Natural Hazards and Disaster

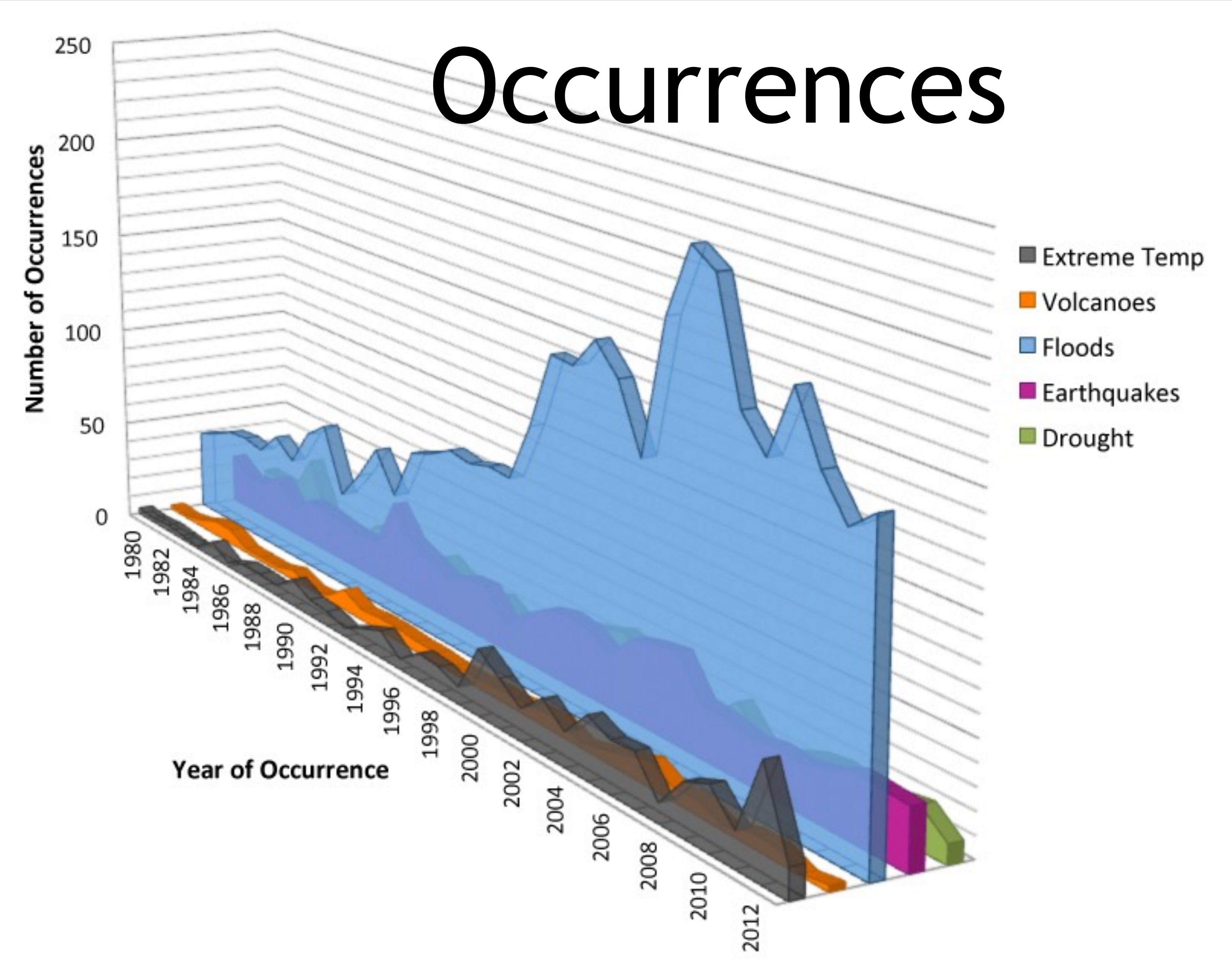
Natural Hazards and Disaster

Class 17: Floods

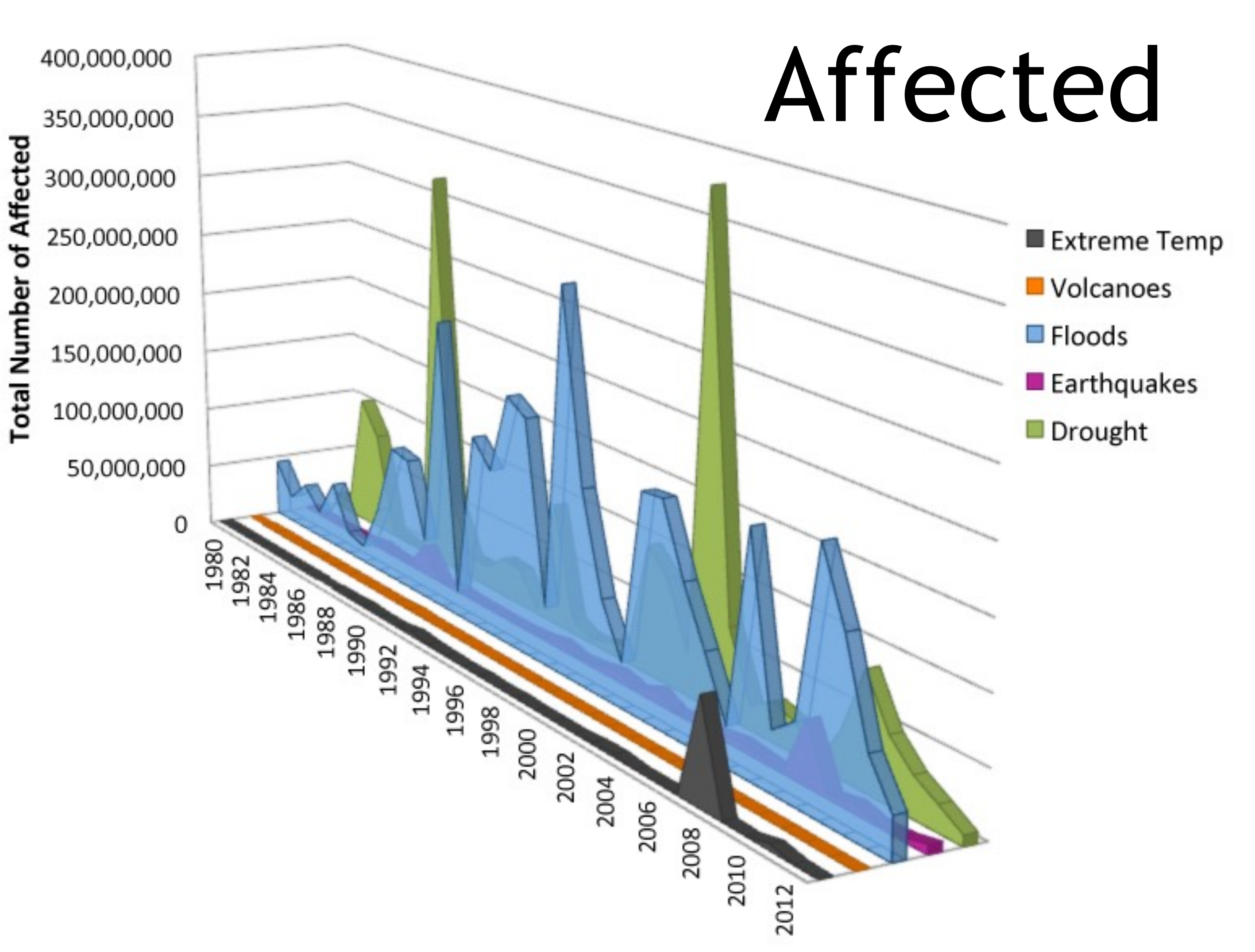
- Water (Energy) cycle
- Flood Risk Management
- Largest Floods
- Deadliest Floods
- River floods
- Flash Floods
- Monsoon
- Water-Energy Cycle: Atmospheric Rivers
- Changing Flood Risk

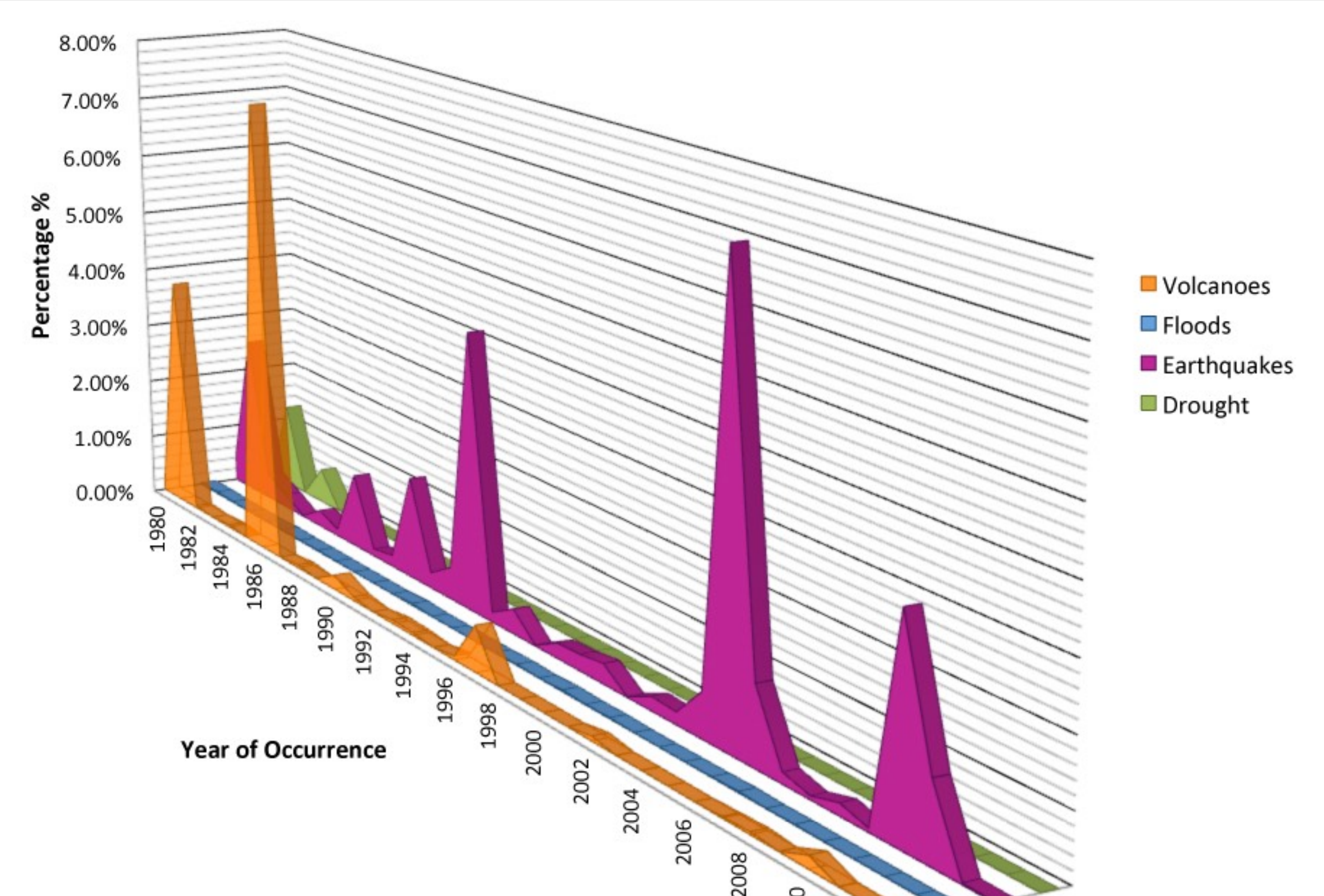
Comparison

Occurrences



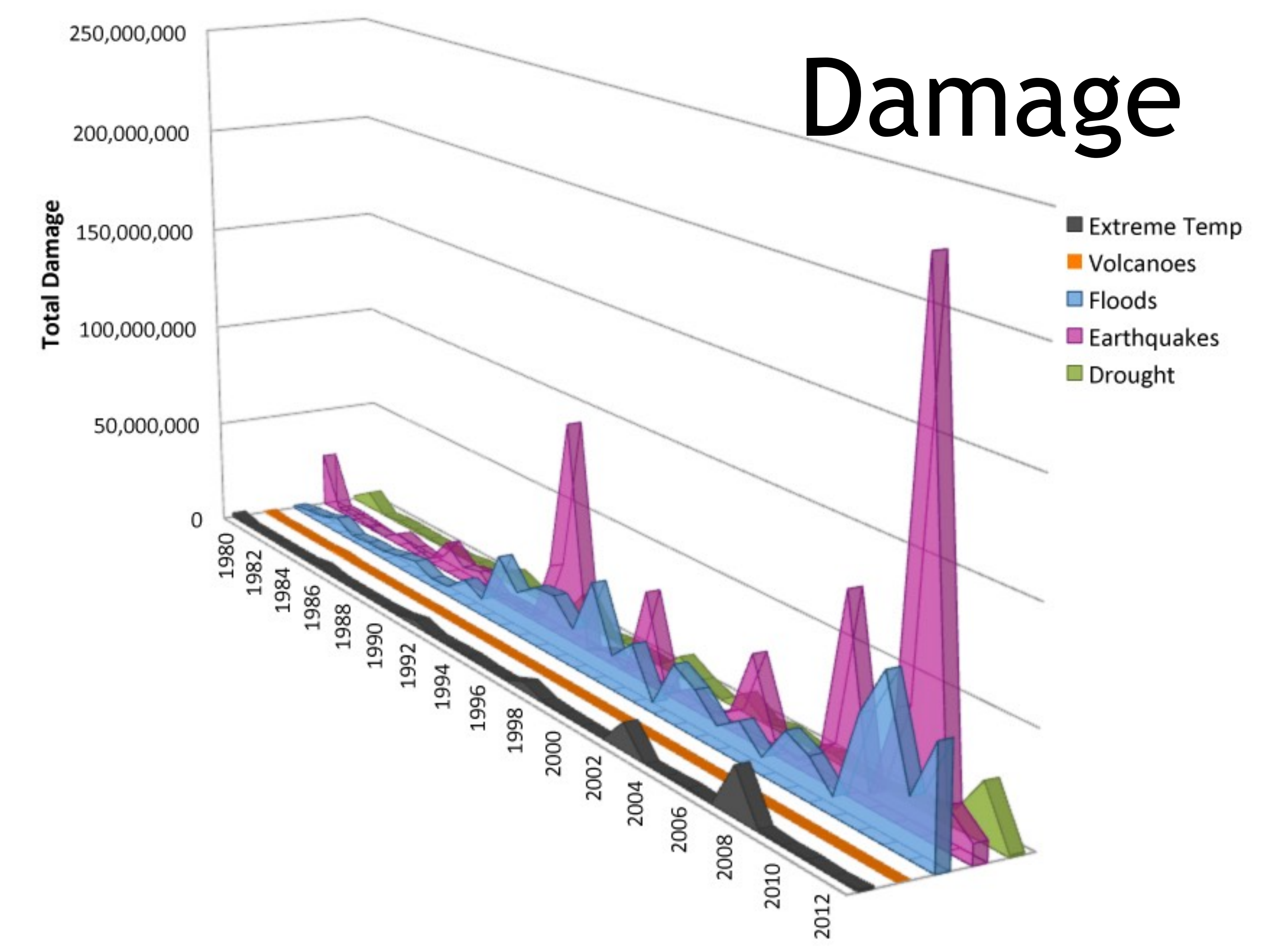
Affected



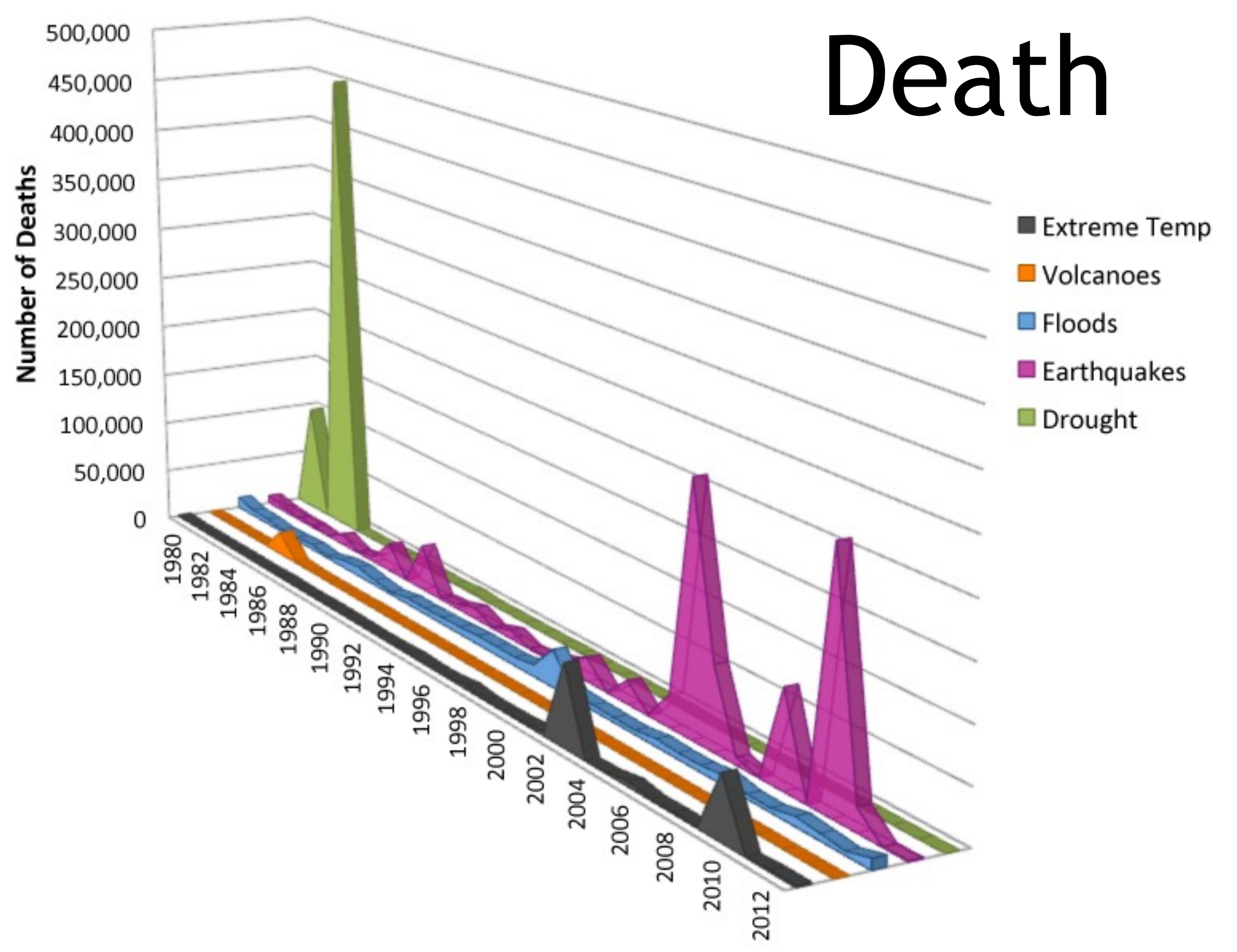


Ratio of Death/Affected

Damage



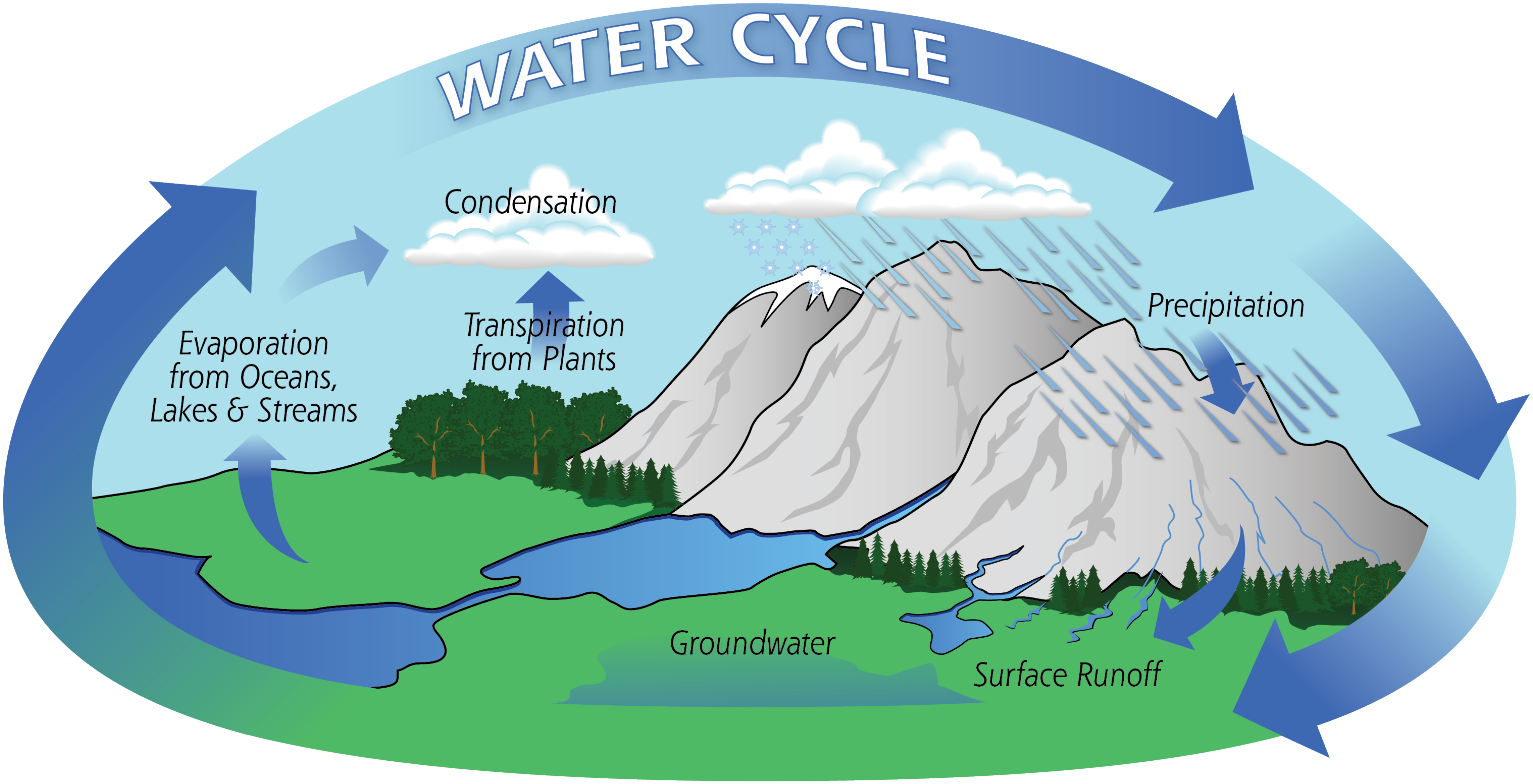
Death



International Disaster Database

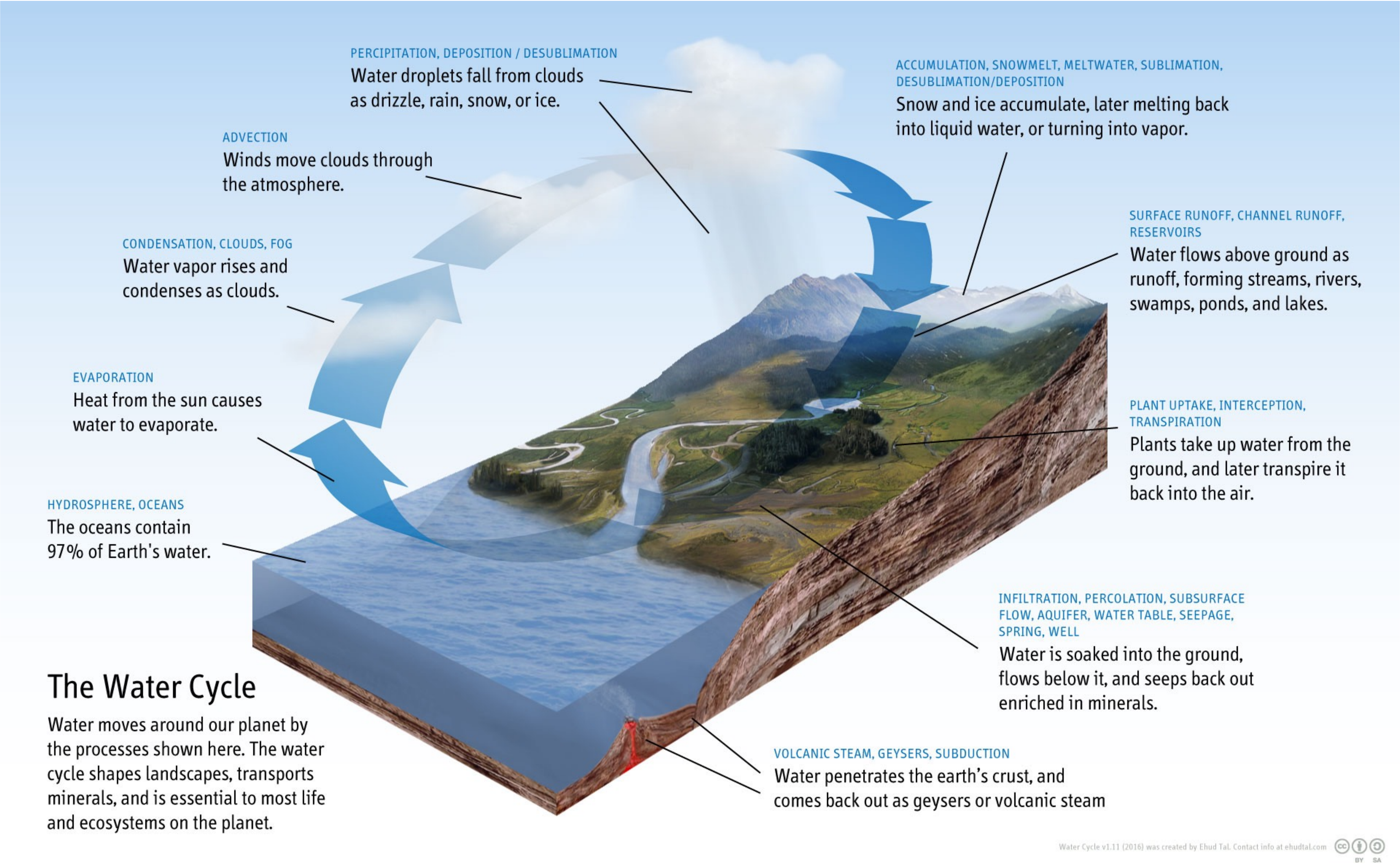
http://www.emdat.be/advanced search/.

Water Cycle



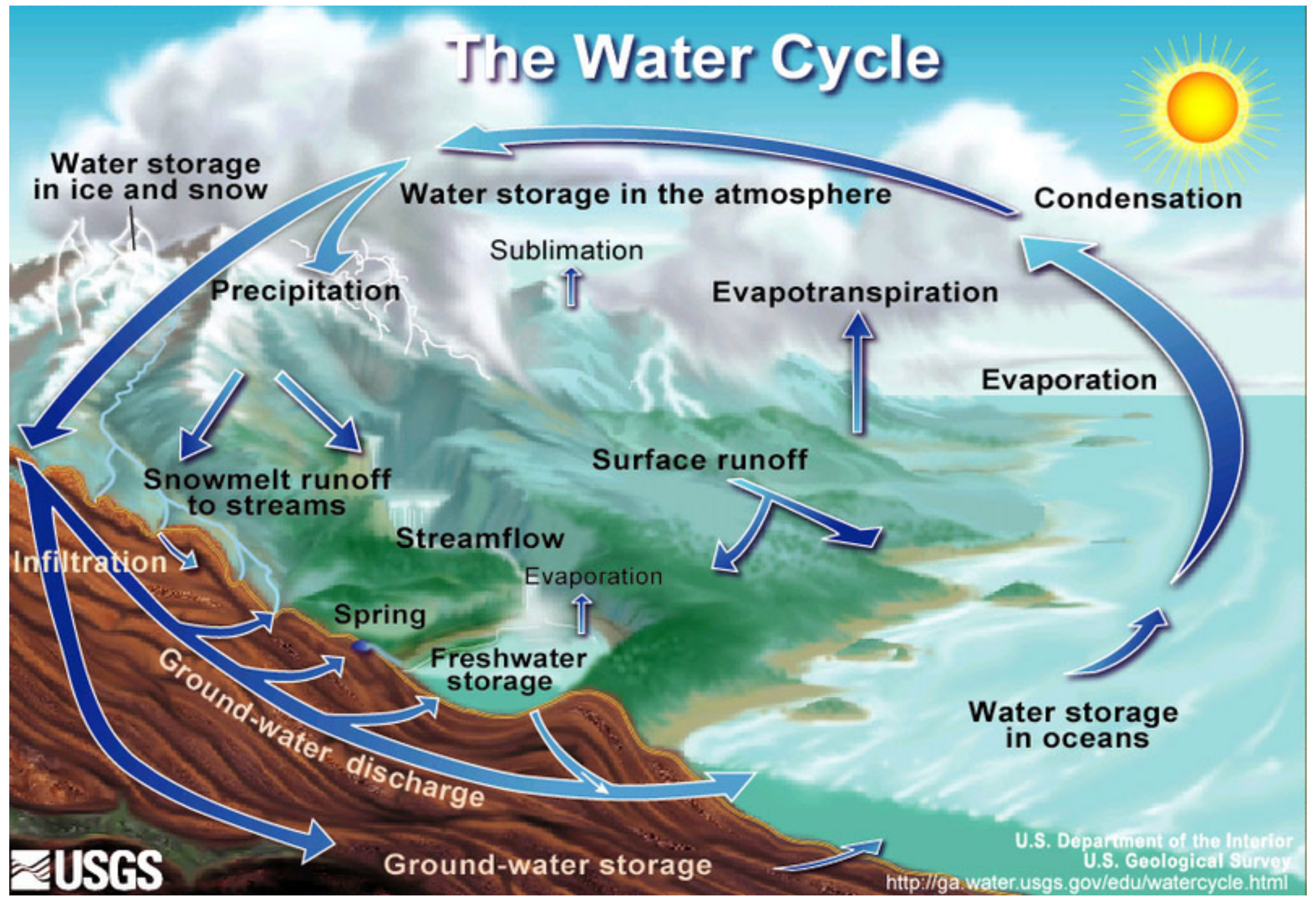
https://pmm.nasa.gov/education/sites/default/files/article_images/Water-Cycle-Art2A.png

Water Cycle

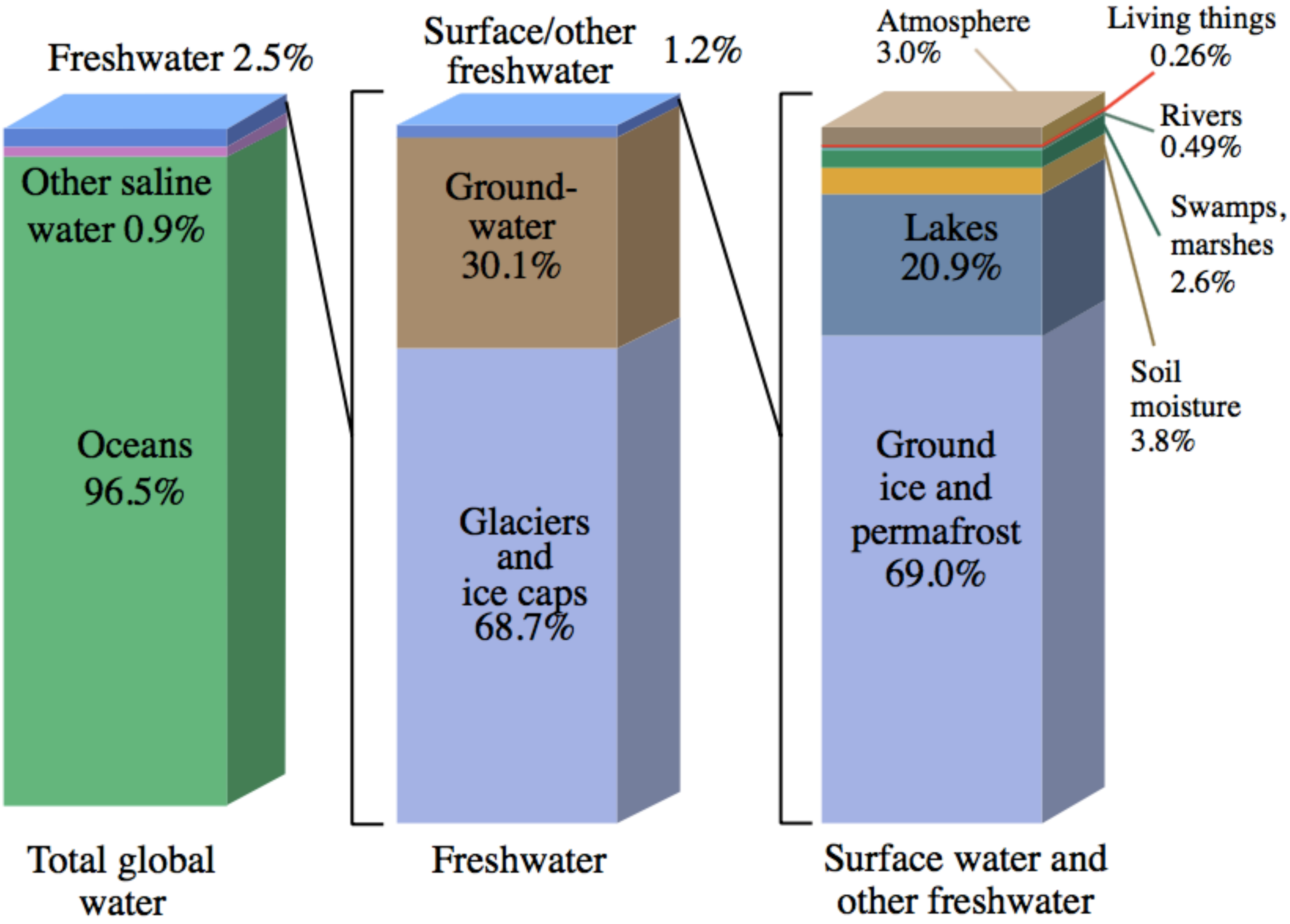


https://en.wikipedia.org/wiki/Water_cycle#/media/File:Diagram_of_the_Water_Cycle.jpg

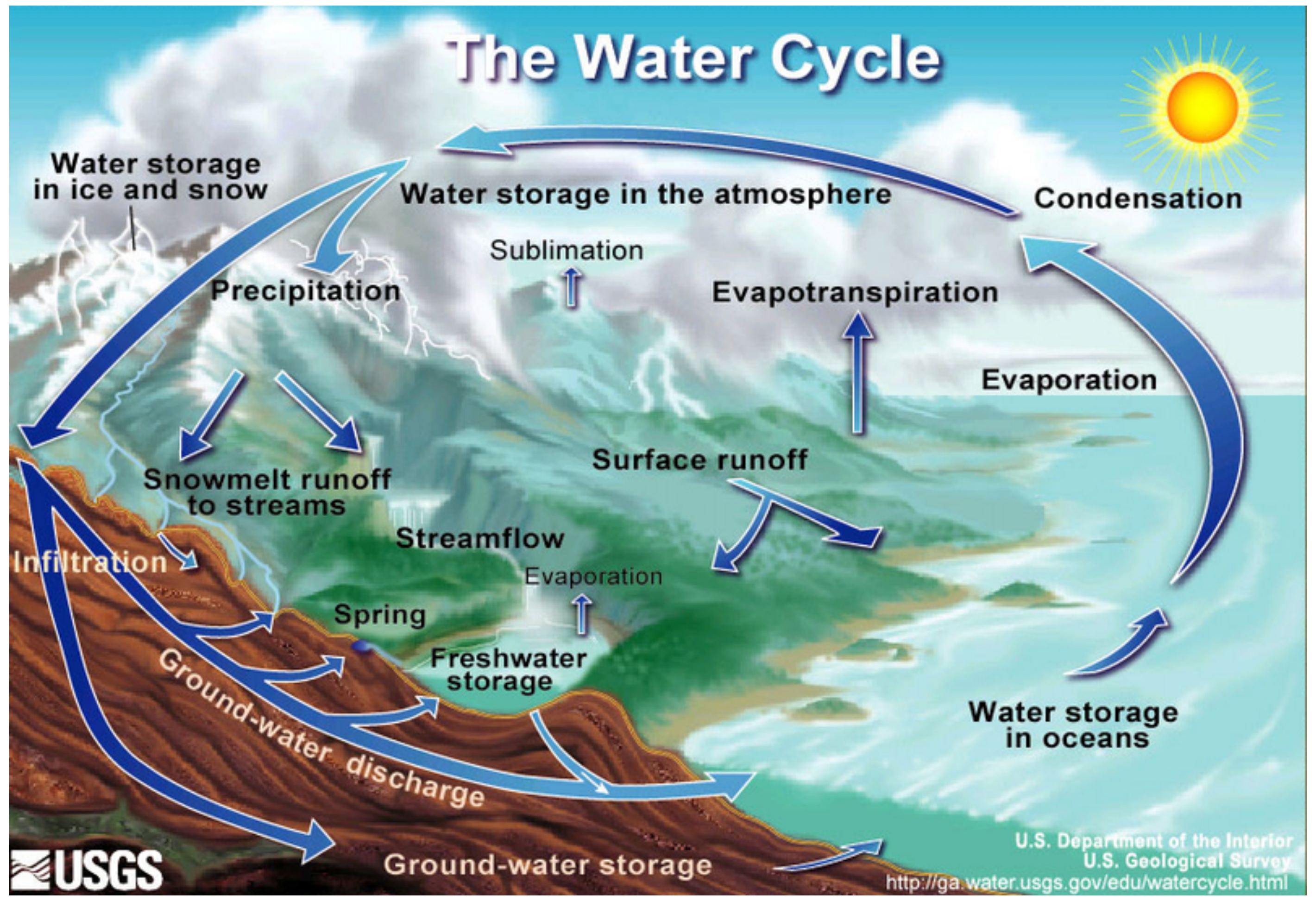
Water Cycle



https://scied.ucar.edu/longcontent/water-cycle



Water Cycle

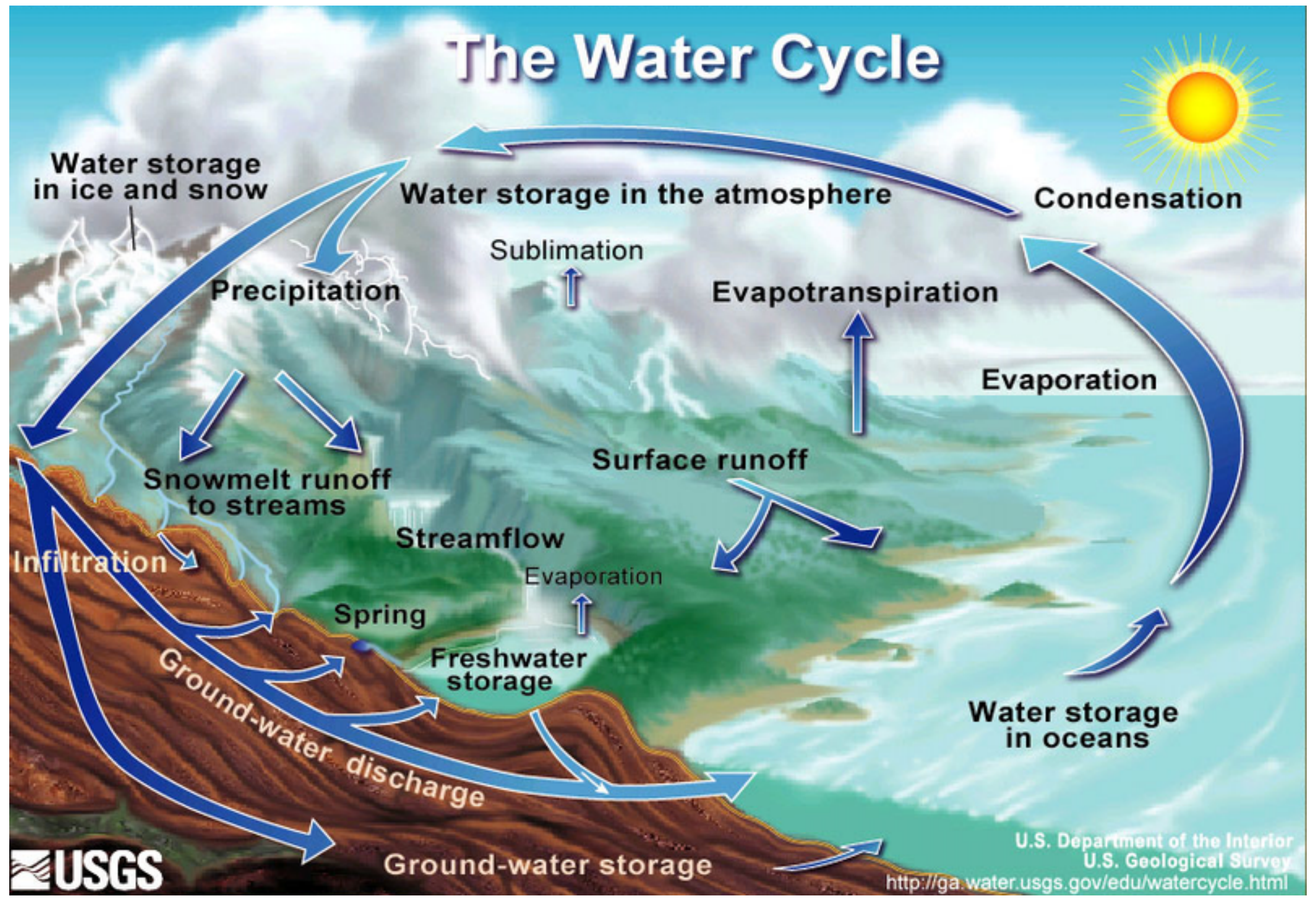


https://scied.ucar.edu/longcontent/water-cycle

Table 1: Amounts of water in the cycle

Reservoir	Volume	% of a larger reservoir
All of Earth's water	1,386,000,000 to 1,460,000,000 km^3	NA
Oceans	1,338,000,000 to 1,400,000,000 km^3	97% of total water
Fresh water	35,030,000 km^3	2.5 to 3% of total water
Ice & snow	43,400,000 km^3	-
Ice caps, glaciers, and permanent snow	24,064,000 to 29,000,000 km^3	68.7% of fresh water about 2% of total water
Antarctic ice & snow	29,000,000 km^3	about 90% of all ice
Greenland	3,000,000 km^3	about 10% of all ice
Mountain Glaciers	100,000 km^3	-
Ground water (saline+fresh)	23,400,000 km^3	-
Ground water (saline)	-	54% of ground water
Ground water (fresh)	10,530,000 km^3	30.1% of fresh water 46% of ground water
Surface water (fresh)	-	1% of fresh water
Lakes	-	87% of surface fresh water
Swamps	-	11% of surface fresh water
Rivers	-	2% of surface fresh water
Atmosphere	12,000 to 15,000 km^3	-

Water Cycle

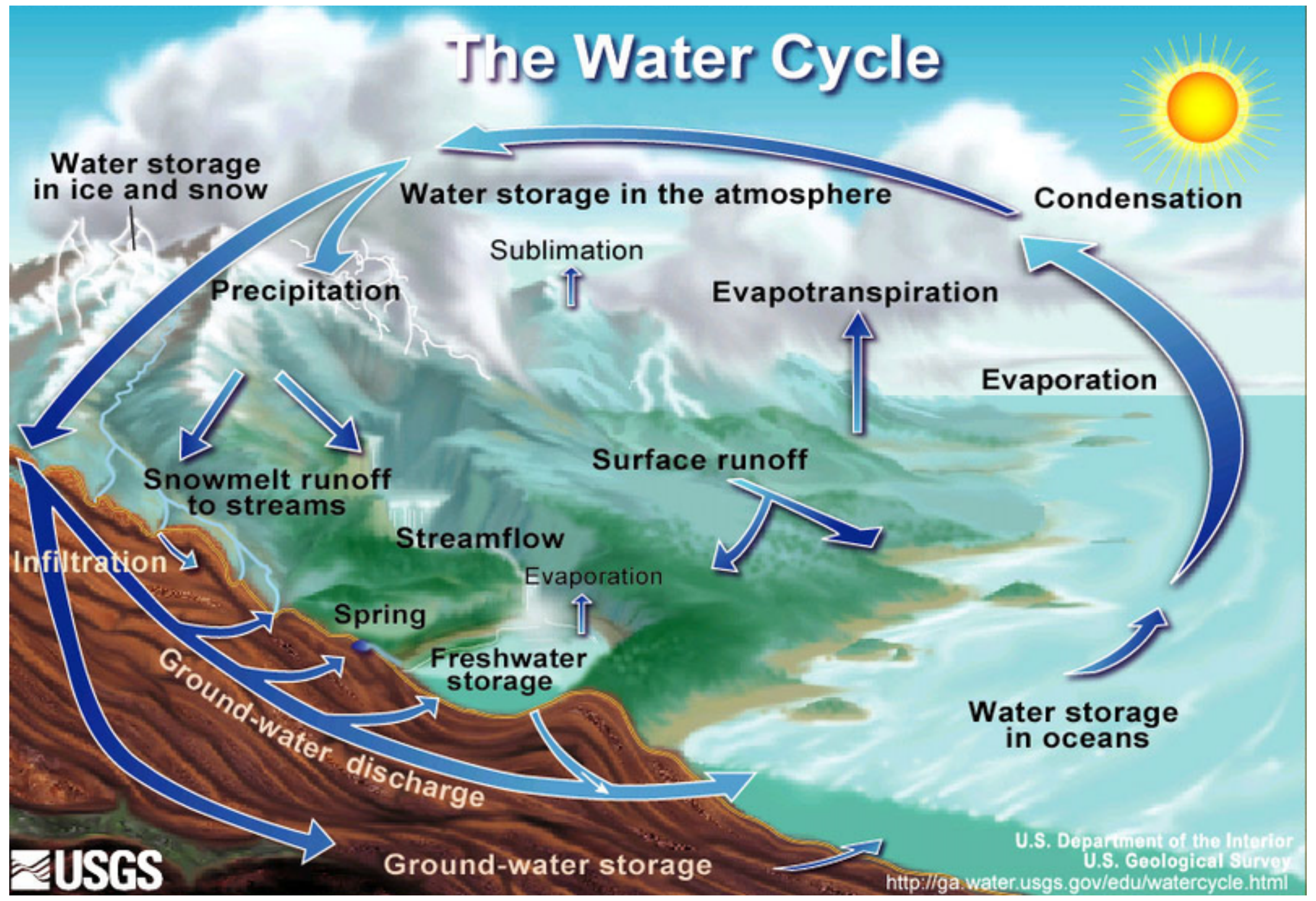


https://scied.ucar.edu/longcontent/water-cycle

Table 2: Flows between reservoirs

Process	From/to Reservoir	>Flow Rate
Precipitation	Atmosphere to Ocean/Land	505,000 km^3/year
Ocean precipitation	Atmosphere to Ocean	398,000 km^3/year
Land precipitation (except snow?)	Atmosphere to Land/surface	96,000 to 107,000 km^3/year
Evapotranspiration	Ocean and Land/surface and Plants to Atmosphere	505,000 km^3/year
Ocean evaporation	Ocean to Atmosphere	434,000 km^3/year
Land evaporation	Land/surface to Atmosphere	50,000 km^3/year
Transpiration	Plants to Atmosphere	21,000 km^3/year
Uptake by plants	Land/surface to Biota	21,000 km^3/year
Runoff	Land/surface to Ocean	36,000 km^3/year
Melting	Ice/snow to Land/surface	11,000 km^3/year
Snowfall (on land only?)	Atmosphere to Ice/Snow	11,000 km^3/year
Percolation	Underground to and from (??) Land/surface	100 km^3/year

Water Cycle

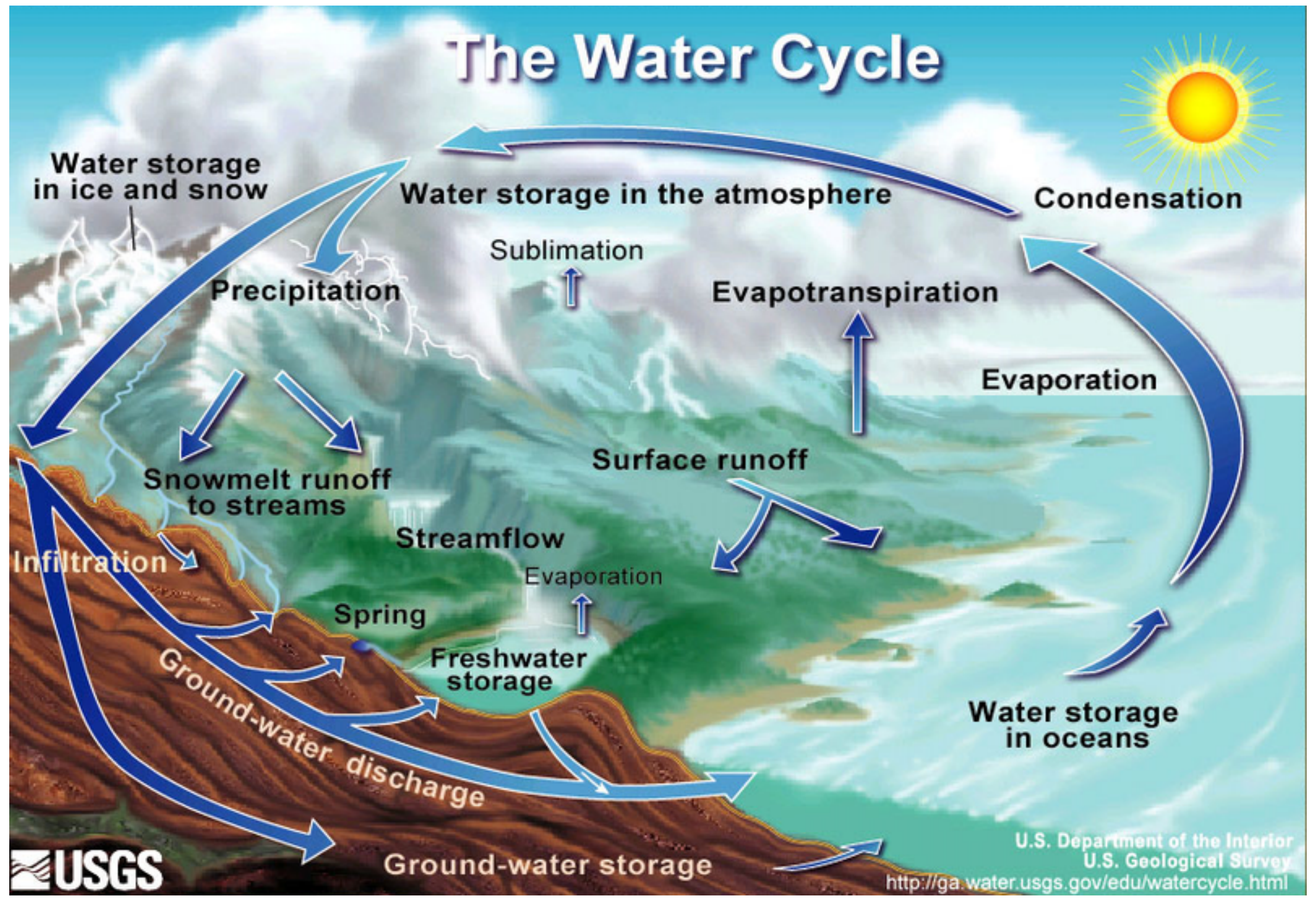


https://scied.ucar.edu/longcontent/water-cycle

Table 3: Residence times in reservoirs

Reservoir	Residence Time (average)
Oceans	3,000 to 3,230 years
Glaciers	20 to 100 years
Seasonal Snow Cover	2 to 6 months
Soil Moisture	1 to 2 months
Groundwater: Shallow	100 to 200 years
Groundwater: Deep	10,000 years
Lakes	50 to 100 years
Rivers	2 to 6 months
Atmosphere	9 days

Water Cycle



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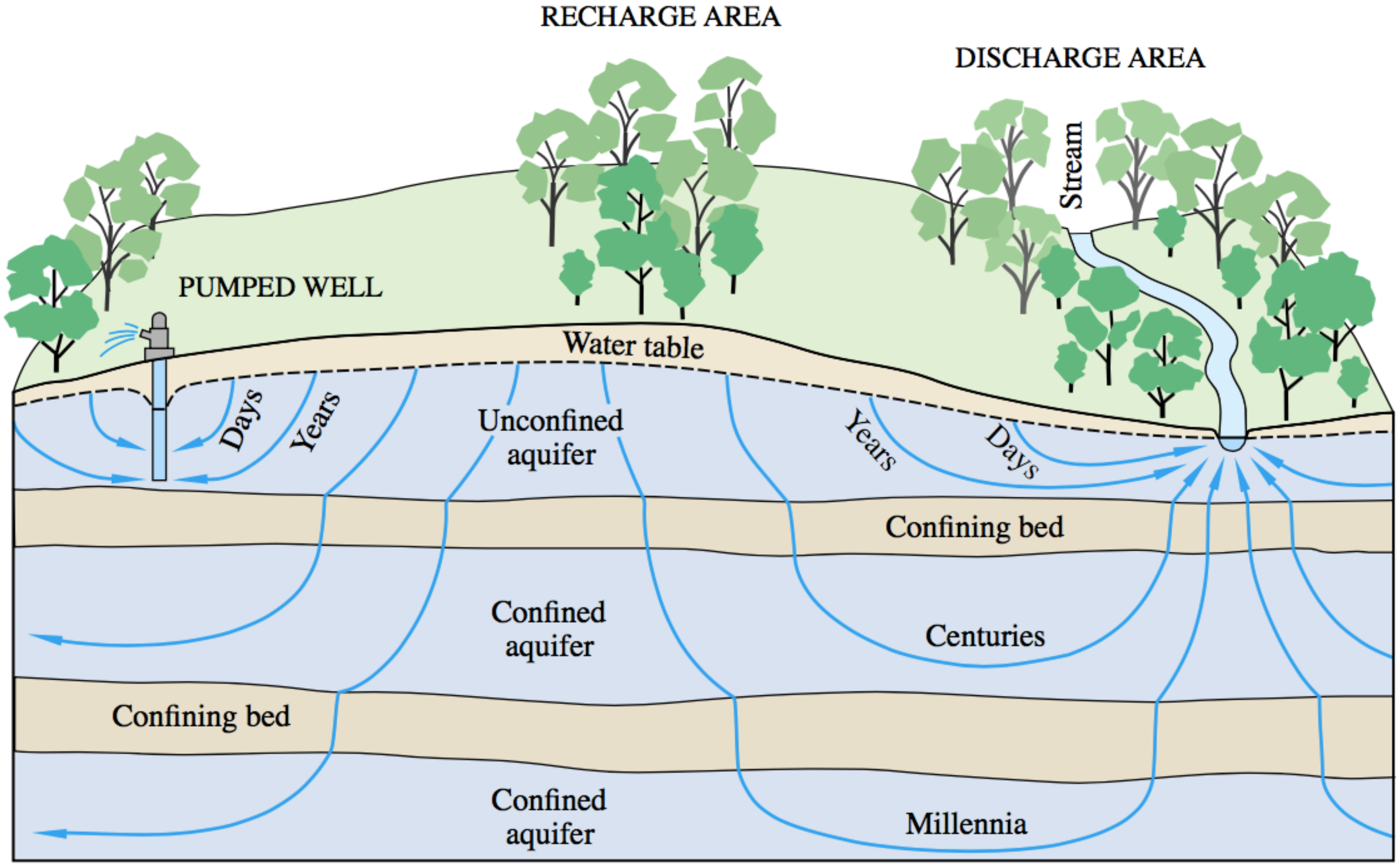
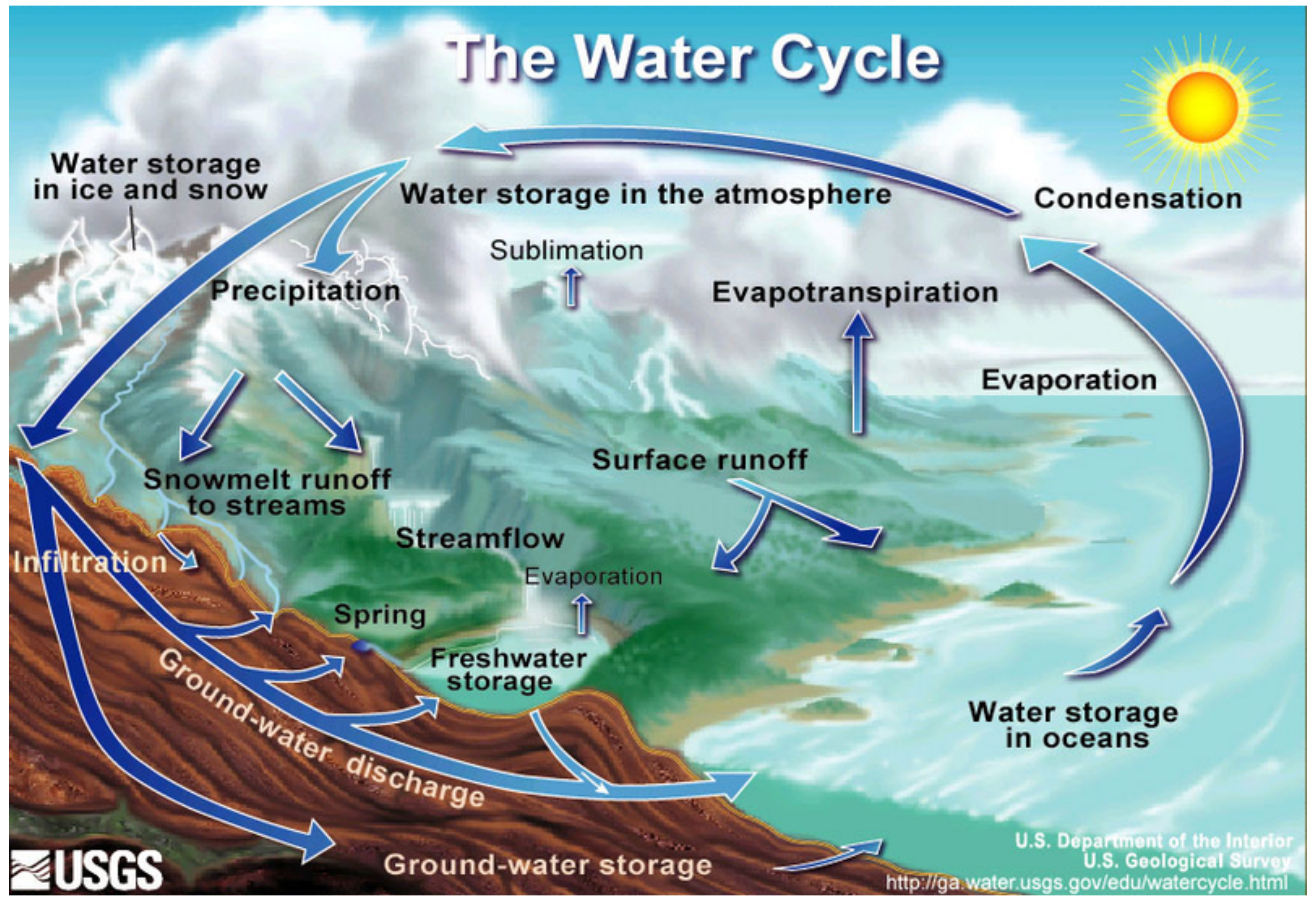


Water Cycle



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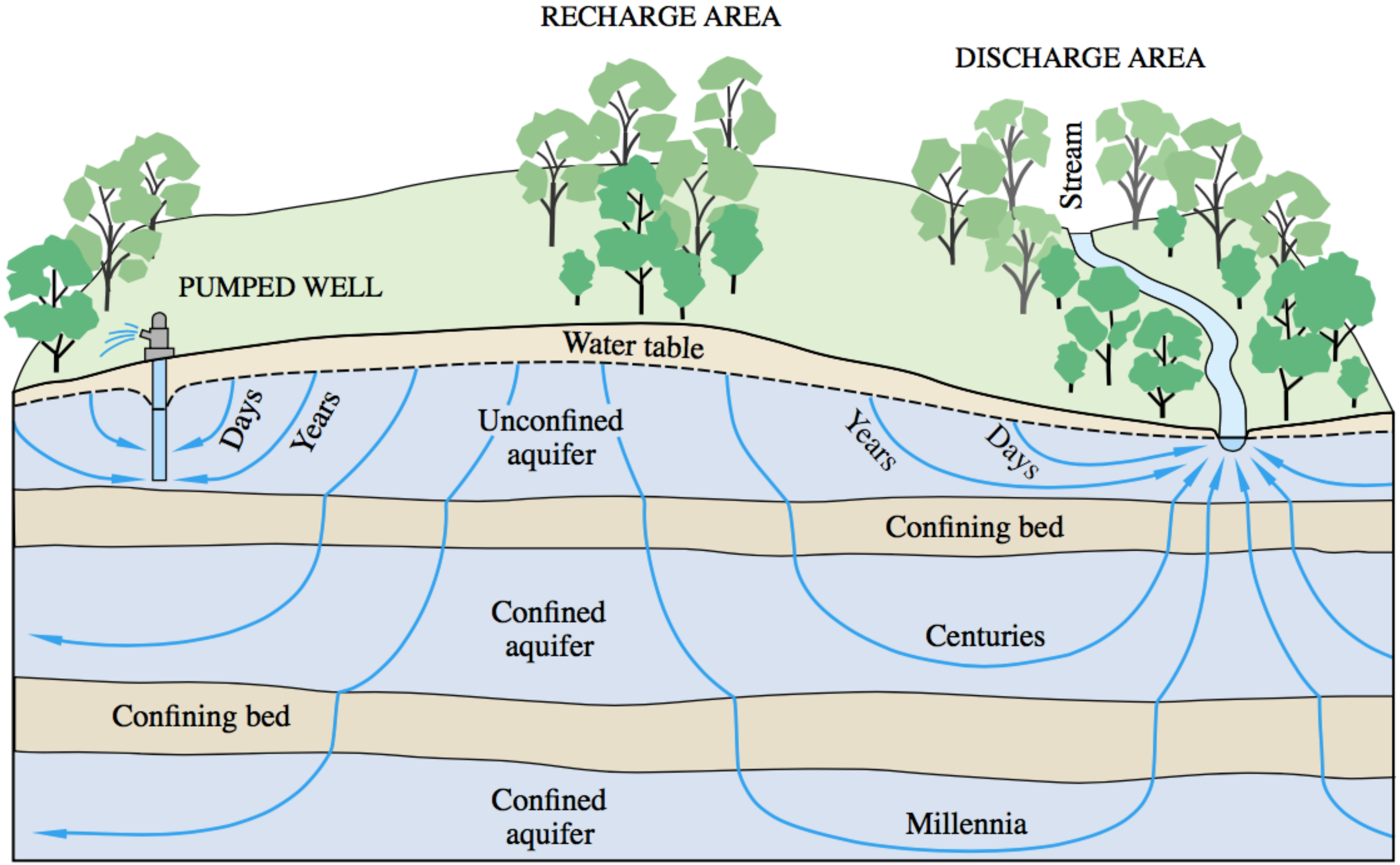
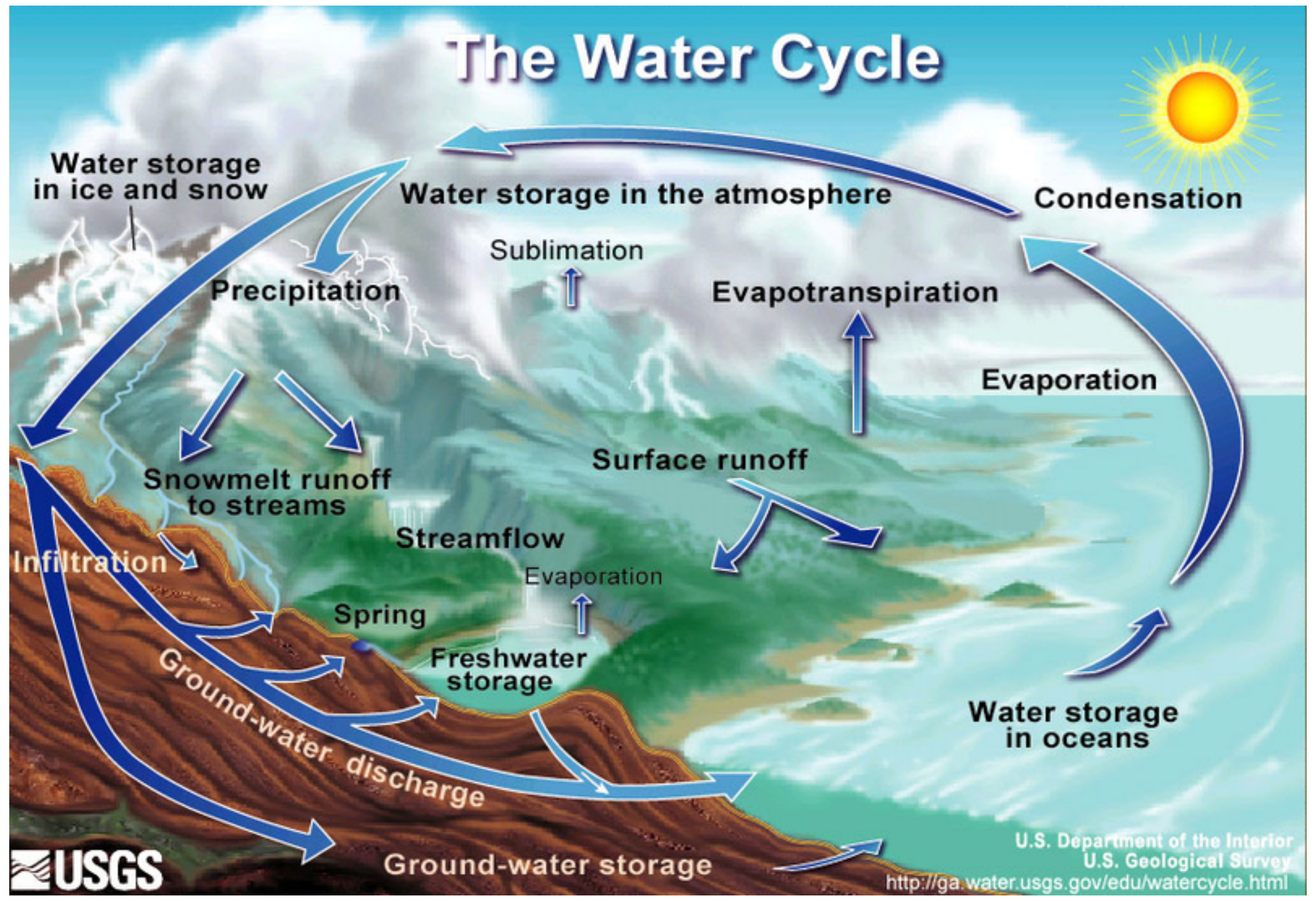
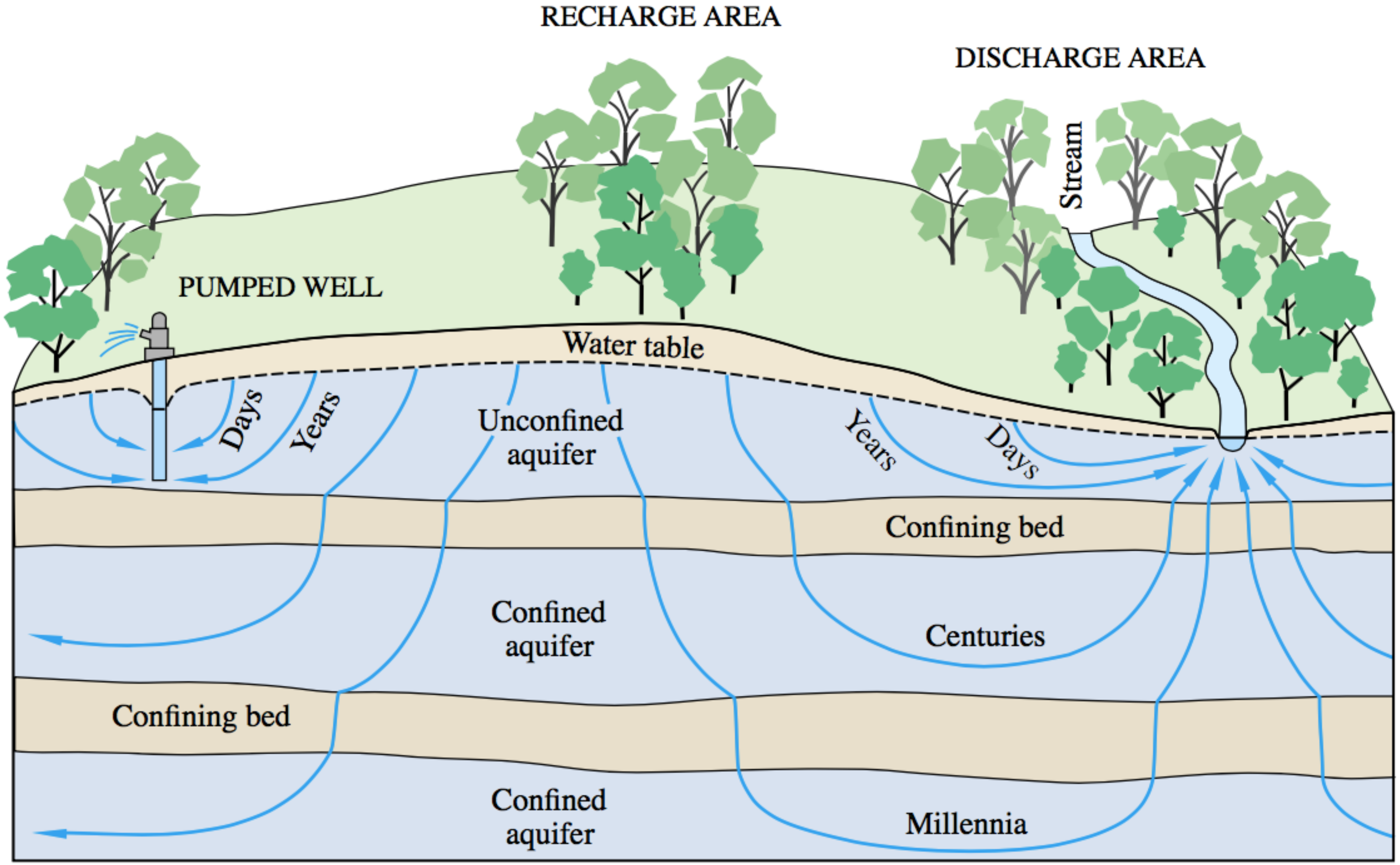


Water Cycle

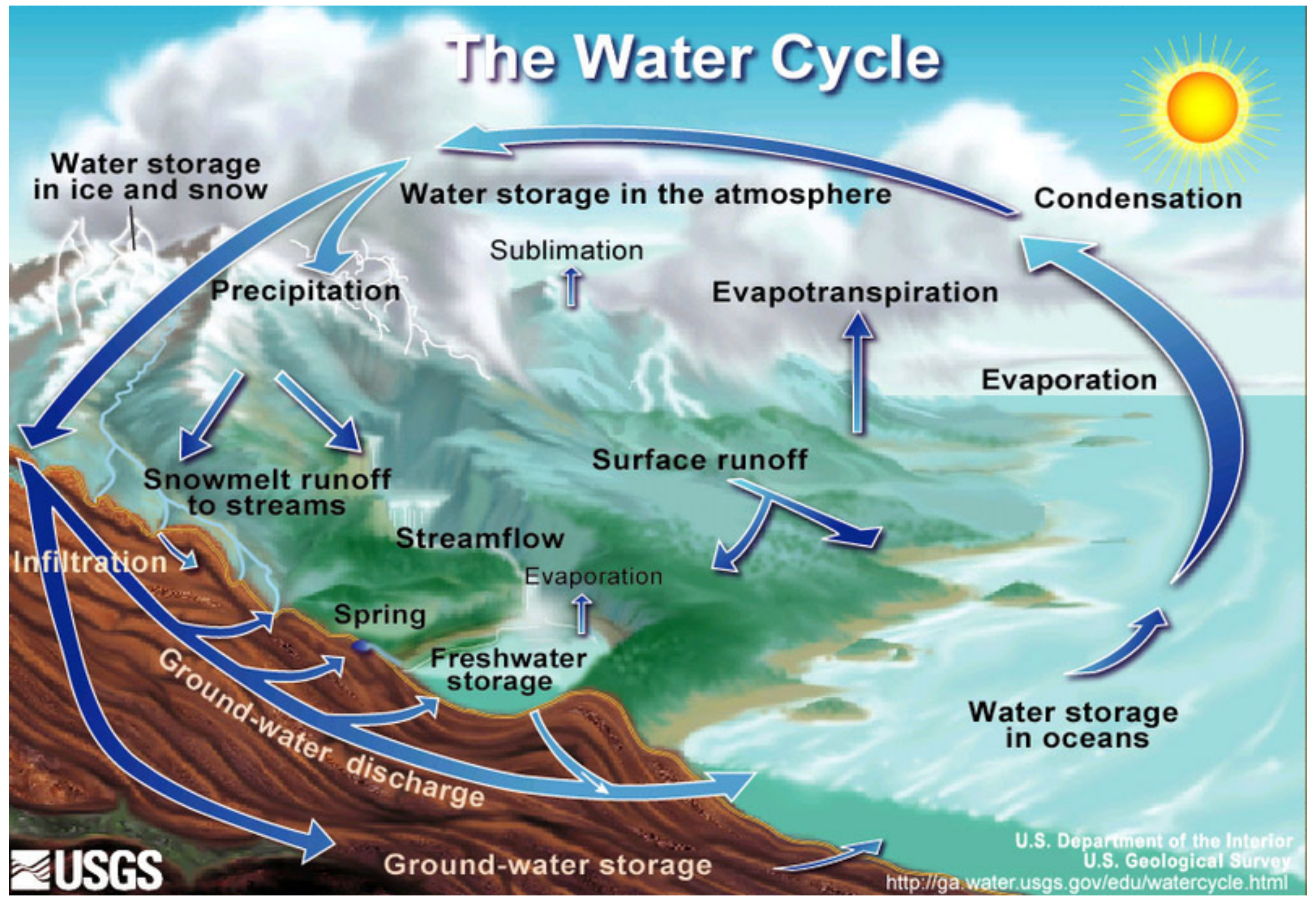


https://scied.ucar.edu/longcontent/water-cycle

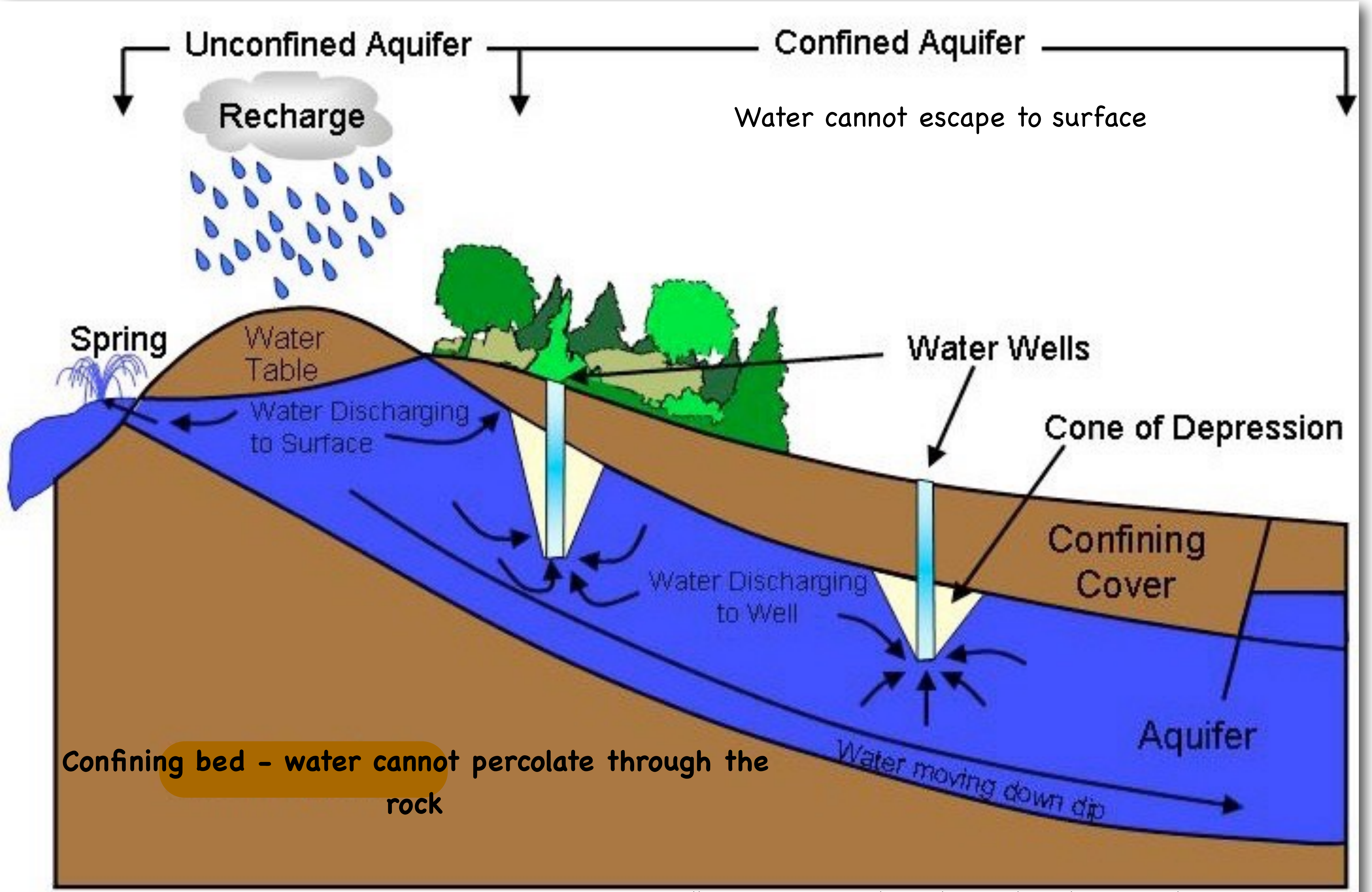
Aquifers are either confined or unconfined



Water Cycle



https://scied.ucar.edu/longcontent/water-cycle

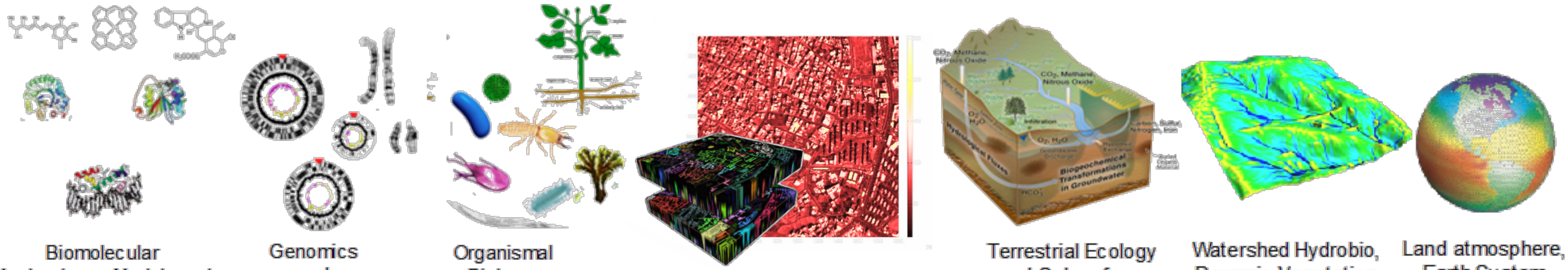


http://www.belmont.sd62.bc.ca/teacher/geology12/photos/erosion-water/aquifer.jpg

Aquifers are either confined or unconfined

So what happens if we pump the water out faster than it is being recharged by rain and snow?

Water-Energy Cycle



Biomolecular Mechanisms, Models and Networks

Genomics and Functional Genomics

Organismal Biology, Dynamics and Interactions

Human earth-system interactions

Terrestrial Ecology and Subsurface Biogeochemistry

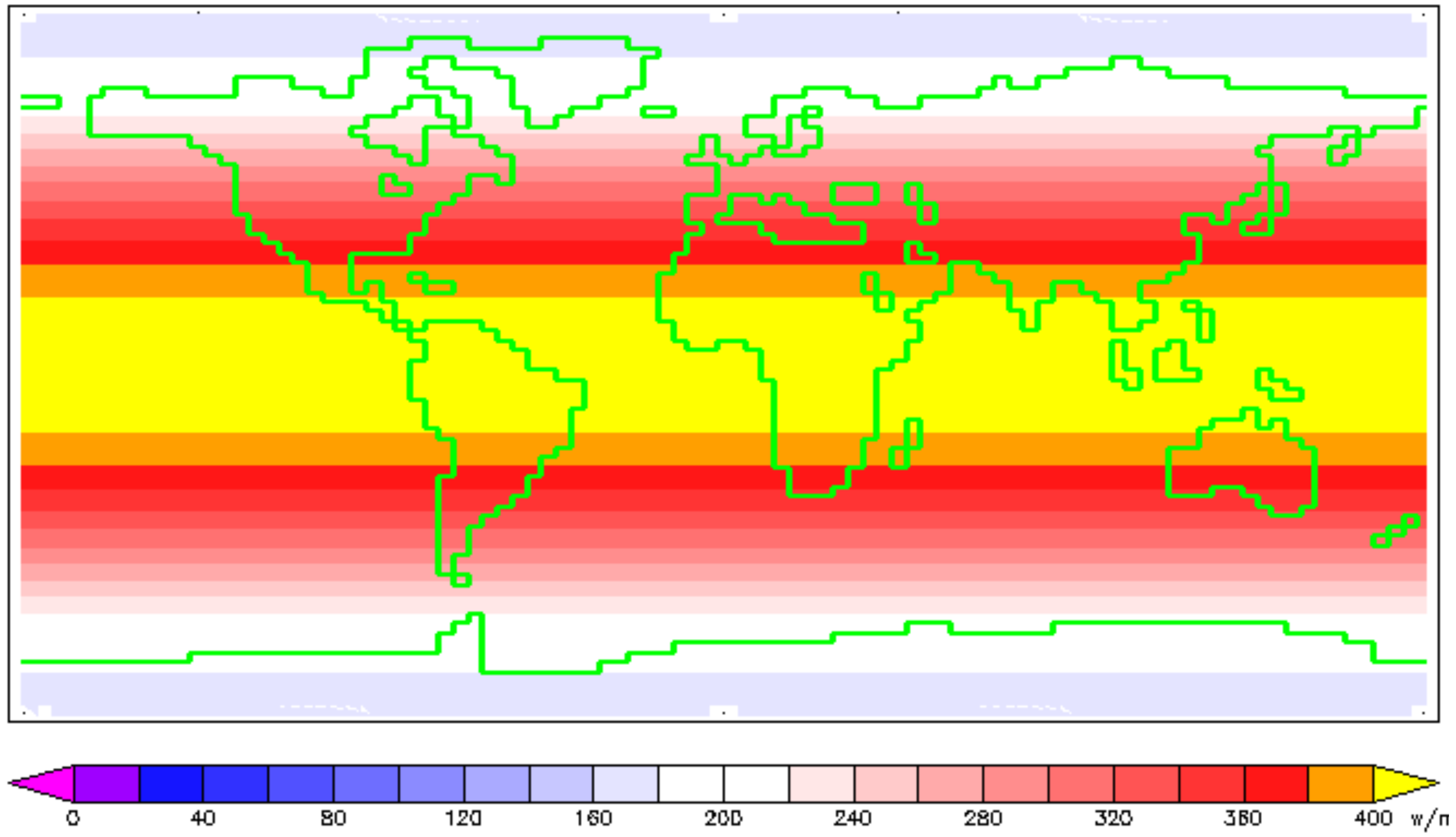
Watershed Hydrobio, Dynamic Vegetation observation and models

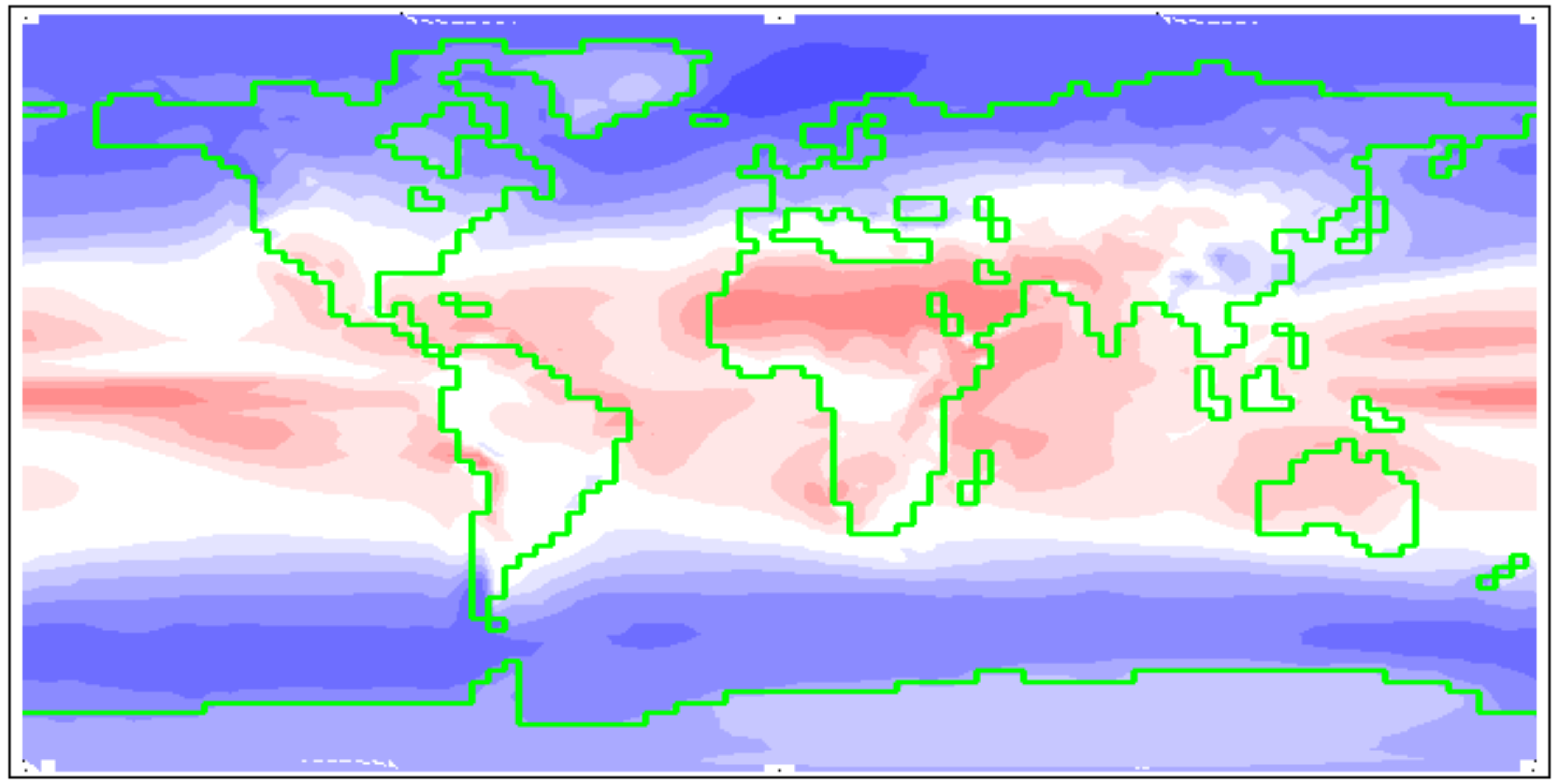
Land atmosphere, Earth System observation and models

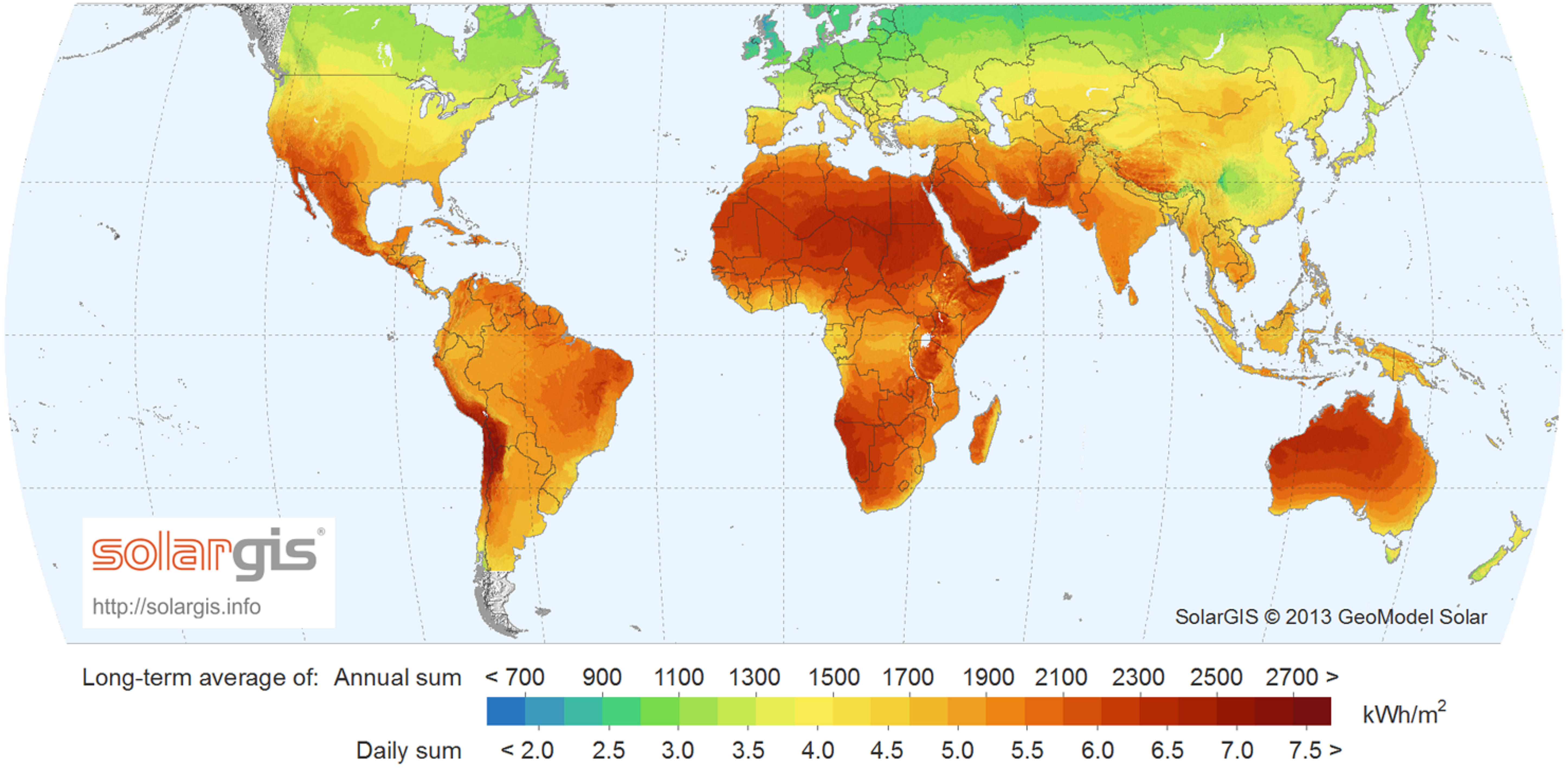
Femtoseconds (10^{-15} s)
Angstroms (10^{-10} m)

Years (10^{12} s)
Kilometers (10^{7} m)

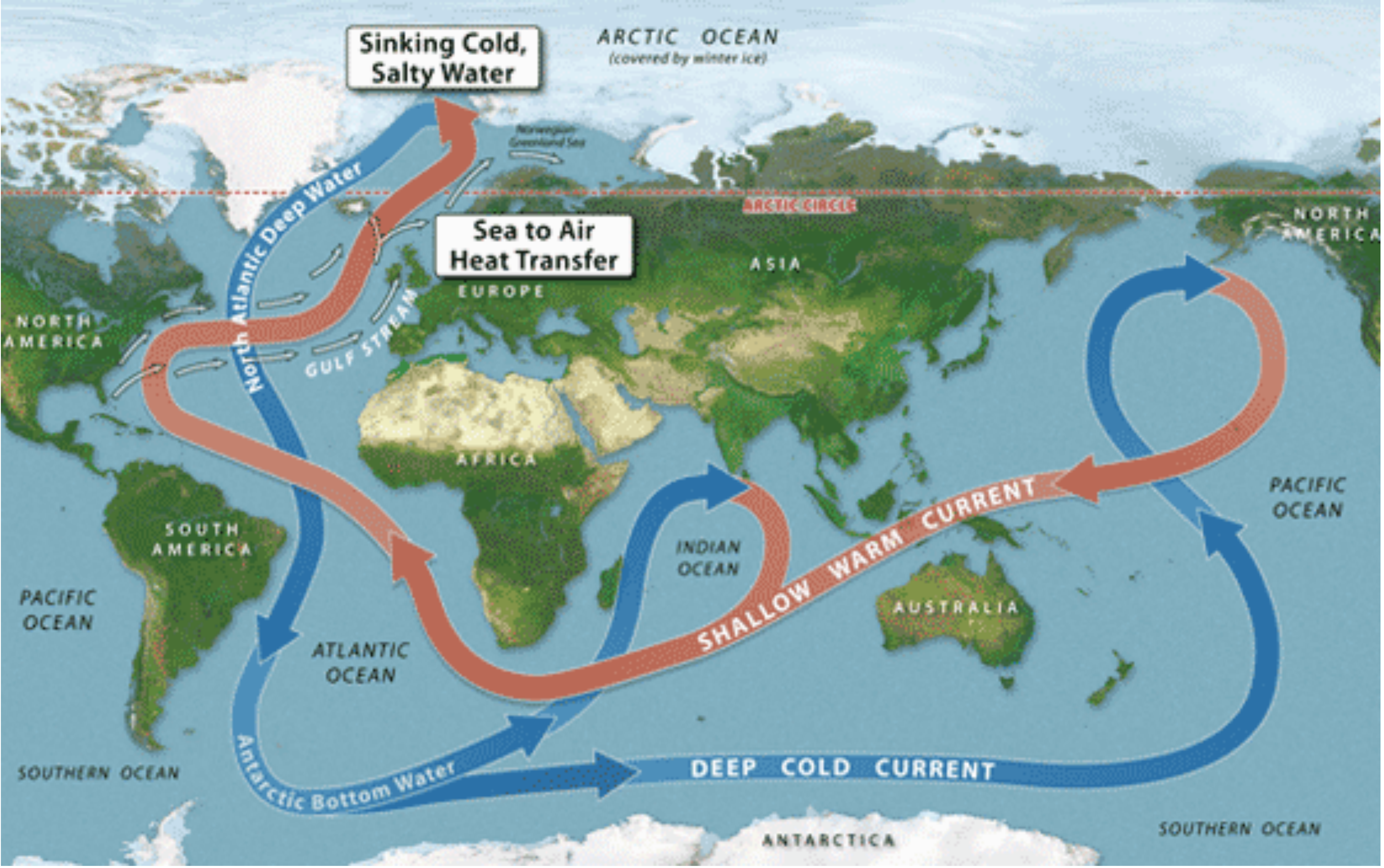
Water-Energy Cycle



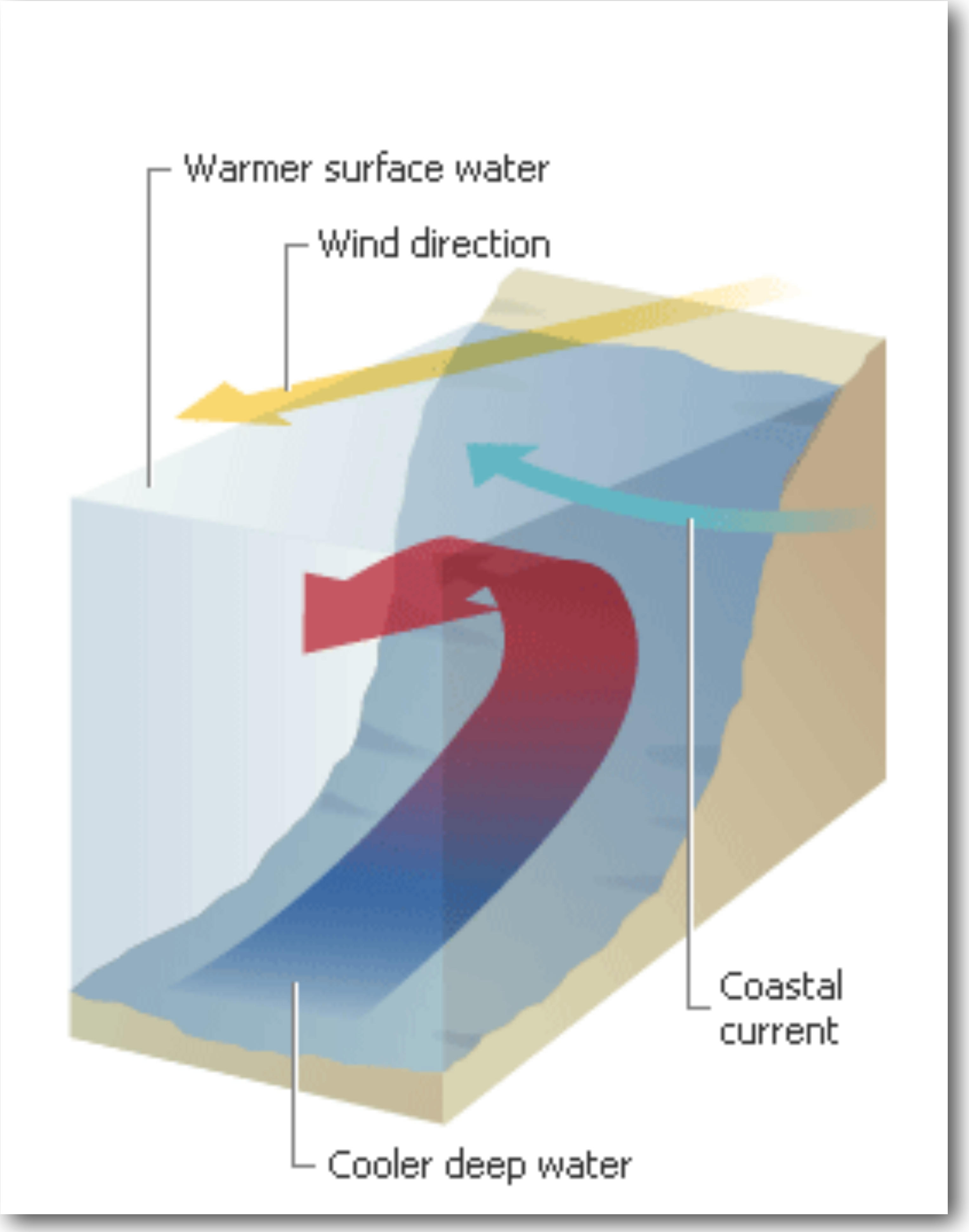




Ocean circulation



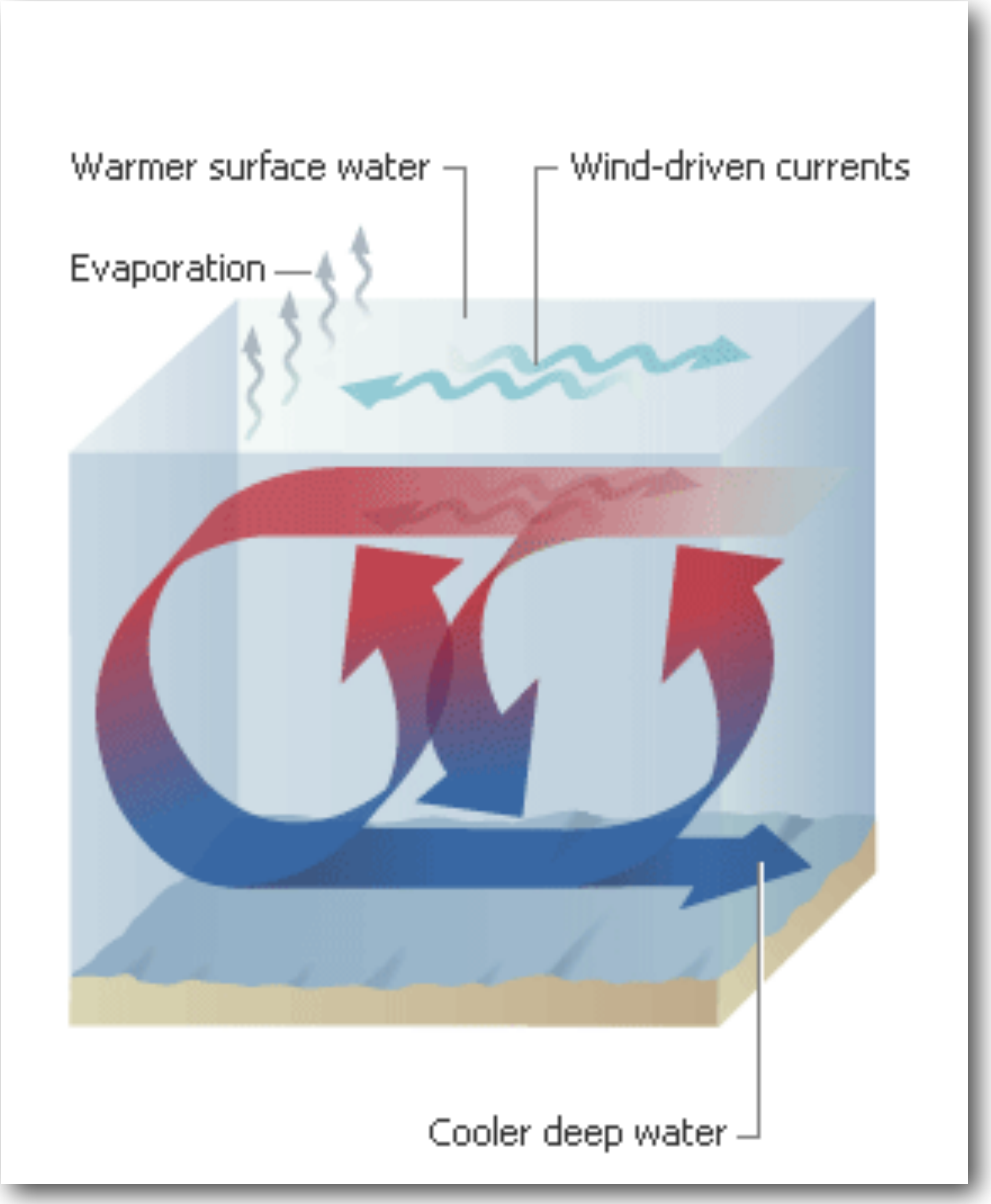
ocean circulation driven by:
(a) wind



http://images.encarta.msn.com/xrefmedia/aencmed/targets/illus/ilt/T014098A.gif

upwelling of cold water as wind pushes warmer water offshore

(b) evaporation



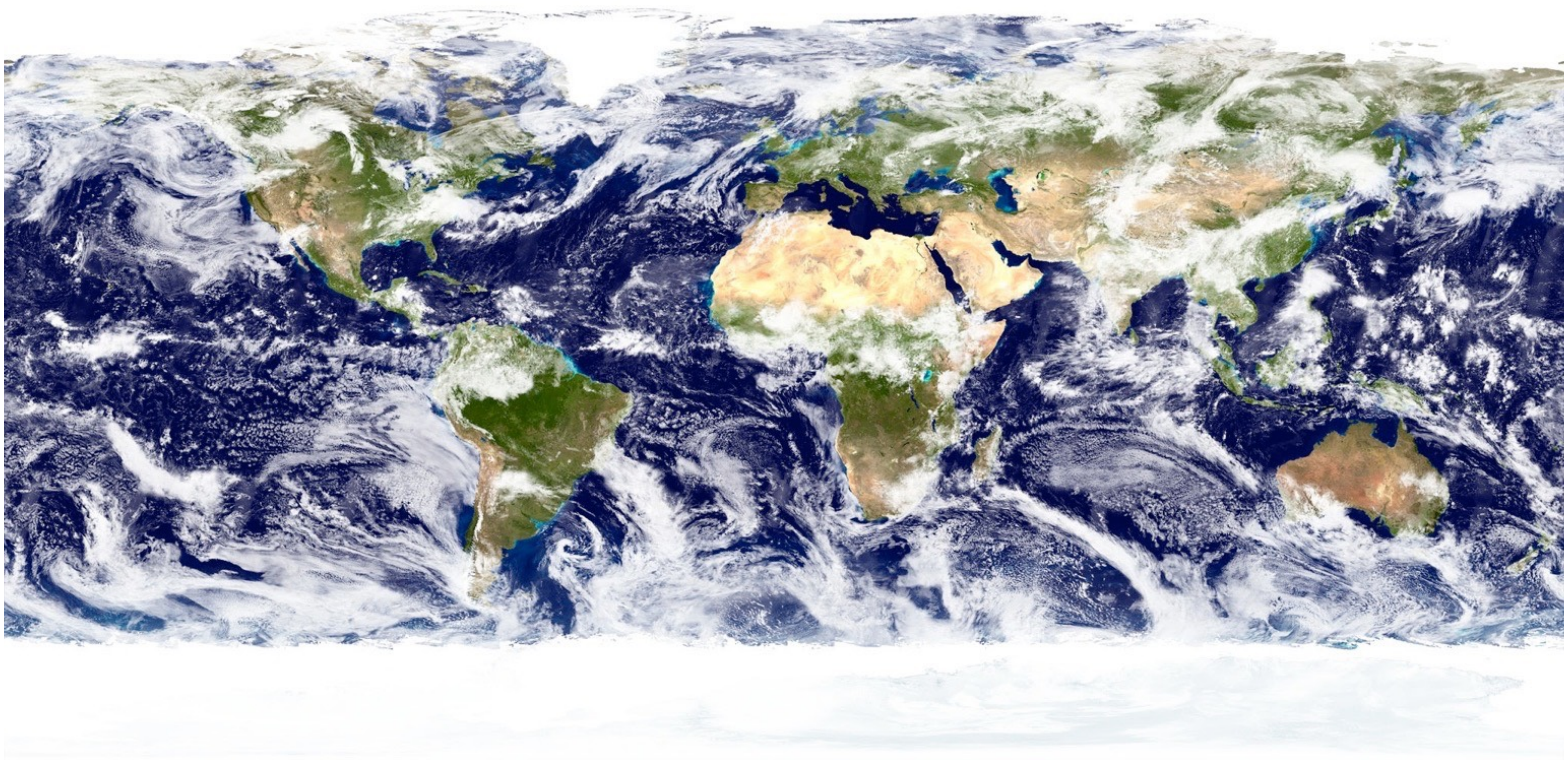
"thermo-haline" circulation

caused by changes in temperature (thermo)and salt (haline) content

colder, salty water is denser
- sinks to bottom of ocean

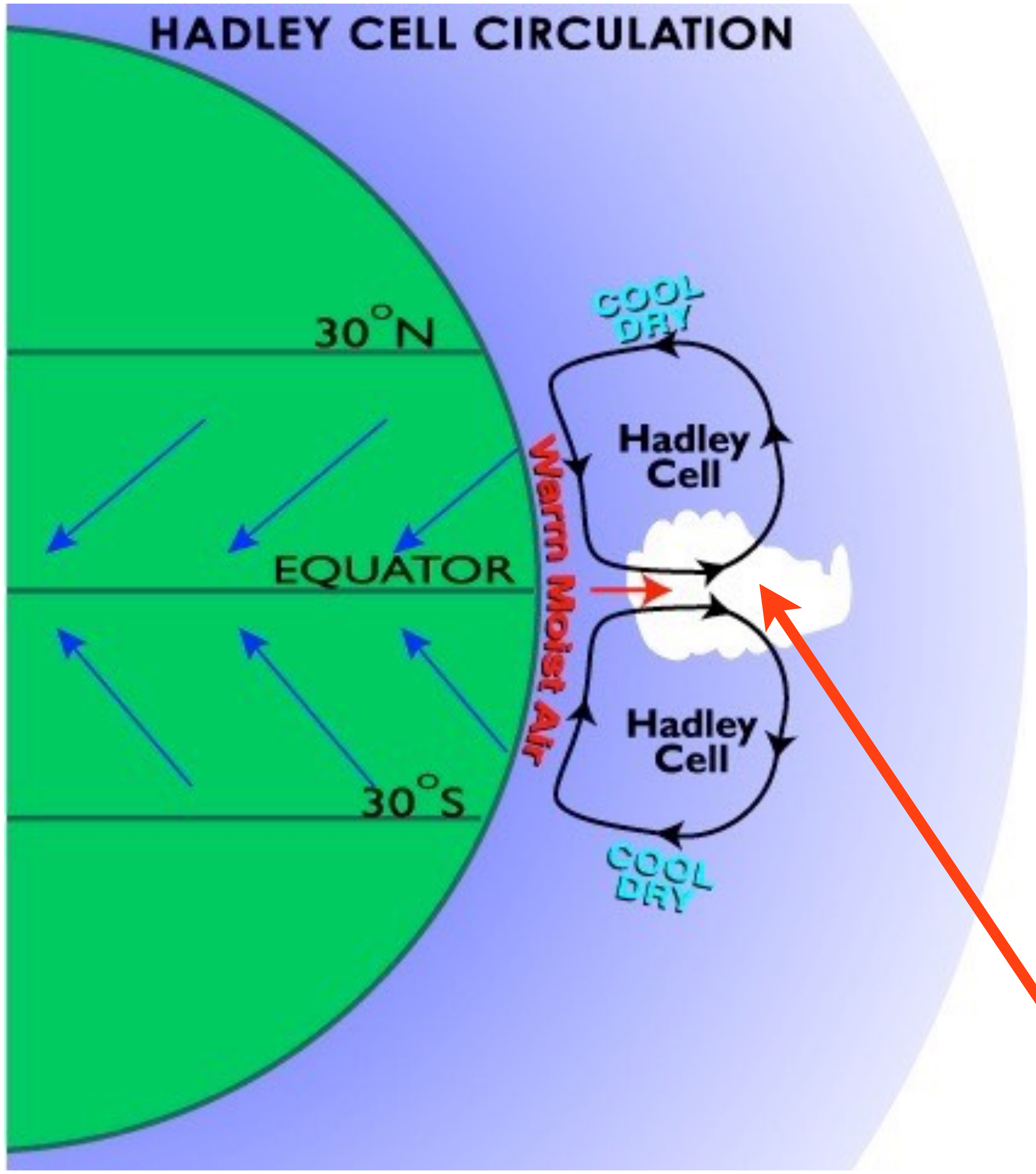
warm, fresh water is less dense
- stays near surface of ocean

Atmospheric circulation



http://earthobservatory.nasa.gov/Features/BlueMarble/Images/land_ocean_ice_cloud_2048.jpg

Hadley cells in tropical zones influence predominant wind direction across entire planet

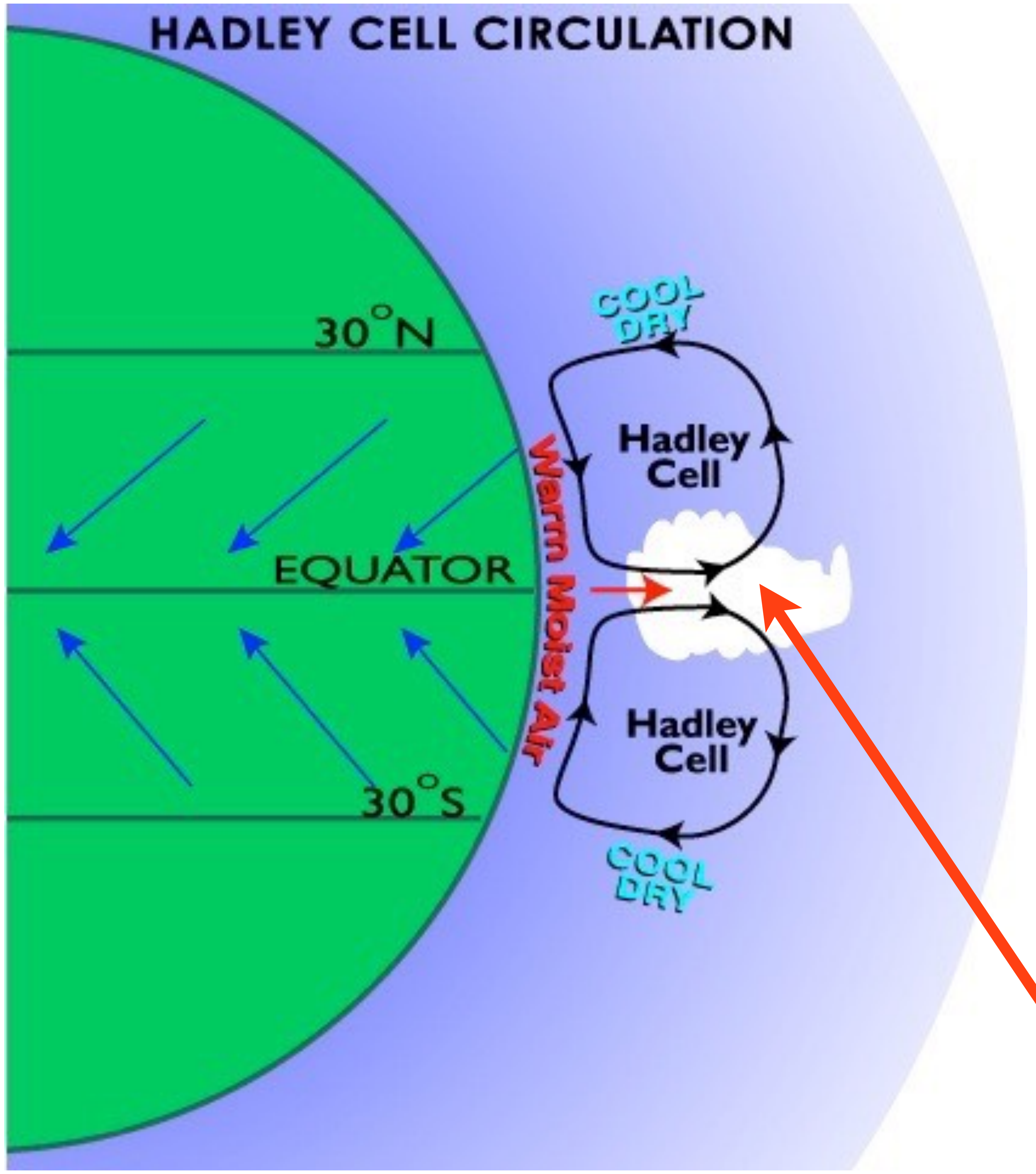


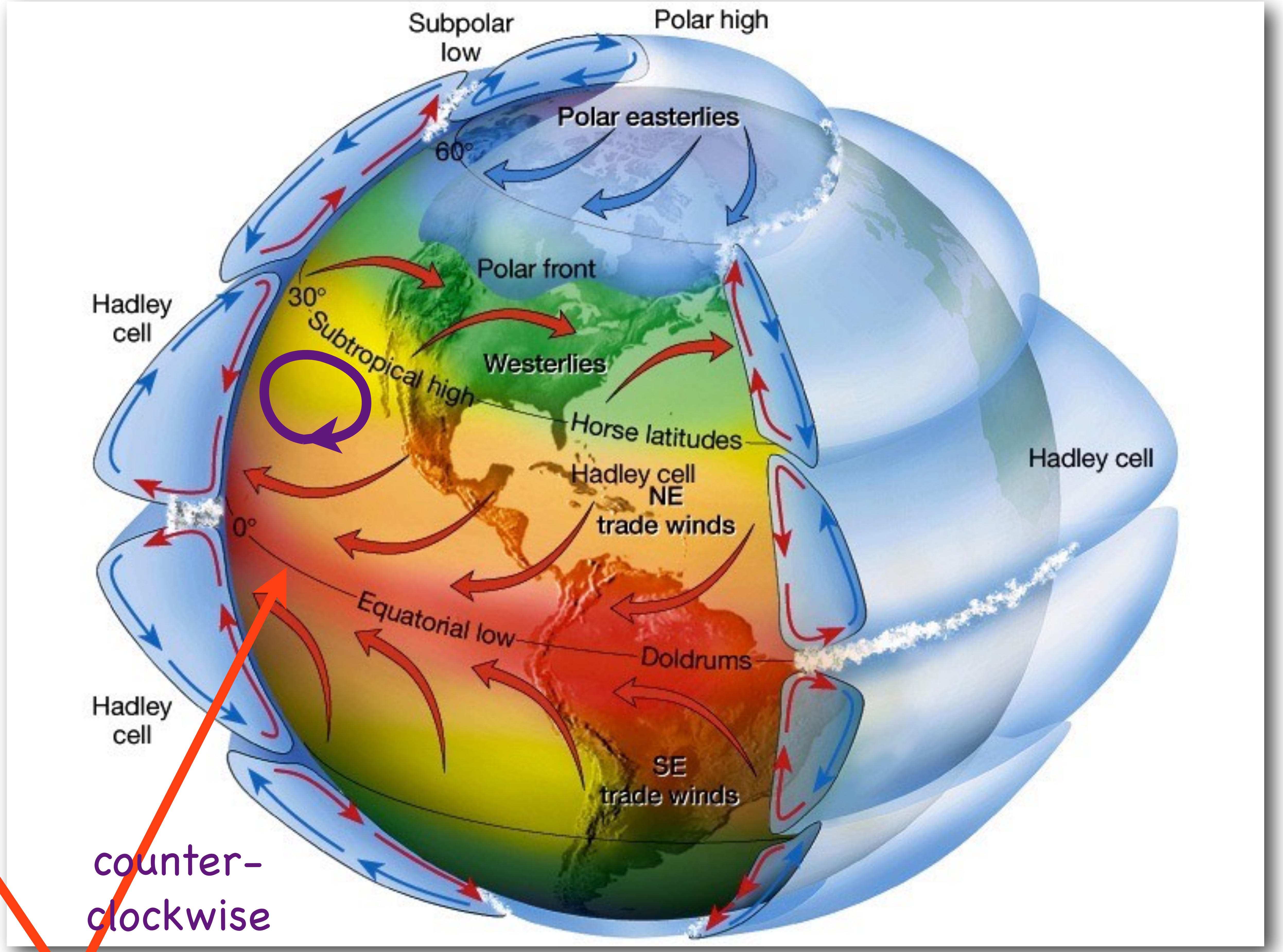
http://www.newmediastudio.org/DataDiscovery/Hurr_ED_Center/Easterly_Waves/Trade_Winds/Trade_Winds_fig02.jpg

Form in the Trade Winds belt (on either side of equator, between 30°N and 30°S)

equatorial "doldrums"
- where warm, moist air rises

Hadley cells in tropical zones influence predominant wind direction across entire planet

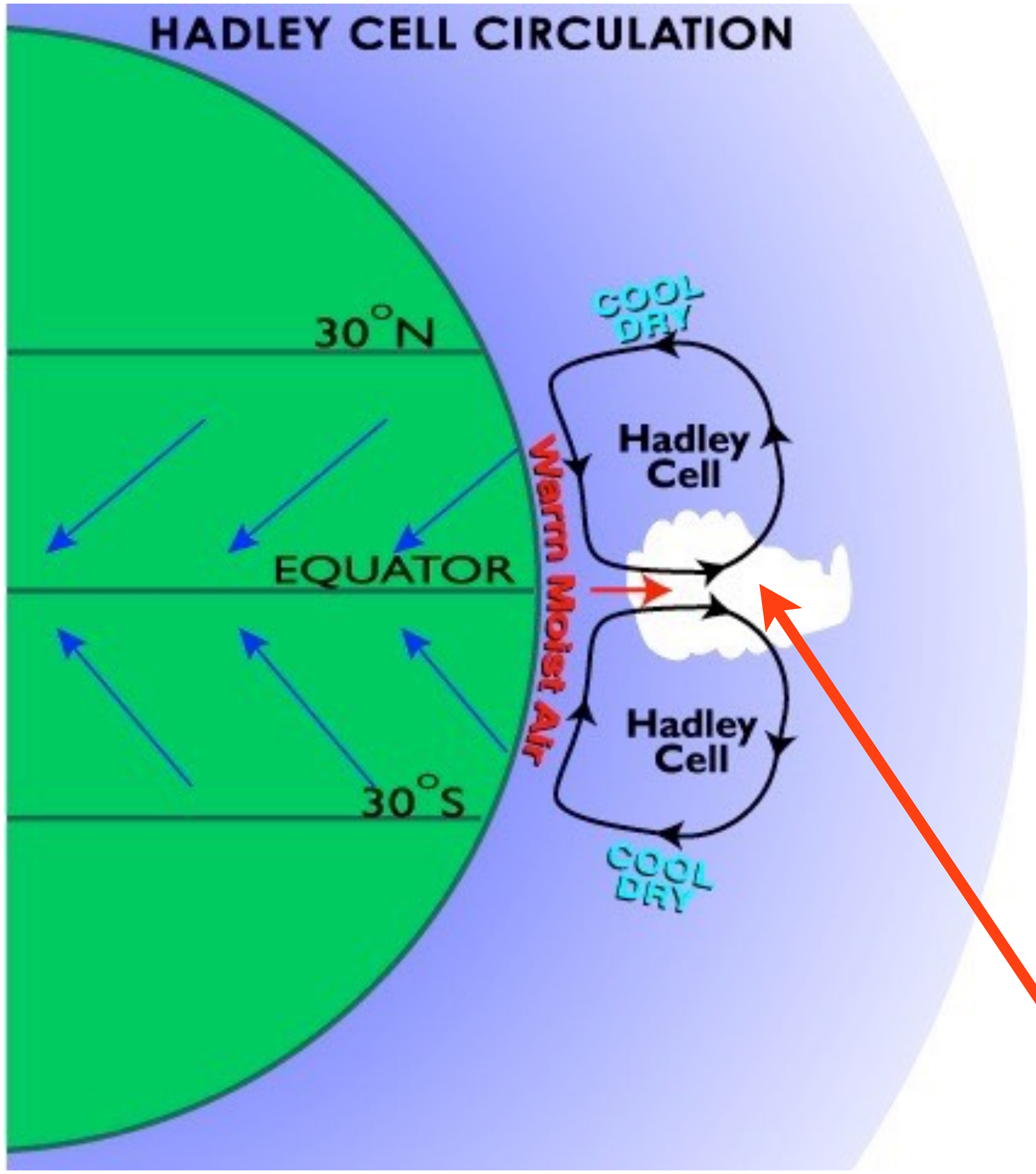


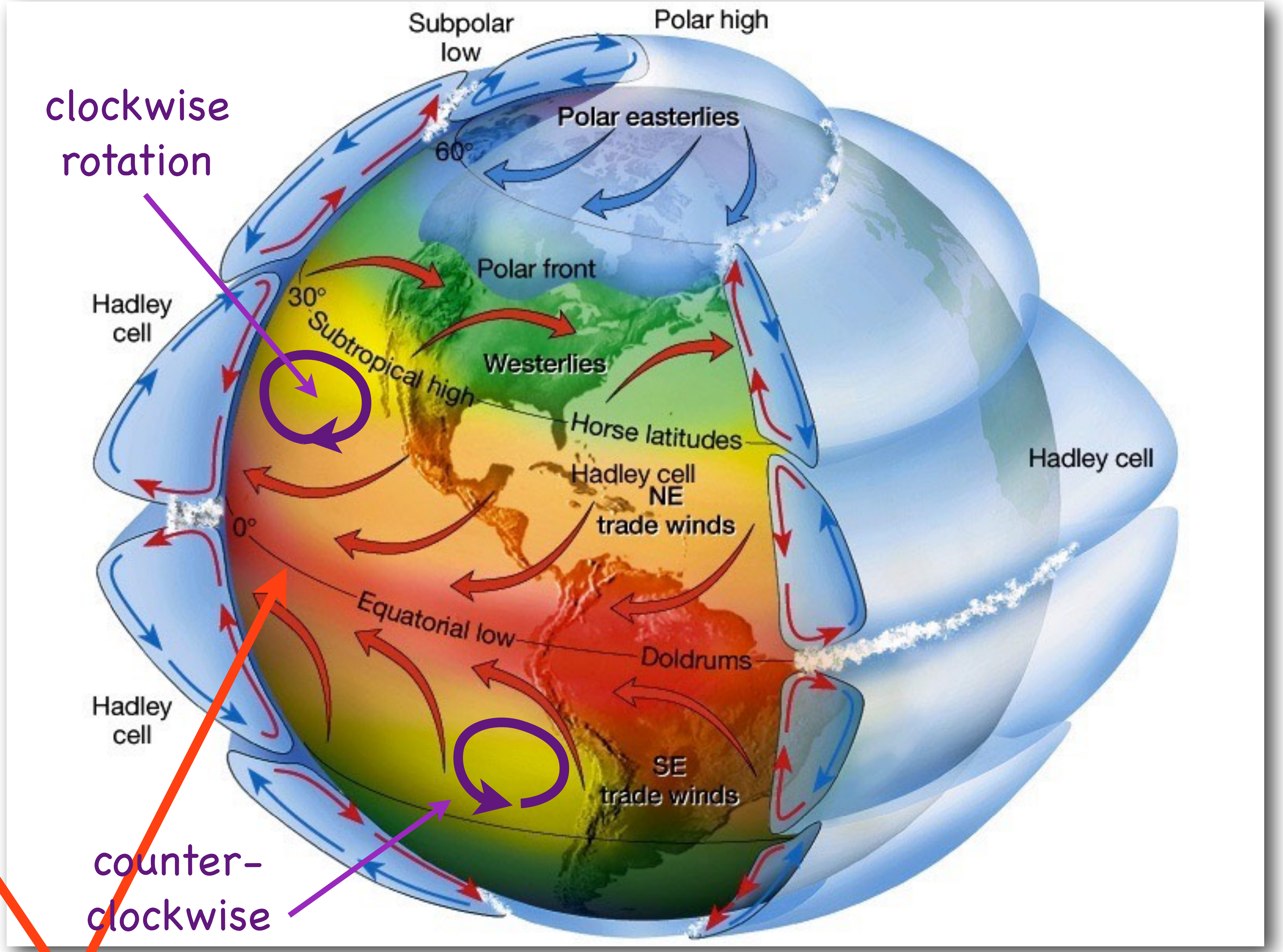


equatorial “doldrums”
- where warm, moist air rises

http://www.geology.um.maine.edu/ges121/lectures/20-monsoons/hadley.jpg

Hadley cells in tropical zones influence predominant wind direction across entire planet





equatorial "doldrums"
- where warm, moist air rises

http://www.geology.um.maine.edu/ges121/lectures/20-monsoons/hadley.jpg

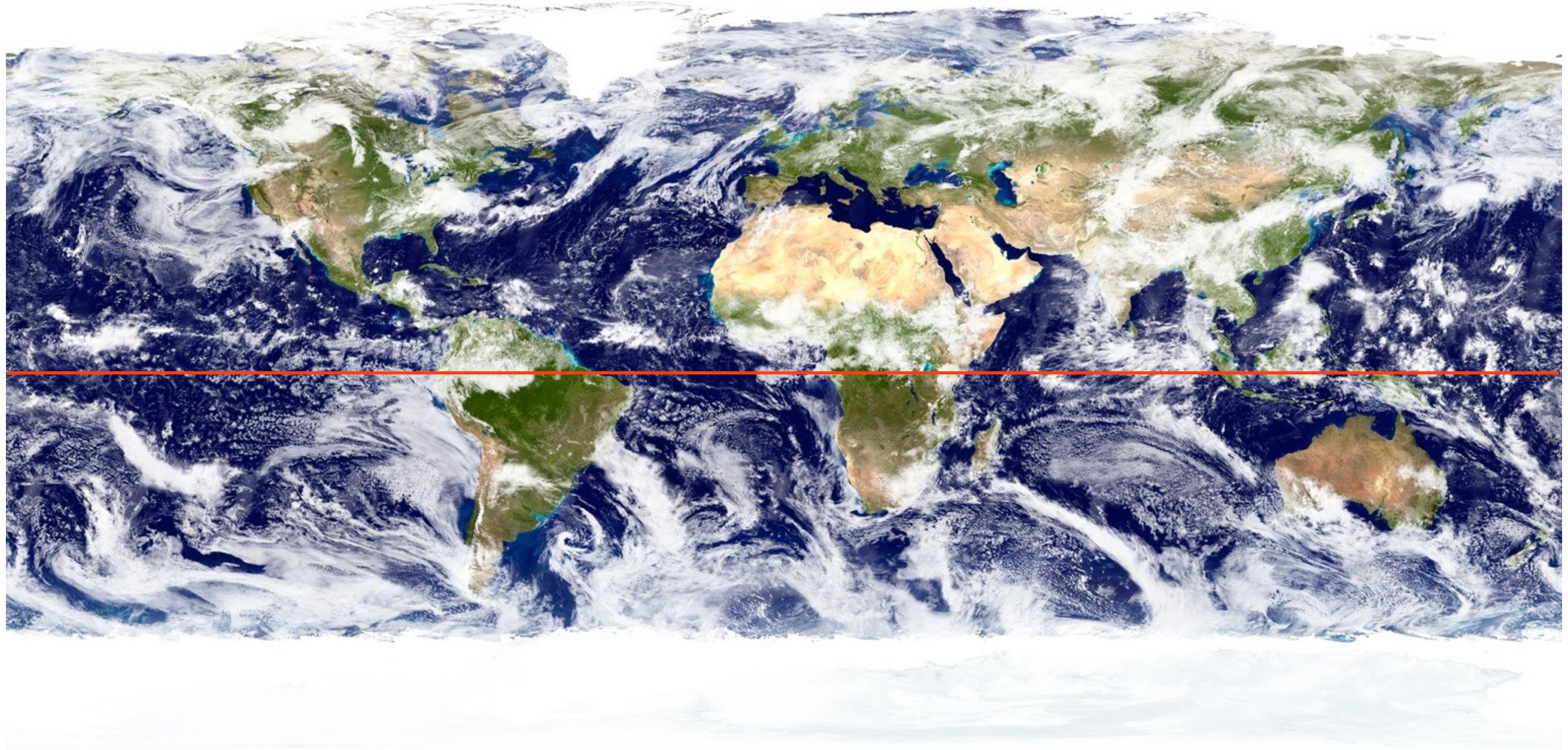
Water-Energy Cycle

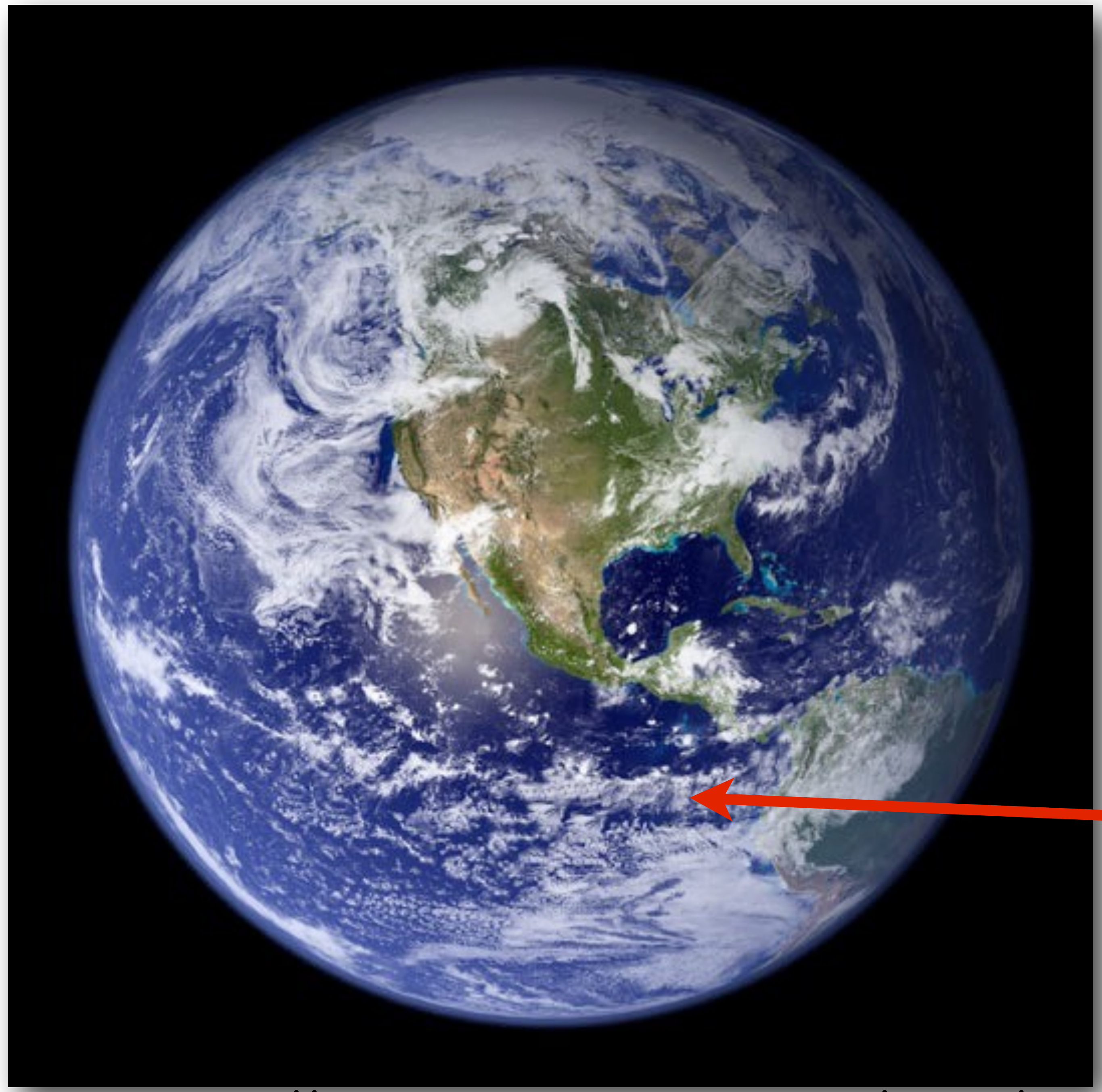
Hadley cells together with Coriolis Force (more later on this) influence prevailing wind direction

prevailing winds NE to SW

equatorial “doldrums”

prevailing winds SE to NW

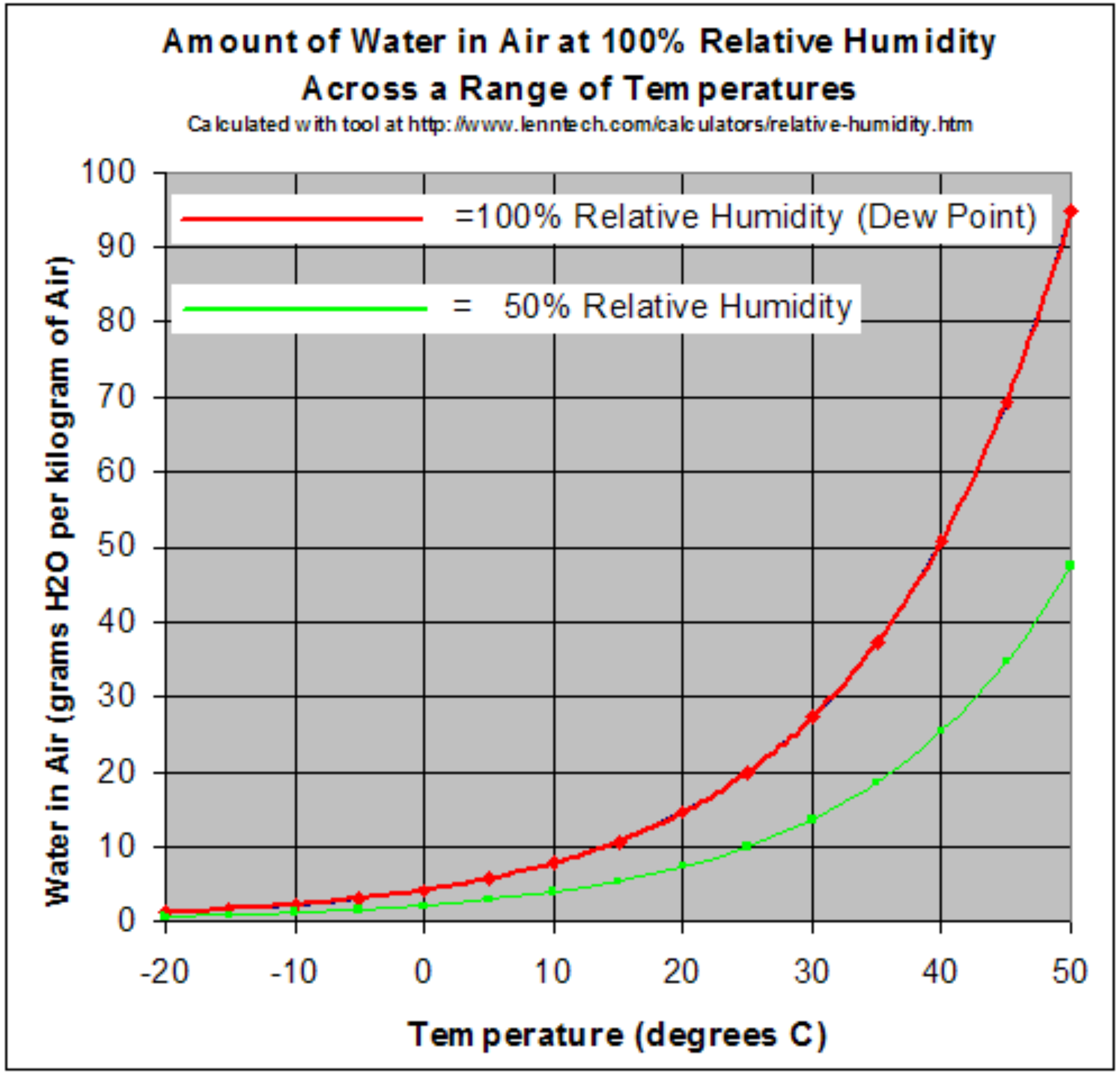




equatorial “doldrums”

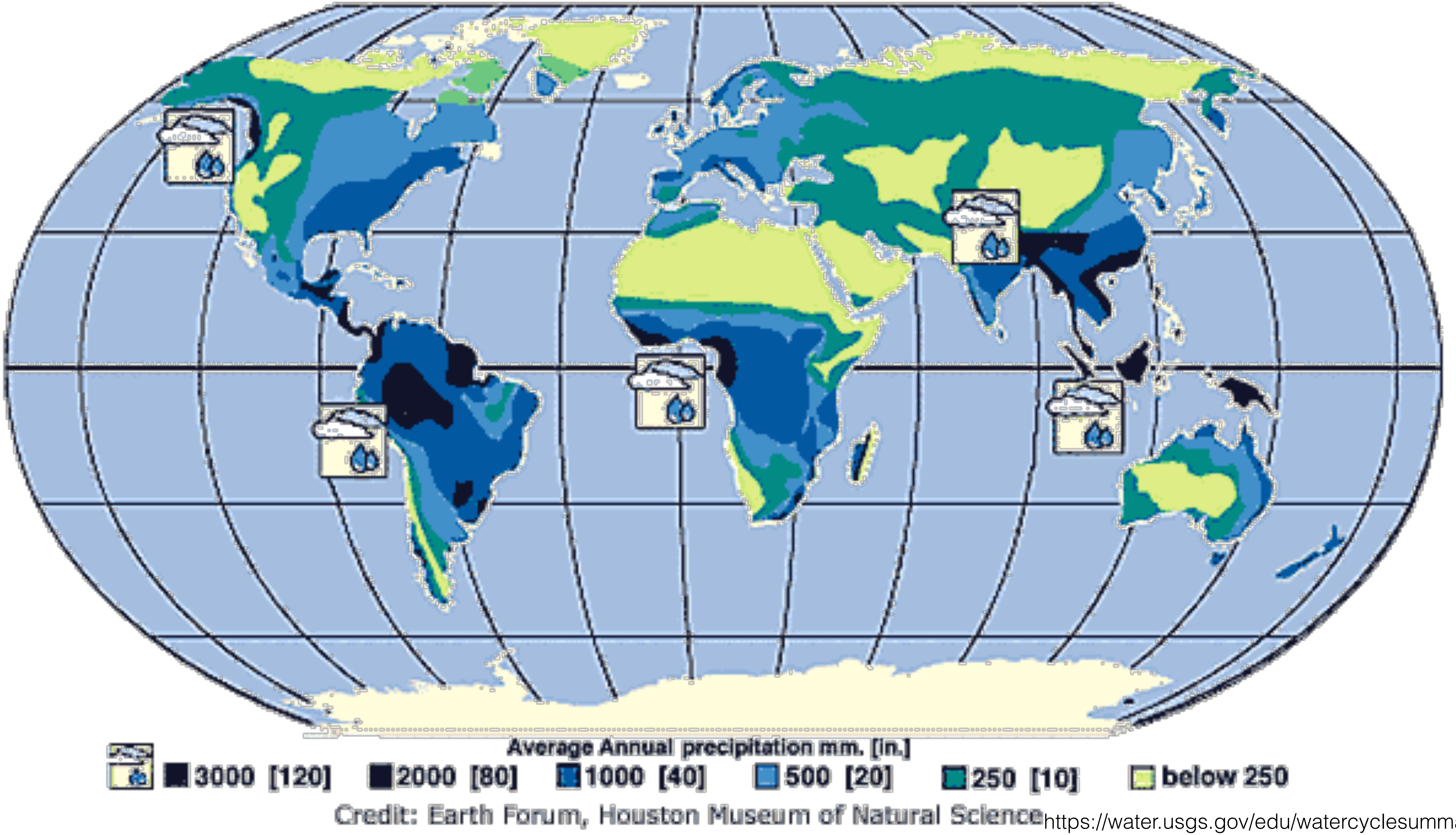
http://veimages.gsfc.nasa.gov/2429/globe_west_540.jpg

Atmospheric Water Content



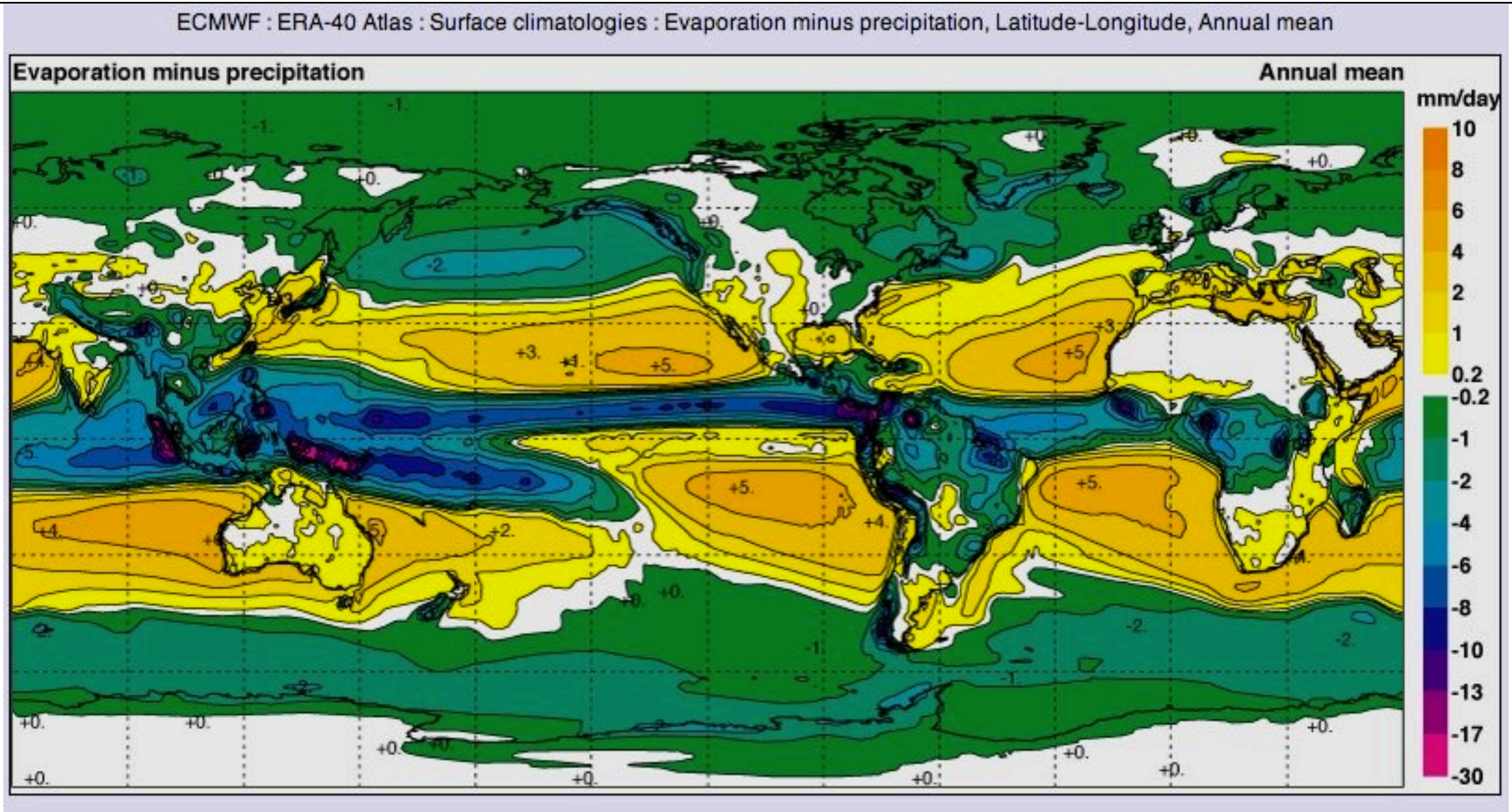
Temperature		Max. Water Content	
(°C)	(°F)	(10^{-3} kg/m^3)	(10^{-3} lb/ft^3)
-25	-13	0.64	0.040
-20	-4	1.05	0.066
-15	5	1.58	0.099
-10	14	2.31	0.14
-5	23	3.37	0.21
0	32	4.89	0.31
5	41	6.82	0.43
10	50	9.39	0.59
15	59	12.8	0.8
20	68	17.3	1.07
30	86	30.4	1.9
40	104	51.1	3.2
50	122	83.0	5.2
60	140	130	8.1

Water-Energy Cycle



https://water.usgs.gov/edu/watercyclesummary.html

Water-Energy Cycle



NASA & European Centre for Medium-Range Weather Forecasts (ECMWF) - ERA-40 Atlas

Floods Risk Management

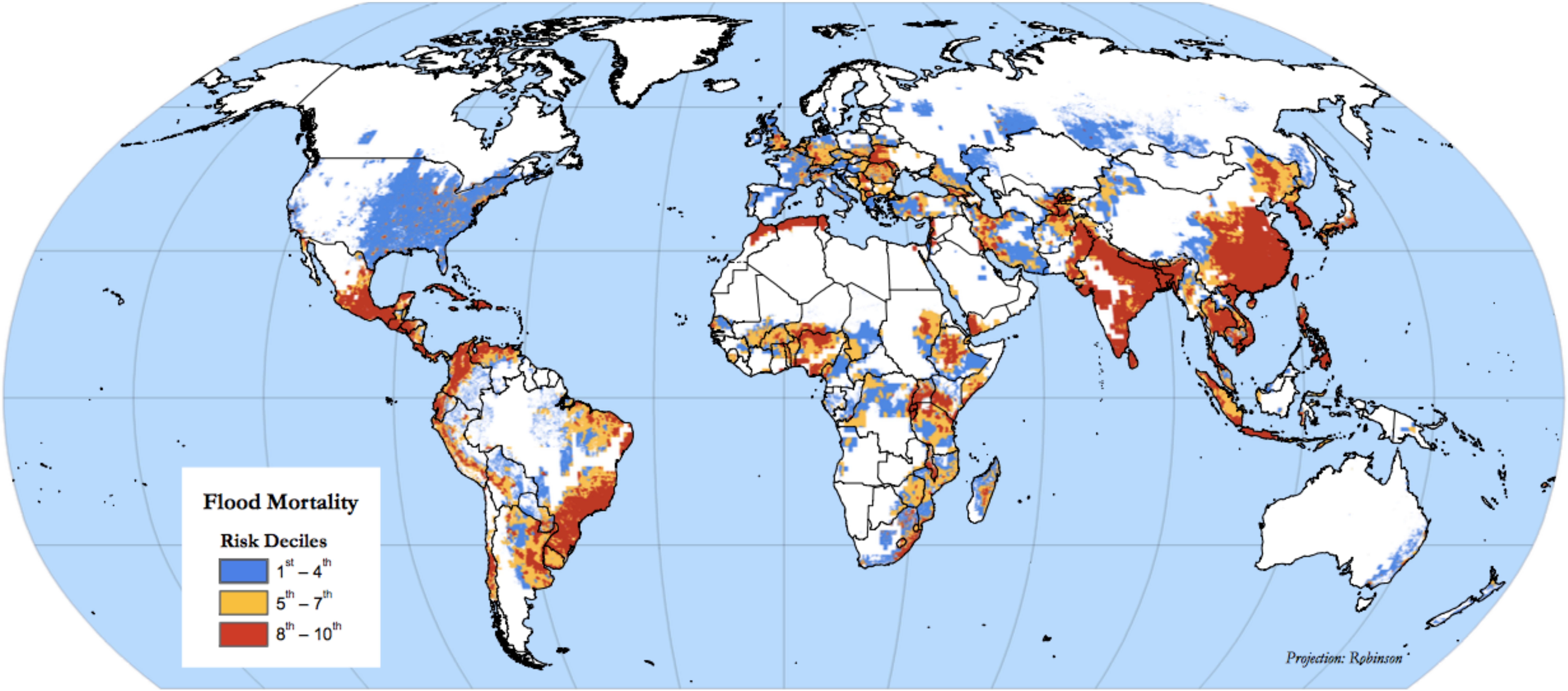
Too often, individuals ignore warnings and build their homes in high flood risk areas, or try to cross flooded areas only to be swept away.

Rio Branco city, Brazil, when the River Acre, which meanders through the city, reached a flood crest of 18.4 m above normal stage on March 4, 2015.

Flood warning signs are not merely 'suggestions.' They are meant to be taken seriously.

More than 150 individuals in the U.S.A. alone are killed each year while attempting to drive or walk through flooded streets. Most of those deaths could have been avoided if flood warning signs had been heeded.

Floods Risk Management



Mortality risk is found by weighting the value of population exposure to floods for each grid cell by a vulnerability coefficient to obtain an estimate of risk. The vulnerability weights are based on historical losses in previous disasters. The mortality weights are applied to population exposure to obtain mortality risks. The weights are an aggregate index relative to losses within each region and country wealth class (classifications based on 2000 GDP) over the 20-year period from 1981 –2000.

Dilley, Maxx, Robert S. Chen, Uwe Deichmann, Arthur L. Lerner-Lam, and Margaret Arnold. 2005. Natural Disaster Hotspots: A Global Risk Analysis. Washington, D.C.: World Bank.

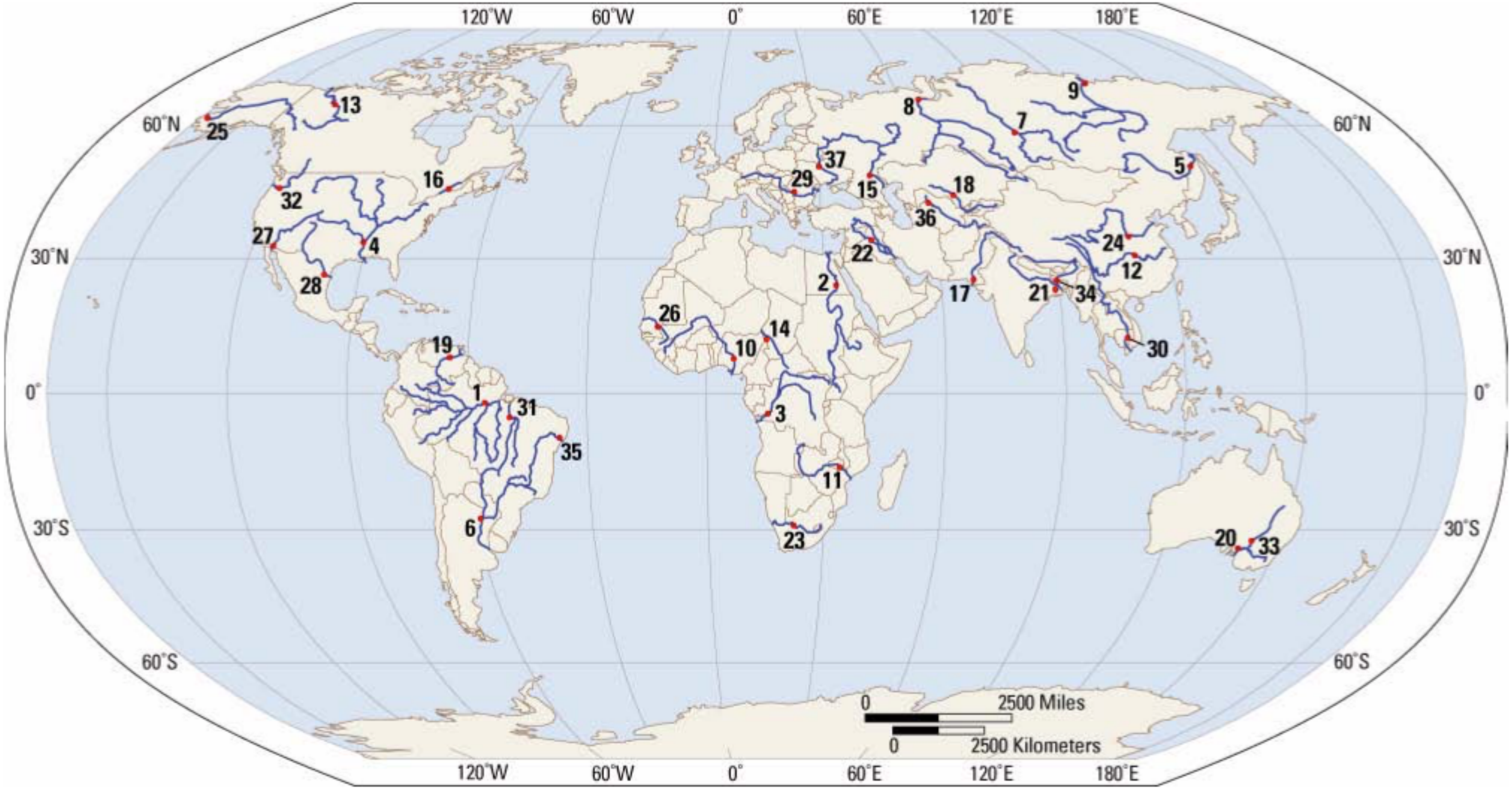


Figure 5. This map shows rivers with drainage basins larger than 500,000 square kilometers. Map numbers are keyed to table 2.

Connor and Costa, 2011

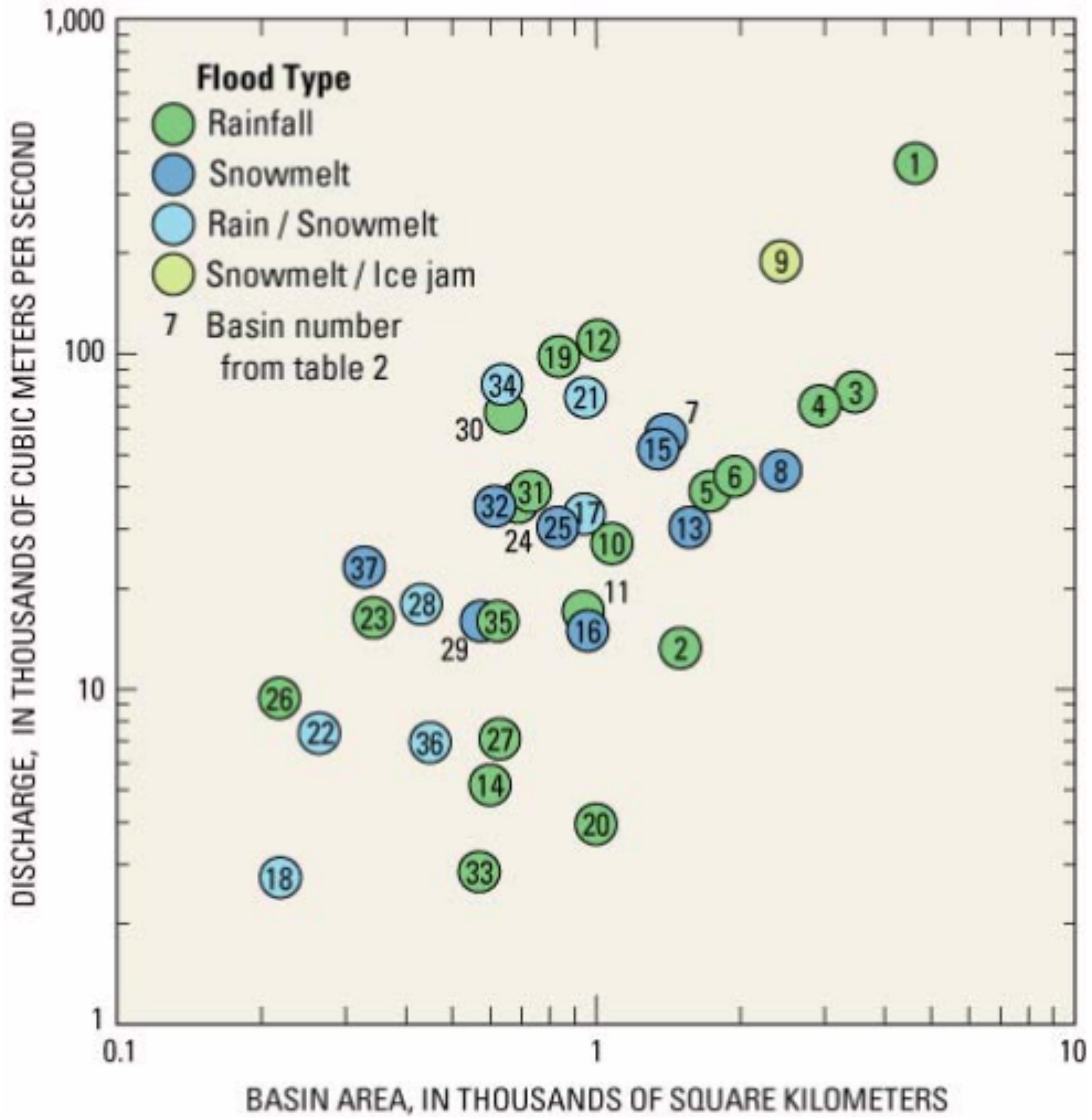
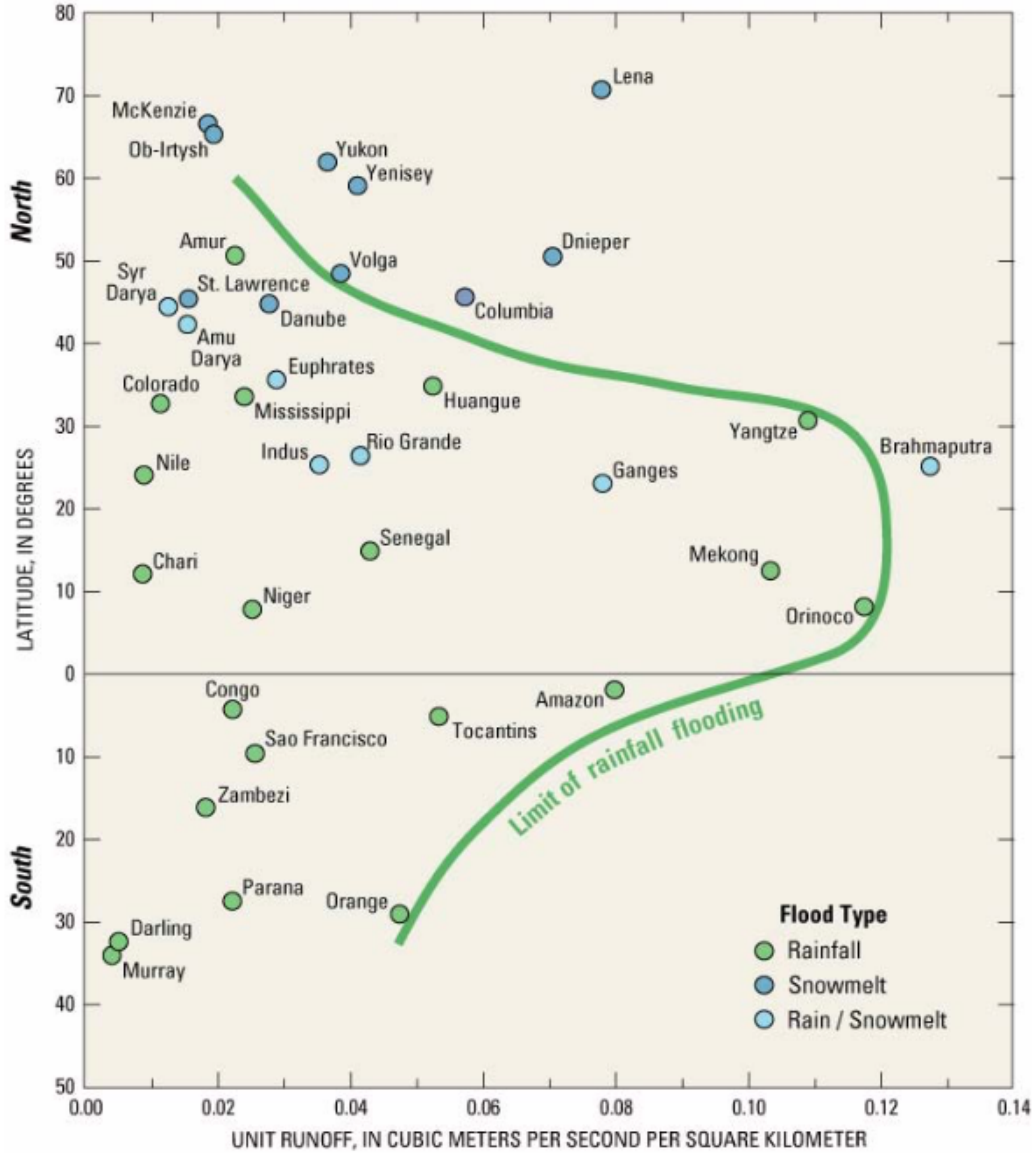


Figure 6. In general, larger river basins produce larger floods, but larger unit discharges in the moist tropics can result in floods of disproportionately large size. Numbers refer to basin numbers in figure 5 and table 2.

Figure 7. Nearly all of the largest floods caused by rainfall have occurred in basins south of latitude 40 degrees N. North of that, snowmelt- and ice-jam-related floods have predominated. Data from table 2.



Connor and Costa, 2011

Floods Risk Management

Evacuation Saves Lives: Early warning and evacuation procedures move vulnerable populations away from flood zones.

May 2009 flooding of the Brahmaputra River, Bangladesh, after Cyclone Aila. Towns and agricultural lands remained flooded through July 2009.

Residents rescued by boat in southern Louisiana, U.S.A.after more than 50 cm of rain in two days in August 2016. Although the flooding caused 9 fatalities and destroyed thousands of homes, evacuation of 20,000 people saved hundreds of lives.

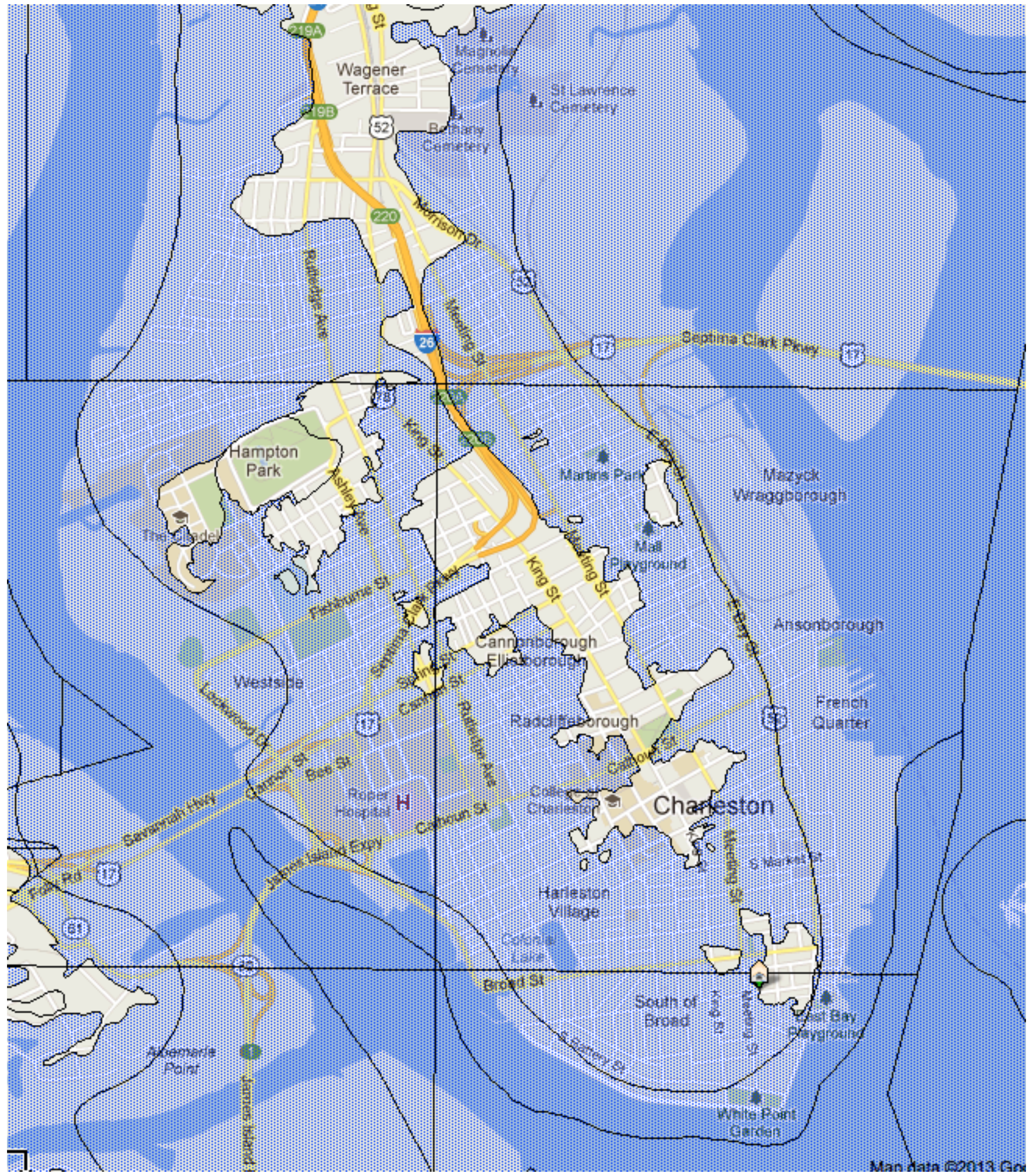
Floods Risk Management

Population Relocation? If frequent flooding cannot be avoided, should entire populations be relocated?

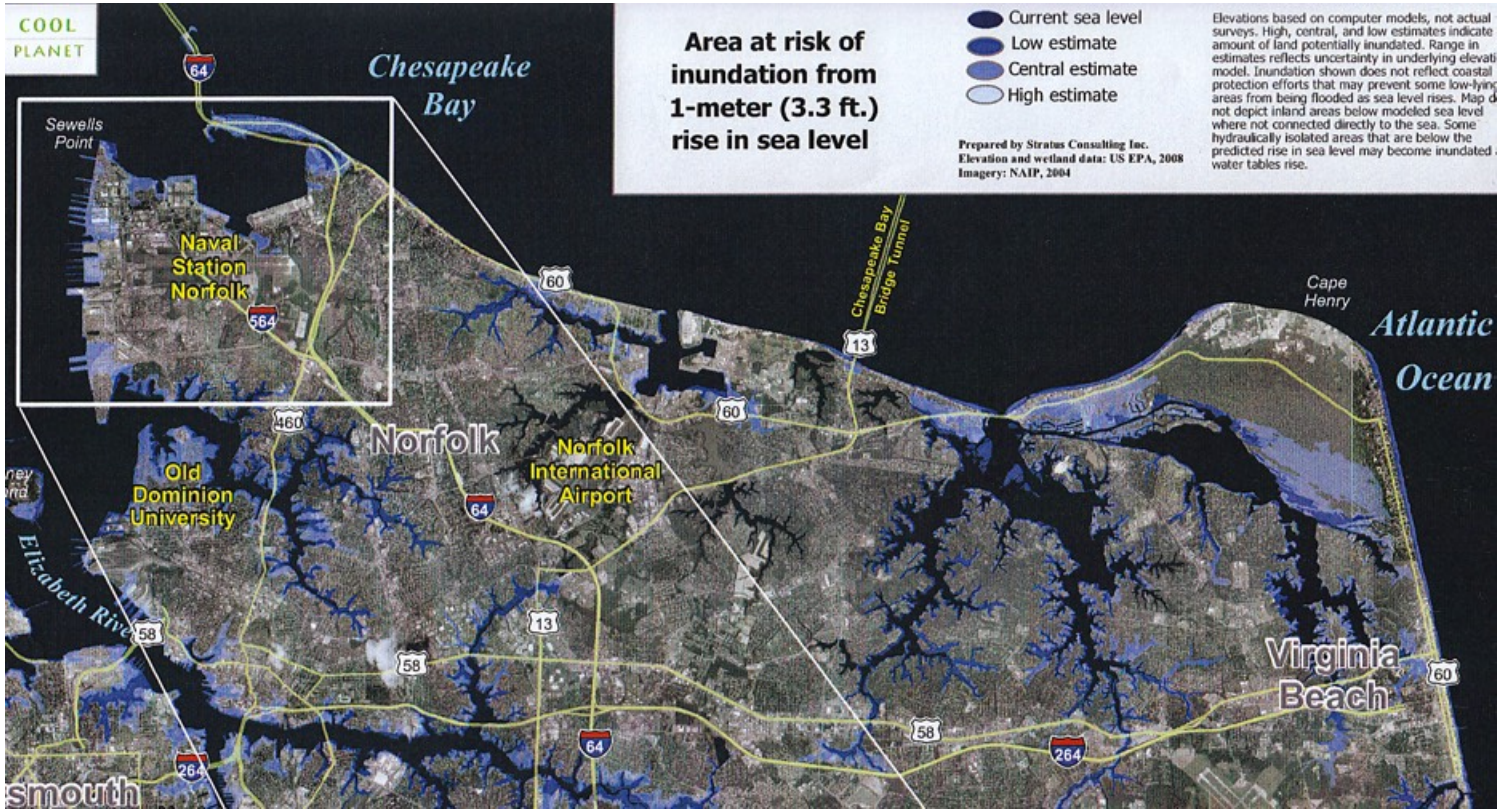
A flooded town in the Lockyer Valley, Queensland, Australia after an 8 m-high flash flood. Heavy and persistent rains during a very strong La Niña event in December 2010 and January 2011 had already saturated the catchment area of the Lockyer and Brisbane Rivers before storms produced rainfall of 40-50 mm (almost 2 inches) in a 30 minute period on January 10, 2011, triggering the flash flood.

Floods Risk Management

Designated Flood Zones: Cities around the world are creating flood zone maps that show the probability of future flooding.



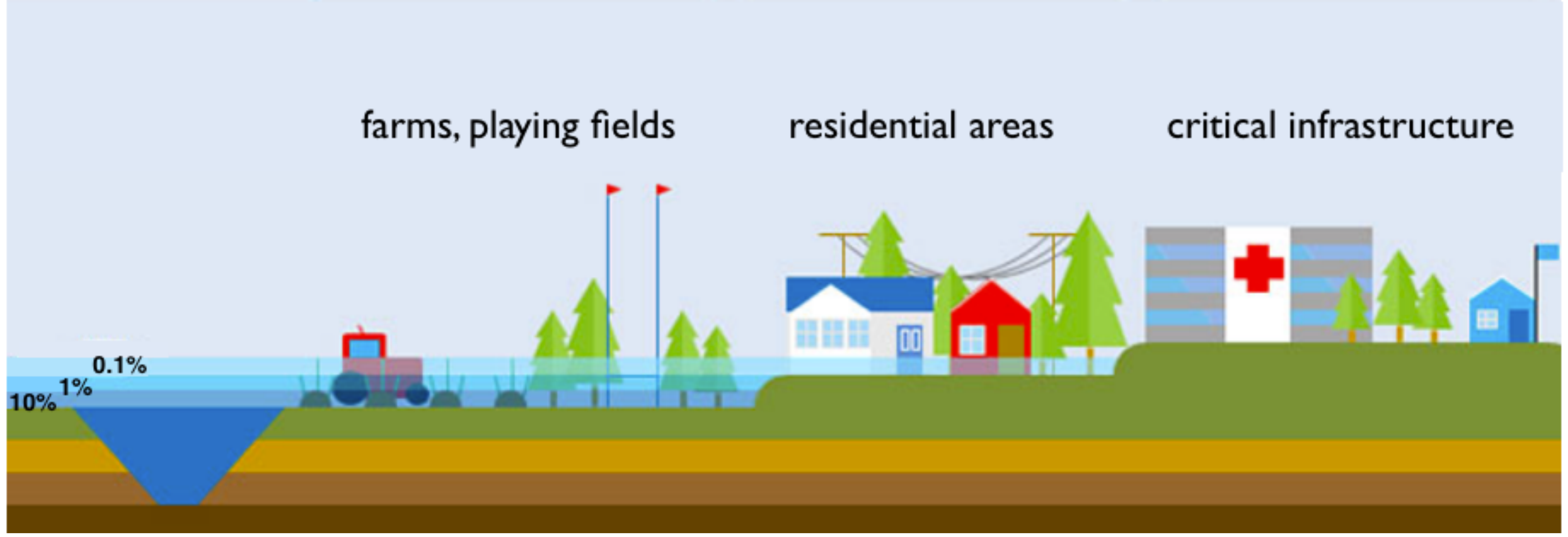
Designated flood zones for the City of Charleston, SC, U.S.A. Darker blue = Atlantic Ocean mean sea level; light blue = developed areas at risk of flooding. The city has flooded more than 20 times since its founding in 1670, most recently in December 2015.



Flood risk map for the city of Norfolk, VA.
Areas in blue = risk of flooding from 1 m sea level rise.

Floods Risk Management

Floodplain Management: Allowing river floodwater to access its floodplain can help prevent flooding of towns and cities.



A floodplain management scheme that allows flooding of farmland in 10- and 100-year flood events. Recommendations for the construction of new, and retrofitting of existing, properties are usually included.

Georgia Power Company released excess rainwater into the Chattahoochee River from two dams above Columbus, GA on December 25, 2015 as part of the city's flood mitigation plan, deliberately flooding the city's riverwalk in order to protect residences.

Flood Mitigation Plans: To be successful, flood mitigation requires a comprehensive approach that involves cooperation between people and governments.

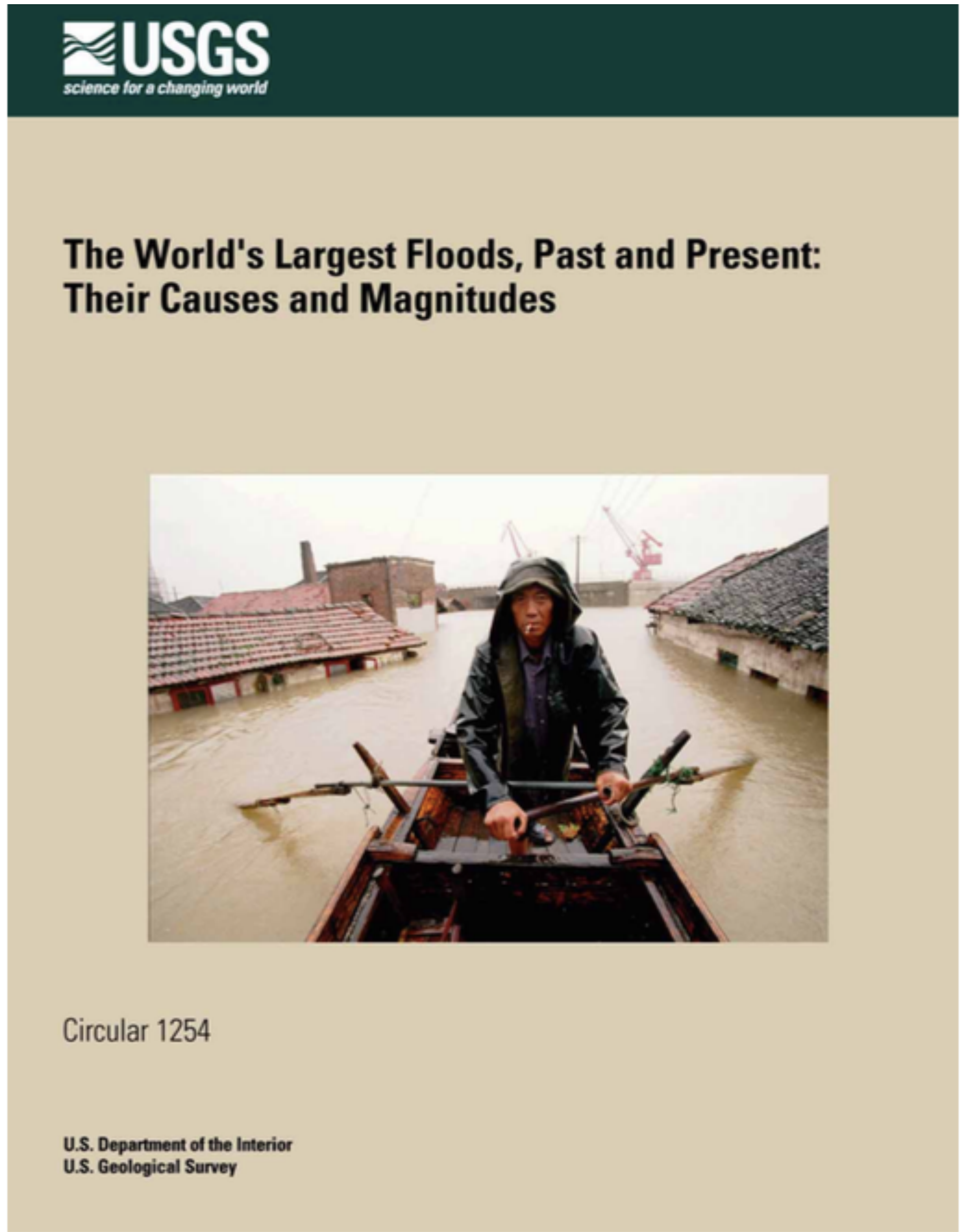
A flash flood of the Santa Cruz River in Tucson, AZ, in October 2015. Over the past 100 years, the river channel has been encased in a concrete-like soil-cement. Restoration of the river to a more natural state is part of the city's flood mitigation plan.

Largest Floods

Table 2. Largest meteorologic floods from river basins larger than about 500,000 square kilometers.

[Data from Rodier and Roche (1984) except as noted. River and station locations shown on figure 5. Station area: $10^3 km^2$, thousand square kilometers. Station latitude and longitude: N, north; S, south; E, east; W, west. Peak discharge: m^3/s, cubic meters per second]

Basin number	River basin[a]	Country	Basin area (10^3 km^2)[b]	Station	Station area (10^3 km^2)	Station latitude (degrees)	Station longitude (degrees)	Peak discharge (m^3/s)	Date	Flood type
1	Amazon	Brazil	5,854	Obidos	4,640	1.9S	55.5W	370,000	June 1953	Rainfall
2	Nile	Egypt	3,826	Aswan	1,500	24.1N	32.9E	13,200	Sept. 25, 1878	Rainfall
3	Congo	Zaire	3,699	Brazzaville B.	3,475	4.3S	15.4E	76,900	Dec. 27, 1961	Rainfall
4	Mississippi[c]	USA	3,203	Arkansas City	2,928	33.6N	91.2W	70,000	May 1927	Rainfall
5	Amur	Russia	2,903	Komsomolsk	1,730	50.6N	138.1E	38,900	Sept. 20, 1959	Rainfall
6	Parana	Argentina	2,661	Corrientes	1,950	27.5S	58.9W	43,070	June 5, 1905	Rainfall
7	Yenisey	Russia	2,582	Yeniseysk	1,400	58.5N	92.1E	57,400	May 18, 1937	Snowmelt
8	Ob-Irtysh	Russia	2,570	Salekhard	2,430	66.6N	66.5E	44,800	Aug. 10, 1979	Snowmelt
9	Lena	Russia	2,418	Kasur	2,430	70.7N	127.7E	189,000	June 8, 1967	Snowmelt/Ice Jam
10	Niger	Niger	2,240	Lokoja	1,080	7.8N	6.8E	27,140	Feb. 1, 1970	Rainfall
11	Zambezi	Mozambique	1,989	Tete	940	16.2S	33.6E	17,000	May 11, 1905	Rainfall
12	Yangtze	China	1,794	Yichang	1,010	30.7N	111.2E	110,000	July 20, 1870	Rainfall
13	Mackenzie	Canada	1,713	Norman Wells	1,570	65.3N	126.9W	30,300	May 25, 1975	Snowmelt
14	Chari	Chad	1,572	N'Djamena	600	12.1N	15.0E	5,160	Nov. 9, 1961	Rainfall
15	Volga	Russia	1,463	Volgograd	1,350	48.5N	44.7E	51,900	May 27, 1926	Snowmelt
16	St. Lawrence	Canada	1,267	La Salle	960	45.4N	73.6W	14,870	May 13, 1943	Snowmelt
17	Indus	Pakistan	1,143	Kotri	945	25.3N	68.3E	33,280	1976	Rain/Snowmelt
18	Syr Darya	Kazakhstan	1,070	Tyumen'-Aryk	219	44.1N	67.0E	2,730	June 30, 1934	Rain/Snowmelt
19	Orinoco	Venezuela	1,039	Puente Angostura	836	8.1N	64.4W	98,120	Mar. 6, 1905	Rainfall
20	Murray	Australia	1,032	Morgan	1,000	34.0S	139.7E	3,940	Sept. 5, 1956	Rainfall
21	Ganges	Bangladesh	976	Hardings Bridge	950	23.1N	89.0E	74,060	Aug. 21, 1973	Rain/Snowmelt
22	Shatt al Arab	Iraq	967	Hit(Euphrates)	264	34.0N	42.8E	7,366	May 13, 1969	Rain/Snowmelt
23	Orange	South Africa	944	Buchuberg	343	29.0S	22.2E	16,230	1843	Rainfall
24	Huanghe	China	894	Shanxian	688	34.8N	111.2E	36,000	Jan. 17, 1905	Rainfall
25	Yukon	USA	852	Pilot Station	831	61.9N	162.9W	30,300	May 27, 1991	Snowmelt
26	Senegal	Senegal	847	Bakel	218	14.9N	12.5W	9,340	Sept. 15, 1906	Rainfall
27	Colorado[c]	USA	808	Yuma	629	32.7N	114.6W	7,080	Jan. 22, 1916	Rainfall
28	Rio Grande[c]	USA	805	Roma	431	26.4N	99.0W	17,850	1865	Rain/Snowmelt
29	Danube	Romania	788	Orsova	575	44.7N	22.4E	15,900	April 17, 1895	Snowmelt
30	Mekong	Vietnam	774	Kratie	646	12.5N	106.0E	66,700	Sept. 3, 1939	Rainfall
31	Tocantins	Brazil	769	Itupiranga	728	5.1S	49.4W	38,780	April 2, 1974	Rainfall
32	Columbia[c]	USA	724	The Dalles	614	45.6N	121.2W	35,100	June 6, 1894	Snowmelt
33	Darling	Australia	650	Menindee	570	32.4S	142.5E	2,840	June 1890	Rainfall
34	Brahmaputra[d]	Bangladesh	650	Bahadurabad	636	25.2N	89.7E	81,000	Aug. 6, 1974	Rain/Snowmelt
35	São Francisco	Brazil	615	Traipu	623	9.6S	37.0W	15,890	April 1, 1960	Rainfall
36	Amu Darya	Kazakhstan	612	Chatly	450	42.3N	59.7E	6,900	July 27, 1958	Rain/Snowmelt
37	Dnieper	Ukraine	509	Kiev	328	50.5N	30.5E	23,100	May 2, 1931	Snowmelt



[a]Basins larger than 500,000 square kilometers for which reliable data were not available include the Nelson River in North America; the Jubba, Irharhar, Araye, Tafassasset and Qattar Rivers in Africa; and the Kolyma and Tarim Rivers in Asia.

[b]Basin areas from Vörösmarty et al. (2000).

[c]Station and discharge data from U.S. Geological Survey National Water Information System (http://water.usgs.gov/nwis).

[d]Station area and drainage basin data from Global Runoff Data Centre in the Federal Institute of Hydrology, Germany (http://www.bafg.de/grdc.htm).

Connor and Costa, 2011