

Long-Term Common Trends of Water Quality in Korean Waters

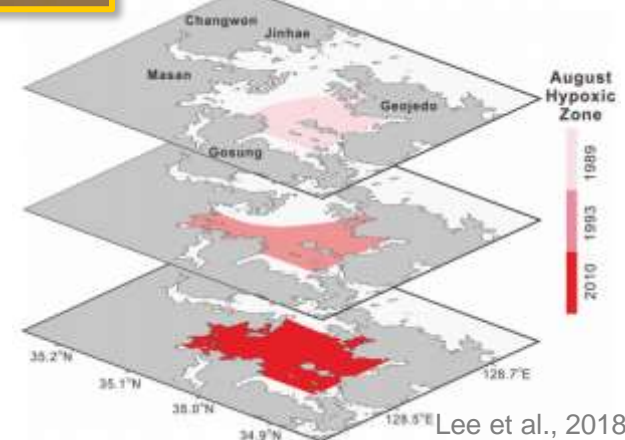
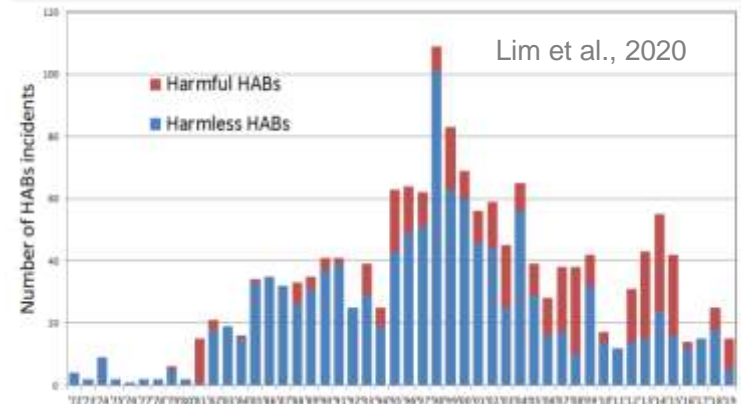
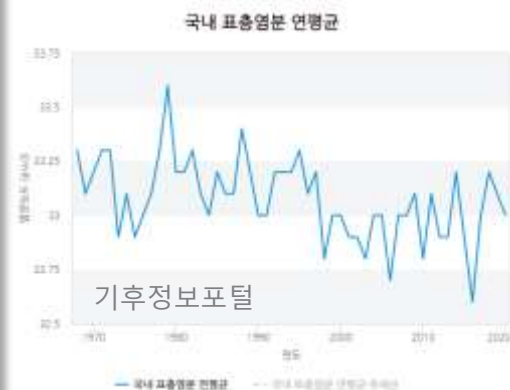
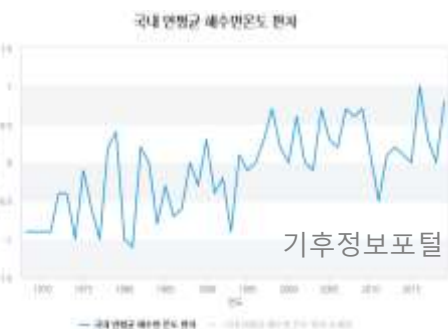
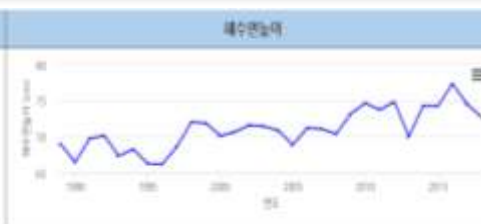
Chun Ok Jo^{1),*}, Jeong Hyeon Kim²⁾, and Jongseong Ryu³⁾

1) Oceanscitech Inc., Incheon, Korean

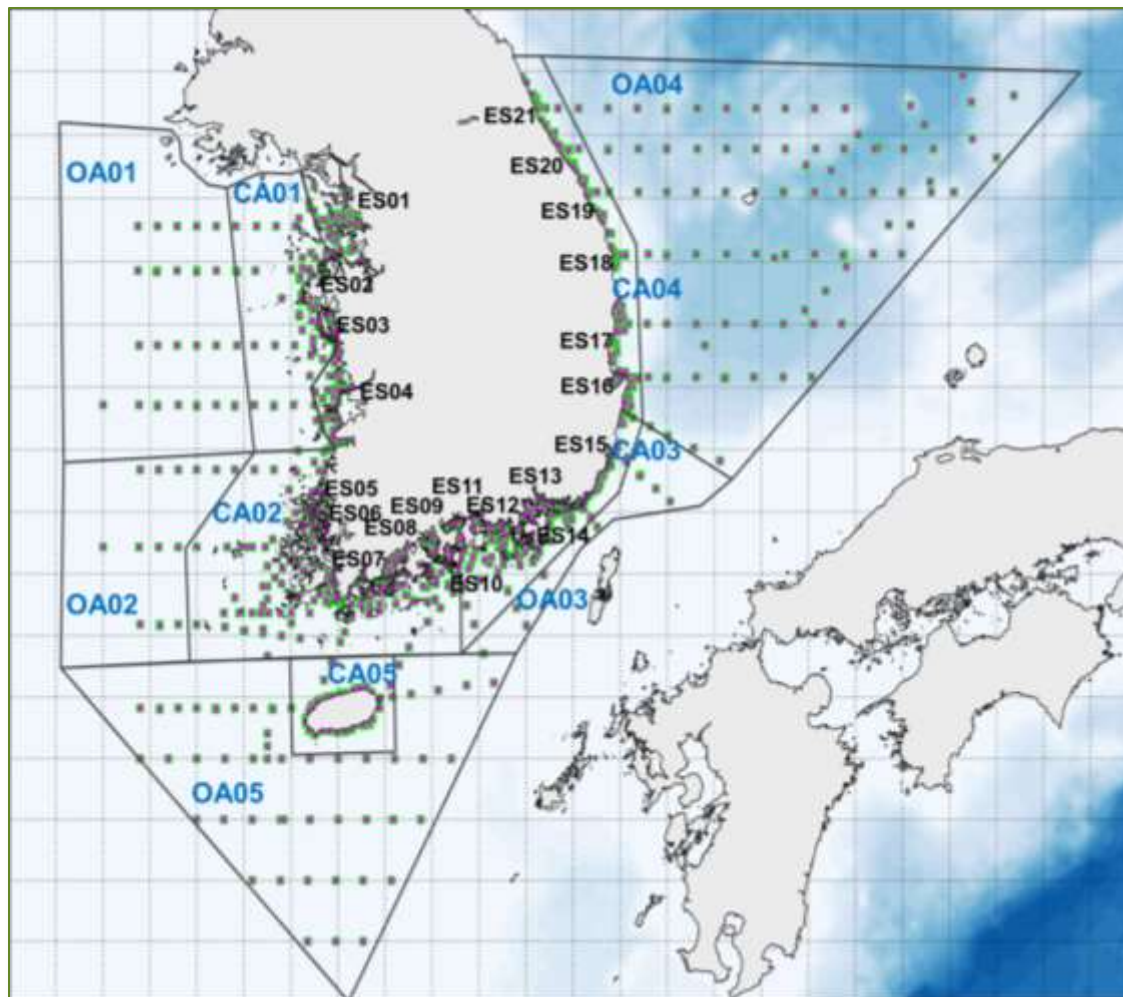
2) Department of Ocean Integrated Science, Chonnam National University, Korea

3) Department of Marine Biotechnology, Anyang University, Korea

Water Quality in Korean Waters and Climate Change



Korean Waters and Long-Term monitoring Stations



Code	Area
CA01	West Sea Central Coast
CA02	Southwestern Coast
CA03	Korean strait Coast
CA04	East Sea Coast
CA05	Jeju Coast
ES01	Han river Estuary
ES02	Garorim Bay
ES03	Cheonsu Bay
ES04	Geum River Estuary
ES05	Hampyeong Bay
ES06	Yeongsan River Estuary
ES07	Doam Bay
ES08	Deungnyang Bay
ES09	Yeoja Bay
ES10	Gamak Bay
ES11	Seomjin River Estuary
ES12	Jinju Bay
ES13	Jinhae Bay
ES14	Nakdong River Estuary
ES15	Tachwa River Estuary
ES16	Yeongil Bay
ES17	Yongdeok Osimcheong Estuary
ES18	Wangpicheon Estuary
ES19	Samcheok Osimcheon
ES20	Gangneung Namdaecheon Estuary
ES21	Yangyang Namdaecheon Estuary
OA01	West Sea central offshore
OA02	Southwestern offshore
OA03	Korean strait offshore
OA04	East Sea offshore
OA05	Jeju offshore

- 31 areas of Korean waters issued by the Marine Environmental and Management Act of Korean

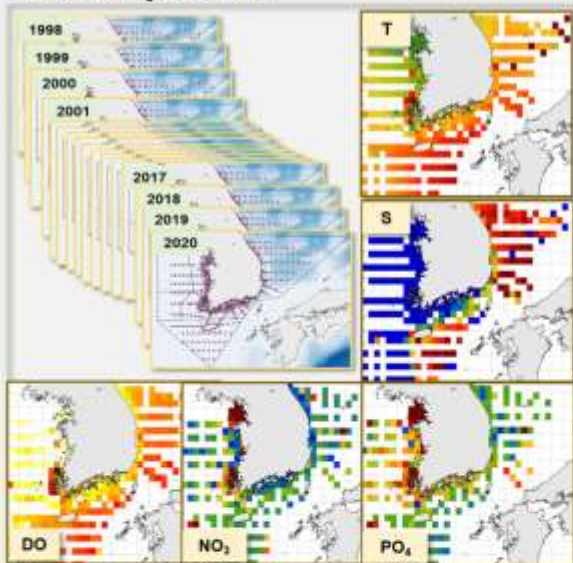
Korean Waters and Long-Term monitoring Stations

법정조사	국립수산과학원		해양환경공단			
	정선해양관측	어장환경모니터링	국가 해양생태계 종합조사			해양환경측정망
			근해조사	연안생태 기본조사	연안생태 중점조사	
조사기간	1961년~현재	2007년~현재	2015년~현재	2015년~현재	2015년~현재	1997년~현재
조사시기	2, 4, 6, 8, 10, 12월	2, 4, 6, 8, 10, 12월	8월	5, 8월	2, 5, 8, 11월	2, 5, 8, 11월
정점갯수	207정점	269정점	20정점	129정점	38정점	425개 정점
조사해역	근해(동해, 서해, 남해, 동중국해)	전국 연안 및 주요 양식어장 주변 해역	근해(동해, 서해, 남해, 동중국해)	전국 연안	연안하구역(한강, 금강, 영산강, 섬진강, 낙동강), 동해 용승해역	전국 연안, 항만, 하천영향 및 반폐쇄성해역

- Water quality parameters: T, S, DO, NO₃, PO₄
- Period: 1998~2020
- Depth: 0 m

Data Processing & Dynamic Factor Analysis

Step 1 Data acquisition

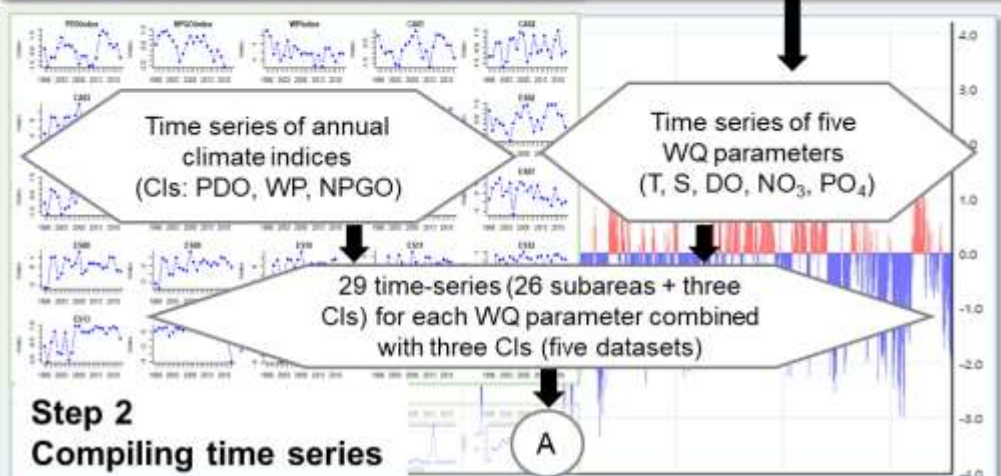


Long-term water quality data from 1088 stations (T, S, DO, NO₃, PO₄)

Dividing 31 subareas of Korean territorial sea and EEZ

Selecting 26 subareas by data availability

Annual ('98~'20) geomeans of five WQ parameters by 26 subareas



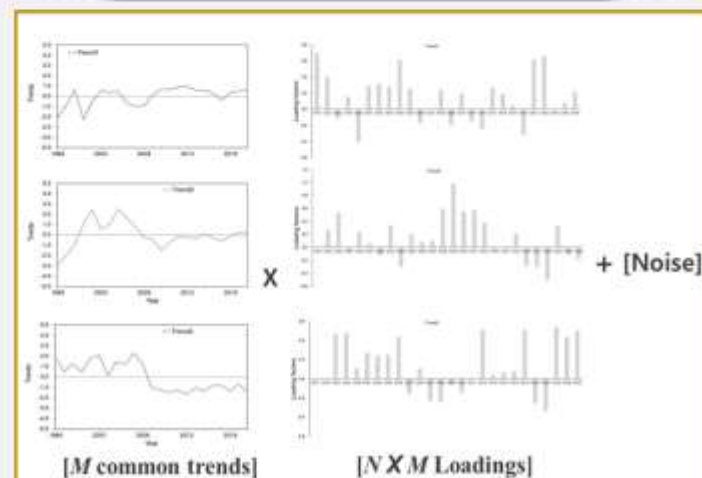
Step 3 Dynamic factor analysis

A

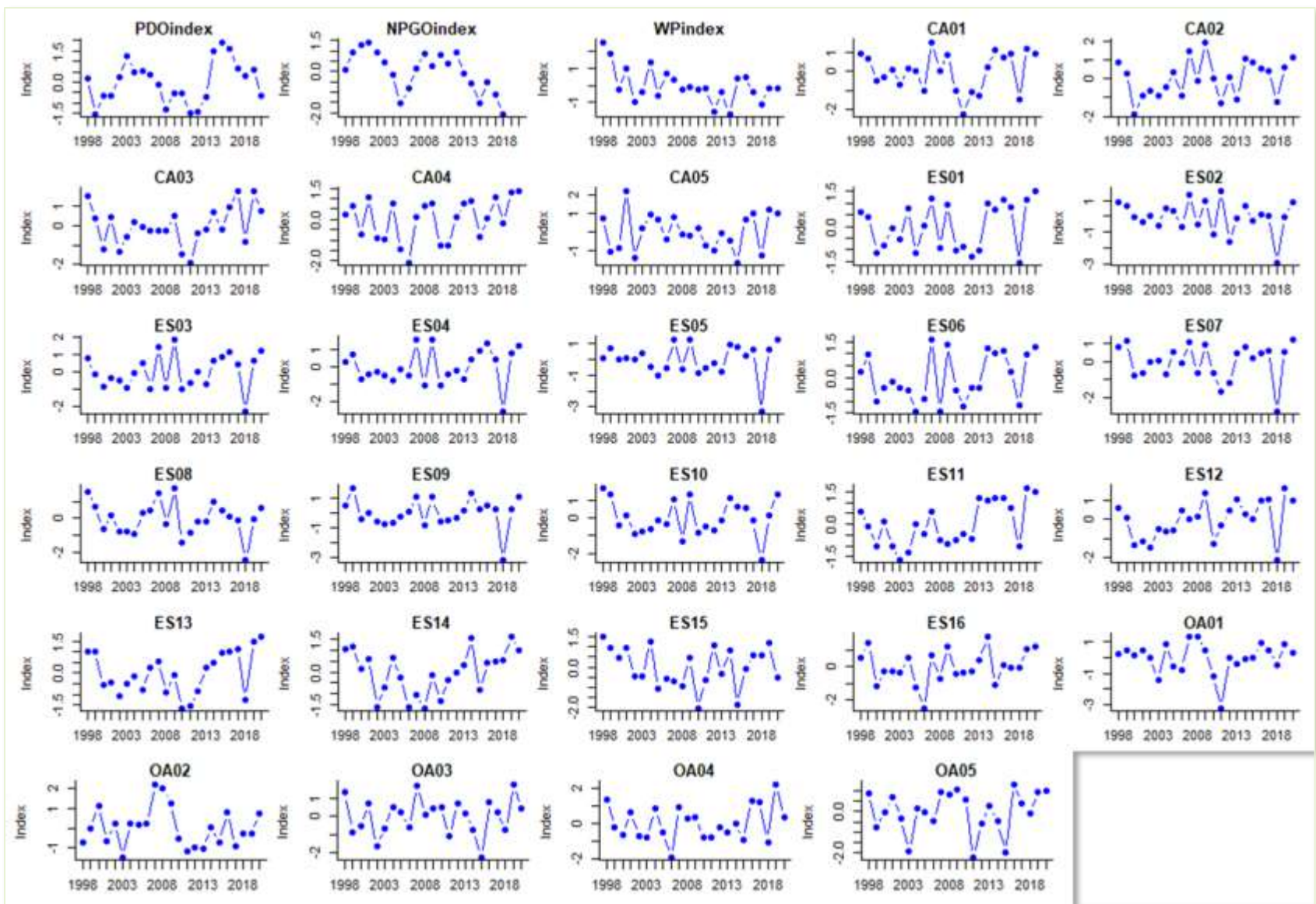
Dynamic factor analysis of 29 time-series data of each WQ parameter and three climate indices



Common trends and loadings for each WQ and three CIs

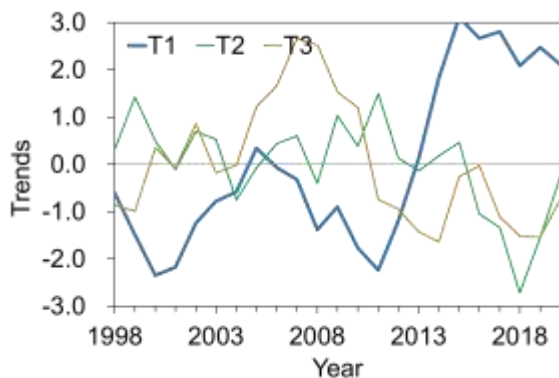


Normalized T-Time Series & Climate indices

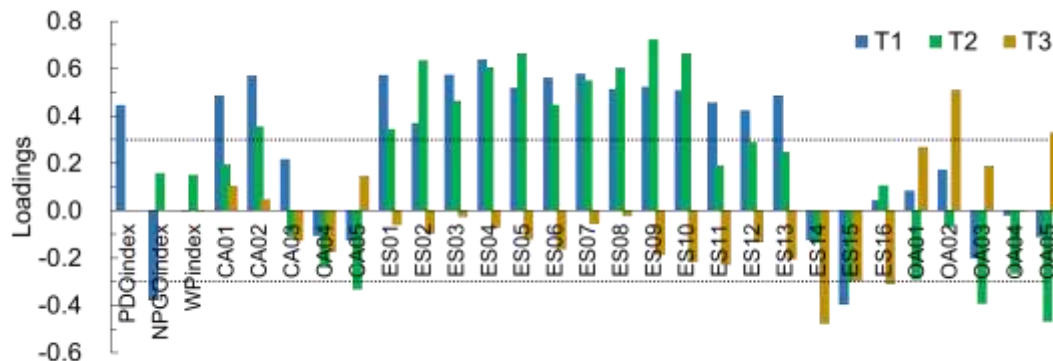


Common Trends for T-Time Series

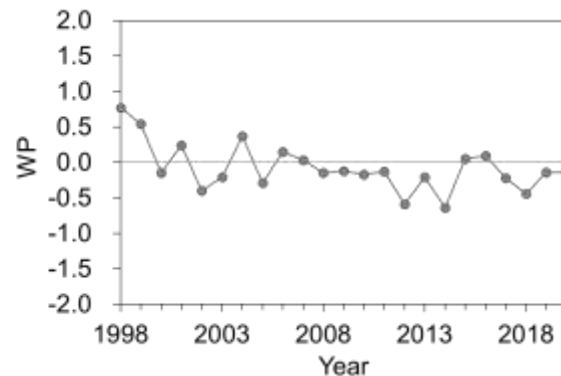
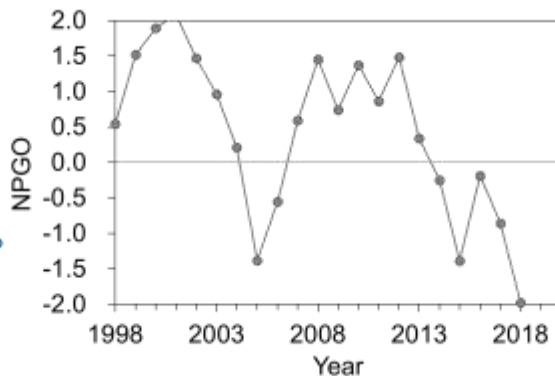
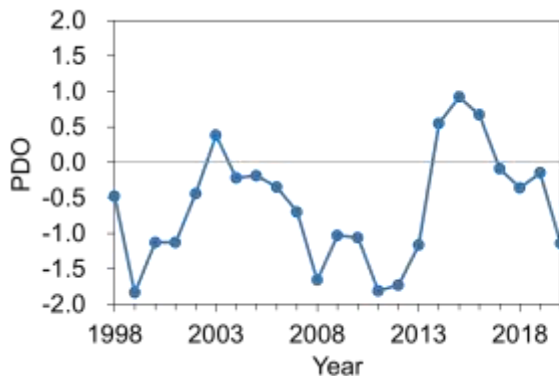
[Common trends]



[Factor loadings]



[Climate indices]



- Three common trends for T-time series in 26 areas
- The close relationship between **T1** and **PDO index**

Dominant Areas for Each Common Trend of T

WQ parameter	Common Trends	Codes
T	T1	CA02, ES01~ES11, ES13, ES15
	T2	CA02, ES01~ES10, ES15
	T3	ES14, ES15, OA02



- The dominant areas identified by criteria of ≥ 0.3 -factor loadings of common trends and ≥ 2.0 -ER ratios

$$y_{it} = z_{i1} \alpha_{1t} + z_{i2} \alpha_{2t} + \dots + z_{iM} \alpha_{Mt} + e_{it}$$

$$y_t = Z\alpha_t + e_t$$

$$ER \text{ ratio} = \frac{\sum_t \hat{c}_{it}^2}{\sum_t \hat{u}_{it}^2}$$

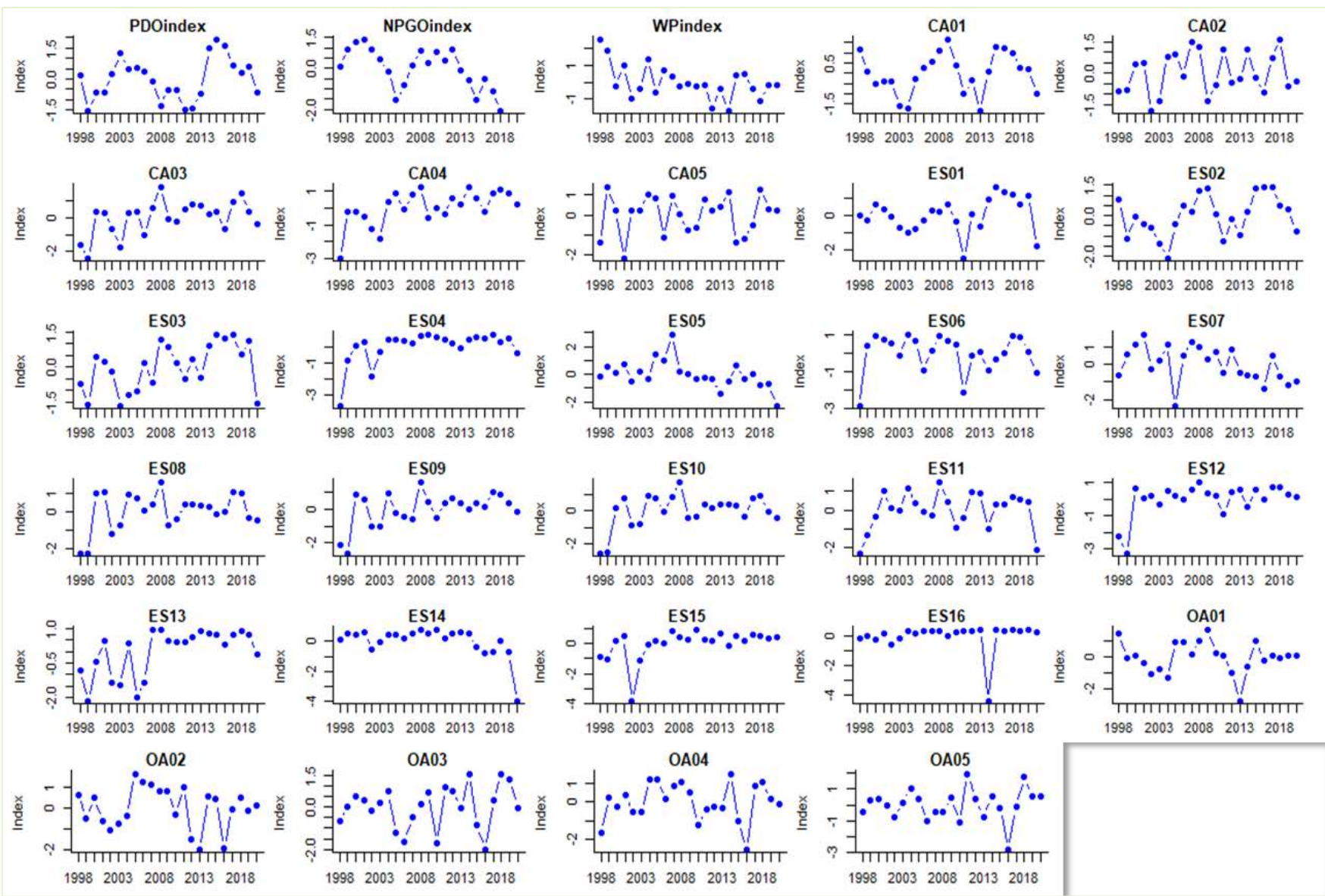
Z : factor loadings ($N \times M$)

α_t : values of the M common trends at time t

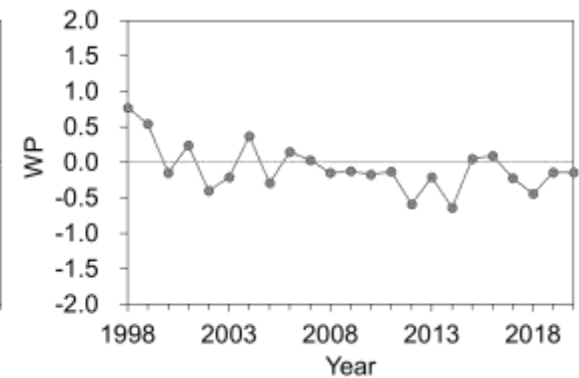
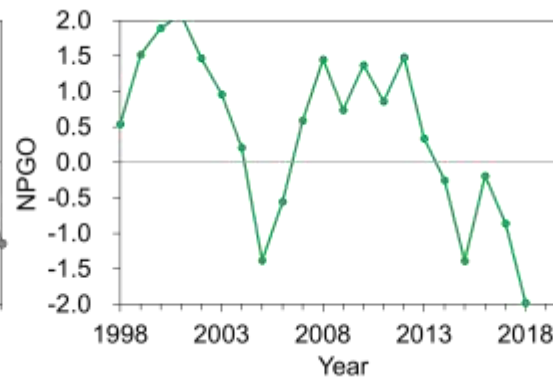
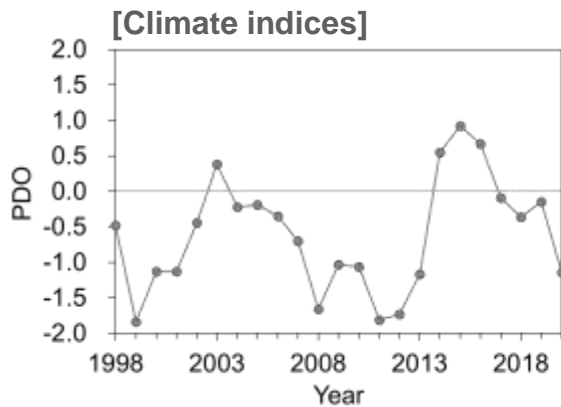
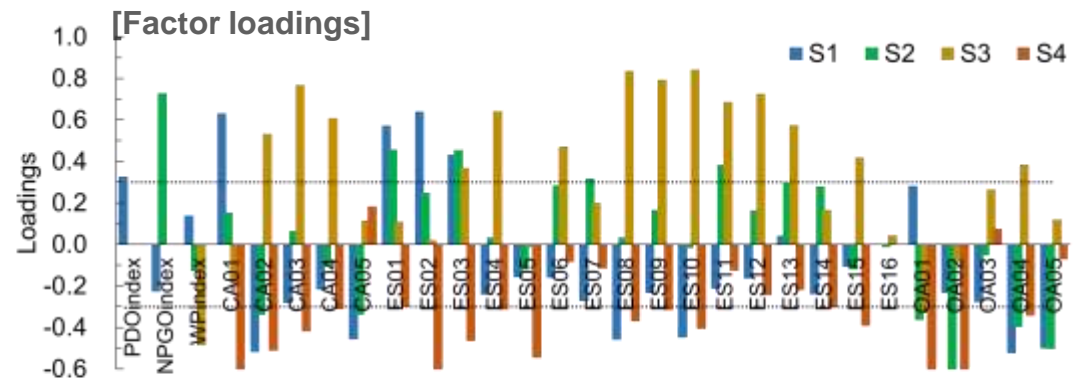
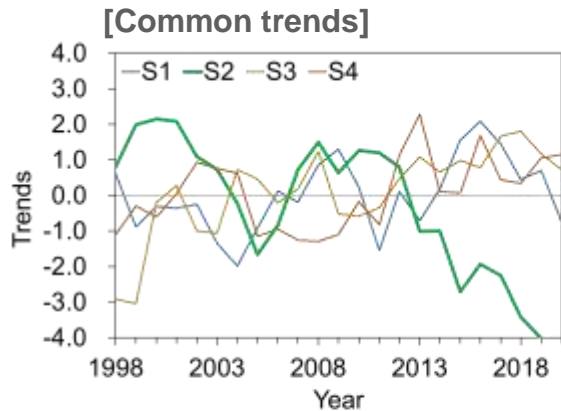
e_t : $N \times 1$ noise component

y_t : $N \times 1$ vector containing the values of the N time series at time t

Normalized S-Time Series & Climate indices



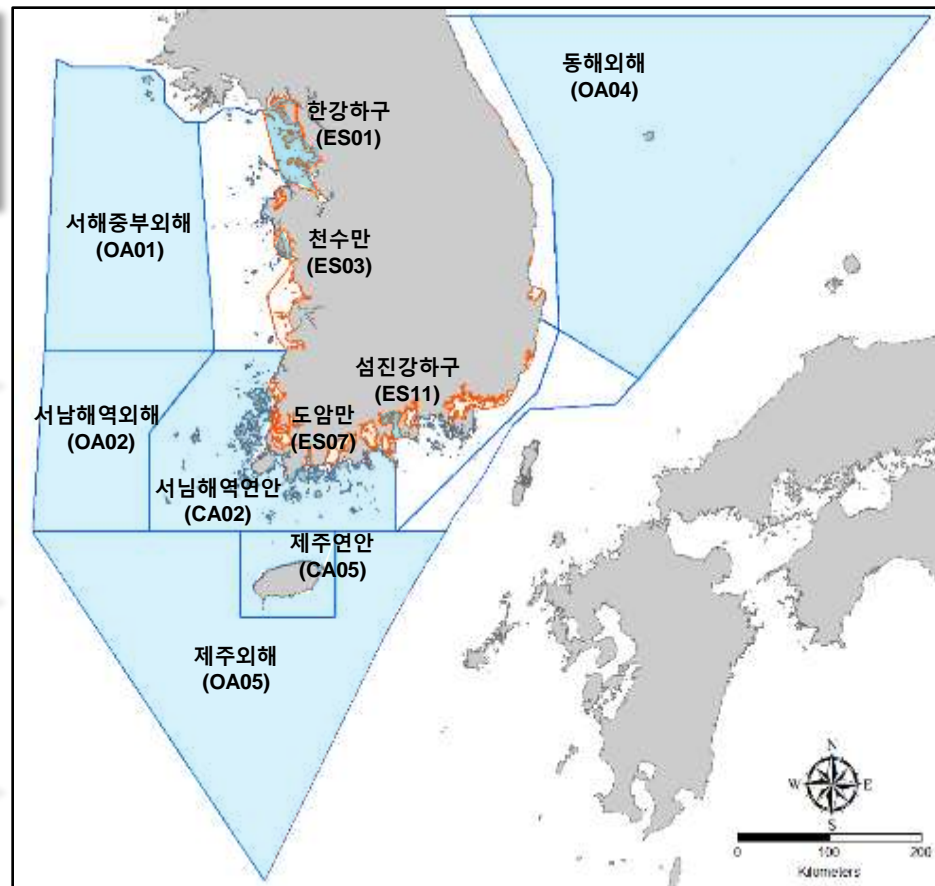
Common Trends for S-Time Series



- Four common trends for S-time series in 26 areas
- The close relationship between **S2** and **NPGO index**

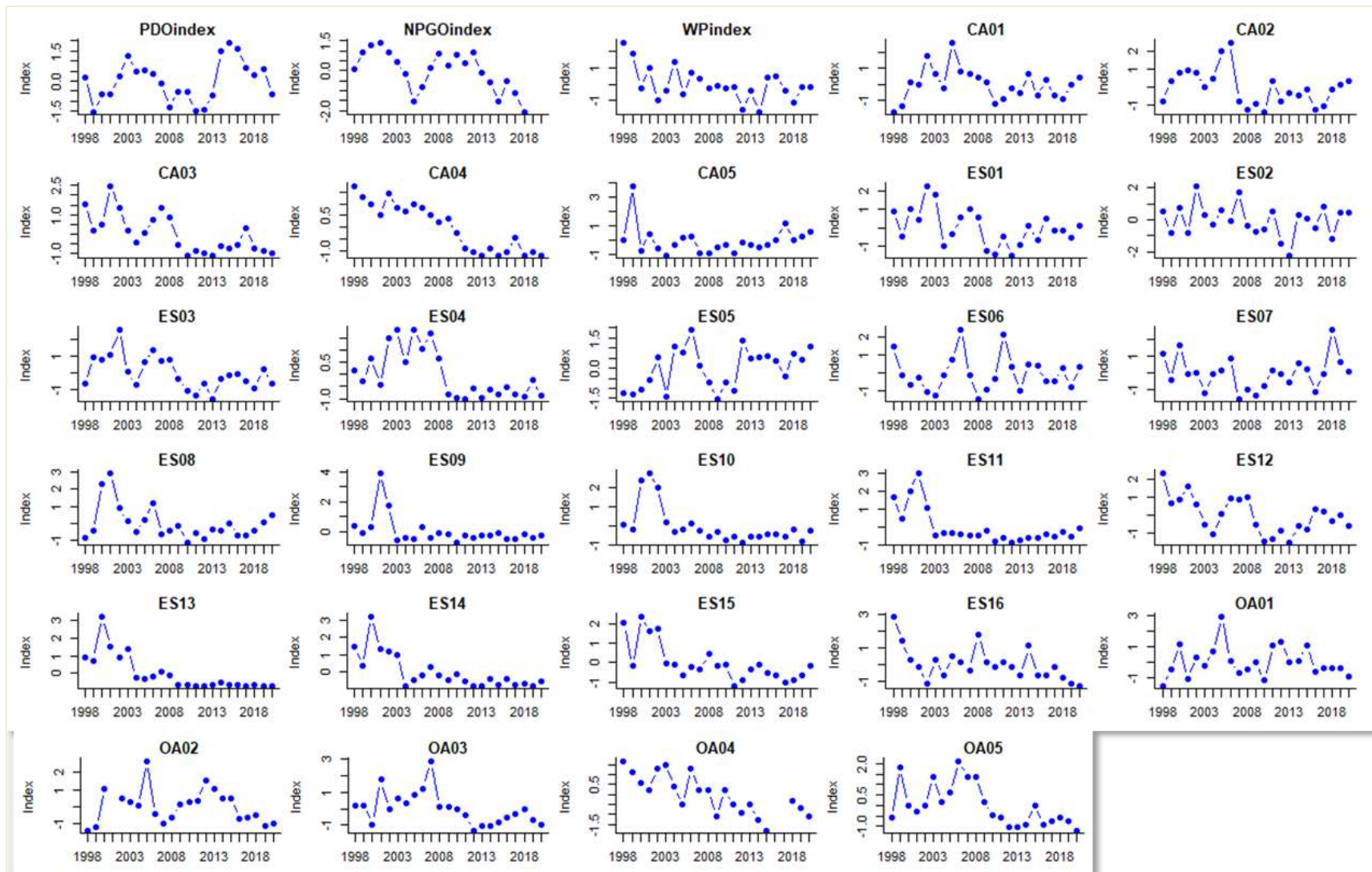
Dominant Areas for Each Common Trend of S

WQ parameter	Common Trends	Codes
S	S1	CA01~CA03, CA05, ES01~ES03, ES08, ES10, OA04, OA05
	S2	CA02, CA05, ES01, ES03, ES07, ES11, OA01, OA02, OA04, OA05
	S3	CA02~CA04, ES03, ES04, ES08~ES13, ES15, OA01, OA04
	S4	CA01~CA04, ES01~ES05, ES08~ES10, ES14, ES15, OA01, OA02, OA04



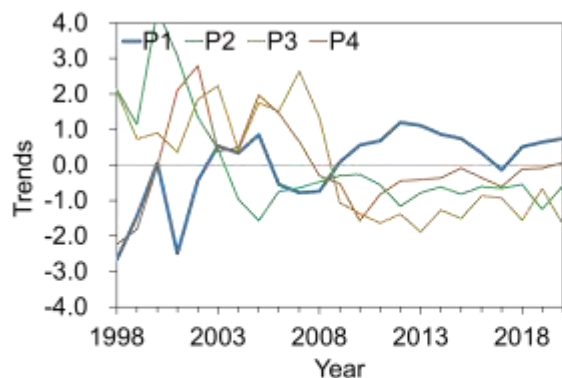
- The dominant areas identified by criteria of ≥ 0.3 -factor loadings of common trends and > 2.0 ER ratios

Normalized PO₄-Time Series & Climate indices

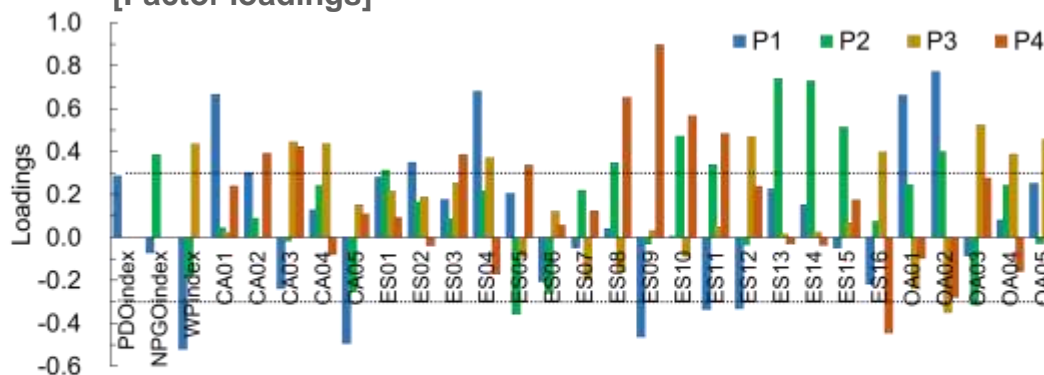


Common Trends for PO₄-Time Series

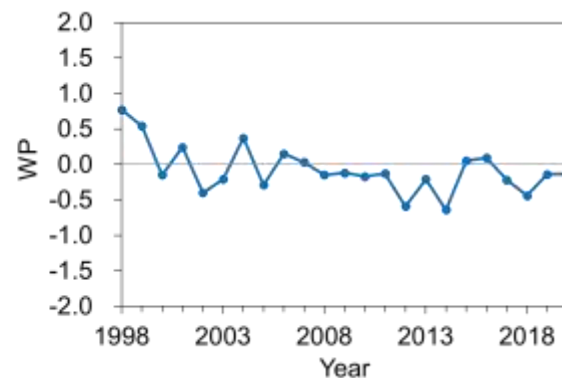
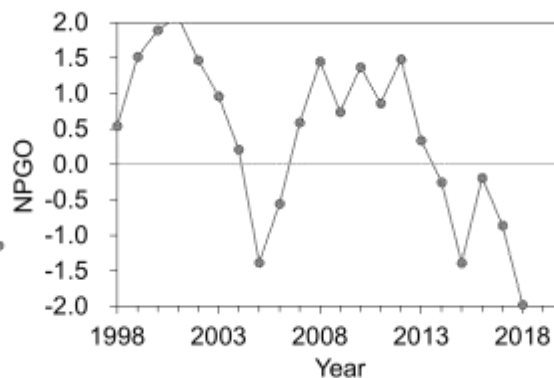
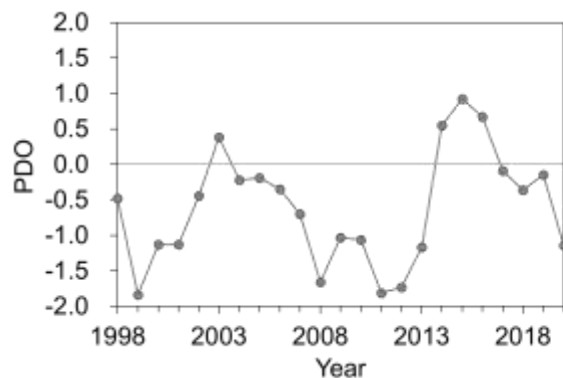
[Common trends]



[Factor loadings]



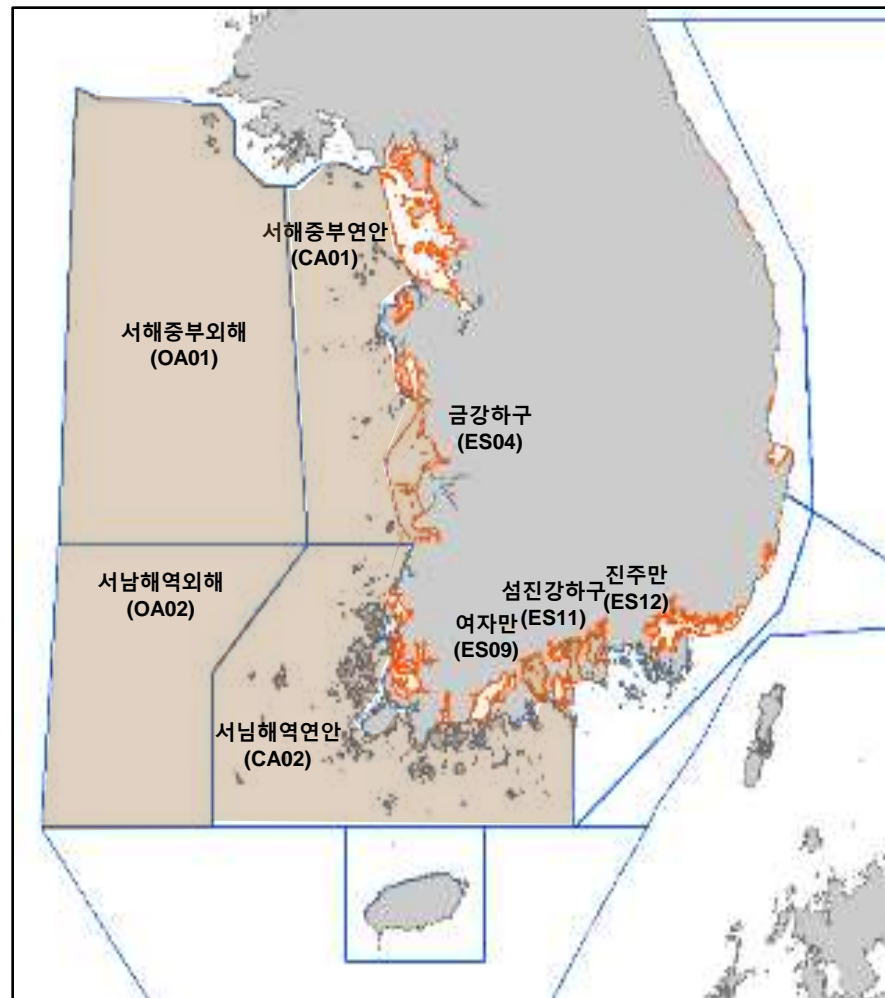
[Climate indices]



- Four common trends for PO₄-time series in 26 areas
- The close relationship between **P1** and **WP index**

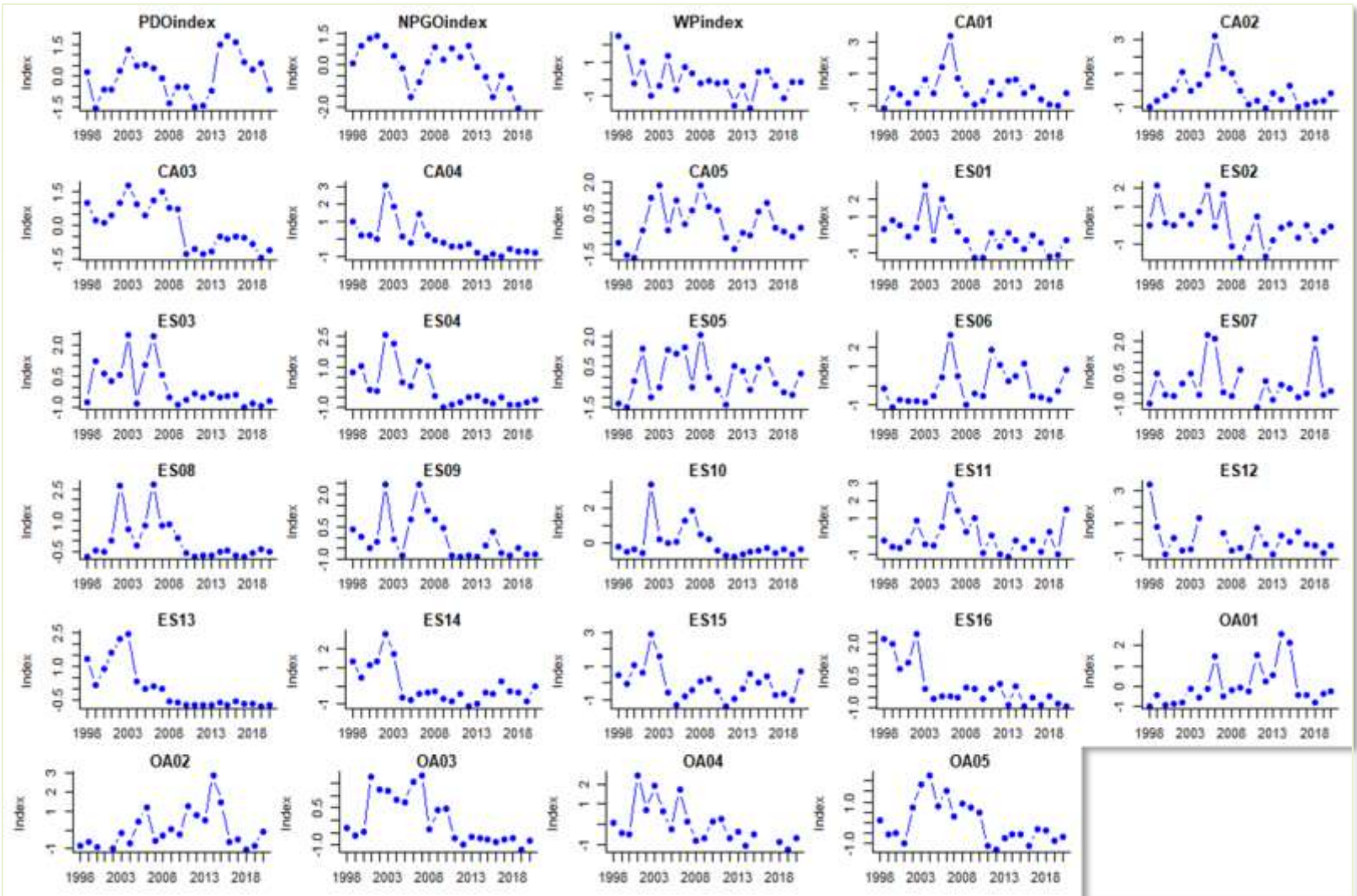
Dominant Areas for Each Common Trend of PO₄

WQ parameter	Common Trends	Codes
PO ₄	P1	CA01, CA02, ES04, ES09, ES11, ES12, OA01, OA02
	P2	ES01, ES05, ES08, ES10, ES11, ES13~ES15, OA02, OA03
	P3	CA03, CA04, ES04, ES12, ES16, OA02~OA05
	P4	CA02, CA03, ES03, ES05, ES08~ES11, ES16

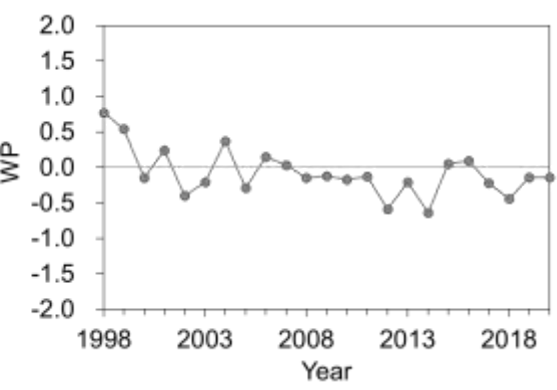
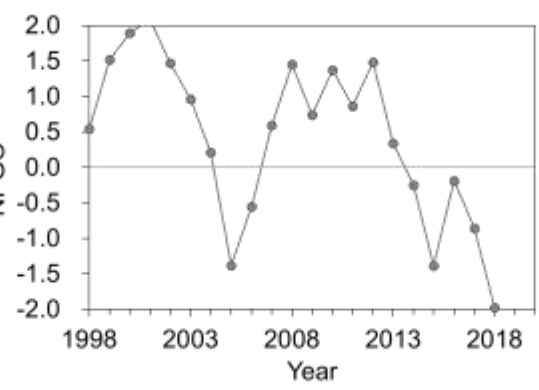
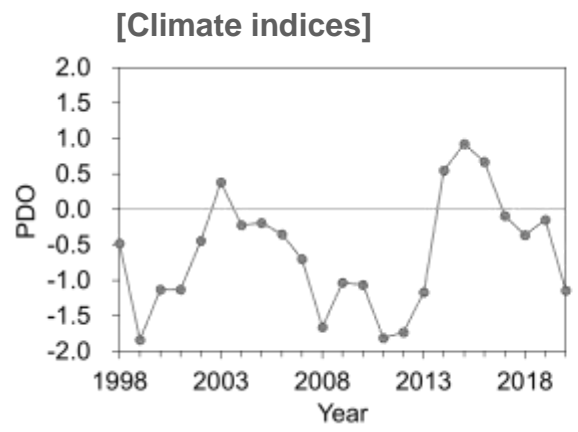
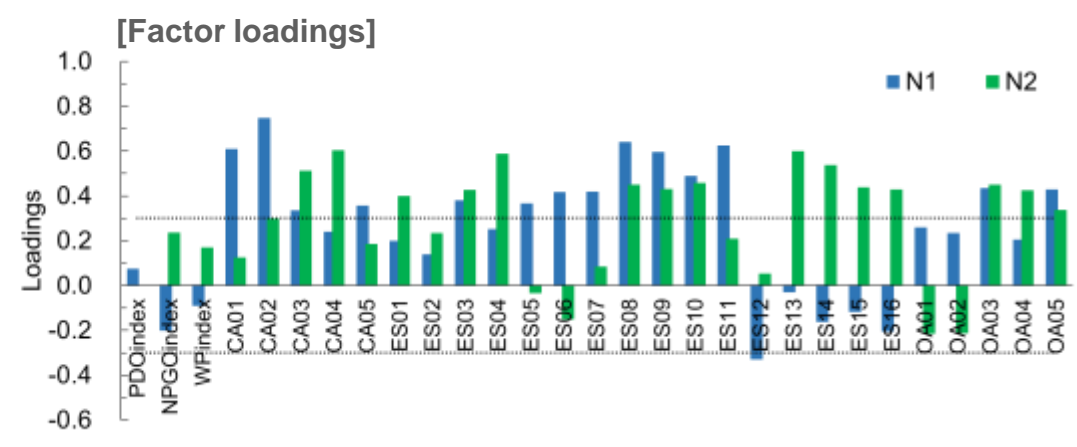
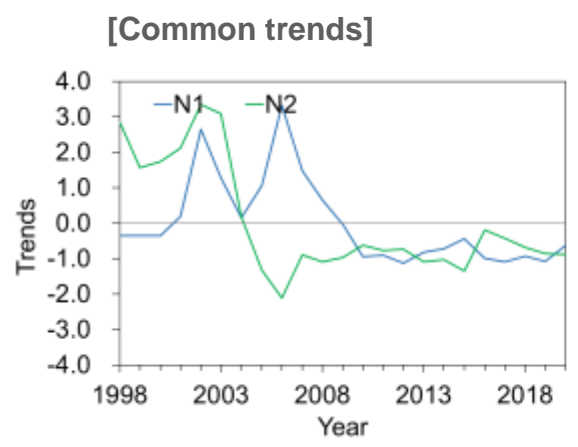


- The dominant areas identified by criteria of ≥ 0.3 -factor loadings of common trends and > 2.0 ER ratios

Normalized NO₃-Time Series & Climate indices



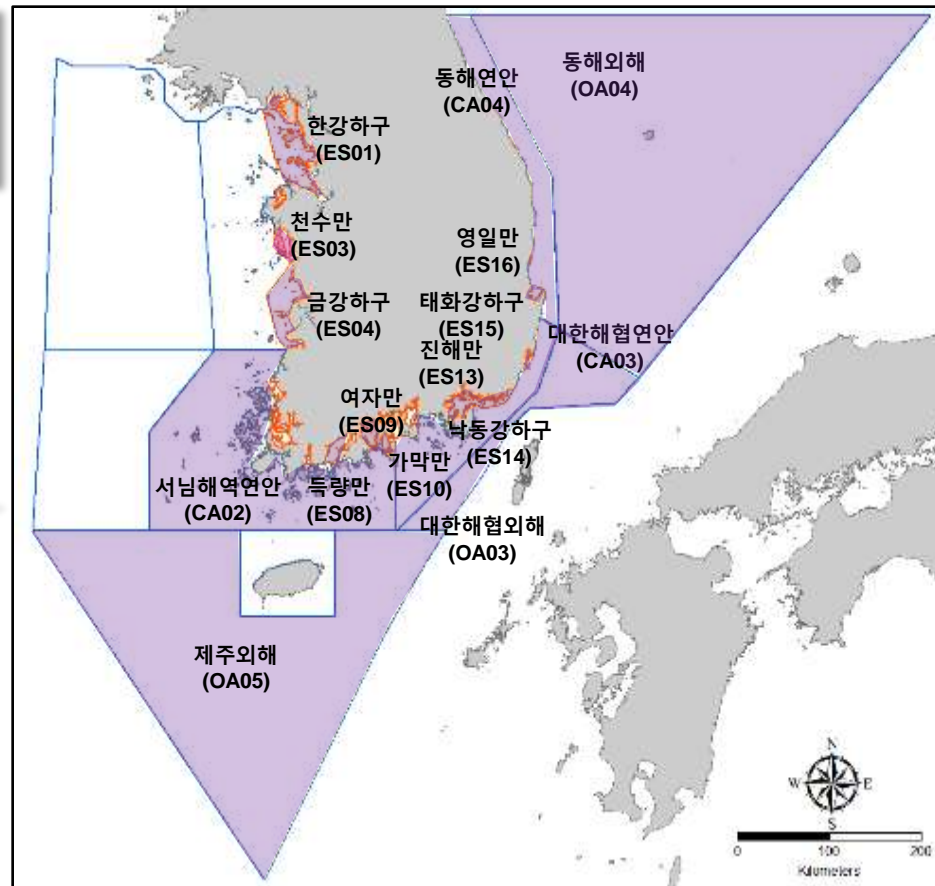
Common Trends for NO₃-Time Series



- Two common trends for NO₃-time series in 26 areas
- NO₃ decrease trend (N2) associated with water quality improvement policy (ex. Total pollution load management system)

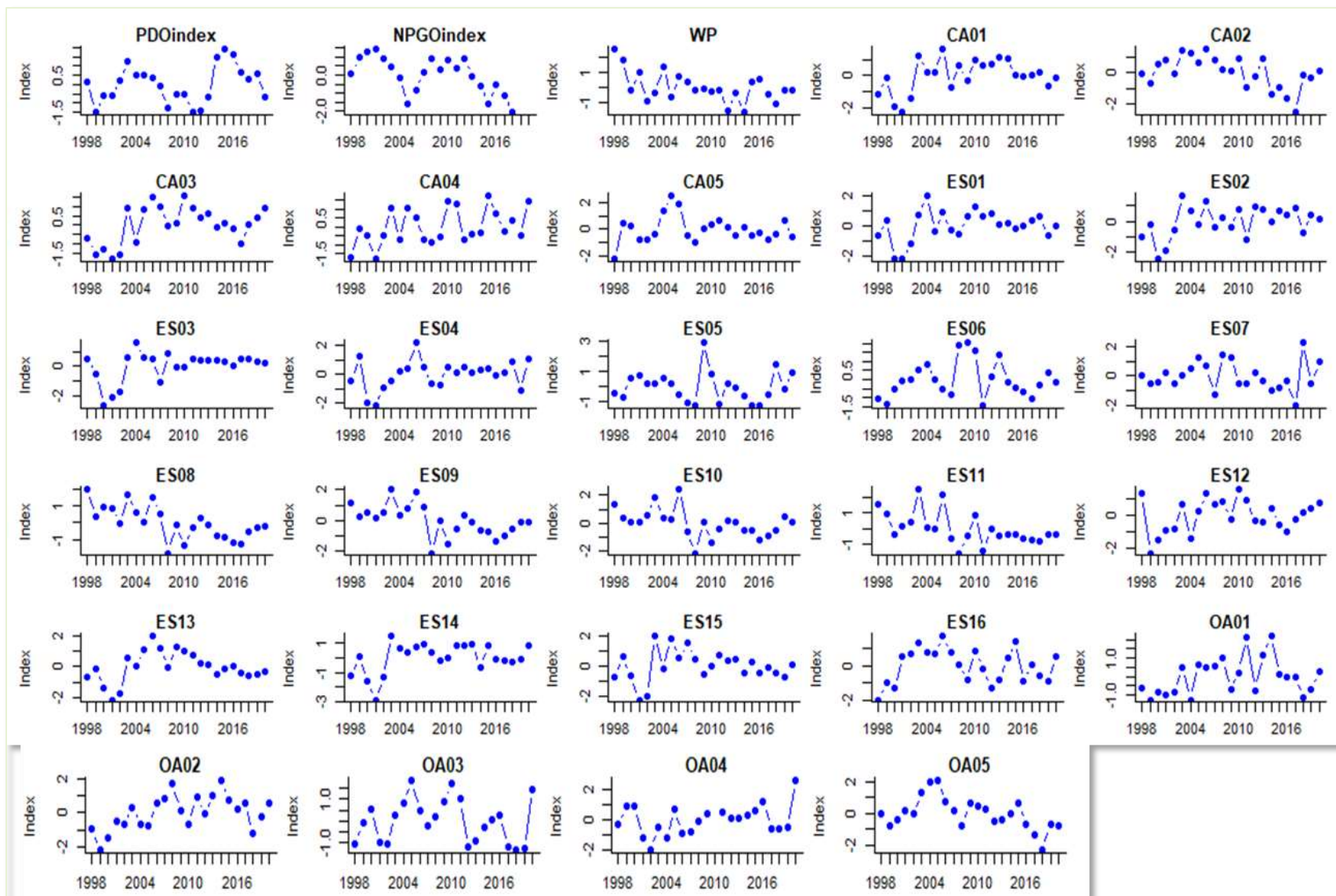
Dominant Areas for Each Common Trend of NO₃

WQ parameter	Common Trends	Codes
NO ₃	N1	CA01~CA03, ES03, ES06, ES08~ES11, OA03, OA05
	N2	CA02~CA04, ES01, ES03, ES04, ES08~ES10, ES13~ES16, OA03~OA05



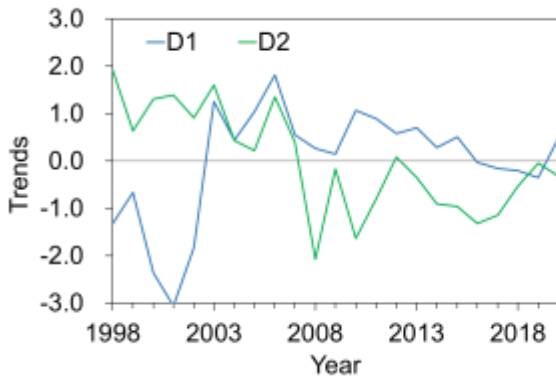
- The dominant areas identified by criteria of ≥ 0.3 -factor loadings of common trends and > 2.0 ER ratios

Normalized DO-Time Series & Climate indices

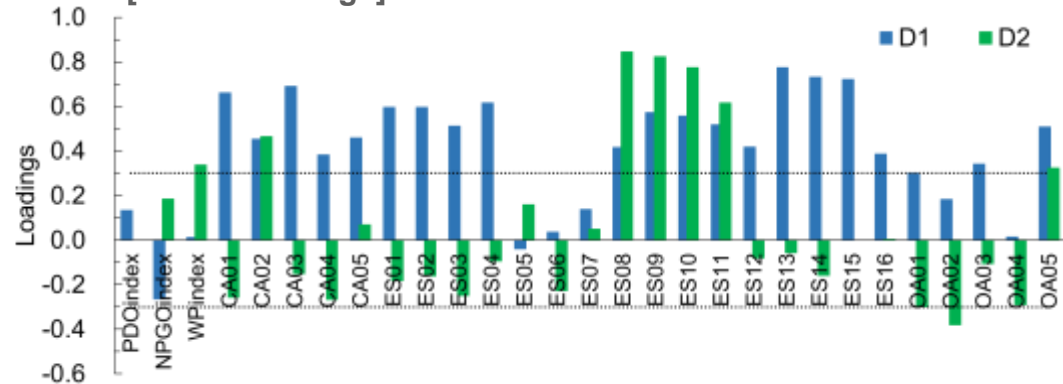


Common Trends for DO-Time Series

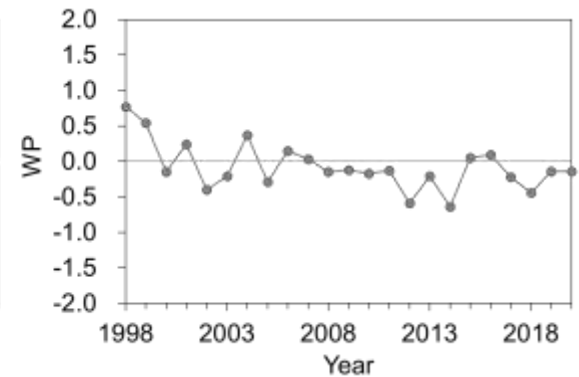
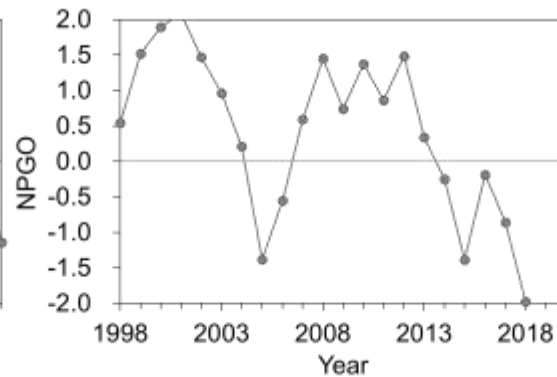
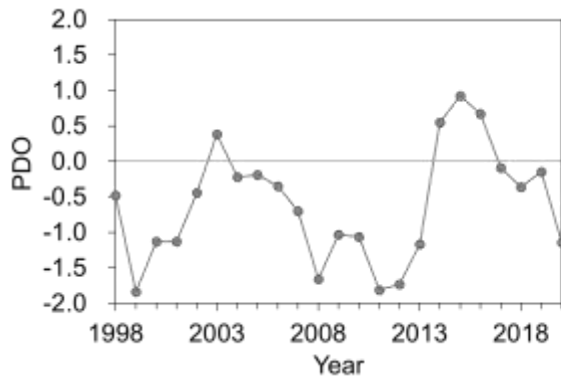
[Common trends]



[Factor loadings]



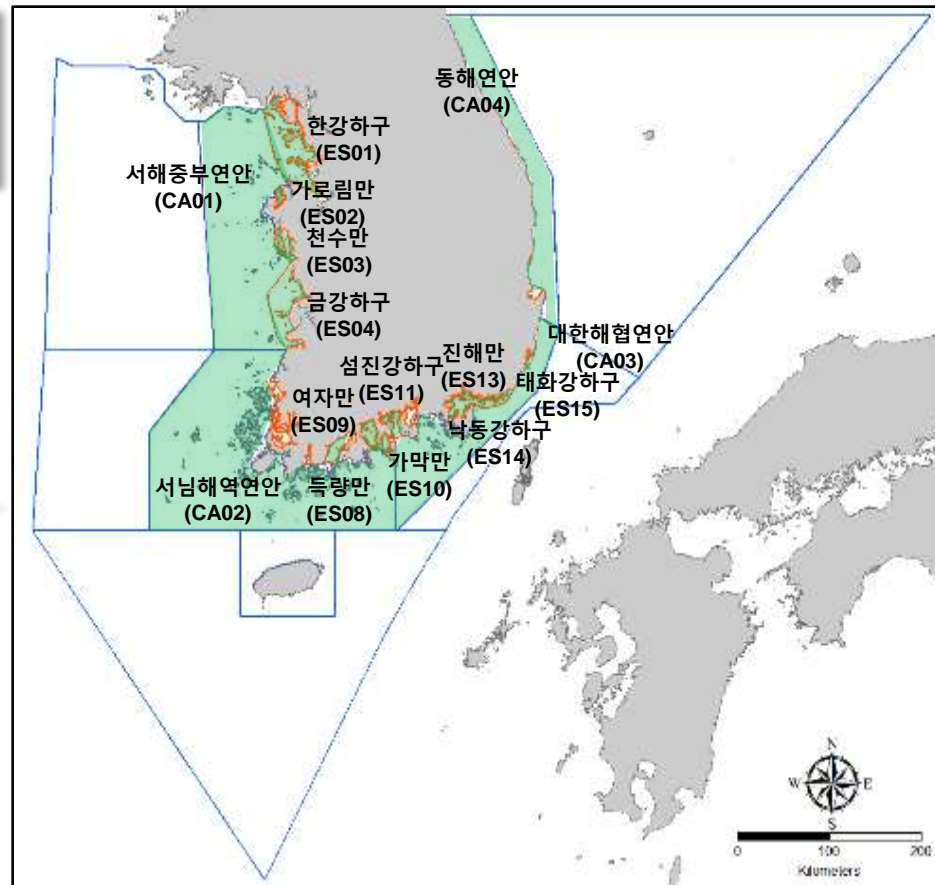
[Climate indices]



- Two common trends for DO-time series in 26 areas
- DO increase trend (D1) associated with water quality improvement policy (ex. Total pollution load management system)

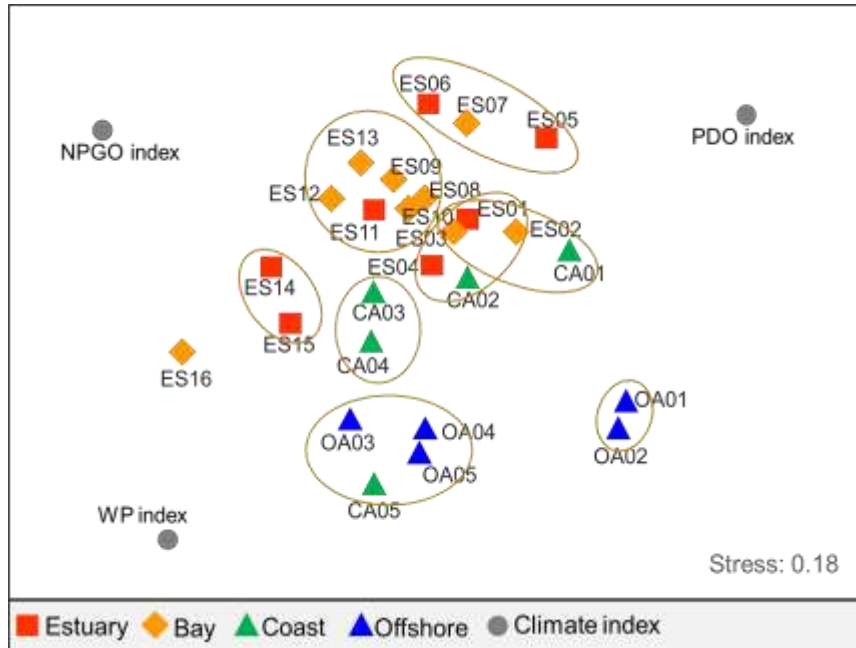
Dominant Areas for Each Common Trend of DO

WQ parameter	Common Trends	Codes
DO	D1	CA01~CA04, ES01~ES04, ES08~ES11, ES13~ES15
	D2	CA01, CA02, CA04, ES03, ES08~ES11



- The dominant areas identified by criteria of ≥ 0.3 -factor loadings of common trends and > 2.0 ER ratios

Similarity of Long-Term Water Quality Trends



[Multi-dimensional scaling ordination results for three climate indices and 26 areas based on similarity of loading factors of 15 common trends]



- The similarities of long-term water quality trends are high in the geographically adjacent estuary and bay areas.
- Differences in the water quality trends between the coastal and offshore regions

Summary

- Long-term common trends of water quality in 26 areas of Korean waters were identified
 → **Three for T**, **Four for S**, **Four for PO₄**, Two for DO, and Two for NO₃

- The common trend dominant in the **T** time series in the **estuary and bay areas of the Yellow and South Sea**, **S** time series in the **offshore regions of the Yellow, South, and East Sea**, and **PO₄** time series in the **coastal areas of the Yellow Sea** was related to the **PDO**, **NPGO**, and **WP** index, respectively.

- The **similarities of long-term water quality trends** were high in the **geographically adjacent estuary and bay areas**. In addition, the results on similarities show differences in the long-term trends between the coastal and offshore regions. The **differences** were more **apparent in the Yellow Sea** compared with the South and East Sea differences.

Thank you !