A systematic review of the scientific literature of geomorphological heritage

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Extended Abstract

Introduction

The geomorphological heritage is a branch of geomorphology and is essentially geography. The concept of geomorphological heritage includes landforms and processes that play a key role in understanding earth history, but also has a link with biological and cultural heritage. The geomorphological heritage is more than ever possible in a position to become a sustainable resource through geotourism and environmental education. The search, selection and systematic classification of studies allows for clear results and reproduction, and helps limit bias potential. Studies and popularity of geomorphological heritage are growing rapidly and require a comprehensive review of literature on the subject. Due to the rapid growth of research and popularity of geomorphological heritage and its use (geotourism, geopark, world heritage, etc.), a comprehensive review of the scientific literature of geomorphological heritage is necessary. However, given the increasing growth of geomorphological heritage over the past few years, there is a need for further understanding of the main themes and methods that exist in geomorphological heritage research and the potential gap of knowledge; therefore, the main purpose of this paper is the systematic review of published scientific literature. In the case of geomorphological heritage in order to answer two questions: (1) what knowledge has been produced in the scientific literature of geomorphological heritage; and (2) what trend is evolving in geomorphological heritage research.

Methodology

In this research, the review of the geomorphological heritage literature carried out in three stages: (1) literary search; (2) selection of relevant studies; (3) classification and compilation of results. In

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this study, 207 research papers published in English have been thoroughly investigated. To ensure the quality of the review, only papers published in high quality journals were reviewed mainly in four valid online databases of scientific research, Scopus, Web of Science, Science Direct and Springer. Given that English is widely used in scientific research, only papers published in English are selected. The key words used to search are "geomorphological heritage" and "geomorphosite". First, book chapters, conferences proceedings, editorials, reviews, research notes, short communications, and reports were excluded from this survey. A total of 207 scientific-research articles have been selected for this review. Papers are also categorized according to their goals and topics, their research methods and their results. Summarizing and synthesizing the most important results provided, identifying the main research trends in the geomorphological heritage and the areas that require further research.

Results and discussion

The results show an increasing concentration of research on geomorphological heritage. In the first decade, the number of papers published has been 1 or 2 articles per year, and since 2004 the number of published Papers has increased rapidly. The results show that researchers are more focused on identifying and evaluating geomorphological heritage. The geographical analysis of the study areas represents a global distribution that includes studies in 46 countries. About 48.38% of the studies focus on the potential for geotourism development of geomorphological heritage and only 4.35% emphasize management and conservation. About 64% of the papers are based on a combination of qualitative and quantitative data and 67% have used the combination of primary and secondary data for research. Primary data was mainly collected through fieldwork, including field survey and sampling. The results also show that researchers are less interested in geomorphological heritage stakeholders, such as tourists and local communities, and very few studies survey the geomorphological heritage in the context of sustainable development. In the present study, the history of geomorphological heritage studies has been studied separately in the three decades 1991-2000, 2001-2010, and 2011-2018. During these three decades of research, the most important published works and the development of geomorphological heritage studies have been discussed and analyzed. These three periods include the appearance of new concepts, the development of theory and methodology, and the focus on specific contexts of geomorphological heritage. The results of this literature review indicate that the subjects studied include identifying, inventorying, describing, assessing the potential of geotourism in study areas, conservation issues, tools for promote geomorphological heritage, modeling for geomorphosite and other methodological approaches as well as tourists' understanding and motivation. Regarding the study process, the main topics that need further research include the feasibility of a geomorphological heritage for inclusion in the World Heritage List, geoparks and national heritage, the management and conservation challenges of the geomorphological heritage, the positive and negative effects of geotourism on geomorphologic heritage and the main challenges faces of managers and different groups of stakeholders of geomorphological heritage. The stability of geomorphological heritage is one of the main goals that should be achieved by raising the awareness of tourists and local people of the importance of preserving the geomorphological heritage.

Conclusion

Given studies of geomorphological heritage, more studies are needed to study how geomorphological heritage related challenges are addressed and how to solve these challenges. Next challenges for the international community of geomorphologists and in general geologists are the creation of guidelines and principles for the development of scientific achievements of the geomorphological heritage. Management and conservation of geomorphological heritage in pursuit of sustainable development goals requires more investigation by the scientific community. The proper management of the geomorphological heritage not only affects the proper characteristics of the sites but also determines their geographic boundaries, which Brilha (2018) also emphasizes on this subject. In addition, in none of the geomorphological heritage studies, so far, integrated management approach has not been considered and this approach has not been studied; therefore, moving towards integrated management of geomorphological heritage with the participation of researchers in the humanities and social / political sciences as well as economists and Communication science professionals are essential. However, other issues require further research to provide the knowledge and understanding necessary for the development and successful management of geomorphological heritage. According to the development trend of studies, at least in the next five years, research is expected to concentrate on the management and conservation challenges of geomorphological heritage and how to solve these challenges.

Keywords: Scientific literature, Geomorphological Heritage, Systematic, Development Trend, Geotourism.

Modeling and Prediction of Dust in Western Iran

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Introduction

Dust in hazardous areas anywhere in the world is harmful for human societiesand life organisms. Dust Mineral Aerosols can significantly affect Earth's climate (Zhiyuan et al., 2019: 3). The prevalence of dust storms is devastating human health and agricultural activities in Central Asia (Tiangang et al., 2019: 16). Dust plays an important role in socio-economic development, but on the other hand, such supply can have a negative impact on the environment of the forest (Narayan et al, 2019: 4). According to the previous studies, the importance of dust and the resulting hazard can show that the dust parameter is important for natural hazards. According to the studies, the existing methods for studying the dust that has been done so far have been general and have not adequately addressed the subject. Dust in the areas under its control anywhere in the world has had a risk for various parts of life. Dust storms have also been growing in recent years (Mohammad Khan, 2017: 495). Dust phenomenon due to recent droughts caused adverse biological effects and damages in agriculture, industry and transportation in the provinces of Khuzestan and other neighboring areas (Darvishi et al., 2017: 1). Today, dust is one of the common phenomena and is one of the major environmental problems in arid and semi-arid areas (Hejazi Zadeh et al., 2018: 108). The purpose of this study is to analyze the dust data first to address this issue and then, using ANFIS and RBF models, to make a modeling comparison. Finally, the results can predict for a better view of the dust situation for the future, in dusty regions of Iran.

Material and methods

In this study, after analyzing 29-year-old dust data for 28 stations the regions afflicted by the phenomena in Iran, they were first analyzed and then normalized. After normalizing the dust data using two new and powerful applied models for modeling and forecasting in climateology, the

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ANFIS and RBF models were modeled. Then, the two models were compared for accurate prediction of the future, and after training the dust data, they were predicted for the coming years. Finally, using the TOPSIS multivariate decision making model, regions are more involved with the priority hazardous dust hazard phenomenon and by utilizing ArcGIS software output data.

RBF neural network model

Neural networks with radial base function are widely used for nonparametric multi-dimensional functions through a limited set of training information. Radial neural networks with a fast and comprehensive learning are very interesting and efficient, and they pay particular attention to it, Hartman et al. (1990). Gyrosy, Pogni, as well as Hartmann and Kepler, in the 1990s proved that radial-basis grid networks are very powerful approximation devices, so that by having a sufficient number of hidden neurons, they can be able to approximate each function accurately with every degree. These networks are often compared to the neural network back propagation error. The main architecture of the RBF consists of a two-tier network (Khanjani et al., 2016).

ANFIS Neural Network Model

In this step, it is possible to model and predict dust in the study area using the ANFIS comparative neuro-fuzzy network model (Ansari, 2010: 29). In this study, the phenomenon of dust in a series of time of 276 months (23 × 12 276) was considered in two ANFIS and RBF neural networks models in each station. In a time series consisting of n examples x_1, 〖x〗 _ (2), ..., x_n is the next value of relation (6) of its previous value (Asghari Oskouei, 2002: 75).

$$x_k = f(x_{k-1}, x_{k-2}, \dots, x_{k-p})$$

The fuzzy system is based on the "conditional-result" logical rules that, using the concept of linguistic variables and fuzzy decision making process depicts the space of input variables on the space of the output variables. The combination of fuzzy systems based on logical rules, and artificial neural network methods can enable the extraction of knowledge from numerical data. It has led to the introduction of a comparative neural system inference. A sogeven fuzzy system was presented with three inputs, one output and two laws and an equivalent ANFIS system. This system has two inputs x and y and one f output.

Proximity to Ideal Mode (TOPSIS)

Huang and Yun proposed TOPSIS in 1981. In this method, m options (A1, A2, ..., Am) were evaluated with n indices (C1, C2, ..., Cn) (Momeni, 2008). Solving this problem with this method was carried out in the following steps (Makvandi et al., 1391; Law and Order, 2014).

Results and discussion

The zoning of dust phenomena in dusty regions of Iran using TOPSIS

The results of the implementation of the Topsis model, using the degree of importance of the criteria derived from the entropy method, indicate that, in terms of dust intensity, places more and less dusty for the next 14 years in dusty areas Iran, three stations of Abadan, Masjed Soleyman and Ahvaz were exposed to dust (1, 95%, and 81%), respectively, for simulated years. The northern stations of the study area including Khoy, Boroujen and Ahar showed a lower dust intensity with percentages (0.1, 0.4 and 0.6), respectively. According to TOPSIS model, south west and west of Iran were exposed to dust for simulated years.

Conclusion

According to comparisons of ANFIS and RBF neural network models, the two models were trained to predict dust. The results obtained from the training of the ANFIS neural network model at best, the RMSE value was 11.67 and the R2 value was 0.5879. But the results obtained from the training of the RBF neural network model, at best, were RMSE equal to 2.19 and the R2 value was 0.9854. By comparing these two models, it was finally concluded that the performance of the RBF neural network model was better. According to the modeling and the results obtained from the comparison of the models, the accuracy and reliability of the RBF neural network model was confirmed for prediction, then it was used modelling in this study.

Keywords: Simulation, hazard, RBF and ANFIS models, Iran's dusty areas, statistical analysis.

Annual Variation of the Height of Urban Boundary Layer of Tehran

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Introduction

Atmospheric Boundary Layer (ABL) is the lowest layer of the Troposphere affected by the land surface. Unlike the free atmosphere above, the land surface has a significant effect on the ABL and this layer, is the only part of the atmosphere in which the effects of friction and the diurnal variation of temperature can be observed. In fact, the ABL plays the role of a dealer of energy and mass between the land surface and the free atmosphere.

Many efforts have been undertaken to understand the behavior of the ABL due to its importance since almost all human activity (except aviation) forms in this layer. This, however, should be mentioned that those efforts are in a strong correlation with the development level of the country and the methods to study the ABL varies country by country. The study methods for ABL observations are divided into three main branches: a) Modeling and Simulation (using dynamic and numerical models); b) Numerical estimation (using atmospheric profiles); and c) Using High-tech devices (Remote Sensing, RADAR, and LiDAR).

Like most climatology phenomena, the ABL probably owns some regular pattern in different time scales. In this research, the variation of the ABL over the city of Tehran is investigated in an annual time scale. The reason to choose the city is the high population, high urban concentration, and constant integration with inversion and air pollution, and above all, lack of knowledge about the ABL over the city.

Methodology

In order to conduct a thorough research, long term data were required from a variety of sources. Therefore, 30 years of data were gathered in daily time scale (at 00:00 GMT and 12:00 GMT equal to 03:30 and 15:30 Tehran Mean Time respectively). Total data records reached a sum of 10958 for each parameter. Data were collected from the European Center for Mid-range Weather Forcast (ECMWF) and the Atmospheric Science Department of the University of

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Wyoming. Data gathered from the ECMWF was in NetCDF format and the air profile gathered was in Notepad form.

To have solid results, the data should be of high certainty and reliability. To investigate the reliability of the ECMWF data, the ABL height was calculated for some days employing the Advanced Parcel Method which defines the top of the ABL as the height in which the virtual potential temperature is equal to that of the surface values. Using Kuchran's method to estimate the volume of the test subject from a society, 372 days were randomly selected and the ABL height was calculated based on radiosonde profiles. Then, the correlation coefficient and the Root Mean Square Error (RMSE) between the two data sets were calculated and since the coefficients were significant, data was used further. As for the maps, data gathered from the ECMWF was averaged usnig the ECMWF tools. This tool uses the R (or Rstudio) software abd the RBridge to calculate integrated NetCDF data. The maps were drawn in ArcMap 10.

Results and discussion

Mean daily ABL height was located almost at 850 meters above ground level (AGL). While nighttime ABL descends to almost 80 meters AGL, the daytime ABL rises to 2300 meter AGL. The ABL height has experienced a total rise of 5 meters per day in the total time period of the research. Spatially, the lowest ABL heights were experienced in northeastern part of the city and the highest ABL were measured in south and southwestern part of the city. Also, the correlation between the mean daily data (the ECMWF uses eight data measurements to calculate the mean daily data) and the maximum and minimum averages were calculated. The results showed that the maximum values are of higher influence in mean daily data rather than the minimum.

The findings also indicate that, during all 6 periods of the study time scale, the position of the minimum and maximum boundary layer values are almost the same. High values occur at south and southwest of the city and low values occur at northeast of the city. There is also a midsection area that is usually extended from Ka valley to the east of the city. There is also a sign of some core area, especially the one located above the Pardisan Park that sometimes affects the ABL patterns.

Furthermore, the correlation between the ABL and some climatic parameters (e.g. sunshine hours, surface temperature, surface heat and moisture flux, relative humidity, air pressure, wind speed at 0, and 10 meter height AGL) was calculated for Tehran. The results indicated that there is some significant correlation between the ABL and climatic parameters. The highest correlation was seen between the ABL variation and the surface temperature. Seemingly, the closer the measured parameters to the surface are, the higher is the correlation coefficient.

Conclusion

The Boundary layer height fluctuates between 80 meters AGL at nights and 2300 meters in daylight. The average height has increased almost five meters per year. However, since 1988 to 2012 it has risen and after 2012 it experienced subsidence. Both in minimum and maximum, the highest boundary layer height has been measured in south and southwestern part of the city and the lowest values were measured in northeastern of the city. The iso-height lines are extended from northwest to southeast. This is probably due to the effect of Alburz Mountain range surrounding Tehran in northern edges. The ABL showed high correlation with some climatic parameters but the coefficient between the ABL height and some other parameters were

insignificant. Moreover, regarding the correlation coefficient and the root mean square error results, the Advanced Parcel Method seem to be of enough reliability to calculate the boundary layer height based on radiosonde profiles.

Keywords: Boundary Layer Height, Radiosonde, ECMWF, Advanced Box Method, Tehran.

Evaluation Seasonal Trend of Iran Aerosol Index (AI) Based on Nimbus 7, Earth Probe and Aura Satellite Data

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Extended Abstract

Introduction

Aerosols are solid or liquid particles in the air with a typical radius of 0.001 to 100 μm, which have significant and harmful effects on human health. Aerosols come from both natural and human sources, and in recent years, human activities associated with urbanization and industrialization has led to a steady increase in the amount of these particles in the airborne state. Atmospheric aerosols play a key role in the energy budget of the Earth's climate system through aerosol–radiation interactions (direct effect) and aerosol–cloud interactions (indirect effect). On the one hand, by absorbing and scattering solar and terrestrial radiation, aerosols generally cool the Earth's surface and heat the atmosphere, depending on the absorption level of the aerosols. The southwestern part of the Asian continent (Middle East, Arabian Peninsula and Iran-Pakistan-Afghanistan, IPA) contains several deserts (Syrian-Iraqi desert, Rub-Al-Khali, An-Nafud, Al-Dahna, Karakum, Margo, Registan) and semi-desert areas (Iranian Plateau, Sistan) responsible for large emissions of dust aerosols that are usually accumulated over the Arabian Sea. The study of the precise variability of the AI index in the long run can provide useful information on aggregates, their origin, spatial temporal variation, climate induction and its feedback in the climate system. This study the purpose of the seasonal evaluation of the Aerosol Absorption Index (AAI) was based on TOMS and OMI sensor data in Iran.

Materials and methods

The study area in this study is Iran based on seasonal period. The climate of Iran ranges from the subtropical dry to extremely dry zone in the eastern half and some central areas, wet to extremely wet zone in the southern coastal plains of the Caspian Sea, relatively wet zone in some areas in the west, and semi arid zones over the rest of the country. In this study, TOMS data from two Nimbus 7 satellites (1992-1979) and Earth Probe (1996-2005) and OMI (2015-

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2005) satellite EOS Aura The non-parametric Mann-Kendall test was used to identify the Aerosol Index trend.

The parametric and non-parametric methods have been used to identify the trend in many researchers, but nonparametric methods have been more considered by researchers due to their ability to monitor the unrelated data and also lack of necessity for the normality of data. Non-parametric Mann-Kendall test was used to evaluate the trend of Aerosol Index in Iran. This method is widely used in the field of environmental science. Like many other nonparametric methods such as Mann-Kendall, this method is based on the evaluation of the difference between time series observations

Results and discussion

Significant reduction in the trend The TOMS Satellite (EP) Earth Probe's Aerosol Index (AI) is far from waiting for dusty days and Aura satellite data. TOMS sensor data is not recommended for decomposition of the EP, because since 2001, due to the lack of proper calibration of this sensor, data from this sensor and the satellite provide irrational figures; The results have shown that TOMS sensor data is not suitable for the study of the EP, since since 2001, it is not calibrated for the data of this meter. The maximum incremental increase of the Aerosol index (AI) was calculated for OMI and the maximum decreasing trend of the Aerosol index (AI) used for the winter (TOMS satellite satellite EP) in autumn (TOMS sensor of two Nimbus7 and EP satellites). In spring, the soil moisture content decreased and the activation of dust springs decreased relative to the winter season from areas with decreasing trend and increased areas with increasing trend. In summer, areas with an increasing trend based on Nimbus7 satellite (100%) and Aura (96.74%) of the total pixels are covered. Maximum incremental rate and also the maximum average value of the Aerosol index (AI) trend are obtained based on the OMI Satellite Aura sensor in the fall season. The increase in the Aerosol Index (AI) in Iran is due to environmental and climatic conditions. Some factors including summer Shamal wind, the dynamic and thermal patterns of West Asia, and the Indus Low Pressure, played the greatest role in increasing the hygiene of Iran.

Conclusion

The maximum trend in the general trend of the AI indicator in Iran in winter is the TOMS satellite Earth Probe satellite in the northeast and central parts. This is mainly due to the lack of calibration of the sensor and the satellite. The maximum incremental trend of the Iranian Aerosol Index (AI) for the OMI and the maximum decrease of the Aerosol Index (AI) were calculated for the fall (Numbus7 Satellite TOMS Sensor). The average trend of Iran's AI index for winter is not significant for any of the two sensors and three satellites. In the spring, the intensity and percentage increase was increased relative to the winter season. The growing trend in most parts of Iran is associated with dusty events originating from dry and desert lands of southwestern Iran, especially in Iraq. In the summer, Nimbus7 and Aura satellite data showed more than 95% of the country's total traffic. Zones with increasing trend of TOMS sensor Nimbus7 satellites are observed in all metropolis of Iran with 500,000 to 1 million and more than one million people. There were no negative trends in any cities. In the autumn, we observe the maximum percentage and the intensity of the significant increase of the Aerosol Index (AI based on the OMI satellite satellite Aura in the country. This trend can be correlated with

decreasing precipitation and the inhibition of the following particles in the airborne atmosphere due to reduced moisture content. The increase in the trend of Huawei index in Iran is resutled from environmental conditions such as land use, soil moisture and drought. The significant factors in HomoSperm regional circulation systems are Caspian Sea–Hindu Kush Index (CasHKI), negative phase of Pacific Decadal Oscillation (PDO)) with fluctuations, Shamal winds, short-term phenomena such as frontal systems, low-level jets (LLJs), and low pressure of the document on the transit of these particles.

Keywords: Absorption Aerosol Index (AAI), TOMS Sensor, OMI Sensor, Mann-Kendal Test (MK), Iran.

Characteristics and Teleconnections of the Extreme Eastern and Central Pacific and Mixed El Niños

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Extended Abstract

Introduction

The El Niño-Southern Oscillation (ENSO) cycle of alternating warm El Niño and cold La Niña events occurs when the tropical Pacific Ocean and its overlying atmosphere deviated from its natural state for at least several consecutive months (Neelin et al., 1998). The neutral phase of the El Niño-Southern Oscillation is derived by the strong zonally asymmetric state of the equatorial Pacific and is characterized by surface easterly trade winds along the equatorial Pacific, rising motion, deep convection and heavy rainfall over the western equatorial Pacific, westerly winds at upper levels and sinking motion over the eastern equatorial Pacific (Bjerknes, 1969). El Niño is characterized by weak and La Niña by strong zonal SST gradients, accompanied respectively by weakening and strengthening of the trade winds across the equatorial Pacific (McPhaden et al. 2006). As a result, compared to the neutral phase of the El Niño-Southern Oscillation, convective systems intensify in the western tropical Pacific and slightly shift to the west during La Niña events, but shift to the central and eastern tropical Pacific during El Niño events. Since this early recognition of the coupling between the atmosphere and the Pacific Ocean by Bjerknes (1966) and Bjerknes (1969), major advances have beenmade toward a comprehensive understanding of the physics of the El Niño-Southern Oscillation. This is particularly achived through development of complex climatemodels for realistic simulation of the El Niño-Southern Oscillation cycle (Bellenger et al., 2014), and great observational advances that have been made during the international Tropical Ocean-Global Atmosphere (TOGA) program conducted between 1985 and 1994 (McPhaden et al., 1998). El

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Niño or the warm phase of the El Niño-Southern Oscillation is a quasi-periodic natural phenomenon that occurs in the tropical Pacific Ocean. The El Niño-Southern Oscillation not only influences the climate of nearby regions, but it is the most important natural climate aggent contributing to the interannual climate variability over many regions across the globe, including North America (e.g. Yu et al., 2015; Guo et al., 2017), the Middle East (e.g. Alizadeh-choobari, 2017; Alizaeh-Choobari et al., 2018a, Alizaeh-Choobari et al., 2018b), East Asia (e.g. Feng and Li, 2011), Southeast Asia (e.g. Lee et al., 2017) and the Indian subcontinent (e.g. Kumar et al., 2006). Depending on the location of the maximum sea surface temperature in the eastern or central equatorial Pacific, the eastern Pacific El Niño or the central Pacific El Niño are identified, while a mixed event has also been diagnosed in the eastern and central Pacific El Niño events.

Materials and methods

In this study, using the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis Interim (ERA-Interim) monthly dataset with a horizontal resolution of $0.75^{o} \times 0.75^{o}$, and the Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5) dataset, we determined the phase of ENSO and the type of El Niño events during the period 1979-2016. In addition, characteristics of the 1997-98 eastern Pacific El Niño, and the 2009-10 central Pacific El Niño and the 2015-16 El Niño are investigated as a mixed event of the eastern and central Pacific El Niño,.

Results and discussion

The results of this research indicateed that during the period 1979-2016, 1979-80, 1982-83, 1986-87, 1987-88, 1991-92, 1994-95, 1997-98, 2002-03, 2004-05, 2006-07, 2009-10, 2014-15 and 2015-16 have been the years for which three-month running means of the Oceanic Niño Index (ONI) for 5 consecutive periods became greater or equal to 0.5 degree Celcius, indicating the occurrence of El Niño in these years. To determine the eastern and central Pacific El Niños during the period 1979-2016, we used the empirical orthogonal function (EOF) by examining spatial correlation between sea surface temperature anomalies in the equatorial Pacific Ocean and results of the empirical orthogonal function. The 1997-98 and 2015-16 El Niño events are both categorized as extreme El Niño events. The 2009-10 El Niño is weaker than the other two events, but over the last century, it has been the strongest central Pacific El Niño event. Results indicated that the onset of all these three events was in June, while some differences are found between termination of the 1997-98 and 2015-16 El Niños, including different time of dissipation for these events. All these three events have shown characteristics of classic El Niño events, such that anomalous positive and negative sea surface temperature are seen in the eastern and western equatorial Pacific, respectively. Nevertheless, maximum positive sea surface temperature is formed in the eastern equatorial Pacific during the 1997-98 El Niño. This is different from the 2009-10 El Niño events with the maximum sea surface temperature in the central (near the dateline) equatorial Pacific. In fact, maximum positive sea surface temperature anomalies are expanded in the eastern and central equatorial Pacific during the 1997-98 and 2009-10 El Niño events, respectively. However, it extends from central to eastern equatorial Pacific during the 2015-16 El Niño. Intensities of the maximum sea surface temperature anomalies and mean sea level pressure have been greater during the 1997-98 El Niño compared

to those during the 2009-10 event, indicating that central Pacific El Niños are generally less intense than eastern Pacific El Niño events. It is shown that positive sea surface temperature anomalies in the 2015-16 El Niño event cover a larger area extending from the central to the eastern equatorial Pacific. It is found that both sea surface temperature and mean sea level pressure anomalies in the equatorial Pacific were larger the 1997-98 eastern Pacific El Niño than those of the 2009-10 central Pacific El Niño. This suggests that the central Pacific El Niño events are generally weaker than the eastern Pacific El Niño events. In all of the three El Niño events, positive (negative) geopotential height anomalies at 300 hPa pressure level in the equatorial Pacific are collocated with positive (negative) sea surface temperature anomalies. Geopotential height anomalies in the upper levels over the tropical Pacific influence weather patterns of other regions. It is discussed that different geopotential height anomalies at upper levels of the equatorial Pacific during the three El Niño events have led to different teleconnections across the globe. For example, temperature anomalies in the Antarctic during the 2009-10 El Niño were opposite to those during the 1997-98 and 2015-16 El Niño events.

Conclusion

Analysis of the ERA-Interim dataset with the horizontal resolution of $0.75^{o} \times 0.75^{o}$ for the period 1979-2016 indicated that the eastern, central and mixed El Niño events have generally different characteristics in the equatorial Pacific. As a result, teleconnection patterns of these events across the globe are also found to be different.

Keywords: The El Niño-Southern Oscillation (ENSO), Eastern Pacific El Niño, Central Pacific El Niño, Mixed El Niño, Teleconnections.

Analysis of Long-Term Mean of Red Band Albedo in Iran

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Extended Abstract

Introduction

Today, the assessment and control of environmental and climate change at the regional and global levels is of particular importance for monitoring the current situation and for predicting future changes. Albedo (or solar reflectivity) plays an important role in the thermal behavior of pavements and other ground surfaces and their resultant impacts on humans and the environment (Li, 2016). Therefore, the study of its temporal and spatial behavior can be a tool for understanding environmental changes. Albedo, as one of the important components in the Earth's Radiation balance, is the ratio of reflected flux density to incident flux density, referenced to some surface. Albedos commonly tend to be broadband ratios, usually referring either to the entire spectrum of solar radiation or just to the visible portion. More precise work requires the use of spectral albedos, referenced to specific wavelengths. Visible albedos of natural surfaces range from low values of ~0.04 for calm, deep water and overhead sun, to > 0.8 for fresh snow or thick clouds. Many surfaces show an increase in albedo with increasing solar zenith angle (American Meteorological Society, 2019). Remote sensing is one of the most suitable tools for measuring albedo. Many researchers have used the parameter and also evaluated its algorithm (Jackson et al., 1987; Schaaf et al., 2002; Wang et al., 2018).

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Data and methods

In this study, for the assessment of long-term mean value of albedo in Iran from the first band of MCD43A4, the Modis sensor was employed in the range of 0.62-0.67 microns during the period from 2000/03/20 to 2018/03/20 for 6574 days. The reason for choosing this product is because it has the Bidirectional Reflectance Distribution Function (BRDF). Indeed, BRDF can determine when the radiation energy reaches a certain level (an opaque surface)and it is reflected in the other direction. The data of this sensor is available as separate tiles at 1200 x 1200 km and Iran generally falls into six tiles. Of course, based on the Inpolygon function in MATLAB software, grid points outside of Iran were clipped. Iran was divided into 4 regions based on digital number of pixels. The basis of division is the quart values (first, second, and third quartiles). After zoning, we calculated statistical characteristics including the average, minimum, maximum, variance, range of changes and coefficient of skewness and Kurtosis of the cells located in each region. These statistical characteristics provide an opportunity to compare albedo in the different regions of Iran. Finally, we calculated four seaboard areas in Iran were mapped and its relation with height.

Results and discussion

The statistical characteristics of the red band albedo over Iran during the study period show alternative shifts (Table 1). The average, minimum, and maximum of the first quartile is 53.15, 1.45 and 85.18, respectively. The coefficient of variation in this class is 21.76%. The highest coefficient of variation is seen in the first quartile, but this may be due to the number of pixels affected. In general, the coefficient of variation shows that the highest coefficient of variation occurs at very low or high levels of Albedo.

Quartile	Fre.	No Data	Min	Max	Average	Range	Standard deviation	Variance	Skewness	Kurtosis	CV %
First quartile: the lowest 25% of values	1878729	6646	1.45	18.85	15.53	17.39	3.39	11.44	-1.88	6.45	21.76
Second quartile: between 25.1% and 50% (up to the median)	1881589	3786	18.85	22.2	2.58	3.35	0.95	0.91	-0.06	1.82	4.62
Third quartile: 51% to 75% (above the median)	1880826	4550	22.2	25.82	23.9	3.62	1.03	1.07	0.11	1.83	4.31
Fourth quartile: the highest 25% of values	1883848	1528	25.82	61.08	29.33	35.25	3.13	9.82	1.67	7.08	10.67

A long-term albedo map was developed for the time period (2000-2018) based on remote sensing data. After preparing the aforementioned map based on the thresholds obtained from the quartile method, Iran was divided into four distinct areas in terms of albedo. The first area covers about 2% of the total area of the country where it is most commonly found in the south-east of the country, the Caspian coast and the water areas within the land, such as Lake Urmia. The second zone covers the range of 22-19 percent and is seen in different parts of the country. The third zone is in the range of 26-22% and is further dispersed in the center of the country. The fourth region has a range of 62-26%, which shows the highest albedo. In this area, snow-covered mountains such as the Alborz and Zagros heights and the zones that have been stained

with white evaporation deposits over time are seen. Larger parts of this area, due to permanent snow or evaporation deposits, have albedo more than the average planet Earth (24%). There is a good relationship between albedo and height, although this is a completely nonlinear relationship. Up to 1200 m altitude, with increasing altitude, albedo decreased and at an altitude from 1400 to 1200 m it is varied from 12 to 36% due to different land use. From a height of 1,400 meters, the strong link is seen between Albedo and the altitude of the sea level in Iran. As Albedo increased with altitude due to lower temperature and also snowfall, it reaches nearly 60% at Altitude 4000 meters. In general, it can be said that this relative relationship between Albedo and altitude of sea level in Iran is due to the complexity of topography and land use. As a result, the relationship is straight above altitudes of 1,400 meters, and with increasing altitude, the albedo is elevated, and there is a decrease in albedo at altitudes less than 1000 meters indirectly with increasing altitude.

Conclusion

The MODIS sensor produces albedo in the surface of the earth continuously on a global scale with low spatial resolution and provides free access to the public. In this study, for measuring the average long-term albedo of Iran, the daily data of Albedo in the region of Iran was extracted from the MODIS website during the period from 2000/03/20 to 2018/03/20 for 6574 days. Then, based on nearly 45 billion cells, the long-term average of Iran's albedo was calculated. The results showed that albedo of Iran with an average of 21% is close to the albedo of the planet average which depends on latitude and topography and land surface conditions in Iran. The relationship between albedo and altitude from sea level was studied. The results of this section indicate that this relationship is a completely nonlinear relationship. Thus, in the first altitudes up to 1200 meters, the albedo has a decreasing behavior, and between the altitudes of 1200 and 1400 meters there is a steady trend; from 1400 to higher the albedo behavior is quite increasing. The increasing behavior of albedo well illustrates the behavior of snow cover in the highlands. In general, it can be concluded that this relationship is due to the diversity of topography and the type of the earth's surfaces. For this reason, this relationship is direct in elevations above 1400 meters. As the altitude increases, the albedo is increased, and at elevations less than 1000 meters the relations are inversed (by increasing the elevation, a decrease is observed in albedo).

Keywords: Iran, Quartile, Albedo, MODIS, Long-term Mean.

Identifying Dynamic and Thermodynamic Patterns of Winter Heavy Rainfall in Iran (1960-2010), a Case Study: 1974/12/05 Heavy Rainfall

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Extended Abstract:

Introduction

Changes and fluctuations in shape and type of precipitation have positive and negative effects and have an important role in different aspects of human life. The change in the pattern produces negative and positive secondary feedback to other climatic parameters followed by changes in hydrological cycles, water resources, natural and artificial ecosystems, human and animal habitats, security and economics. Therefore, the first parameter that can be considered is the study of drought. The presence of many parts of Iran in the dry and semi-arid belt of the world, on the one hand, and the determinant role that play at the water supply in the country on the other hand, thus it is important to be aware of the trend of rainfall changes in Iran. The nature of the heavy rainfall and the consequences of this have caused this phenomenon to be of particular importance in environmental planning and water resource management. The heavy rainfall affects the planning, design, operation and management of water resources. Therefore, it is necessary to know the characteristics of the behavior of such rainfall in order to predict and better manage water resources of the country. Heavy rainfall is one of the natural hazards that being aware of their occurrence can help reduce potential damage .The dynamic state index of the atmosphere, which expresses the degree of deviation from non-static, drought and viscosity of the atmosphere, can be used as a new theory to determine the location and time of high-pressure and low-pressure systems and their intensity.

Iran has arid and semi-arid climate, with its annual rainfall averaging about one-third of the world's annual values. Parts of Iran's rainfall are also more widespread in south-east part of the country, with high rainfall intensities. Therefore, the analysis of the synoptic and dynamic conditions of atmospheric circulation patterns is very important in identifying the factors

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affecting the occurrence of heavy rainfall, in particular, when these types of rainfall can cause floods and catastrophic consequences by converting runoff. Thus, with respect to the importance of the subject, the present study aimed to identify the dynamic and thermodynamic patterns that govern the day of the event of heavy winter precipitation.

Materials and methods

In order to study the dynamic and thermodynamic patterns of the studied day, the vorticity of dynamical quantities include relative vorticity, absolute vorticity, Rossby-Ertel vorticity at pressure level, convergence and divergence, vertical speed at high system and dynamical quantities of potential temperature written and definedTo analyze the temporal variations of the above quantities, their graphs were analyzed in the selected range of 0 to 80 degrees longitude and latitude 10 to 60 degrees north for the 0000 and 1200 Greenwich hours. It should be noted that the maps of the day before and after the day were also examined at different levels to further understand the patterns governing the day of heavy rainfall, but to reduce the amount of content, only the maps of the day of heavy rainfall occurred at 0000 and 1200 Greenwich are provided.

Results and discussion

Examination of the thermodynamic and dynamical quantities during heavy rainfall events of the case series of winter 1960-2010 shows that on the day of the heavy rainfall event, December 5, 1974, the intensities of these quantities at 1200 Greenwich hour were greater than other times. Therefore, it can be said that the peak of heavy rainfall at this day is 1200 hours where the dynamical and thermodynamic quantities changes are as follows:

- Increasing the potential temperature vertical gradient across the country; this increases the velocity of the subtropical jet as well as the potential vorticity values in the upper atmosphere.
- The formation of a strong convergence zone at the country level and its adaptation to the mid-level divergence zones of the atmosphere that has led to the dynamic rise of the air in most areas. The high volume of upward atmospheric movements at this time has occurred in the western half, especially in the windward slopes of the Zagros Mountains.
- Increase in relative vorticity and absolute vorticity of 500 hp levels corresponding to southwest - northeast flows of eastern part of the trough.
- Increasing the potential vorticity values of Rossby-Ertel pressure levels of 500 and 50 hp and the co-entropy level of 330 Kelvin in the western part of the country due to factors such as potential temperature gradient increase, caused absolute vorticity increase, as well as increased static stability in the upper atmosphere.

Conclusion

Changes and fluctuations in shape and type of precipitation have positive and negative effects and they play an important role in different aspects of human life. The change in them produces negative and positive secondary feedback in other climatic parameters in hydrological cycles, water resources, natural and artificial ecosystems, human and animal habitats, security and economics. Heavy rainfall is one of the natural hazards that being aware of their occurrence can help reduce potential damage. Therefore, the analysis of the synoptic and dynamic conditions of

atmospheric circulation patterns is very important in identifying the factors affecting the occurrence of heavy rainfall, in particular, when these types of rainfall can cause floods and catastrophic consequences by converting runoff. Thus, with respect to the importance of the subject, the present study aimed to identify the dynamic and thermodynamic patterns prevailing on the day of the event of heavy winter precipitation. The results show that during the event of heavy rainfall, a strong convergence zone was formed at the country level, which caused the dynamic ascension of the atmosphere in accordance with the atmospheric divergence zone. Under such conditions, the relative vorticity values increases corresponding to the eastern part of the trough, which also results in an increase in absolute vorticity values. In addition, at this time, the potential temperature vertical gradient is also increasing throughout the country. The Rossby-Ertel potential vorticity values of 500 and 50 hp and 330 Kelvin co-entropy levels can also be increased due to potential temperature gradient increase, absolute vorticity, as well as increased static stability at upper atmospheric levels.

***Keywords: Heavy Precipitation, Precipitation, Dynamical, Convergence, Divergence*.**

The Effects of Quasi-Biannial Oscillations on Iran Winter Precipitation

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Extended Abstract

Introduction

Precipitation is resulted from a complex atmospheric and oceanic phenomenon and among other climatic events it has a special importance for the vital role it can play in environment and any human activity. Iran is located in the world's arid and semi-arid belt and receives more than half of its annual rainfall in the winter. Teleconnection is the alternating and continuous anomalies of atmospheric patterns and particularly pressure on the planetary scales with relative prolonged return period. Therefore, it can be considered as one of the key elements on climatic forecasts. Quasi-Biennial Oscillation (QBO), recognized in 1961,is one of the main oscillations on the planetary scale in the stratosphere layer with a mean return period of 26 months and is also one of the main components of short-term fluctuations in the climate. QBO can vary the surface weather with effect on polar atmospheric patterns. It can also affect the amount of ozone depletion on high geographical latitudes, in addition to the effect on solar cycle and connection with other teleconnections such as ENSO resulting in the climate change of the earth.

Material and methods

The total monthly precipitation from 100 synoptic stations from Iranian Meteorological Organization and QBO index data of National Oceanic and Atmospheric Administration (NOAA) during 1988-2017 were applyed as the basic input data of the study. First, rainfalls from December to February were considered as winter precipitation for the corresponding QBO index. Then, precipitation data were standardized in order to make comparable data with QBO. The normalized data of winter rainfall as dependent variable and QBO index as independent

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variable were entered into the STATSTICA software. Pearson correlation coefficients were performed between them in each station. No simultaneous effect may be observed due to long distance between QBO generation areas and Iran, therefore, a three months lack also was tested, and hence, the correlation coefficients were calculated between autumn QBO and winter precipitation of the stations. In order to validate of correlation coefficients, precipitation difference of the stations in the positive phases of QBO compared with negative phases. In the next step, the correlation coefficients outputs entered into the GIS environment and mentioned maps were drawn using IDW approach. Finally, the trend chart of the winter precipitation anomaly was prepared to study the impacts of autumn and winter QBO on.

Result and discussion

The results showed that there is a significant inverse relationship between the positive phases of autumn QBO with winter rainfall in most stations, especially in the central and southern parts of Iran. The increase in the intensity of the positive phases in autumn QBO causes subnormal winter rainfall in the central and southern parts of the country. On the other hand, the occurrence of negative autumn QBO causes a minor increase in the rainfall rates of most parts of Iran. However, the occurrence of rainy winter in the case of autumn negative phases is not conclusive. But, the winter time extreme negative phases of QBO index lead to a significant decrease in the precipitation rates of most areas of the country especially southern and western parts, while the positive phases lead to minor decrease (increase) in the precipitation rates of the southern (northern)parts of Iran. The separate study of positive and negative phases of QBO in autumn and winter seasons revealed a contradictory effect on winter rainfalls in different parts of Iran, and in short, the effect of QBO on winter precipitation is lower in northern parts. The final results showed that the occurrence of rainy winter has been linked to the mild phases of QBO index in the autumn and winter. It can be concluded that the QBO teleconnection is one of the main factors controlling winter precipitation in different parts of the country, especially in the southern, central and western sectors. The main and tangible role of QBO is a reduction in the amount of precipitation. Meanwhile, there is no significant relationship between QBO index and winter precipitation in the northern parts of Iran, especially the northwest and Caspian Sea coasts.

Conclusion

In general, the correlation between the autumn and winter QBO index and winter precipitation is negative in the western half and positive in the eastern and southern parts of the country. Thus, by moving from the extreme negative values of QBO to the positive ones, a relative partial reduction is observed in the precipitation rate of northwest regions, western sides of Alborz Mountains and the western parts, respectively. There is an increase in other parts especially in the Caspian Sea coasts and the southern Iran. The autumn phases of QBO index are slightly more related to winter precipitation. Unlike the previous condition, there is a negative correlation between the positive phases of QBO and winter precipitation rates. This is more significant in most regions especially in central and southern parts of Iran. The highest correlation coefficient (-0.65 to -0.82) was observed on the shores of the Persian Gulf and the positive phases of this index happened to decrease the precipitation rates in the central and southern regions of Iran. There is no significant relationship between the negative phases of

autumn QBO and winter precipitation rates. On the other hand, positive phases of winter QBO can reduce precipitation rate in south and southwest regions and partially increased rainfalls in the northwest of Iran. However, the amount of rainfall decrement is more significant in the southern regions. Also, the occurrence of negative phases in the winter reduced the precipitation rate in most parts especially in the western parts, the coast of Persian Gulf and some parts of the eastern Iran. The occurrence of rainy winter has always been linked to the gentle phases of QBO index and it has not been associated with strong positive and negative phases. It seems that the extreme positive phases in autumn and the extreme negative phases in winter time have more significant effects on the reduction of rainfall in most parts of Iran especially in southern regions.

Keywords: Teleconnection, QBO, winter precipitation, correlation coefficient, Iran.

Effects of Climate Change on Grape Tree Phenological Date Change in Iran

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Extended Abstract

Introduction

Climate change and global warming will endanger the production of agricultural products and food security in the world. The horticulture sector and fruit trees are affected by the climate because of the long distance to the production. Any changes in temperature patterns will change the length of the growth season and dates of the phonological and physiological stages. Air temperature is often considered as the main factor affecting the phonological phases of fruit trees in temperate climates. The increase in the Earth's surface temperature due to greenhouse gas emissions has created a phenomenon called climate change. The perceived effects of climate change on the daily lives of communities around the world have raised the public's attention to climate change. The transformation of the climate and its consequences from different aspects on the planet are not covered by anyone. Today, the challenge of climate change and its effects is the most important challenge facing the country. Fruit trees are subjected to climate change as one of the main sources of agricultural economics and employment in the country. Given the importance of grape product in the country's economy, it is essential to study the effects of climate change on this tree in Iran. Therefore, the present study aimed at revealing the effects of climate change on the time of phonological stages of Grape tree in Iran based on the output of new CMIP5 models and representative concentration pathways scenarios (RCP).

Materials and methods

The realm of this research is the cultivation of grape tree in Iran. The major areas of grape tree cultivation in Iran are located in the northern, western, and eastern regions of cold weather. In the present study, two types of data were used to analyze the process using statistical-analytical method. The data of the baseline or past period have been extracted from IRIMO by the actual

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statistics of 55 meteorological stations in vineyard cultivation areas. These observation data include the statistical period (1985-2005). Future data as simulated data are based on the output of CMIP5 models. These data have been processed in two routings RCP8.5 and RCP4.5 from 2020 to 2090. In the upcoming period, the models (BCC-CSM1.1, MRI.CGCM3, GFDL-CM3, MIROC-ESM and (GISS-E2-R from the CMIP5 models of the MarksimGCM database were used in the RCP8.5 and RCP4.5 scenarios). The results showed that the MRI.CGCM3 model has a higher ability to simulate the future than other models.

Results and discussion

The results showed that the MRI.CGCM3 model, with the higher weight, than the other general circulation models proposed, has a higher ability to simulate temperature and precipitation behavior in the future period relative to the base period. The model has the minimum, maximum and precipitation temperature for weight of 0.40, 0.39 and 0.29, respectively. Therefore, from the model data, in-built comparison model of the CMIP5 is based on RCP radiative forcing scenarios. It was used to assess and detect the effects of climate change in the upcoming period. The results showed that the air temperature in the pessimistic and middle run pattern of RCP8.5 and RCP4.5, respectively, would increase compared with the baseline period. This increase in the pessimism pattern was higher than the midterm pattern. The changes in the far future period (2056-2090) will be greater than the upcoming mid-term (2020-2055). The magnitude of these changes in the RCP8.5 induction trajectory in the period (2020-2055) and (2056-2090) at the selected station level was 1.6 and 2.4 degrees Celsius, respectively, and in the RCP4.5 induction line , Is 1.2 and 2.3 degrees Celsius, respectively, relative to the base period.

Conclusion

Output of the overall model of the MRI.CGCM3 has less simulation abilities in illustrating the climate change of the upcoming period. It has errors that are more than those of the observation period or the baseline period. The results showed that in the most pessimistic case in the middle and distant future, 1.6 and 4.2 degrees Celsius, the minimum temperature would increase compared to the baseline period. The results showed that the most changes occur during the occurrence of phonological stages in cold regions and high latitudes of vineyard cultivations. Due to the increase in the temperature of the air in the future period, it will also alter the date of occurrence of the phonological stages of the grapevine. Due to the increase in the air temperature of the future period, the threshold of biota will occur ahead, and as a result, the vinegrowing period will begin earlier than the previous period. Therefore, in a pessimistic evolutionary pattern, the threshold of biota timing will be ahead in the middle of the future, 8 to 16 days, and the flowering time will be 7 days to 16 days. Therefore, one of the major effects of climate change on fruit trees will evolve in the form of a change in the time of occurrence of the phonological stages. In the future period, the deviation from the optimal temperature conditions of the phonological stages of the grapevine will be increased. In the futures period, the amount of deviations and temperature anomalies will increase significantly from the optimum temperature range over the base period. The regions of northwest and northeast will have the highest deviation from optimal temperature conditions. The range of areas with high temperature deviation was observed at the phonological stage of germination and flowering. The flowering stage shows the highest deviation from optimal temperature conditions. The

amount of deviation from optimal temperature conditions will be increased from the south to the north of the grapevine area .

Changes and displacement of the threshold times of the grapevine biomass increase the risk of possible dangers of frost and late frost in most vineyard cultivation areas, especially in the northern half. It is important to select species and varieties resistant to and adapted to the climatic conditions of each region. In the future period, the range of cultivars of the grapevine will decrease. In the future, the final area of the grapevine area will be limited to 12.64824123 hectares. In fact, due to the rising air temperature in the future, areas susceptible to Ango cultivation in the southern, central, and eastern regions of the grapevine area will lose their climate capability.

Keywords: Climate Change, CMIP5, RCP scenarios, Iran, Grapes.

Evaluation of the Capability of Polarimetric Radar Bands to Extract Biophysical Properties of the Earth's Surface

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Extended abstract

Introduction

Biophysical properties of vegetation, temperature and surface moisture are key parameters to control and evaluate the physical and chemical processes of the land surface. Biophysical properties can be used to monitor various applications such as urban heat island, climate change and drought. Access to timely information and awareness of the changes in land's biophysical properties are required in integrated management and sustainable development. Erath surface biophysical properties can be successful in being retrieved using different types of remote sensing data. From 1970s, remote sensing data provides unique information in surveying dynamic phenomena. Remote sensing imagery provides repetitive data of wide distant area.

Remote sensing sensors collect Earth surface data at different part of electromagnetic spectrum, i.e. optic, thermal and microwave. As a result, the same phenomenon may provide different responses depending on the radiation's wavelength. These responses are complementary and the joint use of them offers more reliable information. That is the reason, multi-sensor approaches gain more attention. Multi-spectral optical sensors such as Landsat have been widely used in earth surface studies; however, their applications are limited mainly in the presence of smoke, fog and clouds. In contrary, radar sensors (e.g. Synthetic Aperture Radar, SAR) operate well even in cloudy sky. SAR sensors are sensitive to the moisture content and structure (shape, direction, roughness) of the surface. Therefore, the main purpose of this study is to evaluate the efficiency of radar bands for extracting surface biophysical properties.

Materials and methods

For the purpose of comprehensive study, three different areas with different types of land cover were considered as the study areas. The first study area, located in the east of Ardebil, encompasses bare land. The second study area is located in the southeast of Ardebil with agricultural land use. The third study area in Mazandaran province is around Noor city. Land cover is dense natural forest.

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Landsat-8 and Sentinel-1 satellite images dated on 2019 were acquired. The Landsat-8 image has already been geo-referenced with UTM coordinates system, zone 39. The coordinate system for Sentinel images is WGS84 ellipsoid. We used the GRD product which has VV and VH polarizations.

In this study, pre-processing steps were done to prepare images including atmospheric correction (Landsat images) and geometric (Sentinel images). FLAASH algorithm has been used for atmospheric correction. Next, spectral indices were computed from Landsat visible and infrared bands to represent surface biophysical properties. Single-channel algorithm is used to calculate surface temperature. Multiple linear regression was applied to model surface biophysical properties by the help of Sentinel polarimetric bands. Finally, based on these models, surface biophysical properties maps were driven.

Results and discussion

In this study, 18 spectral indices were extracted from Landsat image. It should be noted that some of these indices are normalized and some are not normalized, so for all indices to be comparable the values of all indices were set to zero and one normal.

Case study 1

In the first study area, radar's backscattering values showed more significant relationships with LST, NDBI and IPVI indices, while there were weak relationships among radar's backscattering values with MNDWI, GDVI and SR indices. High coefficient of determination between radar responses and LST values could be justified by the effect of soil moisture on soil temperature and radar backscattering, as well. That's why, radar responses can predict LST values.

Case study 2

The investigation of the relationship among spectral indices and radar bands shows that radar bands have high potential to extract biophysical properties in this region. Among 18 spectral indices, EVI, MTVI1 and MTVI2 indices were highly correlated with the radar bands. The LST, SGI and SR indices showed the weakest correlations with radar bands. This indicates, LST, SGI and SR could not be predicted by backscattering values in agricultural land.

Case study 3

In the third study area, MNDWI showed a high correlation with radar responses. MNDWI index was first developed to study the amount of water available to represent vegetation health. Radar bands are also highly sensitive to moisture content. Therefore, it is not surprising that a high correlation between the radar bands and MNDWI index were reported for the third study area, as it is a high moisture forest area. The lowest correlation was observed between radar bands with NDBI spectral index with correlation coefficient of 0.418. The reason for this low value is the nature of the study area, because the study area covers with dense vegetation and the NDBI index has been developed to extract the built-up area.

Conclusion

Remote sensing technology provides valuable information in recognition of patterns and changes of the biophysical properties of the earth surface. Optical data have good spatial,

spectral and radiometric resolution and have been used in a variety of applications. However, optical data is not available in all seasons because the presence of smoke, fog, clouds limits their availability. In contrast to optical data, SAR sensors have the ability to acquire data in all weather conditions. Therefore, the main objective of this study was to investigate the capability of radar data to extract biophysical properties of the land surface. The results showed that radar bands have a high capability to extract surface biophysical properties, so radar data can be considered as a good alternative especially when optical data is not available. Considering the proper relation of spectral indices with the targets' responses in radar bands, the results of this study can further be used in different environmental applications such as heat island, evapotranspiration and coastline extraction.

Based on the findings of the current study, it is recommended that future researches investigate the efficiency of full polarization images in comparison with existing spectral indices to extract biophysical properties of the earth's surface. The full polarized radar images also allow the calculation of radar indices based on the degree of backscattering values in different polarimetric bands. In addition, given the low saturation level of spectral indices (in comparison with radar, responses) and the loss of sensitivity of these indices to phenomena changes, it is highly helpful to investigate the relationship of biophysical properties with radar bands in such a situation.

Keywords: Optical data; Radar data; Biophysical properties; Spectral indices; Regression analysis.