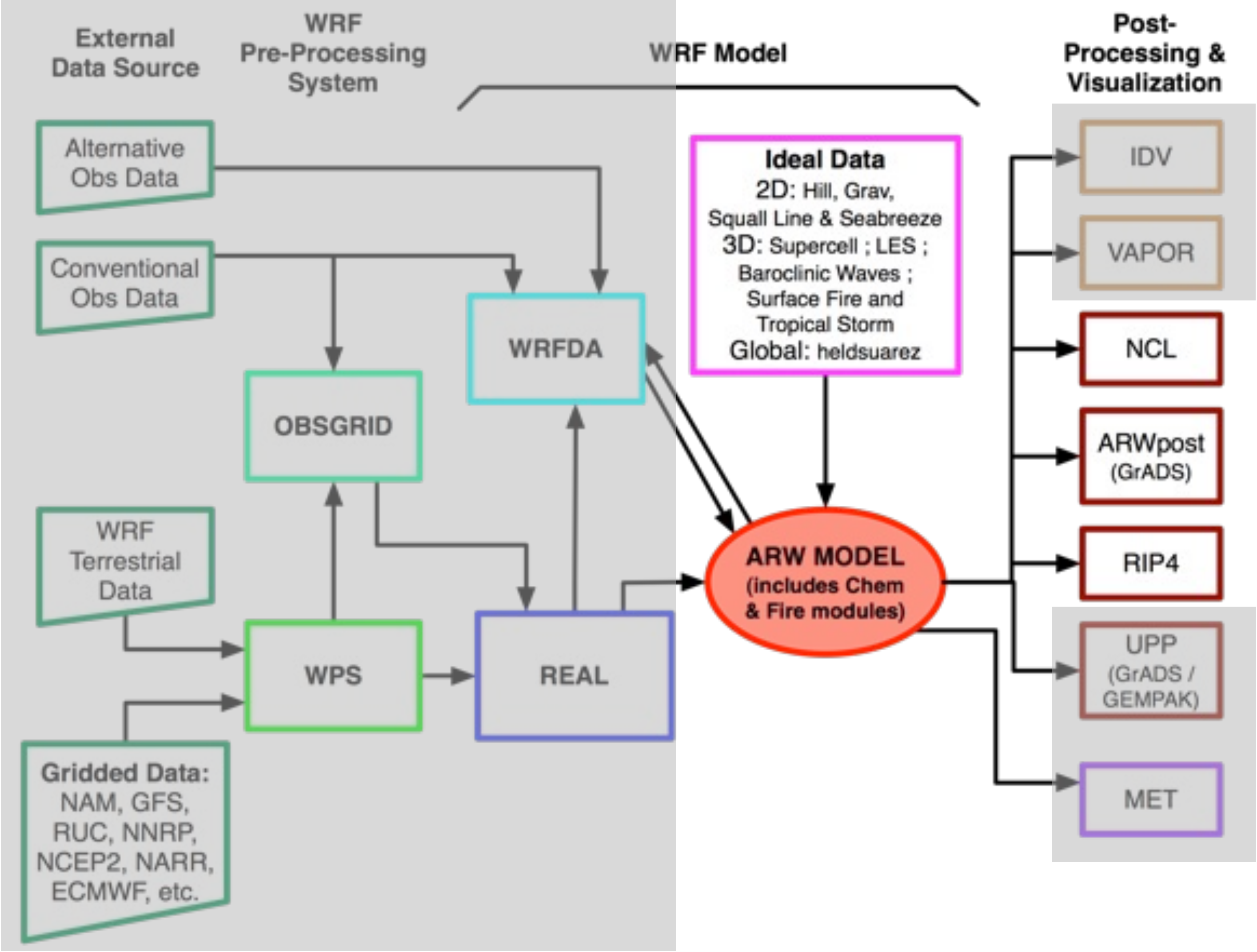
Initialization for Idealized Cases

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.

Idealized Cases: Introduction

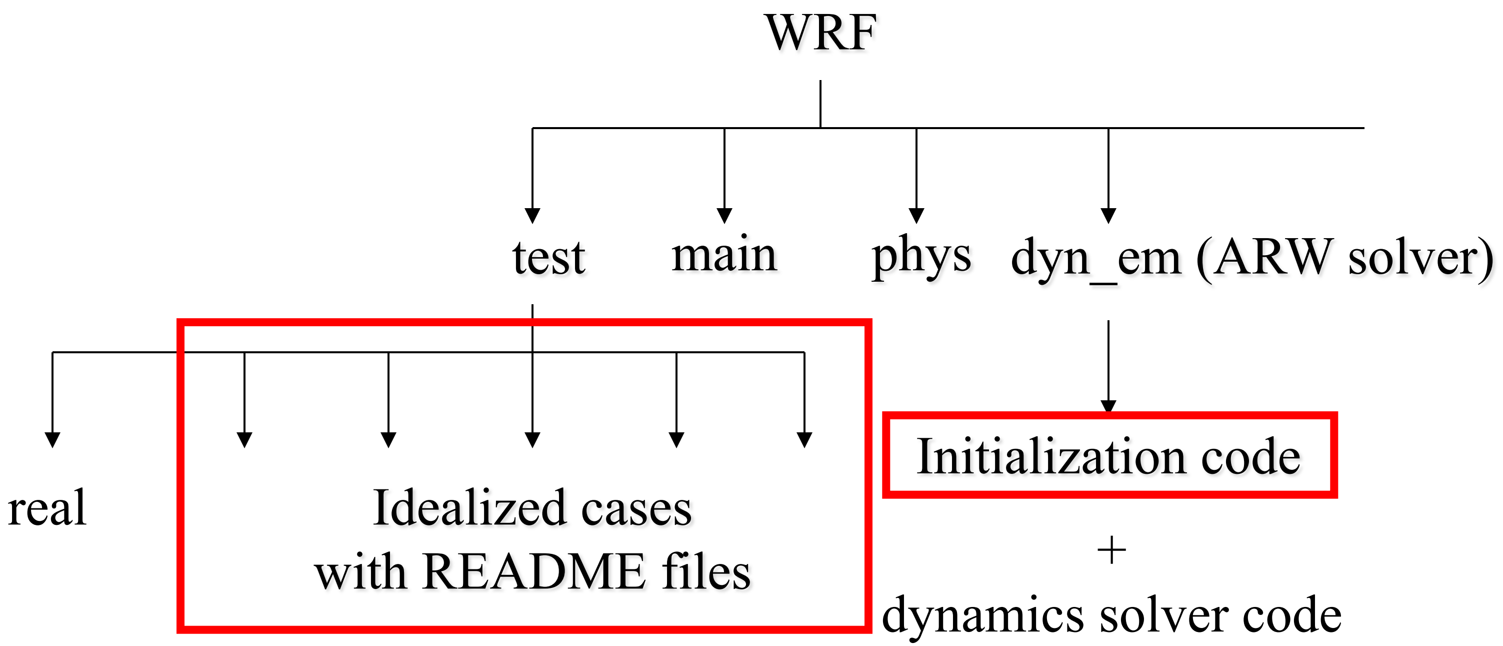


WRF ARW Tech Note

A Description of the Advanced Research WRF Version 4 (March 2019; WRF Version 4.1)

http://www2.mmm.ucar.edu/wrf/users/docs/technote/contents.html

WRF ARW code


WRF
test
main
phys
dyn_em (ARW solver)
real
Idealized cases
with README files
Initialization code
+
dynamics solver code

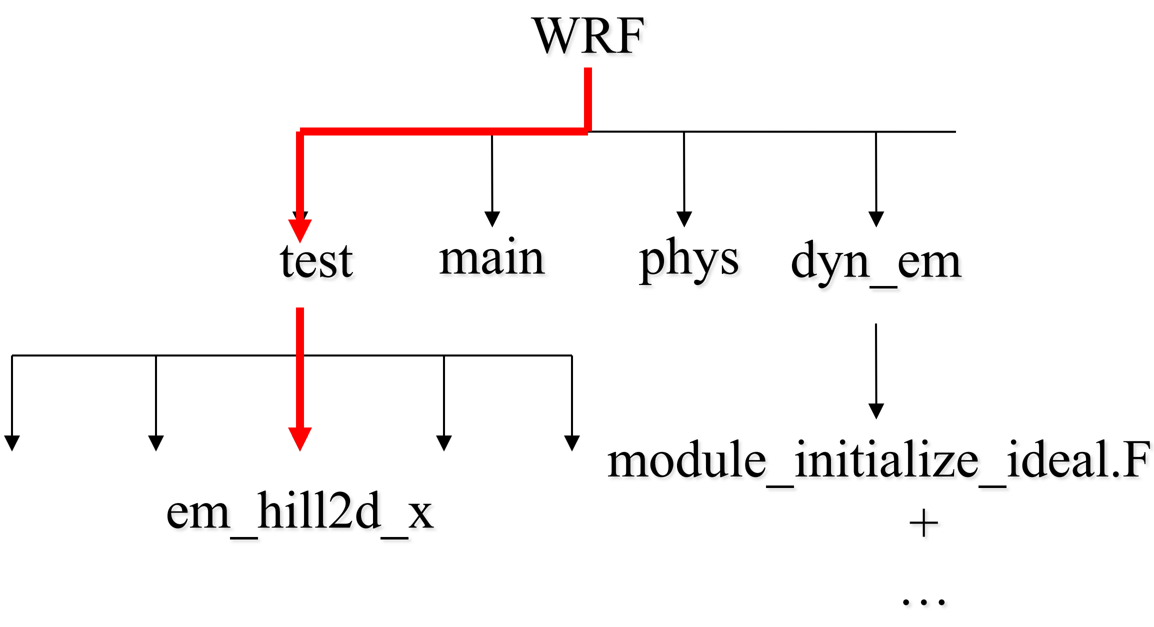
Idealized Test Cases for the WRF ARW Model V4.5

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

Running a test case: *em_hill2d_x* example

2D Flow Over a Bell-Shaped Mountain

Initialization module: dyn_em/module_initialize_ideal.F
Case directory: test/em_hill2d_x



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

From the WRF main directory:

> configure   (choose *serial* build, *no nesting* option)
> compile em_hill2d_x

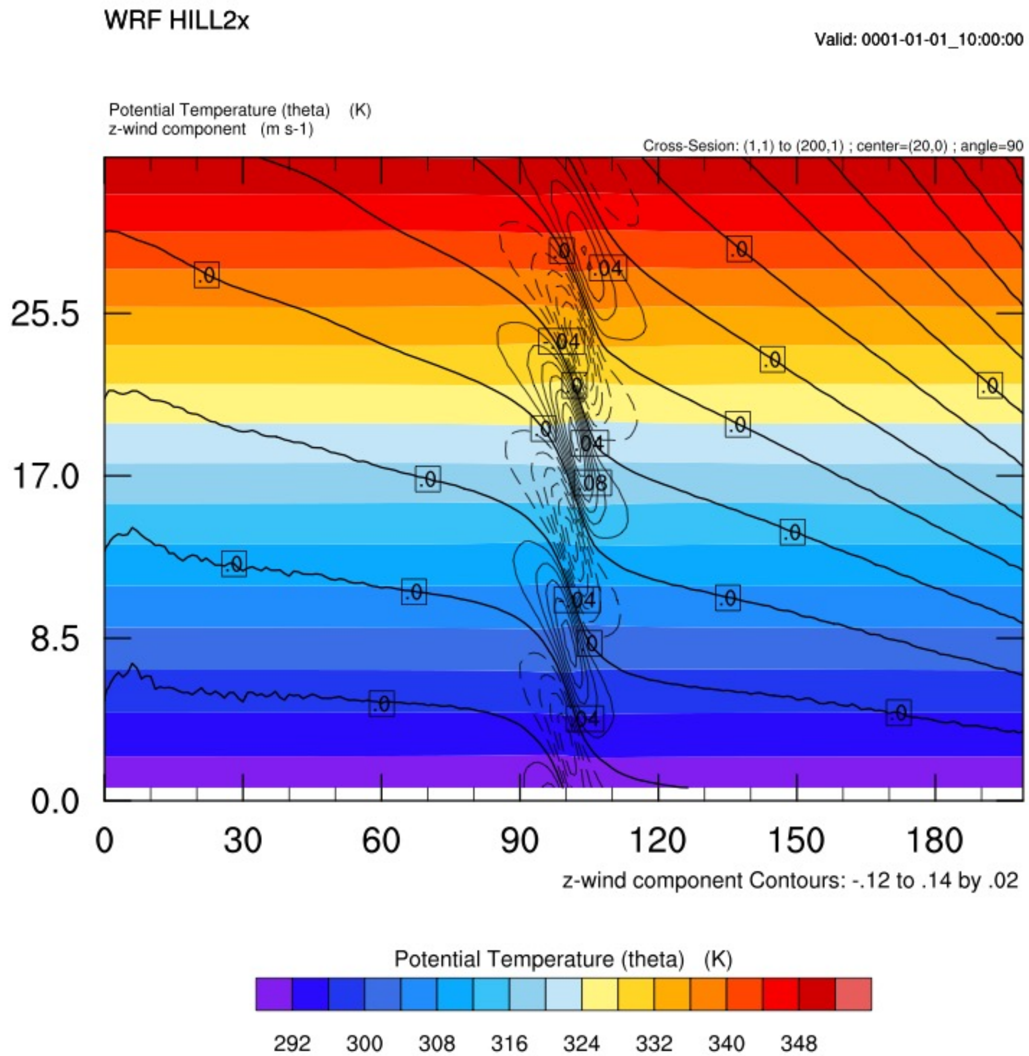
Move to the test directory:

> 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)



What happens during the initialization

Initialization code: *WRF/dyn_em/module_initialize_ideal.F*

- Idealize test specifics are enabled in the code using the Fortran CASE construct.

```
SELECT CASE ( model_config_rec%ideal_case )
 CASE ( hill2d_x )
```

- Model levels are set within the initialization to produce a stretched η coordinate (close to equally spaced z), or equally spaced η coordinate.
- Terrain is set in the initialization code
- A single sounding (z, θ, Q_v, u and v) is read in from *WRF/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.
- Wind fields are interplolated to model η levels.

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 *WRF/dyn_em/module_initialize_ideal.F*

```
SUBROUTINE init_domain_rk ( grid, &

CASE (hill2d_x)
   hm = 100.
   xa = 5.0
   icm = ide/2
```

mountain height and half-width

mountain position in domain (center gridpoint in x)

```
CASE (hill2d_x)
  DO j=jts,jte
  DO i=its,ite
    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
```

Set height field → grid%ht

lower boundary condition → grid%php(i,1,j) = 0.

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

Sounding File Format

File: *WRF/test/em_quarter_ss/input_sounding*

line 1 → first line: surface Pressure (mb), surface potential Temperature (K), surface vapor mixing ratio (g/kg)

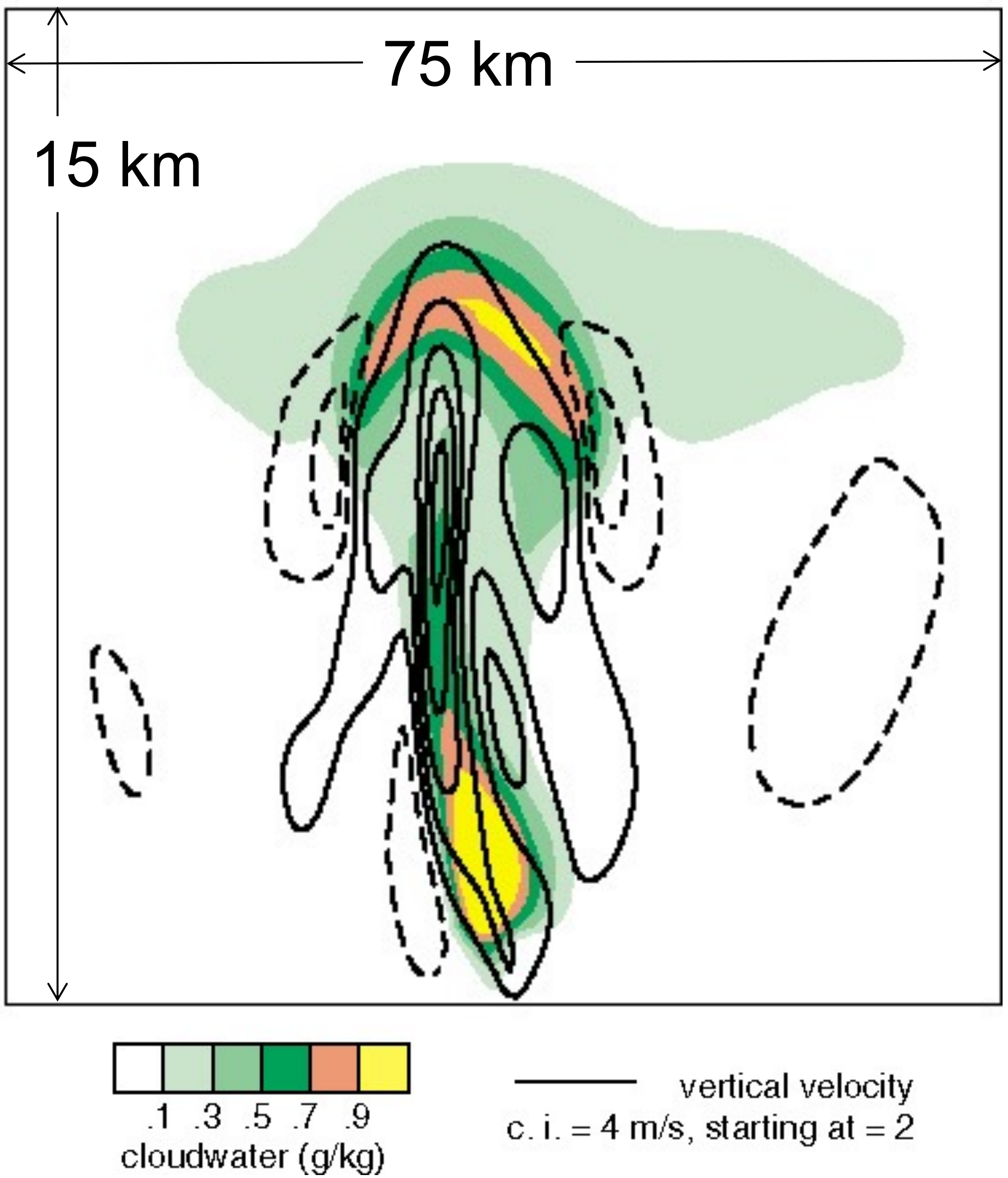
surface Pressure (mb)	surface potential Temperature (K)	surface vapor mixing ratio (g/kg)		
1000.00	300.00	14.00		

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)
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

Idealized Cases: 2d squall line

Squall-line simulation
T = 3600 s
$\Delta x = \Delta z = 250$ meters
$\upsilon = 300\ m^2/s$



Idealized Cases: 2d squall line

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

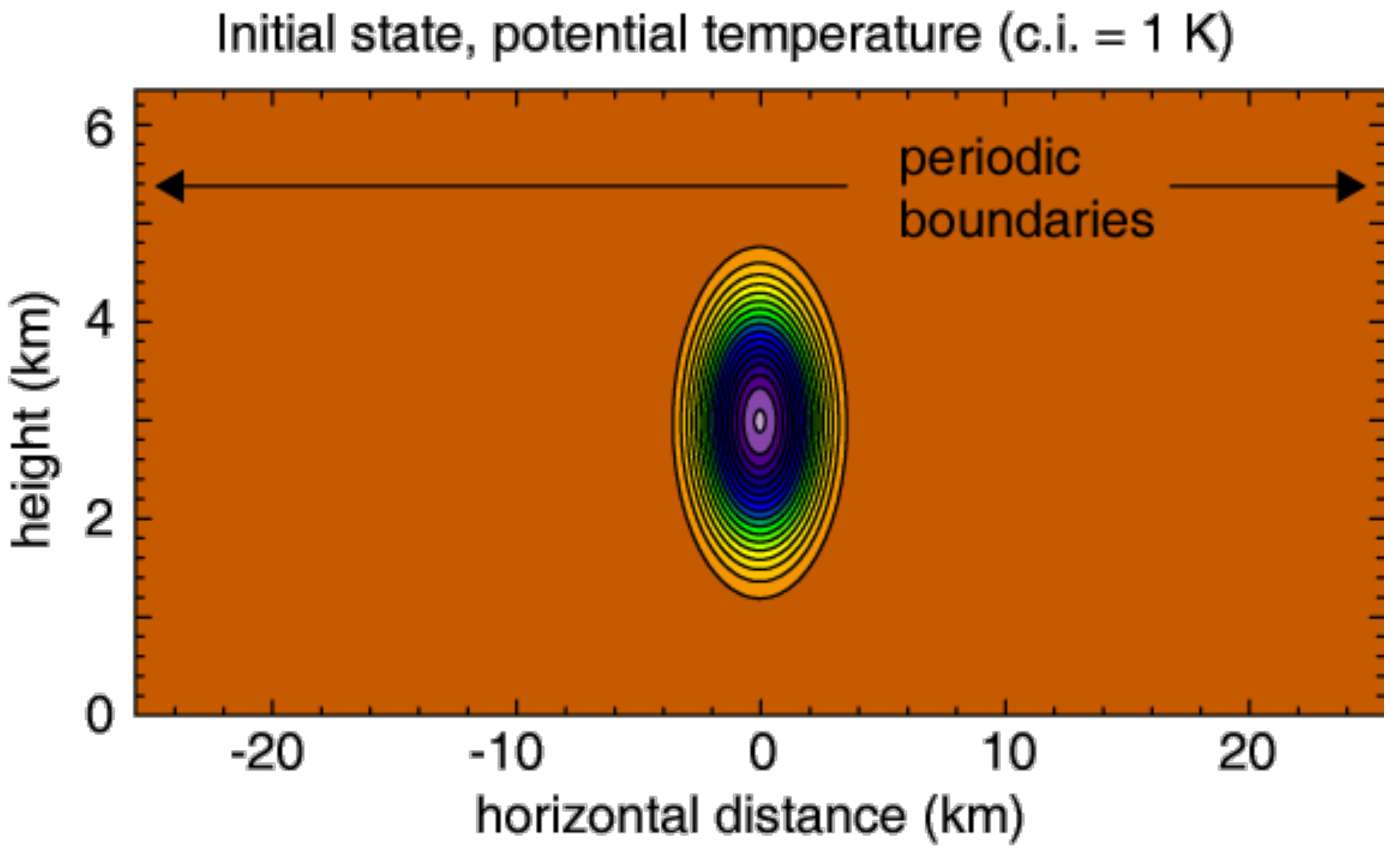
Initialization code is in
WRF/dyn_em/module_initialize_ideal.F
This code also introduces the initial perturbation.

The thermodynamic soundings and hodographs are in the ascii input files
WRF/test/em_squall2d_x/input_sounding
WRF/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 (constant)

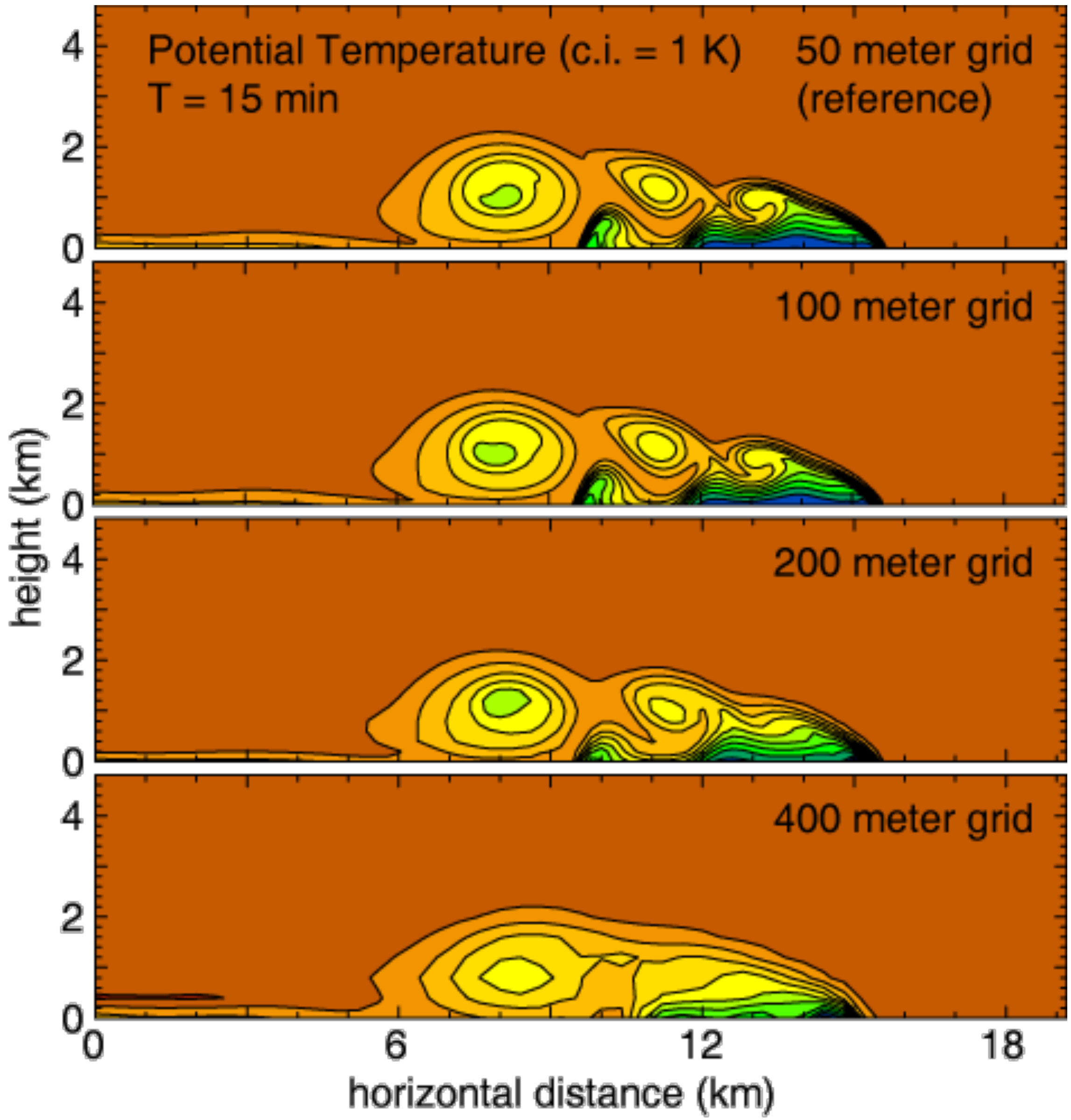


Idealized Cases: 2d gravity (density) current

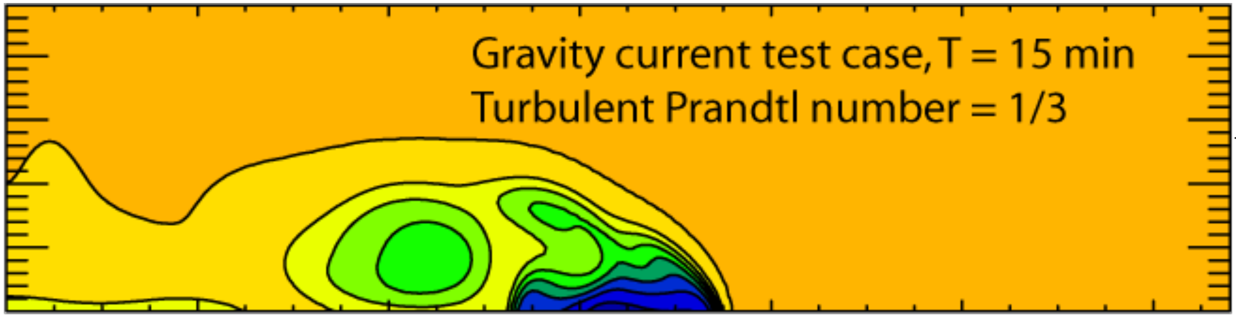
Default case, dx = 100 m,
5^{th} order upwind advection,
uses namelist.input.100m

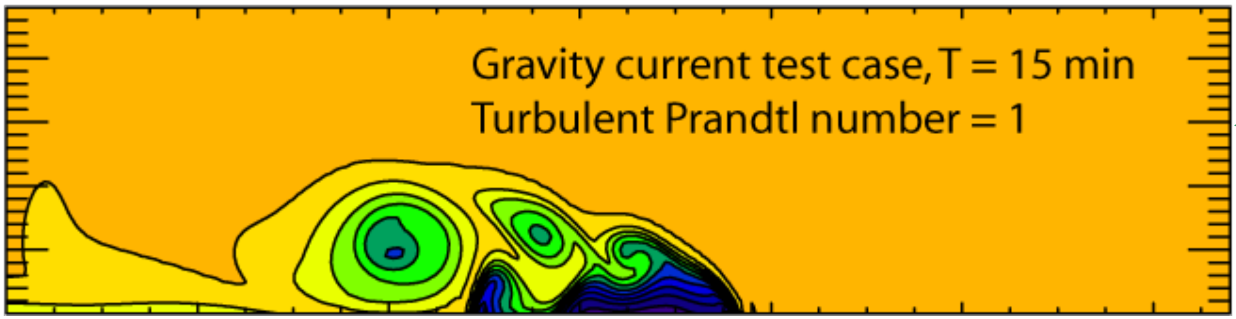
dx = 200 m,
5^{th} order upwind advection,
use namelist.input.200m

dx = 400 m,
5^{th} order upwind advection,
use namelist.input.400m



Idealized Cases: 2d gravity (density) current





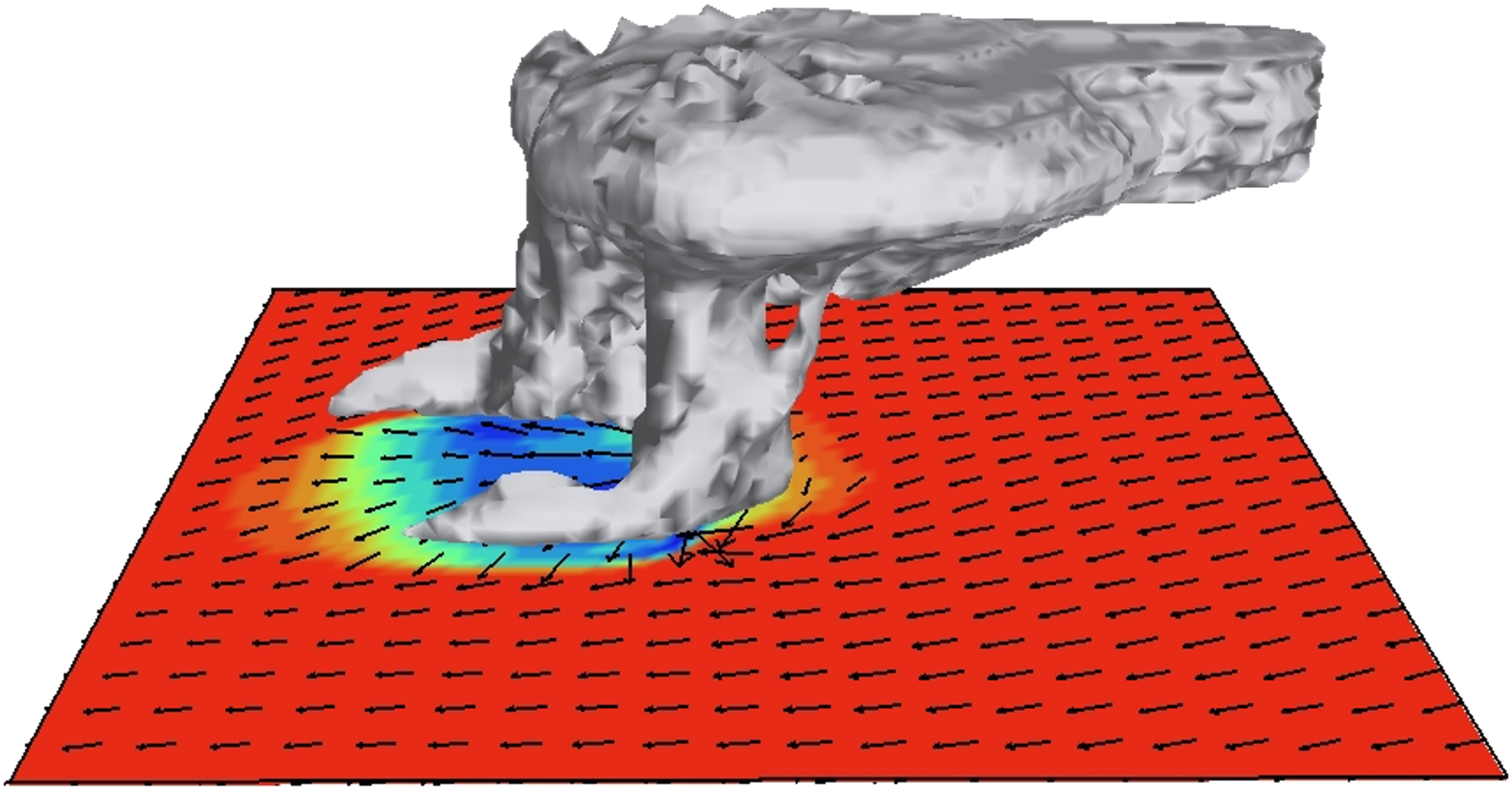
The turbulent Prandtl number in WRF is 1/3,and the default WRF test case will give this solution.

To recover the Straka et al (1993) solution, change the parameter *Prandtl* to 1 (from 1/3) in *WRF/share/module_model_constants.F*

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 Large Eddy Simulation (LES)

Initialization code is in

WRF/dyn_em/module_initialize_ideal.F

Test case directory is in

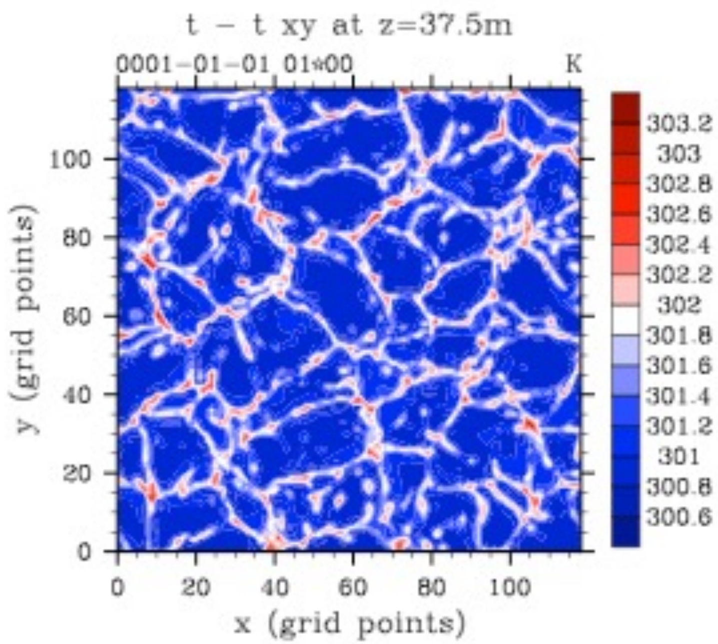
WRF/test/em_les

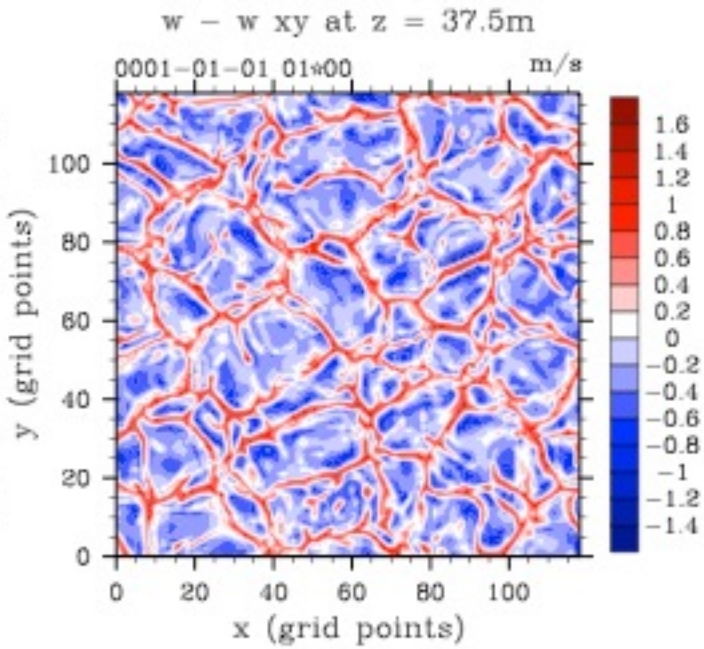
The default case is a large-eddy simulation of free convective boundary layer with no winds. The turbulence of the free CBL is driven and maintained by namelist-specified surface heat flux.

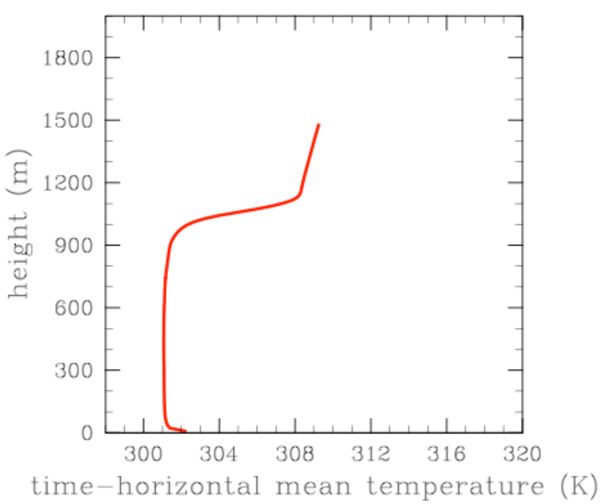
An initial sounding with mean winds is also provided.

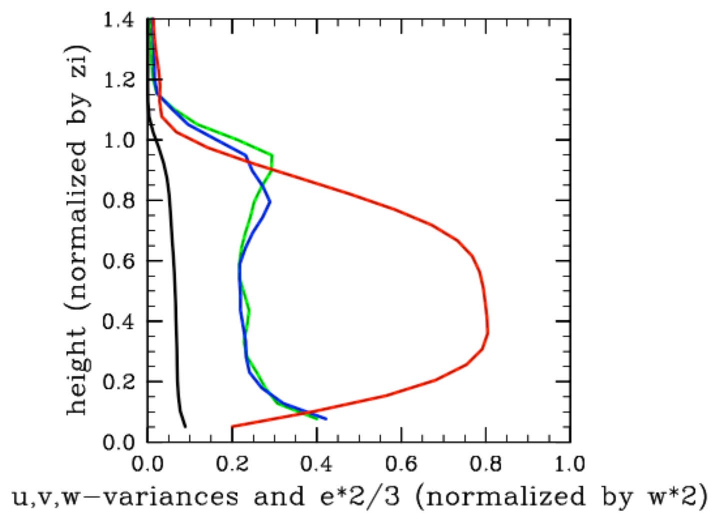
Reference: Moeng et al. 2007 MWR

Idealized Cases: 3d Large Eddy Simulation (LES)









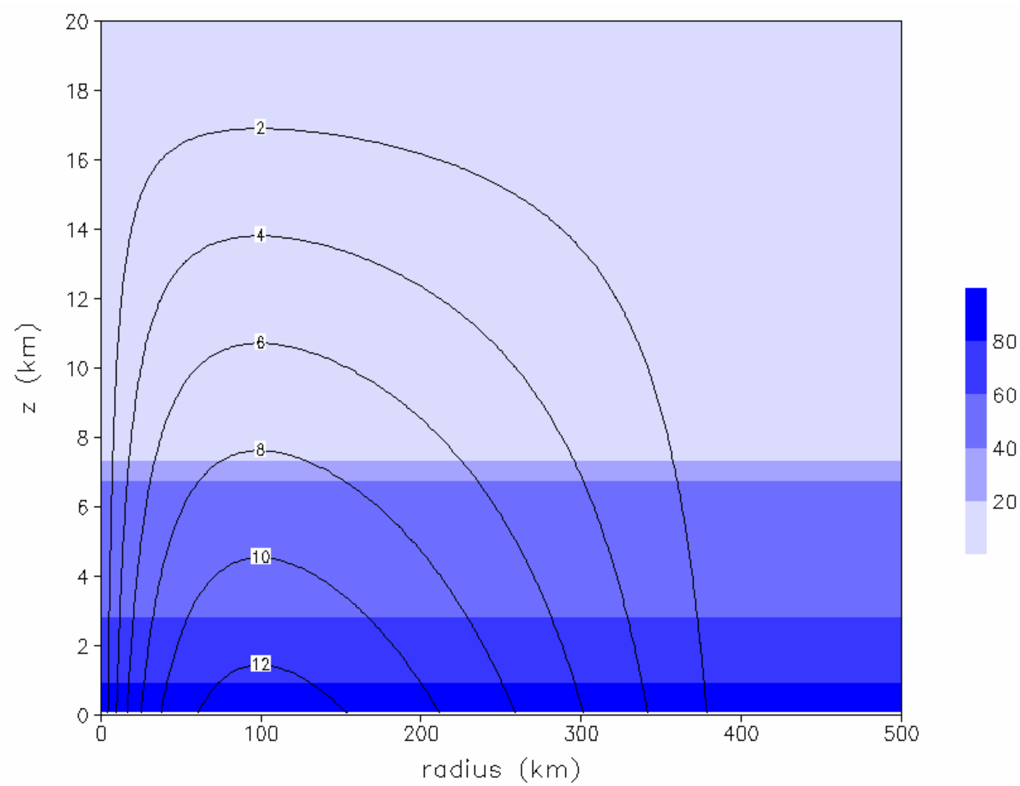
Idealized Cases: 3d tropical cyclone

<u>Default vortex:</u>

• 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)

<u>Default environment:</u>

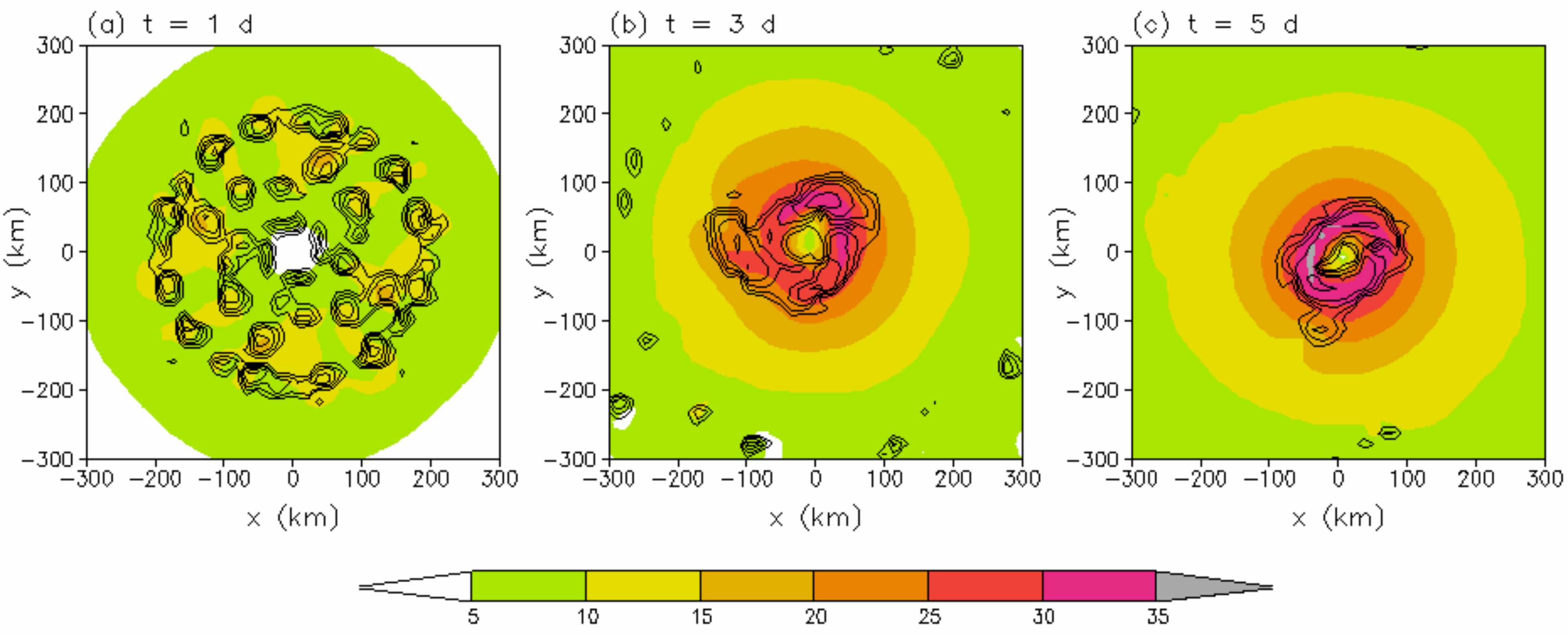
• mean hurricane sounding from Jordan (1958, J. Meteor.)
• SST = 28 degrees C
• f = 5e-5 s^{-1} (20 degrees North)



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

<u>Default domain:</u>
• 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

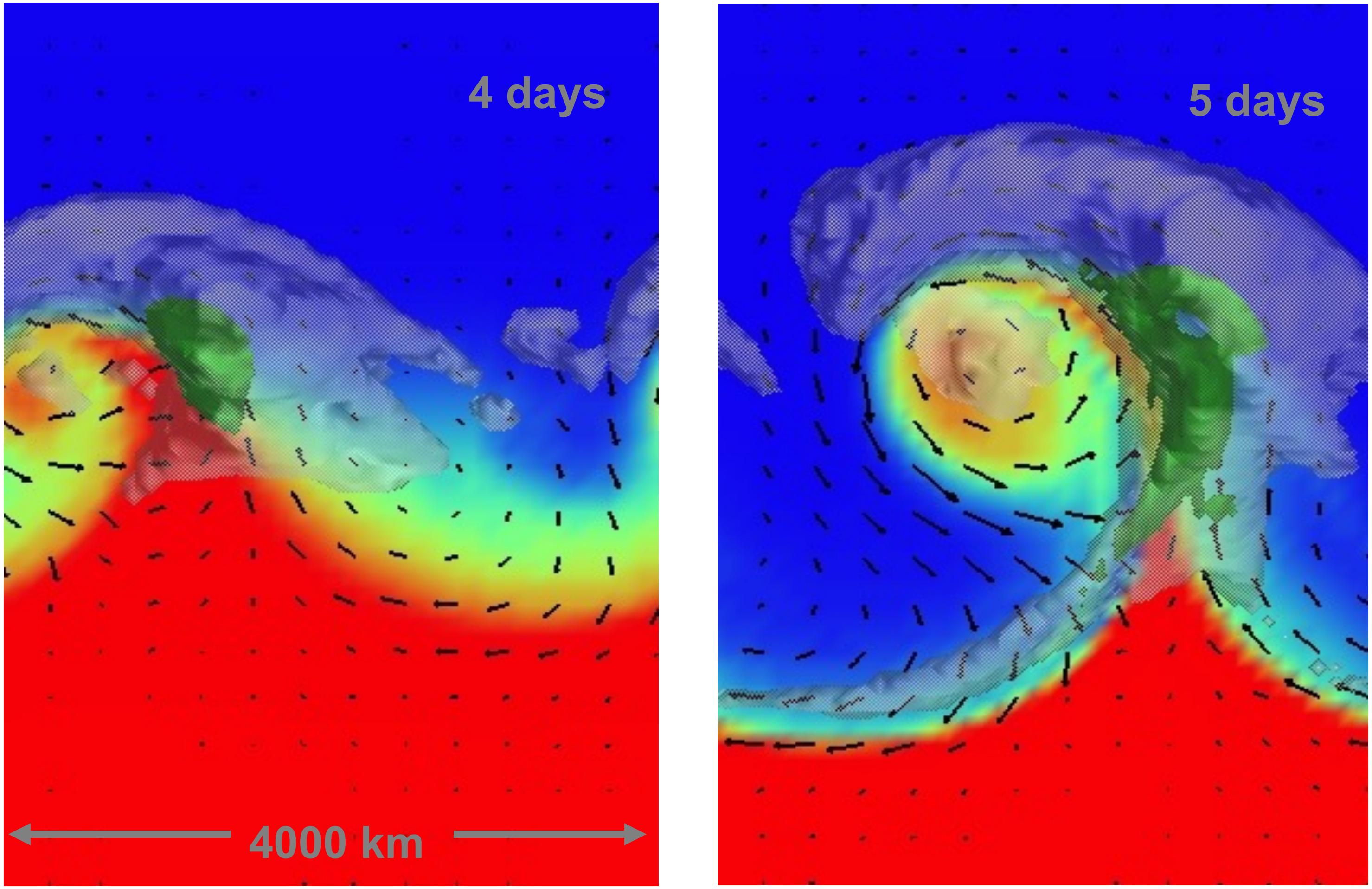
Idealized Cases: 3d tropical cyclone



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
WRF/dyn_em/module_initialize_ideal.F

The initial jet (y,z) is read from the binary input file
WRF/test/em_b_wave/input_jet

The initial perturbation is hardwired in the initialization code.

Default configuration in
WRF/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.

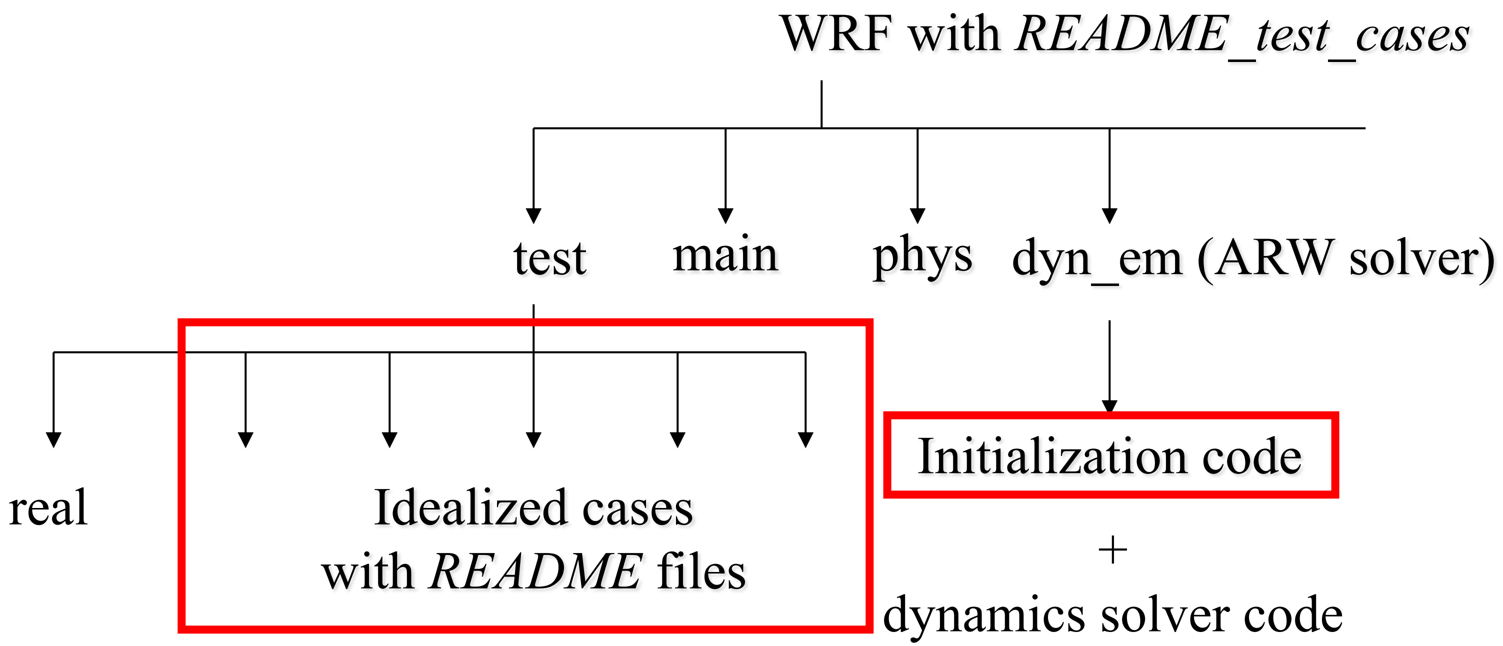
The initial jet only works for dy = 100 km and
81 grid points in the y (south-north) direction.

Idealized Cases: More information

Descriptions:

WRF/README_test_cases

WRF/test/em_*/README



Idealized Test Cases for the WRF ARW Model V4.5

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- 2D gravity current – *WRF/test/em_grav2d_x*
- 2D sea-breeze case – *WRF/test/em_seabreeze2d_x*
- 3D large-eddy simulation case – *WRF/test/em_les*
- 3D quarter-circle shear supercell thunderstorm – *WRF/test/em_quarter_ss*
- 3D convective radiative equilibrium test – *WRF/test/em_convrad*
- 3D baroclinic wave in a channel – *WRF/test/em_b_wave*

These cases are initialized using dyn_em/module_initialize_ideal.F

- 3D global: Held-Suarez case – *WRF/test/em_heldsuarez and dyn_em/module_initialize_heldsuarez.F*
- 1D single column test configuration – *WRF/test/em_scm_xy and dyn_em/module_initialize_scm.F*
- 3D fire model test cases – *WRF/test/em_fire and dyn_em/module_initialize_fire.F*
- 3D tropical cyclone – *WRF/test/em_tropical_cyclone and dyn_em/module_initialize_tropical_cyclone.F*

Idealized Cases: More information

Descriptions:

WRF/README_test_cases

WRF/test/em_*/README