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Changes in recruitment of Pacific cod in the northwestern Bering Sea and their relation to climate variations in the Northern Hemisphere

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and George Moury



OUTLINE

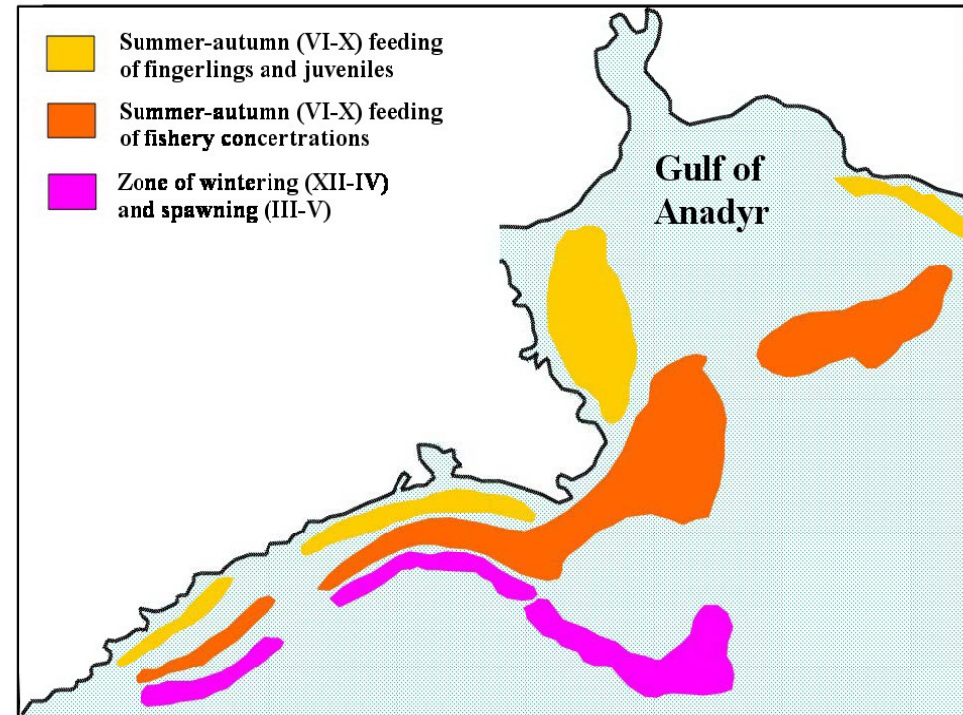
- **Some fishery and biological characteristics of northwestern Bering Sea (NWBS) cod stock**
- **Relationships between recruitment of NWBS cod and the NP climatic patterns**
- **Relationships between recruitment of NWBS cod and hemispheric climatic patterns**
- **Association of decadal variations in recruitment of some NH cod stocks**
- **Conclusion**

DATA

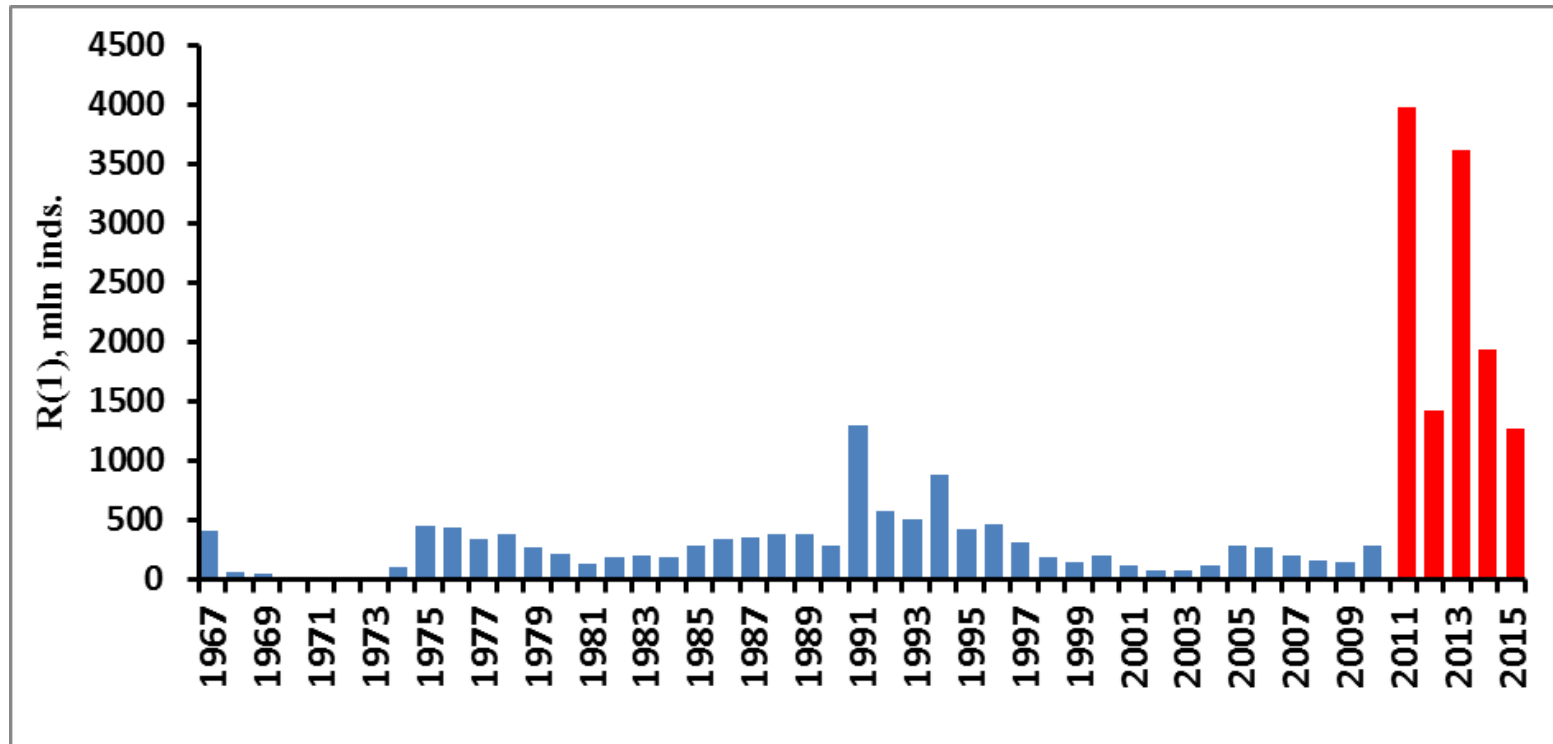
- **Retrospective assessment of NWBS cod stock was made with the use VPA with Saville's adjustment (Maksimenko and Antonov, 2004). The cod catches by year (mln inds.) for 1968-2016 were used as initial data for the assessment (Antonov, 2011 with additional data since 2010 from TINRO-Center)**
- **Mean monthly SST data from NOAA ERSST v3b dataset [www.esrl.noaa.gov/psd/]**
- **Mean monthly data on H500 from NCEP/NCAR Reanalysis [www.esrl.noaa.gov/psd/]**
- **Mean monthly values of the NPGO [www.o3d.org/npgo/data/NPGO.txt] and AO [www.cpc.noaa.gov/products/] indices for 1967-2016**
- **Recruitment of Northeast Arctic cod at age 3 years for 1967-2015 (ICES AFWG, 2016) and eastern Bering Sea cod for 1977-2014 [www.beringclimate.noaa.gov/data/]**

The functional structure of the Northwestern Bering Sea cod areal

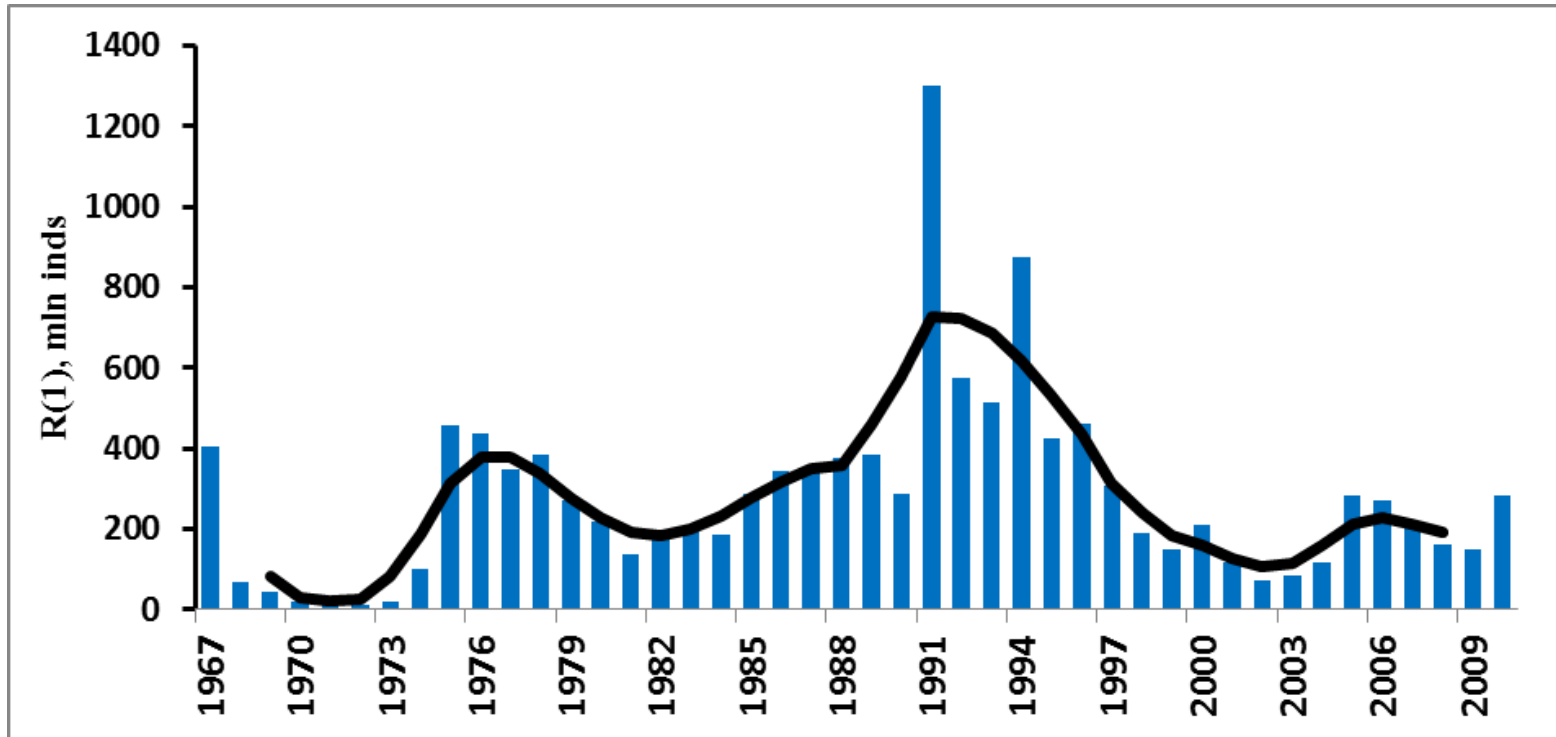
1. Areal	shelf and upper part of the continental slope down to 500 m
1.1. summer-autumn (VI-X) feeding of fingerlings and juveniles	Coastal zone, depths from 20 to 60/70 m
1.2. summer-autumn (VI-X) feeding of fishery concentrations	Depth range of 50 – 170 m
1.3. wintering spawning	XII – IV Depth range of 140 – 250 m III – V Depth range of 140 – 250 m
2. Recruitment at age 1 year	From 13.5 mln up to about 4 bln inds.
3. Catch	
3.1. Annual catch	0.4 – 92 thousand tons.
3.2. Catch per vessel-day	Trawl: 6-15 t Longline: 6-12 t
3.3. Size composition of fish with maximal abundance in catches	Trawl: 36-46 cm Longline: 60-72 cm
3.4. Age composition of catches	Trawl: 3-6 years Longline: 7-9 years
4. Range of fishery stock (10**3 tons)	1968 – 1980: 20 - 400 1981 - 1990: up to 600-800 1991 – 2000: 350 – 800/500 2001 – 2007: 400 – 500 2007 – 2010: 500 – 800 2011 – 2016: 1000 – 2800



Recruitment of northwestern Bering Sea cod at age of 1 year, 1967-2015. The years are the years of spawning.

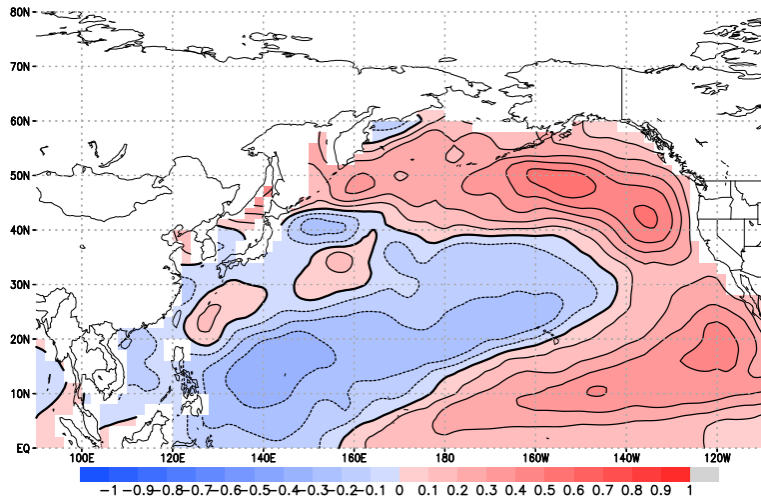


Recruitment of northwestern Bering Sea cod at age of 1 year, 1967-2010. The years are the years of spawning.

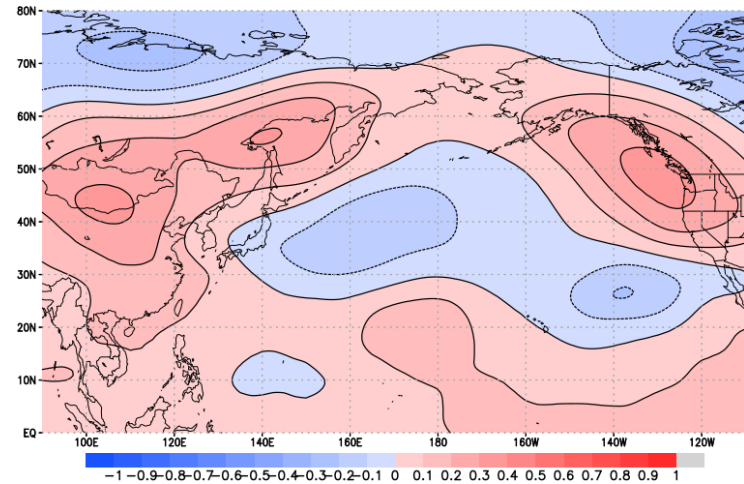


Corr. patterns of NWBS cod recruitment and winter (I-IV) NPGO index with winter NP SSTA (I-IV) and H500 (XII-II) fields (1967-2010)

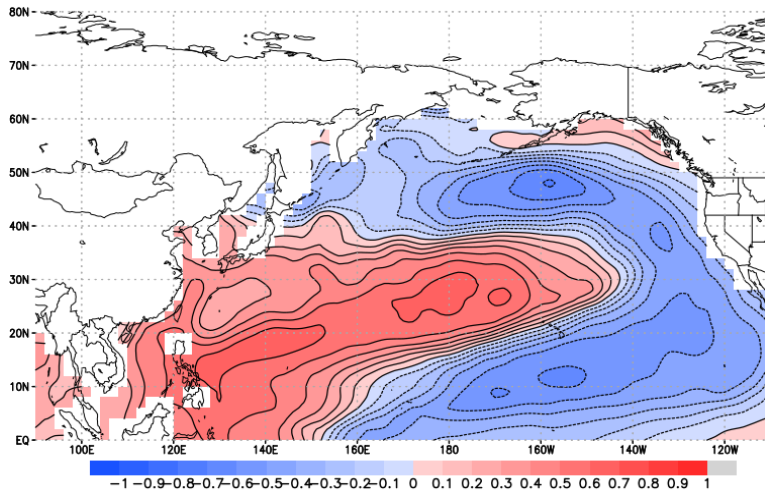
Corr. R(1) to SSTA



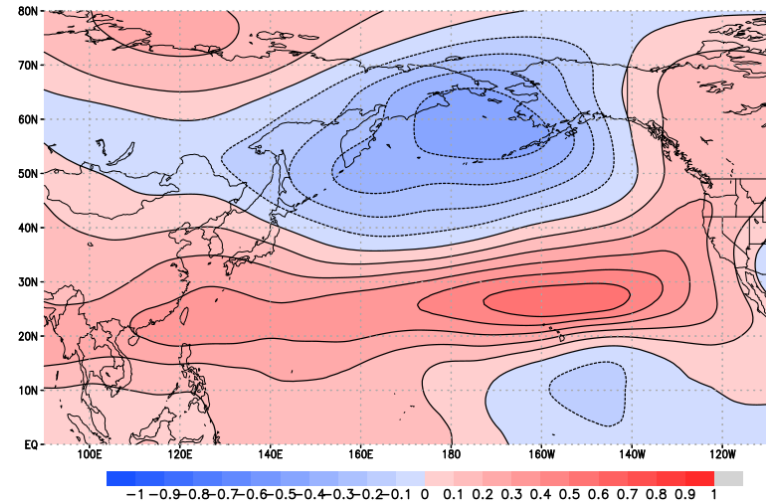
Corr. R(1) to H500



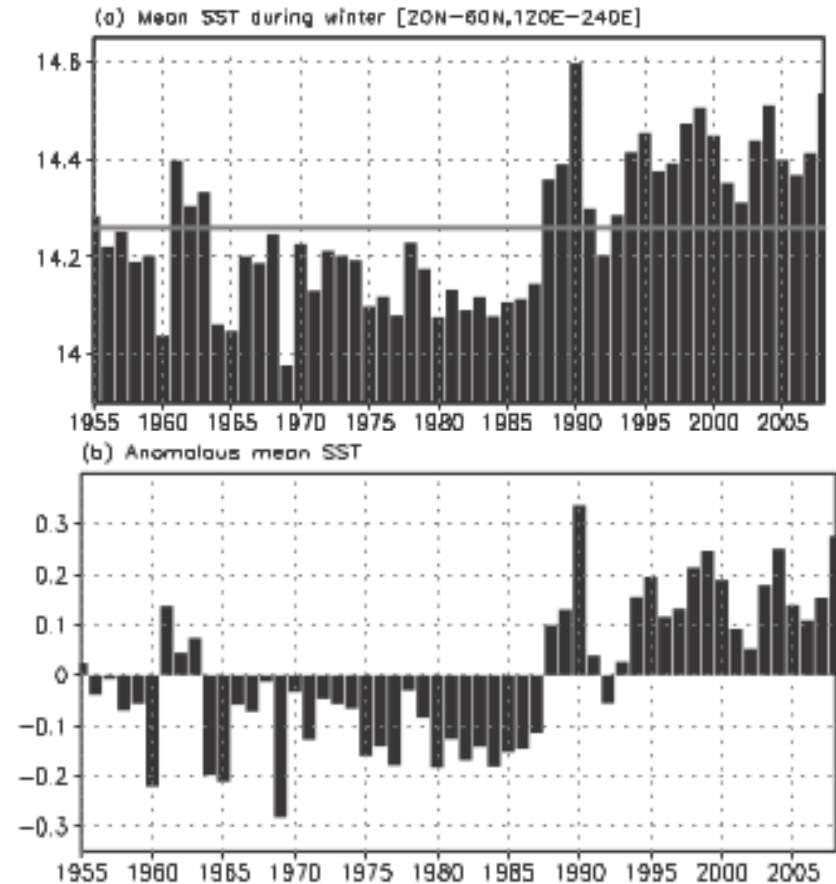
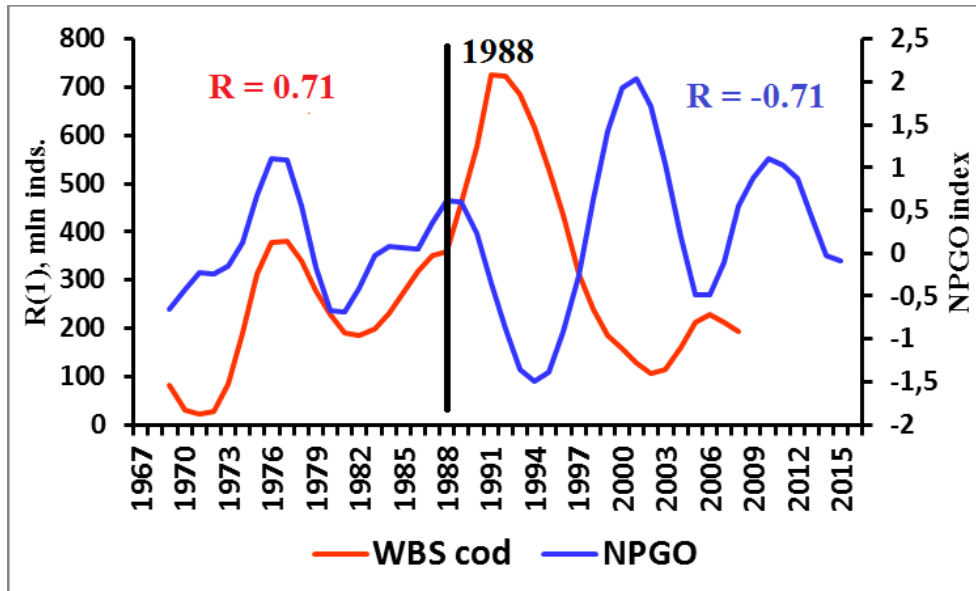
Corr. NPGOI to SSTA



Corr. NPGOI to H500



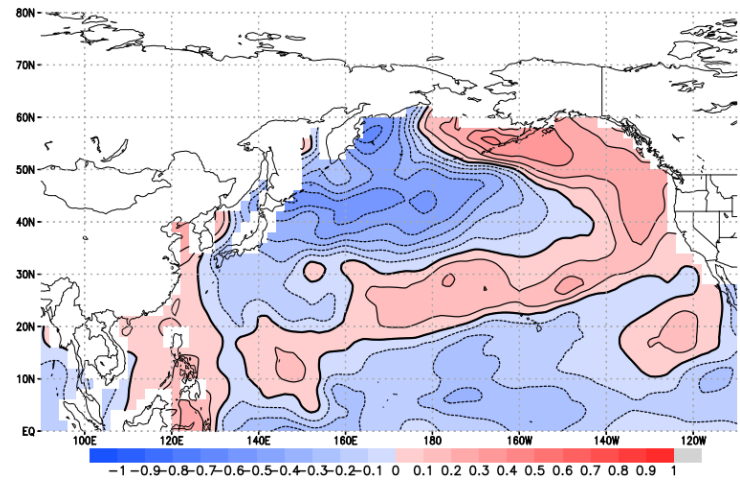
Time series of 5-yr running means of NWBS cod recruitment at age 1 and winter (I-IV) NPGO index



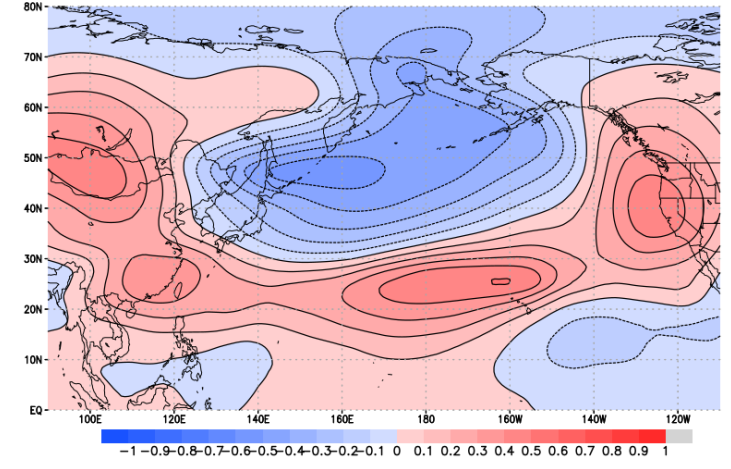
Mean SST in the NP (a) and its anomalies (b) in winter for 1955-2009 (Yeh et al., 2011)

Corr. patterns of NWBS cod recruitment and winter (I-IV) NPGO index with winter NP SSTA (I-IV) and H500 (XII-II) fields (1967-1987)

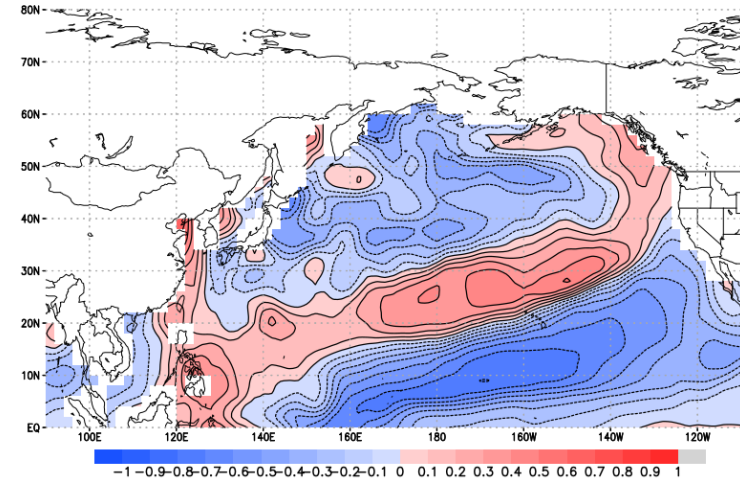
Corr. R(1) to SSTA



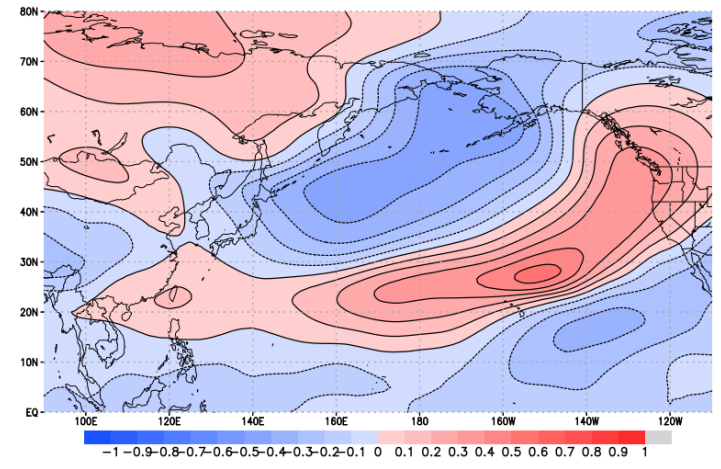
Corr. R(1) to H500



Corr. NPGOI to SSTA

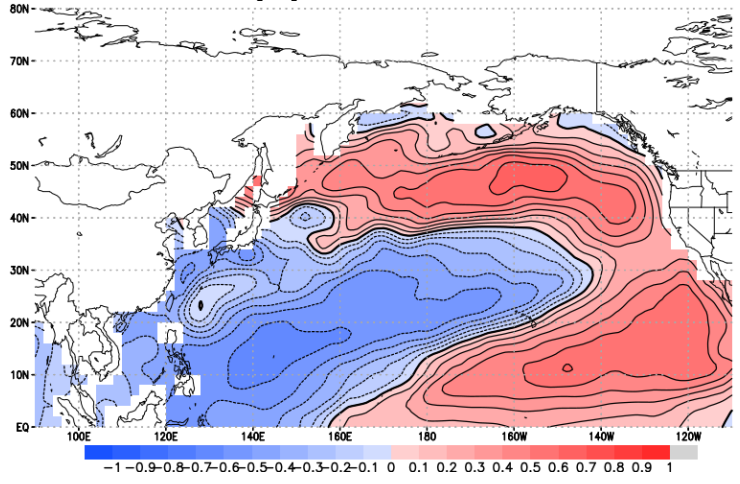


Corr. NPGOI to H500

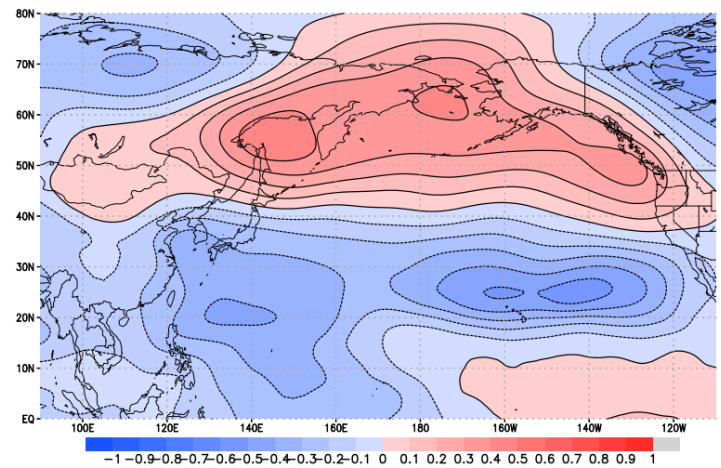


Corr. patterns of NWBS cod recruitment and winter (I-IV) NPGO index with winter NP SSTA (I-IV) and H500 (XII-II) fields (1988-2010)

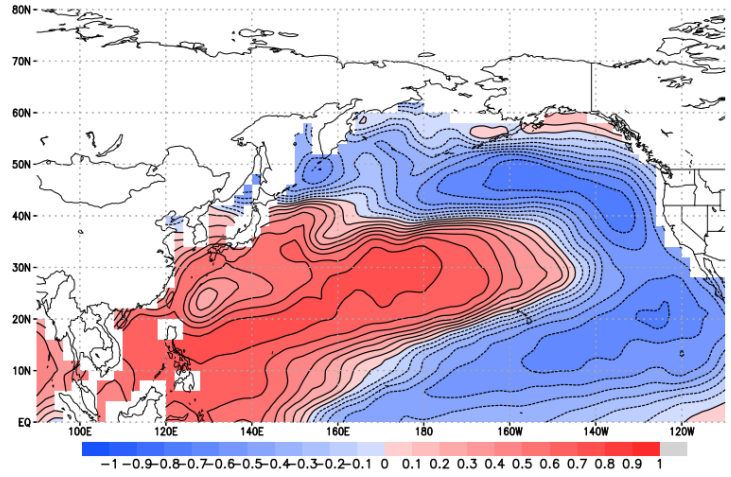
Corr. R(1) to SSTA



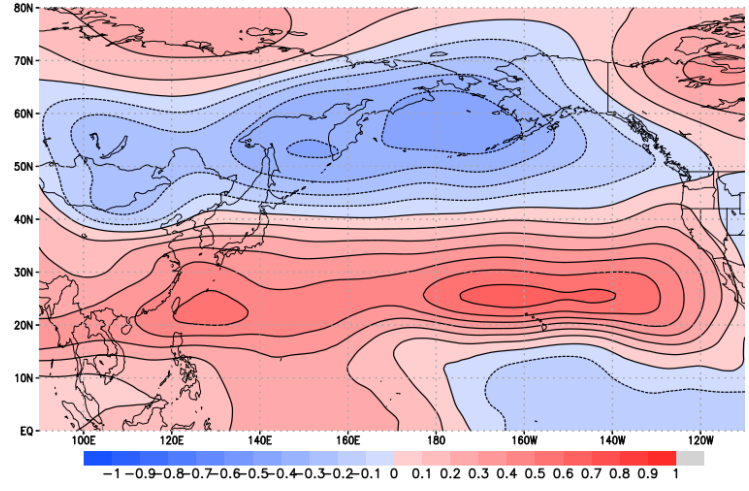
Corr. R(1) to H500



Corr. NPGOI to SSTA

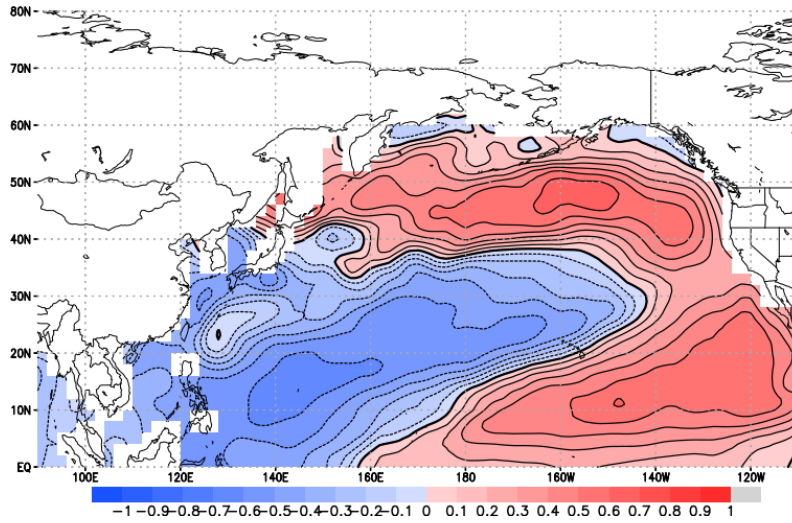


Corr. NPGOI to H500

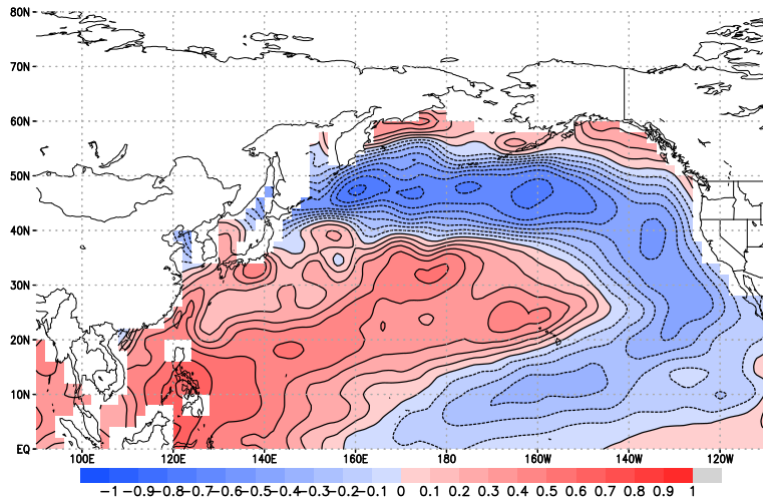


Association of NWBS cod recruitment with EOF3 (7.56%) of winter SSTA field in the northern NP region (50-65°N) for 1987-2010

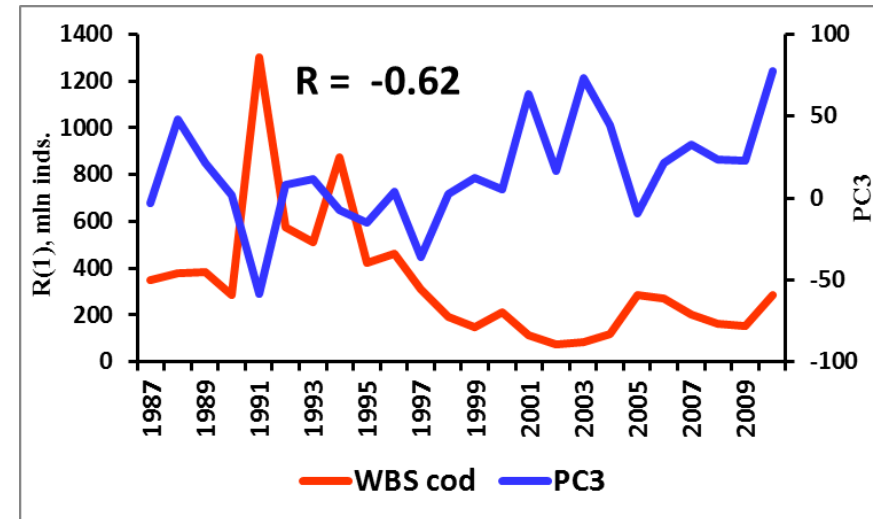
Corr. R(1) to SSTA



Corr. PC3 to SSTA



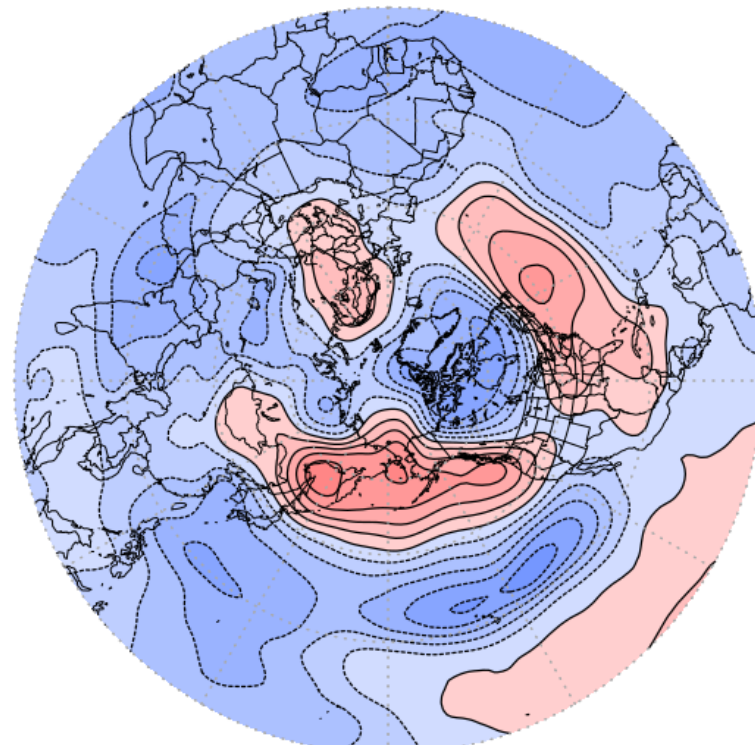
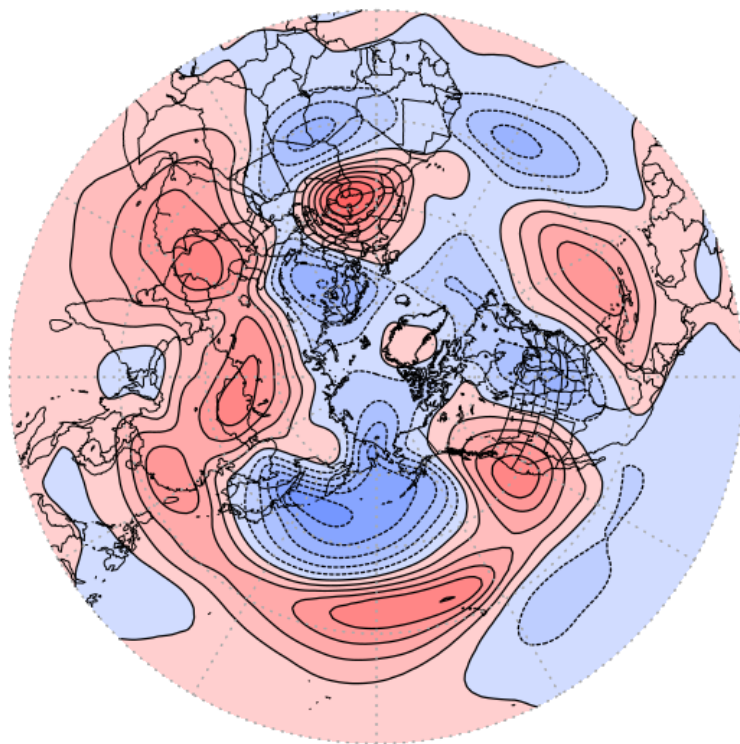
Time series of R(1) and PC3



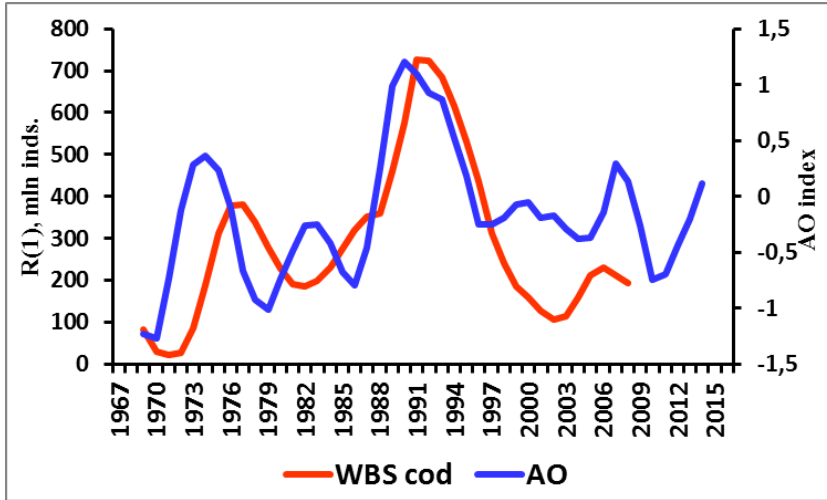
Corr. patterns of NWBS cod recruitment and winter H500 (XII-II) field in the Northern Hemisphere

1967-1987

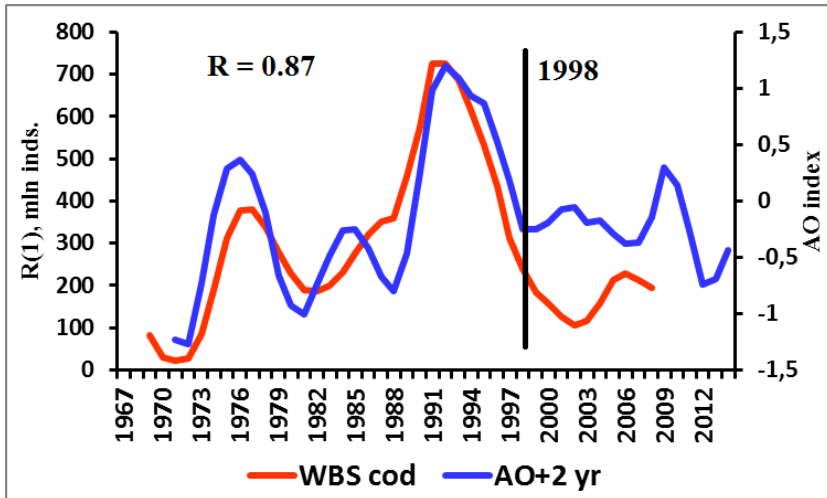
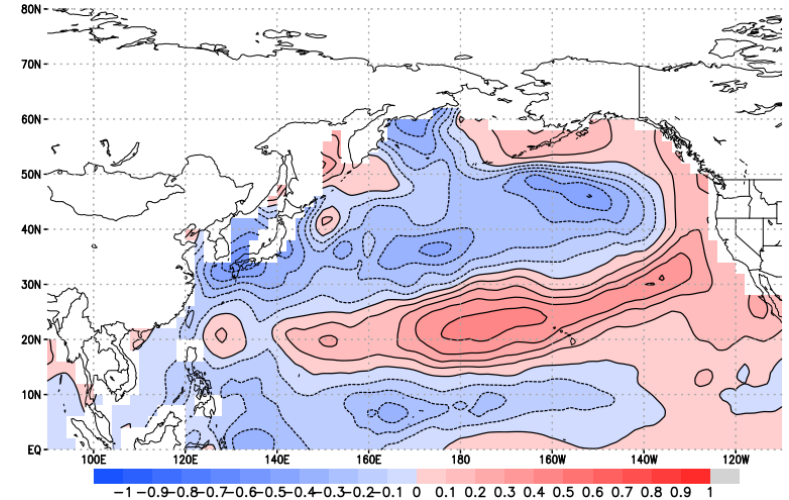
1988-2010



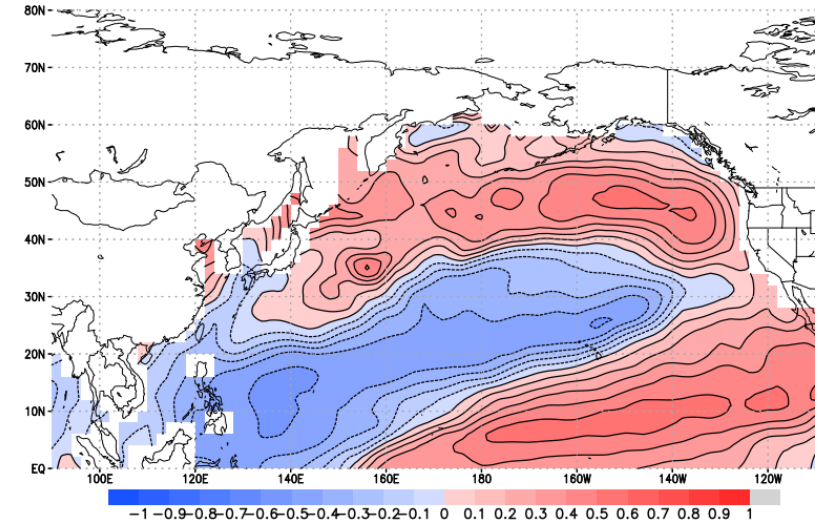
Association of NWBS cod recruitment (left) and winter NP SSTA (right) with winter (XII-II) Arctic Oscillation



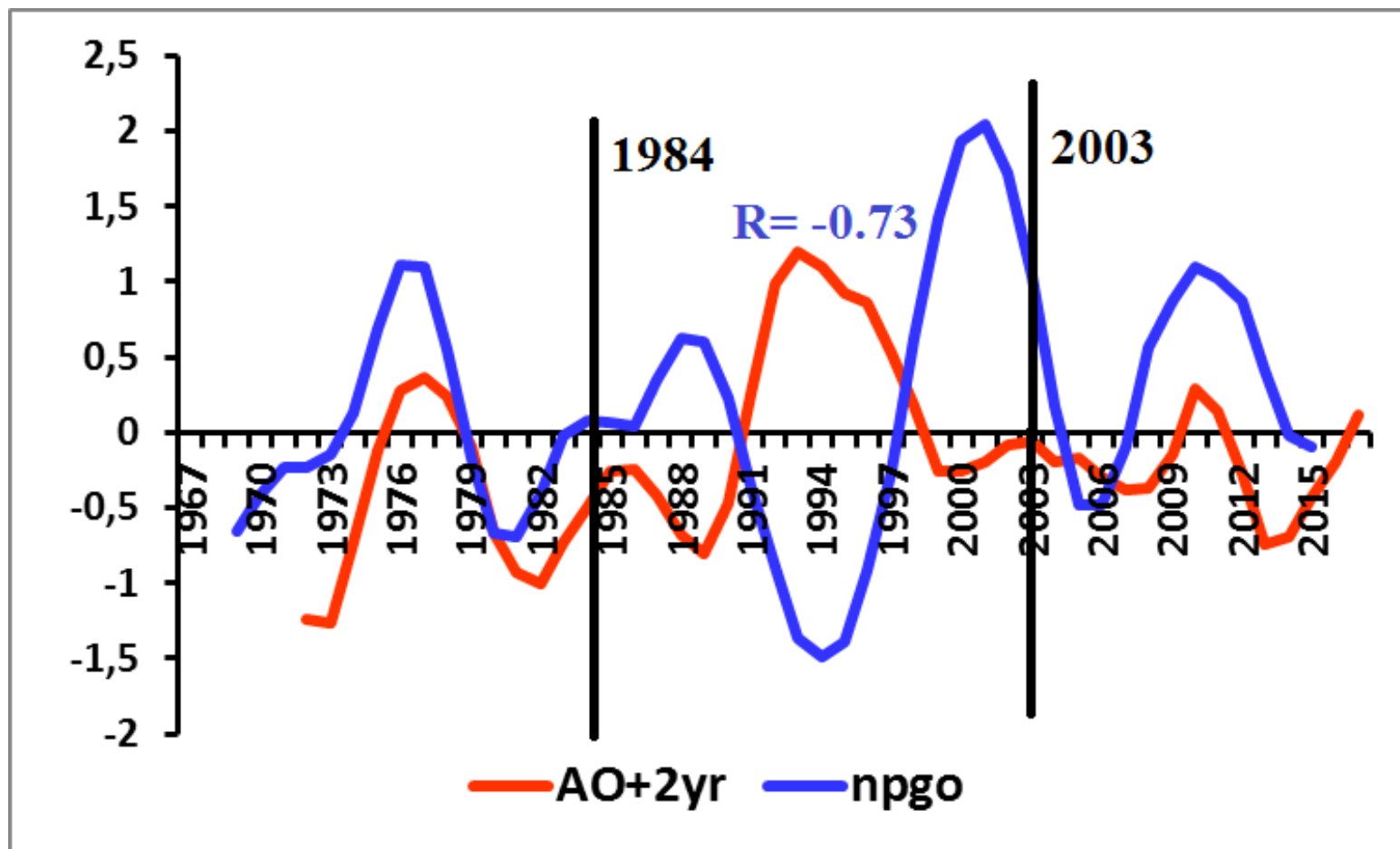
Corr. AOI (+2 yrs) to SSTA (1967-1987)



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

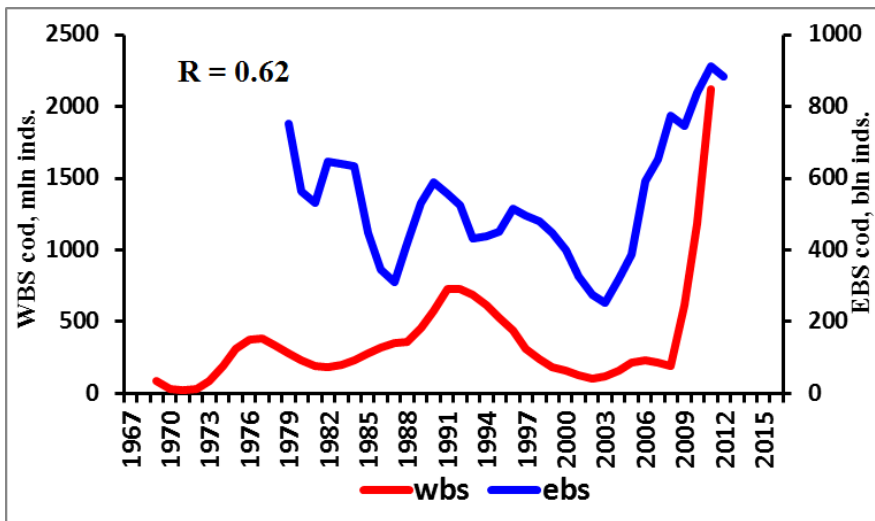
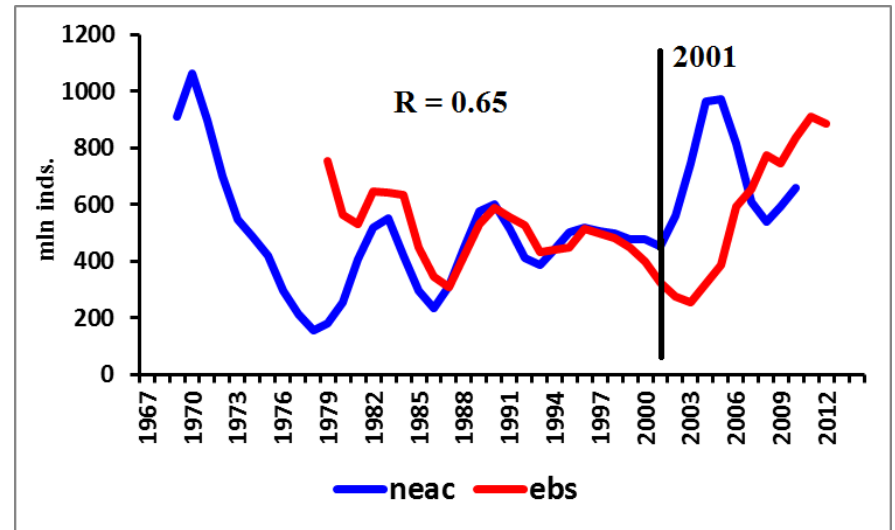
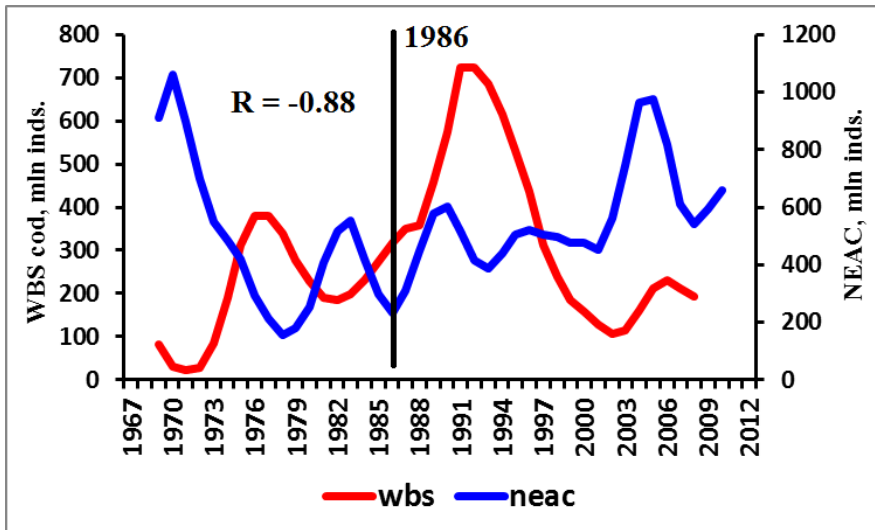


Association between winter NPGO and AO indices



Association of long-term variations in recruitment of 3 NH cod stocks.

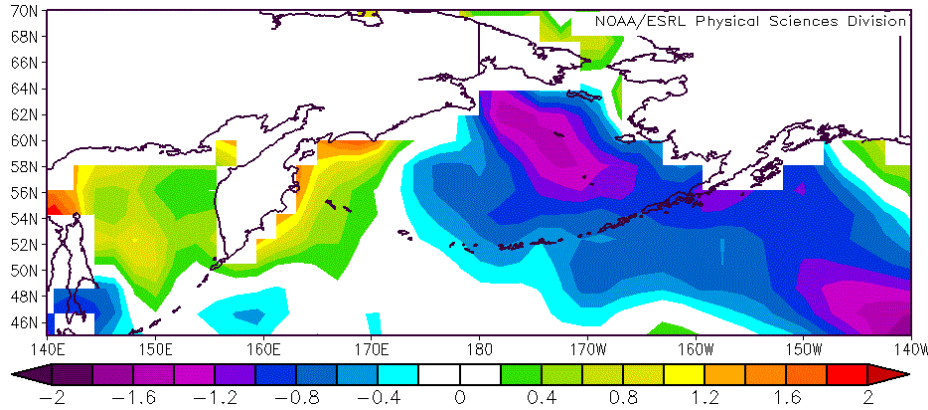
The years are the years of spawning.



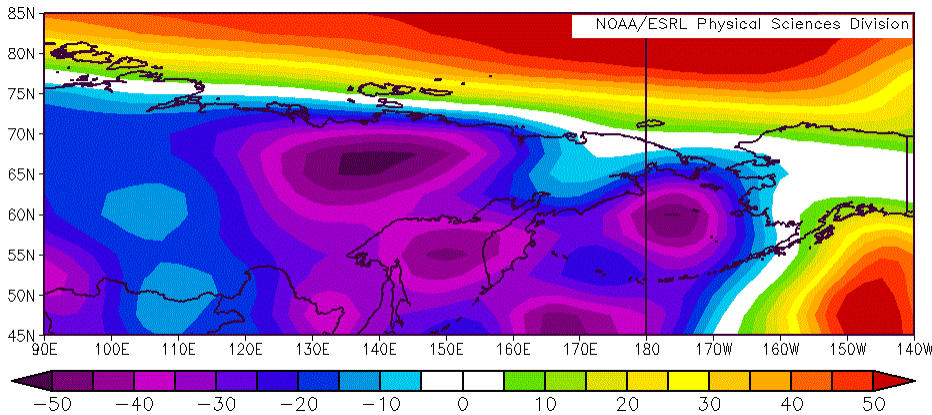
WBS = Northwestern Bering Sea cod
NEAC = Northeast Arctic cod
EBS = Eastern Bering Sea cod

Climatic conditions in June 2011 - years with maximal NWBS cod recruitment

SSTA, 1-20 June 2011



AH500, 1-20 June 2011



Bond and Overland (2005) hypothesized that the strong recruitment of walleye pollock that occurred in 1978, 1982, and 1996 can be attributed in part due to the seasonably strong storms that occurred in the early summer of those years. These storms caused greater than normal mixing of nutrients into the euphotic zone which presumably led to sustained primary productivity after the spring bloom and, possibly, enhanced prey concentrations for pollock larvae and their competitors.

Conclusions

- **Recruitment of NWBS cod during the 1967-2015 was characterized by prominent decadal variations.**
- **These decadal variations were closely related to the winter SSTA pattern in the North Pacific peculiar to NPGO (Victoria) mode but the sign of this relation changed with the regime shift in the second half of the 1980s.**
- **The correlation pattern of NWBS cod recruitment and winter SSTA field may be considered as a proxy for the basin-scale atmospheric dipole, one center of which is located over the Bering Sea. It may be suggested that this center determines, to a large extent, reproductive conditions in the NW Bering Sea.**
- **The sign of pressure anomaly in the “northern” center of atmospheric dipole is closely associated with the phase of Arctic Oscillation with a lag of 2 years. Thus, ultimately the environmental conditions for NWBS cod reproduction depend largely on the AO state which is also responsible for correlations among recruitment of some cod stocks of the NH.**
- **The unusual increase in recruitment of NWBS cod in 2011-2015 requires further analysis.**

Thank you for attention

