...TITUTE OF TECHNOLOGY | **OFFICE OF CONTRACT ADMINISTRATION**

PROJECT ADMINISTRATION DATA SHEET

[XX] ORIGINAL [ ] REVISION NO. ______

Project No. G-35-662 (R6126-0A0) GTRC/~~GIT~~X DATE 5 / 9 / 86

Project Director: George Chimonas School/~~Lab~~ Geophysical Science

Sponsor: National Science Foundation

Type Agreement: Grant No. ATM-8519883

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

Sponsor Amount:

	This Change	Total to Date
Estimated:	$	$ 40,500
Funded:	$	$ 40,500

Cost Sharing Amount: $ 5,607 Cost Sharing No: E-35-366

Title: Theoretical Studies of Waves in the Atmospheric Boundary Layer

ADMINISTRATIVE DATA OCA Contact John B. Schonk X4820

1) Sponsor Technical Contact:	2) Sponsor Admin/Contractual Matters:
Ronald Taylor	Hugh Lee Lyon
National Science Foundation	National Science Foundation
AAEO/ATM	DGC/AAEO
Washington, DC 20550	Washington, DC 20550
202/357-7624	202/357-9621

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.

MAY 1986 RECEIVED SUPPORT SERVICE OCA

COPIES TO: SPONSOR'S I. D. NO. ______

Project Director	Procurement/EES Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	[redacted]	Project File
Accounting	Research Communications (2)	Other Jones/Legal

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 12/20/88

Project No. G-35-662 Center No. R6126-0A0

Project Director G. Chimonas School/Lab Geo. Sci.

Sponsor National Science Foundation

Contract/Grant No. ATM-8519883 GTRC XX GIT ___

Prime Contract No. N/A

Title Theoretical Studies of Waves in the Atmospheric Boundary Layer

Effective Completion Date 10/31/88 (Performance) 1/31/89 (Reports)

Closeout Actions Required:

- X None
- ___ Final Invoice or Copy of Last Invoice
- ___ Final Report of Inventions and/or Subcontracts
- ___ Government Property Inventory & Related Certificate
- ___ Classified Material Certificate
- ___ Release and Assignment
- ___ Other ___

Includes Subproject No(s). ___

Subproject Under Main Project No. ___

Continues Project No. ___ Continued by Project No. ___

Distribution:

- X Project Director
- X Administrative Network
- X Accounting
- X Procurement/GTRI Supply Services
- X Research Property Management
- ___ Research Security Services
- x Reports Coordinator (OCA)
- x GTRC
- x Project File
- x Contract Support Division (OCA)
- ___ Other ___

G35-662

Item 1. Progress Report On ATM-8519883

Results to date have been extremely encouraging. We proposed a theoretical model for waves observed to accompany a moving storm cell. The event was of particular interest because of the extreme amplitude of the waves and the intense boundary-layer turbulence that accompanied them. Following the procedure outlined in the proposal, we performed a detailed study of the normal modes supported by the wind and temperature structure of the local atmosphere. As suspected, the spectrum included waves that had all the characteristics of the observations. We then constructed the detailed bow wave forced by the passage of the storm. This provided a faithful representation of the observed disturbance, confirming our hypothesis on the nature and origin of the event.

We then performed a sensitivity analysis. Atmospheric profiles are obtained with limited accuracy, and we need guidelines for monitoring large-amplitude wave events. We found that the current accuracy of observing systems is barely sufficient for the needs of linearized wave analysis, and is far below that required for non-linear studies. In particular, the different characteristics of solitary waves and linearized normal modes are too small to be distinguished at the present time. Claims that observations "see" solitary waves (rather than large-amplitude dispersive normal modes) are simply not justified. This does not reject the solitary wave concept--rather it establishes the need for better observing networks and a calm appraisal of the more spectacular wave events.

Item 2. Research Plans for the Next Funding Year.

As outlined in the original proposal, we have identified a problem in mixed Kelvin-Helmholz/Rayleigh-Taylor stability that is probably a realistic improvement on conventional stability studies. This problem is now under investigation.

However, the proposal referees recommended that "more-conventional" meteorological studies be added to the group's activities. Accordingly, we are also undertaking a study of the contribution of wave drag to the boundary-layer surface drag. This is a small-scale version of the mountain-wave drag that is proving so important in larger-scale meteorology. There is a also considerable body of related information in the theory of ship-drag.

Preliminary results suggest that in moderately undulating terrain the wave-drag may be as great as the conventional "flat-surface" drag.

These two problems will more-than-utilize the time and funds supplied by the grant.

Item 3. There are no project personnel changes.

Item 4. Chimonas G., and C.J.Nappo, 1986: A thunderstorm bow wave. In press, J.Atmos.Sci.

An updated list of publications following from recent NSF support has been submitted with available reprints.

Item 5. At this time the PI has no other funding current or pending.

Item 6. Attached.

Item 7. There will be no residual funds from the current grant period.

G-35-662

MW

Georgia Institute of Technology

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA

ATLANTA, GEORGIA 30332

SCHOOL OF GEOPHYSICAL SCIENCES

404/894-3893

Dec - 12 - 1988

Dear Mr. Watt:

Please find enclosed final report for an N.S.F. grant.

Sincerely

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
Georgia Institute of Technology Atlanta, GA 30332-0420	Atmospheric Sciences/Meteor	ATM-8519883
	4. Award Period From 5-01-86 To 10-31-88	5. Cumulative Award Amount $90,000

6. Project Title

Theoretical Studies of Waves in the Atmospheric Boundary Layer

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

The grant supported a program of basic research and student training on the topic of conditions in the atmospheric boundary layer. A large number of publications resulted (see b.) and two Doctoral theses are expected within a few months.

The main thrust of the research has been to identify the small-scale dynamics that provides the mixing and turbulence in the lower atmosphere. Much of this activity is related to wave activity, and we have identified and modeled waves that travel along with storms like bow waves from a ship, waves that cause the wind to slow down over hilly terrain (and problably also cause a lot of the mixing of pollution in such regions), and waves that can travel about with the wind.

The concern with the way the boundary layer affects the atmosphere above it has led us to study the relationship between storm strength and surface conditions, namely surface humidity and temperature. Although it is obvious that there is some relation between storms and humidity, our study is the first to show that there is a simple thermodynamic law relating the state of the tropopause (the top of the well-mixed atmosphere) and a single surface parameter which we have called the effective potential temperature.

The research has been very productive, and is continuing with new NSF support.

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				✓	Mid 1989
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
George Chimonas		12/12/88

b. Publications Acknowledging The NSF Support

Chimonas G., and R. Rossi (198-). On the relationship between the midlatitude tropopause potential temperature and the thermodynamics of surface air. Submitted to J.Atmos.Sci.

Chimonas G., and C. J. Nappo (1989). Wave drag in the planetary boundary layer over complex terrain. Accepted for publication in Boundary Layer Meteor.

Chimonas G., and R. Rossi (1987). The relationship between tropopause potential temperature and buoyant energy in storm air. J.Atmos.Sci., 44, 2902-2911.

Chimonas G. (1987). On the depletion of ozone by a height change of the tropical tropopause. J.Geophys.Res., 92, 10,897-10,902.

Chimonas G., and C.Nappo (1987). A thunderstorm bow wave. J.Atmos.Sci., 44, 533-541.

Chimonas G. (1986). Wave associated density disturbances at space vehicle reentry heights. J.Geophys.Res., 91, 14,557-14,560.

Chimonas, G. (1986). On the combined Rayleigh Kelvin-Helmholtz Problem. Phys.Fluids, 29, 2061-2066.

Chimonas, G., and G. Kallos (1986). Flow dynamics and stability in a severe rainband. J.Atmos.Sci., 43, 1505-1516.

Chimonas, G. and C.O.Hines (1986). Doppler Ducting of Atmospheric Gravity Waves, J. Geophys. Sci., 91, 1219-1230.

e. Technical Description and Results from NSF Project

NSF Atmospheric Sciences--Meteorology ATM-8519883.
$90,000, 5/1/86 to 4/30/88.
Theoretical Studies of Waves in the Atmospheric Boundary Layer.

The research initiated a program of investigation and graduate-student training under NSF support, which now continues under

NSF Atmospheric Sciences--Meteorology ATM-8804623.
$143,000, 8/1/88 to 1/31/90.
Studies of waves in the lower atmosphere.

Summary of Results of Completed Work

1. **Boundary-layer waves associated with a storm.** A model was proposed for waves observed to accompany a moving storm. The event was of particular interest because of the extreme amplitude of the waves and the turbulence that accompanied them. Computations showed that the local atmospheric structure supported a spectrum of normal modes including waves that matched the observations. The observations were well explained as a storm bow wave.

A sensitivity analysis of the wave system was performed to see if experiments could be designed to yield more insight into the mechanics of the disturbance. We discovered that current observing facilities are barely able to meet the needs of linearized theory, and are certainly not capable of discriminating between the various nonlinear models that have been proposed. This shows that claims of observed solitary-wave properties are at present unprovable.

2. **The surface drag boundary layers with undulating topography.** This is a novel small-scale application of "mountain-wave drag" familiar in many larger-scale meteorological applications. Our results indicate that even gently-rolling countryside experiences a surface wave drag that can be as large as the conventional surface roughness drag.

3. **Doppler ducting of atmospheric gravity waves.** Jet-like winds are found at many levels and scales of the atmosphere--from the boundary layer to the thermosphere. This study showed that every jet (and also every wind minimum) is a duct that supports a continuous spectum of gravity-wave modes. There is a growing awareness in meteorology that gravity waves transport significant amounts of momentum from one region of the atmosphere to another. These transports may be in the horizontal plane if ducted modes are available.

4. Tropopause potential temperature and surface air conditions. The troposphere is the region of active overturning. Computations of its temperature profile use a parameterization called convective readjustment to reproduce observations. It is understood that convection places limits on the atmospheric lapse rates, and these are included in an empirical manner in radiative-convective models. Our study investigates some of the physics behind the parameterization by relating the thermodynamic properties of the upper and lower boundaries of the troposphere. It computes the potential temperature of the tropopause from the characteristics of boundary-layer air. The computation provides a successful local relationship for mean tropical conditions and summer conditions in the Eastern U.S. For the midlatitudes during the three non-summer quarters the relationship finds that the tropopause characteristics are given by the surface conditions in storm regions back along the air trajectory of the upper-level flow.

5. The impact of surface conditions on the ozone content of the atmosphere. The division of the lower atmosphere between stratosphere and troposphere is closely related to the upper altitude at which convective readjustment is important. From the work described above in 4, this in turn is controlled by the thermodynamic state of boundary-layer air. The marked drop in turbulent activity at the tropopause affects the ozone content of the atmosphere, since the quiescent region at the base of the stratosphere protects the ozone from downward mixing to destruction at the surface. Climate changes that significantly modify the thermodynamic state of the boundary-layer air could therefore result in changes in the ozone column. This work models the influence of tropical tropopause height on the ozone.

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.
nerican Indian or Alaskan Native												
ian or Pacific Islander												
ack, Not of Hispanic Origin												
spanic												
nite, Not of Hispanic Origin	1				2							
U.S. Citizens					2							
J.S. Citizens	1											
U.S. & Non-U.S. ..	1				2							
ber of individuals o have a handicap at limits a major 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.