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FEATURES OF SNOW COVER OF SEMI-DESERTS AND DRY STEPPES OF THE CASPIAN SEA ACCORDING TO SATELLITE DATA FOR THE PERIOD 2001...2020

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The Snow Depth FEWS NET daily product was used to analyze snowy regime of the upper part of the River Emba basin from January 1 to April 30 for the period of 2001...2020. The Emba River basin is situated in Kazakhstan at the Eastern coast of the Caspian Sea. The area is characterized by the arid and extreme continental climate with dry-steppe and semi-desert landscapes. The population is small and the anthropogenic impact on the snow cover is minimal there. These conditions give an opportunity to identify the natural tendency in long-term changes of snow covering in semidesert zone of Kazakhstan. This paper describes the characteristics of the formation and destruction of the snow cover in the last 20 years. It was indicated that snowy regime has a trigger structure including two states; low-snowy regime and others years. It was shown that the snowy conditions are triggered. There are two modes, the first, as a low-snowy regime (up to 50 % of the entire sample) and the second mode includes other years. Significant variations of snow depth in various years masked many years' tendencies of snow cover characteristics. But low-snowy regime was observed four times during five last years that can relate with modern decreasing snow covering in semi-desert zone of Kazakhstan.

Keywords: snow cover, satellite data, snowy conditions, River Emba basin, Snow Depth FEWS NET daily product

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INTRODUCTION

The utilization of satellite data in various applications related to snow cover monitoring in the CIS countries has been widely covered in the scientific literature [1, 2, 4, 10, 15, 22]. Solid precipitation of the cold period in the sharply continental climate of Kazakhstan is a critically important source of water for various economically significant processes. Such processes include: spring flood activity [19]; snow reserves in glacial runoff formation zones mountain rivers and its impact on hydropower industry [18, 17]; hydration of the first half of the growing season [7]; activity of spring sprouting of weed vegetation on agricultural fields [8]; spring planting calendar dates [5, 9], and so on.

The main issue is the applicability of satellite-based assessments of snow cover parameters to practical tasks, and their accuracy. For example, as shown in [2], the product "Snow Water Equivalent (SWE)" from the National Snow & Ice Data Center (http://nsidc.org/data/NSIDC-0271) has larger than usual discrepancies with ground data for northern Eurasia and Russia. This limits the applicability of this satellite product to assessing the direction of long-term climate trends. There are a number of interfering factors for recording snow cover parameters. One of these factors is forest cover. The territory of Central Asia is mainly represented by unforested dry plains (deserts, semi-deserts, dry steppes, steppes, forest-steppes). The lack of forest facilitates the processing of satellite information for snow assessment purposes. Recently, new model snow assessment products ("Snow Depth", "Snow Water Equivalent Anomaly"), specially developed for the territory of Central Asia (https://earlywarning.usgs.gov/fews/product/613) and based on data sets of GDAS (Global Data Assimilation System, https://www.emc.ncep.noaa.gov/gmb/gdas/) and LDAS (Land Data Assimilation System, https://ldas.gsfc.nasa.gov) systems have appeared. The Snow Depth product has been successfully used both for snow assessment in Kazakhstan as a whole [12], and mountain zones of Central Asia [16] and for the local task of forecasting some Tien Shan rivers runoff with snow-glacial nutrition [13].

The sparsely populated, desert and semi-desert areas of Central Asia are of particular interest, where the network of weather stations is rare and strong winds during the cold season (winter storms) significantly interfere with ground measurements of snow amount and height. It is better to use river basins as a test site for monitoring snow changes in the dry steppe and semi-desert areas of Kazakhstan. This makes it possible to have not only data on the snow cover of the area, but also leaves the possibility to characterize and obtain additional information on the humidification regimes of runoff formation zones.

The purpose of this work was to determine the direction of modern trends in changes in snow cover regimes in the dry steppe and semi-desert zones of Kazakhstan, using the Emba River as an example of the zone of runoff formation of the largest regional river in the eastern coast of the North Caspian Sea.

STUDY AREA

The Emba River basin is located within Kazakhstan in the climatic zones of dry steppes and semi-deserts (figure 1). The hydrological regime of the rivers in this region is classified as a specific, kazakhstan's type [6]. It is characterized by high, short spring flood, and low-water periods in summer and winter, i.e. pure snow type of nutrition. The Emba River originates on the Western slopes of the Mugodzhary Mountains (the southern extension of the Ural Mountains). The river is 712 km long and has a catchment area of 40,400 km^2. The main tributary network is concentrated in the upper part of the Emba River basin. The Emba River, which runs from the southern tip of the Ural Mountains to the Caspian Sea, is used by geographers as the border between Europe and Asia [3]. The upper part of the Emba River basin, above the hydrological post of

Fig.1. Snow cover of Kazakhstan and the Emba river basin. Example of a daily snow depth map from FEWS NET (February 1, 2020) with reference to meteorological stations: Altai, Aktobe, and Atbasar.

MATERIALS AND METHODS

As basis we used the "Snow Depth" product FEWS NET, developed at NASA Goddard Space Flight Center and available in the form of overview maps of the snow cover depth for the Central Asian region (CA), determined within the coordinates 25...55° North latitude and 50...85° East longitude (fig. 1). The overview maps are provided in a geographical projection (Lat/Lon) with daily update and a spatial resolution of 0.044°x0, 044°, which is (4,88 x 3,14 km) for latitude 50° (area of interest). The snow depth is calculated by the Asia-LISS model (https://earlywarning.usgs.gov/fews/product/439), which includes not only analysis of satellite spectral characteristics of the underlying surface, but also model estimates of precipitation. Maps are available in "png or tiff" files, with a legend step of 20 cm in the snow depth, as well as through the internal EWX viewer tool, with a step of 1 cm and a resolution of 1 km (fig. 1.)

The Asia-LISS model uses current and historical (11-year retrospective analysis) data and parameters from the GDAS (Global Data Assimilation System, https://www.ncdc.noaa.gov). The depth of the "Snow Depth" archive, linked to TERRA MODIS satellite data, is 20 years: from October 2000 to the present. This archive allows us to analyze 20 winter-spring seasons (2001...2020) and allows to determine the features of the snowy regime.

This paper considered three contours. First, the upper part of the River Emba river, Fig.1. Second contour around the Aktobe weather station (50° 17 North latitude; 57° 12 East longitude). Third, the contour around the Atbasar weather station (51° 48 North latitude; 68° 20 East longitude). Meteorological data on snow depth were taken from the Internet resource "Weather Forecast" http://rp5.kz. To compare Snow Depth FEWS NET data with ground-based meteorological data on snow depth, we used data from the Aktobe weather station (WMO ID-35299), Atbasar (WMO ID-35078) and the average for five Altai weather stations: Verkhneuralsk (WMO ID-28833), Magnitogorsk (WMO ID-8838), Kizilskoye (WMO ID-28939), Energetik (WMO ID-35038), Orsk (WMO ID-35138).

The Snow Depth FEWS NET monitoring period included 120 days, from January 1 to April 30, for 20 seasons (2001...2020). This period covers most of the winter times and the process of spring snowmelt. The following parameters were used for analysis of the test site snow cover: seasonal maximum of snow depth; average seasonal snow depth; duration of period without snow cover during seasonal monitoring.

RESULTS

Twenty seasonal snow depth curves were formed and analyzed for the River Emba basin in the period 2001...2020 (see fig. 2). Long-term trends (2001...2020) are considered for the following parameters: the seasonal maximum of snow depth; the average value of season snow depth; and the number without snow cover days during January 1 to April 30. The confidence of linear approximation values (R^2) of these trends were very low: less than R^2 =0,09 (for tendency for the number without snow cover days). The average long-term seasonal maximum snow depth (33,5 cm) occurs on February 23 (fig. 2). For this day, a histogram of the distribution of snow depth for different years was constructed (see fig. 3).

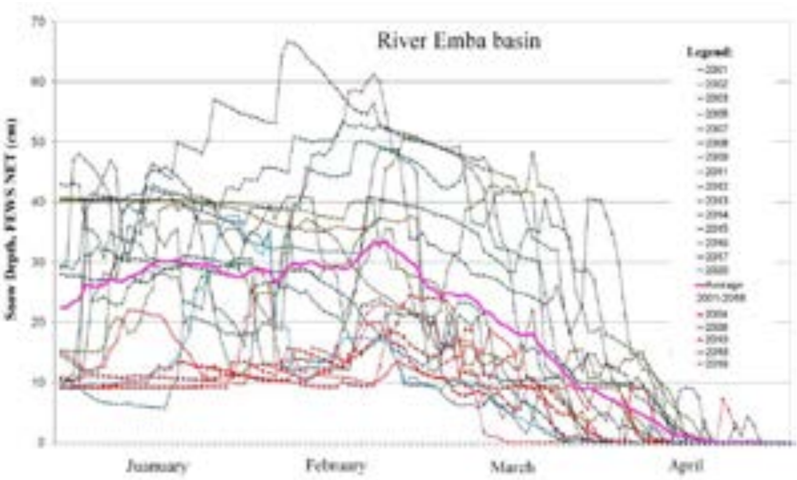

Fig.2. Snow Depth FEWS NET monitoring, period 2001...2020 years.

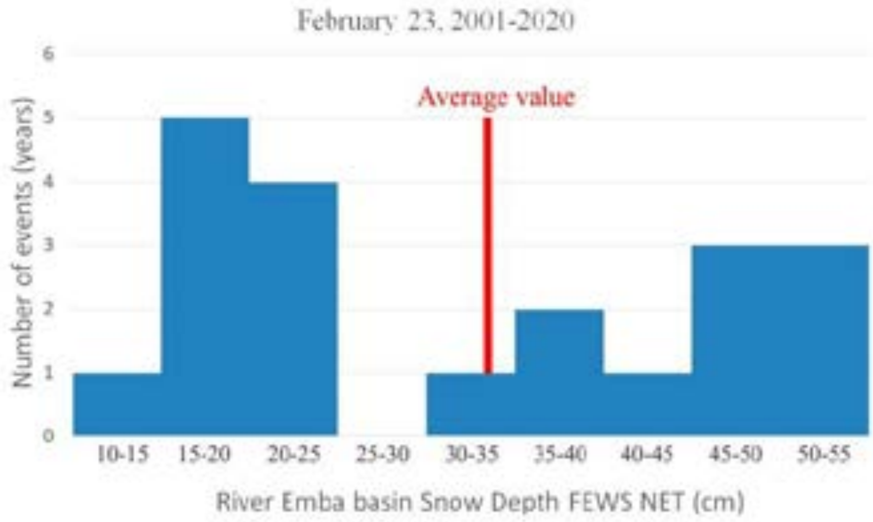

Fig.3. Histogram of the distribution of the average snow depth values in the River Emba basin on February 23 for the seasons 2001...2020.

DISCUSSION

The confidence value of the linear trend approximation strongly depends on outliers in a series of values. Therefore, in the conditions of significant interannual variations of snowy regimes in the River Emba basin, we do not find a pronounced tendency in long-term snowy regimes.

Average long-term (2001...2020) maximum snow cover depth in the River Emba basin is observed on February 23. For this day, a histogram of the distribution of snow depth in the River Emba basin in different years has a pronounced bimodal distribution (fig. 3). Of the 20 seasons (2001...2020) was ten belonged to a low-snowy (2004, 2006, 2009, 2010, 2012, 2013, 2016, 2018, 2019, 2020), with an average snow depth of 19.0 ± 3.9 cm. The cluster of snow depth values for these years is more than 3 Sigma from the average snow depth for the complete row (33.5 cm), which indicates the statistical significance of the low-snow regime as separate type. Out of the last five years (2016...2020), four were snowless, which diagnoses the progressive snow shortage in the zone of dry steppes and semi-deserts of Kazakhstan.

Modern changes in the “Western transfer”, which provides Central Asia with moisture, affect various processes [11, 20, 21].

VALIDATION

Wind snow transfer on the positive and negative terrain configuration forms a snow cover with significantly differ snow depth. On flat surfaces, the wind also forms a specific spatial structure with variable snow depth, similar to the dunes of a sandy desert. Descriptions of snow cover characteristics, which are given together with the measured snow height at the weather station, can sometimes clarify the situation. For example, for the Atbasar weather station in the spring period, typical descriptions of snow cover are "dense, icy snow with a depth of 40...45 cm, which does not completely territory cover". This situation indicates that the snow cover is transformed by a long, strong wind field, and the measurement of snow depth is carried out in areas with positive anomalies.

Figure 4 shows curves that show the relationship between Snow Depth FEWS NET and snow depth measurements at weather stations. The Atbasar weather station is characterized by an almost two times overestimation of the snow depth at the snow measuring ground point relative to the FEWS NET data. The linear equation of the relationship between Snow Depth FEWS NET and snow depth (weather station) has a coefficient equal to (0.5414) Fig. 4. For the Aktobe weather station, the coefficient value is (0.9398), which is close to the theoretically expected value of 1.00. Altai stations, on average, have a coefficient value (1.28), which indicates an overestimation of Snow Depth FEWS NET estimates relative to the data of snow measuring points [14]. The reason for contradictions may be either wind snow transfer, or mistakes in models that calculate the amount of precipitation that are used in calculating Snow Depth FEWS NET.

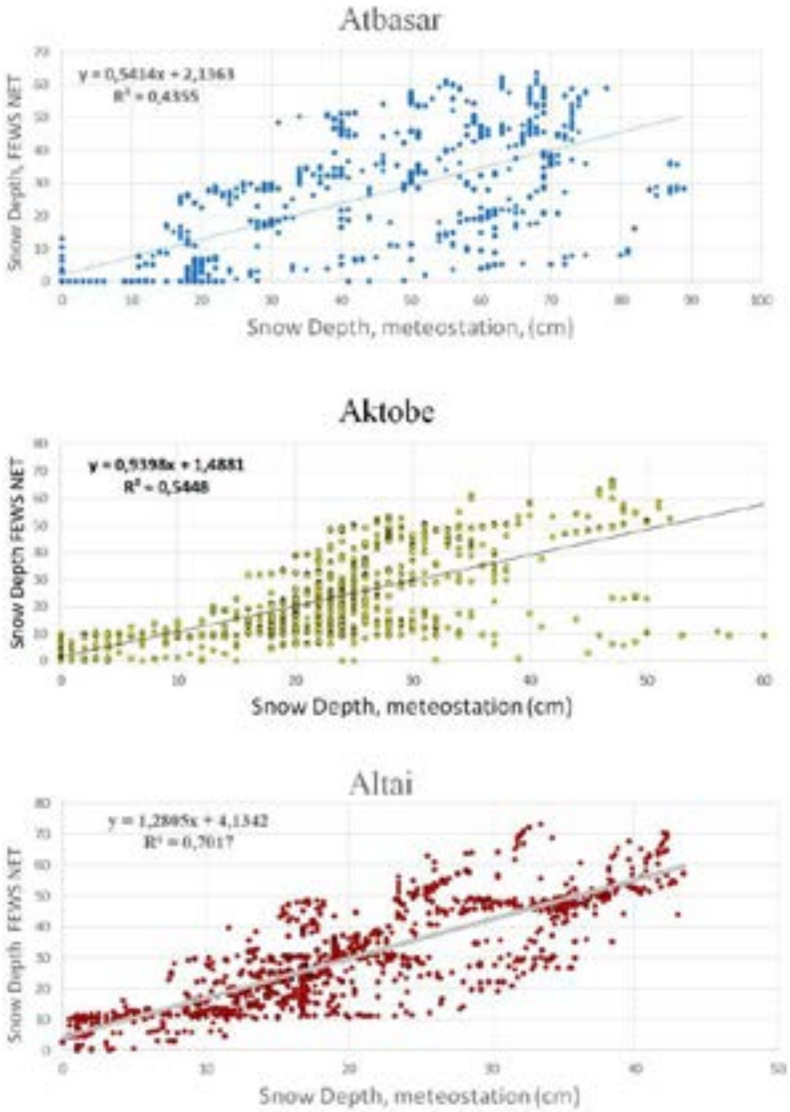

Fig.4. The relationship between snow height estimates at weather stations and daily data from Snow Depth FEWS NET. Data on Altai weather stations are taken from [14].

CONCLUSION

The Snow Depth FEWS NET with a daily renew and archive since 2000 is a competitive informative tool that allows to diagnose long-term snow regimes in arid zones of Central Asia. Ground-based meteorological measurements of snow depth at weather stations in unforested areas of the Central Asian plains with typical strong winds are associated with the probability of significant distortions due to wind snow transfer.

The direction of changes in snow cover parameters on the Caspian plain over the past 20 years has no clear direction. However, in the snow regimes of the desert / semi-desert territories of Kazakhstan, the presence of a separate mode – a low-snowy is significantly highlighted. For the last 5 years in the Emba River basin was recorded for 4 years with low-snowy, which indicates a decrease in the snow cover of semi-desert territories, as the most likely direction of modern changes.

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КАСПИЙ ТЕҢІЗІНІҢ ШӨЛЕЙТ ЖӘНЕ ҚҰРҒАҚ ДАЛАЛАРЫНЫҢ ҚАР ЖАМЫЛҒЫСЫНЫҢ 2001…2020 ЖЫЛҒЫ СПУТНИКТІК ДЕРЕКТЕР БОЙЫНША АНЫҚТАЛҒАН ЕРЕКШЕЛІКТЕРІ

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Жем өзенінің жоғарғы бассейнінің қар режимін талдау үшін 2001...2020 жылдардың 1 қаңтар мен 30 сәуір аралығындағы күнделкті жаңартылатын "Snow Depth" USGS/EROS FEWS NET өнімі қолданылды. Жем өзенінің бассейні Қазақстанда Каспий теңізінің шығыс жағалауында сирек қоныстанған құрғақ дала және шөлейт аймақта, құрғақ, шұғыл континенталды климатта орналасқан. Бұл аумақ үшін антропогендік әсер ету факторы минималды болғандықтан табиғи көпжылдық қар режимдерінің ерекшеліктерін тіркеуге мүмкіндік береді. Жұмыста соңғы 20 жыл ішінде қар жамылғысының пайда болуы мен бұзылуының ерекшеліктері қарастырылған. Бассейннің қар режимі аз қар режимі және қалған жылдар режимідерді қосатын екі күйге ие триггер құрылымында көрсетілген. Әр түрлі жылдардағы қар мөлшерінің айтарлықтай өзгеруі айқын көрінбейтін көпжылдық тенденцияларды жасырады.

Түйін сөздер: қар жамылғысы, спутнитік деректер, қар жағдайы, Жем өзені бассейні, қар тереңдігі, күнделікті таза өнім, “Snow Depth” USGS/EROS FEWS NET өнімі

ОСОБЕННОСТИ СНЕЖНОГО ПОКРОВА ПОЛУПУСТЫНЬ И СУХИХ СТЕПЕЙ КАСПИЙСКОГО МОРЯ ПО СПУТНИКОВЫМ ДАННЫМ ЗА ПЕРИОД 2001...2020 ГГ.

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Продукт “Snow Depth” USGS/EROS FEWS NET за период с 1 января по 30 апреля для 2001-2020 годов с суточным обновлением использовался для анализа режима снежности верхней части бассейна р. Эмба. Бассейн р. Эмба расположен в Казахстане на Восточном побережье Каспийского моря в малонаселенной сухостепной и полупустынной зоне, с аридным, резко континентальным климатом. Для этой территории фактор антропогенного влияния минимален, что позволяет регистрировать особенности естественных многолетних режимов снежности. В работе рассмотрены особенности формирования и разрушения снежного покрова в течение последних 20 лет. Показано, что режим снежности бассейна имеет триггерную структуру, включающую два состояния, малоснежный режим и режим остальных лет. Значительные вариации в количестве снега в различные годы маскируют многолетние тенденции, которые явно не выражены.

Ключевые слова: снежный покров, спутниковые данные, снежные условия, бассейн реки Эмба, Глубина снега, Чистый ежедневный продукт, продукт “Snow Depth” USGS/EROS FEWS NET