PHYSICAL AND POLITICAL IMPACTS

Complex river boundaries at risk

Many international river basins are suffering from climate-driven impacts, with implications for national security. Now, research highlights the need to analyse shifting river boundaries to better understand potential socio-political threats.

Shlomi Dinar

Annual and seasonal water variability is already affecting the flow of international river basins. Yet the effects of climate change are likely to intensify water variability beyond the bounds of previously observed runoff events[1]. Such physical effects may have socio-political consequences, especially in international river basins where states must share a river or lake. Writing in *WIREs Climate Change*, Grainger and Conway[2] suggest a research approach that contributes to a growing literature[3,4] examining how climatic change could potentially affect water relations among countries. Specifically, Grainger and Conway focus on those rivers that make up an entire international boundary, or portions of it, and how physical changes to these rivers (and consequently borders) in the context of floods and droughts affect the likelihood of conflict.

There are currently 276 international river basins across the world overlying 148 countries. Existing studies have demonstrated that many of these basins are already experiencing climate-driven changes in the form of high water variability, with additional basins likely to experience such high variability in the future. High variability is currently evidenced for river basins in transitional climate zones such as the outer tropics and subtropics. Africa, in particular, stands out as the continent with the largest exposure to very high variability — especially parts of the Nile, Niger, Lake Chad, Okavango and Zambezi[3]. In addition to sub-Saharan and North African basins, parts of the Euphrates–Tigris, Kura–Araks, the Colorado and Rio Grande are also predicted to experience very high variability and are therefore at risk of experiencing incidences of conflict and reduced cooperation in the future[3]. From a national security perspective, climate-induced events such as floods and droughts are expected to constitute a large threat to human security and the prospects of sustained peace[5]. In this context, climate change may further act as a 'threat multiplier', exacerbating existing economic, social and political problems[6].


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The Linyanti River forms the boundary between Botswana and Namibia.

Climate change and water variability may have socio-political impacts particularly when an institutional apparatus to deal with these changes is not in place[7]. International water treaties constitute an important institutional mechanism to deal with such changes. Although nearly 450 treaties have been signed since 1820, a number of international river basins are not governed by a treaty. Complicating the situation further is that although a treaty may govern a specific basin, the treaty does not include all concerned riparians. Furthermore, treaties that do govern an international river basin were not negotiated with the impacts and uncertainties of climate change in mind[8,9]. According to a recent report[10] from the United States intelligence community, "even well-prepared river basins are likely to be challenged by increased water demand and impacts from climate change, which probably will lead to greater variability in extreme events."

To that extent, Grainger and Conway's proposed research focus is well placed to encourage scientists and researchers to concentrate attention on the river boundary as a source of possible contention due to the effects of climatic change and water variability. To be fair, studies have long considered the impact of rivers along and across borders, assessing how the geographic configuration of the river may affect instances of conflict and cooperation or treaty design[11,12]. Yet, to date, no study has considered how climate change and water variability specifically affect river boundaries and how these changes impact conflict and cooperation, and the broader security implications. As the authors note, very large increases in stream flow (unless mitigated by management) are likely to alter channel patterns, whereas reductions could shift flow regimes. The approach proposed by Grainger and Conway, therefore, has the potential to contribute to an emerging literature by examining the effects of climate change on international rivers and specifically the impact of changing river boundaries on conflict and cooperation. The new approach can generate knowledge through case studies, as the researchers show in a very preliminary form in the context of Southern Africa. In their assessment, the authors consider those river boundaries where mean annual runoff projected to 2080 exceeds 20%. The physical factors are then juxtaposed with socio-political factors identifying tensions that have historically existed between the riparians. Although causal connections are not made, the authors provide a good starting point for further investigation. In addition to the case-study approach, an analysis of a large number of observations (that is, a large-*n* study) to test a series of hypotheses can also be undertaken. Border length as well as other physical and socio-political factors can be considered in a systematic fashion. Insights into which border areas are most at risk as well as which basins have proper institutional capacity to deal with water variability along river boundaries can then be gleaned and useful policy implications provided. ❐

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OCEANOGRAPHY

Where's the heat?

In recent decades, over nine-tenths of Earth's top-of-the-atmosphere energy imbalance has been stored in the ocean, which is rising as it warms. Combining satellite sea-level data with ocean mass data or model results allows insights into ocean warming.

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One could say that global warming is ocean warming. Quantifying how fast, and where, the ocean is warming is vital to understanding how much and how fast the atmosphere will warm, and seas will rise[1–4]. Historically, sparse and sometimes uncertain *in situ* ocean temperature data have made that quantification challenging[5]. Writing in *Nature Climate Change*, Paul Durack and colleagues[6] argue that previously published 0–700 m ocean warming rates based on *in situ* ocean temperature data are underestimated in the more sparsely sampled Southern Hemisphere, at least from 1970 until the advent of the Argo array of profiling floats[7] in the early 2000s. They reach this conclusion by analysing the *in situ* data together with satellite sea-level data and climate model results. Another study[8] published in *Nature Climate Change* concludes that the deeper half of the ocean (below 2 km depth) has, on average, not warmed from 2005 to 2013. William Llovel *et al.*[8] arrive at this result by combining satellite sea-level and ocean-mass-change data with unprecedentedly dense and high-quality Argo *in situ* temperature data from the upper half of the ocean volume (to depths of 2 km).

Changes in sea level and ocean temperature are closely linked by the fact that seawater expands as it warms. However, at least three factors complicate inferring one from the other directly. First, the transfer of water from land to ocean also contributes to sea-level rise, at a comparable magnitude to ocean warming[1]. This transfer has mostly been owing to melting of glaciers and ice sheets over recent decades. Second, the amount of sea-level rise depends on where the ocean warming occurs, because colder seawater can absorb several times more thermal energy than warmer water while contributing to the same amount of sea-level rise. Finally, regional redistributions of ocean salinity[9] and mass[10] also affect sea level.

Durack *et al.*[6] exploit the close relationship between upper-ocean warming and sea-level rise, the latter being well measured by satellites since 1992, to refine estimates of global ocean warming rates. They find good agreement between modelled and observed sea-level rise and poorer agreement between modelled and reported upper-ocean warming rates from 1970 to 2004, especially in the Southern Hemisphere. They argue that observational estimates of ocean warming rates in the Southern Hemisphere are likely biased low owing to the sparse historical temperature data there, and suggest that these estimates should be increased by 48–152% based on the ratio of observed sea-level rise and upper-ocean warming in the better-observed Northern Hemisphere.

Their results[6] are of importance because they imply an increase of 0.04–0.13 W m^{-2} in the global energy imbalance from 1970 to 2004, important for evaluating the performance of climate models. Also, quantifying how much of sea-level rise is owing to expansion of warming seawater versus transfer of water from land to ocean is important for understanding how much and how fast sea level will rise. However, as noted above, there are other, neglected, contributions to variations in sea level that could affect the results.

Llovel *et al.*[8] report that sea level has been rising at a global average rate of 2.78 mm yr^{-1} from 2005 to 2013 as estimated from satellite altimetry data. Over that period, ocean expansion from warming in the upper 2 km has accounted for 0.9 mm yr^{-1} of that rise, according to *in situ* ocean measurements, and transfer of freshwater into the ocean 2.0 mm yr^{-1}, according to satellite measurements of Earth's changing