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Technical Model Description

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Contents

1	Coupling Dynamics to Physics in ICONAM	5
1.1	The Coupling Interface	5
1.1.1	Flow of Physic Calls	5
2	Diagnostics and Debugging	9
2.1	Testcases and Diagnostics	9
2.1.1	Jablonowski Williamson Test	9
2.1.2	Mountain Rossby wave	9
2.2	Debugging	9
2.2.1	Message Levels	9
2.2.2	Extra output	9
2.2.3	Diagnostics using tendencies	10

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 sketched in Figure 1.1. 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 temperature on both half and full levels.
3. `CALL satadv_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 edges 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

$$\frac{d\Pi}{dt} = \frac{1}{c_{pd}\theta_v\rho} \frac{dp}{dt} \quad (1.1)$$

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

$$\text{where } Q_h = \frac{dT}{dt}|_{phys} \quad (1.3)$$

$$\text{and } Q_m = R_d T \rho \frac{d\alpha}{dt}. \quad (1.4)$$

The resulting tendency can be written as

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

SLOW -PHYSICS	DYNAMICS	HYD – ADV	HYD – UPDATE	SATAD	FAST – PHYSICS	SLOW -PHYSICS
<i>Radiation, Convection, cloud cover</i>	<i>Wind and Exner pressure</i>	<i>Advection of hydrometeors and tracers</i>	<i>Hydrometeor update</i>	<i>Saturation adjustment</i>	<i>Turbulence and Diffusion, Microphysics</i>	<i>Radiation, Convection, cloud cover</i>
$\Delta \vec{v}_{nphys}$	$\vec{v}_n^{t+1} = \vec{v}_n^t + \Delta \vec{v}_{nadv} + \Delta \vec{v}_{nphys}$			$\pi^{t**} = \pi^* + \Delta \pi_{satad}$	$\Delta \vec{v}_{nphys}$	$\Delta \vec{v}_{nphys}$
$\Delta \pi_{sp}$	$\pi^{t*} = \pi^t + \Delta \pi_{dyn} + \Delta \pi_{sp}$			$Qx^{t***} = Qx^{t**} + \Delta Qx_{satad}$	$\pi^{t+1} = \pi^{t*,*} + \Delta \pi_{fp}$	$\Delta \pi_{sp}$
ΔQx_{sp}		$Qx^{t*} = Qx^t + \Delta Qx_{adv}$	$Qx^{t**} = Qx^{t*} + \Delta Qx_{sp}$		$Qx^{t+1} = Qx^{t***} + \Delta Qx_{fp}$	ΔQx_{sp}
$t_{step} = 1$						
$t_{step} = t_{dyn}$						
$t_{step} = t_{adv}$						
$t_{step} = t_{dyn}$						
$t_{step} = t_{slowphys}$						
$t_{step} = t_{dyn}$						
$t_{step} = t_{adv}$						

Figure 1.1: Application flow of Physics calls

2 Diagnostics and Debugging

2.1 Testcases and Diagnostics

For testcase 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 $2.e - 3 kg/kg$ 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 select 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 not 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