

Using climate change to predict Nile flow

In order to assess how climate change will impact the engineering design of the Merowe dam, one must first understand the greenhouse effect and its connection to global warming and the height of Nile floods. It is then necessary to predict Nile floods for the next one hundred years in order to have an understanding of the amount of electricity we expect the dam to produce in future years. This is done by looking at historical Nile flows and using general circulation models to assess effects of climate change. It is only then that we can begin to propose any beneficial changes to the dam design.

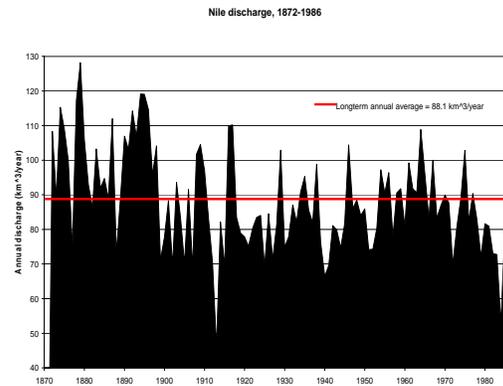
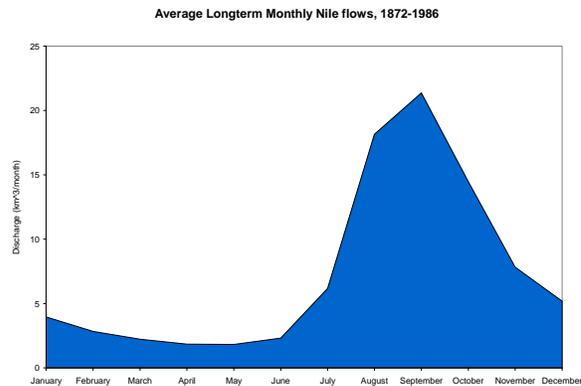
The Greenhouse Effect and Global Warming

As early as the 19th century, a Swedish scientist postulated that the combustion of fossil fuels may be an anthropogenic cause of climate change. The role of carbon dioxide, water vapor, and other “greenhouse” gases in the atmosphere’s heat retention capacity has come into sharper focus in recent decades (AIP 2004b). The theory that gases in the atmosphere cause a “greenhouse effect” that affects the planet’s temperature was all but confirmed in 1958 by a French-Soviet drilling team at Vostok Station in central Antarctica. In a two kilometer long ice core they found a 150,000-year record that contained a complete ice age cycle of warmth, cold and warmth. It showed that the level of atmospheric CO₂ had gone up and down in remarkably close step with temperature (AIP 2004). In an earlier experiment at Mauna Loa Observatory, a man named Keeling found that atmospheric concentrations of CO₂ were increasing linearly at 1 ppm/year. This led many to believe that the planet was undergoing “global warming.”

So what does this have to do with Nile flows? Historical records of Nile floods reveal a strong correlation between low Nile floods and cold summers in Europe, and conversely, high Nile floods and warm summers in Europe (Hassan 1998). Fluctuations in Nile flood levels coincide with climatic changes in the Sahel and even the flow of the Senegal River at the other end of Africa (Hassan 1998). Warmer temperatures increase evapotranspiration which in turn cause higher precipitation, leading to higher Nile floods. Climate change clearly influences the height of Nile floods.

Historical Nile flows

The long term annual average of Nile flows between 1872-1986 is about 88 km³/year. The floods typically occur between the months July-September. Below are graphical representations of the average monthly Nile flows and a record of annual Nile flows, both 1872-1986.



General Mean Circulation models

General circulation models (GCMs) are mathematical representations (i.e. computer simulations) of atmospheric and oceanic properties and processes that attempt to describe earth's climate system. Developed in 1960s, they have become the chief tools in analyzing effects of climate change (AIP 2004b). In the 1980s, a global body of climate scientists, the Intergovernmental Panel on Climate Change (IPCC), was formed to provide scientific advice to growing international political negotiations over how to respond to climatic change.

There are several different GCM scenarios in use, some of which are outlined in (Yates 1998b): UKMO (United Kingdom Meteorological Office), GISS (Goddard Institute for Space Studies, New York, NY), GFDL (Geophysical Fluid Dynamics Laboratory steady-state, Princeton, NJ), GFDLT (Geophysical Fluid Dynamics Laboratory transient, Princeton, NJ), MPI (Max Plank Institute, Hamburg, Germany), and CCC (Canadian Center for Climate, Victoria, Canada).

Literature review of predicted flows

There is a wide disparity in predictions of future Nile flow scenarios. Below are summaries of a few.

(Strzepek et al. 1995) finds changes in runoff from a hydrological model using GCM based climate change scenarios for doubled global atmospheric concentrations ($2\times\text{CO}_2$) provide widely diverging pictures of possible future Nile flows: GISS—a 30% increase; UKMO—a 12% decrease; and GFDL—a 78% decrease. These are postulated for the year 2060. (Conway and Hulme 1996) suggests currently anticipated changes in atmospheric concentrations of CO_2 by year 2025 would lead to air temperature increase of 1°C across Nile Basin, leading to increased evaporation loss and slight increase (2%) in rainfall in Blue Nile Basin and slightly larger increase (5%) over Equatorial Lakes region, spread fairly evenly through wet and dry seasons.

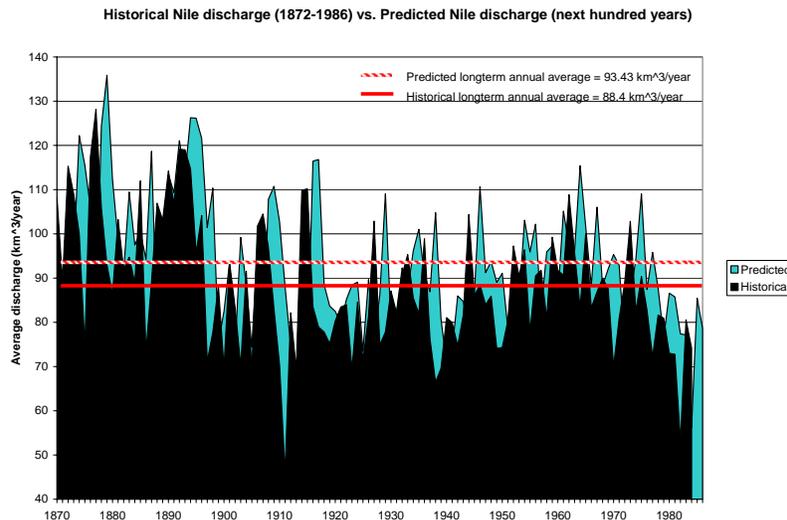
(Yates 1998a) found that Nile water resources declined under GFDL and increased for the GISSA and UKMO scenarios. (Yates 1998b) supports previous findings that changes in precipitation and to a lesser extent temperature over the Nile basin could have serious consequences on regional water resources throughout this large African basin. The $2\times\text{CO}_2$ GCM scenarios gave a wide range of changes both in total water yield

at Aswan and regional hydrologic changes throughout the basin. Five of six GCMs showed increased flows at Aswan, with increases as much as 137% (UKMO). Only one GCM (GFDLT) showed a decline in annual discharge at Aswan (-15%). Five of six GCMs predict increased precipitation in equatorial Africa. With some GCM scenarios predicting large increases in Nile discharge, there will be a need to increase flood protection, particularly in the Sudan.

(Johns 2003) uses the latest data from Special Report on Emission Scenarios (SRES) prepared for the IPCC Third Assessment Report, and finds that relative to 1900, simulated global warming spans a range of about 1.5 to 2.5 K at 2050 rising to 2.6 to 5.3 K in 2100. Global mean annual precipitation is enhanced in the warmer climate, with sensitivity around 1%/K that continues through the 21st century.

Best guess of river flow in Nile in next 100 years

The majority of past studies predict an increase in Nile flow in the next one hundred years. While the exact increase is difficult to predict, it is likely that the (Johns 2003) study is the most accurate, given that it uses the latest emissions scenarios data available from the IPCC. Thus, for the purposes of this project, I will assume that temperatures will warm approximately 5.3 K in the next one hundred years, while global mean annual precipitation will increase by 1% per K increase. While these values do not exactly correspond to the annual average changes in the temperature and precipitation variables for each of the GCM scenarios outlined in (Yates 1998), the one that perhaps best fits is the GFDL scenario, with an average temperature increase of 2.7 K and an average percent change in precipitation of 8.95%, which then corresponds to a 6% increase in the Nile flow measured at Aswan.



Discussion

I would like to continue my literature search of predicted Nile flows, and find a range of uncertainty for my own prediction. The next steps involve inputting the predicted Nile flow values into a reservoir simulation model in order to calculate how much electricity can be generated by the Merowe Dam in future years.

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