

Initialization for Idealized Cases

Bill Skamarock
skamaroc@ucar.edu

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, $\Delta t < \text{second}$;
 - Baroclinic waves - Δx 100 km, $\Delta t = 30$ minutes.
2. The test cases reproduce known solutions (analytic, converged, or otherwise).
3. The cases provide a starting point for other idealized experiments.

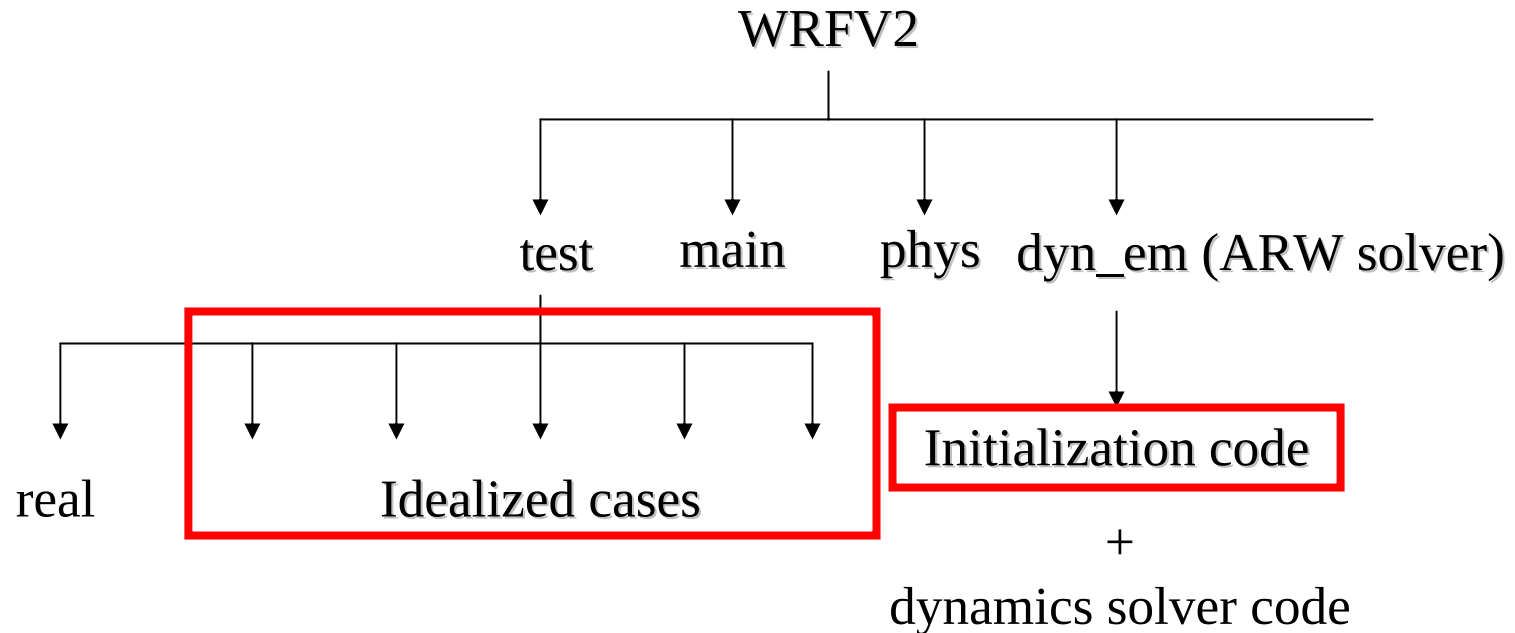
Color Legend

Directories, Files

Commands, Executions

Special Comments

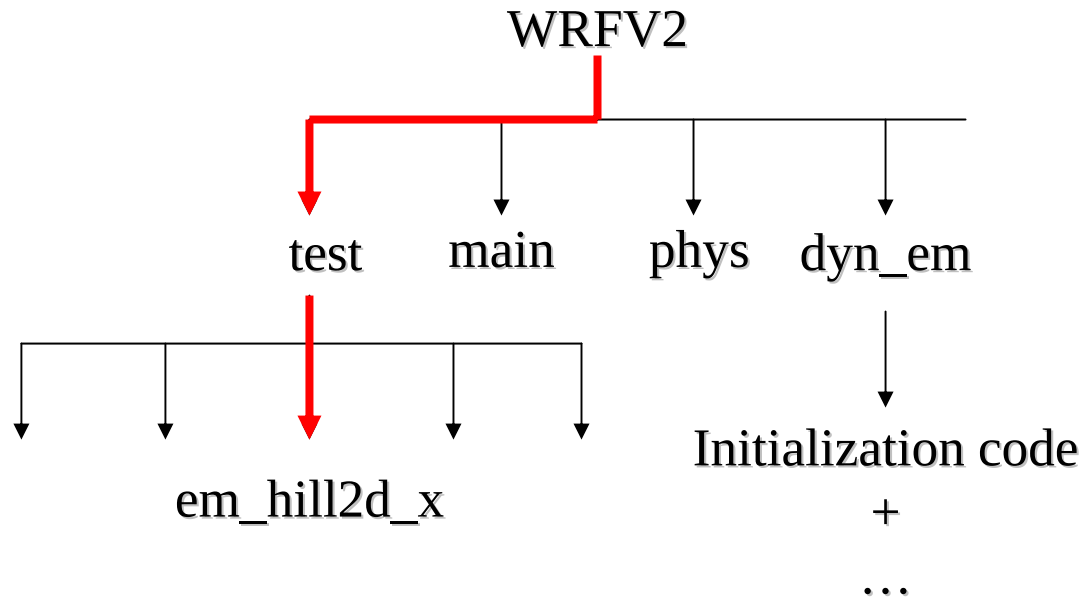
WRF ARW code



Test Cases for the WRF ARW Model

- 2D flow over a bell-shaped mountain

WRFV2/test/em_hill2d_x

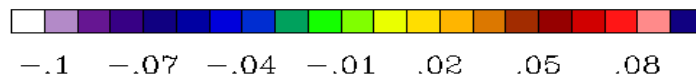
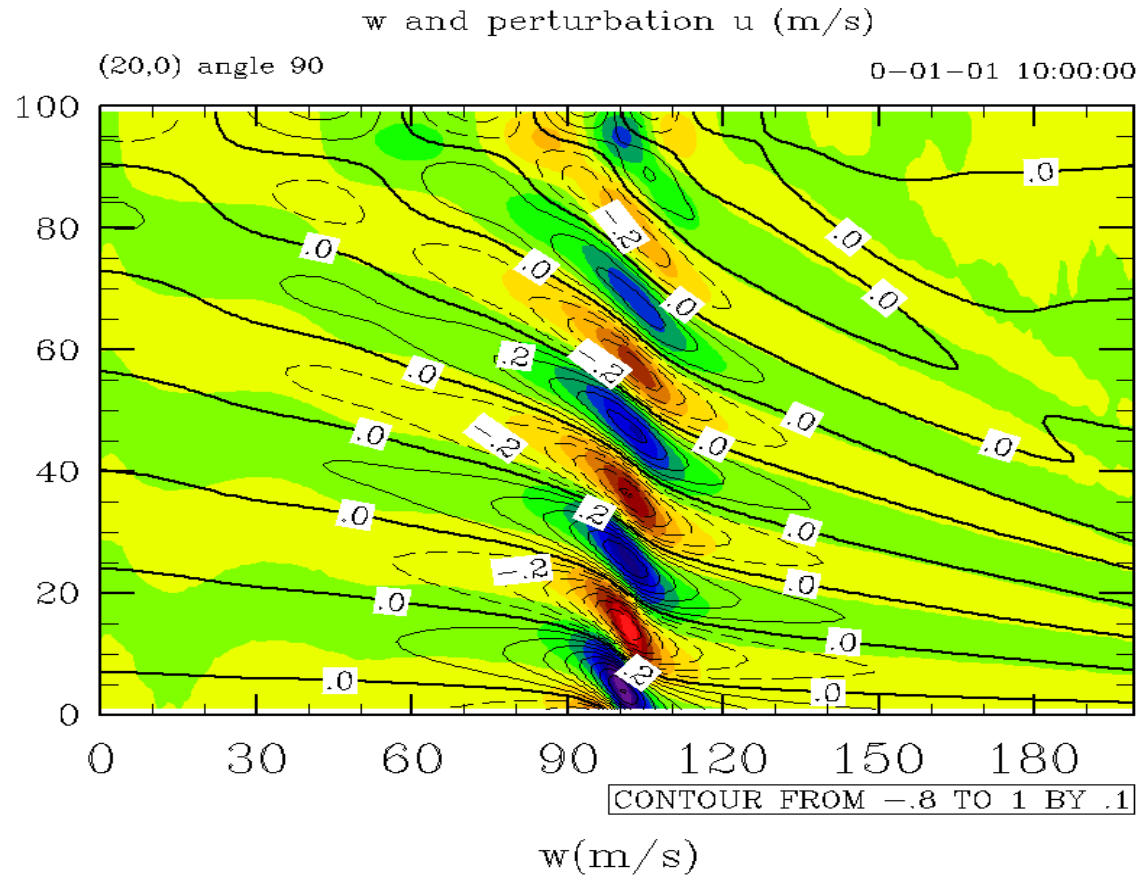


Test Cases for the WRF ARW Model

- 2D flow over a bell-shaped mountain
WRFV2/test/em_hill2d_x
- 2D squall line (x, z ; y, z)
WRFV2/test/em_squall2d_x
WRFV2/test/em_squall2d_y
- 3D quarter-circle shear supercell thunderstorm
WRFV2/test/em_quarter_ss
- 3D baroclinic wave
WRFV2/test/em_b_wave
- 2D gravity current
WRFV2/test/em_grav2d_x

2D Flow Over a Bell-Shaped Mountain

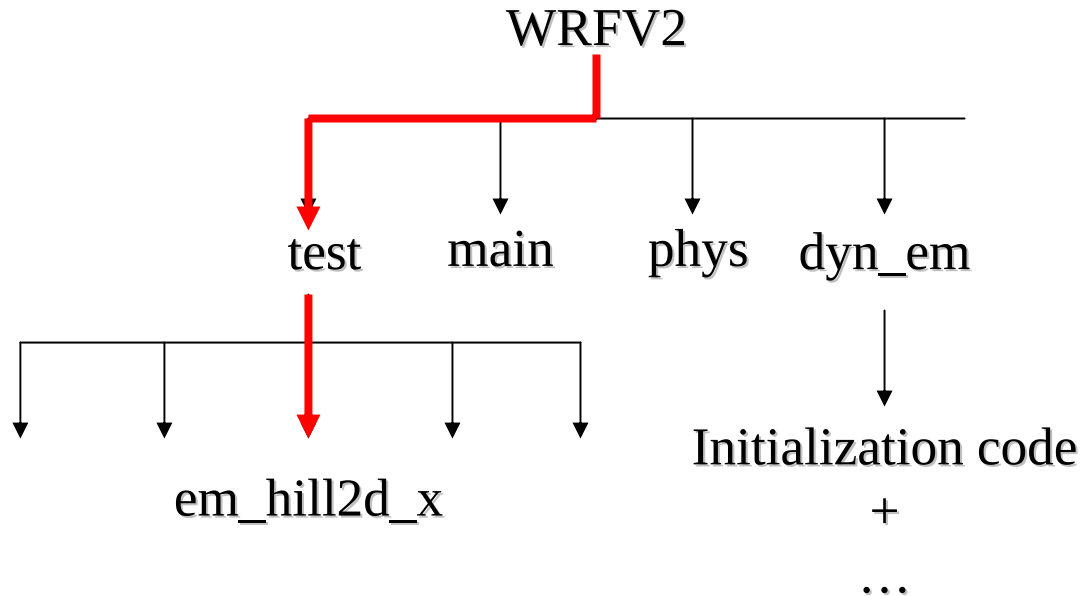
(dx = 2 km, dt = 20 s, T=10 hr)



Run - 2D Flow Over a Bell-Shaped Mountain

From *WRFV2* - *compile em_hill2d_x* ;

From *WRFV2/test/em_hill2d_x* – run *ideal.exe*, run *wrf.exe*



Run 2D Flow Over a Bell-Shaped Mountain

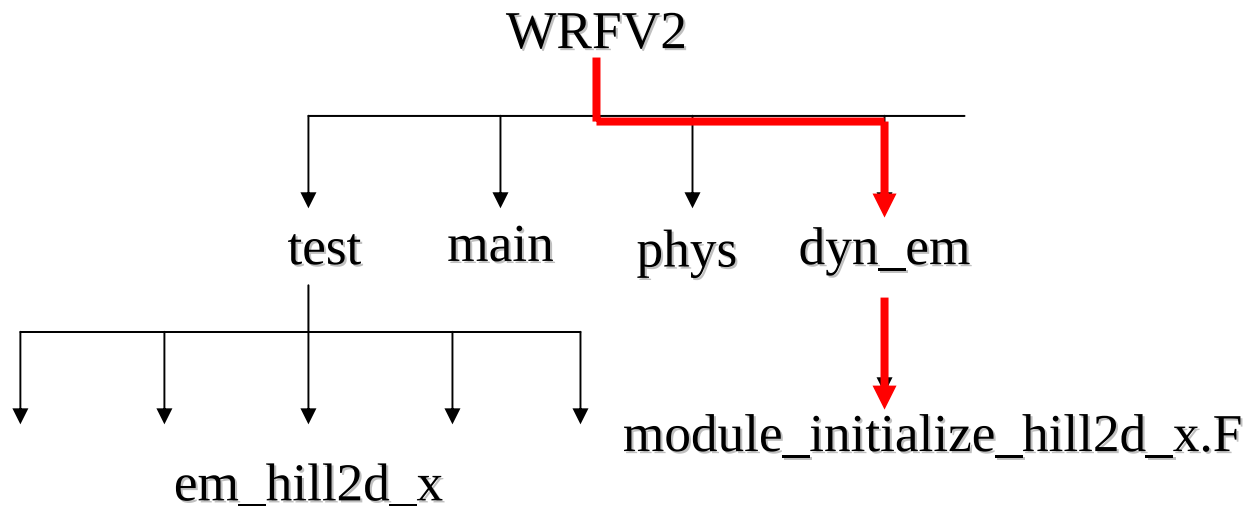
From *WRFV2* - *compile em_hill2d_x* ;

From *WRFV2/test/em_hill2d_x* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_hill2d_x.F

The terrain profile is set in the initialization code.



Run 2D Flow Over a Bell-Shaped Mountain

From *WRFV2* - *compile em_hill2d_x* ;

From *WRFV2/test/em_hill2d_x* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_hill2d_x.F

The terrain profile is set in the initialization code.

The thermodynamic sounding and the initial wind field
is read from the ascii file

WRFV2/test/em_hill2d_x/input_sounding

The 2D solution is computed by integrating the 3D model
with 3 points in periodic direction y; without an initial
perturbation in y the solution remains y-independent.

Setting the terrain heights

In *WRFV2/dyn_em/module_initialize_hill2d_x.F*

```
SUBROUTINE init_domain_rk ( grid, &
```

```
...
```

```
  hm = 100.
```

```
  xa = 5.0
```

← mountain height and half-width

```
  icm = ide/2
```

← mountain position in domain
(central gridpoint in x)

```
...
```

```
  DO j=jts,jte
```

```
    DO i=its,ite ! flat surface
```

```
      ! ht(i,j) = 0.
```

```
      ! ht(i,j) = hm/(1.+(float(i-icm)/xa)**2)
```

```
      ! ht(i,j) = hm1*exp(-(( float(i-icm)/xa1)**2)) &  
      !                               *( (cos(pii*float(i-icm)/xa11))**2 )
```

```
      phb(i,1,j) = g*ht(i,j)
```

```
      php(i,1,j) = 0.
```

```
      ph0(i,1,j) = phb(i,1,j)
```

← lower boundary condition

```
  ENDDO
```

```
ENDDO
```

Set height
field →

Setting the Initial Condition

In *WRFV2/dyn_em/module_initialize_hill2d_x.F*

```
SUBROUTINE init_domain_rk ( grid, &
```

```
...
```

```
! get the sounding from the ascii sounding file, first get dry sounding and  
! calculate base state
```

```
write(6,*) ' getting dry sounding for base state '
```

```
dry_sounding = .true.
```

```
CALL get_sounding( zk, p_in, pd_in, theta, rho, u, v, qv, dry_sounding, &  
                  nl_max, nl_in, .true.)
```

Base state

Dry sounding

```
...
```

```
! calculate full state for each column - this includes moisture.
```

```
write(6,*) ' getting moist sounding for full state '
```

```
dry_sounding = .false.
```

```
CALL get_sounding( zk, p_in, pd_in, theta, rho, u, v, qv, dry_sounding, &  
                  nl_max, nl_in, .false. )
```

Full state

Moist sounding

```
...
```

Sounding File Format

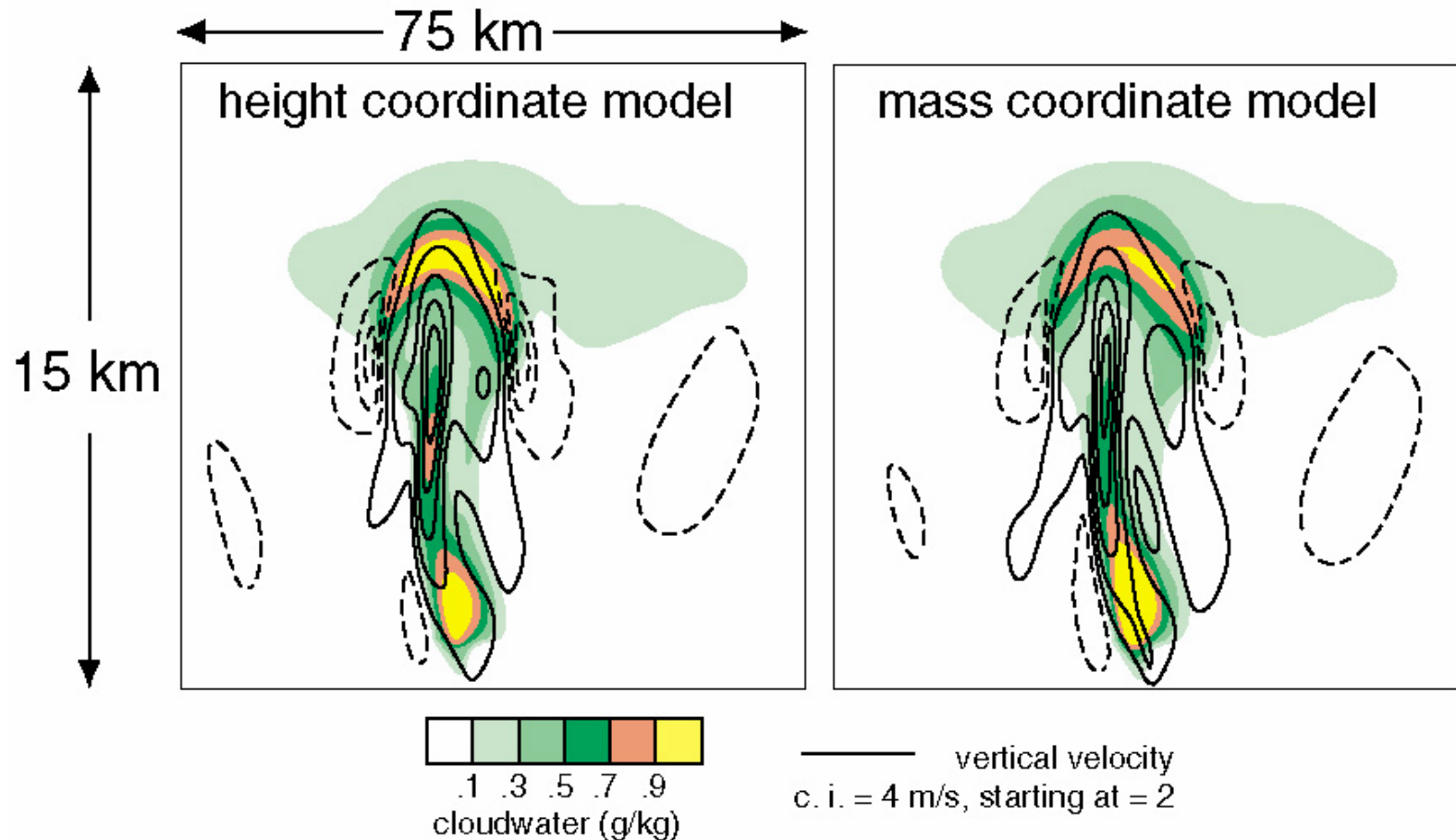
File: *WRFV2/test/em_quarter_ss/input_sounding*

	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
each successive line is a point in the sounding →	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
	height (m)	potential temperature (K)	vapor mixing ratio (g/kg)	U (west-east) velocity (m/s)	V (south-north) velocity (m/s)

2D squall line simulation

Squall-Line Simulations, $T = 3600$ s

$dx = dz = 250$ m, $\nu = 300$ m²/s



Run 2D squall line simulation

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

From *WRFV2* – *compile em_squall2d_x* ;

From *WRFV2/test/em_squall2d_x* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_squall2d_x.F

This code also introduces the initial perturbation.

The thermodynamic sounding and hodograph is in the ascii input file

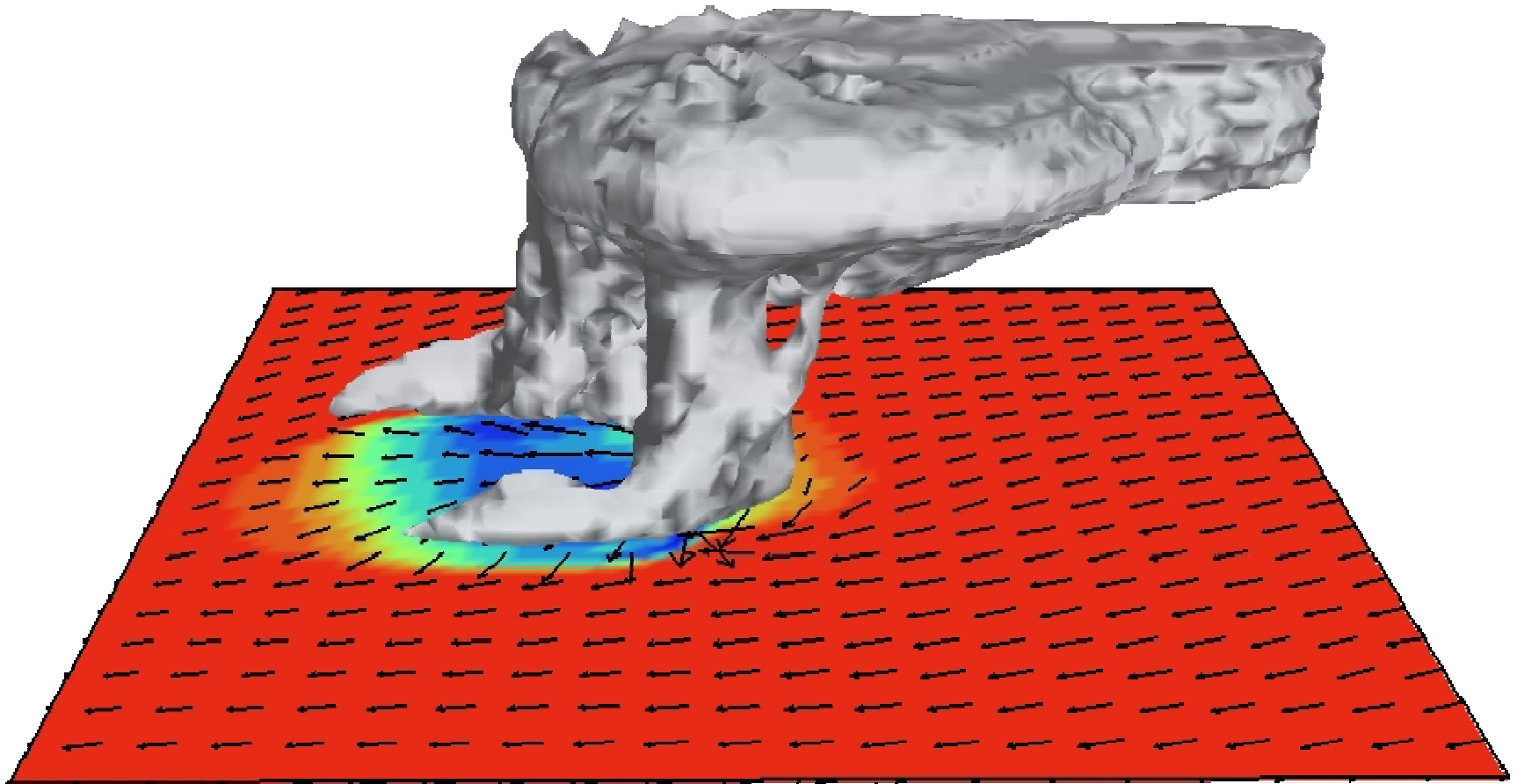
WRFV2/test/em_squall2d_x/input_sounding

3D supercell simulation

Height coordinate model

($dx = dy = 2$ km, $dz = 500$ m, $dt = 12$ s, $160 \times 160 \times 20$ km domain)

Surface temperature, surface winds and cloud field at 2 hours



Run 3D supercell simulation

From *WRFV2* – *compile em_quarter_ss* ;

From *WRFV2/test/em_quarter_ss* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_quarter_ss.F

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

WRFV2/test/em_quarter_ss/input_sounding

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

Setting the initial perturbation

In *WRFV2/dyn_em/module_initialize_quarter_ss.F*

```
SUBROUTINE init_domain_rk ( grid, &  
...  
! thermal perturbation to kick off convection  
...  
DO J = jts, min(jde-1,jte)  
  yrad = dy*float(j-nyc)/10000.  
!  yrad = 0.  
  DO I = its, min(ide-1,ite)  
    xrad = dx*float(i-nxc)/10000.  
!    xrad = 0.  
    DO K = 1, kte-1  
  
! put in preturbation theta (bubble) and recalc density. note,  
! the mass in the column is not changing, so when theta changes,  
! we recompute density and geopotential
```

horizontal radius of the
perturbation is 10 km, centered
at (x,y) gridpoints (nxc, nyc)

```
      zrad = 0.5*(ph_1(i,k,j)+ph_1(i,k+1,j) &  
                +phb(i,k,j)+phb(i,k+1,j))/g  
      zrad = (zrad-1500.)/1500.  
      RAD=SQRT(xrad*xrad+yrad*yrad+zrad*zrad)
```

vertical radius of the
perturbation is 1500 m

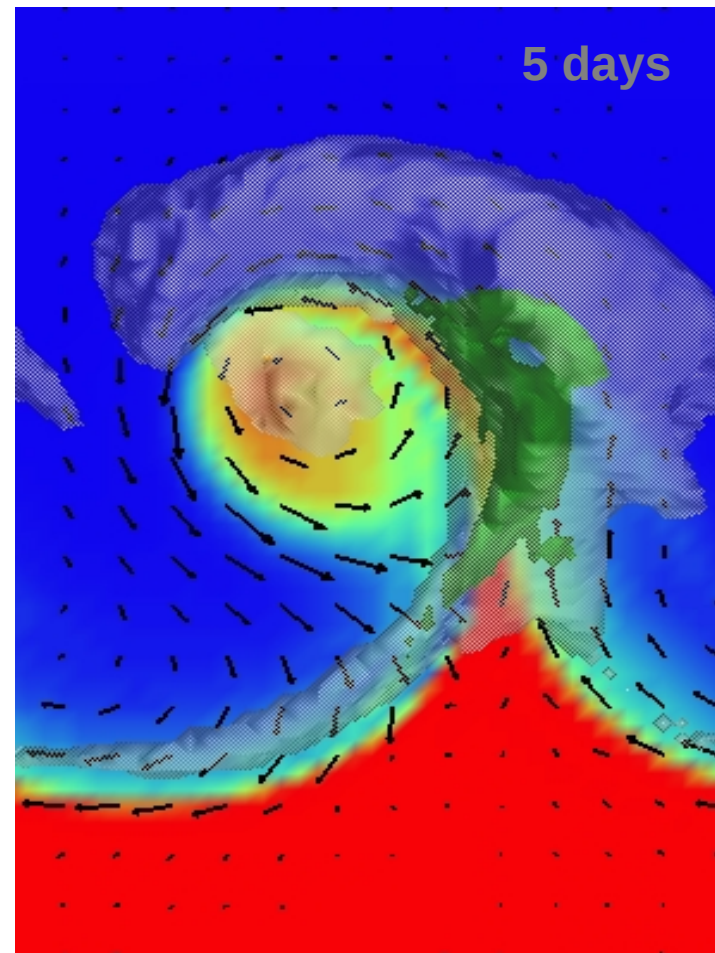
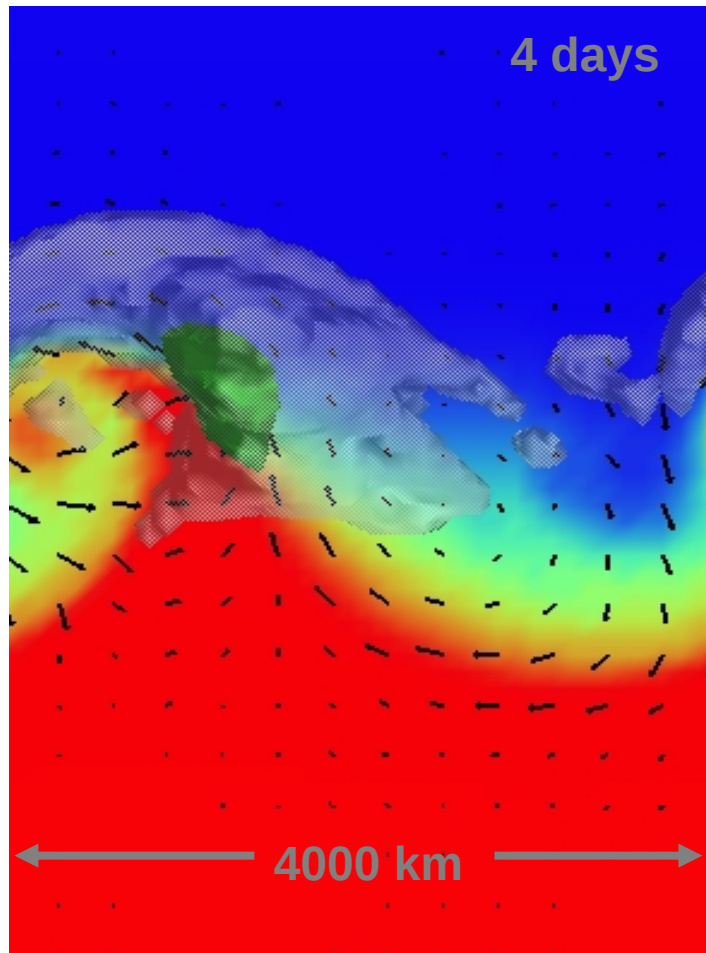
```
      IF(RAD <= 1.) THEN  
        T_1(i,k,j)=T_1(i,k,j)+delt*cos(.5*PI*RAD)**2  
        T_2(i,k,j)=T_1(i,k,j)  
        qvf = 1. + 1.61*moist_1(i,k,j,P_QV)  
        alt(i,k,j) = (r_d/p1000mb)*(t_1(i,k,j)+t0)*qvf* &  
                     (((p(i,k,j)+pb(i,k,j))/p1000mb)**cvpm)  
        al(i,k,j) = alt(i,k,j) - alb(i,k,j)  
      ENDIF  
    ENDDO
```

perturbation added
to initial theta field

maximum amplitude
of the perturbation

Moist Baroclinic Wave Simulation

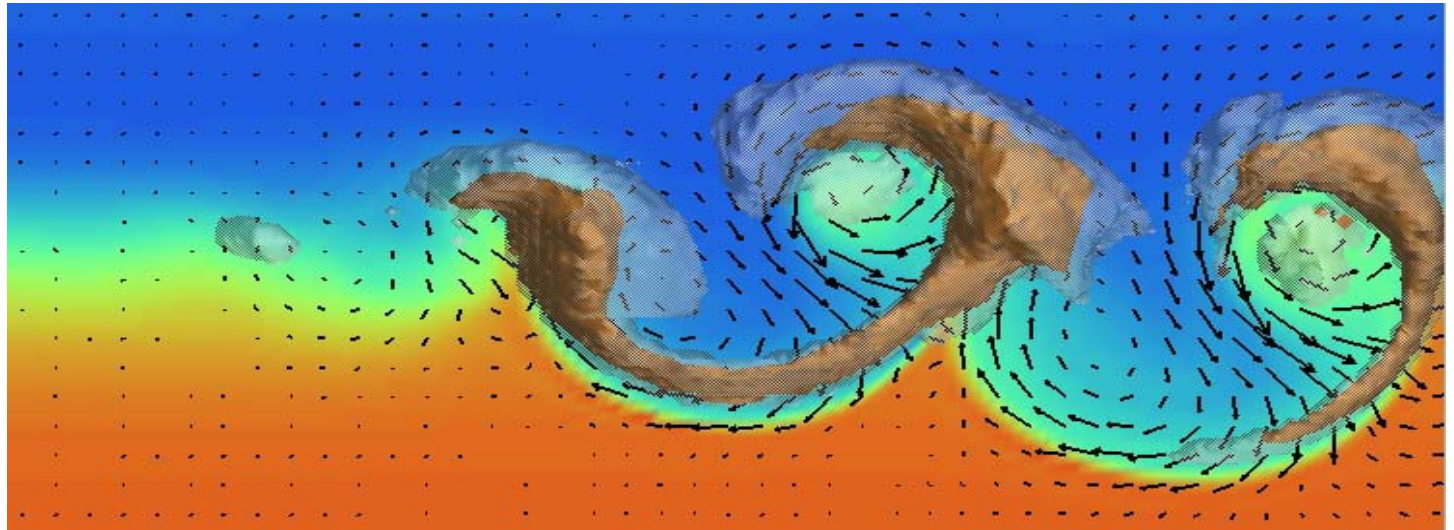
Height coordinate model ($dx = 100$ km, $dz = 250$ m, $dt = 600$ s)
Surface temperature, surface winds, cloud and rain water



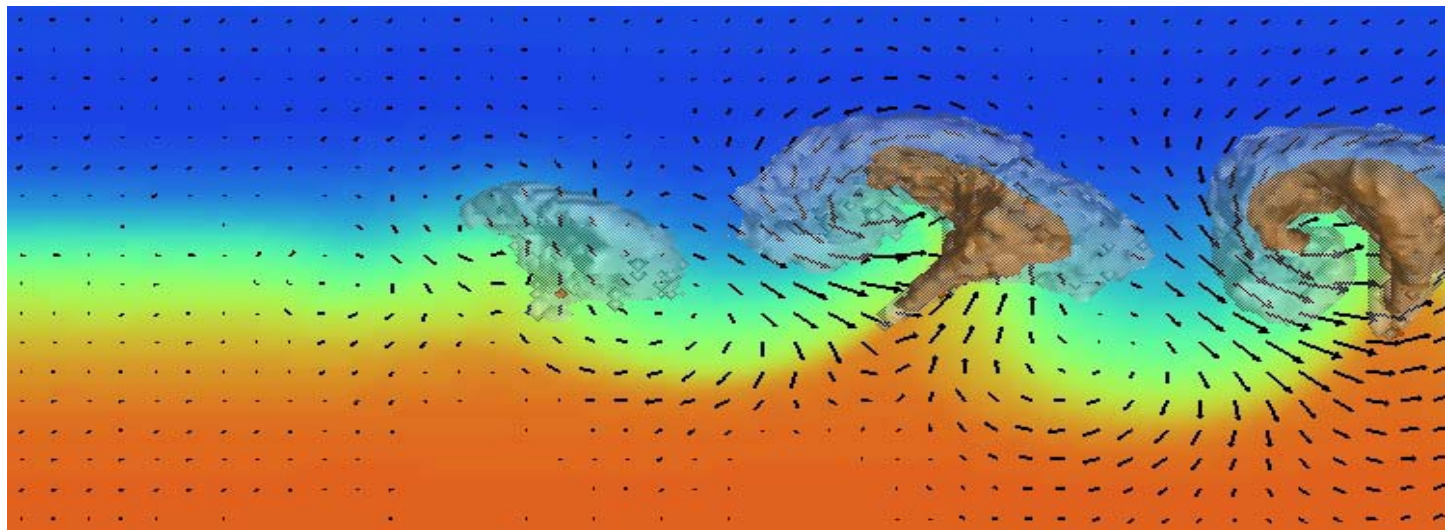
Open Channel Baroclinic Wave Simulation

Day 5, $dt = 600$ s, $dx = dy = 100$ km, 14000×8000 km

Free Slip
Warm Rain



MRF PBL - land
KF Conv. Param.
Ice Microphysics



Run Moist Baroclinic Wave Simulation

From *WRFV2* – *compile em_b_wave* ;

From *WRFV2/test/em_b_wave* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_b_wave.F

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

WRFV2/test/em_b_wave/input_jet

The initial perturbation is hardwired in the initialization code.

Moist Baroclinic Wave Simulation

Default configuration in

WRFV2/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 basic state.

Switching from periodic to open boundary conditions along with lengthening the channel produces a baroclinic wave train.

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

Gravity Current Simulation

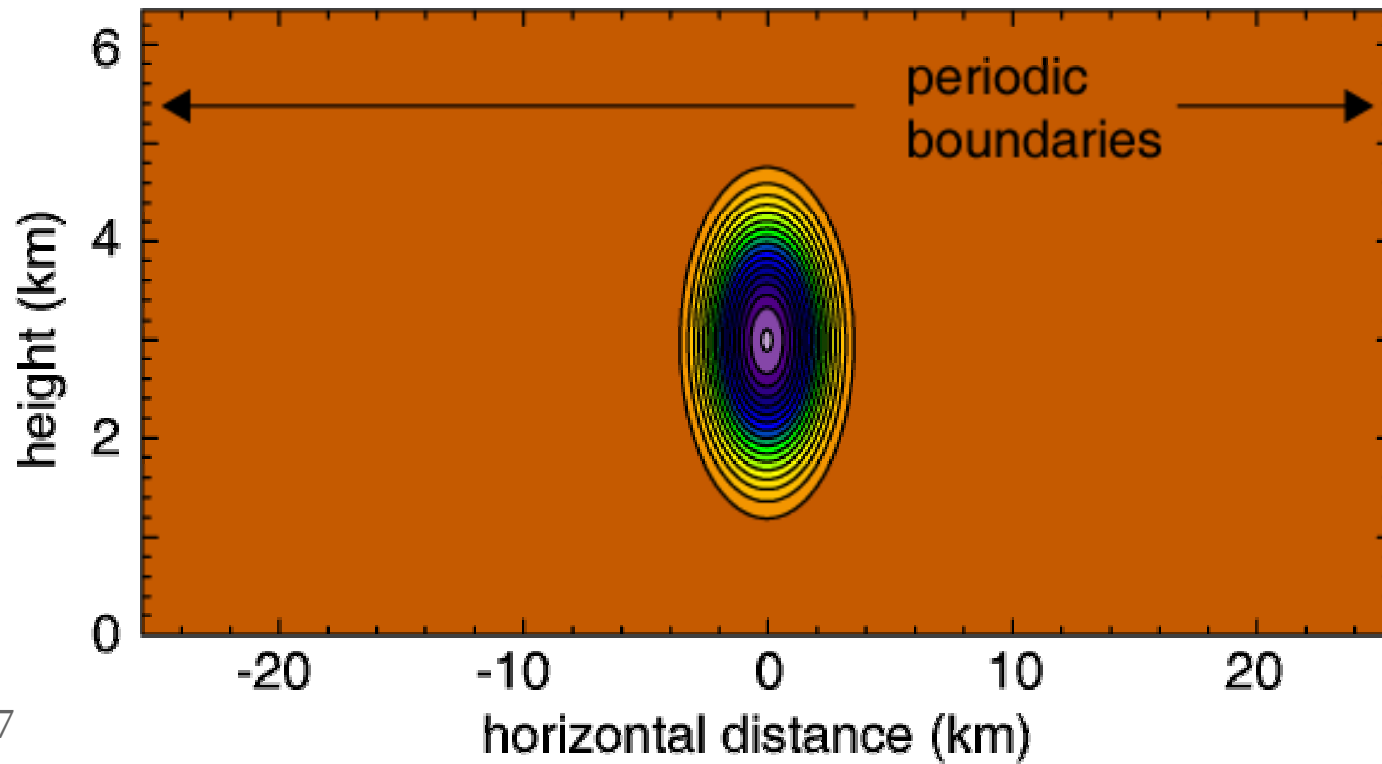
(Straka et al, IJNMF, 1993)

2D channel (x , z ; 51.2 x 6.4 km)

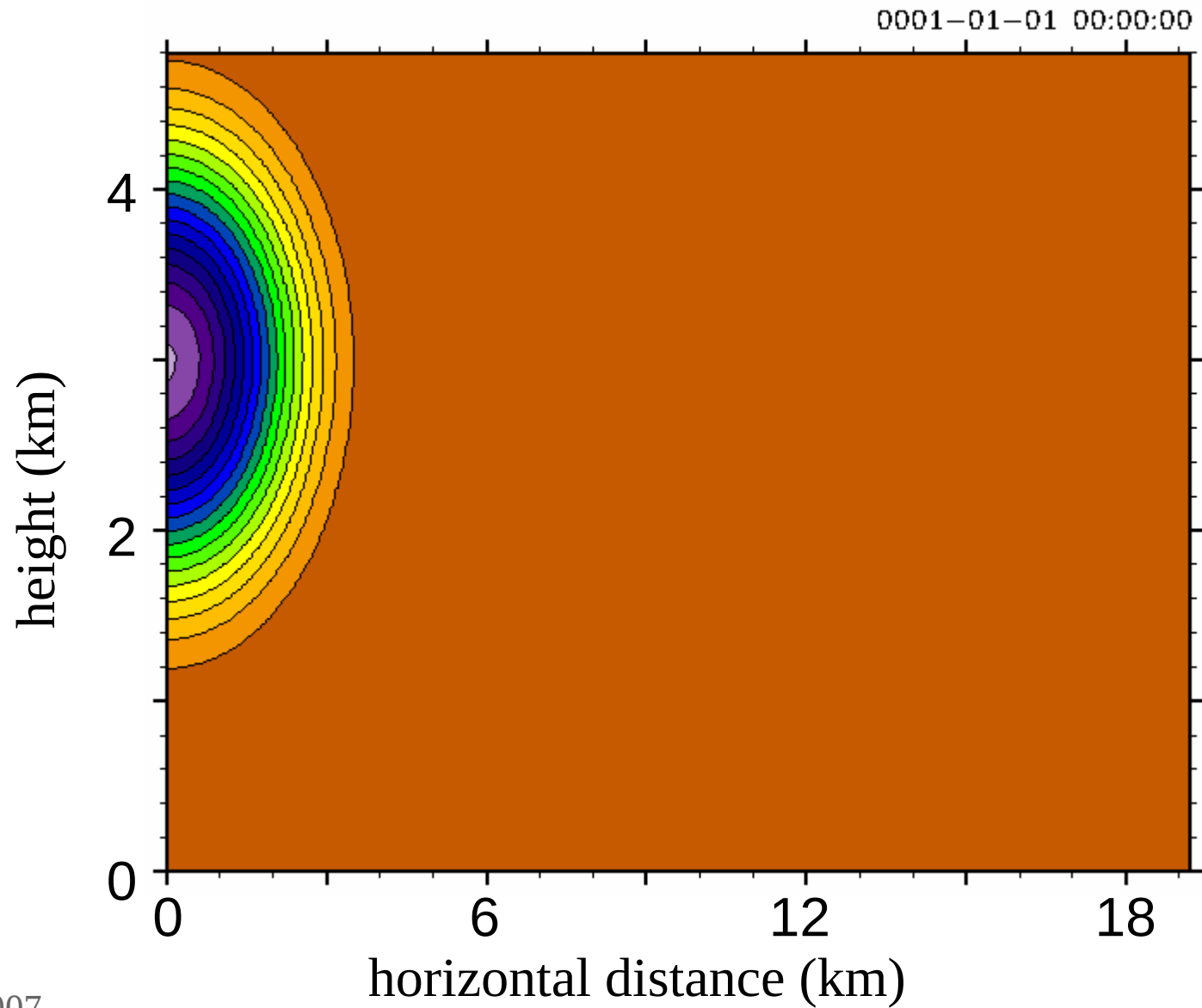
Initial state: $\theta = 300$ K (neutral) + perturbation (max = 16.2 K)

Eddy viscosity = $75 \text{ m}^2/\text{s}^2$ (constant)

Initial state, potential temperature (c.i. = 1 K)



Gravity Current Simulation

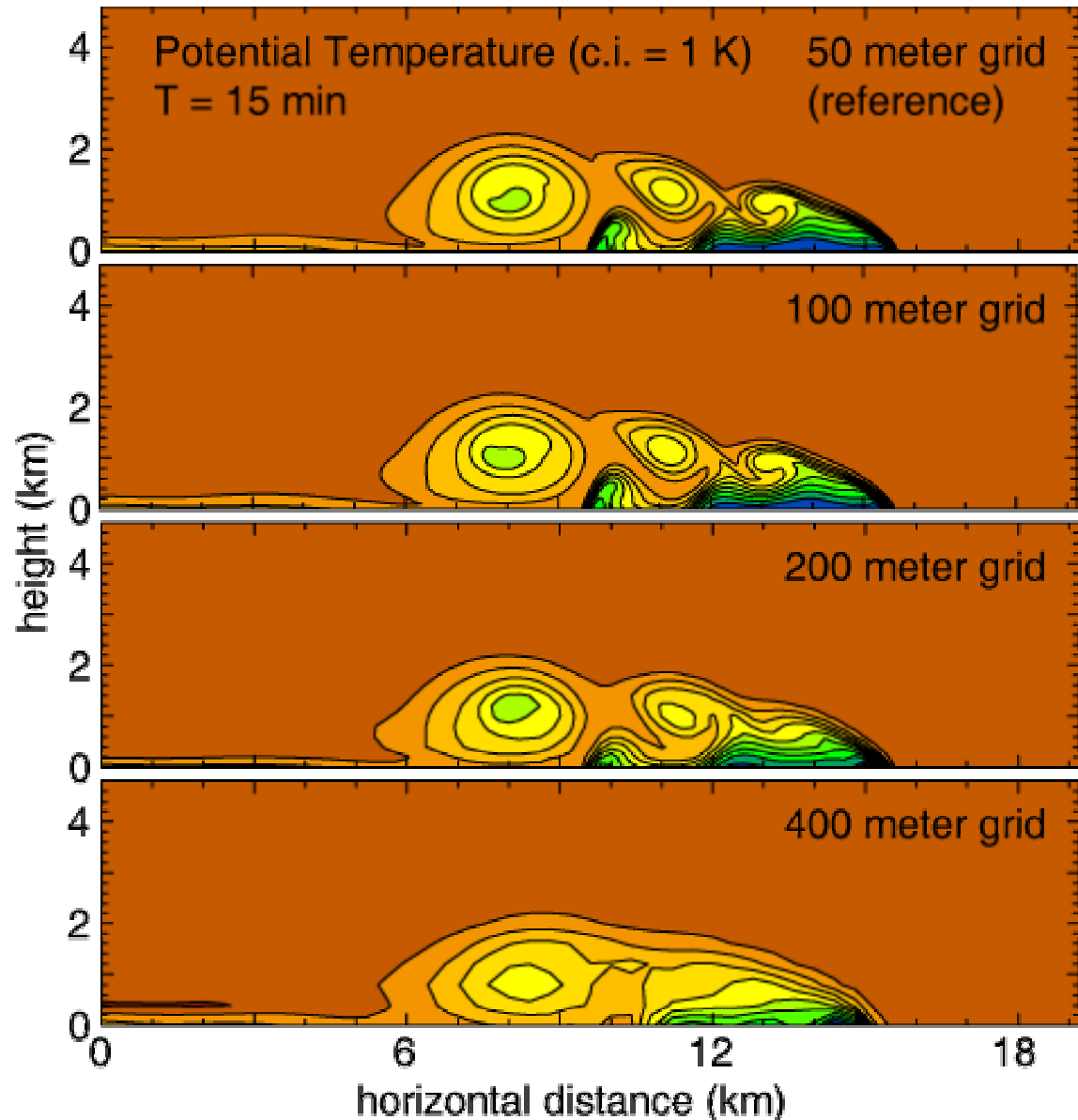


Gravity Current Simulation

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



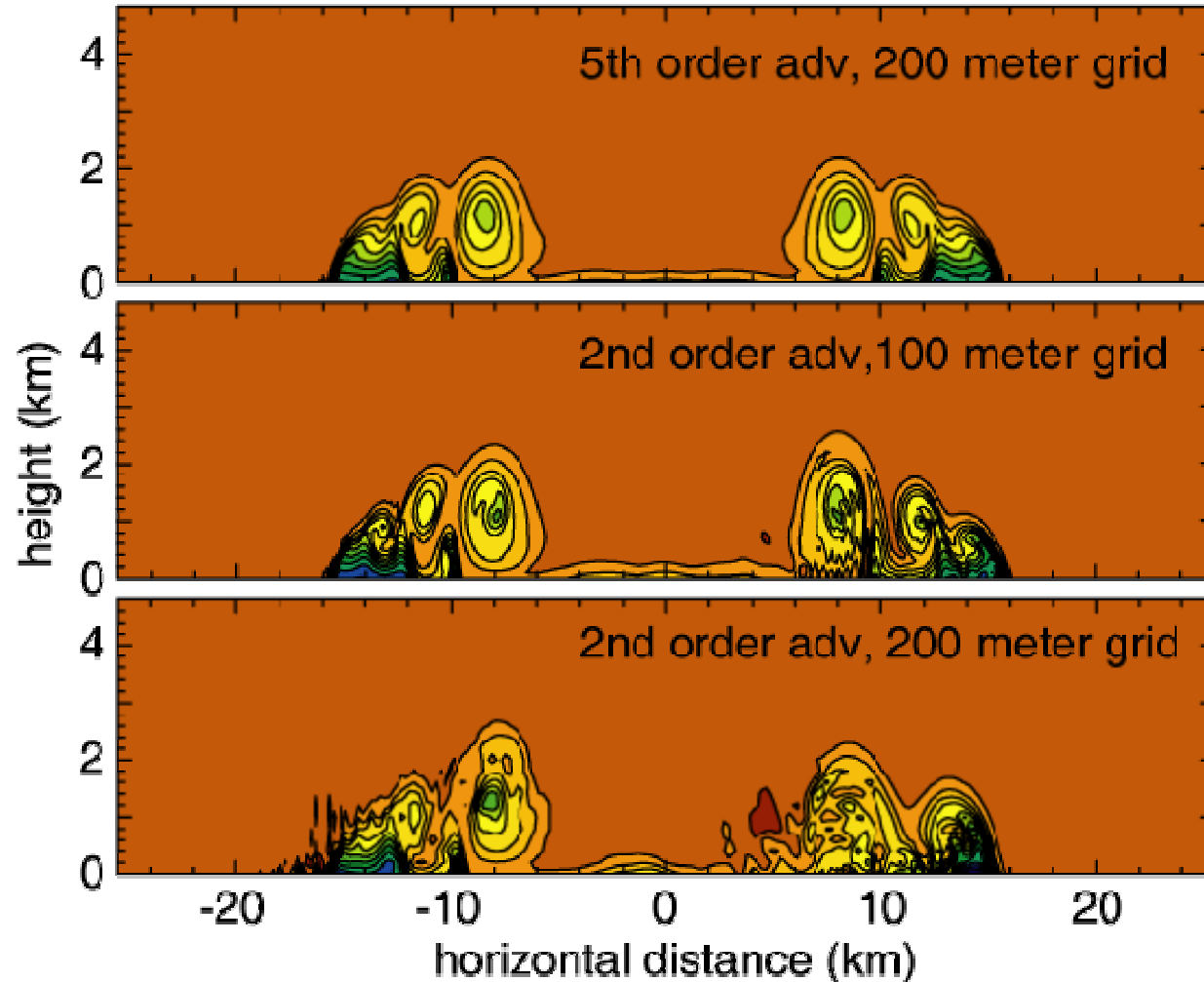
Gravity Current Simulation

Translating Density Current, $U_m = 20$ m/s
Potential Temperature (c.i. = 1 K), $T = 15$ min

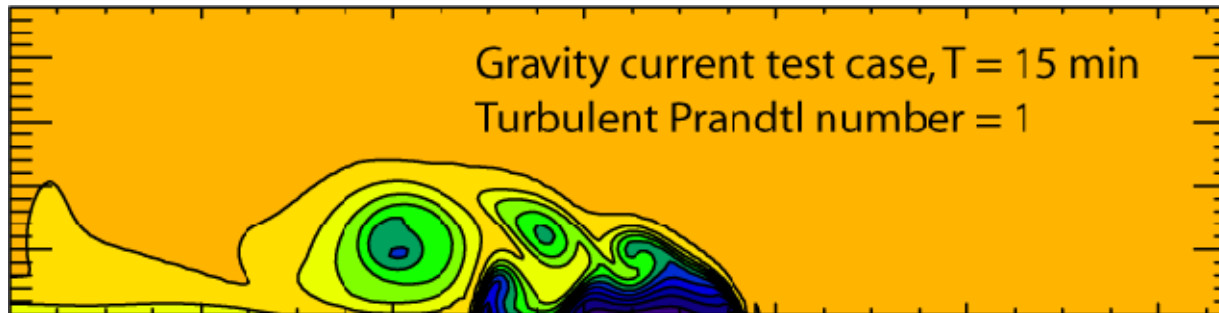
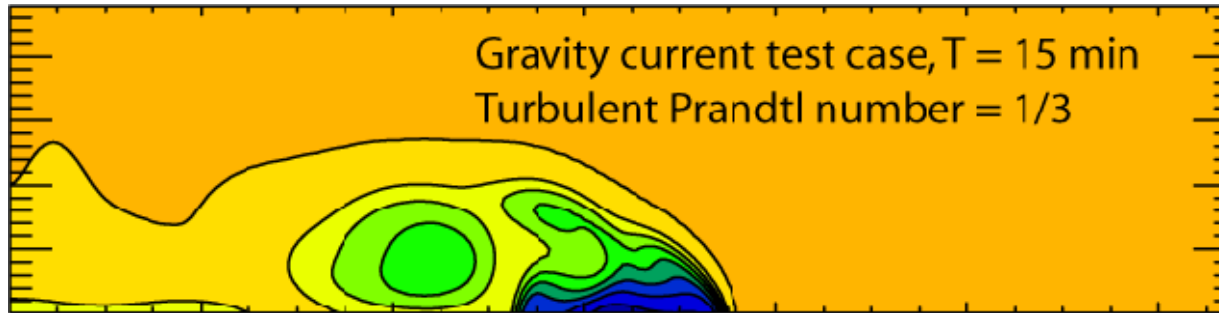
5th order upwind advection,
use namelist.input.200m
and input_sounding.um=20

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



Gravity Current Simulation



The turbulent Prandtl number in WRF $1/3$,
So 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
WRFV2/share/module_model_constants.F
WRFV2/share/module_diffusion_em.F, *module_big_step_utilities.F*

Run Gravity Current Simulation

From *WRFV2* – *compile em_grav2d_x* ;

From *WRFV2/test/em_grav2d_x* – run *ideal.exe*, run *wrf.exe*

Initialization code is in

WRFV2/dyn_em/module_initialize_grav2d_x.F

The initial cold bubble is hardwired in the initialization code.