GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. _____

Project No. G-35-663 (R6125-0A0) GTRC/GIT DATE 5 / 9 / 86

Project Director: W. L. Chameides School/~~Lab~~ Geo Sci

Sponsor: National Science Foundation

Type Agreement: Grant No. ATM-8600888

Award Period: From 5/1/86 To ~~10/31/87~~* 10/31/89 (Performance) ~~1/31/88~~ 1/31/90 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated: $		$ 88,000
Funded: $		$ 88,000

Cost Sharing Amount: $ 889 Cost Sharing No: G-35-367

Title: The Chemistry of Clouds & its Role in Atmospheric Chemical Cycles.

ADMINISTRATIVE DATA OCA Contact John B. Schonk X-4820

1) Sponsor Technical Contact:

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National Science Foundation
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Defense Priority Rating: N/A Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached NSF Supplemental Information Sheet for Additional Requirements.

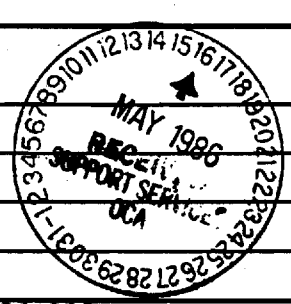
Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT

COMMENTS:

No funds may be expended after 10/31/87.

*Includes 6-month unfunded flexibility period.



COPIES TO:

SPONSOR'S I. D. NO. 02-10-(000)86.021

Project Director	Procurement/EES Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Reports Coordinator (OCA)	Project File
Accounting	Research Communications (2)	Other Jones; Legal

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 06/29/90

Project No. G-35-663 Center No. R6125-0A0

Project Director CHAMEIDES W L School/Lab E & A SCI

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Contract/Grant No. ATM-8600888 Contract Entity GTRC

Prime Contract No.

Title THE CHEMISTRY OF CLOUDS AND ITS ROLE IN ATMOSPHERIC CHEMICAL CYCLES

Effective Completion Date 891031 (Performance) 900131 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

I. Introduction

Funds are requested from the National Science Foundation for the second year of a three year grant (ATM-8600888) to the Georgia Institute of Technology entitled, "The Chemistry of Clouds and Its Role in Atmospheric Chemical Cycles". A brief description of the accomplishments attained during the first year of the granting period, the proposed areas of study for the second year, and the budget for the second year are presented below.

II. First Year's Accomplishments

The effort for the first year of the granting period has focussed on four major areas. The first of these has been on the development and implementation of parameterizations designed to simulate wet-chemical processes in 3-dimensional, Global Chemical Transport Models. A preliminary investigation using the NCAR CCM was completed and the results of this study were reported in Giorgi and Chameides, (The Rainout Parameterization in a Photochemical Model, J. Geophys. Res., 90, 7872-7880, 1985); it was found that the wet-removal lifetime for a soluble gas or aerosol is critically dependent upon the specific characteristics of the precipitation events as well as the species' vertical distribution. The results of this study suggested a possible resolution to a long-standing controversy concerning aerosol lifetimes in the atmosphere. (For more details on this study the reader is referred to Appendix I where a reprint of the article is attached). The current effort is focussed on incorporating the Giorgi and Chameides rainout-parameterization as well as a new washout parameterization into the GFDL Tracer Transport Model; this work is being carried out in collaboration with Drs. Levy and Mahlman.

Another area of investigation underway with support from NSF concerns the coupled gas and aqueous phase chemistry of clouds. Our main effort in this area at the present has been the extension of the Qin and Chameides stratiform cloud model (The Removal of Soluble Species by Warm Stratiform Clouds, Tellus, 38B, 285-299, 1986); to include below cloud chemical and physical processes. The algorithms needed to simulate the physical processes of evaporation of falling raindrops through an undersaturated layer below the cloud have now been developed and we are currently working on incorporating the relevant chemical processes into the algorithm. Mr. Lin Xing, a student of Dr. Qin's from the Peoples Republic of China has recently joined our group as a graduate student and is working on this project.

A third area of research has been focussed on an investigation of the dry deposition of soluble and reactive species to wet-covered surfaces (such as a vegetative surface partially covered by dew). Preliminary theoretical calculations have indicated that depending on the species' solubility and reactivity, the effective dry deposition velocity can often be controlled by the surface resistance rather than the aerodynamic and sublayer resistance (see Figure 1). This result can have important implications for the removal of mass species of interest. For instance, because the reactivity of dissolved S_{IV} is determined by the concentration of oxidants in the solution, the overall deposition velocity SO_2 to dew-covered surfaces at night can often be determined by the atmospheric concentrations of species such as H_2O_2 and O_3. These results suggest that for some species a comprehensive understanding of the dry deposition processes may require measurements of the chemical as well as the physical state of the atmosphere.

A fourth area of investigation has focussed on the analysis of chemical data gathered during the recent NASA GTE/CITE I field experiments; this work was carried with funds from both the subject NSF grant as well as funds from a NASA grant. Efforts in this area have resulted in the publication of two papers; W.L. Chameides, et al., Net Ozone Photochemical Production over the Eastern and Central North Pacific as Inferred from GTE/CITE I Observations During the Fall, 1983, J. Geophys. Res., in press, 1987; An Estimate of the NO_x Production Rate in Electrified Clouds Based on NO Observations from the GTE/CITE I Fall, 1983 Field Operation, J. Geophys. Res., in press, 1987.

III. Research Activities Planned for the Second Year

Research activities for the second year of the granting period will focus on: 1. The continued development of a one-dimensional model of the chemistry and physics of a warm stratiform cloud; 2. The continued collaboration with scientists at the Geophysical Fluid Dynamics Laboratory aimed at developing parameterizations needed for a three-dimensional, global Chemical Transport Model; and 3. The continued investigation of dry deposition to wet surfaces; in the near term work will focus on dew-covered surfaces but it may be extended to dry deposition to intercellular fluids inside selected plant species.

IV. Budgetary Matters

It is presently estimated that less than 10% of the funds granted to Georgia Tech for the first year of the grant will be remaining on the anniversary date of the grant. A sum of $98,500 is requested for the second year of the grant. These funds will include 25% support for the Principal Investigator, Professor W.L. Chameides, as well as support for Mr. Ron Lindsey, a meteorologist with expertise in boundary layer transport

I. INTRODUCTION

Funds are requested from the National Science Foundation for the third year of a three year grant ATM-8600888 to the Georgia Institute of Technology entitled "The Chemistry of Clouds and Its Role in Atmospheric Chemical Cycles." A brief description of the accomplishments attained during the second year of the granting period, the proposed areas of study for the third year, and the budget for the third year are presented below.

II. SECOND YEAR'S ACCOMPLISHMENTS

The effort for the second year of the granting period has focussed on three major areas. These areas are: 1. The study of wet and dry deposition processes and their simulation in 3-dimensional, Global Chemical Transport Models; 2. An investigation of high ozone events in the Atlanta Metropolitan area and the roles of anthropogenic VOC and natural hydrocarbons in causing these events; and 3. An analysis of data gathered during NASA GTE field operations.

A. Wet and Dry Deposition Processes

The study of wet and dry deposition processes has proceeded along a number of different lines. One of these research activities has been concerned with the extension of the Qin and Chameides stratiform model (The Removal of Soluble Species By Warm Stratiform Clouds, Tellus, 38B, 285-299, 1986) to include below cloud chemical and physical processes. Mr. Lin Xing a graduate student in our program from the People's Republic of China, is working on this project and has successfully extended the physics and thermodynamics of the model from the cloud base to the ground, including evaporation of falling raindrops and washout of soluble species. One interesting application of the model that we have been able to make is to study the relative role of washout and rainout in removing soluble species from the atmosphere. The results of these calculations (as illustrated in Figure 1) indicate

that for moderately and highly soluble species, washout can represent an important, if not the major pathway, for wet removal.

Another research activity in the area of wet and dry deposition has focussed on the development and implementation of wet-chemical processes in a 3-dimensional, Global Chemical Transport Model. This work is being carried out in collaboration with Drs. Levy and Mahlman at the Geophysical Fluid Dynamics Laboratory. Having worked over the past two years on wet-chemical parameterizations with the GFDL GASP Tracer Transport Model, we are now making plans to move these parameterizations into the more powerful SKYHI GCM at GFDL. An offer has been made to a Ph.D. scientist to join our group and work at GFDL on this project.

A third research activity in the area of wet and dry deposition has focussed on the chemistry of dry deposition, a major removal pathway for many important trace species whose physics has been studied in detail but whose chemistry is poorly understood. Over the past year work was completed on a study of Acid Dew and the Possible Role of Chemical Reactions in the Dry Deposition of Reactive Species to Wetted Surfaces (J. Geophys. Res., 92, 11,895-11,908, 1987). Model calculations were carried out to simulate the physical and chemical processes responsible for the formation of acidic dew over a nocturnal period. A potentially important outcome of these calculations was the finding that under some conditions the effective dry deposition velocity for SO_2 can be affected by the chemical state of the atmosphere including the SO_2 concentration itself. These results could have some significant implications for the efficacy of proposed SO_2 emission-control strategies. The dry-deposition calculations are now being extended to the study of the dry deposition of ozone to the periplasmic water bathing the mesophyllic cells of plant leaves. Preliminary results of these calculations suggest that the initial chemical interaction in the dry deposition of ozone to plant leaves may actually involve an aqueous-phase reaction with asorbic acid naturally present in the plant's cell-wall

water.

B. High-Ozone Events in the Atlanta Metropolitan Area.

In spite of significant reductions in VOC emissions in the Metro-Atlanta area over the past seven years, the area continues to have problems with regard to oxidant production during periods of stagnation in the summertime and continually fails to be in compliance with the NAAQS on ozone. To determine if the reductions in VOC emissions have had positive impact on ozone production in the Metro-Atlanta area, we have developed an empirical method for determining the amount of ozone produced in Atlanta's urban center during summertime pollution events. The method is described in High Ozone Events in Atlanta, Georgia in 1983 and 1984, (Lindsay and Chameides, Env. Sci. Techn., in press, 1987). A trend analysis of the amount of ozone produced in Atlanta over the past eight years has revealed that the amount of ozone produced is not positively correlated with the VOC emissions in the area (see Figure 2). The results cause one to question the wisdom of continuing to pursue a policy of reducing VOC emissions at ever-increasing costs to the consumer when these reductions have no apparent ameliorative effect on ozone production in Atlanta and perhaps in other cities as well. Work in this area is now focussing on determining through model calculations why VOC emission reductions have, contrary to EKMA-model predictions, not caused a reduction in ozone production; preliminary results suggest that natural emissions of hydrocarbons may play an important but heretofore ignored role in the ozone photochemistry of the city and as a result the system may not be very sensitive to anthropogenic VOC emissions.

C. Diagnostic Analyses of Data Gathered During NASA GTE Field Exercises

This area of study has focussed on the analysis of high resolution, multiple species measurements made during recent NASA GTE field experiments; this work has been carried out with funds from both the subject NSF grant as well as funds from a NASA grant. Efforts in this area during the second year of the granting period have

resulted in the completion of Ozone Precursors and Ozone Photochemistry Over the Eastern North Pacific Ocean During the Spring of 1984 Based on the NASA/CITE 1 Airborne Observations by Chameides and Davis which has been submitted to the Journal of Geophysical Research.

During the first two years of the granting period the following papers have been published or completed with support in part from the subject NSF grant

Chameides, W.L., Photochemistry of the Atmospheric Aqueous Phase, NATO ASI Series, Vol. G6, Ed. W. Jaeschke, Springer-Verlag Berlin Heidelberg, 1986.

Chameides, W.L., Possible Role of NO_3 in the Nighttime Chemistry of a Cloud, J. Geophys. Res., 91, 5331-5337, 1986.

Qin, Yu and W.L. Chameides, The Removal of Soluble Species by Warm Stratiform Clouds, Tellus 38B, 185-229, 1986.

Giorgi, F., and W.L. Chameides, Rainout Lifetimes of Highly Soluble Aerosols and Gases as Inferred from Simulations with a General Circulation Model, J. Geophys. Res., 91, 14,367-14,376, 1986.

Chameides, W.L., D.D. Davis, M.O. Rodgers, J. Bradshaw, S. Sandholm, G. Sachse, G. Hill and G. Gregory, Net Ozone Photochemical Production Over the Eastern and Central North Pacific as Inferred from GTE/CITE 1 Observations During Fall 1983, J. Geophys. Res., 92, 2131-2152, 1987.

Chameides, W.L., D.D. Davis, J. Bradshaw, M.O. Rodgers, S. Sandholm and D.B. Bai, An Estimate of the NO_x Production Rate in Electrified Clouds Based on NO Observations from the GTE/CITE 1 Fall 1983 Field Operation, J. Geophys. Res., 92, 2153-2156, 1987.

Chameides, W.L., Acid Dew and the Role of Chemistry in the Dry Deposition of Reactive Gases to Wetted Surfaces, J. Geophys. Res. 92, 11,895-11,908, 1987.

Lindsay, R.W., and W.L. Chameides, High Ozone Events in Atlanta, Georgia in 1983 and 1984, Env. Science and Technol., in press, 1987.

Stickel, R.E., A.J. Hynes, J.D. Bradshaw, W.L. Chameides, and D.D. Davis, Absorption Cross Sections and Kinetic Considerations of the IO Species as Determined by Laser Flash Photolysis/Laser-Absorption Spectroscopy, J. Phys. Chem., in press, 1987.

Chameides, W.L., and D.D. Davis, Ozone Precursors and Ozone Photochemistry Over the Eastern North Pacific Ocean During the Spring of 1984 Based on the NASA/CITE 1 Airborne Observations, submitted to J. Geophys. Res., in review, 1987.

III. RESEARCH ACTIVITIES PLANNED FOR THE THIRD YEAR

Research activities for the third year of the granting period will include: 1.

Continued development of a one-dimensional model the chemistry and physics of a warm, stratiform cloud; 2. The continued collaboration with scientists at the Geophysical Fluid Dynamics Laboratory aimed at developing parameterizations needed for a three-dimensional global Chemical Transport Model; 3. The continued investigation of the chemistry of dry deposition to wet surfaces with emphasis on the processes involved in the deposition of ozone to the periplasmic fluids of plant leaves; and 4. The continued study of the characteristics and causes of ozone events in the Metro-Atlanta area and other southeastern urban, suburban, and rural regions.

IV. BUDGETARY MATTERS

It is presently estimated that less than 10% of the funds sent thus far to Georgia Tech under the subject grant will be remaining on the anniversary date of the grant. A sum of $102,200 is requested for the third year of the grant. These funds will include 25% support for the Principal Investigator, Professor W.L. Chameides, as well as support for Mr. Ron Lindsay a meteorologist, and Mr. Lin Xing, a Ph.D. candidate in the Atmospheric Sciences Program. Support for a Post-Doctoral scientist to work at GFDL is anticipated from a separate NSF grant.

APPENDIX VI

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
School of Earth & Atmospheric Sciences Georgia Institute of Technology Atlanta, GA 30332		ATM-8600888
	4. Award Period From 5/1/86 To 4/30/89	5. Cumulative Award Amount $276,000

6. Project Title

The Chemistry of Clouds and Its Role in Atmospheric Chemical Cycles

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

The research efforts supported by the three-year grant focussed on four general areas: 1. A time dependent, box model of the coupled gas- and aqueous-phase chemistry of clouds was used to study in-cloud scavenging processes and a variety of chemical mechanisms responsible for the generation of acidic species in cloudwater; 2. The chemistry and physics of the wet removal of soluble gases and aerosols from the atmosphere by rainwater was studied through a hierarchy of models including a 3-dimensional, general circulation model; 3. A mathematical model was used to study the role of aqueous-phase reactions in the dry deposition of reactive gases to vegetation - one such study indicated that reactions of ascorbic acid in mesophilic cells can act to protect leaves from the harmful effects of ozone deposition; and 4. A combination of diagnostic analyses and model calculations were used to study the relative roles of natural and anthropogenic hydrocarbons in the generation of urban photochemical smog - these studies suggested that in sylvan cities such as Atlanta, natural hydrocarbons can have a significant effect on oxidant levels and thus that control strategies which focus on NO_x reductions rather than hydrocarbon reductions may be more effective.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses					
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results					
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Dr. William L. Chameides		6/4/90

PART IV - SUMMARY DATA ON PROJECT PERSONNEL

NSF Division: Atmospheric Sciences

The data requested below will be used to develop a statistical profile on the personnel supported through NSF grants. The information on this part is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. NSF requires that a single copy of this part be submitted with each Final Project Report (NSF Form 98A); however, submission of the requested information is not mandatory and is not a precondition of future awards. If you do not wish to submit this information, please check this box ☐

Please enter the numbers of individuals supported under this NSF grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

*U.S. Citizens/ Permanent Visa	PI's/PD's		Post-doctorals		Graduate Students		Under-graduates		Precollege Teachers		Others	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
American Indian or Alaskan Native												
Asian or Pacific Islander					1	1						
Black, Not of Hispanic Origin												
Hispanic					1							
White, Not of Hispanic Origin	1				2	1						1
Total U.S. Citizens	1				2	1						1
Non U.S. Citizens					2	1						
Total U.S. & Non-U.S. ..	1				4	2						1
Number of individuals who have a handicap that limits a major life activity.												

*Use the category that best describes person's ethnic/racial status. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintains cultural identification through tribal affiliation or community recognition.

ASIAN OR PACIFIC ISLANDER: A person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands. This area includes, for example, China, India, Japan, Korea, the Philippine Islands and Samoa.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

Grant No. ATM-8600888

THE CHEMISTRY OF CLOUDS AND ITS ROLE IN ATMOSPHERIC CHEMICAL CYCLES

Final Report

During the third and final year of the subject grant work continued on the development of a one-dimensional model to simulate the chemistry and physics of warm stratiform clouds. We have also continued our collaboration with scientists at the Geophysical Fluid Dynamics Laboratory at Princeton University in the development of parameterizations for a three-dimensional global Chemical Transport Model and work has continued on the investigation of the chemistry of dry deposition to vegetative surfaces. The continued study of the characteristics and causes of ozone events in the Metro-Atlanta area and other southeastern urban, suburban, and rural regions has developed into a major ongoing project.

The following papers were published during the granting period:

1. Lin Xing and W.L. Chameides, Model simulations of rainout and washout from a warm stratiform cloud, *J. Atmos. Chem.*, **10**, 1-26, 1990.

2. W.L. Chameides, D.D. Davis, G.L. Gregory, G. Sachse, A.L. Torres, Ozone precursors and ozone photochemistry over the eastern North Pacific Ocean in spring based on the GTE/CITE 1 airborne observations, *J. Geophys. Res.*, **94**, 9799-9808, 1989.

3. W.L. Chameides, The chemistry of ozone deposition to plant leaves: The role of ascorbic acid, *Environmental Science & Technology*, **23**, 595-600, 1989.

4. J.S. Levine, C.P. Rinsland, W.L. Chameides, P.J. Boston, W.R. Cofer, III and P. Brimblecombe, Trace gases in the atmosphere of Mars: An indicator of microbial life, Reprinted from *The Case for Mars III: Strategies for Exploration - Technical*, Vol. **75**, *Science and Technology Series*, 277-282, 1990.

5. R.W. Lindsay, W.L. Chameides and J.L. Richardson, Ozone trends in Atlanta: Have emissions controls been effective? *J. Air Pollut. Control Assn.*, **39**, No. 1, 40-43, 1989.

6. W.L. Chameides, R.W. Lindsay, J.L. Richardson and C.S. Kiang, The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study, *Science*, **241**, 1473-1475, 1988.

7. R.E. Stickel, A.J. Hynes, J.D. Bradshaw and W.L. Chameides, Absorption cross sections and kinetic considerations of the IO species as determined by laser flash photolysis/laser-absorption spectroscopy, *J. Phys. Chem.*, **92**, 1862-1864, 1988.

8. R.W. Lindsay and W.L. Chameides, High ozone events in Atlanta, Georgia in 1983 and 1984, *Environmental Science & Technology*, **22**, 426-431, 1987.

9. W.L. Chameides, Acid dew and the role of chemistry in the dry-deposition of reactive gases to wet surfaces, *J. Geophys. Res.*, **92**, 11,895-11,908, 1987.

10. W.L. Chameides, D.D. Davis, M.O. Rodgers, J.D. Bradshaw, S.T. Sandholm, G. Sachse, G. Gill, G. Gregory and R. Rasmussen, Net ozone photochemical production over the eastern and central North Pacific as inferred from GTE/CITE 1 observations during the fall, 1983, *J. Geophys. Res.*, **92**, 2131-2152, 1987.

11. W.L. Chameides, D.D. Davis, J.D. Bradshaw, M.O. Rodgers, S.T. Sandholm and D.B. Bai, Brief Report: An estimate of the NO_x production rate in electrified clouds based on NO observations from the GTE/CITE 1 fall, 1983 field operation, *J. Geophys. Res.*, **92**, 2153-2156, 1987.

The following papers are in press:

1. W.L. Chameides, D.D. Davis, J.D. Bradshaw, S.T. Sandholm, M.O. rodgers, B. Baum, B. Ridley, M.A. Carroll, G.L. Gregory, H.I. Schiff, D.R. Hastie, A. Torres and E. Condon, Observed and model-calculated NO_2/NO ratios in tropospheric air sampled during the NASA GTE/CITE 11 field study, *J. Geophys. Res.*, in press, 1990.

2. H. Berresheim, M.O. Andreae, G.P. Ayers, R.W. Gillett, J.T. Merrill, V.J. Harris and W.L. Chameides, Airborne measurements of dimethylsulfide, sulfur dioxide, and aerosol ions over the southern ocean south of Australia, *J. Atmos. Chem.*, in press, 1990.

3. C. Cardelino and W.L. Chameides, Natural hydrocarbons, urbanization and urban ozone, *J. Geophys. Res.*, in press, 1990.

The folowing graduate students are receiving, or have received, partial support from the subject grant:

Carlos Cardelino	Ph.D.
Lin Xing	Ph.D.
Jiangfen Zheng	Ph.D.
William Hutzell	Ph.D.
Ira Leifer	Ph.D.
Jennifer Richardson	M.S.