Initialization for Idealized Cases

Why do we provide idealized cases?

1. The cases provide simple tests of the dynamics solver for a broad range of space and time scale:
   - LES - $\Delta x$ meters, $\Delta t < $ second;
   - Baroclinic waves - $\Delta x$ 100 km, $\Delta t = $ 10 minutes.
2. The test cases reproduce known solutions
   (analytic, converged, or otherwise).
3. The cases provide a starting point for other idealized experiments.
4. They can be used to test physics development.
5. These tests are the easiest way to test the solver.
Idealized Cases: Introduction

WRF ARW Tech Note
A Description of the Advanced Research WRF Version 3
http://www.mmm.ucar.edu/wrf/users/pub-doc.html
Idealized Cases: Introduction

WRF ARW code

WRFV3

- test
- main
- phys
- dyn_em (ARW solver)

real

Idealized cases with README files

Initialization code

+ dynamics solver code
Idealized Test Cases for the WRF ARW Model V3.7

- 2D flow over a bell-shaped mountain – \textit{WRFV3/test/em\_hill2d\_x}
- 2D squall line (x, z ; y, z) – \textit{WRFV3/test/em\_squall2d\_x, em\_squall2d\_y}
- 2D gravity current – \textit{WRFV3/test/em\_grav2d\_x}
- 2D sea-breeze case – \textit{WRFV3/test/em\_seabreeze2d\_x}
- 3D large-eddy simulation case – \textit{WRFV3/test/em\_les}
- 3D quarter-circle shear supercell thunderstorm – \textit{WRFV3/test/em\_quarter\_ss}
- 3D tropical cyclone – \textit{WRFV3/test/em\_tropical\_cyclone}
- 3D baroclinic wave in a channel – \textit{WRFV3/test/em\_b\_wave}
- 3D global: Held-Suarez case – \textit{WRFV3/test/em\_heldsuarez}
- 1D single column test configuration – \textit{WRFV3/test/em\_scm\_xy}
- 3D fire model test cases – \textit{WRFV3/test/em\_fire}
- 3D convective radiative equilibrium test – \textit{WRFV3/test/em\_convrad}
Idealized Cases: 2d flow over a bell-shaped mountain

Running a test case: *em_hill2d_x* example

2D Flow Over a Bell-Shaped Mountain

Initialization module: `dyn_em/module_initialize_hill2d_x.F`

Case directory: `test/em_hill2d_x`
Idealized Cases: 2d flow over a bell-shaped mountain

From the WRFV3 main directory:

> configure  (choose the *no nesting* option)
> compile em_hill2d_x

Move to the test directory:

> cd test/em_hill2d_x
> ideal.exe  (this produces the ARW initial conditions)
> wrf.exe   (executes ARW)

Finish by plotting output using scripts downloaded from the ARW website (wrf_Hill2d.ncl)
Idealized Cases: 2d flow over a bell-shaped mountain

(dx = 2km, dt=20s, T=10 h, wrf_Hill2d.ncl)
Idealized Cases: 2d flow over a bell-shaped mountain

What happens during the initialization

- Initialization code: `WRFV3/dyn_em/module_initialize_hill2d_x.F`
- A single sounding \((z, \theta, Q_v, u \text{ and } v)\) is read in from `WRFV3/test/em_hill2d_x/input_sounding`
- Sounding is interpolated to the ARW grid, equation of state and hydrostatic balance used to compute the full thermodynamics state. Nonlinearities require that this process be iterative.
- Wind fields are interpolated to model \(\eta\) levels.

*Model levels are set within the initialization:* code in initialization exist to produce a stretched \(\eta\) coordinate (close to equally spaced \(z\)), or equally spaced \(\eta\) coordinate.

*3D meshes are always used,* even in 2D \((x,z; \ y,z)\) cases. The third dimension contains only 5 planes, the boundary conditions in that dimension are periodic, and the solutions on the planes are identical in the initial state and remain so during the integration.
Idealized Cases: 2d flow over a bell-shaped mountain

Setting the terrain heights

In \texttt{WRFV3/dyn_em/module_initialize_hill2d_x.F}

```
SUBROUTINE init_domain_rk ( grid, &
  ...
  hm = 100.  \hspace{2cm} \textcolor{red}{\textit{mountain height and half-width}}
  xa = 5.0  \hspace{2cm} \textcolor{red}{\textit{mountain position in domain}}
  icm = ide/2  \hspace{2cm} \textcolor{red}{\textit{(center gridpoint in x)}}
  ...
  DO j=jts,jte
    DO i=its,ite  \hspace{1cm} \textit{! flat surface}
      grid\%ht(i,j) = hm/(1.+(float(i-icm)/xa)**2)
      grid\%phb(i,1,j) = g*grid\%ht(i,j)
      grid\%php(i,1,j) = 0.  \hspace{1cm} \textcolor{red}{\textit{lower boundary condition}}
      grid\%ph0(i,1,j) = grid\%phb(i,1,j)
    ENDDO
  ENDDO
```

Set height field
### Sounding File Format

File: \textit{WRFV3/test/em\_quarter\_ss/input\_sounding}

<table>
<thead>
<tr>
<th>line 1</th>
<th>height (m)</th>
<th>potential temperature (K)</th>
<th>vapor mixing ratio (g/kg)</th>
<th>U (west-east) velocity (m/s)</th>
<th>V (south-north) velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000.00</td>
<td>300.00</td>
<td>14.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>250.00</td>
<td>300.45</td>
<td>14.00</td>
<td>-7.88</td>
<td>-3.58</td>
</tr>
<tr>
<td></td>
<td>750.00</td>
<td>301.25</td>
<td>14.00</td>
<td>-6.94</td>
<td>-0.89</td>
</tr>
<tr>
<td></td>
<td>1250.00</td>
<td>302.47</td>
<td>13.50</td>
<td>-5.17</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>1750.00</td>
<td>303.93</td>
<td>11.10</td>
<td>-2.76</td>
<td>2.84</td>
</tr>
<tr>
<td></td>
<td>2250.00</td>
<td>305.31</td>
<td>9.06</td>
<td>0.01</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>2750.00</td>
<td>306.81</td>
<td>7.36</td>
<td>2.87</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>3250.00</td>
<td>308.46</td>
<td>5.95</td>
<td>5.73</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>3750.00</td>
<td>310.03</td>
<td>4.78</td>
<td>8.58</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>4250.00</td>
<td>311.74</td>
<td>3.82</td>
<td>11.44</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>4750.00</td>
<td>313.48</td>
<td>3.01</td>
<td>14.30</td>
<td>3.49</td>
</tr>
</tbody>
</table>

Idealized Cases: 2d flow over a bell-shaped mountain
Idealized Cases: 2d squall line

Squall-Line Simulations, $T = 3600$ s

$dx = dz = 250$ m, $v = 300$ m$^2$/s

height coordinate model

mass coordinate model

vertical velocity
c. i. = 4 m/s, starting at = 2

c. i. = 4 m/s, starting at = 2

c. i. = 4 m/s, starting at = 2
Idealized Cases: 2d squall line

\textit{squall2d\textsubscript{x}} is (x,z), \textit{squall2d\textsubscript{y}} is (y,z); both produce the same solution.

Initialization codes are in

\begin{itemize}
  \item WRFV3/dyn_em/module\_initialize\_squall2d\_x.F
  \item WRFV3/dyn_em/module\_initialize\_squall2d\_y.F
\end{itemize}

This code also introduces the initial perturbation.

The thermodynamic soundings and hodographs are in the ascii input files

\begin{itemize}
  \item WRFV3/test/em\_squall2d\_x/input\_sounding
  \item WRFV3/test/em\_squall2d\_y/input\_sounding
\end{itemize}
Idealized Cases: 2d gravity (density) current

(Straka et al, IJNMF, 1993)

2D channel (x, z ; 51.2 x 6.4 km)
Initial state: theta = 300 K (neutral) + perturbation (max = 16.2 K)
Eddy viscosity = 75 m**2/s**2 (constant)
Idealized Cases: 2d gravity (density) current

Default case, $dx = 100$ m, 5th order upwind advection, uses namelist.input.100m

$dx = 200$ m, 5th order upwind advection, use namelist.input.200m

$dx = 400$ m, 5th order upwind advection, use namelist.input.400m
5th order upwind advection, use namelist.input.200m and input_sounding.um=20.

Use namelist.input.100m with 2nd order advection and input_sounding.um=20.

Use namelist.input.200m with 2nd order advection and input_sounding.um=20.
The turbulent Prandtl number in WRF is 1/3, and the default WRF test case will give this solution.

To recover the Straka et al (1993) solution, change the parameter Prandtl to 1 (from 1/3) in WRFV3/share/module_model_constants.F
Idealized Cases: 2d gravity (density) current

Initialization code is in

WRFV3/dyn_em/module_initialize_grav2d_x.F

The initial cold bubble is hardwired in the initialization code.
Idealized Cases: 2d sea breeze

Initialization code is in

\texttt{WRFV3/dyn_em/module_initialize_seabreeze2d_x.F}

Test case directory is in

\texttt{WRFV3/test/em_seabreeze2d_x}

The initial state has no wind, and is perturbed by small random temperature changes

An example to show how to set surface parameters so that one may use full surface physics
Idealized Cases: 3d supercell thunderstorm

Height coordinate model
(dx = dy = 2 km, dz = 500 m, dt = 12 s, 160 x 160 x 20 km domain)
Surface temperature, surface winds and cloud field at 2 hours
Initialization code is in

$WRFV3/dyn_em/module_initialize_quarter_ss.F$

The thermodynamic sounding and hodograph is read from the ascii input file

$WRFV3/test/em_quarter_ss/input_sounding$

The initial perturbation (warm bubble) is hardwired in the initialization code.
Initialization code is in

\textit{WRFV3/dyn_em/module_initialize_les.F}

Test case directory is in

\textit{WRFV3/test/em_les}

The default case is a large-eddy simulation of free convective boundary layer with no winds. The turbulence of the free CBL is driven and maintained by namelist-specified surface heat flux.

An initial sounding with mean winds is also provided.

Reference: Moeng et al. 2007 MWR
Idealized Cases: 3d Large Eddy Simulation (LES)
Default vortex:

- weak (12.9 m/s) axisymmetric analytic vortex (Rotunno and Emanuel, 1987, JAS)
- placed in center of domain
- in “module_initialize_tropical_cyclone.F” users can modify initial size and intensity (see parameters r0, rmax, vmax, zdd)

Default environment:

- mean hurricane sounding from Jordan (1958, J. Meteor.)
- SST = 28 degrees C
- \( f = 5e^{-5} \) s\(^{-1}\) (20 degrees North)

Default domain:

- 3000 km x 3000 km x 25 km domain
- default dx,dy is only 15 km: useful for quick tests of new code (i.e., new physics schemes); research-quality studies should use smaller dx,dy

colors = relative humidity (%)
contours = azimuthal velocity (m/s)
Idealized Cases: 3d tropical cyclone

colors = 10-m windspeed (m/s)
contours = reflectivity (every 10 dBZ)
Idealized Cases: baroclinic wave in a channel

Height coordinate model \((dx = 100\text{ km}, dz = 250\text{ m}, dt = 600\text{ s})\)
Surface temperature, surface winds, cloud and rain water
Idealized Cases: baroclinic wave in a channel

Initialization code is in

\texttt{WRFV3/dyn\_em/module\_initialize\_b\_wave.F}

The initial jet \((y,z)\) is read from the binary input file

\texttt{WRFV3/test/em\_b\_wave/input\_jet}

The initial perturbation is hardwired in the initialization code.
Default configuration in

\texttt{WRFV3/test/em_b_wave/namelist.input}

runs the dry jet in a periodic channel with dimension

(4000 x 8000 x 16 km) (x,y,z).

Turning on any microphysics

(mp\_physics > 0 in namelist.input) puts moisture

into the model state.

The initial jet only works for dy = 100 km and

81 grid points in the y (south-north) direction.
Held-Suarez Case

Initialization code is in

\[ \text{WRFV3/dyn_em/module_initialize_heldsuarez.F} \]

The initial model state is an isothermal atmosphere on flat earth with no winds, and random temperature perturbation

Test case directory is in

\[ \text{WRFV3/test/em_heldsuarez} \]

If you really want to use a global model, then use…
• Global, nonhydrostatic, C-grid Voronoi mesh
• Numerics similar to WRF; WRF-NRCM physics
• No pole problems
• Variable-resolution mesh – no nested BC problems

Available at: http://mpas-dev.github.io/
Idealized Cases: More information

Descriptions:

WRFV3/README_test_cases
WRFV3/test/em_*/*/README

WRFV3 with README_test_cases

- test
- main
- phys
- dyn_em (ARW solver)

Idealized cases with README files

- real

Initialization code

+ dynamics solver code