cycle — thereby avoiding the effects of solar radiation variability — they consider this trend proportional to the long-term trend in thermospheric carbon dioxide levels. This inferred thermospheric trend in CO_x exceeds that predicted by an upper atmospheric model by around 10 ppm per decade.

Emmert *et al.* suggest that this model–measurement discrepancy could result from an increase in vertical mixing and advective transport between the thermosphere and underlying atmosphere — which contains more carbon dioxide — due to a change in atmospheric dynamics. Indeed, they show that temporal trends in CO_x and CO_2 can be reproduced in a global mean climate model when eddy diffusion — a surrogate for vertical mixing and transport — grows by 15% per decade. What's more, the low thermospheric mass densities previously inferred from satellite drag data[3] can also be accounted for by an increase in eddy diffusion, which would lead to further cooling and contraction of the thermosphere.

Emmert and co-authors[1] present a dataset from a little-measured layer of the Earth's atmosphere that provides a glimpse into the impact of anthropogenic carbon dioxide emissions on the upper reaches of the atmosphere. The reported discrepancy between observations and model simulations indicates that our knowledge of this part of the atmosphere is far from complete. Although the study covers just a short period in time, the ACE-FTS instrument is still operational, so there is a good chance that this unique carbon monoxide and carbon dioxide dataset can be extended in the future. With continuing measurements, our understanding of thermospheric trends in the context of climate change is set to improve. ❒

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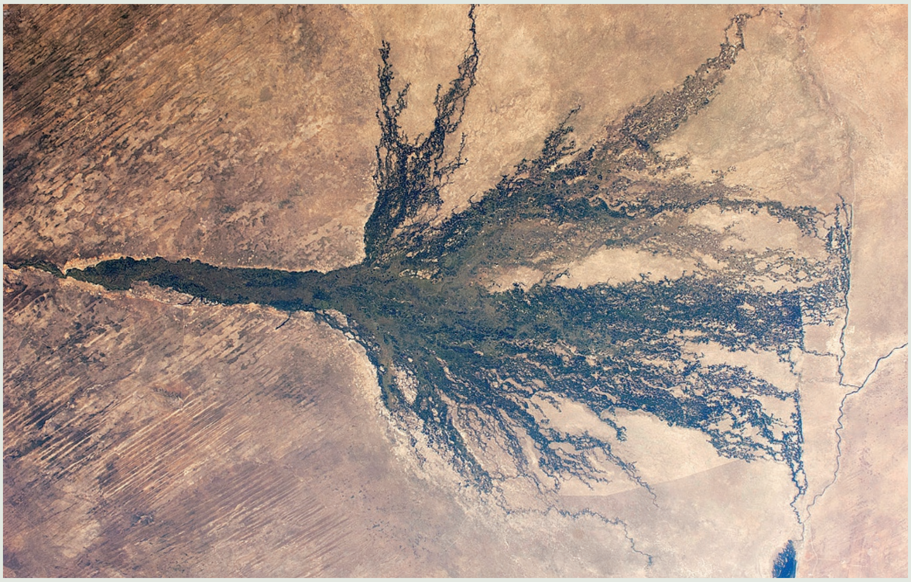
HYDROLOGY

Complex water future

Southwest Africa's Okavango River does not flow into the ocean. Instead, it ends in a swamp in the Kalahari Desert. The vast majority of the water evaporates in the flat delta region at the mouth of the river that supports one of the richest concentrations of wildlife in Africa. Botswana's Moremi Game Reserve located at the eastern flank of the delta is a prime destination for eco-tourism in the region.

The Okavango River drains an area of over 140,000 km^2, including the uplands of central Angola. Here, ample precipitation falls in the Southern Hemisphere summer months, and then flows towards the delta and fan. The Okavango River is thus subject to large seasonal variations in flow. Water level and extent in the delta region ebbs and floods accordingly. In addition to the seasonal cycle, river flow variations on longer timescales of 60 to 80 years have also been documented.



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Using statistical analyses and hydrological modelling, Piotr Wolski and colleagues find that these multidecadal swings between wet and dry phases mainly stem from variations in rainfall, with little influence from temperature-driven evaporation (*J. Hydrol.* http://doi.org/jrx; 2012). They attribute these rainfall variations to internal feedback mechanisms between the ocean, atmosphere and land, as opposed to external influences, for example from humans or solar variability. According to climate model projections, these multidecadal oscillations are likely to continue at similar amplitudes throughout the twenty-first century. At the same time, conditions are expected to become progressively drier in the long term, as a result of higher temperatures and thus evaporation. The multidecadal swings are therefore likely to alternatingly intensify and offset the long-term anthropogenic drying trend.

Water management strategies often assume a stationary basic state, with the implication that departures from this mean state — often on a five-year planning horizon — need to be countered. Wolski and colleagues suggest that a river basin naturally exposed to significant multidecadal oscillations is not well managed by these traditional assumptions. As an example, the water supply infrastructure of the Botswana town of Maun was redesigned in response to dry conditions in the 1990s when precipitation was low — only to be overwhelmed by floods in 2008 to 2010 when the basin returned to a wetter phase.

To keep residents, wildlife and tourists in the Okavango Delta healthy and watered, managers will need to design and build an infrastructure for the supply of drinking water that can cope with frequent swings between a wealth and a dearth of rain and river flow.

HEIKE LANGENBERG