4.1 Introduction to Water systems

Global Water

- Globally, 1.2 billion people live in areas with inadequate water supply. Source: International Water

Importance of Water

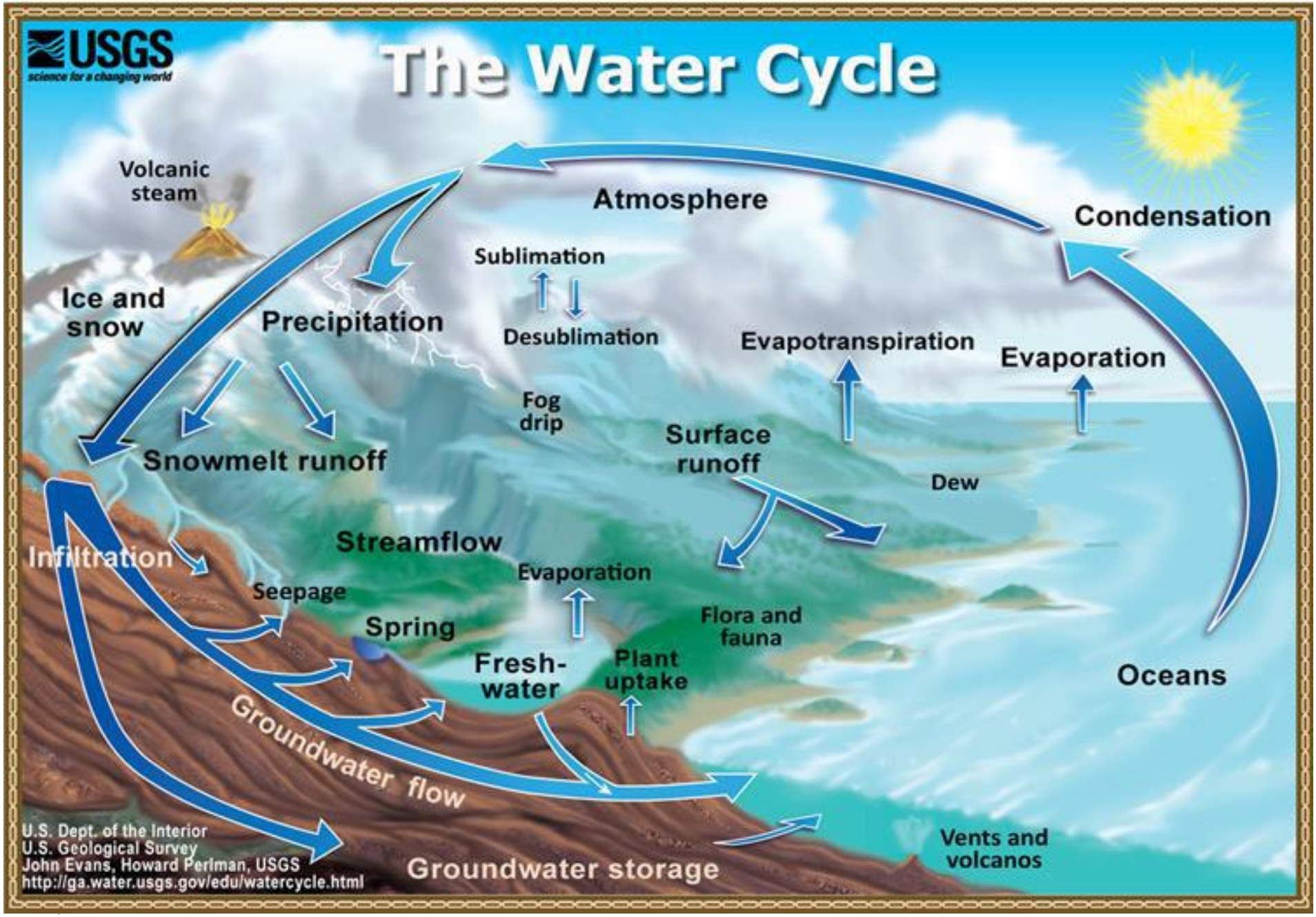
- Water keeps us live
- Moderates climate
- Sculpts the land
- Removes and dilutes wastes and pollution
- Moves continually through the hydrologic cycle

4.1 Introduction to Water Systems

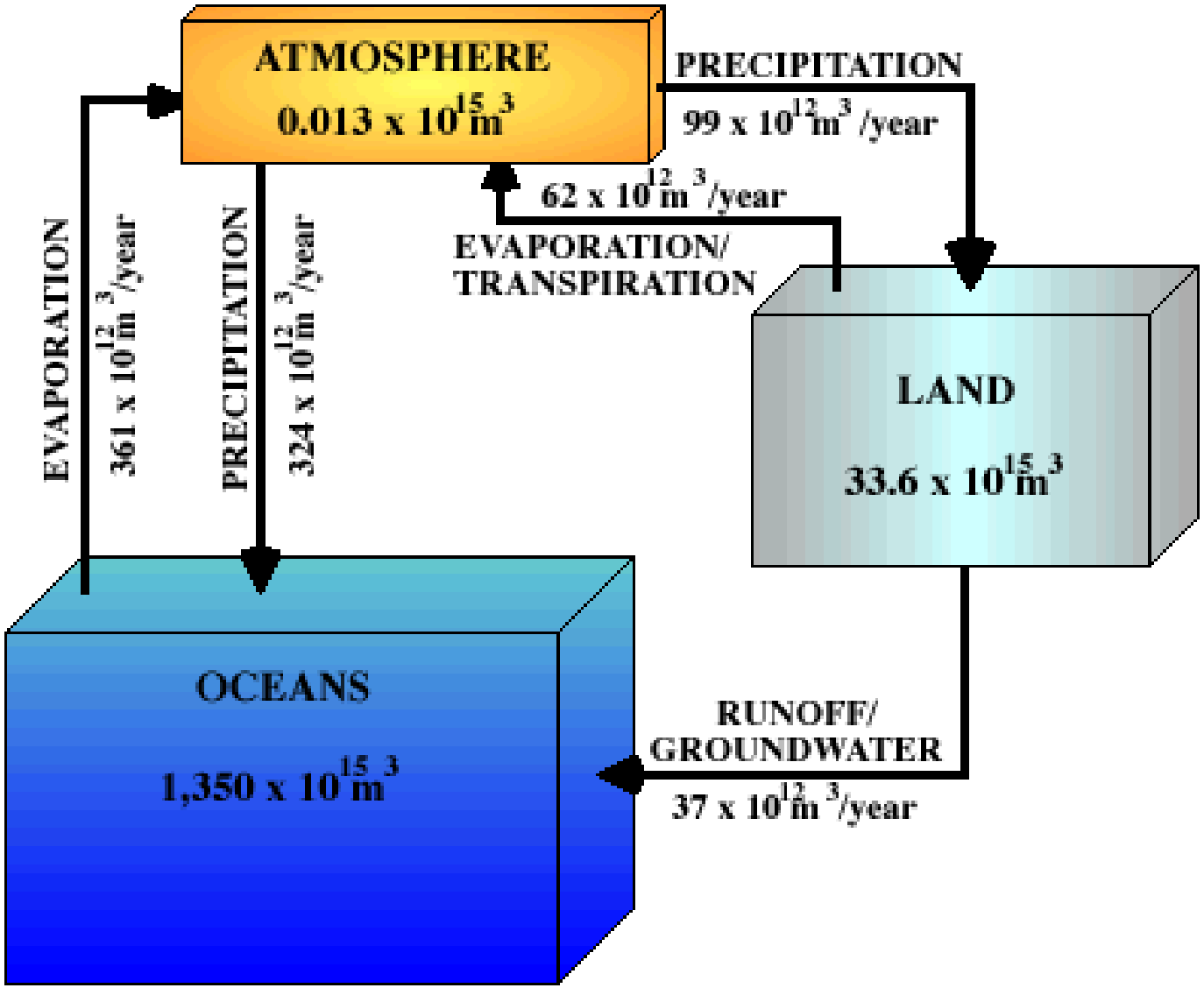
Ocean	Lake
Precipitation	Condensation
Transport	Surface run-off
Evapotranspiration	Percolation
Human management	River Discharge
Infiltration	Evaporation
Ice and Snow	Stream flow
Groundwater (aquifer)	

Starter:

1. Using the words on the worksheet label the water (hydrological) cycle diagram.
2. Highlight the storages and flows in different colours

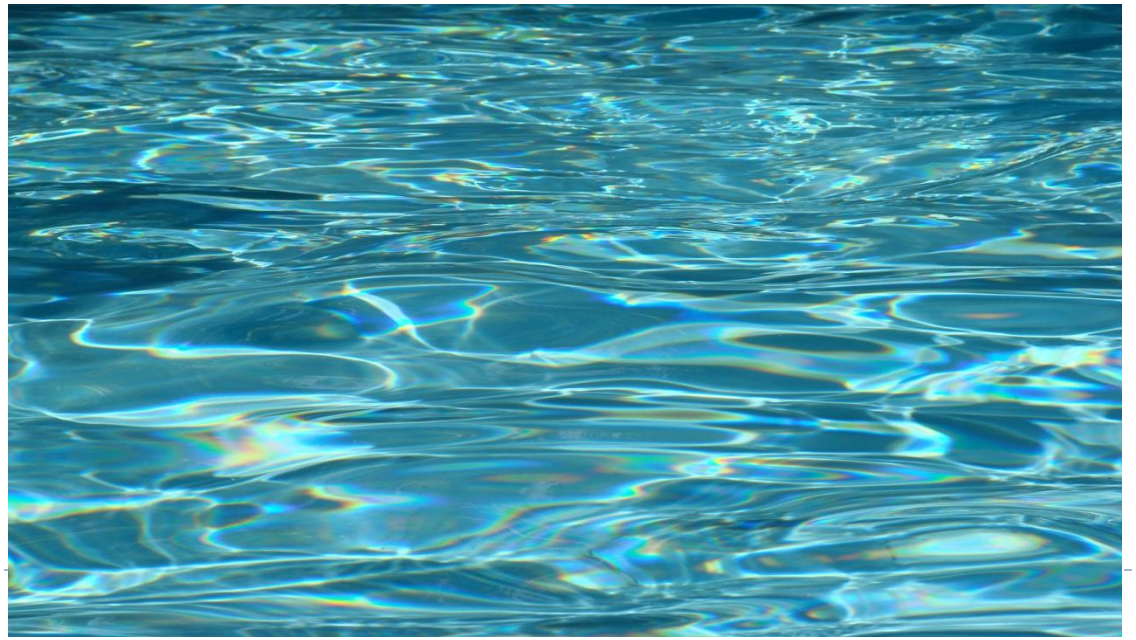

USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Infiltration
Evaporation
Seepage
Spring
Flora and fauna
Fresh-water
Plant uptake
Oceans
Groundwater flow
Vents and volcanos
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html

- Find out the definitions of the following:
  - Precipitation
  - Evapotranspiration
  - Infiltration
  - Surface runoff
  - Groundwater
  - Percolation


ATMOSPHERE
0.013 x 10^15 m^3
PRECIPITATION
99 x 10^12 m^3 /year
62 x 10^12 m^3 /year
EVAPORATION/
TRANSPIRATION
EVAPORATION
361 x 10^12 m^3 /year
PRECIPITATION
324 x 10^12 m^3 /year
LAND
33.6 x 10^15 m^3
OCEANS
1,350 x 10^15 m^3
RUNOFF/
GROUNDWATER
37 x 10^12 m^3 /year

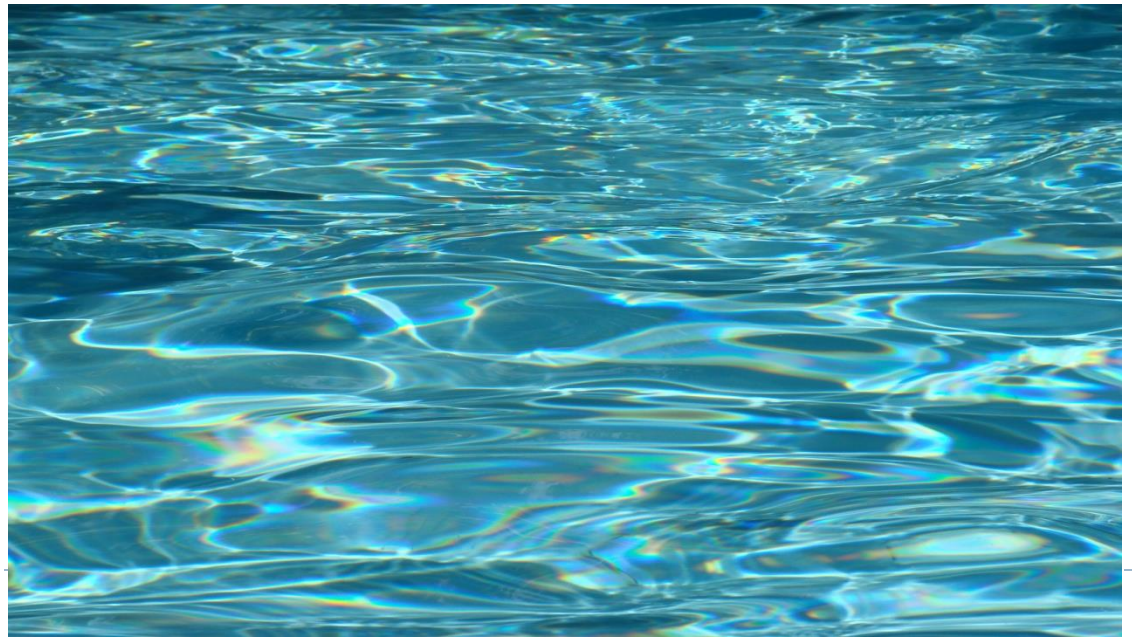
Earth's Water Budget.

- There is a limited amount of water available on Earth
- Not all of this water is usable
- Water can be considered a renewable or a non-renewable resource depending on where it is stored



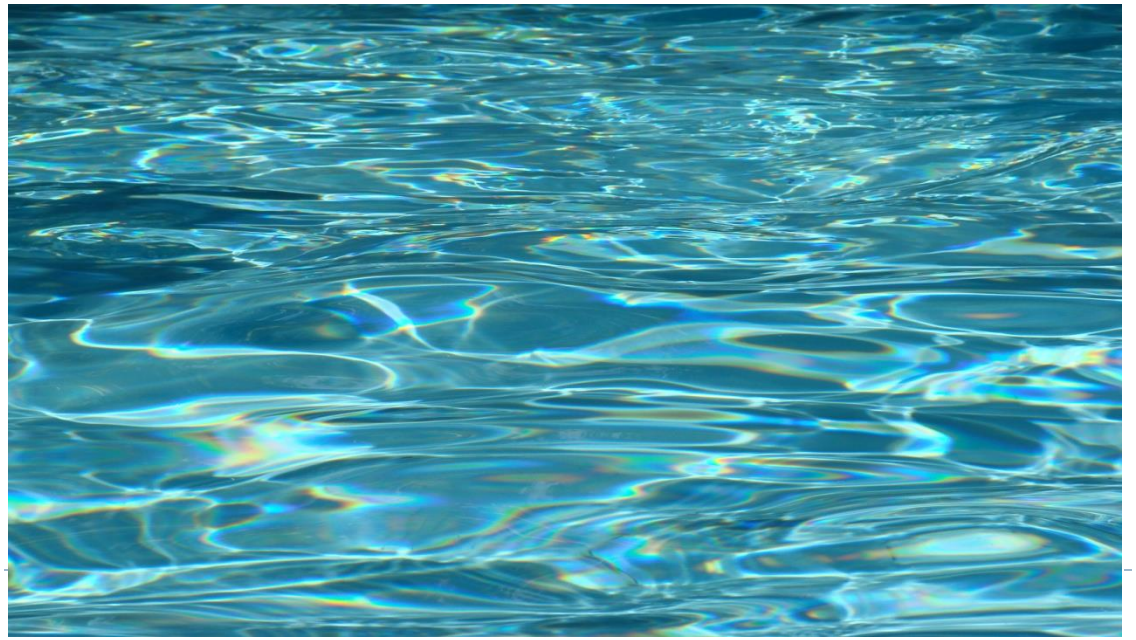
Earth's Water Budget.

- Water molecules in the oceans and ice are locked in place for extremely long periods – non-renewable
- Water in atmosphere and rivers move through cycles more quickly - renewable

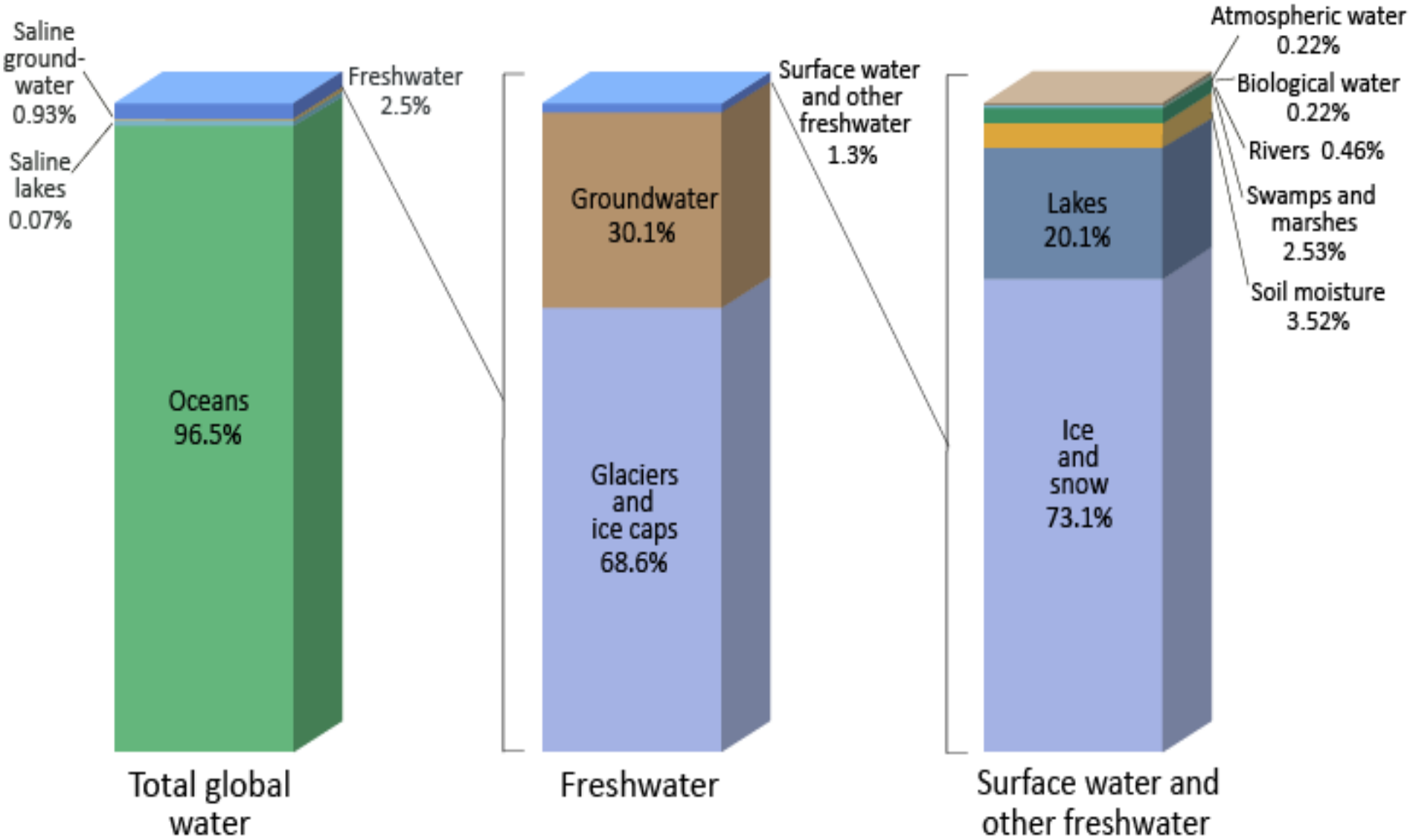


Earth's Water Budget.

- Only about 3% of the water on our planet is fresh water (97% salt water)
- 69% of fresh water is in polar ice caps and glaciers
- 30% is ground water
- The remaining 1% is lakes rivers swamps and in the atmosphere



Distribution of Earth's Water



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

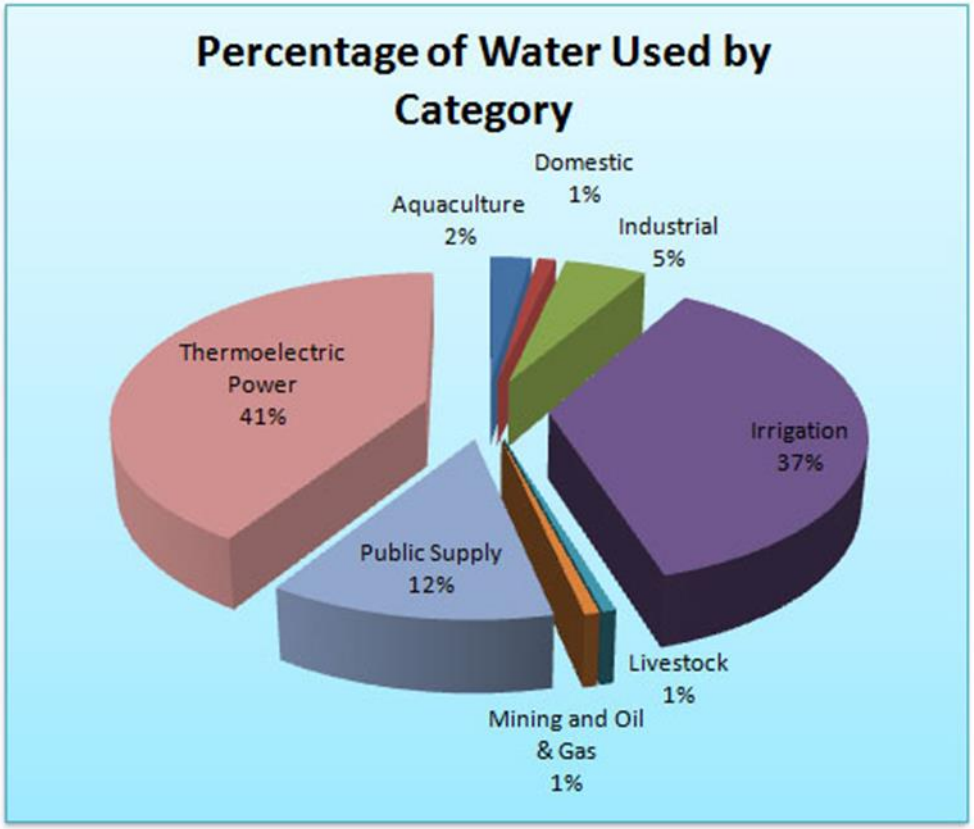
Too Little Freshwater

- About 41% of the world's population live in river basins that do not have enough freshwater
- Many parts of the world are experiencing
  - Rivers running dry
  - Lakes and seas shrinking
  - Falling water tables from over-pumped aquifers

Water Consumption

- Daily water consumption
  - 350 liters in North America and Japan
  - 200 liters in Europe
  - 20 liters in sub-Saharan Africa

Too Little Freshwater



Earth's water budget.

- Turnover time – The time for a water molecule to enter and leave a part of the hydrological system. (the time taken for water to complete replace itself in part of the system)
- These times vary enormously.

Global Water Reservoirs and Turnover Times

	10^3 km^3	%	Turnover time
Oceans	1,370,000	97.61	37,000 y
Polar Ice, Glaciers	29,000	2.06	16,000 y
Groundwater (actively exchanged)	4000	0.29	300 y
Freshwater lakes	125	0.009	10-100 y
Saline Lakes	104	0.008	10-10,000 y
Soil moisture	67	0.005	280 d
Atmosphere (water vapor)	14	0.0009	9 d
Rivers	1.32	0.00009	12-20 d

Earth's water budge.

- River and soil moisture could be considered renewable resources as they recover fairly quickly. (1 year or less)
- However things like ground water aquifers should be considered non-renewable as they take much longer to recover. (300-1500 years)

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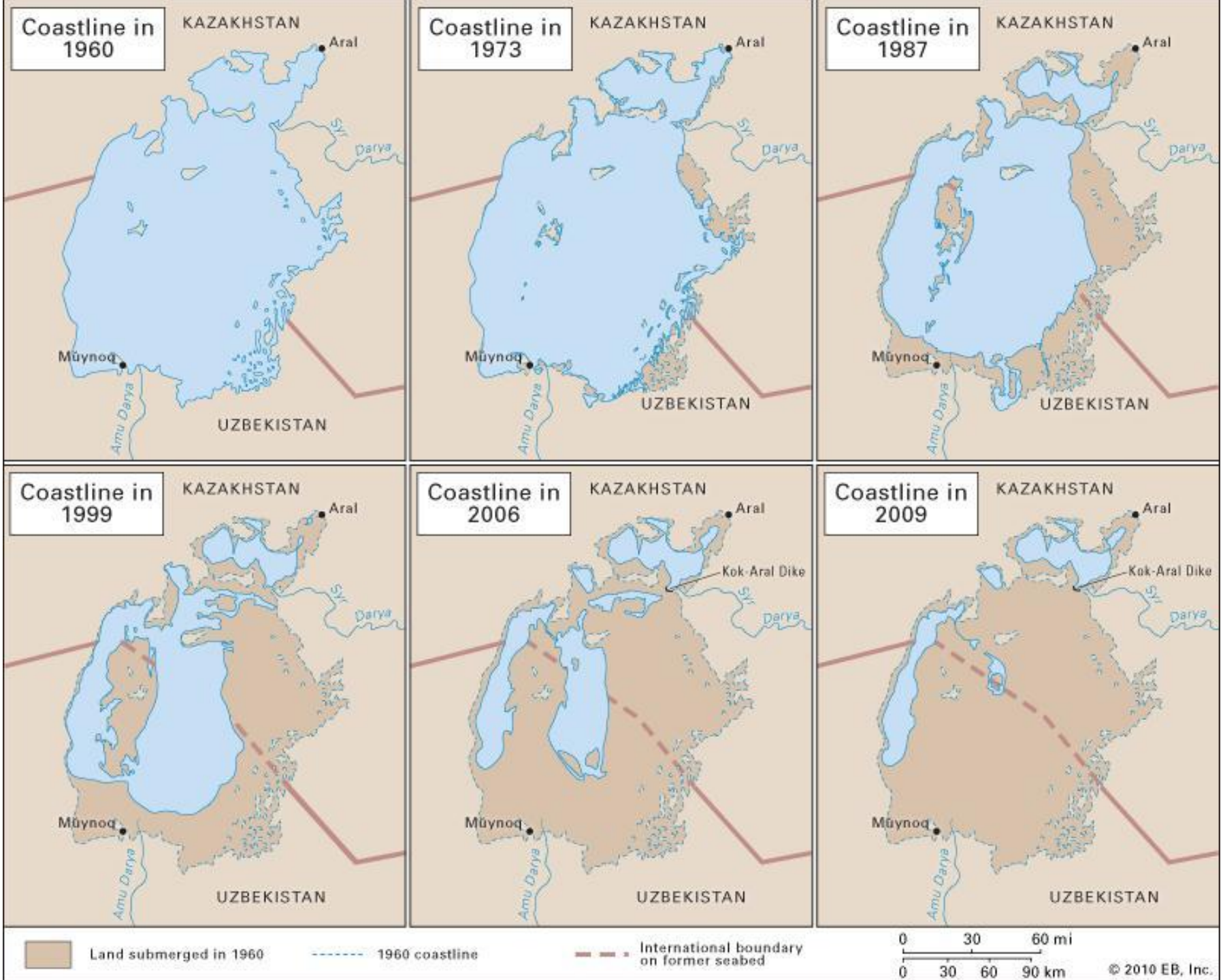
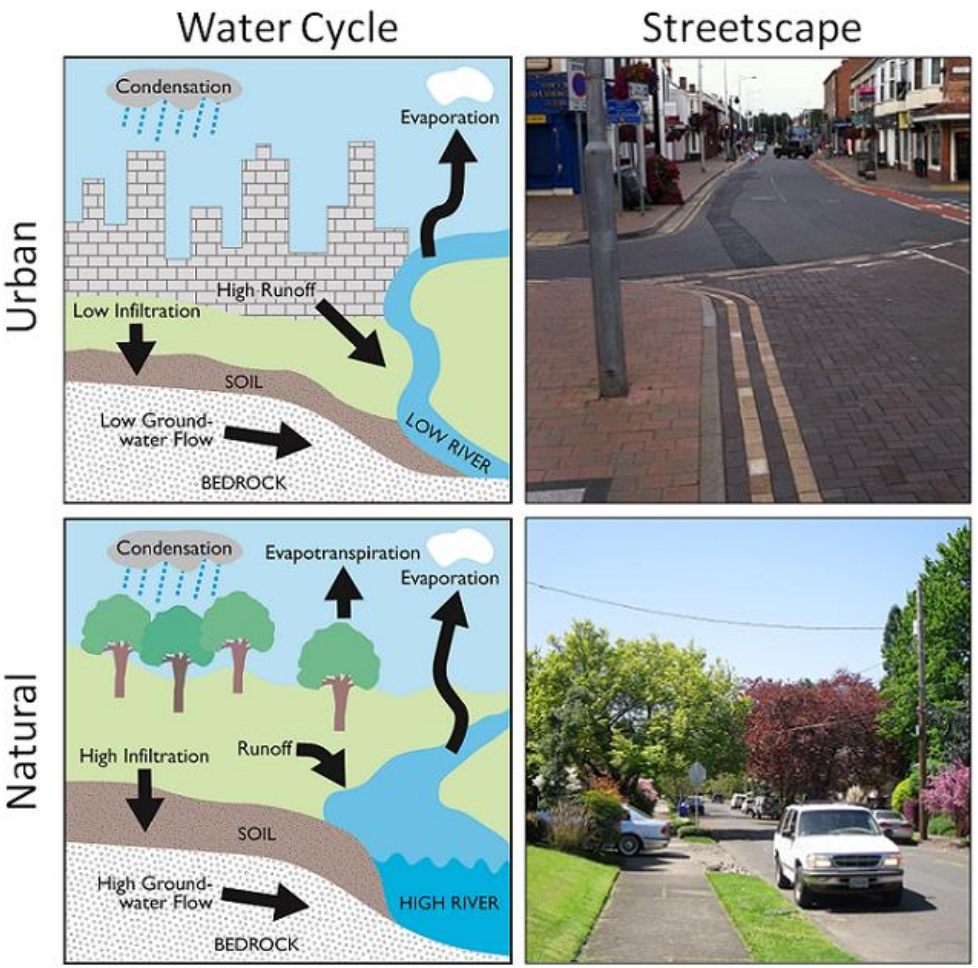
Discuss human impact on the hydrological cycle.

1. Withdrawals
   - Domestic use, irrigation and industry
2. Discharges
   - Adding pollutants – sewage/fertilisers
3. Changing flow speed
   - Rivers are channelled underground
   - Canalising (straightening large sections)
   - Dams/barrages/dykes
4. Diverting rivers
   - Away from important areas to avoid flood damage
   - Towards dams to improve storage


Coastline in 1960
KAZAKHSTAN
Aral
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Coastline in 1973
KAZAKHSTAN
Aral
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Coastline in 1987
KAZAKHSTAN
Aral
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Coastline in 1999
KAZAKHSTAN
Aral
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Coastline in 2006
KAZAKHSTAN
Aral
Kok-Aral Dike
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Coastline in 2009
KAZAKHSTAN
Aral
Kok-Aral Dike
Syr Darya
Mŭynoq
Amu Darya
UZBEKISTAN
Land submerged in 1960
1960 coastline
International boundary on former seabed
0 30 60 mi
0 30 60 90 km
© 2010 EB, Inc.

Blue-green city

- What is a blue-green city?
- What are the aims?
- How do they propose to achieve those aims?



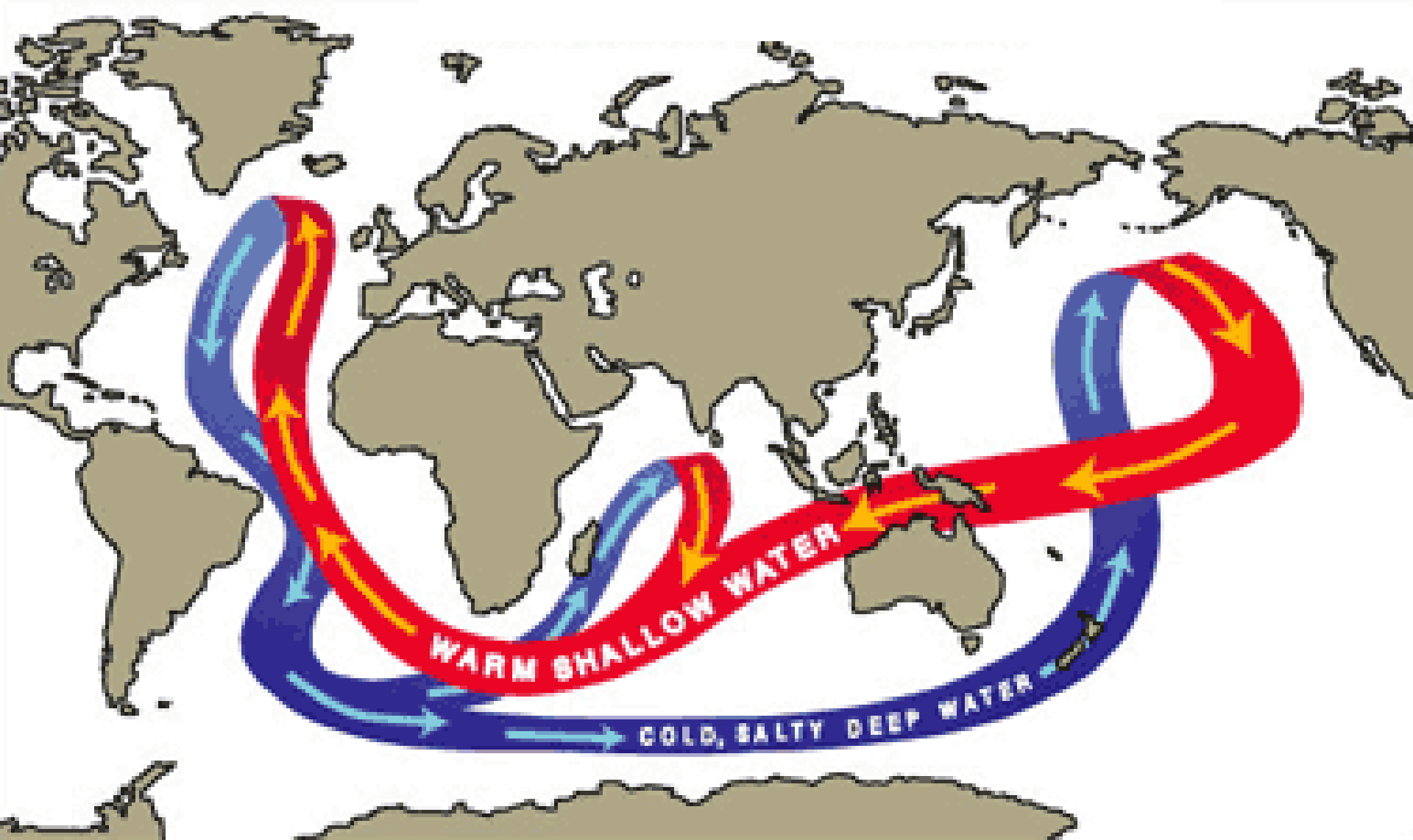
BLUE- GREEN

Human Impact on the Water Cycle

- Overuse from homes, agriculture, irrigation and industry

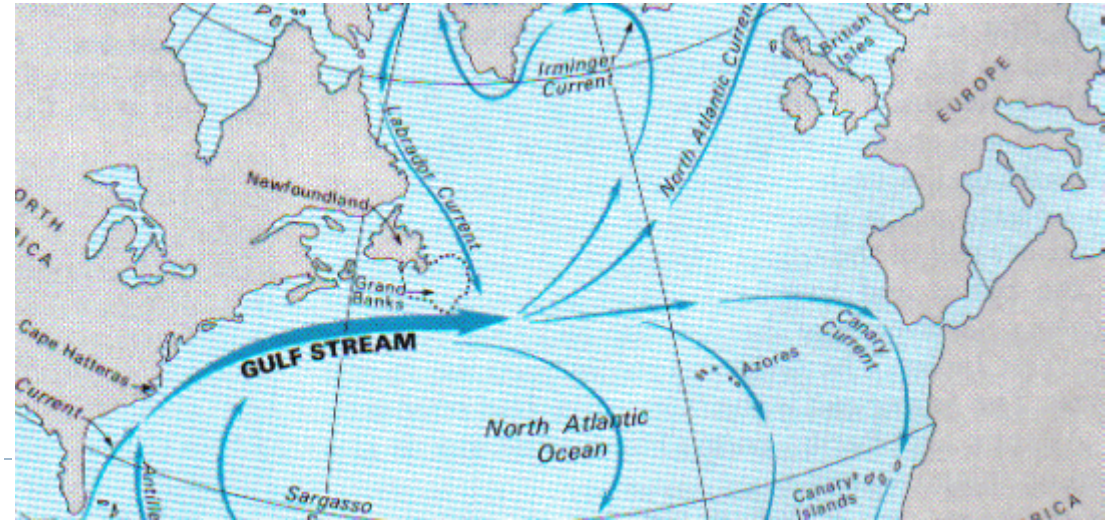
- Rivers that are overused
  - Colorado River & Rio Grande River, North America
  - Indus River, Pakistan
  - Amu Darya River and Syre Darya River (fed Aral sea)
  - Yellow River, China
  - Teesta River, India and Bangladesh
  - Murray River, Australia

Great oceanic conveyor belt

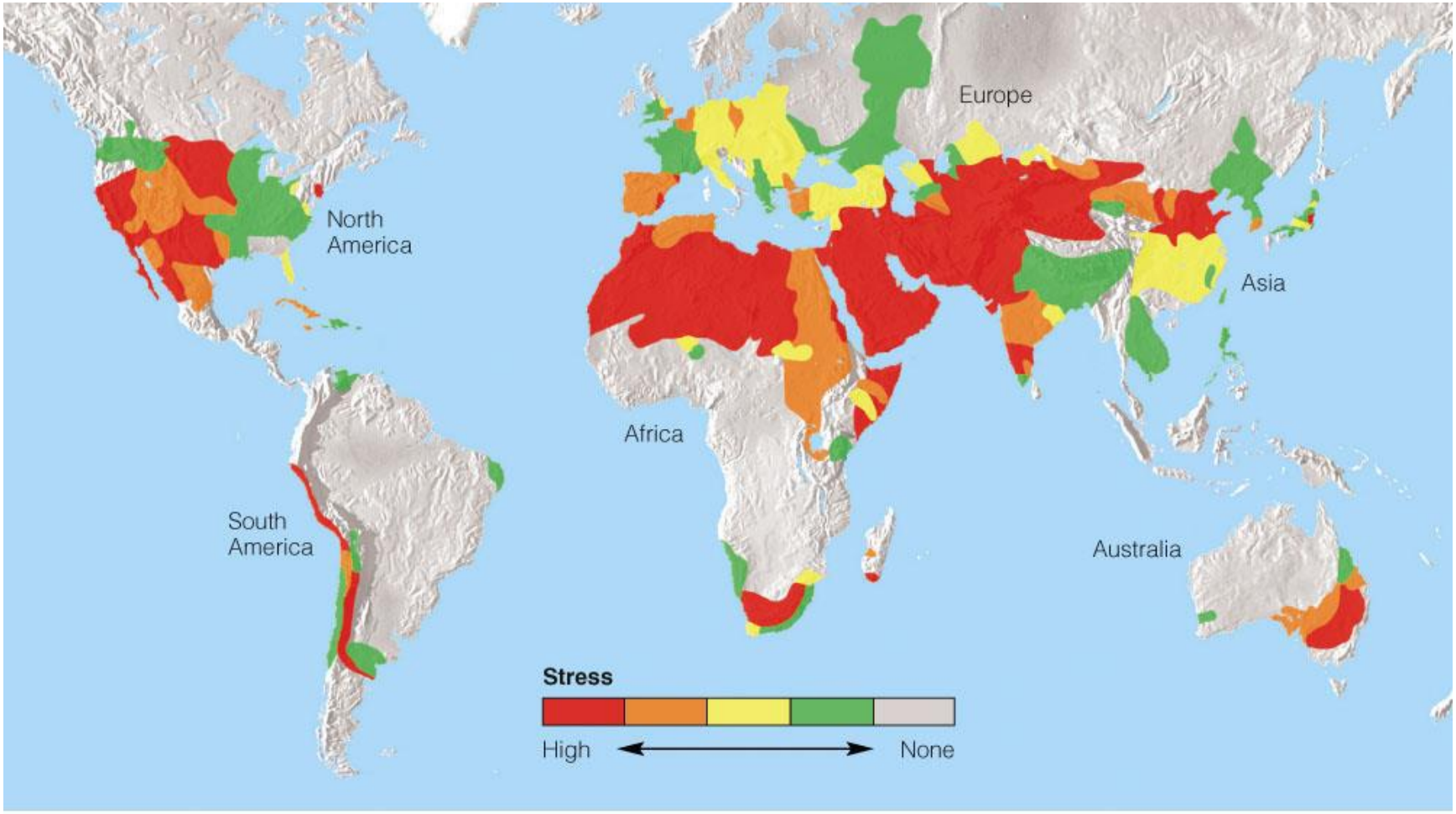


Ocean currents and climate

- Water has a higher specific heat capacity than land.
- Therefore takes longer to heat up/cool down.
- This means land close to the oceans has a mild climate.
  - E.g. The warm gulf stream/north Atlantic drift gives Britain (and NW Europe) a moderate climate when we should have a subarctic climate.

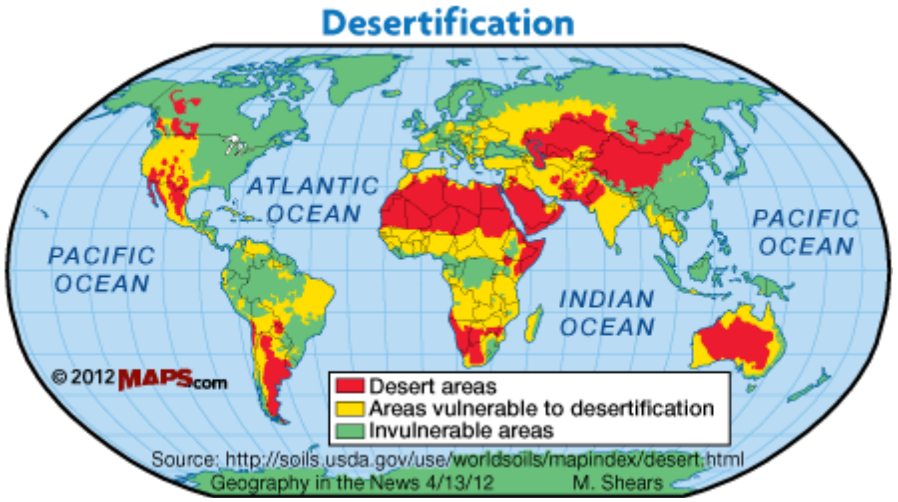


Stress on River Systems



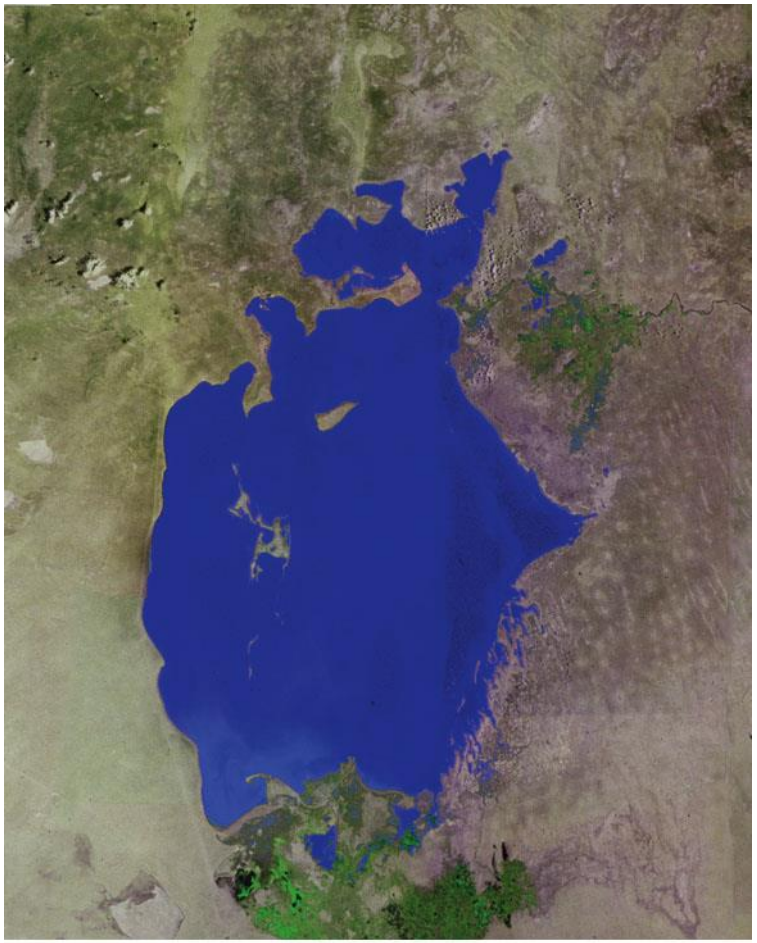
Desertification

- A type of land degradation land in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife. It is caused by a variety of factors, such as climate change and human activities

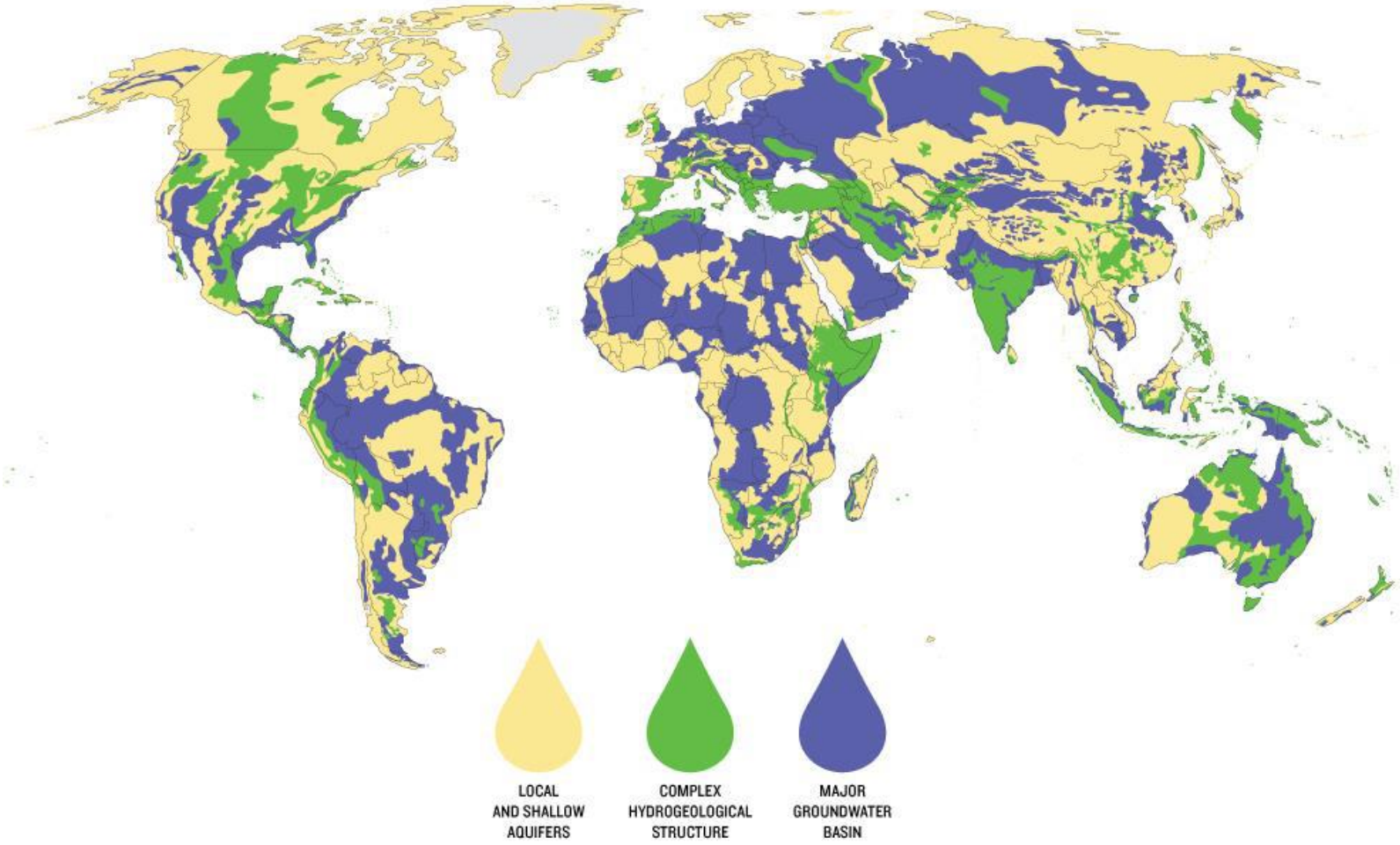


Case Study: Aral Sea

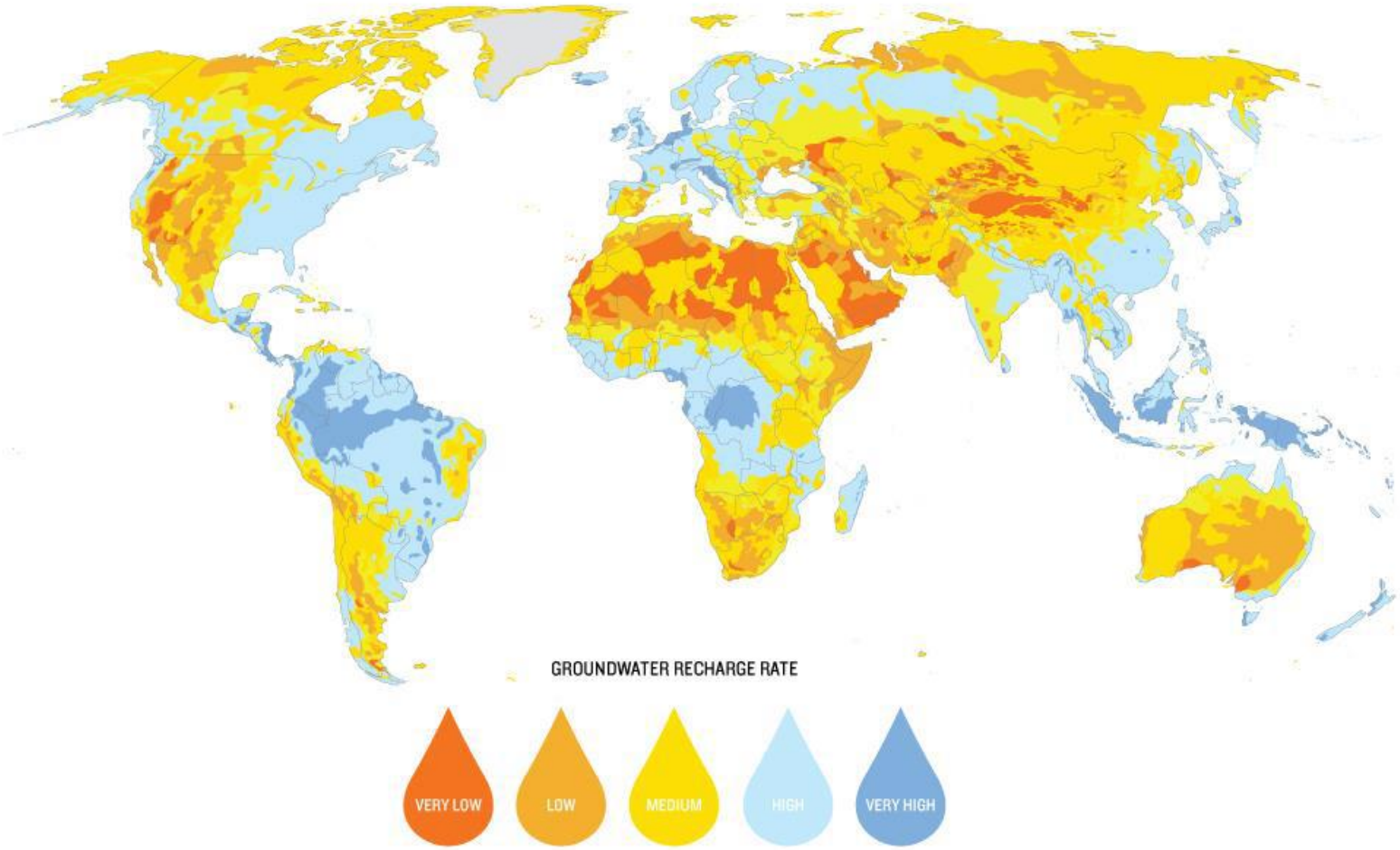
- Was once the world's forth largest freshwater lake



20% of the World's Aquifers are being over pumped

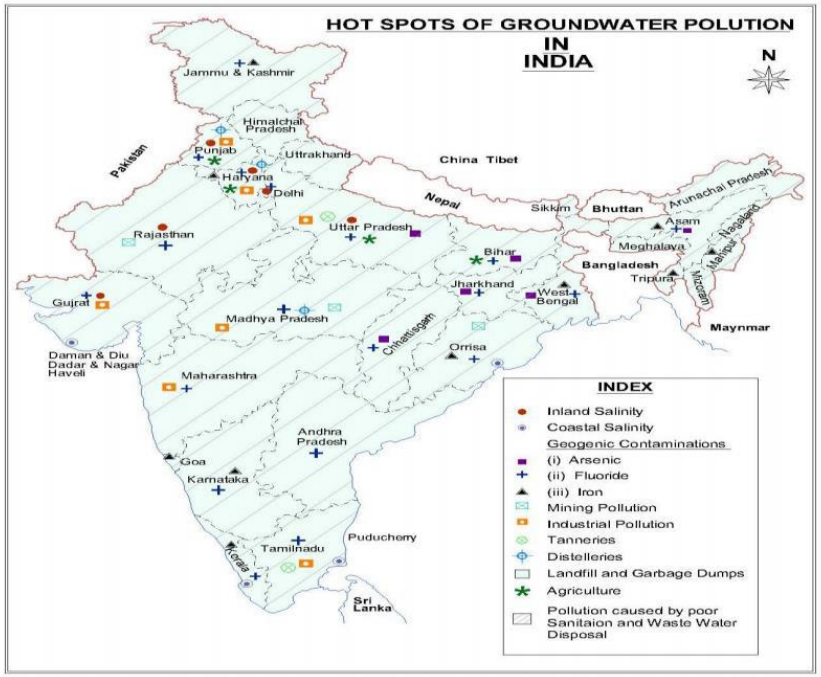


Groundwater Recharge Rates



Case Study: Aquifer Depletion and Groundwater Contamination in India

- Upper Ganges is being pumped more than 50 times its ability to recharge
- Before they are depleted, some aquifers will become unusable because of industrial pollutants, human waste and agricultural chemicals



Source: Romani 2006: Fig. 2.

Withdrawing Groundwater

Advantages

- Useful for drinking and irrigation
- Available year around
- Exists almost everywhere
- Renewable if not over-pumped
- No evaporation losses
- Cheaper to extract that surface water

Disadvantages

- Aquifer depletion from over-pumping
- Sinking of land from over-pumping
- Polluted aquifers
- Saltwater intrusion
- Reduced water flows into surface water
- Increased cost and contaminated deep wells

Solutions to Goundwater Depletion

Prevention

- Waste less water
- Subsidize water conservation
- Ban new wells near surface water
- Buy and retire groundwater rights in critical areas
- Do not grow water intensive crops in dry areas

Control

- Raise price of water
- Tax water pumped near surface water
- Set and enforce minimum stream flow levels

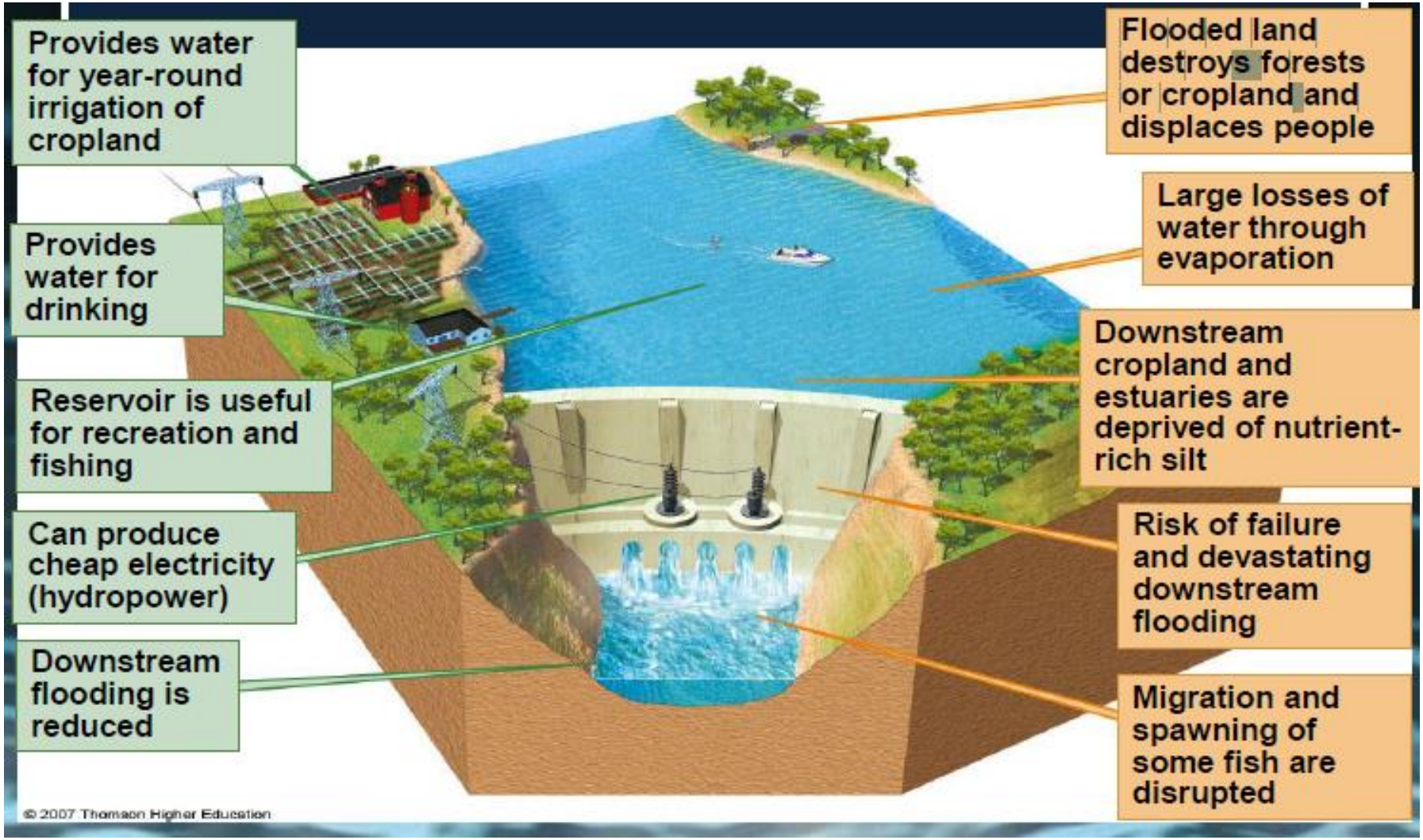
Human Impacts on Water Cycle

- Pollution such as fertilizer, heavy metals and sewage contaminate water sources
  - A World Ban sutdy said four major rivers near Dhaka receive 1.5 million cubic metres of waste water every day from 7,000 industrial units in surrounding areas and another 0.5 million cubic meters from other suorces
- *sources*. "Bangladesh River Pollution Threatens Millions."*Reuters*. Thomson Reuters, 2009. Web. 08 Mar. 2016.

Human Impacts on the Water Cycle

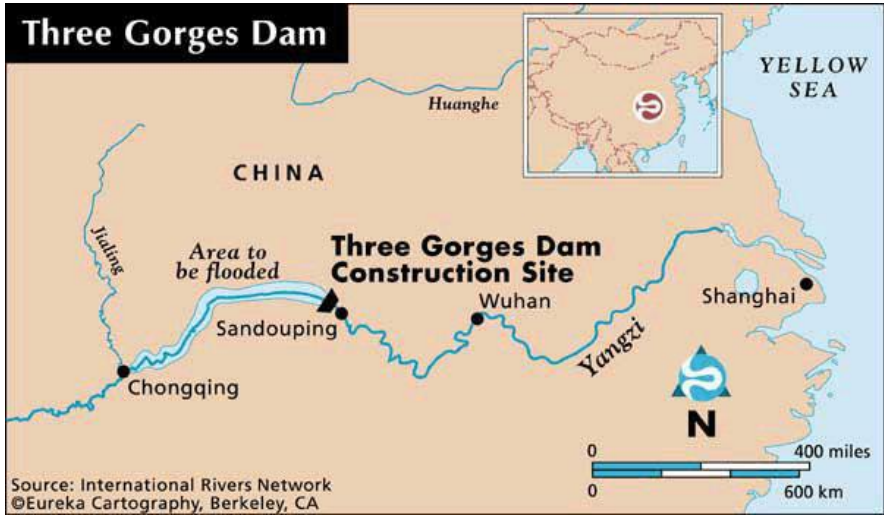
- Changing the flow of rivers
  - Building concrete channels to prevent flooding
  - Straightening rivers
  - Building dams
  - Diverting rivers

Using Dams and Reservoirs



Case Study: Three Gorges Dam

- Does advantages outweigh disadvantages
  - The dam is 2 kilometers long
  - Electric output will be that of 18 large coal burning plants
  - I will facilitate ship travel reducing transportation costs
  - Will displace 1.2 million people
  - Build over seismatic fault

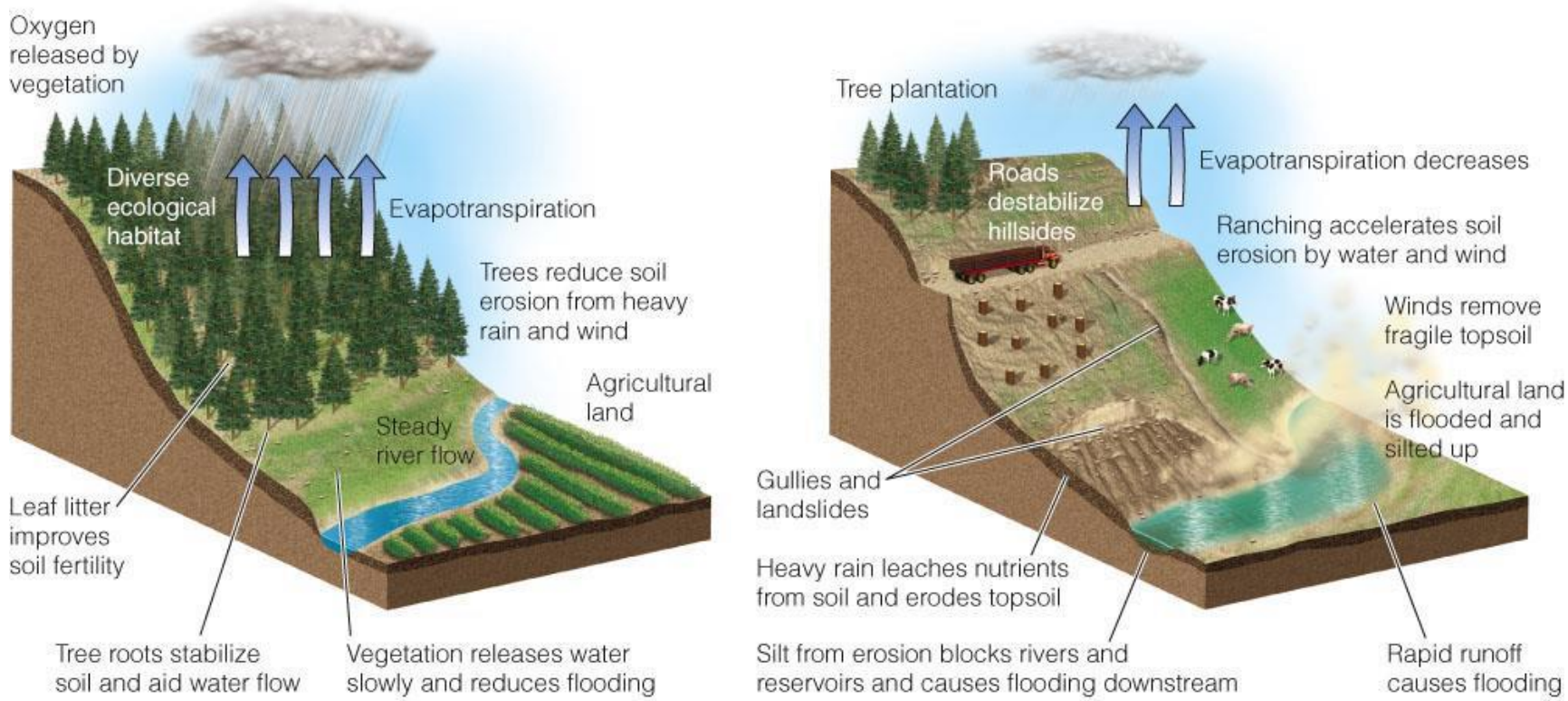


Too Much Water

- Heavy rainfall, rapid snowmelt, removal of vegetation and destruction of wetlands cause flooding
- Floodplains, which usually include highly productive wetlands, help provide natural flood and erosion control, maintain high water quality and recharge groundwater
- To minimize floods, rivers have been narrowed with levees and walls, and dammed to store water

Human Activity and Flooding

- Human activities have contributed to flood deaths and damages



Forested Hillside

After Deforestation

Human Activity and Flash Flooding

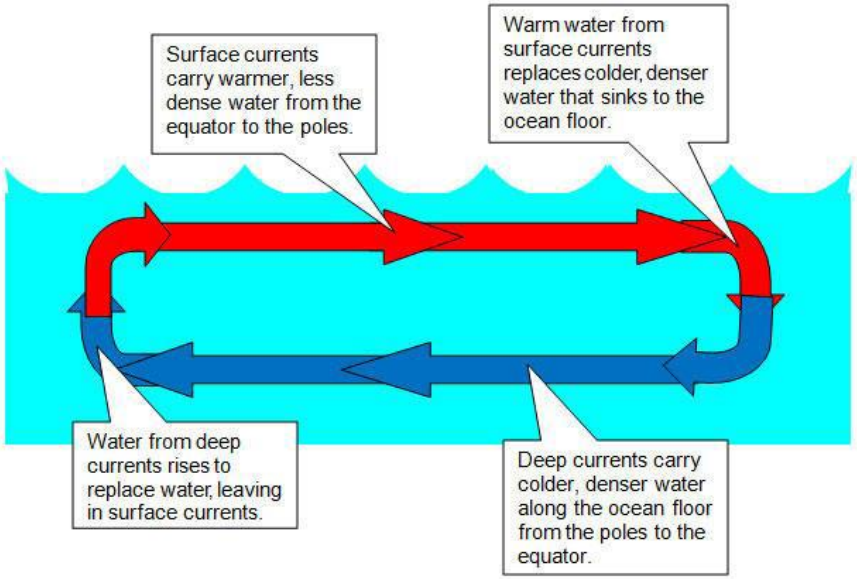
- A flash flood is a rapid flooding of low lying areas usually due to heavy rains.
- •Human urbanization may increase the incidence of flash flooding by increasing the rate of runoff and decreasing the soil absorption rates in an area (deforestation, over-paving)
- •Placing bridges, culverts, and channeling, all decrease the width of a river and increase flow rates
- •Sediment and debris not only raise water levels, but also cause blockages which can further impact flooding

Ocean Currents and Energy Distribution

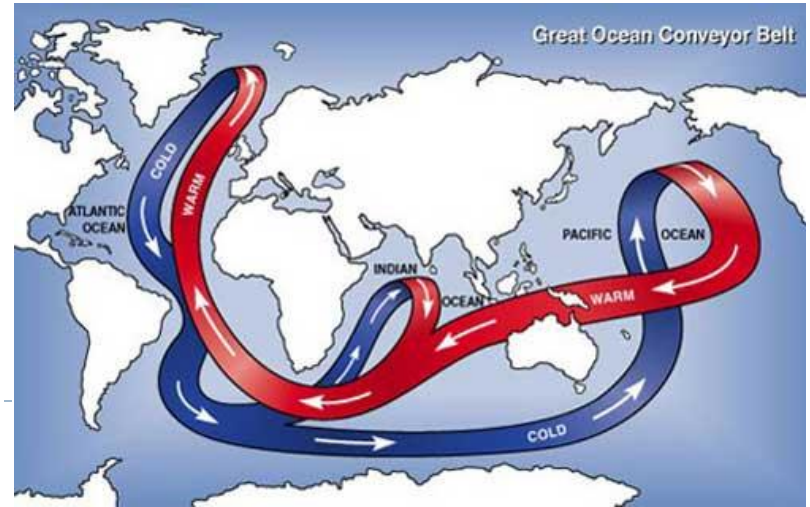
- Ocean currents play a major role in distributing energy around the globe.
- •Surface currents are moved by wind and affect the upper 400 m of the ocean
- •Deep ocean currents (thermohaline) are 90% of the ocean currents
- •These are a type of convection current which move due to differences in density (due to salt levels and temperature)
- •Salt makes water more dense
- •An increase in salt concentration lowers the freezing point of water.
- •Cold water hold more salt and is more dense so sinks.

Ocean Currents and Energy Distribution

- Oceans play an important role in the distribution of energy



- **Upwellings** occur when cold water moves up to replace warm water
- •**Downwellings** occur when warm water moves down to replace cold water.

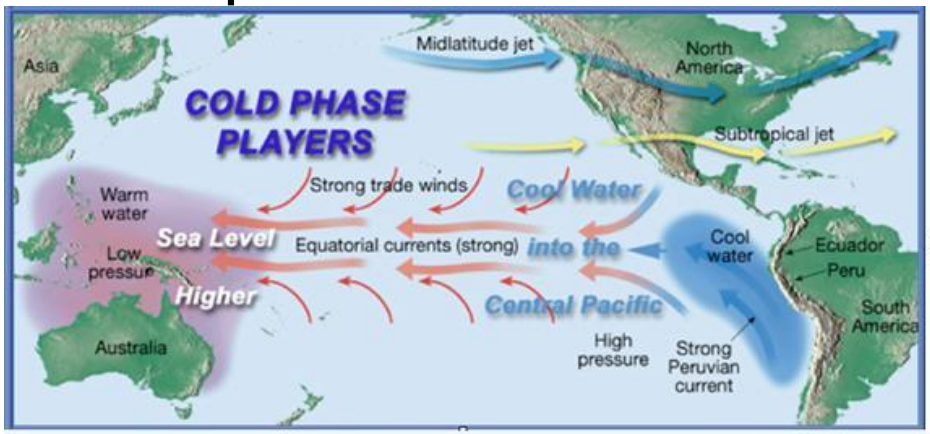


Ocean Currents and Energy Distribution

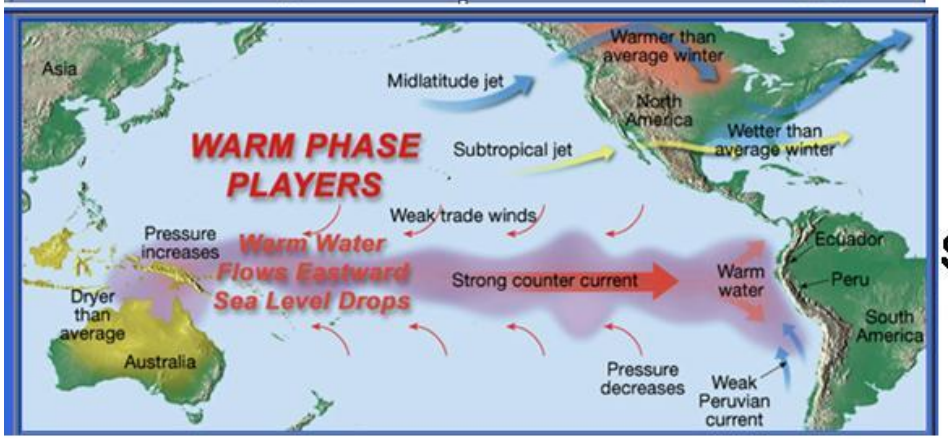
- Water requires more heat energy to warm up than land
- •Water also cools more slowly than land.
- •Because of this, land near large bodies of water tend to have less extreme temperature changes
- •Due to the large surface area (70% of earth) the oceans are also the major area of evaporation, which in turn means that coastal areas are more likely to be humid (if hot) and to receive more precipitation.
- •Therefore the ocean currents play a large role in determining the climate of coastal regions.

Ocean Currents and Energy Distribution

- El Nino Southern Oscillation is a phenomenon in the Pacific that has global consequences.



Normal Situation



El Nino Situation