Mesoscale Rainfall Patterns Observed Around Wetlands in Sub-Saharan Africa

Christopher Taylor [1,2] Simon Dadson [3,1] and Catherine Prigent [4]

[1] Centre for Ecology & Hydrology, Wallingford, UK. [2] National Centre for Earth Observation, UK. [3] University of Oxford, UK.

[4] LERMA, Observatoire de Paris, France. Corresponding author email: cmt@ceh.ac.uk

Centre for Ecology & Hydrology

NATURAL ENVIRONMENT RESEARCH COUNCIL

Background

Wetlands are an important component of the landscape in low-lying tropical regions. Many tropical wetlands exhibit strong seasonal and interannual variations in extent, in response to rain which may have fallen in previous seasons, many hundreds of kilometres upstream. The timing and extent of wetland flooding is also sensitive to upstream water management. Compared to their surroundings, wetlands provide strongly contrasting fluxes of sensible and latent heat into the atmosphere. Previous analysis from the Niger Inland Delta in Mali (Taylor 2010) demonstrated how that wetland affects convective rainfall locally and regionally.

Here we use a range of observational datasets to answer the following questions:

1. Do all major African wetlands affect local rainfall?
2. Where and when is rainfall affected in the proximity of a wetland?
3. How are storms affected by wetlands?
4. Do interannual variations in wetland extent affect rainfall patterns?

Wetland dataset (GIEMS; Prigent et al 2012):
Monthly for 1993-2007 using data from multiple satellites (passive microwave, scatterometer, visible and near infra-red), 0.25x0.25deg

Rainfall dataset (CMORPH v1.0: Joyce et al 2004):
3-hourly from 1998-present using multiple satellites (passive microwave, thermal infra-red), 0.25x0.25deg

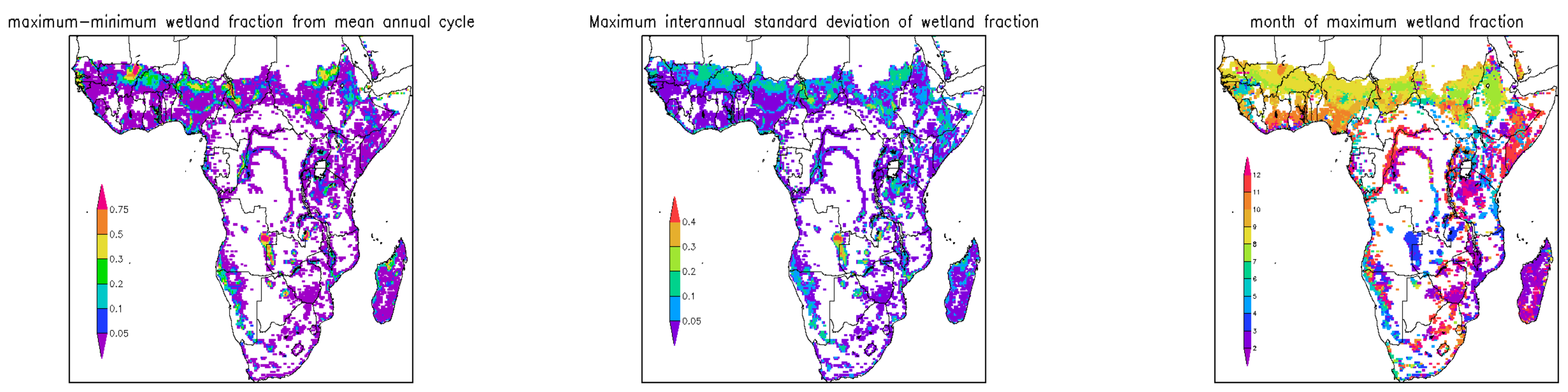


Figure 1 Wetland variability. Left: Mean seasonal maximum minus minimum wetland fraction. Centre: Interannual variability. Right: Month of maximum extent.

3. How are storms affected by wetlands?

Areas of contiguous cold (-40C, -60C) cloud are identified from Meteosat thermal infra-red channel (June to September, 1982-2005). **In the afternoon, areas around wetlands are favoured locations for triggering of new mesoscale convective systems (MCS).** This pattern indicates that convergence zones created by *wetland breezes* play a key role; new rain events are NOT triggered in the most humid air i.e. over and downwind (to the NW in this case) of the wetland.

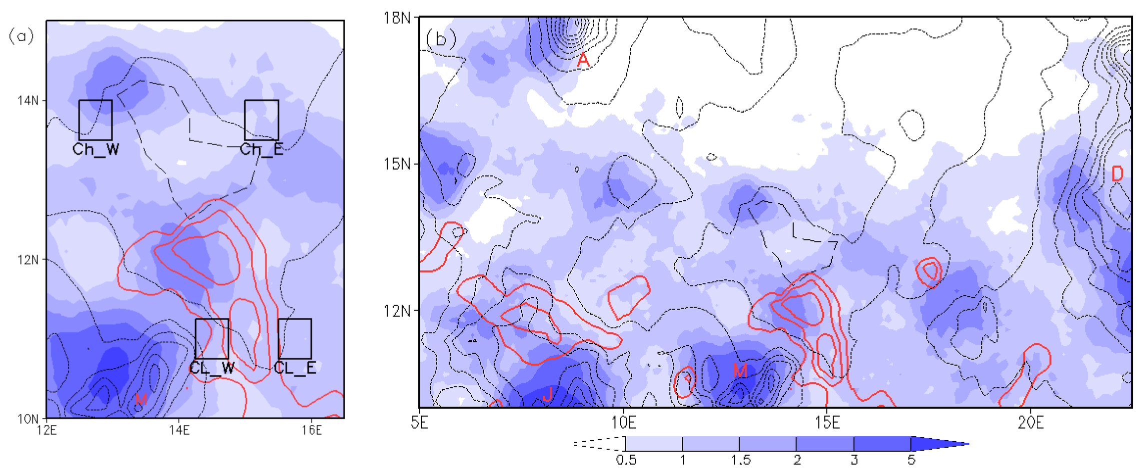


Figure 4 Left: Frequency of MCS observed in the region of the Chari/Logrone wetlands and Lake Chad at 16UTC (shading). Solid red contours denote maximum wetland extent. Note that the permanent water and seasonal wetland area of Lake Chad is not included in the GIEMS dataset. Topographic height contours every 100m shown by short-dashed lines Right: Same variables plotted over a region ~2000 x 900 km^2.The Lake Chad wetlands provide an important trigger for MCS in the Sahel region (~12-18°N), alongside strong topographic forcing (e.g. the mountains of Air "A" and Darfur "D").

Around 80% of Sahelian rain is produced by mature MCS, which travel westwards, typically 100s km. In this case, MCS arriving at the wetland tend to dissipate (consistent with the modelling study of Lauwaet et al 2012) whilst MCS initiated on the western side of the lake often bring rain to regions well to the west. This interaction illustrates how **wetlands can influence regional as well as local rainfall**.

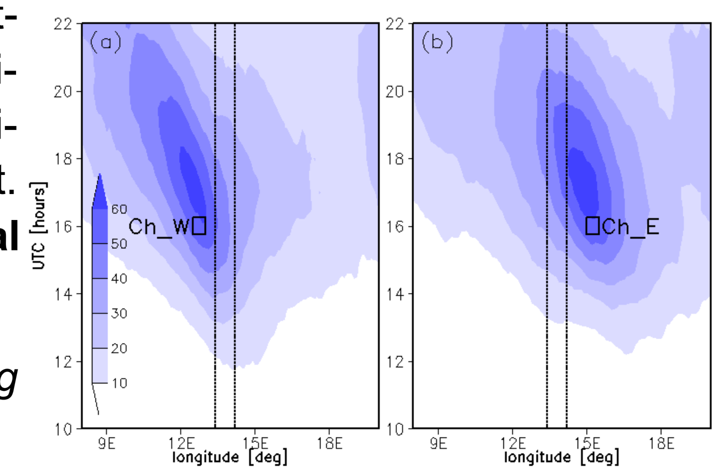


Figure 5 Frequency of cold cloud (-60C; %) from Meteosat based on compositing of mature MCS to the west (left) and east (right) of Lake Chad.

Conclusions

1. Wetland effect on local rainfall evident across all seasons and regions of Africa.
2. Afternoon rain favoured in regions around wetland.
3. New storms tend to be triggered around wetlands, consistent with wetland breeze effect. Evidence that propagating MCS weaken over extensive wetland.
4. Interannual variations in wetland extent can feed back on local rainfall patterns.

This study is **published online in the Quarterly Journal of the Royal Meteorological Society** (doi:10.1002/qj.3311), and was funded by the NERC grant NE/K002309/1 Changing Land-Atmosphere Feedbacks in Tropical African Wetlands.

1. Do all major African wetlands affect local rainfall?

Approach: for every 0.25deg cell in Africa and every month of the year, compute local (5x5 cells) spatial correlation of wetland fraction and climatological mean rainfall for given time of day. Exclude areas of strong topography or coastal zone. Also exclude dry season months where CMORPH unreliable (see also Tian et al 2007).

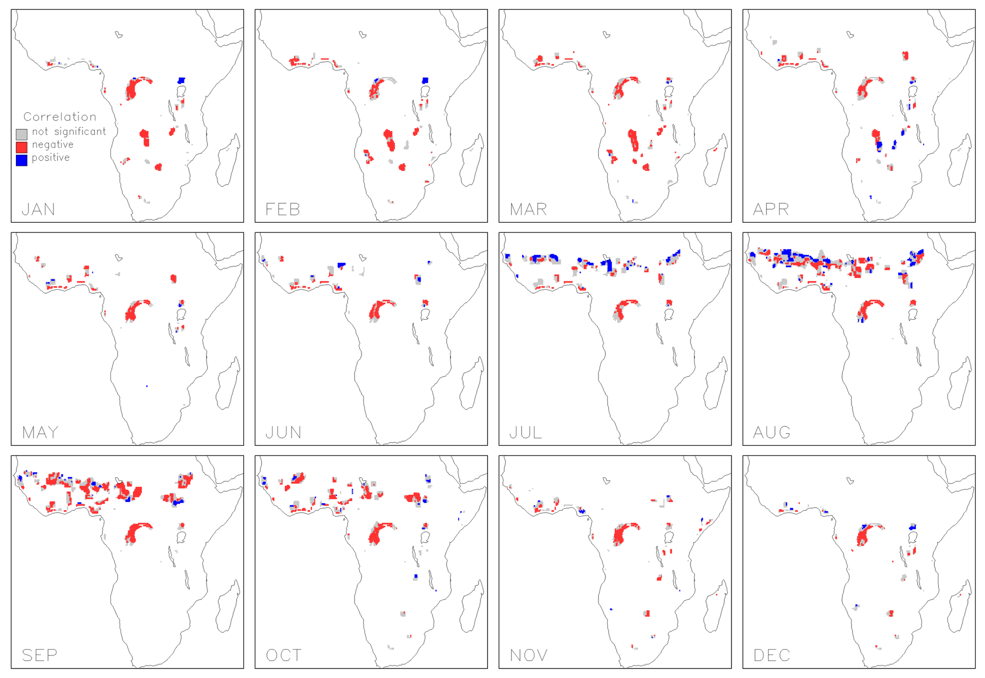
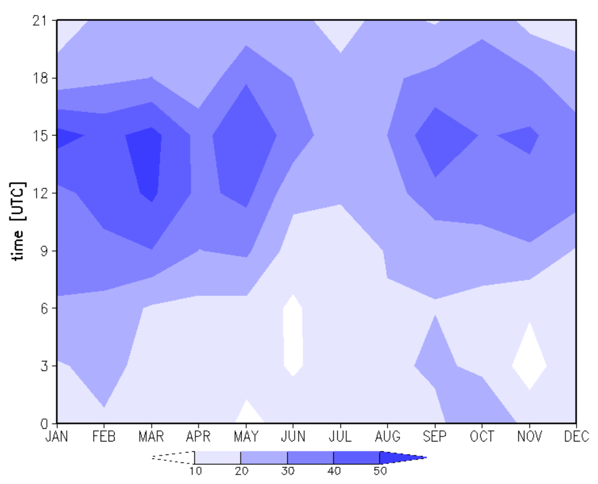


Figure 2 Spatial correlations between wetland extent and 12-15UTC rainfall. Red (blue) shading: negative (positive) correlation significant at the 95% level. Grey shading: no significant correlation. White: no local wetland or masked out due to presence of strong topography

Rainfall patterns (12-15UTC) around all major wetlands exhibit significant correlations with wetland extent. These are predominantly negative, consistent with previous analysis of (non-wetland) soil moisture anomalies (Taylor et al 2012).

2. Where and when is rainfall affected in the proximity of a wetland?



Repeat correlation analysis shown in Figure 2 for all times of day. Signal of **more rain over areas surrounding wetland strongest in late afternoon and evident throughout the year at continental scale.**

Figure 3 Percentage of pixels with significant negative correlations between wetland extent and 3-hourly rainfall as a function of time of day and month of year. Data summed across all wetland regions in Africa. Note that under null hypothesis where local rainfall pattern not correlated with wetland, the expected value is 5%.

4. Do interannual variations in wetland extent influence rainfall patterns?

The impact of interannual variations in wetland extent on rainfall patterns is illustrated for the highly variable Barotse region on the Zambesi river. A very extensive wetland developed during February 2004, in contrast to the very dry conditions 1 year later. Rain is generally higher across the region in March-April 2004 compared to 2005. However over the wetland itself, afternoon rain in 2004 is suppressed, in contrast to increases in its immediate surroundings, and the two patterns are clearly correlated in the region of the wetland. This illustrates that **interannual variability in wetland extent can substantially affect local rainfall patterns.**

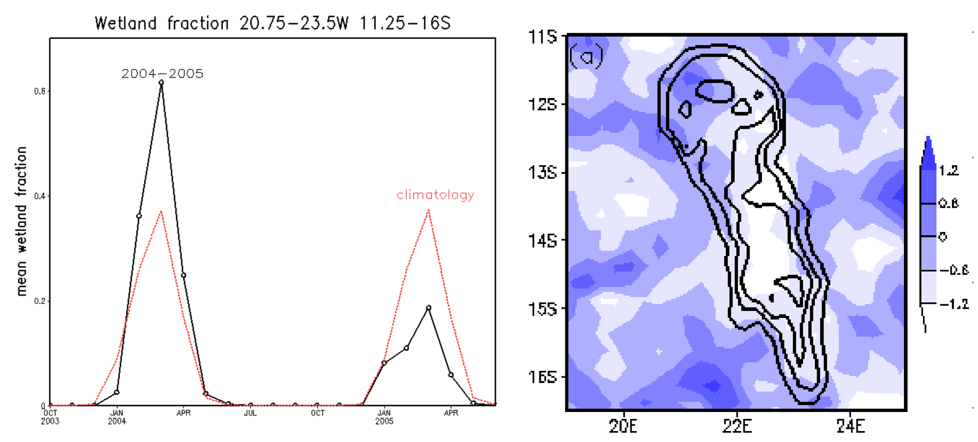


Figure 5 Left: Time-series of Barotse wetland extent during 2004-5 (black). The climatological seasonal cycle is shown in red. Right: Difference in afternoon rain (mm/day; shading) and wetland extent (contours) between March-April 2004 and March-April 2005.

References

Joyce, R. J., J. E. Janowiak, P. A. Arkin, and P. Xie (2004), CMORPH: A Method that Produces Global Precipitation Estimates from Passive Microwave and Infrared Data at High Spatial and Temporal Resolution, *J. Hydromet.*, *5*(3), 487-503.

Lauwaet, D., et al. (2012). "The precipitation response to the desiccation of Lake Chad." Quarterly Journal Of The Royal Meteorological Society **138**(664): 707-719.

Prigent, C., F. Papa, F. Aires, C. Jimenez, W. B. Rossow, and E. Matthews (2012), Changes in land surface water dynamics since the 1990s and relation to population pressure, Geophys. Res. Lett., 39, L08403.

Taylor, C. M. (2010), Feedbacks on convection from an African wetland, Geophys. Res. Lett., 37, L05406.

Taylor, C. M., R. A. M. de Jeu, F. Guichard, P. P. Harris, and W. A. Dorigo (2012), Afternoon rain more likely over drier soils, Nature, 489(7416), 423-426.

Tian, Y., and C. D. Peters-Lidard (2007), Systematic anomalies over inland water bodies in satellite-based precipitation estimates, Geophys. Res. Lett., 34(14), L14403.