ABSTRACT

In this paper, agricultural and hydrological drought definitions are adopted to estimate the severity of drought in northern China in recent years. Particularly crop transpiration as important parameter is added in the drought index algorithm. Land surface model Noah are used and driven by a combination of meteorological reanalysis dataset (NCEP GDAS) and high resolution precipitation (CMORPH) and surface parameters from satellites (MODIS). The seasonal or yearly surface parameters (such as Albedo and LAI) from climatology are replaced by monthly data derived from MODIS, in order to represent the vegetation dynamics more accurately. Products for Crop transpiration and soil evaporation are derived at passing time of MODIS satellites. Temperature products of MODIS are adopted and are validated by simultaneous observation data of Dongping lake in Shandong province of China. Using vegetation transpiration (L_Ev) and latent evaporation (L_E0 = R_n-G) with high every 3 hours time resolution and 1km space resolution in north China, plant water stress index (PWSI) can be got. It is feasible that a combination of the land surface models and the two sources ET remote sensing model to monitoring drought using PWSI drought index according to the application of the method in North China.

Keywords: Drought monitoring, Remote Sensing, Land Surface Modeling

1. INTRODUCTION

A worst drought in 50 years hit western, central and northeastern Chinese regions, causing drink water shortages to at least 10 million people and an economic loss of 9.9 billion Yuan (US$1.24 billion) in 2006. Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. There are different definitions of droughts from different disciplinary perspectives. Defining drought is therefore difficult; it depends on differences in regions, needs, and disciplinary perspectives. Based on the many definitions that have appeared in the literature\[1-4\], for example, we might define drought in A-place as occurring when annual rainfall is less than 180 mm, but in B-place, drought might be considered to occur after a period of only 30 days without rain! In the most general sense, drought originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Whatever the definition, it is clear that drought cannot be viewed solely as a physical phenomenon.

Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some “normal” or average amount) and the duration of the dry period. Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced ground water or reservoir levels, and so forth. Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and...
agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts.

Agricultural and hydrological drought algorithms are adopted to estimate the severity of drought in northern China in recent years in this paper. Particularly crop transpiration as important parameter is added in the drought algorithm.

A drought index value is typically a single number, far more useful than raw data for decision making. So a plant water stress index (PWSI) is adopted for the drought in our study.

2 COMPARISON FOR DROUGHT INDICES

Why is it hard to measure Drought? The wide variety of disciplines affected by drought, its diverse geographical and temporal distribution, and the many scales drought operates on make it difficult to develop both a definition to describe drought and an index to measure it.

There are several indices that measure how much precipitation for a given period of time has deviated from historically established norms. Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better suited than others for certain uses. For example, the Palmer Drought Severity Index\(^1\)\(^2\)\(^3\) has been widely used by the U.S. Department of Agriculture to determine when to grant emergency drought assistance, but the Palmer is better when working with large areas of uniform topography. Regions of China with mountainous terrain and the resulting complex regional microclimates, find it useful to supplement Palmer values with other indices such as the Surface Water Supply Index\(^4\), which takes snowpack and other unique conditions into account.

The percent of normal precipitation is one of the simplest measurements of rainfall for a location. Analyses using the percent of normal are very effective when used for a single region or a single season. Normal precipitation for a specific location is considered to be 100%.

One of the disadvantages of using the percent of normal precipitation is that the mean, or average, precipitation is often not the same as the median precipitation, which is the value exceeded by 50% of the precipitation occurrences in a long-term climate record. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution. Use of the percent of normal comparison implies a normal distribution where the mean and median are considered being the same.

Crop Moisture Index (CMI)\(^2\) uses a meteorological approach to monitor week-to-week crop conditions. It was developed by Palmer (1968) from procedures within the calculation of the PDSI. Whereas the PDSI monitors long-term meteorological wet and dry spells, the CMI was designed to evaluate short-term moisture conditions across major crop-producing regions. It is based on the mean temperature and total precipitation for each week within a climate division, as well as the CMI value from the previous week. The CMI responds rapidly to changing conditions, and it is weighted by location and time so that maps, which commonly display the weekly CMI, can be used to compare moisture conditions at different locations. Weekly maps of the CMI are available. Because it is designed to monitor short-term moisture conditions affecting a developing crop, the CMI is not a good long-term drought monitoring tool. The CMI’s rapid response to changing short-term conditions may provide misleading information about long-term conditions. For example, a beneficial rainfall during a drought may allow the CMI value to indicate adequate moisture conditions, while the long-term drought at that location persists. Another characteristic of the CMI that limits its use as a long-term drought monitoring tool is that the CMI typically begins and ends each growing season near zero. This limitation prevents the CMI from being used to monitor moisture conditions outside the general growing season, especially in droughts that extend over several years. The CMI also may not be applicable during seed germination at the beginning of a specific crop’s growing season.

The Surface Water Supply Index (SWSI)\(^3\) is used as an indicator of mountain-based water supply conditions in the major river basins of the state. It is based on snowpack, reservoir storage, and precipitation for the winter period (November through January). During the winter period, snowpack is the primary component in all basins except the same basin where reservoir storage is given the most weight.

The objective of the SWSI was to incorporate both hydrological and climatological features into a single index value resembling the Palmer Index for each major river basin. These values would be standardized to allow comparisons between basins. Four inputs are required within the SWSI: snowpack, streamflow, precipitation, and reservoir storage. Because it is dependent on the season, the SWSI is computed with only snowpack, precipitation, and reservoir storage in the winter. During the summer months, streamflow replaces snowpack as a component within the SWSI equation.

The procedure to determine the SWSI for a particular basin is as follows: monthly data are collected and summed for all the precipitation stations, reservoirs, and snowpack/streamflow measuring stations over the basin. Each summed component is normalized using a frequency analysis gathered from a long-term data set.

3. CREATING OF ALTERNATIVE DROUGHT INDICES

According to the comparisons among the percent of normal precipitation (PNP), Crop Moisture Index (CMI), The Surface Water Supply Index (SWSI), the plant water
stress index (PWSI) just like the Crop Moisture Index is adopted as drought index in this paper, which is agricultural and hydrological drought algorithms to estimate the severity of drought in northern China in recent years. Particularly crop transpiration as important parameter is adopted in the drought algorithm. Land surface model Noah are used and driven by a combination of meteorological reanalysis dataset (NCEP GDAS) and high resolution precipitation (CMORPH) and surface parameters from satellites (MODIS). The seasonal or yearly surface parameters (such as Albedo and LAI) from climatology are replaced by monthly data derived from MODIS, in order to represent the vegetation dynamics more accurately. Products for Plant (Crop) transpiration and soil evaporation are derived at passing time of MODIS satellites using two-layer model that we proposed in 2005[7]. A combination of the land surface models and the two sources ET remote sensing model, transpiration with high every 3 hours time resolution and 1km pixel resolution in north China can be got. Following text is how to obtain PWSI from above products.

The relationship between Bowen Ratio and the rate of soil water supply is the theoretical basis of this kind of method that separating energy. There is an explicit functional relationship between the rate of soil moisture availability \( M \) and latent heat flux \( LE \). When \( M \) is a constant and combines with plant water stress index \( PWSI \) and Bowen Ratio \( \beta \), where \( H \) is the sensible heat flux. \( M \) and \( \beta \) are related, the relationship is the following:

\[
1 - PWSI = M = \frac{LE}{LE_0} = \frac{H}{\beta LE_0}, \beta = \frac{H}{MLE_0} \tag{1}
\]

Eq (1) shows the simple physical relationship among the rate of soil water supply, plant water stress index and Bowen Ratio. The key equation is the function of \( M \) and \( \beta \) which can be achieved through PCACA[7]. After the layered net radiation and the layered Bowen Ratio of pixel has been gotten, the following surface flux can be retrieved.

\[
M_{vi} \approx \frac{T_{vi}-T_{v0}}{T_{vi}-T_{vi}}, \quad LE_{vi} \approx \frac{LE_{v0}}{LE_{v0}} \tag{2}
\]

\[
\beta_{vi} \approx \frac{T_{vi}-T_{vi}}{T_{vi}-T_{vi}} = 1 \tag{3}
\]

\[
LE_{vi} \approx \frac{R_{net}}{1 + \beta_{vi}} \tag{4}
\]

where \( M_{vi}, \beta_{vi}, T_{vi} \) are soil moisture availability, Bowen ratio and temperature of plant surface i-th pixel in the image respectively, \( T_{v0}, T_{vi}, T_{vi} \) are plant surface temperature of pixel i on the dry line and on the wet line in the same VFC. Caparisoning \( LE_{vi} \) products of Land surface model Noah and \( LE_{vi} \) obtained by using expression (4), \( PWSI \) can be expressed and calculated pixel by pixel and drought index is defined by \( PWSI > 0.9 \) that is called \( DPWSI \), seen from Fig.1.

\[
PWSI_{vi} = 1 - \frac{LE_{v0}}{LE_{v0}} \approx 1 - \frac{LE_{v0}}{Rn_{vi}} \tag{5}
\]

It is agricultural and hydrological drought algorithm which is adopted to estimate the severity of drought in northern China in recent years.

3. RESULTS

Temperature products of MODIS are adopted and are validated by simultaneous observation data of Dongping lake in Shandong province of China[8]. Then the land surface models are run at 1km and predict the land surface states and fluxes every 3 hours. We also can expend time resolution of \( LE_{vi} \) using \( LE_{v0} \) products of Land surface models. The high resolution land surface modeling provides an unprecedented opportunity to examine the spatial and temporal pattern of drought in Northern China. The performance of the \( DPWSI \) monitoring in this region is
evaluated by the site observation of Yuchen station\textsuperscript{[9]} in ChinaFLUX and Chinese Ecosystem Research Network (CERN). We can see very good relationship between precipitation and \(PWSI\) from Fig.2 and Fig.3. Drought emerges from 5 to 18 Jul 2005 according to \(PWSI_y > 0.9\). We also can see regional distribution of \(PWSI_y\) where drought emerges in term of white color in Fig.4. Therefore, it is feasible that a combination of the land surface models and the two sources ET remote sensing model to monitoring drought. It is feasible that a combination of the land surface models and the two sources ET remote sensing model to monitoring drought.

![Image of Fig. 3](image1)

**Fig. 3** Correlation between Precipitation and \(PWSI_y\)

![Image of Fig. 4](image2)

**Fig. 4** Distribution of PWSI at 14:00 on 16 JUL 2005 in North China

However, It still is hard to measure drought. Because the wide variety of disciplines affected by drought, its diverse geographical and temporal distribution, and the many scales drought operates on make it difficult to develop both a definition to describe drought and an index to measure it. The uncertainty of this method mainly results from ignoring advection. \(LE_0 = R_n - G\) is reasonable only when there is no advection, However, According to its regular, it only has effects on the edge of the pixel and the advection effects caused by surface’s heterogeneous inside the pixel are eliminated by pixel’s average action. Of course, it is an important work about scale transform of surface flux.

## 4. CONCLUSIONS AND DISCUSSIONS

Using \(LE_v\) and \(LE_h = R_n - G\) with high every 3 hours time resolution and 1km space resolution in north China \(PWSI_y\) can be got. It is feasible that a combination of the land surface models and the two layer ET remote sensing model to monitoring drought.

## 5. REFERENCES


