NASA/CR-97- 205864

Progress Report on Period 1 of NAG-1-1748

Development and Validation of a Polar Cloud Algorithm for CERES

The objectives of this phase of the project, as described in the original proposal, were to develop an algorithm for diagnosing cloud properties over snow- and ice-covered surfaces using satellite radiances from the Advanced Very High Resolution Radiometer (AVHRR) and High-resolution Infrared Radiation Sounder (HIRS) sensors. This algorithm will include a cloud mask, and additional characteristics such as cloud phase, amount, and height. The SIVIS software package, developed as a part of the CERES project, is the primary tool being used to determine relationships between satellite radiances and cloud properties.

Polar clouds present some unique challenges not encountered in other regions of the globe, as they are often difficult to detect in both visible and infrared satellite imagery. Contrast between clear and overcast scenes is small because clouds have little effect on the planetary albedo of a snow surface, and clouds often reside below surface-based temperature inversions, resulting in little contrast in the infrared wavelengths, as well. The top-of-the-atmosphere cloud forcing, consequently, is much smaller than in other regions. The effect of clouds on the *surface* energy balance, however, is profound, especially in winter. Clouds greatly increase the amount of downwelling infrared radiation, and substantially reduce the amount of energy lost by the snow/ice surface.

Period 1 has been devoted to developing a nighttime cloud mask over snow and ice using AVHRR radiances only, as the SIVIS software package does not yet have the capability to incorporate HIRS data in its cloud mask tool. This shortcoming is in the process of being remedied. Even with the limited information contained in three AVHRR channels, the cloud mask appears to be performing well, capturing both the “normal” clouds that are colder than the background as well as the “abnormal” clouds that are warmer than the surface. These abnormal clouds occur frequently in polar regions and represent the greatest challenge in determining high-latitude cloud characteristics. The cloud mask relies on differences in brightness temperatures between the AHVRR channels 3, 4, and 5, which correspond to wavelengths near 3.7, 11, and 12 µm. Cloud particles exhibit different absorption and emission characteristics at these wavelengths depending on the cloud lapse rate, cloud thickness, and particle phase. It is these properties that are exploited to detect clouds and estimate their characteristics. Figure 1 illustrates the differences in water and ice absorption versus wavelength, along with selected AVHRR and HIRS. Table 1 presents a summary of the AVHRR channels used for the cloud mask, as well as those from HIRS that, when they become available, will aid in determining additional cloud properties. The notion is that two

Figure 1: Absorption coefficients of ice (dashed line) and water (dotted) versus wavelength. Selected HIRS and AVHRR channels are indicated.

Table 1: Summary of AVHRR and HIRS channels used to infer cloud properties.

Channels	Advantages	Disadvantages
AVHRR 3-5 (3.7 - 12 μm)	• High sensitivity to clouds • IR scattering in Ch. 3 -- aids detection of water clouds	• Solar contamination in daylight • IR scattering in Ch. 3 -- complicates interpretation of signal • Low signal-to-noise in Ch. 3 over polar areas
AVHRR 4-5 (11 - 12 μm)	• Works day and night • Little IR scattering	• Less sensitivity than 3-5
HIRS 19 - 8 (3.7 - 11 μm)	• Similar to AVHRR 3-4 • Ch. 19 has less noise than AVHRR Ch. 3 • Use to remove "noise clouds" detected by AVHRR Ch. 3-5	• Lower resolution than AVHRR (17 km versus 5 or 1 km)
HIRS 19-18 (3.7 - 4 μm)	• Detects water clouds in day and night	• Solar contamination complicates interpretation
HIRS 10-8 (8.3 - 11 μm)	• Detects cloud phase in day and night	• Some ambiguity due to weighting function peak differences
HIRS 6-15 (13.7-4.46 μm)	• Used to estimate cloud thickness	• Saturates for thick clouds

channels with differing amounts of absorption by cloud particles will change relative to each other as the cloud characteristics change. For example, a cirrus cloud will result in a positive difference between AVHRR channels 3 and 5 at night because clouds are more transparent at 3.7 μm, resulting in more energy from deeper within the cloud (where it is warmer) to reach the satellite in that channel. The opposite would occur in an abnormal cloud, resulting in a negative 3-5 difference.

Several AVHRR orbits from NOAA-9 during October 1, 1986, were used to develop and test the cloud mask. A variety of nighttime situations over Arctic and Antarctic sea ice and snow illustrate several typical cloud types, including normal clouds that are colder than the surface and abnormal clouds that are either warmer than or nearly indistinguishable from the surface in infrared imagery. Figure 1 presents an example of an orbital swath over the Laptev and East Siberian Seas, north of Siberia. The first image (a) is a false-color combination of AVHRR channels 5, 3-5, and 4-5. The cold, high clouds associated with a frontal system are clearly visible as yellow and green areas, while dark purple areas represent warm, low clouds. Figure 1b shows the result of the cloud mask using channels 3, 4, and 5, with components of the cloud mask shown in 1c and 1d. Magenta areas are cold clouds detected by the difference $4 - 5 > 1$ K, cyan areas are warm clouds detected by $4 - 5 > 0$ K, and yellow areas are warm clouds detected by $3 - 5 > -2$ K. The noise in

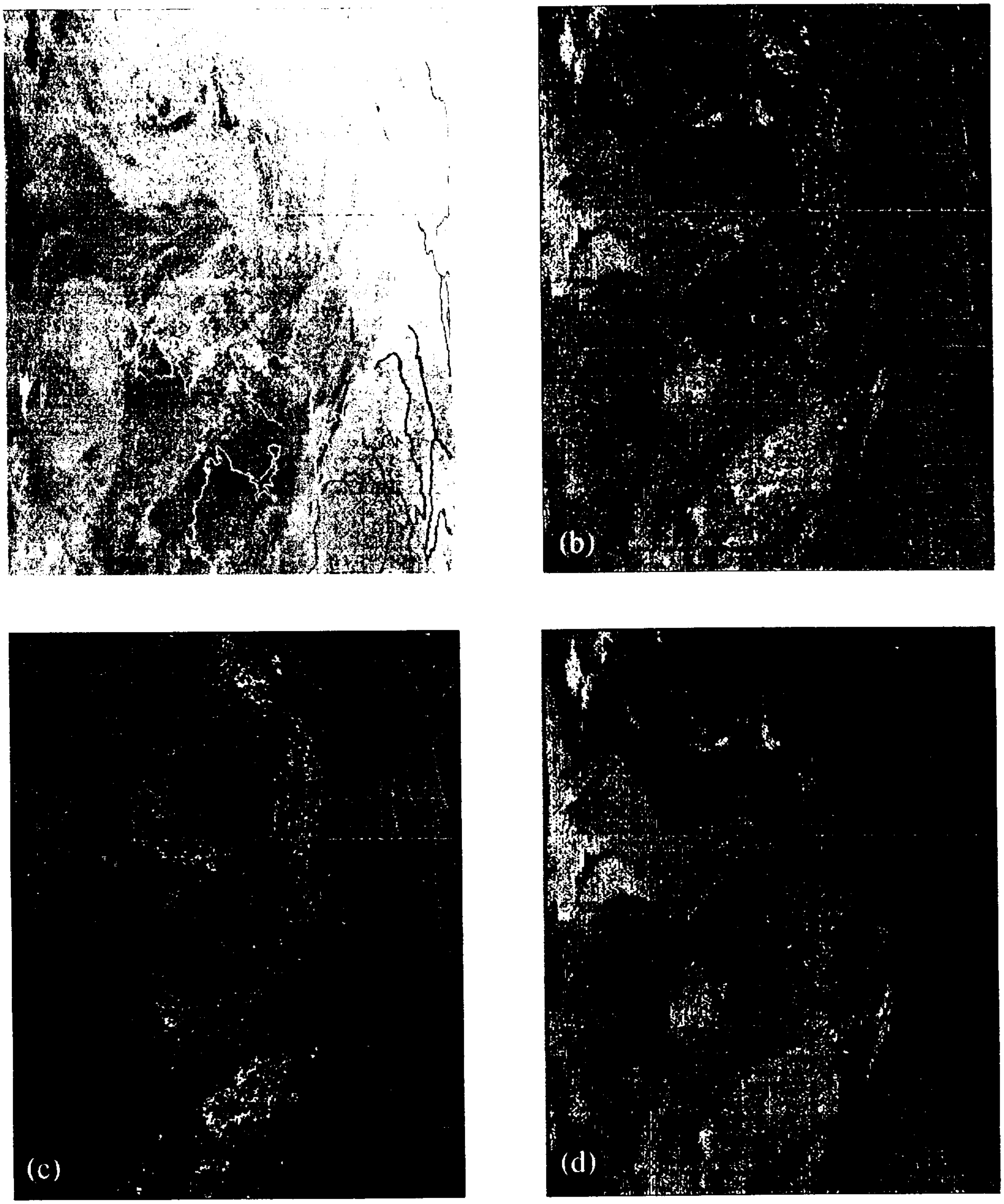

Figure 1: Example of cloud mask results for the Arctic Ocean north of Siberia at 22 UTC on 1 October 1986. (a) is a false-color combination of AVHRR channels 5, 3-5, and 4-5. (b) is the cloud mask for all channels. (c) shows cold (magenta) and warm (cyan) clouds from 4-5, and (d) shows warm clouds from 3-5

channel 3 results in some random cloud detection errors that should be removed by using comparable HIRS channels, which have a much higher signal to noise ratio owing to their larger pixel sizes. Otherwise the cloud detection appears to capture most of the clouds discernible by eye in the multi-channel image. Further analysis using surface-based observations may provide additional information, but surface based cloud observations, particularly during nighttime, are problematic. Not only is it often difficult for observers to see clouds at night, but surface observations are a bottom-up perspective while satellites see from the top down.

Another interesting example is presented in Figure 2, which shows the area around Greenland. This is a challenging case because of the low stratus cloud over the unfrozen northern Baffin Bay that is apparently being advected onto the Greenland ice sheet just south of Thule (**X** in Figure 2a). The cloud is apparently transforming from one that is colder than the water surface to one that is colder than the ice surface as it ascends the ice cap. The cloud mask easily captures the low stratus over open water and the warm cloud over the ice, but has some difficulty identifying it in its transition period. The addition of HIRS data should improve the cloud mask's ability to detect this cloud.

In summary, efforts on this project to date have produced what appears to be a feasible nighttime cloud mask for polar regions that is based on AVHRR data alone. The next step requires modifications to the SIVIS analyzation tool, which are in progress at present. These modifications will access information from the HIRS instrument by the cloud mask tool, which will not only improve the cloud mask accuracy, but will also allow the estimation of cloud phase and thickness. Effort during the remainder of this funding period and Period 2 will be focused on accomplishing these goals, as described in more detail in the original proposal.

Figure 2: Cloud mask results for an area near Greenland at 0900 UTC on 1 October 1986. Colors are as described in Figure 1, with the addition of 3-5 > 8 shown in red.

Revised Budget to NASA/Langley Atmospheric Research Division

Clouds and the Earth's Radiant Energy System (CERES) Program

Title: Development and Validation of a Polar Cloud Algorithm for CERES

NASA Grant No.: NAG-1-1748

Organization: Institute of Marine and Coastal Sciences
PO Box 231, Rutgers University
New Brunswick NJ 08903-0231

Principal Investigator: Dr. Jennifer Francis (908) 932-7684

Business contact: Ms. Aline Kelsey (908) 932-6555 ext. 511

Date of Submission: 22 May 1997

Proposed Start Date: 1 September 1997

Project Duration and Resources Requested:

Period 2: 1 September 1997 - 31 August 1998 $29,615

Other organizations evaluating this proposal: none

____

PI: Jennifer Francis
Inst. of Marine and Coastal Sci.
PO Box 231, Rutgers University
New Brunswick NJ 08903-0231

____

Frederick Grassle, Director
Inst. of Marine and Coastal Sci.
PO Box 231, Rutgers University
New Brunswick NJ 08903-0231

____

Andrew B. Rudczynski
Associate V.P. for Research
Policy and Administration
PO Box 1179
Piscataway NJ 08855-1179

Revised Budget Summary for Period 2

CERES: NAG-1-1748	**Period 2:** 1 Sept. 1997 to 30 Aug. 1998	
Salary P.I. Francis Fringe @ 20% Total salary and fringe	 2.5 months @ 4,600/month	 $11,500 2,300 13,800
Miscellaneous expenses: Computer equipment Supplies Telecommunications Travel Total Misc. expenses	 2 domestic U.S. round-trips	 1700 550 430 3000 5450
Total direct costs		19,480
Indirect Cost (excluding software) Rutgers overhead @ 57%		 10,135
TOTAL		29,615

RUTGERS

ENDORSEMENT OF AN APPLICATION FOR EXTERNAL FUNDING

THE ENDORSEMENT PROCEDURE MUST BE COMPLETED BEFORE A PROPOSAL IS SUBMITTED TO THE FUNDING AGENCY. PLEASE REFER TO THE ATTACHED INSTRUCTION SHEET FOR SPECIFIC DETAILS WHEN SUBMITTING THIS FORM FOR UNIVERSITY ENDORSEMENT. APPEND TO IT THE ORIGINAL PROPOSAL AND ONE COPY (TO BE RETAINED IN ORSP/OCLTT). THIS FORM MUST BE TYPED.

97 1805
LOG NUMBER

PROJECT INFORMATION:

01 Principal Investigator/Project Director: FRANCIS (Last) JENNIFER (First) A (MI)

02 Is the PI/PD a full-time faculty member? YES ☒ NO ☐ [If NO, attach required letter]

03 Co-investigator: (Last) (First) (MI)

04 Project Title (max. 100 characters, including spaces): Cloud Parameters Retrieved from HIRS and ... Data: Algorithm Development

05 Project period from 9/1/97 (MM DD YY) to 8/31/98 (MM DD YY)

06 Funding Agency: NASA Langley/Atmospheric Sciences Division
[Please refer to the instructions for clarification when completing this item]

07 University Department or Unit where the grant will be administered: IMCS
Campus: CAMDEN ☐ NEWARK ☐ NEW BRUNSWICK ☒ Account Number: 2- 0 0 8 6 8

08 University Department or Unit where salary of PI/PD is charged: IMCS
Campus: CAMDEN ☐ NEWARK ☐ NEW BRUNSWICK ☒ Account Number: 2- 0 0 8 6 8

09 For faculty only: If different from either 07 or 08 above, Department or Unit where PI/PD is tenured (tenure track):
Campus: CAMDEN ☐ NEWARK ☐ NEW BRUNSWICK ☐ Account Number: 2-

10 If Indirect Cost Recycling (ICR) credit will be shared with another department or unit, indicate the percentage to be credited to each:
Dept./Unit Account #: %: Dept./Unit Account #: %:

PROJECT CHARACTERISTICS:

11. Application Type: New ☐ Continuation ☐ Renewal ☐ Supplement

12. Support requested primarily for (check one): Research ☒ Instruction ☐ Training ☐ Fellowship ☐ Public Service ☐ Other ☐

13. Will this project fund:
Post-Doctoral Associates/Fellows? If YES, how many? YES ☐ NO
GA's/TA's? If YES, how many? YES ☐ NO
Undergraduate Students? If YES, how many? YES ☐ NO

14. Does the project involve research with human subjects? YES NO
If yes, provide approved protocol number (Access No.)
or date request for review or exemption was filed

15. Does the project involve the use of live vertebrate animals? YES NO
If yes, provide the approved protocol number

16. Does the project involve the use of Class III or IV LASERS, ionizing radiation producing devices, microwave devices, radioactive materials, biohazardous microorganisms or agents, recombinant DNA molecules, chemical carcinogens, or other toxic or hazardous chemicals? YES NO

17. Does the budget request funding for equipment costing more than $1,000 per unit? YES ☐ NO

18. Will this project be conducted off campus? YES ☐ NO

19. Will Rutgers University issue subcontract(s) to other organization(s)? YES NO

20. Does the funding agency require cost sharing? If YES, attach cost sharing statement. YES NO

21. Would the funding of this proposal present any potential conflict of interest? If YES, complete a "Significant Financial Interest Disclosure" form. YES NO

22. Does the project involve international programs or activities within the University having international implications? YES NO

23. Does the funding agency require submission through or review by a clearinghouse, Federal regional office, or state agency? YES ☐ NO

REQUIRED CERTIFICATIONS/SIGNATURES:

Principal Investigator/Project Director: I have read and agree to abide by current University policies on conflict of interest, intellectual property, the use of human subjects and/or vertebrate animals in research, and other University research policies as appropriate. I certify that the required actions regarding compliance with these policies have been taken.

Signature: [signature] Date: 5/27/97 Campus Phone: 2-7684

Email Address: francis@imcs.rutgers.edu

Department Chairperson: [signature] Date: 5/27/97

College/School Dean or Unit Director: [signature] Date: 5/27/97

OTHER SIGNATURES, AS APPROPRIATE (to be obtained BEFORE submitting this form and proposal to ORSP/OCLTT):

Campus Provost: Date:

Rutgers University Foundation: Date:

For ORSP/OCLTT use only:

AMOUNT REQUESTED: PRIME FUNDING SOURCE, IF KNOWN

First year: $ 37615

Total: $ — NASA

COMMENTS: Add ORSP contract to ... Regional by NASA

Non-Budgetary Sign-off: Budgetary Sign-off:

DISTRIBUTION White - ORSP/OCLTT File Blue - ORSP Database Manager Green - Original

REV 6/96