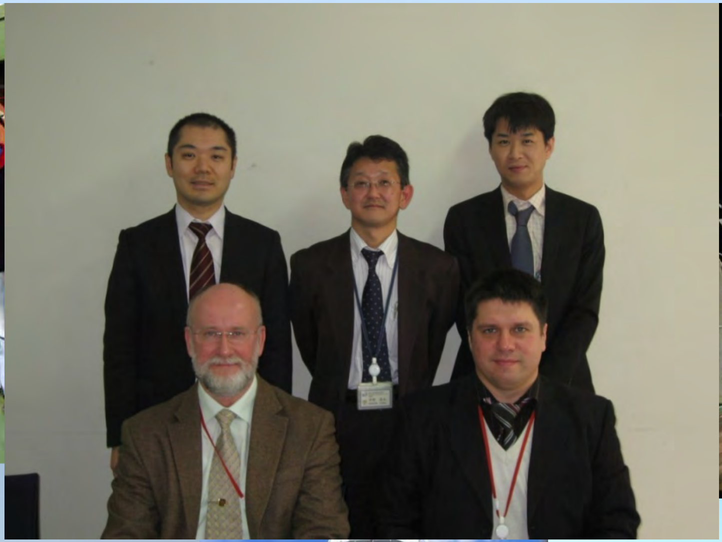
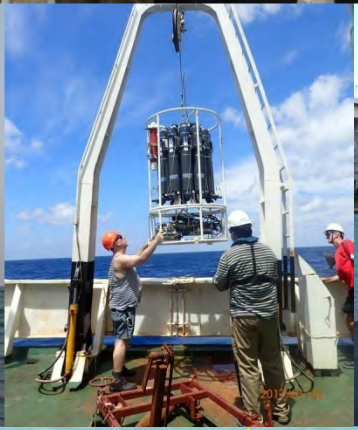
Recent reduction of dissolved oxygen in the North-western Pacific and Japan Sea


Dmitry **Kaplunenko**[1], Vyacheslav Lobanov[1], Pavel Tischenko[1], Sergey Sagalaev[1], Sho Hibino[2], Toshiya Nakano[2], Shi Xuefa[3] and Liu Yanguang[3]

[1]V.I. Il'ichev Pacific Oceanological Institute (POI), Vladivostok, Russia. E-mail: dimkap@poi.dvo.ru

[2]Japan Meteorological Agency (JMA), Japan

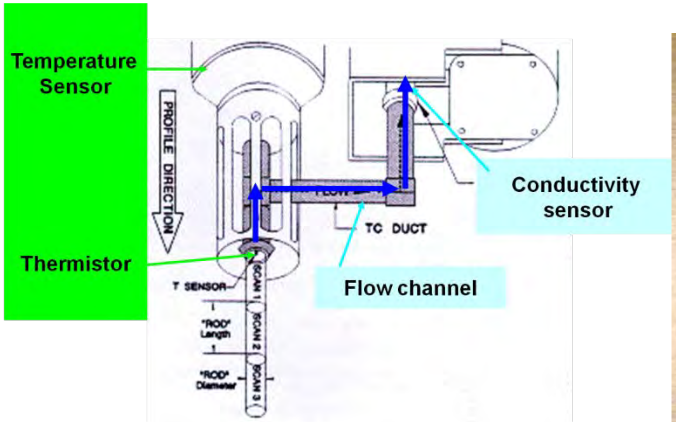
[3]First Institute of Oceanography (FIO), State Oceanic Administration (SOA), PR China

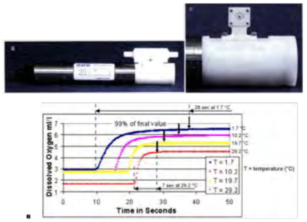
e-mail: dimkap@poi.dvo.ru

Contents

- High-accuracy data obtaining problem
- **P**recision of used sensors and data processing features
- Data for this presentation
- Cross-Basins GOOS and NEAR-GOOS climate monitoring features
- Results of measurements in the Japan Sea
- Results of measurements in the North-western Pacific
- Result of measurements in the Indian Ocean
- Conclusions

Equipment for measurements





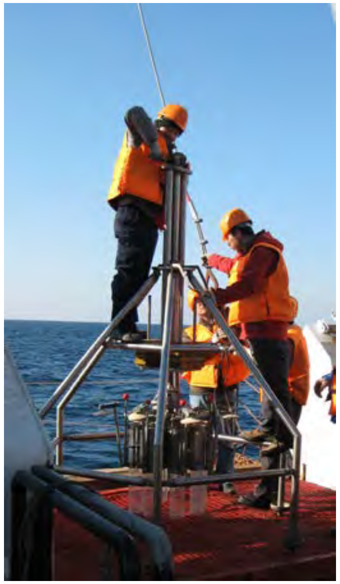
SBE 43 – O_2 sensor
with polarographic membrane

Rinko III – O_2 sensor
with optical sensor

Standard recent Oceanographic Equipment:
CTD-Unit SBE-911+SBE32 sampler
Equipped with two sets of temperature-conductivity sets and oxygen sensors

SBE35

Equipment for measurements II



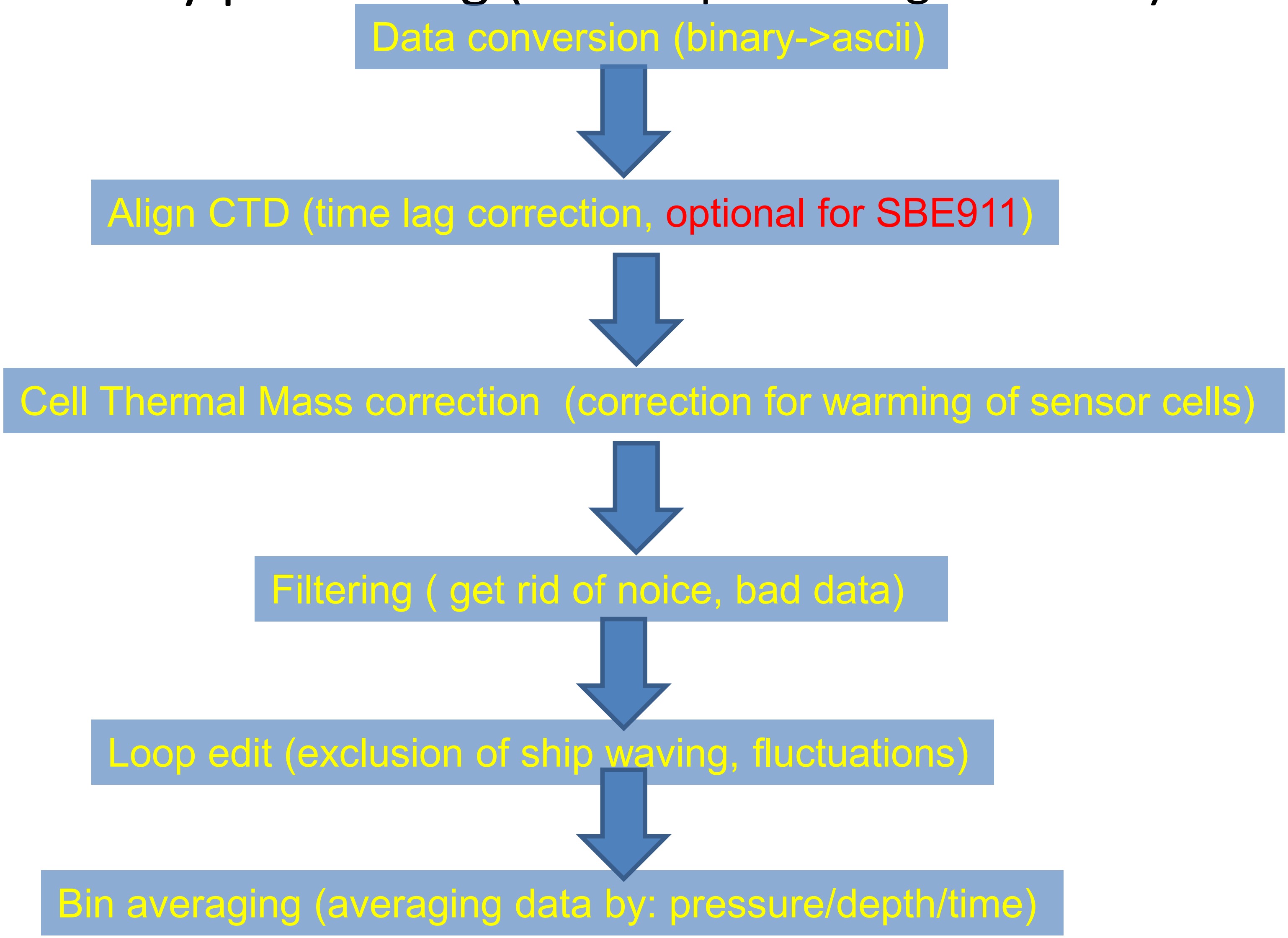
Accuracy of SBE sensors

	SBE-35	Temp. SBE-3+	Cond. SBE 4C	$O_2^{(SBE-43)}$	$O_2^{(RINKO-III)}$
Depth measure	to 6800 m	to 7000 m	to 7000 m	to 7000 m	To 7000
Initial accuracy	± **0.001 °C**	0.001 **℃**	0.0003 S/m (0.001 psu)	2% saturation	±2%
Stability	0.001 °C per year	0.0002 ℃/month	0.0003 S/m/mon. (0.001 psu/mon.)	0.5% per 1000 hours	±5% (1 month)
Range:	-5 to +35 °C	-5 to 35 ℃	0 to 7 S/m	Until 120% surf. sat.	0-200%

• During the study of East Sea deep waters structure within long time it necessary to pay attention on basic characteristics of used sensors for CTD-unit.

SBEDataProcessing : simple case

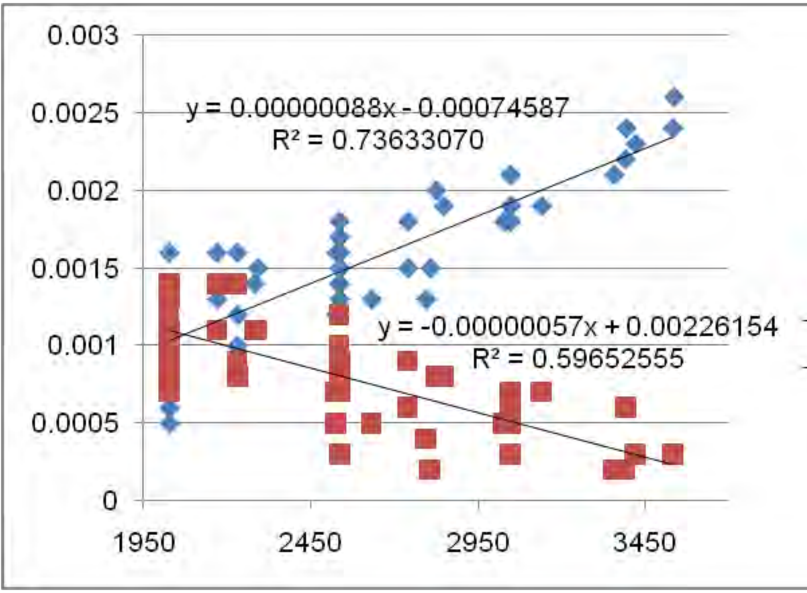
- Preliminary processing (SBEdataprocessing software.)

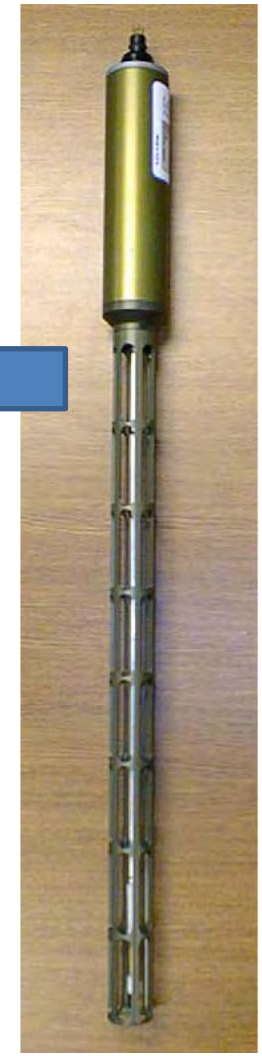


Temperature measurements

La66-2014

[WHP-P9(2010) cruise report. JMA]



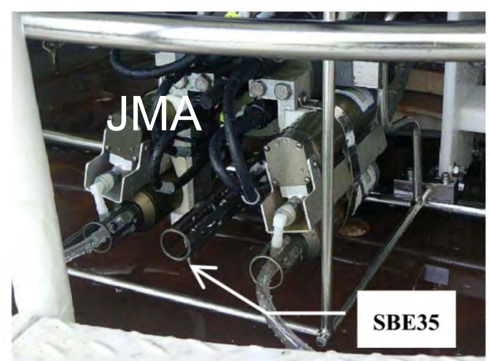


SBE35

Each SBE-sensor is individual. Its deformation can be corrected at depths more than 2000 m by the calibration using SBE-35 (platinum thermometer).

Usual calibration formula for this case:

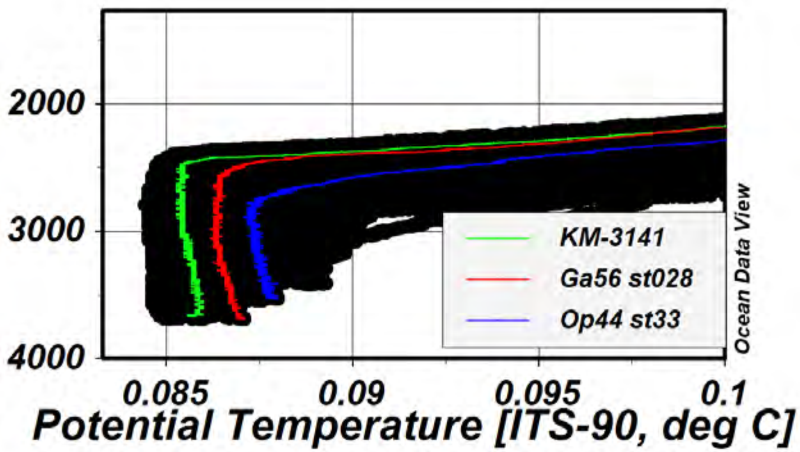
$$T_{cal} = T_{raw} - (C_0 + C_1 \times P)$$



- We used second sensors set (POI) for analysis due to the problem with the 1st one

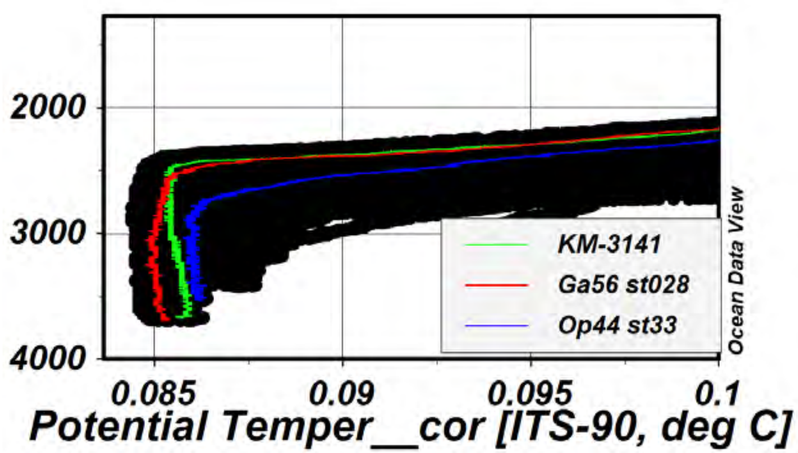
Temperature correction: with SBE35

unCalibrated Theta



Ga56 and Op44 data before correction
KM3141 – corrected data for reference

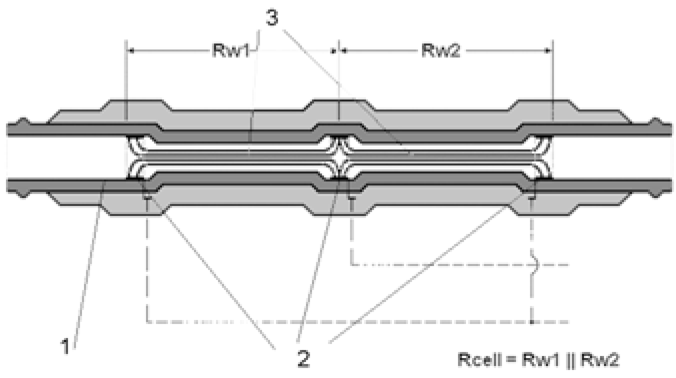
Calibrated Theta



Ga56 and Op44 data after correction
KM3141 – corrected data for reference

- Correction of temperature on sensitivity to pressure may cause change of T value on +- 0.003 C which may be important during the study of climatic changes

Salinity correction



SBE 4C – conductivity sensor

- to obtain high accuracy it is not enough a standard SBE-processing procedures
- it is necessary to consider pressure effect for SBE conductivity sensor by calibration with data from sampling bottles (together with SBE 35 measurements)

- Correction may be defined using the following formula:

$$C_{cal} = C - \left(\sum_{i=0}^{I} c_i \times C^i + \sum_{j=1}^{J} p_j \times P^j \right) \quad , I = J = 2$$

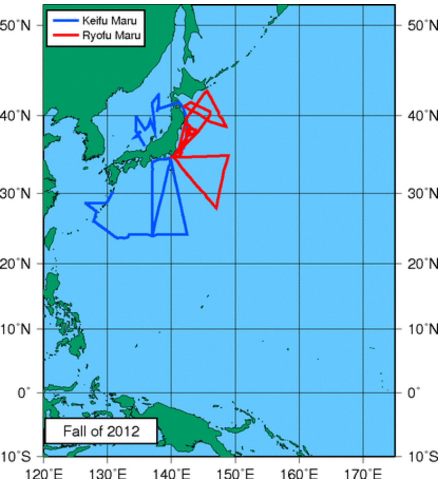
The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines

IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1, 2010

NOTES ON CTD/O2 DATA ACQUISITION AND PROCESSING USING SEA-BIRD HARDWARE AND SOFTWARE (AS AVAILABLE)

K.E. McTaggart, G.C. Johnson, M.C. Johnson, F.M. Delahoyde, and J.H. Swift

Salinity correction



JMA data of cruises of R/V "Keifu Maru" (blue line on map):

http://www.data.kishou.go.jp/kaiyou/db/vessel_obs/data-report/html/ship/ship_e.php

- During the cruise the Laboratory Salinometer was available onboard, which allowed one to make a calibration;

Laboratory Salinometer Autosal 8400B

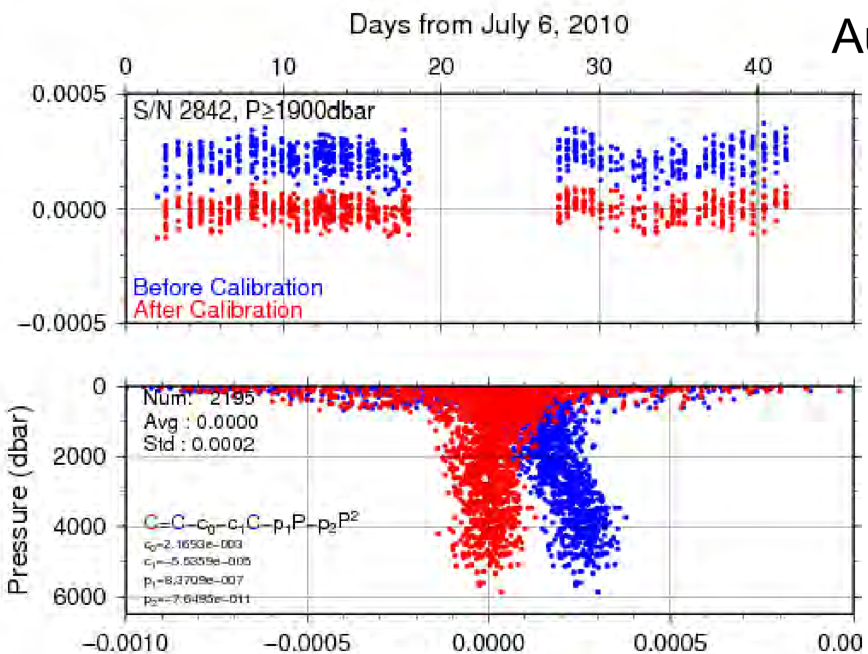
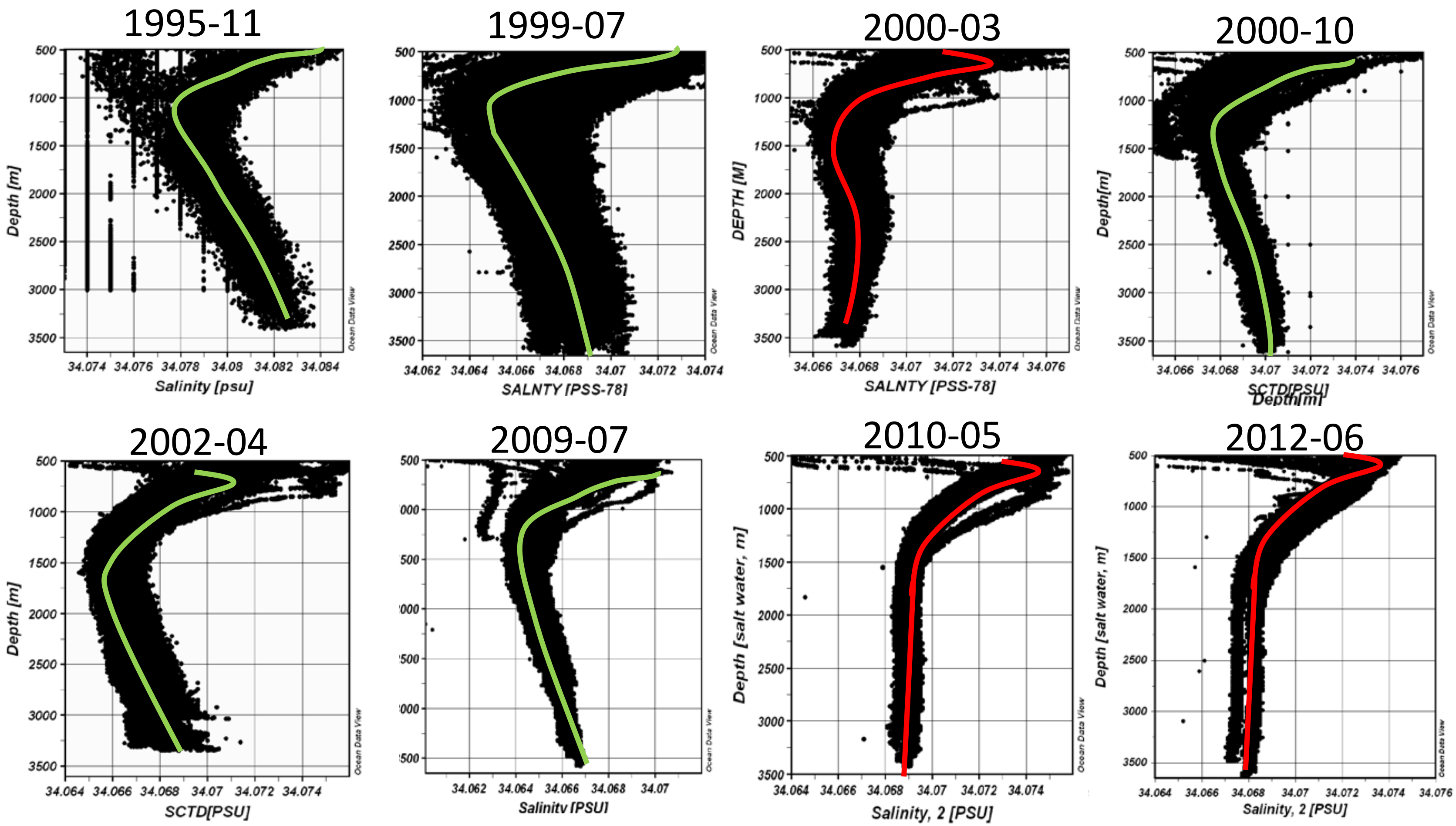


Table C.1.2. Conductivity Calibration Coefficient Summary.

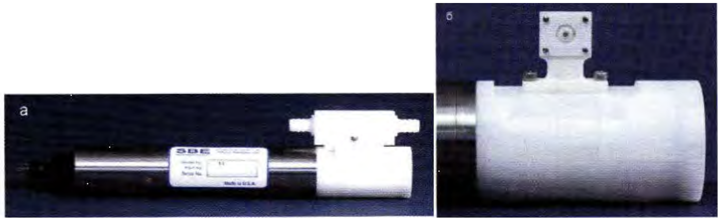
S/N	Num	c_0(mS/m)	c_1	c_2(mS/m)	Stations
			p_1(mS/dbar)	p_2(mS/m/dbar^2)	
3670	1274	1.5107e−3	−7.4144e−5	0.0000e−0	Stn. 1 – 67
			6.6856e−7	−8.3866e−11	
3670	308	2.2680e-3	−8.0696e−5	0.0000e · 0	Stn. 68 – 83,
			−1.2437e−8	0.5038e−11	Stn. 105 – 107
3670	608	1.0048e-3	−7.6991e−5	0.0000e−0	Stn. 84 – 104,
			3.9031e−7	−4.2466e−11	Stn. 108 – 124
2849	2195	2.1693e-3	−5.5359e−5	0.0000e−0	Stn. 1 124
			8.3709e 7	7.6495e 11	

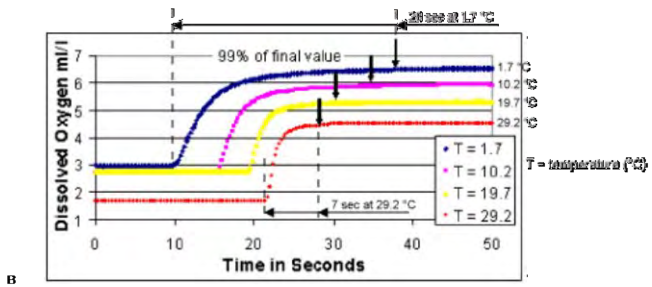
Mysterious Deep Salinity Minimum



- Due to polynomial equation of second order sometimes slope and curl is not correctly obtained for intermediate and deep waters of JES

Dissolved Oxygen Measurements





Ref: Gordon, Garcia

Ref: Uchida et al.

SBE 43 – O_2 sensor
with polarographic membrane

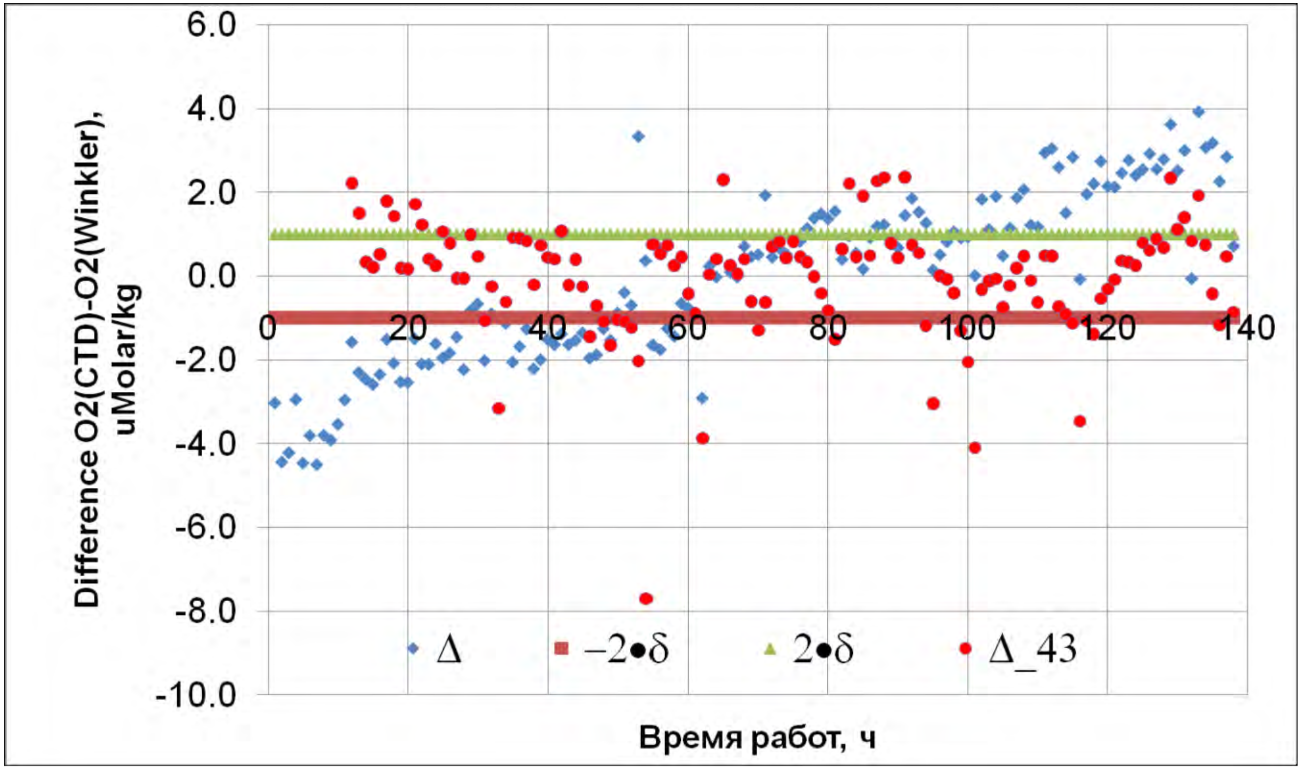
$$O_2 = S_{oc} \cdot \left(V + V_{off} + \tau_{20} \cdot e^{(D_1 \cdot p + D_2 \cdot (T-20))} \cdot dV/dt\right) \cdot O_{sat} \cdot (1 + A \cdot T + B \cdot T^2 + C \cdot T^3) \cdot e^{[(E \cdot p)/(273.15+T)]}$$

Rinko III – O_2 sensor
with optical sensor

$$P_0 = 1.0 + c_4 \times t$$
$$P_c = c_5 + c_6 \times v + c_7 \times T + c_8 \times T \times v$$
$$K_{sv} = c_1 + c_2 \times t + c_3 \times t^2$$
$$coef = (1.0 + c_9 \times P/1000)^{1/3}$$
$$[O_2] = \{(P_0/P_c - 1.0)/K_{sv} \times coef\}$$

Owens, W. B., and R. C. Millard Jr., 1985: A new algorithm for CTD oxygen calibration. J. Physical Oceanography., 15, 621-631.
Garcia and Gordon (1992) "Oxygen solubility in seawater: Better fitting equations", Limnology & Oceanography, vol 37(6), p1307-1312.
Uchida, H., T. Kawano, I. Kaneko, and M. Fukasawa (2008): In –situ calibration of optode-based oxygen sensors. J. Atmos. Oceanic Technol., 25, 2271-2281.

Optical (Rinko)/ Membrane (SBE43) correction

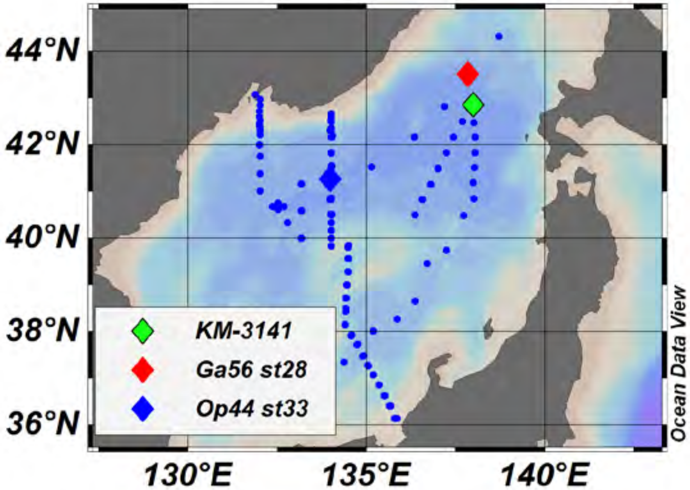


Comparatively with the SBE43 RinkoIII has a temporal drift which is not similar for different cruises

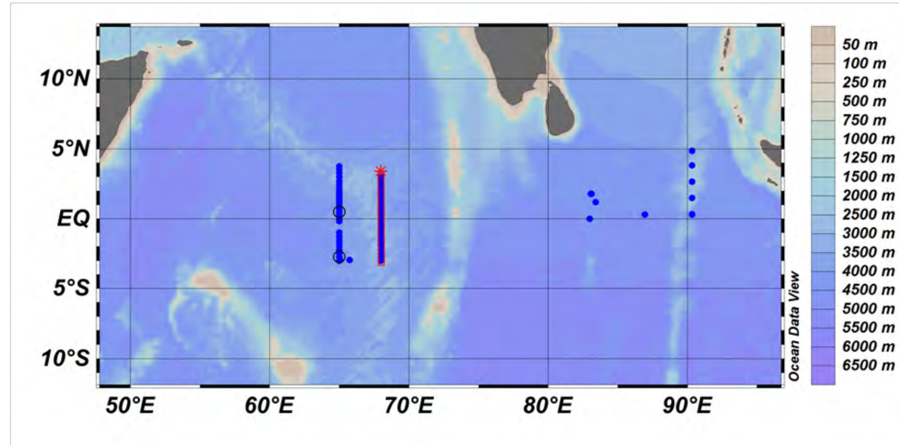
This cause us to use only 30% of obtained data for calibration in the La66 cruise

According with this the RinkoIII sensors needs to be inspected and controlled during the further cruises

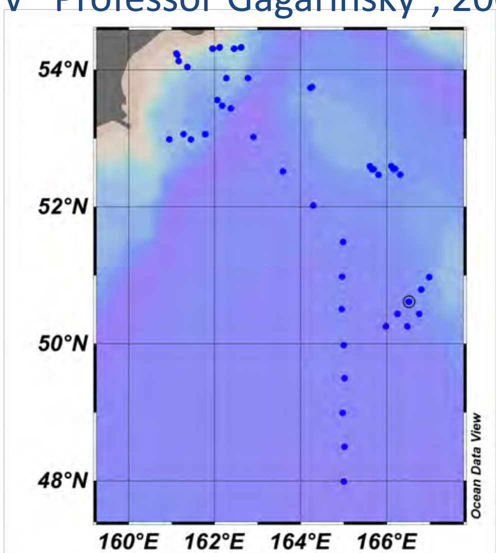
Observations areas of joint works/used Data

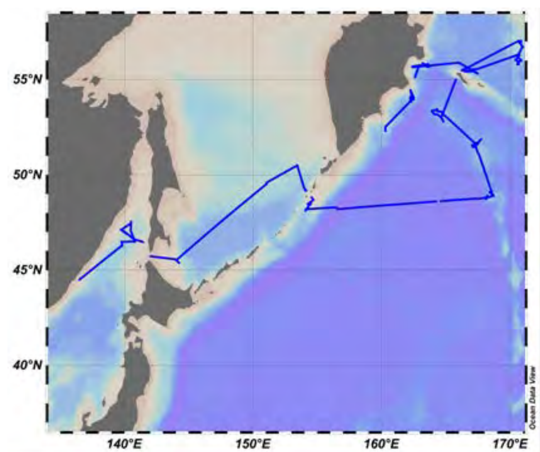


R/V “Akademik Oparin”, R/V “Akademik Lavrentyev”, R/V “Professor Gagarinsky”, 2009-2015



R/V “Akademik Boris Petrov” – 2017 , cruise #42

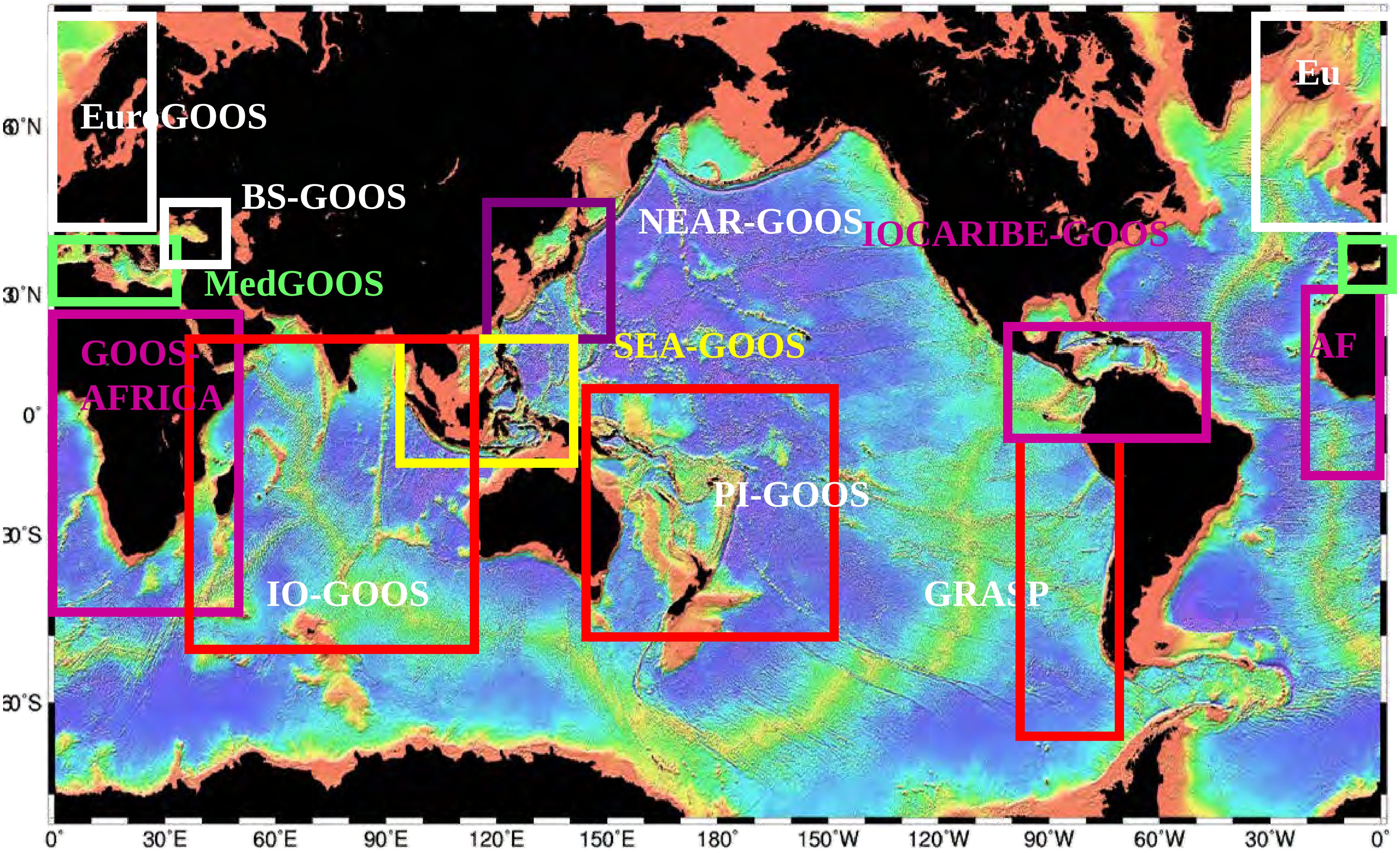




-Historical dataset from eWOCE:
North-Western Pacific;
Indian Ocean;

La 63, Jul- Sep 2013 La 76, Jul-Aug 2017

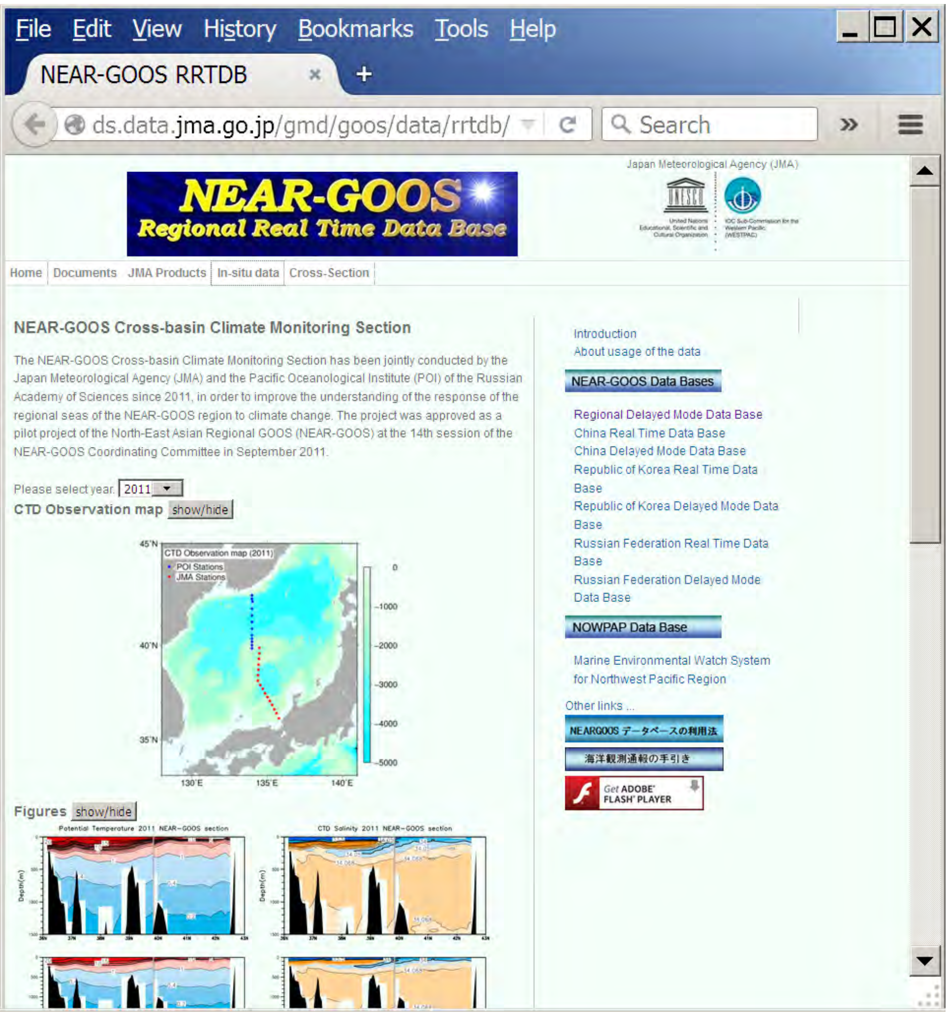
GOOS Regions




NORTH
EAST
ASIAN
REGIONAL
GOOS
RUSSIAN
FEDERATION
CHINA
REPUBLIC
OF
KOREA
JAPAN
CHINA

NEAR-GOOS Pilot Project: Cross-Basin Climate Monitoring Section

http://ds.data.jma.go.jp/gmd/goos/data/rrtdb/cross-section/cross-section.html



Objectives for project:

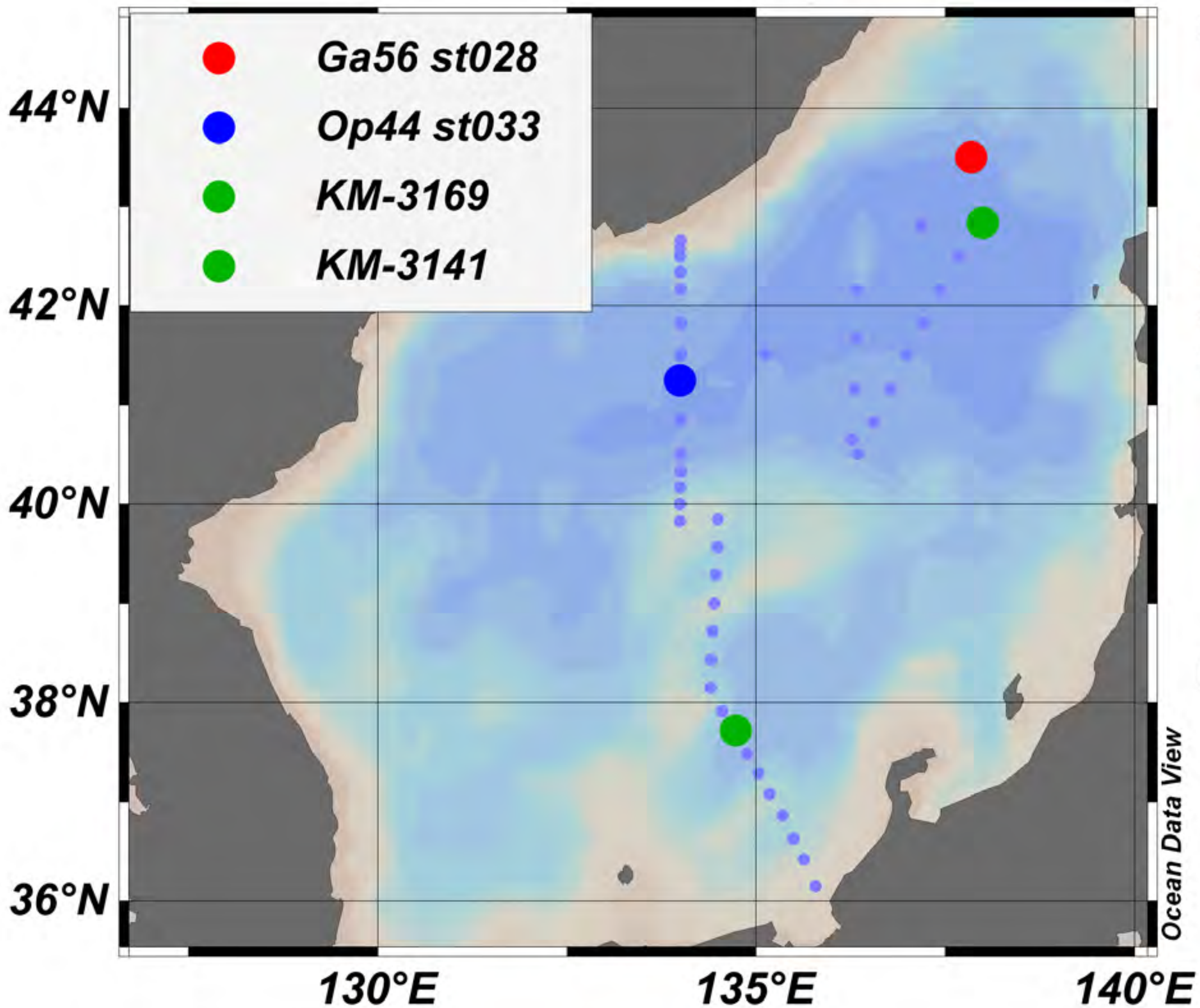
- JES is semi-enclosed basin with the stable hydrographic structure e.g. cool deep water with the salinity and oxygene anomalies within the intermediate waters;
-The monitoring of these parameters gives a key for understanding of global warming the World Ocean;
- The main idea is to compare the temperature, salinity and oxygene observations made within the close locations which allow to suggest about data quality and compatibility of measurements made independently by the JMA and POI;

Data error assessment by NEAR-GOOS data

- Talley at al. 2004
- Cruise La58 R/V Akademik M.A. Lavrentyev", Ga56 R/V "Professor Gagarinsky", Op44 R/V "Akademik Oparin"
- R/V "Keifu Maru"
- Ga56 St028 – 19/Jun/12
- Op44 St033 – 24/Oct/12
- KM-3141 – 30/Oct/12
- KM-3169 – 4/Nov/12

Talley:

La58-s



68

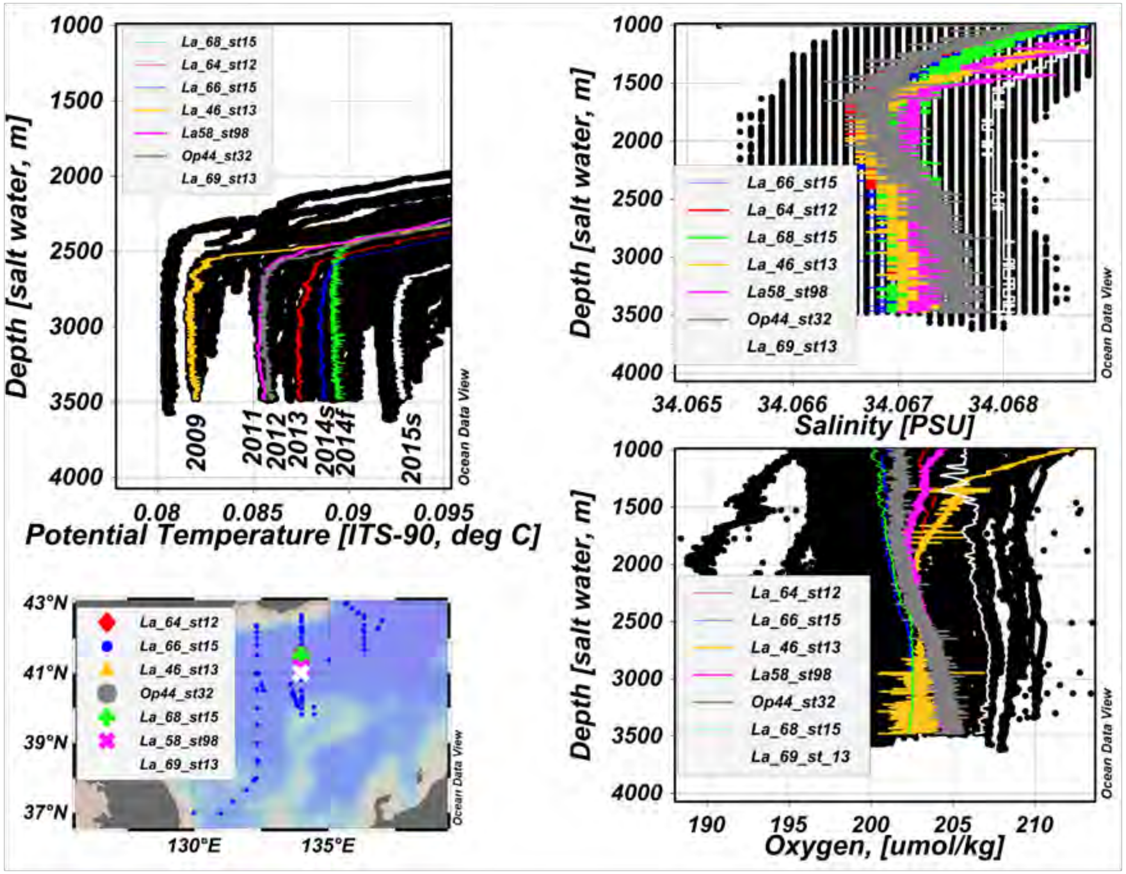
34.068

5

195

La58-st98 (raw): 196
(calibrated
1000m-bottom): 210

Calibrated data comparison (2009-2015) Observations in the Japan sea



Finally were defined:

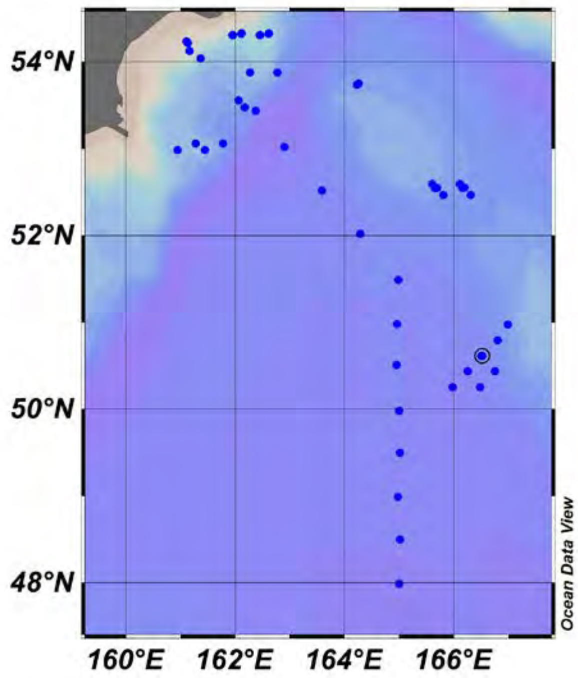
-Temperature corrected in the same manner for the last 5 years essentially increases;

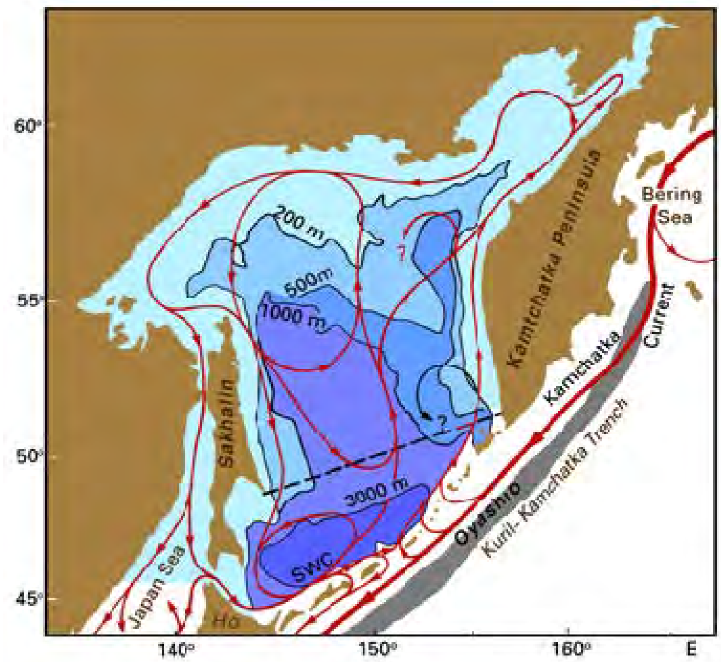
- The temperature growth is not regular from year to year;

- The salinity minimum is stable within the frames of instrument sensitivity;

- The oxygen in the deep layer has some variations and now is lower than 3 years before;

Studies in the North-western Pacific





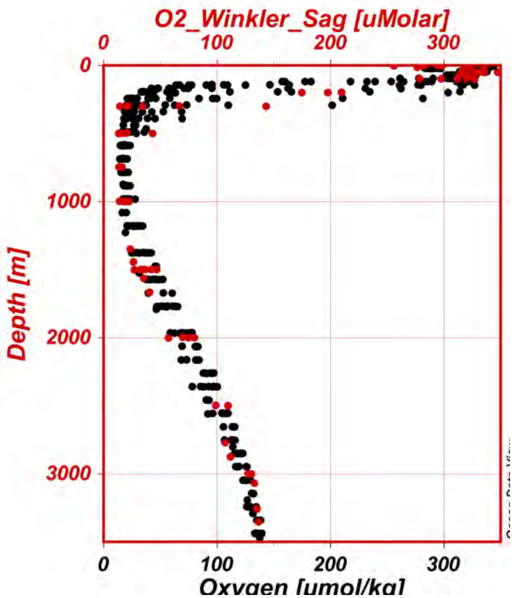
-For result validation the WOCE atlas have been used:

-Research Vessel R/V John Vickers (NOAA Pacific Marine Environmental Laboratory (PMEL), USA, Chief Scientist - John L. Bullister, bullister@pmel.noaa.gov, Leg 2: 16 August- 15 September 1992)

Measurements:

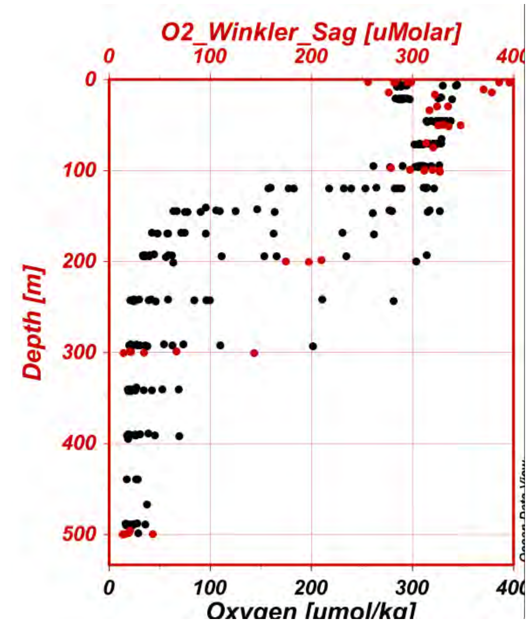
Oxygen	J. Bullister	PMEL bullister@pmel.noaa.gov
nutrients	K. Fanning	USF KAF@MSL1.Marine.USF.edu

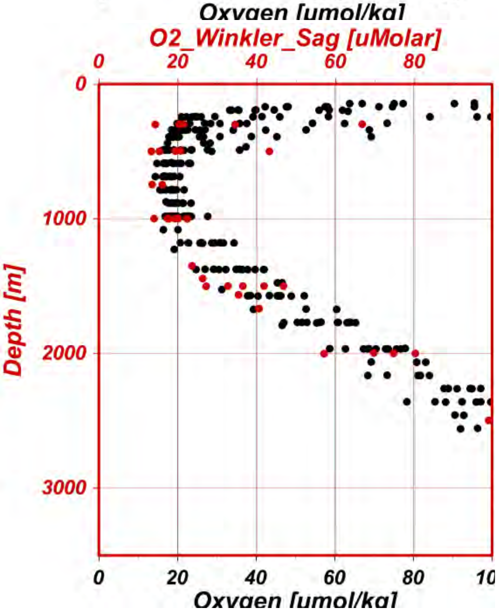
O2 by the hydrochemical analysis

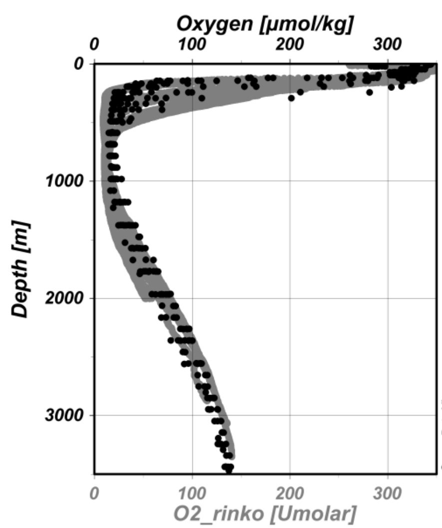


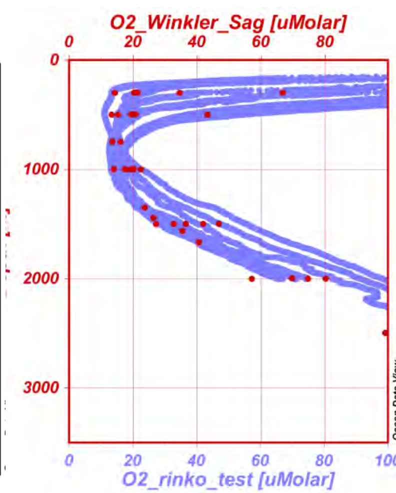
-The profiles measured 20 years ago and in the our cruises have good matched to each other;

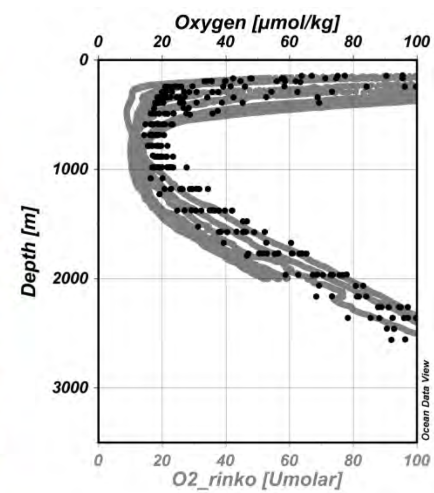
- During this cruise wi have used new type of optical sensor for oxygen measurements;



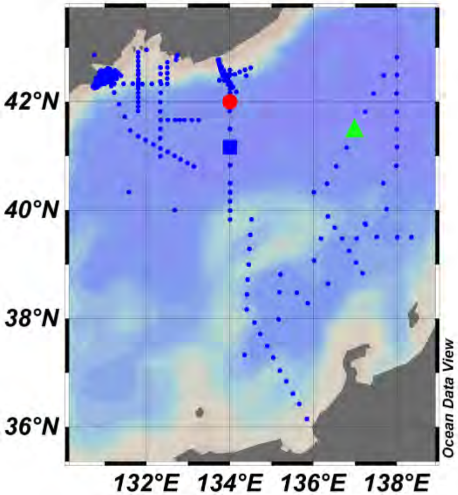


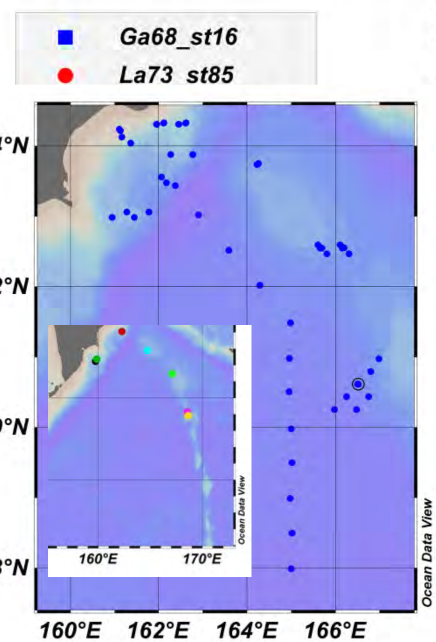


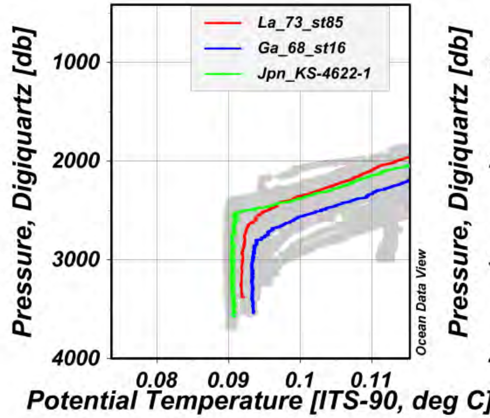


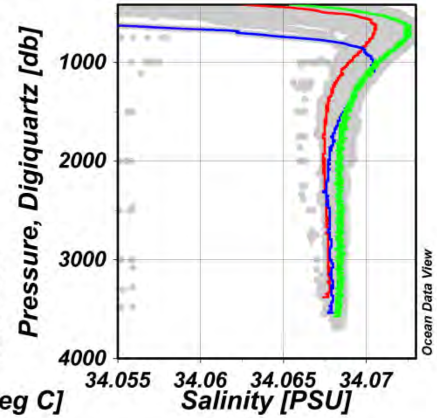


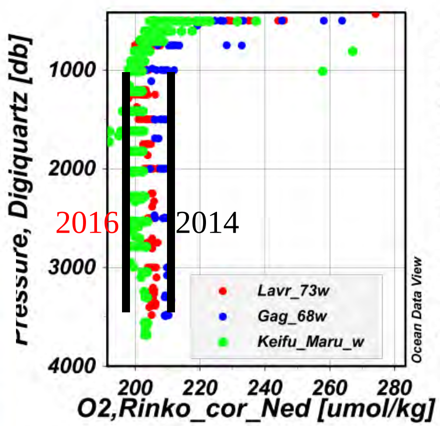
O2 decreasing for last 3-4 years in the Japan Sea and North-Western Pacific

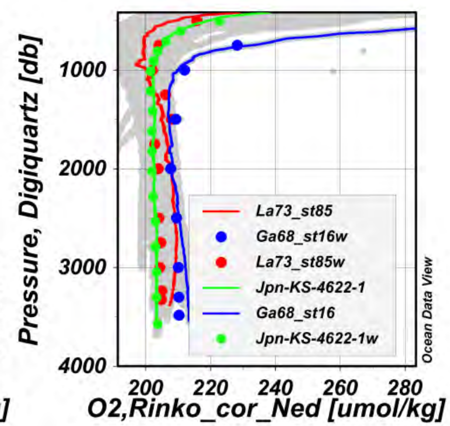


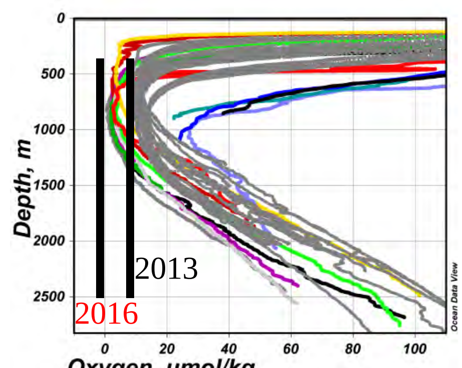


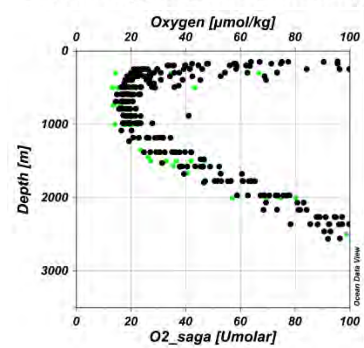












Essential fact for the Japan Sea that Θ is continuing slightly increasing, while the deep waters loose their DO, via advection from east to west of Japan Basin;

At the same time OMZ values in the North-Western Pacific become critical:

2013:

Winkler: 13 uMol/kg;

RincoIII: 8 uMol/kg;

2016:

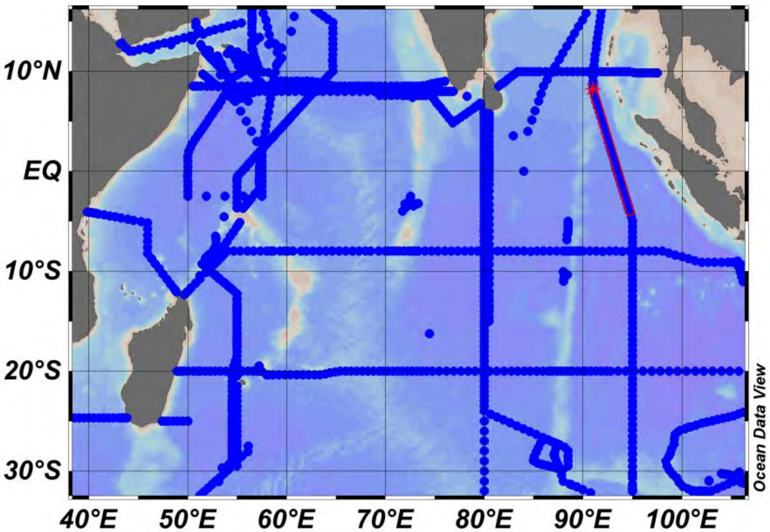
Winkler: No data;

RincoIII: 2-3 uMol/kg(!!!);

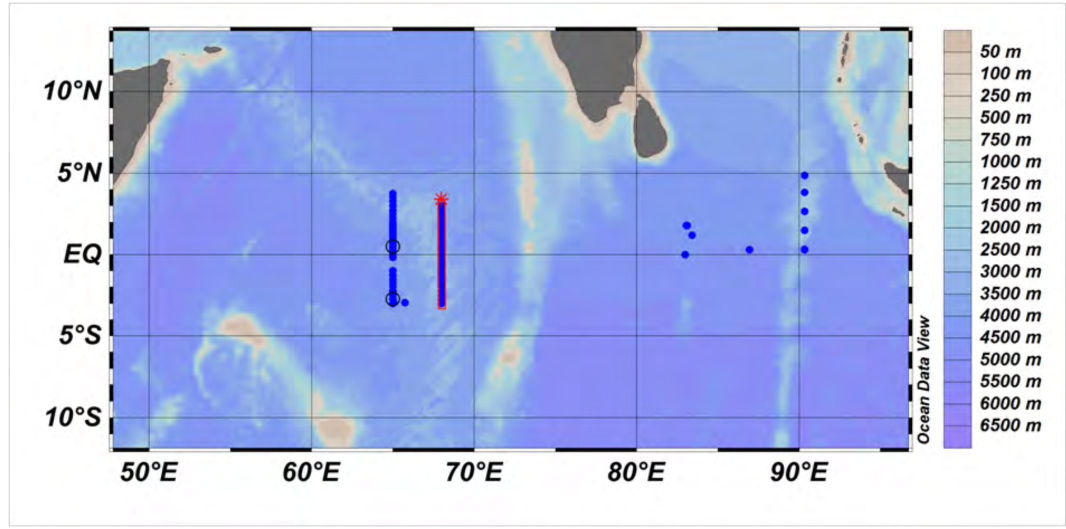
1992:

Winkler: over 20 uMol/kg

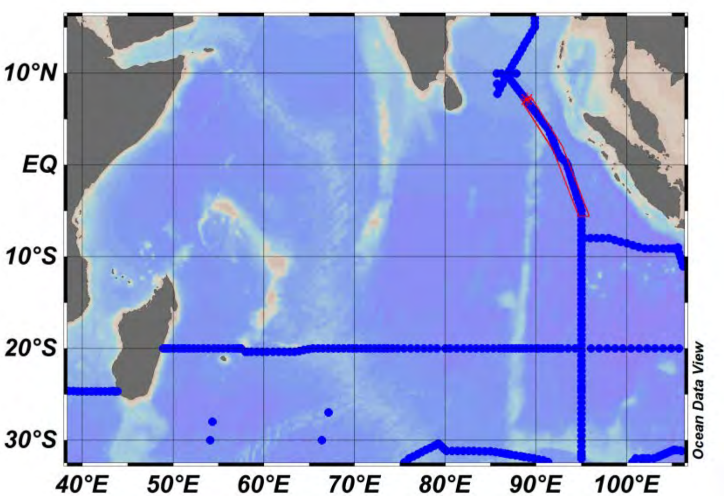
Meanwhile in the Indian Ocean….



Coverage of 1990s



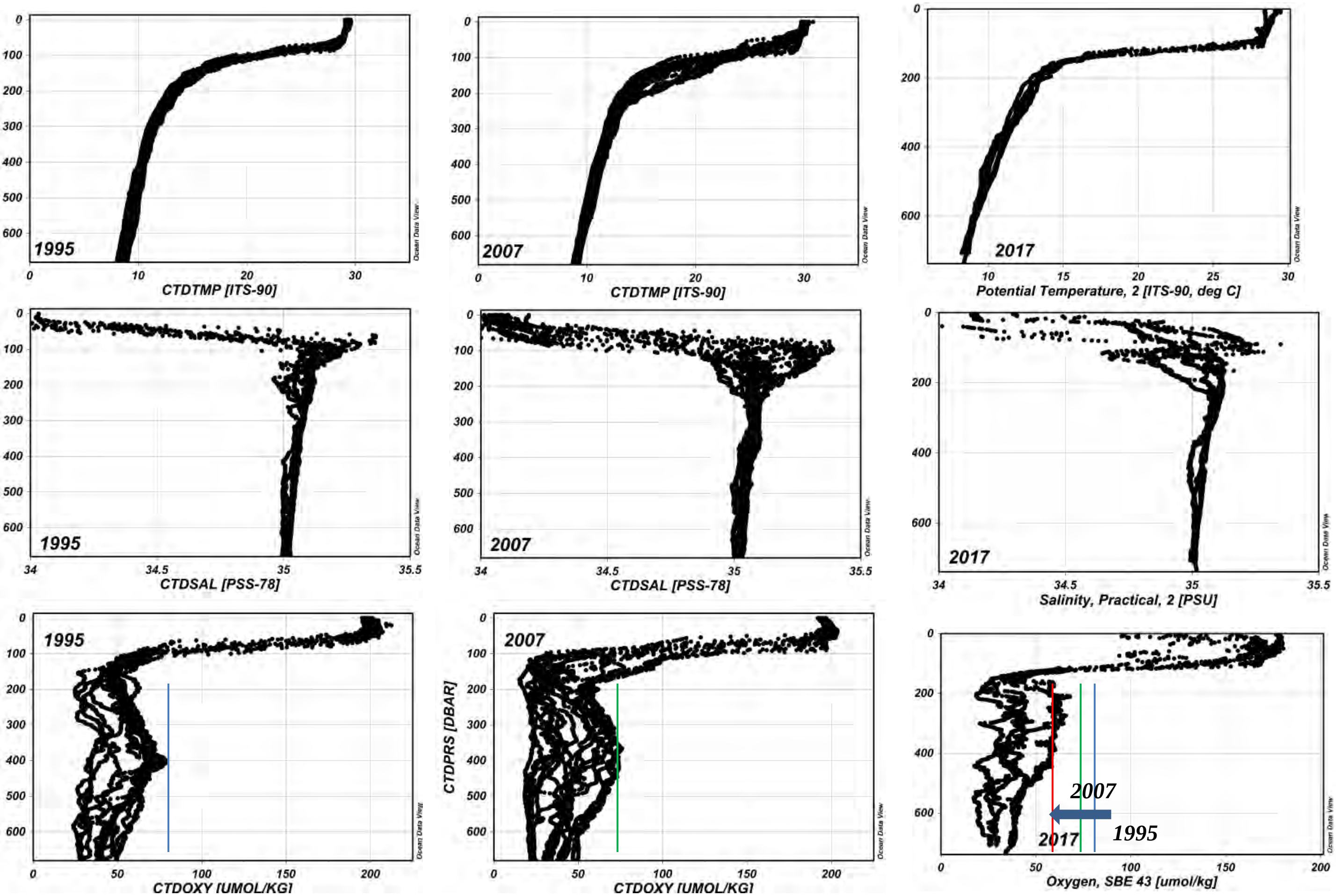
Observations of 02/2017



Coverage of 2000s

The Indian Ocean – is very unstudied place for last 50 years. Recently the 2nd International Indian Ocean Expedition (IIOE-2) has started by the SCOR.

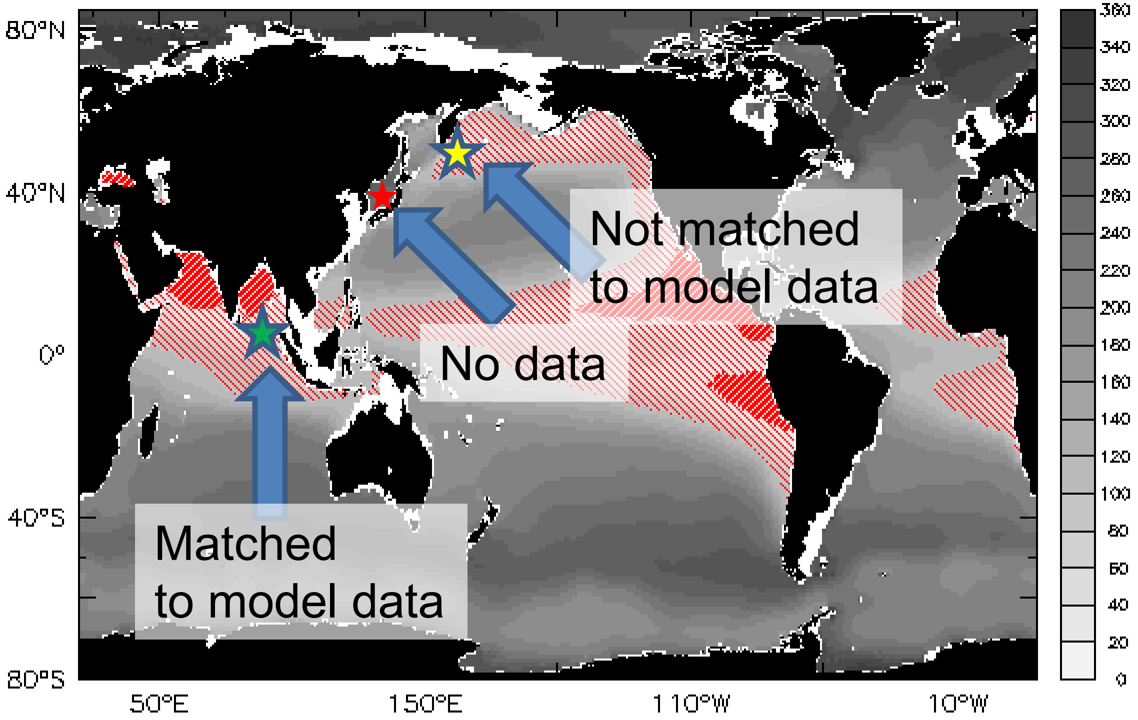
Features of 90°E



Profiles of oxygen content, obtained during the ABP42 cruise (bottom right), and correspondent to eWOCE data from 1995 and 2007, but the content is lower on 20% than 22 years ago, and about ~15% than 10 years ago.

What is the truth?

Sub-surface oxygen concentrations averaged between 200m and 600m from World Ocean Atlas 2009 (μmol per kg)
(by Maciej Telszewski and Laurent Bopp **)**



Light and dark red stripes indicate waters with O_2 <100 μmol per kg and O_2 <20 μmol per kg respectively.

Conclusions

- As the result of NEAR-GOOS activity our team has a chance to make our CTD-unit well calibrated and make measurements in the far geographic locations of one sea and two oceans (well, actually more than one sea – but the subject of this report is our activity within the frames of international cooperation)
- The measurements gave unexpected results which is not good matched to the model output for study deoxygination but probable they should be taken into account due to used methods and obtained results;
- Most of the works described here at the beginning was not supported by any grants and was like a third-party works within the frames of other big projects, but finally we talk about serious things which (we hope) might be the interesting for the whole scientific society;


Thank you for your attention!
СПАСИБО!