Stable Carbon Isotopes: A Tool for Understanding Carbon Uptake of a Semi-Arid Forest & a Tropical Rainforest

Gretchen Miles
Mentor: Nate McDowell

AU

Overview

- In our world today…
- Global Carbon Cycle
- Photosynthesis & Stable Carbon Isotopes
- Applications of Tree Rings and $\delta^{13}C$: Understanding Photosynthesis
- Contrast Tropical Rainforest with Arid Southwest


Burn
GLOBAL WARMING
USA

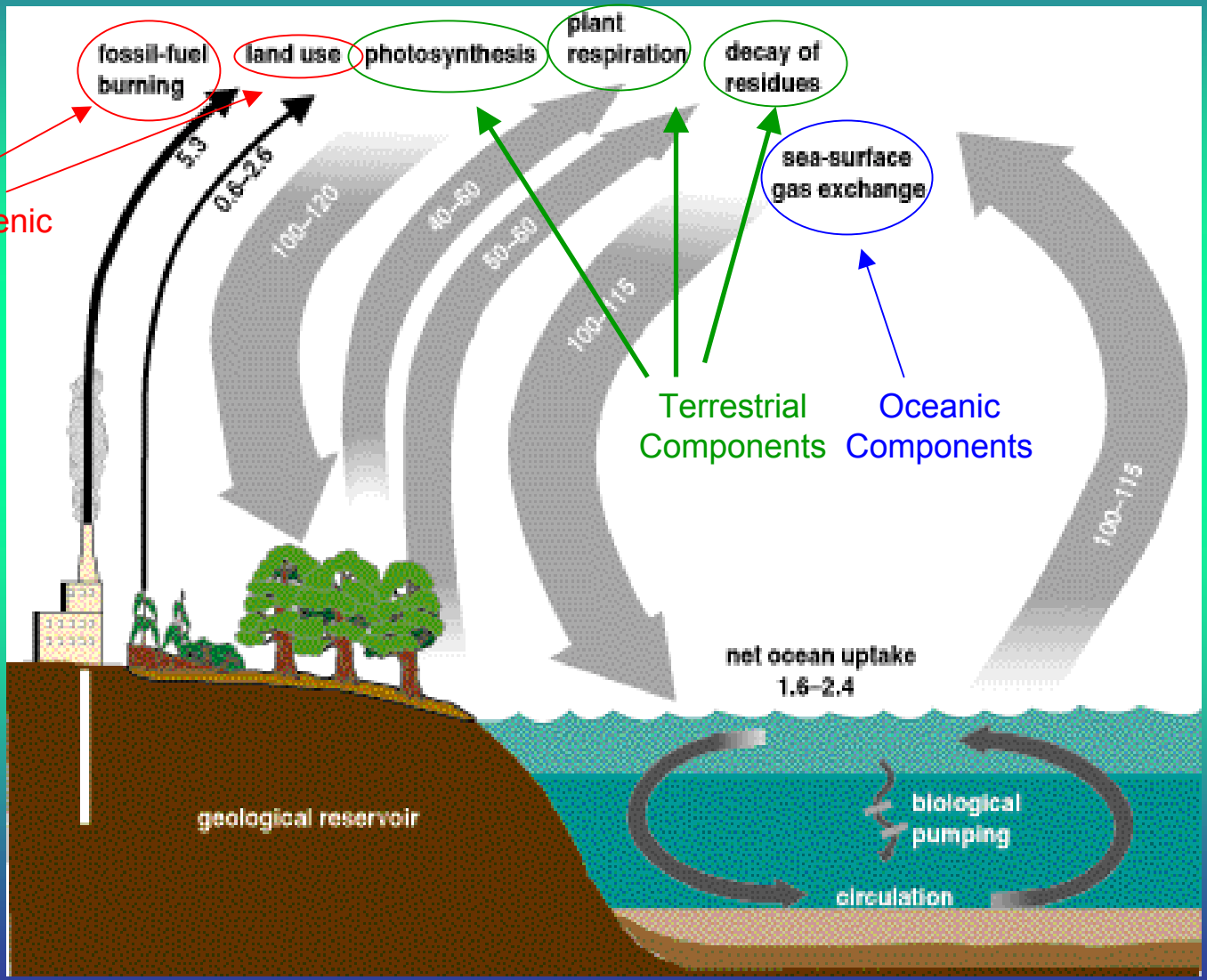
Problem: Elevated Levels of Atmospheric CO_2

- Causes:
  - Increased anthropogenic CO_2 emissions worldwide
  - Land Use Changes & Deforestation
    - Major issue in tropical and third world countries
- Effects:
  - Imbalance in Carbon Cycle
  - Global Climate Change
  - Influence Ecosystem Processes

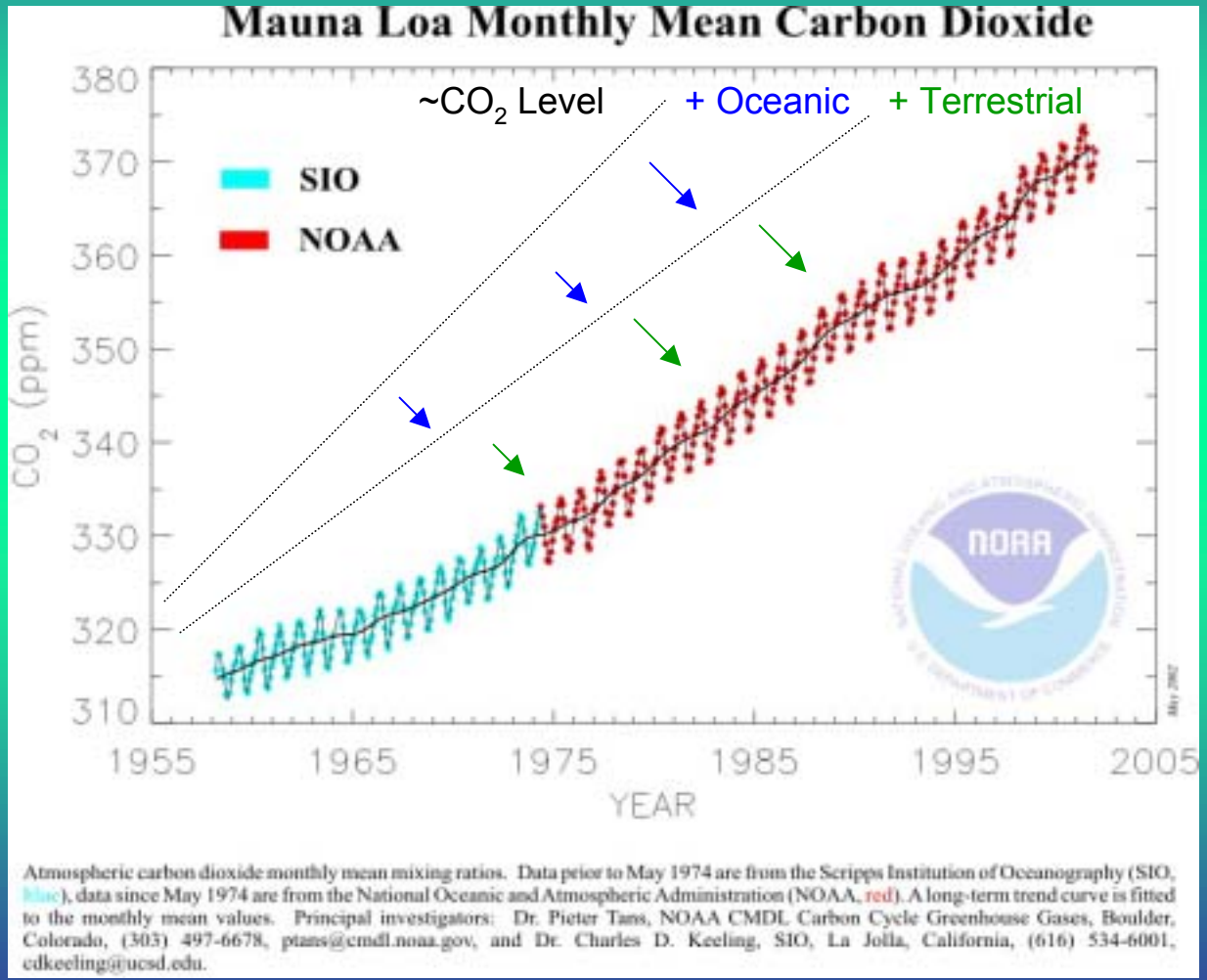
Eucalyptus saligna plantations in our world today

- Increasing in frequency in Africa, Australia, China, Latin & South America (Brazil)
- Economic Incentive:
  - Sell pulp on world market
  - Use and sell as poles, and fuel
- Ecologic Incentive:
  - short-term carbon storage in plant material
  - Replacing previously deforested lands
  - Reduces pressure on slower-growing forests

Global Carbon Cycle:Imbalance



Seasonal Pattern and Overall Trend in Atmospheric CO_2 Concentrations: Oceanic & Terrestrial Components



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (SIO, blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (NOAA, red). A long-term trend curve is fitted to the monthly mean values. Principal investigators: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678, ptans@cmdl.noaa.gov, and Dr. Charles D. Keeling, SIO, La Jolla, California, (616) 534-6001, cdkeeling@ucsd.edu.

Photosynthesis & CO_2

$$6CO_2 + 6H_2O \leftrightarrow 6O_2 + C_6H_{12}O_6$$

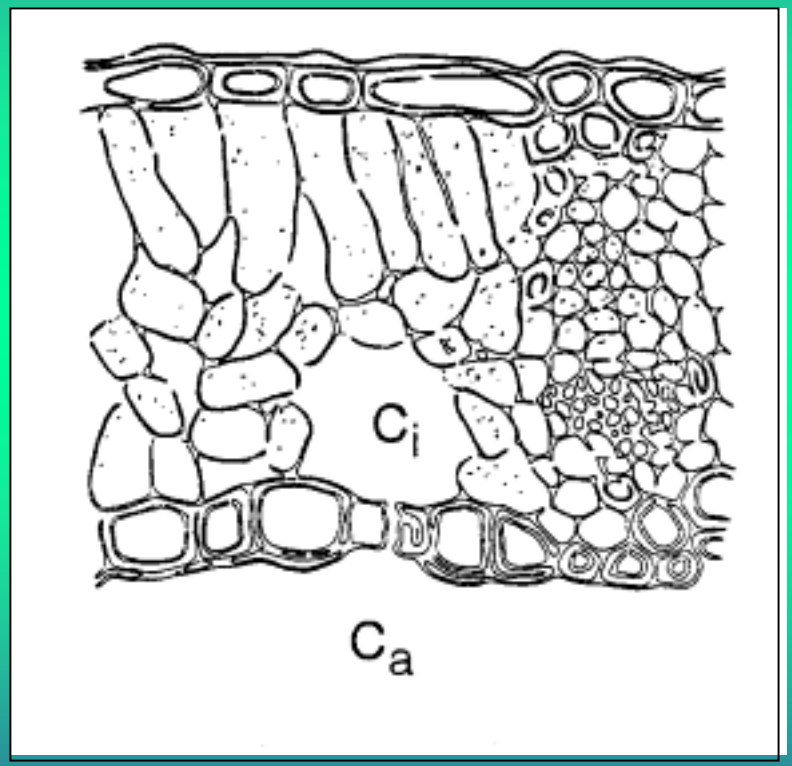
Basic Factors Affecting Photosynthetic Rate

- Water
- Light
- Nutrients (Rubisco: Enzyme)

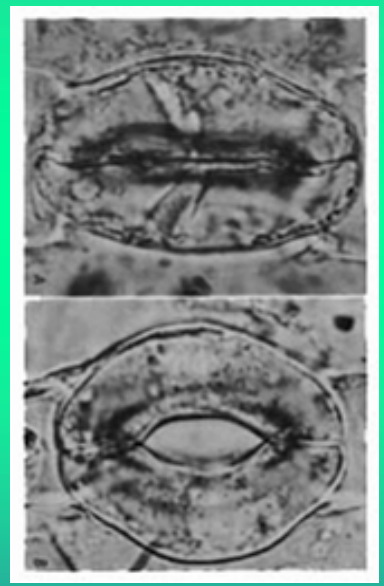
Stomata: Carbon-Water interface

Closed Stomate:
No CO_2 intake
No Water Loss
(Less Water)

Open Stomate:
CO_2 intake
Water Loss
(More Water)



Less Water:
Closed



More Water:
Open

$$\text{Photosynthesis} = \text{conductance}*(C_a - C_i)$$

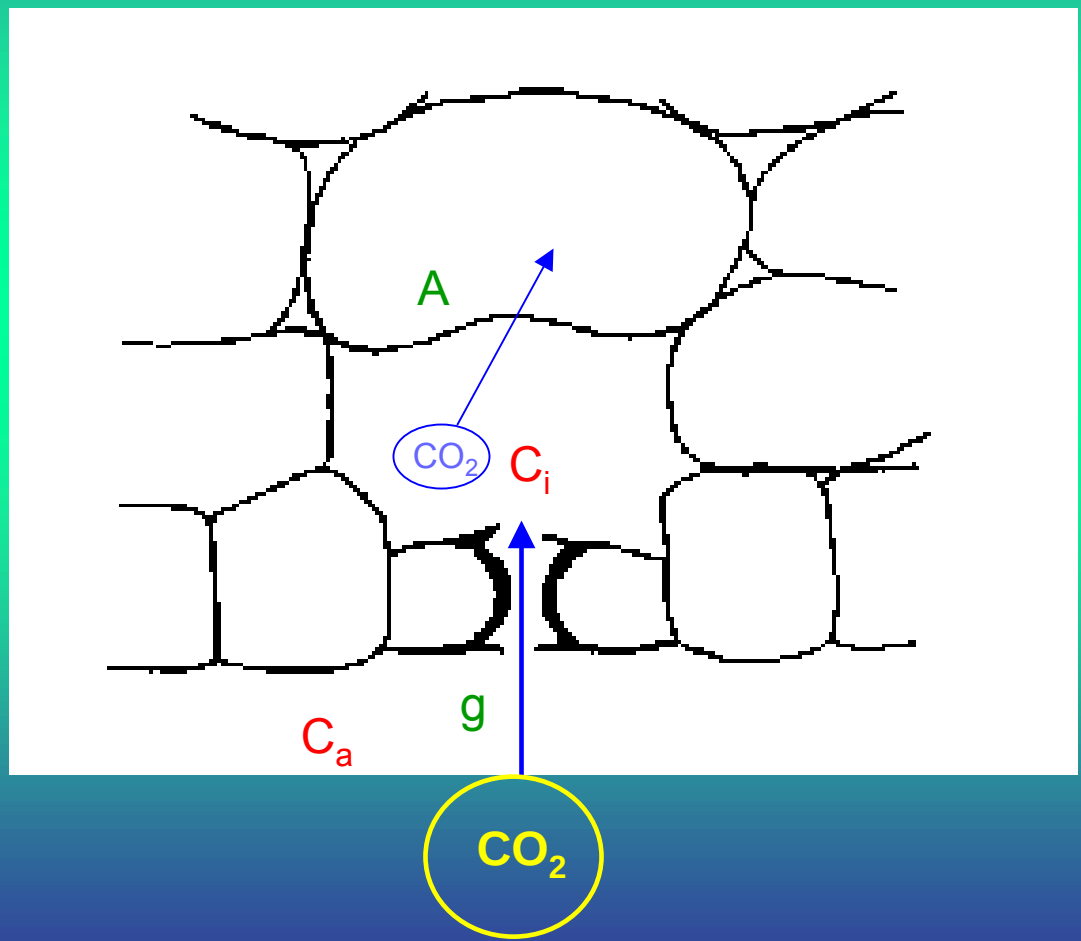
CO_2 Fixation Path: Decrease in Concentration

g = Stomatal Conductance

A = Assimilation or Net Photosynthesis

C_i: Leaf Internal Concentration CO_2

C_a: Atmospheric CO_2 Concentration



g : Dependent on Availability of Water & CO_2

A : Dependent on Availability of Light & Rubisco (N)

C_i = ~200 ppm

C_a = ~370 ppm

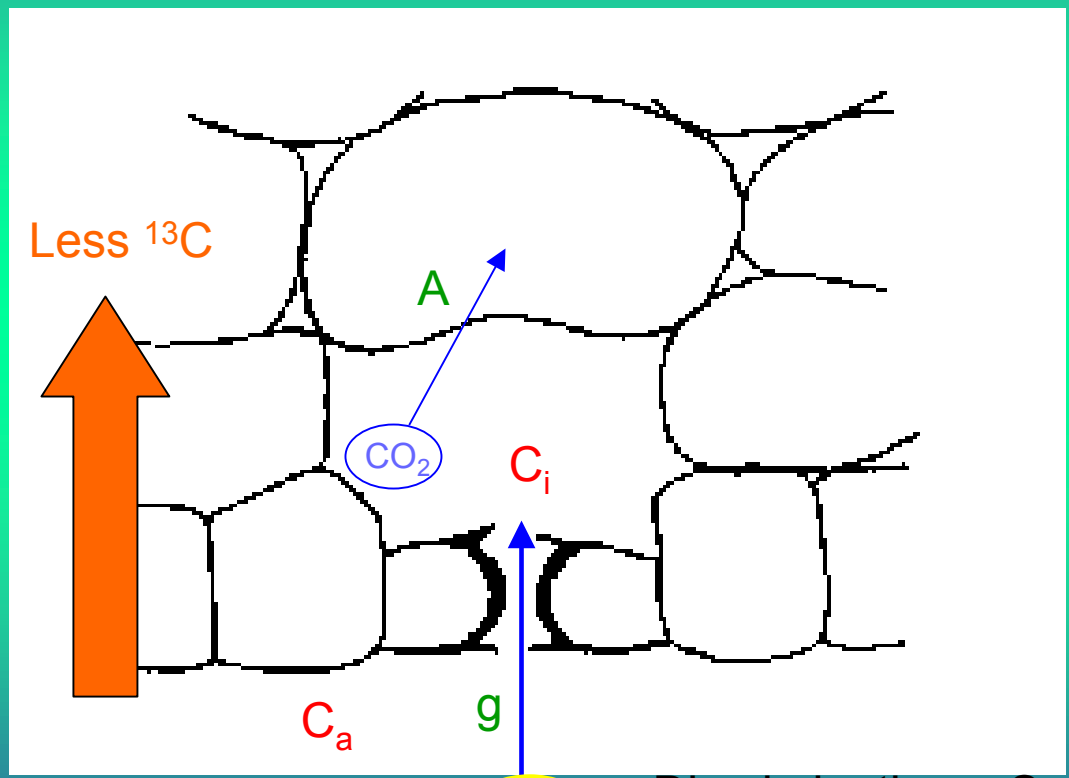
CO_2 Fixation & Discrimination

g = Stomatal Conductance

A = Assimilation or Net Photosynthesis

C_i: Leaf Internal CO_2 Concentration

C_a: Atmospheric CO_2 Concentration



$\Delta = a + (b - a) \cdot C_i/C_a$

a = conductance fractionation (diffusivity) 4.4‰

b = Assimilation fractionation (Rubisco) 27 – 29‰

Fractionation = Preferential assimilation of the lighter isotope of carbon

Discrimination = Sum of Conductance and Assimilation Fractionations

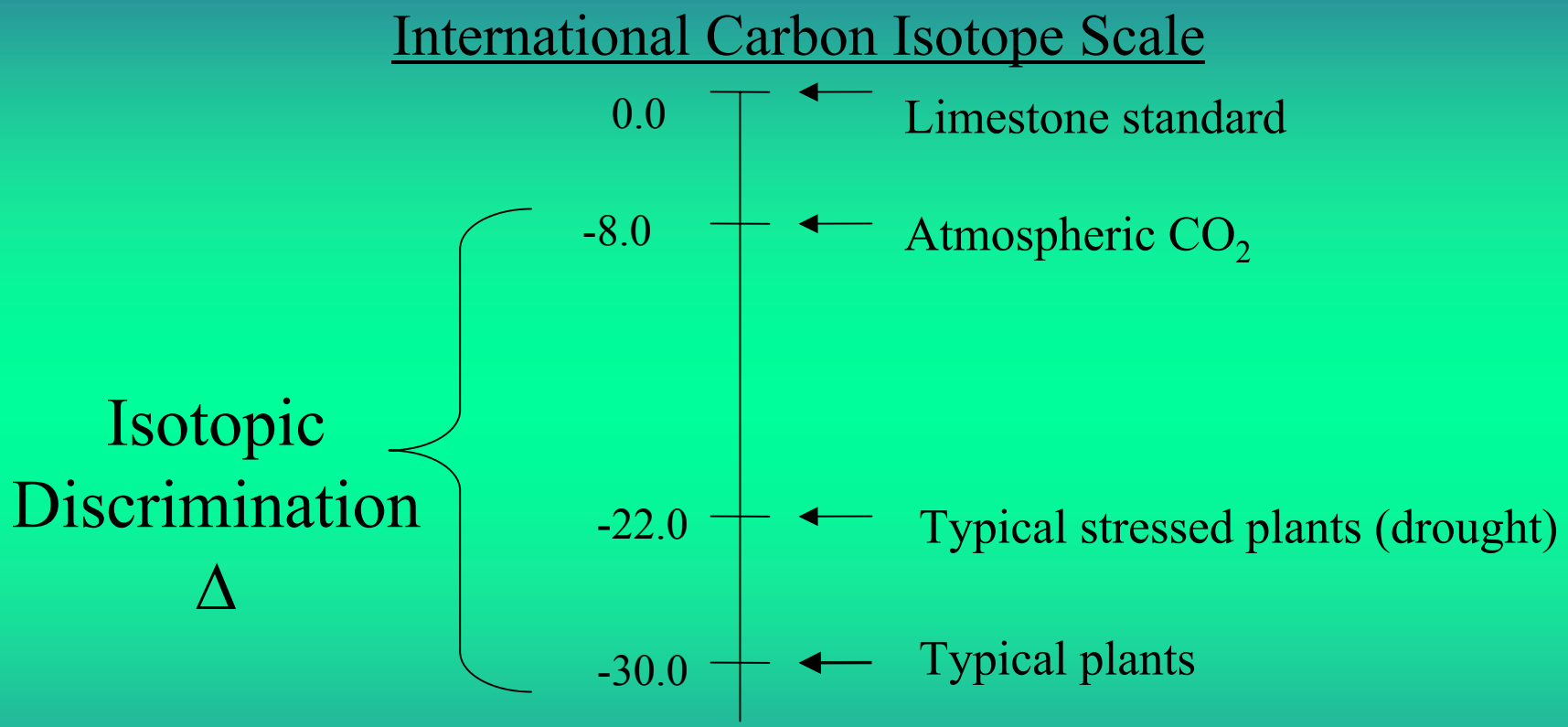
From Photosynthesis to Isotope Ratios ($\delta^{13}C$)

- ^{12}C ~ 99 % of atmospheric CO_2
- ^{13}C ~ 1 % of atmospheric CO_2
- Closed Stomata = Lower C_i = Less Discrimination = More Positive $\delta^{13}C$

  $\delta^{13}C \sim -22‰$
- Open Stomata = Higher C_i = More Discrimination = More Negative $\delta^{13}C$

  $\delta^{13}C \sim -30‰$

$\delta^{13}C$: Stable Carbon Isotope Ratios



Discrimination: 2 Equations

$$\Delta \approx a + (b - a) \cdot C_i/C_a$$

$$\Delta \approx \delta^{13}C_p - \delta^{13}C_a$$

Applications of Tree Rings & $\delta^{13}C$

- Analyze $\delta^{13}C$ values: study photosynthesis
- Investigate Effects of:
  - Water Availability
  - Light Availability
  - Nutrient Availability
- Understand Growth → Best Conditions

Why Study?

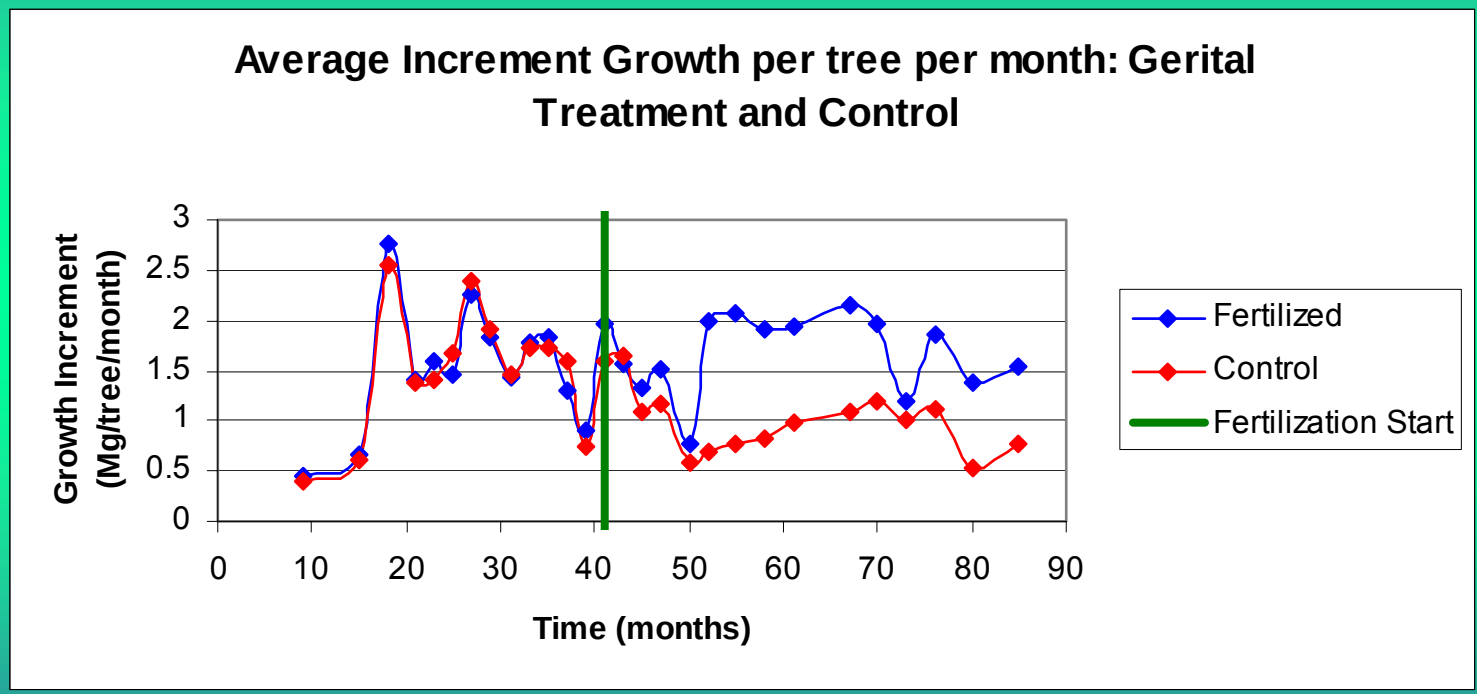
- Improve Understanding of Carbon Cycle
  - Understand constraints on growth and photosynthetic rates
- Tropical Rainforest *Eucalyptus Plantation*
  - Hypothesis: $\delta^{13}C$ is correlated with photosynthesis because **<u>water is not limiting</u>**
  - Key Factors Examined:
    - Light Nutrients Age Density

Fast growing *Eucalyptus saligna* plantation: Hawaii

9 year old stand

All Plantations

Available Data: Growth Response to Nutrient Availability



Sorry, No $\delta^{13}C$ Data!

Due to LANL Work Suspension.

Ponderosa Pine Restoration Study: Southwest

In contrast with tropical rainforest…

Hypothesis: $\delta^{13}C$ is correlated with conductance because **<u>water is limiting</u>**

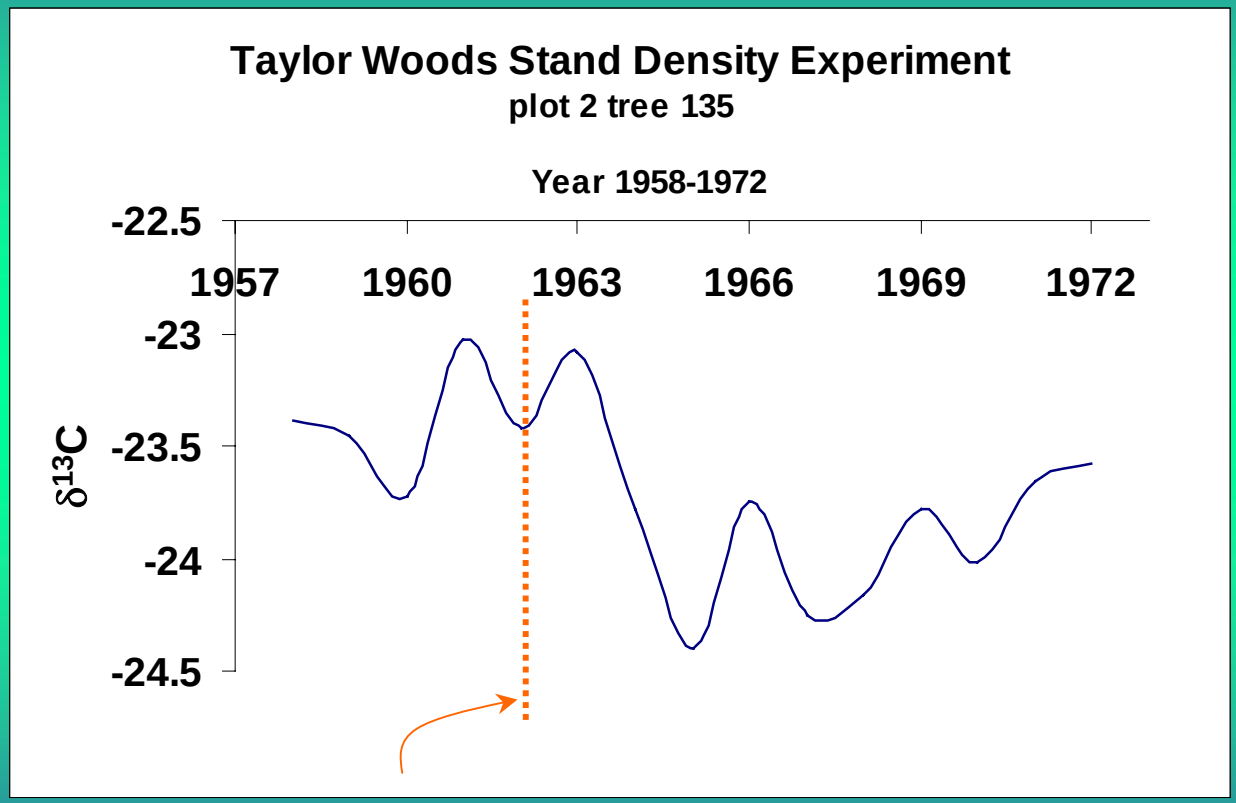
Restoration Treatment: thinning

More Discrimination after treatment

(More negative $\delta^{13}C$)

Views from Field Site

$\delta^{13}C$ Data of Restoration Study: Typical Response



Thinned 1962

Water availability

Less

More

Southwest Conclusion

- $\delta^{13}C$ directly controlled by water availability
- Photosynthetic rate improved by restoration treatments

Control Plot (AZ)

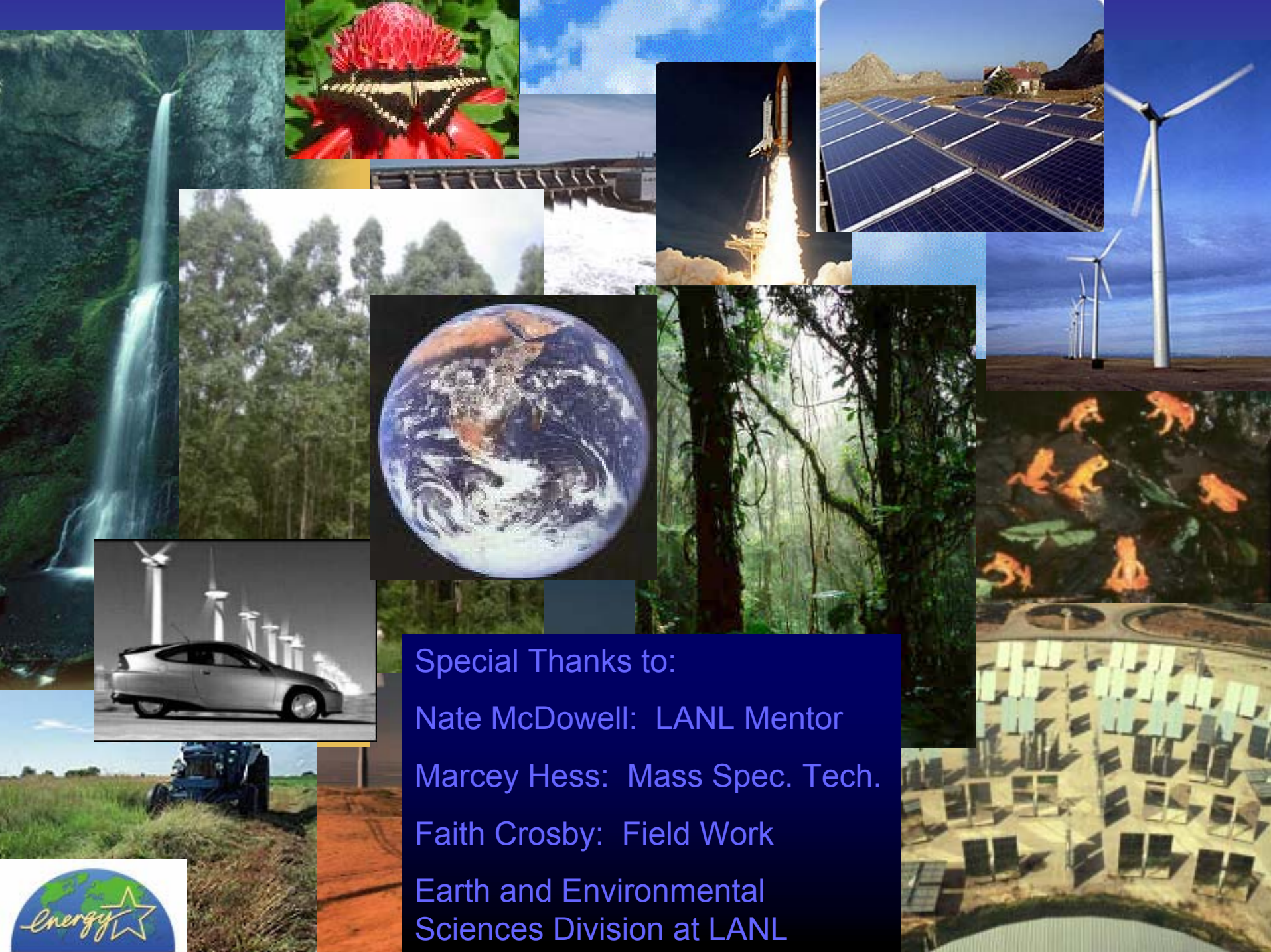
Ponderosa Pines (NM)

Fire Scar (NM)

Restored Plot (AZ)

Future Study: As Senior Project

1. Get Data!
2. Investigate isotopic response to changing environmental conditions
3. Understand relationship between environmental conditions and photosynthetic rates
4. Future applications in tropical plantations more efficient growth and photosynthesis



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