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WHAT AND HOW MUCH INFORMATION ABOUT LAKES IN PANAMA CAN A WEB APPLICATION, CLIMATES OF LAKE BASINS PROVIDE?

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ABSTRACT

Lakes are very important for multi-sectors including water sector in Panama because of large demand of water use and of hydroelectric power generations. Panamanian know lakes in their own country but foreign researchers do not always so. For an example, Wikipedia contains only 6 dams with a hydroelectric power reservoir. It is interesting to know how much information about lakes in Panama we can obtain on the Internet. This study investigates what information and how much about lakes in Panama are accessible for preliminary scientific investigations through the Internet.

A web application, Climates of Global Lake Basins (CGLB) have been developed for providing lake information from the view point of hydrological and water resources by the combination of existing data sets. The distinction of CGLB from other web applications is that CGLB has a drawing functions of climatological information on demand. CGLB also provides landscape photographs provided by Global Confluence Project as well as quasi-real time monitoring of lake water levels using satellite altimetry provided by U.S. Department of Agriculture. The first version of CGLB contained about 600 lakes or more in the world. Recently, CGLB has been upgraded by changing a lake information database from the World Lake Database (WLDB; http://wldb.ilec.or.jp/) to the HydroLAKES following a new development of the source code due to introduction of a free database module to treat more than more than 1 million of lakes.

Lake database targeting the entire world contains some lakes only due to the coverage of the whole globe. For example, WLDB contains only 2 lakes in Panama: Chiriqui Lagoon and Gatun Lake. These selections may be importance of the lake. On the other hand, CGLB based on HydroLAKES contains 73 lakes in Panama. As an example, we demonstrate what information and how much data of Gatun Lake are available from CGLB.

Keywords: global; lake; climate; Panama; web application; database

1 INTRODUCTION

Lakes has roughly 0.5% of the global land area (Nakaegawa 2012) and hold more than 90% of the world's liquid freshwater in readily accessible bodies. Lakes are also one of the important components of hydrological cycles and at the same time have biogeochemical and ecological processes. In a changing climate under greenhouse gas emissions, these aspects will be affected by the global warming and will impact on human societies as well as on readily accessible water bodies.

Future projections of climates require the biogeo-chemical and ecological processes in lakes since they are embedded in the Earth system and interact with each other. Future projections of lakes require the lake information about their hydrological properties of distribution, volume and residence time. Therefore, global lake databases have been developed. Such databases are usually based on only the lake information because of their objectives. Public may want to know a climate in a target lake.

Then, we developed web application, Climates of Global Lake Basins (CGLB; http://hydro.iis.u-tokyo.ac.jp/CGLB/), combines existing datasets and interactively displays geographical, hydrological, and climatological information for hundreds of lakes around the world in 2015. The lake information in CGLB is

based on the World Lake database (WLDB) (International Lake Environmental Committee, 1999). Unique features of WLDB is comprehensive information about lakes from geographical information to biogeochemical one but lists only about 650 lakes. The number of the lakes in WLDB for each country is distinctly biased since they are selected as important order for people. Recently, a new lake database, HydroLAKES has been developed with more than 1 million entry Messager et al. (2016). We upgraded CGLB based on HydroLAKES. This study investigates what information and how much about lakes in Panama are accessible for preliminary scientific investigations through the Internet.

2 DESIGN OF WEB APPLICATION

We designed CGLB as provision of climatological information for a target lake basin so that one who want to look into the lake basin can obtain the information interactively for each own purpose. SQLite is employed to deal with more than 1 million entry. SQLite is a relational database management system and often embedded into the end program but not client-server database engine. New features of the CGLB are summarized below:

1. replace of base lake geo-spatial information: HydroLAKES; more than 1 million lakes are listed in CGLB and other components such pouring points are newly included in CGLB,
2. figures of lake shapes with either elevation or land cover type can be drawn interactively,
3. lake surface temperature can be drawn in one- or two-dimensional time series,
4. link to submonthly climatology in ClimatView developed by Japan Meteorological Agency: daily data can be seen but the number of the stations are small, and
5. SQLite is embedded into the end program, allowing more than 1 million entry and search by keywords.

3 LAKES OF PANAMA IN CGLB

Lake database targeting the entire world contains some lakes only due to the coverage of the whole globe. For example, WLDB contains only 2 lakes in Panama: Chiriqui Lagoon and Lake Gatun. Nobody knows the rationale of these selections. On the other hand, CGLB based on HydroLAKES contains 73 lakes in Panama. However, only Lake Gatun is identified with name; the other 72 lakes do not have their own names. Then, we combined HydroLAKES with Geonames, a geographical name database and successfully name 8 lakes in Panama. The other 66 lakes do not have their names still. The largest lake in Panama is Lake Gatun followed by Lake Bayano with the surface water area of 254 km^2. As an example, we demonstrate what information and how much data of Lake Gatun are available from CGLB.

Lake Gatun is the largest lake in Panama and located at the narrowest part of the Isthmus of Panama. It is developed under a construction of the Panama Canal and serve as a water reservoir providing water to the sluices of the Panama Canal. Therefore, Lake Gatun has two outlets to both the Pacific Ocean and Caribbean Sea. The surface water area is 332 km^2.

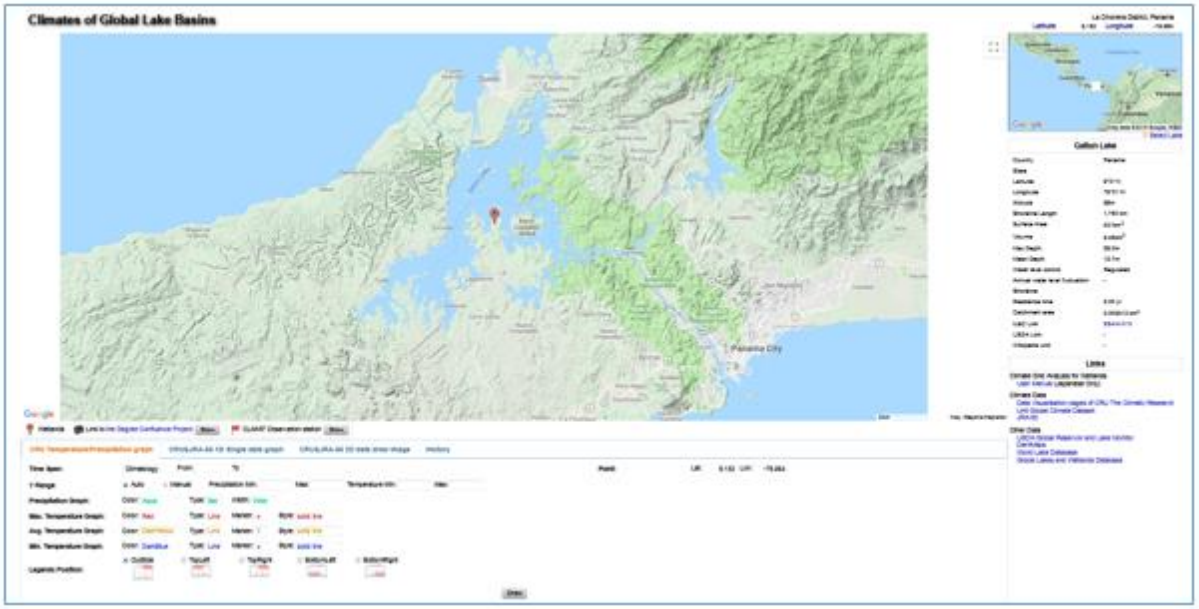


Figure 1. Screenshot of CGLB for Lake Gatun. Main panel shows the geographical map in Google Maps; right top panel shows a broad geographical map; lower right panel lists the hydro- and limnological features of Lake Gatun; and bottom panel functions graphical user interface for interactive drawing figures.

(a) (b)

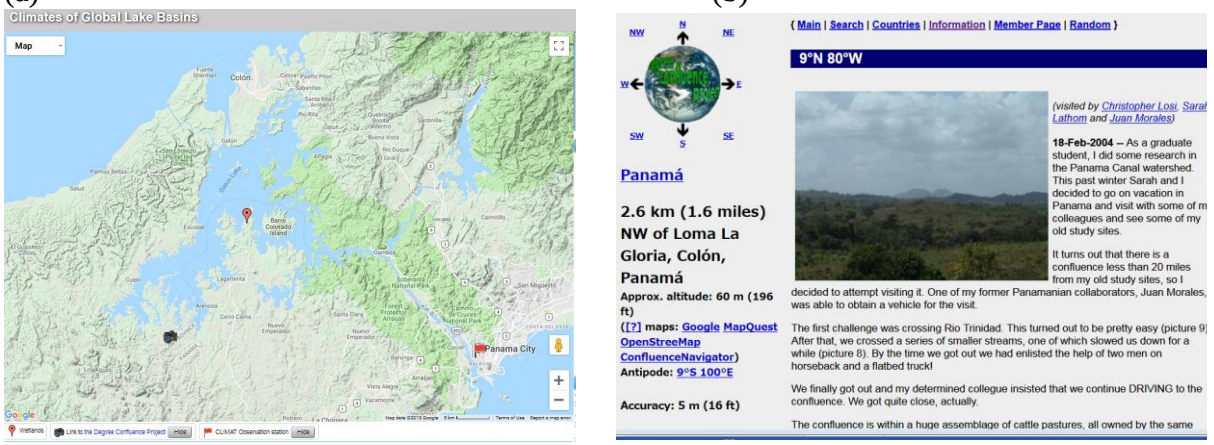
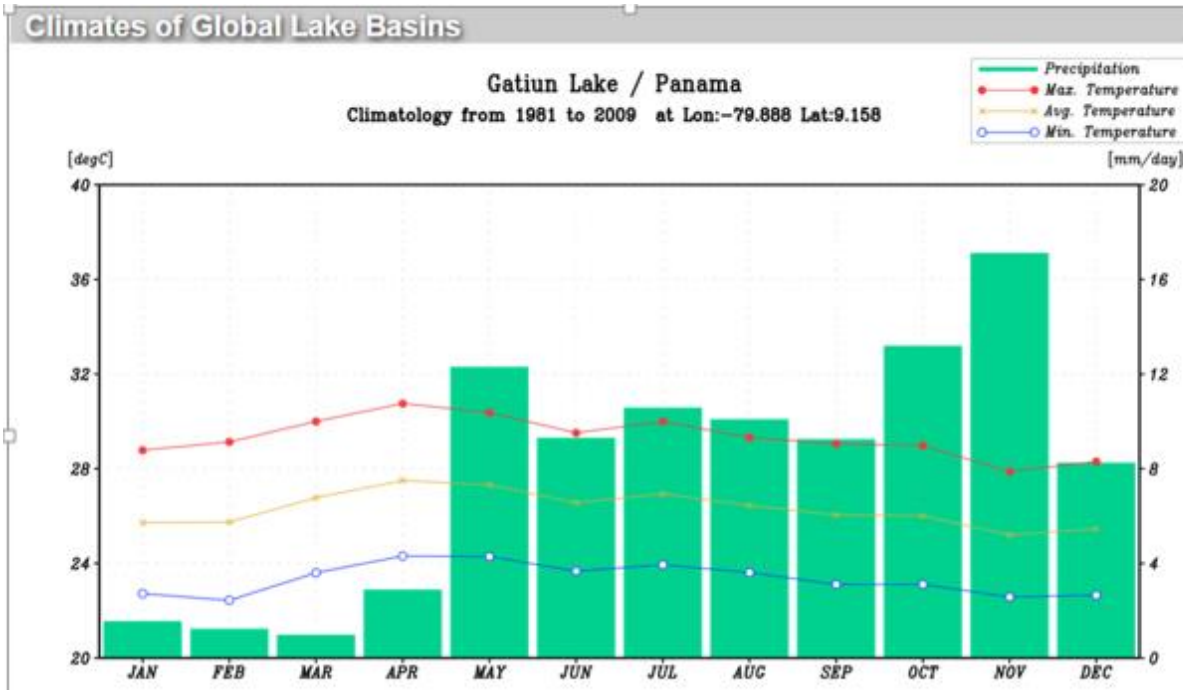


Figure 2. (a) Screenshot of location of observation stations operated by National Meteorological and Hydrological Service, ETESA. Red flags denote the location of the observation station and a red circle denotes the station at Panama City near the mouth to the Pacific Ocean. Flag and camera icons with circles in (a) represent the surface meteorological station registered in WMO CLIMAT stations. (b) Screenshot of Degree Confluence Spots at 9ºN 80ºW. http://confluence.org/confluence.php?lat=9&lon=-80.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation [mm/day]	1.561	1.240	0.981	2.896	12.304	9.311	10.582	10.094	9.254	13.200	17.121	8.253
Max. Temperature [degC]	28.783	29.134	30.000	30.755	30.376	29.517	29.997	29.314	29.059	28.972	27.883	28.307
Avg. Temperature [degC]	25.724	25.745	26.772	27.500	27.317	26.562	26.938	26.445	26.048	26.007	25.200	25.462
Min. Temperature [degC]	22.721	22.438	23.603	24.310	24.290	23.672	23.941	23.614	23.110	23.110	22.579	22.652

Figure 3. Climatological monthly mean, maximum, and minimum surface air temperatures and precipitation around Lake Gatun for each month at the center point of the map. This figure is drawn interactively on CGLB. The data used is gridded global dataset of CRU TS3.2.

Maps on the left-hand side and lake information based on WLDB and HydroLAKES are displayed on the right-hand side. Left-bottom below the Google Maps provides interactive draw of figures: 1-dimensional time series and 2-dimensional geographical distribution of land surface meteorological variables. Observation stations operated by National Meteorological and Hydrological Services appear on this Google Map by one click (Fig. 2a) and climatological monthly mean surface air temperature and precipitation can be seen on ClimatView developed by Japan Meteorological Agency if the data are provided to the WMO on time. These data are called as CLMAT and provided through World Meteorological Organization (WMO, 2009). CLIMAT is the names of the codes for reporting monthly values of meteorological parameters from weather stations and for reporting monthly aerological means from weather stations; unfortunately, the climatological information at the site of Panama City closest to Lake Gatun is not available. One degree confluence points of longitude and latitude appear on the Google Map by one click as well (Fig. 2a). If a confluence point is traveled by an explorer, landscape pictures are seen on the Web (Fig. 2b). This confluence point is located in the basin of Lake Gatun. Land cover type at this point is categorized as shrub and grassland.

Although the meteorological information at the station in Fig. 2a is unavailable, CGLB provides the same information but for global gridded dataset of CRU TS3.2 by interactively drawing a figure of Fig. 3 depicting the climatological mean precipitation and mean, maximum, and minimum surface air temperatures. The values are also listed in a table as the bottom panel. The representative spatial scale of the global gridded dataset is 50 km or 0.5 degrees. Climatological annual mean temperature at Lake Gatun is about 26ºC in annual range of 25ºC to 27ºC. Climatological annual rainfall total is 2944 mm/year and monthly mean rainfall reaches a peak in November. The merit of gridded global dataset have no missing values which is very useful for global database like CGLB when there is no meteorological station near a lake and the meteorological data at a close meteorological station are unavailable as in the case of Lake Gatun.

Figure 4 depicts the climatological mean monthly precipitation around Lake Gatun for each month in two-dimensional form or geographical one. The area drawn in each panel is completely same area as in Fig.1. This figure is drawn interactively on CGLB based on your request. Table 1 lists the variables which can be drawn interactively on CGLB. The total number of the variables are 20 including surface meteorological variables affecting land-surface processes and atmospheric water flows.

Global Framework for Climate Service (GFCS) led by WMO is a global partnership of governments and organizations that produce and use climate information and services. It seeks to enable researchers and the producers and users of information to join forces to improve the quality and quantity of climate services worldwide, particularly in developing countries. CGLB may contribute to GFCS by bridging dialogues between lake-relevant communities and climate ones. Since CGLB is developed by climatologists and/or producers, more ideas by limnologists and/or lake-relevant users must be required for further developments. Although CGLB provides figures on demand, but not even simple analysis. This implementation may depend on users' request. CGLB contains comprehensive information, and therefore would provide an opportunities in a variety of unique research on global lakes.

Table 1. Dataset used in the web application: CGLB

Name	Items	Number of items	References
CRU	Cloud cover, diurnal temperature range, precipitation, daily mean temperature, monthly average daily mini-mum temperature, monthly average daily	9	Harris et al. (2014) http://www.cru.uea.ac.uk/data

	maximum tem-perature, vapor pressure, wet day frequency, potential evapotranspiration		
JRA-55	Downward longwave radiation, downward shortwave radiation, divergence of column total vapor water flux, precipitation, relative humidity, air temperature, zonal wind, meridional wind, column total zonal water vapor flux, column total meridional water vapor flux, geopotential height at 500 hPa	11	Kobayashi et al. (2015) http://jra.kishou.go.jp/JRA-55/index_en.html

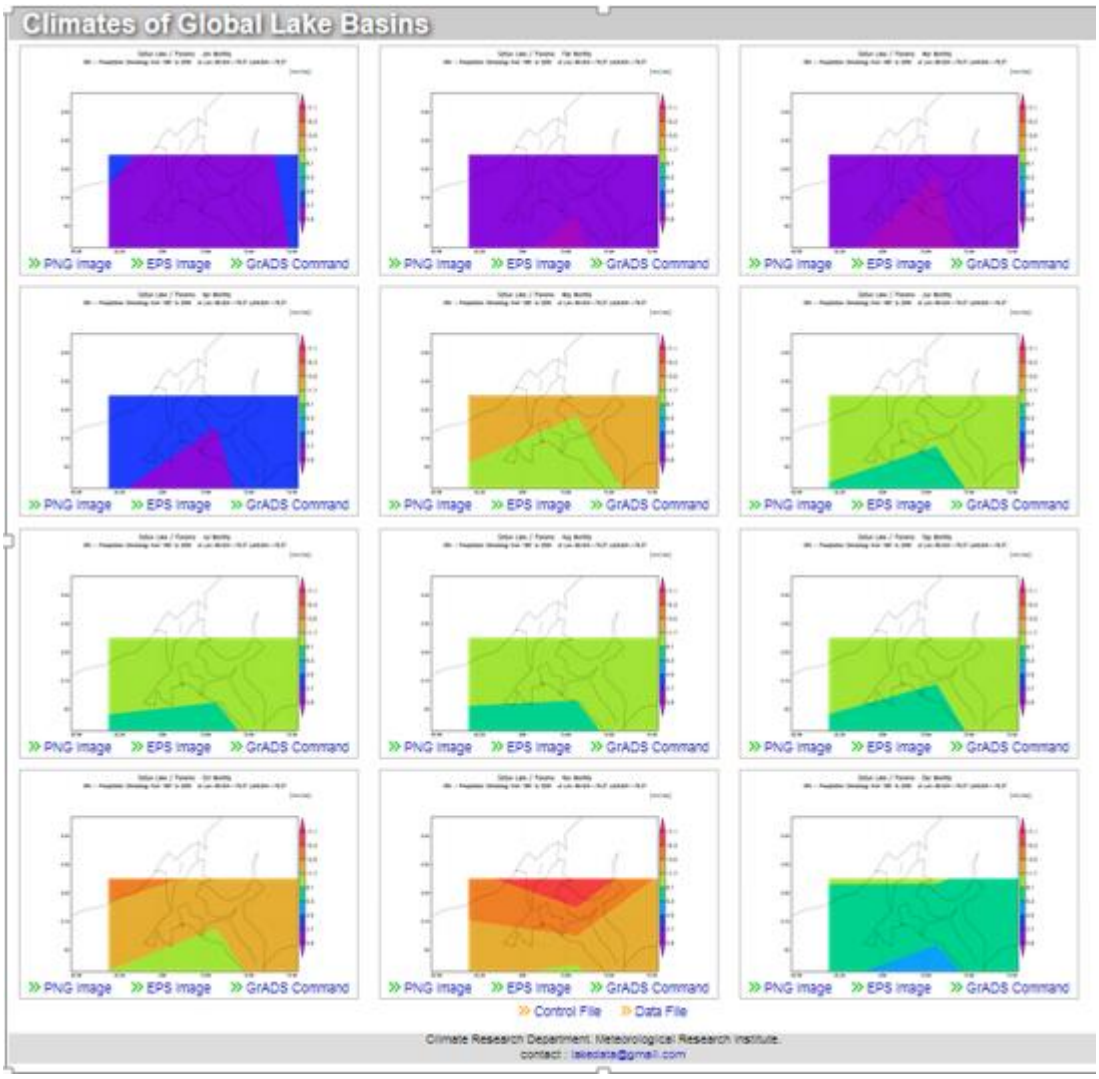


Figure 4. Climatological mean monthly precipitation around Lake Gatun for each month in two-dimensional form or geographical one. The area drawn in each panel is completely same area as in Fig.1. This figure is drawn interactively on CGLB. White area represents no data in CRU TS3.2.

4 CONCLUSIONS

We upgraded a web application of CGLB by introducing a new lake database, HydroLAKES with more than 1 million entry of lakes by combining existing datasets and interactively displays geographical, hydrological, and climatological information around the world. These functions are useful for education, expedition planning, and scientific research.

For an integrated lake basin managements, socio-economic information is also required. The information will be implemented in a next updates. Another upgrade may be an implementation of a numerical simulation together using the information in CGLB. Dialogue with the users may help us with considering further developments of CGLB.

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