An EDMF comparison

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Introduction

This document describes the setup for the Stevens (2007) and ARM ideal cases, including initial conditions and required data files. Prototype runs with the TEMF scheme in WRF are used as examples. The document is a work in progress, please send comments and/or questions to Wayne Angevine (email above).

Many Eddy Diffusivity – Mass Flux (EDMF) parameterizations exist or are planned. They all use the same conceptual framework, but differ in detailed ways that could be important. A single-column comparison study is proposed to understand the impact of different implementations. Two simple cases with strong theoretical or observational backing are suggested.

Science questions:

1. Do EDMF schemes produce the expected results for well-characterized cases?

2. How different are the results from different schemes?

3. Can differences in results be attributed to choices in scheme design?

Stevens case setup

- Specified surface buoyancy flux (see below for details)
- PBL schemes only
- No radiation

- Vertical resolution at participants' discretion
- All simulations run for 30 hours
- Moisture in air at the surface is 0.9 times the saturation value at the surface (skin) temperature (note that this differs from 0.8 in Stevens 2007).
- Surface pressure 1000 mb for simplicity
- No geostrophic wind (mean u and v = 0 at all times)

Run number	Buoyancy flux (m^2s^{-3})	Theta lapse rate Γ ($K\ km^{-1}$)	Moisture scale height γ (m)
1	7.0x10-4	6	1500
2	4.2x10-4	6	1500
3	11.2x10-4	6	1500
4	7.0x10-4	8	1500
5	7.0x10-4	4	1500

Table 1: Simulations to be run for the ideal case, selected from Table 2 of Stevens (2007).

Surface buoyancy flux is specified, sensible and latent heat fluxes must be calculated. Fortran code is provided in the Appendix.

Initial profiles may be calculated with the Matlab code, also provided in the Appendix.

ARM case setup

- Specified surface sensible and latent heat fluxes (Table 2) as in EUROCS ARM case specifications (http://www.knmi.nl/samenw/eurocs/ARM/index.html)
- Skin temperature, near-surface moisture, and surface friction must be calculated
- PBL schemes only
- No radiation
- Vertical resolution at participants' discretion
- Simulation runs for 15 hours

- Surface pressure 970 mb (be careful, theta and T are not equal at the surface!)
- Geostrophic wind u=10, v = 0 at all times
- Advection and radiation tendencies as specified in Table 2

Table 2: Advective and Radiative tendencies of potential temperature and total water on a regular time grid. NOTE units! Adapted from EUROCS ARM case specifications.

Time (hr)	Sensible heat flux ($W\ m^{-2}$)	Latent heat flux ($W\ m^{-2}$)	dthdt ($K\ h^{-1}$)	dqtdt ($g/kg\ h^{-1}$)
0	-30	5.000	-0.1250	0.0800
0.5000	-15	35.625	-0.1042	0.0700
1.0000	0	66.250	-0.0833	0.0600
1.5000	15	96.875	-0.0625	0.0500
2.0000	30	127.500	-0.0417	0.0400
2.5000	45	158.125	-0.0208	0.0300
3.0000	60	188.750	0	0.0200
3.5000	75	219.375	0	0.0100
4.0000	90	250.000	0	0.0000
4.5000	100	290.000	0	-0.0100
5.0000	110	330.000	0	-0.0200
5.5000	120	370.000	0	-0.0300
6.0000	130	410.000	0	-0.0400
6.5000	140	450.000	-0.0133	-0.0500
7.0000	140	475.000	-0.0267	-0.0600
7.5000	140	500.000	-0.0400	-0.0700
8.0000	132	484.000	-0.0533	-0.0800
8.5000	124	468.000	-0.0667	-0.0900
9.0000	116	452.000	-0.0800	-0.1000
9.5000	108	436.000	-0.0933	-0.1100
10.0000	100	420.000	-0.1067	-0.1200
10.5000	78	372.000	-0.1200	-0.1300
11.0000	56	324.000	-0.1333	-0.1400
11.5000	34	276.000	-0.1467	-0.1500
12.0000	12	228.000	-0.1600	-0.1600
12.5000	-10	180.000	-0.1800	-0.1880
13.0000	-10	135.000	-0.2000	-0.2160
13.5000	-10	90.000	-0.2200	-0.2440
14.0000	-10	45.000	-0.2400	-0.2720
14.5000	-10	0	-0.2600	-0.3000

Output

Output is to be provided in two files, one each for profiles and 1D time series, plus a text file describing the model. Profiles and time series should be given at ten-minute intervals. For file names, "case" is the case abbreviation (“STE” or “ARM”), “model code” is a four-character code chosen by the participant (e.g. “TEMF”) and “version number” is a two digit number indicating the version of output (e.g. 01). No decimal point in the number, please.

Model description file:

Vertical grid spacing, staggering, and terminology. How many levels, how specified. What variables are on which type of levels.

Values of all relevant constants, especially those used to calculate saturation.

Time series file: Name ts_<case>_<model code>_v<version number>.txt (e.g. ts_STE_TEMF_v01.txt)

Format: Space-separated ASCII, one row for each time (10 minute intervals)

Columns: Time (hhmm), skin temperature (K), sensible heat flux (W/m^2), latent heat flux (W/m^2), potential temperature at lowest model level (K), water vapor mixing ratio at lowest model level (g/kg), lifting condensation level (m), maximum cloud fraction in the column, cloud top height (m)

Other columns may be added after these nine, give details in the model description file

Profile file: Name pr_<case>_<model code>_v<version number>.nc (e.g. pr_ARM_TEMF_v01.nc)

Format: netCDF – adapted from format for ASTEX comparison

(http://www.euclipse.nl/wp3/ASTEX_Lagrangian/SCM_output.shtml)

Dimensions:

{time} Number of output times (should be 180 for STE, 90 for ARM)

{zf} Number of layers (“full” levels) NOTE explain terminology in the model description file!

{zh} Number of layers (“half” levels)

Independent variables:

{time} Time [s] (10-minute intervals)

Required dependent variables, indexed (time and zf or zh):

{zf} Altitude of “full” levels [m]

{zh} Altitude of “half” levels [m]

{pres} Pressure [Pa]

{theta} Potential temperature [K]

{qv} Water vapor [g/kg]

{ql} condensed water (liquid) [g/kg]

{cf} cloud fraction [0-1]

{rho} density [kg/m^3]

Required for ARM case only:

{zforce} Altitude of forcing levels [m] (may be same as model levels above, or not)

{theta_tend} Radiative + advective tendency of theta [K/s]

{q_tend} Advective tendency of water vapor [g g^{-1} s^{-1}]

Optional dependent variables (feel free to provide any variables you like, with explanation in the model description file):

{wthl} thetal flux [K m/s]

{wth} theta flux [K m/s]

{wqt} qt flux [kg/kg m/s]

{wqv} qv flux [kg/kg m/s]

{wql} ql flux [kg/kg m/s]

{Mf} Mass flux [kg/(m ^2 s)]

{prec} Precipitation flux (positive downward) [kg m/s?]

{w_up} vertical velocity in the updraft [m/s]

{thl_up} potential liquid water temperature l,u in cloudy updraft [K]

{qt_up} total water specific humidity in the cloudy updraft [g/kg]

{ql_up} liquid water in cloudy updraft [g/kg]

{thv_up} potential virtual temperature v,u in cloudy updraft [K]

{TKE} turbulent kinetic energy [m^2/s^2]

Notes

1. Stevens (2007) eq. 8 has an error. The first term (theta0/g) should be inverted.

Timeline

Commitments to participate: 1 February 2013

Initial data submission: 1 April 2013

Future additions:

Optional tracers: Two passive tracers, emitted at constant rates at the surface and at/above the top of the PBL. Tracers provide direct visualization of vertical mixing. Participants will be encouraged to also participate in the proposed GABLS tracer study, and tracer specifications for this study will be the same.

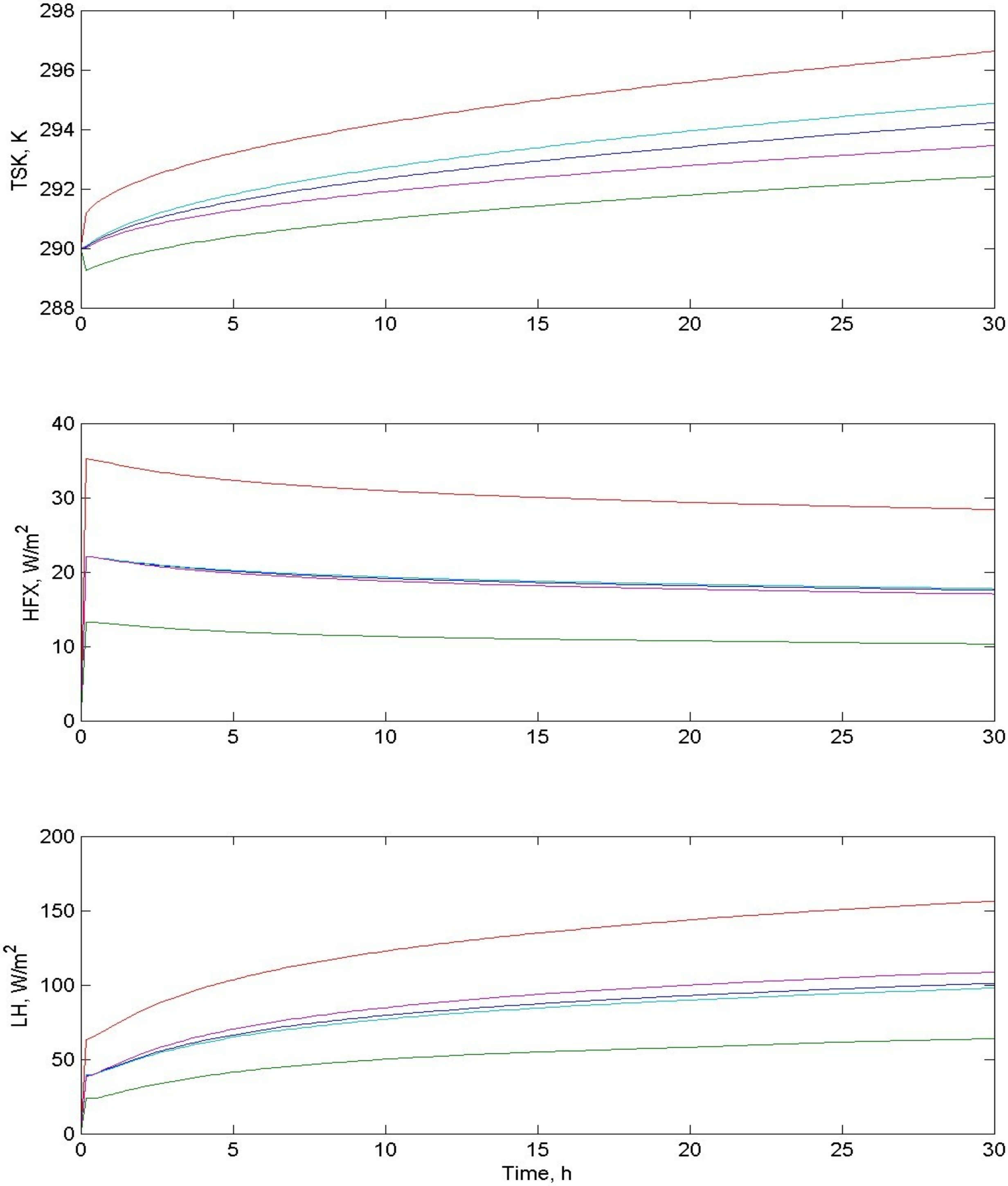
Appendix

Fortran code to calculate surface fluxes from specified buoyancy flux for the STE case:

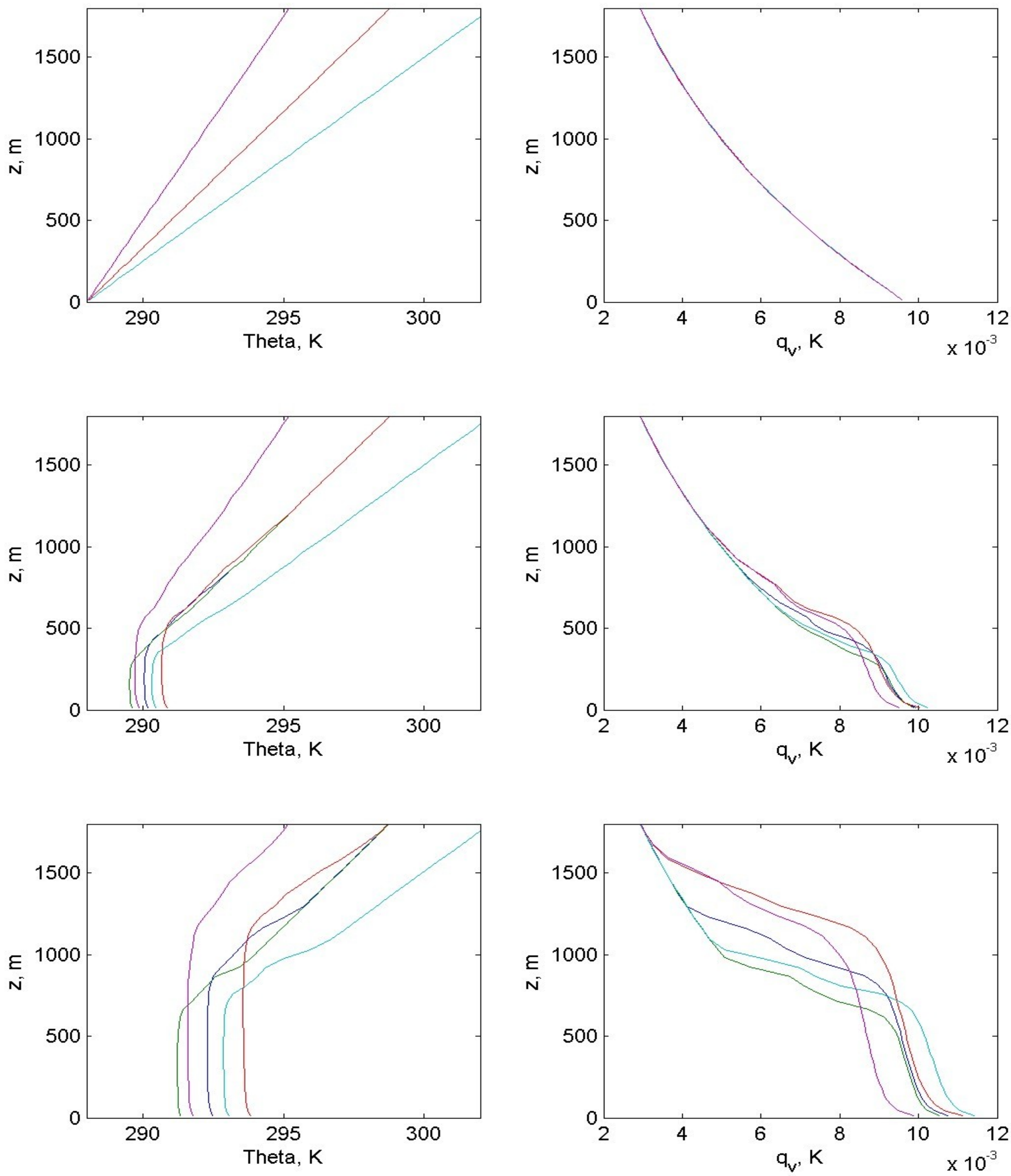
```
! Variable explanations
! tsk = skin temperature
! e1 = an intermediate result
! psfc = surface pressure (Pa)
! qv1d = water vapor mixing ratio in the column
! th1d = potential temperature in the column
! kqfx = exchange coefficient for water vapor (used in qfx calculation below)
! Constants for saturation calculation:
R_d = 287.0
R_v = 461.6
ep2 = R_d/R_v
svp1 = 0.6112
svp2 = 17.67
svp3 = 29.65
svpt0 = 273.15

! Beta0 = 7e-4   ! Fixed specified buoyancy flux (25 W/m^2)
! Beta0 = 4.2e-4   ! Fixed specified buoyancy flux (15 W/m^2)
Beta0 = 11.2e-4   ! Fixed specified buoyancy flux (40 W/m^2)
Vs = 0.01      ! Specified velocity scale
mav = 0.90    ! Surface moisture availability

do i = its,ite      ! Main loop (over one horizontal dimension)

  ! Calculate saturation mixing ratio at SST (from previous timestep)
  ! The rest of the buoyancy flux goes to sensible heat
  ! Calculate surface saturated q and q in air at surface
  e1=svp1*exp(svp2*(tsk(i)-svpt0)/(tsk(i)-svp3))
  qsfc(i)=ep2*e1/((psfc(i)/1000.)-e1)
  qsfc_air(i) = qsfc(i) * mav

  ! Calculate hfx,qfx, and SST to keep buoyancy flux constant
  ! Could calculate moisture flux first, but should be OK either way
  kqfx(i) = Vs * (qsfc_air(i) - qv1d(i))
  khfx(i) = Beta0 * th1d(i)/g - 0.608 * th1d(i) * kqfx(i)
  tsk(i) = khfx(i) / Vs + th1d(i)

  ! Convert units
  hfx(i) = rho(i) * cp * khfx(i)
  qfx(i) = rho(i) * kqfx(i)
  lh(i)= xlv * qfx(i)

end do  ! Main loop
```

Matlab script to make input_sounding file

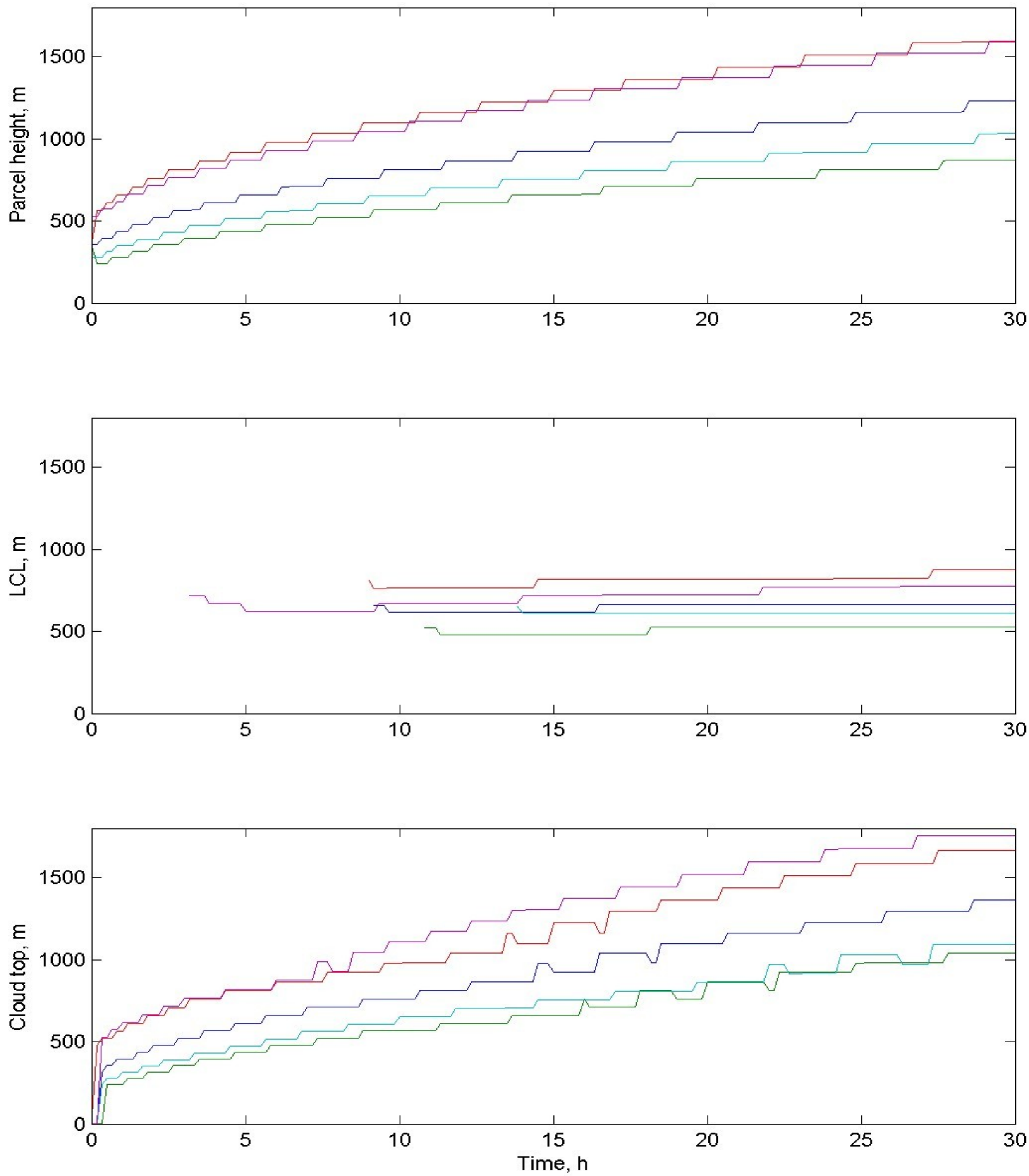
```
% make_input_sounding.m
% Makes input sounding table for Stevens EDMF comparison case.

gamma = 4e-3;    % Theta lapse rate (K/m)
lambda = 1500;   % Scale height for moisture (m)
theta0 = 288;    % Surface theta
p0 = 1000;       % Surface pressure
nhts = 50;
qsfc_factor = 0.9;  % Factor to reduce surface air q from water surface q

q0 = rsat(theta0-273,p0);
q0p = qsfc_factor .* q0;

for i = 1:nhts
	z(i) = 100.*i;
	q(i) = q0p .* exp(-z(i)./lambda);
	theta(i) = theta0 + z(i).*gamma;
end

fstr = ['input_sounding_',num2str(gamma.*1000),'_',num2str(qsfc_factor.*10),'.txt']
fid = fopen(fstr,'w');
fprintf(fid,'%3.1f %3.1f %3.1f %6.2f %7.5f %8.1f\n',0,0,0,theta0,q0p,p0.*100);
for i = 1:nhts
	fprintf(fid,'%7.1f %3.2f %3.2f %6.2f %7.5f\n',z(i),0,0,theta(i),q(i));
end
fclose(fid);
```



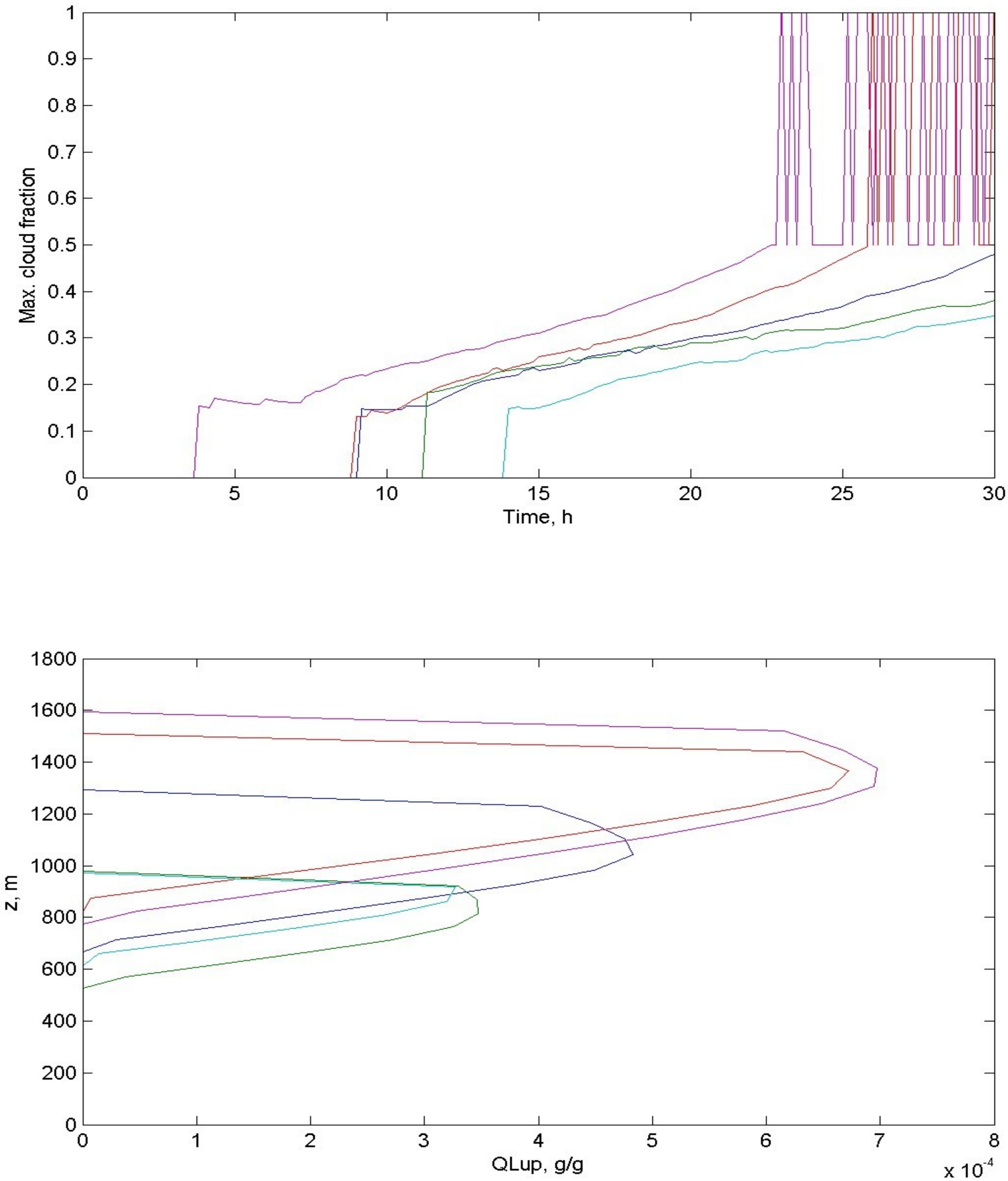
Example Figure 1: Skin temperature and fluxes for the five STE runs with WRF-TEMF. Blue = run 1, green = 2, red = 3, cyan = 4, magenta = 5.



Example Figure 2: Potential temperature and water vapor profiles at times 0, 24000, and 96000 s for the five STE runs with WRF-TEMF. Blue = run 1, green = 2, red = 3, cyan = 4, magenta = 5.



Example Figure 3: Parcel method BL height, lifting condensation level, and cloud top for the five STE runs with WRF-TEMF. Blue = run 1, green = 2, red = 3, cyan = 4, magenta = 5.



Example Figure 4: Column maximum cloud fraction (top) vs. time and updraft liquid water at time 96000 s for the five STE runs with WRF-TEMF. Blue = run 1, green = 2, red = 3, cyan = 4, magenta = 5.