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Convergence actions on the physics-dynamics interface

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- The physics-dynamics interface couples the physics parameterizations to the dynamical core.
- At this moment, AROME uses an interface that is different from the one used by ARPEGE/ALARO.
- This divergence hinders collaboration

$\Rightarrow$ **convergence actions**:

- harmonization between different models
- increase flexibility regarding interface input, number and type of water species, . . .

- Aspects of the physics-dynamics that are considered:
  - The slow sedimentation of cloud species
  - The interface input variables
  - The correction of negative humidities
  - Treatment of the kinetic energy in the enthalpy equation
- At this time, nonhydrostatism and its consequences are not considered

Advective and diffusive transport

- Water species are transported by advection (precipitation) or diffusion (turbulence).
- Modeling sedimentation of suspended species (cloud water droplets and cloud ice particles) as a combined advective/diffusive process is not a very good idea:
  - The distinction between advection and diffusion is a matter of scale.
  - Due to the vertical staggering, the sedimentation speed cannot be determined unambiguously from the flux.
  - A strict distinction between precipitating and suspended species is consistent with the impact of the δ_m switch on the interface equations (see later).
- The slow sedimentation can be modeled with an enhanced diffusive flux. This comes down to neglecting the influence of these terms in the kinetic energy.

$\Rightarrow$ Water species will be considered to be *either* suspended (q_v, q_l, q_i) *or* precipitating (q_r, q_s, q_g, $\ldots$)

The interface input variables

- The interface should be capable to treat an arbitrary number of water species.
- The contribution of local processes to specific humidities can be described with
  - pseudo-fluxes: currently used in ALARO
  - tendencies: currently used in AROME

  The aim is to develop a harmonized interface that accepts pseudo-fluxes and tendencies.
- Besides the pseudo-fluxes/tendencies, the interface also needs the absolute precipitation fluxes and diffusive fluxes at all vertical levels.
- Compactness or detail?

Equations for a mixed pseudo-fluxes/tendencies interface with an arbitrary number of water species:

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- Transform absolute fluxes into relative (w.r.t. the barycenter) fluxes:

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- The water species tendencies are given by

$$\frac{\partial q_k}{\partial t} = \underbrace{-\, g \frac{\partial}{\partial p}\left[P_k^\delta + J_k\right]}_{\text{transport}} \; \underbrace{-\, g \frac{\partial}{\partial p}\left[\sum_{i\in\mathcal{F}} \sum_{j=1}^{n} P_{kj}^i\right]}_{\text{pseudo-fluxes}} \; \underbrace{+ \sum_{i\in\mathcal{T}} \frac{\partial q_k^i}{\partial t}}_{\text{tendencies}}$$

where $\mathcal{T}$ and $\mathcal{F}$ represent the sets of processes returning tendencies and pseudo-fluxes, respectively.

The interface equations (2)

- The enthalpy tendency equation is given by

$$\frac{\partial}{\partial t}(c_p T) = -\,g\frac{\partial}{\partial p}\left[\sum_{k=1}^{n}(c_k - c_{pd})TP_k^{\delta}\right] \qquad \text{(transport)}$$

$$-\,g\frac{\partial}{\partial p}\left[J_s + J_{rad}\right] \qquad \text{(heat diffusion + radiation)}$$

$$+\sum_{i\in\mathcal{T}}\sum_{k=1}^{n} L_{kv}(T_0)\frac{\partial q_k^i}{\partial t} \qquad \text{(tendencies)}$$

$$-\,g\frac{\partial}{\partial p}\left[\sum_{i\in\mathcal{F}}\sum_{k=1}^{n}\sum_{j=k+1}^{n} L_{kj}(T_0)P_{kj}^{i}\right] \qquad \text{(pseudo-fluxes)}$$

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&- g\frac{\partial}{\partial p}\left[J_s + J_{rad}\right] && \text{(heat diffusion + radiation)}\\
&+ \sum_{i\in\mathcal{T}}\sum_{k=1}^{n} L_{kv}(T_0)\frac{\partial q_k^i}{\partial t} && \text{(tendencies)}\\
&- g\frac{\partial}{\partial p}\left[\sum_{i\in\mathcal{F}}\sum_{k=1}^{n}\sum_{j=k+1}^{n} L_{kj}(T_0)P_{kj}^i\right] && \text{(pseudo-fluxes)}
\end{aligned}
$$

- Notes:
  - The physics parameterizations cannot provide temperature tendencies directly because of the nonlinear character of $c_p T$. This is in contrast with the AROME philosophy.
  - For AROME, J_k and J_s may need to be inferred from the total tendencies $\partial q_k/\partial t$ and $\partial T/\partial t$.

Correction of negative humidities

- One can adopt two strategies:
  - consider them as a part of the physics (i.e. current situation)
  - consider them as a task of the interface, such that the same method can be used for different physics packages
- Should the corrective fluxes be (fully) included in the thermodynamic equation?

Kinetic energy treatment

- include the kinetic energy change in the thermodynamic equation?
- attribute the kinetic energy change to the macroscopic kinetic energy or to the TKE
- transfer the full change of the TKE to the enthalpy equation, or only the dissipation term of the pTKE equation.

Organization

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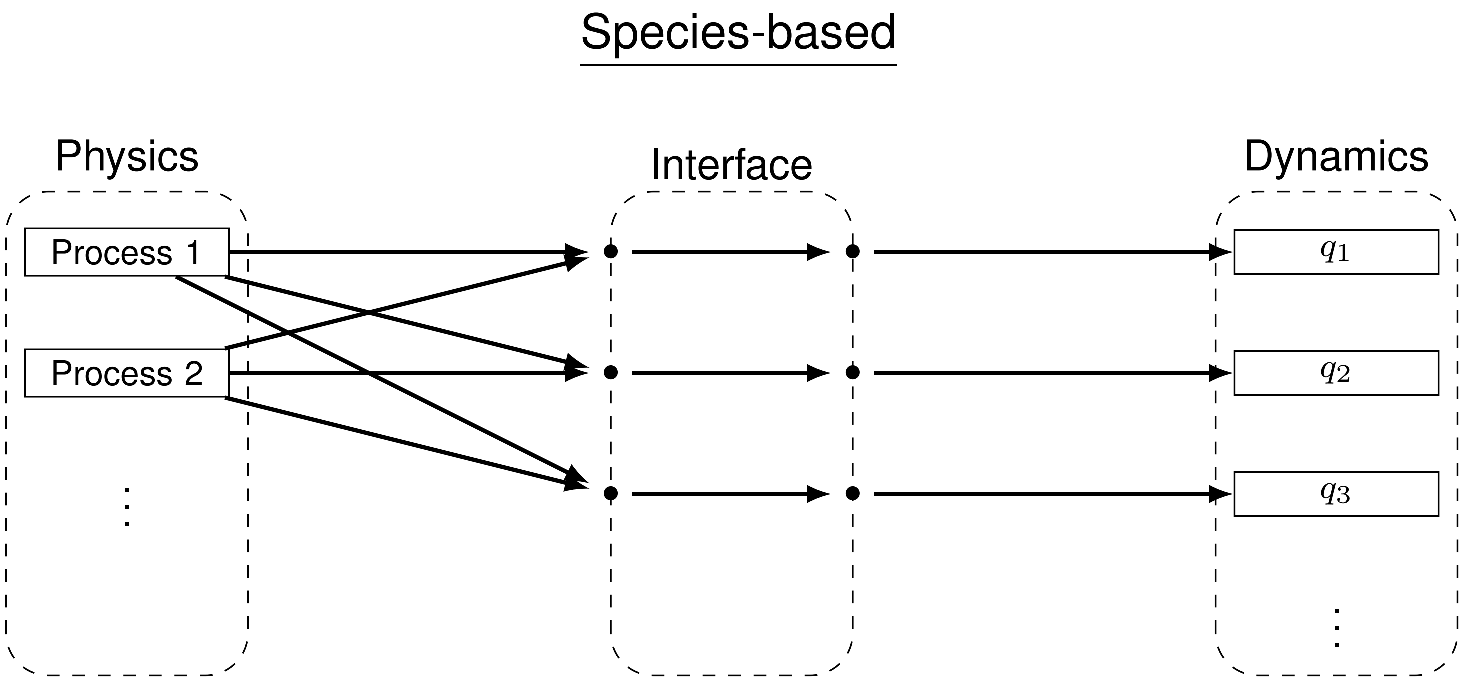

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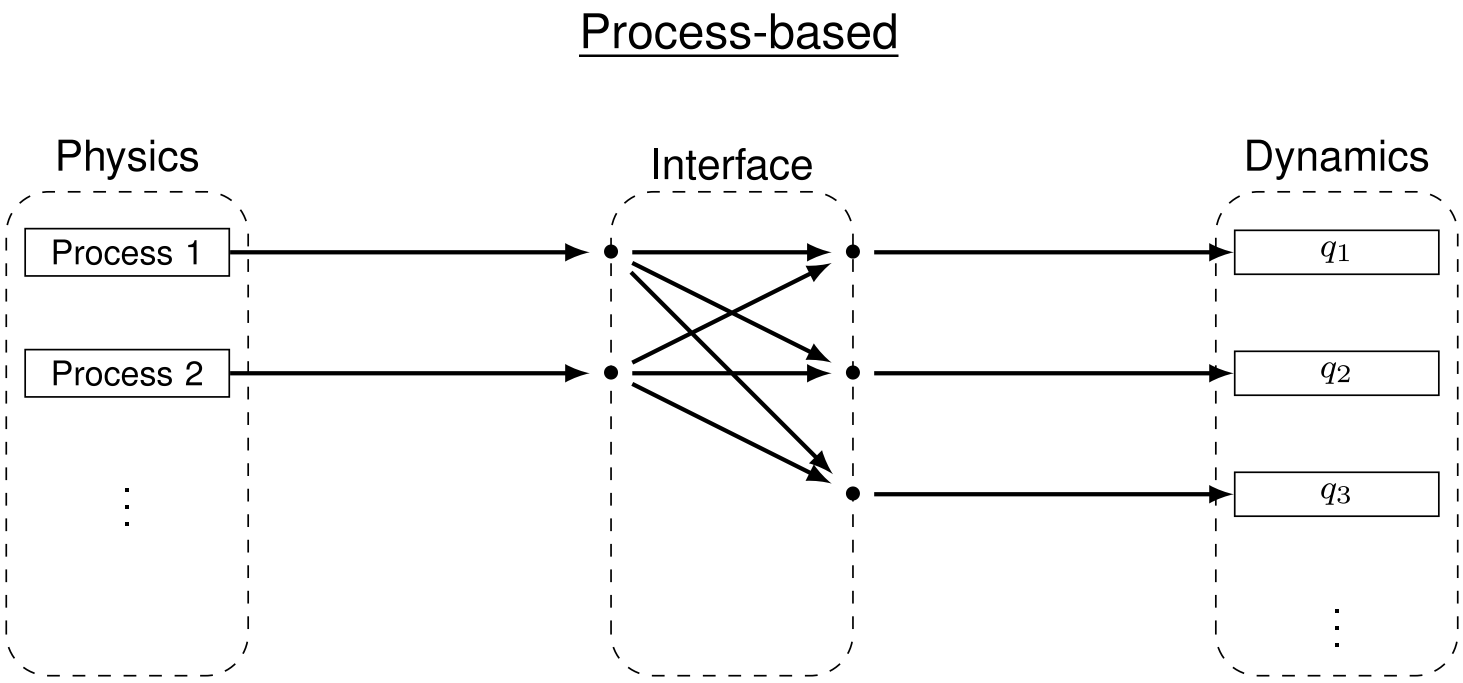

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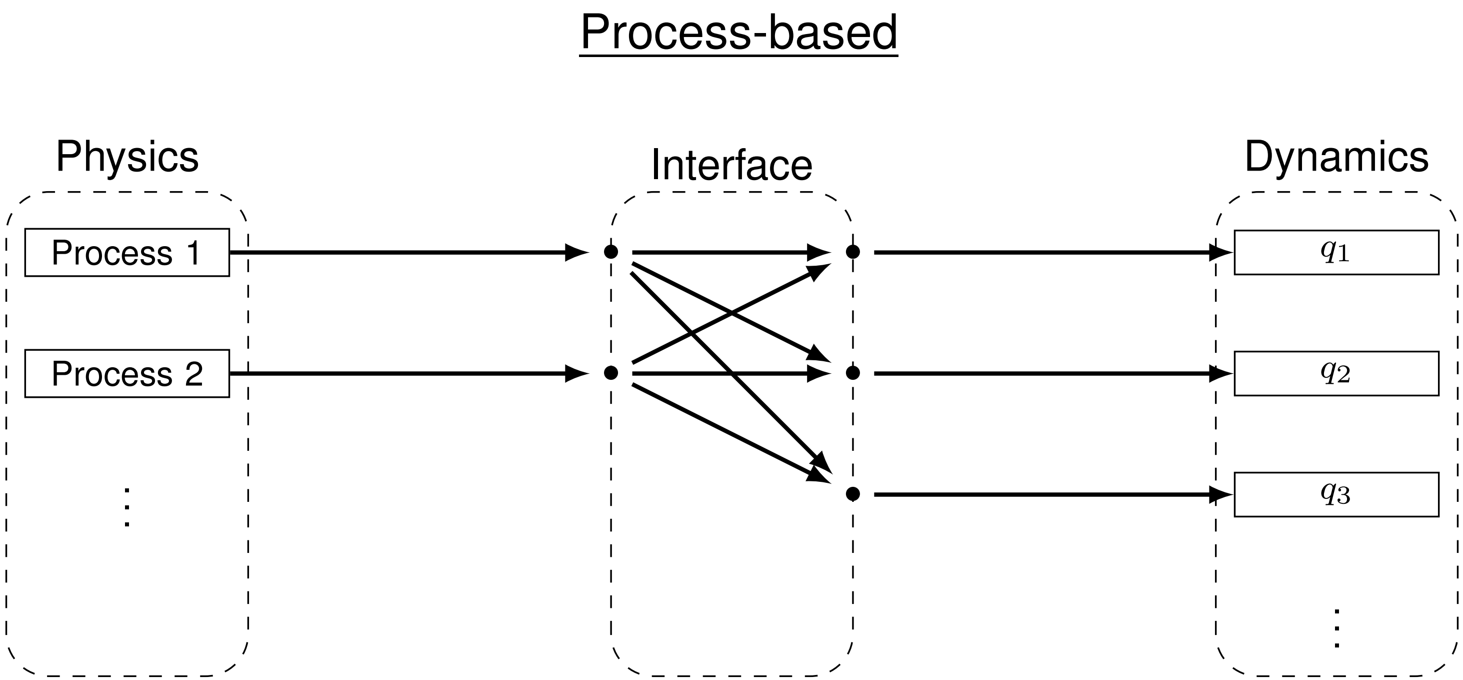

- Advantages:
  - increased flexibility w.r.t. process selection
  - increased flexibility w.r.t. number of water species
  - interface input is highly conform to diagnostics input

Technical side

- Process-based interface requires possibility to transfer metadata along with variables
- This is achieved with Fortran derived data types
- Two-level hierarchy:
  - `INTFIELD`: very similar to `DDHFLEX` structure.

`CNAME`	identification of the field
`CFLUX`	the type of the field: precipitation flux, pseudo-flux, tendency or variable
`CTARGET`	target species of a pseudo-flux or a tendency
`CSOURCE`	source species of a pseudo-flux
`RFIELD`	pointer to an array containing the field values
`LDDH`	whether the field should be passed to DDH

  - `INTPROC`: group different `INTFIELD` structures that belong to the same process.

`CPROC`	identification of the process
`NFIELD`	number of fields belonging to this process
`RFIELD`	pointer to an array of `INTFIELD` structures

Implementation plan

- Proposals that do not change the model output:
  - process-based interface organization
  - generalization towards an arbitrary number of water species
  - input representation as pseudo-fluxes or tendencies

  The feasibility will be tested by considering the complete physics as one single prototype process.

- Other proposals that may (slightly) modify the model output:
  - sedimentation of cloud species
  - correction of negative humidities
  - treatment of kinetic energy

  Implementation in parallel, using the existing routines.

Summary

Several propositions are made to harmonize and generalize the physics-dynamics interface:

- cope with tendencies or pseudo-fluxes
- consider an arbitrary number of water species
- account for slow sedimentation of cloud species
- unification of negative humidities correction
- include different treatments of kinetic energy
- flexibility with process-based organization