Delineation of Groundwater Dependent Ecosystems based on a Water Balance Approach

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ABSTRACT:

Around the world, groundwater is one of the main sources of water which is used as water supply, in irrigation, production of mineral water, aqua-culture, and for the production of energy. Although groundwater is useful in many ways, the extraction of groundwater has jeopardized the ecosystem's health by decreasing the life expectancy rate of plants that survive by up taking groundwater such as phreatophytes. This study analyzed a 1 degree by 1 degree area in Arizona in order to assess if there is dependence of the ecosystems on the groundwater. The method used to estimate if an ecosystem is groundwater dependent (GDE) is based on a water balance approach in which two scenes, one at the beginning of the dry season and one at the end of the dry season, were compared to analyze ET (evapotranspiration). This hydrological parameter can be useful in identifying areas where groundwater use by vegetation in the absence of precipitation is occurring (Orellana et al., 2011). Results show that in 2004 a relatively constant precipitation [illegible] antecedent soil moisture conditions, GDEs could be identified.

INTRODUCTION:

With increasing population coupled to fast development of new urban areas, humans consume increasing amounts of water for agricultural, industrial and domestic uses (Eamus et al., 2006b). Due to the worth of groundwater, it is a challenge to balance the amount of groundwater used for human consumption and environmental water requirements for the surrounding area. Aquifer, caves, springs, wetlands, estuaries, and terrestrial vegetation are groundwater dependent ecosystems that get the water that is necessary for survival groundwater. The lack of groundwater can lead fundamental alterations and the destruction of these ecosystems. This study focuses on vegetation, specifically phreatophytes, which are plants that contain roots that can penetrate the capillary fringe and

OBJECTIVE:

The purpose of this study is to analyze a 1 degree by 1 degree area in Arizona in order to asses if there is dependence of the ecosystems on the groundwater.

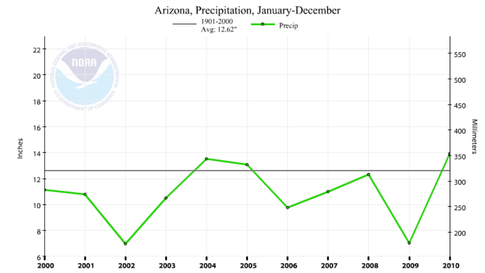
STUDY AREA:

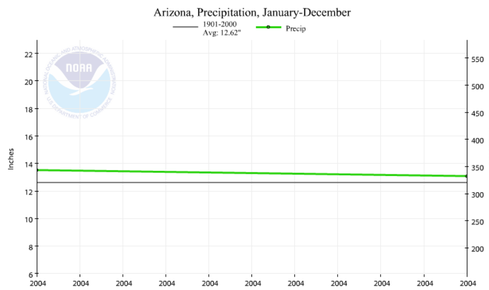
The site study is a 1 degree by 1 degree area located in Arizona(center coordinates 33.17°N latitude and 110.70° W longitude). It is characterized by a hot and dry continental climate which can often vary throughout the region. On average, Arizona receives approximately 0.1 inches of rain between June and August.

Due to the lack of precipitation, it is hypothesized that the ecosystem apparent in this location is groundwater dependent .

METHODOLOGY:

In order to analyze the dependency of ecosystems on groundwater, MODIS Evapotranspiration datasets from 2000 to 2012 with a monthly temporal resolution and 1 km spatial resolution (upscaled to 5 km) were used. Evapotranspiration is measured in millimeter per day.





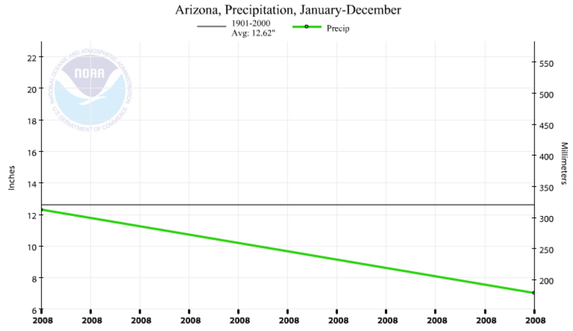


Figure 1a-c. Times Series for Annual Precipitation for 2004 and 2008
[source: http://www.ncdc.noaa.gov/cag/time-series/us]

The time period in which evapotranspiration data was collected was determined by analyzing the Annual precipitation rate in 2004 and in 2008. As shown in figure 1a precipitation was at its highest at 350 millimeters in 2004. On the other hand, precipitation was at its lowest in 2002 with approximately 180 millimeters. This pattern occurred again in 2008 where precipitation was at approximately 325 millimeters and a precipitation rate at 250 millimeters in 2006. However, it has come to attention that even though these patterns are very similar, there is a extreme difference in precipitation in 2008 (figure 1c) as oppose to precipitation in 2004 (figure 1b) which for the most part remained constant.

The datasets for evapotranspiration were collected from June 2004, June 2008, August 2004, and August 2008 in millimeters per day. Groundwater dependent ecosystems rely mostly on groundwater. Therefore, it was ideal that groundwater dependent ecosystems were analyzed at the beginning of the dry season (June) and at the end of the dry season (August) in an area that does not receive a lot of precipitation on average as shown if Figures 1a-d to quantify that the plants in this ecosystem are in fact using the groundwater.

RESULTS:

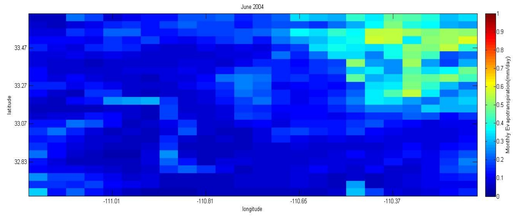


Figure 2. Evapotranspiration in June 2004 (mm/day) [source: MODIS]

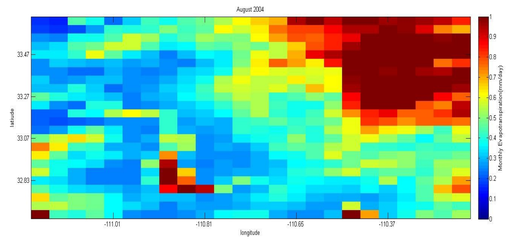


Figure 3. Evapotranspiration in August 2004 (mm/day) [source: MODIS]

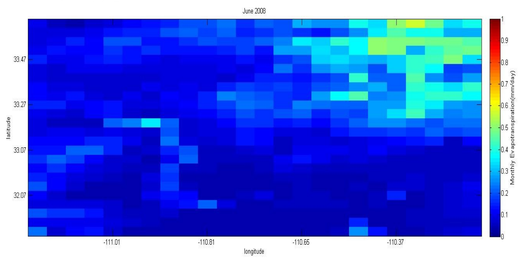


Figure 4. Evapotranspiration in June 2008 (mm/day) [source :MODIS]

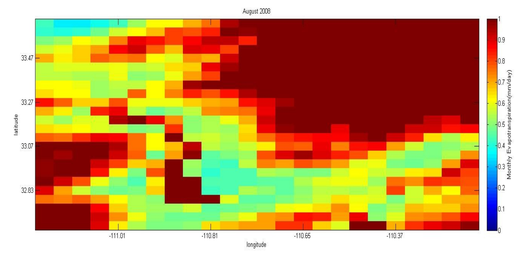


Figure 5. Evapotranspiration in August 2008 (mm/day) [source: MODIS]

These datasets were obtained from MODIS and computed into a MATLAB code for the interpretation of evapotranspiration for each pixel. MODIS provides the key components for water resource management. MATLAB is an efficient, high-level language and interactive environment for numerical computations, visualization, and programming. MATLAB is used to analyze data, develop algorithms, and create models and applications.

Pixels that are similar in initial evapotranspiration (June) and final evapotranspiration (August) have a high potential of being a groundwater dependent ecosystem because despite of the reduced amount of precipitation, evapotranspiration still occurs and it is hypothesized that this would be the result of groundwater being accessed.

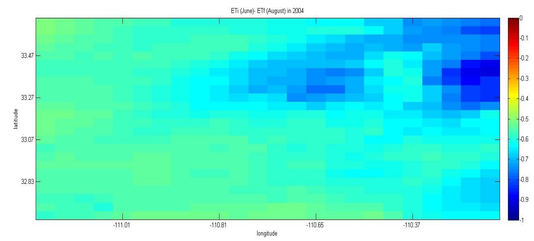


Figure 6. The difference between Initial Evapotranspiration and Final Evapotranspiration in 2004

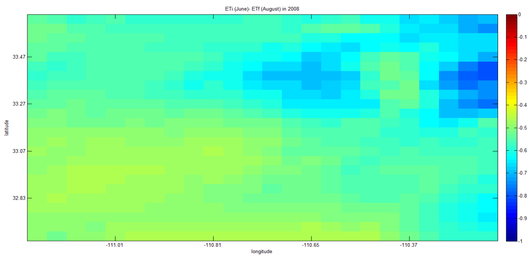


Figure 7. The difference between Initial Evapotranspiration and Final Evapotranspiration in 2008

A MATLAB code was created to calculate the difference for evapotranspiration between June 2004 and August 2004, and between June 2008 and August 2008. Pixels that showed the high difference between initial ET and final ET represent ecosystems that are not groundwater dependent.

CONCLUSIONS:

Results show that for the years of 2004 and 2008 the seasonal variability in evapotranspiration differs greatly from what was expected. Typically, in the southern parts of the United States like Arizona, ET occurs during the winter months, even though comparatively small, and generally is the greatest in the early summer to midsummer months (June and July), when the leaf area of plants is fully developed. However, for the area selected ET was higher at the end of the dry season (August and September), which resulted in negative values for the final difference maps. This could be the result of the summer monsoon season. Most of the monsoon rainfall in the Southwestern US arrives in short-duration, low-volume pulse events. These small, frequent precipitation events that only penetrate the top few cm of the soil, control the water availability for plants in arid ecosystems [illegible].

LITERATURE CITED:

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