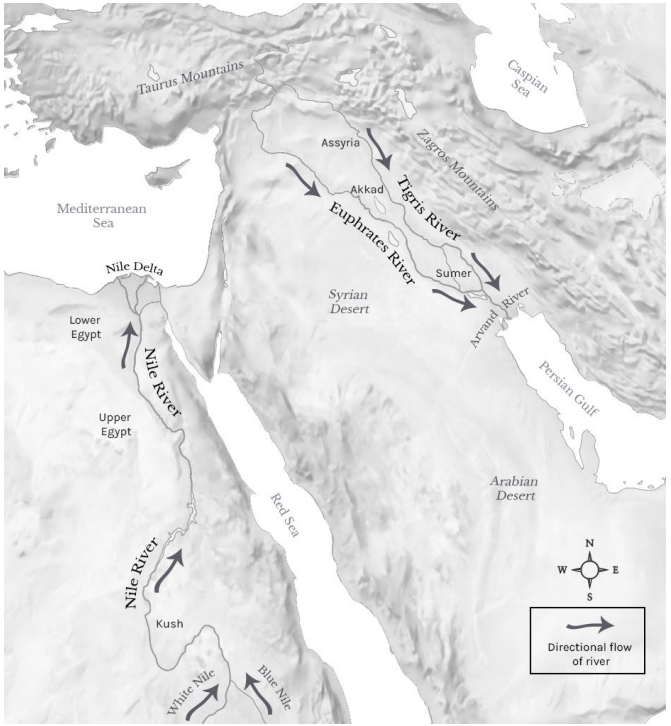
Climate Change Impacts on the Tigris and Euphrates

Presentation: Wednesday, Nov 2, 2022
Presenters: Joanne Im and Minghao Chen

Tigris and Euphrates



Area: 879,790 km^2 (339,690 sq mi)

Countries:

- Turkey
- Syria
- Iraq
- Iran
- Kuwait (lesser)

Fed by rain and snowmelt

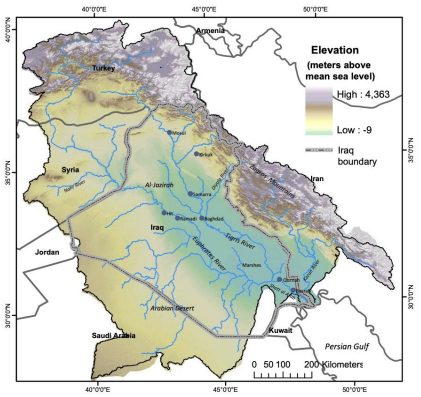


Figure 1. Map of Tigris Euphrates River System, including country boundaries and elevation.

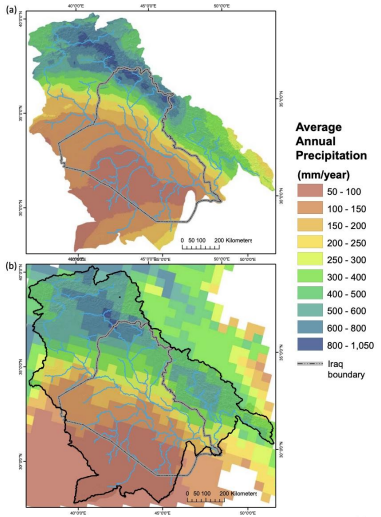


Figure 3. Map of average annual precipitation for the Tigris Euphrates River System at (a) 180-m spatial resolution used for Basin Characterization Model, and (b) original spatial resolution of 51.6 km from data available from the Climatic Research Unit (University of East Anglia, Norwich, UK; http://www.cru.uea.ac.uk/cru/data/hrg/).

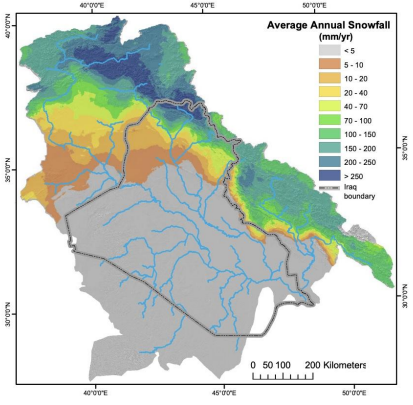


Figure 6. Map of average annual snowfall for the Tigris Euphrates River System . Snowfall is calculated from air temperature and precipitation data (Hijmans and others, 2005; http://worldclim.org/) using the Basin Characterization Model (Flint and Flint, 2007a).

Mesopotamia

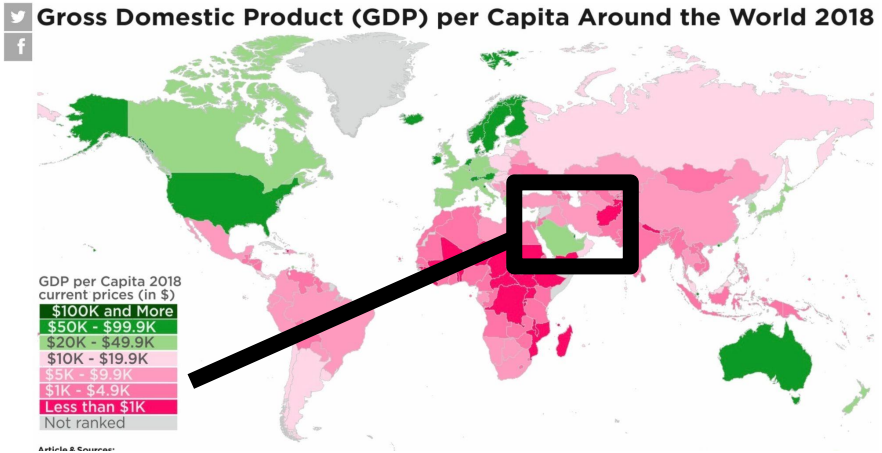
Faith Traditions

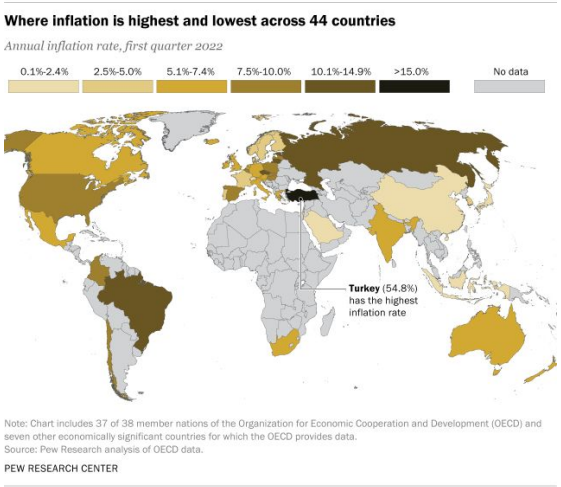
Torah/Bible: Genesis- A river flowed out of Eden to water the garden, and there it divided and became four rivers. The name of the first is the Pishon. It is the one that flowed around the whole land of Havilah, where there is gold. And the gold of that land is good; bdellium and onyx stone are there. The name of the second river is the Gihon. It is the one that flowed around the whole land of Cush. And the name of the third river is the Tigris, which flows east of Assyria. And the fourth river is the Euphrates.

Bible: Revelation - The sixth angel poured out his bowl on the great river Euphrates, and its water was dried up, to prepare the way for the kings from the east.

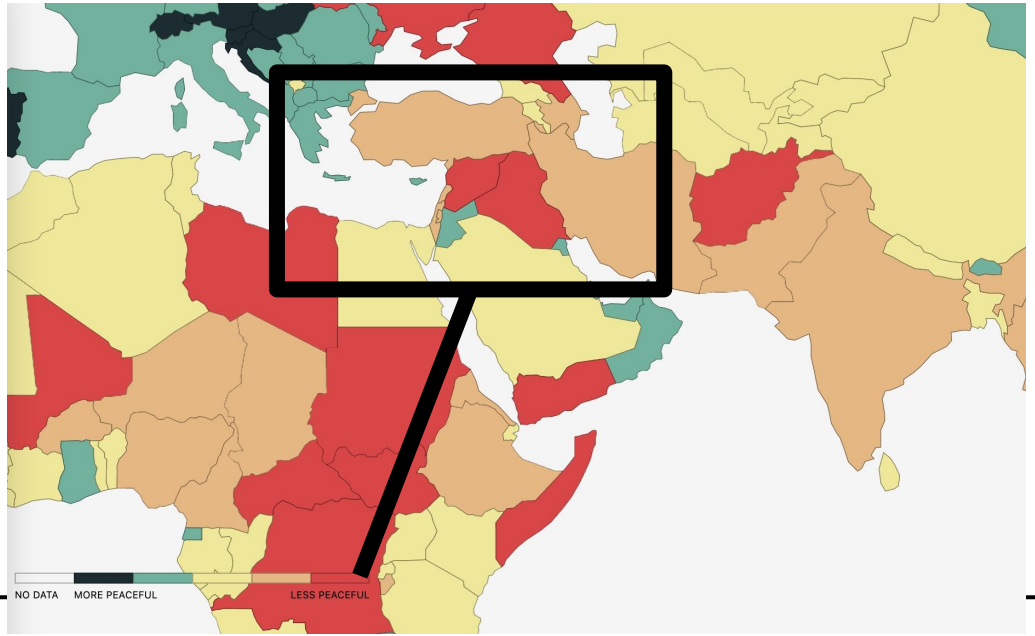
Quran - "Doomsday will not strike before the Euphrates uncovers a mountain of gold. People will fight for it. Ninety-nine out of each one hundred will be killed. Every one of them will think, 'I will probably win the fight.'"

Region: Economically Distressed and Politically Unstable



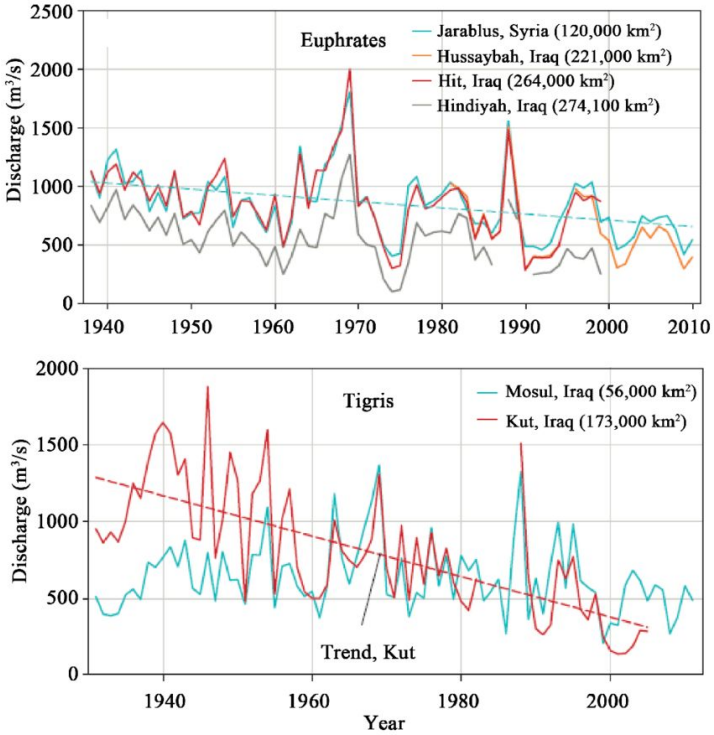


Region: Economically Distressed and Politically Unstable



Livelihoods directly related to the raw water quantity and quality

Local trends: Water Discharge



Water Volume: High Human Water Demands

- Agriculture (already accounts for 66% of water demand)
- Energy (hydropower which spreads water out over a large exposed surface area, facilitating rapid evaporation)
- Population growth
  - Turkey = +.8%
  - Iran = +1.2%
  - Iraq = 2.4%
  - Syria = 4.3%
- Dams (next slide)

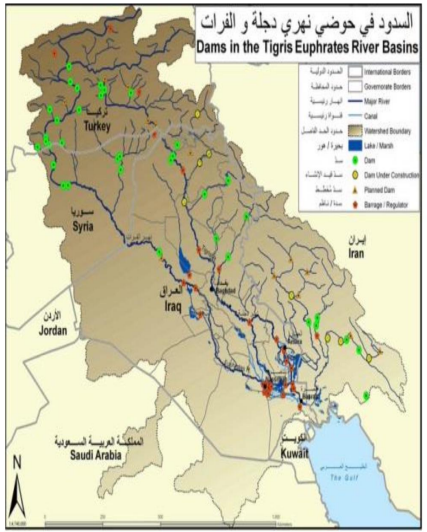
Consequences of Decreased Water Quality

- Increased salinization
- Increased political conflict
- Increased efforts to secure water supply, with consequences for neighboring countries that increases political conflict

Water Volume: Direct Effect on Political Tensions

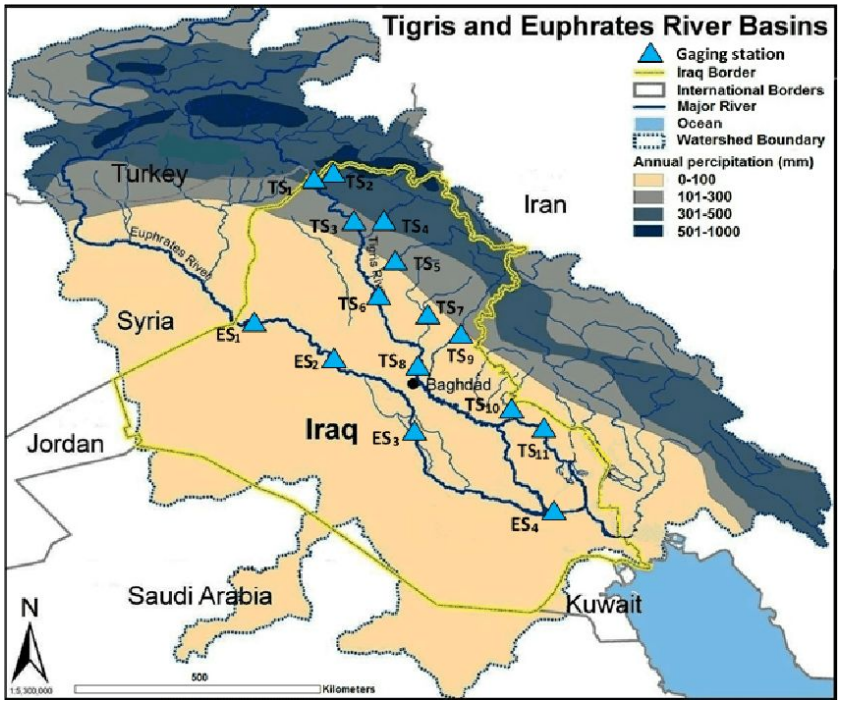
- Episodes of drought can trigger political conflict.
- Water scarcity has meant tensions increase even if scarcity is naturally generated.

Water Volume: Reacting to Water Scarcity

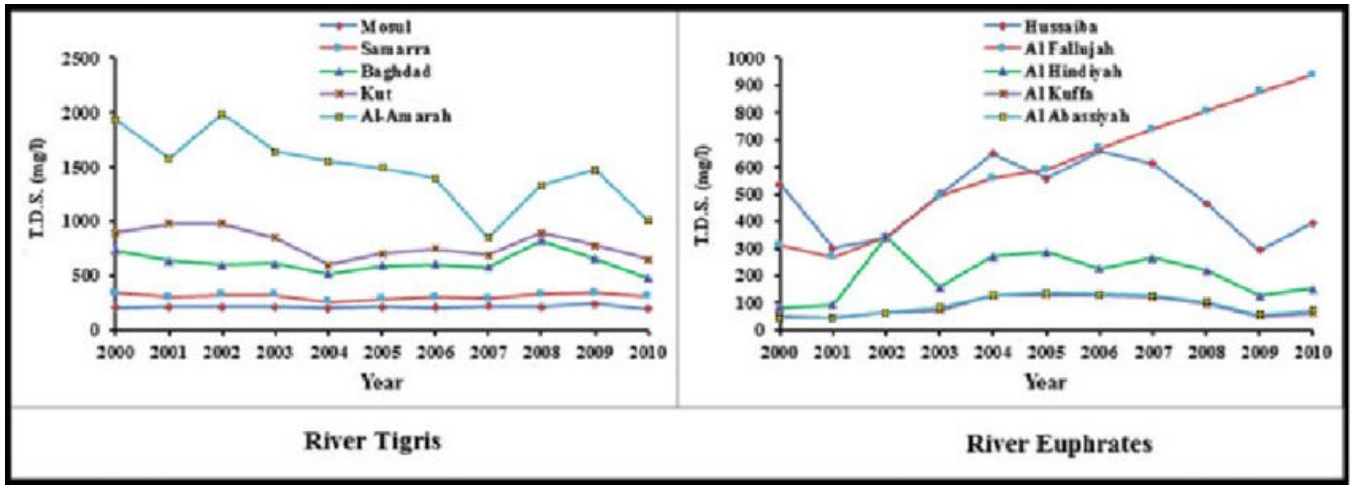


- Water scarcity has made water terrorism - attacks on water systems - even more effective
- Water scarcity has led to zero/negative sum behavior as countries endeavor to secure their water supply which further contributes to declining water quantity and quality in “good” states of the world

Turkey's Power



Local trends: Water Qualified - Total Dissolved Salts



Consequences of Decreased Water Quality

- Existing political conflicts exacerbated
- Dehydration
- Outbreaks of cholera and diarrhea

How will climate change impact on water in TER?

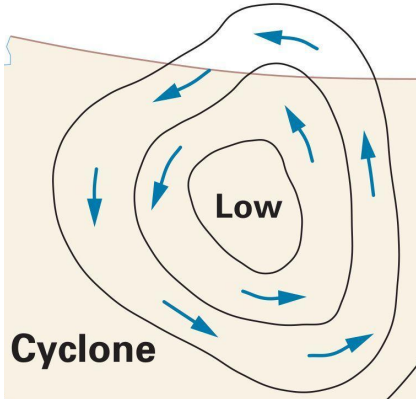
1. How does water flow into TER?

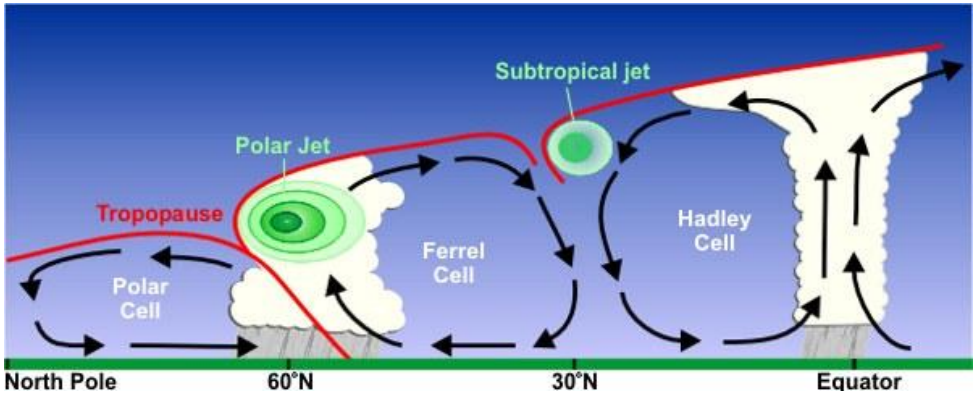
- **Snowmelt**

Snow during winter begins to melt in spring, flowing into the downstream region.

- **Rainstorm [extratropical cyclone, jet stream movement]**

Choi, Y. W., & Eltahir, E. A. (2022). Uncertainty in future projections of precipitation decline over Mesopotamia. *Journal of Climate*, 1-30.





How will climate change impact on water in TER?

1. Models forecast

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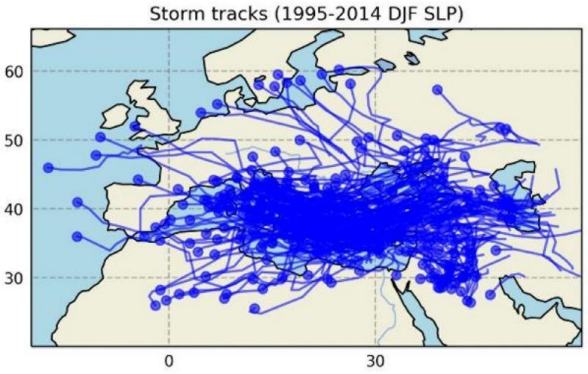
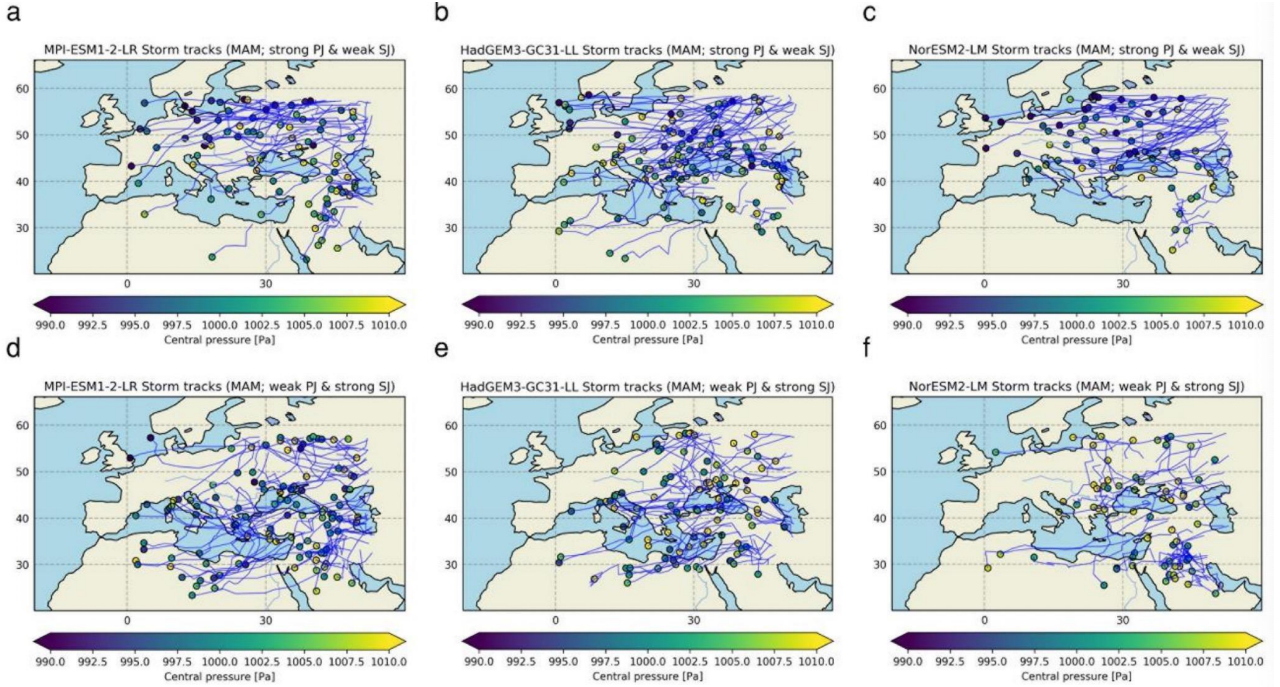
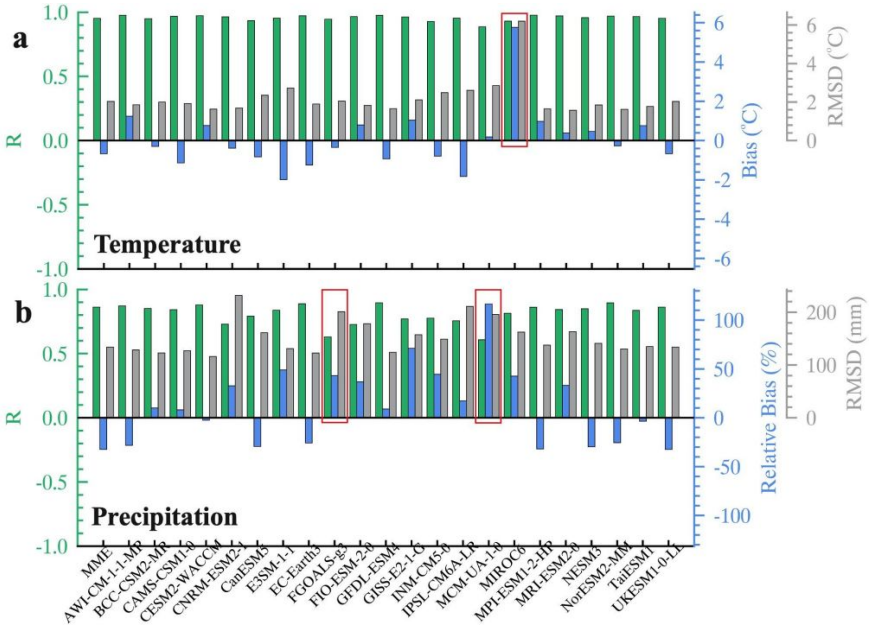
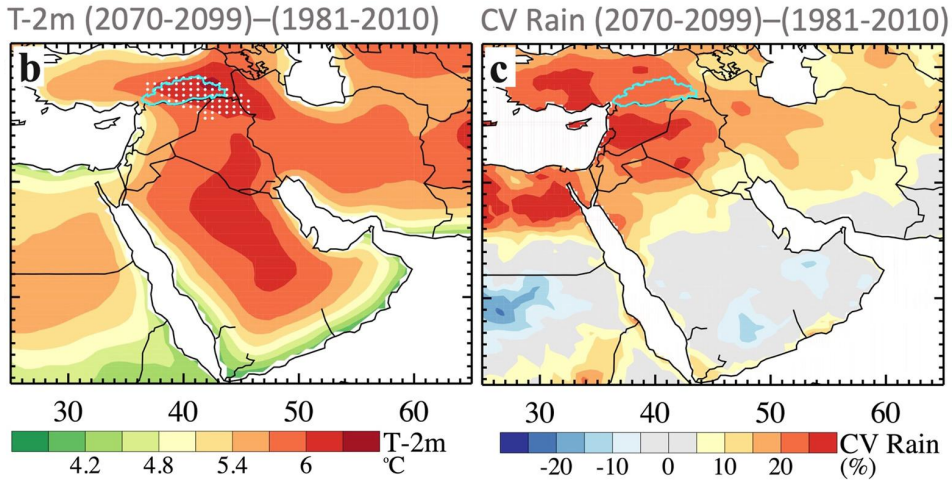




Comparison of climate models' forecast results on Tigris & Euphrates Rivers (TER)

Dezfuli, A., Razavi, S., & Zaitchik, B. F. (2022). Compound effects of climate change on future transboundary water issues in the Middle East. *Earth's Future*, *10*(4), e2022EF002683.





22 CMIP6 GCMs: excluding MIROC6 (Temperature), MCM-UA-1-0 (Precipitation), and FGOALS-g3 (Precipitation)

Comparison of climate models' forecast results on Tigris & Euphrates Rivers (TER)

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22 CMIP6 GCMs: excluding MIROC6 (Temperature), MCM-UA-1-0 (Precipitation), and FGOALS-g3 (Precipitation)

	GCM ID	Country	Horizontal resolution (lon x lat)
1	AWI-CM-1-1-MR	Germany	0.9° x 0.9°
2	BCC-CSM2-MR	China	1.1° x 1.1°
3	CAMS-CSM1-0	China	1.1° x 1.1°
4	CanESM5	Canada	2.8° x 2.8°
5	CESM2-WACCM	USA	1.25° x 0.9°
6	CNRM-ESM2-1	France	1.4° x 1.4°
7	E3SM-1-1	USA	1° x 1°
8	EC-Earth3	Europe	0.7° x 0.7°
9	FGOALS-g3	China	2° x 2.3°
10	FIO-ESM-2-0	China	1.25° x 0.9°
11	GFDL-ESM4	USA	1.25° x 1°
12	GISS-E2-1-G	USA	2.5° x 2°
13	INM-CM5-0	Russia	2° x 1.5°
14	IPSL-CM6A-LR	France	2.5° x 1.25°
15	MCM-UA-1-0	USA	3.75° x 2.2°
16	MIROC6	Japan	1.4° x 1.4°
17	MPI-ESM1-2-HR	Germany	0.9° x 0.9°
18	MRI-ESM2-0	Japan	1.1° x 1.1°
19	NESM3	China	1.9° x 1.9°
20	NorESM2-MM	Norway	1.25° x 0.9°
21	TaiESM1	Taiwan	1.25° x 0.9°
22	UKESM1-0-LL	UK	1.9° x 1.25°

Comparison from other literature

Climate Model	Study Area	Forecast Result (Trend) / Historical verification	Consistency	Reference
Satellite missions and global land surface models (NCA-LDAS NOAH-3.3 model)	Tigris-Euphrates Watershed (30 dams; storage capacity: 250 km^3)	A prolonged (2007–2018) and intense drought in the past 100 years and an impressive recovery (113 ± 11 km^3) in 2019 (high precipitation variability)	High	Abdelmohsen K et al.
Hydrological Predictions for the Environment Model (IRAQ-HYPE)	Tigris & Euphrates basin (50 years range)	Less average yearly precipitation and higher average yearly temperature. Volume of water available is less by around 30%.	High	Hasan, A.et al.
WaterGAP (Water – Global Assessment and Prognosis) & Global general circulation model ECHAM4	Mediterranean & North Africa (2061-2090)	100-year drought could occur 10 times more frequently in the future over the large part of the northern Mediterranean, while in North Africa, today's 100-year drought will occur less frequently	Relatively high, but with some abnormal region	M. Weiß
PRECIS (Providing Regional Climates for Impact Studies) regional climate model	Middle East (the period 1901-2006)	A continual, gradual and relatively strong warming of about 3.5–7°C between the 1961–1990 reference period and the period 2070–2099.	High in trend, but relatively large temp forecast	J. Lelieveld
GCM Japan Meteorological Agency's (JMA) operational numerical weather prediction model	Middle East (2080-2099)	The Euphrates River annual flow; as one case, might suffer a reduction of, (29–73) %, as well as the stream flow of the Jordan River	High	A Kitoh et al.
A statistical downscaling model (SDSM)	The Euphrates River (predict from 2022 to 2028)	Receive a flowrate of 1,535,945 m^3 in 2026, which is the highest value when compared with the values of flowrate for the years 2022, 2024, and 2028	High	HH Kareem et al.

How will climate change impact on water in TER?

2. Direct climate change impact on water

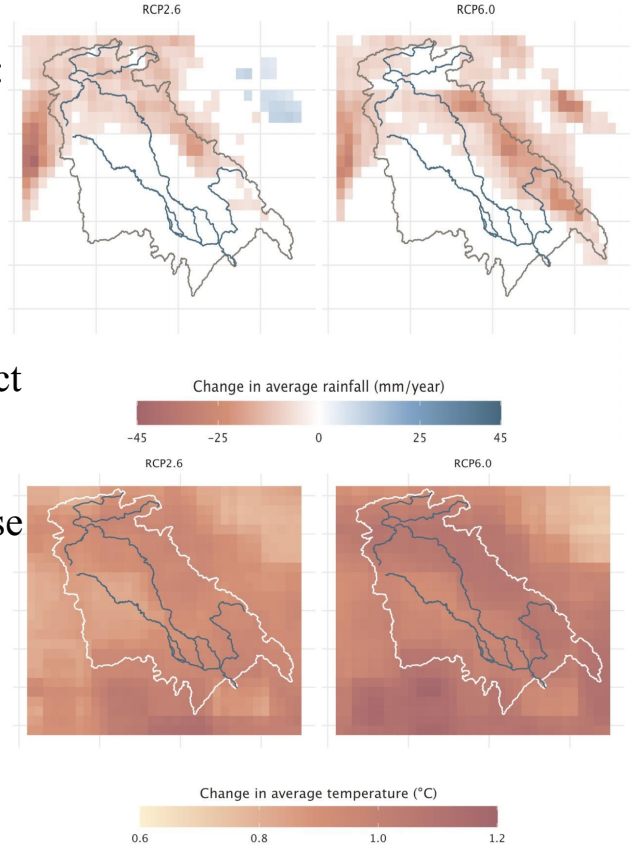
- Meteorological and climate impact:

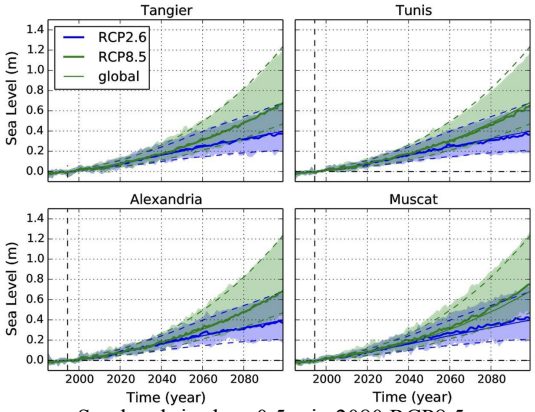
1. Precipitation decreases
2. Temperature rises
3. Evaporation changes
4. Snowpack decreases

…

- Hydrological and biophysical impact

1. Runoff, higher variability
2. Soil moisture decreases
3. Droughts, more frequent and intense
4. Sea-level rise & Flood, frequent





Sea-level rise by ~0.5m in 2080 RCP8.5

How will climate change impact on water in TER?
3. Water-related impacts

Livelihoods, food, and water security

- Crops, agriculture (food security)
- water quality, ecosystems
- drinking water supply & sanitation

Based on World Bank data 2018, it is estimated that about 15% of deaths of children in Syria are related to poor water services and exposure to waterborne diseases.

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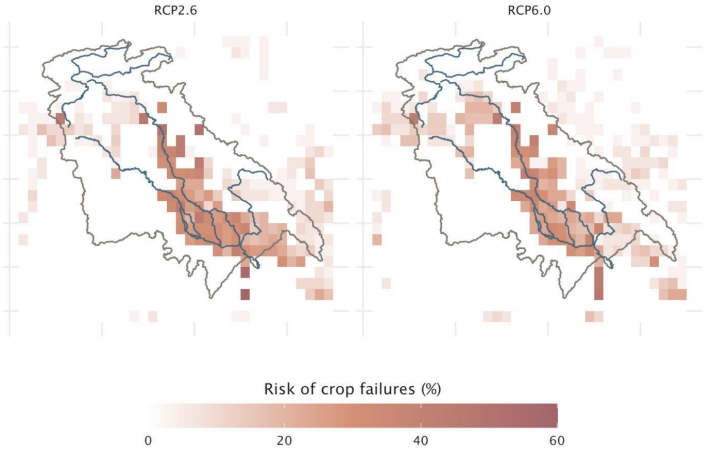
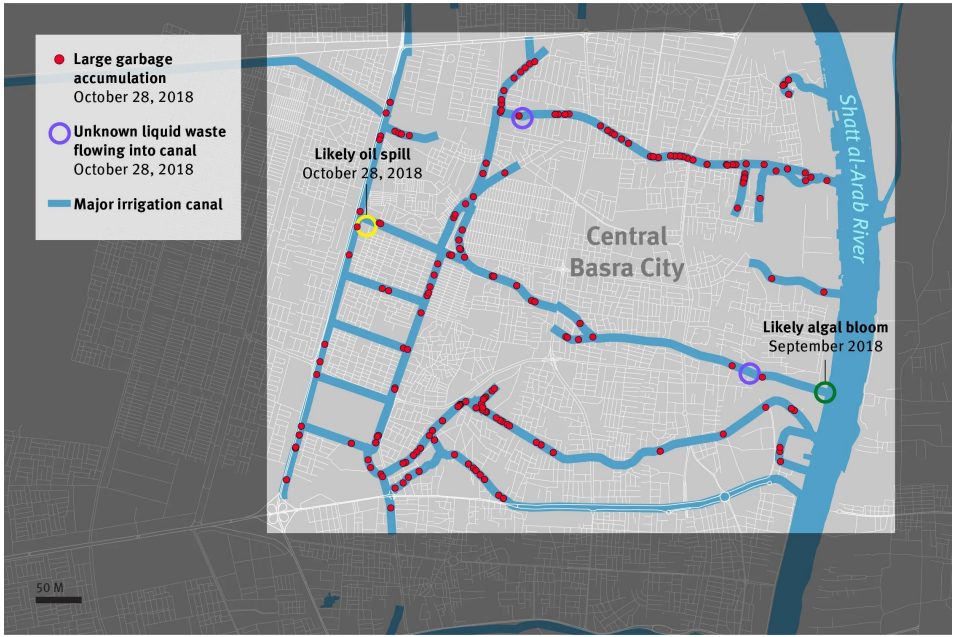


Droughts and crop failures based on ISIMIP model over next 30 years

How will climate change impact on water in TER?
3. Water pollution problem (2018 water crisis in Basra, Iraq)



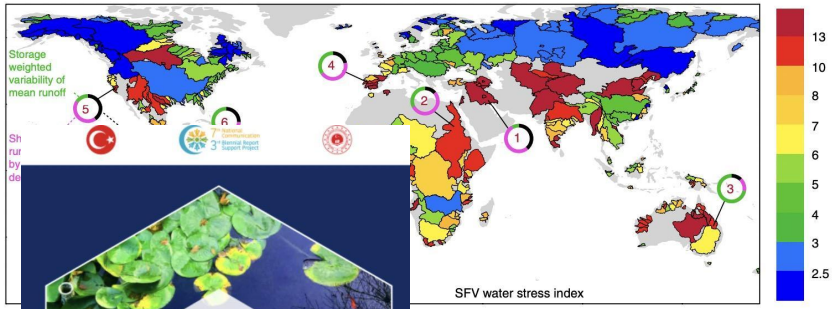
A range of contaminants in the Shatt al-Arab and connected waterways in central Basra city during the health crisis from September to October 2018 that Human Rights Watch identified in satellite imagery.

a likely large harmful algal bloom along the Shatt al-Arab in the middle of the city of Basra that may have contributed to the health crisis in the summer of 2018.

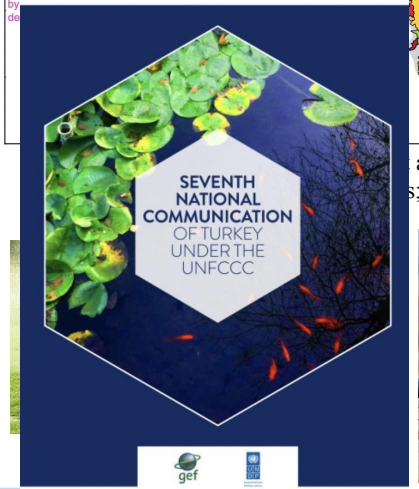
Human adaptation to climate change in TER

1. Water management

- **Water management**
  - **Demand management**
    - flexible water use in agriculture
    - water-saving techniques in irrigation
    - create water-usage efficiency projects
  - **Supply augmentation**
    - expanding wastewater treatment rate
    - wastewater reuse
  - **Water pollution & quality**
    - salinisation
    - reducing pesticide
    - fertilizer application
    - limiting untreated wastewater discharge
  - **Conservation of freshwater ecosystems**
    - conservation projects such as rehabilitation of the Mesopotamian Marshes
  - **Build dam reservoirs**
    - Bufering the impacts of extreme climate variability in the highly engineered Tigris Euphrates river system



al. 2019 Nature sustainability)
s; (2) fixing leakages (urban)



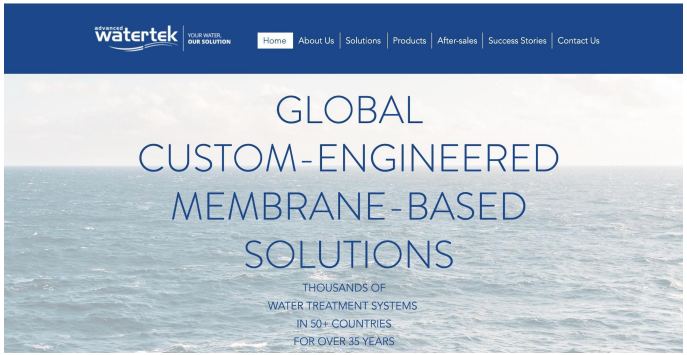
Drip Irrigation

Human adaptation to climate change in TER

1. Water management

- Supply augmentation
  - expanding wastewater treatment rate
  - wastewater reuse
- Water pollution & quality
  - salinisation
  - reducing pesticide
  - fertilizer application
  - limiting untreated wastewater discharge
- Conservation of freshwater ecosystems
  - conservation projects such as rehabilitation of the Mesopotamian Marshes

- Activated Sludge (AS) improvements
- Passive aeration biofilm oxygenation technique
- Advances in Ultrafiltration (UF) membranes

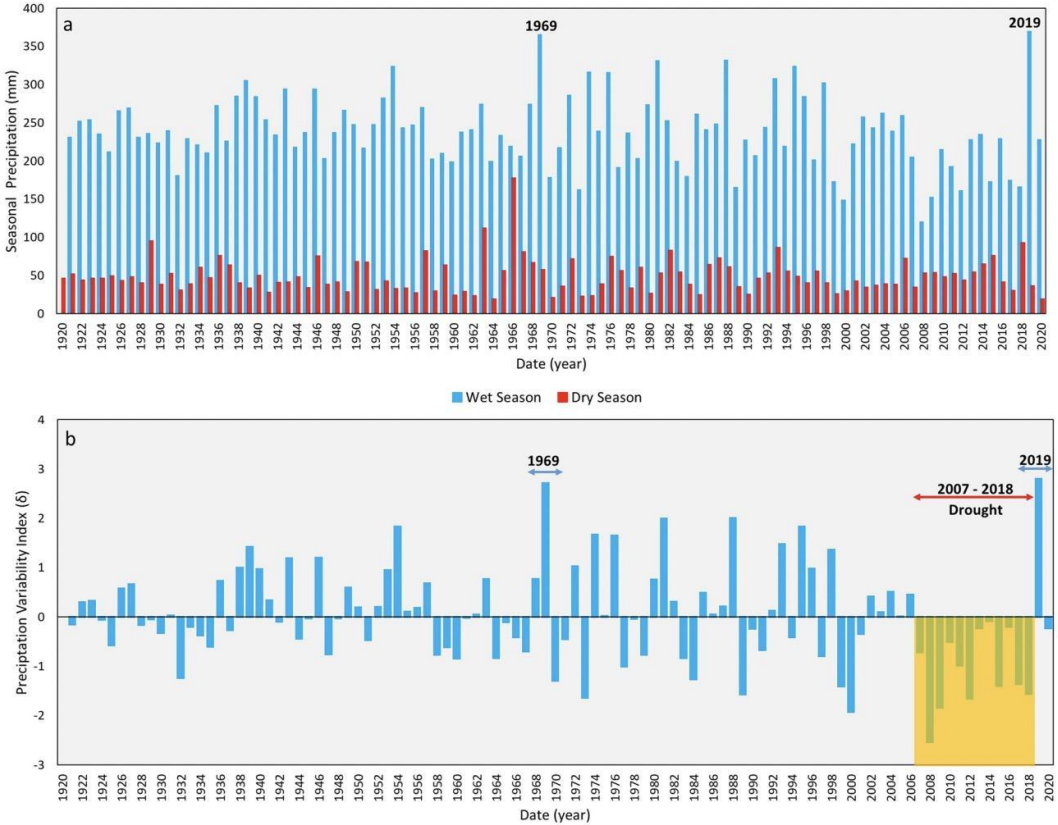


A UF membranes tech in Dubai, UAE

Mesopotamian Marshes, 1.4% compared with 16% global

Human adaptation to climate change in TER

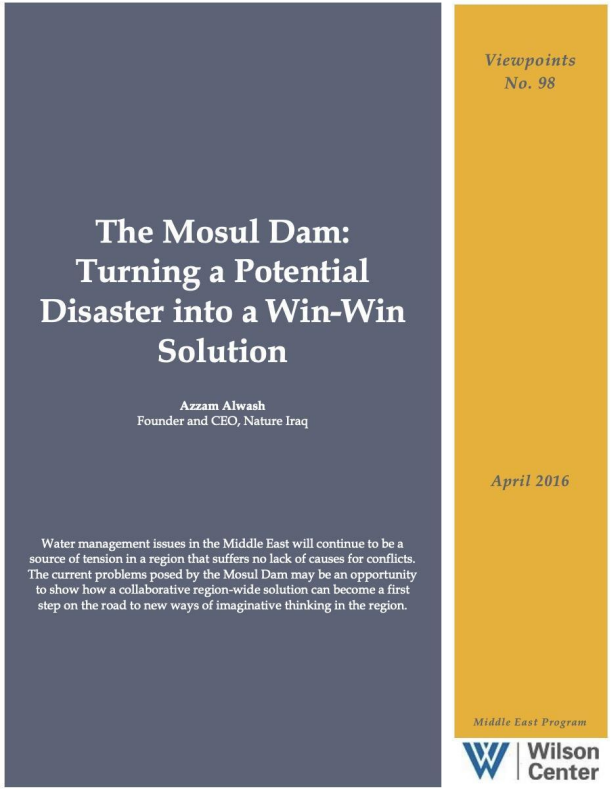
1. Building dam reservoirs? (case study)



- Abdelmohsen K, Sultan M, Save H, et al. Buffering the impacts of extreme climate variability in the highly engineered Tigris Euphrates River system[J]. Scientific reports, 2022, 12(1): 1-13.
- Modulate the projected climate change-related extreme foods and droughts in the twenty-first century
- Negative impacts?

1. disputes over water rights
2. increase surface water area and losses to evaporation
3. modify river sediment transport
4. cause biotic changes in downstream ecosystems

Human adaptation to climate change in TER
2. Transboundary & regional cooperation



- Turkey could store water for Iraq in its territory, where evaporation losses are low and the topography is more suitable for building reservoirs;
- While Iraq offers Turkey cheap energy in exchange (including solar power and fossil gas)

Human adaptation to climate change in TER

Many others for further discussion, like national-level water governance and water affordability and equity problems…

Bibliography - Minghao

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Bold citations represent key references to the presentation & report.

Tigris and Euphrates Rivers

Thank You!

Questions?

Photograph by JANE SWEENEY, National Geographic

Water in Tigris and Euphrates Rivers:

Group 1: Joanne Im & Minghao Chen