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

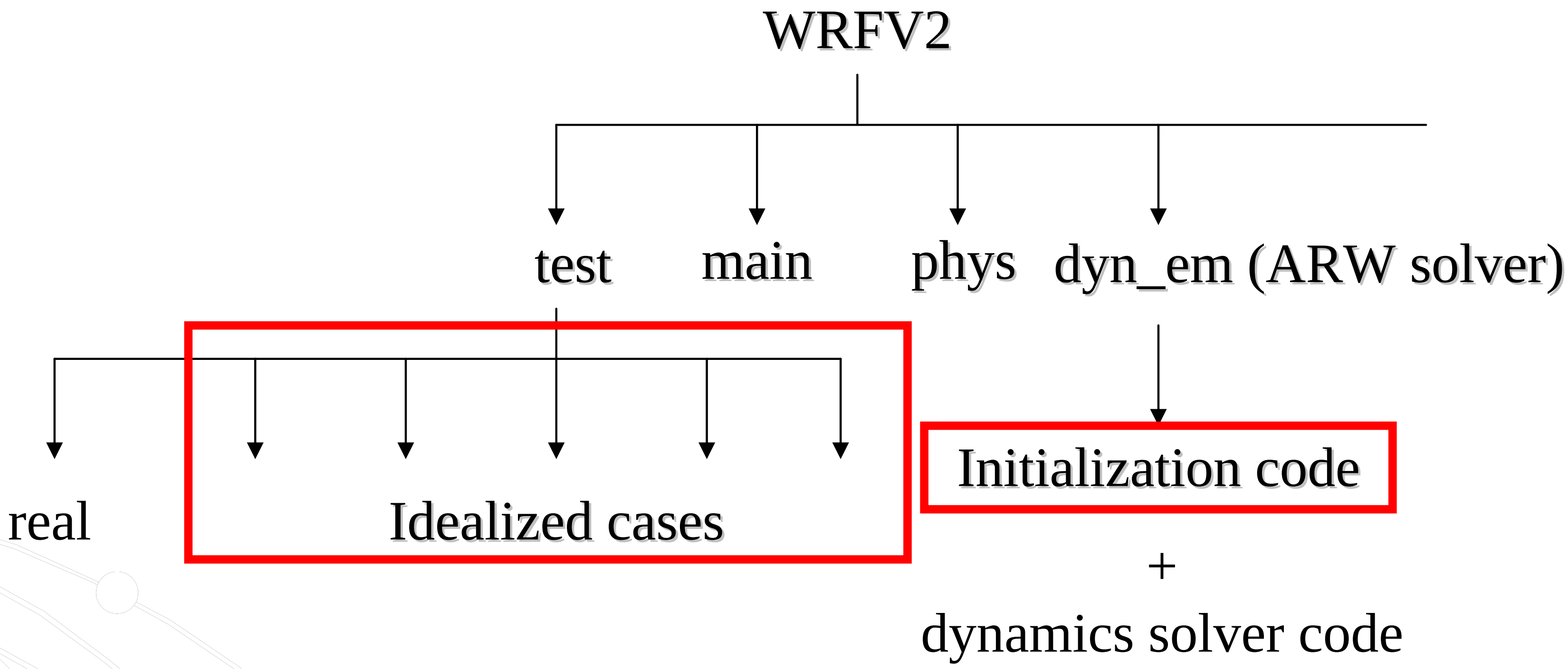
Color Legend

Directories, Files

Commands, Executions

Special Comments

WRF ARW code



WRFV2

test

main

phys

dyn_em (ARW solver)

real

Idealized cases

Initialization code

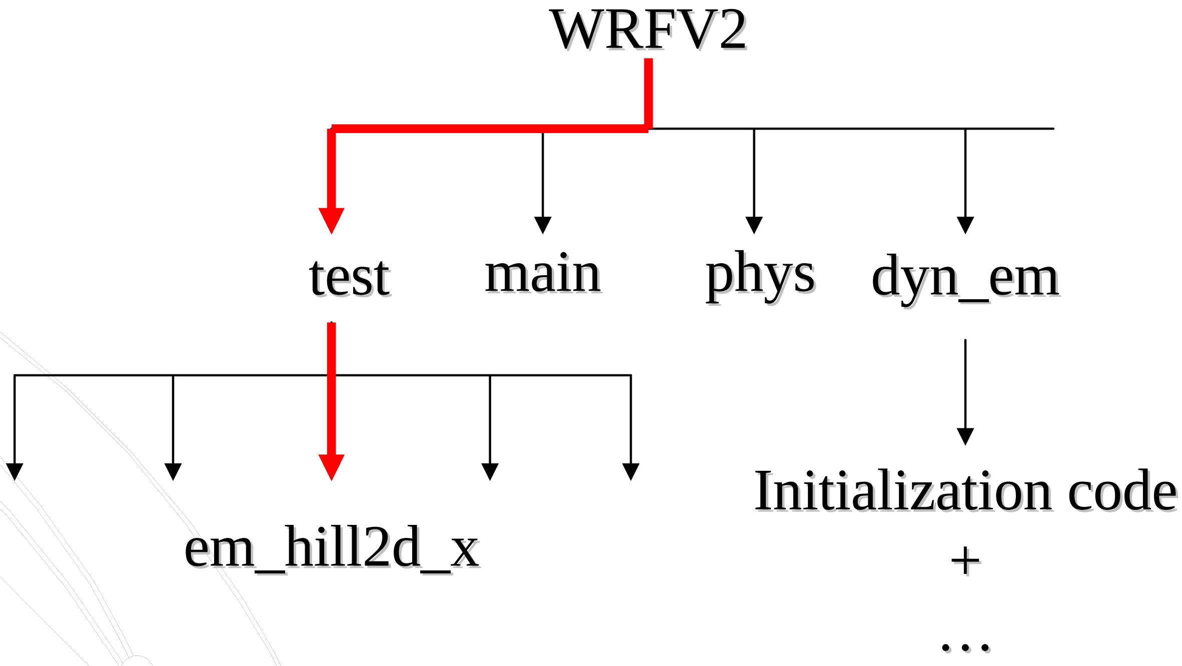
+

dynamics solver code

Test Cases for the WRF ARW Model

- 2D flow over a bell-shaped mountain

  WRFV2/test/em_hill2d_x



WRFV2

test

main

phys

dyn_em

em_hill2d_x

Initialization code

\+

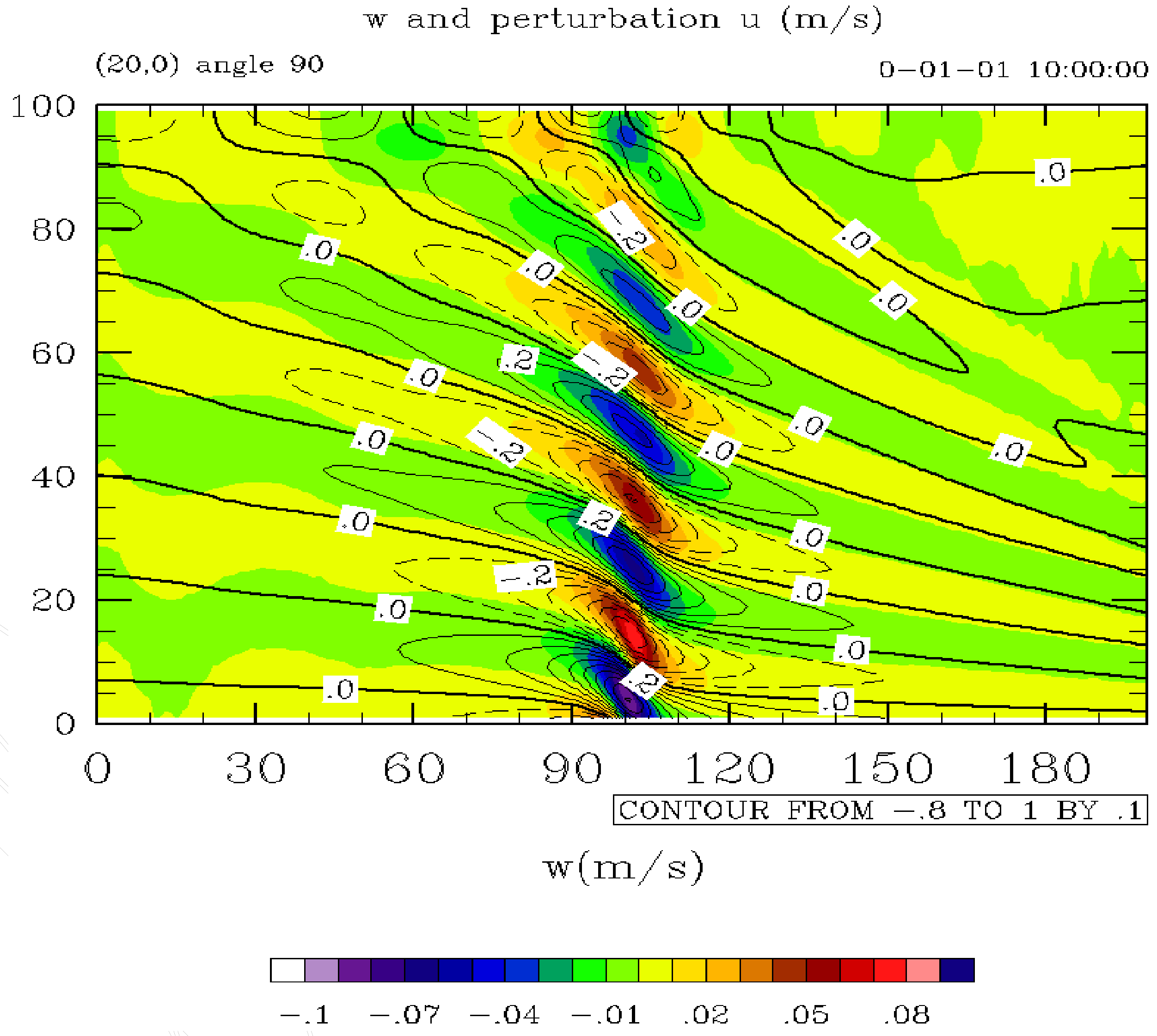
…

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

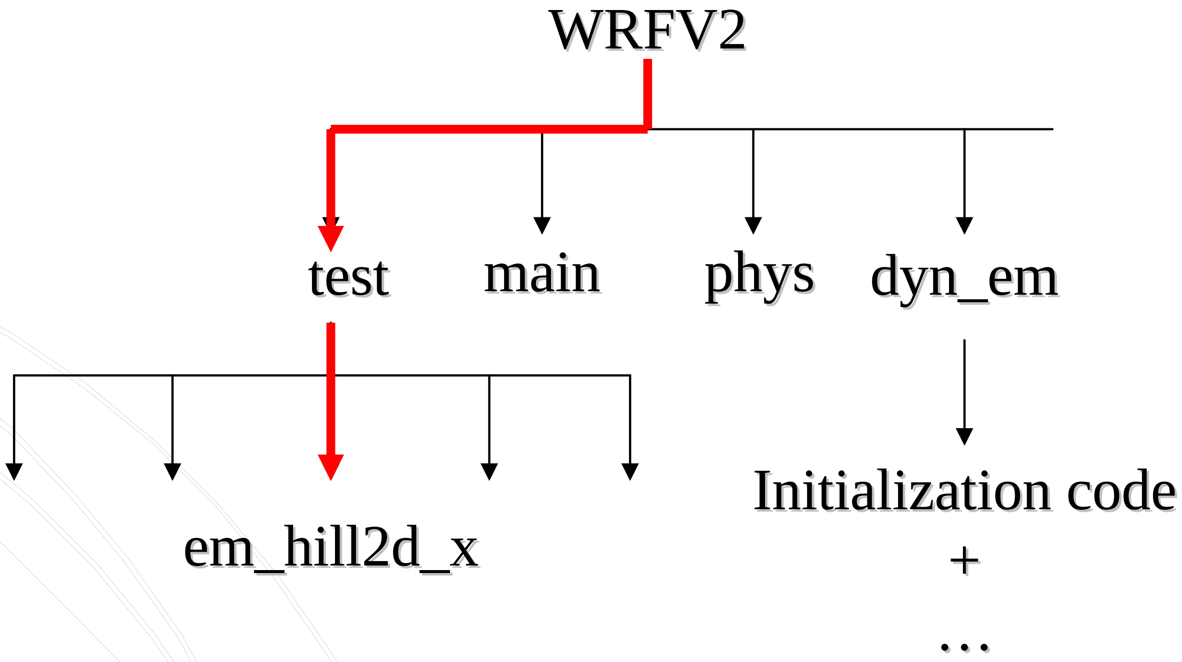
2D Flow Over a Bell-Shaped Mountain

(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*



WRFV2

test

main

phys

dyn_em

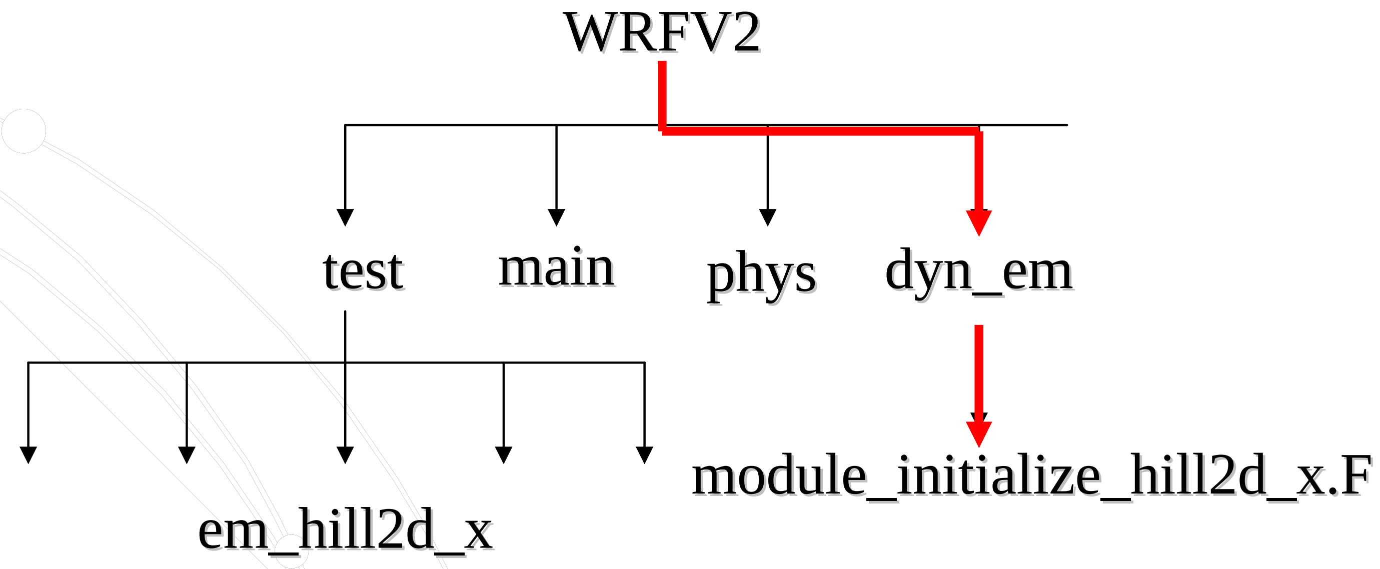
em_hill2d_x

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.



WRFV2

test

main

phys

dyn_em

em_hill2d_x

module_initialize_hill2d_x.F

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

   icm = ide/2
...

  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)/xal1))**2 )
    phb(i,1,j) = g*ht(i,j)
    php(i,1,j) = 0.
    ph0(i,1,j) = phb(i,1,j)
  ENDDO
  ENDDO
```

mountain height and half-width

...mountain position in domain (central gridpoint in x)

Set height field

lower boundary condition

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
 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)

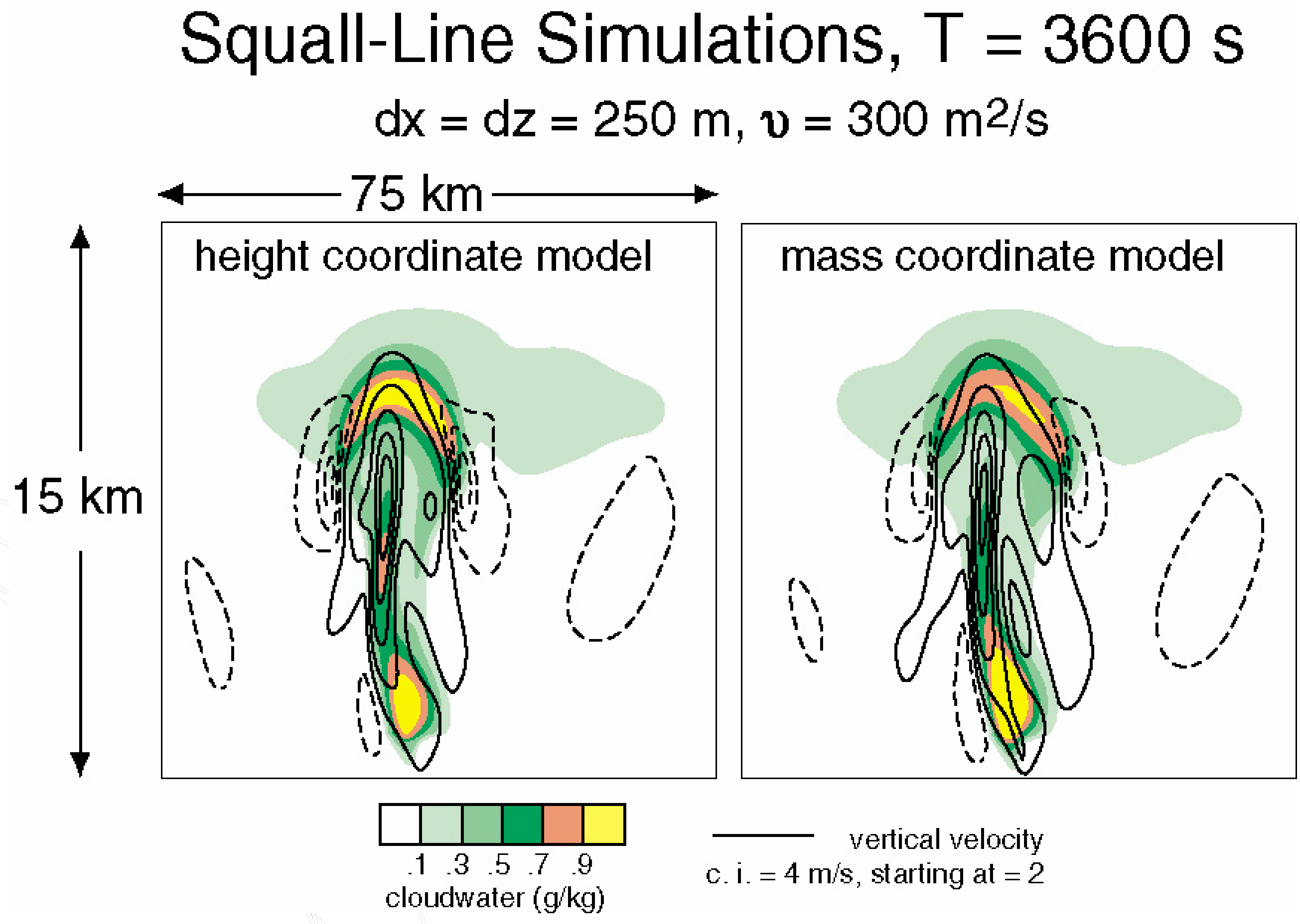
potential temperature (K)

vapor mixing ratio (g/kg)

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

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

2D squall line simulation



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.

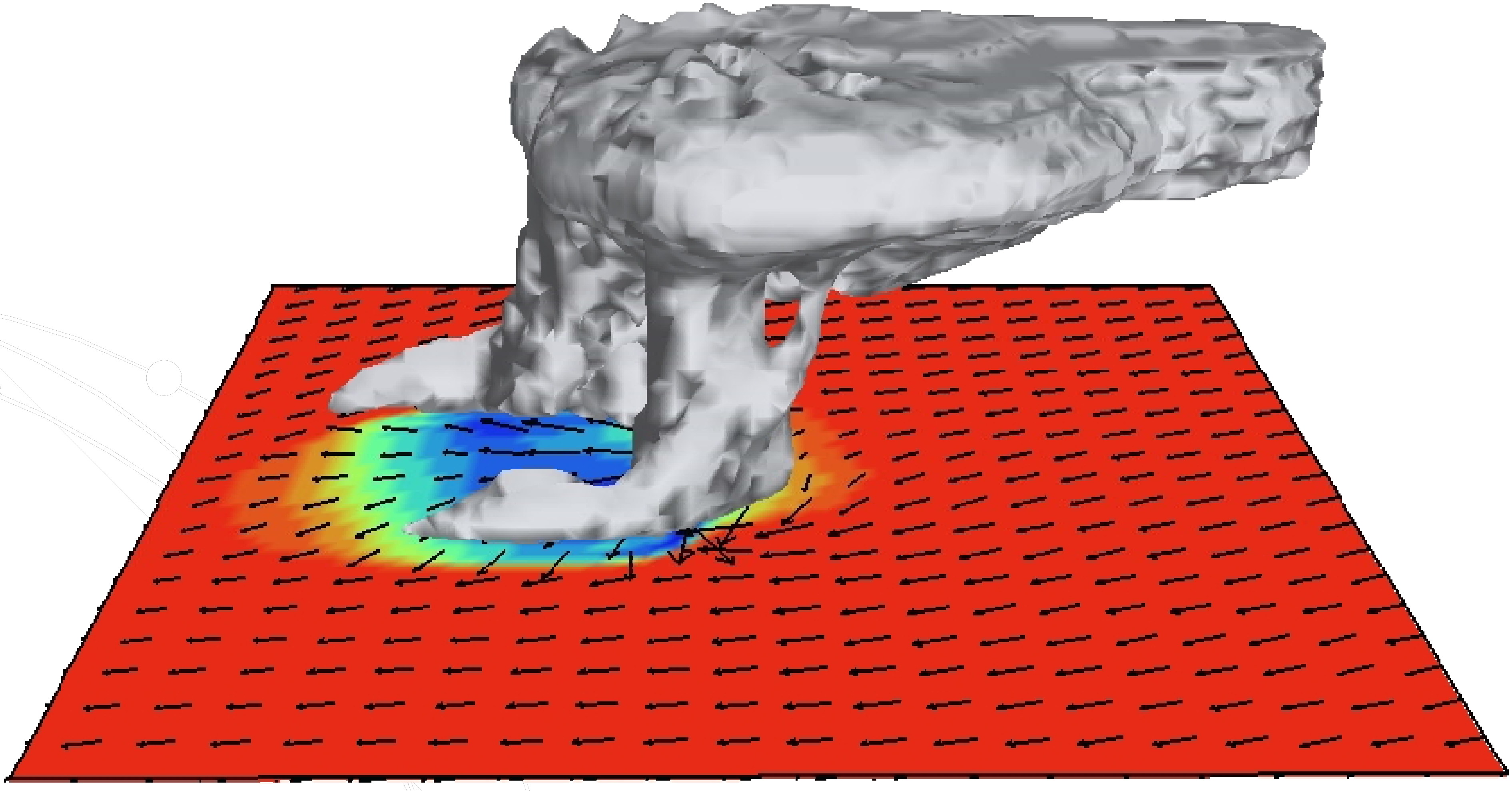
The thermodynamic sounding and hodograph is in the ascii input file
WRFV2/test/em_squall2d_x/input_sounding

3D supercell simulation

Height coordinate model

(dx = dy = 2 km, dz = 500 m, dt = 12 s, 160 x 160 x 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

        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)
        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
```

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

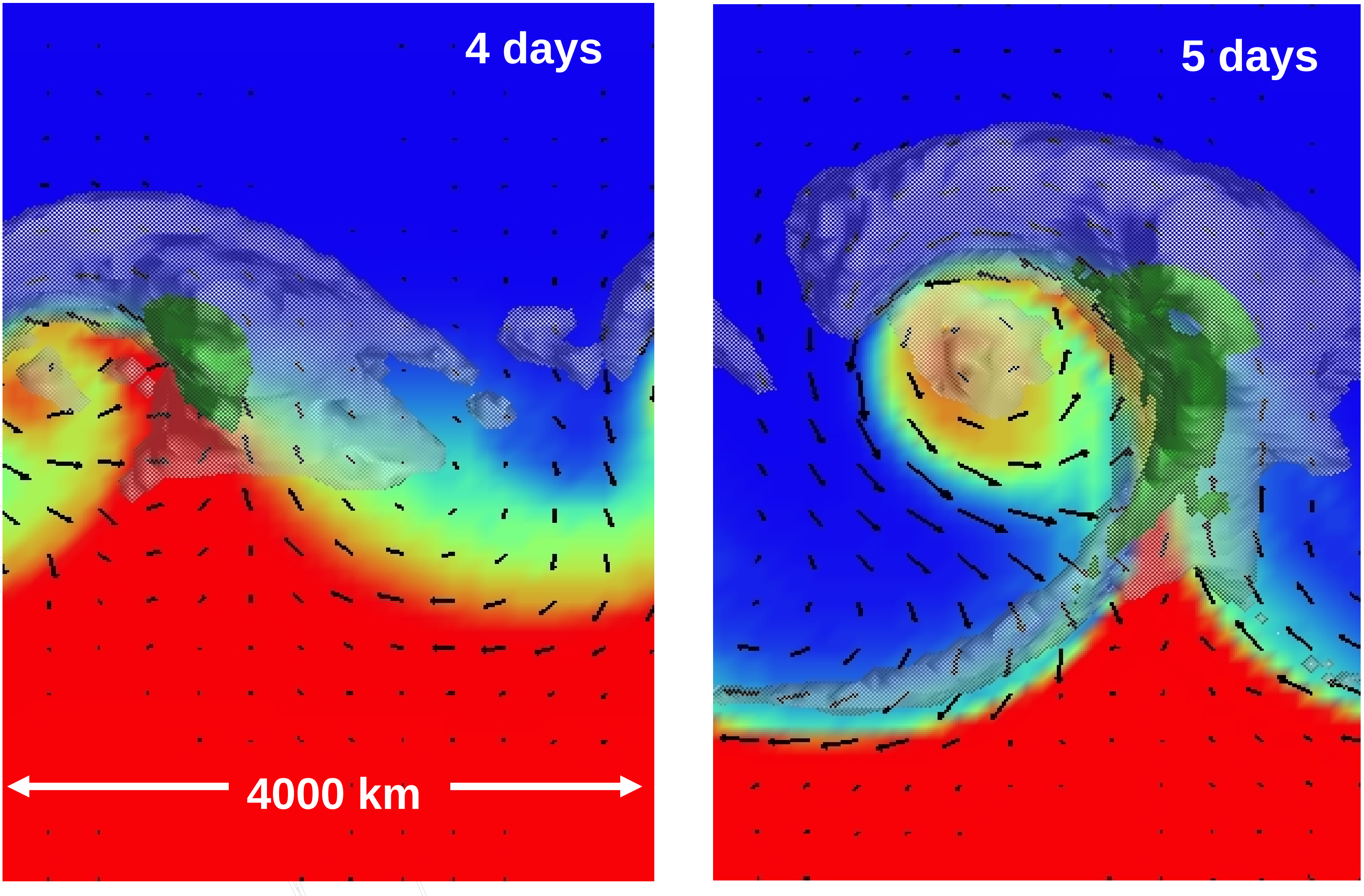
vertical radius of the perturbation is 1500 m

perturbation added to initial theta field

maximum amplitude of the perturbation

Moist Baroclinic Wave Simulation

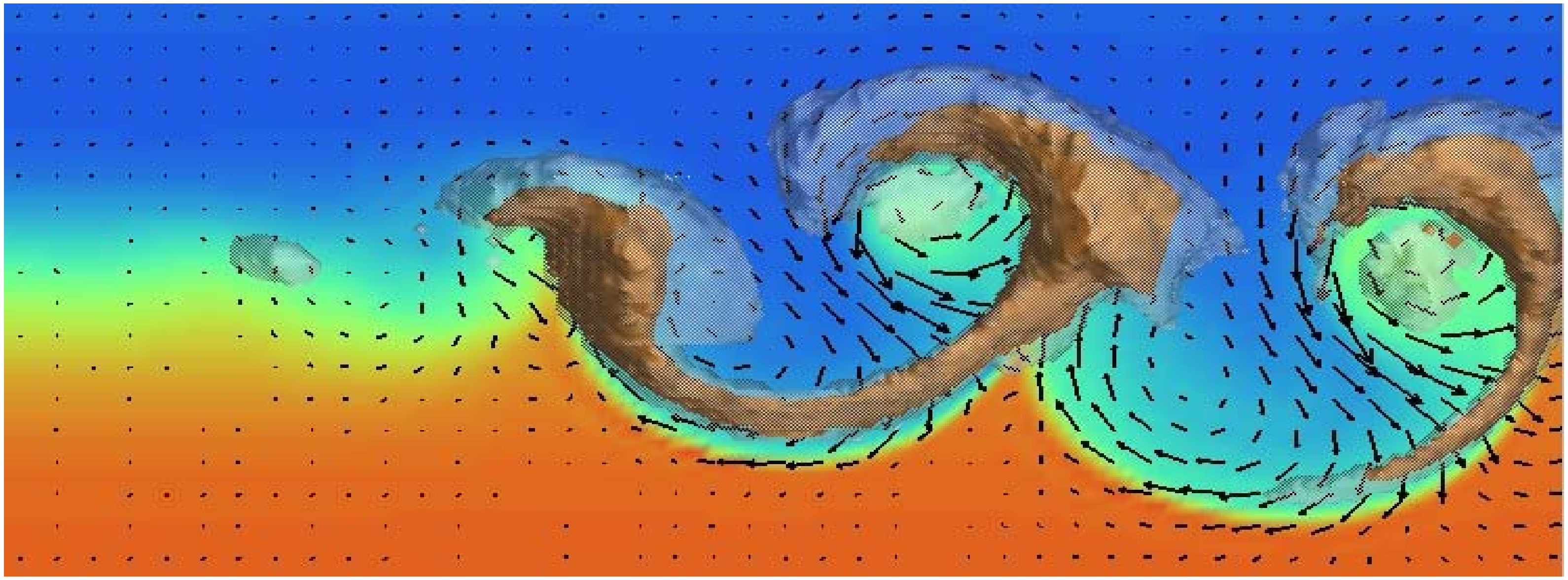
Height coordinate model (dx = 100 km, dz = 250 m, dt = 600 s)
Surface temperature, surface winds, cloud and rain water



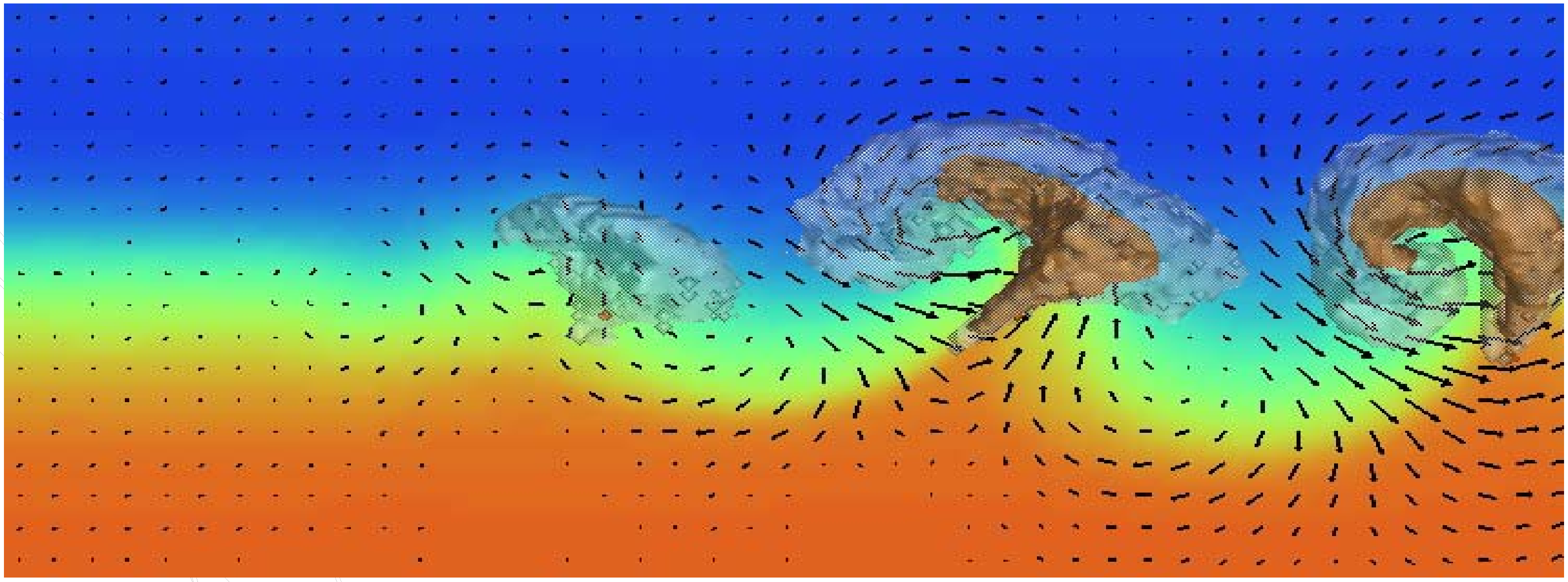
Open Channel Baroclinic Wave Simulation

Day 5, dt = 600 s, dx = dy = 100 km, 14000 x 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.

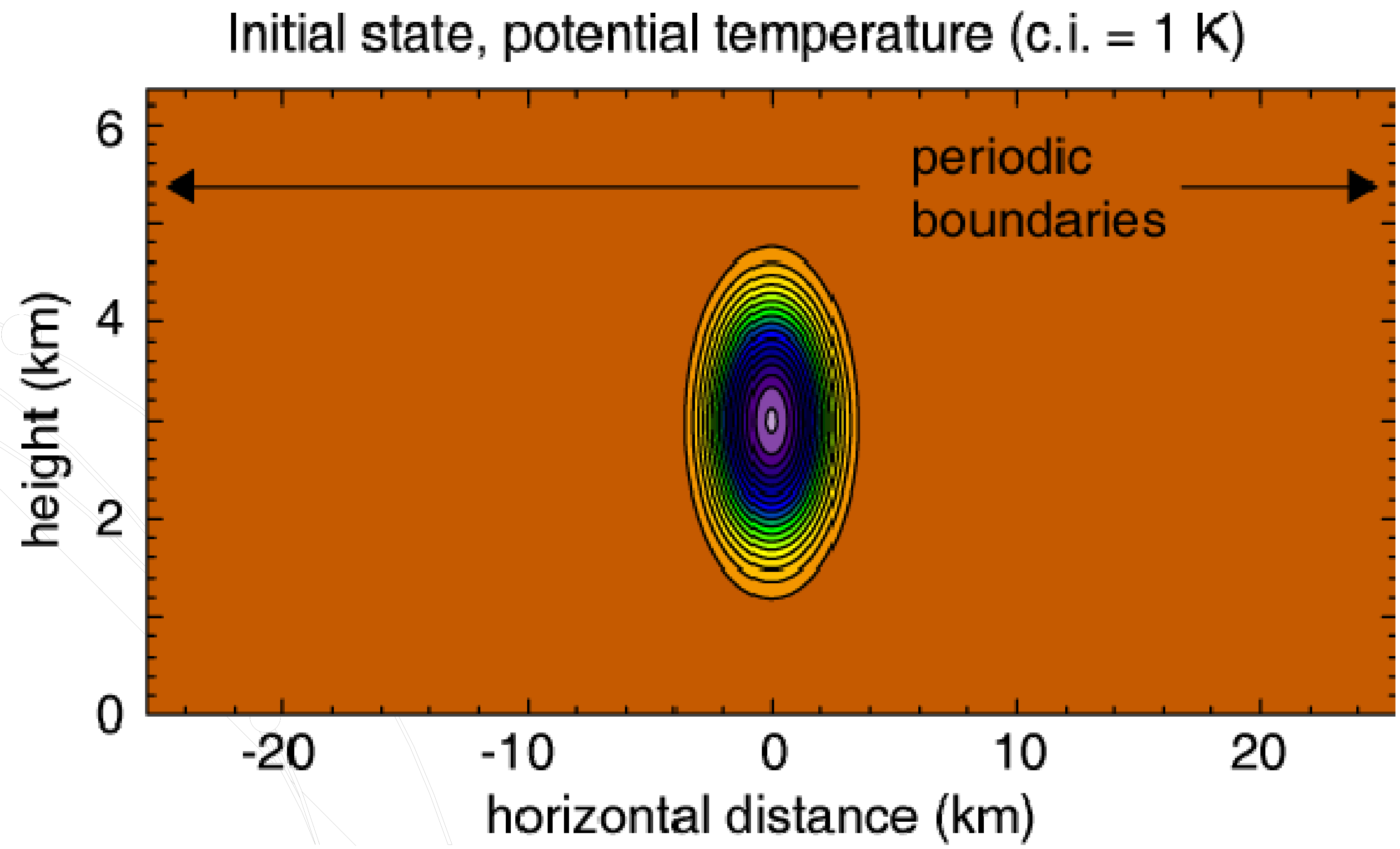
Switching from periodic to open boundary conditions along with lengthening the channel produces a baroclinic wave train.

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

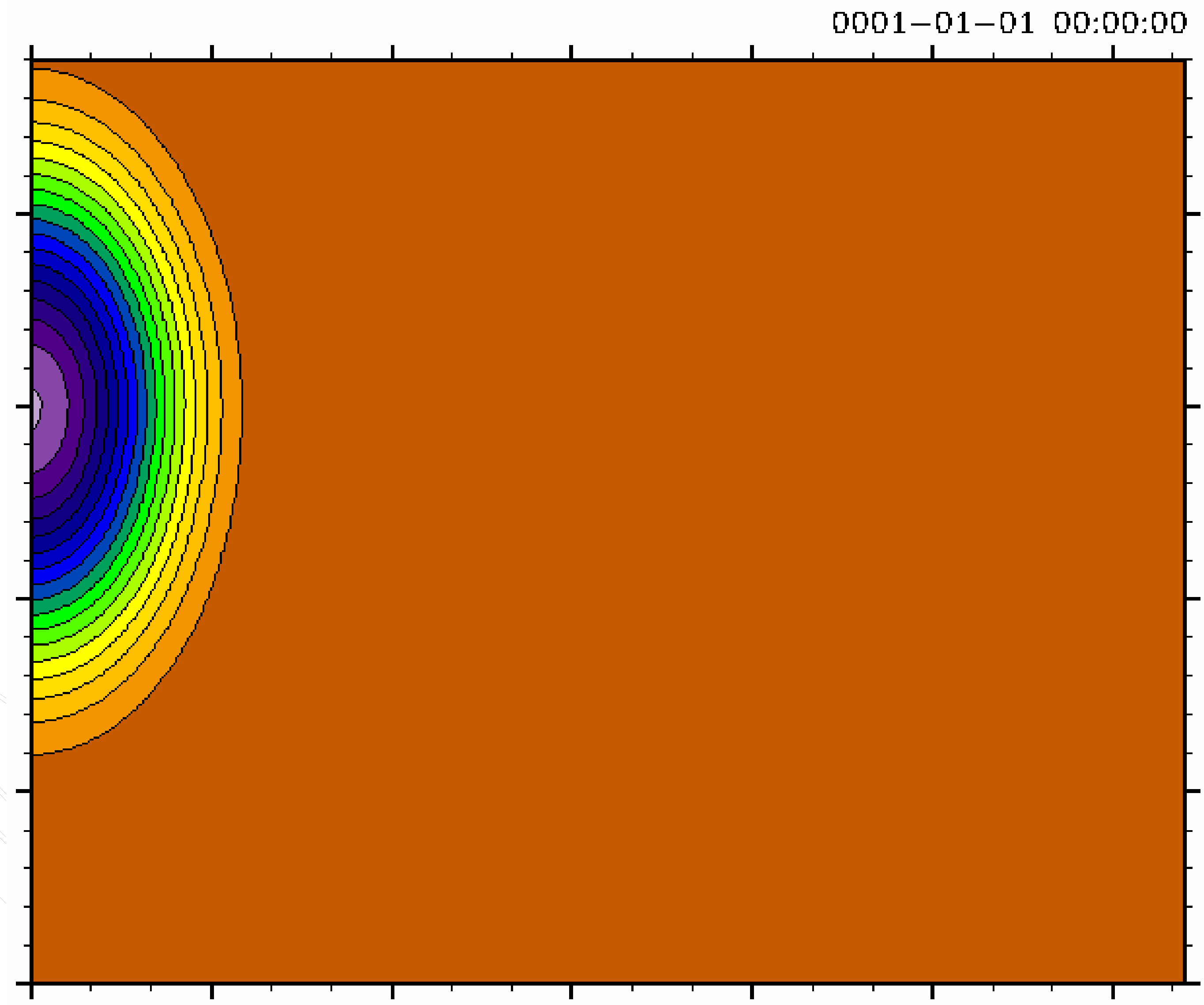
Gravity Current Simulation

(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 m**2/s**2 (constant)



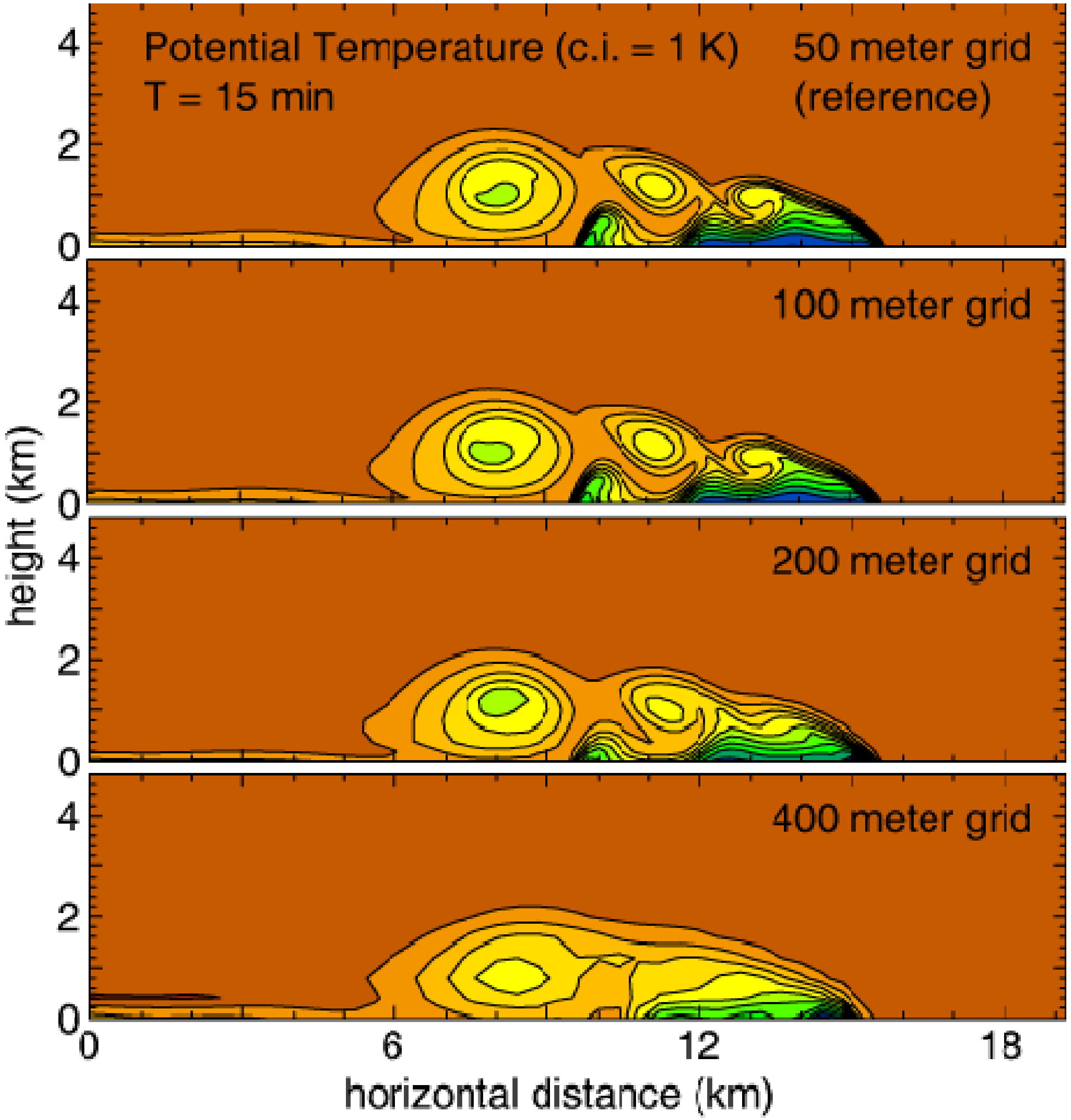
Gravity Current Simulation



height (km)

horizontal distance (km)

Gravity Current Simulation

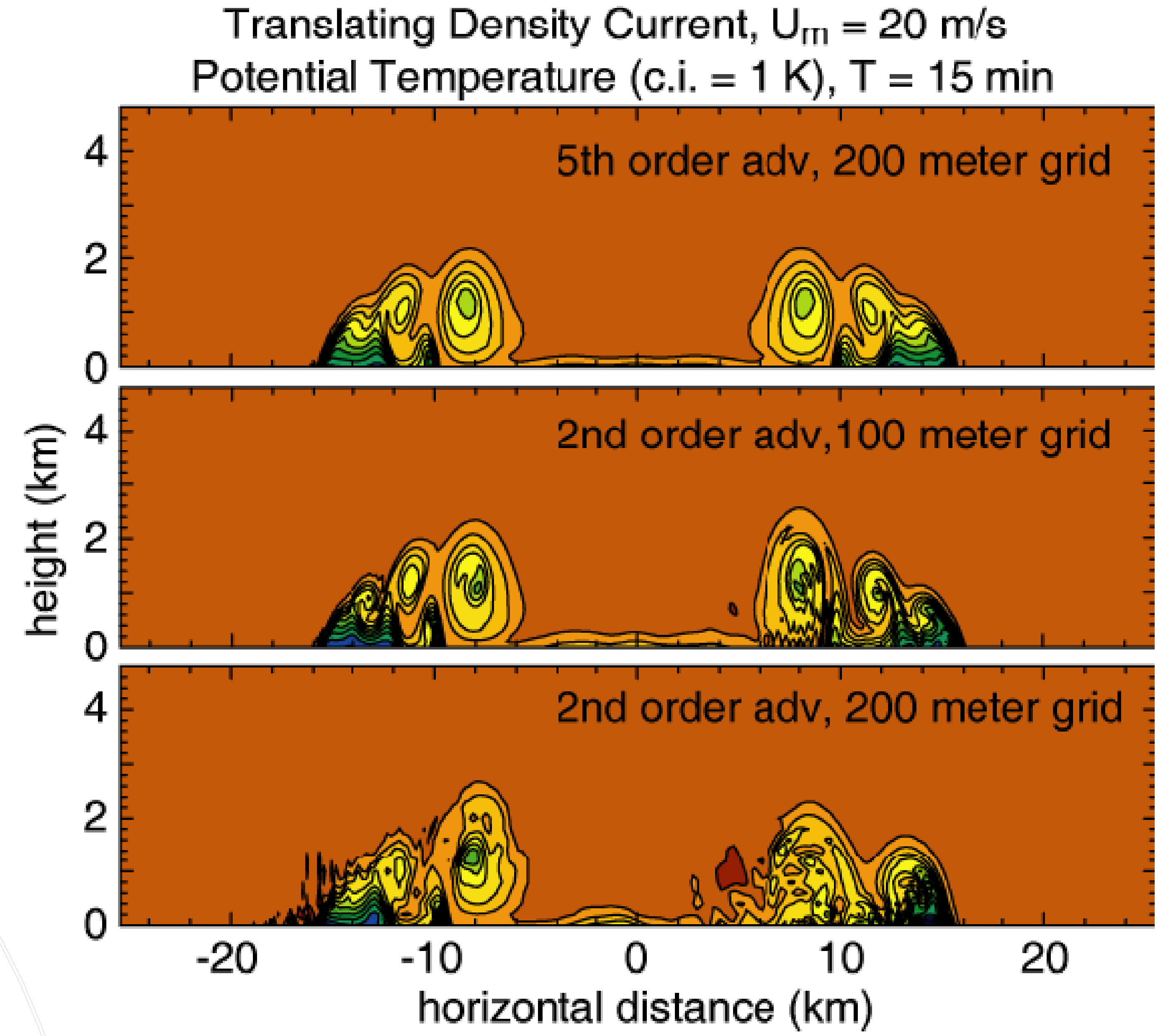


Default case, dx = 100 m,
5th order upwind advection,
uses namelist.input.100m

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

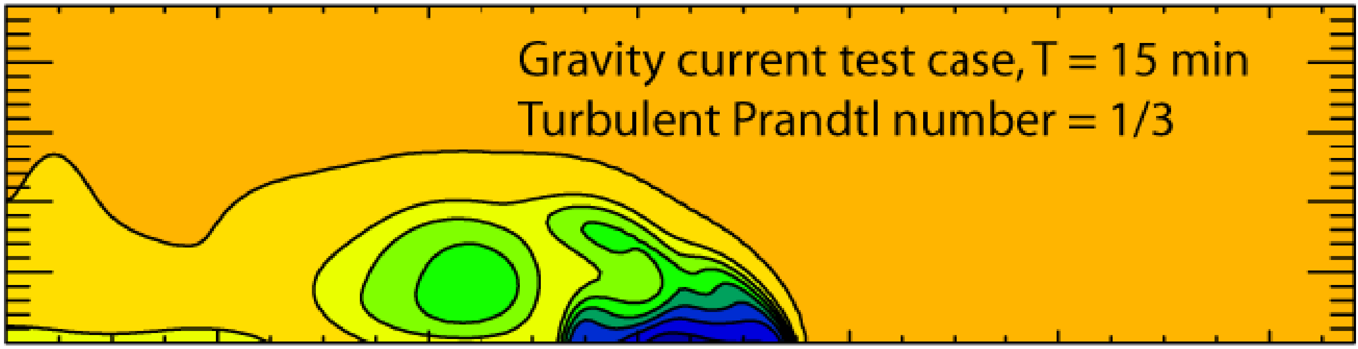


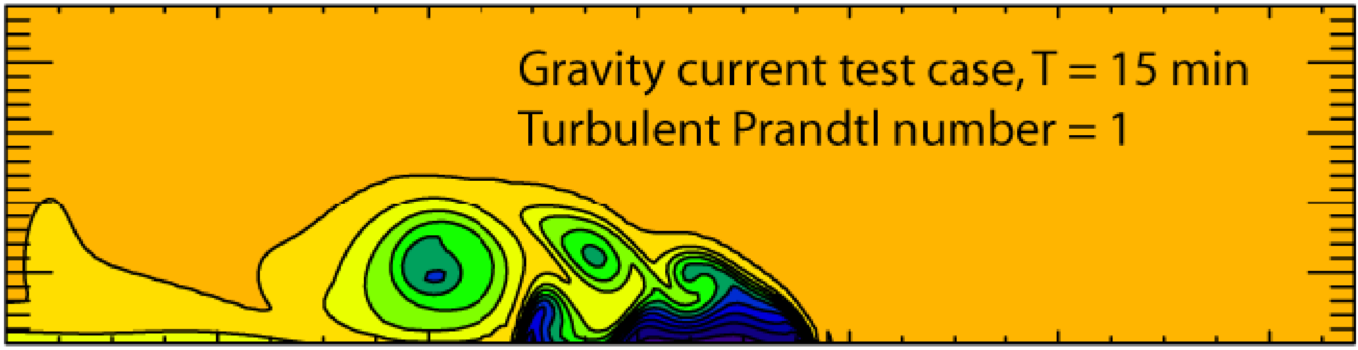
5th order upwind advection,
use namelist.input.200m
and input_sounding.um=20

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.