PICES 2019 Annual Meeting
October 16-27, 2019, Victoria, B.C., Canada

Prospects of long-range prediction of changes in fish stocks based on the large-scale climatic factors in the Northern Hemisphere

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AND OCEANOGRAPHY

Outline

- Data;

- Modes of variability of fish stocks in the NW Pacific;

- Their relation to the large-scale climatic patterns;

- Some possibilities for stock prediction;

- Conclusion.

DATA

Biological data

- Russian salmon catches (1911-2015): 1911-1986 – from Klyashtorin & Smirnov (1992) and INPFC Bulletin (1993); 1987-2018 – from NPAFC Reports (www.npafc.org)
- Japanese sardine catches (1905-2014) – from FAO Fishery Statistics
- Northern Sea of Okhotsk walleye pollock recruitment at age 3 and SSB (1983-2013)– from VNIRO (Moscow, Russia)
- Catch and CPUE data of Pacific saury – Reports of 1st Meeting of the Technical WG on Pacific Saury Stock Assessment, 20-22 February 2017
- Retrospective assessment of NWBS cod stock was made with the use VPA with Saville's adjustment (Maksimenko and Antonov, 2004). The cod catches by year (mln inds.) for 1968-2016 were used as initial data for the assessment (Antonov, 2011 with additional data since 2010 from TINRO-Center)

Physical data

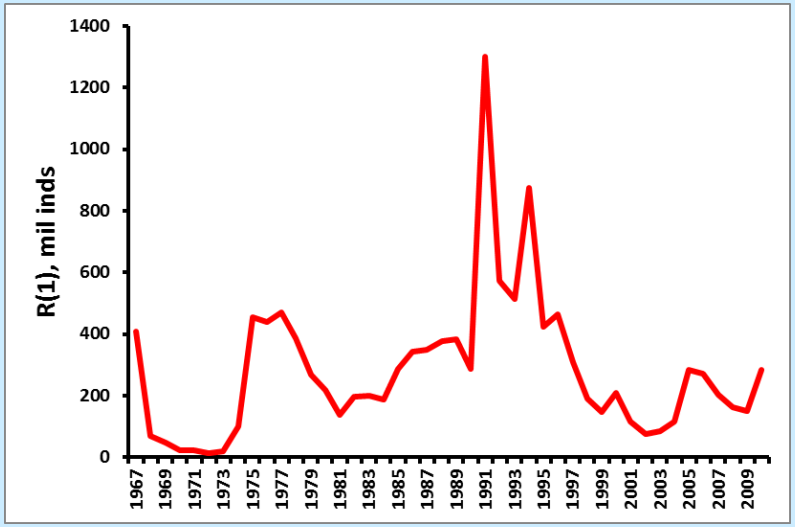
- Sea surface temperature datasets: monthly Reynolds OI.v2 SST data (1982-2016) and ERSST v.3b (1856-2016) data from NOAA

(www.esrl.noaa.gov/psd/data/gridded/ data.ncep.reanalysis.html)

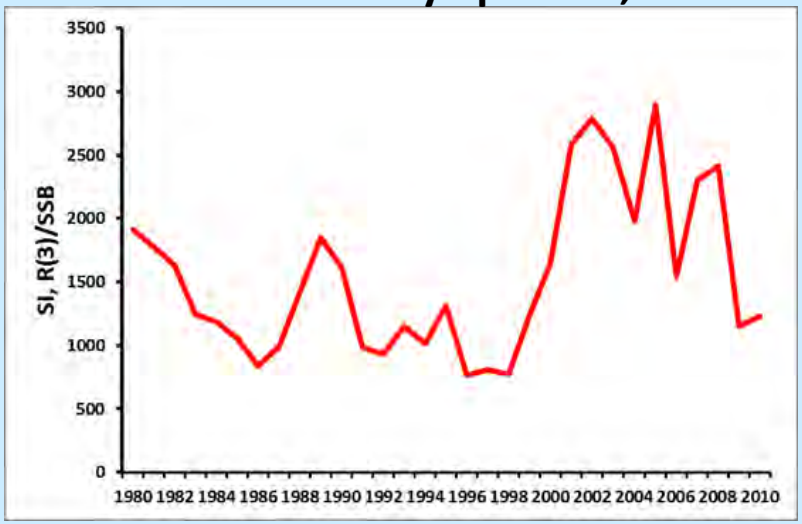
- Time series of the AO index from http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml
- NPGO index (1950-2018) – from www.o3d.org/npgo/data/NPGO.txt

Quasi-decadal variation in some NW Pacific fish stocks

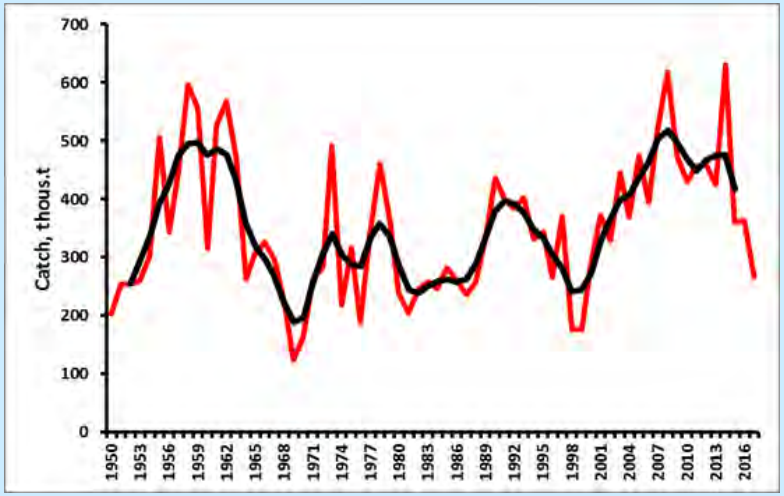
Recruitment of NW Bering Sea cod at age 1, 1967-2010



Survival indices (R(3)/SSB) of northern Okhotsk Sea walleye pollock, 1980-2010

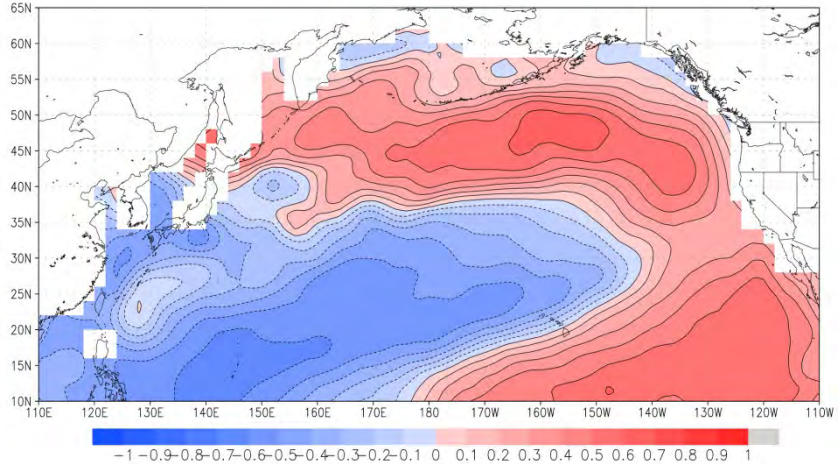


Total catch of Pacific saury, 1950-2017

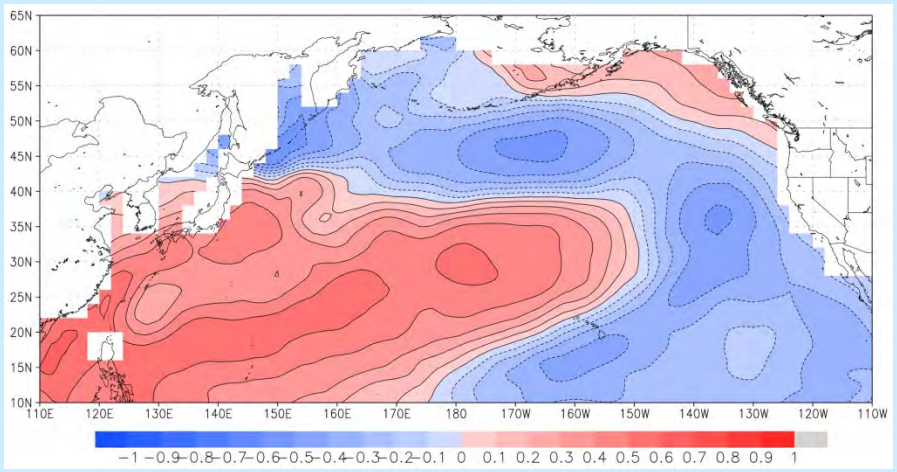


Association of some NW Pacific fish stocks with NPGO

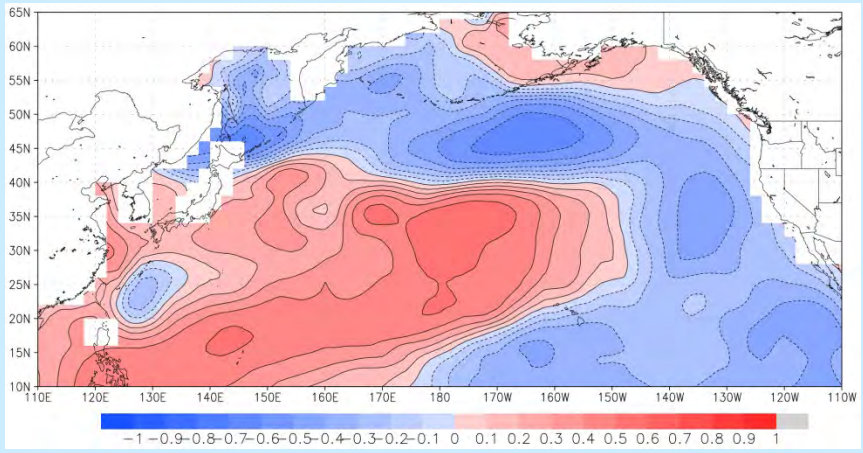
Corr. R(1) of NW Bering Sea cod to mean winter SSTA, 1988-2010



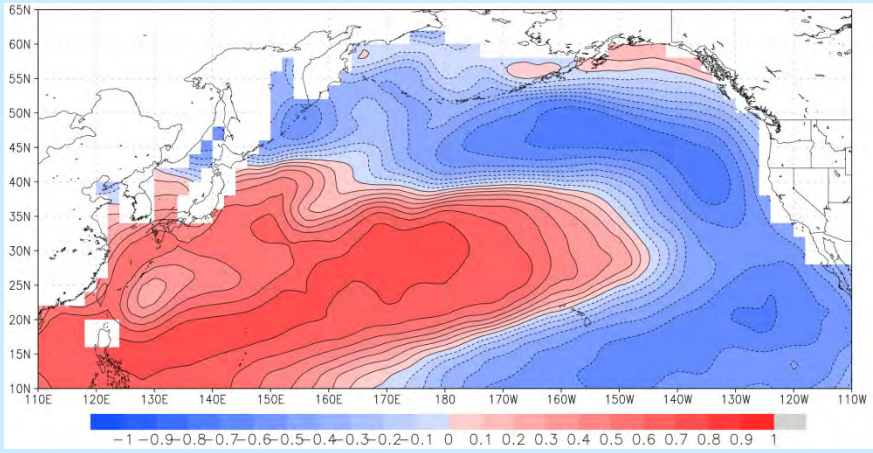
Corr. SI of walleye pollock in the northern Sea of Okhotsk catch to mean winter SSTA with t=2 yr, 1980-2010



Corr. Japanese cpue of Pacific saury to mean winter SSTA with t= 5yr, 1994-2016

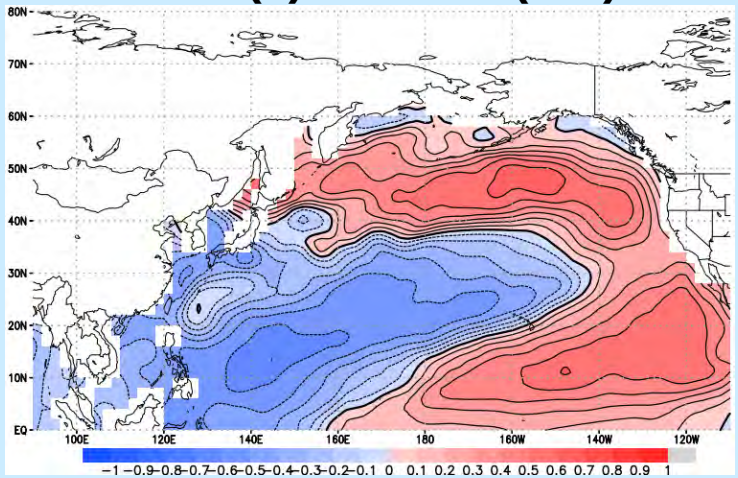


Mean winter NPGO pattern, 1988-2010

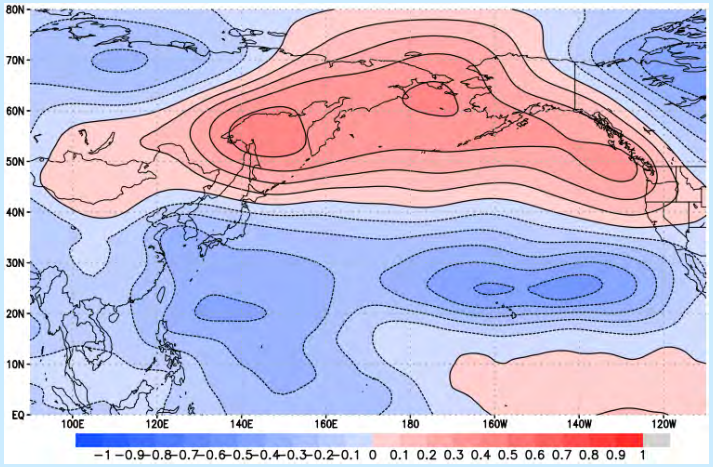


NW Bering Sea cod and climate (1988-2010)

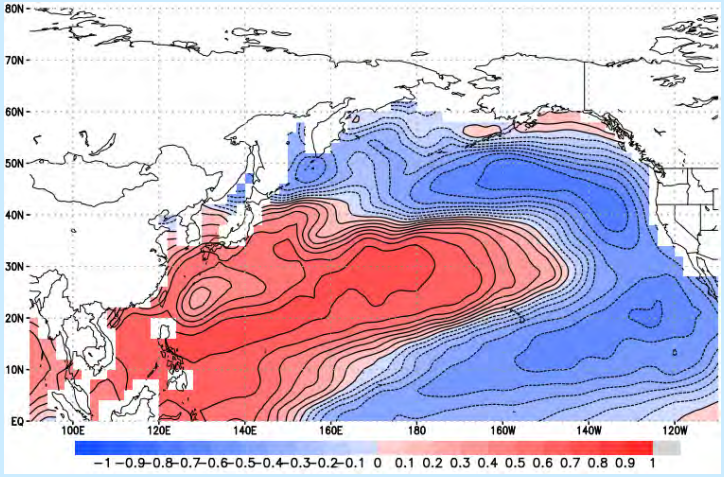
Corr. R(1) to SSTA (I-IV)



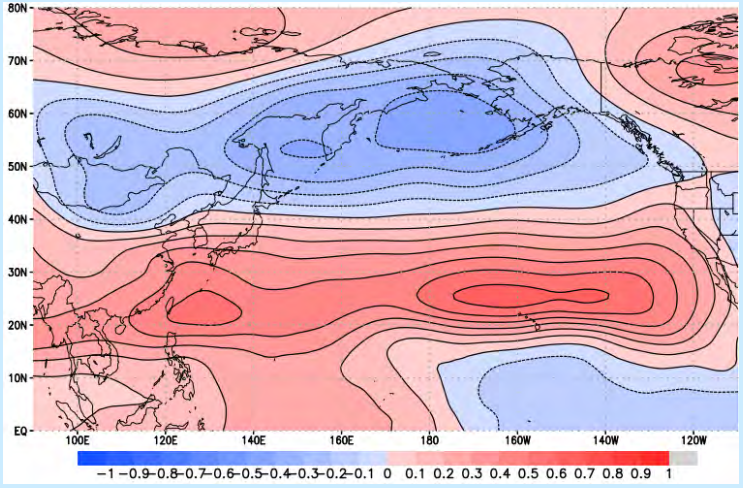
Corr. R(1) to H500 (XII-II)



Corr. NPGOI to SSTA (I-IV)

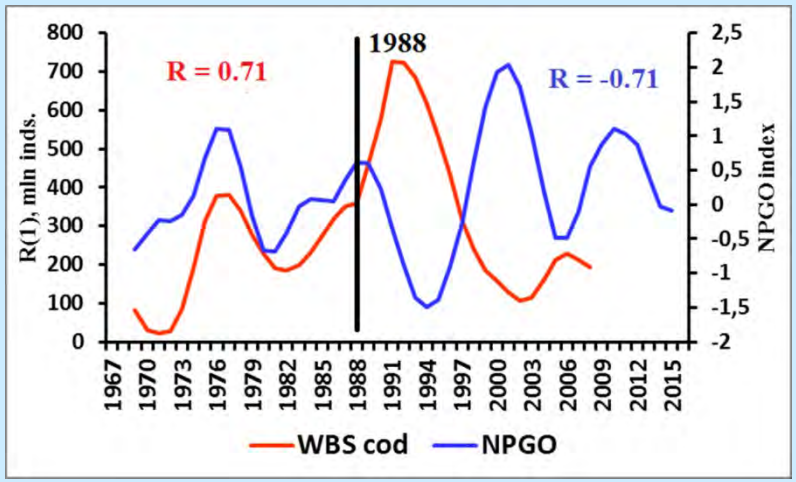


Corr. NPGOI to H500 (XII-II)

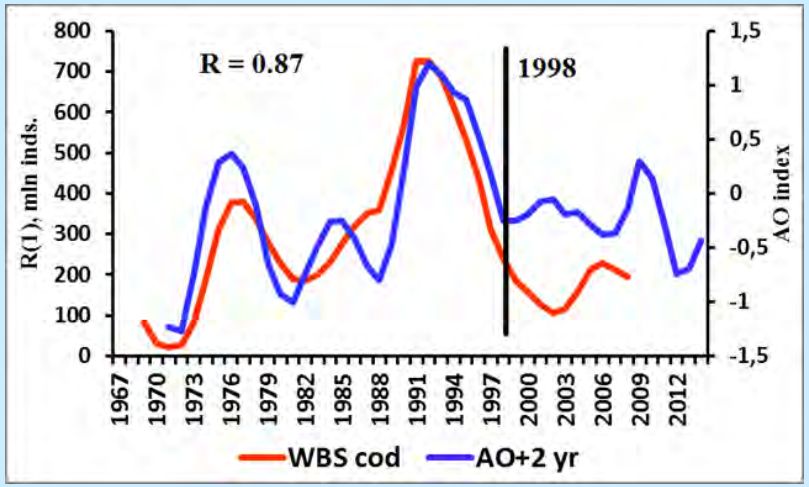


NW Bering Sea cod and climate

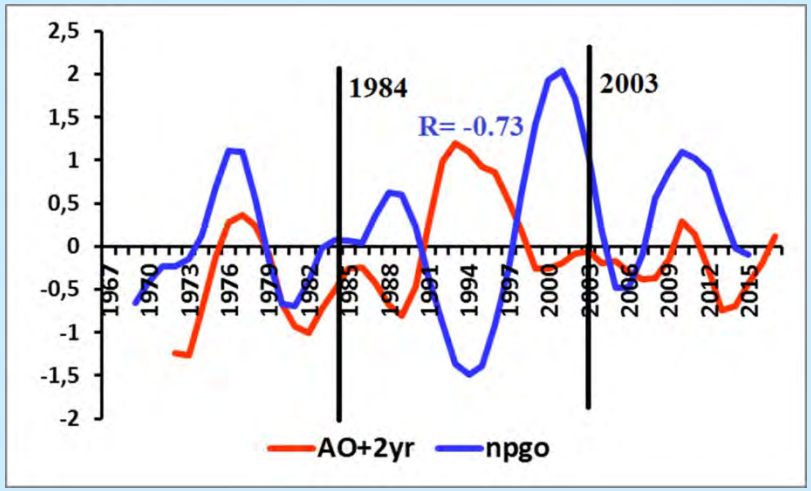
Time series of 5-yr running means of NWBS cod recruitment at age 1 and winter (I-IV) NPGO index



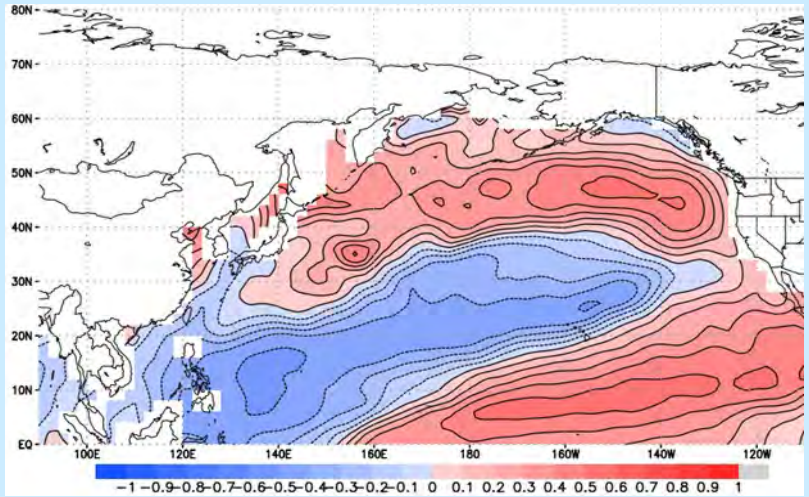
Association of NWBS cod recruitment with winter (XII-II) Arctic Oscillation



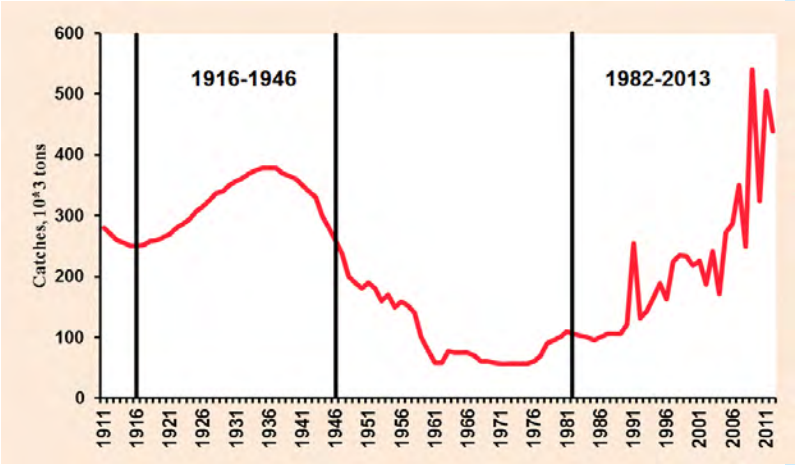
Association of winter NPGO and AO indices

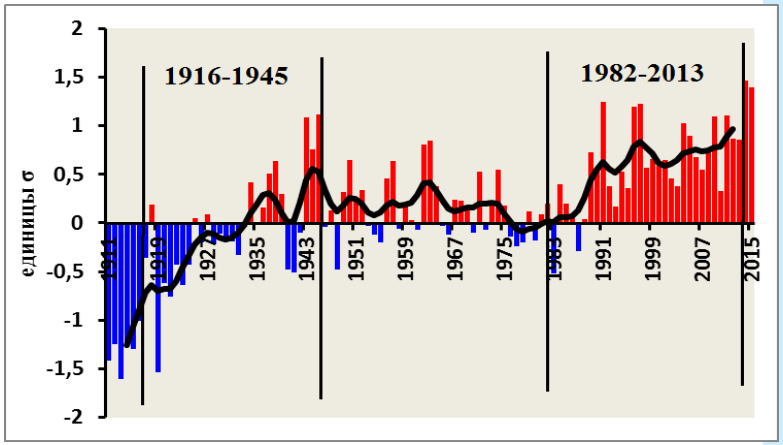


Corr. AOI (+2 yrs) to SSTA (1988-2010)



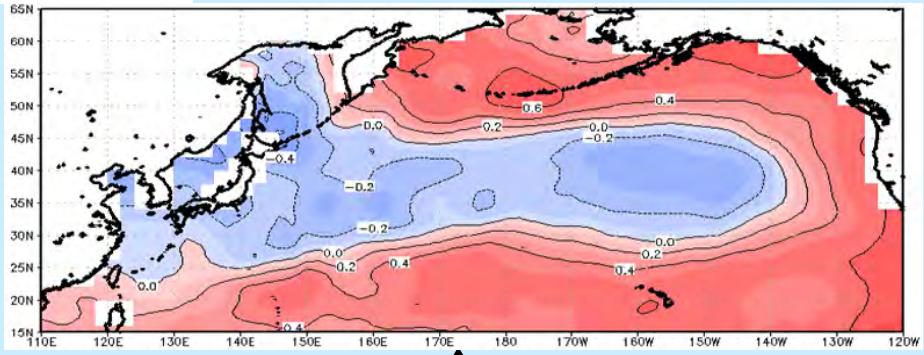
Two periods of high salmon production in Russia and their association with winter SSTA in the NP





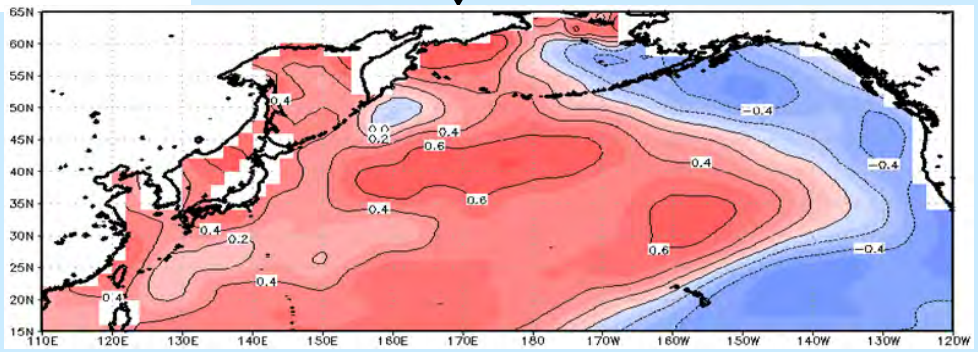
Warming trend

1916-1945

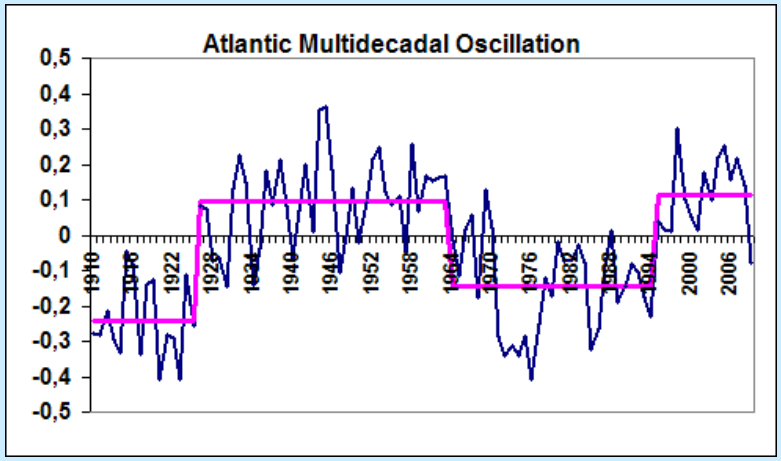


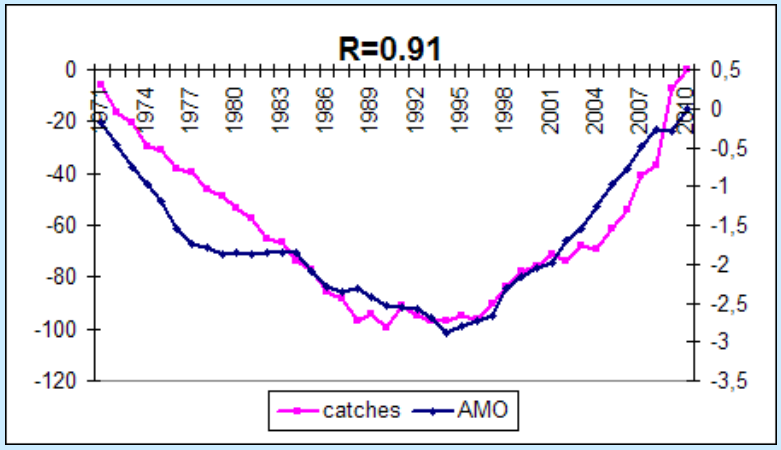
Correlation patterns between salmon catches and mean winter SSTA field for two high salmon periods

1982-2013



Variations in AMO index; CS of total FE pink salmon catches and AMO index (c)

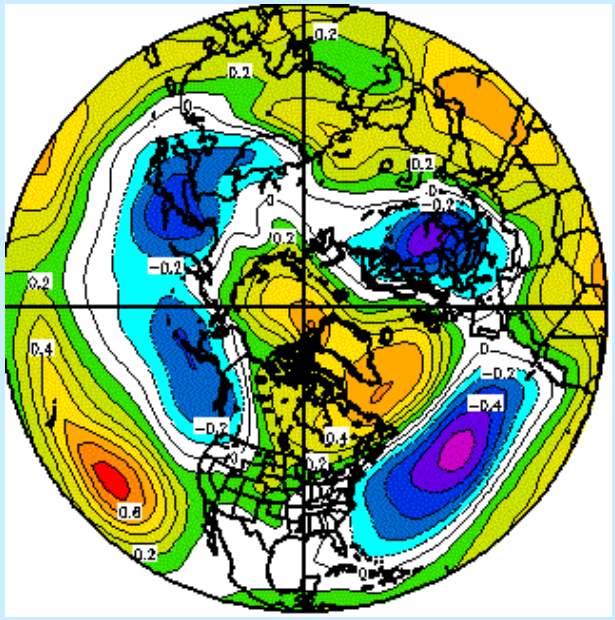


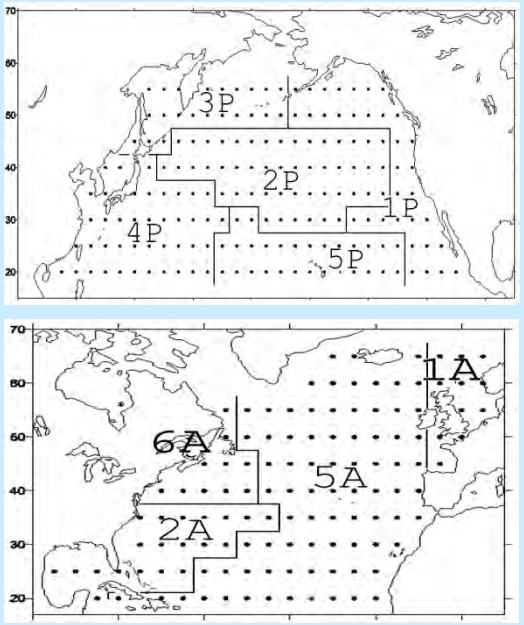


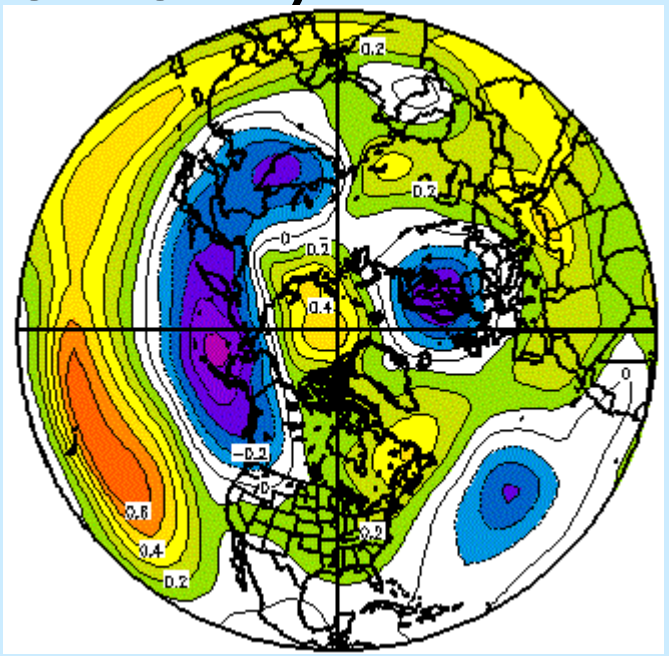
Loadings of the first 2 principal components of the 34 climatic and salmon time series for the 1972-2010 period

VARIABLE	PC1	PC2
	27,60%	17,30%
North Atlantic Oscillation (XII-III)	-0,04	0,53
Arctic Oscillation (XII-III)	0,00	0,72
West Atlantic TP	0,19	-0,65
East Atlantic TP	0,19	-0,05
Scandinavia pattern	-0,33	-0,38
Tropical/NH pattern	-0,27	0,53
Pacific/North American TP (XII-III)	0,43	-0,46
North Pacific Index	0,55	0,58
West Pacific TP	0,32	-0,05
Southern Oscillation Index (XII-III)	-0,14	0,51
Atlantic Multidecadal Oscillation	0,91	-0,26
Tw at Kola Section (0-200 m)	0,42	0,44
Tropical North Atlantic	0,66	-0,56
Region 1A	0,56	0,45
Region 2A	0,54	0,40
Region 3A	0,75	-0,18
Region 4A	0,59	-0,46
Region 5A	0,94	-0,04
Region 6A	-0,12	0,31
Region 1P	0,24	-0,53
Region 2P	0,13	0,70
Region 3P	-0,22	-0,16
Region 4P	0,78	0,25
Region 5P	0,74	0,45
PC1 (28.9%)	0,84	-0,28
PC2 (17.6%)	0,34	0,62
Pacific Decadal Oscillation	0,18	-0,78
North Pacific Gyre Oscillation	0,29	0,22
WK pink (even years)	0,86	-0,01
EK pink (odd years_	0,67	0,22
South Kurils pink	0,60	0,12
WK sockeye	0,85	0,10
EK sockeye	0,57	-0,06
EK chum	0,46	-0,44

Association between central NA and southwestern NP (1986-2014)

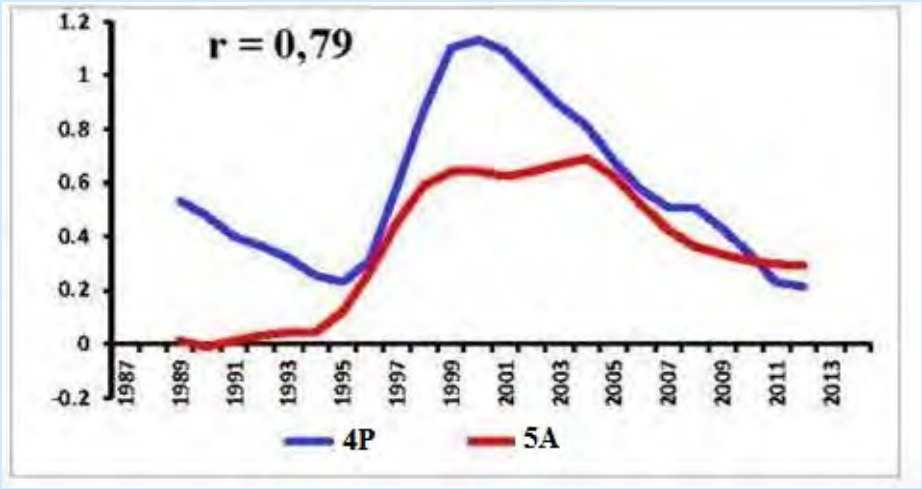






5-yr running SSTA means

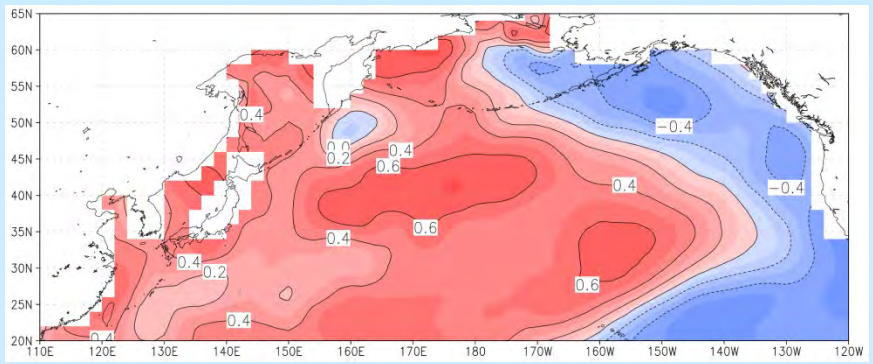
Correlation:
central NA
(region 5A) to H500



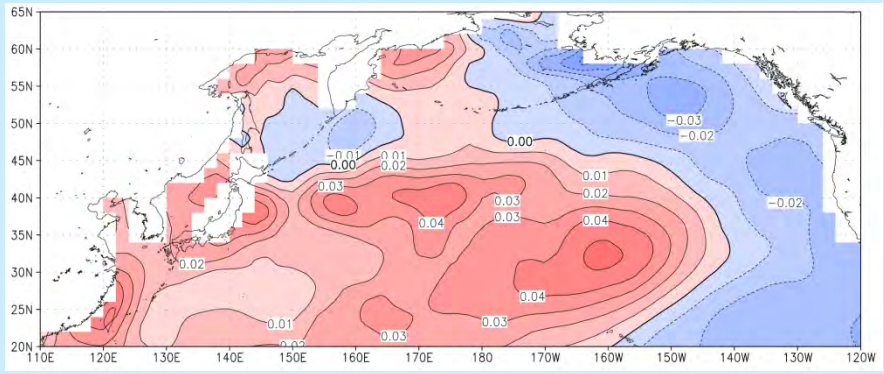
Correlation:
southwestern NP
(region 4P) to H500

Association of total Far East salmon catch with climatic characteristics of the Northern Hemisphere during period of 1982-2013

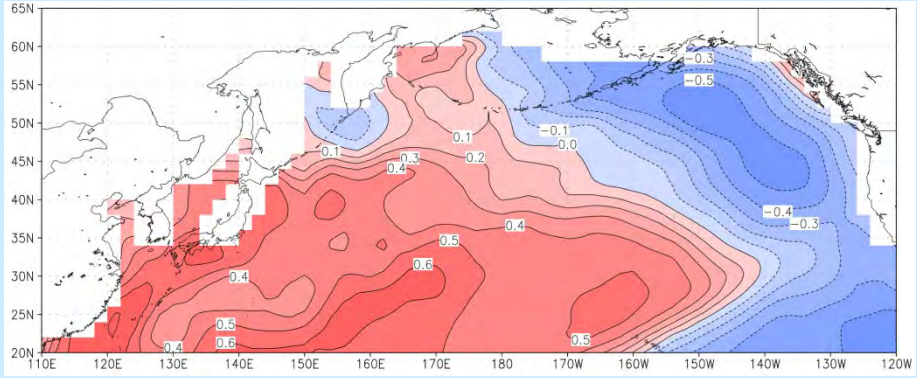
Corr. total salmon catch to mean winter (I-IV) SSTA in the NP in 1982-2013



Values of linear trends (ºC/year) of mean winter SST in the North Pacific for 1982-2013

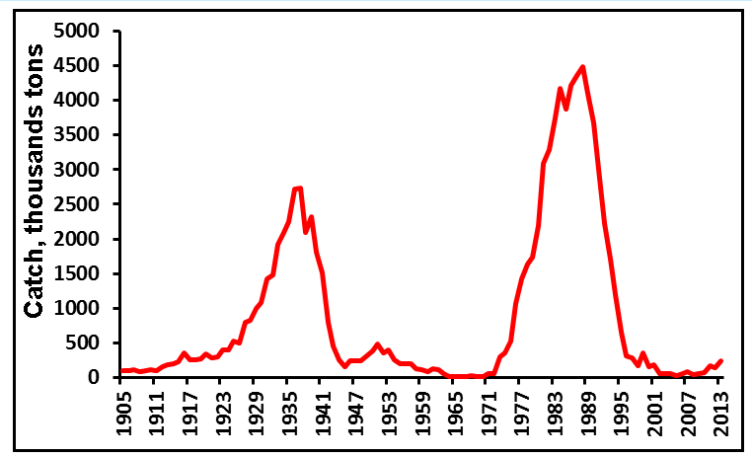


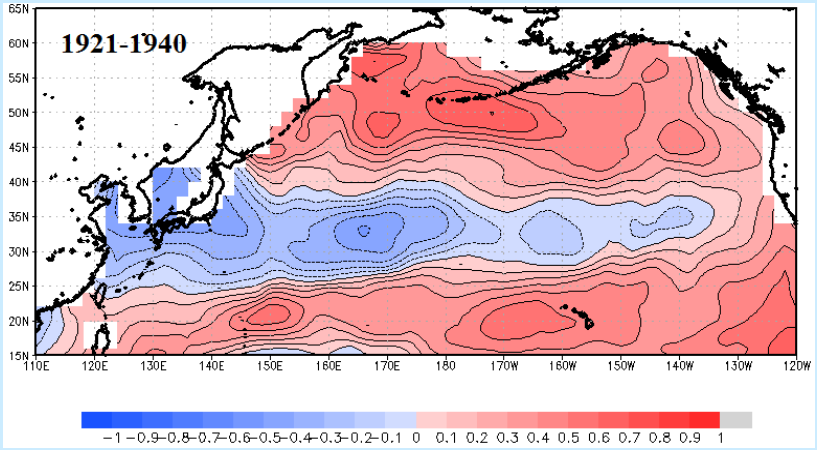
Corr. sum of normalized winter anomalies of Azores High and Icelandic Low longitudes in winter seasons of 1977-2005 to SSTA in the North Pacific with t=6 years



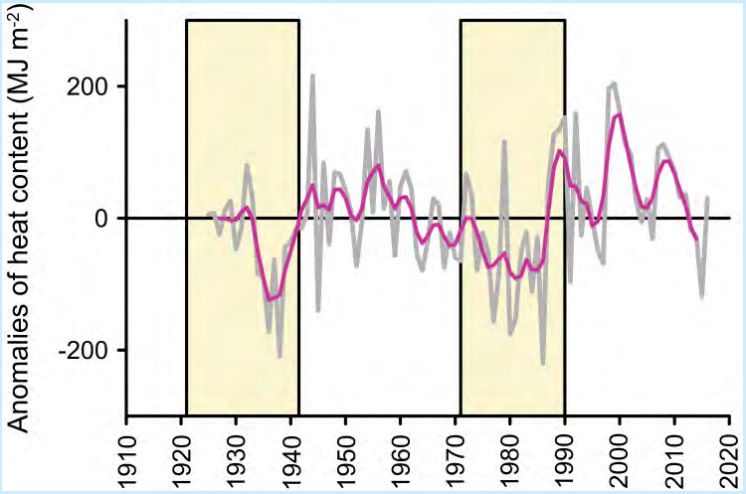
Japanese sardine and NP climate

Sardine catches by Japan, 1905-2014

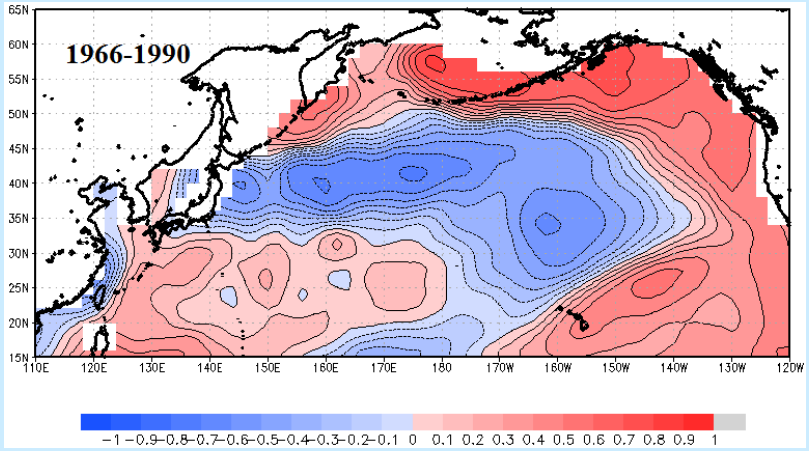




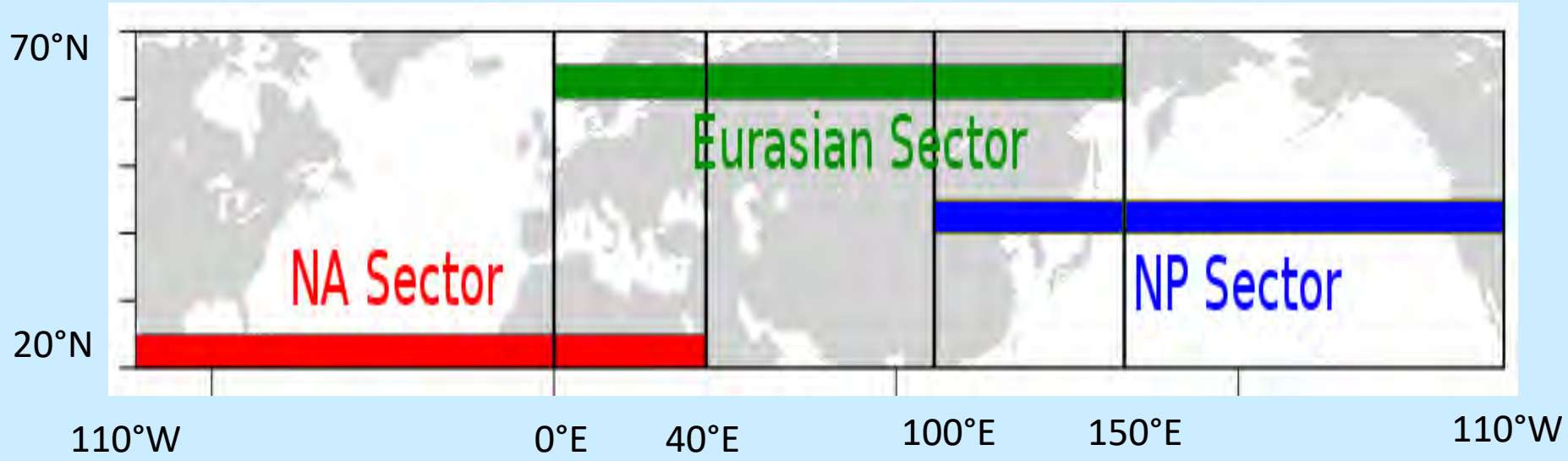
Anomalies of heat content in the 0-50 m layer in February east of Japan (30-35°N, 145-180°E), 1925-2016. Vertical bars show "sardine epochs"



Corr. sardine catch to NP SSTA in January-February for two "sardine epochs"

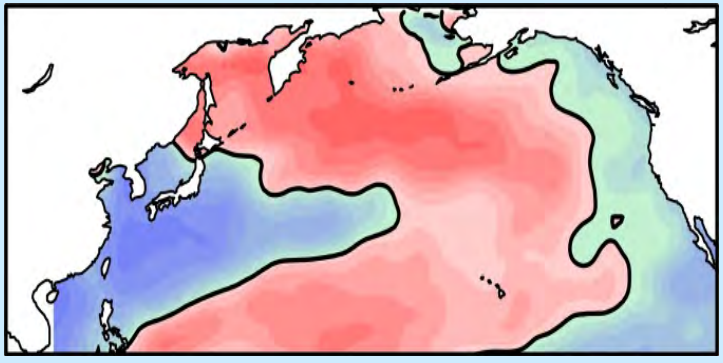


Scheme of the NH partitioning into 3 sectors

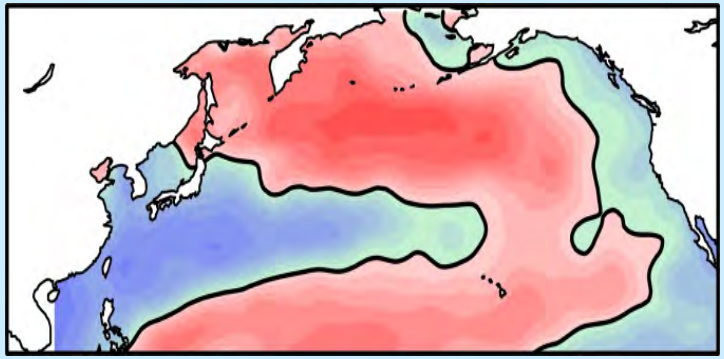


We divided the NH into 3 sectors and calculated the first 3 PCs of normalized winter (DJF) H500 anomalies for each sector and combined sectors (NA+Eu, Eu+NP) for 2 periods: 1916-1945 and 1966-1995. All these components are strongly related to the well-known atmospheric TP, such as the EA, SCA, EA/WR, WP, and PNA patterns.

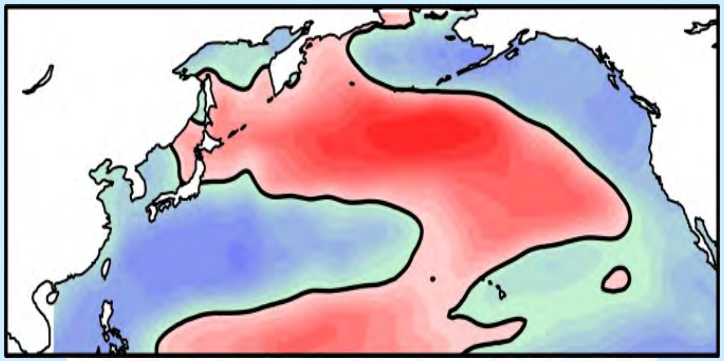
Corr. patterns of atmospheric PCs associated with NP1 and winter (JFM) NP SSTA (1916-1945)



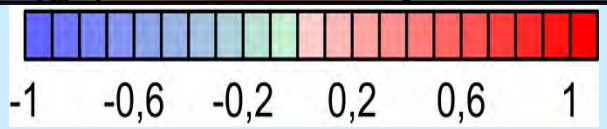
Corr. NAEu1 (20.0%) to SSTA



Corr. EuNP1 (23.3%) to SSTA

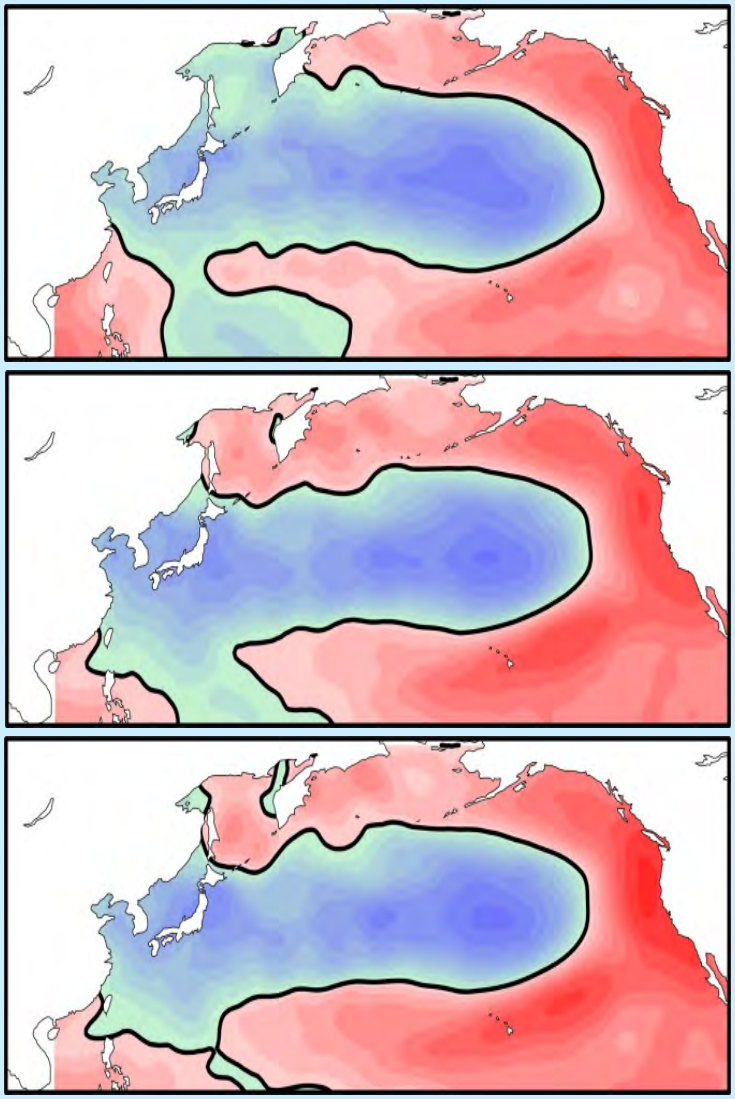


Corr. NP1 (28.8%) to SSTA



NaEu1 $\xrightarrow{0.92}$ Eu1 $\xrightarrow{0.96}$ Eu NP1 $\xrightarrow{0.94}$ NP1 (- WP)

Corr. patterns of atmospheric PCs associated with NP2 and winter (JFM) NP SSTA (1916-1945)



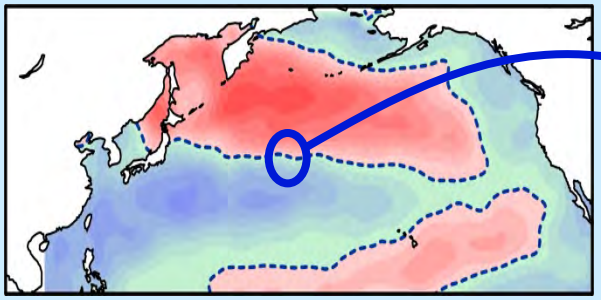
Corr. NAEu2 (18.5%) to SSTA

Corr. EuNP2 (15.9%) to SSTA

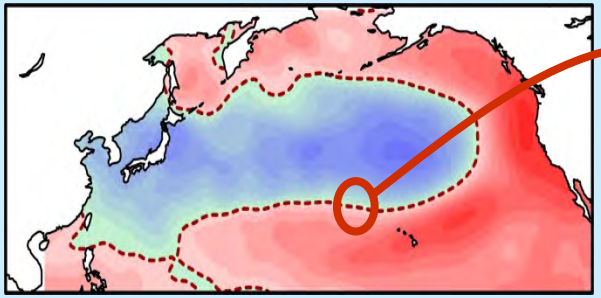
Corr. NP2 (22.4%) to SSTA

$$\mathrm{NaEu2} \xrightarrow{0.82} \mathrm{EuNP2} \xrightarrow{0.88} \mathrm{NP2\,(+PNA)}$$

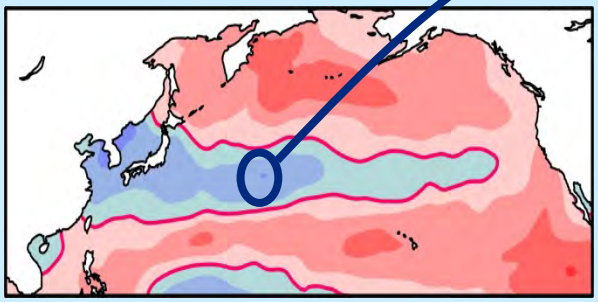
Which climate modes determine favorable conditions?



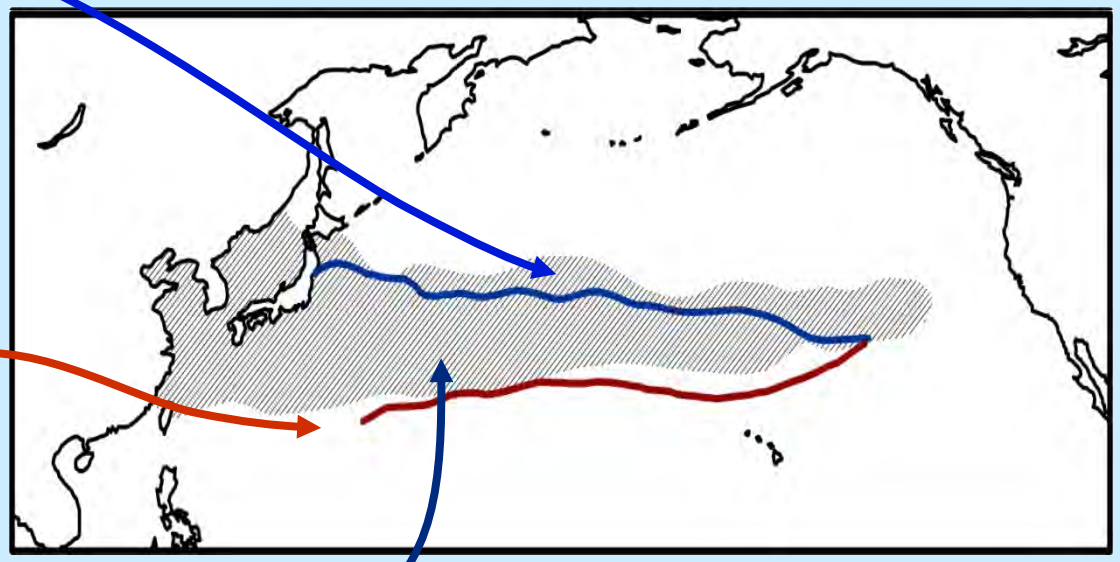
Corr. NP1 to SSTA



Corr. NP2 to SSTA

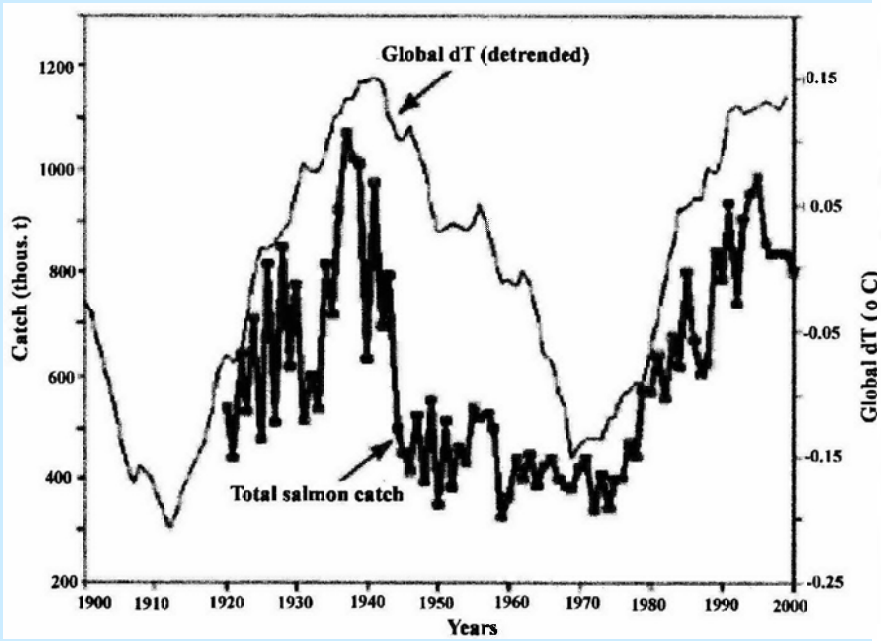


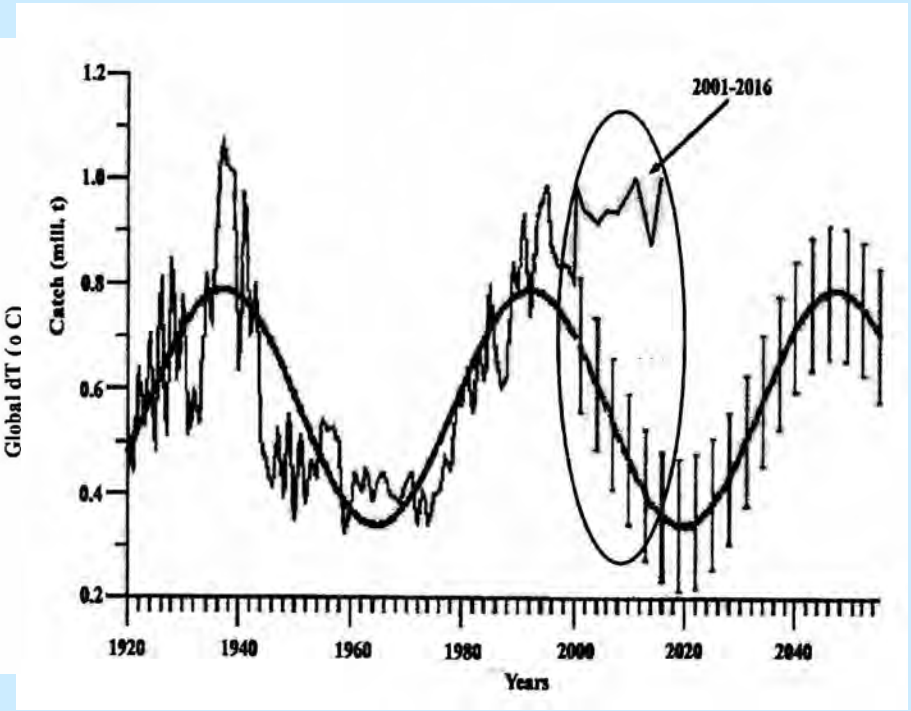
Corr. Catch to SSTA



Both PC1 and PC2 of climate variability across North Pacific contributed to establishment of sardine period in 1916-1940

Long-range forecast of total Pacific salmon catches based on cyclic character of changes in their stock (Klyastorin and Lyubushin, 2007)

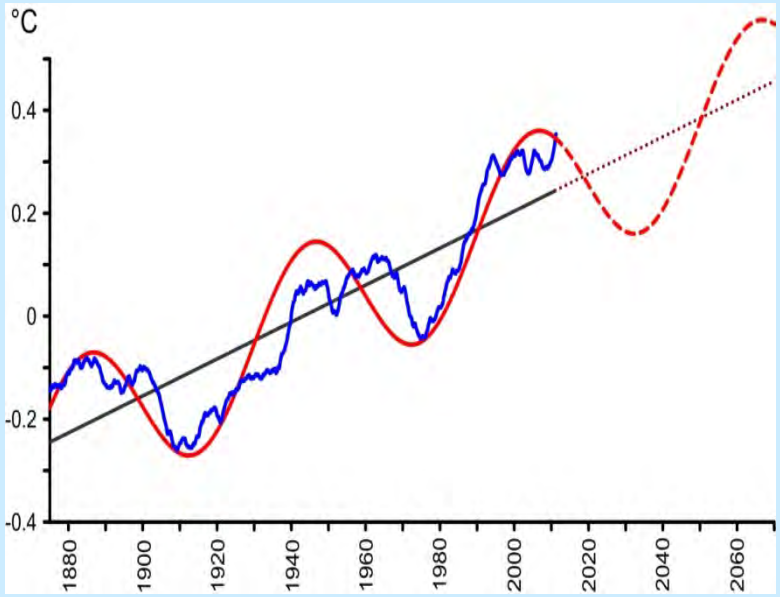




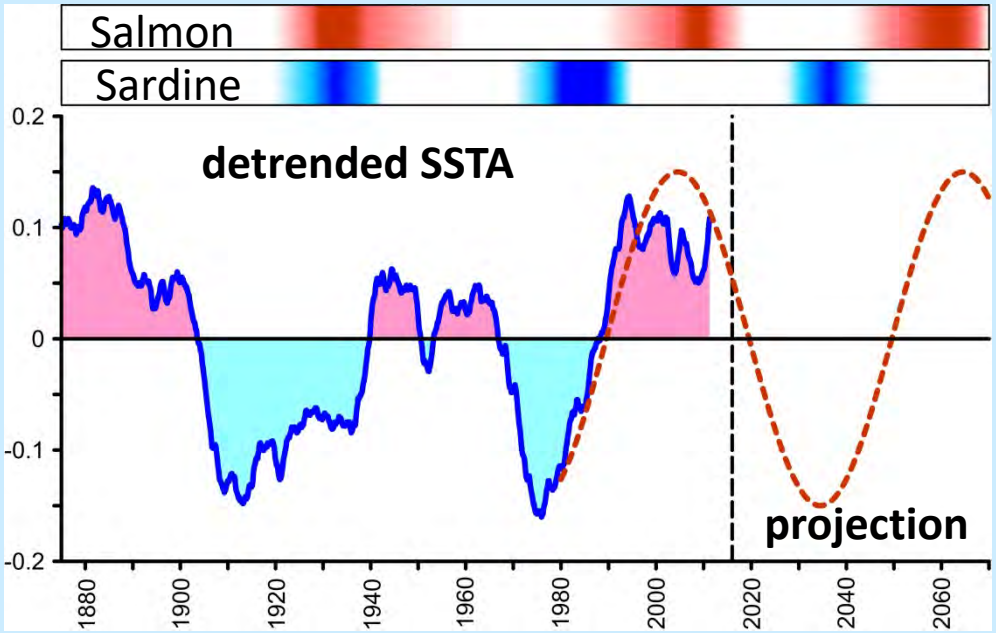
Long-term dynamics of total Pacific salmon catch (bold line) and detrended Global dT (thin line)

The projected trend of total commercial catches (bold line) of Pacific salmon Oncorhynhus spp. with a 50 year future perspective. Thin line shows commercial catch; bold line shows predicted trend marked with standard deviation vertical bars

The North Pacific SSTA vs. salmon and sardine periods



SSTA in the NP (0-65°N, 110-260°E) smoothed by 121-month filter



New sardine period – 2030s
New salmon period – 2040s-2070s

CONCLUSION

There are, at least, 2 modes of variability of fish stocks in the NW Pacific:

1) **Quasi-decadal mode (~15 yrs) associated with the NPGO in the ocean and North Pacific Oscillation and Arctic Oscillation in the atmosphere.**

2) **Multi-decadal mode (~ 60 yrs) associated with the corresponding climatic "epochs" of the hemispheric scale. The variations of fish stocks at this time scale may be predicted with some degree of certainty**


Thank you for attention