

Marine Heatwaves and Ocean-Atmosphere Synergies in the North Atlantic

Supplementary material

Table S1. Longhurst provinces modified from [35]. On the left the common name and on the right the short name used in this study.

Province Name	Short name
Polar – Atlantic Arctic	Polar - Arctic
Polar – Atlantic Subarctic	Polar – Subarctic
Polar – Boreal Polar	Polar – Boreal
Coastal – NE Atlantic Shelves	Coastal – NE Shelves
Coastal – NW Atlantic Shelves	Coastal – NW Shelves
Coastal – Canary Coastal	Coastal - Canary
Westerlies – N. Atlantic Subtropical Gyre (East)	Westerlies- East
Westerlies – N. Atlantic Subtropical Gyre (West)	Westerlies- West
Westerlies – N. Atlantic Drift	Westerlies - Drift
Westerlies – Gulf Stream	Westerlies – Gulf Stream
Trades – N. Atlantic Tropical Gyrals	Trades – Tropical
Trades – Caribbean	Trades – Caribbean

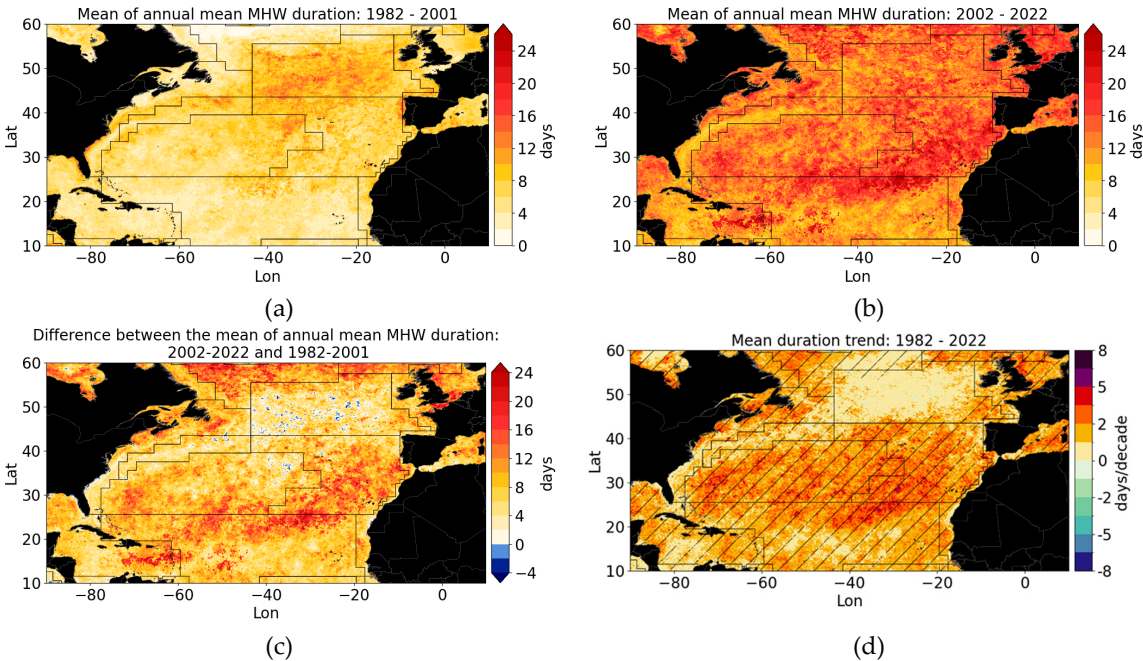


Figure S1. Annual mean duration of MHW events: a) mean between 1982 and 2001, b) mean between 2002 and 2022, c) difference between the two periods, d) trend between 1982 and 2022. The diagonal lines indicate areas where the trends are statistically significant (p-value < 0.05).

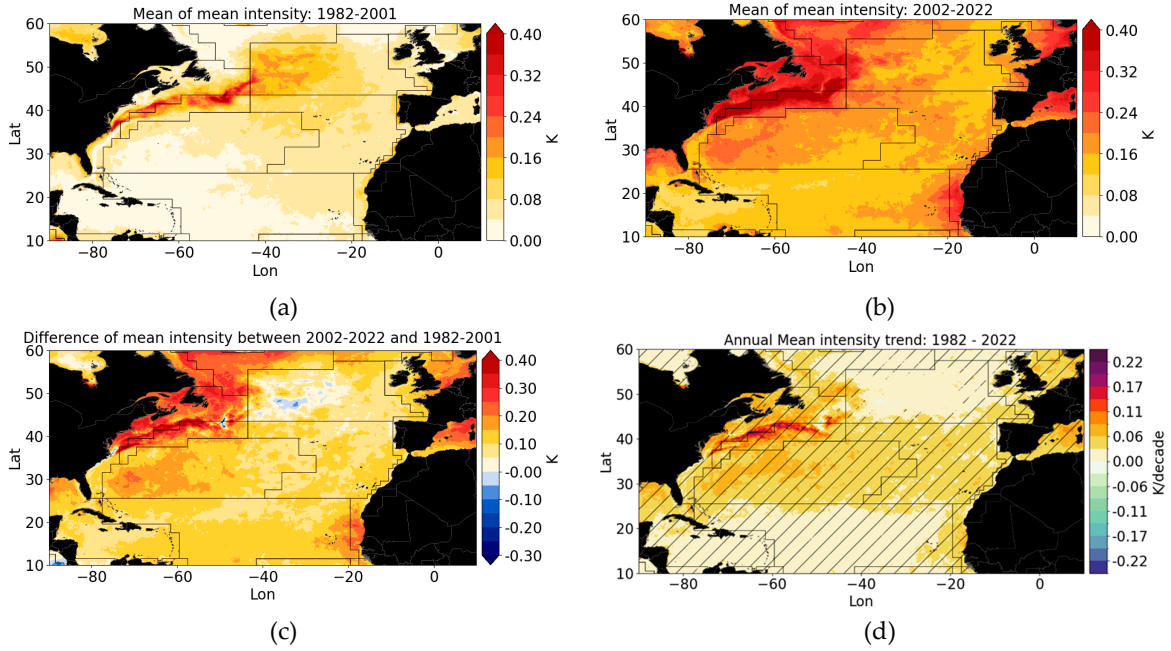


Figure S2. Annual mean intensity of MHW events: a) mean between 1982 and 2001, b) mean between 2002 and 2022, c) difference between the two periods, d) trend between 1982 and 2022. The diagonal lines indicate areas where the trends are statistically significant (p -value < 0.05).

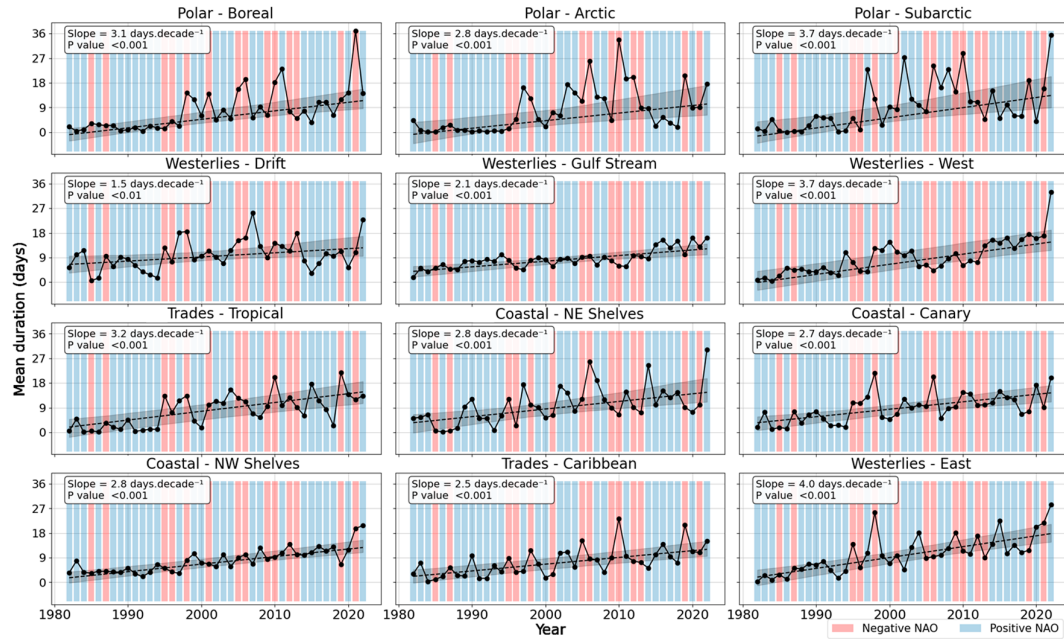


Figure S3. Annual mean MHW duration in each Longhurst province and the corresponding trend. The black-shaded area represents the uncertainty of the trend line. Blue bars denote years with a positive North Atlantic Oscillation (NAO) index, while red bars denote years with a negative NAO index.

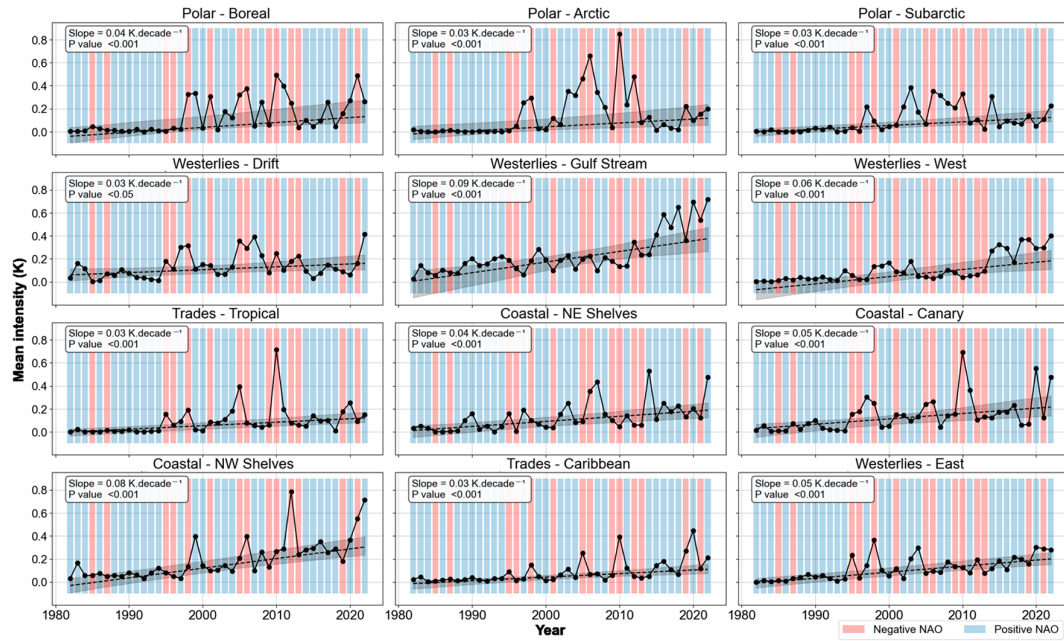


Figure S4. Annual mean MHW intensity in each Longhurst province and the corresponding trend. The black-shaded area represents the uncertainty of the trend line. Blue bars denote years with a positive North Atlantic Oscillation (NAO) index, while red bars denote years with a negative NAO index.

Table S2. Aggregation parameterisation and spatial scale conversion (k is the size of the aggregation window in number of grid cells).

k	Window (°)	Lat size (km)	Lon size (km 45°N)	Interpretation
1	0.05°	~5.5 km	~4 km	Native resolution
2	0.10°	~11 km	~8 km	Sub-mesoscale
4	0.20°	~22 km	~16 km	Mesoscale
8	0.40°	~44 km	~32 km	Regional mesoscale
16	0.80°	~89 km	~64 km	Large regional
32	1.60°	~178 km	~128 km	Basin-scale smoothing
64	3.20°	~356 km	~256 km	Basin-scale smoothing

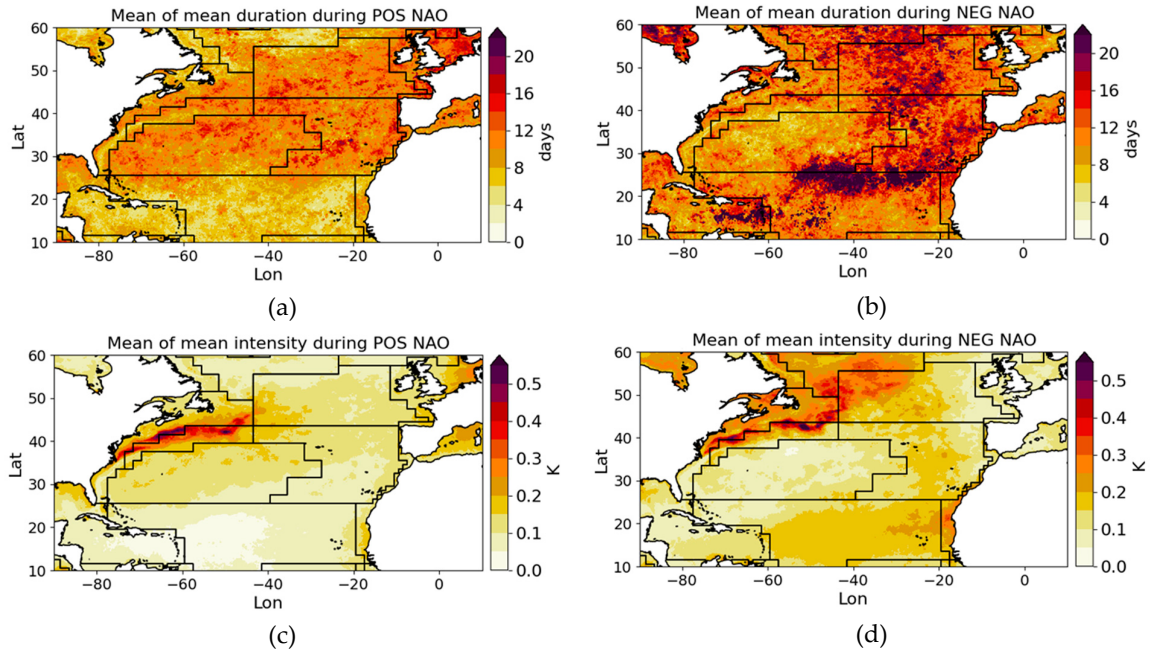


Figure S5. Mean MHW properties for composites of positive and negative NAO years: a), b) mean duration, c), d) mean intensity.

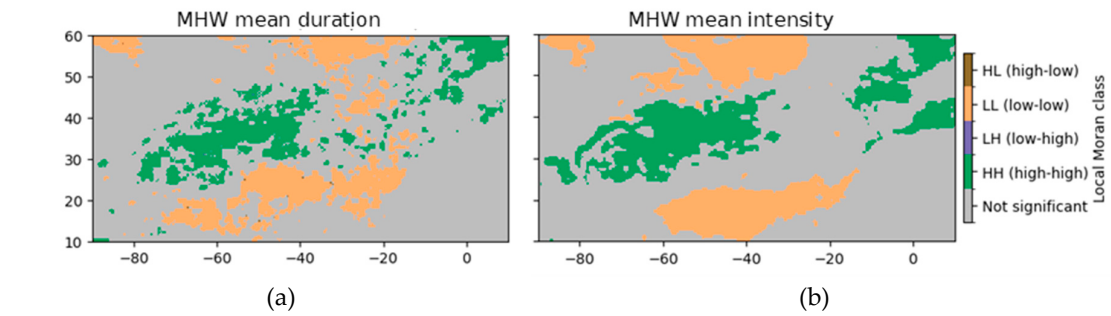
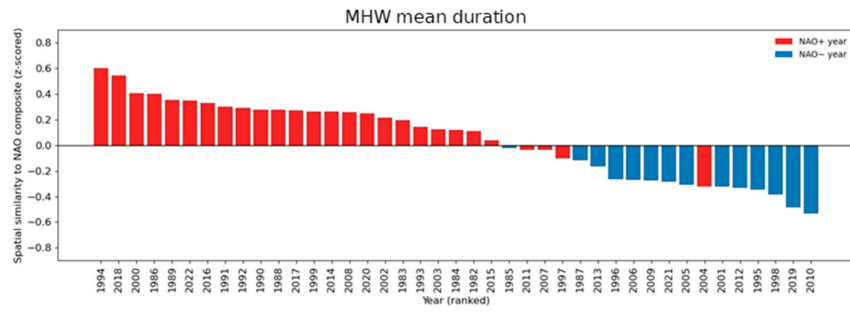
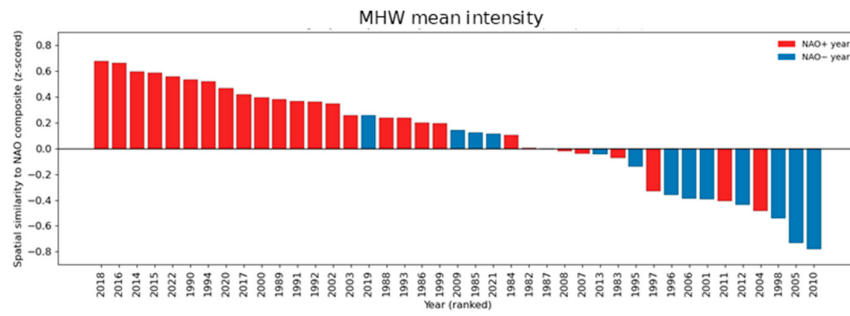


Figure S6. Local Moran's I (LISA) cluster maps for NAO-conditioned composite differences in a) MHW mean duration, b) MHW mean intensity. Results are shown at an aggregation scale of $k = 8$.



(a)



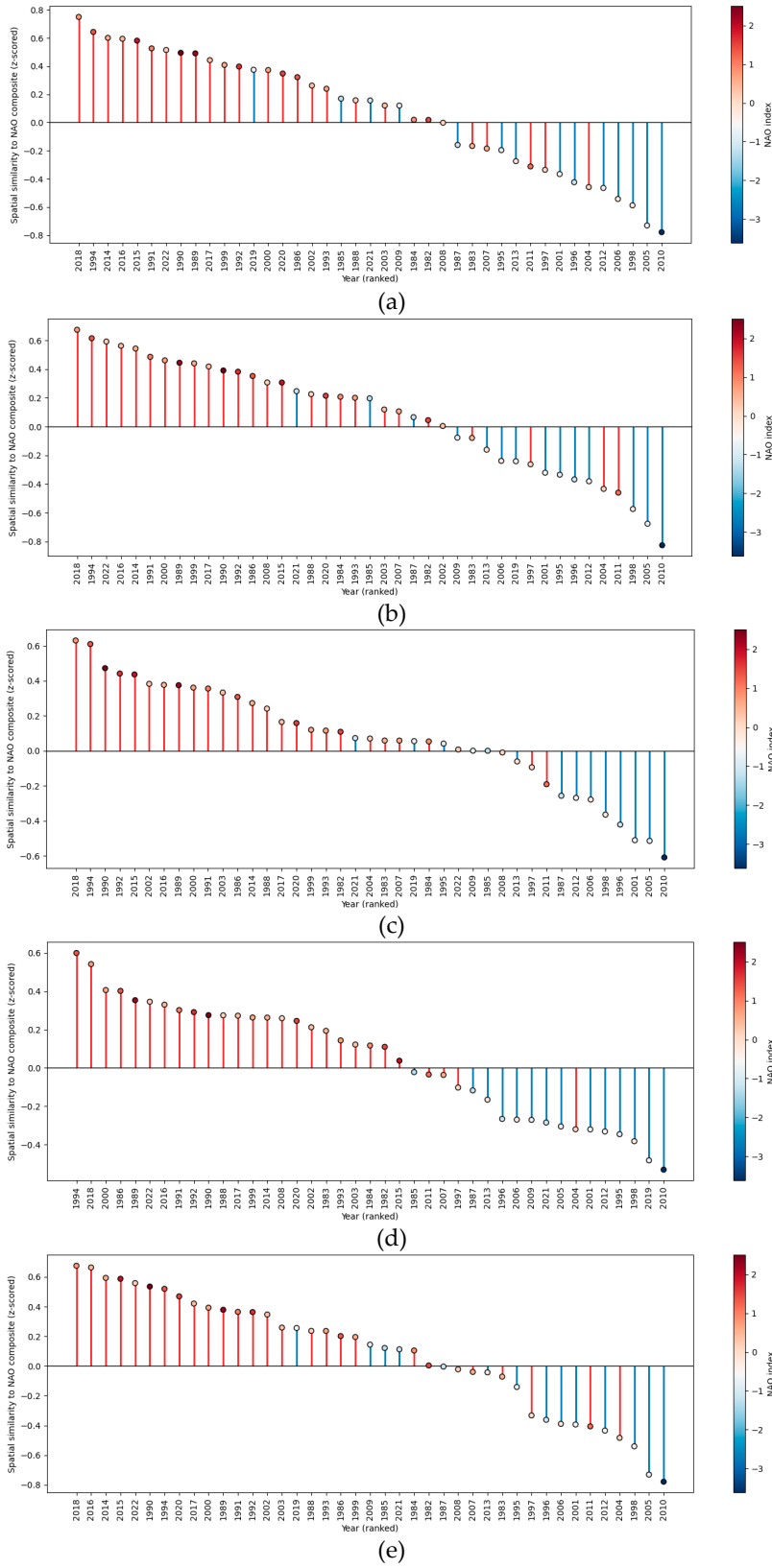


Figure S8. Spatial similarity to the NAO composite and NAO annual index: a) frequency, b) max duration, c) max intensity, d) mean duration, e) mean intensity.

Table S1. Moran's I, RMSE and MAD statistics and p-values calculated with a permutation test for aggregation levels 2 to 32.

MHW metric	k	Window (°)	Moran's I	p-value	RMSE	p-value	MAD	p-value
MHW frequency (n events)	2	0.1	0.97	0.05	0.85	0.06	0.59	0.07
	4	0.2	0.96	0.05	0.84	0.07	0.59	0.07
	8	0.4	0.95	0.05	0.83	0.07	0.58	0.07
	16	0.8	0.94	0.05	0.81	0.07	0.57	0.07
	32	1.6	0.92	0.05	0.80	0.07	0.57	0.07
MHW max duration (days)	2	0.1	0.99	0.03	9.60	0.02	5.91	0.04
	4	0.2	0.98	0.03	9.54	0.02	5.87	0.04
	8	0.4	0.97	0.03	9.50	0.02	5.81	0.04
	16	0.8	0.96	0.03	9.35	0.02	5.72	0.05
	32	1.6	0.94	0.04	9.23	0.02	5.65	0.05
MHW max intensity (K)	2	0.1	0.97	0.01	0.53	0.03	0.42	0.04
	4	0.2	0.95	0.01	0.52	0.04	0.41	0.04
	8	0.4	0.93	0.01	0.51	0.05	0.41	0.05
	16	0.8	0.91	0.01	0.50	0.05	0.40	0.05
	32	1.6	0.89	0.03	0.49	0.05	0.40	0.05
MHW mean duration (days)	2	0.1	0.92	0.02	4.41	0.02	2.74	0.03
	4	0.2	0.89	0.02	4.27	0.02	2.67	0.04
	8	0.4	0.88	0.02	4.10	0.02	2.58	0.04
	16	0.8	0.87	0.02	3.88	0.03	2.46	0.04
	32	1.6	0.84	0.03	3.71	0.03	2.38	0.04
MHW mean intensity (K)	2	0.1	1.00	0.04	0.09	0.03	0.07	0.04
	4	0.2	0.99	0.03	0.09	0.03	0.07	0.04
	8	0.4	0.98	0.04	0.09	0.04	0.07	0.04
	16	0.8	0.95	0.04	0.09	0.04	0.07	0.04
	32	1.6	0.93	0.05	0.08	0.04	0.04	0.04

Table S2. Similarity metrics (correlation) and number of significant cells for different aggregation levels.

k	MHW Frequency		MHW Max Duration		MHW Mean Duration		MHW Max Intensity		MHW Mean Intensity	
	Similarity	N Sig. cells	Similarity	N Sig. cells	Similarity	N Sig. cells	Similarity	N Sig. cells	Similarity	N Sig. cells
2	0.63	192883	0.62	159133	0.73	141669	0.74	130608	0.61	158922
4	0.62	49135	0.62	41690	0.72	32713	0.73	34034	0.60	40853
8	0.61	11981	0.60	9651	0.71	8878	0.72	8989	0.60	9685
16	0.60	3093	0.59	2397	0.70	2242	0.71	2160	0.61	2426
32	0.59	794	0.58	609	0.69	537	0.70	573	0.61	683

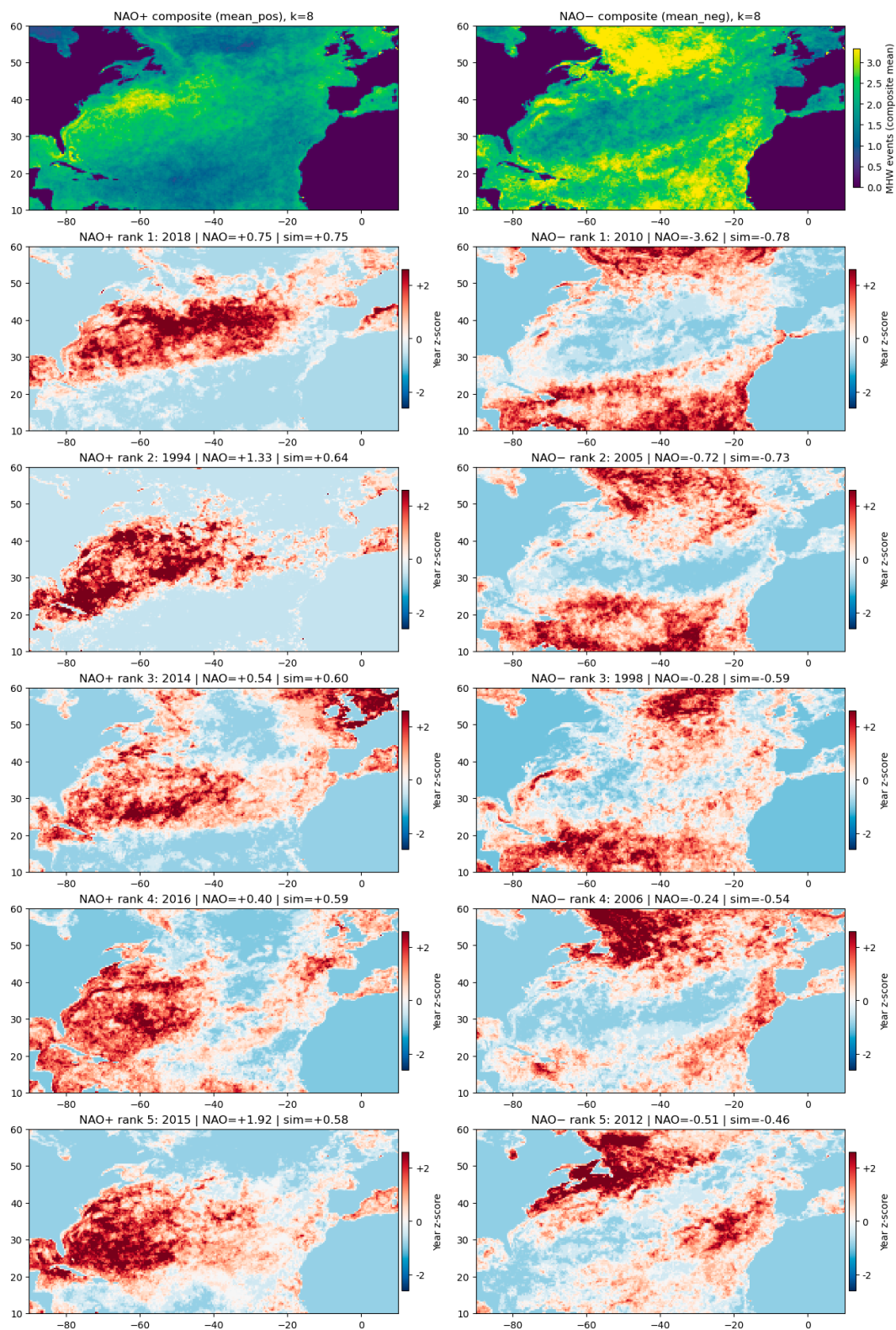


Figure S9. Years exhibiting the highest similarity to the NAO composite pattern for the annual frequency metric. Left panels correspond to positive NAO phases, while right panels correspond to negative NAO phases.

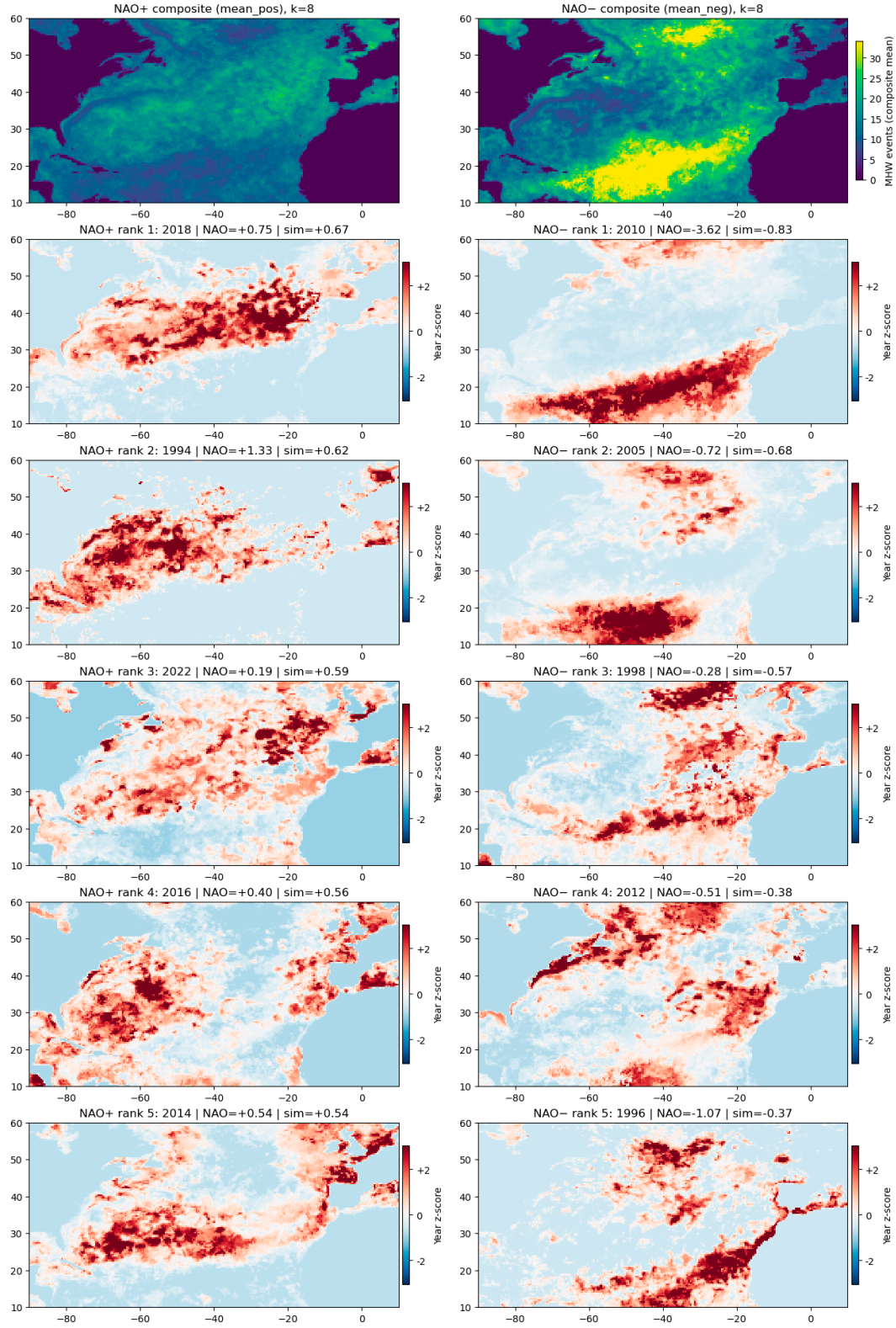


Figure S10. Years exhibiting the highest similarity to the NAO composite pattern for the annual maximum duration metric. Left panels correspond to positive NAO phases, while right panels correspond to negative NAO phases.

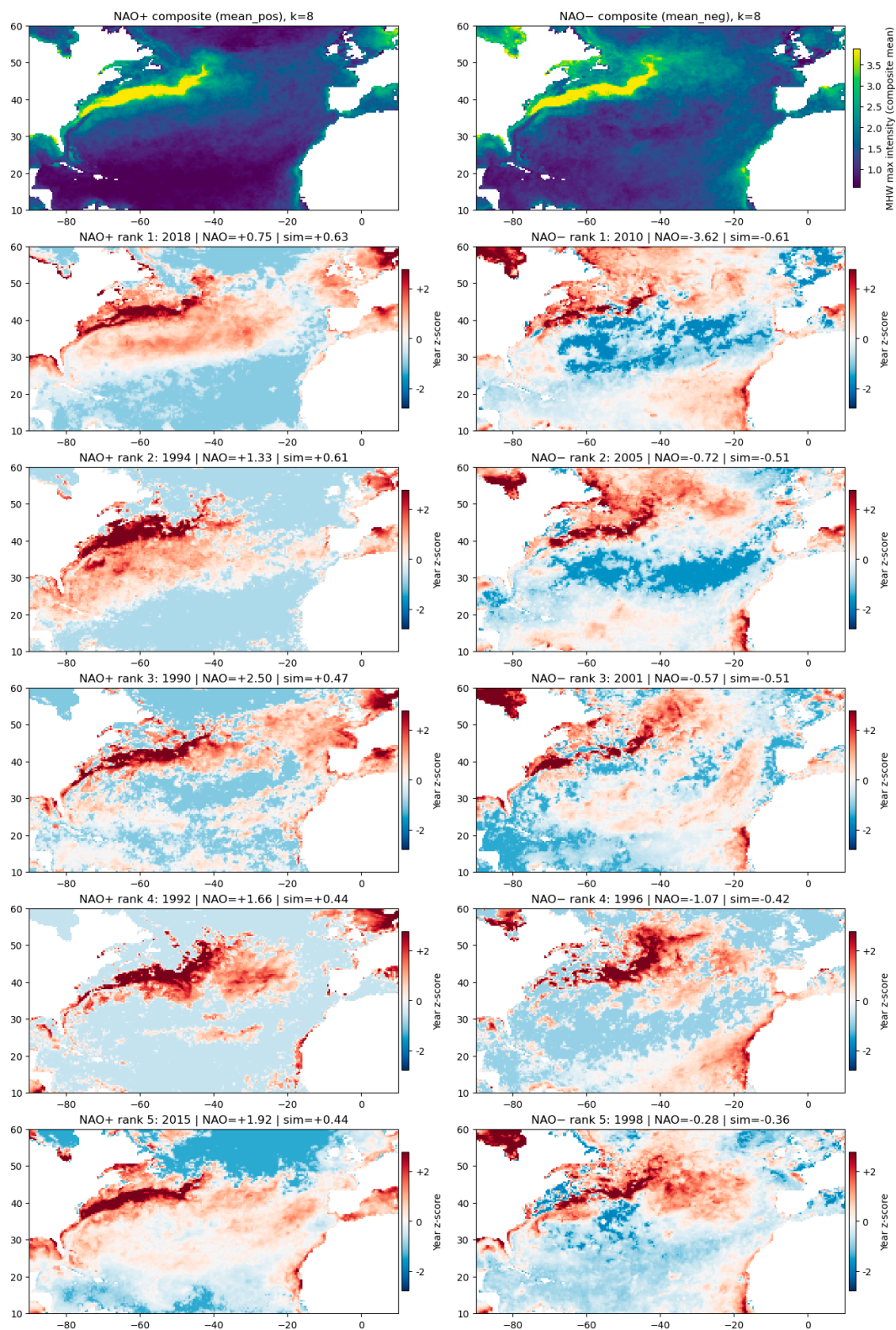


Figure S11. Years exhibiting the highest similarity to the NAO composite pattern for the annual maximum intensity metric. Left panels correspond to positive NAO phases, while right panels correspond to negative NAO phases.