

Title: Data from the EGIM deployment at Station M, Norwegian Sea, 27 September 2024- 5 Mar 2025

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Summary

As part of WP5 in the European Infratech project GEORGE, a field test of the EGIM (EMSO Generic Instrument Module) was conducted next to the Station M oceanographic mooring in the Norwegian Sea (65° 59.2 N, 001° 58.0 E, 2000 m depth). The goal was to demonstrate the technological readiness level (TRL) of the system equipped with a CONTROS HydroC CO₂ sensor from 4H-Jena that measures the partial pressure of CO₂ (pCO₂), in deep ocean environment for a duration of several months.

The EGIM was developed in the EU project EMSO (<https://emso.eu/2022/05/06/the-emso-generic-instrument-module-egim-standardized-and-interoperable-instrumentation-for-ocean-observation/>). EGIM payload was slightly modified to integrate the power-hungry 4H-Jena pCO₂ sensor. SBE54 precise pressure sensor was removed. EGIM used in this deployment was equipped with an RDI Workhorse 300 kHz acoustic Doppler current profiler (ADCP), a Wetlabs NTURTD, Aanderaa optode 4831, a SeaBird SBE37 and a 4H-Jena CONTROS HydroC CO₂ sensor. All EGIM components have been calibrated and pressure tested.

The inorganic carbon data regularly collected at Station M facilitated the possibility of validating the carbon data acquired from the EGIM.

Furthermore, the R/V G. O. Sars used for the deployment is one of the ICOS (<https://www.icos-cp.eu/>) Ship Of Opportunity lines, and is equipped with an instrument (General Oceanics system with direct air-sea equilibration, infra-red CO₂ detection, and three non-zero reference gases) for semi-continuous and very precise underway measurements of pCO₂ in the surface ocean and the atmosphere. This offered the opportunity to also test the EGIM functionality in the surface waters by comparing the EGIM measurements to those acquired from the pCO₂ instrument onboard the G.O. Sars

The EGIM was tested thoroughly at IFREMER's laboratory during the spring 2024 and furthermore in Bergen on arrival in August 2024. Then the equipment was sent to Tromsø, where the cruise started. The EGIM was deployed on 27 September 2024. The timestamps of EGIM data in all files are UTC + 1 h, and the user must correct this accordingly.

Prior to the deployment, the EGIM was lowered near surface from the side of the vessel and collected data at approximately 18 m depth for 3.5 hours in period 27 Sep 2024, 12:30 to 16:00 UTC, to compare the EGIM pCO₂ data with the high-precision measurements from the ship's underway pCO₂ system. Before the deployment of the mooring and the EGIM, a CTD profile was

taken together with water samples for carbon system analysis at 12 depth levels between surface and sea floor (2027 m).

Then the EGIM was deployed close to the sea floor. According to the pressure record from the EGIM's SBE37, the mooring reaches the bottom at 16:35 UTC, and there's some adjustment until about 17:00 UTC. The mooring diagram (Figure 1), and the sampling configuration of the EGIM sensors (Table 1) are given below.

The recovery planned in January 2025 was postponed due to bad weather conditions, and the EGIM was successfully recovered on 5 March 2025 from R/V *G.O. Sars*. According to the EGIM SBE37 pressure record, the last good data point before mooring was released was on 5 Mar 2025 12:30 UTC.

The temperature sensor on the oxygen sensor (AADI) saturates at 0°C, not measuring negative temperatures.

The CO₂ was logged at 2 s intervals for 4 hours every 2 days. Unintentionally, the CO₂ logging frequency of the EGIM was twice that of the CONTROS HydroC sensor. This made the data processing slightly more complicated as the EGIM did not store the full suite of carbon variables produced from the CONTROS HydroC. More importantly, the internal pressure of the CONTROS HydroC sensor was too high throughout the deployment period of the EGIM, and in addition, the sensor stopped working well on 24 November 2024. After the EGIM recovery, the CONTROS HydroC sensor was sent back to 4H-Jena, which discovered that the sensor was flooded. The reason for the flooding has not been found, but the flooding was the reason why the sensor stopped working well in November 2024.

During the data processing, we have used the xCO₂ values acquired by the CONTROS HydroC sensor in further calculations. We have compared the xCO₂ sensor data with those calculated from discrete carbon samples collected at the site. Discrete samples were only collected on 27 September, limiting the basis for comparison to only one point. At approximately 2000 m depth, the CONTROS HydroC sensor showed an xCO₂ value of 407.8 ppm, while the calculated xCO₂ value from discrete water samples collected from 2000 m depth was 357.5 ppm. Thus, the CONTROS HydroC xCO₂ data was approximately 50 ppm too high at 2000 m depth. Consequently, 50 ppm should be subtracted from the CONTROS HydroC xCO₂ values prior to further use.

An additional comparison was made between the xCO₂ data acquired by the CONTROS HydroC sensor while resting at 18 m depth, the xCO₂ data acquired by the pCO₂ system onboard R/V *G. O. Sars*, and the xCO₂ calculated from discrete samples collected from 10 m depth. These xCO₂ values were 311.7 ppm, 364.3 ppm, and 365.2 ppm, respectively. This comparison showed that the pCO₂ system onboard R/V *G. O. Sars* measured xCO₂ values relatively similar to the xCO₂ value calculated from the discrete samples collected at 10 m depth, while the xCO₂ values acquired by the CONTROS HydroC sensor were approximately 50 ppm too low. However, it should be mentioned that the CONTROS HydroC sensor was calibrated for a temperature range up to 4°C, similar to temperatures of the deep water at Station M, while at 18 m depth, the temperature was about 10.3°C, i.e., outside the calibrated temperature range for the CONTROS HydroC sensor. Thus, we could not trust the results from the comparison experiment performed in the surface water.

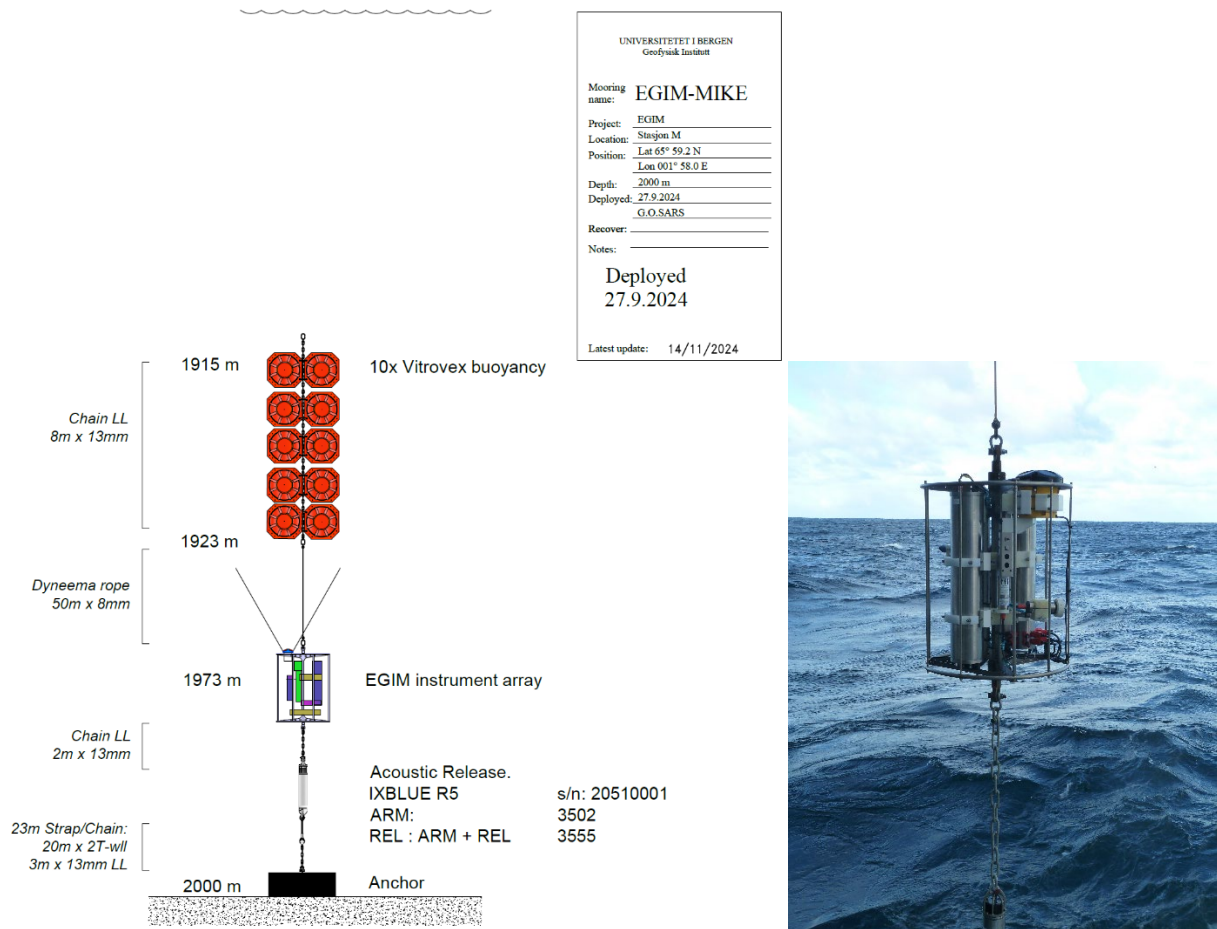


Figure 1. (left) Mooring diagram. (right) EGIM frame being lowered during deployment (Photo: Tor de Lange, University of Bergen)

Table 1. Sensors and configuration

Sensor			COSTOF S/N RTSYS 1708001			
Manufacturer	Model	S/N	Board nb	COSTOF port nb	Sampling period	Comments
4H-Jena	CONTROS HydroC CO2	CO2T 0623 004	8	1	2 days	7200 measurements at 2-s intervals
Anderaa	4831	679	8	2	15 min	
RDI	Workhorse 300 kHz	24492	9	1	15 min	- nbcells = 80 - depthcellsize=200 cm - pingsperensemble=20 - blankaftertransmit=176 - ambiguityvelocity=175 - timebetweenpings=10
Wetlabs	ECONTU	719	9	2	15 min	
Sea-Bird Scientific	SBE37	37-15877	9	3	2 min	

Overview of data files

File: RDI_WORKHORSE_ADCP_pos3.csv

Current profile data from the upward looking ADCP installed on EGIM. Center of the first vertical bin (measurement cell) is at 2.8 m. Cell thickness is 2 m. In total there are 80 cells.

Column #	Variable
1	Date/Time [UTC + 1 hour]
2, 3, 4, 5, 6	Heading [deg], Pitch [deg], Roll [deg]
5, 6	Temperature [degC], Sound speed [m/s]
7 to 86	Eastward velocity [mm/s]
87 to 166	Northward velocity [mm/s]
167 to 246	Upward velocity [mm/s]
247 to 326	Error velocity [mm/s]
327 to 406	Echo amplitude, beam 1 [dB]
407 to 486	Echo amplitude, beam 2 [dB]
487 to 566	Echo amplitude, beam 3 [dB]
567 to 646	Echo amplitude, beam 4 [dB]

File: HHHHJENA_CO2_pos0.csv

Time series data from the 4H-Jena sensor installed on EGIM, as downloaded from EGIM, which logged only a selection of the variables. In addition, two text files are provided, as extracted from the 4H-Jena sensor (raw data, CO2T-0623-004.txt) and postprocessed data (CO2T-0623-004_pp.txt), both provided by 4H-Jena during service and inspection.

Column	Variable	Description	Unit
1	date-time	[UTC + 1 hour]	d/m/Y H:M:S
2	p_NDIR	Pressure in the gas stream behind the NDIR (non-dispersive infrared) unit	mbarx100
3	p_in	Pressure in the gas stream behind the semi-permeable membrane	mbarx100
4	Runtime	Seconds of operation since last calibration	s
5	SIG_RAW	Raw detector signal	digit
6	SIG_REF	Raw reference signal	digit
7	T_SENSOR	Temperature of the NDIR unit	degCx1000
8	CONC_ESTIMATE	Fraction of CO2 (estimate) in headspace; valid until 1000 ppm	ppm
9	PCO2	Partial pressure of CO2, corrected for p and T	uatmx100
10	xCO2	Fraction of CO2 in headspace at 100% relative humidity (rH), corrected for p and T	ppmx100
11	T_GAS	Temperature of the gas stream behind the NDIR unit	degCx1000
12	RH_GAS	Relative humidity (rH) of the gas stream behind the NDIR unit	%RHx1000

Additional file: CO2T-0623-004.txt

Time series of raw data extracted from the 4H-Jena sensor during service and inspection.

Column	Variable	Description	Unit
1	Date	Date	yyyy-mm-dd
2	Time	Time [UTC + 1 hour]	Hh:mm:ss
3	Weekday	Weekday	
4	P_pump	External pump power	W
5	p_NDIR	Pressure in the gas stream behind the NDIR (non-dispersive infrared) unit	mbar
6	p_in	Pressure in the gas stream behind the semi-permeable membrane	mbar
7	I_total	CONTROS HydroC current	mA
8	U_supply	Supply voltage	V
9	Zero	Status zeroing (0=off; 1=zeroing running)	
10	Flush	Status flush (0=off; 1=flush running)	
11	external_pump	Status of the external pump ("0" = off; "1" = external pump running)	
12	Runtime	Seconds of operation since last calibration	s
13	Signal_raw	Raw detector signal	digits
14	Signal_ref	Raw reference signal	digits
15	T_sensor	Temperature of the NDIR unit	degC
16	Signal_proc	Signal corrected for T-influences and drift	digits
17	Conc_estimate	Fraction of CO ₂ (estimate) in headspace; valid until 1000 ppm	ppm
18	pCO ₂ _corr	Partial pressure of CO ₂ , corrected for p and T	uatm
19	xCO ₂ _corr	Fraction of CO ₂ in headspace at 100% relative humidity (rH), corrected for p and T	ppm
20	T_control	Probe temperature for the temperature control	degC
21	T_gas	Temperature of the gas stream behind the NDIR unit	degC
22	%rH_gas	Relative humidity (rH) of the gas stream behind the NDIR unit	%

Additional file CO2T-0623-004_pp.txt:

Time series of postprocessed data from the 4H-Jena sensor during service and inspection.

Column	Variable	Description	Unit
1	Date_Time	Date and time	yyyy-mm-dd
2	Date	Date	yyyy-mm-dd
3	Time	Time [UTC + 1 hour]	Hh:mm:ss
4	Weekday	Weekday	
5	P_pump	External pump power	W
6	p_NDIR	Pressure in the gas stream behind the NDIR (non-dispersive infrared) unit	mbar
7	p_in	Pressure in the gas stream behind the semi-permeable membrane	mbar
8	I_total	CONTROS HydroC current	mA
9	U_supply	Supply voltage	V
10	Zero	Status zeroing (0=off; 1=zeroing running)	
11	Flush	Status flush (0=off; 1=flush running)	
12	external_pump	Status of the external pump ("0" = off; "1" = external pump running)	
13	Runtime	Seconds of operation since last calibration	s
14	Signal_raw	Raw detector signal	digits
15	Signal_ref	Raw reference signal	digits
16	T_sensor	Temperature of the NDIR unit	degC
17	Signal_proc	Signal corrected for T-influences and drift	digits
18	Conc_estimate	Fraction of CO ₂ (estimate) in headspace; valid until 1000 ppm	ppm
19	pCO ₂ _corr	Partial pressure of CO ₂ , corrected for p and T	uatm
20	xCO ₂ _corr	Fraction of CO ₂ in headspace at 100% relative humidity (rH), corrected for p and T	ppm
21	T_control	Probe temperature for the temperature control	degC
22	T_gas	Temperature of the gas stream behind the NDIR unit	degC
23	%rH_gas	Relative humidity of the gas stream behind the NDIR unit	%
24	S_2beam	Used for data processing	
25	slope	Used for data processing	
26	y_intercept	Used for data processing	
27	S_2beamZt_	Used for data processing	
28	S_DC	Used for data processing	
29	S_proc	Used for data processing	
30	xCO ₂ _pp		ppm
31	pCO ₂ _pp		uatm

File: WETLABS_ECO_NTU_pos4.csv

Time series from the Wetlabs installed on EGIM.

Column #	Variable	Unit
1	date-time [UTC + 1 hour]	d/m/Y H:M:S
2	WAVELENGTH_1	nm
3	NTU_SIGNAL_1	NTU
4	WAVELENGTH_2	nm
5	NTU_SIGNAL_2	NTU
6	THERMISTOR	counts

File: AANDERAA_4831_pos1.csv

Time series from the Aanderaa installed on EGIM.

Column #	Variable	Description	Unit
1	date-time	[UTC + 1 hour]	d/m/Y H:M:S
2	OXYGEN	oxygen concentration	uM = umole/litre
3	SATURATION	oxygen saturation	%
4	TEMPERATURE	temperature close to sensing foil of the optode	degC
5	CALPHASE	Calibrated phase	deg
6	TCPHASE	Temperature compensated phase	deg
7	C1RPH	Phase measurement with blue excitation light	deg
8	C2RPH	Phase measurement with red excitation light	deg
9	C1AMP	Amplitude measurement with blue excitation light	mV
10	C2AMP	Amplitude measurement with red excitation light	mV
11	RAWTEMP	voltage from thermistor bridge	mV

File: SEABIRD_SBE37_pos5.csv

Time series of the SBE37 installed on EGIM.

Column #	Variable	Unit
1	date-time [UTC + 1 hour]	d/m/Y H:M:S
2	TEMPERATURE	degC
3	CONDUCTIVITY	S/m
4	PRESSURE	dbar
5	SALINITY	PSU
6	Sound Speed	m/s

File: GOSars_Thermosalinograph.csv

Time series from the *G.O. Sars*' underway pCO₂ system. The unit [umol mol⁻¹] is equivalent to [ppm].

Column #	Variables
1	Date/Time [UTC]
2,3,4,5	Longitude, QC Flag, QC Comment, Type
6,7,8,9	Latitude, QC Flag, QC Comment, Type
10,11,12,13	Depth [m], QC Flag, QC Comment, Type
14,15,16,17	Temp [degC], QC Flag, QC Comment, Type
18,19,20,21	P_sal [psu], QC Flag, QC Comment, Type
22,23,24,25	Temperature of Equilibration [degC], QC Flag, QC Comment, Type
26,27,28, 29	Equilibrator Pressure, QC Flag, QC Comment, Type
30,31,32,33	xCO ₂ In Water - Calibrated In Dry Air [umol mol ⁻¹], QC Flag, QC Comment, Type
34,35,36,37	xCO ₂ in atmosphere [umol mol ⁻¹], QC Flag, QC Comment, Type
38,39,40,41	Atmospheric Pressure [hPa], QC Flag, QC Comment, Type
42, 43,44	pCO ₂ [uatm], QC Flag, QC Comment
45, 46,47	fCO ₂ [uatm], QC Flag, QC Comment
48, 49, 50	pCO ₂ in atmosphere [uatm], QC Flag, QC Comment,
51, 52,53	fCO ₂ in atmosphere [uatm], QC Flag, QC Comment

File: GS2024001013_st495.txt

A reference CTD profile near Station M, collected from G.O Sars on 27 September 2024 03:10 UTC at 65.9942N, 1.9965E.

Column #	Variable	Description	Unit
1	PRES	Pressure	dbar
2	TEMP	Temperature	degC
3	SAL	Salinity	PSU
4	COND	Conductivity	mS/m
5	DEPTH	Depth	M
6	QUAL	IGOSS quality	IGOSS scale

IGOSS quality flag (5 digits):

- First digit : Pressure quality
- Second digit : Temperature quality
- Third digit : Salinity quality
- Fourth digit : Conductivity quality
- Fifth digit : Depth quality

Flag value descriptions:

- 0 - No quality control: No quality control has been performed.
- 1 - Correct: Appears to be correct.
- 2 - Inconsistent: Appears to be inconsistent with other elements.
- 3 - Doubtful: Appears to be doubtful.
- 4 - Erroneous: Appears to be erroneous. The flag indicates a value outside the permitted range.
- 5 - Corrected: The value has been corrected. The flag indicates a change has been made by the operator. Only obvious errors are corrected. The previous value is not saved.
- 8 - Inter-/extrapolated, Reserved. Local definition: The value is interpolated/extrapolated by observer.
- 9 - Missing: the value of the element is missing.