Multiple scale climate variability in the North Pacific and features of recent climatic regime

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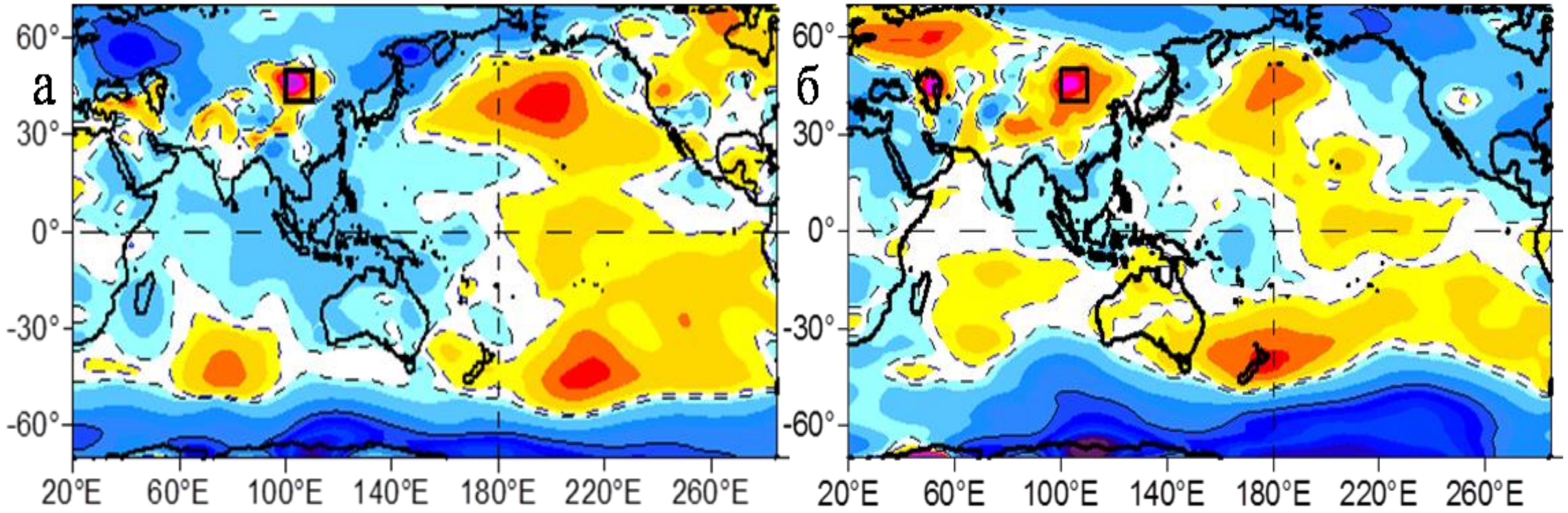


The main goals are

- to reveal climate regime change in the in the Asian Pacific region and Indian Ocean based on the observation data analyses,

- to find its relation to the climate anomalies in Mongolia and Baikal Lake water basin.

Methods

To analyze observation data we apply different statistical methods including cluster analysis Fuzzy C-means method via PCA.

Observation data
monthly/daily mean time series of the:

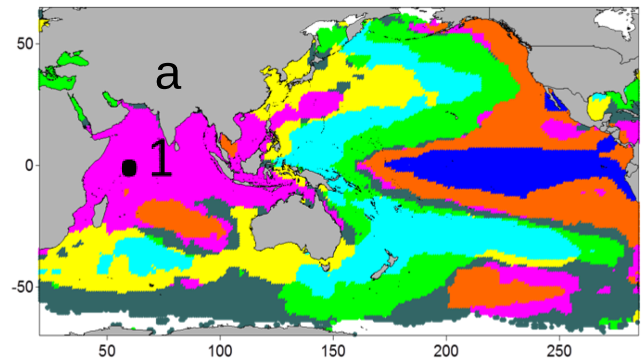
1. Hadley (GB) Sea Surface Temperature (SST) from 1870 to 2015,

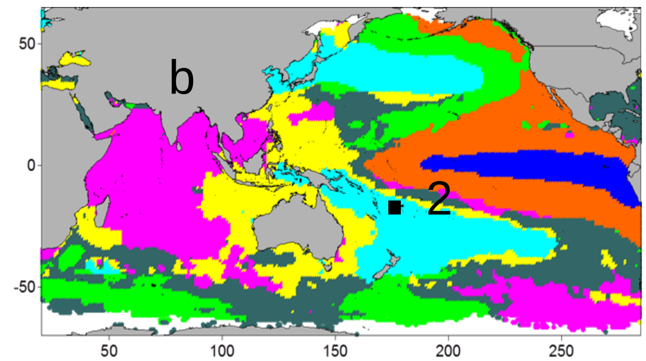
2. NCER NCAR meteorological reanalyses (1948-2015) pressure atmospheric pressure (SLP), air temperature (SAT), surface net heat flux,

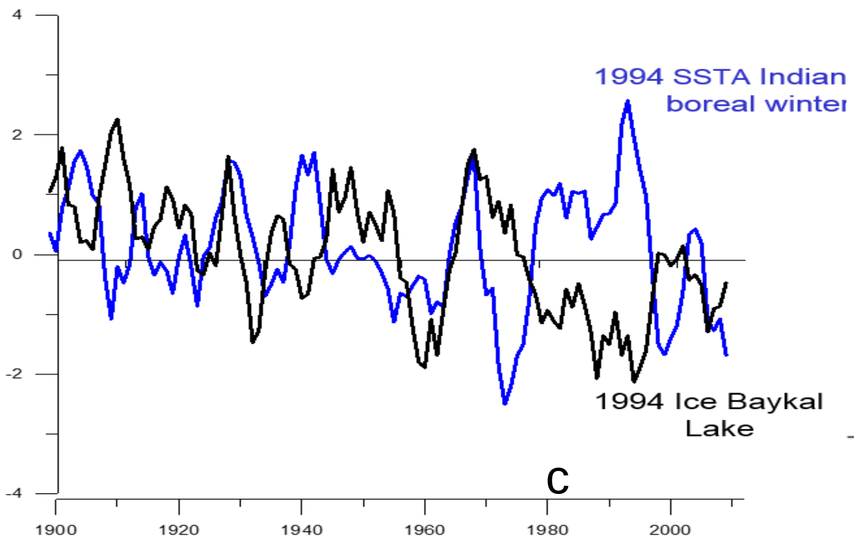
3. Baykal Lake Ice Thickness (1946-2013) and duration of the seasonal Ice Cover (in days) from 1900 to 2012 in the Baikal Lake.

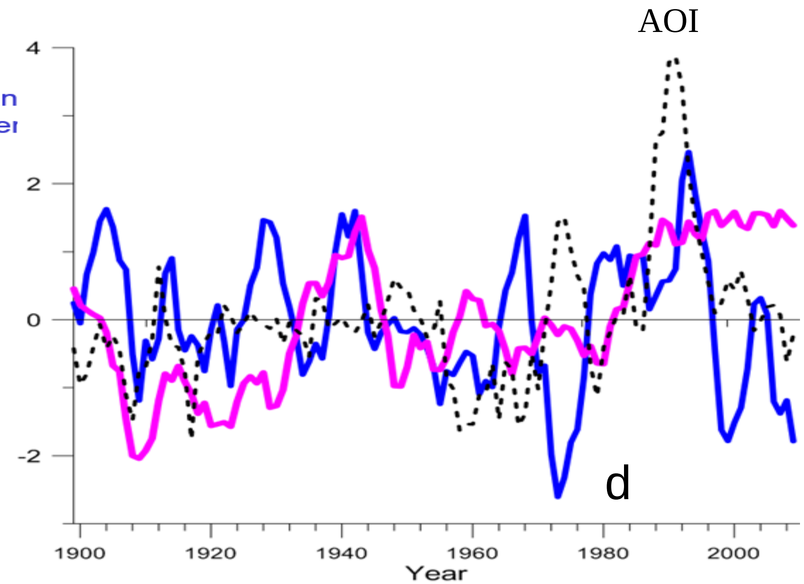
7 clusters of SST Anomalies in the Pacific, Indian and Southern Oceans averaged for hydrological boreal winter (a) - Jan-Mar and boreal summer (b) - Jul-Sep, as well as time series (1870 – 2014) of the 5-years running mean SSTA (c) in characteristic (central) points of two selected clusters:

boreal winter, **boreal summer**









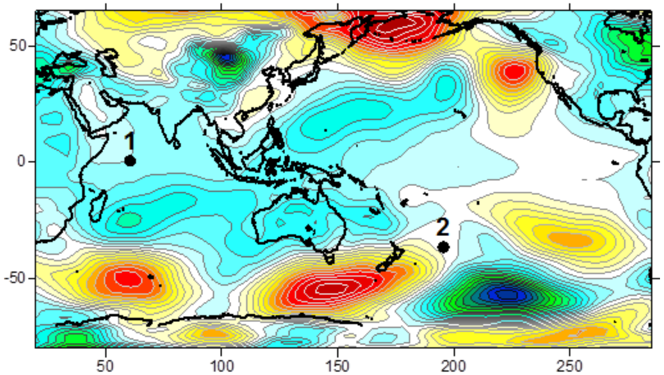
Time series of normalized anomalies of 3-years running mean: (c) - seasonal ice duration (days) in the Baykal Lake (black); (d) - SST in Indian Ocean central point of cluster (point 1 in the equatorial zone) in boreal winter (Jan-March) (c); in boreal winter, boreal summer (Jul-Sep) and annual Arctic Oscillation Indices (AOI, dashed curve).

Positive SST anomalies in Indian Ocean accompany winter warming in the Baykal Lake area. Maximal decadal warm anomaly was in mid 90s when the annual AOI was also maximal.

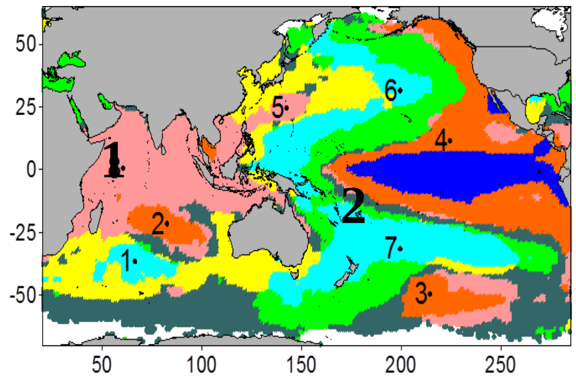
Sea Level Pressure (SLP) anomalies in the inversed phases of bidecadal oscillation, in 1971 and 1994 for boreal winter and summer

boreal winter,

1971

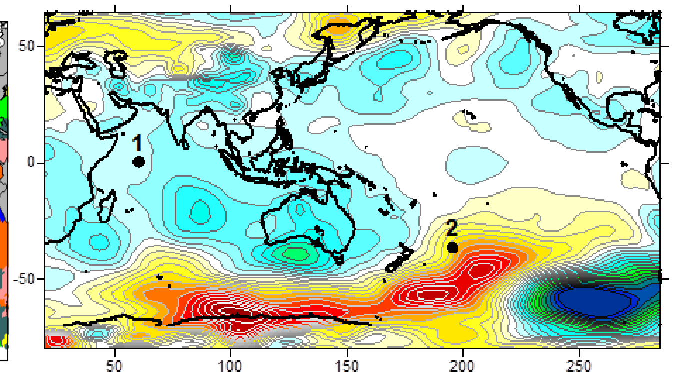


SSTA clusters

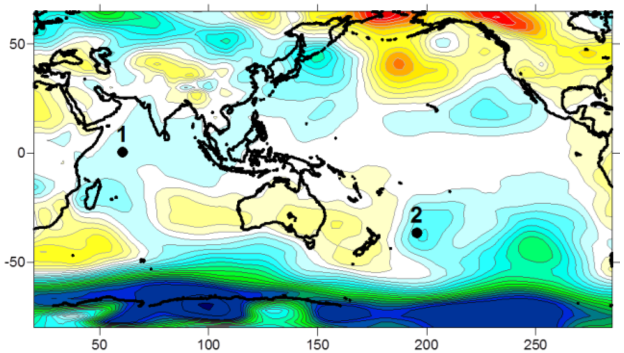


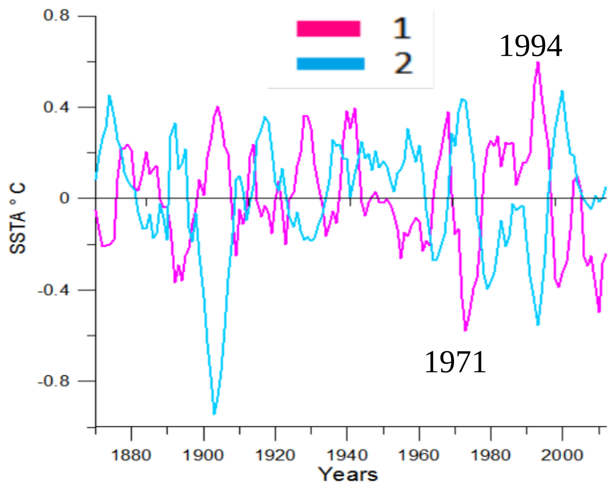
boreal summer

1971

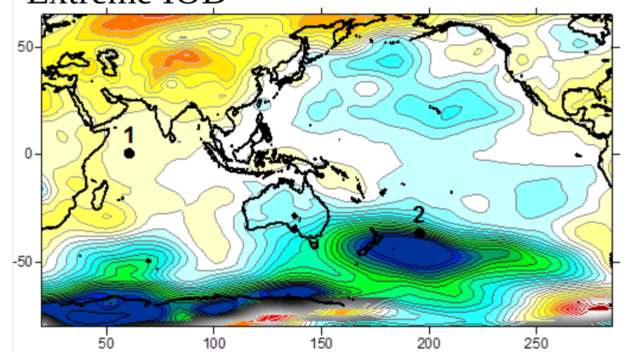


1994 Extreme IOD





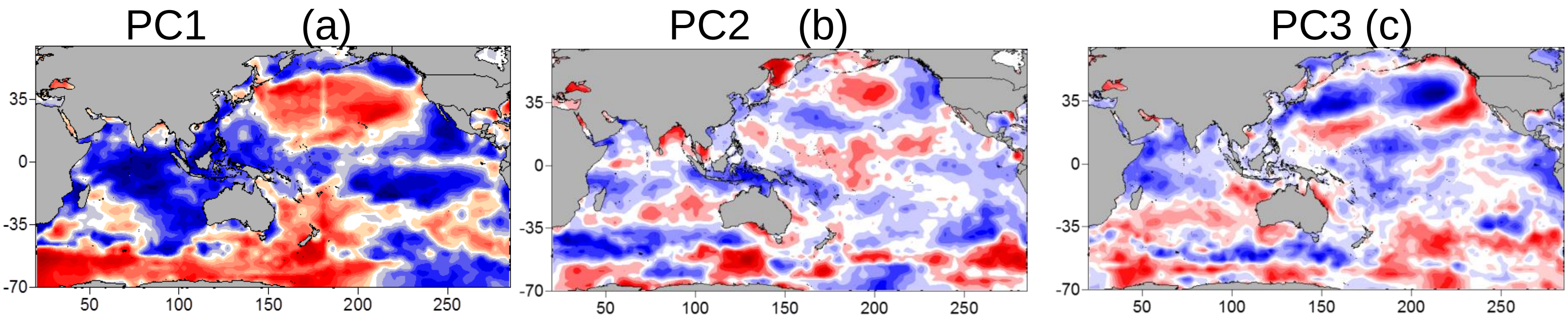
Extreme IOD 1994

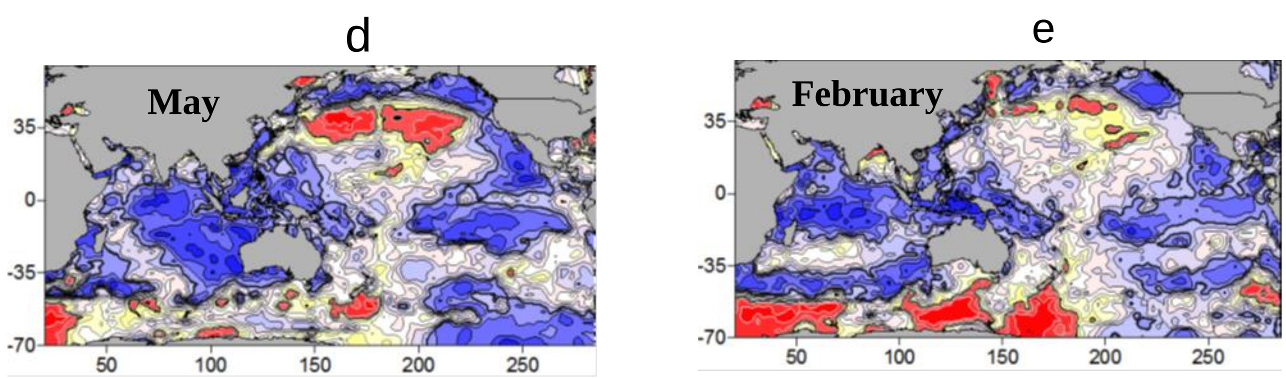


Time series of the 3 years running mean SST anomalies (SSTA) in the equatorial Indian Ocean (1) and in moderate latitudes of the South Pacific (2), central point of blue cluster (7) being in an inversed phase.

Both decadal and extreme warming in the Indian Ocean is accompanied by prevailing negative anomalies of SLP in South Pacific of moderate latitudes and in the South Ocean. It is associated with positive SLP anomalies in Australia, central extratropic North Pacific, south Siberia, Eastern Arctic region in boreal winter, and increased SLP in whole Asia with maximum in Mongolia and Baikal Lake region in boreal summer.

PC1, PC2, PC3 of SSTA EOF decomposition in area of the Pacific, Indian and Southern Oceans (a-c)





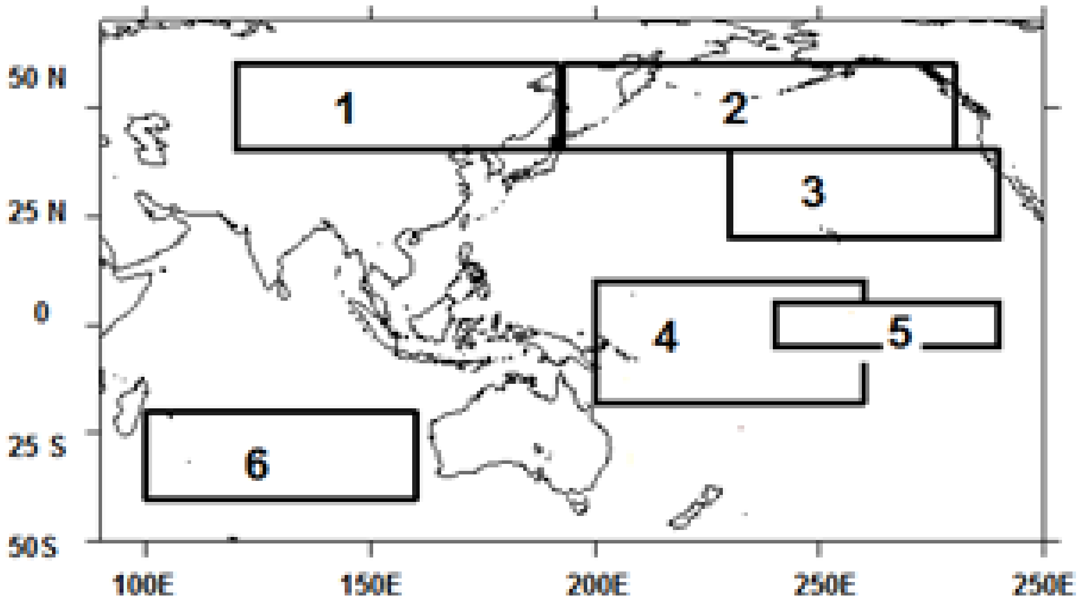
Correlation patterns between SSTA in Boreal Winter and Seasonal Ice Duration in Baykal Lake in May(d) and February (e).

The inversed patterns in PC1 of the SSTA (in centers of clusters) are similar to inversed correlation patterns between SSTA and Seasonal Ice Duration in the Baykal Lake. The similarity is clear seen in Indian, Pacific and Southern Oceans.

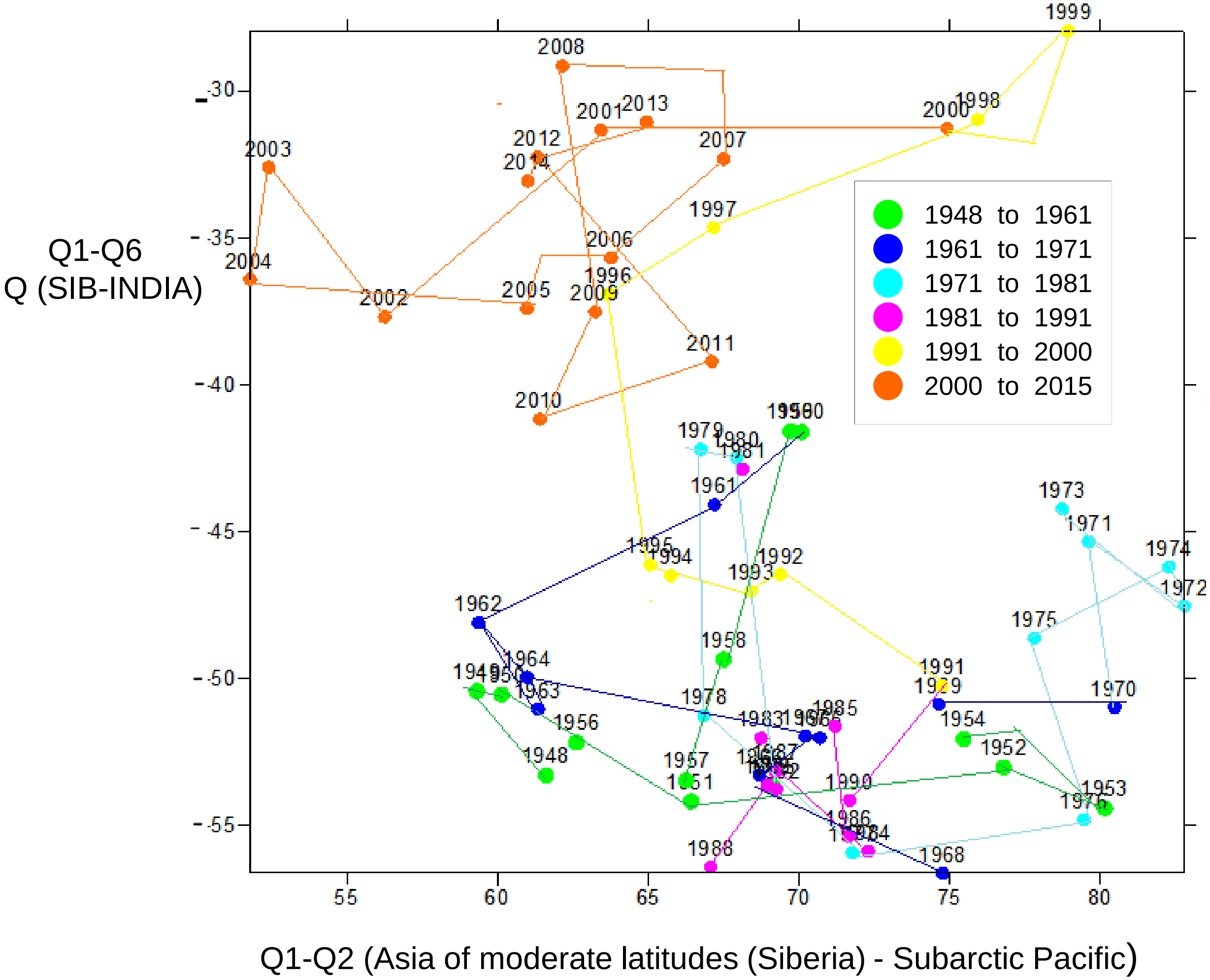
Areas of the Asian Pacific and Indian Ocean selected by using correlation analyses and EOF decomposition.

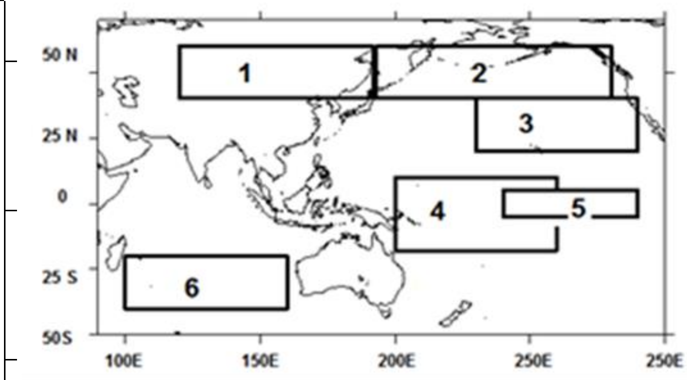
1 – Asia of moderate latitudes, 2 – North Pacific of moderate latitudes, 3 – Eastern subtropical zone, 4 –Western equatorial zone, 5 – NINO 3-4, 6 – southern zone of Indian Ocean.

Differences in both net heat flux (Q) and SLP is calculated between its values averaged in selected areas for both boreal winter and summer.



Phase trajectories in a plane Q1- Q6 (Y axes), Q1- Q2 (X axes), W/m2 in boreal winter from 1948 to 2015.

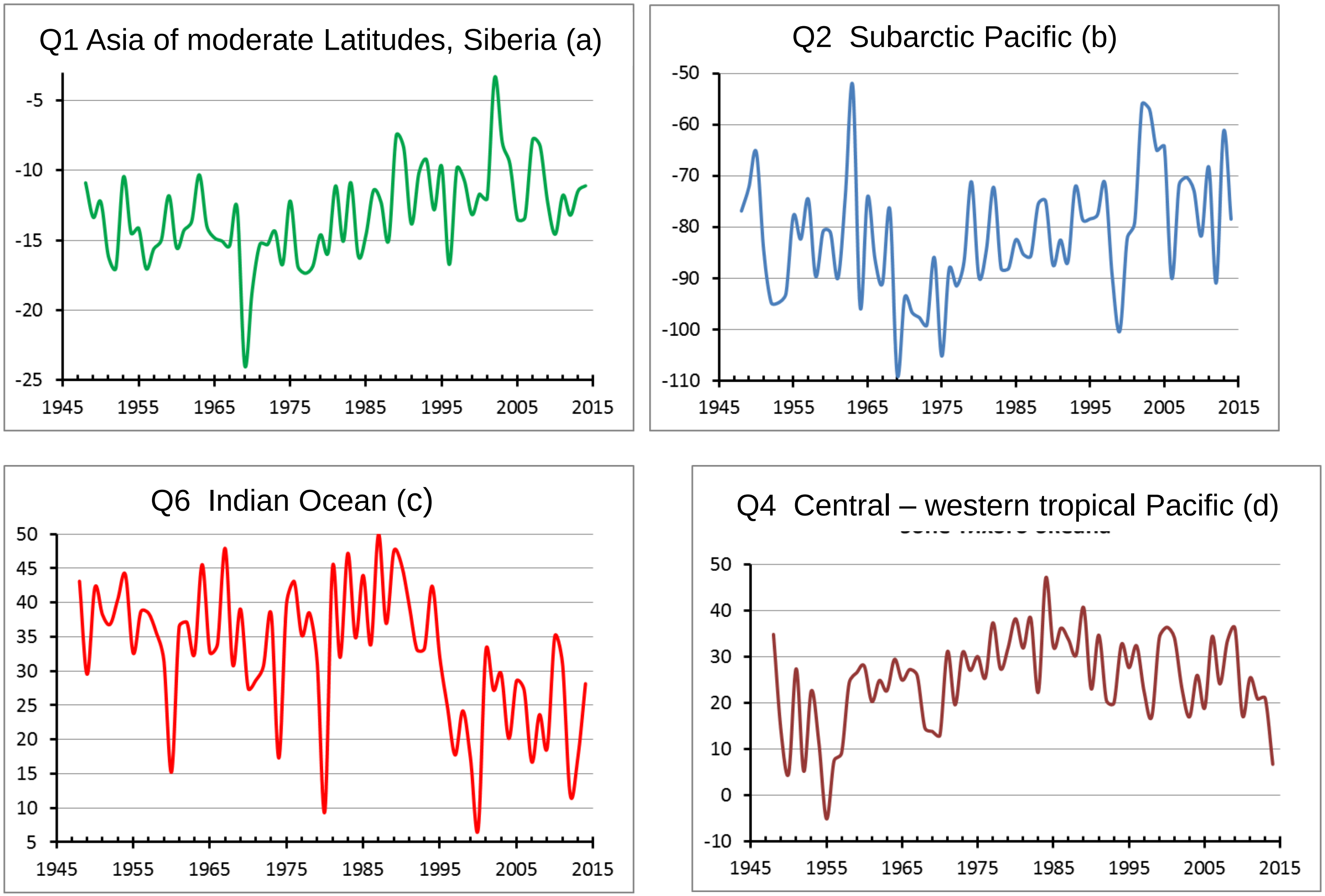




Absolute values of the net heat flux (Q) differences between Q1 in Asia of moderate latitudes (Siberia, Mongolia) and Q2 in Subarctic Pacific (X axes), between Q1 and O6 in Indian Ocean (Y axes) decrease after late 90s of the 20th century.

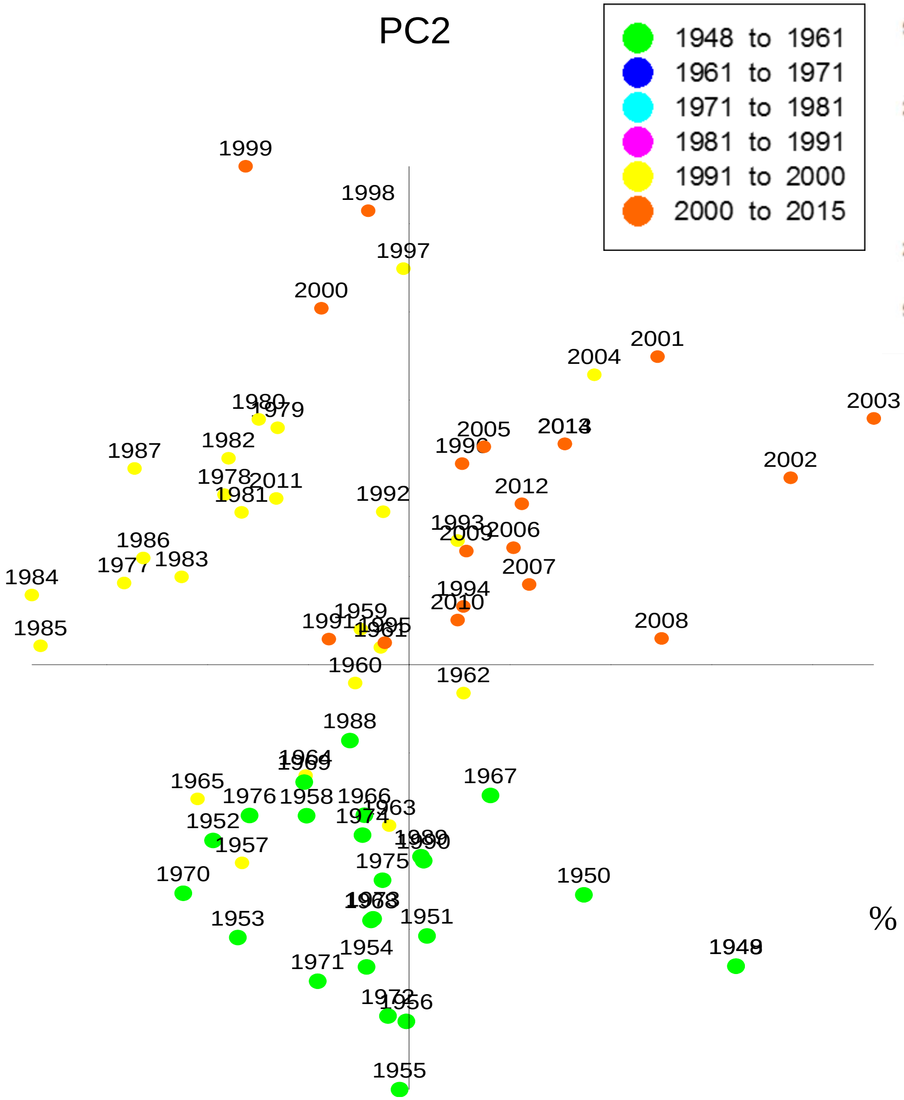
The winter climate regime in terms of Q differences is changed both after mid 70s and after late 90s of the 20th century in the Asian Pacific and Indian Ocean.

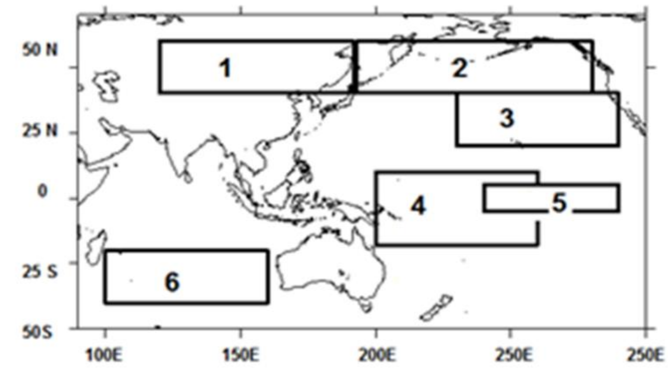
Time series of the Net Heat Flux (Q, W/m2) in Siberia (a), Subarctic Pacific (b), Indian Ocean (c), and western and central equatorial- south tropical Pacific (d) in boreal winter from1948 to 2015.

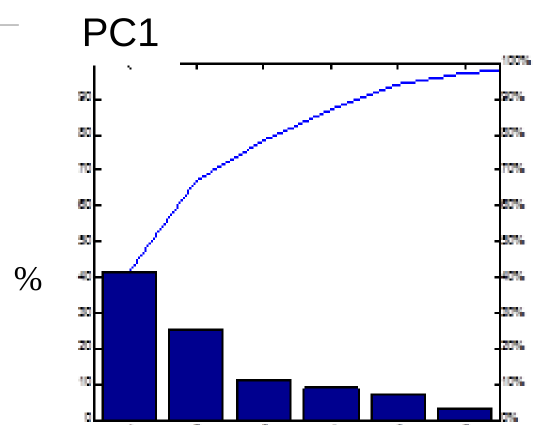


The absolute values of the Net Heat Flux decrease in all of the areas shown after late 90s.

Classification of 18 unsmoothed monthly mean time series (1948-2015) of differences in both net heat flux (Q) and SLP between its values in selected key areas (a) in boreal winter.





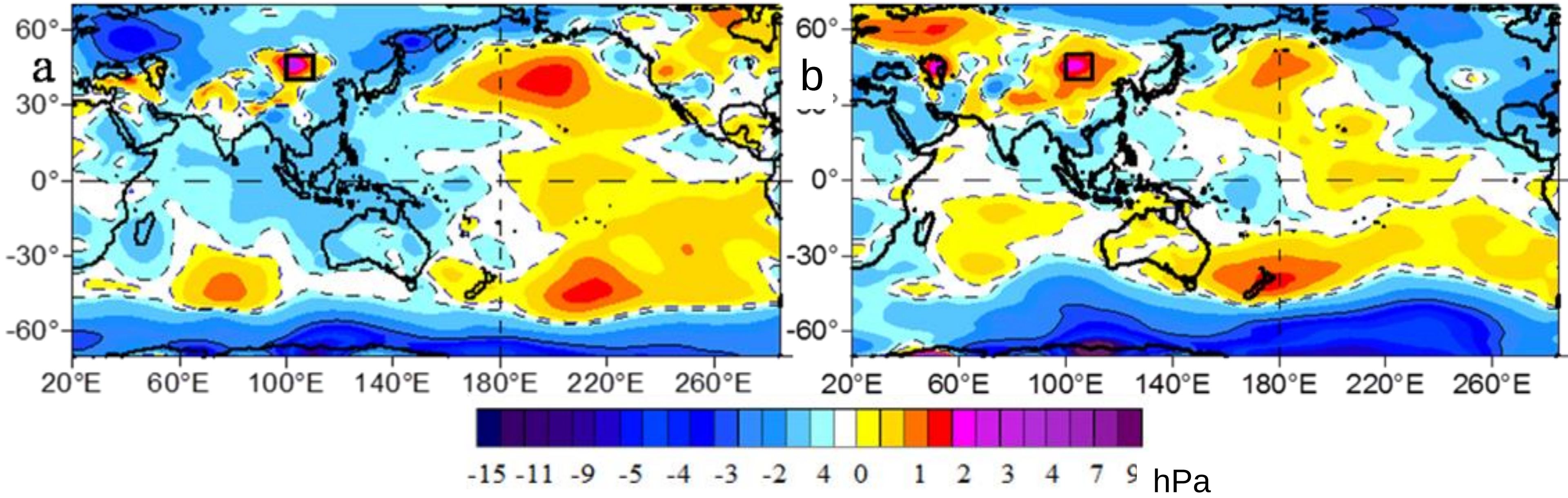


18 differences

Q1-Q2	Q(Sib-SBT)
Q1-Q3	Q(Sib-Nino3)
Q1-Q4	Q(Sib-HAWAII)
Q1-Q5	Q(Sib-INDIAN)
Q1-Q6	Q(Sib-MODOKI)
Q2-Q3	Q(SBT-NINO3)
Q2-Q4	Q(SBT-HAW)
Q2-Q5	Q(SBT-Indian)
Q2-Q6	Q(SBT-MODOKII)
SLP1-SLP2	SLP(Sib-SBT)
SLP1-SLP3	SLP(Sib-Nino3)
SLP1-SLP4	SLP(Sib-HAWAII)
SLP1-SLP5	SLP(Sib-INDIAN)
SLP1-SLP6	SLP(Sib-MODOKI)
SLP2-SLP3	SLP(SBT-NINO3)
SLP2-SLP4	SLP(SBT-HAW)
SLP2-SLP5	SLP(SBT-Indian)
SLP2-SLP6	SLP(SBT-MODOKII)

Using PC method we also found change of climatic regimes both after late 70s and after late 90s in terms of differences Q and SLP between its values in the regions of moderate latitudes of the Asia Pacific (1,2) and subtropical (3,6), equatorial - tropical regions (4,5)

Differences of SLP (hPa) between averaged in recent climate regime 1996 – 2014 and previous one 1971-1991 in boreal winter (a) and boreal summer (b)



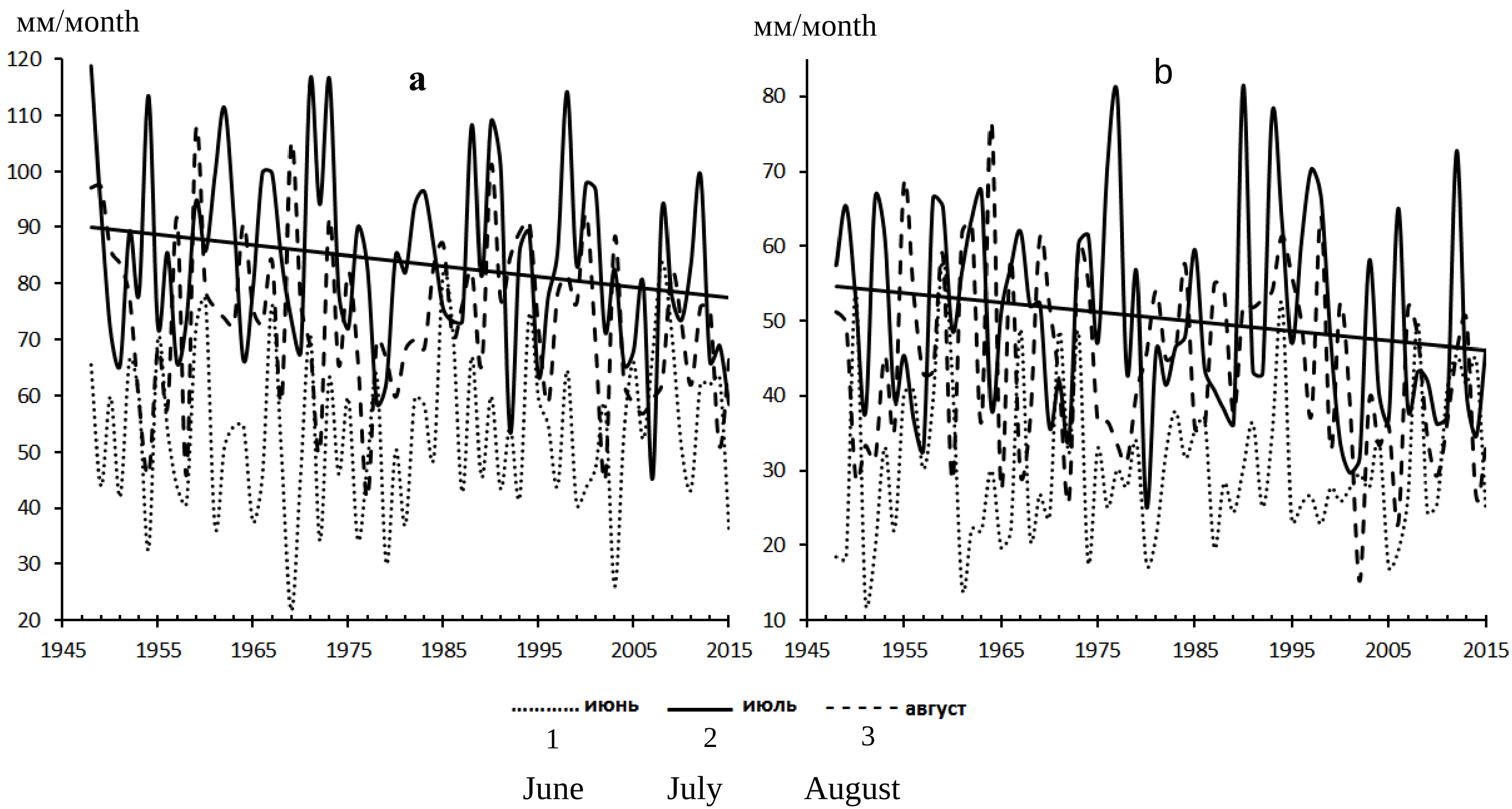
After late 90s of the 20 century SLP decrease both in winter and summer in Southern Ocean with maximum in winter, in Indonesia, all of the western North Pacific marginal zone and Arctic regions.

The SLP increase in winter and summer in central subarctic and subtropical North Pacific, central, western tropical Pacific, subtropical region of the South Pacific and Indian Ocean.

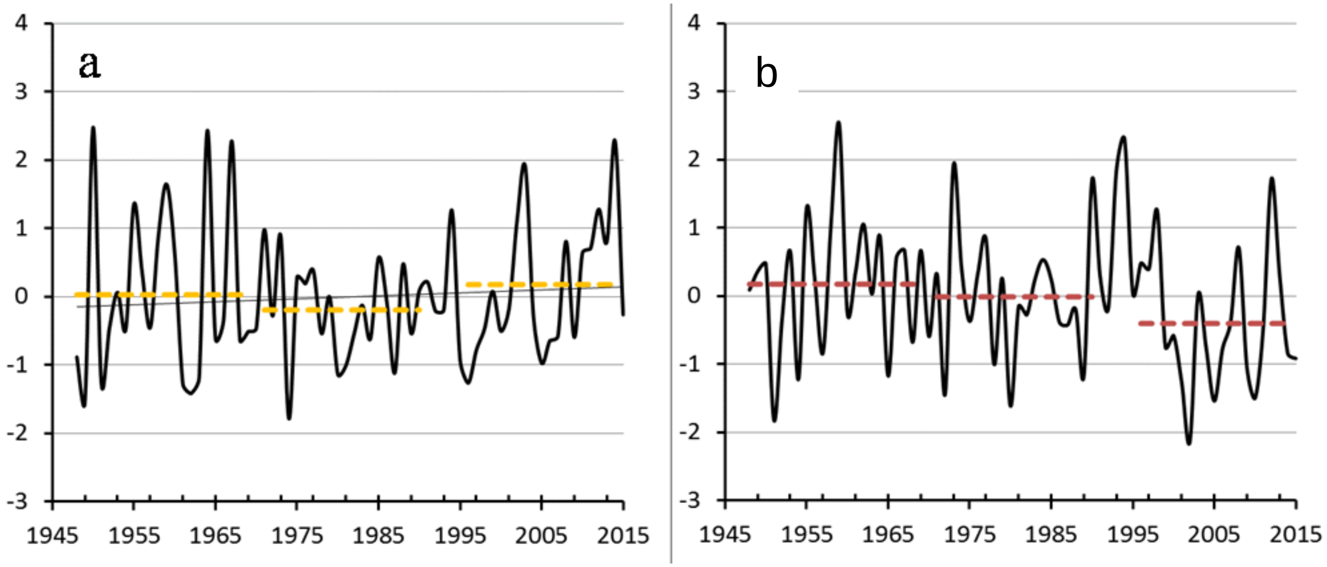
The anomalies in the ocean accompany the SPL increase in Mongolia and Baikal Lake region in both winter and summer.

In summer the SLP increases in Europe and most of the East Asia with maximal anomaly in Mongolia and Baikal Lake water basin. It corresponds to summer warming and decrease of precipitation in this area in recent climate regime.

Decrease of precipitation (мм/мonth) in the Baikal Lake water basin in June, July and August during last 18 years and high anomaly in 2015 is like a signal of the climate regime change in late 90s



Normalized anomalies of precipitation in spring (a) and summer (b) in Mongolia which includes southern Selenga River basin.



Summer precipitation in Mongolia becomes decreases during last 18 years and high anomaly in Mongolia including Mongolian basin of Selenga River (50% water run off to the Baikal Lake).

The negative anomaly of precipitation in Mongolia and Baikal Lake Basins, as well as extremely low Selenga River discharge is observed in summer 2015.

The extremely low total water inflow to the Baikal Lake in summer 2015 is also effected by anthropogenic forcing related to the increased human activity in Selenga river and Baikal basins.

Conclusion

- The decadal and interdecadal climate oscillations in the Indo-Pacific Ocean are closely related to SLP, SST, SAT anomalies in both moderate latitudes of Asia (South Siberia, Baikal Lake region) and moderate latitudes of Southern Hemisphere and Southern Ocean.

- After climate regime shift in late 70s the decadal anomaly in both Indian and Arctic Oceans accompany winter warming in South Siberia (Baykal Lake).

- The climate regime is also changed in the Asian Pacific region and Indian Ocean in late 90s in terms of horizontal gradients of the net heat flux and SLP.

- The recent climate regime after late 90s is characterized by the:

- SLP decrease in both winter and summer in Southern Ocean (with maximum in winter), in Indonesia, all of the western North Pacific marginal zone and Arctic regions;
- SLP increase in both winter and summer in central subarctic and subtropical North Pacific, central, western tropical Pacific, subtropical region of the South Pacific and Indian Ocean.

- The anomalies in the ocean accompany the SPL increase in Mongolia and Baikal Lake region all the year round. In summer the SLP increases in Europe and most of the East Asia with maximal anomaly in Mongolia and Baikal Lake water basin. It corresponds to summer warming and decrease of precipitation in this area in recent climate regime.

- High negative anomaly of precipitation and extremely low Selenga River discharge is observed in summer 2015. The extremely low total water inflow to the Baikal Lake is also effected by anthropogenic forcing related to the increased human activity in Selenga river and Baikal basins.