Analyzing Groundwater Depletion in the Valley of Mexico Aquifer Using GRACE

By Avriel Null

Introduction

- Spanish conquering of Aztec capital of Tenochtitlan on Lake Texcoco
  - Layers of soft sands and clays
- Cocos plate subducting beneath the North American Plate
  - Increased elasticity and decreased stability of the sediments
- Oldest capital in the Americas has regional population of nearly 22 million
  - Most populous city in North America
- 43.9 percent below poverty line
  - 9 percent lived in extreme poverty

Introduction

- As population densities continue to soar, access to basic resources grows scarcer and levels of pollution increase.
- Water availability continues to decline as water management practices are unable to meet demands
- Aquifers: Valley of Mexico, Lerma-Balsas river basin, and Cutzamala river basin
  - Rivers not channelized are polluted by wastewater
  - Steep transportation & pumping costs
  - Overexploitation of aquifers & land subsidence
- Landcover changes & deforestation from overpopulation

Introduction

- Five drainage systems
  - Still lack proper drainage systems and water supply infrastructure
  - Vulnerable to earthquakes
- Poor water quality & Heavily-tariffed water
  - Based on amount of consumption and type of user
- Extreme levels of water are unaccounted for due to:
  - Illegal network connections, aging pipes, lack of maintenance, & poor construction
- Nearly 20 percent without access to clean water critical for drinking, laundry, cleaning, and hygiene.
- Unless current trends and practices change, steep investment costs to transport more water from distant and expensive sources will be required

Objectives

- Determine water equivalent thickness measurements in regions surrounding Mexico City from 2002 to 2022
- Provide classified Landsat imagery of Mexico City region defining changes in landcover
- Examine water management practices and describe potential options for future water management strategies.

Methods

- GRACE Data Analysis Tool by NASA
  - Land-based water equivalent thickness measurements from April 2002 to April 2022 in the four surrounding regions
- NASA Earth Systems Data Explorer
  - Model-Calculated Monthly Mean Soil Moisture from April 2002 to April 2022 over the Mexico City region
- USGS Global Visualization Viewer (GloVis)
  - Landsat imagery from multiple years between April 2002 to April 2022 over the Mexico City Region
  - Classified based on landcover

Figure 1: Targeted study site of Mexico City region

Methods

- The GRACE twin satellites measure Earth's gravity field changes and improve knowledge of about Earth's water reservoirs over land, ice and oceans by measuring changes in the local pull of gravity as water shifts around Earth due to changing seasons, weather and climate processes (NASA, 2023).
- The Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission was launched as a successor to the original GRACE mission and continues the work of tracking Earth's water movement to monitor changes in underground water storage, the amount of water in large lakes and rivers, soil moisture, ice sheets and glaciers, and sea level caused by the addition of water to the ocean (NASA, 2023). GRACE-FO collects accurate measurements due to two advanced technologies:
  - Microwave ranging system based on Global Positioning System (GPS) technology
  - Extremely sensitive accelerometer, an instrument that measures the forces on the satellites besides gravity
- The observed monthly changes in gravity are caused by monthly changes in mass which can be thought of as concentrated in a very thin layer of water thickness changes near the Earth's surface in a layer up to several kilometers thick (NASA, 2023).
- Most monthly gravity changes are caused by changes in water storage in hydrologic reservoirs, by moving ocean, atmospheric and land ice masses, and by mass exchanges between these Earth system compartments (NASA, 2023).

Results

- Using the GRACE Data Analysis Tool by NASA, land-based monthly water equivalent thickness measurements were averaged from April 2002 to April 2022 in the four surrounding regions (Figure 2).

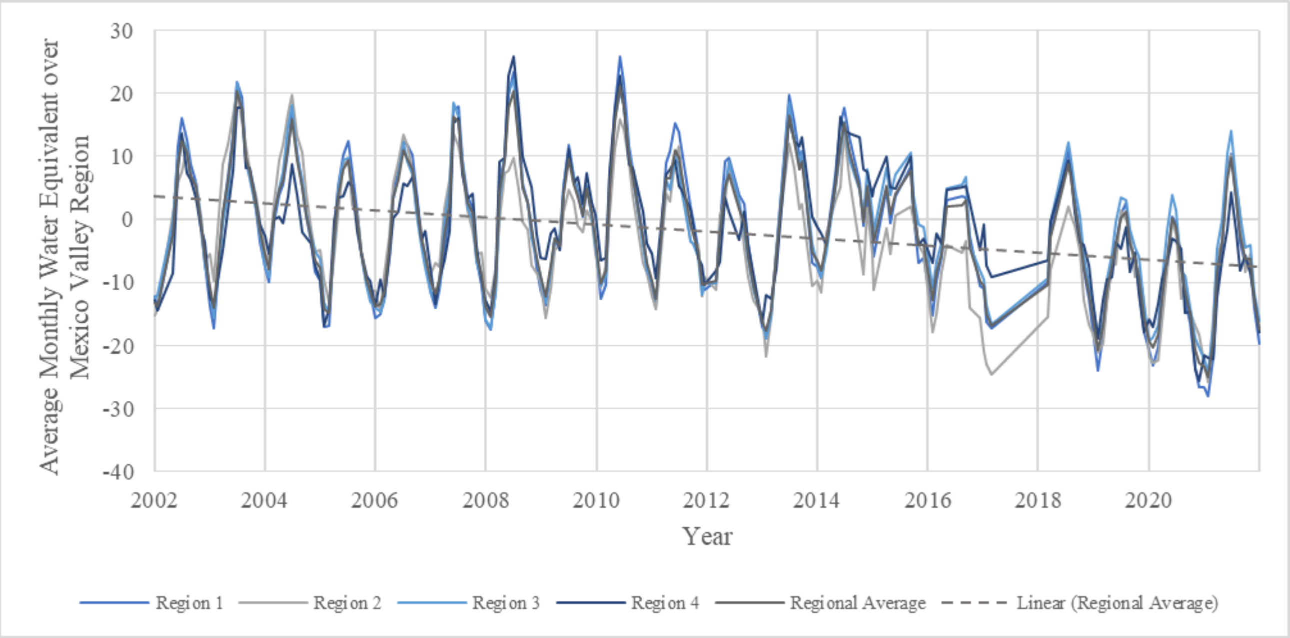


Figure 2: Average monthly water equivalent thickness measurements over Mexico Valley Region from April 2002 to April 2022

Results

- Using the GRACE Data Analysis Tool by NASA, land-based annual water equivalent thickness measurements were averaged from April 2002 to April 2022 in the four surrounding regions (Figure 3).

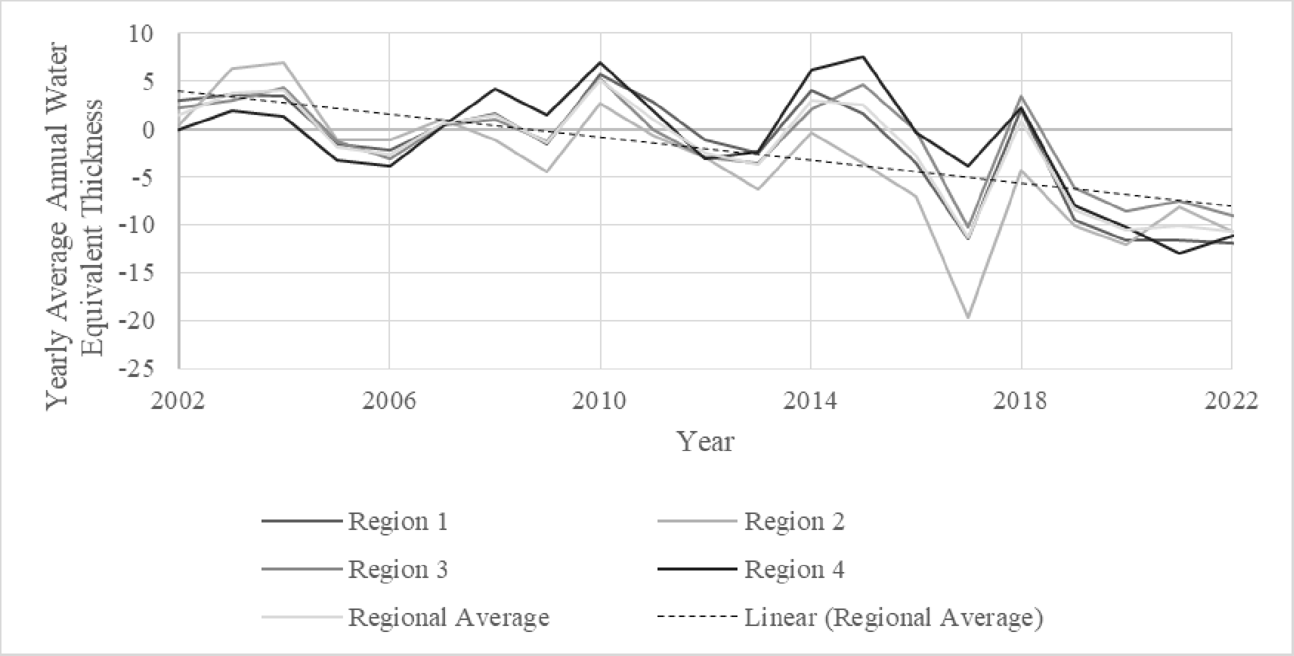
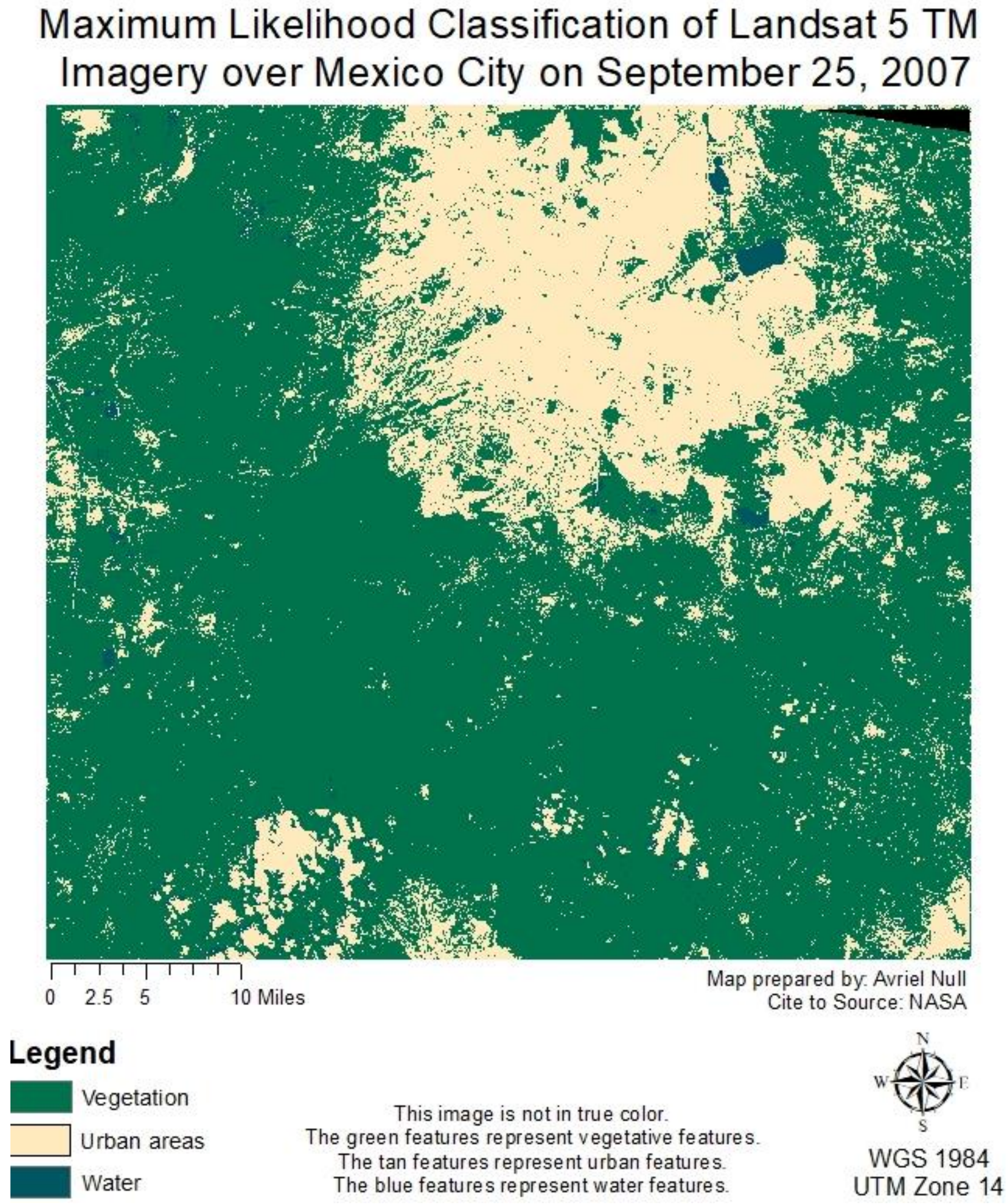


Figure 3: Average annual water equivalent thickness measurements over Mexico Valley Region from April 2002 to April 2022

Results

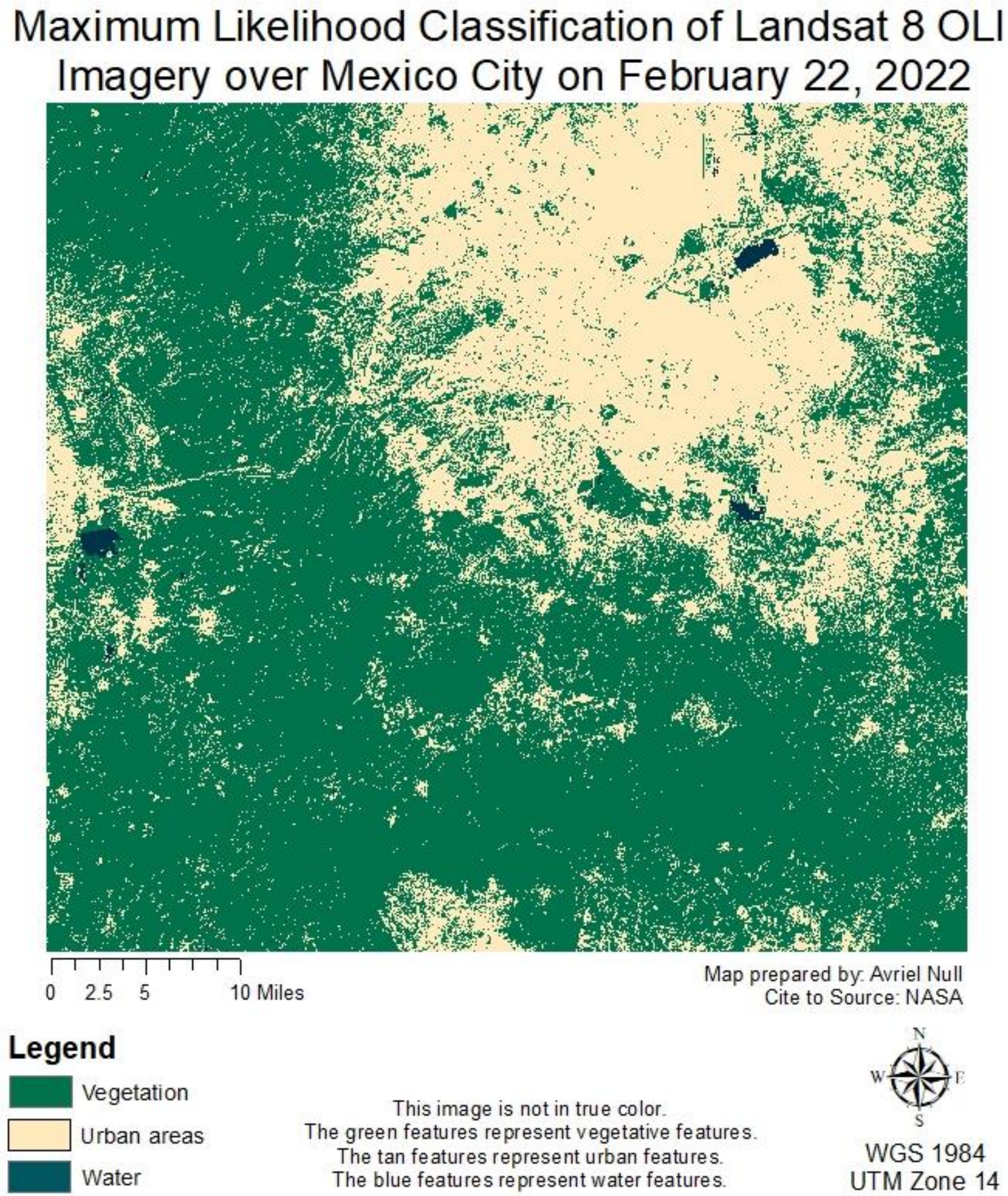
- Model-Calculated Monthly Mean Soil Moisture (millimeters) was calculated using the NASA Earth Systems Data Explorer from April 2002 to April 2022 over the Mexico City Region (Figure 4).
- Monthly Mean Soil Moisture describes the monthly amount of moisture in the soil and is the volume of water found 0-10 cm below the soil surface.
- Soil moisture volume is measured in cubic centimeters of water per cubic centimeter of soil.

Figure 4: Model-Calculated Monthly Mean Soil Moisture (millimeters) over Mexico Valley Region from April 2002 to April 2022.



Results

- Area of Vegetated Features: 4,161,474,000 m^3
- Area of Urban Features: 1,441,248,300 m^3

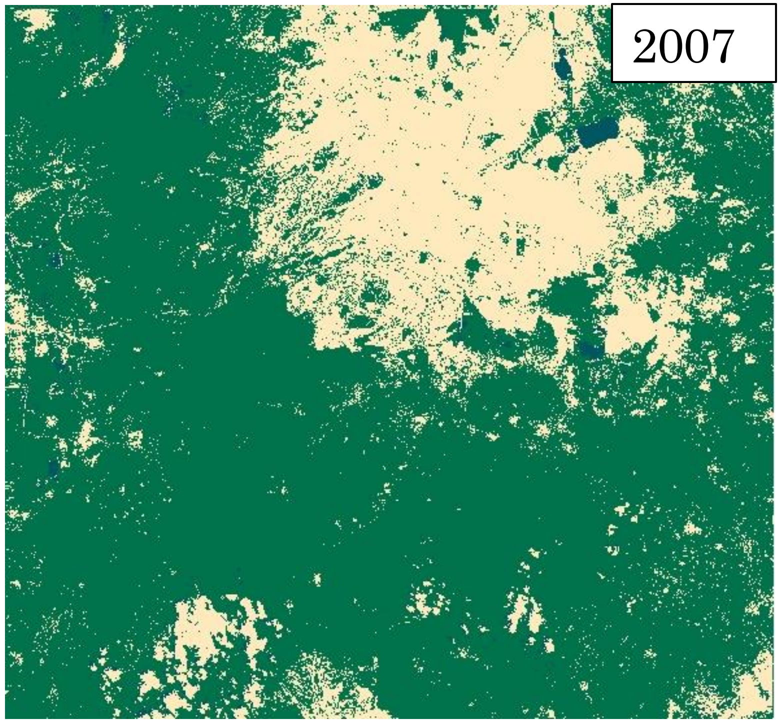


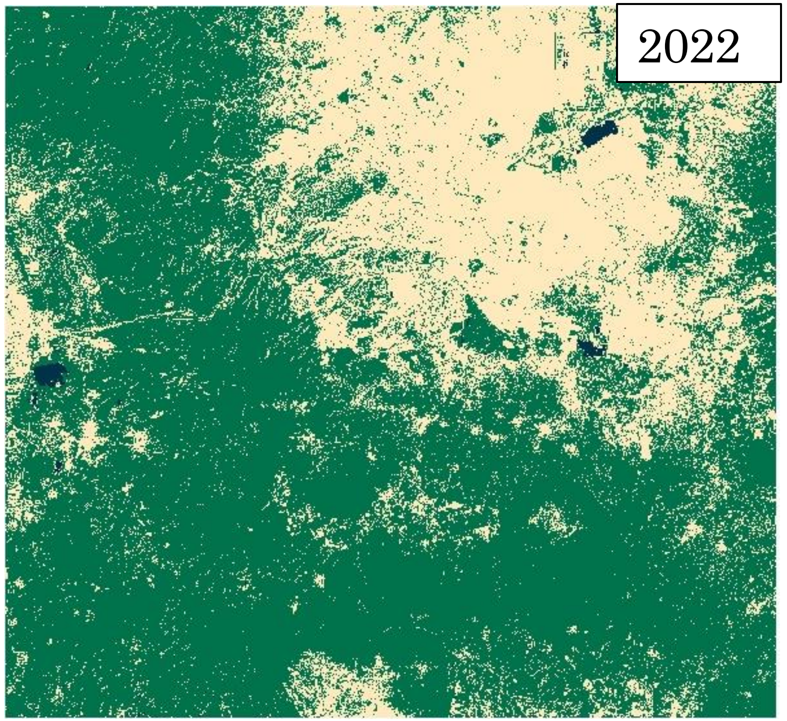
Results

- Area of Vegetated Features: 3,755,612,700 m^3
- Area of Urban Features: 1,941,646,500 m^3

Results

- The area of the vegetated features decreased by 405,861,300 m^3 or by 9.75% in the selected region. Insert graph
- The area of the urban features increased by 500,398,200 m^3 or by 25.77 % in the selected region.





Discussion

- Water equivalent thickness and soil moisture decreasing in Mexico City region from 2002 to 2022
- As urban population and housing demand continues to grow, changes in land-use from increased cover of concrete and asphalt contribute to decreased groundwater recharge and higher volumes of stormwater discharges.
  - Contribute to large hydrologic fluxes
  - Drier climates have low infiltration rates and heavy runoff amounts
- High volumes of untreated wastewater have been polluting the region for years, creating significant health and environment-related problems and concerns (Tortajada, 2007).
  - Cost of infrastructure and maintenance for wastewater treatment/recycling causes hesitation

Discussion

- All of these concerns are exacerbated by climate change. Impacts include:
  - High surface temperatures
  - Increased drought and glacial melt
  - More severe storms and climate disasters
  - Food scarcity
  - Increased health concerns
  - Increased poverty and displacement.
- Many of these factors affect water availability.
- The sustainability of Mexico City's water management and availability differs based on
  - Increasing energy demands needed to pump water and to extract untreated wastewater to the ocean
  - Increased dependence on farther water sources
  - Water source pollution
  - Decreased water quality and availability
  - Wastewater flood occurrence
  - Health and environment-related problems and concerns beyond its political boundaries

Questions?

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