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Progress Report on NASA MTPE Grant:

Summer Research Internships at Biosphere 2 Center

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I. Introduction

Through the support of NASA's Mission to Planet Earth, Biosphere 2 Center hosted 11 research interns for 6 to 8 weeks each during the summer of 1997. In addition, we were able to offer scholarships to 14 students for Columbia University summer field courses. These two types of programs engaged students in much of the range of activity of practicing Earth Scientists, with an emphasis on the collection and analysis of data in both the field and the laboratory. Research interns and students in the field courses also played an important part in the design and evolution of their research projects. In addition to laboratory and field research, students participated in weekly research seminars by resident and visiting scientists. Research interns were exposed to the geology and ecology of the region via short field trips to the Arizona Sonora Desert Museum, Mount Lemmon, Aravaipa Canyon and the Gulf of California, while field course students were exposed to laboratory-based research via intern-led hands-on demonstrations of their work. All students made oral and written presentations of their work during the summer, and two of the research interns have applied to present their results at the National Conference on Undergraduate Research in Maryland in April, 1998.

II. Summer 1997 Student Profiles

Research Interns:

Research interns spent 6 to 8 weeks on their projects, receiving a stipend, housing and support for field excursions from the NASA grant. Both individual and team research projects were assigned. Research interns were chosen by a number of criteria, including the following:

1. Demonstrated interest and ability in science (evaluated via letter of interest, letter or phone reference, and transcript)
2. Likelihood that research experience would advance their career goals (evaluated by letter of interest, resume and letter or phone reference)
3. Desire to provide research experience for students of high ability with little access to research at their home institutions
4. Desire to increase participation by underrepresented groups in Earth System Science education and research.

Of the twelve research interns, 3 were African-American, 1 was Hispanic-American, 2 were Asian-American and 7 were women.

The following students were interns during the summer of 1997:

Debbie Brewer is a biology major at Arizona State University, with plans for a career in ecology and biodiversity research (GPA, 3.34). Her statement of interest and strong letter of reference indicated that she would benefit greatly from the opportunity to pursue independent research, and had the maturity, intellegence and motivation to excel in a research environment. Debbie completed a project on the effects of calcification on photosynthesis and nutrient uptake in marine algae.

Koben Christianson is an environmental policy major at Colorado College (GPA 3.5) who is committed to creating sound environmental policy via thorough understanding of the underlying natural science, as well as social, economic and political factors. The world is his classroom, and he has spent previous semesters in Nairobi at the American University International Environment and Development Program, in the Sea Semester at Woods Hole, doing policy research in Costa Rica, and in the Earth Semester at Biosphere 2 Center. Koben completed a project analyzing the educational role for complex systems theory in helping to integrate the teaching of physical, biological and social sciences.

Adam Clanton is a double-major in environmental studies and political science at Brown University (GPA 3.4). He had previous internship experience in politics, and community service, and expressed a strong interest in personally helping to bridge the gap between scientists and policy-makers. He felt that he could best do this with some experience in hands-on research, and we agreed with him. Adam completed a project documenting gradients in light, water and soil characteristics in the agricultural biome of Biosphere 2.

Kelven Goodridge is a biology major at Morehouse College (GPA 2.6) and previous research experience in behavioral toxicology. He felt that this research experience would help him to decide among various disciplinary paths within environmental science, and had not had much exposure to the physical aspects of environmental science previously. Kelven completed a project on methane sources and sinks from the various biomes inside Biosphere 2.

Leone McCreary is an environmental science major at Barnard College (GPA 3.83). She intends to pursue a career in environmental research on her home island, St. Croix, USVI. Her participation in the Spring 1997 Earth Semester at Biosphere 2 revealed that Leone has truly outstanding capabilities in both research and leadership skills. She completed an analysis of the Biosphere 2 biotic database, making strong recommendations for improvements.

Jennifer Molnar is an environmental engineering major at Harvard University (GPA 3.2). She plans to devote her career to improving the environment through scientific problem solving. She had former experience in environmental assessment and field studies, but little experience in scientific research. Jennifer completed a project on methane sources and sinks from the various biomes inside Biosphere 2, and plans to present her results at the National Conference on Undergraduate Research.

Megan Rathfon is a biology major at Wellesley College (GPA 3.35), who has a strong background in field studies and community service, who wished to gain experience with focused scientific research. She hopes to teach environmental science in the future. She completed a project on the effects of calcification on photosynthesis and nutrient uptake in marine algae.

Debika Shome is an environmental science major from Barnard College (GPA 3.25). She is one of two students who completed both a summer field course and a research internship at Biosphere 2. She expressed the hope that her summer experience would help her choose between careers in environmental research or management. Debika completed a project on sources of copper in the Biosphere 2 ocean.

Kendra Stamps is a biology major at Mississippi Valley State University (GPA 3.36). She had strong recommendations from professors, as well as a stated desire to broaden her research experience to include more environmental science. Unfortunately, Kendra had to withdraw from the program after one week due to a family emergency.

Motofumi Tohda is an environmental studies and chemistry double-major at Oberlin College (GPA 3.76). He hopes to apply his education to a career in bioremediation, and was eager for this first opportunity for focused research. Motofumi completed a project on light, temperature and nutrient distributions in the Biosphere 2 rainforest.

Paul Wigton is a geology major at the University of Colorado (GPA 3.14) with a passion for designing and engineering solutions to environmental problems. Paul was an excellent fit to a project to design open-topped growth chambers with controlled-CO2. He was one of two students who attended a field program and completed a research project.

Veronica Vieira is a major in environmental engineering at the Massachusetts Institute of Technology, GPA (4.5/5). She demonstrated strong interest and ability in paleoceanography research on a research project at MIT, and expressed specific interest in working directly with some of the organisms used as paleococeanographic proxies. She completed a project on the effects of pCO2 on isotopic signals in marine algae.

***Field Scholars*:**

Field scholars attended one of the two field courses described below. They received need-based scholarships of up to $1000 from the NASA MTPE grant, which allowed them to supplement their classroom work with practical and perspective-changing field experience. As a whole, they did very well in the courses. Of 14 field scholars, none were African American, none were Hispanic American, one was Asian-American and 8 were women.

Name	College	Major	Grade in course
Sharon Fredrickson	Sam Houston	Env Sci	B+
Brooke Heins	Columbia Univ	premed	A
Amey Libman	Bradley Univ	Env Sci	A-
Joshua Snyder	Penn. State	Env Stud	A
Angela Venuto-Ashton	Salem College	Biology	B
Peter Teal	Clarkson Univ	undeclared	A+
Campbell Austin	Univ Penn	undeclared	A
Filip Jagodzinski	Columbia Univ	Engineering	A
Daniel Jarrous	UCSD	Urban Planning	B
Felicia Kaldi	Auburn Univ	Wildlife Science	B
Stewart Mackie	Bowdoin Coll	Biochem and Env Sci	A
Danette Miller	Univ Oklahoma	undeclared	B
Rebecca Sanford	Scripps Coll	Env Sci	C
Jennifer Wu	UCSD	Geochemistry	B

III. Plans for program enhancement

After reviewing evaluations from students and mentors, the following changes will be implemented for the 1998 and 1999 intern programs:

Improve the diversity and equity of opportunity for interns and field school students: We had very little time to recruit interns last summer, due to the late notification of the grant award. With more time this year, we will be able to improve our outreach to community college and minority students for both the intern program and field school.

Increase length of internships: The original length of 6 weeks was chosen to allow students to avail themselves of both a field program and research experience during the summer. Our first summer experience taught us that the 12-week commitment is too long for most. Both students and mentors felt that 6 weeks was not enough time to gain sufficient mastery of a subject and complete a project. Future internships will be 10 weeks, giving students time for a more satisfactory research experience.

Hire a Resident Assistant: The proposed budget has been amended to include funding for a resident assistant to provide scheduled transportation for those without cars, and to provide a first level of guidance and counseling when problems arise. The RA will also help to organize day trips for interns. The RA will be trained by the Director of Student Affairs. He/she will be a graduate student doing research at Biosphere 2 during the summer.

Improve laboratory facilities: All equipment and labs on site have been upgraded over the past year to best serve the current research program.

Provide more opportunity for student-intern interaction: We plan to run joint orientation activities for students and interns, encourage interns to attend selected field school lectures on topics of general interest, increase the time available for intern-led tours of their research in the Biosphere and in their laboratories, arrange the field school schedule so that students can attend research and intern lectures, house interns and students in close proximity, and include interns in all student-life activities.

Revise format of weekly mentor-intern lunches: In 1997 we had weekly lunches for interns and mentors in which interns were to give a five-minute update on progress on their project. Student interns felt that these were not very useful or interesting, as they tended to talk about their research outside of this brown-bag format anyway. As an alternative, interns will be asked to lead discussion of a paper from the scientific literature related to research activities at Biosphere 2. Interns will work in teams of two, and can consult their mentors for suggested papers.

Increase number of research seminars: We plan to increase the number of lectures from one to two per week by re-directing some of the NASA funding toward honoraria for outside lecturers, and by inviting interns to specific field school lectures. We will also arrange for video-link of four lectures between Biosphere 2 and Lamont-Doherty Earth Observatory, so that interns in each place can be introduced to research at the other.

Improve housing facilities: Intern housing last summer was very crowded and cooking facilities were limited. In future summers, interns will be housed in new dormitories installed in the fall of '97. Ten interns will reside with an RA in a large 6-bedroom house with living, cooking and dining areas. This house is located adjacent to field student housing.

IV. Summer 1998 Research Projects:

Intertidal Zonation in the Sea of Cortez: Richard Brusca, Ann Holmes

The intertidal region of the Sea of Cortez (=Gulf of California) is known to be one of the richest and most diverse marine habitats on Earth. However, virtually nothing is known of how the animals and plants share this highly diverse, but poorly explored area. Students involved in this project would work under the direction of Dr. Richard C. Brusca and Dr. Ann Holmes (at Biosphere 2 Center) and Peggy Turk-Boyer (Director of CEDO, Puerto Peñasco, Mexico) to investigate aspects of intertidal zonation in on a rocky shore in the northern Sea of Cortez. The goal would be to develop the first detailed description of Intertidal zonation for this region. The project would require laboratory and library work at the Biosphere 2 Center and CEDO, as well as several 4-5 day field trips to the Sea of Cortez. Scuba
diving is not necessary, as the tides in the northern Gulf of California are extreme and allow sufficient exposure during new and full moon periods.

Zoological Inventory of the Ocean Biome at Biosphere 2 Center: Richard Brusca, Heidi West

The Ocean Biome was originally seeded with organisms from two source areas, the Caribbean and the Sea of Cortez. Although initial records were maintained, the Ocean Biome has not been fully censused to see what species have survived since closure, nor to discover what incidental species of small invertebrates might have been introduced along with the larger coral and algal species. This project would require scuba diving and snorkeling in the Ocean Biome to non-destructively sample and census its biodiversity. It would also require considerable identification work, using microscopes and library materials. The goal would be to produce a new, complete census of the Ocean Biome's biodiversity, including species lists and estimates of population sizes.

CO_2 and H_2O exchange in desert and rainforest ecosystems: Guang-hui Lin

Many basic questions about the functioning of terrestrial ecosystems can be addressed with stable isotope studies. The key question we will try to address this summer is how changes in precipitation affect the functioning of both moist and arid ecosystems. We will study CO_2/H_2O fluxes and associated isotopic exchanges inside the rainforest of Biosphere 2 as well as on desert ecosystems (Sacaton meadow and Mesquite forest) of the San Pedro River Basin (about 2 hrs drive from B2C). Common ecophysiological instuments (e.g. LI-COR photosynthesis and soil respiration systems) and stable isotope techniques will be used during the study. Interns who participate the project will have opportunities to get training on applications of these technologies to ecological/environmental research and will work in both humid and dry climates.

Environmental controls on methane concentrations in Biosphere 2: Debra Colodner, William Reeburgh (UC Irvine), Joost van Haren

Methane is an important greenhouse gas which has been increasing in our atmosphere due to a variety of human activities. The Biosphere 2 facility offers the opportunity to study the interaction of atmospheric methane sources and sinks with other environmental parameters, such as temperature, moisture and atmospheric CO_2. One can study these interactions on the unique scale of Biosphere 2 - somewhere between a growth chamber and a real ecosystem. Controls, sensors and frequent sampling allow response mechanisms to be explored and quantified. Students will gain experience with environmental trace gas sampling and gas chromatography, as well as the biogeochemistry of methane.

Interpreting Earth Systems Research for the Public: Debra Colodner, Alexis Faust

Biosphere 2 Center is visited by almost 200,000 people every year, and has the opportunity to reach even more people through our web site. Working with our public programs staff, this project will involve creating web pages, hand-outs, and interpretive materials for tour guides that will explain the research of the Biosphere interns and students to the public.

The effects of increased atmospheric CO2 on coral reefs: Chris Langdon
One of the factors affecting the declining health of coral reefs around the globe may be increasing atmopheric CO2. This project utilizes the coral population of the Biosphere 2 ocean to study the effects of elevated atmospheric CO2 on coral reef community metabolism. Students can chose to look at either the changes in community photosynthesis in response to higher dissolved CO2, or the change in community calcification in response to decreased carbonate saturation state.

The construction of leaves: Kevin Griffin
The construction cost of leaves (energy required to form new leaf material) is sensitive to leaf age, leaf type and environmental resource availability. This project will take advantage of wide rage of species (consisting of many different physiologies, chemistries, functional types and natural histories), growing inside the Biosphere 2 wilderness area to perform a survey of leaf construction cost as it compares to leaf age and physiology. Laboratory techniques for measuring leaf construction cost will be combined with "field" measurements of leaf expansion and age, leaf gas-exchange and environment. Another part of the project will look at leaf ultra structure, which is sensitive to leaf age, leaf type and environmental resource availability. Electron microscope techniques for looking at leaf ultra structure will be combined with "field" measurements of leaf expansion and age, leaf gas-exchange and environment. This project will require travel to Lamont-Doherty earth observatory in NY for the electron microscope analysis.

Plant responses to variable CO_2 concentrations: Kevin Griffin, Blake Farnsworth
This research focuses on an evaluation of the biological impact of an unique feature of Biosphere 2: the diurnal cycling of the CO_2 partial pressure of its atmosphere. The central question is whether or not the predictably variable CO_2 environment of Biosphere 2 creates substantial difficulties in understanding the responses of plants, from the level of genes to ecosystems, to elevated atmospheric CO_2. Physiological, biochemical and molecular measurements of the photosynthetic and respiratory characteristics of plants within open-top chambers will be analyzed over time in order to identify the effects of elevated and variable CO2 partial pressure at a variety of biological scales.

The effect of elevated CO_2 on forested ecosystems: Kevin Griffin
This project is an experimental evaluation of the Biosphere 2 IAB for long-term experiments on carbon, water and nitrogen fluxes in forested ecosystems. An Eastern Cottonwood plantation will be established in the IAB. Baseline data will be collected to quantify the plant growth and physiology under ambient and elevated CO2 concentrations. The results of leaf level measurements will be compared to system level responses.

In addition to the projects listed above, we will have 6-8 new research collaborators from the University of Arizona by this summer, and expect that many of them will want to supervise an intern.

V. Field course descriptions

NASA-funded Field Scholars participated in one of two field courses (6 in session 1 and 8 in session 2). Descriptions of these courses are listed below.

Earth Systems Field School, Session 1: Field Course in Earth Systems

This six-week summer field course is designed to equip students with practical and state-of-the-art experience in the use of field techniques that address a broad range of Earth system, environmental, and research problems. The course was designed especially for students of Earth System Science, and stresses the connections between the various Earth "spheres" (geo-, bio-, atmo- and hydro-). Students learn to assess various sites in an integrated fashion, including biological, geological, geochemical and geophysical techniques. The unique Biosphere 2 global change research facility, together with the incomparable environmental resources within a day's drive of campus (the Grand Canyon, Meteor Crater, Gulf of California, archaeological sites, the Sonoran Desert), give students a view of methods used to understand past, present, and future Earth system problems.

Week 1: Introduction and Orientation
The first week of the course is devoted to field methods, as well as developing basic computer and statistical skills. During this week, students get an introduction to various field and computer techniques, organism and rock identification, arid ecosystems and the special issues of sky islands, map-reading and orienteering skills, Biosphere 2, including a tour and safety walk and to the geology of Arizona. In addition, they review basic Earth System concepts.

Week 2: Northern Arizona trip: Deep time processes
The second week is devoted to a trip around Northern Arizona to focus on Earth History as revealed in the landscape. Students visit the Salt River Canyon to study and sketch the stratigraphic section, as well as get an introduction to water management issues in Arizona. They stop at Meteor Crater to discuss evolution and mass extinctions. A trip to Sunset Crater focuses them on the important roles of volcanoes in the Earth System, over various time scales. Along the way, stops at archaeological sites are used to illustrate the changing relationship between humans and the environment through time. Students finally visit the Grand Canyon and describe the stratigraphic section as well as the biological gradients they find on a walk part-way down and up.

Weeks 3, 4: Systems analysis in the field
Students are introduced to mapping using Electronic Total Stations and Geographic Information Systems by producing a base map for one of the biomes of Biosphere 2. They create a layered geological and vegetation map of the field site in the Catalina mountains. Geophysical techniques are introduced so that students can include features of the sub-surface as well. During week 3, student teams design a research project for the site to be carried out during the following week. In addition to collecting data during week 4, students receive additional instruction in class and on field trips about ecological, climatological and hydrological gradients, biogeochemical cycles, and soil characterisitics and processes. They use the information they collect in the field as well as historical data to formulate and test their research hypotheses. Areas for student investigation include the relationships among soil moisture, texture, mineralogy, chemistry, microfauna and vegetation; the relationships among bedrock, soils and vegetation; the partitioning of carbon or other nutrients in different parts of the field area, etc. Because the field area is likely to be very dry, we also bring students to a canyon stream to complete mini-projects on the physical, chemical and biological gradients associated with these features.

Week 5: Biome management

During this week students are introduced to the challenges of managing an ecosystem using examples primarily from Biosphere 2. Student teams collect data for projects such as relating water quality and quantity to vegetation and microfauna, comparing the morphology of plants grown inside and outside Biosphere 2, designing solutions for some of the technological or design problems of Biosphere 2, examining the role of human management in determining changes in the biotic communities in Biosphere 2, modeling nutrient cycles inside Biosphere 2, etc. Students compare their results to those from their field exercises, where appropriate.

Week 6: Coastal environments and marine ecosystems
During this week students travel to Rocky Point, at the northern edge of the Gulf of California. There, they help to collect data on the distribution and abundance of intertidal organisms, adding to a 15-year data set for this ecologically sensitive region. Students analyze pieces of this data set in an attempt to relate trends in commercial, residential and industrial development in the area and fresh water availability (tremendously depleted because of upstream use and diversion of the Colorado River) to changes in intertidal populations. Students also compare and contrast the limiting factors in marine and terrestrial ecosystems, and organism adaptations to these different environments.

Earth Systems Field School Session 2: Ecological Stewardship

Humans are changing the environment on a planetary scale. In a sense, we are planetary managers, whether consciously or unconsciously. This course is designed to teach basic skills in ecosystem management using the high-desert terrain outside, and the varied ecosystems inside Biosphere 2. The course stresses systems thinking and modeling skills that can be applied to management challenges at the global, as well as local scales.

This four-week course introduces students to field and computer-based techniques for observing, measuring, monitoring, modeling and managing ecosystems. The focus of Session 2 is management for the future, and complements Field School session 1 (six weeks) in that the first session focuses on understanding how the Earth and living systems arrived at their present state.

Biosphere 2 Center is set in a high desert-savanna landscape just north of the Santa Catalina mountains. Within a two-hour drive students can access pine forest (9000 feet), desert, grasslands, agricultural areas, cattle ranches, urban areas, and the varied ecosystems within Biosphere 2 (rainforest, mangroves, ocean, savanna and desert). This broad range allows students to learn about a number of different challenges to the sustainability of these ecosystems, such as changes in temperature, moisture, nutrient availability, acidity, salinity, light and toxic chemicals.

Week 1: Students are oriented to the area, learn basic rock and desert/savanna plant identification, tour inside Biosphere 2, explore ecological gradients in the Santa Catalina Mountains and inside Biosphere 2, and take a number of conditioning hikes to learn and practice map-reading, observational and record-keeping skills. They also get an introduction to systems and system modeling using Stella software.

Week 2: Students are introduced to scientific field methods by making and testing hypotheses about the distribution of life in the desert outside and the desert inside Biosphere 2. They look at the effects of cattle grazing, enhanced moisture and near-by development (ie, buildings, lawns, roads) on species distribution and soil properties.

Week 3: Students learn to make ecological comparisons by studying the various biomes inside Biosphere 2, as well as the gradients outside. From these exercises they gain insight into the limiting and critical factors that structure organisms as well as ecosystems. They concurrently build simple computer models of the carbon cycle inside Biosphere 2 and on the Earth. They then

develop management strategies for maintaining carbon dioxide at specified levels and test these strategies with their models.

Week 4: Students travel to several regional sites to study current environmental management issues: management of groundwater supply, biodiversity in riparian ecosystems, biodiversity of sky islands, the impacts of copper mining, range management and fire management.

Curriculum Vitae Kevin Lee Griffin

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Education

Duke University, Department of Botany, Durham, NC
Ph.D., Botany, August 1994

Yale University, School of Forestry and Environmental Studies, New Haven, CT
M.E.S., Forest Ecology, May 1987

Whittier College, Whittier, CA
B.A., Environmental Studies, May 1985

Professional Experience

Assistant Professor, Columbia University, Palisades, NY, May 1997

Assistant Research Professor, Desert Research Institute, Reno, NV, July 1996 - May 1997

Acting Director, Frits Went Laboratory, Desert Research Institute, Reno, NV, July 1996 - January 1

US Department of Energy, Global Change Distinguished Postdoctoral Fellow
Desert Research Institute, Reno, NV, September 1994 - July 1996

Research Assistant, Duke University, Durham, NC, August 1990 - August 1994

Laboratory Technician, Carnegie Institution of Washington, Stanford, CA, January 1988 - August 1

Biological Technician, US Forest Service Northeastern Forest Experiment Station, Hamden, CT Jun
September 1987

Research Assistant, Yale School of Forestry and Environmental Studies, New Haven, CT
September 1985 - May 1987

Field Research Assistant, Hubbard Brook Experimental Forest, NH, May - September 1986

Teaching Experience

Professor, EES 2100, The Climate System, Spring 1998

Professor, EES 2300, The Life System, Fall 1997

Guest Lecturer, General Ecology, Duke University, Fall 1991

Teaching Assistant, General Biology, Duke University, Fall 1990, Spring 1991

Laboratory Instructor, Historical Geology, Whittier College, Spring 1985

Grants Received

National Science Foundation, Integrative Plant Biology. 1997
$256,000 / 3 years

National Science Foundation, International Opportunities for Scientist and Engineers. 1996
$35,000 / 2 years

Nevada EPSCoR proposal development funds. 1996
$4,000 / 3 months

Biosphere 2 Center, seed grant. 1996
$25,000/year

Global Change Distinguished Postdoctoral Fellowship, U.S. Department of Energy. 1994
$74,000 / 2 years

Robert R. Bryden Graduate Research Award, North Carolina Academy of Sciences. 1991 & 1992.
/ 1 year

Catherine Kiever/Duke Botany Department research funds. 1991
$500 / 1 year

Mellon Foundation, student awards. 1986
$500 / 1 year

Societies and Activities

American Association for the Advancement of Science

American Society of Plant Physiologist

Ecological Society of America

Sigma Xi

Reviewer: *Canadian Journal of Forest Research, Ecological Applications, Ecology, Forest Science, (*
Change Biology, Journal of Experimental Botany, Oecologia, Tree Physiology
NSF - Ecological and Evolutionary Physiology Program
DOE - Terrestrial Carbon Processes Program

Judge, Murray F. Buell Student Award, Ecological Society of America, 1995 & 1996

Publications

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Griffin K.L., Winner W.E. & Strain B.R. (1995) Growth and biomass partitioning in loblolly and ponderosa pine seedlings in response to carbon and nitrogen availability. *New Phytologist*, **129**, 547-556.

Griffin K.L., Ball J.T. & Strain B.R. (1996) Direct and indirect effects of elevated CO_2 on whole shoot respiration in ponderosa pine seedlings. *Tree Physiology*, **16**, 33-41.

Griffin K.L Winner W.E. & Strain B.R. (1996) Construction cost of loblolly and ponderosa pine leaves grown with varying carbon and nitrogen availability. *Plant, Cell and Environment*, **19**, 729-738.

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Griffin K.L. & Luo Y. (1996) Plants, Paleo Climate and CO_2: a review of ESA symposium #3, Transdisciplinary Evidence for Biome Responses to CO_2 * Climate Change across Glacial/Interglacial Boundaries. *Bulletin of the Ecological Society of America*, **77**, 164-166.

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Griffin K.L., Thomas R.B. & Strain B.R. (1992) Effects of nutrient supply and elevated [CO_2] on construction cost in *Pinus taeda* seedlings. *Supplement to the Bulletin of the Ecological Society of America*, **73**:194.

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Tissue D.T., **Griffin** K.L., Thomas R.B. & Strain B.R. (1993) Effects of subambient and elevated CO_2 on rubisco in C_3 and C_4 plants. *Supplement to the Bulletin of the Ecological Society of America*, **74**:456.

Griffin K.L., Tissue D.T., Thomas R.B. & Strain B.R. (1993) Effects of subambient and elevated CO_2 on photosynthesis in C_3 and C_4 plants. *Supplement to the Bulletin of the Ecological Society of America*, **74**:258.

Griffin K.L, Bashkin M.A., Thomas R.B. & Strain B.R. (1994) Interactive effects of soil nitrogen and atmospheric carbon dioxide on root system carbon dioxide efflux from loblolly and ponderosa pine seedlings. *Global Change and Terrestrial Ecosystems: The first GCTE science conference*, Woods Hole, Massachusetts

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Griffin K.L., Ball J.T. & Strain B.R. (1995) Direct and Indirect effects of elevated CO_2 on whole shoot respiration in ponderosa pine seedlings. *International Union of Forestry Research Organizations, Workshop on Interactive Environmental Effects on Forest Stands.*

Griffin K.L., Ross P.D., Seemann J.R. & Ball J.T. (1995) Mesocosm scale measurements of gas exchange. *Supplement to the Bulletin of the Ecological Society of America*, **76**:100.

Ross P.D., **Griffin** K.L. & Ball J.T. (1995) An integrated system for the measurement of mesocosm scale materials fluxes. *Supplement to the Bulletin of the Ecological Society of America*, **76**:230.

Lewis J.D., **Griffin** K.L., Thomas R.B. & Strain B.R. (1995) Diurnal patterns of photosynthetic response to elevated CO_2 and nitrogen supply in *Pinus taeda* seedlings. *Supplement to the Bulletin of the Ecological Society of America*, **76**:356-357.

Griffin K.L., Ross P.D., Severinghause J., Keeling R.F. & Ball J.T. (1996) Respiratory quotient: direct effects of CO_2 on carbon and oxygen flux in the dark. *Plant Acclimation to Elevated CO_2, 2nd International IGBP-GCTE Workshop Proceedings.*

Johnson D.W., Thomas R.B., **Griffin** K.L., Ball J.T., Strain B.R. & Walker R.F. (1996) Effects of CO_2 and N on growth and n uptake in ponderosa and loblolly pine. *Plant Acclimation to Elevated CO_2, 2nd International IGBP-GCTE Workshop Proceedings.*

Lewis J.D., **Griffin** K.L., Thomas R.B. & Strain B.R. (1995) Effects of short-term vs. Long-term needle carbohydrate accumulation on the photosynthetic response of loblolly pine seedlings to elevated

atmospheric carbon dioxide. *Plant Acclimation to Elevated CO_2, 2nd International IGBP-GCTE Workshop Proceedings.*

Griffin K.L., Ross P.D., Severinghause J., Keeling R.F. & Ball J.T. (1996) Respiratory quotient: direct effects of CO_2 on carbon and oxygen flux in the dark. *Supplement to the Bulletin of the Ecological Society of America*, **77**:172.

Griffin K.L., Tissue D.T., Whitehead D. & Turnbull M.H. (1997) Photosynthetic acclimation in field-grown *Pinus radiata* after 4 years of exposure to elevated CO_2. *Supplement to the Bulletin of the Ecological Society of America*, **78**:98.

Tissue D.T., **Griffin** K.L. & Ball J.T. (1997) Photosynthetic acclimation in field-grown *Pinus ponderosa* after 5 years of exposure to elevated CO_2. *Supplement to the Bulletin of the Ecological Society of America*, **78**:321.

Turnbull M.H., Tissue D.T., **Griffin** K.L., Rodgers G.N.D. & Whitehead D. (1997) Seasonal transience in the acclimation response *Pinus radiata* to elevated CO_2 concentration. *Supplement to the Bulletin of the Ecological Society of America*, **78**:323.

Invited Seminars

1. Department of Biology, **Texas Tech University**, Lubbock, Texas, December 5, 1995
2. Lamont-Doherty Earth Observatory, **Columbia University**, Palisades, New York, April 22, 1996
3. NASA **Goddard Institute for Space Studies**, New York, New York, April 24, 1996
4. Department of Plant Biology, **University of Illinois**, Urbana-Campaign, Illinois, October 9, 1996
5. Department of Plant Biology, **Carnegie Institution of Washington**, Stanford, California, November 26, 1996.
6. Critical assessment of the response of forest ecosystems to elevated atmospheric carbon dioxide, 3rd International IGBP-GCTE workshop, **Duke University**, Durham, NC, October 13, 1997
7. Department of Environmental Sciences, **Rutgers University**, New Brunswick, NJ, October 24, 1997
8. **Landcare Research Institute**, Lincoln, New Zealand, November 1997
9. Department of Biology, **Long Island University**, Southhampton, NY, March 11, 1998
10. Harvard Forest, Petersham, Ma March 6, 1998

Service

Graduate Student Admissions Committee - Department of Earth and Environmental Sciences, 1997
Strategic Planning - Desert Research Institute
Business Development Group - Desert Research Institute

Officially Advised Graduate Students and Post-docs

Mark Potosnak, Columbia University, MSc. September 1997
Ph.D. candidate - present
Victor Engel, Columbia University, Ph.D. candidate - present
Hector Maza Cabezas, Universidad del Pais Vasco, Visiting Scolar - October - December 1997

Budget Detail Sheet

TITLE: Undergraduate Internships in Earth Systems Research at Bios 2 Center

PRINCIPAL INVESTIGATOR(S): W.S. Broecker/D. Colodner/K. Griffin
PERIOD: 9/15/98 - 8/31/99
AMT. REQUESTED: $75,000

A. Salaries and Wages		Mos.	Yr. II
Senior Personnel			
W. S. Broecker	Newberry Professor		N/C
D. Colodner	Associate Research Sci.		N/C
K. Griffin	Assistant Professor	1	5,062
Other Personnel			
Resident advisor	TBD		2,500
(10) Student Interns (10wks@2500)			25,000
temp labor (work study)			500
TOTAL SALARIES & WAGES			33,062
Fringe @ 28.4%			1,438
Fringe @ 19% (work-study)			95
Total Salaries, Wages and Fringe			34,595
D. Permanent Equipment			0
E. Travel: Domestic			
10 (RT)coach airfares to Tucson @ $400/ea			4,000
Travel to/from Tucson (collaborating sci.)			4,000
Housing 10@ $5/day x 70 days			3,500
RA Housing 1 @ $5/dayx70 days			350
RA travel @ $400			400
Intern field trips (van rentals, gas, fees, etc.)			1,000
Total Travel			13,250
G. OTHER DIRECT COSTS:			
1. Materials/Supplies:			
Misc. lab supplies			775
office supplies			0
2. Publication costs/page charges			500
3. Computer charges			0
6. Other			0
Communications, phone (to include videolink), Fax			1,000
Shipping			0
Scholarships @ $1000/student			10,000
Total Other Costs: (G1-G6)			12,275
H. Total Direct Costs (A-G)			60,120
I. Indirect Costs @ 24.75%			14,880
J. Total Requested			75,000

Current and Pending Support
4/20/98

WALLACE BROECKER

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. Cal.	F Location
A. Current Support					
NSF OCE 97-30371	EXPERIMENTAL DETERMINATION OF EQUILIBRIUM AND KINETIC FRACTIONATION OF BORON, CARBON AND OXYGEN ISOTOPES DURING CARBONATE PRECIPITATION. (ORTIZ, J., PI; SANYAL, A., BROECKER, W., CO-PIs)	120,906	3/1/98 - 2/28/99	N/C	LDEO
NSF EAR 97-26009	A TEST FOR THE INTERPRETED CAUSE OF THE MID-MIOCENE "MONTEREY EXCURSION: USING THE BORON ISOTOPIC COMPOSITION OF BENTHIC FORAMINIFERA". (HEMMING, G., PI; BROECKER, W., CO-PI)	109,000	1/1/98 - 12/31/99	N/C	LDEO
NASA NAG5-6294	UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; GRIFFIN, K, COLODNER, D., CO-PI's)	75,000	9/15/97 - 9/14/98	N/C	LDEO
DOE DE-FG02-97ER62441	MANAGING THE ATMOSPHERE CO2 CONTENT. (BROECKER, W., PI)	105,400	8/15/97 - 8/14/98	2	LDEO
##AWI AWI CU01618201	ANALYSIS OF THE STABLE BORON ISOTOPIC COMPOSITION OF FORAMINIFERAL SHELLS. (BROECKER, W., Advisor; SANYAL, A., PI)	120,978	10/1/96 - 9/30/98	N/C	LDEO
NSF OCE 95-04512	SYMPOSIUM ON STUDIES OF OCEAN CIRCULATION BY NATURAL AND ANTHROPOGENIC TRACERS. (SCHLOSSER, P., PI; SMETHIE, W., BROECKER, W., CO-PIs)	25,000	9/1/95 - 8/31/98	N/C	LDEO
DOE DE-FG02-95ER14572	THE DISTRIBUTION IN SPACE AND TIME OF WET EVENTS IN THE WESTERN NORTH AMERICAN DRY LANDS. (BROECKER, W., PI)	401,285	9/1/95 - 8/31/98	1/1/1	LDEO
NSF EAR 95-06425	GLACIAL PALEOTEMPERATURES FOR THE CONTINENTAL TROPICS DERIVED FROM NOBLE GASES DISSOLVED IN GROUNDWATER. (STUTE, M., PI; SCHLOSSER, P., BROECKER, W., CO-PIs)	250,000	8/15/95 - 7/31/98	N/C	LDEO

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. Cal.	F Location
*SIO UCSIO P.O.10075411 F4	MODELING. (SCHLOSSER, P., PI-Advisory Capacity Only; BROECKER, W., PI of Scope)	124,939	5/1/94 - 12/31/98	.85/.85/.5	LDEO
*SIO UCSIO P.O. 10075411 B1	ABRUPT CLIMATE CHANGE. (SCHLOSSER, P., PI-Advisory Capacity Only; BROECKER, W., PI of Scope)	322,016	5/1/94 - 12/31/98	N/C/1	LDEO
NASA NGT-30277	ESTIMATION OF PALEO pH OF OCEANS BASED ON BORON ISOTOPIC COMPOSITION OF FORAMINIFERA. (BROECKER, W., Advisor; PEACOCK, S., PI)	22,000	9/1/96 - 8/31/98	N/C	LDEO

B. Pending Support

NASA	YEAR 2 NAG5-6294: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; GRIFFIN, K, COLODNER, D., CO-PI's)	75,000	9/15/98 - 8/31/00	N/C	LDEO
NASA #8772	CLIMATE DRIVEN SR ISOTOPE CYCLICITY IN SOUTH ATLANTIC SEDIMENTS-EXPLORING THE CONTROLS. (BROECKER, W., Advisor; RUTBERG, R., PI)	22,000	9/1/98 - 8/31/99	N/C	LDEO
NASA #8771	RENEWAL OF NGT-30277: FORMATION RATES OF SOUTHERN HEMISPHERE DEEP WATER INFERRED FROM GLOBAL TRACER DISTRIBUTIONS. (BROECKER, W., Advisor; PEACOCK, S., PI)	22,000	9/1/98 - 8/31/99	N/C	LDEO
NASA #8767	MULTIVARIATE STATISTICAL ANALYSIS OF REGIONAL SNOWLINES: INSIGHTS INTO LONG-TERM CLIMATE VARIABILITY. (BROECKER, W., Advisor; GREENE, A., PI)	22,000	9/1/98 - 8/31/99	N/C	LDEO
DOE #8768	RENEWAL OF DE-FG02-97ER62441: MANAGING THE ATMOSPHERE'S CO2 CONTENT. (BROECKER, W., PI; TAKAHASHI, T., STUTE, M., CO-PI)	136,298	9/1/98 - 8/31/99	2	LDEO
DOE #8761	RENEWAL OF DE-FG02-95ER14572: ROCK VARNISH RECORD OF HOLOCENE CLIMATE VARIATIONS IN THE GREAT BASIN OF WESTERN UNITED STATES. (LIU, T., PI; BROECKER, W., CO-PI)	284,474	9/1/98 - 8/31/00	.5/.5	LDEO
NSF #8692	ROCK VARNISH RECORDS OF HOLOCENE CLIMATE VARIATIONS IN THE SUBTROPICAL DESERTS OF THE MIDDLE EAST. (LIU, T., PI; BROECKER, W., CO-PI)	251,707	7/1/98 - 6/30/00	.5/.5	LDEO
DOE #8644	A PILOT EXPERIMENT DESIGNED TO EVALUATE THE OPTION OF SEA FLOOR DISPOSAL OF POWER PLANT CO2 EXHAUSTS. (BROECKER, W., PI; TAKAHASHI, T., CO-PI)	1,900,158	5/1/98 - 4/30/02	NC/1/NC/1	LDEO

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. Cal.	F Location
NSF #8555	SQUEEZING THE JUICE OUT OF PALEOCLIMATE PROXIES. (BROECKER, W., PI)	240,870	3/1/98 - 2/28/01	1/1/1	LDEO
*SIO #8506	RENEWAL OF UCSIO P.O. 10075411 B1: ABRUPT CLIMATE CHANGE - NOAA CONSORTIUM PROPOSAL. (SCHLOSSER, P., PI-Advisory Capacity Only; BROECKER, W., PI of Scope)	210,000	1/1/98 - 6/30/01	1.25/1.25/1.25/.5	LDEO

C. Outstanding Increments

NSF OCE 97-30371	YEAR 2 & 3: EXPERIMENTAL DETERMINATION OF EQUILIBRIUM AND KINETIC FRACTIONATION OF BORON, CARBON AND OXYGEN ISOTOPES DURING CARBONATE PRECIPITATION. (ORTIZ, J., PI; SANYAL, A., BROECKER, W., CO-PIs)	226,155	3/1/99 - 2/28/01	N/C	LDEO
NASA NAG5-6294	YEAR 3: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; GRIFFIN, K., COLODNER, D., CO-PI's)	75,000	9/1/99 - 9/14/00	N/C	LDEO

D. Proposals Planned to be Submitted in Near Future:

NONE

E. Transfer of Support:

NONE

F. Other Agencies to Which Proposal Has Been/Will be Submitted:

NONE

Current and Pending Support
4/20/98

KEVIN GRIFFIN

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. %Effort	F Location
A. Current Support					
NASA NAG5-6294	UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; COLODNER, D., GRIFFIN, K., CO-PIs)	75,000	9/15/97 - 9/14/98	N/C	LDEO
##BLACK ROCK BRFC CU01877601	SEASONAL AND TOPOGRAPHICAL VARIATION IN WATER AVAILABILITY: IMPLICATIONS FOR CARBON AND NITROGEN CYCLING IN THE CASCADE WATERSHED OF BLACK ROCK FOREST. (GRIFFIN, K., PI)	4,849	4/1/98 - 3/31/99	N/C	LDEO
NSF IBN 96-03940	PLANT RESPIRATION IN ELEVATED CO2: MECHANISMS OF RESPONSE. (GRIFFIN, K., PI; SEEMANN, J., CO-PI)	98,506	8/1/97 - 7/31/98	2	LDEO
NSF	BIOCHEMICAL MECHANISMS CONTROLLING LEAF EXPANSION AND TREE RESPONSES TO ELEVATED CO2. (TISSUE, D., PI; GRIFFIN, K., CO-PI)	34,356	1/1/96 - 12/31/98	N/C	TEXAS UNIV.
B. Pending Support					
NASA	YEAR 2 NAG5-6294: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; GRIFFIN, K, COLODNER, D., CO-PI's)	75,000	9/15/98 - 8/31/00	N/C	LDEO
##MELLONFOUNDA #8799	ENVIRONMENTAL CONTROLS ON TREE GROWTH: A COMPARISON BETWEEN THE CASCADE BROOK WATERSHED OF BLACK ROCK FOREST, NY AND A NATIVE NEW ZEALAND FOREST. (GRIFFIN, K., PI)	246,841	6/1/98 - 5/31/01	N/C	LDEO
NASA #8745	PLANT RESPONSES TO ALTERED NIGHTTIME CO2 PARTIAL PRESSURE: A SCOPING PROPOSAL TO EXAMINE THE EFFECTS OF EXPERIMENTAL CO2 FUMIGATION PROTOCALS. (GRIFFIN, K., PI; SEEMANN, J., CO-PI)	105,738	8/1/98 - 7/31/99	1	LDEO

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. %Effort	F Location
NSF #8753	2ND INCREMENT TO IBN 96-03940: PLANT RESPIRATION IN ELEVATED CO2: MECHANISMS OF RESPONSE. (GRIFFIN, K., PI; SEEMANN, J., CO-PI)	78,217	8/1/98 - 7/31/99	2	LDEO
SDSMT #8472	EXPERIMENTAL STUDIES OF THE ECOLOGY OF THE RHIZOSPHERE - THE ROLE OF PLANT - PROTOZOAN INTERACTIONS IN SOIL FERTILITY. (ANDERSON, O.R., PI GRIFFIN, K., CO-PI)	33,482	1/1/98 - 12/31/99	N/C	LDEO

C. Outstanding Increments

NASA NAG5-6294	YEAR 3: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; COLODNER, D., GRIFFIN, K., CO-PIs)	75,000	9/15/99 - 9/14/00	N/C	LDEO
NSF IBN 96-03940	YEAR 3: PLANT RESPIRATION IN ELEVATED CO2: MECHANISMS OF RESPONSE. (GRIFFIN, K., PI; SEEMANN, J., CO-PI)	79,331	8/1/99 - 7/31/00	2	LDEO

D. Proposals Planned to be Submitted in Near Future:

NONE

E. Transfer of Support:

NONE

F. Other Agencies to Which Proposal Has Been/Will be Submitted:

NONE

Current and Pending Support
4/20/98

DEBRA COLODNER

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. %Effort	F Location
A. Current Support					
NASA NAG5-6294	UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; COLODNER, D., GRIFFIN, K., CO-PIs)	75,000	9/15/97 - 9/14/98	N/C	LDEO
NSF OCE 94-02927	GEOCHEMICAL ANALYSES OF HYDROTHERMAL FLUIDS AND MASSIVE SULFIDES FROM THE LUCKY STRIKE SITE, 37 N, MID-ATLANTIC RIDGE. (COLODNER, D., PI)	44,841	12/15/94 - 11/30/97	3.25/1	LDEO
NSF OCE 93-14634	TRACE ELEMENT PROXIES OF CARBON FLUX AND BOTTOM WATER OXYGEN CONCENTRATION. (ANDERSON, R.F., PI; COLODNER, D., CO-PI)	562,531	1/1/94 - 12/31/98	1/2/3/3	LDEO
B. Pending Support					
NASA	YEAR 2 NAG5-6294: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; GRIFFIN, K, COLODNER, D., CO-PI's)	75,000	9/15/98 - 8/31/00	N/C	LDEO
NSF #8706	A NEW FIELD PROGRAM FOR STUDENTS OF EARTH SYSTEMS SCIENCE. (GREGORY, K., PI; COLODNER, D., CO-PI)	27,706	6/1/98 - 11/30/99	N/C	LDEO
NOAA #8608	EDUCATING FOR PLANETARY STEWARDSHIP: A NATIONAL PROGRAM FOR THE USGCRP. (EISENBERGER, P., PI; COLODNER, D., MOLITOR, M., CO-PI)	3,488,820	10/1/97 - 9/30/00	3/2/1	BIO2
NSF #8607	EDUCATING FOR PLANETARY STEWARDSHIP: A NATIONAL PROGRAM FOR THE USGCRP. (EISENBERGER, P., PI; COLODNER, D., MOLITOR, M., CO-PI)	3,255,126	10/1/97 - 9/30/00	3/2/1	BIO2

A Supporting Agency	B Project Title	C Award Amount	D Period Covered By Award	E Man-Months Acad. Sum. %Effort	F Location
NASA #8606	EDUCATING FOR PLANETARY STEWARDSHIP: A NATIONAL PROGRAM FOR THE USGCRP. (EISENBERGER, P., PI; COLODNER, D., MOLITOR, M., CO-PI)	3,488,820	10/1/97 - 9/30/00	3/2/1	BIO2

C. Outstanding Increments

NASA NAG5-6294	YEAR 3: UNDERGRADUATE INTERNSHIPS IN EARTH SYSTEMS RESEARCH AT BIOSPHERE 2 CENTER. (BROECKER, W., PI; COLODNER, D., GRIFFIN, K., CO-PIs)	75,000	9/15/99 - 9/14/00	N/C	LDEO

D. Proposals Planned to be Submitted in Near Future:

NONE

E. Transfer of Support:

NONE

F. Other Agencies to Which Proposal Has Been/Will be Submitted:

NONE