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Analysis of the water balance under regional scenarios of climate change for arid zones of Colombia

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RESUMEN

En este trabajo se analizan en detalle los parámetros implicados en el balance hídrico. Se consideran las condiciones actuales y el cambio climático en una zona representativa de clima árido en Colombia: la región desértica de Uribia en el departamento de La Guajira. Con este fin se seleccionaron algunas estaciones climatológicas que, de acuerdo con los valores registrados de temperatura y precipitación, pueden considerarse representativas de áreas climáticas áridas o desérticas según el índice de Lang (PCP/T_{avg}). Se construyó una línea de referencia a partir de los registros históricos de precipitación y temperatura y se analizó su comportamiento. Los datos de las estaciones se obtuvieron de la base de datos del Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia. Después de calcular los escenarios de referencia, se estimó el balance hídrico actual tomando en cuenta las variables originales e incluyendo, cuando fue necesario, nuevos parámetros para el cálculo de la ecuación simplificada de continuidad. El análisis incluyó parámetros como potencial de evapotranspiración, humedad del suelo, almacenamiento o recarga y sus cambios, déficit y exceso hídrico, escorrentía, periodos de recarga y uso del agua. Las anomalías de temperatura y precipitación se calcularon tomando en cuenta los nuevos escenarios climáticos “trayectorias representativas de concentración” para diferentes periodos (de corto y largo plazo). Con las anomalías encontradas se ajustó la línea de referencia para las variables mencionadas anteriormente, y los parámetros asociados se analizaron en el contexto del balance hídrico. En escenarios de cambio climático, el balance hídrico proyecta una posible intensificación de las condiciones desérticas en la región de Uribia-Guajira, ya que se espera una disminución en el índice de Lang de su valor actual de 18.7 (desértico) a 17 en 2050 y 14.5 en 2070, como resultado de una reducción de las precipitaciones (2.4 y 11%) y un incremento de la temperatura anual promedio de alrededor de 1.7 ºC con el modelo HadGEM2-ES para el periodo 2041-2060 y de 3.7 ºC con el modelo GFDL-CM3 para el periodo 2061-2080. Esto se comprueba mediante la clasificación climática de Thornthwaite, que tipifica el área de estudio como una zona árida con recursos hídricos limitados y sin excedentes. Este déficit podría acarrear graves consecuencias ambientales, problemas sociales y declinación de la productividad agrícola e industrial de la región.

ABSTRACT

This work discusses in detail the parameters involved in water balance. The analysis is performed by considering the current conditions and climate change in a climatic zone that represents the arid regions of Colombia: The municipality of Uribia (desert) in the state of La Guajira. For this purpose, some climatological stations, which by their reported values of temperature and precipitation can be considered representative of the arid or desert climatic zones according to the Lang’s index (PCP/T_{avg}), were selected. Then, with historical temperature and precipitation values registered at the station of the area, the baseline was built and its behavior analyzed. The station data were obtained from the database of the Instituto de Hidrología, Meteorología y Estudios Ambientales (Institute of Hidrology, Meteorology and Environmental Studies) of Colombia. After estimating the baseline scenarios, the current water balance on the site was calculated by taking into account the original variables and including new parameters, if necessary, for the calculation of the simplified continuity equation. The analysis included parameters such as potential and actual evapotranspiration, moisture of soil, storage or recharge and their changes, water deficit and excess, runoff, periods of recharge, and water use. Anomalies in temperatures (ºC) and precipitation were calculated by taking into account the new climate scenarios "representative concentration pathways" for different periods (short- and long-term). With the anomalies identified, the baseline for the above-mentioned variables was adjusted. Again, the associated parameters were analyzed and discussed in the context of water balance. In climate change scenarios, the water balance projects a prospective exacerbation of desert conditions in the Uribia-Guajira region, since a decrease in the Lang's index from its current value of 18.7 (desert) to 17.0 in 2050 and 14.5 in 2070 is expected, as a consequence of a decrease in precipitation (2.4 and 11.0%) and an increase in annual temperature of about 1.7 ºC with the HadGEM2-ES model for the period 2041-2060 and 3.7 ºC with the GFDL-CM3 model for the period 2061-2080. This can be verified by means of the Thornthwaite climate classification, which categorizes the area of study as an arid zone with limited and no excess of water. This deficit could lead to serious environmental consequences, social problems and a decline in the industrial and agricultural productivity of the zone.

Keywords: Cimate change, water balance, climatic scenarios, arid zones.

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC, 2013), the increase of greenhouse gases in the atmosphere may have an influence on the mean global warming of the Earth's surface within the range of 0.5 to 1.3 ºC during the period 1951-2010. Regarding the natural internal variability, it is expected that average annual and seasonal temperature increases will be higher in the tropics and subtropics than in the mid-latitudes. For the period 2081-2100, the average Earth's temperature is expected to be in the ranges derived from the new climate change scenarios brought into consideration, that is, with increases of 0.3-1.7 ºC (RCP 2.6), 1.1-2.6 ºC (RCP 4.5), 1.4-3.1 ºC (RCP 6.0), and 2.6-4.8 ºC (RCP 8.5). Likewise, by the end of the century the average annual precipitation estimated for the RCP 8.5 scenario is expected to increase in high latitudes and in the equatorial Pacific Ocean, while it could decrease in many dry zones in mid-latitudes and subtropics. This scenario also suggests huge impacts in zones with climates similar to the study area. Arid and semi-arid regions in mid-latitudes and subtropics are likely to have less rain, hence, it is estimated that for each degree of global warming, approximately 7% of the global population will be exposed to a reduction of at least 20% in hydric resources (IPCC, 2013, 2014; Jiménez Cisneros et al., 2014).

This results in alterations of the hydrological cycle, such as increase or reinforcement of evaporation due to higher temperatures, and an increase in actual, global and regional evapotranspiration, which will be affected by variations in precipitation levels, spatiotemporal changes in rain distribution, values of daily temperature, aerosols concentration, alteration of net radiation, vapor pressure deficit, and wind speed (IPCC, 2007; Bates et al., 2008; Fu et al., 2009; McVicar et al., 2010; Miralles et al., 2011; Wang A. et al., 2011; Kundzewicz et al., 2007). These features could have a negative influence on the water sources.

Among the main factors that have an effect on the natural water supply and its quality, other than climate, we may find change in land use, water damming for different activities, polluting emissions in the atmosphere, treatment of wastewater, and social, economic and technological changes and their respective relations, including lifestyle changes (van Vuuren et al., 2012; IPCC, 2007). Furthermore, the demand of the hydric resource for its use and consumption directly affects the demographic factor, food security and sovereignty, politics, economy, technology, lifestyle and water consumption priorities (IPCC, 2007). Among these non-climatic factors, land use change stands out, since it could significantly affect drinking water systems. For example, soil degradation attributable to urban activities could increase the risks of floods and decrease the aquifer recharge, due to the settlement of communities near the channels or the limitation of recharge from natural ground currents