INSTRUMENTATION FOR ATMOSPHERIC TEMPERATURE SOUNDINGS: STATUS AND PLANS

Stan Schneider
Advanced Systems Planning Division
Office of Systems Development
NOAA/NESDIS
Washington D. C. 20233

The following correspondence and attachments serve as a useful summary of the plans of NESDIS in collaboration with NASA and NMC to improve the operational sounders and their impact on numerical weather prediction. While this material provides an overview, more detailed questions should be addressed to the Advanced Systems Planning Division in NESDIS.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
National Meteorological Center
Washington, DC 20233

July 21, 1989 W/NMC:WDB

MEMORANDUM FOR: E/SP - Helen M. Wood

FROM: W/NMC - William D. Bonner

SUBJECT: Satellite Temperature Soundings

As I'm sure you're aware, NESDIS, NASA, and NMC are embarking upon a cooperative program to improve the impact of operational satellite soundings on NMC numerical forecasts. A number of us have been concerned for some years that budget cut-backs and shifts in priority have limited the ability of the U.S. to achieve the maximum possible benefit from satellite temperature soundings in forecast improvements in the Northern Hemisphere. We believe that much can be accomplished by pulling together the talent at NMC, NESDIS, and NASA in sounding retrieval, data assimilation, and quality control areas, by making it easier for these scientists to test new ideas already developed here or in Europe and by ensuring that sounding improvements can be quickly adopted in NESDIS and NMC operational systems.

The improvements that we are aiming at in this program are both short and long term. However, improvements that can be made are limited, of course, by the capabilities of current and planned satellite sounding instruments.

In this regard, there are exciting new possibilities for greatly improving the vertical resolution and accuracy of future operational soundings. As numerical models become increasingly complex and accurate, the requirements that they place upon satellite soundings continue to grow. NMC models, in the early 1970's, had 6 or 7 layers in the vertical, current models have 16 or 18. Models that we project for 1992 will have 30 or more levels. The solution to the problem of vertical resolution is clearly not to provide more levels of information from current satellite instruments, but instead to fly instruments that can provide many more independent levels of temperature information than available from current sounders. We may have to live for some time with satellite temperature accuracy of roughly 2° C; however, this level of accuracy is clearly not sufficient to meet the needs of modern numerical weather prediction systems. I hesitate to state requirements because requirements can be interpreted as things that must be met regardless of the cost. However, I would like to make clear NMC's strong interest in improved satellite instrumentation in the future that could provide much higher vertical resolution and significantly more accurate temperatures than available from current and planned operational infrared or microwave sensors. We need the kind of accuracy and vertical resolution that radiosondes provide but with the time frequency and global coverage that only satellites can offer. It may be years before we get there, but the closer we approach that goal, the more accurate our forecasts will be. Instrument capabilities now lag the capabilities of modern weather prediction models and unless every opportunity is taken to incorporate research instrument capabilities into future NESDIS operations, this lag will continue to increase.

I would greatly appreciate your support in both of the areas mentioned in this memo and would welcome the opportunity to discuss them further with you.

cc:
W/NMC2 - E. Kalnay
E/RA - P. K. Rao
W/OM22 - F. S. Zbar

POLAR ORBITING SATELLITE LAUNCHES

- **NOAA-D (AM)** FEBRUARY 6, 1990
- **NOAA-I (PM)** APRIL 1991
- **NOAA-J (AM)** SEPTEMBER 1992
- **NOAA-K (PM)** NOVEMBER 1993
- **NOAA-L (AM)** APRIL 1995
- **NOAA-M (PM)** JUNE 1996

CURRENT POLAR-ORBITING SATELLITE INSTRUMENTS

AVHRR - Advanced Very High Resolution Radiometer

HIRS - High Resolution Infrared Sounder

SSU - Stratospheric Sounding Unit

MSU - Microwave Sounding Unit

SEM - Space Environment Monitor

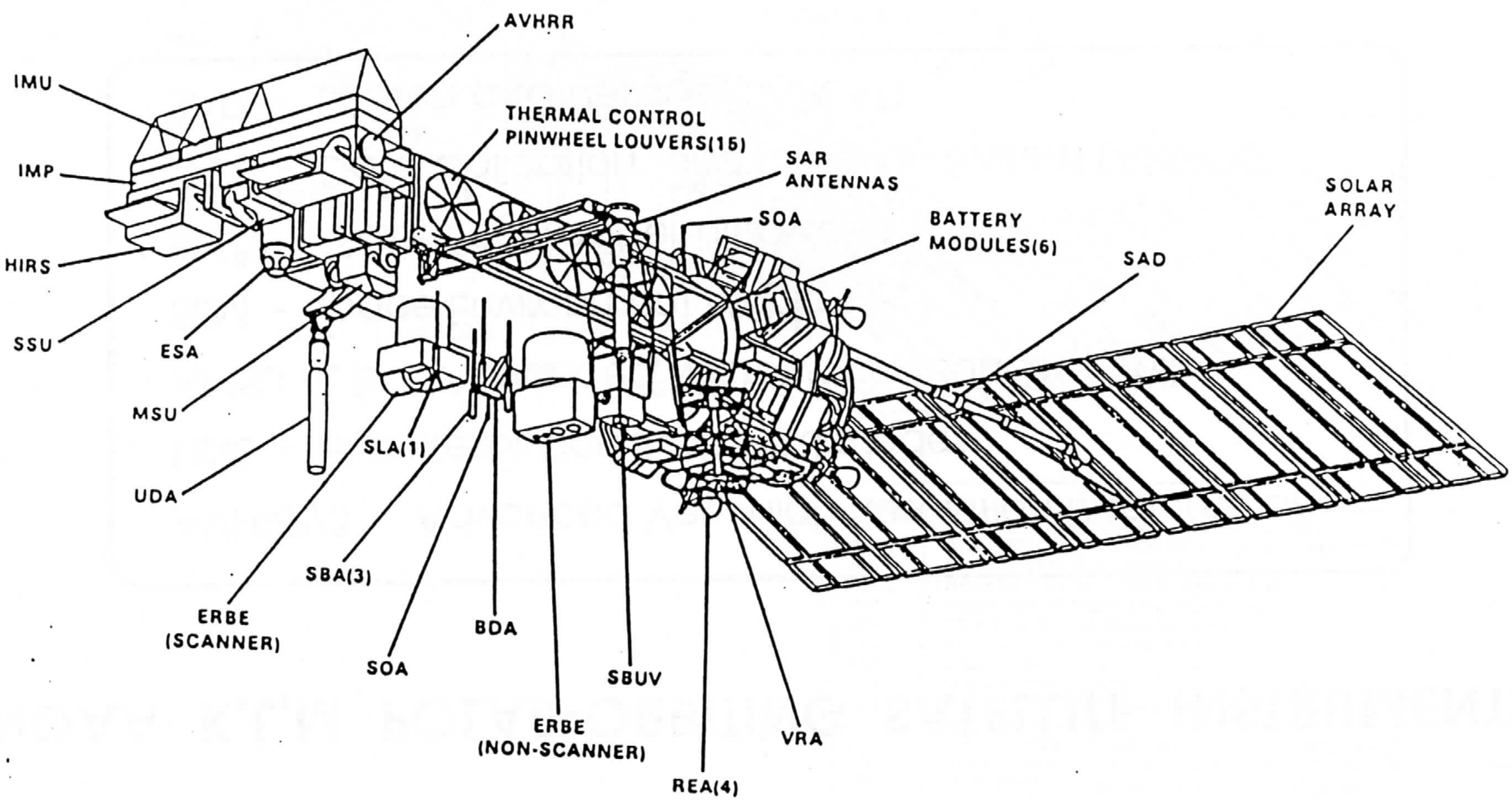
ERBE - Earth Radiation Budget Experiment

SBUV - Solar Backscatter Ultraviolet

DCS - Data Collection System (ARGOS)

SAR - Search and Rescue (SARSAT)

Advanced TIROS — N (ATN)



NOAA K,L,M POLAR-ORBITING SATELLITE INSTRUMENTS

AVHRR/3 - Advanced Very High Resolution Radiometer

HIRS - High Resolution Infrared Sounder

AMSU A, B - Advanced Microwave Sounding Units

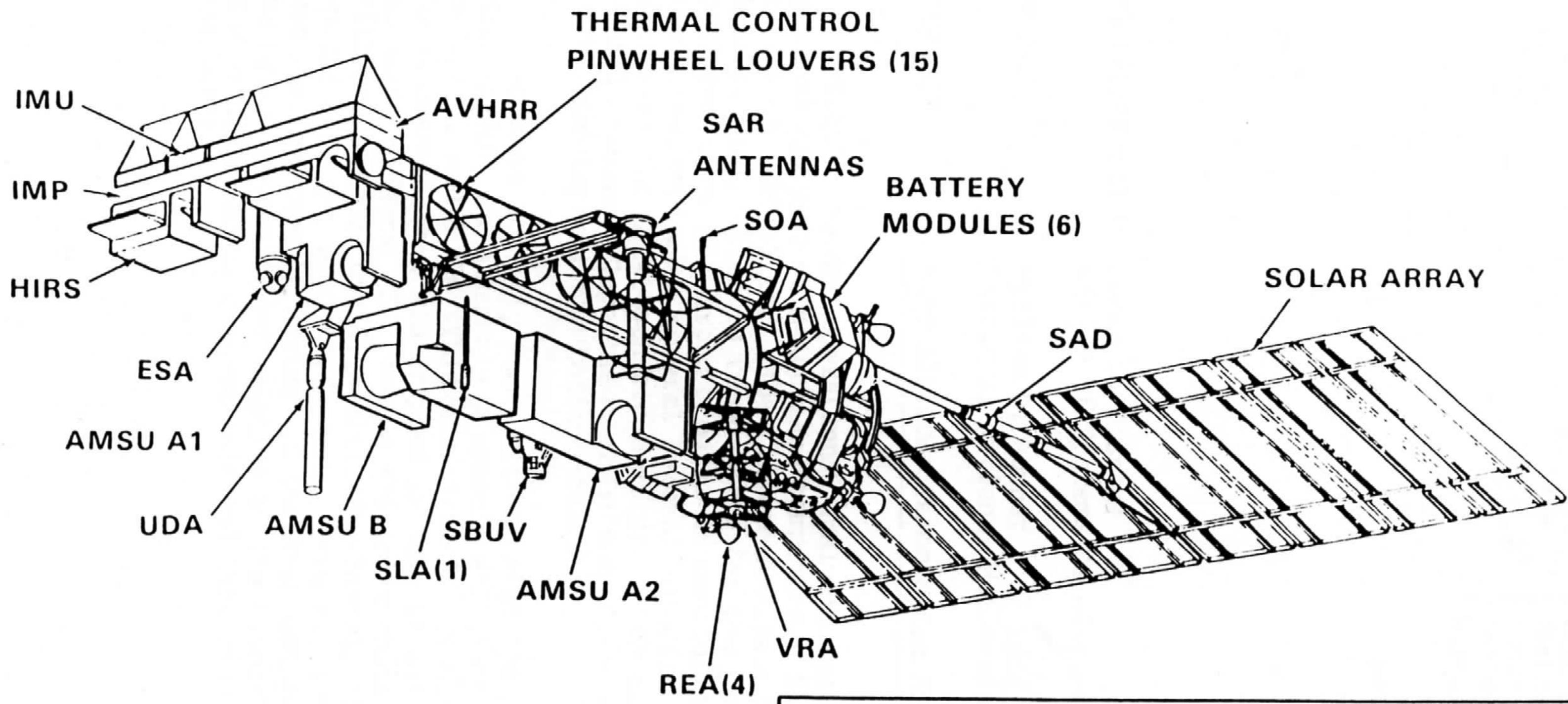
SEM - Space Environment Monitor

SBUV - Solar Backscatter Ultraviolet

DCS - Data Collection and Location System (ARGOS)

SAR - Search and Rescue (SARSAT)

NOAA K, L, M SPACECRAFT CONFIGURATION



LEGEND	
AMSU	ADVANCED MICROWAVE SOUNDING UNIT
AVHRR	ADVANCED VERY HIGH RESOLUTION RADIOMETER
ESA	EARTH SENSOR ASSEMBLY
HIRS	HIGH-RESOLUTION INFRARED SOUNDER
IMP	INSTRUMENT MOUNTING PLATFORM
IMU	INERTIAL MEASUREMENT UNIT
REA	REACTION ENGINE ASSEMBLY
SAD	SOLAR-ARRAY DRIVE
SAR	SEARCH AND RESCUE
SBUV	SOLAR BACKSCATTER ULTRAVIOLET SOUNDING SPECTRAL RADIOMETER
SLA	SEARCH-AND-RESCUE TRANSMITTING ANTENNA (L BAND)
UDA	ULTRA-HIGH-FREQUENCY DATA COLLECTION SYSTEM ANTENNA
VRA	VERY-HIGH-FREQUENCY REALTIME ANTENNA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
National Meteorological Center
Washington, D.C. 20233

MAY 22 1987

W/NMC53:AJM

MEMORANDUM FOR: James C. Fischer
Office of Systems Development, NESDIS

FROM: William D. Bonner
Director, National Meteorological Center, NWS

SUBJECT: High Altitude Temperature Retrievals from AMSU

Within the NMC operational analysis system, we produce a daily, global gridded analysis of height and temperature for the stratospheric levels 30- to 0.4 mb (~20-55 km). The Climate Analysis Center, Analysis and Information Branch (AIB), which is responsible for the production of these charts, utilizes them in a broad program of monitoring, development and research that interacts with several Federal agencies. Amongst the uses of these data are: the Stratospheric Monitoring Program (Public Law 95-95), Space Shuttle reentry, Department of Defense space systems reentry, numerical model development and basic research.

We have recently been informed that the Advanced Microwave Sounding Unit (AMSU), as currently proposed, will have weighting functions that peak between 2 and 3 mb. This configuration represents a deletion of a higher-level channel that was dropped because it was considered to be sensitive to magnetic effects. Not having the noise characteristics of the retrievals with and without the high-altitude channel, it is difficult for us to be specific in our recommendations. However, in view of our above requirements and the imminent "freezing" of the AMSU design, we ask that the channel design be reconsidered relative to the Federal requirements. Any questions can be directed to the Analysis and Information Branch, Mr. Alvin J. Miller (763-8071).

STUDIES IN SOUNDING THE MESOSPHERE AND UPPER STRATOSPHERE WITH MICROWAVE RADIOMETERS

Report 9505

Contract No. NAS 5-29402

June 1989

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771

Prepared by

Alex Stogryn and Glen Martner

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Azusa, California 91702-0296

PROPOSED POST NOAA K,L,M PROGRAM

- NOAA to continue afternoon Metsat service with a NOAA-N (same as NOAA K,L,M) and a competed new series beginning at NOAA-O.
- Europe to assume responsibility for morning Metsat service with EPOP series in 1997.
- NASA to assume responsibility for development of prototype operational instruments on NPOP.
- NPOP's, EPOP's, and "NOAA-O" series to have standardized instrument interfaces.

PROPOSED POST NOAA K,L,M INSTRUMENTS

- New Operational Common Interface Instruments for NOAA-O series and EPOP's

  - -Advanced Microwave Sounding Unit (AMSU) upgraded for upper atmosphere soundings
  - -Advanced Medium Resolution Imaging Radiometer (AMRIR) replaces AVHRR and HIRS
  - -Global Ozone Monitoring Radiometer (GOMR) upgrades capabilities of SBUV with added mapping capability

- NASA Prototype Operational Instruments for NPOP's

  - -Altimeter
  - -Scatterometer
  - -Passive Microwave Imager
  - -Ozone and Trace Gas Limb Scanner
  - -Advanced Infrared Sounder
  - -Earth Radiation Budget Instrument

BENEFITS OF AMRIR VS. AVHRR/HIRS

SYSTEM

- o REPLACES TWO INSTRUMENTS WITH ONE (MASS AND POWER)
- o DESIGNED FOR LONGER LIFETIME
- o SPECIFICALLY DESIGNED FOR FLIGHT ON NEXT GENERATION SPACECRAFT

IMAGING

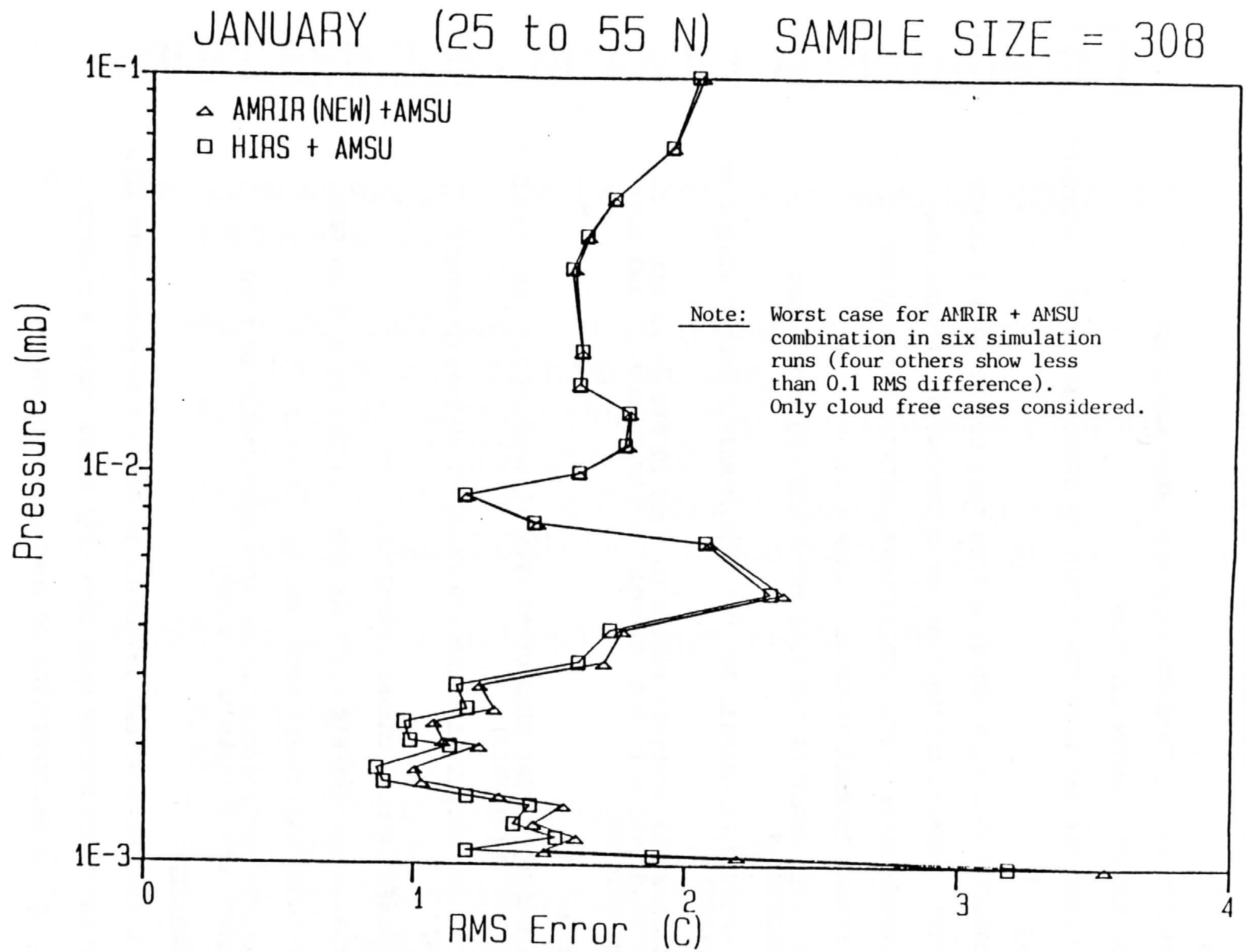
- o INCREASED SPATIAL RESOLUTION FROM 1100 METERS TO 800 METERS
- o VISIBLE CHANNEL CALIBRATION FOR QUANTITATIVE APPLICATIONS
- o UPGRADED BLACK BODIES FOR IMPROVED THERMAL CALIBRATION
- o INCREASED THERMAL RESOLUTION FROM 0.25K TO 0.1K
- o DEDICATED CHANNELS FOR FIRE DETECTION AND SNOW/CLOUD DESCRIMINATION
- o AN ADDITIONAL CHANNEL FOR SST DETERMINATION (SPLIT WINDOW AT 3.8 MICRON)
- o INCREASED RADIOMETRIC PRECISION FROM 10 BIT TO 12 BIT (IMPROVES SENSITIVITY FOR AEROSOL, RADIATION BUDGET, AND SST DETERMINATIONS)

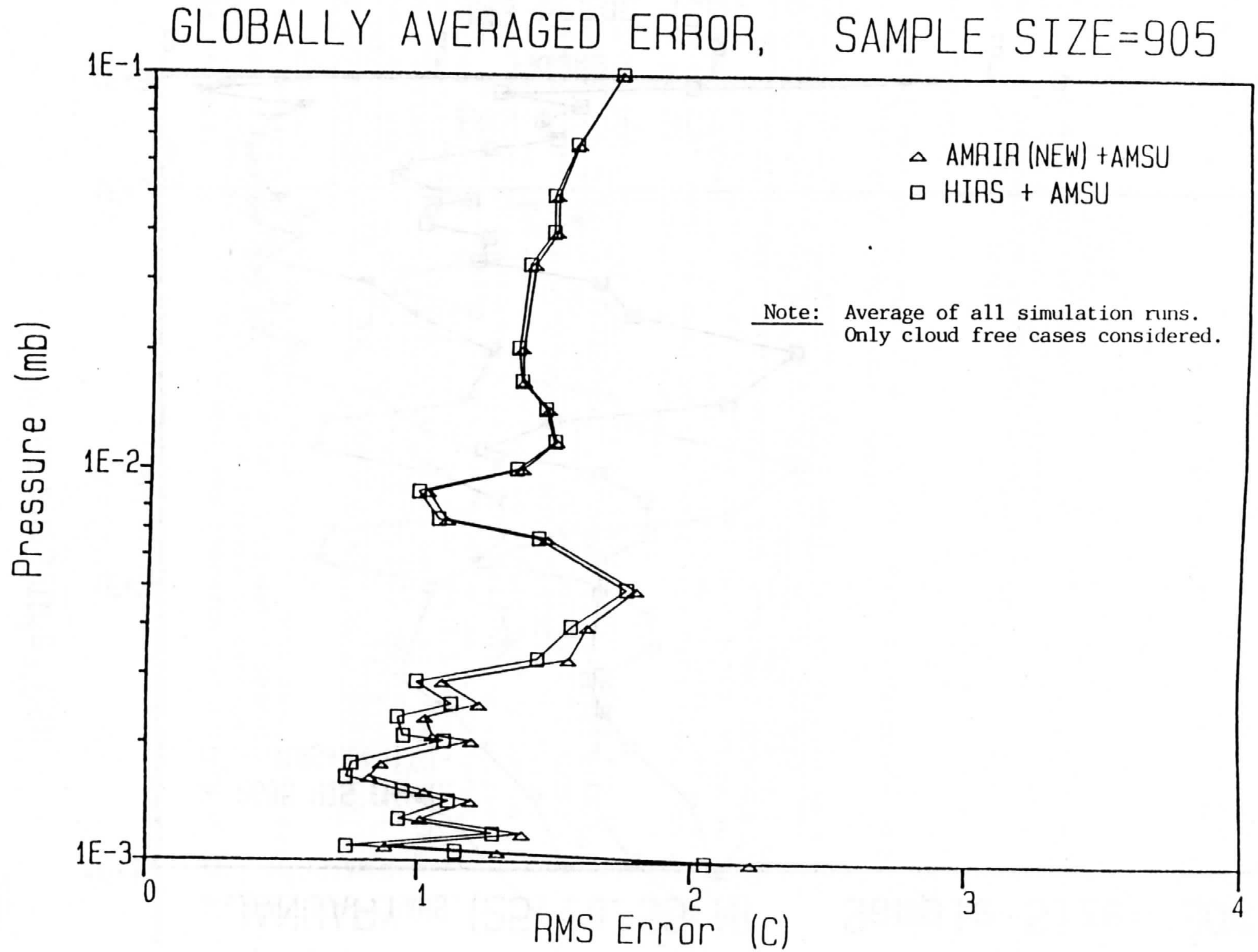
SOUNDING

- o INCREASED SPATIAL RESOLUTION FROM 21.0 KM TO 3.75 KM (MORE CLOUD FREE RETRIEVALS)
- o INCREASED RETRIEVAL YIELD AND ACCURACY IN PARTLY CLOUDY REGIONS
- o INCREASED WINDOW CHANNEL CAPABILITY
- o INCREASED GEOGRAPHIC COVERAGE (FROM 49 DEG SCAN TO 56 DEG)
- o ABSOLUTE COALIGNMENT WITH IMAGING CHANNELS
- o DESIGNED FOR COREGISTRATION WITH AMSU FIELDS OF VIEW (PRECISELY ONE QUARTER AMSU-B FOV)

PROGRAMMATIC

- O WILL PROVIDE LONGTERM INSURANCE IN CASE OF PROBLEMS WITH AIRS
- O ITT AND WESTINGHOUSE HAVE DEVELOPED AMRIR PHASE B DESIGNS
- o ALLOWS FOR RECOMPETITION OF IMAGER/IR SOUNDER


JANUARY (25 to 55 N) SAMPLE SIZE = 308
AMRIR (NEW) +AMSU
HIRS + AMSU
Note: Worst case for AMRIR + AMSU combination in six simulation runs (four others show less than 0.1 RMS difference). Only cloud free cases considered.
Pressure (mb)
1E-1
1E-2
1E-3
0
1
2
3
4
RMS Error (C)


GLOBALLY AVERAGED ERROR, SAMPLE SIZE=905
AMRIR (NEW) +AMSU
HIRS + AMSU
Note: Average of all simulation runs.
Only cloud free cases considered.
1E-1
1E-2
1E-3
Pressure (mb)
0
1
2
3
4
RMS Error (C)

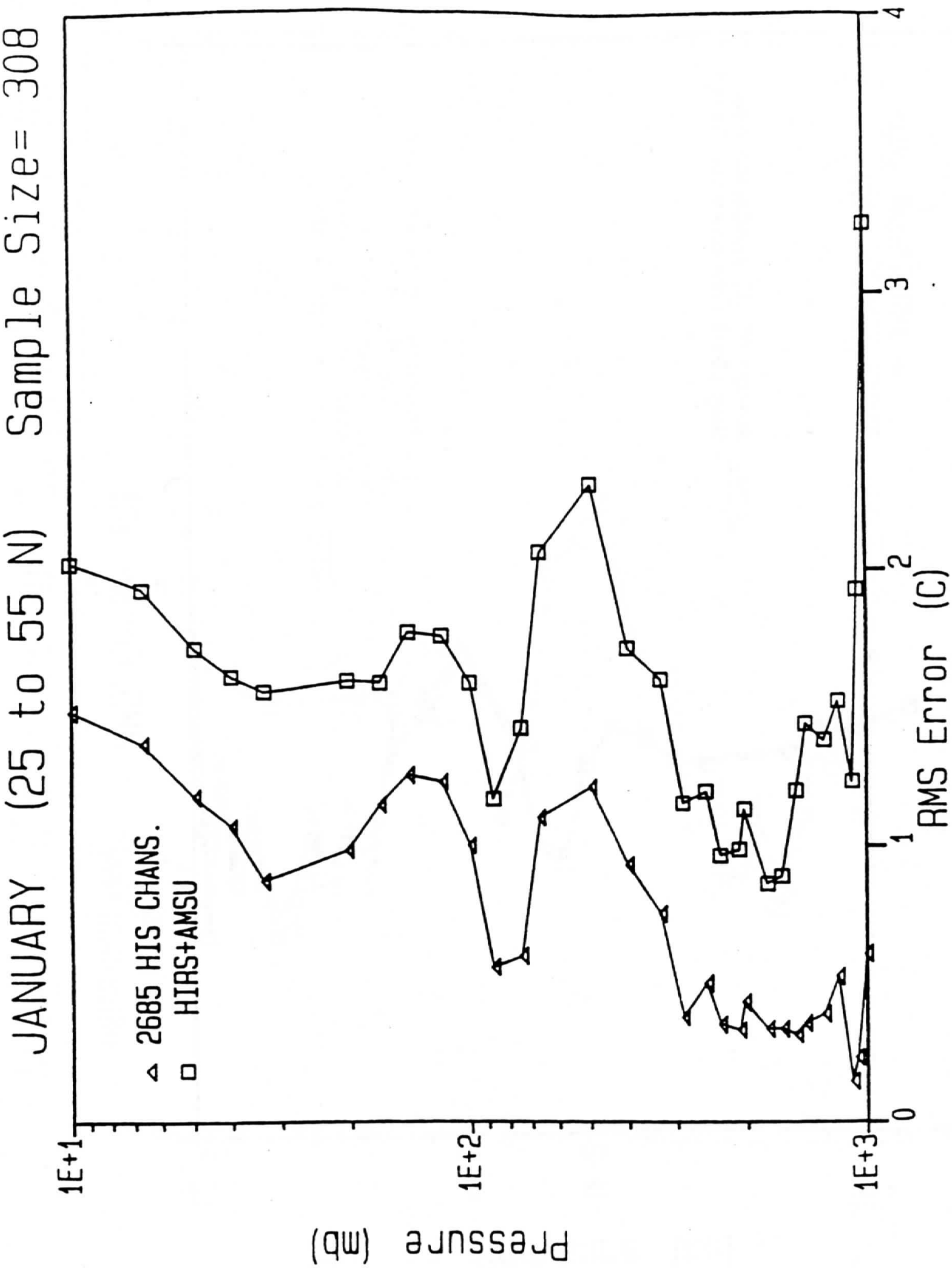

JANUARY (25 to 55 N) Sample Size= 308
2685 HIS CHANS.
HIRS+AMSU
RMS Error (C)
Pressure (mb)
1E+1
1E+2
1E+3
0
1
2
3
4

FIGURE 3

337 UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ASSISTANT ADMINISTRATOR FOR ENVIRONMENTAL SATELLITE,
DATA, AND INFORMATION SERVICES
Washington, DC 20233

OCT 9 1987

Dr. Shelby G. Tilford
Director, Earth Science
and Applications Division
Office of Space Science and Applications
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Shelby,

I am glad that we recently had the opportunity to discuss plans for an interagency temperature sounder.

The National Weather Service has outlined its own requirements for what is needed from a polar-orbiter sounder: reduced temperature errors, and most of all, vertical resolution of 1 km. It is exciting to hear that members of the NASA-NOAA Interagency Sounding Team believe that they have reached a design which would achieve these goals. It is doubly heartening to hear that their proposed instrument is under consideration for NASA funding as a polar platform facility instrument.

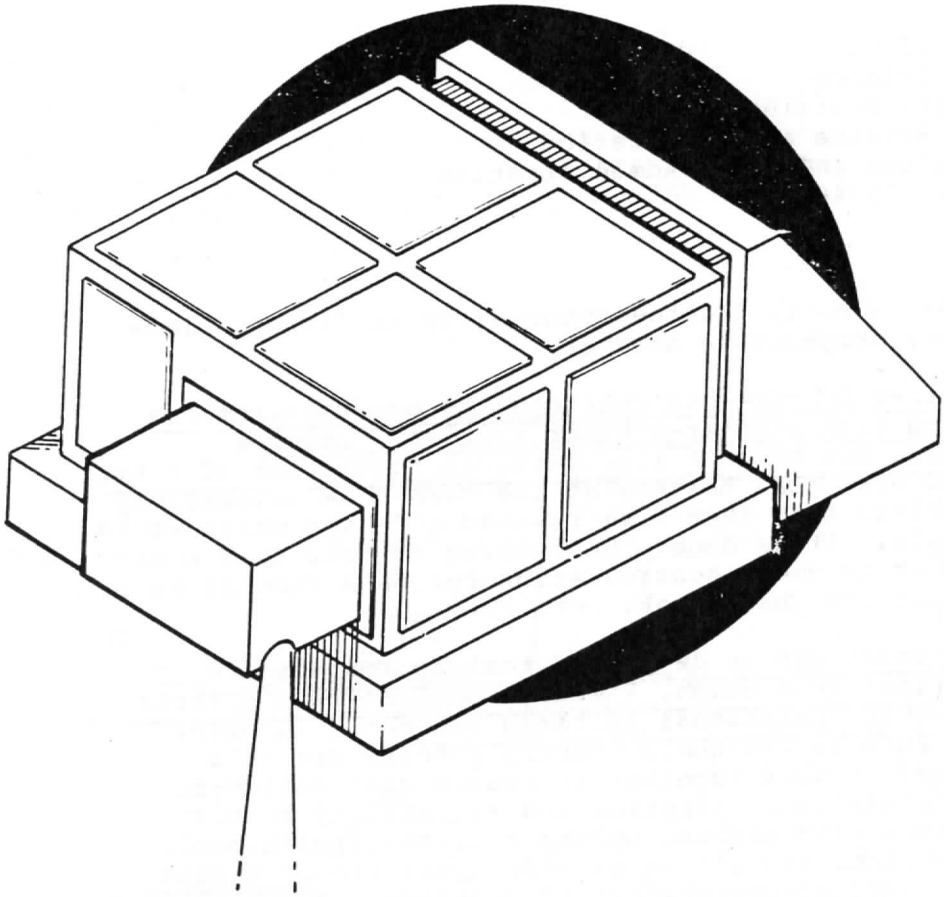
If an infrared sounder can be developed that approaches the radiosonde's vertical resolution, I pledge NESDIS' best efforts to make it the future operational infrared sounder. In order for NESDIS to be able to eventually secure funding for this instrument, we need to work together to assure that follow-on copies will meet operational lifetime and reliability requirements, be compatible with planned upgrades to the operational data processing system, as well as be made available at a cost commensurate with current operational IR sounders. Assuming that the instrument will be built, I recommend that our Interagency Sounding Team begin planning for an operational appraisal of the sounder's data alongside AMSU-A, AMSU-B, and the proposed AMRIR imager/sounder.

In conclusion, I wish to commend NASA for its continued interest in the development of instruments for atmospheric soundings of temperature and humidity. I look forward to continued cooperation between the operational and research communities on this project.

Sincerely,

Thomas N. Pyke, Jr.

Atmospheric Infrared Sounder



AIRS is an infrared sounder of atmospheric temperature and other properties. AIRS will have an IFOV of 50 km for most of its channels with an IFOV of 15 km for some selected channels and will be capable of scanning cross-track to ± 49°. It will provide continuous atmospheric sounding over this entire swath. AIRS will include measurements with a v/dv of 1,200 in 115 spectral bands in the 3 to 5 μm and 8 to 17 μm spectral regions. The temperature retrievals obtained with AIRS will be accurate to 1 km throughout the vertical extent of the troposphere.

AIRS has a mass of 80 kg, data rate of 1.7 Mbps, and requires 300 watts of power. AIRS is baselined for the Eos-1 platform.

Team Leader

Moustafa Chahine

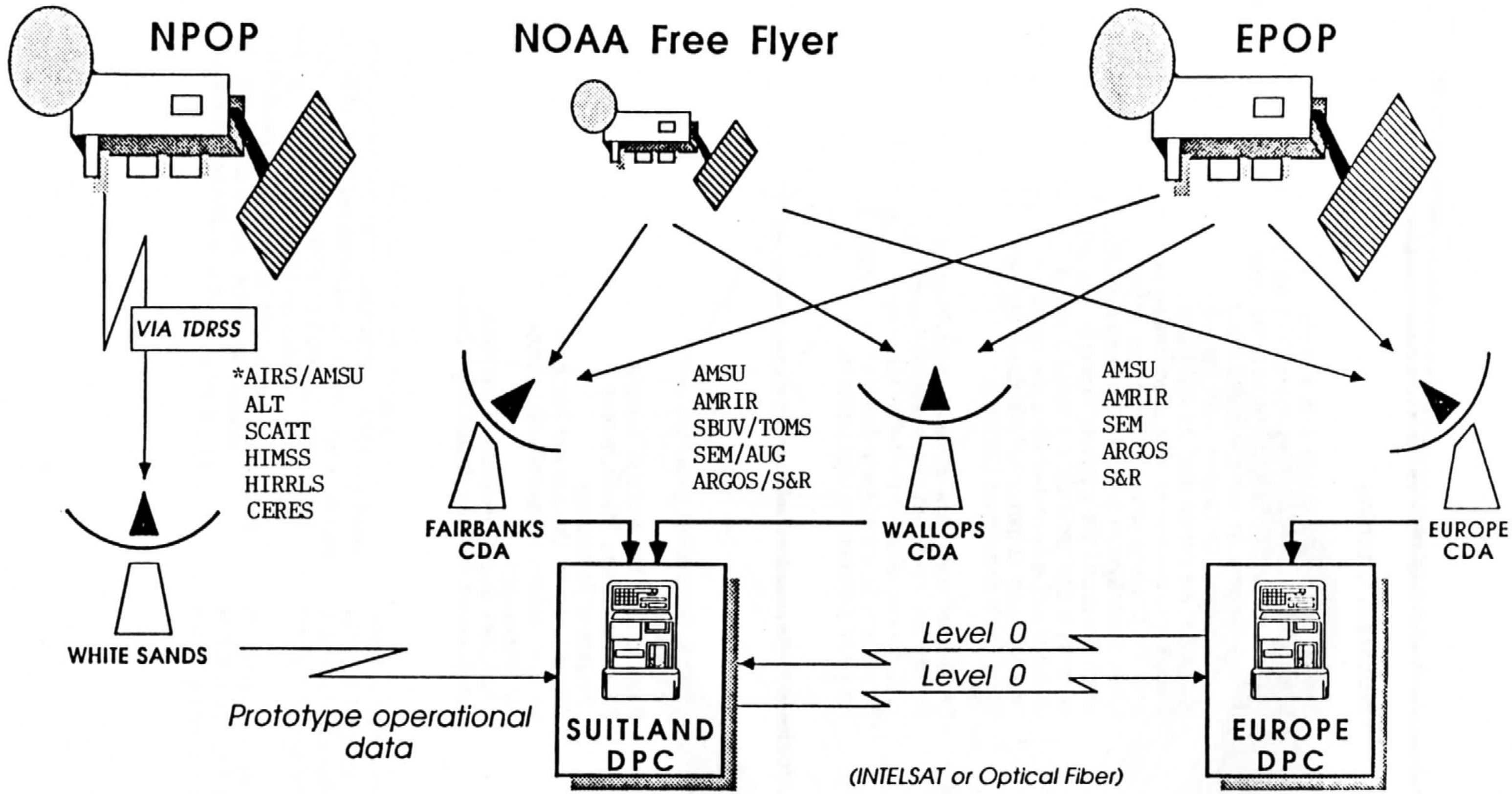
Moustafa Chahine was awarded his Ph.D. degree in fluid physics from the University of California at Berkeley in 1960. He is Chief Scientist at the Jet Propulsion Laboratory, where he has been affiliated for nearly 30 years. From 1978 to 1984, he was Manager of the Division of Earth and Space Sciences at JPL; as such he was responsible for establishing the Division and managing the diverse activities of its 400 researchers.

For 20 years, Dr. Chahine has been directly involved in remote sensing theory and experiments. His resume reflects roles as Principal Investigator, designer and developer, and analyst in remote sensing experiments. He developed the Physical Relaxation Method for retrieving atmospheric profiles from radiance observations. Subsequently, he formulated a multispectral approach using infrared and microwave data for remote sensing in the presence of clouds. These data analysis techniques were successfully applied in 1980 to produce the first global distribution of the Earth surface temperature using the HIRS/MSU sounders data. Dr. Chahine was integrally involved in the design study of AMTS, the precursor to the current AIRS spectrometer as well. Dr. Chahine served as a member of the NASA Earth System Sciences Committee (ESSC), which developed the program leading to Eos and currently is Chairman of the Science Steering Group of a closely-related effort, the World Meteorological Organization's Global Energy and Water Cycle Experiment (GEWEX).

Dr. Chahine is a Fellow of the American Physical Society and the British Meteorological Society. In 1969, he was awarded the NASA Medal for Exceptional Scientific Achievements and, in 1984, the NASA Outstanding Leadership Medal.

Team Members

Hartmut H. Aumann, Jet Propulsion Laboratory
Alan Chedin, CNRS/CNES/LMD
Henry E. Fleming, NOAA/NESDIS
Catherine Gautier, Scripps Institution of Oceanography
John Francis LeMarshall, Bureau of Meteorology Research Centre
Larry M. McMillin, U.S. Department of Commerce
Ralph Alvin Petersen, NOAA/NWS/NMC
Henry E. Revercomb, University of Wisconsin
Rolando Rizzi, Universita di Bologna
Philip Rosenkranz, Massachusetts Institute of Technology
William L. Smith, University of Wisconsin
David H. Staelin, Massachusetts Institute of Technology
L. Larrabee Strow, University of Maryland
Joel Susskind, Goddard Space Flight Center

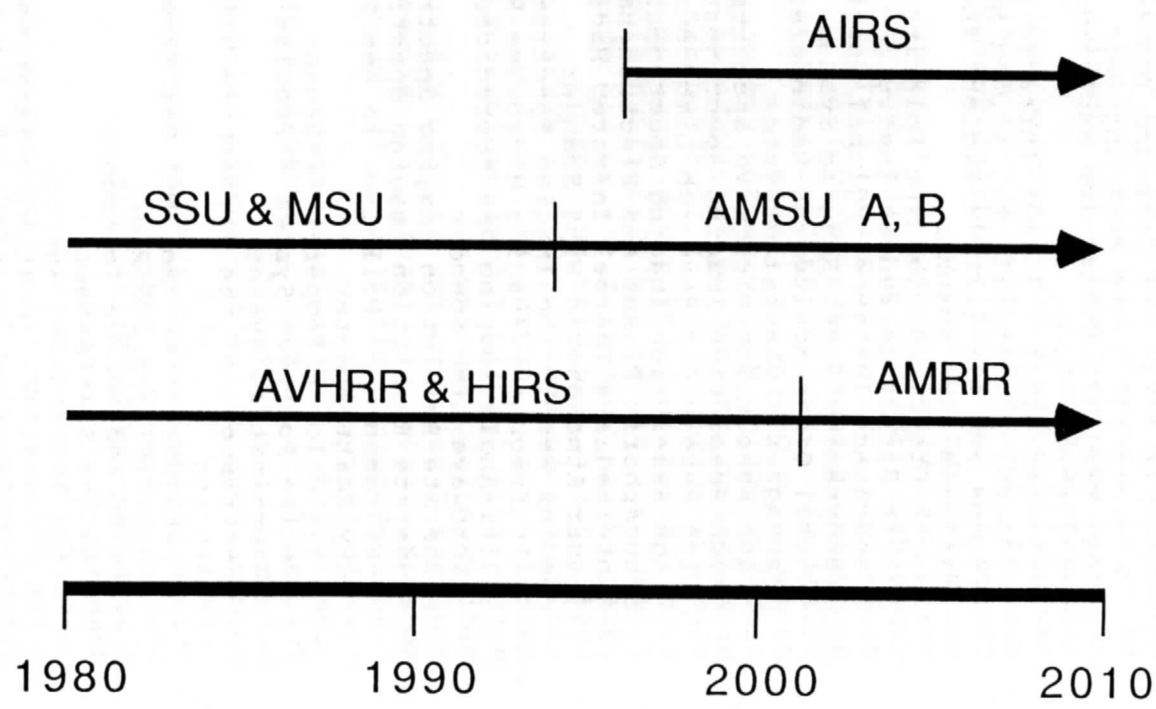


PROPOSED PLATFORM GLOBAL OPERATIONAL DATA FLOW

*NOTE: AIRS is currently baselined for NPOP. NOAA plans to disseminate AIRS data from NPOP to the global community for operational use. In addition, NOAA Free Flyers will be designed with payload margin to make it possible to accomodate AIRS when proven. Status of AIRS on EPOP is currently under discussion.

IMAGING AND SOUNDING INSTRUMENTATION

FOR OPERATIONAL USE (PM)



Appendix A. Eos Instrument Acronyms

ACRIM	Active Cavity Radiometer Irradiance Monitor
AIRS	Atmospheric Infrared Sounder
ALT-1	Radar Altimeter
AMI	Active Microwave Instrument
AMIR	Advanced Microwave Imaging Radiometer
AMRIR	Advanced Medium Resolution Infrared Radiometer
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
ARGOS	Advanced Data Collection and Location System
ATLID	Atmospheric Lidar
AVNIR	Advanced Visible & Near Infrared Radiometer
CCDH	Command, Communications, & Data Handling System
CERES	Clouds and the Earth's Radiant Energy System
DLS	Dynamics Limb Scanner
EOSP	Earth Observing Scanning Polarimeter
ERBI	Earth Radiation Budget Instrument
GGI/GPS	Geoscience Instrument/Global Positioning System
GLRS	Geodynamics Laser Ranging System
GOMR	Global Ozone Monitoring Radiometer
GOS	Geomagnetic Observing System
HIMSS	High Resolution Microwave Spectrometer Sounder
HIRIS	High Resolution Imaging Spectrometer
HIRRLS	High Resolution Research Limb Sounder
HRIS	High Resolution Imaging Spectrometer
IPEI	Ionospheric Plasma and Electrodynamics Instrument
ITIR	Intermediate Thermal Infrared Radiometer
LAWS	Laser Atmospheric Wind Sounder
MERIS	Medium Resolution Imaging Spectrometer
MIMR	Multifrequency Imaging Microwave Radiometer
MISR	Multi-Angle Imaging Spectroradiometer
MLS	Microwave Limb Sounder
MODIS-N	Moderate Resolution Imaging Spectrometer - Nadir
MODIS-T	Moderate Resolution Imaging Spectrometer - Tilt
MOPITT	Measurements of Pollution in the Troposphere
NSCAT	Navy Scatterometer
OCTS	Ocean Color & Temperature Sensor
PPS-PODS	Precise Position System - Precise Orbit Determination System
SAFIRE	Spectroscopy of the Atmosphere Using Far-IR Emission
SAGE-III	Stratospheric Aerosol and Gas Experiment III
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Instrument
SCANSAT	Scanning Scatterometer
SEM	Space Environment Monitor
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SWIRLS	Stratospheric Wind Infrared Limb Sounder
TES	Tropospheric Emission Spectrometer

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
National Meteorological Center
Washington, D.C. 20233

July 24, 1986 W/NMC:WDB

Dr. Robert J. Curran
National Aeronautics and Space Adm.
Code EE
Washington, DC 20546

Dear Dr. Curran:

This letter is a reply to your question concerning the value attributed by the National Meteorological Center to global wind profiles.

Experience at the National Meteorological Center has convinced forecasters that, given the swath size in which polar-orbiting satellite data becomes available to the forecast operation, the addition of global wind profiles offers the best opportunity for significant improvement in medium and large-scale forecasts. Stated another way, global wind profiles are, we feel, relatively more desirable than either more, or more accurate, temperature profiles.

I do not mean that the need for soundings has diminished. Our interest continues in all-weather soundings, and sounding data with usable signal levels from smaller fields of view. For such mesoscale uses as forecaster support for severe storm forecasts, we have a substantial interest in geostationary cloud-penetrating soundings, especially for the area of the continental United States.

However, given the forecast-model's tendency in certain situations which frequently occur, to accept wind data in preference to sounding data, our conviction is that wind data will enhance forecasts on all scales. This is especially true for low-latitude regions, were measurement of pressure-surface heights by direct or remote-sensing means is virtually impossible.

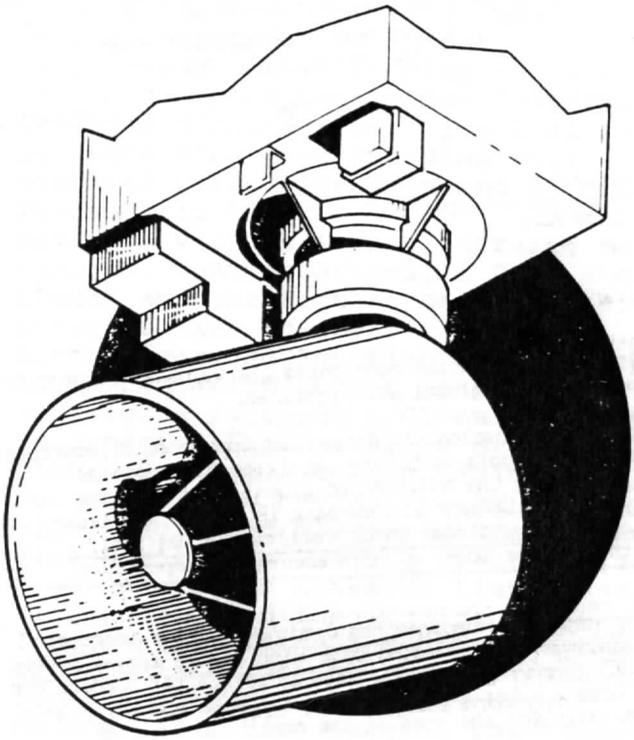
I hope this reply will be useful to you in your planning for future satellite instruments.

Sincerely,

William D. Bonner
Director
National Meteorological Center

cc:
D. Fitzjarrald, MSFC, ED43
W. Baker, GSFC, Code 611
J. Sparkman, NESDIS, E/SPD-1

Laser Atmospheric Wind Sounder



LAWS is a Doppler lidar system for direct tropospheric wind measurements. The instrument consists of a pulsed, frequency-stable CO_2 laser transmitter, a continuously scanning transmit/receive telescope (1.5 m diameter), a heterodyne detector, and a signal processing subsystem. The laser operates at approximately 10 J and 10 Hz pulse repetition rate. The telescope conically scans the subsatellite area and provides coverage of wind profiles through the troposphere, with a grid spacing on the order of 100 km at a height resolution of 1 km and with an accuracy of 1 to 5 m/s.

LAWS has a mass of 875 kg, data rate of 1.5 Mbps, and requires 2,500 watts of power. LAWS will have a continuous duty cycle. LAWS is baselined for the Japanese polar platform.

Team Leader

Wayman Baker

Wayman Baker is Deputy Chief of the Development Division at the National Meteorological Center of the NOAA. Blending academic skills in mathematics and the atmospheric sciences (Ph.D. University of Missouri, 1978) and professional experience as a meteorologist, he has focused his scientific research on atmospheric dynamics, general circulation, and numerical weather prediction.

Dr. Baker is thoroughly familiar with the LAWS instrument. In 1985 he organized and co-chaired the NASA Symposium and Workshop on Global Wind Measurements, in which more than 100 meteorologists and instrument technologists participated. The recommendations which resulted from the workshop contributed significantly to the selection of the LAWS instrument as one of the NASA Research Facility instruments and helped put the development of the necessary technology on a well-defined path. Since then he has continued his involvement in a wide range of activities relevant to the LAWS instrument. These include: refining the science requirements through participation in the LAWS Working Group, collaborating with scientists participating in related experiments; and exploring various hardware options and data-producing capabilities.

In addition to his work with LAWS, Dr. Baker has contributed often to refereed publications and many technical reports and papers; and frequently serves as a reviewer of proposals for NSF, NASA, and NOAA. Dr. Baker has received several citations and awards including a NASA Special Achievement Award in 1983, the NASA/Goddard Laboratory for Atmospheres Scientific Research Award in 1986, and a NOAA Performance Award in 1989.

Team Members

John R. Anderson, University of Wisconsin
Robert M. Atlas, Goddard Space Flight Center
George Emmitt, Simpson Weather Associates, Inc.
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Robert Menzies, Jet Propulsion Laboratory
Timothy L. Miller, Marshall Space Flight Center
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John Molinari, State University of New York
Jan Paegle, University of Utah

Associate Members

David Bowdle, University of Alabama
Dan Fitzjarrald, Marshall Space Flight Center

THE TECHNICAL PROCEEDINGS OF THE FIFTH INTERNATIONAL TOVS STUDY CONFERENCE

Toulouse, France

July 24-28, 1989

Edited by A. CHEDIN

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January 1990