

## The Holocene Record: Climate Change in the Late Cenozoic

### What Do We Know?

- Ancient Sea Level Records, including the Holocene
- Historical Temperatures past 150 yrs
- Ancient Temperature Records based on proxies:
  - Annual ice layer thickness records
  - Oxygen isotope data from both fossils and ice
  - Tree ring data provide growth rates that reflect climate change
- CO<sub>2</sub> record in detail for past 400,000 yrs

### What Do We Know?

- Sea Level rose about 100 m since the peak of the last glaciation about 20 ka.
- Peak sea level was 50-100 m higher in an ice-free world.
- Global temperatures have risen overall about 0.8°C since records started in the 1870s.
- Climate change has been common, and sometimes rapid, during the past 20,000 years.
- Temperatures have been warmer at times in the past 10,000 years than currently.
- The Medieval Warm Period, or “Climate Optimum”, at about 1000-1200 C.E. was warmer than now.

### What Do We Know?

- The Little Ice Age extended from about 1400-1800 C.E. This ended the Medieval Warm Period and changed agricultural patterns in Europe.
- The world has been warming since the end of the Little Ice Age starting around 1800.

- There are debates about the details of temperature records over the last 1000 years.
- The glaciers on Mt. Kilimanjaro in Kenya have been melting during the 20th Century. But why?
- CO<sub>2</sub> in the atmosphere has risen over 33% since the 1800s. CO<sub>2</sub> is a greenhouse gas.

### What Do We Know?

- Global temperature and CO<sub>2</sub> patterns are correlated over the past 400,000 years.
- CO<sub>2</sub> curve lags temperature curve by about 800 years.
- The ocean holds 50X more CO<sub>2</sub> than the atmosphere.
- As atmospheric temperatures warm, so does the ocean, which releases CO<sub>2</sub> into the atmosphere. When the ocean cools it absorbs more CO<sub>2</sub>. CO<sub>2</sub> is more soluble in cold water than warm water.
- So temperature changes may drive CO<sub>2</sub> changes rather than the other way around.

### What is Debatable?

- Is the rise in global temperatures since ~1980 mostly caused by burning fossil fuels?
- CO<sub>2</sub> is a greenhouse gas, but what about the role of water vapor?
- Is the recent temperature rise part of a natural cycle of temperature change?
- What is the role of solar output variation as shown by sunspot activity?

## What does the Future Hold?

- Rising global temperatures in the next century? Yes, but how much? Models depend a great deal on estimates of atmospheric water vapor levels.
- Rising sea level in the next century? Yes, but how much?
- More and stronger hurricanes? Maybe.

## Response by Humanity?

- Find alternatives to burning fossil fuels
  - CO<sub>2</sub> from fossil fuels is adding to global warming, even if we are not sure of the magnitude of this effect.
  - Fossil fuels will be greatly depleted within a century, civilization needs other energy sources.
- Adapt to changing climate and rising sea level
  - Changes in climate and sea level are part of natural cyclical processes.
  - Find political solutions to conflicts over water, fuel, and food resources. Otherwise regional wars will be common.
  - Be realistic about development along coasts. Can't fight long-term rising sea levels. Move back!

## Shorelines are Moving

- Shorelines composed of sediments are geologically unstable. They shift position from various geologic variables including:
  - Sea level change
  - Subsidence
  - Erosion
  - Deposition
- Shoreline shift is a reality humans must face.