ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 415-419

Comparing and assessment of TRMMdata and ground based measurements data for drought monitoring

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Abstract—Providing a spatial and temporal drought monitoring and precipitation patterns for dry periods is very essential for different applications specially for drought adaptation plans. Due to short period of measured data and inappropriate distribution of weather stations, the study of water resources / climate in some regions of the province is carried out with difficulty. Therefore, it is necessary to recognize other reliable climatic data resources. Accordingly, in this research data from 10 synoptic stations and monthly data of TRMM satellite was used to monitor drought in Khorasan Razavi province. Standardized precipitation index (SPI) of 1, 3, 6 and 12 months were calculated for 13 years period (1998-2010) and compared with those of satellite based data for the same period. The evaluation was measured using CSI (Critical Success Index) and R^2 (Coefficient of Determination). The results showed that there was a very good consistency between earth borne and satellite borne SPIs for 6 and 12 months' SPIs. Moreover, monthly data from TRMM portraits the 2000 and 2008 droughts in the province more accurately. Based on the results, it can be concluded that the TRMM satellite data has the capability of drought monitoring over the province.

***Keywords*—**drought monitoring, SPI, TRMM, CSI.

I. Introduction

MOSTof the conventional drought monitoring indices are based on data acquired from meteorological stations. While these indices have made a vast contribution to drought monitoring, but it seems still there is a need for improvement of drought monitoring indices, involving other sources of data. The need magnifies if we consider short length of records, inadequate number and poor distribution of weather stations. Hence, other sources of data should be assessed, in their capacity to satisfy this need [2].

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Satellite images are example of such alternative data. TRMM satellite provides precipitation data and hence is selected for drought monitoring in this research. TRMMsatellitewas launched on 28November 1997in collaboration withthe spaceagency'sof boththeUSAand Japan.The Satellitecanmeasureprecipitation over land and sea.Especially it is useful for areasthat lack data or have inappropriate data.Thesatelliteis locatedata height of approximately350km fromearth surface with an inclinationangle of 35degrees.The satellite covers from -50° to 50° latitude. The data is distributed by NASA GSFC Distributed Active Archive Center [8].

BaraniZadeh et al (2011) compared TRMM monthly precipitation data with Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) in Iran for period of 2000-2007. Correlation coefficients for winter, spring and autumn precipitations was 0.83, 0.86 and 0.83, respectively; which showed that the satellite data has the capability of precipitation estimation in Iran [1].

Another research, in a region of India, was concluded that there was a very good consistency between TRMM satellite data and Doppler radar (Correlation Coefficient ~0.9) [13].

Vegetation indices with combine visible and infrared bands are also used for drought monitoring. Moreover, using a combination of precipitation radar and microwave in TRMM satellite has brought about possibilities of drought evaluation with the satellite datavia measurement of precipitation.

Li et al (2010) have taken the drought occurred in the winter wheat areas of North China from October 2008 to February 2009 as a monitor case, the TRMM 3B43 precipitation data product was used with the index of precipitation anomaly percentage, finally the spatial evolution process of this meteorological drought was monitored. Due to the better temporal and spatial continuity than the ground-based meteorological observation, TRMM precipitation data had good application prospects in the meteorological drought monitoring at a national or regional macro-scale [4].

Zang et al (2010), based on the index of precipitation anomaly percentage, have monitored and analyzed the severe

ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 415-419

meteorological drought of China in the early 2010 by utilizing the 3B42 and 3B43 precipitation datasets of TRMM Satellite. The monitoring results indicated that the TRMM precipitation data showed good results in meteorological drought monitoring and it can be applied to large-scale meteorological drought monitoring and analysis in China [15].

In another research, during the period from 1998 to 2009, the potential of the version-6 monthly TRMM multi-satellite precipitation analysis (TMPA; 3B43 V.6) was assessed for droughtmonitoring at the 1and 3-monthes scale in a basin with strongheterogeneity of terrain and climate. The assessment was carried out by using standard precipitation index (SPI), at the grid point (0.25°×0.25°). [16].

In addition, TRMM monthly data captured the occurrence and development of two severe droughts happened in 2006 and 2009 in China. Based on these, their analysis showed that TMPA (the version-6 monthly TRMM multi-satellite precipitation analysis) has the potential for drought monitoring in data-sparse regions [16].

In this research 3b43 product of TRMM satellite (monthly precipitation) was used as a new source of data for spatio-temporal drought monitoring. Accuracy of the results was assessed based on the observed error at weather stations.

II. MATERIALS AND METHODS

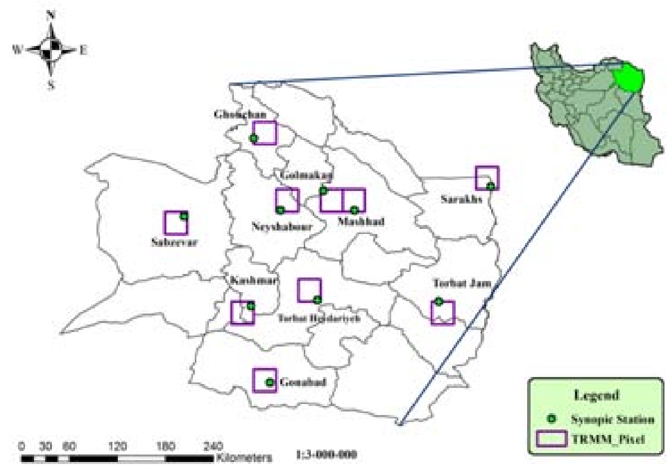
A. Study area

Khorasan Razavi Province is located in the North East of Iran. The area of province is 118851 km^2, the 5th greatest province in Iran,and is located between 56°-61° E and 33°-37° N. There are 13 synoptic stations within the province. Mashhad station has the longest record length (about 60 years) and Fariman station has the shortest record length (about 5 years).

B. Data and Methodology

The data set used includes monthlyprecipitation depth from both synoptic stations and TRMM data (3B43 V.7, in ASCII format). A thirteen year (1998–2010) period were chosenfor the analysis.The starting year is due to TRMM lunch date, and the last year was sat to 2010 due to inaccessibility of synoptic stations data. Only 10 of synoptic stations had data throughout the 13 years time span.Then, to have enough accordance between satellite and ground data, pixels thatcover theground stationswere determined.Figure 1shows locationof stations and the relevant pixelused. From TRMM monthly precipitation products, those with a 0.25°×0.25° spatial resolution were used [9]. This is the highest resolution found in TRMM. Therefore its usage gives the best spatial estimates for SPI.

In drought monitoring, one should decide whether to include only weather stations with lengthy and temporally commensurate time series, or to supplement such records with other stations having shorter records in order to improve the spatial resolution of stations. Since calculating some drought index values requires 30 years data or longer, typically only limited weather stations with a long history have been included for drought index mapping. However, prior studies suggested that, stations with a mid length of history (about 10 years) may represent the climate (drought condition in this case) of their locations better than nearby stations [12]. In other words, the weather stations with long-term historical records have been used for drought monitoring. But using weather stations with mid lengths of records (usually at least 10 years) improves the spatio–temporal characterization of drought [14].



ISSN (Online): 2305-0225
Issue 15(3), May 2014, pp. 415-419

For data analysis, Data seriesshouldmach somebasiccriteria including randomness, homogeneity, stabilityand inspection and rejection of outlierdata [11]. The accuracy of precipitation data that are used from synopticstationsand TRMMsatellite are provided by the source provider.

SPI, anindexthat depends ontheprobabilityof precipitationforany time range, can be calculatedfordifferenttime scales [5]. The method was presented in 1993 by McKee, Doesken and Kleist, members of the Colorado Climate Center.SPIindexis obtained with equation(1).

$$\mathrm{SPI} = \frac{P_i - \overline{P}}{S} \quad (1)$$

P_i =amountof precipitationfor the period
P=Long-termaverageprecipitationfor the period
S= Standard deviation ofprecipitation

To calculatethisindex, thegamma distributionis usedto normalize theprecipitation data. TheSPIis categorizedintodifferent classes [6].Inthisstudy,DIPsoftwarewas used to calculate theStandardized Precipitation Index [7].To check the accuracy ofsatellitedata in different time spans,1, 3, 6and 12 months SPIwere calculated.

Qualitative validation for monitoring results of TRMM satellite data is based on R2 and CSI. Critical Success Index (CSI) is defined as the percentage of times that SPI category is determined correctly (similar TRMM-based and Ground-based SPI categories) out of total number of SPI values calculated [16]. Accordingly, the CSI and R2 for all of the pixels and stations were calculated in order toevaluatethe accuracy of the satellite results.

III. RESULTS AND DISCUSSION

Results ofCSIand thecoefficient of determination(R2)forTRMM-based 1, 3, 6and 12 months SPIsagainst those of stationsare shown inTable (1). The R2 results show an improvement trend from 1-monthtoward 12-months time scales. This may be, due to randomness of errors. That is, such errors cancel each other in longer time scales. However, this is not exactly the case with CSI. The values for CSI are somewhat vaguer. But, an overall improving trend still is observable.

LowConsistentindicesinthe 1-monthtime scale, also,canbeinterpreted as: Khorasan Razavi province (located in north east of Iran)is in arid and semiaridclimate. The annualprecipitationinthis regionis very low. In addition,approximately in half of theyear,there is noprecipitationin the province and consequentlytheone-month time scale of SPI index isaffected by themoisture conditionsof theMonth.Lackof precipitationis also causingthe error in determiningthescale of 1-month drought.

This is backed by conclusion of some other researchers that the SPI index for short-term time scales in the low precipitation areas is not reliable [10].CSIandR2values increasedover timeinthe stationsis visible (Table 1).The importantthingaboutR2 is that it increases with increasingtime period. This could be because of the impact oflow rainfallperiods. The value of thiscoefficienthas increasedsignificantly.

During year 2000,a moderately droughthas occurredin the province.In addition,in 2008,SPI was calculated based on long-termprecipitationstations data and showed that a severe droughtoccurredall over the province [3]. Accordingly,to checkconformityof droughtsfor the same events in 2000 and2008,ground-based and TRMM-baseddata was used to produce12-months SPIzoning maps via IDW method. Paired comparison of these maps shows high similarity.

Table 1. Results of the evaluation indices

Name of Synoptic Station	Station Coordinates		Annual Precipitation (mm)	Elevation (m)	1- Month		3-Month		6- Month		12-Month	
	longitude	latitude			%CSI	R^2	%CSI	R^2	%CSI	R^2	%CSI	R^2
Ghouchan	58.74	37.07	313.1	1287	66.7	0.64	63.0	0.58	65.6	0.74	73.1	0.79
Golmakan	59.28	36.48	214.5	1176	70.5	0.56	61.7	0.53	56.3	0.70	56.6	0.73
Gonabad	58.68	34.35	144.4	1056	45.5	0.24	68.8	0.56	76.8	0.74	76.6	0.80
Mashhad	59.63	36.27	255.2	999	72.4	0.67	66.9	0.78	68.2	0.81	65.5	0.87
Neyshabour	58.80	36.27	239.8	1213	64.3	0.41	64.9	0.60	70.2	0.77	73.8	0.83
Kashmar	58.47	35.2	203.9	1110	65.4	0.51	70.8	0.73	77.5	0.81	78.6	0.90
Sabzevar	57.72	36.2	189.6	978	68.6	0.58	69.5	0.75	70.2	0.84	78.6	0.87
Sarakhs	61.17	36.53	188.9	235	63.5	0.55	66.9	0.72	67.5	0.87	80.7	0.93
Torbat Heydariyeh	59.22	35.27	273.9	1451	73.7	0.61	73.4	0.81	71.5	0.81	64.8	0.87
Torbat Jam	60.58	35.2	175.6	950	54.5	0.44	67.5	0.60	68.2	0.69	63.4	0.86

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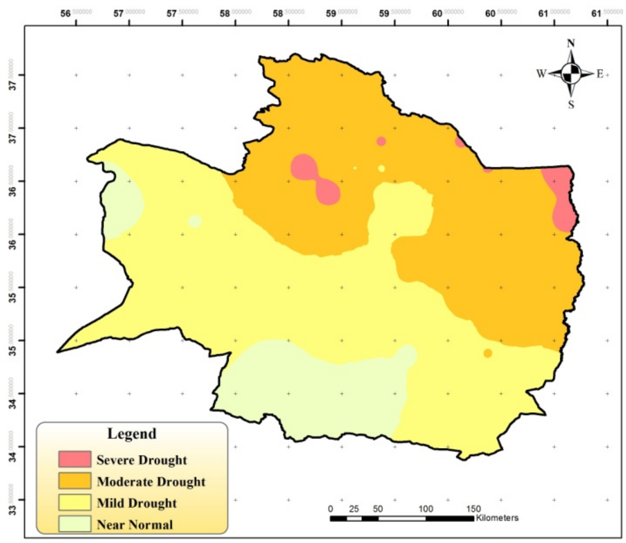

Fig. 2. SPI zoning map for year of 2000 via TRMM-based data

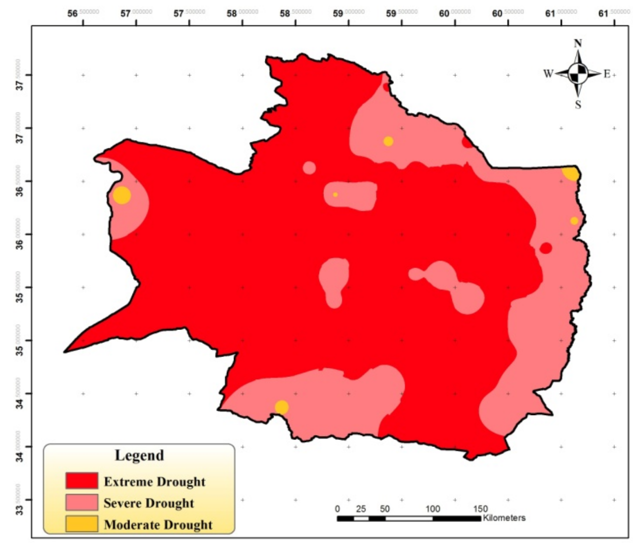

Fig. 3. SPI zoning map for year of 2008 via TRMM-based data

IV. CONCLUSIONS

In this research, to monitor drought in Khorasan Razavi province, data from 10 synoptic stations around the province, and the monthly data of TRMMsatellite was used. The study was to check the validity of TRMM-based SPI values. To do this, 1, 3, 6 and 12 months SPIs were calculated. The results were evaluatedbased on CSI and R2.

An improving trend of results with the increaseofSPI time scales was reviled. Moreover, TRMM-based SPIstruly evaluated2000 and2008 droughts.

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