DROUGHT MONITORING

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Material for practical on Drought monitoring

Introduction:

The goal of this exercise is to introduce some methods in drought analysis and drought monitoring. In the first part of this exercise, you will first analyze the spatial and seasonal variation in precipitation. Afterwards, you will analyze the Standardized Precipitation Index (SPI) variations to investigate droughts on a global scale. In the second part, you will use the given precipitation (P), soil moisture (SM) and evapotranspiration (ET) data to calculate the anomalies to analyze the trends in monthly P, SM, ET times series. This analysis gives you an idea on how these data sets can be used for drought analysis.

Exercise steps:

Part 1.

- Analyze the spatial and seasonal variation in time series of precipitation.
- Analyze droughts using SPI indices on a global scale.

Part 2.

- Calculate soil moisture and precipitation anomalies.
- Analyze trends in time series of P, SM, ET.

Data sets

- a) Precipitation from GPCP (Global Precipitation Climatology Project (version 2018)
- Monthly total precipitation
- Spatial coverage: global
- Temporal coverage: January 1987 to December 2016
- Spatial resolution:2.5°
- Unit: mm/month
- b) Pre-processed SPI for various time scales (1,3,6 and 12 months)

SPI was calculated using the GPCP data (1987 - 2010) based on the algorithm developed by (McKee, Doesken et al. 1993).

SPI =(P-P(mean))/P(std)

P= precipitation of a specific month.P(mean)= mean long term precipitation of a specific monthP(std)= standard deviation of long term precipitation of a specific month

The monthly precipitation P for a certain time scale was initially normalized using the Gamma distribution function. The SPI was calculated for each of the time scales (1,3,6,12 months) for the period 1987-2016.

According to McKee, a drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less, and the event ends when the SPI becomes positive.

- c) Soil moisture data simulated by GLDAS Noah land surface model
- Monthly average layer 1 (0-10cm) soil moisture data

- Spatial coverage: China
- Temporal coverage: January 2003 to December 2010
- Temporal resolution: monthly average
- Spatial resolution: 0.25°
- Unit: mm
- d) SEBS-based evapotranspiration time series
- Monthly total evapotranspiration time series estimated by SEBS model
- Spatial coverage: China
- Temporal coverage: January 2003 to December 2010
- Spatial resolution: 0.1°
- Format: an image list with 96 bands/maps, one for each month. Floating points.
- Unit: cm/month

Software

- ILWIS
- Excel

Exercise Steps

Part 1.

Start ILWIS and navigate to the exercise folder (e.g. D:\data\exercise_data). Note that always use this folder as your working directory for the exercise.

1.1) Analyze the spatial and seasonal variation in time series of precipitation

Data: P monthly from GPCP (1987-2016)

a) Open the GPCP_precip maplist, there will be 360 precipitation monthly images, one image for each month (1987-2016)

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🚇 Map List "GPC	P_precip"									
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🔜 GPCP199702	E GPCP199902	GPCP200102	🄜 GPCP200302	GPCP200502	GPCP200702	🇱 GPCP200902	E GPCP201102	🄜 GPCP201302	E GPCP201502	
🛅 GPCP199703	GPCP1 99903	GPCP200103	🔛 GPCP200303	GPCP200503	🔛 GPCP200703	GPCP200903	E GPCP201103	🕅 GPCP201303	E GPCP201503	
🖽 GPCP199704	E GPCP199904	GPCP200104	🌇 GPCP200304	GPCP200504	GPCP200704	🌇 GPCP200904	E GPCP201104	🌇 GPCP201304	E GPCP201504	
🛅 GPCP199705	GPCP1 99905	GPCP200105	GPCP200305	GPCP200505	🔛 GPCP200705	GPCP200905	🏬 GPCP201105	🏬 GPCP201305	🏬 GPCP201505	
E GPCP199706	🌇 GPCP1 99906	GPCP200106	🌇 GPCP200306	🌇 GPCP200506	🌇 GPCP200706	🌇 GPCP200906	🔛 GPCP201106	🌇 GPCP201306	E GPCP201506	
🛄 GPCP199707	0 GPCP1 99907	E GPCP200107	🌉 GPCP200307	GPCP200507	🔛 GPCP200707	GPCP200907	E GPCP201107	🏬 GPCP201307	E GPCP201507	
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🔜 GPCP199709	E GPCP1 99909	🇱 GPCP200109	🏬 GPCP200309	🛄 GPCP200509	E GPCP200709	🏬 GPCP200909	E GPCP201109	E GPCP201309	E GPCP201509	
🖽 GPCP199710	🛄 GPCP199910	E GPCP200110	🔛 GPCP200310	E GPCP200510	E GPCP200710	GPCP200910	E GPCP201110	🔛 GPCP201310	E GPCP201510	
🔜 GPCP199711	E GPCP199911	🛄 GPCP200111	GPCP200311	GPCP200511	E GPCP200711	E GPCP200911	E GPCP201111	E GPCP201311	E GPCP201511	
B GPCP199712	E GPCP199912	E GPCP200112	E GPCP200312	GPCP200512	E GPCP200712	E GPCP200912	E GPCP201112	E GPCP201312	E GPCP201512	
🔜 GPCP199801	GPCP200001	GPCP200201	🔜 GPCP200401	GPCP200601	GPCP200801	🔜 GPCP201001	E GPCP201201	🔜 GPCP201401	🌇 GPCP201601	
🛅 GPCP199802	E GPCP200002	🇱 GPCP200202	E GPCP200402	GPCP200602	E GPCP200802	E GPCP201002	E GPCP201202	E GPCP201402	E GPCP201602	
🖽 GPCP199803	GPCP200003	GPCP200203	GPCP200403	GPCP200603	GPCP200803	GPCP201003	E GPCP201203	🄜 GPCP201403	GPCP201603	
🔜 GPCP199804	GPCP200004	E GPCP200204	🔜 GPCP200404	E GPCP200604	E GPCP200804	E GPCP201004	E GPCP201204	🏬 GPCP201404	E GPCP201604	
🛅 GPCP199805	E GPCP200005	E GPCP200205	E GPCP200405	GPCP200605	GPCP200805	E GPCP201005	E GPCP201205	🌇 GPCP201405	GPCP201605	
🔜 GPCP199806	GPCP200006	GPCP200206	GPCP200406	GPCP200606	GPCP200806	GPCP201006	GPCP201206	E GPCP201406	E GPCP201606	
🛅 GPCP199807	GPCP200007	E GPCP200207	GPCP200407	GPCP200607	E GPCP200807	GPCP201007	E GPCP201207	E GPCP201407	E GPCP201607	
🔜 GPCP199808	GPCP200008	GPCP200208	GPCP200408	GPCP200608	GPCP200808	GPCP201008	GPCP201208	GPCP201408	GPCP201608	
🛅 GPCP199809	GPCP200009	GPCP200209	GPCP200409	GPCP200609	GPCP200809	GPCP201009	GPCP201209	GPCP201409	GPCP201609	
GPCP199810	GPCP200010	GPCP200210	GPCP200410	GPCP200610	GPCP200810	GPCP201010	GPCP201210	GPCP201410	GPCP201610	
GPCP199811	GPCP200011	GPCP200211	GPCP200411	GPCP200611	GPCP200811	GPCP201011	GPCP201211	GPCP201411	GPCP201611	
🔛 GPCP199812	E GPCP200012	E GPCP200212	E GPCP200412	GPCP200612	E GPCP200812	E GPCP201012	GPCP201212	E GPCP201412	E GPCP201612	

b) Open at least one image to understand value ranges, image size and resolution.

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- c) Display the time series as animation and examine the spatial and temporal variations of precipitation.
 - Right on maplist GPCP_precip. Go to Open as animation.
 - Click on "Run". Animation Manage window will appear, leave the settings as they are and click "Run".
 - Now examine the spatial and temporal variations of precipitation in different areas carefully.



151.624211. 91.433120 91°25'59.23"N.151°37'27.16"E

- d) Analyze seasonal variation of precipitation (Maplist > Statistics > Maplist Graph)
 - Open one of the monthly precipitation (P) maps.
 - Move the cursor over the P monthly map.
 - Plot the precipitation time series for specific different areas.
 - Examine the changes carefully in Maplist Graph. The maplist graph shows the temporal behavior in P for pixel/area you click.

At the bottom right of the display window, you can read the image coordinates and the geographic coordinates of the pixel. Take note of them (as you are going to use these data also for the successive steps).

 \Rightarrow

Can you explain the different precipitation behaviour taking into account the different geographic locations?



Rainfall distribution for a selected location (1987-2016)

- Select Clipboard Copy and copy all the information in to an Excel file.
- Plot the precipitation values and determine the trend.

Does the product shows a seasonal trend?

• Choose different locations, then plot the temporal behavior, and compare them.

 \Rightarrow

Is there a variation in the trend when you change the observation area?

1.2) Analyze SPI indices for drought analysis (1987-2016)

Data: SPI for 4 time scales (1,3,6 and 12 months), spi01, spi03, spi06, spi12.

According to McKee, a drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less, and the event ends when the SPI becomes positive.

- a) Observe the spatial and temporal variations of the SPI06, using time series show, maplist graphs for two specific locations (e.g. places you suspect to have drought).
 - Plot the SPI06 time series
 - Investigate drought occurrence
 - Identify the most extreme drought event and duration(number of dry months)



- **b**) Linear trend analysis for the SPI06 time series
 - In the maplist graph window, click on "Clipboard Copy" and copy all the information in to an Excel file.
 - Plot the linear trend and the temporal SPI06 values over time
 - Is the slope of the linear trend significant different from zero?
 - \Rightarrow

What can you conclude from these trends?

- Repeat the same steps for spi01, spi03,spi12, for the same pixel, plot them together with the temporal trend of the SPI06 and compare them.
- Compute the linear trend for the SPI data sets.

SPI	Linear trend equation	R^2	
1-month			
3-months			
6-months			
12-months			



Do you see significant differences between the SPIs (1,3,6,12 months)?

What can you conclude from these trends?

If you repeat the same comparison of different places, can you arrive at the same conclusion?

c) Classify SPI values and identify the spatial extent of drought In this exercise, drought intensity is divided into seven classes :

SPI values	Drought Class
-2 or less	extreme drought
-21.5	severe drought
-1.5 – -1	moderate drought
-1 - 1	near normal
1 - 1.5	moderate wet
1.5 - 2	very wet
2 and above	extremely moist

You will classify the SPI values using the Slicing function. Slicing classifies the values of a raster map. Ranges of values of the input map are grouped together into one output class. A domain Group should be created beforehand; it lists the upper boundaries of the groups and the group names.

1

- Create a domain (File > Create > Domain)
- Set up the parameters as shown in the figure below •

🚯 Create	Domain	×
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Width Description Domain alr	15 n ready exists OK Cancel	Help
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- Go to Operations > Raster operations > Maplist Calculation
- Specify the parameters as shown in the figure below and click on "Show"

MapList Calculation	\times
Expression:	
MapSlicing(@1,spi_group.dom)	
Start Band 1 🕂 End Band 360 🔆	1 -
Input MapLists	
MapList @1 😰 spi12 💌 👱	
Relate names to first map list names	
Output MapList spi12_classes	
Description:	
Show Define Ca	ncel

- After these steps, a list of the classified maps will appear. Open the newly created image to understand the values.
- Display the time series as animation and identify the drought areas. observe the spatial extent of drought.



Example the classified SPI (SPI12) values

• Repeat the same steps for the classification of the SPI with other time scales (1,3,6-months) and compare the results.

Part 2.

2.1) Compute anomalies

- Data : Precipitation (P) monthly from GPCP (2003-2010) Soil moisture (SM) monthly from GLDAS (GLDAS_SM 2003-2010)
 - a) Compute the yearly average and anomalies of the SM from 2003 to 2010 (each year)
 - Create SM maplists separately for each year from the monthly SM maps. File menu > Create menu > Script ...

Map List Description	gldas_sm_2004	^		gidas_s	m_sm_200406	^
gldas_sn gldas_sn gldas_sn gldas_sn gldas_sn gldas_sn gldas_sn	n_sm_200311 n_sm_200312 n_sm_200401 n_sm_200402 n_sm_200403 n_sm_200404 n_sm_200405	~	> <	mini gidas_s gidas_s gidas_s gidas_s gidas_s gidas_s gidas_s	m_sm_200407 m_sm_200408 m_sm_200409 m_sm_200410 m_sm_200411 m_sm_200412	~
					OK Ca	ncel Help

• Calculate the yearly SM for each year (Operations>Statistics>Maplist>Maplist Statistics)

Maplist Statistics	;		×
MapList	🚇 gldas_s	m_2003	▼ <u>*</u>
Statistic function	fn Sum		•
Start band	1 <u></u>	ind band 12	÷
Output Raster Map	SM_2003		
Description:			
	Show	Define	Cancel

Hint: you can create scripts as below to make it faster!

Script "solimoisture_sum" - ILWIS
File Edit View Help
Description
📂 🖬 🕨 % 🖻 🛍 🛤 🚭 😭
Script Parameters Default Values
SM_2003 := MapMaplistStatistics(gldas_sm_2003.mpl, Sum, 0, 11) SM_2004 := MapMaplistStatistics(gldas_sm_2004.mpl, Sum, 0, 11) SM_2005 := MapMaplistStatistics(gldas_sm_2005.mpl, Sum, 0, 11) SM_2006 := MapMaplistStatistics(gldas_sm_2006.mpl, Sum, 0, 11) SM_2007 := MapMaplistStatistics(gldas_sm_2007.mpl, Sum, 0, 11) SM_2008 := MapMaplistStatistics(gldas_sm_2008.mpl, Sum, 0, 11) SM_2009 := MapMaplistStatistics(gldas_sm_2009.mpl, Sum, 0, 11) SM_2009 := MapMaplistStatistics(gldas_sm_2009.mpl, Sum, 0, 11) SM_2010 := MapMaplistStatistics(gldas_sm_2010[mpl, Sum, 0, 11)

• Compute the average of all the yearly values(2003-2010) Using ILWIS command line

SM_mean_annual= (sm_2003+sm_2004+sm_2005+sm_2006+sm_2007+sm_2008+sm_2009+sm_2010)/8

Or using ILWIS "Map Calculation"

Map Calculation					×
Expression: (sm_2003+sm_2004+	•sm_2005+sm_2006+s	m_2007+sm_2	008+sm_2009+s	:m_2010)/8	~
Output Raster Map Domain Value Range Precision Description: Map will use 4 bytes p	SM_mean_annual WALUE -10000000.0 1000 0.100 1000 ber pixel 1000	00000.0	. <u>≗</u> <u>D</u> efa	ults	
		<u>S</u> how	<u>D</u> efine	Cancel	Help

• Compute the anomalies subtracting the yearly average from each yearly image (using ILWIS command line)

```
SM_anomaly_2003 = SM_2003 - SM_mean_annual
SM_anomaly_2004 = SM_2004 - SM_mean_annual
...
```

Hint: you can make scripts to make it fast!

- Create an image list containing all the SM anomaly maps calculated (named for example, SM_anomaly.mpl).
- Plot the SM anomalies time series and observe the spatial and temporal changes.



b) Compute the year average and anomalies of precipitation, as done for SM time series in step 3.a) (named P anomalies for example, P_anomaly.mpl)

2.2) Analyze trends in time series of P, SM, ET

- Open one of the SM anomaly map, right click on the Display Tools in the left panel of the display window and select the Cross Section.
- Add the maplists SM_anomaly.mpl, and maplist P_anomaly.mpl in the "Add data source" window that appears.
- Move the cursor over the SM map, observe the changes in Cross section graph window. The Cross section graph shows the temporal behavior of SM anomalies together with the P anomalies.

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	🚆 Cross section Graph	🚆 Add data source 🛛 🕹	×
Global tools Software and tools Global tools Software and tools Global toools Global toools Global toools Global toools Gl		Data source gpcp_anomaly Add Close	
Coordinate 46°42'2 mas anomaly 0.69 China 29,214	1 Source Probe Index range Value pdss_anomaly 1 1:8 -48.5 gpcp_anomaly 1 1:8 -158. Save as Table Save as Spectrum	é range Selected index Value :47.07 771.180.364	

• In the cross section graph, click on Save as Table, and plot the graph as shown in figure below

🚺 Tal	ble "CrossSection	2" - ILWIS			\Box \times	
File	Edit Columns F	lecords \	/iew Help			
	2 × 4 6	! 🗠	I I I	► FL		
						•
	Index	gldas_a	anomaly_0	gpcp	_anomaly_0	*
1	1		1.930		-10.223	
2	2		1.240		10.193	
3	3		-0.270		-13.723	
4	4		-0.300		-0.140	
5	5		-2.780		-2.890	
6	6		0.490		15.193	
7	7		1.340		1.610	
8	8		-1.670		-0.057	
						-
Min	1		-2.780		-13.723	
Max	8		1.930		15.193	
Avg	5		-0.003		-0.005	İ.
StD	2		1.603	ĺ	9.551	
Sum	36		-0.020	İ	-0.037	-
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• Compute correlation between SM an P data (Column > Statistics

🚺 Tal	ble "CrossSection	4" - ILWIS				\times	
File Edit Columns Records View Help							
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clmstatistics							
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1	1		-0.570		-2.	993	
2	2		1.580		-2.	910	
3	3		4.510		2.	840	
4	4		0.670		-8.	077	
5	5		-3 820		-3	002	
6	٤.	🔛 Column Sta	atistics			X	
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Do you see a correlation between GLDAS soil moisture and precipitation data? Is there a variation in the trend when you change the observation area? Note

In addition SEBE based ET time series are available in case that you want to correlate this to P and SM.