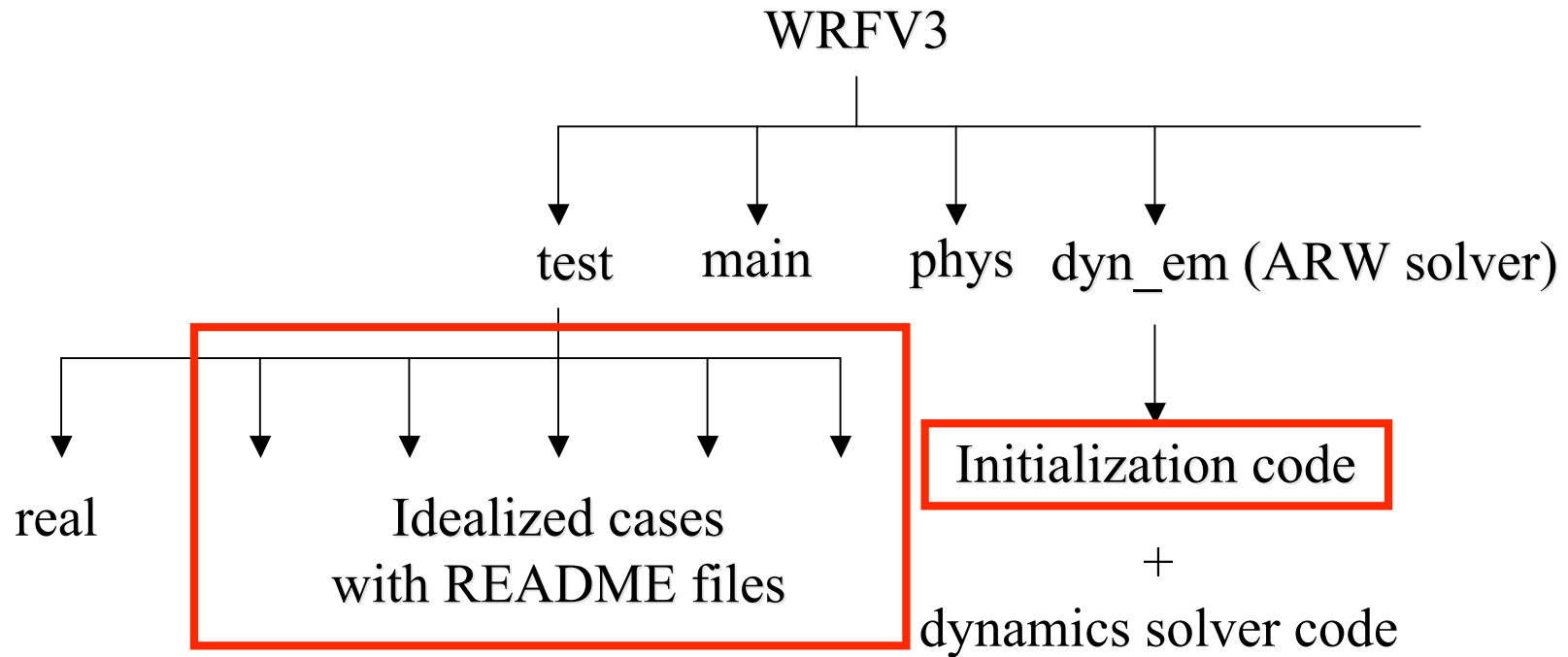# Initialization for Idealized Cases

Bill Skamarock

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.
4. They can be used to test physics development.
5. They are an easy starting point to test the code.

WRF ARW code

WRFV3

test   main   phys dyn_em (ARW solver)

real   Idealized cases
with README files

Initialization code
+
dynamics solver code

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

- 3D quarter-circle shear supercell thunderstorm

  WRFV3/test/em_quarter_ss

- 3D baroclinic wave

  WRFV3/test/em_b_wave

- 2D gravity current

  WRFV3/test/em_grav2d_x

- 3D large-eddy simulation case

  WRFV3/test/em_les

- 3D global: Held-Suarez case

  WRFV3/test/em_heldsuarez

- 2D sea-breeze case

  WRFV3/test/em_seabreeze2d_x

new in V3

Initialization Tasks

- Read in a single sounding (h, θ, Q_v, u and v) or pre-computed, balanced 2D profile (in the case of b_wave)

- Compute full pressure and (inverse) air density from input sounding

- Compute thermodynamic reference state, based on the sounding without moisture (dry pressure, dry inverse air density)

- Compute dry column pressure μ_d, and then model η levels

- Interpolating θ to η levels, compute inverse air density, and then geopotential - μ_d, θ, and geopotential are in exact hydrostatic balance

- Interpolating other fieds to model η levels

- Model levels are set automatically; they can be stretched in η (close to equally spaced z), or equally spaced in η
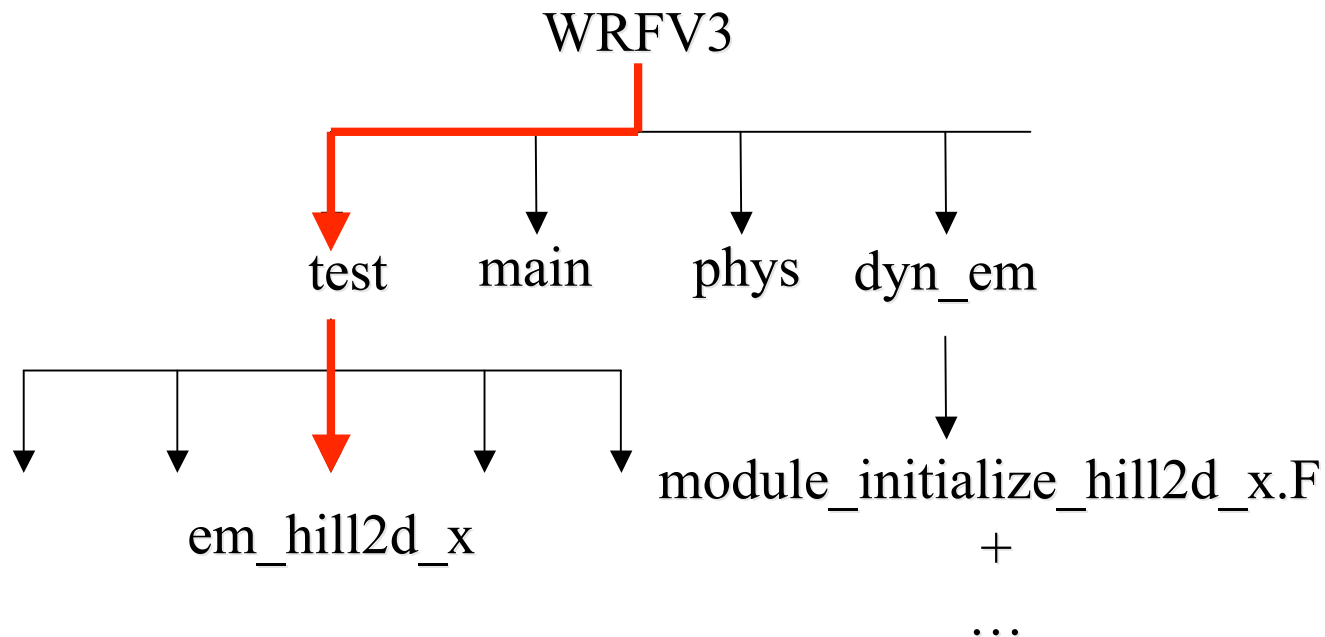
2D Flow Over a Bell-Shaped Mountain

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

w and perturbation u (m/s)

January 2010
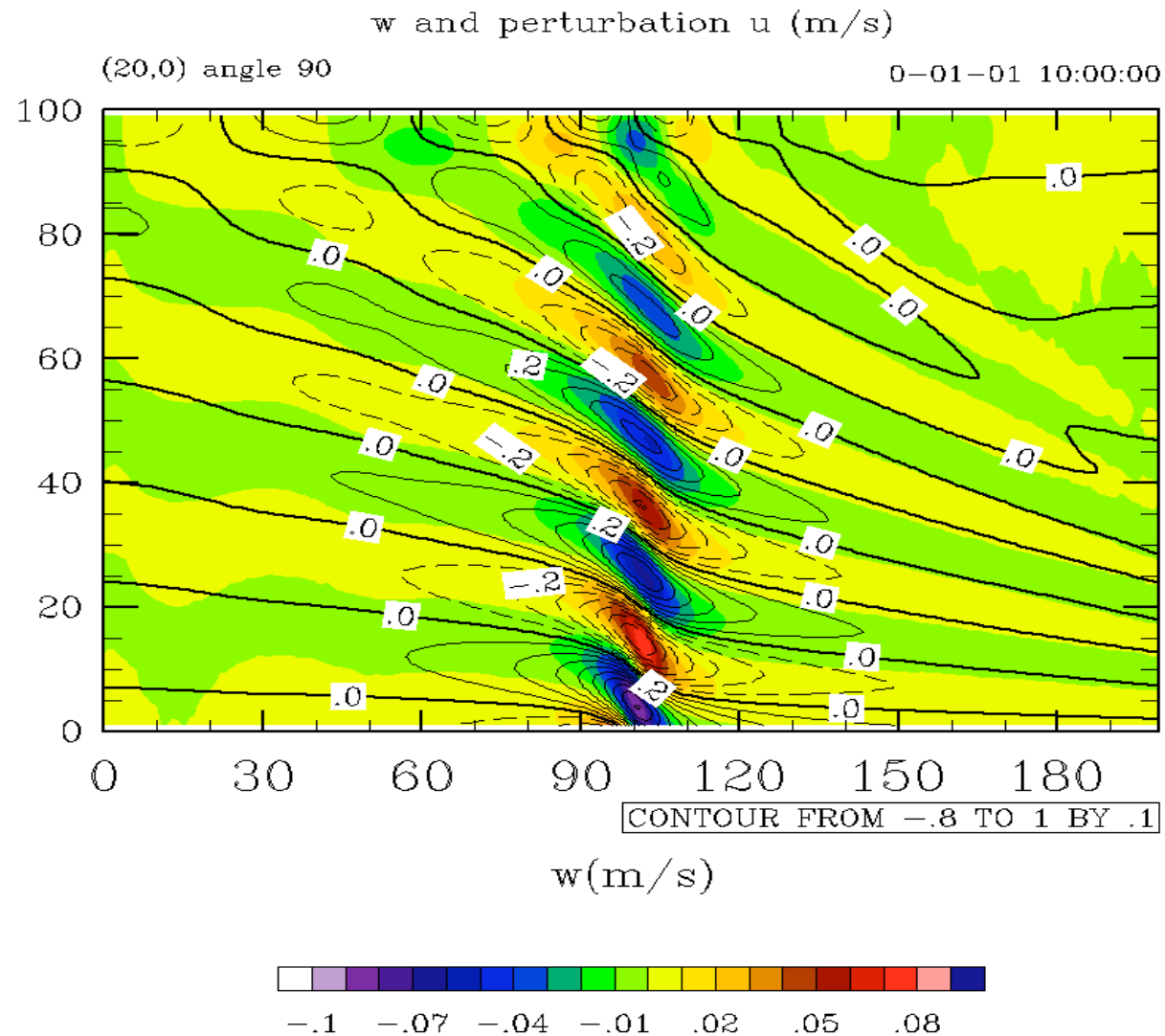
2D Flow Over a Bell-Shaped Mountain

Initialization module: dyn_em/module_initialize_hill2d_x.F
Case directory: test/em_hill2d_x

2D Flow Over a Bell-Shaped Mountain

Initialization code is in
   WRFV3/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
   WRFV3/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 *WRFV3/dyn_em/module_initialize_hill2d_x.F*

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

```
...
  hm = 100.        ←——— mountain height and half-width
  xa = 5.0

  icm = ide/2     ←——— mountain position in domain
...                      (center gridpoint in x)
```

Set height field ——→
```
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.   ←——— lower boundary condition
  grid%ph0(i,1,j) = grid%phb(i,1,j)
ENDDO
ENDDO
```

Setting the Initial Condition

In *WRFV3/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.)
...


!  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. )
...
```
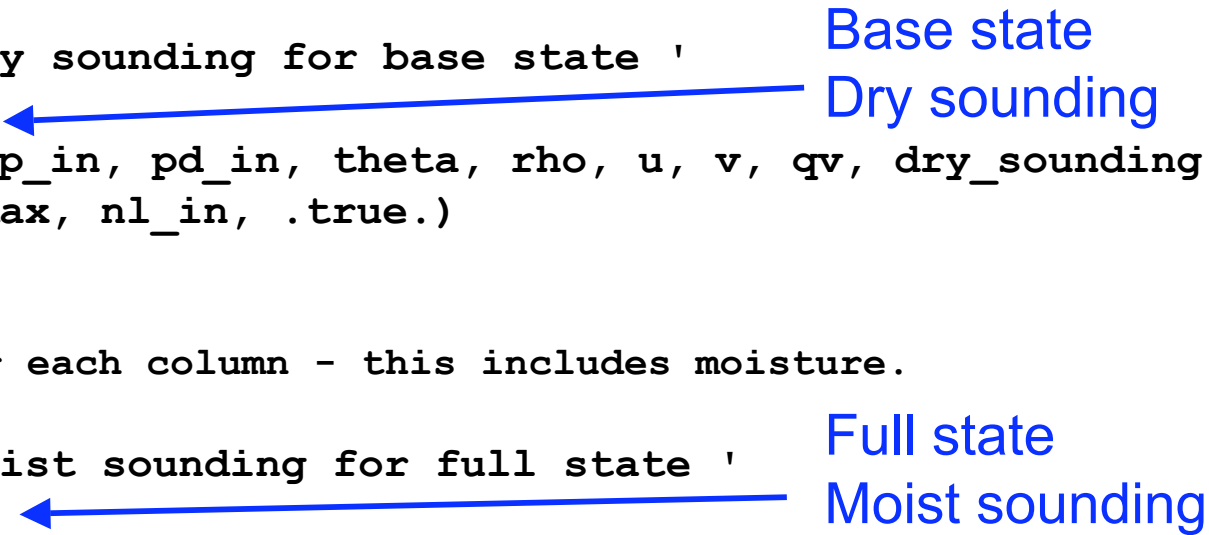
Base state
Dry sounding
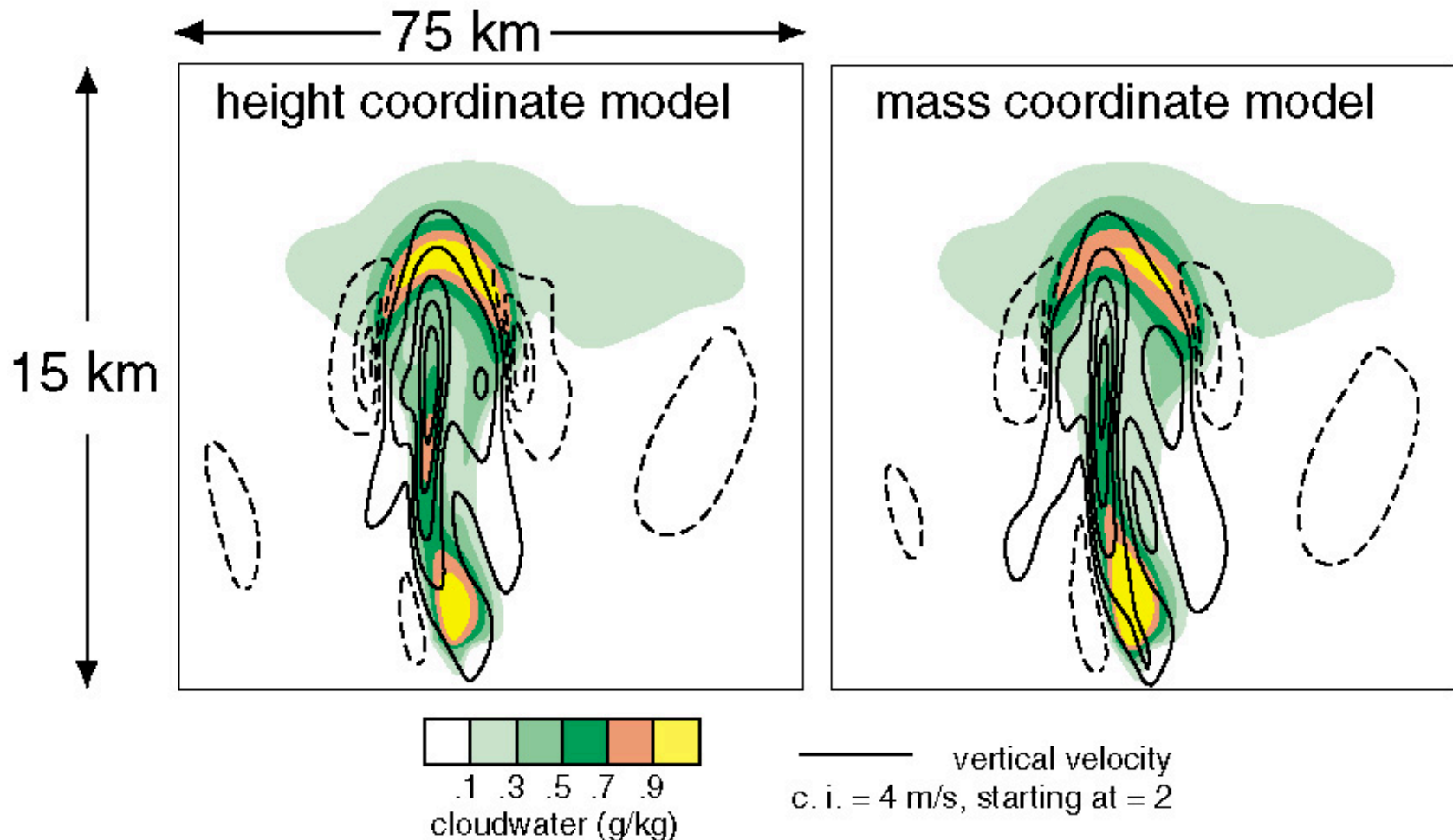
Full state
Moist sounding

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
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)

January 2010

2D squall line simulation

Squall-Line Simulations, T = 3600 s

dx = dz = 250 m, v = 300 m²/s

75 km

15 km

height coordinate model

mass coordinate model

.1 .3 .5 .7 .9
cloudwater (g/kg)

vertical velocity
c. i. = 4 m/s, starting at = 2

2D squall line simulation

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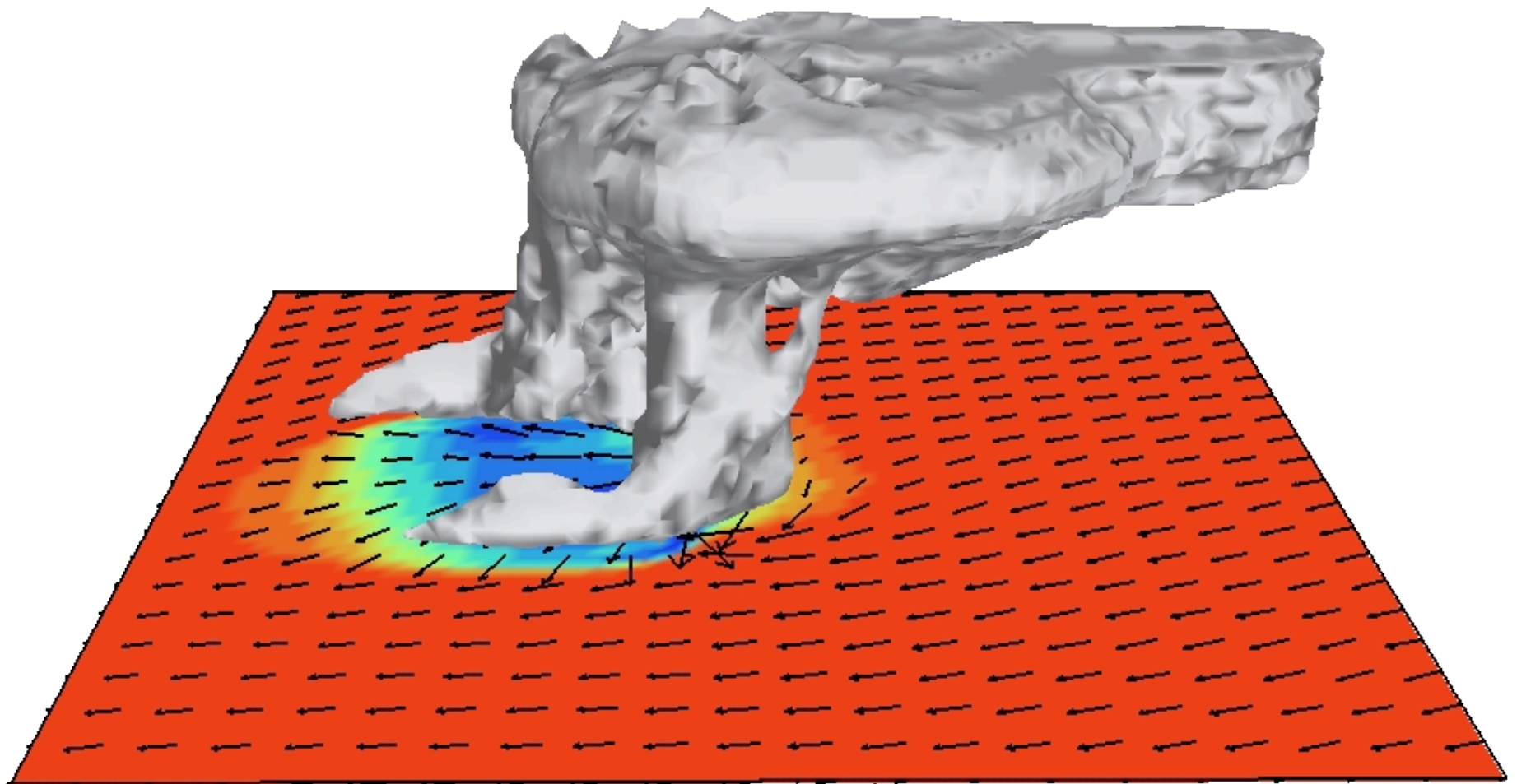   *WRFV3/test/em_squall2d_x/input_sounding*
    WRFV3/test/em_squall2d_y/input_sounding

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

3D supercell simulation

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.

Setting the initial perturbation

In *WRFV3/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
          grid%t_1(i,k,j)=T_1(i,k,j)+delt*COS(.5*PI*RAD)**2
          grid%t_2(i,k,j)=T_1(i,k,j)
          qvf = 1. + 1.61*moist_1(i,k,j,P_QV)
          grid%alt(i,k,j) = (r_d/p1000mb)*(t_1(i,k,j)+t0)*qvf* &
                    (((p(i,k,j)+pb(i,k,j))/p1000mb)**cvpm)
          grid%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
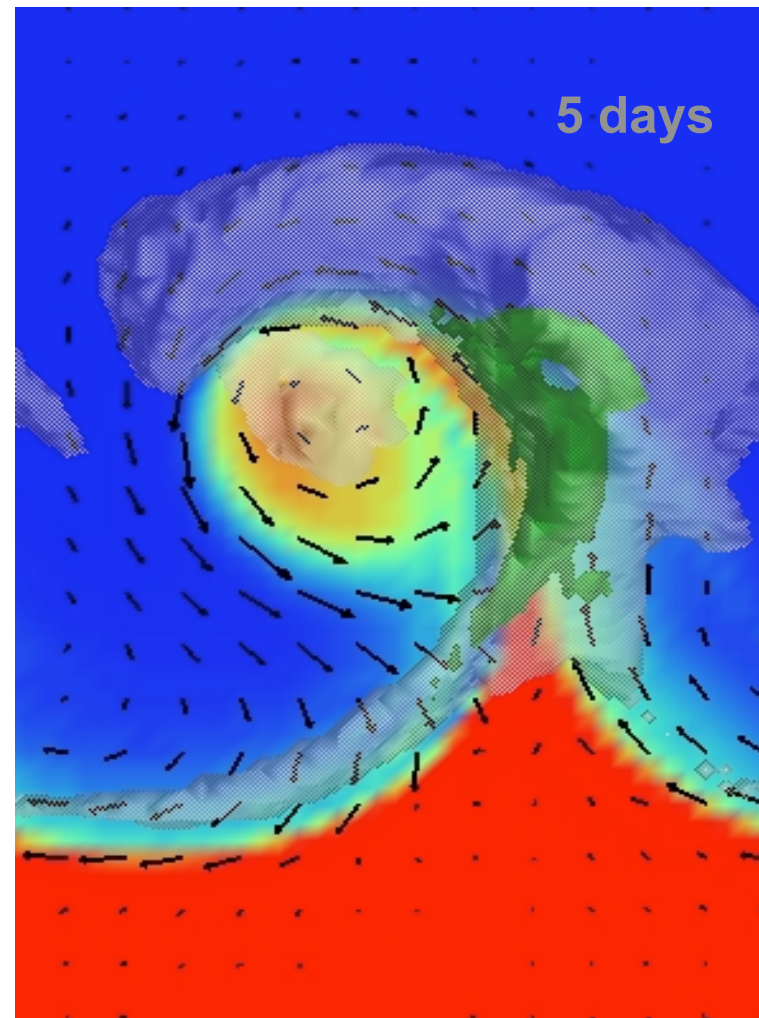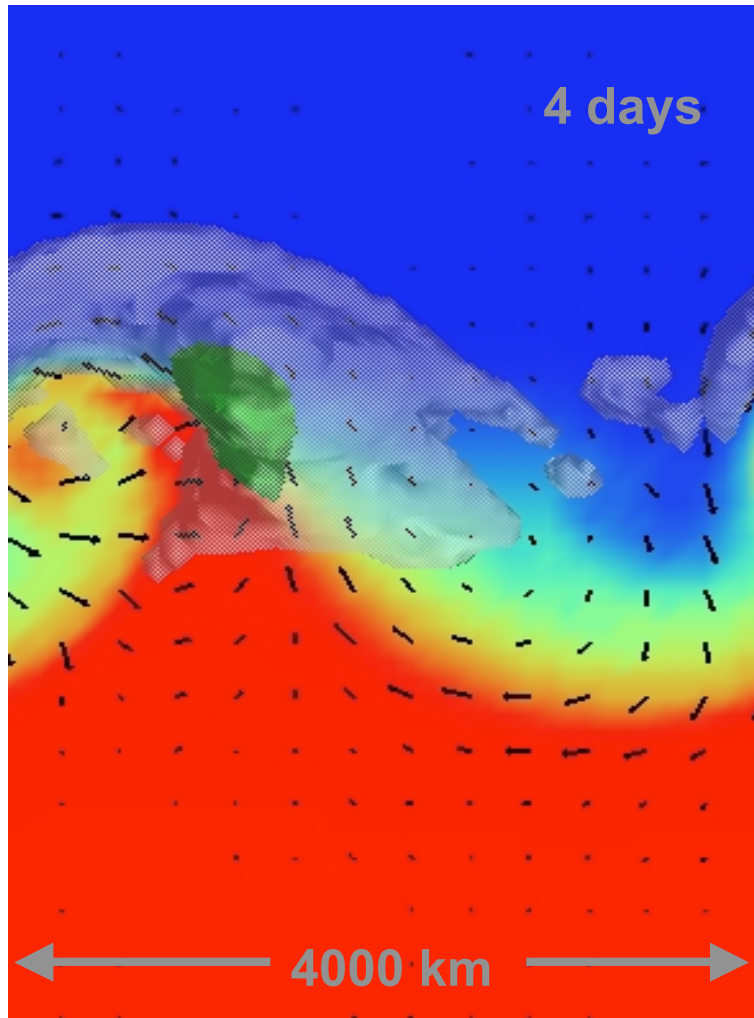
Moist Baroclinic Wave Simulation

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

Moist Baroclinic Wave Simulation

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.

Moist Baroclinic Wave Simulation

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
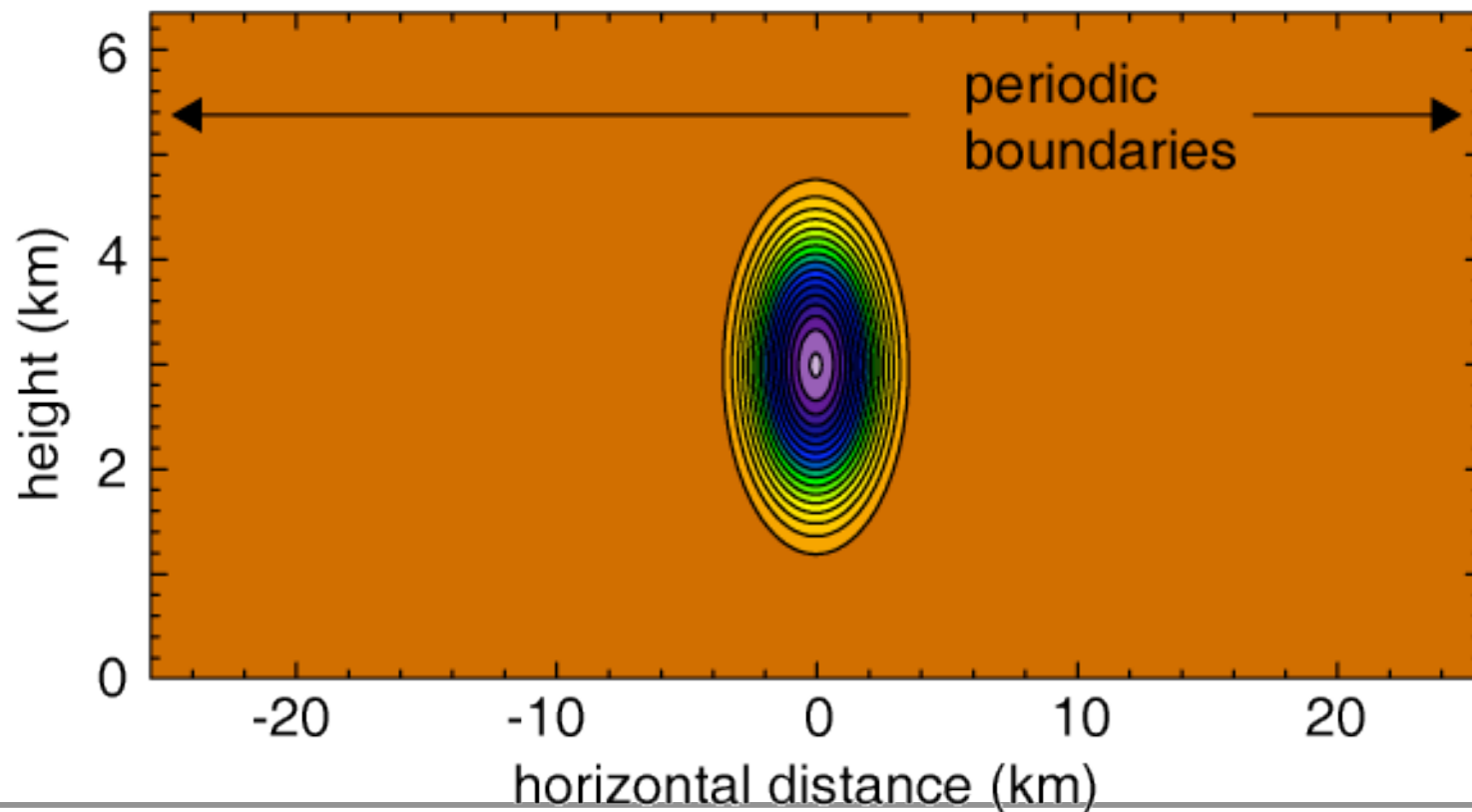   81 grid points in the y (south-north) direction.

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)
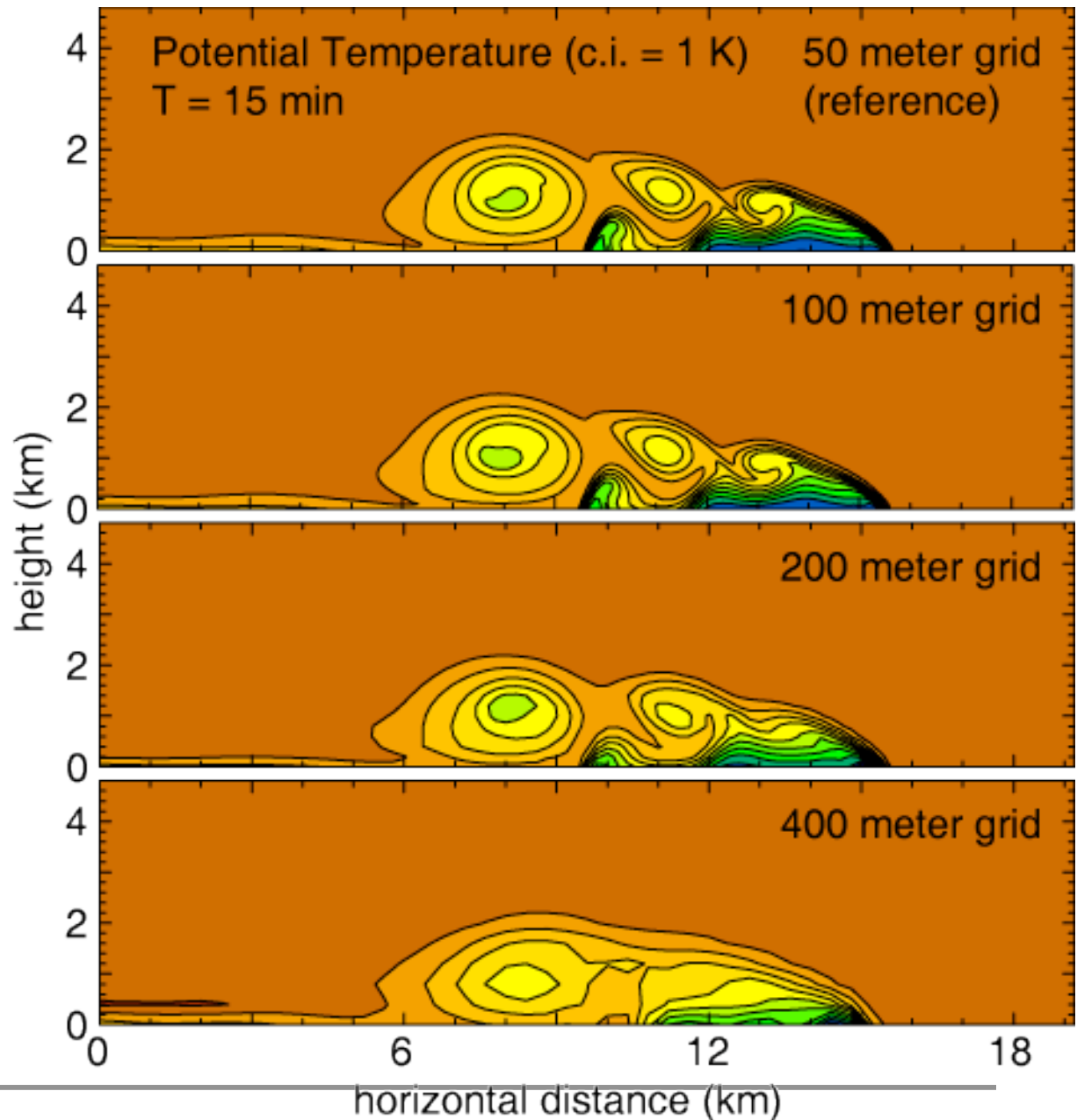

Initial state, potential temperature (c.i. = 1 K)

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,
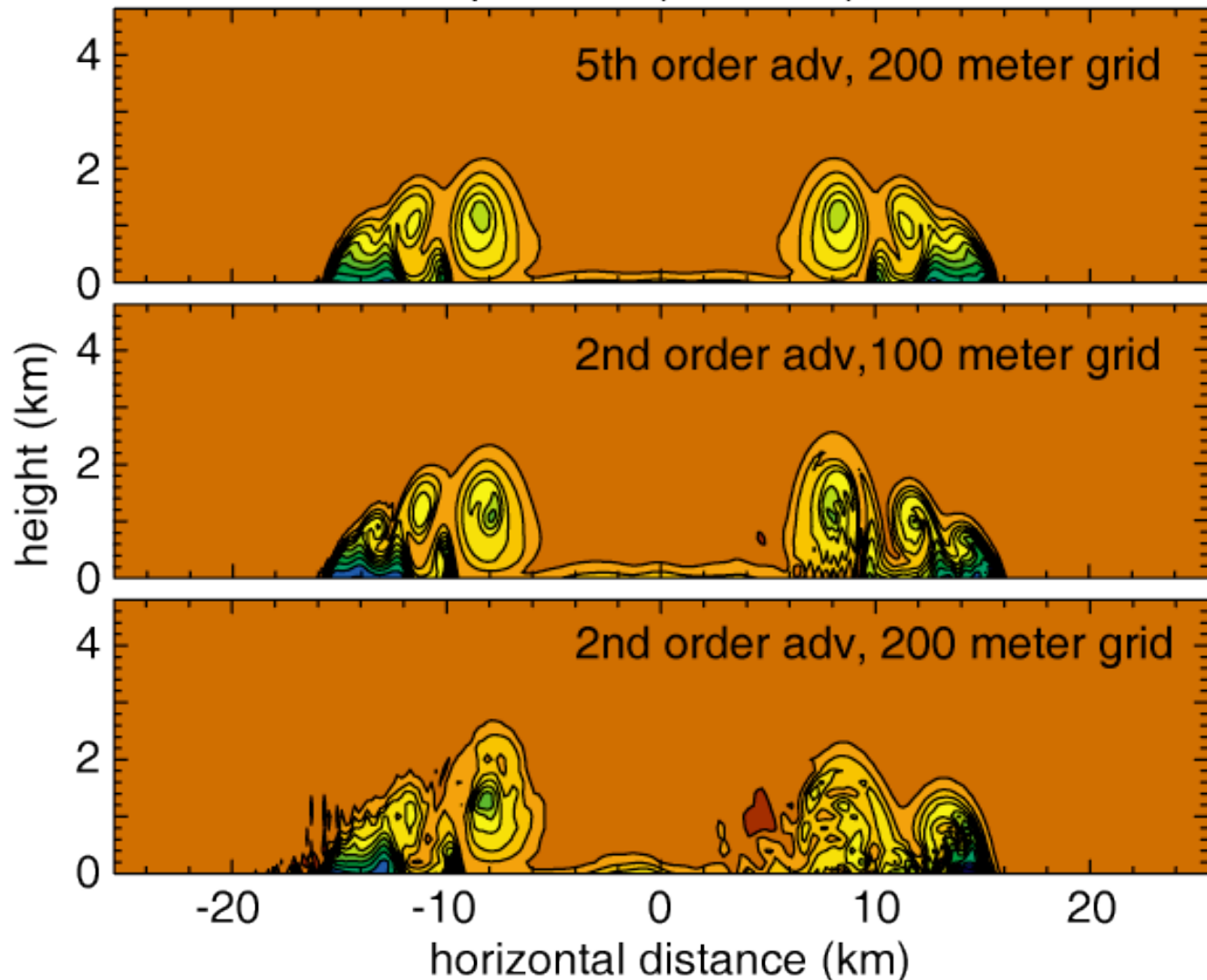5th order upwind advection,
use namelist.input.400m
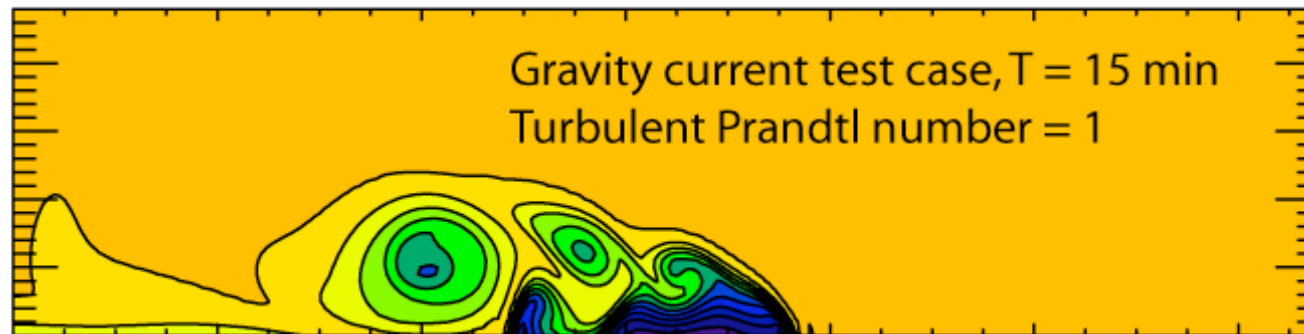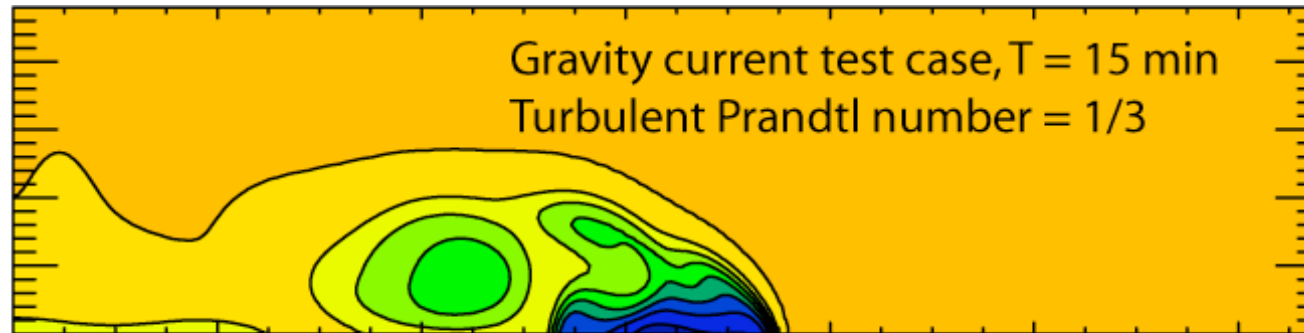
Gravity Current Simulation

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

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

5th order adv, 200 meter grid

2nd order adv, 100 meter grid

2nd order adv, 200 meter grid

height (km)

horizontal distance (km)

Gravity Current Simulation

Gravity current test case, T = 15 min
Turbulent Prandtl number = 1/3

Gravity current test case, T = 15 min
Turbulent Prandtl number = 1

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
WRFV3/share/module_model_constants.F
WRFV3/share/module_diffusion_em.F, module_big_step_utilities.F

Gravity Current Simulation

Initialization code is in
  WRFV3/dyn_em/module_initialize_grav2d_x.F

The initial cold bubble is hardwired in the
  initialization code.

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

Large-Eddy Simulation Case

Initialization code is in
  WRFV3/dyn_em/module_initialize_les.F
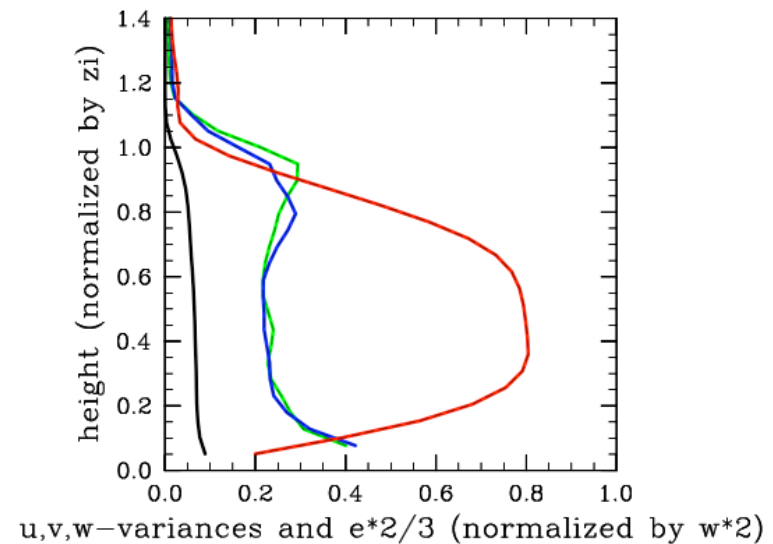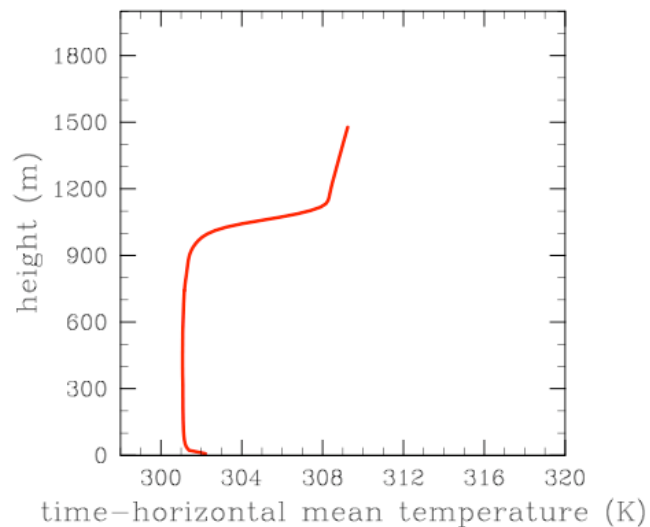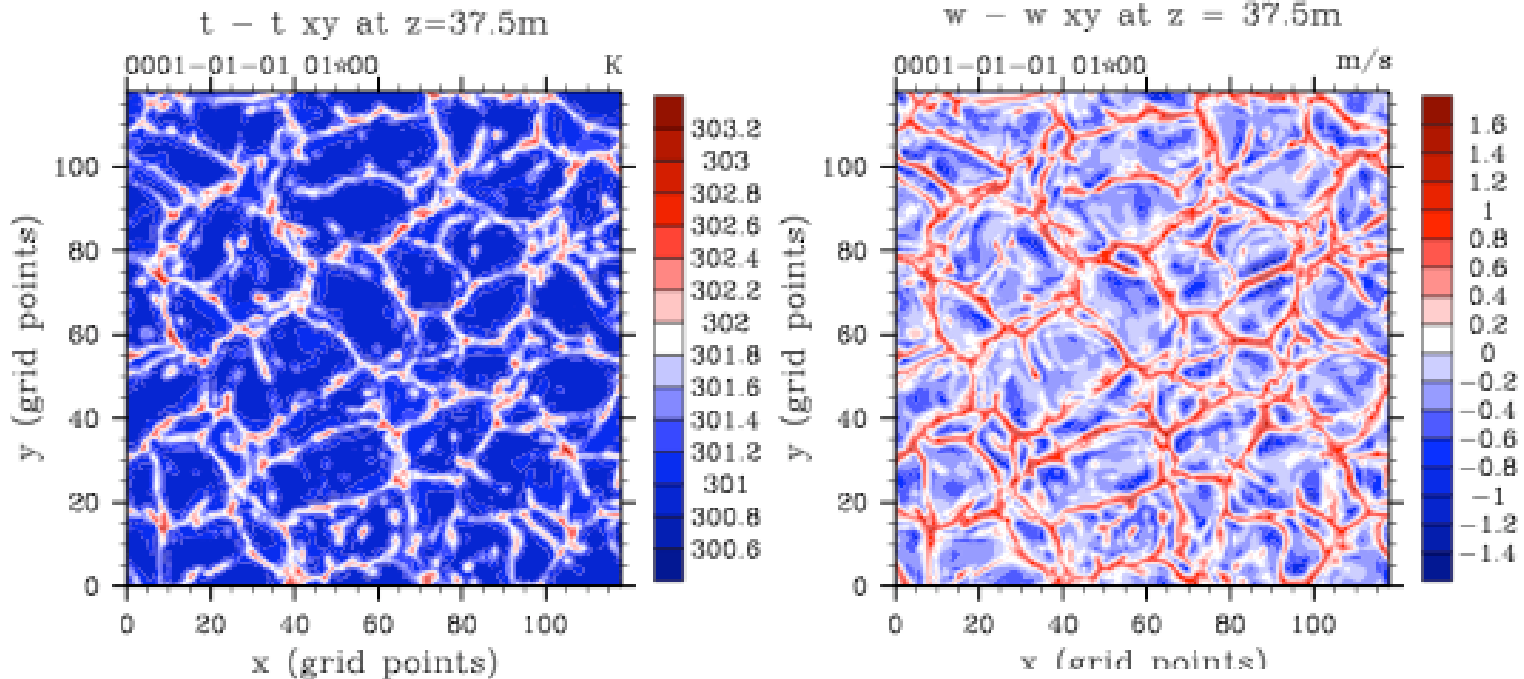
Test case directory is in
  WRFV3/test/em_les

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

Large-Eddy Simulation Case

2D Sea-Breeze Simulation Case

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

More on Idealized Cases ..

Descriptions:
WRFV3/README_test_cases
WRFV3/test/em_*/README