

Practical Session

Drought Monitoring

(Adapted from ESA-Most Dragon III Advanced Training Course, Nanchang, 2014)

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Drought monitoring

General objectives

The commonly used methods for drought monitoring are by indices. In this exercise, we will assess the spatial and temporal variability of drought in the regions of south-west/north/north-east China (e.g. Chongqing, Chengdu, Inner Mongolia, and North China Plain) for the time period from 2003 to 2010 using drought indices derived from satellite and GLDAS model fields. For this you need to perform the following tasks:

- calculate the drought indices:
 - Rainfall anomaly index (RAI)
 - Standardized precipitation index (SPI)
 - Soil moisture deficit index (SMDI)
 - Evapotranspiration anomaly
- Identify the drought occurrence in the given region
 - Spatial analysis in a GIS environment
 - Temporal behavior by time series plots
- Assess and compare the monitoring capabilities among the calculated drought indices.

Study area

- The regions of south-west/north/north-east China (e.g. Chongqing, Chengdu, Inner Mongolia, and North China Plain).

Data sets needed

GPCP precipitation data

a) GPCP precipitation (version 2.2)

- Monthly total precipitation
- Spatial coverage: global
- Temporal coverage: January 2003 to December 2010
- Spatial resolution: 1.25°
- Format: an image list with 96 bands/maps, one for each month. Floating points.
- Unit: cm/month

b) 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

c) Soil moisture (SM) simulated by GLDAS Noah land surface model

- Monthly-mean soil moisture (sum of 4 layers, of a soil layer 2 m deep) from GLDAS data (<http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings>)
- Spatial coverage: China
- Temporal coverage: January 2003 to December 2010
- Temporal resolution: monthly average
- Spatial resolution: 0.25°

- Format: an image list with 96 bands, one for each month. Floating points.
- Unit: cm

Tools

- ILWIS 3.8, and Excel

Exercise Steps

1) Start ILWIS

Start ILWIS3.8 and navigate to the folder (e.g. D:\DT_out) for training data. Always use this folder as your working directory for the whole exercise.

2): Calculate and analyze drought indices

2.1) Precipitation Anomaly (PA)

PA is defined after removing the mean long-term monthly value from the actual monthly precipitation:

$$PA = P_j - P_j(\text{mean}) \quad (1)$$

j = a specific month in the time series

P_j = actual monthly precipitation for a specific month j and year

$P_j(\text{mean})$ = long-term monthly mean of precipitation for a specific month

a) Calculate the long-term monthly mean of precipitation for each month. This can be done in the following steps:

- Create an image list containing all maps of precipitation for a specific month from the 8 years' time series data:
 - Go to File > Create > Map List... (see Fig. 1)
 - Select the all gpcp maps from a specific month (e.g. January)
 - Type a new name (e.g. gpcp_m1 for January) for the map list and click on OK.
- Repeat the steps above 11 times for other months
- You can create scripts to make it faster (see Fig. 2):
 - Go to File > Create > Script...

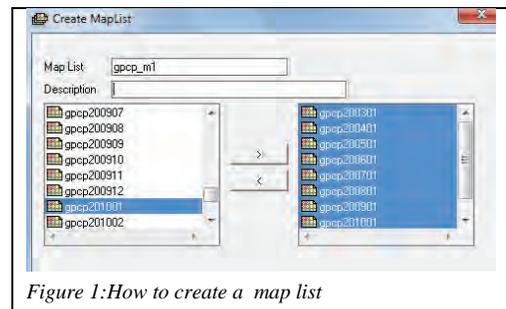


Figure 1: How to create a map list

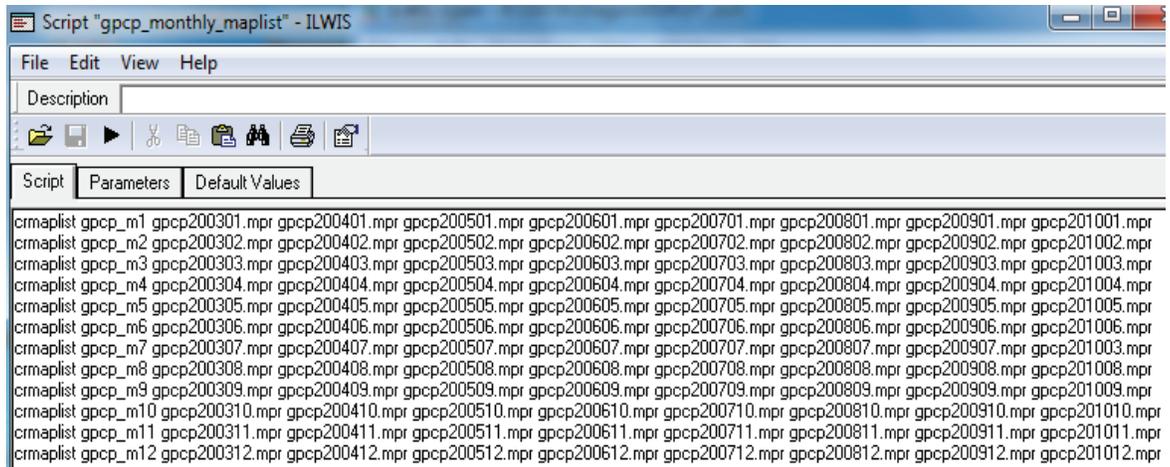


Figure 2: How to make a script to create 12 map lists for each month

- Run the script: *gpcp_monthly_maplist.isl*
 - After these steps, you will see 12 new map lists. There will be one image list for each month (named for example gpcp_m1, gpcp_m2...gpcp_m12)
- Calculate the mean long-term monthly precipitation P(mean)
 - Operations > Statistics > Maplist Statistics (See Fig. 3)
 - Select e.g. gpcp_m1 maplist as the input file
 - Select Average as the Method
 - Type gpcp_m1_mean as the output file
 - Repeat the steps above 11 times for other months or create scripts and run the script
gpcp_longterm_monthly_mean
- b) Calculate precipitation anomaly
- Go to Operations > Raster Operations > MapList calculation, type the expression and use the settings as shown (see Fig. 4) to calculate the precipitation anomaly (PA)
 - After these steps, you will see a new maplist named PA containing 96 images of monthly PA for the period January 2003 to December 2010.
- c) Analyze the precipitation anomaly
- Open PA as animation, use maplist graph to observe the spatial temporal changes of PA
 - Identify the driest and wettest locations / periods
 - Note that long lasted negative rainfall anomaly leads to severe drought, short-term shortage of precipitation does not necessarily result in drought.

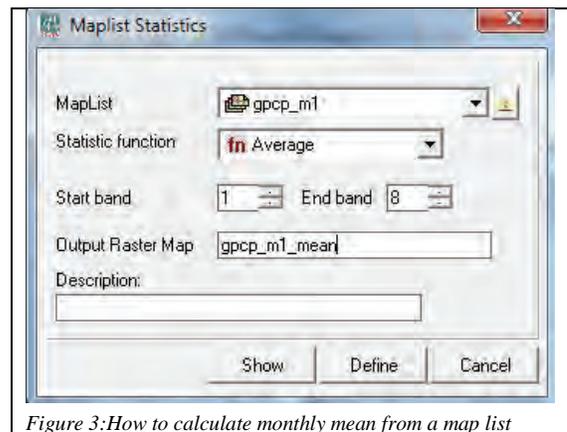


Figure 3: How to calculate monthly mean from a map list

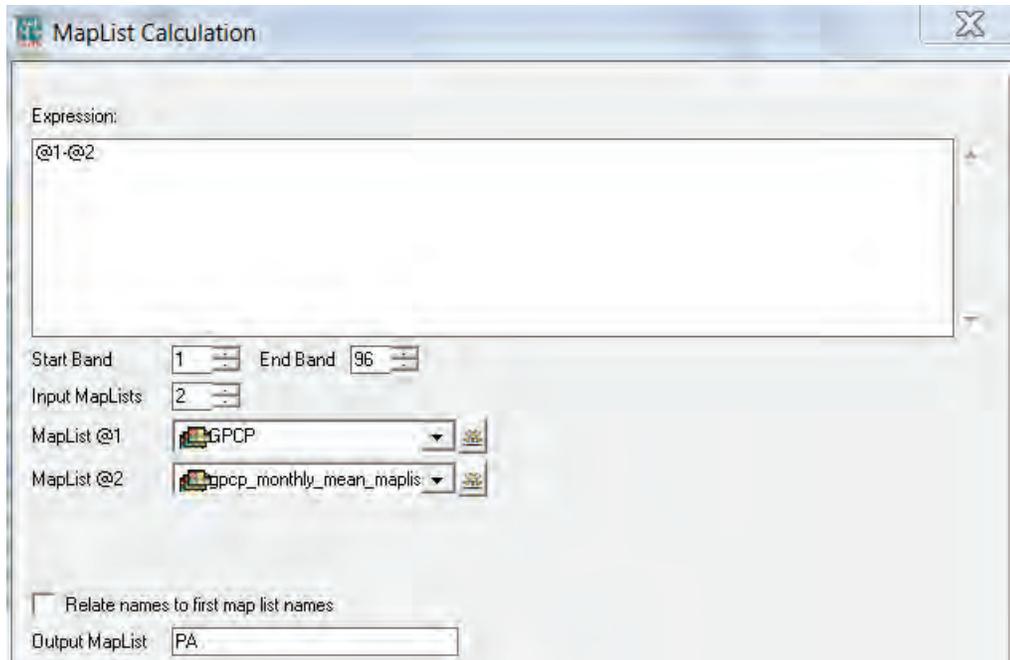


Figure 4: How to calculate precipitation anomaly

2.2) Standardized precipitation index (SPI)

SPI is defined as:

$$SPI = \Delta P / P(\text{std})$$

ΔP = monthly precipitation anomaly of a specific month and year

$P(\text{std})$ = long-term monthly standard deviation of precipitation for a specific month

a) Calculate long-term monthly standard deviation

- Run the script ***gpcp_longterm_monthly_std***

b) Calculate SPI:

- Go to Operations > Raster Operations > MapList calculation, type the expression and use the settings as shown in Figure 5 below to calculate SPI

c) Analyze SPI value.

- Open SPI as animation
- Open world polygon map and zoom into the study area
- use the “Threshold Marking” tool to identify the extremely dry locations
- Note that Negative SPI values indicate dryness and positive indicate wetness (see table 1: Drought classification by SPI value)

SPI values	category
2.0 and above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.48	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

Table 1: Drought classification by SPI

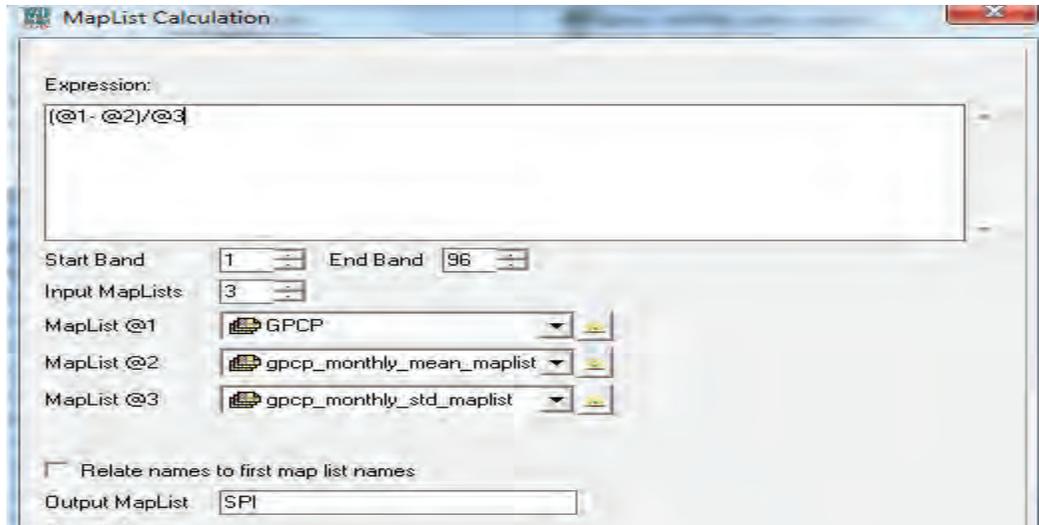


Figure 5: How to calculate SPI

2.3) Soil moisture deficit index (SMDI)

SMDI is defined as:

$$\mathbf{SMDI_j = 0.5SMDI_{j-1} + SD_j/50}$$

SMDI_j = SMDI at month j (current month)

SMDI_{j-1} = SMDI at month j-1 (previous month)

SD_j = monthly soil deficit at month j

$$\mathbf{SD_j = (SW_j - MSW_j) / (MSW_j - \min SW_j) * 100 \text{ if } SW_j = MSW_j}$$

$$\mathbf{SD_j = (SW_j - MSW_j) / (\max SW_j - SW_j) * 100 \text{ if } SW_j > MSW_j}$$

SW_j = actual monthly soil moisture at month j

MSW_j = long-term monthly median available soil water at month j

maxSW_j = long-term monthly maximum available soil water at month j

minSW_j = long-term monthly minimum available soil water at month j

SMDI₁ = SD₁/50 for initial month

a) Calculate the long-term median, maximum and minimum monthly soil water

- Run the script *gldas_monthly_maplist* to create 12 image lists (one image list for each month of time series soil moisture)
- After these steps, you will see 12 new map lists. There will be one image list for each month of soil moisture (named for example sm_m1, sm_m2...sm_m12)
- Run script *sm_longterm_monthly_median* to calculate MSW - the long-term monthly median soil water
- Run script *sm_longterm_monthly_max* to calculate maxSW - long-term monthly maximum soil water
- Run script *sm_longterm_monthly_min* to calculate minSW - long-term monthly minimum soil water

b) Calculate monthly soil deficit SD : Go to Operations > Raster Operations > MapList calculation, type the expression and use the settings as shown in Figure 6 below to calculate the soil moisture deficit SD.

Type the following in the expression (see Fig. 6):

$\text{iff}(@1 > @2, ((@1 - @2) / (@3 - @2)) * 100, ((@1 - @2) / (@2 - @4)) * 100)$

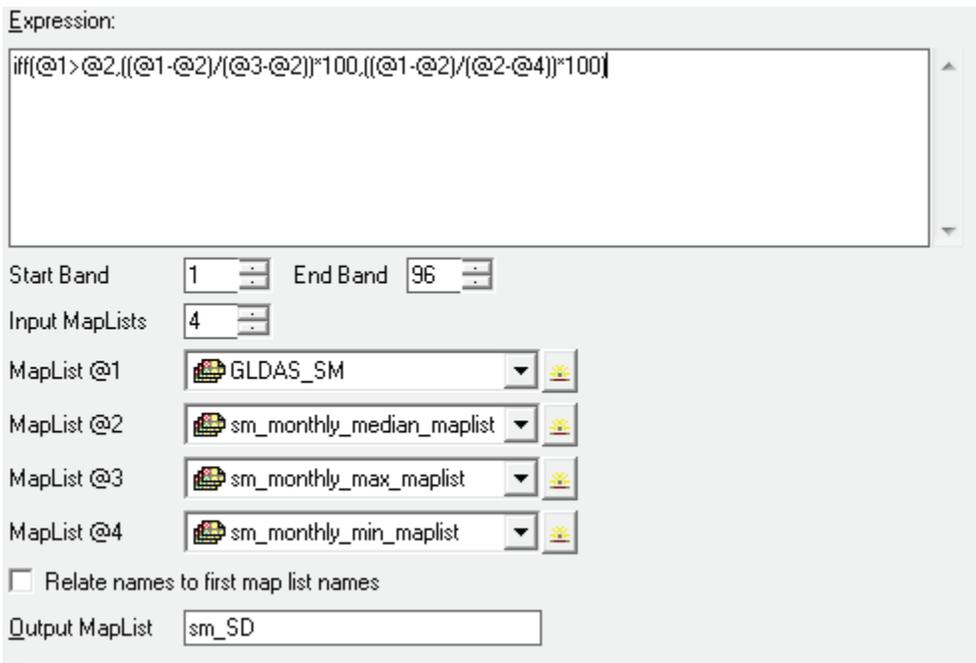


Figure 6: How to calculate soil moisture deficit SD

c) Calculate SMDI

- Run script *sm_SMDI*
- SMDI values range from -4 to 4 indicating from very dry to very wet conditions

d) Analyze SMDI

- SMDI values range from -4 to 4 indicating from very dry to very wet conditions
- Identify the very dry areas

2.4) Monthly evapotranspiration anomaly

Low evapotranspiration values are indicators of plant moisture stress. Actual ET anomaly is a good indicator for monitoring the agriculture conditions (growing-season conditions) and early warning of drought.

ET anomaly is defined as:

$$\mathbf{ET(anomaly)_j = ET_j - ET_j (mean) \quad (1)}$$

j = a specific month at the time series

ET_j = actual monthly ET at a specific month j and year

$ET_j (mean)$ = mean long-term monthly value of actual ET for a specific month

a) Calculate the long-term mean monthly evapotranspiration (ET)

- Run script *sebs_monthly_maplist* to create 12 image lists (one image list for each month of time series ET)
- After these steps, you will see 12 new map lists. There will be one image list for each month of ET (named for example *et_m1*, *et_m2*...*et_m12*)
- Run script *sebs_longterm_monthly_mean* to calculate the monthly long-term mean ET

b) Calculate monthly ET anomaly: Go to Operations > Raster Operations > MapList calculation, type the expression and use the settings as shown in Fig. 7 below to calculate the ET anomaly.

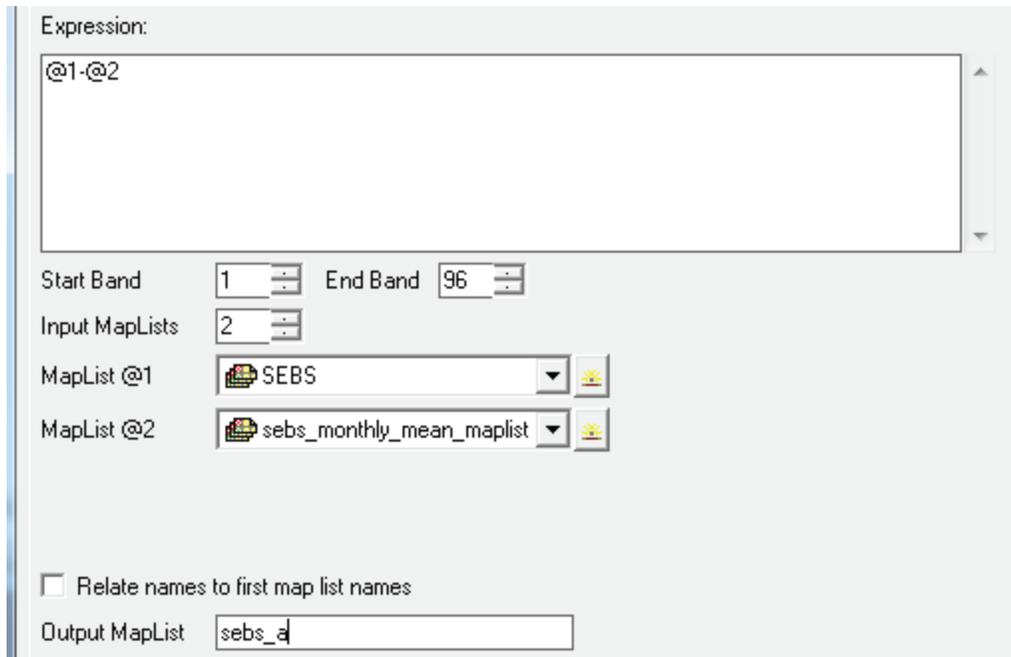


Figure 7: How to calculate ET anomaly

c) Identify the locations with extremely low ET anomaly to understand the drought locations

3): Assess and compare the different drought indices

a) Open as Animation to:

- ⇒ observe the spatial and temporal variations of PA, SPI, SMDI and ETDI in different regions of China;
- ⇒ Determine the spatial extent of drought;
- ⇒ Identify the driest and wettest areas from the different drought index products.

b) Use Cross section graph to:

- ⇒ Plot time series drought indices;
- ⇒ Compare two different drought indices for two specific regions of your choice (in south-west/north/north-east China, e.g. Chongqing, Chengdu, Inner Mongolia, and North China Plain).

c) For the students who like to do more

- ⇒ Copy all information in to an Excel file
- ⇒ Plot the drought indices

- ⇒ Plot the linear trend and correlate between the different drought indices
- ⇒ Calculate drought class maps