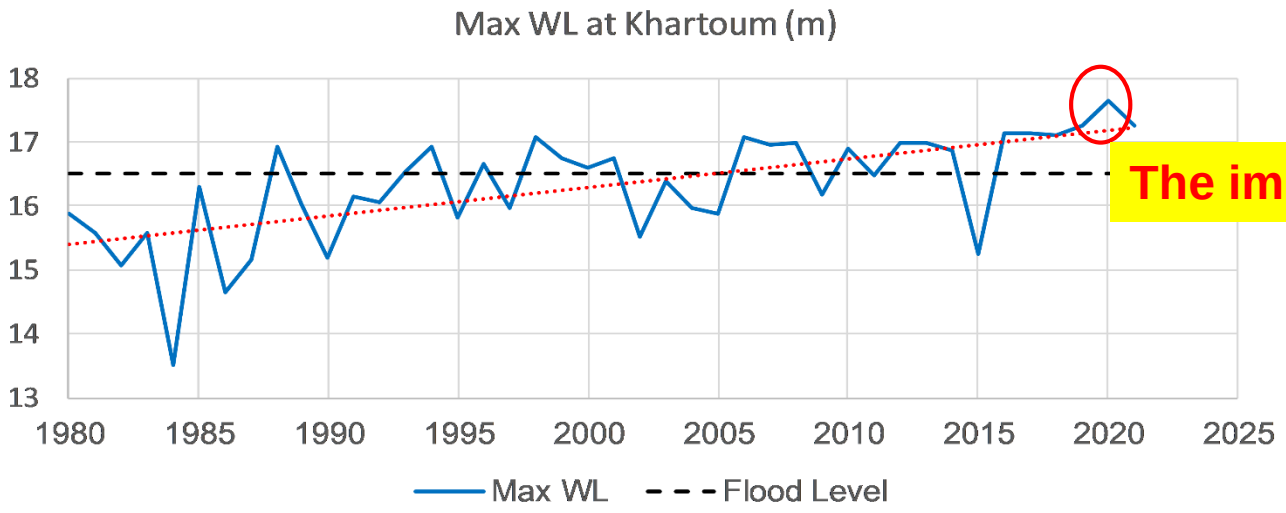
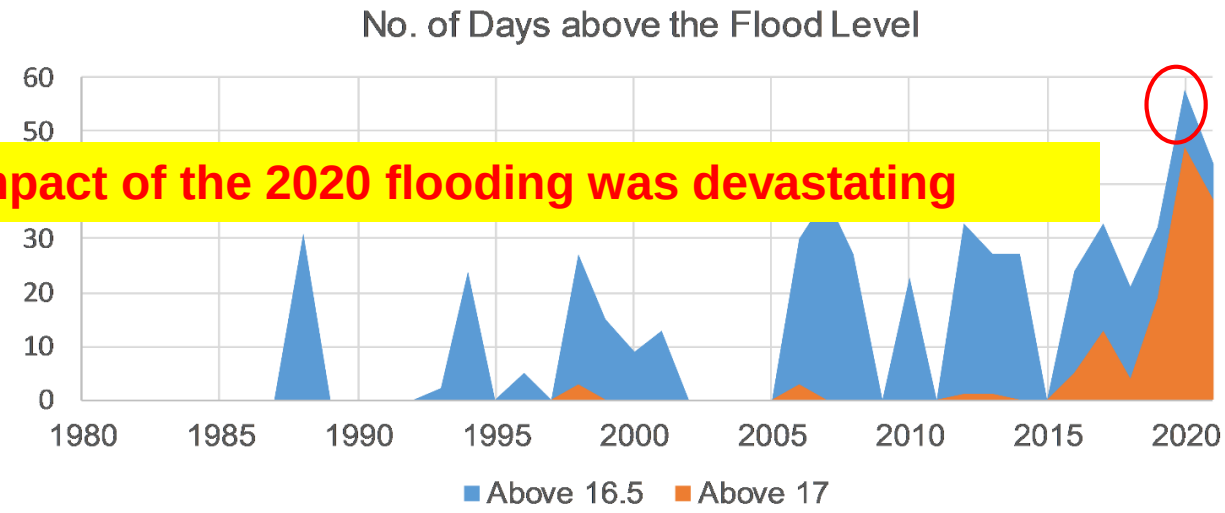
Revolutionizing Flood Risk Reduction in Khartoum, Sudan: An Integrated Hydrologic and Hydraulic Approach with Upstream Reservoir Storage

By: Mohammed A. Hassan

Motivation & Intro

- Climate Change and the Recurrence of Floods in Sudan
- Sudan is prone to flood disasters (According to UN-OCHA about 200,000 people affected every year)





The impact of the 2020 flooding was devastating

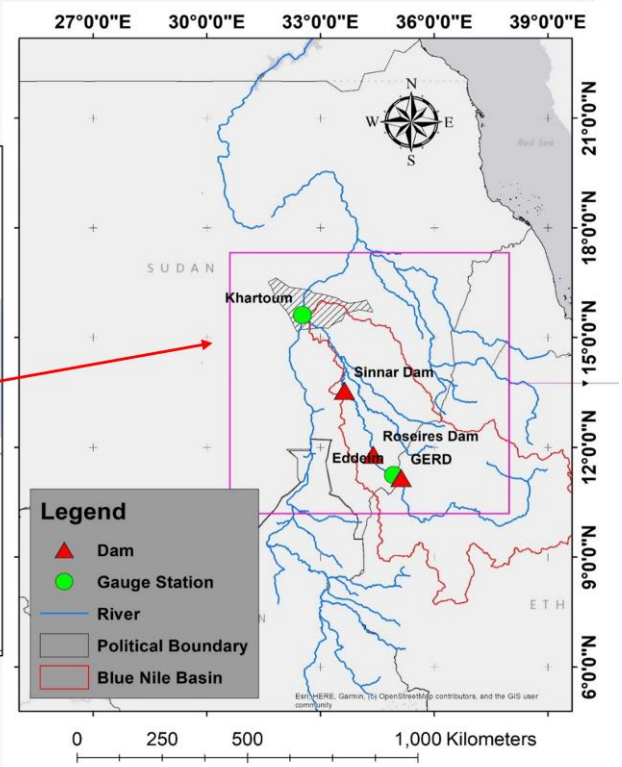
- The BN reached its highest record in the last 100 years. It was 1.16 m higher than the flood level.
- Thousands homes and properties have been damaged, some completely, others partially.
- Dozens of lives have been lost. And more than 100,000 affected people.
- An area of 500 square Km^2 in Khartoum State has been inundated.

Motivation & Intro

- Then the government declared the **STATE OF EMERGENCY** fro 3 months.

The Study Area

- Khartoum State in Sudan was the most severely affected by the 2020 floods.
- Located at the heart of Sudan, Khartoum State has witnessed substantial population growth and urbanization, currently housing approximately 10 million people (Elagib, 2011)
- The Blue Nile originates from the Ethiopian Plateau and joins the White Nile in Khartoum.
- It has seasonal characteristics, with 70–80% of its flow occurring in only four months and totally contribute to the River Nile's flow by about 60% (NBI, 2020).



- Eddeim station, at the border, accumulates the UBN inflow and represent the inflow to Roseires dam.
- Roseires Dam, positioned as the most upstream dam on the Blue Nile in Sudan, was initially constructed in 1966, and heightened by 10 m in 2012.
- This most upstream dam plays a key role in our study.

Methodology

Forecasted Rainfall (t_0-t_{15})

Calibrated & Validated R-R Model (mHM)

GERD inflow (t_0-t_{15})

GERD info.

GERD W.B

Roseires inflow (t_0-t_{15})

Dam Safety issues

Yes

Release = Inflow - Losses

No

Room Availability

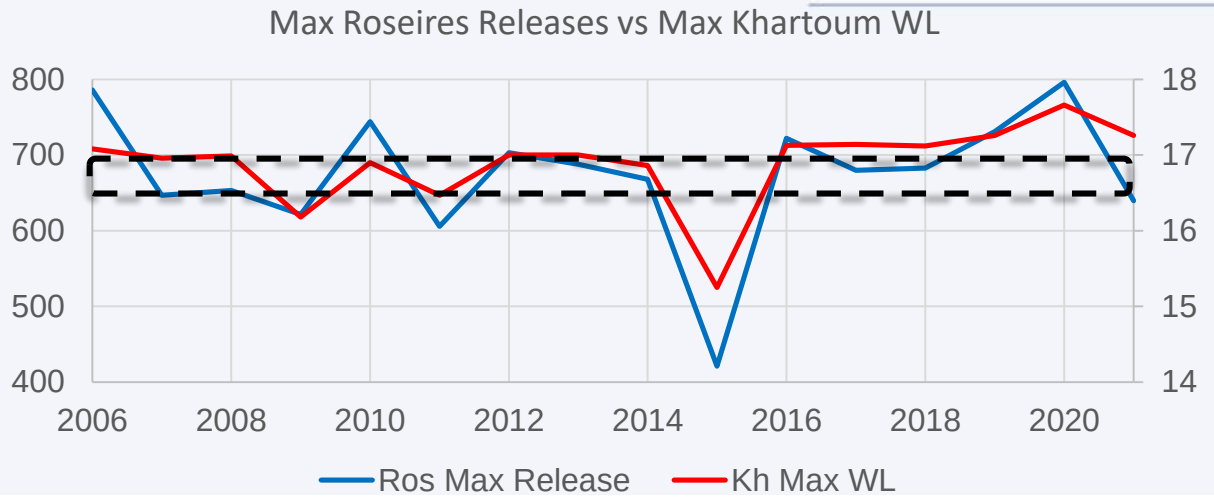
Yes

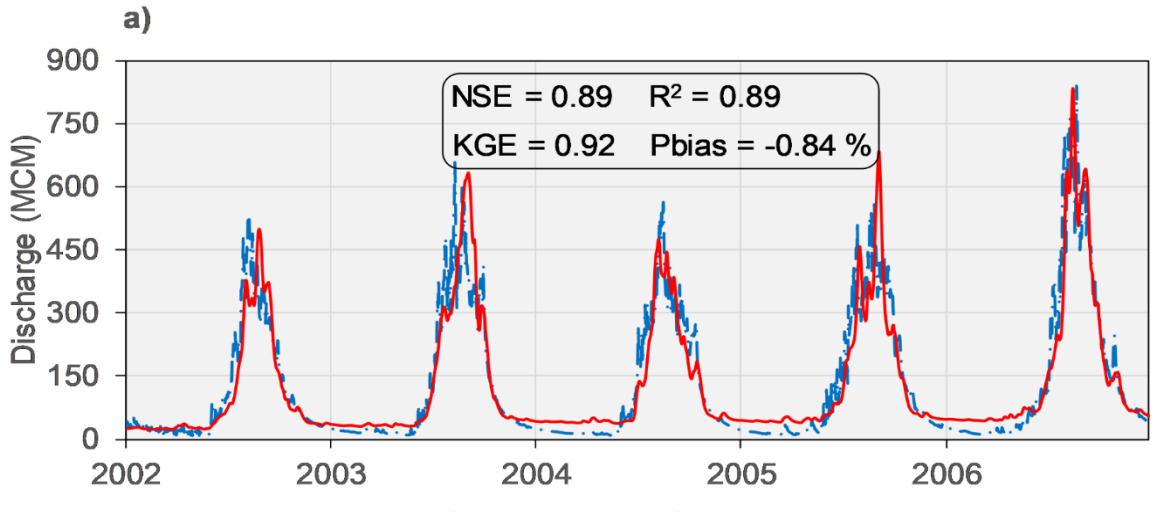
No

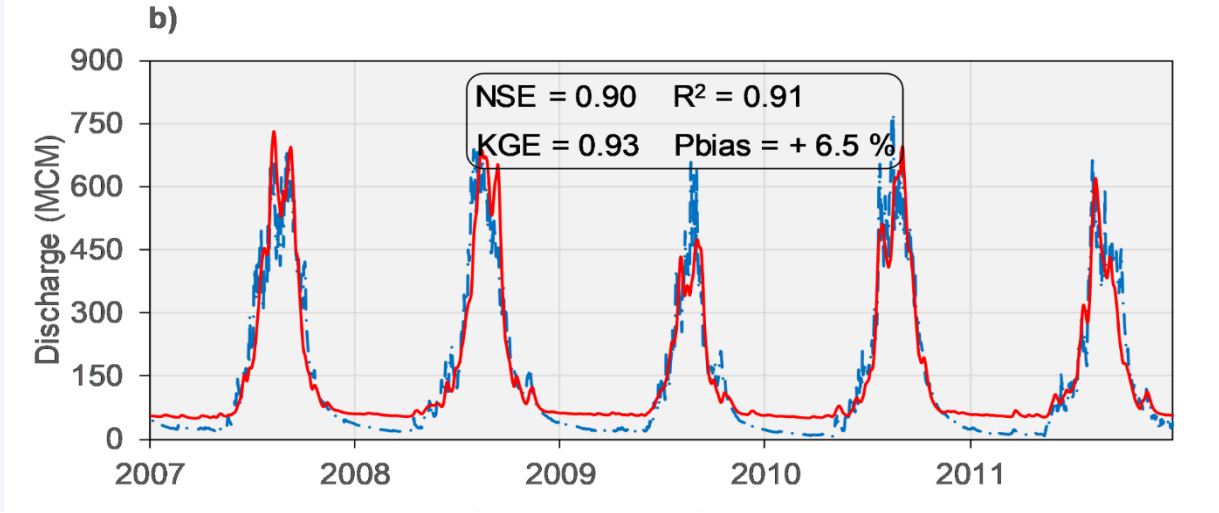
Release < 650 MCM, If the inflow is above

Methodology cont.

So, Why 650 MCM??

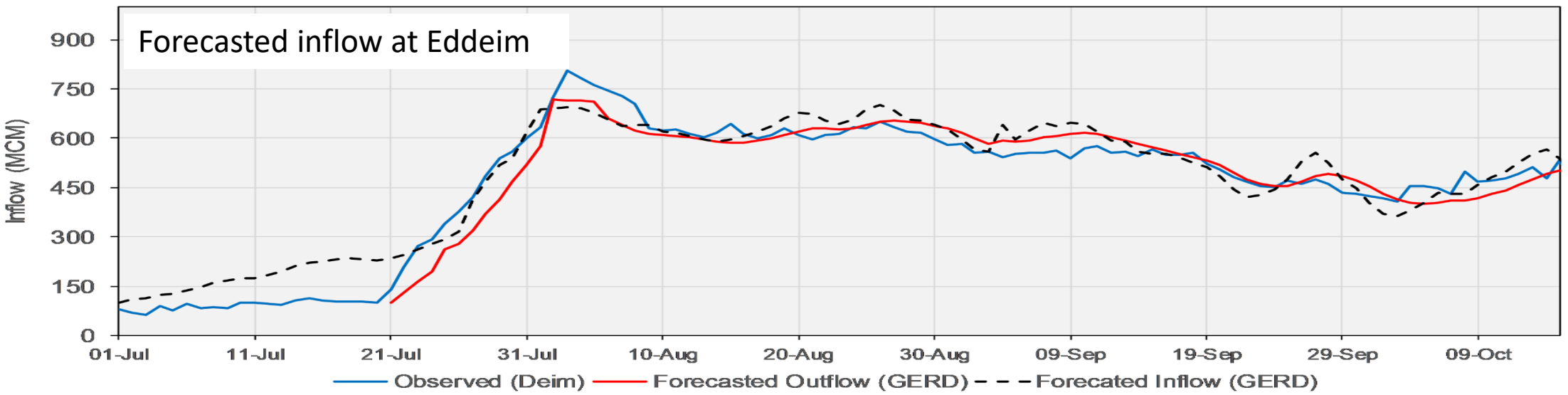


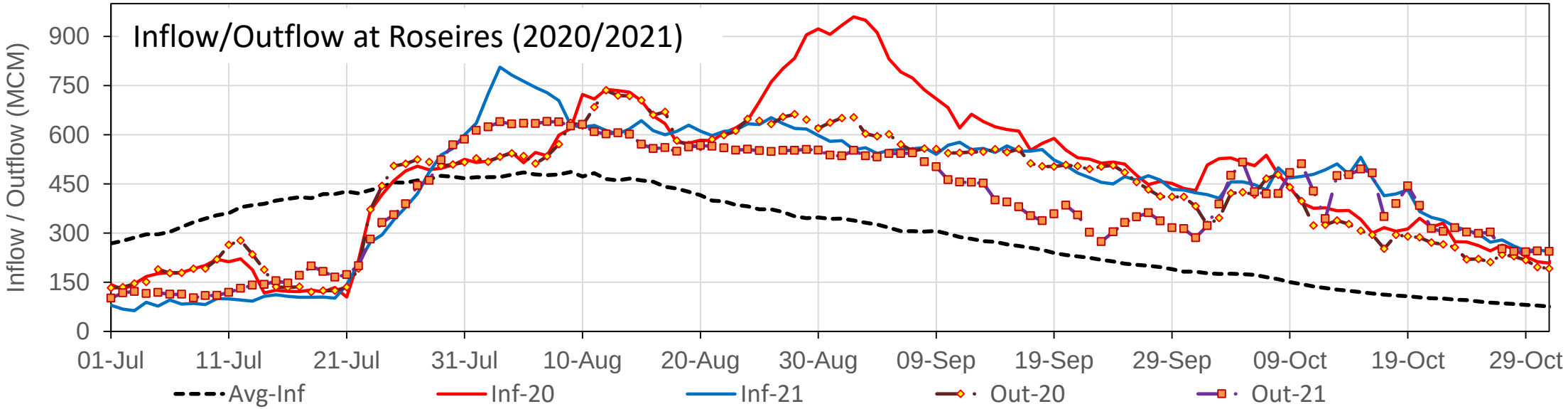




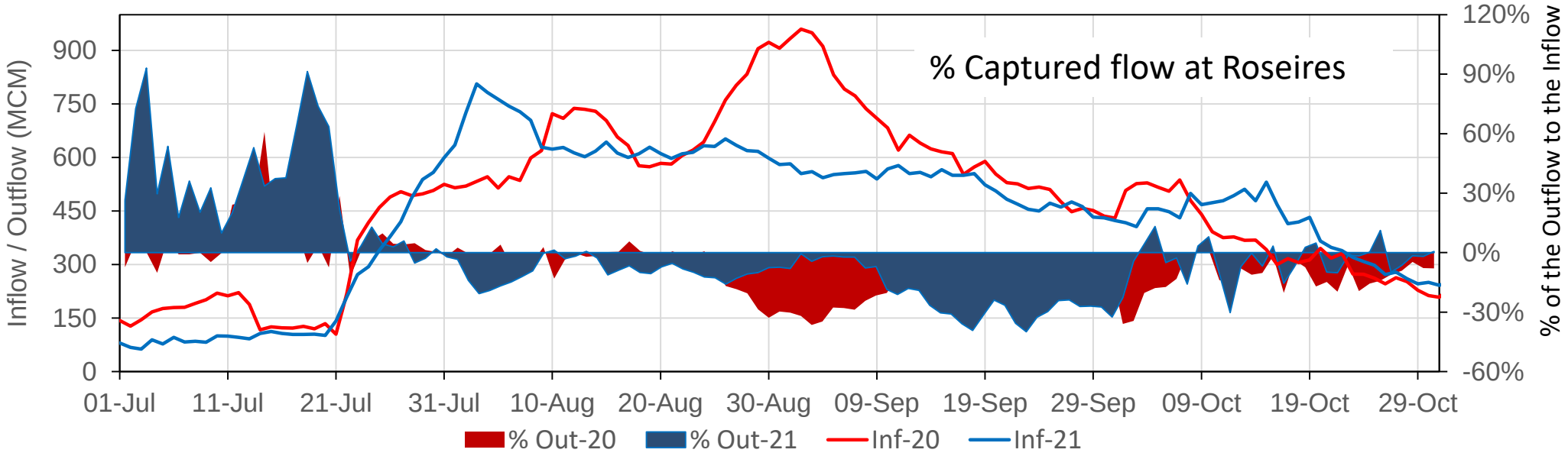
Rainfall-Runoff Model: The four parameters show "excellent" model performance for the calibration (a) and validation (b) period according to performance rating guidelines for daily and monthly flow statistics by (Donigian 2002)

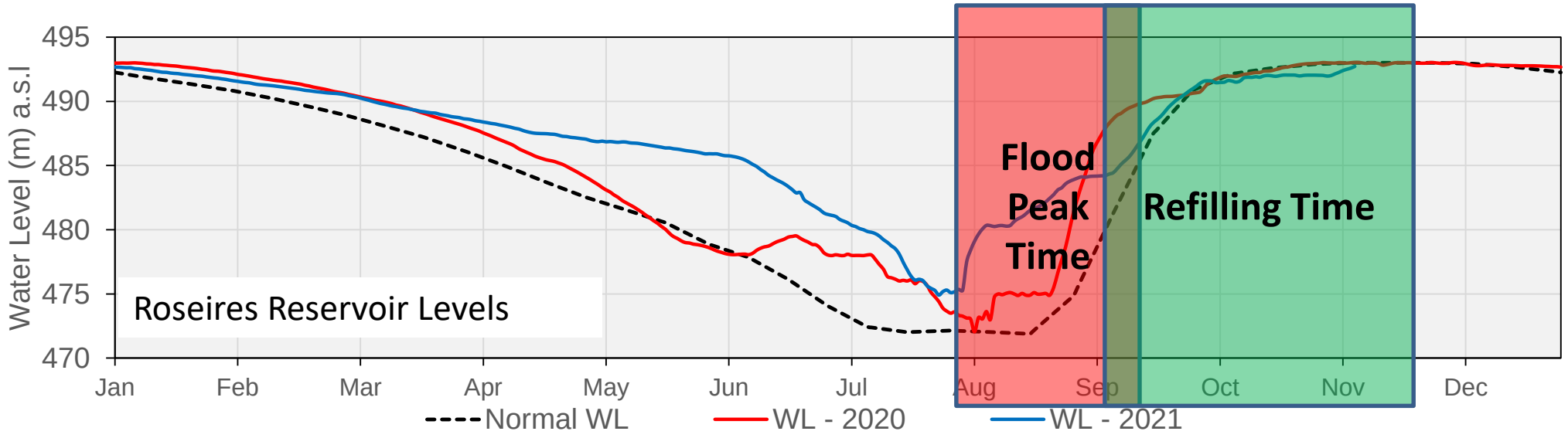
Results


Forecasted inflow at Eddeim
Inflow (MCM)
900
750
600
450
300
150
0
01-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
09-Sep
19-Sep
29-Sep
09-Oct
Observed (Deim)
Forecasted Outflow (GERD)
Forecated Inflow (GERD)


Inflow/Outflow at Roseires (2020/2021)
Inflow / Outflow (MCM)
900
750
600
450
300
150
0
01-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
09-Sep
19-Sep
29-Sep
09-Oct
19-Oct
29-Oct
Avg-Inf
Inf-20
Inf-21
Out-20
Out-21

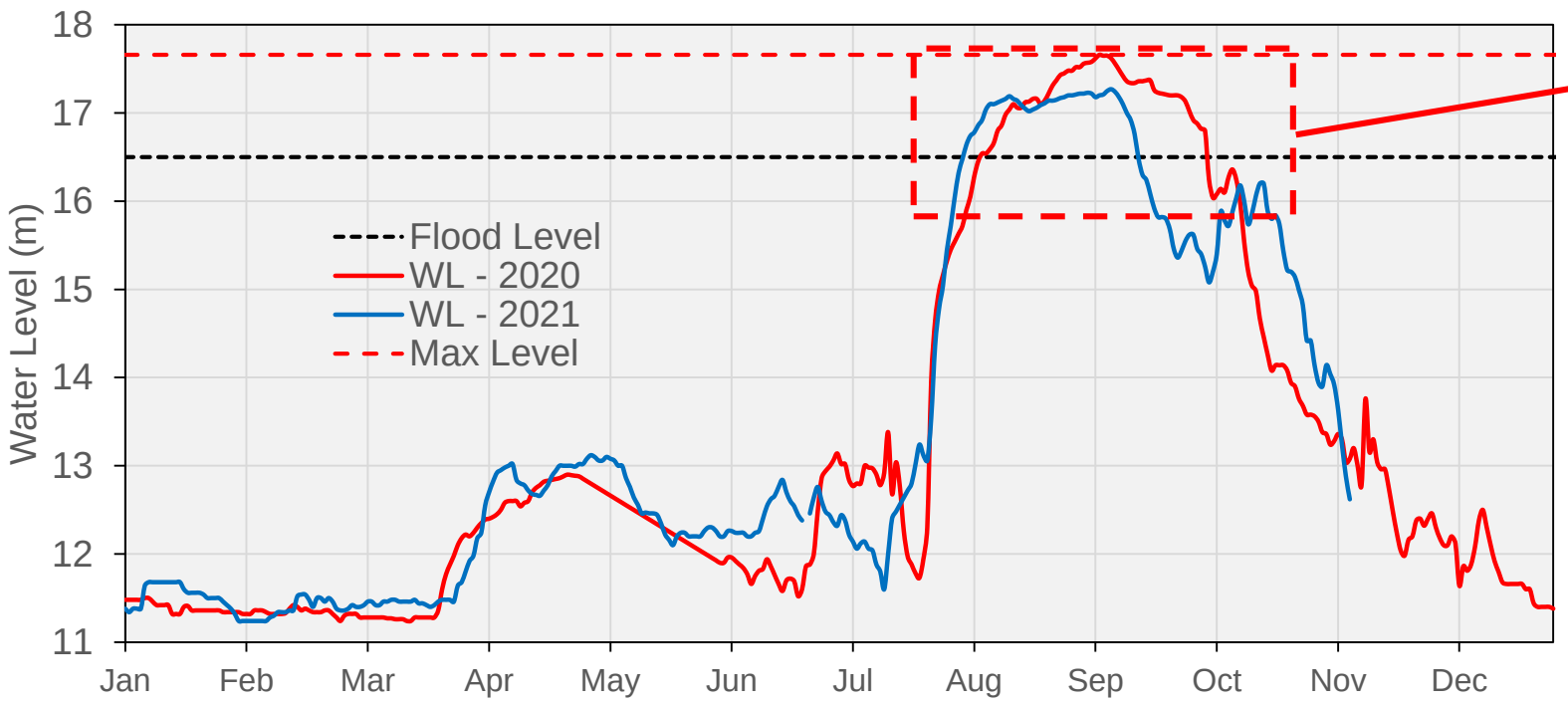
Results

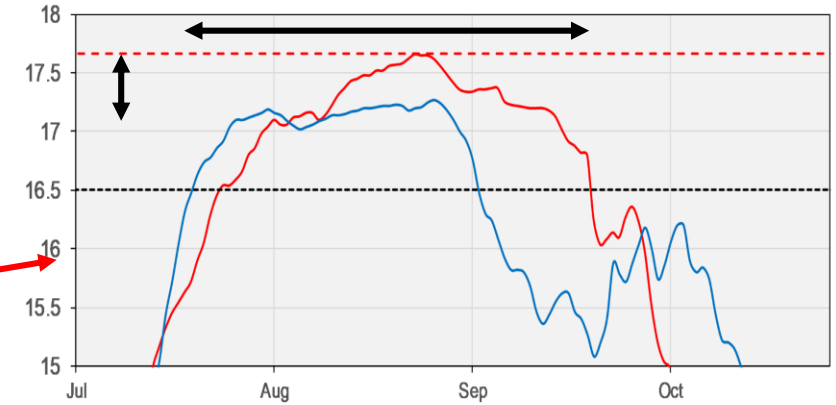

% Captured flow at Roseires
Inflow / Outflow (MCM)
% of the Outflow to the Inflow
900
750
600
450
300
150
0
120%
90%
60%
30%
0%
-30%
-60%
01-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
09-Sep
19-Sep
29-Sep
09-Oct
19-Oct
29-Oct
% Out-20
% Out-21
Inf-20
Inf-21


Water Level (m) a.s.l
495
490
485
480
475
470
Roseires Reservoir Levels
Flood Peak Time
Refilling Time
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Normal WL
WL - 2020
WL - 2021

Results

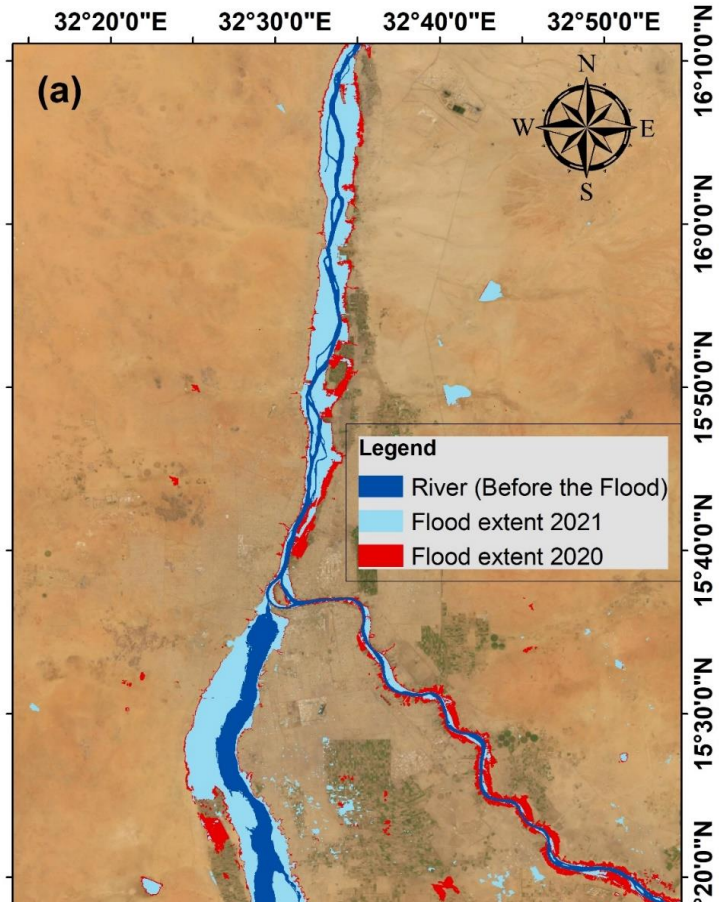
- The water level in Khartoum decreased by more than 40 cm. From 17.66 m in 2020 to 17.22 meters in 2021



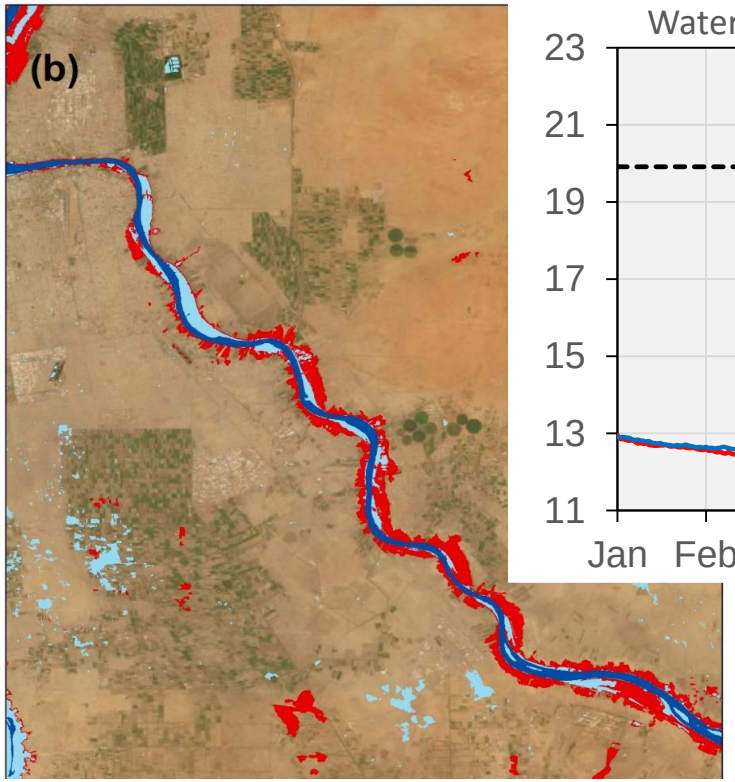


- The number of days with water levels above the flood threshold dropped from 60 days in 2020 to 44 days in 2021

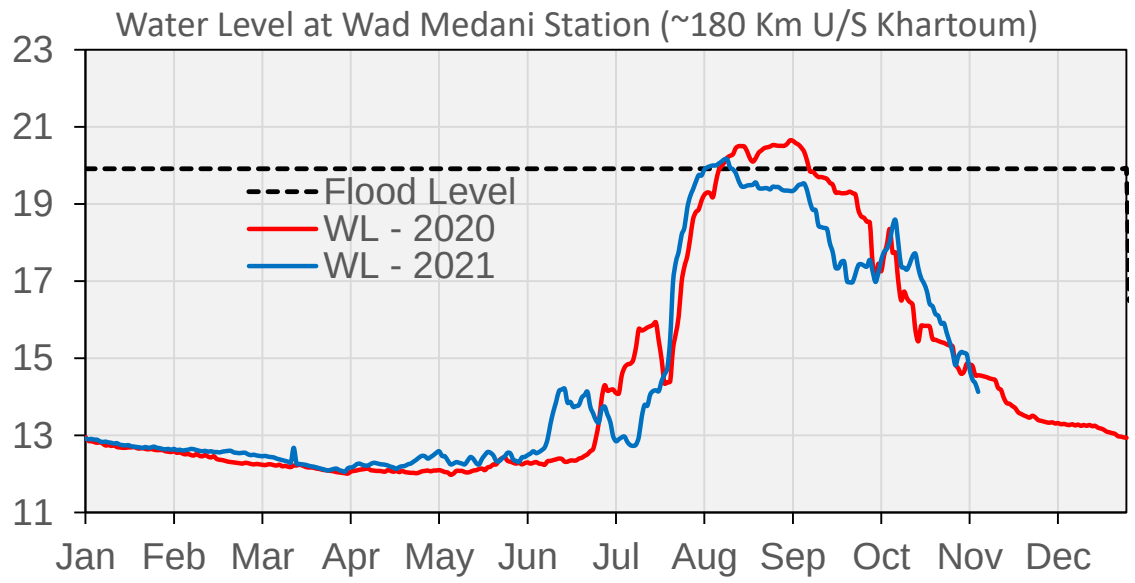
Results



A decrease of **53%** in flood extent in 2021 compared to 2020.



A decrease of **74%** in flood extent in 2021 compared to 2020.



- Wad Medani, located 180 kilometers upstream, benefited significantly from the Applied Flood Reduction Measure (FRR) compared to Khartoum, which saw a lesser benefits from the approach.
- This difference was due to the exceptional White Nile inflows impacted Khartoum.

Conclusions and Recommendations

Conclusions:

- **Climate Change Impact:** Climate change exists and has caused massive rainfalls in the Blue Nile Basin and recently the White Nile, leading to more frequent and severe floods.
- **Integrated Approach:** The application of an integrated approach, guided by good inflow forecasts with sufficient lead-time, Hydraulic knowledge of the river memory, and take proactive & inclusive decisions from a roundtable discussion by using upstream reservoir, **proved effective in mitigating flood risks in the study area, especially during the 2021 flood season**.
- **Flood Risk Reduction Results:** Water level dropped about 40 cm in Khartoum in 2021 vs. 2020. Sentinel-2 data showed a 53% decrease in the whole flood extent, while it was 74% in the Blue Nile extent inside Khartoum State. In addition, UN-OCHA reports that only around 4,000 affected people in 2021, compared to more than 100,000 in 2020.

Conclusions and Recommendations

Recommendations:

- **Enhanced Climate Resilience:** Develop and implement national and regional climate resilience strategies that incorporate climate adaptation measures into water resource management to address the increasing flood risks associated with climate change.
- **Enhanced Flood Preparedness:** Given the increasing frequency and duration of floods in the region, it is crucial to enhance flood preparedness and response mechanisms, including early warning systems, capacity building, awareness, and emergency plans.
- **Transboundary Collaboration:** Collaborate with neighbouring countries, especially Ethiopia and South-Sudan for our case, on the coordinated management of water resources in the Blue Nile and the White Nile Basins. Joint efforts can lead to more effective flood risk reduction and water resource management strategies.


NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL
THANK
YOU!