	TION PAGE	Chille No. 0704.0100	
	ersee I nour der researne, including the time har revenung intervetiene, intervetiene coming dete seurce, the collection of information, Sand comments reparting the burden comment or any other search to the I Wesnington recedulariers Service, Orectories for information Overseare and any other search to the Assegment and Sudget, Passiver's Assures Argent (0754-0128), Wesnington, OC 2012		
1. August	ANNULAT OF	AND DATES COVERED	
A TITLE AND SUBTITLE		S. PUNDING NUMBERS	
CLOUDSTHEIR PREDICTION AND SIMU	JALTION	AFOSR-91-0269 PE - 61102F	
C AUTHOR(S)		PR - 2310 $TA - CS$	
Dr William R. Cotton			
7. PERFORMING ORGANIZATION NAME(S) AND ADD	MESS(ES)	B. PERFORMING ORGANIZATION	
Department of Atmospheric Science Colorado State University	2		
Fort Collins, CO 80523	AFOSR-	TR. 92 0280	
S. SPONSORING / MONITORING AGENCY NAME(S) AN	ND ADDRESS(ES)	18. SPONSORING/MONITORING AGENCY REPORT MANUAR	
AFOSR/NL	DTIC	Y	
Building 410 Bolling AFB DC 20332-6448	DIK	<u></u>	
20112ng m 2 20 20002-0440	ELECTE		
11. SUPPLEMENTARY NOTES	MAY 2 0 1992		
	VA		
124. DISTRIBUTION / AVAILABILITY STATEMENT		126. DISTRIBUTION CODE	
Approved for public release; dist	ribution unlimited		
13. ABSTRACT (Maximum 200 words)			
Piotr Flatau has nearly completed	a new comprehensive tw	o-stream radiative transfer	
(PT) and which includes aloud wa	tor and ice costering	properties The code is	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud	ter and ice scattering microphysics module.	properties. The code is Several algorithmic improve-	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three	ter and ice scattering microphysics module. major components of th	properties. The code is Several algorithmic improve- e RT package: molecular	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver h	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticinated in the FIRE I	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NCM do	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NGM da ures, and relevant meter	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information.	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict <u>Piotr Flatau and Graeme</u> Stephens	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver has ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I l2-December 12). This casting mode, ans data ially tailored for mesos athered MAPS and NGM da ures, and relevant meter also served as mission	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information. planning scientists for the	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict Piotr Flatau and Graeme Stephens 14 SUMMET THANS NCAR Saberliner airc	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NGM da ures, and relevant meter also served as mission raft.	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information. planning scientists for the	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict Piotr Flatau and Graeme Stephens 14 SUBSCI TIME NCAR Saberliner airc	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NGM da ures, and relevant meter also served as mission raft.	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information. planning scientists for the 15. NUMBER OF FAGES	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict Piotr Flatau and Graeme Stephens 14 SUBJECT TIME NCAR Saberliner airc	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver has ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I l2-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NGM da ures, and relevant meter also served as mission raft.	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information. planning scientists for the 15. NUMBER OF PAGES 14. PAGE COOL	
(RT) code which includes cloud wa interfaced to the RAMS bulk cloud ments have been made to all three gases, single scattering properti Reduction and elimination algorit has been efficiently written to t issues. New interfaces to LOWTRA properties are included using the members of our research group par in Coffeyville, Kansas (November mission. RAMS was used in a fore cases studies including data spec Intensive Observing Period. We g project, collected satellite pict Piotr Flatau and Graeme Stephens 14. SUBJECT THEMS NCAR Saberliner airc (U)	ter and ice scattering microphysics module. major components of the es of clouds, and radia hms for the RT solver ha ake advantage of vector N7 and MODTRAN are also anomalous diffraction ticipated in the FIRE I 12-December 12). This casting mode, ans data ially tailored for meso athered MAPS and NGM da ures, and relevant meter also served as mission raft.	properties. The code is Several algorithmic improve- e RT package: molecular tive transfer solver. ave been developed. The code ization and parallelization provided. Single scattering theory (ADT). A number of I Cirrus field experiment was an extremely successful were gathered for future scale modeling during the ta for all the days of the orological information. planning scientists for the 15. NUMBER OF PAGES 14. INCL COOL ISSUERATION 24. UNITATION OF ADSTRACT (U) (U)	

,

Introduction

This represents a Research Progress and Forecast Report on our AFOSR contract #AFOSR-91-0269 for June 1991 to December 1991.

۲.

2 5 15 025

Research completed

Piotr Flatau has nearly completed a new comprehensive two-stream radiative transfer (RT) code which includes cloud water and ice scattering properties. The code is interfaced to the RAMS bulk cloud microphysics module. Several algorithmic improvements have been made to all three major components of the RT package: molecular gases, single scattering properties of clouds, and radiative transfer solver. Reduction and elimination algorithms for the RT solver have been developed. The code has been efficiently written to take advantage of vectorization and parallelization issues. New interfaces to LOWTRAN7 and MODTRAN are also provided. Single scattering properties are included using the anomalous diffraction theory (ADT).

A number of members of our research group participated in the FIRE II Cirrus field experiment in Coffeyville, Kansas (November 12-December 12). This was an extremely successful mission. RAMS was used in a forecasting mode, and data were gathered for future cases studies including data specially tailored for mesoscale modeling during the Intensive Observing Period. We gathered MAPS and NGM data for all the days of the project, collected satellite pictures, and relevant meteorological information. Piotr Flatau and Graeme Stephens also served as mission planning scientists for the NCAR Saberliner aircraft.

Forecast Report and planned research

We are now in the process of acquiring data for case study simulations to develop and test the ability of RAMS to forecast clouds.

The November 25 and 26 and December 5 and 6 FIRE II cases have been selected as candidates for refining and testing RAMS ability to forecast cirrus clouds. Moreover, on several days, including 25 November, both cirrus clouds and low-level stratus clouds were observed. This will offer the opportunity to test RAMS ability to predict both cloud forms. Both Piotr Flatau and Jerry Harrington, a new M.S. student will be concentrating on cirrus cloud prediction.

For stratus cloud prediction we are selecting cases from the FIRE I stratus experiment in July 1987 off of the California coast. Dave Mocko, a new M.S. student is concentrating on the stratus cases. For deep convective cloud prediction we are concentrating on the 1991 CAPE cases over Florida. We plan to coordinate with Kevin Knupp, University of Alabama-Huntsville in the analysis of those cases. Ben Edwards, an AFIT M.S. student will concentrate on cumulus cloud forecasting.

We plan to finish up the radiative transfer parameterization and test and evaluate it in some of the FIRE cirrus cases.



1

Submitted publications

Work on mesoscale RT has been submitted (Flatau et al., 1992).

The simulation of the 28 October FIRE I cirrus case is nearly ready for submission (Air Force approval for publication via AFOSR is now being sought).

The technical report and related publication has been completed (Flatau et al., 1991).

		the second se		
Accesio	n For			
NTIS	CRA&I	d d		
DTIC	EAT			
Unanno	unced	[]		
Justific	ation			
By Dist.ibution /				
Availability Codes				
Dist	Avait a Spe	rict j or cial		
A-1				



References

Flatau, P. J., W. R. Cotton, and G. L. Stephens, 1992: Clouds and two-stream radiative transfer approximation — algorithms, codes, and error analysis. Paper submitted for presentation at the 11th international conference on clouds and precipitation. Montreal, Canada.

r

Flatau, P. J., R. L. Walko, and W. R. Cotton, 1991: Polynomial fits to saturation vapor pressure. Paper submitted to Journal of Applied Meteorology.