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ComparabilityAnalyses of the *SPI* and *RDI*Meteorological Drought Indices in South Khorasan province in Iran

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ABSTRACT

Comparability analyses are performed to investigate similarities/differences of the standard precipitation index (SPI) and the reconnaissance drought index (RDI), respectively, utilizing precipitation and ratio of precipitation over potential evapotranspiration (ET0). Data are from six synoptic stations in south Khorasan province in Iran.At the first for calculating SPI, the elevation-precipitation regression of each period was obtained then this relationship was applied on DEM layer using GIS software. The result showed that the most severity droughts occurred in 2008, 2000, 2006 and 2001 respectively. In order to obtain RDI index, we used yearly temperature, precipitation data from the stations and potential evapotranspiration were obtained by Torrentwhite method. The resultshowed that 4 stations classified in extremely and severely classes and there was no medium and small class in 2008. The results of RDI indicate that the frequency of droughts with high severity in this area. The calculation of the standardized RDI seems to be as complicated as the computation of the SPI.

Key words: SPI, RDI, ArcGIS9.3, Drought, South Khorasan

INTRODUCTION

Drought is a recurring phenomenon that affects a wide variety of sectors, making it difficult to develop a single definition of drought. Droughts occur in virtually all climatic zones, such as high as well as low rainfall areas and are mostly related to the reduction in the amount of precipitation received over an extended period of time, such as a season or a year. Temperatures; high winds; low relative humidity;

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timing and characteristics of rains, including distribution of rainy days during crop growing seasons, intensity and duration of rain, and onset and termination, play a significant role in the occurrence of droughts. In contrast to aridity, this is a permanent feature of climate and is restricted to low rainfall areas (Wilhite, 1992).It is very difficult to objectively quantify their characteristics in terms of intensity, magnitude, duration, and spatial extent. For this reason, much effort has been devoted to developing techniques for drought analysis and monitoring. Among these, objective indices are the most widely used, but subjectivity in the definition of drought has made it very difficult to establish a unique and universal drought index (Heim, 2002). In order to determine the drought severity this phenomenon should be quantitative instead of qualitative and some indices must be introduced. Drought indices are normally continuous functions of rainfall and temperature, river discharge or other measurable variable. Rainfall data alone may not reflect the spectrum of drought- related conditions, but they can serve as a pragmatic solution in data_ poor regions (Smakhtin and Huges, 2004; Safari Shad *et al*, 2013; Rohina *et al*, 2013). The choice of indices for drought monitoring in a specific area should eventually be based on the quantity of climate data available and on the ability of the index to consistently detect spatial and temporal variations during a drought event.(Morid *et al*, 2006; (Khosravi *et al*, 2013, Mazloom *et al*, 2013, Dashti Marvili and Dabiri, 2013). The Standardized Precipitation Index (SPI), which is one of the most widely used drought indices, was designed by McKee and his colleagues at Colorado State University (McKee *et al*, 1993). It is based on the consideration that each component of a water resources system reacts to a deficit in precipitation over different time scales. . In Portugal, in order to analyze drought a regional distribution model was used, and zoning maps of drought and curves of drought severity, drought area and drought frequency were depicted (Henriques *et al*., 1998). Barouti *et al* (2009) used SPI Index as one of the most common meteorological indices that is used for drought studies and drought analyze based on temporal scales of six, twelve and twenty-four months and showed that SPI with timescales of higher than 12 months is most appropriate to study wet and dry periods but this index must be used cautiously in timescales 6 months and lower. After a systematic study of the various indices applied to identify and assess the meteorological drought severity it was concluded that although all these indices were useful, none of them seemed to attract universal applicability. Nevertheless, during the last decade the SPI has become very popular due to its low data requirements. (Tsakiris *et al*, 2006). A new reconnaissance drought identification and assessment index was first presented in the coordinating meeting of MEDROPLAN (Tsakiris 2004), while, a more comprehensive description was presented in other publications (Tsakiris and Vangelis 2005; Tsakiris *et al*, 2006).The index, which is referred to as the Reconnaissance Drought Index, RDI. Tsakiris *et al* (2007) compared SPI, DI and RDI indexes in Mediterranean area, used correlation between SPI and RDI to evaluated RDI performance and said that RDI is a high behavioral similarity with SPI. Khalili *et al* (2011) in their study as comparability analyses of the SPI and RDI meteorological drought indices in different Climatic Zones, concluded that RDI requires much more analytical details and information as compared with the SPI, i.e., computation of ETo requires long-term availability of a number parameters and data.

The main objective of this research is comparability analysis of the SPI and RDI indices based on the data from selected stations in South Khorasan in Iran, one of the provinces in Iran that has face with the most losses due to drought in the last 10 years.

MATERIALS AND METHODS

The Study Area

South Khorasan province, the Easternmost province of Iran, with 82864 km2 located in 57° 46' to 60° 57' eastern longitudes and 30° 35' to 34° 14' northern latitudes. The Province is border with Afghanistan at the east, from the north with Razavi Khorasan province, at the west to Yazd and Kerman Provinces and from the south is neighbor with Sistan and Baluchistan province. According to the latest divisions, South Khorasan has 8 cities including Birjand, Qaen, Ferdows, Darmiyan, Sarayan, Sarbisheh and Nehbandan. The climate is dry and desert type and the average annual rainfall of the province is 150mm. The maximum temperature of 44°c (Boshrooyeh) and the lowest recorded temperature of -21.5 have been reported. It has a dry and arid climate. In this study the data of six stations: Birjand, Khoor, Qaen, Nehbandan, Boshrooyeh, and Ferdos have been used (Fig.1).

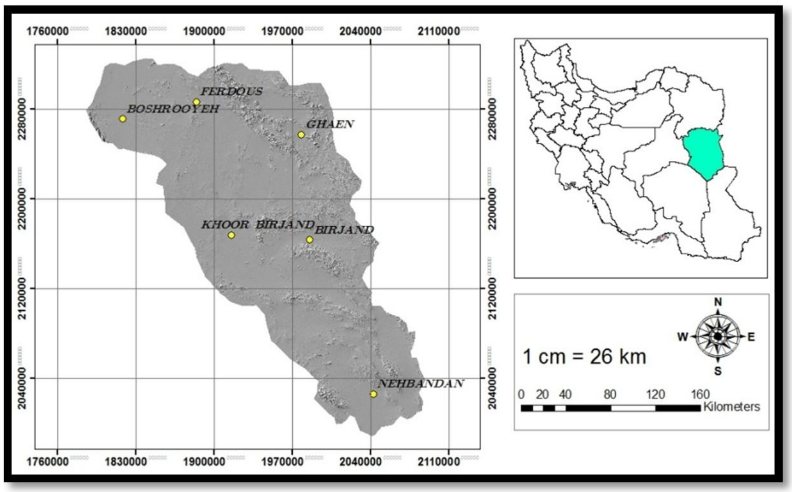

Fig1. Location of the studied stations

Methodology

SPI

To calculate the SPI, a long-term precipitation record at the desired station is first fitted to a probability distribution (e.g. gamma distribution), which is then transformed into a normal distribution so that the mean SPI is zero (McKee *et al*, 1993, 1995; Edwards and McKee, 1997). The SPI may be computed with different time steps (e.g. 1 month, 3 months, 24 months). Guttman (1998) showed that the use of SPI at longer time steps was not advisable as the sample size reduces even with originally long-term data sets. The use of different timescales allows the effects of a precipitation deficit on different water resource components (groundwater, reservoir storage, soil moisture, stream flow) to be assessed. Positive SPI values indicate greater than mean precipitation and negative values indicate less than mean precipitation. The SPI may be used for monitoring both dry and wet conditions. Six stations located in the study area were selected in period of 1990 to 2011 (table2). Homogeneity test data (Ran Test method)was done to ensure the data quality and homogeneity of data sets; in required case, the data were corrected. Correlation method among stations was used to reconstruct the incomplete stations data. On the other hand, the data ofstations withhighcorrelation were used to reconstruct monthly data of incomplete stations.

Table1. Properties of used meteorological stations

Station	Latitude	Longitude	Elevation (m)	Average rainfall (mm)
Birjand	32° 52 E	59° 12 N	1491	155.65
Boshrooyeh	33° 54 E	57° 27 N	885	88.59
Ferdous	34° 1 E	58° 10 N	1293	135.05
Ghaen	33° 43 E	59° 10 N	1432	167.78
Nehbandan	31° 32 E	60° 2 N	1211	129.51
Khoor	32° 56 E	58° 26 N	1117.4	91.77

In order to obtain SPI index, first precipitation map of each year was prepared by ArcGIS9.3 software (Fig.1). To do this, elevation-precipitation regression of each period was obtained using elevation and precipitation of meteorological stations, and then relationship between elevation and precipitation for each period was obtained in Excel software.

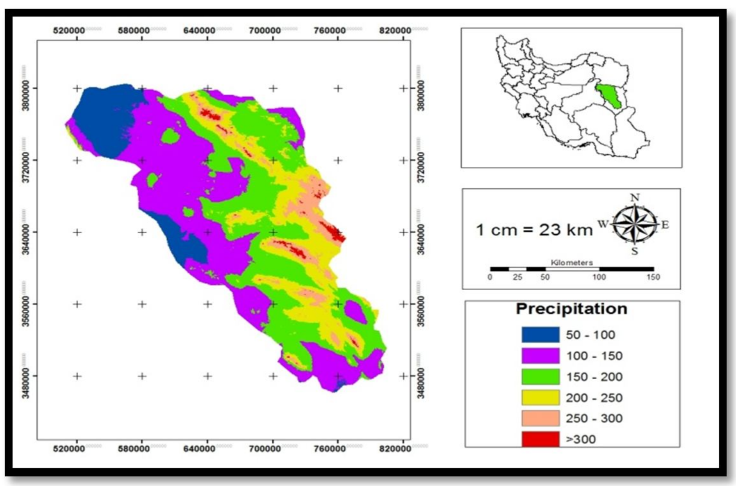

Fig2. Average precipitation of the study area (1990-2011)

Then in ArcGIS9.3 software, DEM[1] map with precision of 30m was inserted in this relation instead of elevation and precipitation map of each period was obtained. After obtaining precipitation map using ArcGIS9.3, precipitation maps of each year was inserted in SPI equation instead of precipitation data. Finally, SPI map of each year was obtained by the map obtained from precipitation map of each year minus map of average precipitation of total period divided with map of standard deviation.

RDI

[1] . Digital Evaluation Model

RDI may be calculated by the following expressions: For illustrative purposes the yearly expressions are presented first. The first expression, called the initial value of RDI (α_0), is presented in aggregated form using a monthly time step and may be calculated for each month of the hydrological year or a complete year. The α_0 is usually calculated for the ith year in an annual basis using the following equation:

(1)

$$\alpha^{i} = \frac{\sum_{j=1}^{12} p(\mathrm{ij})}{\sum_{j=1}^{12} PET(ij)}$$

In which Pij and PETij are the precipitation and potential evapotranspiration of the jth month of the ith year, starting usually from October as it is customary for Mediterranean countries. A second expression, the Normalized RDI (RDIn) is computed using the following equation for each year, in which it is evident that the parameter ao is the arithmetic mean of ao values calculated for the N years of data.

(2)

$$RDI = \frac{\alpha}{\bar{\alpha}} - 1$$

The third expression, the Standardized RDI (RDIst), is computed following a similar procedure to the one that is used for the calculation of the SPI: The expression for the

Standardized RDI is:

(3)

$$RDI = \frac{Y_K - \overline{Y_K}}{\sigma_{yk}}$$

In which y_i is the ln (α^i), $\overline{y_k}$is its arithmetic mean and$\sigma_{yk}$is its standard deviation.It is noted that the above expression is based on the assumption that the α_0 values follow a lognormal distribution. The Standardized RDI behaves similar to the SPI and so is the interpretation of results. Therefore, the RDIst can be compared to the same thresholds as the SPI. In the present research RDI is used to represent RDIst. Drought category classification suggested for the RDI (Tsakiris et al. 2007) is similar to the SPI (McKee et al. 1993), as illustrated in Table 2.

Table2. Classes of SPI and RDI_S indexes

SPI and RDI_S values Class	
Special Wet	>2
Extremely Wet	1.6 – 2
Severely Wet	1.3 – 1.6
Medium Wet	0.8 – 1.3
Small Wet	0.5 – 0.8
Normal	-0.5 – 0.5
Small Drought	-0.8 – -0.5
Medium Drought	-1.3 – -0.8
Severely Drought	-1.6 – -1.3
Extremely Drought	-2 – -1.6
Special Drought	<-2

In order to obtain RDI index, we used yearly temperature, precipitation data from the six stations and potential evapotranspiration were obtained by Torrentwhite method. Equations 1, 2 and 3 were used with these data to Excel software.

RESULTS

SPI

The result of SPI index showed that the most severity droughts occurred in 2008, 2000, 2006 and 2001 respectively. In 2008 more that 66 percent of the study area were classified in extremely drought class, (fig.3); whereas 53.43% of area including just Birjand and Ghaen stations were classified in this class in 2000 (Fig.4).

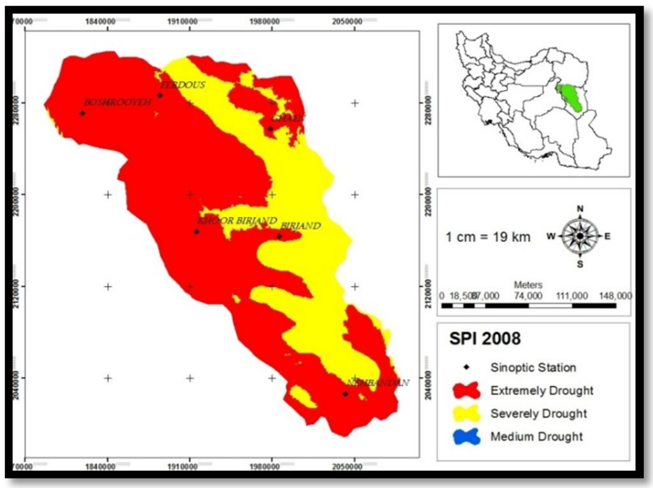

Fig3. Zoning map of annual drought in 2008

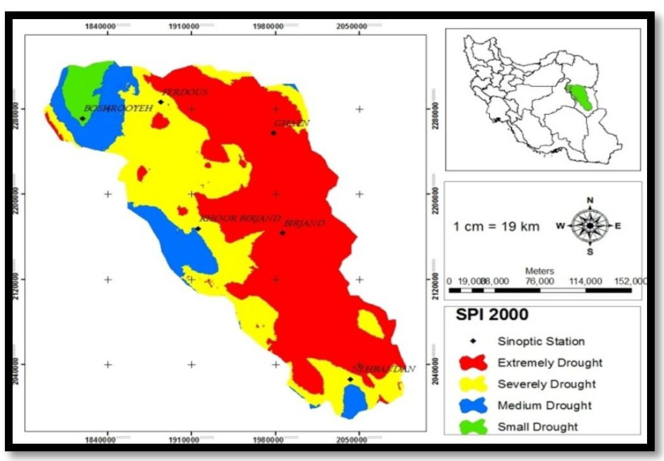

Fig4. Zoning map of annual drought in 2000

RDI

The result of RDI index showed that the most severity droughts occurred in2000, 2008 and 2006 respectively. the most drought severity occurred in2000, so that just 1 station of six stations of study area classified in medium drought (Nehbandan station) and other stations classified in extremely drought and severely drought class .whereas 2 stations including just Birjand and Ghaen stations were classified in severely drought class in 2006; On the other hand 4 stations classified in extremely and severely classes and there was no medium and small class in 2008.
The results of RDI indicate that the frequency of droughts with high severity in this area.

Comparison of SPI and RDI

Fig 5 and 6 show comparison graphs for SPI and RDI of the study area in Ghaen and Birjand stations during the period of time as example.

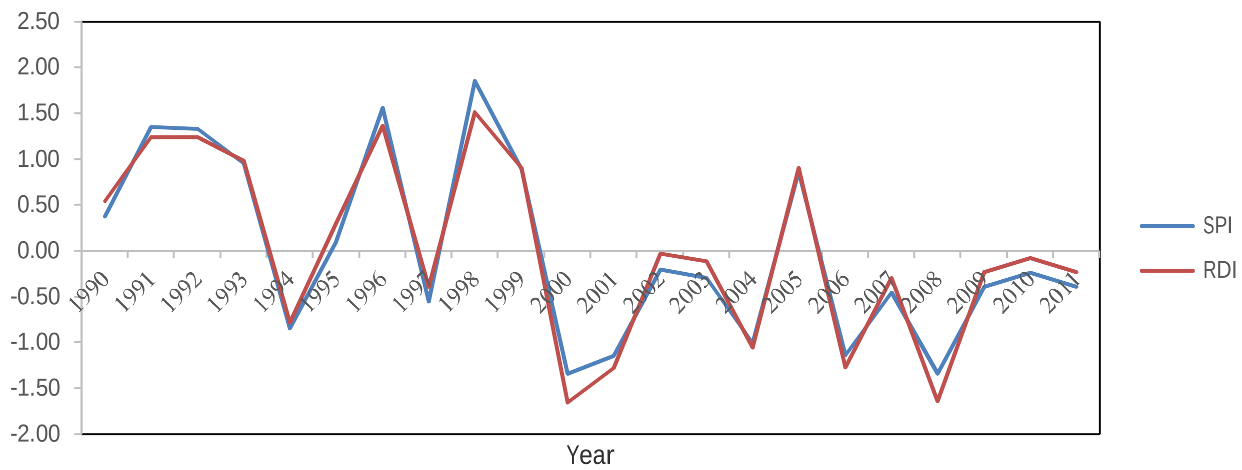

Fig 5: Comparison graphs for Ghaen station

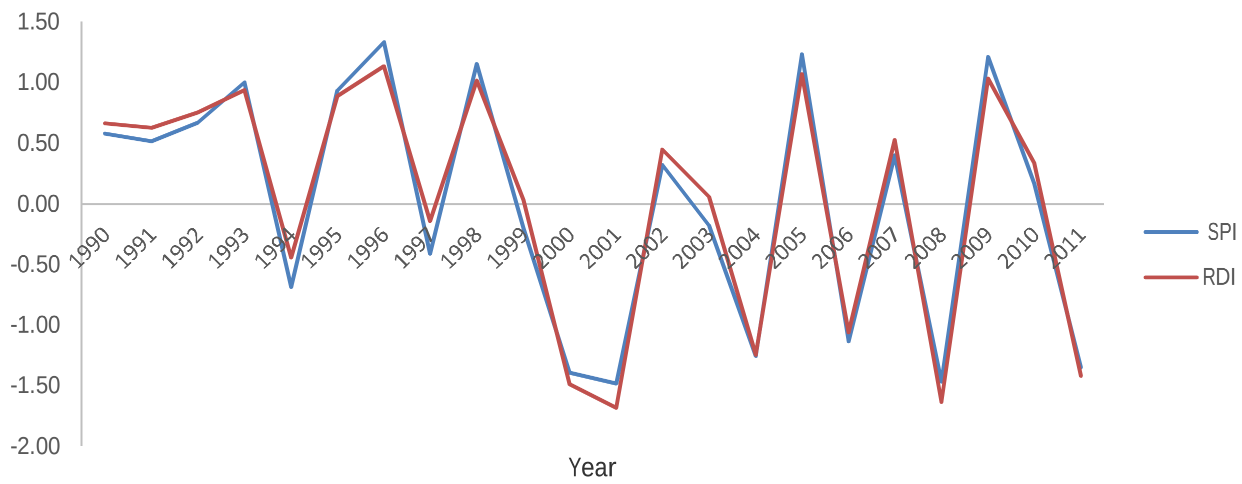

Fig 6: Comparison graphs for Birjand station

Discussion and Conclusion

The results show that both indices exhibit an overall similar behaviour. As indicated by the results that the RDI by including ET0 in the calculations can be very sensitive to climatic variability. This is rather important since it can viewed as an indication of the fact that if the drought analyses is to be applied for agricultural applications, then the RDI would be more representative of climatic variability conditions. (Khalili *et al*, 2011). The calculation of the standardized RDI seems to be as complicated as the computation of the SPI. This is clearly shown in Figures 5 and 6. However, once this calculation is completed for a certain area, then the thresholds are defined for using α_0 or RDIn, which can be calculated easily. If the levels of drought for the α_0 are needed and there is no better way to calculate them (e.g., anticipated damage), they can be produced by being expressed as the corresponding values of the levels − 1, − 2 and − 3 of the standardized RDI, (Tsakiris *et al*, 2007) and we used standardized RDI for this reason.

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Table3. Average of SPI index in stations during the period of time.

year	Ghaen	Birjand	Boshrooye	Ferdows	Khoor	Nehbandan
1990	0.381135139	0.579620265	0.55522005	0.378237102	0.193565976	-0.043423752
1991	1.355376781	0.516013103	3.02747792	1.079494211	1.214872913	2.428652838
1992	1.336187172	0.670260471	1.091190458	0.606467762	-0.61592987	0.035217689
1993	0.956823382	1.004198073	1.030799426	0.256759493	0.885622012	1.620583542
1994	-0.84404753	-0.68616226	-0.411036461	-0.411367359	-0.99131784	-0.754615911
1995	0.097719389	0.934230194	0.015475202	1.721853086	1.831431927	-0.281627536
1996	1.564986346	1.333365137	0.185324979	0.179455559	1.414101166	2.026327787
1997	-0.54882279	-0.40788092	-0.614856194	-0.956176032	-0.47122725	0.371438341
1998	1.854306591	1.156855262	0.219294935	2.886933795	1.485403909	-0.352290859
1999	0.891873939	-0.19638711	-0.093983543	0.764756769	-0.08745072	0.700820606
2000	-1.33559672	-1.38902140	-1.54336831	-1.44208647	-1.48204849	-0.517551858
2001	-1.14074839	-1.48125178	-0.728089379	-1.015074267	-1.24507172	-0.967745612
2002	-0.19898147	0.32201125	-0.886615838	-0.565975226	-0.3202332	-0.72042398
2003	-0.29050114	-0.17730496	0.623159961	0.216266956	0.552176831	-0.630385229
2004	-1.00642114	-1.25226600	0.902468483	0.008282564	-0.42718732	-1.008775929
2005	0.865303712	1.23795439	0.056994036	-0.339585136	0.692685177	0.884317301
2006	-1.1348439	-1.13141239	-0.777157092	-0.527323259	-0.94308363	-0.773991338
2007	-0.4499225	0.40152021	0.011700762	-0.277005761	0.032086234	0.175404605
2008	-1.33854897	-1.46534999	-1.381067411	-0.932248624	-1.16328328	-1.066902211
2009	-0.38792531	1.21410170	-0.214765607	-0.004601425	1.074364567	0.266583086
2010	-0.23883681	0.16935406	0.019249641	-0.562294086	-0.88646087	-1.040688398
2011	-0.38792531	-1.35085710	-1.082886691	-1.061088513	-0.74175824	-0.350011397

Table4. Average of RDI_S index in stations during the period of time

Year	Ghaen	Nehbandan	Khoor	Ferdows	Boshrooye	Birjand
1990	0.54318	0.27	0.99	0.54	0.64	0.66
1991	1.245302	1.77	-0.30	1.13	2.32	0.63
1992	1.244572	0.38	0.82	0.78	1.15	0.75
1993	0.986371	1.42	-0.84	0.46	1.07	0.94
1994	-0.78036	-0.73	1.24	-0.27	-0.29	-0.44
1995	0.301487	0.01	1.07	1.53	0.11	0.89
1996	1.368791	1.61	-0.18	0.35	0.34	1.13
1997	-0.39107	0.66	1.09	-1.05	-0.53	-0.14
1998	1.518185	-0.09	0.15	2.15	0.34	1.02
1999	0.904817	0.87	-1.98	0.84	0.01	0.03
2000	-1.64967	-0.33	-1.35	-2.04	-1.94	-1.49
2001	-1.27418	-1.27	-0.07	-1.17	-0.71	-1.68
2002	-0.02905	-0.70	0.62	-0.51	-0.94	0.45
2003	-0.11115	-0.52	-0.17	0.38	0.69	0.06
2004	-1.05112	-1.39	0.70	0.18	0.91	-1.25
2005	0.907496	1.01	-0.79	-0.19	0.19	1.07
2006	-1.27178	-0.80	0.26	-0.46	-0.78	-1.06
2007	-0.28856	0.47	-1.15	-0.13	0.14	0.53
2008	-1.63823	-1.57	0.89	-1.01	-1.60	-1.63
2009	-0.22754	0.55	-0.71	0.15	-0.11	1.03
2010	-0.07553	-1.50	-0.51	-0.51	0.11	0.34
2011	-0.23196	-0.10	-0.70	-1.28	-1.21	-1.42