



Quality and Availability of Water in 21st Century (INTRODUCTION)

Core areas (syllabus)

- ▶ Processes of water cycle
- ▶ Quality and availability of water in different parts of the world
- ▶ Water demands in ecosystems, agriculture, and industry
- ▶ Availability and quality of soil water
- ▶ Vulnerability of water resources
- ▶ Strategies for dealing with water scarcity, fundamentals of irrigation and drainage engineering
- ▶ Emerging contaminants and water treatment

Main issues related to water quality/availability

- ▶ agriculture
 - 1st aspect: use of agrochemicals (fertilizers, pesticides → part of applied agrochemicals “end up” in water)
 - 2nd aspect: agriculture consumes more water than any other human activity
- ▶ lack of water treatment in urbanized/highly populated areas (certain parts of the world)
- ▶ polluted areas
- ▶ old landfills and waste dumps without proper insulation/management
- ▶ abandoned industrial areas and facilities
- ▶ mining/industrial waste deposits
- ▶ chemical industry (mainly organic)
- ▶ climate related issues (floods, droughts, desertification)

Water – important substance with anomalous properties

- ▶ provides the very basis of all known forms of life (many plants contain > 90%, adult human > 65%, newborn > 75%, human blood $\approx$ 88% of water)
- ▶ it is more important than oxygen—there are anaerobic life forms that don't require oxygen, but none can survive without water in the long term (days to weeks)
- ▶ key predisposition for life is liquid water. Conditions on earth's surface enable water to exist in liquid state due to specific ranges of temperature and pressure.
- ▶ 71% of earth's surface are covered with water, but only 3% is “fresh” (i.e., low concentration of dissolved salts), and that amount is unevenly distributed
- ▶ the world contains an estimated 1 400 million km³ of water. But only 0.003% of this vast amount (about 45 000 km³) are “fresh” water resources and only 9 000 to 14 000 km³ is available for human use (FAO)
- ▶ water is partaking on global climate and temperature control, mainly due to its high specific heat and other thermal properties

a)



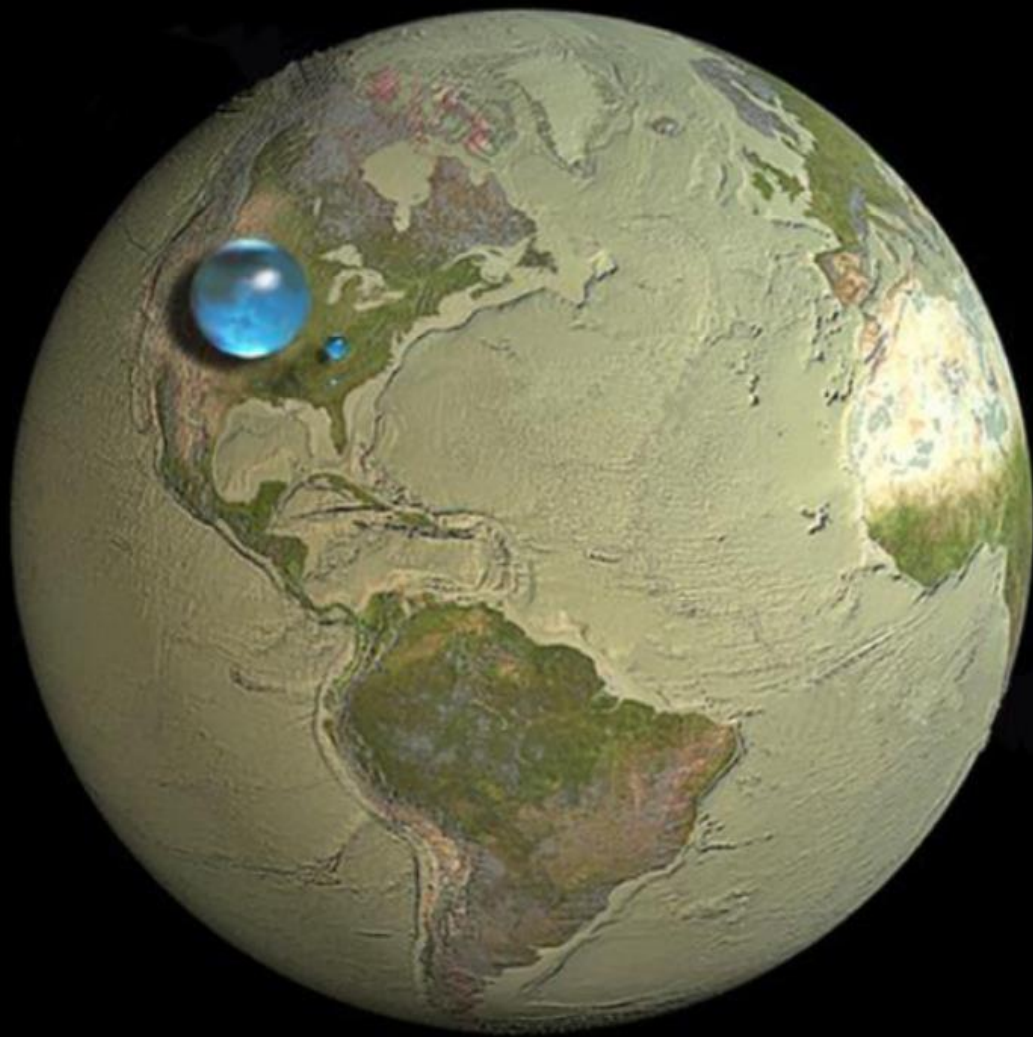
All water on, in, and above the Earth



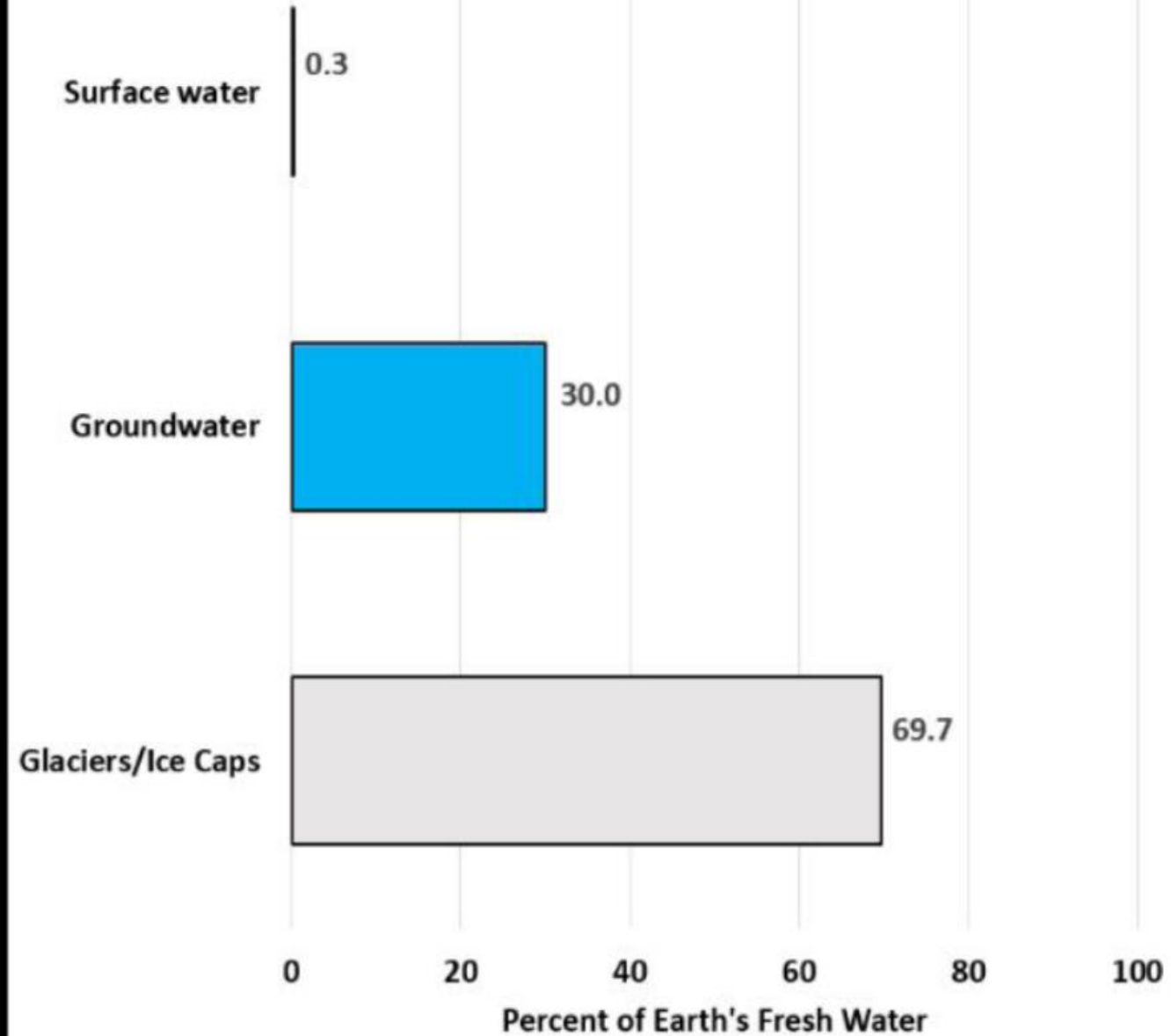
Fresh Groundwater



Fresh Surface Water



b) Fresh (low salinity) water



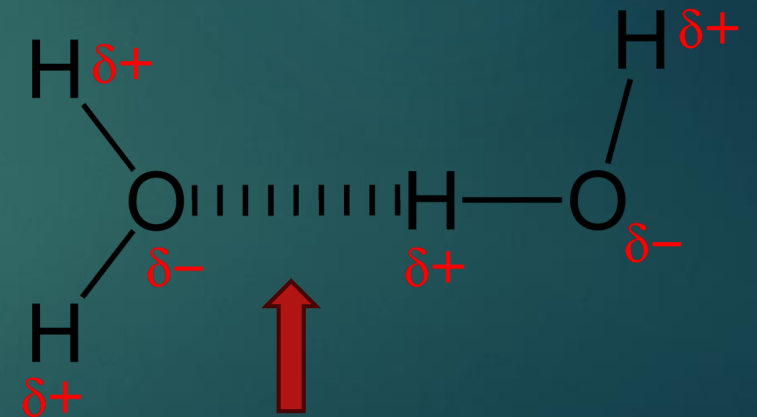
Water – important substance with anomalous properties

- ▶ being composed of two gases and having relatively low molecular weight, water is a liquid and not a gas at normal temperatures
- ▶ in nature no other liquid occurs in liquid, vapor and solid states in relatively narrow temperature range

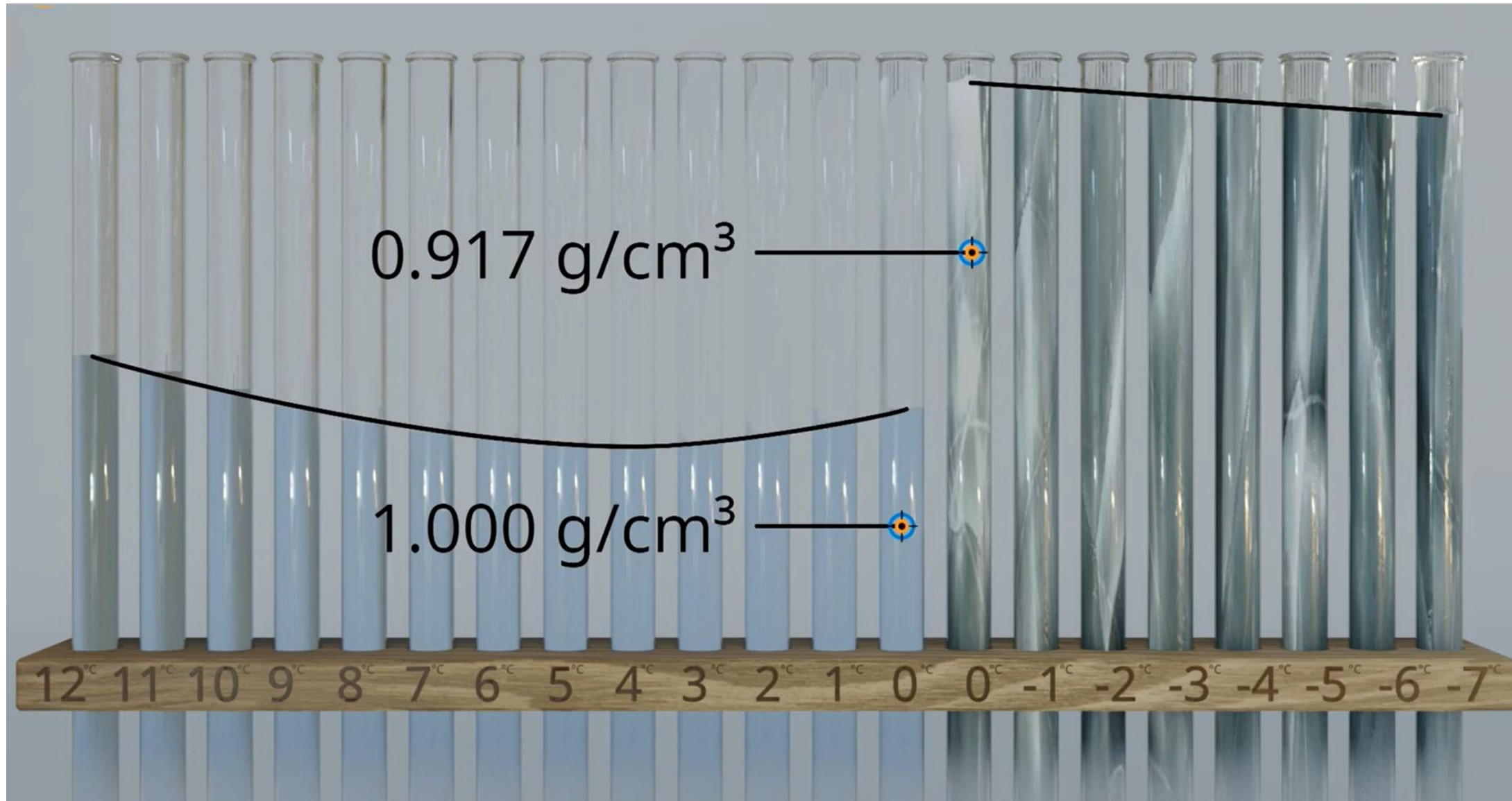
Compared to other liquids, water has unusually high:

- ▶ melting and boiling points,
- ▶ heats of fusion and vaporization,
- ▶ specific heat,
- ▶ dielectric constant,
- ▶ viscosity and surface tension

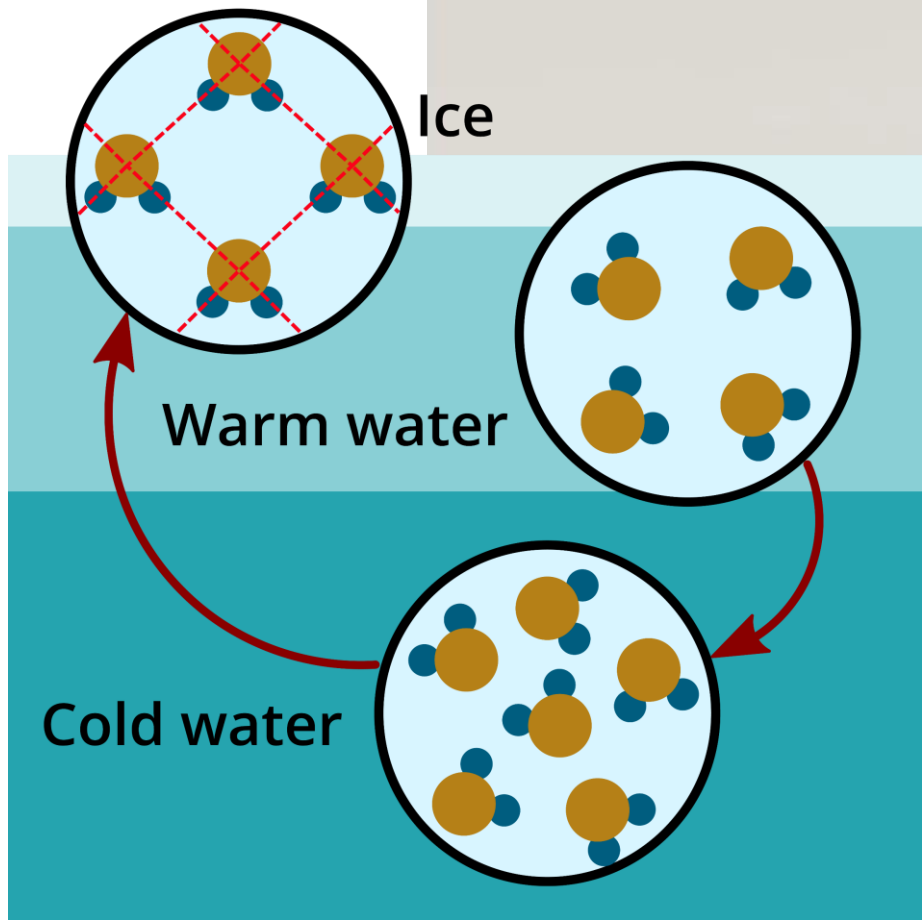
several of these “anomalies” are caused by relatively strong intermolecular forces (hydrogen bonds) that attract H₂O molecules



Density anomaly:



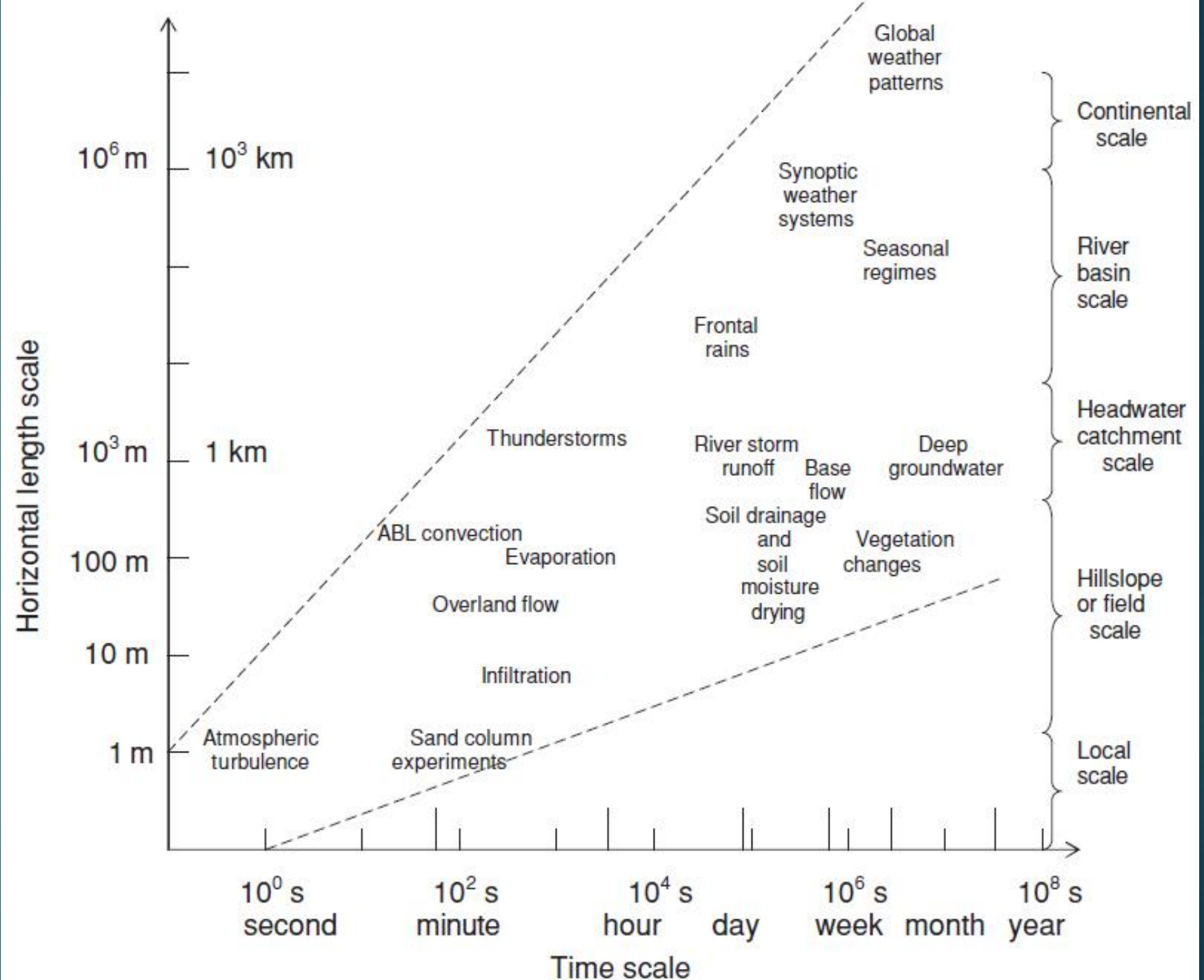
Since density of ice is approximately 90% liquid water $\rightarrow$ approximately 90% portion of ice's volume will be located beneath the water-air interface



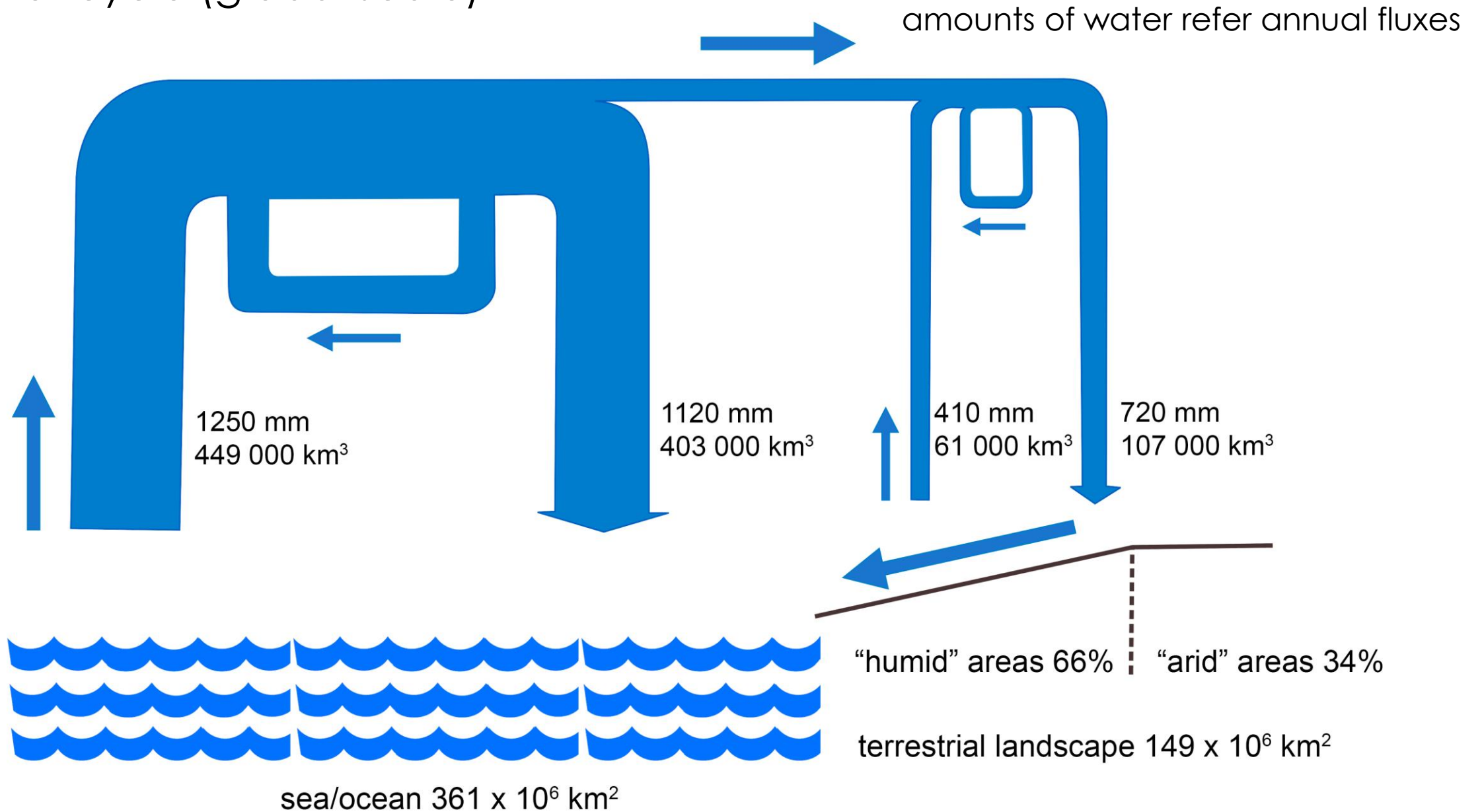
Water cycle (general info)

- ▶ continuous movement of water in the Earth-atmosphere system
- ▶ driven mainly by sun energy and gravity
- ▶ various physical (evaporation, condensation, precipitation), biological (photosynthesis), and chemical (reactions between water and gases in the atmosphere, or soils and sediments) processes are involved
- ▶ three components are distinguished:
 - blue flux/component (water in the atmosphere, rivers, lakes) → hydrosphere
 - green flux/component (water in ecosystems available for the plants) → biosphere
 - grey flux/component (water used in industry)
- ▶ “virtual” water (e.g. water footprint data, amount of water consumed per mass of beef meat)

Spatial and temporal scales of hydrological processes



Water cycle (global scale)

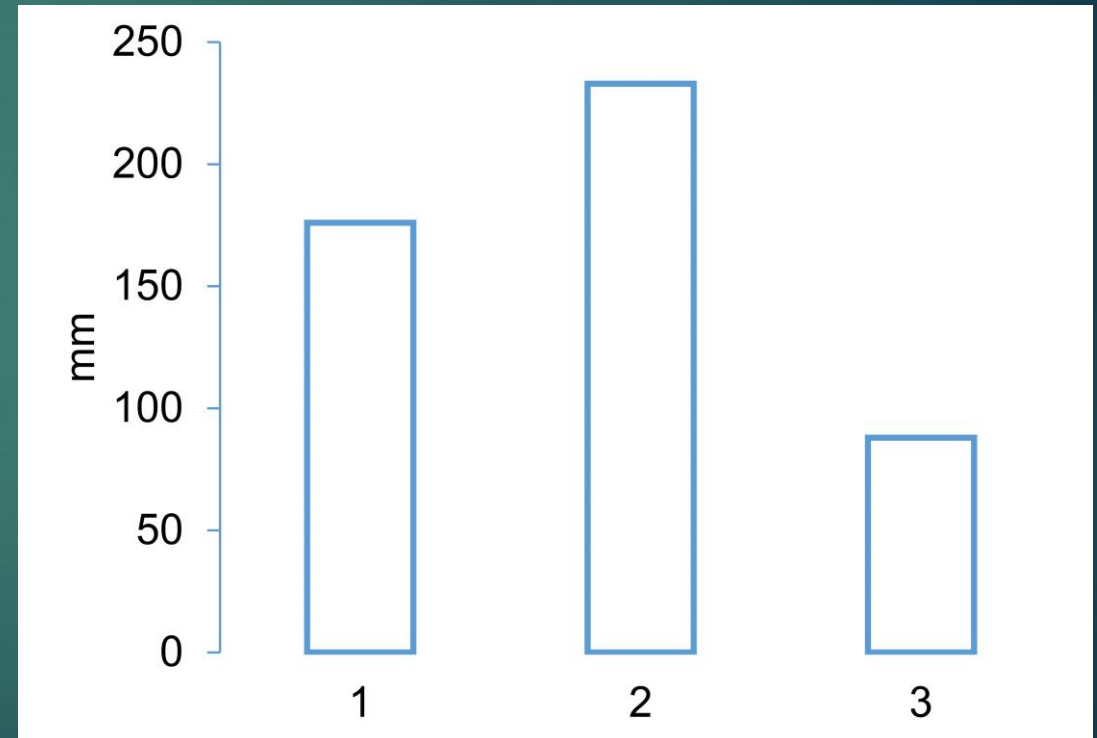


Water cycle (processes)

- ▶ Evaporation: change of liquid water to a gaseous state
- ▶ Transpiration: evaporation of water from plants into the atmosphere
- ▶ Sublimation: snow and ice change to vapor without becoming liquid
- ▶ Condensation: formation of water droplets (clouds)
- ▶ Water movement through the atmosphere in its solid, liquid or gaseous form
- ▶ Precipitation: fall of water from the atmosphere in liquid or solid form
- ▶ Infiltration: water entry into the soil
- ▶ Surface flow: rivers, lakes and stream flow to the ocean
- ▶ Subsurface flow (saturated or unsaturated)
- ▶ Plant uptake

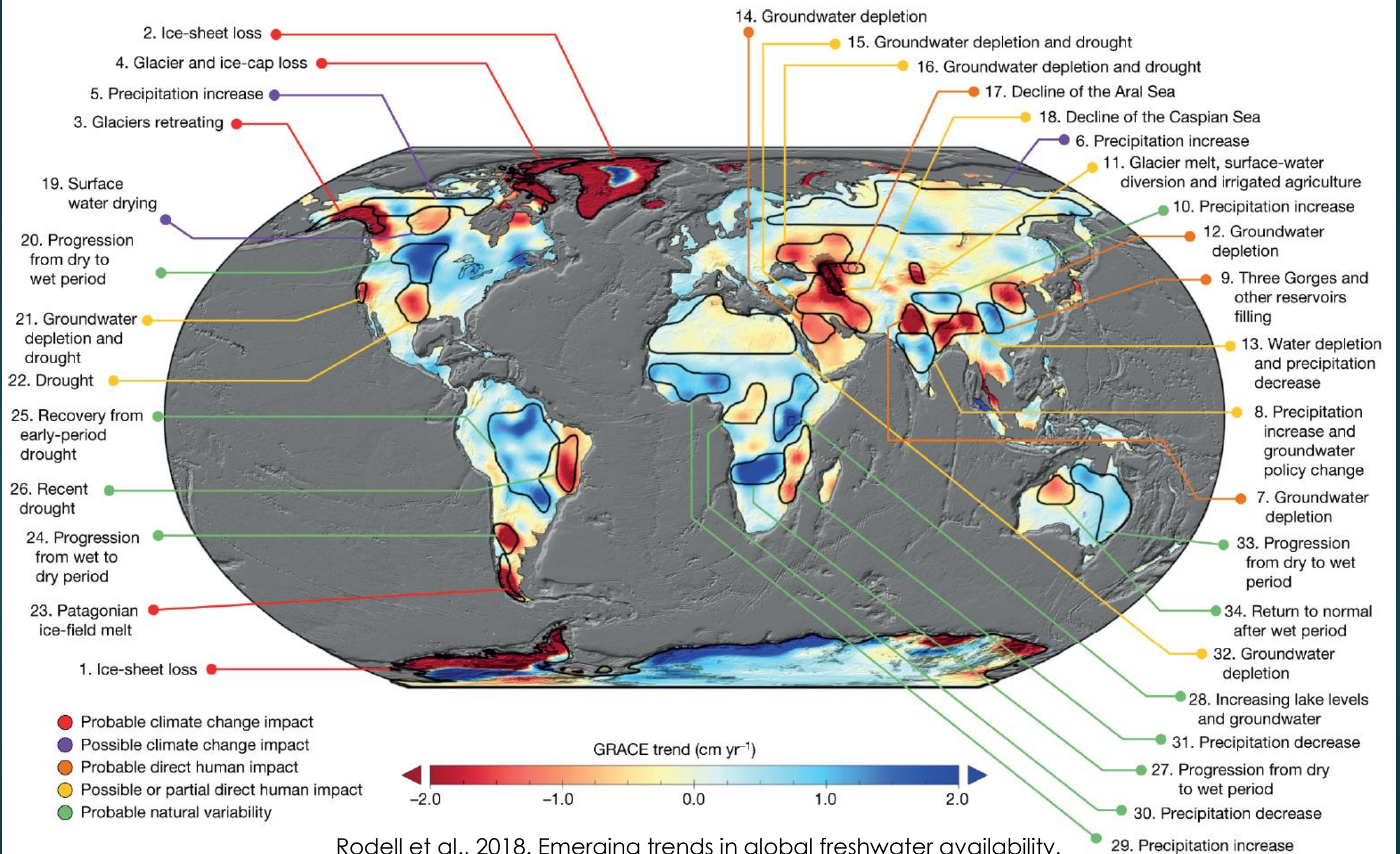
Terrestrial water cycle (global scale)

- ▶ 836 mm/year = average rainfall
- ▶ 59% evapotranspiration:
 1. evaporation from soil surface ≈ 176 mm/year
 2. transpiration by plants ≈ 233 mm/year
 3. evaporation without entering the soil or plants ≈ 88 mm/year



Water cycle (recent changes)

- ▶ Intensification of water cycle (evapotranspiration and precipitation)
- ▶ Occurrence of extreme hydrological events:
 1. Intense precipitation followed by Flooding
 2. Drought / Water scarcity
- ▶ Changes in freshwater reservoirs (glaciers, seasonal snow cover, wetlands and lakes)
- ▶ Groundwater (rate of extraction exceeds recharge rate)
- ▶ Changes in terrestrial Water Storage
- ▶ Anthropogenic aerosols
- ▶ Water pollution (nitrates, phosphates, petroleum compounds, risk elements and heavy metals, pesticides, pharmaceuticals, etc.)



Rodell et al., 2018. Emerging trends in global freshwater availability.

GRACE mission (Gravity Recovery and Climate Experiment)

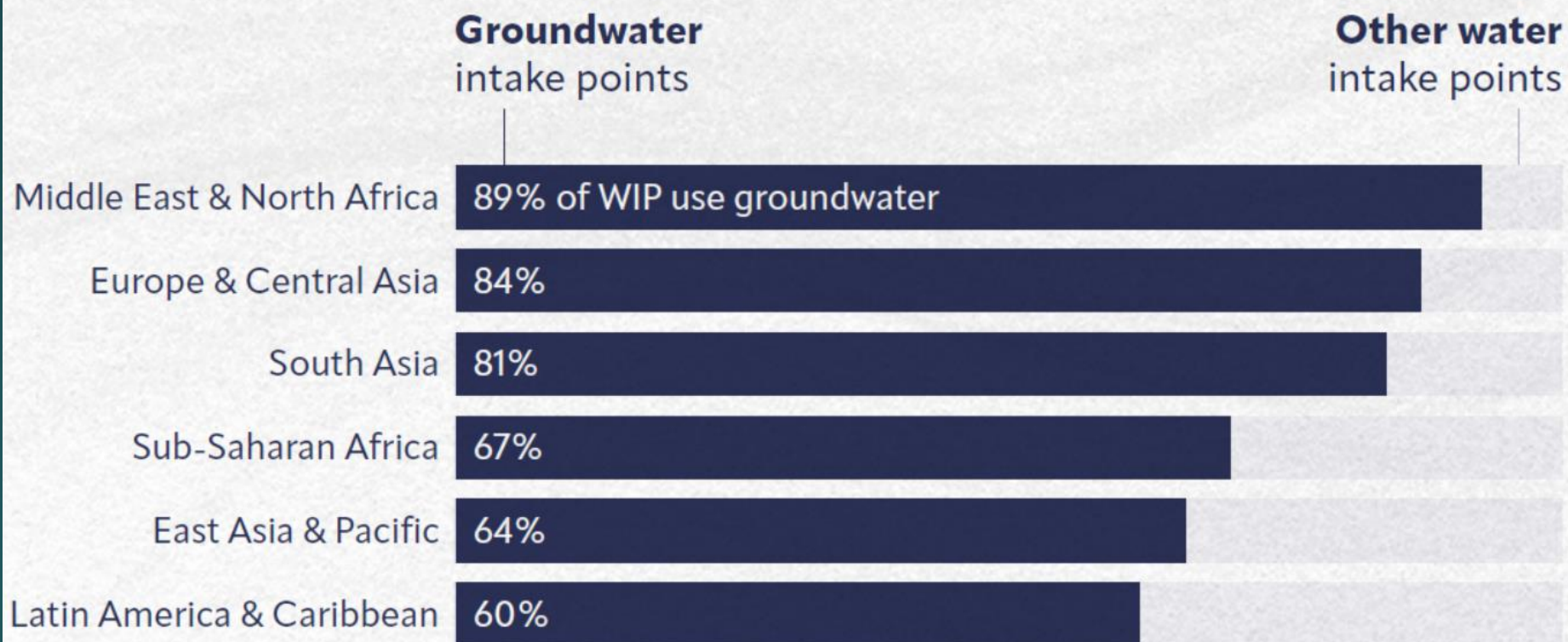
- ▶ satellites detect changes in Earth's gravity field over time
- ▶ because mass moves — and water is mass.
- ▶ if a region gains or loses large amounts of water (e.g. groundwater depletion, ice melt, reservoir filling), that region's gravity slightly increases or decreases
- ▶ can detect mass changes equivalent to ~1.5 cm of water over areas ~200,000 km² (about the size of a US state like Nebraska or Greece).
- ▶ trends are often averaged over regions or gridded at 0.5° (~50 km) resolution.
- ▶ it's not good at small, local-scale water tracking — but excellent at regional to continental scale trends, which is what you see in your map

Water resources – groundwater

- ▶ groundwater resources are the world's third largest source of water behind oceans (97%) and glaciers (2%), and represent 0.6% of the earth's water content
- ▶ approximately 53% of the US population uses groundwater as a drinking water source, but this percentage increases to almost 97% for rural house-holds
- ▶ in Bratislava 100% of drinking water comes from groundwater
- ▶ groundwater is in general cleaner considering organic pollution or harmful (micro)organisms and it contains inorganic components which are essential for human health, unlike rainwater, where mineralization is much lower

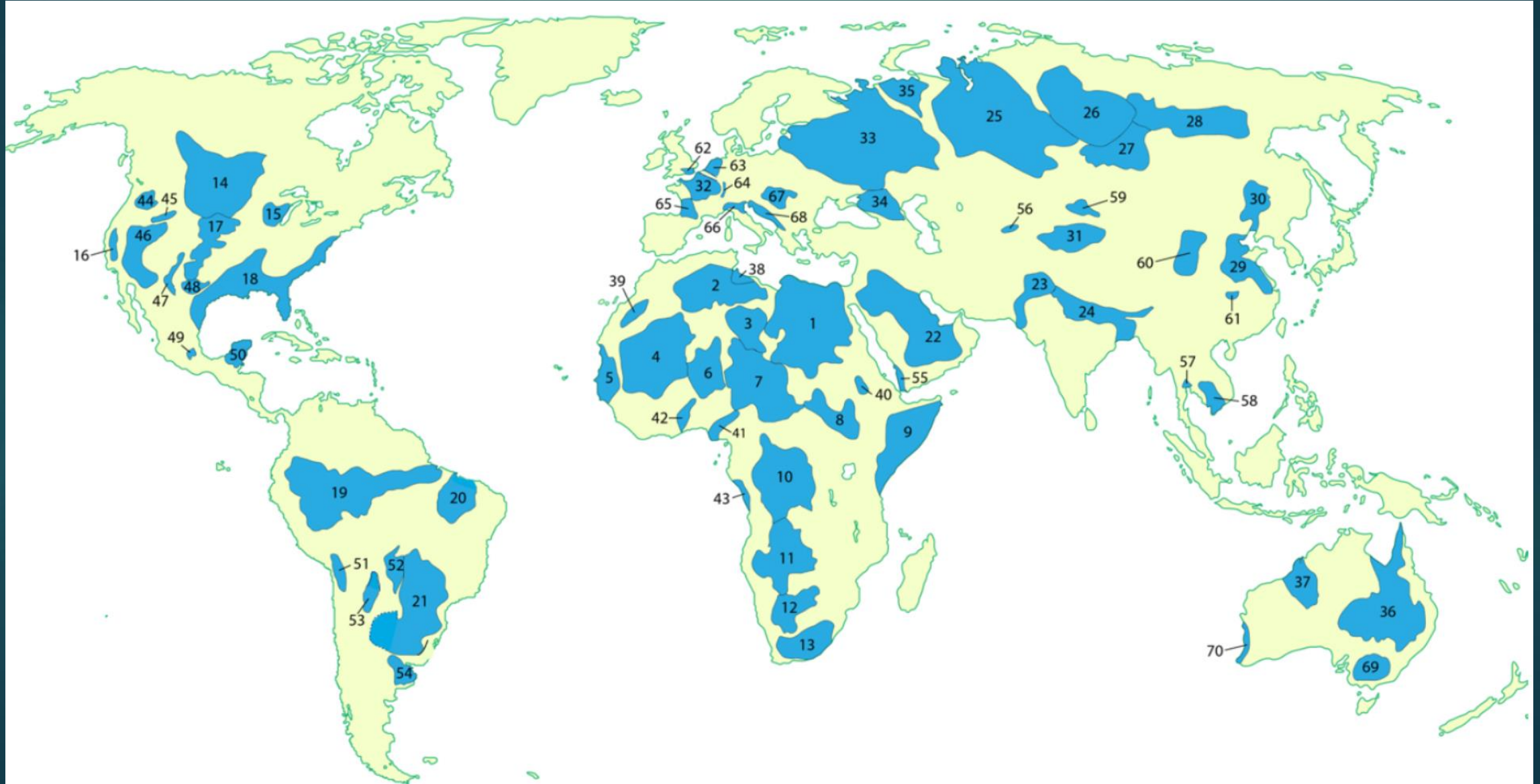
Water resources – groundwater

Reliance on groundwater intake for drinking water source



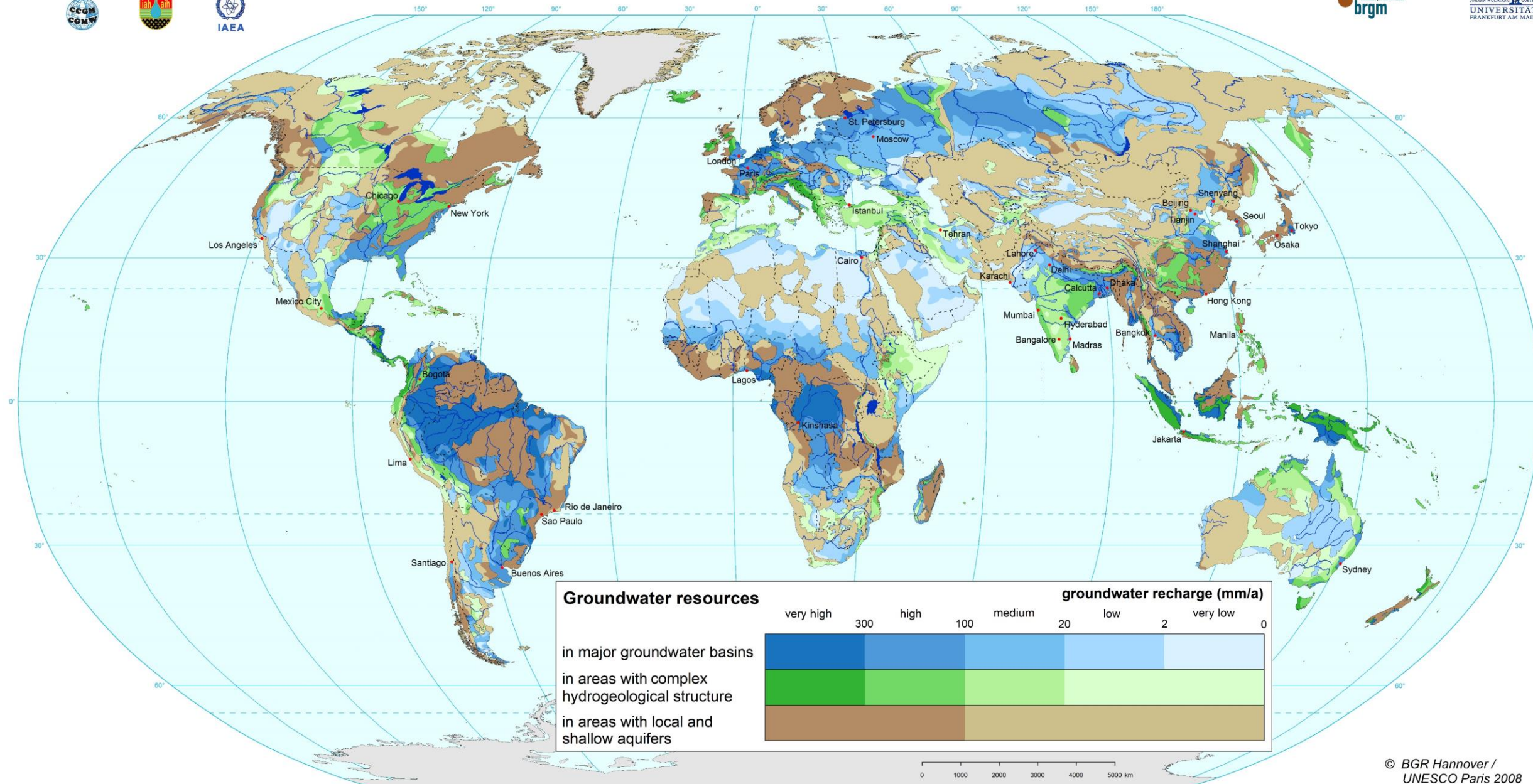
Source: World Bank calculation using data on urban water intake points from The Nature Conservancy and McDonald (2016).

Water resources – groundwater (large aquifers around the world)

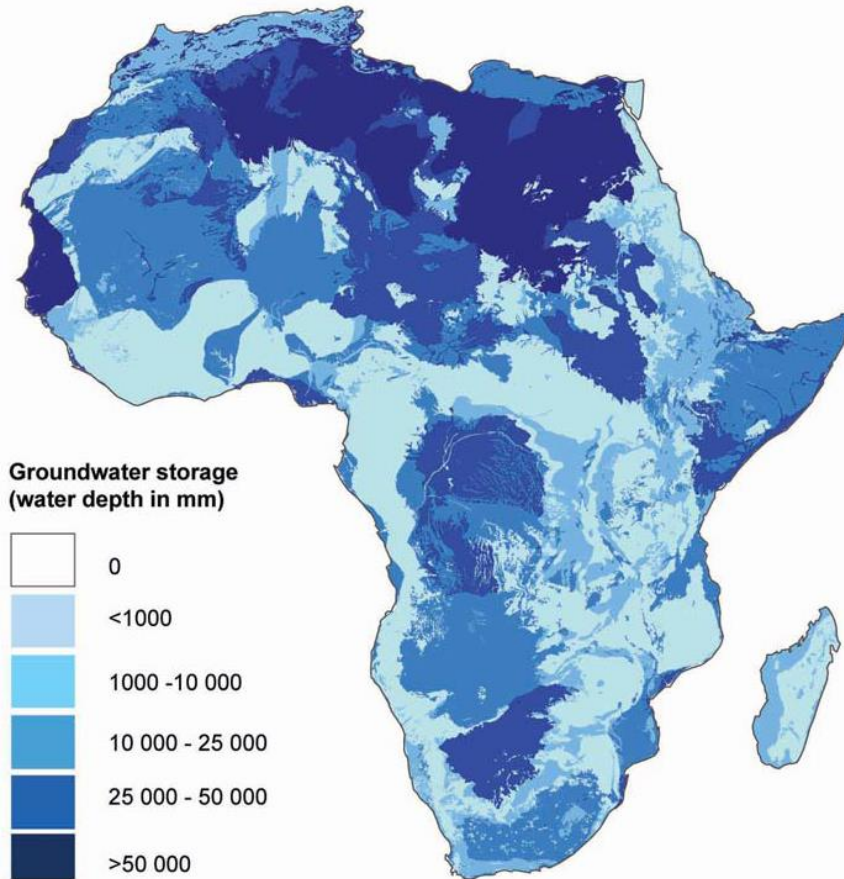




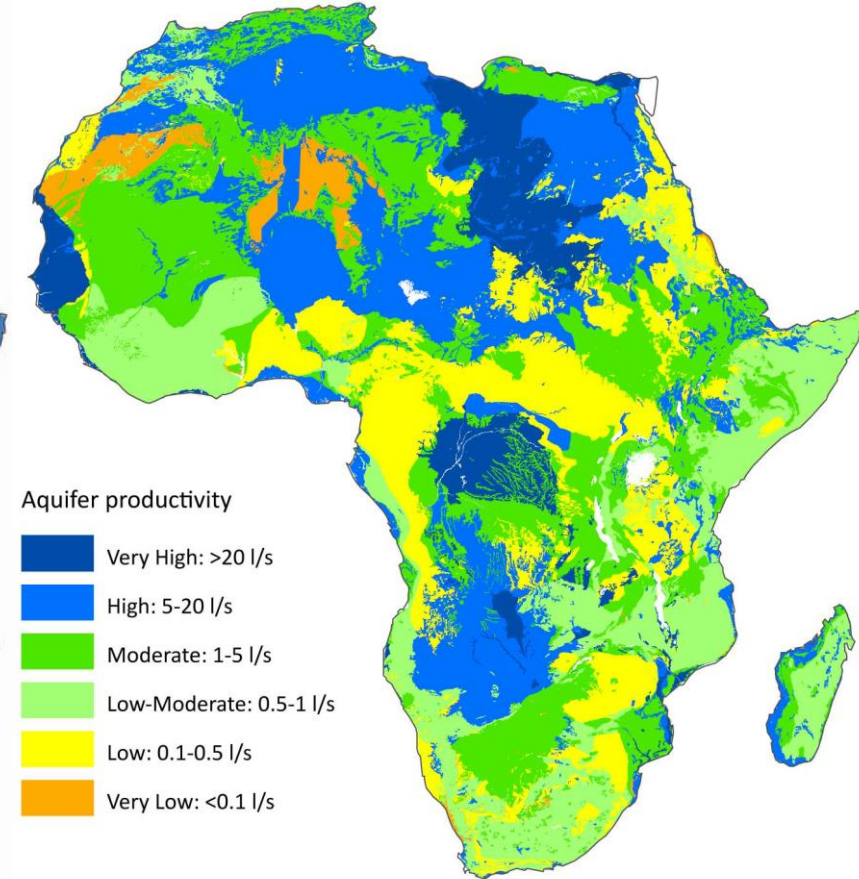
Groundwater Resources of the World



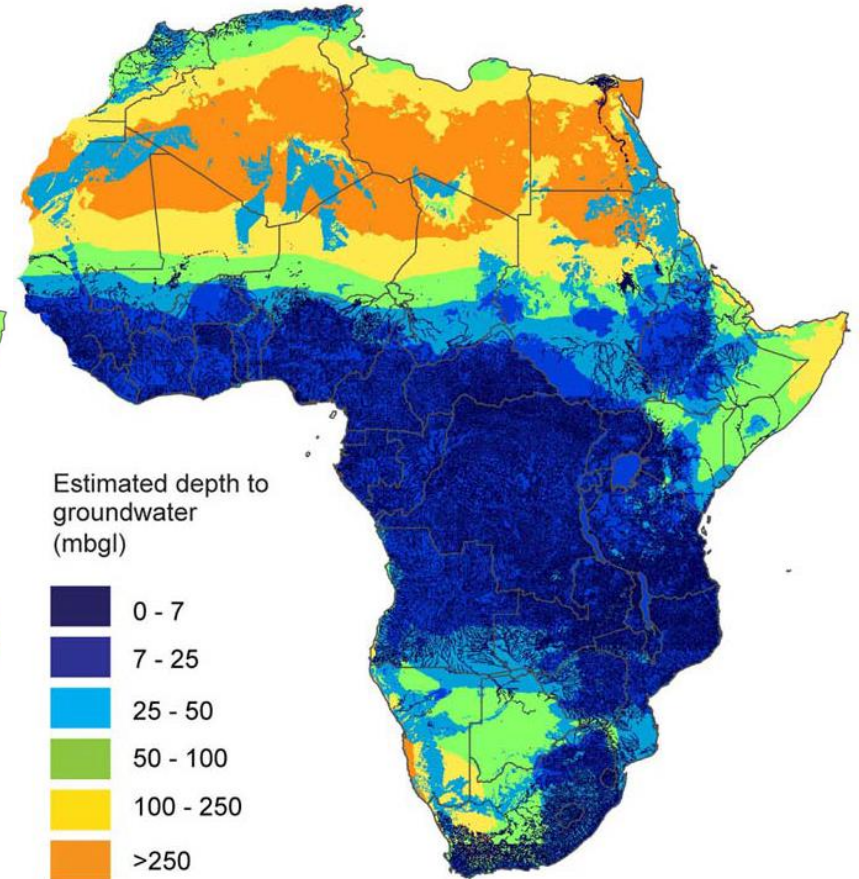
Groundwater in Africa (storage, productivity, depth of water table)



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Important Hydrogeological Characteristics of a Site That Determine Groundwater Quantity and Quality

Geological

Type of water-bearing unit or aquifer (rock type, overburden).

Thickness and areal extent of water-bearing units and aquifers.

Type of porosity (primary, such as intergranular pore space, or secondary, such as bedrock discontinuities, e.g., fracture or solution cavities).

Presence or absence of impermeable units or confining layers.

Depths to water tables; thickness of vadose zone.

Permeability and connectivity to other voids or conduits.

Hydraulic

Hydraulic properties of water-bearing unit or aquifer (hydraulic conductivity, transmissivity, storability, permeability, dispersivity).

Pressure conditions (confined, unconfined, leaky confined).

Groundwater flow directions (hydraulic gradients, both horizontal and vertical), volumes (specific discharge), rate (average linear velocity).

Recharge and discharge areas.

Groundwater or surface water interactions; areas of groundwater discharge to surface water or vice versa.

Seasonal variations of groundwater conditions.

Water quality and availability

- ▶ in present and in the near future, lack of water availability is expected to be bigger problem compared to water quality, mainly due to growing population
- ▶ infrastructure and technology enables water treatment and distribution
- ▶ even a low-quality water is better option than no water at all
- ▶ (obviously) in many parts of the world partially due to natural conditions and lack of infrastructure / technology water is not available