From Ethiopian Falls

Nile River

To Egyptian Pyramids

# A Blueprint for Adapting High Aswan Dam Operation to Challenges of Filling and Operation of the Grand Ethiopian Renaissance Dam

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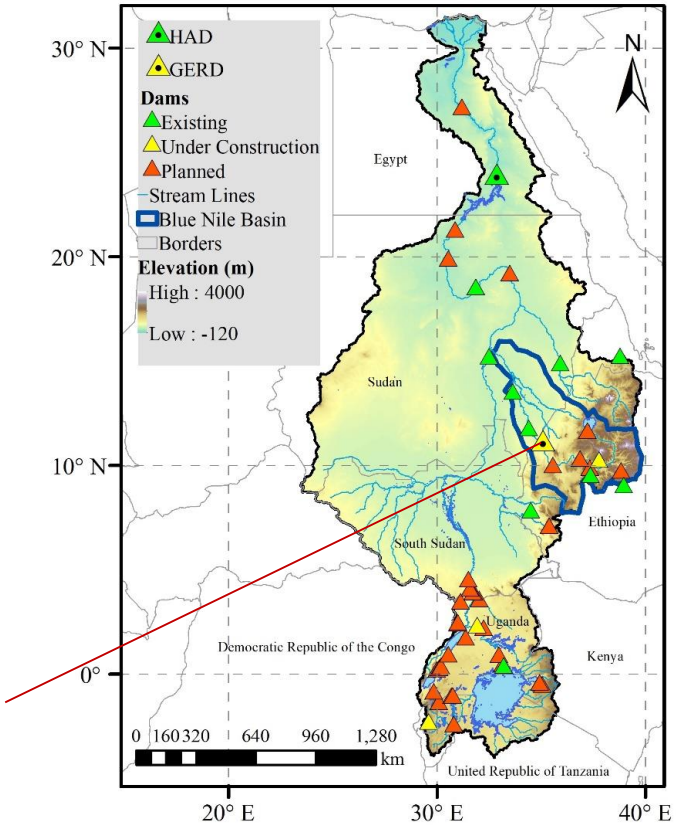
# Nile River Basin (NRB)

- Transboundary river
- Population growth
- Increasing food/energy demand
- Climate variability
- Planned dams

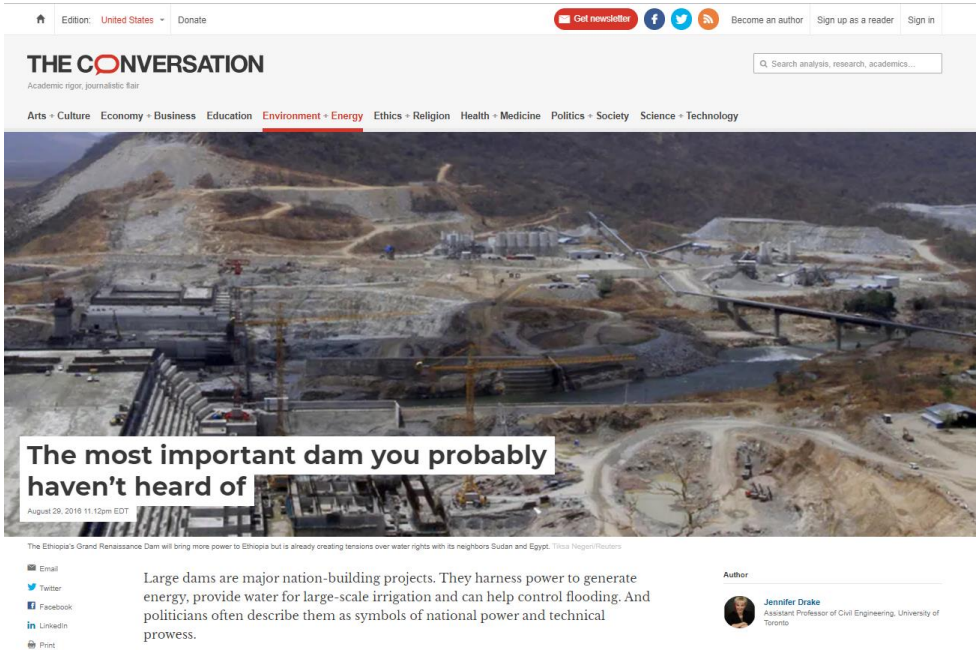
# Dams in NRB

- 11 existing dams
- 35 planned hydropower dams
- 4 dams under construction




*GRanD Database (Lehner et al., 2011) and Zarfl et al. (2015)*

***Grand Ethiopian Renaissance Dam (GERD)***

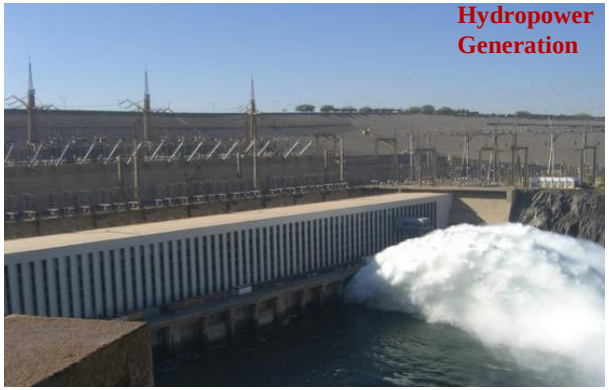



- **currently under construction in Ethiopia**
- **controlling the Blue Nile (Political Tensions)**
- **the largest hydropower dam in Africa**
- **74 km3 of reservoir storage**

*6 times Grand Coulee dam in Washington~ 12 km3*

# Overarching Goal

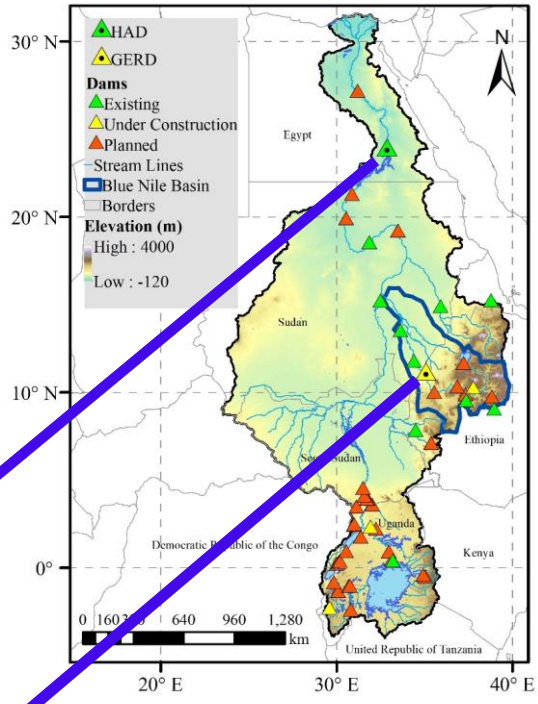
The overarching goal is to **derive adaptive reservoir operating policy** under the combined impacts from climate variability, planned transboundary dams and population pressures.


***Research Question*** ***How can existing reservoirs adapt their operation to intrinsic and extrinsic transboundary challenges?***

*Wikipedia Ranking of Reservoirs by Volume*

| Rank | Name of dam | Reservoir | River | Country | Year | Nominal volume km³ |
|---|---|---|---|---|---|---|
| 1 | Kariba Dam | Lake Kariba | Zambezi River | Zambia and Zimbabwe | 1959 | 180.6 |
| 2 | Bratsk Dam | Bratsk Reservoir | Angara River | Russia | 1964 | 169 |
| 3 | Akosombo Dam | Lake Volta | Volta River | Ghana | 1965 | 150 |
| 4 | Daniel-Johnson Dam | Manicouagan Reservoir | Manicouagan River | Canada | 1968 | 141.851 |
| 5 | Guri Dam | Lake Guri | Caroní River | Venezuela | 1986 | 135 |
| 6 | Aswan High Dam | Lake Nasser | Nile River | Egypt | 1971 | 132 |
| 7 | Grand Ethiopian Renaissance Dam | | Blue Nile River | Ethiopia | under construction | 79 |
| 8 | W. A. C. Bennett Dam | Williston Lake | Peace River | Canada | 1967 | 74.3 |
| 9 | Krasnoyarsk Dam | Krasnoyarsk Reservoir (ru) | Yenisei River | Russia | 1967 | 73.3 |
| 10 | Zeya Hydroelectric Station (ru) | Zeya Reservoir | Zeya River | Russia | 1978 | 68.4 |




# Acronyms

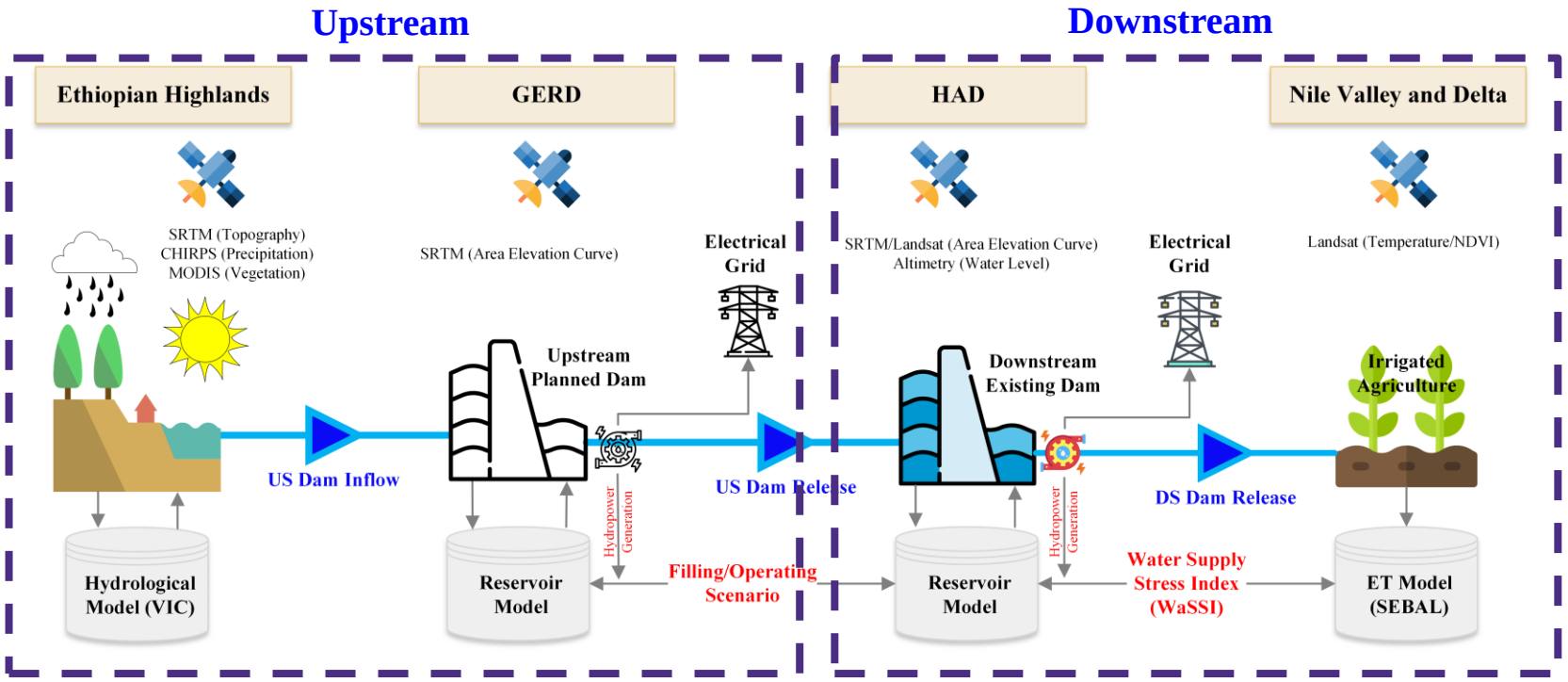

**HAD: High Aswan Dam**

*(existing downstream dam in Egypt)*

**GERD: Grand Ethiopian Renaissance Dam**

*(planned upstream dam in Ethiopia)*

# Satellite-Based Blueprint




*Eldardiry, H., & Hossain, F. (2019). Understanding Reservoir Operating Rules in the Transboundary Nile River Basin Using Macroscale Hydrologic Modeling with Satellite Measurements. Journal of Hydrometeorology, 20(11), 2253-2269.*

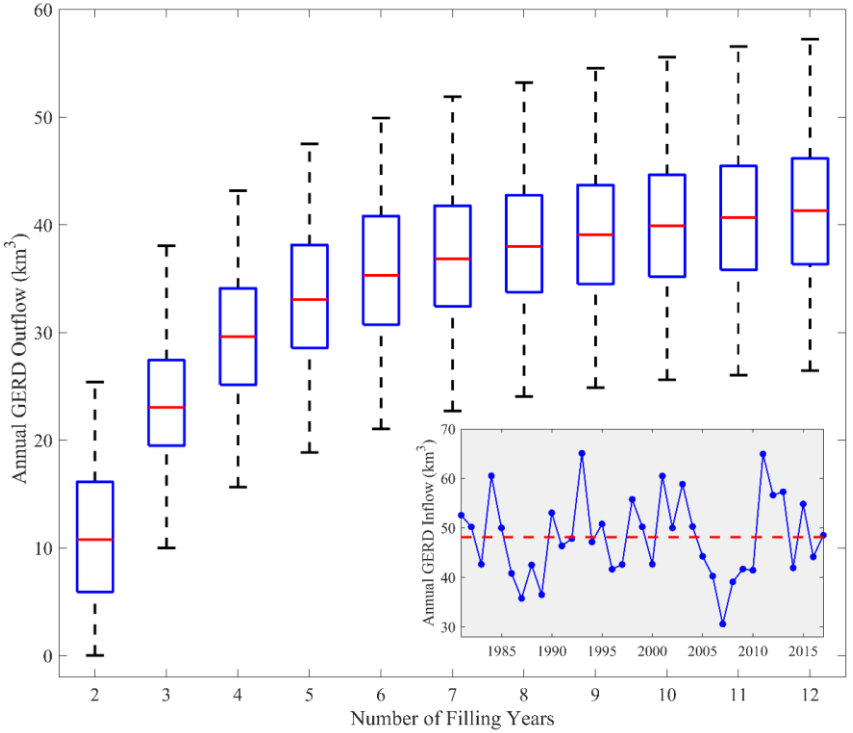
*Eldardiry, H., and Hossain, F. (In revision). A Blueprint for Adapting High Aswan Dam Operation in Egypt to Challenges of Filling and Operation of the Grand Ethiopian Renaissance Dam, Journal of Hydrology.*

# GERD Filling Scenarios

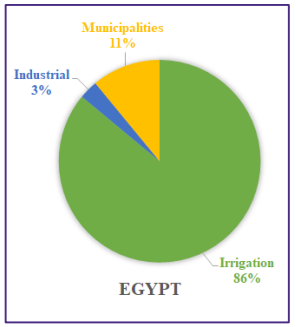
- Filling scenarios of GERD (from 2- to 12-years)
- Using the historical inflow (1981-2017) simulated by the VIC model.
- Less impacts downstream for filling scenarios of greater than 7 years.

Median Flow=47.5 $km^3$/year

Reservoir Storage=74 $km^3$

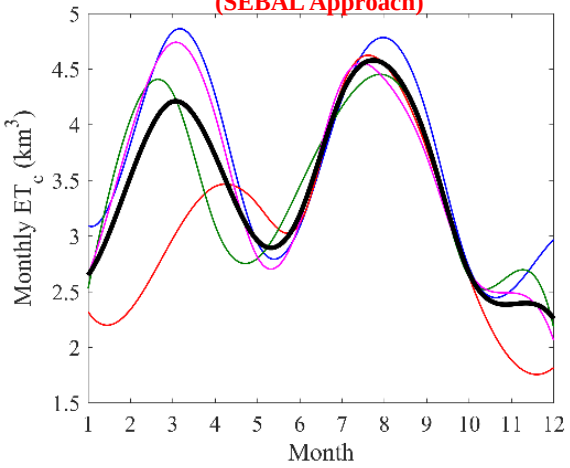


# HAD Adaptation

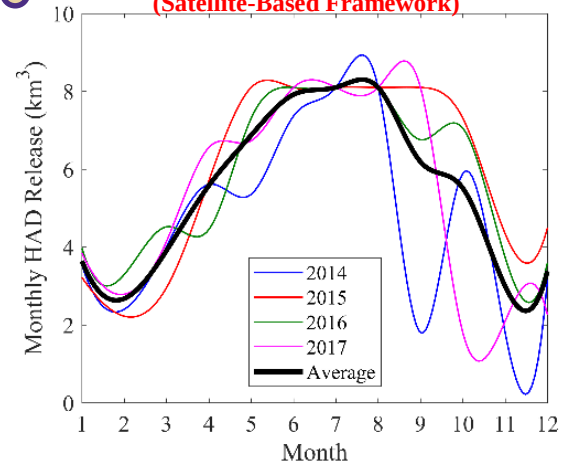



**Water Supply Stress Index (WaSSI)** $= \dfrac{\text{Water Consumption}}{\text{Water Supply}}$

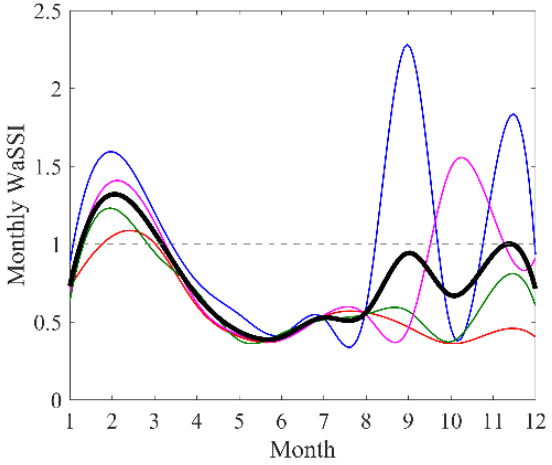
**Water Consumption**
(SEBAL Approach)




**Water Supply**
(Satellite-Based Framework)




**WaSSI**



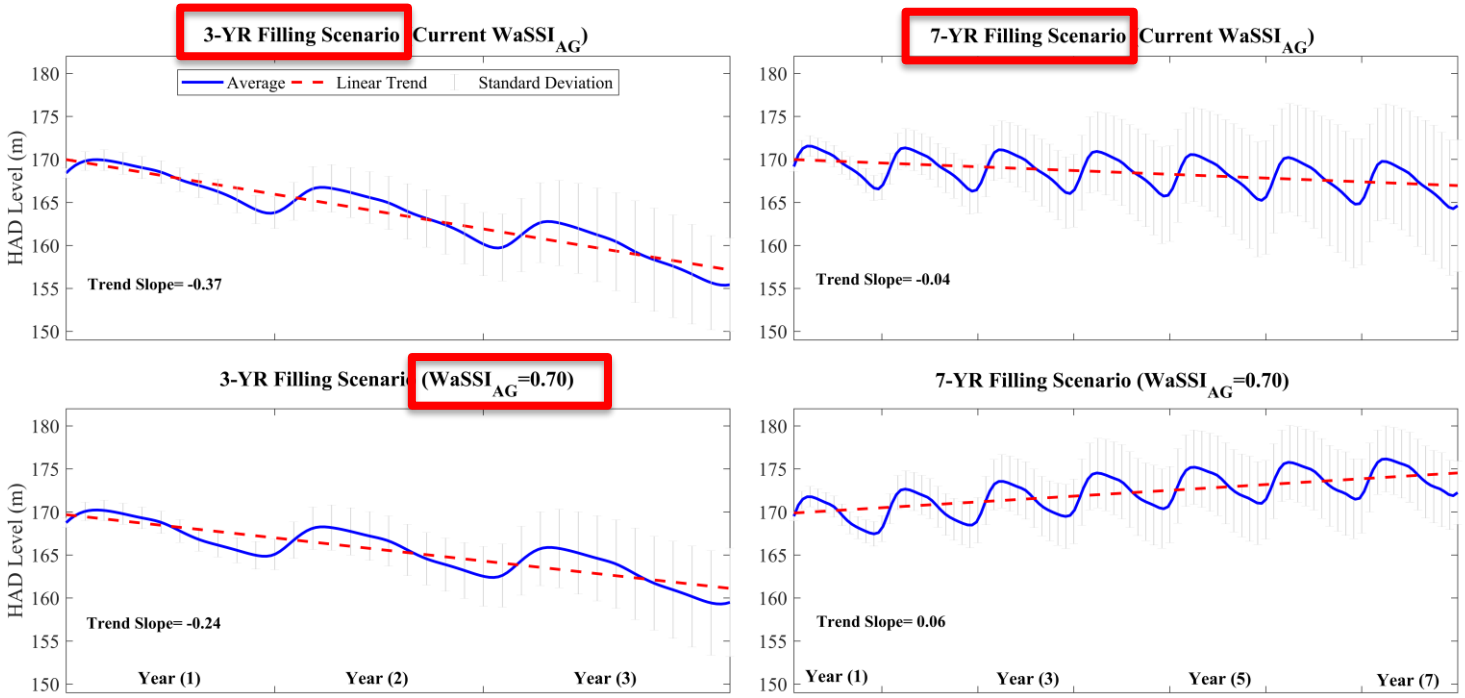

- Lower stress levels are noticed in the summer months (opportunities to adapt)
- Insufficient supply of HAD releases is encountered by relying on rainfall or groundwater

# HAD Level during GERD Filling Scenarios

*Testing different filling scenarios (Upstream conditions)*
*Testing different stress scenarios (Downstream Conditions)*

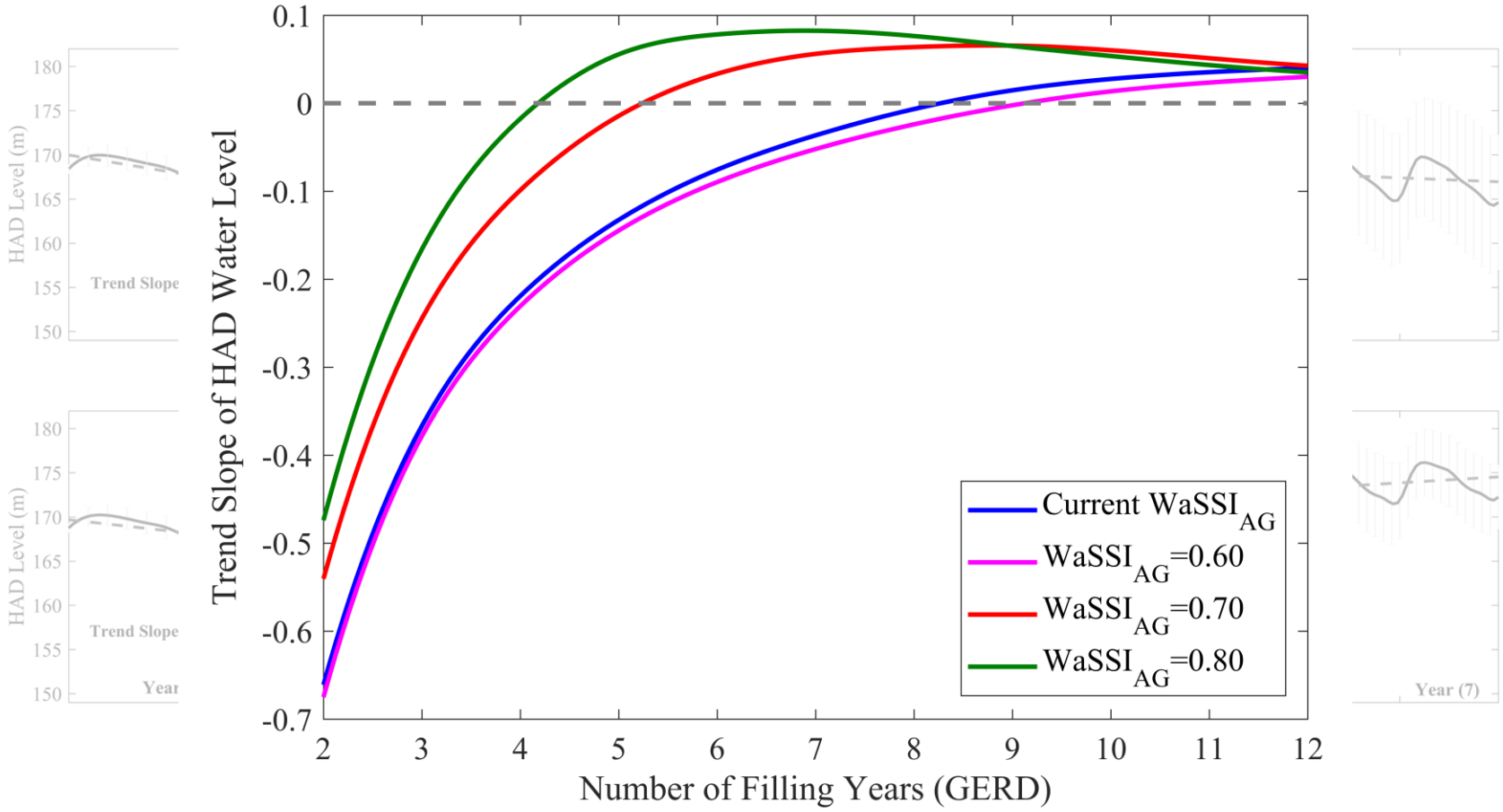
**FSL=182 m AMSL**

**MOL=147 m AMSL**



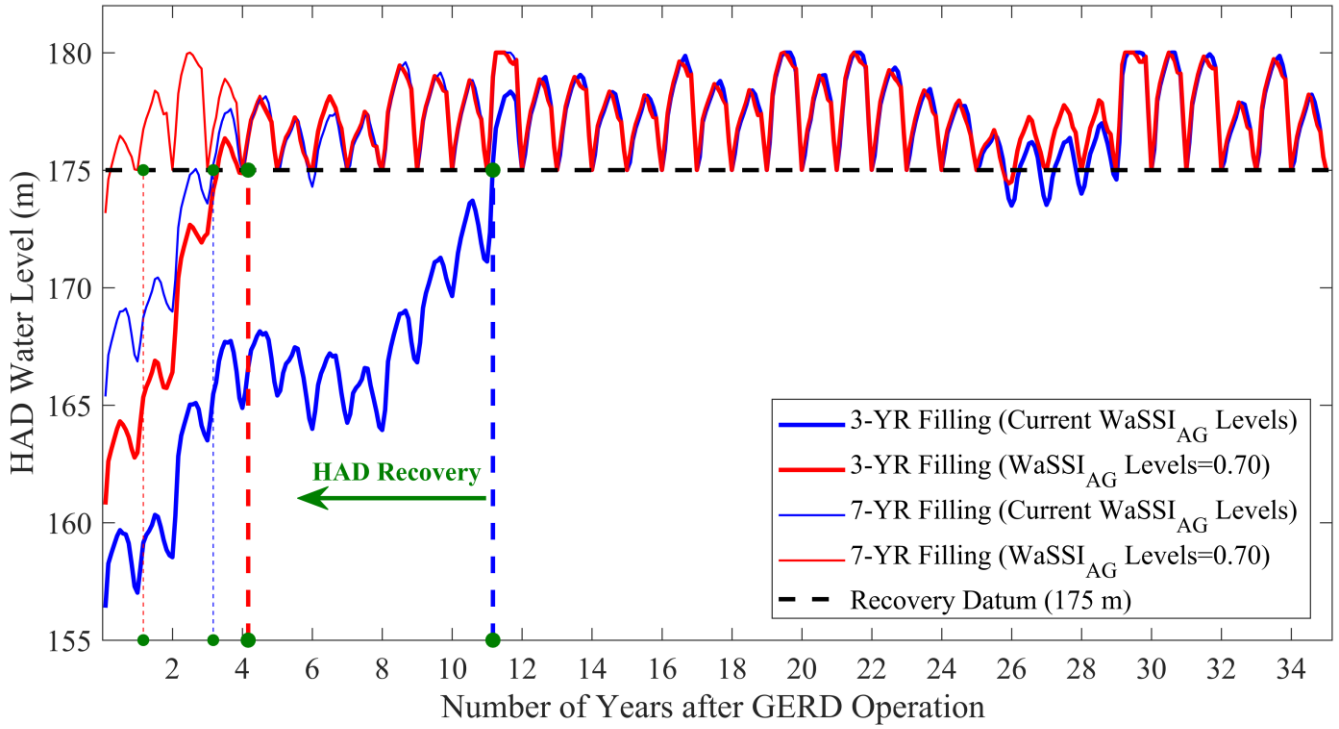

- A significant drop in the HAD level when assuming a 3-year filling scenario.
- A flatter pattern is noticed for 7-year filling scenario with negligible trends.

# HAD Level during GERD Filling Scenarios



# HAD Recovery during GERD Operation

**Recovery:** How long it will take for HAD to recover its normal operation level?



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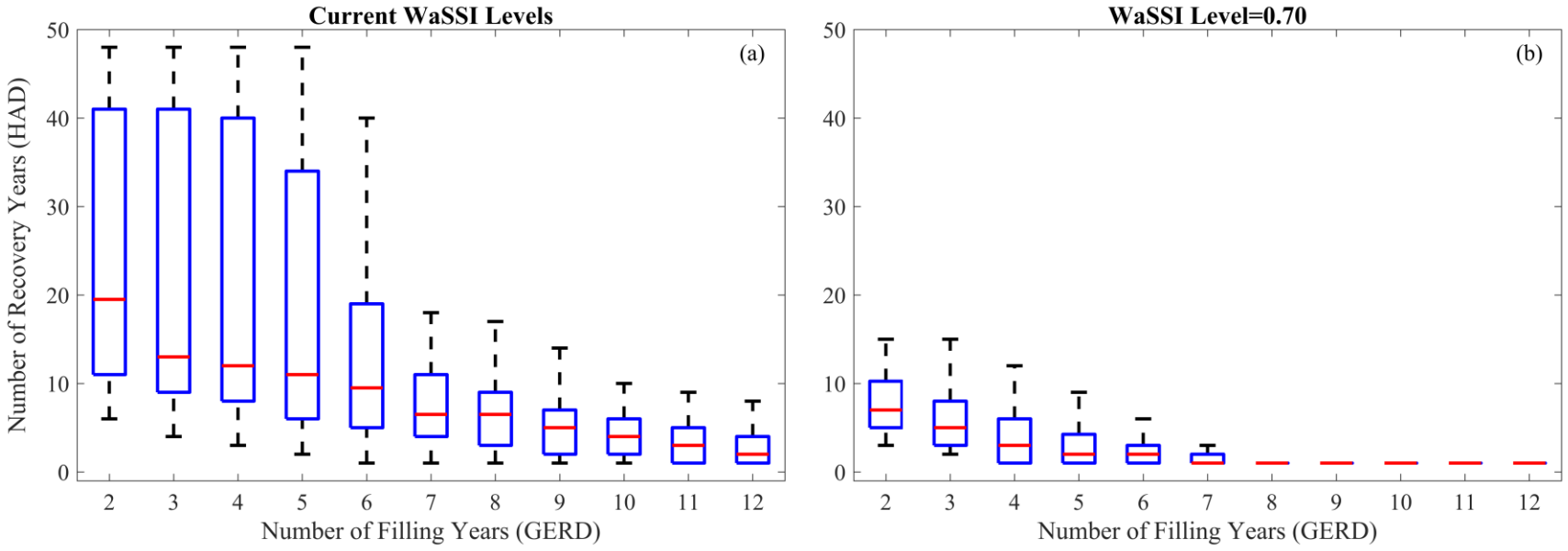


# Assessment of GERD/HAD

| Location | Factor | Scenario |
|---|---|---|
| Upstream Planned Dam (GERD) | **GERD Inflow** | **Dry vs Normal vs Wet** |
| | GERD Storage Capacity | 74 vs 80 |
| | GERD FSL | 640 vs 650 |
| | **GERD Filling** | **3 vs 7 Years** |
| | GERD Starting Filling Month | January vs August |
| | GERD HP Demand | Uniform vs Varying (Demand Curve) |
| | GERD HP Load Factor | LF=0.3 vs 0.4 vs 0.5 |
| | GERD Starting Operation Climate | Dry vs Normal vs Wet |
| | GERD Filling Strategy | Summer vs Yearly vs Agreed Outflow |
| Downstream Existing Dam (HAD) | Sudan Share | 0.75 vs 0.70 vs 0.60 |
| | White Nile inflow | Low vs Average vs High |
| | HAD Starting Level | Low vs Average vs High |
| | HAD HP | By-product vs Optimization |
| | HAD HP Load Factor | CF=0.3 vs 0.45 vs 0.6 |
| | HAD HP Demand | Uniform vs Varying (Demand Curve) |
| | **HAD DS WaSSI** | **Status Quo WaSSI vs Predefined WaSSI** |

# Key Findings and Future Pathways

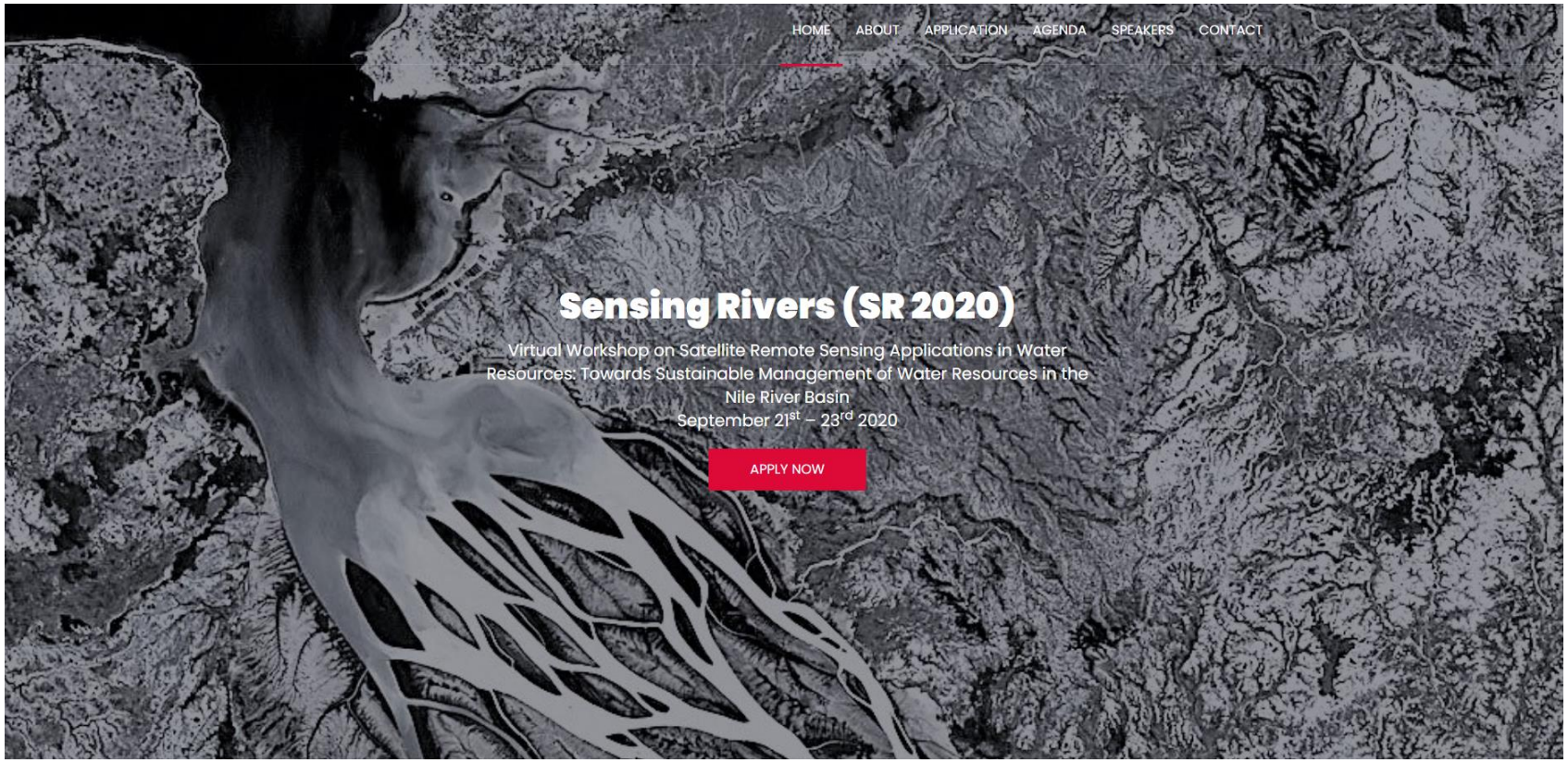
- Filling scenario (> 7-year) has less impacts on HAD operation.
- HAD can adapt to GERD filling in summer months.
- Forecast-based Adaptive Reservoir Operation (FARO).
- Foster negotiations to agree upon a long-term framework that explicitly accounts for the impacts of transboundary projects.

*The leaders of Egypt, Ethiopia and Sudan all gathered in Khartoum to sign the agreement of principles in 2015 (Source: BBC).*


Thank You!
“Egypt is the Gift of the Nile”
Greek Historian Herodotus (440 BC)
Sunset on the Nile
Aswan, Egypt (August 2007)

# If interested

## 3-day workshop on using satellite remote sensing in the Nile River Basin

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