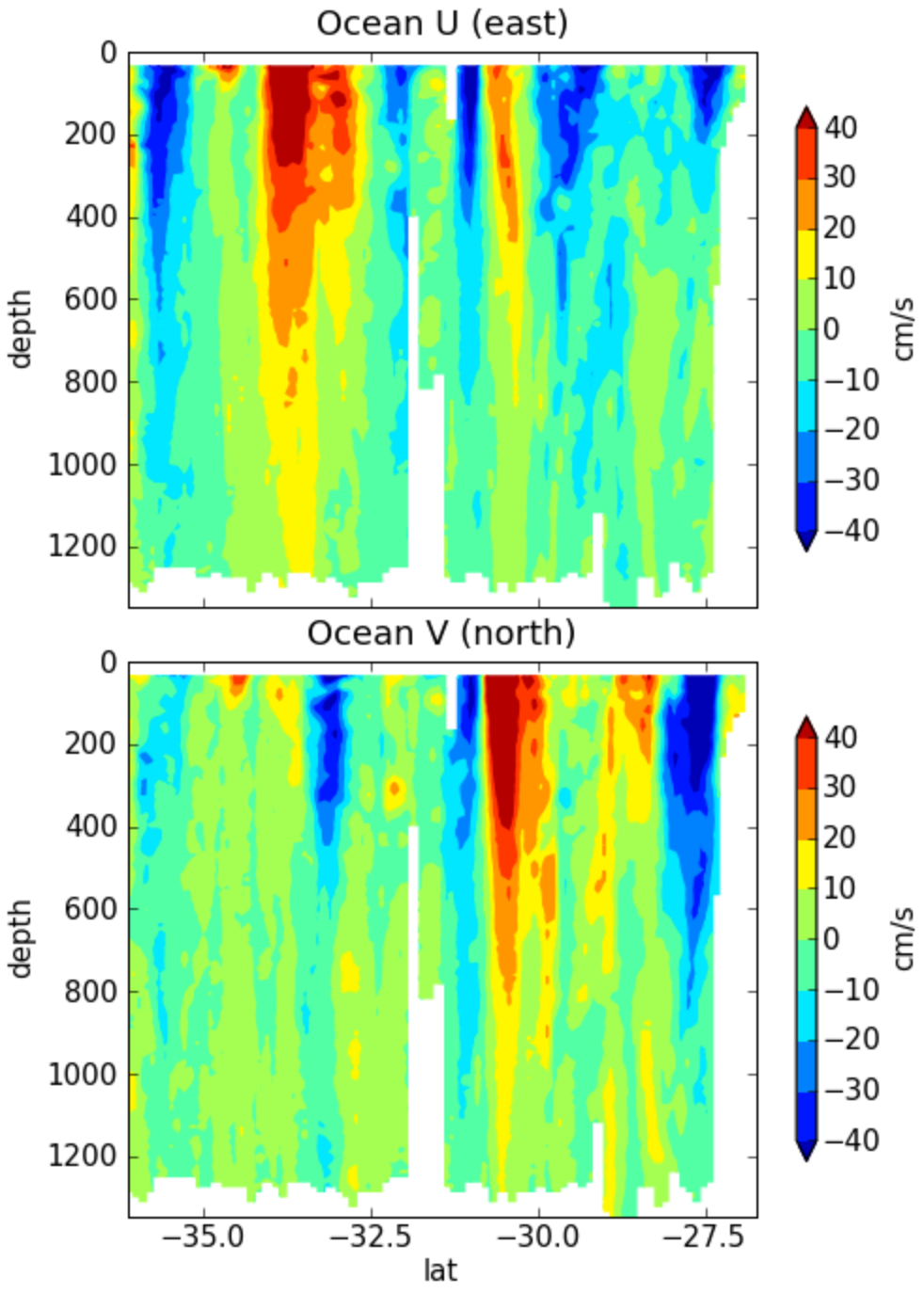

km0701_os38bb
Ocean U (east)
depth
0
200
400
600
800
1000
1200
40
30
20
10
0
−10
−20
−30
−40
cm/s
Ocean V (north)
depth
0
200
400
600
800
1000
1200
40
30
20
10
0
−10
−20
−30
−40
cm/s
−6
−3
0
3
lat
os38bb: last time = 2007/01/16 15:21:04


km0701_os38bb
Ocean U (east)
Ocean V (north)
depth
lat
cm/s
0
200
400
600
800
1000
1200
−9
−6
−3
0
40
30
20
10
0
−10
−20
−30
−40
os38bb: last time = 2007/01/19 10:56:05


km0701_os38bb
Ocean U (east)
depth
0
200
400
600
800
1000
1200
20
15
10
5
0
−5
−10
−15
−20
cm/s
Ocean V (north)
depth
0
200
400
600
800
1000
1200
20
15
10
5
0
−5
−10
−15
−20
cm/s
−18
−16
−14
−12
lat
os38bb: last time = 2007/01/22 09:06:02


km0701_os38bb
Ocean U (east)
Ocean V (north)
depth
lat
cm/s
0
200
400
600
800
1000
1200
−32
−28
−24
−20
40
30
20
10
0
−10
−20
−30
−40
os38bb: last time = 2007/01/29 16:20:00

km0701_os38bb



os38bb: last time = 2007/02/11 03:34:20

References

Project Website:
http://www.soest.hawaii.edu/oceanography/zij/wp2/
includes project summary, cruise report (this document), images from cruise, access to data, and more!
Additional data, manuscripts, and other reports will be posted as they come available.

Major Funding Agency:
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
http://www.nsf.gov

University of Hawaii Marine Center (R/V Kilo Moana)
http://www.soest.hawaii.edu/UMC/index.html

Satellite Imagery Data (NASA MODIS)
http://modis.gsfc.nasa.gov/

Ocean Data View: Data Visualization Software
http://odv.awi-bremerhaven.de/

ARGO
http://www.argo.ucsd.edu/
ARGO project description
http://www.usgodae.org/argo/argo.html
ARGO data storage site
http://www.usgodae.org/cgi-bin/argo_select.pl
ARGO data retrieval