Final Report

for

NASA Langley Research Center

Contract NAS1-00070

Engineering and Scientific Support for the National Polar-orbiting Operational Environmental Satellite System Airborne Sounder Testbed Interferometer (NAST-I) Instrument

University of Wisconsin
Space Science and Engineering Center

May 31, 2001

1.0 Introduction

This is the final report for NASA Contract NAS1-00070 awarded from NASA LaRC to the University of Wisconsin, Space Science and Engineering Center to provide "Engineering and Scientific Support for the National Polar-orbiting Operational Environmental Satellite System Airborne Sounder Testbed Interferometer (NAST-I) Instrument." All the work has been completed on each of the seven tasks. A summary of the activities on each of the seven tasks is provided below. Appendices are provided with more detailed information.

2.0 Summary of Task activities

Task 1: Technical Support of Sounder Operational Algorithm Team (OAT)
A draft CrIS sounder Validation Plan (10 November 2000) was developed and sent to Steve Mango of the IPO. Elements of this plan are being incorporated in the NPP Validation Plan.

The UW has supported the all the OAT meetings, which were chaired (through calendar year 2000) by Paul Menzel. Minutes of these minutes are included in this report. The UW has supported the CrIS TIM's with vendors and participated in the downselect process. A report to the Sounder OAT team by H. Revercomb, UW-Madison, on the testing of algorithms using aircraft observations was presented at the 1-29-01.

The following more detailed information relating to this task is presented in the Appendices:
[1-A] Draft Sounder Validation Plan (11-10-2000): <cris_product_valv2.doc>
[1-B] Minutes of 2-3-00 SOAT Meeting: <SOAT_00.02.03.doc>
[1-C] Minutes of 6-6-00 SOAT Meeting: < SOAT_00.06.06.doc>
[1-D] Minutes of 10-12-00 SOAT Meeting: < SOAT_00.10.12.doc>
[1-E] H. Revercomb presentation to OAT team on 1-29-01: <SOAT_1-29-01.PPT>

Task 2: Scanning High-resolution Interferometer Sounder (Scanning-HIS)
Laboratory testing was performed on the UW Scanning-HIS to isolate the source of vibration induced tilt errors. Testing indicated that the significant contributor to these errors was in the flexure based Michelson drive. A new Michelson drive was designed, fabricated, integrated, and successfully tested on the S-HIS during the SAFARI mission in Africa (September 00). The new drive has significantly reduced the vibration tilt errors in the Scanning-HIS.

A correction technique for removing vibration induced tilt artifacts in S-HIS data, using instrument generated tilt measurement data was investigated and found to be plausible. Analysis of both amplitude modulated and sample position tilt errors are included in this report.

The following more detailed information relating to this task is presented in the Appendices:
[2-A] New Scanning-HIS Michelson Mirror Assembly: <S-HIS Michelson Drive>

[2-B] Vibration Induced Tilt Error Analysis: <Tilt_exercise-01Mar00.xls>
[2-C] Vibration Induced Sample Position Error Analysis: <Sample_Position_errors-01Mar00.xls>

Task 3: Support of NAST-I/Proteus Aircraft Integration
The UW supported the NAST-I/Proteus aircraft integration at Scaled Composites in Mohave, CA by providing analysis of the interferometer performance. The conclusion from the analysis (contained in this report) is that there is 50 to 100% more interferometric noise on the Proteus as compared to the NASA ER-2.

The following more detailed information relating to this task is presented in the Appendices:
[3-A] Performance Evaluation on PROTEUS: <Proteus_Integration.doc>

Task 4: Science Analysis of NAST-I Data From CY2000 Airborne Missions
The UW has processed NAST-I flight data from several missions. This processing includes measurement, retrieval, and product visualizations. A complete list of missions to date for which NAST data has been processed is included as a separate document in this report. A summary presentation of science analysis results is included from the International Radiation Symposium 2000 meeting that was held in St. Petersburg Russia. Results of an application of an algorithm for sea surface temperature retrieval from NAST-I data is included in this report. A data compression study was performed using the NAST-I data. Details of this work can be found in Paolo Antonelli's PhD Thesis, "Principle Component Analysis: A Tool for Processing Hyperspectral Infrared Data," University of Wisconsin-Madison, 2001.

The following more detailed information relating to this task is presented in the Appendices:
[4-A] NAST Mission Summary <NASTI_Mission_Summary.doc>
[4-B] IRS2000 Meeting Presentation: <irs2000_bobk.ppt>
[4-C] Sea Surface Temperature: </SST/SST.htm>
[4-D] Compression; Paolo Antonelli's PhD Thesis: < available upon request >

Task 5: Technical Support of NAST-I WVIOP3 and AFWEX Deployments
UW supported the NAST-I team during the WVIOP3 and AFWEX deployments. This support consisted of processing and analysis of real-time scientific data from the NAST-I instrument. Seven flights were processed for the WVIOP3 experiment and nine flights for the AFWEX deployment.

The following more detailed information relating to this task is presented in the Appendices:
[5-A] Analysis and interpretation of WVIOP3 NAST-I data: <WVIOP3.html>
[5-B] Analysis and interpretation of AFWEX NAST-I data: <AFWEX.html>

Task 6: NAST-I Cloud IOP Data Analysis

UW analyzed NAST-I data from the March 2000 Cloud IOP and made calibrated radiance products available to LaRC and to the SOAT via website. Five flights of the NAST-I on the Proteus aircraft were processed for this deployment.

The following more detailed information relating to this task is presented in the Appendices:
[6-A] Analysis of NAST-I with calibrated radiances from Cloud IOP: <CloudIOP.html>

Task 7: NAST-I Data Warehouse Development
In order to facilitate on-line access to NAST-I data, UW implemented a data storage warehouse with 500 GB capacity. This tool supports web based access to the NAST-I data (NAST-I link on the web page cimss.ssec.wisc.edu). The reprocessing software developed under this task was delivered on a CD to the NAST-I Principal Investigator.

The following more detailed information relating to this task is presented in the Appendices:
[7-A] Data Warehouse description: <Data_Warehouse.doc>
[7-B] Reprocessing Software Deliverable: <nasti_454.iso>

[1-A]

Draft Sounder Validation Plan (11-10-2000)

<cris_product_valv2.doc>

CROSS TRACK INFRARED SOUNDER (CrIS)

Product Validation Plan

for the

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

Prepared by

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DRAFT VERSION 2

10 November 2000

Table of Contents

1 EXECUTIVE SUMMARY

The product validation for CrIS focuses on (1) operational algorithm assessment, and (2) validation of system performance. The NAST and Scanning HIS aircraft instruments are two of the primary tools for performing a product validation; another is the MODIS Airborne Simulator. The Sounder-Operational Algorithm Team is preparing the plan to conduct these activities. With the support of the IPO, the Sounder-OAT provides expertise to assure that performance options and algorithm approaches get reviewed and thoroughly tested with real atmospheric data. The Sounder-OAT will efficiently combine the government and university community experience base with the expertise of the selected vendor for algorithm development.

Aircraft data is important to the program both before and after launch. Before launch, it will provide the means to demonstrate expected EDR performance and to establish algorithm approaches that will work in the presence of actual atmospheric cloud conditions. After launch, it will form the basis for system validation. In addition other remote sensing systems and in situ systems will be incorporated into the validation activities. Early work to validate MODIS, AIRS, and IASI will establish some of the CrIS validation procedures detailed in this plan.

Part of the program can be established on the basis of shared costs. While expenses associated with maintaining and fielding aircraft instruments can be significant, the requirements for IPO are compatible with those of ongoing NASA scientific programs, NOAA Calibration and Validation of its operational observing capabilities, NASA plans for EOS validation, and DOE field programs for climate studies. Plans are already in place from these other organizations to support a substantial number of field programs that can be used to leverage IPO support. Some of the relevant planning documents (including the MODIS Validation Plan, the AIRS Validation Plan, and the NOAA Polar Products Assurance Plan (POPAP)) are available on the web. More specifically, NASA has plans to conduct missions with these instruments in 2000, including the SAFARI mission in South Africa, and a joint water vapor experiment with the DOE centered around the Atmospheric Radiation Measurement (ARM) site in Oklahoma. NOAA will be conducting calibration / validation of the operational polar orbiting infrared and microwave sounders in 2001; intercalibration of the ongoing series of POES sensors and the associated sounding products is a high priority for these efforts.

However, it is important for the IPO to plan with the SOAT the necessary data gathering and data analysis that can suggest instrument processing adjustments and algorithm evolution that will foster the maximum utilization of CrIS data. This will be an intenseive effort after CrIS launch on NPP and continue annually for some time after that.

2 INTRODUCTION

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is a joint NASA, NOAA, and DOD program merging the current POES & DMSP systems into a common system (i.e. NPOESS) of polar satellites with the goal of providing meteorological and other environmental data products operationally. In order to achieve these goals, these programs must produce accurate and precise long-time series of radiometric measurement data from multiple instruments on multiple platforms. Understanding and correctly interpreting these data require the ability to separate geophysical variability from instrument response changes in the observed signal during the missions. This requires a detailed instrument system-level characterization pre-launch, as well as extensive in-flight calibration and validation activities.

Validation is the process of assessing by independent means the uncertainties of derived geophysical data products from instrument system outputs. This is generally approached by direct comparison with independent correlative measurements from ground-based networks, comprehensive test sites, and field campaigns; along with comparisons with independent satellite retrieval products from instruments on the same and different platforms. Pre-launch activities usually focus on algorithm development and characterization of instrument uncertainties, while post-launch emphasis is on algorithm refinement and measured/retrieved data product assessments. It is essential to have an integrated strategy for validation, including contributions from airborne field campaigns, surface networks, as well as satellites.

2.1 SCOPE

2.1.1 IDENTIFICATION

This Product Validation Plan document provides a roadmap for the validation of Level I Products (calibrated/navigated radiances), Level II Primary Products (temperature and water vapor vertical profiles), and selected Level II Secondary Products (including sea and land surface temperature and selected cloud products) from the Cross-track Infrared Sounder (CrIS) which is part of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) series of polar-orbiting spacecraft. The CrIS instrument forms a key component of the larger Cross-track Infrared/Microwave Sounding Suite (CrIMSS) and is intended to operate within the context of the CrIMSS architecture. For each validation area, the general validation strategy and specific implementation plans are presented. For this DRAFT version, the implementation approaches are not meant to be comprehensive. Emphasis is placed on validation of the fundamental CrIS radiance observations.

The validation of CrIS algorithms, including calibration, forward model, and retrieval, is (to be) presented in a separate document, the *CrIS Operational Algorithm Assessment Plan.*

2.1.2 SENSOR OVERVIEW

The CrIS provides cross-track measurements of scene radiance to permit the calculation of the vertical distribution of temperature and moisture in the Earth's atmosphere. It also provides supporting measurements for a variety of other geophysical parameters as listed in the Integrated Operational Requirements Document (IORD) (Paragraph 3.2.1.1). The CrIS shall consist of a Michelson interferometer infrared sounder covering the spectral range of approximately 3.5 to 16 microns. It will be operated together with a co-registered microwave cross-track sounder suite of instrument(s). Note: The current notional baseline performance level assumed for this microwave suite specification will be no less than that currently projected for the Advanced Microwave Sounder Unit-A (AMSU-A) and the Advanced Microwave Sounder Unit-B/Microwave Humidity Sounder (AMSU-B/MHS) microwave sounders, as scheduled to fly on the National Oceanic and Atmospheric Administration (NOAA) K-N' series spacecraft. One CrIS flight unit is intended to be provided to meet an early flight opportunity on the NOAA N' satellite to be available for launch in 2004. The NOAA N' microwave sounding sensor channels will be provided by the AMSU-A and MHS instruments. Three additional CrIS flight units are needed for the NPOESS C1, C3, and C5 spacecraft which will be available for launch in 2007, 2009, and 2010. The microwave sensors to be used with the CrIS as part of the larger CrIMSS sounding suite are TBS. The purpose of a possible early flight opportunity on NOAA N' is to meet user requirements in advance of the first NPOESS launch and to provide early improved IR sounder capability. These data are processed and delivered to the users in the form of Raw Data Records (RDRs), Sensor Data Records (SDRs), and Environmental Data Records (EDRs).

2.1.3 RELATION TO OTHER VALIDATION EFFORTS

The CrIS product validation plans and efforts benefit greatly from the validation efforts and infrastucture of several existing programs. These include the EOS AIRS and MODIS programs, NPOESS Atmospheric Sounder Testbed (NAST) program, the Atmospheric Radiation Measurement (ARM) Program, the NASA NMP EO-3 Geostationary Imaging Fourier Transfrom Spectrometer (GIFTS), NOAA GOES, and the EUMETSAT IASI program. Where applicable and possible, the CrIS validation efforts will draw from these existing programs. Specific examples include:

1. Radiance and atmospheric state validation using ARM site observations
2. SST and radiance validation using ship cruise observations (MAERI)
3. NAST-Interferometer (NAST-I) and Scanning High Resolution Infrared Sounder (S-HIS) aircraft facilities
4. Radiance and land surface temperature validation using Polar AERI observations
5. Water vapor validation using airborne LASE observations
6. Intercomparison with other high resolution satellite borne sensors including AIRS, GIFTS, and IASI.

While the infrastructure for many of these approaches is, or will be, in place for CrIS product validation, additional resources may be required for implementation and analysis of CrIS validation. Specifically, arrangement and funding of aircraft campaigns involving the NASTI, SHIS, and/or LASE and other special field campaigns (Polar AERI and ship cruises) are required.

2.1.4 DOCUMENT OVERVIEW

This document contains a general overview and a list of specific implementation plans for the validation of each of the Level I and Level II data products from the CrIS sensor. Section 4 is a brief summary of the CrIS primary products. The validation approaches listed in section 5 follow a common format. Each implementation plan defines the following; product name, primary validation source, ancillary data source, techniques to be used, scope and schedule, comparison and accuracy, supporting documents, cost sharing, and the plan author. The term "(TBD)" applies to an element of the draft validation plan that remains "to be determined".

Appendix A presents a more detailed description of the use of aircraft based radiance measurements for satellite validation. Appendix B contains a definition of the terms used throughout the document.

2.2 UTILIZATION OF AIRCRAFT DATA

Aircraft data is important to the NPOESS program both before and after launch. Before launch, it will provide the means to demonstrate expected performance and to establish algorithm approaches that will work in the presence of actual atmospheric cloud conditions. After launch, it will form the basis for system validation.

Product validation for the NPOESS program can be established on the basis of shared costs. While expenses associated with maintaining and fielding aircraft instruments can be significant, the requirements for IPO are compatible with those of ongoing NASA scientific programs, NOAA Calibration and Validation of its operational observing capabilities, NASA plans for EOS validation, and DOE field programs for climate studies. Plans are already in place from these other organizations to support a substantial number of field programs that can be used to leverage IPO support. More specifically, NASA has plans to conduct missions with these instruments in 2000, including the SAFARI mission in South Africa, and a joint water vapor experiment with the DOE centered around the Atmospheric Radiation Measurement (ARM) site in Oklahoma. NOAA will be conducting calibration / validation of the operational polar orbiting infrared and microwave sounders in 2000; intercalibration of the ongoing series of POES sensors and the associated sounding products is a high priority for these efforts.

See Appendix A for a more detailed, self-contained report on the utility of NAST-I and S-HIS for CrIS validation.

3 APPLICABLE DOCUMENTS

- Sensor Requirements Document (SRD) Cross Track Infrared Sounder (CrIS), Version Two, 8 March 1999

- CrIS Operational Algorithm Assessment Document, Draft Version, 5 June 2000
- ITT Calibration / Validation Plan, Version submitted with CrIS Proposal

4 CRIS PRODUCTS SUMMARY

The CrIS products summary presented here is derived from information found in the CrIS Sensor Requirements Document (SRD).

4.1 LEVEL I PRODUCT

Sensor Data Records (SDRs) are full resolution sensor data that are time referenced, Earth located, and calibrated by applying the ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters such as platform ephemeris. These data are processed to sensor units (e.g., radiance). Calibration, ephemeris, and any other ancillary data necessary to convert the sensor data back to sensor raw data (counts) are included.

The operational SDR should, at a minimum, consist of the following information:

- Spacecraft ID tag
- CrIS sensor ID or serial number
- Flight software version number
- Orbit number
- Beginning Julian day and time tag
- Ending Julian day and time tag
- Ascending Node Julian day and time tag
- Spectral radiance in all channels
- Signal levels from all visible detectors.
- Geolocation: geodetic latitude and longitude for each sample
- Time tag information - beginning of scan time
- Scan index

4.2 LEVEL II PRODUCTS (PRIMARY)

Environmental Data Record (EDR) requirements are broken into two categories: primary and secondary. Primary EDRs are those EDR attributes for which a sensor contractor has been assigned primary sensor and algorithm development responsibility. The algorithm may or may not require the use of additional data from other than the primary sensor. Secondary EDRs are those EDR attributes for which the sensor may provide data as a secondary input to an EDR algorithm assigned as a primary EDR to another NPOESS sensor contractor.

Atmospheric Vertical Moisture Profile

An atmospheric vertical moisture profile is a set of estimates of average mixing ratio in three-dimensional cells centered on specified points along a local vertical. For this EDR, horizontal cell size is specified at nadir only. The mixing ratio of a sample of air is the ratio of the mass of water vapor in the sample to the mass of dry air in the sample. Clear refers to cases in which the average fractional cloudiness in the array of CrIS spots falling within an "AMSU-A like" footprint is up to 50%. The instrument shall be capable of meeting sounding requirements in situations where none of the individual spots **is cloud-free**. The sounding requirements represent errors in a given layer. There is no requirement that errors in adjacent layers be uncorrelated.

Units: g/kg

Para. No.		Thresholds	Objectives
K40.2.1-1	a. Horizontal Cell Size	15 km @ nadir	2 km @ nadir
K40.2.1-2	b. Horizontal Reporting Interval	(TBD)	(TBD)
K40.2.1-3	c. Vertical Cell Size	2 km	2 km
	d. Vertical Reporting Interval		
K40.2.1-4	1. surface to 850 mb	20 mb	5 mb
K40.2.1-5	2. 850 mb to 100 mb	50 mb	15 mb
K40.2.1-6	e. Horizontal Coverage	N/A*	N/A*
K40.2.1-7	f. Vertical Coverage	Surface to 100 mb	Surface to 100 mb
K40.2.1-8	g. Measurement Range	0 - 30 g/kg	0 – 30 g/kg
	h. Measurement Uncertainty (expressed as a percent of average mixing ratio in 2 km layers)		
	Clear ($\leq$ 50% cloudy)		
K40.2.1-9	1. surface to 600 mb	15% or 0.2g/kg (TBR)	10%
K40.2.1-10	2. 600 mb to 300 mb	20% or 0.1g/kg (TBR)	10%
K40.2.1-11	3. 300 mb to 100 mb	25% or 0.1g/kg (TBR)	10%
	Cloudy		
K40.2.1-12	4. surface to 600 mb	20% or 0.2g/kg (TBR)	10%
K40.2.1-13	5. 600 mb to 300 mb	40% or 0.1g/kg (TBR)	10%
K40.2.1-14	6. 300 mb to 100 mb	40% or 0.1g/kg (TBR)	10%
K40.2.1-15	i. Mapping Uncertainty		
	j. Deleted		
	k. Deleted		
K40.2.1-16	l. Minimum Ground Swath-width (833 km, circular, polar-orbit altitude)	2,200 km (TBR) See*	(TBD)

* Horizontal Coverage is a system level specification determined by the number of satellites, orbitology, and sensor swath width. Thus, only "Minimum Ground Swath-width" is specified at the sensor level.

Atmospheric Vertical Temperature Profile

An atmospheric temperature profile is a set of estimates of the average atmospheric temperature in three-dimensional cells centered on specified points along a local vertical. Clear refers to cases in which the average fractional cloudiness in the array of CrIS spots falling within an "AMSU-A like" footprint is up to 50%. The instrument shall be capable of meeting sounding requirements in situations where none of the individual spots **is cloud-free**. The sounding requirements represent errors in a given layer. There is no requirement that errors in adjacent layers be uncorrelated.

Units: K

Para. No.		Thresholds	Objectives
	a. Horizontal Cell Size		

Para. No.		Thresholds	Objectives
K40.2.2-1	1. Clear, nadir	18.5 km	5 km
K40.2.2-2	2. Clear, worst case	100 km	(TBD)
K40.2.2-3	3. Cloudy, nadir	48 km (TBR)	5 km
K40.2.2-4	4. Cloudy, worst case	160 km (TBR)	(TBD)
K40.2.2-5	b. Horizontal Reporting Interval	(TBD)	(TBD)
	c. Vertical Cell Size		
	Clear (≤ 50% cloudy)		
K40.2.2-6	1. Surface to 300 mb	1 km	(TBD)
K40.2.2-7	2. 300 mb to 30 mb	3 km	(TBD)
K40.2.2-8	3. 30 mb to 1 mb	5 km	(TBD)
K40.2.2-9	4. 1 mb to 0.01 mb	5 km (TBR)	(TBD)
	Cloudy		
K40.2.2-10	5. Surface to 700 mb	1 km	(TBD)
K40.2.2-11	6. 700 mb to 300mb	1 km	(TBD)
K40.2.2-12	7. 300 mb to 30 mb	3 km	(TBD)
K40.2.2-13	8. 30 mb to 1 mb	5 km	(TBD)
K40.2.2-14	9. 1 mb to 0.01 mb	5 km (TBR)	(TBD)
	d. Vertical Reporting Interval		
K40.2.2-15	1. Surface to 850 mb	20 mb	15 mb
K40.2.2-16	2. 850 mb to 300 mb	50 mb	15 mb
K40.2.2-17	3. 300 mb to 100 mb	25 mb	15 mb
K40.2.2-18	4. 100 mb to 10 mb	20 mb	10 mb
K40.2.2-19	5. 10 mb to 1 mb	2 mb	1 mb
K40.2.2-20	6. 1 mb to 0.1 mb	0.2 mb	0.1 mb
K40.2.2-21	7. 0.1 mb to 0.01 mb	0.02 mb (TBR)	0.01 mb (TBR)
K40.2.2-22	e. Horizontal Coverage	N/A**	N/A**
K40.2.2-23	f. Vertical Coverage	Surface to 0.01 mb (TBR)	Surface to 0.01 mb (TBR)
K40.2.2-24	g. Measurement Range	180 - 335 K (TBR)	(TBD)
K40.2.2-25	Not used		
	h. Measurement Uncertainty		
	Clear (≤ 50% cloudy)		
K40.2.2-26	1. Surface to 300 mb	1.0 K / 1 km layers	0.5K / 1km
K40.2.2-27	2. 300 mb to 30 mb	1.0 K / 3 km layers	0.5K / 1km
K40.2.2-28	3. 30 mb to 1 mb	1.5 K / 5 km layers	0.5K / 1km
K40.2.2-29	4. 1 mb to 0.01 mb*	3.5 K / 5 km layers (TBR)	0.5K / 1km (TBR)
	Cloudy		
K40.2.2-30	5. Surface to 700 mb	2.5 K / 1 km layers	0.5K / 1km
K40.2.2-31	6. 700 mb to 300 mb	1.5 K / 1 km layers	0.5K / 1km
K40.2.2-32	7. 300 mb to 30 mb	1.5 K / 3 km layers	0.5K / 1km
K40.2.2-33	8. 30 mb to 1 mb	1.5 K / 5 km layer	0.5K / 1km
K40.2.2-34	9. 1 mb to 0.01 mb	3.5 K / 5 km layers (TBR)	0.5K / 1km (TBR)
K40.2.2-35	i. Mapping Uncertainty	5 km	1 km
	j./k. Deleted		
K40.2.2-36	l. Minimum Ground Swath-width (833 km, circular, polar-orbit altitude)	2,200 km (TBR) See**	(TBD)

Measurement Uncertainty as specified in K40.2.2-29 shall be referenced to the Cloudy Horizontal Cell Size thresholds and objectives as listed under K40.2.2-3 and K40.2.2-4.

** Horizontal Coverage is a system level specification determined by the number of satellites, orbitology, and sensor swath width. Thus, only "Minimum Ground Swath-width" is specified at the sensor level.

Pressure (Surface/Profile)

A pressure profile is a set of estimates of the atmospheric pressure at specified altitudes above the Earth's surface. The requirements below apply under both clear and cloudy conditions. Pressure is assumed to be a derived quantity. The pressure profile is derived from the temperature and moisture profile as well as an external estimate of pressure at some level in the atmosphere.

Units: mb

Para. No.		Thresholds	Objectives
K40.3.5-1	a. Horizontal Cell Size	55 km (TBR)	5 km
K40.3.5-2	b. Horizontal Reporting Interval	(TBD)	(TBD)
K40.3.5-3	c. Vertical Cell Size	1 km	0 km
	d. Vertical Reporting Interval		
K40.3.5-4	1. 0 - 2 km	1 km	0.25 km
K40.3.5-5	2. 2 - 5 km	1 km	0.5 km
K40.3.5-6	3. > 5 km	1 km	1 km
K40.3.5-7	e. Horizontal Coverage	N/A*	N/A*
K40.3.5-8	f. Vertical Coverage	0 – 30 km	0 - 30 km
K40.3.5-9	g. Measurement Range	10 – 1050 mb	10 - 1050 mb
	h. Measurement Accuracy		
K40.3.5-10	1. 0 - 2 km	1 % (TBR)	(TBD)
K40.3.5-11	2. 2 - 10 km	1 % or or 10 mb (TBR)	0.5 % (TBR)
K40.3.5-12	3. 10 - 30 km	1 % or or 1 mb (TBR)	0.5 % (TBR)
K40.3.5-13	i. Measurement Precision	4 mb	2 mb
K40.3.5-14	j. Mapping Uncertainty	7 km	1 km
	k. Deleted		
	l. Deleted		
K40.3.5-15	m. Minimum Ground Swath-width (833 km, circular, polar-orbit altitude)	2,200 km (TBR) See*	(TBD)

* Horizontal Coverage is a system level specification determined by the number of satellites, orbitology, and sensor swath width. Thus, only "Minimum Ground Swath-width" is specified at the sensor level.

5 PRODUCT VALIDATION IMPLEMENTATION PLANS

5.1 LEVEL 1 PRODUCTS

5.1.1 RADIANCE

Radiance validation consists of independent assessment of the spectral, spatial, and radiometric accuracy of the calibrated CrIS radiances. For spectral validation, the efforts are focussed on top-of-atmopshere calculations using known spectral features. For radiometric calibration, the primary validation is done with coincident observations from the NPOESS aircraft instruments, NASTI and SHIS, with top-of-atmosphere calculations using validation site atmospheric profiles and surface characterization, and with intercomparison with other satellite sensors.

5.1.1.1 Approach 1: Aircraft Radiance Observations

Product: High Resolution Spectral Radiance

Primary Validation Source: Aircraft Radiances from NAST-I and Scanning HIS

Ancillary Data Sources:
1. Image data from Aircraft-based Imager (MAS) to assess spatial variations over the CRIS field-of-view.
2. Atmospheric state (from radiosondes supplemented by other high altitude data sources, even including CRIS retrievals above the aircraft altitude) for input to model used to simplify spectral comparisons.

Techniques:
1. Coincident Observing: Conduct an aircraft field campaign in which NPOESS under-flights are made with aircraft flight tracks arranged parallel to the sub-satellite track. Adjust the aircraft view-angle to match the appropriate CRIS cross-track angle.
2. Target Selection: Select reasonably uniform targets with a range of radiance levels (e.g. uniform ocean for a range of latitudes, deserts, and uniform cloud decks).
3. Spectral Weighting: Basically, the approach is to compare both CRIS and aircraft spectral radiances at a common spectral resolution. This is possible since the NAST-I and S-HIS are both Fourier Transform Spectrometers as is the CrIS sensor.
4. Spatial Weighting: The higher resolution aircraft pixels are summed with appropriate weights to represent the larger CRIS Spatial Response Function. Unsampled regions are represented by using imager data to assign spectra from similar sampled regions.

Scope and Schedule:
At least 40 flight hours per year from field campaigns of opportunity will be supported by CRIS throughout the instrument lifetime to perform this type of validation. If necessary, CRIS will organize a special campaign during the second half of its first year in orbit to insure that a timely comparison is achieved. The radiometric characteristic of NAST-I and Scanning HIS will be documented before CRIS launch, in preparation for estimating errors.

Comparison and Accuracy:
The spectral comparison of CRIS to aircraft spectrometers is based on comparing the direct comparison of radiances. If the calibration of both instruments were perfect and the scene were uniform, the difference between residual spectra would be noise. It would be nearly uncorrelated with wavelength and dominated by the CRIS single sample noise (many aircraft samples are averaged to match CRIS spatial sampling). We are really looking for differences that are correlated with wavelength that represent consistent radiometric or spectral calibration differences. For reasonably uniform scenes, we expect to be able to detect differences that are on the order of the peak calibration uncertainties for both instruments (less than 1 K brightness temperature for the critical spectral

regions). By achieving a number of comparisons, it will be possible to separate consistent, significant differences from differences attributable to spatial sampling errors.

Supporting Documents: (TBD)

Funding: IPO support is required for dedicated aircraft flight hours.

5.1.1.2 Approach 2: Calculations of TOA radiance, ARM sites

Product: High Resolution Spectral Radiance (Cloud Cleared)

Primary Validation Source: Calculated clear sky upwelling TOA radiance spectra

Ancillary Data Sources:

1. Atmospheric state from ARM (SGP, NSA, and TWP) site temperature and water vapor best estimates.
2. Surface skin emissivity from the following sources: USGS land type maps, temporal and spatial collocated ground-based SAERI measurements, calculated sea-surface values.
3. Surface skin temperature from broadband infrared measurements at the ARM sites or fitted to the CRIS observations.
4. Imager Data for assessing spatial variability of surface characteristics.

Technique:
The basic approach is to compare CRIS cloud cleared radiance spectra to calculations of the upwelling clear sky radiance for NPOESS overpasses of the ARM sites. The calculations will be performed using input from the ARM site temperature and water vapor best estimate products from the Southern Great Plains (central facility), North Slope of Alaska (Barrow site), and the Tropical Western Pacific (Nauru site) sites. The CRIS fast model and line-by-line radiative transfer codes will be used to perform these clear sky calculations. The differences between the observed and calculated radiances are then analyzed with respect to the calculation uncertainties (spectroscopic accuracy, fast model parameterization, atmospheric state uncertainty, and surface emissivity and temperature characterization) to assess the accuracy of the observed radiances. The AER Optimal Spectral Sampling will be compared to other fast transmittance models (including a PFAAST-based model for CrIS). These comparisons will be done for all-sky conditions and will therefore serve not only to assess the accuracy of the clear sky CRIS radiances but also the accuracy of the cloud-clearing algorithm and resulting radiances under cloudy and partly cloudy conditions.

Scope and Schedule:
The calculations will be performed following the ARM site T/q best estimate production for NPOESS overpasses of the ARM sites. This includes periods using the on-going routine ARM observations as well as periods with dedicated NPOESS overpass radiosonde launches.

Comparison and Accuracy:
The accuracy of the calculated radiances will depend largely on the specification of the surface temperature and emissivity, as well as the atmospheric state. The surface emissivity and temperature used in the calculations will likely be determined by fitting a linear combination of the known pure scene type emissivities and the effective, area weighted surface temperature such that window region residuals (CRIS – calculation) are

minimized. In this sense, this validation activity does not address absolute calibration accuracy, but rather has an emphasis on spectral and relative radiometric accuracy. That is, the technique of fitting the surface characteristics to the observed radiances sets the residuals to zero in specific spectral regions in the 10 micron region, but allows for meaningful comparisons of the observed and calculated radiances in spectral regions which do not see the surface. The spectral performance of the CRIS will be assessed by taking differences between the observed and calculated spectra. Using a large number of comparisons, radiometric differences between the observed (or cloud cleared) and calculated radiances will be analyzed statistically using, for example, scatter plots of radiance differences, or distributions of radiances for selected, limited wavenumber regions.

Funding: (TBD)

5.1.1.3 Approach 3: Satellite Sensor Intercomparisons

Product: High to Moderate Spectral Resolution Radiance
Primary Validation Data Source: AIRS, IASI, MODIS, GIFTS, VIIRS, GOES, POES radiances
Ancillary Data Sources:
Technique:
The general technique is to reduce the CrIS and the validation sensor radiances to the same spectral resolution and to spatially average the data in a consistent manner. Comparisons to the validation sensor radiances are then made for selected scene types of varying homogenaity and signal level. Thee intercomparisons can be conducted for climate applications (leo/leo is available daily in the polar regions and geo/leo is available hourly in the equatorial regions).

Collocation in space and time (within thirty minutes) is required. Data is selected within 10 degrees from nadir for each instrument in order to minimize viewing angle differences. Measured means of brightness temperatures of similar spectral channels from the two sensors are compared. Data collection is restricted to mostly clear scenes with mean IRW radiances greater than 80 $mW/m^2/ster/cm^{-1}$, and no effort is made to screen out clouds from the study area. Data from each sensor is averaged to 100 km resolution to mitigate the effects of different field of view (fov) sizes and sampling densities. Mean radiances are computed within the study area. Clear sky forward calculations (using a global model for estimation of the atmospheric state) are performed to account for differences in the spectral response functions (when comparing to broad band radiometers). The observed radiance difference minus the forward-calculated clear sky radiance difference is then attributed to calibration differences.

$$\Delta R_{cal} = \Delta R_{mean} - \Delta R_{calc}$$

Scope and Schedule: will depend on the individual sensor lifetimes and observation geometries and times.
Comparison and Accuracy:
Supporting Documents:
Funding:

5.1.1.4 Approach 4: Calculations of TOA Radiance, Polar Validation Site

Product: High Spectral Resolution Radiance

Primary Validation Data Source: PAERI observations of ground-based high spectral resolution radiance, and overpass coincident radiosondes

Ancillary Data Sources:
1. GPS and/or tethersonde profiles of water vapor
2. Broadband radiometer measurements of surface temperature to characterize gradients within the CrIS footprints
3. Cloud Lidar or ceiliometer for cloud detection

Technique: This approach uses accurate sensors (PAERI and broadband radiometers) to derive the land surface temperature and spectral emissivity of a homogeneous polar site. Using these surface parameters and temperature and water vapor profiles from overpass coincident soundings, line-by-line calculations of the TOA upwelling radiances will be performed and compared to the CrIS observations. This approach is advantageous due to the very homogeneous polar targets that are available (e.g. Dome Concordia in Antarctica), the large number of satellite overpasses, the accurate surface measurements, and the small atmospheric effects due to very low water vapor amounts (and the resultingly small errors in the line-by-line radiance calculations). These comparisons will provide a very stringent test of the CrIS radiances at low values.

Scope and Schedule: The field measurements should consist of several two-week long campaigns, preferably at Dome Concordia in Antarctica. These should occur after an initial CrIS check-out period and following other less stringent radiometric validation efforts. Observations during austral winter are preferred, although austral summer conditions are sufficient. Clear-sky satellite overpass conditions are required for the comparisons to the clear-sky line-by-line calculations.

Comparison and Accuracy: The radiance validation will consist of comparisons of the CrIS radiances to calculations performed with the PAERI observations of surface temperature and emissivity and sonde measurements of temperature and water vapor profiles. Due to the very low water vapor amounts (~0.3 mm in winter), and the relatively high accuracy of research grade temperature profile measurements, errors in the sonde profiles will not contribute significantly to errors in the calculated radiances. Similarly, due to the very low water vapor amounts, uncertainties in the line-by-line models associated with water vapor absorption (which scale with water vapor amount) will be insignificant. The main source of error in the calculations are expected to arise from uncharacterized gradients in the surface temperature within the CrIS footprints. Comparisons are expected to be made on the 0.1K to 0.2K level.

Funding: (TBD)

5.1.1.5 Approach 5: Calculations of TOA Radiance, Ocean Ship Cruise

Product: High Spectral Resolution Radiance
Primary Validation Data Source: MAERI SST, overpass coincident sondes
Ancillary Data Sources: MWR
Technique: The general technique is the same as that of the ARM site and Polar site radiance calculations, but is implemented using a ocean (or appropriately large sea or lake) ship cruise equipped with accurate skin surface temperature and atmospheric profile measurements.
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.1.2 NAVIGATION

The goal of navigation validation is to ensure that the CrIS radiances and atmospheric profiles are navigated to Earth located footprints to the required accuracy. Candidate approaches include the comparison of CrIS images to calculated images for well defined, high contrast coastlines and similar surface features, and the comparison of CrIS images with VIRS and other high spatial resolution image data.

5.1.2.1 Approach 1: Coastline Crossings

Product: Navigated CrIS Radiances

Primary Validation Data Source: Coastline location database

Technique:
The basic approach is to compare the navigated CrIS radiances with high IR contrast coastlines. This will be done by comparing images of CrIS radiances obtained over well-defined coastlines for clear sky conditions to coastline locations from the database. This can be done manually or automated given the scope of the effort. Potential coastline databases include ETOPO-5 and GLOBE.

Scope and Schedule:
This effort should be conducted during initial instrument check-out periods and continued throughout the mission. It should include views from a range of satellite scan angles and for a number of TBD earth locations.

Comparison and Accuracy:
The coastline databases available for this purpose report elevation maps to an accuracy of 1 km (e.g. GLOBE). The analysis should include nighttime and daytime comparisons and also address infrared (versus visible) effects.

Funding: TBD

5.2 LEVEL 2 PRODUCTS, PRIMARY

5.2.1 WATER VAPOR

Water vapor is highly variable in space and time and is difficult to measure in the atmosphere, especially over the dynamic range required for atmospheric applications. Many observing platforms are however making significant improvements in our ability to measure atmospheric water vapor with the accuracy required for satellite validation. A recent workshop held to discuss the current observation capabilities and to define the future needs concluded that (a) moisture demonstrates considerable variability in the horizontal and vertical, (b) measurements of total precipitable water (TPW) from different systems agree within 5 – 10%, (c) ground based profile measurements offer new opportunities to depict rapid small scale boundary layer moisture changes, (d) remote sensing at high spectral IR resolution offers the promise of depicting vertical H2O layer patterns, (e) assimilation of moisture information is challenging as all observations are interdependent and influence H2O balance (forecasts are accurate to within 15 – 20% for TPW), (f) moisture profiles are especially useful in NWS Forecast Offices and centers and geo-soundings are very timely for subjective forecasting because pre-storm environments initiate in moist clear skies often near outflow boundaries (which present good opportunities for IR systems), and (g) there is a need for a coherent national program for moisture measurements and NWP utilization.

5.2.1.1 Approach 1: ARM Sites Observations

Product: Water Vapor profiles (and integrated column water vapor)

Primary Validation Source: Routine ARM site observations and dedicated NPOESS overpass radiosondes. (ARM site T/q best estimate).

Ancillary Data Sources:
1. GOES and Oklahoma Mesonet data for assessing spatial variability.

Technique:
The basic technique is to use the routine ARM site observations (at the Southern Great Plains site in central Oklahoma, at the North Slope of Alaska site in Barrow, Alaska, and the Tropical Western Pacific site in Nauru) along with dedicated NPOESS overpass radiosondes to measure the temperature and water vapor profiles for validation of the CRIS retrievals. Temporally continuous profiling at the ARM sites will be used to assess small scale spatial variability. GOES, surface networks, and the relative variability of the single-FOV CRIS retrievals will be used to address larger scale spatial gradients. Best estimate profiles and quantitative error estimates will be provided and compared with the coincident CRIS retrieved profiles which have been interpolated in space (using single-FOV CRIS retrievals) to the validation profile locations. Additional information on the technique and estimated uncertainties are given in the supporting document.

Scope and Schedule:
The best estimate products produced from the routine ARM observations will be available for validation purposes from the launch of NPOESS onward. During yearly three month long periods, dedicated NPOESS overpass sondes will be launched and incorporated into the best estimate products. During these periods, sondes will be launched ~90 minutes and ~5 minutes prior to overpass time to provide improved collocation with the satellite overpasses, for the lowest view angle (closest to nadir) overpass of the ARM site each day (e.g. 1 overpass per day, 2 sondes per overpass). Estimates of the number of clear and cloudy overpasses of each site are given in the supporting document.

Comparison and Accuracy:
Rough estimates of the validation profiles show that their accuracies surpass the validation needs of CRIS. Supporting information is given in the supporting document.

Supporting Documents: "Position Paper on ARM T/q Best Estimate Profiles for AIRS Validation", D. Tobin et al., March 1, 2000.

Funding: (TBD)

5.2.1.2 Approach 2: International Validation Sites

Product: Water Vapor profiles (and integrated column water vapor)

Primary Validation Source: International Validation sites

Ancillary Data Sources:
1. Overpass coordinated Vaisala radiosondes with GPS or Microwave Radiometer (MWR) or a high quality surface met station for independent radiosonde water vapor calibration. Imager data (GOES, GMS, MODIS, etc) data for assessing cloud cover and spatial and temporal variability

Techniques:
The basic approach is to make measurements of temperature and water vapor profiles coincident with CRIS retrievals via overpass coordinated radiosonde launches. Sonde water vapor calibration errors will be addressed by scaling the sonde integrated column water vapor to values measured by a GPS or MWR, or alternatively by scaling to point measurements made with a high quality met station coincident with the sonde measurements just prior to launch. Imager data will be used to assess cloud cover and spatial and temporal variability.

Scope and Schedule:
Potential sites include UW-Madison, U. Hawaii, INPE/Brazil, BOM/Australia, Perth/Australia, Lannion/Meteo France, KMA/Korea, and SMC/China. Depending on site resources and funding, overpass coordinated launches will be conducted for three month periods every year for the life of CRIS.

Comparison and Accuracy:
Expected accuracies are comparable to those from DOE ARM sites, although they will be slightly degraded due to the lack of continuous profiling to assess small scale spatial variability. Upper level water vapor measurements will lack the benefit of Raman Lidar observations, although it is expected that Raman Lidar/sonde comparisons from the Southern Great Plains ARM site can be used to assess the accuracy of global upper level radiosonde measurements.

Supporting Documents:
AIRS Validation Plan input: AIRS_inorbit_validation_corrected.doc, A.Huang, Dec, '99.

Funding: (TBD)

5.2.1.3 Approach 3: Retrievals from NASTI and SHIS aircraft observations

Product: Water Vapor Profiles

Primary Validation Data Source: NAST-I and S-HIS retrievals

Ancillary Data Sources: NAST-M, MAS, CLS

Technique:
For high altitude NAST-I and/or S-HIS underflights of the CrIS overpasses, retrievals of atmospheric water vapor profiles derived from the NAST-I and/or S-HIS observations will be compared to the CrIS products. Cross-track scanning will allow the aircraft observations to be averaged to match the CrIS footprint. As with radiance validation approaches with S-HIS and NAST-I (5.1.1.1), the flight paths and sensor scan angles can be tailored to match the CrIS viewing angles. These flights should be performed at maximum aircraft altitude.

A complimentary technique is to perform slow ascents with the aircraft sensors to derive profiles from NAST-I and/or S-HIS data using opaque spectral channels which represent the local temperature and gas concentrations. Such experiments have recently been performed with NAST-I on the Proteus aircraft during the ARM WVIOP 2000 experiment. Due to the slow ascents, these comparisons would be performed on a limited scope for stable, homogeneous meteorological conditions in order to provide meaningful comparisons to the CrIS product.

Scope and Schedule:
A large number of overpass underflights should be performed in order to sample a range of conditions. Initial comparisons should focus on clear sky underflights over water (e.g. ocean , Great Lakes, Gulf of Mexico). Following underflights would involve more diverse meteorological (including clouds) and surface conditions. In particular, the higher spatial resolution aircraft data can be used to determine the effects of partially cloudy scenes on the CrIS retrieval performance. Aircraft-based Cloud Lidar (CLS) and/or high spatial resolution imagery (MAS) can be used to further assess the cloudiness of the scenes. Several aircraft field campaigns per year, each targeting on the order of 10 CrIS overpasses, for the duration of the mission are desired.

Funding: TBD

5.2.1.4 Approach 4: Active and In-situ Aircraft-based observations

Product: Low to upper level water vapor profiles
Primary Validation Data Source: LASE and frost-point and/or Diode Laser water vapor in-situ sensors
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.2.1.5 Approach 5: Comparison to Other Satellite Retrievals

Product: Water Vapor profiles
Primary Validation Data Source: AIRS, GIFTS, IASI, HIRS, MODIS, …
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.2.1.6 Approach 6: WVSS (ACARS water vapor observations)

Water vapor (and temperature) measurements provided from Water Vapor Sensor System (WVSS) units mounted on United Parcel Service (UPS) aircraft offer another source of water vapor information complementing radiosondes, an Atmospheric Emitted Radiance Interferometer (AERI), global positioning system, Vaisala ceilometer, and surface meteorological stations. Preliminary results from prior intercomparions indicate WVSS water vapor measurements are of reasonable quality above the boundary layer, however they exhibit a moist bias occur during ascent and descent through the boundary layer. This problem has been remedied with the WVSS-II which shows improved performance in accuracy due to a single mode diode laser, probe placement on aircraft, and longer maintenance intervals. Ascending and descending aircraft WVSS-II data will be intercompared to CrIS moisture profiles.

Product: Water Vapor level and profile measurements

Primary Validation Data Source: commercial aircraft based water vapor in-situ sensors

Ancillary Data Sources: Radiosondes, an Atmospheric Emitted Radiance Interferometer (AERI), global positioning system, Vaisala ceilometer, and surface meteorological stations.

Technique: A suite of meteorological instruments including radiosondes, an Atmospheric Emitted Radiance Interferometer (AERI), global positioning system, Vaisala ceilometer, and surface meteorological stations will be deployed at a site to be selected. Ascending and descending UPS aircraft WVSS data will be intercompared to research grade radiosonde data as well as CrIS moisture profile retrievals.

Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.2.2 TEMPERATURE

Obtaining temperature profile information similar to radiosonde quality soundings, both in absolute accuracy and vertical structure, is a primary goal of advanced sounders. The stated accuracy objective for the CrIS temperature profiles is 1K in 1km layers for clear (<= 50% cloudy) scenes. The combination of high spectral (to resolve the temperature sounding CO_2 spectral lines) and spatial resolution from CrIS measurements is capable of reaching these goals. Opposed to water vapor measurements, temperature measurements of this accuracy (and better) are widely available for validation purposes, although complications due to spatial inhomogeneaity and cloudiness need to be taken into account in any validation effort. Candidate validation efforts include comparisons to national radiosonde network observations, observations from validation sites such as the ARM sites, retrievals from aircraft based measurements (remotely-sensed, active, and in-situ), and other satellite retrievals.

5.2.2.1 Approach 1: ARM Site Observations

Product: Temperature profiles

Primary Validation Source: Routine ARM site observations and dedicated NPOESS overpass radiosondes. (ARM site T/q best estimate).

Ancillary Data Sources:
2. GOES and Oklahoma Mesonet data for assessing spatial variability.

Technique:
The basic technique is to use the routine ARM site observations (at the Southern Great Plains site in central Oklahoma, at the North Slope of Alaska site in Barrow, Alaska, and the Tropical Western Pacific site in Nauru) along with dedicated NPOESS overpass radiosondes to measure the temperature and water vapor profiles for validation of the CRIS retrievals. Temporally continuous profiling at the ARM sites will be used to assess small scale spatial variability. GOES, surface networks, and the relative variability of the single-FOV CRIS retrievals will be used to address larger scale spatial gradients. Best estimate profiles and quantitative error estimates will be provided and compared with the coincident CRIS retrieved profiles which have been interpolated in space (using single-FOV CRIS retrievals) to the validation profile locations. Additional information on the technique and estimated uncertainties are given in the supporting document.

Scope and Schedule:
The best estimate products produced from the routine ARM observations will be available for validation purposes from the launch of NPOESS onward. During yearly three month long periods, dedicated NPOESS overpass sondes will be launched and incorporated into the best estimate products. During these periods, sondes will be launched ~90 minutes and ~5 minutes prior to overpass time to provide improved collocation with the satellite overpasses, for the lowest view angle (closest to nadir) overpass of the ARM site each day (e.g. 1 overpass per day, 2 sondes per overpass). Estimates of the number of clear and cloudy overpasses of each site are given in the supporting document.

Comparison and Accuracy:
Rough estimates of the validation profiles show that their accuracies surpass the validation needs of CRIS. Supporting information is given in the supporting document.

Supporting Documents: "Position Paper on ARM T/q Best Estimate Profiles for AIRS Validation", D. Tobin et al., March 1, 2000.

Funding: (TBD)

5.2.2.2 Approach 2: Retrievals from NASTI and SHIS aircraft observations

Product: Temperature Profiles

Primary Validation Data Source: NAST-I and S-HIS retrievals

Ancillary Data Sources: NAST-M, MAS, CLS

Technique:
For high altitude NAST-I and/or S-HIS underflights of the CrIS overpasses, retrievals of atmospheric water vapor profiles derived from the NAST-I and/or S-HIS observations will be compared to the CrIS products. Cross-track scanning will allow the aircraft observations to be averaged to match the CrIS footprint. As with radiance validation approaches with S-HIS and NAST-I (5.1.1.1), the flight paths and sensor scan angles can be tailored to match the CrIS viewing angles. These flights should be performed at maximum aircraft altitude.

A complimentary technique is to perform slow ascents with the aircraft sensors to derive profiles from NAST-I and/or S-HIS data using opaque spectral channels which represent the local temperature and gas concentrations. Such experiments have recently been performed with NAST-I on the Proteus aircraft during the ARM WVIOP 2000 experiment. Due to the slow ascents, these comparisons would be performed on a limited scope for stable, homogeneous meteorological conditions in order to provide meaningful comparisons to the CrIS product.

Scope and Schedule:
A large number of overpass underflights should be performed in order to sample a range of conditions. Initial comparisons should focus on clear sky underflights over water (e.g. ocean , Great Lakes, Gulf of Mexico). Following underflights would involve more diverse meteorological (including clouds) and surface conditions. In particular, the higher spatial resolution aircraft data can be used to determine the effects of partially cloudy scenes on the CrIS retrieval performance. Aircraft-based Cloud Lidar (CLS) and/or high spatial resolution imagery (MAS) can be used to further assess the cloudiness of the scenes. Several aircraft field campaigns per year, each targeting on the order of 10 CrIS overpasses, for the duration of the mission are desired.

Funding: TBD

5.2.2.3 Approach 3: Comparison to Other Satellite Retrievals

Product: Temperature profiles
Primary Validation Data Source: AIRS, GIFTS, IASI, HIRS, MODIS, ...
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.2.2.4 Approach 4: Comparison to ACARS Data

Product: CRIS Temperature Profile

Primary Validation Source: ACARS ascent/descent temperature profiles at UPS hub in Louisville, Kentucky, USA.

Ancillary Data Sources:
None

Techniques:
1. Coincident Observing: ACARS ascent and descent profiles from the United Parcel Service Louisville hub will be collected coincident with the NPOESS overpasses (nightly).
2. Target Selection: Fixed target. Louisville airport.
3. Spatial Weighting: The numerous takeoffs and landings will map out a spatial volume in three dimensions which can be weighted appropriate to the CRIS sounding.

Scope and Schedule:
At least 10 days per month will be analyzed for the year following the CRIS checkout period. The data analyzed will be restricted to the ascent and descent profiles from the Louisville airport location.

Comparison and Accuracy:
The ACARS temperature measurements have been validated to an accuracy of better than 1 K in 0.5 km vertical layers (Feltz, et al., 1999) using a combination of radiosonde and groundbased remote sensing data. An uncertainty in the validation product can be obtained from computing the variance of temperature measurements within the measured data volume from many different aircraft observations. This estimate will include both the ACARS reproducibility error and the natural variability of the atmosphere over the measurement volume.

Supporting Documents: ACARS WebPage: http://acweb.fsl.noaa.gov/

Funding: (TBD)

5.2.2.5 Approach 5: International Radiosonde Network

Product: Temperature Profiles

Primary Validation Data Source: International radiosonde network

Ancillary Data Sources:

Technique:

Scope and Schedule:

Comparison and Accuracy:

Supporting Documents:

Funding:

5.2.3 PRESSURE

Introduction

5.3 LEVEL 2 PRODUCTS, SECONDARY

Surface temperature and cloud parameters are discussed in this section.

5.3.1 SURFACE TEMPERATURE

Introduction

5.3.1.1 Sea Surface Temperature (SST)

Primary Validation Source: Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) from University of Miami.

Ancillary Data Sources:
1. Imager data from NPOESS platform
2. GOES SST product for temporal stability from NOAA
3. Buoy data from NOAA

Techniques:

1. Coincident Observing: Collect CRIS SST product data along M-AERI cruise tracks within a predefined time window.

2. Target Selection: Select reasonably uniform and temporally stable targets with a range of radiance levels encompassing the range of surface temperatures observed by M-AERI and atmospheric water column amounts measured by CRIS.

3. Spatial Characterization: The imagery will be used to characterize the area for which the CRIS SST is considered valid. The M-AERI SST value coincident in time with the NPOESS overpass will be weighted by the ratio of the sum of image data window channel radiance over the entire CRIS field of view to the sum of image data window channel radiances over the portion of the ship track within the CRIS field of view. Error bars will be assigned to the comparison to characterize the variability of the scene. When available, high resolution GOES products will be used to characterize temporal change of the scene during the comparison period. A comparison of CRIS SST, M-AERI SST, and buoy SST measurements will be made wherever possible to assist in the interpretation of CRIS SST and buoy comparisons made elsewhere.

Scope and Schedule:

Validation of the CRIS SST product will begin when the M-AERI SST data is available. Between one and five sets of cruise data is anticipated during the year following the CRIS checkout period. This effort assumes that MAERI data from a MODIS validation cruise will be available from existing funding.

Comparison and Accuracy:

The comparison of CRIS SST and M-AERI SST products is simplified by the high absolute accuracy of the M-AERI (order 0.1 K) but complicated by the large mismatch between the CRIS SST domain (order 45 km) and the point M-AERI measurements. The largest source of uncertainty in the SST product comparison is expected to be the spatial variability within the CRIS scene. Uncertainty estimates will be developed to allow error bars to be attributed to each CRIS/M-AERI comparison. The goal of this activity will be to validate the CRIS SST product to within about 0.5 degree Kelvin over as wide a range of atmospheric column water vapor amounts as possible.

Funding: (TBD)

5.3.1.2 Land Surface measurements

Primary Validation Source: University of Wisconsin S-AERI measurements of land surface temperature and emissivity

Ancillary Data Sources:
Land surface/Land cover maps.
Imager data from NPOESS platform.
Broadband measurements (KT-19) of surface emitted radiance.

Techniques:
The focus of this activity is to provide a limited number of case studies for the validation of the CRIS land surface temperature product which take advantage of the accurate point measurements from the University of Wisconsin S-AERI system. Examples of both uniform and mixed scenes will be chosen. For a mixed surface scene, the CRIS land surface temperature product is actually an emissivity-weighted temperature.
1. <u>Coincident Observations</u>: Collect surface temperature and emissivity from the S-AERI system co-incident with NPOESS overpasses on a limited campaign basis. Coincident imager data from the NPOESS platform are also required.
2. <u>Target Selection</u>: The DOE SGP ARM site will be used for one of the case studies. Uniform non-vegetated scenes (e.g. desert) will be used in additional case studies.
3. <u>Spatial Characterization</u>: In order to properly handle the relatively large CRIS footprint (15 km), SAERI measurements of the surface emissivity and temperature of one to three pure scene types within an CRIS footprint are made. KT-19 radiometers are used to monitor surface temperature changes at the sites while the SAERI measurements are made during the overpass. Land surface maps and satellite imagery are then used to create area-weighted emissivities and emissivity-weighted temperatures for direct comparison with CRIS products.

Scope and Schedule:
The S-AERI measurements of land surface temperature and emissivity at the SGP site will be performed once during each season (Spring, Summer, Fall, and Winter) beginning about 120 days after launch in order to capture the sensitivity of the product to changing land cover. The S-AERI measurements at the uniform non-vegetated sight(s) will be performed within one year of- launch but timed to coordinate with any supporting measurements.

Comparison and Accuracy:
The standard CRIS surface emissivity and temperature products (derived for individual 15 km CRIS footprints) will be validated in this effort. The point measurement accuracy of land surface temperature from the S-AERI is high (order 0.2 K), so the largest anticipated error is expected from the extrapolation to the land surface temperature for the CRIS footprint based on satellite imagery and a detailed surface emissivity map. The

goal of this project is to validate the CRIS land surface temperature and emissivity products to better than 2 K and 2% over a range of atmospheric conditions.

Funding: (TBD)

5.3.2 CLOUD PARAMETERS

CrIS will provide greatly enhanced remote sensing capability for the characterization of atmospheric clouds. Current low spectral resolution sounders such as HIRS are limited in their ability to provide information on multi-layer clouds (Menzel et al. 1992), while AIRS, CrIS, IASI, GIFTS, and ABS will overcome this limitation with their high spectral longwave cloudy radiance measurements.

Algorithms will be developed for retrieving cloud-top pressure (CTP) and effective cloud amount (ECA; which is defined as the product of the cloud emissivity and the fractional cloud coverage) from the longwave advanced sounder radiances. Advanced sounder radiances (CrIS) and co-located imaging radiances (VIIRS) will be directly used to retrieve cloud properties from a single CrIS FOV. The algorithms can be tested with AIRS and MODIS data, and usd operationally in future with CrIS and VIIRS data.

Algorithms will be developed for high spectral resolution sounder radiances and co-located high spatial resolution multi-spectral imaging radiances which retrieve the multi-layer atmospheric CTPs and ECAs from a single FOV. A simulation study will be carried out to evaluate quantitatively the multi-layer cloud retrieval capability of CrIS/VIIRS.

Algorithms will be refined to (a) combine CO_2-slicing plus 1DVAR with high spectral resolution data, and (b) high spectral resolution sounder radiances (CrIS/) with co-located high spatial resolution multi-spectral imaging data (VIIRS).

5.3.2.1 Cover/Layers

Primary Validation Data Source:
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.3.2.2 Cloud Effective particle size

Primary Validation Data Source: Aircraft replicator profiles from Cloud Particle Imager (CPI)

Ancillary Data Sources: Imagers with three or four broad band (spectral resolution around 10 - 20 cm^{-1}) measurements in the infrared window region between 800 to 1000 cm^{-1} are likely to be able to distinguish large from small particle size cirrus and to provide IWP estimates.

Technique: Calculations of high-spectral resolution infrared radiances in cirrus cloud situations indicate that cloud forcing (clear minus cloudy) spectra are sensitive to ice particle size, ice water path, and cloud altitude. A numerical procedure based on the DISORT algorithm is used to retrieve the effective radius and ice water path of cloud layers with known optical depths and cloud boundaries and with nearby clear sky atmospheric conditions also known. The reasonable reproduction in a rather wide window region suggests that the DISORT based algorithm can distinguish small from large particle clouds as well as provide a fair estimate of IWP.
Cirrus clouds with small ice particles ($r_{eff} < 10$ μm) exhibit a non-linear *S*-shaped cloud forcing in 800 - 1000 cm^{-1} that gradually disappears as the particle size is increased. Clouds with ice water path (IWP) greater than 50 gm^{-2} (130 gm^{-2}) and small (large) particles of $r_{eff} = 7.5$ μm ($r_{eff} = 30$μm) are found to be opaque (upwelling radiance is unchanged within 1 K).

Scope and Schedule:

Comparison and Accuracy: Ice particle size and ice water path are estimated with 20% variation in the inferred values. The best sets of effective radius and ice water path can reproduce the observed HIS cloud forcing within 2 K in 800-1000 cm^{-1} and within 4.5 K in 1150-1250 cm^{-1} for both small ($r_{eff} < 10$ μm) and large ($r_{eff} > 10$ μm) particle clouds.

Supporting Documents: Chung, S., S. A. Ackerman, P. F. van Delst, and W. P. Menzel, 2000: Calculations and Interferometer Measurements of Ice Cloud Characteristics. Jour Appl. Meteor., 39, 634-644.

Funding:

5.3.2.3 Cloud ice water path

Primary Validation Data Source: Aircraft data

Ancillary Data Sources: VIIRS with three or four broad band (spectral resolution around 10 - 20 cm^{-1}) measurements in the infrared window region between 800 to 1000 cm^{-1} will likely be able to provide complementary IWP estimates.

Technique: Calculations of high-spectral resolution infrared radiances in cirrus cloud situations indicate that cloud forcing (clear minus cloudy) spectra are sensitive to ice particle size, ice water path, and cloud altitude. A numerical procedure based on the DISORT algorithm is used to retrieve the effective radius and ice water path of cloud layers with known optical depths and cloud boundaries and with nearby clear sky atmospheric conditions also known. The reasonable reproduction in a rather wide window region suggests that the DISORT based algorithm can distinguish small from large particle clouds as well as provide a fair estimate of IWP. Ice particle size and ice water path are estimated with 20% variation in the inferred values.

Cirrus clouds with small ice particles ($r_{eff} < 10$ μm) exhibit a non-linear *S*-shaped cloud forcing in 800 - 1000 cm^{-1} that gradually disappears as the particle size is increased. Clouds with ice water path (IWP) greater than 50 gm^{-2} (130 gm^{-2}) and small (large) particles of $r_{eff} = 7.5$ μm ($r_{eff} = 30$μm) are found to be opaque (upwelling radiance is unchanged within 1 K).

Scope and Schedule:

Comparison and Accuracy: Ice particle size and ice water path are estimated with 20% variation in the inferred values. Measured spectra from the HIS have been used to infer a range of ice particle sizes between 7.5 and 40 μm with ice water paths between 10 and 600 gm^{-2}.

Supporting Documents: Chung, S., S. A. Ackerman, P. F. van Delst, and W. P. Menzel, 2000: Calculations and Interferometer Measurements of Ice Cloud Characteristics. Jour Appl. Meteor., 39, 634-644.

Funding:

5.3.2.4 Cloud liquid water

Primary Validation Data Source:
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.3.2.5 Cloud optical thickness

Primary Validation Data Source:
Ancillary Data Sources:
Technique:
Scope and Schedule:
Comparison and Accuracy:
Supporting Documents:
Funding:

5.3.2.6 Cloud top height / pressure / temperature

5.3.2.6.1 **Approach 1:** Aircraft Cloud Lidar Sensor

Ancillary Data Sources: geometric stereo determinations from leo / geo high spatial resolution imagers viewing the same cloud at the same time from different view angles

Technique: CO_2-slicing will be followed by 1DVAR algorithms for high spectral resolution sounder (e.g., CrIS or AIRS or IASI) radiances and co-located high spatial resolution multi-spectral imaging radiances (e.g., VIIRS or MODIS) which retrieve the single layer atmospheric CTP and ECA from a single field-of-view (FOV) with higher accuracy than the current operational sounders (HIRS).

Scope and Schedule:

Comparison and Accuracy: Cloud pressure will be determined within 30 hPa.

Supporting Documents: Wylie, D. P. and W. P. Menzel, 1999: Eight years of global high cloud statistics using HIRS. Jour. Clim., 12, 170-184.

Funding: TBD

5.3.2.6.2 Approach 2: ARM site ARSCL product

Product: Cloud top height (and base)

Primary Validation Data Source: ARM site Micropulse Lidar (MPL) and Cloud Radar (MMCR), combined with the Active Remotely Sensed Cloud Layers (ARSCL) algorithm (Clothiax et al., 2000)

Ancillary Data Sources:
1. Vaisala ceiliometer
2. Winds from Wind Profiler, model output, or radiosondes

Technique: This approach uses the ARM site ARSCL product to validate the CrIS cloud top heights. ARSCL combines the MPL and MMCR measurements into a single product of cloud layers (base, top, thickness) versus time at each of the primary ARM sites (Southern Great Plains (SGP), Tropical Western Pacific (TWP), and North Slope of Alaska (NSA)). The technique then is to perform temporal averaging of the ARSCL product that produces an equivalent spatial averaging to match the extent of the CrIS footprint at that ARM site overpass time and compare the averaged product to the CrIS product. Winds data from the Wind Profiler network (for SGP), model data, and/or sondes can be used to determine the averaging times.

Scope and Schedule:
These comparisons can be preformed regularly for CrIS overpasses of each ARM site (SGP, TWP, and NSA) for the duration of the mission. Initial analysis should focus on cases of single layer clouds, followed by cases of overlapping clouds. A large number of cases of different types of clouds from each site should be compiled in order to perform statistically meaningful comparisons.

Comparison and Accuracy:
The ARSCL cloud top height product should be considered a lower bound on the cloud top height. In general, the MMCR has trouble detecting very high clouds, and the MPL will miss high clouds if low, thick clouds are present. The most accurate comparisons and analysis should therefore focus on single layer clouds at any altitude of optical depths <=1. For these cases, the ARSCL product is expected to be accurate to better than ~100m.

Supporting Documents: Clothiax et al., JAM, **39**, pp 645-665, 2000.

Funding: TBD

6 SCHEDULE OVERVIEW

6.1 CRIS SCHEDULE

6.2 PLANNED FIELD CAMPAIGNS

6.3 OTHER SATELLITE SCHEDULES

6.3.1 NASA AQUA

6.3.2 IASI

6.3.3 NASA EO-3 (GIFTS)

6.3.4 NOAA GOES

6.3.5 NOAA POES

Appendix A: Space-based instrument validation using the npoess Aircraft sounder testbed (NAST) and scanning high resolution interferometer sounder (SHIS) airborne sensors

Table of Contents

1.0 Introduction

1.1 The need for validation

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is a joint NASA, NOAA, and DOD program merging the current POES & DMSP systems into a common system (i.e. NPOESS) of polar satellites with the goal of providing meteorological and other environmental data products operationally. The Earth Observing System (EOS) is an international multi-satellite program for global remote sensing of the Earth, with a mission goal to advance the scientific understanding of the Earth system (i.e., including land, oceans, and atmosphere) as well as the influences of natural and anthropogenic processes on this system. In order to achieve these goals, these programs must produce accurate and precise long-time series of radiometric measurement data from multiple instruments on multiple platforms. Understanding and correctly interpreting these data require the ability to separate geophysical variability from instrument response changes in the observed signal during the missions. This requires a detailed instrument system-level characterization pre-launch, as well as extensive in-flight calibration and validation activities. Validation is the process of specifying the transformations required to extract estimates of high-level geophysical quantities from calibrated basic instrument measurables (i.e. radiances) and specification of the uncertainties in the high-level geophysical quantities. It requires detailed knowledge of the relationship between measurables and geophysical quantities of interest over the full range of possible observable conditions.

1.2 Advantage of airborne observations

Field validation measurements from high-altitude airborne sensors are critical for successful space-based instrument validation, since only observations from such platforms can provide the proper spatial & temporal context needed as well as be used to simulate expected satellite measurements for the instrument being validated. The higher spectral and spatial resolution aircraft sensor data can be spectrally and spatially convolved, respectively, to simulate what should be measured by the concurrent satellite observations during overpass events. The much higher spatial resolution of the aircraft sensor data can play an important role in validating satellite-derived data products under the conditions of variable surface and atmospheric radiance (e.g., due to clouds) within the satellite sensor footprint.

1.3 Overview and purpose of NAST & SHIS sounding sensor suite

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Atmospheric Sounding Testbed (NAST) is a suite of airborne infrared and microwave spectrometers, developed for the Integrated Program Office (IPO), that has been flying on the NASA high altitude ER-2 aircraft as part of the risk reduction effort for NPOESS. In addition to their stand alone scientific value, data from these airborne instruments have been used to simulate possible satellite-based radiance measurements, therefore enabling experimental validation of instrument system specifications and data processing techniques for future advanced atmospheric remote sensors (e.g., CrIS, the proposed sounder component for NPOESS). The NAST-I is a high resolution Michelson interferometer that derives its heritage from the nonscanning High resolution Interferometer Sounder (HIS) developed by researchers at the University of Wisconsin and serves as one important component of the NAST instrument suite. It scans the Earth beneath the ER-2 with a nominal spatial resolution of approximately 2.5 km within a cross-track swath width of about 46 km; its unapodized spectral resolution of 0.25 cm-1 within the 3.6 - 16.1 micron spectral range will enable experimental simulation of future infrared sounding instruments. NAST-M is the microwave component of NAST, currently with channels covering the 54 & 118 GHz oxygen bands; this microwave component enables atmospheric sounding in the presence of clouds. The Scanning High –resolution Interferometer Sounder (S-HIS) is an angular scanning Michelson interferometer also deriving its heritage from the non-scanning HIS instrument. While initially developed for operation on an unpiloted aircraft, S-HIS has flown on both the NASA DC-8 & ER-2 platforms. NAST-I & -M have both participated in the Wallops98, CAMEX-3, and WINTEX field measurement campaigns, and S-HIS served as an integral part of both CAMEX-3 & WINTEX. The NAST & SHIS are validated airborne sensors that are available to: support NPOESS sounding instrument (i.e., CrIS & ATMS) development & validation activities; serve as an EOS Validation Tool (e.g., AIRS, CERES, MODIS, MOPITT, & TES); provide mesoscale Earth science observations (from field experiment campaigns, e.g. CAMEX-3, WINTEX, and other flights of opportunity, e.g. Wallops98/99); as well as to serve as an engineering testbed for infusion of new technology (i.e., to explore enhancing airborne sounding; optimizing space-based sounding performance; and applicability toward other measurements, e.g. chemistry).

2.0 Validation approach

2.1 Overview & goals

Validation is the process of assessing by independent means the uncertainties of derived geophysical data products from instrument system outputs. This is generally approached by direct comparison with independent correlative measurements from ground-based networks, comprehensive test sites, and field campaigns; along with comparisons with independent satellite retrieval products from instruments on the same and different platforms. Pre-launch activities usually focus on algorithm development and characterization of instrument uncertainties, while post-launch emphasis is on algorithm refinement and measured/retrieved data product assessments. It is essential to have an integrated strategy for validation, including contributions from airborne field campaigns, surface networks, as well as satellites. LEO satellites provide measurements within a spatial context, while surface networks bring in the temporal context; airborne field measurements, however, provide both spatially & temporally registered observations from a configuration geometry (i.e. nadir viewing) similar to the space-based sensor being validated. Multi-platform observation campaigns can provide simultaneous radiometric and geophysical parameter measurements over spatially and spectrally homogeneous Earth scenes enabling validation of the on-orbit satellite radiometric calibration as well as geophysical parameter retrieval validations. The overall goal is to enable a timely assessment of data product uncertainty for the new space-based sensor being validated.

2.2 NAST-I, NAST-M, & SHIS airborne sensors

2.2.1 Measurement & science objectives

The primary focus of the combined NAST & SHIS payload will be to provide upwelling infrared and microwave radiance measurements and retrieved geophysical parameters to assist with or enable the following:

- ✓ accurate, spatially & temporally registered infrared & microwave calibrated radiance spectra for observed Earth scenes

- ✓ detailed characterization of atmospheric thermal and moisture structure, under clear to cloudy conditions

- ✓ radiative trace gas detection & transport (e.g. O3, CO, CH4, N2O, CO2)

- ✓ biomass burning studies: atmospheric radiative impact; radiative temperatures of fires; and Earth scene type classification

- ✓ NPOESS IPO instrument and forward model pre-launch specification optimization and post-launch calibration/validation (e.g. CrIS & ATMS)
- ✓ EOS instrument and forward model calibration/validation (e.g. CERES, MODIS, MOPITT, AIRS, TES)
- ✓ NAST-I, NAST-M, & S-HIS instrument performance verification/calibration/validation
- ✓ synergistic retrieval studies (e.g., NAST-I + NAST-M, MAS + S-HIS), including other platform measurements,etc.)
- ✓ EOS & NPOESS follow-on sensors for T, H2O, & chemistry: instrument concept definition and optimization studies
- ✓ advanced geostationary Earth orbit (GEO) sounding & chemistry applications: instrument concept definition and optimization studies

2.2.2 Data products

The following radiance and geophysical data products may be obtained from field implementation of the NAST-I, NAST-M, and S-HIS instrument suite:

<u>Direct Products</u>

- ✓ calibrated radiances (IR & U-wave)

<u>Derived Products</u>

- ✓ atmospheric temperature profiles
- ✓ atmospheric water vapor profiles
- ✓ surface temperature & emissivity
- ✓ cloud properties (altitude, temp. & emiss., LWP, effective particle size)
- ✓ tropospheric species column concentrations & some profiling (e.g. ozone, carbon monoxide, methane, & water vapor)
- ✓ atmospheric transport via H2O winds
- ✓ aerosol IR optical depth

2.2.3 Observation platforms

Up until this point, NAST-I & NAST-M have flown exclusively on NASA's high-altitude ER-2 aircraft. SHIS has flown the bulk of its time on the NASA DC-8 (i.e. during the CAMEX-3 field mission), while also having several flights on the ER-2 (i.e., during WINTEX). Plans are currently underway to enable accommodation of NAST-I & NAST-M on the new high-altitude Proteus aircraft. In addition to enabling flight opportunities when the ER-2 is booked, the Proteus has several beneficial flight attributes making it very attractive stand-alone or for flying combined sorties with the ER-2 during field deployments. The Proteus-unique platform attributes include:

- Ultra-fine and variable spatial resolution by not being constrained with a minimum flight altitude
- Improved geophysical data product quality with increased sample averaging afforded by slower ground speed
- Extended time observation capability of pollution episode evolution and transport processes with long duration flight capability
- Measurement altitude profiling capability using platform cruise altitude variations

Further complementary benefits may be achieved by combining Proteus flights with ER-2 field deployments, including:

- Inter-platform validation capability
- Radiation Divergence (cooling rate) measurements via formation flying at different levels
- Enhanced total measurement set through combined instrument diversity
- Extend effective swath width of airborne remote sensing observations through offset formation flying
- Broader spatial scale coverage through varying simultaneous flight patterns

2.2.4 Data archive and dissemination

The NASA LaRC DAAC will be used as a focal point for data archiving and dissemination. Other data products, such as experimental retrieved quantities, and miscellaneous instrument information will be available from the official NAST web page residing at NASA LaRC. The LaRC NAST-I page will also provide virtual links to the

SHIS and NAST-M home pages at the University of Wisconsin and MIT LL, respectively, for access to data products and/or information pertaining to those sensors.

2.3 Other complementary measurements

While the NAST/S-HIS airborne package can play a critical role in future space-based sensor validation, other complementary measurement components (i.e., other measurements from the same or different platforms) may be required depending on the particular validation task being addressed. Additionally, in-situ and ground based remote sensing data (e.g., from the DOE ARM CART sites) can provide independent validation of the airborne data products used to validate the space-based sensors.

Useful contributing measurements may include some of the following:

Ground-based Instruments

1) Surface observations of temperature, humidity, winds, and pressure
2) Radiosondes, for T & H2O profiles
3) Ozonesondes for direct measurement of Ozone profiles.
4) LIDAR for high vertical resolution H 2 O and aerosol profiles in the lower to middle troposphere.
5) Up-looking microwave radiometer for total column H 2 O.
6) Up-looking IR interferometer (e.g. AERI) for high resolution spectral measurements and PBL thermodynamic profiles
7) Cloud LIDAR for cloud altitude and thickness.

Airborne Instruments
1) Aircraft in situ spectrometer for IR active trace gases at platform altitude
2) Airborne LIDAR (i.e. LASE) for upper tropospheric H 2 O and aerosol profiles; co-incident observations with NAST-I/S-HIS would be invaluable to addressing H 2 O spectroscopic issues, particularly in the hard to measure upper troposphere.
3) MAS for much higher spatial resolution to address small-scale scene variability
4) FIRSC for far-IR measurements and cirrus cloud characterization
5) MicroMAPS for measurements of layer integrated CO amounts
6) MIR for microwave measurements of water vapor profiles

2.4 Objectives for data usage

Space-based instrument validation tasks can be divided into two categories, pre-launch and post-launch activities. For both of these categories, multi-instrument field experiment data are needed to address validation goals such as the following:

Pre-launch activities

1) Spectroscopic validation
2) Forward model test & development

3) Catalogue spectral information about clouds/homogeneous land surfaces
4) Investigate land surface inhomogeneity effects
5) Algorithm/data system verification and error analysis

Post-launch activities

1) Absolute calibration for and validation of radiance products
2) Spectroscopic validation
3) Forward Model Validation and refinement
4) Validation of retrieved geophysical parameters under varying surface types and atmospheric conditions

3 Planned experiments

3.1 Space-based missions

Figure 1 summarizes the transition of the POES & DMSP sensors into the NPOESS operational fleet. It also shows the EOS AM-1 & PM-1 platforms and how the NPOESS Preparatory Platform (NPP) to be launched in 2005 will "bridge" sounding observations between the PM-1 AIRS/AMSU (scheduled for launch in 2001) and NPOESS CrIS/ATMS (scheduled for launch in 2008) sensors.

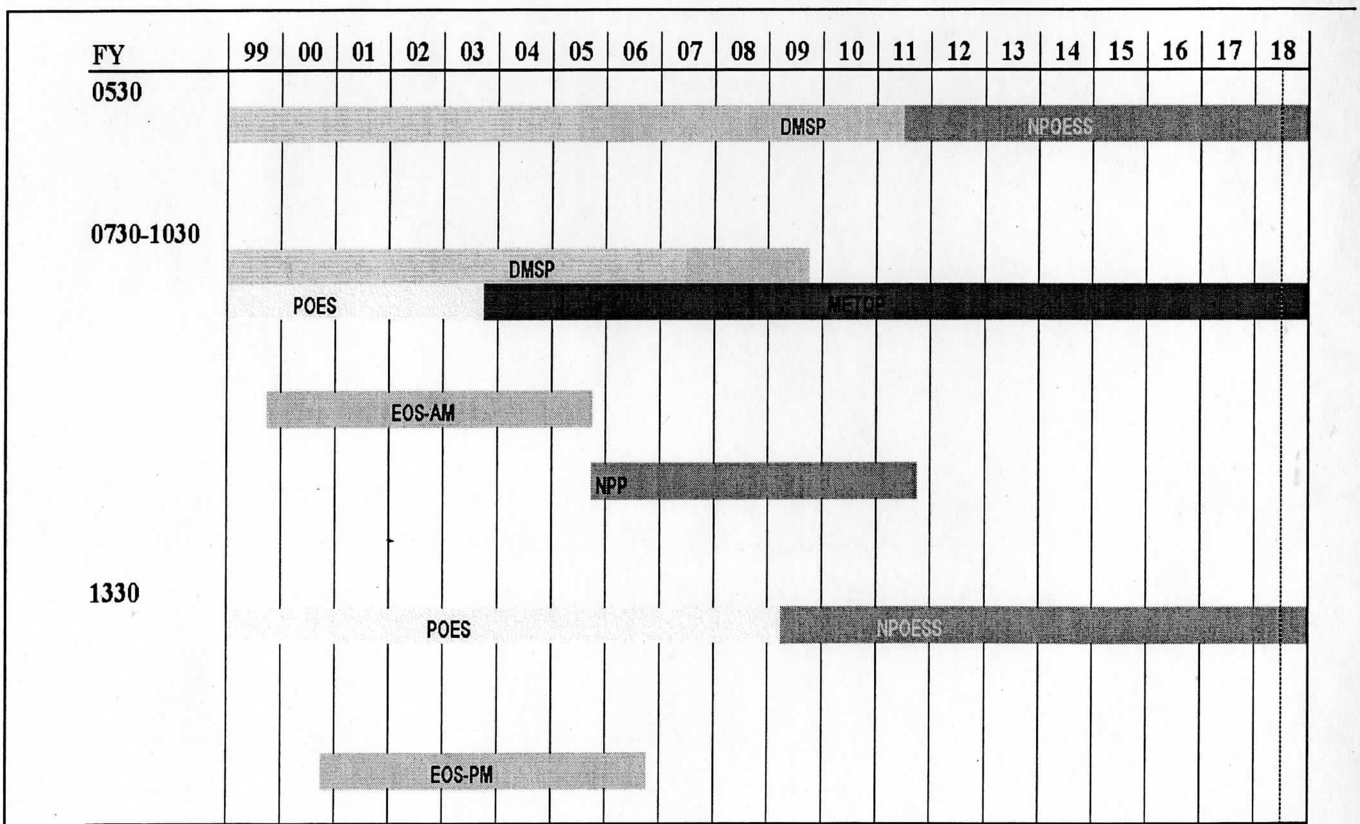

Figure 1: Polar Orbiting Earth Remote Sensing Mission Profile

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Space-based missions which would greatly benefit from including the NAST & S-HIS airborne sounding suite in their field validation programs include:

Terra (a.k.a. EOS AM-1, 08/1999) CERES, MODIS, MOPITT
The Terra satellite is the flagship of EOS. It will provide global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another.

METEOR 3M-1 (SAGE III - 12/1999)
The SAGE III mission on the Russian Meteor 3M-1 spacecraft seeks to enhance our understanding of natural and human-derived atmospheric processes by providing high latitude long-term measurements of the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere.

EOS PM (12/2000) AIRS, AMSU, CERES, MODIS
The focus for the EOS PM satellite is the multidisciplinary study of the Earth's interrelated processes (atmosphere, oceans, and land-surface) and their relationship to Earth system changes.

ADEOS II (12/2000) ILAS-2
The Advanced Earth Observing Satellite II (ADEOS II), the successor to the Advanced Earth Observing Satellite (ADEOS) mission, is a joint mission with the National Space Development Agency (NASDA) of Japan. The mission will take an active part in the research of global climate changes and their effect on weather phenomena.

SAGE III (2001 Flight of Opportunity - 2001)
SAGE III (Stratospheric Aerosol & Gas Experiment) is the fifth in a series of spaceborne remote sensing instruments developed by NASA's Langley Research Center for monitoring global distribution of aerosols and gaseous consitiuents using the solar occultation approach.

International Space Station (SAGE III - 10/2002)
The SAGE III mission on the Space Station seeks to enhance our understanding of natural and human-derived atmospheric processes by providing high latitude long-term measurements of the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere.

EOS Chemistry (12/2002) TES, MLS, HIRDLS
The EOS Chemistry-1 satellite will focus on measurements of atmospheric trace gases and their transformations. The objective of the mission is to study the chemistry and dynamics of the Earth's atmosphere from the ground through the mesosphere.

Earth System Science Pathfinders (2003+) PICASSO-CENA, CloudSat
The Earth System Science Pathfinder (ESSP) Project is a component of the Earth Science Enterprise (ESE) that addresses unique, specific, highly-focused mission requirements in Earth science research.

NMP EO-3 (2004) GIFTS
Geostationary sounding and/or chemistry mission currently under study. GIFTS would provide first high spectral resolution mesoscale meteorological profiles and cloud optical and geometric property observations with high temporal frequency.

NOAA polar series HIRS, AMSU, AVHRR
polar-orbiting meteorological operational satellites; K (launched 5/13/98), L (12/99), M (5/2001), N (12/2003), N' (1/2008)

METOP polar series IASI, MHS, AVHRR
polar-orbiting operational meteorological satellites; 1 (6/2003), 2 (SPR/2008)

NPOESS platforms NPP (2005), NPOESS (2008 & 2011) CrIS/ATMS/VIIRS

GOES platforms ABS, ABI
geostationary operational meteorological satellites; L – Q, 1999 – 2008

3.1 Field deployments

Figure 2 shows the current NASA ER-2 flight schedules for FY99-FY03. Specific field deployments for which the NAST/S-HIS package could significantly contribute toward both field mission science goals and EOS instrument validation include:

Wallops-99	East Coast USA	NAST, AVIRIS, INTESA	Aug/99
SCAR-99	Pacific NW	MOPITT, MAS	Oct/99
CALVEX-M	CART/GMEX	MAS, CLS, SHIS MOPITT-A (ER-2) NAST, FIRSC (Proteus)	Mar-Apr/00
SAFARI-2000	South Africa	MAS, CLS, SHIS MOPITT-A (ER-2) NAST, FIRSC, Micro-maps (Proteus)	Aug-Sep/00
CRYSTAL	Guam	NAST, MAS, CLS, LASE, S-HIS	Jul-Aug/01 or 02
CAMEX-4	PAFB, FL	NAST, MAS, CLS, SHIS	Aug-Sep/01 or 02

We propose to fly NAST/S-HIS on the Proteus aircraft to participate in the above field deployments as well as for new campaigns (TBD) focusing specifically on NPOESS sensor underflight validation activities. Flying NAST-I + S-HIS on same platform provides inter-sensor validation, enabling an independent check of infrared radiance spectra quality. However, the maximum benefit from implementing this airborne sounding suite as a space-based instrument validation tool can be achieved by simultaneously flying S-HIS & NAST on two independent high-altitude platforms (e.g. using both the ER-2 & Proteus, as mentioned earlier).

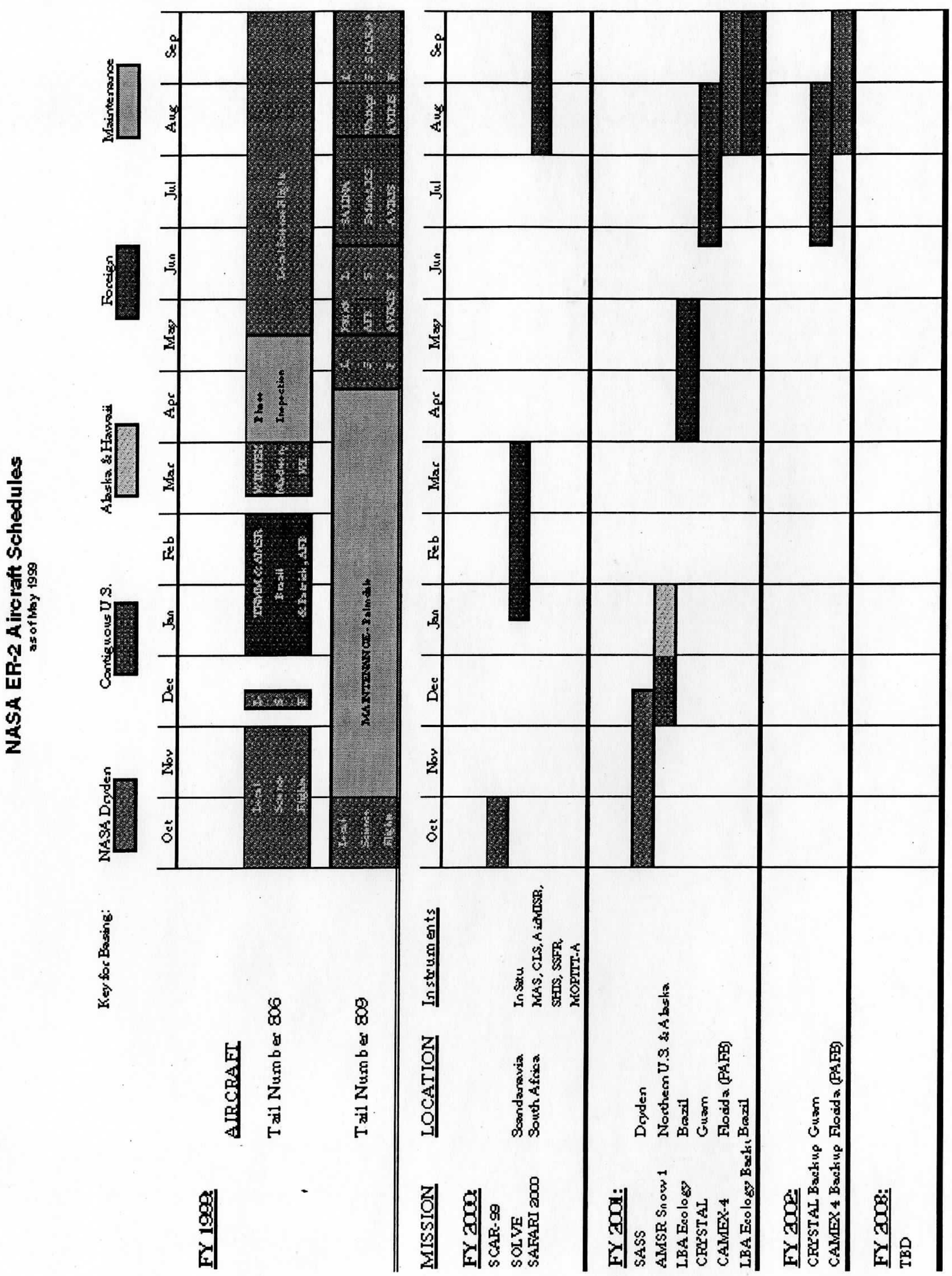

Figure 2: Deployment schedule for NASA's high-altitude ER-2 aircraft.

7 APPENDIX B WATER VAPOR WORKSHOP SUMMARY AND CONCLUSIONS

On November 22-23, 1999, National Environment Satellite and Data Information Service (NESDIS) and the National Weather Service (NWS) hosted A Workshop on "Improving Observation and Analysis of Atmospheric Moisture for Operational Weather Forecasting" at the Space Science and Engineering Center, Madison, Wisconsin. The workshop was intended to start activities toward determining the necessary moisture sensing components of national mesoscale observing system of the future and to improve utilization of those measurements for weather analyses, nowcasting and forecasting.

The workshop had presentations on moisture measurements, assimilation of moisture measurements, impact on numerical weather prediction, utilization at forecast offices, and needs for the future. The agenda can be found in Attachment A; attendees are in Attachment B. The major points from the workshop were (a) moisture demonstrates considerable variability in the horizontal and vertical, (b) measurements of total precipitable water (TPW) from different systems agree within 5 – 10%, (c) ground based profile measurements offer new opportunities to depict rapid small scale boundary layer moisture changes, (d) remote sensing at high spectral IR resolution offers the promise of depicting vertical H2O layer patterns, (e) assimilation of moisture information is challenging as all observations are interdependent and influence H2O balance (forecasts are accurate to within 15 – 20% for TPW), (f) moisture profiles are especially useful in NWS Forecast Offices and centers and geo-soundings are very timely for subjective forecasting because pre-storm environments initiate in moist clear skies often near outflow boundaries (which present good opportunities for IR systems), and (g) there is a need for a coherent national program for moisture measurements and NWP utilization.

Relevant parts of the conclusions from the workshop are appended.

1. Moisture measurements of TPW from different systems agree within 5 – 10%
   Differences are beginning to be understood

2. AERI boundary layer temperature / moisture profiles every ten minutes are providing good mesoscale data sets from CART deployment
   2a. A network of AERIs along the coast of the Gulf of Mexico could provide valuable information on moisture intrusions into the continent and possible return flow

3. Bias from sonde to sonde is being characterized (e.g. Viz sondes have moist bias)

   3a. More accurate sondes, even at only selected sites, are needed for validation of many moisture measurements
   3b. There is an evolution to better definition of sonde performance from more intercomparisons with other profile measurements (more colocations with GPS were encouraged)

4. Water vapor lidar measures boundary layer H2O profiles within 5%
   4a. A low cost DIAL version is under development

5. WVSS are producing about 1500 moisture profiles per day from six aircraft
   5a. Sep-Oct 99 Louisville field experiment showed WVSS data comparing well with raobs

5b. The number of units installed are expected to increase rapidly in 2000 on UPS and American Airlines
5c. A second generation WVSS will be ready for testing in 2000
5d. The concept of an atmospheric sounding system (including WVSS, AERI, DIAL, sondes, GOES, POES,...) covering the Eastern US is under consideration

6. Ground based GPS are measuring total column moisture (there is good potential for use as stable reference)
6a. Biases with respect to other measurements are under investigation
6b. A GPS network of 18 units provided small positive impact in the RUC during a test period (the RUC already included GOES TPW)
6c. GPS offers geometric validation of other measurements
6d. 59 GPS are operating in (a demonstration network of more than 200 is planned in 3 to 5 years)
6e. There is some progress being made in reducing the data delay
6f. The combination of GPS and GOES PW is largely untapped
6g. Explore BUFR distribution in real time to NWP centers via GTS (action)

7. Remote sensing at high spectral IR resolution is revealing vertical H2O patterns
7a. Information content is approaching radiosonde-like
7b. Surface emissivity can be separated from Ts (with an on line off line analysis) assisting use of radiances over land
7c. Determination of cloud heights are improved
7d. Advent of AIRS, IASI, CrIS requires preparations for successful assimilation

8. GOES moisture measurements in NWP are providing positive impact
8a. Three layers of moisture from GOES-8/10 are going in to the Eta
8b. Modest but consistent positive impact has been realized (5% improvement in equitable threat score during wet season)

9. Assimilation of moisture information is challenging
9a. Forecasts are within 15 – 20%
9b. all observations (wind, temperature, moisture,...) are interdependent and influence the H2O balance
9c. Discriminating moisture flux from motion and static H2O is important
9d. There is a need for moisture observation impact tests
9e. The combination of IR and microwave measurements is more powerful than either by itself
9f. Each new measurement system (or existing ones not being used) requires at least one person two years for introduction to NWP operations, plus ther are ongoing maintenance considerations

10. EDAS testing suggests positive impact from all sensing systems in ops
10a. Removal of remote sensing assets would have negative impact of the forecast

11. Physics in the forecast model is most important part of moisture assimilation

11a. Assimilation of new systems often requires improved physics in model

12. A Composite Moisture Observing System is necessary (components complement but don't replace one another)
    12a. Adequate horizontal, vertical, and temporal sampling necessitates a composite system
    12b. Remote sensing from ground, satellite radiances, and in situ aircraft all play an important role
    12c. Placement of continuous between intermittent observation systems should be considered (e.g. AERI between airports)
    12d. Geographical complementarity must also be considered

13. NWS-Forecast Offices are deriving benefit from geo-soundings in subjective forecasting
    13a. Pre-storm environments initiate in moist clear skies often near outflow boundaries (thus presenting good opportunities for IR systems)
    13b. More meso-scale data assimilation efforts are needed for forecasters in the field

14. Better initialization of clouds in NWP is showing promise
    14a. This merits more attention but is complicated by cloud-moisture physics interactions
    14b. Soundings above clouds need to be generated in operations and their utility needs to be explored further

15. A matrix of observing systems is needed to effectively summarize current and future opportunities
    15a. It must include hor res, vert res, cycle time, delay time, accuracy, bias, profile domain, cost, maturity, financial status, external collaboration
    15b. Oct 99 BAMS article by T. Weckworth provides background information

16. There is no coherent program for moisture measurements and NWP utilization
    16a. There is a need for NESDIS & OAR & NWS coordination
    16b. Proven observing systems need to be posted in a demonstration area (phased demonstration would occur as new observing systems become available)
    16c. A Moisture Program in phases would look something like the following (including forecast office assessment, 4DDA development, and model physics investigations)
        16c1. 2000 CART Site Campaign with mesoscale model studies
        16c2. 2002 start of Eastern US Network line of observations along Gulf of Mexico with regional scale model studies
        16c3. Therafter establish an observing network over the Eastern US (maximizing use of newly launched satellite assets)

8 APPENDIX C: GLOSSARY OF TERMS

ABBA - Automated Biomass Burning Algorithm

ABI – Advanced Baseline Imager
ABS – Advanced Baseline Sounder
ACARS - Aeronautical Radio Incorporated Communications Addressing and Reporting System
AERI - Atmospheric Emitted Radiance Interferometer
AIREP - AIRcraft REPort
AIRS - Atmospheric Infrared Sounder
AMDAR - Aircraft Meteorological Data Relay
AMSU – Advanced Microwave Sounding Unit
ARAD – Atmospheric Research and Applications Division
ARM - Atmospheric Radiation Measurement (DOE)
ASOS - Automated Surface Observing Stations
ASPT – Advanced Satellite Products Team (ORA)
ATS - Applications Technology Satellites
AVHRR - Advanced Very High Resolution Radiometer
AWC – Aviation Weather Center
AWIPS - Advanced Weather Interactive Processing System
CART – Clouds and Radiation Testbed
CICS – Cooperative Institute for Climate Studies
CIMMS – Cooperative Institute for Mesoscale Meteorological Studies
CIMSS - Cooperative Institute for Meteorological Satellite Studies
CIPSU - Cooperative Institute at Pennsylvania State University
CIRA - Cooperative Institute for Research in the Atmosphere
COMET - Cooperative Program for Operational Meteorology, Education and Training
CONUS - Continental United States
CRAD – Climate Research and Applications Division
CrIS - Cross track Infrared Sounder
CST - Convective Stratiform Technique
DMSP - Defense Military Satellite Program
DPI – Derived Product Image
EDAS – Eta Data Assimilation System
EMC - Environmental Modeling Center
EOS – Earth Observing System
ERBE - Earth Radiation Budget Experiment
ERB - Earth Radiation Budget Satellite
ERL - Environmental Research Laboratory
ESA - European Space Agency
EUMETSAT - EUropean organization for the exploitation for METeorological SATellites
FAA - Federal Aviation Administration
FPA - Focal Plane Arrays
FPDT – Forecast Products Development Team (ORA)
FSL - Forecast Systems Laboratory of ERL
FTS – Fourier Transform Spectrometer
FOV - field of view
GCIP – GWEX Continental scale International Project

GDAS - Global Data Assimilation System
GFDL – Geophysical Fluid Dynamics Laboratory
GHCC - Global Hydrology and Climate Center
GIFTS – Geostationary Imaging Fourier Transform Spectrometer
GMS - Geoststionary Meteorological Satellite (Japan)
GOES - Geostationary Operational Environmental Satellite
GPS – Global Positioning System
GSFC - Goddard Space Flight Center
GWEX – Global Energy and Water Cycle Experiment
HIRS - High resolution Infrared Radiation Sounder
HIS - High spectral resolution Interferometer Sounder
HT – Hydrology Team (ORA)
IASI - Infrared Atmospheric Sounding Interferometer
IFFA - Interactive Flash Flood Analyzer
INR - Image Navigation and Registration
IRIS - Infrared Radiation Interferometer Spectrometer
ISCCP - International Satellite Cloud Climatology Project
LAPS - Local Area Prediction System
M-AERI - Marine AERI
METEOSAT - METEOrological SATellite
METOP - Meteorological Operational Platform
MIMR - Multifrequency Imaging Microwave Radiometer
MISR - Multi-angle Imaging Spectro-Radiometer
MODIS – Moderate resolution Imaging Spectroradiometer
MSFC - Marshall Space Flight Center
MTF - modulation transfer function
MTSAT - Multi-functional Transport Satellite
NASA - National Aeronautics and Space Administration
NCAR – National Center for Atmospheric Research
NCDC - National Climate Data Center
NCEP - National Center for Environmental Prediction
NEDT - noise equivalent temperature
NESDIS - National Environmental Satellite Data and Information Service
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
NORPEX – Northern Pacific Experiment
NOVA - NOAA Operational VAS Assessment
NPOESS - National Polar-orbiting Operational Environmental Satellite System
NWS - National Weather Service
NWSTC - National Weather Service Training Center
OAR - Office of Oceanic and Atmospheric Research
OGE - Operational Ground Equipment
ORA - Office of Research and Applications
ORAD – Ocean Research and Development Division
OSD – Office of Systems Development
OSDPD - Office of Satellite Data Processing and Distribution

POP - Product Oversight Panel
QI - Quality Indicator
QPF – Quantitative Precipitation Forecast
RAMMT - Regional and Mesoscale Meteorology Team (ORA)
RAMSDIS - Regional and Mesoscale Meteorology Branch Advanced Meteorological Satellite Demonstration and Interpretation System
RDAS - Regional Data Assimilation System
RFF – Recursive Filter Flag
RUC – Rapid Update Cycle
SAB – Synoptic Analysis Branch (OSDPD)
SAO - Systems Acquisition Office
SCP – Satellite Cloud Product
SOCC - Satellite Operations Control Center
SOO - Science Operations Officers
SPC - Storm Prediction Center
SPOP - Sounding Product Oversight Panel
SPOT - Systeme Probatoire d'Observation de la Terre satellite
SPSRB - Satellite Products and Services Review Board
SSMI - Special Sensor Microwave/Imager
SSMT - Special Sensor Microwave/Temperature
SST - Sea Surface Temperature
SSU - Stratospheric Sounding Unit
TAC – Technical Advisory Committee
TIROS - Television InfraRed Operational Satellite
TOA - Top of the Atmosphere
TOMS - Total Ozone Mapping Spectrometer
TOVS - TIROS Operational Vertical Sounder
TPC - Tropical Prediction Center
TRMM - Tropical Rainfall Measuring Mission
VAS - VISSR Atmospheric Sounder
VDUC - VAS Data Utilization Center
VIIRS - Visible Infrared Imager Radiometer Suite
VISSR - Visible and Infrared Spin Scan Radiometer
VORTEX - Verifications of the Origins of Rotation in Tornadoes Experiment
WSFO - Weather Service Forecast Office

[1-C]

Minutes of 6-6-00 SOAT Meeting

< SOAT_00.06.06.doc>

June 9, 2000

MEMORANDUM FOR: Record

FROM: W. Paul Menzel
Chair, Sounder Operational Algorithm Team

SUBJECT: Minutes of meeting on 6 June 2000

On June 6, the Sounder Operational Algorithm Team met in Silver Spring, MD. The agenda included discussion of design trades for the Cross track Infrared Sounder (CrIS), presentations on the sounding algorithm, and a brief status report on the Advanced Technology Microwave Sounder (ATMS).

The meeting opened with a discussion regarding the CrIS field of view (FOV). References were cited demonstrating the diminishing probability for finding a cloud free FOV as the FOV size increases (see attachment 4). The SOAT continued to press for transition from the current 14 km FOV to a 10 km FOV as soon as possible. The IPO assured the SOAT that a 10 km FOV was still an option.

A review of the action items revealed that ITT data regarding the CrIS field of view and noise tradeoffs had not been distributed or reviewed, the ITT cal / val plan was still pending, distribution of the AER (Atmospheric Environment Research) transmittance code using optimal spectral sampling was still pending, and the explanation of the EDU1 noise performance issues was still pending. Some of this information was available on the ITT CrIS web site; the SOAT requested IPO help in transferring the appropriate files to the NPOESS library or helping SOAT members gain password access to the ITT CrIS web site.

This prompted some discussion on contract deliverables that belong in the public domain; the IPO was encouraged to generate a plan for the release of the vendor algorithms as soon as feasible so that the SOAT could plan and conduct a rigorous calibration / validation campaign.

Dr. Xu Liu from AER presented the CrIS sounding algorithm; key features include a profile solution accomplished with a modified Rodgers maximum likelihood approach, radiative transfer calculations using optimal spectral sampling patented by AER, scene classification attempted with a principle component analysis of the infrared spectrum in each of the 3 by 3 field of view sounding areas, accommodation of multiple retrieval strategies (cloud clearing, hole hunting, and combined clear sky and cloud properties retrieval), and utilization of only part of the available spectrum in the profile retrieval based on information content analysis with a training data set.

The SOAT was updated on ATMS. The ATMS phase B contracts were awarded in November 1999; vendors will conduct preliminary design reviews in July 2000. ATMS spectral bands include 23, 31, several 50, 89, 166, and several 183 GHz bands. The SOAT noted that the ATMS represents a nice improvement over the Advanced Microwave Sounding Unit (AMSU) in several respects. ATMS will have no gaps in its earth coverage; this enhances hurricane, water vapor, and precipitation monitoring. ATMS will have 33 km resolution near 50 GHz (better than the AMSU 50 km). ATMS will have a signal to noise ratio as good as AMSU within a CrIS field of view. ATMS oversampling near 54 GHz will exceed Nyquist across track and equal Nyquist along track. ATMS spectrally close band pairs will generally have about the same spatial beam width to facilitate multispectral applications.

The next SOAT will occur in September 2000.

Attachment 1

Attendance

Jim Duda	IPO
Stan Schneider	IPO
Stephen Mango	IPO
Art Schwalb	IPO
Narinder Chauhau	IPO
Allen Larar	LaRC
Paul Menzel	NESDIS
Mitch Goldberg	NESDIS
Chris Barnet	GSFC
Joel Susskind	GSFC
Dave Staelin	MIT/LL
Gail Bingham	Utah State
Hank Revercomb	Univ of Wisconsin
Peter Schluessel	EUMETSAT
Judy Fennelly	ITT
Xu Liu	AER

Attachment 2

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Attachment 3

Action Items

(1) Review CrIS field of view and noise tradeoffs. (ITT, Bingham, Kelly, Jul 00)

(2) Make proposed cal / val plan available to SOAT. (ITT, Jul 00)

(3) Explain the noise performance of EDU1 versus that expected from CrIS. (ITT, Jul 00)

(4) Make arrangements for AER transmittance algorithms transfer to interested SOAT members. (Mango, Jul 00)

(5) Transfer appropriate CrIS data files to the NPOESS library or help SOAT members gain password access to the ITT CrIS web site. (Mango, Jul 00)

(6) Generate a plan for the release of the vendor instrument characteristics and sounding algorithms as soon as feasible so that the SOAT can plan and conduct a rigorous calibration / validation campaign. (IPO, Sep 00)

(7) Present lessons learned from AIRS cloud clearing. (Barnet, Sep 00)

(8) Arrange for a presentation on IASI at a future SOAT meeting. (Menzel, Sep 00)

Attachment 4

References regarding Cloud Field of View Studies

1. Cuomo, V., C. Serio, V. Tramutoli, C. Pietrapertosa, and F. Romano, 1992: Assessing the impact of higher spatial resolution on cloud filtering applied to infrared radiances. Universita della Basilicata Rep., Basilicata, Italy.

2. Derrien, M., 1992: Influence of the size of field of viewon contamination by clouds. Issue O contract report to EUMETSAT.

3. Smith, W., H. Huang, and J. Jenney 1996: An Advanced Sounder Cloud Contamination Study. J. Appl. Meteor., Vol. 35, No. 8.

Summary of findings

Relative Probability of Finding a Clear FOV Within a 50 km AMSU Footprint (with respect to 12 km FOV probability)

Study	4 km	8 km	12 km	16 km
AVHRR (EUROPE)[1]	2.7	1.5	1.0	0.8
AVHRR (EUROPE)[2]	-	1.3	1.0	0.8
GOES (3x3); All Cases[3]	1.4	1.2	1.0	0.8
GOES: Cloudy AMSU Only[3]	1.6	1.3	1.0	0.7
Average	1.9	1.3	1.0	0.8

[1-B]

Minutes of 2-3-00 SOAT Meeting

<SOAT_00.02.03.doc>

February 7, 2000

MEMORANDUM FOR: Record

FROM: W. Paul Menzel
Chair, Sounder Operational Algorithm Team

SUBJECT: Minutes of meeting on 3 February 2000

On February 3, the Sounder Operational Algorithm Team met in Silver Spring, MD. This was the first meeting since vendor down-select, and thus it was the first meeting where ITT was present. EUMETSAT also sent a scientist to attend the meeting. The agenda included discussion of design trades for the Cross track Infrared Sounder (CrIS), presentations on the research results achieved with the NPOESS Airborne Sounder Testbed (NAST) infrared and microwave data from 1999 ER-2 deployments, a presentation on cloud and precipitation detection with the Advanced Microwave Sounding Unit (AMSU), and a status report on the Advanced Technology Microwave Sounder (ATMS). Each team member also outlined their CrIS related year 2000 activities.

The SOAT meeting was preceded by a 90-minute briefing on CrIS to Dr. Ghassem Asrar. A presentation by Ron Glumb from ITT amplified the points that the major advantages are an established interferometer approach, a compact folded telescope, a large aperture mirror with plenty of signal, a flat mirror interferometer with dynamic alignment and two sided interferogram sampling, linear HgCdTe PV detectors for all bands, 4 stage passive cooling achieving excellent LWIR detector performance, preprocessing that corrects for self apodization to create Sensor Data Records (SDR) of radiance spectra, and a retrieval algorithm that points to total system compliance with Environmental Data Record (EDR) specifications. A working engineering design unit with many of the major components already in place is being used to anticipate issues concerning packaging and performance. The ITT presentation was informative and introduced a formidable design and team that will deliver a CrIS that meets or exceeds SRD expectations.

The SOAT opened with a discussion of the options for realizing a 10 km field of view as soon as possible. Two were apparent: (1) changing the current 3 x 3 14 km FOV detector configuration to an under-sampled 3 x 3 10 km FOV configuration, or (2) increasing the number of detectors to a 4 x 4 10 km FOV configuration. Option (2) requires bandwidth relief. Option (1) suggested one more inspection of the noise differences for 10 and 14 km detectors (see actions). It is unlikely that the first CrIS on the NPOESS Preparatory Project will be changed; there is determination that the second or third CrIS will have an improved FOV.

Another design trade concerns a modest sensor volume increase that enables using standard electronics cards. The SOAT felt that this would not only reduce cost but also increase reliability and encouraged that serious consideration be given to this request.

Ralph Welsh gave a status report on the ATMS. Good progress has been made. The channel selection will occur in April 2000; the SOAT repeated their guidance given January 1999: "ATMS spectral bands should include 23, 31, several 50, 89, 166, and several 183 GHz bands. Addition of 118 GHz bands should be explored as a first priority and 58 GHz bands as a second priority."

Bill Smith presented the NAST research. Good data has been realized from deployments in Wallops 1998 (validation), CAMEX-3 in 1998 (hurricanes), WINTEX 1999 (clouds, snow, and ice), and Wallops 1999 (chemistry). Several comparisons between RAOBs and retrievals from NAST revealed the small-scale variability of moisture in the atmosphere. It was reiterated that one needs airborne measurements to validate space-borne measurements in order to account for atmospheric variability. Several campaigns planned for 2000 were summarized; European participation was invited.

John Solman showed recent results from AMSU research. Measurements at 183 GHz are useful for delineating a rain area and measurements at 54 GHz (that do not sense the surface) help to quantify the rain rates; a neural algorithm trained on NEXRAD data has been developed. Good comparison with NEXRAD observations (exclusive from the training data set) were presented.

The role of the SOAT was then discussed. The SOAT chair suggested that there are five activity areas that the SOAT must continue to pursue:

(1) Algorithm development wherein test data sets are generated (e.g. simulated as well as actual from airborne testbed) and algorithm tradeoffs are investigated (e.g. cloud clearing vs hole hunting, optimum spectral sub-sampling, physical and/or statistical retrievals),
(2) Calibration/validation procedures wherein instrument performance is characterized /verified (e.g. field experiments with NAST et al., instrument inter-comparisons, assimilation impacts) and operational procedures are evolved (e.g. streamlining for real-time application, QC, connecting with NESDIS OSDPD),
(3) Instrument evolution wherein efforts are made to fix obvious problems (h/w, s/w) and there is a transition to more capable performance (e.g. bigger spectral range, better NEDT, smaller fov, ...),
(4) Long term environmental monitoring wherein archive procedures are suggested (e. g. metadata content, ancillary data, ...) and linkage with EOS is established, and
(5) Training / mentoring wherein the continuity of expertise is assured for the longer term by engaging young scientists in CrIS science.

The IPO concurred and indicated that efforts were being made to invoke a longer term strategy for maintaining a science partnership with the vendor for improving instrument and algorithm performance as well as maintaining an independent science capability for validating CrIS instrument and EDR performance.

Each team member presented their plans for 2000. They are summarized by laboratories in the following paragraphs.

Lincoln Laboratory will continue to evaluate the design, development, and performance of CrIS, CMIS, and ATMS instruments for the IPO in FY00. Lincoln will alert the IPO to design changes that adversely affect performance and support the SOAT with periodic performance assessments as coordinated by the instrument managers. In addition, in a separate effort, Lincoln will use AMSU and NAST-M data to evolve the microwave algorithms for cloud detection, precipitation estimation, as well as temperature and moisture profile retrieval.

Langley Research Center will be deploying the NAST on an ER-2 and the Proteus in three field experiments in attempts to gather more scientific test data sets in differing seasons and atmospheric conditions. This will facilitate inter-comparison of data and derived geophysical parameters from several instruments such as AERI, NAST, SHIS, LASE, and FARSC. In addition they will begin processing NAST infrared and microwave data to study the strengths of combined profile retrievals.

Goddard Space Flight Center will be conducting ATMS trade studies to assess the utility of the 188 GHz and 56 GHz channels. They will continue their work in cloud clearing using HIRS / AMSU as well as NAST- I / M data. CrIS instrument work will include noise sensitivity and field of view trade studies as well as investigations of new fast transmittance codes.

The Space Dynamics Laboratory of Utah State will support three activities. (1) SDL will support CrIS instrument development and RDR to SDR software evaluation. SDL will review CrIS performance estimates, calibration data, and EDU response and advise the SOAT on the performance of the actual hardware with respect to the design estimates. (2) SDL will develop data compression techniques in the time domain to facilitate possible expansion to larger FPA. SDL has been looking at time domain (interferogram) data compression issues for the new Geostationary Imaging FTS (GIFTS) sensor that well be developed under NASA leadership and will keep that effort closely tuned to CrIS needs. (3) SDL will provide technical liaison between the CrIS and GIFTS teams with respect to instrument performance, design and calibration issues. SDL will attempt to keep the SOAT aware of the technical issues and the design choices.

The University of Wisconsin will be studying cloud properties and how they affect upwelling high spectral resolution infrared data; this will be done using the MODIS Airborne Simulator (to infer cloud type) and NAST and Scanning HIS. In addition they will be exploring algorithms for determination of land surface temperature as well as emissivity using on line off line techniques. Radiative transfer codes will be tested; cases specifically suited for forward RTE model validation will be created and comparisons against reference calculation will be performed. Finally, a calibration / validation plan will be created by merging the various contributions from the vendor and the science team.

The SOAT welcomed the opportunity to work closely with AER on the development of the CrIS algorithms. AER indicated that their focus for the coming year was refinement of the optical spectral sampling (OSS), study of hole hunting versus cloud clearing, code optimization, and adjustment of the code to CrIS plus ATMS (rather than the AMSU). More details of their planned activities can be found in attachment 2.

Attachment 1

Attendance

Jim Duda	IPO
Tim Bode	IPO
Stan Schneider	IPO
Stephen Mango	IPO
Art Schwalb	IPO
Bill Smith	LaRC
Allen Larar	LaRC
Paul Menzel	NESDIS
Mitch Goldberg	NESDIS
Bob Murphy	GSFC
Chris Barnet	GSFC
Joel Susskind	GSFC
Ralph Welsh	GSFC
Mike Kelly	MIT/LL
John Solman	MIT/LL
Dan Mooney	MIT/LL
Mike Griffin	MIT/LL
Gail Bingham	Utah State
Peter Schluessel	EUMETSAT
Steve Johnson	ITT
Judy Fennelly	ITT
Ron Isaacs	AER
Jean-Luc Moncet	AER
Xu Liu	AER
Frank Kelly	AER
Scott Shipley	Raytheon
Leah Wilson	Raytheon

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Attachment 3

Action Items

(1) Review CrIS field of view and noise tradeoffs. (ITT, Bingham, Kelly, Mar 00)

(2) Provide references to clear sky and field of view size studies. (Smith, Feb 00)

(3) Make proposed cal / val plan available to SOAT (ITT, Feb 00)

(4) Invite European participation in the Water Vapor Experiment scheduled for October 2000 (Revercomb, Feb 00)

(5) Investigate procedures for making the AER transmittance algorithms available to the SOAT (Bode, Feb 00)

(6) Arrange for an in depth review of the CrIS EDR algoritgms (IPO and AER, next SOAT)

(7) Explain the noise performance of EDU1 versus that expected from CrIS (ITT, next SOAT)

(8) Pursue appropriate action in response to the SOAT recommendation that conversion of radiances from slant path to vertical path is undesirable. (IPO, Mar 00)

(9) Arrange for a presentation on IASI at a future SOAT meeting. (Menzel, Mar 00)

Attachment 4

Tasks being undertaken by AER in the coming year

Technical Tasks:

OSS / Apodization:
Extend current OSS to non-localized ILS and study the impact on EDR retrievals

Trace Gases:
Correction for O3,CH4,N2O and CO

Edge of Scan/Scan Variations:
Analyse algorithm performace at all angles over wider array of atm. and scene conditions

Slant to vertical:
Need to discuss with IPO

NWP external interface:
Surface pressure first guess/Graceful degradation

QC and SDR interface:
Interface with SDR and further develop quality control module

Scene Classification:
Refining FOV clustering strategy, need some I&As at some point (such as cloud effect, EDR scenes)

Science S/W infrastructure:
Develop and optimize software infrastructure for easier modification and new technology insertion, more operational-like

Performance testing:
Test algorithm using real and similated data from future sensors

New technology:
Update spectroscopic data, development and update of the algorithm after CDR

I&A tasks:

ATMS:

Channel trades + impact on the CrIS EDR performance

Microwave algorithm:

Part of it depends on new ATMS task.
Retrieval of surface emissivities (test with AMSU data). Further work on pre-detection of precipitation

Radiative Transfer:

Optimize and speed up radiative transfer model

Cloud effects:

Further study different way of handling clouds.
Validate with NAST/ScanHIS data

Surface Emissivity:

Finalize the number of parameters needed to model complex surface emissivity, study the impact of non-Lambertian reflectance on retrieval and improve the retrieval algorithm to handle these surfaces (prelimenary assessment needed), investigate the use of external information to derive appropriate constraint

CO2:

Preliminary assessment needed to see the impact of local departure from mean CO2 profile and possibilities of retrieving CO2 if applicable

Algorithm tuning and customization

Retrieval of H2O above 300 mb, MW/IR retrieval integration, cut-off of NLTE in shortwave band, atmspheric covariance over elevated terrain

Cross-suite Algorithms:

Evaluate the benefit of using VIIRS over standalone baseline to perform hole hunting and detect potential anomoalies cloud-cleared radiance
CMIS for graceful degration and enhance pre-detection of snow/ice

SCPR:

Simultaneous Cloud Parameter Retrievals

EDR scenes:

Evaluation of perfirmance understressing scenes compliments scene classification and QC

Secondary EDR:

Trace gases, surface properties (skin temperature, surface emissivity) and cloud parameters

[1-D]

Minutes of 10-12-00 SOAT Meeting

< SOAT_00.10.12.doc>

October 18, 2000

MEMORANDUM FOR: Record

FROM: W. Paul Menzel
Chair, Sounder Operational Algorithm Team

SUBJECT: Minutes of meeting on 12 October 2000

On October 12, the Sounder Operational Algorithm Team met in Silver Spring, MD. The agenda included review of progress on past action items, discussion of recent developments with the Cross track Infrared Sounder (CrIS), updates on the Advanced Technology Microwave Sounder (ATMS) and the Visible Infrared Imager Radiometer Suite (VIIRS), a report on the NPOESS Preparatory Project, briefings on the Infrared Atmospheric Sounding Interferometer (IASI) and the Atmospheric Radiation Advanced Spectrometer (ATRAS), and a summary of lessons learned from the cloud clearing simulations of Advanced IR Sounder (AIRS) data.

The meeting opened with a review of the actions resulting from the last Sounder OAT meeting. Little progress was made in gleaning information on CrIS field of view and noise tradeoffs, vendor cal / val plans, noise performance of engineering unit (Actions 1 – 3) or in obtaining access to optimal spectral sampling transmittance code, appropriate CrIS data files in the NPOESS library (Actions 4 – 5), or in generating a plan for the release of the vendor instrument characteristics and sounding algorithms (Action 6). The newly appointed liaison with ITT, Hal Bloom, promised more activity on these actions in the next few months. He noted that some of these issues could be taken up at monthly data reviews and also announced several scheduled reviews on the algorithm (Dec 2000 in the Boston area), the interferometer (Jan 2001 in the Quebec area), and the CrIS instrument (Mar 2001 in the Ft. Wayne area). All agreed that improved information exchange between the Sounder OAT and ITT and AER was highly desirable.

The Sounder OAT reiterated their desire to investigate the feasibility of going to a 10 km field of view; information on the field of view and noise tradeoffs must be part of this investigation. Further Mike Kelly from MIT/LL explained that corrections have been made to the engineering data unit (EDU) noise prediction; the modulation efficiency is lower than was thought in the past, and the full mechanisms are not yet fully understood. The Sounder OAT hopes to hear more on this at next month's data review via Hal Bloom.

Paul Menzel reported that the international user community of polar orbiting sounder data had recently requested more information regarding access to level 1B global and direct broadcast data. It was proposed that the IPO and NOAA be invited to the next meeting to present information on data distribution and the mechanisms available to global users.

Allen Larar and Dave Staelin reported on good progress in processing NPOESS Airborne Sounder Testbed – Infrared and Microwave data. Several papers were presented at the recent IGARRS meeting; copies will be forwarded to the IPO. New data were acquired during the Water Vapor Intensive Observing Period in September/October and more will follow in November 2000. A data assimilation flight, a validation flight, and a water vapor motion flight were all accomplished; the web site http://danspc.larc.nasa.gov/NAST contains more information. There will be a data presentation at the next meeting. In the interim highlights will be forwarded to the IPO to assist with annual reviews.

The SOAT was updated on ATMS. Ball and Aerojet are the competing vendors; selection is expected in the first quarter of 2001. There was a question as to why the polarizations appear to be different than what was recommended. The Sounder OAT resolved to do a science impact assessment on this issue. VIIRS is still in the process of downselect; ITT and Raytheon have submitted proposals. The Sounder OAT suggested that a VIIRS cloud algorithm presentation be arranged for the next meeting.

Bob Murphy from NASA/GSFC summarized recent events in the NPOESS Preparatory Project. An Interim Science Panel has been meeting to advise NASA on the global change science possible with CrIS, VIIRS, and ATMS. Algorithm development and production of data are being configured to conform with NASA science and NOAA operational needs; the Archive and Data Distribution System is being designed to perform the latter function. Scientists will have two opportunities to propose NPP activities: (a) propose a better algorithm than being provided; (b) participate in cal/val of NPP. The mission system design review is scheduled to March 2001.

In response to an action from the Sounder OAT, Dr. Peter Schluessel from EUMETSAT presented the IASI instrument and algorithm plans. IASI is based on a Michelson interferometer with spectral range from 3.6 to 15.5 um (645 to 2760 cm^{-1}), spectral sampling before apodization at 0.25 cm^{-1}, and spectral resolution after apodization at 0.5 cm^{-1}. IASI is nadir-viewing and across track scanning; the 30 fields-of view along the scan line are sampled in a 2x2 matrix of circular pixels with a diameter of 12 km. IASI has an integrated imager for co-registration with AVHRR, is synchronised with AMSU-A and MHS, and reduces the data rate to 1.5 Mbit/sec via an onboard Fourier transform. The first of three IASIs will be launched into an am orbit on METOP 1 in late 2005. The IASI presentation is attached.

Dr. Makoto Suzuki from NASDA gave a summary of the current status of ATRAS. This follow on to the Interferometric Monitoring of Greenhouse Gases (IMG) is a candidate for the Global Change Observation Mission (GCOM). It would observe greenhouse gas sources and sinks. It would cover 625 to 3000 cm-1 at .05 cm-1 resolution with an 8 km FOV. A first opportunity for launch would be in 2007 on the B1 platform of GCOM; however the instrument has not been selected for the mission to date.

Chris Barnett gave a presentation on the lessons learned about cloud clearing from the AIRS simulations. The algorithm, results from simulations, lesson learned, and plans for further work were contained in his briefing and are available from him upon request.

The meeting concluded by welcoming Allen Larar as the new Sounder OAT chairman and thanking past chairman Paul Menzel for his efforts.

Attachment 1

Attendance

Jim Duda	IPO
Stan Schneider	IPO
Art Schwalb	IPO
Narinder Chauhau	IPO
Andy Christensen	IPO
Hal Bloom	IPO
Amy Bleich	IPO
Allen Larar	LaRC
Paul Menzel	NESDIS
Mitch Goldberg	NESDIS
Fuzhong Weng	NESDIS
Chris Barnet	GSFC
Joel Susskind	GSFC
Bob Murphy	GSFC
Jack Xiong	GSFC
Dave Staelin	MIT/LL
Dan Mooney	MIT/LL
Mike Kelly	MIT/LL
Peter Schluessel	EUMETSAT
Makoto Suzuki	NASDA

Attachment 2

Action Items

(1) Review CrIS field of view and noise tradeoffs. (Bloom, Kelly, Dec 00)

(2) Make proposed cal / val plan available to SOAT. (Bloom, Fennelly, Nov 00)

(3) Explain the noise performance of EDU1 versus that expected from CrIS. (Bloom, Kelly, Nov 00)

(4) Make arrangements for AER transmittance algorithms to be transfered to Menzel at UW, Goldberg at NESDIS/ORA, Barnet at GSFC, Larar at LaRC, and Mooney at MIT/LL. (Bloom, Nov 00)

(5) Transfer appropriate CrIS data files to the NPOESS library or help SOAT members gain password access to the ITT CrIS web site. (Bloom, Nov 00)

(6) The instrument characteristics and the algorithm must be defined with sufficient completeness and accuracy that the scientific and user communities can, as they always have, independently evaluate and validate the results, and potentially improve the methodology and system performance. Therefore a plan must be generated for the release of the vendor instrument characteristics (including FOV, encircled energy, NEDT, spectral coverage, spectral resolution before and after apodization, detector array size and uniformity, coregistration of spectral bands, A/D conversion, and characterization of any unsteady calibration or noise behavior, or other anomalous characteristics) and sounding algorithms (transmittance, scene classification, cloud clearing, spectrum utilization, physical and statistical retrieval approaches (e.g. an Algorithm Theoretical Basis Document (ATBD)), and the algorithms themselves, including any coefficients necessary to execute them) as soon as feasible so that the SOAT can plan and conduct a rigorous calibration / validation campaign. (Bloom, Jan 01)

(7) Highlights from the NAST-I/M activities of the past year will be forwarded to the IPO to assist with annual reviews. (Smith, Staelin, Nov 00)

(8) Investigate why the ATMS polarizations appear to be different than what was recommended. Make a science impact assessment on this issue. (Staelin, Nov 00)

(9) Sounder OAT members will coordinate with Hal Bloom to suggest agenda items and to attend pending reviews. The algorithm review is scheduled for Dec 2000 in the Boston area, the interferometer review is Jan 2001 in the Quebec area, and the CrIS instrument review is Mar 2001 in the Ft. Wayne area. More details will be provided by Hal Bloom to team members as they become available. (All, Dec 00)

(10) Present options for access to level 1b data globally and from direct broadcast. (Lawrence and Coronado, Mar 00)

(11) Arrange for a presentation on VIIRS cloud algorithm at a future SOAT meeting. (Bloom, Mar 00)

[1-E]

H. Revercomb presentation to OAT team on 1-29-01

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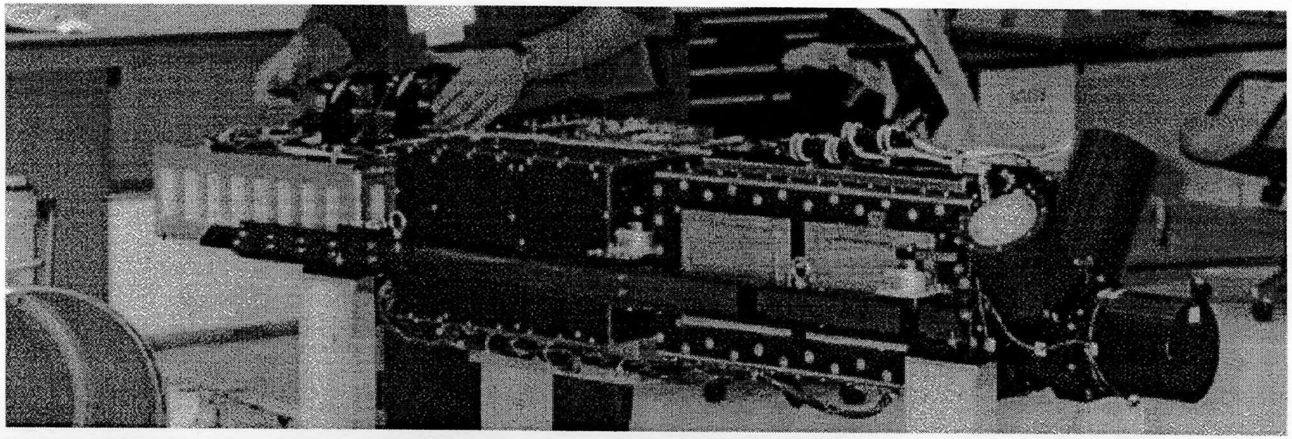
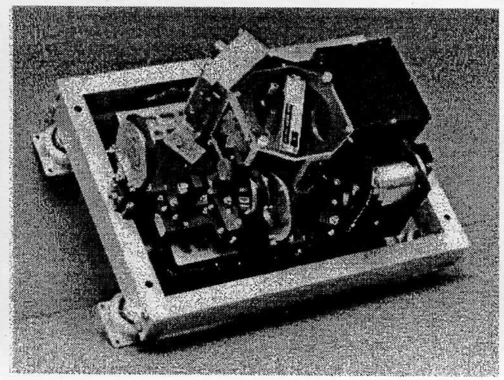
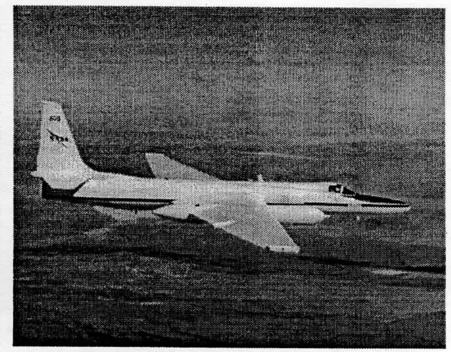
Scanning-HIS Update:
SAFARI (ER-2) & AFWEX (DC-8)







Hank Revercomb
University of Wisconsin, Space Science and Engineering Center

IPO SOAT Meeting, MIT/LL, 29 January 2001

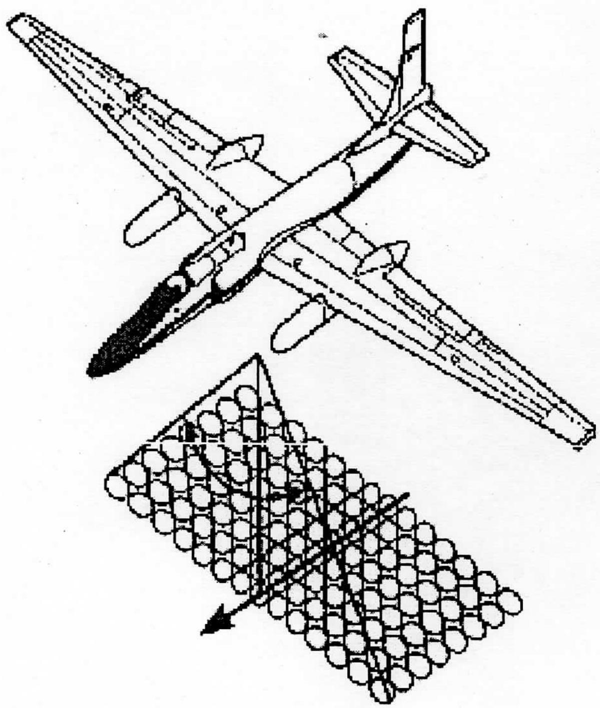
S-HIS Mission Summary

Experiment	Location	Time	Aircraft	# Flights/# Hours
CAMEX-3	Patrick AFB, Florida	September 1998	DC-8	6 / 36
WINTEX	Madison, Wisconsin	March 1999	ER-2	8 / 30
KWAJEX	Kwajalein Atoll	Aug-Sept 1999	DC-8	35 / 172
WISC-T2000	Madison, Wisconsin	March 2000	ER-2	8 / 30
SAFARI	Pietersburg, South Africa	Aug-Sept 2000	ER-2	15 / 80
AFWEX	ARM CF, Oklahoma	Nov-Dec 2000	DC-8	8 / 50
		TOTAL	DC-8	258 hours
			ER-2	140 hours

Scanning HIS: ER2 Centerline Pod

(HIS= High-resolution Interferometer Sounder)

Roots:
- U. of Wisconsin HIS Program, 1978-present
- 1st U2/ER2 HIS, 1985-present
- NAST-I, close cousin, for NPOESS testbed (Wingpod)
- First ER-2 Mission: Wintex, 1999

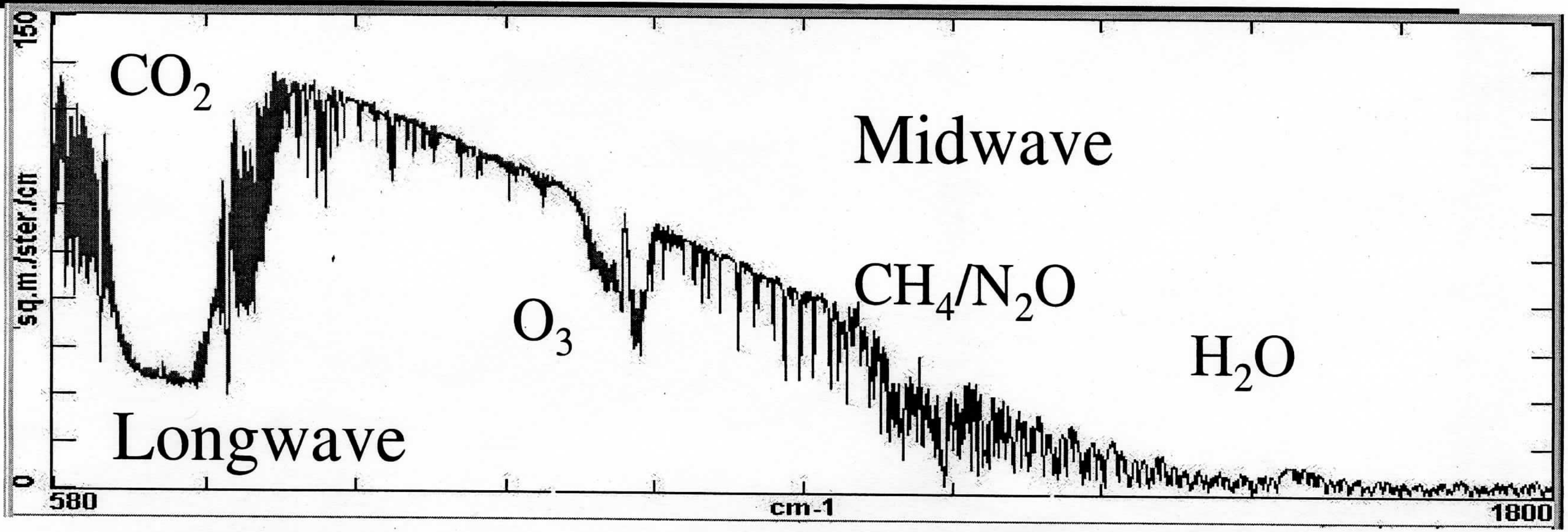


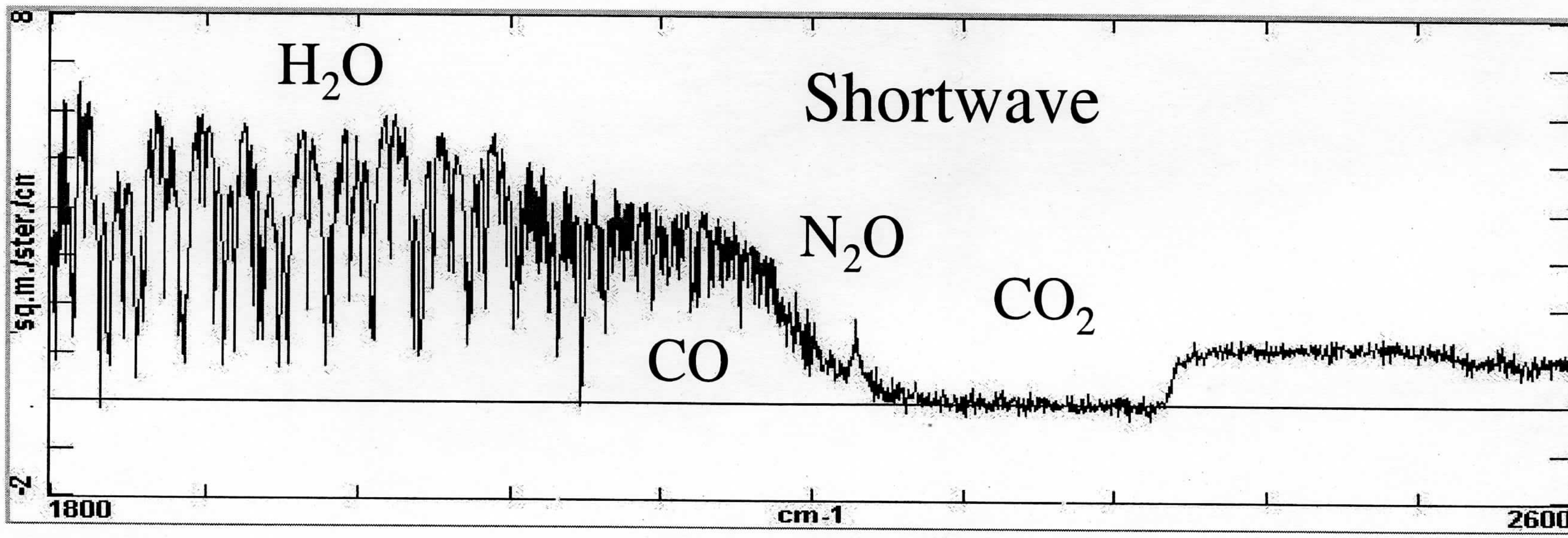
Characteristics:

Spectral Coverage:	3-17 microns
Spectral Resolution:	0.5 cm^{-1}
Resolving power:	1000-6000
Footprint Diameter:	2 km
Cross-Track pattern:	Programmable
SAFARI Swath width:	30 km or Nadir only

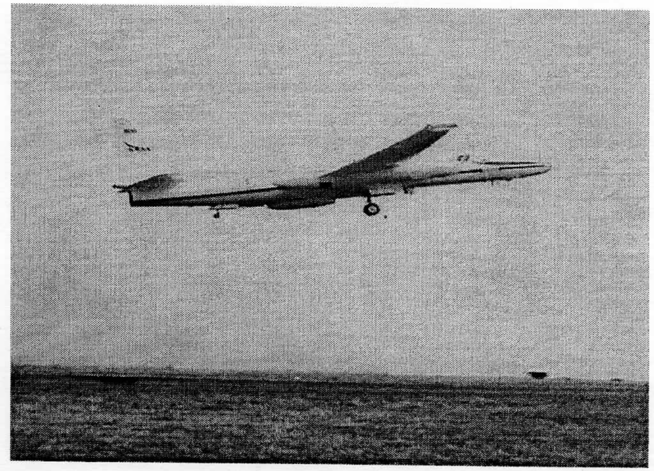
Scanning HIS Radiances-24 August 2000

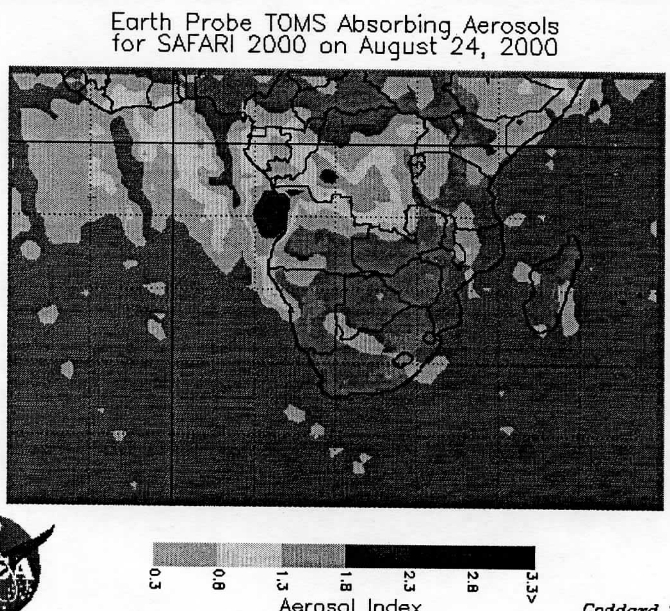
SAFARI Terra Overpass-Clear Water





SAFARI 2000: Scanning HIS on ER-2



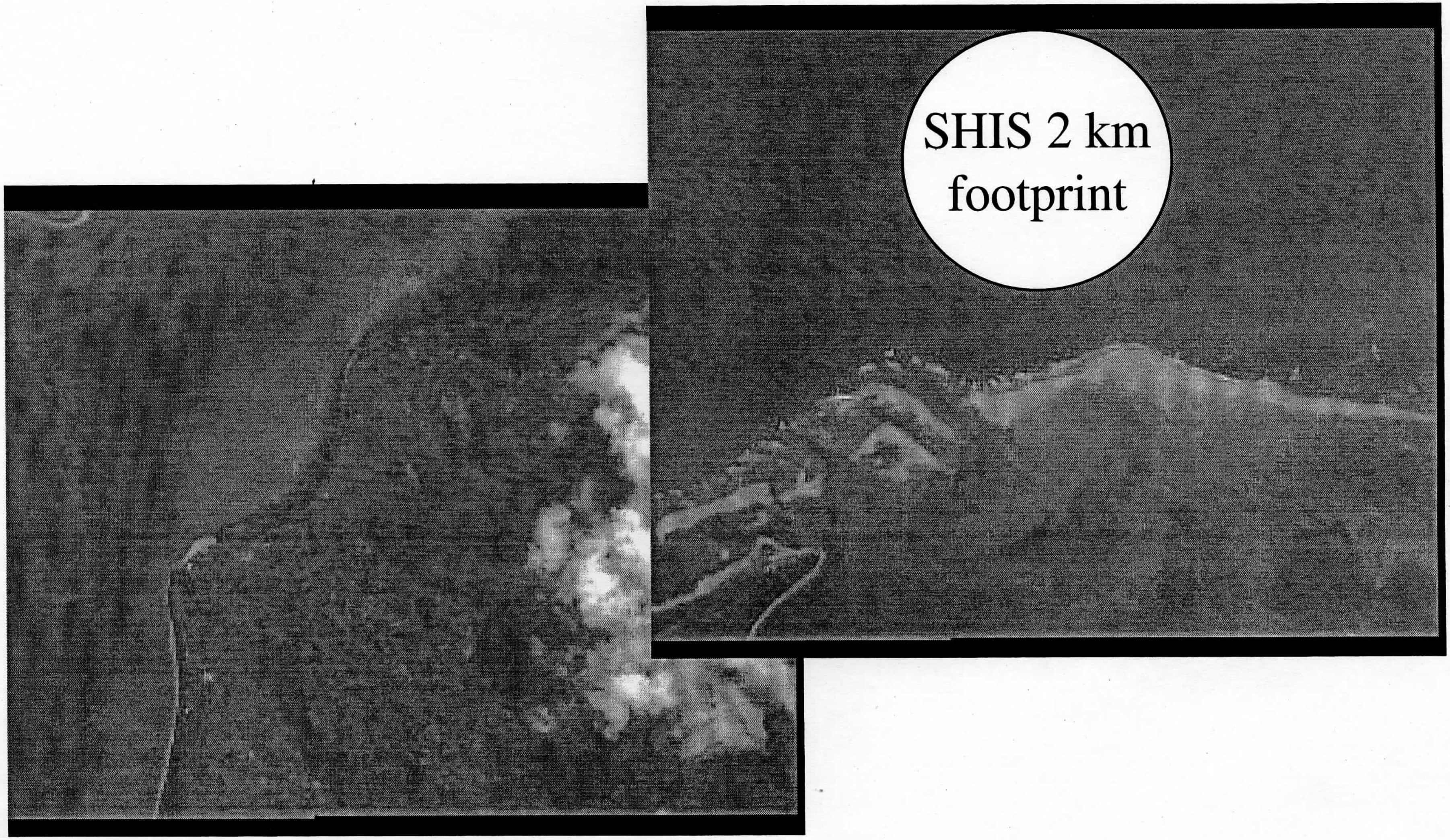


Goddard Space
Flight Center

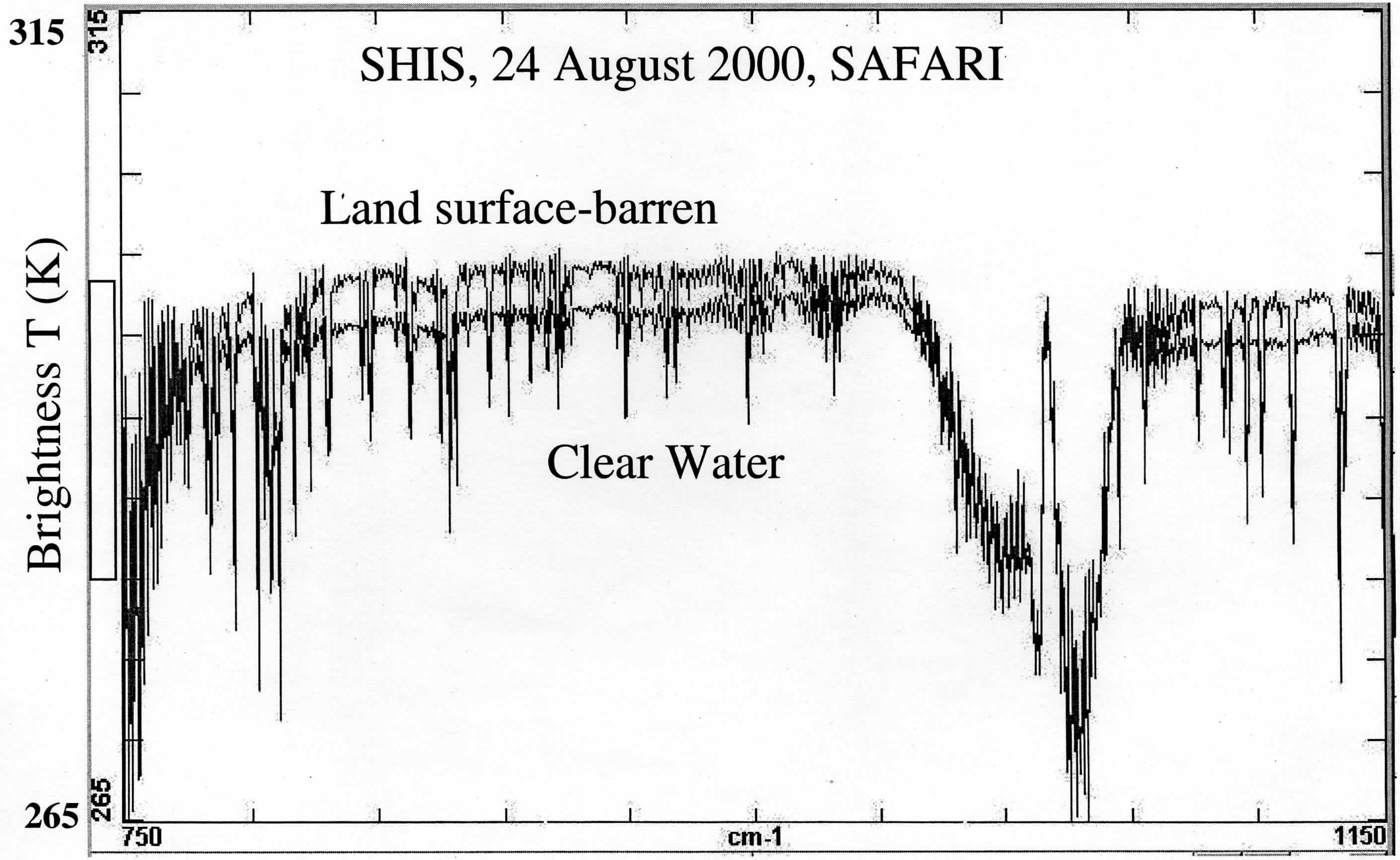
SHIS Goals for SAFARI

- IR Spectral Characteristics of Smoke/Haze
- CO Detection -- MOPITT comparisons
- Surface Emissivity Variations over wide range of surface types
- Cloud Radiative Properties associated with burning
- Terra/MODIS Validation

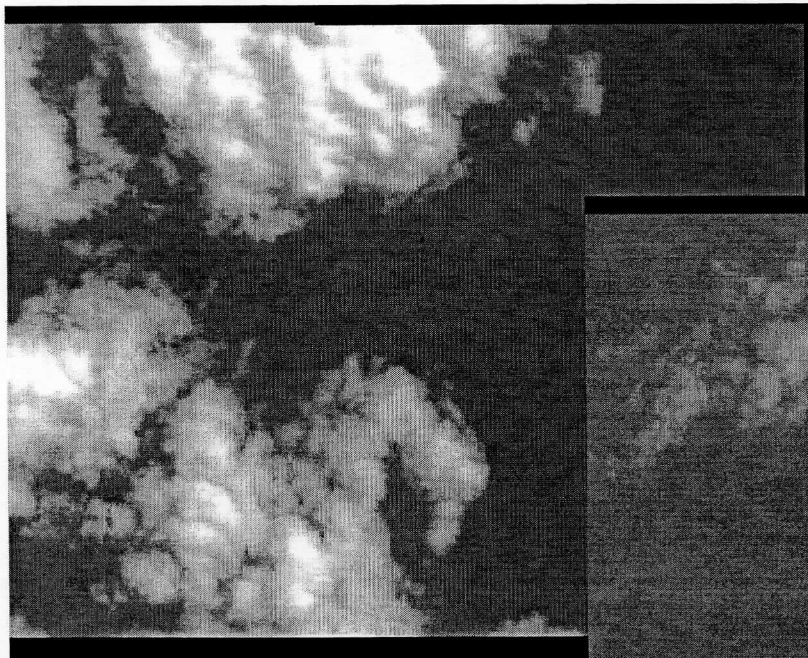
Inhaco Island at Terra Overpass--
24 August, 8:16 UTC (MOPITT-A Video)



Inhaco Island Surface Emissivity Restrahlung

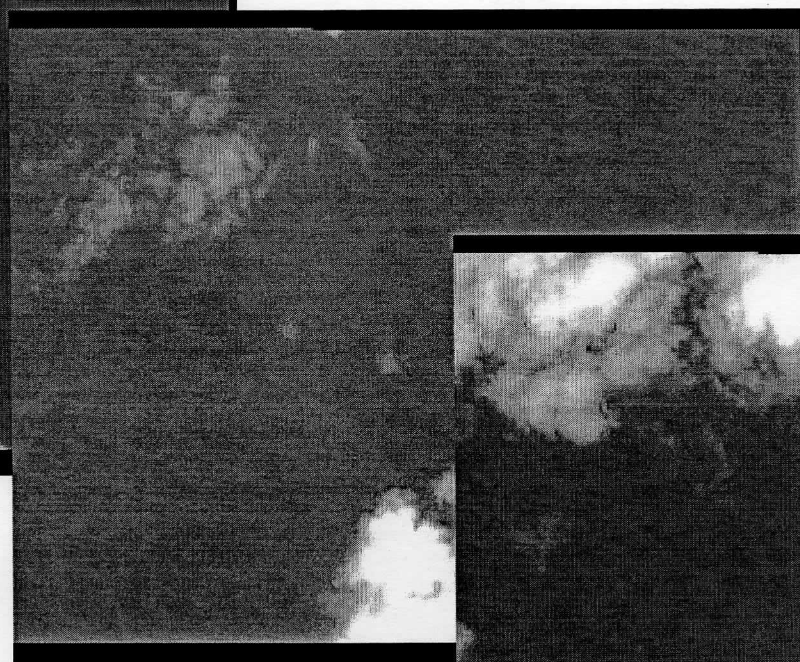


24 August: Clouds and Haze, and Clear over Mozambique (MOPITT-A Video)

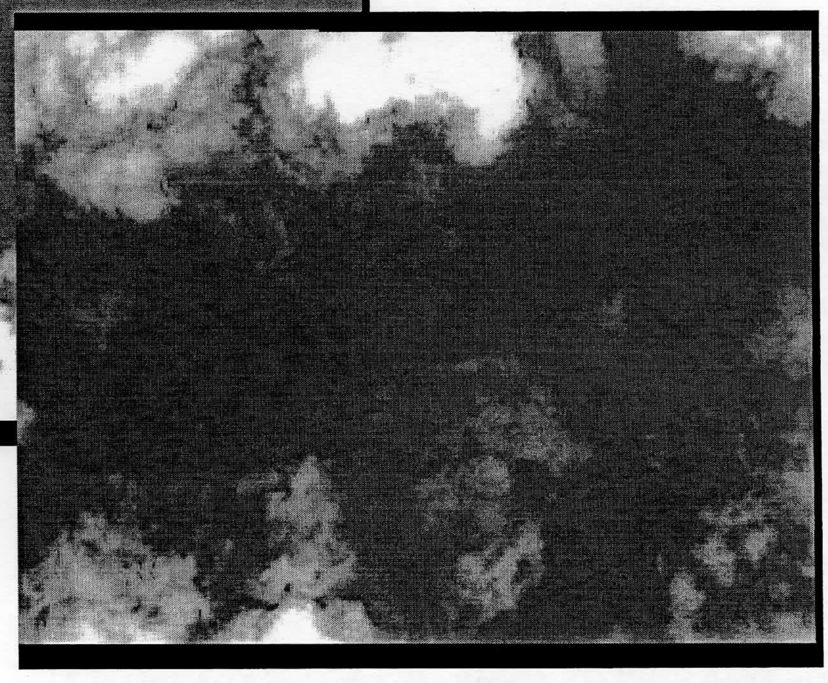


"Black" Clouds

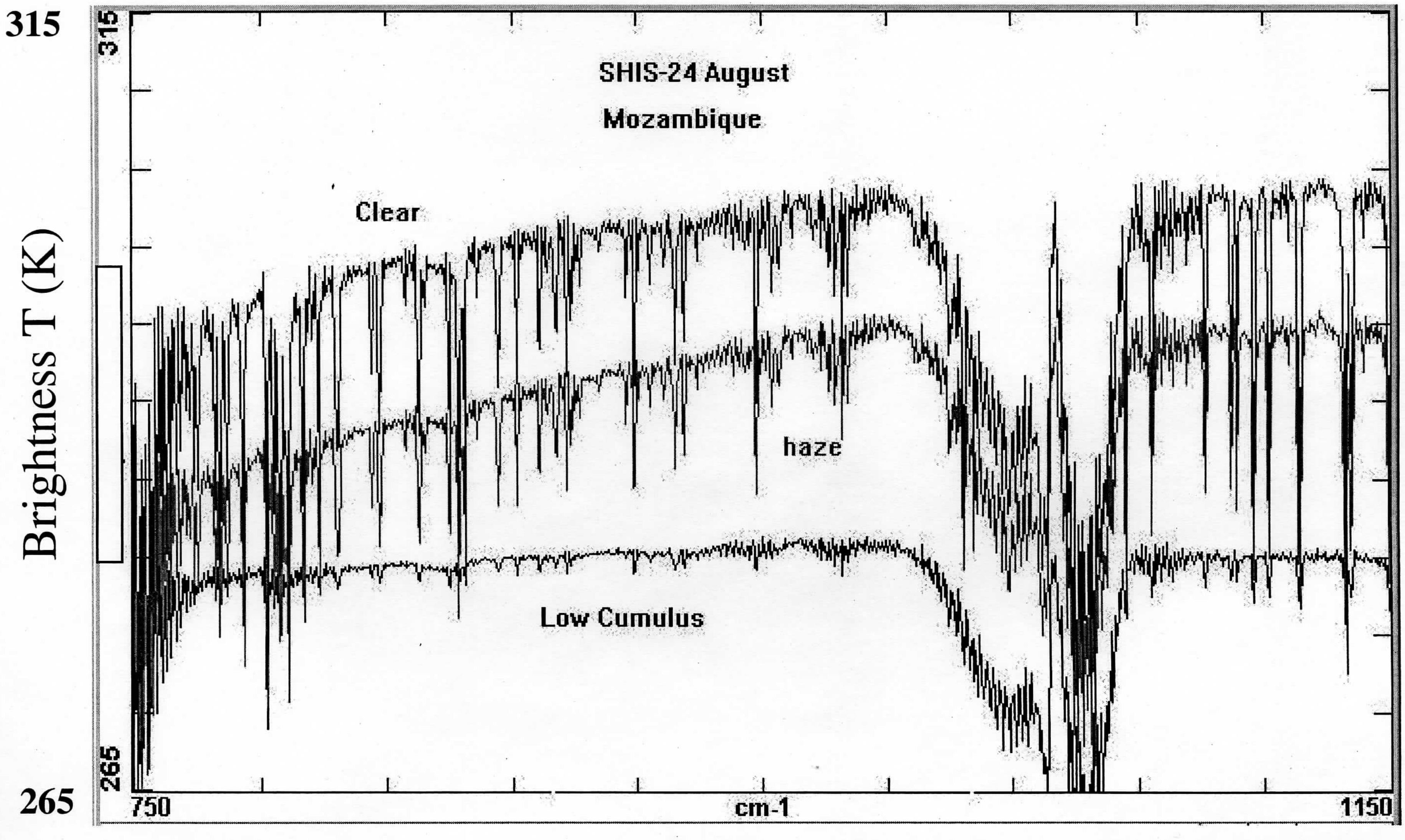
Heavy Haze



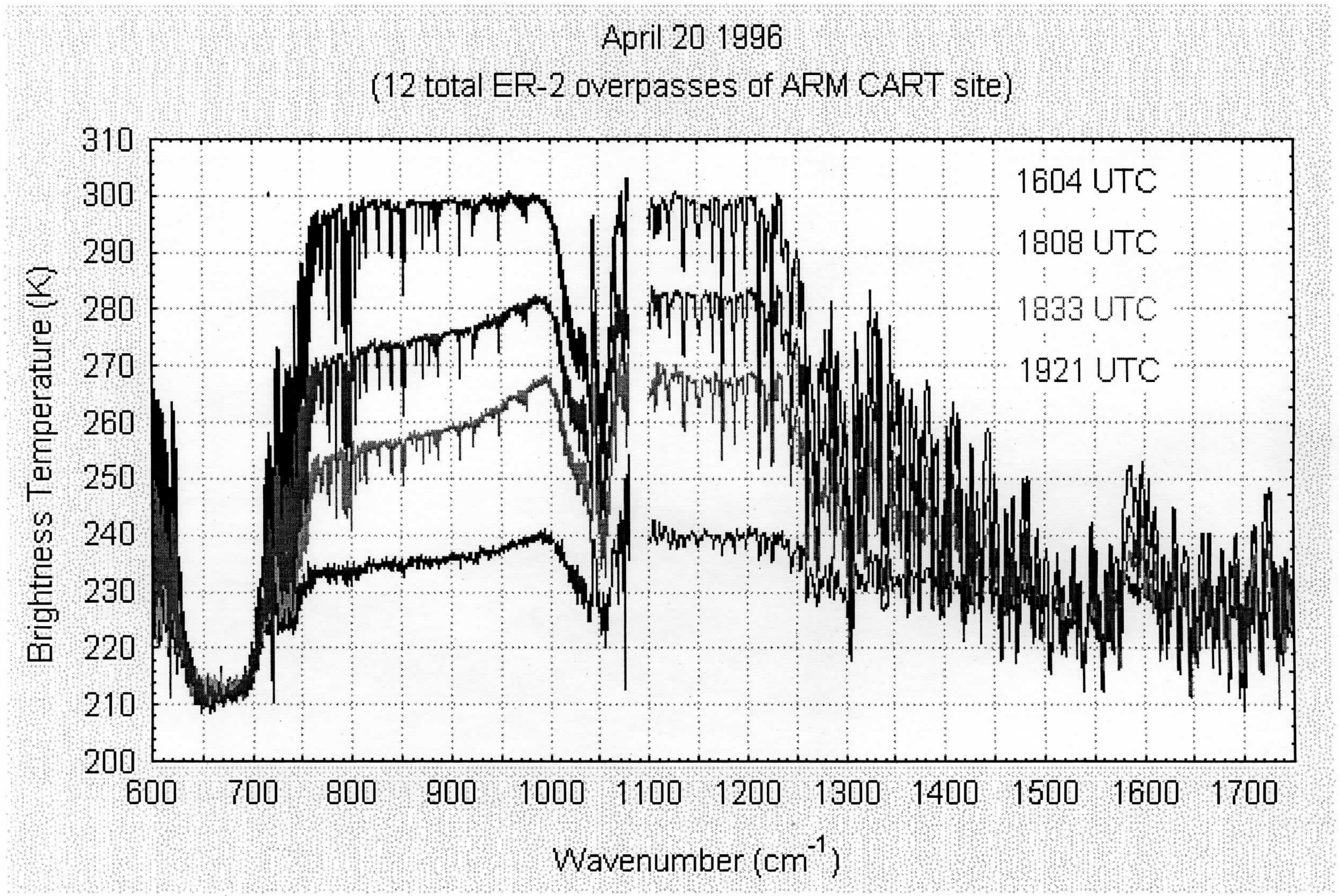
Mixture



Black Cloud, Haze, and Clear skies over Mozambique

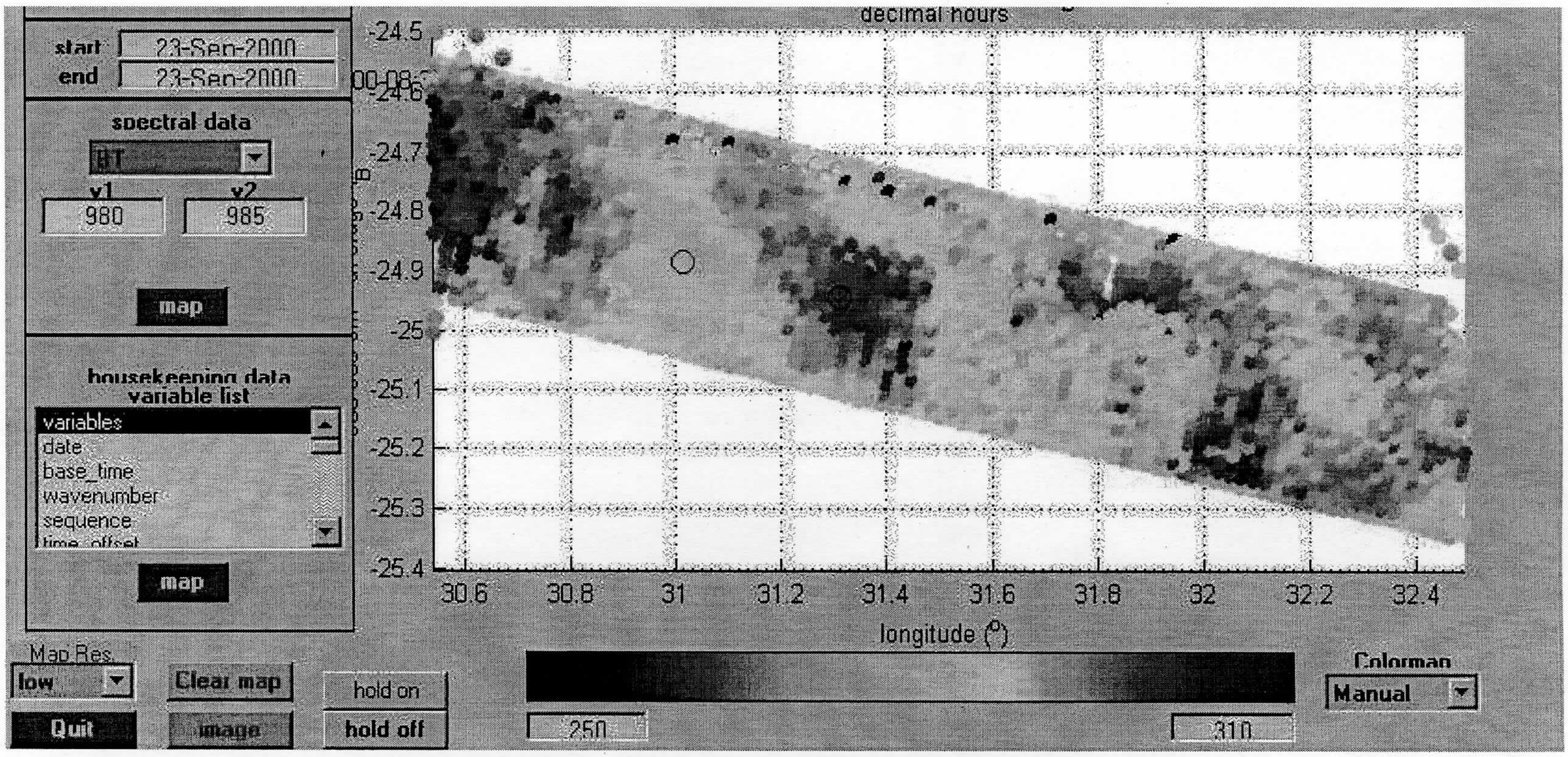


HIS Data- Ice Clouds from SUCCESS



SHIS Cross-track Scanning During SAFARI

Skukuza, Mozambique — 23 Sept 2000, 08:30 UTC



X-Track Scan

• 30 km swath • 2 km IFOV • 5000 spectral channels

ARM-FIRE Water Vapor Experiment (AFWEX)
November/December 2000

Goal: Assess accuracy limitations of Sondes and Calibrate /Validate ARM Raman lidar for satellite Validation

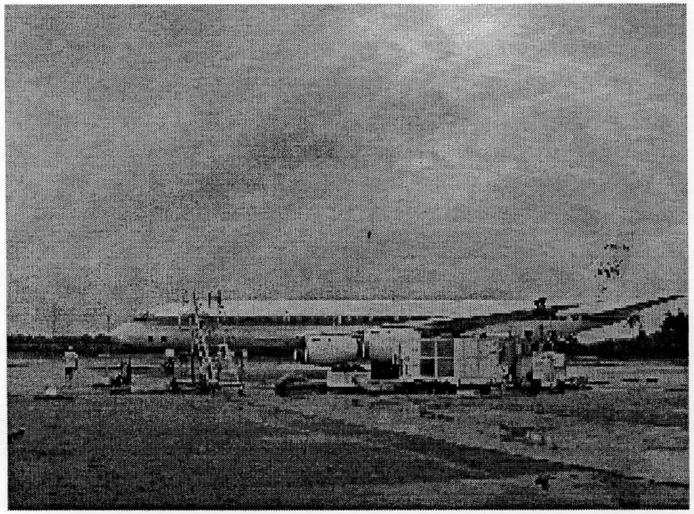
Approach:

(1) NASA DC-8 provides accurate in situ sensors (Cryogenic Chilled Mirror and Tunable Diode Laser) & Laser Atmospheric Sounding Expt (LASE) to accurately characterize upper atmospheric water vapor

(2) Ground-based Raman lidar (ARM & NASA GSFC) & DIAL (Max Planck Institute), plus sondes, including Chilled Mirror Sondes to demonstrate ground-based capabilities

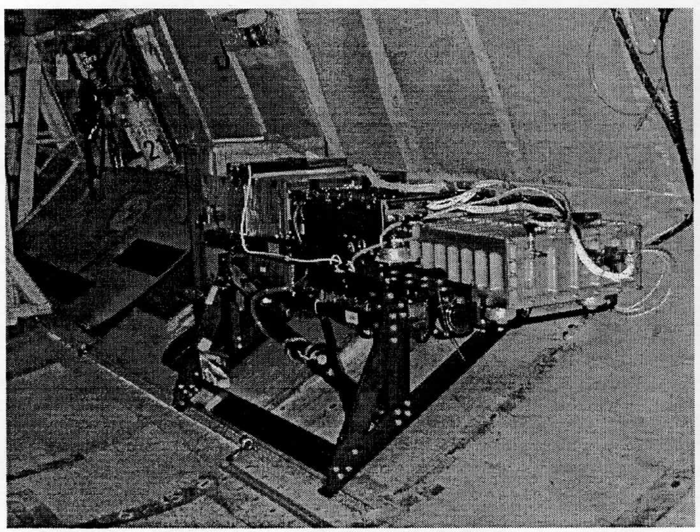
(3) Use Scanning HIS on DC-8 & NAST-I on Proteus for radiative constraints on upper level water vapor

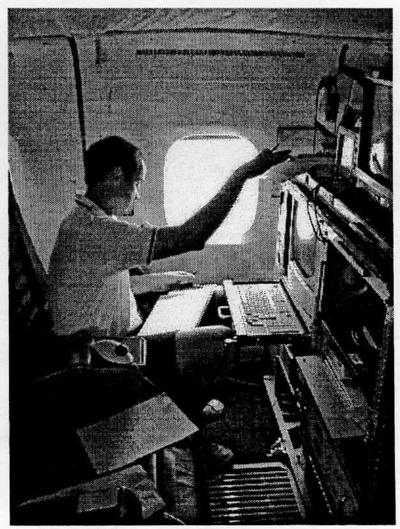
SHIS on the NASA DC-8

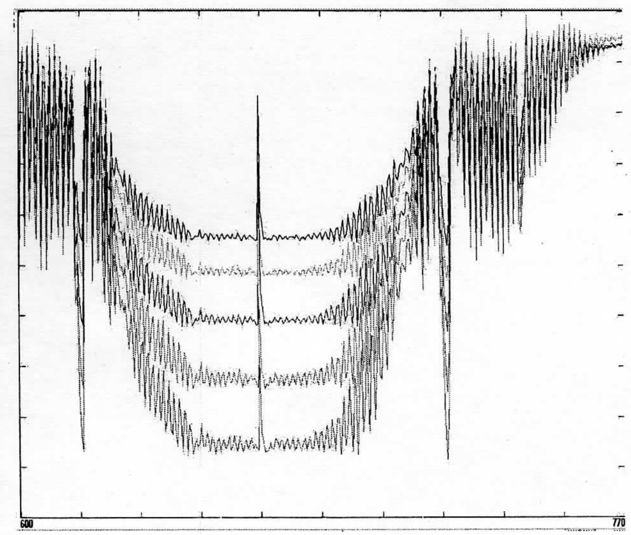


<u>Advantages of the DC-8 Platform</u>

- Profiling from 0-12 kilometer.
- Interactive fly-along capability.
- Coincident observations with NASA LASE instrument.

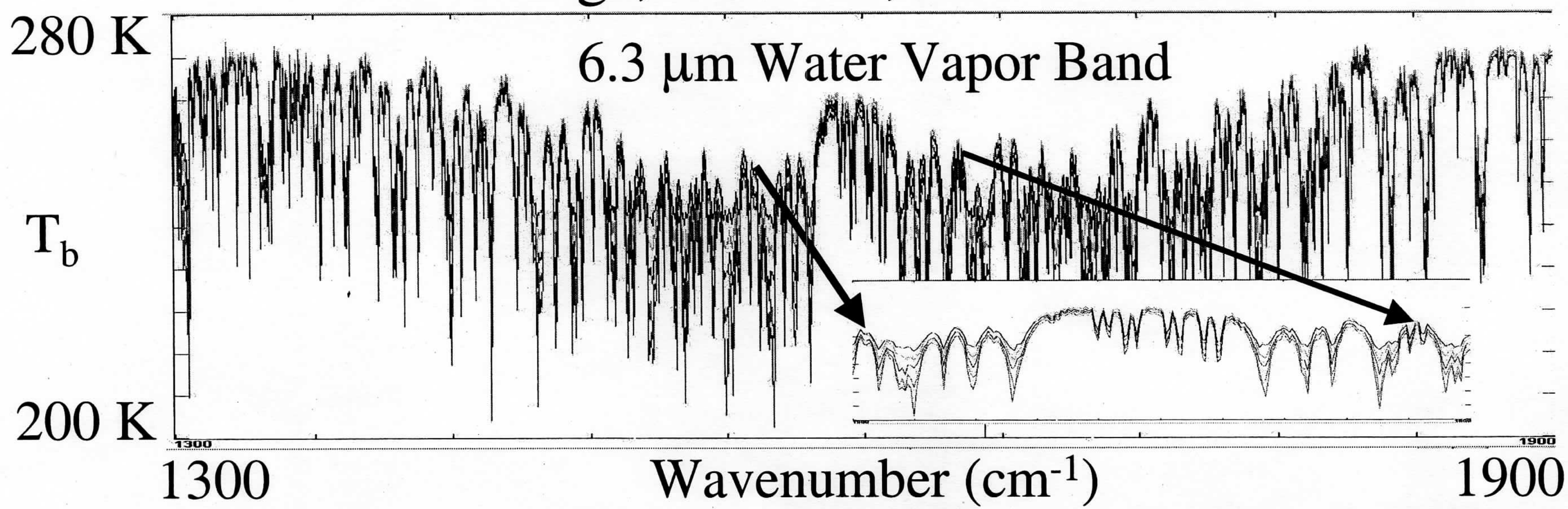


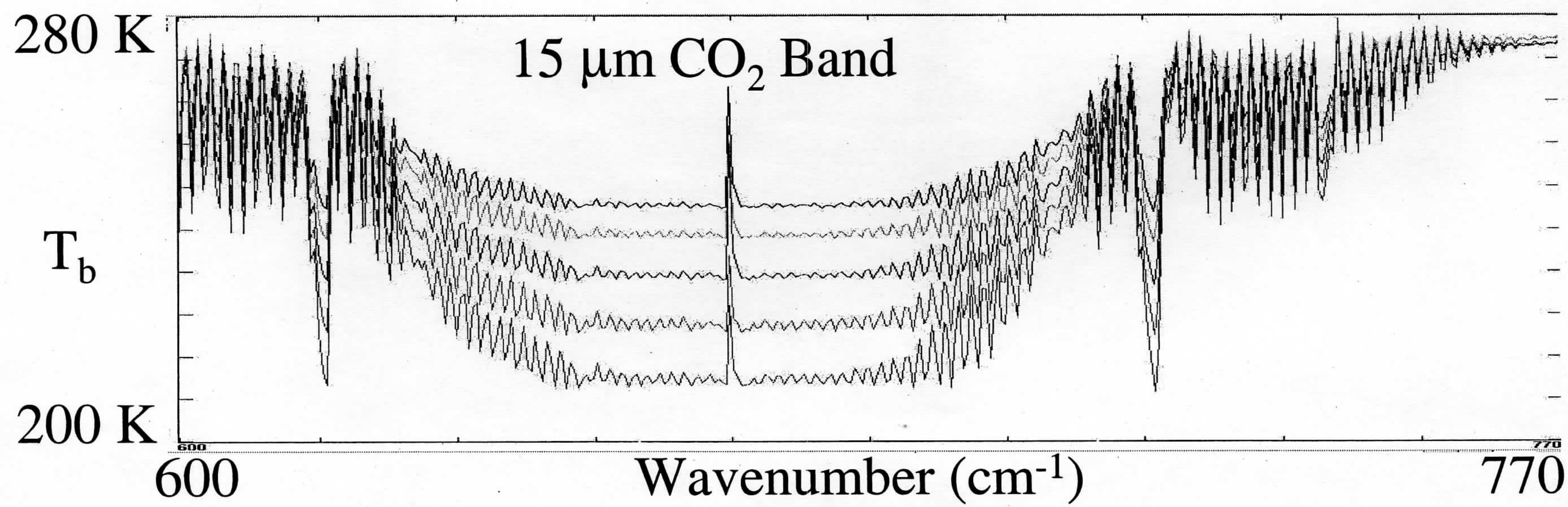




Scanning HIS Spectra from AFWEX:

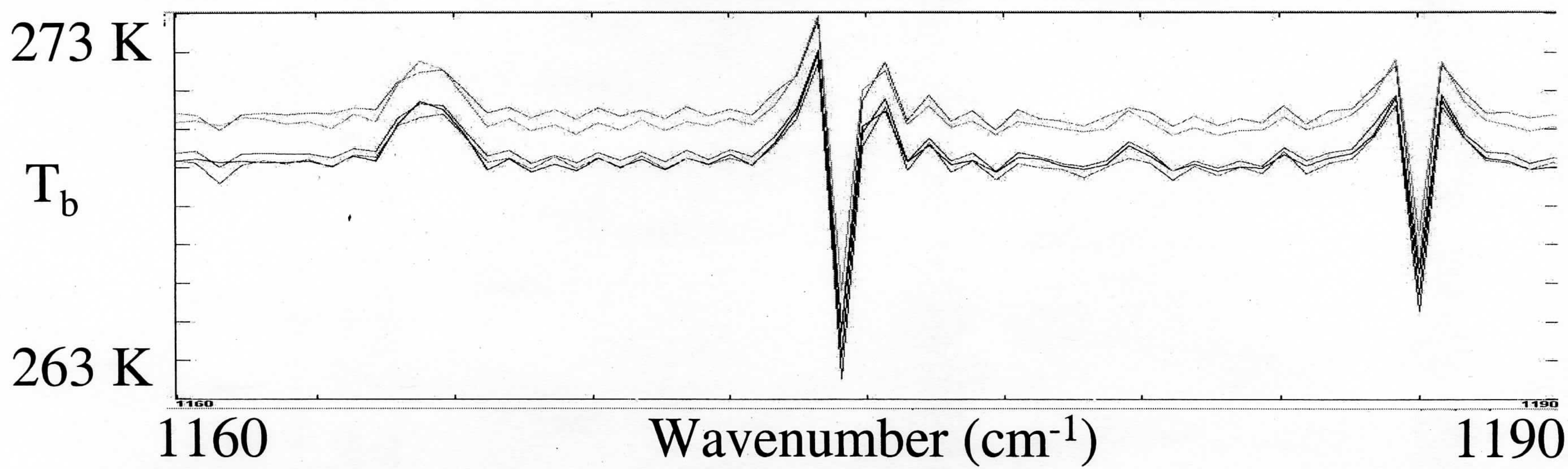
5 level legs, 8-13 km, 29 Nov 2000

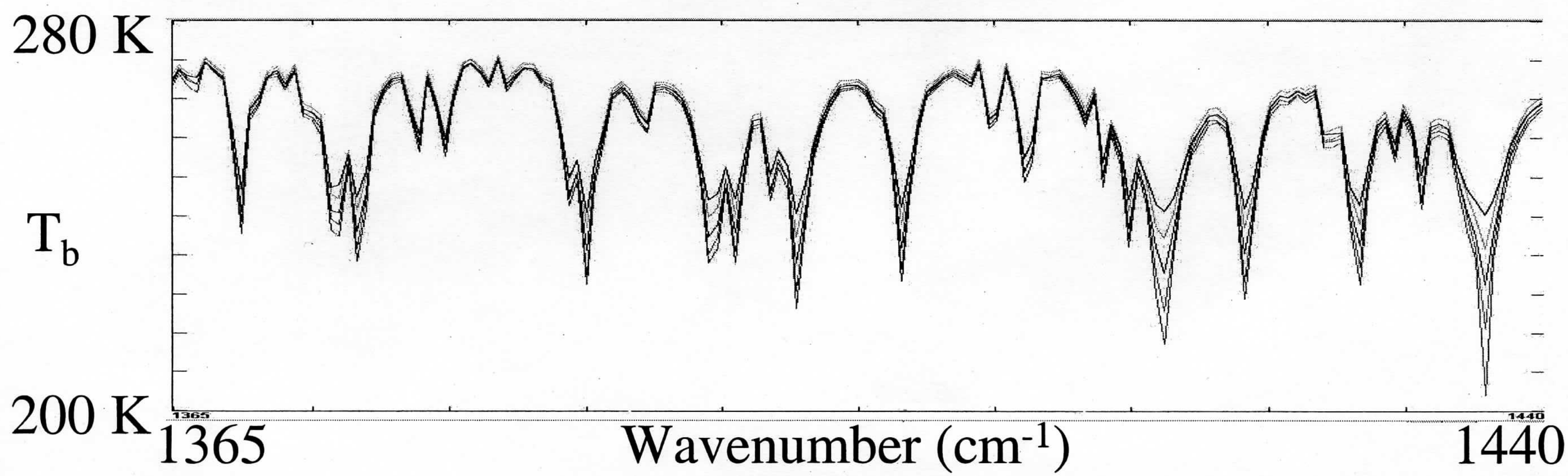




Scanning HIS Spectra: Water Vapor Close-up

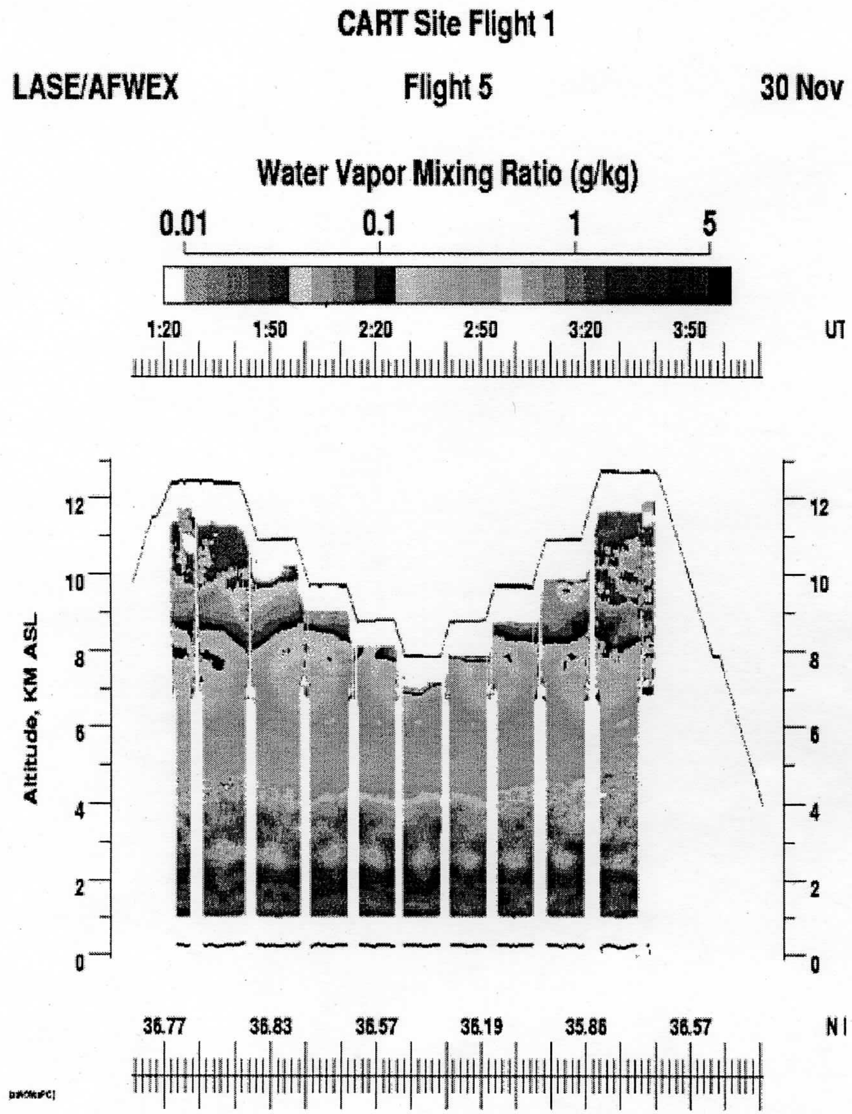
5 level legs, 8-13 km, 29 Nov 2000

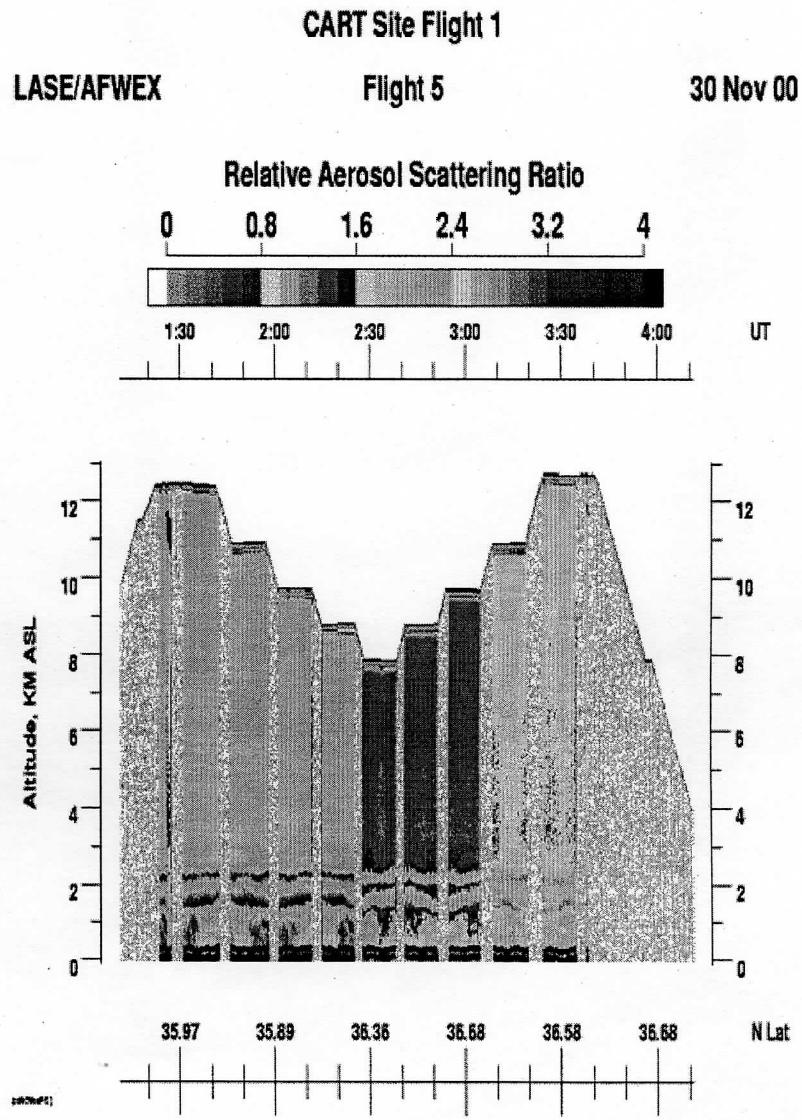




LASE (Lidar Atmospheric Sounding Expt) on DC8

29 November 2000

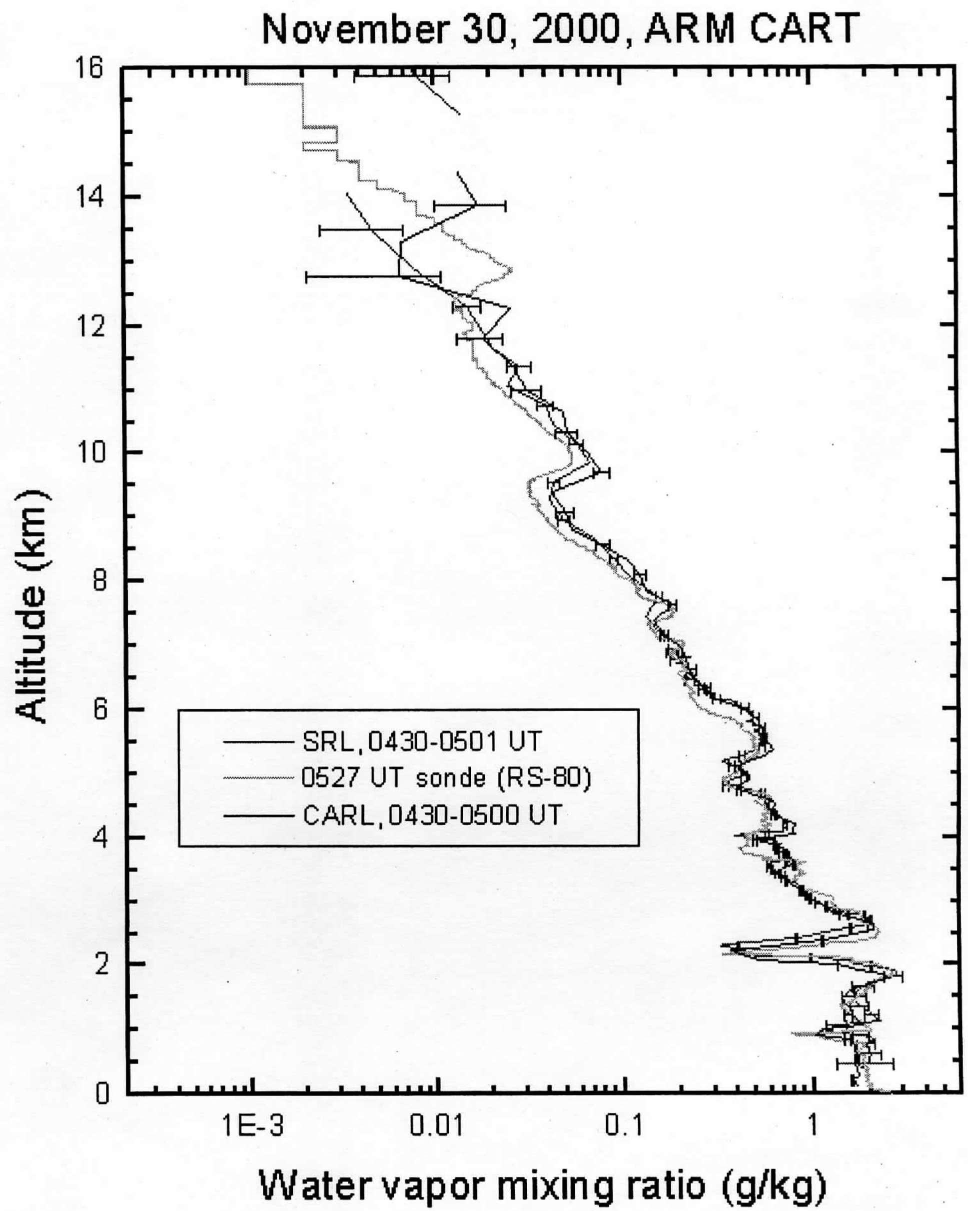




Preliminary

Raman Lidar/Sonde Intercomparisons

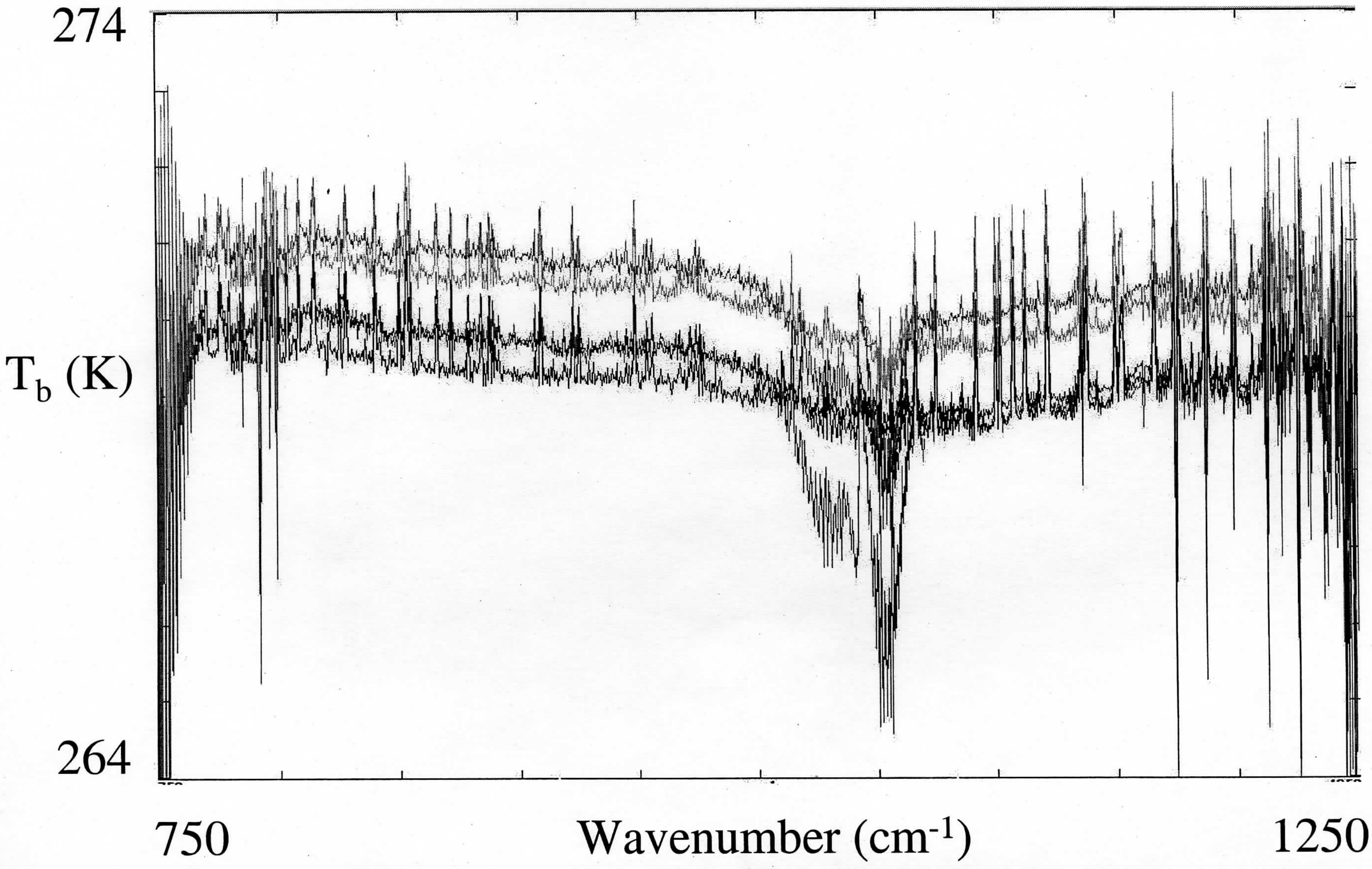
Goal is calibration /validation of Raman lidar as bootstrap to key Satellite validation



Preliminary

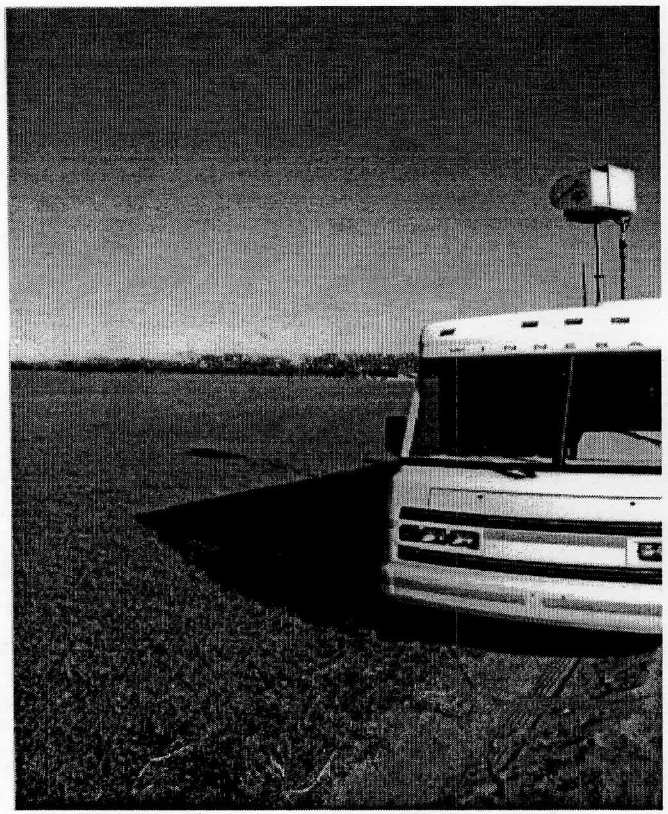
Scanning HIS Window Brightness T from AFWEX:

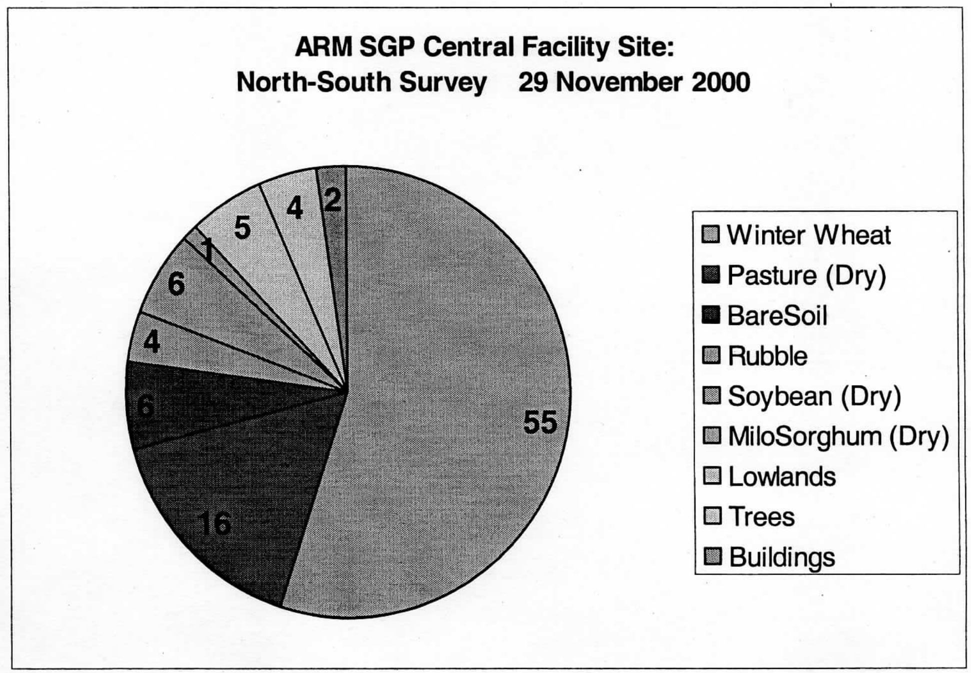
Multiple passes of ARM Central Facility, 29 November 2000



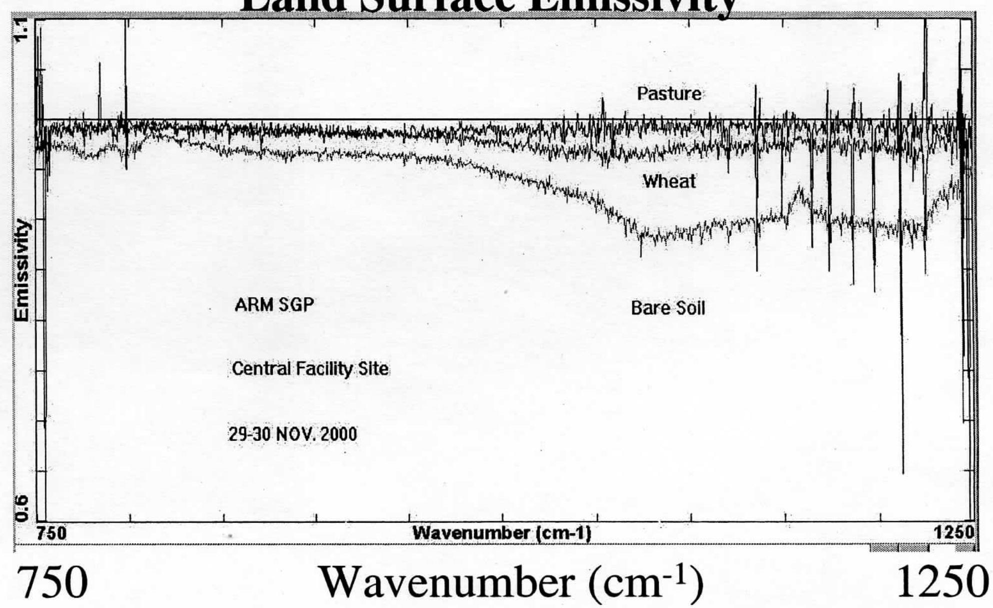
ARM Site Survey, 29 November 2000

A survey was conducted to characterize the land type in the vicinity of the ARM Southern Great Plains Central Facility site.





Land Surface Emissivity



[2-A]

New Scanning-HIS Michelson Mirror Assembly

<S-HIS Michelson Drive>

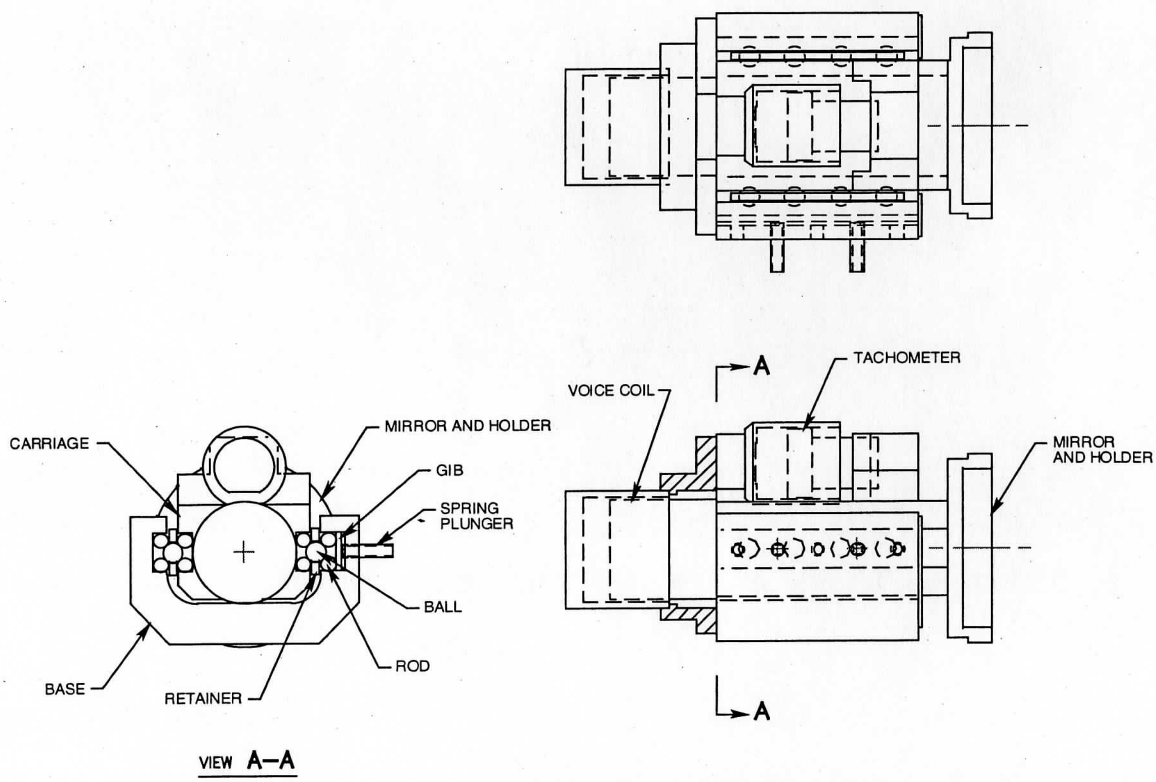
New Scanning-HIS Michelson Mirror Assembly

Background

The original Scanning-HIS Michelson Mirror assembly was a double beam flexure porch swing configuration that provided mirror translation with small accompanying tilt. This system worked well in the lab environment but contributed to significant interferometric errors when the Scanning HIS was operated in a high vibration environment (during flight). It was discovered through testing in the laboratory that the vibration sensitivity was due to the fact that the low stiffness flexures gave the suspended Michelson mirror a relatively low natural frequency and hence high mirror tilt amplitudes when subjected to broadband random vibration. This lack of stiffness also reduced the practical amount of gain that could be used in the Dynamic Alignment servo system that was designed to reduce interferometric errors. As an upgrade to the original Michelson drive, the beam flexures were stiffened by a factor of four – the practical limit, given the fixed displacement and desired fatigue life. The stiffer system reduced interferometric errors, but the fundamental vibration susceptibility remained.

New Michelson Drive Design

A fundamentally new Michelson Mirror assembly based on ball slide technology was proposed and successfully implemented as a way to dramatically increase system stiffness. In this concept the carriage that supports the mirror slides on a set of rods and balls as indicated in Figure 1.



S-HIS SCANNING MIRROR MECHANISM

Figure 1. The new Scanning HIS Michelson Mirror assembly is based on ball slide technology. This configuration provides far greater mechanical stiffness than the original flexure based S-HIS Michelson Mirror assembly.

The new assembly uses the same mirror, voice coil actuator, and tachometer as the stiffer flexure-based assembly. To prevent rattling, a controlled preload is applied between the base and carriage rod/ball assemblies by running-in spring plunger screws to a controlled displacement against a load-distributing gib plate. Preload is set high enough to prevent rattling under the expected vibration environment, but can not be arbitrarily high because the force to translate the carriage must be within the voice coil capabilities (6.7 N).

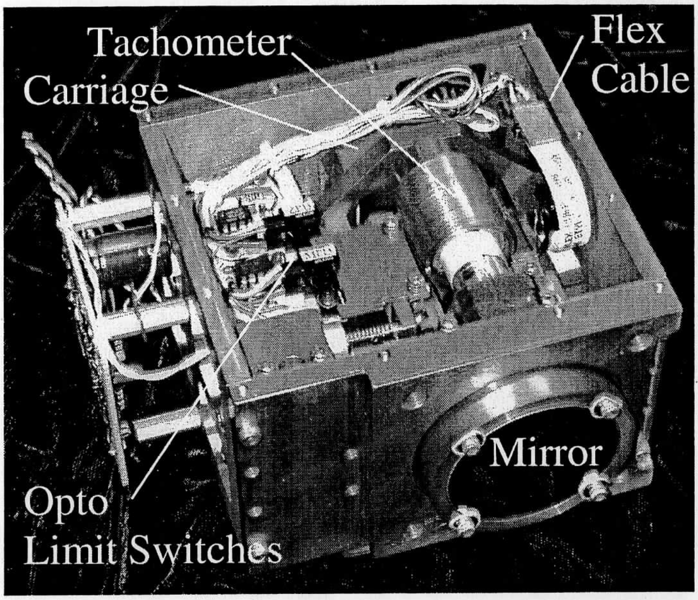


Figure 2. The new Scanning-HIS Michelson Mirror assembly. The mirror is attached to the moving carriage assembly.

Retainer Creep

"Retainer creep" was observed during the initial assembly and testing of the Scanning-HIS Michelson Mirror assembly. This was not unexpected, since all non-recirculating ball slides have this potential. Retainer creep occurs when the retainer and its ball complement undergo a slow long-term creep from its original centered position. Eventually the retainer encounters an end stop, and the rolling friction must now be replaced with sliding friction to move the retainer. If the preload is too high, the motor may be incapable of developing the required force, and the ball slide carriage will not move. This occurred during the initial testing of the S-HIS scanning mirror mechanism. The solution was to reduce the preload in the mechanism. This was done by reducing the number of spring plungers that provide the preload from five to two. (The spring force in each spring plunger could also have been reduced, but was not necessary in this case. Subsequent testing demonstrated that the voice coil actuator had enough force to slide the retainer and its ball complement with adequate margin, should retainer creep occur.

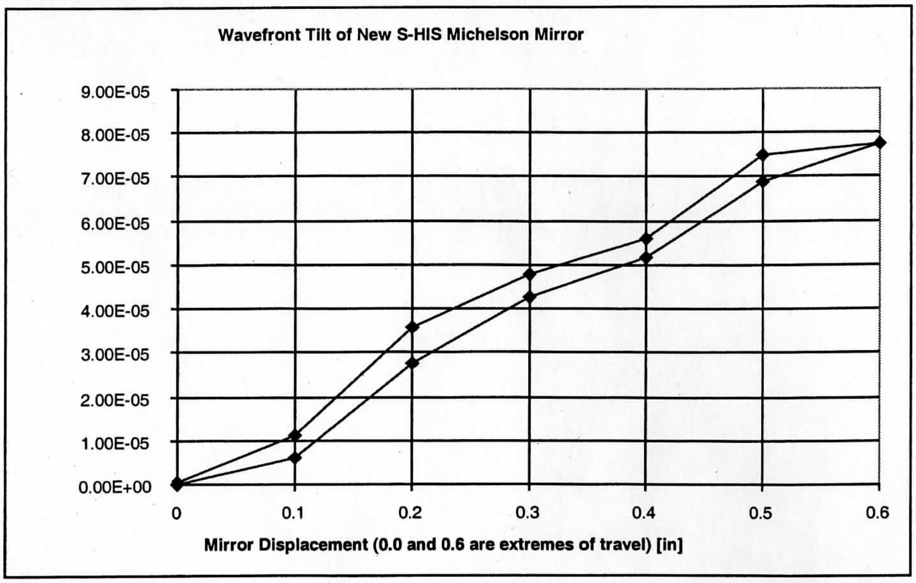


Figure 3. Michelson mirror tilt as a function of displacement as measured prior to integration into the interferometer. In normal use the mirror travels approximately between 0.1 and 0.5 inches. These tilts are comparable to the original flexure based drive.

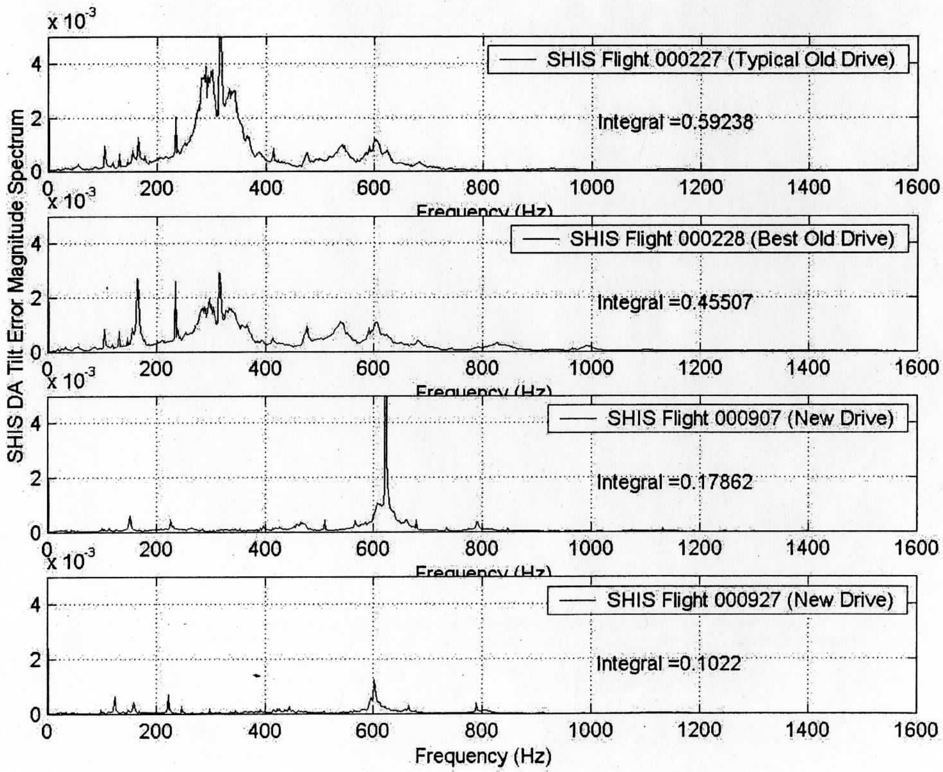


Figure 4. Comparison of Tilt Spectra measured during flight from the old and new Michelson Drive assemblies as measured by the S-HIS laser based dynamic alignment system. The new drive eliminates significant tilt dynamic amplitude below 600 Hz. In addition, the overall tilt magnitude is lower by almost a factor of 6 with the new drive.

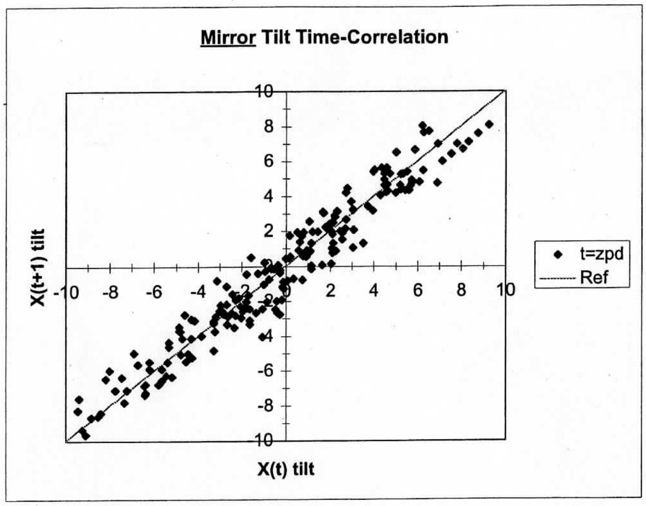
Performance
The mirror tilt during normal back-and-forth motion was measured prior to integrating the assembly into the interferometer; these results are presented in Figure 3. The maximum tilt amplitude of approximately 80 μradians compares to 100 for the stiffer flexure based assembly.

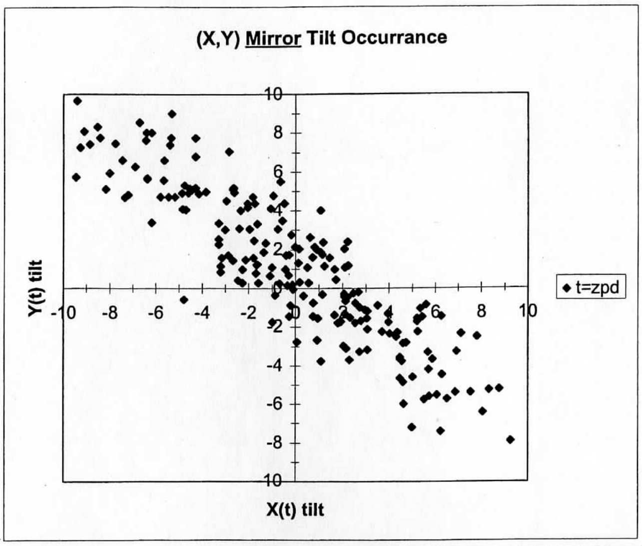
The comparison of tilt spectra measured during flight from the old and new Michelson Mirror assemblies is presented in Figure 4. The new stiffer system eliminates significant tilt amplitudes at frequencies below 600 Hz and reduces the overall tilt amplitude by a factor of 6. The new Michelson Mirror assembly has dramatically reduced the Scanning-HIS susceptibility to vibration and thereby significantly improved the quality of interferometer data produced by the instrument.

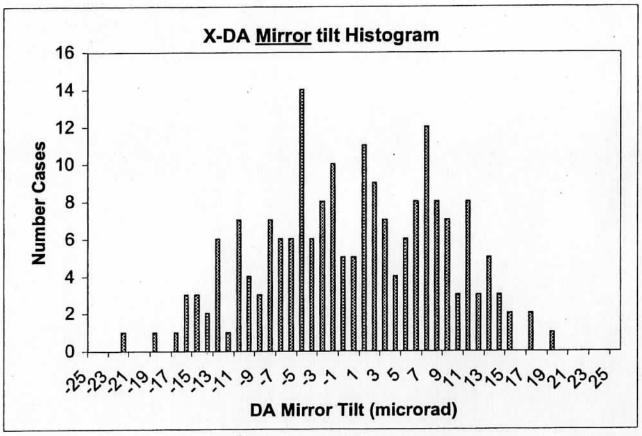
[2-B]

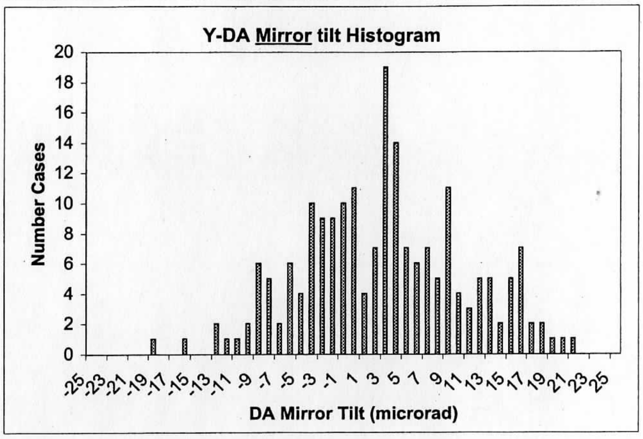
Vibration Induced Tilt Error Analysis

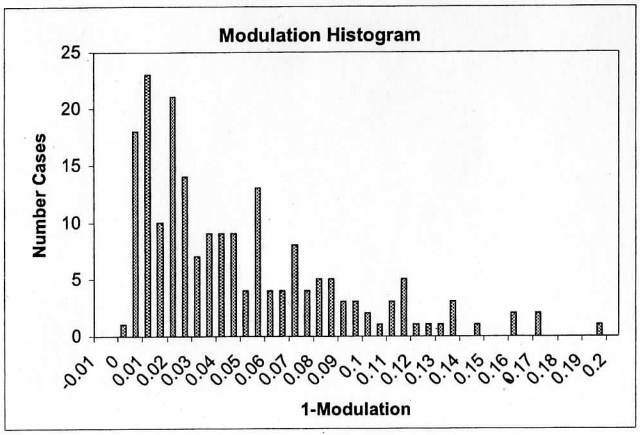
<Tilt_exercise-01Mar00.xls>


Mirror Tilt Time-Correlation
X(t+1) tilt
X(t) tilt
t=zpd
Ref


(X,Y) Mirror Tilt Occurrance
Y(t) tilt
X(t) tilt
t=zpd


X-DA Mirror tilt Histogram
Number Cases
DA Mirror Tilt (microrad)


Y-DA Mirror tilt Histogram
Number Cases
DA Mirror Tilt (microrad)


Modulation Histogram
Number Cases
1-Modulation

[2-C]

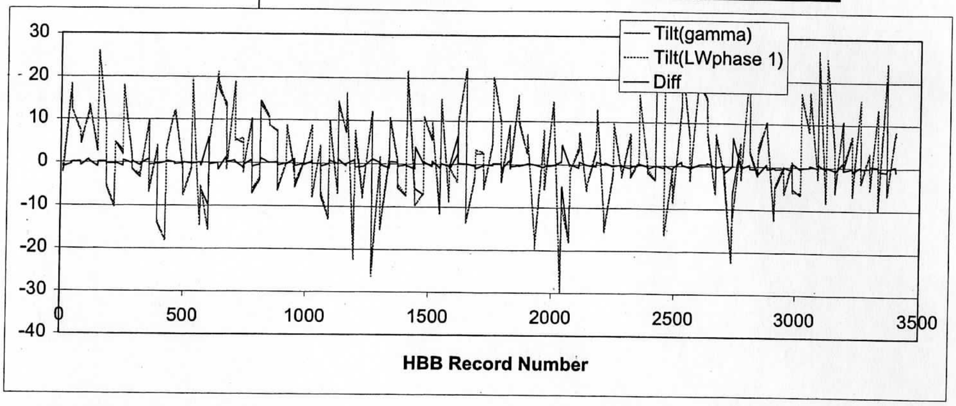
Vibration Induced Sample Position Error Analysis

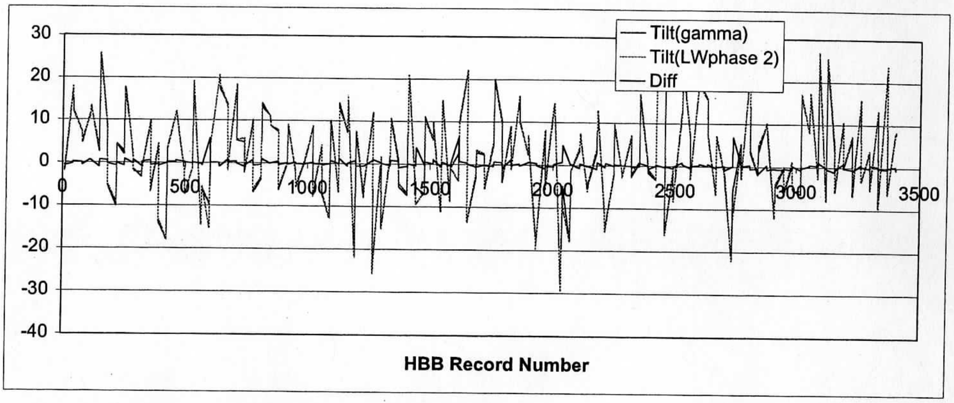
<Sample_Position_errors-01Mar00.xls>

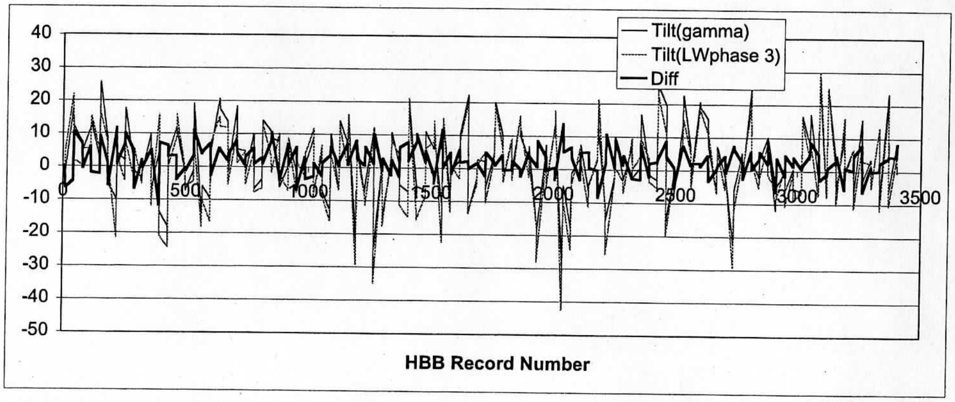
Input Variables and Quanties for Solver to minimize

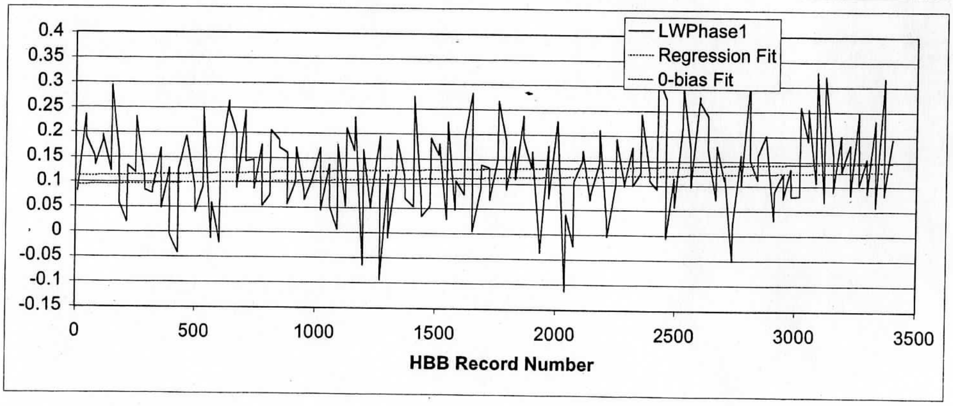
Longwave					
	dm	1.6204204	1.785436	1.65	cm
	gamma	52	55.309224	56	deg
	STDEV	1.0569055	1.0060863	4.3054597	

Intercept	0.11179876	0.2077897	-0.1482399
X Variable	1.0346E-05	9.804E-06	8.947E-06
new interc	0.094	0.19	-0.1482399
new slope	1.0346E-05	9.804E-06	8.947E-06



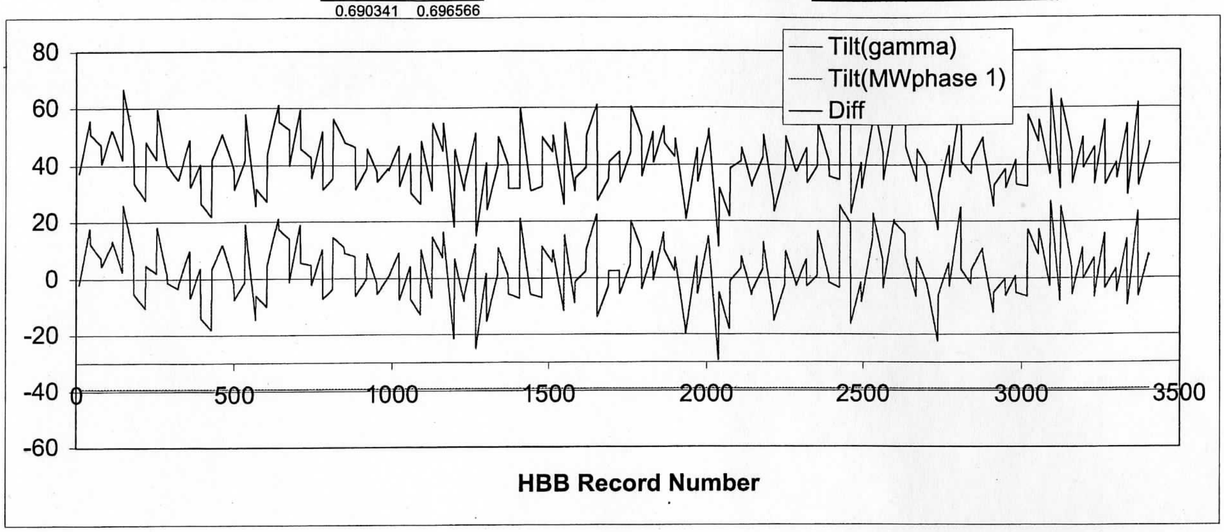


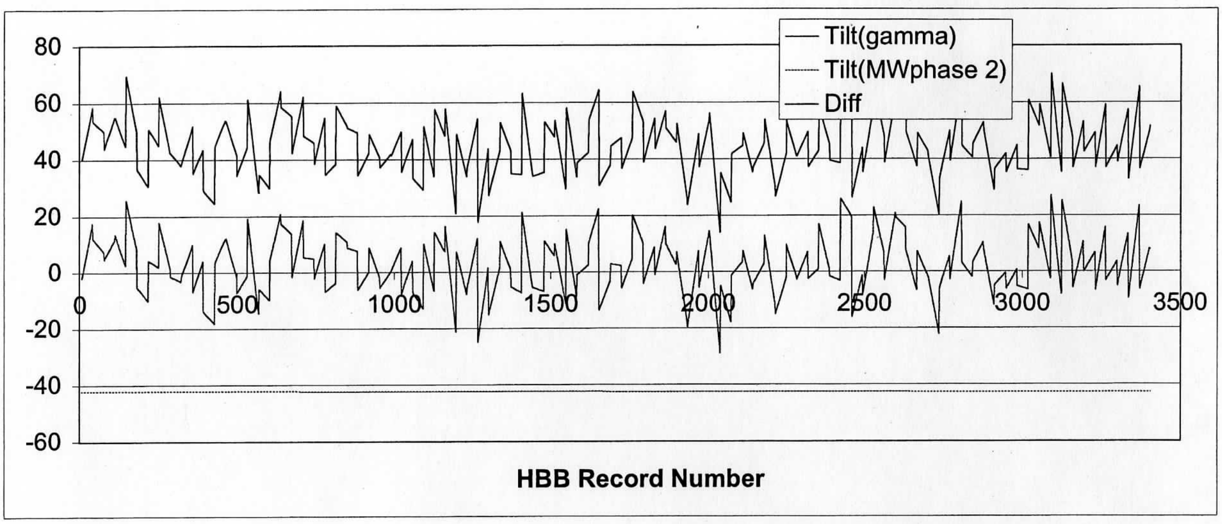


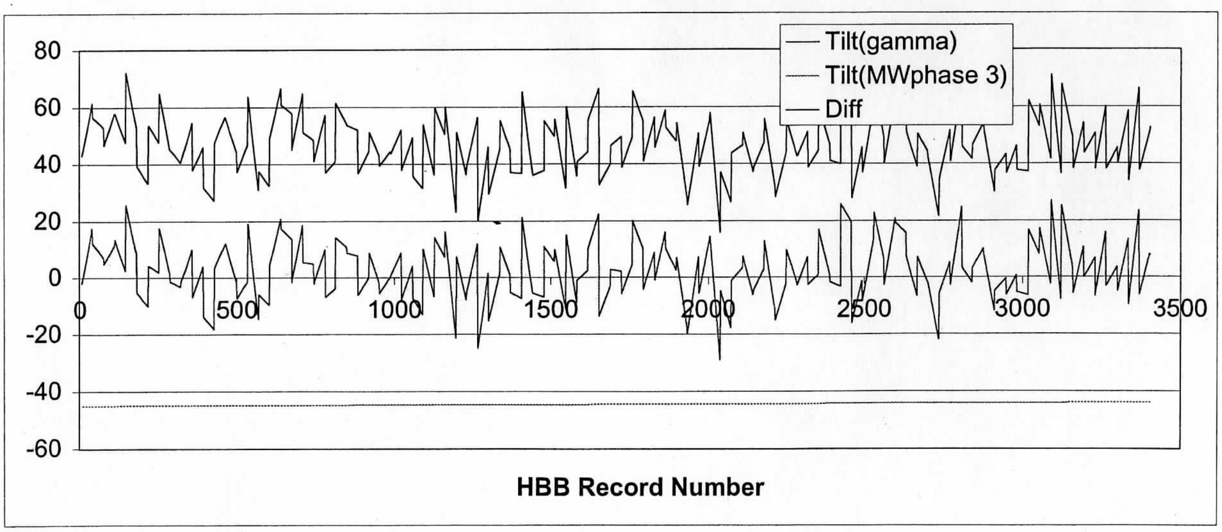


Midwave						
	-1.124634	**dm**	-1.125502	-1.073219	-1.6	cm
	39.5703	**gamma**	35.5	39.42321	38	deg
	0.690341	**STDEV**	10.86871	10.93949	10.9177	microrad
			0.690341	0.696566		

X Variable	7.1E-06	6.29E-06	1.25E-05
new interc	-0.366	-0.368	-0.6
new slope	0.00E+00	-2.00E-06	0.000004

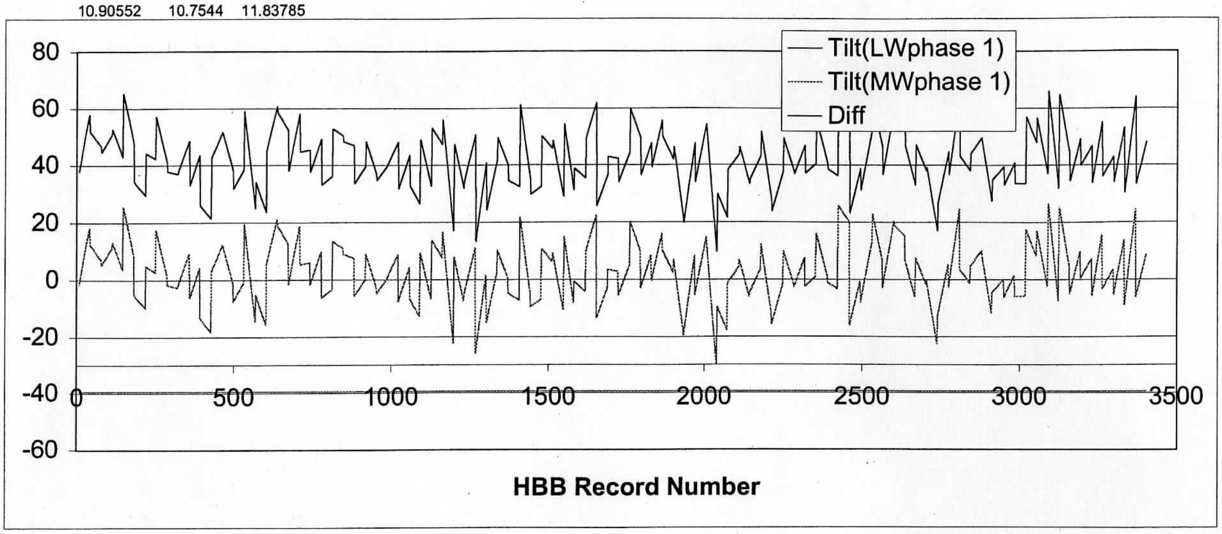


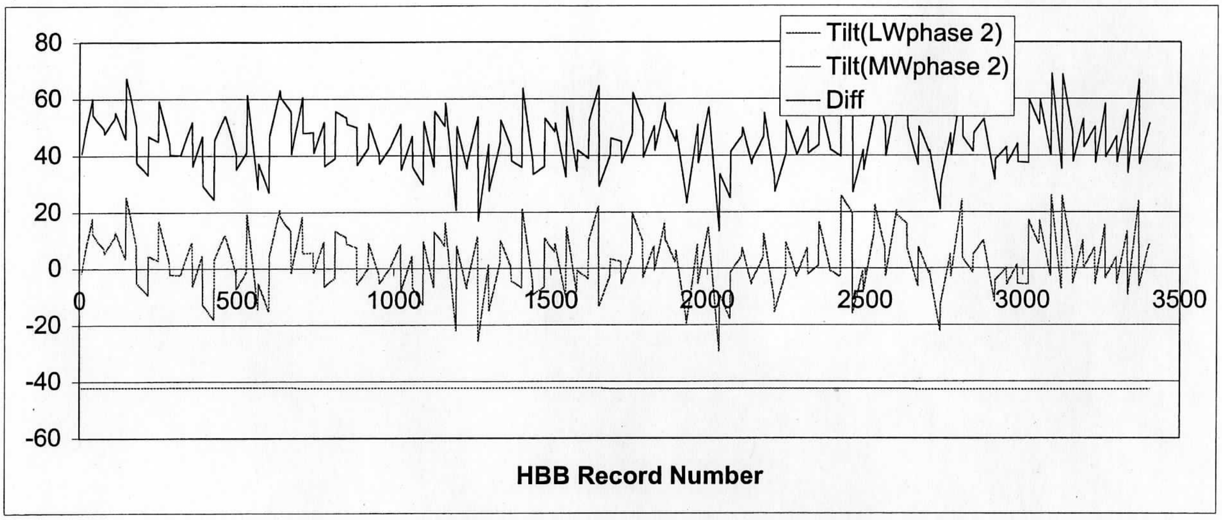


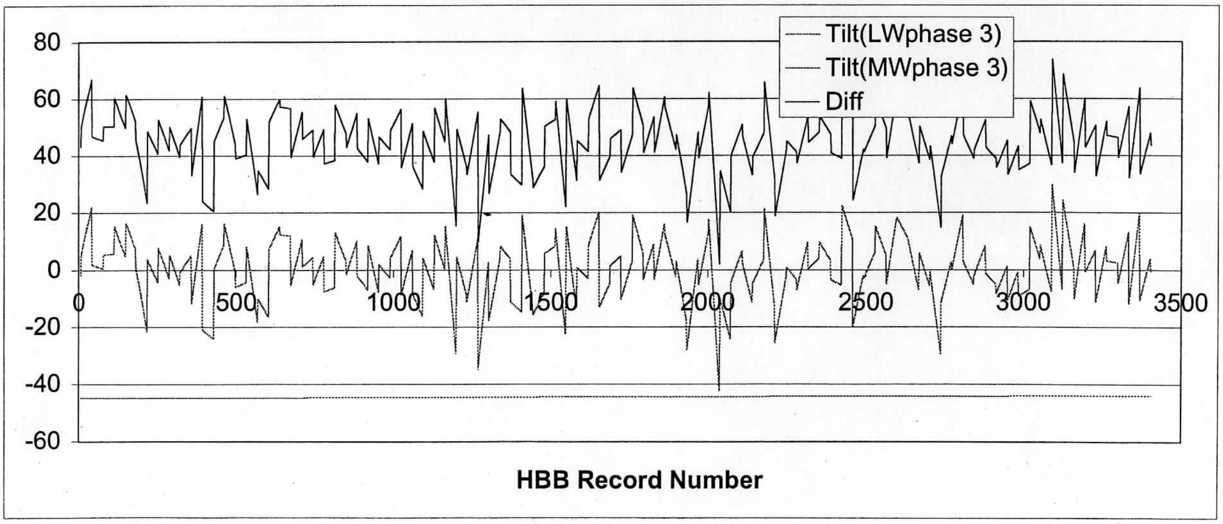


LW - MW

STDEV	10.88143	10.73116	11.80795
	10.90552	10.7544	11.83785







[3-A]

Performance Evaluation on PROTEUS

<Proteus_Integration.doc>

Performance Evaluation of NAST-I on the Proteus (April 2001, UW-Madison)

The UW supported the integration of the NAST-I on the Proteus aircraft in March 2000 with the analysis of performance data in ground tests and in flight configuration. Up until this time the NAST-I was operated only from the NASA ER-2. Figure 1 shows the NAST-I as it was installed in the ER-2 SuperPod at Patrick AFB during CAMEX3 and the installation on the Scaled Composites PROTEUS aircraft during a deployment to Stillwater, Oklahoma.

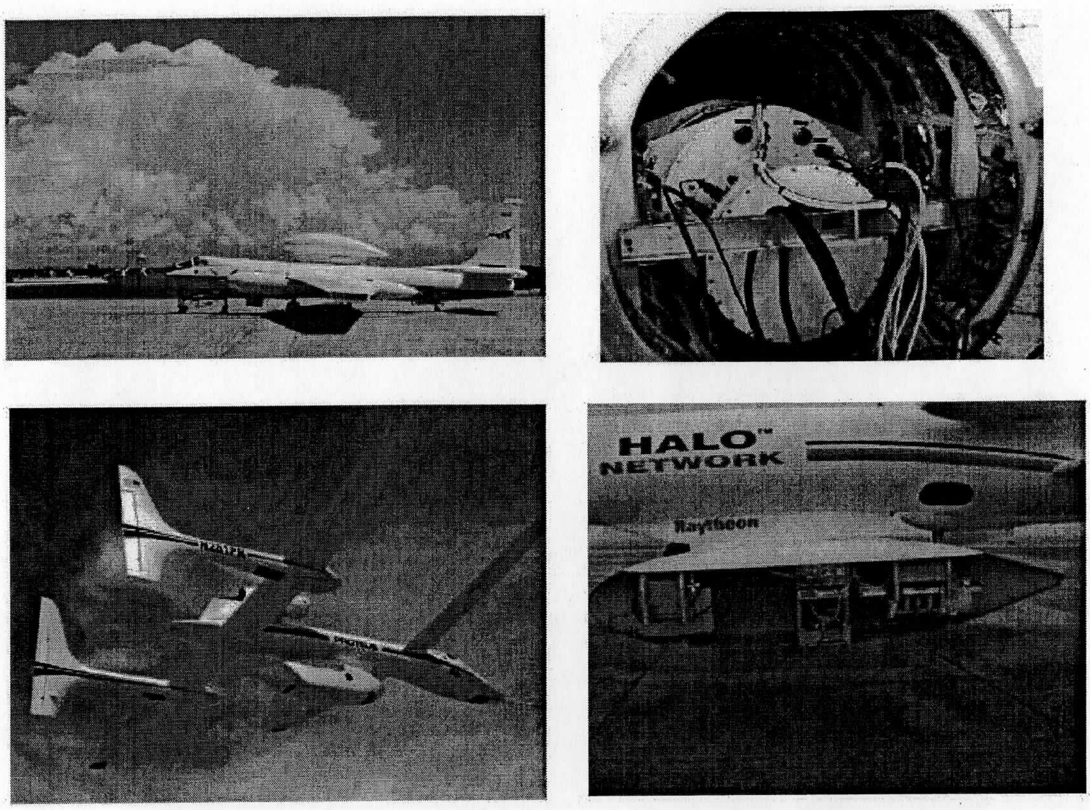


Figure 1. NAST-I installed in right SuperPod on the ER-2 (upper) and in the PROTEUS belly pod.

The performance of the NAST-I instrument during flight is typically characterized through analysis of a set of calibrated radiance views of the on-board ambient blackbody (about 260 K). This analysis uses the known temperature of the on-board reference blackbody to estimate the residual error for each blackbody spectrum. The statistics of this error analysis are divided into a spectrally uncorrelated component, a spectrally correlated component, and the total system noise. This analysis is typically performed on so-called "three line smoothed" data of the NAST-I instrument. This is a running weighted average of three cross-track scan lines (0.25, 0.5, 0.25) used to reduce the noise on an individual field of view.

The comparison of performance of the NAST-I between the Proteus and the ER-2 is shown in Figure 2. This measure of noise performance shows a total noise increase of between 50-100% depending upon wavelength. The increase is due to an increase in correlated noise, presumably because the PROTEUS is a higher vibration environment (at flight altitude) than the NASA ER-2.

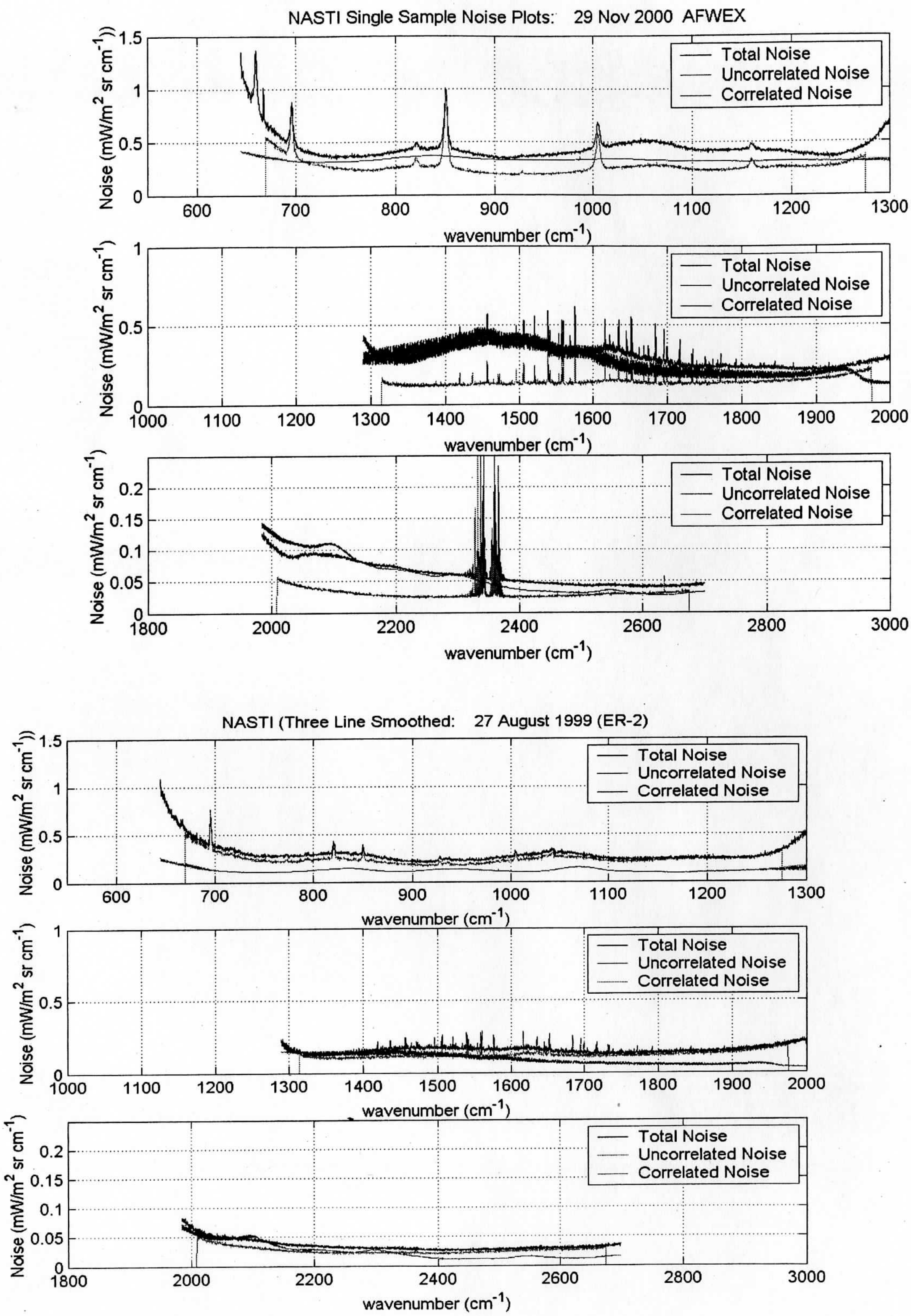


Figure 2. Comparison of NAST-I performance on a typical Proteus flight (29 Nov 2000) with the last flight of the NAST-I on the NASA ER-2 (27 Aug 1999).

[4-A]

NAST Mission Summary

<NASTI_Mission_Summary.doc>

NAST-I Mission Summary

Table 1 contains a list of experiments for which NAST-I data has been collected and processed.

Table 1. NAST-I Missions Summary (as of May 2001)

EXPERIMENT NAME	DATE	Aircraft	Number of Flights	Location
Wallops-98	June 23, 1998 to July 16, 1998	ER-2	1	NASA Wallops Island Flight Facility, Virginia
CAMEX-3	August 5, 1998 to September 28, 1998	ER-2	20	Patrick AFB, Florida
WINTEX	March 15, 1999 to April 4, 1999	ER-2	9	Madison, Wisconsin
Wallops-99	August 7, 1999 to August 27, 1999	ER-2	4	NASA Wallops Island Flight Facility, Virginia
MOHAVE	March 11, 2000 to March 13, 2000	PROTEUS	2	Scaled Composites Flight Facility, Mohave, California
CLOUD IOP	March 14, 2000 to March 21, 2000	PROTEUS	5	Stillwater, Oklahoma
WVIOP00	October 1, 2000 to October 9, 2000	PROTEUS	7	Stillwater, Oklahoma
AFWEX	November 27, 2000 to December 9, 2000	PROTEUS	9	Stillwater, Oklahoma
TRACE-P Honolulu	February 21, 2001 to February 25, 2001	PROTEUS	3	Honolulu, Hawaii
TRACE-P Okinawa	March 1, 2001 to March 16, 2001	PROTEUS	6	Okinawa, Japan
TRACE-P Alaska	March 17, 2001 to March 26, 2001	PROTEUS	5	Fairbanks, Alaska

Table 2. NAST-I Data Processing Status

[4-B]

IRS2000 Meeting Presentation

<irs2000_bobk.ppt>

FTIR Airborne Remote Sensing with the HIS, S-HIS, and NAST-I

Robert O. Knuteson
University of Wisconsin - Madison

International Radiation Symposium

24-28 July 2000

Contributors

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Allen Larar

Contents

- **Overview**
- **Instrumentation**
- **Calibration**
- **Applications**
- **Summary**

Overview

- Remote sensing of the atmosphere using Earth emitted radiation is about to make a quantum leap forward.

- This decade will see the biggest advance in satellite infrared observation since development of the filter wheel radiometers (e.g. HIRS) in the 1970s .

- The AIRS, CrIS, and IASI instruments in polar orbits and the GIFTS, ABS, and next generation Meteosat instruments in geo-synchronous orbits will bring a wealth of new high spectral resolution infrared observations for global weather and climate applications.

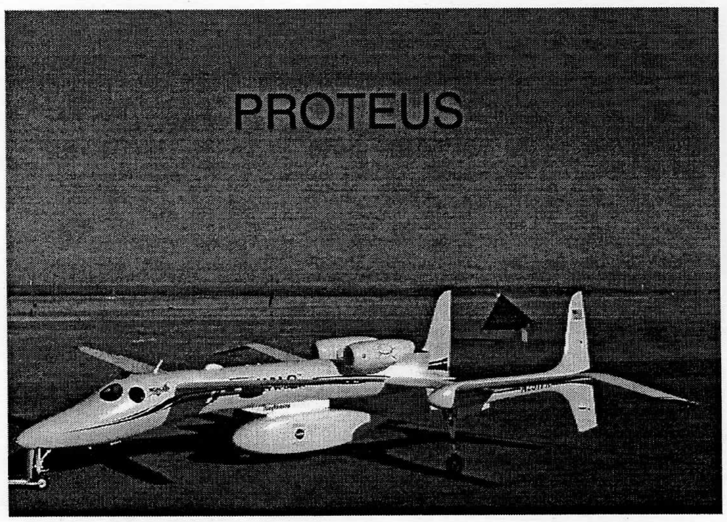
Overview

- A new generation of airborne instruments for Earth remote sensing of the atmosphere have also been developed for operation from research aircraft. These instruments will be used in the validation of satellite measurements and algorithms.

- The INTESA (Harvard), ARIES (UK MET), and TES (JPL) instruments are all relatively new aircraft instruments which will make valuable contributions to Earth remote sensing in this decade.

- The focus of this presentation will be on two aircraft instruments that have been developed in the last several years (SHIS and NAST-I) with the active participation of the University of Wisconsin.

Research Aircraft Platforms



Aircraft Platforms:

- NASA DC-8 (0-12 km)
- NASA ER-2 (20 km)
- PROTEUS (12-20 km)

Instrumentation Heritage

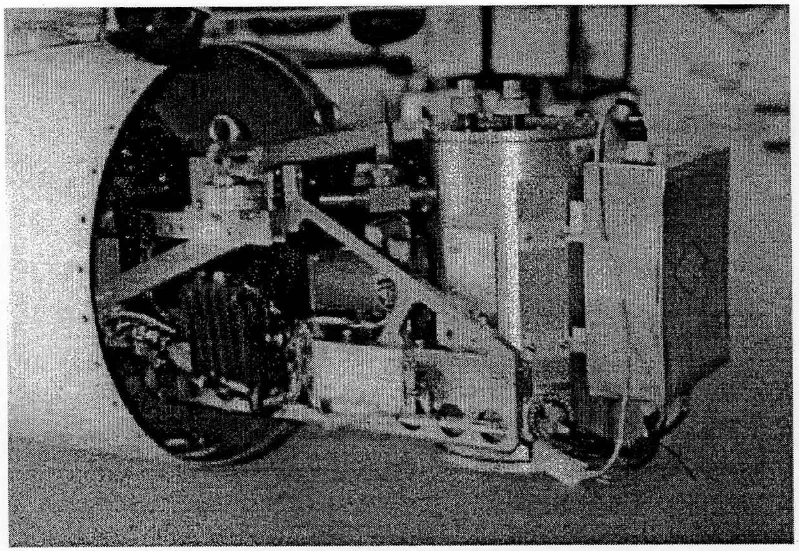
High-resolution Interferometer Sounder (HIS)

- Designed as demonstration platform for future geostationary sounder.
- Development team of Uni. Wisc. and Bomem, Inc. of Quebec, Canada.
- Development funded by NOAA and NASA in 1985.
- Over 100 successful flights between 1986 and 1998 on the NASA ER-2

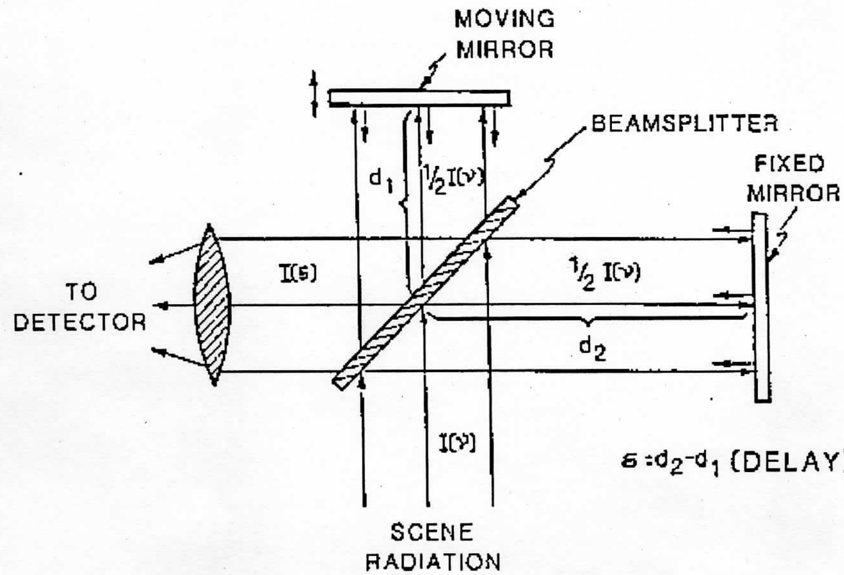
Unique Characteristics

- Measurement of upwelling infrared emitted radiance at high altitude (20 km) using a Michelson interferometer with "dynamic alignment" .
- On-board precision blackbody sources provide accurate radiometric calibration (< 1K absolute).
- On-board reference laser to provide accurate spectral calibration.
- Arsenic doped Silicon detectors operated at 6 Kelvin provide linear response from 16.7 to 3.8 microns in three spectral bands.
- On-axis optical design minimizes interferometer self-apodization.

Instrumentation: HIS

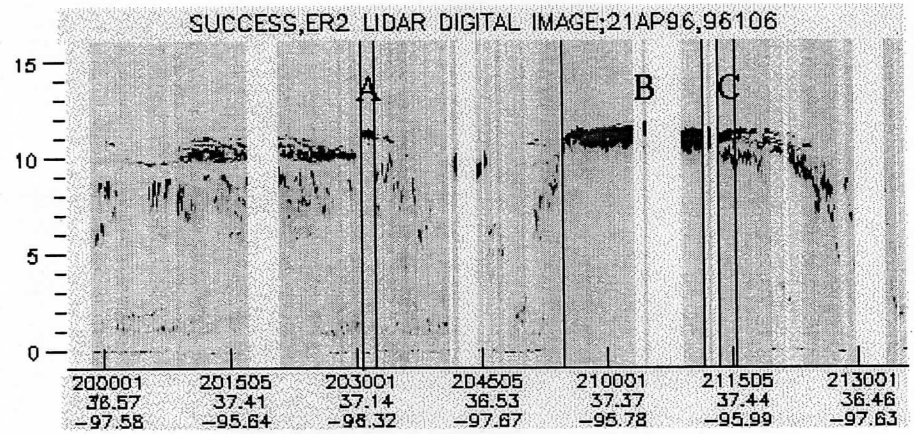


HIS Instrument in "Belly Pod" of NASA ER-2

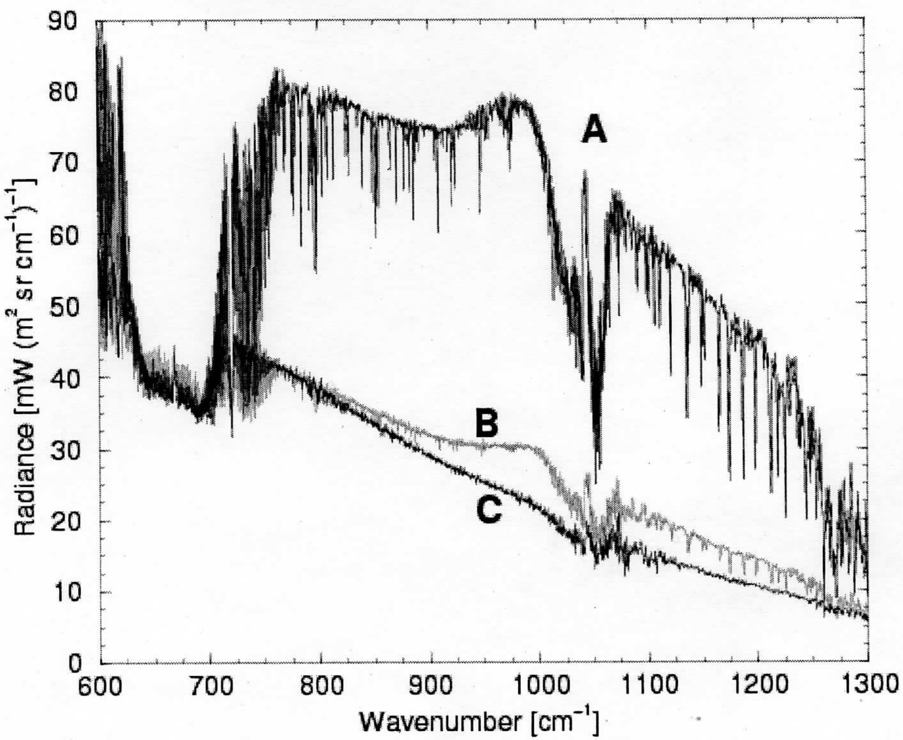


SCHEMATIC OF A MICHELSON INTERFEROMETER

Cloud Radiation



ER-2 LIDAR
Cirrus Cloud
Image
(Spinhirne)



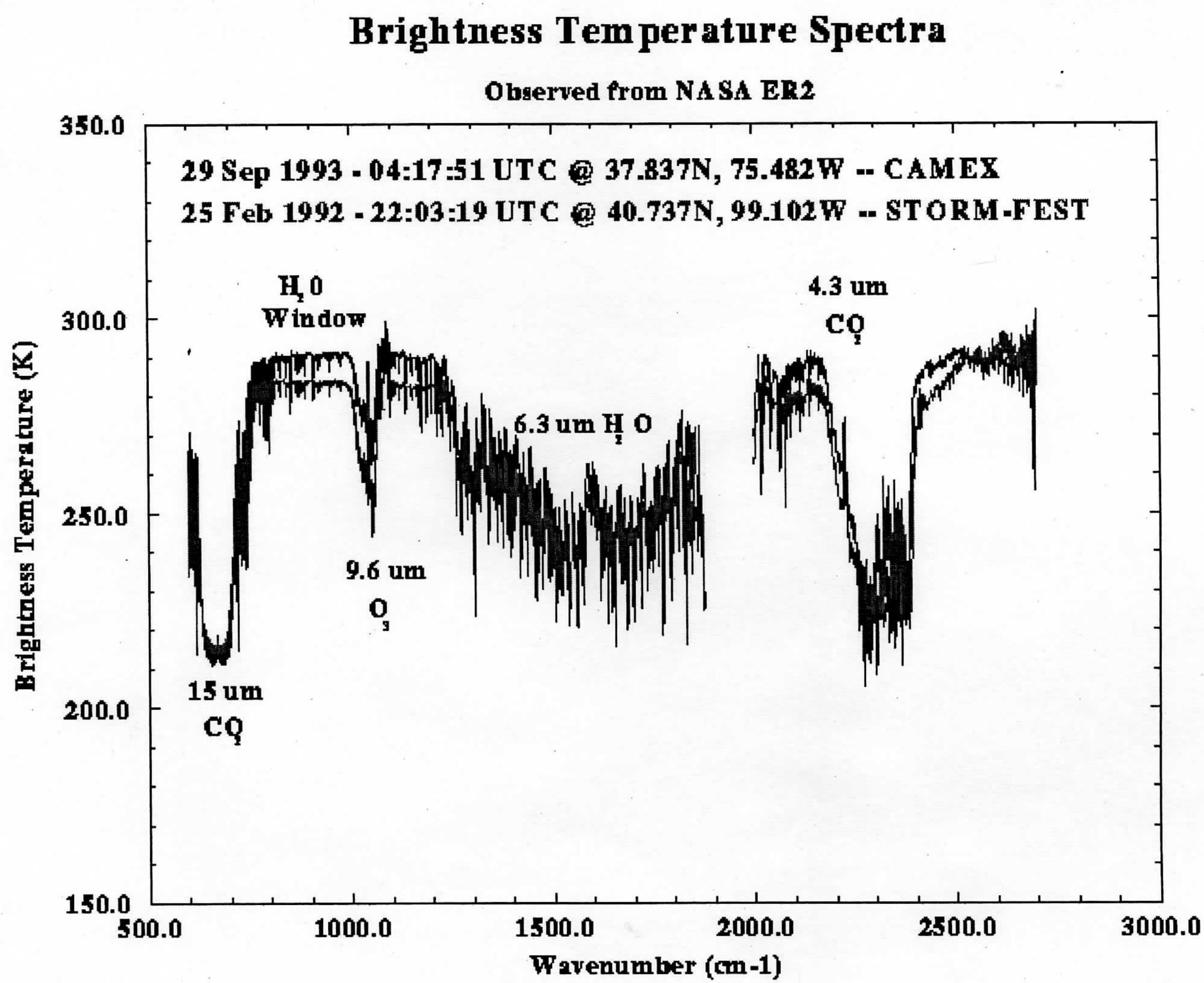
ER-2 HIS
Cirrus Cloud
Radiation

Instrumentation: HIS

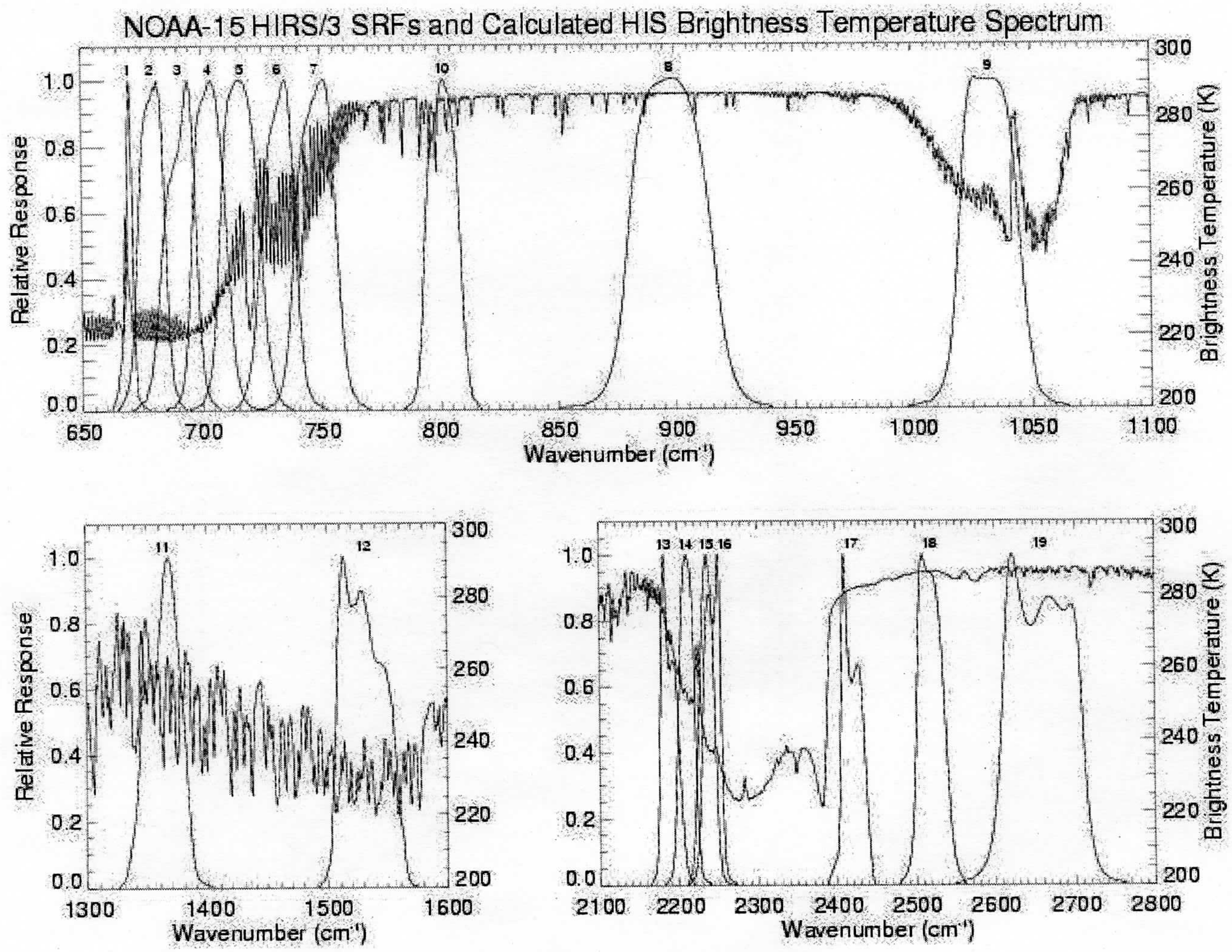
Characteristics of the HIS aircraft instrument

Spectral range (cm^{-1})	
Band I	590 - 1080
Band II	1080 - 1850
Band III	2000 - 2700
Field of view diameter (mr)	
Telescope	100
Interferometer	30
Blackbody reference sources	
Emissivity	>0.998
Aperature diameter (cm)	1.5
Temperature stability (K)	-0.1
Auto-aligned interferometer	modified Bomem HBDA2.1
Beamsplitter	
Substrate	KCl
Coatings (1/4 g at 3.3 mm)	Ge + Sb_2S_3
Maximum delay (double-sided) current configuration (cm)	
Band I (hardware limit is -2.0)	-1.8
Band II and III (limited by data system)	+1.2,-0.8
Michelson mirror optical scan rate ($cm\ s^{-1}$)	0.6
Aperature stop (at interferometer exit window)	
Diameter (cm)	4.1
Central obscuration area fraction	0.17
Area (cm^2)	10.8
Area-solid angle product ($cm^2\ sr$)	0.0076
Detectors	
Type	Ar doped Si
Diameter (cm)	0.16
Temperature (K)	6

Instrumentation: HIS

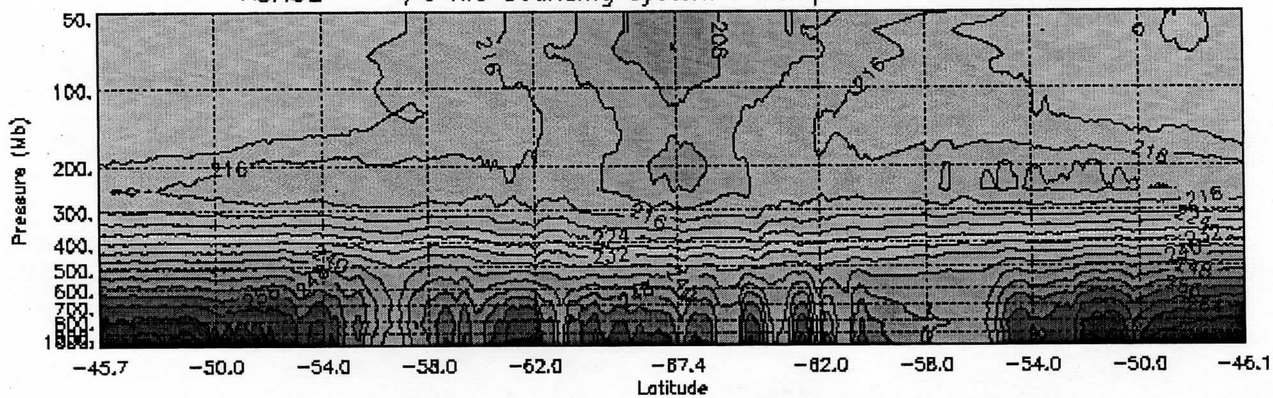


Instrumentation: HIS

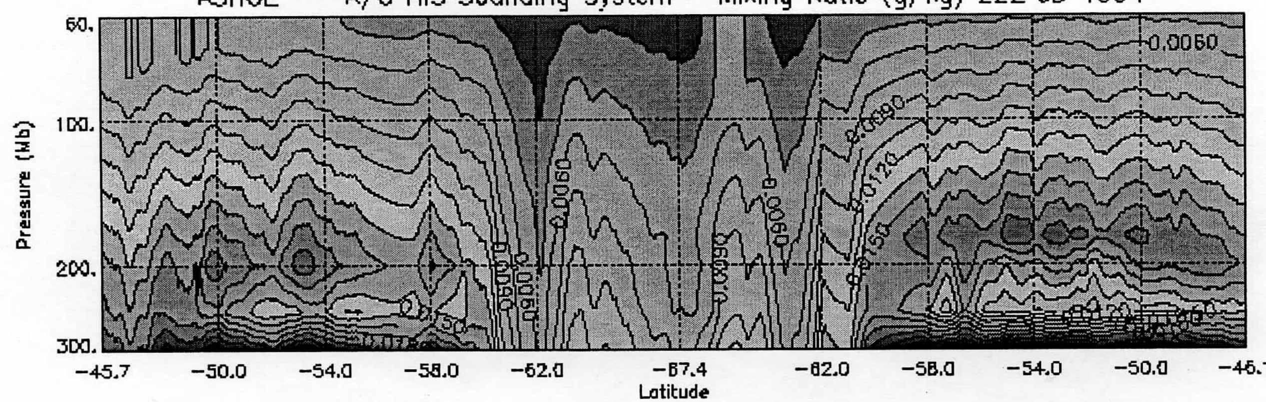


Instrumentation: HIS

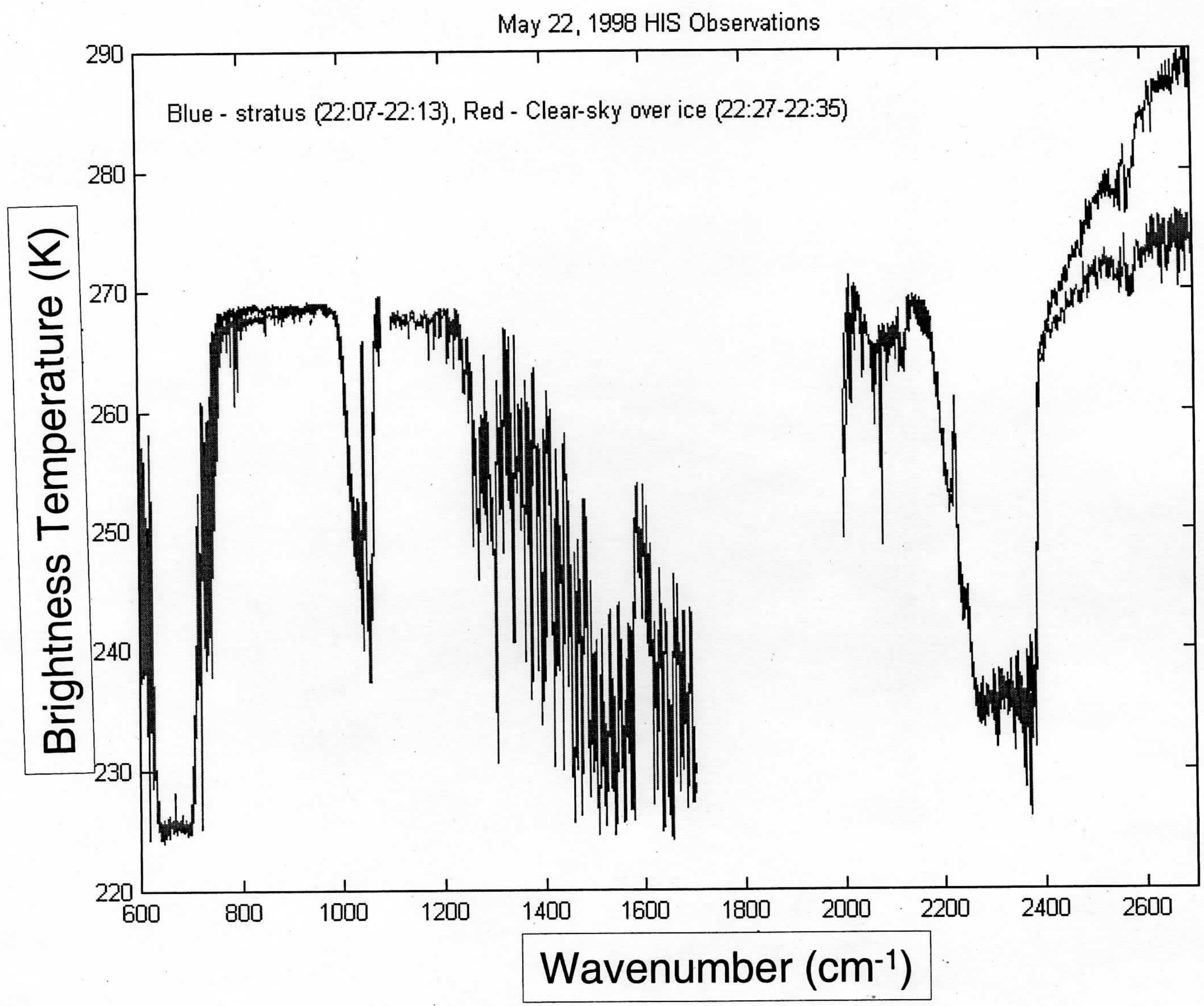
ASHOE -- A/C HIS Sounding System - Temperature 222 JD 1994



ASHOE -- A/C HIS Sounding System - Mixing Ratio (g/kg) 222 JD 1994



Instrumentation: HIS



Spectral Resolution: 0.5 - 1.0 cm^{-1}

Max OPD: 1.8 cm

Dwell Period: 6 seconds

Altitude: 20 kilometers

Field of View: 2 kilometers at the surface

Instrumentation: S-HIS

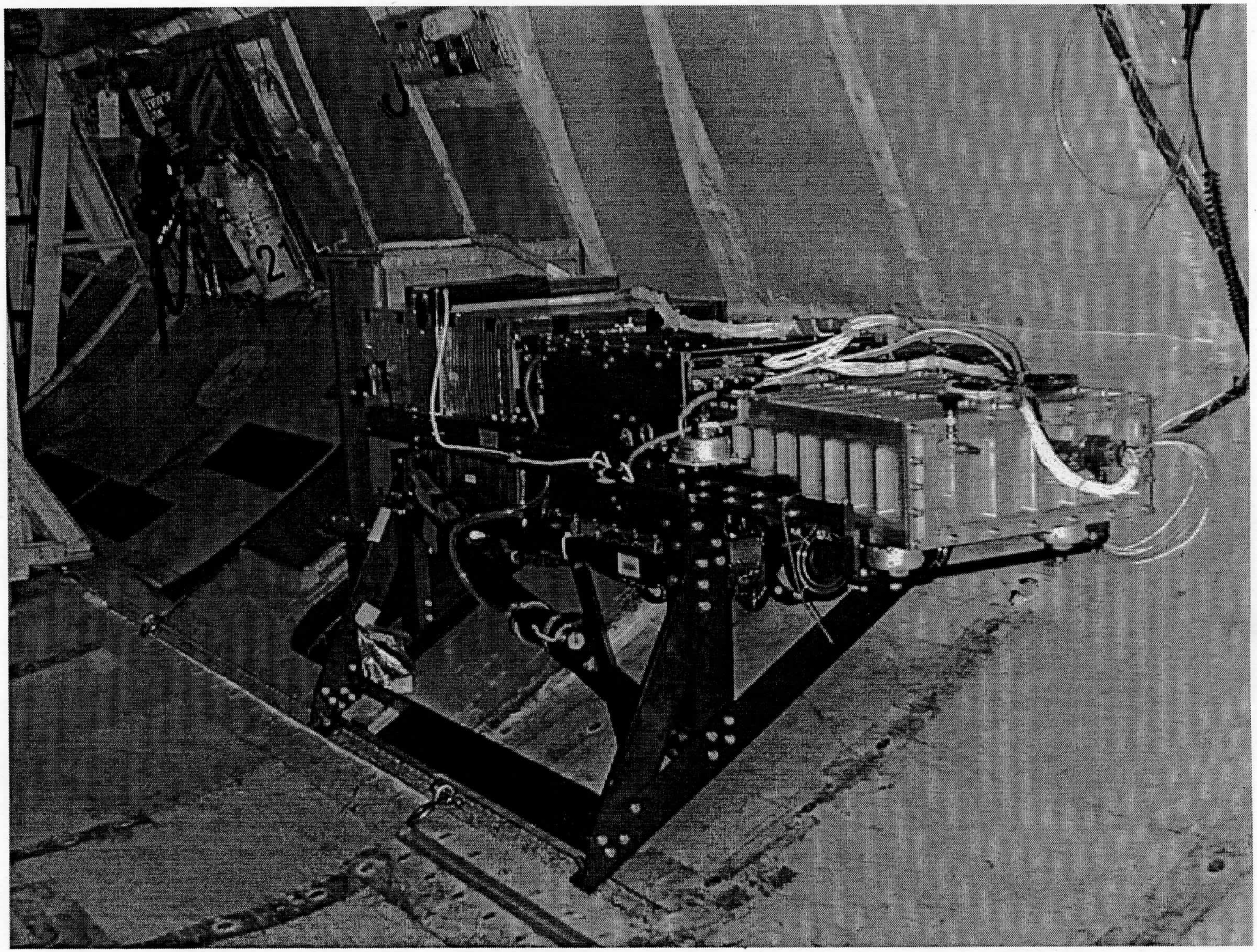
Scanning - HIS (SHIS)

- Originally designed for operation on Unmanned Airborne Vehicle (UAV) Later adapted for flight on NASA ER-2 and DC-8 aircraft.
- Development team of Uni. Wisc. and Bomem, Inc. of Quebec, Canada.
- Development funded by DOE and IPO in 1996-1998.
- Over 30 successful flights between 1998 and present.

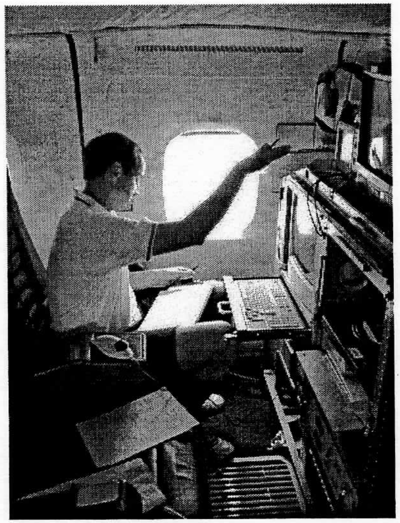
Unique Characteristics

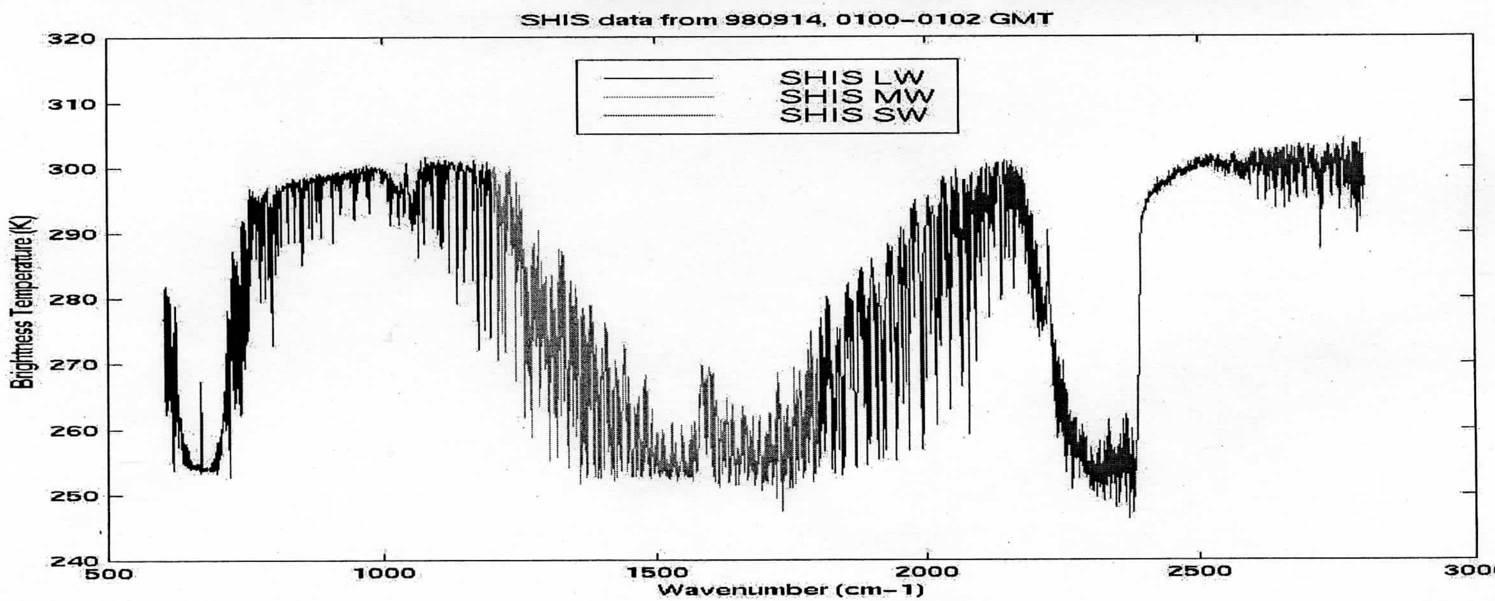
- Light-weight, modular design incorporating main characteristics of the original HIS instrument.
- Mechanical cooler used for maintaining MCT/InSb detectors at 77K.
- Scan mirror in fore optics allows for side scanning.
- Max OPD of 1 cm (double sided) achieved in 0.5 second dwell.

Instrumentation: S-HIS

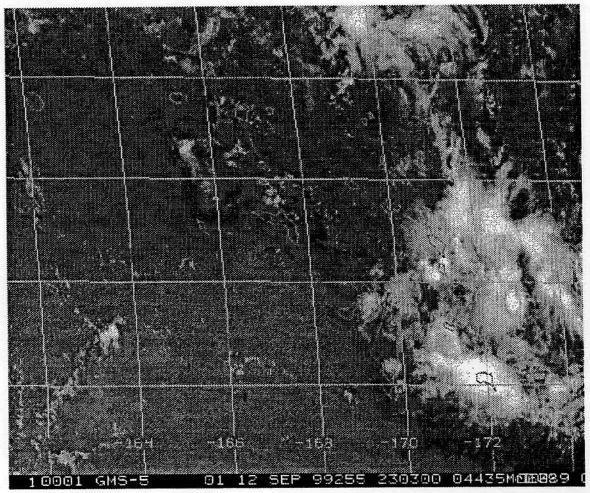


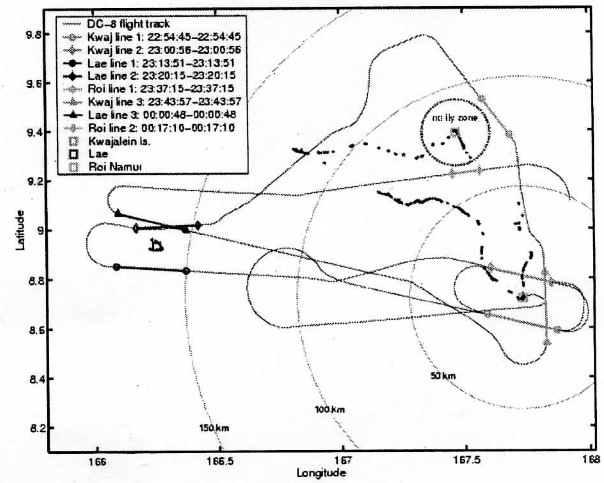
Instrumentation: S-HIS

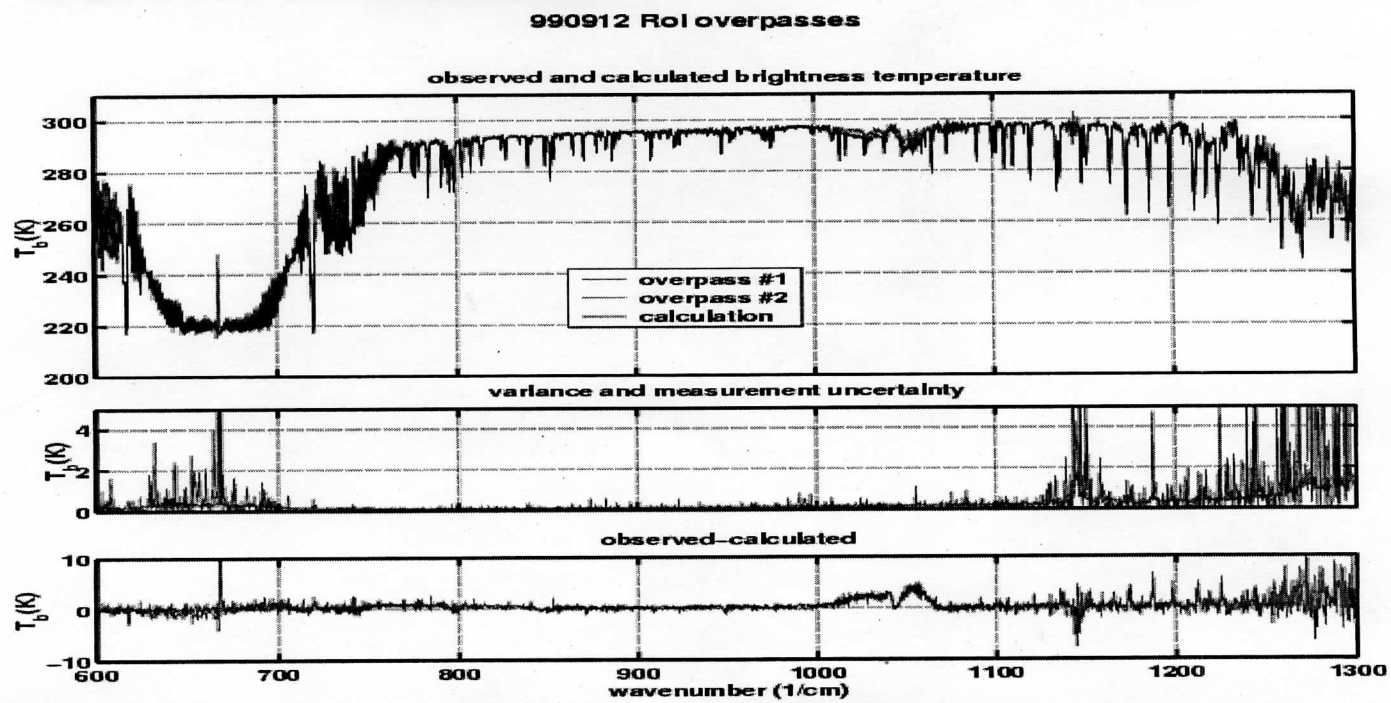


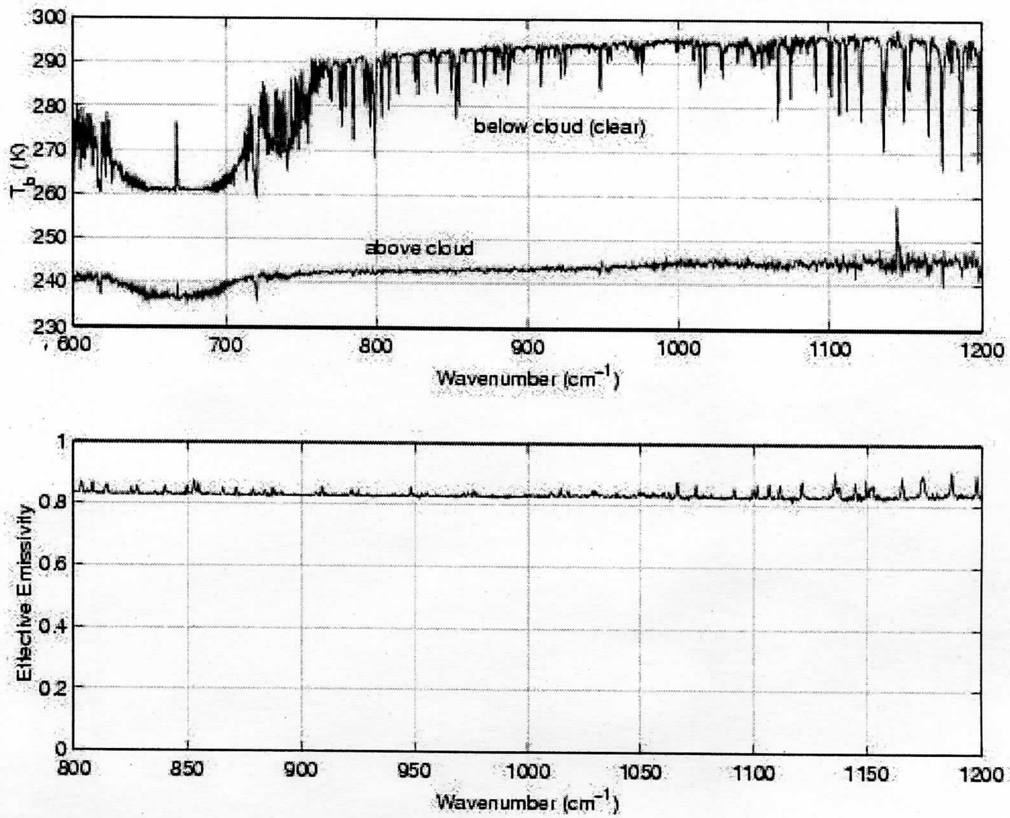


S-HIS


-164
-166
-168
-170
-172
10001 GMS-5 01 12 SEP 99255 230300 04435

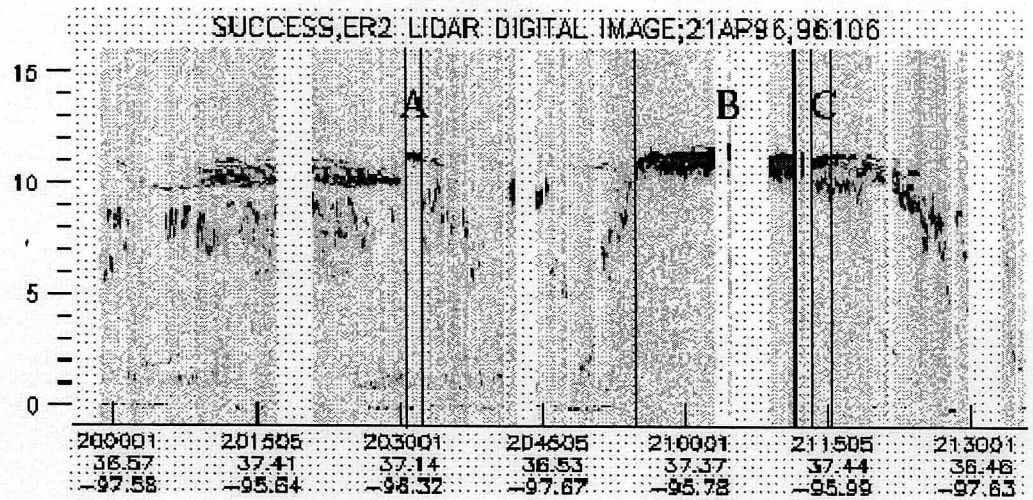

DC-8 flight track
Kwaj line 1: 22:54:45–22:54:45
Kwaj line 2: 23:00:56–23:00:56
Lae line 1: 23:13:51–23:13:51
Lae line 2: 23:20:15–23:20:15
Roi line 1: 23:37:15–23:37:15
Kwaj line 3: 23:43:57–23:43:57
Lae line 3: 00:00:48–00:00:48
Roi line 2: 00:17:10–00:17:10
Kwajalein Is.
Lae
Roi Namur
no fly zone
50 km
100 km
150 km
Latitude
Longitude

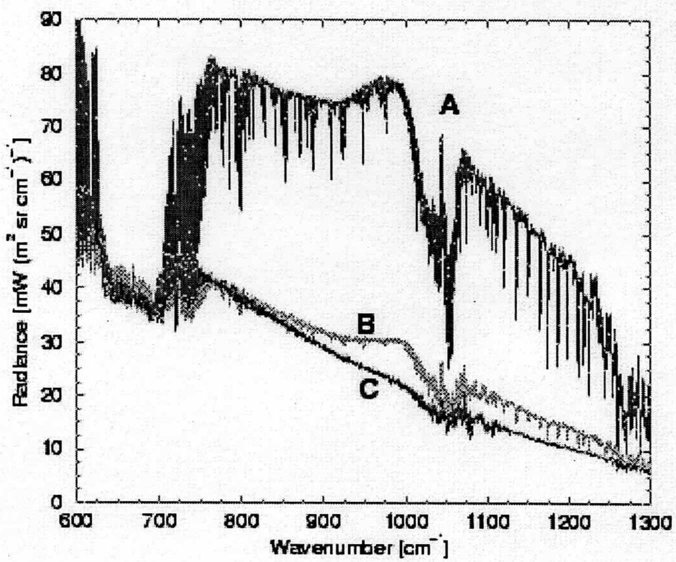

990912 Roi overpasses
observed and calculated brightness temperature
overpass #1
overpass #2
calculation
T_b(K)
variance and measurement uncertainty
observed–calculated
wavenumber (1/cm)

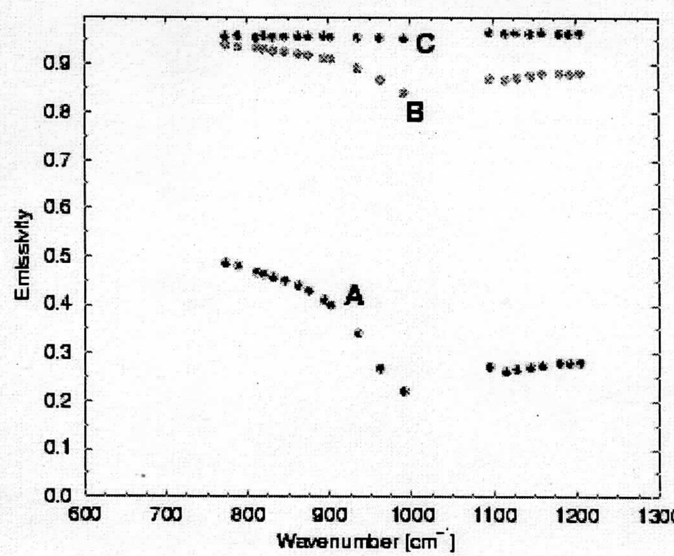


This figure shows the upwelling brightness temperature observed by the Scanning HIS during KWAJEX from above and below a cloud deck (upper panel) and a derived cloud top effective emissivity (lower panel). The spectrally uniform cloud emissivity, near 0.83 across the longwave window, is indicative of ice particles with effective radius greater than 50 microns (DeSlover et al., 1999). This is consistent with measurements from a 2D probe on the DC-8 aircraft.

Aircraft-based Cirrus
Cloud Emissivity Retrieval







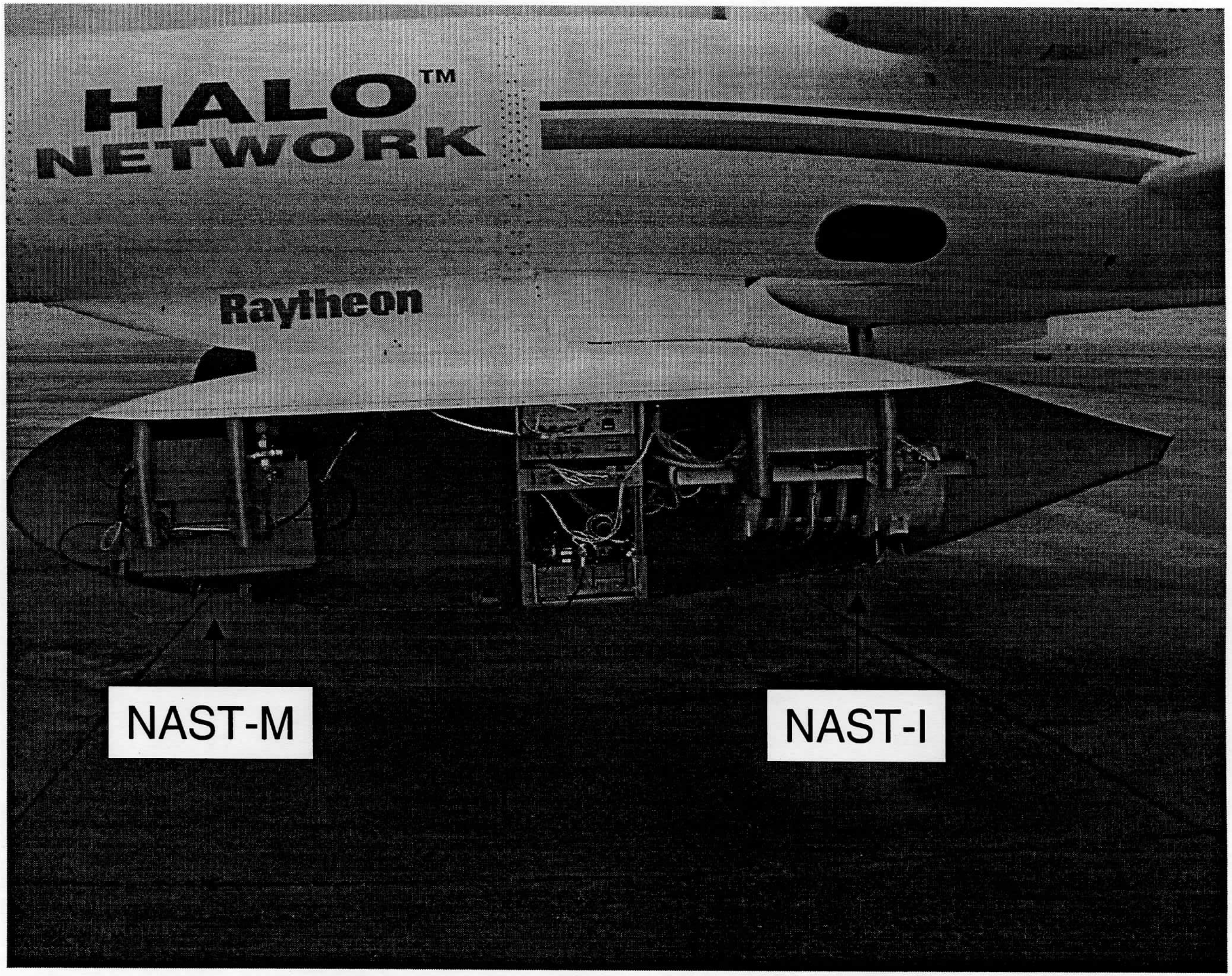
Instrumentation: NAST-I

National Polar Orbiting Earth Sounding System (NPOESS) Atmospheric Sounder Testbed - Interferometer (NAST-I)

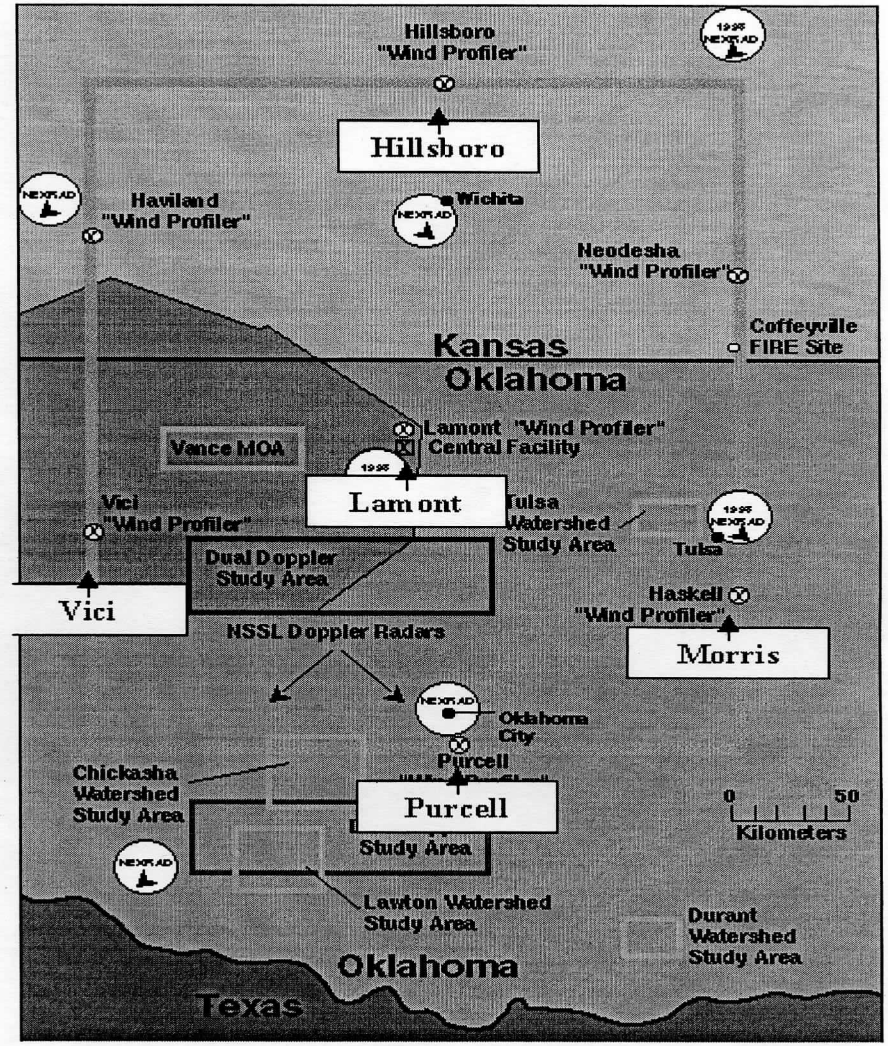
- Designed as the infrared portion of a combined infrared/microwave sounder "testbed" for pre-launch algorithm development and post-launch validation.
- Development team of MIT-Lincoln Labs, Bomem, Inc., and the Uni. Of Wisconsin. Operated by NASA Langley Research Center with support from MIT-LL and UW-Madison.
- Development funded by IPO in 1997-1998.
- Over 30 successful flights between 1998 and present.

Unique Characteristics

- Incorporates main characteristics of the original HIS instrument.
- Cross-track scanning at 13 angles (+45 to -45 degrees)
- Max OPD of 2 cm (double sided) achieved in 0.8 second dwell.

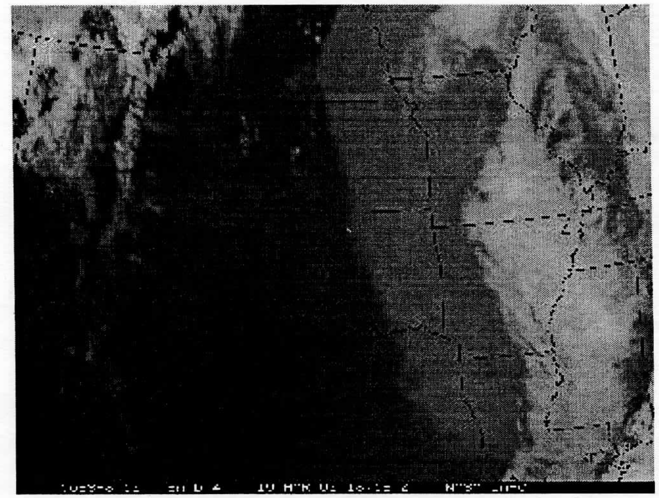

HALO™
NETWORK
Raytheon
NAST-M
NAST-I

DOE ARM CART SITE



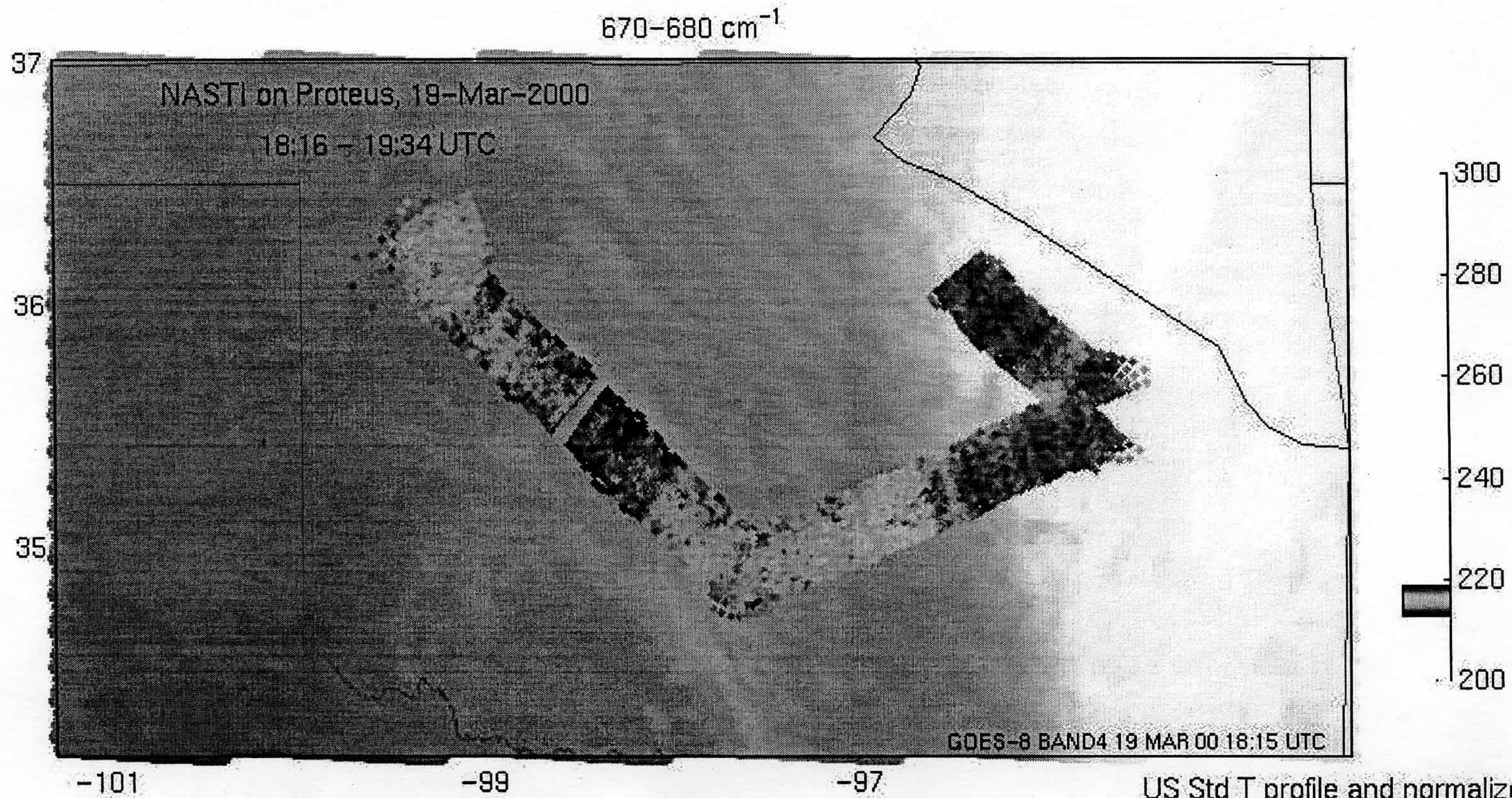
NAST-I

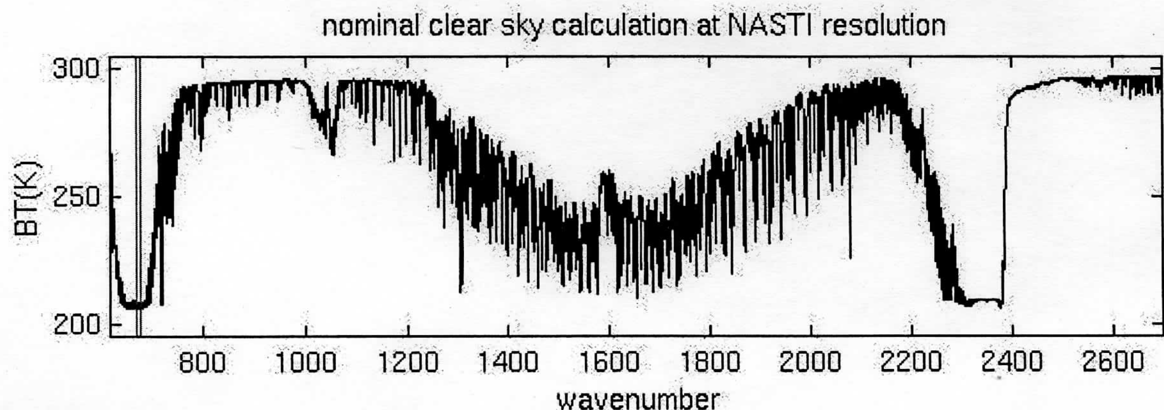
- ARM CLOUD IOP
- 19 March 2000
- Oklahoma, USA
- NAST-I on Proteus

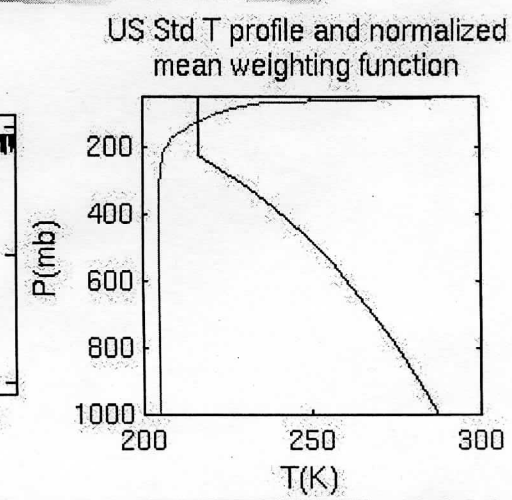


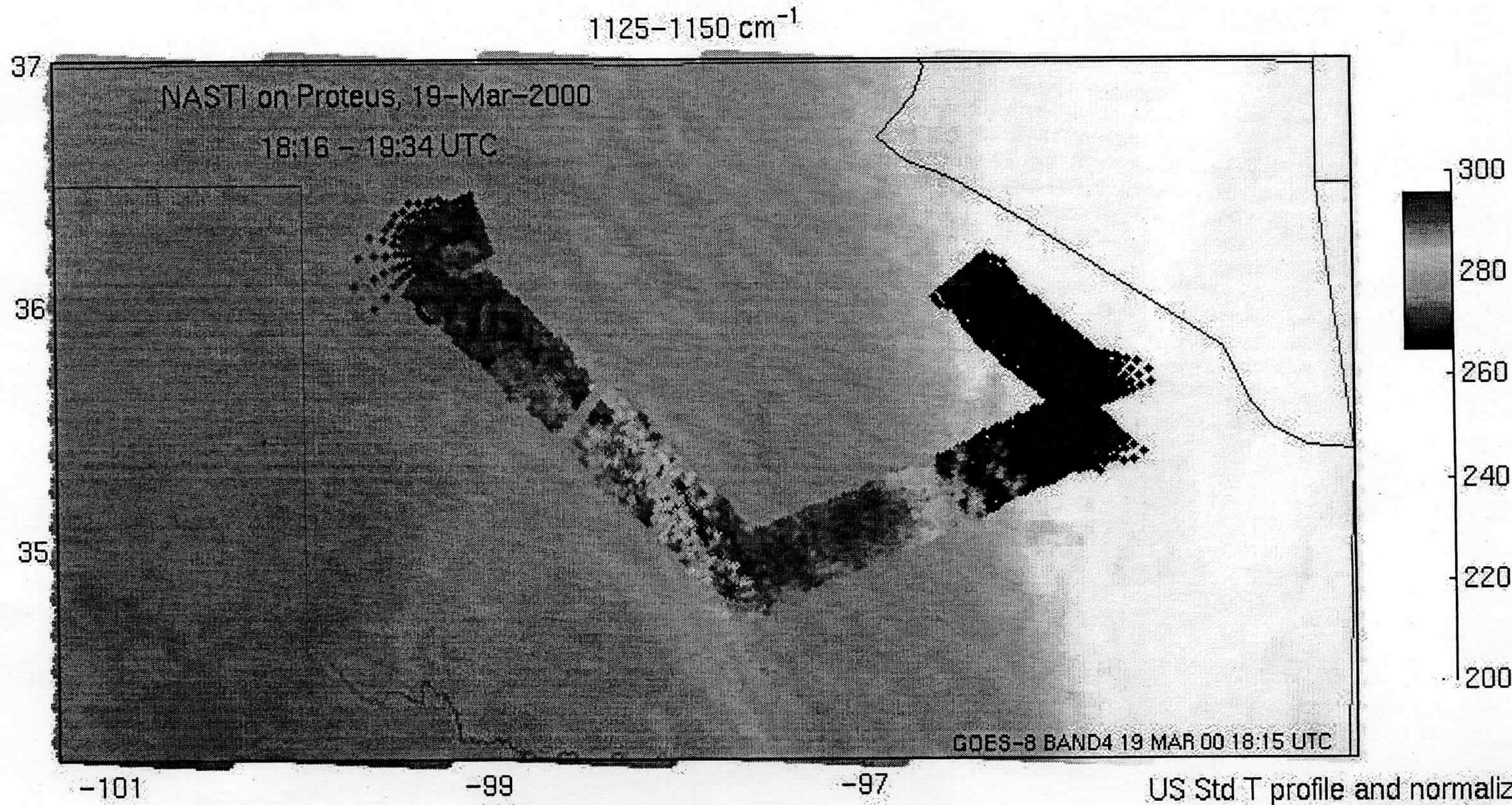
GOES Visible Channel

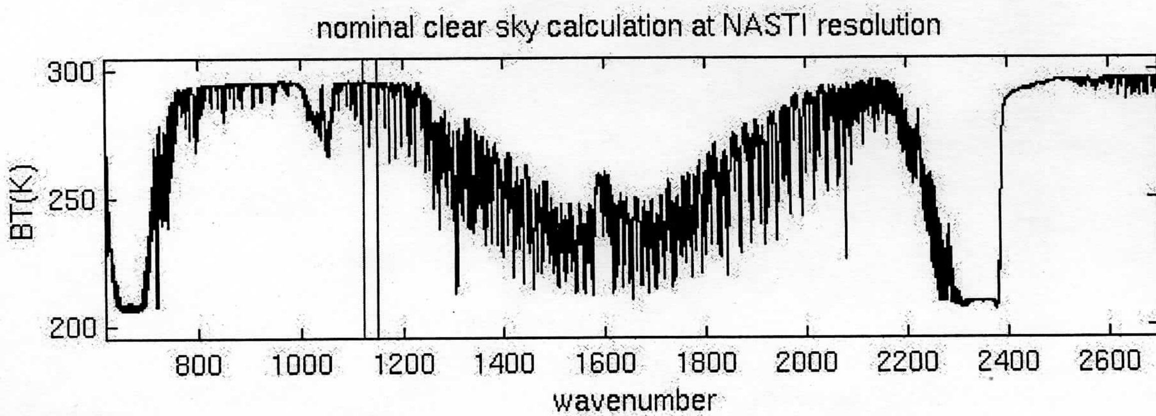
GOES Water Vapor Channel

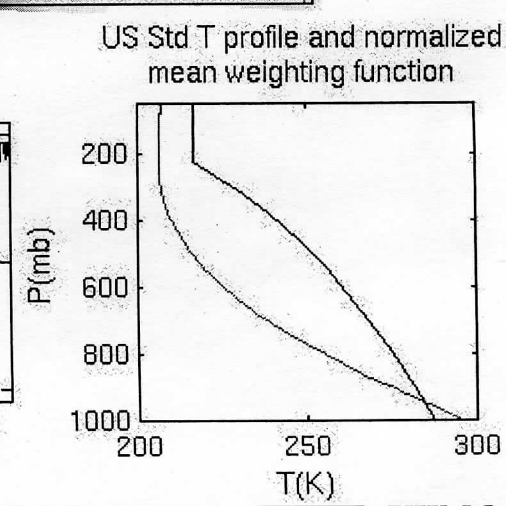

670–680 cm-1
NASTI on Proteus, 19–Mar–2000
18:16 – 19:34 UTC
GOES-8 BAND4 19 MAR 00 18:15 UTC
37
36
35
-101
-99
-97
300
280
260
240
220
200

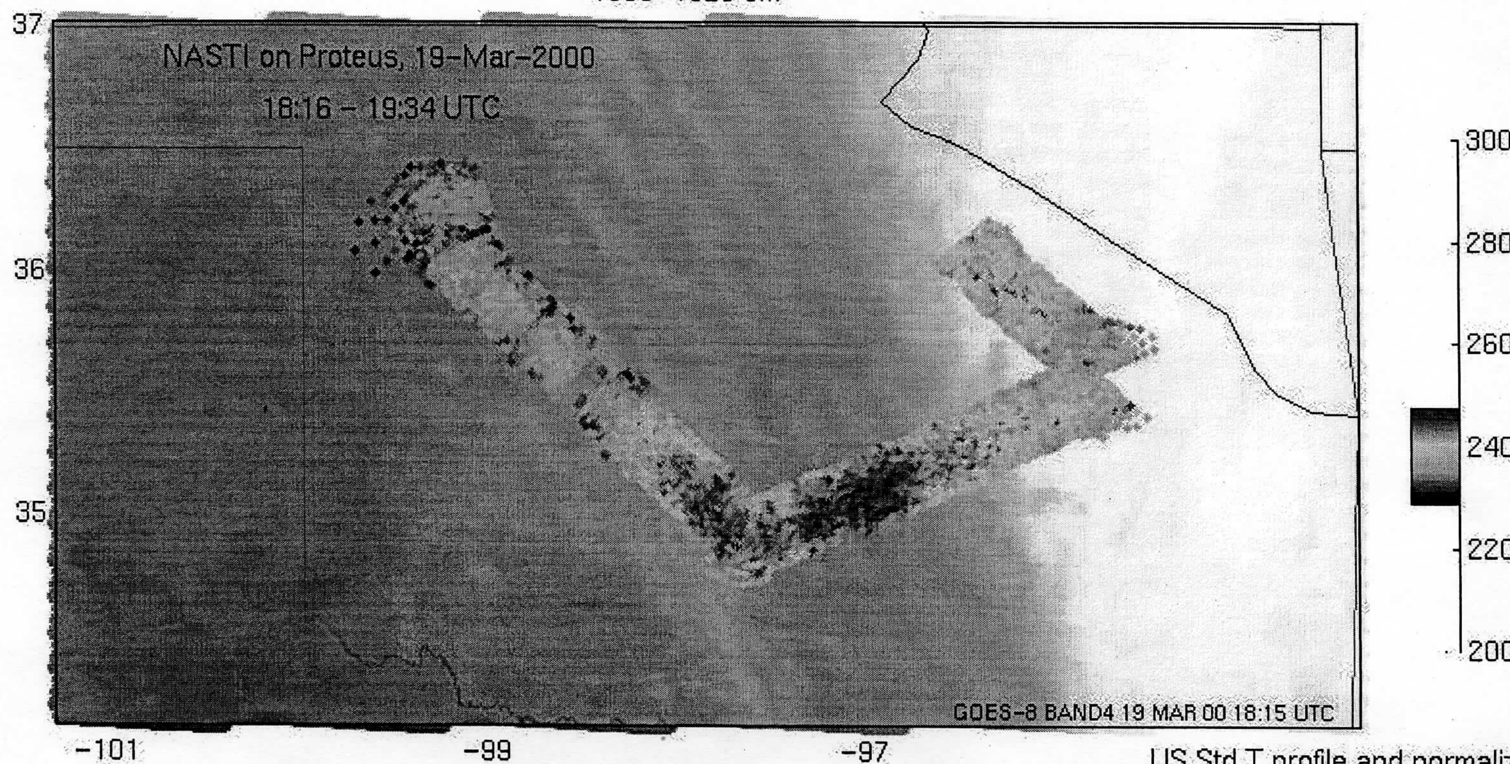

nominal clear sky calculation at NASTI resolution
BT(K)
300
250
200
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
wavenumber

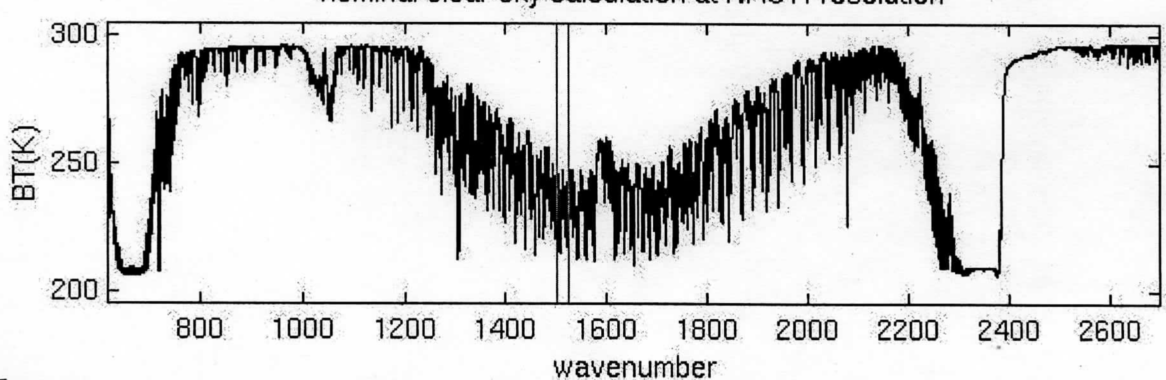

US Std T profile and normalized
mean weighting function
P(mb)
200
400
600
800
1000
200
250
300
T(K)

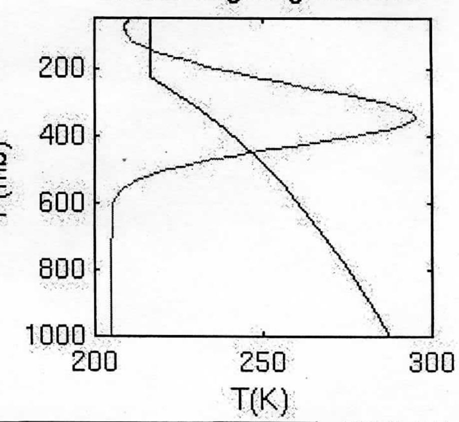

1125–1150 cm^{-1}
NASTI on Proteus, 19–Mar–2000
18:16 – 19:34 UTC
37
36
35
−101
−99
−97
GOES–8 BAND4 19 MAR 00 18:15 UTC
300
280
260
240
220
200


nominal clear sky calculation at NASTI resolution
BT(K)
300
250
200
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
wavenumber


US Std T profile and normalized mean weighting function
P(mb)
200
400
600
800
1000
200
250
300
T(K)

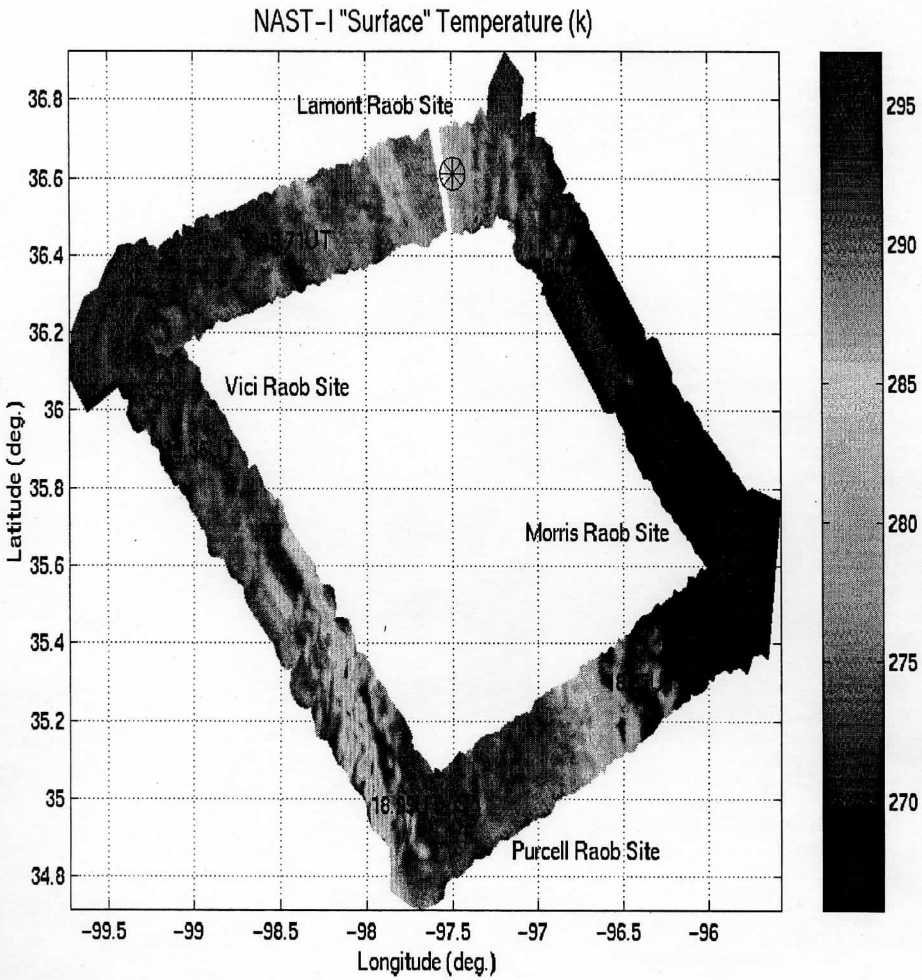

1500–1525 cm^{-1}
NASTI on Proteus, 19–Mar–2000
18:16 – 19:34 UTC
GOES–8 BAND4 19 MAR 00 18:15 UTC
37
36
35
−101
−99
−97
300
280
260
240
220
200

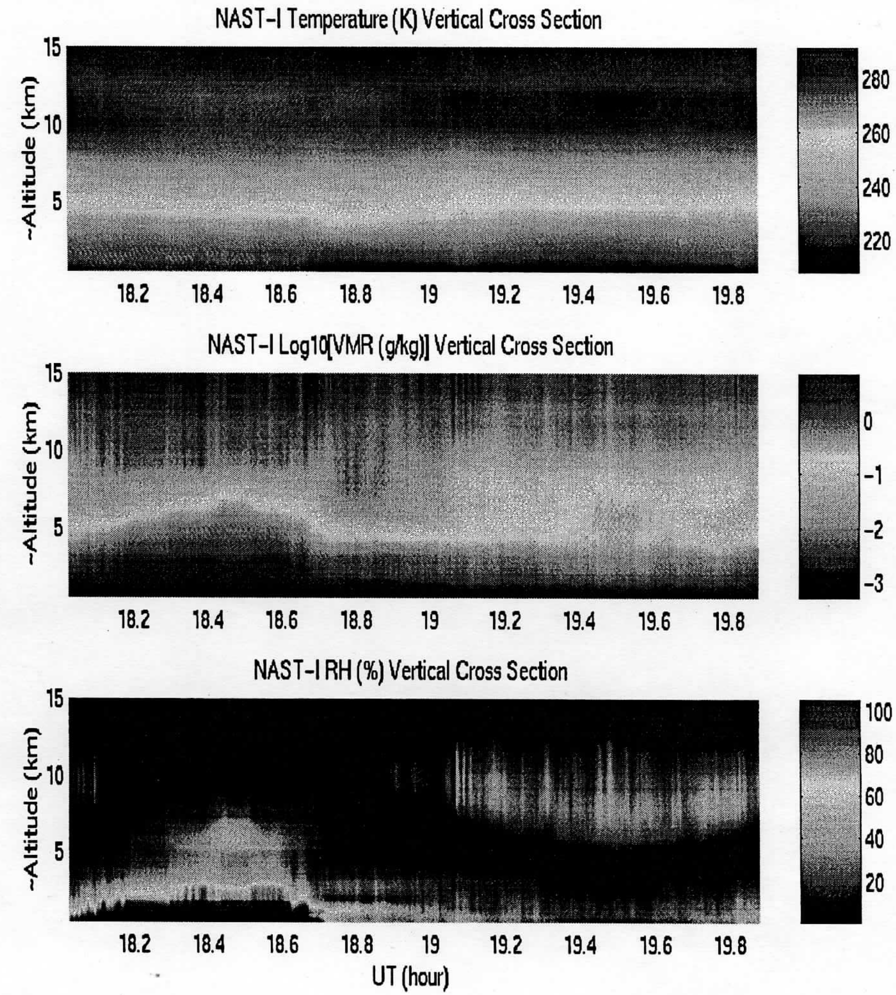

nominal clear sky calculation at NASTI resolution
BT(K)
300
250
200
800 1000 1200 1400 1600 1800 2000 2200 2400 2600
wavenumber


US Std T profile and normalized mean weighting function
P(mb)
200
400
600
800
1000
200 250 300
T(K)

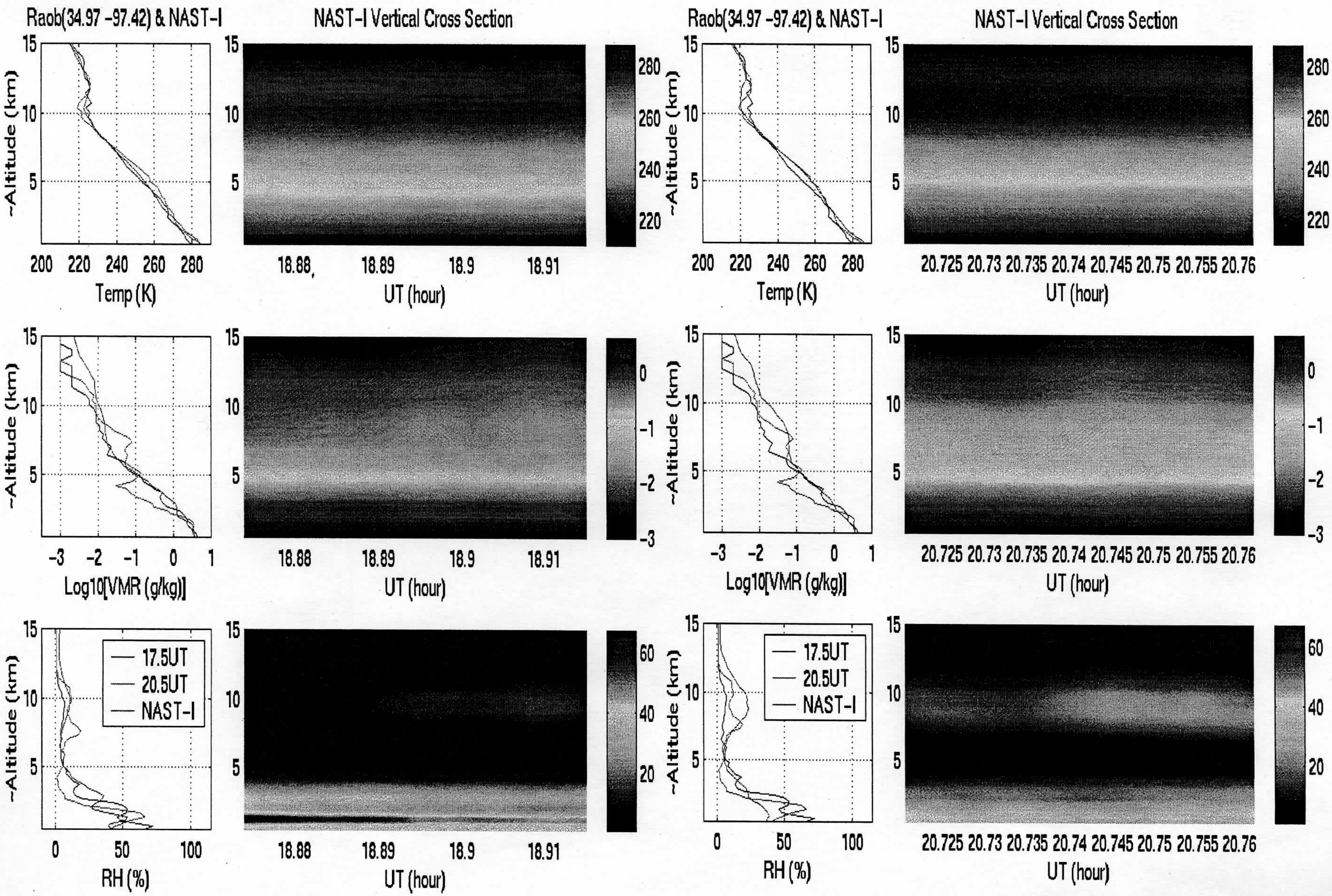
PROTEUS NAST-I Flight Over CART Site

Loop 1 [18:06 – 19:50 UT, March 19, 2000]

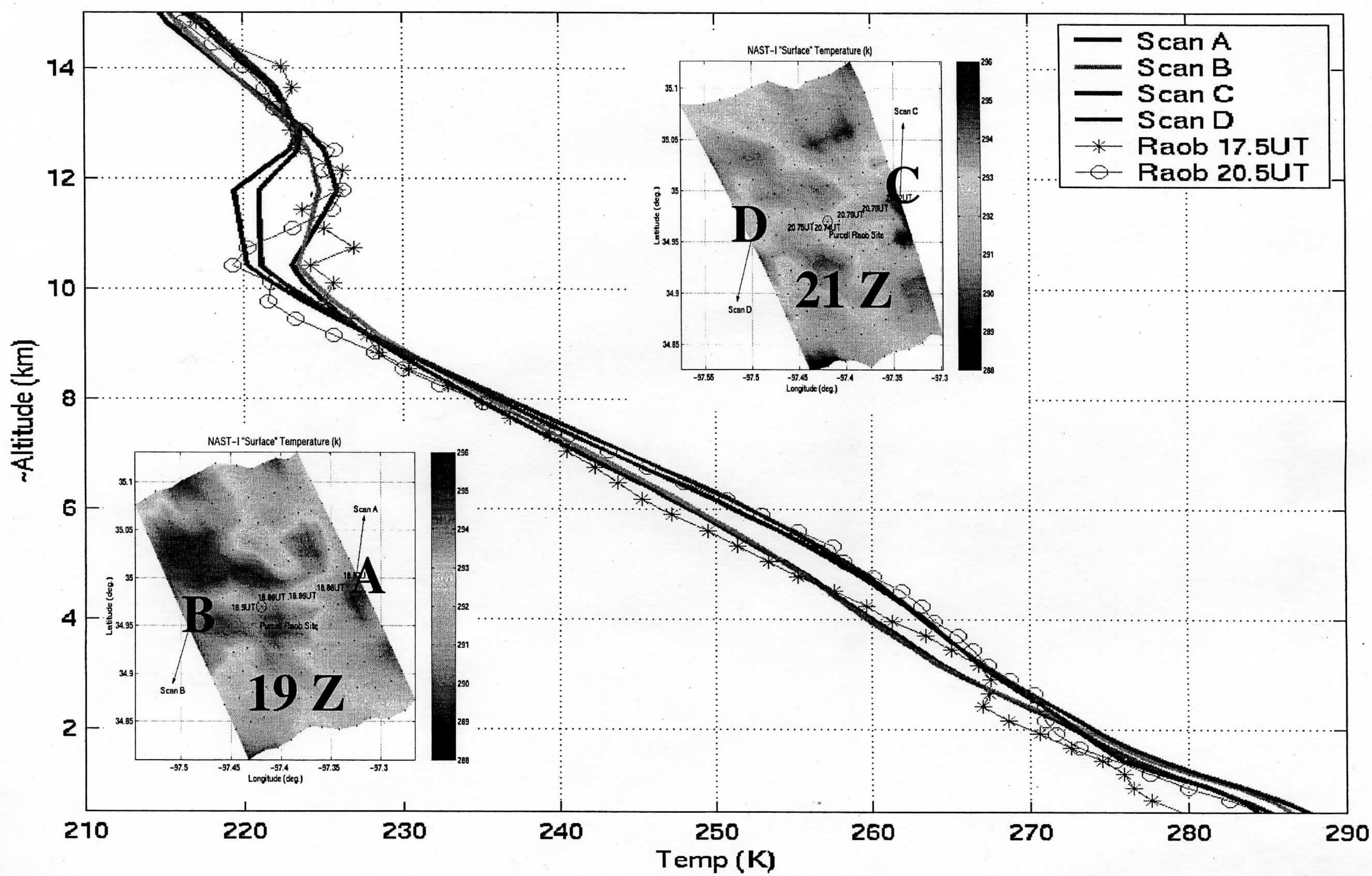




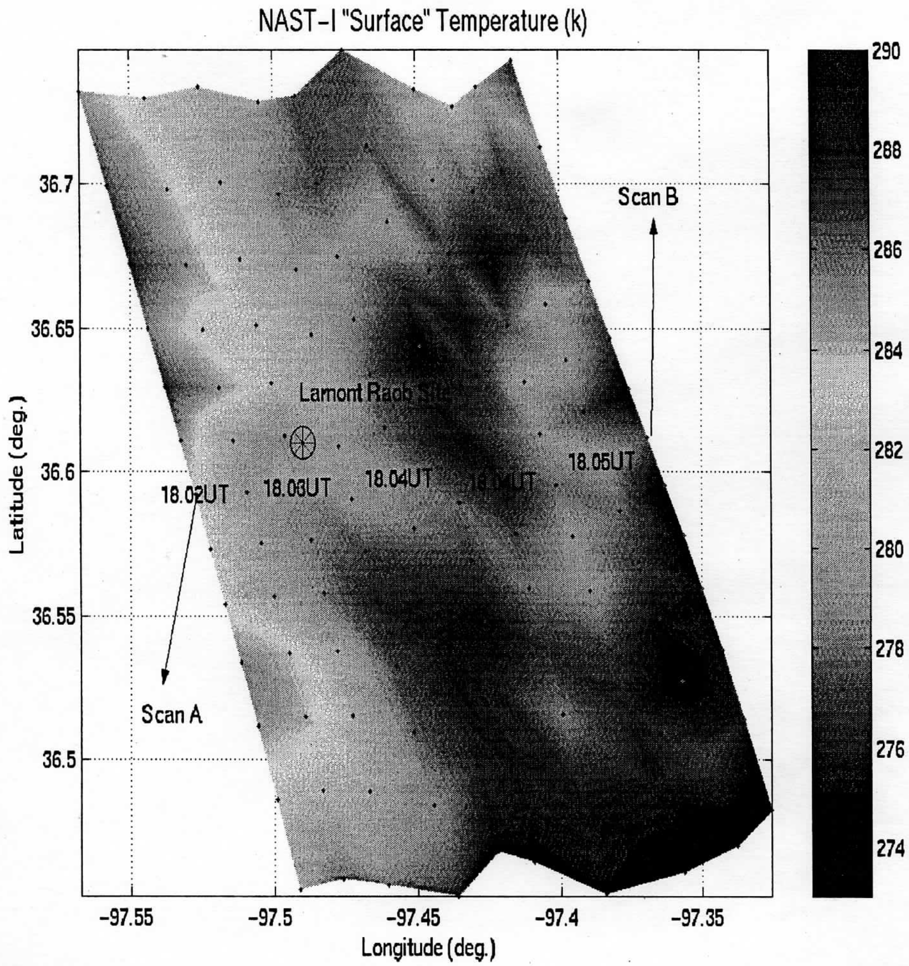
PROTEUS/NAST-I Over Purcell



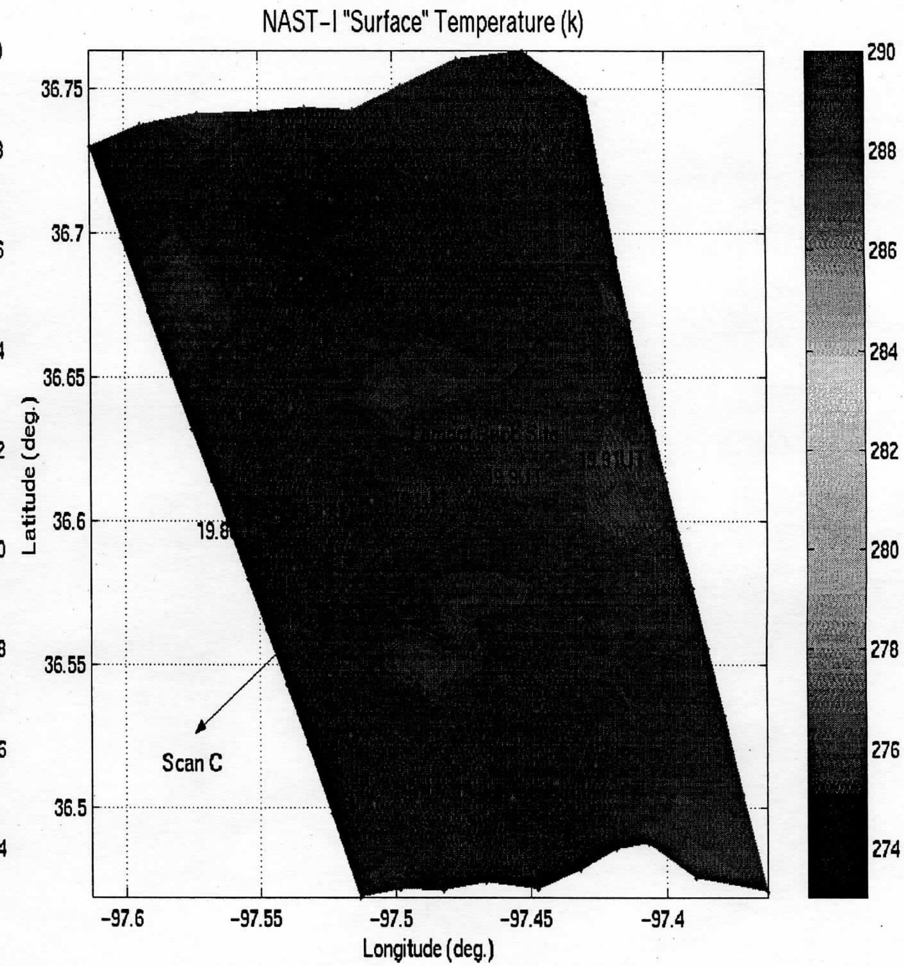
NAST-I Spatial (~22km) and Temporal (~2-3hr) Variation of Temp Over Purcell



PROTEUS/NAST-I
Over Lamont (March 19, 2000)

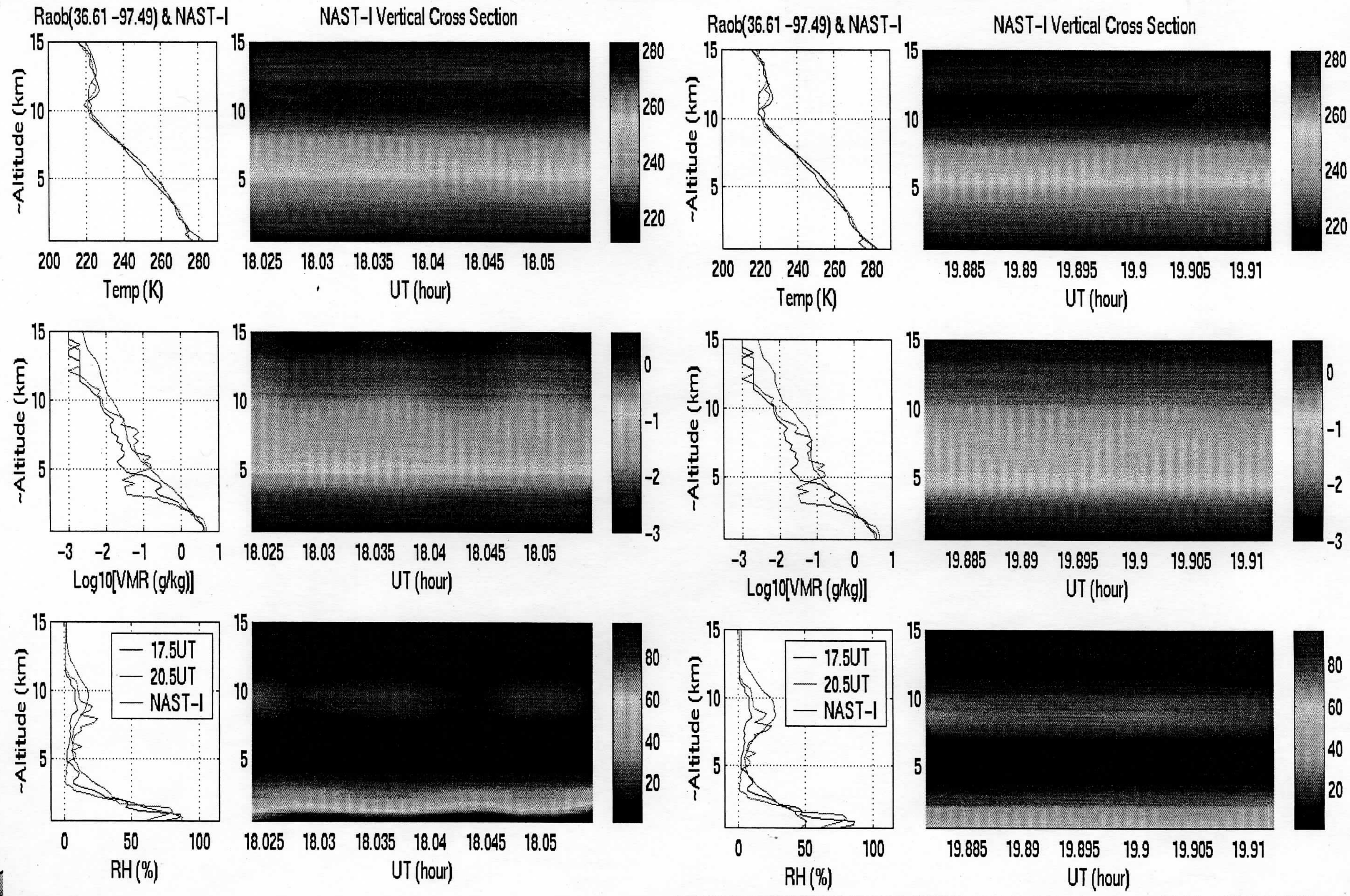


~18 UT

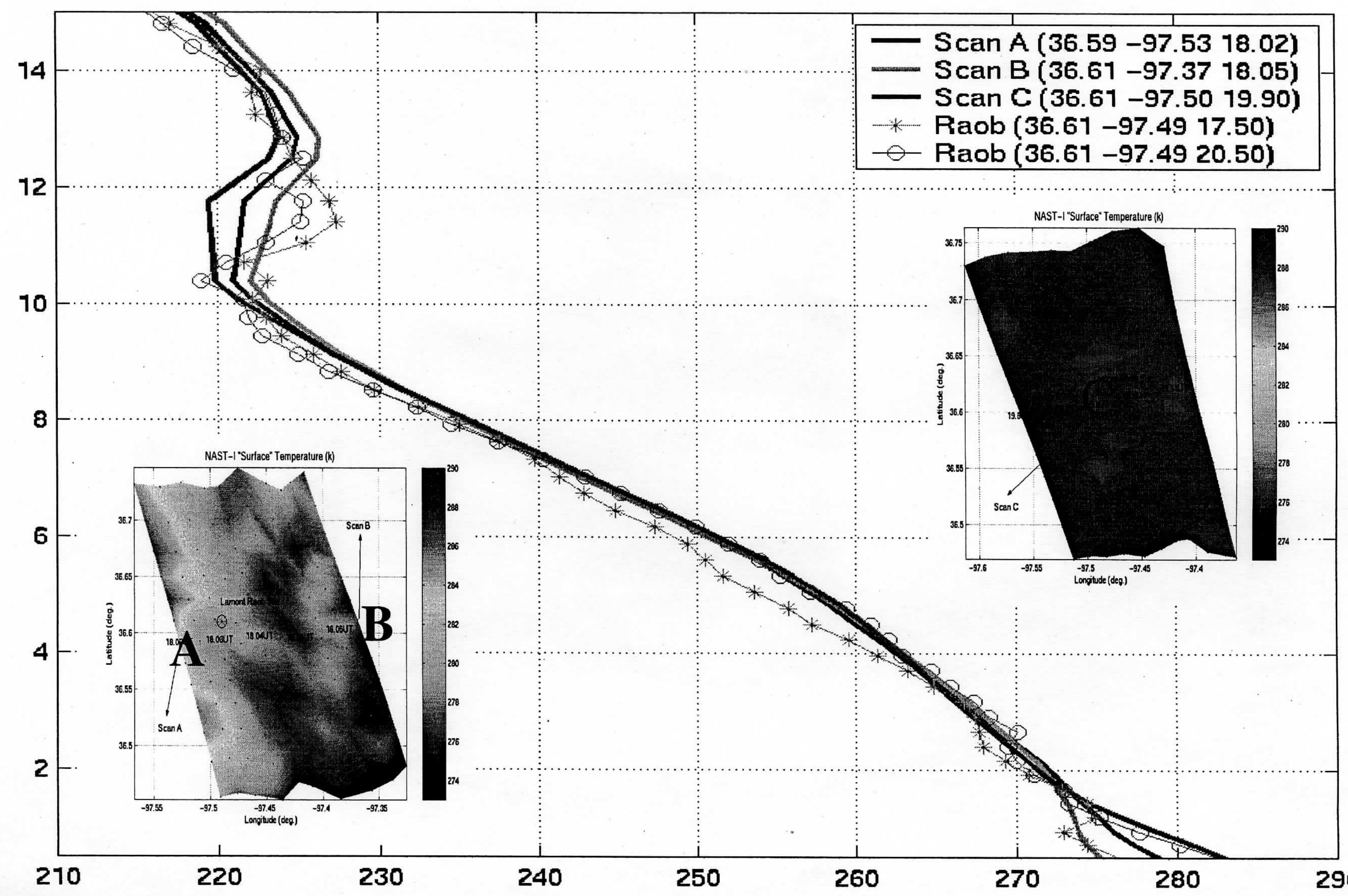


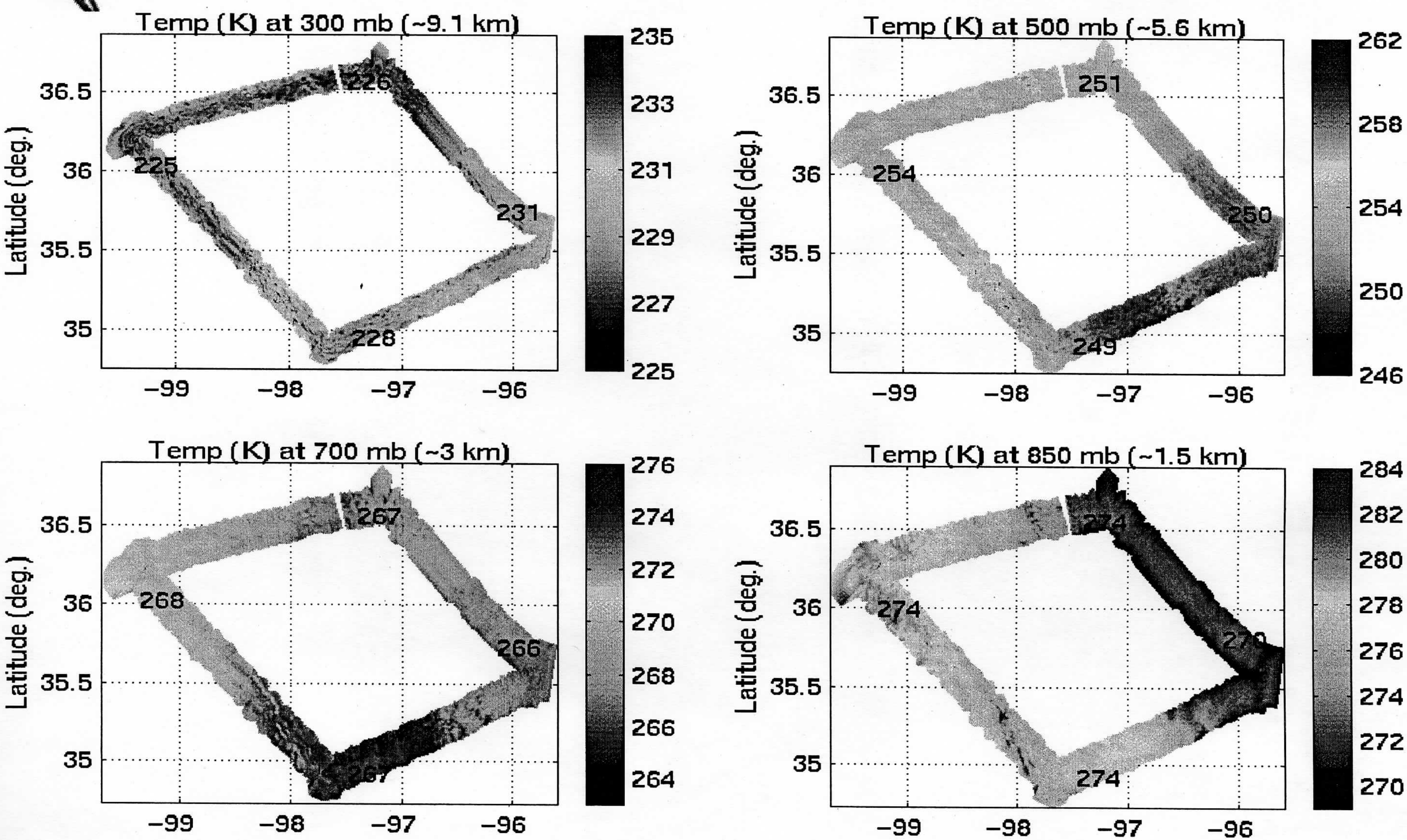
~20 UT

PROTEUS/NAST-I Over Lamont



NAST-I Spatial (~16km) and Temporal (~2-3Hr) Variation of Temperature Over Lamont




Temp (K) at 300 mb (~9.1 km)
Latitude (deg.)
36.5
36
35.5
35
-99
-98
-97
-96
226
225
231
228
235
233
231
229
227
225
Temp (K) at 500 mb (~5.6 km)
Latitude (deg.)
251
254
250
249
262
258
254
250
246
Temp (K) at 700 mb (~3 km)
Latitude (deg.)
267
268
266
276
274
272
270
268
266
264
Temp (K) at 850 mb (~1.5 km)
Latitude (deg.)
274
274
274
284
282
280
278
276
274
272
270

Summary

- Aircraft observations of upwelling infrared spectral radiance from S-HIS and NAST-I have the absolute radiometric and spectral accuracy needed for satellite radiance and algorithm validation.

- High spectral resolution observations provide the key information needed for high vertical resolution temperature and water vapor sounding.

- High spectral resolution (online/offline) techniques also provide important insight into the interpretation of cloud and surface radiative properties (optical depth and emissivity).

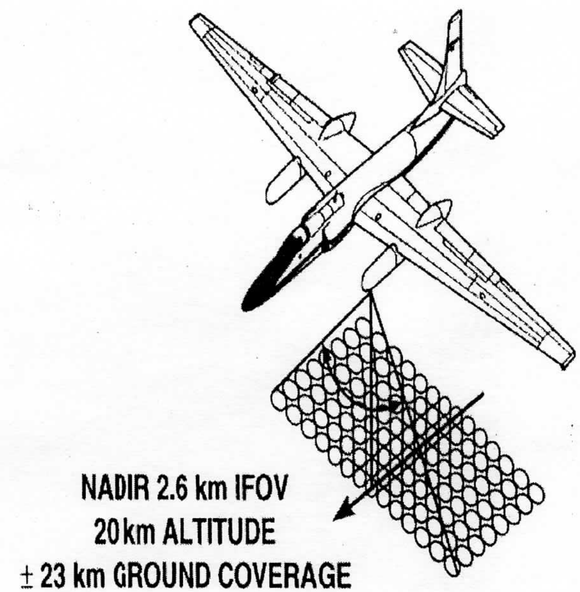
NPOESS Airborne Sounder Testbed (NAST) Interferometer

On board ER-2 (~20 km) with a ±45° swath (7.5° step) scanning mirror to provide ~46 km ground coverage along the flight track.

Michelson interferometer band spectral coverage and resolution:

- Longwave (Band 1): 645–1300 cm^{-1}.
- Midwave (Band 2): 1290–2000 cm^{-1}.
- Shortwave (Band 3): 1980–2700 cm^{-1}.
- All with spectral resolution of 0.25 cm^{-1}.

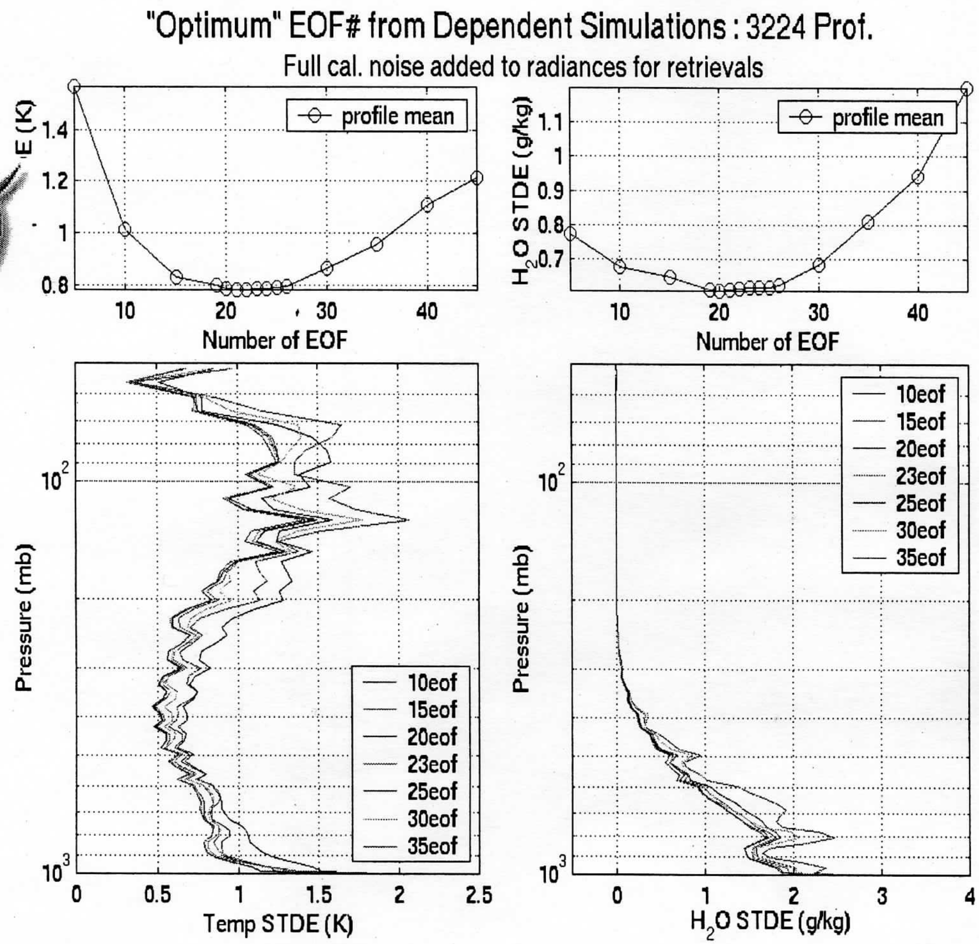
Vertical profiles of Temperature and moisture retrieved from spectrally resolved radiances to produce vertical and horizontal spatial distributions



Dan Zhou Paper:

- Importance of accurate regression:
  - Providing first guess to the "ill-posed" physical retrieval.
  - Affecting the computation time in the physical retrieval and the final result.
- Approach for better understanding the nature of statistical linear regression:
  - How does the number of EOFs affect the retrieval?
  - How does the noise level affect the "optimal" number of EOFs selection?
  - How do the retrieval accuracy and retrieval vertical resolution affect each other?

Dependent Sample Retrieval Analysis



"Noise-free" regression coefficients used (i.e., generated by noise-free radiances)

Full NAST-I calibration estimated random noise added to the radiance for retrieving temperature and water vapor profiles.

STD of retrieval error over the dependent samples (3224) as a function of the number of EOFs and pressure.

The "optimal" number of EOFs is 23.

Remarks on Retrieval Analyses

An "optimal" number of EOFs can be determined to perform the "optimal" linear regression retrieval by the simulation analysis when the noise level is accurately estimated.

An "optimal" number of EOFs also can be determined by the measured radiances in comparison with the retrieval simulated radiances without knowing the noise level (under the clear sky conditions).

The noise level plays an important role in the retrieval accuracy and the vertical resolution. With the same training data set, the "optimal" EOF number increases and the retrieval error decreases when the noise level decreases.

A fast, but accurate, retrieval application for NAST-I is developed and the vertical profiles of temperature and moisture are retrieved without resort to "Radiosonde tuning," a very important feature for a "state of the art" remote sensing system.

[4-C]

Sea Surface Temperature

</SST/SST.htm>

NAST-I Sea Surface Temperature Retrieval

I. Abstract

The sea surface temperature (SST) is retrieved from NAST-I radiances observed during Wallops 99 activities. An infrared quasi-specular ocean reflectivity model (Nalli, Smith, and Huang, 2001) is used. Compared with the buoy SST, the retrieved SST accuracy is within 0.3 K.

II. Algorithm

The rough surface ocean reflectivity is computed by the infrared quasi-specular ocean reflection model of Nalli, Smith and Huang (2001). The ocean emissivity is taken as one minus the ocean reflectivity. The model is a function of wavenumber, view angle, wind speed and total uplooking transmittance (Nalli, 2000). A training data set of temperature, water vapor and ozone profiles representative for Wallops 99 activities is selected from a much larger 10-year global RAOB data set based on a fast penalized library search method. Instead of using the windows channels only, we take full advantage of high spectral resolution of NAST-I and include the channels of other atmospheric absorbing gases which may have effects on SST retrieval. The NAST-I SST retrieval is based on the EOF regression approach (Smith & Woolf, 1976) with a more complete radiative transfer equation with surface reflection term (Huang, 1998).

III. Results

Figure 1 shows the model ocean emissivity for various view angles within the NAST-I spectral range. A surface wind speed of 3.5 m/s is taken in compliance with buoy wind observation during Wallops 99. It is obvious that the ocean emissivity is less than unity, i.e. the ocean surface is not a blackbody.

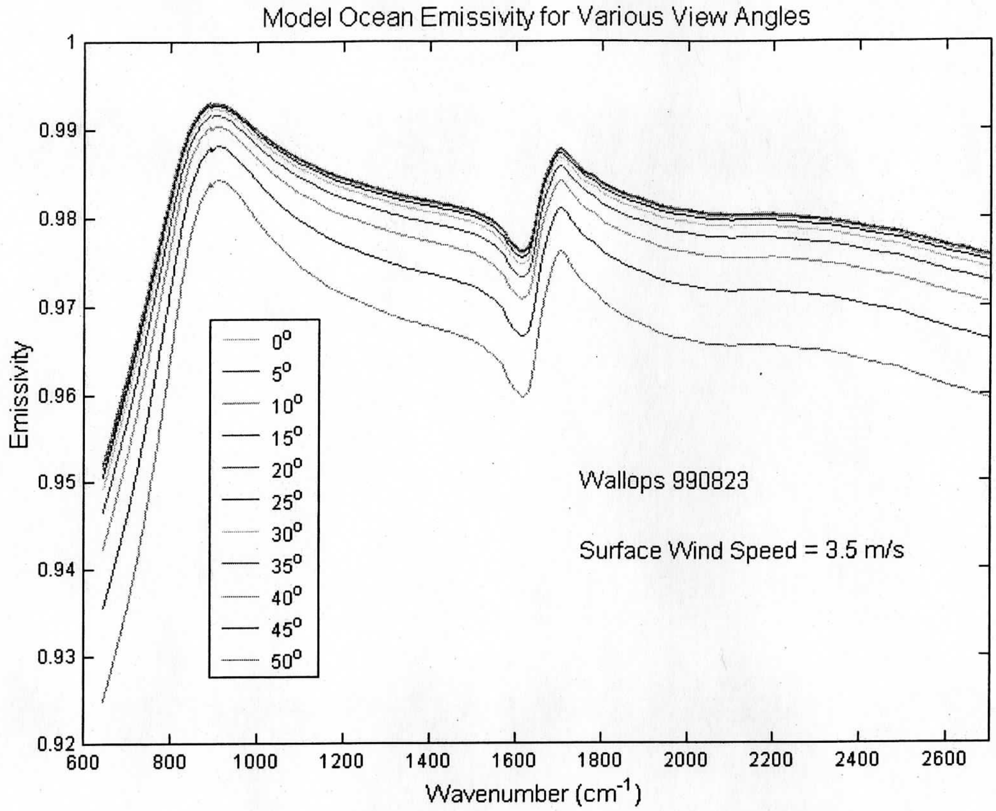


Figure 1

Figure 2 shows the brightness temperature difference between the simplified blackbody ocean emissivity and our more realistic model ocean emissivity. The error due to the blackbody ocean assumption is quite comparable to the NAST-I instrument noise.

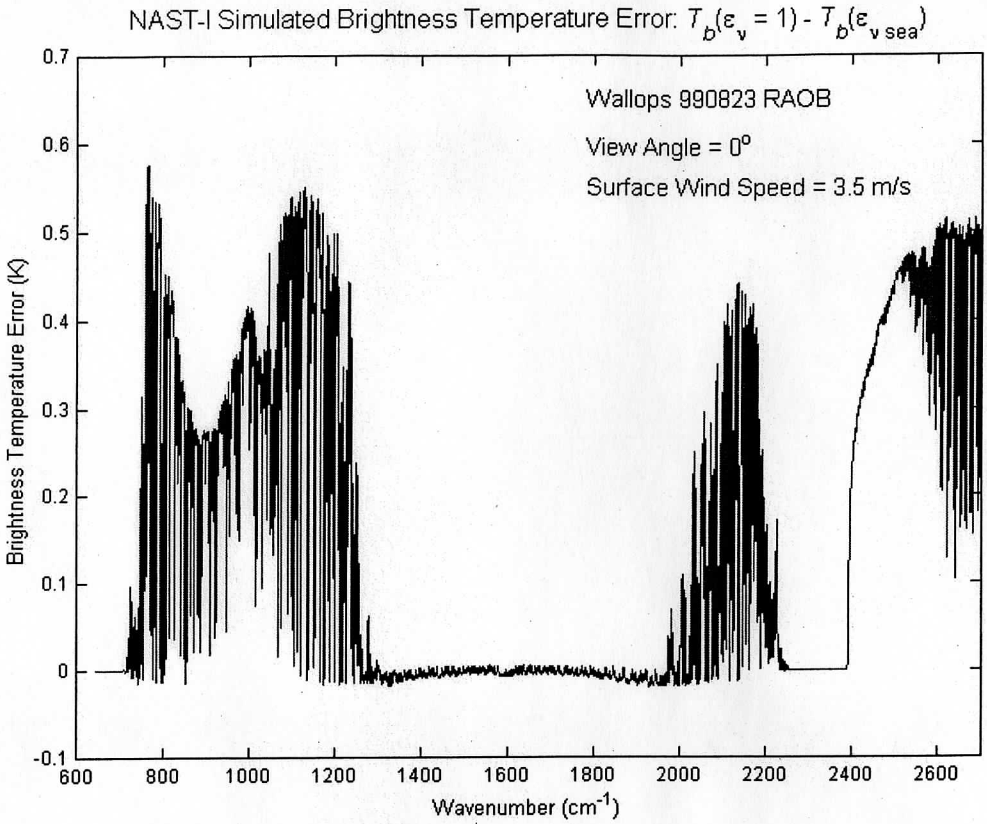


Figure 2

Figure 3 shows NAST-I channel selection for SST retrieval. Note that highly noisy channels are excluded.

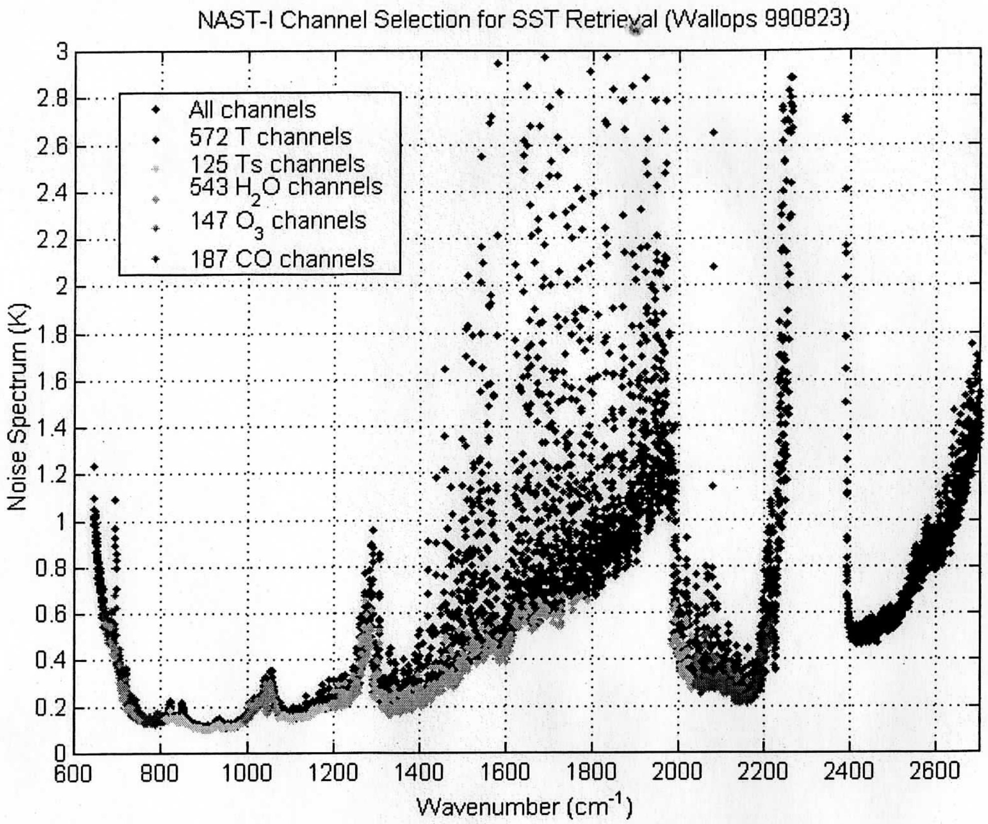


Figure 3

Figs. 4-6 show the selected temperature, water vapor and ozone training profiles, respectively (in red). The profiles in blue and black are the raobs collected from various sources during Wallops 99 activities.

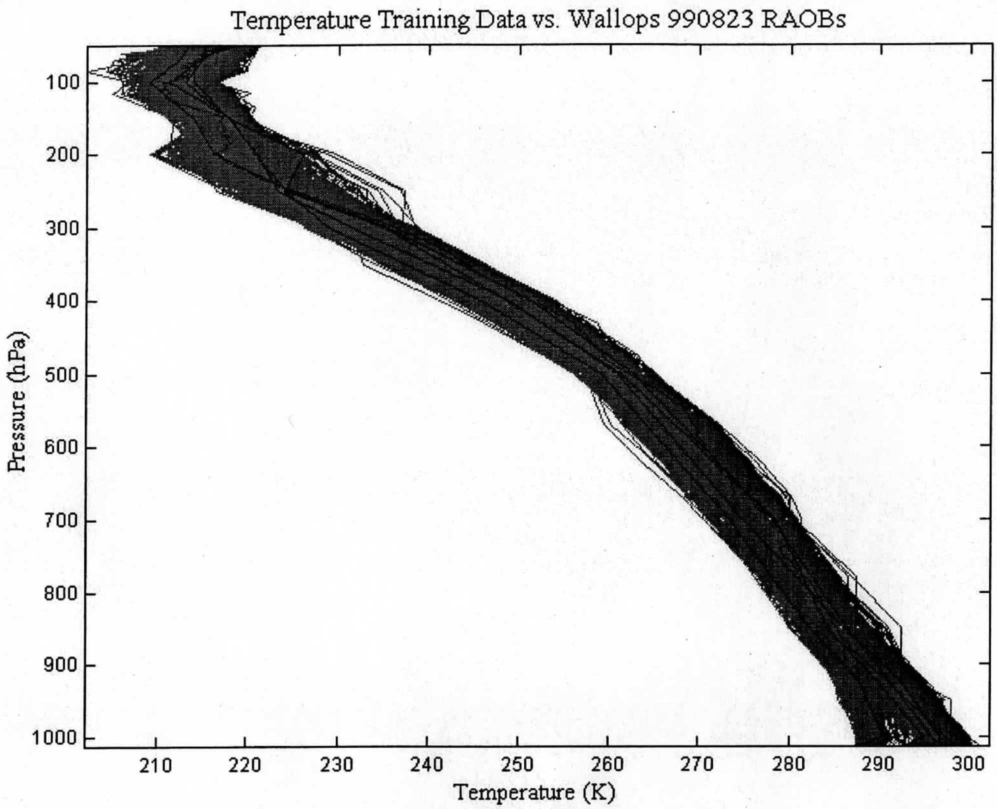

Temperature Training Data vs. Wallops 990823 RAOBs
Pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
210
220
230
240
250
260
270
280
290
300
Temperature (K)

Figure 4

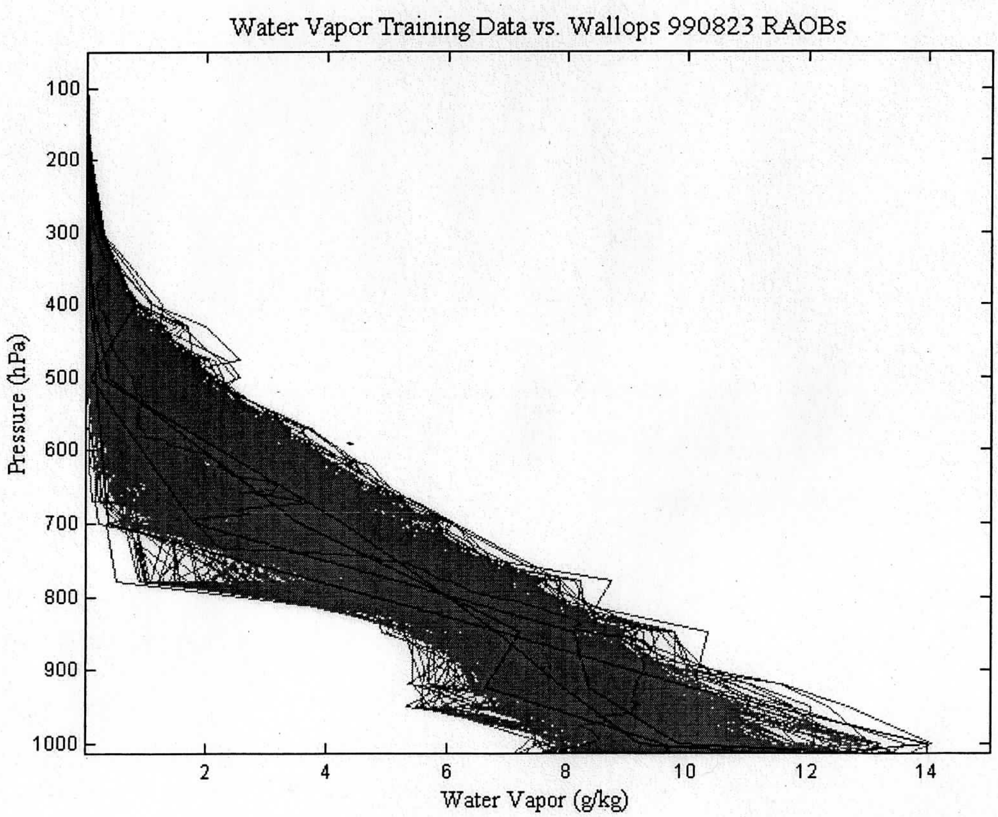

Water Vapor Training Data vs. Wallops 990823 RAOBs
Pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
2
4
6
8
10
12
14
Water Vapor (g/kg)

Figure 5

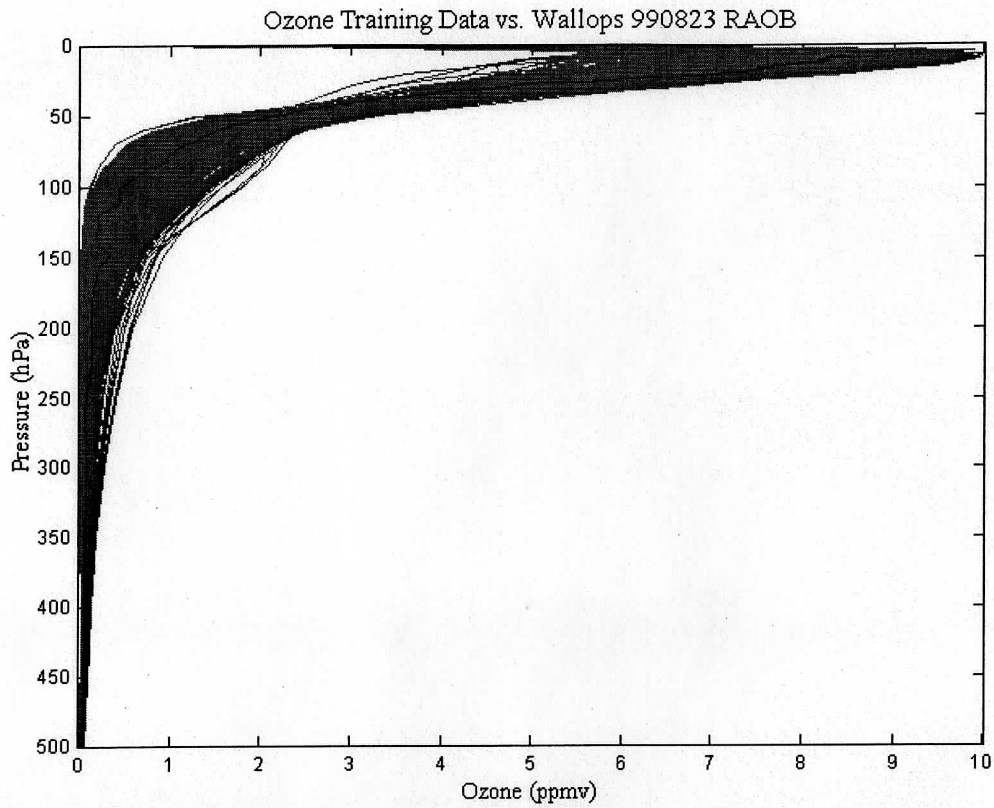


Figure 6

Figure 7 shows the NAST-I SST retrieval result. The approximate NAST-I field of views are also shown. The co-located buoy SST is listed for comparison. The difference between the two SST's is 0.3 K.

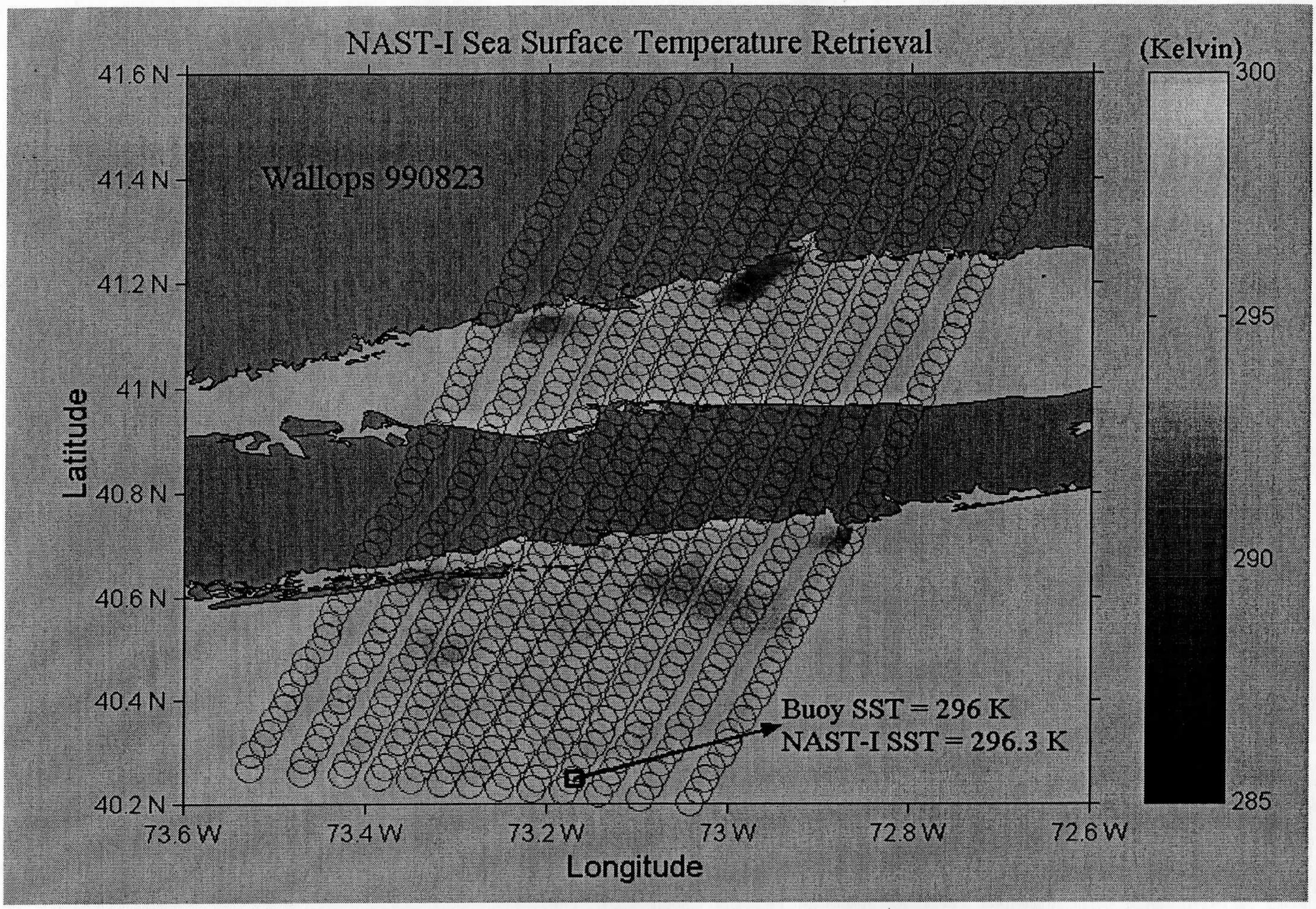


Figure 7

III. Conclusion

The NAST-I, a high resolution Michelson interferometer, provides a reliable estimate of sea surface temperature. The 0.3 K of SST accuracy, suggested by the World Climate Research program (WCRP) for climate studies, is achievable by NAST-I using a simple and fast EOF regression approach without the need of obtaining accurate status of atmospheric temperature and absorbing gases profiles.

IV. Reference

Huang, B., 1998: New Approaches for the Simultaneous Retrieval of Atmospheric Profiles from Spectral Radiances. Ph.D. dissertation, University of Wisconsin-Madison, 146 pp.

Nalli, N. R., 2000: A Physical Multispectral Method for the Retrieval of Ocean and Lake Surface Temperatures via Scanning Spectrometer. Ph.D. dissertation, University of Wisconsin- Madison, 162 pp.

Nalli, N. R., W. L. Smith, and B. Huang, 2000: A quasi-specular model for calculating the reflection of atmospheric emitted IR radiation from a rough water surface. Applied Optics (accepted).

Smith, W. L. and Woolf, H. M., 1976: The Use of Eigenvectors of Statistical Covariance Matrices for Interpreting Satellite Sounding Radiometer Observations. J. Atmos. Sci., 33, 1127-1140.

[4-D]

Compression; Paolo Antonelli's PhD Thesis:

Principle Component Analysis: A Tool for Processing Hyperspectral Infrared Data

University of Wisconsin-Madison, 2001

< available upon request >

[5-A]

Analysis and interpretation of WVIOP3 NAST-I data

<WVIOP3.html>

NAST-I DATA INDEX

Results of your search

Disk	Experiment	Launch Date	Calibration	Comments	Sortie
NASTI-267	WVIOP3	000824	Raw Data	NAST-I Calibration data	Ground Tes
NASTI-268	WVIOP3	000824	Raw Data	NAST-I Calibration data	Ground Tes
NASTI-269	WVIOP3	000824	Raw Data	NAST-I Calibration data	Ground Tes
NASTI-270	WVIOP3	000930	Raw Data	Calibration Data	Ground Tes
NASTI-271	WVIOP3	001001	Raw Data	Ferry Flight, Mojave to Stillwater	Flight#93
NASTI-272	WVIOP3	001001	Raw Data	Ferry Flight, Mojave to Stillwater	Flight#93
NASTI-285	WVIOP3	001001	QCed Radiances	Water Vapor IOP3	Flight#94
NASTI-309	WVIOP3	001001	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#93
NASTI-310	WVIOP3	001001	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#93
NASTI-273	WVIOP3	001003	Raw Data	Water Vapor IOP3	Flight#95
NASTI-274	WVIOP3	001003	Raw Data	Water Vapor IOP3	Flight#95
NASTI-275	WVIOP3	001003	Raw Data	Water Vapor IOP3	Flight#95
NASTI-276	WVIOP3	001003	Raw Data	Water Vapor IOP3	Flight#95
NASTI-286	WVIOP3	001003	QCed Radiances	Water Vapor IOP3	Flight#95
NASTI-287	WVIOP3	001003	QCed Radiances	Water Vapor IOP3	Flight#95
NASTI-305	WVIOP3	001003	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#95
NASTI-306	WVIOP3	001003	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#95
NASTI-307	WVIOP3	001003	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#95
NASTI-308	WVIOP3	001003	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#95
NASTI-277	WVIOP3	001004	Raw Data	Water Vapor IOP3	Flight#96
NASTI-278	WVIOP3	001004	Raw Data	Water Vapor IOP3	Flight#96
NASTI-279	WVIOP3	001004	Raw Data	Water Vapor IOP3	Flight#96
NASTI-280	WVIOP3	001004	Raw Data	Water Vapor IOP3	Flight#96
NASTI-288	WVIOP3	001004	QCed Radiances	Water Vapor IOP3	Flight#96
NASTI-289	WVIOP3	001004	QCed Radiances	Water Vapor IOP3	Flight#96

NASTI-301	WVIOP3	001004	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#96
NASTI-302	WVIOP3	001004	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#96
NASTI-303	WVIOP3	001004	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#96
NASTI-304	WVIOP3	001004	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#96
NASTI-281	WVIOP3	001006	Raw Data	Water Vapor IOP3	Flight#97
NASTI-282	WVIOP3	001006	Raw Data	Water Vapor IOP3	Flight#97
NASTI-290	WVIOP3	001006	QCed Radiances	Water Vapor IOP3	Flight#97
NASTI-291	WVIOP3	001006	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#97
NASTI-291	WVIOP3	001006	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#97
NASTI-283	WVIOP3	001008	Raw Data	Water Vapor IOP3	Flight#98
NASTI-284	WVIOP3	001008	Raw Data	Water Vapor IOP3	Flight#98
NASTI-292	WVIOP3	001008	QCed Radiances	Water Vapor IOP3	Flight#98
NASTI-293	WVIOP3	001008	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#98
NASTI-294	WVIOP3	001008	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#98
NASTI-295	WVIOP3	001009	Raw Data	Water Vapor IOP3	Flight#99
NASTI-296	WVIOP3	001009	Raw Data	Water Vapor IOP3	Flight#99
NASTI-297	WVIOP3	001009	QCed Radiances	Water Vapor IOP3	Flight#99
NASTI-298	WVIOP3	001009	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#99
NASTI-299	WVIOP3	001009	3-Line Smooth(with tilt corr)	Water Vapor IOP3	Flight#99
NASTI-300	WVIOP3	001009	3-Line Smooth(w/o tilt corr)	Water Vapor IOP3	Flight#99

| Query Again || With Wintex Quicklook Frame |

Created 5/30/2000 by Denny John Hackel

Last updated 5/30/2000

[5-B]

Analysis and interpretation of AFWEX NAST-I data

<AFWEX.html>

NAST-I DATA INDEX

Results of your search

Disk	Experiment	Launch Date	Calibration	Comments	Sortie
NASTI-311	AFWEX	001115	Raw Data	AFWEX	Flight#104
NASTI-312	AFWEX	001127	Raw Data	AFWEX	Flight#105
NASTI-313	AFWEX	001127	Raw Data	AFWEX	Flight#105
NASTI-314	AFWEX	001127	Raw Data	AFWEX	Flight#105
NASTI-315	AFWEX	001127	QCed Radiances	AFWEX	Flight#105
NASTI-316	AFWEX	001127	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#105
NASTI-317	AFWEX	001127	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#105
NASTI-318	AFWEX	001129	Raw Data	AFWEX	Flight#106
NASTI-319	AFWEX	001129	Raw Data	AFWEX	Flight#106
NASTI-320	AFWEX	001129	Raw Data	AFWEX	Flight#106
NASTI-321	AFWEX	001129	Raw Data	AFWEX	Flight#106
NASTI-322	AFWEX	001129	QCed Radiances	AFWEX	Flight#106
NASTI-323	AFWEX	001129	QCed Radiances	AFWEX	Flight#106
NASTI-323	AFWEX	001129	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#106
NASTI-324	AFWEX	001129	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#106
NASTI-325	AFWEX	001201	Raw Data	AFWEX	Flight#107
NASTI-326	AFWEX	001201	Raw Data	AFWEX	Flight#107
NASTI-327	AFWEX	001201	QCed Radiances	AFWEX	Flight#107
NASTI-328	AFWEX	001201	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#107
NASTI-329	AFWEX	001203	Raw Data	AFWEX	Flight#108
NASTI-330	AFWEX	001203	Raw Data	AFWEX	Flight#108
NASTI-331	AFWEX	001203	QCed Radiances	AFWEX	Flight#108
NASTI-332	AFWEX	001203	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#108
NASTI-333	AFWEX	001204	Raw Data	AFWEX	Flight#109
NASTI-334	AFWEX	001204	Raw Data	AFWEX	Flight#109
NASTI-335	AFWEX	001204	Raw Data	AFWEX	Flight#109
NASTI-336	AFWEX	001204	QCed Radiances	AFWEX	Flight#109
NASTI-337	AFWEX	001204	QCed Radiances	AFWEX	Flight#109
NASTI-353	AFWEX	001204	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#109
NASTI-354	AFWEX	001204	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#109
NASTI-338	AFWEX	001206	Raw Data	AFWEX	Flight#110

NASTI-339	AFWEX	001206	Raw Data	AFWEX	Flight#110
NASTI-340	AFWEX	001206	QCed Radiances	AFWEX	Flight#110
NASTI-355	AFWEX	001206	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#110
NASTI-341	AFWEX	001207	Raw Data	AFWEX	Flight#111
NASTI-342	AFWEX	001207	Raw Data	AFWEX	Flight#111
NASTI-343	AFWEX	001207	QCed Radiances	AFWEX	Flight#111
NASTI-356	AFWEX	001207	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#111
NASTI-344	AFWEX	001209	Raw Data	AFWEX	Flight#112
NASTI-345	AFWEX	001209	Raw Data	AFWEX	Flight#112
NASTI-346	AFWEX	001209	Raw Data	AFWEX	Flight#112
NASTI-347	AFWEX	001209	Raw Data	AFWEX	Flight#112
NASTI-357	AFWEX	001209	QCed Radiances	AFWEX	Flight#112
NASTI-358	AFWEX	001209	QCed Radiances	AFWEX	Flight#112
NASTI-359	AFWEX	001209	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#112
NASTI-360	AFWEX	001209	3-Line Smooth(w/o tilt corr)	AFWEX	Flight#112

| Query Again || With Wintex Quicklook Frame |

Created 5/30/2000 by Denny John Hackel

Last updated 5/30/2000

[6-A]

Analysis of NAST-I with calibrated radiances from Cloud IOP

<CloudIOP.html>

NAST-I DATA INDEX

Results of your search

Disk	Experiment	Launch Date	Calibration	Comments	Sortie
NASTI-256	Proteus CLOUD IOP	000314	Raw Data	Ferry Flight	Flight#70
Not Available	Proteus CLOUD IOP	000314	QCed Radiances	Ferry Flight	Flight#70
Not Available	Proteus CLOUD IOP	000314	3-Line Smooth(w/o tilt corr)	Ferry Flight	Flight#70
Not Available	Proteus CLOUD IOP	000314	3-Line Smooth(with tilt corr)	Ferry Flight	Flight#70
Not Available	Proteus CLOUD IOP	000317	3-Line Smooth(with tilt corr)	Cloud IOP	Flight#71
Not Available	Proteus CLOUD IOP	000317	3-Line Smooth(w/o tilt corr)	Cloud IOP	Flight#71
Not Available	Proteus CLOUD IOP	000317	QCed Radiances	Cloud IOP	Flight#71
NASTI-257	Proteus CLOUD IOP	000317	Raw Data	Cloud IOP	Flight#71
NASTI-258	Proteus CLOUD IOP	000319	Raw Data	Cloud IOP	Flight#72
NASTI-259	Proteus CLOUD IOP	000319	Raw Data	Cloud IOP	Flight#72
Not Available	Proteus CLOUD IOP	000319	QCed Radiances	Cloud IOP	Flight#72
Not Available	Proteus CLOUD IOP	000319	3-Line Smooth(w/o tilt corr)	Cloud IOP	Flight#72
Not Available	Proteus CLOUD IOP	000319	3-Line Smooth(with tilt corr)	Cloud IOP	Flight#72
Not Available	Proteus CLOUD IOP	000320	3-Line Smooth(with tilt corr)	Cloud IOP	Flight#73
Not Available	Proteus CLOUD IOP	000320	3-Line Smooth(w/o tilt corr)	Cloud IOP	Flight#73
Not Available	Proteus CLOUD IOP	000320	QCed Radiances	Cloud IOP	Flight#73
NASTI-260	Proteus CLOUD IOP	000320	Raw Data	Cloud IOP	Flight#73
NASTI-261	Proteus CLOUD IOP	000321	Raw Data	Ferry Flight	Flight#74
Not Available	Proteus CLOUD IOP	000321	QCed Radiances	Ferry Flight	Flight#74
Not Available	Proteus CLOUD IOP	000321	3-Line Smooth(w/o tilt corr)	Ferry Flight	Flight#74
Not Available	Proteus CLOUD IOP	000321	3-Line Smooth(with tilt corr)	Ferry Flight	Flight#74

| Query Again || With Wintex Quicklook Frame |

Created 5/30/2000 by Denny John Hackel

Last updated 5/30/2000

[7-A]

Data Warehouse description

<Data_Warehouse.doc>

NAST-I Data Warehouse Development (Thru April 2001)

The on-line storage capability for NAST-I data products has been greatly increased through the development of a data warehousing capability at UW-SSEC. The purpose, specifications, and functions of the NAST-I data warehouse are presented in the following sections. A link to the NAST-I index of warehouse contents is available from the NAST-I web page at *cimss.ssec.wisc.edu* with access privileges open to domain larc.nasa.gov. A copy of the software used for reprocessing the NAST-I data has been provided to the NAST-I Principal Investigator as CD volume NASTI-454 (nasti_454.iso).

Purpose:

A computer named "spigot" at UW-SSEC is a *data warehouse* for NAST-I instrument data. Essentially, this requires that it act as a fileserver with a large quantity of hard disk space (500GB), and a gigabit ethernet connection allowing it to serve data to a large number of workstations simultaneously. It is not an archive. An archive functionality would imply that all NAST-I data is available online. Warehousing implies cache-like function; data relevant to current studies are available immediately. Warehouse turnover occurs as new data sets become available, new results are archived to permanent media (e.g. CD-R), or older data sets return to the working set.

Specifications:

- Dell Server
    - 2x Pentium III 733MHz
    - 256MB SDRAM
    - Intel fiber optic gigabit ethernet
    - Adaptec LVD SCSI adapter
- Disk array ('*/reservoir*')
    - 8x Seagate LVD 73G disk drive
    - Granite Digital enclosure and cables
- Software: Mandrake 7.2 Linux
    - Samba 2.2: file service to Windows hosts
    - NFS: file service to UNIX hosts
    - optionally, AFP: file service to Macintosh hosts
    - Apache HTTP server: web access
    - PostgreSQL database server: NAST-I data set tracking
    - PHP scripting language: web database front-end
    - Python scripting language: maintenance scripts

Functions:

This hardware-software suite allows:

- The loading of NAST-I raw and calibrated data CD-ROMs.
- Fileserver access to the stored data from external machines (e.g. *nast-cal*).
- External machines are provided space to queue calibrated results and analyses for backup and distribution.
- Database facilities for tracking and querying NAST-I data products.

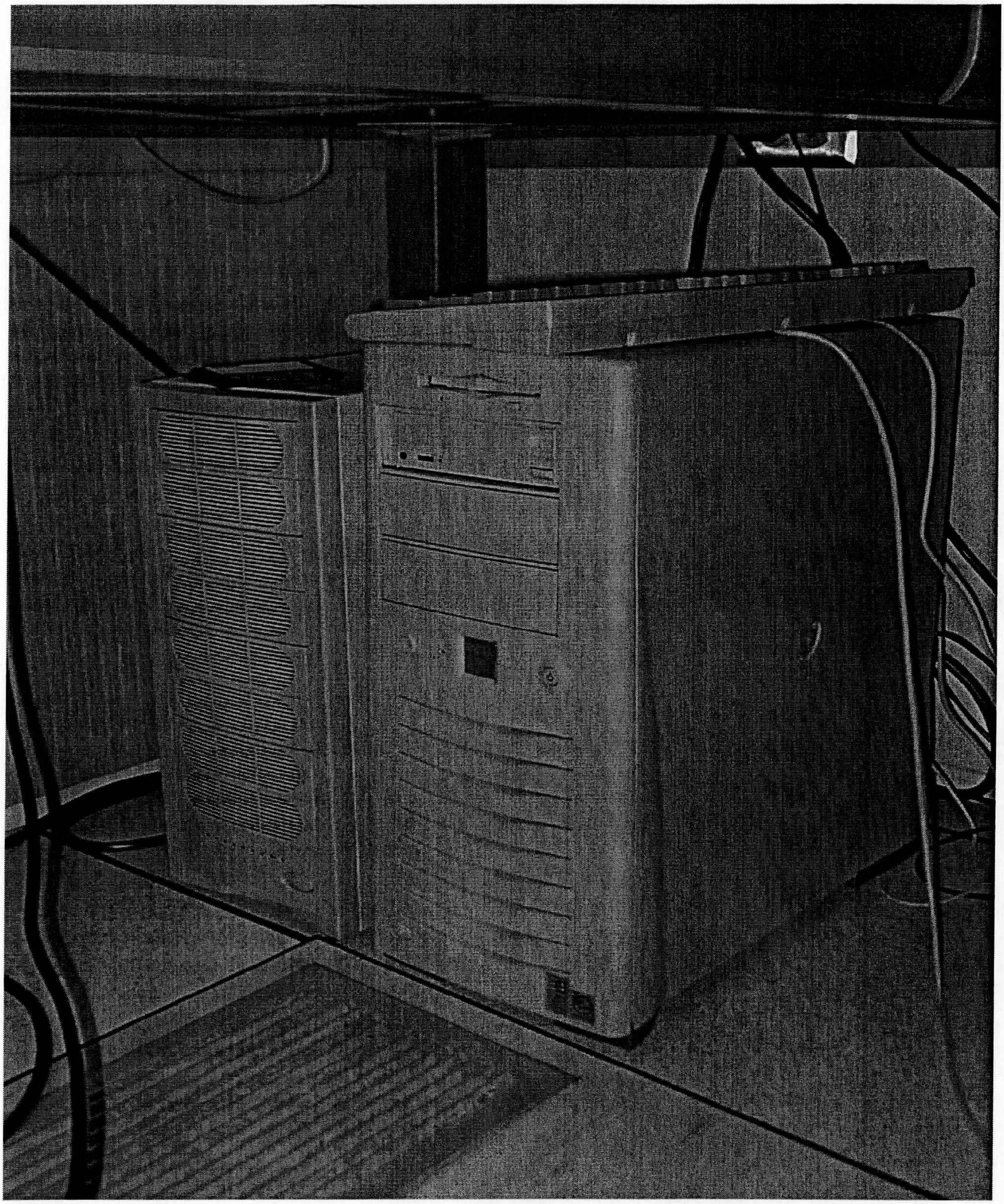


Figure XXX. NAST-I Data Warehouse at UW-SSEC (spigot.ssec.wisc.edu)

[7-B]

Reprocessing Software Deliverable

<nasti_454.iso>