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DWD

Technical Model Description

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June 3, 2011

Contents

1 Coupling Dynamics to Physics in ICONAM

1.1 The Coupling Interface

The motivation to create a coupling interface between physics and dynamics comes from several demands

1. have a clean port to dock the physical parametrizations when new developments come into the model
2. define all fields and variables coming from the dynamics at one place to be valid for all schemes
3. to recalculate the prognostic fields from the dynamical core in different definition (e.g. θ_v) or from different place (winds at the edges and not at the center) forth and back.

1.1.1 Flow of Physic Calls

One important task of the interface is the organisation of physical contributions to the prognostic variables.

In order to be stable and consistent but also efficient in computation we do a compromise between sequential and accumulated updating of the prognostic stage of our fields. Therefore we consider some physical processes as fast ones which should update their contributions in a cumulative way, meaning that each process see the contributions of the one acting before it. Currently the cloud microphysics, the turbulence scheme and the surface model fall into this category.

At which place the surface model has to be called is still under discussion.

Other processes are considered to act more slowly on the atmosphere. Therefore they will be called less often, they see the updated stage of the fast processes and they give out *tendencies* working on the dynamical fields at the next time step. These are the radiation, convection, cloud cover, and the gravity wave related schemes.

This introduces an additional complexity and care must be taken on the place and time of the diagnostic of the variables *temperature* and *pressure* The overall flow - how physics works together with dynamics is scetched in Figure1.1. The full inner flow is described below:

- THE FAST PROCESSES
  1. `CALL nh_update_prog_phy` The hydrometeor variables are updated at first, immediately after their advection is completed.
  2. `CALL diagnose_pres_temp` Temperature and pressure will be diagnosed out of exner pressure and the moist potential temperautre on both half and full levels.
  3. `CALL satad_v_3D` The saturation stage of the atmosphere is checked and water vapor is converted into cloud water or vice versa.

4. Out this the set of prognostic fields is recalculated and so updated.
5. `CALL rbf_vec_interpol_cell` Interpolation of winds from egdes to cells
6. `CALL diagnose_pres_temp` diagnose Pressure, Temperature at half and full levels
7. `CALL nwp_turbulence` Currently the COSMO turbulence and the ECHAM turbulence scheme are available
8. `CALL diagnose_pres_temp` only diagnose pressure, since temperature is at actual state!
9. `CALL nwp_microphysics` Currently this leads to the current COSMO microphysics with 5 prognostic hydrometeors.
10. `CALL pre_radiation_nwp` calculates the zenith angle for the heating rates
11. `CALL radheat` heating rates are calculated each time step
12. recalculate the prognostic variables

- THE SLOW PROCESSES

1. `CALL diagnose_pres_temp` At the first timestep diagnose Pressure and temperature, later on only the pressure needs to be diagnosed since temperature is up to date.
2. `CALL nwp_convection` Currently the Tiedtke-Bechtold code is implemented
3. `CALL cover_koeh` 3 different types of cloud diagnostics are behind.
4. `CALL nwp_radiation` two Radiation sets: RRTM and Ritter-Geleyn
5. `CALL pre_radiation_nwp` calculates the zenith angle for the heating rates
6. `CALL radheat` heating rates are calculated each time step because of the diurnal cycle
7. `CALL nwp_sso`
8. `CALL nwp_gwd`
9. collect the scalar tendencies of the slow processes
10. recalculate the prognostic variable

    convert temperature tendencies into exner tendencies Since the exner function shows up as $\Pi = \frac{T_v}{\theta_v}$ this relates to pressure and virtual temperature tendencies

$$\frac{d\pi}{dt} = \frac{1}{c_{pd}\theta_v\rho}\frac{dp}{dt} \tag{1.1}$$

$$\frac{dp}{dt} = (c_p/c_v - 1)Q_h + c_p/c_v Q_h \tag{1.2}$$

$$\text{where } Q_h = \frac{dT}{dt}|_{phys} \tag{1.3}$$

$$\text{and } Q_m = R_d\, T\, \rho\frac{d\alpha}{dt}. \tag{1.4}$$

The resulting tendency can be written as

$$\frac{d\pi}{dt} = \frac{R}{c_v \theta_v} \left(\frac{dT}{dt} + T \frac{d\alpha}{dt} \right) \tag{1.5}$$

Figure 1.1: Application flow of Physics calls

2 Diagnostics and Debugging

2.1 Testcases and Diagnostics

For tescase details the reader is referred to ... Here only some special setups are described.

2.1.1 Jablonowski Williamson Test

This test can be run for dry dynamics only - as it is intended for- but full physics can be also tested. For the latter two additional namelist parameters are introduced in the `testcase_ctl` to control the initial moisture in the atmosphere:

- here `rh_at_1000hpa` to be set between 0 and 1. The default is set to 0.7 which gives a quite smooth start. If you really want to see early onsets of convection and microphysics just tuned this parameter.
- `qv_max` is usually set to $2.e-3kg/kg$ and refers to the maximum value in the tropics

2.1.2 Mountain Rossby wave

In order to test the model dynamics in dry stage but with real or any complex topography one can choose the mountain rossby wave test and selet different types of topography. By setting this you might want to have the turbulence scheme switched on while the rest of physics is switched OFF. Simulating dry physics means to set the tracer fields to zero. The transport is nto necessary but should be switched off via the transport namelist, so the resulting namelist setting for this case is:

- `testcase_ctl`
  - `nh_test_name = 'mrw_nh'`
- - `nh_test_name = 'mrw_nh'`

2.2 Debugging

2.2.1 Message Levels

2.2.2 Extra output

1. In the namelist **`run_ctl`** set the number of fields with `inextra_2d` or `inextra_3d`. The logical variable for output `lwrite_extra` then will be set automatically. Note, the number of extra fields is limited by 9 each for 2D and 3D.

2. `USE` these variables in the module needed.

3. Implement the storage of wished fields by using the nonhydrostatic diagnostic type with `p_diag%extra_2d/3d`.

Example for the use of `p_diag%extra_2d`:

```
  USE mo_global_variables, ONLY: inextra_2d
...
  DO jc = i_startidx, i_endidx
       p_diag%extra_2d(jc,jb,1)= yxz(jc,jb)
  ENDDO
```

2.2.3 Diagnostics using tendencies

3 Transport

3.1 Argument lists

Argument lists of the following subroutines are documented below:

- step_advection (table 3.1)
- vert_upwind_flux (table 3.2)
- hor_upwind_flux (table 3.3)

Table 3.1: Argument list of driver subroutine **step_advection**

Name	physical variable ICOHAM	physical variable ICONAM	units ICOHAM	units ICONAM	INTENT	description
p_patch	–	–	–	–	IN	patch on which computation is performed
p_int_state	–	–	–	–	IN	interpolation state
p_dtime	Δt	Δt	s	s	IN	time step
k_step	–	–	1	1	IN	time step counter
p_tracer_now	$\overline{q}_k^n$	$\overline{q}_k^n$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	IN	4D tracer array
$p\_mflx\_contra\_h$	$\Delta p^{n+\alpha} v_n^{n+\alpha}$	$\rho^{n+1/2} \Delta z\, v_n^{n+1/2}$	$kg\,s^{-3}$	$kg\,m^{-1}\,s^{-1}$	IN	horizontal mass flux at edge midpoints
$p\_vn\_contra\_traj$	$v_n^{n+\alpha}$	$v_n^{n+1/2}$	$m\,s^{-1}$	$m\,s^{-1}$	IN	normal velocity component at edge midpoints
$p\_mflx\_contra\_v$	$(\dot{\eta}\frac{\partial p}{\partial \eta})_{k-1/2}^{n+\alpha}$	$\rho_{k-1/2}^{n+1/2} w_{k-1/2}^{n+1/2}$	$Pa\,s^{-1}$	$kg\,m^{-2}\,s^{-1}$	INOUT	contravariant vertical mass flux at half level centers
$p\_w\_contra\_traj$	$(\dot{\eta}\frac{\partial p}{\partial \eta})_{k-1/2}^{n+\alpha}$	$w_{k-1/2}^{n+1/2}$	$Pa\,s^{-1}$	$m\,s^{-1}$	IN	contravariant vertical velocity at half level centers
$p\_cellhgt\_mc\_now$	Δp_k^n	Δz_k	Pa	m	IN	cell height at cell circumcenter
$p\_delp\_mc\_new$	Δp_k^{n+1}	$\rho_k^{n+1} \Delta z_k$	Pa	$kg\,m^{-2}$	IN	new weighted density
$p\_delp\_mc\_now$	Δp_k^n	$\rho_k^n \Delta z_k$	Pa	$kg\,m^{-2}$	IN	old weighted density
$p\_pres\_mc\_now$	p_k^n	z_k	Pa	m	IN	full level height
$p\_pres\_ic\_now$	$p_{k-1/2}^n$	$z_{k-1/2}$	Pa	m	IN	half level height
$p\_grf\_tend\_tracer$	$\Delta t \frac{\partial q}{\partial t}$	$\Delta t \frac{\partial q}{\partial t}$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	INOUT	interpolated tracer time tendencies
p_tracer_new	$\overline{q}_k^{n+1}$	$\overline{q}_k^{n+1}$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	INOUT	updated 4D tracer array

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Table 3.1: Argument list of driver subroutine **step_advection**

	physical variable		**units**		**INTENT**	
Name	ICOHAM	ICONAM	ICOHAM	ICONAM		description
p_mflx_tracer_h	F_i^n	F_i^n	$kg\,s^{-3}$	$kg\,m^{-1}\,s^{-1}$	INOUT	horizontal tracer mass flux at edge midpoints
p_mflx_tracer_v	$F_{k-1/2}^n$	$F_{k-1/2}^n$	$Pa\,s^{-1}$	$kg\,m^{-2}\,s^{-1}$	INOUT	vertical tracer mass flux at half level centers
opt_rho_ic	–	$\rho_{k-1/2}^{n+1/2}$	–	$kg\,m^{-3}$	OPT IN	half level density (NH-core only)
opt_topflx_tra	–	$F_{1/2}^n$	$Pa\,s^{-1}$	$kg\,m^{-2}\,s^{-1}$	OPT IN	vertical tracer flux at upper boundary (NH-core only)
opt_q_int	–	$\overline{q}_{1/2}^n$	–	$kg\,kg^{-1}$	OPT OUT	tracer value at upper boundary of child nest (NH-core only)
opt_ddt_tracer_adv	$\frac{\partial q}{\partial t}$	$\frac{\partial q}{\partial t}$	$kg\,kg^{-1}\,s^{-1}$	$kg\,kg^{-1}\,s^{-1}$	OPT INOUT	advective tendency (NH-core only)

Table 3.2: Argument list of subroutine **vert_upwind_flux**

	physical variable		units		INTENT	
Name	ICOHAM	ICONAM	ICOHAM	ICONAM		description
p_patch	–	–	–	–	IN	patch on which computation is performed
p_cc	$\overline{q}^n$	$\overline{q}^n$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	IN	advected cell centered variable (3D field)
$p\_mflx\_contra\_v$	$(\dot{\eta}\frac{\partial p}{\partial \eta})^{n+\alpha}$	$\rho^{n+1/2}w^{n+1/2}$	$Pa\,s^{-1}$	$kg\,m^{-2}\,s^{-1}$	INOUT	contravariant vertical mass flux at half level centers
p_w_contra	$(\dot{\eta}\frac{\partial p}{\partial \eta})^{n+\alpha}$	$w^{n+1/2}$	$Pa\,s^{-1}$	$m\,s^{-1}$	IN	contravariant vertical velocity at half level centers
p_dtime	Δt	Δt	s	s	IN	time step
p_pres_ic	$p^n_{k-1/2}$	$z_{k-1/2}$	Pa	m	IN	half level height
p_pres_mc	p^n_k	z_k	Pa	m	IN	full level height
$p\_cellhgt\_mc\_now$	Δp^n	Δz	Pa	m	IN	cell height at cell circumcenter
$p\_rcellhgt\_mc\_now$	$1/\Delta p^n$	$1/\Delta z$	Pa^{-1}	m^{-1}	IN	reciprocal cell height at cell circumcenter
$p\_cellmass\_now$	Δp^n	$\rho^n \Delta z$	Pa	$kg\,m^{-2}$	IN	$1D$ cell mass
p_ivadv_tracer	–	–	1	1	IN	selects numerical scheme for vertical transport
p_itype_vlimit	–	–	1	1	IN	selects limiter for vertical transport
p_iubc_adv	–	–	1	1	IN	selects upper bpoundary condition
p_iadv_slev	–	–	1	1	IN	vertical start level
p_upflux	$F^n_{k-1/2}$	$F^n_{k-1/2}$	$Pa\,s^{-1}$	$kg\,m^{-2}\,s^{-1}$	OUT	vertical tracer mass flux at half level centers
opt_topflx_tra	–	$F^n_{1/2}$	–	$kg\,m^{-2}\,s^{-1}$	IN	vertical tracer flux at upper boundary (NH core only)

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Table 3.2: Argument list of subroutine **vert_upwind_flux**

	physical variable		**units**		**INTENT**	
Name	ICOHAM	ICONAM	ICOHAM	ICONAM		description
opt_q_int	–	$\overline{q}^{n}_{1/2}$	–	$kg\,kg^{-1}$	OUT	tracer value at upper boundary of child nest (NH core only)
opt_rho_ic	–	$\rho^{n+1/2}_{k-1/2}$	–	$kg\,m^{-3}$	OPT IN	half level density (NH-core only)
$opt\_rlstart$	–	–	1	1	OPT IN	refinement control start level
opt_rlend	–	–	1	1	OPT IN	refinement control end level

Table 3.3: Argument list of subroutine **hor_upwind_flux**

	physical variable		**units**		**INTENT**	
Name	ICOHAM	ICONAM	ICOHAM	ICONAM		description
p_cc	$\overline{q}^n$	$\overline{q}^n$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	IN	advected cell centered variable (3D field)
p_c0	$\overline{q}^n$	$\overline{q}^n$	$kg\,kg^{-1}$	$kg\,kg^{-1}$	IN	advected cell centered variable (3D field) step (n)
$p\_mass\_flx\_e$	$\Delta p^{n+\alpha} v_n^{n+\alpha}$	$\rho^{n+1/2} \Delta z\, v_n^{n+1/2}$	$kg\,s^{-3}$	$kg\,m^{-1}\,s^{-1}$	IN	horizontal mass flux at edge midpoints
p_vn	$v_n^{n+\alpha}$	$v_n^{n+1/2}$	$m\,s^{-1}$	$m\,s^{-1}$	IN	normal velocity component at edge midpoints
p_dtime	Δt	Δt	s	s	IN	time step
p_patch	–	–	–	–	IN	patch on which computation is performed
p_int	–	–	–	–	IN	interpolation state
p_ihadv_tracer	–	–	1	1	IN	selects numerical scheme for horizontal transport
$p\_igrad\_c\_miura$	–	–	1	1	IN	selects gradient reconstruction method at cell centers
p_itype_hlimit	–	–	1	1	IN	selects limiter for horizontal transport
p_iadv_slev	–	–	1	1	IN	vertical start level
$p\_iord\_backtraj$	–	–	1	1	IN	selects method for backward trajectory computaion
p_upflux	F_i^n	F_i^n	$kg\,s^{-3}$	$kg\,m^{-1}\,s^{-1}$	INOUT	horizontal tracer mass flux at edge
opt_rlend	–	–	1	1	OPT IN	refinement control end level