The objective of this project was to analyze observational atmospheric data collected by the University of Wisconsin for the investigation of issues in spectroscopy and remote sensing. The specific tasks performed under this research were the preparation of a data set for the International Radiation Commission and a preliminary effort at determining refinements to the water vapor continuum as used in the line-by-line transmittance model, FASCODE.
VALIDATION OF FASCOD3P USING UNIVERSITY OF WISCONSIN HIS DATA

A REPORT
from the space science and engineering center
the university of wisconsin-madison
madison, wisconsin
VALIDATION OF FASCOD3P USING UNIVERSITY OF WISCONSIN HIS DATA

A Report to the

Air Force Geophysics Laboratory
Hanscom, AFB, MA 01731

Under contract # F19628-91-K-0007 (mod #6)

by the

University of Wisconsin-Madison
Space Science and Engineering Center
1225 W. Dayton St.
Madison, WI 53706

Project Director: Henry E. Revercomb

November 12, 1993
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I. PROJECT DESCRIPTION

This report summarizes work performed at the University of Wisconsin - Madison during FY93 under contract #F19628-91-K-0007 for the Air Force Phillips Laboratory. The portion of work summarized here is restricted to the efforts under the direction of Dr. Henry E. Revercomb (mod #6 of the above contract) and includes the contributions of R. O. Knuteson, S. C. Lee and others at the Space Science and Engineering Center at the UW.

The objective of this funding was to support the analysis of observational atmospheric data collected by the UW for the investigation of issues in spectroscopy and remote sensing. The specific tasks performed under this research were the preparation of a data set for the International Radiation Commission and a preliminary effort at determining refinements to the water vapor continuum as used in the line-by-line transmittance model, FASCODE.
II. ITRA DATA SET

One of the main tasks performed under this contract was the final preparation of a small data sample containing both observations of atmospheric radiance and coincident observations of the atmospheric state for use in validating atmospheric line-by-line transmittance models. This section provides some background information on the observations and on the international working group using the data, lists the contents of the compiled data set, and documents the comparison of observations to the Phillips Laboratory FASCODE radiative transfer model calculations.

A. Background.

The atmospheric radiance contained within this data set was observed using the High-resolution Interferometer Sounder (HIS), a Fourier transform spectrometer developed at the University of Wisconsin (W.L. Smith, PI) for remote sensing of the atmosphere and earth at high spectral resolution and with high absolute accuracy [Revercomb, H. E., et al, Mikrochimica Acta, 1988, II, 439-444]. The instrument is a Michelson interferometer with laser sampling for wavenumber accuracy and onboard precision blackbodies for radiometric accuracy. The HIS has been operated both from aircraft looking down at the atmosphere and the earth’s surface and from the surface looking upward to measure the upwelling and downwelling atmospheric radiance, respectively. The HIS data consists of atmospheric radiance divided into three broad bands (I, II, and III) spanning the infrared spectrum from 3.7 to 16.7 \textmu m at a spectral resolution of between 0.3 and 1.0 cm$^{-1}$ depending on band. The instrument field of view is approximately 2 km at 20 km range.

The HIS data was collected during three separate field deployments of the HIS; (1) test flights of the HIS from the NASA AMES flight center in California over the Eastern Pacific ocean, (2) ground-based observations in Denver, Colorado as part of the Ground-based Atmospheric Profiling Experiment (GAPEX), and (3) aircraft data flights over Kansas during the joint agency field experiment known as STORMFEST. The aircraft data is from the NASA high altitude U2/ER-2 research aircraft which flies in the lower stratosphere at about 20 km altitude. Balloon sonde data was used to characterize the atmospheric state at times coincident with the HIS observations.

The motivation for the compilation of this HIS data set was to provide the Intercomparison of Transmittance and Radiance Algorithms (ITRA) working group, a sub-committee of the International Radiation Commission, with real atmospheric data for use in analyzing the performance of state-of-the-art radiative transfer models. The current ITRA chairperson, Dr. Noell Scott of the Polytechnique Institute of Paris, is the person responsible for the distribution of this data set to interested users. The Phillips Laboratory model FASCODE has been and continues to be included in the model intercomparisons.

B. UW ITRA Data Set 1993.

The HIS and coincident radiosonde data together are referred to by the shorthand notation UWITRA93 data set. The following table contains a listing of the contents file containing the file names which comprise the UWITRA93 data set.

TABLE 1. CONTENTS.DOC

###############################################################
This directory contains the following files:

CONTENTS.DOC -- This file.
UWITRA93.DOC -- Description of the UW HIS DATA SET - UWITRA93

DOWNLOOKING CASES:

-- 14 April 1986 Pacific Ocean
HIS104B1.TXT -- HIS BAND 1
HIS104B2.TXT -- HIS BAND 2
HIS104B3.TXT -- HIS BAND 3
14AP1800.TXT -- Average profile from NWS balloon sondes
             (OAKLAND+SAN DIEGO: 0Z+12Z: Time and Space Average)

-- 01 March 1992 Seneca, Kansas
HIS1MRB1.TXT -- HIS BAND 1
HIS1MRB2.TXT -- HIS BAND 2
HIS1MRB3.TXT -- HIS BAND 3
01MR1221.TXT -- Profile data from NCAR CLASS balloon sonde.

UPLOOKING CASES from GAPEX Experiment:

-- 31 October 20 UTC Denver (Surface)
GPXO31B1.TXT -- HIS BAND 1
GPXO31B2.TXT -- HIS BAND 1
GPXO31B3.TXT -- HIS Band 3 Not Available for GAPEX Data.
GPXO3120.TXT -- Profile data from NCAR CLASS balloon sonde

-- 1 November 11 UTC Denver (Surface)
GPXN01B1.TXT -- HIS BAND 1
GPXN01B2.TXT -- HIS BAND 2
GPXN0111.TXT -- HIS Band 3 Not Available for GAPEX Data.
GPXN0111.TXT -- Profile data from NCAR CLASS balloon sonde

NOTE: See the headers of all files (including radiance data)
for more information on the observations.

Directory UWITRA93:
CONTENTS DOC 2089 9-16-93
UWITRA93 DOC 8426 8-29-93
HIS104B1 TXT  40838 8-29-93
HIS104B2 TXT  35111 8-29-93
HIS104B3 TXT  34146 8-29-93
14AP1800 TXT  3069 8-30-93
HIS1MRB1 TXT  40836 8-29-93
HIS1MRB2 TXT  35110 8-29-93
HIS1MRB3 TXT  34143 8-29-93
01MR1221 TXT  4320 9-16-93
GPXO31B1 TXT  33872 8-29-93
GPXO31B2 TXT  14950 8-29-93
GPXO3120 TXT  4288 8-30-93
GPXN0111 TXT  4290 8-30-93
GPXN01B1 TXT  33872 8-29-93
GPXN01B2 TXT  14950 8-29-93
#.......................................................................
The contents of the document file describing the dataset is given in Table 2.

Table 2. UWITRA93.DOC

This file describes the infrared spectral data and temperature and moisture profiles provided by the University of Wisconsin to the ITRA line-by-line intercomparison (1993).

The High-resolution Interferometer Sounder (HIS) is a Fourier Transform Spectrometer (FTS) which uses laser controlled sampling and on-board blackbodies to achieve highly accurate wavelength and spectral radiance absolute calibration. The HIS data described below was collected under United States and State of Wisconsin funded projects lead by Principal Investigator William L. Smith, Professor of Meteorology, and Director of the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin -- Madison. The scientist responsible for the HIS instrument development and calibration is Dr. Henry E. Revercomb also of the University of Wisconsin -- Madison.

The HIS data are unapodized and the interferometer finite field of view effect has been removed. All wavenumbers listed in the following tables are in reciprocal centimeters (cm⁻¹). Only the data within the optical filter bandpass has been included in the HIS data files. Also, the large number of points in the balloon sonde data from the CLASS sondes (400-500) has been reduced to 50 profile points spanning the range of pressures measured. The file 14AP1800.TXT containing the raob data for April 14th deserves special mention since it is composed of a time and space average of NWS radiosondes which make the characterization of the atmosphere much more uncertain for that case. Only measured data has been provided. This means that some quantities must default to their climatic means.

DATA FILES: (See CONTENTS.DOC for further information)

NAMING CONVENTION:
- HIS104 -- 14 April 1986 (HIS on NASA ER-2 Aircraft during TEST FLIGHT)
- HIS1MR -- 1 March 1992 (HIS on NASA ER-2 Aircraft during STORMFEST)
- GPKX031 -- 31 October 1988 (Ground-Based Atmospheric Profiling Experiment)
- GPKX01 -- 1 November 1988 (Ground-Based Atmospheric Profiling Experiment)

HIS OBSERVATIONAL BAND LIMITS:
- BAND 1: 600 - 1080 cm⁻¹
- BAND 2: 1080 - 1850 cm⁻¹
- BAND 3: 2000 - 2600 cm⁻¹ (Band 3 not available for GAPEX data)

IMPORTANT INFORMATION ABOUT THE HIS DATA PROVIDED IN UWITRA93.

WAVENUMBER SCALE OF HIS DATA:
The wavenumber scale of the HIS data is determined by an on-board HeNe laser. For UWITRA93 the laser wavenumber has been assumed to be 15799.00 cm⁻¹. A numerical filter applies a reduction factor (R=14,8,8 for bands 1,2,3) to the observed data which defines a starting (or reference) wavenumber for
each HIS band. The reference wavenumbers which correspond to the laser
wavenumber 15799.00 cm⁻¹ are 564.25 cm⁻¹, 987.4375 cm⁻¹, and 1974.875 cm⁻¹
for bands 1, 2, and 3, respectively. The point spacing of the output data
also depends on the laser wavenumber assumed and the reduction factor
appropriate for each HIS band. In addition, the point spacing in wavenumber
depends on the number of points used in the FFT to transform from the
Fourier domain to the spectral domain. The difference in point spacing
between the Band 2 uplooking and downlooking observed data is due to
using 2048 points versus 1024 points in the data processing.

SPECTRAL RESOLUTION OF HIS DATA:
Spectral resolution here refers to the information content of the
observation and is always equal to (minimally sampled) or greater than
(oversampled) the data's point spacing in wavenumber. Since the
instrument used to obtain the observation is a Fourier Transform
Spectrometer,
the spectral resolution is defined in terms of the maximum Optical Path
Difference of the measurement. Since the HeNe laser is used to define
the optical path difference, the maximum OPD as well as the spectral
resolution depends on the assumed laser wavenumber. The differences
in spectral resolution between HIS bands and from one observation to the
next reflect different choices made during data processing; the same
instrument hardware was used to make all the observations in UWITRA93.

RADIOMETRIC CALIBRATION OF HIS DATA:
All the HIS data was calibrated using a two point calibration scheme
whereby periodic views of hot and cold reference sources are used
to remove the background contributions of the instrument. In flight
configuration two high precision cavity blackbodies are used as
reference sources. During surface operations, the cold reference target
is replaced with an open mouthed dewar of liquid nitrogen. Note especially
that the HIS instrument operates in ambient air, that is the path
between the calibration reference sources and the interferometer contains
both CO₂ and H₂O normal atmospheric concentrations. This means that
certain individual channels, e.g. near 667 cm⁻¹, 1500 cm⁻¹, and 2380 cm⁻¹,
can be "blinded" by very opaque absorption near the instrument. The result
is that these few channels appear anomalous (spikes) because they are much
noisier than less opaque channels nearby. In particular, the HIS
calibration
is undefined in the narrow spectral range 667.016 to 669.771 cm⁻¹.
This narrow region should *not* be used for spectroscopic comparisons.

<table>
<thead>
<tr>
<th>POINT SPACING OF HIS DATA (CM⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVspacing = VLASER/(2<em>R</em>N)</td>
</tr>
<tr>
<td>DATA</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>HIS104</td>
</tr>
<tr>
<td>HIS1MR</td>
</tr>
<tr>
<td>GPX031</td>
</tr>
<tr>
<td>GPXN01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPECTRAL RESOLUTION (UNAPODIZED) (CM⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVres = 1./(2.*X)</td>
</tr>
<tr>
<td>DATA</td>
</tr>
<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>BAND 1</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>HIS104</td>
</tr>
<tr>
<td>HIS1MR</td>
</tr>
</tbody>
</table>
GPX031  0.3640322  0.9642944
GPXN01  0.3640322  0.9642944

MAXIMUM OPTICAL PATH DIFFERENCE (CM)
[X = DX * DSPTS / 2.]

<table>
<thead>
<tr>
<th>DATA</th>
<th>BAND 1</th>
<th>BAND 2</th>
<th>BAND 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIS104</td>
<td>1.373505</td>
<td>0.7848598</td>
<td>0.7848598</td>
</tr>
<tr>
<td>HIS1MR</td>
<td>1.550731</td>
<td>0.7342236</td>
<td>0.5185138</td>
</tr>
<tr>
<td>GPX031</td>
<td>1.373505</td>
<td>0.5185138</td>
<td></td>
</tr>
<tr>
<td>GPXN01</td>
<td>1.373505</td>
<td>0.5185138</td>
<td></td>
</tr>
</tbody>
</table>

NUMBER OF POINTS USED IN DOUBLE SIDED INTERFEROGRAM (DSPTS)
[Exclusive of ZPD]

<table>
<thead>
<tr>
<th>DATA</th>
<th>BAND 1</th>
<th>BAND 2</th>
<th>BAND 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIS104</td>
<td>3100</td>
<td>3100</td>
<td>3100</td>
</tr>
<tr>
<td>HIS1MR</td>
<td>3500</td>
<td>2900</td>
<td>2048</td>
</tr>
<tr>
<td>GPX031</td>
<td>3100</td>
<td>2048</td>
<td></td>
</tr>
<tr>
<td>GPXN01</td>
<td>3100</td>
<td>2048</td>
<td></td>
</tr>
<tr>
<td>DX</td>
<td>8.861320E-4</td>
<td>5.063612E-4</td>
<td>5.063612e-4</td>
</tr>
</tbody>
</table>

Please refer questions about HIS data to:
Robert O. Knuteson
Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin -- Madison
1225 W. Dayton
Madison, WI 53706 USA
phone (608-263-4085)
fax (608-262-5974)
email (bobk@ssecmail.ssec.wisc.edu)

The radisonde data is contained in four files the contents of which are contained in Tables 3-6.

Table 3. 14AP1800.TXT

Filename: 14AP1800.TXT (Created 30 August 1993, ROK)
Date: 14 April 1986
Time: 1800 UTC
Location: Off the California Coast (-120.5,+34.7)
Comment: Area and Time Average of Conventional NWS sondes. Retrieved 03.
Surface Skin Temperature: 287.3 K (HIS estimate)
Surface Skin Emissivity: Unknown (Ocean surface)
Surface Altitude: Unknown (Ocean surface)
Surface Pressure: Unknown
Surface Air Temperature: Unknown
Surface Air Relative Humidity: Unknown
Raob Source File: HIS86104.RAO (average of four raobs)
Oakland OZ+12Z and San Diego OZ+12Z

Number of Profile Points: 25

Notes:
(1) The upper level H2O retrieval is for diagnostic purposes only and should not be considered a realistic representation of the true atmospheric state.
(2) All other constituents should default to the climatological mean found in the AFGL U.S. Standard Atmosphere.

Recommended Profile Values:

<table>
<thead>
<tr>
<th>Index</th>
<th>Altitude (km)</th>
<th>Pressure (mb)</th>
<th>Temp (K)</th>
<th>H2O RH (%)</th>
<th>CO2 (ppmv)</th>
<th>O3 (g/kg)</th>
<th>H2O RH (%)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>1000.0</td>
<td>286.9</td>
<td>62.9</td>
<td>349.0</td>
<td>0.045E-3</td>
<td>62.9</td>
</tr>
<tr>
<td>2</td>
<td>0.4310</td>
<td>950.0</td>
<td>285.2</td>
<td>44.4</td>
<td>349.0</td>
<td>0.045E-3</td>
<td>43.7</td>
</tr>
<tr>
<td>3</td>
<td>0.6290</td>
<td>920.0</td>
<td>284.6</td>
<td>26.5</td>
<td>349.0</td>
<td>0.046E-3</td>
<td>33.9</td>
</tr>
<tr>
<td>4</td>
<td>1.3570</td>
<td>850.0</td>
<td>282.2</td>
<td>15.7</td>
<td>349.0</td>
<td>0.047E-3</td>
<td>17.5</td>
</tr>
<tr>
<td>5</td>
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<td>780.0</td>
<td>278.6</td>
<td>11.9</td>
<td>349.0</td>
<td>0.048E-3</td>
<td>14.7</td>
</tr>
<tr>
<td>6</td>
<td>2.9390</td>
<td>700.0</td>
<td>273.4</td>
<td>27.2</td>
<td>349.0</td>
<td>0.050E-3</td>
<td>24.4</td>
</tr>
<tr>
<td>7</td>
<td>3.2880</td>
<td>670.0</td>
<td>271.0</td>
<td>30.7</td>
<td>349.0</td>
<td>0.050E-3</td>
<td>29.3</td>
</tr>
<tr>
<td>8</td>
<td>3.9000</td>
<td>620.0</td>
<td>267.0</td>
<td>39.0</td>
<td>349.0</td>
<td>0.050E-3</td>
<td>36.5</td>
</tr>
<tr>
<td>9</td>
<td>4.5530</td>
<td>570.0</td>
<td>263.0</td>
<td>47.1</td>
<td>349.0</td>
<td>0.052E-3</td>
<td>39.4</td>
</tr>
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<td>10</td>
<td>5.5500</td>
<td>500.0</td>
<td>256.1</td>
<td>36.9</td>
<td>349.0</td>
<td>0.057E-3</td>
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</tr>
<tr>
<td>11</td>
<td>5.9330</td>
<td>475.0</td>
<td>253.6</td>
<td>61.1</td>
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<tr>
<td>12</td>
<td>6.6650</td>
<td>430.0</td>
<td>248.4</td>
<td>44.5</td>
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<td>65.1</td>
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<tr>
<td>13</td>
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<td>0.070E-3</td>
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<tr>
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<td>8.1310</td>
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<td>237.9</td>
<td>17.9</td>
<td>349.0</td>
<td>0.085E-3</td>
<td>42.2</td>
</tr>
<tr>
<td>15</td>
<td>9.1870</td>
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<td>229.7</td>
<td>2.8</td>
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<td>0.120E-3</td>
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</tr>
<tr>
<td>16</td>
<td>10.3880</td>
<td>250.0</td>
<td>220.2</td>
<td>2.5</td>
<td>349.0</td>
<td>0.173E-3</td>
<td>12.3</td>
</tr>
<tr>
<td>17</td>
<td>11.7930</td>
<td>200.0</td>
<td>211.5</td>
<td>11.9</td>
<td>349.0</td>
<td>0.270E-3</td>
<td>30.9</td>
</tr>
<tr>
<td>18</td>
<td>13.5900</td>
<td>150.0</td>
<td>213.7</td>
<td>4.8</td>
<td>349.0</td>
<td>0.500E-3</td>
<td>12.6</td>
</tr>
<tr>
<td>19</td>
<td>14.2480</td>
<td>135.0</td>
<td>213.3</td>
<td>4.9</td>
<td>349.0</td>
<td>0.600E-3</td>
<td>14.2</td>
</tr>
<tr>
<td>20</td>
<td>15.2450</td>
<td>115.0</td>
<td>211.1</td>
<td>10.1</td>
<td>349.0</td>
<td>0.850E-3</td>
<td>40.2</td>
</tr>
<tr>
<td>21</td>
<td>16.1090</td>
<td>100.0</td>
<td>211.3</td>
<td>3.5</td>
<td>349.0</td>
<td>1.150E-3</td>
<td>31.2</td>
</tr>
<tr>
<td>22</td>
<td>17.1180</td>
<td>85.0</td>
<td>212.8</td>
<td>1.2</td>
<td>349.0</td>
<td>1.650E-3</td>
<td>14.2</td>
</tr>
<tr>
<td>23</td>
<td>18.3270</td>
<td>70.0</td>
<td>212.4</td>
<td>1.2</td>
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<td>2.400E-3</td>
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</tr>
<tr>
<td>24</td>
<td>19.2870</td>
<td>60.0</td>
<td>212.6</td>
<td>1.0</td>
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<td>3.200E-3</td>
<td>17.7</td>
</tr>
<tr>
<td>25</td>
<td>20.4230</td>
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<td>213.1</td>
<td>.6</td>
<td>349.0</td>
<td>4.200E-3</td>
<td>12.1</td>
</tr>
</tbody>
</table>

Table 4. 01MR1221.TXT

###################################################################################################################################
Filename: 01MR1221.TXT (created 30 August 1993 ROK)
Date: 1 March 1992
Time: 12:21 UTC
Location: Seneca, Kansas, USA (-96.11,+39.83)
Comment: NCAR CLASS data using a Vaisala sonde
Surface Skin Temperature: 278.2 K (HIS estimate)
Surface Skin Emissivity: Unknown (land surface)
Surface Altitude: 0.3840 km
Surface Pressure: 966.0 mb
Surface Air Temperature: 9.5 degrees Celsius
Surface Air Relative Humidity: 53.3 %
Raob Source File: X3011221.62K
Number of Profile Points: 42
Notes:
(1) Raob ends at index 40. Index 41 is an interpolated point. Index 42 is from in-situ ER-2 aircraft measurements.
(2) The upper level H2O retrieval is for diagnostic purposes only and should not be considered a realistic representation of the true atmospheric state.
(3) All other constituents should default to the climatological mean found in the AFGL Mid-latitude Winter atmosphere.
### Table 5.

<table>
<thead>
<tr>
<th>Index</th>
<th>Altitude (km)</th>
<th>Pressure (mb)</th>
<th>OBS Temp (K)</th>
<th>OBS RH (%)</th>
<th>OBS H2O ppmV</th>
<th>CO2 (g/kg)</th>
<th>RET O3</th>
<th>RET H2O RH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3840</td>
<td>966.0</td>
<td>282.65</td>
<td>53.3</td>
<td>358.0</td>
<td>0.0492E-3</td>
<td>53.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.4139</td>
<td>962.5</td>
<td>284.95</td>
<td>43.5</td>
<td>358.0</td>
<td>0.0492E-3</td>
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Raob Source File: GPX03120.CLS / ECC SONDE 4A3061
Number of Profile Points: 50

Notes:
(1) The CLASS sounding was used from the surface to 43 mb. The temperature above this level was obtained from the 1 Nov 18:30 UTC ozone sonde as was the entire ozone profile. The H2O profile above 43 mb has been set to 1 %.
(2) All other constituents should default to the climatological mean found in the AFGL U.S. Standard Atmosphere.

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Table 6. GPXN0111.TXT

Filename: GPXN0111.TXT (Created 30 August 1993 ROK)
Date: 1 November 1988
Time: 11:30 UTC
Location: Denver, Colorado USA (-104.867,+39.767)
Comment: Combined NCAR CLASS and ECC Ozone sonde data
Surface Skin Temperature: Unknown
Surface Skin Emissivity: Unknown
Surface Altitude: 1.6100 km
Surface Pressure: 840.7 mb
Surface Air Temperature: 4.9 degrees Celsius
Surface Air Relative Humidity: 37.0 %
Raob Source File: GPXN0111.CLS / ECC SONDE 4A3061
Number of Profile Points: 50
Notes:
(1) The CLASS sounding was used from the surface to 60.8 mb. The
temperature above this level was obtained from the 1 Nov 18:30 UTC
ozone sonde as was the entire ozone profile. The H2O above
60.8 mb has been set to 1 %.
(2) All other constituents should default to the climatological mean
found in the AFGL U.S. Standard Atmosphere.

Recommended Profile Values:

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<th>Altitude (km)</th>
<th>Pressure (mb)</th>
<th>Temp (C)</th>
<th>H2O RH (%)</th>
<th>CO2 (ppmv)</th>
<th>O3 (ppmv)</th>
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36  19.3638  60.8  -65.1  2.0  349.0  1.300  
37  19.9640  49.2  -60.8  1.0  349.0  2.274  
38  20.7690  43.0  -57.5  1.0  349.0  2.956  
39  21.6010  33.5  -56.3  1.0  349.0  3.631  
40  23.1810  26.1  -56.7  1.0  349.0  5.030  
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43  28.0910  15.6  -49.9  1.0  349.0  5.829  
44  29.8280  11.9  -50.2  1.0  349.0  6.530  
45  31.5420  9.2  -49.9  1.0  349.0  6.115  
46  33.3200  7.0  -50.1  1.0  349.0  6.116  
47  36.7370  4.2  -42.4  1.0  349.0  6.197  
48  38.3900  3.3  -36.5  1.0  349.0  5.042  
49  39.6380  2.8  -31.1  1.0  349.0  4.400  

The HIS radiance files are too large to print in their entirety, so only the first 25 lines of the files are included in tables 7-10.

Table 7.  14 April 1986  HIS Radiance data

FILENAME: HIS104B1.ASC  
COMMENT: DOWNLOOKING HIS DATA BAND 1 (UWITRA93)  
DATE:  14 APRIL 1986  
TIME:  18:00 UTC  
LOCATION: PACIFIC OCEAN OFF CALIFORNIA COAST (-120.5,+34.7)  
OBSERVATION ALTITUDE: 19.637 km (NASA U2)  
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)  
SPECTRAL RESOLUTION (UNAPODIZED): 0.3640322 CM-1  
REFERENCE WAVENUMBER (VO): 564.2500  
WAVENUMBER INCREMENT (DV): 0.2755127  
NUMBER OF RADIANCE VALUES IN THIS FILE: 1743  
WAVENUMBER UNITS: CM**-1  
RADIANCE UNITS: mW/(M**2 CM**-1 SR)  
NOTES:  
(1) Use the following formula to compute the correct  
  wavenumber value corresponding to the index number provided.  
  \[ V = V_0 + DV \times FLOAT(INDEX-1) \]  (Double Precision)  

HIS MEASUREMENT:  
INDEX  RADIANCE  
131  54.7433  
132  88.8154  
133  103.5435  
134  107.2112

FILENAME: HIS104B2.ASC  
COMMENT: DOWNLOOKING HIS DATA BAND 2 (UWITRA93)  
DATE:  14 APRIL 1986  
TIME:  18:00 UTC  
LOCATION: PACIFIC OCEAN OFF CALIFORNIA COAST (-120.5,+34.7)  
OBSERVATION ALTITUDE: 19.637 km (NASA U2)  
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)  
SPECTRAL RESOLUTION (UNAPODIZED): 0.6370564 CM-1  
REFERENCE WAVENUMBER (VO): 987.43750  
WAVENUMBER INCREMENT (DV): 0.4821472
NUMBER OF RADIANCE VALUES IN THIS FILE: 1494
WAVENUMBER UNITS: CM**-1
RADIANCE UNITS: mW/(M**2 CM**-1 SR)
NOTES:
(1) Use the following formula to compute the correct
wavenumber value corresponding to the index number provided.
V = V0 + DV * FLOAT(INDEX-1) (Double Precision)

HIS MEASUREMENT:
INDEX RADIANCE
194 68.0208
195 63.9362
196 65.1847
197 66.5262

FILENAME: HIS104B3.ASC
COMMENT: DOWNLOOKING HIS DATA BAND 3 (UWITRA93)
DATE: 14 APRIL 1986
TIME: 18:00 UTC
LOCATION: PACIFIC OCEAN OFF CALIFORNIA COAST (-120.5,+34.7)
OBSERVATION ALTITUDE: 19.637 km (NASA U2)
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.6370564 CM-1
REFERENCE WAVENUMBER (V0): 1974.8750
WAVENUMBER INCREMENT (DV): 0.4821472
NUMBER OF RADIANCE VALUES IN THIS FILE: 1452
WAVENUMBER UNITS: CM**-1
RADIANCE UNITS: mW/(M**2 CM**-1 SR)
NOTES:
(1) Use the following formula to compute the correct
wavenumber value corresponding to the index number provided.
V = V0 + DV * FLOAT(INDEX-1) (Double Precision)

INDEX RADIANCE
54 4.0110
55 4.0897
56 4.1655
57 4.2416

Table 8. 1 March 1992 HIS Radiance data

FILENAME: HIS1MRB1.TXT
COMMENT: DOWNLOOKING HIS DATA BAND 1 (UWITRA93)
DATE: 1 MARCH 1992
TIME: 12:21 UTC
LOCATION: SENECA, KANSAS, USA (-96.11,+39.83)
OBSERVATION ALTITUDE: 19.725 km (NASA ER-2)
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.3224285 CM-1
REFERENCE WAVENUMBER (V0): 564.2500 CM-1
WAVENUMBER INCREMENT (DV): 0.2755127 CM-1
NUMBER OF RADIANCE VALUES IN THIS FILE: 1743
WAVENUMBER UNITS: CM-1
RADIANCE UNITS: mW/(M**2 CM-1 SR)
NOTES:
(1) Use the following formula to compute the correct
wavenumber value corresponding to the index number provided.
V = V0 + DV * FLOAT(INDEX-1) (Double Precision)
HIS MEASUREMENT:
INDEX  RADIANCE
131  59.2751
132  92.1262
133 108.6515
134 110.7373

FILENAME: HIS1MRB2.TXT
COMMENT: DOWNLOOKING HIS DATA BAND 2 (UWITRA93)
DATE:  1 MARCH 1992
TIME: 12:21 UTC
LOCATION: SENECA, KANSAS, USA (-96.11,+39.83)
OBSERVATION ALTITUDE: 19.725 km (NASA ER-2)
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.6809913 CM-1
REFERENCE WAVENUMBER (V0): 987.4375 CM-1
WAVENUMBER INCREMENT (DV): 0.4821472 CM-1
NUMBER OF RADIANCE VALUES IN THIS FILE: 1494
WAVENUMBER UNITS: CM-1
RADIANCE UNITS: mW/(M**2 CM-1 SR)

NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
   \[ V = V_0 + DV \times \text{FLOAT(INDEX-1)} \] (Double Precision)

HIS MEASUREMENT:
INDEX  RADIANCE
194  54.2272
195  55.7616
196  54.9653
197  54.4897

FILENAME: HIS1MRB3.TXT
COMMENT: DOWNLOOKING HIS DATA BAND 3 (UWITRA93)
DATE: 1 MARCH 1992
TIME: 12:21 UTC
LOCATION: SENECA, KANSAS, USA (-96.11,+39.83)
OBSERVATION ALTITUDE: 19.725 km (NASA ER-2)
OBSERVATION VIEW ANGLE: NADIR TO EARTH (DOWNLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.9642944 CM-1
REFERENCE WAVENUMBER (V0): 1974.875 CM-1
WAVENUMBER INCREMENT (DV): 0.4821472 CM-1
NUMBER OF RADIANCE VALUES IN THIS FILE: 1452
WAVENUMBER UNITS: CM-1
RADIANCE UNITS: mW/(M**2 CM-1 SR)

NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
   \[ V = V_0 + DV \times \text{FLOAT(INDEX-1)} \] (Double Precision)

HIS MEASUREMENT:
INDEX  RADIANCE
54  3.0723
55  3.1365
56  3.1947
57  3.2477
Table 9.  31 Oct 1988 HIS Radiance data

FILENAME: GPXO31B1.TXT
COMMENT: UPLOOKING GAPEX HIS DATA BAND 1 (UWITRA93)
DATE:  31 OCTOBER 1988
TIME:  20:36 UTC
LOCATION: DENVER, COLORADO, USA (-104.867, +39.767)
OBSERVATION ALTITUDE: SURFACE
OBSERVATION VIEW ANGLE: VERTICAL TO SPACE (UPLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.3640322 CM-1
REFERENCE WAVENUMBER (V0): 564.2500 CM-1
WAVENUMBER INCREMENT (DV): 0.2755127 CM-1
NUMBER OF RADIANCE VALUES IN THIS FILE: 1743
WAVENUMBER UNITS: CM-1
RADIANCE UNITS: mW/(M**2 CM-1 SR)
NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
V = V0 + DV * FLOAT(INDEX-1) (Double Precision)
HIS MEASUREMENT:
INDEX RADIANCE
131 145.8298
132 134.9205
133 117.6674
134  88.6085

FILENAME: GPXO31B2.TXT
COMMENT: UPLOOKING GAPEX HIS DATA BAND 2 (UWITRA93)
DATE:  31 OCTOBER 1988
TIME:  20:36 UTC
LOCATION: DENVER, COLORADO, USA (-104.867, +39.767)
OBSERVATION ALTITUDE: SURFACE
OBSERVATION VIEW ANGLE: VERTICAL TO SPACE (UPLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.9642944 CM-1
REFERENCE WAVENUMBER (V0): 987.4375 CM-1
WAVENUMBER INCREMENT (DV): 0.9642944 CM-1
NUMBER OF RADIANCE VALUES IN THIS FILE: 747
WAVENUMBER UNITS: CM-1
RADIANCE UNITS: mW/(M**2 CM-1 SR)
NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
V = V0 + DV * FLOAT(INDEX-1) (Double Precision)
HIS MEASUREMENT:
INDEX RADIANCE
 98 2.5099
 99 5.9017
100 -0.8277
101 5.4657

Table 10.  1 Nov 1988 HIS Radiance data

FILENAME: GPXN01B1.TXT

15
COMMENT: UPLOOKING GAPEX HIS DATA BAND 1 (UWITRA93)
DATE: 1 NOVEMBER 1988
TIME: 11:30 UTC
LOCATION: DENVER, COLORADO, USA (-104.867, +39.767)
OBSERVATION ALTITUDE: SURFACE
OBSERVATION VIEW ANGLE: VERTICAL TO SPACE (UPLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.3640322 CM⁻¹
REFERENCE Wavenumber (V₀): 564.2500 CM⁻¹
WAVENUMBER INCREMENT (DV): 0.2755127 CM⁻¹
NUMBER OF RADIANCE VALUES IN THIS FILE: 1743
WAVENUMBER UNITS: CM⁻¹
RADIANCE UNITS: mW/(M² CM⁻¹ SR)
NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
\[ V = V₀ + DV \times \text{FLOAT(INDEX)} \] (Double Precision)
HIS MEASUREMENT:
INDEX RADIANCE
131 129.7319
132 121.7713
133 107.3717
134 77.4460

FILENANE: GPXN01B2.TXT
COMMENT: UPLOOKING GAPEX HIS DATA BAND 2 (UWITRA93)
DATE: 1 NOVEMBER 1988
TIME: 10:30 UTC
LOCATION: DENVER, COLORADO, USA (-104.86'7, +39.767)
OBSERVATION ALTITUDE: SURFACE
OBSERVATION VIEW ANGLE: VERTICAL TO SPACE (UPLOOKING)
SPECTRAL RESOLUTION (UNAPODIZED): 0.9642944 CM⁻¹
REFERENCE Wavenumber (V₀): 987.4375 CM⁻¹
WAVENUMBER INCREMENT (DV): 0.9642944 CM⁻¹
NUMBER OF RADIANCE VALUES IN THIS FILE: 747
WAVENUMBER UNITS: CM⁻¹
RADIANCE UNITS: mW/(M² CM⁻¹ SR)
NOTES:
(1) Use the following formula to compute the correct wavenumber value corresponding to the index number provided.
\[ V = V₀ + DV \times \text{FLOAT(INDEX)} \] (Double Precision)
HIS MEASUREMENT:
INDEX RADIANCE
98 1.6226
99 5.2298
100 0.3932
101 4.8593

The contents of the UWITRA93 dataset are best represented graphically. Figures 1-5 represent the radiosonde measurements for the four case days. Figures 6-9 represent the HIS radiance spectra corresponding to those days. In addition to the observed data, the retrieved profiles of ozone and upper level water vapor are included in the downlooking cases.
Figure 1a. 14 April 1986 Observed temperature and moisture profiles.
Figure 2a. 1 March 1992 Observed temperature and moisture profiles.
Figure 2b. 1 March 1992 Retrieved ozone and upper level H2O profiles.
Figure 3. 31 October 1988 Observed temperature and moisture profiles.
Figure 4. 1 November 1988 Observed temperature and moisture profiles.
Figure 5. GAPEX Observed ozone profile. 1 November 1988 18:30 UTC.
Figure 6a. 14 April 1986  HIS observed radiance data. Band I.
Figure 6b. 14 April 1986  HIS observed radiance data. Band II.
Figure 6c. 14 April 1986 HIS observed radiance data. Band III.
Figure 7a. 1 March 1992 HIS observed radiance data. Band I.
Figure 7b. 1 March 1992  HIS observed radiance data. Band II.
Figure 7c. 1 March 1992  HIS observed radiance data. Band III.
Figure 8a. 31 October 1988  HIS observed radiance data. Band I.
Figure 8b. 31 October 1988 HIS observed radiance data. Band II.
Figure 9a. 1 November 1988 HIS observed radiance data. Band I.
Figure 9b. 1 November 1988  HIS observed radiance data. Band II.
C. Comparison to FASCODE

The line-by-line radiative transfer model developed at the United States Air Force Phillips Laboratory (formerly the Geophysics Laboratory, AFGL) is the Fast Atmospheric Signature CODE (FASCODE). A recent version of the FASCODE model was used to calculate the upwelling (or downwelling) radiance using the atmospheric state data provided in the UWITRA93 data set. This section contains the preliminary results of comparing the observed radiances to the calculated spectra using the balloon sonde data to define the atmospheric state.

FASCODE version three (FASCOD3P, March 1992) was used on an IBM RS/6000 computer running the IBM unix operating system AIX. The HITRAN92 database was also used as input to the program LNFL92 containing the line mixing parameters to create an input line datafile for use with FASCOD3P. The FASCODE model results, at the very high resolution of the natural atmosphere, were reduced in spectral resolution to carefully match the observation. The method of spectral resolution reduction was to perform a Fast Fourier Transform (FFT) upon the spectral data then truncate the resulting interferogram at the resolution of the instrument data and transform back into the spectral domain. This resolution reduction process accurately matches the calculated spectral resolution to the observed data and samples the atmospheric spectrum at the same points sampled by the HIS instrument.

The observed-minus-calculated differences were formed for both the measured temperature and moisture profiles and for the case where the measured moisture profile was replaced by a retrieved moisture profile above 500 mb. The resulting differences, given in Figures 10-13, are a preliminary result. The FASCOD3P runs are subject to review and possible revision, however the principal features shown are consistent with previous results.
April 14, 1986 Pacific Ocean

Figure 10a. 14 April 1986 HIS observed minus FASCOD3P calculation. Band 1.
Figure 10b. 14 April 1986  HIS observed minus FASCOD3P calculation. Band II.
Figure 10c. 14 April 1986 HIS observed minus FASCOD3P calculation. Band III.
March 1, 1992  Seneca, Kansas

Figure 11a.  1 March 1992  HIS observed minus FASCOD3P calculation.  Band I.
March 1, 1991  Seneca, Kansas

![Graph showing radiance vs. wavenumber]

- HIS - RAOB
- HIS - RET
March 1, 1992 Seneca, Kansas

Figure 11c. 1 March 1992 HIS observed minus FASCOD3P calculation. Band III.
Figure 12a. 31 October 1988 HIS observed minus FASCOD3P calculation. Band I.
Figure 12b. 31 October 1988 HIS observed minus FASCOD3P calculation. Band II.
Figure 13a. 1 November 1988 HIS observed minus FASCOD3P calculation. Band I.
Figure 13b. 1 November 1988 HIS observed minus FASCOD3P calculation. Band II.
The detailed comparison of HIS observations with FASCOD3P calculations given in Figures 10-13 needs some interpretation. There are three possible sources of error in the comparisons: (1) HIS instrumental error whether random or systematic, (2) uncertainty in the characterization of the atmospheric state, and (3) model errors either in the HITRAN92 database or the FASCOD3P program. The possible additional error caused through improper matching of spectral resolutions or spectral point sampling is believed to be negligible because of the extreme care taken to match the calculation to the observation.

The random instrumental error has been minimized through the use of temporal averaging of spectra, however, due to the nature of the measurement, the noise near the band edges is enhanced relative to the remainder of the band. Since the data has been corrected for the instrument finite field of view, no known systematic bias is present in the HIS data contained within UWITRA93.

The characterization of the atmospheric state depends on 1) the random and systematic errors in the sondes used, 2) the time and space coincidence of the in situ sonde measurement compared to the remotely sensed radiance measurement, 3) the number and choice of atmospheric levels used to define the atmosphere, and 4) the presence or absence of aerosols and cloud. All cases are nominally clear, but the 14 April 1986 is suspected of containing some cirrus contribution. There was no lidar data available for any of these cases. The 14 April 1986 case is also the only one which uses National Weather Sonde (NWS) data, in addition, it is an area average of four sondes launched from coastal radiosonde stations. In all other cases the balloon data is from spatially coincident NCAR CLASS launch sites using state-of-the-art Vaisala sonde packages. The 14 April 1986 case is also reported only at "significant levels" whereas the CLASS data have been edited through manual selection to reduce the 10 second data (>400 levels) to about fifty atmospheric levels.

The objective of this work is, of course, to minimize the effects of the first two error sources in order to allow the validation of line-by-line radiative transfer models, such as FASCODE. Model dependent errors can often be readily identified through a process of varying the model parameters and noting the effect on observed minus calculated difference spectra. Some of the issues that HIS data can be used to study are 1) the CO2 line strengths and widths, 2) CO2 line mixing, 3) H2O line strengths throughout the infrared spectrum, 4) H2O continuum contributions and to some extent their temperature dependence, and 5) ozone band strengths. The single largest modeling error currently identified is the H2O foreign broadened continuum in the region 1200-2000 cm⁻¹. The HIS data included in UWITRA93 is most useful for studying this effect in the region 1200-1800 cm⁻¹ as is evident by inspection of figures 10b, 11b, 12b, and 13b. An empirical correction to the H2O foreign continuum has been obtained from these and other FTS measurements.
III. H2O CONTINUUM VALIDATION

Another of the major tasks performed under this contract was the preliminary determination of a correction factor for the foreign-broadened water vapor continuum as implemented in FASCOD3P (March 1992 release) based on available atmospheric measurements using instrumentation developed at the University of Wisconsin.

A. Background

The continuum contribution of H2O is divided into a "self"-broadened (i.e. H2O-H2O collision induced) and a "foreign"-broadened (i.e. N2-H2O collision induced) portion with varying strengths in different spectral regions. The total water vapor absorption (or emission) spectrum is a superposition of both line and continuum contributions at each wavelength in the infrared.

The water vapor continuum as implemented in FASCOD3P (and FASCOD2) is divided into three parts; the self-broadened cross-section at both 296K and 260K and the foreign-broadened cross-section at 296K. Thus the self-broadened continuum is implemented as a temperature dependent function whereas the foreign-broadened continuum implementation does not have temperature dependence. Each of these cross-sections is defined (using data statements) at 1 cm⁻¹ intervals from zero to 5000 cm⁻¹ using a definition proposed by Clough, Kneizys, and Davies based upon laboratory measurements.

The absorption and emission of radiation by the water vapor molecule at infrared wavelengths plays a very important role in the radiation balance of the earth-atmosphere system. In certain relatively transparent spectral regions the water vapor continuum has the dominant contribution to the greenhouse trapping of heat emitted by the earth's surface, thus indirectly influencing the earth's average temperature. In addition to climate applications, accurate knowledge of the water vapor continuum is important for remote sensing of the atmosphere. In particular, the retrieval of water vapor profiles from infrared data is strongly biased by the foreign broadened continuum error which impacts strongly the radiation from the 6.3 micron water vapor band.

B. Review of Spectroscopy in the Water Vapor Band

Four cases were used in the determination of a correction to the water vapor foreign continuum, three of these are included in the UWITRA93 data set; 14 April 1986 (downlooking), 1 March 1992 (downlooking), and 31 October 1988 (uplooking). The fourth case (uplooking) was from the SPECTral Radiance Experiment in Coffeyville, Kansas obtained using the Atmospheric Emitted Radiance Interferometer (AERI) on 18 November 1991. The AERI data is particularly useful for analysis in the 1850 - 2000 cm⁻¹ spectral region where HIS data is not available. The AERI was developed at the University of Wisconsin as a groundbased observing system of downwelling radiance for use in the Department of Energy Atmospheric Radiance Measurement program.

The spectroscopic details relevant to the middle infrared region are summarized in figures 14-17 below. Figure 14 shows a portion of the HIS spectrum obtained 31 October 1988 as an apodized radiance (BEER apodization). Figure 15 shows a difference spectrum obtained using FASCOD3P and the HITRAN92 database illustrating a feature near 1350 cm⁻¹ which has been identified as the foreign-broadened water vapor continuum. Figure 16 compares graphically the foreign continuum residual for
three distinct atmospheres. Note that the wavenumbers which are sensitive to this effect appear to change depending upon air mass and also are different for the uplooking from the surface and the downlooking from 20 km altitude cases. Figure 17 shows the effect dividing the foreign continuum cross-section by a factor of four at all wavenumbers. This indicates that a wavenumber dependent reduction factor is required to fit the data properly.

C. Preliminary Foreign-broadened Correction Function

In order to make a "first cut" estimate of the wavenumber dependent function required to correct the foreign-broadened water vapor continuum, a modification to FASCOD3P was made to allow for a constant factor to multiple the foreign-broadened cross-section contained in data statements in the FASCOD3P program. A series of FASCODE runs were made with various reduction factors for each of the four cases indicated and the radiance difference plots compared. For each case a set of wavenumbers was selected which appeared to provide significant information on the continuum contribution and an estimate of the continuum reduction factor required to minimize the observed minus calculated difference was obtained. Figure 18 shows the data points obtained from this process as well as an approximate model of the data. The function used to model the data points is given as

\[ R(v) = a \times (1 - b \times (v/v_o)^c \times \sin(2\pi(v-v_o)/d)^2)^{-1}, \]

and

\[ C_{f,new}(v) = C_f(v) / R(v), \]

where \(a, b, c,\) and \(d\) are parameters of the model and \(v\) refers to wavenumber. Through a process of manual adjustment of parameters and allowing for variability in the estimation of each of the HIS/FASCODE data points the following set of parameters was determined to provide a best estimate of the foreign-broadened water vapor continuum correction:

\( a = 1.15, \quad b = 0.74, \quad c = 0.6, \quad d = 1000, \quad v_o = 1610 \ cm^{-1}, \) for \( 1100 \ cm^{-1} < v < 2100 \ cm^{-1} \)

As is clear from the scatter of points in figure 18, the magnitude of the water vapor foreign continuum correction is somewhat uncertain from this initial estimate from HIS/AERI data. However, the importance of the spectral region affected to climate and remote sensing research is such that it is imperative that this initial estimate be refined and/or verified by more sophisticated analysis techniques and with additional quality measurement comparisons. One of the tasks for which future funding is desired is the implementation of this functional correction into a modified version of FASCODE and the validation of the functional form of the correction against both historical and recent HIS/AERI radiance measurements.

Furthermore, a comparison of this correction function to another independent functional form found by Jean-Marc Theriaux of the Canada Defense Institute of Quebec, Canada is shown in figure 19. This figure shows that the two estimates, one using radiance data and the other using transmission measurements, are in quite reasonable agreement in the overall size and shape of the required correction. The differences between the estimated corrections in the 1800-2000 cm\(^{-1}\) region are of considerable interest and further analysis to understand the reasons for the differences would be appropriate.

Finally, a comparison of the corrected foreign-broadened cross-section derived from HIS data with the original FASCOD3P continuum cross-section is given in Figure 20.
Figure 14. HIS observation from 31 October 1988 used in continuum analysis.

High-resolution Interferometer Sounder (HIS) Observation
Figure 15. Calculated minus observed difference showing remaining spectroscopic issues.

Spectroscopy with the HIS, 1993

FASCOD3P/HITRAN92 minus HIS Observation

Cross-sections are included in calculations

- O₃ Profile Not Measured
- Foreign Broadened Water Vapor Continuum Too Strong
- Remaining Issues With Water & CO₂

Radiance (mW/m² sr cm⁻¹)

Wavenumber (cm⁻¹)

University of Wisconsin, GAPEX Expt.
Denver, CO 31 Oct 1988 14:24 UTC
Figure 16. Summary of foreign continuum induced errors shown as apodized radiance.
Figure 17. Summary of foreign continuum reduced by a constant factor of four.
Figure 18. Water vapor foreign continuum correction factor compared to AERI/HIS data.
Figure 19. Comparison of two independent determinations of required foreign-broadened water vapor continuum correction.
Figure 20. Original and corrected foreign-broadened water vapor continuum cross-sections.
IV. SUMMARY AND FUTURE WORK

As described in the text of the report, the main tasks performed under this contract were the preparation of a data set of observed radiances and associated atmospheric state observations for use in the validation of line-by-line radiative transfer models, and the deduction of a correction function for the foreign-broadened water vapor continuum contribution as defined in the March 1992 release of FASCOD3. In addition, the above mentioned data set (UWITRA93) was delivered to the chairperson of the ITRA working group for further distribution and the preliminary water vapor continuum results were presented at the annual review conference at Phillips laboratory.

Future work would include refinement of the parameters of the water vapor foreign-broadened continuum correction function through incorporation of the function into the FASCOD3P program and performing new calculations for the original cases. Also the number of cases studied would be increased, in particular, to include recent data from the Convection and Moisture Experiment (CAMEX, Wallops Island, VA, Sept-Oct 1993). CAMEX has an exceptional amount of ground truth with multiple coincident temperature and moisture radiosondes, ozone soundings, and raman lidar data. CAMEX also has coincident downlooking aircraft data from the HIS and uplooking data from the surface based AERI instrument which will provide additional useful constraints on the radiative transfer validation.