The Global Water Cycle

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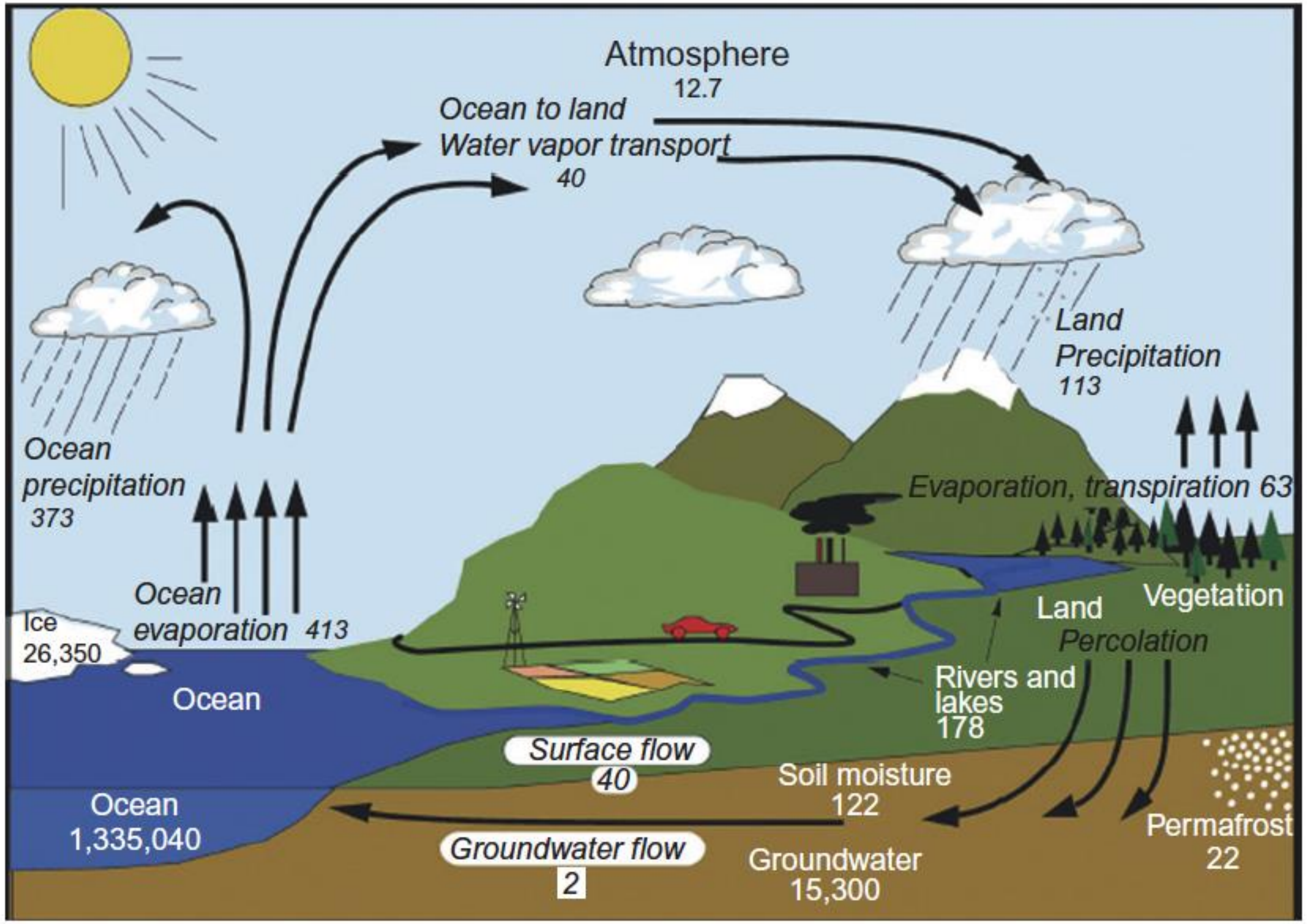


FIGURE 10.1 The global hydrologic cycle, with pools in units of 10^3 km^3 and flux in 10^3 km^3/yr. *Source: Modified from Trenberth (2007). Used with permission of the American Meteorological Society.*

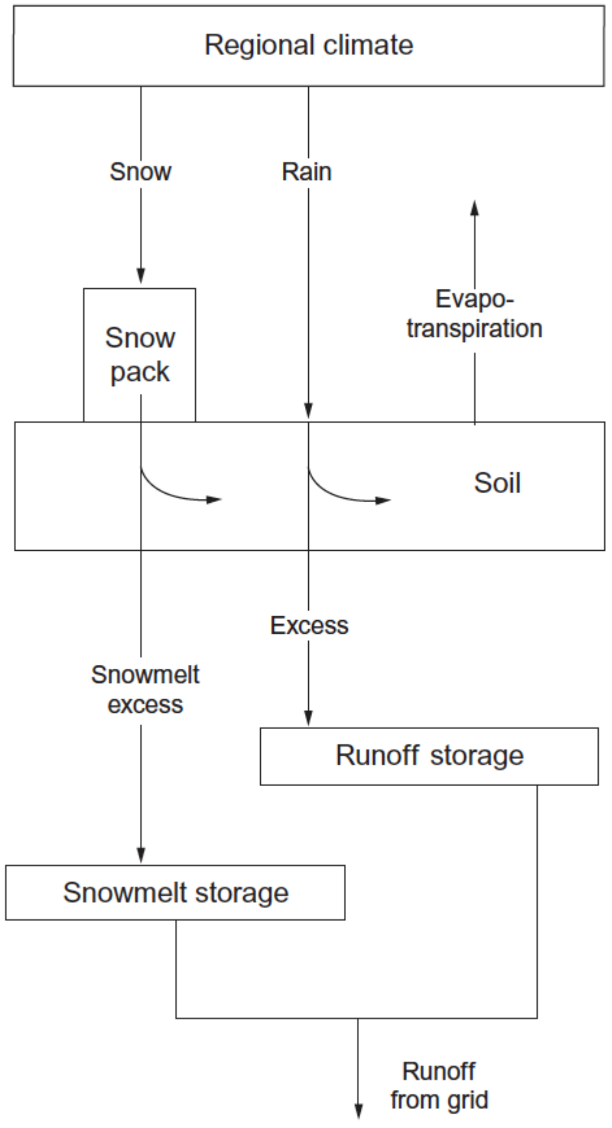


FIGURE 10.5 Components of a model for the hydrologic cycle of South America. *Source: From Vörösmarty et al. (1989). Used with permission of the American Geophysical Union.*

Potential Evapotranspiration

maximum evapotranspiration that would be expected to occur under the climatic conditions of a particular site, assuming that water is always present in the soil and plant cover is 100%.

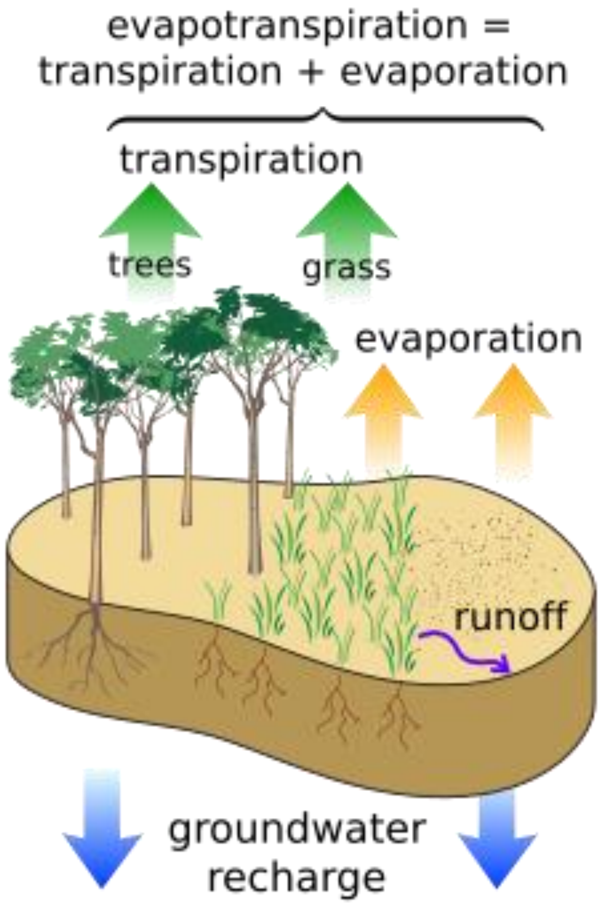


TABLE 10.1 Relative Importance of Pathways Leading to the Loss of Water from Terrestrial Ecosystems (except for T/ET, all data are shown in % of precipitation)

Vegetation	Precipitation (mm/yr)	Transpiration	Evaporation	Runoff and recharge	T/ET × 100	References
Tropical Rainforest						
	1623	45	56		45	Banerjee, cited in Galoux et al. 1981
	2000	49	26	26	65	Salati and Vose 1984
	2000	62	19	19	77	
		40	10	50	80	Shuttleworth 1988
	2209	56	11	32	84	Leopoldo et al. 1995
	2851	31	21		60	Calder et al. 1986
	3725	14	9		61	Frangi and Lugo 1985
Desert						
	150	35	65		35	Smith et al. 1995
	150	38	62		38	Liu et al. 2012
	165	27	73		27	Lane et al. 1984
	210	72	28		72	Schlesinger et al. 1987
	200	80	20		80	Liu et al. 1995
	260	21	36		37	Cavanaugh et al. 2011[a]
	212	21	27		44	

[a] *Growing season only*

[b] *Values are percentage of soil moisture lost at each site.*

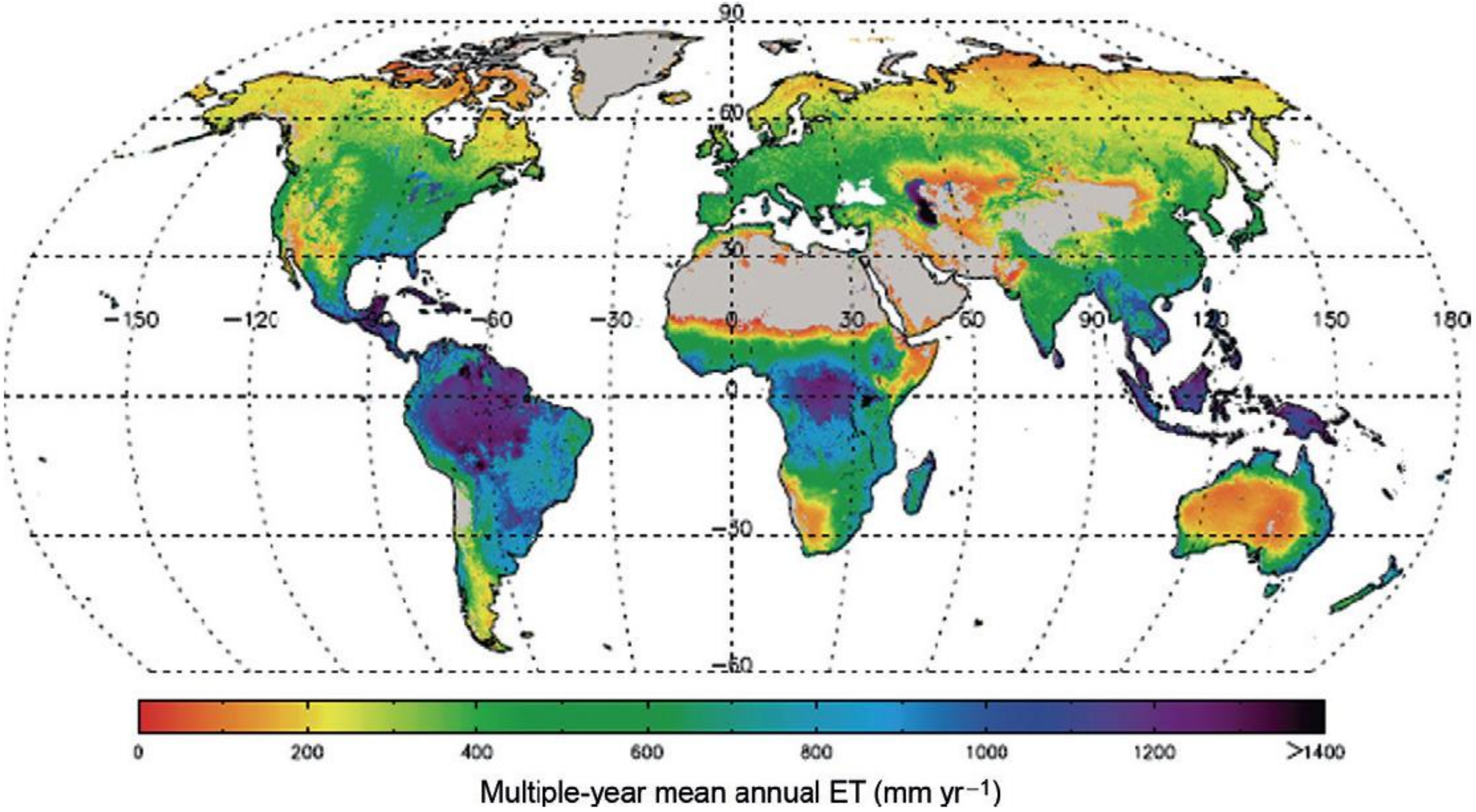


FIGURE 10.2 Global loss of water from the land surface by evapotranspiration. *Source: From Zhang et al. (2010). Used with permission of the American Geophysical Union.*

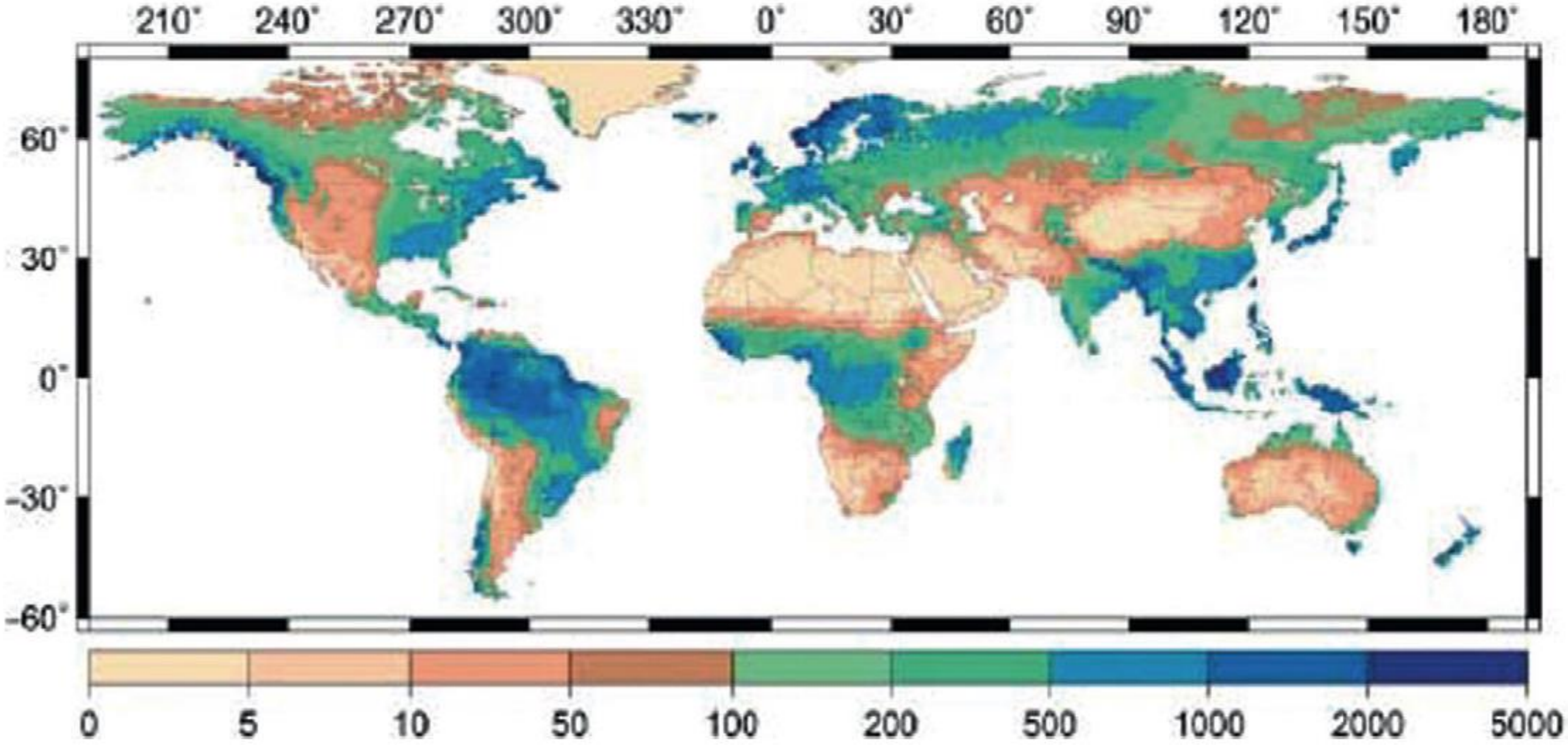
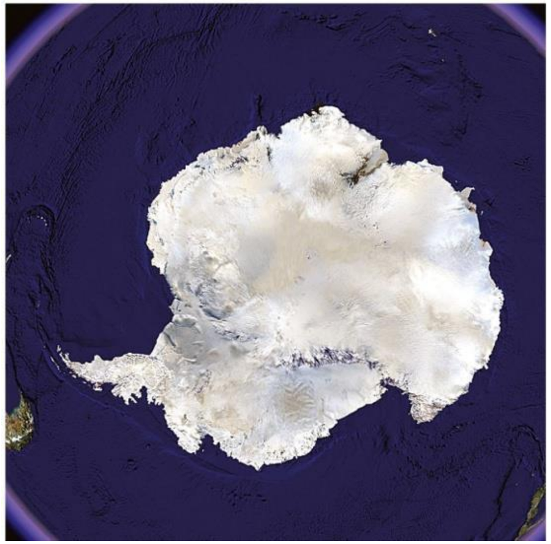


FIGURE 10.3 Annual runoff to the oceans, in mm/yr. *Source: From Oki and Kanae (2006). Used with permission of the American Association for the Advancement of Science.*

Cryosphere

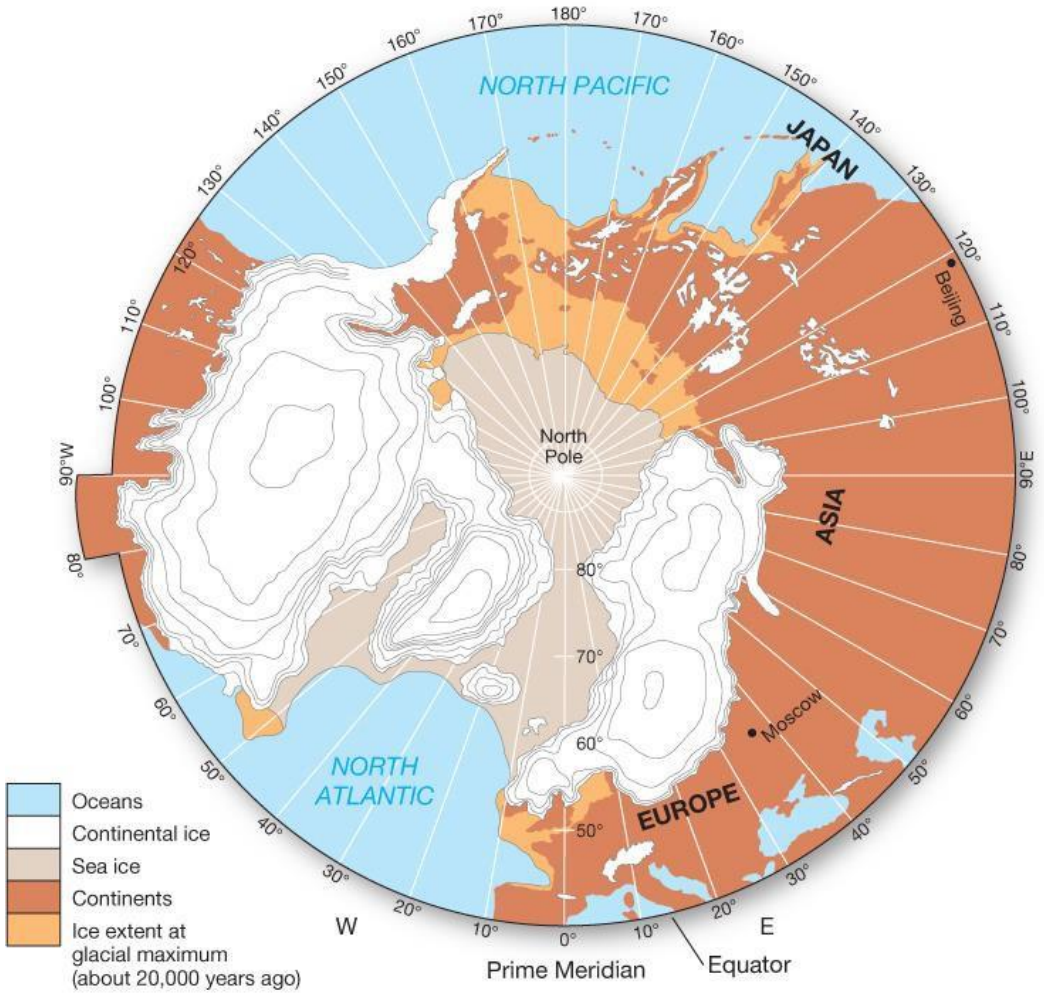
- The cryosphere is the portions of hydrosphere and lithosphere that are perennially, i.e. continuously, frozen
- Includes cold regions at high latitudes and elevations- extent can fluctuate seasonally, annually, and over geologic time spans
- Includes freshwater frozen into snow, ice, ground, and glaciers and saltwater frozen in sea ice



- ~ 3/4 of the Earth's freshwater is frozen, with the largest ice sheets in Greenland and Antarctica
- Glaciers are large masses of ice resting on land, or floating in the ocean attached to landmasses that are constantly moving downsystem

The Pleistocene Epoch

- The Pleistocene epoch occurred from ~2.6 million to 10,000 years ago, it is one of at least 5 ice ages experienced over geologic time
- Extended periods of cold are glacials, periods of ice advance
- These can last several million years, ~ 18 occurred over N. America
- Glaciation takes ~ 100,000 years to build up and <10,000 to deglaciate
- Brief warm periods called interglacials (we are in one)

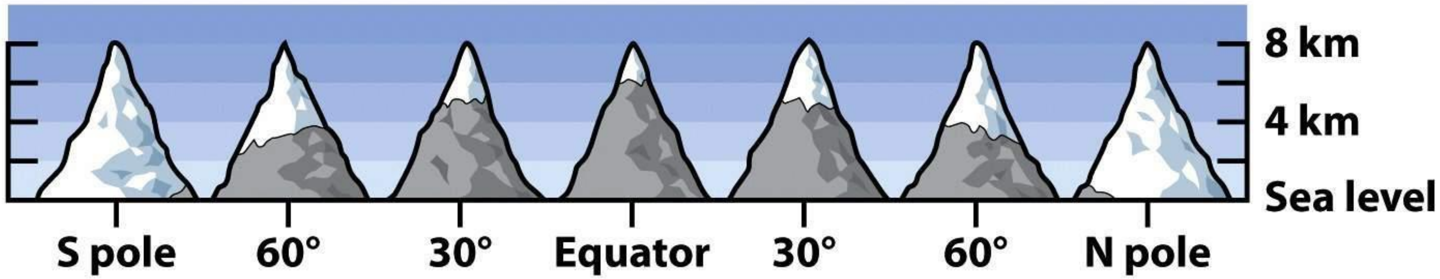


(b) Polar perspective, 18,000 years ago.

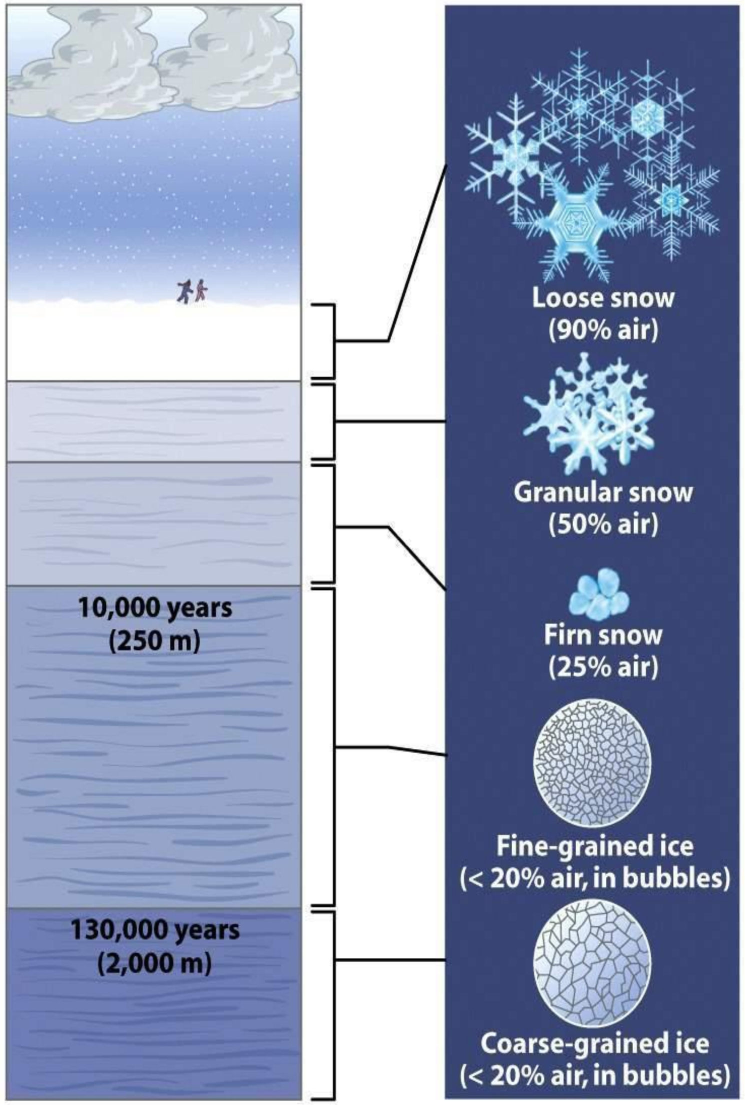
Sea levels were lower, land bridges were exposed at that time, and paleolakes proliferated during pluvials, or wetter climatic periods

Glacial Ice

- Forms at high latitude/high elevations where snow is permanent, i.e. above the snowline- the lowest elevation where snow remains year round
- The snowline is higher near the equator than near the poles

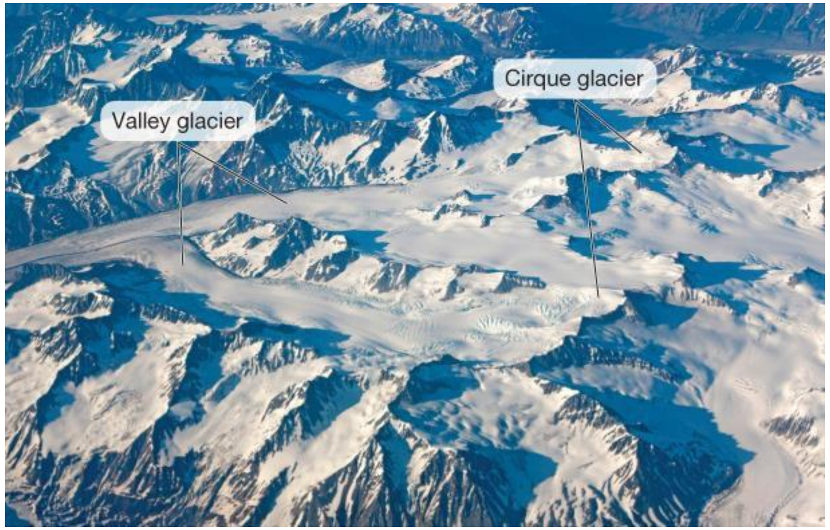


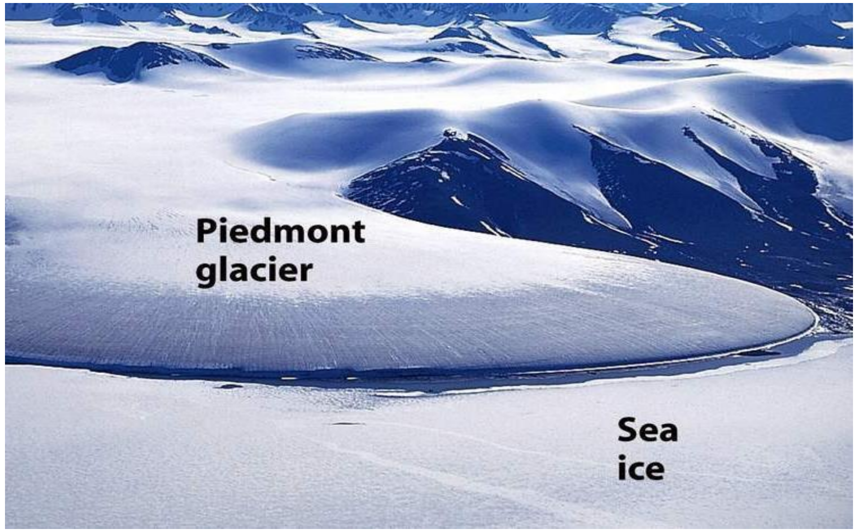
- Snow becomes more compact and dense, under burial and compression recrystallizing to forming firn, then glacial ice
- Can take a long time in dry polar regions

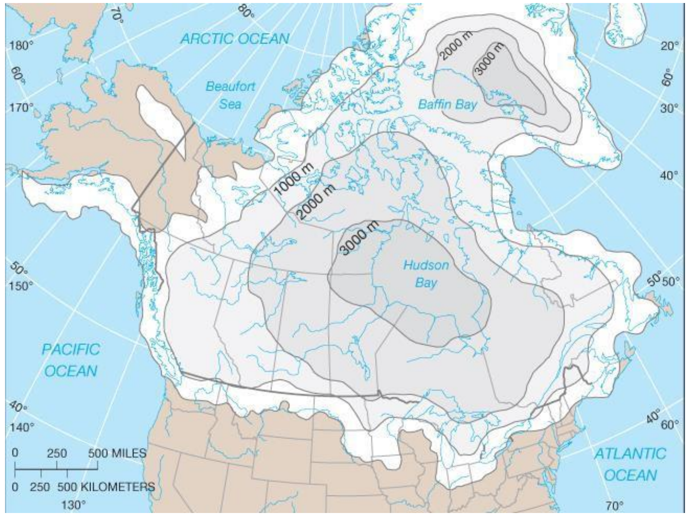


Types of Glaciers

- Glaciers flow outward and downward under their own weight and the force of gravity, moving in stream-like patterns across the landscape
- Two general groups, alpine and continental:
  - Alpine (mountain) glaciers form in mountain ranges, have several subtypes named by where they are found
  - Continental ice sheets are extensive forming on a continental scale

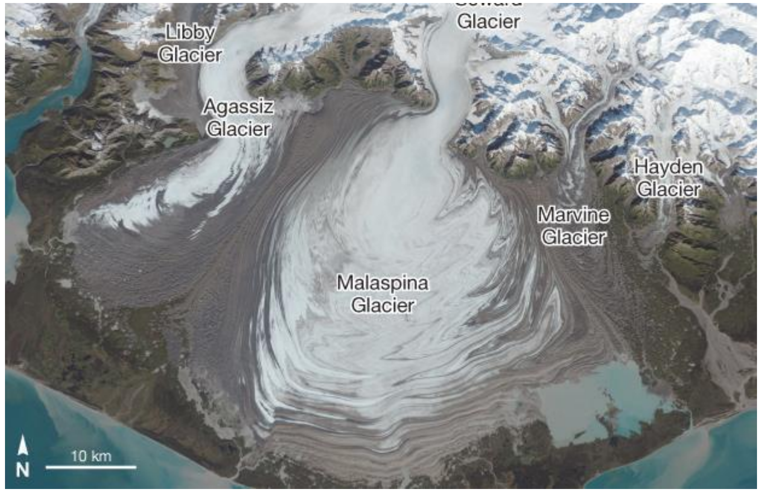


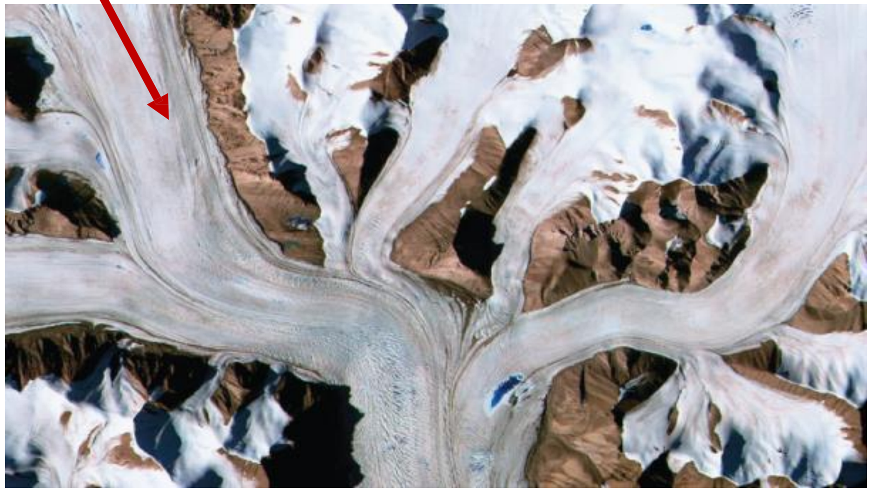




Types of Glaciers- Alpine

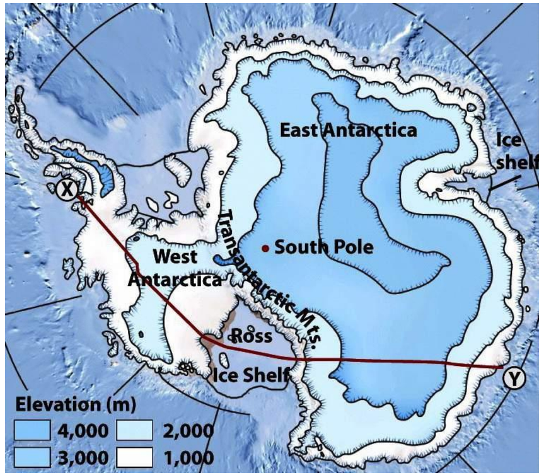
- Mountain glaciers and cirque glaciers (in a bowl-shaped head of a valley) occur higher upsystem
- Valley glaciers form in valleys formed by streams
- Piedmont glaciers form where valley glaciers coalesce at the base of a mountain range
- Tidewater glaciers end in the sea and calve (break off) into the water forming icebergs

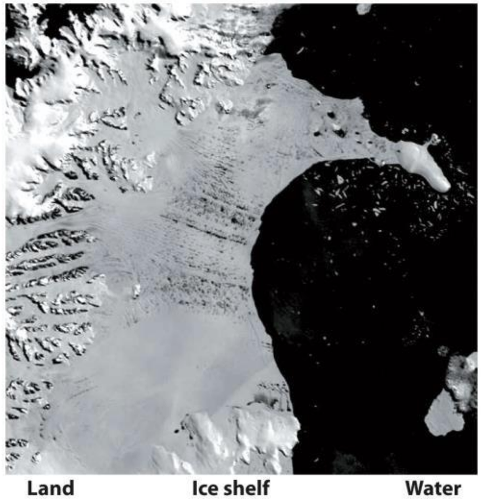


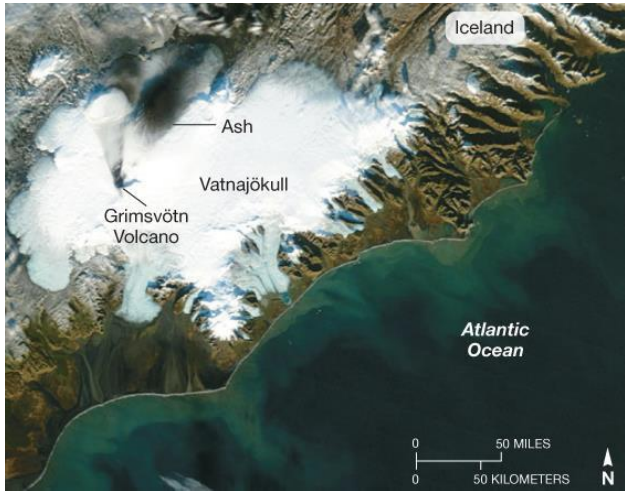


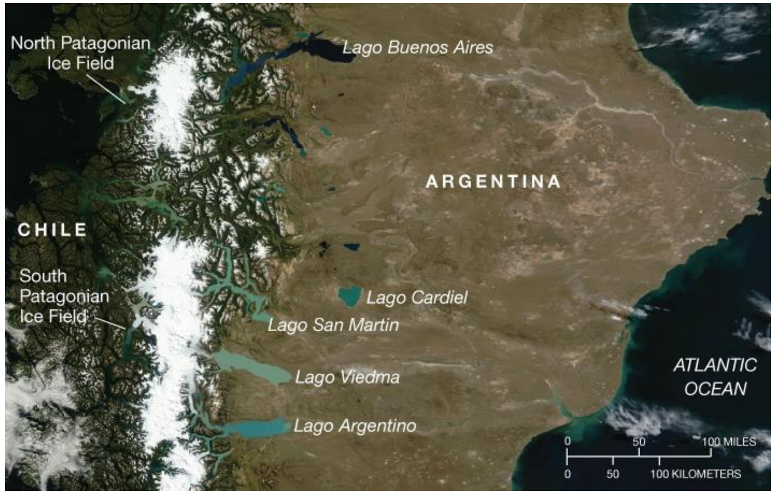
Types of Glaciers- Continental

- Ice sheets are extensive masses of ice averaging ~ 2000 m thick
- These cover 81% of Greenland and 90% of Antarctica, causing isostatic depression below sea level of the landmasses
- At the coast, a continental ice sheet can form an ice shelf ~1000 m thick
- Ice caps are smaller < 50,000 km^2, ex. covering parts of Iceland
- Ice fields are elongate, covering parts of mountain ranges









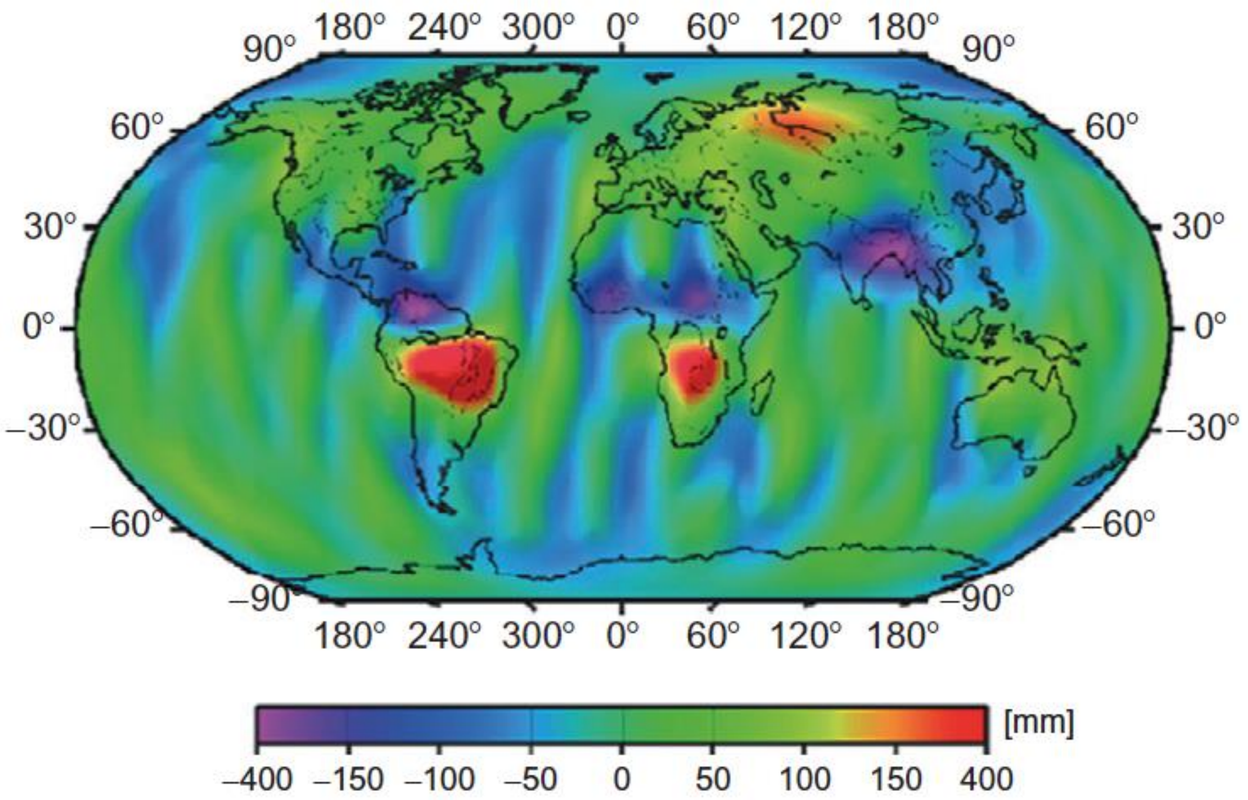
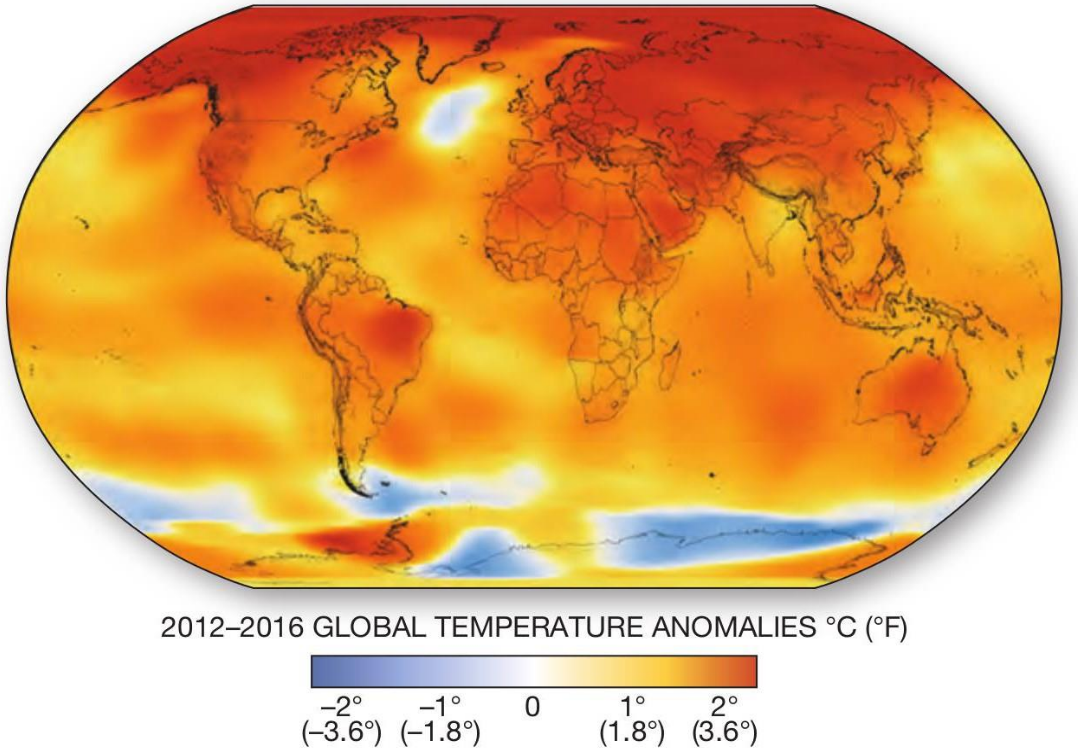


FIGURE 10.6 Changes in water content of the Earth's land surface, as measured by the GRACE satellite, April to August 2003. Note the large increase in water storage during the wet season in the Amazon. *Source: From Schmidt et al. (2006).*



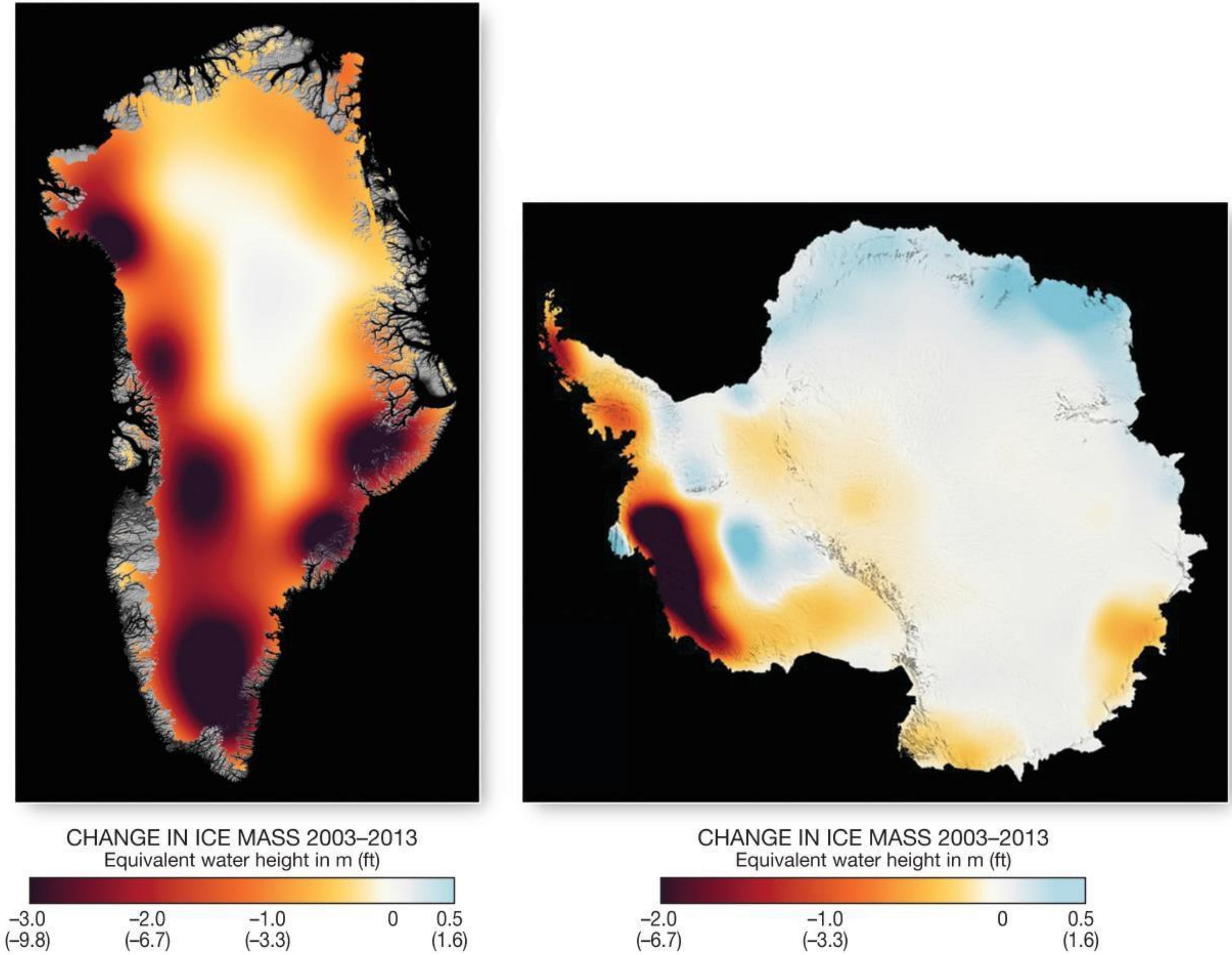

CHANGE IN ICE MASS 2003–2013
Equivalent water height in m (ft)
–3.0 (–9.8)
–2.0 (–6.7)
–1.0 (–3.3)
0
0.5 (1.6)
CHANGE IN ICE MASS 2003–2013
Equivalent water height in m (ft)
–2.0 (–6.7)
–1.0 (–3.3)
0
0.5 (1.6)

Figure 8.24

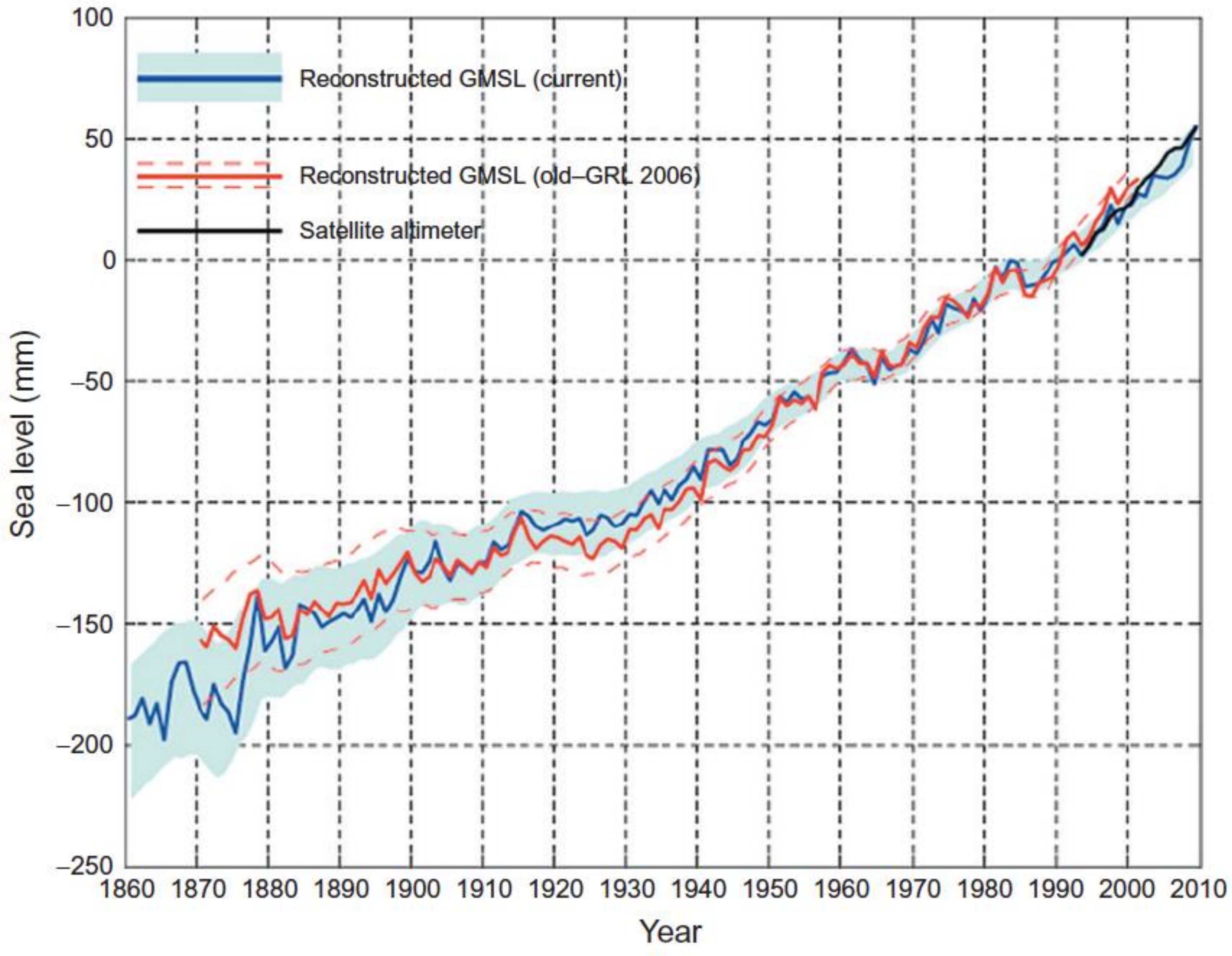


FIGURE 10.7 Global average sea level from 1860 to 2009. *Source: From Church and White (2011). Used with permission of Springer.*

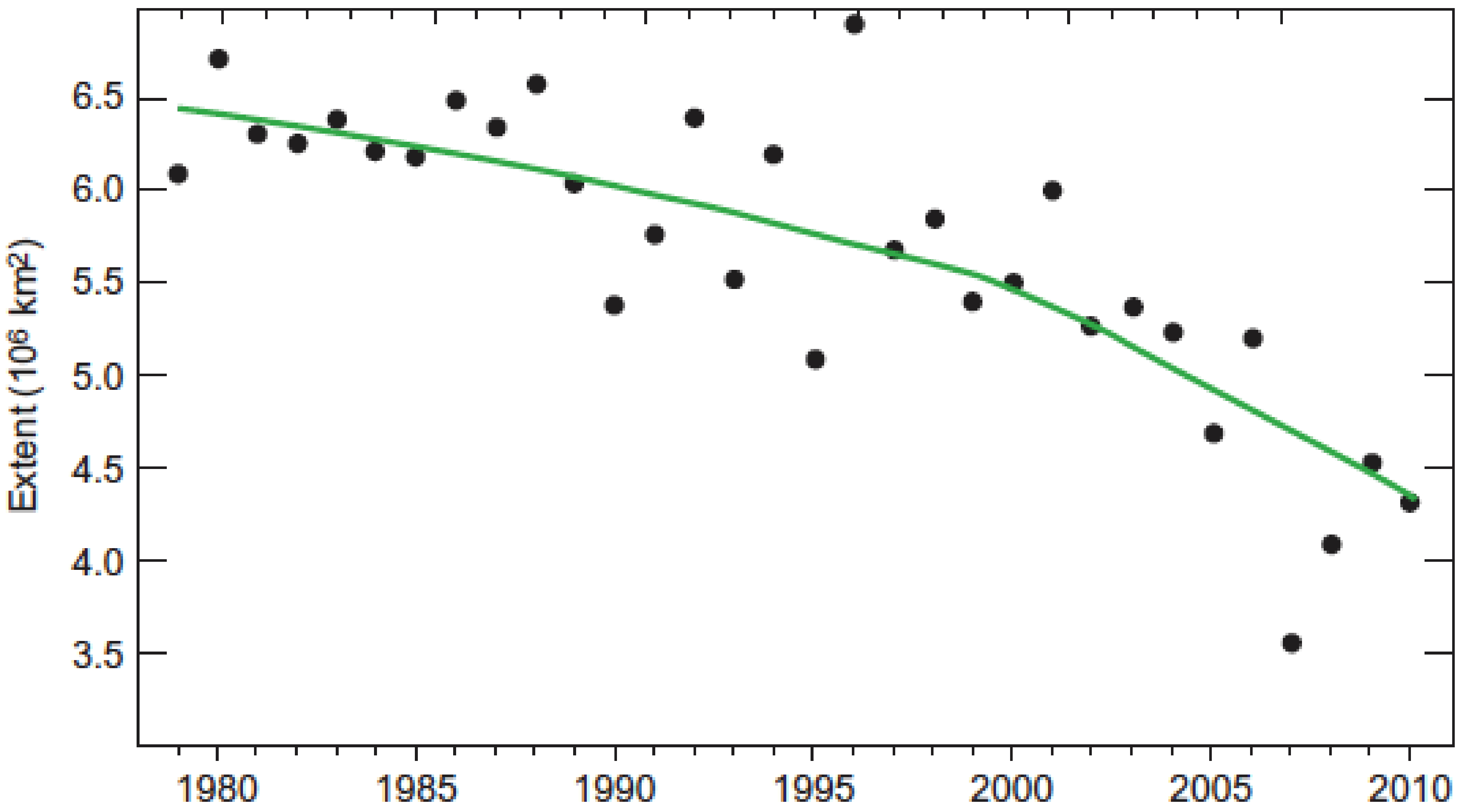


FIGURE 10.8 September sea ice extent, 1979 to 2010 in the Arctic. *Source: From Stroeve et al. (2012). Used with permission of Springer.*

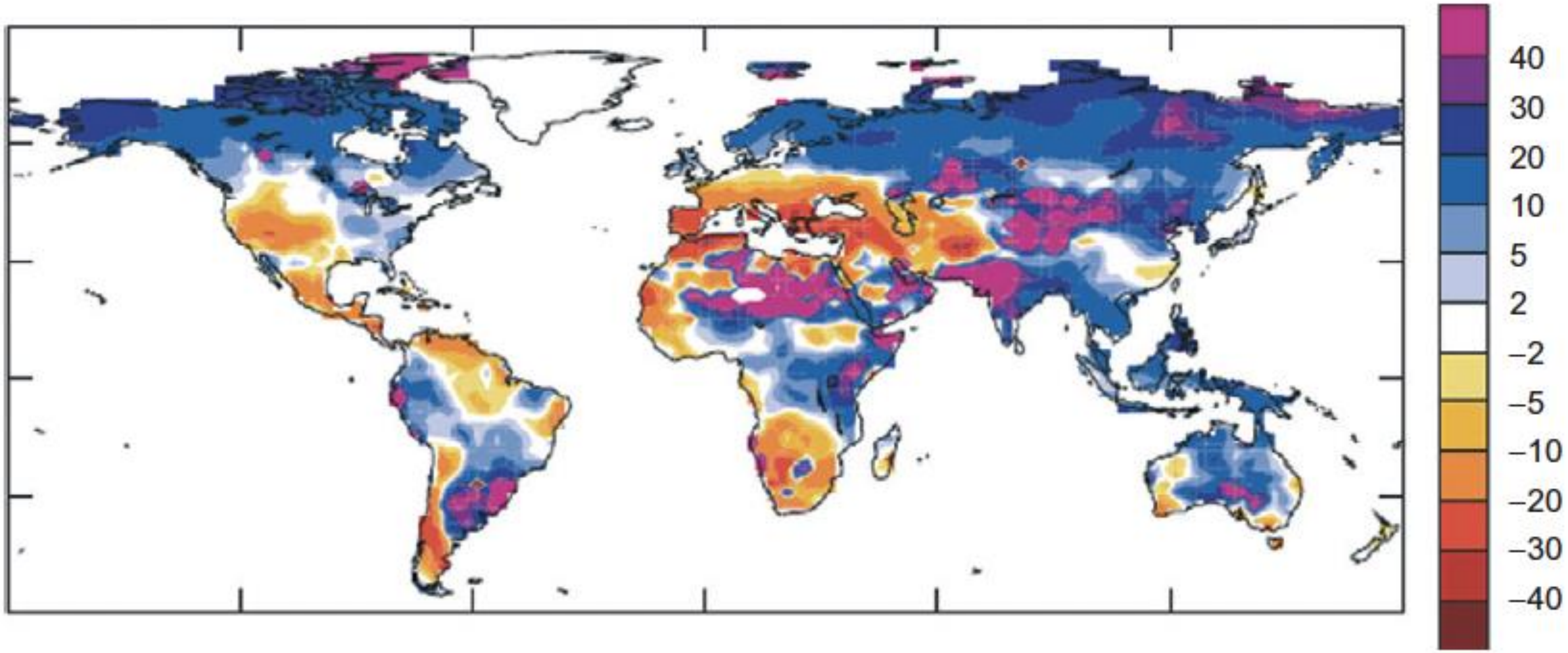


FIGURE 10.9 Projected percent changes in runoff from the Earth's land surface for 2041–2060, compared to the mean for 1900–1970. *Source: From Milly et al. (2005). Used with permission of the American Association for the Advancement of Science.*

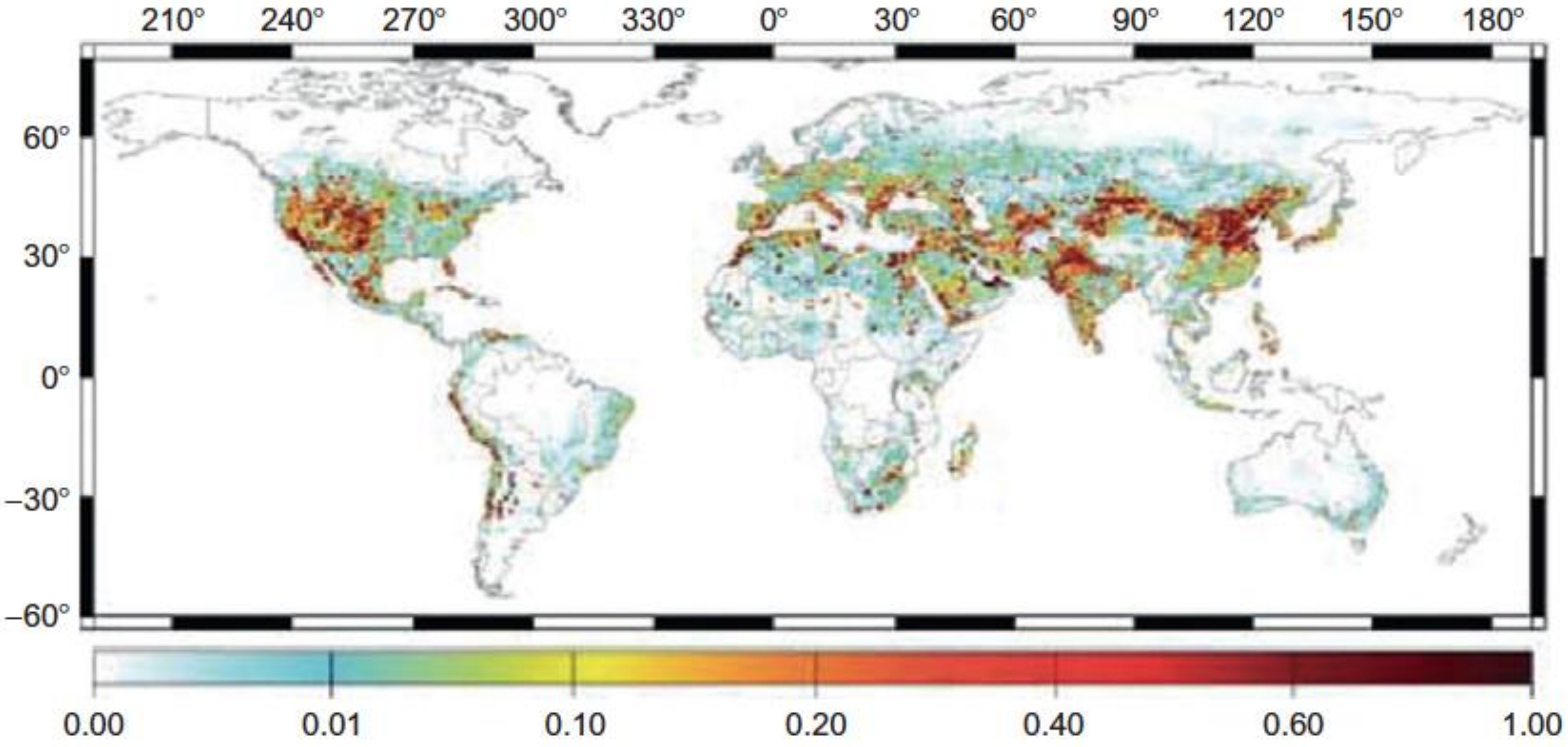


FIGURE 10.10 A water scarcity index for the Earth's land surface. Water scarcity is defined as the withdrawal from surface water divided by recycling, adjusted for regional supplements from desalinization. *Source: From Oki and Kanae (2006).*