

Prospects of a new ‘sardine epoch’ in the Northwest Pacific

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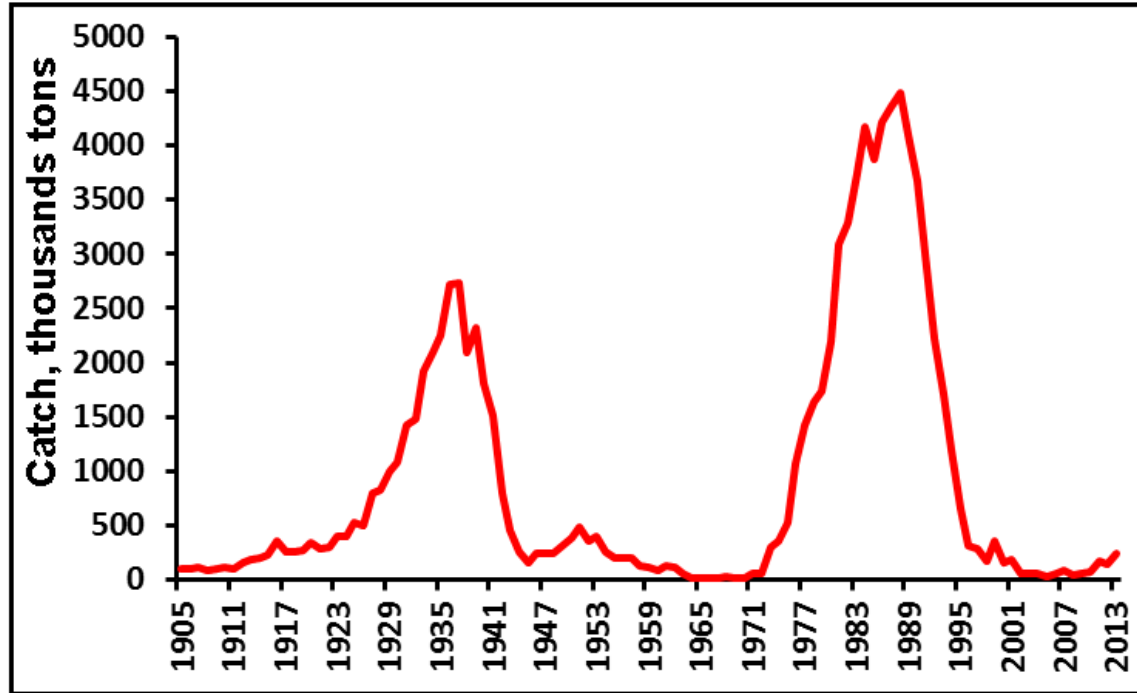
OUTLINE

- **Why do we consider Japanese sardine – importance for the Russian fishery**
- **Some known physical mechanisms of sardine stock growth**
- **Association of the sardine periods in the XX century with the large –scale SSTA patterns in the NP**
- **Relation of these SSTA patterns to the large-scale modes of atmospheric variability in the NH**
- **The ‘place’ of sardine periods in multi-decadal variability of the NP SSTA and when we could expect a new sardine period**
- **Conclusion**

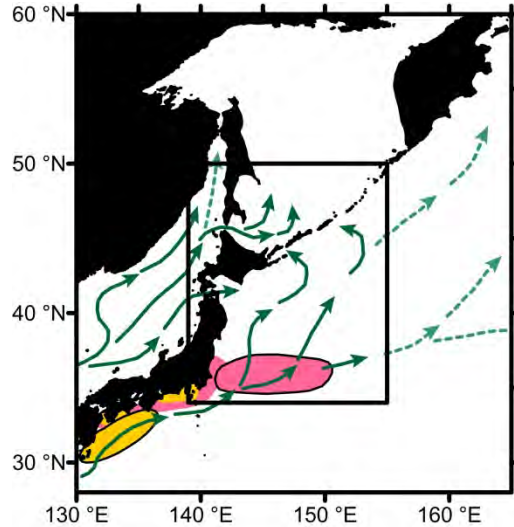
DATA

- **Sardine catches by Japan for the 1905-2014 period (FAO Statistics)**
- **Mean monthly data on H500 for the 1910-1950 period – from NOAA-CIRES 20th Century Reanalysis V2C [www.esrl.noaa.gov/psd/]**
- **Mean monthly data on H500 for the 1951-1995 period – from NCEP/NCAR Reanalysis [www.esrl.noaa.gov/psd/]**
- **Mean monthly SST data from NOAA ERSST v4 dataset [www.esrl.noaa.gov/psd/]**

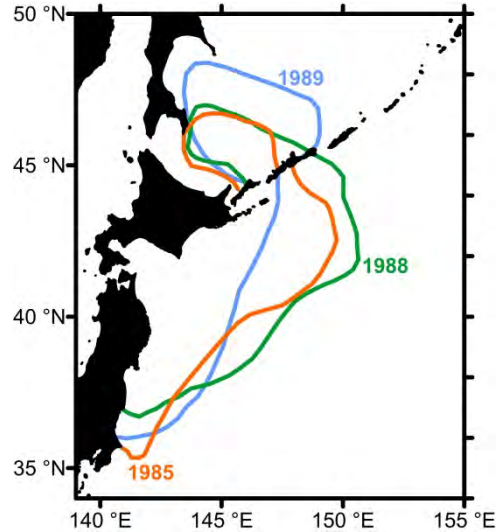
Sardine catches by Japan, 1905-2014



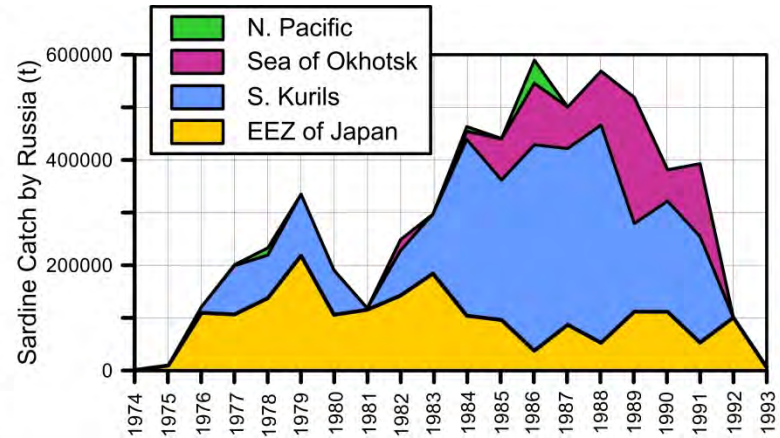
Importance of Japanese sardine for Russian fishery



Scheme of spawning and nursery grounds (Wada & Oozeki, 1999) and northward migrations of Japanese sardine (Kuroda, 1991)



Boundaries of maximal distribution of fishery concentrations of Japanese sardine in the 1980s (Belyaev, 2003)

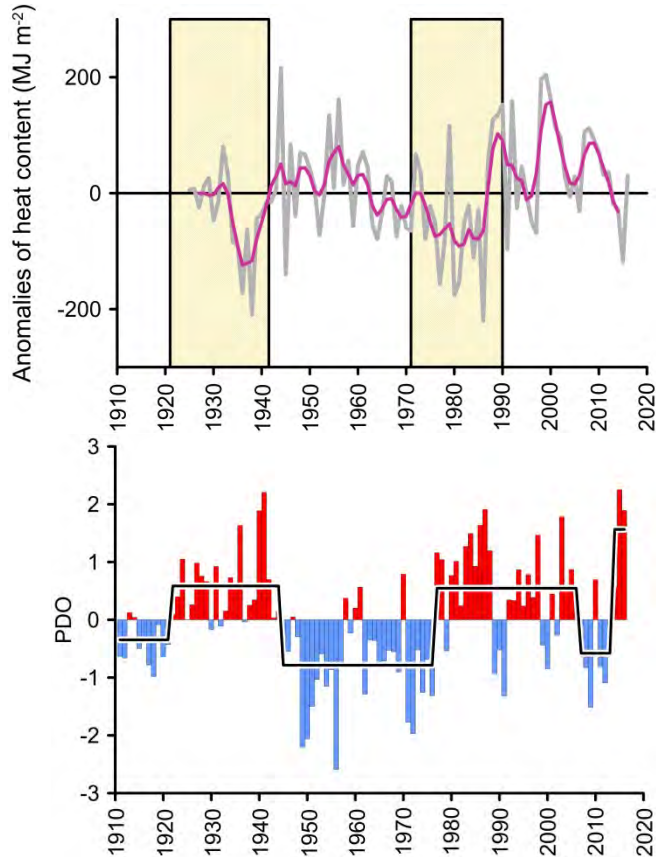


Russian sardine catches in the North Pacific and the Sea of Okhotsk (Belyaev, 2003)

Some mechanisms relating sardine abundance with environment and climate

- **Negative correlation between SST (February) on the nursery grounds and sardine at age 0+ - cold periods east of Japan (Noto, Yasuda, 1999, 2003; Yasuda et al., 1999; Yatsu et al., 2005, 2013)**
- **Sardine epochs are associated with the PDO dynamics (Takasuka et al., 2008).**
- **The combined effect of El Nino and Asian Monsoon (Sugimoto et al., 2001; Kasai et al., 1997; Sugimoto and Tadokoro, 2002; Wada and Kashiwai, 1991; Yasuda et al., 1999).**
- **In the Northwest Pacific, the AO and Asian Winter Monsoon correlate with anchovy/sardine regime shifts (Alheit & Bakun, 2010).**

Some mechanisms relating sardine abundance with environment and climate



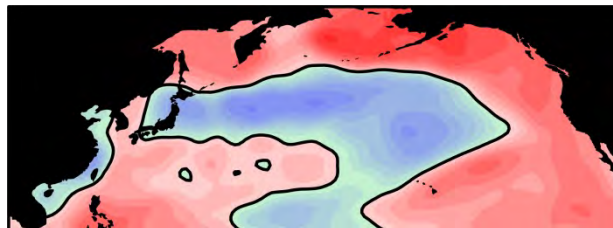
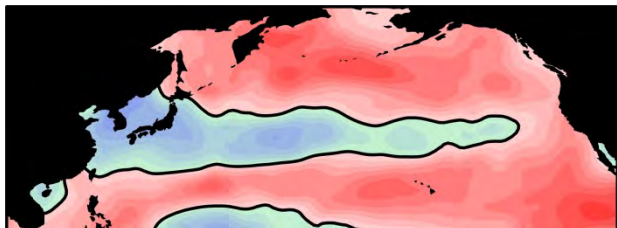
Anomalies of heat content in the 0-50 m layer in February east of Japan (30-35°N, 145-180°E), 1925-2016. Vertical bars show sardine epochs

Changes in PDO index (January-February), 1910-2016

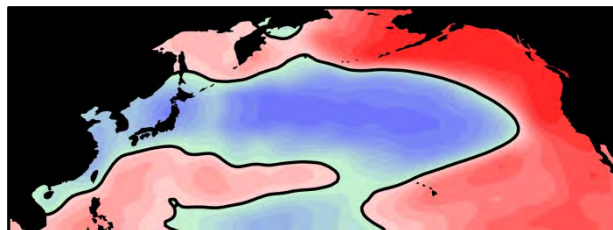
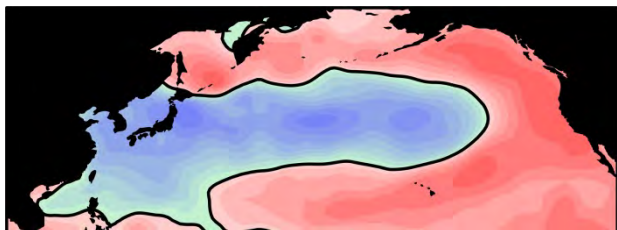
Results

1921-1940

1966-1990



Corr. catch to
SSTA (I-II) field



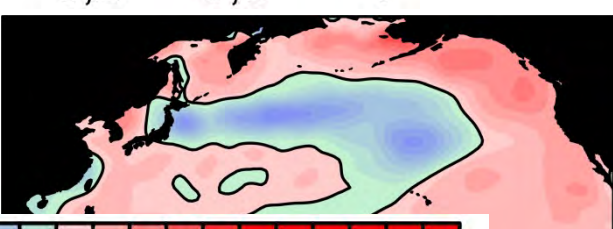
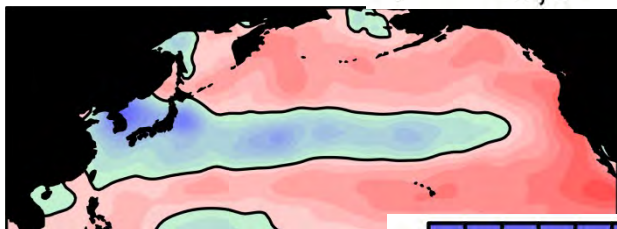
Corr. PDO to
SSTA (I-II) field

R (PDOI, catch)= 0.23



R (PDOI, catch)= 0.66

-1 -0,6 -0,2 0,2 0,6 1

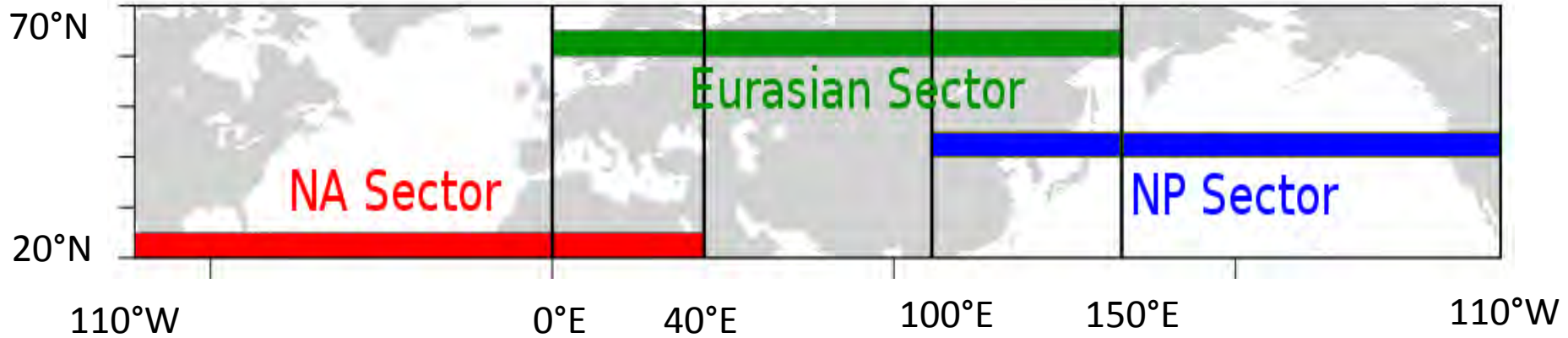


Trend in SSTA
changes (°C/yr)



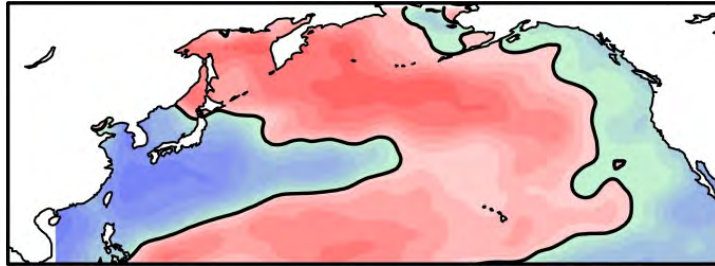
-0,2 -0,1 0 0,1 0,2

Scheme of the NH partitioning into 3 sectors

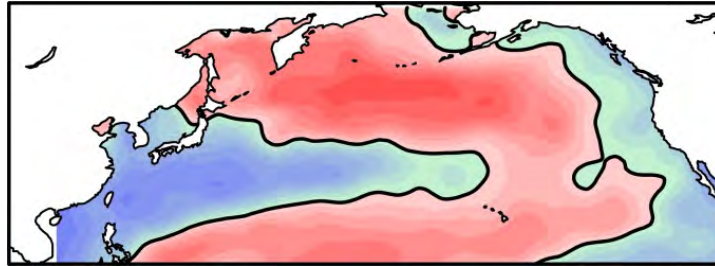


We divided the NH into 3 sectors and calculated the first 3 PCs of normalized winter (DJF) H500 anomalies for each sector and combined sectors (NA+Eu, Eu+NP) for 2 periods: 1916-1945 and 1966-1995. All these components are strongly related to the well-known atmospheric TP, such as the EA, SCA, EA/WR,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

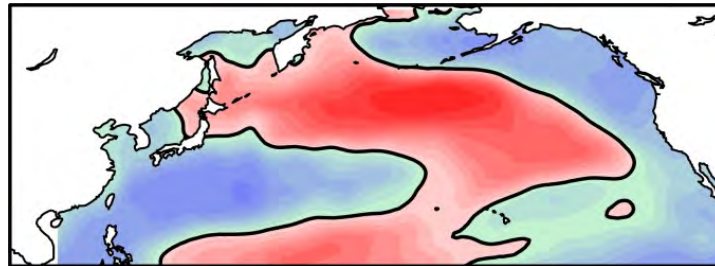
Corr. patterns of atmospheric PCs associated with NP1 and winter (JFM) NP SSTA (1916-1945)



Corr. NAEu1 (20.0%) to SSTA

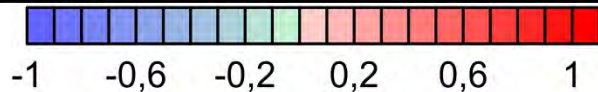


Corr. EuNP1 (23.3%) to SSTA

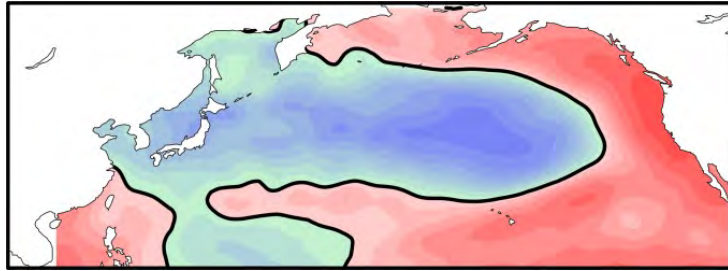


Corr. NP1 (28.8%) to SSTA

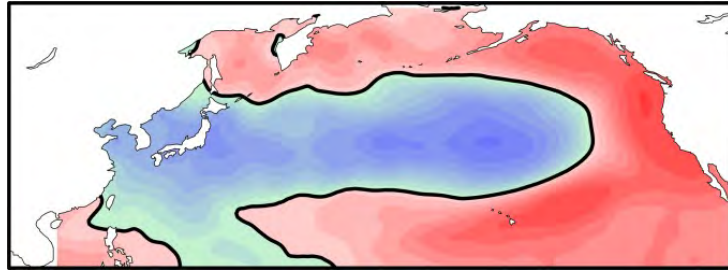
NaEu1 $\xrightarrow{0.92}$ Eu1 $\xrightarrow{0.96}$ EuNP1 $\xrightarrow{0.94}$ NP1 (- WP)



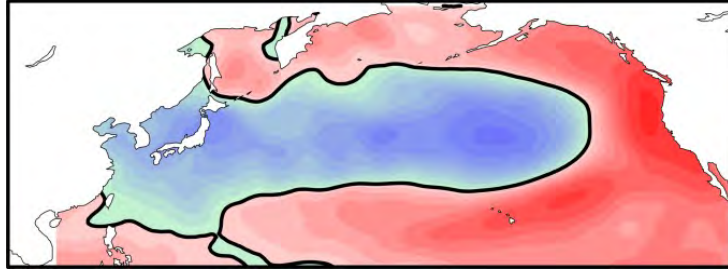
Corr. patterns of atmospheric PCs associated with NP2 and winter (JFM) NP SSTA (1916-1945)



Corr. NAEu2 (18.5%) to SSTA



Corr. EuNP2 (15.9%) to SSTA

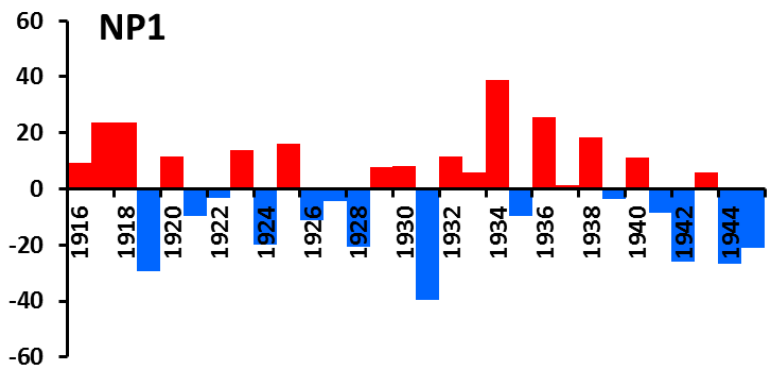
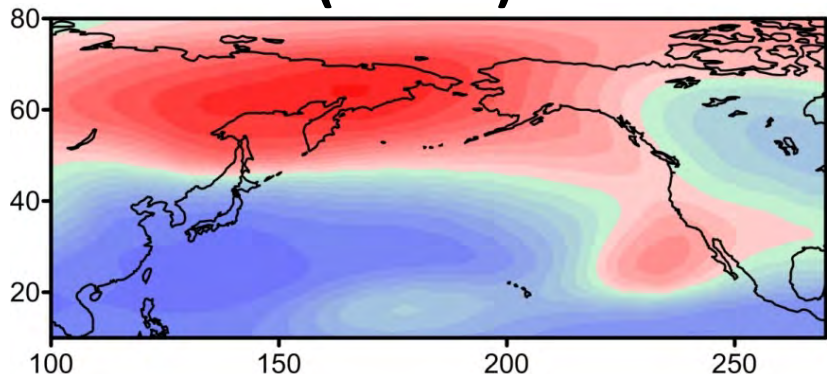


Corr. NP2 (22.4%) to SSTA

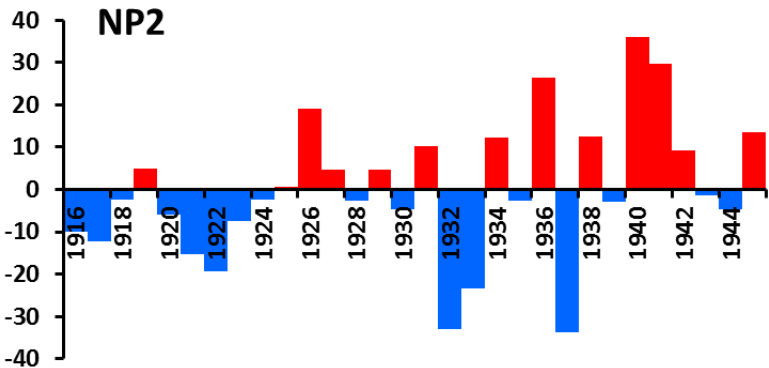
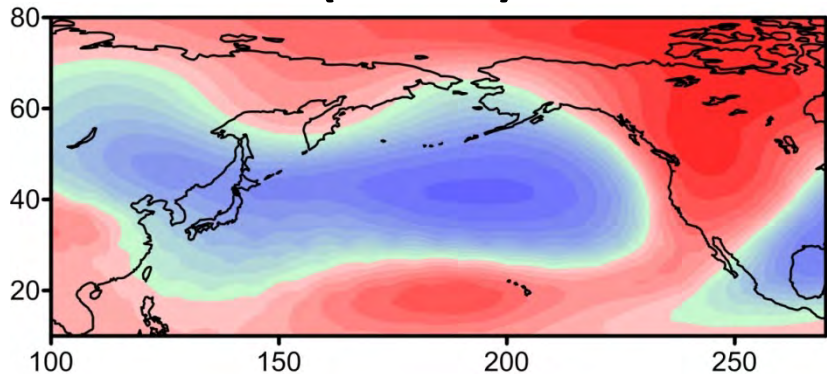


Two first modes of winter atmospheric variability in the NP sector (1916-1945)

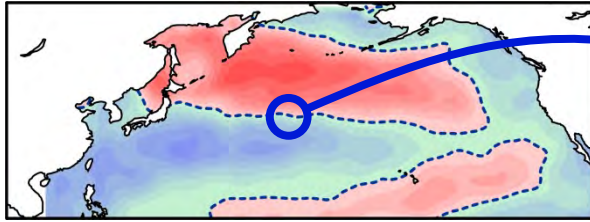
NP1 (28.8%) -WP



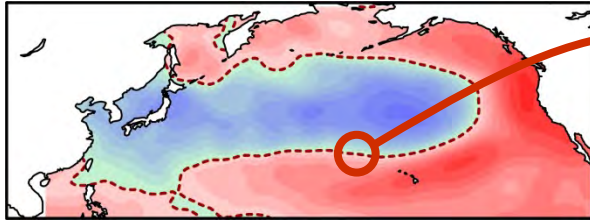
NP2 (22.4%) +PNA



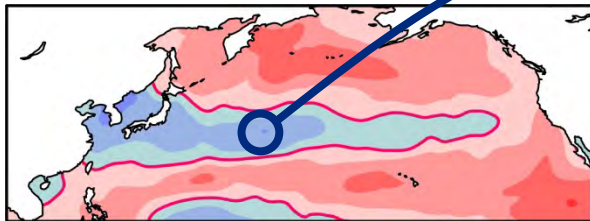
Which climate modes determine favorable conditions?



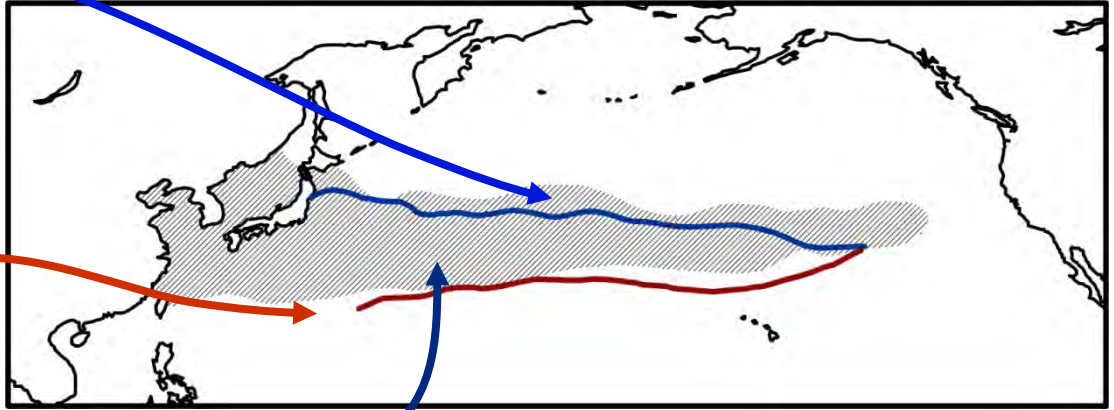
Corr. NP1 to SSTA



Corr. NP2 to SSTA

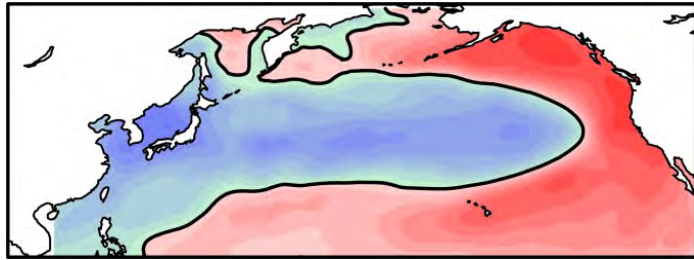


Corr. Catch to SSTA

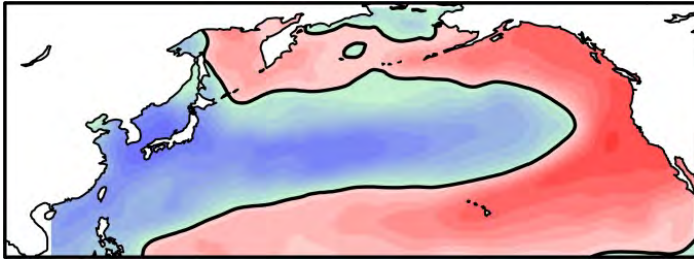


Both PC1 and PC2 of climate variability across North Pacific contributed to establishment of sardine period in 1916-1940

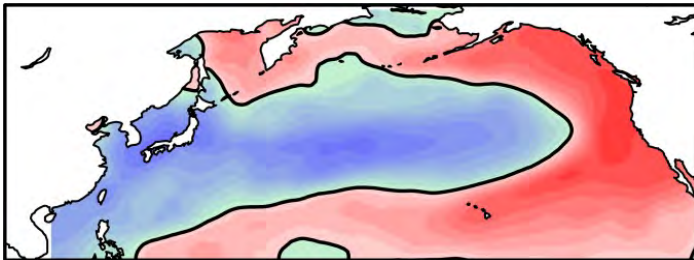
Corr. patterns of atmospheric PCs associated with NP1 and winter (JFM) NP SSTA (1966-1995)



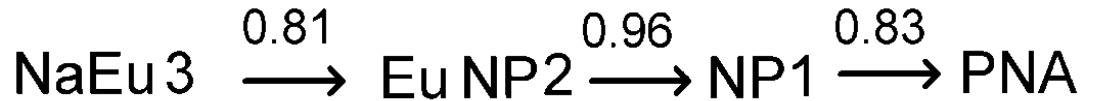
Corr. NAEu3 (14.1%) to SSTA



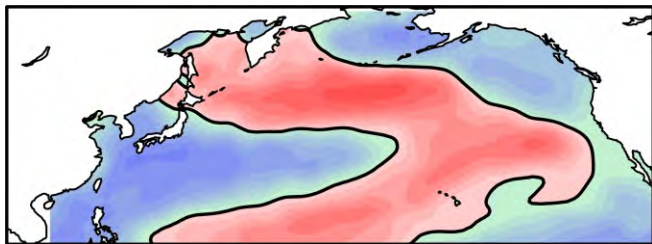
Corr. EuNP2 (22.2) to SSTA



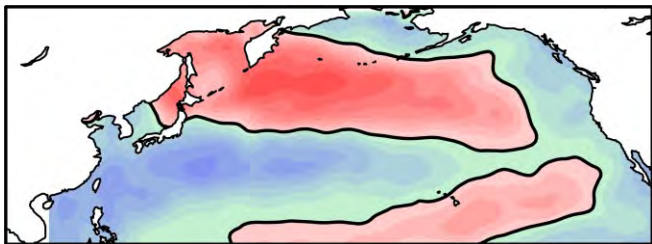
Corr. NP1 (29.6%) to SSTA



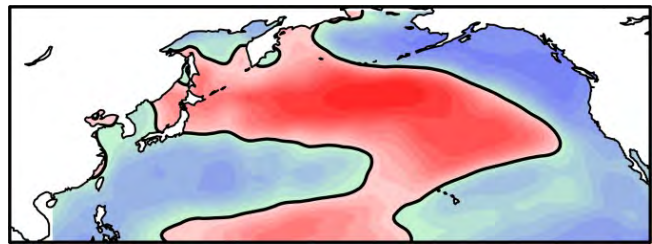
Corr. patterns of atmospheric PCs associated with NP2 and winter (JFM) NP SSTA (1966-1995)



Corr. NAEu1 (25.5%) to SSTA



Corr. EuNP1 (27.1%) to SSTA



Corr. NP2 (27.0%) to SSTA

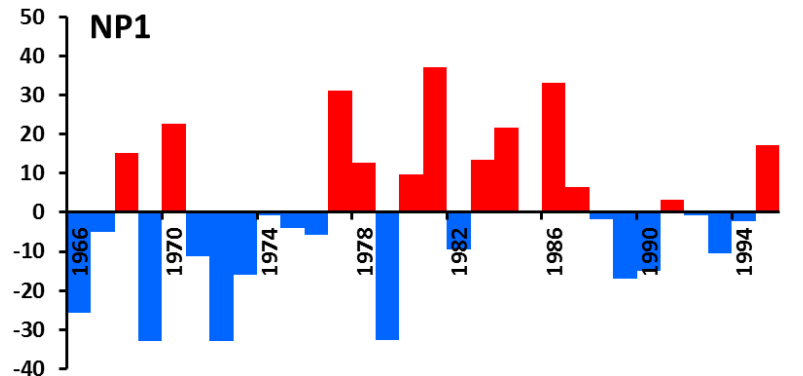
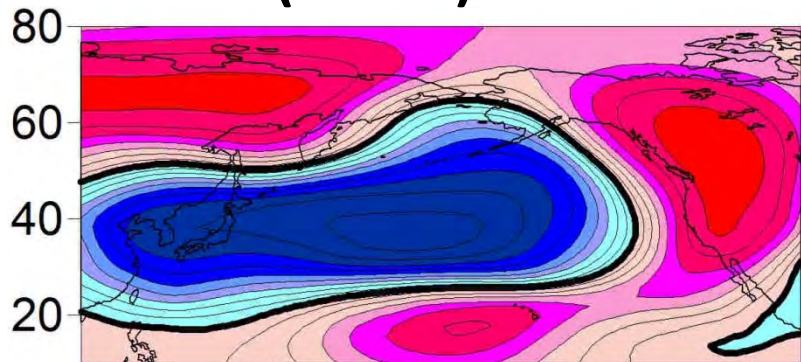


-1 -0,6 -0,2 0,2 0,6 1

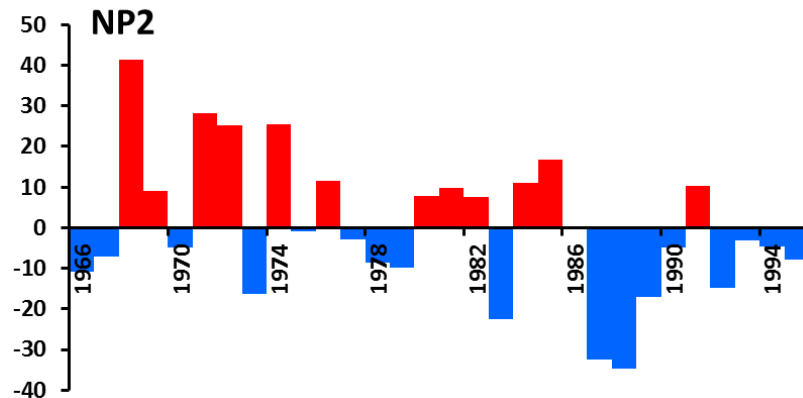
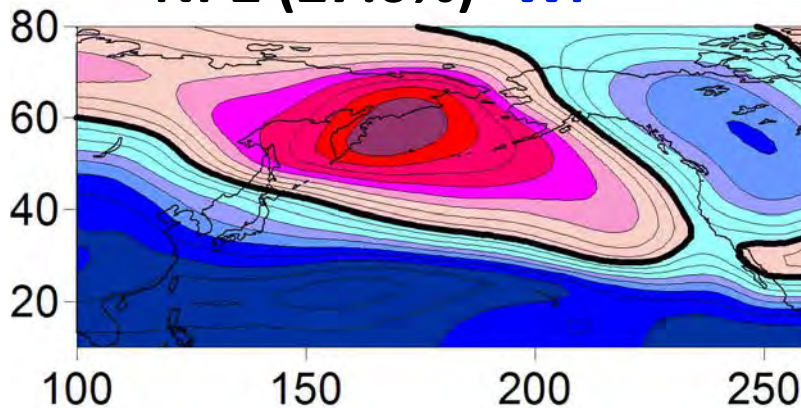


Two first modes of winter atmospheric variability in the NP sector (1966-1995)

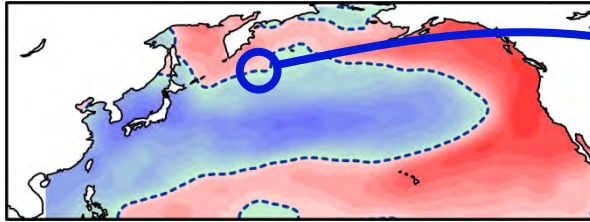
NP1 (29.6%) +PNA



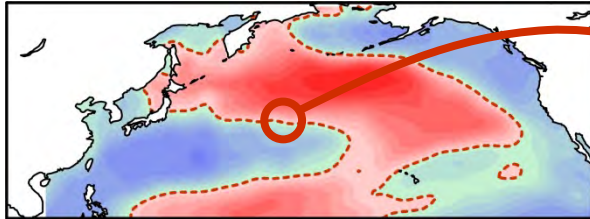
NP2 (27.0%) -WP



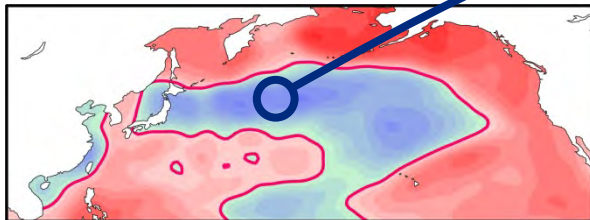
Which climate modes determine favorable conditions ?



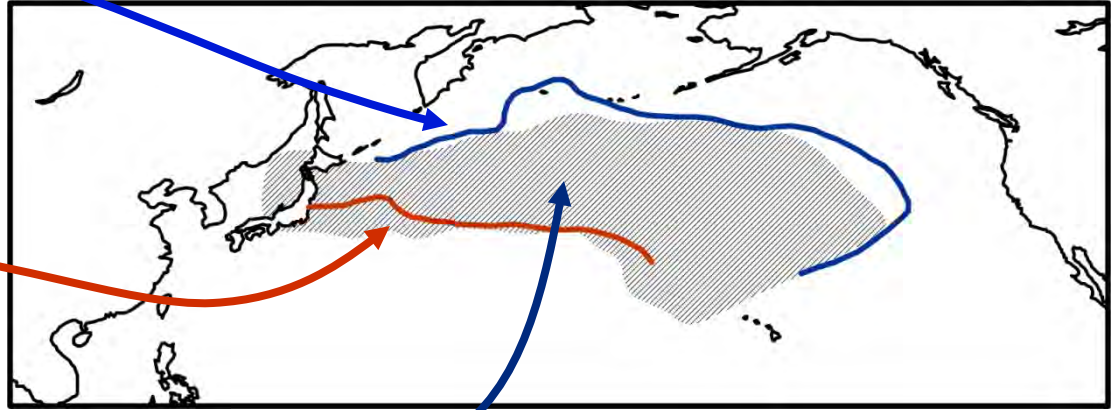
Corr. NP1 to SSTA



Corr. NP2 to SSTA

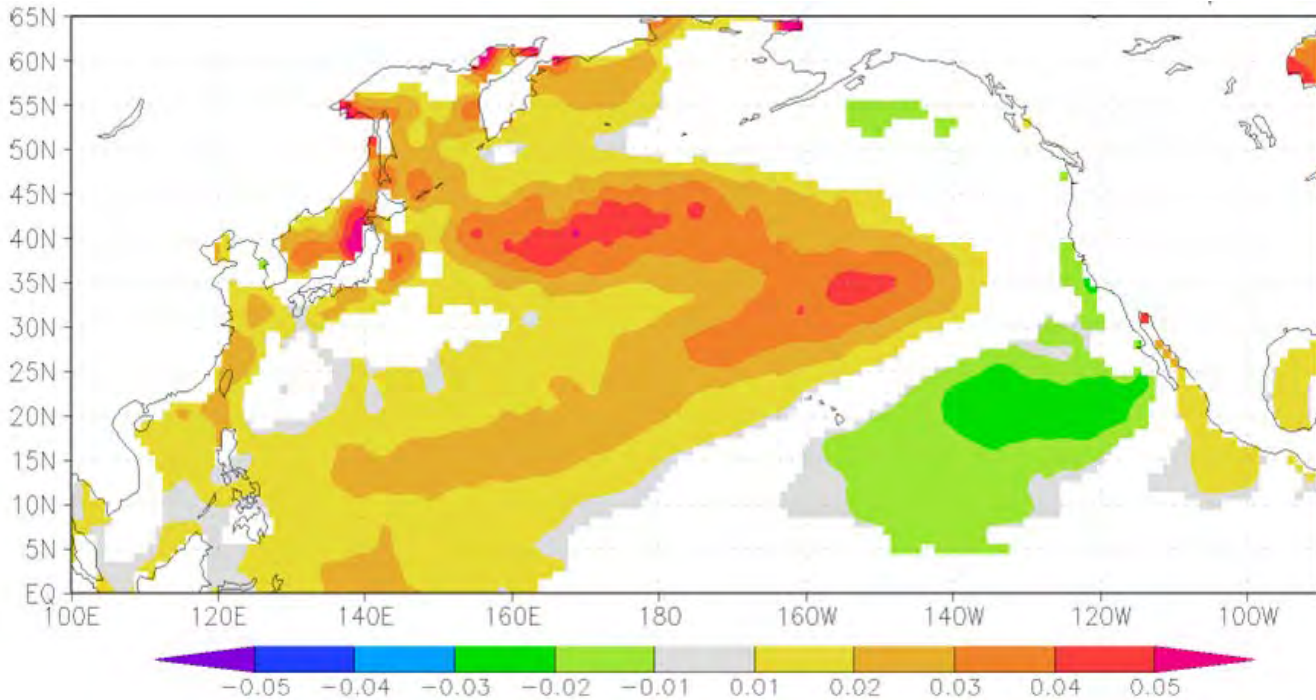


Corr. Catch to SSTA

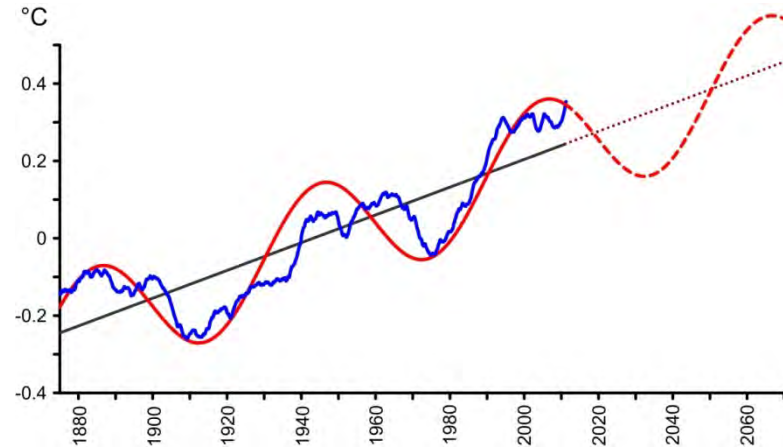


Both 1st and 2nd PCs of climate variability across the NP contributed to establishment of sardine period in 1966-1990, with larger contribution of PC1

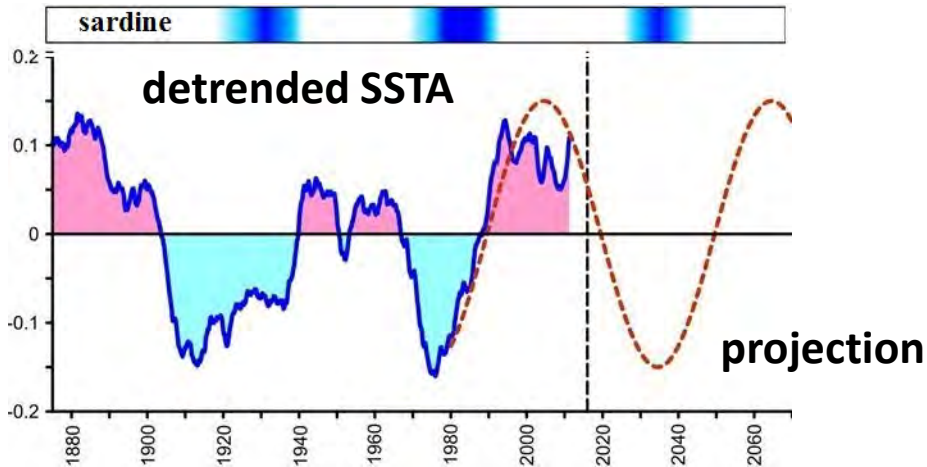
NP SST A Trends ($^{\circ}\text{C}/\text{year}$) – 1988-2013 (Reynolds OI v2)



The North Pacific SSTA and sardine periods



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



Periods of high sardine abundance in the 20th century began around the minimum of multi-decadal cycle in the NP SSTA variations and ended with transition to its positive phase. Hence, the beginning of a new sardine period may be expected in the 2030s.

Conclusions

- **Two periods of high abundance of Japanese sardine in the 20th century revealed rather strong association with trends and large-scale modes of the winter SSTA variability in the North Pacific**
- **These SSTA modes, in turn, reflected different states of the large-scale atmospheric circulation across the NH, which in its NP sector appeared as the West Pacific pattern (in its negative phase) and Pacific/North American pattern (in its positive phase)**
- **Periods of high sardine abundance begin around the minimum of multi-decadal cycle in the NP SSTA variations and end with transition to its positive phase. Hence, the beginning of a new sardine period may be expected in the 2030s.**

Thank you for attention

