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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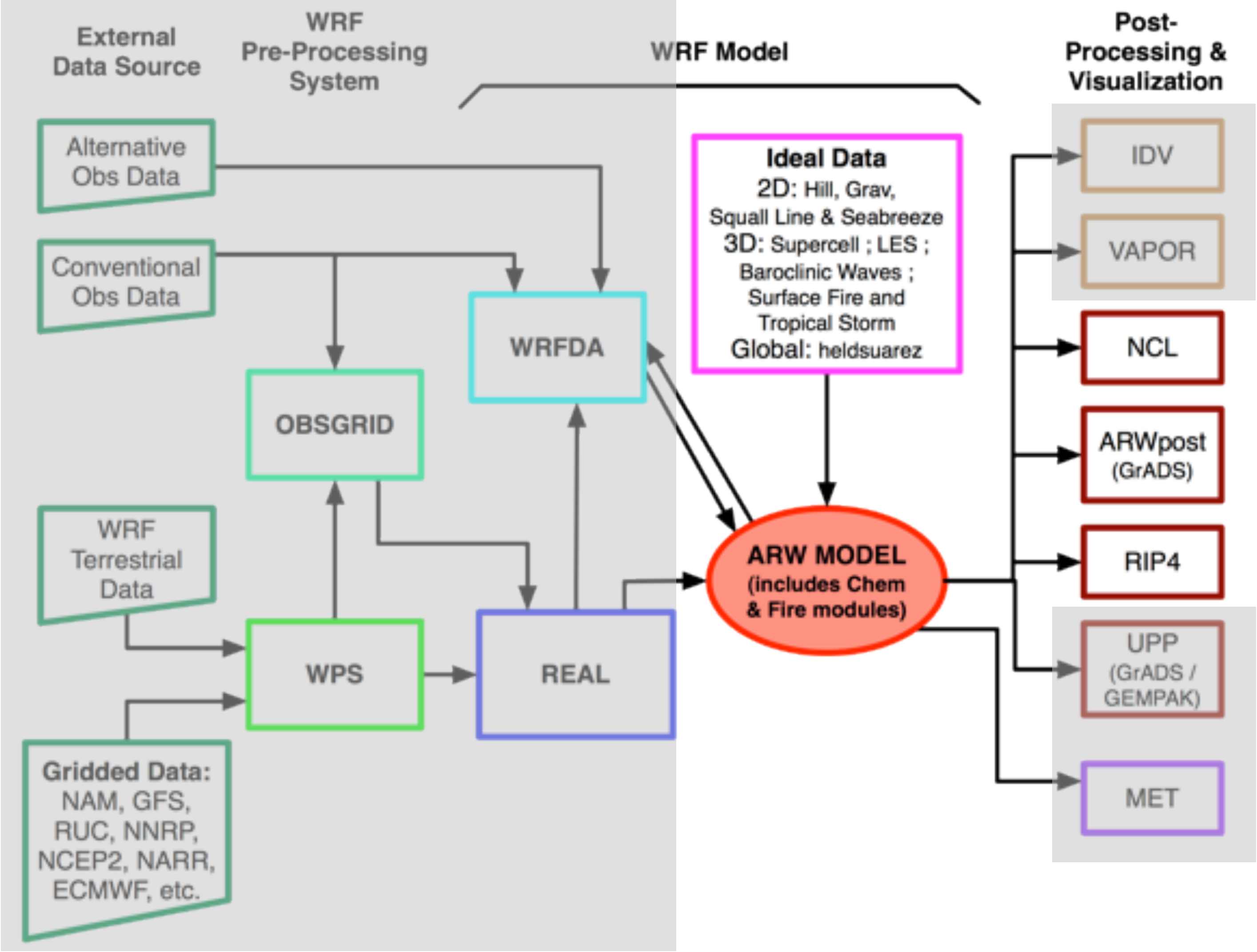
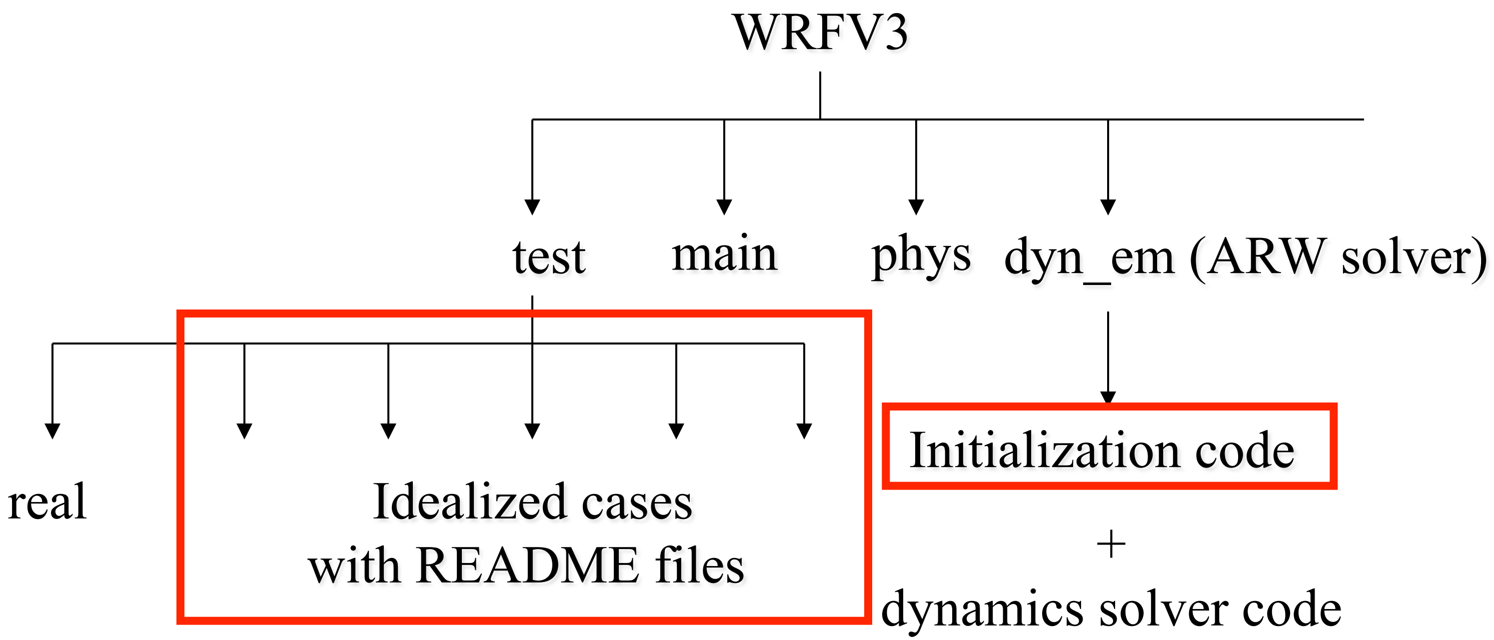
Idealized Cases: Introduction



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

WRF ARW code


WRFV3
test
main
phys
dyn_em (ARW solver)
real
Idealized cases
with README files
Initialization code
+
dynamics solver code

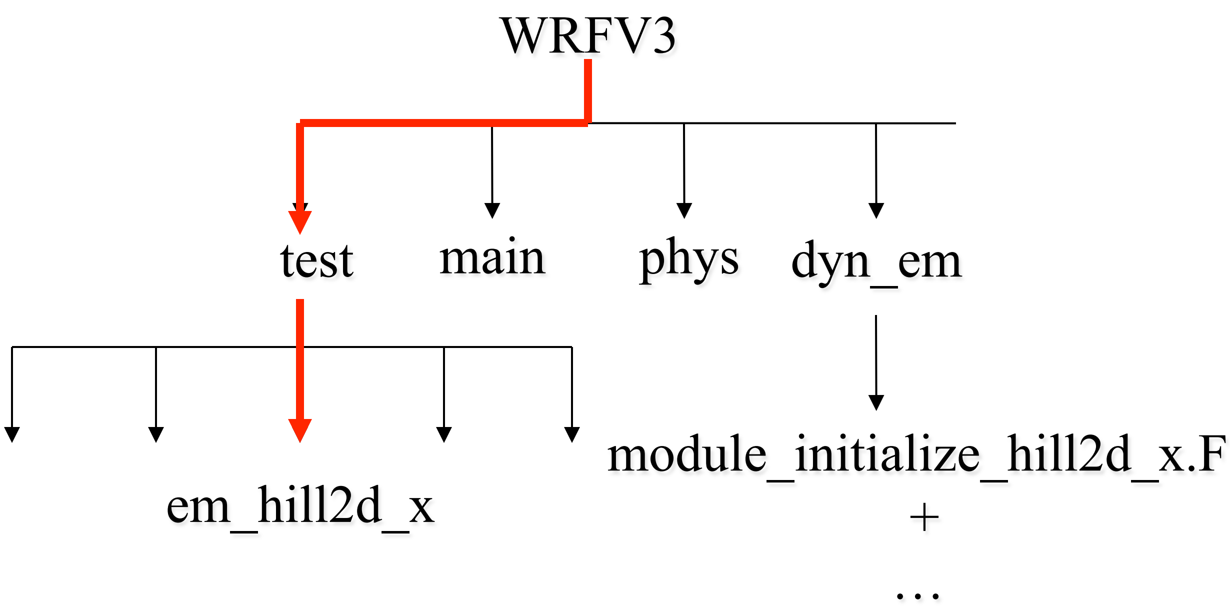
Idealized Test Cases for the WRF ARW Model V3.7

- 2D flow over a bell-shaped mountain – *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_xy*
- 3D fire model test cases – *WRFV3/test/em_fire*
- 3D convective radiative equilibrium test – *WRFV3/test/em_convrad*

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

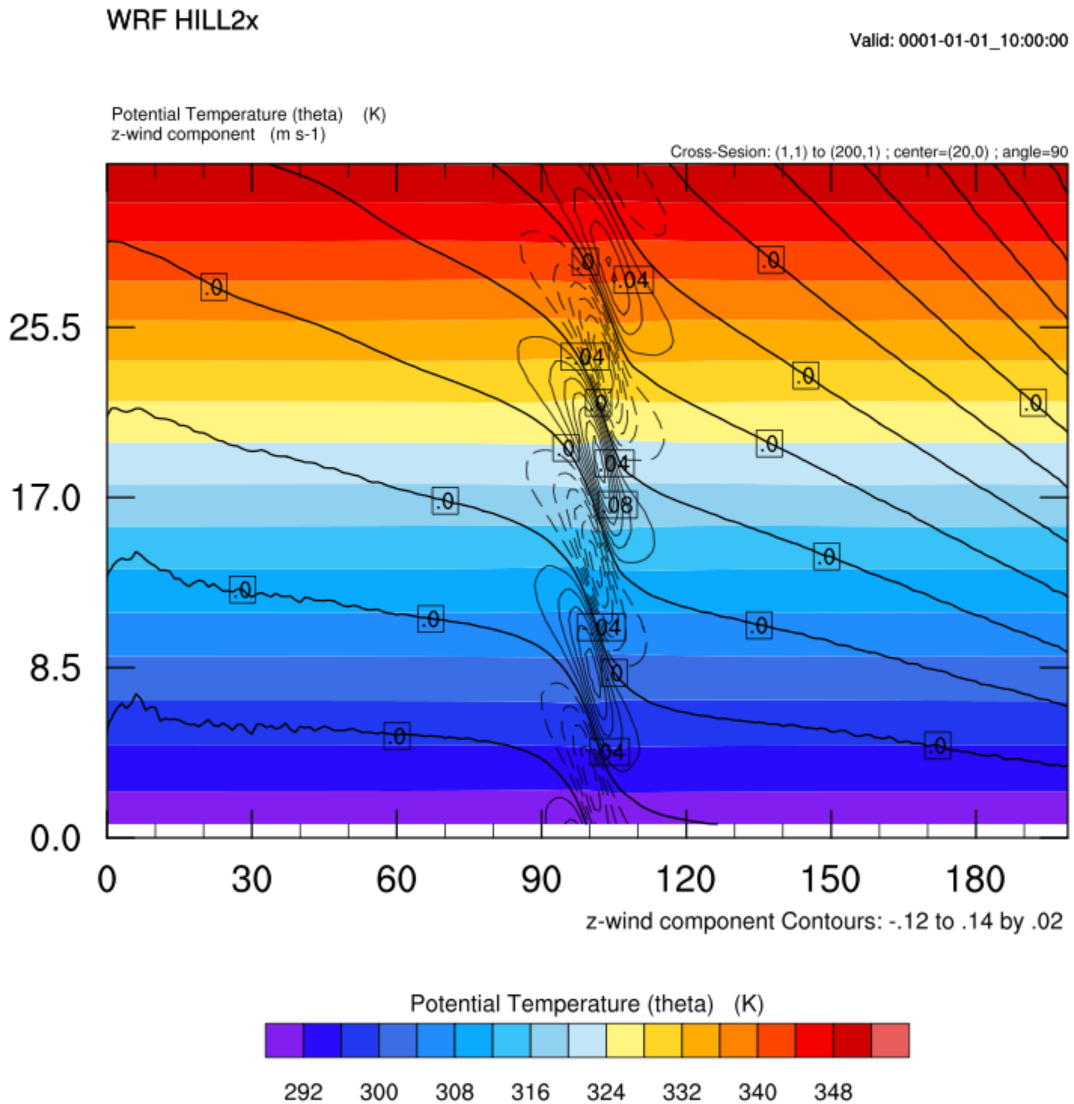
Move to the test directory:

> 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)



What happens during the initialization

Initialization code: *WRFV3/dyn_em/module_initialize_hill2d_x.F*

- 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.
- Terrain is set in the initialization code
- 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.
- 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.

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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
```

- hm, xa: mountain height and half-width
- icm: mountain position in domain (center gridpoint in x)
- Set height field (grid%ht)
- grid%php(i,1,j) = 0.: lower boundary condition

Sounding File Format

File: *WRFV3/test/em_quarter_ss/input_sounding*

line 1 → first line (surface values):

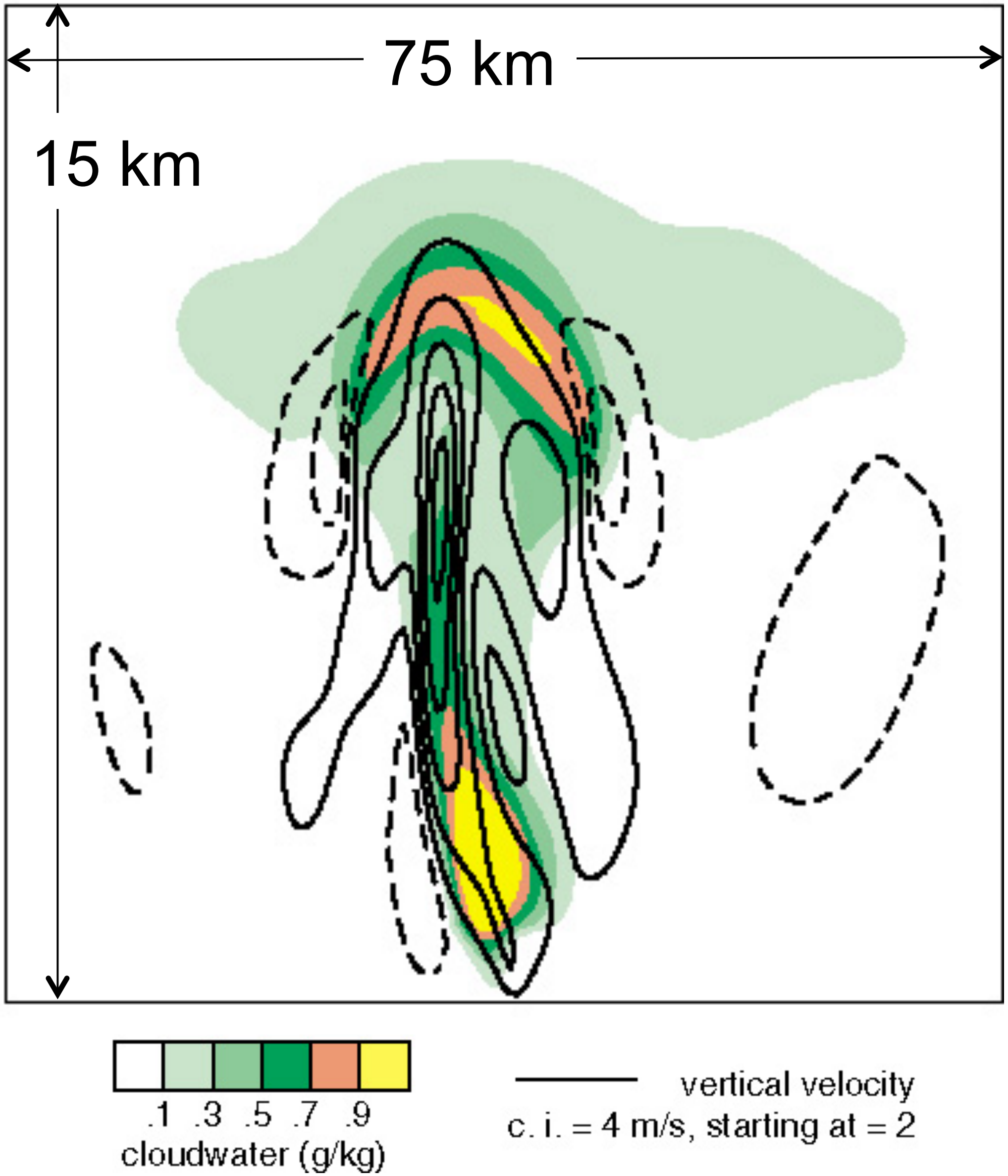
surface Pressure (mb)	surface potential Temperature (K)	surface vapor mixing ratio (g/kg)
1000.00	300.00	14.00

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 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

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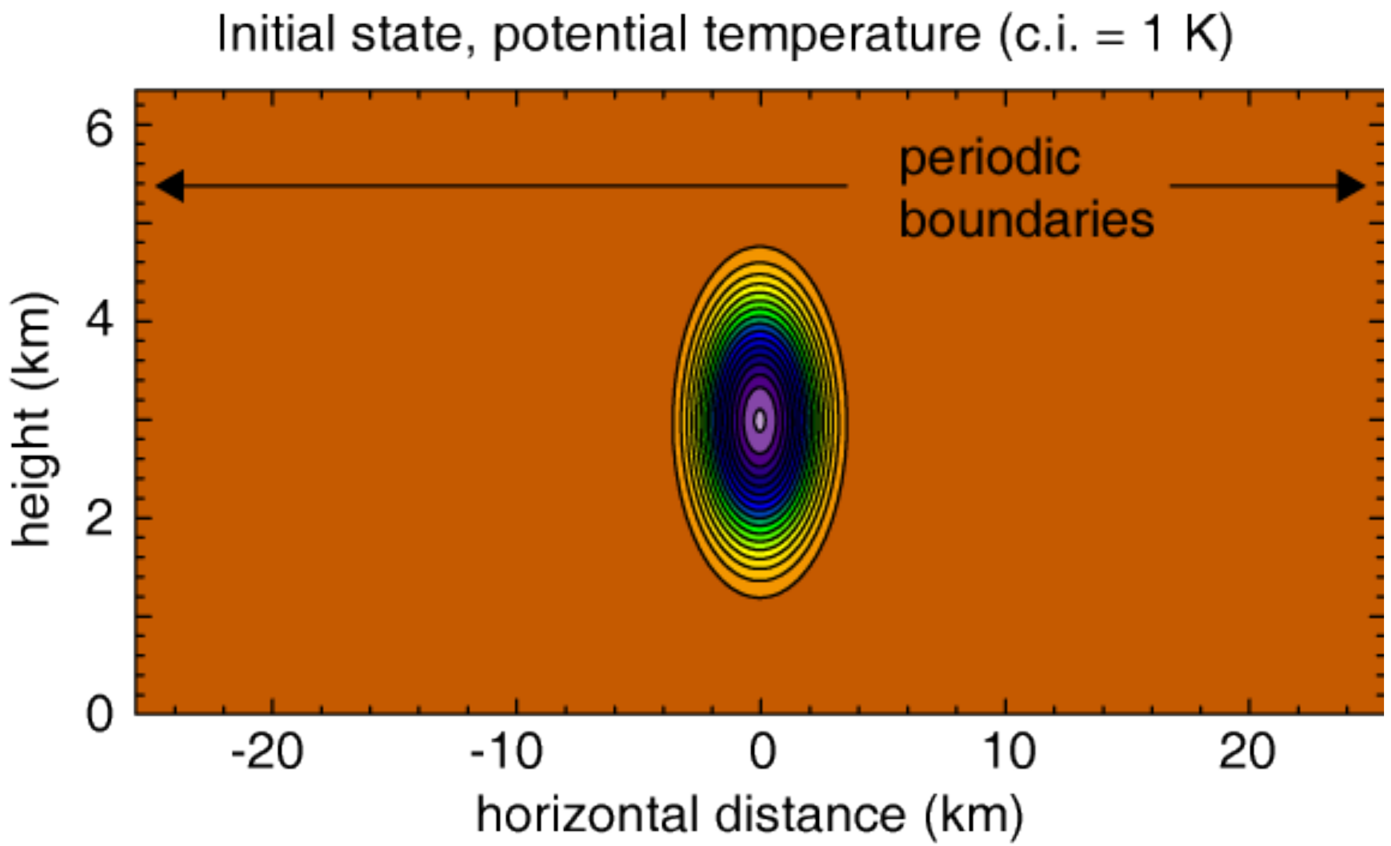
Idealized Cases: 2d gravity (density) current

(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)

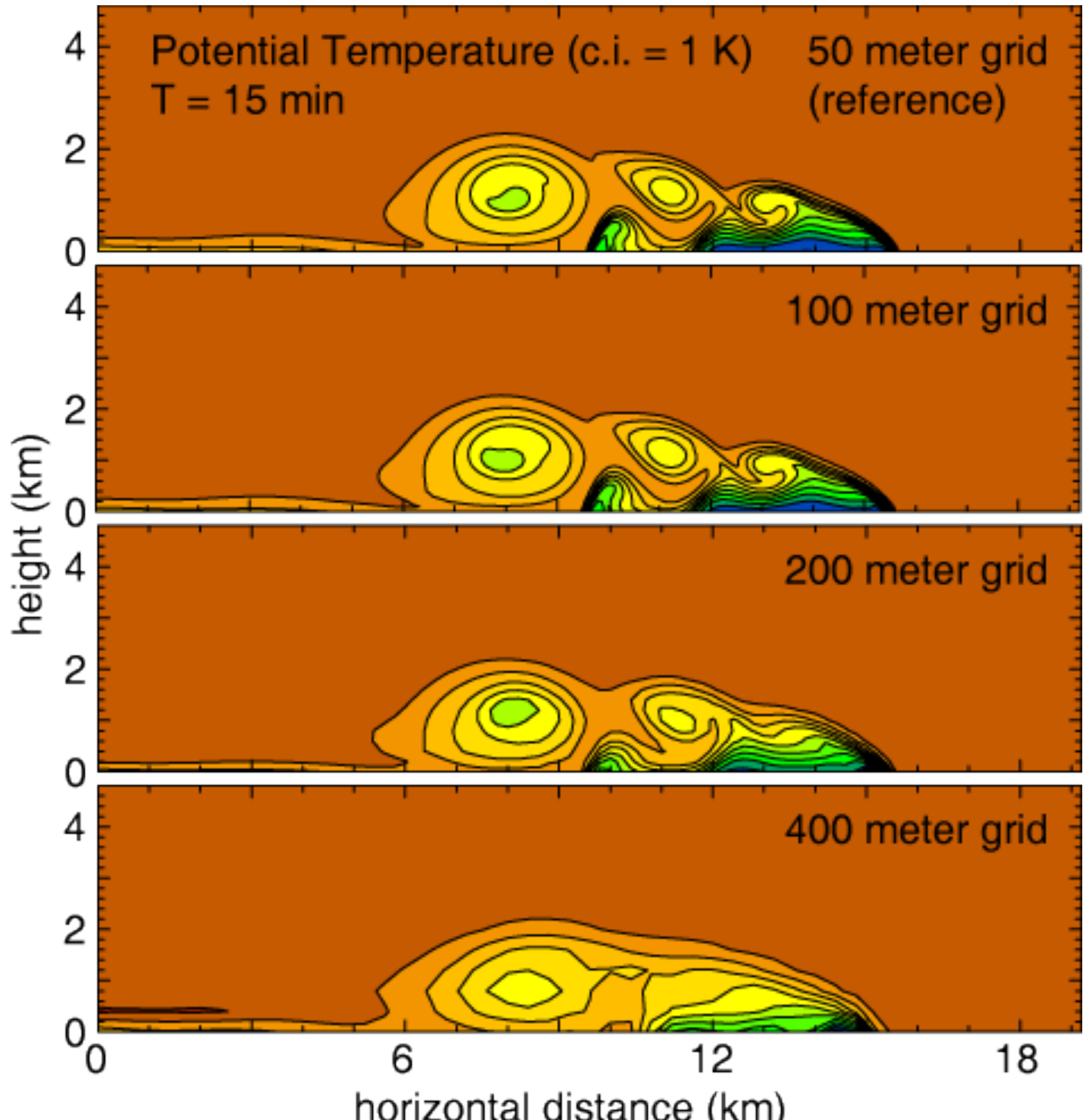


Idealized Cases: 2d gravity (density) current

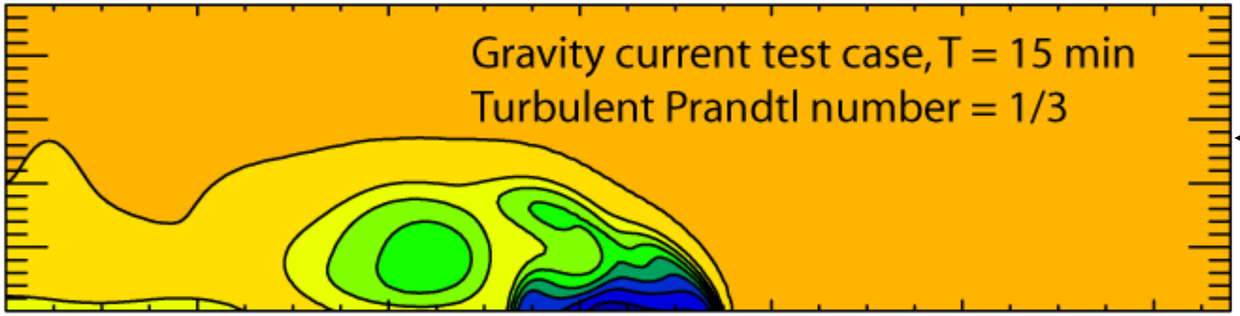
Default case, dx = 100 m,
5^{th} order upwind advection,
uses namelist.input.100m

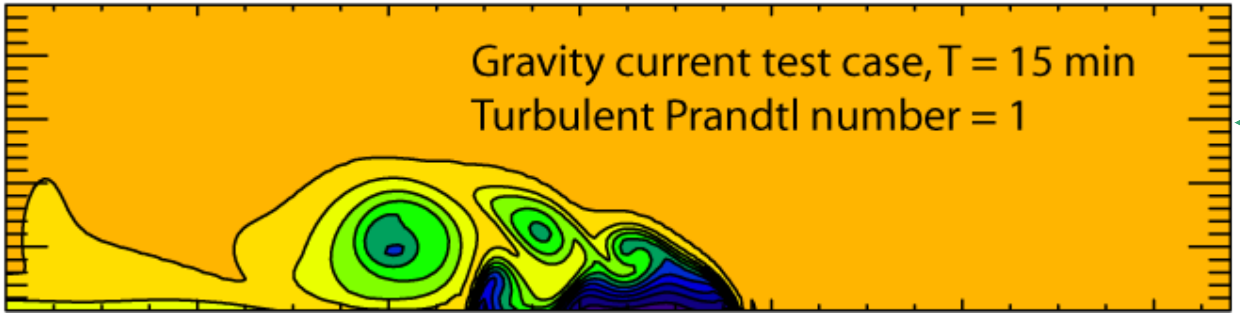
dx = 200 m,
5^{th} order upwind advection,
use namelist.input.200m

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 *WRFV3/share/module_model_constants.F*

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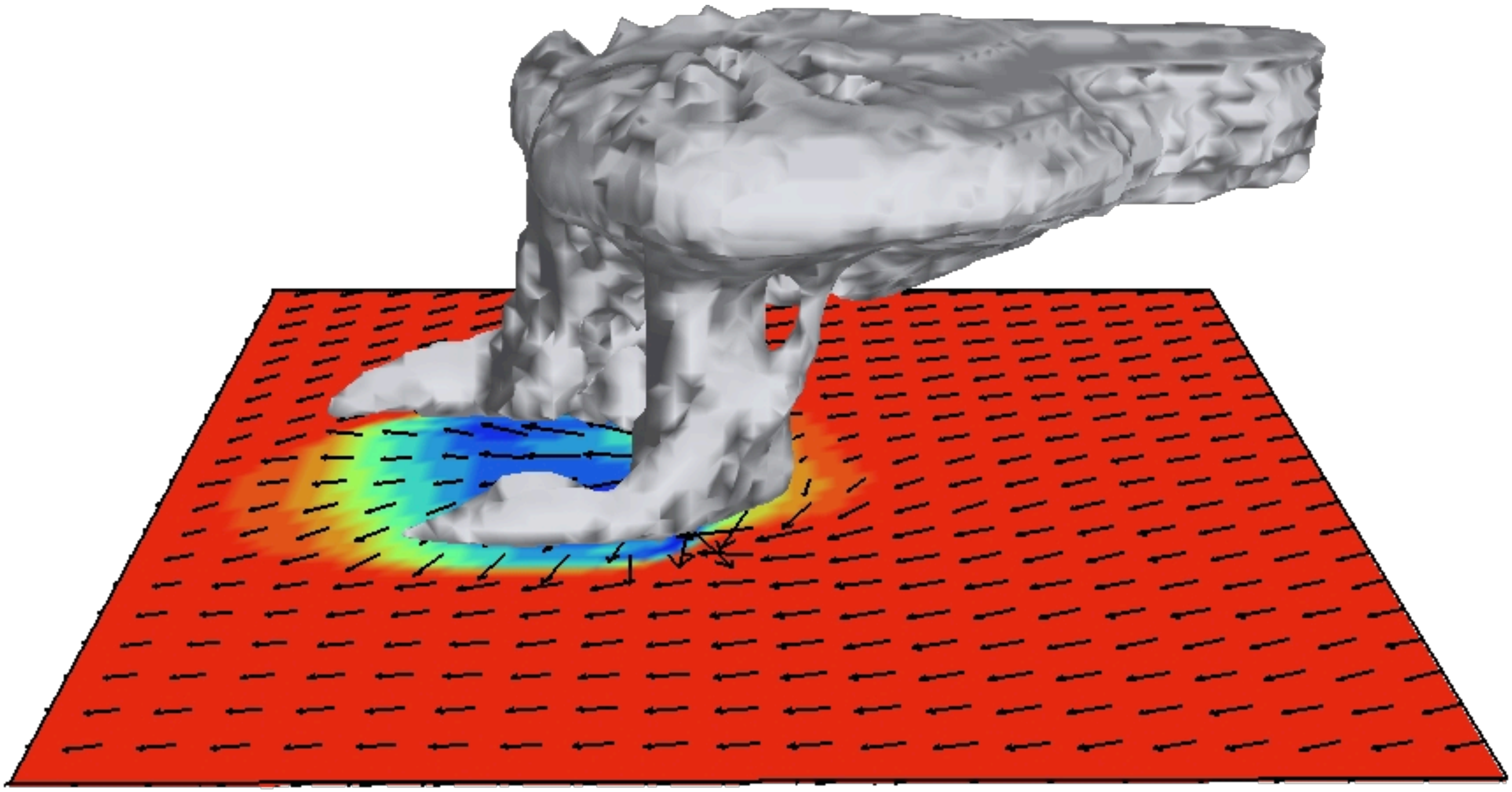
Idealized Cases: 3d supercell thunderstorm

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_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

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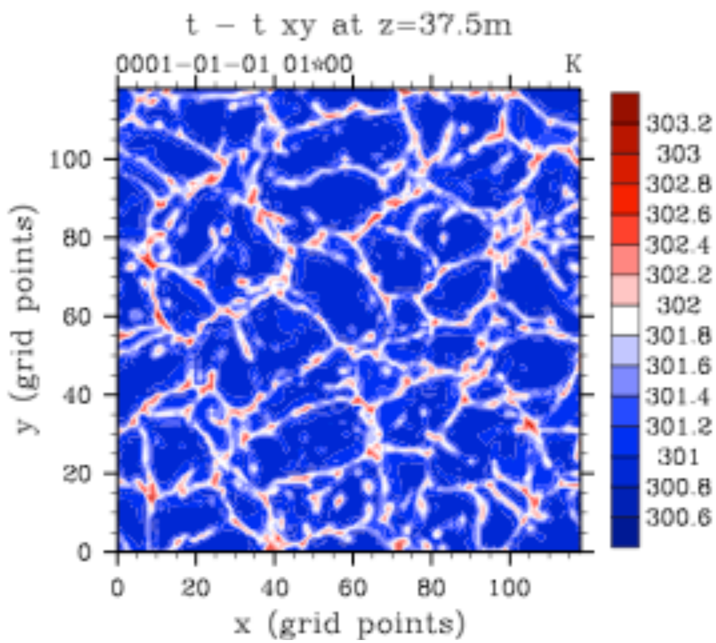
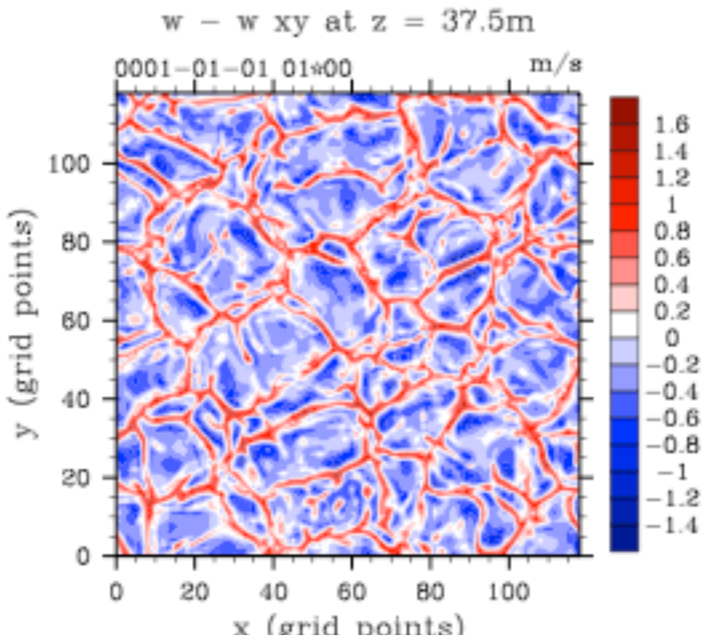
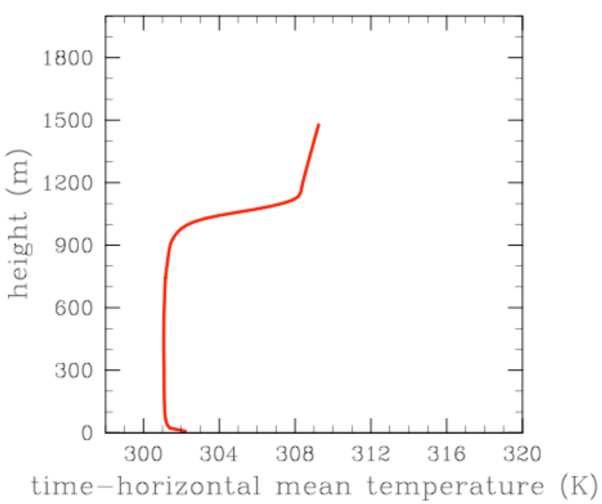
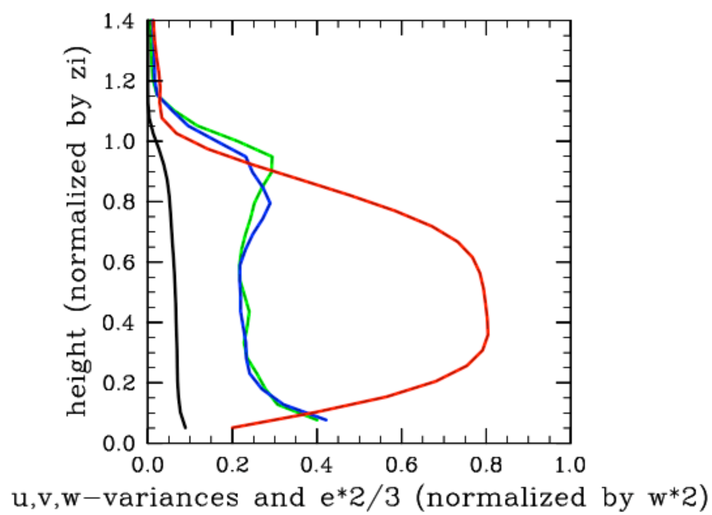
Idealized Cases: 3d Large Eddy Simulation (LES)





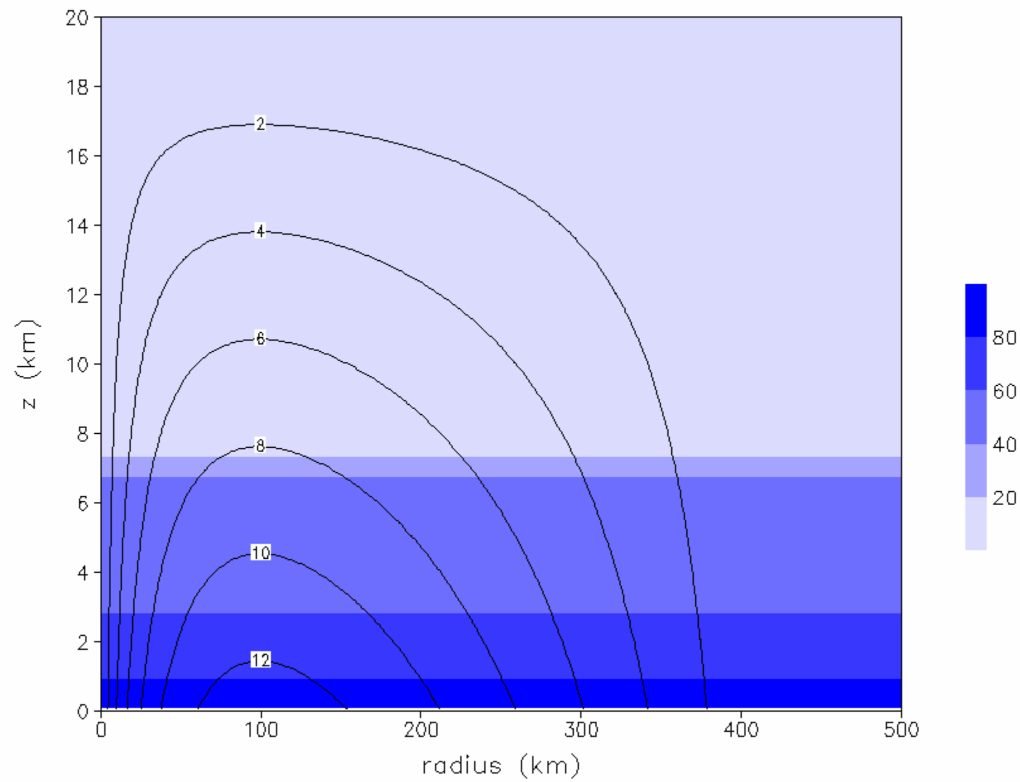




Idealized Cases: 3d tropical cyclone

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)



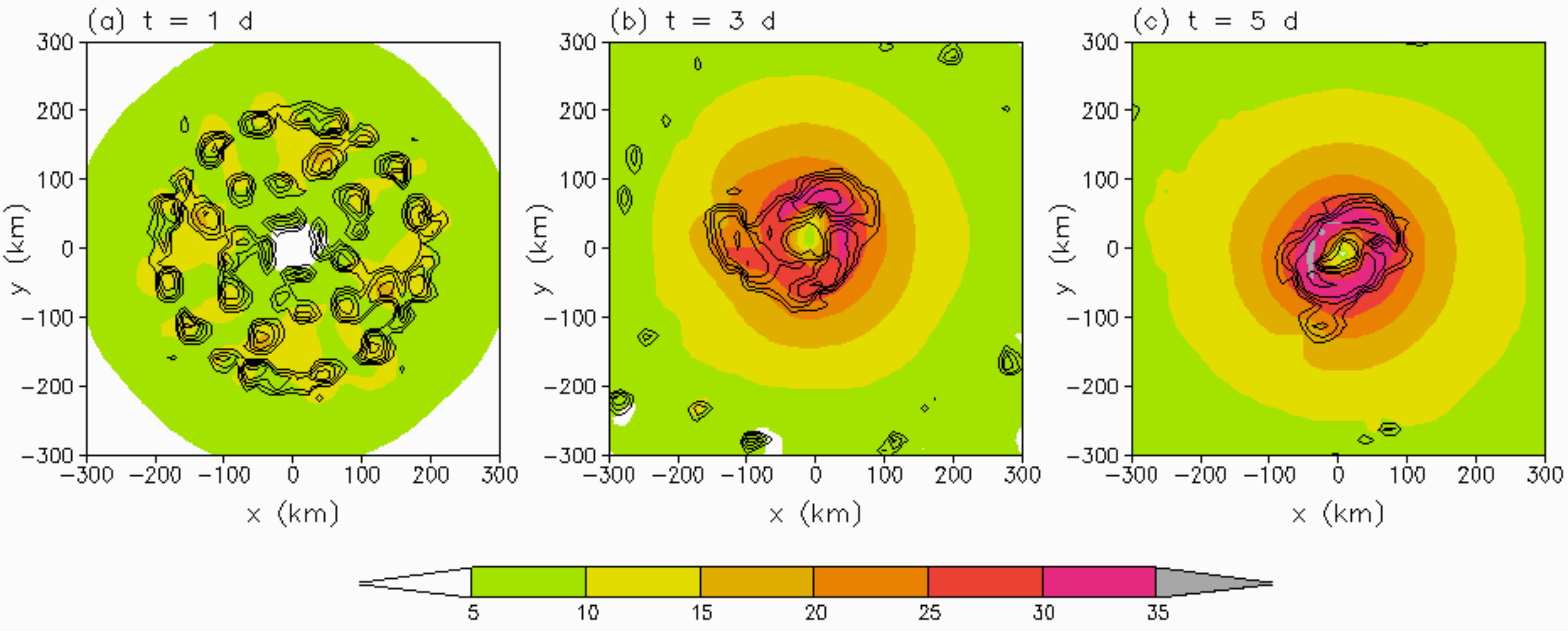
colors = relative humidity (%)
contours = azimuthal velocity (m/s)

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

Idealized Cases: 3d tropical cyclone



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

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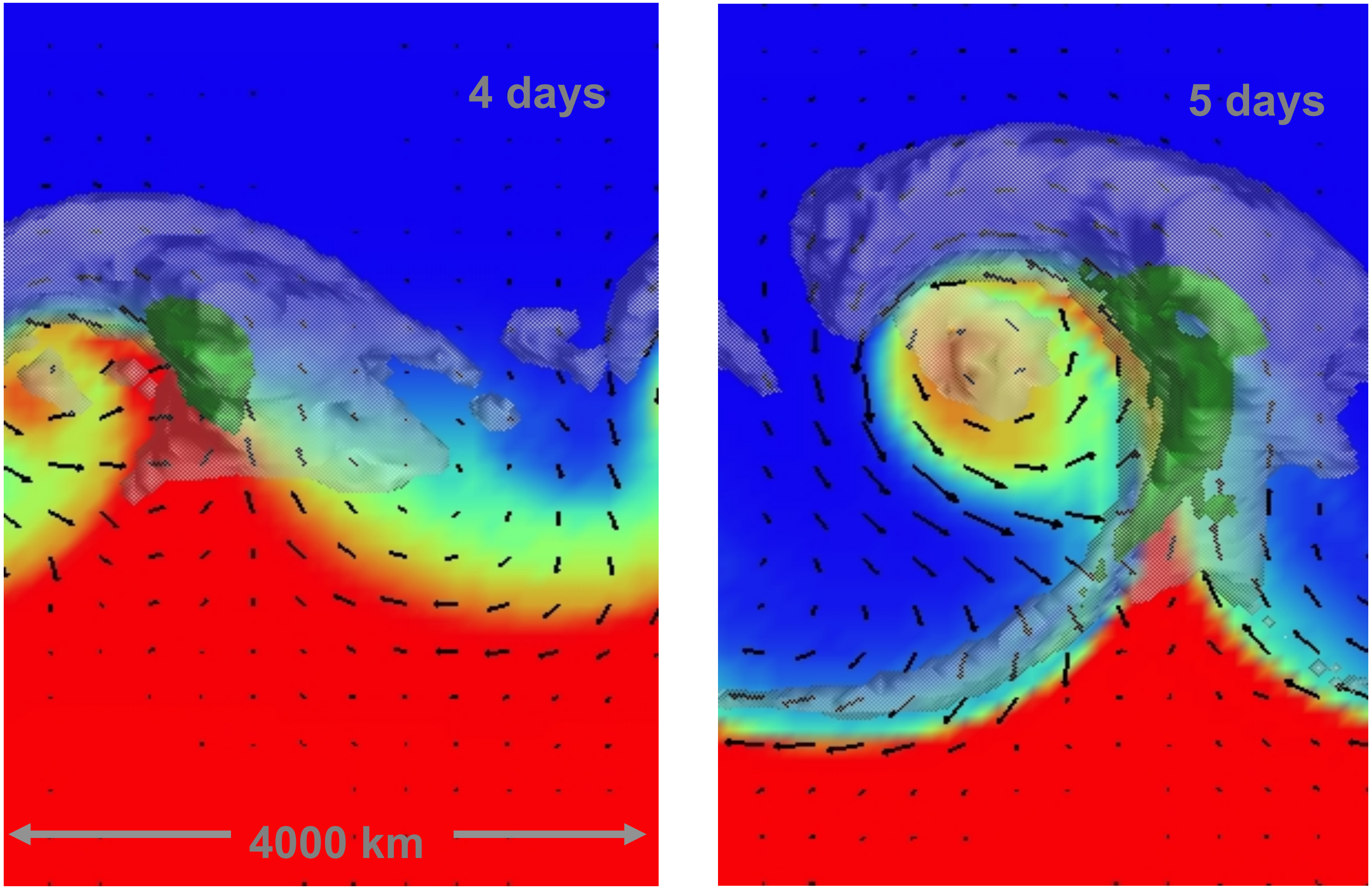
Idealized Cases: baroclinic wave in a channel

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



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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.

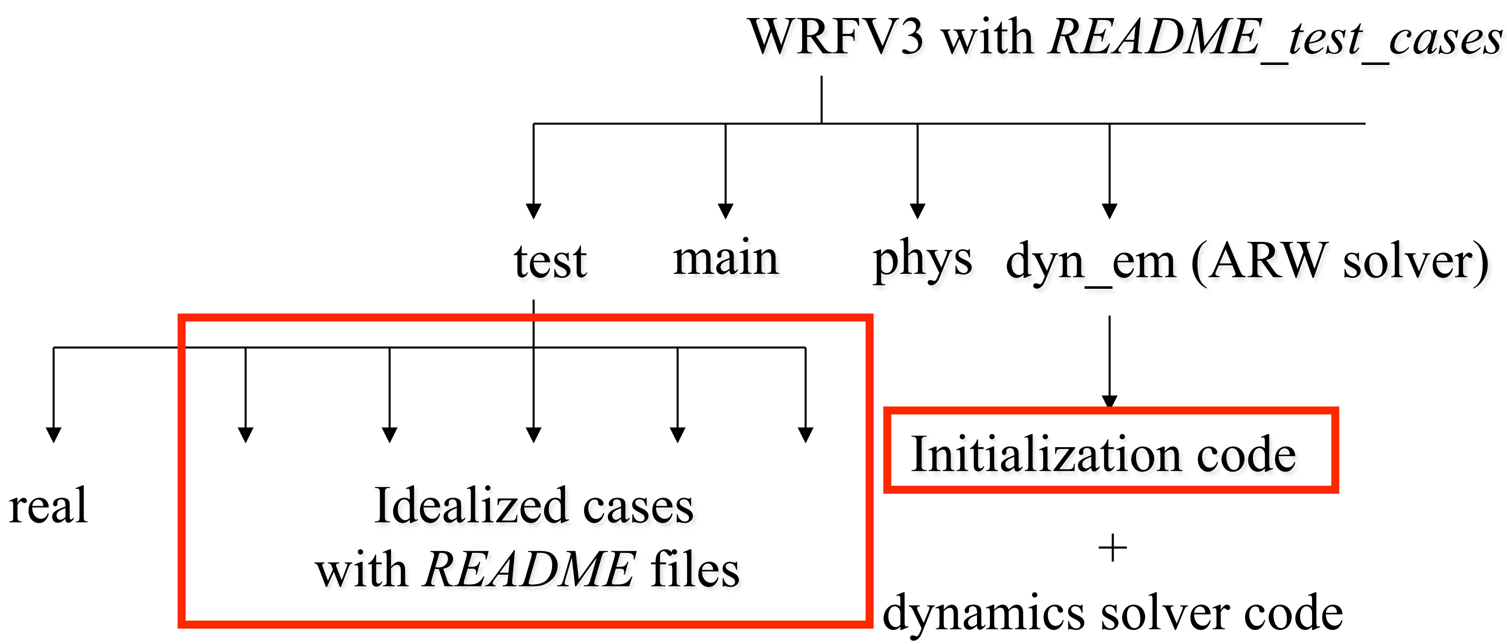
The initial jet only works for dy = 100 km and
81 grid points in the y (south-north) direction.

Idealized Cases: More information

Descriptions:

WRFV3/README_test_cases

WRFV3/test/em_*/README



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