PICES-2016
November 2-13, 2016 San Diego, USA

Climate variability and changes in the marginal Far-Eastern Seas

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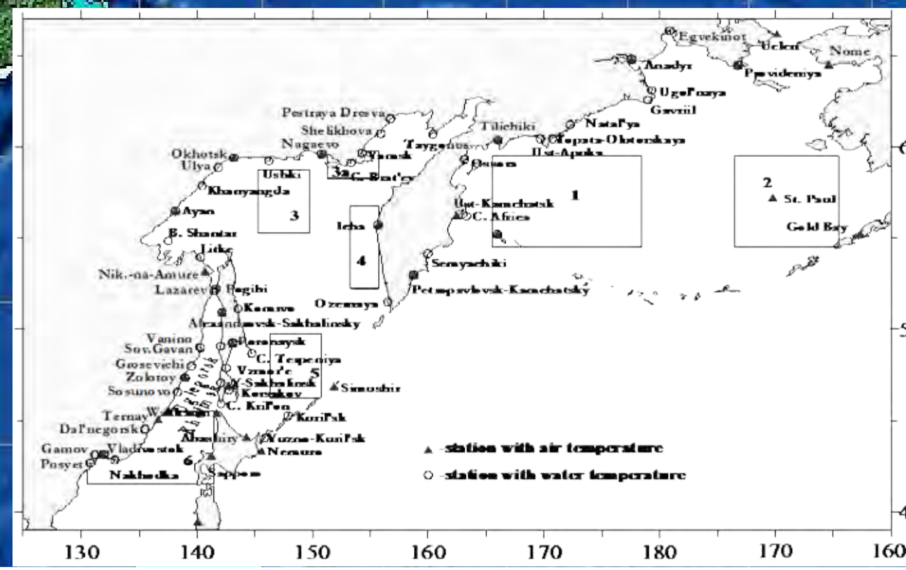
The presentation summarizes our recent studies on the features of climate variability and change in the Okhotsk, Bering and Japan/East Seas. We investigated the structure and evolution of regional climate variability and instabilities in the relationships between large-scale and regional-scale climate processes in the seas.

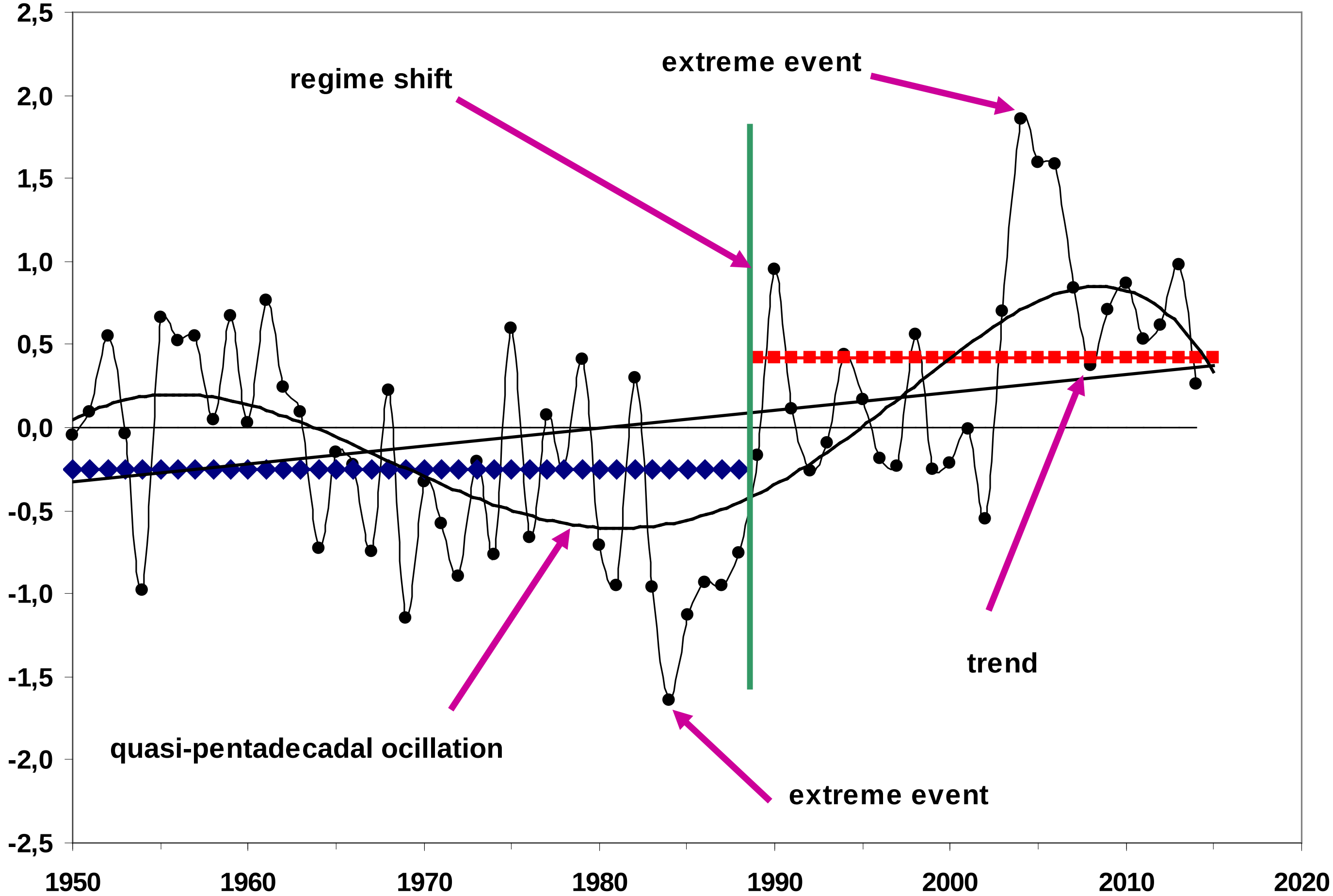
Regional climatic variables:

SST, ice cover, air temperature, cyclonisity index (by Glebova, 2011), macro-scale pressure gradients and intensity of the Far-Eastern centers of atmosphere action (by Vasilevskaya et al, 2003



Determination of the climatically significant parameters for the analysis is realized on following principles: duration, uniformity and regularity of the observations and utility of the climatic variables for the marine ecosystem researches and for fisheries forecasts. For example, the timing of the spring bloom, seasonal and interannual dynamics of zooplankton communities, seasonal fish migrations and other features of marine ecosystems are closely connected with variability such important climatic parameter as sea ice coverage.

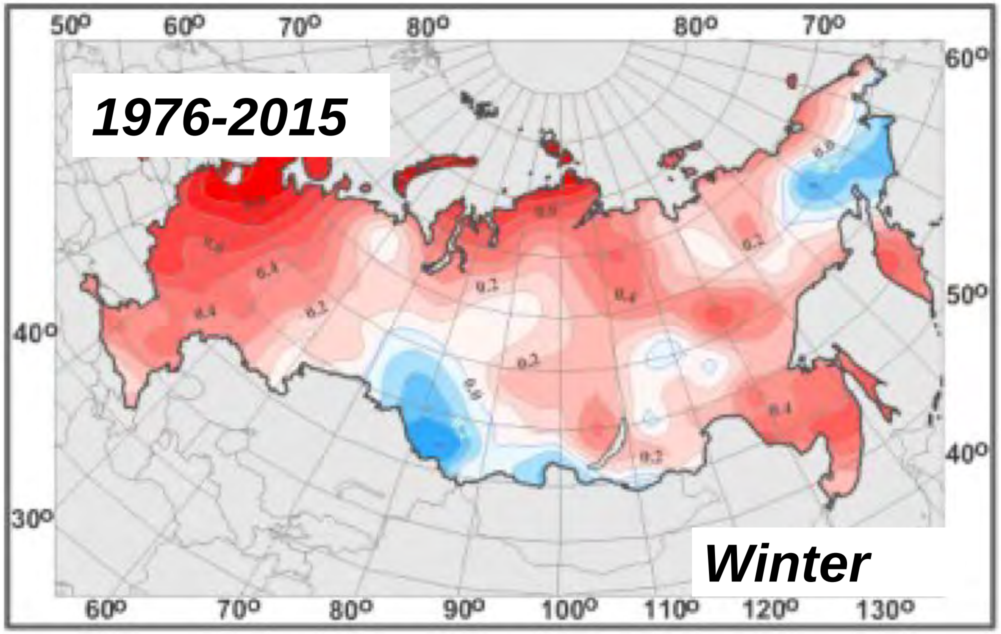
The main components of the structure of climate variability: the trend (change), regime shift, quasi-periodical components (as an example quasi-pentadecadal oscillation), extreme events for SST anomalies in the northern part of the Japan Sea in autumn

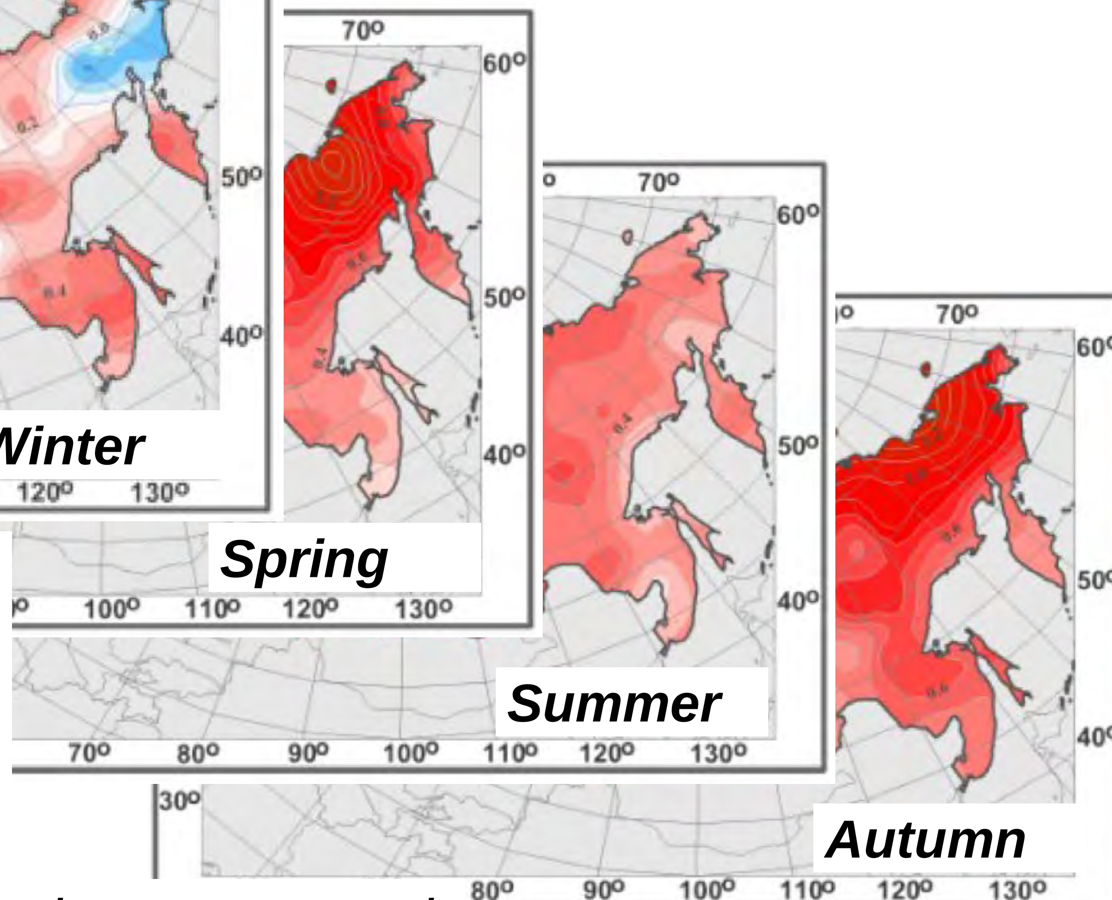


Air temperature trends, °C/10 years

Trends

(Report on climate features on the territory of the Russian Federation…, 2016)



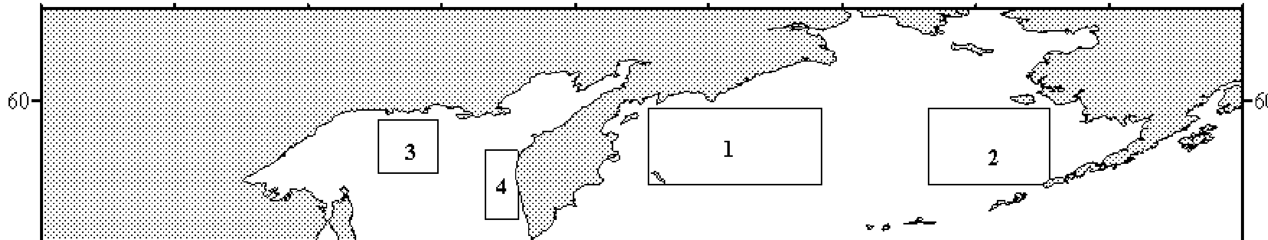
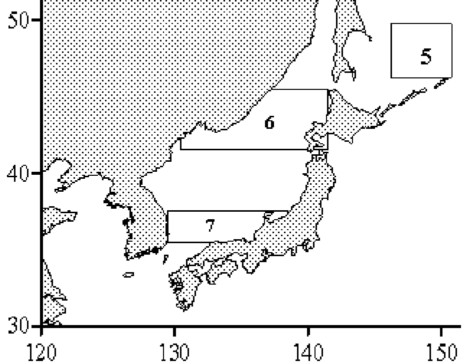


- maximal trends to warming:
in spring and autumn in the northern part of the Far-Eastern region;
- negative trends in the area to the north-east from the Okhotsk Sea and to the west from the Bering Sea in winter;

- tendency to decreasing of the difference between summer and winter air temperatures at the Japan/East Sea and its increases at the northern Okhotsk Sea; i.e. the continentality increases in the northern part of Far East and decreases in its southern part

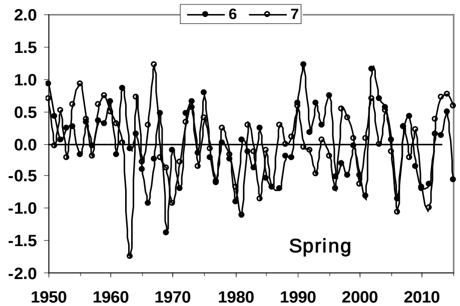
Trends

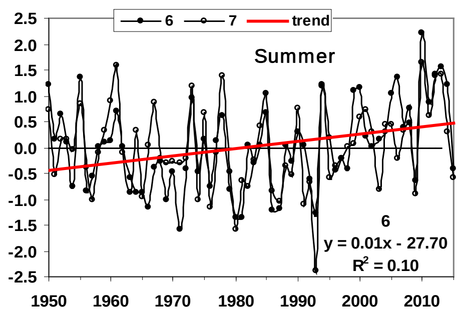
SST updated trends in the selected sub-regions of the Far-Eastern Seas

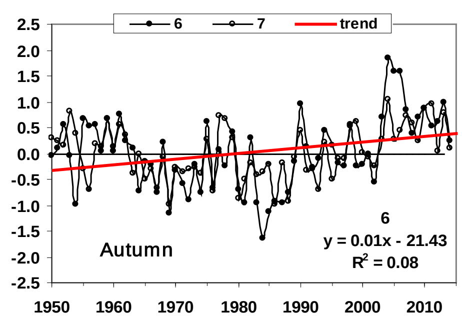



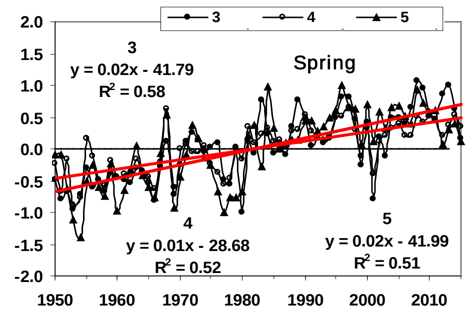
The main feature of the SST changes is warming of the surface layer (0.1-0.2°C per decade), although in the southern Japan/East Sea the positive trend to warming is not significant in all seasons.

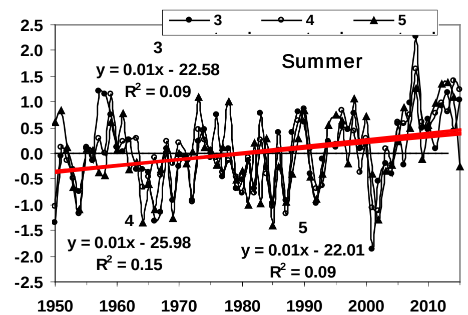
The contribution of the positive trend to total variance of SST is substantially less in summer than in other seasons.

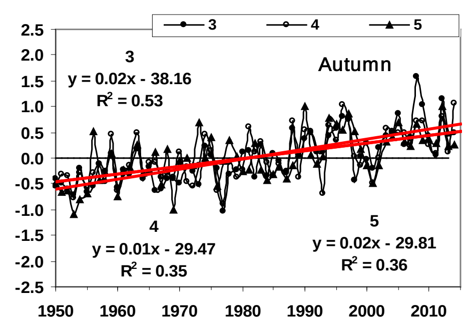


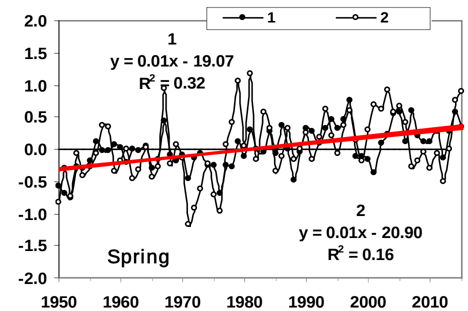


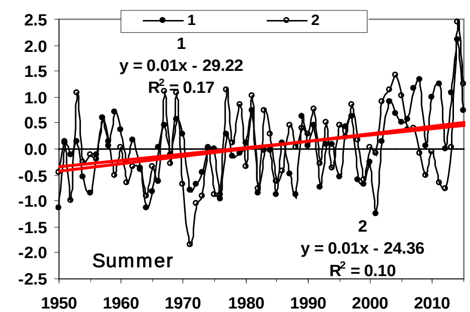


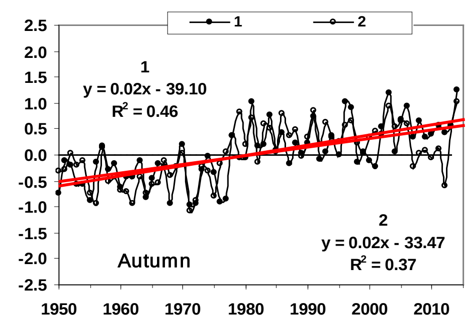






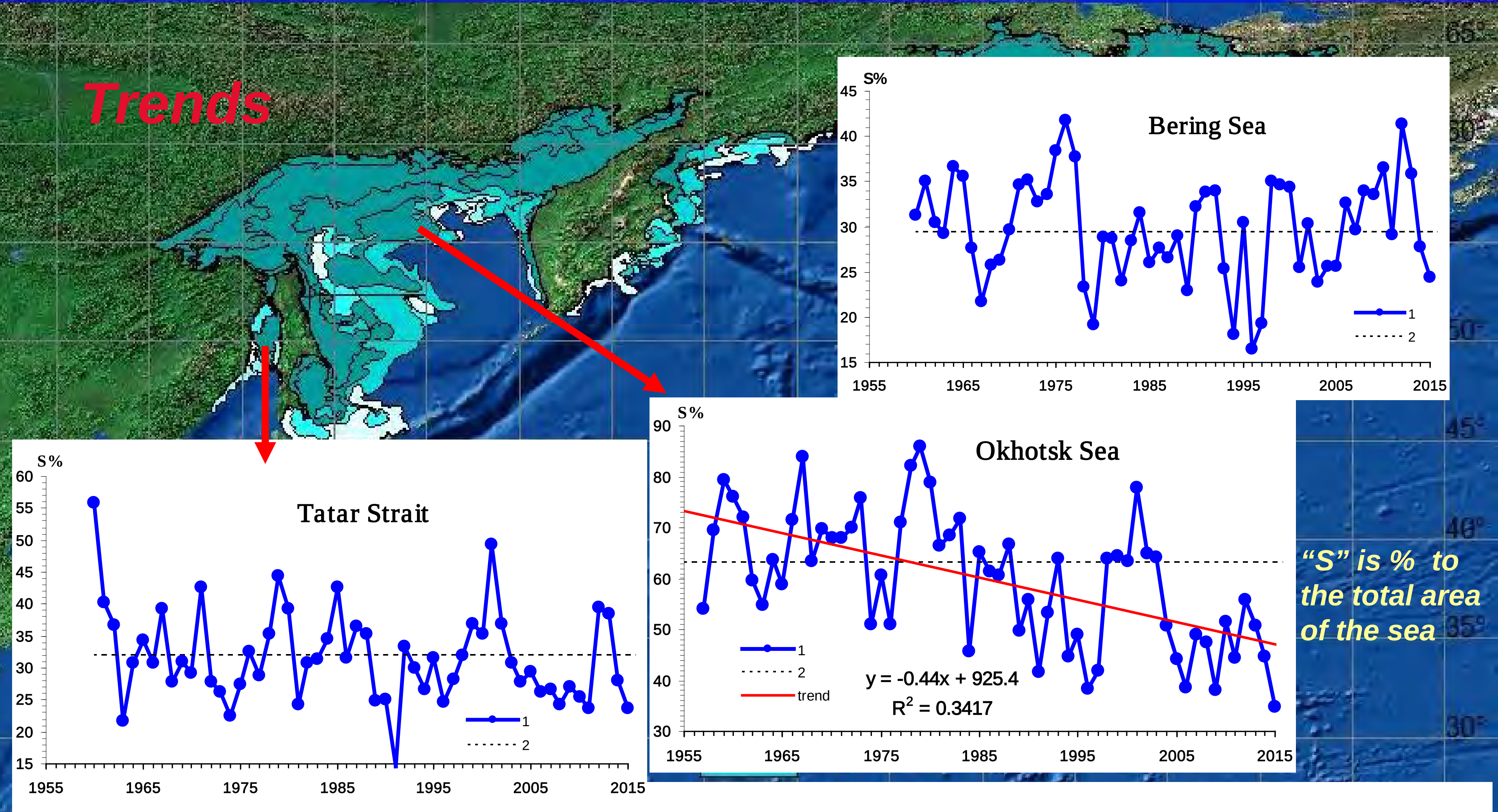






Japan/East Sea **Okhotsk Sea** **Bering Sea**

Mean winter ice cover (1), mean multi-year value (2) and statistically significant trend *with regression equation and determination coefficient R^2*

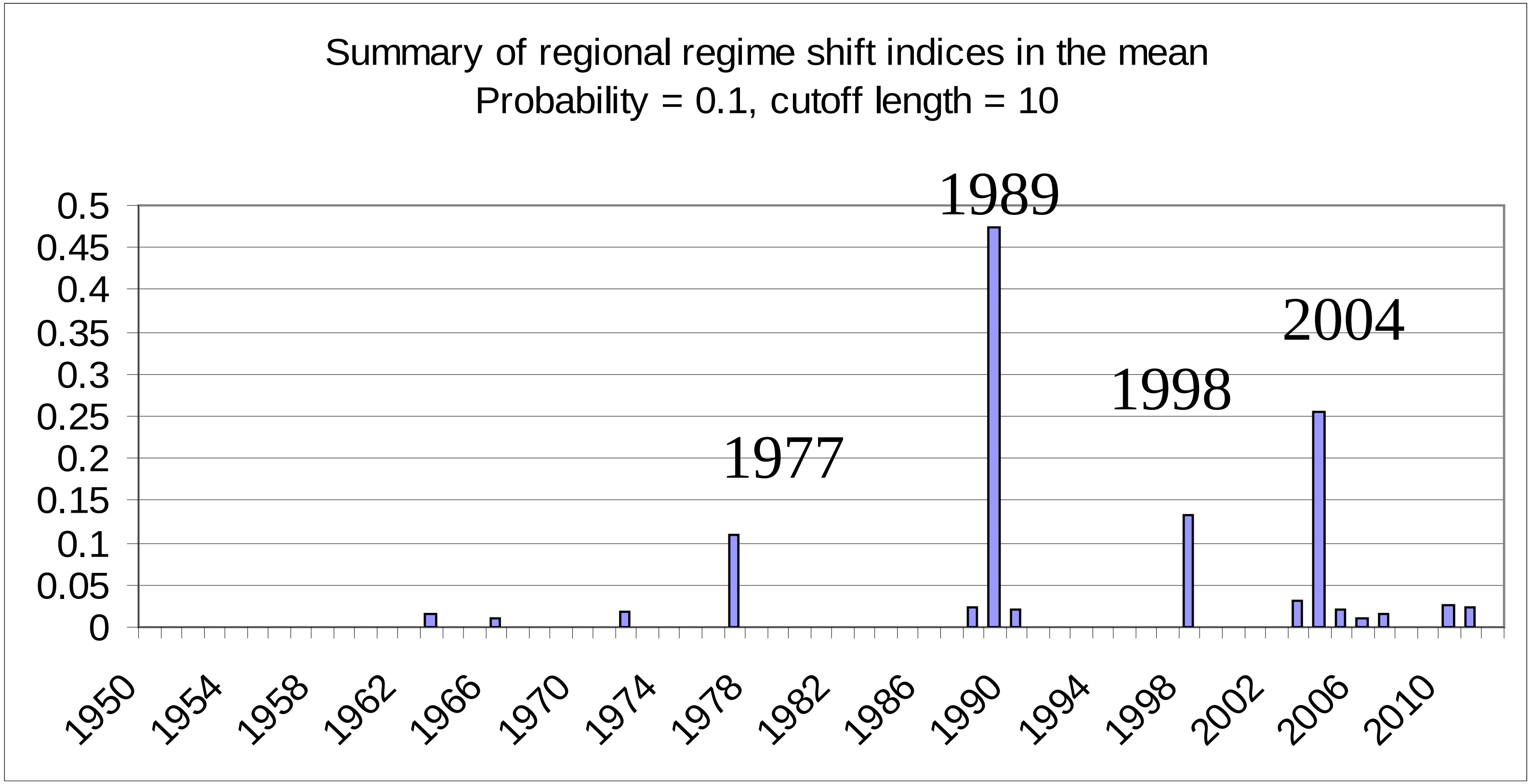


The warming is accompanied by decreasing sea ice cover that is the most significant in the Okhotsk Sea (4,4% per decade) where the ice cover tendency agrees well with the changes of air temperature of the Northern Hemisphere. Reduction of mean winter ice extent in the Bering Sea and the Tatar Strait is not statistically significant during the period 1960-2016.

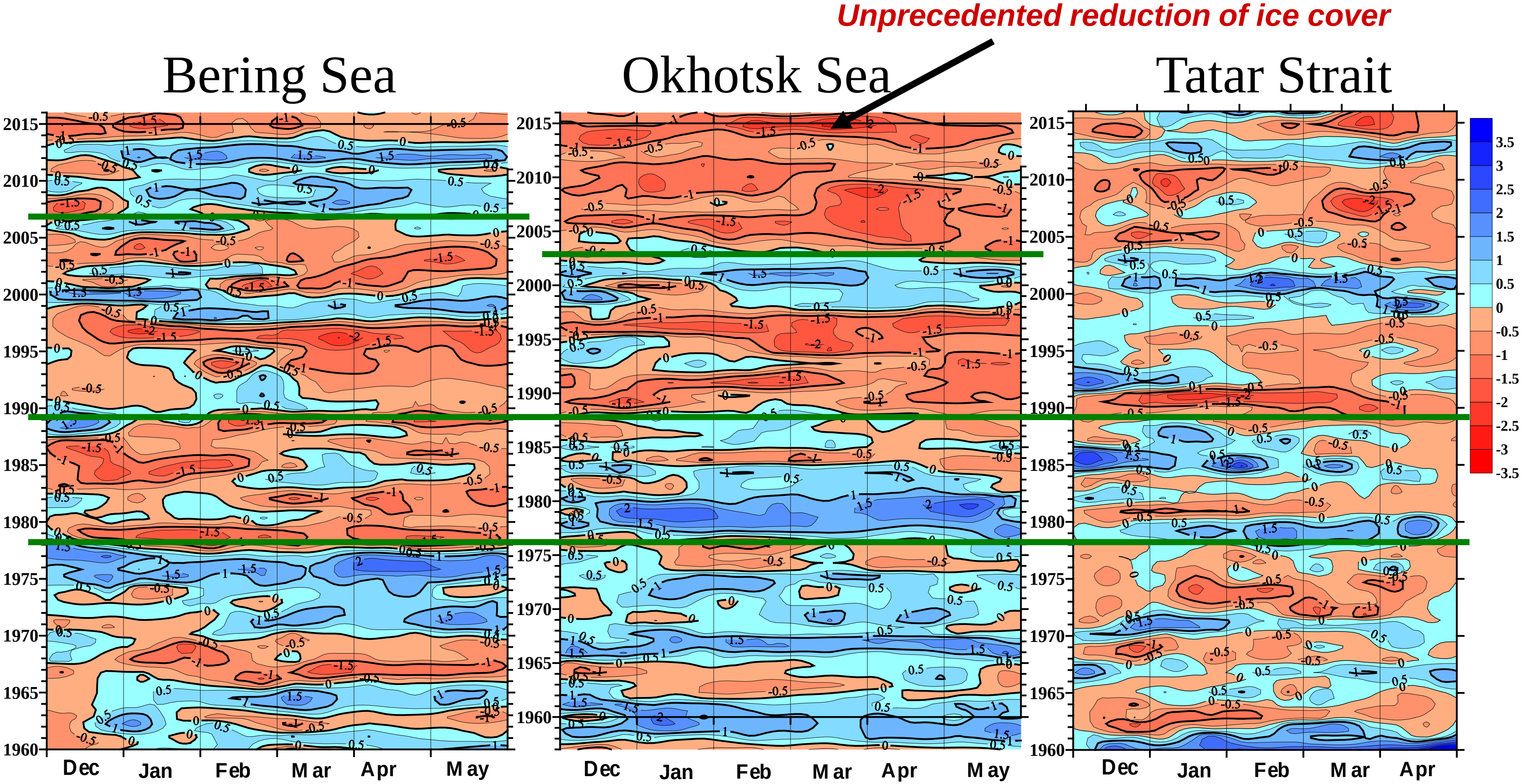
Regime shifts

We summarize sharp transitions in the Far-Eastern Seas ("regime shifts") analyzing the time series of environmental parameters with the use of the "regime shift index" (RSI) by means of the automated procedure for regime shift detection, with improved performance at the time series ends (Rodionov, 2004).

For the "thermal variables", the 1977/78 shift (to relative warming) and 2007/2008 shift (to relative cooling) are strongest in the Bering Sea, while the 1988/1989 shift (to relative warming) is strongest in the Japan/East Sea. In the Okhotsk Sea the regional shift of 1983/84 (to warming) is more importance. Combined RSI for regional climatic variables (air temperature, SST, ice cover) in the Far-Eastern Seas has maximum value in 1989.



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.

During the period 2004-2011 predominance of warm conditions is evident. In spite of the fact that winter ice extent in the Tatar Strait is closely connected with ice in the Okhotsk Sea, during several periods the synchronism can be broken, especially in 1980s.

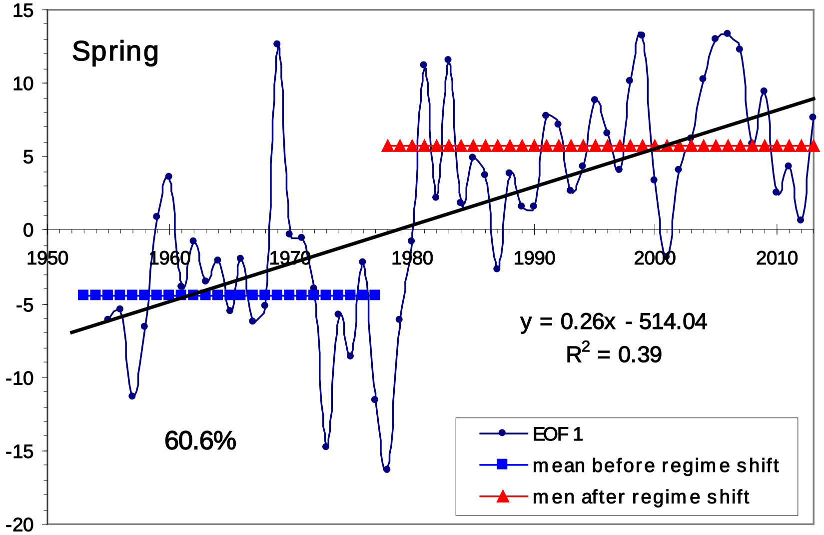
The most significant reduction of the mean winter ice extent occurred in the Okhotsk Sea, while in the Tatar Strait a negative trend isn't statistically significant.

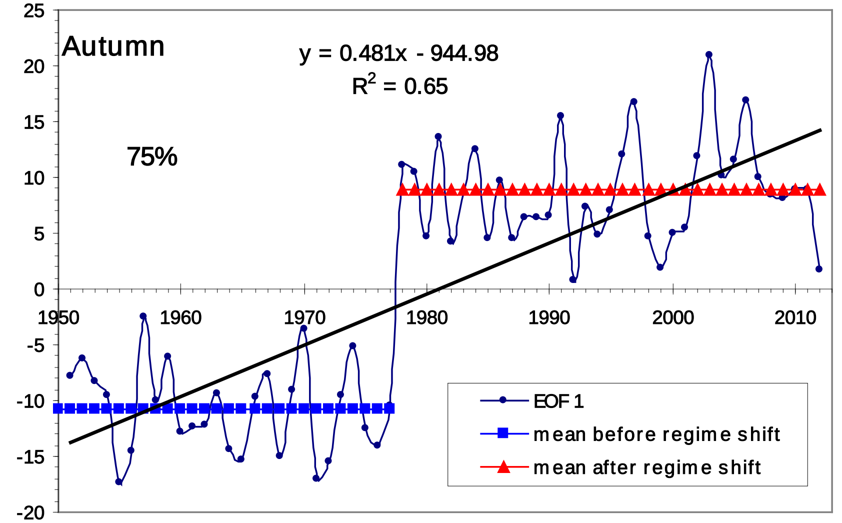
Regime shift *and* trends:

EOF-1 for SST time series in the Bering Sea

Regime shift:

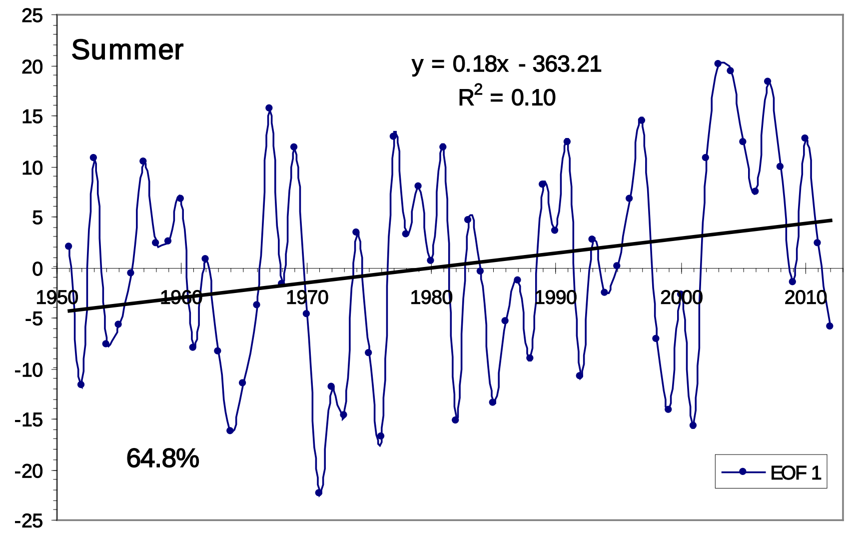
In spring and autumn the climate regime shift of 1977/78 was detected.





Trend:

In summer "true" trend is observed.

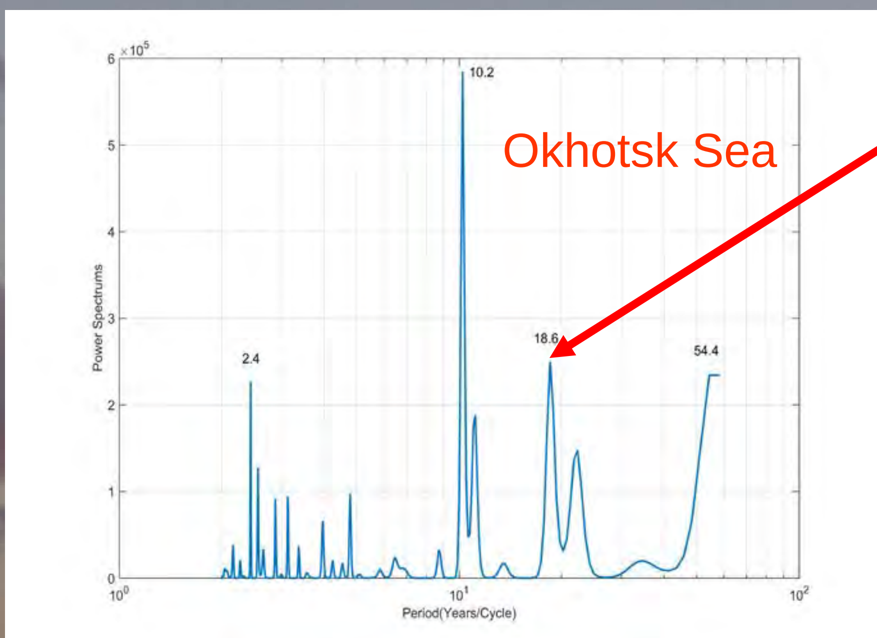


Geophysical nature
of the quasi-periodical components

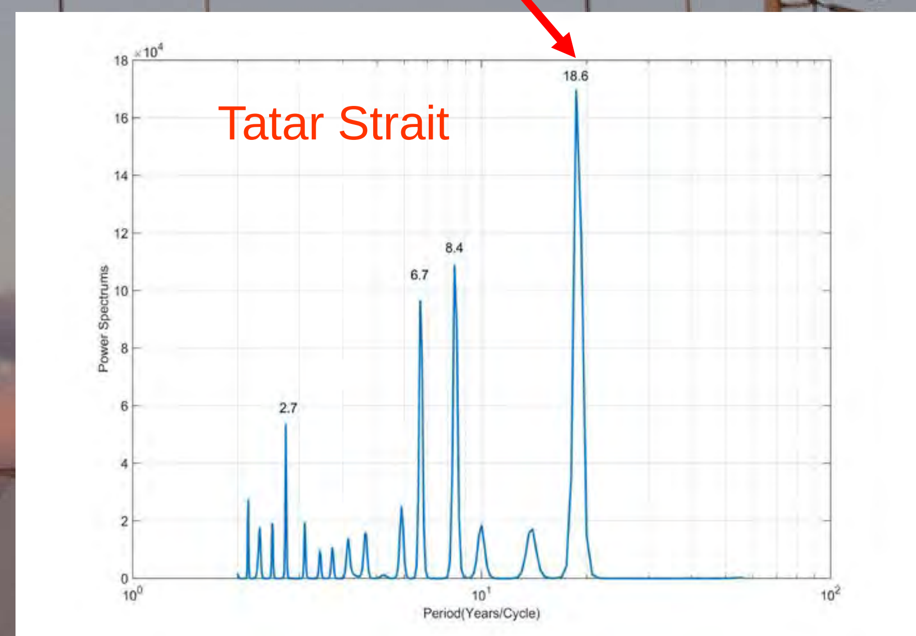
for example, 18.6 years cyclicity is associated with long-term fluctuations of "lunar tide“: in the

- **ice cover time series for *the Okhotsk Sea and Tatar Strait***
- **winter air temperature in *the Okhotsk and Bering Seas***
- **spring SST *in the eastern Bering Seas and* summer SST *in the Okhotsk Sea***

Long-term fluctuations of the “lunar tide”: *18.6 years in the ice cover time series*



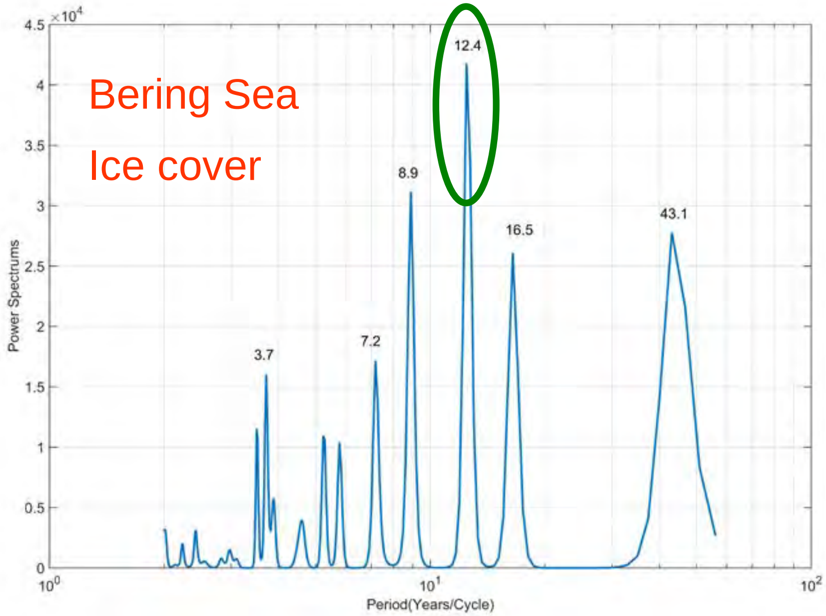
(Methodology by Liepins, 1997)



Quasi-periodical components

Quasi-decadal scale:

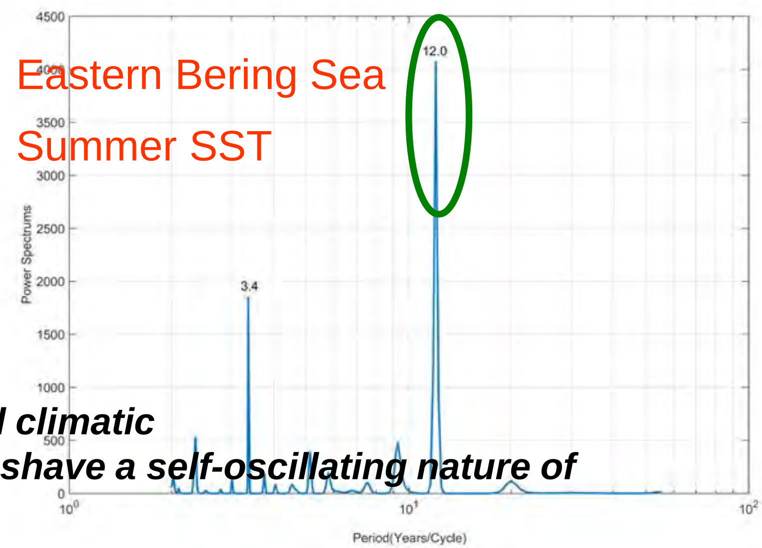
in the ice cover time series (Okhotsk and Bering Seas)



And in the :

-**all SST time series** excluding the autumn SST in the western Bering Sea and in the southern Japan/East Sea and summer SST in the Japan/East Sea;

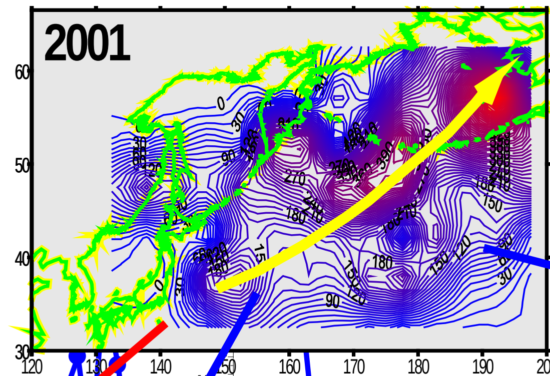
- **air temperature time series** (Okhotsk and Bering Seas and northern Japan/East Sea)



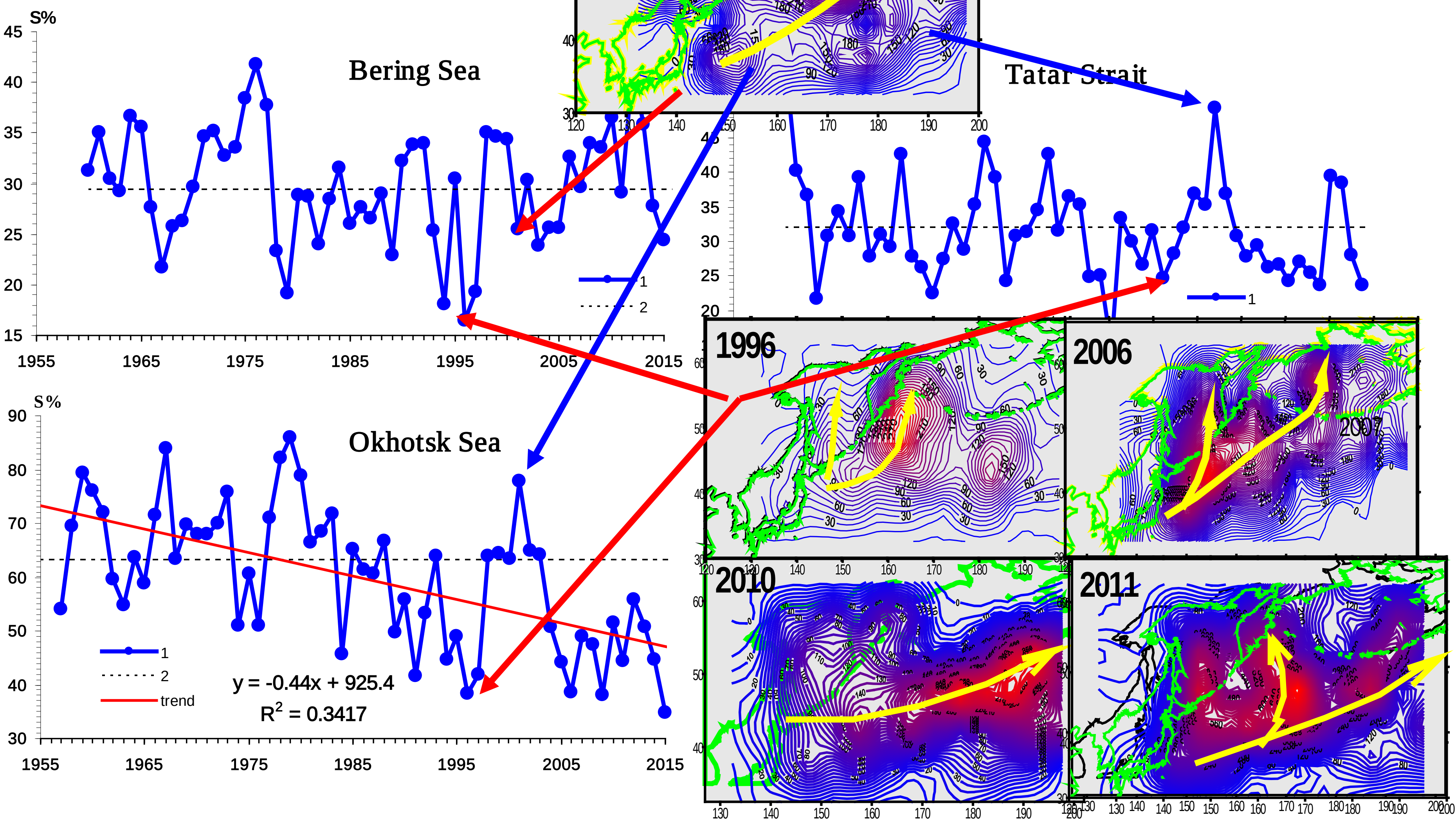
In our opinion, quasi-periodical components of the regional climatic variability about 10 and 50 years (Okhotsk and Bering Seashave a self-oscillating nature of hemispheric and basin scale.

Cyclonic intensity *(Kunitsin's index by Glebova, 2012)* in winter and ice cover in the Far-Eastern Seas

Extreme events ***are influenced by specific macrocirculating atmospheric processes on the boundary between Eurasian continent and the Pacific Ocean***



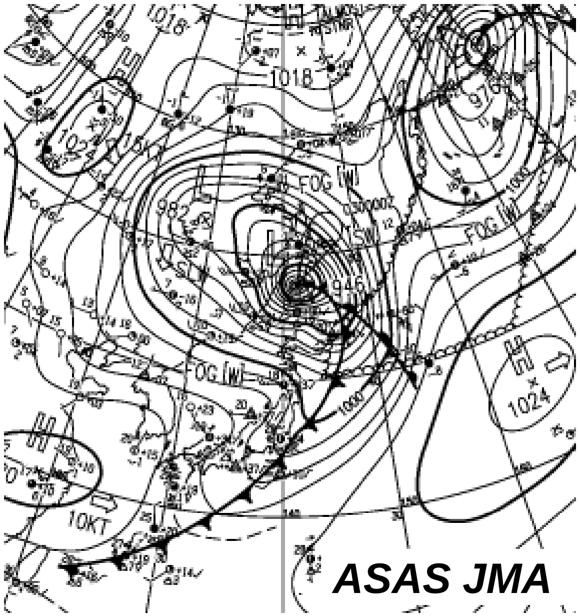
Extreme events



Example of the extreme event: ***"dramatic" role***

Extreme events

extreme cyclone and Japanese sardine (*Sardinops melanostictus*) in the Tatar Strait, October 2015



Very deep cyclone (October, 2 2015)

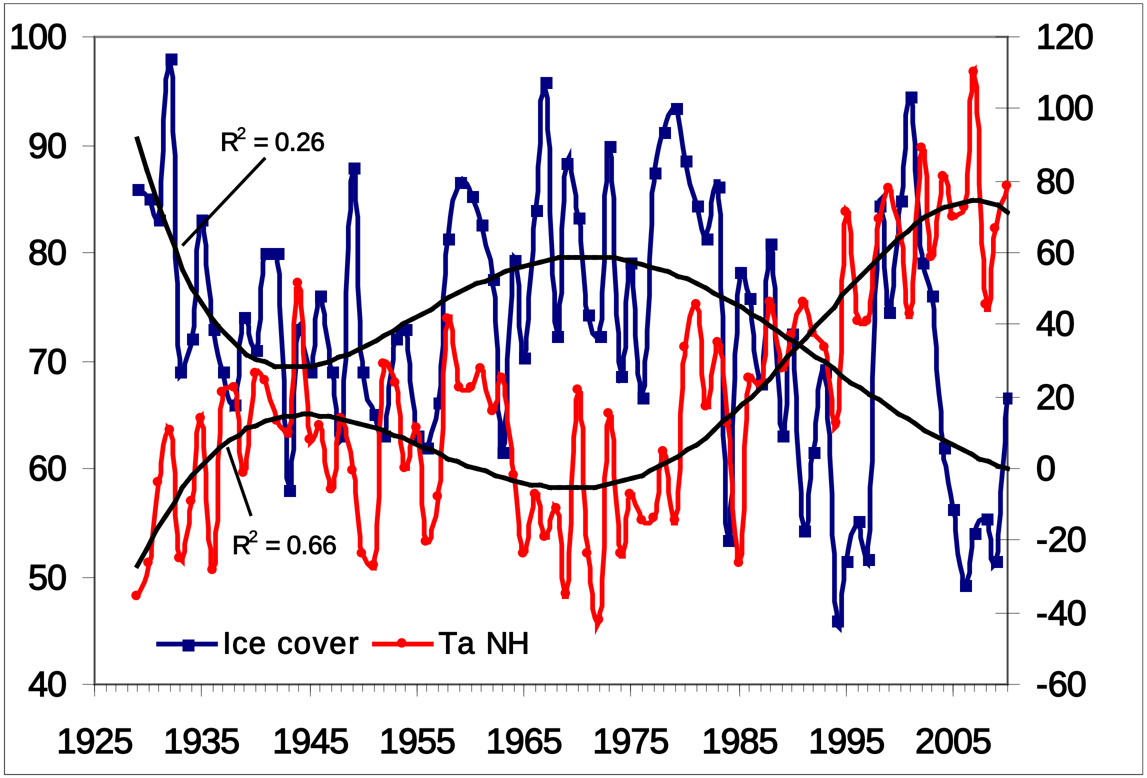
http://www.topnews.ru

http://static.sakh.com/info/p/photos/

increasing abundance(?) + arrival in the Tatar Strait with warm waters of subtropical origin + the impact of extreme cyclone

Relationships between the large-scale and regional-scale climate processes

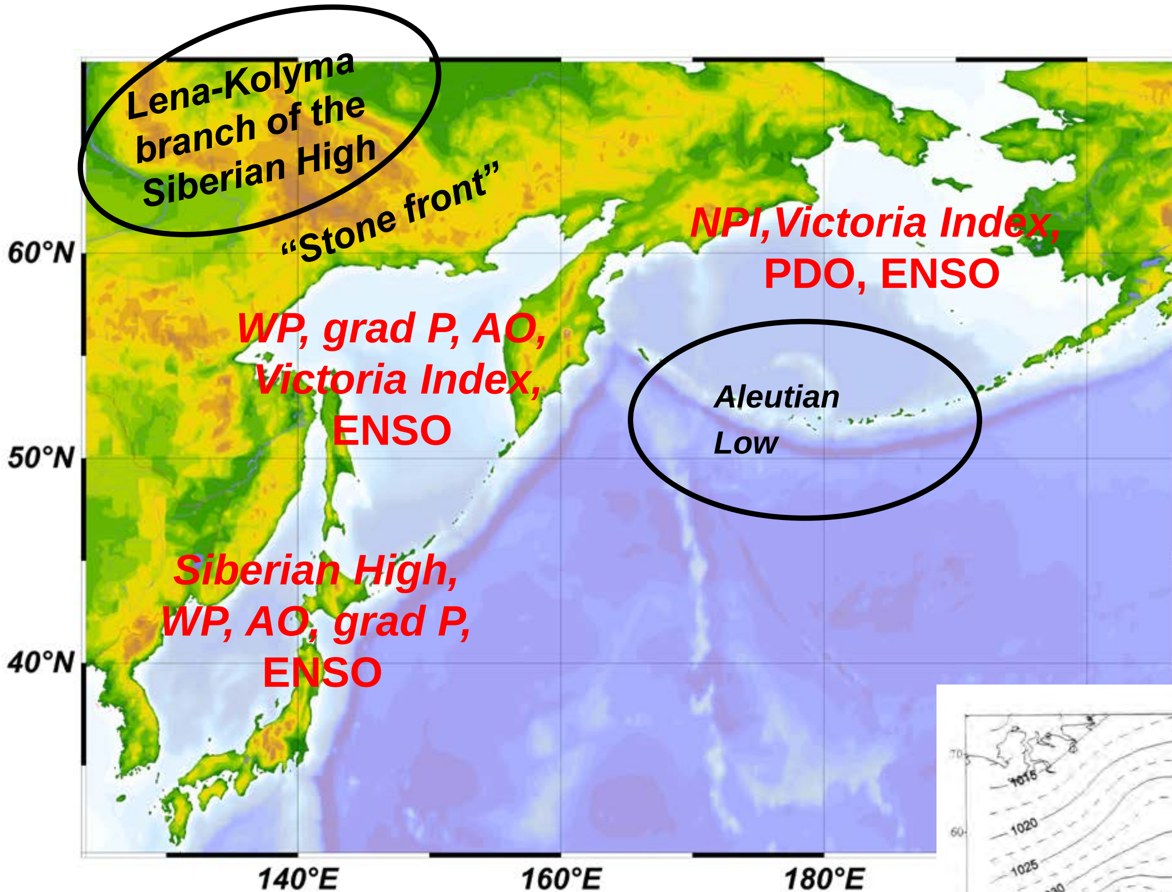
Winter North Hemispheric temperature anomalies, annual maximal ice cover in the Okhotsk Sea and its polynomial trends



Ice cover variations in the Okhotsk and Bering Seas have the connection with the variations of Northern Hemisphere (NH) winter air temperature anomalies for the time scale >7 years (R=-0.71 and -0.48, respectively). For the Tatar Strait these linkages are not found.

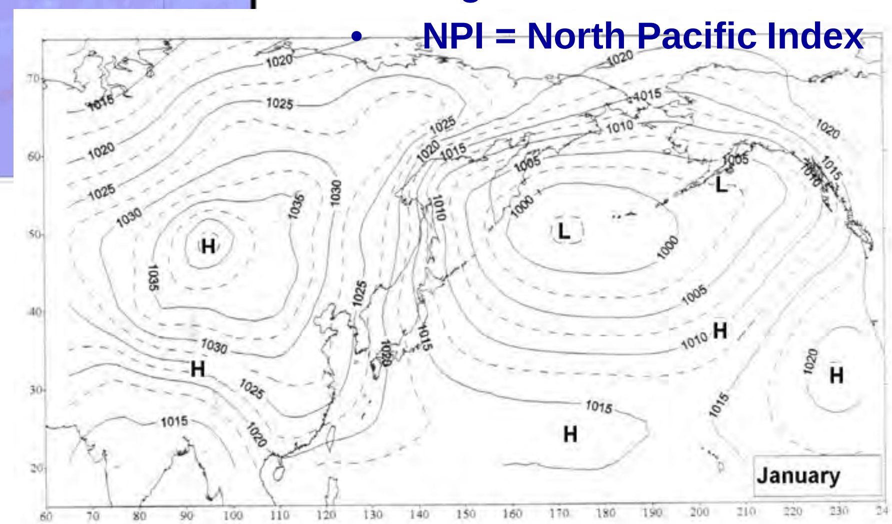
Okhotsk Sea ice cover is sensitive to global temperature variations. This feature is explained mainly by trends and quasi-pentadecadal contributions.

Relationships between the large-scale and regional-scale climate processes



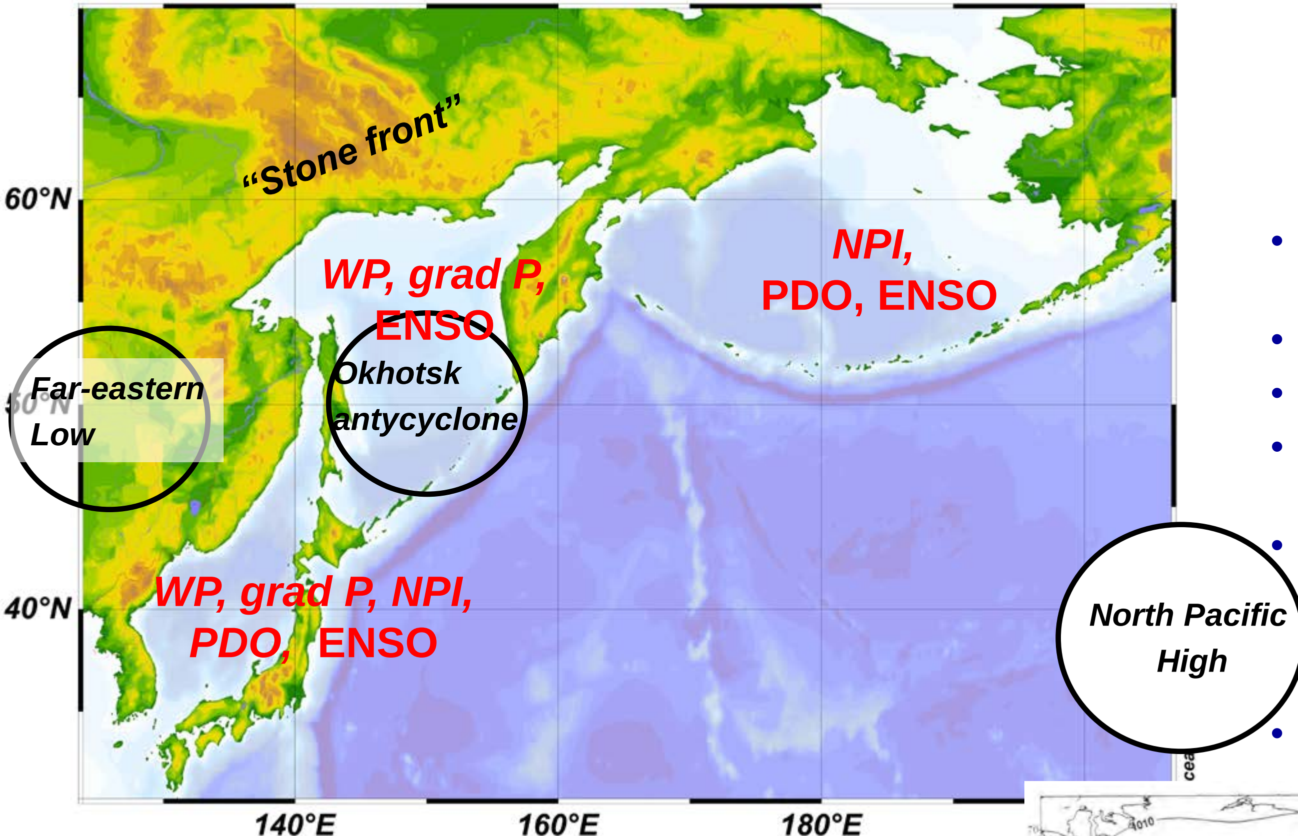
Winter

- **PDO = Pacific Decadal Oscillation,**
- **AO = Arctic Oscillation,**
- **WP = West Pacific index,**
- **MEI = Multivariate ENSO Index,**
- **grad P = macro-scale pressure gradient between the Siberian High and Aleutian Low**
- **NPI = North Pacific Index**



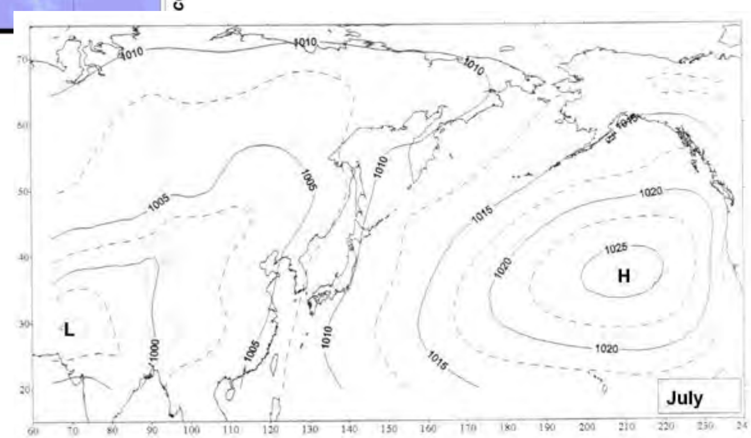
Strong cyclone season

Relationships between the large-scale and regional-scale climate processes



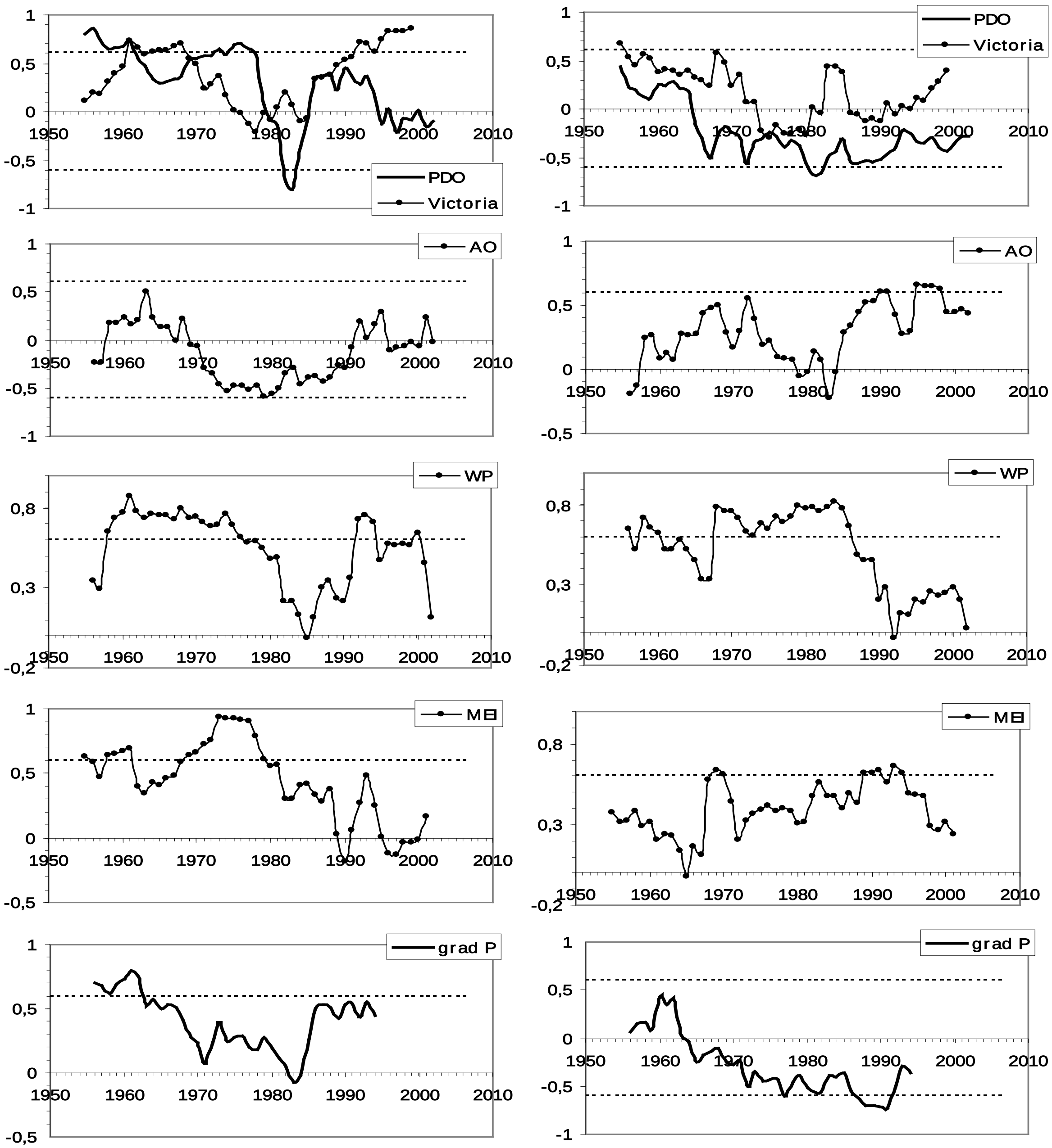
Summer

- PDO = Pacific Decadal Oscillation,
- AO = Arctic Oscillation,
- WP = West Pacific index,
- MEI = Multivariate ENSO Index,
- grad P = macro-scale pressure gradient between the North Pacific High and Far-Eastern Low
- NPI = North Pacific Index



Okhotsk antycyclone, Far-Eastern Low and typhoon season

Examples for Far-Eastern Seas: shifts in the relationships



“Running correlation” with 11-year period between annual maximum ice cover (left) in the Okhotsk Sea, winter SST in the Southern Japan/East Sea (right), and winter large-scale climatic indices (dashed line is 95% confidence level)

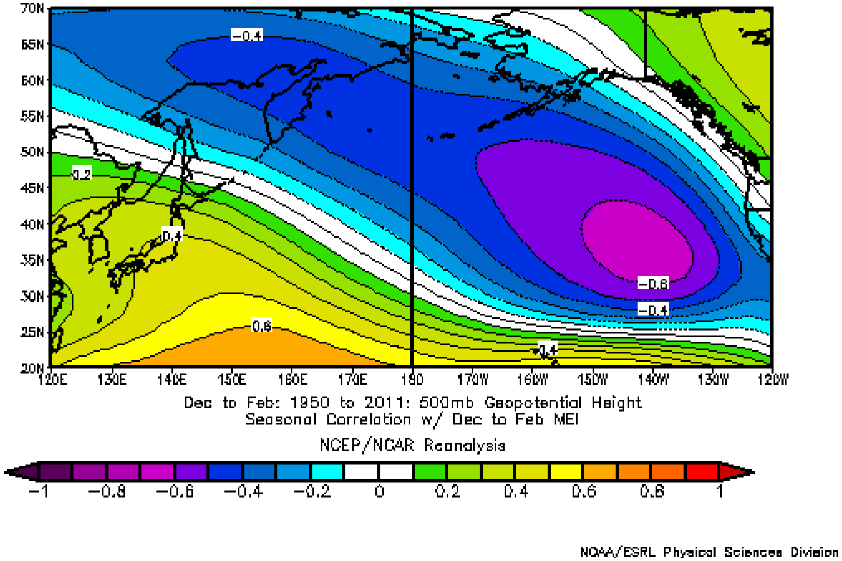
PDO = Pacific Decadal Oscillation,
AO = Arctic Oscillation,
WP = West Pacific index,
MEI = Multivariate ENSO Index,
grad P = macro-scale pressure gradient between the Siberian High and Aleutian Low

Dashed line:
confidence level 95%

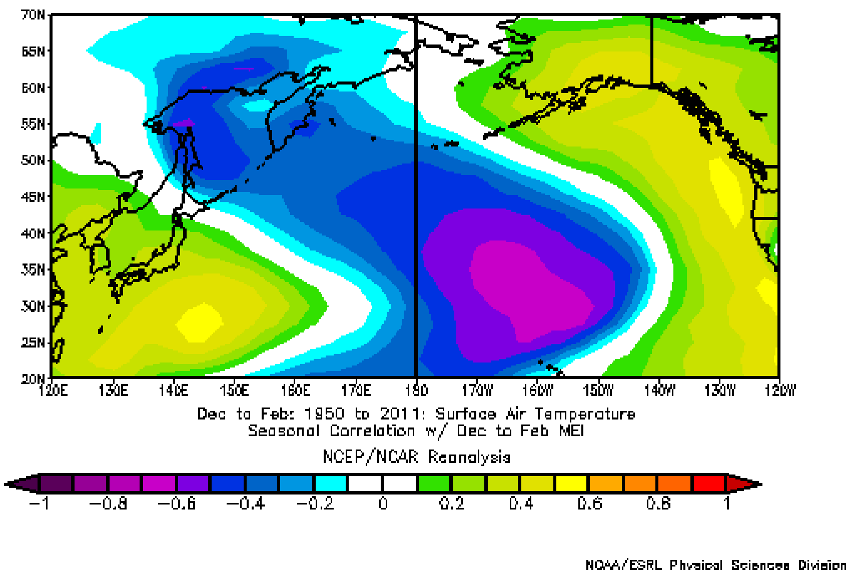
The strongest 1989 shift occurred in the Arctic Oscillation

Relationships with large-scale climatic processes: El Nino

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.



Changes in the sign correlation between some large-scale climate indices (e.g., AO, ENSO, etc.) and regional climatic parameters occur over the Tatar Strait.



http://www.esrl.noaa.gov/psd/data/correlation/

Summary

Among the Far-Eastern Seas, the most significant warming occurred in the Okhotsk Sea during the last 25 years. Unprecedented reduction in the Okhotsk Sea ice extent occurred in winter 2014/2015 on the background of the statistically significant long-term negative trend.

The total variance of the many “thermal variables” has increased over the last 25 years in the Far-Eastern Seas. Frequency of extreme situations occurrence has also increased, especially in the Okhotsk Sea.

Changes in the sign correlation between some large-scale climate indices (e.g., AO, ENSO, etc.) and regional climatic parameters occur over the Tatar Strait.

We consider that the regime shifts and extreme events played more "dramatic" role for marine ecosystems in comparison with long-term trends and low-frequency quasi-periodical oscillations through high rates of change.

Questions

Historical and contemporary sources of regional data

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

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 (1998-2016).

DATA SOURCES OF LARGE-SCALE CLIMATE INDICES:

Climatic indices

Aleutian Low Pressure Index (ALPI),

Siberian High Index (SHI)

North Pacific Index (NPI),

Pacific Circulation Index (PCI),

West Pacific (WP) Index,

Pacific Decadal Oscillation (PDO) and Victoria index;

Arctic Oscillation (AO) Index,

ENSO,

global and Northern Hemisphere averaged surface air temperature

from:

http://www.beringclimate.noaa.gov/data/index.php,

http://www.cgd.ucar.edu/cas/catalog/climind/,

http://www.cpc.ncep.noaa.gov/products/, http://jisao.washington.edu/,

http://www.pac.dfo-mpo.gc.ca/sci/sa-mfpd/climate/clm_index.htm.

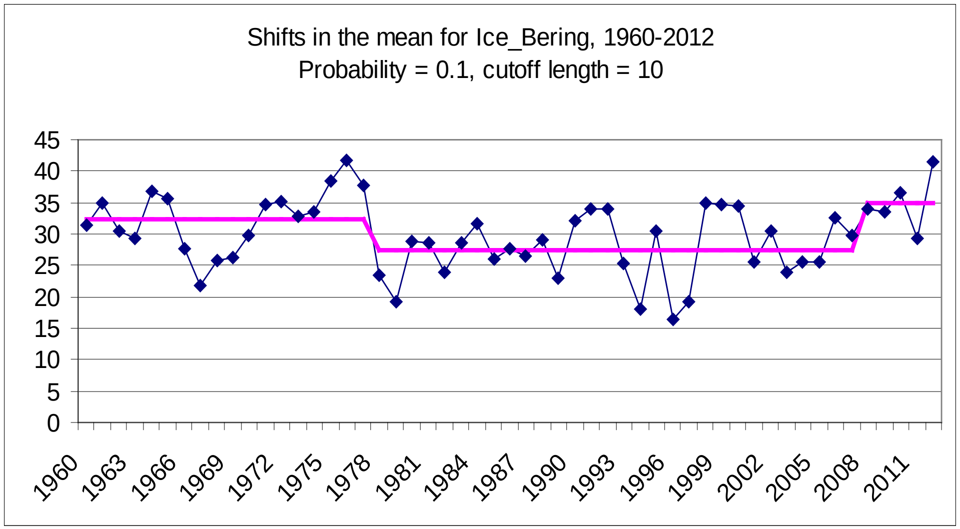
Macro-scale pressure gradient between the Siberian High and Aleutian Low and intensity of the Far-Eastern centers of atmosphere action (by Vasilevskaya et al, 2003)

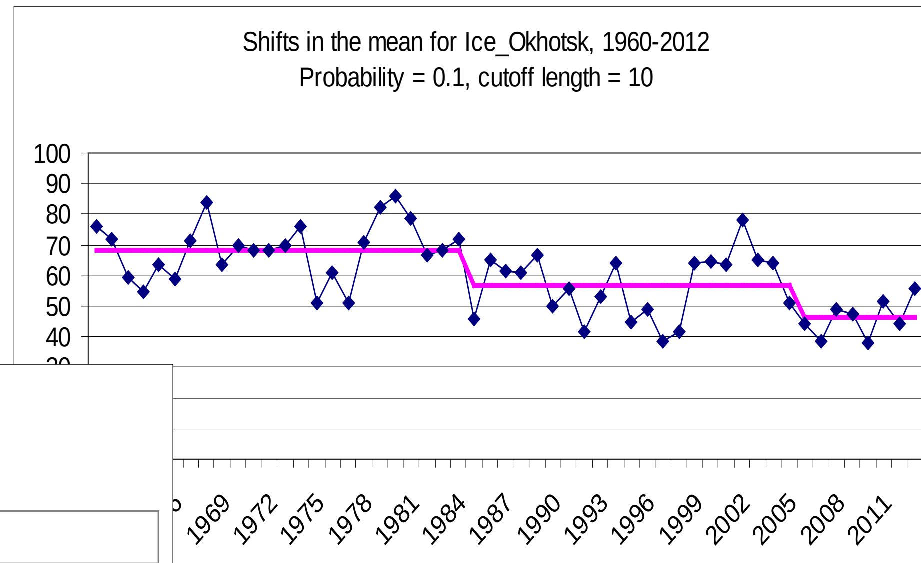
We have summarized our studies of the sharp transitions in the Far-Eastern Seas ("regime shifts"). We examined the time series for the presence of climatic shifts by Regime shift index (RSI) and by tools with automatic detection of regime shifts and improved performance at the ends of time series (Rodionov, 2004).

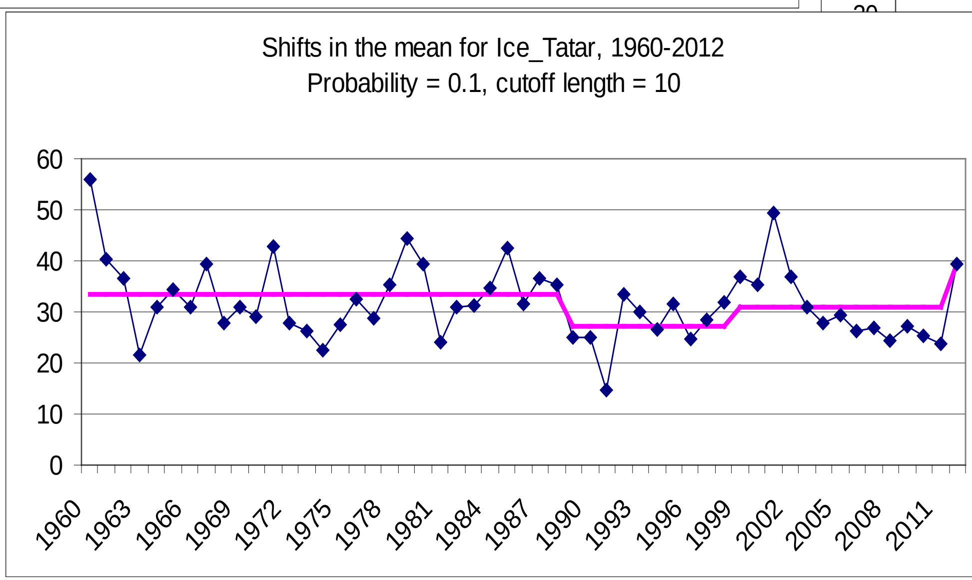
The shift of 1978 and 2008 is strongest for the Bering Sea in the last 52 years.

The shift of 1989 is strongest for the Tatar Strait

The shift of 1984 : is strongest for the Okhotsk Sea







Summary

The structure of regional climate variability in the Far-Eastern Seas were analyzed: trends, regimes and regime shifts, quasi-periodical components and extreme events.

- *Trends:* The main feature of the SST 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 warming is accompanied by decreasing sea ice cover that is the most significant in the Okhotsk Sea (4,4% 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 ice cover trends are non-significant.
- *Regimes:* For "thermal variables", the regime shifts of 1977/78 (to warming) are the strongest for the Bering Sea and the shift of 1988/1989 (to warming) for the Japan/East Sea including the Tatar Strait. In the Okhotsk Sea the regional shift of 1983/84 (to warming) is more importance. Combined RSI for regional climatic variables (air temperature, SST, ice cover) has maximum value in 1989 in the Far-Eastern Seas. The well-known 1988/89 shift is associated with the sharp weakening of the Siberian High and its influence on the Japan/East Sea. The nature of the recent shift of 2003/2004 in the Okhotsk Sea is not quite clear yet.
- *Quasi-periodical components:* a self-oscillating nature of hemispheric and basin scale (as an example, quasi-pentadecadal and decadal oscillations, ENSO), as well as a geophysical nature (for example, 18.6-year cyclicity is associated with long-term fluctuations of the "lunar tide").
- *Extreme events:* as a rule, they are the result of a combination of large-scale factors (e.g., the intensity of winter and summer monsoons) and regional specificities. The variations in intensity and shifts of cyclone trajectories in the zonal and/or meridional direction played an appreciable role in the Far-Eastern Seas, especially in the cold season (from November to March).

For marine ecosystems, all of these types of the variability are important. However, we consider that the regime shifts and extreme events played a more "dramatic" role because of limited adaptive capacity of living organisms to high rates of change.