RECENT TRENDS OF AIR AND WATER TEMPERATURE AND ICE COVER IN THE FAR-EASTERN SEAS

Elena I. Ustinova and Yury D. Sorokin

Pacific Fisheries Research Centre (TINRO-Centre)
690091 Shevchenko Alley, 4, Vladivostok, Russia
E-mail: eustinova@mail.ru

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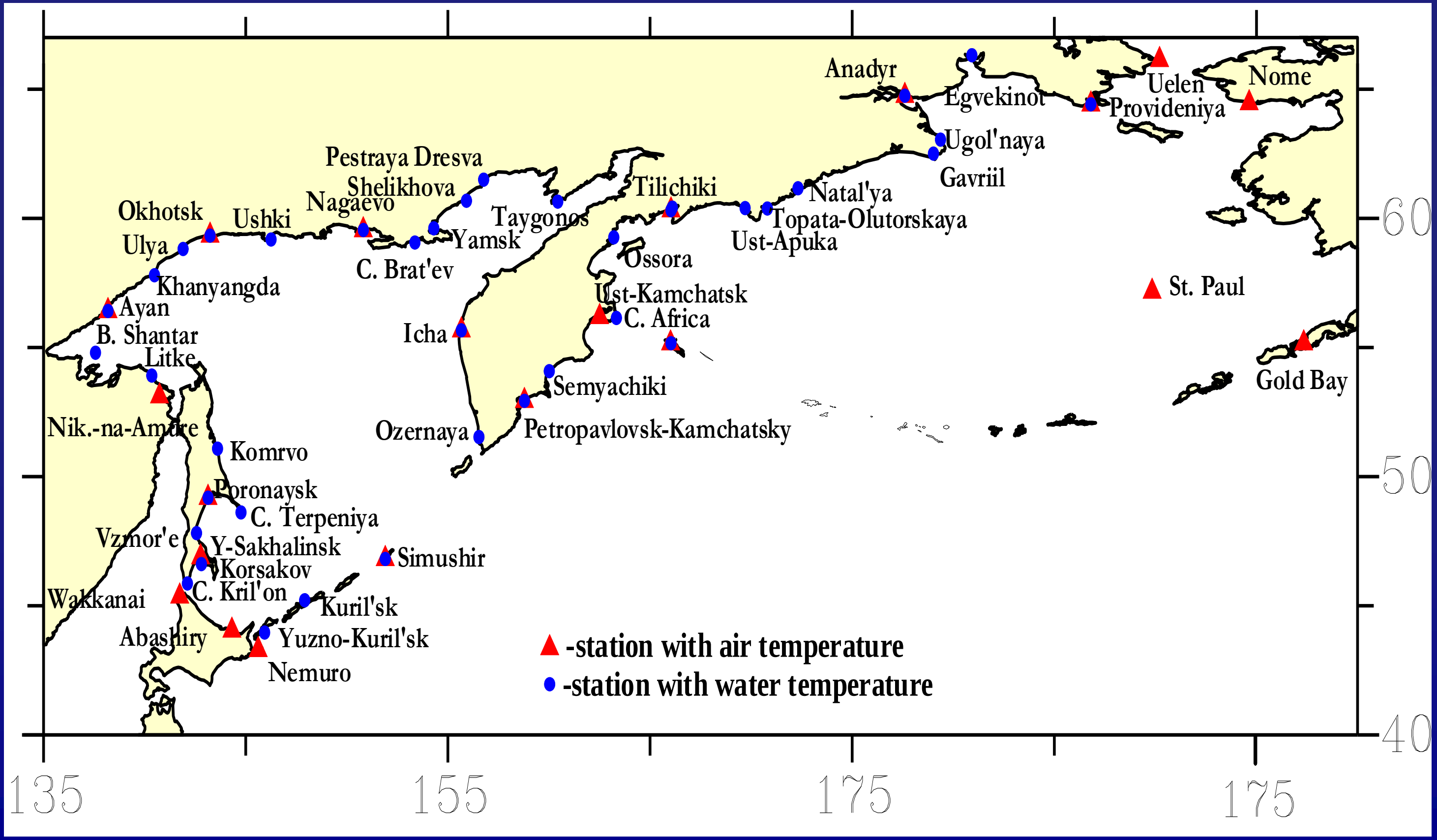
Recent climatic trends (for the last semicentennial period and 30-year running trends) and low-frequency variability of various environmental parameters are evaluated for different areas of the Japan/East, Okhotsk, and Bering Seas.

Climatically significant parameters for monitoring are selected on the following principles: duration, uniformity and regularity of observations and the parameters' utility for marine ecosystem studies

Historical and contemporary sources of regional data of the observations on various “thermal” parameters

Air temperature:
Monthly mean air temperature data at coastal meteorological stations published by Russian Hydrometeorological Agency (as monthly and annual reports and climatic directories).

Monthly mean air temperature data at the meteorological stations data from NASA GISS (http://www.giss.nasa.gov/data/update/gistemp)

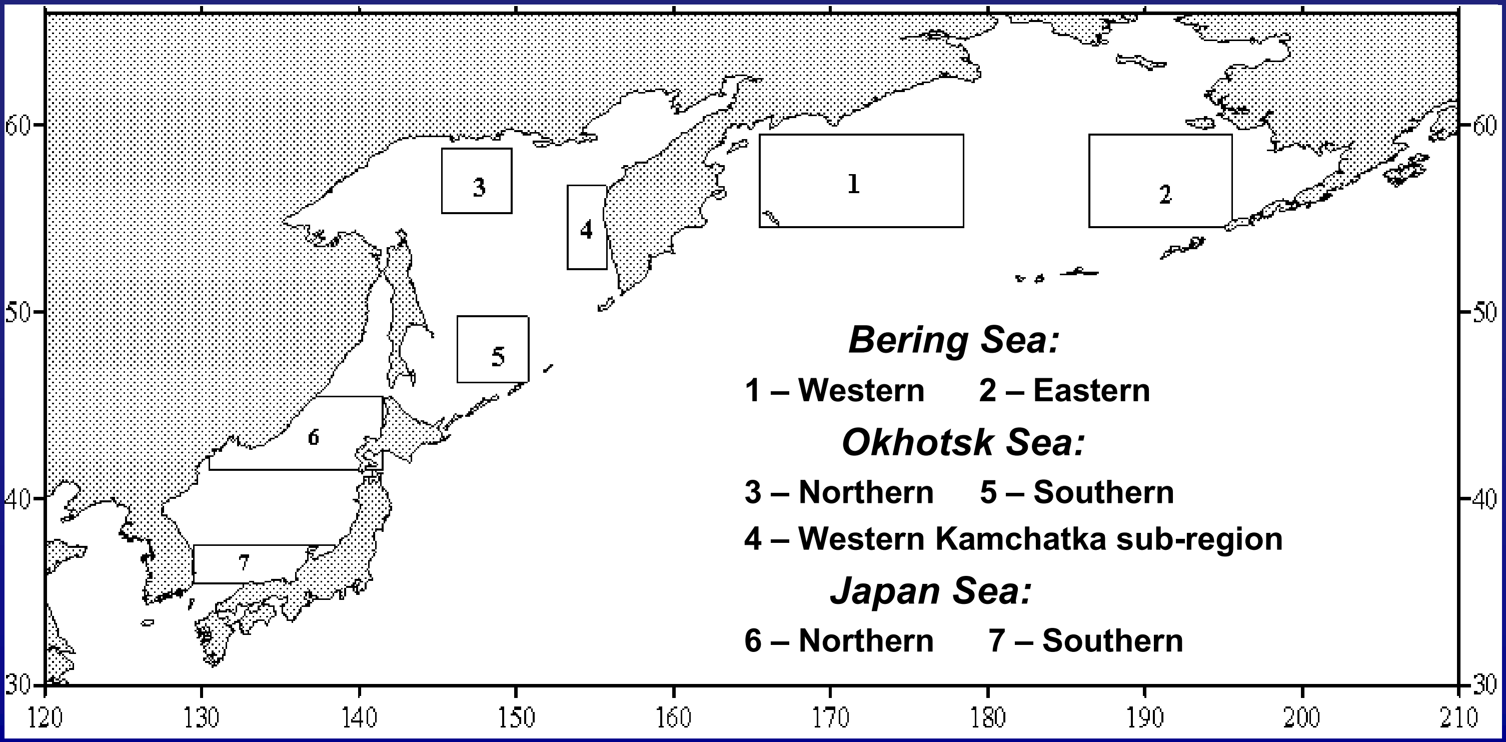


SST:

Time series of the monthly mean SST (COBE-SST) and 10-day mean from 1950 to latest month for 1 degree square of the Pacific Ocean from the Real Time Data Base, NEAR-GOOS http://goos.kishou.go.jp/rrtdb

Time series of the monthly mean SST (HadISST) for 1 degree square from the Hadley Centre (Rayner et al., 2003) http://www.metoffice.gov.uk/hadobs/hadisst

SST trends are estimated for the selected sub-regions 1-7 and using empirical orthogonal functions for each sea.



Ice cover:

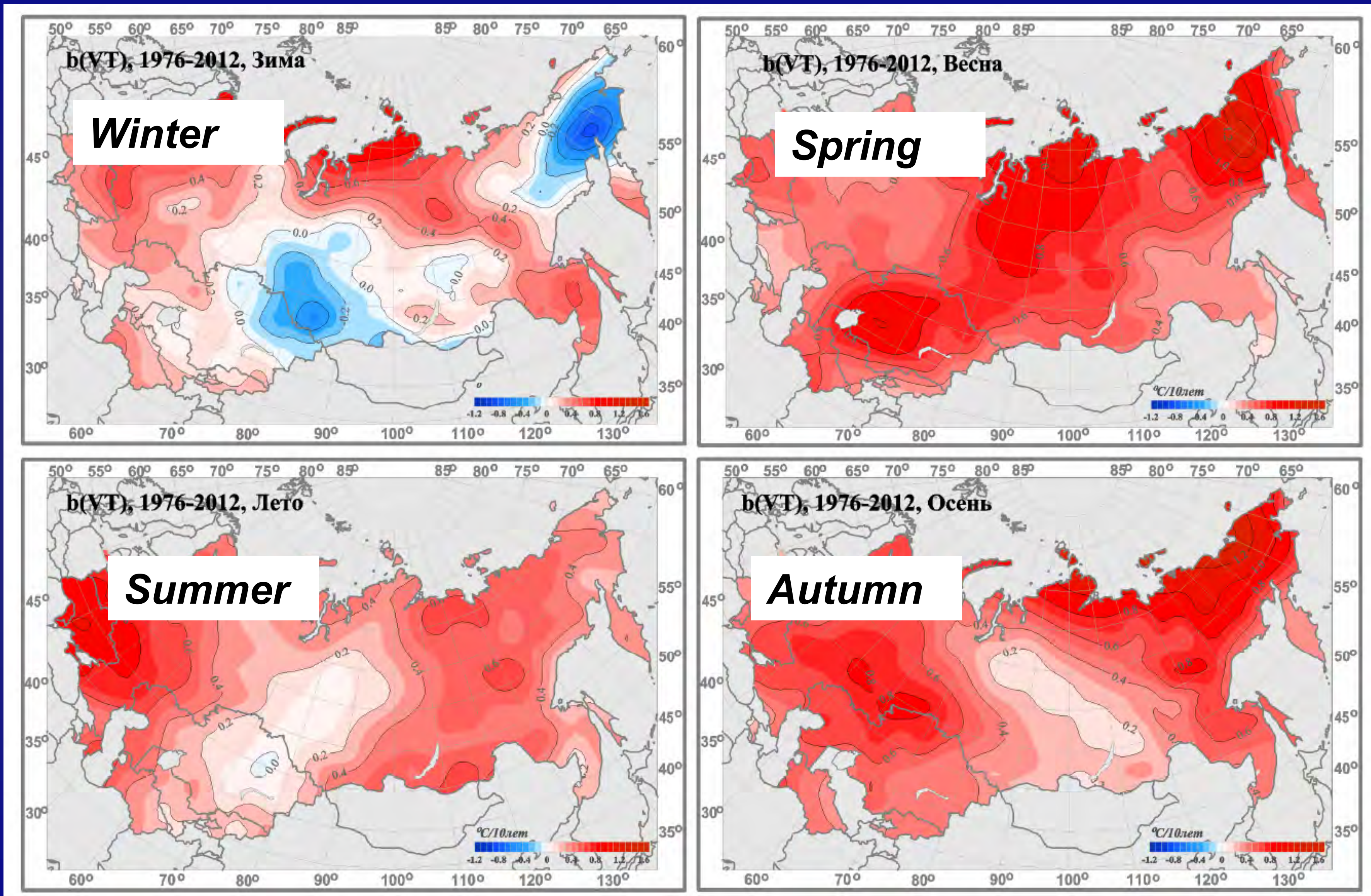
Time series of the ice cover in the Okhotsk Sea in March (annual maximum) for 1929-1956 collected by Kryndin (1964) from various visual observations (shipboard, aircraft, coastal).

Regular ten-days aircraft observations conducted by Russian Hydrometeorological Service: Okhotsk Sea for 1957-1991, Bering Sea and Japan Sea (Tatar Strait) for 1960-1991.

Satellite information obtained from Far-Eastern Regional Center, Khabarovsk (1992-1998) and from National Ice Center U.S.A (since 1999) (http://www.natice.noaa.gov/pub/west_arctic)

Ice charts of the Japanese Meteorological Agency for the Okhotsk Sea (1998-2013).

SAT trends (Review of the state and tendencies of climate, 2012)



SAT trends

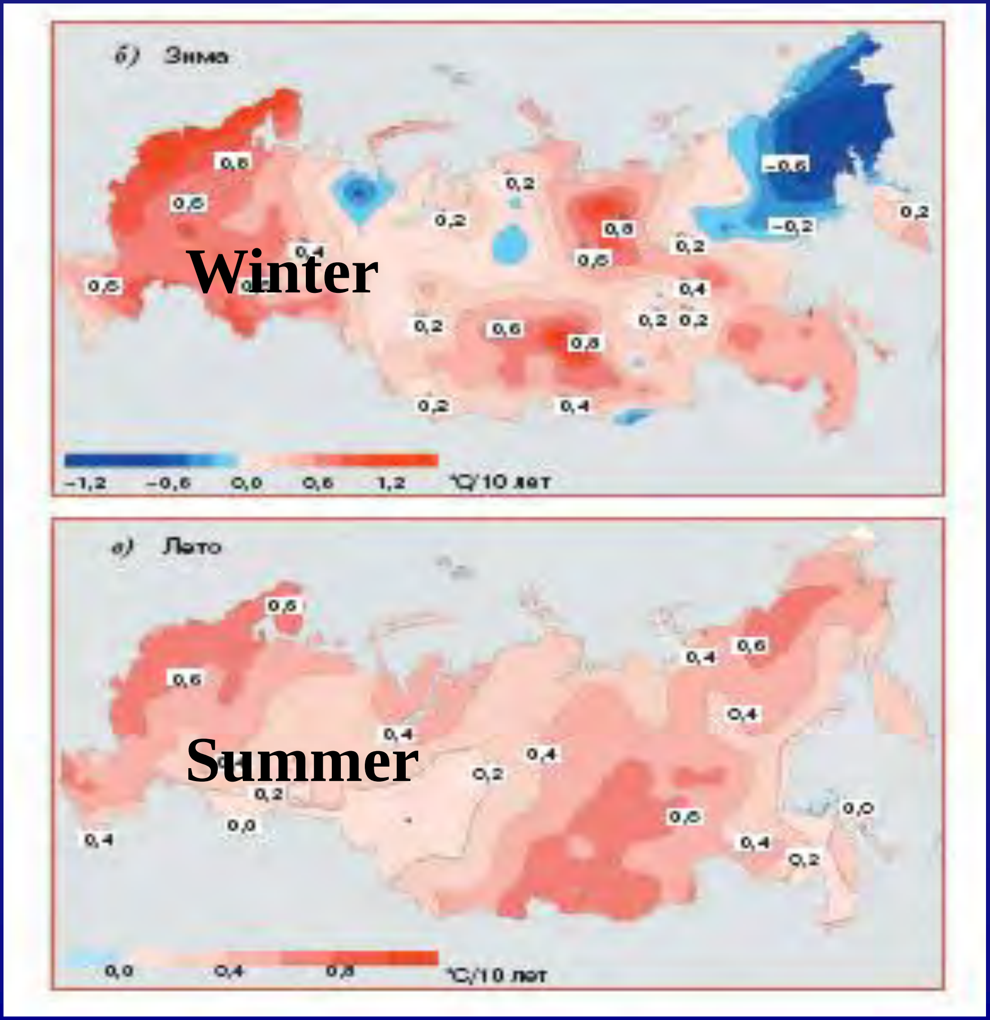
The principal features of the regional climatic tendencies in the air temperature:

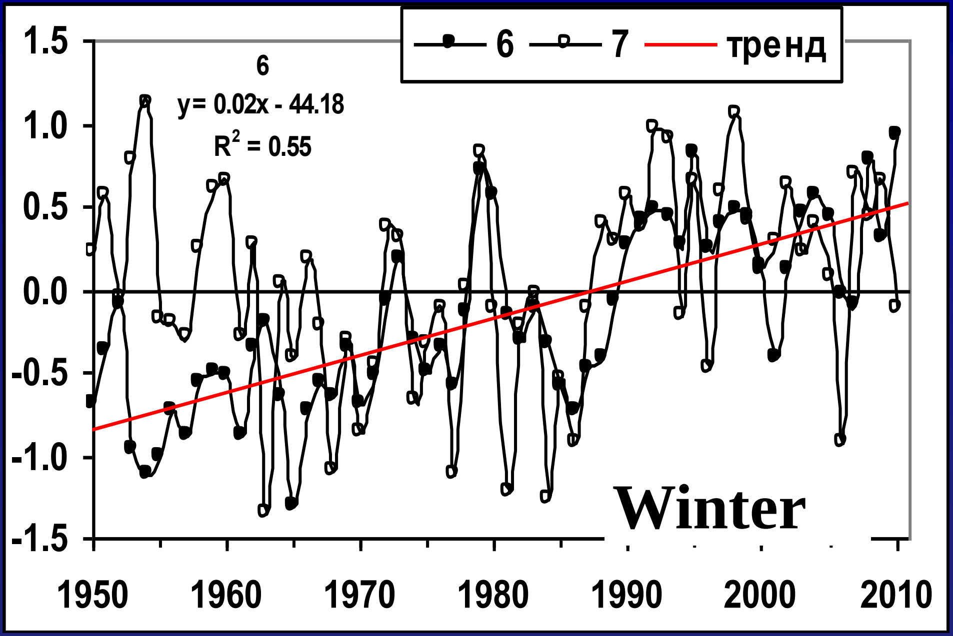
-strong irregularity and inhomogeneity in time and space connected with specific macrocirculating atmospheric processes on the boundary between Eurasian continent and the Pacific Ocean;

- maximal warming in winter and spring over southern part of Russian Far East and over the coast of Japan and Southern Kamchatka;

- weak negative trends in the areas to the north from the Okhotsk Sea and to the west from the Bering Sea in winter;

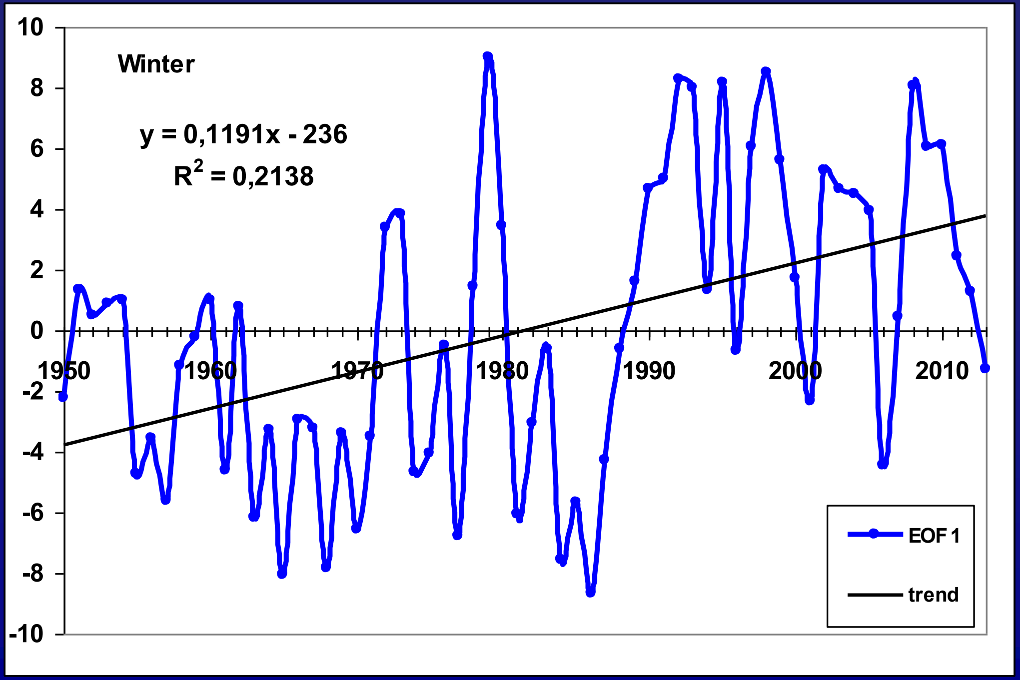
- difference between summer and winter temperatures decreases on the coast of the Japan/East Sea and increases on the North-Western coast of the Okhotsk Sea, i.e., the continentality increases on the Northern Far East



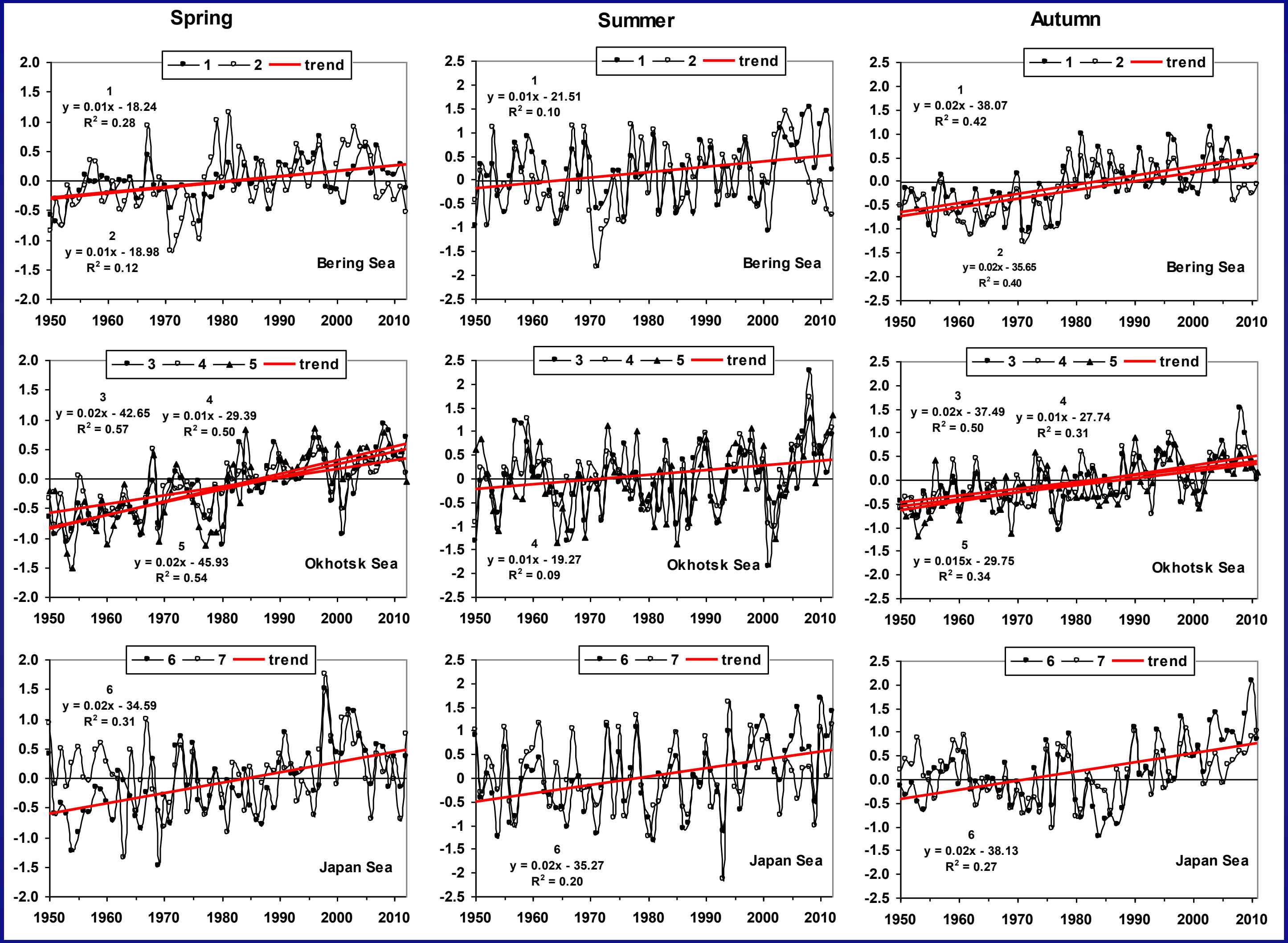


SST anomalies in the selected sub-regions of the Japan/East Sea (6-7)

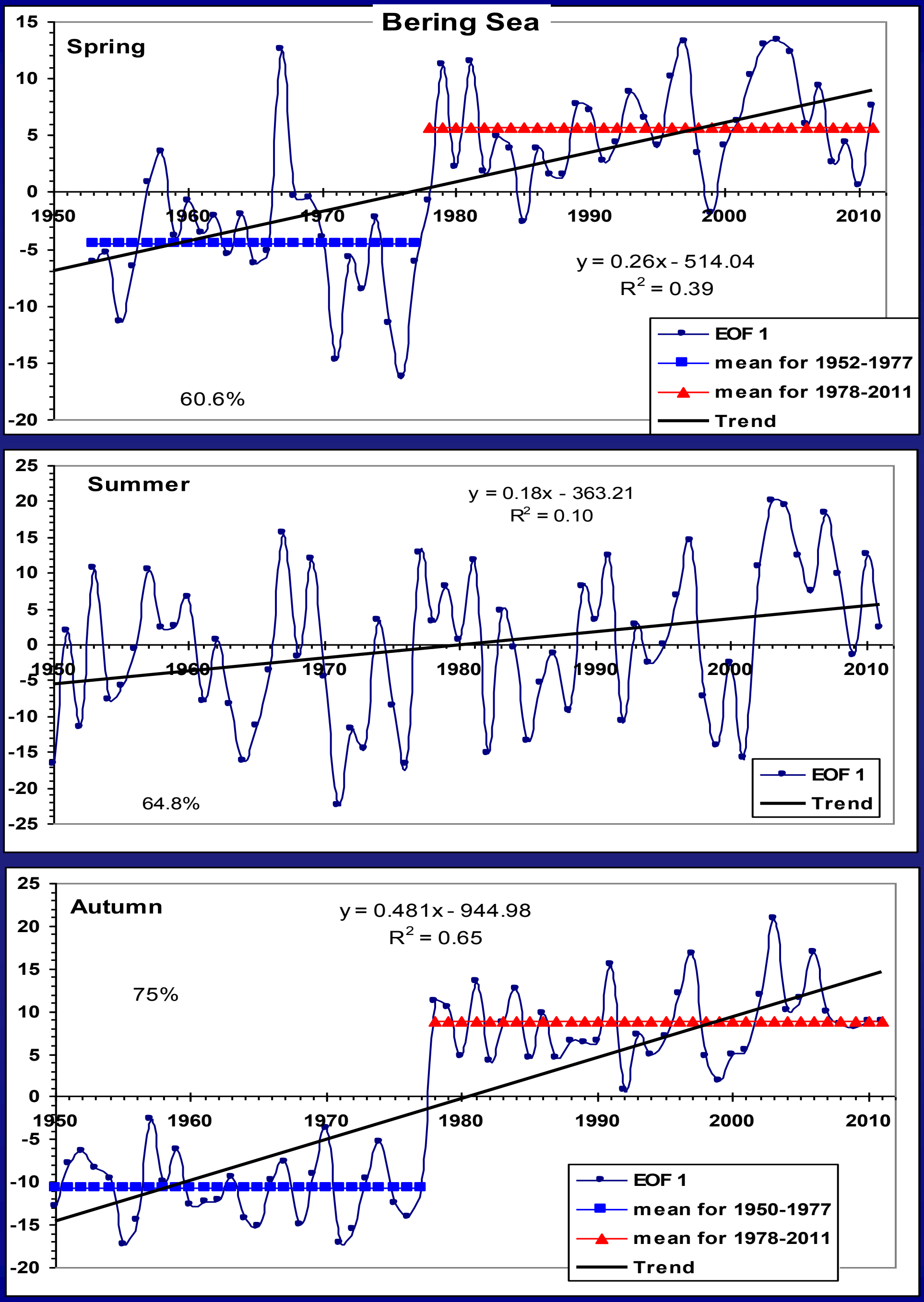
1 EOF of SST in the Japan/East Sea



SST anomalies in the selected sub-regions of the Far-Eastern Seas (1-7)



The main feature of the changes is warming of the surface layer (0.1-0.2 ° C per decade), although in the southern Japan/East Sea the positive trend to warming is not significant in all seasons. The contribution of the positive trend to total variance of SST is substantially less in summer than in other seasons.



SST trends are estimated using empirical orthogonal functions for each sea.

1 EOF of SST in the Bering Sea

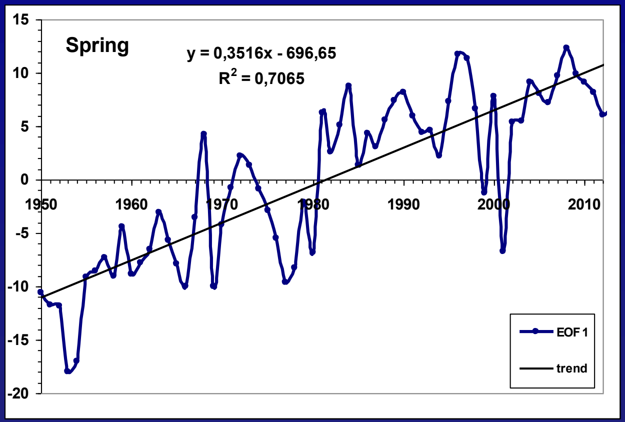
In spring and autumn the climate regime shift of 1977/78 was detected.

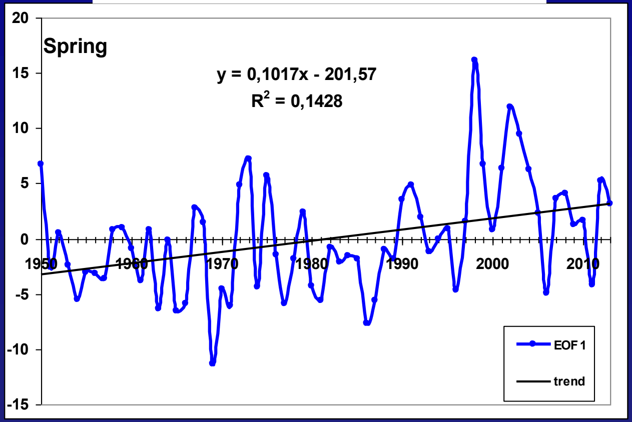
In summer “true” trend is observed.

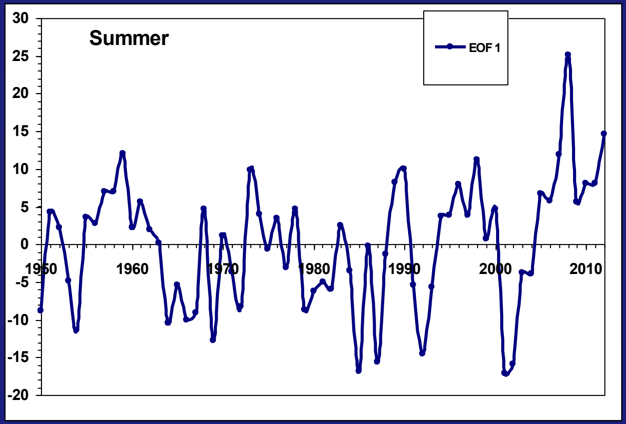
Okhotsk Sea

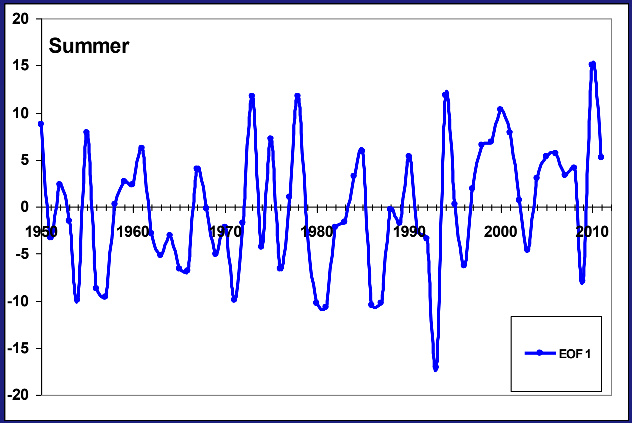
EOF 1 of SST

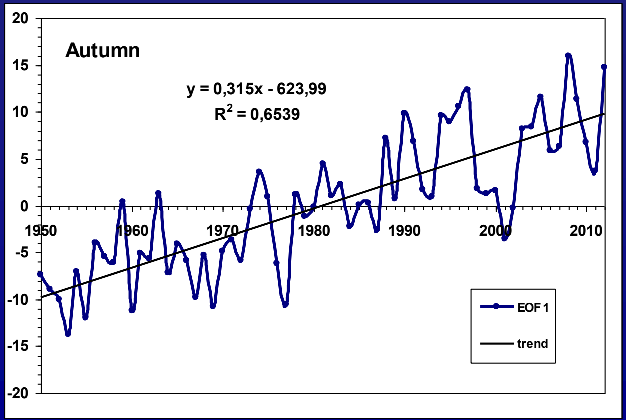
Japan/East Sea

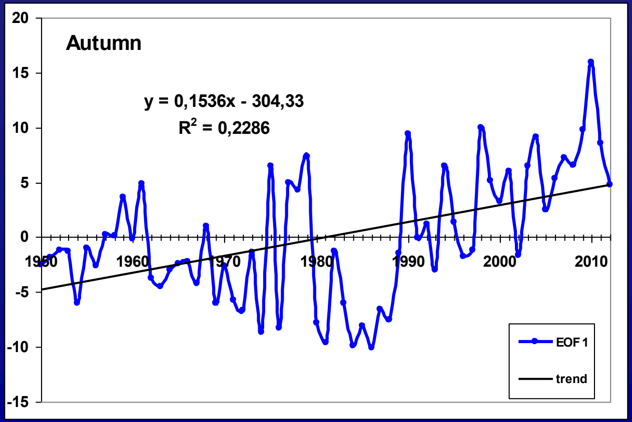






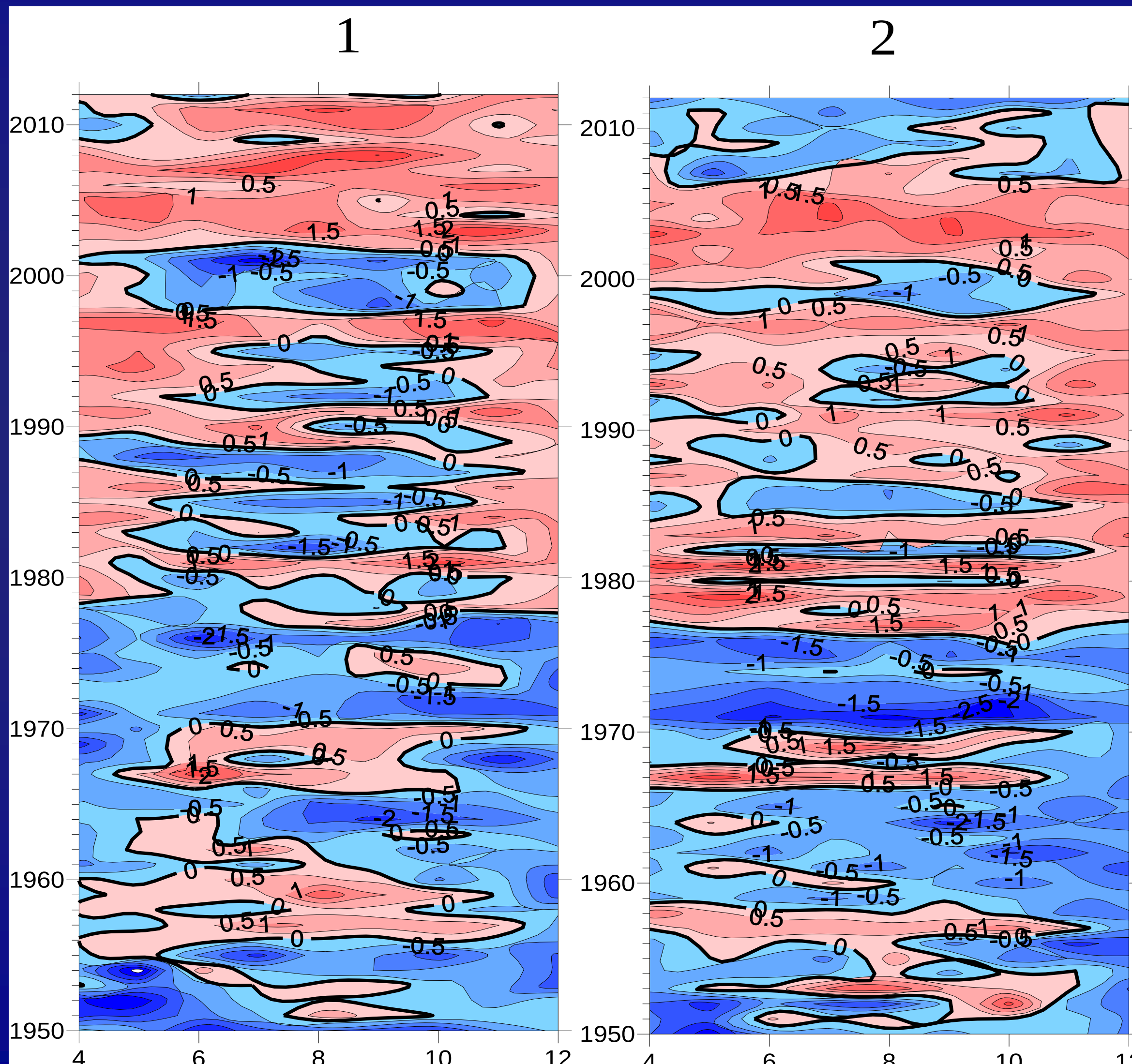






Variability of SST anomalies in the Bering Sea

Positive (negative) anomalies in red (blue) color correspond to warm (cold) conditions. ***Time series are standardized.***



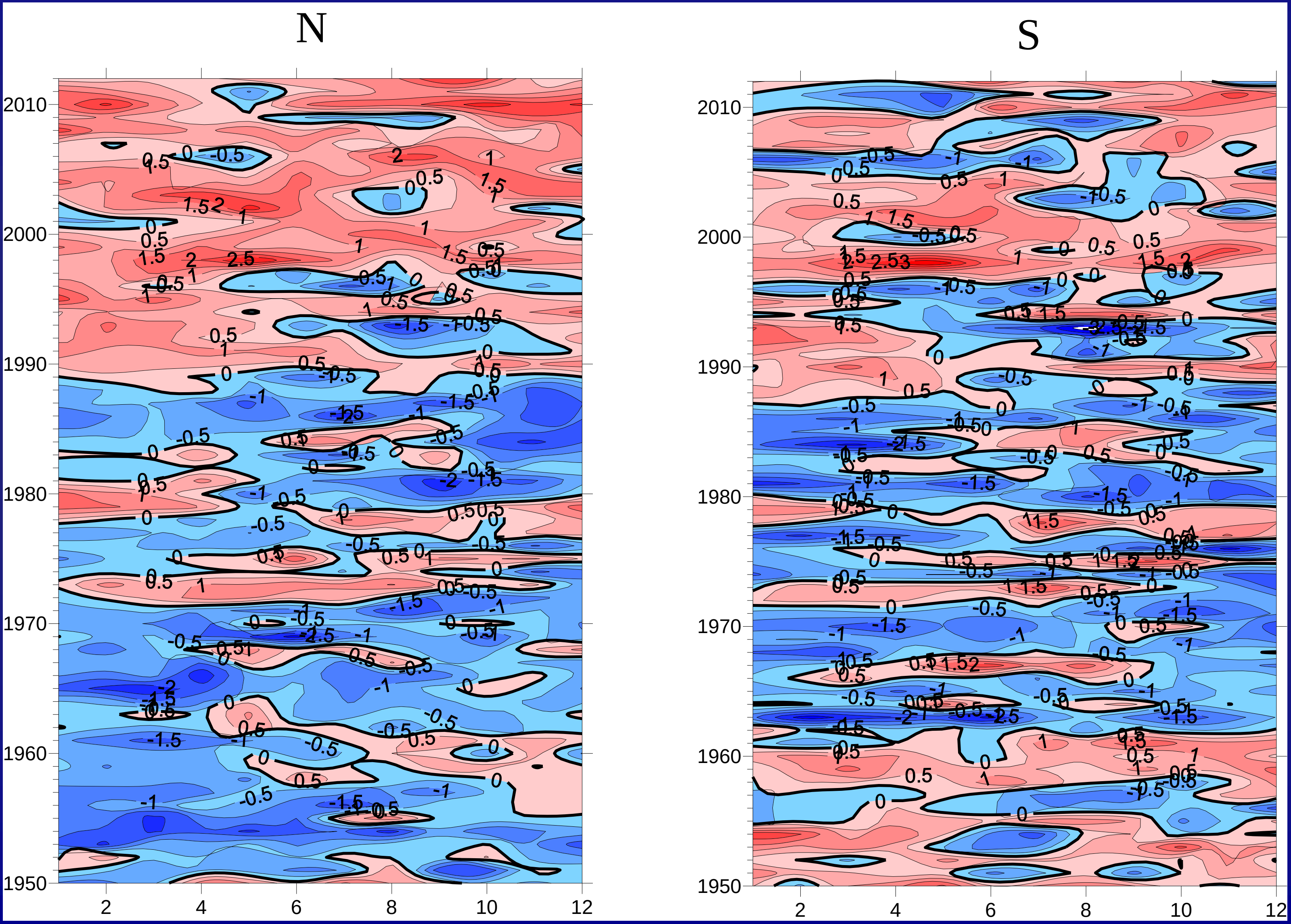
Variability of SST anomalies in the Okhotsk Sea

Positive (negative) anomalies in red (blue) color correspond to warm (cold) conditions.

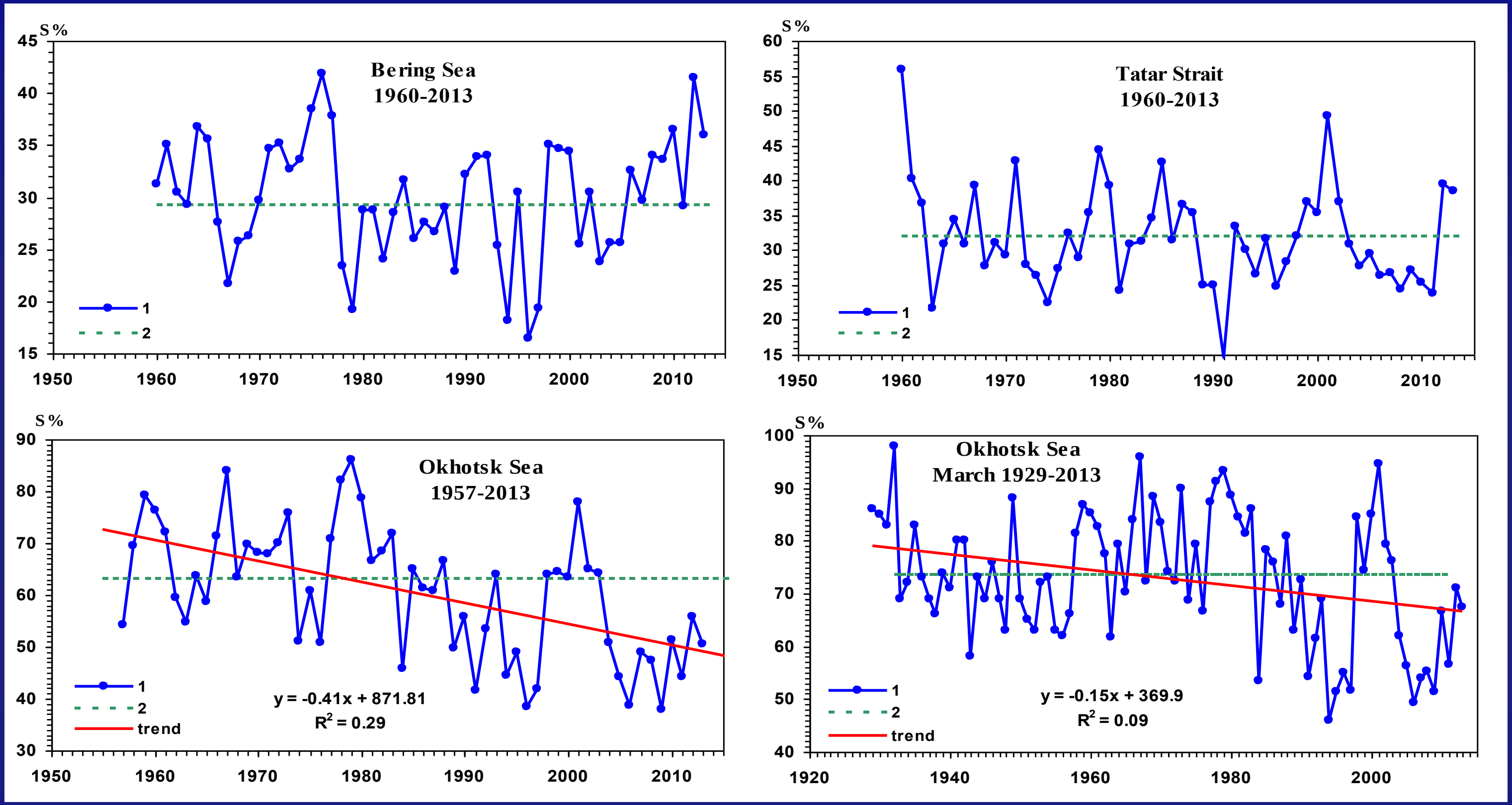
Time series are standardized.

Variability of SST anomalies in the Japan Sea

Positive (negative) anomalies in red (blue) color correspond to warm (cold) conditions. Time series are standardized.



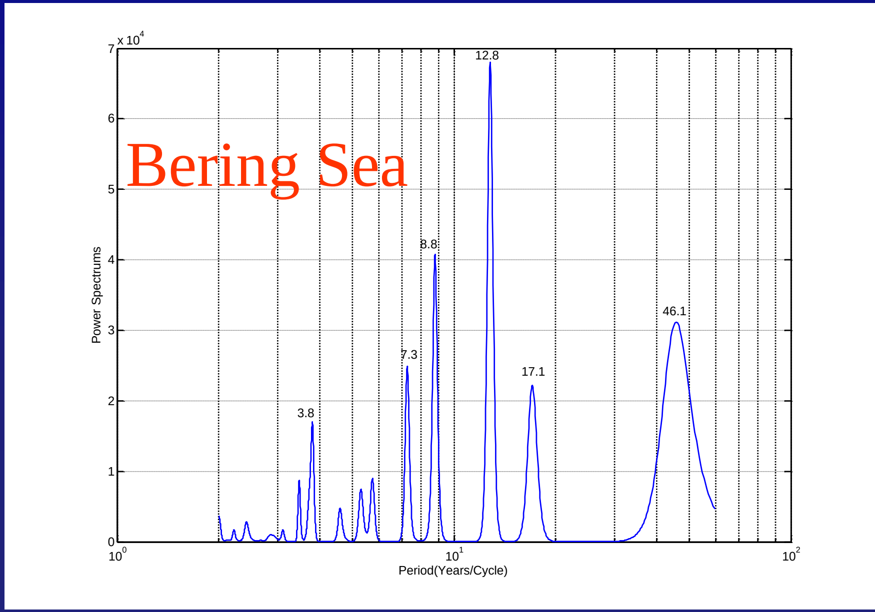
Mean winter (Bering Sea, Okhotsk Sea and Tatar Strait) and annual maximum ice cover (in March) in the Okhotsk Sea (1), mean multi-year value (2) and statistically significant trends with regression equations and determination coefficients R^2

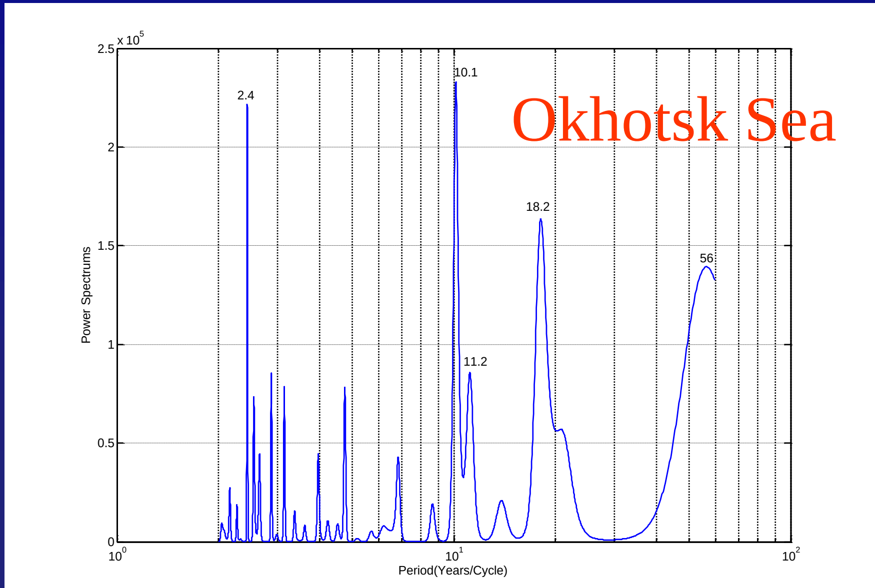


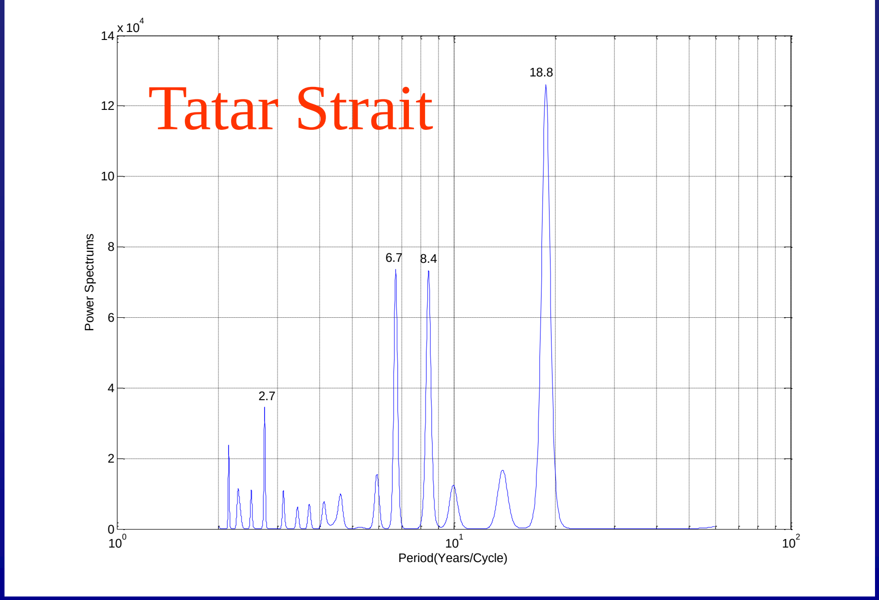
"S" is % to the total area of the sea.

The warming is accompanied by decreasing sea ice cover that is the most significant in the Okhotsk Sea (4% per decade) where the ice cover variation agrees well with the changes of air temperature of the Northern Hemisphere. In the Bering Sea and the Tatar Strait the negative trends in ice cover are not statistically significant for 1960-2013. While the Okhotsk Sea ice cover is sensitive to global temperature variations, large-scale oscillations such as El Niño and the Pacific Decadal Oscillation are more important for the Bering Sea ice cover.

Power spectrums of ice cover in the Far-Eastern Seas



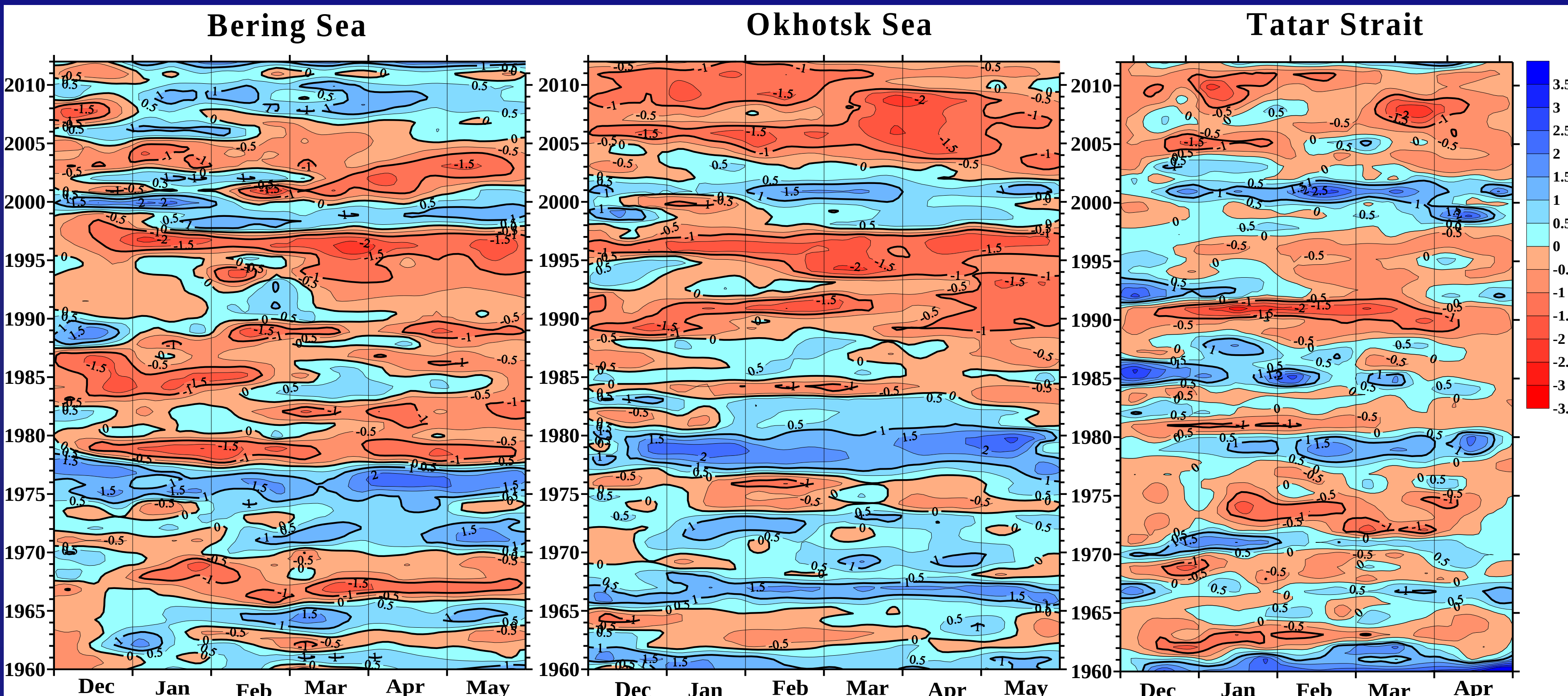




The spectral analysis of time series of the maximum annual ice cover showed that now the basic contribution to the variance gave the scale about 50 years (Okhotsk and Bering Seas), 18,2 (Okhotsk Sea)-18.8 (Tatar Strait), quasy-decadal scale (Okhotsk and Bering Seas), and 7-8 years (Bering Sea and Tatar Strait) oscillations. In the Okhotsk Sea 2.4 year scale is very significant.

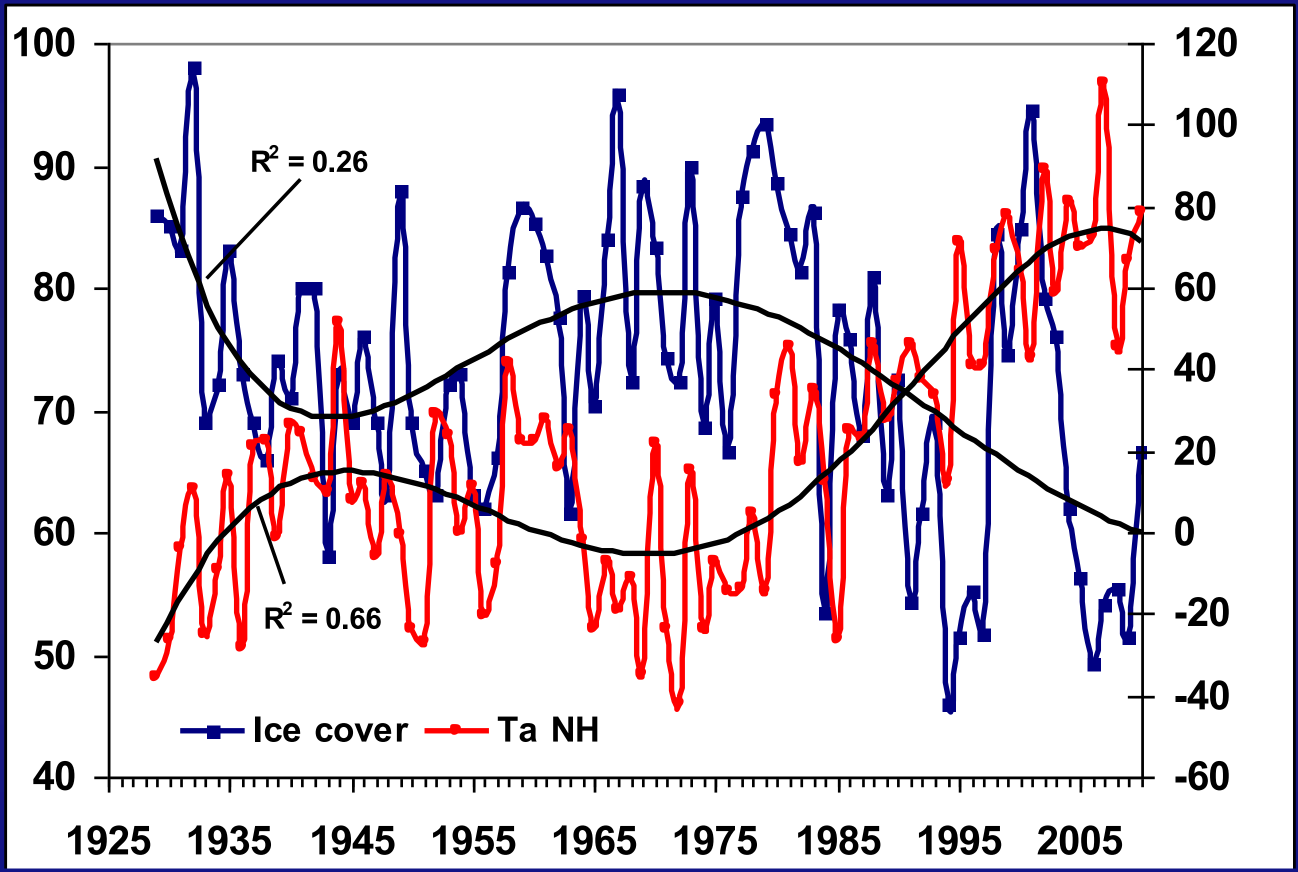
(Methodology by Vilnis Liepins, 1997)

Variability of ice coverage anomalies in the Far-Eastern Seas



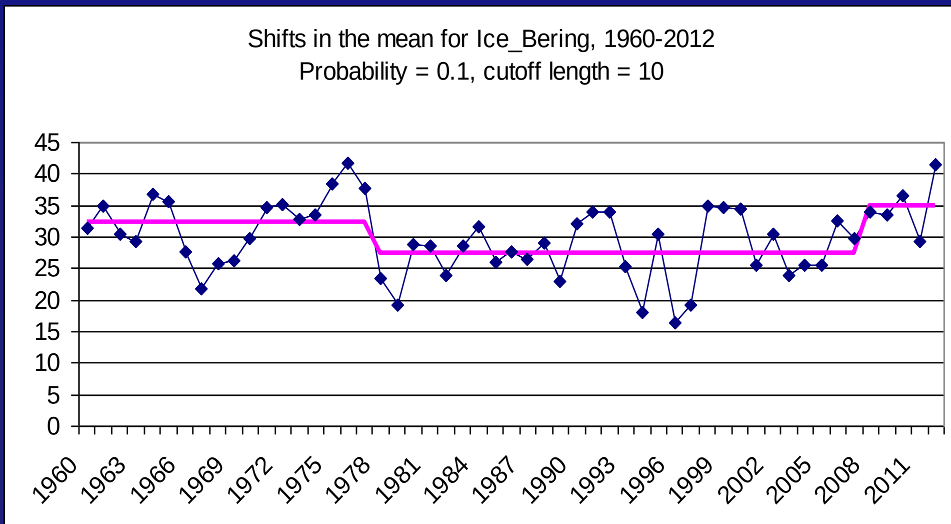
Positive (negative) ice coverage anomalies in blue (red) color correspond to cold (warm) conditions. ***Time series are standardized.***

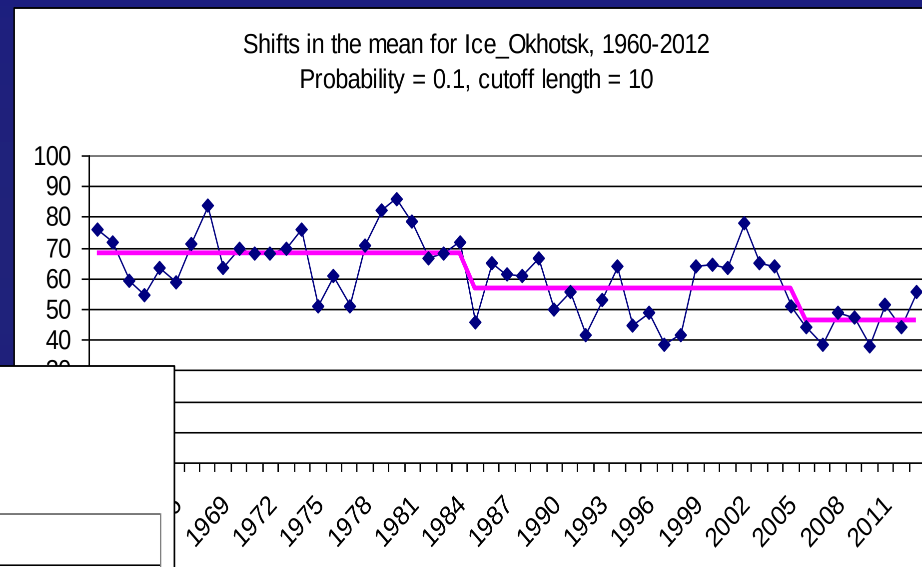
Winter North Hemispheric temperature anomalies, annual maximal ice cover in the Okhotsk Sea and its polynomial trends

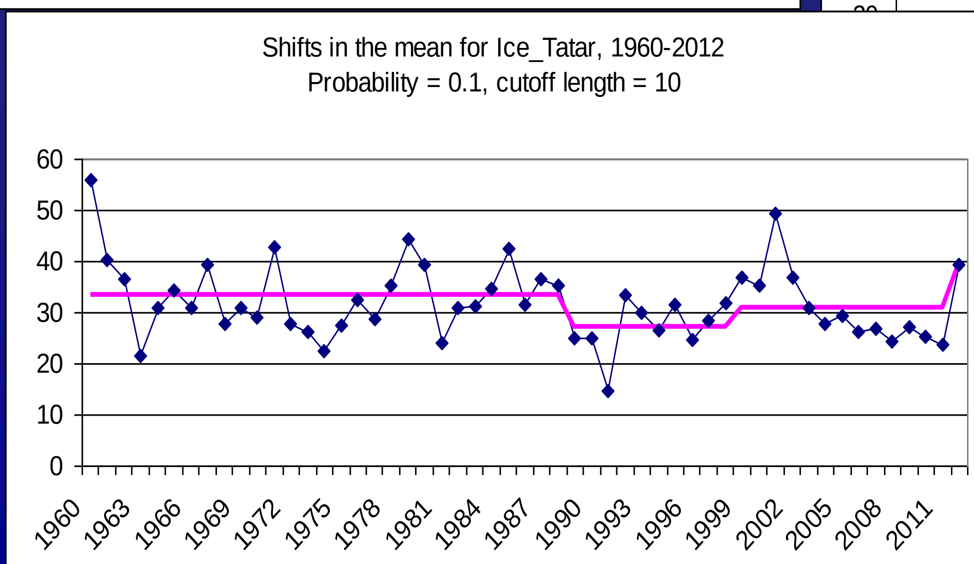


Examples for Far-Eastern Seas: shifts in ” ice variables”

The shift of 1978 and 2008 is strongest for the Bering Sea in the last 52 years.
The shift of 1989 is strongest for the Tatar Strait
The shift of 1984 : is strongest for the Okhotsk Sea

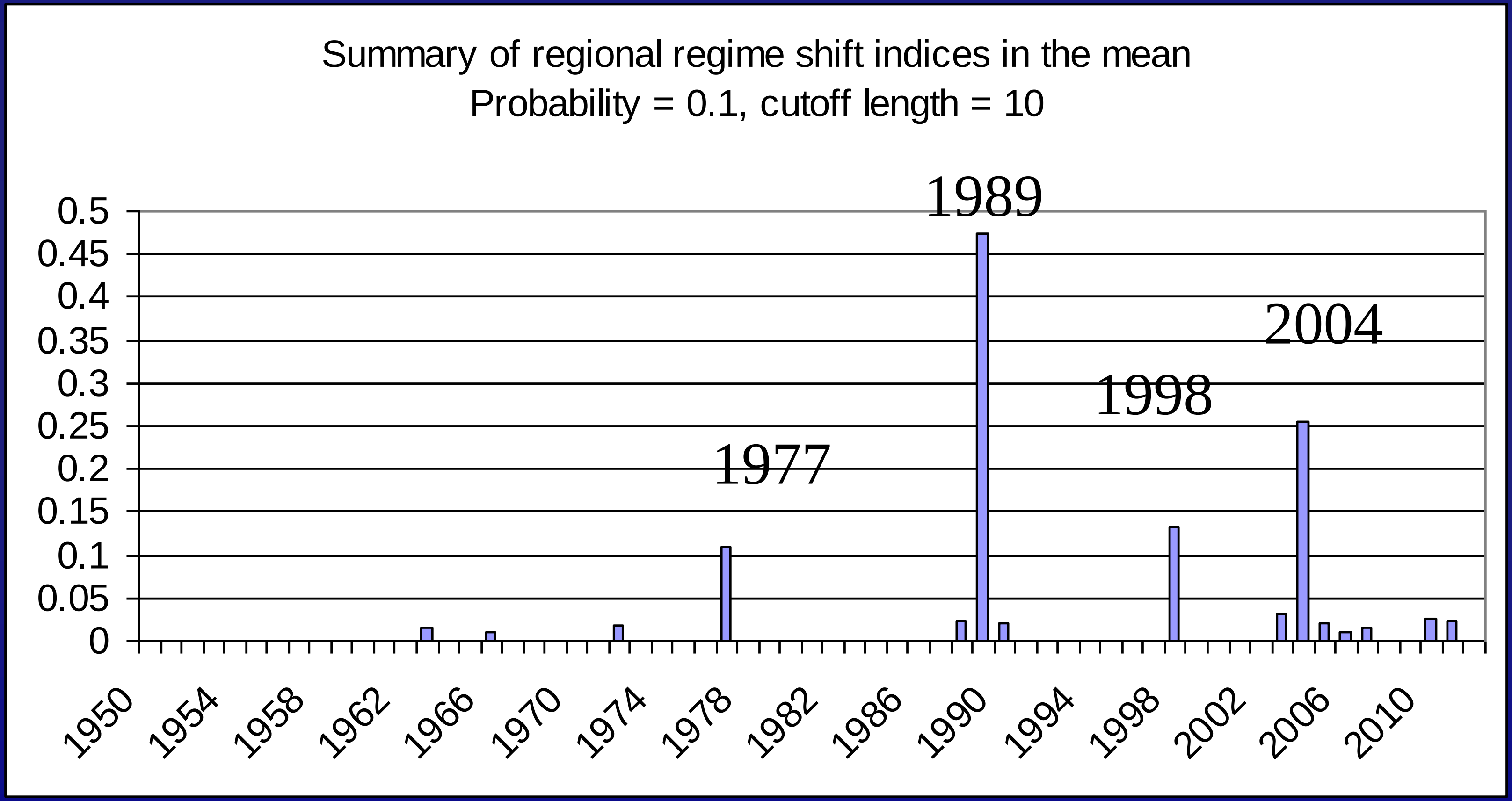






This is the RS index for regional "thermal" time series. The shift of 1989 is strongest.

The shift of 1989: to relative warming for the Japan/East and Okhotsk seas



Conclusions

Recent climatic trends and low-frequency variability of various environmental parameters are evaluated for different areas of the Japan/East, Okhotsk, and Bering Seas:

SST trends are estimated using empirical orthogonal functions for each sea. The main feature of the changes is warming of the surface layer (0.1-0.2 ° C per decade), although in the southern Japan/East Sea the positive trend to warming is not significant in all seasons. The contribution of the positive trend to total variance of SST is substantially less in summer than in other seasons.

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While the Okhotsk Sea ice cover is sensitive to global temperature variations, large-scale oscillations such as El Niño and the Pacific Decadal Oscillation are more important for the Bering Sea ice cover.

For thermal variables, the regime shifts of 1977/78 (to warming) and 2007/2008 (to cooling) are the strongest for the Bering Sea, the shift of 1988/1989 (to warming) for the Japan/East Sea, and regional shift of 1983/84 (to warming) for the Okhotsk Sea.


Thank you for attention!