



Observational approaches to oxygen depletion

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Workshop on Ocean Biology Observatories
Venezia, Italia, September 17, 2009

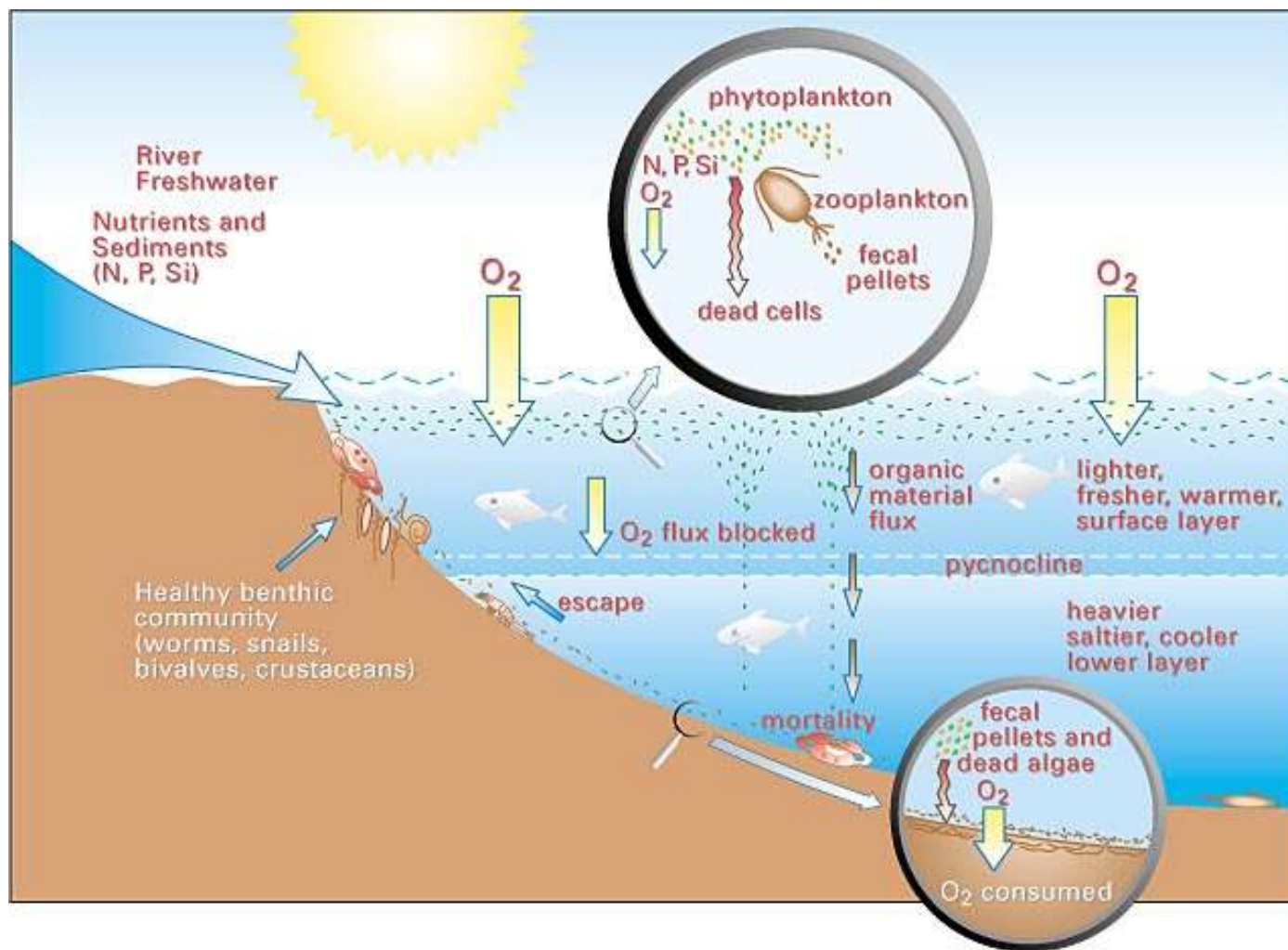


OUTLINE

- Oxygen change: predictions from ocean circulation & biogeochemistry models
- Sensors used – polarographic & optical
- Results and lessons learned from Argo
- Estimates of long-term drift
 - Deep data (1900 m)
 - Surface data (in air measurements)
- Data management issues – O2



Increased nutrient inputs from rivers can cause hypoxia





Pêches et Océans
Canada

Fisheries and Oceans
Canada

Global climate change – Oxygen



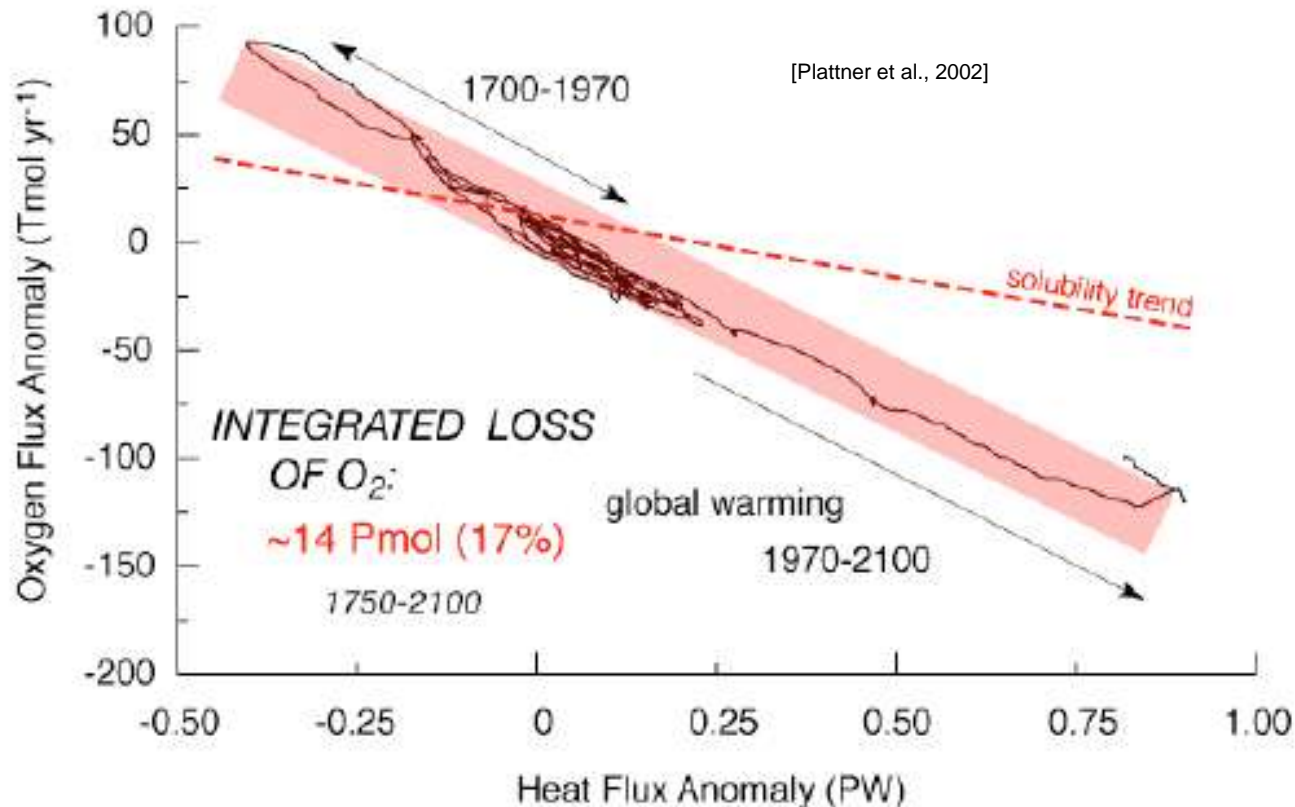
Canada

Coupled atmosphere-ocean-ice & biogeochemistry models suggest that...

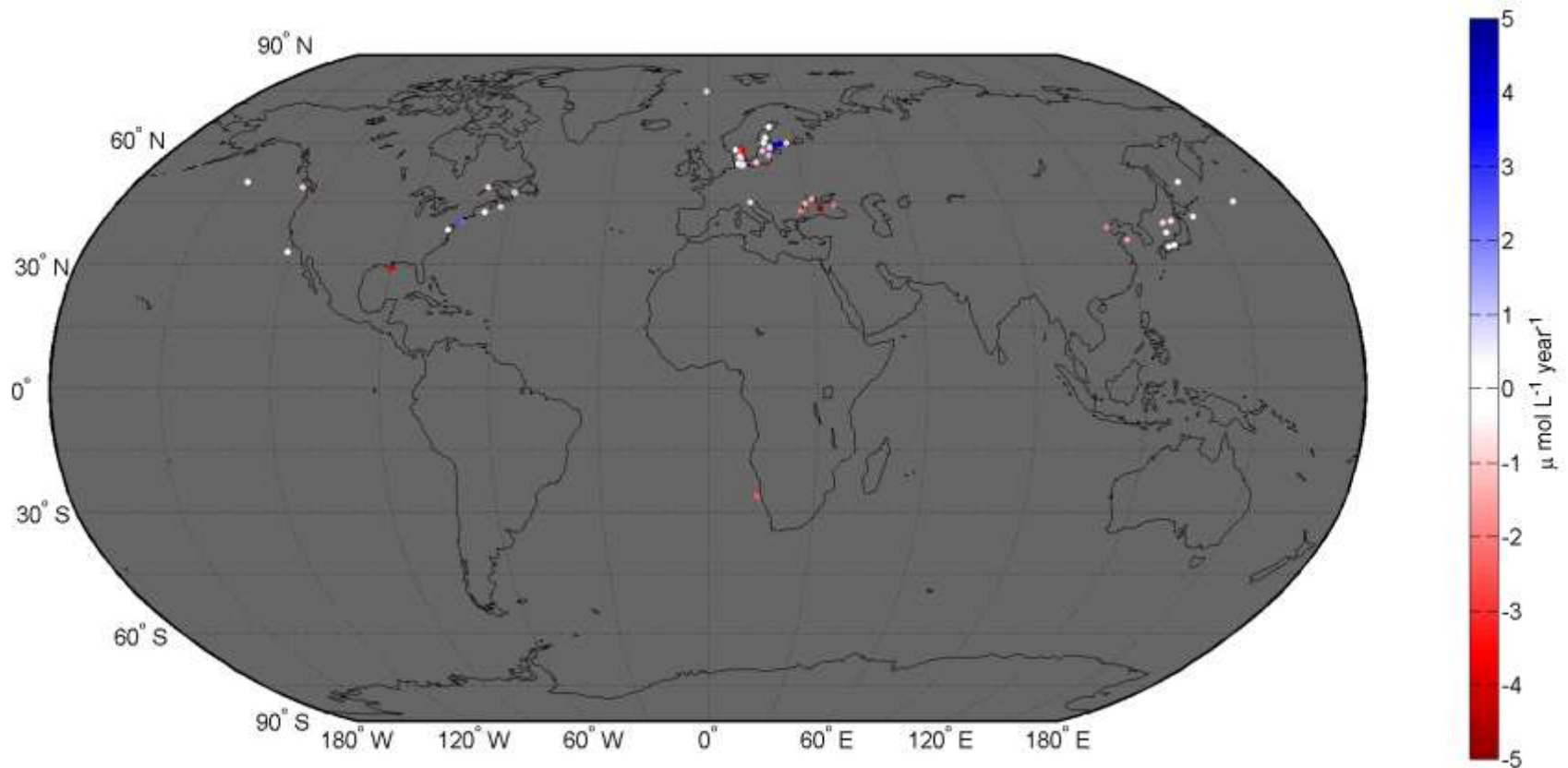
- Oxygen levels will decline in the intermediate and deep ocean
- Oxygen decline reflects changes due to solubility, ocean dynamics and ocean biology
- An expansion of oxygen minimum zones ($\approx 20\%$ increase in volume)
- We need better global observations to monitor oxygen changes

Richard Matear, CSIRO, Australia

Prediction: oxygen will decrease three times faster than one would expect from decreased solubility at higher water temperatures



Trends from published O₂ timeseries

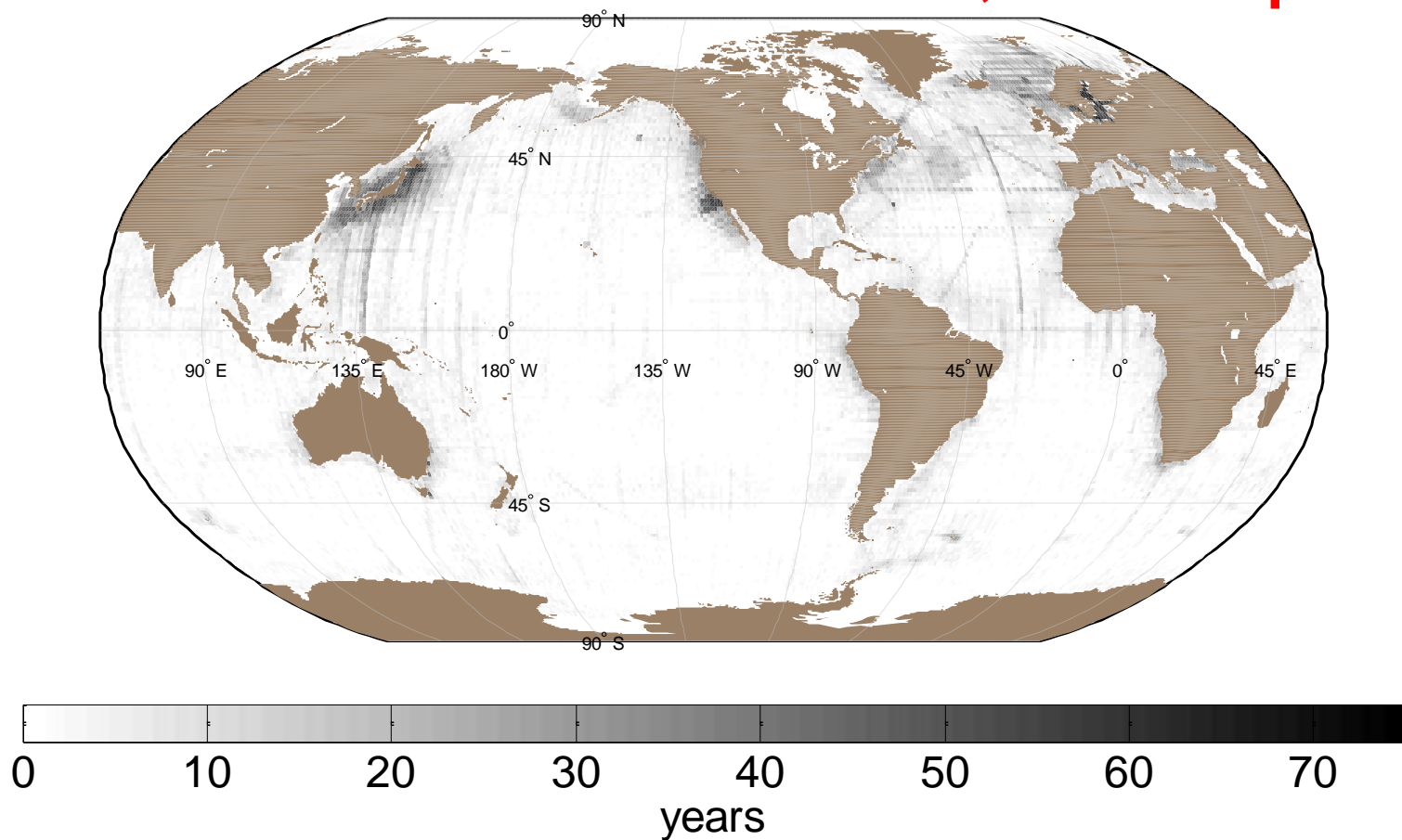


Oxygen trends published ($\mu\text{mol L}^{-1} \text{ yr}^{-1}$)

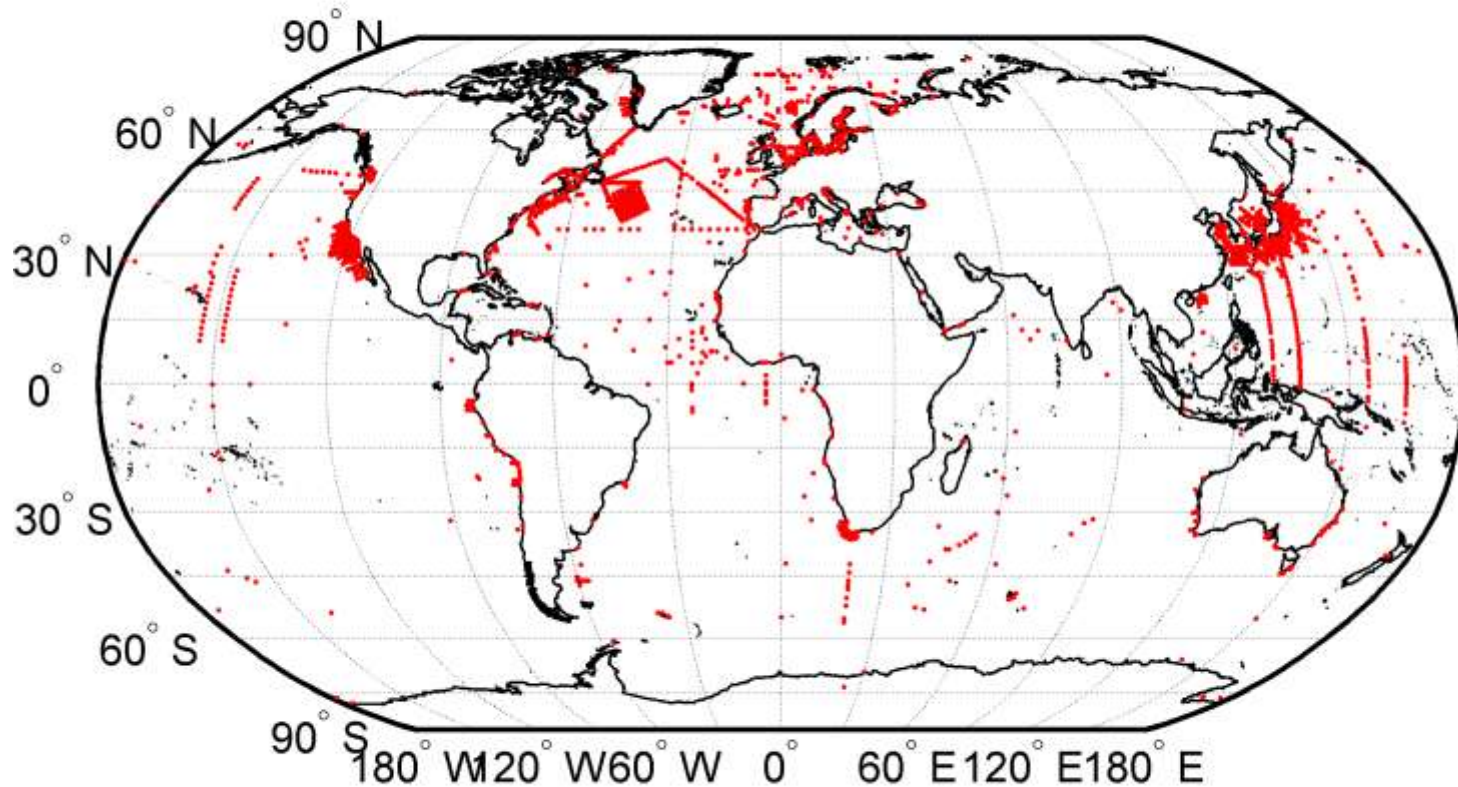
Distance from coast (km)	Median	Mean	Mean 95% C.I.	Std Dev	N	Perc. Neg.
0-30	-0.98	-0.46	[-1.43, 0.52]	3.09	41	70.7
30-100	-0.88	0.64	[-0.92, 2.21]	3.25	19	68.4
100+	-0.54	-0.74	[-1.18, -0.30]	1.38	40	77.5
0-100+	-0.62	-0.36	[-0.88, 0.16]	2.61	100	73.0



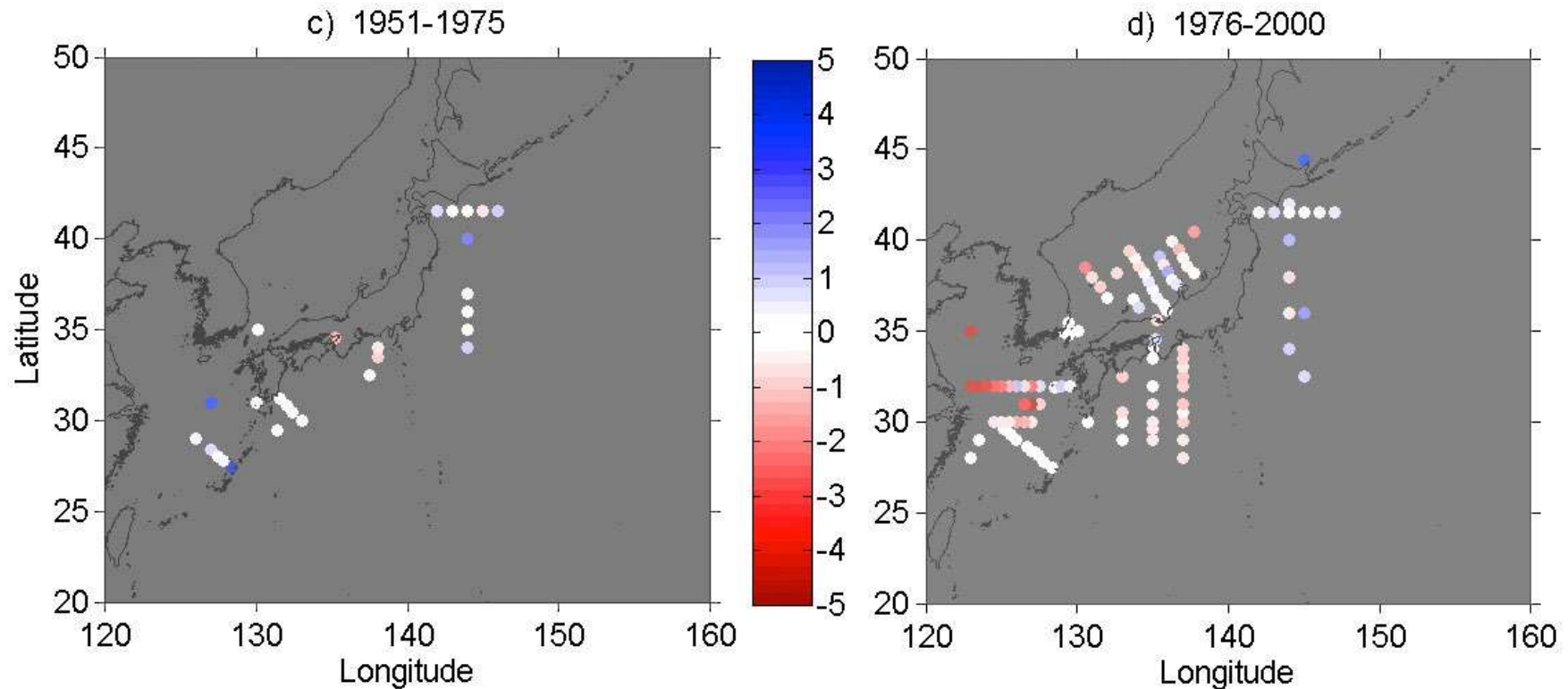
YEARS with O2 DATA, all depths



Fixed stations – oxygen trends



Analysis of ocean oxygen time-series from databases (NODC, ICES, ISDM): journals:

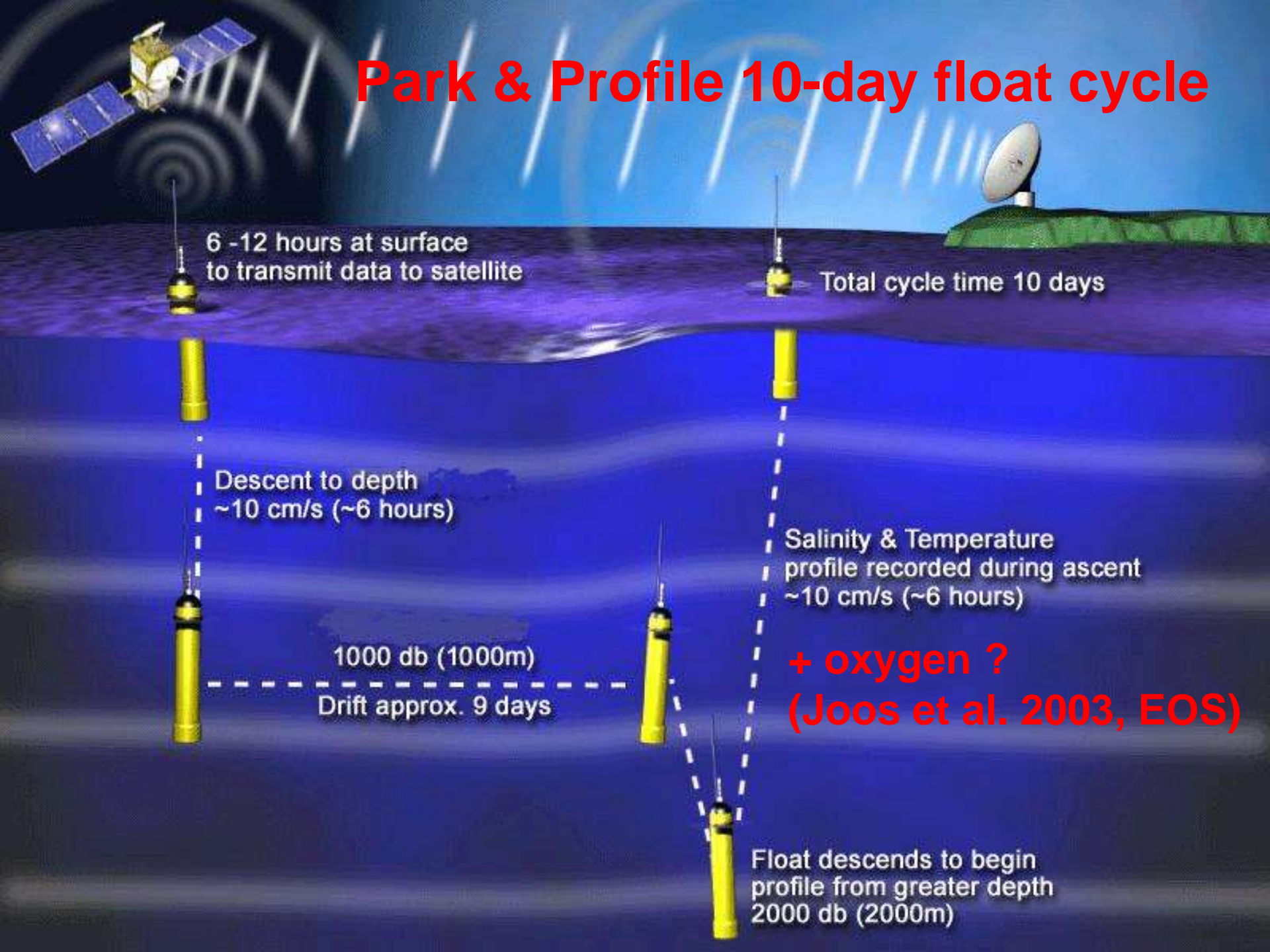


Oxygen trends in $\mu\text{mol L}^{-1} \text{yr}^{-1}$

Oxygen trends - Results

- The median published oxygen trends are more negative than the median trends computed from raw oxygen data, suggesting a publication bias in favor of strongly negative trends that is likely due to the adverse ecosystem implications of hypoxia.
- Based on the raw data analysis, oxygen trends in the 1976–2000 period are more negative than in the 1951–1975 period, indicating a recent worsening of hypoxia.
- Based on the raw data analysis for the 1976–2000 period, oxygen concentrations are declining faster in the coastal ocean ($-0.35 \pm 0.12 \mu\text{mol L}^{-1}\text{yr}^{-1}$) than in the open ocean ($-0.09 \pm 0.06 \mu\text{mol L}^{-1}\text{yr}^{-1}$) between 0 and 300m depth.

Park & Profile 10-day float cycle





Oxygen white paper

Presented at the 8th Argo Steering Team Meeting in Paris, France in March 2007.

Updated version will be presented next week at OceanObs'09

Prepared by

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Oxygen white paper – main points

- Introduction of non-standard sensors must not jeopardize the main Argo mission: T & S
- Careful energy budget associated with O₂ measurements must be performed, taking into account extra time required for telemetry.
- Impact on battery and float lifetime must be compensated by funding from the proponents.
- Similar business model proposed for addition of Chla, irradiance, pH, and other sensors



Argo oxygen sensors

- Seabird Electronics – SBE43F
- Aanderaa - Optode 3830 mostly & 4330

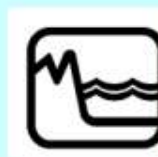
Two different O2 sensors on two different Argo float models



WEBB RESEARCH CORPORATION
E. Falmouth, Massachusetts, U.S.A.



Aanderaa Instruments
Bergen, Norway



Martec
Serpe-lesm
France

Ifremer



Provor CTS3_DO



Provor



Arvor

The smaller Arvor has enough space on its top cap to accommodate an optode sensor.

How to get oxygen on ARGO floats: Promising oxygen sensors

Electrochemical sensor (Seabird SBE 43/IDO)

Principle:

Clark-type polarographic membrane sensor

Measurement range:

120% of surface saturation

Initial accuracy:

2% of saturation

Response time:

6 s (e-folding time)

Optode sensor (Aanderaa 3830)

Principle:

Life time based dynamic fluorescence quenching

Measurement range:

0-120% of surface saturation
(0-500 μM)

Precision:

<1 μM (0.4%)

Initial accuracy:

8 μM or 5% (whichever is greater)

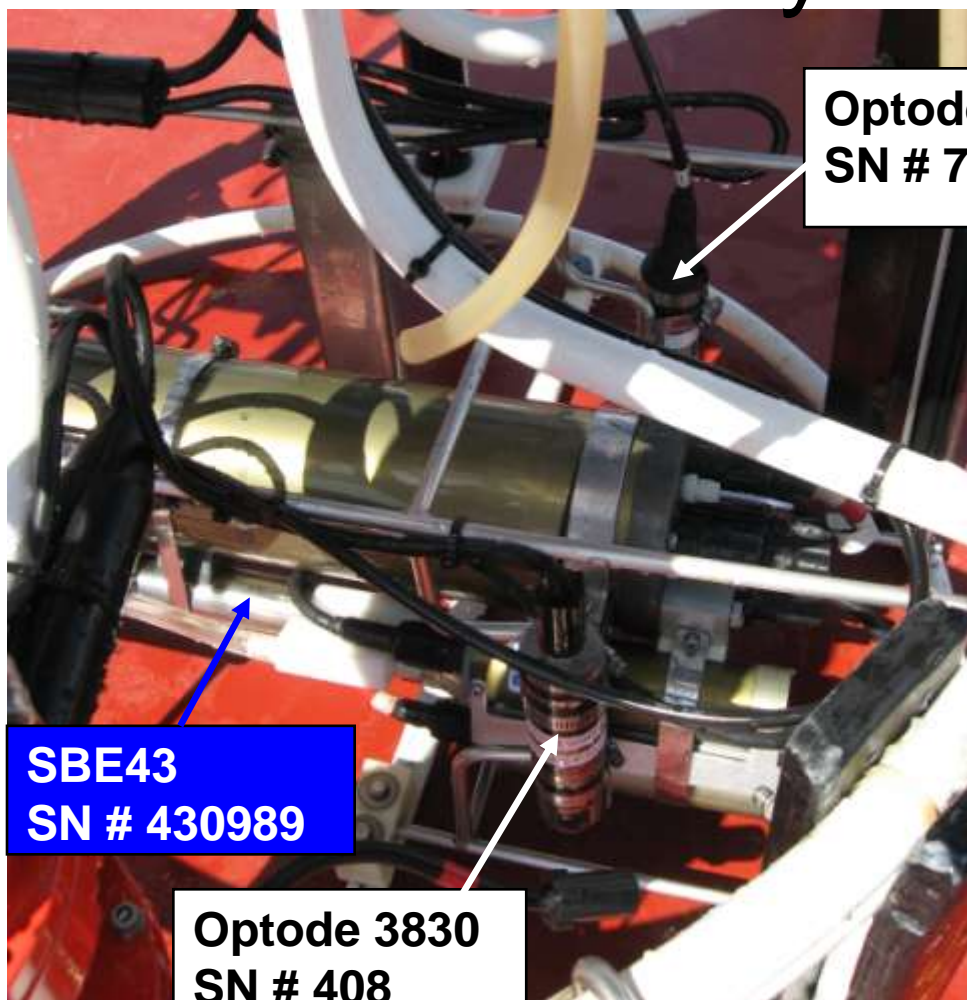
Response time:

25 s (63% e-folding time)
New 4330 model: 8 s





Oxygen sensors – May 5-9, 2008



**Optode 3830
SN # 798**

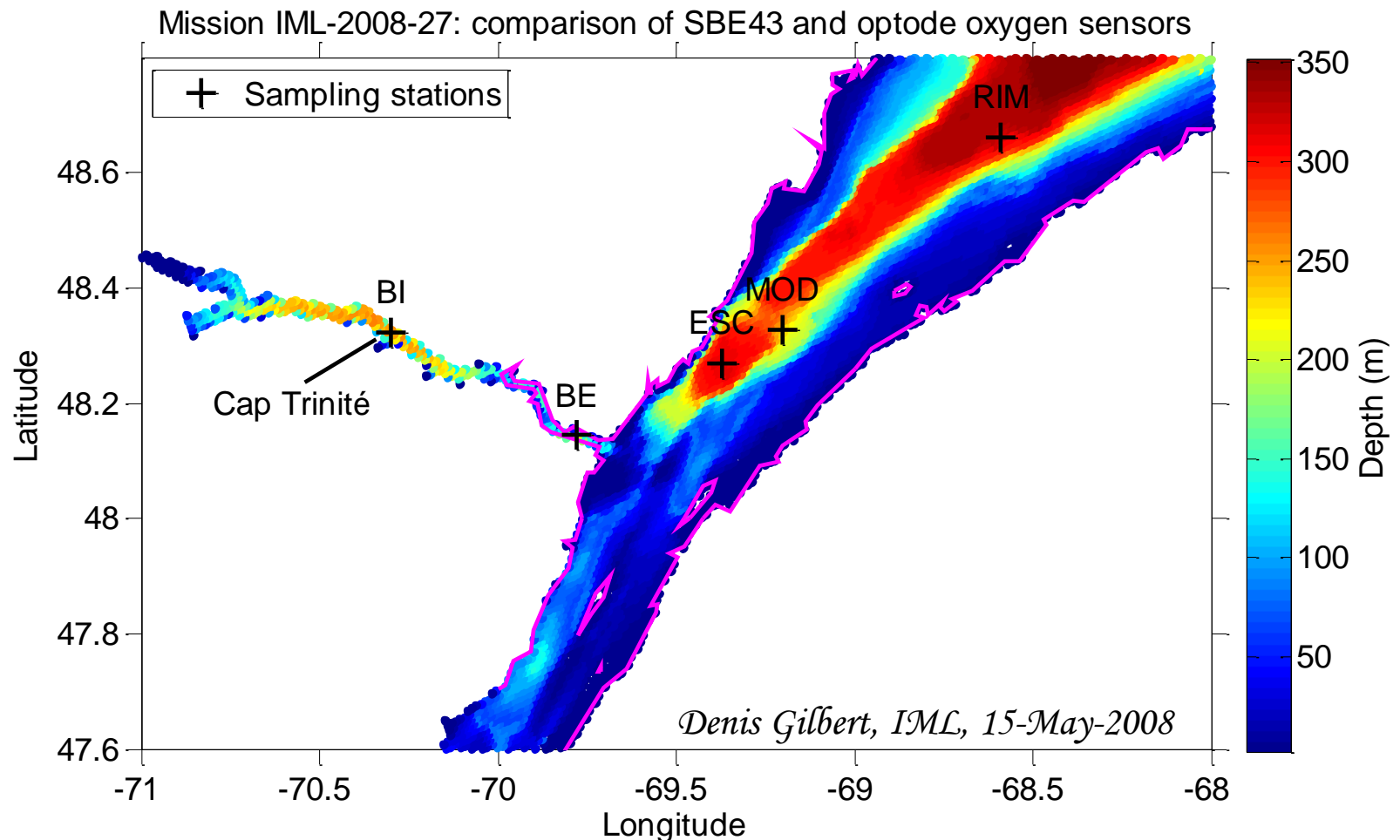
**SBE43
SN # 430989**

**Optode 3830
SN # 408**

Denis Gilbert, IML, 2009-09-17

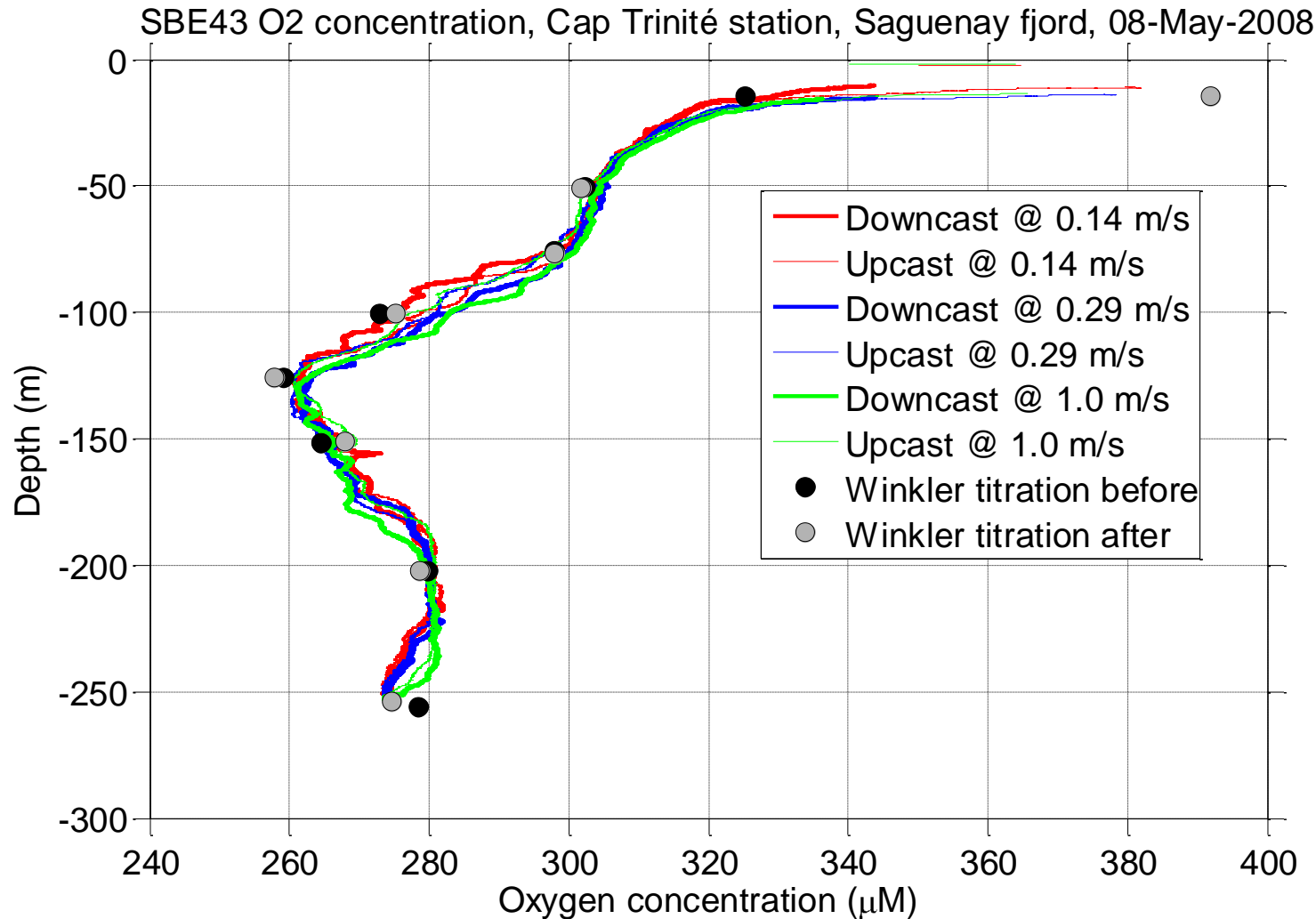


O2 sensor study in LSLE and Saguenay fjord





SBE43 oxygen, Saguenay fjord, 2008-05-08

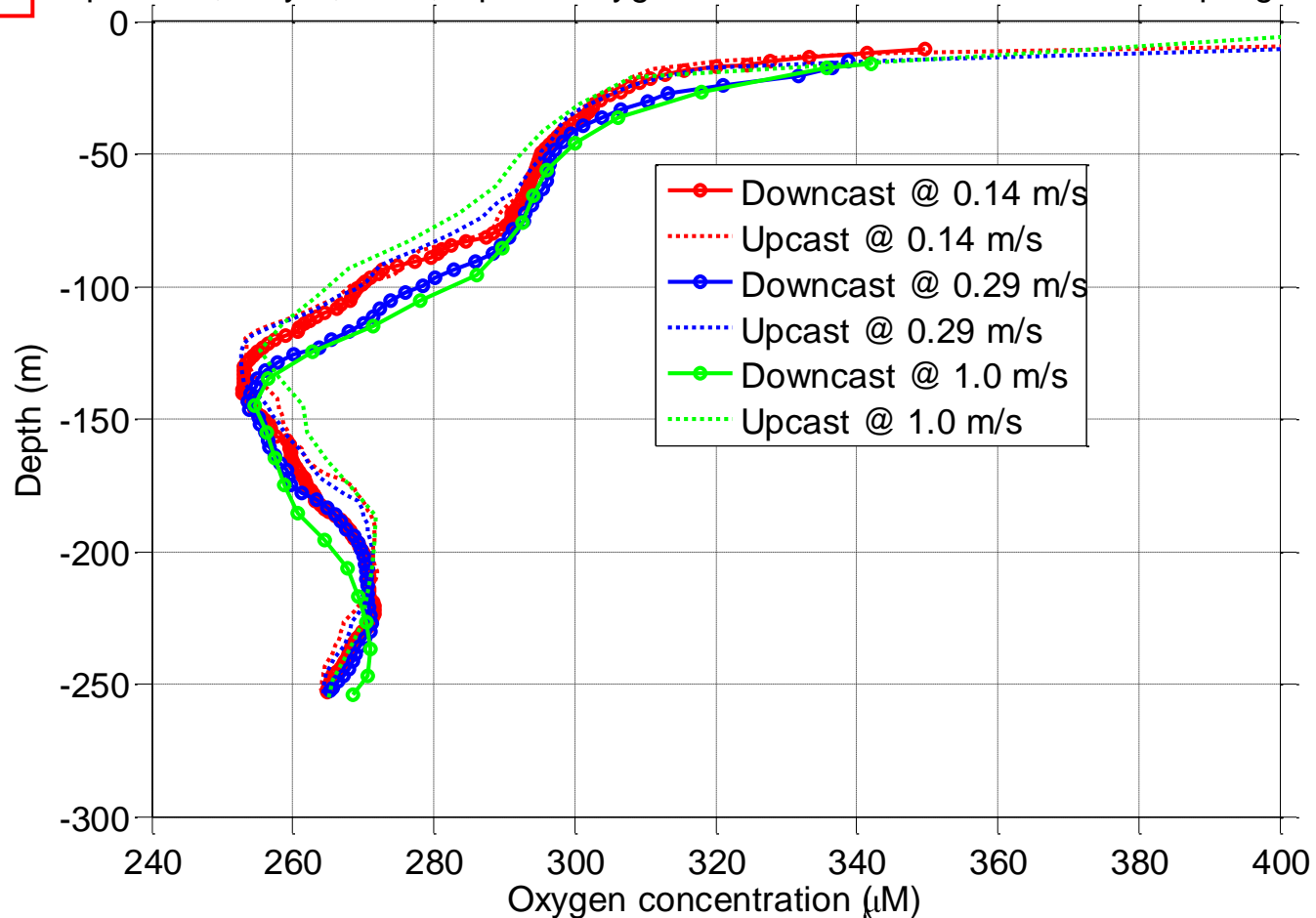




Optode oxygen, Saguenay fjord, 2008-05-08

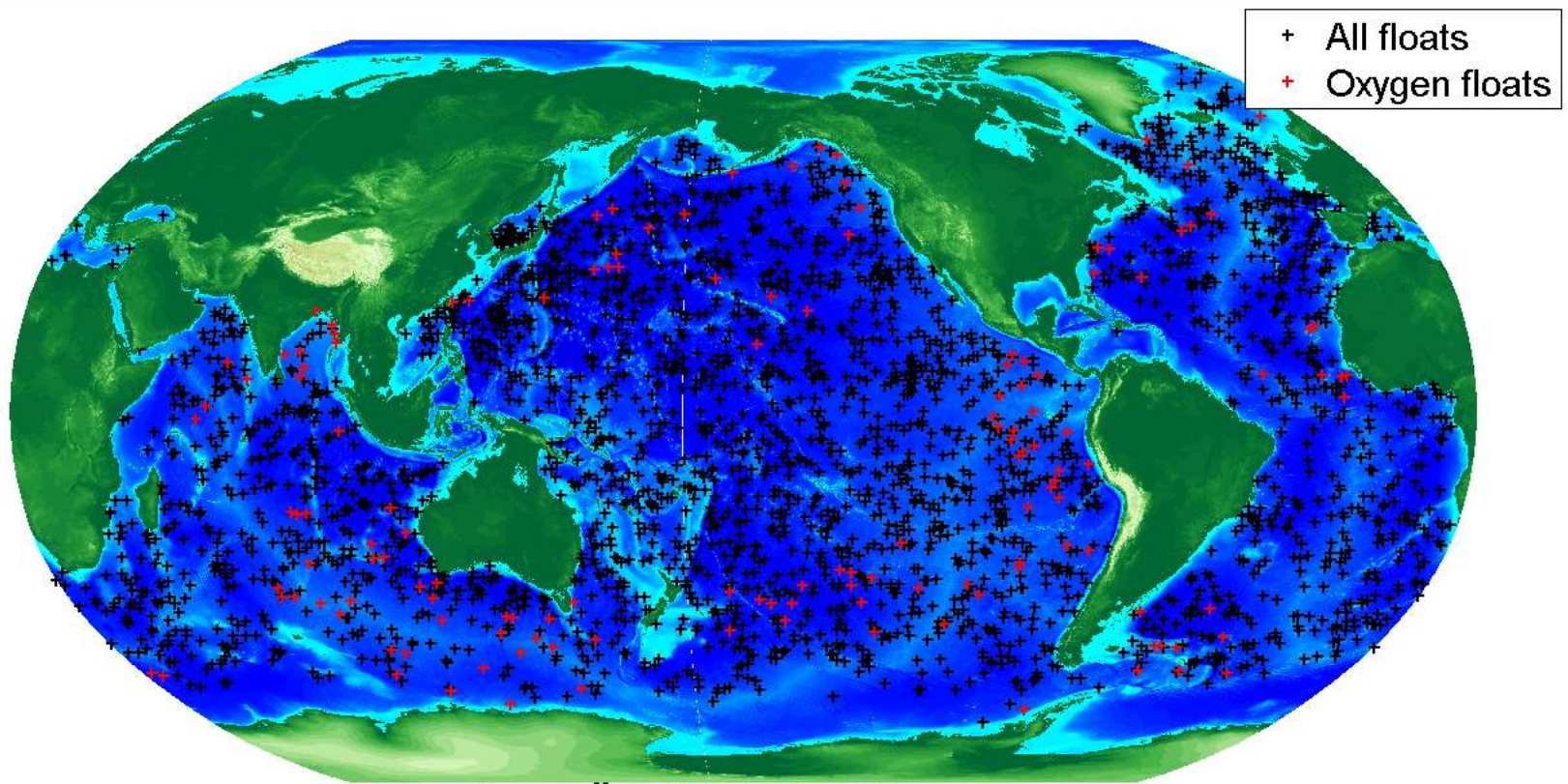
Serial # 408

Cap Trinité, May 8, 2008, Optode oxygen sensor on acoustic modem sampling at 0.1 Hz



Argo floats with oxygen data (DOXY)

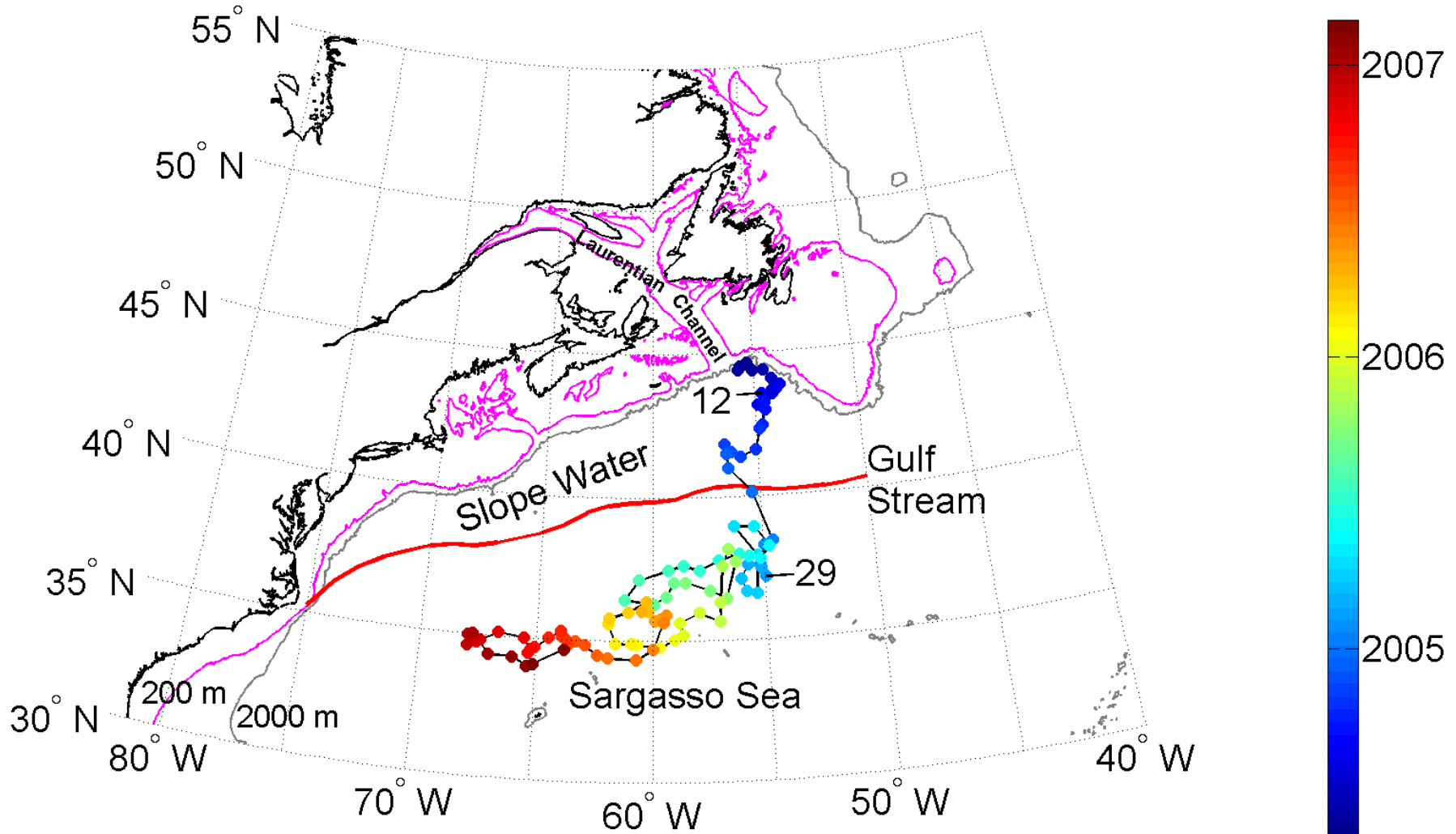
Argo float positions: 2009-08-01_to_2009-08-31



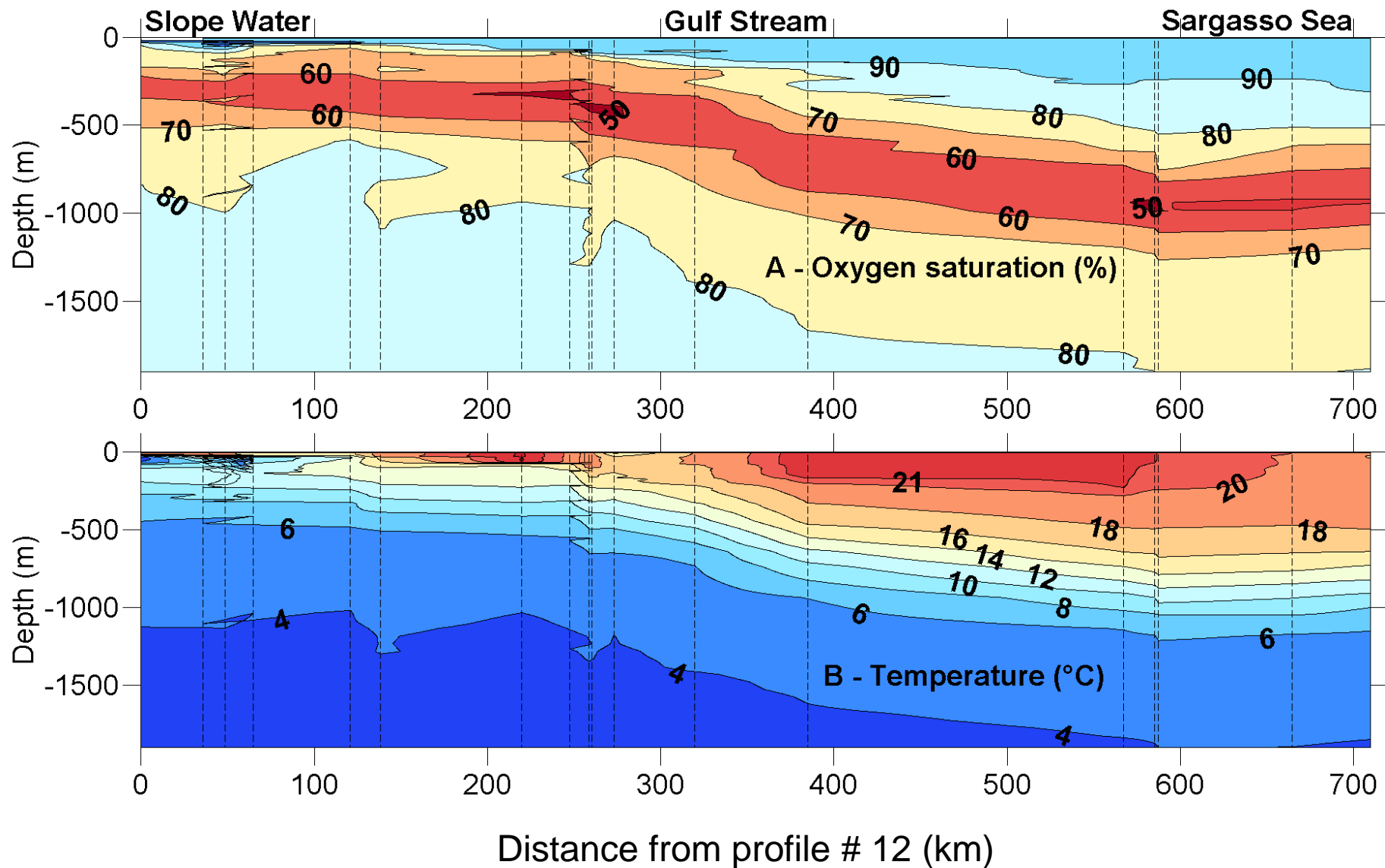
Denis Gilbert, IML, 01-Sep-2009

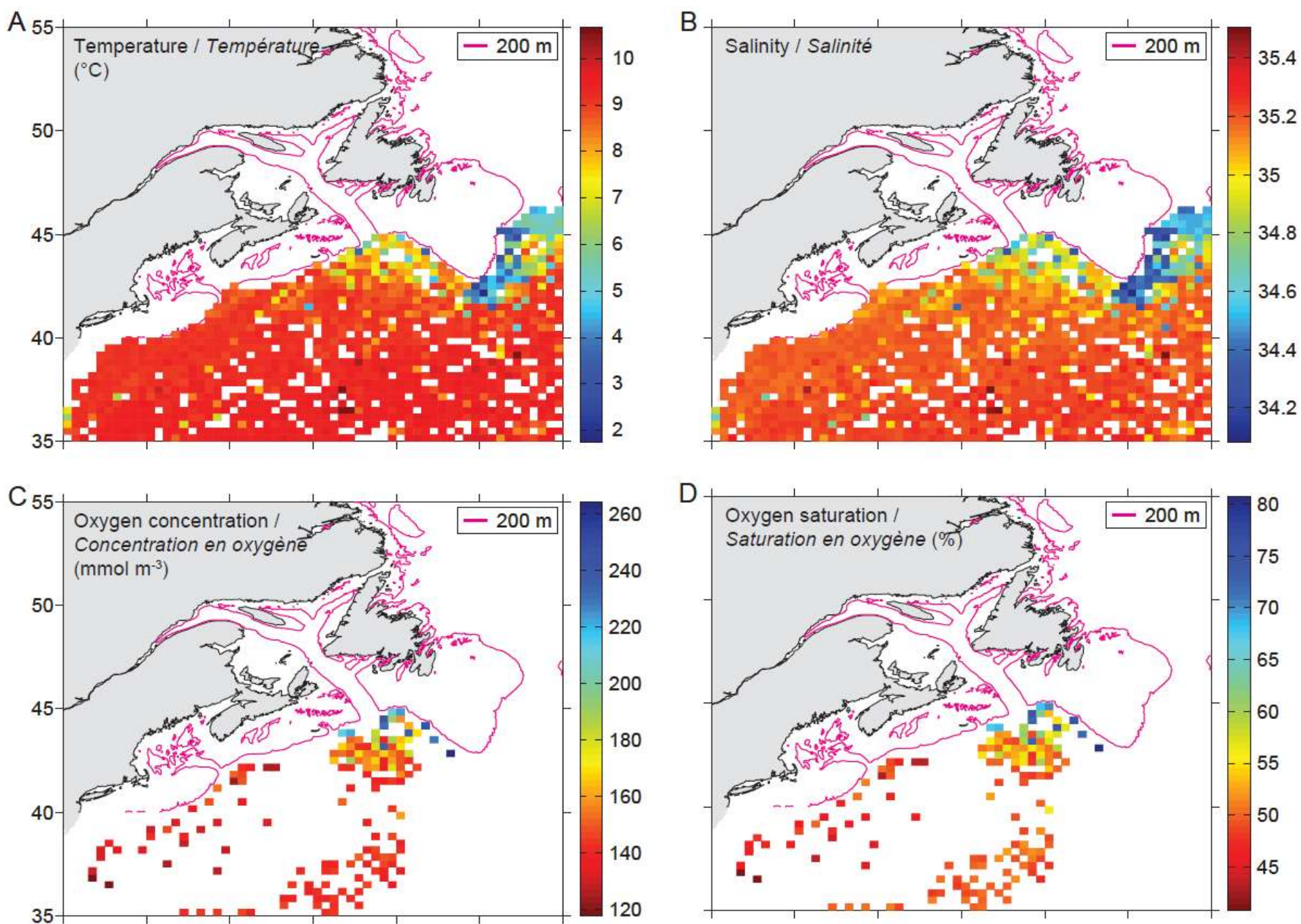
143 profilers, after removing WMOID duplicates

Float 4900497 crossing the Gulf Stream



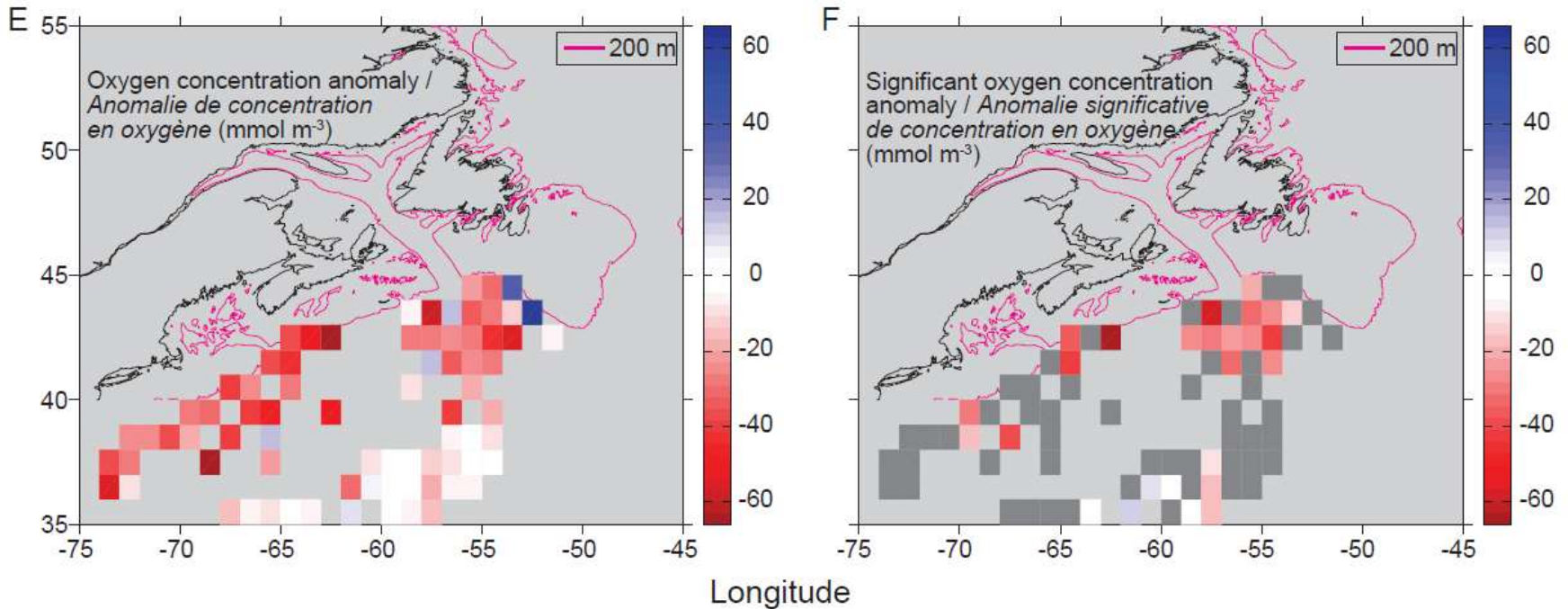
Float 4900497 crossing the Gulf Stream







Oxygen anomaly



Gilbert et Nault, AZMP Bulletin PMZA, 2008



Data management issues – Oxygen

Argo real-time quality control

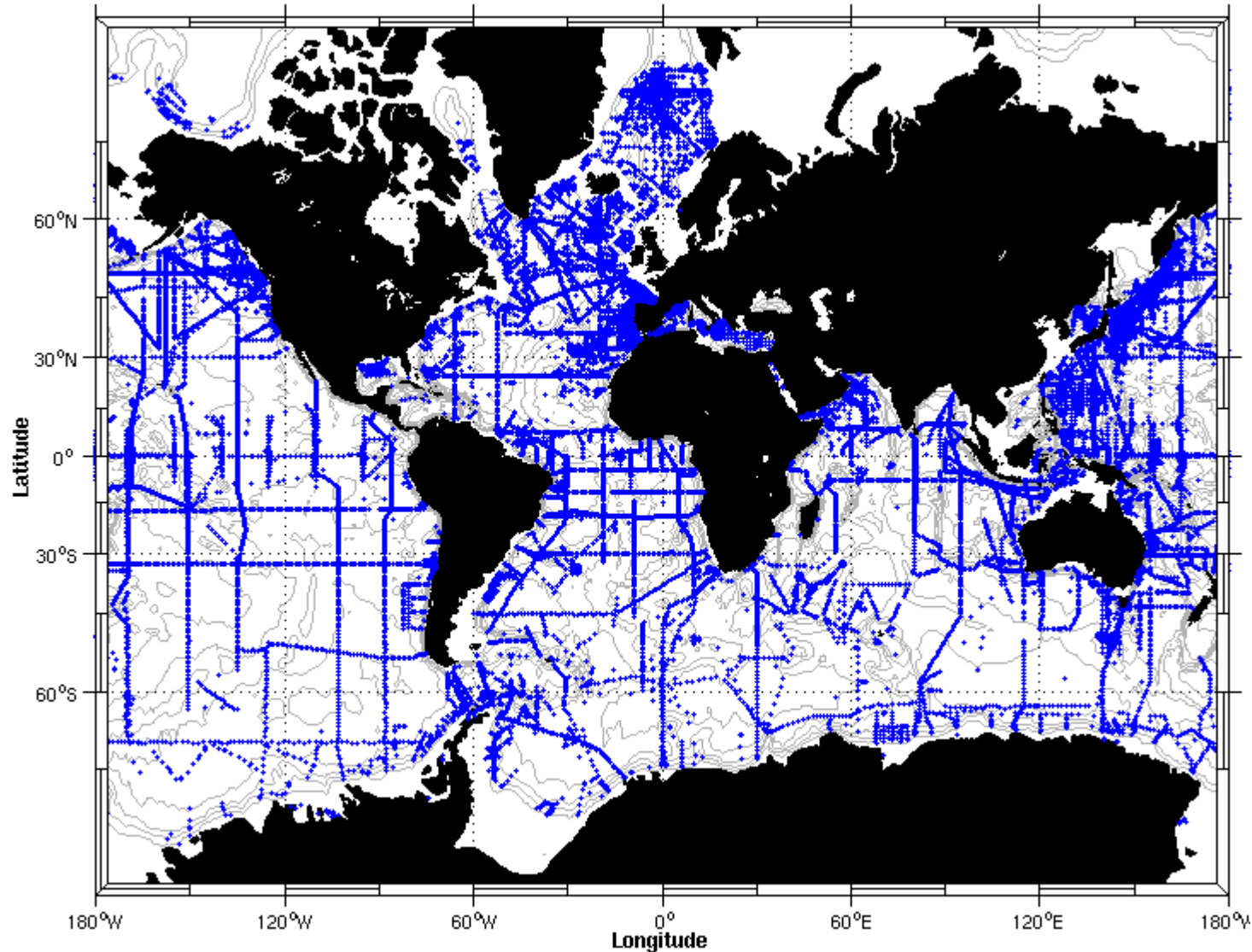
- Profiles : 17 automatic QC tests performed before gdac and gts distribution
 - 1 Platform Identification
 - 2 Impossible Date
 - 3 Impossible Location
 - 4 Position on Land
 - 5 Impossible Speed
 - 6 Global Range
 - 7 Regional Range
 - 8 Pressure Increasing
 - 9 Spike
 - 10 Top and Bottom Spike : removed
 - 11 Gradient
 - 12 Digit Rollover
 - 13 Stuck Value
 - 14 Density Inversion
 - 15 Grey List
 - 16 Gross salinity or temperature or oxygen sensor drift
 - 17 Visual QC (*not mandatory*)
 - 18 Frozen profile
 - 19 Deepest pressure

■ QC flag scale

0 No QC was performed

- 1 Good data
- 2 Probably good data
- 3 Bad data that are potentially correctable
- 4 Bad data
- 5 Value changed
- 6 Not used
- 7 Not used
- 8 Interpolated value
- 9 Missing value

Reference data base for delayed mode QC :
A need for more recent **Winkler titrations**



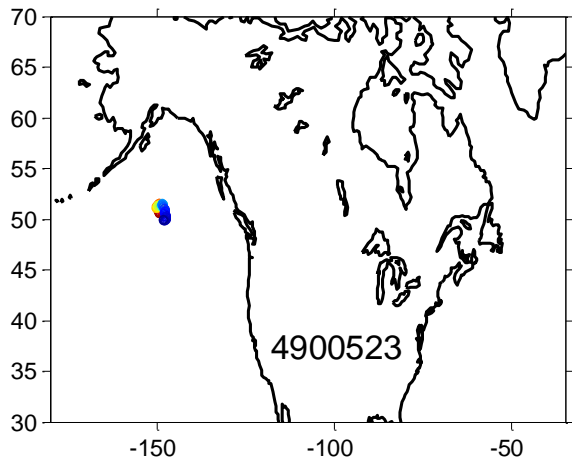
Coordinated by ????????

Collaboration with **Clivar/CCHDO** ? NODC/USA and PIs

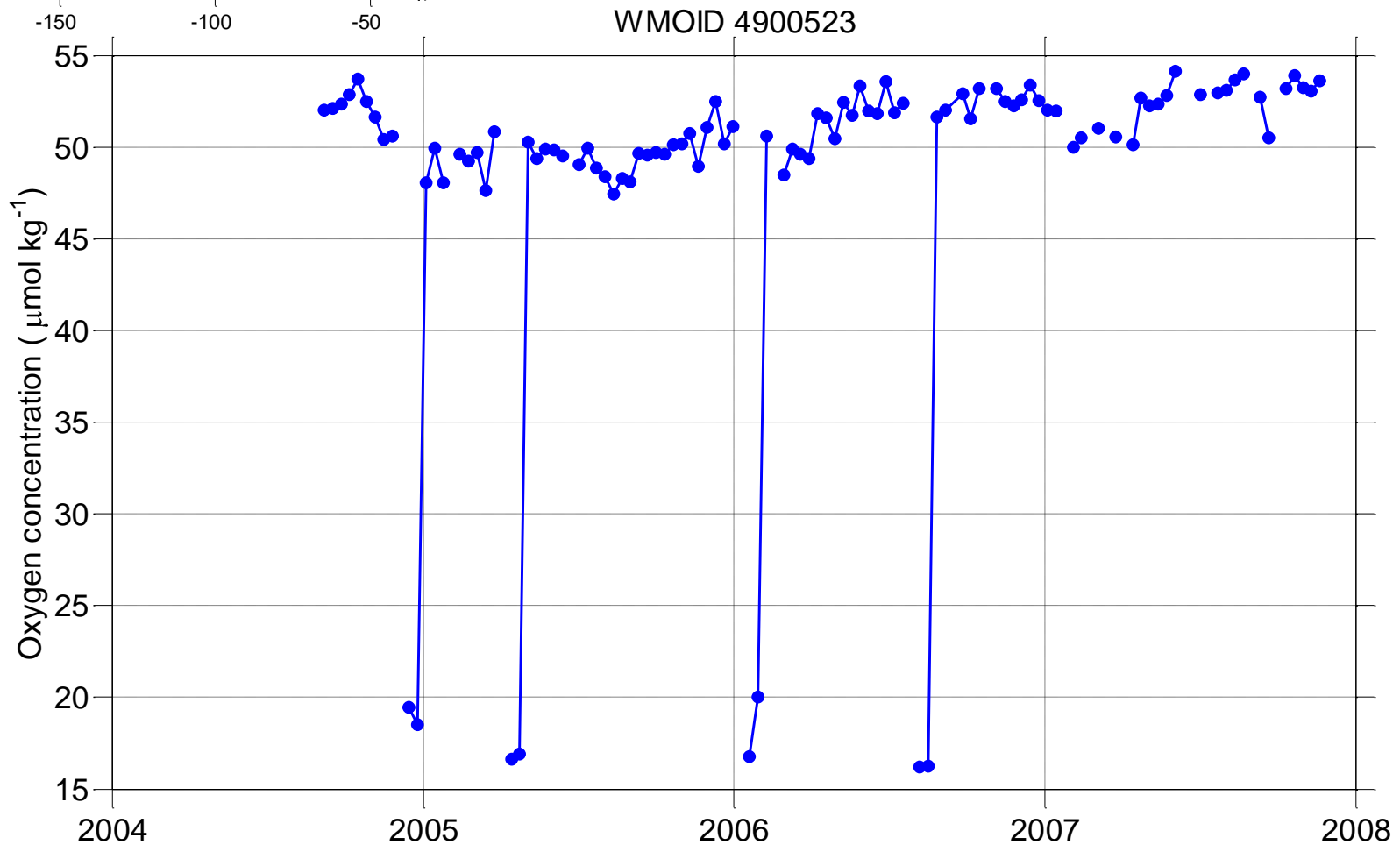


Estimates of long-term drift

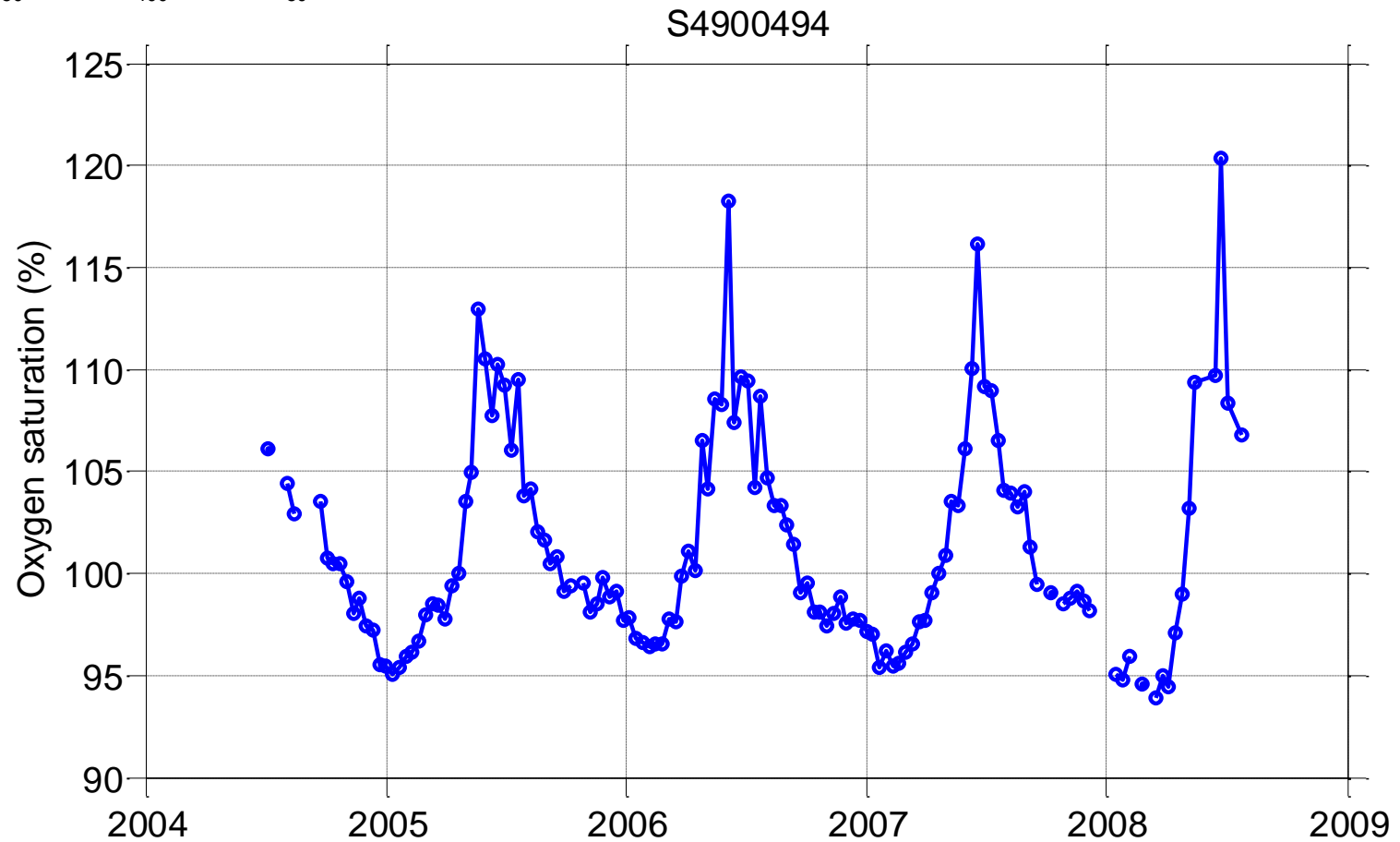
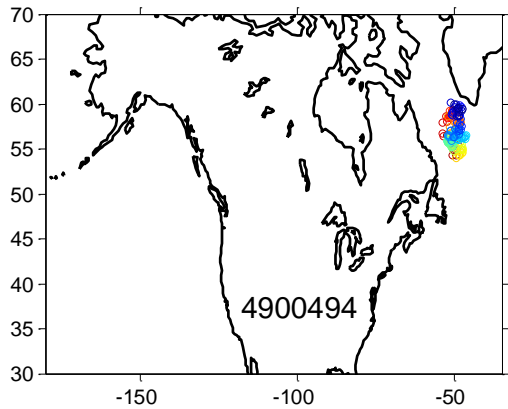




Oxygen at 1900 m, float 4900523



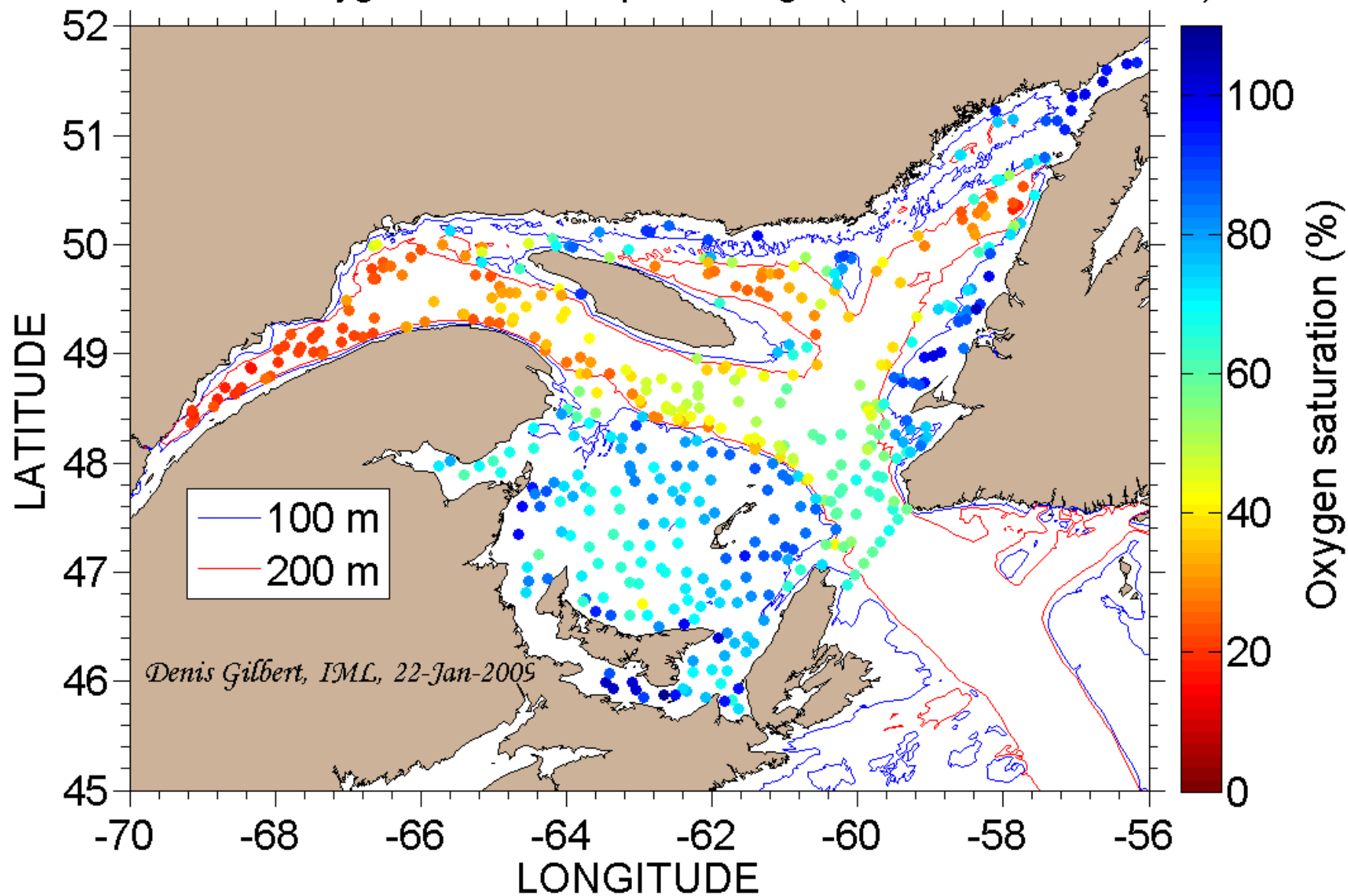
Seasonal cycle at 4 m depth; WMOID 4900494



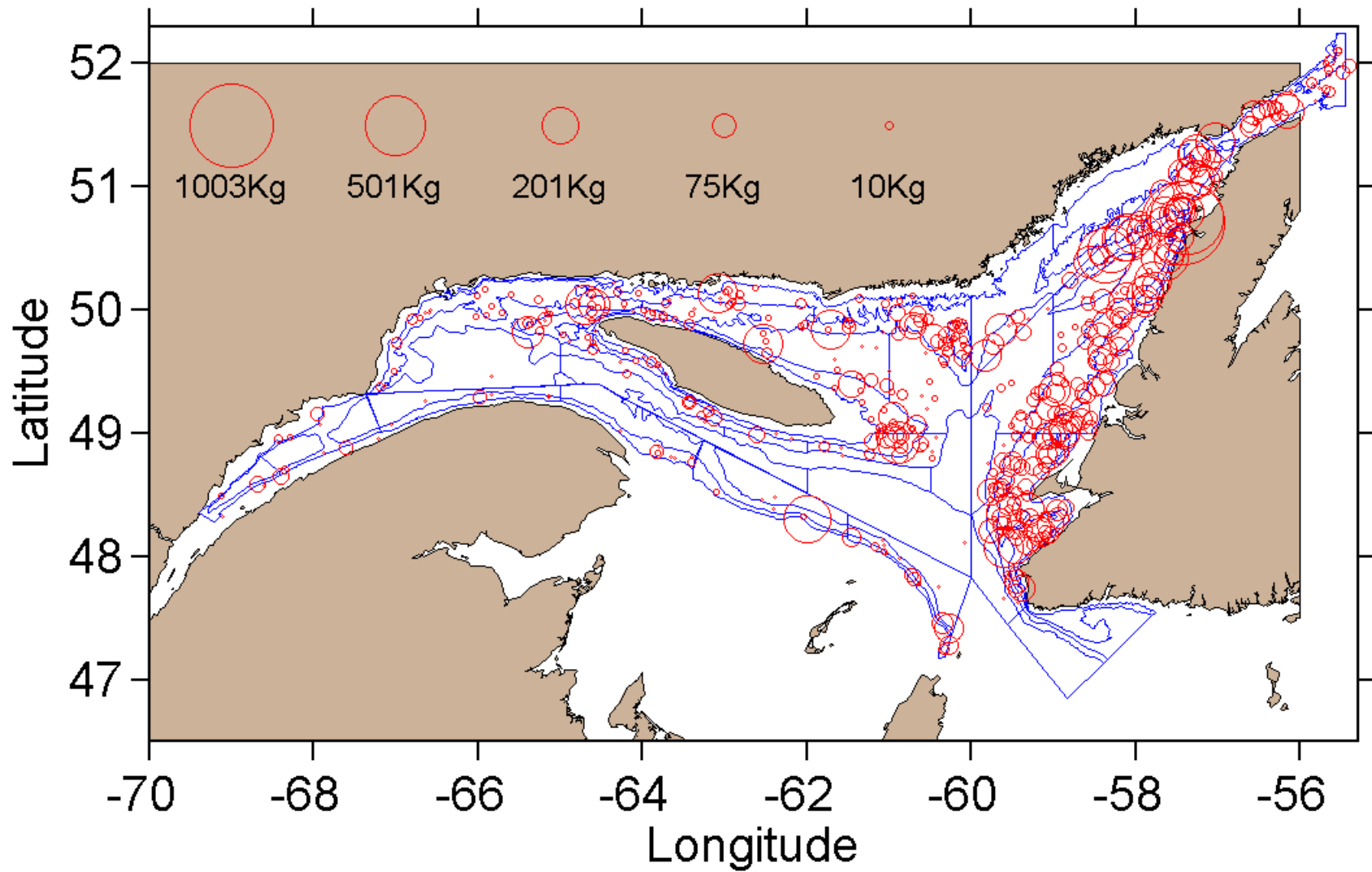
CTD sled on
fishing trawl



Near-bottom oxygen saturation percentage (summer 2004-2005)



Atlantic Cod, Total catch: 20604Kg



The end