AMS Short Course on Experimentation and Development of Physical Parameterizations for Numerical Weather Prediction Using a Single-Column Model and the Common Community Physics Package (CCPP)

Hands-on Exercises Supplemental Slides

Suite Definition File (SDF) Syntax

```
<?xml version="1.0" encoding="UTF-8"?>

<suite name="MyFirstSDF" lib="ccppphys" ver="4">
  <group name="group_name">
    <subcycle loop="1">
      <scheme>scheme_name</scheme>
    </subcycle>
  </group>
</suite>
```

SDF Syntax

name of the suite,
for example
SCM_GFS_v15p2

```
<?xml version="1.0" encoding="UTF-8"?>

<suite name=”MyFirstSDF" lib="ccppphys" ver=”4">
  <group name="group_name">
    <subcycle loop="1">
      <scheme>scheme_name</scheme
    </subcycle>
  </group>
</suite>
```

don’t change

SDF Syntax

name of the group of
schemes to run, e.g.
physics, radiation, time_vary

```
<?xml version="1.0" encodi

<suite name=”MyFirstSDF" lib="ccppphys" ver=”4">
  <group name="group_name">
    <subcycle loop="1">
      <scheme>scheme_name</scheme>
    </subcycle>
  </group>
</suite>
```

SDF Syntax

```
<?xml version="1.0" encodi

<suite name=”MyFirstSDF" lib=
  <group name="group_name">
    <subcycle loop="1">
      <scheme>scheme_name</scheme>
    </subcycle>
  </group>
</suite>
```

how often to run the group per physics time step (can use for surface iteration)

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SDF Syntax

```
<?xml version="1.0" encodin

<suite name="MyFirstSDF" li
  <group name="group_name">
    <subcycle loop="1">
      <scheme>scheme_name</scheme>
    </subcycle>
  </group>
</suite>
```

name of the scheme to run,
e.g. gfdl_cloud_microphys

GFS_v15p2 vs "csawmg"

Vast majority of two suites are identical

suite_SCM_GFS_v15p2.xml

```
<group name="physics">
  <subcycle loop="1">
    <scheme>GFS_suite_interstitial_phys_reset</scheme
    <scheme>GFS_suite_stateout_reset</scheme>
       ne>get_prs_fv3</scheme>
              uite_interstitial_1</scheme>
                ace_generic_pre</scheme>
                  e_composites_pre</scheme>
                    heme>
                     composites_inter</scheme>
                     terstitial_2</scheme>

                ion loop -->
            2">
          c_diff</scheme>
     scheme>GFS_surface_loop_control_part1</scheme>
    <scheme>sfc_nst_pre</scheme>
    <scheme>sfc_nst</scheme>
    <scheme>sfc_nst_post</scheme>
    <scheme>lsm_noah</scheme>
    <scheme>sfc_sice</scheme>
    <scheme>GFS_surface_loop_control_part2</scheme>
  </subcycle>
  <!-- End of surface iteration loop -->
  <subcycle loop="1">
    <scheme>GFS_surface_composites_post</scheme>
    <scheme>dcyc2t3_post</scheme>
    <scheme>sfc_diag</scheme>
    <scheme>sfc_diag_post</scheme>
    <scheme>GFS_surface_generic_post</scheme>
    <scheme>GFS_PBL_generic_pre</scheme>
    <scheme>hedmf</scheme>
    <scheme>GFS_PBL_generic_post</scheme>
    <scheme>GFS_GWD_generic_pre</scheme>
    <scheme>cires_ugwp</scheme>
    <scheme>cires_ugwp_post</scheme>
    <scheme>GFS_GWD_generic_post</scheme>
    <scheme>rayleigh_damp</scheme>
    <scheme>GFS_suite_stateout_update</scheme>
    <scheme>ozphys_2015</scheme>
    <scheme>h2ophys</scheme>
    <scheme>GFS_DCNV_generic_pre</scheme>
    <scheme>get_phi_fv3</scheme>
    <scheme>GFS_suite_interstitial_3</scheme>
    <scheme>samfdeepcnv</scheme>
    <scheme>GFS_DCNV_generic_post</scheme>
    <scheme>GFS_SCNV_generic_pre</scheme>
    <scheme>samfshalcnv</scheme>
    <scheme>GFS_SCNV_generic_post</scheme>
    <scheme>GFS_suite_interstitial_4</scheme>
    <scheme>cnvc90</scheme>
    <scheme>GFS_MP_generic_pre</scheme>
    <scheme>gfdl_cloud_microphys</scheme>
    <scheme>GFS_MP_generic_post</scheme>
    <scheme>maximum_hourly_diagnostics</scheme>
  </subcycle>
</group>
suite>
```

suite_SCM_csawmg.xml

```
    <scheme>get_prs_fv3</scheme>
    <scheme>GFS_suite_interstitial_1</scheme>
    <scheme>GFS_surface_generic_pre</scheme>
    <scheme>GFS_surface_composites_pre</scheme>
    <scheme>dcyc2t3</scheme>
    <scheme>GFS_surface_composites_inter</scheme>
    <scheme>GFS_suite_interstitial_2</scheme>
  </subcycle>
  <!-- Surface iteration loop -->
  <subcycle loop="2">
    <scheme>sfc_diff</scheme>
    <scheme>GFS_surface_loop_control_part1</scheme>
    <scheme>sfc_nst_pre</scheme>
    <scheme>sfc_nst</scheme>
    <scheme>sfc_nst_post</scheme>
    <scheme>lsm_noah</scheme>
    <scheme>sfc_sice</scheme>
    <scheme>GFS_surface_loop_control_part2</scheme>
  </subcycle>
  <!-- End of surface iteration loop -->
  <subcycle loop="1">
    <scheme>GFS_surface_composites_post</scheme>
    <scheme>dcyc2t3_post</scheme>
    <scheme>sfc_diag</scheme>
    <scheme>sfc_diag_post</scheme>
    <scheme>GFS_surface_generic_post</scheme>
    <scheme>GFS_PBL_generic_pre</scheme>
    <scheme>hedmf</scheme>
    <scheme>GFS_PBL_generic_post</scheme>
    <scheme>GFS_GWD_generic_pre</scheme>
    <scheme>cires_ugwp</scheme>
    <scheme>cires_ugwp_post</scheme>
    <scheme>GFS_GWD_generic_post</scheme>
    <scheme>rayleigh_damp</scheme>
    <scheme>GFS_suite_stateout_update</scheme>
    <scheme>ozphys_2015</scheme>
    <scheme>h2ophys</scheme>
    <scheme>GFS_DCNV_generic_pre</scheme>
    <scheme>get_phi_fv3</scheme>
    <scheme>GFS_suite_interstitial_3</scheme>
    <scheme>cs_conv_pre</scheme>
    <scheme>cs_conv</scheme>
    <scheme>cs_conv_post</scheme>
    <scheme>GFS_DCNV_generic_post</scheme>
    <scheme>GFS_SCNV_generic_pre</scheme>
    <scheme>samfshalcnv</scheme>
    <scheme>GFS_SCNV_generic_post</scheme>
    <scheme>GFS_suite_interstitial_4</scheme>
    <scheme>cnvc90</scheme>
    <scheme>GFS_MP_generic_pre</scheme>
    <scheme>m_micro_pre</scheme>
    <scheme>m_micro</scheme>
    <scheme>m_micro_post</scheme>
    <scheme>cs_conv_aw_adj</scheme>
    <scheme>GFS_MP_generic_post</scheme>
    <scheme>maximum_hourly_diagnostics</scheme>
  </subcycle>
</group>
```

GFS_v15p2 vs GSD_v1

suite_SCM_GFS_v15p2.xml

```
</group>
<group name="physics">
  <subcycle loop="1">
    <scheme>GFS_suite_interstitial_phys_reset</scheme>
          GFS_suite_stateout_reset</scheme>
             rs_fv3</scheme>
               te_interstitial_1</scheme>
               e_generic_pre</scheme>
                composites_pre</scheme>
                heme>
                composites_inter</scheme>
               interstitial_2</scheme>

              ration loop -->
           op="2">
    cheme>sfc_diff</scheme>
    <scheme>GFS_surface_loop_control_part1</scheme>
    <scheme>sfc_nst_pre</scheme>
    <scheme>sfc_nst</scheme>
    <scheme>sfc_nst_post</scheme>
    <scheme>lsm_noah</scheme>
    <scheme>sfc_sice</scheme>
    <scheme>GFS_surface_loop_control_part2</scheme>
  </subcycle>
  <!-- End of surface iteration loop -->
  <subcycle loop="1">
    <scheme>GFS_surface_composites_post</scheme>
    <scheme>dcyc2t3_post</scheme>
    <scheme>sfc_diag</scheme>
    <scheme>sfc_diag_post</scheme>
    <scheme>GFS_surface_generic_post</scheme>
    <scheme>GFS_PBL_generic_pre</scheme>
    <scheme>hedmf</scheme>
    <scheme>GFS_PBL_generic_post</scheme>
    <scheme>GFS_GWD_generic_pre</scheme>
    <scheme>cires_ugwp</scheme>
    <scheme>cires_ugwp_post</scheme>
    <scheme>GFS_GWD_generic_post</scheme>
    <scheme>rayleigh_damp</scheme>
    <scheme>GFS_suite_stateout_update</scheme>
    <scheme>ozphys_2015</scheme>
    <scheme>h2ophys</scheme>
    <scheme>GFS_DCNV_generic_pre</scheme>
    <scheme>get_phi_fv3</scheme>
    <scheme>GFS_suite_interstitial_3</scheme>
    <scheme>samfdeepcnv</scheme>
    <scheme>GFS_DCNV_generic_post</scheme>
    <scheme>GFS_SCNV_generic_pre</scheme>
    <scheme>samfshalcnv</scheme>
    <scheme>GFS_SCNV_generic_post</scheme>
    <scheme>GFS_suite_interstitial_4</scheme>
    <scheme>cnvc90</scheme>
    <scheme>GFS_MP_generic_pre</scheme>
    <scheme>gfdl_cloud_microphys</scheme>
    <scheme>GFS_MP_generic_post</scheme>
    <scheme>maximum_hourly_diagnostics</scheme>
  </subcycle>
</group>
```

suite_SCM_GSD_v1.xml

```
    <scheme>GFS_suite_interstitial_phys_reset</schem
    <scheme>GFS_suite_stateout_reset</scheme>
    <scheme>get_prs_fv3</scheme>
    <scheme>GFS_suite_interstitial_1</scheme>
    <scheme>GFS_surface_generic_pre</scheme>
    <scheme>GFS_surface_composites_pre</scheme>
    <scheme>dcyc2t3</scheme>
    <scheme>GFS_surface_composites_inter</scheme>
    <scheme>GFS_suite_interstitial_2</scheme>
  </subcycle>
  <!-- Surface iteration loop -->
  <subcycle loop="2">
    <scheme>sfc_diff</scheme>
    <scheme>GFS_surface_loop_control_part1</scheme>
    <scheme>sfc_nst_pre</scheme>
    <scheme>sfc_nst</scheme>
    <scheme>sfc_nst_post</scheme>
    <scheme>lsm_ruc</scheme>
    <scheme>lsm_ruc_sfc_sice_pre</scheme>
    <scheme>sfc_sice</scheme>
    <scheme>lsm_ruc_sfc_sice_post</scheme>
    <scheme>GFS_surface_loop_control_part2</scheme>
  </subcycle>
  <!-- End of surface iteration loop -->
  <subcycle loop="1">
    <scheme>GFS_surface_composites_post</scheme>
    <scheme>dcyc2t3_post</scheme>
    <scheme>sfc_diag</scheme>
    <scheme>sfc_diag_post</scheme>
    <scheme>GFS_surface_generic_post</scheme>
    <scheme>mynnedmf_wrapper</scheme>
    <scheme>GFS_GWD_generic_pre</scheme>
    <scheme>cires_ugwp</scheme>
    <scheme>cires_ugwp_post</scheme>
    <scheme>GFS_GWD_generic_post</scheme>
    <scheme>rayleigh_damp</scheme>
    <scheme>GFS_suite_stateout_update</scheme>
    <scheme>ozphys_2015</scheme>
    <scheme>h2ophys</scheme>
    <scheme>GFS_DCNV_generic_pre</scheme>
    <scheme>get_phi_fv3</scheme>
    <scheme>GFS_suite_interstitial_3</scheme>
    <scheme>cu_gf_driver_pre</scheme>
    <scheme>cu_gf_driver</scheme>
    <scheme>GFS_DCNV_generic_post</scheme>
    <scheme>GFS_SCNV_generic_pre</scheme>
    <scheme>GFS_SCNV_generic_post</scheme>
    <scheme>GFS_suite_interstitial_4</scheme>
    <scheme>cnvc90</scheme>
    <scheme>GFS_MP_generic_pre</scheme>
    <scheme>mp_thompson_pre</scheme>
    <scheme>mp_thompson</scheme>
    <scheme>mp_thompson_post</scheme>
    <scheme>GFS_MP_generic_post</scheme>
    <scheme>cu_gf_driver_post</scheme>
    <scheme>maximum_hourly_diagnostics</scheme>
  </subcycle>
</group>
```

Vast majority of two suites are identical

*also added interstitial schemes to pass SGS clouds from MYNN PBL scheme to radiation in the radiation group

Case Configuration Namelist

Defines which initial conditions and forcing to use

Determines how forcing terms are applied

Determines whether using LSM or specified values for surface fluxes

```
$case_config
model_name = 'FV3',
n_columns = 1,
case_name = 'twpice',
dt = 600.0,
time_scheme = 1,
runtime = 2138400,
output_frequency = 600.0,
n_levels = 64,
output_file = 'output',
case_data_dir = '../data/processed_case_input',
vert_coord_data_dir = '../data/vert_coord_data',
thermo_forcing_type = 2,
mom_forcing_type = 3,
relax_time = 7200.0,
sfc_flux_spec = .false.,
sfc_type = 0,
reference_profile_choice = 1,
year = 2006,
month = 1,
day = 19,
hour = 3,
column_area = 2.0E9,
$end
```

Case Data File Format

```
netcdf arm_sgp_summer_1997_A {
dimensions:
        time = UNLIMITED ; // (32 currently)
        levels = UNLIMITED ; // (35 currently)
variables:
        float time(time) ;
                time:units = "s" ;
                time:description = "elapsed time since the beginning of the simulation" ;
        float levels(levels) ;
                levels:units = "Pa" ;
                levels:description = "pressure levels" ;

// global attributes:
                :description = "GMTB SCM forcing file for the ARM SGP Summer of 1997 case (Pe

group: scalars {
  variables:
        float lat ;
                lat:units = "degrees N" ;
                lat:description = "latitude of column" ;
        float lon ;
                lon:units = "degrees E" ;
                lon:description = "longitude of column" ;
  } // group scalars
```

Case Data File Format

```
group: initial {
  variables:
        float thetail(levels) ;
                thetail:units = "K" ;
                thetail:description = "initial profile of ice-liquid water potential temperatu
        float qt(levels) ;
                qt:units = "kg kg^-1" ;
                qt:description = "initial profile of total water specific humidity" ;
        float ql(levels) ;
                ql:units = "kg kg^-1" ;
                ql:description = "initial profile of liquid water specific humidity" ;
        float qi(levels) ;
                qi:units = "kg kg^-1" ;
                qi:description = "initial profile of ice water specific humidity" ;
        float u(levels) ;
                u:units = "m s^-1" ;
                u:description = "initial profile of E-W horizontal wind" ;
        float v(levels) ;
                v:units = "m s^-1" ;
                v:description = "initial profile of N-S horizontal wind" ;
        float tke(levels) ;
                tke:units = "m^2 s^-2" ;
                tke:description = "initial profile of turbulence kinetic energy" ;
        float ozone(levels) ;
                ozone:units = "kg kg^-1" ;
                ozone:description = "initial profile of ozone mass mixing ratio" ;
  } // group initial
```

Case Data File Format

```
group: forcing {
  variables:
        float p_surf(time) ;
                p_surf:units = "Pa" ;
                p_surf:description = "surface pressure" ;
        float T_surf(time) ;
                T_surf:units = "K" ;
                T_surf:description = "surface absolute temperature" ;
        float sh_flux_sfc(time) ;
                sh_flux_sfc:units = "K m s^-1" ;
                sh_flux_sfc:description = "surface sensible heat flux" ;
        float lh_flux_sfc(time) ;
                lh_flux_sfc:units = "kg kg^-1 m s^-1" ;
                lh_flux_sfc:description = "surface latent heat flux" ;
        ...

        float omega(levels, time) ;
                omega:units = "Pa s^-1" ;
                omega:description = "large scale pressure vertical velocity" ;
        float v_advec_thetail(levels, time) ;
                v_advec_thetail:units = "K s^-1" ;
                v_advec_thetail:description = "prescribed theta_il tendency due to vertical ad
        float h_advec_qt(levels, time) ;
                h_advec_qt:units = "kg kg^-1 s^-1" ;
                h_advec_qt:description = "prescribed q_t tendency due to horizontal advection"
        float v_advec_qt(levels, time) ;
                v_advec_qt:units = "kg kg^-1 s^-1" ;
                v_advec_qt:description = "prescribed q_t tendency due to vertical advection" ;
  } // group forcing
```

Run Script Options

- Single Run
  - ./run_gmtb_scm.py -c CASE_NAME [-s SUITE_NAME] [-n PHYSICS_NAMELIST_WITH_PATH] [-g]
- Multiple Runs
  - ./multi_run_gmtb_scm.py {[-c CASE_NAME] [-s SUITE_NAME] [-f PATH_TO_FILE]} [-v{v}] [-t]
  - If no arguments, will run through all permutations of supported suites and cases
  - Optionally specify one of CASE_NAME, SUITE_NAME, PATH_TO_FILE
  - -v,-vv for more verbose output
  - -t for timing the runs

Multiple Runs Configuration File

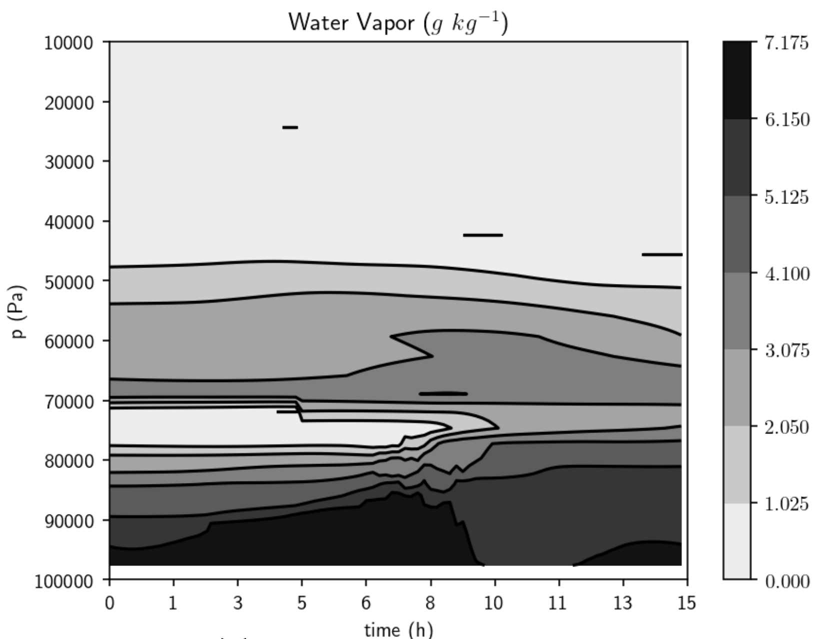
gmtb-scm/scm/src/short_course_runs.py

```
cases = ["twpice","LASSO_2016051812"]
suites = ["SCM_GFS_v15p2","SCM_GSD_v1","SCM_csawmg"]
namelists = 
["input_GFS_v15p2.nml","input_GSD_v1.nml","input_csawmg.nml"]
```

Running…

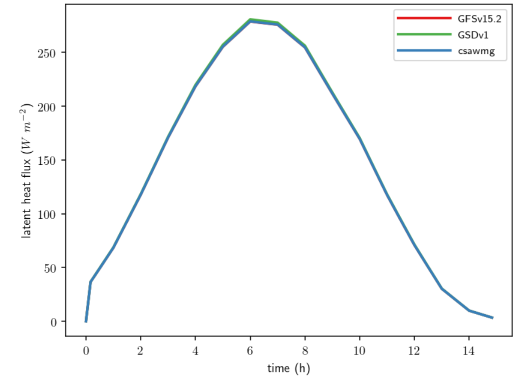
```
(py2) bin>./multi_run_gmtb_scm.py -f ../src/short_course_runs.py
INFO: Importing ../src/short_course_runs.py to run requested combinations
INFO: Cases, suites, and namelists were specified in ../src/short_course_runs.py, so running all cases with all suites,
INFO: Executing process 1 of 6 (./run_gmtb_scm.py -c twpice -s SCM_GFS_v15p2 -n input_GFS_v15p2.nml)
INFO: Executing process 2 of 6 (./run_gmtb_scm.py -c twpice -s SCM_GSD_v1 -n input_GSD_v1.nml)
INFO: Executing process 3 of 6 (./run_gmtb_scm.py -c twpice -s SCM_csawmg -n input_csawmg.nml)
INFO: Executing process 4 of 6 (./run_gmtb_scm.py -c LASSO_2016051812 -s SCM_GFS_v15p2 -n input_GFS_v15p2.nml)
INFO: Executing process 5 of 6 (./run_gmtb_scm.py -c LASSO_2016051812 -s SCM_GSD_v1 -n input_GSD_v1.nml)
INFO: Executing process 6 of 6 (./run_gmtb_scm.py -c LASSO_2016051812 -s SCM_csawmg -n input_csawmg.nml)
```

LASSO Case Overview

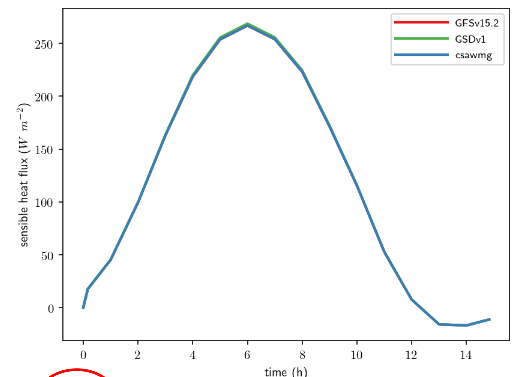


Time →

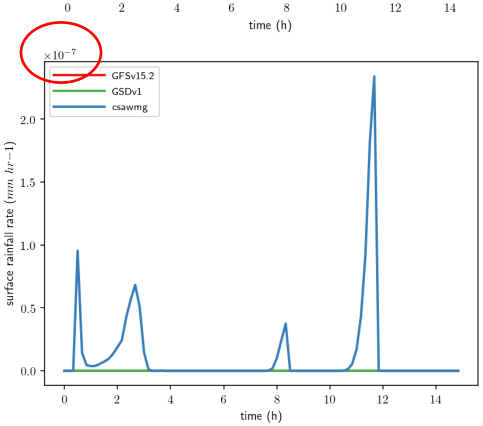
Sensible heat flux



Latent heat flux



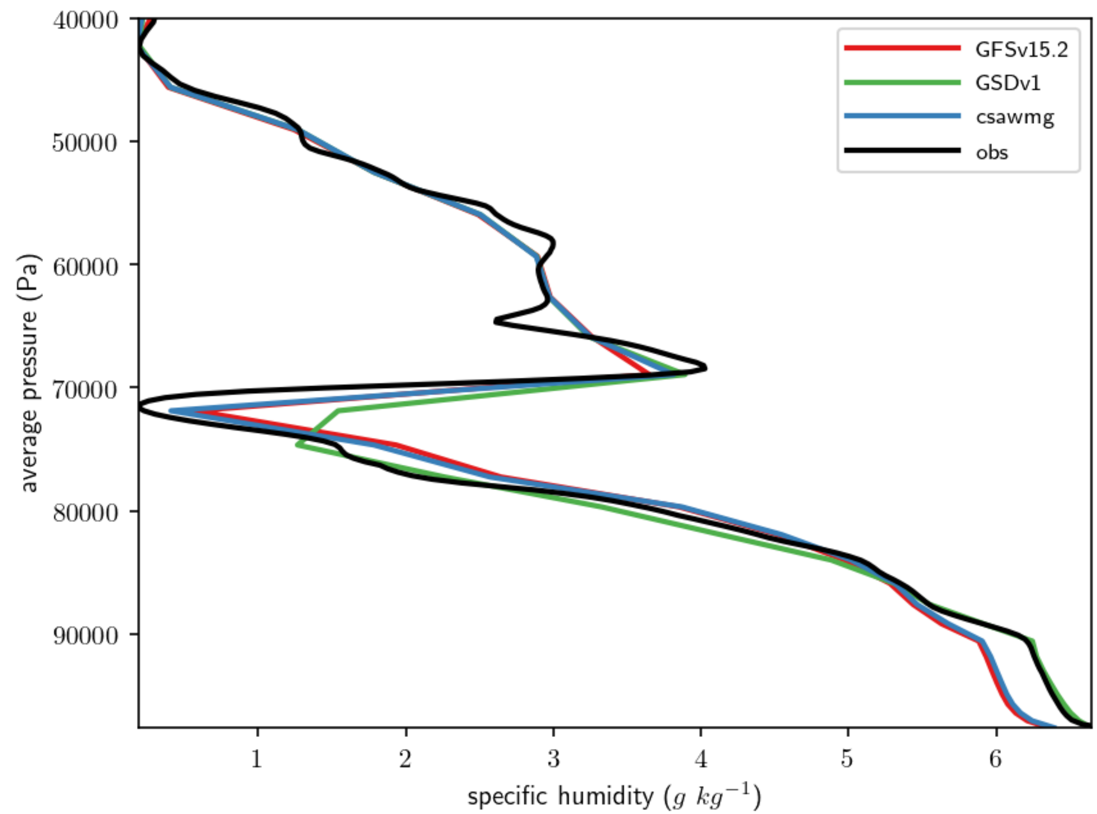
Surface precip.



LASSO Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_LASSO_2016051812/comp/full`

`profiles_mean_qv.png`



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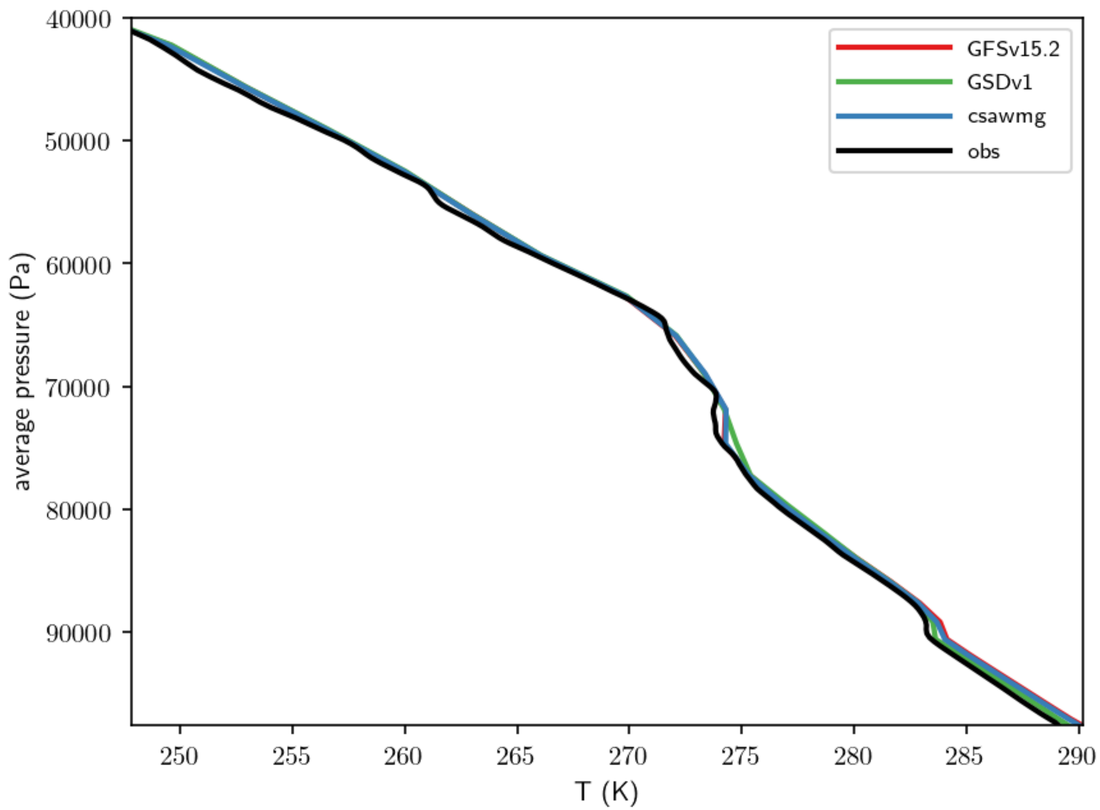
LASSO Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_LASSO_2016051812/comp/full`

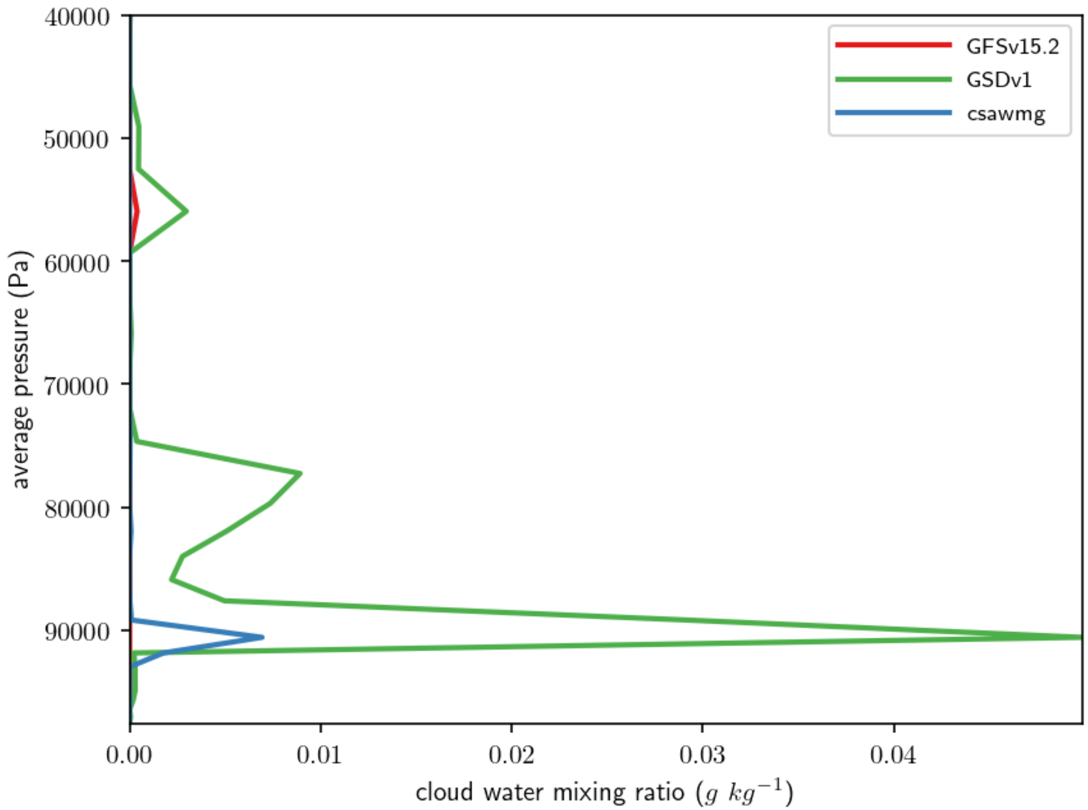
`profiles_mean_T.png`



LASSO Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_LASSO_2016051812/comp/full`

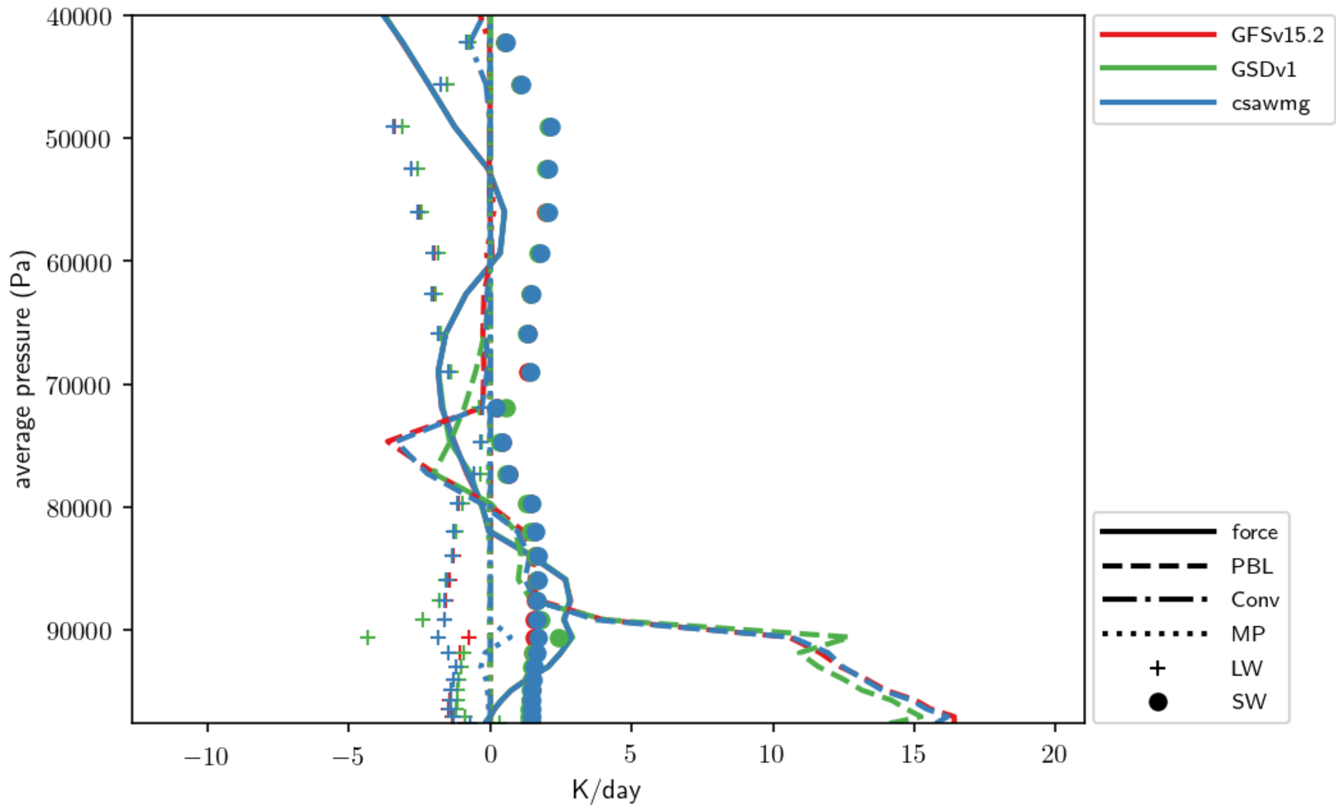
`profiles_mean_qc.png`



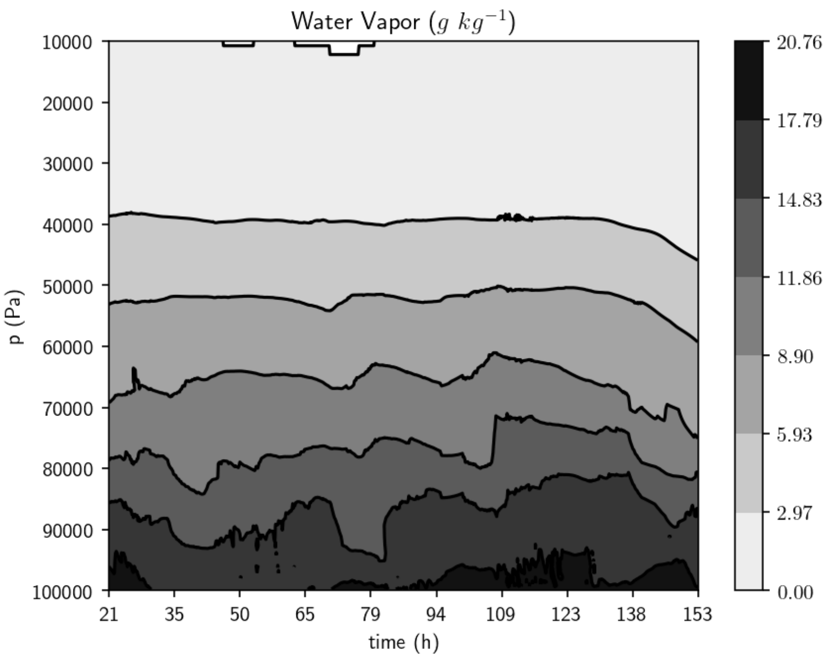
LASSO Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_LASSO_2016051812/comp/full`

`profiles_mean_multi_T_forcing.png`



TWP-ICE Case Overview

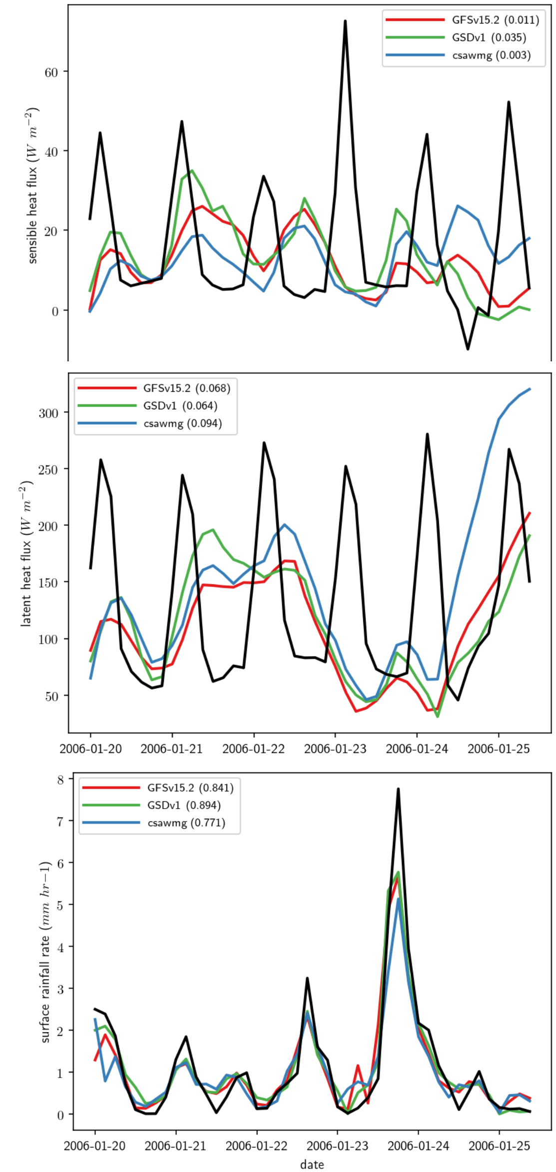


Time →

Sensible heat flux

Latent heat flux

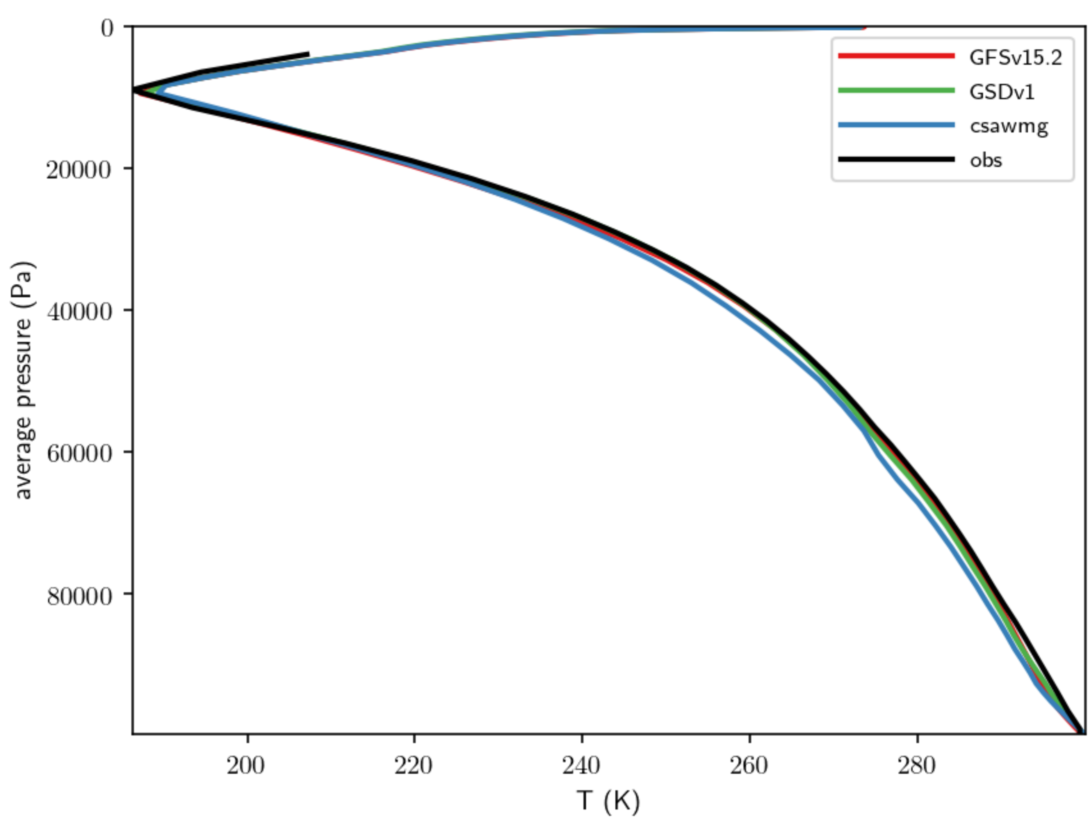
Surface precip.



TWP-ICE Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_twpice_short_course/comp/active`

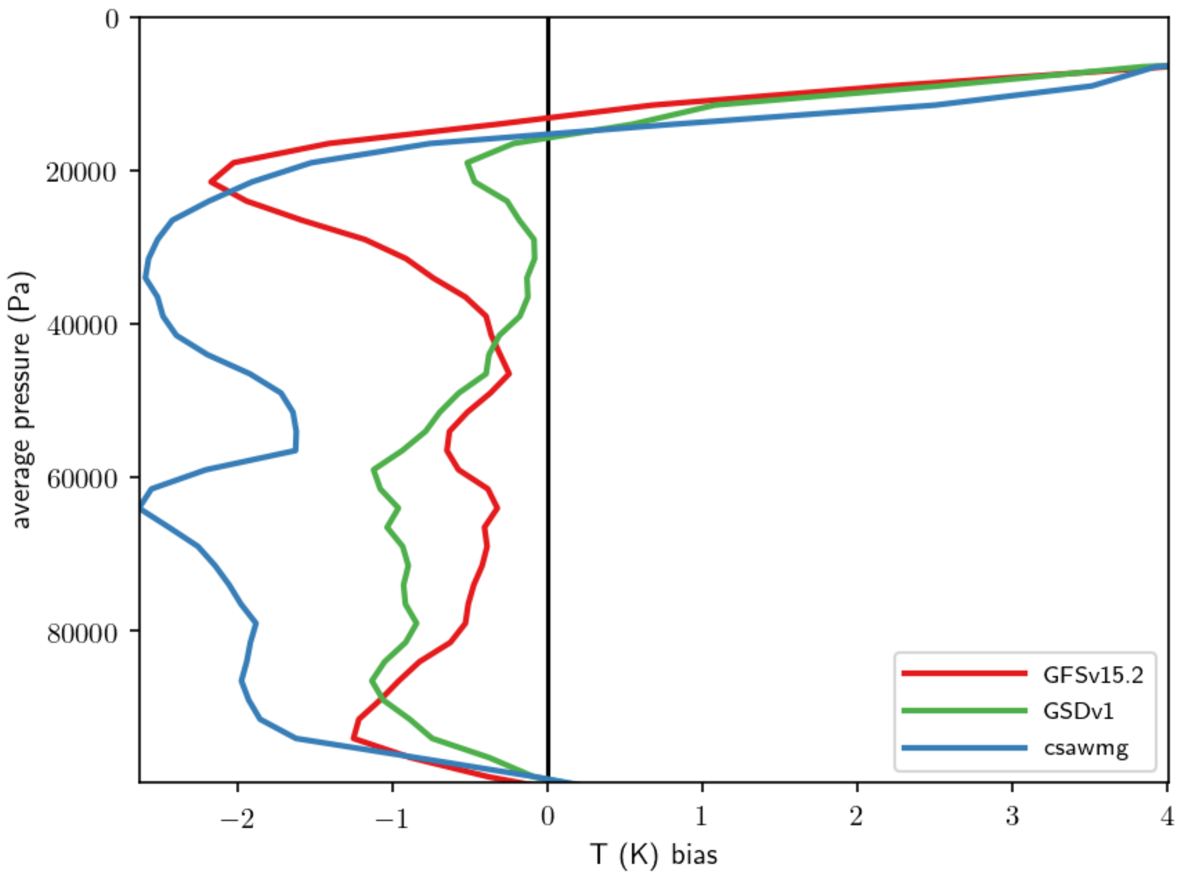
`profiles_mean_T.png`



TWP-ICE Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_twpice_short_course/comp/active`

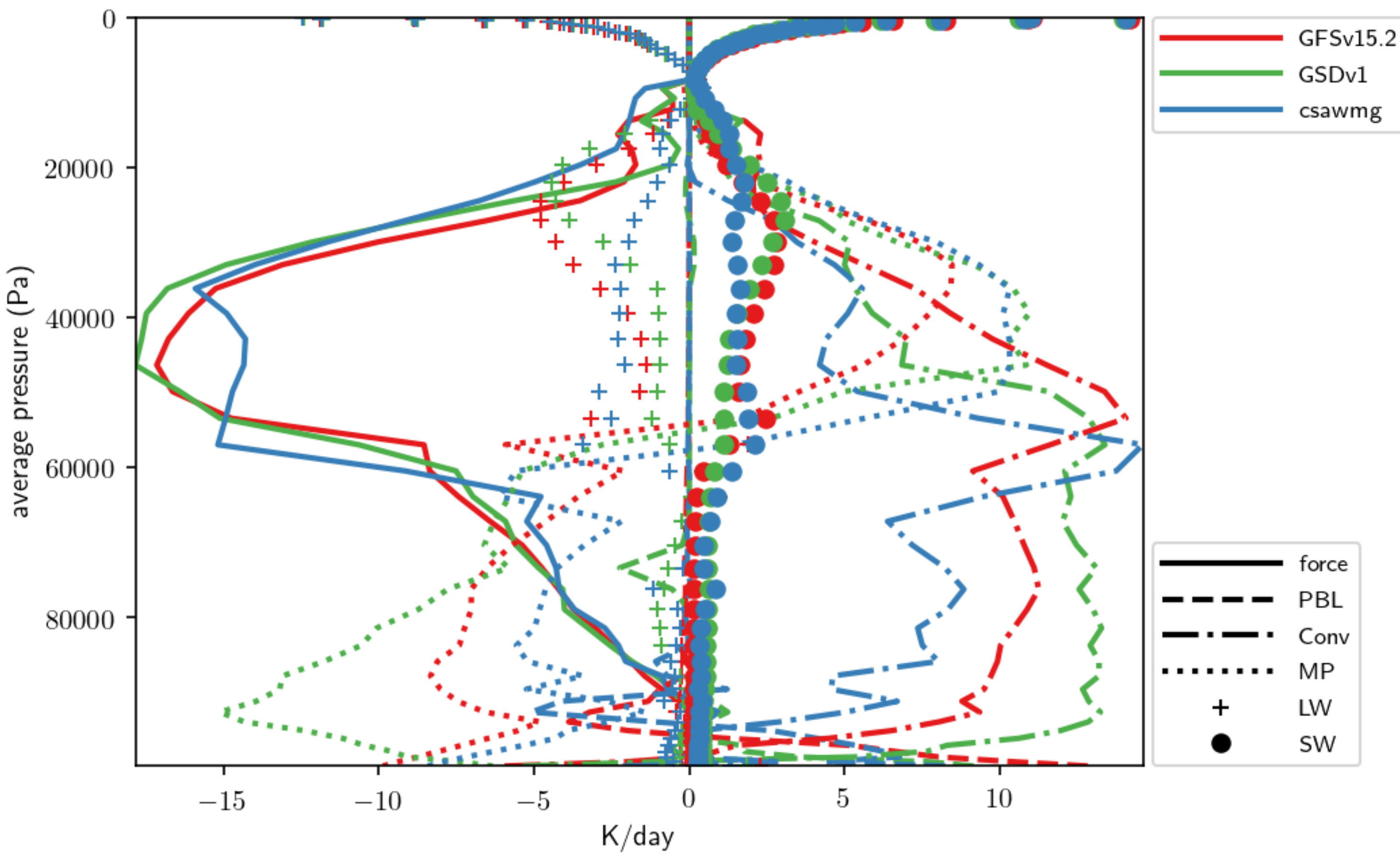
`profiles_bias_T.png`



TWP-ICE Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_twpice_short_course/comp/active`

`profiles_mean_multi_T_forcing.png`



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Modifying the Chikira-Sugiyama convection scheme

- Define a new variable to multiply temperature tendency and make it editable through the physics namelist
- Steps
  1. Add the new variable in cs_conv.F90.
  2. Edit the scheme's CCPP metadata.
  3. Add the new variable on the host side.
  4. Edit the host's CCPP metadata.
  5. Create a new namelist to provide non-default value of new variable.

Modifying the Chikira-Sugiyama convection scheme: Step 1

- Add the new variable in `gmtb-scm/ccpp/physics/physics/cs_conv.F90`

```
6 physics/cs_conv.F90

@@ -301,7 +301,7 @@ subroutine cs_conv_run(IM     , IJSDIM ,  KMAX     , ntracp1 , NN,       &
                                 lprnt   , ipr, kcnv,                             &
                                 QLCN, QICN, w_upi, cf_upi, CNV_MFD,              & ! for coupling to MG microphysics
                                 CNV_DQLDT,CLCN,CNV_FICE,CNV_NDROP,CNV_NICE,      &
-                                mp_phys,errmsg,errflg)
+                                mp_phys,dTdt_mult,errmsg,errflg)


      implicit none
@@ -322,7 +322,7 @@ subroutine cs_conv_run(IM     , IJSDIM ,  KMAX     , ntracp1 , NN,       &
      real(r8), intent(in)    :: zm(IM,KMAX)         ! geopotential at mid-layer (m)
      real(r8), intent(in)    :: zi(IM,KMAX+1)       ! geopotential at boundaries (m)
      real(r8), intent(in)    :: fscav(ntr), fswtr(ntr), wcbmaxm(ijsdim)
-     real(r8), intent(in)    :: precz0in, preczhin, clmdin
+     real(r8), intent(in)    :: precz0in, preczhin, clmdin, dTdt_mult
   ! added for cs_convr
      real(r8), intent(inout) :: u(IM,KMAX)          ! zonal wind at mid-layer (m/s)
      real(r8), intent(inout) :: v(IM,KMAX)          ! meridional wind at mid-layer (m/s)
@@ -566,6 +566,8 @@ subroutine cs_conv_run(IM     , IJSDIM ,  KMAX     , ntracp1 , NN,       &
   !
      do k=1,KMAX
        do i=1,IJSDIM
+         GTT(i,k)      = dTdt_mult*GTT(i,k)
+
         q(i,k)         = max(zero, GDQ(i,k,1)  + GTQ(i,k,1) * delta)
         t(i,k)         = GDT(i,k)    + GTT(i,k)   * delta
         u(i,k)         = GDU(i,k)    + GTU(i,k)   * delta
```

Add new variable to the argument list

Declare new variable as intent(in)

Modify T-tendency

Modifying the Chikira-Sugiyama convection scheme: Step 2

- Add the new variable in `gmtb-scm/ccpp/physics/physics/cs_conv.meta`
  - Add the following under

```
[ccpp-arg-table]
  name = cs_conv_run
  type = scheme
```

Be sure to add metadata for the right subroutine

```
9 physics/cs_conv.meta

@@ -707,6 +707,15 @@
      type = integer
      intent = in
      optional = F
+ [dTdt_mult]
+   standard_name = temperature_tendency_multiplication_factor_for_deep_convection
+   long_name = temperature tendency multiplication factor for deep convection schemes
+   units = none
+   dimensions = ()
+   type = real
+   kind = kind_phys
+   intent = in
+   optional = F
  [errmsg]
    standard_name = ccpp_error_message
    long_name = error message for error handling in CCPP
```

Add metadata for the new variable in the correct order.

Modifying the Chikira-Sugiyama convection scheme: Step 3

- Add the new variable in `gmtb-scm/scm/src/GFS_typedefs.F90`

```
scm/src/GFS_typedefs.F90

@@ -788,6 +788,7 @@ real (kind=kind_phys), pointer :: prsik (:,:) => null()   !< Exner function at i
                                                     !< used in the GWD parameterization
       integer              :: jcap               !< number of spectral wave trancation used only by sascnv shalcnv
       real(kind=kind_phys) :: cs_parm(10)        !< tunable parameters for Chikira-Sugiyama convection
+      real(kind=kind_phys) :: global_ttend_mult !< tunable temperature tendency multiplication factor for Chikira-Sugiya
       real(kind=kind_phys) :: flgmin(2)          !< [in] ice fraction bounds
       real(kind=kind_phys) :: cgwf(2)            !< multiplication factor for convective GWD
       real(kind=kind_phys) :: ccwf(2)            !< multiplication factor for critical cloud
@@ -2810,6 +2811,7 @@ subroutine control_initialize (Model, nlunit, fn_nml, me, master, &
       integer              :: jcap          =  1                !< number of spectral wave trancation used only by sascnv
!     real(kind=kind_phys) :: cs_parm(10) = (/5.0,2.5,1.0e3,3.0e3,20.0,-999.,-999.,0.,0.,0./)
      real(kind=kind_phys) :: cs_parm(10) = (/8.0,4.0,1.0e3,3.5e3,20.0,1.0,-999.,1.,0.6,0./)
+      real(kind=kind_phys) :: global_ttend_mult = 1.0
       real(kind=kind_phys) :: flgmin(2)     = (/0.180,0.220/)         !< [in] ice fraction bounds
       real(kind=kind_phys) :: cgwf(2)       = (/0.5d0,0.05d0/)        !< multiplication factor for convective GWD
       real(kind=kind_phys) :: ccwf(2)       = (/1.0d0,1.0d0/)         !< multiplication factor for critical cloud
@@ -2991,7 +2993,8 @@ subroutine control_initialize (Model, nlunit, fn_nml, me, master, &
                                shinhong, do_ysu, dspheat, lheatstrg, cnvcld,          &
                                random_clds, shal_cnv, imfshalcnv, imfdeepcnv, isatmedmf,     &
                                do_deep, jcap,                                        &
-                               cs_parm, flgmin, cgwf, ccwf, cdmbgwd, sup, ctei_rm, crtrh,    &
+                               cs_parm, global_ttend_mult, flgmin, cgwf, ccwf, cdmbgwd, sup,&
+                               ctei_rm, crtrh,                                        &
                                dlqf, rbcr, shoc_parm, psauras, prauras, wminras,      &
                                do_sppt, do_shum, do_skeb, do_sfcperts,                &
                           !--- Rayleigh friction
@@ -3295,6 +3298,7 @@ subroutine control_initialize (Model, nlunit, fn_nml, me, master, &
       Model%cal_pre            = cal_pre
       Model%do_aw              = do_aw
       Model%cs_parm            = cs_parm
+      Model%global_ttend_mult = global_ttend_mult
```

Add the new variable to the GFS_control_type DDT

Set a default value in control_initialize

Include the new variable in the namelist variable list

Set the variable's value

Modifying the Chikira-Sugiyama convection scheme: Step 4

- Add the new variable in `gmtb-scm/scm/src/GFS_typedefs.meta`

```
7 scm/src/GFS_typedefs.meta

@@ -3019,6 +3019,13 @@
    dimensions = ()
    type = real
    kind = kind_phys
+ [global_ttend_mult]
+   standard_name = temperature_tendency_multiplication_factor_for_deep_convection
+   long_name = temperature tendency multiplication factor for deep convection schemes
+   units = none
+   dimensions = ()
+   type = real
+   kind = kind_phys
  [cgwf]
    standard_name = multiplication_factors_for_convective_gravity_wave_drag
    long_name = multiplication factor for convective GWD
```

Add metadata for the new variable in the correct derived type

Note that local names do not need to match between the host and scheme

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Modifying the Chikira-Sugiyama convection scheme: Step 5

- Add a new namelist to set the value of the new variable in

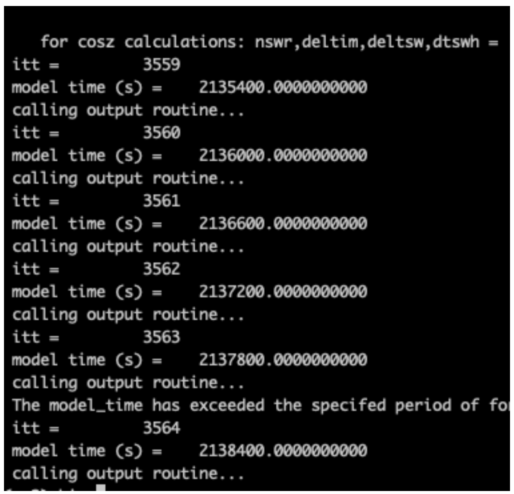
`gmtb-scm/ccpp/physics_namelists/input_csawmg_short_course.nml`

```
iccn            = .false.
aero_in         = .false.
mg_do_graupel   = .true.
mg_do_hail      = .false.
do_sb_physics   = .true.
mg_do_ice_gmao  = .false.
mg_do_liq_liu   = .true.
cs_parm         = 8.0,4.0,1.0e3,3.5e
ctei_rm         = 0.60,0.23
max_lon         = 8000
max_lat         = 4000
rhcmax          = 0.9999999
effr_in         = .true.

nstf_name       = 2,1,1,0,5
ltaerosol       = .false.
lradar          = .false.
```

```
aero_in         = .false.
mg_do_graupel   = .true.
mg_do_hail      = .false.
do_sb_physics   = .true.
mg_do_ice_gmao  = .false.
mg_do_liq_liu   = .true.
cs_parm         = 8.0,4.0,1.0e3,3.5e
global_ttend_mult = 1.15
ctei_rm         = 0.60,0.23
max_lon         = 8000
max_lat         = 4000
rhcmax          = 0.9999999
effr_in         = .true.

nstf_name       = 2,1,1,0,5
ltaerosol       = .false.
lradar          = .false.
```

Running the Modified Suite

- Run the TWP-ICE case again with the modified suite
  - `./run_gmtb_scm.py -c twpice -s SCM_csawmg -n input_csawmg_short_course.nml`

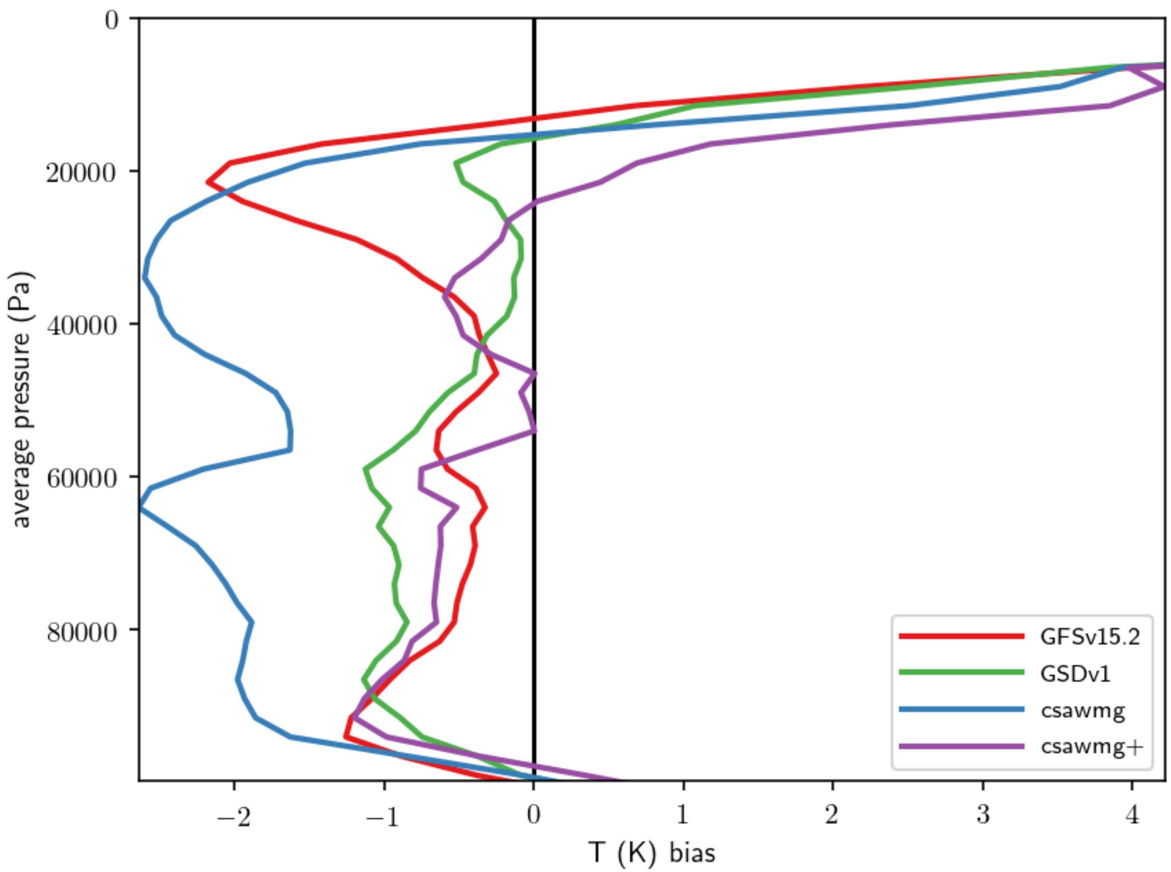


- Re-run the analysis using a plot configuration file that adds the new run
  - `./gmtb_scm_analysis.py twpice_short_course_mod.ini`

TWP-ICE Case Analysis (Modified)

Plots are generated in `gmtb-scm/scm/bin/plots_twpice_short_course/comp/active`

`profiles_bias_T.png`

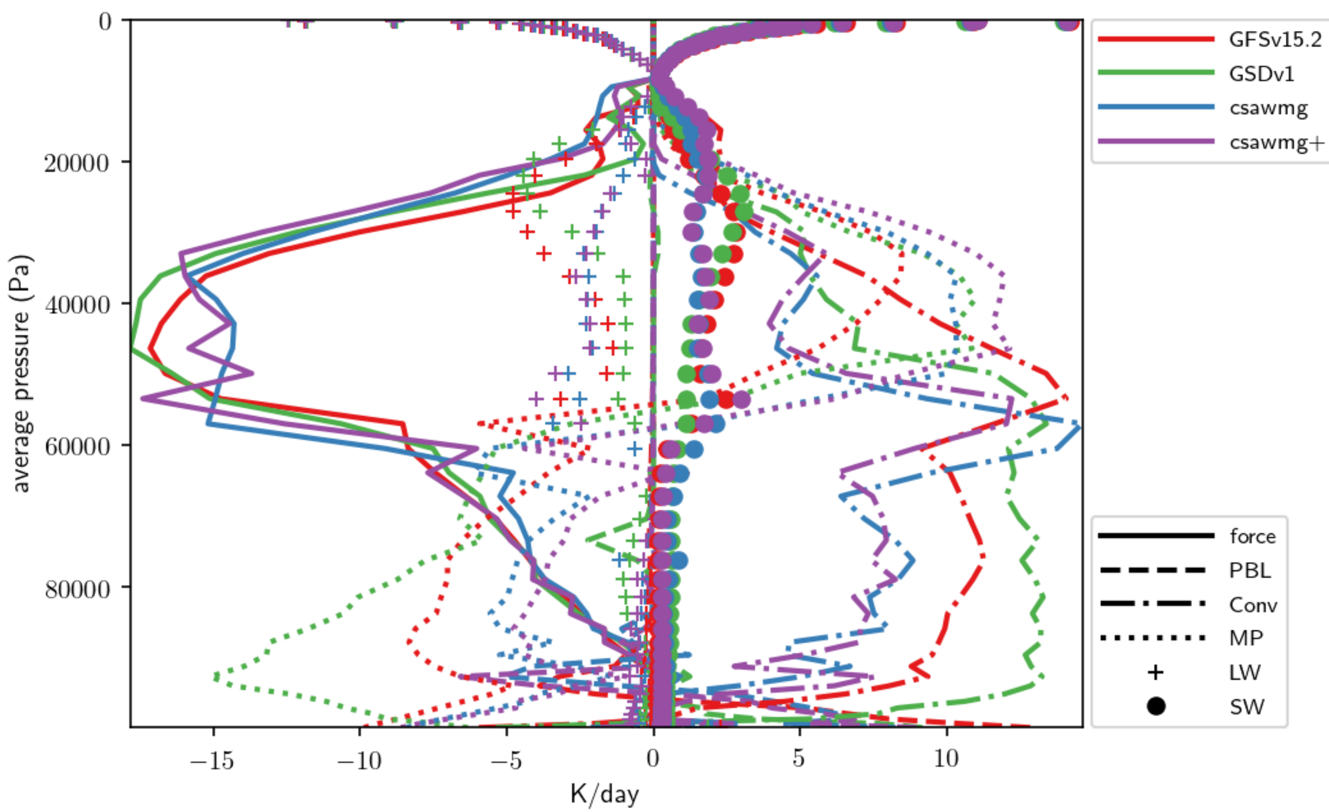


'csawmg+' (purple) is the modified suite

TWP-ICE Case Analysis

Plots are generated in `gmtb-scm/scm/bin/plots_twpice_short_course/comp/active`

profiles_mean_multi_T_forcing.png



Continental Deep Convection Case

- ARM SGP Summer 1997 ("A" time period)
- Run the SCM with all 4 suites

gmtb-scm/scm/src/short_course_runs2.py

```
cases = ["arm_sgp_summer_1997_A"]
suites =
["SCM_GFS_v15p2","SCM_GSD_v1","SCM_csawmg","SCM_csawmg"]
namelists =
["input_GFS_v15p2.nml","input_GSD_v1.nml","input_csawmg.nm
l","input_csawmg_short_course.nml"]
```

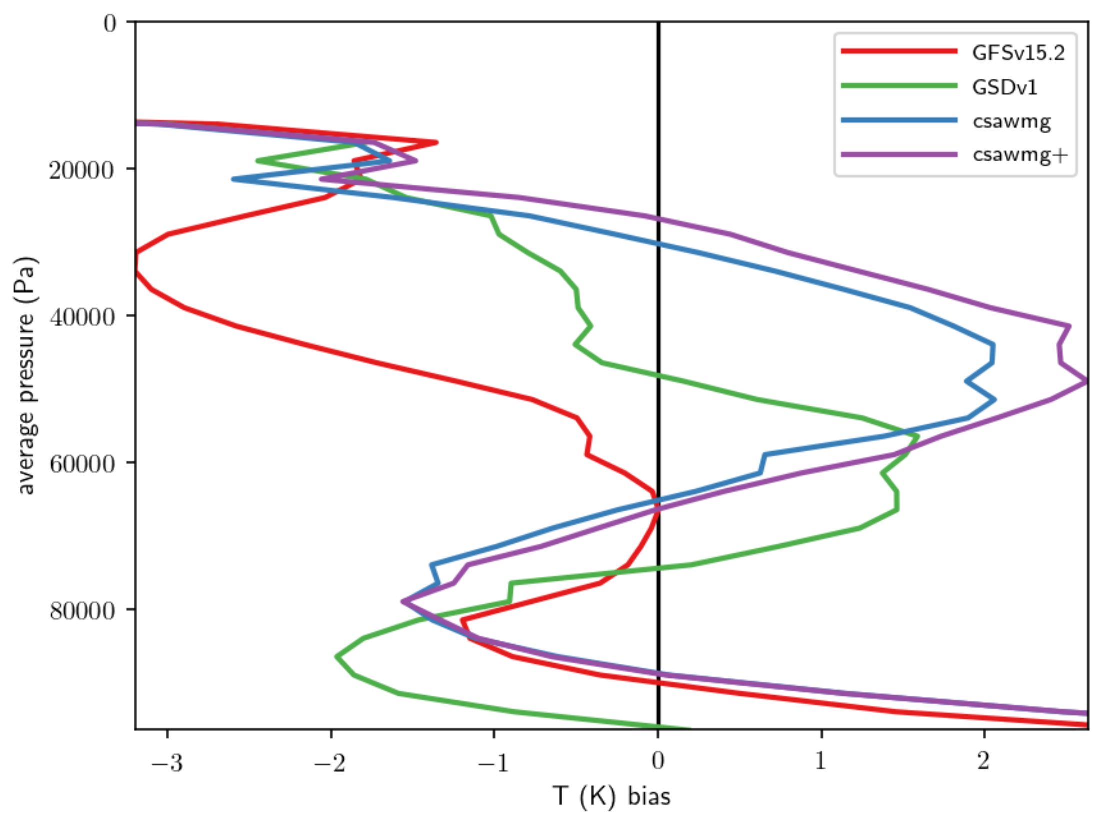
```
(py2) bin>./multi_run_gmtb_scm.py -f ../src/short_course_runs2.py
INFO: Importing ../src/short_course_runs2.py to run requested combinations
INFO: Cases, suites, and namelists were specified in ../src/short_course_runs2.py, so running all cases with all suites, matc
INFO: Executing process 1 of 4 (./run_gmtb_scm.py -c arm_sgp_summer_1997_A -s SCM_GFS_v15p2 -n input_GFS_v15p2.nml)
INFO: Executing process 2 of 4 (./run_gmtb_scm.py -c arm_sgp_summer_1997_A -s SCM_GSD_v1 -n input_GSD_v1.nml)
INFO: Executing process 3 of 4 (./run_gmtb_scm.py -c arm_sgp_summer_1997_A -s SCM_csawmg -n input_csawmg.nml)
INFO: Executing process 4 of 4 (./run_gmtb_scm.py -c arm_sgp_summer_1997_A -s SCM_csawmg -n input_csawmg_short_course.nml)
```

ARM Case Analysis

Rerun the analysis script: `./gmtb_scm_analysis.py arm_short_course_mod.ini`

Plots are generated in `gmtb-scm/scm/bin/plots_arm_short_course/comp/A`

`profiles_bias_T.png`



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