

# OCEANS and CLIMATE

## PART II

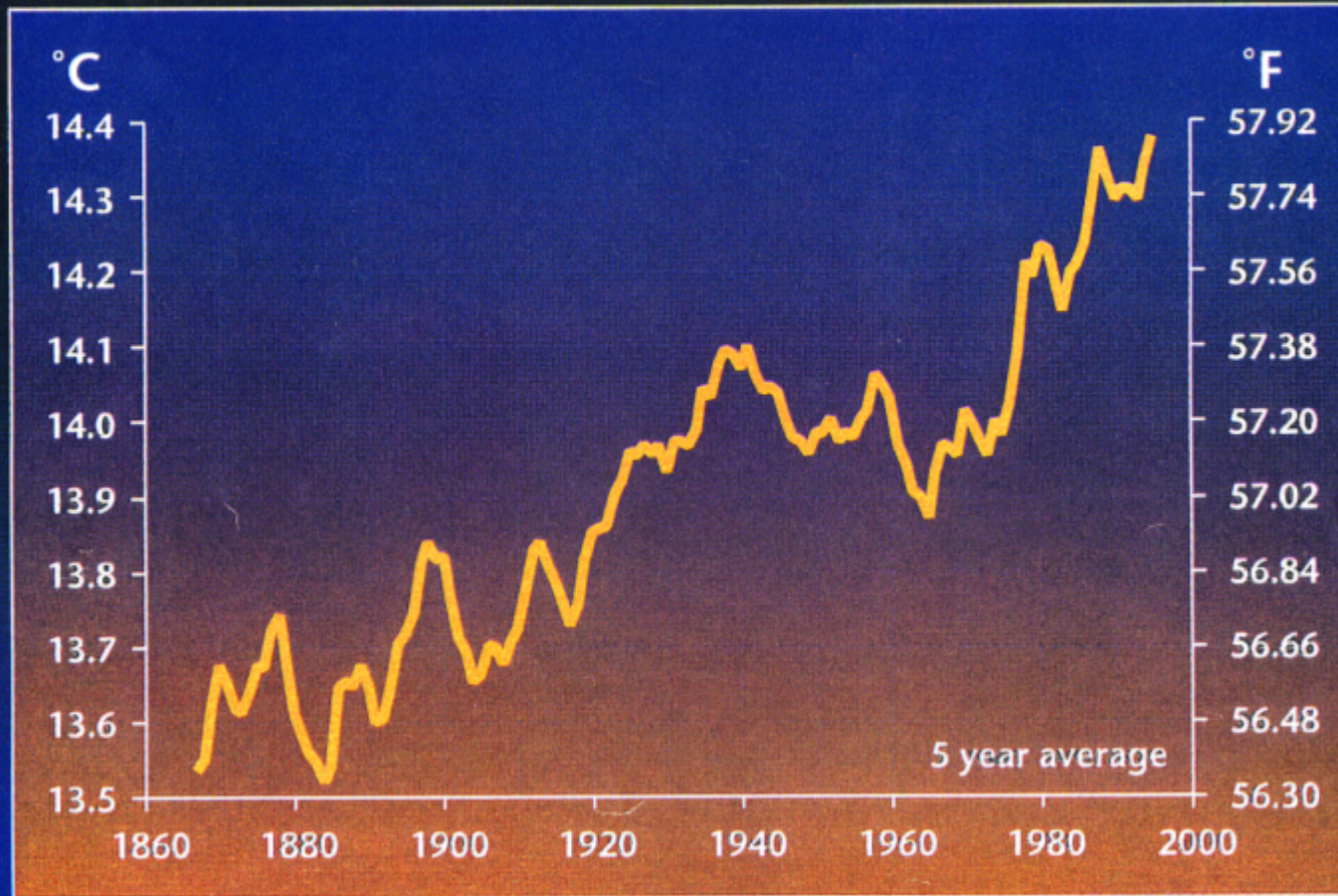
**V.M. CANUTO**

*NASA*

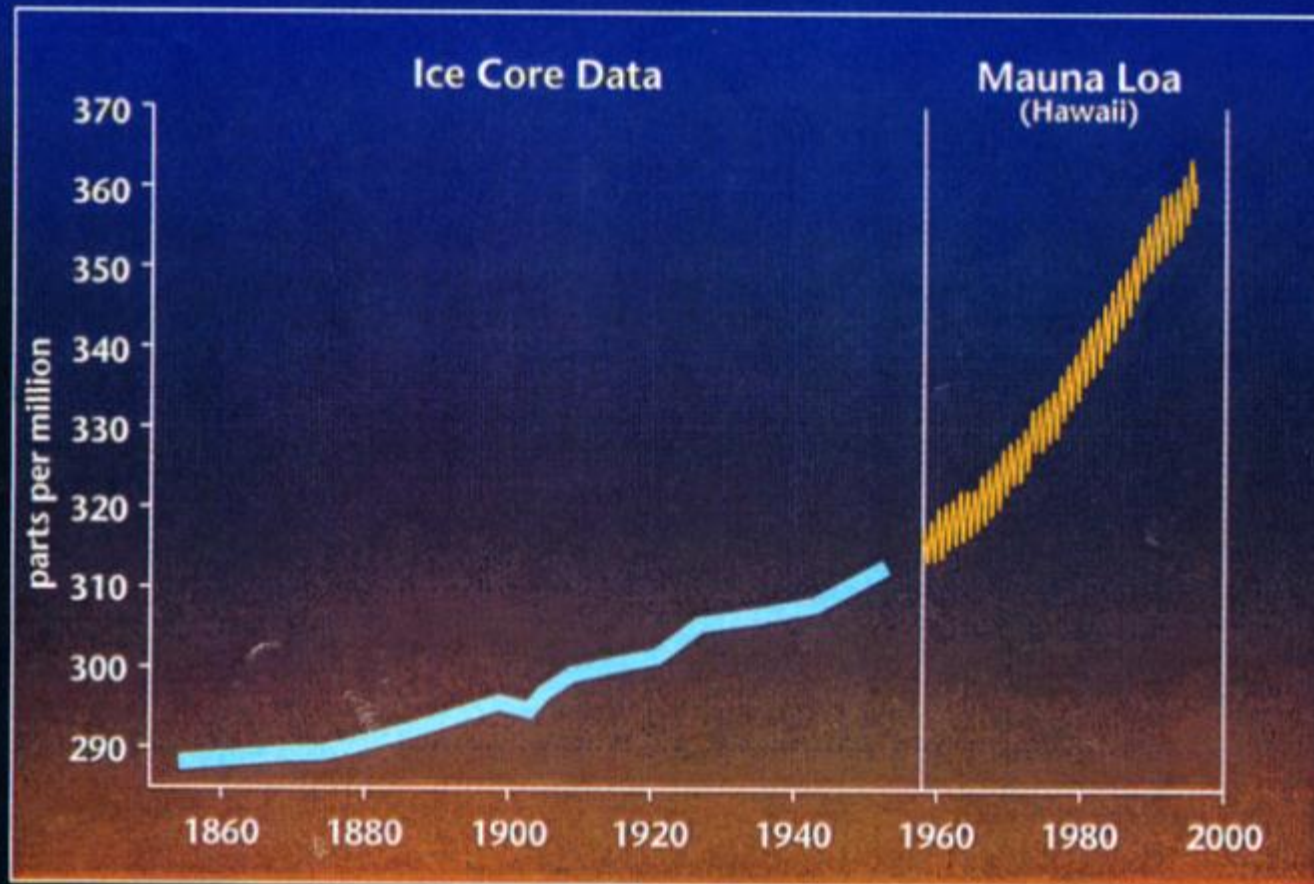
*GODDARD INSTITUTE FOR SPACE STUDIES  
NEW YORK*

*DEPT. APPLIED PHYS. AND APPLIED MATH.  
COLUMBIA UNIVERSITY  
NEW YORK*

# Global Average Temperature

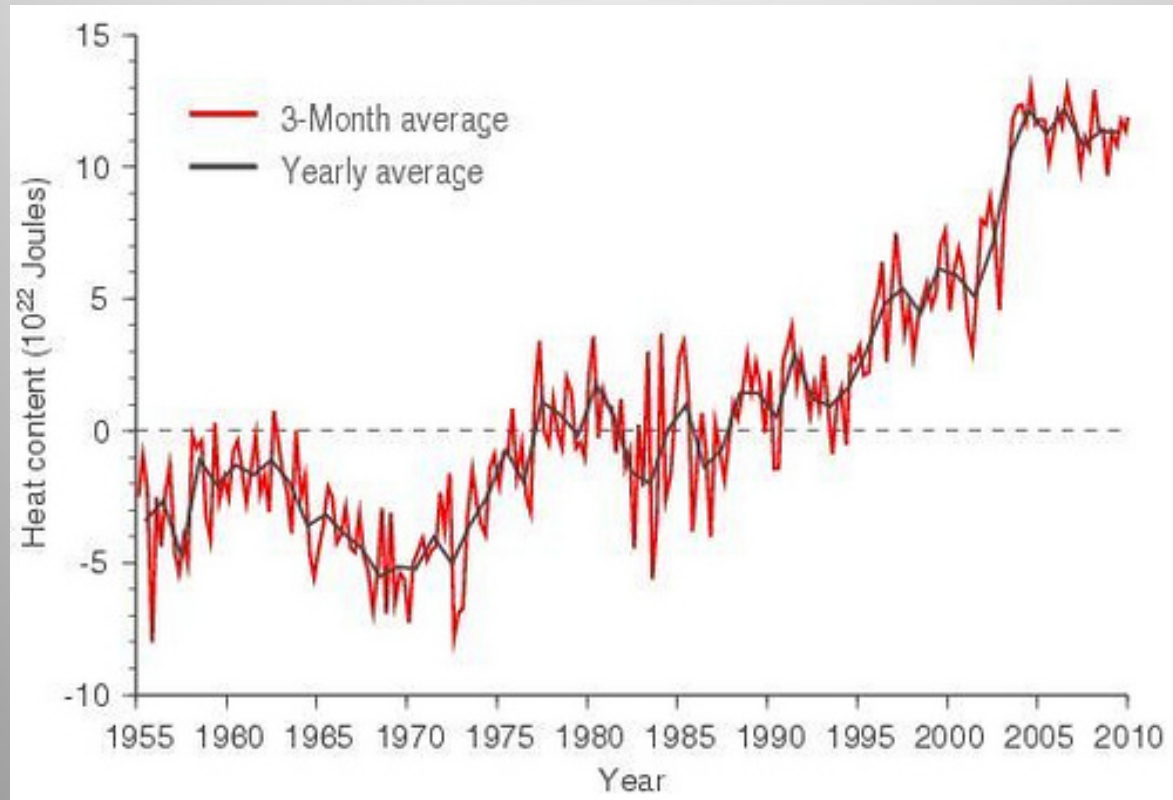


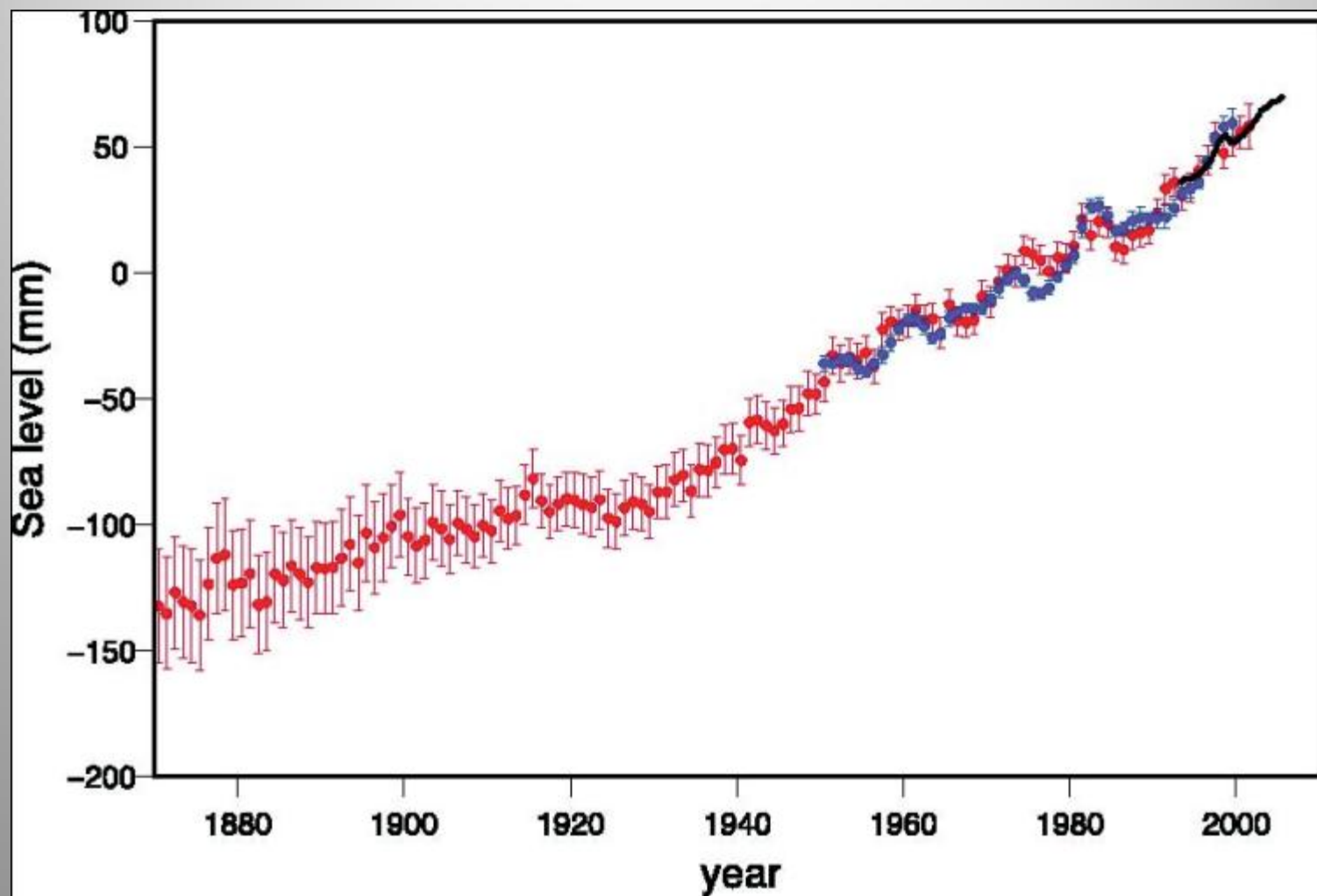
# Carbon Dioxide Concentrations



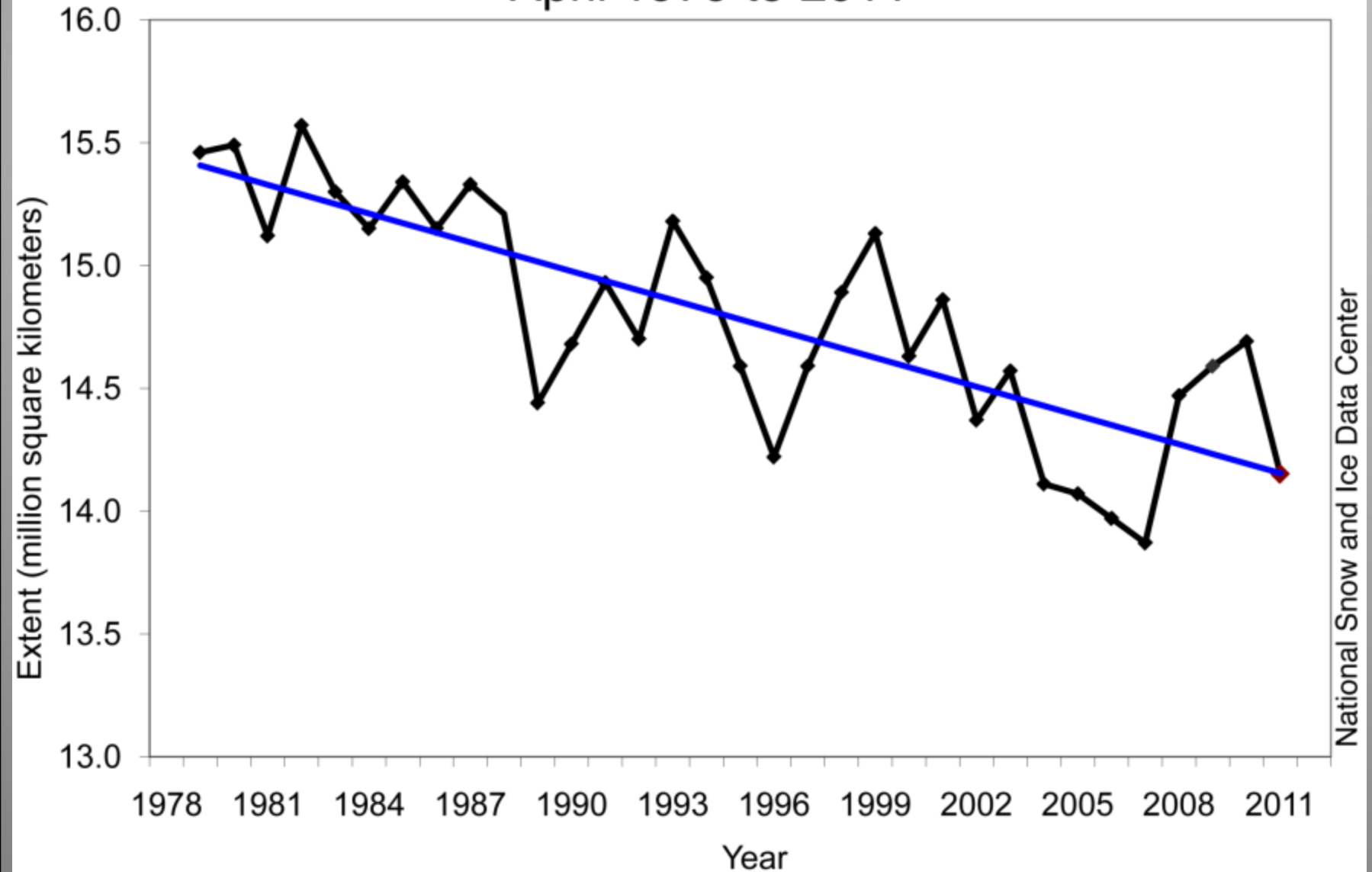


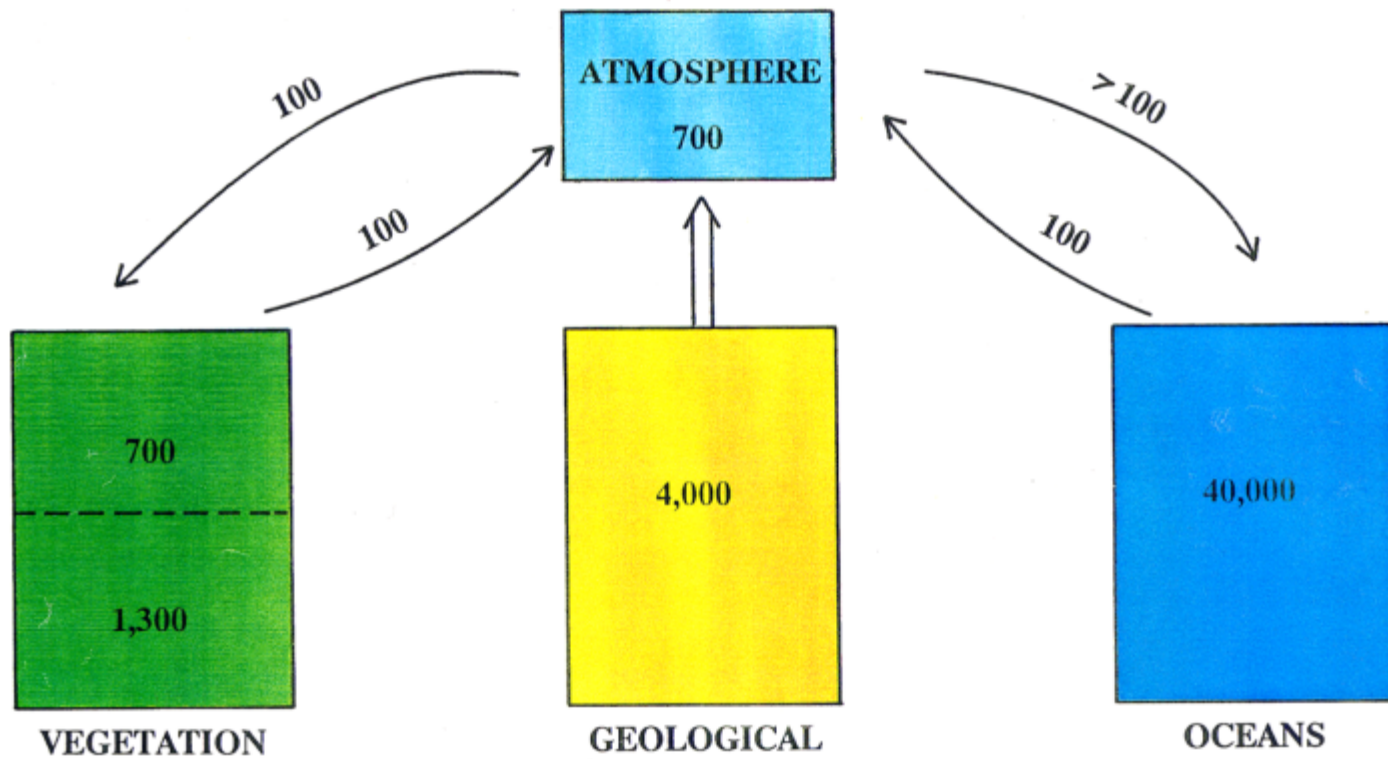
# OCEANS ARE WARMING UP

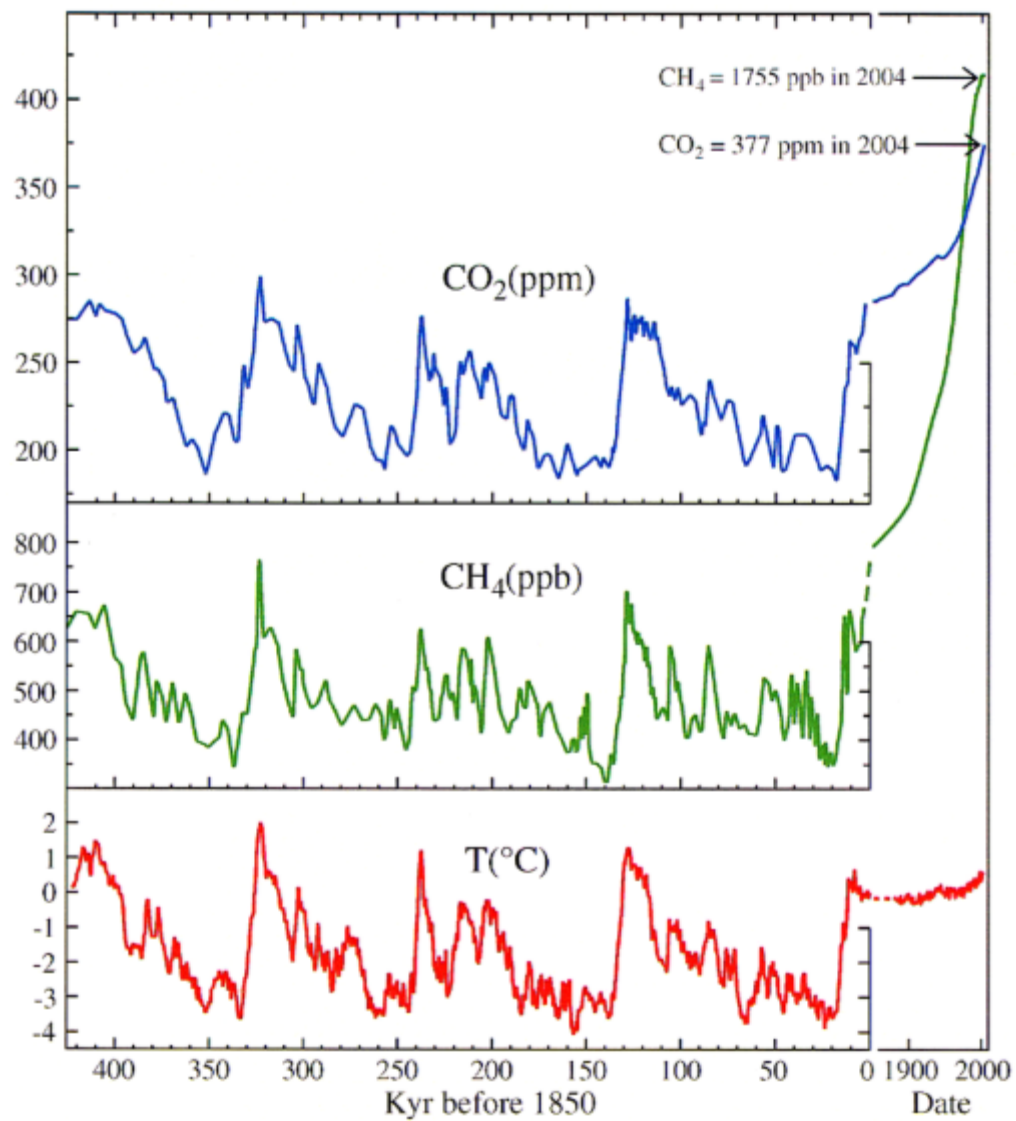




# Average monthly Arctic sea ice extent April 1979 to 2011







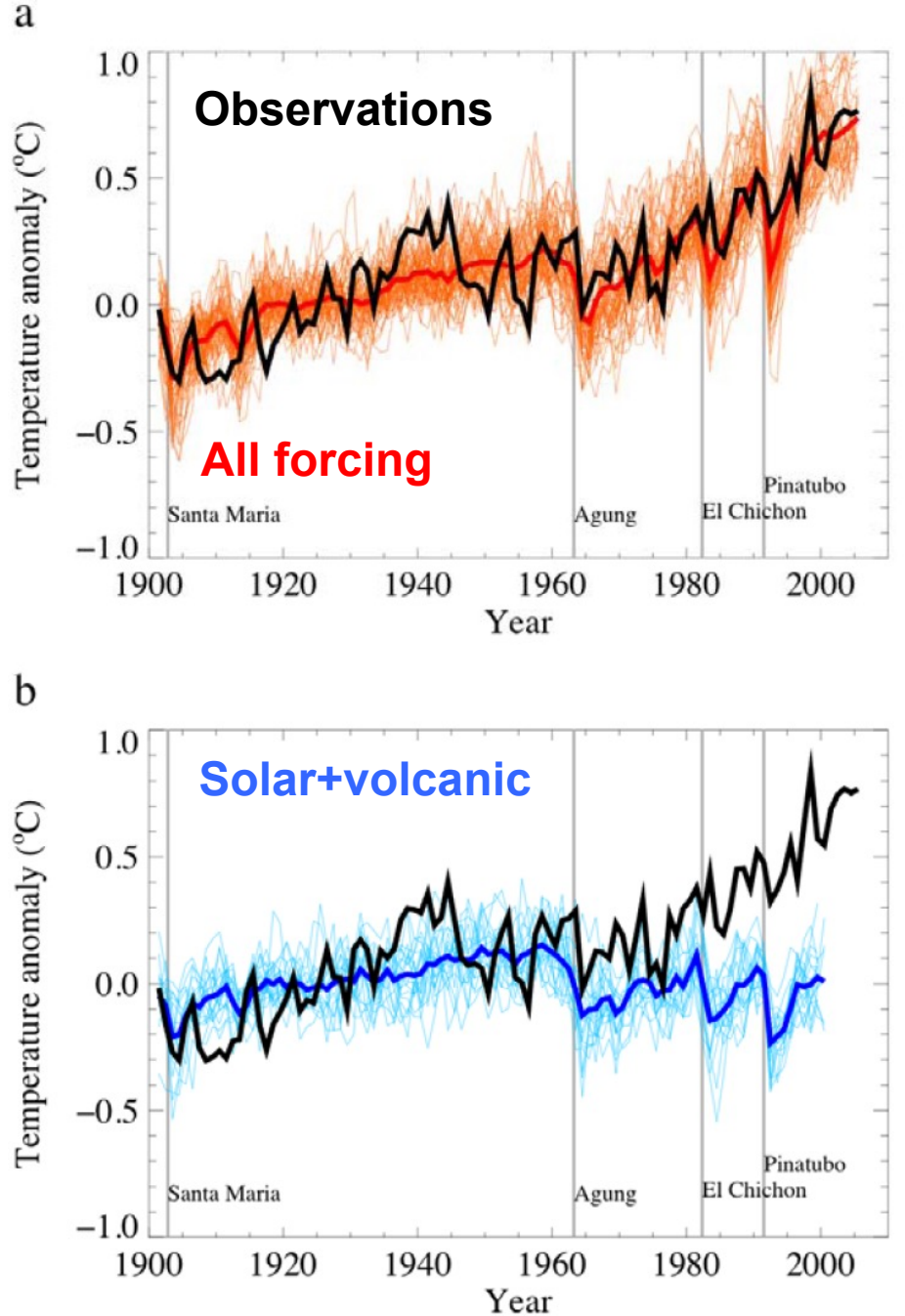


**S. Arrhenius:**

**We are evaporating our coal  
mines into the air**

# Attribution

- are observed changes consistent with
  - ☒ expected responses to forcings
  - ☐ inconsistent with alternative explanations



**CO<sub>2</sub>**

- **40% STAYS IN THE ATMOSPHERE**
- **60% OCEAN AND VEGETATION**




**SINCE THE BEGINNING OF THE  
INDUSTRIAL REVOLUTION**

**ANTHROPOCENE**

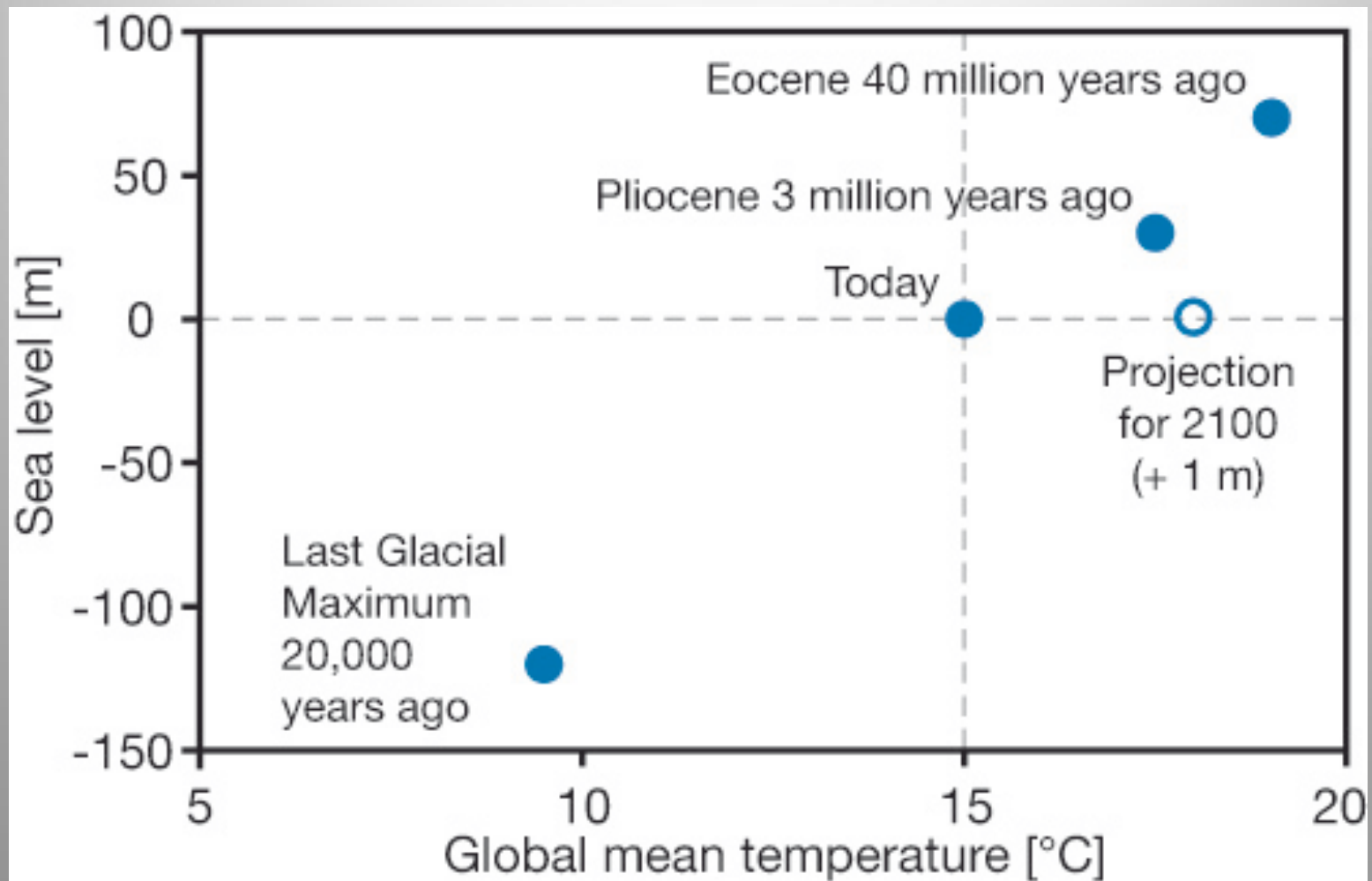
**REAL WORLD:      TODAY: 380 ppm**

**NO OCEANS:      TODAY:**  
**380+55 = 435 ppm**

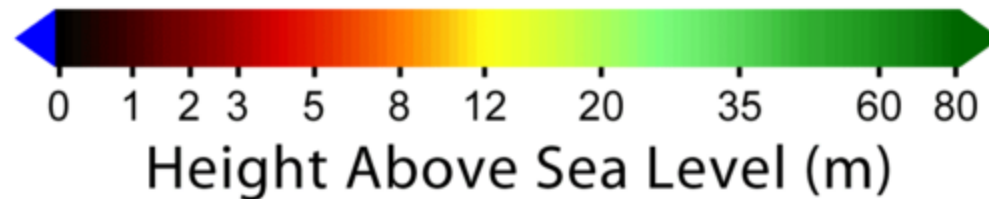
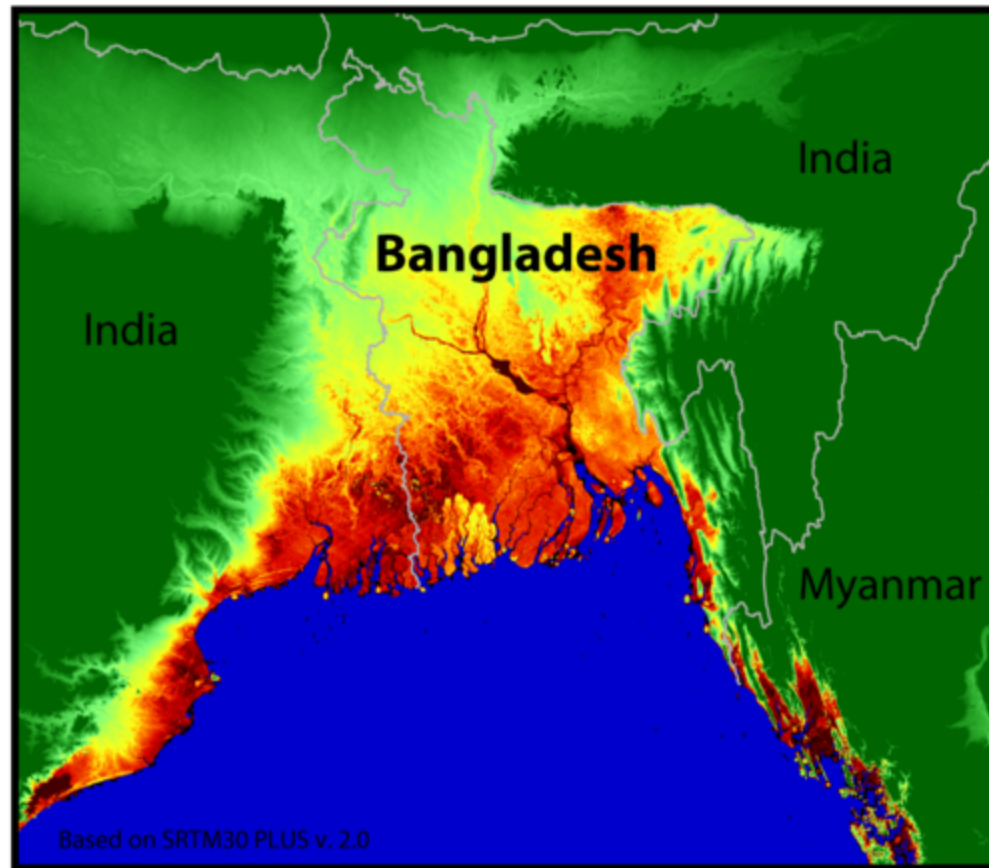
## **INCREASE CO<sub>2</sub>:**

- **MEAN TEMPERATURE** 
- **SEA LEVEL** 
- **OCEAN ACIDITY** 





# Sea Level Risks - Bangladesh



# OCEAN ACIDIFICATION

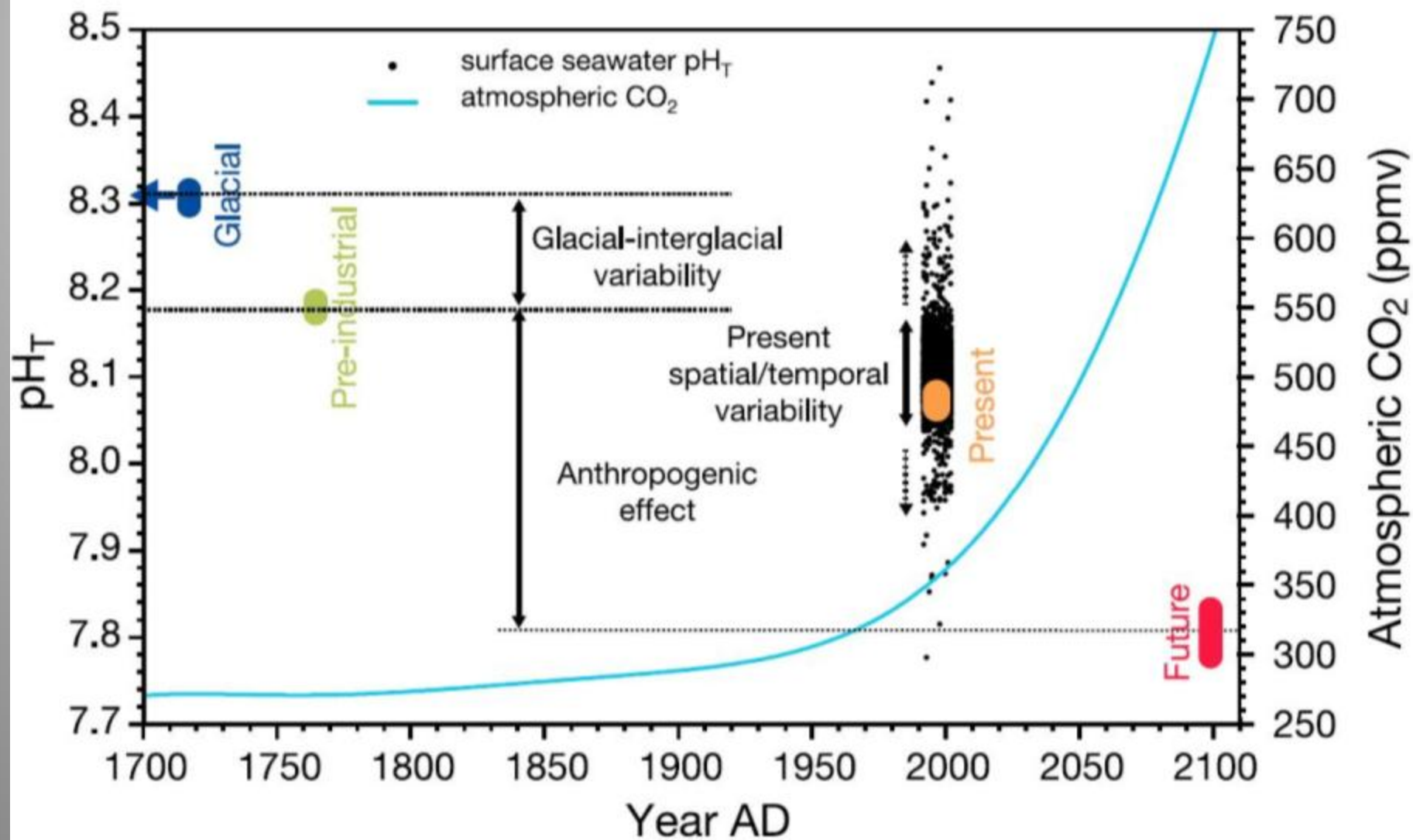


**OCEANIC pH**



**CALCIFICATION**



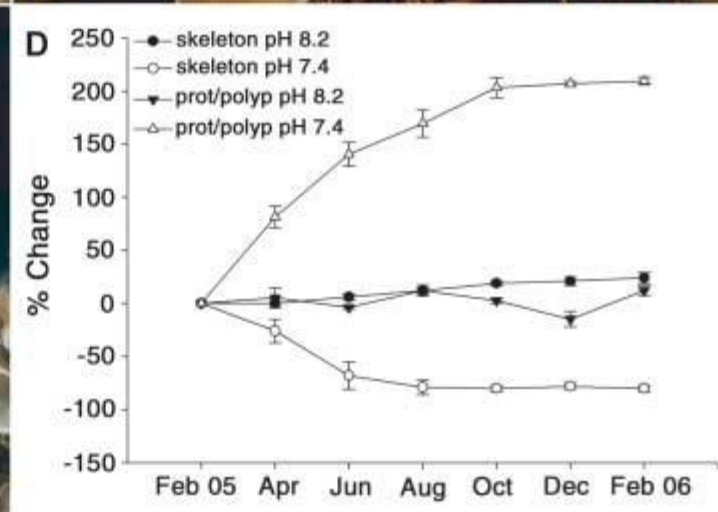
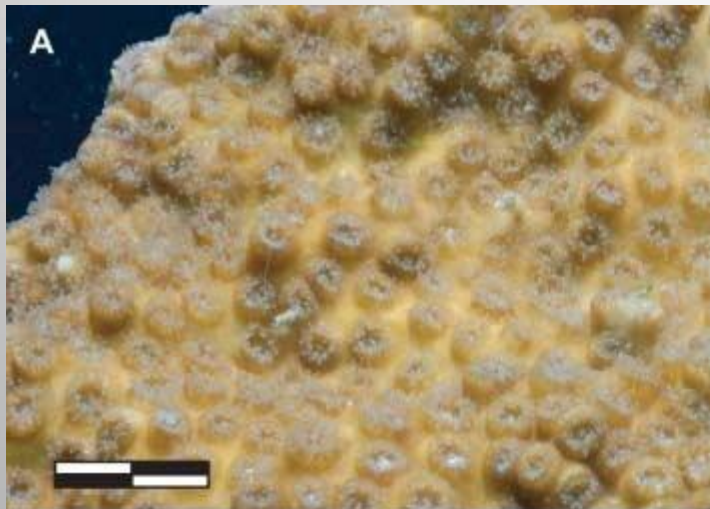


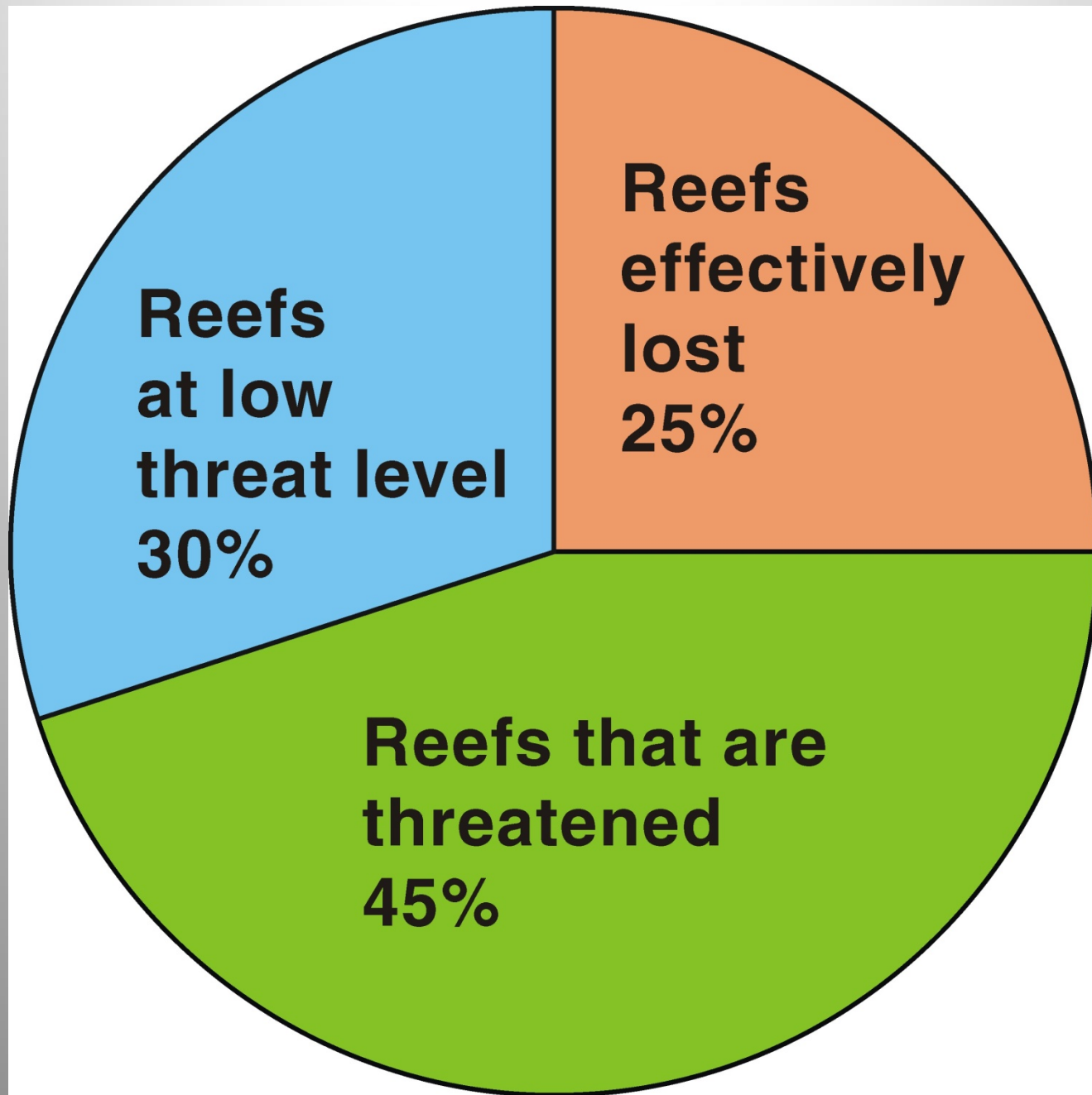
# Decalcification

- Acidification lowers the saturation level of  $\text{CaCO}_3$
- Aragonite
- **Coral Reefs** harbor 25% world fish population
- **Pteropods**, snails, food for Salmon, Cod, Mackerel









**MARKET FORCES BRING: TECHNOLOGY**



**TECHNOLOGY IS A PRODUCT OF: INVENTIONS**

**IT IS NOT SUFFICIENT TO HAVE INVENTIONS**



**WE NEED TO CONTINUE: INVENTING INVENTIONS**



**WHAT DO WE NEED TO DO THAT? KNOWLEDGE**

**WHY?**

**TECHNOLOGY GIVES INFORMATION**

**KNOWLEDGE GIVES WISDOM**

Greenhouse effect:

Irreversible in Time

Planetary in Scale

TransGenerational

TransNational

A Trend, not an Event



# **CIVILIZATION : AN INTERLUDE ?**

# **Future Oceans ...**

**Warming Up**

**Rising High**

**Turning Sour**

# **OCEANS - LIFE**

- **$4 \times 10^9$  yrs ago: life on earth began in the oceans**
- **$500 \times 10^6$  yrs ago: life emerged from the oceans**
- **0.004%: humankind on earth**
- **working against the oceans' buffering action  
as a CO<sub>2</sub> sink**
- **future: will the oceans suffocate us?**

- **GROWTH RATE: 10,000 PEOPLE/HOUR**
- **ONLY A MADMAN (OR AN ECONOMIST)  
BELIEVES THAT EXPONENTIAL GROWTH CAN  
GO ON FOREVER**
- **TENDENCY IS NOT DESTINY**
- **HUMANITY: NOT THE SUM OF ITS PEOPLE  
SUM OF ITS NECESSITIES (J.P. SARTRE)**

**THE CHIEF AIM OF SCIENCE  
IS NOT TO OPEN THE DOOR TO  
INFINITE WISDOM**

**IT IS TO PUT SOME LIMIT TO  
INFINITE ERROR**

**Bertolt Brecht**