User's Guide to Nonhydrostatic Axisymmetric Hurricane Model of Rotunno and Emanuel (1987)

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Reference: Rotunno, R., and K. A. Emanuel, 1987: An air-sea interaction theory for tropical cyclones. Part II. *J. Atmos. Sci.*, **44,** 542-561.

The model was written by Richard Rotunno and has been slightly modified from the original 1987 version, by K. Emanuel, adding dissipative heating and using the full (rather than initial state) virtual potential temperature in the pressure gradient terms of the momentum equations.

Quick Start:

1. Compile the FORTRAN program *hurricane.f*. The code is fairly standard and should compile with most compilers. It is known to compile with g95 and with Portland Group Fortran. For the latter, the settings -fast -Mipa=fast –Mconcur are known to work well on machines with multiple processors.

2. If necessary, give execute permission to the file *runhurr* (Linux) or *runhurr.bat* (Windows).

3. Open the regular ASCII file *hurr.in* and set parameter values. The code uses the values in the first column; the second column just lists the standard values of the parameters. It is a good idea to study this file before first use, and see the section below that describes some of the parameters in more depth.

4. Execute the program by typing at the command prompt *runhurr <outputfilename>,* where *<outputfilename>* is a name you assign to the folder that will contain the output. (For example, *runhurr test* will create and output folder *output_test*.) You will usually want to run the program in background (*runhurr <outputfilename> &* in Linux or *Start /B runhurr <outputfilename>* in Windows). On a high end desktop, the program should run with standard parameters in about 30 minutes.

5. After the program finishes, you can display the output using MATLAB. Type *tcmenu* at the MATLAB prompt. You will be asked to enter the output filename (omitting "output", so for example you would enter "test" in the example above), whether you want to display the output at the final time or some other time, and the maximum radius to display in the plots. The rest is menu-driven and the plots are fairly self-explanatory. If you do not have MATLAB, you can still examine the file *tcmenu.m* to see how it reads output.

Initial Sounding File

The sea surface temperature and the initial sounding, used also in the outer boundary condition, are contained in the ASCII file *s.in*. This sounding is interpolated to the model grid. One can substitute any sounding for this one as long as the vertical line spacings (e.g. header lines) in the file are preserved. Note also that the code produces an outer sounding at the final time, contained in the file *s.out* in the output directory. The *s.in* sounding provided in this package is a model-neutral sounding, and the use of conditionally unstable soundings is discouraged.

The Input File *hurr.in*

The code reads many parameters from the first column of the ASCII file *hurr.in*, which is used here in place of a makefile. The second column contains the “normal” values of the parameters, the third column lists the names of the variables as they are used by the code itself, and the last column has brief descriptions of the parameters.

Note that the number of grid points in the radial and vertical directions are not currently set in the hurr.in file. To change these, you must change the parameters *M* and *N* in the main program and in subroutine *DIFFUSE*.

Here are some further notes on parameters in *hurr.in* that are not already obvious:

CD and **CE** are the base surface exchange coefficients for momentum and enthalpy.

CD1 is the coefficient of the wind-dependence of surface fluxes of both momentum and enthalpy.

CDCAP and **CKCAP** are upper bounds on the surface flux coefficients of momentum and enthalpy.

Thus the actual surface flux coefficients are given by

$$C_D = \min\left(C_D + C_{D1}|\mathbf{V}|,\ CDCAP \right),$$
$$C_k = \min\left(C_E + C_{D1}|\mathbf{V}|,\ CKCAP \right),$$

where $|\mathbf{V}|$ is the wind speed used by the model to calculate surface fluxes.

VCAP is the maximum allowed wind speed used in the surface fluxes, useful for exploring how this affects storm intensity and intensification. Use a large value if no cap is desired.

PDEP (‘y’ or ‘n’) indicates whether the actual calculated surface pressure is used in calculating the sea surface potential temperature and saturation specific humidity. Setting this to ‘n’ shuts off the heat input from isothermal expansion.

XHL and **VHL** are the horizontal and vertical mixing lengths used in the model’s turbulence schemes.

DISS controls dissipative heating. Setting it to zero ignores dissipative heating while setting it to one assumes that all the dissipated turbulence energy is used to heat the air. It can be set to any value between zero and one.

ACT is an autoconversion threshold. All condensed water with values greater than ACT is assumed to fall at its terminal velocity.

VTERM is the terminal fall speed of all precipitation (regardless of type) of condensed water in excess of ACT. But if it is set to zero, then the code calculates the fall speed according to the amount of condensed water, air density, etc. and also transitions smoothly to the constant value VTERMSNOW as the air temperature falls to -20 C.

VTERMSNOW is the fall speed of snow, assumed constant. But this is only used when VTERM=0, otherwise the fall speed of all precipitation is VTERM.

EVAP set the evaporation rate of precipitation. If set to 'n', evaporation is turned off, if to 'y' it is calculated from a rate equation that depends on the condensed water content, the saturation deficit of the air, etc. When set to 'i' (for 'instantaneous'), the original formulation is used, wherein enough rain evaporates instantaneously to saturate the air.

TMIN is a lower bound on temperature (K) in the domain. This is useful for testing outflow temperature dependencies without having to change the input sounding. Its default value is low enough that the bound is never invoked.

TMID is the amplitude (C) of an imposed sea surface temperature anomaly centered at the storm center.

RSST is the decay length scale (km) of the imposed sea surface temperature anomaly.

ETIME is the end time of the simulation, in days.

TAVE is the averaging time (days) for quantities used in radial and contour plots (but the time-radius sections do not use time averaging).

PLTIME is the time interval (days) between contour plots.

TIMMAX is the time interval (hrs) between writes to the file *texout.txt.*

TIMEPL is the time interval (days) used for the time series and time-radius plots.

ROG is the outer limit (km) in radius, contour, and time-radius plots.

ZOG is the upper limit (km) in contour plots.