A&OS C115/C228 – Experiment # 4: Supercell/multicell storms and hydraulic jumps

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http://www.atmos.ucla.edu/∼fovell/DTDM
http://www.atmos.ucla.edu/∼fovell/ARPS

The fourth experiment can use ARPS to explore supercell or multicell storms or DTDM/DTDM2 to examine multicell storms and hydraulic jumps. (ARPS can incorporate a corrugated lower boundary, including an isolated mountain, but the mountain cannot be represented properly in GrADS so the results are distorted. If you want to explore ARPS w/ terrain, please feel free to do so; I will provide you with different plotting software.) Here are a few suggestions; again, you may design your own experiment. As usual, start with a prediction/hypothesis, plan a set of simulations to test the hypothesis, and conclude with an evaluation of the hypothesis. As before, you can work in teams of two if you wish, and deliver the report to me in PowerPoint or Keynote format.

You can find DTDM2 on the DTDM web page and on the Synoptic Lab machines as `/home/fovell/DTDM2_package.tar`.

DTDM/DTDM2 for hydraulic jumps, etc.

DTDM does not have the ability to incorporate topography in its lower boundary. But, we can fake it by using a momentum source (the streamfunction) placed at the ground. This will force air passing into the streamfunction zone to rise and respond in a manner analogous to obstacle-deflected flow. This will require some serious trial and error, so budget time for exploration.

Turn on the streamfunction in the `&streamfunction` section. The settings below cause an isolated (since `s_repeat` = 0) and steady (`s_period` = 0) momentum source centered at the surface `s_znaught` = 0) with the specified horizontal and vertical dimensions.

```
 &streamfunction
istrfcn = 1,
s_repeat = 0,
s_ampl = 120.,
s_znaught = 0000.,
s_hwavel = 15000.,
s_vwavel = 4000.,
s_period = 0.,
 $
```

In `&environ`, set up environments with more stable layers underlying less stable ones, and vice-versa, to ascertain the conditions that favor or disfavor hydraulic jumps. Manipulate the wind by varying the strength of the flow and/or the shear. Don't forget that the acceleration terms may be useful in interpreting the atmospheric responses. In DTDM2, moisture can be turned on. DTDM2 removes supersaturation but does not carry cloud water; the presence of clouds would be indicated at places where the relative humidity is at or close to 100%. When `imoist` = 1, the relative humidity field is written to the GrADS output file.

You can consider making `s_repeat = 1` and looking at the flow over a series of mountain ranges.

Multicell storms

Multicell storms (the principal component of squall lines) can be simulated in 2D by DTDM2 or ARPS or in 3D with ARPS. DTDM2 lacks cloud microphysics, so the subcloud cold pool has to be externally supplied. This can be done in several ways. You can turn on moisture and supply an cold block of air (`icoolzone` = 2). This block will collapse and spread along the ground, lifting air to saturation depending on how you set up the humidity in the environment (in `&environ`). The atmosphere may respond by forming individual buoyant updrafts that propagate upward and rearward from the gust front, or leading edge of the cold air. However, this cold pool will become thinner as it spreads, so at some point, the lifting will become too weak to lift air. Does the storm weaken or strengthen during this time? Remember the acceleration terms may be useful in your analysis.

DTDM2 can also incorporate a cold pool maintained through a lower tropospheric heat sink, active when `icoolzone` = 1. The remaining parameters in `&cooling_zone` control the size and strength of the cooling zone. Once a cold pool is created, it will propagate relative to the ground. At this point, the cooling zone will be automatically repositioned to follow the cold pool, thereby maintaining it. With moisture on, study the nature of the buoyant updrafts created by this spreading pool, in the context of Rotunno et al. (1988) [see the discussion in the squall line presentation]. How does cell strength, behavior, motion change as the shear is altered? Does the depth, intensity or width of the cooling zone affect the results? You may be surprised.

More realistic multicell storms can be simulated in 2D or 3D in ARPS, which includes microphysics, including ice. You can start with the `arps.input.2D` and `may22.d5p0.snd` files on my ARPS page. The former is set up to do a relatively low resolution (2 km horizontal, 500 m vertical) simulation of a squall line initiated by a warm bubble. The latter is an ARPS sounding file, which does Fovell and Dailey's (1995, MWR) and Fovell and Tan's (1998, MWR) "D=5" case. That case had constant wind shear in the lowest 5 km.

Some ideas: Play with microphysics (warm rain and ice options; `mphyopt` in the `arps.input.2D` file) to see how it affects storm structure. Change the sounding in some way, altering low level moisture or the wind profile, etc.. You can edit the sounding file in a text editor or Excel or whatever. *See the section on ARPS sounding files below for important information.*

The `2d.gs` script can be invoked immediately after opening your 2D GrADS output file to put the display mode to 2D x-z. Depending on your computing platform, you may be forced to open each control file (called *.gradscntl for the ARPS output) to add “options byteswapped” manually somewhere near the top of the file.

Supercell storms

We saw in class that supercells are 3D rotating storms that require relatively large shear relative to the CAPE. On my ARPS page, the `arps.input.delcity`, `may20,snd` and `may20_calm.snd` may be used to simulate the classic Del City splitting storm. You can edit the sounding files by hand, adjusting the relative humidity at low levels (changing the CAPE) or manipulating the shear. As mentioned above, you might edit these files in a text editor or in Excel.

Some ideas: with Weisman and Klemp's (1982) experiment in mind, vary the low level moisture and shear and see how the convection changes. Make simulations with and without directional shear to see how the former causes the left and right movers to become different in strength and appearance.

ARPS sounding files

An ARPS sounding file consists of a set of header lines followed by sounding data arranged with height decreasing from the top down. Levels included in the sounding file do NOT necessarily correspond to model levels. If the model levels are different, the sounding data are interpolated. However, the model top cannot exceed the highest level included in the sounding file.

An example: This is part of the Del City sounding file:

```
 1-D Sounding Input for ARPS
 supercell storm
 15:00:00 CST
 20 May, 1977 - Domain speed subtracted (umove=3,vmove=14)
 Ft. Sill, OK (for Del City Storm)
 'height' 'potential temperature' 'relative humidity' 'uv'
   0.0 9.65e4
          35
 ZSND THSND QVSND USND-3.0  VSND-14.0
     16750.00000    414.00000      0.00000     15.00000     -5.40000
    16250.00000    406.00000      0.00000     15.00000     -5.40000
    15750.00000    398.00000      0.00000     15.00000     -5.40000
[lines excised]
     1250.00000    304.00000      0.85490     -9.20000      4.70000
      750.00000    303.00000      0.80820    -10.40000      2.00000
      250.00000    303.00000      0.71020    -12.00000     -3.00000
        0.00000    303.00000      0.71020    -12.00000     -3.00000
```

Most of the header lines are irrelevant. The important stuff is:

- 'height' 'potential temperature' 'relative humidity' 'uv' = the fields that will be provided below, in that order
- 0.0 9.65e4 = height of surface is 0 meters, and surface pressure is 96500 Pa
- 35 = the number of levels included in the sounding data
- The " ZSND THSND QVSND USND-3.0 VSND-14.0" is irrelevant
- DATA are height in meters, potential temperature in Kelvin, relative humidity in percent, and u and v wind components in m/s

ARPS input files

Important information in every ARPS input file

- runname = sets name for GrADS output files
- runmod = 1 (for 3D) or 2 (for 2D)
- pt0opt = 1 turns on the initial thermal
- ptpert = gives amplitude of initial thermal, in Kelvin
- pt0radx, pt0radz, pt0ctrx, pt0ctrz = control where thermal is placed and its dimensions
- sndfile = gives name of the ARPS sounding file
- mphyopt = microphysics option (1 for warm rain; 2 for scheme including ice, snow and graupel)
- grdtrns = 1 and umove = 12.0 would tell ARPS to subtract 12 m/s from the base state east-west wind profile, to help keep storm from getting too close to the west or east boundaries. Set to 0 to render it moot

Please see http://www.atmos.ucla.edu/~fovell/ARPS for much more information