Triggering Climate Change
Radiative forcing in July (W m\(^{-2}\)), preindustrial to present
Earth-Sun Geometry: Solar Input

100% → 80% → 64% → 5 km path → 64% → 53% → Earth surface

80% → 64% → 53% → 100%
North Pole
Radiation spread over a large area

Equator
Radiation focused on a small area

South Pole
Radiation spread over a large area

Equal-area beams of incoming solar radiation
Eccentricity
Tilt of Earth’s Spin Axis

North Pole

Equator

South Pole

23.5°

Plane of Earth's orbit
Sun

N. Hemisphere mild winter
S. Hemisphere hot summer

N. Hemisphere mild summer
S. Hemisphere cold winter

Today
Sept 22 (autumn equinox)
Dec 21
Jun 21
Mar 20 (spring equinox)
Tilt

22° 23° 24°

One 41,000-year cycle

Eccentricity

ε=0 → ε=0.06

Myr ago

0.0 0.3 0.6

0.5

1.0

1.5

413,000 years

100,000 years
Precession

Precession of Earth's spin axis (wobble)

North Star (Polaris)

Spin axis today

25,700 years
Angular motion of precession (23,000 years)

Eccentricity (100,000 years)

Eccentricity-modulated precession (23,000 years)

Precessional index ($\varepsilon \sin \omega$)
A Individual sine-wave cycles

B Combination of cycles
Changes in Insolation Depend on Latitude

A June insolation changes

30 W/m²
(A) Preglaciation phase

- Insolation
- Glaciation threshold
- Ice volume

No ice present

Time
(B) Small glaciation phase

Insolation
Glaciation threshold
Lag
Ice volume

41,000 years

Time
Glaciation threshold

Insolation

Lag

Ice volume

Time

(C) Large glaciation phase
Glaciation threshold
Insolation
Ice volume

Time

(D) Permanent glaciation phase
Holocene, Pleistocene Glaciers