

AtlantNIRO-VNIRO (Russia)

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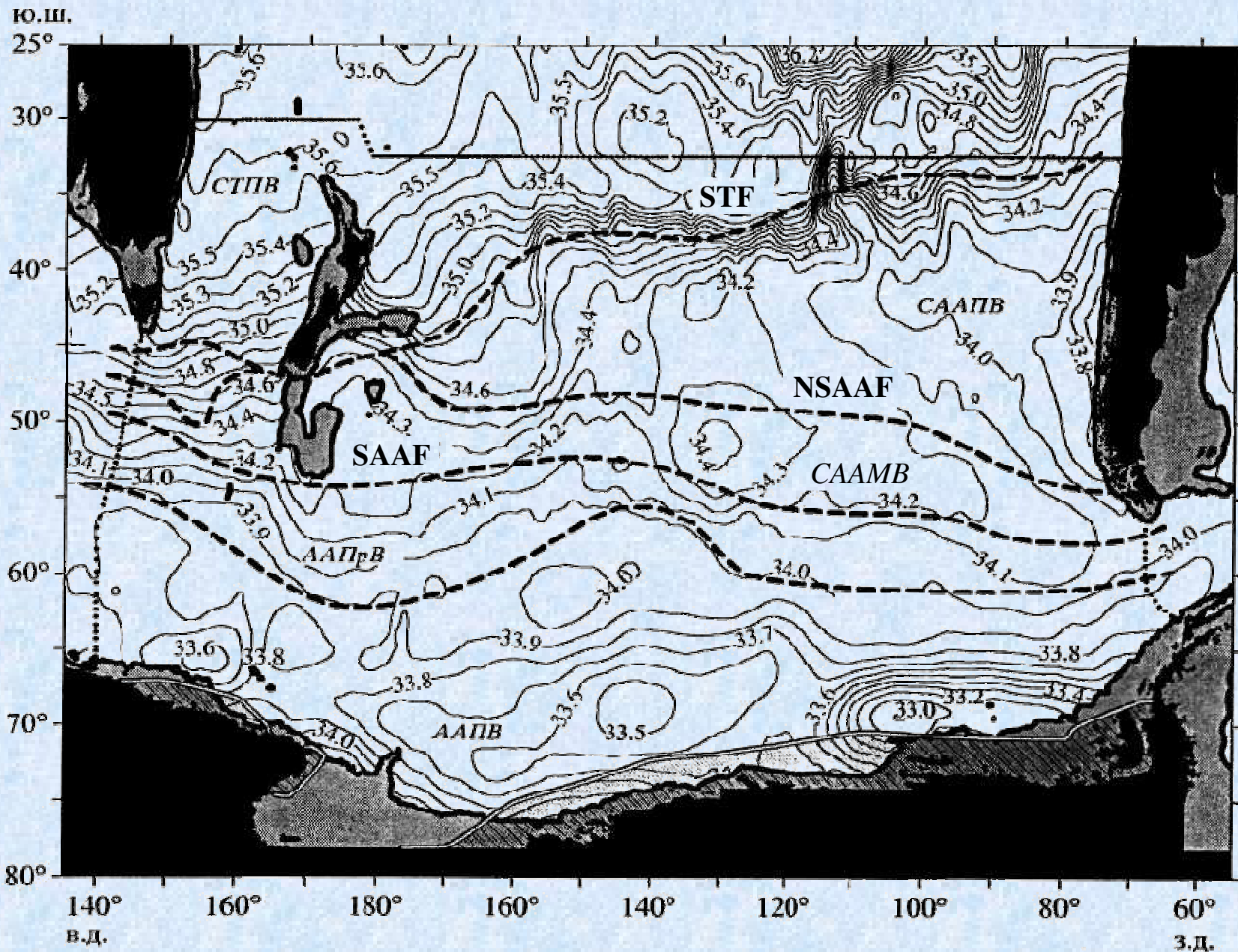
**Inter-annual and seasonal
variability of oceanological
conditions in the Southern Pacific
Ocean**

Chilean Jack Mackerel
Workshop

INTRODUCTIONS

The water structure and dynamics considerably affect the biological productivity in the upper layers and structure of the pelagic ecosystem in the open ocean. As far as the southern part of the Pacific Ocean has more extended (about 3500 n.m.) with Antarctica as compared to the Atlantic and Indian Oceans, the larger volumes of the intermediate Antarctic water rich in nutrients penetrate into the temperate latitudes. Under the impact of cyclonic and anticyclonic circulations occurred in the ocean frontal zones, this water mass is ascending to the surface, where relatively isolated zones of high biological productivity, able to support individual jack mackerel stock units, are formed.

However, at present the water structure and dynamics in the Southern Pacific Ocean is researched insufficiently.



Location of the main fronts in the Southern Pacific Ocean and salinity climatic.

Materials used

Data type	Spatial resolution	Discrecity	Period	Source
Atmospheric pressure at the sea level	2.5°x2.5°	month	1960-2008	NCEP/NCA Reanalysis
Sea surface temperature	1°x1°	month	1982-2008	IGOSS
Sea level anomalies	1°x1°	month	1992-2008	AVISO
Climatic temperature and salinity values	1°x1°	month		WOA -2004
World Ocean Circulation Experiments (projects WOCE, ARGO)	Transects		1993-2002	WOCE Globale Data,2004 Copernicus, 2008

Methods used:

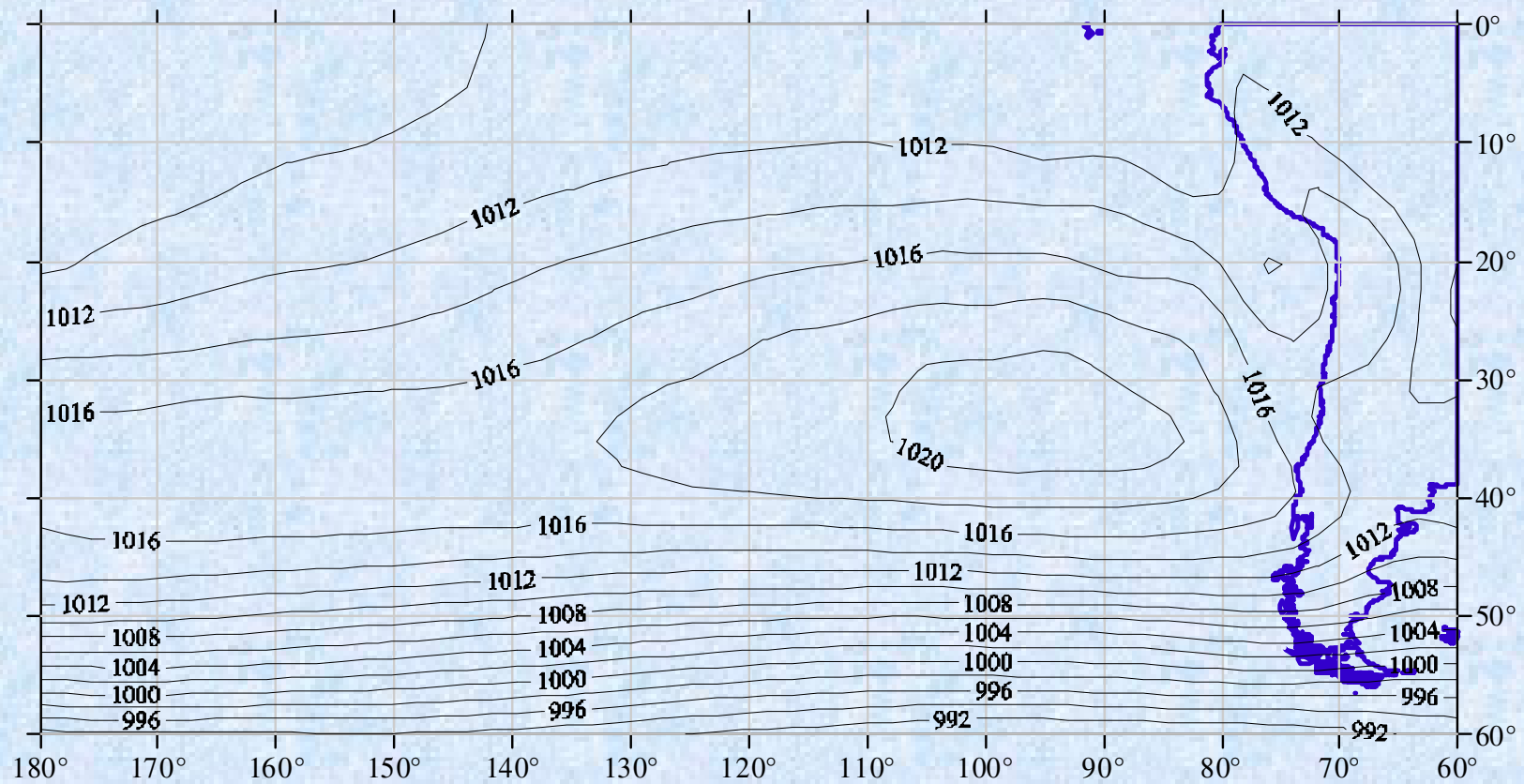
- Analysis of principle component (PC): for compression of information and discovery main processes

loading - positive or negative relationship PC with source fields;

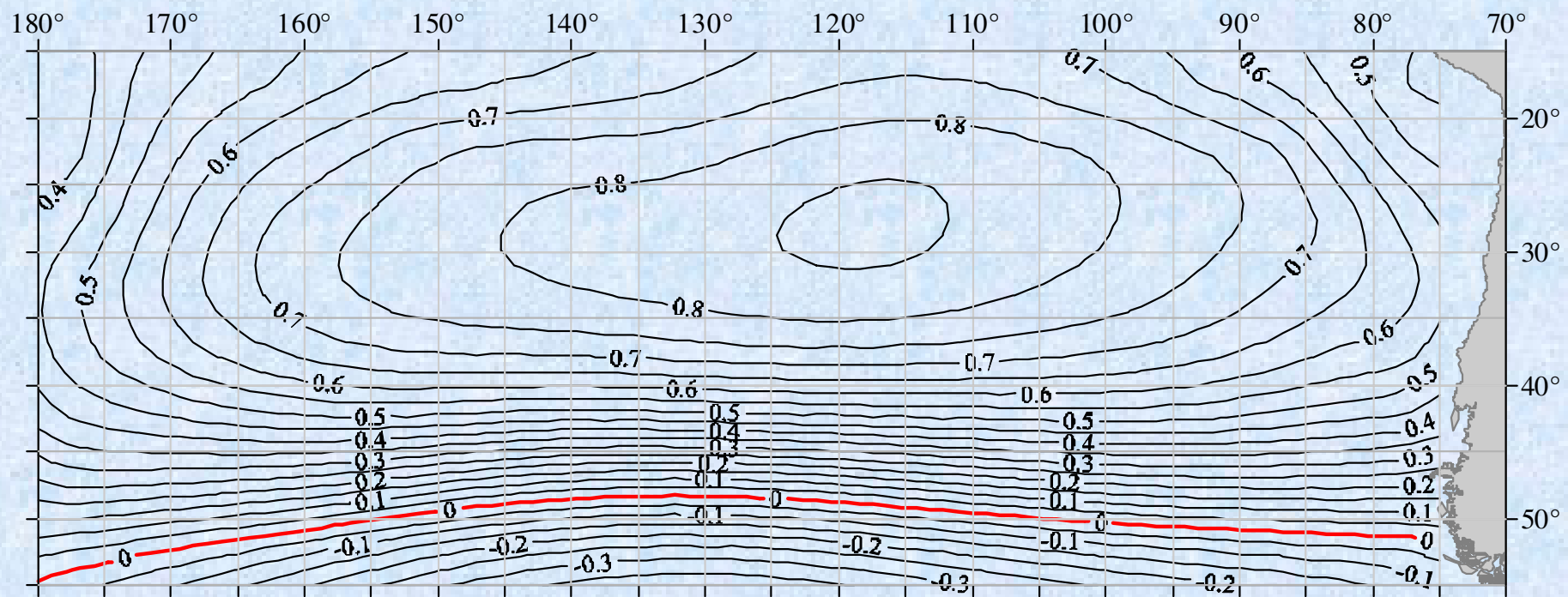
- Cluster analysis (Word's hierarchical method): for revealing the areas with alike parameter of variability;

- Spectral analysis:

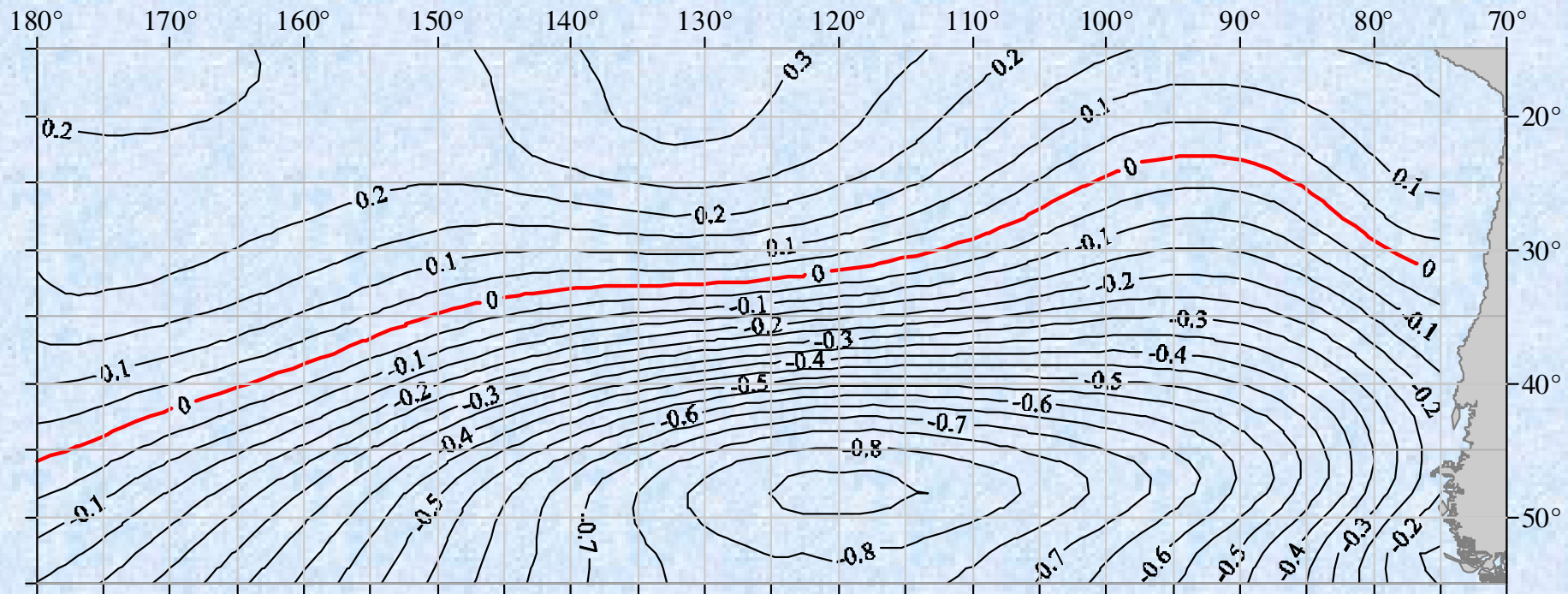
for discovery of hidden periodicity



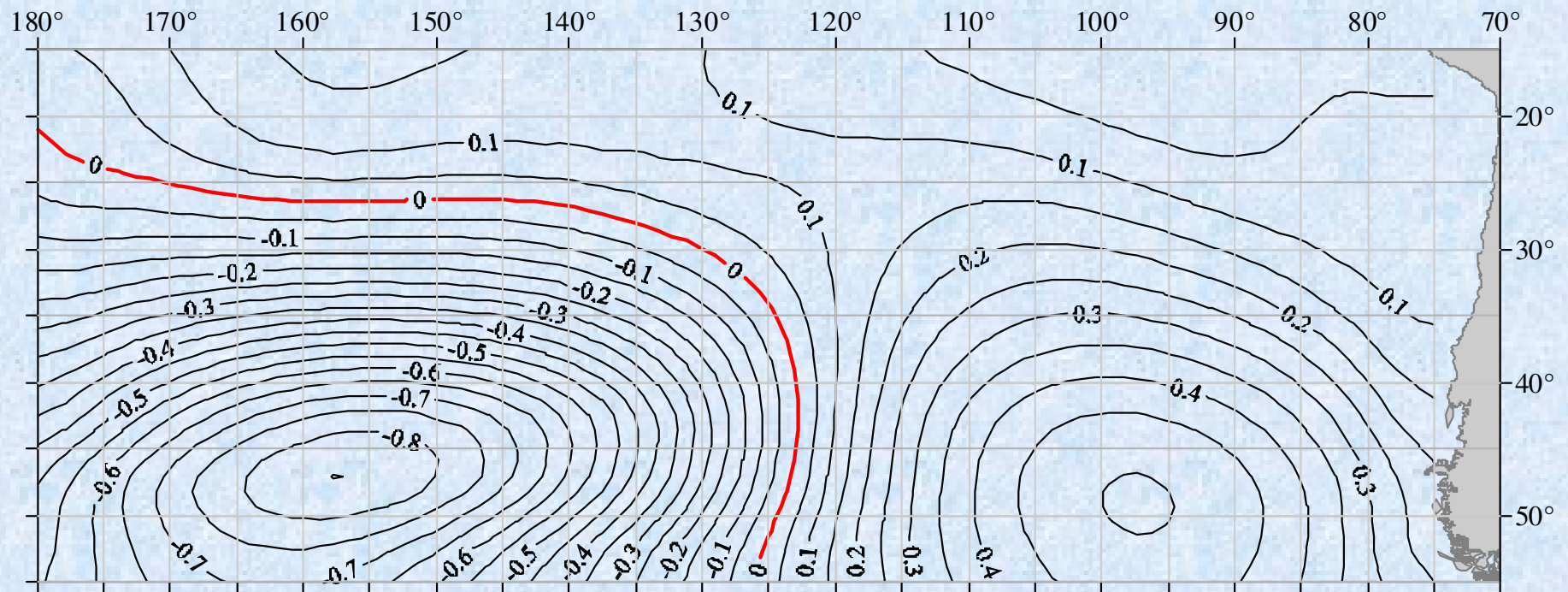
Spatial distribution of the mean atmospheric pressure at the sea level during 1960 -2008



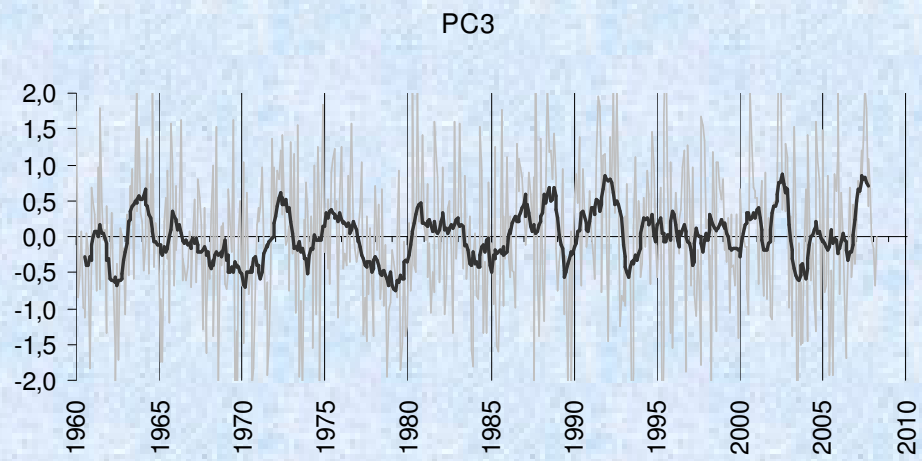
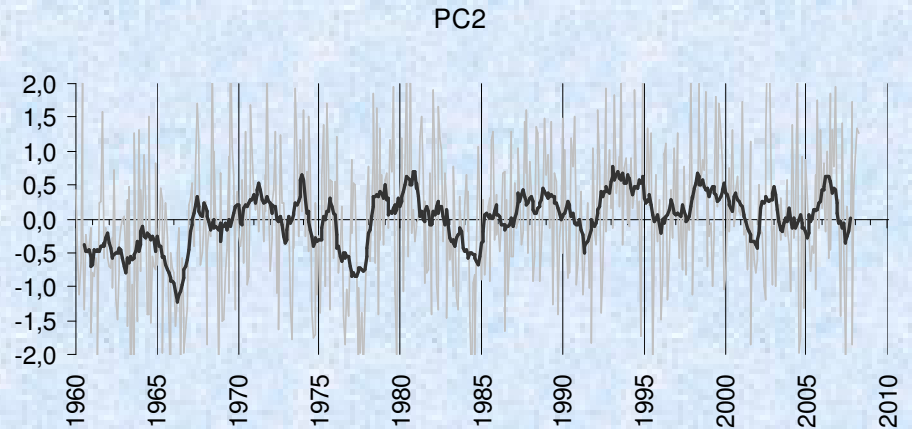
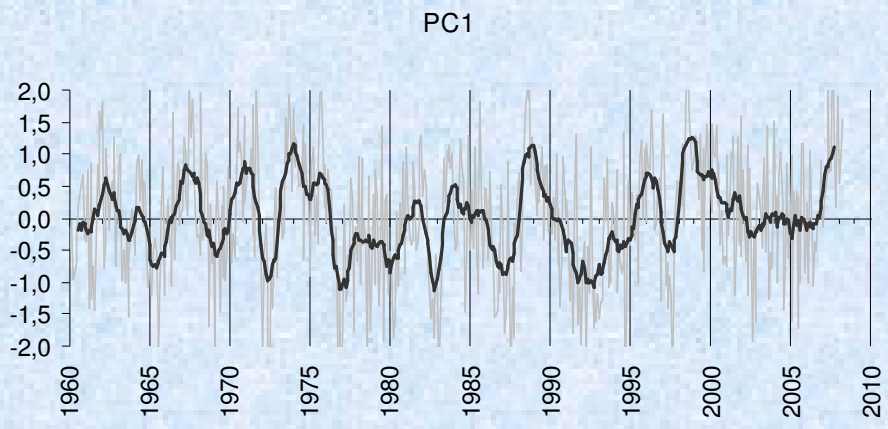
Distribution of 1 PC loading for pressure anomalies reduction in 5-degree strata



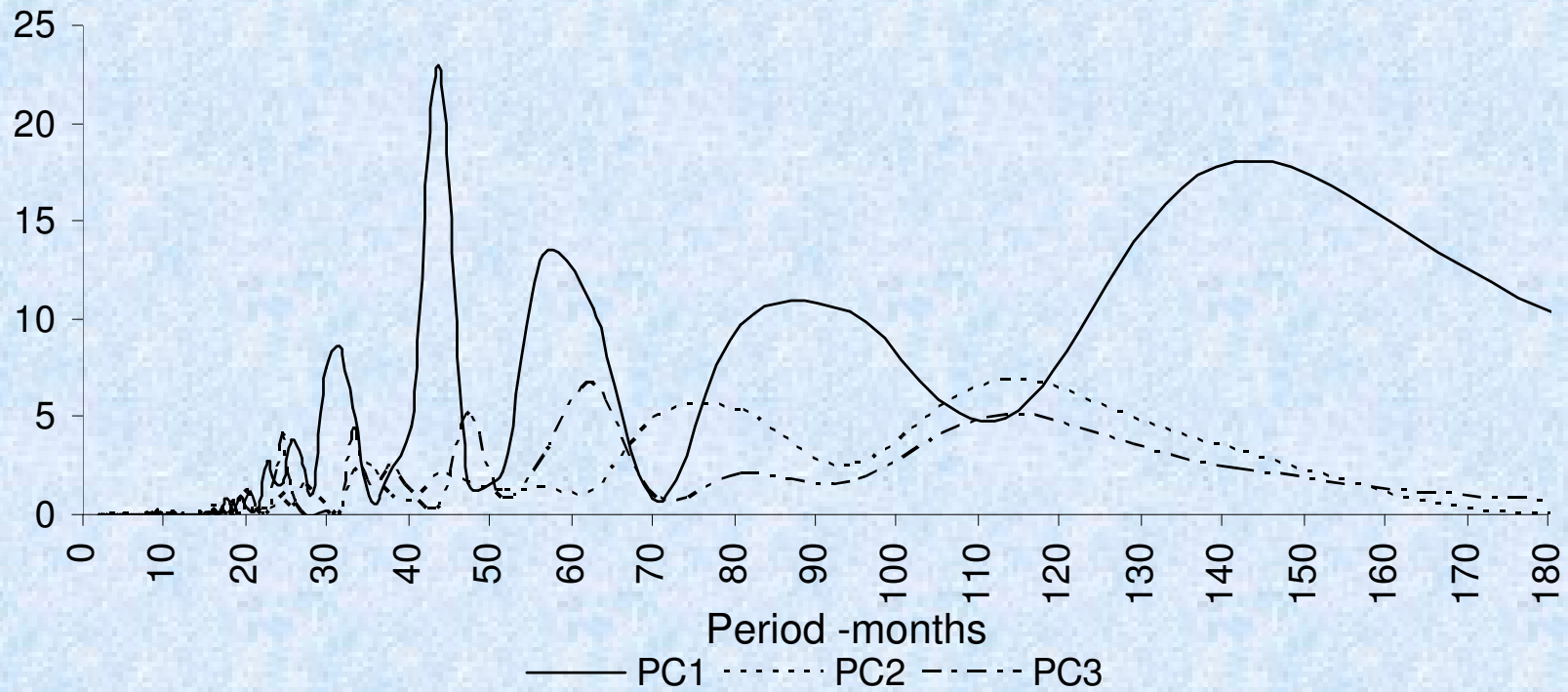
Distribution of 2 PC loading for pressure anomalies reduction in 5-degree strata



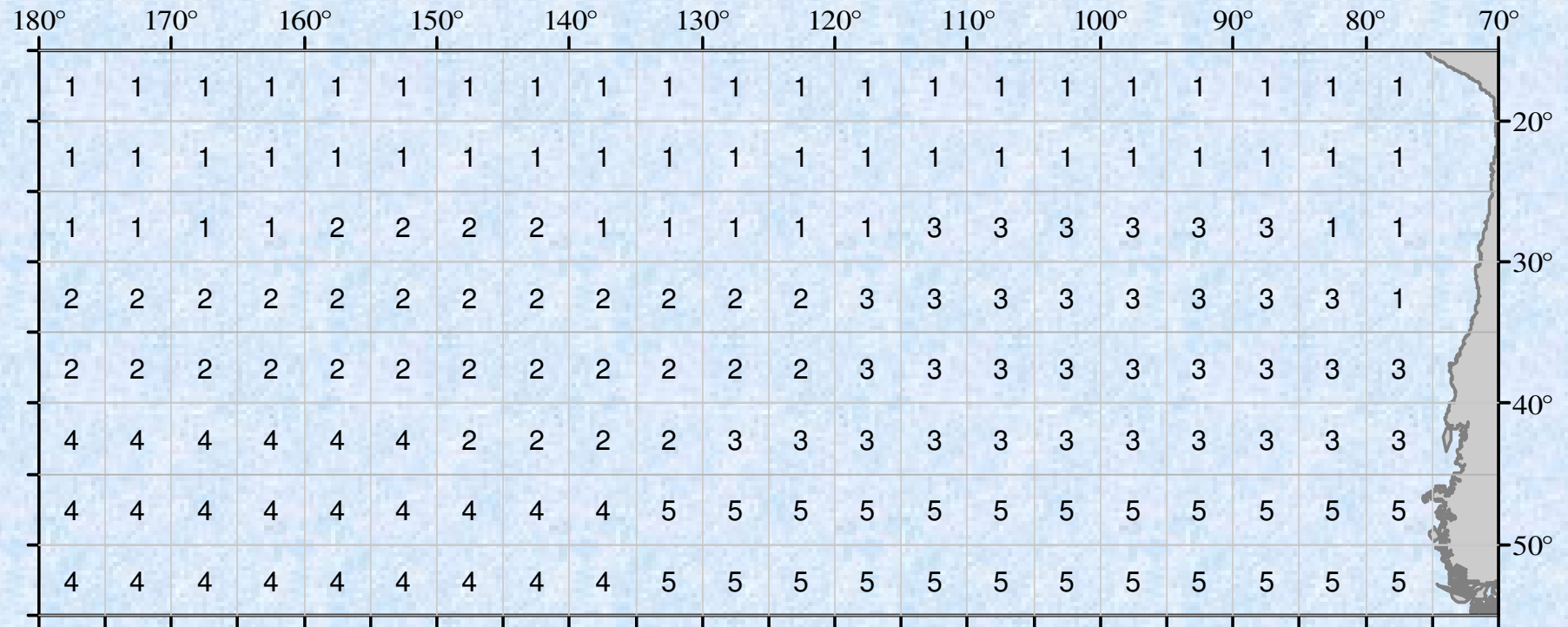
Distribution of 3 PC loading for pressure anomalies reduction in 5-degree strata



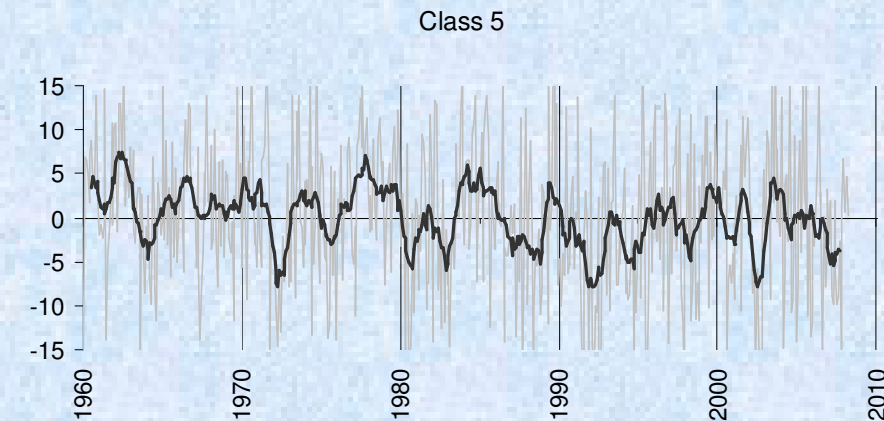
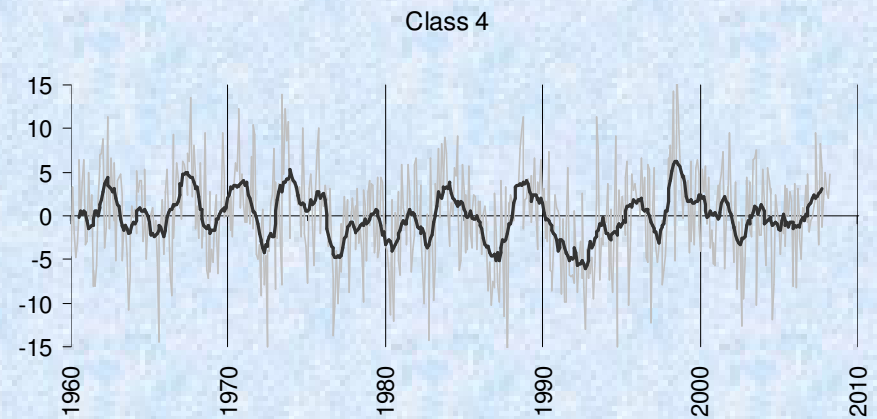
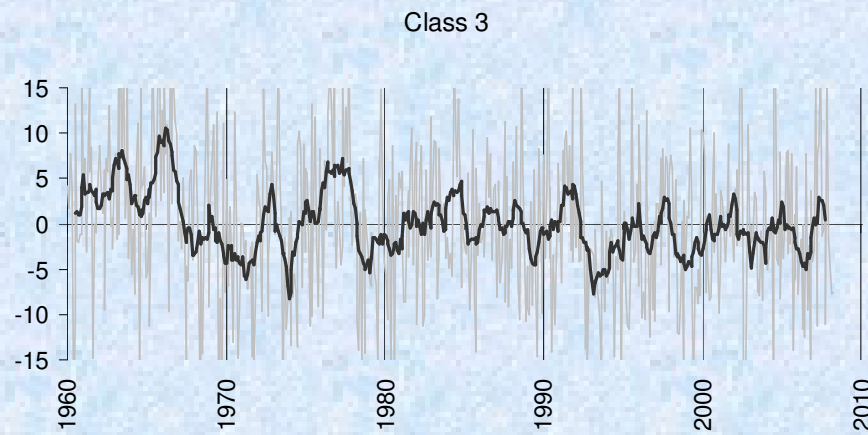
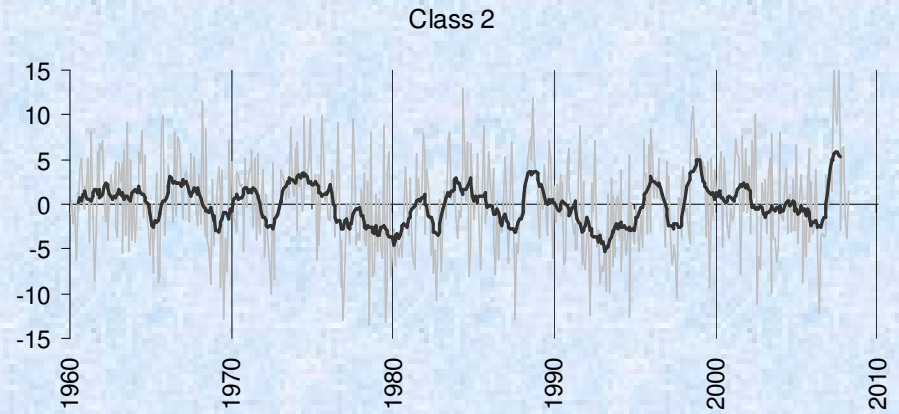
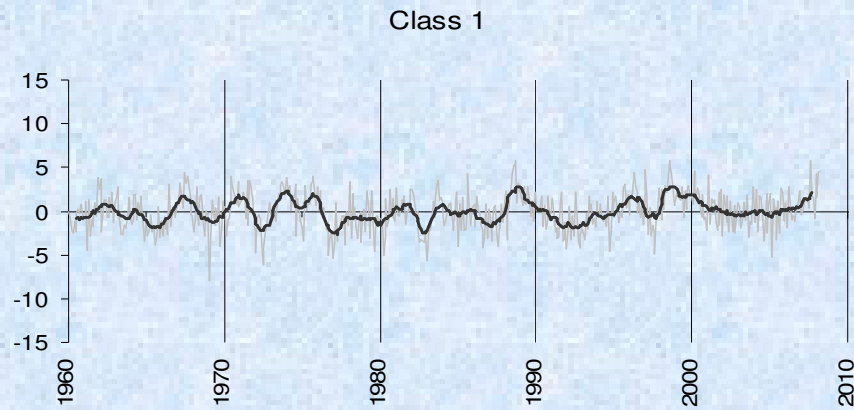
Temporal trend of the first three PC for pressure anomalies reduction in 5-degree strata



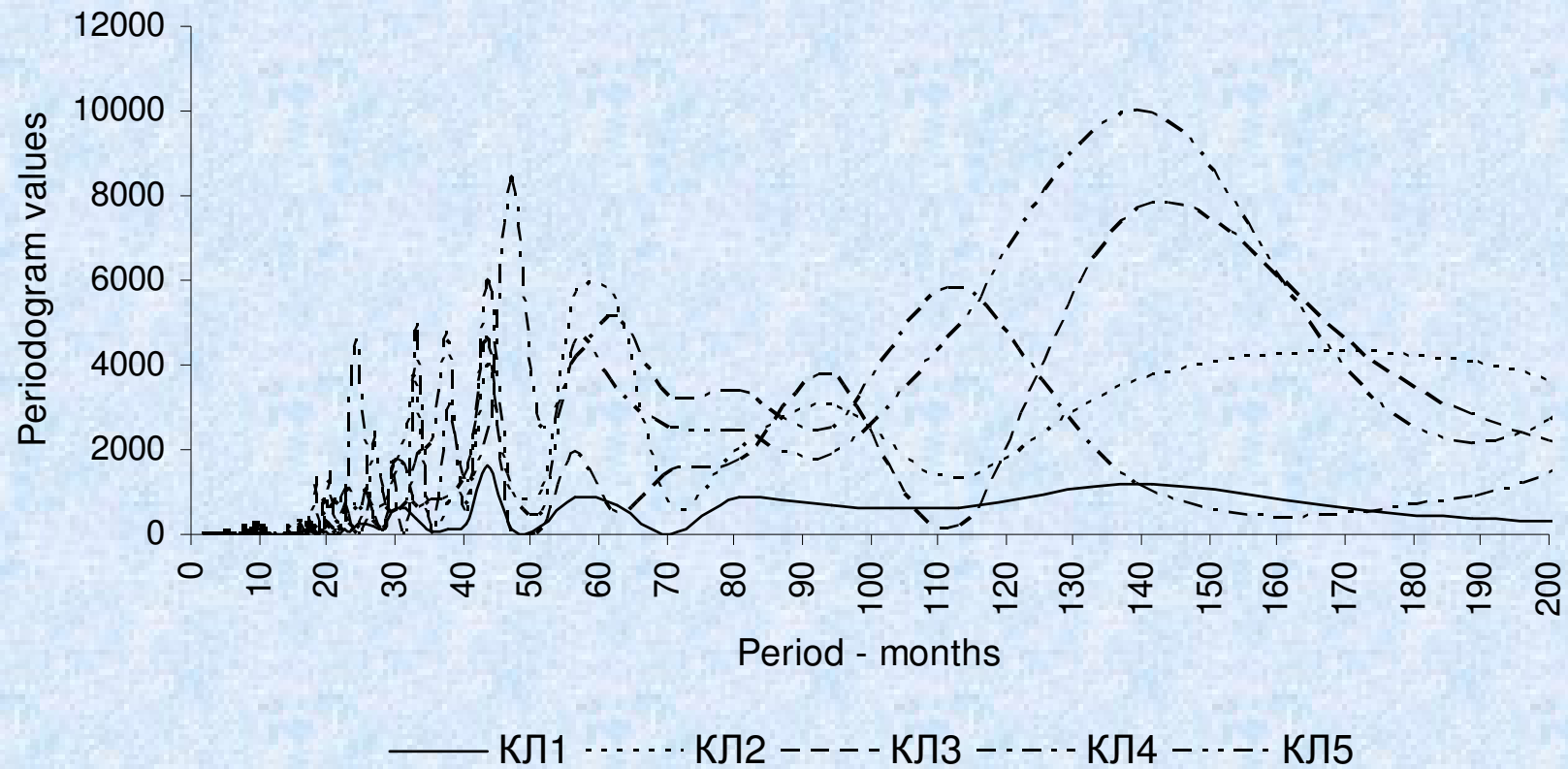
Periodogram of temporal variability of the first three PC for pressure anomalies field reduction in 5-degree strata smoothed by 13 months



Spatial classification of pressure anomalies in 5-degree strata based on Word's method (5 classes)



Temporal trend of pressure anomalies for 5 classes of spatial classification



Periodogram of temporal variability of average class pressure anomalies in 5-degree strata smoothed by 13 months

Resume for the atmospheric pressure fields

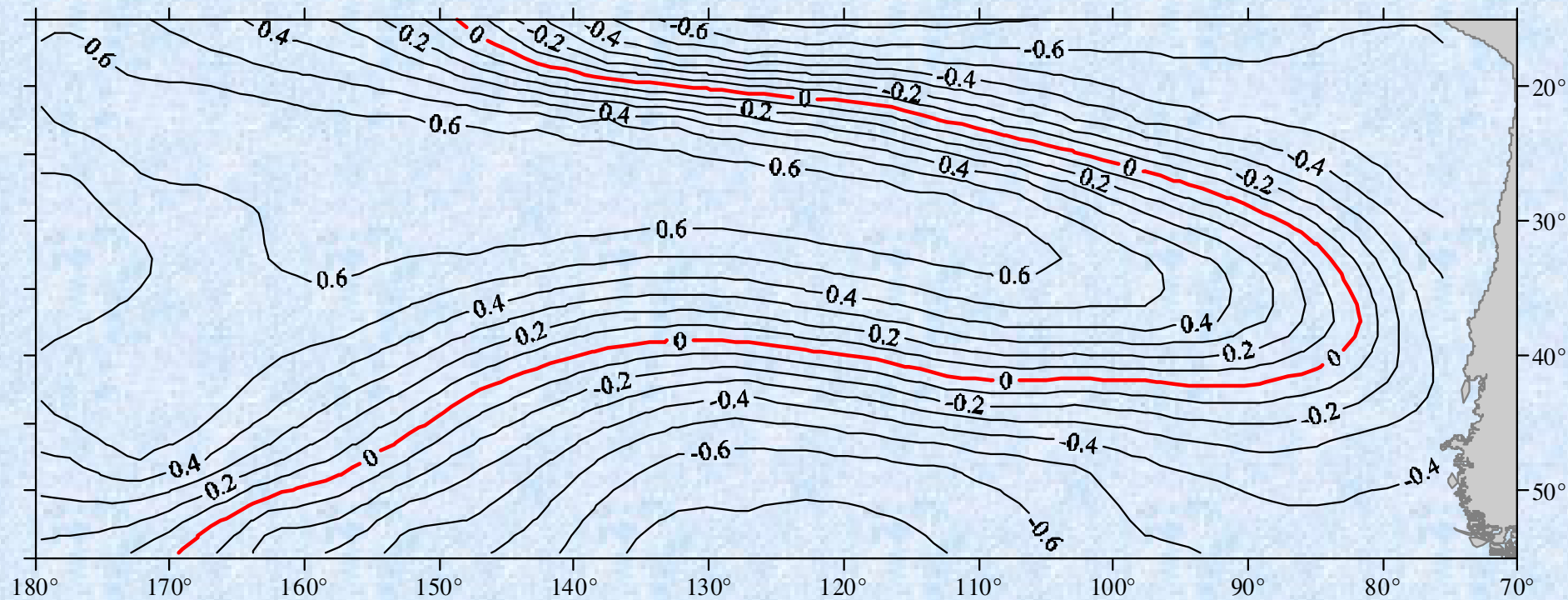
The first principle component (PC) of the atmospheric pressure field is positively related to the pressure anomalies field in the subtropical zone and negatively related to those southwards of 50°S . This component characterizes the general background of the atmospheric pressure over the South Pacific Ocean (SPO), while its maximum loads characterize the centers of positive and negative anomalies formation. Inter-annual variability of cycles is similar to variability of the far relations index SOI (ENSO).

The second PC characterized variability of the zonal redistribution of the atmospheric pressure anomalies and has positive loads to the north of 30°S in the area at 120°W , while the maximum negative loads occur at $45\text{-}50^{\circ}\text{W}$, $105\text{-}130^{\circ}\text{S}$.

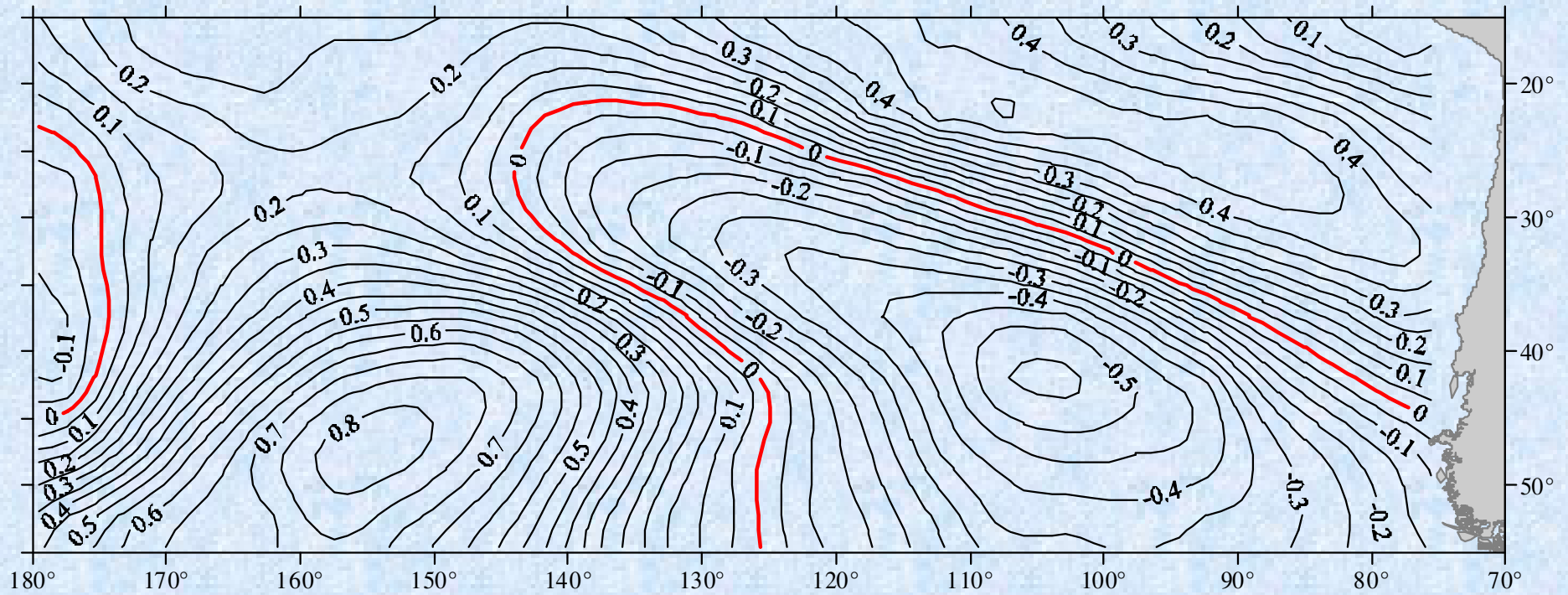
The third PC reflects the meridional division of SPO area into 2 parts – eastern and western with the boundary between them extended up to 30°S in the south and at 125°W . This component is positively related to pressure anomalies field in the eastern part (50°S , $95\text{-}100^{\circ}\text{W}$), which may be the result of more frequent formation of the high pressure peaks (in the inter-annual variability) between Antarctica and STO. In the western part the third PC has a higher negative relationship to the to pressure anomalies field in the area at $45\text{-}50^{\circ}\text{S}$, $150\text{-}165^{\circ}\text{W}$, which may characterized this area as a zone of high cyclonic activity.

The first class – tropical, with low amplitude of pressure anomalies variability. **The second and the third classes** – subtropical, with meridional division between $30\text{-}40^{\circ}\text{S}$ approximately at 120°W . **The fourth and the fifth classes** are referred to the temperate latitudes zone to the south of 45° . The boundary between them is located along 135°W . Here the highest amplitude of the pressure anomalies inter-annual variability is observed.

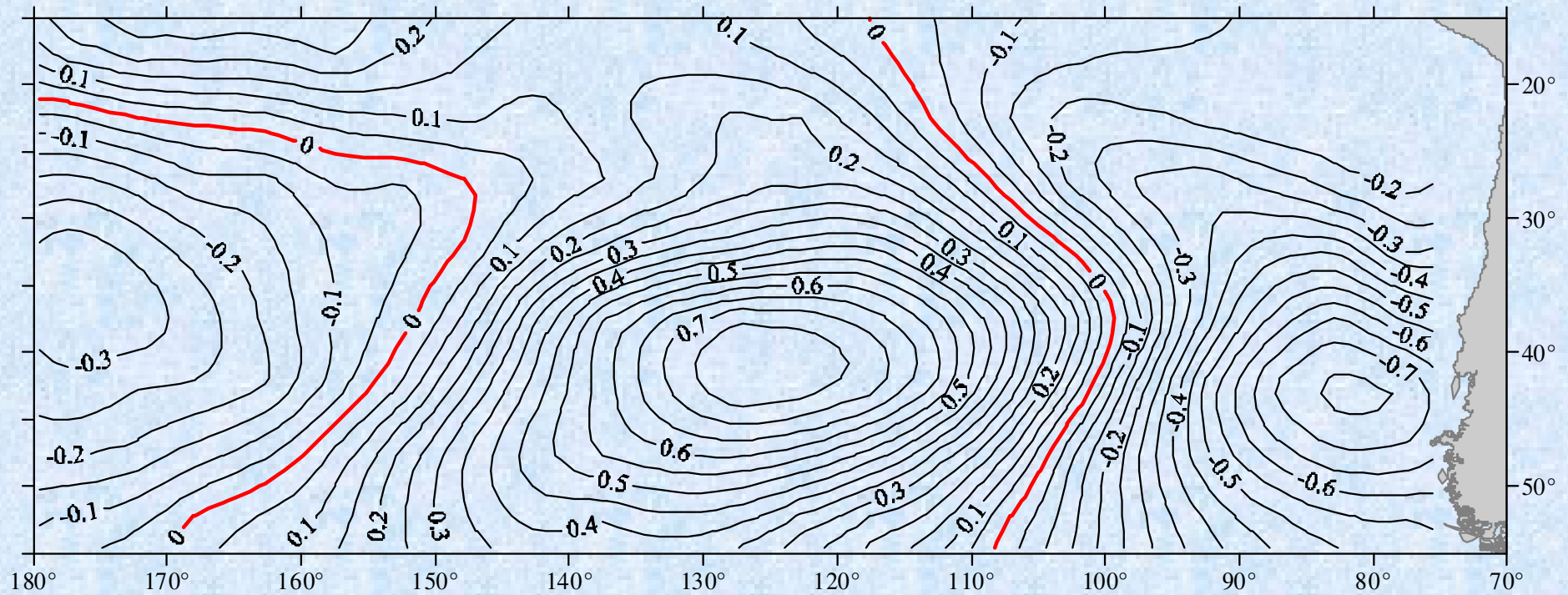
ENSO cycles are available in the inter-annual trends of all classes, while in the third and fifth classes they are supplemented with the solar activity cycle (11.6 years).



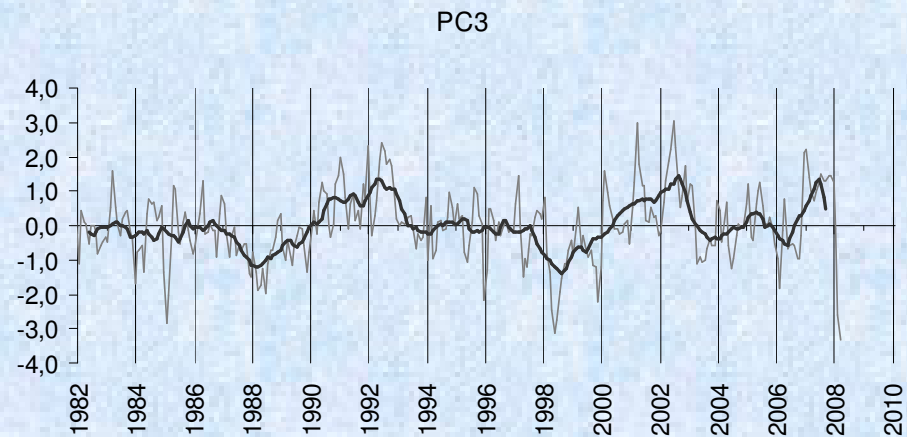
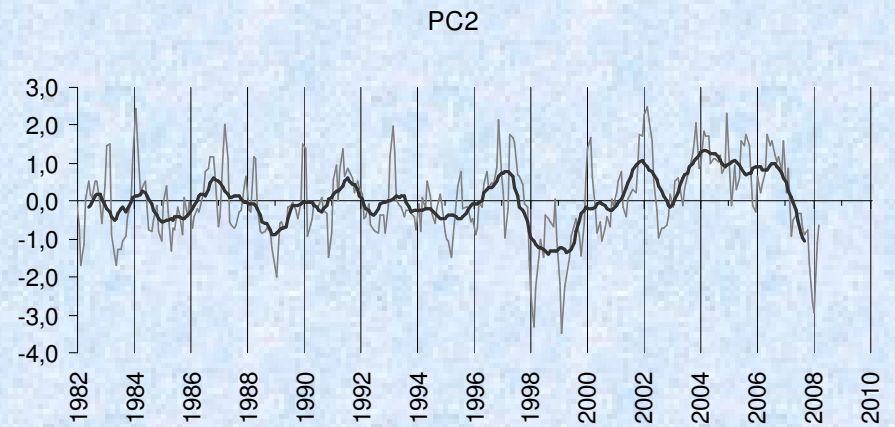
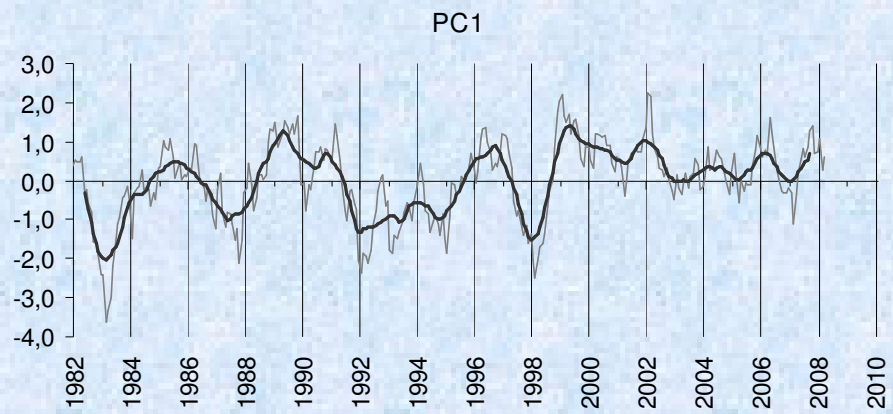
Distribution of 1 PC loading for SST anomalies reduction in 5-degree strata



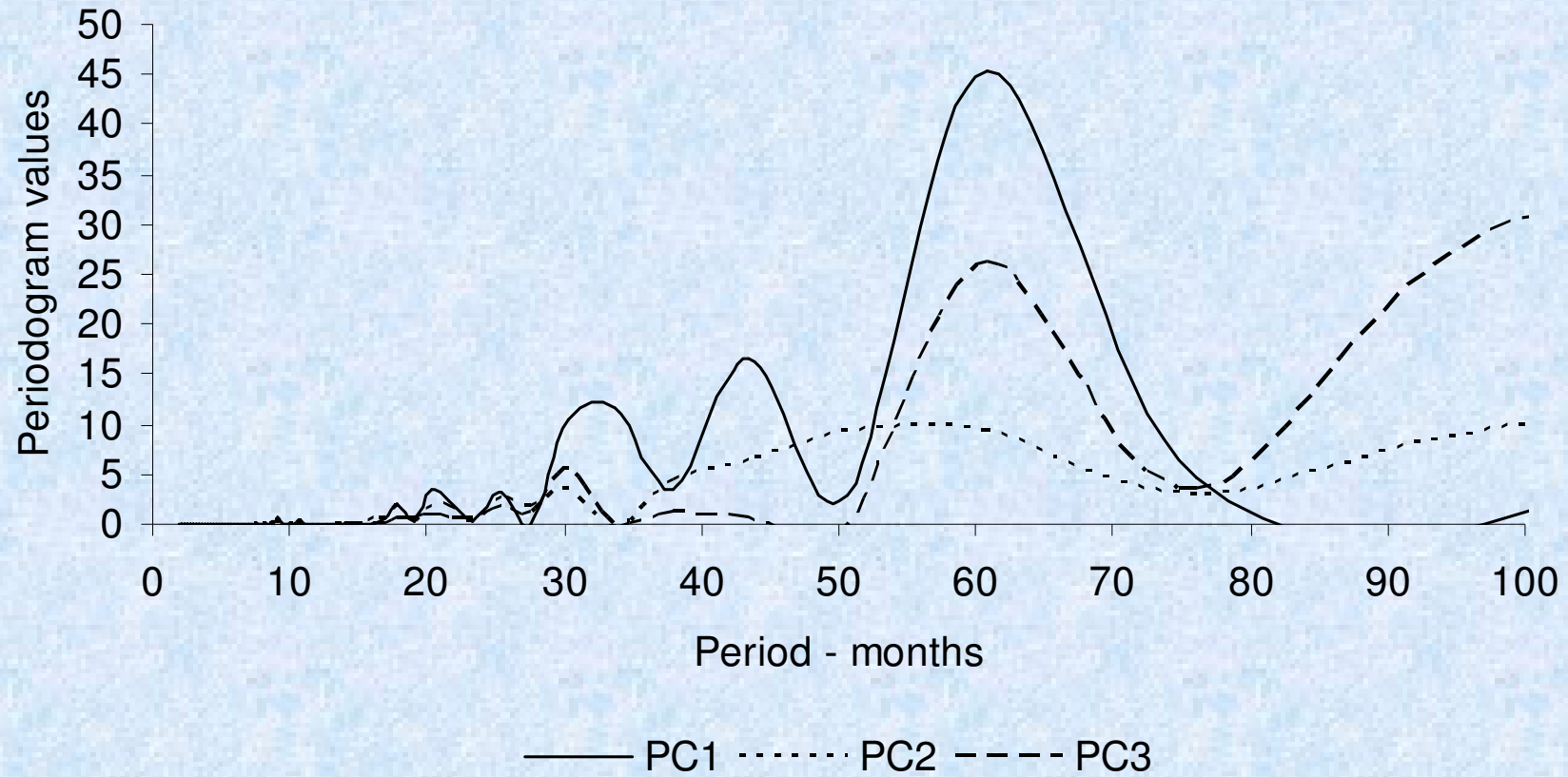
Distribution of 2 PC loading for SST anomalies reduction in 5-degree strata



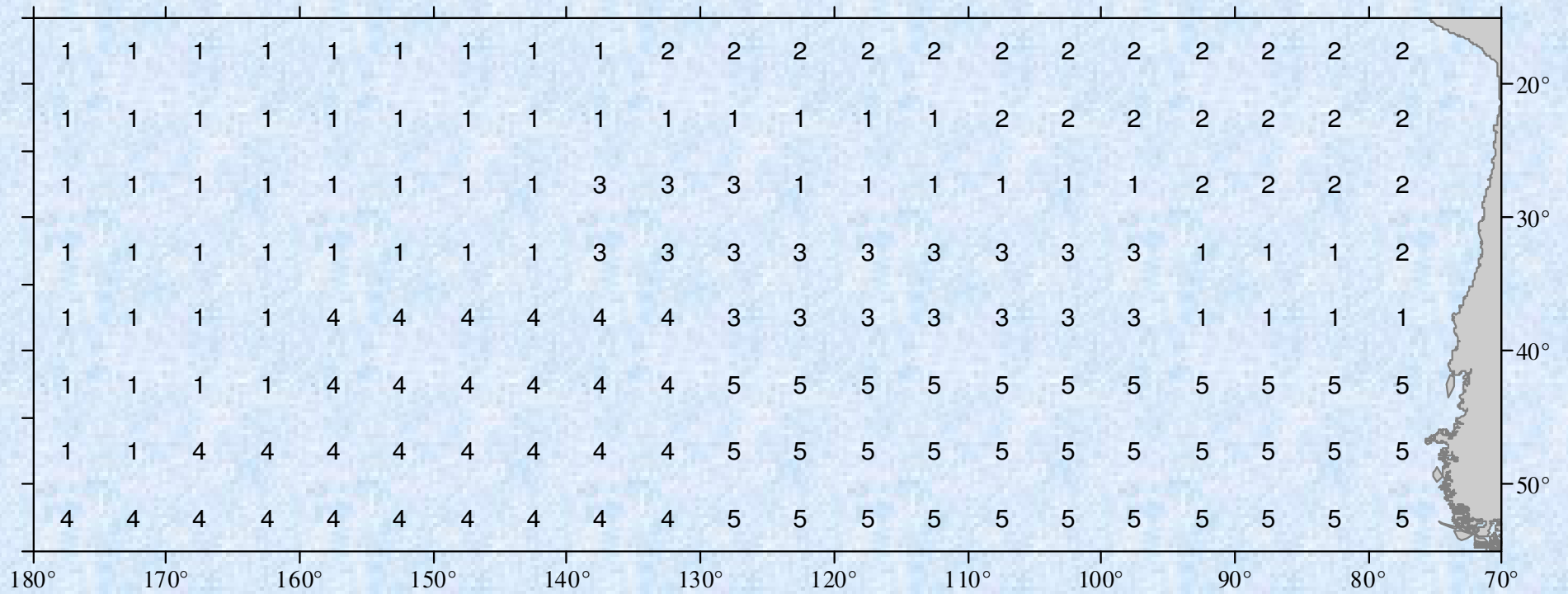
Distribution of 3 PC loading for SST anomalies reduction in 5-degree strata



Temporal trend of the first three PC for SST anomalies reduction in 5-degree strata

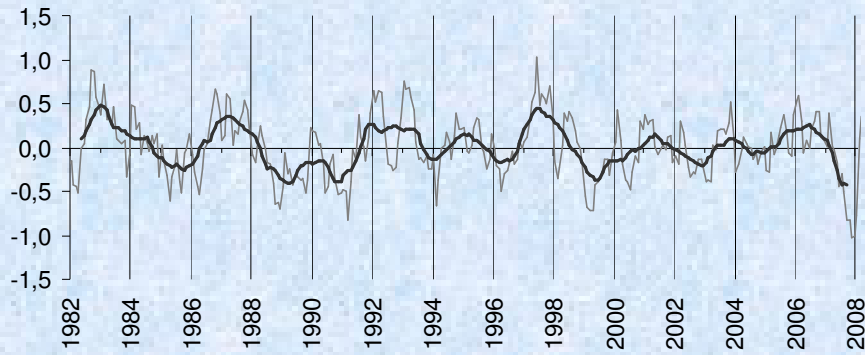


Periodogram of temporal variability of the first three PC for SST anomalies field reduction in 5-degree strata smoothed by 13 months

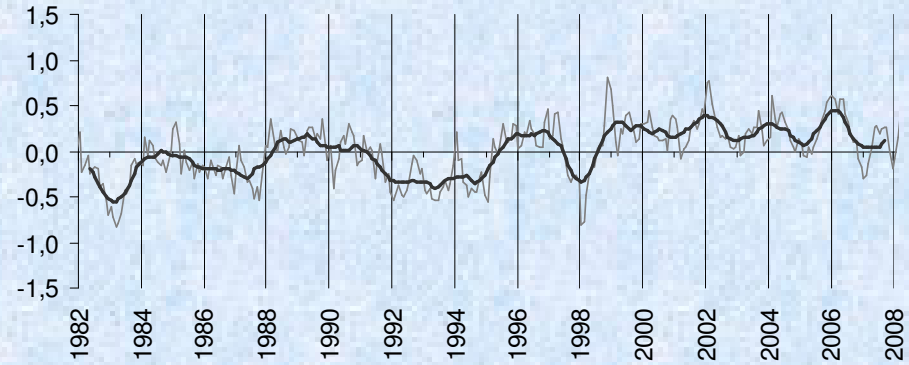


Spatial classification of SST anomalies in 5°-strata obtained with Word's method (5 classes)

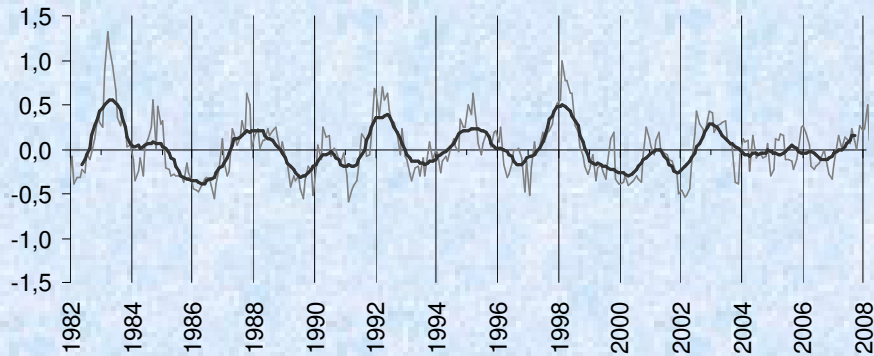
Class 1



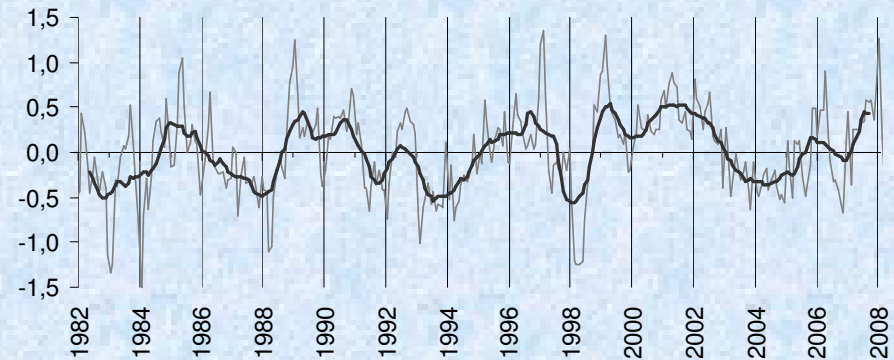
Class 2



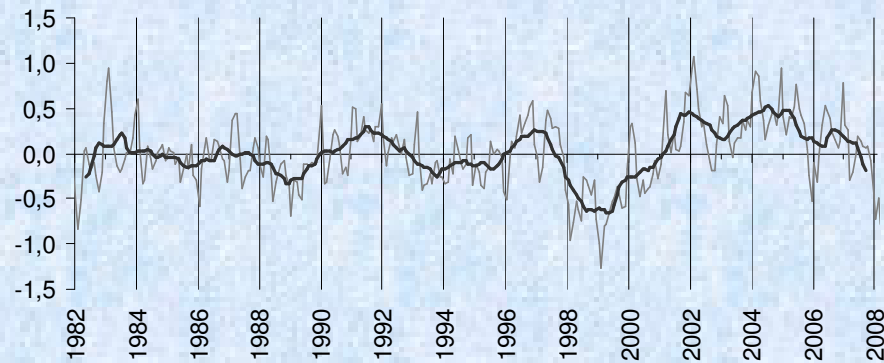
Class 3



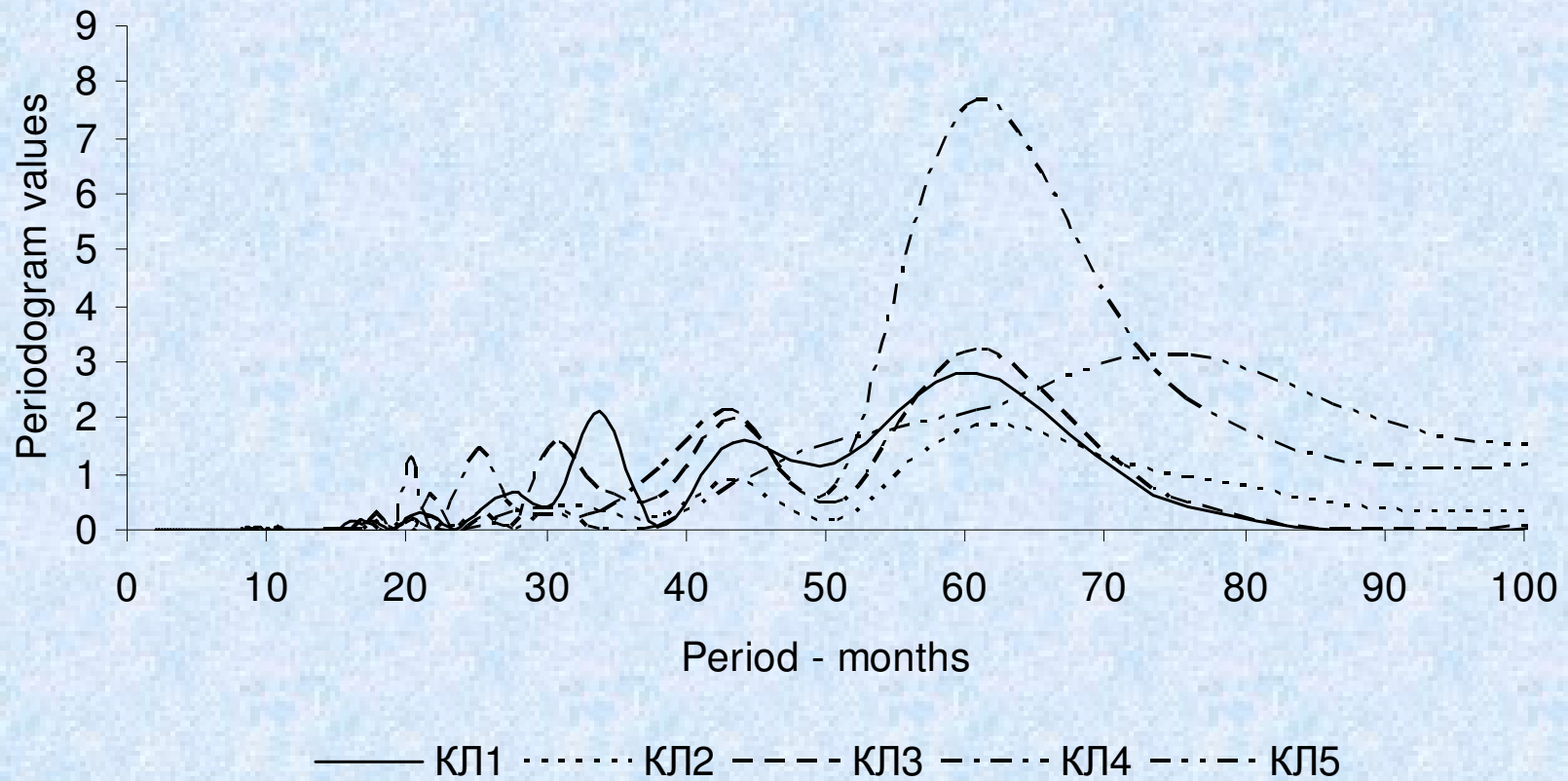
Class 4



Class 5



Temporal trend of SST anomalies for 5 classes of spatial classification



Periodogram of temporal variability of average-class SST anomalies in 5-degree strata smoothed by 13 months

Resume for the SST anomalies field.

In the subtropical circulation SST positive anomalies are formed in the areas of the positive thermal balance of the ocean. The negative anomalies of SST are formed in the areas of the negative thermal balance and permanent intrusion of the cold intermediate water to the surface.

The background distribution of SST anomalies indicates loads of the first PC of SST anomalies field decomposition. **The positive loads of the first PC** characterize subtropical areas, while the negative loads – temperate latitudes, zones of the cold intermediate water upwelling and distribution to the north and north-west.

The second and third PC loads demonstrate zonal and meridional heterogeneity of SST anomalies.

The extended area of the second component positive loads, stretched from the south-east to the north-west along the Peruvian current axis, is distinguished in the north-east. Another extended area with high positive loads of the second PC is located in the south-west between $40\text{-}50^{\circ}\text{S}$, $145\text{-}165^{\circ}\text{W}$. The area of the second PC negative loads extends from the Drake Strait to the north-west with a peak between $42\text{-}48^{\circ}\text{S}$, $95\text{-}110^{\circ}\text{W}$.

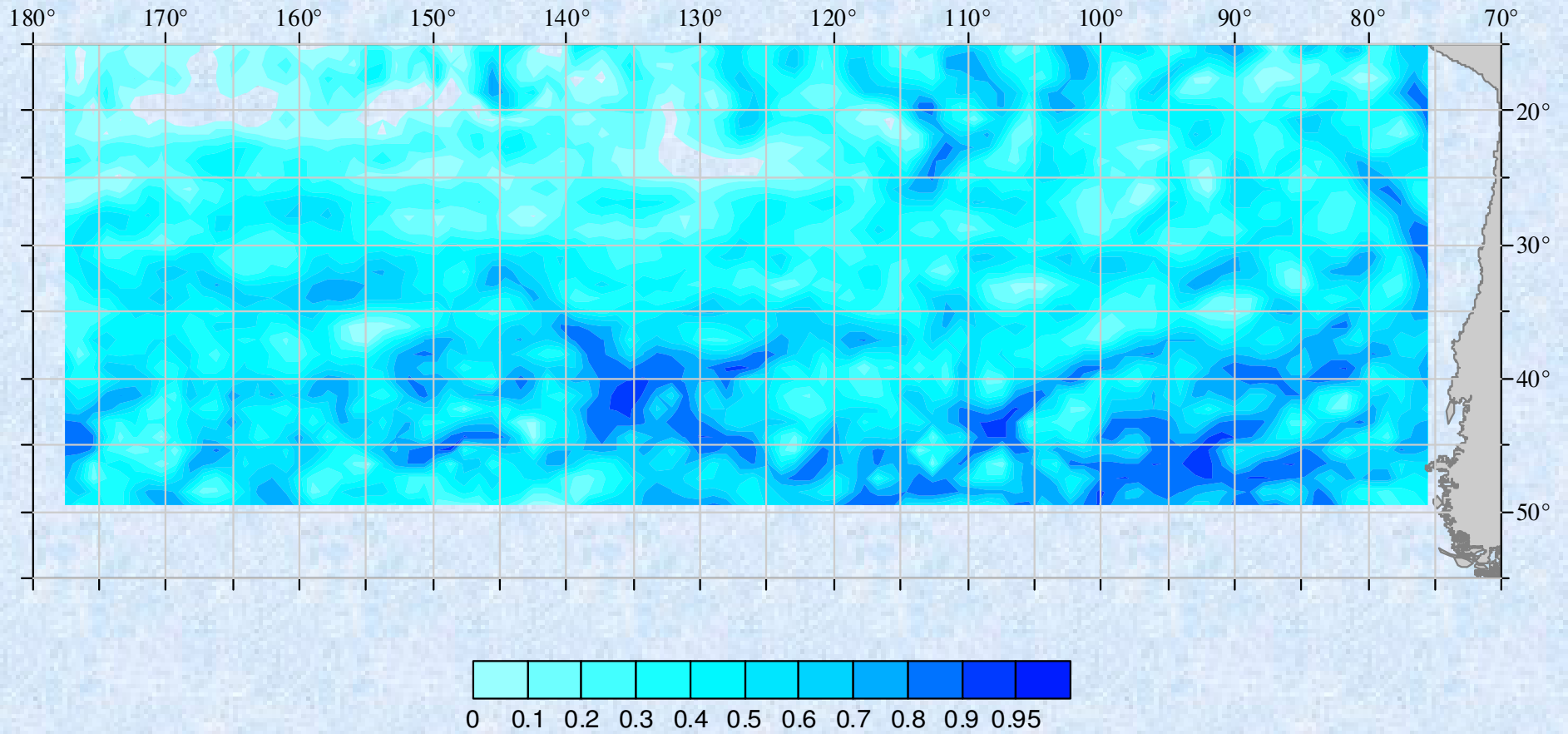
According to the third PC loads, STO is divided into 3 large sub-areas with the boundaries between them at 40 parallel extended approximately along 100°W and 155°W , with the centers at 80° , 125° and 175°W . If one draws the line through these centers, it will approximately correspond to the southern boundary of the subtropical front.

The cycles of 2.8, 3.6 and 5.2 years are clearly distinguished in the inter-annual trend of the first and the second PC.

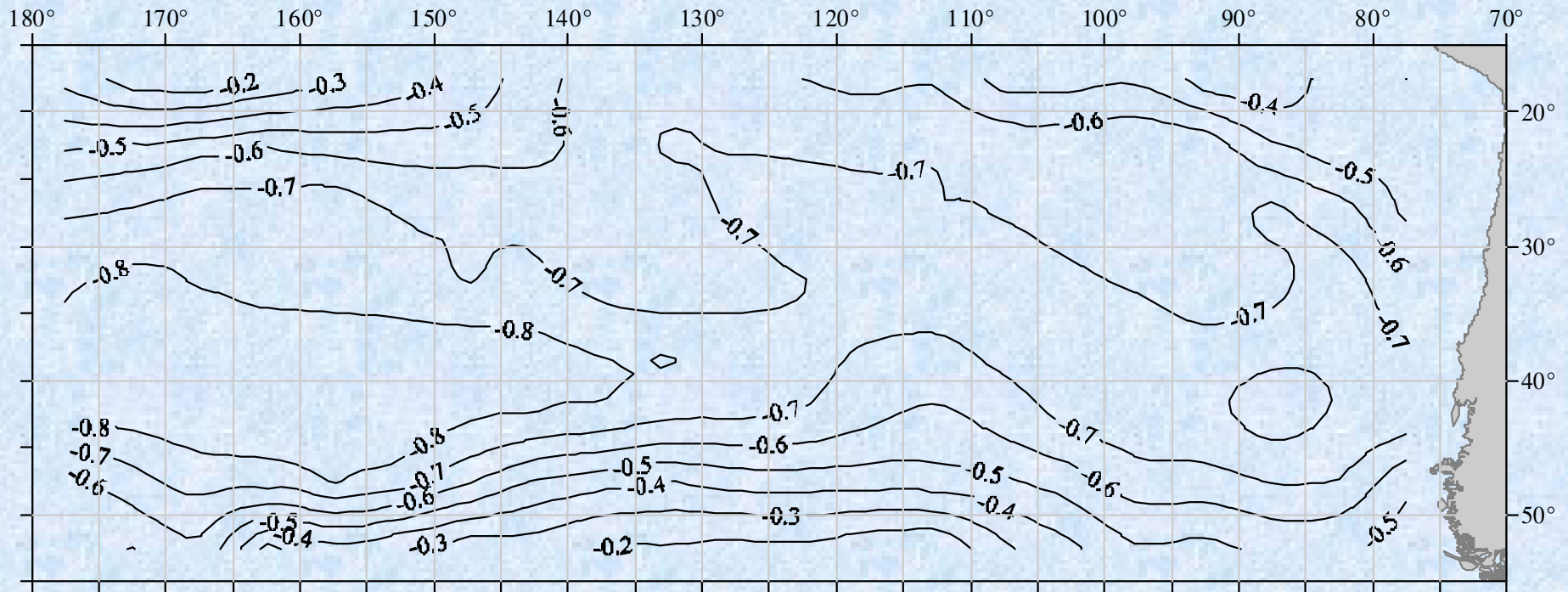
The area classification with the cluster analysis divides it into 5 classes.

Class 1 surrounds STO area from the South America coast at $35\text{-}40^{\circ}\text{S}$ to the north-west, west and south-west up to 50°S and $175\text{-}180^{\circ}\text{W}$. Class 2 is located in the Peruvian Current and Southern Trade-Wind Current areas. Class 3 is situated closer to the central part of the subtropical circulation ($30\text{-}40^{\circ}\text{S}$, $95\text{-}135^{\circ}\text{W}$). Classes 4 and 5 cover the most part of STO to the south of 40°S . The boundary between them is at 130°S .

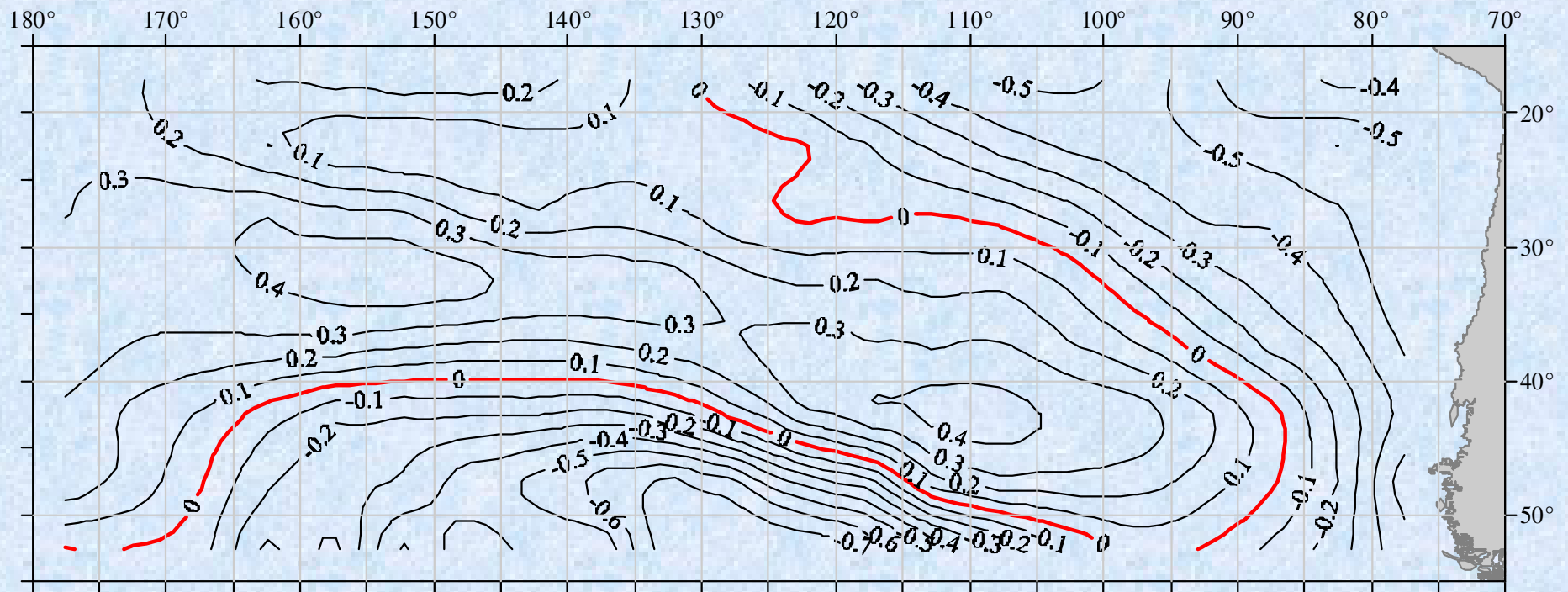
In the inter-annual trend of the mean-class SST anomalies the cycles similar to PC are observed.



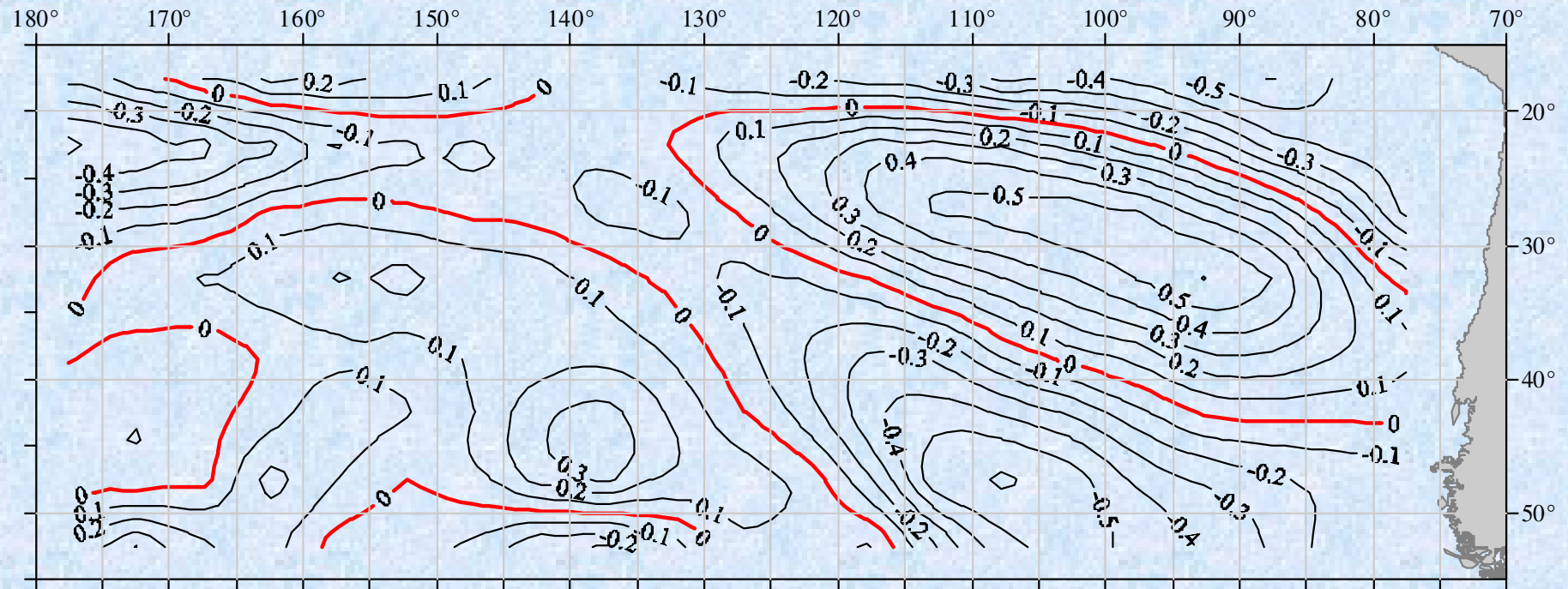
Loading distribution of the first PC of the eddy kinetic energy



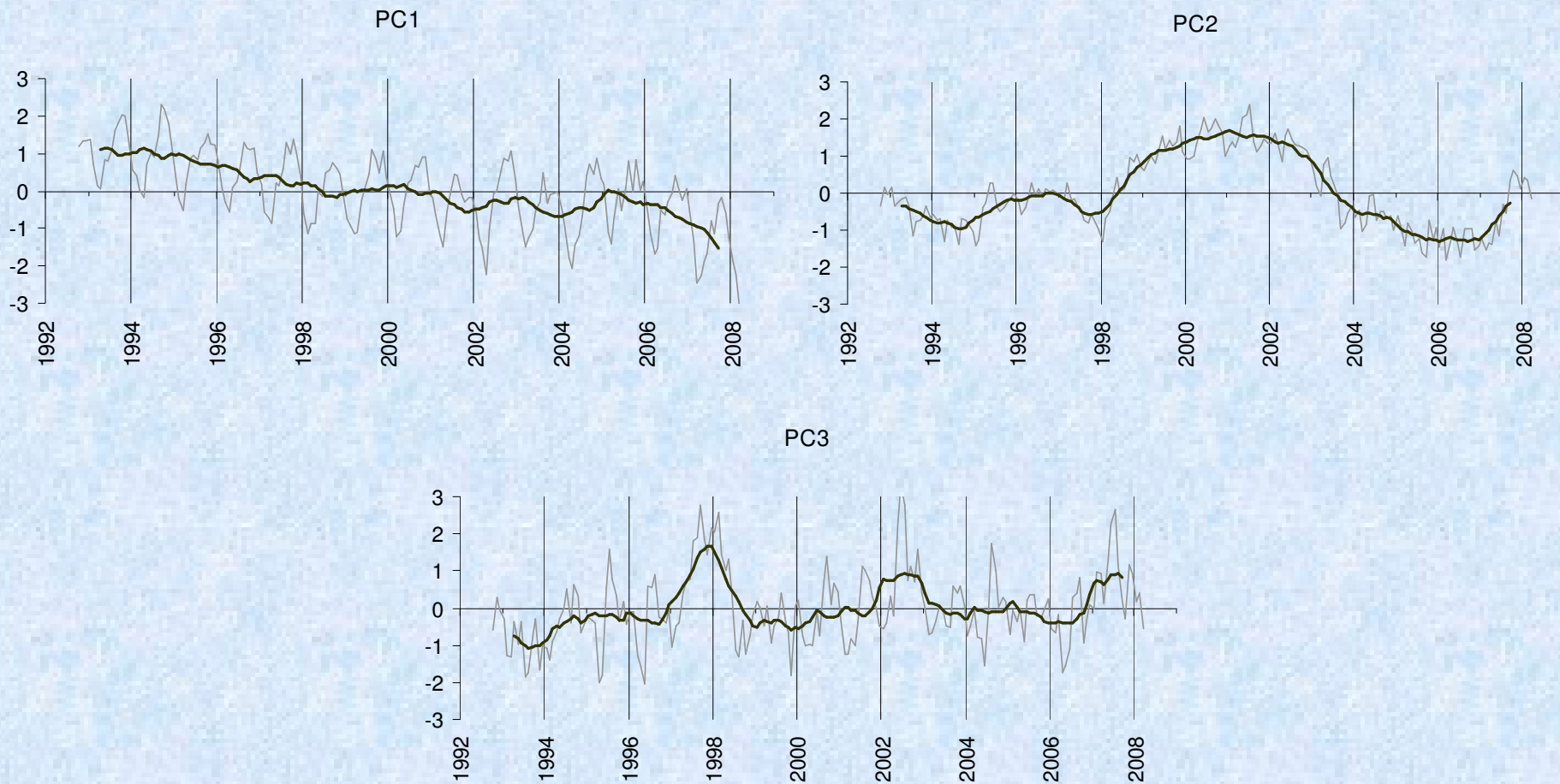
Loading distribution of 1 PC of the sea level anomalies (SLA) field reduction



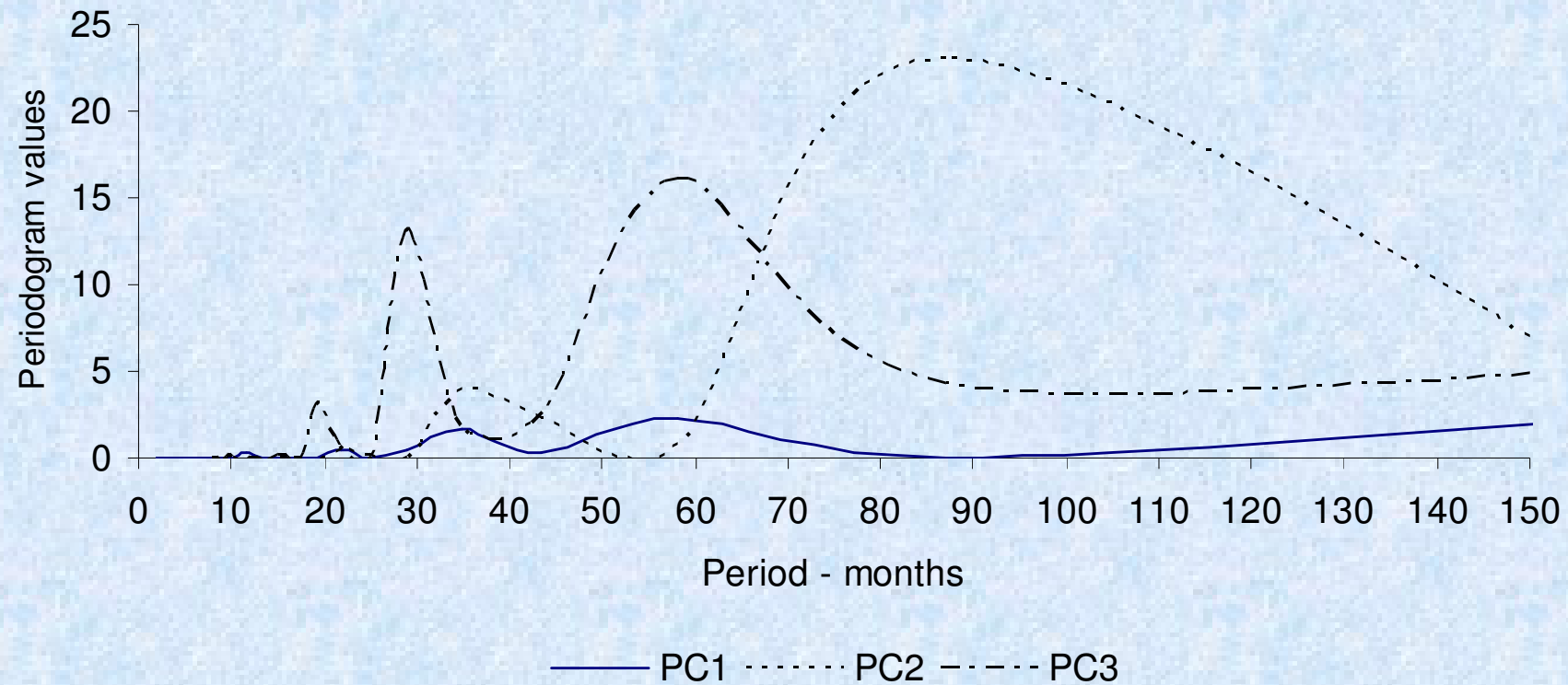
Loading distribution of 2 PC of the sea level anomaly (SLA) field reduction



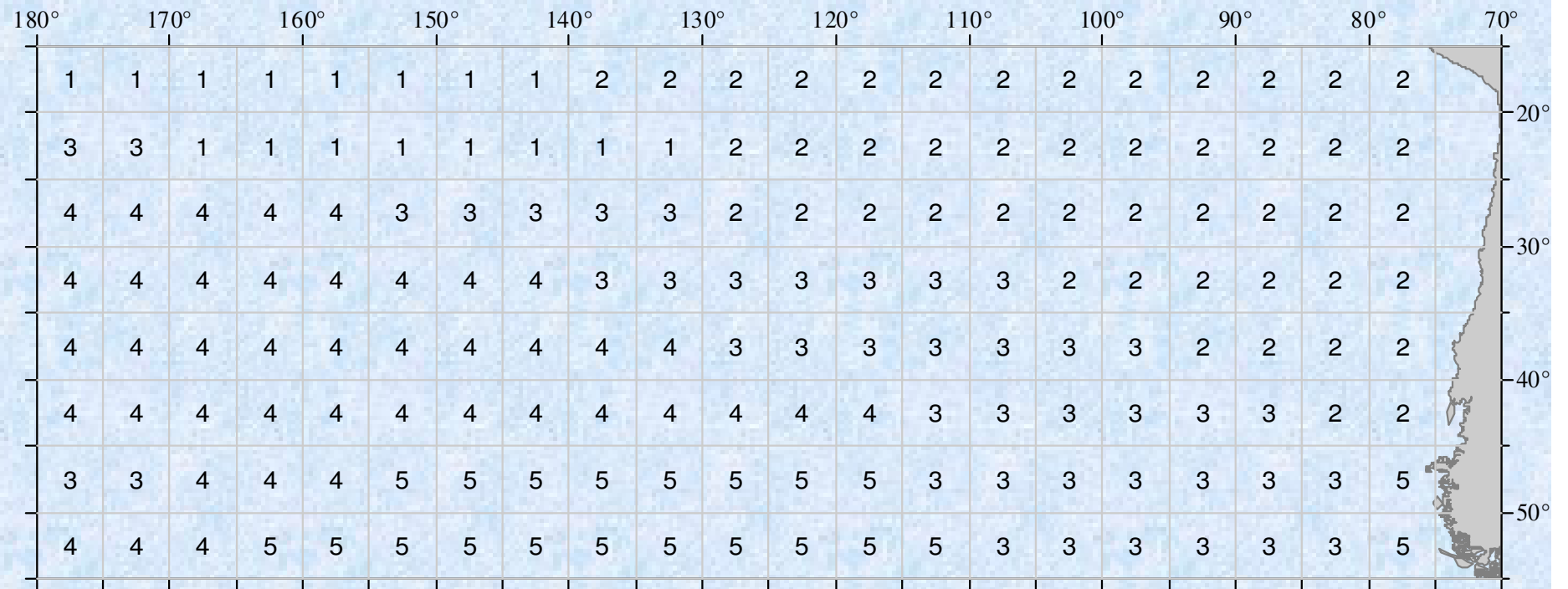
Loading distribution of 3 PC of the sea level anomaly (SLA) field reduction



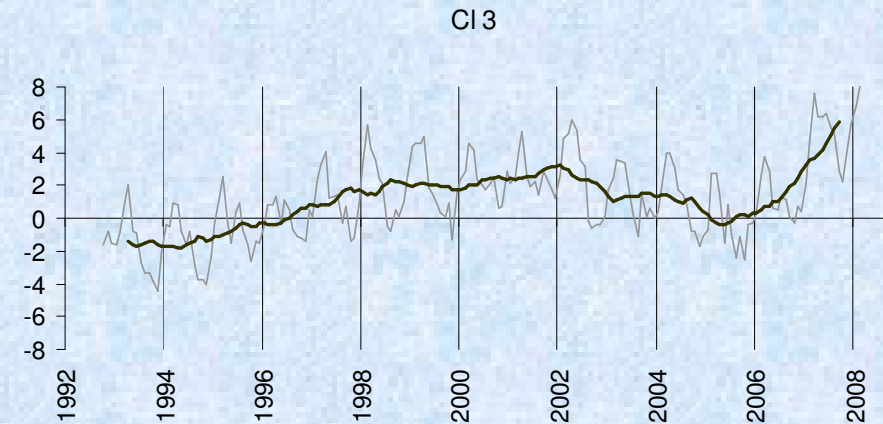
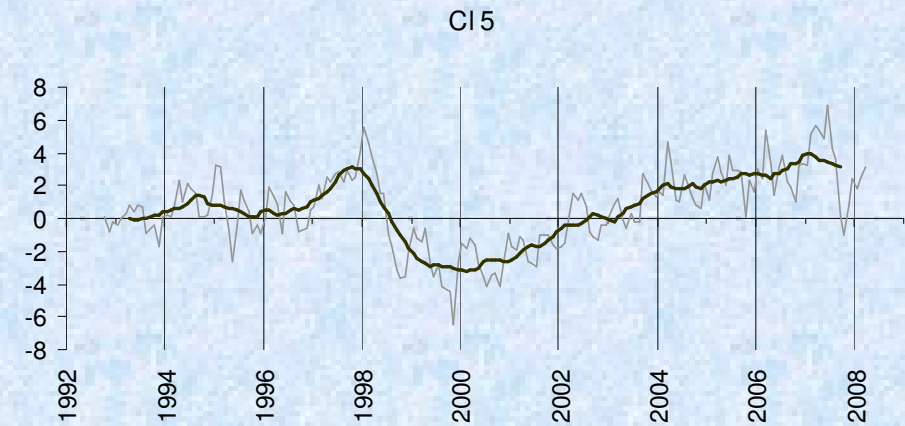
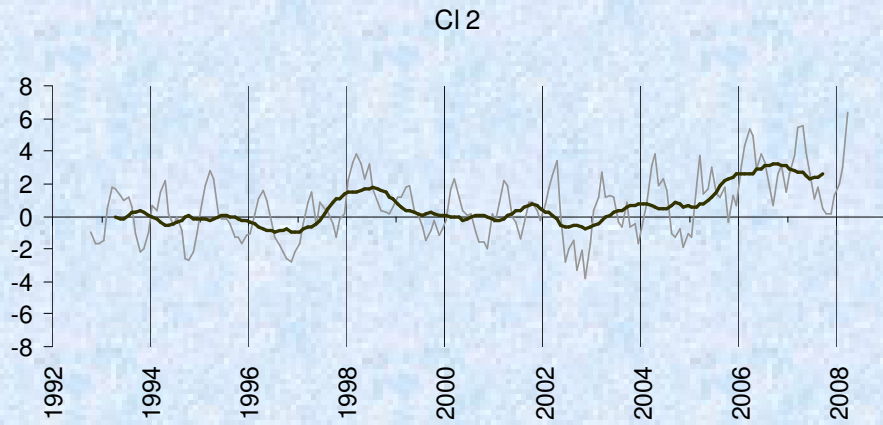
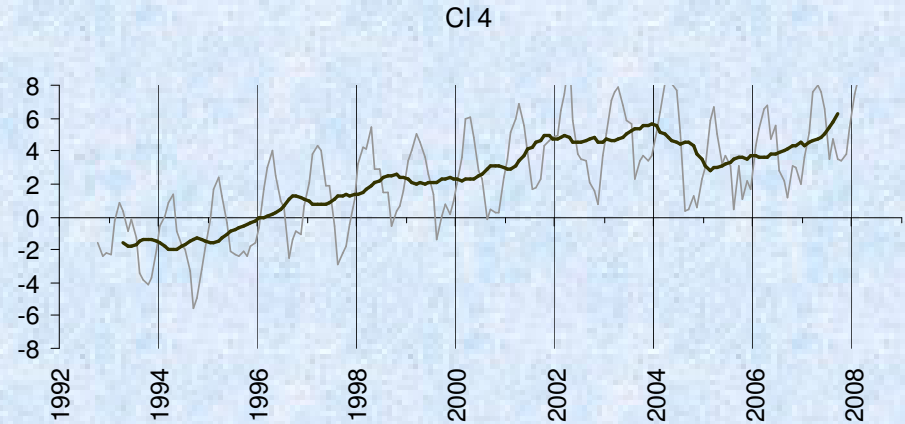
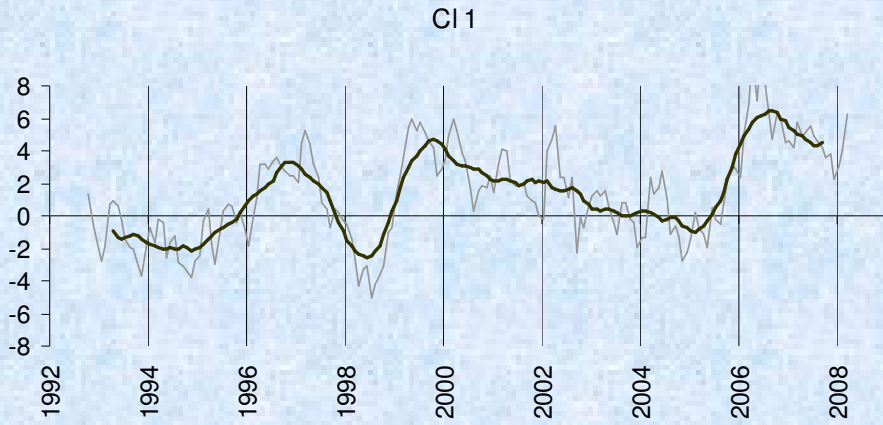
Temporal trend of the first three principle components of SLA field reduction in 5-degree strata



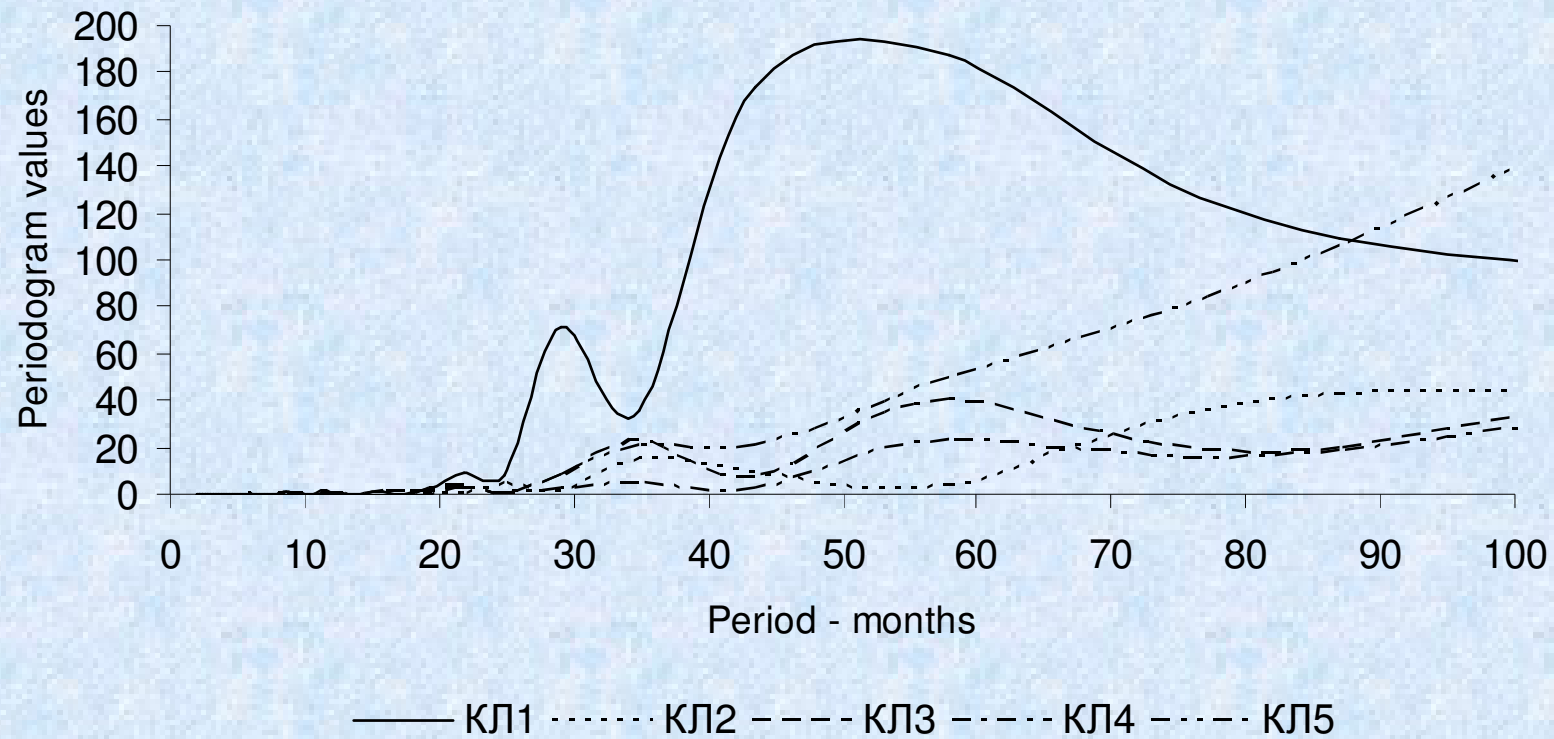
Periodogram of temporal variability of the first three PC for SLA field reduction smoothed by 13 months



Spatial classification of the sea level anomalies in 5°-strata obtained with Word's method (5 classes)



**Temporal trend of SLA anomalies
for 5 classes of spatial
classification**



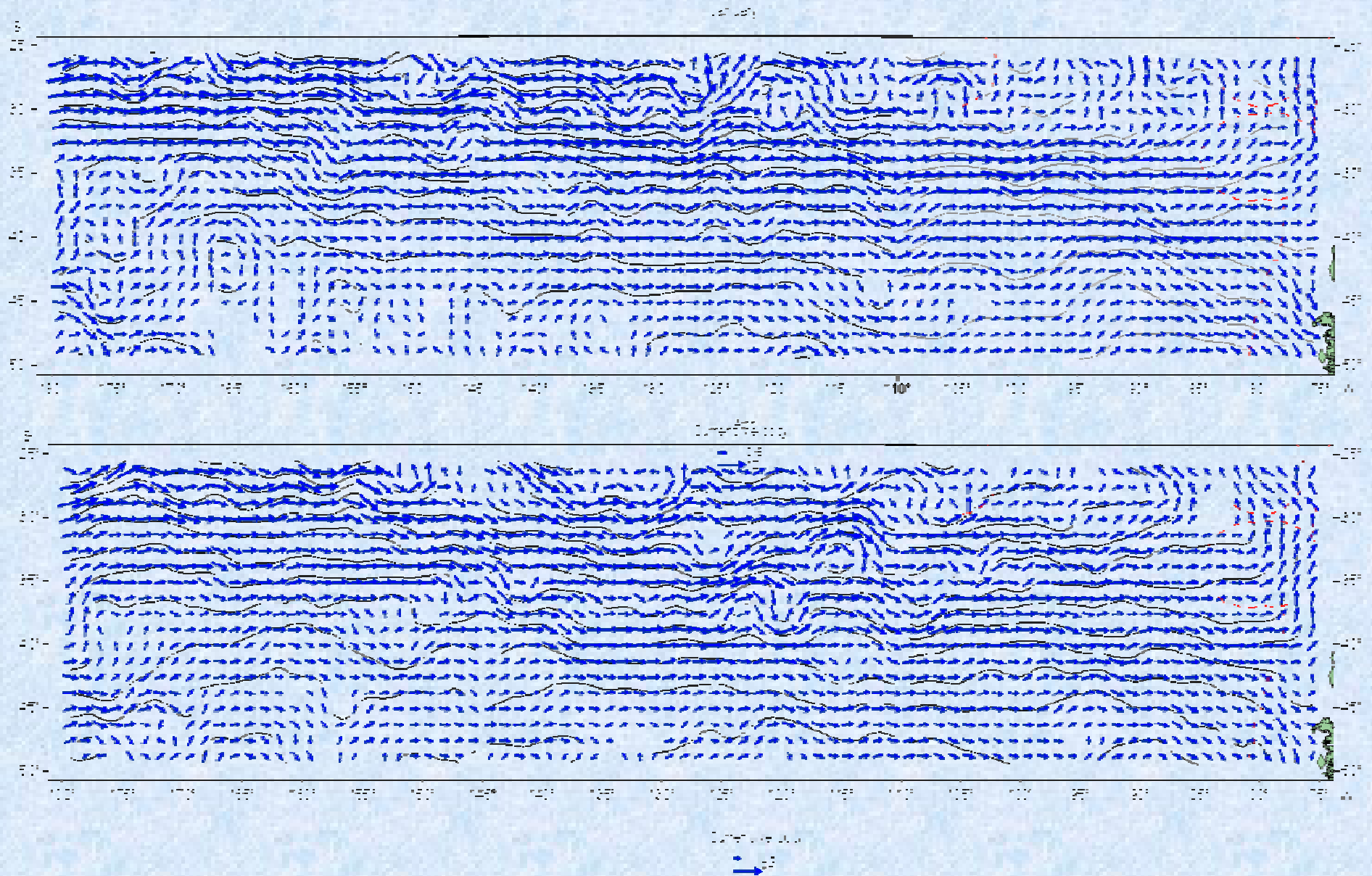
Periodogram of temporal variability of average-class sea level anomalies in 5-degree strata smoothed by 13 months

Resume for the fields of the ocean level anomalies field.

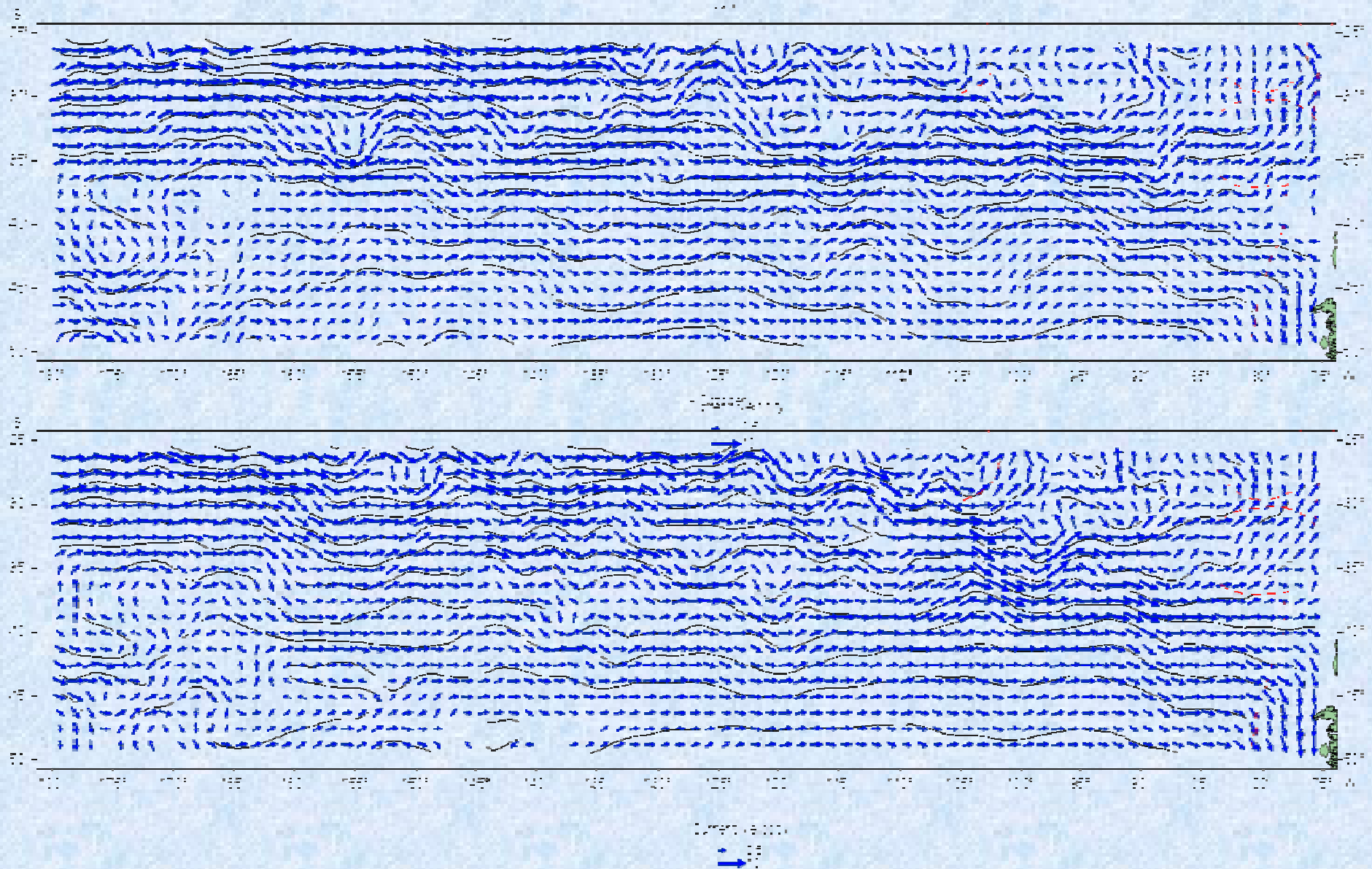
The ocean level anomalies provide information on the currents field. They allow to calculate the geostrophic velocity anomalies, absolute velocity of the geostrophic currents, kinetic eddy energy (KEE) being maximum in the jet flows with high velocities from 25 to 50 cm/s and higher.

Currents at the boundaries of STO subtropical circulation are characterized with velocities from 1 to 20 cm/s on average. On the map of average long-term eddy energy their velocity values do not exceed 25 cm²/c².

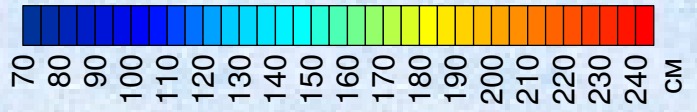
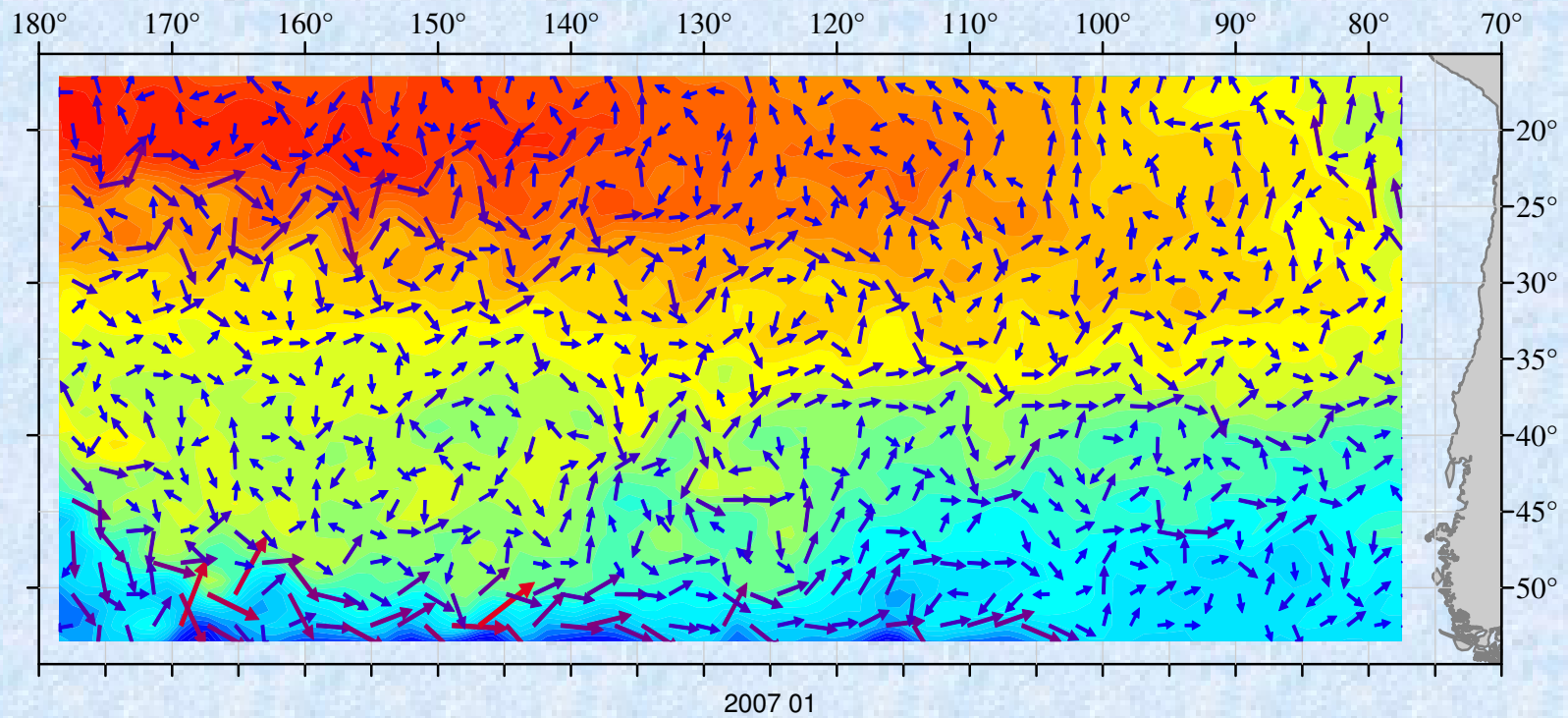
The first principle component characterizes redistribution of the eddy kinetic energy (EKE) over the entire study area during the whole observation period. Its maximum loads (correlated with EKE field) are concentrated in the areas with EKE concentration (accumulation), i.e. in the areas with the most frequent formation of eddies and meanders.



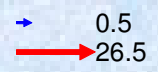
Current velocity distribution in January and April (Levitus 2003)

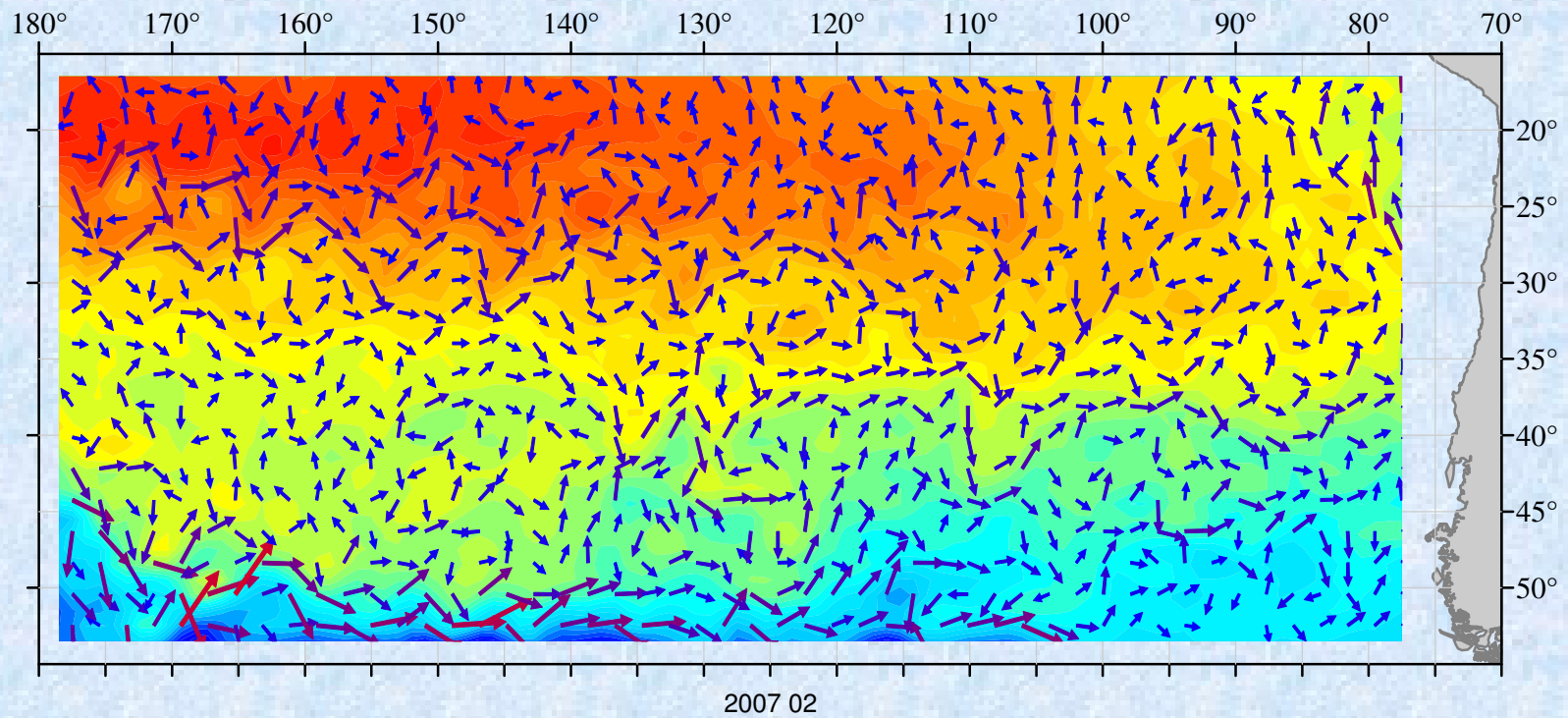


Current velocity distribution in July and October (Levitus 2003)

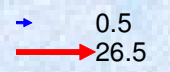


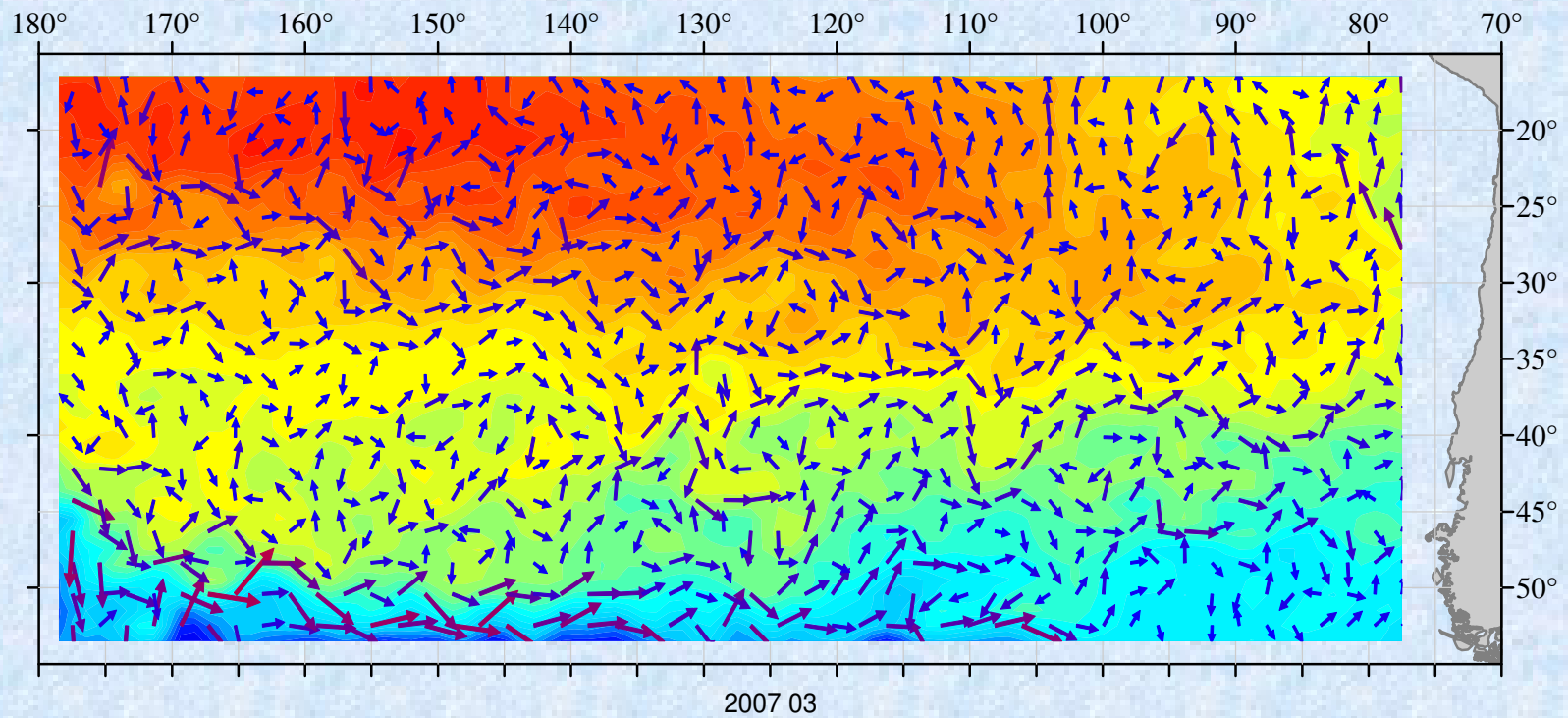
Вектора течений, см/с



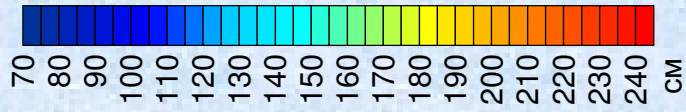


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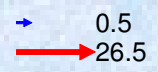


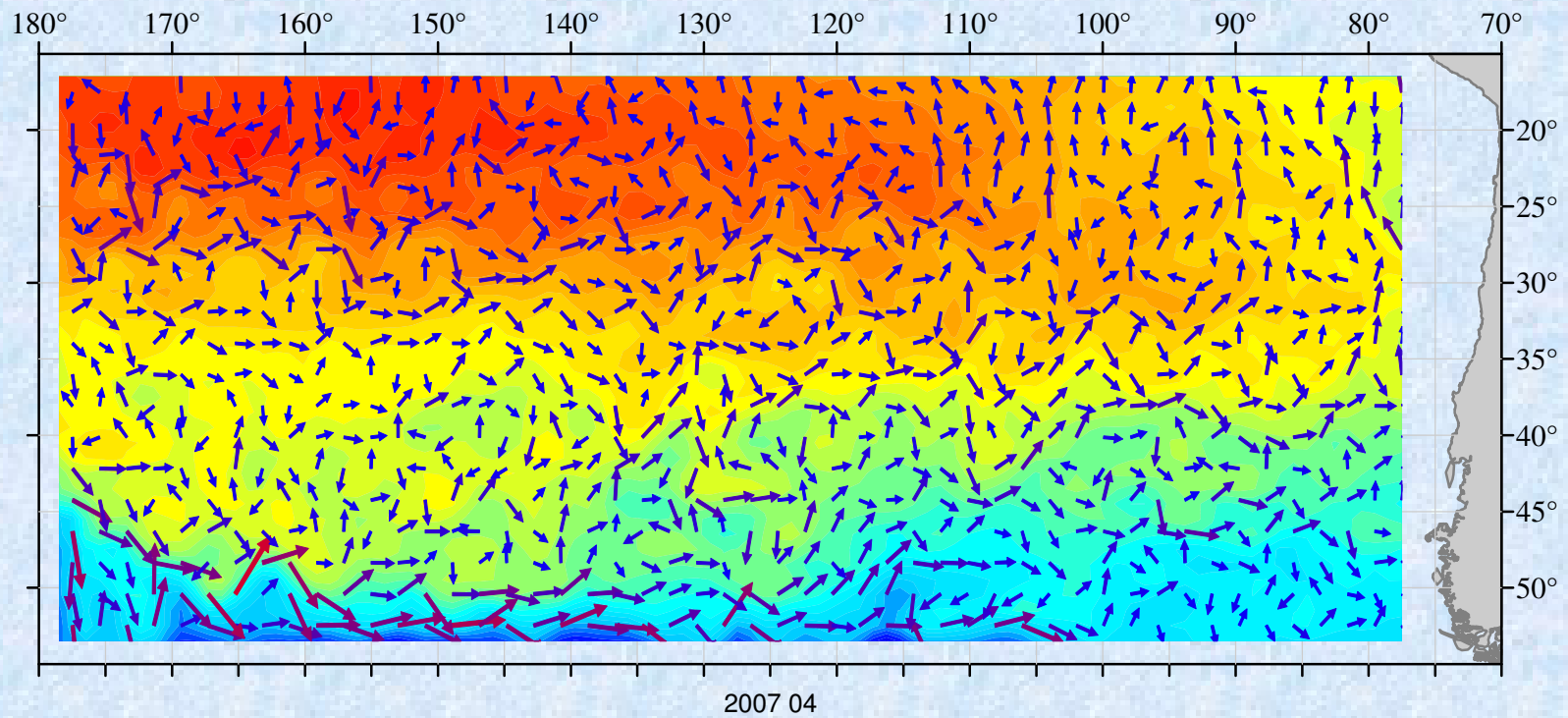


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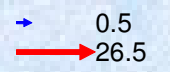


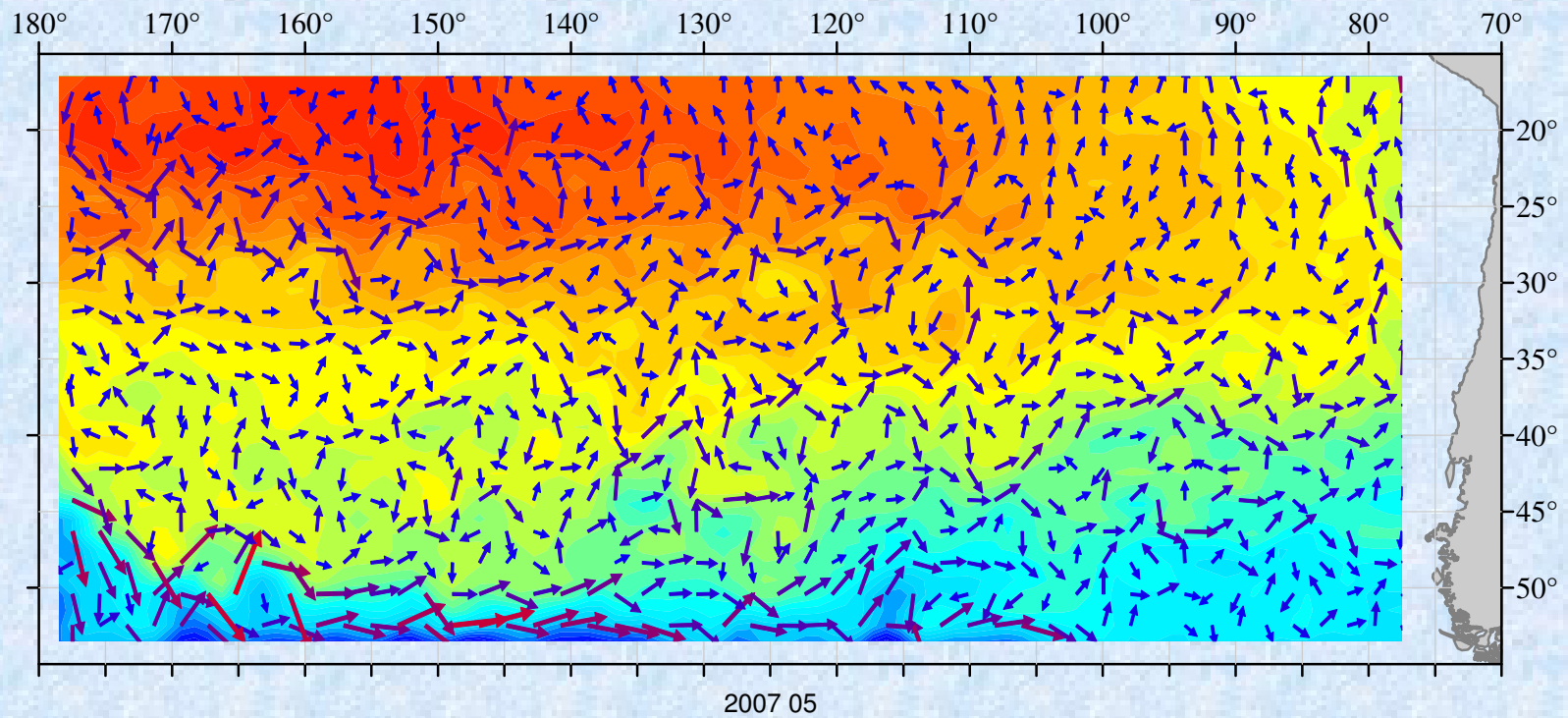
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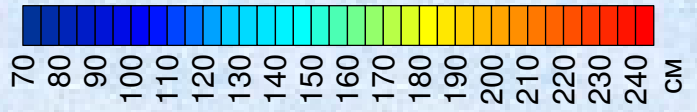
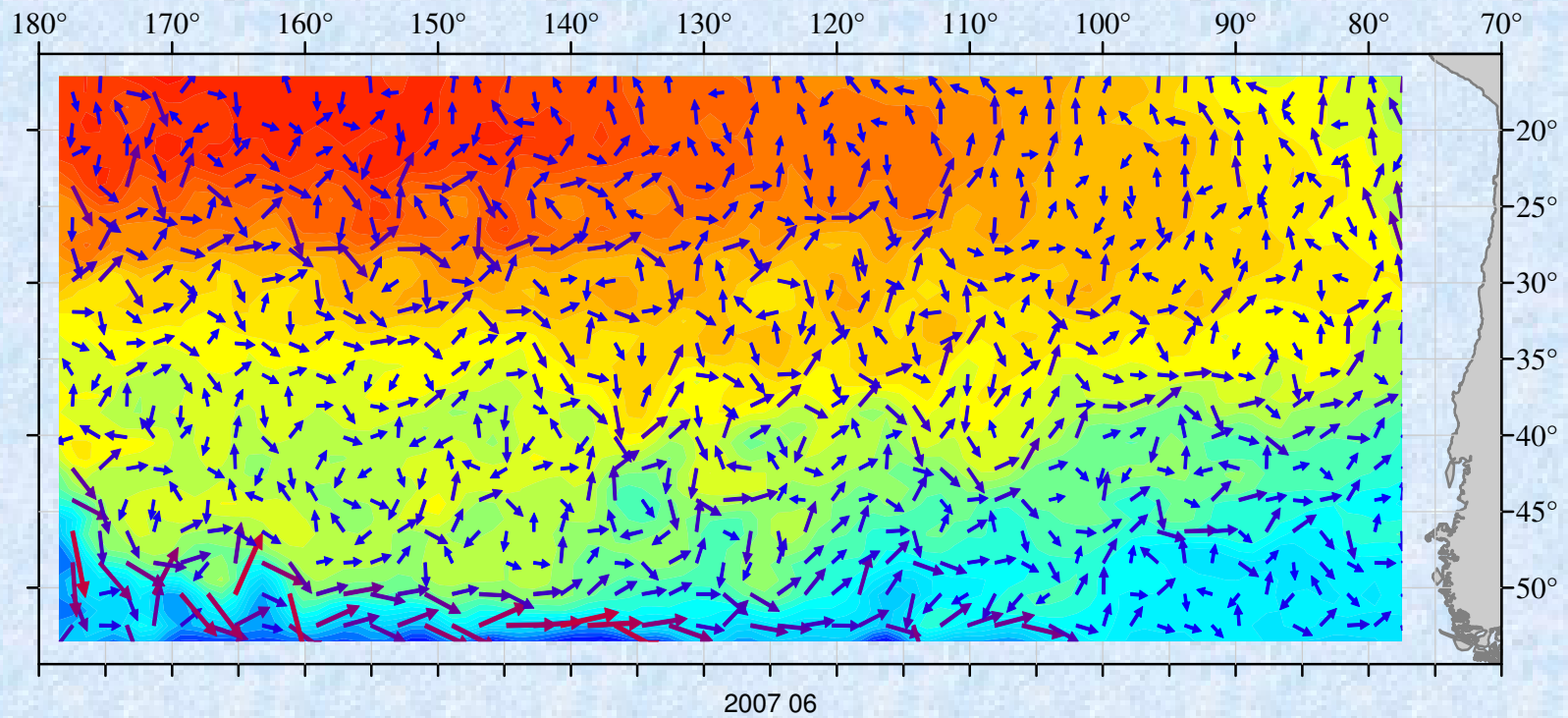




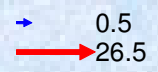
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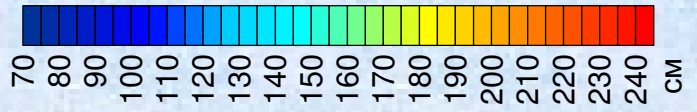
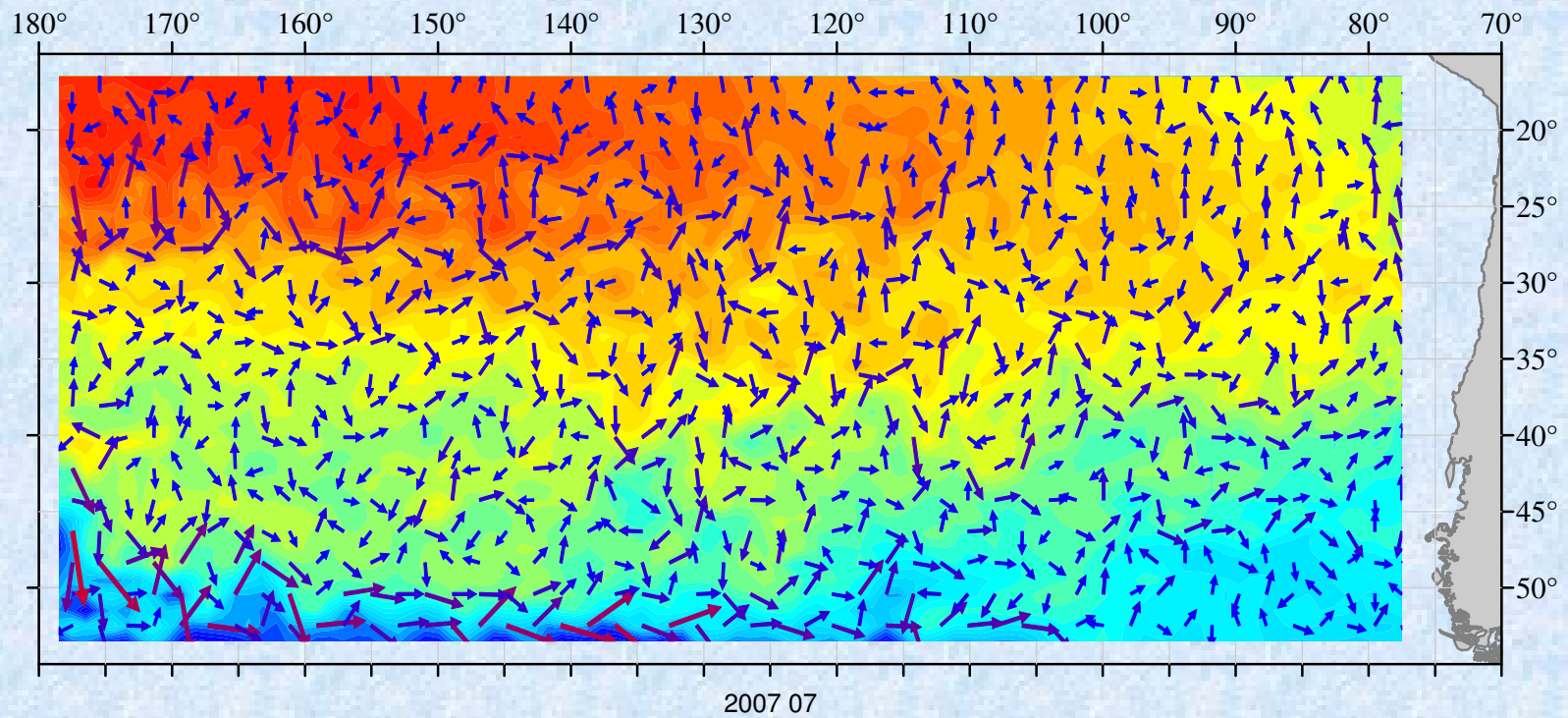




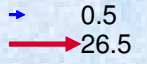


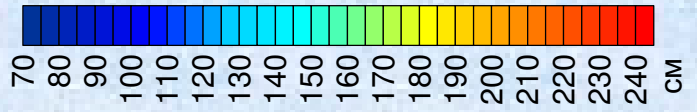
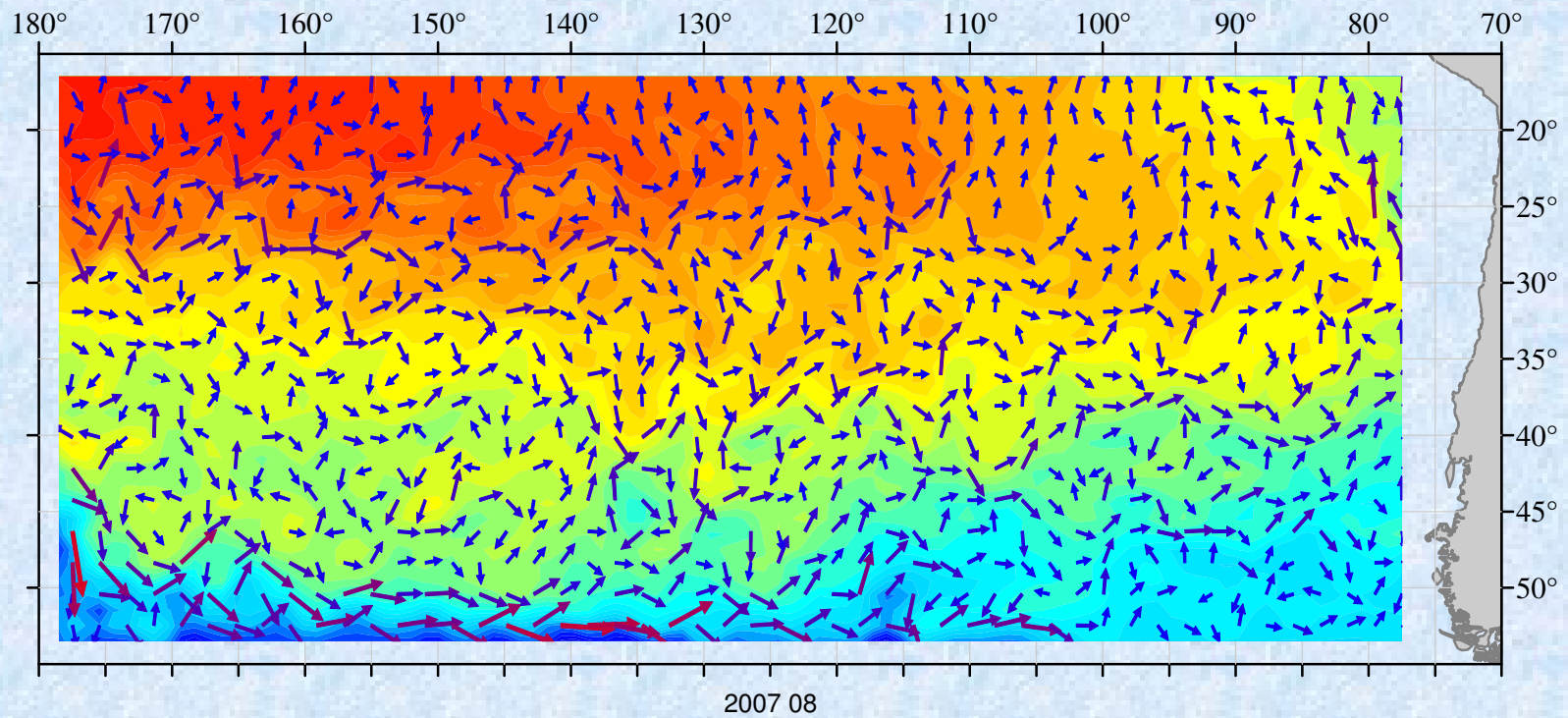
Вектора течений, см/с



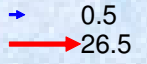


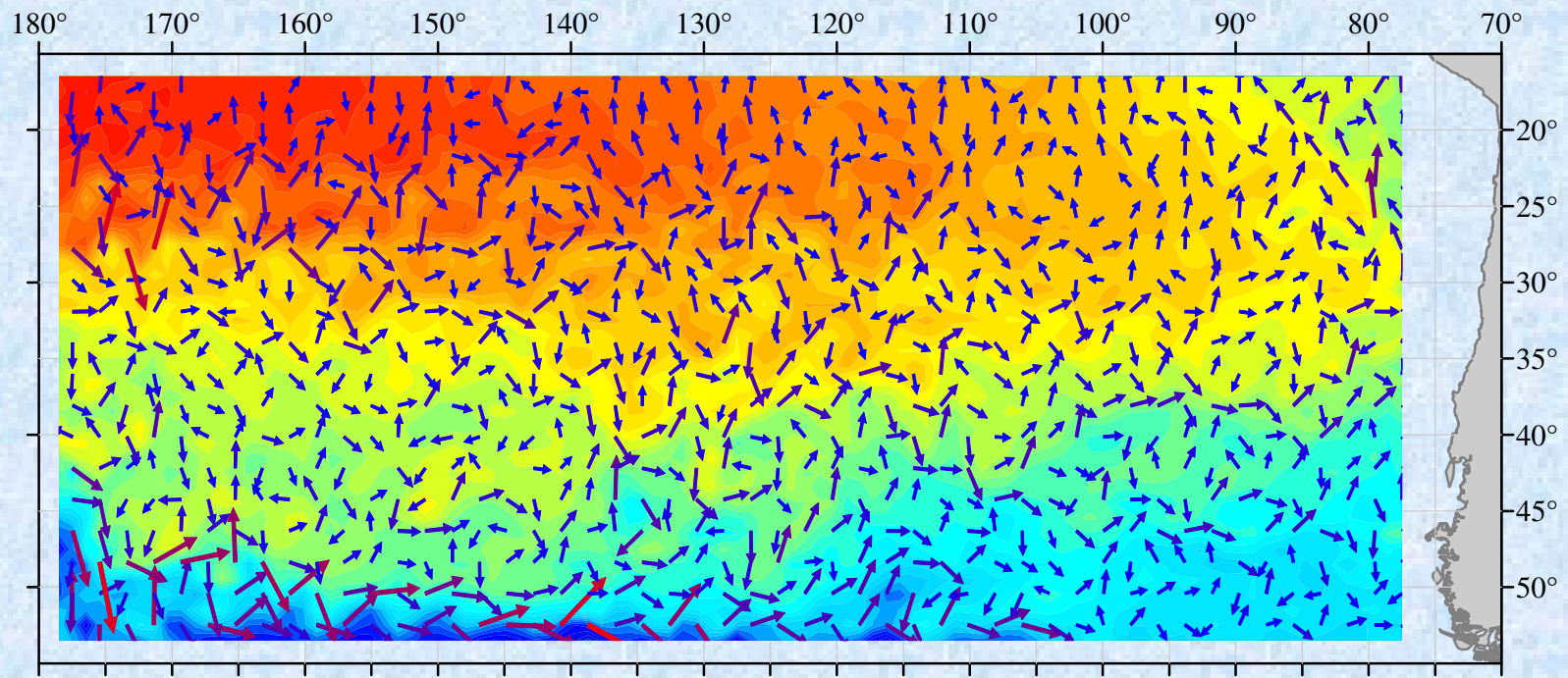
Вектора течений, см/с



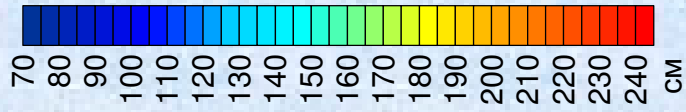


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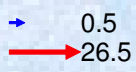


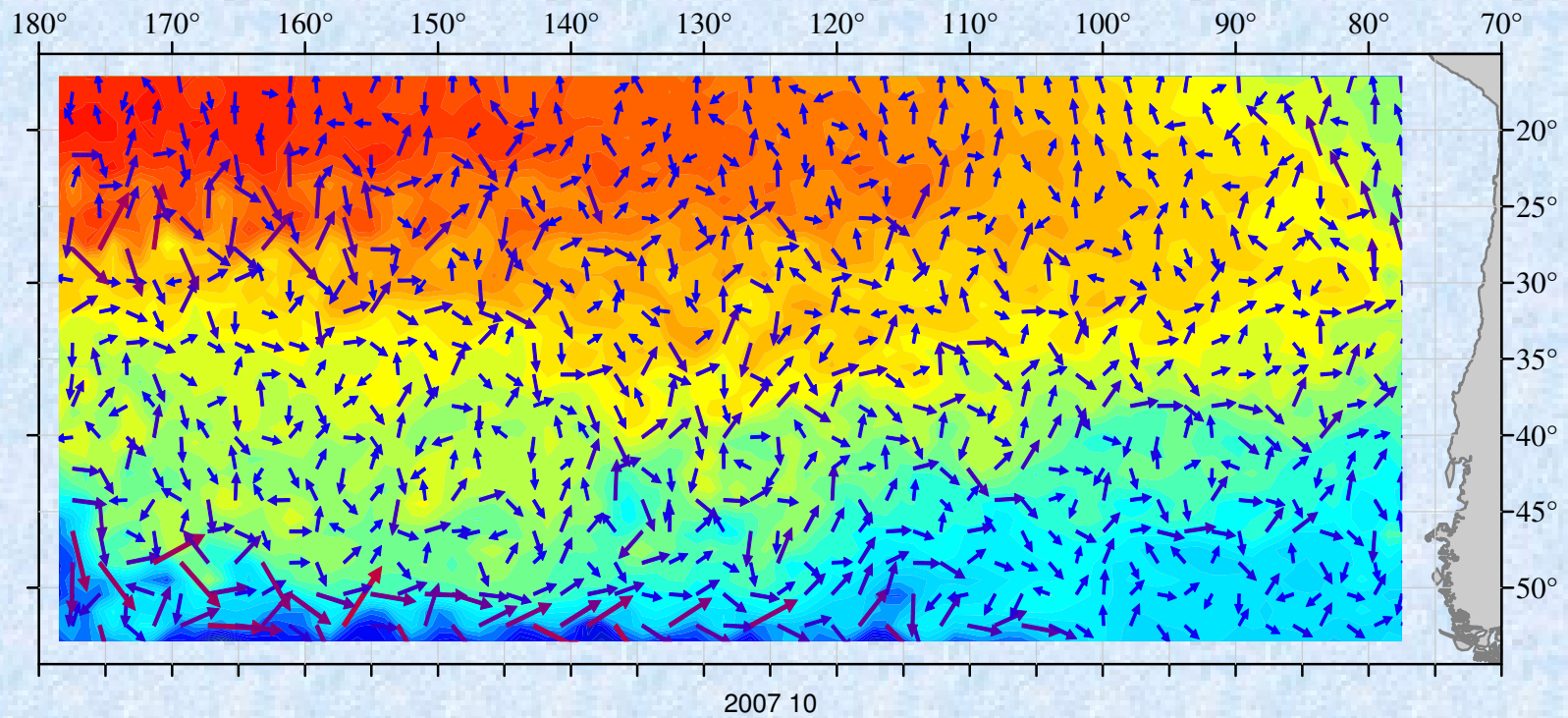


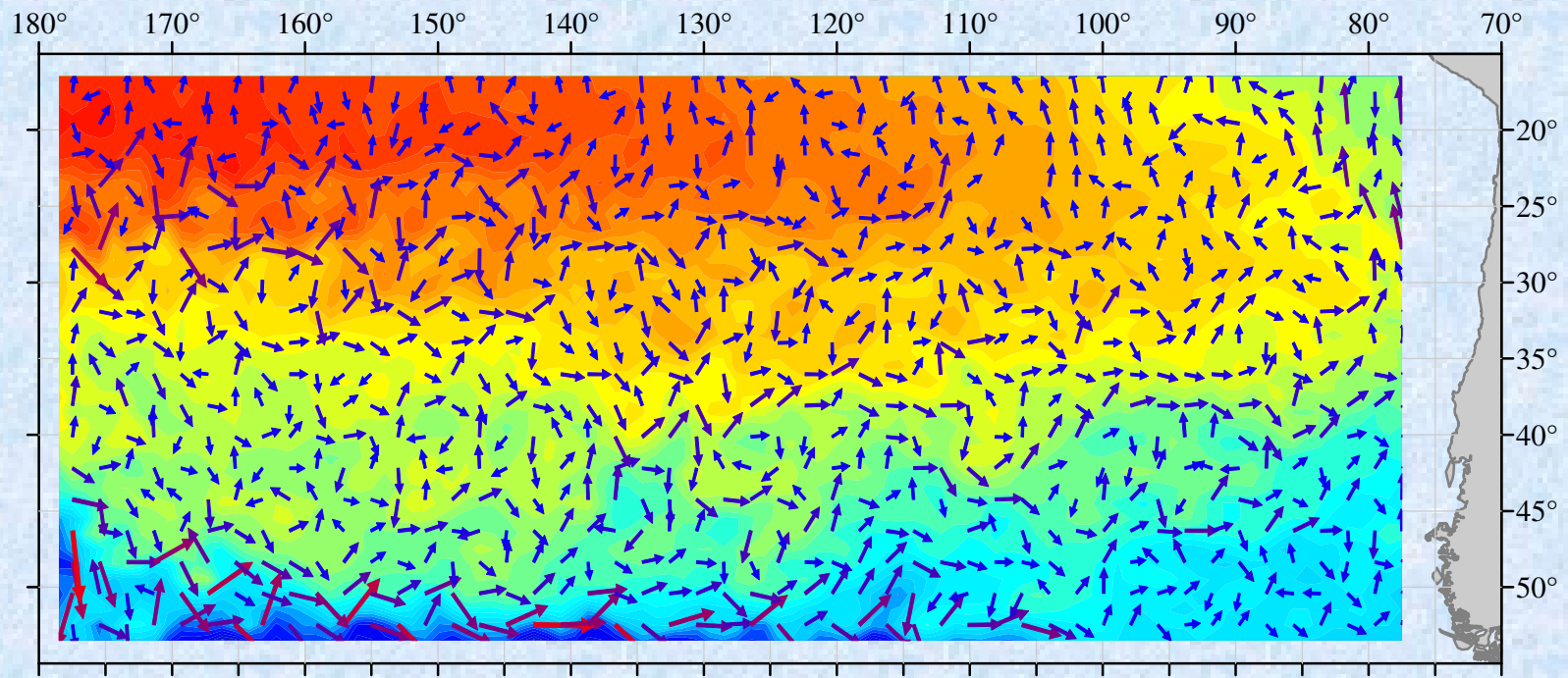
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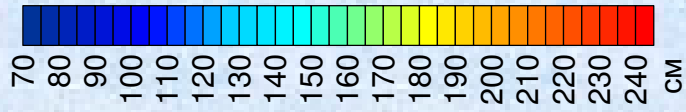
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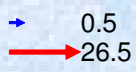


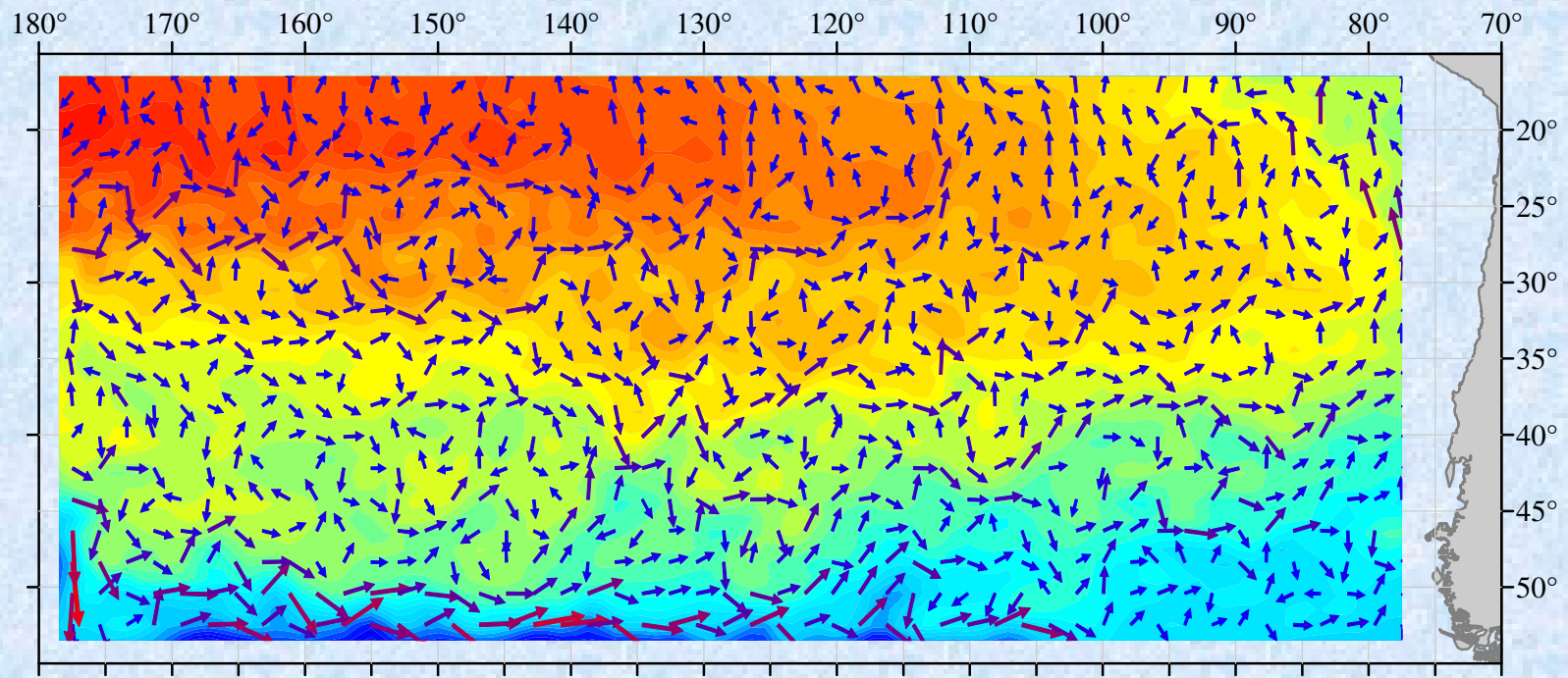


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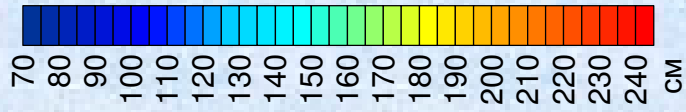


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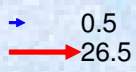


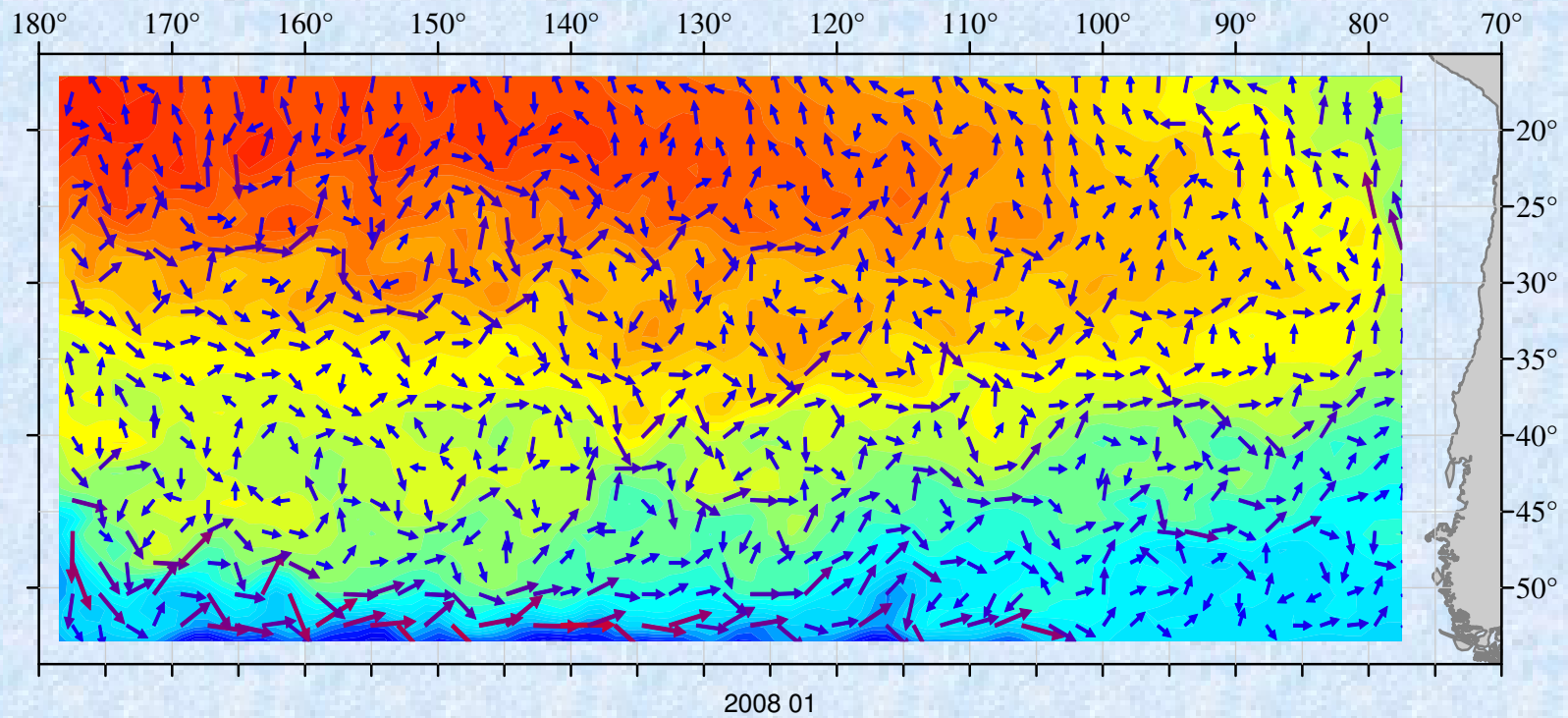


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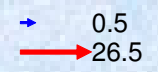


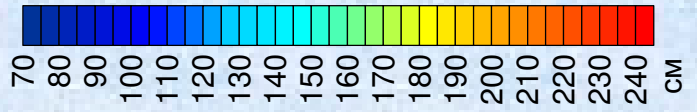
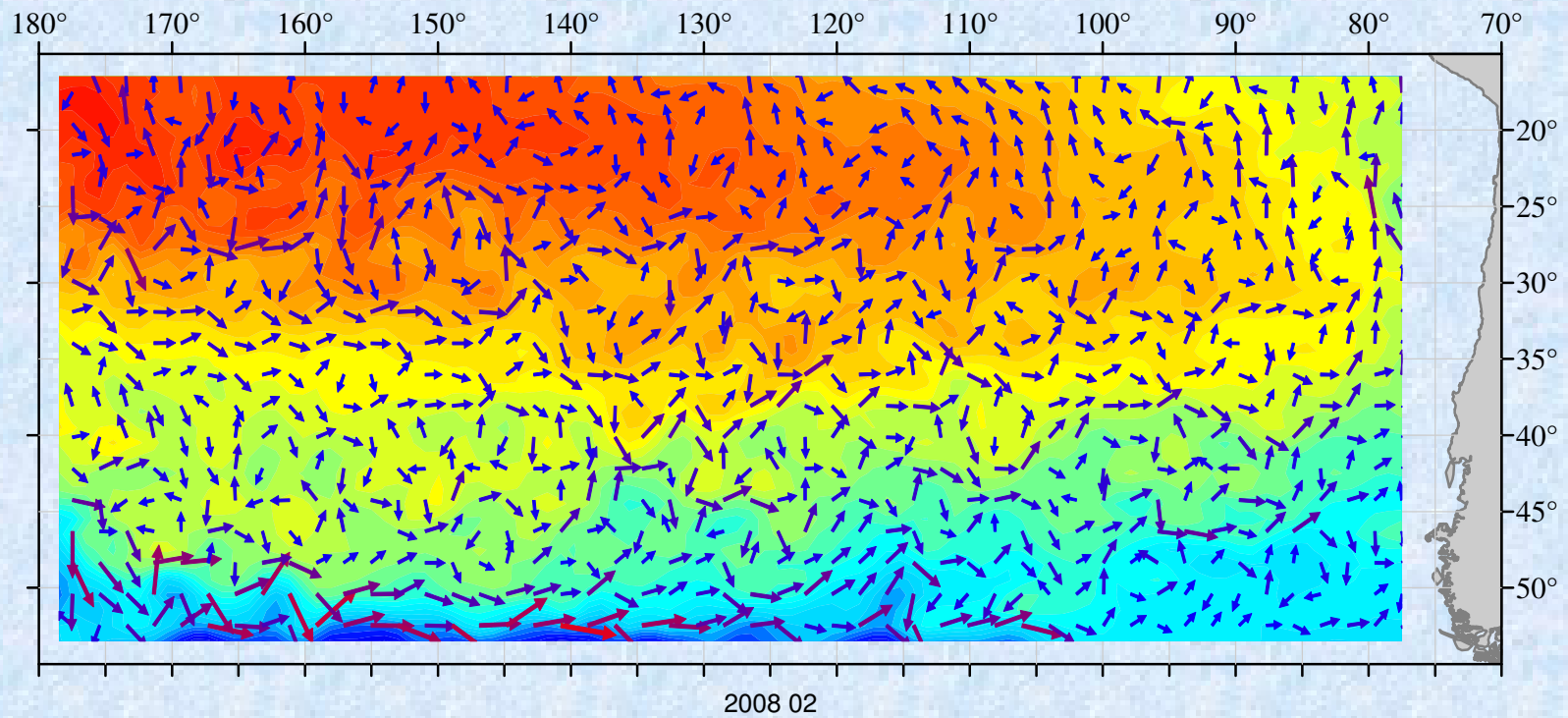
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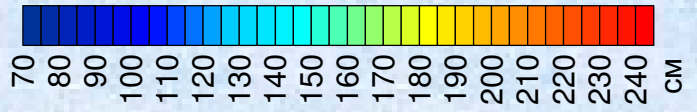
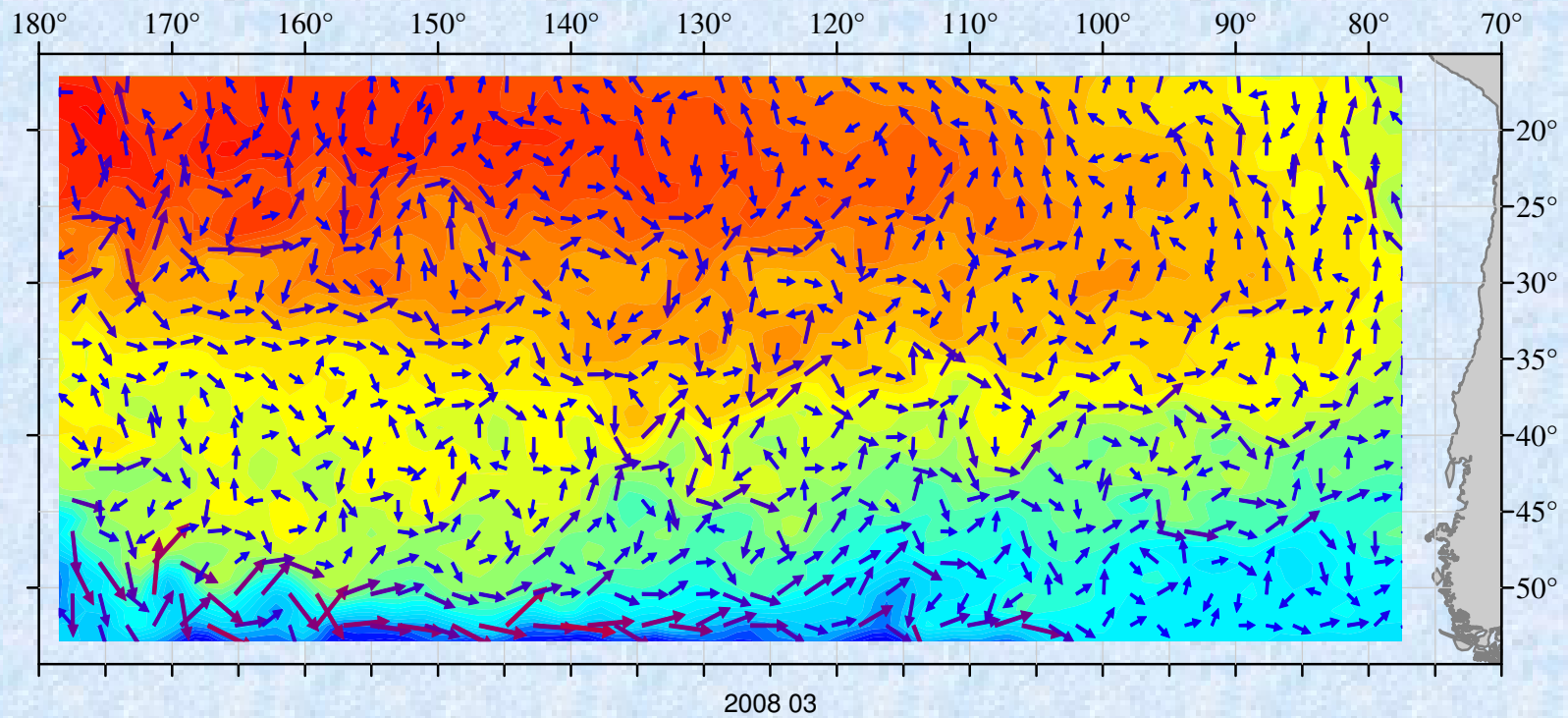
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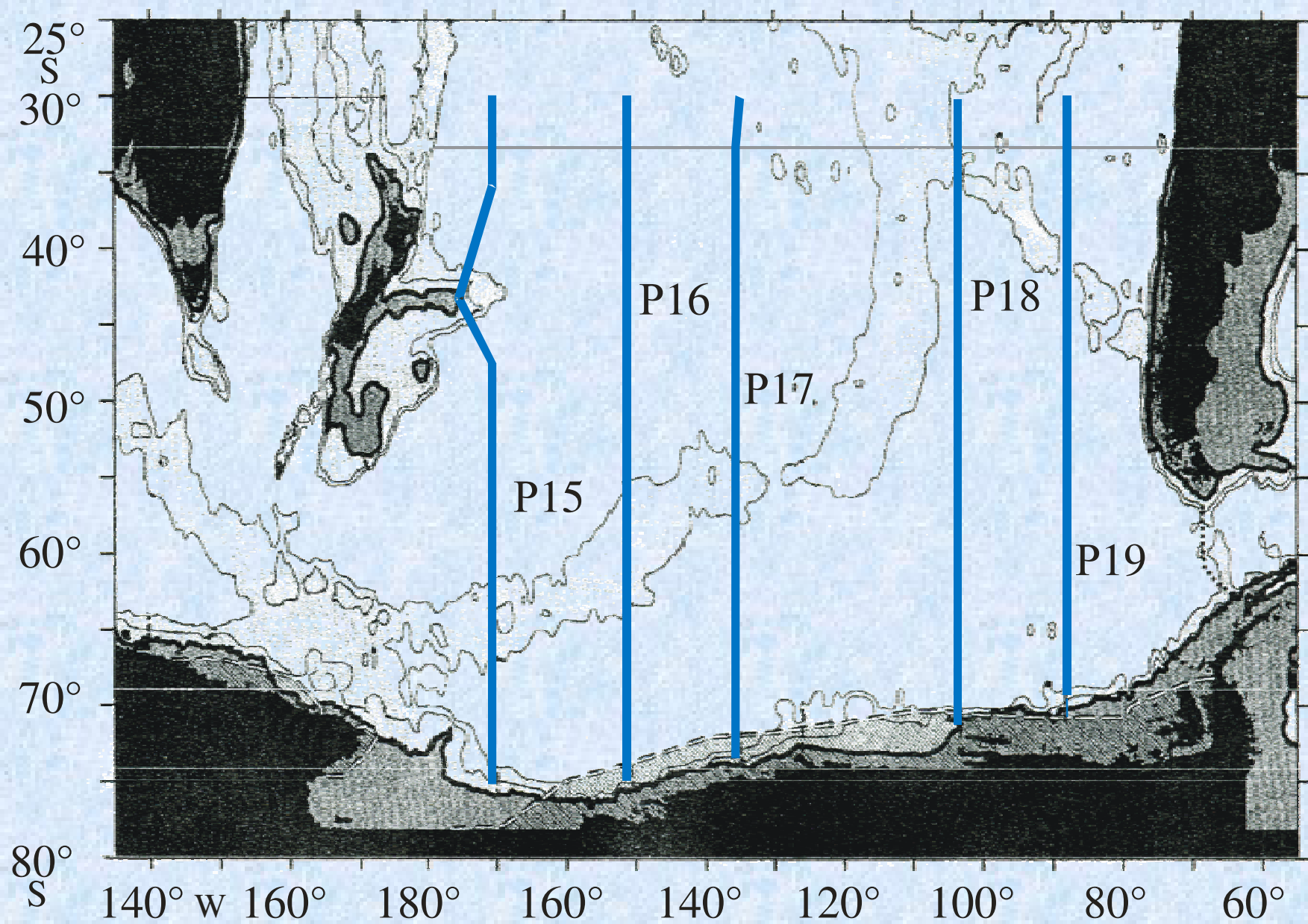
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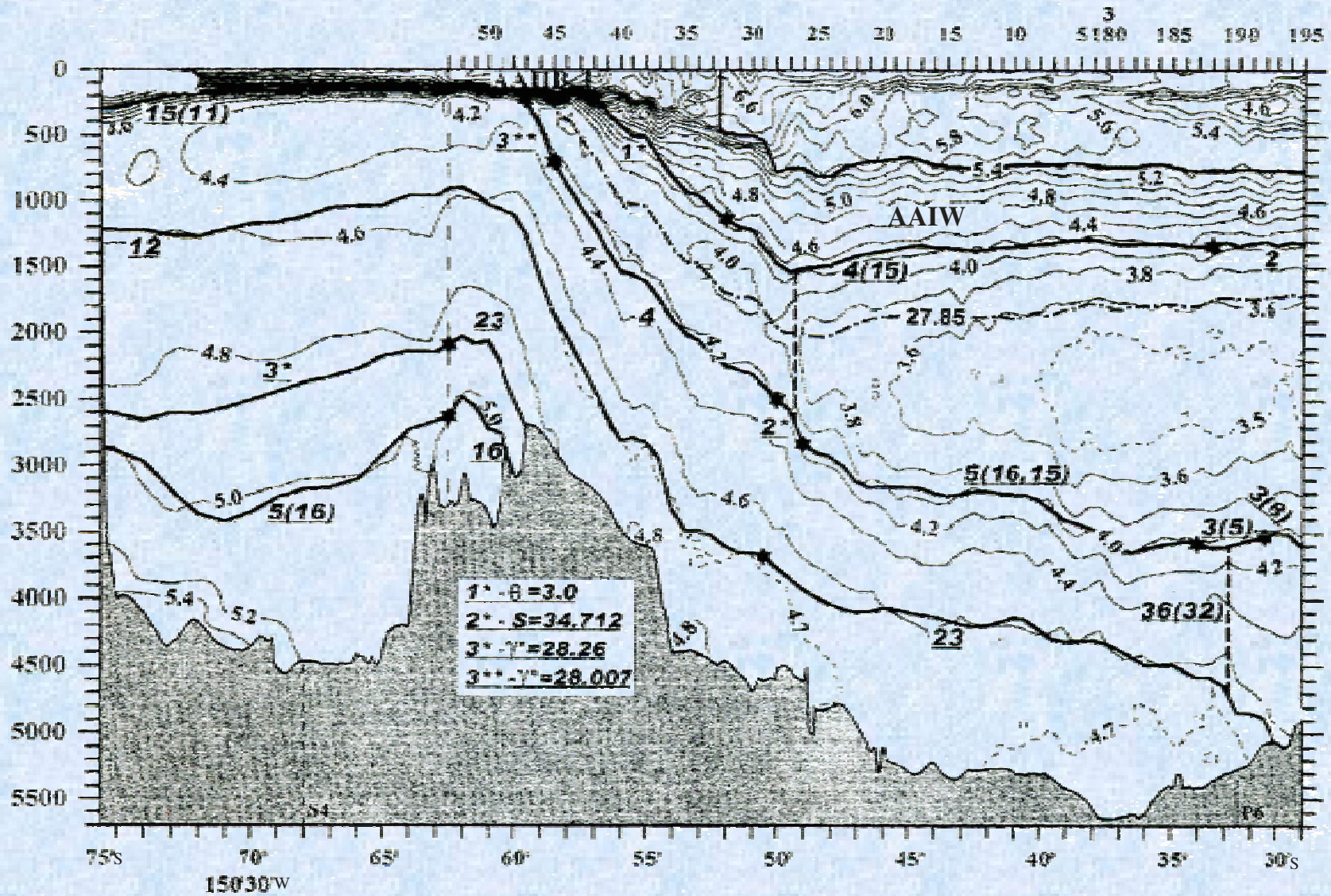


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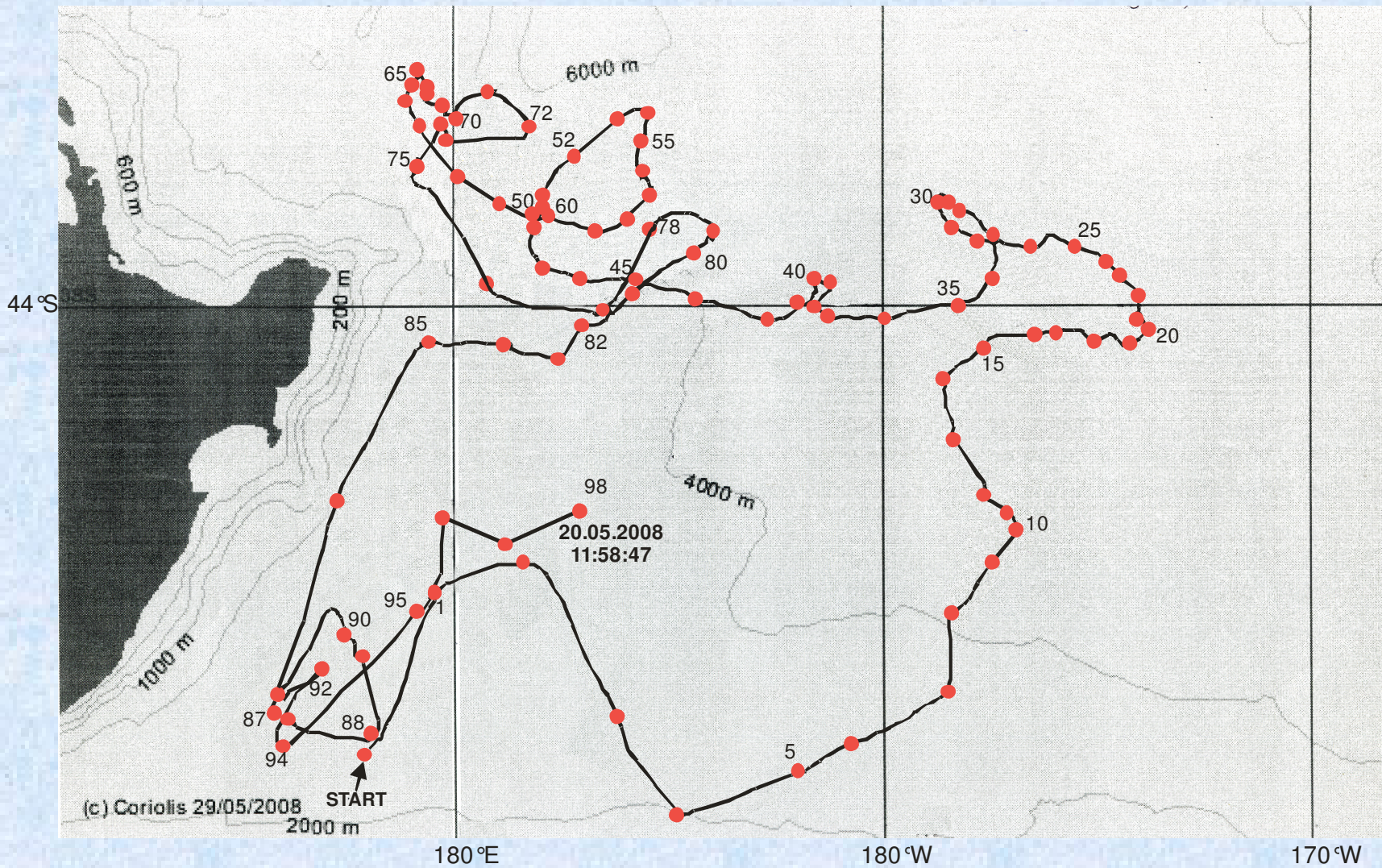




Oceanological transects, WOCE project (1993-2002)



Distribution of the main water masses in the Southern Pacific Ocean



Trajectory of drifting buoy (project “Argo”) 22.10.2005-20.05.2008

CONCLUSIONS

Analysis of the principle components and classification (Word's method) of the atmospheric pressure and sea-surface temperature fields allowed to reveal the areas considerably differed in the seasonal and inter-annual variability pattern in the South Pacific Ocean.

Analysis of the ocean level anomalies on the basis of satellite altimetric data allowed to determine zones of intensive eddies formation associated to the main frontal zones of the ocean upper layers.

The results of measurements under WOCE and ARGO programmes indicated the existence of 3 closed circulations of the Antarctic intermediate water mass rich in nutrients. This water mass is ascending to the surface with mesoscale eddies facilitating existence of relatively isolated zones with high biological productivity. In these zones the existence of individual jack mackerel stock units is possible.

Since the oceanological conditions considerably affect the pelagic ecosystem structure and jack mackerel stock in the Southern Pacific Ocean, the further researches in the following directions are required:

- creation of the uniform data base of retrospective oceanological data applying the advanced methods of the data storage, processing and analysis (e.g. GIS-technologies);
- development of the efficient monitoring system for oceanological conditions, using satellite sounding the ocean surface and measurements from the research and fishing vessels.