Modeling the impacts of climate variability on three Colombian wetlands

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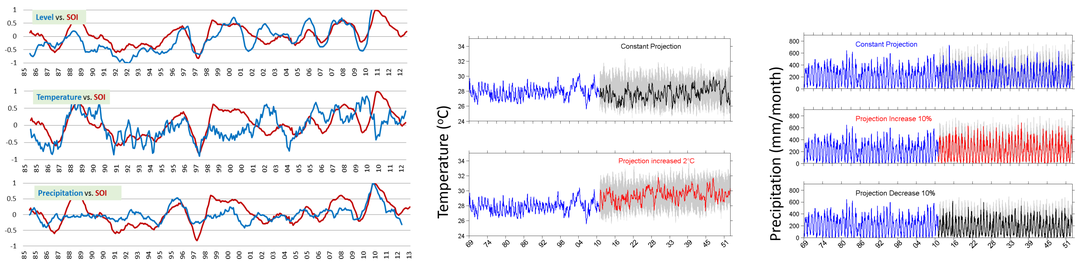
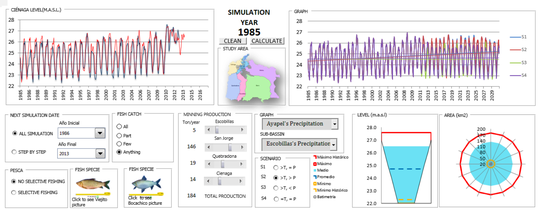
Abstract

Our project aims at understanding the recent past, present and future hydrology of three natural wetlands in Colombia: the mountain lakes Tota and La Cocha and the lowland cienaga of Ayapel. These wetlands represent a range of conditions, from the environmentally protected (La Cocha) to the highly intervened (Tota, Ayapel). For each site we developed hydrological models to represent monthly water balances, water quality conditions (i.e., concentration of nutrients) and factors of human intervention (i.e., irrigation, withdrawals for aqueducts and industries, fisheries, government regulations). Based on these models we projected several climate scenarios for rainfall and temperature, and modeled the effects of human activities to determine if the wetlands will be preserved until 2050. We also built and installed hydrological stations at each site with mixed degrees of success. We also designed a website that is continually updated with new information from the project. We received the support of local governmental institutions and NGOs at each site, and have shared the results with community members and stakeholders through in-site workshops and local conferences. This poster highlights some of the project's results and outcomes for each wetland.

Ayapel is part of a large complex of marshes and wetlands located on flat, floodable areas between the Cauca and San Jorge rivers. Under normal conditions, Ayapel experiences a rainfall-runoff driven pulse of low and high levels that determine the productivity of the system, associated with diverse ecosystems and socio-economic activities (fishing, livestock, rice agriculture and tourism). There is a growing concern about the future of Ayapel and its ecosystems, mainly due to the boom of gold mining with mercury and changes in the flooding regime due to engineering interventions (levees).



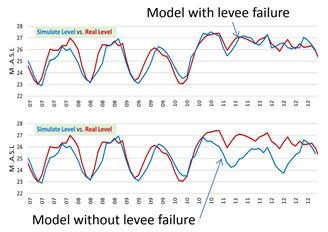
Ayapel levels and precipitation show a direct correlation with ENSO. Temperature also show positive correlation. P and T were projected to 2050 according to scenarios of higher temperature and higher and lower precipitation.



We are interested in modeling the behavior of Ayapel under different scenarios of climate and environmental change, involving the actors who affect or are affected by the changes in the flooding pulse. This is the model´s GUI that allows users to select scenarios and determine monthly stages in Ayapel. It also allows to determine the catch of endemic and migratory fish.

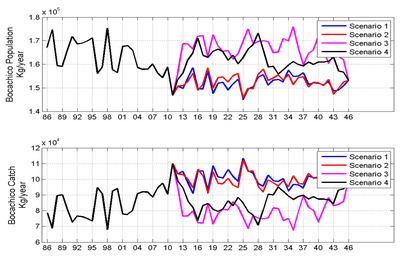
CorpoAyapel

In Ayapel we worked in close collaboration with the NGO CorpoAyapel, in whose facilities we have developed workshops with students and stakeholders, and installed the hydrometeorologic station.



In 2010 a levee failure in Cauca river flooded the cienaga, altering the natural pulse for several years. We used the model to estimate in around 100 m^3/s the amount of water diverted to the system from 2010 to 2013.

The model estimates the fish population growth with dynamic equations and the catches made monthly, based on the cienaga levels, for the projected period.



Tota is the largest Andean lake in Colombia with a history that dates back to indigenous populations and continues today with communities that depend on the lake for their economic development in agriculture (welsh onion), tourism, livestock and fish farming activities.

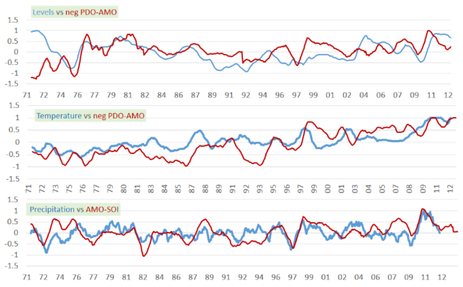

Bathymetry of Tota

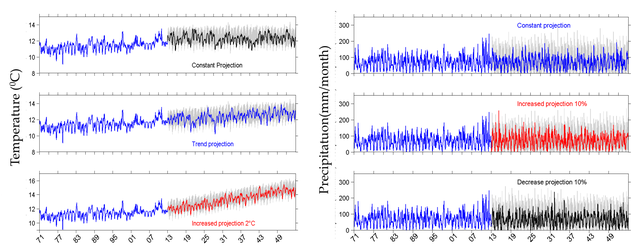

Cattle raising


Trout fisheries

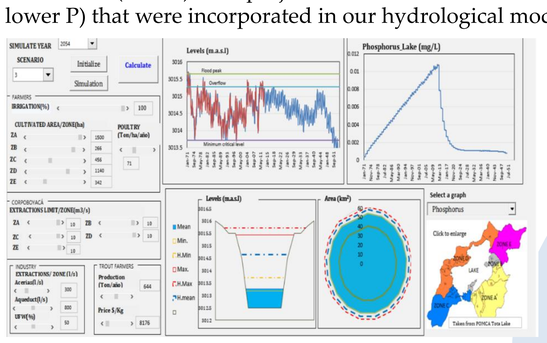

Onion farming

In Tota, we installed a hydrological station and participated in several workshops with students and stakeholders. Our activities receive support from Corpoboyacá (the Government Environmental Protection Agency) and the NGO Montecito.



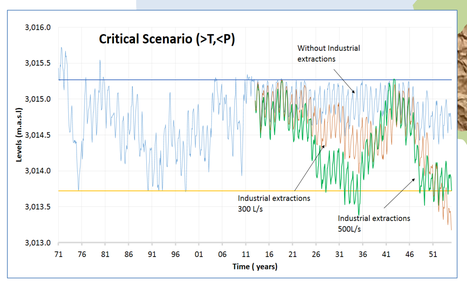


We found that Precipitation (P), temperature (T) and water levels in Tota are related to global climate indices such as the Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO) and El Niño Southern Oscillation (ENSO). We projected P and T until 2050 for different climate scenarios (higher T and higher and lower P) that were incorporated in our hydrological model.

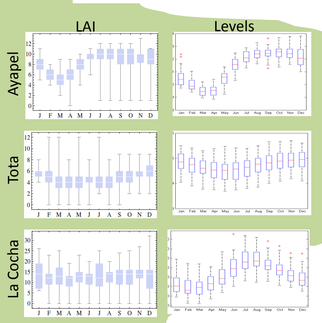


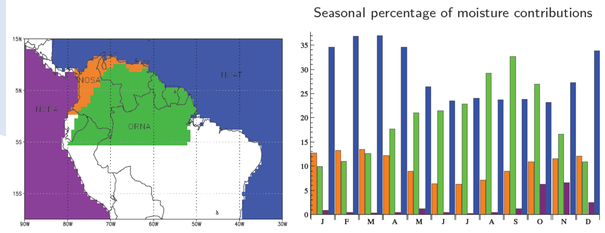
Tota waters are diverted by multiple aqueducts, irrigation districts and industries. Our model incorporates the effect of different stakeholders in the monthly water balance, estimating nutrient loads of phosphorus and the associated growth of *Egeria Densa* (the green circle in the area plot) in the lake.

Lake levels are highly influenced by transfer withdrawals. In the critical scenario (high T and low P), sustained extractions of 0.5 m^3/s may cause levels to drop down significantly. Although irrigation would not have such an impact on levels, it would affect water quality by incorporation of phosphorus and nitrogen, fostering the growth of *Egeria densa* in the lake and leading to eutrophication.



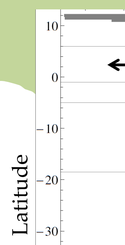
The monthly Leaf Area Index over the wetlands reveals some similarities with the monthly variation of water levels, particularly in Ayapel and Tota.



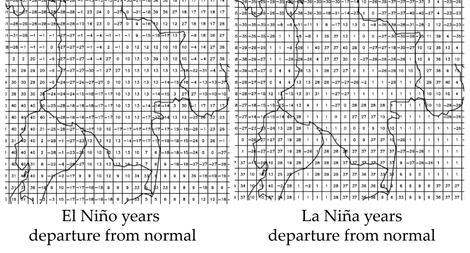


Going from global to local

Together with the US partner, we tracked the origin of moisture fluxes over the Andean region in Colombia, finding that most of the water comes from the Atlantic with important contributions from the Amazon and Orinoco basins and from recycled precipitation of the Andes themselves. Contributions from the Pacific Ocean were less significant.



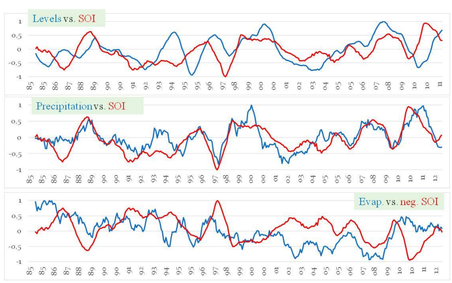
The Andes "wall" largely controls circulation patterns and moisture transport processes in South America. From ERA-Interim reanalysis we have found that certain low altitude locations along the Andes play an important role in horizontal moisture transport. The vertically integrated vapor flux (VIVF) in the portion of the Andes above 500 m, for instance, show some orographic passageways in the northern Andes (over 10 S), strengthening the west regime in the northern Pacific Basin. The opposite effect occurs towards 36 S with zonal vapor transport occurring to the east due to the westerlies.

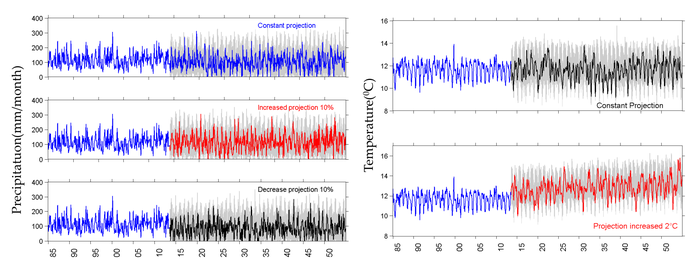

El Niño years departure from normal

La Niña years departure from normal

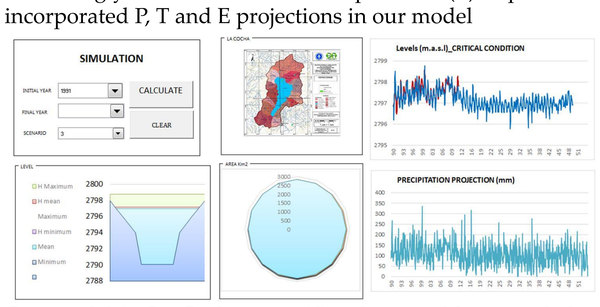
The country experiences different responses to El Niño and la Niña years. We have determined how these differences occur at the local level as departures from normal conditions (positive or negative) in a grid.

La Cocha is the second largest natural mountain lake in Colombia. It is considered a sanctuary for migratory birds and it is protected by the Ramsar convention. Tourism, agriculture and fish farming are controlled activities within the basin. La Cocha represents a baseline to understand the effects of climate variability in a low-intervened human environment, allowing its comparison with lakes like Tota.

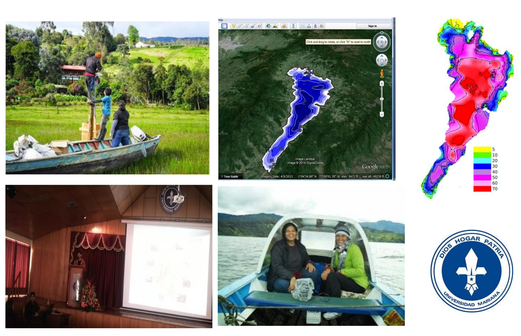




We are interested in understanding the correlation of La Cocha levels, precipitation and evaporation with ENSO and PDO indices and in projecting the lake levels under different climate change scenarios. Precipitation and lake levels are strongly related to ENSO. Evaporation (E) experienced, in turn, a decreasing trend in historical years. We incorporated P, T and E projections in our model



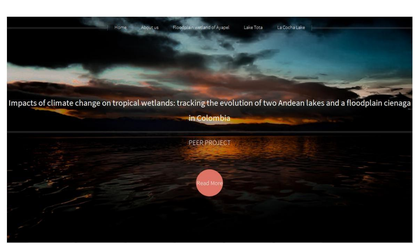
Our model in La Cocha quantifies the monthly water balance and the discharges to river streams within the basin and in the lake's outlet. Projected conditions in the most critical scenario indicates a likely decrease in the lake levels, although sustained in their seasonal variations.



We installed a hydrological station in the lake, made an initial bathymetry and presented partial results of our research in local conferences and workshops, with the support of Universidad Mariana (Pasto).

Final remark

Our PEER project has allowed us to model the three wetlands, incorporating their particularities and projecting their future conditions facing critical climate scenarios. We also improved our understanding of regional atmospheric dynamics in the country, tracking the origin of moisture sources over the studied sites. In the process, we received the support of local governmental and NGO organizations and shared the results with community members, students and stakeholders. We are in the last stage, planning the final workshops at each site and a documentary. We expect to publish the work in several research papers and will update the project website regularly.



For more information about the project, reports, data and outcomes, please visit our website: http://peerlagoscolombia.udea.edu.co/index.html

Acknowledgements

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