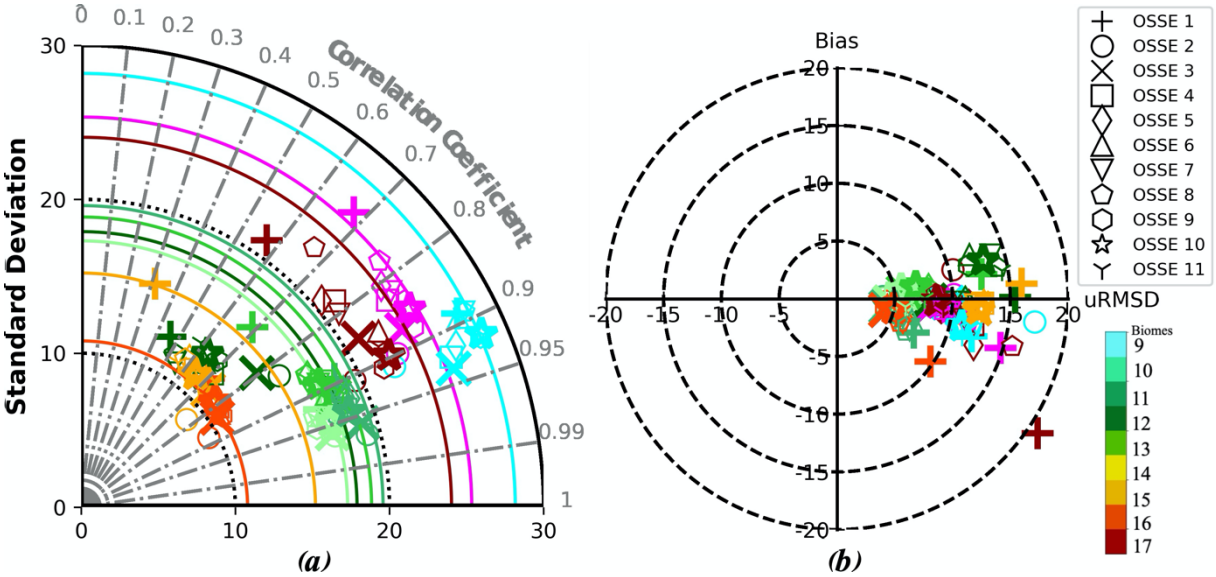

Figure S1: (a) Taylor Diagram and (b) Target Diagram of 11 OSSEs summarized in Table 2; colour code corresponds to Fig. 2. Standard Deviations, normalised RMS differences (uRMSD) and biases are measured in μatm.

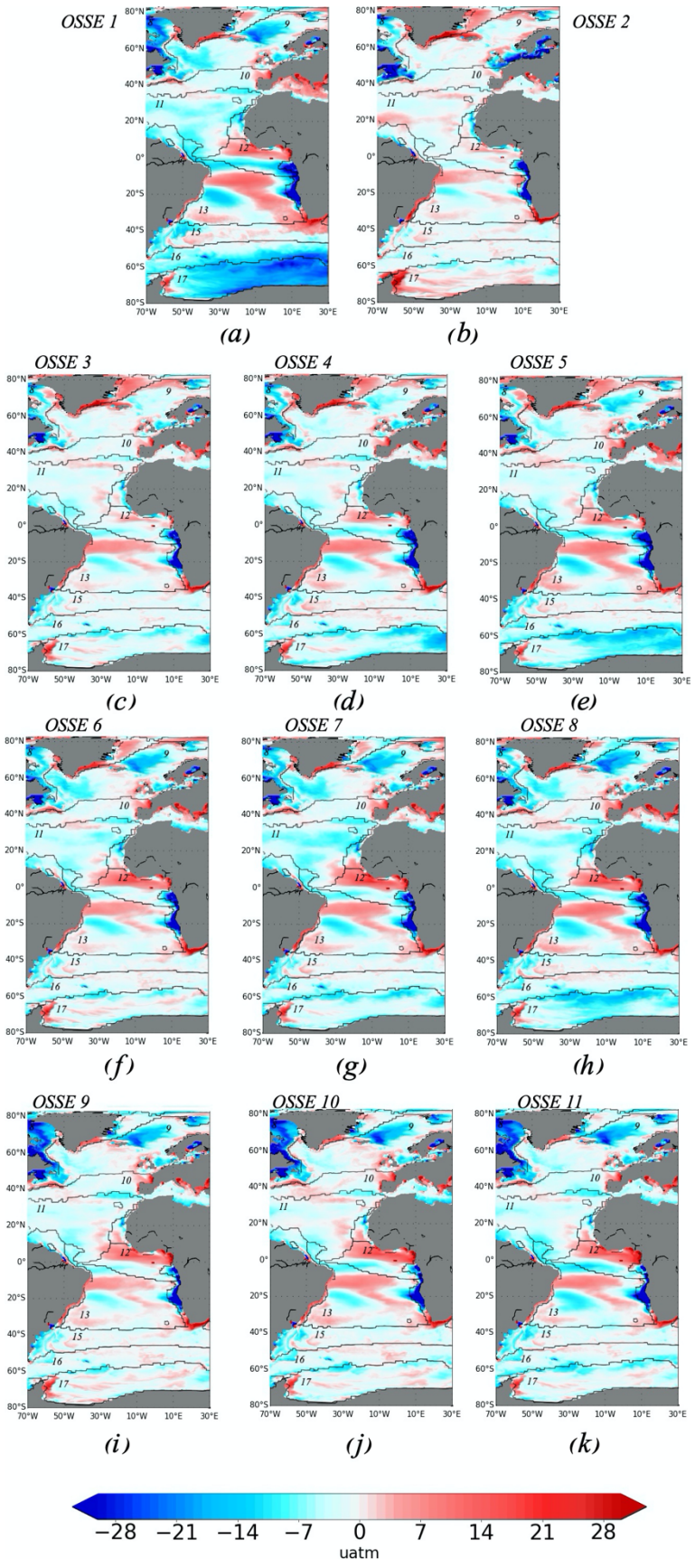

Figure S2: Differences between the OSSE FFNN outputs and NEMO/PISCES pCO_2: its maximum in absolute value from 4 outputs for each OSSE FFNN, Eq. 4: (a) – OSSE 1, (b) – OSSE 2, (c) – OSSE 3, (d) – OSSE 4, (e) – OSSE 5, (f) – OSSE 6, (g) – OSSE 7, (h) – OSSE 8, (i) – OSSE 9, (j) – OSSE 10, (k) – OSSE 11.

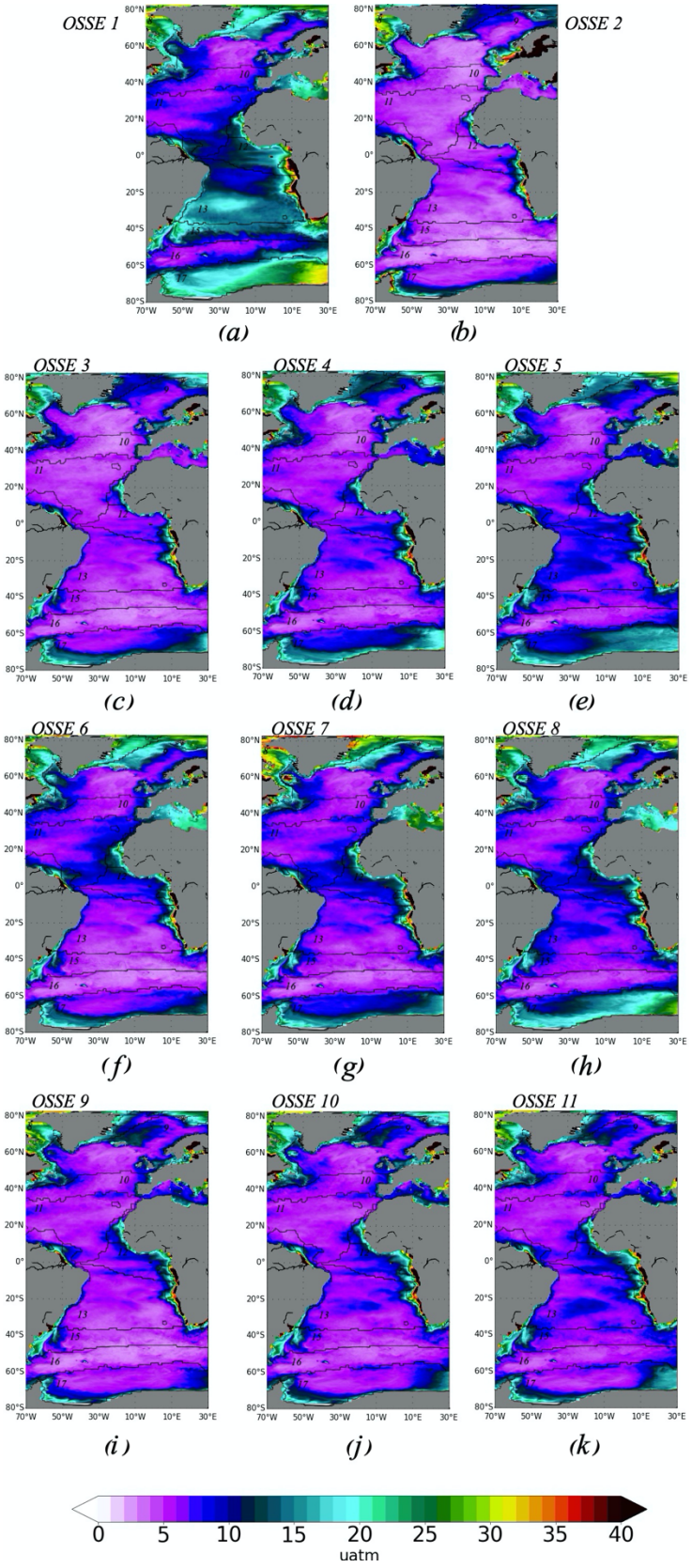

Figure S3: Standard deviation of differences for all 4 outputs for each OSSE FFNN, Eq. 5: (a) – OSSE 1, (b) – OSSE 2, (c) – OSSE 3, (d) – OSSE 4, (e) – OSSE 5, (f) – OSSE 6, (g) – OSSE 7, (h) – OSSE 8, (i) – OSSE 9, (j) – OSSE 10, (k) – OSSE 11.

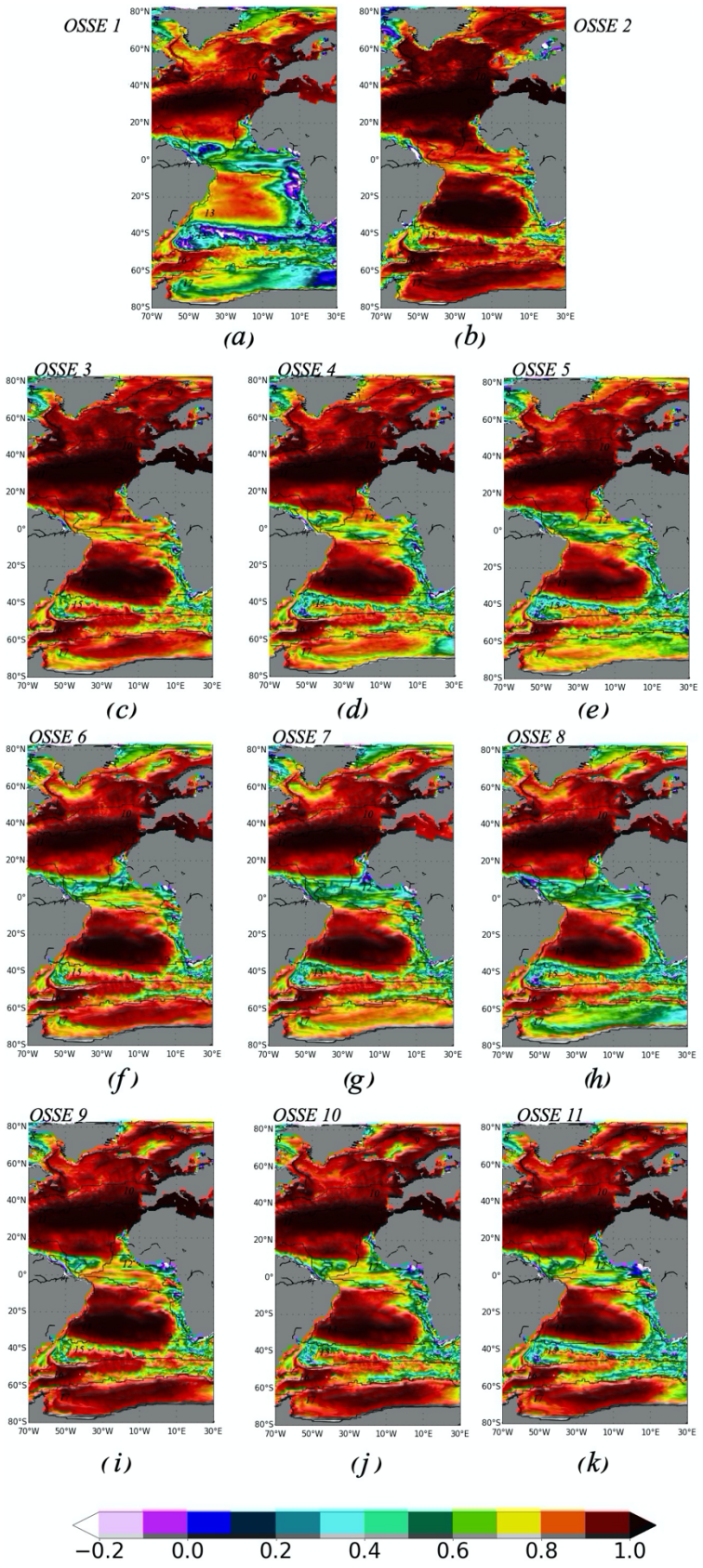

Figure S4: Correlation coefficient between different OSSEs and NEMO/PISCES pCO_2: (a) – OSSE 1, (b) – OSSE 2, (c) – OSSE 3, (d) – OSSE 4, (e) – OSSE 5, (f) – OSSE 6, (g) – OSSE 7, (h) – OSSE 8, (i) – OSSE 9, (j) – OSSE 10, (k) – OSSE 11.

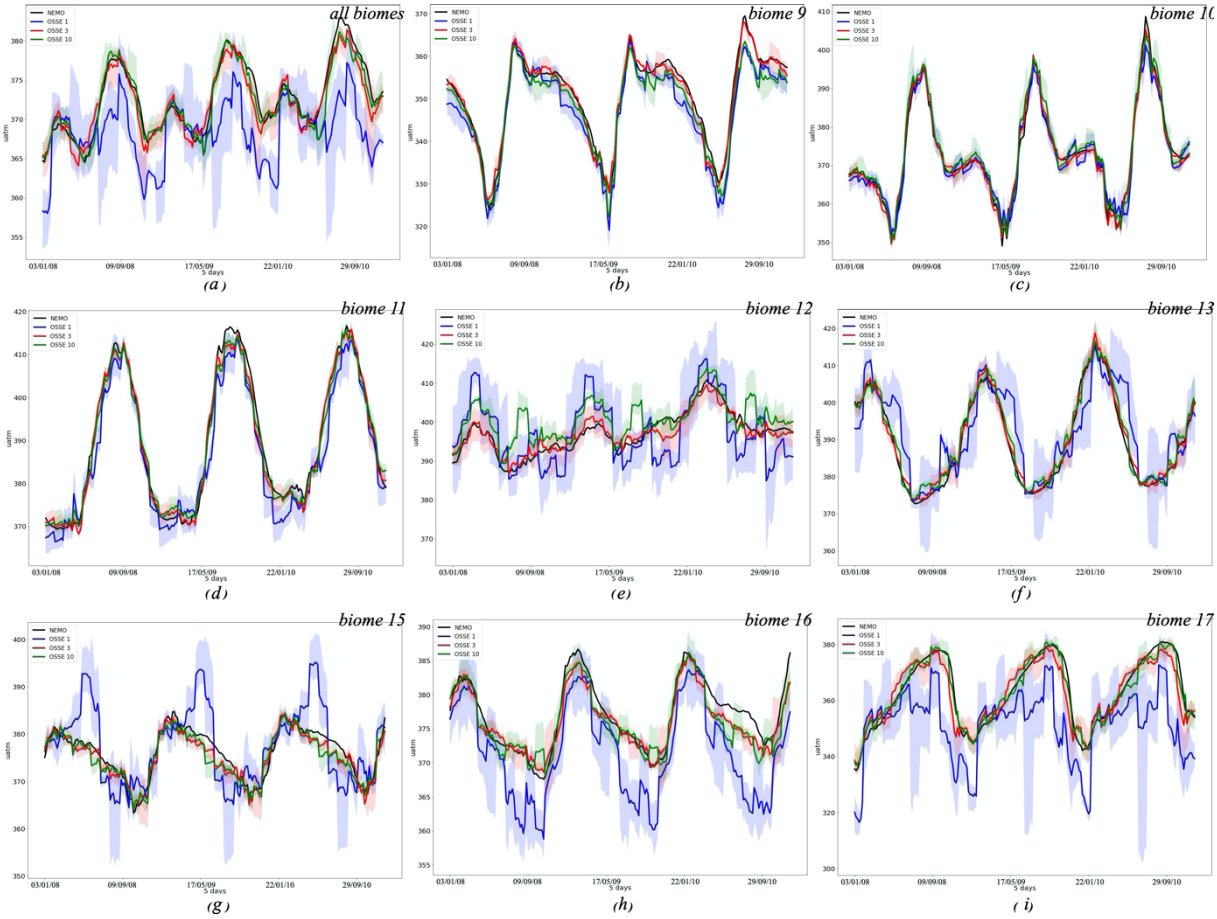

Figure S5: Mean of 4 FFNN outputs for OSSE 1 (blue), 3 (red), 10 (green); shadow is the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES pCO_2. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

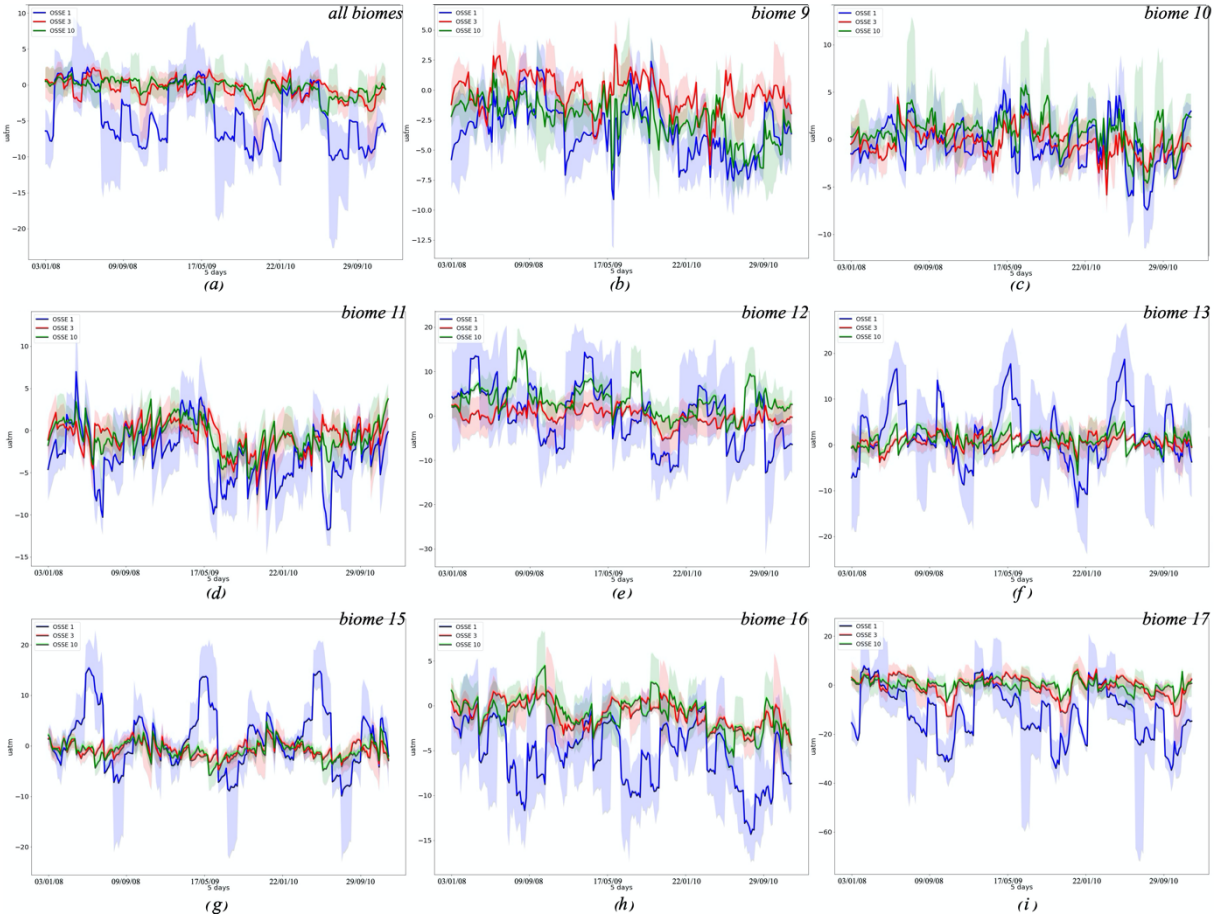

Figure S6: Mean of differences between OSSE 1 (blue), 3 (red), 10 (green) of 4 FFNN outputs and NEMO/PISCES pCO_2; shadow is the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

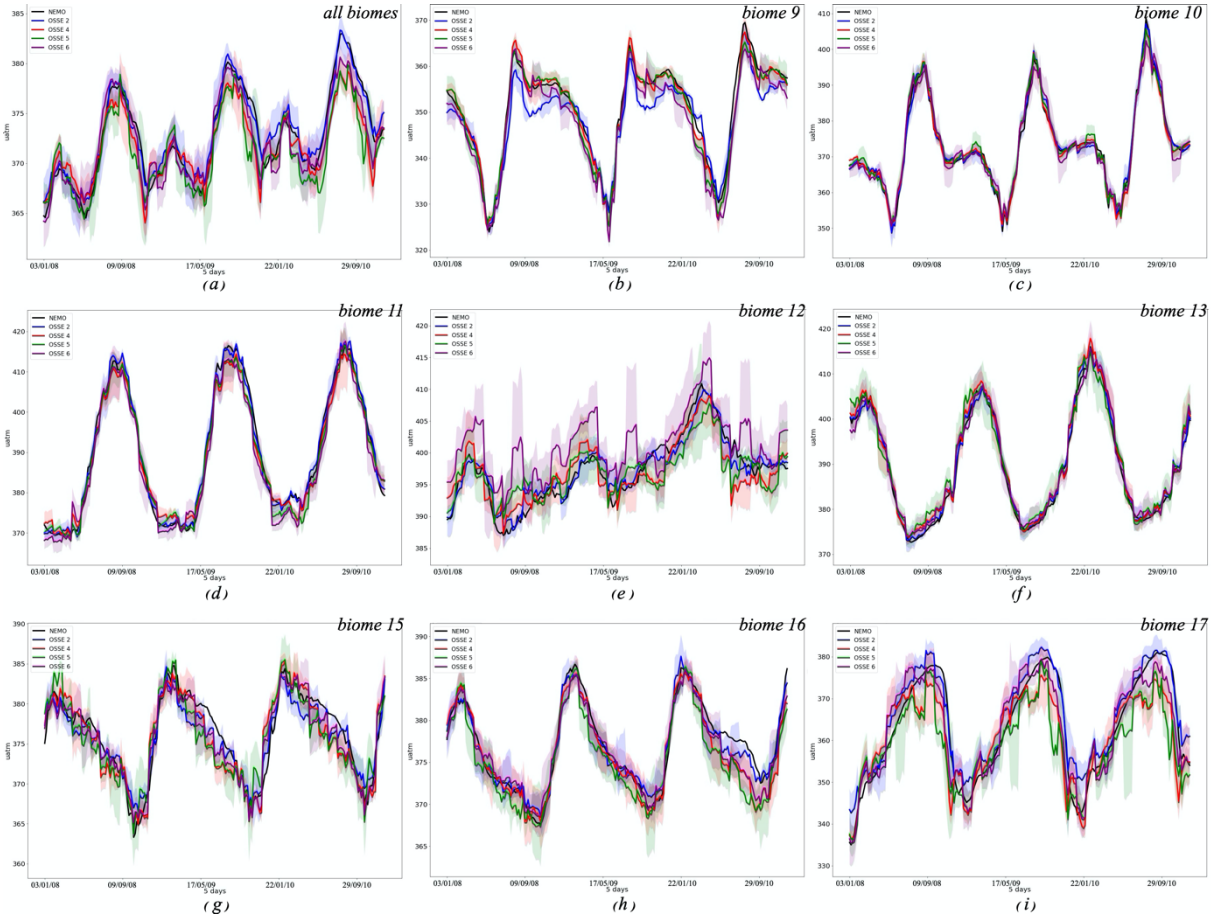

Figure S7: Mean of 4 FFNN outputs for OSSE 2 (blue), 4 (red), 5 (green), 6 (purple); shadow is the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES pCO_2. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

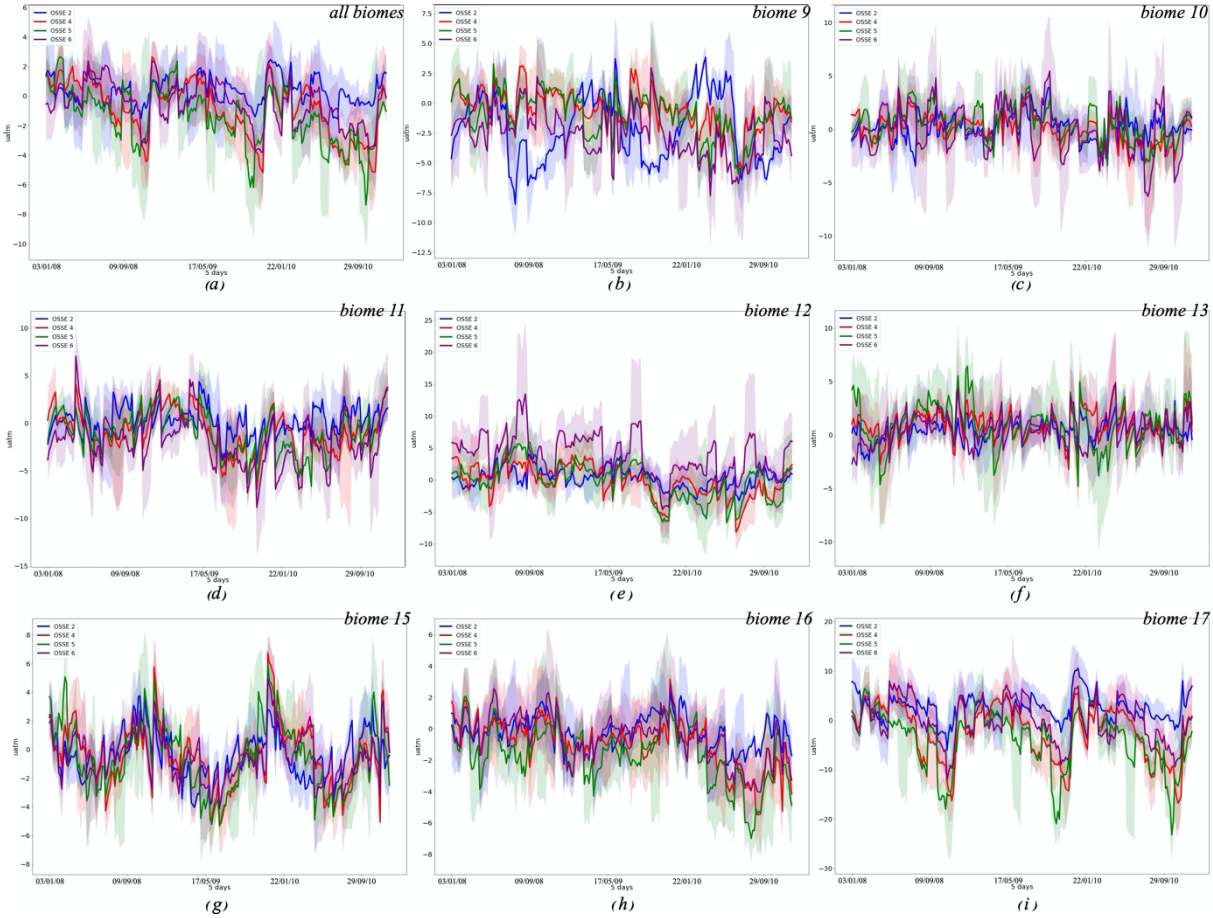

Figure S8: Mean of differences between OSSE 2 (blue), 4 (red), 5 (green), 6 (purple) of 4 FFNN outputs and NEMO/PISCES pCO_2; shadow is the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

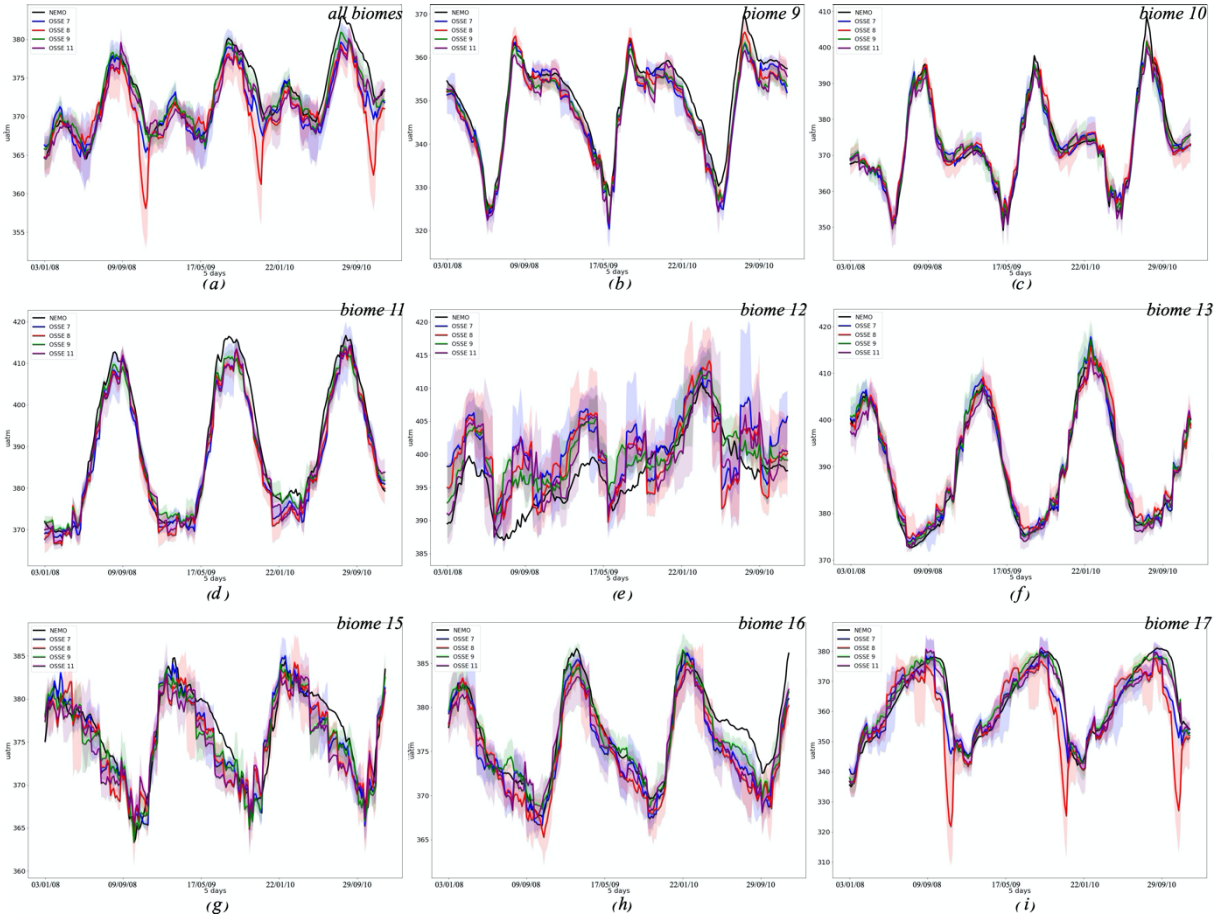

Figure S9: Mean of 4 FFNN outputs for OSSE 7 (blue), 8 (red), 9 (green), 11 (purple); shadow is the maximum and minimum values from 4 FFNN outputs for each OSSE. Black curve - NEMO/PISCES pCO_2. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

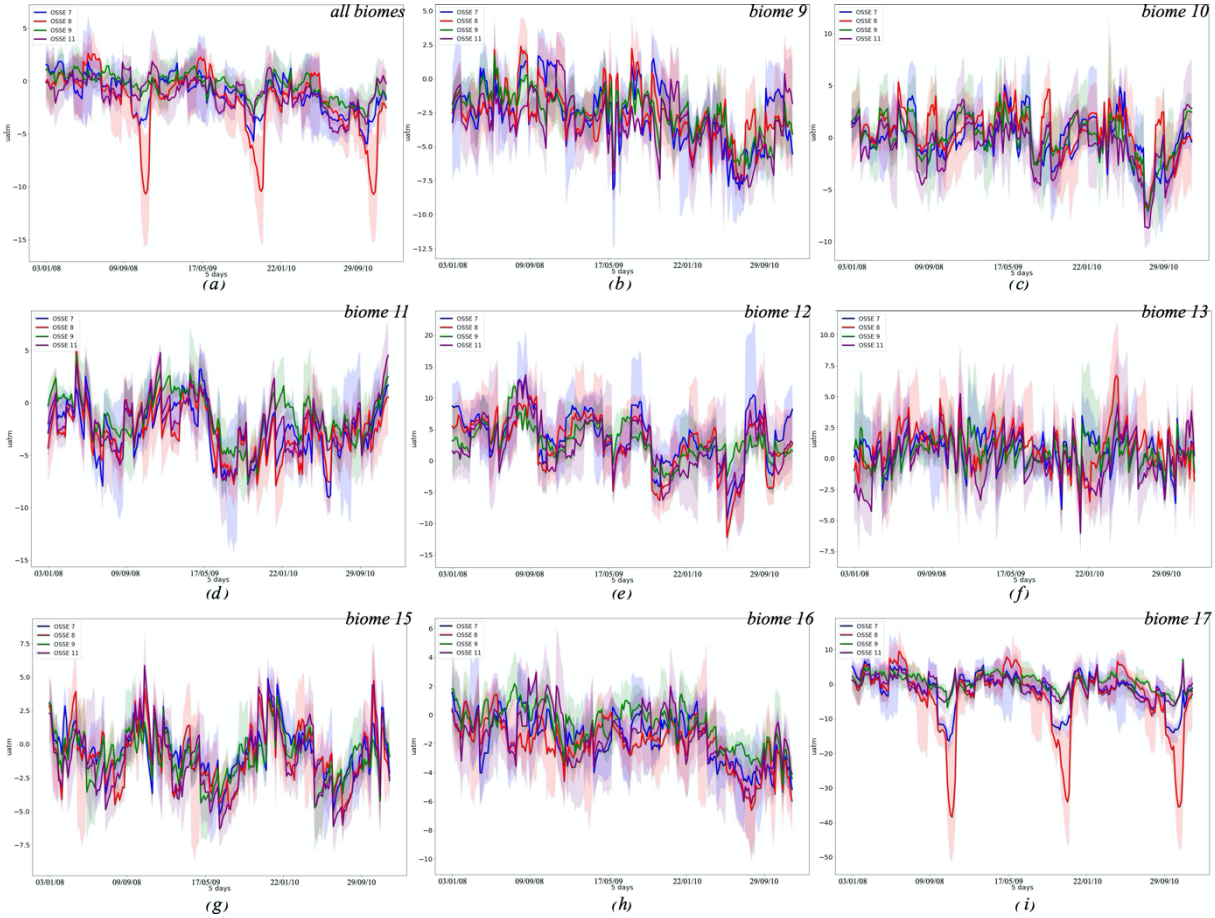

Figure S10: Mean of differences between OSSE 7 (blue), 8 (red), 9 (green), 11 (purple) of 4 FFNN outputs and NEMO/PISCES pCO_2; shadow is the maximum and minimum values of differences from 4 FFNN outputs for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

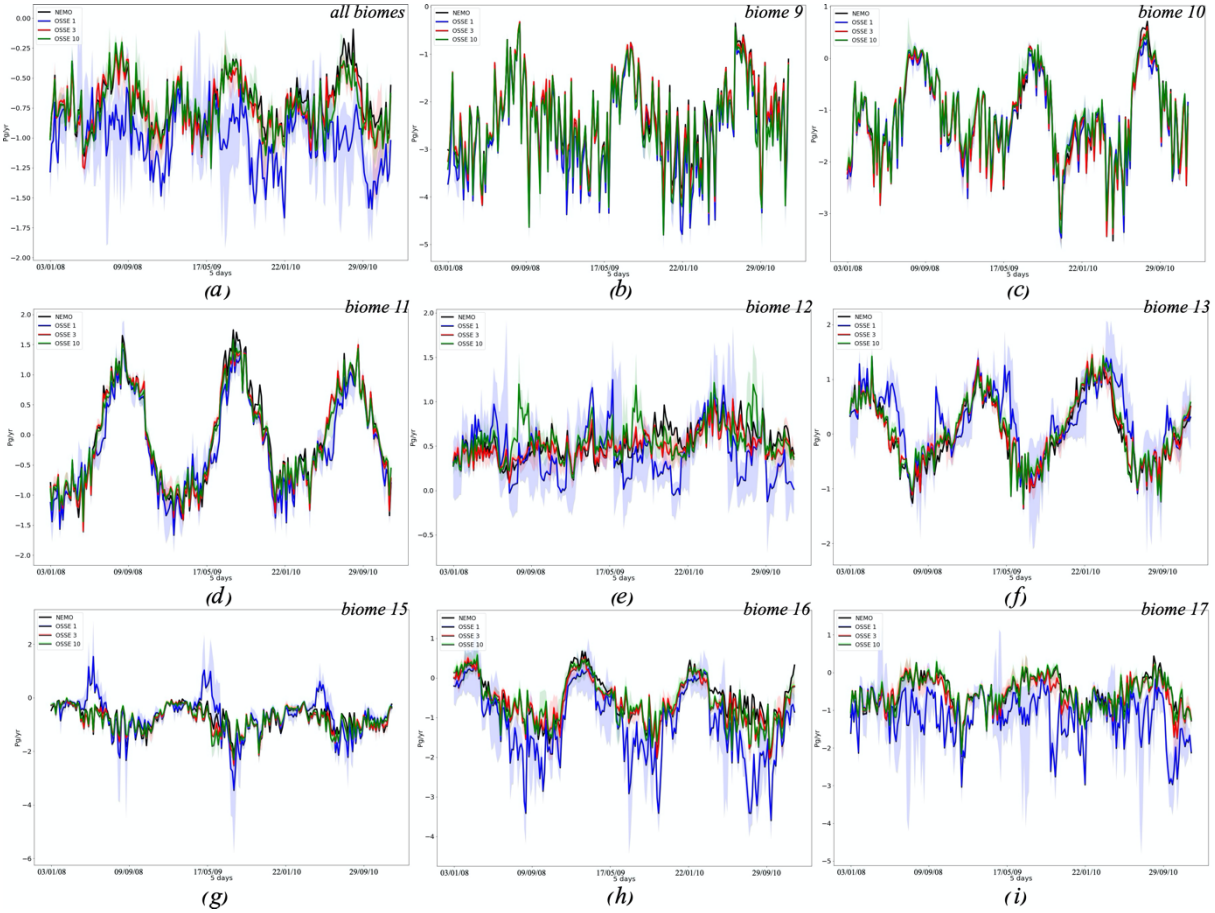

Figure S11: Mean of air-sea CO_2 flux from 4 FFNN outputs for OSSE 1 (blue), 3 (red), 10 (green); shadow is the maximum and minimum values from 4 FFNN sea-air CO_2 flux for each OSSE. Black curve - NEMO/PISCES *fg*CO_2. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

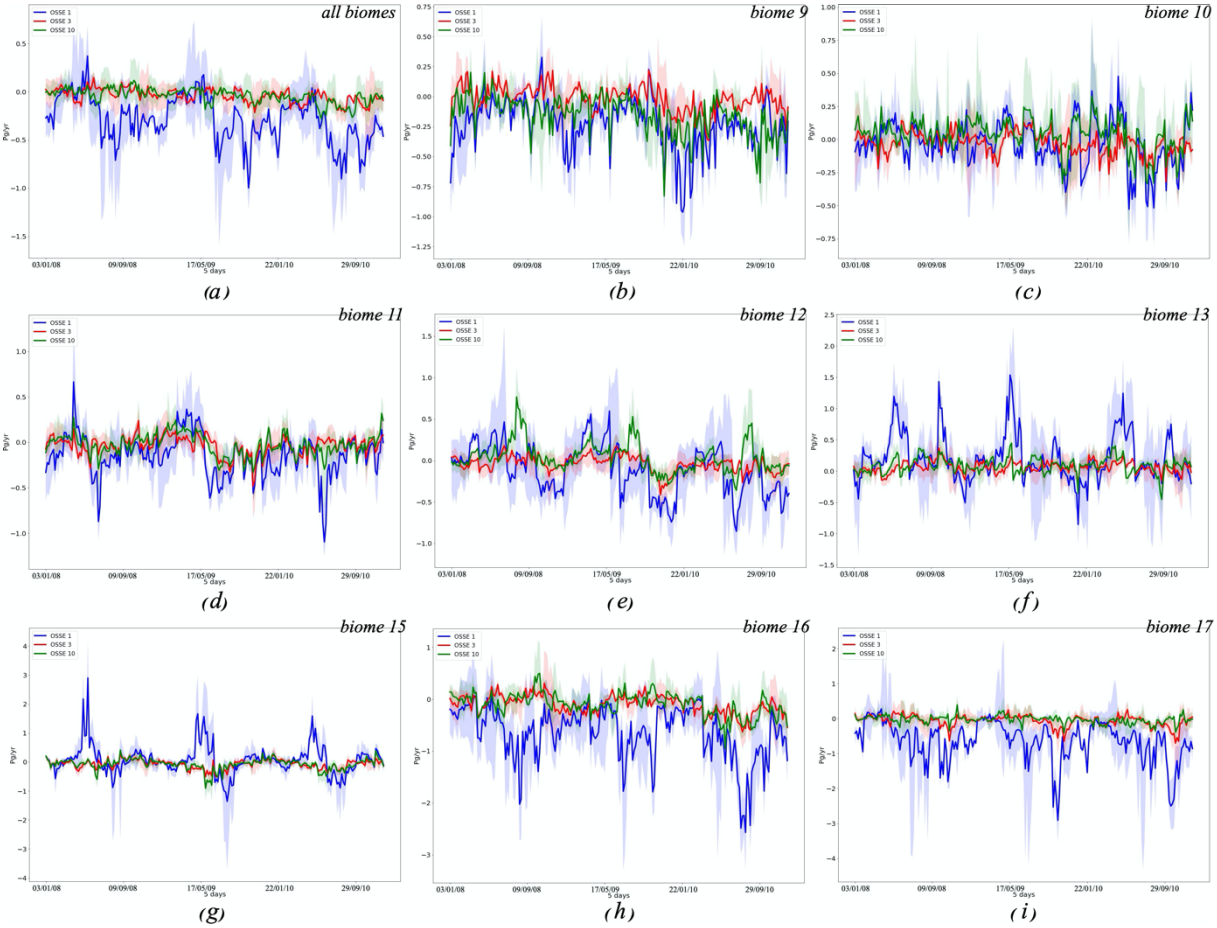

Figure S12: Mean of differences between OSSE 1 (blue), 3 (red), 10 (green) *fg*CO_2 of 4 FFNN outputs and NEMO/PISCES fgCO_2; shadow is the maximum and minimum values of differences from 4 FFNN *fg*CO_2 for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

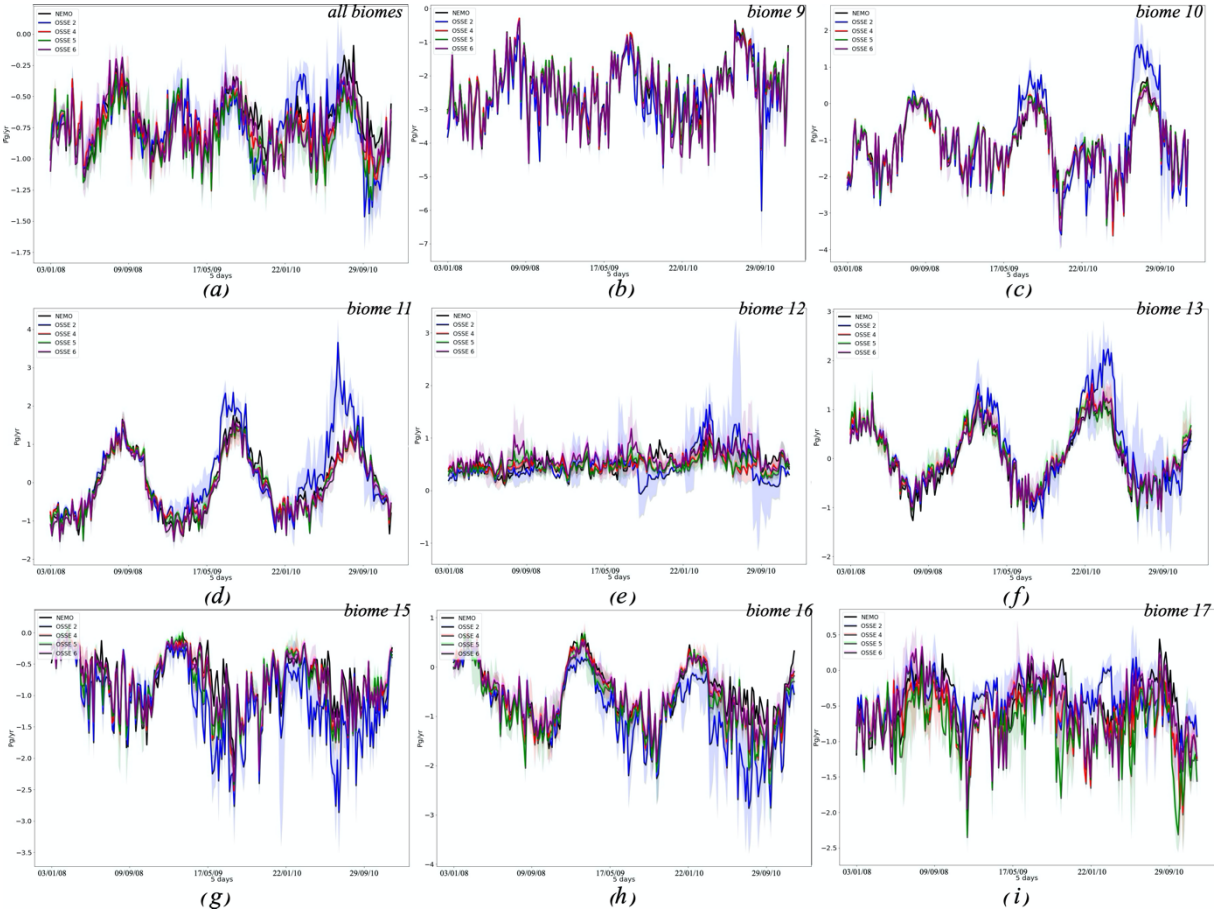

Figure S13: Mean of air-sea CO_2 flux from 4 FFNN outputs for OSSE 2 (blue), 4 (red), 5 (green), 6 (purple); shadow is the maximum and minimum values from 4 FFNN sea-air CO_2 flux for each OSSE. Black curve - NEMO/PISCES $fgCO_2$. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

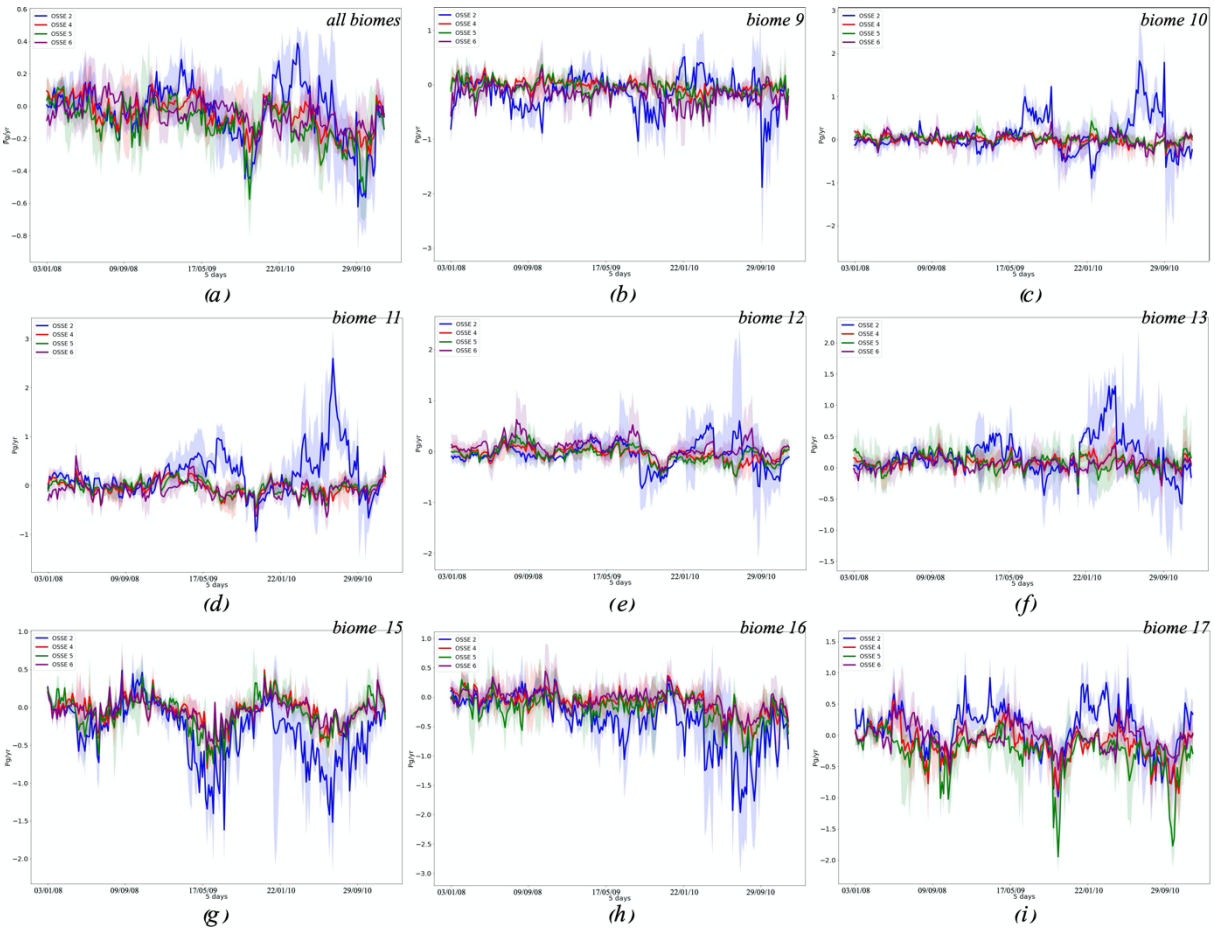

Figure S14: Mean of differences between OSSE 2 (blue), 4 (red), 5 (green), 6 (purple) $fgCO_2$ of 4 FFNN outputs and NEMO/PISCES $fgCO_2$; shadow is the maximum and minimum values of differences from 4 FFNN $fgCO_2$ for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

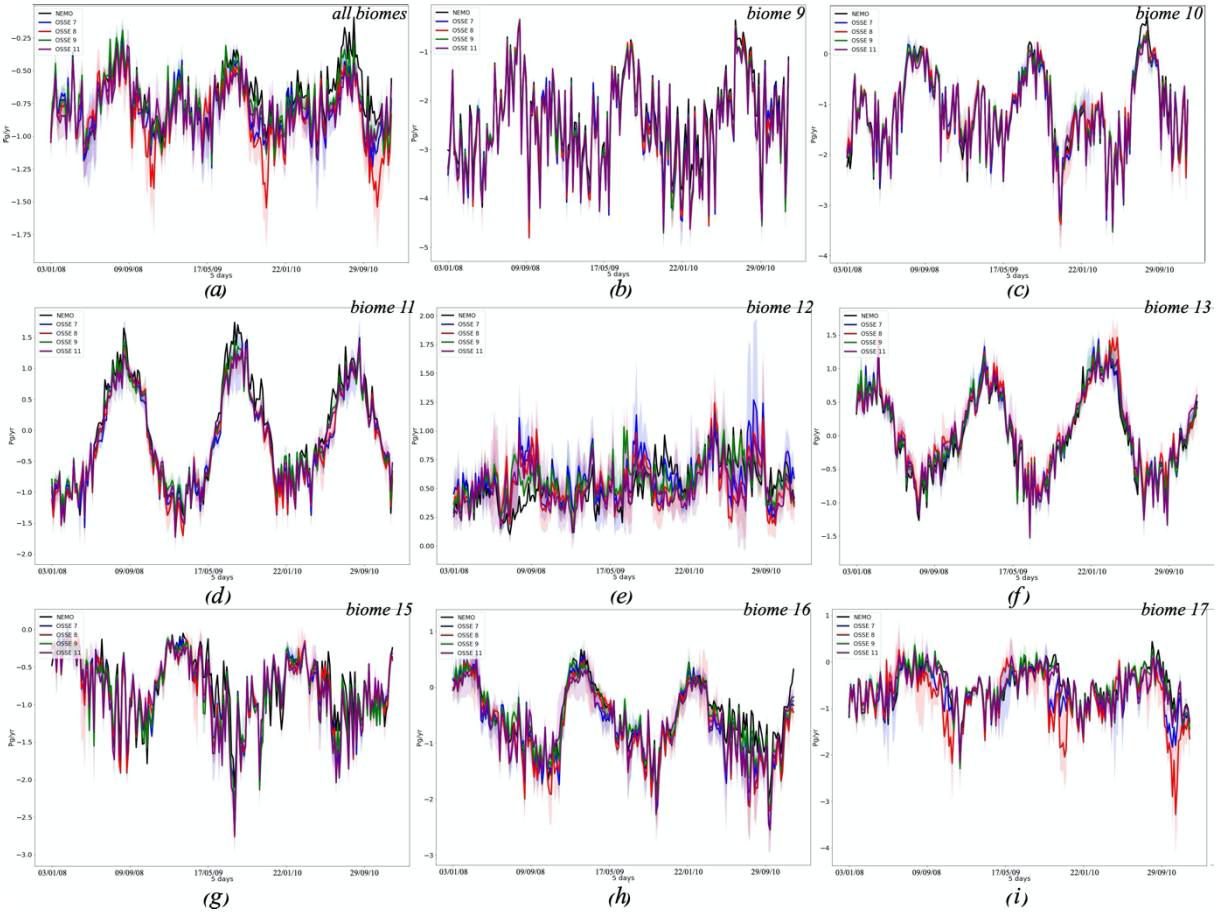

Figure S15: Mean of air-sea CO_2 flux from 4 FFNN outputs for OSSE 7 (blue), 8 (red), 9 (green), 11 (purple); shadow is the maximum and minimum values from 4 FFNN sea-air CO_2 flux for each OSSE. Black curve - NEMO/PISCES *fg*CO_2. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

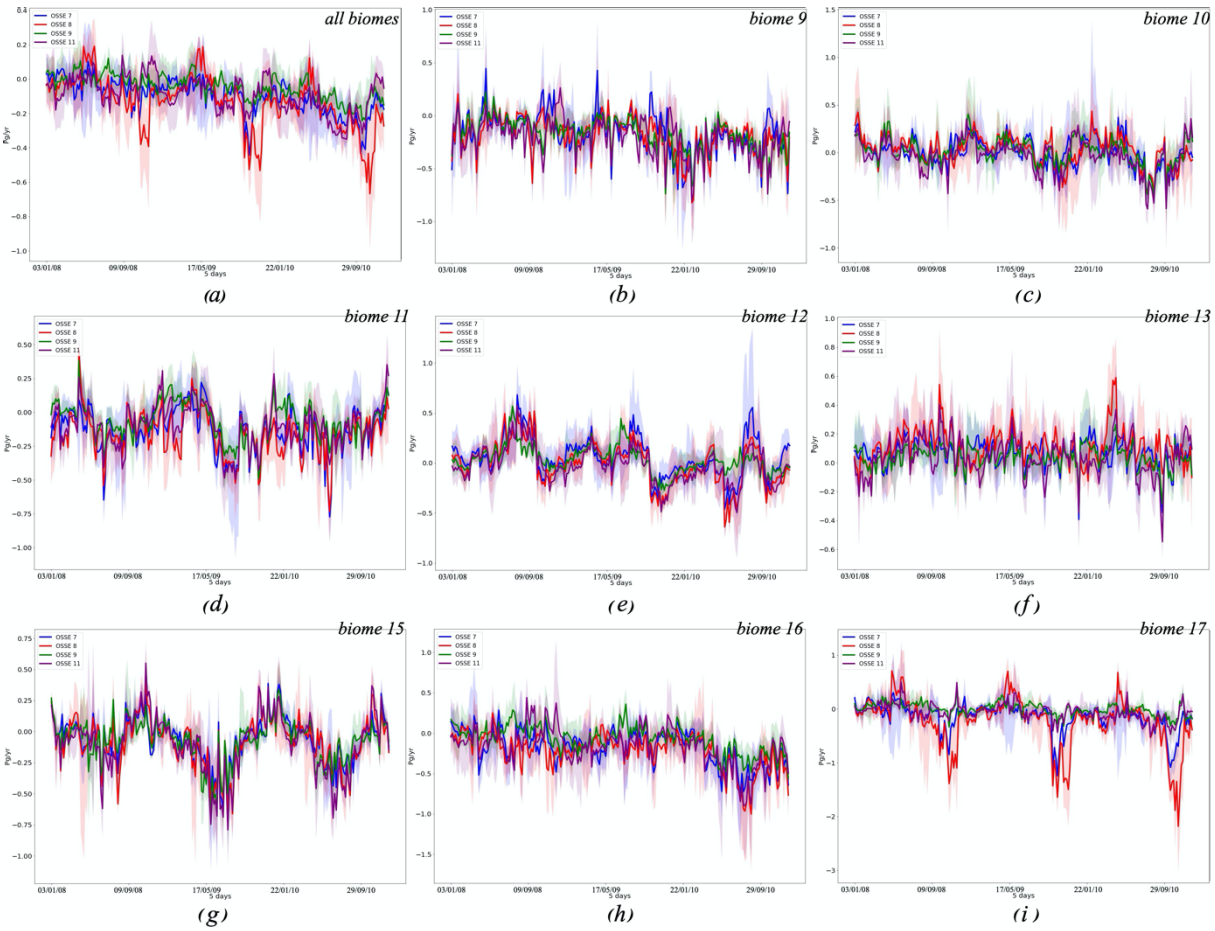

Figure S16: Mean of differences between OSSE 7 (blue), 8 (red), 9 (green), 11 (purple) $fgCO_2$ of 4 FFNN outputs and NEMO/PISCES $fgCO_2$; shadow is the maximum and minimum values of differences from 4 FFNN $fgCO_2$ for each OSSE. (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

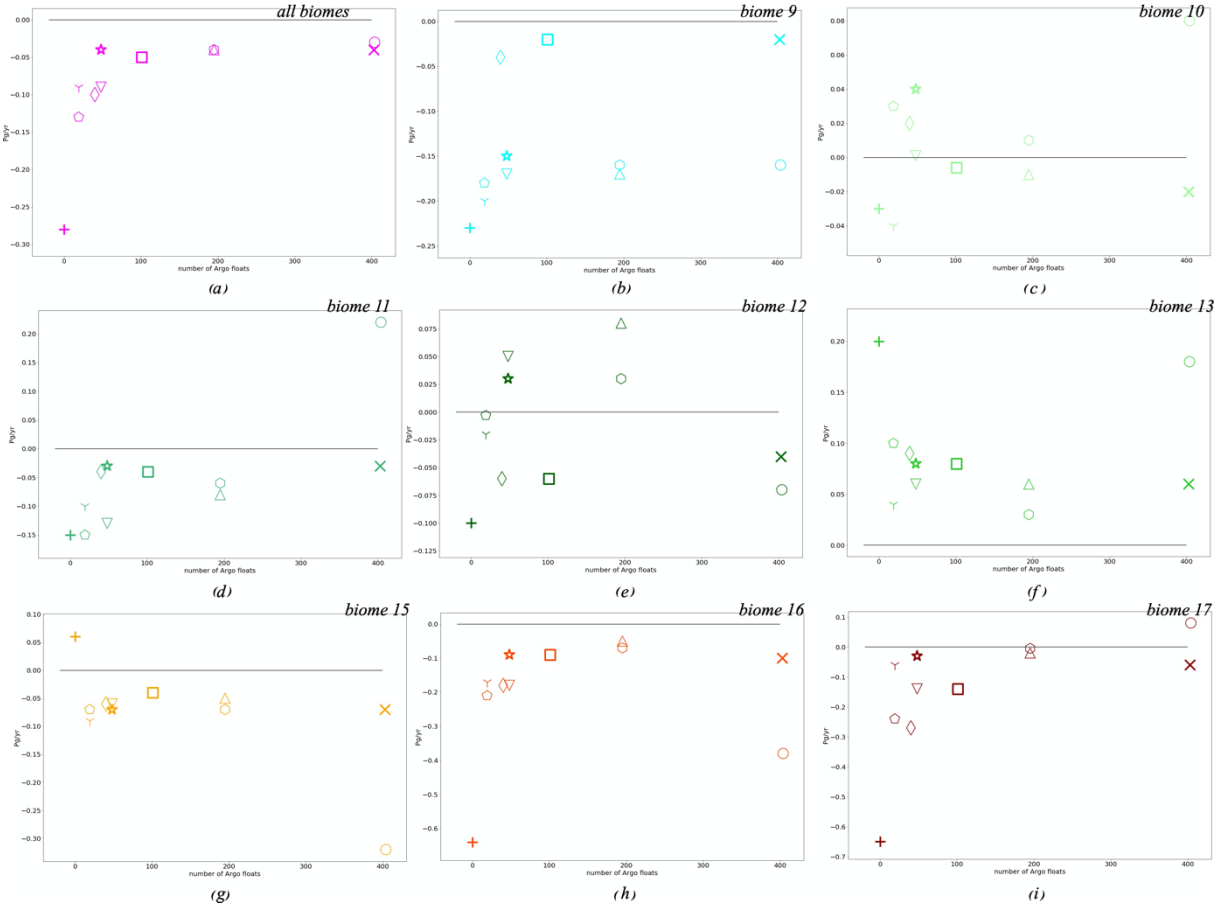

Figure S17: Averaged number of Argo profiles per 5 day time step over 2008-2010 versus averaged differences between each OSSEs $fgCO_2$ and NEMO/PISCES $fgCO_2$ (in Pg/yr). (a) - all 8 biomes; (b) - biome 9; (c) - biome 10; (d) - biome 11; (e) - biome 12; (f) - biome 13; (g) - biome 15; (h) - biome 16; (i) - biome 17.

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

Month OSSE	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 pCO_2 and its standard deviation (STD) (Eq. 5) in μatm.

Biome OSSE	Region 70ºW-30ºE 80ºS-80ºN	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

Table S3: Correlation coefficient between OSSEs and NEMO/PISCES pCO_2.

Biome OSSE	Region 70ºW-30ºE 80ºS-80ºN	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: pCO_2 averaged over the region 70ºW-30ºE 80ºS-80ºN 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	Region 70ºW-30ºE 80ºS-	All 8 biomes	9	10	11	12	13	15	16	17

OSSE	80ºN									
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: *fg*CO_2 averaged over the region 70ºW-30ºE 80ºS-80ºN 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 OSSE	Region 70ºW-30ºE 80ºS-80ºN	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