Tipping points: shifts in climatic variables or their relationships?

Examples for the Far-Eastern Seas

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In the paper we have summarized our studies of the sharp transitions in the Far-Eastern Seas ("regime shifts") analyzing the time series of environmental parameters: the regional climatic characteristics (mainly sea ice coverage, air and water temperature) and large-scale climatic oscillations and patterns.

We used historical and contemporary sources of regional data of the observations on various thermal and atmospheric circulation parameters

- **State of atmosphere: thermal (air temperature) and dynamic (SLP, H500, trajectories of cyclones, Kunicin's index, types of regional atmospheric circulation, *etc*)**

- **Thermal parameters in the Seas:**

  long time series:

  ice cover (regular ten-days aircraft observations conducted by Russian Hydrometeorological Service and satellite information**)**

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

- **T and S by oceanographic expedition researches (National Russian Programs on the Bering Sea, Okhotsk Sea, Japan Sea, North-Western Pacific and Program on Salmon)**

DATA SOURCES OF LARGE-SCALE CLIMATE INDICES:

Climatic indices

- Aleutian Low Pressure Index (ALPI),
- 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)

Methodology

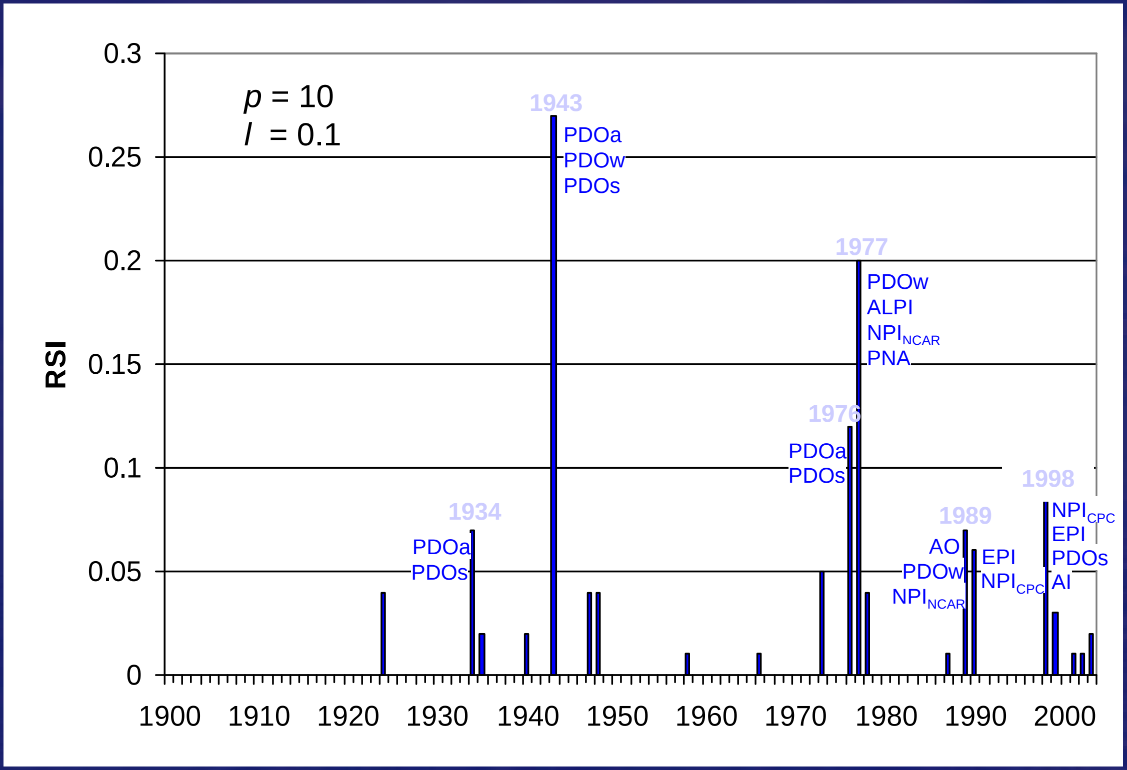
For the detection regime shifts we used mainly
a sequential regime shift detection method and tools
according to Rodionov (2004, 2006).

Automatic detection of regime shifts and Improved performance at the ends of time series;

Good for the time series containing a trend

Regime shift index

RSI



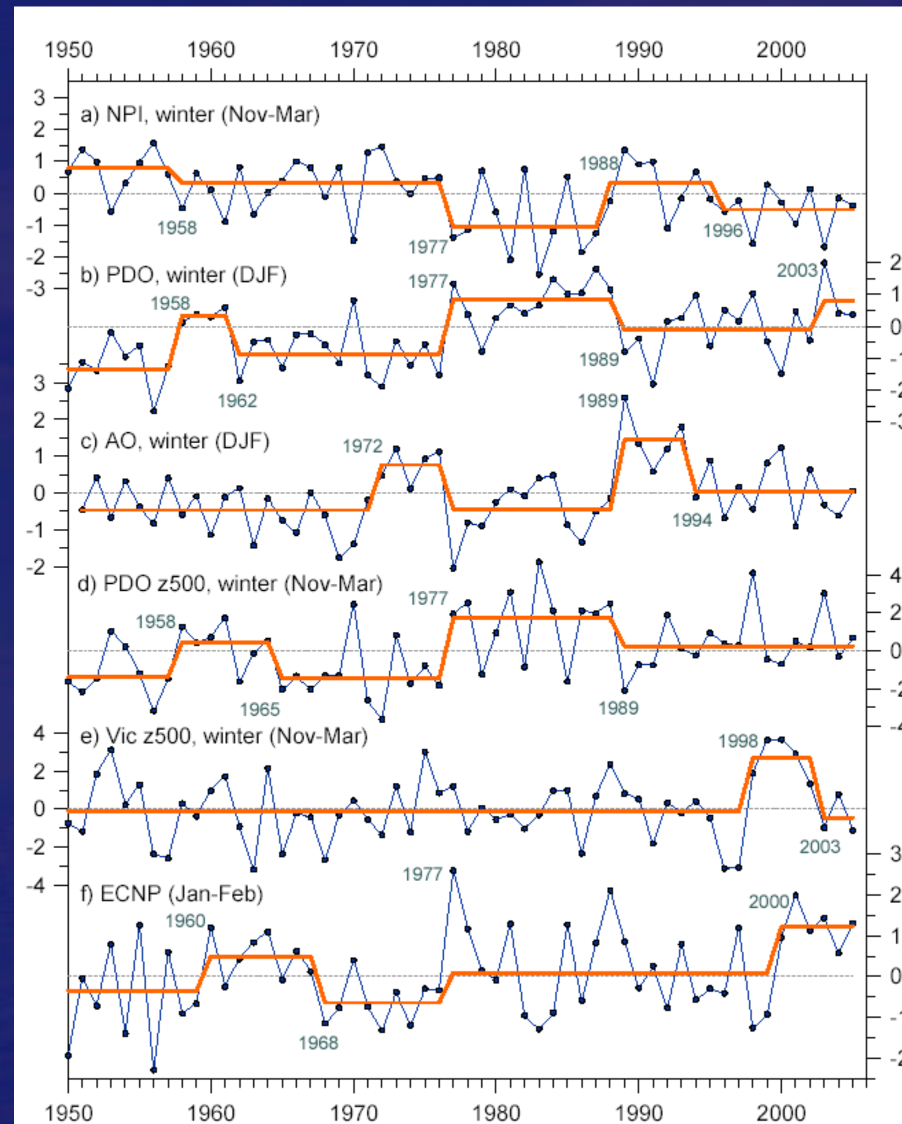
Rodionov and Overland, 2005: Regime Shifts in Climatic Indices

Methodology

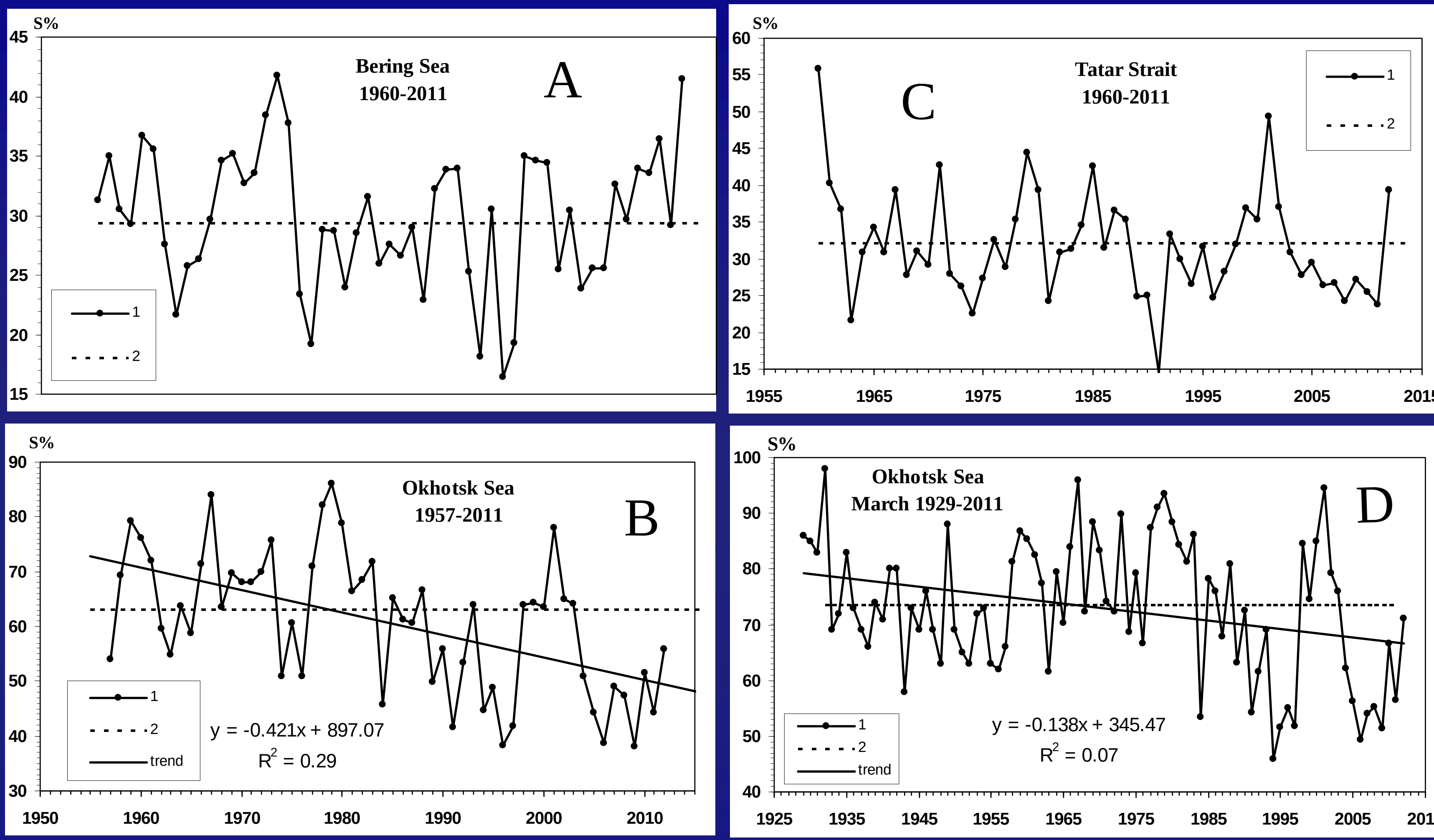
Rodionov et al, 2005

a) Mean winter (Nov-Mar) NPINCAR, 1950-2005,
b) Mean winter (DJF) PDO index, 1950-2005,
c) Mean winter (DJF) Arctic Oscillation index
d) Mean winter (Nov-Mar) atmospheric PDO index at the 500-hPa level
e) Mean winter (Nov-Mar) atmospheric Victoria index at the 500-hPa level
f) January-February East-Central North Pacific index

The stepwise functions (orange lines) characterize regime shifts in the level of fluctuations of the indices.

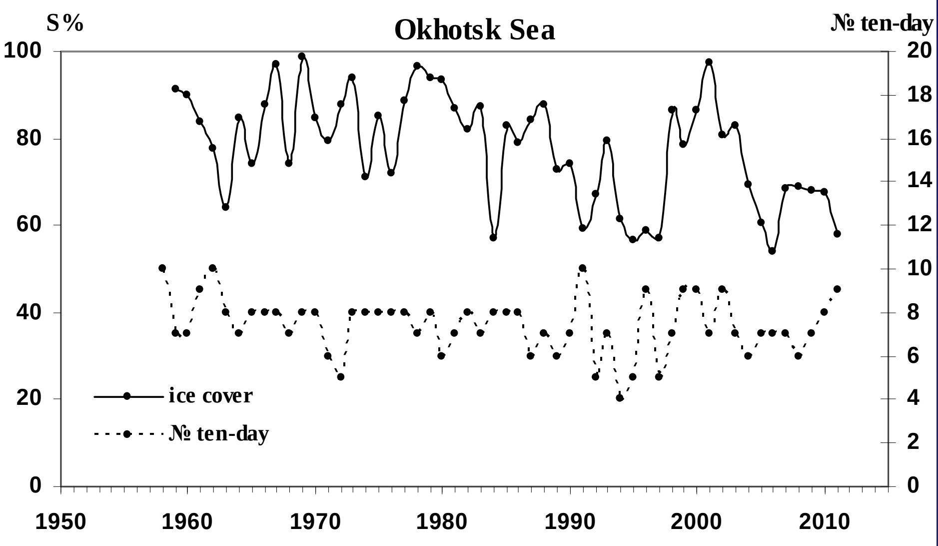


Examples for Far-Eastern Seas

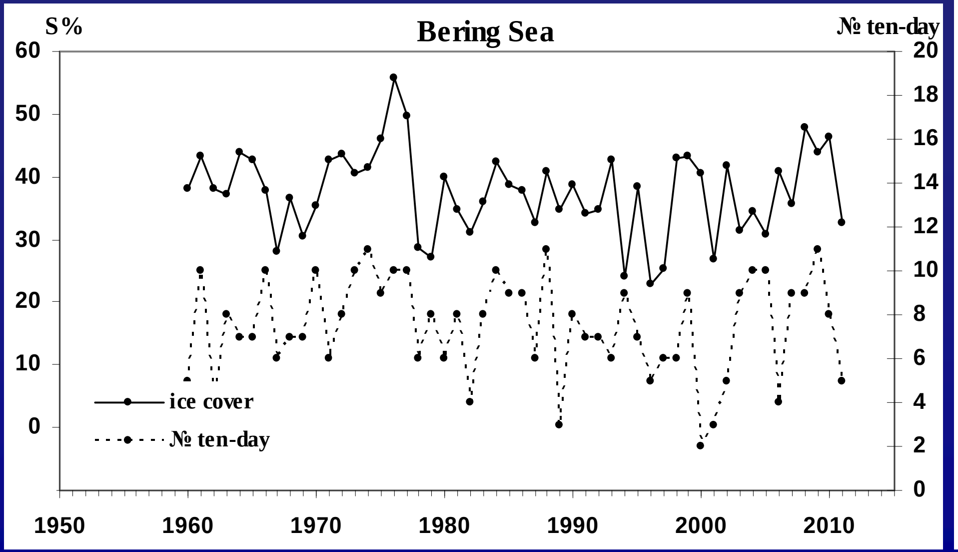


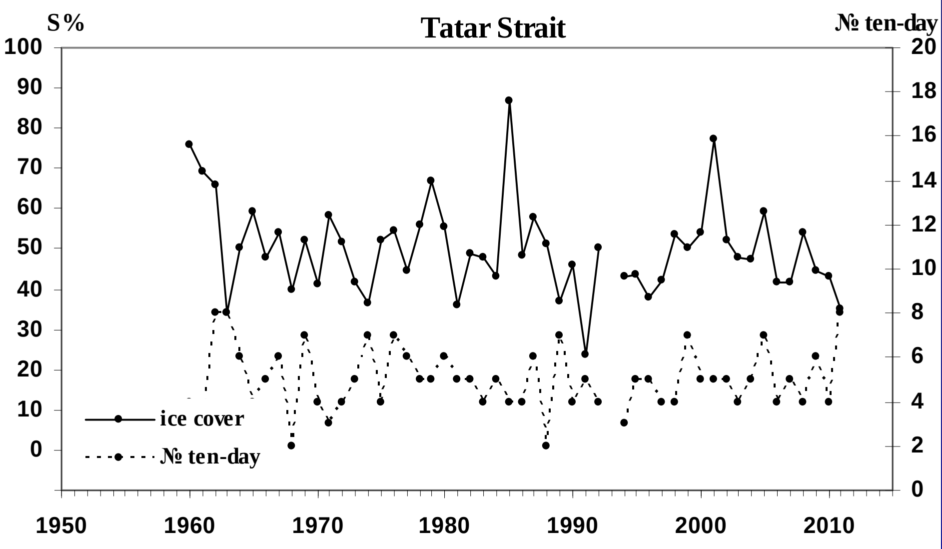
Mean winter (January – April) - A, B, C and annual maximum ice cover (in March) D (1), mean multi-year value (2), long-term contributions (3) and linear trend. “S” is % to the total area of the Sea

Examples for Far-Eastern Seas:



Annual maximum ice cover (% to the total area of the Sea) and its terms (number of ten-day from the beginning of the year)

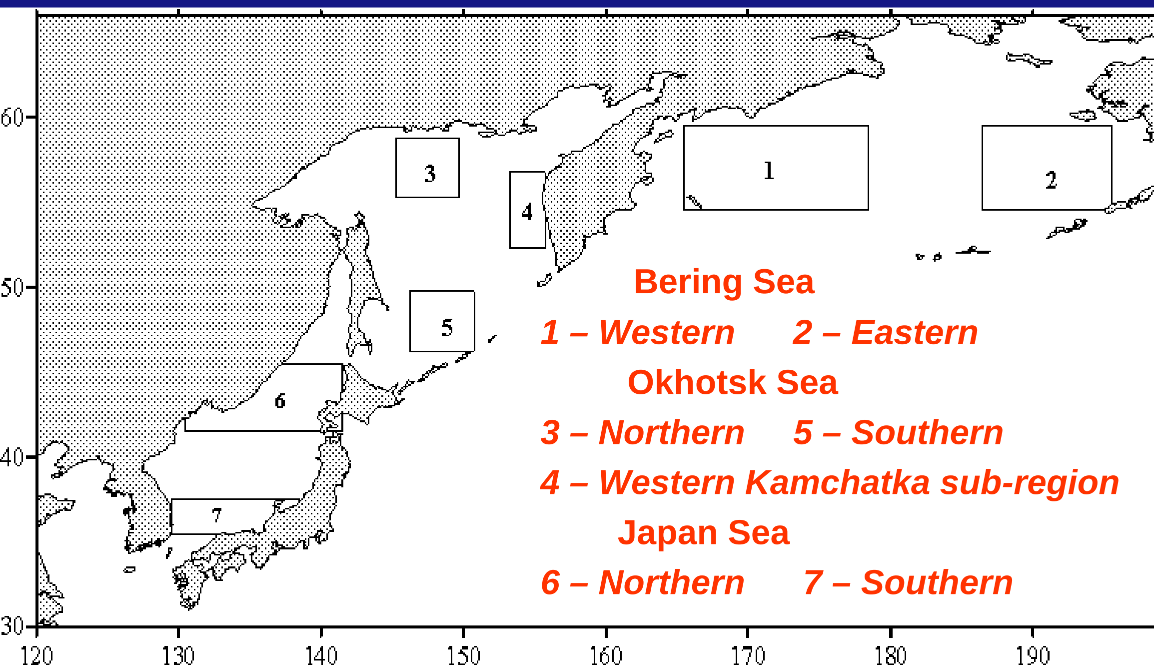


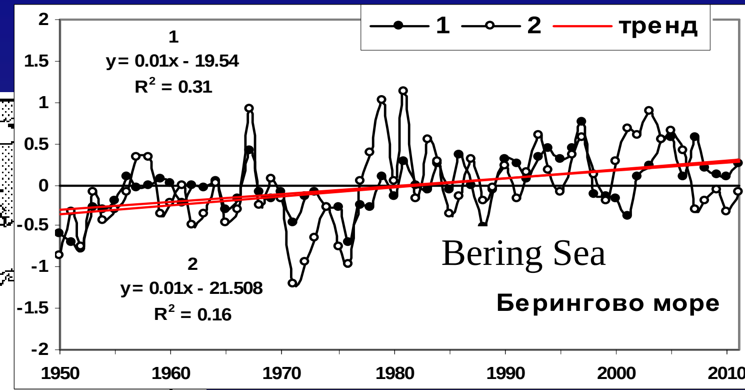


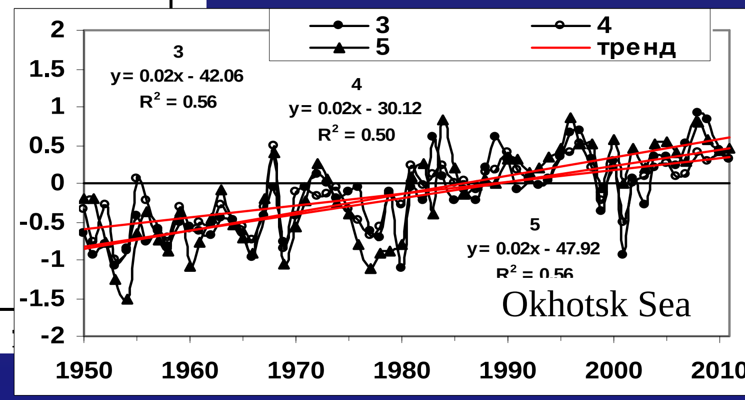
Examples for Far-Eastern Seas

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

Spring

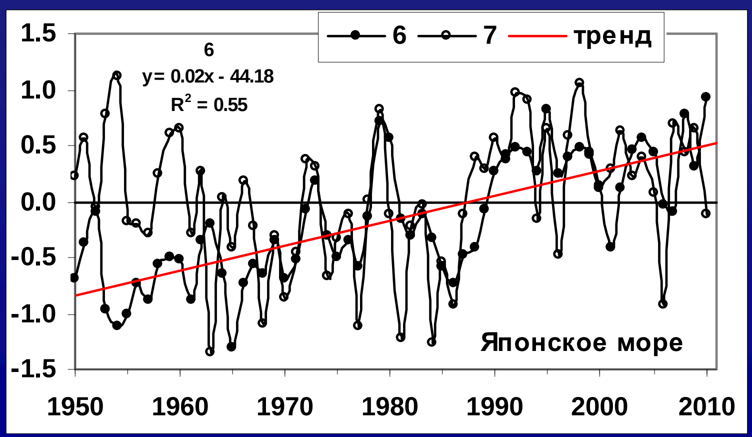


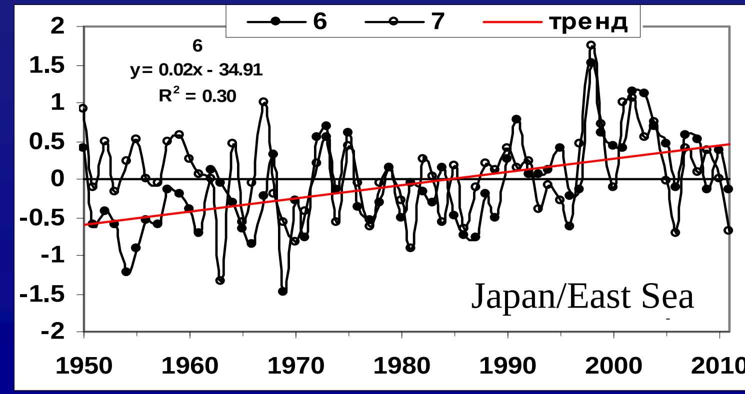




Winter

Japan/East Sea

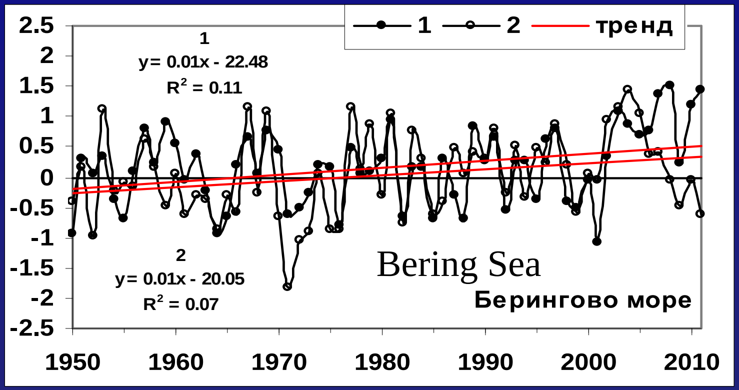


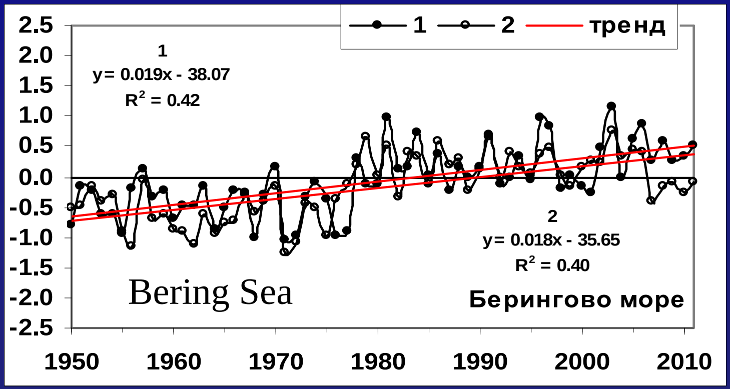


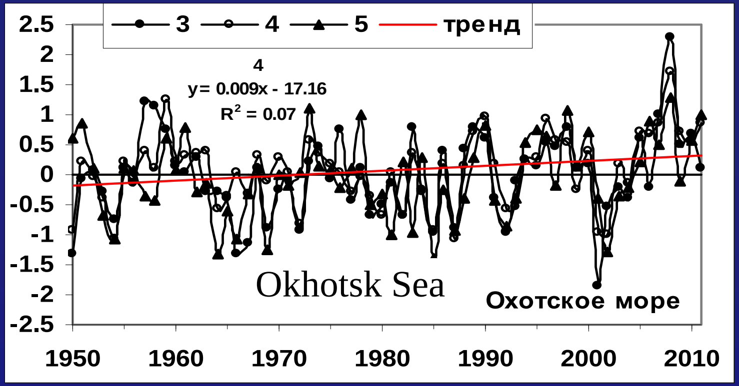
Examples for Far-Eastern Seas:

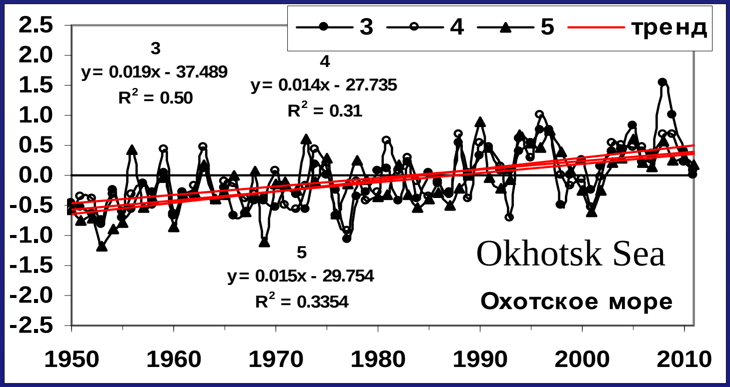
SST in the selected sub-regions of the Far-Eastern Seas (1-7)

Summer

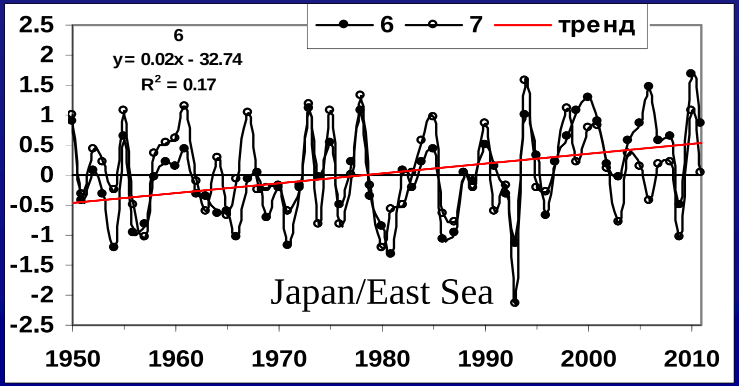


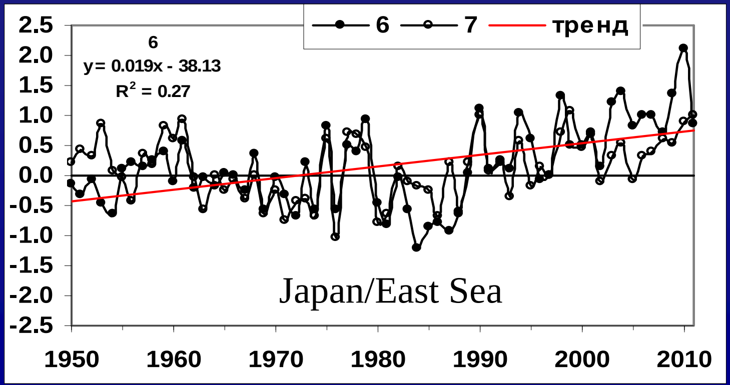






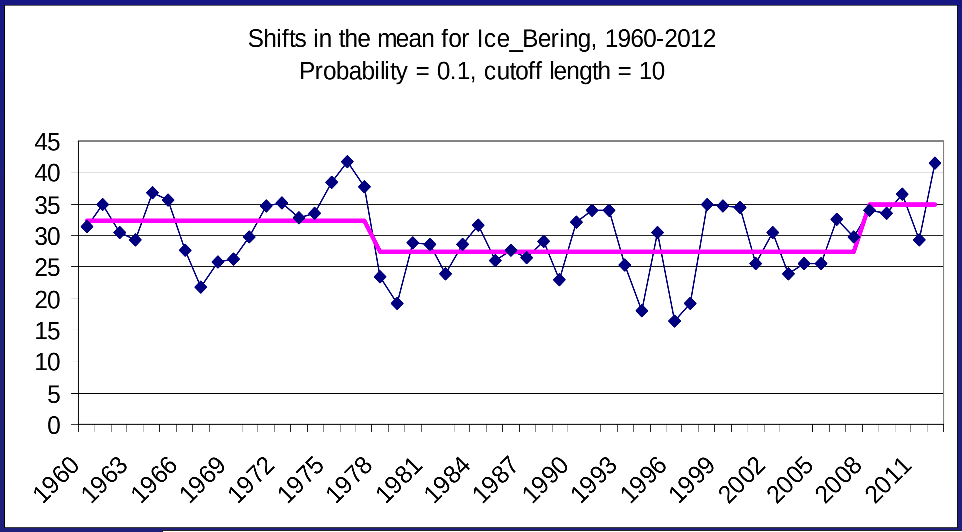
Autumn

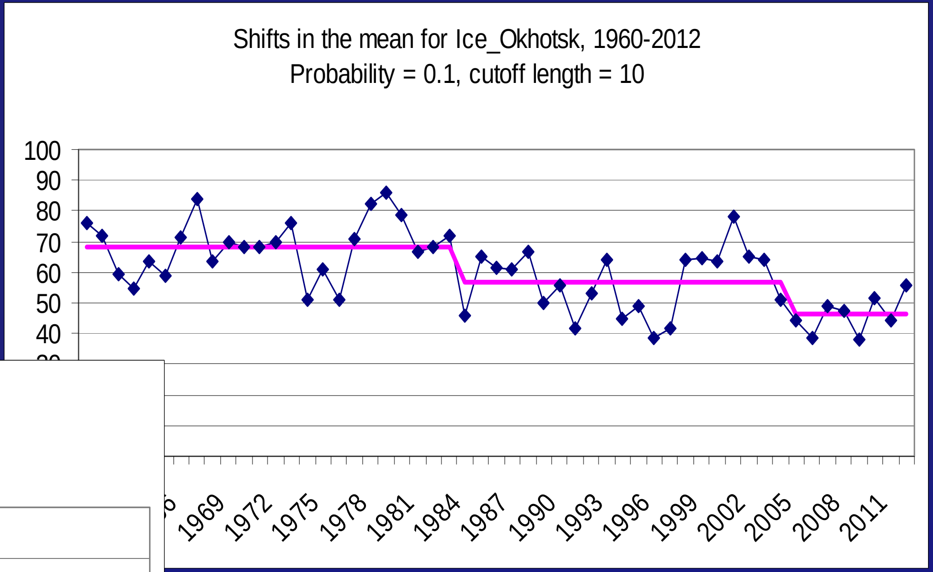


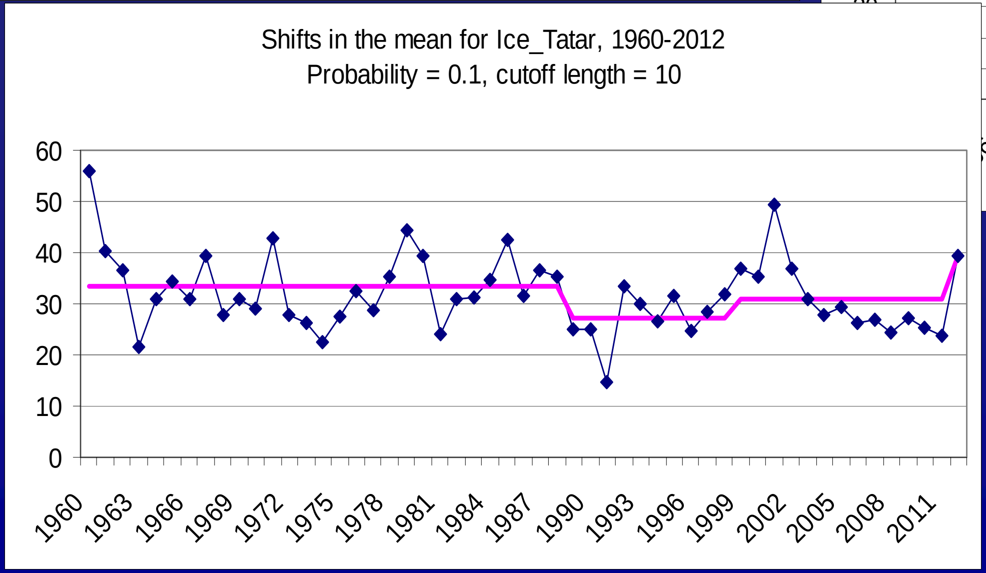


Examples for Far-Eastern Seas: shifts in ” ice variables”

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



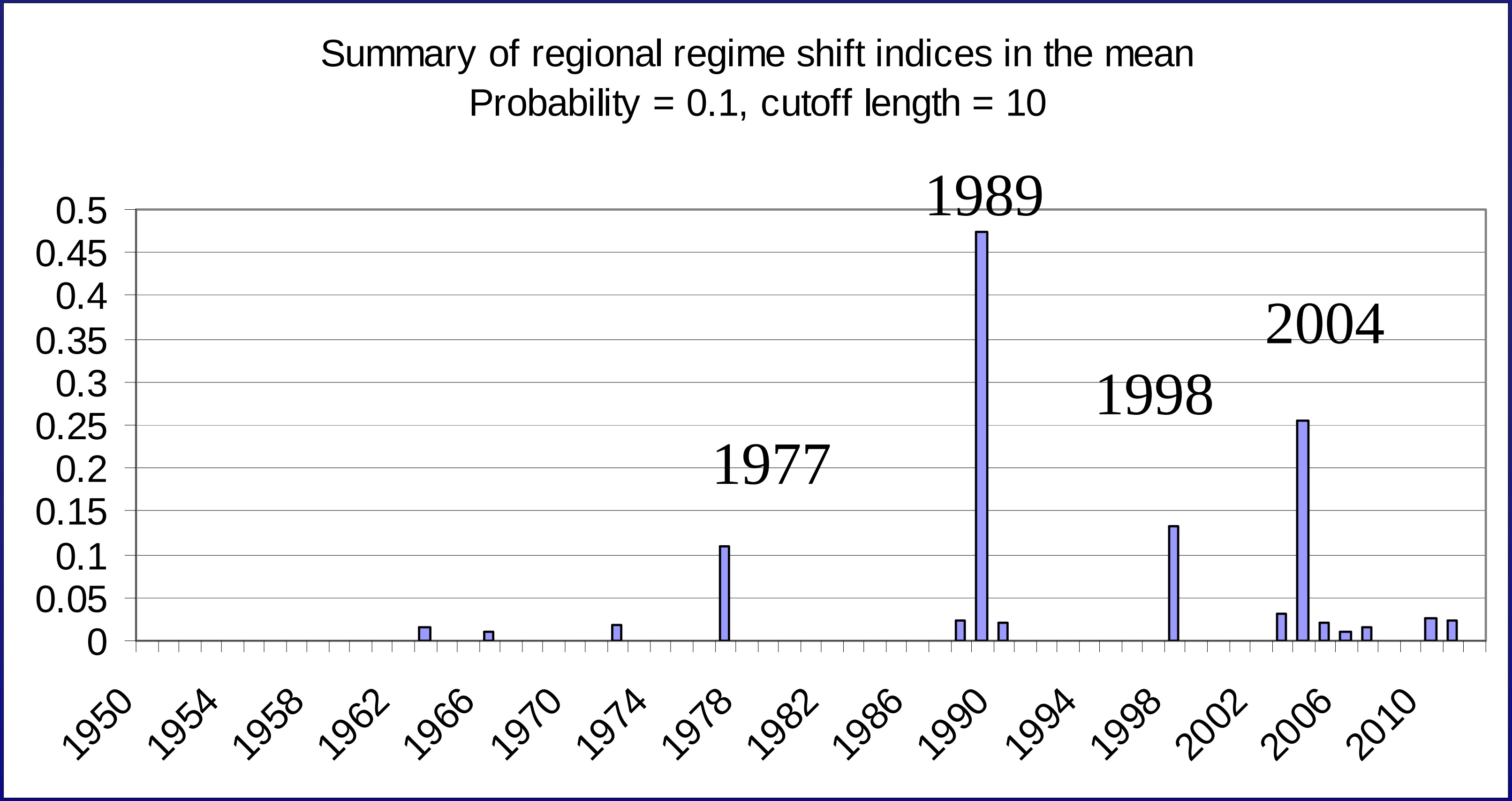




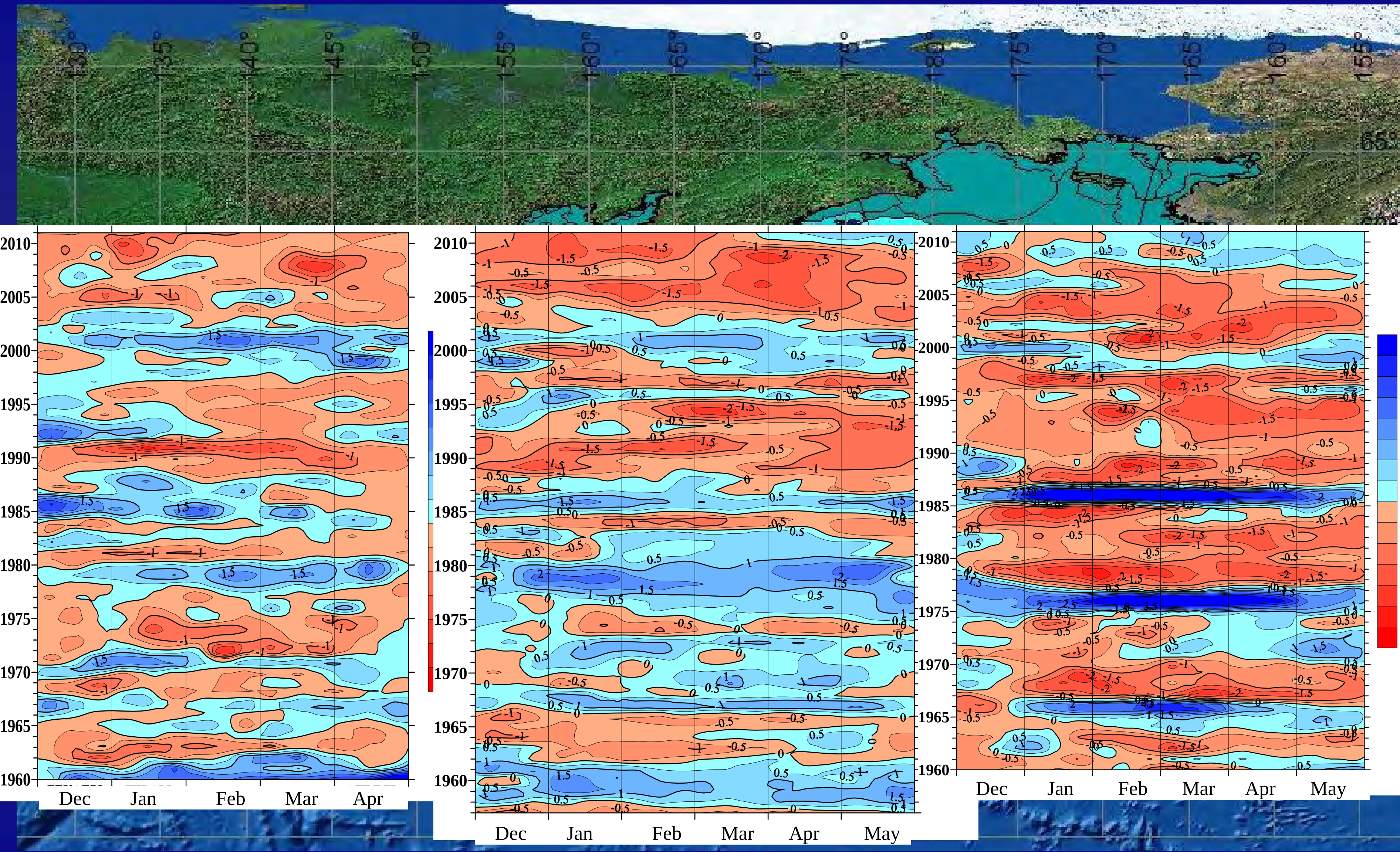
Examples for Far-Eastern Seas: shifts in climatic variables

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



Examples for Far-Eastern Seas: shifts in climatic variables

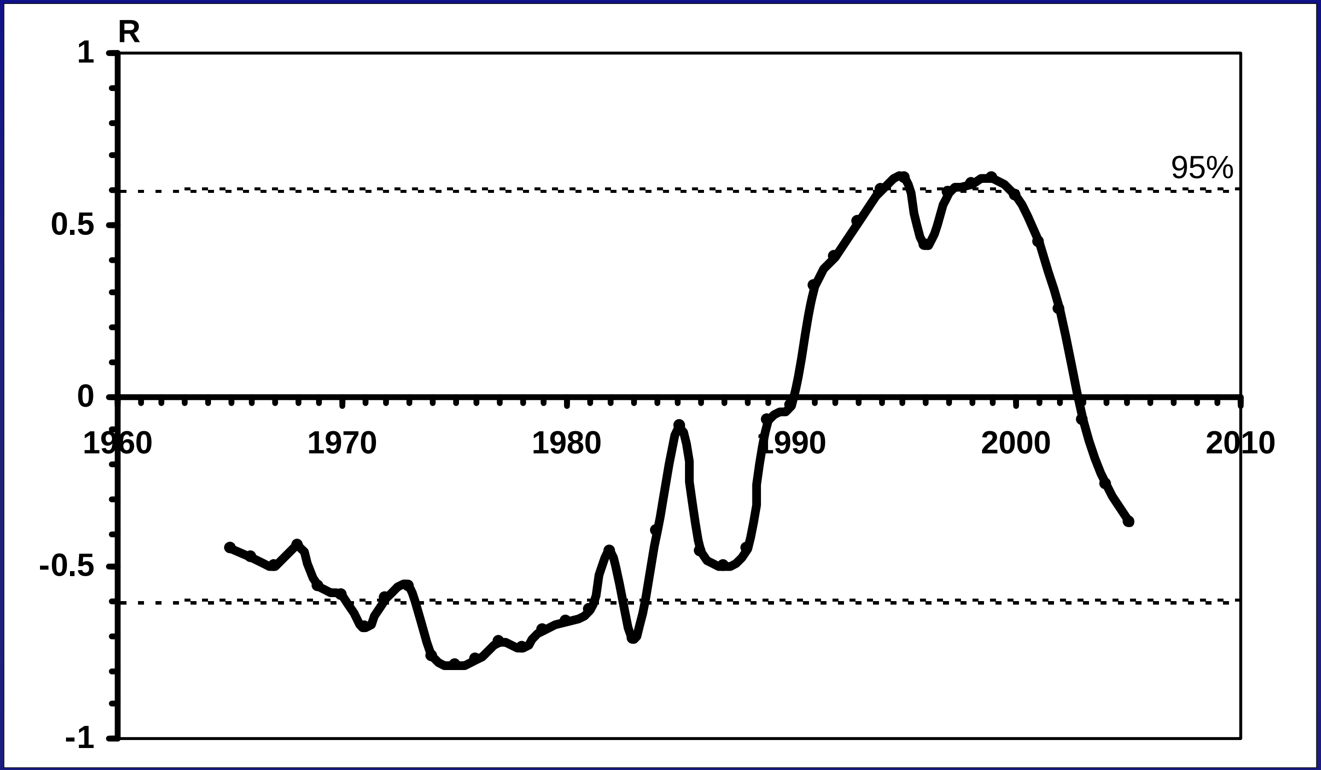


Interannual variability of ten-day ice coverage anomalies in the Far-Eastern Seas

Time series are standardized.

Examples for Far-Eastern Seas: shifts in climatic variables

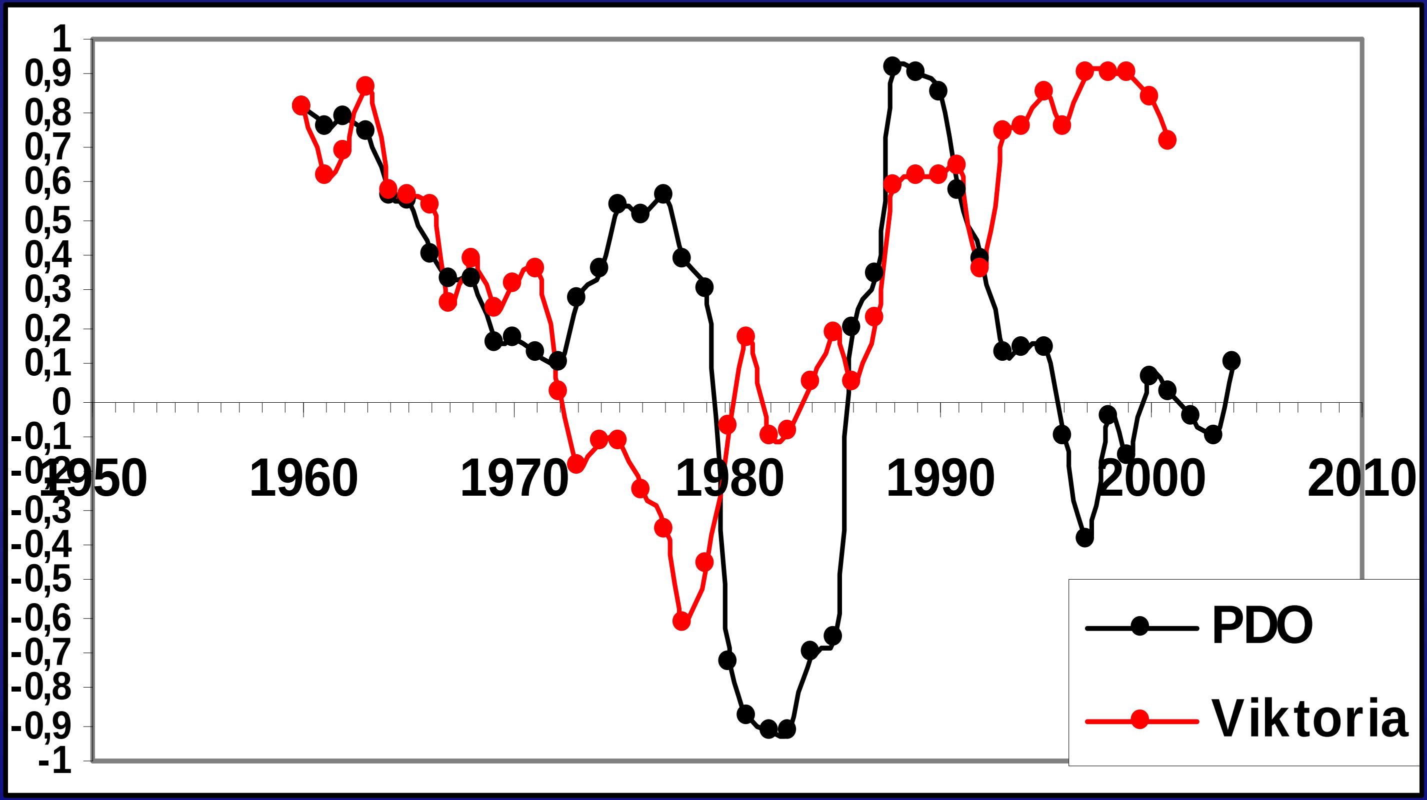
11-year "running correlation" of the mean winter ice extents in the Okhotsk and Bering Sea



The ice cover fluctuations show a remarkable feature: their phases are opposite between the Okhotsk and Bering Seas (Yakunin, 1966; Khen, 1997; Plotnikov, 1997; 2002). However, after the long period of anti-phase variability, the ice cover in these seas began to fluctuate synchronously since late 1980s. Recently, ice extent is decreasing in the Okhotsk and Japan/East Seas: the last severe winter was there in 2000-2001, and the ice extent is low during the last 8 years. Recent changes of ice cover in the Bering Sea have positive tendency, and its year-to-year variations are opposite to the Okhotsk Sea again, with a high ice cover percentage in 2009 and 2012.

Examples for Far-Eastern Seas: shifts in the relationships

11-year "running correlation" mean winter ice cover in the Okhotsk Sea with Victoria Index (winter) и PDO

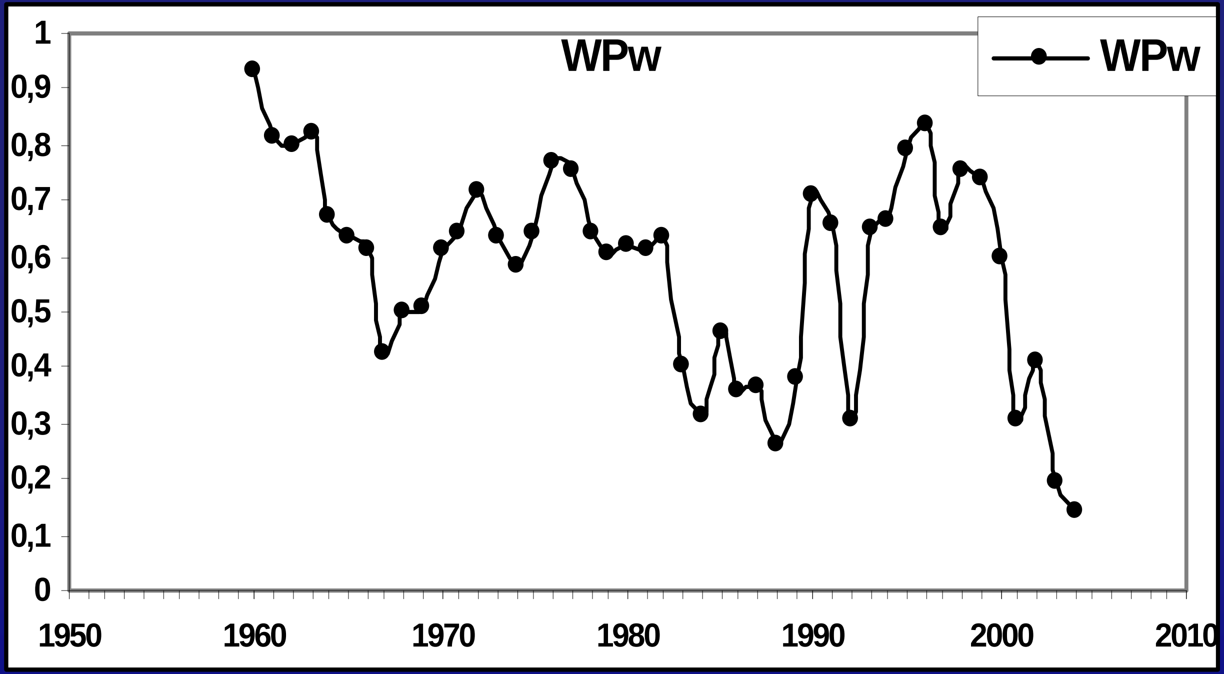


For the period 1976-1987, the correlation between mean winter ice cover and Victoria pattern was insignificant.

Examples for Far-Eastern Seas

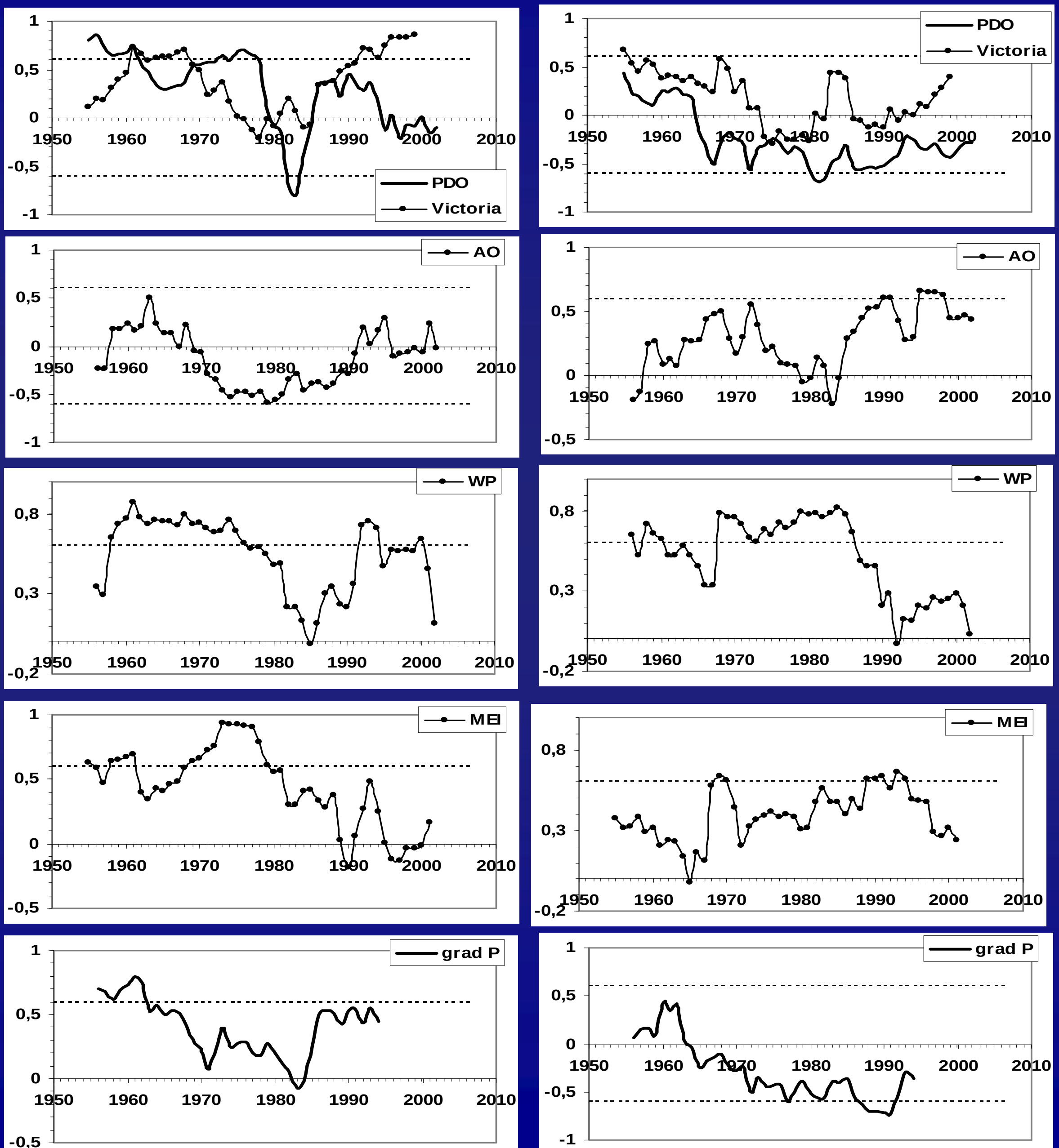
11-year "running correlation" mean winter ice cover in the Okhotsk Sea with WPw

Among the climatic indices winter West Pacific Index has the steadiest connections with the regional thermal characteristics, since it reflect a state of the Far-Eastern upper-level trough in atmosphere. The "geometry" and intensity of the trough determines regional thermal conditions in many respects.



However, in the beginning of 1980s and since 2006 correlation between winter WP and ice cover in the Okhotsk Sea sharply decreases. In the Sea "sub-regional" regime shift occurred at the beginning of the 1980s.

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

SUMMARY

We have summarized our studies of the sharp transitions in the Far-Eastern Seas (“regime shifts”) analyzing the time series of environmental parameters: the regional climatic characteristics and large-scale climatic oscillations and patterns (Siberian High Index (SHI), West Pacific (WP) Index, Pacific Decadal Oscillation (PDO), Victoria patter and Arctic Oscillation (AO) indices, SOI, etc).

Well-known large-scale climate regime shifts (1976/77 for northern and 1988/89 for southern areas of the seas) and regional and “sub-regional” regime shifts (e.g., 1984 in the Okhotsk Sea) have been found.

There are tipping points in the relationships between regional climatic parameters and large-scale climatic patterns. Pronounced reorganizations of the relationships with accompanied inverse (for example, between ice cover in the Okhotsk Sea and AO/PDO, winter SST in the Japan/East Sea and AO) correspond to the 1976/77 and 1988/89 regime shifts most often. After the climate shift in 1976/77 the correlation between SOI and ice cover in the Okhotsk Sea tended to decrease. Correlation between winter WP and ice cover in the Okhotsk Sea decreases sharply in the early 1980s (“sub-regional” regime shift) and started to decrease again in 2006.

SUMMARY

In a number of cases spatial boundary between distinct types of the relationship in large-scale climatic indices and regional thermal characteristics is the Polar front in the Japan/East Sea.

Thus, there are two appearances of "tipping-points": large-scale and regional regime shifts in the climatic variables and significant changes in the relationships between regional climatic parameters and large-scale climatic patterns for the Far-Eastern Seas.

The quasi-steady state of the climatic system (from one regime shift to other) can be broken locally in the Far-Eastern Seas because of moving climatic atmospheric and oceanic fronts, trajectories of cyclones, change of blocking processes and other boundary phenomena.