

Outline

- What is happening? Global Climate Changes
- Why CO₂ is important to study?
- FACE project
- Current results from FACE project
- Future directions
- References

Main factor — greenhouse gases - carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) - CO₂ contributes 70-80% of greenhouse gases - Trap heat in the atmosphere

Why is it important to study CO₂? CO₂ trend Other greenhouse gases trend U.S. Enistators of CO2: Historical (1990) and Projected to 2010) http://www.gcro.org/Cni.oldoc/pd/CSclimate-13 pdf U.S. Enisators of CH4, N2O, and NFC, NFC, and SFE Historical (1990) and Projected (to 2010) http://www.gcro.org/Cni.oldoc/pd/CSclimate-13 pdf

Why is it important to study CO₂? Known as one of the main greenhouse gases Due to human activities & natural activities Steadily rising since industrial revolution Atmospheric CO₂ level 393.18 (Apr.2011) ⇒ 50% more by 2050 (IPCC, 2007) Comes with increasing O₃ Www.estf.noaa.gov National Oceanic and Atmospheric administration

Why is it important to study CO₂?

- Roles of CO₂
 - Positive roles on plants
 - Photosynthesis rate
 - Growth rate
 - Productivities
 - Negative roles on ecosystems
 - Increase of seawater acidity
 - Historical average pH 8.2 → pH 8.1 since industrial revolution → expecting pH 7.8-7.7 by the end of this century (NOAA climate services 2009)
 - Melting iceberg
 - Comes with O₃ toxic

Motivation of FACE project

- Limitation of previous studies
 - Greenhouse scale, short-term, potted plants.
 - Significant limitations in predicting the real responses of plants to the higher CO₂ level.





History of FACE project

- Initiation of Free Air CO₂ Enrichment (FACE) project
 - Designed to study the effects of higher CO₂ on ecosystems under natural environments.
 - Long-term, open-top chamber experiment.
- H. Z. Enoch talked about the need for the multinational scientific community to study the elevated atmospheric CO₂ in 1982 (Lemon 1983).
- L. Hartwell Allen coined the acronym (FACE), attempted to simulate the effects of CO₂ releases on plant responses (Allen 1992).
- The Brookhaven National Laboratory designed a FACE release system in 1993 (Hendrey 1993).

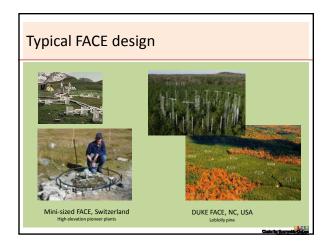
FACE sites over the world ASPENIACE DESCRIPTACE DESCRIPTACE DESCRIPTACE Australia FACE Australia FACE Australia FACE New Zealand FACE O Small sized ring diameter FACE sites (< 10m)

Typical FACE design

- Typical FACE plot
 - Circular, surrounded by a ring of pipes
 - The pipes release $\mathrm{CO_2}$ (or $\mathrm{O_3},\,\mathrm{CO_2} + \mathrm{O_3})$ at vertical intervals
 - Treatment during growing season for trees
 - Computer-controlled system adjust the CO₂ flow rate
 - The system uses wind direction information to turn on only the pipes upwind of the plots
 - → CO₂—enriched air always flows across the plots







Consistent effects of elevated CO₂ on plants 40% increases in leaf photosynthetic rates (Ainsworth & Rogers. 2007) 22% decreases in stomatal conductance of water (Ainsworth & Rogers. 2007) 5-20% decreases in whole plant water usage, possible changes in hydrological cycle of entire ecosystems (Leakey et al. 2009)

Results from current FACE studies • Variety of changes due to higher CO₂ — Physiological changes (faster growth rate) • 17% increase in aboveground dry matter production • 30% increase in belowground dry matter production > Higher crop yields - 12-14% increases with wheat, rice, and soybean in FACE experiments (Ainsworth. 2008; Long et al. 2006)

Pesults from current FACE studies • Variety of changes due to higher CO₂ — Changes in chemical composition of plant tissue • 30-40% increases of nonstructural carbohydrates (Ainsworth. 2008; Ainsworth & Long. 2005) • 13% decrease in nitrogen per unit leaf mass (Ainsworth & Long. 2005) • decrease in protein concentration of plant tissue — Similar trend with nitrogen (decreases under higher CO₂) ✓ Insect herbivores feeding performance was diminished (Zverava & Kozlov. 2006) → worse food quality? ✓ 5-14% decreased protein concentration in wheat, rice, barley, and potato (Taub et al. 2008) ✓ Decreases in concentration of minerals (Ca, Mg, P) (Loladze. 2002; Taub

& Wang. 2008)

Percentage Results from current FACE studies Introduction Variety of changes due to higher CO₂ — More carbon, but same amount of soil mineral Less enhancement of photosynthesis under low N soil condition (Ainsworth 2008) Net primary productivity declined over time (Norby 2010) Biological State of Co. Ambient CO. Ambient

Results from current FACE studies
 Other effect of higher CO₂
- Atmospheric ozone (O ₃)
• Increases with CO ₂
Gaseous toxin
 Cause damage to leaves, decreases plant growth, photosynthesis (Feng et al. 2008) – negative effect of CO₂
Decreased stomata openness under higher CO ₂
→ decrease exposure of sensitive tissues to O ₃ (positive effect of CO ₂)
 Complex interactions between CO₂ and O₃

Future directions

Introduction

• Primary concern

prediction of the future behavior of ecosystems under higher CO₂ environment

- Agricultural systems predict productivity or quality of the marketable product
- Unmanaged systems effects of CO₂ on diversity (spread of invasive grass, fire cycle, reduce biodiversity, alter ecosystem function)
- ➤ Forest system testing specific hypotheses about forest response
- Additional study direction- Carbon sequestration: possibilities of feedbacks to the climate system

Future directions

Introduction

- "Future ecosystem will be impacted not just by rising CO₂ concentration, but by a suite of atmospheric and climatic changes" (Norby 2001)
- Data resulting from all CO₂ studies should be used to draw correlations among plants, animals, soil responses, and also used to build models to predict future behavior of changing environments.

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