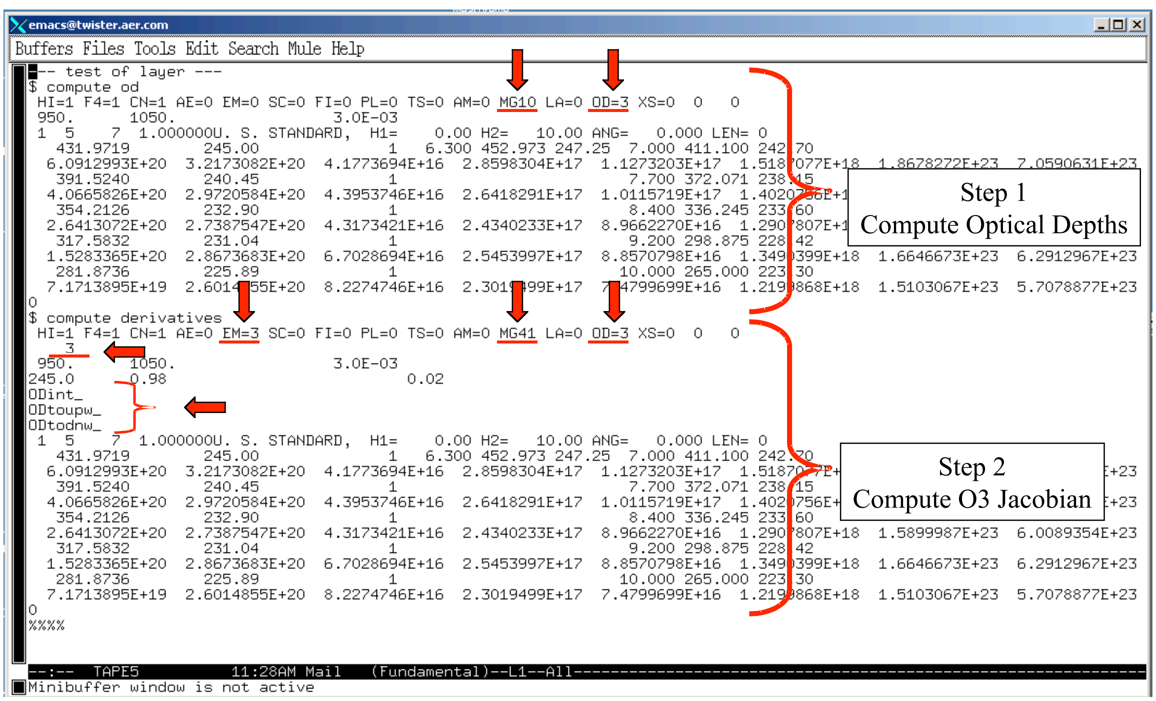
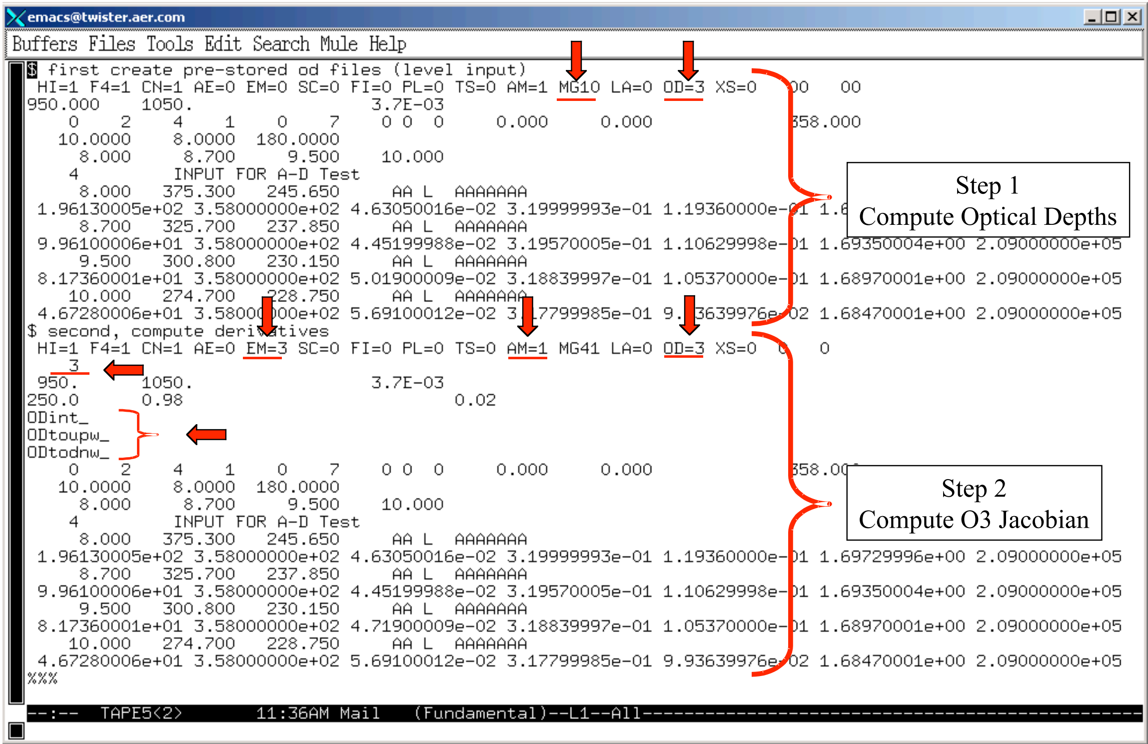
The implementation of analytic Jacobians in LBLRTM was designed to require a minimal amount of setup on the part of the user while exploiting pre-existing LBLRTM calculation options. It is apparent from the equations for analytic derivatives that a number of different optical depth files are required: layer optical depth and total optical depth from the layer to the top and bottom of the atmosphere. These are created in a pre-processing run of LBLRTM using the IMRG=10 option. This option (modified slightly for the calculation of analytic Jacobians) will create, for each layer, files containing the total optical depth (ODint) and files containing the total optical depth from the layer to the top (ODtoupw) and bottom (ODtodnw) of the atmosphere (that is, the upwelling "upw" and downwelling "dnw" terms). As described in the specific user instructions, below, these files are created for a user-specified, fixed wavenumber grid for all layers using the "odint" and "dvset" options. Following this run of LBLRTM, subsequent runs are done using the IMRG=40,41 options with IEMIT=3 to create the analytic derivative files. If the user has requested the derivative for upwelling radiation, the code automatically makes the calculation of downwelling derivatives required for the upwelling derivatives. A single run of LBLRTM is required for each of the desired derivatives. The layer to level conversion is done after the layer derivative files are created, but only if level information was provided in the LBLRTM input file. Note that in order to compute accurate layer to level conversion it is required that the input profile values be on the same grid as the specified model levels. It is also possible to "scan" the derivative files (IMRG=42,43 options with IEMIT=3) to create files representative of a particular sensor response function. Examples of the TAPE5 format are given in Figure 1 and Figure 2.





```
emacs@twister.aer.com
Buffers Files Tools Edit Search Mule Help
$ first create pre-stored od files (level input)
 HI=1 F4=1 CN=1 AE=0 EM=0 SC=0 FI=0 PL=0 TS=0 AM=1 MG10 LA=0 OD=3 XS=0     00    00
950.000     1050.                   3.7E-03
    0     2     4     1     0     7     0 0  0       0.000       0.000                358.000
   10.0000     8.0000   180.0000
     8.000       8.700       9.500      10.000
    4          INPUT FOR A-D Test
     8.000     375.300     245.650       AA L   AAAAAAA
 1.96130005e+02 3.58000000e+02 4.63050016e-02 3.19999993e-01 1.19360000e-01 1.6
     8.700     325.700     237.850       AA L   AAAAAAA
 9.96100006e+01 3.58000000e+02 4.45199988e-02 3.19570005e-01 1.10629998e-01 1.69350004e+00 2.09000000e+05
     9.500     300.800     230.150       AA L   AAAAAAA
 8.17360001e+01 3.58000000e+02 5.01900009e-02 3.18839997e-01 1.05370000e-01 1.68970001e+00 2.09000000e+05
    10.000     274.700     228.750       AA L   AAAAAAA
 4.67280006e+01 3.58000000e+02 5.69100012e-02 3.17799985e-01 9.93639976e-02 1.68470001e+00 2.09000000e+05
$ second, compute derivatives
 HI=1 F4=1 CN=1 AE=0 EM=3 SC=0 FI=0 PL=0 TS=0 AM=1 MG41 LA=0 OD=3 XS=0     0     0
   3
 950.       1050.                   3.7E-03
250.0       0.98                            0.02
ODint_
ODtoupw_
ODtodnw_
    0     2     4     1     0     7     0 0  0       0.000       0.000                358.00
   10.0000     8.0000   180.0000
     8.000       8.700       9.500      10.000
    4          INPUT FOR A-D Test
     8.000     375.300     245.650       AA L   AAAAAAA
 1.96130005e+02 3.58000000e+02 4.63050016e-02 3.19999993e-01 1.19360000e-01 1.69729996e+00 2.09000000e+05
     8.700     325.700     237.850       AA L   AAAAAAA
 9.96100006e+01 3.58000000e+02 4.45199988e-02 3.19570005e-01 1.10629998e-01 1.69350004e+00 2.09000000e+05
     9.500     300.800     230.150       AA L   AAAAAAA
 8.17360001e+01 3.58000000e+02 4.71900009e-02 3.18839997e-01 1.05370000e-01 1.68970001e+00 2.09000000e+05
    10.000     274.700     228.750       AA L   AAAAAAA
 4.67280006e+01 3.58000000e+02 5.69100012e-02 3.17799985e-01 9.93639976e-02 1.68470001e+00 2.09000000e+05
%%%
--:--  TAPE5<2>        11:36AM Mail    (Fundamental)--L1--All---------------------------------------------
```


Figure 2. Example TAPE5 format for level calculation.

Within the code, the calculation of analytic derivatives is as follows. As mentioned above, the first run of the code (IMRG=10) is used to compute the total optical depth for each layer and the transmission to the top and bottom of the atmosphere (in LBLRTM nomenclature, transmission from each layer to H1 and H2). For the derivative run of the code, all molecules are zeroed (automatically) except for the geophysical parameter desired for the calculation (care is taken to ensure that the other amounts are properly included in the calculation of broadening gases) in order to compute the single-species optical depth required for the molecular Jacobian calculation. For each layer, the code loops over each panel to compute the layer derivative. For the case of upwelling derivatives, the code is first set (automatically) to compute the downwelling derivative. These files are then used in the subsequent upwelling calculation (along with information about surface emissivity, temperature, and reflectivity, as necessary).