

# Use of TIGR-3 Atmospheric Profiles as Input for SBDART

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## **Abstract**

For the development of the GERB ground segment, a large data base of spectral radiance fields at the top of the atmosphere is needed. This data base is built using the SBDART radiative transfer code. An important physical input for radiative transfer computation, specially in the thermal part of the spectrum, is the vertical profiles of temperature, humidity, ... These profiles have been extracted from an existing data base, the TIGR3 data base, provided by the Laboratoire de Meteorologie Dynamique. This document describes shortly this data base and the transformations we had to do to use these profiles as input for SBDART.

## **1 Introduction**

For the development of the GERB ground segment, a large data base of spectral radiance fields at the top of the atmosphere is needed. This data base is built using the SBDART radiative transfer code as fully explained in document [1]. An important physical input for radiative transfer computation, specially in the thermal part of the spectrum, is the vertical profiles of temperature, humidity, ... These profiles have been extracted from an existing data base, the TIGR3 data base, provided by the Laboratoire de Meteorologie Dynamique. This document describes shortly this data base and the transformations we had to do to use these profiles as input for SBDART.

The TIGR-3 data base is available from the *Laboratoire de Meteorologie Dynamique* (LMD). The responsible persons are Noelle Scott (+33-1-69334532) and Raymond Armante (+33-1-69333630).

## 2 Original data format

The TIGR3 data base contains 2311 measured atmospheric profiles. The all data base is stored in the single ASCII file, profile by profile. Copy of this file is available on our server at:

`/planet/nic/Atmosphere/TIGR3/atm4atigr3.dsf`

For each profile, the file gives:

- TIGR *number*,
- latitude and longitude (in centi-degrees),
- date of the profile measurement, format is YYMMDD,
- temperature at the 40 pressure levels ( $K$ ),
- temperature ( $K$ ) and pressure ( $mb$ ) at the surface level,
- water vapor concentration ( $g/g$ ) at the 40 pressure levels,
- ozone concentration ( $g/g$ ) at the 40 pressure levels.

The 40 pressure levels, which are the same for all profiles in the data base, are defined in the file **lectigr.f** ( $mb$ ):

0.05	0.09	0.17	0.30	0.55	1.00	1.50	2.23	3.33	4.98
7.43	11.11	16.60	24.79	37.04	45.73	56.46	69.71	86.07	106.27
131.20	161.99	200.00	222.65	247.87	275.95	307.20	341.99	380.73	423.85
471.86	525.00	584.80	651.04	724.78	800.00	848.69	900.33	955.12	1013.00

### Important note :

The surface temperature and pressure seem not be valid: for all the element in the database the surface pressures is 1013  $mb$  and the surface temperature is equal to the last value in temperature profile! In fact these 2 quantities seem not be measured.

### 3 Computation of the level heights

When using atmospheric profile as input for SBDART, the height profile must be given. The height profiles have been computed as follow. The variation of height with pressure is (*hydrostatic equation*):

$$\Delta z = - \frac{1}{\rho g} \Delta p \quad (1)$$

where  $\rho$  is the volumic mass (density)

$$\rho = \frac{nM}{V} = \frac{nM}{\frac{nRT}{p}} = \frac{Mp}{RT} \quad (2)$$

combining equations (1) and (2):

$$\Delta z = - \frac{RT(p) \Delta p}{Mg p} \quad (3)$$

Integrating equation (3) on a small interval within the profile ( $T(p)$  must be supposed constant):

$$z_1 - z_0 = \frac{R}{Mg} \langle T \rangle \ln \frac{p_0}{p_1} \quad (4)$$

where:

- $R = 8.31434 \text{ J mol}^{-1} \text{ K}^{-1}$
- $M = (1 + C_{H_2O}) M_a$  is the molar mass
- $M_a = 28.9644 \cdot 10^{-3} \text{ kg mol}^{-1}$  is the molar mass of the dry air
- $C_{H_2O}$  is the water vapor concentration in  $g/g$ .

Using these values, equation (4) the difference of height in a small layer is :

$$z_1 - z_0 = \frac{29.26134}{(1 + \langle C_{H_2O} \rangle)} \langle T \rangle \ln \frac{p_0}{p_1}$$

where  $\langle T \rangle$  and  $\langle C_{H_2O} \rangle$  are the mean temperature and water vapor concentration between  $z_0$  and  $z_1$ . In practice each layer in the profile is split in 10 sub-layers. For more detail about the implementation see the library routine:

```
MP_vector *ATM_HeightProfile( MP_vector *p, MP_vector *t, MP_vector *h2o );
```

## 4 Unit change for $C_{H_2O}$ and $C_{O_3}$

The unit for water vapor and ozone concentration is the TIGR-3 profiles are  $g/g$ . To be used as SBDART input, these concentration must be converted into  $g/m^3$ . The conversion is done by multiplying the  $g/g$  value by the air density  $\rho$ :

$$C_{H_2O}(gm^{-3}) = \rho(gm^{-3}) C_{H_2O}(g/g)$$

where the air density is depend on the temperature, pressure and water vapor concentration:

$$\rho(gm^{-3}) = \frac{M_a(g\ mol^{-1})(1 + C_{H_2O})p(Pa)}{RT} = (1 + C_{H_2O}) \frac{28.9644 p(Pa)}{8.31434 T(K)}$$

$$\rho(gm^{-3}) = 348.367 (1 + C_{H_2O}) \frac{p(mb)}{T(K)}$$

## 5 Vertical Integration for $C_{H_2O}$ and $C_{O_3}$

The concentrations can then be integrated on the vertical profile to obtain the integrated water vapor and ozone amount in  $g\ cm^{-2}$ .

For the ozone, the integrated amount can be converted into Dobson Unit (DU) using:

$$1\ DU = 2.7\ 10^{16}\ molecule\ cm^{-2} \frac{48\ g\ mol^{-1}}{6.02\ 10^{23}\ molecule\ mol^{-1}} = 2.153\ 10^{-6}\ g\ cm^{-2}$$

## 6 Profiles extraction

The `extract_tigr.c` program is used to transform the original file into a set of files containing each a single atmospheric profile under a specific ASCII format that can be easily used as input for SBDART. This program is located in:

```
/planet/nic/Atmosphere/Src/extract_tigr.c
```

This program supports 2 main options:

- `-w` : write resulting file on the disk
- `-i` : interpolate if the difference of temperature between two adjacent layers is higher than 20K. In this case, the interpolation creates a new layer between these 2 layers and the profiles (z,p,T,H2O, O3) is linearly interpolated. This options has been used because SBDART may experiment some problem when using atmospheric profile with  $dT > 20K$  between layers. If the number of such interpolation is higher than 2, the profile is discarded. This appends only once in the data base.

So, the files are created using the command line:

```
cd /planet/nic/Atmosphere/TIGR3_DATA_20  
../Src/extract_tigr ../TIGR3/atm4atigr3.dsf -i -w
```

The created files are stored in the working directory:

```
/planet/nic/Atmosphere/TIGR3_DATA_20
```

with file names :

```
tigr_%04d.dat
```

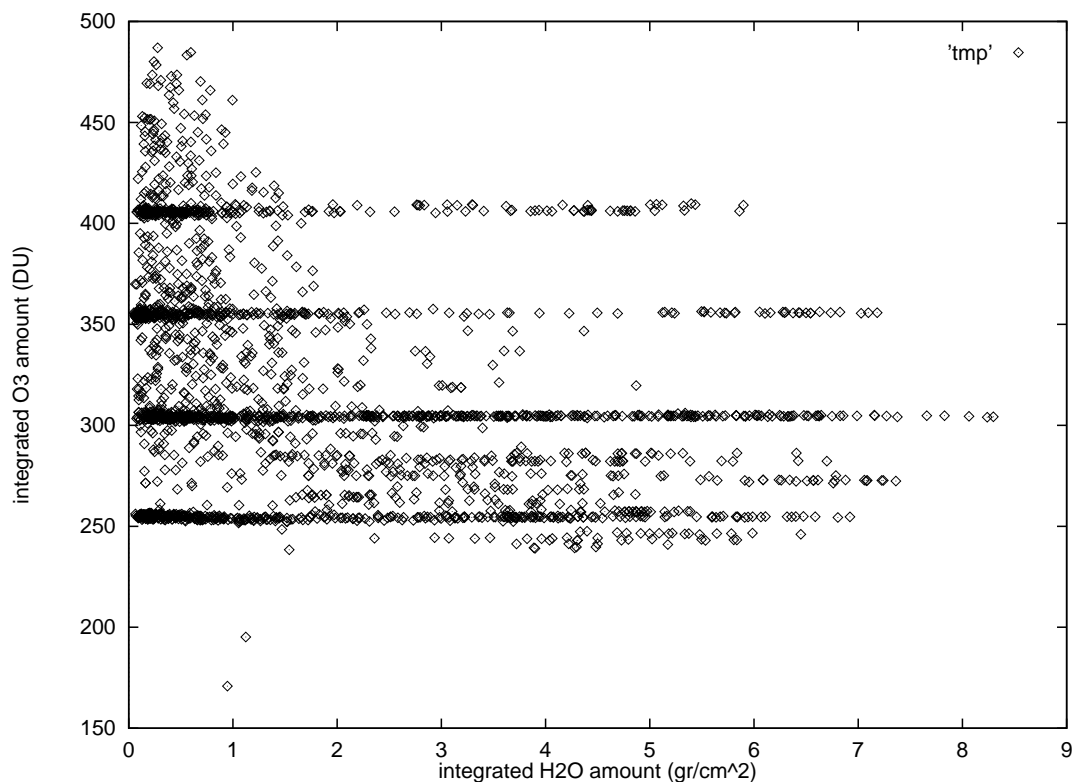


Figure 1: integrated water vapor and ozone concentration for the profiles in the TIGR-3 data base.

## 7 Validations

The figure (1) shows the distribution of the integrated concentration for the 2133 profiles of the data base. For most of the profiles, the measurement of ozone was not done and standard profiles have been used. This is the cause of the clustering that appears on figure (1).

Figure (2) shows the distribution of the surface level temperature versus the temperature at  $z = 10 \text{ km}$ .

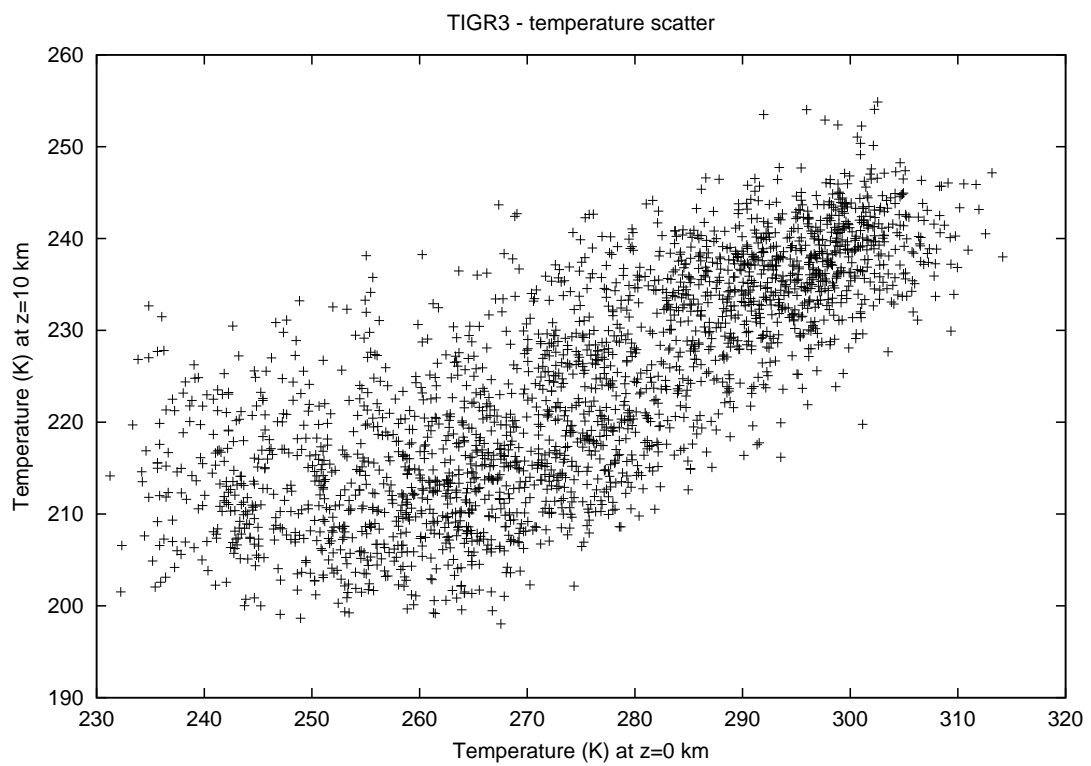


Figure 2: distribution of the surface temperature for the TIGR-3 data base.

## 8 Example of profile file

```
# Atmospheric profile from the TIGR-3 data base
# Conversion from the ../Src/extract_tigr program
# Nicolas Clerbaux, december 1999
# TIGR3_profile_number = 7
# TIGR3_profile_id = 1
# Lat = -8948
# Lon = 2803
# Date = 820200
# Surface_temperature = 289.480000
# Surface_pressure = 1013.000000
# Integrated_WV_amount_(gr/cm^2)= 2.981256
# Integrated_O3_amount_(gr/cm^2)= 0.000555
# Integrated_O3_amount_(DU)= 257.703271
# Integrated_rho_(gr/cm^2)= 1027.860614
# number_of_vertical_interpolation = 0
# Units:
# km      pascal    kelvin      g/m^3      g^m3
68.448361 0.050000 211.080000 1.65041e-07 2.1532e-08
64.808155 0.090000 222.430000 2.81914e-07 3.67799e-08
60.657339 0.170000 234.710000 5.04644e-07 6.58384e-08
56.747356 0.300000 245.680000 8.50784e-07 3.90038e-07
52.381333 0.550000 255.340000 1.50076e-06 2.03308e-06
47.911540 1.000000 258.780000 2.69239e-06 7.13361e-06
44.838795 1.500000 262.940000 3.97468e-06 1.44041e-05
41.786397 2.230000 265.460000 5.85293e-06 2.82785e-05
38.673730 3.330000 262.130000 8.85106e-06 5.13008e-05
35.594448 4.980000 249.100000 1.39291e-05 8.95015e-05
32.684798 7.430000 237.750000 2.17739e-05 0.00013563
29.893435 11.110000 224.970000 3.44078e-05 0.000195712
27.252478 16.600010 220.780000 5.23862e-05 0.000243171
24.663742 24.789990 217.230000 7.95105e-05 0.000283041
22.115396 37.039990 210.200000 0.000122774 0.000293878
20.820283 45.730000 206.340000 0.000154414 0.000278168
19.549281 56.460010 201.060000 0.000195651 0.000271701
18.309723 69.710010 198.780000 0.000244338 0.000238449
17.083608 86.070010 198.410000 0.000302243 0.000170178
15.858401 106.270000 202.400000 0.000643918 0.000144604
14.607963 131.200000 209.980000 0.00144197 0.000123856
13.310940 161.990000 215.630000 0.00326327 9.09131e-05
11.979187 200.000000 221.500000 0.00738178 6.92724e-05
11.283565 222.650000 223.360000 0.0112432 6.92146e-05
```



10.581983 247.870000 225.210000 0.0171288 6.83973e-05  
9.874227 275.950000 228.940000 0.0258834 6.61383e-05  
9.154910 307.200000 233.330000 0.0390075 6.26532e-05  
8.421536 341.990000 239.510000 0.189775 5.75689e-05  
7.668834 380.730000 245.420000 0.212805 5.12448e-05  
6.897678 423.850100 251.630000 0.156311 4.3364e-05  
6.106844 471.860100 257.870000 0.289313 3.37832e-05  
5.301090 525.000000 263.650000 0.65514 2.39439e-05  
4.468757 584.800000 269.510000 0.89598 1.55516e-05  
3.622671 651.040000 275.390000 1.67812 9.18241e-06  
2.759494 724.780000 278.160000 4.66505 4.89588e-06  
1.959180 800.000000 283.340000 6.25973 2.40834e-06  
1.472208 848.689900 285.890000 7.16396 1.48236e-06  
0.981463 900.330100 286.550000 10.6219 8.73785e-07  
0.490738 955.120100 288.170000 13.0496 4.84297e-07  
0.000000 1013.000000 289.480000 13.5423 2.52766e-07

## References

- [1] N. Clerbaux. Generation of a data base of toa spectral radiance fields. Internal Document MSG-RMIB-GE-TN-0030, RMIB, December 1999.