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 - Δx meters, Δt < second;
   Baroclinic waves - Δx 100 km, Δt = 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.

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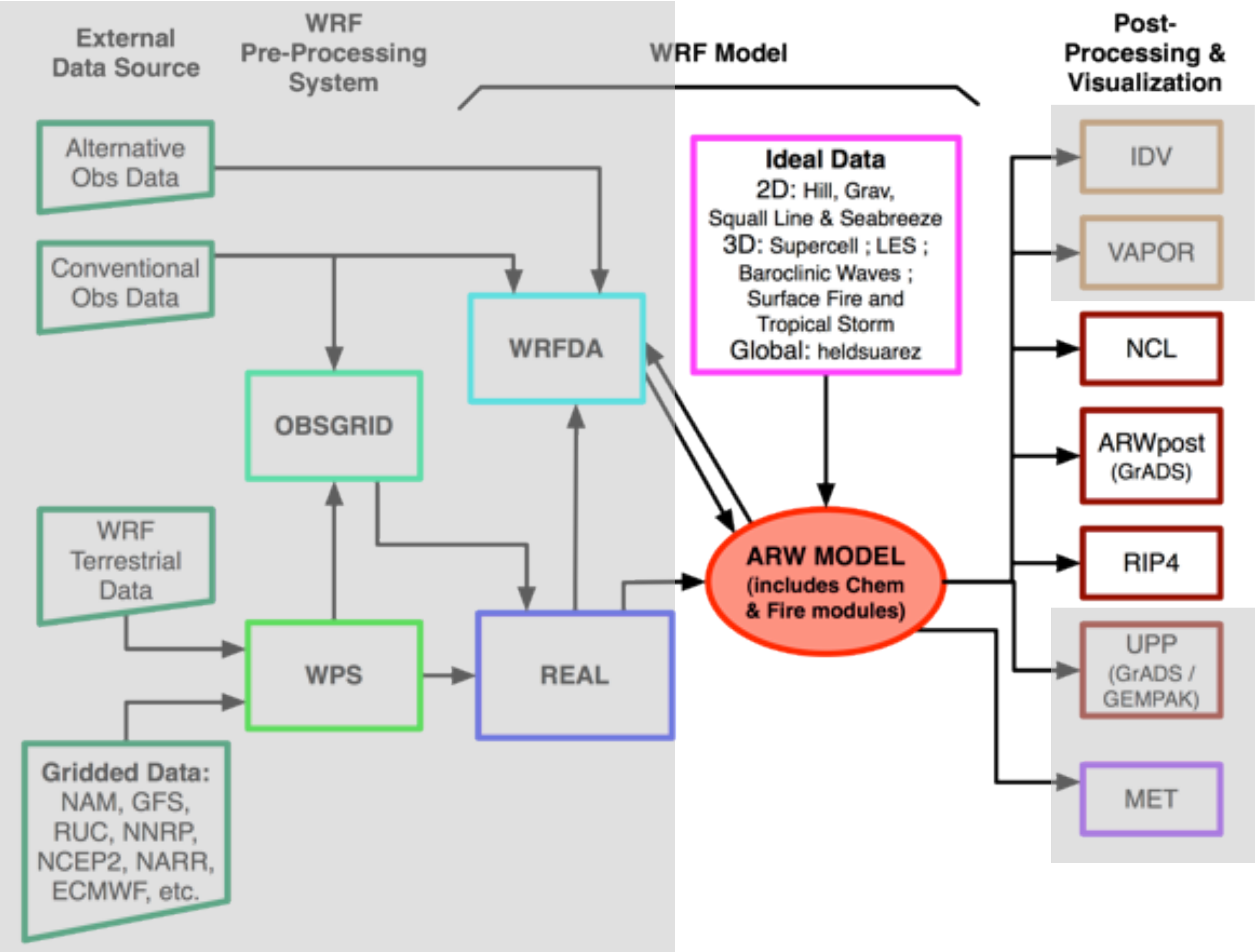
Idealized Cases: Introduction



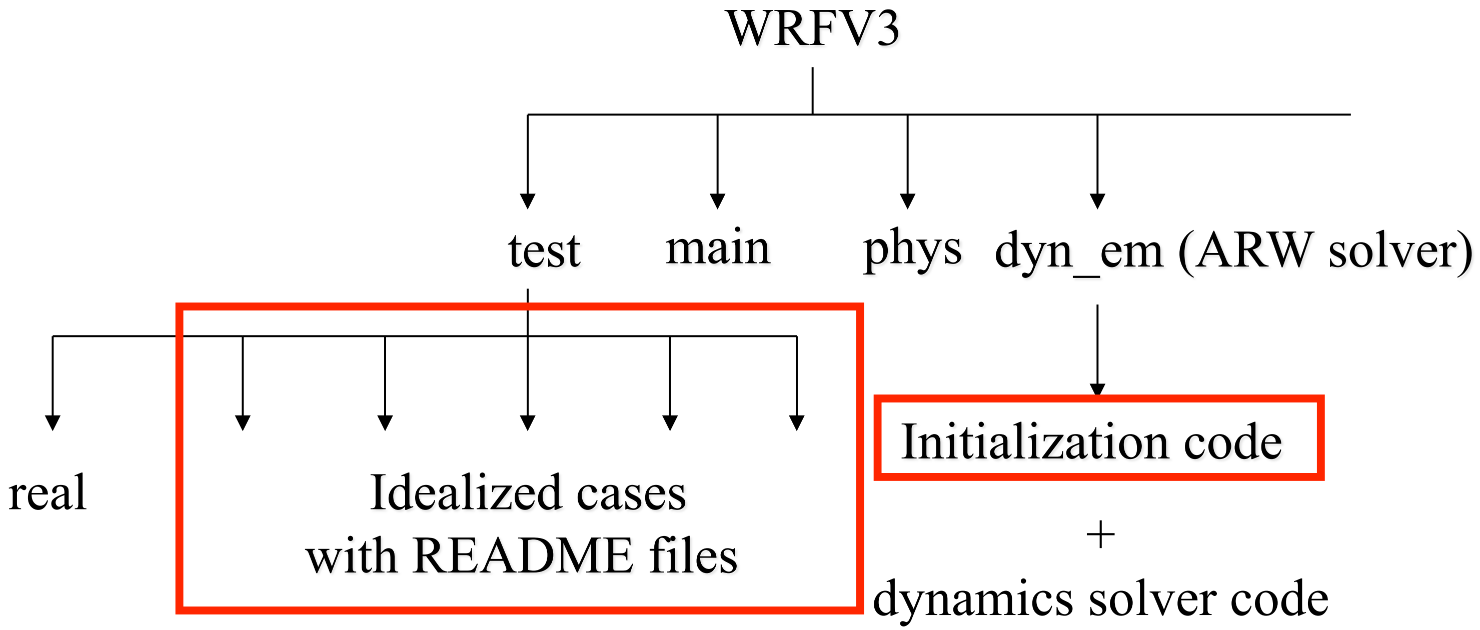
WRF ARW Tech Note

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 Cases: Introduction

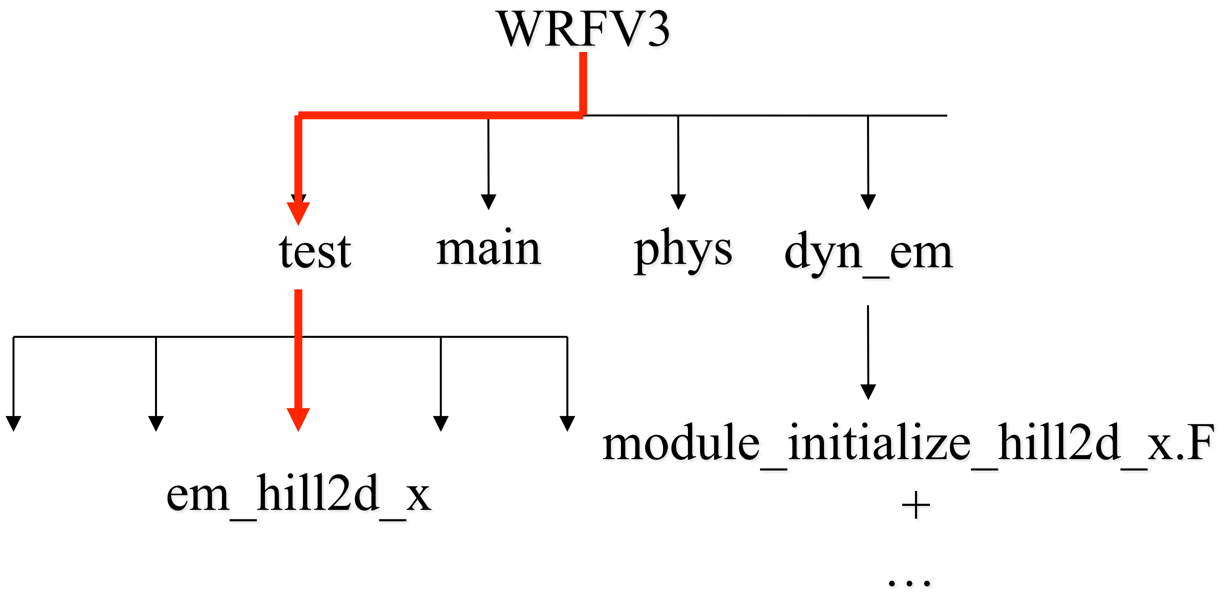
Idealized Test Cases for the WRF ARW Model

- 2D flow over a bell-shaped mountain – *WRFV3/test/em_hill2d_x*
- 2D squall line (x, z ; y, z) – *WRFV3/test/em_squall2d_x, em_squall2d_y*
- 2D gravity current – *WRFV3/test/em_grav2d_x*
- 2D sea-breeze case – *WRFV3/test/em_seabreeze2d_x*
- 3D large-eddy simulation case – *WRFV3/test/em_les*
- 3D quarter-circle shear supercell thunderstorm – *WRFV3/test/em_quarter_ss*
- 3D tropical cyclone – *WRFV3/test/em_tropical_cyclone*
- 3D baroclinic wave in a channel – *WRFV3/test/em_b_wave*
- 3D global: Held-Suarez case – *WRFV3/test/em_heldsuarez*
- 1D single column test configuration – *WRFV3/test/em_scm*
- 3D fire model test cases – *WRFV3/test/em_fire*

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)

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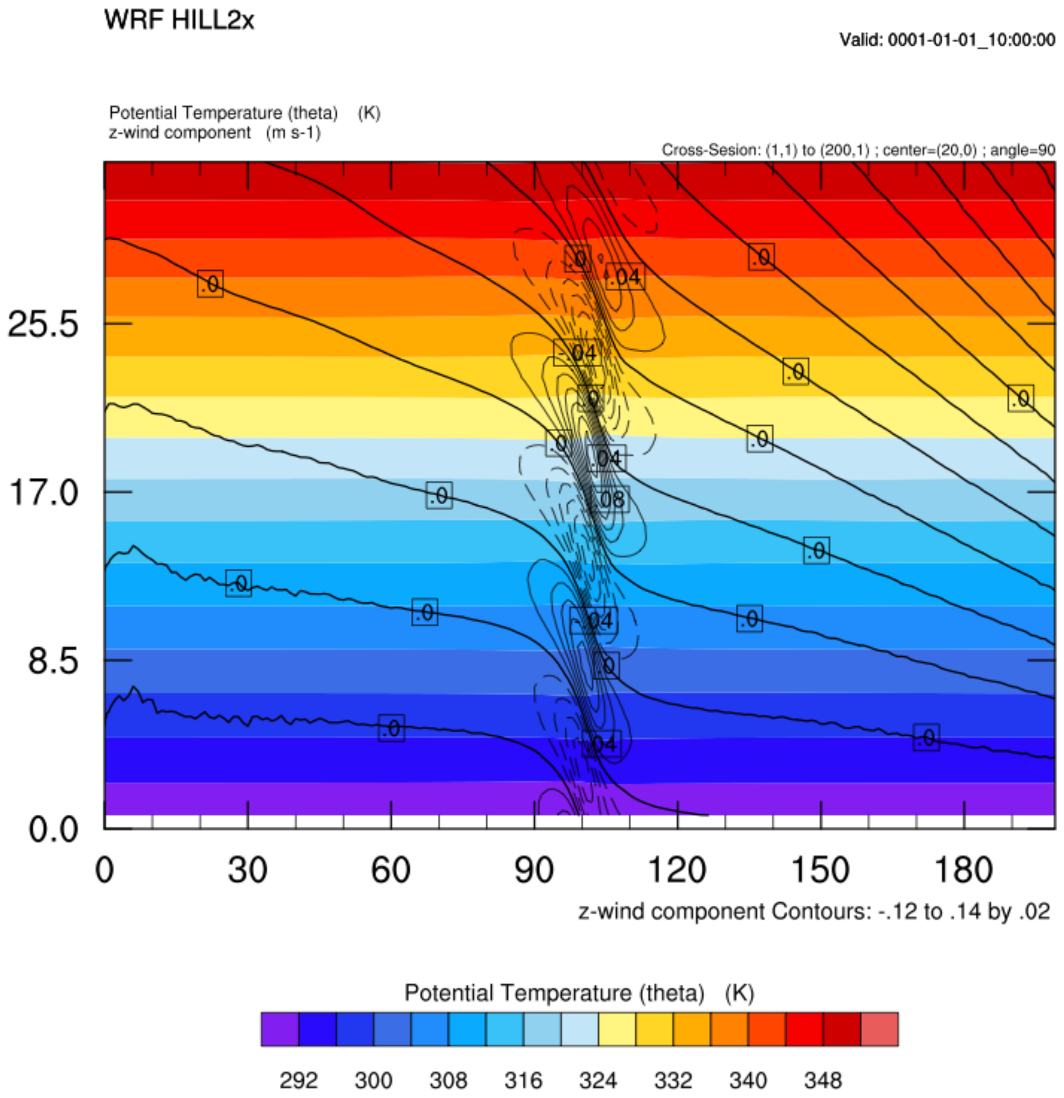
Idealized Cases: 2d flow over a bell-shaped mountain

(dx = 2km, dt=20s, T=10 h, wrf_Hill2d.ncl)



What happens during the initialization

- Initialization code: *WRFV3/dyn_em/module_initialize_hill2d_x.F*
- A single sounding (z, θ, Q_v, u 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 interplolated to model η levels.

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

Setting the terrain heights

In *WRFV3/dyn_em/module_initialize_hill2d_x.F*

```
   SUBROUTINE init_domain_rk ( grid, &

...
   hm = 100.
   xa = 5.0

   icm = ide/2
...

  DO j=jts,jte
  DO i=its,ite   ! 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.
    grid%ph0(i,1,j) = grid%phb(i,1,j)
  ENDDO
  ENDDO
```

mountain height and half-width

mountain position in domain (center gridpoint in x)

Set height field

lower boundary condition

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

Sounding File Format

File: *WRFV3/test/em_quarter_ss/input_sounding*

surface Pressure (mb)

surface potential Temperature (K)

surface vapor mixing ratio (g/kg)

line 1 →

```
1000.00     300.00      14.00
  250.00    300.45      14.00      -7.88      -3.58
  750.00    301.25      14.00      -6.94      -0.89
 1250.00    302.47      13.50      -5.17       1.33
 1750.00    303.93      11.10      -2.76       2.84
 2250.00    305.31       9.06       0.01       3.47
 2750.00    306.81       7.36       2.87       3.49
 3250.00    308.46       5.95       5.73       3.49
 3750.00    310.03       4.78       8.58       3.49
 4250.00    311.74       3.82      11.44       3.49
 4750.00    313.48       3.01      14.30       3.49
```

each successive line is a point in the sounding

height (m)

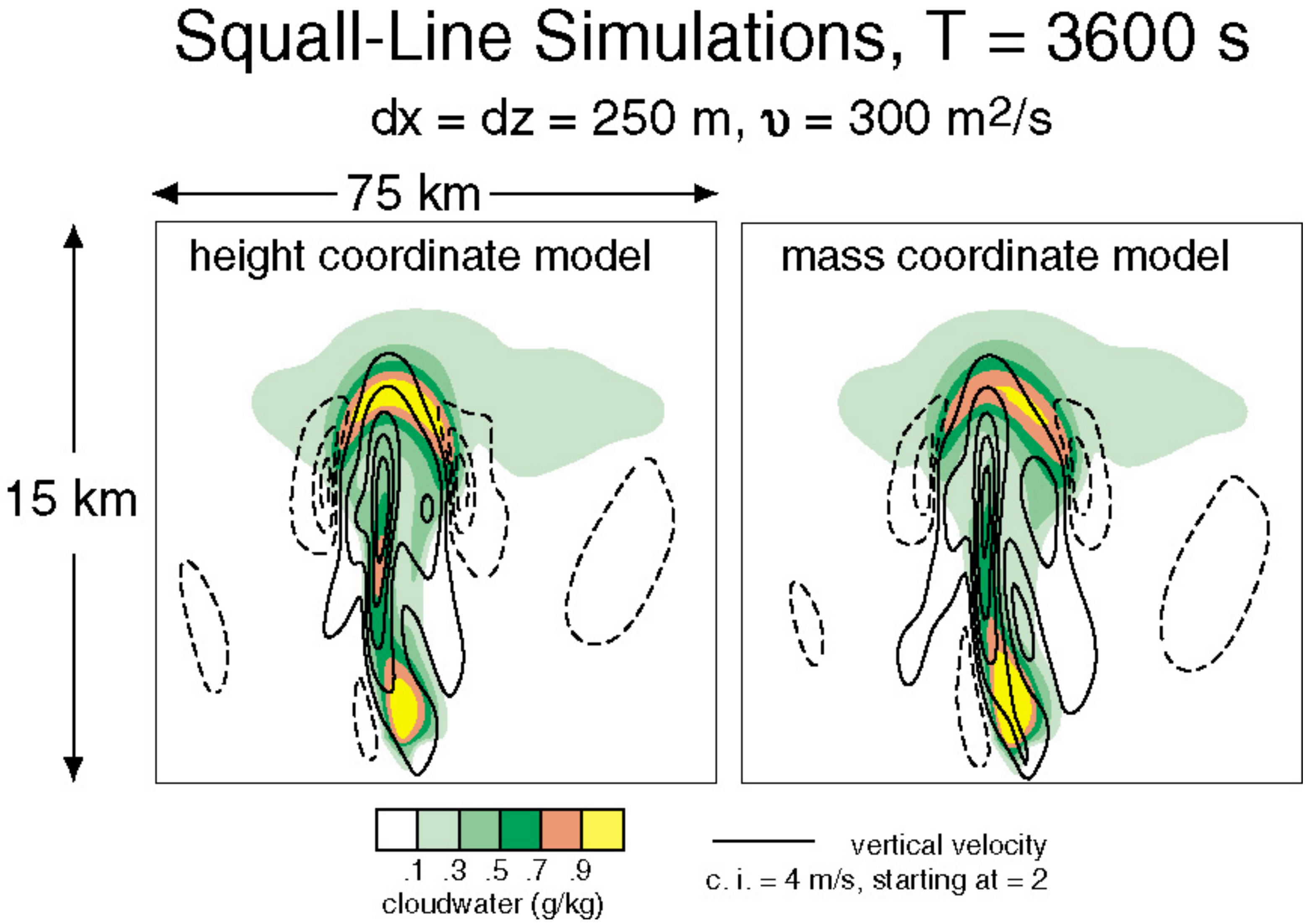
potential temperature (K)

vapor mixing ratio (g/kg)

U (west-east) velocity (m/s)

V (south-north) velocity (m/s)

Idealized Cases: 2d squall line



Idealized Cases: 2d squall line

squall2d_x is (x,z), *squall2d_y* is (y,z); both produce the same solution.

Initialization codes are in

WRFV3/dyn_em/module_initialize_squall2d_x.F
WRFV3/dyn_em/module_initialize_squall2d_y.F
This code also introduces the initial perturbation.

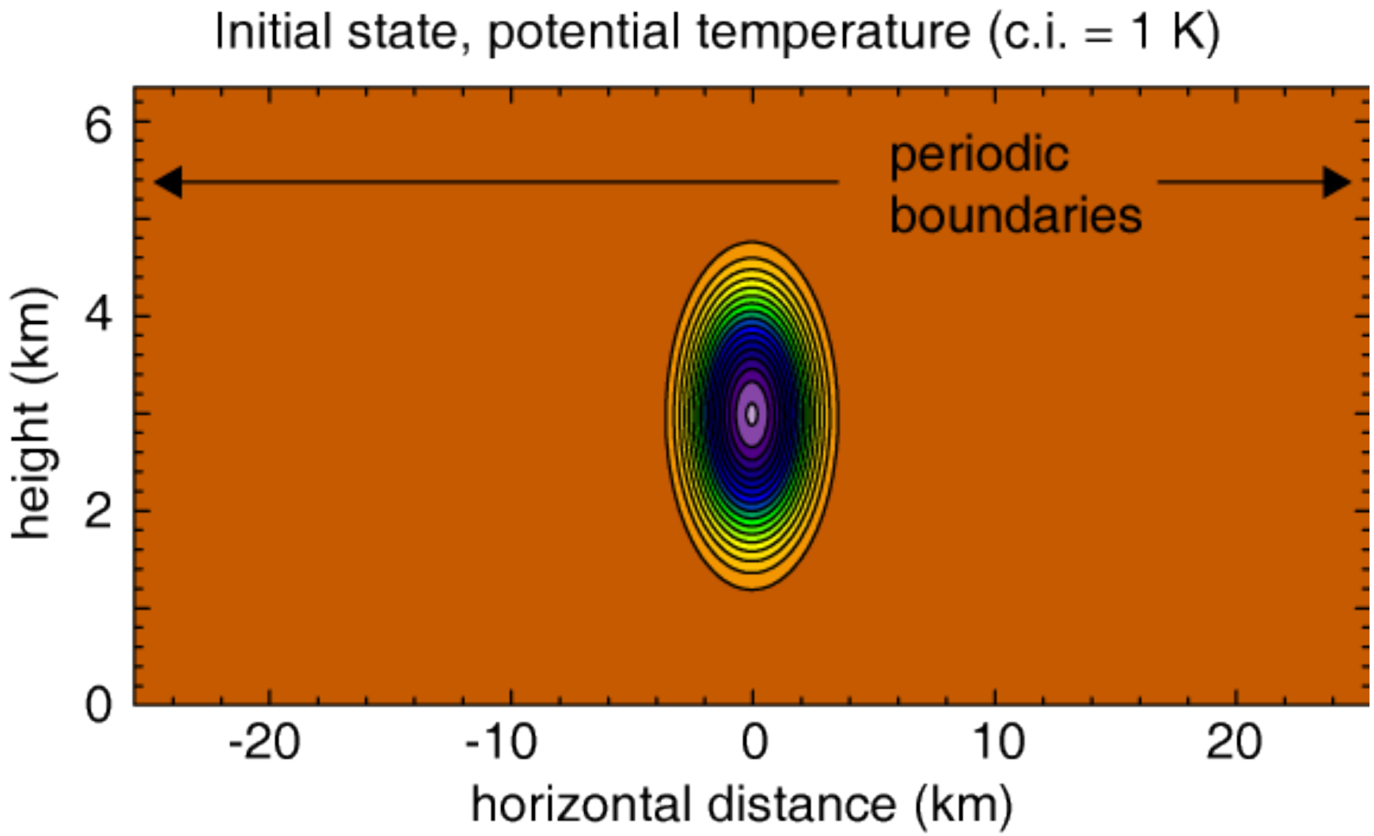
The thermodynamic soundings and hodographs are in the ascii input files

WRFV3/test/em_squall2d_x/input_sounding
WRFV3/test/em_squall2d_y/input_sounding

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)

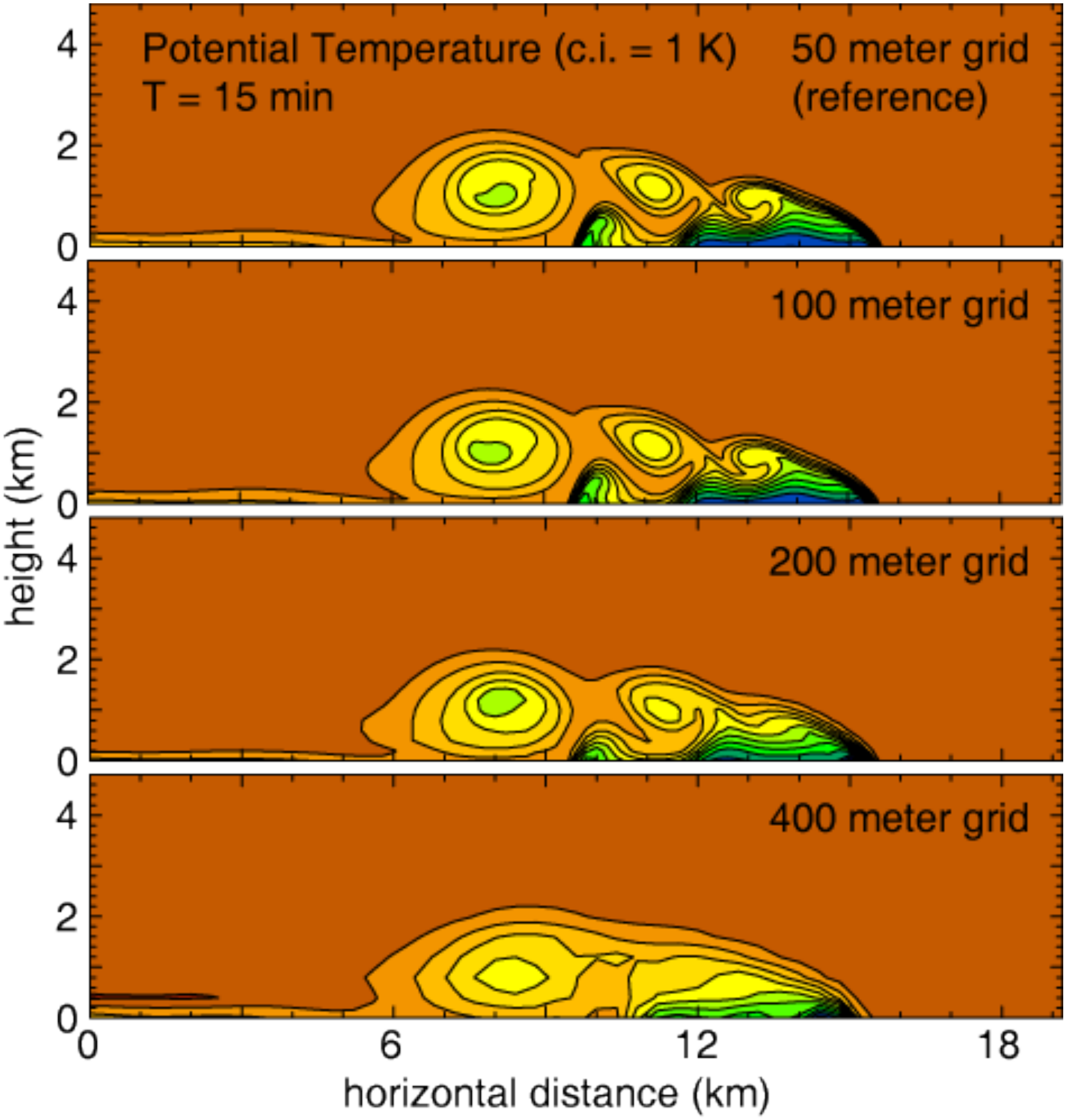


Idealized Cases: 2d gravity (density) current

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

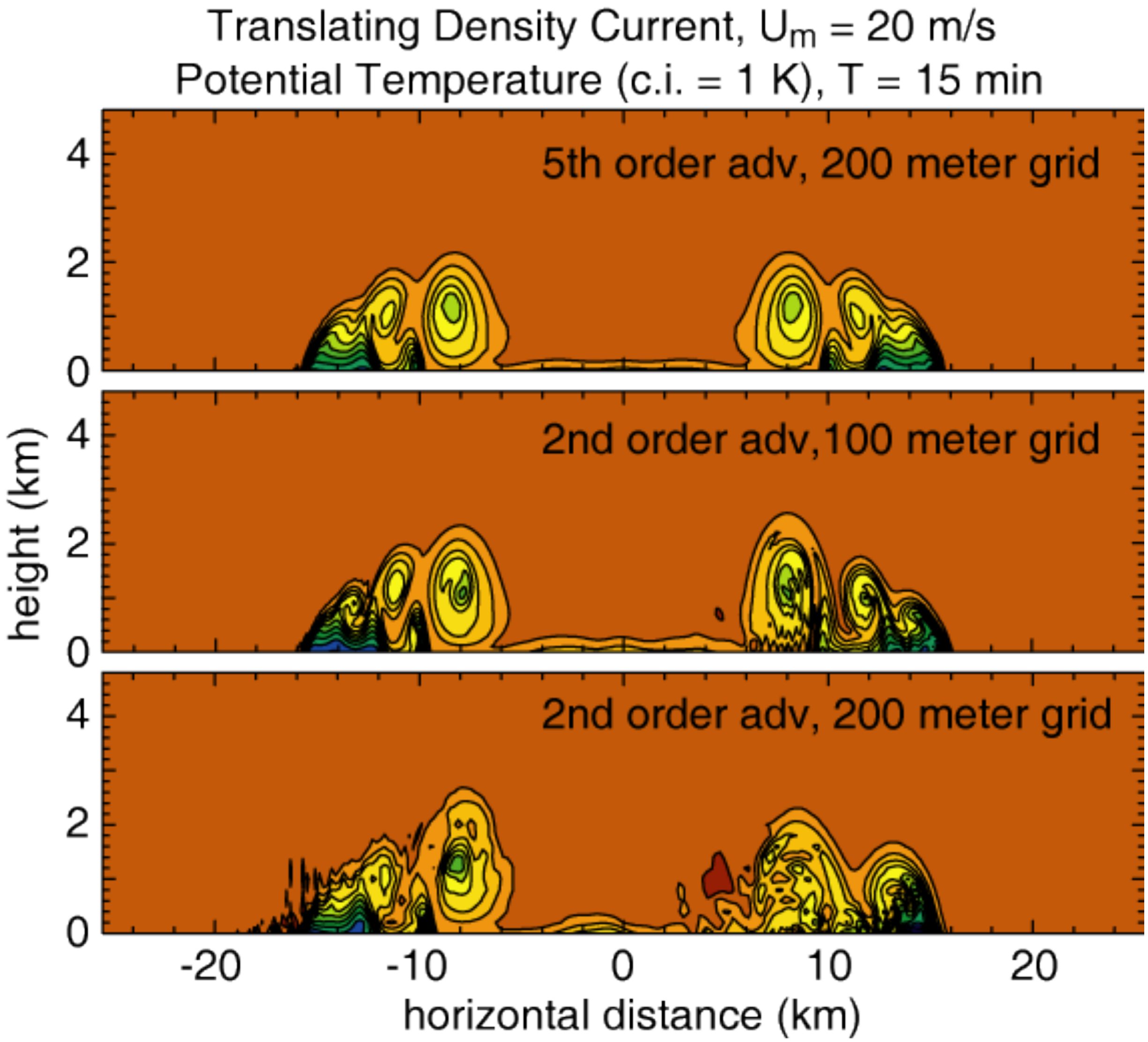


Idealized Cases: 2d gravity (density) current

5^{th} order upwind advection,
use namelist.input.200m
and input_sounding.um=20

use namelist.input.100m
with 2^{nd} order advection
and input_sounding.um=20

use namelist.input.200m
with 2^{nd} order advection
and input_sounding.um=20



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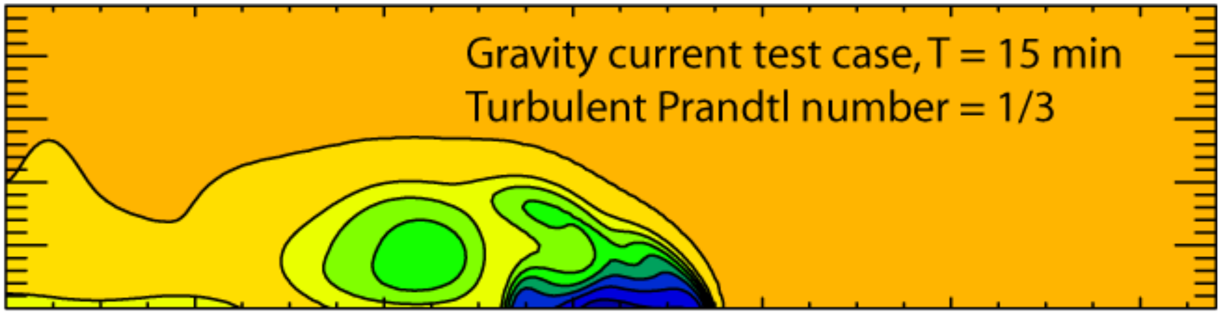
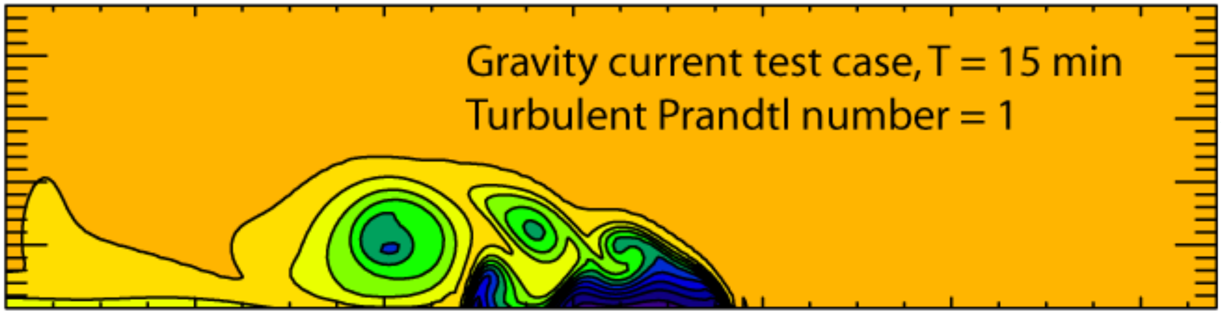
Idealized Cases: 2d gravity (density) current





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.

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Idealized Cases: 2d sea breeze

Initialization code is in

WRFV3/dyn_em/module_initialize_seabreeze2d_x.F

Test case directory is in

WRFV3/test/em_seabreeze2d_x

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

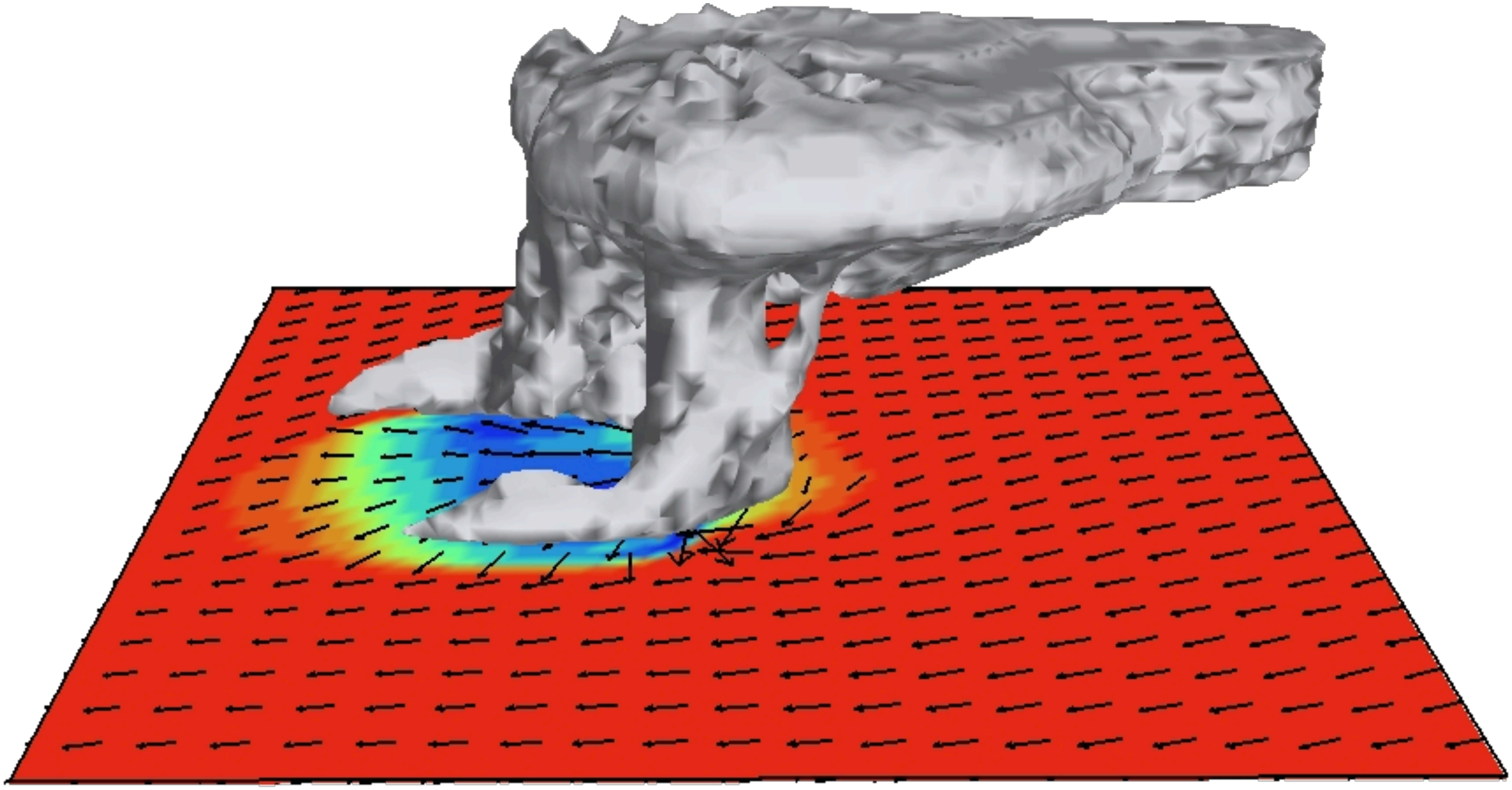
An example to show how to set surface parameters so that one may use full surface physics

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



Idealized Cases: 3d supercell thunderstorm

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.

Idealized Cases: 3d Large Eddy Simulation (LES)

Initialization code is in

WRFV3/dyn_em/module_initialize_les.F

Test case directory is in

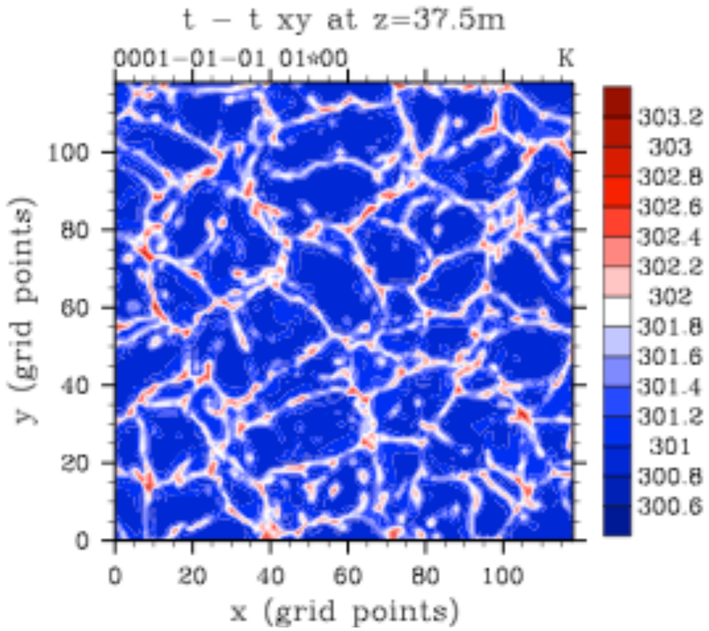
WRFV3/test/em_les

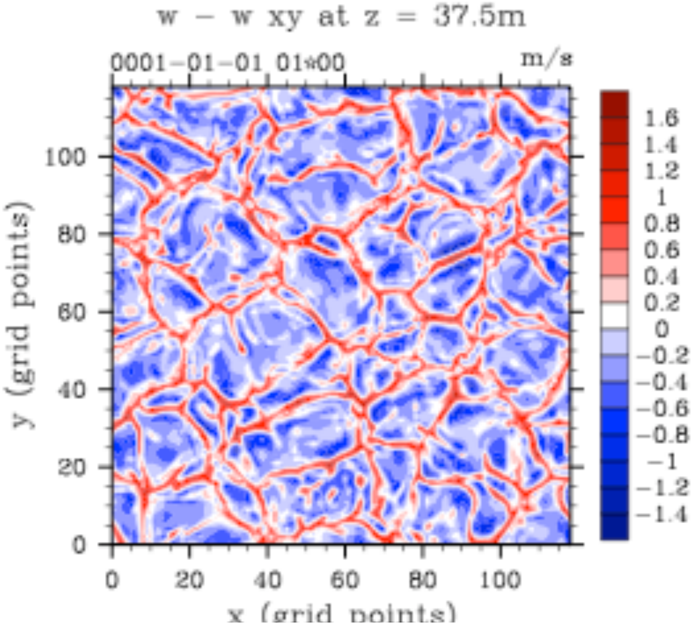
The default case is a large-eddy simulation of free convective boundary layer with no winds. The turbulence of the free CBL is driven and maintained by namelist-specified surface heat flux.

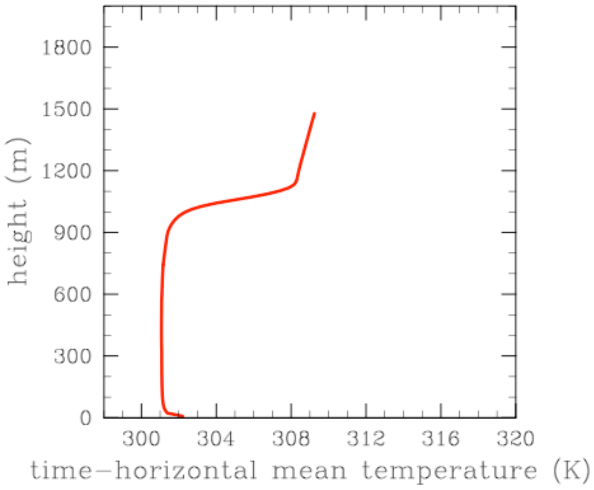
An initial sounding with mean winds is also provided.

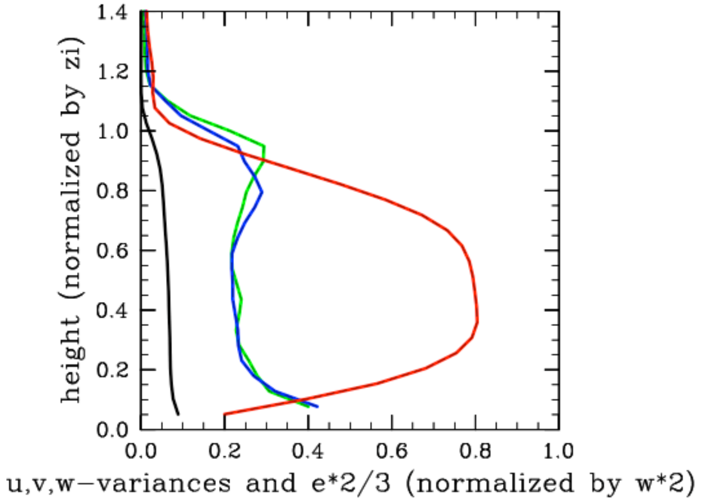
Reference: Moeng et al. 2007 MWR

Idealized Cases: 3d Large Eddy Simulation (LES)









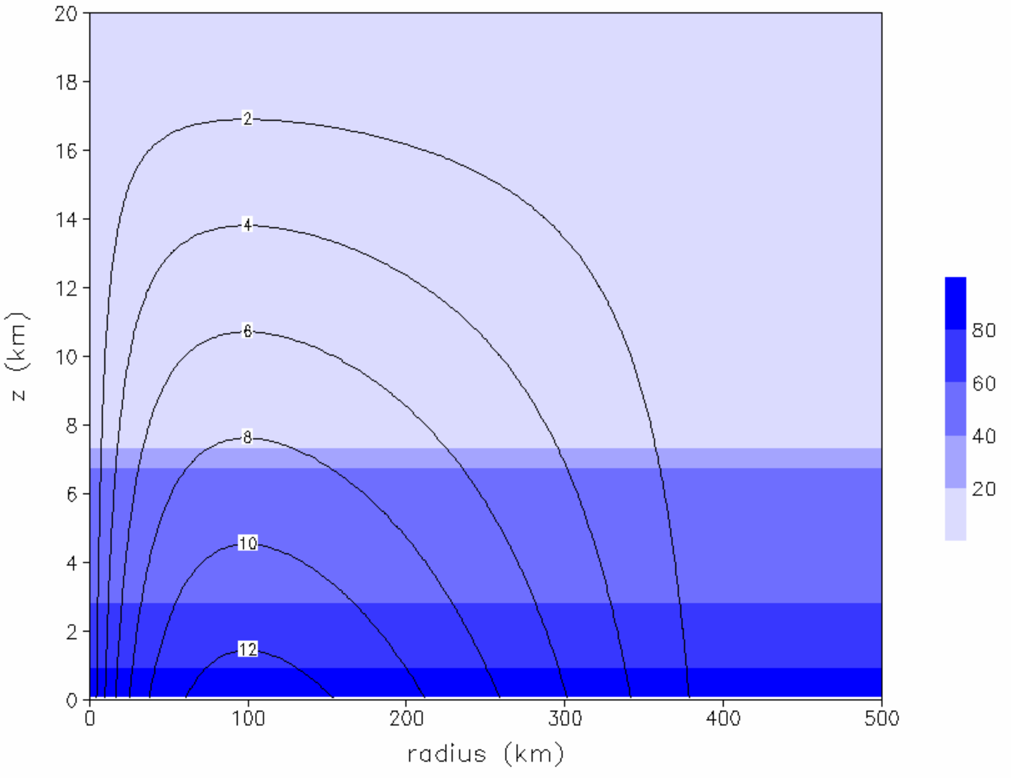
Idealized Cases: 3d tropical cyclone

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)

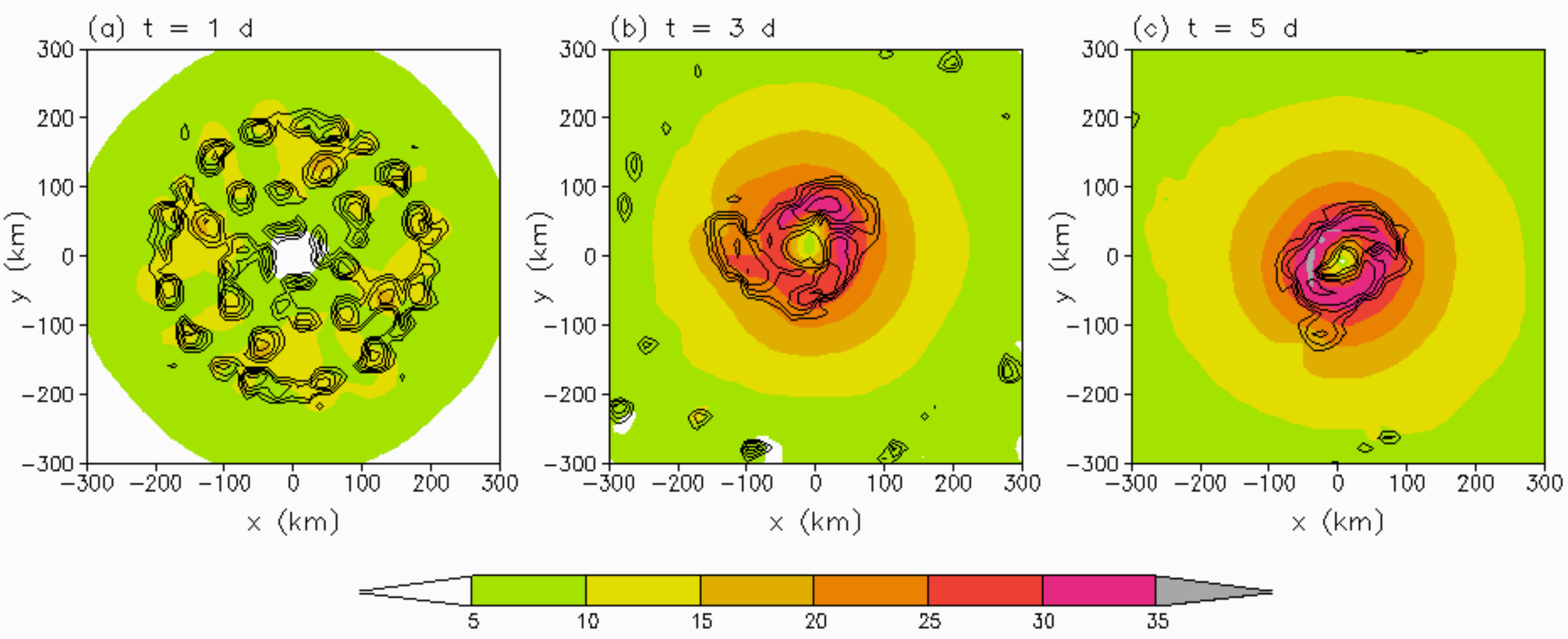


colors = relative humidity (%)
contours = azimuthal velocity (m/s)

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

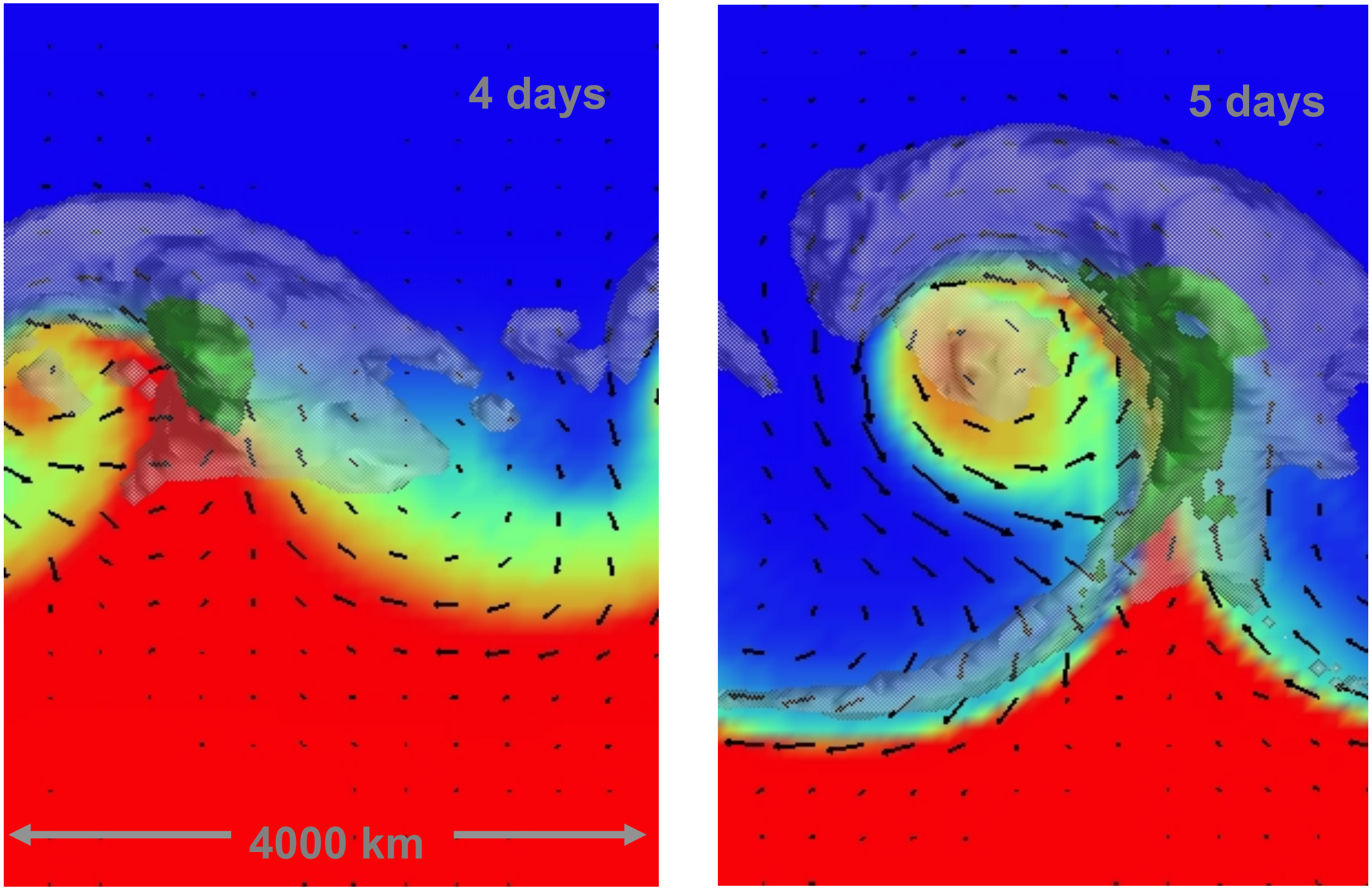
Idealized Cases: 3d tropical cyclone



colors = 10-m windspeed (m/s)
contours = reflectivity (every 10 dBZ)

Idealized Cases: baroclinic wave in a channel

Height coordinate model (dx = 100 km, dz = 250 m, dt = 600 s)
Surface temperature, surface winds, cloud and rain water



Idealized Cases: baroclinic wave in a channel

Initialization code is in

WRFV3/dyn_em/module_initialize_b_wave.F

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

WRFV3/test/em_b_wave/input_jet

The initial perturbation is hardwired in the initialization code.

Idealized Cases: baroclinic wave in a channel

Default configuration in
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
WRFV3/dyn_em/module_initialize_heldsuarez.F

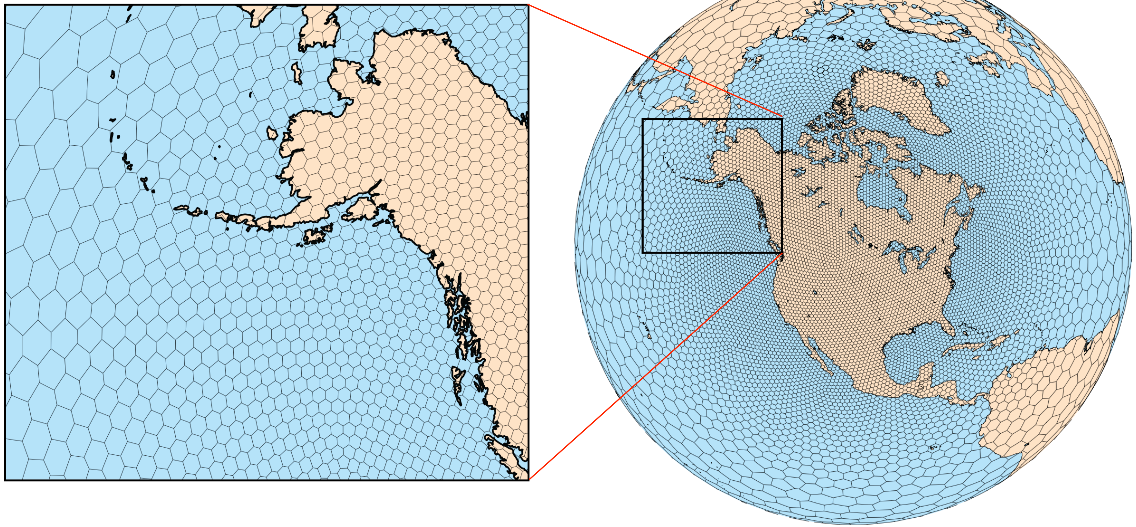
The initial model state is an isothermal atmosphere on flat earth with no winds, and random temperature perturbation

Test case directory is in
WRFV3/test/em_heldsuarez

If you really want to use a global model, then use…

Idealized Cases: Global ARW – Held_Suarez test case

MPAS
Model for Prediction Across Scales



- 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