



Supplement of

Observation system simulation experiments in the Atlantic Ocean for enhanced surface ocean $p\text{CO}_2$ reconstructions

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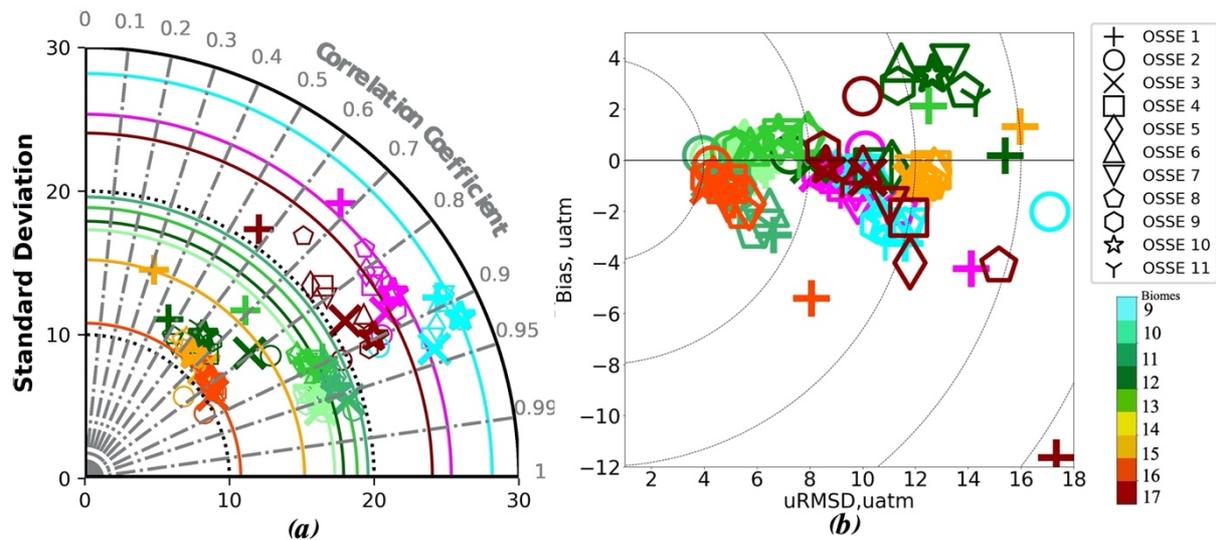


Figure S1: (a) Taylor Diagram and (b) Target Diagram of 11 OSSEs summarized in Table 2; the colour code corresponds to Fig. 2. Standard Deviations, normalised RMS differences (uRMSD) and biases are measured in μatm . OSSE 1: SOCAT data only; OSSE 2: synthetic Argo data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere; OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations. Biome 9: Subpolar seasonally stratified North Atlantic, biome 10: Subtropical seasonally stratified North Atlantic, biome 11: Subtropical permanently stratified North Atlantic, biome 12: Equatorial Atlantic, biome 13: Subtropical permanently stratified South Atlantic, biome 15: Subtropical seasonally stratified Southern Ocean, biome 16: Subpolar seasonally stratified Southern Ocean, biome 17: Southern Ocean ice.

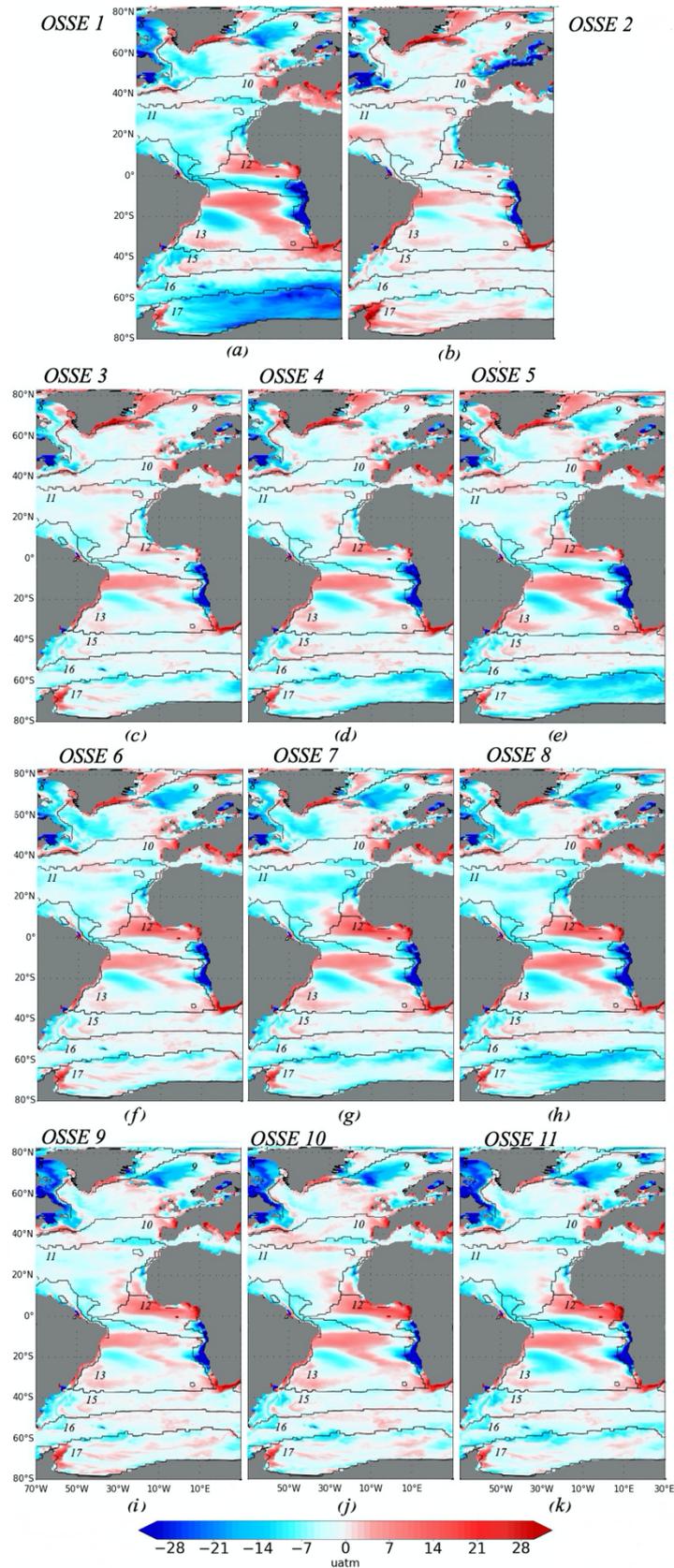


Figure S2: Differences between the OSSE FFNN outputs and NEMO/PISCES $p\text{CO}_2$ in μatm : its maximum and minimum values from 4 outputs for each OSSE FFNN, Eq. 4: (a) - OSSE 1: SOCAT data only; (b) - OSSE 2: synthetic Argo data only; (c) - OSSE 3: SOCAT and synthetic Argo data; (d) - OSSE 4: SOCAT data and 25% of original synthetic Argo data; (e) - OSSE 5: SOCAT data and 10% of original synthetic Argo data; (f) - OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere; (g) - OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; (h) - OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; (i) - OSSE 9: SOCAT data and 25% of original synthetic Argo data in the Northern Hemisphere; (j) - OSSE 10: SOCAT data and 10% of original synthetic Argo data in the Northern Hemisphere; (k) - OSSE 11: SOCAT data and synthetic Argo data in the Northern Hemisphere.

Hemisphere; (i) - OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; (j) - OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations; (k) - OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

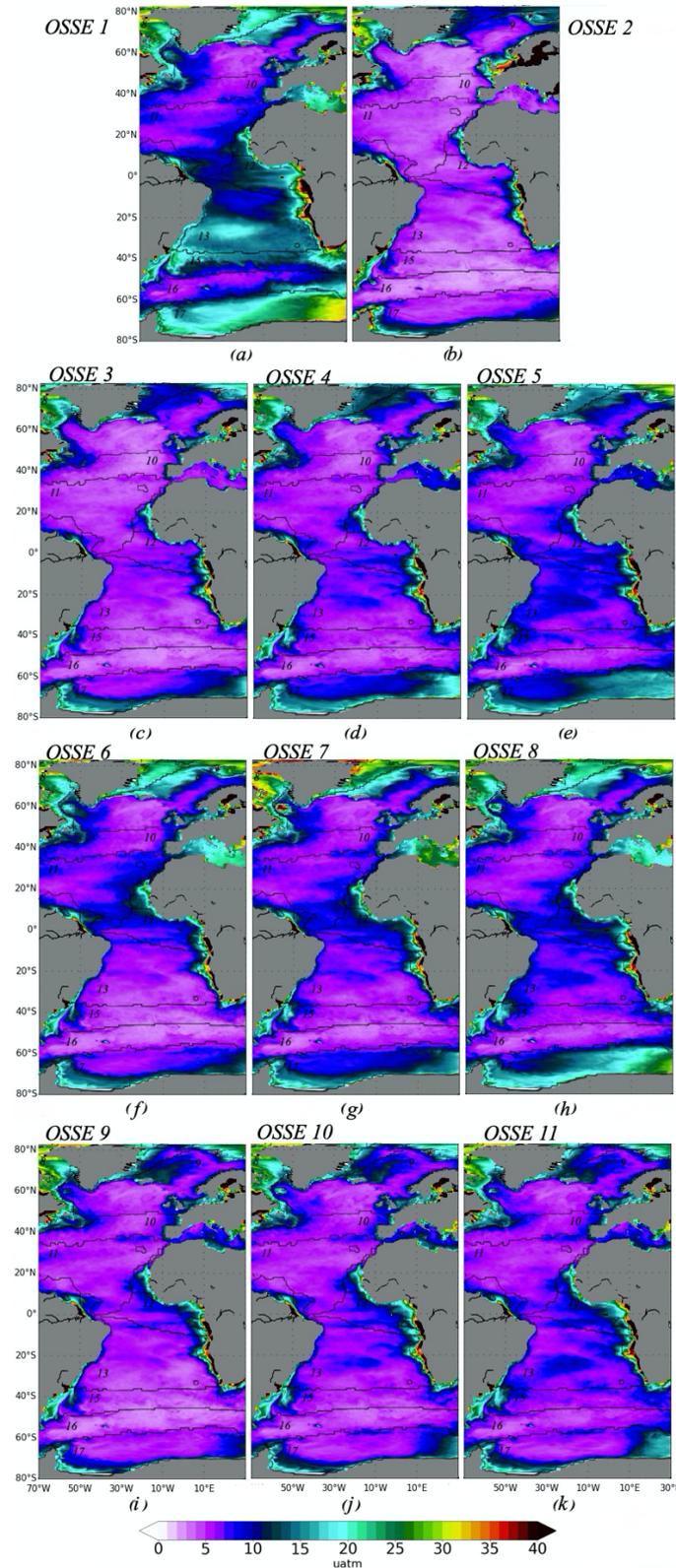


Figure S3: Standard deviation of differences for all 4 outputs for each OSSE FFNN in μatm , Eq. 5: (a) - OSSE 1: SOCAT data only; (b) - OSSE 2: synthetic Argo data only; (c) - OSSE 3: SOCAT and synthetic Argo data; (d) - OSSE 4: SOCAT data and 25% of original synthetic Argo data; (e) - OSSE 5: SOCAT data and 10% of original synthetic Argo data; (f) - OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere; (g) - OSSE 7: SOCAT data and 25% of

original synthetic Argo data in the Southern Hemisphere; (h) - OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; (i) - OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; (j) - OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations; (k) - OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

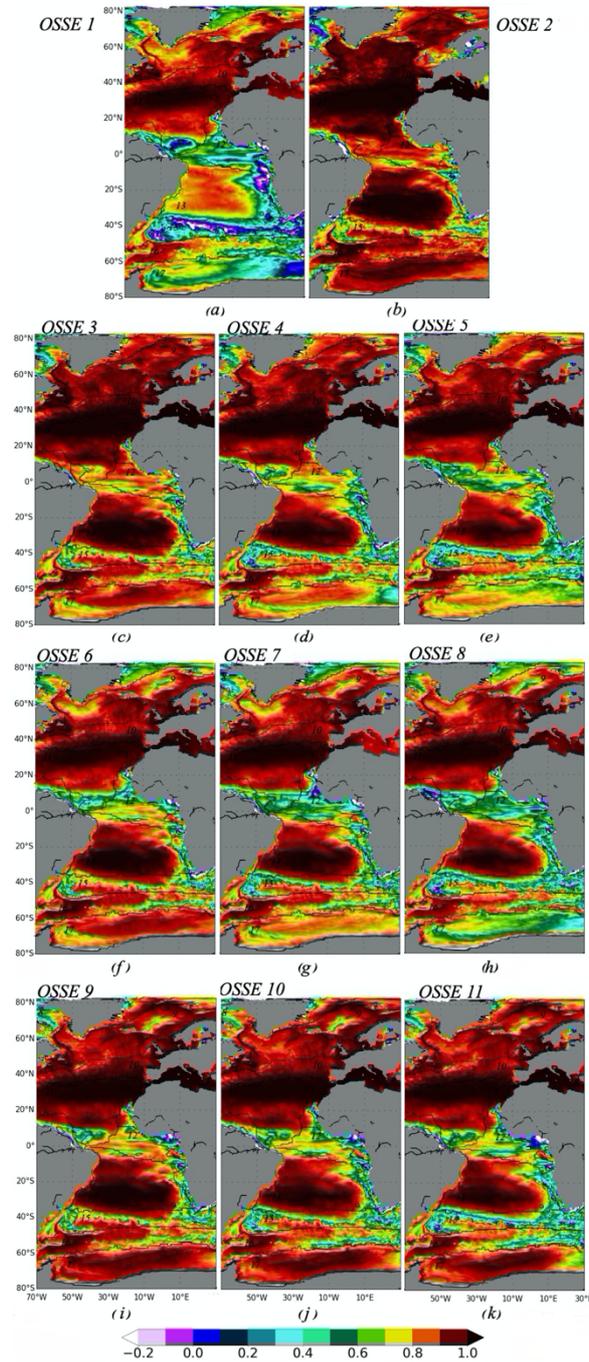


Figure S4: Correlation coefficient between different OSSEs and NEMO/PISCES $p\text{CO}_2$: (a) - OSSE 1: SOCAT data only; (b) - OSSE 2: synthetic Argo data only; (c) - OSSE 3: SOCAT and synthetic Argo data; (d) - OSSE 4: SOCAT data and 25% of original synthetic Argo data; (e) - OSSE 5: SOCAT data and 10% of original synthetic Argo data; (f) - OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere; (g) - OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; (h) - OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; (i) - OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; (j) - OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations; (k) - OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

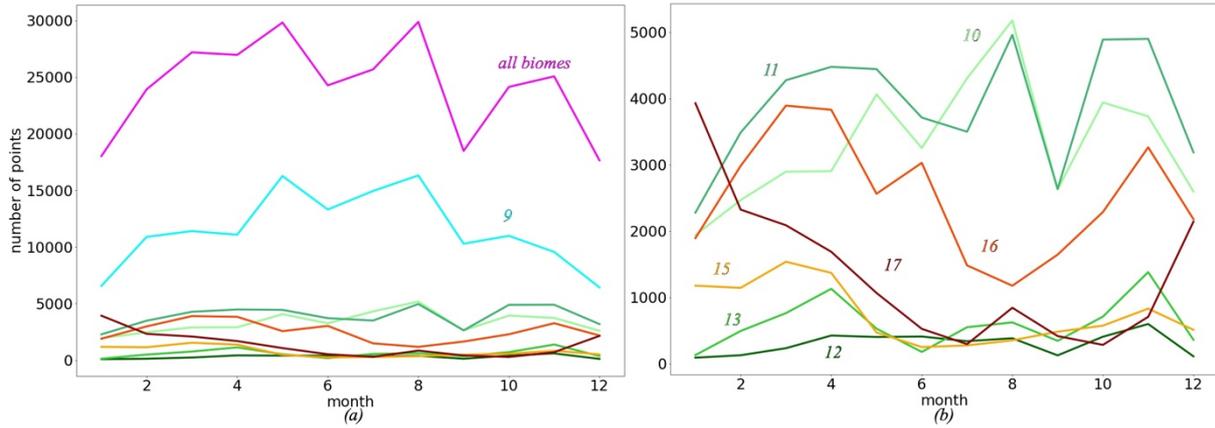


Figure S5: Seasonal distribution of SOCAT data for the period 2001-2010: (a) – distribution for all biomes and per biomes; (b) – zoom of the distribution for biomes 10, 11, 12, 13, 15, 16 and 17. Numbers correspond to biome numbers. Biome 9: Subpolar seasonally stratified North Atlantic, biome 10: Subtropical seasonally stratified North Atlantic, biome 11: Subtropical permanently stratified North Atlantic, biome 12: Equatorial Atlantic, biome 13: Subtropical permanently stratified South Atlantic, biome 15: Subtropical seasonally stratified Southern Ocean, biome 16: Subpolar seasonally stratified Southern Ocean, biome 17: Southern Ocean ice.

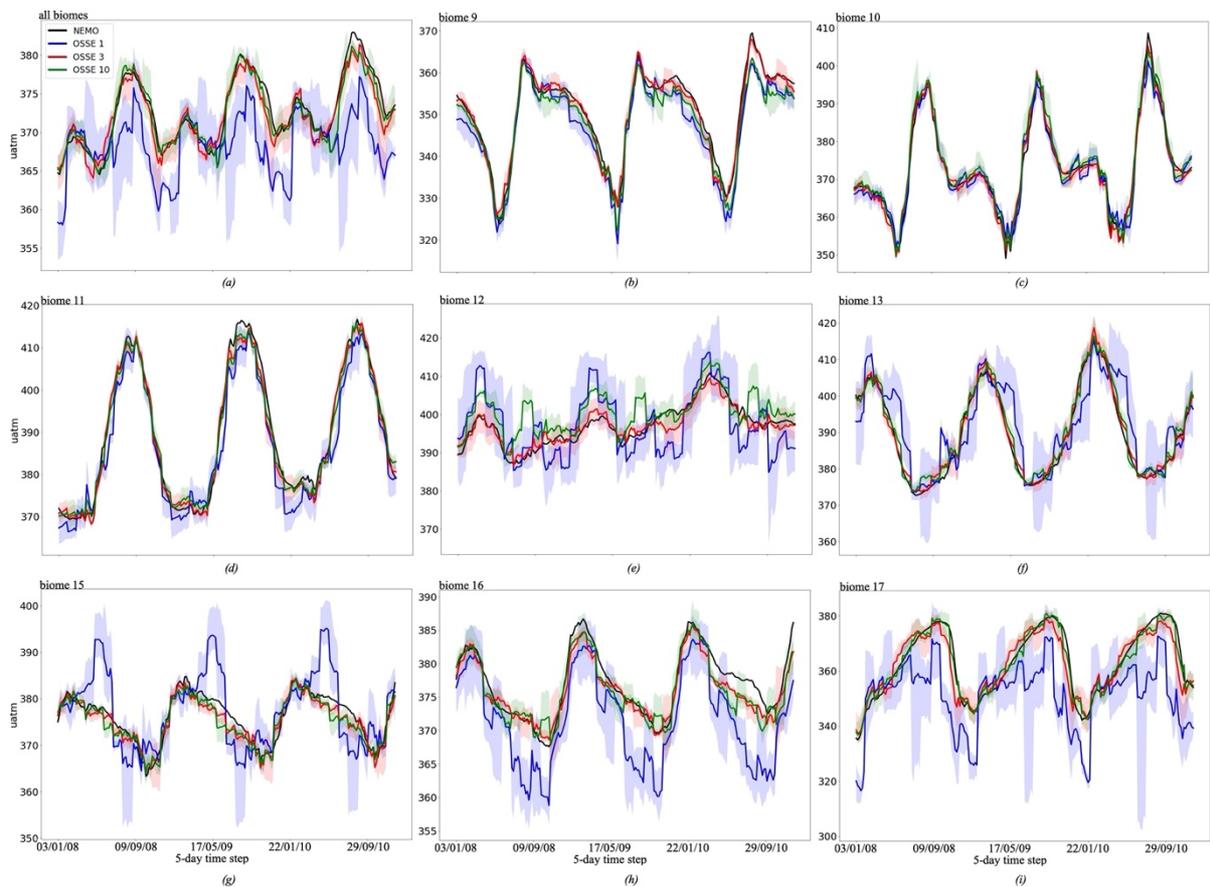


Figure S6: Mean of 4 FFNN outputs for OSSE 1 (blue), 3 (red), 10 (green); shading corresponds to the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES $p\text{CO}_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 1: SOCAT data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

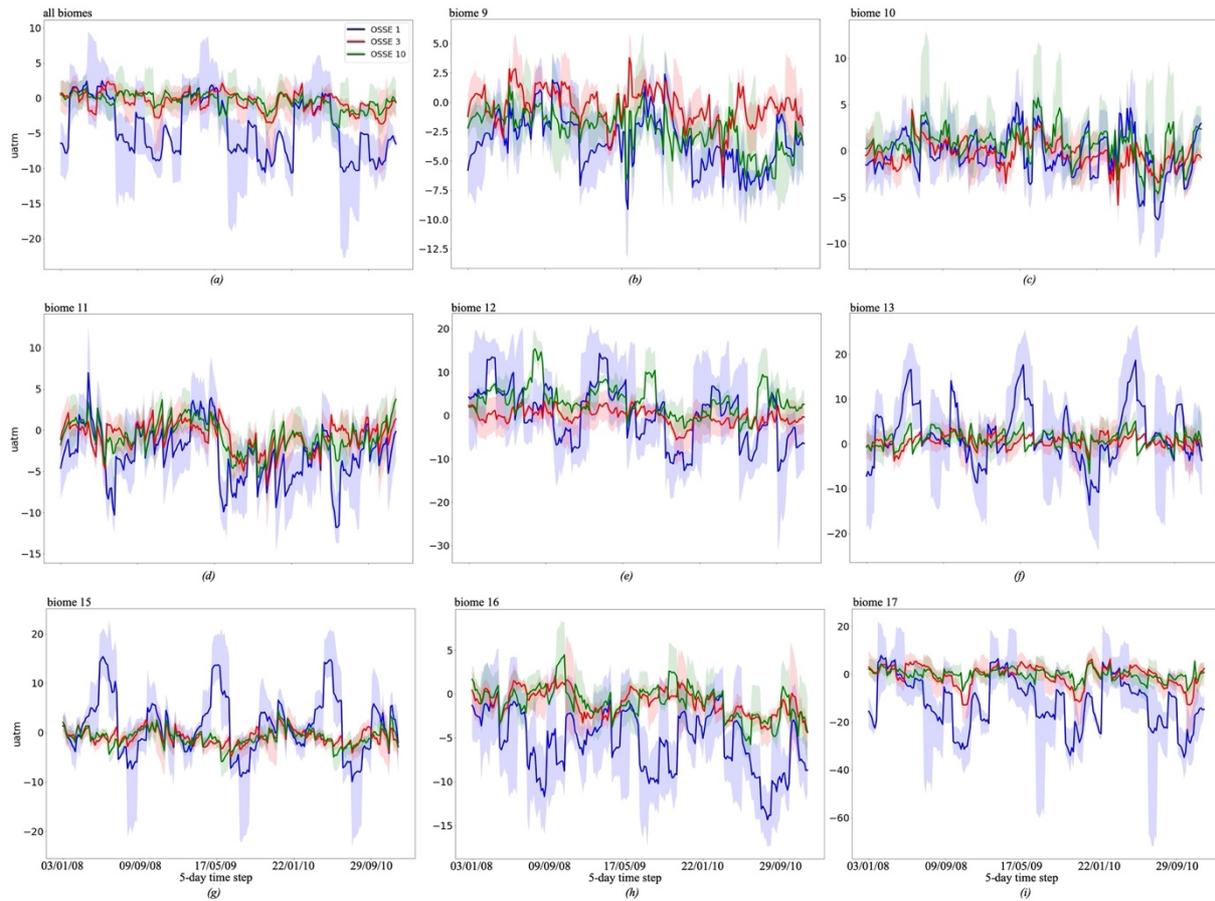


Figure S7: Mean of differences between OSSE 1 (blue), 3 (red), 10 (green) of 4 FFNN outputs and NEMO/PISCES $p\text{CO}_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 1: SOCAT data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

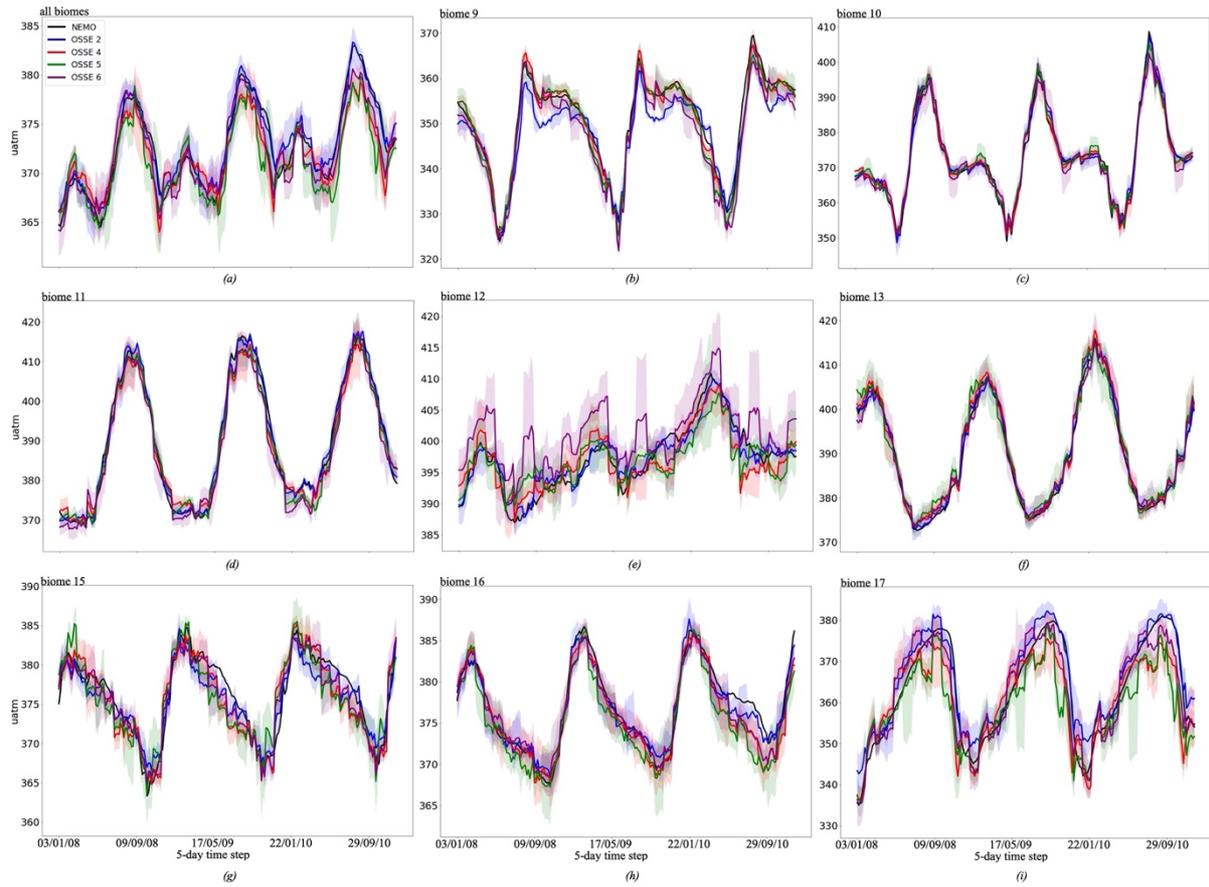


Figure S8: Mean of 4 FFNN outputs for OSSE 2 (blue), 4 (red), 5 (green), 6 (purple); shading corresponds to the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES $p\text{CO}_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 2: synthetic Argo data only; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere.

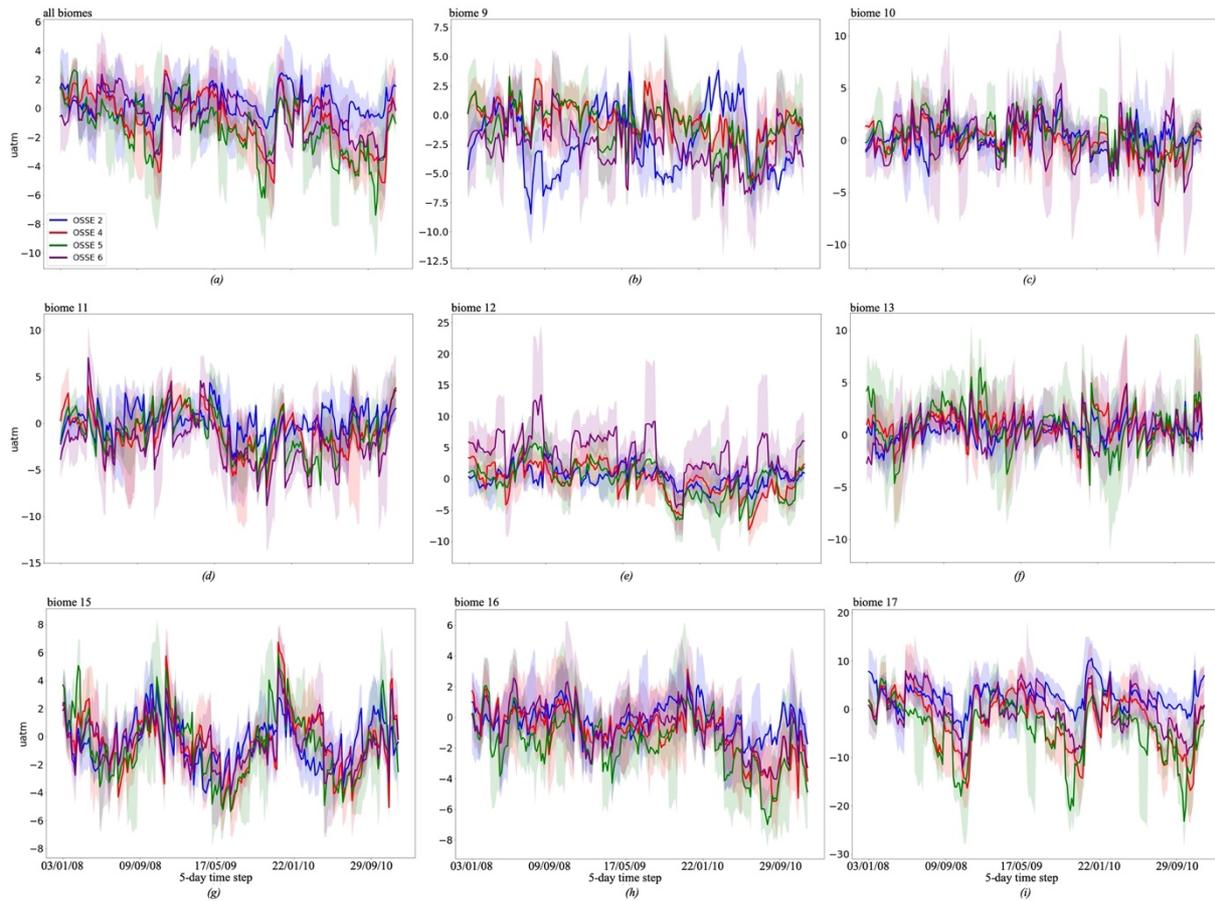


Figure S9: Mean of differences between OSSE 2 (blue), 4 (red), 5 (green), 6 (purple) of 4 FFNN outputs and NEMO/PISCES $p\text{CO}_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 2: synthetic Argo data only; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere.

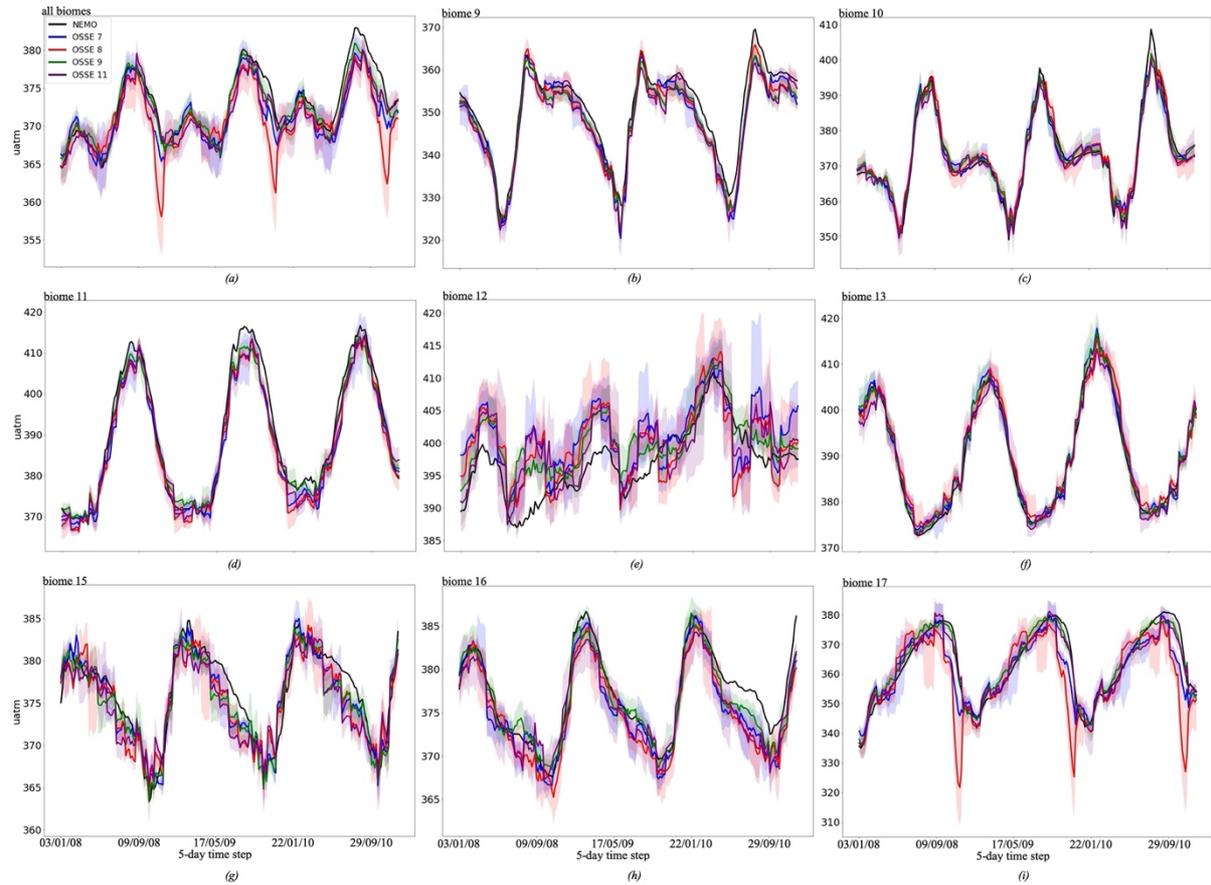


Figure S10: Mean of 4 FFNN outputs for OSSE 7 (blue), 8 (red), 9 (green), 11 (purple); shading corresponds to the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES $p\text{CO}_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

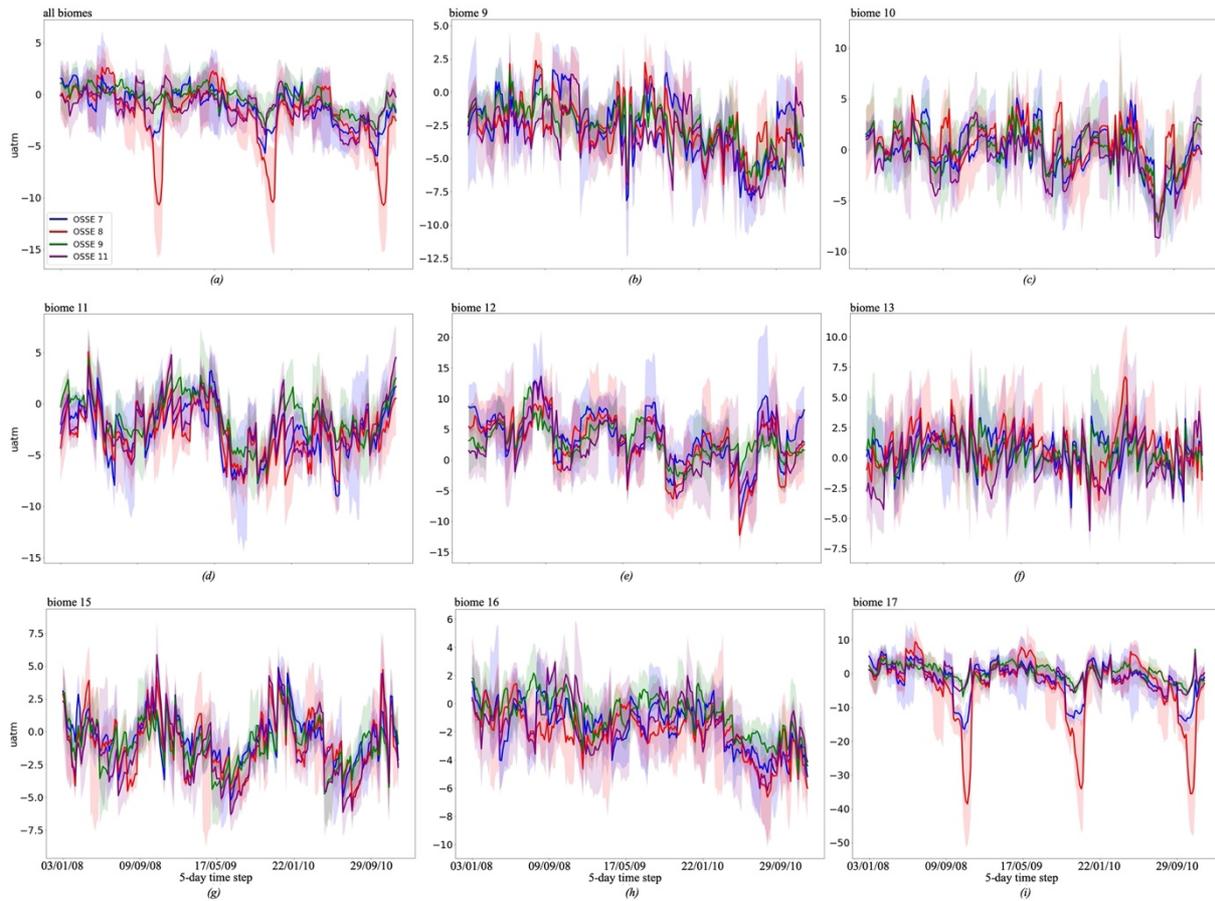


Figure S11: Mean of differences between OSSE 7 (blue), 8 (red), 9 (green), 11 (purple) of 4 FFNN outputs and NEMO/PISCES $p\text{CO}_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

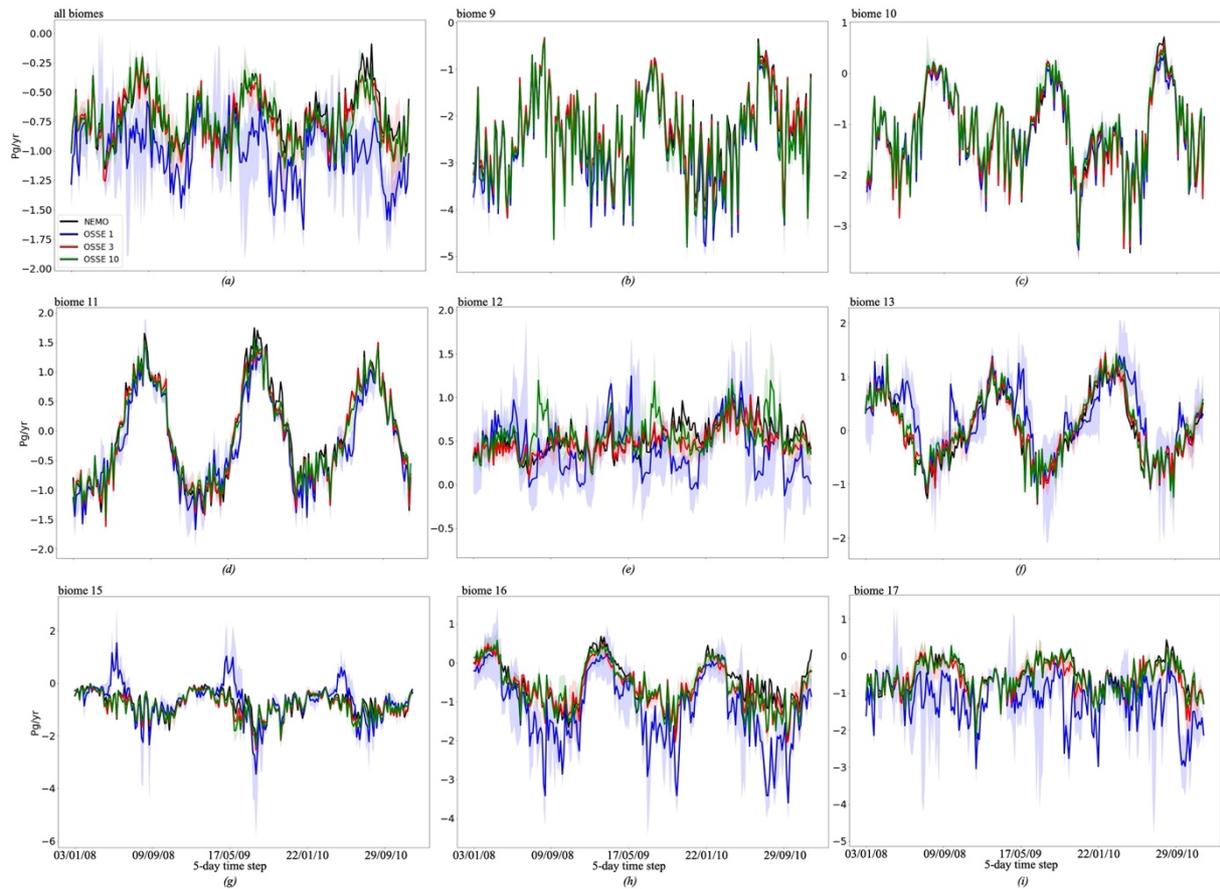


Figure S12: Mean of $fgCO_2$ from 4 FFNN outputs for OSSE 1 (blue), 3 (red), 10 (green); shading corresponds to the maximum and minimum values from 4 FFNN $fgCO_2$ estimates for each OSSE. Black curve - NEMO/PISCES $fgCO_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 1: SOCAT data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

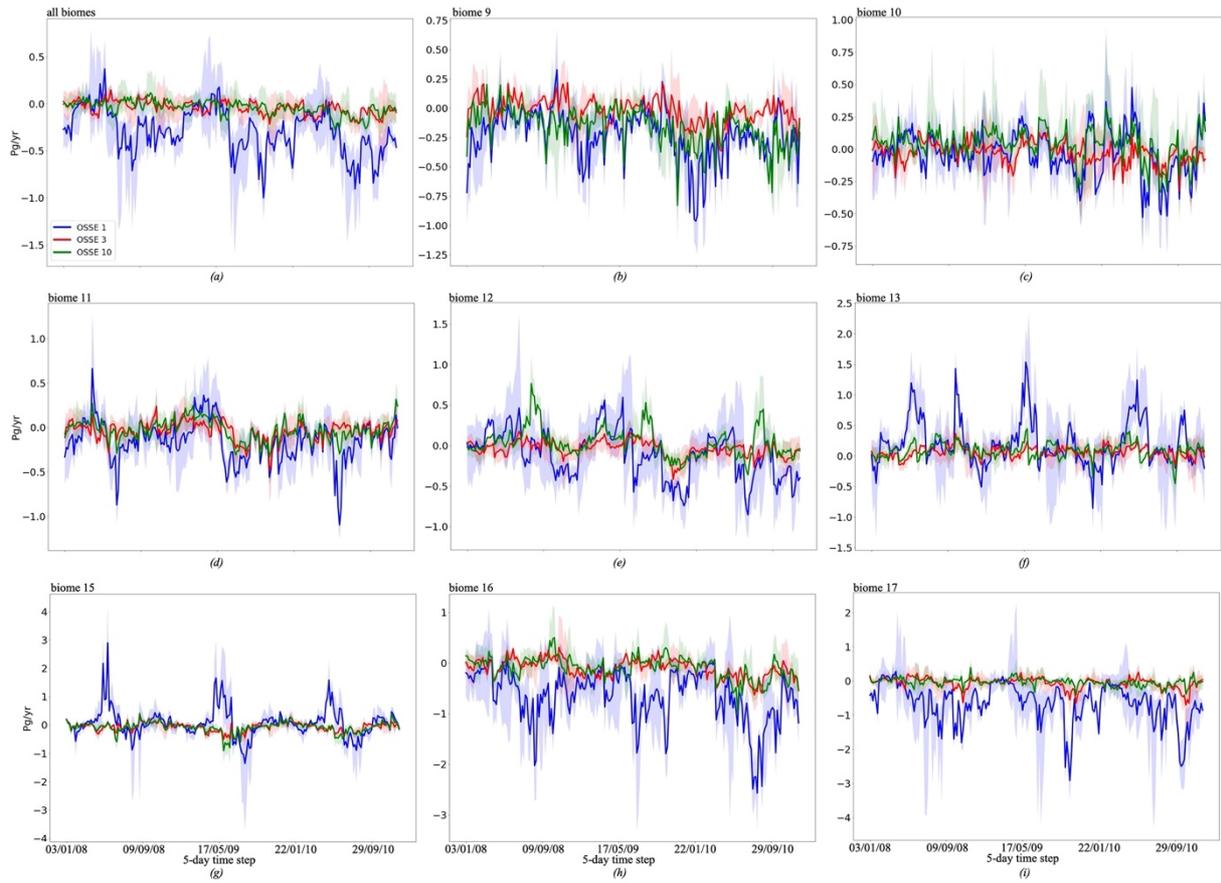


Figure S13: Mean of differences between OSSE 1 (blue), 3 (red), 10 (green) $fgCO_2$ of 4 FFNN outputs and NEMO/PISCES $fgCO_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN $fgCO_2$ for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 1: SOCAT data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

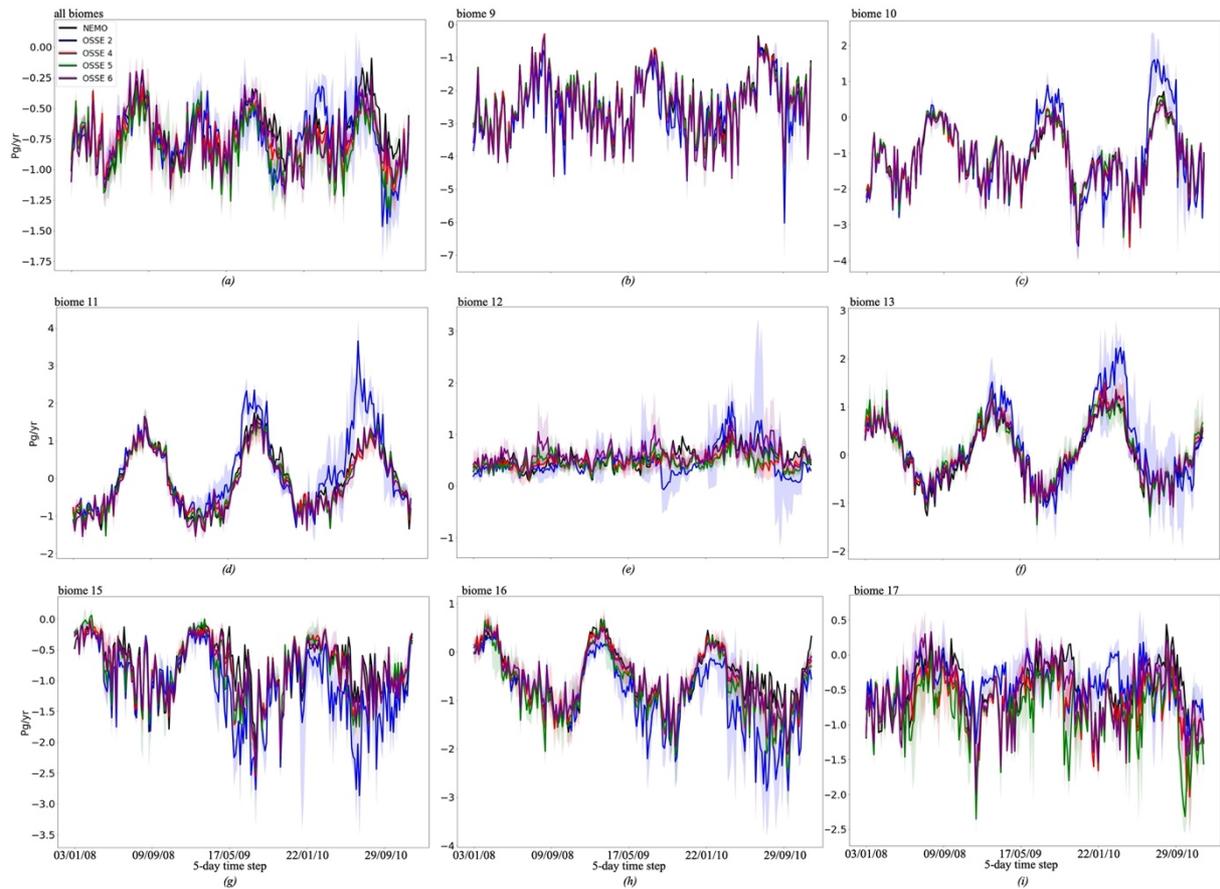


Figure S14: Mean of $fgCO_2$ from 4 FFNN outputs for OSSE 2 (blue), 4 (red), 5 (green), 6 (purple); shading corresponds to the maximum and minimum values from 4 FFNN $fgCO_2$ estimates for each OSSE. Black curve - NEMO/PISCES $fgCO_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 2: synthetic Argo data only; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere.

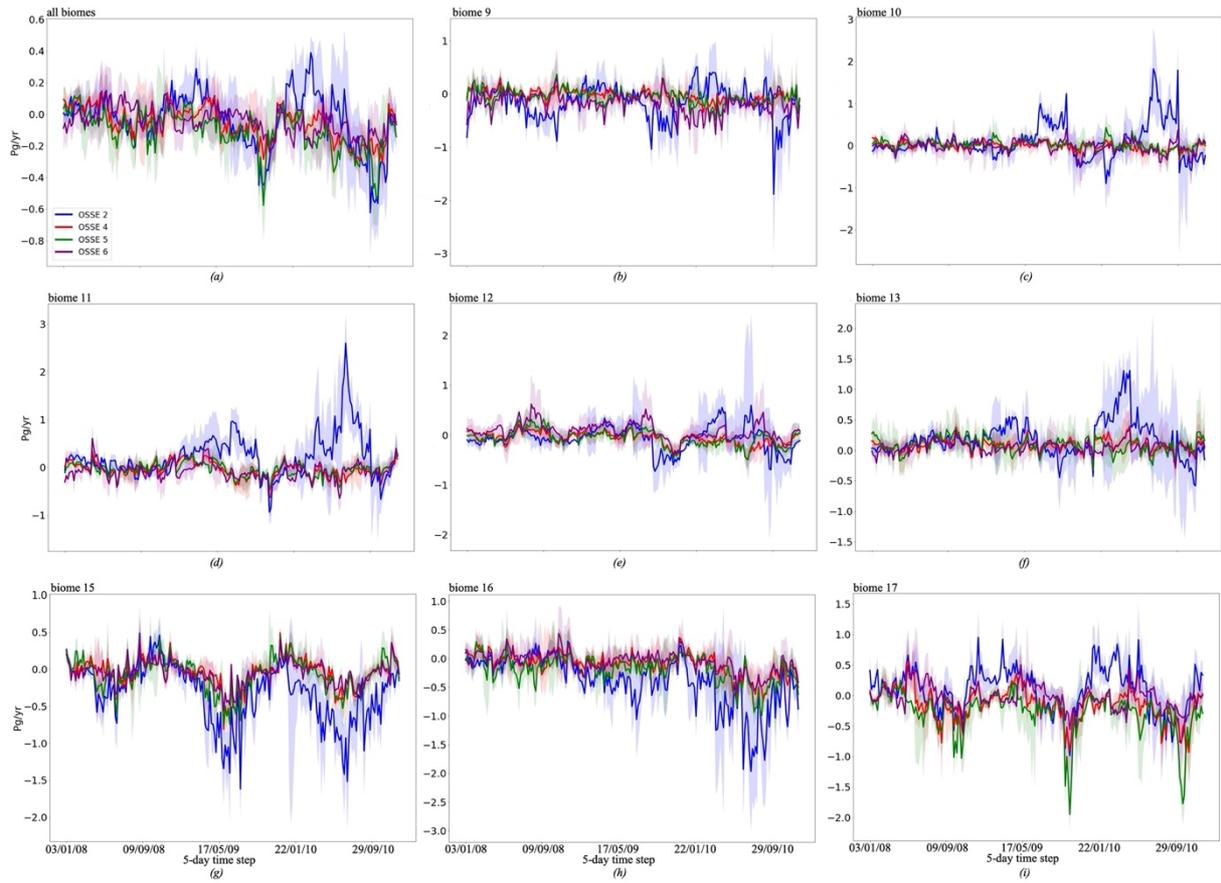


Figure S15: Mean of differences between OSSE 2 (blue), 4 (red), 5 (green), 6 (purple) $fgCO_2$ of 4 FFNN outputs and NEMO/PISCES $fgCO_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN $fgCO_2$ for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 2: synthetic Argo data only; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere.

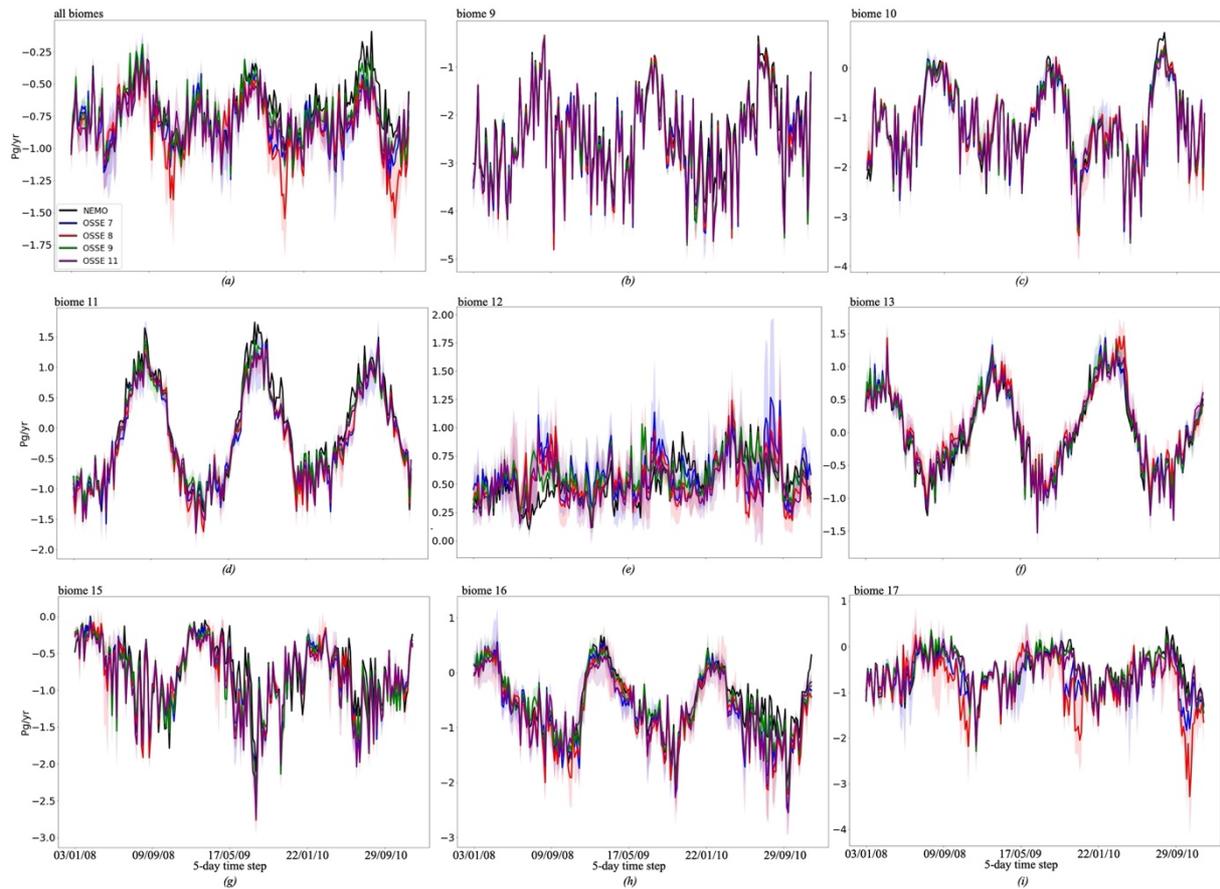


Figure S16: Mean of $fgCO_2$ from 4 FFNN outputs for OSSE 7 (blue), 8 (red), 9 (green), 11 (purple); shading corresponds to the maximum and minimum values from 4 FFNN $fgCO_2$ estimates for each OSSE. Black curve - NEMO/PISCES $fgCO_2$. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

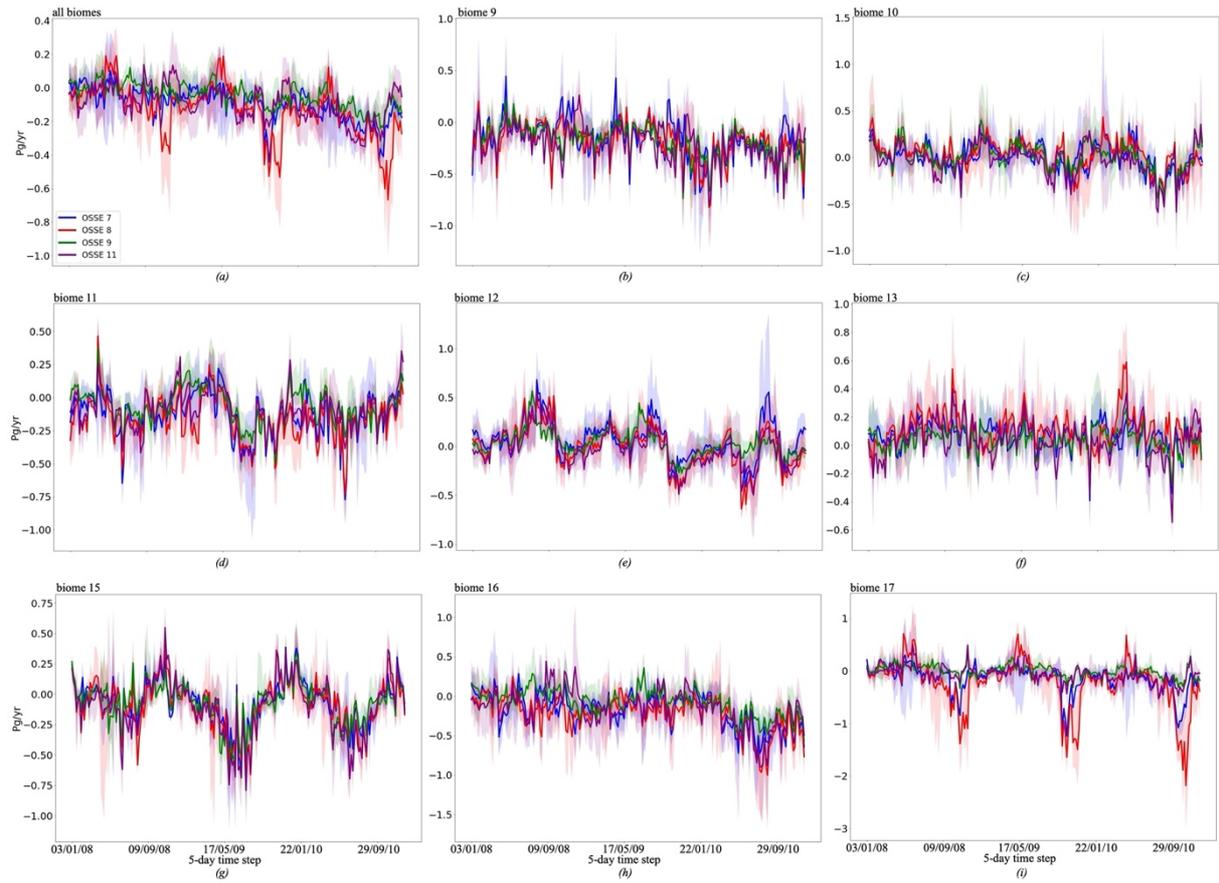


Figure S17: Mean of differences between OSSE 7 (blue), 8 (red), 9 (green), 11 (purple) $fgCO_2$ of 4 FFNN outputs and NEMO/PISCES $fgCO_2$; shading corresponds to the maximum and minimum values of differences from 4 FFNN $fgCO_2$ for each OSSE. a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations.

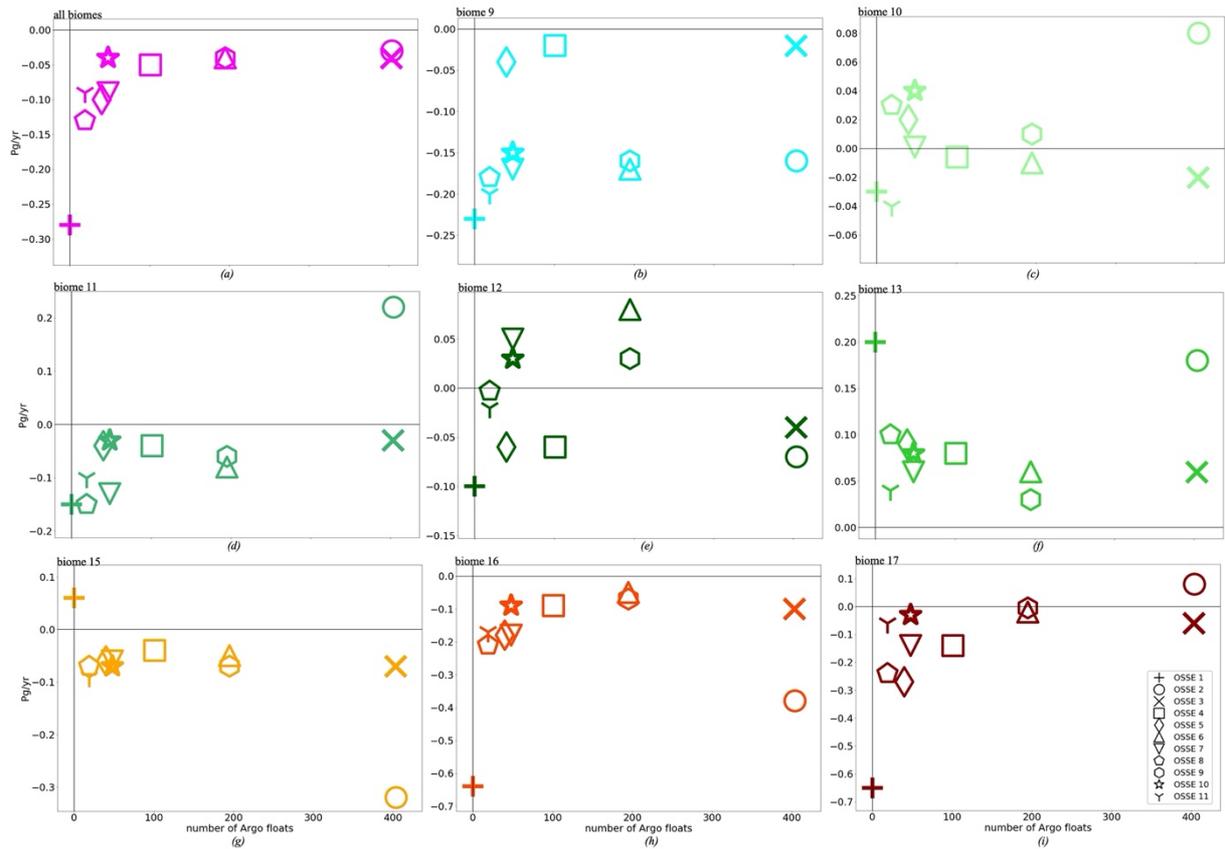


Figure S18: Averaged number of Argo profiles per 5 day time step over 2008-2010 versus averaged differences between each OSSEs $fgCO_2$ and NEMO/PISCES $fgCO_2$ (in Pg/yr). a) - all 8 biomes, (b) - biome 9 (Subpolar seasonally stratified North Atlantic), (c) - biome 10 (Subtropical seasonally stratified North Atlantic), (d) - biome 11 (Subtropical permanently stratified North Atlantic), (e) - biome 12 (Equatorial Atlantic), (f) - biome 13 (Subtropical permanently stratified South Atlantic), (g) - biome 15 (Subtropical seasonally stratified Southern Ocean), (h) - biome 16 (Subpolar seasonally stratified Southern Ocean), (i) - biome 17 (Southern Ocean ice). OSSE 1: SOCAT data only; OSSE 2: synthetic Argo data only; OSSE 3: SOCAT and synthetic Argo data; OSSE 4: SOCAT data and 25% of original synthetic Argo data; OSSE 5: SOCAT data and 10% of original synthetic Argo data; OSSE 6: SOCAT data and synthetic Argo data in the Southern Hemisphere; OSSE 7: SOCAT data and 25% of original synthetic Argo data in the Southern Hemisphere; OSSE 8: SOCAT data and 10% of original synthetic Argo data in the Southern Hemisphere; OSSE 9: SOCAT data, synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 10: SOCAT data, 25% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations; OSSE 11: SOCAT data, 10% of original synthetic Argo data in the Southern Hemisphere and data from mooring stations. OSSEs 1, 3 and 10 are in bold as they represent main OSSEs of our comparisons.

Table S1: Number of training data per month and per OSSE.

Month	January	February	March	April	May	June	July	August	September	October	November	December
OSSE 1	9788	13186	15179	15076	16458	13428	14698	16991	10564	13679	13836	9871
OSSE 2	3802	3578	3678	3730	3803	3594	3744	3730	3455	3655	3651	3886
OSSE 3	13582	16756	18850	18804	20253	17020	18431	20710	14012	17324	17482	13744
OSSE 4	10738	14080	16098	16009	17408	14328	15632	17921	11426	14590	14748	10840

OSSE 5	10168	13544	15547	15450	16838	13788	15071	17364	10910	14044	14202	10259
OSSE 6	11710	14991	17036	16962	18302	15120	16442	18700	12158	15372	15562	11758
OSSE 7	10270	13638	15644	15548	16921	13852	15135	17418	10964	14104	14268	10344
OSSE 8	9982	13368	15366	15266	16642	13598	14874	17162	10723	13848	14010	10061
OSSE 9	12753	16034	18074	18008	19340	16158	17510	19845	13202	16410	16600	12797
OSSE 10	11313	14682	16681	16594	17959	14890	16202	18563	12009	15142	15307	11383
OSSE 11	11026	14411	16403	16312	17680	14636	15941	18306	11768	14888	15048	11100

Table S2: Differences (Eq. 4) between the OSSE FFNN outputs and NEMO/PISCES $p\text{CO}_2$ and its standard deviation (STD) (Eq. 5) in μatm .

Biome OSSE	Region 70°W- 30°E 80°S- 80°N	All 8 biomes	9	10	11	12	13	15	16	17
OSSE 1	-6.57/ 14.49	-6.57/ 13.54	-4.84/ 10.17	-1.46/ 6.98	-4.21/ 7.62	-2.03/ 13.88	0.11/ 13.88	-1.35/ 14.96	-8.04/ 8.99	-14.9/ 20.83
OSSE 2	-1.09/ 7.99	-0.68/ 6.77	-3.41/ 9.61	-0.58/ 4.65	-0.5/ 4.37	-0.63/ 6.24	-0.3/ 4.76	-1.18/ 6.85	-0.88/ 3.87	0.93/ 8.94
OSSE 3	-1.7/ 8.12	-1.5/ 7.15	-1.36/ 7.52	-0.9/ 4.62	-1.48/ 4.64	-1.49/ 7.09	-0.32/ 5.58	-1.93/ 7.16	-1.89/ 4.42	-2.05/ 10.59
OSSE 4	-2.57/ 9.45	-2.36/ 8.39	-1.97/ 8.44	-1.08/ 5.31	-2.06/ 5.67	-1.46/ 8.15	-0.19/ 6.58	-1.75/ 8.57	-1.79/ 5.18	-4.72/ 12.56
OSSE 5	-3.19/ 10.36	-3.16/ 9.33	-2.33/ 9.01	-0.22/ 5.79	-2.08/ 5.99	-1.68/ 9.13	-0.2/ 7.88	-2.06/ 9.59	-3.15/ 6.23	-6.84/ 13.81
OSSE 6	-2.07/ 9.49	-1.8/ 8.03	-4.07/ 10.08	-1/ 6.67	-3.01/ 7.53	1.97/ 9.48	-0.49/ 5.66	-1.68/ 7.26	-1.48/ 4.52	-1.62/ 10.2
OSSE 7	-2.92/ 10.43	-2.66/ 8.86	-4.29/ 10.54	-1.01/ 6.67	-4.44/ 7.01	2/ 10.38	-0.36/ 6.49	-1.7/ 8.29	-2.98/ 5.13	-3.45/ 12.01
OSSE 8	-3.62/ 11.53	-3.38/ 10.29	-4.46/ 10.2	-0.37/ 6.47	-3.99/ 6.59	0.79/ 10.85	-0.29/ 7.57	-2.32/ 9.47	-2.98/ 5.82	-5.99/ 16.38
OSSE 9	-2.16/ 8.08	-1.42/ 6.87	-3.7/ 8.37	-1.05/ 5.85	-2.36/ 5.52	1.74/ 8.62	-0.28/ 5.32	-1.85/ 7.31	-1.35/ 4.33	-0.72/ 8.24
OSSE 10	-2.34/ 8.64	-1.54/ 7.5	-3.54/ 8.59	-0.1/ 6.18	-1.52/ 5.42	1.93/ 9.38	-0.04/ 6.51	-2.15/ 8.18	-1.91/ 5.21	-1.55/ 8.99

OSSE 11	-3.22/ 9.14	-2.45/ 8.07	-4.47/ 8.64	-1.85/ 6.33	-2.76/ 5.73	0.82/ 10.37	-1.14/ 7.3	-2.46/ 9.18	-2.92/ 5.81	-2.2/ 9.72
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Table S3: Correlation coefficient between OSSEs and NEMO/PISCES $p\text{CO}_2$.

Biome OSSE	Region 70°W- 30°E 80°S- 80°N	All 8 biomes	9	10	11	12	13	15	16	17
OSSE 1	0.68	0.67	0.88	0.92	0.89	0.46	0.68	0.31	0.7	0.57
OSSE 2	0.88	0.89	0.91	0.96	0.96	0.83	0.93	0.77	0.87	0.9
OSSE 3	0.86	0.87	0.93	0.96	0.95	0.79	0.91	0.73	0.83	0.85
OSSE 4	0.82	0.83	0.92	0.95	0.93	0.7	0.88	0.64	0.8	0.77
OSSE 5	0.79	0.8	0.92	0.94	0.92	0.65	0.86	0.59	0.75	0.76
OSSE 6	0.84	0.85	0.89	0.93	0.91	0.64	0.91	0.72	0.82	0.86
OSSE 7	0.8	0.82	0.89	0.93	0.91	0.54	0.88	0.66	0.8	0.8
OSSE 8	0.76	0.77	0.89	0.93	0.91	0.52	0.86	0.57	0.79	0.66
OSSE 9	0.86	0.88	0.92	0.95	0.94	0.68	0.92	0.72	0.84	0.91
OSSE 10	0.85	0.85	0.92	0.94	0.94	0.63	0.88	0.65	0.78	0.89
OSSE 11	0.82	0.83	0.92	0.94	0.93	0.58	0.86	0.56	0.74	0.88

Table S4: $p\text{CO}_2$ averaged over the region 70°W-30°E 80°S-80°N and biomes from Fig. 2 for NEMO/PISCES model and each OSSEs, and its averaged differences between each OSSEs and NEMO/PISCES (in μatm).

Biome OSSE	Region 70°W- 30°E 80°S- 80°N	All 8 biomes	9	10	11	12	13	15	16	17
NEMO	371.13	372.65	350.36	373.18	390.11	397.18	389.54	376.14	376.99	363.08

OSSE 1	367.09/ -4.04	368.39/ -4.25	347.1/ -3.26	372.78/ -0.39	387.17/ -2.93	397.36/ 0.17	391.66/ 2.12	377.46/ 1.32	371.58/ -5.41	351.44/ -11.63
OSSE 2	371.25/ 0.11	373.01/ 0.36	348.34/ -2.02	373.28/ 0.09	390.3/ 0.19	397.41/ 0.23	389.92/ 0.38	375.7/ -0.44	376.78/ -0.21	365.58/ 2.5
OSSE 3	370.62/ -0.51	372.18/ -0.46	350.04/ -0.32	372.88/ -0.3	389.39/ -0.71	397.04/ -0.14	390.1/ 0.57	375.29/ -0.85	376.02/ -0.97	362.42/ -0.66
OSSE 4	370.21/ -0.92	371.8/ -0.84	349.83/ -0.53	373.13/ -0.05	389.22/ -0.88	396.88/ -0.29	390.38/ 0.85	375.74/ -0.4	376.06/ -0.93	360.83/ -2.25
OSSE 5	369.8/ -1.33	371.2/ -1.46	349.53/ -0.83	373.68/ 0.5	389.12/ -0.98	396.93/ -0.25	390.39/ 0.85	375.59/ -0.54	375.3/ -1.69	359.06/ -4.02
OSSE 6	370.57/ -0.56	372.11/ -0.54	347.79/ -2.57	373.21/ 0.03	388.25/ -1.86	401.01/ 3.82	390.07/ 0.53	375.63/ -0.51	376.43/ -0.56	362.9/ -0.18
OSSE 7	369.94/ -1.2	371.42/ -1.22	347.72/ -2.64	373.08/ -0.1	387.42/ -2.68	400.96/ 3.77	390.12/ 0.58	375.58/ -0.56	375.32/ -1.68	361.28/ -1.8
OSSE 8	369.26/ -1.87	370.75/ -1.89	347.77/ -2.59	373.68/ 0.49	387.29/ -2.81	399.89/ 2.71	390.44/ 0.9	375.25/ -0.89	374.96/ -2.03	358.95/ -4.12
OSSE 9	370.22/ -0.91	372.2/ -0.44	347.84/ -2.52	373.18/ -0.001	388.77/ -1.33	400.09/ 2.91	389.95/ 0.41	375.25/ -0.88	376.24/ -0.75	363.46/ 0.37
OSSE 10	370.14/ -0.99	372.26/ -0.39	348.01/ -2.35	373.98/ 0.79	389.39/ -0.71	400.53/ 3.35	390.55/ 1.01	375.22/ -0.92	376.09/ -0.9	362.87/ -0.21
OSSE 11	369.33/ -1.8	371.45/ -1.18	347.14/ -3.21	372.5/ -0.68	388.13/ -1.97	399.6/ 2.41	389.54/ 0.002	374.96/ -1.18	375.44/ -1.56	362.31/ -0.76

Table S5: $fgCO_2$ averaged over the region 70°W-30°E 80°S-80°N and biomes from Fig. 2 for NEMO/PISCES model and each OSSEs, and its averaged differences between each OSSEs and NEMO/PISCES (in Pg/yr).

Biome	Region 70°W- 30°E 80°S- 80°N	All 8 biomes	9	10	11	12	13	15	16	17
NEMO	-0.76	-0.7	-2.34	-1.14	-0.03	0.53	-0.004	-0.74	-0.5	-0.52
OSSE 1	-1.03/ -0.26	-0.99/ -0.28	-2.57/ -0.23	-1.17/ -0.03	-0.18/ -0.15	0.42/ -0.1	0.19/ 0.2	-0.68/ 0.06	-1.15/ -0.64	-1.17/ -0.65
OSSE 2	-0.81/ -0.04	-0.74/ -0.03	-2.5/ -0.16	-1.05/ 0.08	0.19/ 0.22	0.46/ -0.07	0.17/ 0.18	-1.07/ -0.32	-0.89/ -0.38	-0.44/ 0.08
OSSE 3	-0.8/ -0.04	-0.74/ -0.04	-2.36/ -0.02	-1.16/ -0.02	-0.07/ -0.03	0.49/ -0.04	0.05/ 0.06	-0.82/ -0.07	-0.61/ -0.1	-0.59/ -0.06
OSSE 4	-0.82/ -0.05	-0.76/ -0.05	-2.37/ -0.02	-1.14/ -0.006	-0.07/ -0.04	0.46/ -0.06	0.08/ 0.08	-0.79/ -0.04	-0.6/ -0.09	-0.67/ -0.14
OSSE 5	-0.86/ -0.09	-0.81/ -0.1	-2.39/ -0.04	-1.11/ 0.02	-0.07/ -0.04	0.47/ -0.06	0.08/ 0.09	-0.81/ -0.06	-0.69/ -0.18	-0.79/ -0.27

OSSE 6	-0.81/ -0.04	-0.75/ -0.04	-2.52/ -0.17	-1.15/ -0.01	-0.11/ -0.08	0.61/ 0.08	0.05/ 0.06	-0.79/ -0.05	-0.56/ -0.05	-0.55/ -0.02
OSSE 7	-0.86/ -0.01	-0.8/ -0.09	-2.51/ -0.17	-1.14/ 0.001	-0.16/ -0.13	0.59/ 0.05	0.06/ 0.06	-0.8/ -0.06	-0.69/ -0.18	-0.67/ -0.14
OSSE 8	-0.89/ -0.12	-0.83/ -0.13	-2.53/ -0.18	-1.11/ 0.03	-0.18/ -0.15	0.53/ -0.003	0.1/ 0.1	-0.82/ -0.07	-0.72/ -0.21	-0.77/ -0.24
OSSE 9	-0.83/ -0.06	-0.75/ -0.04	-2.51/ -0.16	-1.12/ 0.01	-0.09/ -0.06	0.56/ 0.03	0.03/ 0.03	-0.81/ -0.07	-0.58/ -0.07	-0.53/ -0.005
OSSE 10	-0.83/ -0.06	-0.74/ -0.04	-2.5/ -0.15	-1.09/ 0.04	-0.06/ -0.03	0.56/ 0.03	0.08/ 0.08	-0.82/ -0.07	-0.6/ -0.09	-0.56/ -0.03
OSSE 11	-0.88/ -0.11	-0.79/ -0.09	-2.55/ -0.2	-1.17/ -0.04	-0.13/ -0.1	0.51/ -0.02	0.03/ 0.04	-0.84/ -0.09	-0.67/ -0.17	-0.58/ -0.06