Yale 耶鲁大学–南京信息工程大学大气环境中心
Yale-NUIST Center on Atmospheric Environment

A discusion on the paper "*Droughts in a warming climate: A global assessment of Standardized precipitation index (SPI) and Reconnaissance drought index (RDI)*"

Mohammad Amin Asadi Zarch et al. ,2015

Reporter：PanCongcong

2016/3/25

Outline

- Introduction
- Materials and Methods
- Results
- Discussion and Conclusions

Introduction

This problem becomes far more complicated during periods of droughts.It is particularly in this context that there are serious concerns about the impacts of climate change on our water security, socio-economic development, and environmental sustainability

The primary cause of any drought is a deficiency in rainfall and, in particular, the timing, distribution, and intensity of this deficiency in relation to the existing water storage, demand, and use.

Materials and Methods

- Observed data
- Drought indexes
- Mann–Kendall test
- GCM data

Materials and Methods

- **Observed data**

This study uses high spatial resolution (0.5° * 0.5°) gridded monthly data CRU TS 3.1, an observational data source, from the Climatic Research Unit, University of East Anglia.

The CRU TS 3.1 dataset covers the period 1901–2009 and data are available over land areas excluding Antarctica.

The CRU TS3.1 provides a monthly time series of global gridded data based on observations from more than 4000 stations

mean temperature, diurnal temperature range, precipitation, wet-day frequency, vapor pressure, cloud cover

Materials and Methods

- **Drought indexes**

SPI (**Standardized precipitation index**)

arguably a more popular drought index, is based solely on precipitation, and measures how much precipitation for a given period of time has deviated from historically established norms.

RDI (**Reconnaissance drought index**)

uses PET, in addition to precipitation, as a key variable for assessing the severity of drought

Materials and Methods

- SPI

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy$$

$$x_k^{(i)} = \sum_{j=1}^{k} P_{ij},\ i = 1 \text{ to } N,$$

$$g(x_k) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x_k^{a-1} e^{-x_k/\beta} \quad for\ :\ x_k > 0$$

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$A = \ln(\overline{x_k}) - \frac{1}{n}\sum_{i=1}^{n} \ln((x_k)_i)$$

$$\beta = \frac{\overline{x_k}}{\alpha}$$

$$G(x_k) = \int_0^{x_k} g(x_k) dx_k = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^{x_k} x_k^{\alpha-1} e^{-x_k/\beta} dx_k$$

Materials and Methods

- SPI

t=x/ β

$$G(x_k) = \frac{1}{\Gamma(\alpha)} \int_0^{x_k} t^{\alpha-1} e^{-t} dt$$

$$H(x_k) = q + (1 - q)G(x_k)$$

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right), \quad t = \sqrt{\ln\left(\frac{1}{H(x_k)^2}\right)} \ for\, 0 < H(x_k) < 0.5$$

$$Z = SPI = \left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right), \quad t = \sqrt{\ln\left(\frac{1}{(1 - H(x_k))^2}\right)} \ for\, 0.5 < H(x_k) < 1.0$$

Materials and Methods

- RDI

$$a_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} \mathrm{PET}_{ij}}, i = 1 \text{ to } N$$

$$y_k = \ln(a_k^{(i)})$$

$$\mathrm{RDI}_{n(k)}^{(i)} = \frac{a_k^{(i)}}{\bar{a}_k} - 1$$

$$\mathrm{RDI}_{st(k)}^{(i)} = \frac{y_k^{(i)} - \bar{y}_k}{\hat{\sigma}_{yk}}$$

Drought classification according to SPI and RDI Values.

SPI and RDI range	Drought classes
2 or more	Extremely wet
1.5–1.99	Very wet
1–1.49	Moderately wet
0.99–0.0	Normal
0.0 to –0.99	Near normal
–1 to –1.49	Moderately dry
–1.5 to –1.99	Severely dry
–2 and less	Extremely dry

Materials and Methods

- **Mann–Kendall test**

H0： the data {Xi} are a sample of n independent and identically distributed random variables.

H1： Each value {Xi|i = 1, 2,. . ., N-1} is compared with all subsequent values of {Xj|j = i+1, i+2, ..., N} and sum of the times of Xj > Xi.

$$p = \sum_i n_i$$

$$S = \left(\frac{4p}{(N(N-1))}\right) - 1$$

$$E(S) = 0$$

$$Var(S) = 2(2N+5)/(9N(N-1))$$

$$Z = S/(Var(s))^{\frac{1}{2}}$$

Materials and Methods

- GCM data

We use the atmospheric data, including precipitation, maximum and minimum temperature, relative humidity, wind speed, and cloud cover for the period 1850–2100 provided by the CSIRO Mk3.6 model based on RCP8.5

Materials and Methods

- PET assessment

The FAO56-PM model, which is a physically-based approach and incorporates thermodynamic and aerodynamic aspects, has proved to be a relatively accurate method in both humid and arid climates

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma[900/(T + 273)]\, U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\, U_2)}$$

Results

- **Drought trend analysis: Mann–Kendall test**

Area percentage of observed SPI and RDI trends in different climatic zones based on Z values of Mann–Kendall test (a < 0.05). Z > 1.96 represents a significant increasing trend and Z < -1.96 represents a significant decreasing trend.

Climatic zone	Area percentage	Area percentage					
		Non-significant trend		Decreasing trend		Increasing trend	
		SPI	RDI	SPI	RDI	SPI	RDI
Hyper-arid	4.4	77.2	80.1	0.6	1.5	13.1	9.6
Arid	13.0	86.7	89.1	0.8	1.9	12.1	9.0
Semi-arid	14.9	87	85.9	5.6	9.7	6.3	4.3
Sub-humid	13.5	86.2	85.6	6.2	10.4	7.1	4.0
Humid	54.2	80.7	83.8	2.8	8.0	14.5	8.2

Results

- **SPI and RDI areal extent**

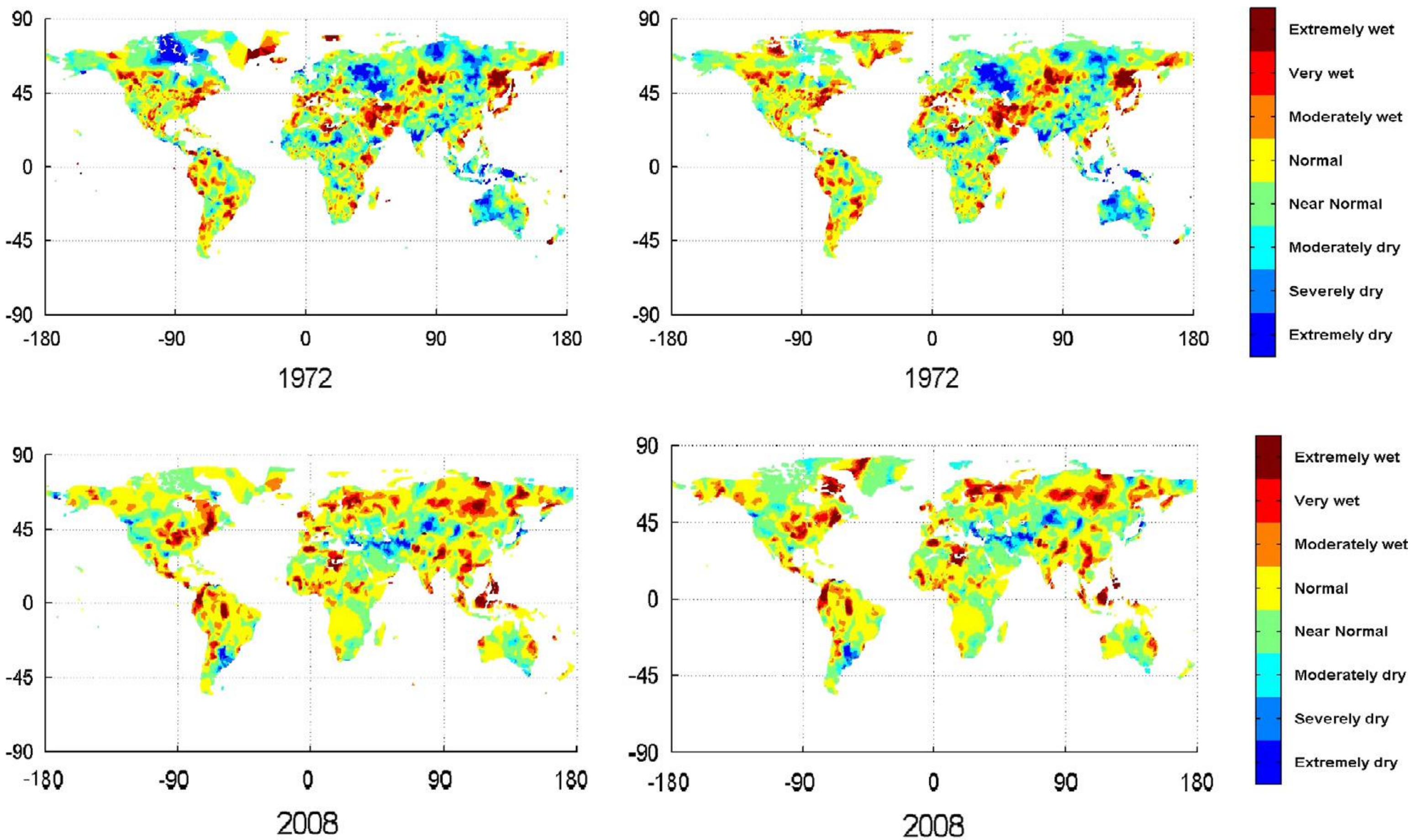
Global drought areal extent (SPI and RDI <=–1) based on percentage during 1960–2009.

Year	Drought area		Year	Drought area		Year	Drought area		Year	Drought area		Year	Drought area	
	SPI	RDI		SPI	RDI		SPI	RDI		SPI	RDI		SPI	RDI
1960	16.7	16.3	1970	19.8	16.2	1980	18.4	16.8	1990	20.2	22.8	2000	13.2	11.9
1961	18.7	16.1	1971	19.0	17.4	1981	15.3	15.9	1991	16.7	17.4	2001	12.4	14.2
1962	21.8	22.1	1972	27.5	20.9	1982	19.2	16.1	1992	18.7	15.8	2002	14.7	17.1
1963	17.7	14.9	1973	15.4	16.8	1983	22.6	20.3	1993	17.8	15.8	2003	13.0	15.1
1964	19.1	14.1	1974	17.7	16.2	1984	21.7	20.0	1994	14.9	15.4	2004	8.5	10.1
1965	25.6	20.8	1975	16.2	15.9	1985	21.4	18.2	1995	15.7	16.5	2005	11.2	14.5
1966	15.6	11.9	1976	22.1	18.3	1986	20.0	17.2	1996	12.0	10.6	2006	8.2	11.9
1967	16.6	16.0	1977	15.6	13.5	1987	21.5	19.7	1997	11.3	10.7	2007	9.1	11.7
1968	18.0	14.6	1978	16.3	12.9	1988	16.5	18.2	1998	9.7	12.5	2008	9.0	9.7
1969	21.5	17.4	1979	15.3	12.8	1989	17.6	18.1	1999	10.4	10.7	2009	11.9	14.1

SPI average = 16.6%

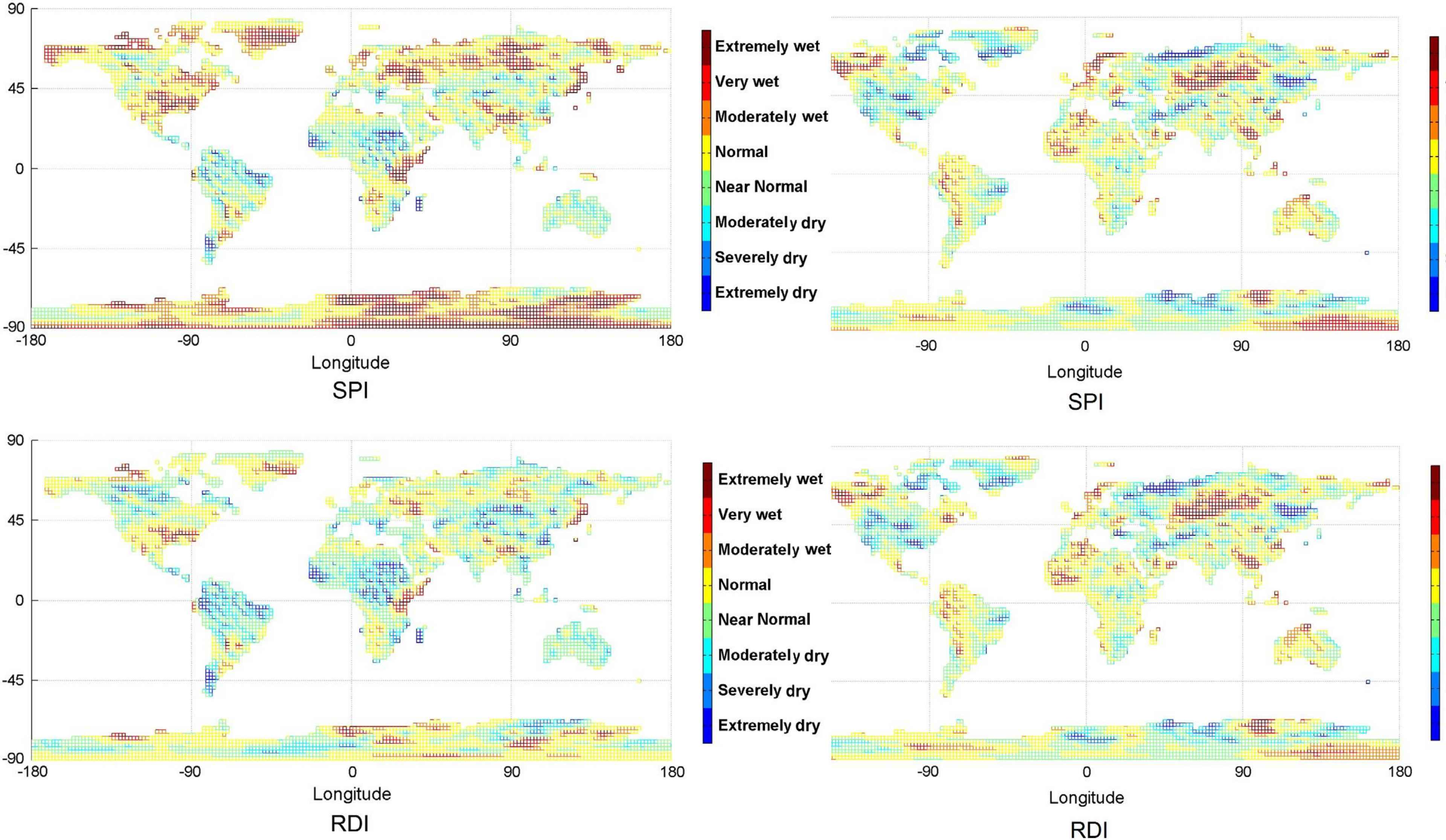
RDI average = 15.7%

Results



Global drought map based on SPI (left) and RDI (right): a dry year (1972) and a wet year (2008).

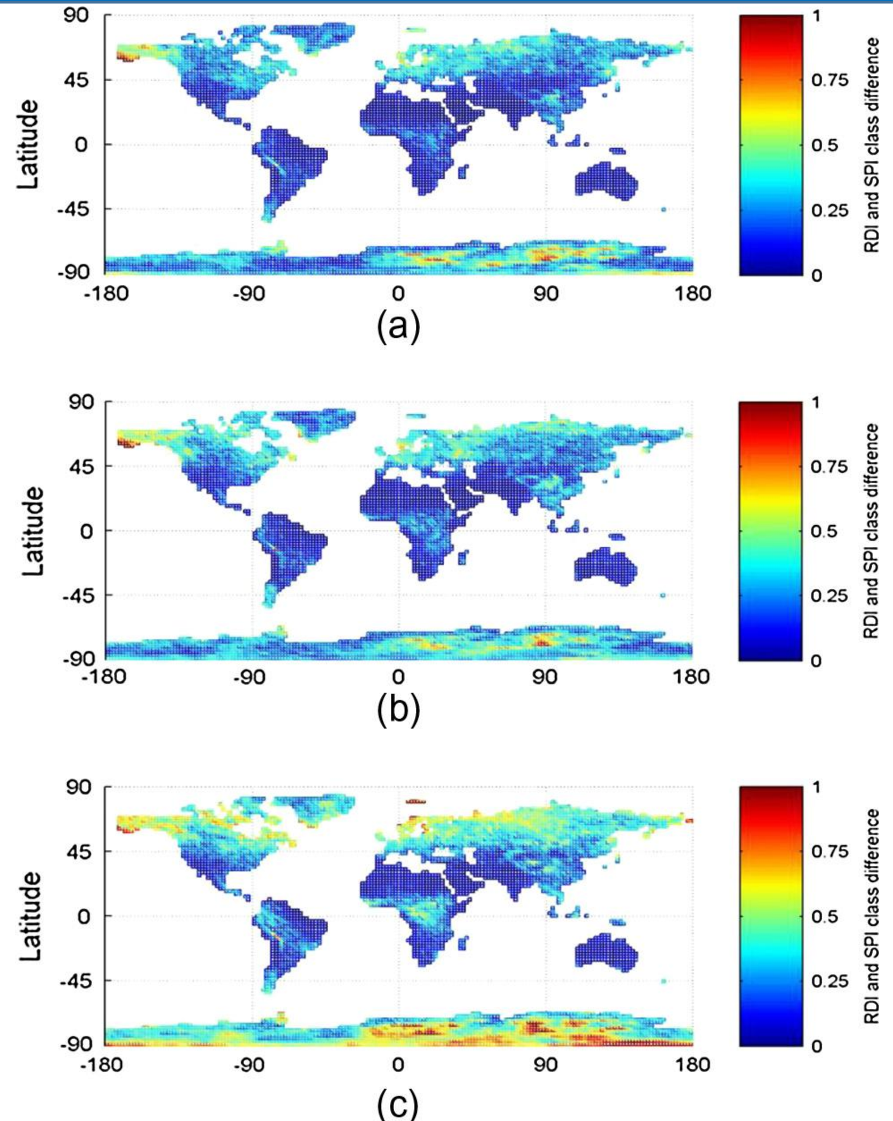
Results



90
45
0
-45
-90
-180
-90
0
90
180
Longitude
SPI
Extremely wet
Very wet
Moderately wet
Normal
Near Normal
Moderately dry
Severely dry
Extremely dry
-90
0
90
180
Longitude
SPI
90
45
0
-45
-90
-180
-90
0
90
180
Longitude
RDI
Extremely wet
Very wet
Moderately wet
Normal
Near Normal
Moderately dry
Severely dry
Extremely dry
-90
0
90
180
Longitude
RDI

Results

Average drought class difference between SPI and RDI for periods
(a) 1951–2000,
(b) 2001–2050 and
(c) 2051–2100



Discussion and Conclusions

Analysis of trends in drought for the period 1960–2009

(1) the agreement between SPI and RDI reduces from the hyper-arid zone toward the humid zone

(2) when the drought tendencies are different between the indexes, RDI shows more trends toward dryness than SPI does

Discussion and Conclusions

The land area affected by drought during 1960–2009

	1962–1973	1974–1985	1986–1997	1998–2009
T_{mean}/℃	4.72	4.92	5.30	5.73
SPI/%	19.80	18.48	16.91	10.94
RDI/%	16.93	16.41	16.52	12.79
P_{mean}/mm	683.57	685.95	683.92	699.29

Rising trends of temperature in recent decades have caused positive trends of PET in considerable parts of the world and have resulted in higher drought prone areas indicated by RDI than SPI.

Discussion and Conclusions

- Future climate changes, even under conservative scenarios, are likely to cause further increases in mean temperature.
- Its inclusion in a drought index should improve not only the accuracy of the index in detecting droughts but also in representing the sensitivity of the index to climate changes to capture the related impacts.
- PET, which is an important component in the hydrologic cycle and shows the atmospheric demand for moisture, should no longer be ignored in drought forecasting

THANK YOU