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Microclimatic variations of land surface temperature on Galindez Island (western part of the Antarctic Peninsula)

Abstract. The study presents analysis of microclimatic conditions on Galindez Island (western part of the Antarctic Peninsula), in particular: seasonal variability and spatial heterogeneity. Based on land surface temperature (LST) data derived from loggers and MicroClimate Monitoring Station, we analyzed areas with active growth of local plants. Seasonal variations formed mainly under annual and semi-annual cycles, with no dependencies of amplitudes and phases form area location. LST highly correlates with air temperature and total incoming irradiance. It is emphasized that spatial orientation of relief microforms plays the most significant role for LST formation on micro-level. Using cluster analysis, it was found that temperature loggers which are located along shoreline and oriented to the north—north-east could be grouped by similar LST distribution.

Keywords: Antarctica, land surface temperature, logger, microclimate, seasonality

1 Introduction

Under current climate change, polar regions are among the most vulnerable territories (Vaughan et al., 2003). Observed changes influence local ecosystems and risks of their damage increase (Frenot et al., 2005). Ecosystems in the Antarctic, being the most remote from anthropogenic impact, became a good indicator of climate change. Understanding the relation between the polar ecosystem and global atmospheric conditions is important for climate modelling and prediction. Polar flora, in this case, could play a crucial role as a climate change indicator. However, the mentioned task is very complex due to extreme weather conditions and large microclimatological uncertainties (Convey, 2012, Chapter 5). It complicates the research of polar ecosystem dynamics and variability under climate change.

Both microclimate and plants' populations vary under the influence of relief forms and external impact. As a result, distinct parts of relief formations with similar macro- and mesoclimates can have different microclimatic features. These features are formed by wind erosion, relief microforms' orientation and numerous other factors (Convey, 2012). Plants' populations on Galindez Island differ under the strength of tidal bores, influence of penguins, hills' orientation, locations of cliffs, etc. (Parnikoza et al., 2009; Parnikoza et al., 2018b). Microclimate significantly depends on the level of irradiance absorption by the surface. Moreover, the impact of changeable wind flows adds complexity to radiation influence (Oliphant et al., 2015). Some studies discuss that plants might influence microclimate and, consequently, other plants' species (Casanova-Katny et al., 2014; Molina-Montenegro et al., 2013; Frenot et al., 2005). Distance to marine surface impacts air temperature distribution: microclimatological features smooth over closer to the sea. Strong winds and high frequency of cloudy conditions also decrease temperature differences. If the wind speed exceeds 10 m/s, the microclimate features are strongly smoothed (Bartak et al., 2019).

Microclimate cannot be studied without knowledge about the climate over the territory. In case of Galindez Island, this is well researched (Klok, 2016; Kravchenko et al., 2010; Martazinova & Tymofeyev, 2007; Parnikoza et al., 2018b; Tymofeyev et al., 2017), therefore results of the current paper do not contain analysis of its macroclimate conditions. Conclusions about macro features were made using previous studies and the meteorological data from the Ukrainian Antarctic Akademik Vernadsky station located here.

Climate on the west coast of Antarctic Peninsula is relatively mild with yearly average temperature of about –2.4—5.4 °C (Parnikoza et al., 2018b). Relief complexity results in heterogeneity of meteorological fields, hence data are not representative over large distances. Topography features could even impact the spatial variance in precipitation (van Lipzig et al., 2002). The air temperature regime of the Antarctic Peninsula is characterized by significant differences between weather stations; however, better correlation was found in winter (Tymofeyev, 2007). Warming on Galindez Island is a typical response to climate change (Krakovska & Pysarenko, 2017), moreover wind speed increase is also detected (Tymofeyev et al., 2017). Winter air temperature increase is accompanied by periods of warming and cold snaps (Kravchenko et al., 2010). This increase coincides with the displacement of the large-scale baric formation (Martazinova & Tymofeyev, 2007). Some authors emphasized that decadal temperature changes reflected the extreme natural internal variability of the regional atmospheric circulation (Turner et al., 2016). Another typical feature which could influence microclimatological conditions is slower snow accumulation (Klok, 2016). It was shown that snow cover impacts local flora populations (Sancho et al., 2017). Observed changes are expected to be amplified, which will be the most pronounced for the decreasing of cold season (Chyhareva et al., 2019a) and total precipitation increase (Chyhareva et al., 2019b). All these environmental features caused the plants' population growth in abiotically-driven systems (Hogg et al., 2006).

Considering the relevance and complexity of studying the causal links between climate change, microclimate and polar plants activity, the present study aimed to analyze microclimatological features on Galindez Island by using air temperature data derived from the bio-microclimatological polygon. For the purpose of describing the main microclimatological conditions, the study is focused on two aspects:

- intra-annual variability of land surface temperature and its connection with other meteorological parameters, which could show the general contribution of macro-scale processes to microclimatic conditions;
- level of similarity between different areas, which might indicate the crucial patterns for land surface temperature distribution at micro scale.

Understanding the microclimate of different areas is crucial for research of biological activity and response to climate change.

2 Data and methods

2.1 Area and data description

The study was carried out for Galindez Island (Argentine Islands), located near Antarctic Peninsula's western shore. There were used 13 temperature loggers which were set on the ground near the populations of local flora species: *Deschampsia antarctica* E. Desv. 1837 and *Colobanthus quitensis* (Kunth) Bartl. 1831 (1 logger). 8 loggers were located in the northern part of Galindez Island and 5 loggers on the east and west from the central part (Fig. 1).

Loggers' locations represent the most appropriate areas for plants activity, i.e. show significant microclimatological features. Because the loggers were set directly on the ground (Fig. 2a), we can assume that they measured land surface temperature (LST), which is the most important parameter for polar plants' populations. Despite strong connection between LST and air temperature, the differences between them increase in complex terrain with high microclimatological variability (Mutiibwa et al., 2015) and under cloudiness changes (Gallo et al., 2011). These data have already been used for studies (Parnikoza et al., 2018a), where the detailed description of loggers' technical characteristics is given. Logger "D-08" is located near the heating station and so it is influenced not only by natural environment, but also sensitive to additional artificial impact.

Raw LST data for current study cover the period from April 6th 2017 to March 31st 2019 with the temporal resolution of 30 minutes. As the aim of the study is to estimate microclimatological features at the background of particular weather and climate conditions, 30-min data were averaged to daily values. Daily averaging removed diurnal variations and helped to improve the signal-to-noise ratio for the analysis of seasonality.

Loggers' data were compared with the measurements of the MicroClimate Monitoring Station (MCMS) (Fig. 2b) kindly provided by Masaryk University (Brno, Czech Republic) in 2002. The MCMS is located on a small flat area on the north side of the island (near the logger "Magn" on the Fig. 1), usually freed from snow cover in summer. The underlying surface is covered with typical moss vegetation. Comparison between LST and other meteorological variables could indicate which of the parameters at the macro-scale influence microclimatic variations most of all. For comparison we selected radiation fluxes going upward and downward (including the long-wave radiation), temperature of moss surface and snow surface, LST, 0.5-m (near-surface air temperature (NSAT)) and 2-m air temperature, atmospheric air pressure, 0.5-m and 2-m wind speed.

Comparison was implemented using Pearson's correlation coefficient:

$$r = \frac{cov(X, Y)}{\sigma_X \sigma_Y}, \quad (1)$$

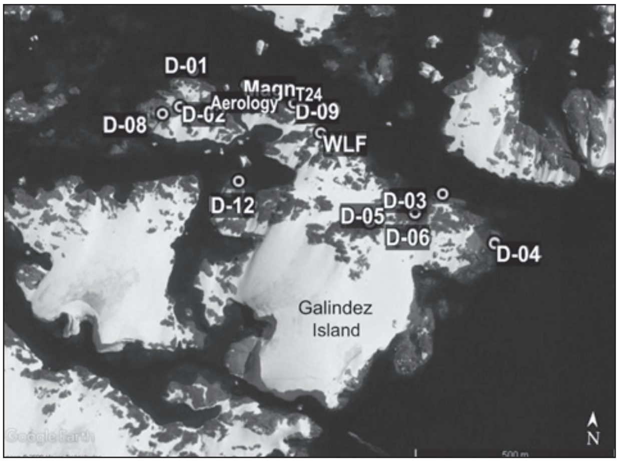

Figure 1. Galindez Island and loggers' location

where $cov(X, Y)$ is the covariance of the time series X (particular logger) and Y (meteorological variable from MCMS).

σ_X and σ_Y are the standard deviations of X and Y time series, respectively.

2.2 Loggers' data quality control

Unlike the MCMS or weather stations, loggers aren't fixed as usual sensors and suffer from more external influences including the activity of local fauna species. While monthly averaging provides enough smoothing for data usage, 30-min values might have many significant errors and atypical anomalies that could distort results based on the daily averaging.

The methodology of data quality control was partially taken from (Savenets, 2019) and was modified for loggers' LST. The main idea is the comparison of experimental and theoretical statistical distributions. The theoretical number of values in statistical distribution is always greater than the number of experimental values, because statistical population is always greater then statistical sample. If the number of experimental values exceeds expected theoretical ones in the particular interval, it might contain errors.

At the first step of the data quality control, statistical distributions were calculated for experimental LST. Mean values ($\bar{X}$) of unchecked time series were

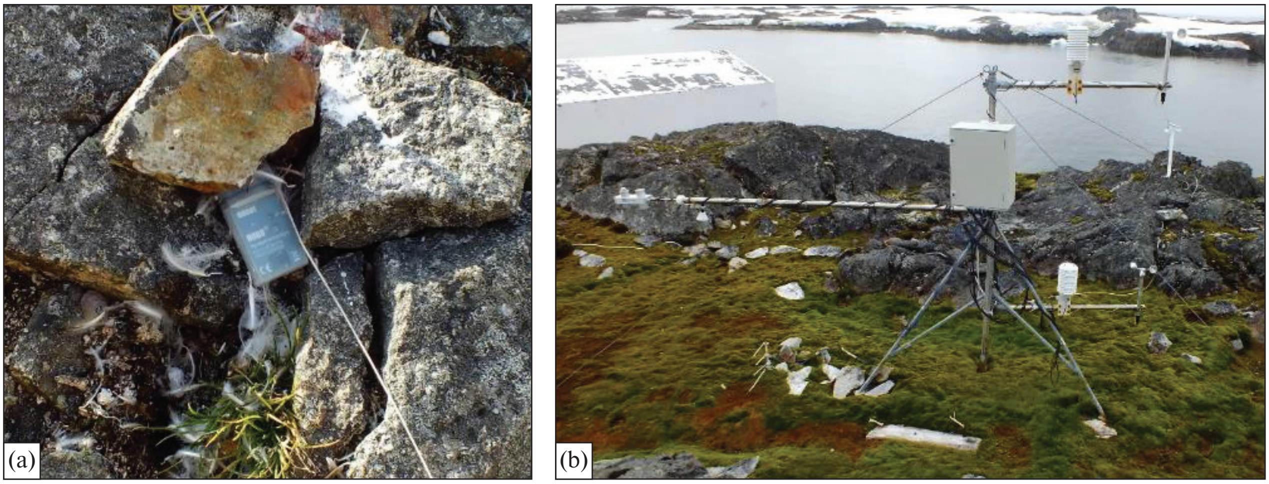

Figure 2. Example of the logger (a) and the MicroClimate Monitoring Station (MCMS) (b)

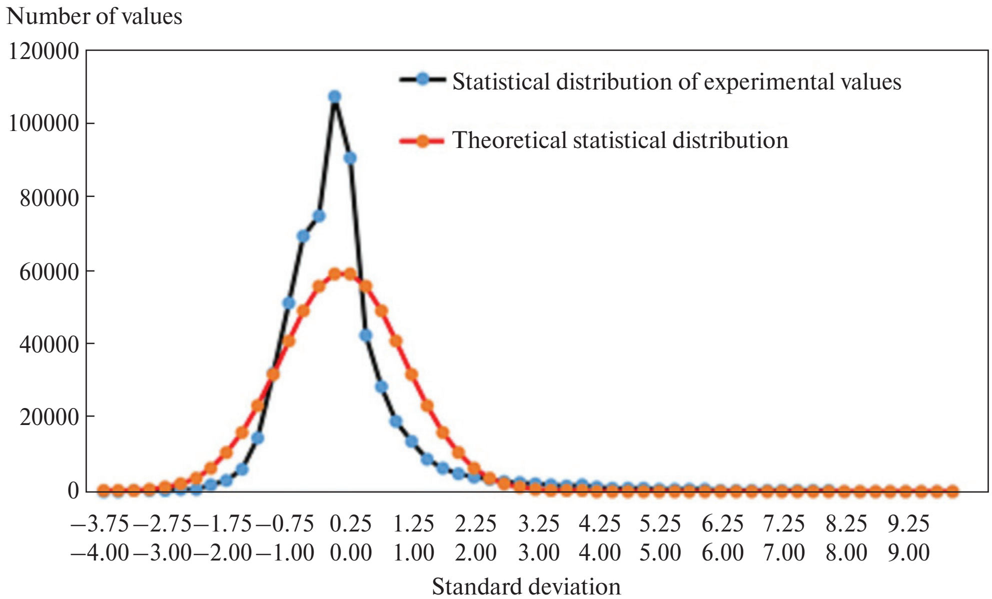

Figure 3. Generalized for all loggers experimental and theoretical statistical distributions

taken for this purpose, thus no seasonality had been considered firstly. For each time step (i) the value was presented as an anomaly (X') and recalculated from °C to units of the standard deviation (σ):

$$X_i' = \frac{X_i - \bar{X}}{\sigma}. \quad (2)$$

We estimate the discrete statistical distributions at the intervals with 0.25σ step. All distributions could be classified into two types: close to normal with right asymmetry and bimodal. Two peaks in a statistical distribution are not typical for LST or air temperature. However, it was found that bimodality formed when the loggers were covered by snow and inertia of temperature changes was observed. Hence, it was a consequence of natural conditions and with high probability did not contain errors, which was considered during further quality control.

Secondly, theoretical distributions were calculated for each logger. Let us suppose that in nature LST is distributed normally with $\bar{X}$ – C and σ – 1. The standard normal distribution function is:

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}. \quad (3)$$

Consequently, we know the theoretical cumulative distribution and the probability of value (x) appearance (Px_k) in time series. We know the length of experimental loggers' time series (l), hence the theoretical number of values (num) in the gradation of 0.25σ step is:

$$num(k...k + 0.25) = (|Px_k - Px_{k+0.25}|) \cdot l. \quad (4)$$

Thirdly, the differences between experimental and theoretical distribution are calculated. There must not be cases when the number of experimental values exceeds the number of theoretical values for particular gradation in the statistical distribution. If such cases exist, possible errors might exist in gradation. LST data had two intervals where the number of experimental values exceeded: from –0.75σ to 0σ and higher than 2.25σ.

The interval from –0.75σ to 0σ appeared in the bimodal distribution where two maxima exist. Bimodality is the result of loggers' inertia under snow when LST varies from –1.5 °C to 0 °C. These values have natural prerequisites, moreover such small deviations from the mean values could not significantly distort results. Thus, all of them remain in time series.

The interval higher than 2.25σ induces doubts. Errors within the mentioned deviations could significantly influence statistical estimations. Overall, the total number of loggers' data reach 600 803 values and 17 283 of them are higher than 2.25σ (Fig. 3).

All values higher than 2.25σ were checked by comparison with other loggers. If the value was confirmed at least once, anomaly was considered as real. Certainly, microclimatological features might cause high anomalous values only for some particular logger. Nevertheless, it does not seem that microclimatological features strongly differ from the background. To avoid false filtering, we suppose that the difference in LST within ±0.5σ from each other is not an error. As a result, 3017 values out of 17 283 were not confirmed and considered as errors. All of them are located within the 3.6—5.3σ interval. As expected, there was not found any spatial or temporal dependence of possible errors' distribution.

2.3 Seasonality estimation

Seasonal variability was calculated using the harmonic analysis. All variables were decomposed to harmonics, where the lowest frequency corresponds to the 1 year period (annual cycle) and the highest one — to the Nyquist frequency (2 days). The significance of a particular harmonic was checked using a Student t-test with a p-value threshold of 0.05. All harmonics whose significance was confirmed by the t-test allowed us to calculate mean value for particular day ($\bar{X}_l$) and estimate seasonal variability:

$$\bar{X}_l = \bar{X} + \Sigma_{k=1}^{n} A_k \cos(\omega_k t - \varphi_k), \quad (5)$$

where k is a number of significant harmonic (n — total amount of significant harmonics); $\bar{X}$ — mean value, A_k — harmonic amplitude; ω_k — harmonic frequency ($\omega_k = 2\pi/T_k$; T_k — harmonic period); φ_k — harmonic phase; t — time.

The intensity of significant variations was estimated using the harmonic amplitude, which is calculated knowing the Fourier coefficients a_k and b_k:

$$A_k = \sqrt{a_k^2 + b_k^2} \quad (6)$$

$$a_k = \tfrac{2}{N} \Sigma_{i=1}^{N} [X_i \sin(\omega_k \cdot t_i)] \quad (7)$$

$$b_k = \tfrac{2}{N} \Sigma_{i=1}^{N} [X_i \cos(\omega_k \cdot t_i)]. \quad (8)$$

The harmonic phase shows the time when maximum value appears. It is also calculated using the Fourier coefficients:

$$\varphi_k = \mathrm{arctg} \frac{a_k}{b_k} \pm \pi. \quad (9)$$

However, the most appropriate way of the phase analysis is recalculation to the ordinal day in a year (φ_{kt}):

$$\varphi_{kt} = \frac{\varphi_k T_k}{2\pi}. \quad (10)$$

2.4 Loggers' classification

Area classification was implemented using the cluster analysis, particularly its hierarchical methods. All loggers were grouped by their similarity. Conclusion about similarity was made after a so-called distances calculation. There were selected 6 algorithms for the distances and 3 algorithms for the matrix correction (average, "latter" and "nearest neighbor"). The formulas for the distances are given in the Table. After group forming there are three possible ways for selecting distance and the correct matrix. The "latter neighbor" takes the highest distance value among previously grouped, the "nearest neighbor" — the lowest value, and the average — the mean of previously grouped values. All 3 correction methods were implemented for each algorithm of distances calculations. Therefore, 18 algorithms were used in the study.

3 Results

3.1 Seasonal variability

The seasonality of loggers' LST forms under the influence of the first and second harmonics. Expectedly, the highest impact on the LST variations has the annual cycle (1-year period). It represents the temperature regime under annual changes of the incoming solar radiation. The annual cycle explains from 63 to 76% of total LST variability (Fig. 4a). "D-08" is the only logger where R^2 do not exceed 0.4. However, logger "D-08" is located near the heating station with a diesel generator. As a result of slight artificial warming near the station, we did not use logger "D-08" for further analysis. The amplitude of the annual LST variations varies from 3 °C to 6 °C. There were not found any regularities for the amplitudes' spatial distribution (both annual and semiannual) which means that microclimatological differences in seasonality depend on the particular location.

Table. The distances used for the cluster analysis

Distance name	Equation
Euclidean	$d = \sqrt{\Sigma(a_i - b_i)^2}$
Manhattan	$d = \Sigma\lvert a_i - b_i\rvert$
Square Euclidean	$d = \Sigma(a_i - b_i)^2$
Chebyshev	$d = \max\lvert a_i - b_i\rvert$
Minkowski (3rd order)	$d = (\Sigma\lvert a_i - b_i\rvert^{1/p})^p$
Divergence	$d = \Sigma(a_i - b_i)^2 / (a_i + b_i)^2$

Data from the MCMS showed that the annual cycle explained 75% of total LST variance and 50% of total NSAT variance. All typical features of intra-annual loggers' LST variability are similar to LST behavior derived from the MCMS. Therefore, we consider that loggers' data better represent LST than air temperature data.

The phases of the first harmonic after recalculation to the ordinal day in the year vary within 26th January–20th February (see Fig. 5a). These dates represent the average day with maximum loggers' LST. Like the amplitudes, the phases also do not have any regularities in spatial distribution. It means that particular relief microforms and spatial orientation play more crucial role than elevation or closeness to the seashore. Overall, the temporal difference of the annual phases between loggers reaches 25 days.

Semiannual variations exert the second impact on the LST variability. These variations form under the influence of circulation changes caused by the air temperature contrast between the middle and the high latitudes (Meehl et al., 2017; van Loon, 1967). R^2 of the semiannual variations is low but still significant and varies from 0.03 to 0.07 (see Fig. 4b). The amplitudes reach up to 1.5 °C.

The phases of the semiannual variations are more scattered in time in comparison with the annual phases. The difference between the earliest and the latest phases reaches 51 day: from 28th June to 19th August (Fig. 5b). These phases indicate the average dates when the semiannual variations provide the highest influence, resulting in air temperature growth. Spatial distribution of the phases is heterogeneous regardless of loggers' location.

There are no other significant variations, however, 11 loggers have slight quasi-bimonthly oscillation. Their impact is of about 1.1–2.7% of the total temperature variance and might appear in the spectrum as the result of the Madden-Julian Oscillation. Nevertheless, they are too slight for being considered as significant in seasonal variability. LST from the MCMS also contain local spectral maxima near two months, but they

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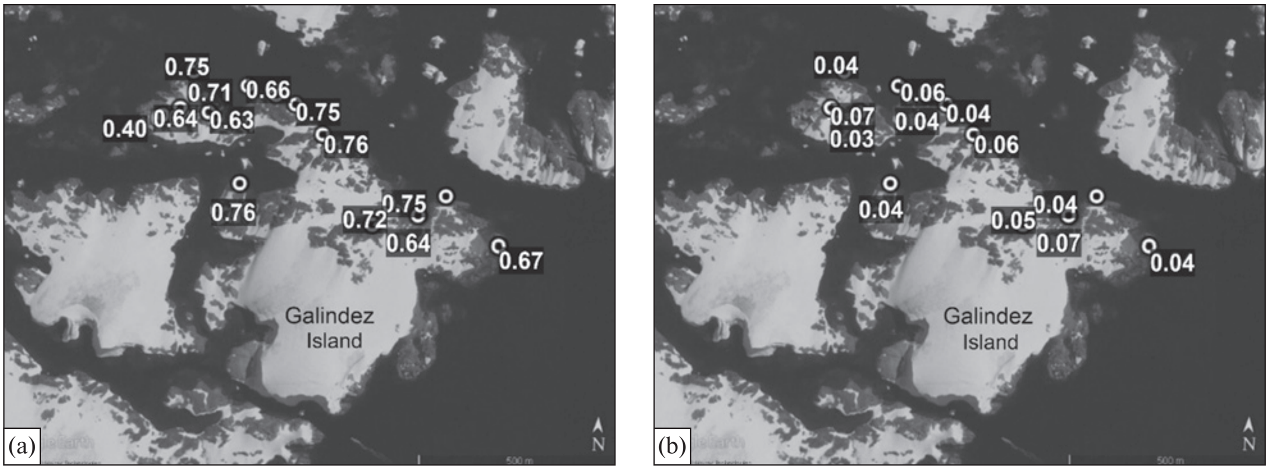

Figure 4. R^2 of the annual (a) and the semiannual (b) loggers' LST variations

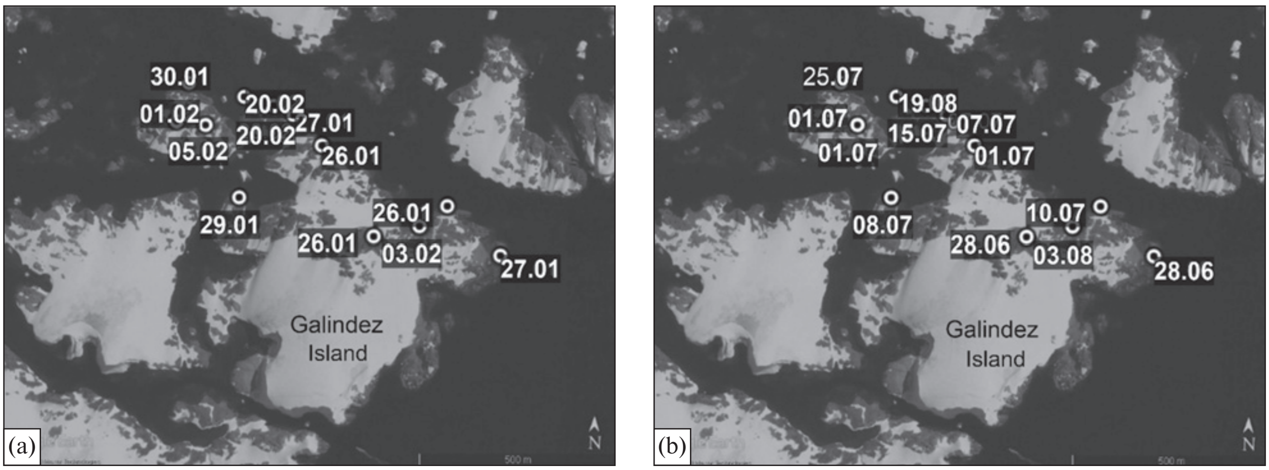

Figure 5. The phases of the first harmonic (a) — the average day with maximum loggers' LST, and the second harmonic (b) — the first day of the highest influence caused by the semiannual variation

are absent for NSAT. LST from both loggers and the MCMS do not have variations which are connected with synoptic periods — the quasiperiodic weather variability due to cyclones and anticyclones alternation. However, NSAT contains local spectrum maxima of about 9 days, which are expected to be the generalization of the quasiperiodic changes in synoptic processes.

The intra-annual air temperature variations showed meteorological changes that are typical for Galindez Island (Fig. 6). Neither elevation differences nor closeness to the seashore play significant role for the seasonality of particular territory within island. The differences in amplitudes, however, might represent the damping-off effect of the relief microforms — the more protected is the location of logger from wind and differences of income/outcome radiation fluxes, the lower amplitudes are observed.

Loggers' LST correlates with meteorological parameters derived from the MCMS: total radiation flux, LST and NSAT. The highest correlation was found with NSAT reaching 0.70–0.92 depending on the logger. The correlation with surface snow temperature is 0.72–0.86. Significant correlation is found with the downward total radiation flux (r = 0.60–0.76), where-as correlation with the upward total radiation flux is weaker (r = 0.43—0.55). There are no direct dependencies with the longwave radiation fluxes (r = = –0.05— –0.23), relative humidity (r = 0.23—0.39), wind speed (r = 0—–0.11) and atmospheric pressure (r = –0.24—–0.40).

3.2 Area classification by LST regime

Loggers' classification for Galindez Island was performed using cluster analysis. As temperature is the only available meteorological parameter, clustering faced a number of limitations. There are a number of features among them by which loggers could be combined into clusters. Two were selected for the analysis: the mean loggers' LST and the first harmonic (annual cycle) amplitude. Mean LST represents typical temperature where logger is located. The first harmonic amplitude indicates the strength of typical seasonal variability. The Euclidean distance was selected as the main algorithm for similarity estimation. However, all results were checked by using other algorithms and such distances: Manhattan, Square Euclidean, Chebyshev, Minkowski distance of third order and divergence. The clustering matrix for all algorithms was corrected by using three methods of optimization: average, "latter" and "nearest neighbor". Overall, the classification was checked using 18 different algorithms (6 distances and 3 types of matrix correction). Clustering results on some of steps (iterations) are given in Appendix.

At the first step (iteration) loggers "D-03" and "D-05" were combined in one group (see Appendix, Iteration 1). It means that LST of these loggers are the most similar among others. Both loggers are located on the N-NE part of the peculiar relief forms: the foot of the highest point on the island and near the shoreline. Loggers' spatial orientation resulted in the similarity of incoming solar radiation.

Another group of loggers located at the opposite parts of the shoreline was formed in the second iteration (see Appendix, Iteration 2). However, they are similar by orientation to the sea which is located to the north–northern-east. The third iteration formed yet another group (see Appendix, Iteration 3) of loggers which are among the most remote to each other. Their similarity and conjunction at the third iteration showed that microclimatic features strongly depend on the spatial orientation. As a result, these loggers receive almost the same solar irradiance and face the same winds.

At the fourth and fifth iterations all previously appeared groups were combined into a single unit (see Appendix, Iteration 5). These processes during the clustering are very important and the fifth iteration became a key point. Grouping to one unit showed that these 6 loggers were more similar than others located a bit farther from the shoreline. It allows to delimit area of the Galindez Island with typical microclimatological regime — the territory along the shoreline oriented to the north–northern-east. LST of this part usually differs from LST on the rest of is-

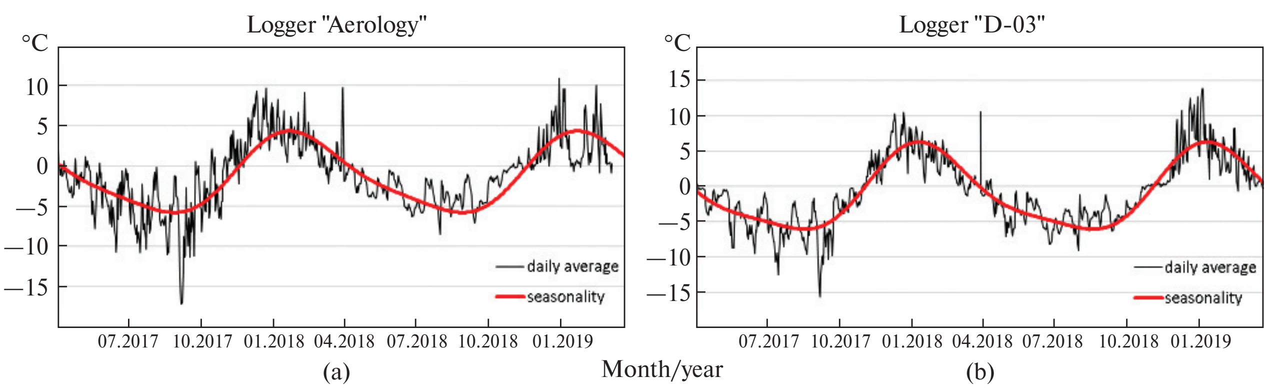

Figure 6. Daily average LST and its seasonal variations (sum of the first and the second harmonics) on the logger "Aerology" (a) and "D-03" (b)

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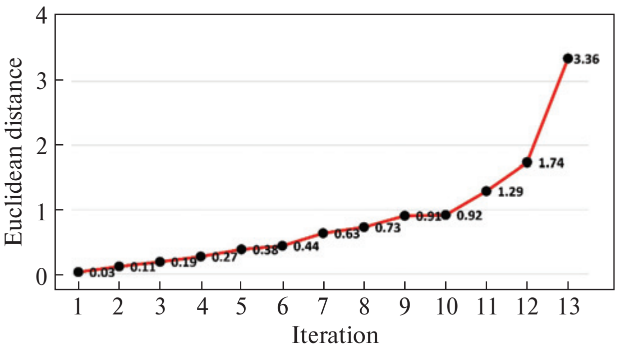

Figure 7. Dependence of the Euclidean distance on the iteration number during the clustering process

land. This conclusion is significant for the study of biological activity. Populations of *D. antarctica* in this particular area grow under a particular temperature regime and wind/ moisture influences. It is to be emphasized that clustering using other algorithms of the distances calculation and the matrix correction gave the same grouping in the fifth iteration, even the order at previous iterations was different.

Further four iterations of clustering were characterized by two processes: formation of a new group on the north of Galindez Island and adding more loggers to the main group. The first atypical clustering appeared in the 10th iteration when a new group of loggers formed (see Appendix, Iteration 10). However, it is seen from Fig. 7 that dependence of the Euclidean distance from the order of iteration lost its tendency. Obviously, loggers in the 10th iteration start to combine by the principle of the "lowest differences" rather than the "highest similarity". The sharp bend upward in Fig. 7 proves it, i.e. further clustering is not statistically reliable and the classification does not have sense.

Clustering results showed that spatial orientation plays a more significant role in LST formation on the microscale than other influences. Similarity in spatial orientation results in similar availability of the incoming solar radiation on relief microforms. In general, heating of the same-oriented relief forms causes identical snow melting, heat accumulation, etc. Differences in shadowing during changeable cloudiness provide local effects on LST variations, however the longer timescale the lower significance it has. On Galindez Island the shoreline with north—north-eastern orientation together with the same-oriented elevated parts of relief create similarities of LST field.

Further clustering showed the tendency for loggers to combine in the group along the shoreline rather than to form new groups with the loggers further away from the sea. As we used two features: seasonality amplitude and mean values, the impact of humidity might take place due to its significance for the temperature seasonality.

4 Conclusions

LST variations on different relief microforms have two significant intra-annual variations with similar seasonality features. The annual cycle influenced by the changes of the incoming solar radiation explains from 63% to 76% of loggers' LST variability. The semiannual cycle is responsible for 3—7% of temperature changes, however all values showed statistical significance. The differences in amplitude and phase characteristics showed that the semiannual variations (circulation impact) have more uncertainties and depends more strongly on the loggers' orientation and location than the annual cycle (solar radiation impact). Loggers' data which are used as temperature characteristics for the studies of local flora are more compatible with LST than with NSAT. LST derived from the loggers has significant relation with the temperature parameters and the total incoming irradiance, but not with the longwave radiation fluxes, relative humidity, wind speed and atmospheric pressure. There was not found any quasiperiodic LST changes connected with synoptical processes, even the NSAT has them.

Loggers' classification allowed us to find similarities of LST microclimatological conditions. The spatial orientation of relief microforms where loggers are located plays a crucial role. It is a more important factor than closeness to each other and possible humidity influence. The highest similarity of microclimatological features was found for the territory along the shoreline oriented to the north—northern-east. LST differences between mentioned area and the rest of the territory could be used to study the impact of heat accumulation on local flora, e.g. *D. antarctica*.

As the results showed the possibility to link microclimate and the atmospheric processes at macroscale, future studies could be dedicated to the parameterization of that link. It will be important to obtain statistical equations for the relation between LST and other meteorological parameters. These equations are necessary for microclimate modelling and understanding of the changes of climate which are the most relevant to the local plants' development.

Author contribution. MS: Conceptualization, Methodology, Investigation, Writing — Original & Draft. LP: Investigation, Writing — Review & Editing. DP: Methodology, Writing — Review & Editing. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest. The authors declare that they have no conflict of interest.

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Мікрокліматичні варіації температури підстильної поверхні на острові Галіндез (захід Антарктичного півострова)

Реферат. У роботі представлено аналіз мікрокліматичних особливостей розподілу температури підстильної поверхні острова Галіндез. У дослідженні використано дані температури на 13 логерах, встановлених поблизу популяцій рослин на острові. Для детального аналізу та порівняння результатів використано низку параметрів на основі даних мікрокліматичної станції моніторингу. Розроблено метод критичного контролю якості даних логерів температури. Основні результати отримані із застосуванням гармонічного аналізу для оцінки сезонності та кластерного аналізу для класифікації території. Сезонність температури підстильної поверхні формується під дією першої та другої гармонік, тобто річного та піврічного коливань. Річні коливання пояснюють від 63 до 76% загальної дисперсії температури підстильної поверхні, тоді як піврічні коливання — від 3 до 7%. Для температури підстильної поверхні не характерна наявність коливань, пов'язаних із процесами синоптичного масштабу, на відміну від приземної температури повітря, де подібні коливання спостерігаються. Фази першої гармоніки варіюють в межах 26 січня–20 лютого. Піврічні коливання більш неоднорідні з фазами в межах 28 червня–19 серпня. Температура підстильної поверхні корелює із потоком сумарної радіації та температурою повітря, натомість практично відсутній зв'язок із потоками довгохвильової радіації, відносною вологістю, швидкістю вітру та атмосферним тиском. Просторова орієнтація мікроформ рельєфу є більш визначальною характеристикою формування розподілу температури підстильної поверхні, аніж близькість розташування логерів чи залежність від умов зволоження. Кластерний аналіз дозволив виділити територію острова вздовж берегової лінії, орієнтовану на північ–північний схід, що найбільш подібна між собою за зміною характеристик температури підстильної поверхні.

Ключові слова: амплітуда, варіації температури, логер, річні коливання, сезонність

APPENDIX

Groups of loggers formed in particular iterations. Each color represents classified group by loggers' LST similarity.