Hazardous thunderstorms over Lake Victoria under present and future climate conditions

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Motivation and objectives

Extreme precipitation over Lake Victoria

(Severe-wx.pbworks.com)
Motivation and objectives

clear lake imprint on thunderstorm occurrence
Motivation and objectives

Lethal weather on 'world's most dangerous lake'
From Errol Barnett, CNN
January 17, 2013 — Updated 1448 GMT (2248 HKT)

(Lake Kivu)

model skill? future climate change?
CCLM² model setup

CCLM 0.44°
CORDEX Africa

CCLM² 0.0625°

COSMO-CLM 4.8
(CORDEX-Africa set-up)

CLM 3.5
FLake

(Davin and Seneviratne, 2012)

“RCM4-CU” (1999-2008)

Extreme precipitation over Lake Victoria
How well does our model perform?
Evaluation: lake surface temperature

(Smiery et al., 2014 GMD; 2014 TA; 2015 JC)
Evaluation: Precipitation

Extreme precipitation over Lake Victoria
What happens to precipitation over Lake Victoria under global warming?
Extreme precipitation over Lake Victoria

**Climate change**

- **T$_{2m}$**
  - **Domain:** $+4.16^\circ\text{C}$
  - **AGL:** $+3.74^\circ\text{C}$
  - **IPCC:** $+4.0^\circ\text{C}$ ($+2.4^\circ\text{C} - +5.6^\circ\text{C}$)

- **Precipitation**
  - **Domain:** $-7.95\%$
  - **AGL:** $-7.46\%$
  - **IPCC:** $+11\%$ ($-11\% - +34\%$)
Extreme precipitation over Lake Victoria

Climate change impact on extremes
climate change: extreme precipitation

Why? ➔ First understand extremes in present-day climate
Role of soil moisture for afternoon land rainfall.

- Positive temporal coupling might enhance precipitation persistence, while negative spatial coupling tends to regionally homogenize land surface conditions.

(Guillod et al., 2015 Nat. Comm.)
Afternoon controls on nighttime thunderstorms

CC: +27% MFC entirely due to enhanced moisture content

PD: +200% MFC during extremes, ¾ due to mesoscale dynamics

Changing with CC?
Towards an early warning system

Log. Reg.: “tonight there will be an extreme event” (X% threshold prob.)

Issue warning

Forecast 67% of all events

15% of warnings is a false alarm
Thank you for your attention

Acknowledgements: FWO, BELSPO

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Conclusions

• Extremes and climate change
  
  – using a high-resolution RCM simulation we project an average precipitation decrease over the AGL

  – despite the average precipitation decrease, LV extremes will become more intense under global warming

  – this result is robust and more pronounced compared to surrounding land

  – Afternoon land precipitation controls nighttime lake precipitation by moistening and cooling the land

  – Clausius-Clapeyron scaling only holds over LV where future evaporation increase ensures moisture availability
Extreme precipitation over Lake Victoria

Although $T_{bot}$ is extremely sensitive to extpar and forcing, $T_{surf}$ predictions are robust (Thiery et al., GMD 2014)
Although $T_{\text{bot}}$ is extremely sensitive to extpar and forcing, $T_{\text{surf}}$ predictions are robust.
Evaluation: SEB and clouds

SW_{\text{net}}  LW_{\text{net}}  LHF  SHF  CCF

Obs

CTL

Extreme precipitation over Lake Victoria
### Evaluation: relative skill

<table>
<thead>
<tr>
<th>Physical quantity (units)</th>
<th>COSMO-CLM(^2)</th>
<th>ERA-Interim</th>
<th>CORDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias</td>
<td>RMSE</td>
<td>Bias</td>
</tr>
<tr>
<td>TRMM 3B42 precipitation (mm yr(^{-1}))</td>
<td>-261</td>
<td>683</td>
<td>612</td>
</tr>
<tr>
<td>GPCC precipitation (mm yr(^{-1}))</td>
<td>68</td>
<td>631</td>
<td>941</td>
</tr>
<tr>
<td>GPCP precipitation (mm yr(^{-1}))</td>
<td>30</td>
<td>554</td>
<td>903</td>
</tr>
<tr>
<td>UDEL precipitation (mm yr(^{-1}))</td>
<td>84</td>
<td>604</td>
<td>957</td>
</tr>
<tr>
<td>CMORPH precipitation (mm yr(^{-1}))</td>
<td>-330</td>
<td>712</td>
<td>739</td>
</tr>
<tr>
<td>TRMM 2B31 precipitation (mm yr(^{-1}))</td>
<td>-273</td>
<td>678</td>
<td>599</td>
</tr>
<tr>
<td><strong>Ensemble precipitation</strong> (mm yr(^{-1}))</td>
<td>-116</td>
<td>554</td>
<td>757</td>
</tr>
<tr>
<td>GEWEX-SRB SW(_{net}) (W m(^{-2}))</td>
<td>-12</td>
<td>22</td>
<td>39</td>
</tr>
<tr>
<td>GEWEX-SRB LW(_{net}) (W m(^{-2}))</td>
<td>-5</td>
<td>8</td>
<td>-21</td>
</tr>
<tr>
<td>LandFlux-EVAL LHF (W m(^{-2}))</td>
<td>-22</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>FLUXNET-MTE SHF (W m(^{-2}))</td>
<td>10</td>
<td>22</td>
<td>-2</td>
</tr>
<tr>
<td>ISCCP CCF (%)</td>
<td>4</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td><strong>ARC-Lake LSWT Victoria (K)</strong></td>
<td>0.40</td>
<td>0.53</td>
<td>-4.16**</td>
</tr>
<tr>
<td><strong>ARC-Lake LSWT Tanganyika (K)</strong></td>
<td>1.09</td>
<td>1.16</td>
<td>-7.58**</td>
</tr>
<tr>
<td><strong>ARC-Lake LSWT Albert (K)</strong></td>
<td>0.90</td>
<td>0.94</td>
<td>—</td>
</tr>
<tr>
<td><strong>ARC-Lake LSWT Kivu (K)</strong></td>
<td>1.80</td>
<td>1.83</td>
<td>—</td>
</tr>
</tbody>
</table>

* Average of the six gridded precipitation products.
** Given the coarse resolution of this product and associated limited number of lake pixels, nearest neighbour interpolation was used in this case instead of bilinear interpolation.
AGL impact on the mean climate

Extreme precipitation over Lake Victoria

Wim Thiery – 05/09/2015, Oslo
SEB decomposition: day-night contrast

(source: NASA)

(source: Stanford U.)

(source: SignTech)

Extreme precipitation over Lake Victoria
Cross section

Extreme precipitation over Lake Victoria
Dynamical response: daytime

Wim Thiery – 05/09/2015, Oslo

Extreme precipitation over Lake Victoria
Dynamical response: night-time

 CTL

 CTL - NOL

 Extreme precipitation over Lake Victoria
Change in convective mass flux density at cloud base height

![Change in convective mass flux density at cloud base height](image)
Future mixed layer warming by far exceeds seasonal variability. This has massive implications for ecosystem functioning.
TRMM average precipitation

Extreme precipitation over Lake Victoria
Climate of East Africa

Extreme precipitation over Lake Victoria
Comparing skill of different configurations

 Extreme precipitation over Lake Victoria
LakeMIP T05, T30, T60

Extreme precipitation over Lake Victoria
LakeMIP BSS and Taylor

Extreme precipitation over Lake Victoria
LakeMIP understanding

Extreme precipitation over Lake Victoria
LakeMIP space versus time
Evaluation: precipitation

Extreme precipitation over Lake Victoria
Evaluation: precipitation

The diagram shows the evaluation of precipitation over Lake Victoria using COSMO-CLM 4.8 and FLakeCLM 3.5. The graph compares various datasets, including CTL, TRMM 3B42, GPCC, GPCP, UDEL, CMORPH, and TRMM 2B31. The x-axis represents the months of the year, while the y-axis indicates precipitation in millimeters per month. The data is divided into two phases: long rains and short rains.
Evaluation: precipitation

Extreme precipitation over Lake Victoria
Evaluation: lake temperature

COSMO-CLM 4.8
CLM 3.5 FLake

Extreme precipitation over Lake Victoria
Impact: seasonal and diurnal

Extreme precipitation over Lake Victoria
SEB decomposition

\[
\delta T_s = \frac{1}{4e}\sigma T_s^3 \left( -SW_{in}\delta \alpha + (1 - \alpha)\delta SW_{in} + \delta LW_{in} - \delta LHF - \delta SHF - \delta G - \sigma T_s^4 \epsilon \right)
\]

**All pixels**

- Energy Balance
  - SW\text{net}, LW\text{net}, LHF, SHF, G

**Lake pixels**

- Energy Balance
  - SW\text{net}, LW\text{net}, LHF, SHF, G

Extreme precipitation over Lake Victoria
SEB decomposition: Lake Kivu versus other lakes

Lake pixels

Lake Kivu

![Graphs showing contribution to δT_s for Lake Kivu and Lake pixels](image-url)
Evaluation: survival plots

Extreme precipitation over Lake Victoria
Evaluation: extreme precipitation over Lake Victoria

COSMO-CLM 4.8
CLM 3.5
FLake

00-06 UTC
06-12 UTC
12-18 UTC
18-00 UTC

obs
cosmo-clm
era-interim

P [mm 6h⁻¹]
0 5 10 15 20 25 30 35 40 45

Wim Thiery – 05/09/2015, Oslo

Extreme precipitation over Lake Victoria
CORDEX ensemble: evidence for over-lake precipitation decrease

Absolute difference (mm/day)

Relative difference (%)

(Courtesy: Niels Souverijns)
CORDEX ensemble: “CCLM² projections are robust”
Sensitivity to scenario and percentile choice

Scaling over the lake twice as strong compared to land for P99.9 under RCP8.5
"Lake breeze strength"
FLake: improved stratification

- Mendota: $\beta = 0.35 \text{ s}^{-1}$
- Kinneret: $\beta = 0.33 \text{ s}^{-1}$
- Arend: $\beta = 0.37 \text{ s}^{-1}$
- Kivu: $\beta = 0.37 \text{ s}^{-1}$
- Stechlin: $\beta = 0.44 \text{ s}^{-1}$