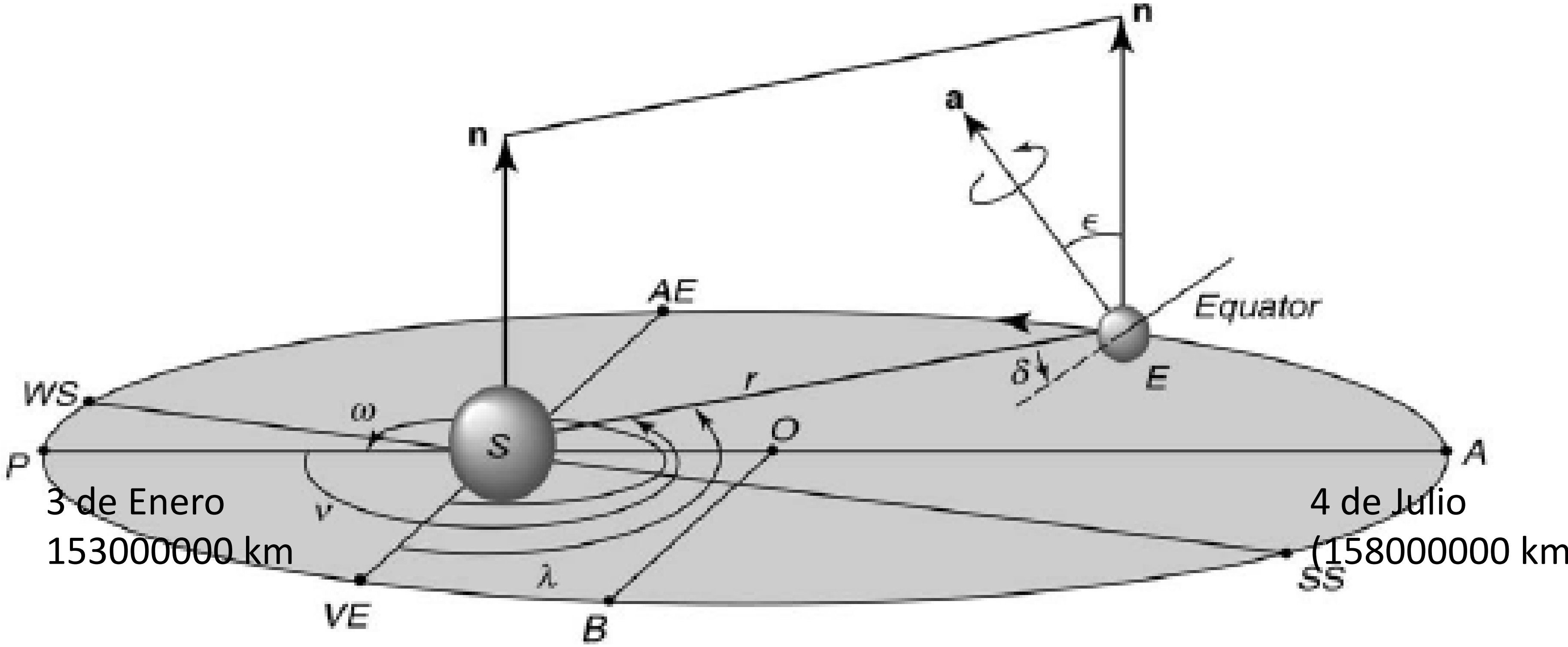
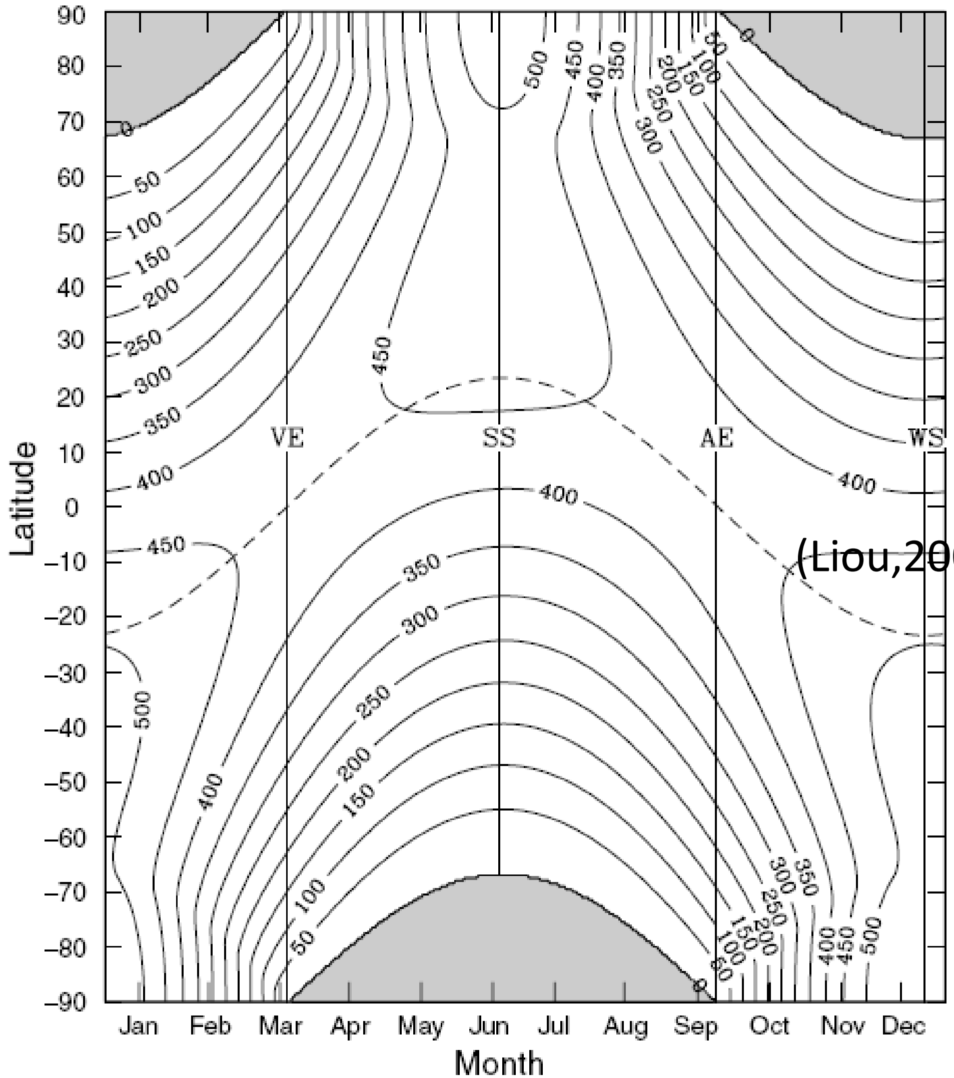
Control Orbital de la luminosidad terrestre

Parámetros orbitales y su efecto en la luminosidad



Distribución espacial y temporal de la radiación incidente



(Liou,2002)

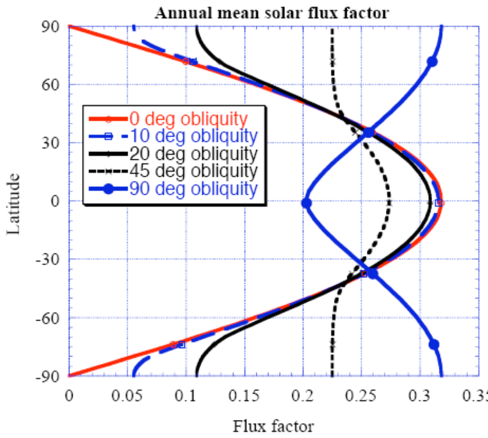
Obliquidad respecto del plano orbital es una *variable*

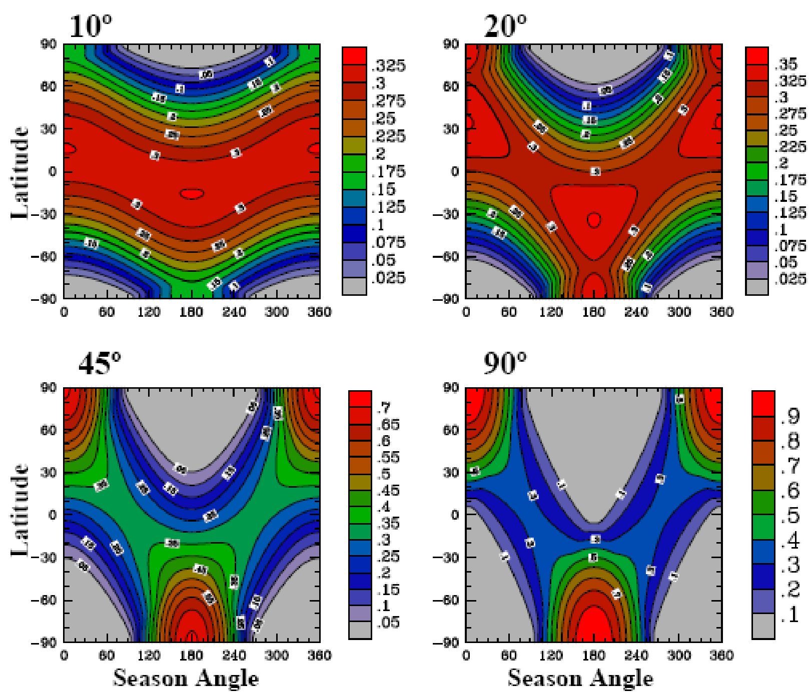
Planetary obliquities (angles between equatorial and orbital planes)

Planet	Present obliquity (°)	Range or past obliquity (°)	Mechanism for variation	Reference for variation of obliquity
Mercury	0	< 90	tidal torque and core–mantle dissipation	Peale (1976)
Venus	177	0 to ~ 180	tidal torques and core–mantle dissipation	Goldreich and Peale (1970)
		0 to ~ 180	tidal torques and	Lago and Cazenave (1979)
Moon	6.7	77 to 6.7	tidal torque	Ward (1975)
Mars	25.2	24.4 ± 13.6	axial–orbital precession	Ward (1979)
		27.5 ± 18.5	axial–orbital precession (prior to Tharsis uplift)	Ward et al. (1979)
		25.8 ± 25.6	axial–orbital precession	Bills (1990b)
		0 to ~ 20 +	polar ice-cap loading	Rubincam (1990)
Jupiter	3.1			
Saturn *	26.7	0 to ~ 27	twist of orbital plane	Tremaine (1991)
Uranus	97.9	0 to ~ 98	planetary impact	Safronov (1966)
		0 to ~ 98	planetary impact	Korycansky et al. (1990)
		0 to ~ 98	tidal torque	Greenberg (1974)
		0 to ~ 98	twist of orbital plane	Tremaine (1991)
		0 to ~ 98	axial–orbital precession	Harris and Ward (1982)
Neptune *	28.8	0 to ~ 29	twist of orbital plane	Tremaine (1991)
Pluto	104.5	99 ± 14	axial–orbital precession	Dobrovolskis (1989)
	118	0 to 118	twist of orbital plane	Tremaine (1991)

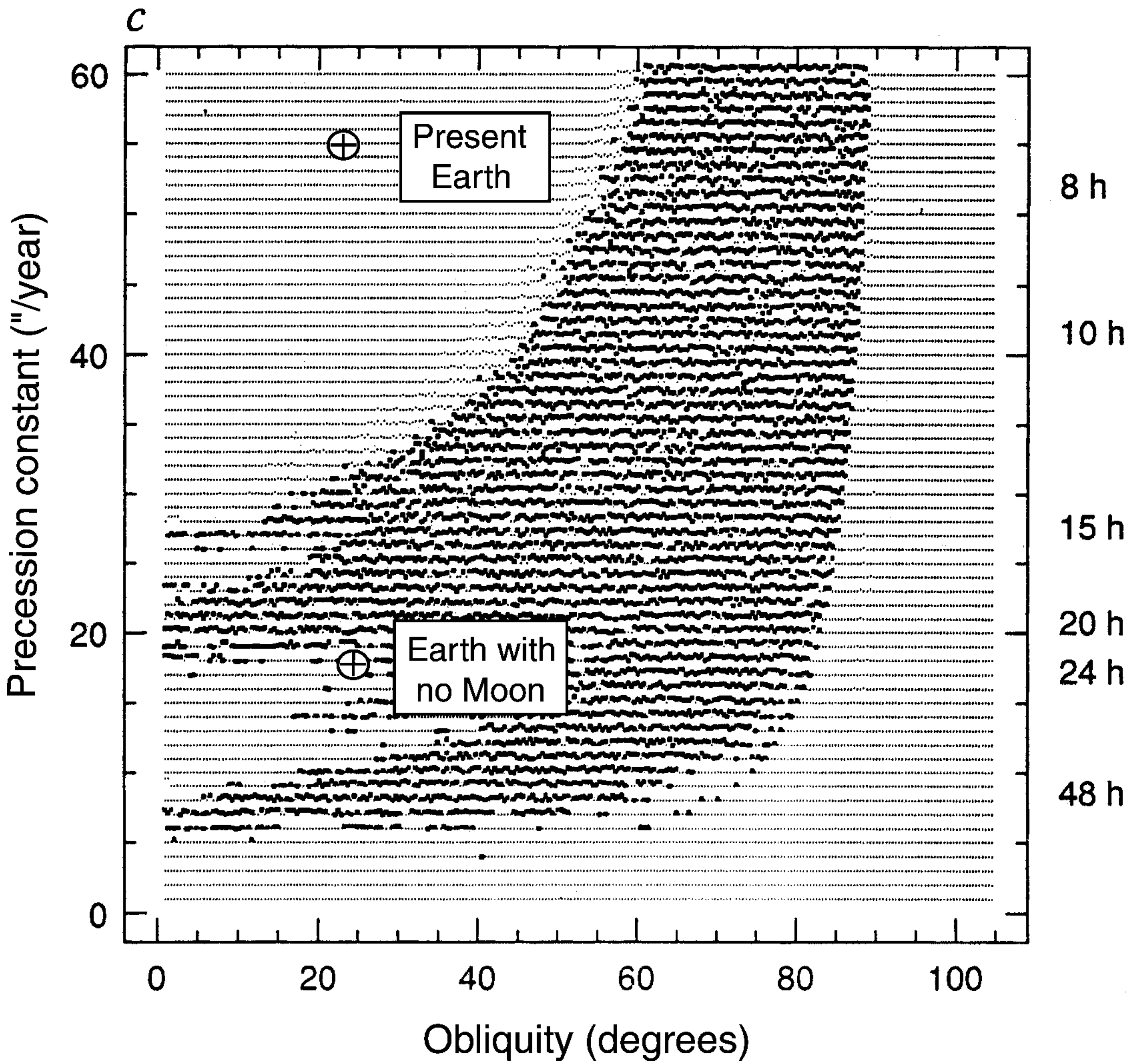
* Krimigis (1992) gives post-Voyager 2 obliquities of Saturn and Neptune as 29.0° and 29.6°, respectively.

Williams (1993)

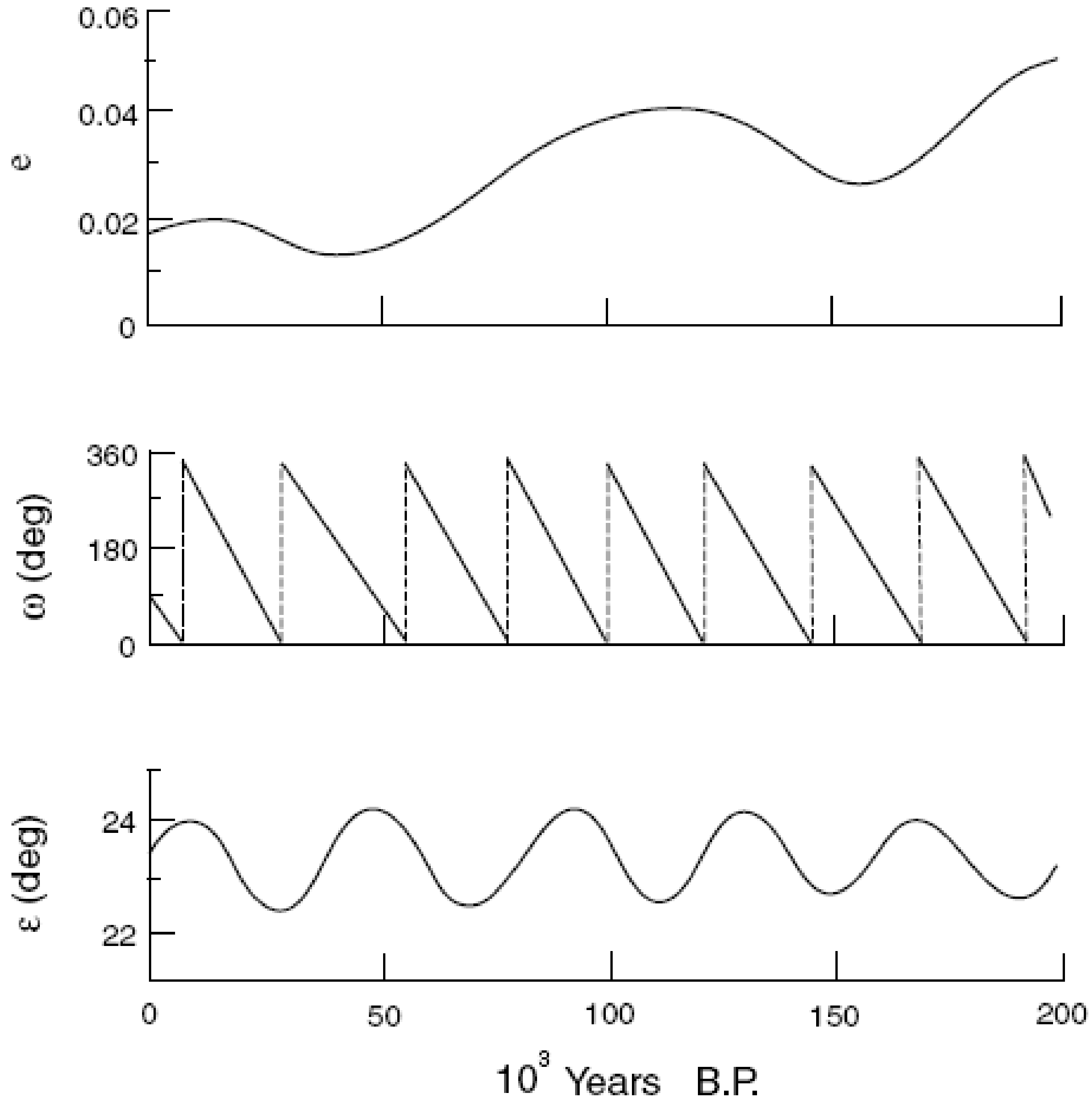




Pierrehumbert (2009)



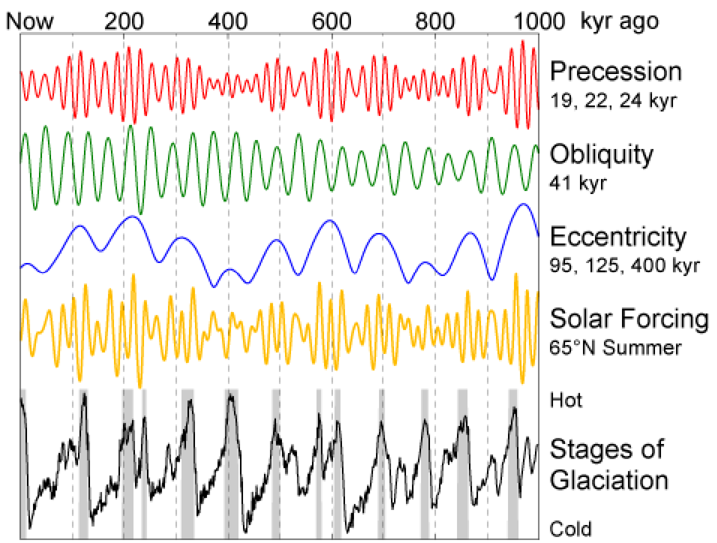
Kasting and Catling (2003)

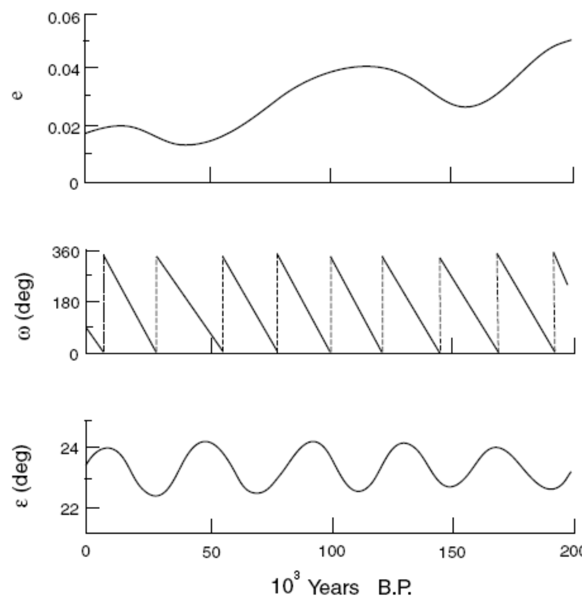


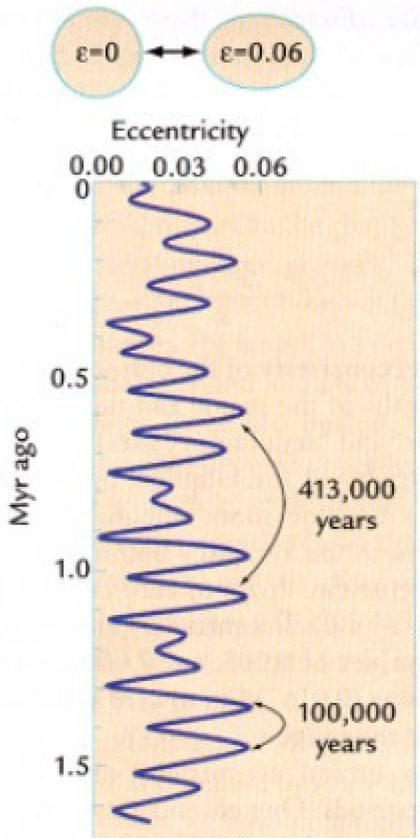
0.06
0.04
e
0.02
0
360
180
ω (deg)
0
24
ε (deg)
22
0
50
100
150
200
10^3 Years B.P.

Teoría de Milankovitch

- Variaciones en los parámetros orbitales y por tanto en la insolación terrestre debieran verse reflejados en cambios en el clima. En particular en el control (extensión y duración) de las glaciaciones terrestres.
- El parámetro crítico es la insolación recibida en verano







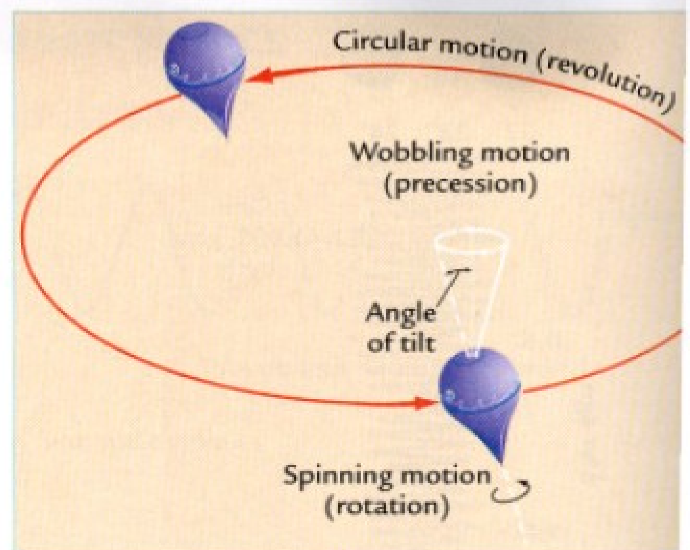
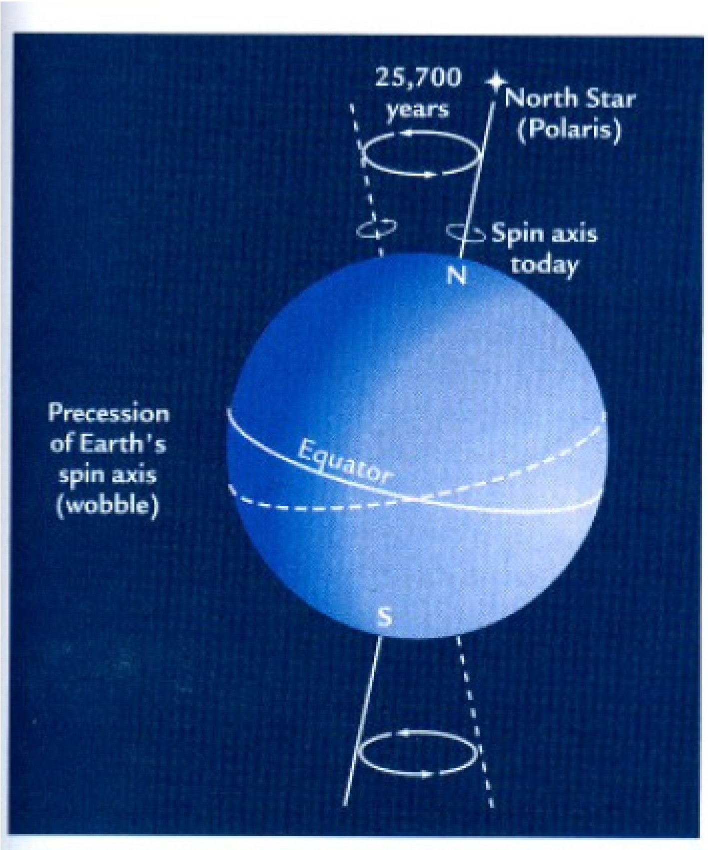


FIGURE 7-8 Earth's wobble In addition to its rapid (d rotational spin and its slower (yearly) revolution around Sun, Earth wobbles slowly, like a top, with one full wobb every 25,700 years.



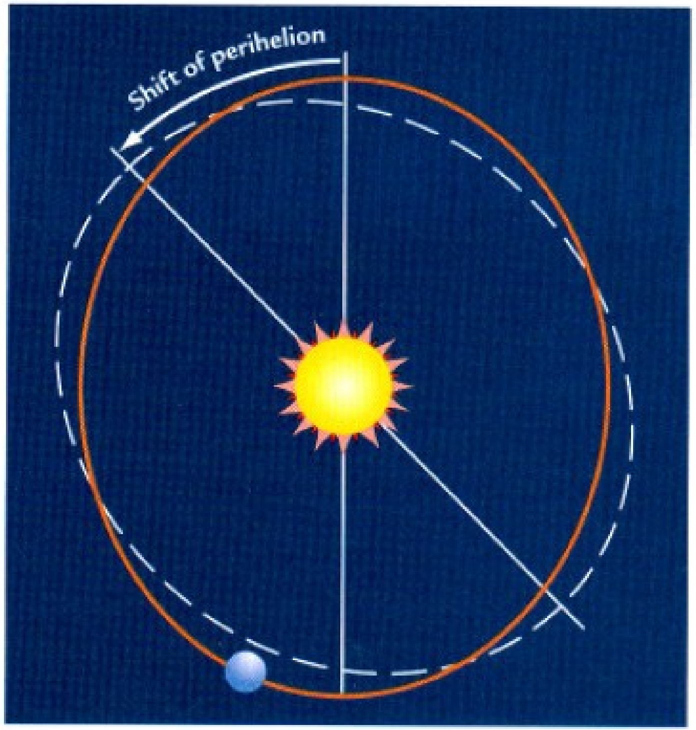


FIGURE 7-10 Precession of the ellipse The elliptical shape of Earth's orbit slowly precesses in space so that the major and minor axes of the ellipse slowly shift through time. (Adapted from N. Pisias and J. Imbrie, "Orbital Geometry, CO_2, and Pleistocene Climate," *Oceanus* 29 [1986–87]: 43–49.)

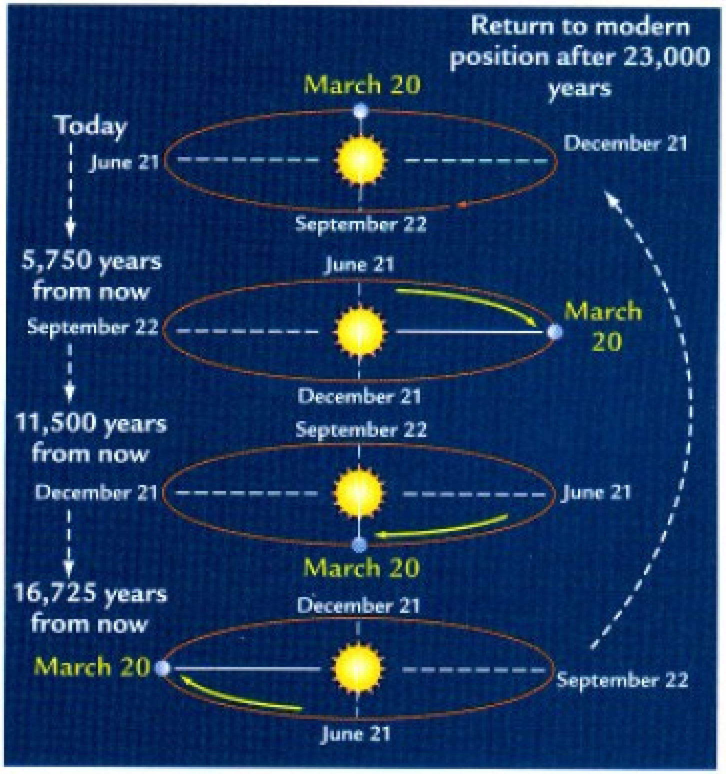
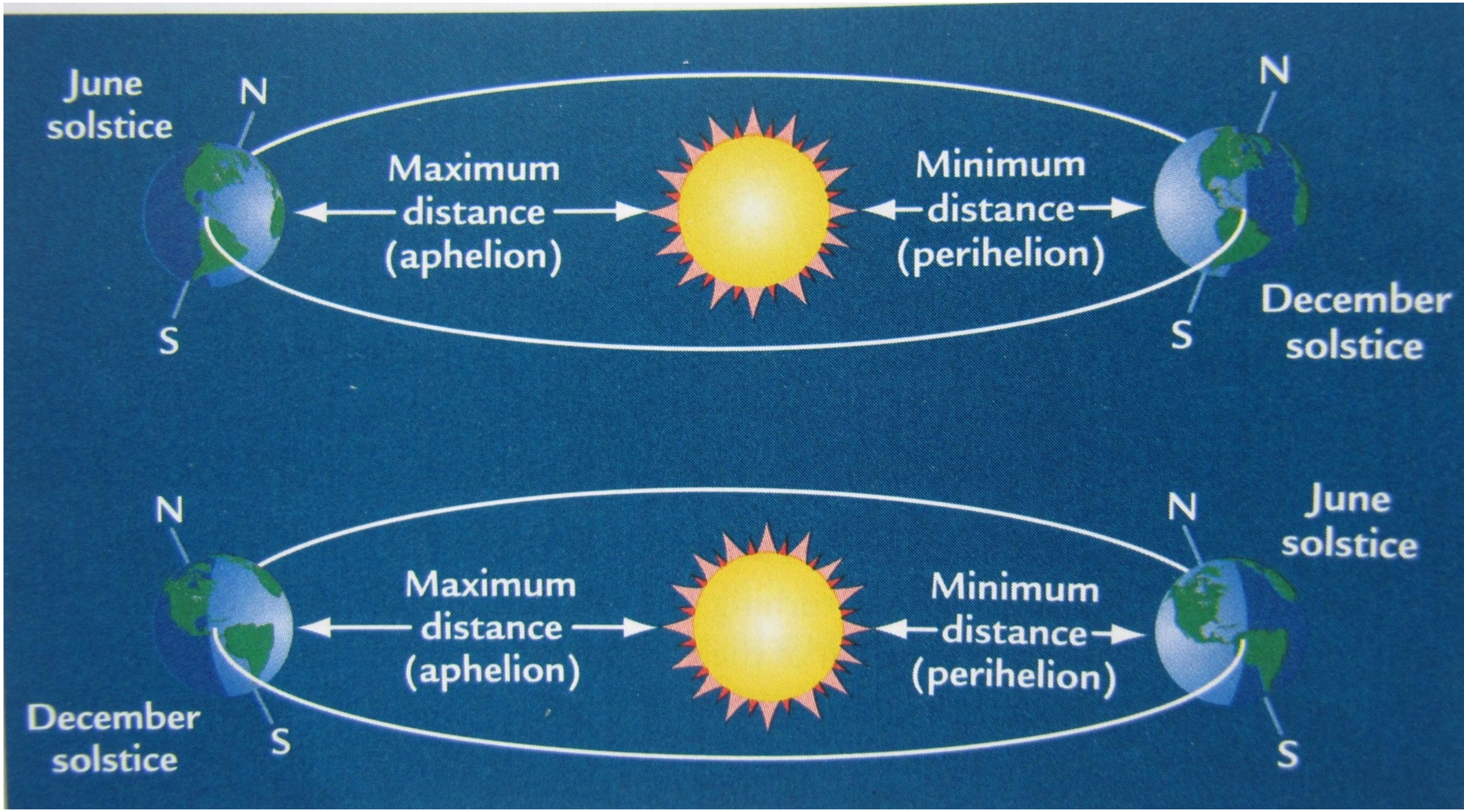
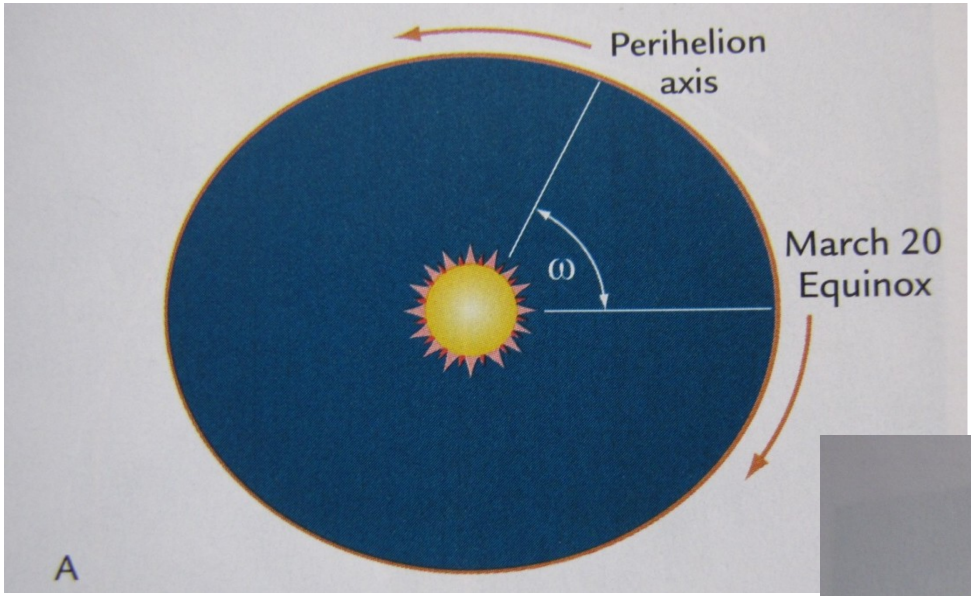
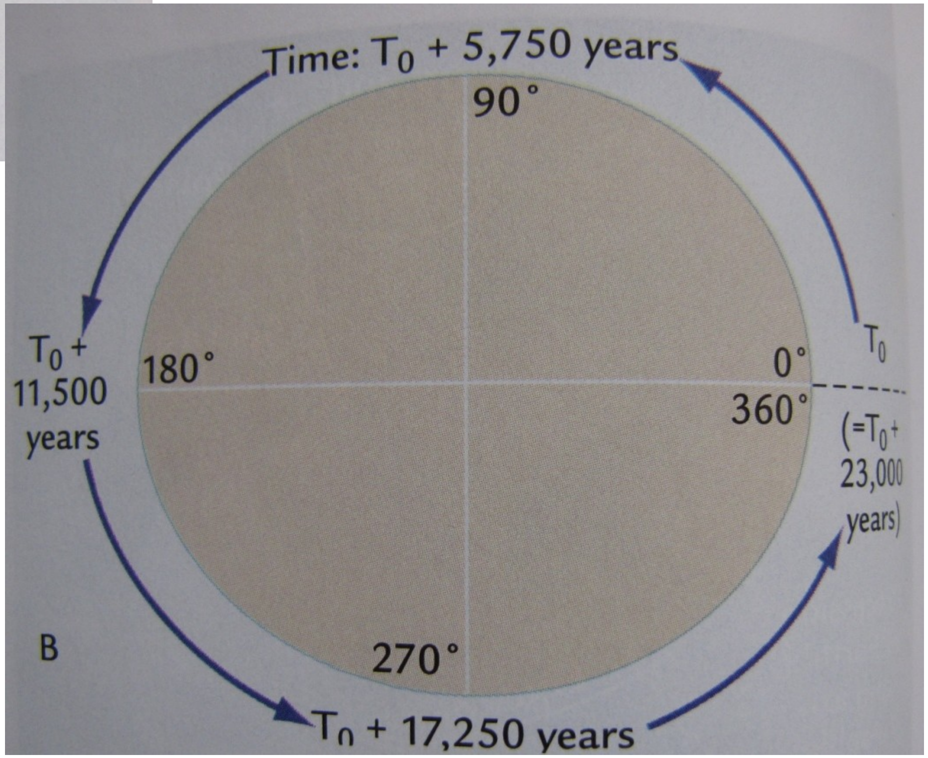
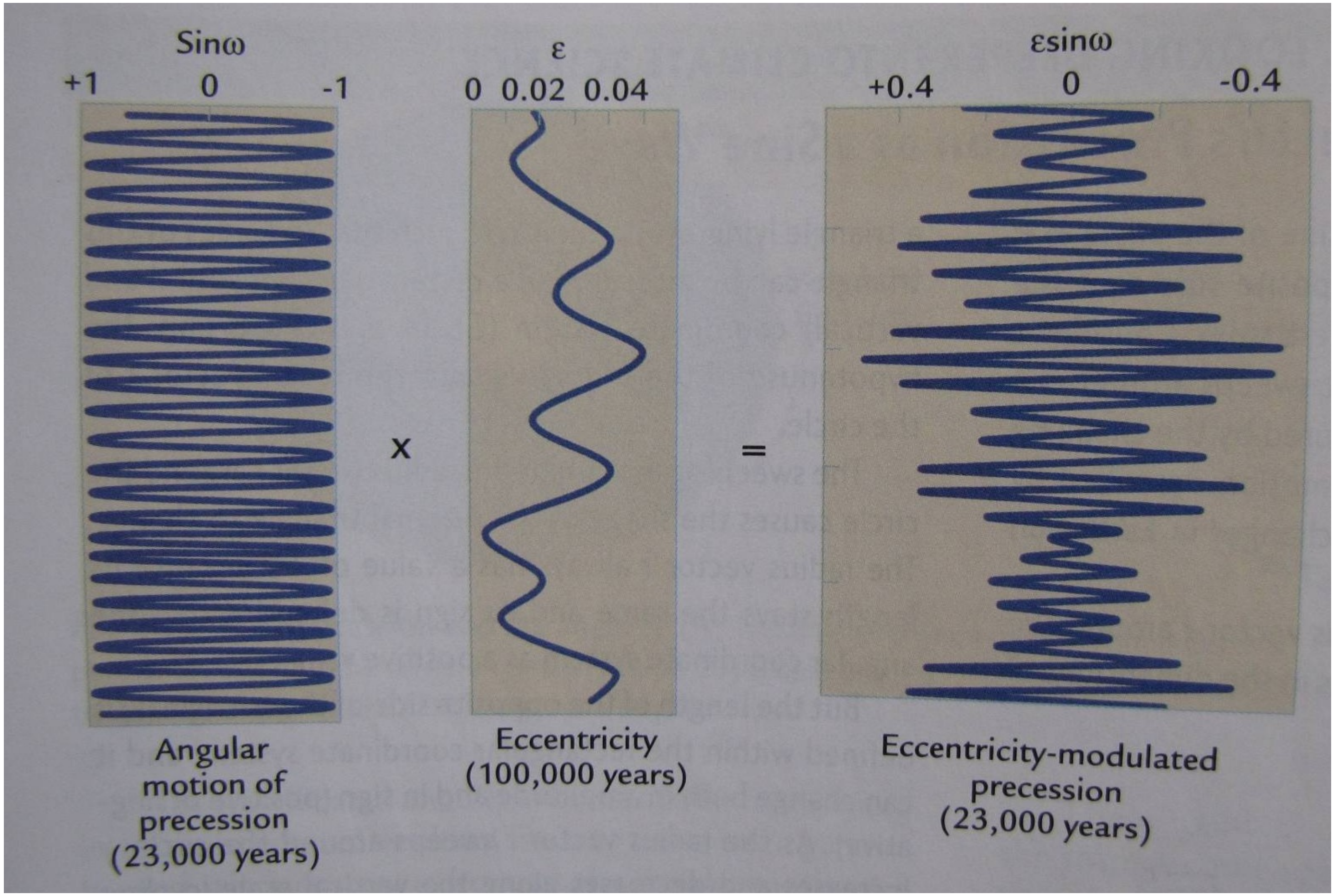


FIGURE 7-11 Precession of the equinoxes Earth's wobble and the slow turning of its elliptical orbit combine to produce the precession of the equinoxes. Both the solstices and equinoxes move slowly around the eccentric orbit in cycles of 23,000 years. (Adapted from J. Imbrie and K. P. Imbrie, *Ice Ages: Solving the Mystery* [Short Hills, NJ: Enslow, 1979].)


June solstice
N
S
Maximum distance (aphelion)
Minimum distance (perihelion)
N
S
December solstice
N
S
December solstice
Maximum distance (aphelion)
Minimum distance (perihelion)
N
June solstice
S


Perihelion
axis
ω
March 20
Equinox
A


Time: T0 + 5,750 years
90°
T0 +
11,500
years
180°
0°
360°
T0
(=T0+
23,000
years)
270°
B
T0 + 17,250 years


Sinω
+1
0
-1
x
ε
0 0.02 0.04
=
εsinω
+0.4
0
-0.4
Angular motion of precession (23,000 years)
Eccentricity (100,000 years)
Eccentricity-modulated precession (23,000 years)

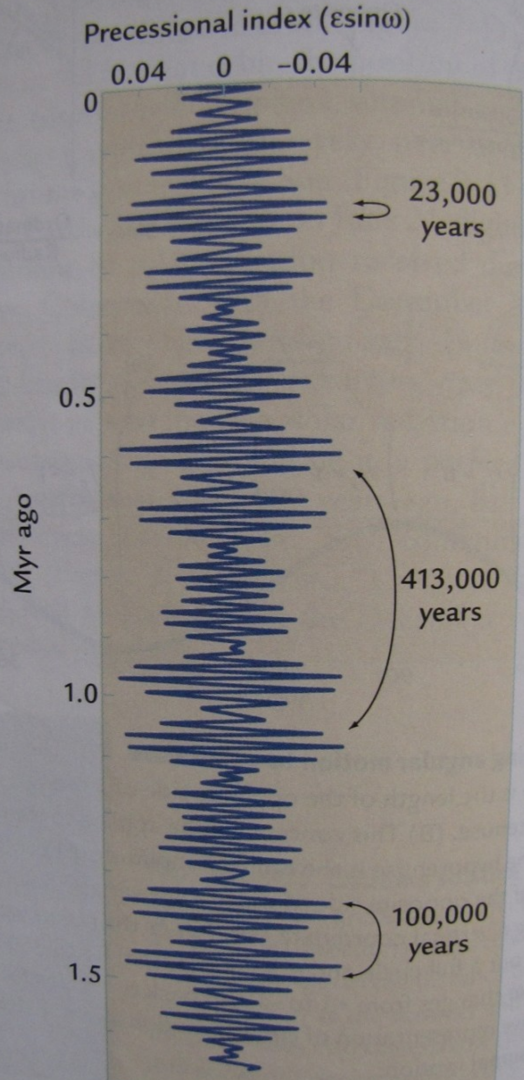
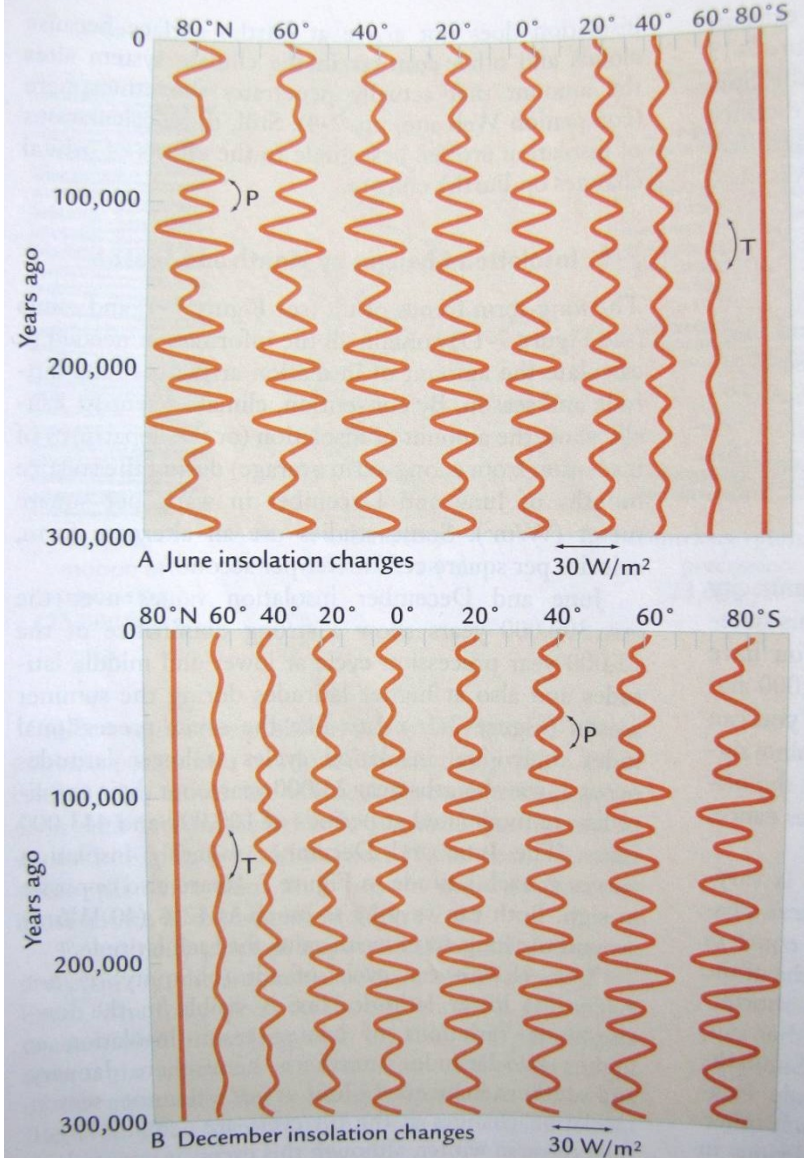

Precessional index (εsinω)
0.04
0
−0.04
0
0.5
1.0
1.5
Myr ago
23,000 years
413,000 years
100,000 years

FIGURE 7.1



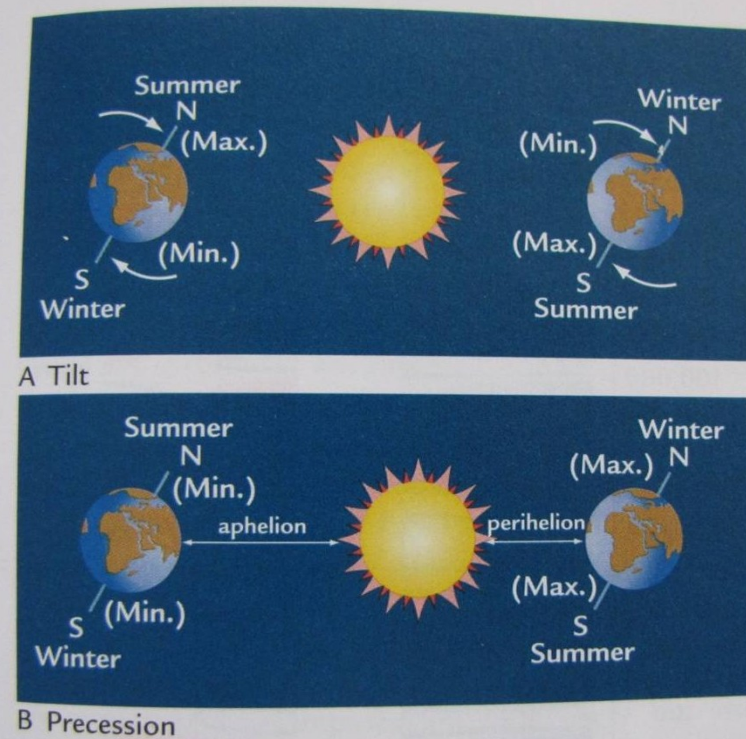
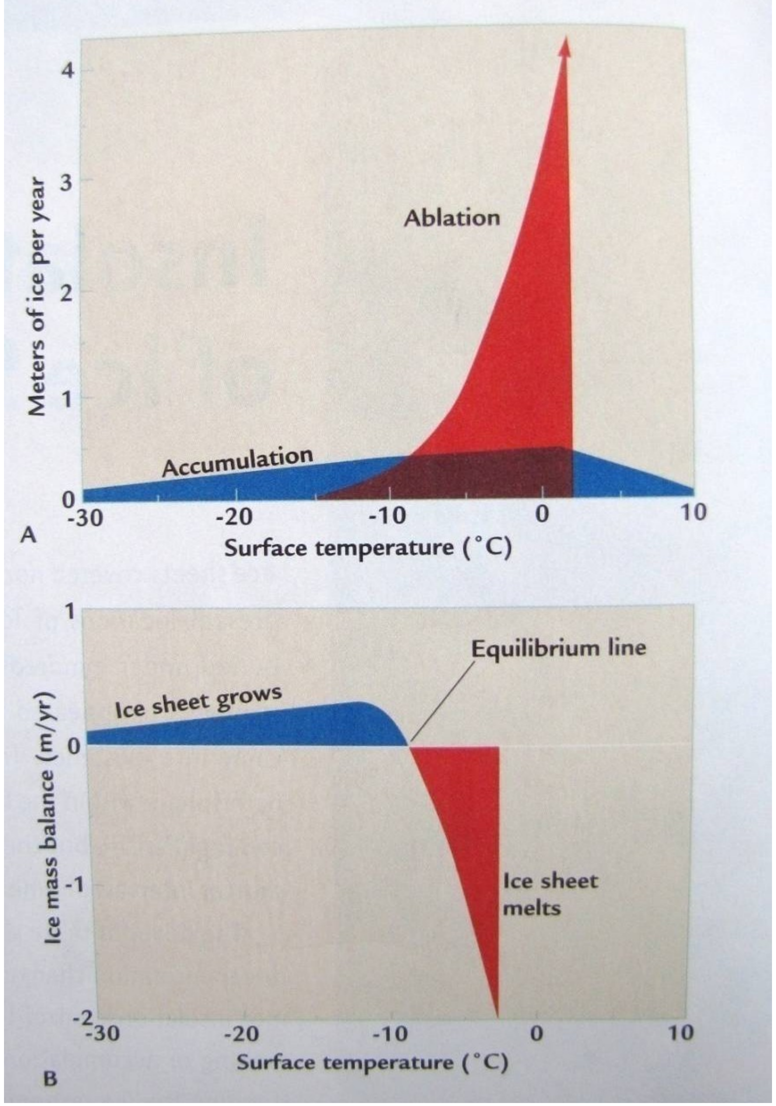
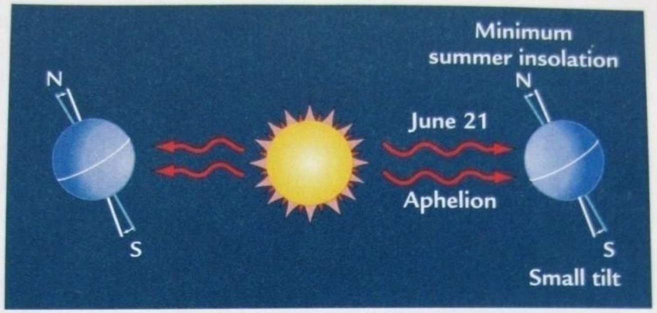
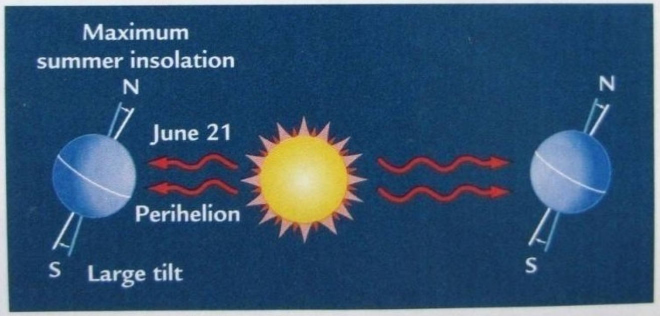


FIGURE 7-17 Phasing of insolation maxima and minima
(A) Tilt causes in-phase changes for polar regions of both hemispheres in their respective summer and winter seasons. (B) Precession causes out-of-phase changes between hemispheres for their summer and winter seasons.



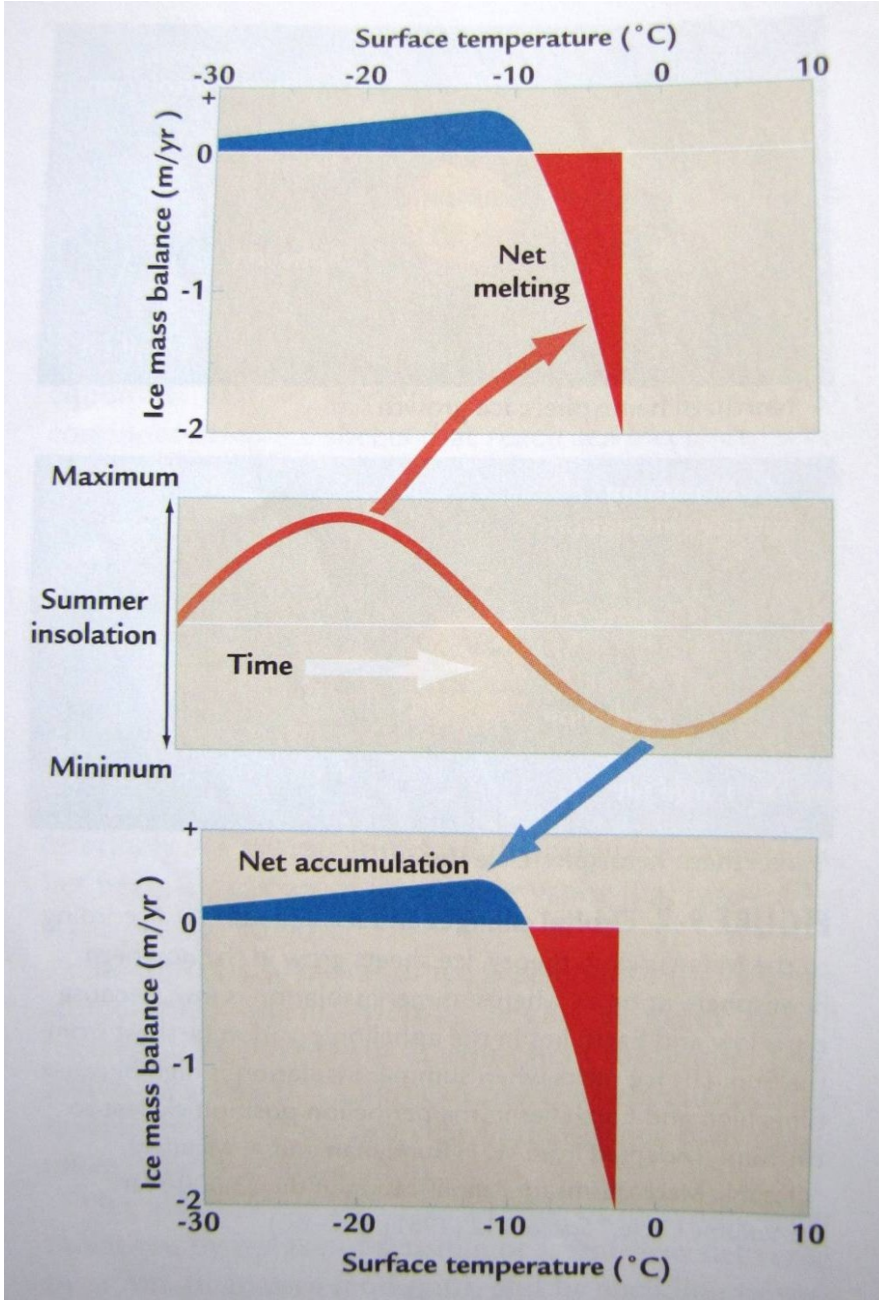


A Northern hemisphere ice growth

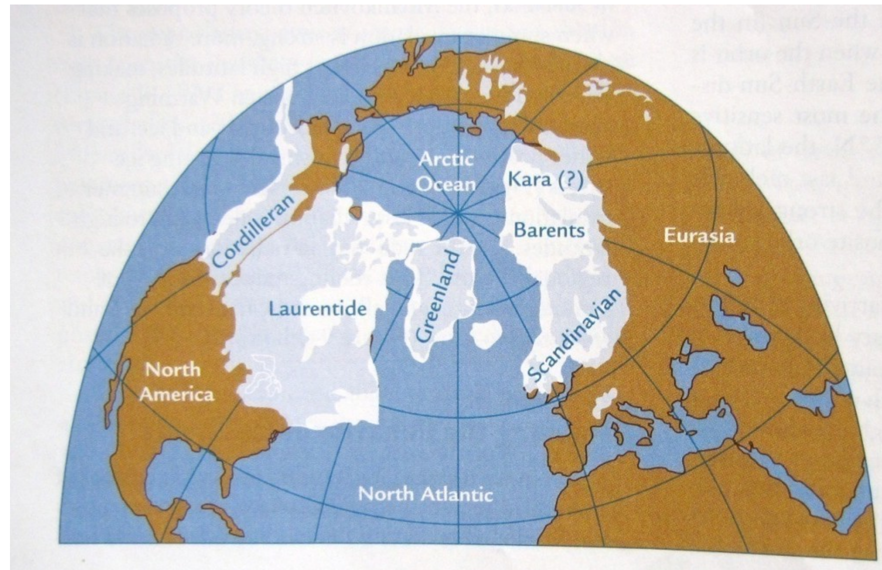


B Northern hemisphere ice decay

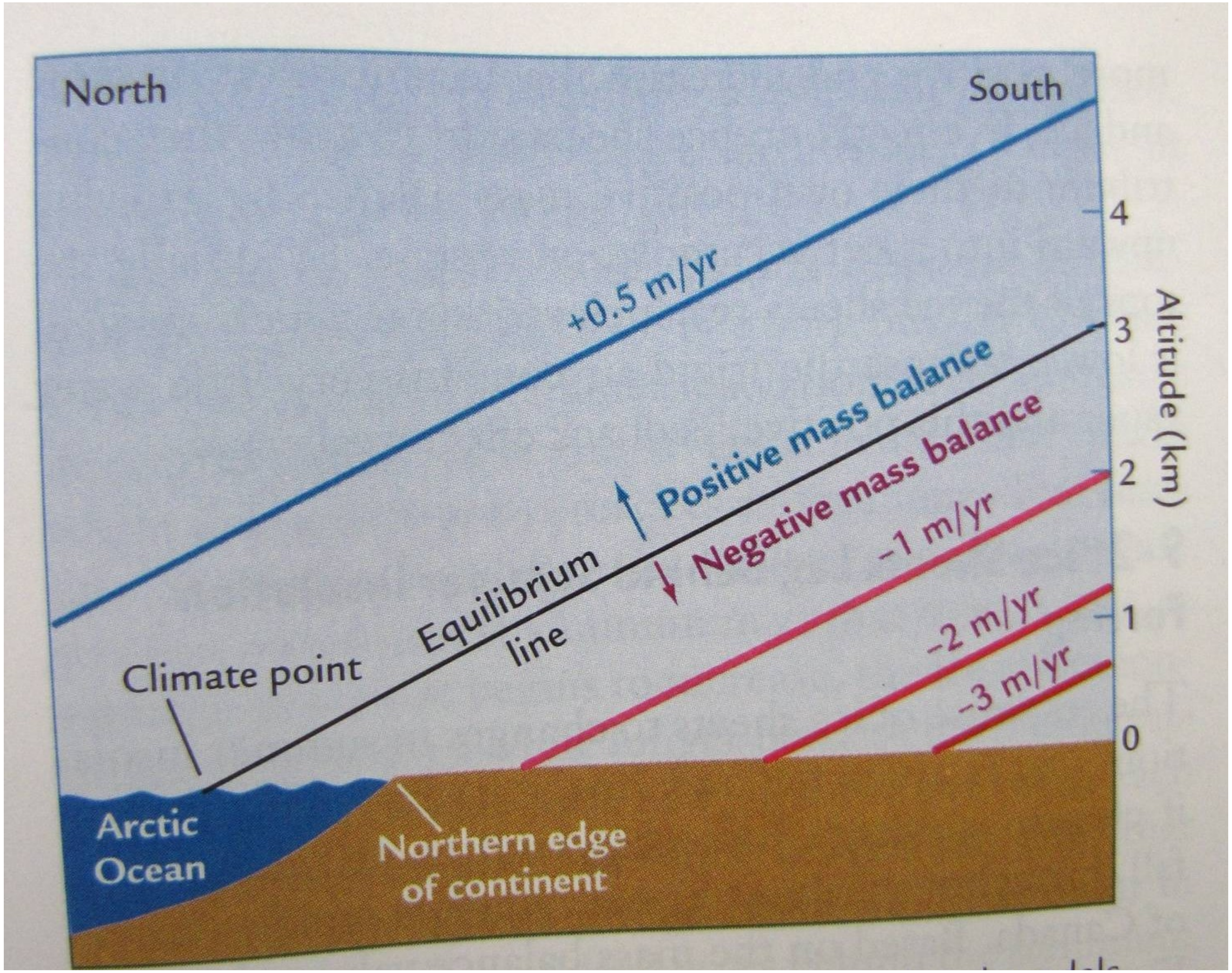
FIGURE 9-2 Orbital changes and ice sheets (A) According to the Milankovitch theory, ice sheets grow in the northern hemisphere at times when summer insolation is low, because tilt is low and Earth lies in the aphelion position farthest from the Sun. (B) Ice melts when summer insolation is high because tilt is high and Earth lies in the perihelion position closest to the Sun. (Adapted from W. F. Ruddiman and A. McIntyre, "Oceanic Mechanisms for Amplification of the 23,000-Year Ice-Volume Cycle," *Science* 212 [1981]: 617–27.)

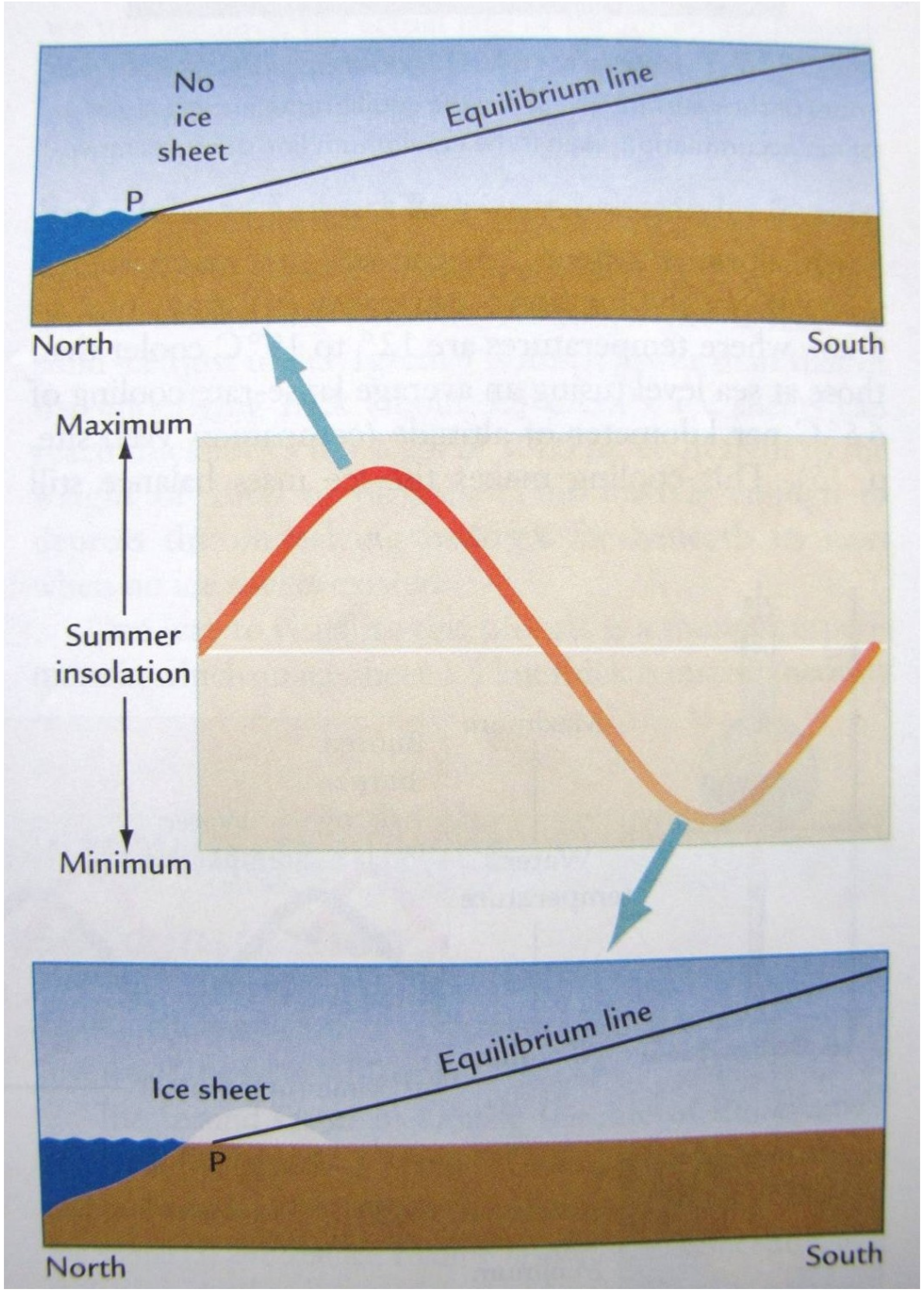


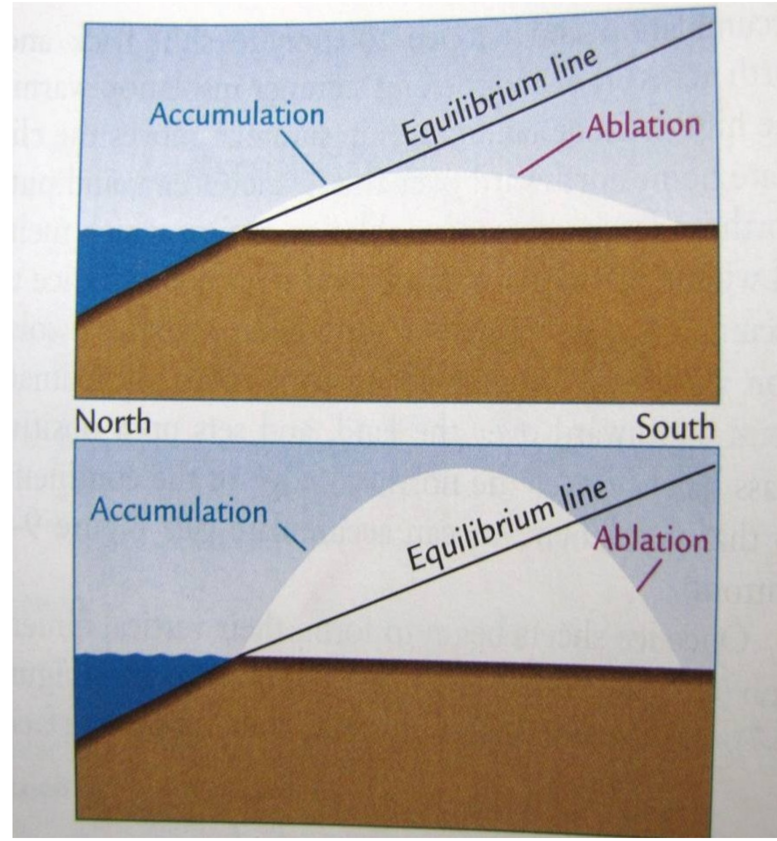
Surface temperature (°C)
-30
-20
-10
0
10
Ice mass balance (m/yr)
+
0
-1
-2
Net melting
Maximum
Summer insolation
Time
Minimum
Net accumulation

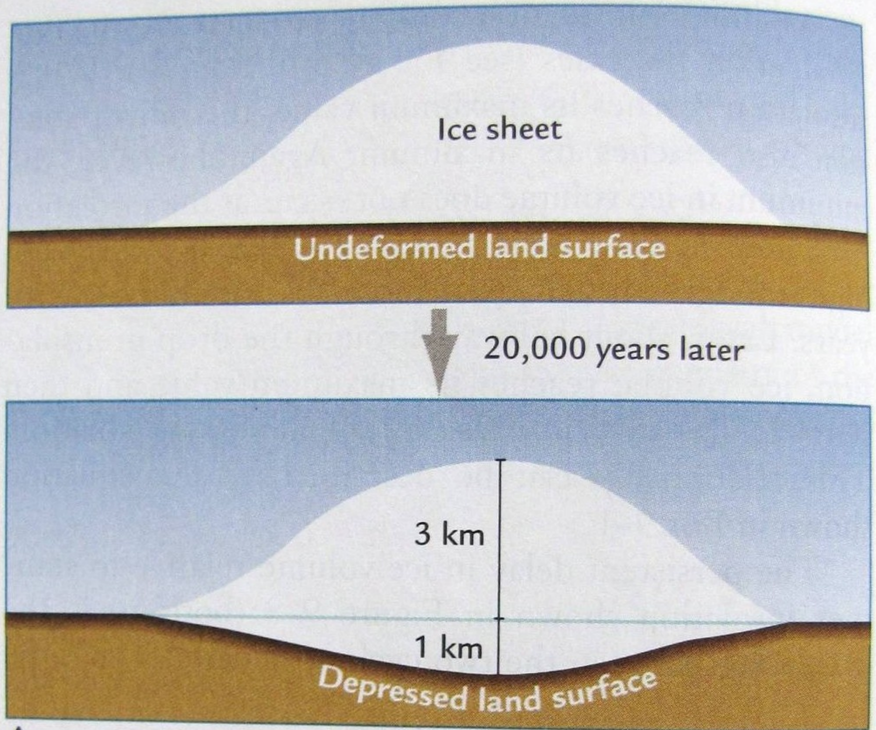


Arctic Ocean
Kara (?)
Barents
Eurasia
Cordilleran
Laurentide
Greenland
Scandinavian
North America
North Atlantic

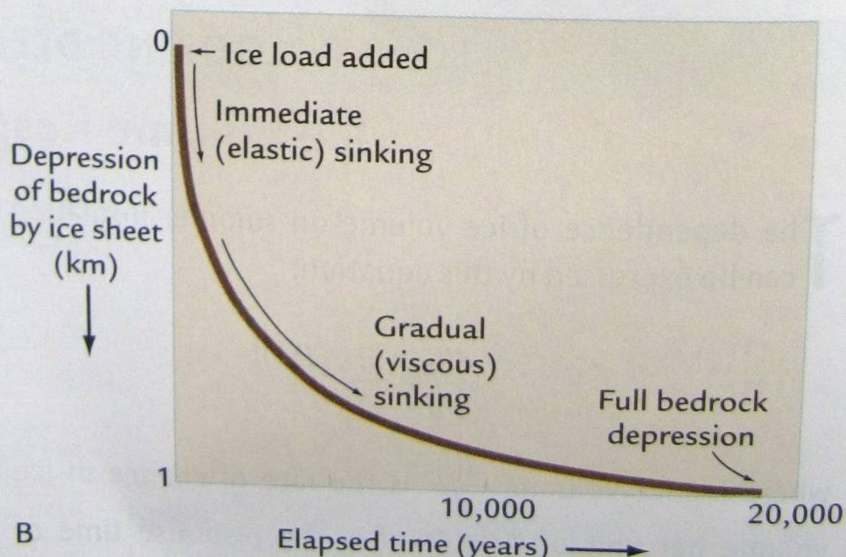

North
South
+0.5 m/yr
Positive mass balance
Negative mass balance
Equilibrium
line
Climate point
–1 m/yr
–2 m/yr
–3 m/yr
Altitude (km)
4
3
2
1
0
Arctic
Ocean
Northern edge
of continent


No ice sheet
Equilibrium line
P
North
South
Maximum
Summer insolation
Minimum
Ice sheet
Equilibrium line
P
North
South

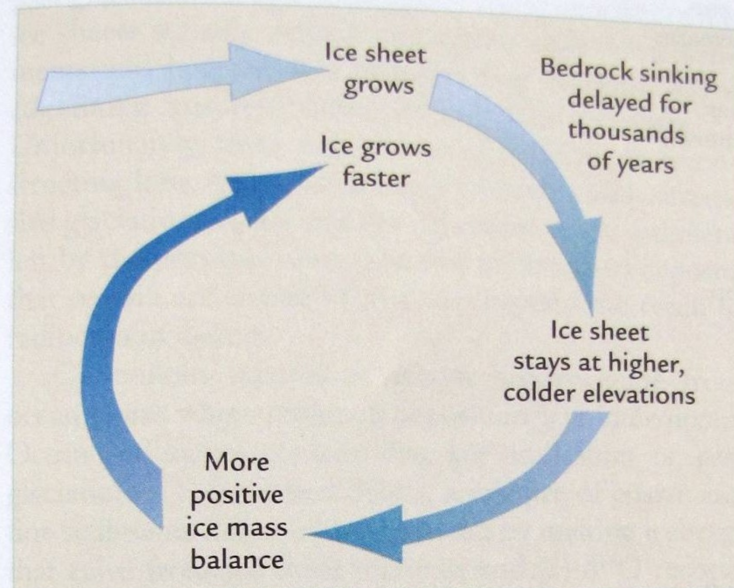

Accumulation
Equilibrium line
Ablation
North
South
Accumulation
Equilibrium line
Ablation



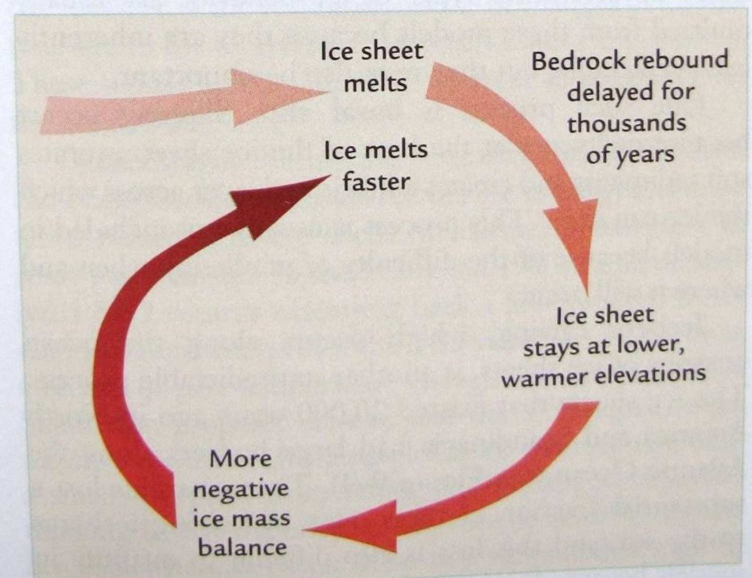
A



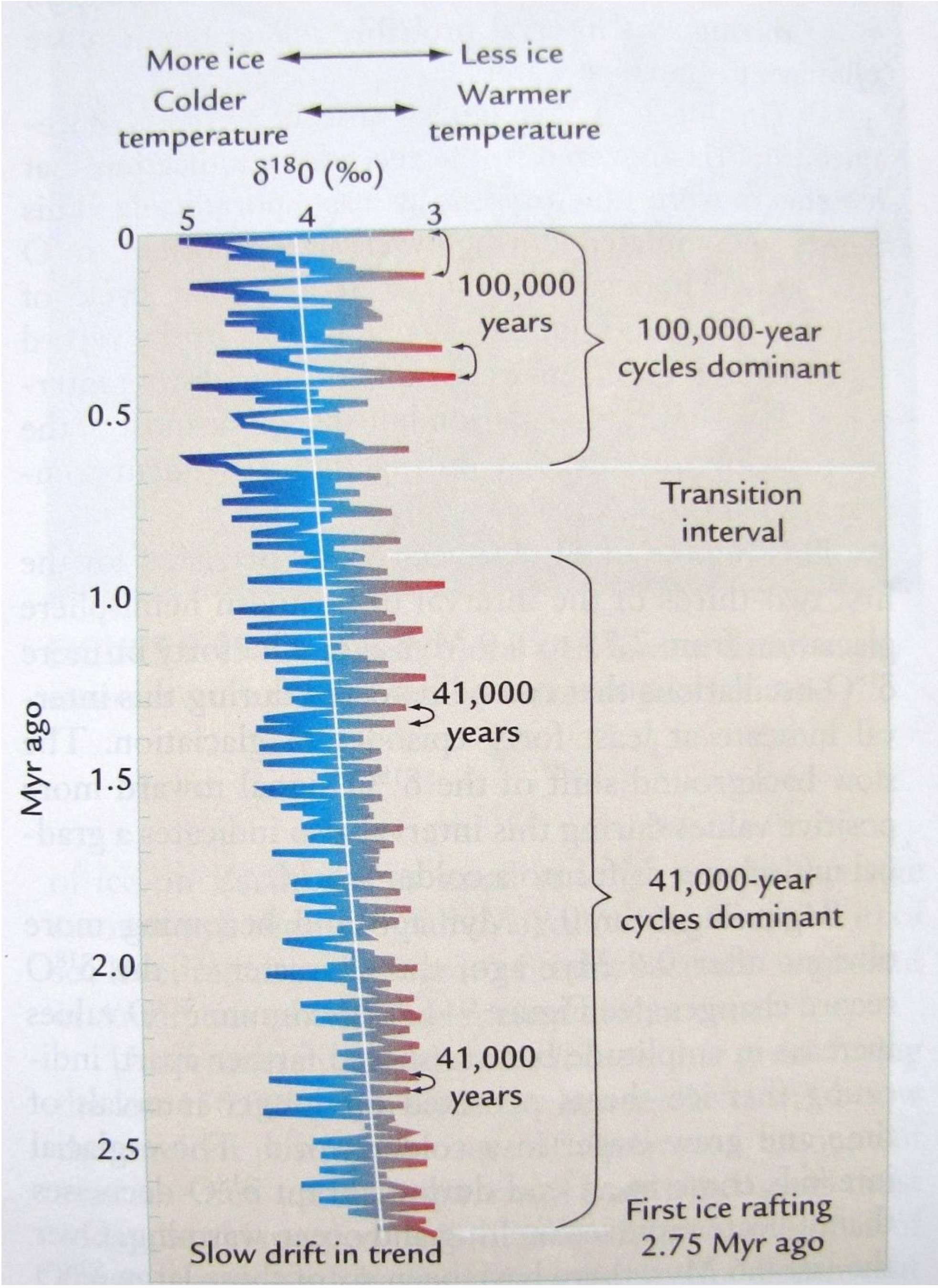
B

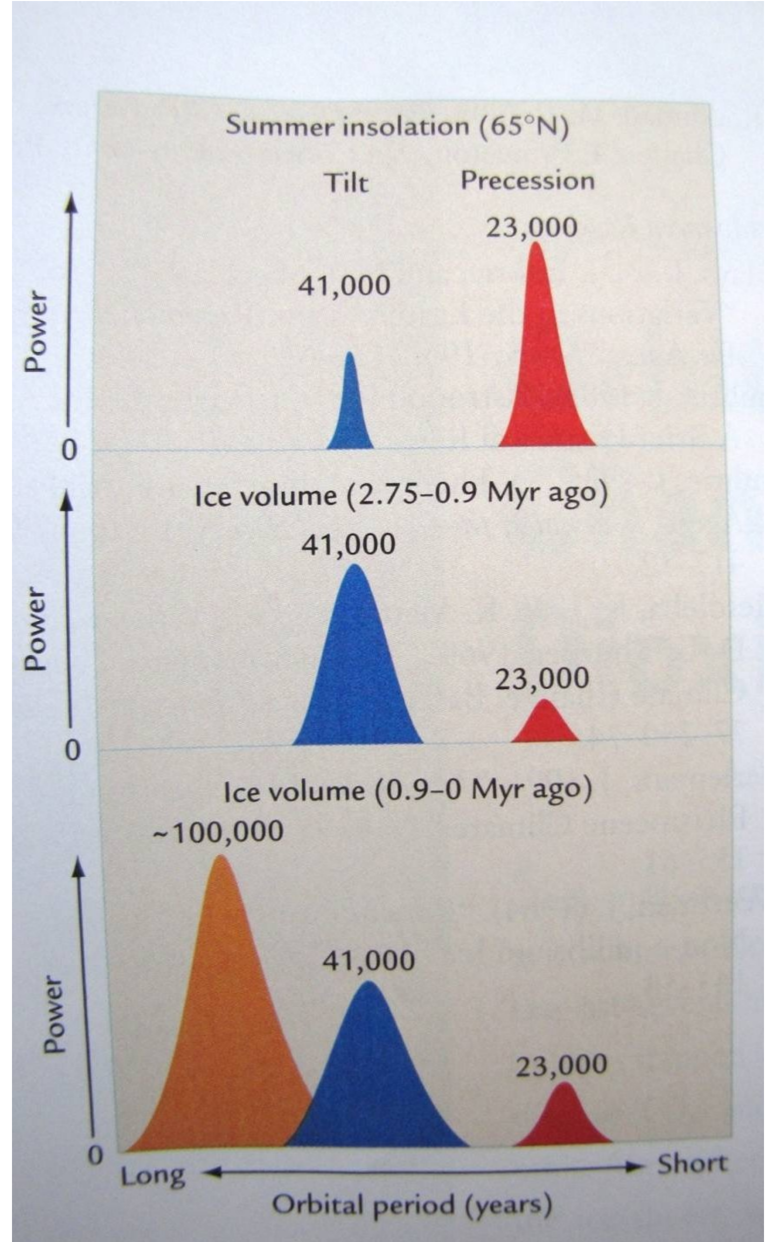


A Low summer insolation



B High summer insolation


More ice
Less ice
Colder temperature
Warmer temperature
δ18O (‰)
5
4
3
0
0.5
1.0
1.5
2.0
2.5
Myr ago
100,000 years
100,000-year cycles dominant
Transition interval
41,000 years
41,000 years
41,000-year cycles dominant
First ice rafting 2.75 Myr ago
Slow drift in trend


Summer insolation (65°N)
Tilt
Precession
23,000
41,000
Power
0
Ice volume (2.75–0.9 Myr ago)
41,000
23,000
Power
0
Ice volume (0.9–0 Myr ago)
~100,000
41,000
23,000
Power
0
Long
Short
Orbital period (years)