Initialization for Idealized Cases

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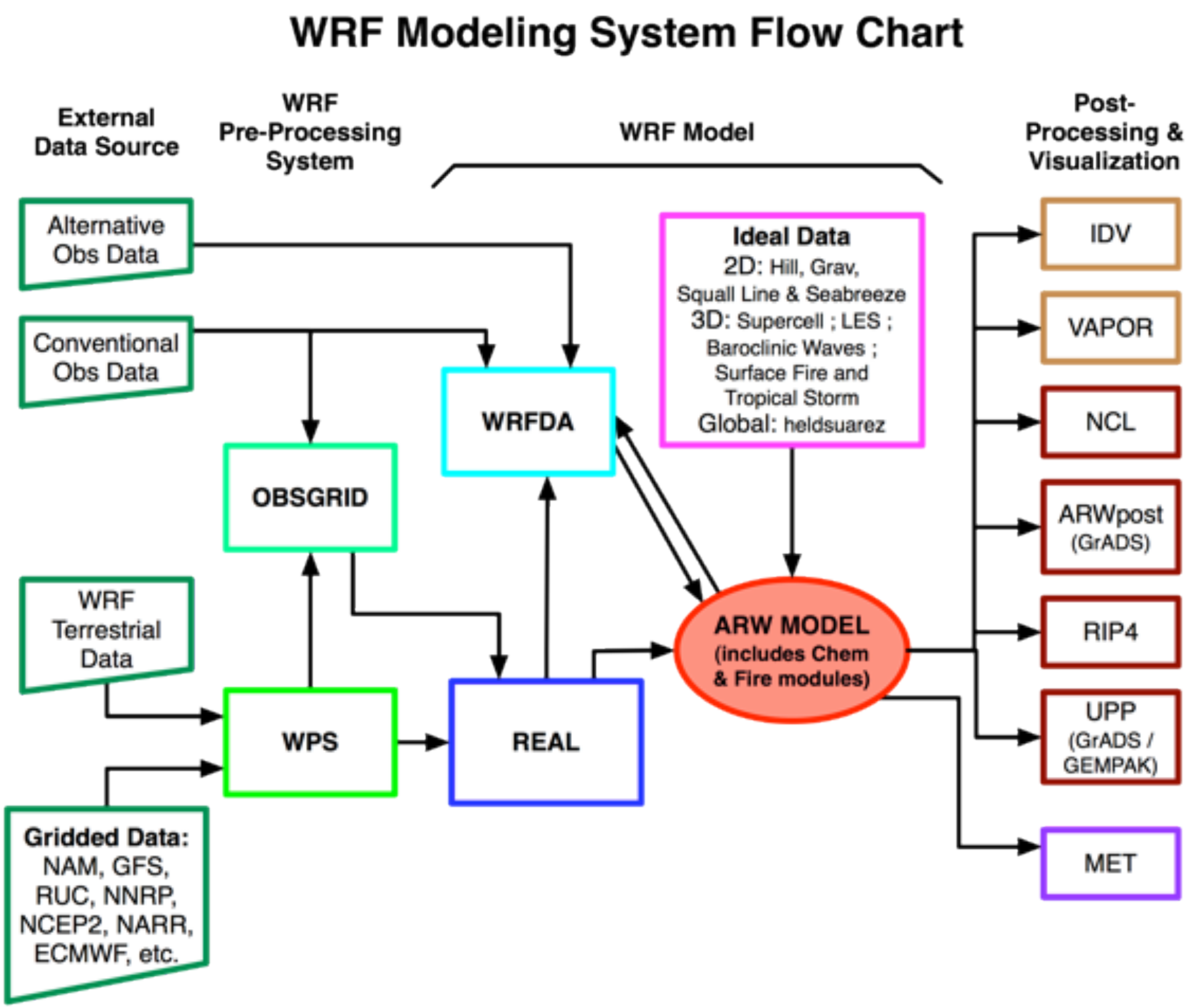
Why do we provide idealized cases?

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. These tests are the easiest way to test the solver.

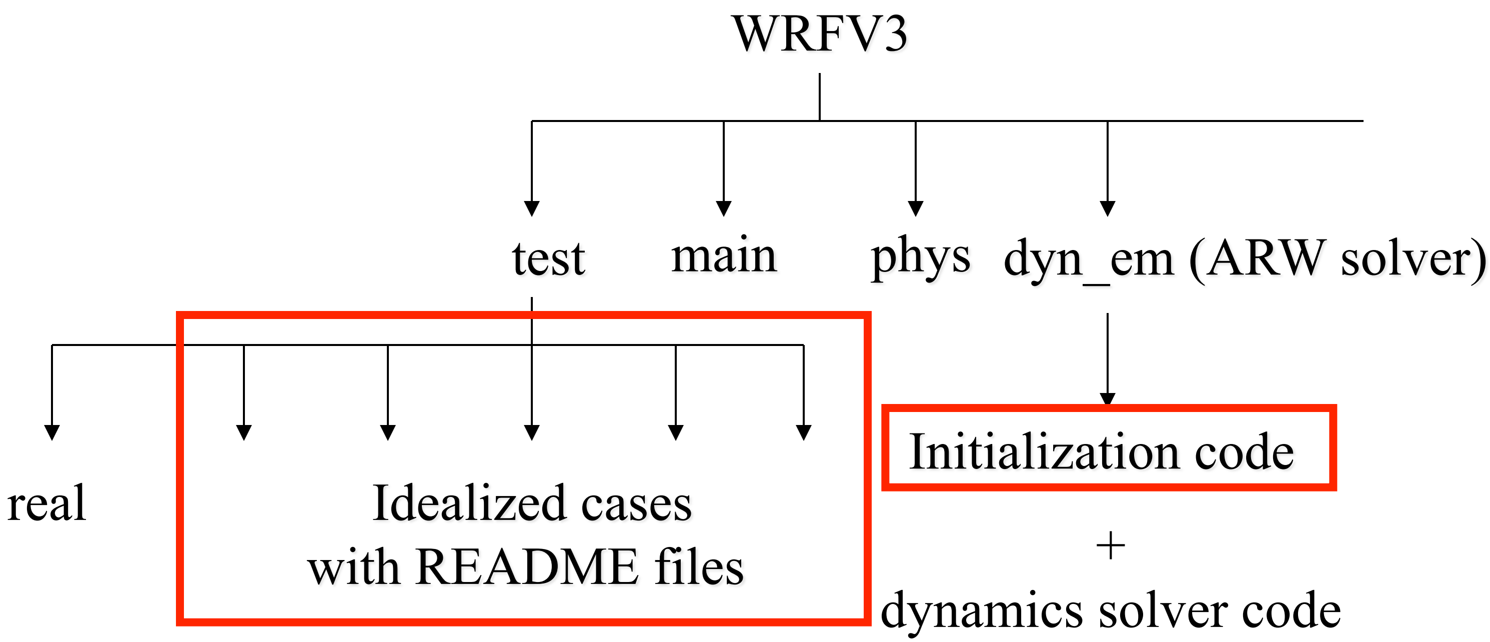


WRF ARW Tech Note

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

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*
- 3D tropical cyclone – *WRFV3/test/em_tropical_cyclone*

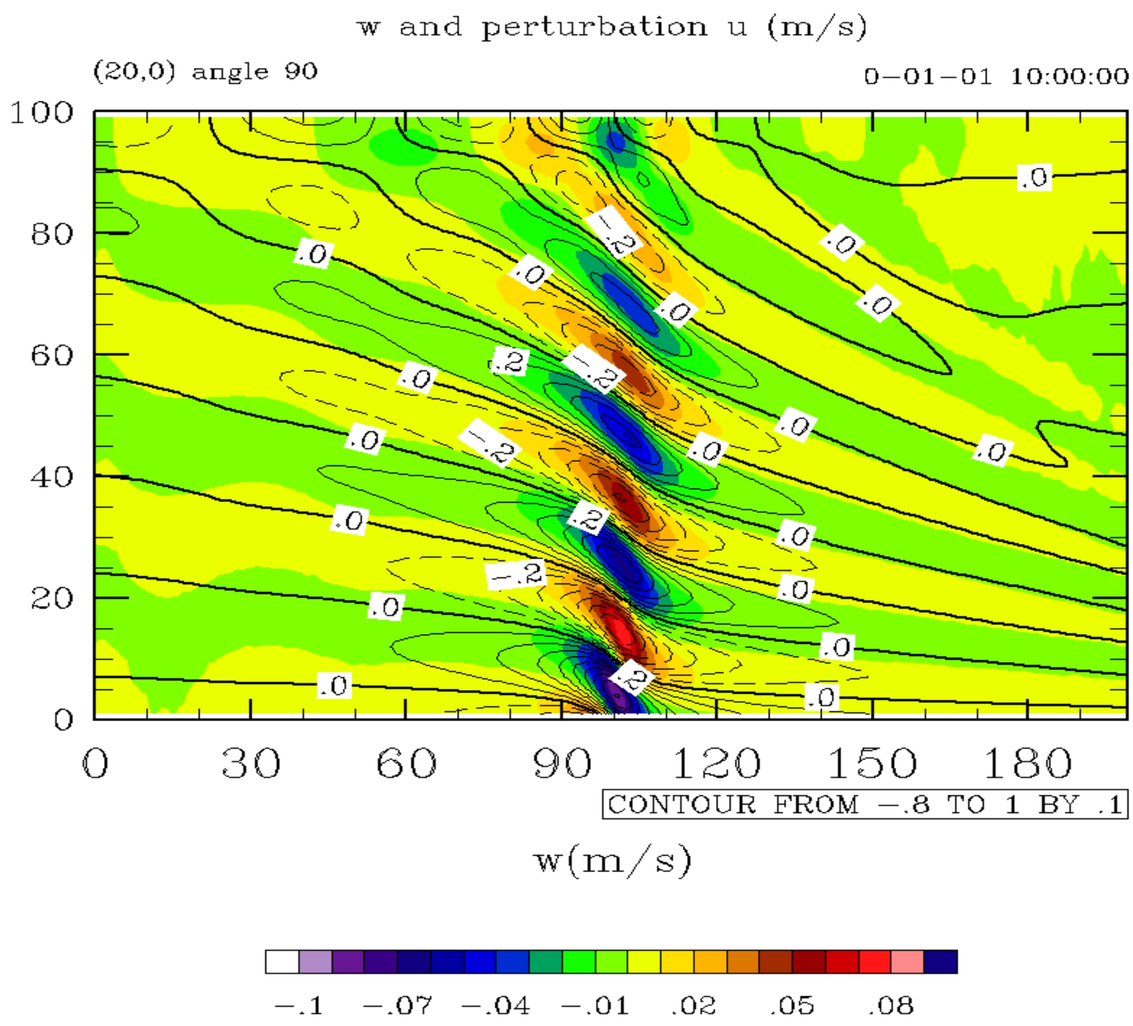
What happens during the initialization

- A single sounding (z, θ, Q_v, u and v), or a pre-computed, balanced 2D profile (in the case of b_wave), is read in.
- Full pressure and (inverse) air density is computed from the input sounding
- The thermodynamic reference state is computed based on the sounding without moisture (dry pressure, dry inverse air density)
- Dry column pressure μ_d is computed, and then model η levels are assigned.
- θ is interpolated to η levels, then inverse air density, geopotential and μ_d, are computed assuming a hydrostatic balance.
- Other fields are interplolated to model η levels.

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.

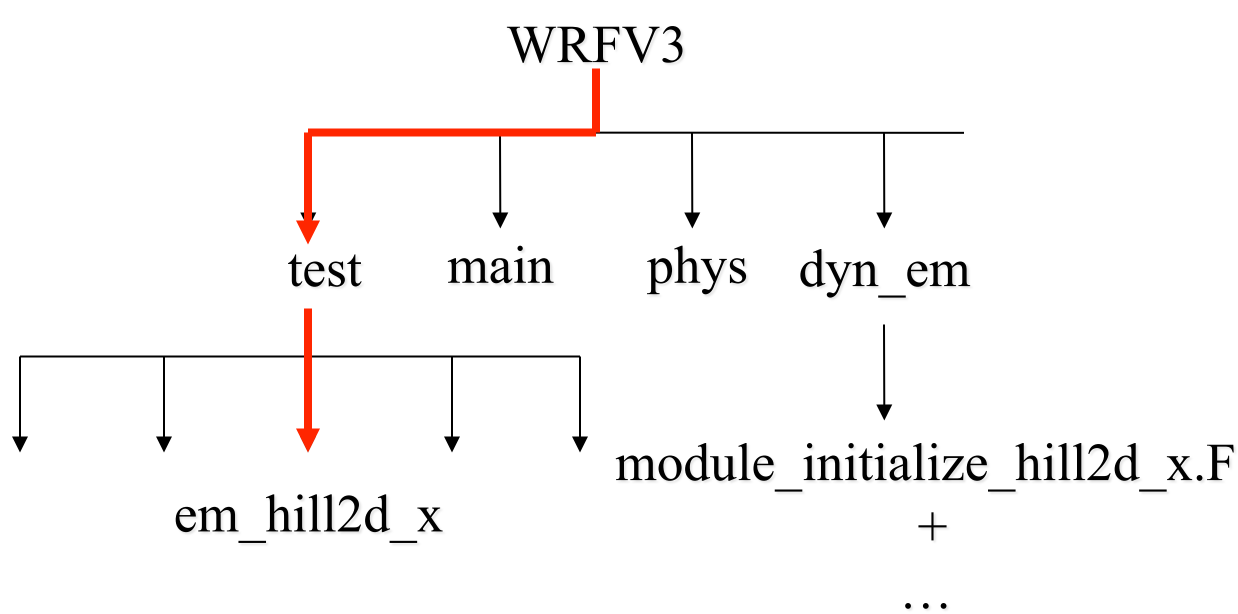
2D Flow Over a Bell-Shaped Mountain

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



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.
    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
```

mountain height and half-width (hm, xa)

mountain position in domain (center gridpoint in x) (icm = ide/2)

Set height field (grid%ht(i,j))

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

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

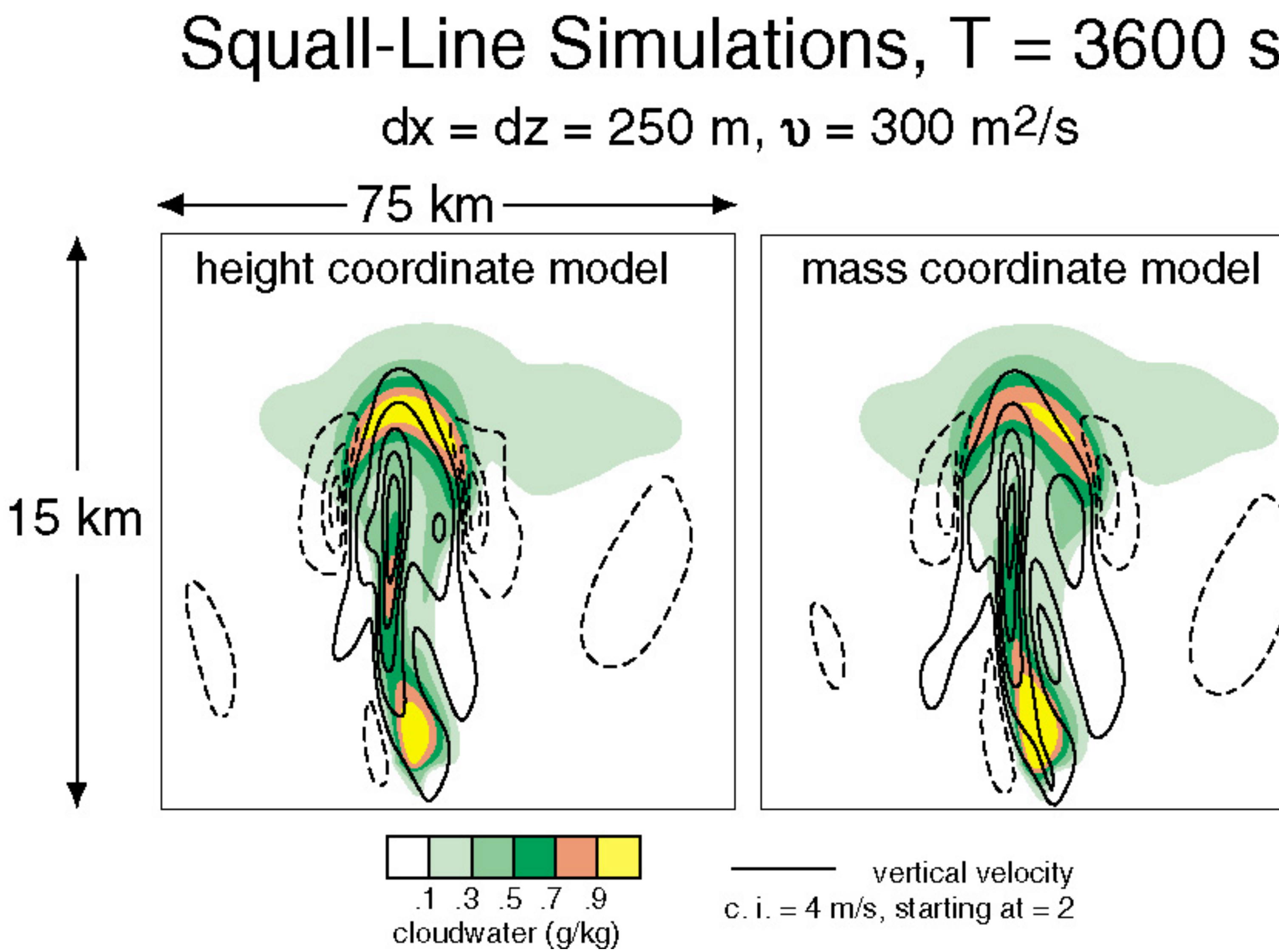
File: *WRFV3/test/em_quarter_ss/input_sounding*

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

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)
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

2D squall line simulation



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

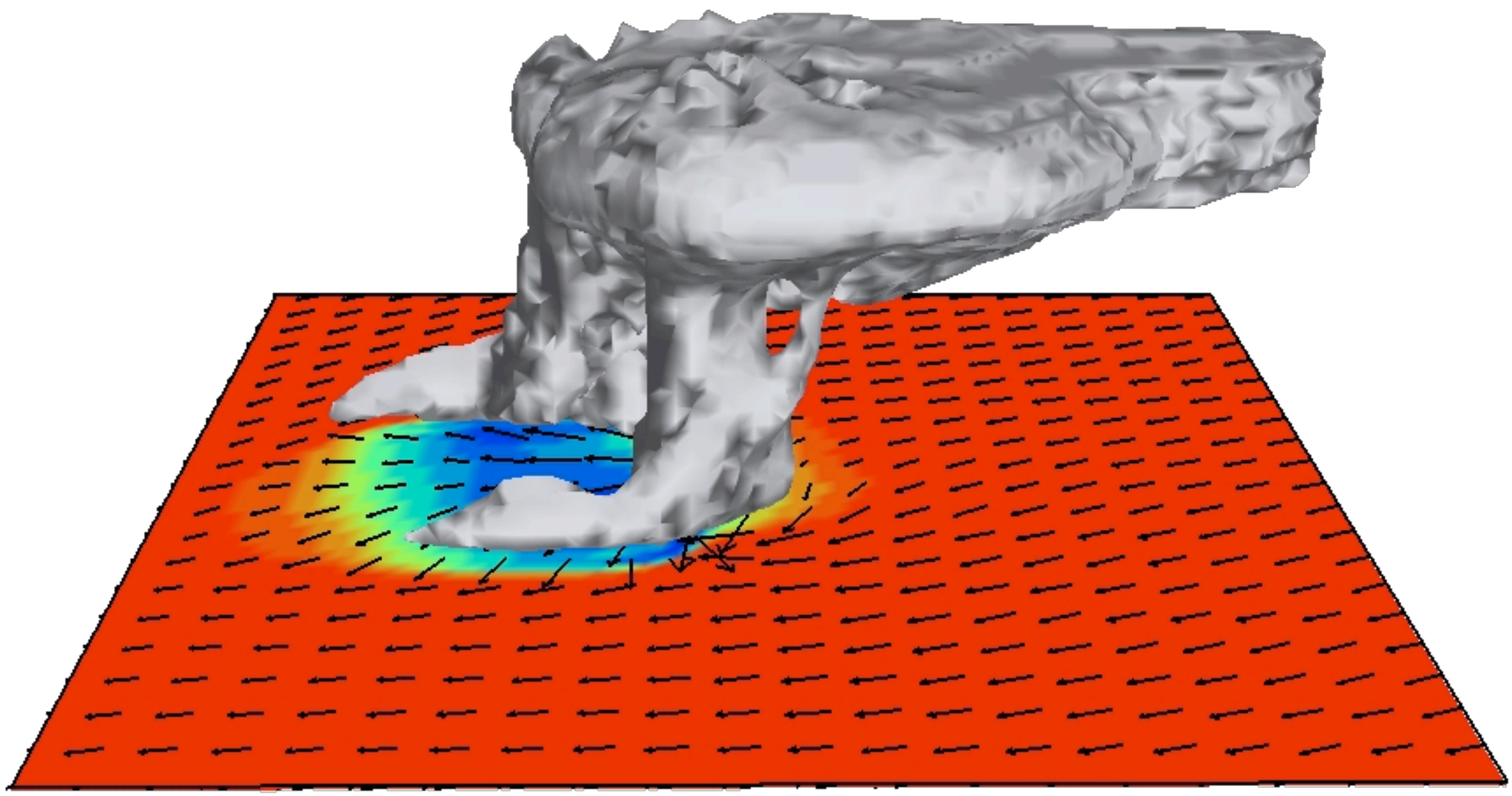
WRFV3/test/em_squall2d_x/input_sounding
WRFV3/test/em_squall2d_y/input_sounding

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)

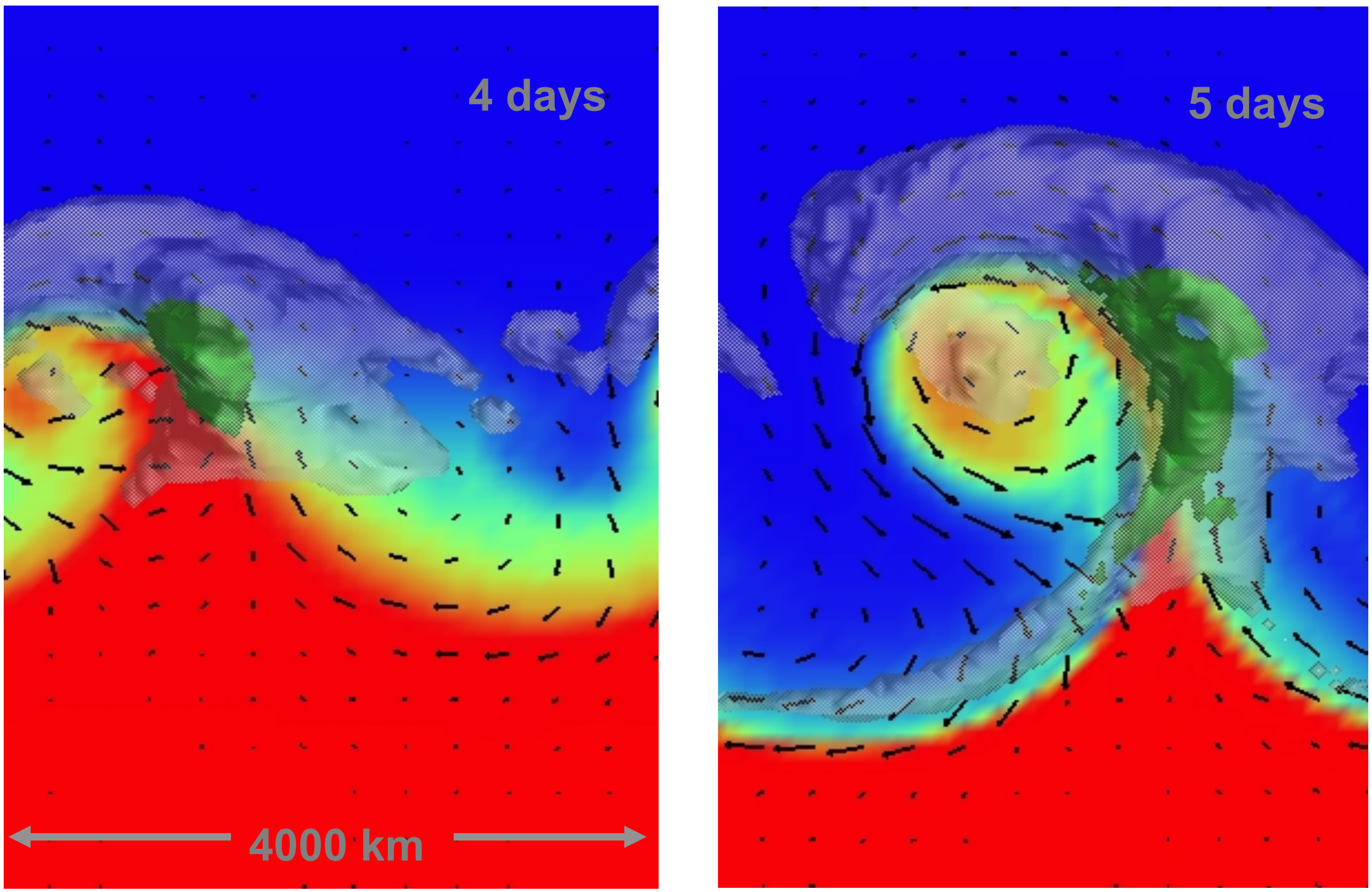
vertical radius of the perturbation is 1500 m

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.

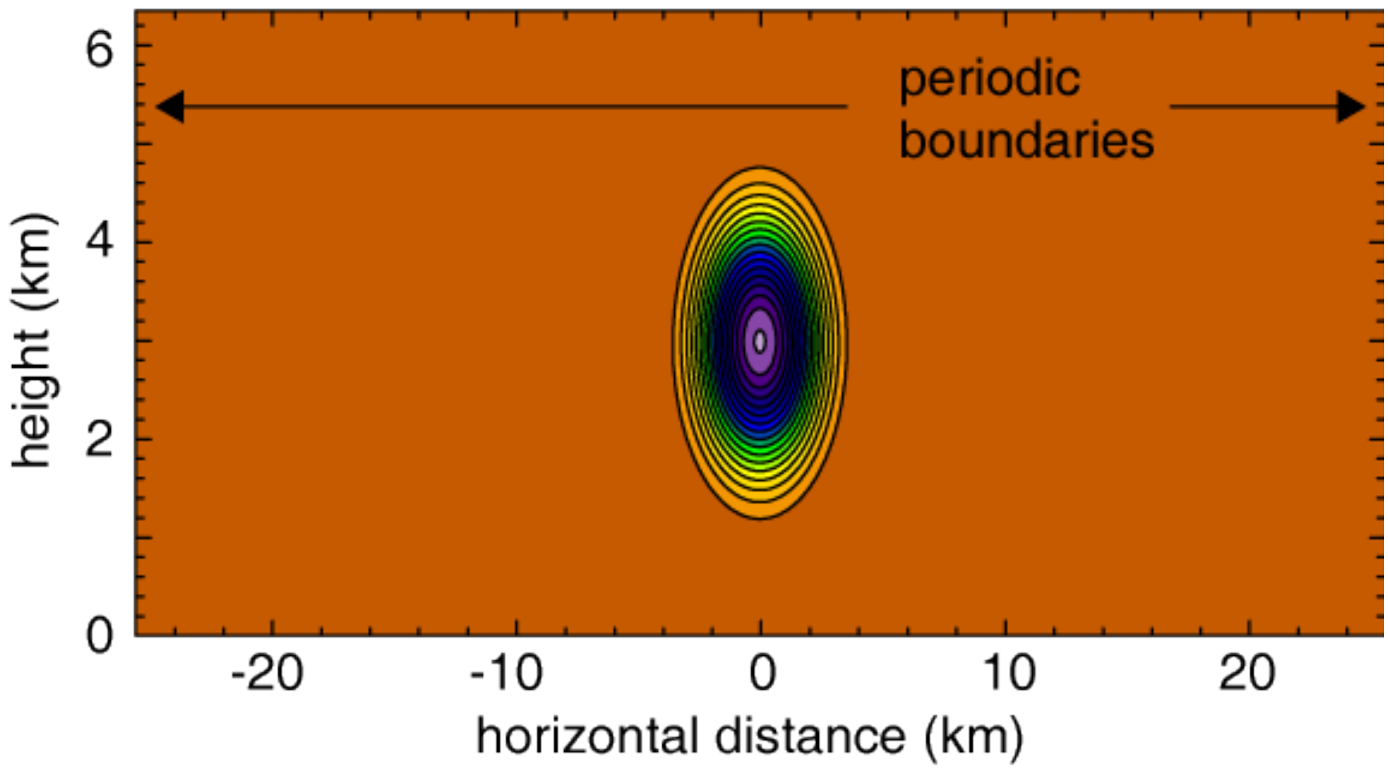
The initial jet only works for dy = 100 km and
81 grid points in the y (south-north) direction.

Gravity Current Simulation

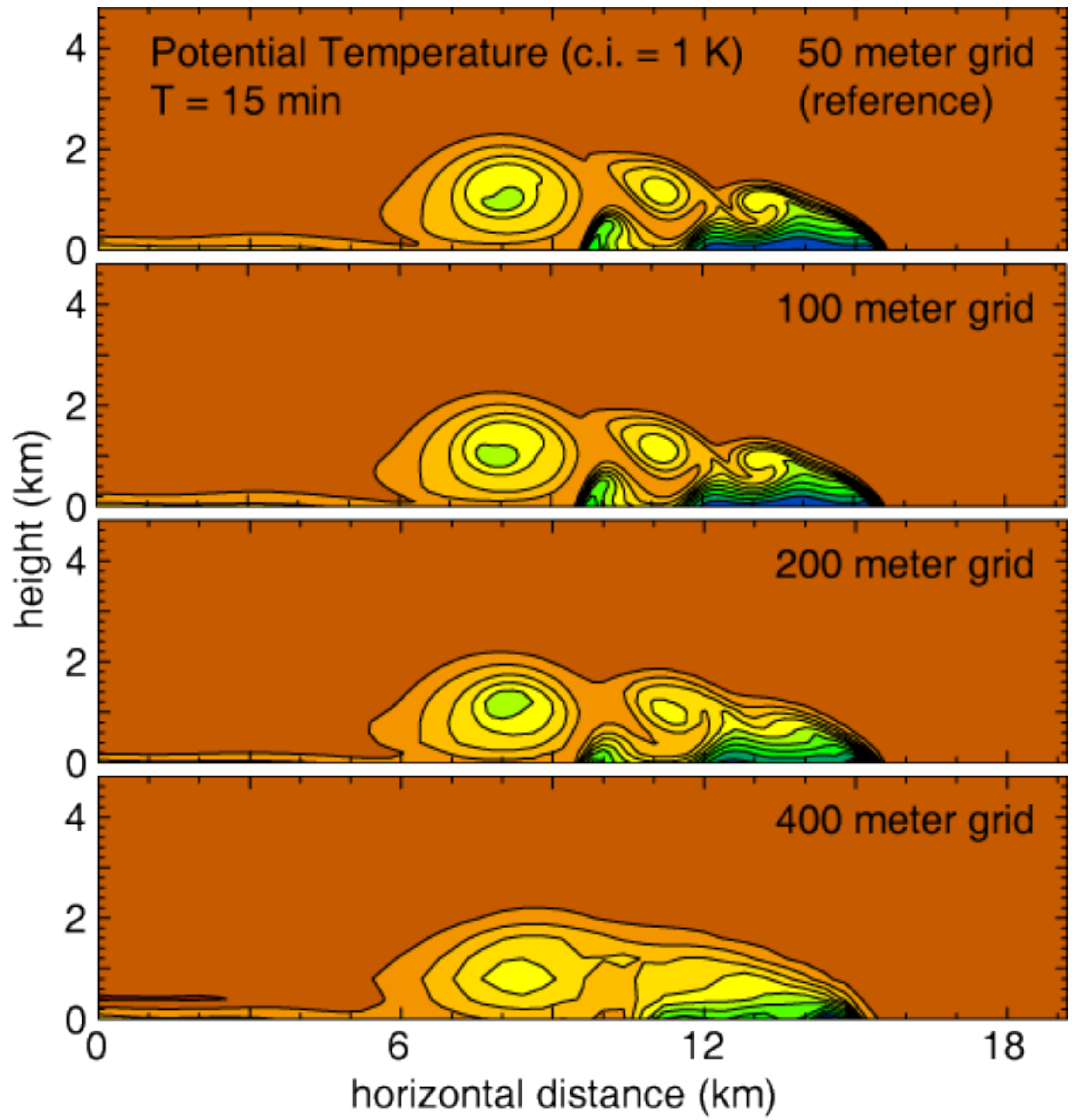
(Straka et al, IJNMF, 1993)

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

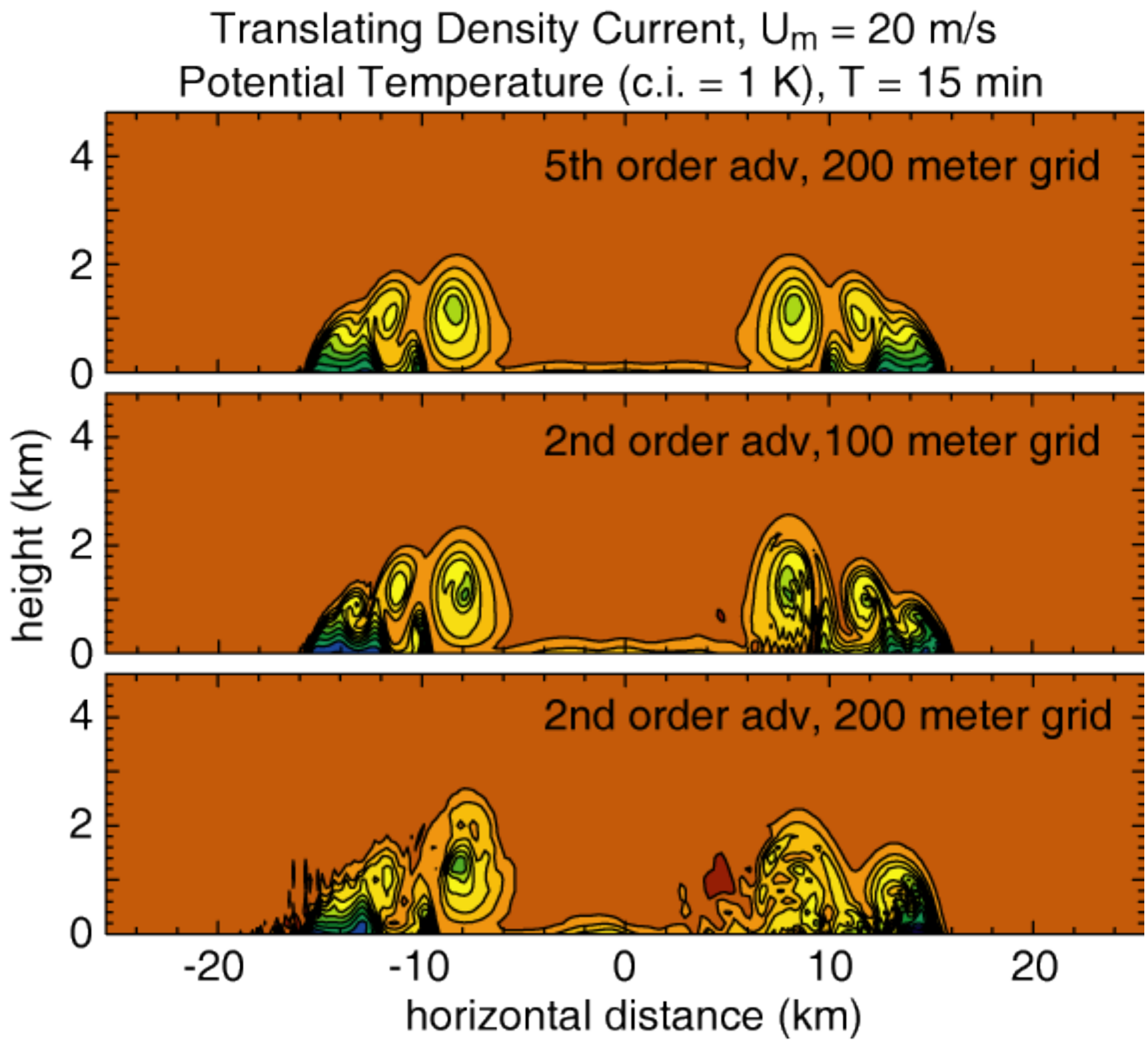


Default case, dx = 100 m,
5th order upwind advection,
uses namelist.input.100m

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

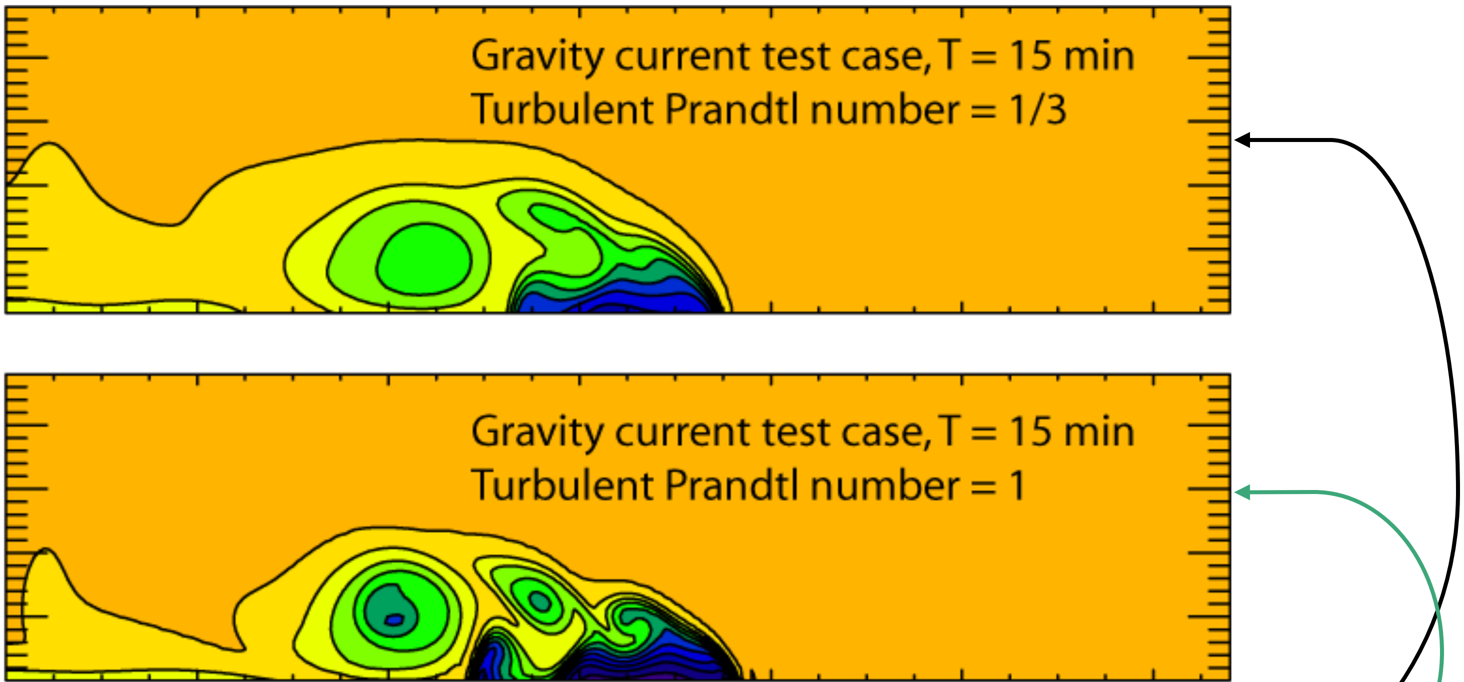


5[th] order upwind advection, use namelist.input.200m and input_sounding.um=20

use namelist.input.100m with 2[nd] order advection and input_sounding.um=20

use namelist.input.200m with 2[nd] 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
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

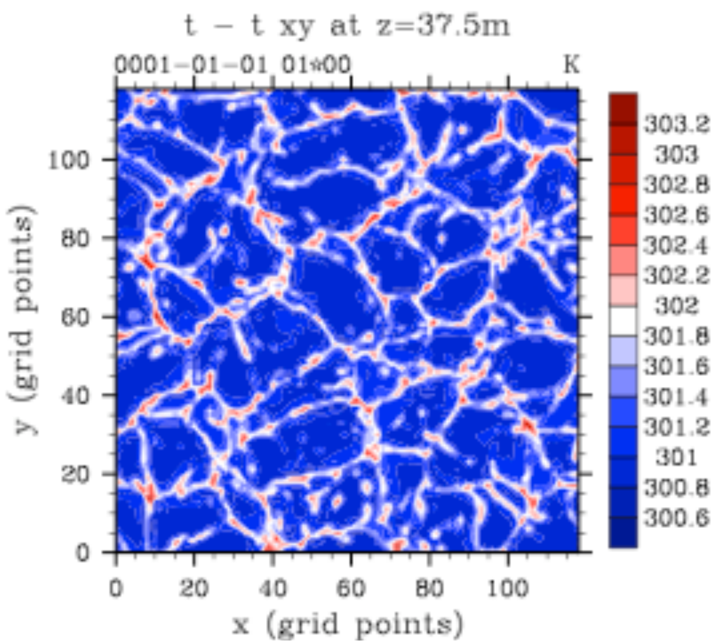
WRFV3/test/em_les

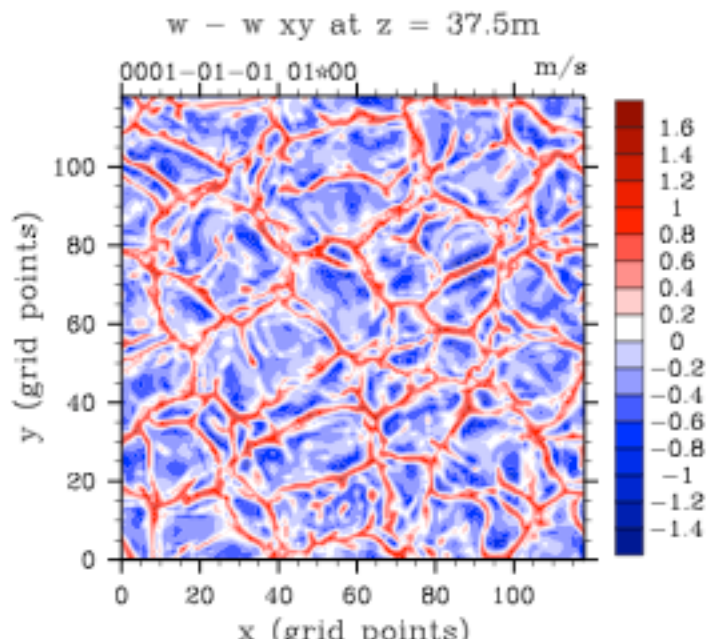
The default case is a large-eddy simulation of free convective boundary layer with no winds. The turbulence of the free CBL is driven and maintained by namelist-specified surface heat flux.

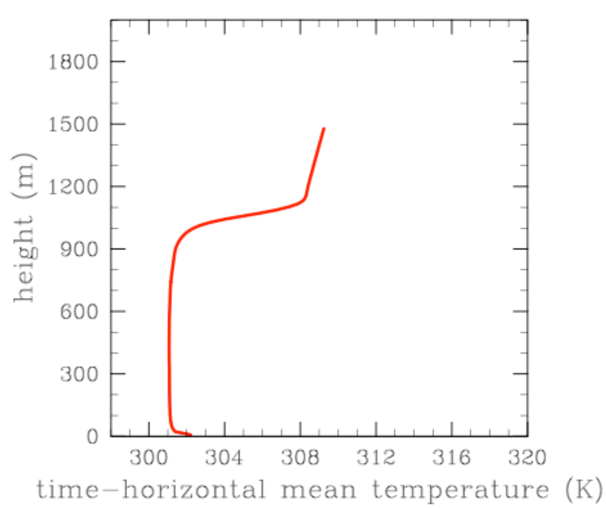
An initial sounding with mean winds is also provided.

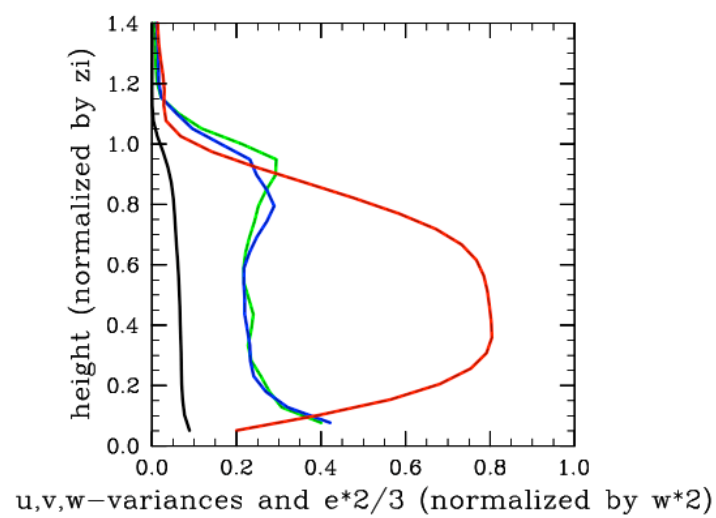
Reference: Moeng et al. 2007 MWR

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

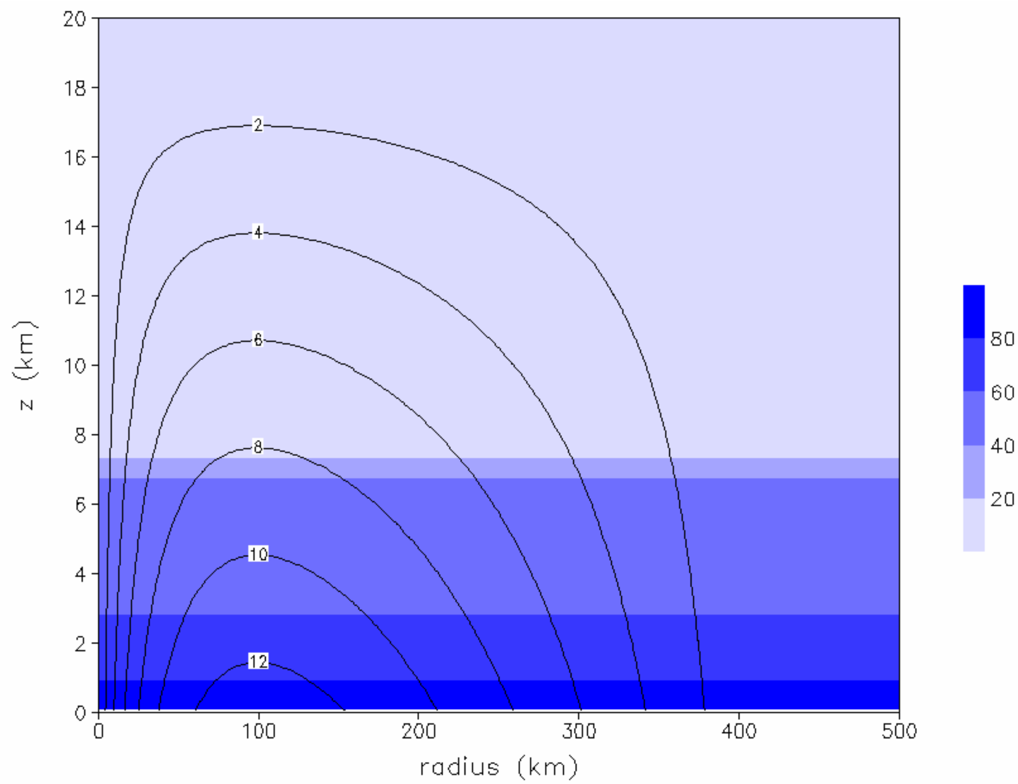
The initial state has no wind, and is perturbed by small random temperature changes

An example to show how to set surface parameters so that one may use full surface physics

Idealized tropical cyclone test case: Setup

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)



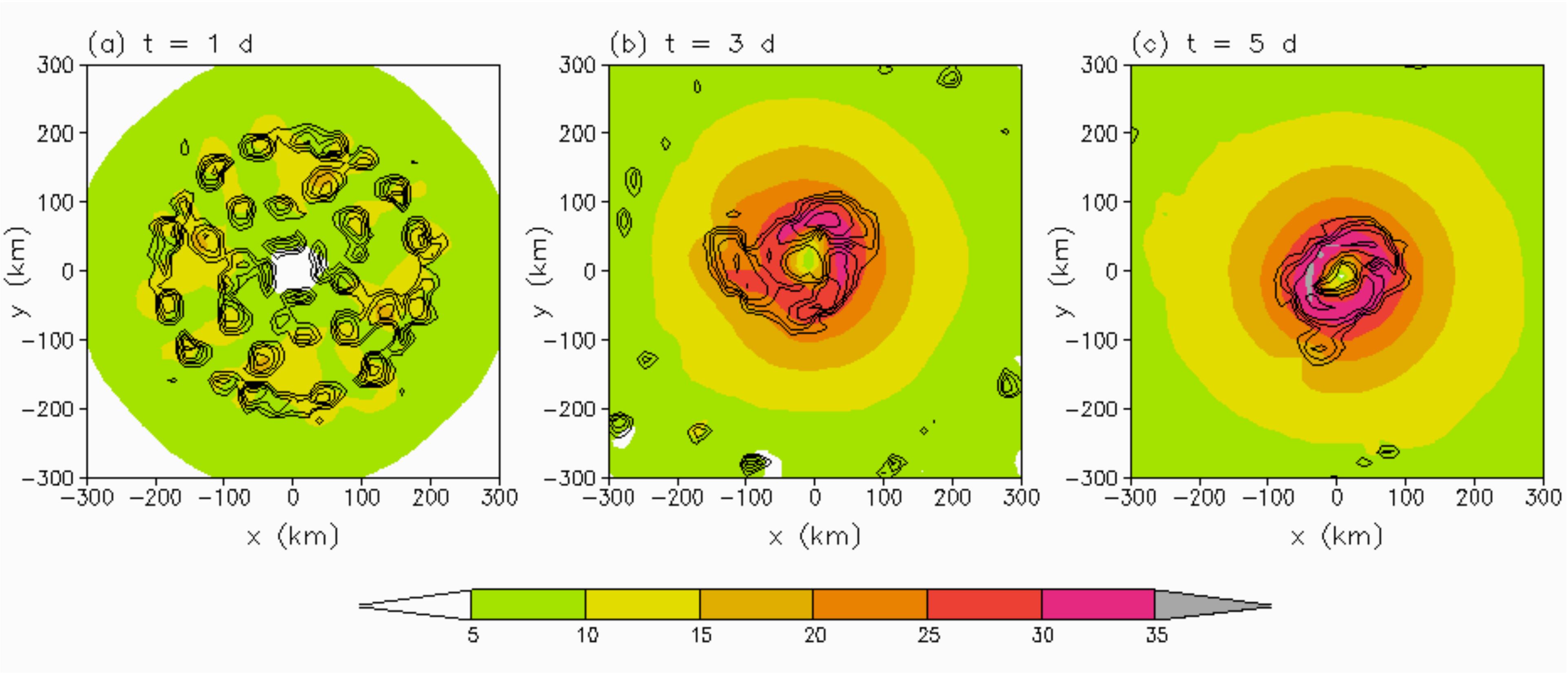
colors = relative humidity (%)
contours = azimuthal velocity (m/s)

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 tropical cyclone test case: Results



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

More on Idealized Cases ..

Descriptions:

WRFV3/README_test_cases
WRFV3/test/em_*/README