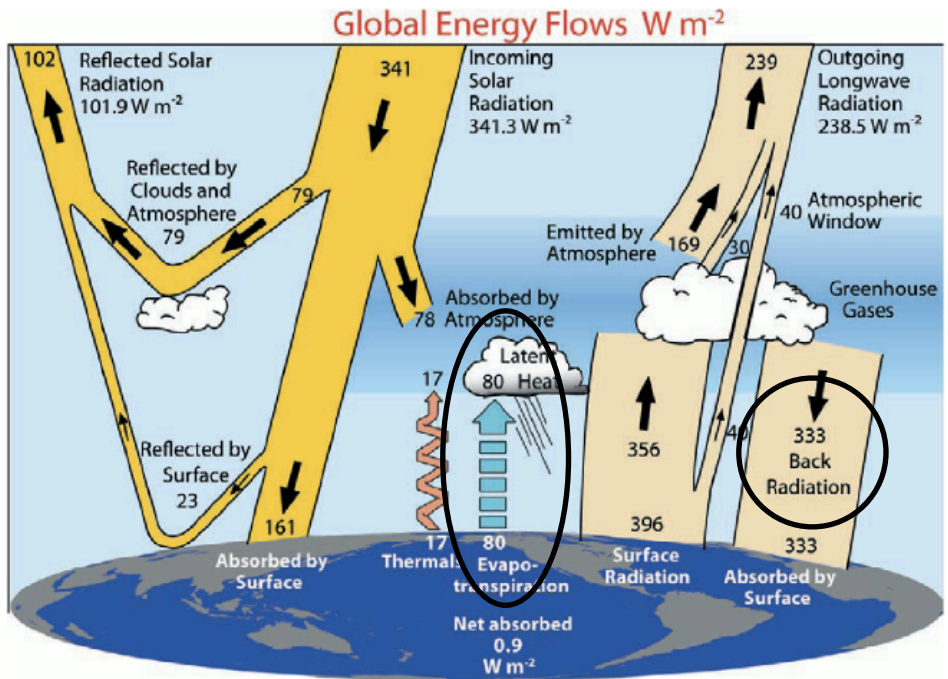


1. To obtain climate information about the past, we use oxygen isotopes measured in the **shells of marine organisms and in ice cores**. Put the following in order from **Heaviest** $\delta^{18}\text{O}$ to **Lightest** $\delta^{18}\text{O}$ value.
- $\delta^{18}\text{O}$ of shells of deep sea benthic organisms living during the last interglacial period
 - $\delta^{18}\text{O}$ of precipitation in summer over Greenland
 - $\delta^{18}\text{O}$ of shells of deep sea benthic organisms living at the last glacial maximum
 - $\delta^{18}\text{O}$ of water vapour over Antarctica

- ii, iii, i, iv
- iv, iii, i, ii
- iii, ii, i, iv
- iii, i, ii, iv
- iv, iii, ii, i

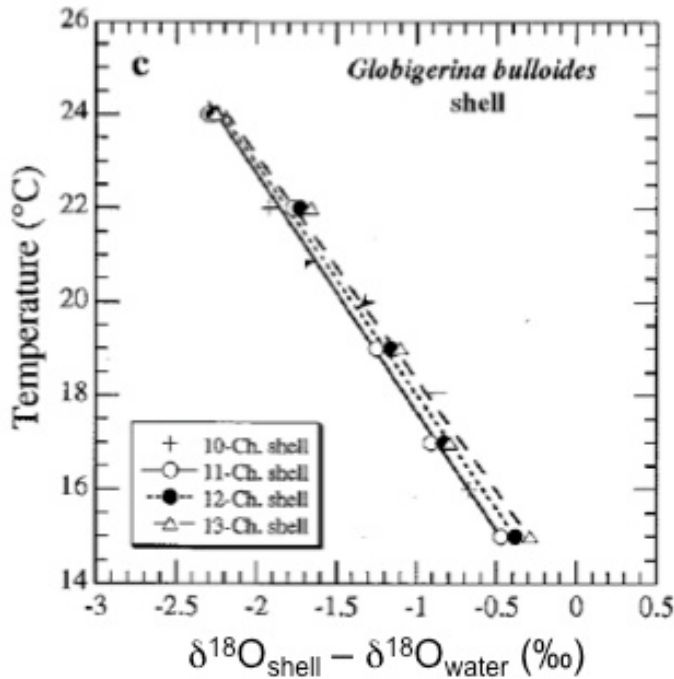
2. Which of the following statements about the circled regions in the diagram below are true?



During the last ice age _____ than today.

- “Evapotranspiration” would have been **smaller**; “Back Radiation” would have been **larger**
- “Evapotranspiration” would have been **larger**; “Back Radiation” would have been **larger**
- “Latent Heat” would have been **larger**; “Back Radiation” would have been **~ the same**
- “Latent Heat” would have been **smaller**; “Back Radiation” would have been **smaller**
- “Latent Heat” would have been **larger**; “Back Radiation” would have been **smaller**

3. Use the figure below to answer this question. Say you measured $\delta^{18}\text{O} = -2$ in a foram shell (in this case, *Globigerina bulloides*), and you knew, independently, that the water $\delta^{18}\text{O}$ value was 0.8. What was the temperature of the water in which this foram grew?



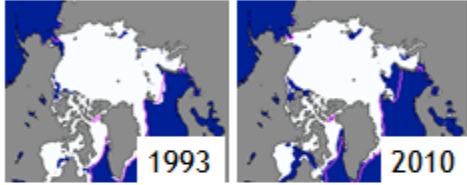
- A) colder than 15°C
 B) about 17°C
 C) about 19°C
 D) about 23°C
 E) warmer than 24°C
4. Suppose an anti-science candidate ascended to the presidency of a future world government. With their folksy charm/vacuity, they convinces the IPCC to reconsider its estimates of climate sensitivity, preindustrial CO₂ levels and estimates of carbon fluxes in exchange for a willingness to set new, binding targets for CO₂ reductions. They aim to stabilize global temperature at 4°C above pre-industrial values. How many **TOTAL** Gtons of C can we emit if we are to achieve this goal, **starting the count at the beginning** of the industrial revolution?
Notably extreme assumptions to use: (1) assume climate sensitivity of 1°C per doubling, (2) assume pre-industrial atmospheric CO₂ is 300 ppm, (3) assume 30% of what's emitted stays in the atmosphere on the time scale of interest.
5. Which of the following systems would be useless a proxies for paleotemperature or carbon fluxes?
- A) $^{14}\text{C}/^{12}\text{C}$
 B) $^{13}\text{C}/^{12}\text{C}$
 C) Ca/Mg
 D) $^{18}\text{O}/^{16}\text{O}$
 E) $^2\text{H}/^1\text{H}$

6.

In June, say the Arctic gets 500 W/m^2 (no clouds).

In June 1993, 90% of the Arctic was ice-covered.

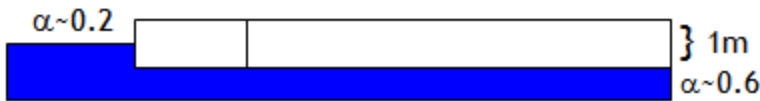
In June 2010, 80% of the Arctic was ice-covered.



How much energy did the Arctic absorb in June 2010 compared to June 1993?

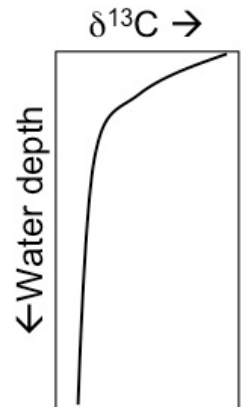


- A. 240 W/m^2 MORE in June 2010
- B. 40 W/m^2 MORE in June 2010
- C. 20 W/m^2 MORE in June 2010
- D. 20 W/m^2 LESS in June 2010
- E. 240 W/m^2 LESS in June 2010



7. The figure at right shows how $\delta^{13}\text{C}$ changes with water depth in the ocean, with “heavier” values near the surface and “lighter” values in the deeper water. Which of the following will have the heaviest signature?

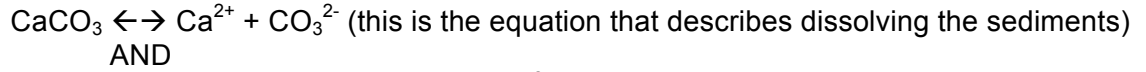
- A) Organic tissues of phytoplankton
- B) Mineralized shells of benthic forams
- C) Mineralized shells of benthic clams
- D) mineralized shells of planktonic forams



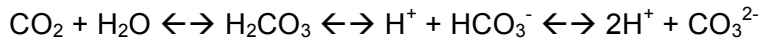
8. During parts of the Paleozoic, the southern continents (Australia, Africa, S. Am., Antarctica, Madagascar + India—it moved a bunch!) were united into one southerly supercontinent called Gondwana. There is evidence for major glaciations over this landmass during the Permian. Which of the following configurations would be amenable to such a glaciation?

- A) Minimum eccentricity, minimum tilt, southern summer at aphelion
- B) Minimum eccentricity, maximum tilt, northern summer at perihelion
- C) Maximum eccentricity, minimum tilt, northern summer at perihelion
- D) Maximum eccentricity, maximum tilt, southern summer at perihelion
- E) Maximum eccentricity, minimum tilt, northern summer at aphelion

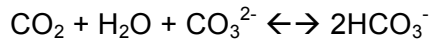
9. What does **dissolving CO₂** do to the carbon chemistry in the ocean? Here are the relevant chemical reactions:



AND



AND



- A) **Lowers** the pH because adding CO₂ to the ocean water will increase H⁺
B) **Raises** the pH because adding CO₂ to the ocean water will decrease H⁺
C) **Lowers** the pH because adding CO₂ from the ocean water will increase H⁺
D) **Raises** the pH because adding CO₂ from the ocean water will increase H₂CO₃
E) **Does not change** the pH because the Ca²⁺ balances the CO₂
10. Which of the following statements summarizes a **correct part** of Ruddiman's arguments supporting the early anthropogenic hypothesis?
- A) Rapid atmospheric recovery to preindustrial carbon levels is supported by the record of CO₂ during the bubonic plague.
B) Based on estimates of rice irrigation by early humans, the amount of CH₄ added to the atmosphere by that activity contributed significantly to the CH₄ rise.
C) Because of the low eccentricity and high seasonal contrast during our present interglacial period, Earth should have gone into the next ice age already.
D) The increase in δ¹⁸O in benthic forams since 3000 years ago matches what would be expected from deforestation and agricultural activities by early humans.
E) Atmospheric greenhouse gases CO₂ and CH₄ both increase in the last several thousand years due to human activity.