A PC-based ITPP-3 Synthetic Retrieval Package

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Introduction

The International TOVS Processing Package (ITPP) has been made available by CIMSS (Smith et al, 1985) for user evaluation and experimentation, for alternative algorithm development, and for comparison of algorithm performances. The ITPP version 3 (ITPP-3) includes the simultaneous retrieval procedure. Two of the authors (Gumley et al, 1988) have evaluated the ITPP-3 against a data set comprising simultaneously acquired NOAA polar orbiter data and ship sondes (the latter supported with sea surface temperature information) released during cruises off the coast of Western Australia. This work was directed specifically at recovering the lower level temperature and moisture structure and studying the implications of these profiles for microwave signal ducting (Lynch et al, 1988).

Using the DEC-VAX version of the ITPP-3 code, difficulties were experienced obtaining retrieved profiles that were consistent with observations (Figure 1). We had also found that different retrievals were returned depending on whether a full orbit or an orbit subset (typically a 10*10 FOV) was processed. This difficulty was reported to CIMSS (Gumley, 1988). It also should be stressed that these retrievals were made under quite severe conditions; that is, without the support of a forecast model to guide the first guess and without the input of surface data. The former was not available routinely and the latter, while measured from shipboard instrumentation, would not normally be available and here was to be used as the verification.

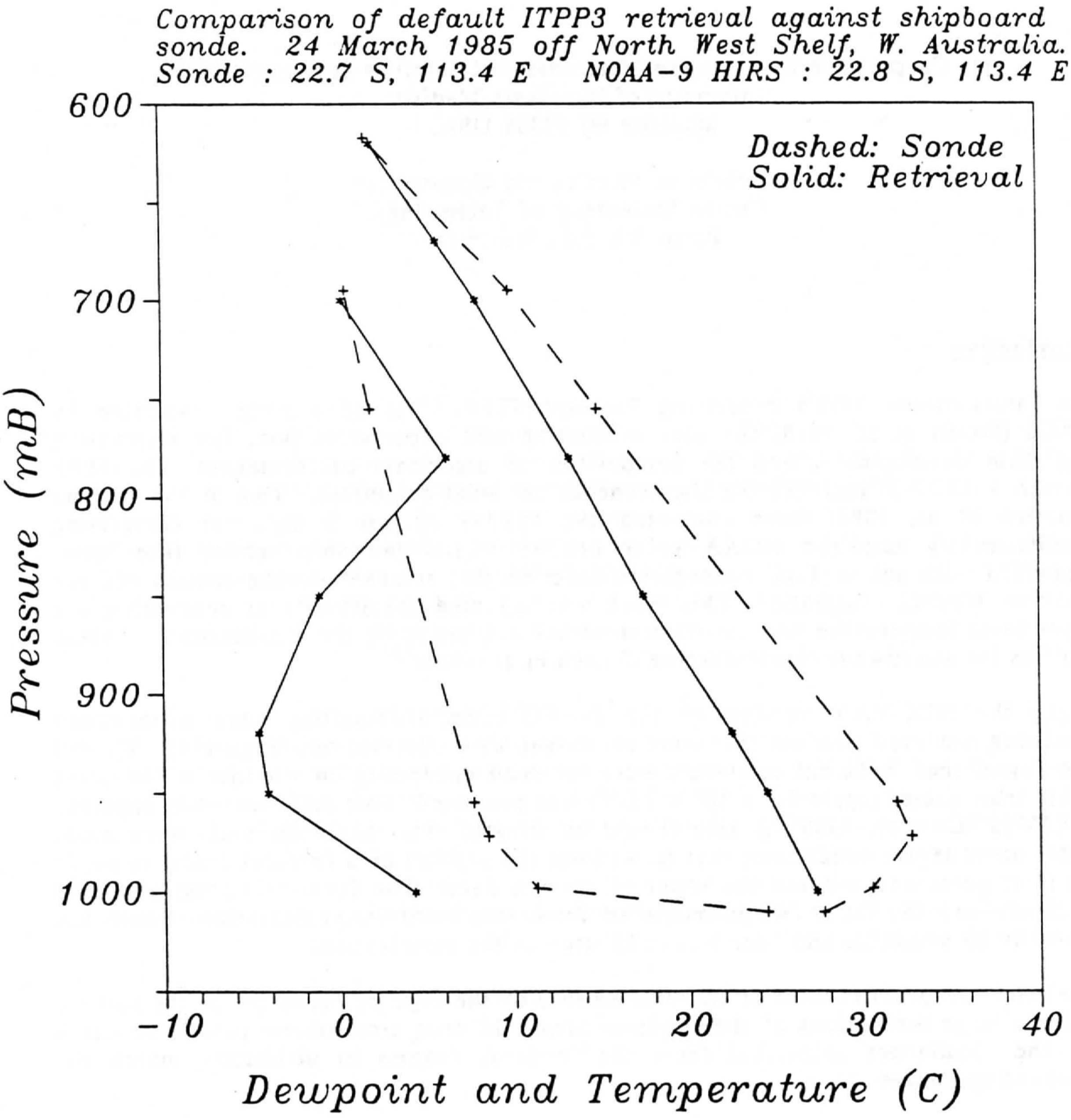
The retrieved profiles were of concern because of the poor performance at the surface and the large oscillations of the retrieval about the true atmospheric profile required for the radiances calculated from the retrieval process to ultimately match the observed radiances.

ITPP-3/PC Implementation

In parallel with developments at the CIMSS (CIMSS, 1988), experience had been gained at Curtin University in porting the ITPP-3 code to the PC environment. The thrust of this work was to produce a well documented retrieval package with training sets for use in graduate teaching programs at Curtin (Lynch, Prata, Waring and

Figure 1

An example of a degraded temperature and moisture retrieval using the ITPP-3 code with a climatology first guess and no surface data.



Comparison of default ITPP3 retrieval against shipboard sonde. 24 March 1985 off North West Shelf, W. Australia.
Sonde : 22.7 S, 113.4 E NOAA-9 HIRS : 22.8 S, 113.4 E

Puchmayer, 1988). This PC-based package was a convenient tool to use in the identification of retrieval problems experienced with the ITPP-3 code when applied to ocean regions off Western Australia. It was decided to develop the PC code initially into a synthetic retrieval package which would permit some experimentation with the way in which the retrieved products responded to perturbations to the synthetic input profiles.

Synthetic Retrieval Software on a PC

The strategy adopted in configuring the ITPP-3 synthetic package to run in the PC environment was to modify the programs which calculate the forward radiances (RAOBHIRS and RAOBMSU) and the retrieval program (TOVRET) and include

(1) development of software tools which would provide interactive capability for the testing of the performance of the retrieval code, including the selection of a range of processing options such as cloud tests, radiance tuning parameters and the first guess profile,

(2) entry of user generated synthetic temperature and moisture profiles and surface parameters for use in the forward radiance calculation,

(3) ability to run the code with satellite/sonde verification data sets for evaluation of performance on real atmospheres.

(4) provision of the diagnostic output data to enable the brightness temperature differences between the forward and retrieved profiles to be compared,

(5) structuring of the code and the internal documentation to simplify the incorporation of user-provided algorithms for estimation of such quantities as surface skin temperature (SKT), surface air temperature, and alternate retrieval schemes.

Evaluation

During the development and testing of this PC-based package the problem with the updating of the moisture guess in TOVRET was identified (Olesen, 1988) and a patch incorporated to rectify the error. Subsequent testing showed that this patch remedied the problem we had experienced in processing subsets of a full orbit (Gumley, 1988).

Initial testing with the synthetic retrieval code was done using a TOVRET climatological first guess profile as input to the forward calculation. The output radiances were then input to TOVRET, and using the same climatological first guess a retrieval was produced. Since TOVRET in these circumstances uses a guess identical to the synthetic profile, the retrieved profile should match the climatological guess. Figure 2 shows the retrieval performance for this situation. It should be noted that in this test the tuning parameters in the forward radiance calculation (gammas=1.0, deltas=0.0) differed from those used in the retrieval (gammas and deltas set to the default values in TOVRET). This was because the forward calculation was assumed to provide a 'true' reference, and hence needed no radiance correction. It should be noted that TOVRET assumes values of gamma and delta which are not necessarily 1.0 and 0.0 respectively.

Figure 3 is a similar test to Figure 2 with the difference that the gammas and deltas in both the forward calculation and the retrieval were made consistent (gammas=1.0, deltas=0.0). It can be seen that the moisture retrieval was degraded as a result of this

Figure 2

A comparison of the synthetic input profile and the retrieval. The forward radiance calculation was performed with the gammas and deltas initialized to 1.0 and 0.0 respectively. The retrieval was performed using the default gammas and deltas.

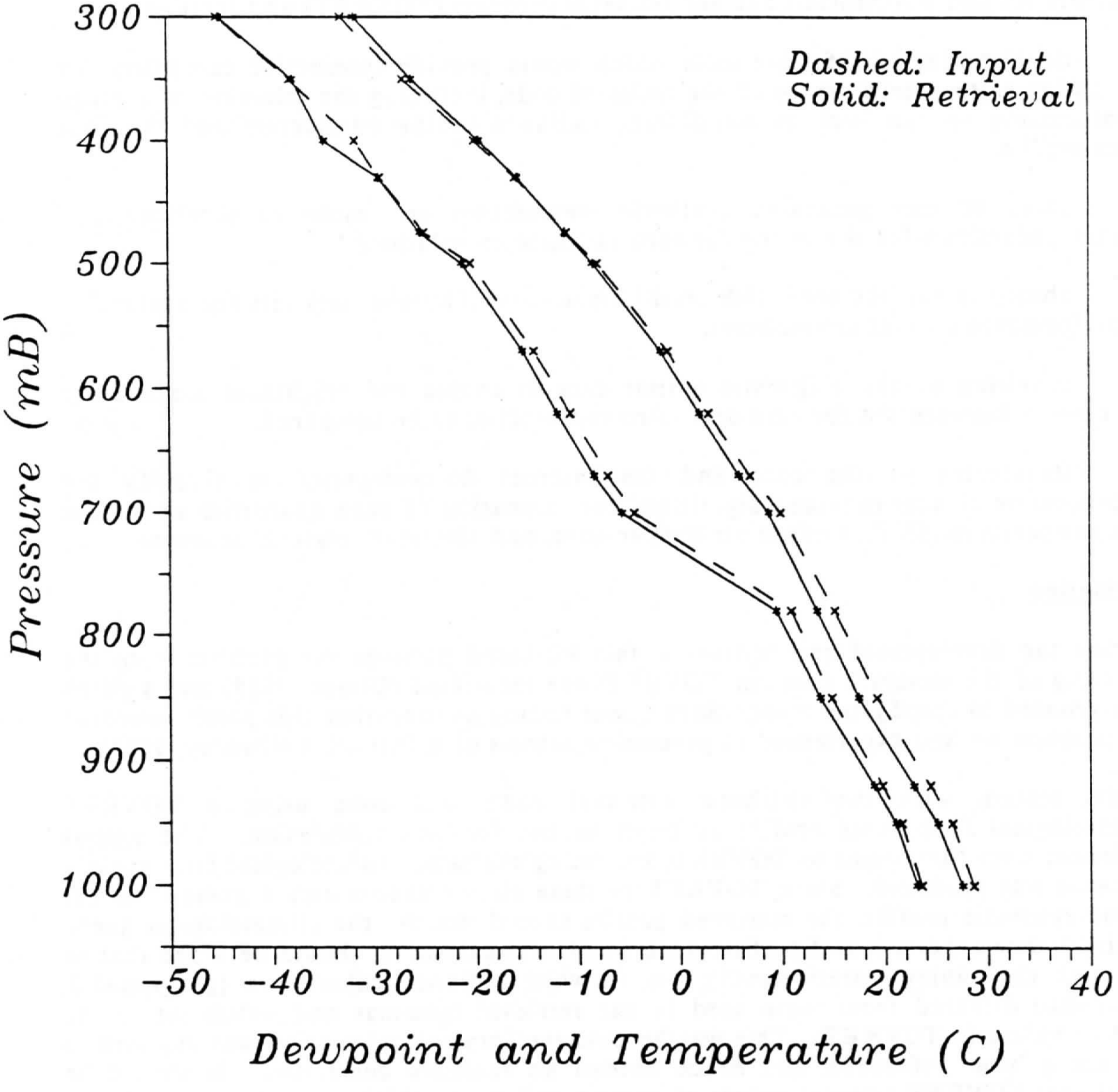
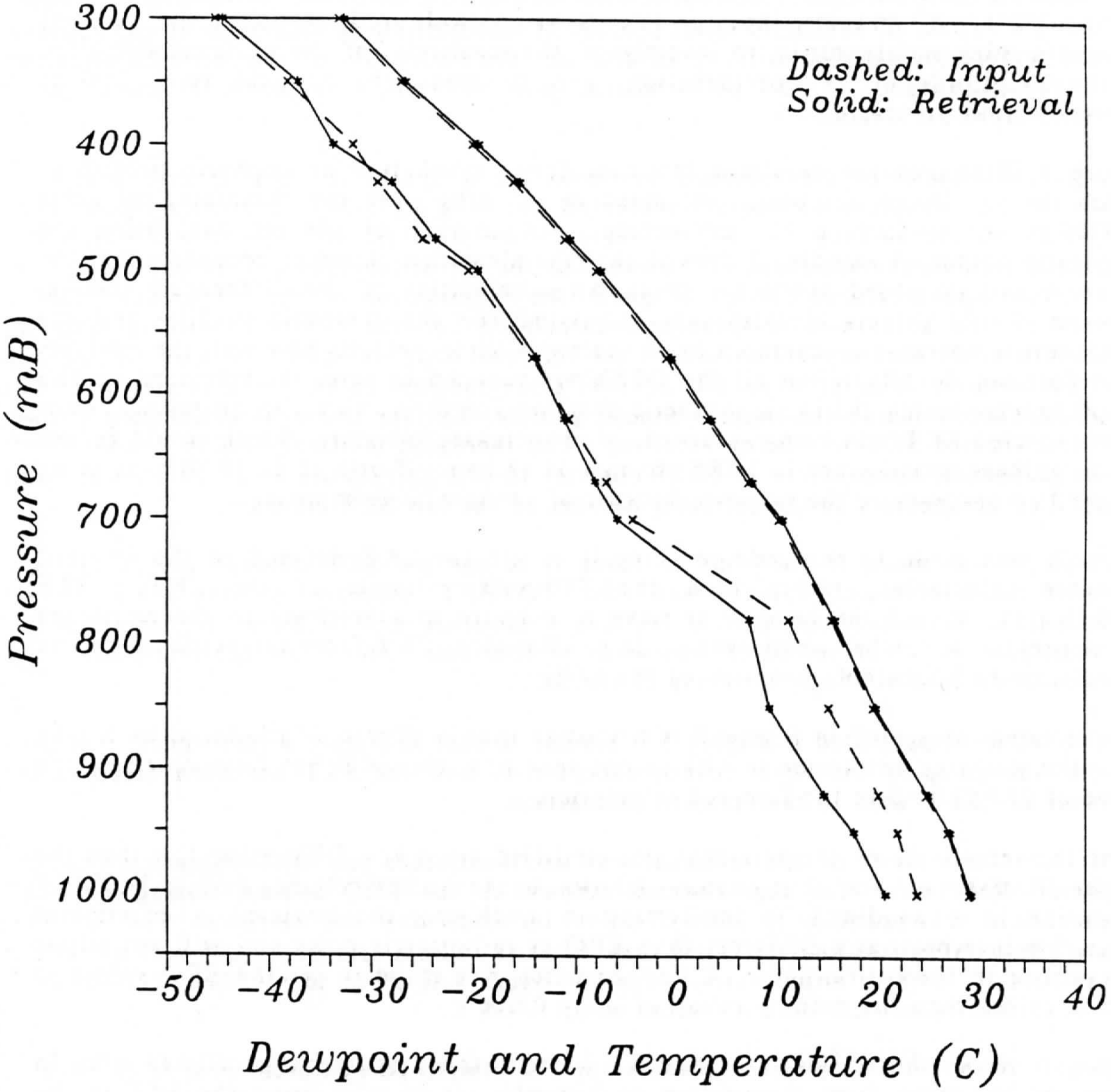


Figure 3

The same input data as used in Figure 2 with the exception that the gammas and deltas in both the forward calculation and the retrieval were initialized to 1.0 and 0.0 respectively. The retrieval is degraded compared with that obtained in Figure 2.



modification. This appears to be due to the TOVRET default gammas and deltas not compensating for a bad SKT estimate, whereas in the previous case, the bad SKT estimate was compensated for. To maintain consistency and enable isolation of the effects of the SKT estimate, the gammas and deltas were set at 1.0 and 0.0 respectively for all subsequent forward and retrieval calculations.

A series of tests were done in which the synthetic input profile was constructed by perturbing the guess profile. For example, the moisture profile near the surface was increased or decreased by increments of several g/kg, then the forward calculation and retrieval done. Similarly, structure such as a boundary layer inversion was embedded in the temperature profile and the response in the retrieved profile studied. Using a variety of synthetic input profiles it was possible to determine if the retrieval was performing satisfactorily, to investigate the sensitivity of the retrieval algorithm to the amplitude of the perturbation, and to study the vertical resolution of thermodynamic structure.

Figure 4 illustrates the resultant retrieval for a synthetic atmospheric profile in which the moisture has been increased by 5 g/kg over the climatological guess profile in the surface to 750 mb region. An analysis of the retrieval using the diagnostic output (Appendix 1) showed that the algorithm failed to recognize that the moisture had increased above the guess. An examination of the differences (DBT's) between the brightness temperatures calculated for the synthetic profile, and the brightness temperatures generated by the retrieval code reflects how well the retrieval is performing. Ideally, when all the DBT's are reduced to zero, the retrieved profile would exactly match the input synthetic profile. For the retrieval in question a lower than expected SKT was being returned. The increased moisture, which would reduce the brightness temperature in HIRS channel 10 (8.3 um) (Smith et al, 1979), was being handled erroneously in the retrieval because of the low SKT estimate.

A patch was made to the code to force it to use the SKT defined in the forward radiance calculation, rather than the TOVRET estimate of the SKT. This modification caused the code to retrieve a moisture profile closer to the moistened input profile. A further patch was made to eliminate SKT from the retrieval matrix calculation to inhibit any lowering of the SKT.

The retrieval presented in Figure 5 is similar to that in Figure 4 (moistened by 5 g/kg over the guess in the lower levels) except that now the SKT has been fixed to the value of 28.6 C used in the forward calculation.

Next the sensitivity of the retrieval was modified since any DBT value less than the preset "RMS error" for that channel (shown by the ERO column during TOVRET execution in Appendix 1) is ineffective in modifying the retrieval. The retrieval algorithm interprets any DBT less than ERO as radiometric noise and will not adjust the profile in these situations. A further patch was made to set the ERO values to 0.25 K rather than the default values of up to 0.8 K.

Figure 6 shows the retrieved profile for the moistened synthetic profile (5 g/kg in excess of the guess from the surface to 750 mb). In this situation the SKT in the retrieval again was set to the value 28.6 C used in the forward calculation. Additionally, the ERO values noted above were invoked. This retrieval shows a good response to the increased mixing ratio in the lower atmosphere. It is clear that a good estimate of the SKT removes the ambiguity in the observed radiances, and when combined with the increased sensitivity to the DBT's, permits the retrieval code to correctly interpret the information in the water vapor channels.

Figure 4

For this example the input profile to the forward calculation is a modification of the climatological guess. The input profile has been moistened by 5 g/kg between 750 mb and the surface. The increased moisture is not recovered in the retrieval.

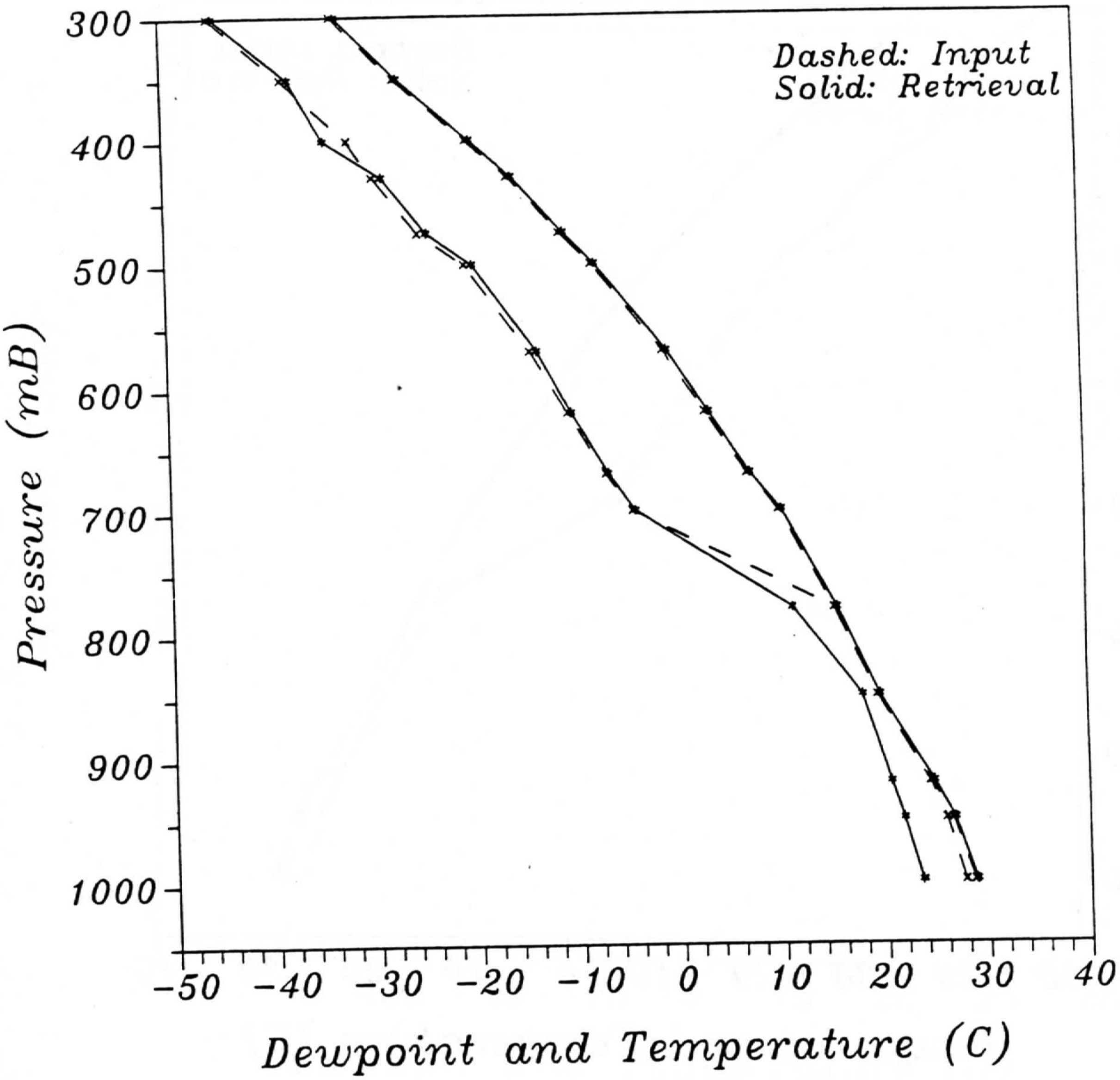


Figure 5

The same input profile as for Figure 4. In the retrieval the surface skin temperature has been assigned the value used in the synthetic input profile (28.6 C). The moisture profile is somewhat improved in the surface to 750 mb region.

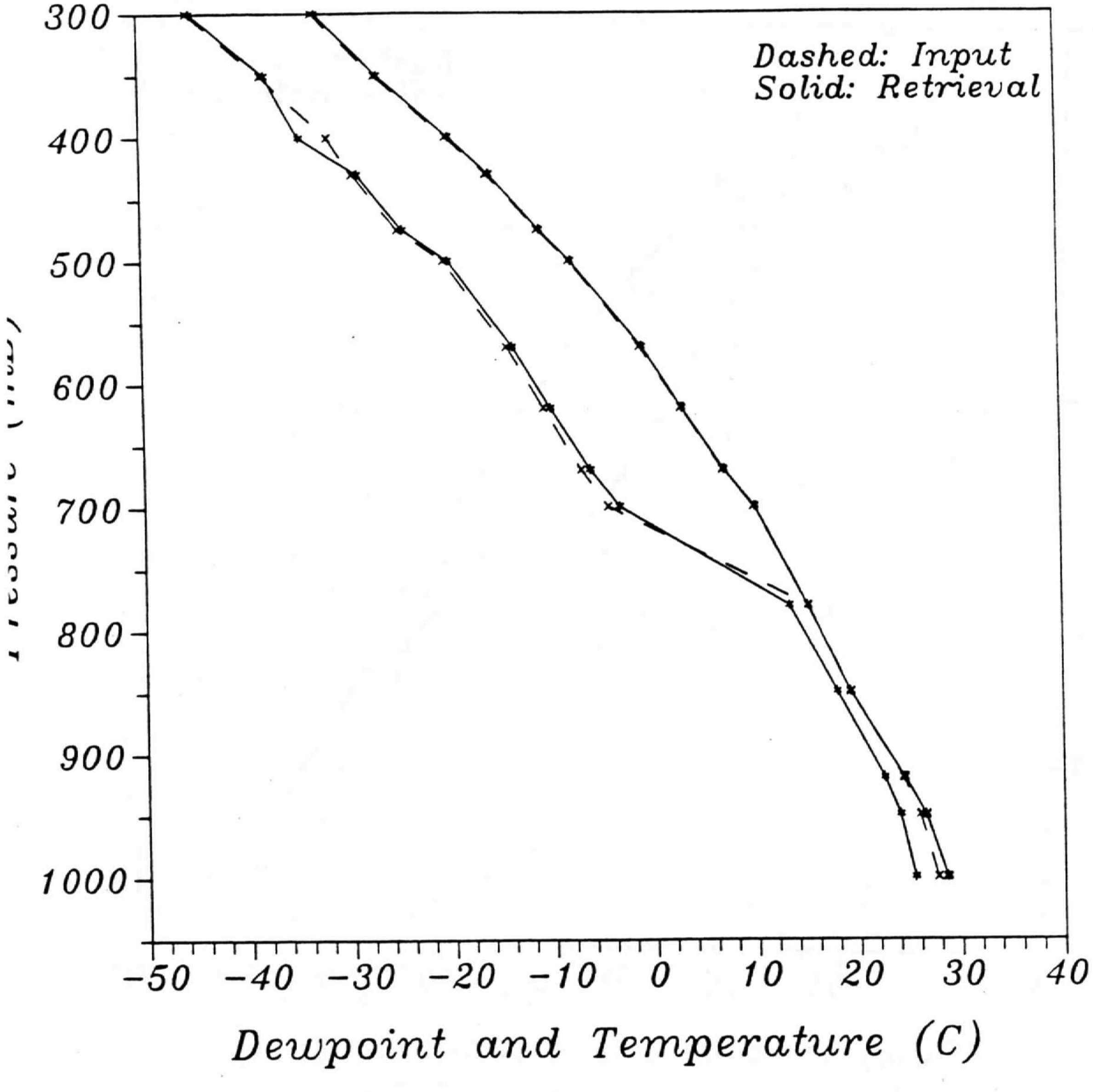
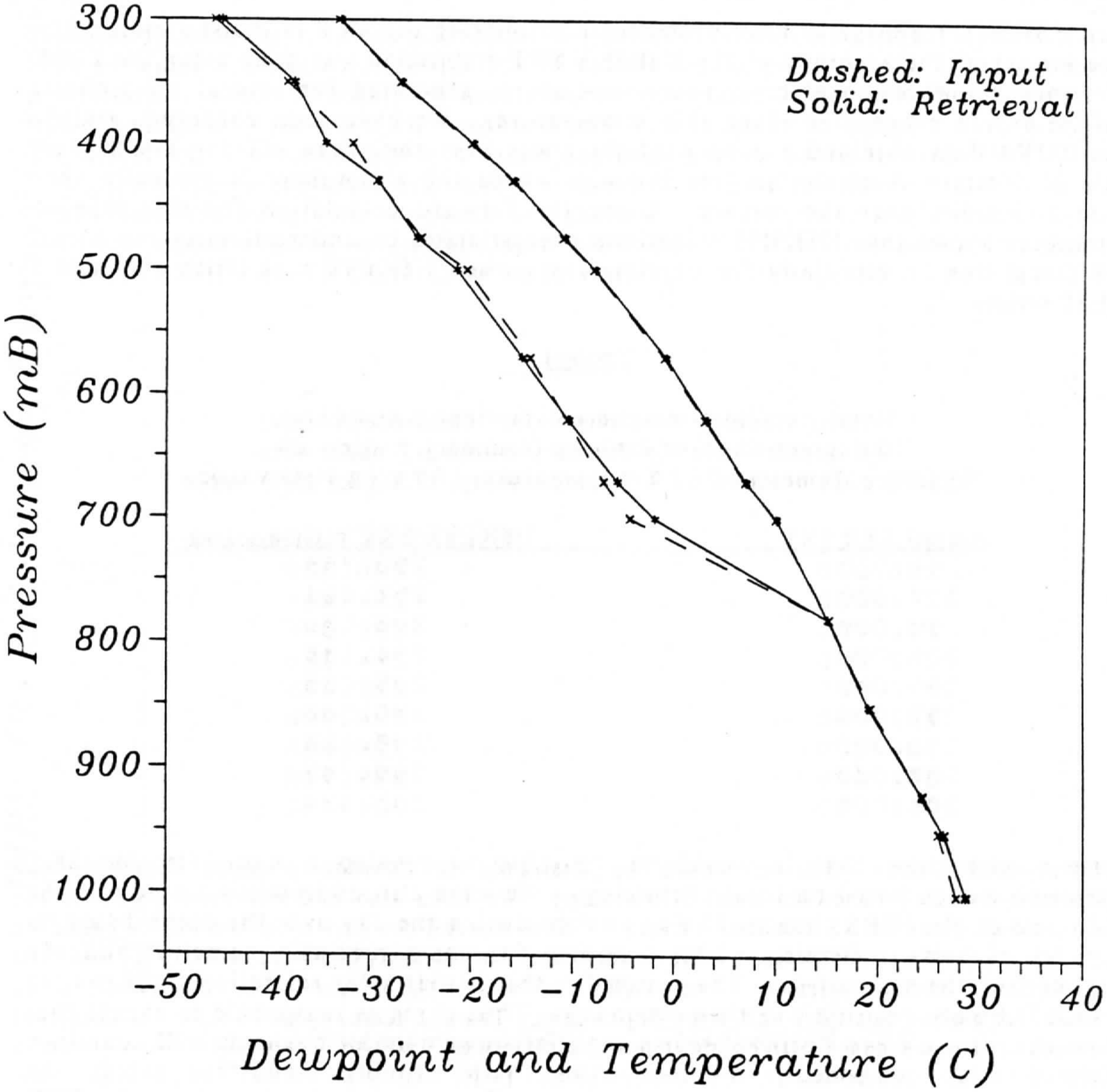


Figure 6

Again the same input profile as used for Figures 4 and 5. The retrieval surface skin temperature was assigned the value used in the synthetic input profile (28.6 C). The ERO value in TOVRET was reduced to 0.25 K for all spectral channels. The improvement in the lower level moisture retrieval over that in Figure 5 is significant.



Surface Skin Temperature Estimation

The algorithm used for SKT estimation in ITPP-3 (function HSKINT) uses the brightness temperatures measured in HIRS channels 8 (11.1 um), 10 (8.3 um) and 18 (4.0 um). HSKINT uses a set of empirical coefficients in a regression relationship to derive an SKT of the form

$$SKT = C1 + C2*T(8) + C3*T(10) + C4*T(18) \qquad (1)$$

HIRS channel 18 data is only used at night to avoid the possibility of reflected solar contamination.

Since HSKINT appeared to have problems in estimating the SKT in moist atmospheres, some testing of the accuracy of the HSKINT SKT estimation was done using the ITPP-3 forward radiance model brightness temperatures generated for several atmospheric profiles over a range of surface skin temperatures. We have been concerned mainly with TOVS data obtained during daylight hours over the ocean off the North West Shelf of Western Australia in late summer, where the atmosphere is typically very warm and moist near the surface. Using the forward calculation for this type of atmosphere shows that HSKINT sometimes overestimates or underestimates the actual SKT (see Table 1), especially for daytime cases when HSKINT uses HIRS channels 8 and 10 only.

Table 1

Moist tropical atmosphere over clear ocean (day),
10 degrees south in January (summer), nadir view.
Surface parameters: 27.9 C temperature, 17.5 g/kg H_2O vapor.

Actual SKT (K)	HSKINT SKT estimate (K)
285.000	290.355
287.000	291.444
290.000	293.086
292.000	294.186
295.000	295.485
297.000	296.956
300.000	298.628
302.000	299.748
305.000	301.434

These results show that it would be desirable to develop a more flexible SKT estimation model, based on local climatology. We have also undertaken a study of the usefulness of the HIRS channel 18 and 19 data during the day over the ocean based on a model of solar reflection which accounts for sun-spacecraft geometry, and the roughness of the sea surface. The reason for this is that solar reflection from the sea surface is highly position and time dependent. Thus it seems reasonable to expect that although in some cases during daytime the shortwave window channels will contain a reflected solar component, in other cases (with suitably cloud-free skies), the shortwave channels will contain recoverable unambiguous information about the SKT. The reason that it is desirable to utilize the data in the shortwave window channels is that they are much less sensitive to changes in the temperature and moisture profiles than are the longwave window and surface water vapor channels. This is demonstrated in Figures 7 and 8, which show the responses to surface skin temperatures in HIRS channels 8 and 18 for several different atmospheric profiles.

Figure 7

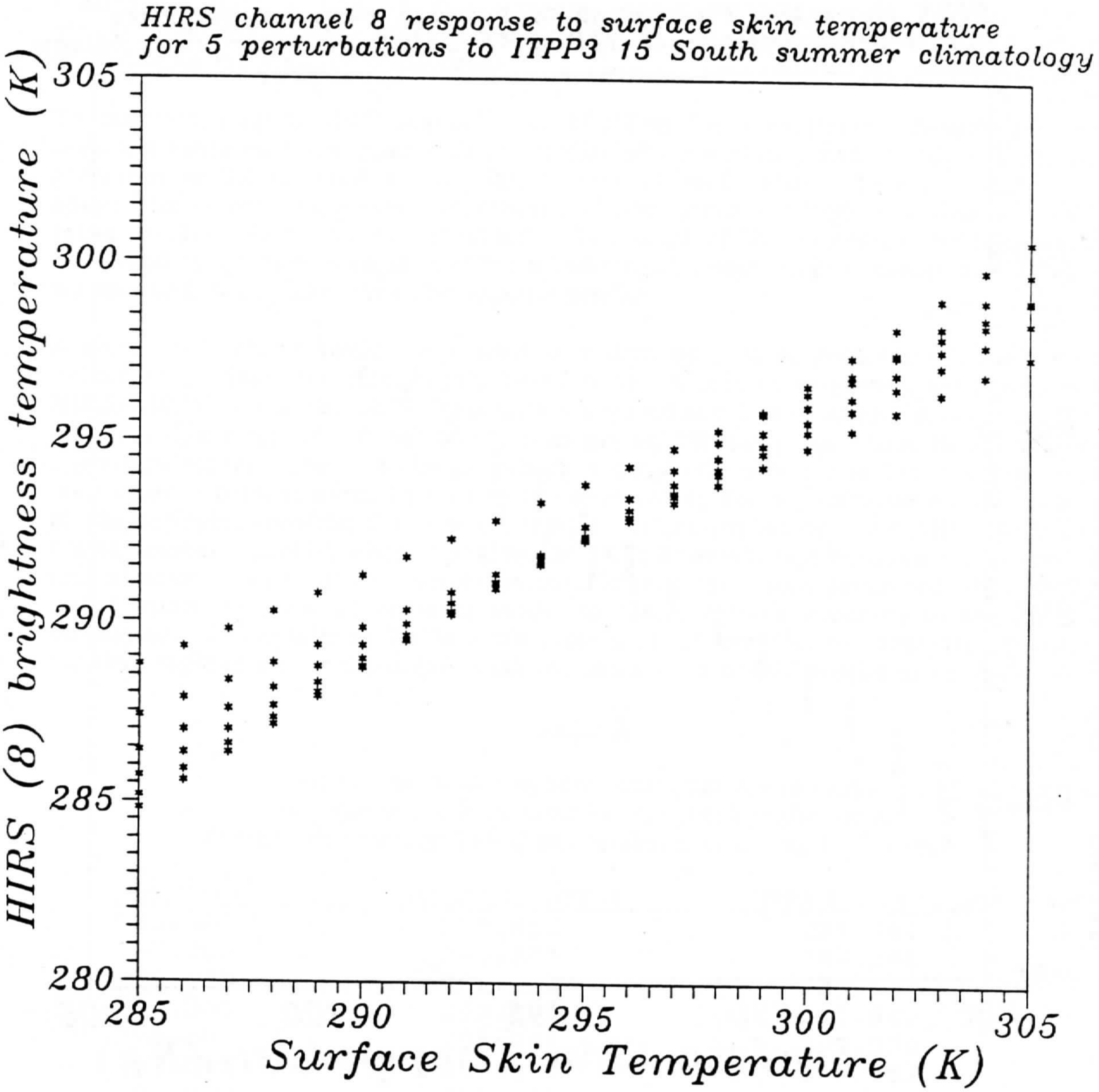
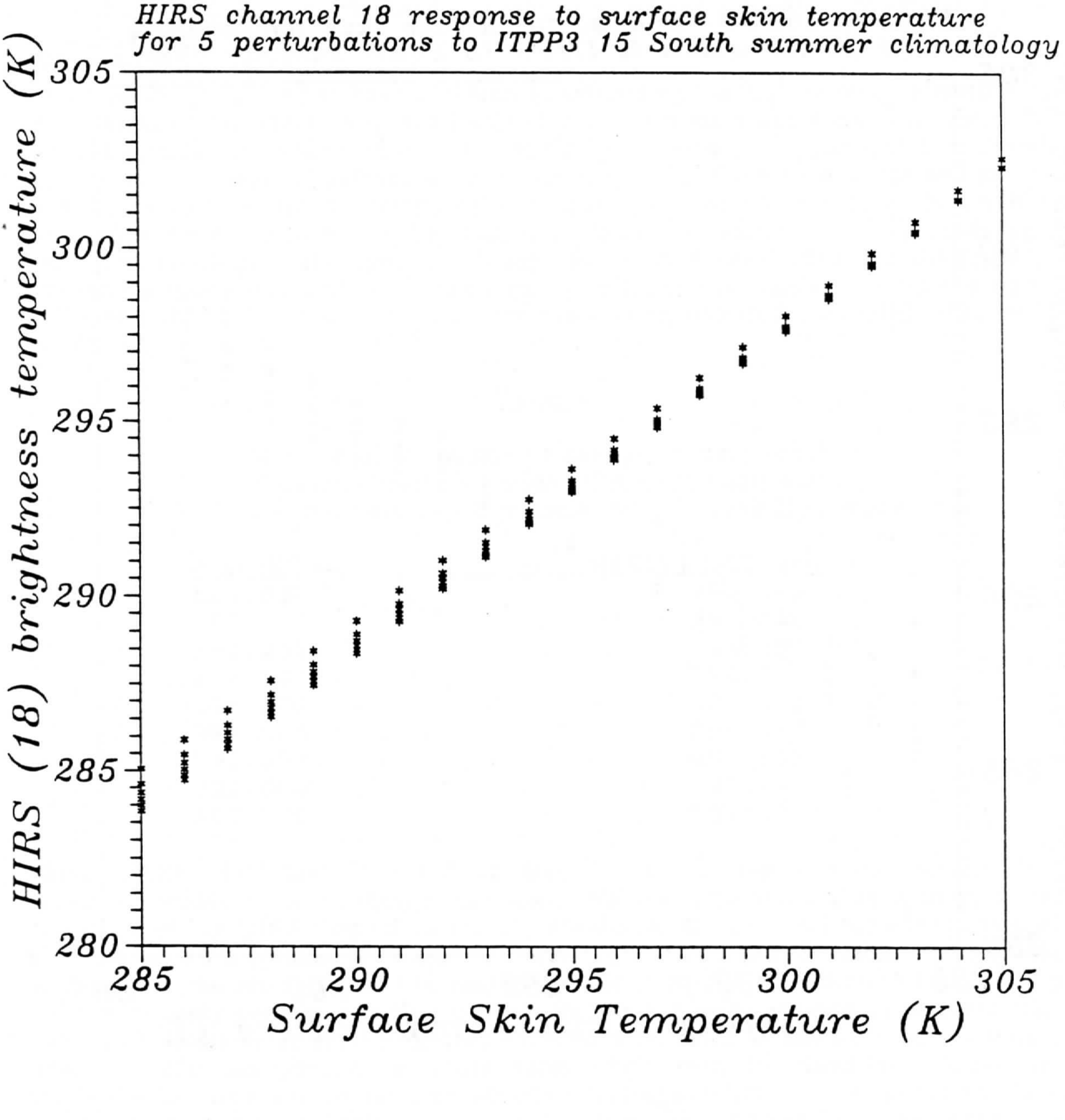

HIRS channel 8 response to surface skin temperature
for 5 perturbations to ITPP3 15 South summer climatology
HIRS (8) brightness temperature (K)
305
300
295
290
285
280
285
290
295
300
305
Surface Skin Temperature (K)

Figure 8


HIRS channel 18 response to surface skin temperature
for 5 perturbations to ITPP3 15 South summer climatology
HIRS (18) brightness temperature (K)
305
300
295
290
285
280
285
290
295
300
305
Surface Skin Temperature (K)

To generate a regression model for SKT, a similar relation to (1) is required. We have also included HIRS channel 19, with the understanding that sun-spacecraft geometry is being taken into account. The ITPP-3 forward radiance model is used to generate nadir viewing brightness temperatures in HIRS channels 8,10,18 and 19 over a range of SKT values, and the process is repeated for several perturbations to a representative climatological profile. A multiple linear regression model is then used to calculate the coefficients needed in (1) for estimation of the SKT. Coefficients are calculated for the HIRS 8 and 10 combination only, and also for HIRS 8,10,18 and 19 together. The atmospheric profiles used are derived from the ITPP-3 retrieval climatology first-guess routine CLMGES. This is a convenient source of data which provides typical atmospheres in 6 latitude zones in the northern and southern hemispheres, and a means of including the seasonal dependence.

To generate a set of SKT regression coefficients for a particular latitude zone and season, a representative climatological profile of temperature and moisture is obtained for input to the forward model with a range of SKT values. In our case, the SKT approximates the brightness temperature of the ocean surface, and thus a realistic range for the SKT can be estimated. The original climatological profile is then perturbed to produce several profiles which for example may be cooler and drier, or warmer and more moist than the original profile.

A linear multiple regression algorithm may then be used to generate the coefficients needed in (1) from the relationship between the calculated brightness temperatures in HIRS 8,10,18,19 and the SKT. Typically we would use 5 atmospheric profiles with the SKT varying from 285 K to 305 K, thus giving 100 cases for input to the multiple regression model. The selection of which atmospheric profiles to use is arbitrary, as they could represent perturbations to the climatology for a particular month, or a set of climatological profiles for several months. At present we do not modify the base of the atmospheric profile when changing the SKT; however, this obviously does occur in real atmospheric situations. Once the coefficients have been generated, they may be tested using the forward radiance model to compare their accuracy to the HSKINT estimation. The results in Table 2 are from a set of coefficients generated for nadir viewing radiances over the ocean, with the same atmospheric profile as in Table 1.

Table 2

Moist tropical atmosphere over clear ocean (day),
10 degrees south in January (summer), nadir view.
Surface parameters: 27.9 C temperature, 17.5 g/kg H_2O vapor.

SKT (K)	HIRS 8,10 SKT (K)	HIRS 8,10,18,19 SKT (K)
285.000	288.859	284.984
287.000	290.283	286.966
290.000	292.432	289.952
292.000	293.871	291.949
295.000	296.041	294.950
297.000	297.493	296.953
300.000	299.681	299.961
302.000	301.145	301.966
305.000	303.349	304.974

These results show that when HIRS channel 18 and 19 data are available over the ocean, and are known from the solar reflection model to be not significantly affected by reflected sunlight, a much better estimate of the SKT may be obtained in a moist tropical atmosphere than that derived from HIRS channel 8 and 10 only.

Synthetic retrieval studies have shown that an error of 1 or 2 degrees in the SKT estimation can lead to significant errors in the retrieved profile; thus, the use of a locally developed SKT regression model should help the retrieval algorithm to obtain a better sounding at locations over the ocean, particularly in relation to water vapor retrieval.

While we believe that further work is required on this aspect of the retrieval process, some evaluation of the performance of the regression scheme has been undertaken using purely synthetic data sets. Figures 9 and 10 provide examples of retrieved soundings where the temperature and moisture synthetic profiles have been modified by introducing a percentage offset from the climatological guess profile. In all these situations the quality of the retrieval is dependent upon an accurately regressed SKT.

The derivation of the regression coefficients and a comparison of the two and four channel SKT regression approaches must ultimately be done using real data. This is intended but meanwhile we have examined the performance using synthetic data. Of course it will not always be possible to utilize the information in the shortwave window channels because of reflected solar contamination. However the potential usefulness of the shortwave window data shows it is necessary to examine the conditions under which the solar reflected component is significant.

Shortwave Window and Solar Contamination

In order to justify the use of the HIRS shortwave channels 18 and 19 for the estimation of SKT, it was essential to test the effect of solar reflection from the ocean surface on shortwave brightness temperatures using a model which accounts for the geometric configuration of the sun and the sensor.

The calculation of the solar radiance reflected from the sea is based on a statistical model (Cox and Munk, 1954) which approximates the reflection from the sea surface in directions other than the specular direction depending on the roughening of the sea surface caused by the wind. In general, the rougher the sea surface, the more radiance will be reflected in directions other than the specular direction. While this model is not believed to be exact enough to correct for the reflected solar radiance, we believe it does give a reasonable indication of the presence or absence of solar reflection, and hence the usefulness of the HIRS shortwave channels in estimating the SKT.

The sun glint radiance (Guzzi et al, 1987) is given by

$$R = F_0 * TO_3(z,z_0) * TRA(z,z_0) * r(z) * p(z) \qquad (2)$$

F_0 : Incoming solar irradiance
TO_3 : Transmittance due to ozone
z : Sensor zenith angle
z_0 : Solar zenith angle
TRA : Transmittance due to molecules and aerosols
$r(z)$: Fresnel reflectivity at angle z
$p(z)$: Probability function for direct reflection at angle z depending on ocean surface wind speed

Figure 9

The input profile has been derived from a perturbation to the climatological guess throughout the whole atmospheric column. Specifically, the temperature profile has been warmed and the moisture increased as may be shown in a comparison with the climatological guess shown in Figure 2. The retrieval is made with the four channel regression surface skin temperature estimator.

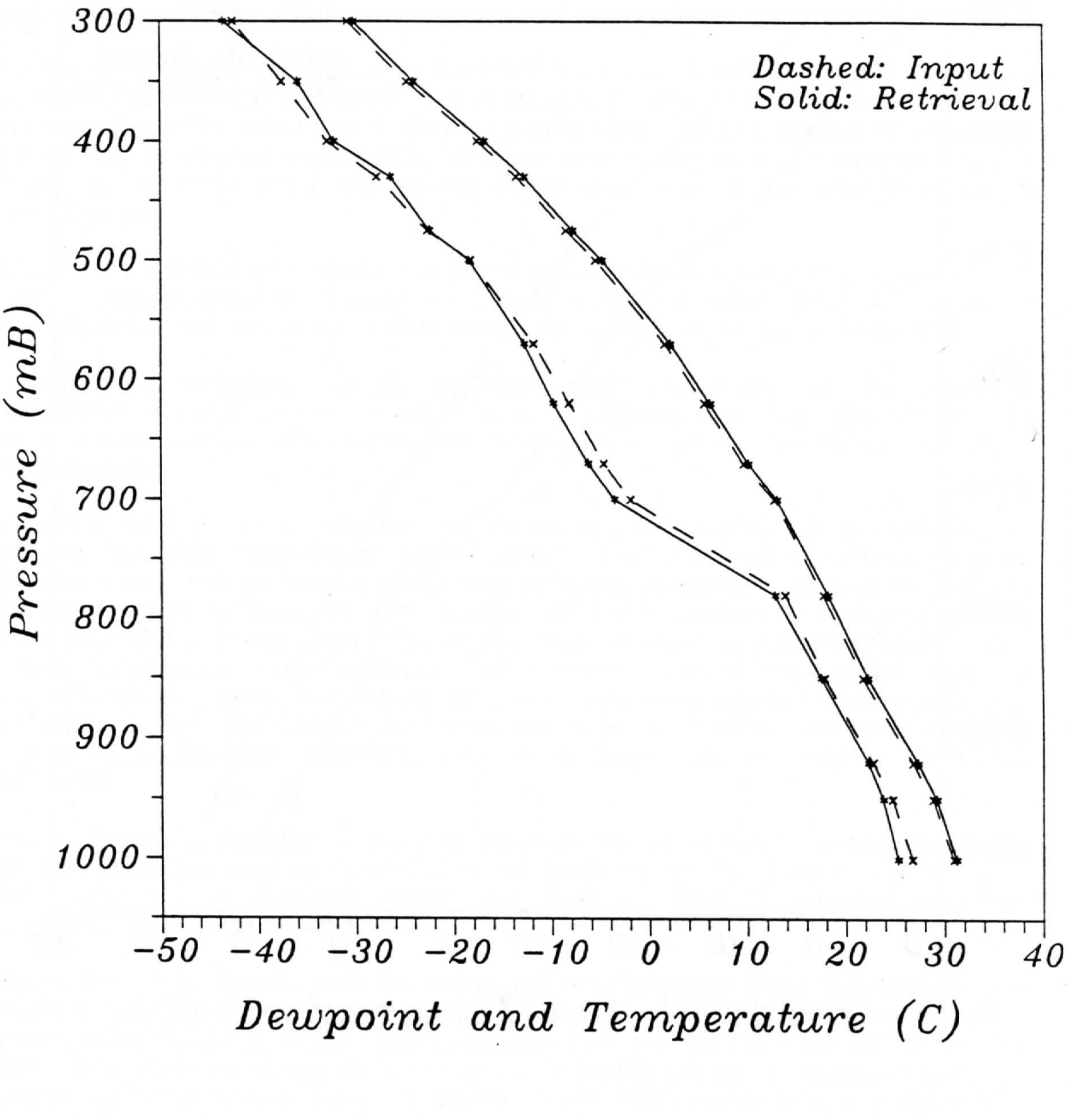
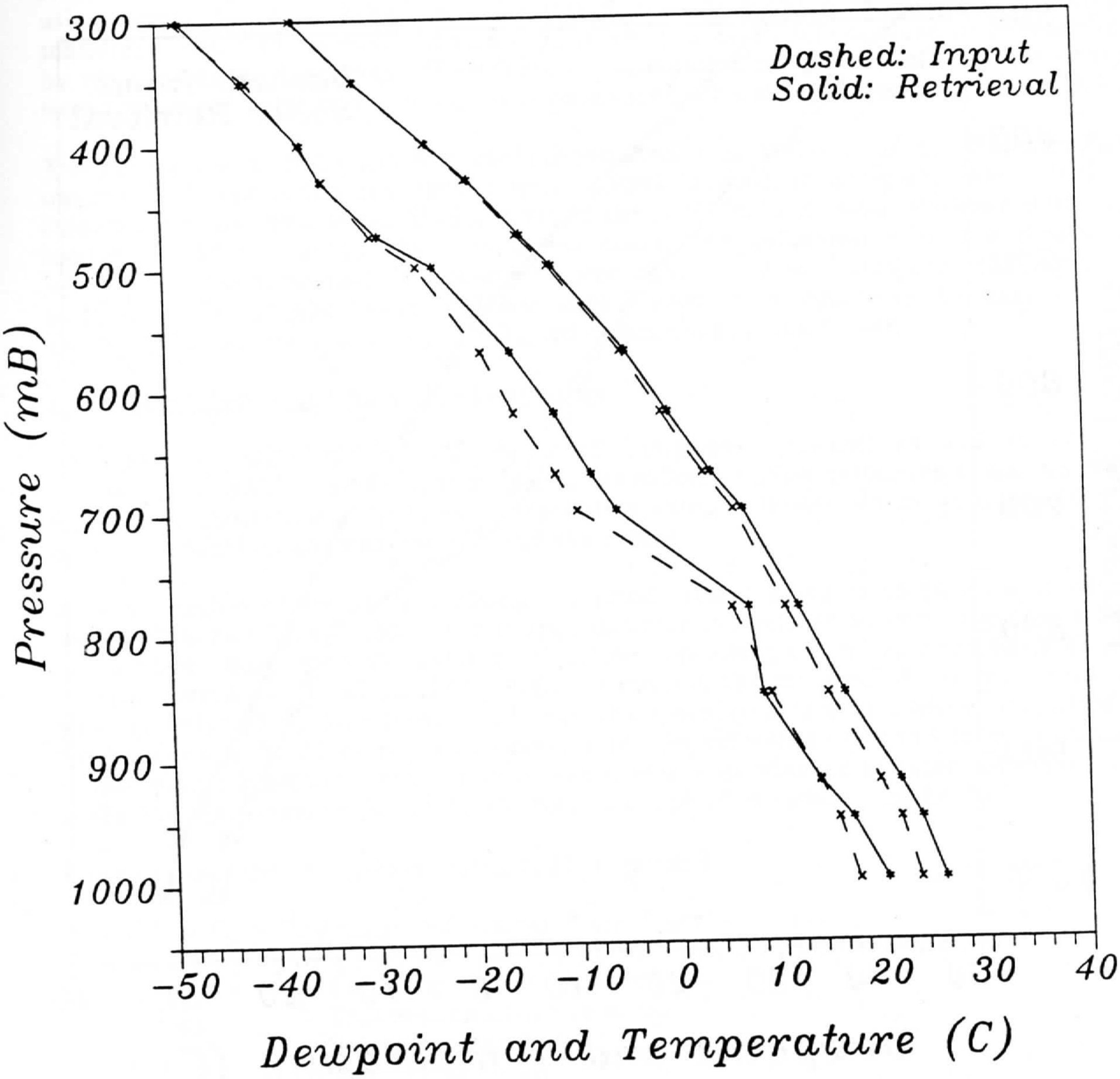


Figure 10

Similar to Figure 9 except that the input profile has been cooled and dried relative to the climatological guess. The retrieval performance is less satisfactory than that in Figure 9.



As a test case, we used a collocated TOVS radiance/radiosonde data set supplied by L. McMillin of NOAA/NESDIS (McMillin, 1988) as a source of HIRS nadir viewing cases over the oceans during daylight. The reflected solar radiance which would be measured by the sensor is then calculated for all such cases, taking into account the sun-sensor geometry, and then converted to an equivalent brightness temperature. Since only nadir viewing cases were considered, only the solar zenith angle (and not the sensor zenith or sensor/solar azimuth angles) will cause variation in the reflected solar radiation encountered. Figures 11 and 12 show the change in HIRS channel 18 and 19 brightness temperatures caused by wind speeds of 7.5 meters/sec and 10 meters/sec versus the solar zenith angle.

Conclusions and Further Work

We have configured a PC version of the ITPP-3 code to permit a range of simulation activities to be investigated. Synthetic profiles may be entered and the performance of the retrieval studied using the diagnostic output data. Various processing options in the code may be selected interactively. A measure of experimentation with segments of the code has revealed useful information on the sensitivity of the retrieval algorithm to modification.

We have found that a good estimation of the surface skin temperature is a prerequisite to an acceptable retrieval. Failure to comply with this requirement will result in extremely inaccurate soundings which bear little relation to the actual atmosphere.

A preliminary modelling of the scattered solar contribution to the brightness temperatures of the shortwave window channels suggests that these channels may be used to aid the surface skin temperature estimation, in certain well defined situations during daytime.

There is a limit to the extent that simulation may be used to aid the recovery of soundings from real observations. Accordingly, further work will be undertaken using collocated sonde and satellite radiance measurements. A prerequisite will be data sets with surface skin temperature information. We have acquired such data sets from several ship cruises in the Indian Ocean. We will use these data to investigate further the skin temperature regression issue and to assess retrieval performance with real data. A difficulty arises with doing definitive tests using satellite observations over land since surface skin temperatures have not been included in collocated data sets compiled by L. McMillin (McMillin, 1988) or in those being collected by the BUAN (WMC, 1988).

When applying the package to satellite observations the radiance tuning parameters (gammas and deltas) need to be applied in the retrieval process. Clearly, confidence in these parameters is essential (Kelly and Flobert, 1988) if retrieval algorithm performance alone is to be investigated.

None of the work reported here has attempted to incorporate cloud information. It is possible to interactively switch the ITPP-3 cloud check on. At times we have had cloud reported using purely synthetic clear radiances. This may be the result of the window channel brightness temperatures in the synthetic profiles being set independently, and at times consistent with a cloudy or partly cloudy FOV, rather than a problem with the cloud detection algorithm. Some investigation here may be meaningful.

Finally, apart from being a convenient research tool for studying retrieval performance and applications (Lynch et al 1988), the synthetic retrieval package may

Figure 11

Change in HIRS channel 18 (4.0 micron) brightness temperature caused by solar reflection from the ocean surface with surface wind speeds of 10 meters/second and 7.5 meters/second

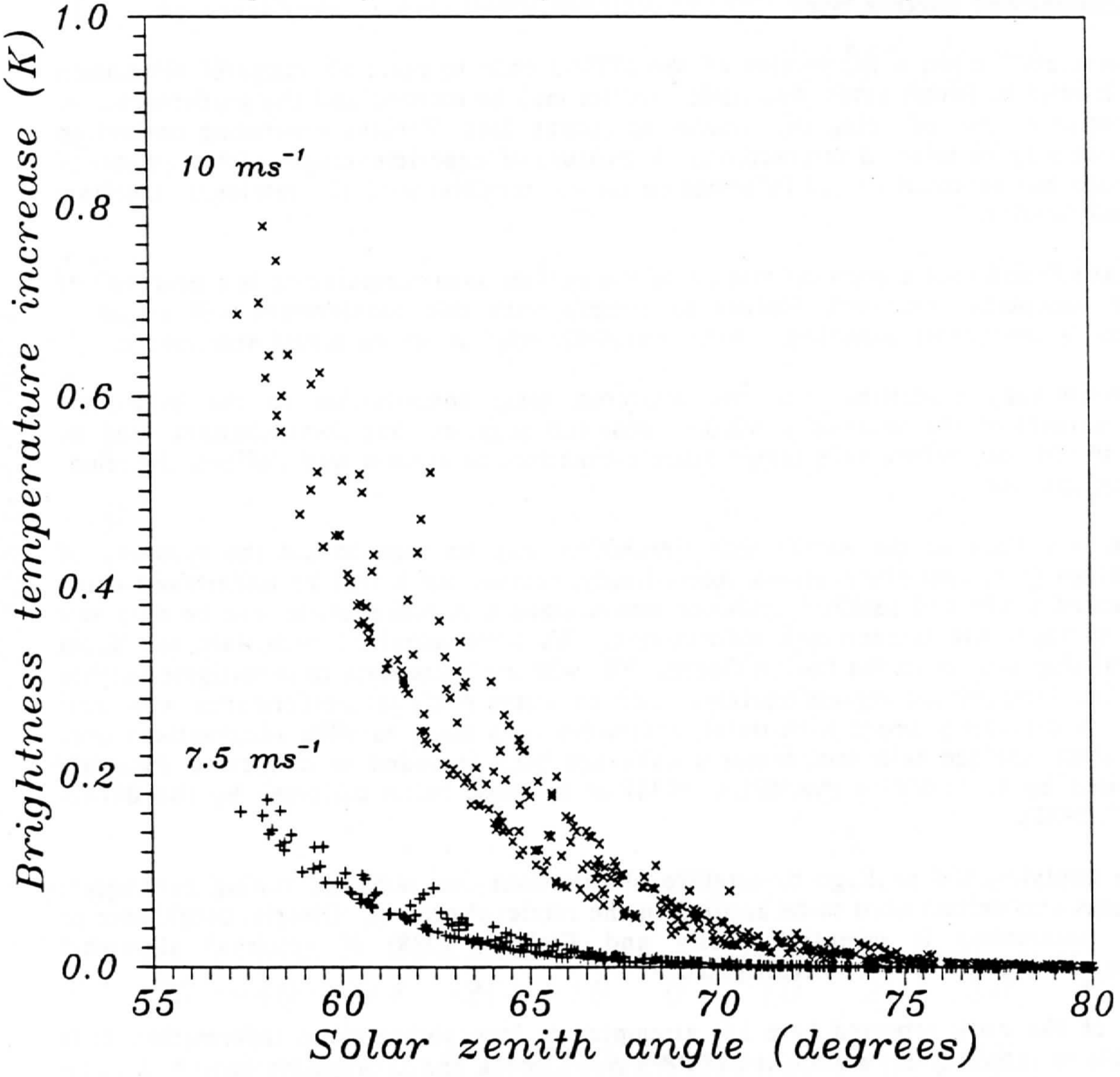
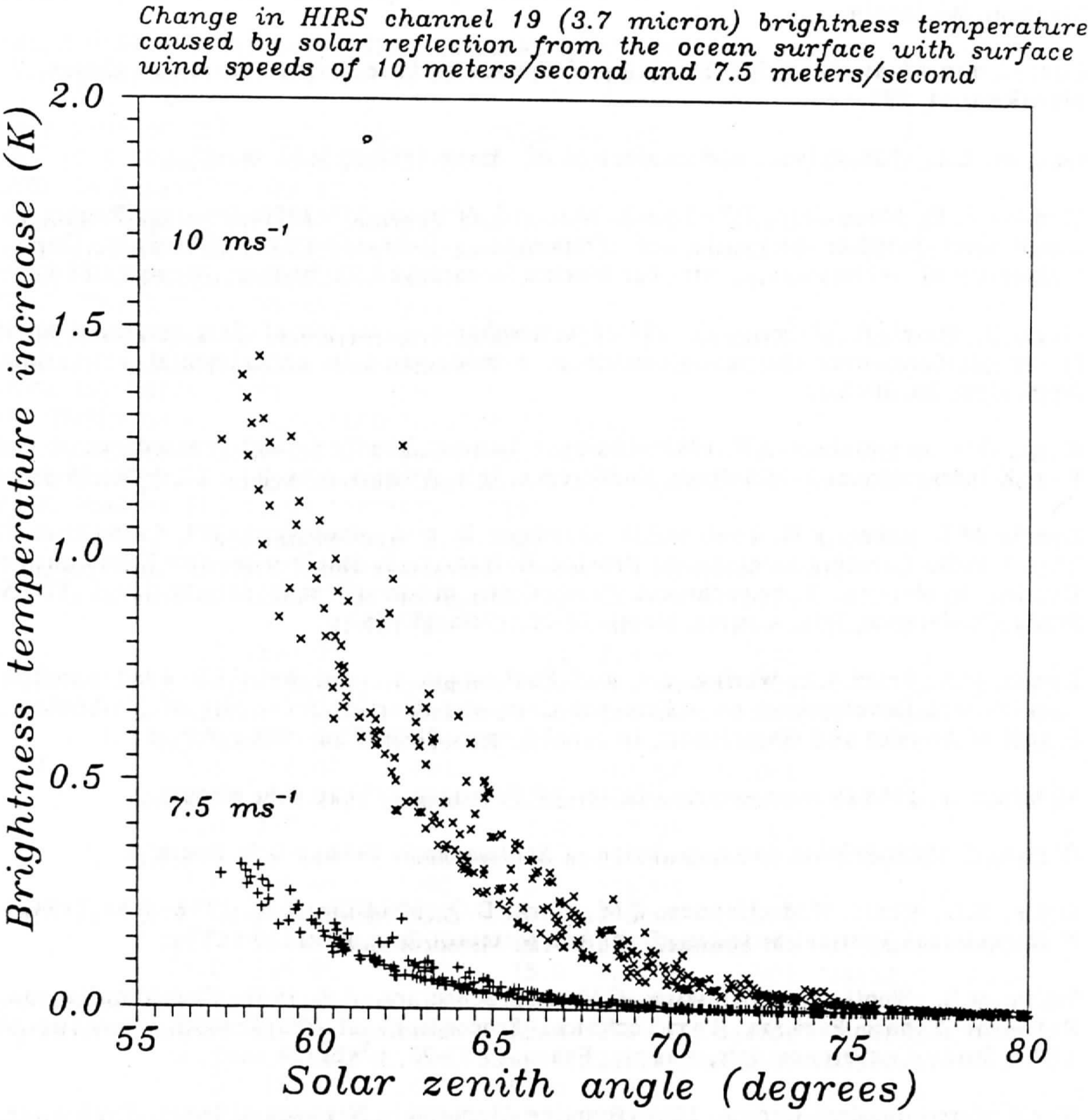


Figure 12


Change in HIRS channel 19 (3.7 micron) brightness temperature caused by solar reflection from the ocean surface with surface wind speeds of 10 meters/second and 7.5 meters/second
Brightness temperature increase (K)
2.0
1.5
1.0
0.5
0.0
10 ms⁻¹
7.5 ms⁻¹
55
60
65
70
75
80
Solar zenith angle (degrees)

have value as a teaching tool in universities or in meteorology training courses where multiple PC systems are likely to be available and the cost of mainframe time too high.

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Appendix 1

Forward radiance calculation and ITPP-3 retrieval for climatological guess profile with 750 mb to surface moistened by 5 g/kg. Gamma and delta set to 1.0 and 0.0 respectively in forward calculation and retrieval.

```
HIRS/2 RADIANCE AND BRIGHTNESS TEMPERATURE CALCULATION
------------------------------------------------------

ENTER NAME OF INPUT DATA FILE      : CLIM4_29.DAT
DATA IS T,DEW (1) OR T,MIXRAT (2): 1
ENTER SATELLITE NUMBER (7-10)      : 9
SET ALL GAMMAS=1, DELTAS=0 (Y/N) : Y
GAMMAS AND DELTAS RESET
ENTER H2O VAPOUR ZERO LEVEL (MB) : 0
ENTER TEMPERATURE INVERSION(Y/N) : N
ENTER H2O PARTIAL PRESSURE (Y/N) : N
ENTER MIX.  RATIO INVERSION(Y/N) : Y
ENTER INVERSION LEVEL        (MB) : 750
PUT INVERSION ABOVE OR BELOW THIS LEVEL (A/B) : B
ENTER INVERSION VALUE      (G/KG) : -5
ENTER SCAN ANGLE (DEGREES, 0-61) : 0
ENTER 1000 MB ELEVATION (METERS) : 116
ENTER SURFACE PRESSURE        (MB) : 1013

        P(ORIG) T(ORIG) W(ORIG) P(INTP) T(INTP) W(INTP)

             .1  233.06    .001      .1  233.06    .001        .0        .0
             .2  248.06    .001      .2  248.06    .001        .0        .1
             .5  265.06    .001      .5  265.06    .001        .0        .1
            1.0  270.06    .001     1.0  270.06    .001        .0        .3
            1.5  266.06    .001     1.5  266.06    .001        .0        .4
            2.0  261.06    .001     2.0  261.06    .001        .0        .6
            3.0  257.06    .001     3.0  257.06    .001        .0        .9
            4.0  249.06    .001     4.0  249.06    .001        .0       1.2
            5.0  246.06    .001     5.0  246.06    .001        .0       1.6
            7.0  240.06    .001     7.0  240.06    .001        .0       2.3
           10.0  235.06    .001    10.0  235.06    .001   31188.6    4899.9
           15.0  229.06    .001    15.0  229.06    .001   28432.6    4469.0
           20.0  225.06    .001    20.0  225.06    .001   26519.4    4170.4
           25.0  222.06    .001    25.0  222.06    .001   25058.2    3942.9
           30.0  219.06    .001    30.0  219.06    .001   23880.4    3759.8
           50.0  209.06    .001    50.0  209.06    .001   20677.6    3264.9
           60.0  205.06    .001    60.0  205.06    .001   19571.9    3095.5
           70.0  201.06    .001    70.0  201.06    .002   18655.1    2955.9
           85.0  197.06    .001    85.0  197.06    .003   17523.1    2784.6
          100.0  193.06    .003   100.0  193.06    .005   16594.5    2645.5
          115.0  198.06    .006   115.0  198.06    .008   15794.0    2524.7
          135.0  205.06    .016   135.0  205.06    .013   14847.4    2382.2
          150.0  209.06    .020   150.0  209.06    .018   14208.4    2286.4
          200.0  220.06    .020   200.0  220.06    .043   12400.5    2017.4
          250.0  231.06    .051   250.0  231.06    .084   10926.2    1799.5
```

```
         300.0  240.06    .146   300.0  240.06    .146   9668.2   1615.3
         350.0  246.06    .279   350.0  246.06    .279   8570.6   1456.9
         400.0  253.06    .667   400.0  253.06    .667   7594.3   1317.5
         430.0  257.06    .779   430.0  257.06    .779   7053.8   1240.3
         475.0  262.06   1.057   475.0  262.06   1.057   6296.7   1133.6
         500.0  265.06   1.494   500.0  265.06   1.494   5900.4   1079.1
         570.0  272.06   2.210   570.0  272.06   2.210   4868.6    937.2
         620.0  276.06   2.717   620.0  276.06   2.717   4192.6    845.8
         670.0  280.06   3.333   670.0  280.06   3.333   3559.8    761.6
         700.0  283.06   3.890   700.0  283.06   3.890   3197.7    714.3
         780.0  288.26  10.392   780.0  288.26  15.392   2287.0    654.0
         850.0  292.36  12.312   850.0  292.36  17.312   1548.9    569.8
         920.0  297.56  15.510   920.0  297.56  20.510    857.3    498.9
         950.0  299.66  16.887   950.0  299.66  21.887    573.0    470.8
        1000.0  301.76  18.005  1000.0  301.76  23.005    116.0    422.2

SATELLITE : NOAA-09  SFC. TEMP:  301.76K  SCAN ANGLE :   .00
TOVRET CLIM. GUESS NOAA9-1436 L,E,4 29

      CHAN        WAVE NO       RADIANCE        EBB-TEMP       TAU (1000MB)
        1        667.6690        58.6766        233.2939       .000000E+00
        2        679.8360        43.5752        219.0929       .716259E-11
        3        691.4650        43.1742        219.8796       .869915E-04
        4        703.3690        54.4020        232.8686       .215284E-04
        5        717.1590        70.9994        249.1817       .847093E-03
        6        732.6380        83.5718        260.7084       .361227E-02
        7        749.4760        98.5030        273.0659       .126893E-01
        8        898.5290       108.9681        294.7510       .262343E+00
        9       1031.6100        96.4911        301.7600       .100000E+01
       10       1224.7400        51.9131        290.8574       .246832E+00
       11       1365.1200        17.2251        262.9039       .847606E-04
       12       1483.2400         6.5976        245.6960       .660023E-07
       13       2189.9700         1.8346        283.1666       .208127E+00
       14       2209.1800         1.0772        271.9775       .831746E-01
       15       2243.1400          .3749        252.3125       .742189E-02
       16       2276.4600          .1181        233.9501       .775958E-03
       17       2359.0500          .1212        241.2847       .496150E-03
       18       2518.1400         1.0645        299.4832       .809673E+00
       19       2667.8000          .6139        298.9214       .711094E+00
       20      14453.1000          .0000           .0000       .000000E+00

ENTER SCAN ANGLE (DEGREES, 0-61) : -1
RAOBHIRS PROGRAM ENDED


MSU RADIANCE AND ANTENNA TEMPERATURE CALCULATION
-----------------------------------------------

ENTER NAME OF INPUT DATA FILE    : CLIM4_29.DAT
DATA IS T,DEW (1) OR T,MIXRAT (2): 1
ENTER SATELLITE NUMBER (7-10)    : 9
ENTER LAND/SEA FLAG (0:L,1:S)    : 1
ENTER RAINCLOUD FLAG (0:OFF,1:ON): 0
ENTER LIQUID WATER NUMBER ???    : 0
```

```
ENTER H2O VAPOUR ZERO LEVEL (MB) : 0
ENTER TEMPERATURE INVERSION(Y/N) : N
ENTER H2O PARTIAL PRESSURE (Y/N) : N
ENTER MIX.  RATIO INVERSION(Y/N) : Y
ENTER INVERSION LEVEL       (MB) : 750
PUT INVERSION ABOVE OR BELOW THIS LEVEL (A/B) : B
ENTER INVERSION VALUE     (G/KG) : -5
ENTER SCAN ANGLE (DEGREES, 0-61) : 0

          P(ORIG) T(ORIG) W(ORIG) P(INTP) T(INTP) W(INTP)

               .1  233.06    .001      .1  233.06    .001
               .2  248.06    .001      .2  248.06    .001
               .5  265.06    .001      .5  265.06    .001
              1.0  270.06    .001     1.0  270.06    .001
              1.5  266.06    .001     1.5  266.06    .001
              2.0  261.06    .001     2.0  261.06    .001
              3.0  257.06    .001     3.0  257.06    .001
              4.0  249.06    .001     4.0  249.06    .001
              5.0  246.06    .001     5.0  246.06    .001
              7.0  240.06    .001     7.0  240.06    .001
             10.0  235.06    .001    10.0  235.06    .001
             15.0  229.06    .001    15.0  229.06    .001
             20.0  225.06    .001    20.0  225.06    .001
             25.0  222.06    .001    25.0  222.06    .001
             30.0  219.06    .001    30.0  219.06    .001
             50.0  209.06    .001    50.0  209.06    .001
             60.0  205.06    .001    60.0  205.06    .001
             70.0  201.06    .001    70.0  201.06    .001
             85.0  197.06    .001    85.0  197.06    .001
            100.0  193.06    .003   100.0  193.06    .003
            115.0  198.06    .006   115.0  198.06    .006
            135.0  205.06    .016   135.0  205.06    .016
            150.0  209.06    .020   150.0  209.06    .020
            200.0  220.06    .020   200.0  220.06    .020
            250.0  231.06    .051   250.0  231.06    .051
            300.0  240.06    .146   300.0  240.06    .146
            350.0  246.06    .279   350.0  246.06    .279
            400.0  253.06    .667   400.0  253.06    .667
            430.0  257.06    .779   430.0  257.06    .779
            475.0  262.06   1.057   475.0  262.06   1.057
            500.0  265.06   1.494   500.0  265.06   1.494
            570.0  272.06   2.210   570.0  272.06   2.210
            620.0  276.06   2.717   620.0  276.06   2.717
            670.0  280.06   3.333   670.0  280.06   3.333
            700.0  283.06   3.890   700.0  283.06   3.890
            780.0  288.26  10.392   780.0  288.26  15.392
            850.0  292.36  12.312   850.0  292.36  17.312
            920.0  297.56  15.510   920.0  297.56  20.510
            950.0  299.66  16.887   950.0  299.66  21.887
           1000.0  301.76  18.005  1000.0  301.76  23.005

TOVRET CLIM. GUESS NOAA9-1436 L,E,4 29              SFC.TEMP. = 301.76
```

```
SATELLITE : NOAA-09, SURFACE IS SEA , CLOUD TOP =    0.MB, BASE =    0.MB


        CHANNEL           FREQUENCY (GHz)        TEMP. (K)       TAU (1000MB)
           1                 50.3500             233.8590        .607701E+00
           2                 53.7900             256.5942        .717615E-01
           3                 55.0200             226.0637        .113127E-02
           4                 58.0100             206.5304        .161787E-12

ENTER SCAN ANGLE (DEGREES, 0-61) : -1
RAOBMSU PROGRAM ENDED


                    NOAA TOVS ATMOSPHERIC PROFILE RETRIEVAL
                     ITPP3  DEVELOPMENT  VERSION  FOR IBM/PC
                     ---------------------------------------


                           SATELLITE    : NOAA -  9
                           DATE         : 850324
                           PASS STARTS  :  651.48 GMT
                           PASS   ENDS  :  659.35 GMT


                TOVS processing package -- TOVRET

 Enter number of file to process : 26
 Enter surface data flag (0-NO,1-YES) : 0
 Enter guess type (0-REGRESSION,1-CLIMATOLOGY) : 1
 Enter start line      : 04
 Enter start element : 29
 Enter number of lines      : 001
 Enter number of elements : 01
 Enter line increment       : 3
 Enter element increment   : 3
 Enter topography flag (0-HIRES,1-LORES) : 0
 MWHS - Retrieval using MSU+HIRS (stratospheric) channels
        If MWHS - 0, output only full-HIRS soundings
        If MWHS - 1, output MWHS sounding if full-HIRS fails
        If MWHS - 2, output only MWHS soundings
 Enter value of MWHS :   1
 Enter diagnostic print flag (0-NO,1-YES) : 2
 Enter Retrieval File Initialisation flag (0-NO,1-YES) : 1


 RETREIVAL MATRIX GAMMA IS          1.000000 CHANGE (Y/N)
 N
 HIRS NOT LIMB CORRECTED : PERFORM LIMB CORRECTION (0:NO, 1:YES)
 1
 MSU  NOT LIMB CORRECTED : PERFORM LIMB CORRECTION (0:NO, 1:YES)
 1
 RETRIEVAL FILE INITIALIZED
     CHAN        GAMMA       DELTA      SATELLITE:            9
```

```
        1        .94300     .00000
        2        .97100     .00000
        3       1.15600     .00000
        4       1.04900     .00000
        5        .94400     .00000
        6        .97100     .00000
        7        .95300     .00000
        8       1.00000     .00000
        9       1.00000     .00000
       10       1.04200     .00000
       11       1.01500     .00000
       12       1.04100     .00000
       13        .99200     .00000
       14        .97000     .00000
       15        .94700     .00000
       16       1.00000     .00000
       17       1.20000     .00000
       18       1.00000     .00000
       19       1.00000     .00000
       20       1.00000     .00000
SET GAMMAS TO 1.0 AND DELTAS TO 0.0 (0-NO,1-YES)
1
CHANGE RMS ERROR VALUES FOR HIRS CHANNELS (Y/N)
N
ENTER NEW VALUES FOR LAT/LONG (0:NO 1:YES)
0
REPLACE THIR/TMSU WITH SYNTHETIC DATA (0:NO 1:YES)
1
ALLOW CALLS TO CLOUD CHECK SUBROUTINE KLOUD (0:NO 1:YES)
1
RUN ITPP3 GESPRO (0) OR FIXED VERSION (1)
1
USE ITPP3 RETRIEVAL (0) ,WET/DRY RETRIEVAL (1) STAT. RETRIEVAL (2), McIDAS RETR
IEVAL (3)
0

LINE,ELEM,LAT,LON:  4 30  -14.45  113.58 SURFACE DATA  116  30175  29691 1013
HSKINT SKIN TEMP =        296.631300 TBSWC =        299.483200
USE HIRS REGRESSION TO ESTIMATE SKIN TEMP (Y/N)
N

HIRS AND MSU DATA JUST BEFORE HMTWR

HIRS    TEMP    MSU    TEMP
----    ----    ---    ----

  1     233.3    1     233.9
  2     219.1    2     256.6
  3     219.9    3     226.1
  4     232.9    4     206.5
  5     249.2
  6     260.7
  7     273.1
  8     294.8
```

```
  9     301.8
 10     290.9
 11     262.9
 12     245.7
 13     283.2
 14     272.0
 15     252.3
 16     234.0
 17     241.3
 18     299.5
 19     298.9
 20        .0
 21     299.5
ENTERING ORIGINAL ITPP3 HMTWR RETRIEVAL, IPASS = 0
CHANGE WEIGHTING FUNCTION CHANNELS (0=NO, 1=YES)
0
BEGIN CLEAR-CHECK
TSKIN = 296.63
ICLR = 0, ICLD = 0
TSKIN ADJUSTED IN "HMTWR" - CLEAR CHECK FAILURE :TSKIN = TSTA =
    301.750000
CHAN  1 TBO = 233.29 TBC = 233.26 DTB =   .04 ERO =   .41 IUSE = 1
CHAN  2 TBO = 219.09 TBC = 219.07 DTB =   .03 ERO =   .36 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.75 DTB =   .13 ERO =   .29 IUSE = 0
CHAN  4 TBO = 232.87 TBC = 232.53 DTB =   .33 ERO =   .25 IUSE = 0
CHAN  5 TBO = 249.18 TBC = 248.59 DTB =   .59 ERO =   .25 IUSE = 0
CHAN  6 TBO = 260.71 TBC = 260.46 DTB =   .25 ERO =   .28 IUSE = 0
CHAN  7 TBO = 273.07 TBC = 273.42 DTB =  -.36 ERO =   .53 IUSE = 0
CHAN 10 TBO = 290.86 TBC = 290.22 DTB =   .63 ERO =   .88 IUSE = 0
CHAN 11 TBO = 262.90 TBC = 263.22 DTB =  -.31 ERO =   .49 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 245.98 DTB =  -.29 ERO =   .64 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 281.60 DTB =  1.57 ERO =   .81 IUSE = 0
CHAN 14 TBO = 271.98 TBC = 271.08 DTB =   .90 ERO =   .46 IUSE = 0
CHAN 15 TBO = 252.31 TBC = 252.10 DTB =   .21 ERO =   .26 IUSE = 0
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =   .00 ERO =   .50 IUSE =
CHAN 18 TBO = 256.59 TBC = 256.42 DTB =   .18 ERO =   .25 IUSE =
CHAN 19 TBO = 226.06 TBC = 225.97 DTB =   .09 ERO =   .25 IUSE =
CHAN 20 TBO = 206.53 TBC = 206.47 DTB =   .06 ERO =   .34 IUSE =
AFTER RETRIEVAL ...
TSKIN = 301.75
CHAN  1 TBO = 233.29 TBC = 233.31 DTB =  -.02 IUSE = 1
CHAN  2 TBO = 219.09 TBC = 219.12 DTB =  -.03 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.81 DTB =   .07 IUSE = 0
CHAN  4 TBO = 232.87 TBC = 232.63 DTB =   .24 IUSE = 0
CHAN  5 TBO = 249.18 TBC = 248.71 DTB =   .48 IUSE = 0
CHAN  6 TBO = 260.71 TBC = 260.60 DTB =   .11 IUSE = 0
CHAN  7 TBO = 273.07 TBC = 273.58 DTB =  -.51 IUSE = 0
CHAN 10 TBO = 290.86 TBC = 290.34 DTB =   .51 IUSE = 0
CHAN 11 TBO = 262.90 TBC = 263.39 DTB =  -.49 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 246.14 DTB =  -.44 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 281.71 DTB =  1.46 IUSE = 0
CHAN 14 TBO = 271.98 TBC = 271.22 DTB =   .76 IUSE = 0
CHAN 15 TBO = 252.31 TBC = 252.24 DTB =   .07 IUSE = 0
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =   .00 IUSE =
```

```
CHAN 18 TBO = 256.59 TBC = 256.57 DTB =   .02 IUSE =
CHAN 19 TBO = 226.06 TBC = 226.08 DTB =  -.01 IUSE =
CHAN 20 TBO = 206.53 TBC = 206.52 DTB =   .01 IUSE =

HIRS AND MSU DATA JUST BEFORE HMTWR

HIRS     TEMP    MSU     TEMP
----     ----    ---     ----

  1      233.3    1      233.9
  2      219.1    2      256.6
  3      219.9    3      226.1
  4      232.9    4      206.5
  5      249.2
  6      260.7
  7      273.1
  8      294.8
  9      301.8
 10      290.9
 11      262.9
 12      245.7
 13      283.2
 14      272.0
 15      252.3
 16      234.0
 17      241.3
 18      299.5
 19      298.9
 20         .0
 21      299.5
ENTERING ORIGINAL ITPP3 HMTWR RETRIEVAL, IPASS = 0
CHANGE WEIGHTING FUNCTION CHANNELS (0=NO, 1=YES)
0
BEGIN CLEAR-CHECK
TSKIN = 296.63
ICLR = 0, ICLD = 0
TSKIN ADJUSTED IN "HMTWR" - CLEAR CHECK FAILURE :TSKIN = TSTA =
    301.750000
CHAN  1 TBO = 233.29 TBC = 233.31 DTB =  -.02 ERO =   .41 IUSE = 1
CHAN  2 TBO = 219.09 TBC = 219.12 DTB =  -.03 ERO =   .36 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.81 DTB =   .07 ERO =   .29 IUSE = 0
CHAN  4 TBO = 232.87 TBC = 232.63 DTB =   .24 ERO =   .25 IUSE = 0
CHAN  5 TBO = 249.18 TBC = 248.71 DTB =   .48 ERO =   .25 IUSE = 0
CHAN  6 TBO = 260.71 TBC = 260.60 DTB =   .11 ERO =   .28 IUSE = 0
CHAN  7 TBO = 273.07 TBC = 273.58 DTB =  -.51 ERO =   .53 IUSE = 0
CHAN 10 TBO = 290.86 TBC = 290.34 DTB =   .51 ERO =   .88 IUSE = 0
CHAN 11 TBO = 262.90 TBC = 263.39 DTB =  -.49 ERO =   .49 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 246.14 DTB =  -.44 ERO =   .64 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 281.71 DTB =  1.46 ERO =   .81 IUSE = 0
CHAN 14 TBO = 271.98 TBC = 271.22 DTB =   .76 ERO =   .46 IUSE = 0
CHAN 15 TBO = 252.31 TBC = 252.24 DTB =   .07 ERO =   .26 IUSE = 0
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =   .00 ERO =   .50 IUSE =
CHAN 18 TBO = 256.59 TBC = 256.57 DTB =   .02 ERO =   .25 IUSE =
CHAN 19 TBO = 226.06 TBC = 226.08 DTB =  -.01 ERO =   .25 IUSE =
```

```
CHAN 20 TBO = 206.53 TBC = 206.52 DTB =   .01 ERO =   .34 IUSE =
AFTER RETRIEVAL ...
TSKIN = 301.75
CHAN  1 TBO = 233.29 TBC = 233.32 DTB =  -.02 IUSE = 1
CHAN  2 TBO = 219.09 TBC = 219.12 DTB =  -.03 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.81 DTB =   .07 IUSE = 0
CHAN  4 TBO = 232.87 TBC = 232.63 DTB =   .24 IUSE = 0
CHAN  5 TBO = 249.18 TBC = 248.72 DTB =   .46 IUSE = 0
CHAN  6 TBO = 260.71 TBC = 260.61 DTB =   .09 IUSE = 0
CHAN  7 TBO = 273.07 TBC = 273.60 DTB =  -.53 IUSE = 0
CHAN 10 TBO = 290.86 TBC = 290.36 DTB =   .50 IUSE = 0
CHAN 11 TBO = 262.90 TBC = 263.41 DTB =  -.51 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 246.15 DTB =  -.45 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 281.72 DTB =  1.44 IUSE = 0
CHAN 14 TBO = 271.98 TBC = 271.23 DTB =   .74 IUSE = 0
CHAN 15 TBO = 252.31 TBC = 252.26 DTB =   .05 IUSE = 0
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =   .00 IUSE =
CHAN 18 TBO = 256.59 TBC = 256.58 DTB =   .01 IUSE =
CHAN 19 TBO = 226.06 TBC = 226.08 DTB =  -.01 IUSE =
CHAN 20 TBO = 206.53 TBC = 206.52 DTB =   .01 IUSE =
ITERATE RETRIEVAL AGAIN (Y/N)
N
TSS(1) = TBSWC
CHANGE SURFACE SKIN TEMP TO HIRS CH. 9 VALUE (Y/N)
N
BEGIN KLOUD, MS = 37
CLOUD LEVEL = 37, AMOUNT =  .60
ENTERING ORIGINAL ITPP3 HMTWR RETRIEVAL, IPASS = 1
CHANGE WEIGHTING FUNCTION CHANNELS (0=NO, 1=YES)
0
BEGIN CLEAR-CHECK
TSKIN = 299.48
T4.0 - T11.0 > 3K
ICLR = 1, ICLD = 1
CHAN  1 TBO = 233.29 TBC = 233.32 DTB =  -.02 ERO =   .41 IUSE = 1
CHAN  2 TBO = 219.09 TBC = 219.12 DTB =  -.03 ERO =   .36 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.81 DTB =   .06 ERO =   .29 IUSE = 1
CHAN  4 TBO = 232.87 TBC = 232.63 DTB =   .24 ERO =   .25 IUSE = 1
CHAN  5 TBO = 249.18 TBC = 248.70 DTB =   .48 ERO =   .25 IUSE = 1
CHAN  6 TBO = 260.71 TBC = 260.58 DTB =   .13 ERO =   .28 IUSE = 1
CHAN  7 TBO = 273.07 TBC = 273.56 DTB =  -.50 ERO =   .53 IUSE = 1
CHAN 10 TBO = 290.86 TBC = 291.28 DTB =  -.42 ERO =   .88 IUSE = 1
CHAN 11 TBO = 262.90 TBC = 263.40 DTB =  -.49 ERO =   .49 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 246.15 DTB =  -.45 ERO =   .64 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 282.76 DTB =   .41 ERO =   .81 IUSE = 1
CHAN 14 TBO = 271.98 TBC = 271.83 DTB =   .15 ERO =   .46 IUSE = 1
CHAN 15 TBO = 252.31 TBC = 252.37 DTB =  -.06 ERO =   .26 IUSE = 1
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =   .00 ERO =   .50 IUSE =
CHAN 18 TBO = 256.59 TBC = 256.58 DTB =   .02 ERO =   .25 IUSE =
CHAN 19 TBO = 226.06 TBC = 226.08 DTB =  -.01 ERO =   .25 IUSE =
CHAN 20 TBO = 206.53 TBC = 206.52 DTB =   .01 ERO =   .34 IUSE =
AFTER RETRIEVAL ...
TSKIN = 299.48
CHAN  1 TBO = 233.29 TBC = 233.35 DTB =  -.05 IUSE = 1
```

```
CHAN  2 TBO = 219.09 TBC = 219.15 DTB =   -.05 IUSE = 1
CHAN  3 TBO = 219.88 TBC = 219.87 DTB =    .01 IUSE = 1
CHAN  4 TBO = 232.87 TBC = 232.72 DTB =    .15 IUSE = 1
CHAN  5 TBO = 249.18 TBC = 248.77 DTB =    .42 IUSE = 1
CHAN  6 TBO = 260.71 TBC = 260.61 DTB =    .10 IUSE = 1
CHAN  7 TBO = 273.07 TBC = 273.53 DTB =   -.46 IUSE = 1
CHAN 10 TBO = 290.86 TBC = 291.19 DTB =   -.33 IUSE = 1
CHAN 11 TBO = 262.90 TBC = 263.11 DTB =   -.21 IUSE = 1
CHAN 12 TBO = 245.70 TBC = 245.84 DTB =   -.15 IUSE = 1
CHAN 13 TBO = 283.17 TBC = 282.75 DTB =    .42 IUSE = 1
CHAN 14 TBO = 271.98 TBC = 271.87 DTB =    .11 IUSE = 1
CHAN 15 TBO = 252.31 TBC = 252.47 DTB =   -.16 IUSE = 1
CHAN 17 TBO = 233.86 TBC = 233.86 DTB =    .00 IUSE =
CHAN 18 TBO = 256.59 TBC = 256.71 DTB =   -.12 IUSE =
CHAN 19 TBO = 226.06 TBC = 226.20 DTB =   -.14 IUSE =
CHAN 20 TBO = 206.53 TBC = 206.52 DTB =    .01 IUSE =
ITERATE FINAL RETRIEVAL AGAIN (Y/N)
N

PRESSURE GES TEMP GES DEWP GES MIXR RTV TEMP RTV DEWP RTV MIXR  DT     DD     DM
-------- -------- -------- -------- -------- -------- --------  --     --     --

  1000.0    28.6     23.5     18.0     28.8     23.5     18.0   .2    -.0    -.0
   950.0    26.5     21.6     16.9     26.7     21.7     17.0   .3     .1     .1
   920.0    24.4     19.7     15.5     24.7     20.5     16.3   .3     .9     .8
   850.0    19.2     14.8     12.3     19.5     17.8     14.9   .3    3.0    2.6
   780.0    15.1     10.9     10.4     15.4     11.1     10.6   .3     .2     .1
   700.0     9.9     -4.5      3.9     10.2     -4.2      4.0   .4     .2     .1
   670.0     6.9     -7.1      3.3      7.2     -6.8      3.4   .4     .3     .1
   620.0     2.9    -10.7      2.7      3.3    -10.3      2.8   .4     .4     .1
   570.0    -1.1    -14.3      2.2      -.7    -13.6      2.3   .4     .7     .1
   500.0    -8.1    -20.5      1.5     -7.7    -19.7      1.6   .4     .8     .1
   475.0   -11.1    -25.0      1.1    -10.7    -24.1      1.1   .4     .9     .1
   430.0   -16.1    -29.4       .8    -15.7    -28.5       .8   .4     .9     .1
   400.0   -20.1    -31.8       .5    -19.7    -34.1       .5   .4   -2.4     .0
   350.0   -27.1    -38.2       .3    -26.7    -37.5       .3   .4     .6     .0
   300.0   -33.1    -45.2       .1    -32.7    -44.8       .2   .4     .4     .0
   250.0   -42.1    -55.1       .1    -41.8   -273.1       .1   .4  *****     .0
   200.0   -53.1    -63.8       .0    -52.9   -273.1       .0   .3  *****     .0
   150.0   -64.1    -65.8       .0    -64.0   -273.1       .0   .2  *****     .0
   135.0   -68.1    -68.1       .0    -68.0   -273.1       .0   .1  *****     .0
   115.0   -75.1    -75.1       .0    -75.1   -273.1       .0   .0  *****     .0
   100.0   -80.1    -80.1       .0    -80.2   -273.1       .0  -.0  *****     .0
    85.0   -76.1    -76.1       .0    -76.2   -273.1       .0  -.0  *****     .0
    70.0   -72.1    -72.1       .0    -72.2   -273.1       .0  -.0  *****    -.0
    60.0   -68.1    -72.0       .0    -68.1   -273.1       .0   .0  *****     .0
    50.0   -64.1    -73.2       .0    -64.1   -273.1       .0   .1  *****     .0
    30.0   -54.1    -76.5       .0    -54.1   -273.1       .0   .1  *****     .0
    25.0   -51.1    -77.6       .0    -51.0   -273.1       .0   .1  *****     .0
    20.0   -48.1    -79.0       .0    -48.0   -273.1       .0   .1  *****     .0
    15.0   -44.1    -80.8       .0    -44.0   -273.1       .0   .1  *****     .0
    10.0   -38.1    -83.2       .0    -38.0   -273.1       .0   .1  *****     .0
     7.0   -33.1    -85.3       .0    -33.0   -273.1       .0   .1  *****     .0
     5.0   -27.1    -87.2       .0    -27.0   -273.1       .0   .1  *****     .0
```

```
       4.0   -24.1     -88.4         .0     -24.0    -273.1        .0       .1 *****    .0
       3.0   -16.1     -56.1         .0     -16.0    -273.1        .0       .1 *****    .0
       2.0   -12.1     -52.1         .0     -12.0    -273.1        .0       .1 *****    .0
       1.5    -7.1     -47.1         .0      -7.1    -273.1        .0       .1 *****    .0
       1.0    -3.1     -43.1         .0      -3.1    -273.1        .0       .1 *****    .0
        .5    -8.1     -48.1         .0      -8.1    -273.1        .0       .1 *****    .0
        .2   -25.1     -65.1         .0     -25.1    -273.1        .0       .1 *****    .0
        .1   -40.1     -80.1         .0     -40.1    -273.1        .0       .1 *****    .0

 PRESSURE GEOP ALT RI CURVE RI  FLAT
 -------- -------- -------- --------


   1000.0    116.0    375.5    393.7
    950.0    572.6    353.3    443.2
    920.0    856.3    341.3    475.8
    850.0   1547.2    314.1    557.0
    780.0   2284.4    269.1    627.8
    700.0   3194.8    212.4    714.0
    670.0   3557.3    202.8    761.2
    620.0   4190.9    187.7    845.6
    570.0   4867.8    173.1    937.3
    500.0   5901.1    152.9   1079.3
    475.0   6298.0    145.2   1133.8
    430.0   7056.2    132.9   1240.6
    400.0   7597.5    124.4   1317.1
    350.0   8575.4    111.7   1457.9
    300.0   9674.6     97.5   1616.3

  NUMBER OF RETRIEVALS OUTPUT =    1

  PASS BEGINS 850324/ 65148 GMT, ENDS  65935 GMT.

 SUMMARY OF HMTWR FAILURES ...

   PASS 0 ...       0       0       0       0       0
   PASS 1 ...       0       0       0       0       0
 Stop - Program terminated.
```

THE TECHNICAL PROCEEDINGS OF THE FIFTH INTERNATIONAL TOVS STUDY CONFERENCE

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