CLIMATIC REGIME CHANGE IN THE ASIAN PACIFIC REGION, INDIAN AND SOUTHERN OCEANS AT THE END OF THE 20TH CENTURY

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Motivation

- **Multidecadal oscillation with period 60-70\textsuperscript{th} years**
  

  Minobe, A 50–70 year climatic oscillation over the North Pacific and North America (GRL, 24, 1997)


- **Climate regime shift in both 70s (Wu, et al) and late 90s (Bond et al., 2003; Jo, Yeh, Kim, 2008)**

- **Features of different multidecadal climate regimes**
  
  North Atlantic (Byshev et. al., 2011, 2013, in Russian)
  North Pacific (Jo, Yeh, Kim, 2013)

  **Changing phase of interdecadal / decadal oscillation and climate transitions**

Main goals are

- to reveal features of the recent climate regime change in the atmospheric pressure at sea level (SLP), net heat flux (Q) at the ocean, land surface, Precipitable Water Content in the atmosphere (PWC, kg/m2), surface air temperature (SAT) and precipitation over the Asia Pacific region, Indian and Southern oceans,

- to define scenarios of extreme events in precipitations strongly effected on the catchment areas and coast of Lake Baikal (South of Siberia) and Lake Khanka (north of Vladivostok) during recent climatic regime.
Observation Data

- gridded monthly mean time series of Hadley Sea Surface Temperature (SST) from 1870 to 2015, Reynolds SST,

- Sea Level atmospheric Pressure (SLP), air temperature (SAT), surface net heat flux (Q), Precipitable Water Content (PWC, kg/m²) in the atmosphere, precipitation (Pr), from NCEP NCAR meteorological reanalyses, particularly monthly mean gridded (2.5 \times 2.5) from 1948 to 2015,

- monthly mean time series of precipitation, SAT at the meteorological stations and correspondent gridded time series (1 \times 1) over land from 1900 to 2015.

Methods

To analyze observation data we apply different statistical methods including cluster analysis Fuzzy C-means method via Principal Component Analyses (PCA).
Fig. 1. Regions of $Q$, SLP, Pr, TWC averaging in the Asian Pacific Region and Indian Ocean:
1 – the zone of temperate latitudes of Asia;
2 – subarctic zone;
3 – Eastern subtropical zone;
4 – Western Equatorial zone;
5 – El Nino (NINO 3-4); 6 – South Indian Ocean

Fig. 2. Phase trajectory of the net heat fluxes ($Q$, W/m²) of 3-years running mean time series (1969 - 2015) averaged in Subarctic Pacific ($Q_2$) and South Indian Ocean ($Q_6$) in boreal winter.
Time series (1948 - 2015) of the net heat fluxes (Q, W/m²) averaged in Subarctic Pacific (Q2, a,b) and Indian Ocean (c,d) in winter JFM (a, c) and summer JJA (b,d).

Recent climate shift the net heat flux in 90s in both Subarctic Pacific (Q2) and South Indian Ocean (Q1) is most prevailed in boreal winter (Fig. 1a, Fig. 2a). Rapid reduction of Q directed to the ocean in South Indian (summer in Southern hemisphere) accompany rapid reduction of Q directed from the ocean to the atmosphere in the Subarctic Pacific (Northern Hemisphere).

The net heat fluxes Q decrease in both South Indian Ocean (Q6) and Subarctic Pacific (Q2) in 1996-2015 climate regime after rapid shift mainly in boreal winter JFM (a) (summer in Indian Ocean of Southern hemisphere) .
Fig. 5. Phase trajectory of 3-years running mean PC1 and PC2 of set, which includes 18 time series (1948-2015) of differences between the values of both Q and SLP in boreal winter averaged within all of 6 selected areas. Three classes of the time series determined by cluster analyses are marked by color symbols.

Fig. 6. Phase trajectory of 3-years running mean PC1 and PC2 of set, which includes 12 time series (1948 - 2015) of annual Q and TWC in all of 6 selected areas. Three classes of the time series determined by cluster analyses are marked by color symbols.

Two shifts of the climate regime both in mid 70s and late 90s are also revealed in terms of phase trajectory of PC1, PC2 of set included 18 time series of differences between values of both Q and SLP in boreal winter in all of 6 selected areas (Fig. 1).
Two climate regime shifts are also found in terms of phase trajectory of 3-years running mean annual SAT differences, particularly between regions T2-T4, T1-T2 (Fig.6), as well as in phase trajectory of PC1 and PC2 of set (Fig. 7), which includes 12 time series (1948 - 2015) of annual Q and TWC in all of 6 selected areas.

Thus, the climate regime is significantly changed in the Asian Pacific region, Indian and Southern Ocean at the end of the 20th century in terms of Q, SLP, SST, SAT, TWC, Precipitation, and their horizontal gradients on the planetary scale.

Recent climate regime in comparison with previous one is characterized by reduce of Q amplitude in annual cycle and meridional gradients of annual and seasonal Q. Absolute values of Q directed to the ocean in summer and to the atmosphere in winter are usually reduced after late 90s of the 20th century. It accompanies change in the ocean vertical structure, circulation and meridional heat transport.
After the recent climate regime in late 90s the SLP increases mainly in central extratropics of both North and South Pacific, in South Indian Ocean, being maximal changed in winter. The SLP also increases in central continental Asia of temperate latitudes, particularly in Mongolia and South Siberia, Baikal Lake Basin, where maximal large scale SLP change in typical for summer.

The SLP decrease and intensification of cyclonic activity occur in the marginal areas of the North and South Pacific, Indian, Southern and Arctic oceans including their marginal seas.

Total water content in the atmosphere and precipitation significantly increase in this zone. Surface air temperature in most of marginal areas rises in fall and winter while decrease in spring and early summer. Repeatability of number of strong storms has increased in the Western Pacific and its marginal Seas, Western and Eastern Atlantic Ocean.
Fig. 9. Anomalies of monthly precipitation sum in catchment area of Lake Baikal and Selenga River averaged for **July** 2015 (a) and in **June - August** 2015 (b). Black dashed curve is a boundary between Russia and Mongolia. Yellow dashed curve is boundary of catchment area of Selenga River.
Fig. 10. Time series (1948 - 2015) of precipitation (mm/mon) averaged in April-June (a) and June-August (b) in the large scale area (46°-57° N, 97°-114° E) including catchment areas of the Lake Baikal, Irkutsk and Bratsk water reservoirs of hydroelectric power stations.

The negative anomaly of precipitation from June to August 2015 is prevailing in the whole area presented in Fig. 9 and in catchment areas of Lake Baikal and Selenga River. The positive anomaly occurs only over surrounding regions, particularly over Hahgay and Yablony Ridges, as well as in northern region adjacent to Bratsk water reservoirs.

The recent climate regime is also associated with high SLP and low precipitation in this area (Fig. 10) that is in agreement with [17]. The sharp drop of precipitation began from 1997 and reached low level in 2002, 2007, 2014 and 2015. The effect of accumulated anomalies of precipitation has an important impact on the Lake Baikal level drop in 2015.
High anomaly of precipitation occurs in South of Primorskii Region of Russia in 2015-2016. In late August 2015 to summer 2016 considerable flood of the Lake Khanka after passing of the typhoon "GONI" in the south of Primorskii Krai was observed on August 26, 2015. Increase of level of the lake and flooding of adjacent lands continues till summer 2016 (recent time) that isn't related to passing of strong typhoons any more.

It is basically due to both extreme rise of rainfall in fall 2015, snow in winter 2016 in the Lake Khanka Basin especially over the Pogranichny Ridge (Fig.11, 12, 13) and positive decadal anomaly of mean precipitation from Jan. to Aug. in this area during previous long-term period 2004 to 2015 (Fig. 13).
Fig. 12. Anomaly of monthly precipitation sum (mm/mon) in August (a) 2015 and averaged from January to August (b) 2015 in the catchment areas of the Lake Khanka, Amur, Mulinkhe, Ussury Rivers.

Fig. 13. Time series (1948 - 2015) of monthly mean precipitation (mm/mon) in August (a) and from January to August 2015 (b) over Pogranichny Ridge (44.5 N, 130.5 -131.5°), averaged in two green grid points in Fig.12 in the area of maximal precipitation 175 mm/mon situated southwest of Lake Khanka, as well as mean precipitation in all grid points of red area (c), isolated by curve 110 mm/mon in Fig.12.

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Table 2. CTD Stations in the Tatarskii Strait from 1999 to 2015.

Typical vertical subarctic water structure of temperature and salinity with subsurface local temperature minimum is observed in July 1999, weak in August 2012, maximal in late June 1913, weak in late July 14, while in mid July 2015 the vertical structure became subtropical with significantly increased both temperature and salinity in total water column.

This change of the water structure in the Tatarskii Strait in June 2015 is due to increase of subtropical water transport to the northern area of the Japan Sea in this year. This event is associated with warm SST anomaly in the Northeast Pacific in 2014 and in the large scale area of the extratropic Pacific in 2015.
**Summary**

**on the climate change in ocean coastal areas**

The climatic regime is significantly changed at the turn of the 20 - 21 centuries over land and the ocean in the Asia Pacific and Arctic region, Indian and Southern oceans.

Characteristic features of the recent climate regime 1996/1999 – 2016 is associated with the decrease of atmospheric pressure at sea level (SLP) and rise of cyclonic activity in most of land - ocean marginal zone including sea coast.

Repeatability of strong cyclones, storms and rainfall is significantly increase in the coastal areas.

It is a main cause of the extreme and catastrophic floods in the Lake Khanka in 2015-2016, in the Amur River in 2013, and Rivers in the Primorskiy Region of Russian Far East in 2012, 2015, and 2016.

An impact on the sea, lake and river coast is significantly increasing during recent climate regime after 2000.
Summary
on the climate change in central ocean and continental areas

Another major feature of the recent climate regime is the cyclonic activity reduce and SLP rise being prevailed in winter in central extra-tropical Pacific and in South Indian Ocean. It is accompanies a reduce of the net heat flux at the ocean surface and heat exchange between ocean and atmosphere.

Similar SLP rise being prevailed in summer occurs in central continental regions of temperate latitudes, in Mongolia, South Siberia, and catchment area of the Lake Baikal. It is accompanied by significant warming, wildfires, reduction of precipitation, river discharge and fast falling of level of the Lake Baikal.