Impacts of atmospheric climate changes on ecosystems:

(Free Air Carbon dioxide Enrichment)

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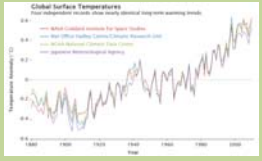
Outline

- What is happening? – Global Climate Changes
- Why CO_2 is important to study?
- FACE project
- Current results from FACE project
- Future directions
- References

What's happening?

- Greenhouse gas emission
- Rising temperature → **Global Climate Changes**
- Changes of precipitation patterns

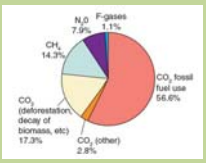
http://www.gcrio.org/OnLnDoc/pdf/CRSclimate-13.pdf



http://climate.nasa.gov/news/index.cfm?FuseAction=ShowNews&NewsID=468

Main factor – greenhouse gases

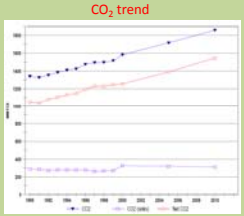
- carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6)
- CO_2 contributes 70-80% of greenhouse gases
- Trap heat in the atmosphere



IPCC 4th Assessment Report:Climate Change 2007: Synthesis Report

Why is it important to study CO_2 ?

CO_2 trend



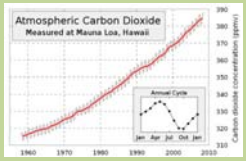
U.S. Emissions of CO2: Historical (1990s) and Projected (to 2010)
http://www.gcrio.org/OnLnDoc/pdf/CRSclimate-13.pdf

Other greenhouse gases trend

U.S. Emissions of CH4, N2O, and HFCs, PFCs, and SF6: Historical (1990s) and Projected (to 2010)
http://www.gcrio.org/OnLnDoc/pdf/CRSclimate-13.pdf

Why is it important to study CO_2 ?

- Known as one of the main greenhouse gases
- Due to human activities & natural activities
- Steadily rising since industrial revolution
  - Atmospheric CO_2 level 393.18 (Apr.2011)
    ⟹ 50% more by 2050 (IPCC, 2007)
- Comes with increasing O_3



www.esrl.noaa.gov
National Oceanic and Atmospheric administration

Why is it important to study CO_2 ?

- Roles of CO_2
  - 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 O_3 – toxic

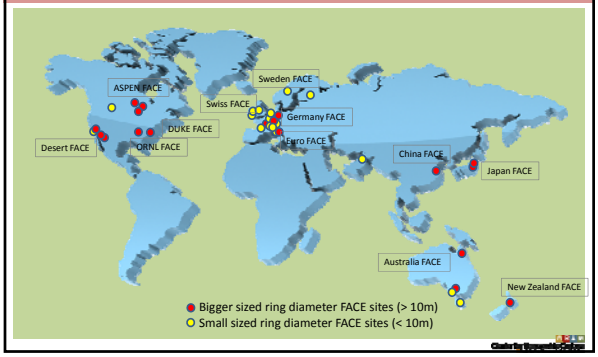
Motivation of FACE project

- Limitation of previous studies
  - Greenhouse scale, short-term, potted plants.
  - Significant limitations in predicting the real responses of plants to the higher CO_2 level.

History of FACE project

- Initiation of Free Air CO_2 Enrichment (FACE) project
  - Designed **to study the effects of higher CO_2 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 CO_2 in 1982 (Lemon 1983).
- L. Hartwell Allen coined the acronym (FACE), attempted to simulate the effects of CO_2 releases on plant responses (Allen 1992).
- The Brookhaven National Laboratory designed a FACE release system in 1993 (Hendrey 1993).

FACE sites over the world



FACE Sites characteristics

Number of Countries	16
Number of FACE sites	36
Biomass types	Grass, wheat, rice, bog, soybean, desert scrub, chaparral, softwood, hardwood
Sizes	1m—30m ring diameters
Site conditions	CO_2: 370ppm—600ppm
Additional conditions	O_3: ambient X 1.5 (Rhinelander, USA) 2 nitrogen rings (Braunschweig, Germany) CO_2 550ppm + 2˚C warming (Pontville, Austrailia)

http://public.ornl.gov/face/global_face.shtml

Typical FACE design

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

Typical FACE design

Aspen FACE site: Rhinelander, WI USA

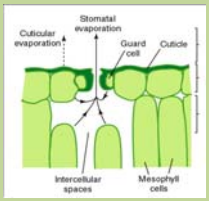
Typical FACE design

Mini-sized FACE, Switzerland
High elevation pioneer plants

DUKE FACE, NC, USA
Loblolly pine

Results from current FACE studies

- Consistent effects of elevated CO_2 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

Introduction

- Variety of changes due to higher CO_2
  - **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)**

Results from current FACE studies

Introduction

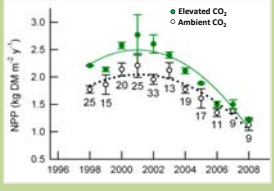
- Variety of changes due to higher CO_2
  - **Changes in chemical composition of plant tissue**
    - 30-40% increases of nonstructural carbohydrates (Ainsworth. 2008; Ainsworth & Long. 2005)
    - 13% decrease in nitrogen per unit leaf mass (Ainsworth & Long. 2005)
    - decrease in protein concentration of plant tissue
      - Similar trend with nitrogen (decreases under higher CO_2)

    - ✓ 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)

Results from current FACE studies

Introduction

- Variety of changes due to higher CO_2
  - **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)



(Data from Norby et al. 2010)

Results from current FACE studies

Introduction

- Other effect of higher CO_2
  - **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 CO_2
    - Decreased stomata openness under higher CO_2
      → decrease exposure of sensitive tissues to O_3 (positive effect of CO_2)
  - **Complex interactions between CO_2 and O_3**


Future directions

Introduction

- **Primary concern**
  prediction of the future behavior of ecosystems under higher CO_2 environment
  - **Agricultural systems** – predict productivity or quality of the marketable product
  - **Unmanaged systems** – effects of CO_2 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 CO_2 concentration, but by a suite of atmospheric and climatic changes" (Norby 2001)
- **Data resulting from all CO_2 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.**

References

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