Supplement of

Extending the Modular Earth Submodel System (MESSy v2.54) model hierarchy: the ECHAM/MESSy IdeaLized (EMIL) model setup

Hella Garny et al.

Correspondence to: Hella Garny (Hella.Garny@dlr.de)

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.
S1 User Manual: Set-up of an EMIL simulation

The “EMIL” dynamical core model is implemented as a set-up of ECHAM/MESSy, i.e. it can be run by modifying the namelist files and the initial files (i.e. no recompilation is necessary), as described in the following.

S1.1 Namelist set-up

The namelist set-up for an EMIL simulation is described in the following. An example set-up can also be found in the MESSy source code (under messy/nml/EMIL).

The following namelist files need to be modified:

- **switch.nml**  In the switch namelist, the only necessary submodel to be switched on is RELAX. Diagnostic submodels and submodels that control the set-up of tracers can optionally be used as usual.

- **relax.nml**  The RELAX namelist file consists of a “coupling” (CPL) namelist, in which the options for temperature relaxation, wind damping and additional diabatic heating can be chosen and the according parameters that define the variables needed (e.g. wind damping coefficients, equilibrium temperature and inverse relaxation time scale) are set (see Sec. S1.2).

- **ECHAM5.nml**  The set-up for the ECHAM-internal sponge layer is controlled here (DYNCTL namelist), and as the sponge is calculated in RELAX in the EMIL set-up, the ECHAM-sponge needs to be switched off (by setting spdrag = 0).

Furthermore, it is advisable to change the output via channel.nml, as many fields in the standard ECHAM output are meaningless in the EMIL set-up (see example under messy/nml/EMIL/channel.nml).

S1.2 The RELAX namelist

As described in Sec. 2.1 of the main paper, the RELAX submodel incorporates functions for three processes: Newtonian cooling \((\text{newco})\), Rayleigh friction \((\text{rayfr})\), and currently three different diabatic heating routines \((\text{tteh}}_{\text{cc}}, \text{tteh Waves}, \text{tteh Mons}\)). Each process can be switched on/off via namelist entry (see lines 10-14 in the example namelist given in Fig. S1), and for each process the variables to be used can be chosen.

For the Newtonian cooling routine, the equilibrium temperature \((T_{eq})\) to be relaxed to, as well as the inverse relaxation time scale \((\kappa)\) have to specified, and for Rayleigh friction the wind damping coefficient \((k_{\text{damp}})\) has to be specified. As described in Sec. 2.1 of the main paper, the options for these variables are either constant values, pre-implemented functions or any field defined by a given channel and object pair.

The options with all parameters are summarized in Tables S1 to S2, with the meaning of the parameters explained in example namelists (Figs. S1 and S2) and in Sec. 2.1 of the main paper. For the equilibrium temperature with ‘PK’ set-up, there is an additional switch to “turn” the polar vortex off \((k_{\text{no_polar_vortex}}, \text{line 111-112 in Fig. S2})\). If this switch is set to TRUE, the equilibrium temperature of the winter polar region is set to the standard US Atmosphere as for all other latitudes (i.e. the weighting function given by Eq. (5) of the main paper is set to zero for all latitudes).

The parameters for the diabatic heating routines described in Sec. 2.1.3 of the main paper, are also set by namelist entry, as summarized in Table S3.

S1.3 Initial files

Several modifications to the initial files are necessary for running the EMIL model set-up. For any set-up with the idealized model, the initial values for specific humidity need to be set to zero to obtain
dry dynamics (in the ECHAM spectral initial file, set \( Q = 0 \) everywhere). Since there are no sources of water vapour, the humidity will remain zero throughout the simulation. To run the model with flat or idealized topography, both the surface geopotential in the surf input file, as well as the initial values for dynamical variables need to be modified. There are several solutions to set the dynamical variables divergence, vorticity and temperature to appropriate values, with one of them listed below.

**Surface initial file:** The topography is controlled by the variable surface geopotential (GEOSP) within the “surface” initial file. For flat topography, set GEOSP = 0 everywhere. For idealized topography, the surface geopotential is set to the height of the chosen topography (e.g. wavenumber-2 mountain). All other variables in this file are not used by the idealized model.

**Spectral initial file:** The initial values for vorticity, divergence and temperature in spectral coordinates and humidity in latitude-longitude coordinates are given in the spectral initial file. In all cases, the specific humidity has to be set to zero (\( Q = 0 \)) everywhere (to obtain dry dynamics). For running flat topography, the following initial conditions can be used: temperature \( STP = 0 \) for all wavenumbers \( > 0 \), and for wavenumber zero, \( STP \) is set to a global mean temperature profile with height (e.g. taken from the initial file from a full ECHAM simulation), divergence \( SD = 0 \) and vorticity \( SVO = 1 \times 10^{-8} s^{-1} \). The small value for vorticity is included to break the zonal symmetry (otherwise, the simulations will always remain in a zonally symmetric state). For running idealized topography, the initial values need to be modified to be not too far from the atmosphere’s state. One way to achieve this is to modify the topography step-wise, e.g. for introducing a wavenumber-2 mountain, the amplitude of the mountain needs to be slowly increased (e.g. by steps of 500 m every year).
Table S1: Overview of parameter setting for the temperature relaxation (Newtonian cooling) for equilibrium temperature (namelist variable `newco_t_inp`) and relaxation time (namelist variable `newco_k_inp`) in the RELAX namelist.

### Temperature relaxation (Newtonian cooling)

#### Equilibrium Temperature: namelist variable `newco_t_inp`

| Parameter | Default value | Symbol in Equ. | Description |
|-----------|---------------|----------------|-------------|
| $h_{\text{fac}}$ | (HS:0/PK:1) | $h_{\text{fac}}$ in (A3)/(A5) | hemispheric factor: $h_{\text{fac}} > / < 0$ NH / SH winter |
| $p_0$ | (101325 Pa) | $p_0$ in (A1)/(A4) | reference pressure |
| $T_0$ | (200 K) | $T_0$ in (A1) | minimum equilibrium temperature |
| $T_1$ | (315 K) | $T_1$ in (A1)/(A4) | maximum equilibrium temperature in troposphere |
| $\delta_y$ | (60 K) | $\delta_y$ in (A1)/(A4) | meridional temperature gradient in troposphere |
| $\delta_z$ | (10 K) | $\delta_z$ in (A1)/(A4) | vertical temperature gradient in troposphere |
| $|\epsilon|$ | (HS:0/PK:10 K) | $|\epsilon|$ in (A3) | absolute value of asymmetry factor in troposphere |
| $\gamma$ | (4 K/km) | $\gamma$ in (A4) | polar vortex lapse rate |
| $\phi_0$ | (50) | $\phi_0$ in (A5) | transition latitude to polar vortex in stratosphere |
| $\delta\phi$ | (10) | $\delta\phi$ in (A5) | rapidity of transition to polar vortex in stratosphere |
| $p_{T_{\text{SH}}}$ | (10000 Pa) | $p_{T_{\text{SH}}}$ in (A6) | transition pressure in summer hemisphere |
| $p_{T_{\text{WH}}}$ | (10000 Pa) | $p_{T_{\text{WH}}}$ in (A6) | transition pressure in winter hemisphere |

#### Relaxation time: namelist variable `newco_k_inp`

| Parameter | Default value | Symbol in Equ. | Description |
|-----------|---------------|----------------|-------------|
| $\kappa_a$ | (40 days) | $1/\kappa_a$ in (A2) | relaxation time outside of tropical troposphere |
| $\kappa_s$ | (4 days) | $1/\kappa_s$ in (A2) | relaxation time at surface of tropical troposphere |
| $\sigma_b$ | (0.7) | $\sigma_b$ in (A2) | topmost sigma level with shorter relaxation time |

### Parameters for Options 3

| Parameter | Default value | Symbol in Equ. | Description |
|-----------|---------------|----------------|-------------|
| $\kappa_a$ | (40 days) | $1/\kappa_a$ in (A2) | relaxation time outside of tropical troposphere |
| $\kappa_s$ | (4 days) | $1/\kappa_s$ in (A2) | relaxation time at surface of tropical troposphere |
| $\sigma_b$ | (0.7) | $\sigma_b$ in (A2) | topmost sigma level with shorter relaxation time |
Table S2: Overview of possible parameter settings for the wind damping coefficient (namelist variable `rayfr_k_inp`) in the RELAX namelist.

Wind damping (Rayleigh Friction)

| Damping coefficient: namelist variable `rayfr_k_inp` |
|-----------------------------------------------------|
| `rayfr_k_inp` = channel, object                     |
| Option 1    `#const` `value`                         |
| Option 2    `import_grid` `object`                  |
| Option 3.1  `#fct` `HS,kmaxHS,sig0`                |
| Option 3.2  `#fct` `HS,kmaxHS,sig0,PK,kmaxPK,psp`  |
| Option 3.3  `#fct` `HS,kmaxHS,sig0,EH,spdrag,enfac`|

Parameters for Options 3

| Parameter  | Default value | Symbol in Equ. | description |
|------------|---------------|----------------|-------------|
| kmaxHS     | (1.1574e-05 1/s) $k_{max}^{HS}$ in (A7) | maximum wind damping at surface |
| sig0       | (0.7)         $\sigma_0$ in (A7) | sigma level at which surface wind damping stops |
| kmaxPK     | (2.3148e-05 1/s) $k_{max}^{PK}$ in (A8) | wind damping at model top |
| psp        | (50 Pa)       $p_{sp}$ in (A8) | sponge layer above which damping starts |
| spdrag     | (5.0200e-07 1/s) $k_{drag}$ in (A9) | damping prefactor |
| enfac      | (1.5238)      $c$ in (A9) | enhancement factor |
Table S3: Overview of namelist settings for the diabatic heating routines tteh_cc_tropics and tteh_cc_tropics.

### Diabatic heating functions

#### Zonal mean heating: routine tteh_cc_tropics

| Parameter | Default value | Symbol in Equ. | description |
|-----------|---------------|----------------|-------------|
| q0_cct    | (0.5 K/day)   | $q_0^{cc}$     | amplitude of heating |
| lat0      | (0 degree)    | $\phi_0^{cc}$  | latitudinal center of heating |
| sigma_lat | (0.4 rad)     | $\delta_{\phi}^{cc} \times (\pi/180)$ | latitudinal half width of heating |
| z0        | (0.3)         | $\sigma_z^{cc}$ | sigma level center of heating |
| sigma_z   | (0.11)        | $\delta_{z}^{cc}$ | vertical half width of heating |

#### Wave-like heating: routine tteh_waves

| Parameter | Default value | Symbol in Equ. | description |
|-----------|---------------|----------------|-------------|
| q0        | (6 K/day)     | $q_0^{w}$      | amplitude of heating for planetary wave generation |
| m_WN      | (2)           | $m$            | longitudinal wave number |
| phi0      | (45 degree)   | $\phi_0^{w}$   | latitudinal center of heating |
| sigma_phi | (0.175 rad)   | $\delta_{\phi}^{w} \times (\pi/180)$ | latitudinal decay rate of heating |
| p_bot     | (80000 Pa)    | $p_{bot}$      | bottom pressure boundary |
| p_top     | (20000 Pa)    | $p_{top}$      | top pressure boundary |
Table S4: Overview of namelist settings for the diabatic heating routine *tteh_mons*.

**Diabatic heating functions**

| Localized heating: routine *tteh_mons* |
|----------------------------------------|
| routine | namelist parameter | channel | object (parameter) |
| *tteh_mons* | *tmpht_h_inp* | '#fct' | 'offset, amplitude, heating period, spin up' |
| *tteh_mons* | *reght_h_inp* | '#fct' | 'pbot, ptop, lat0, latd, lon0, lond' |

*Parameters for *tteh_mons* (NOTE: no default values implemented)*

| Parameter | Unit | Symbol in Equ. | description |
|-----------|------|----------------|-------------|
| offset    | (K/day) | $q^m_0$ in (A13) | heating strength without temporal variation |
| amplitude | (K/day) | $q^m_{temp}$ in (A13) | amplitude of heating with temporal variation |
| heating period | (days) | $\delta t^m$ in (A13) | period of temporal heating variations |
| spin up   | (days) | $t^s$ in (A13) | spin up time of heating |
| pbot      | (Pa)  | $p^m_{bot}$ in (A14) | bottom pressure boundary |
| ptop      | (Pa)  | $p^m_{top}$ in (A14) | top pressure boundary |
| lat0      | (deg) | $\phi^m_0$ in (A15) | latitudinal center of heating |
| latd      | (deg) | $\delta \phi^m$ in (A15) | latitudinal decay rate of heating |
| lon0      | (deg) | $\lambda^m_0$ in (A16) | longitudinal center of heating |
| lond      | (deg) | $\delta \lambda^m$ in (A16) | longitudinal decay rate of heating |
S2 Implementation of the RELAX submodel

The RELAX submodel is implemented as MESSy submodel, and the call tree is shown in Fig. S3. During the initialization phase, the namelist is read and depending on the settings, new channel objects for the necessary fields are created or the variables are set to the given channel objects (all in the submodel interface layer, SMIL). During run time, relax_physc is called from messy_physc. For Newtonian cooling and Rayleigh friction, if the option '#fct' is selected, the chosen functions for the equilibrium temperature, relaxation time and damping coefficient are evaluated at the current time step (call to implemented functions within the submodel core layer, SMCL). Then, the temperature / wind tendencies are calculated (call to SMCL routines relax_newco_smcl / relax_rayfr_smcl) and added to the overall tendencies (in the SMIL routine).

For the diabatic heating functions, the selected routines implemented in the SMCL are called from relax_physc as function of selected parameters and current pressure. The routines directly return the temperature tendency to be added.
&CPL

switches whether to calculate rayleigh friction (damping of horizontal winds)

5      ! newtonian cooling (relaxation of temperature)
      ! idealized diabatic heating for climate change-like tropical upper-tropospheric warming
      ! idealized diabatic heating for planetary-wave generation (substitute for topography)
      ! idealized diabatic heating for monsoon

10     ! rayfr  = T      ! (T)rue / (F)alse
     ! newco  = T      ! (T)rue / (F)alse
     ! liheat_cc_tropics = F  ! (T)rue / (F)alse
     ! liheat_waves = F   ! (T)rue / (F)alse
     ! liheat_mons = F   ! (T)rue / (F)alse for monsoon-like idealized heating

! set horizontal wind damping coefficient kdamp (rayfr_k_inp),
!     equilibrium temperature tequ (newco_t_inp),
!     inverse relaxation time scale kappa (newco_k_inp)

! options:
! 1. channel = '#const', object = 'value'       : set to constant value given by 'value'
! 2. channel = '#fct', object = ' ,  ,  , '   : set to functions explained below
! 3. channel = 'import_rgt', object = 'var name'    : set to imported field from file (via import nml)

! Explanation of parameters with default values in brackets:
!         HS                    Held-Suarez set-up
!         PK                    Polvani-Kushner set-up
!         EH                    ECHAM-like wind damping in sponge layer

! ---Rayleigh friction---------------------------------------------------------------------------
! wind damping close to surface: [HS]
! [HS]    kmaxHS    (1.1574e-05 1/s) maximum wind damping at surface
!         sig0      (0.7)            sigma level at which surface wind damping stops
! wind damping at model top: [PK,EH]
! [PK]    kmaxPK    (2.3148e-05 1/s) approximate wind damping at model top
!         psp       (50 Pa)          sponge layer above which damping starts
! [EH]    spdrag    (5.0200e-07 1/s) damping prefactor
!         enfac     (1.5238)         enhancement factor
!         nlevs     (10)             number of levels with wind damping counted from model top

! ---Newtonian cooling---------------------------------------------------------------------------
! Equilibrium temperature: [HS,PK]
! [HS]    hfac      (0)         hemispheric factor, hfac>0 winter in NH (January), hfac<0 winter in SH (July)
!         p0        (101325 Pa) reference pressure
! [PK]    gamma     (4 K/km)    polar vortex lapse rate
!         hfac      (1)         hemispheric factor, hfac>0 winter in NH (January), hfac<0 winter in SH (July)
!         p0        (101325 Pa) reference pressure

! T0       (200 K) minimum equilibrium temperature
! T1       (315 K) maximum equilibrium temperature in troposphere
! Ty       (60 K) meridional temperature gradient in troposphere
! Tz       (10 K) vertical temperature gradient in troposphere
! eps_abs  (0)         absolute value of asymmetry factor in troposphere
! l0_abs   (50)        absolute value of transition latitude from inversion to polar vortex in stratosphere

! dl       (10)         rapidity of transition from inversion to polar vortex in stratosphere
! pT_SH    (10000 Pa)   transition pressure in summer hemisphere

Figure S1: Example of RELAX namelist file, part 1
!   pT_WH    (10000 Pa)  transition pressure in winter hemisphere
!
!   Inverse relaxation time: [HS,PK]
!   ts (40 days)  relaxation time outside of tropical troposphere
!   sigb (0.7)  sigma level below which a short relaxation time is used in the tropics

70 ! [HS,PK] ta (40 days)  relaxation time at surface of tropical troposphere
!
!   ---idealized heating for climate change-like tropical upper-tropospheric warming-----------------
!   q0_cct (0.5 K/day) amplitude of heating  
!   lat0 (0)  latitudinal center of heating  [degree]
!   sigma_lat (0.4)  latitudinal half width of heating  [rad]
!   z0 (0.3)  sigma level center of heating  [1]
!   sigma_z (0.11)  vertical half width of heating  [1]

80 !   ---idealized heating for generation of planetary-wave activity-----------------------------------
!   q0 (6 K/day)  amplitude of heating for planetary wave generation  [K/day]
!   m_WN (2)  longitudinal wave number  [1]
!   phi0 (45)  latitudinal center of heating  [degree]
!   sigma_phi (0.175)  latitudinal decay rate of heating  [rad]
!   p_bot (80000 Pa)  bottom pressure boundary  [Pa]
!   p_top (20000 Pa)  top pressure boundary  [Pa]

90 !   ATTENTION: maximum number of characters stored in object file string = 133
!
!   ATTENTION: You can leave parameters of rayfr_k_inp (except the first [HS] and the fourth [PK,EH])
!                of newco_t_inp (except the first [HS])
!                of newco_k_inp (except the first [HS])
!                of cct_h_inp
!                and of waves_h_inp
!                empty to use the default values written in brackets above.
!
!   ----------------------------------------------------------------------------------------------
!   Params kdamp
!     with HS,PK set-up:'HS,kmaxHS,sig0,PK,kmaxPK,pssp'
!     rayfr_k_inp='#fct','HS,      ,    ,PK,      ,   '
!     with HS,EH set-up:'HS,kmaxHS,sig0,EH,spdrag,enfac'
!     rayfr_k_inp='#fct','HS,      ,    ,EH,      ,     '

105 !   Params tequ
!     with HS set-up:   'HS,hfac,p0,T0,T1,Ty,Tz,eps_abs'
!     newco_t_inp='#fct','HS,    ,  ,  ,  ,  ,  ,       '  
!     with PK set-up:   'PK,gamma,hfac,p0      ,T1   ,Ty  ,Tz  ,eps_abs,l0_abs,dl  ,pT_SH,pT_WH'
!     newco_t_inp='#fct','PK,    4,    ,        ,     ,    ,    ,       ,      ,    ,     ,10000'
!
!   Logical parameter for turn on/off polar vortex; if True, W_function is set to zero in relax_tequpk
l_no_polar_vortex = F ! (T)rue / (F)alse
!
!   Params kappa:'[HS,PK],ta,ts,sigb' (both HS and PK represent the same function for inverse relaxation time scale)
newco_k_inp='#fct','HS,  ,  ,    '
!

120 !   Params teh_cc_tropics:'q0, cct, lat0, sigma_lat, z0, sigma_z'
!     cct_h_inp='#fct','   ,  ,  ,  ,  ,  '
!
!   Params teh_waves:'q0, m_WN, phi0, sigma_phi, p_bot, p_top'
!     waves_h_inp='#fct','   ,  ,  ,  ,  ,   '  ! (heating for planetary wave generation)
!

125 !   !The following parameters are needed for monsoon-like idealized heating
!   !Parameter plot (Pa), prop (Pa), lat0(deg) , latd , lon0(deg), lond
!   reght_h_inp='#fct','80000,10000,20.0,10.0,90.0,0.0,0.0,30.0'

130 !Parameter offset (K/day), amplitude (K/day), heating period (days), spin up (days)
tmpht_h_inp='#fct','8.0,0.0,15.0,20.0'  ! offset (K/day), amplitude (K/day), heating period (days), spin up (days)
!

Figure S2: Example of RELAX namelist file, continued (part 2)
Submodel RELAX

Purpose: relaxation of variables:

1) Temperature: calculates Newtonian cooling as \( \frac{dT}{dt} = -\kappa(T - T_{eq}) \)
2) Horizontal winds: calculates Rayleigh friction as \( \frac{du}{dt} = -Ku \) (and the same for \( v \))
3) Diabatic heating: additional fixed temperature tendencies as \( \frac{dT}{dt} = Q \)

Input: Temperature \( t_{m1} \), winds \( u_{m1}, v_{m1} \), temperature tendency \( t_{te} \), wind tendencies \( v_{ol}, v_{om} \), pressure \( a_{pm1} \)

Output: Temperature and wind tendencies

Needs: Equilibrium Temperature \( T_{eq} \), Time scale \( \kappa \), Damping coefficients \( K \), Diabatic heating parameters

Namelist relax.nml

``` namelist relax.nml
&cpl
lnewco = T/F ! logical switch for newco
lrayfric = T/F ! logical switch for rayfric
liheat_cc_tropics = T/F ! logicals for diabatic heating
liheat_waves = T/F ! diabatic heating
liheat_mons = T/F ! functions
! settings
newco_t_inp = 'channel', 'object' (TEQU)
newco_k_inp = 'channel', 'object' (KAPPA)
rayfr_k_inp = 'channel', 'object' (KDAMP)
! for diabatic heating functions
cc_t_h_inp = '#fct', 'parameter' (tteh_cc_tropics)
waves_h_inp = '#fct', 'parameter' (tteh_waves)
reght_h_inp = '#fct', 'parameter' (tteh_mons)
tmpht_h_inp = '#fct', 'parameter' (tteh_mons)
```

SMIL

messy/echam5/smil/messy_relax_e5.f9

SMCL

messy/smcl/messy_relax.f90

``` subroutine relax_initialize
! read nml
CALL relax_read_nml_cpl
```

``` subroutine relax_init_coupling
! get or create T_{eq}, \kappa, K_{damp}
IF (LNEWCO) / (LRAYFRIC) / (LIHEAT_*)
IF (#const OR #fct)
CALL new_channel_object (TEQU, KAPPA) / (KDAMP) / (TTEH_*)
ELSE
CALL get_channel_object ! from import
ENDIF
```

``` subroutine relax_physc
! called from physc.f90 / messy_physc
USE messy_main_data bi
tm1,um1,vm1,tte,vol,vom,apm1
IF (LNEWCO)
! set T_{eq}, \kappa, K_{damp}
IF (#const)
TEQU = value , KAPPA = value
ELSEIF (#fct)
CALL fctname(TEQU) / CALL fctname(KAPPA)
ENDIF
CALL relax_newco_smcl(T,TEQU,kappa,tte1)
tte = tte + tte1  ! enable MESSYTENDENCY
ENDIF
IF (LRAYFRIC)
! set K_{damp}
IF (#const)
KDAMP= value
ELSEIF (#fct)
CALL fctname(KDAMP,p)
ENDIF
CALL relax_rayfr_smcl(um1,vm1,kdamp,ute,vte)
vol = vol + vte; vom = vom + ute;
ENDIF
IF (LIHEAT_*)
! set parameter from namelist / default
CALL relax_tteh_*_smcl(apm1,parameter,tteh_*)
tte = tte + tteh_*
ENDIF
```

``` subroutine relax_read_nml_cpl```

``` subroutine relax_newco_smcl```

``` subroutine newco_tequhs```

! calculate T_{eq} as function according to Held and Suarez

``` subroutine newco_kappahs```

! calculate \( \kappa \) as function according to Held and Suarez

``` subroutine rayfr_kdamphs```

! calculate K_{damp} as function according to Held and Suarez

Functions for K_{damp}, \kappa and T_{eq}:

``` subroutine relax_tteh_cc_tropics_smcl```

! calculate tropical zonal mean diabatic heating

``` subroutine relax_tteh_waves_smcl```

! calculate wave-like diabatic heating

``` subroutine relax_tteh_mons_smcl```

! calculate localized diabatic heating

``` Call Tree
1) (MESSY PHYSIC) CALL relax.physic
2) in MESSY MAIN CONTROL_E5.F90
3) Subroutine messy_physc
4) IF (USE_RELAX) CALL relax_physc
5) Subroutine relax.read_nml_cpl
6) Subroutine relax.initialize
7) subroutine physc.f90
8) CALL messy_physc
9) in MESSY_MAIN_CONTROL_E5.F90
10) Subroutine messy_physc
```