DKRZ
DEUTSCHES
KLIMARECHENZENTRUM

Max-Planck-Institut
für Meteorologie

The Coupling Library YAC

Moritz Hanke (DKRZ), René Redler (MPI-M), and Nils-Arne Dreier(DKRZ)

YAC-Team

- Main developer:
  - Moritz Hanke (DKRZ)
- With contributions from:
  - René Redler (MPI-M)
  - Nils-Arne Dreier (DKRZ)
  - Teresa Holfeld (MPI-M, student assistant)
  - Maxim Yastremsky (MPI-M, student assistant)
  - Thomas Jahns (DKRZ)
  - Uwe Schulzweida (MPI-M)
  - Hendryk Bockelmann (DKRZ)
  - Jörg Behrens (DKRZ)
  - Sergey Kosukhin (MPI-M)

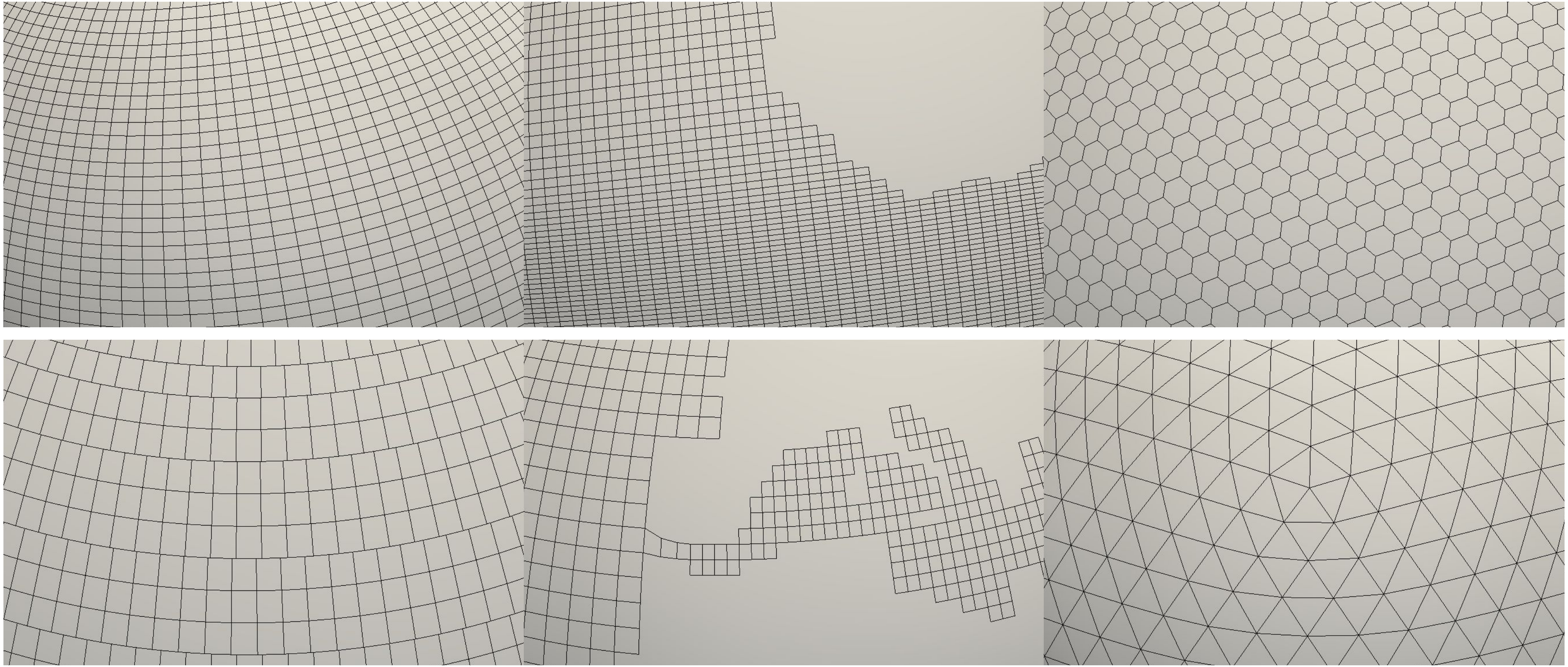
Introduction

- What does a coupler do?
  - exchange of data between independent components (e.g. atmosphere and ocean) at predefined time intervals
  - components can use different grids
    - coupler takes care of regridding between both grids
  - components can have different decompositions
    - coupler takes care of data redistribution
  - components can have different exchange periods
    - coupler takes care of matching of the exchanges and data aggregation if necessary

Introduction

- Library linked to components
  - Written in C
  - Unit tests cover 99.5% of the code
  - C-, Fortran-, and Python-Interface
- Supports all common grid types
- Provides various 2D-interpolation schemes
  - All computation on the unit sphere using cartesian coordinates
- Parallel online weight computation
- Licenced unter BSD 3-Clause License
- Used in official ICON-release (but developed independently)
- runs on Piz Daint[1], JUWELS[2], Levante[3], LUMI[4], MAC OS, and Linux systems with little to no porting effort

Supported grids



Interpolations

- 2D inter- and extrapolation
  - Various methods with different properties
  - All grid combinations are supported
- Fields can be defined on cells, vertices, or edges

Interpolation Stack

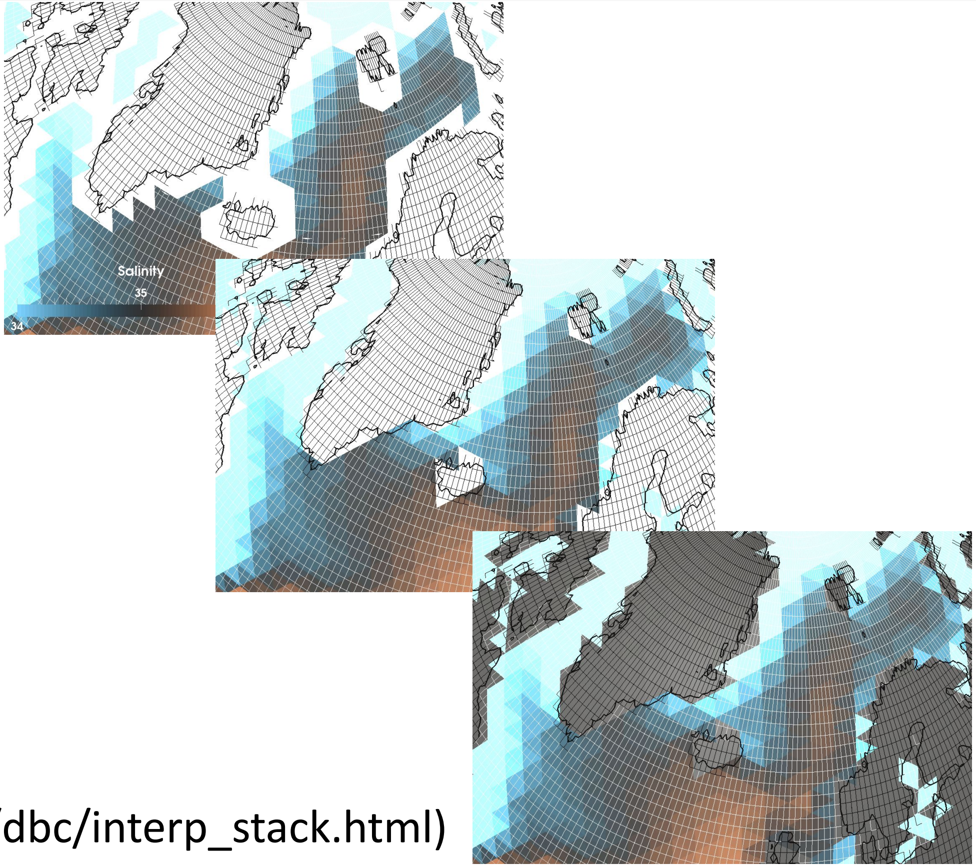
Conservative 1st order

↓

HCSBB

↓

Fixed

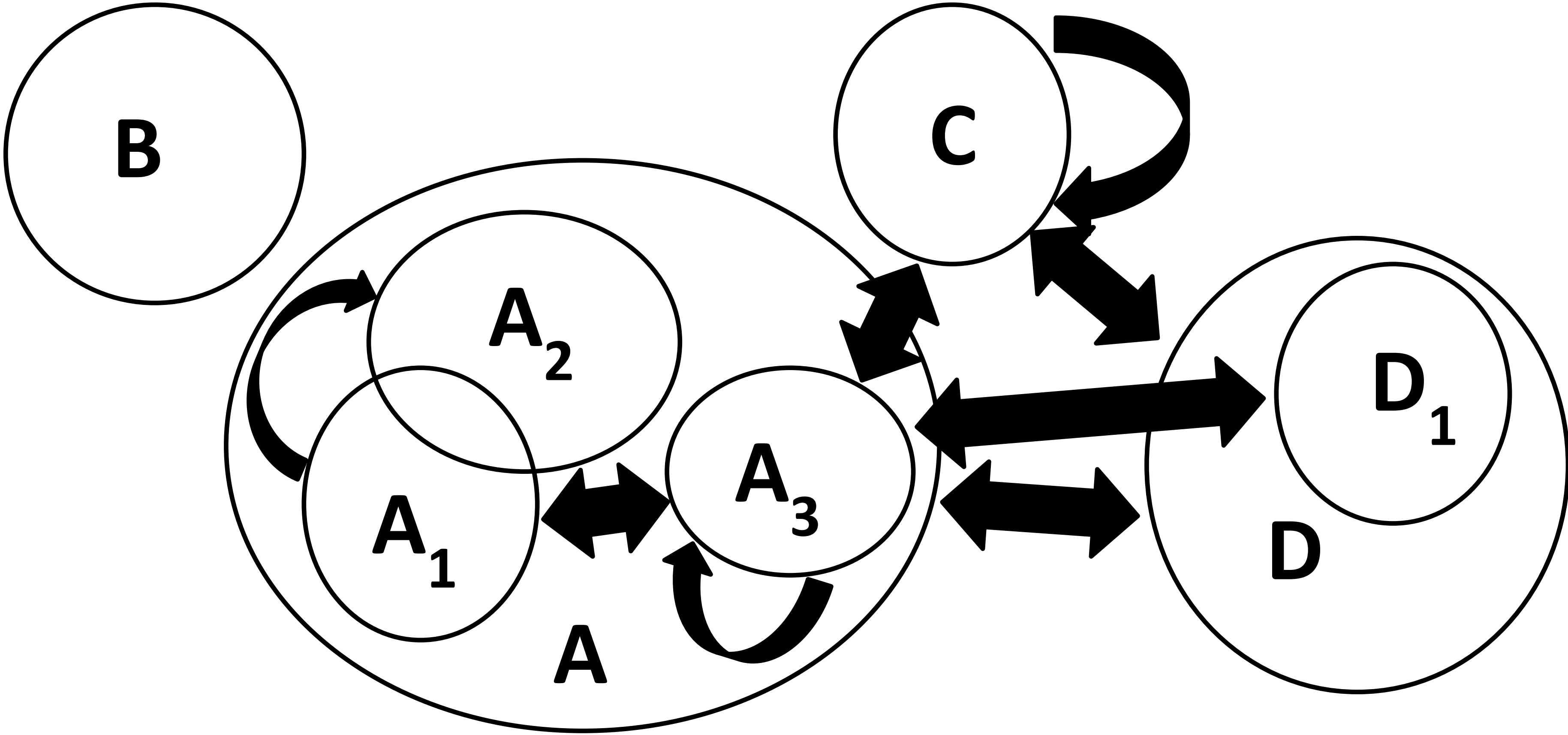


(https://dkrz-sw.gitlab-pages.dkrz.de/yac/db/dbc/interp_stack.html)

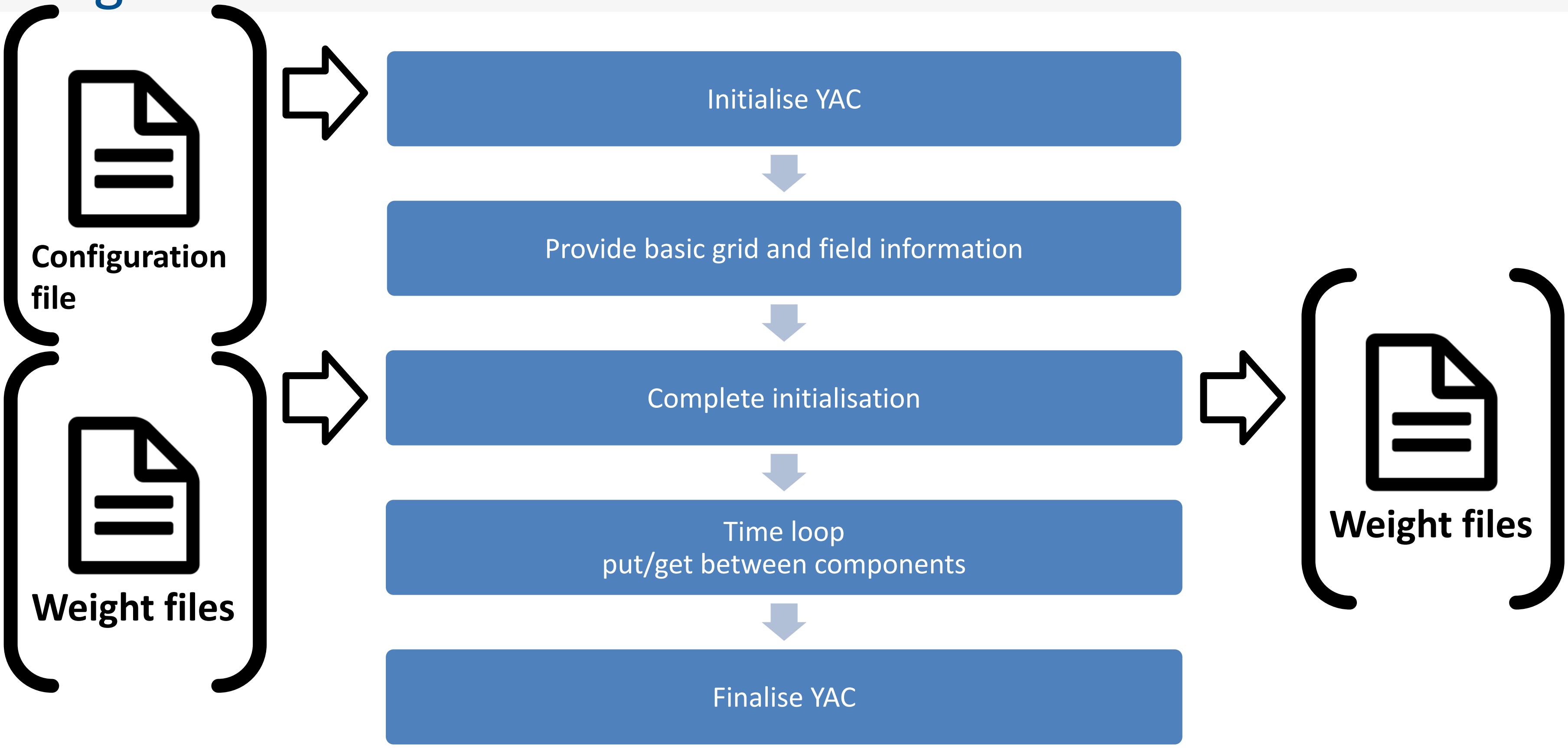
Interpolation Quality

- Benchmark on regridding quality by CERFACS in the frame of ISENES-Project
  - "This benchmark leads us to conclude that YAC, ESMF, and XIOS can all three be considered as high-quality regridding libraries [...]"
  - Valcke, S.; Piacentini, A.; Jonville, G. Benchmarking Regridding Libraries Used in Earth System Modelling. Math. Comput. Appl. 2022, 27, 31. https://doi.org/10.3390/mca27020031

Supported coupling configurations



Usage


Configuration file
Weight files
Initialise YAC
Provide basic grid and field information
Complete initialisation
Time loop
put/get between components
Finalise YAC
Weight files

Fortran example

```
USE mo_yac_finterface

CALL yac_finit()
CALL yac_fdef_calendar(&
  YAC_PROLEPTIC_GREGORIAN)
```

Fortran example

```
CALL yac_fread_config_yaml( &
   "coupling.yaml")
```

Fortran example

```
INTEGER :: comp_id
INTEGER :: comp_comm

CALL yac_fdef_comp( &
  “atmosphere”, comp_id)
CALL yac_fget_comp_comm( &
  comp_id, comp_comm)
```

Fortran example

```
INTEGER, PARAMETER :: nbr_vertices = …
INTEGER, PARAMETER :: nbr_cells = …
INTEGER, PARAMETER :: nbr_vertices_per_cell = …
REAL, ALLOCATABLE :: vertex_lon(nbr_vertices)
REAL, ALLOCATABLE :: vertex_lat(nbr_vertices)
INTEGER, ALLOCATABLE :: &
    cell_to_vertex(nbr_vertices_per_cell,nbr_cells)

INTEGER :: grid_id

CALL yac_fdef_grid( &
    "atmosphere_grid", nbr_vertices, nbr_cells, &
    nbr_vertices_per_cell, vertex_lon, vertex_lat, &
    cell_to_vertex, grid_id)
```

Fortran example

```
REAL, ALLOCATABLE :: cell_lon(nbr_cells)
REAL, ALLOCATABLE :: cell_lat(nbr_cells)

INTEGER :: cell_point_id

CALL yac_fdef_points( &
   grid_id, nbr_cells, &
   YAC_LOCATION_CELL, &
   cell_lon, cell_lat, &
   cell_point_id)
```

Fortran example

```
INTEGER, PARAMETER :: collection_size = …

INTEGER :: taux_field_id

CALL yac_fdef_field( &
   “TAUX”, comp_id, &
   (/cell_point_id/), 1, &
   collection_size, “600”, &
   YAC_TIME_UNIT_SECOND, &
   taux_field_id)
```

Fortran example

```
CALL yac_fenddef()
```

Fortran example

```
REAL :: taux_buffer(nbr_cells, &
                    collection_size)
INTEGER :: info, error

DO t = 1, ntimes
  …
  CALL yac_fput( &
    taux_field_id, nbr_cells, &
    collection_size, taux_buffer, &
    info, error)
  …
END DO
```

Fortran example

```
REAL :: taux_buffer(nbr_cells, &
                    collection_size)
INTEGER :: info, error

DO t = 1, ntimes
  …
  CALL yac_fget( &
    taux_field_id, nbr_cells, &
    collection_size, taux_buffer, &
    info, error)
  …
END DO
```

Fortran example

```
CALL yac_ffinalize()
```

End

- Questions?
- Download: https://gitlab.dkrz.de/dkrz-sw/yac
- Documentation: https://dkrz-sw.gitlab-pages.dkrz.de/yac/
- References

  - M. Hanke, R. Redler, T. Holfeld und M. Yastremsky, 2016: YAC 1.2.0: new aspects for coupling software in Earth system modelling. Geoscientific Model Development, 9, 2755-2769, https://doi.org/10.5194/gmd-9-2755-2016
  - M. Hanke und R. Redler, 2019: New features with YAC 1.5.0. Reports on ICON, No 3. https://doi.org/10.5676/DWD_pub/nwv/icon_003
  - E. Kritsikis, M. Aechtner, Y. Meurdesoif, and T. Dubos: Conservative interpolation between general spherical meshes, Geosci. Model Dev., 10, 425–431, https://doi.org/10.5194/gmd-10-425-2017, 2017
  - Xiaoyu Liu, Larry L. Schumaker, Hybrid Bézier patches on sphere-like surfaces, Journal of Computational and Applied Mathematics, Volume 73, Issues 1–2, 1996, Pages 157-172, ISSN 0377-0427, https://doi.org/10.1016/0377-0427(96)00041-6

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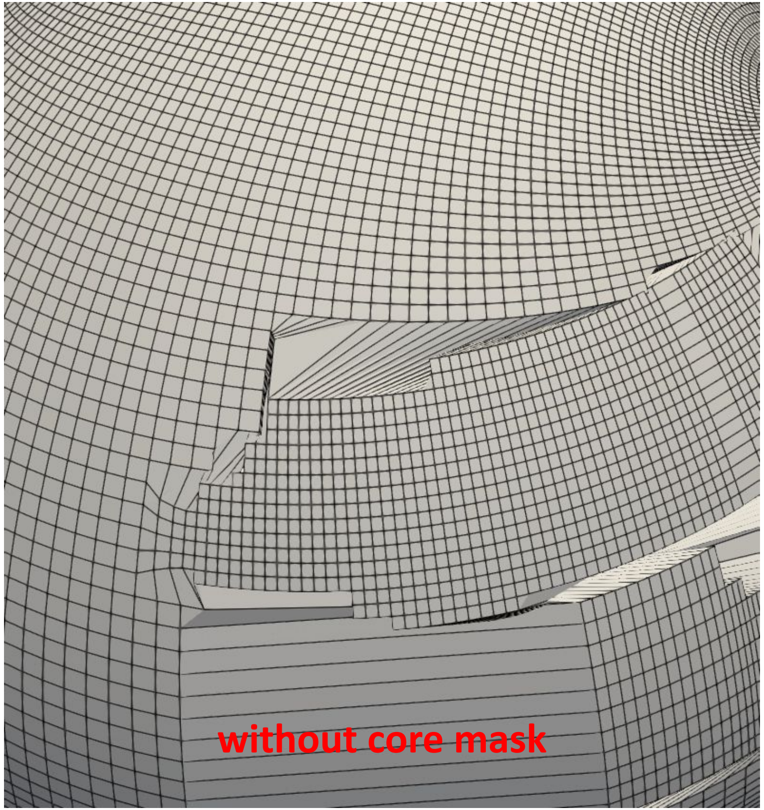
Topics

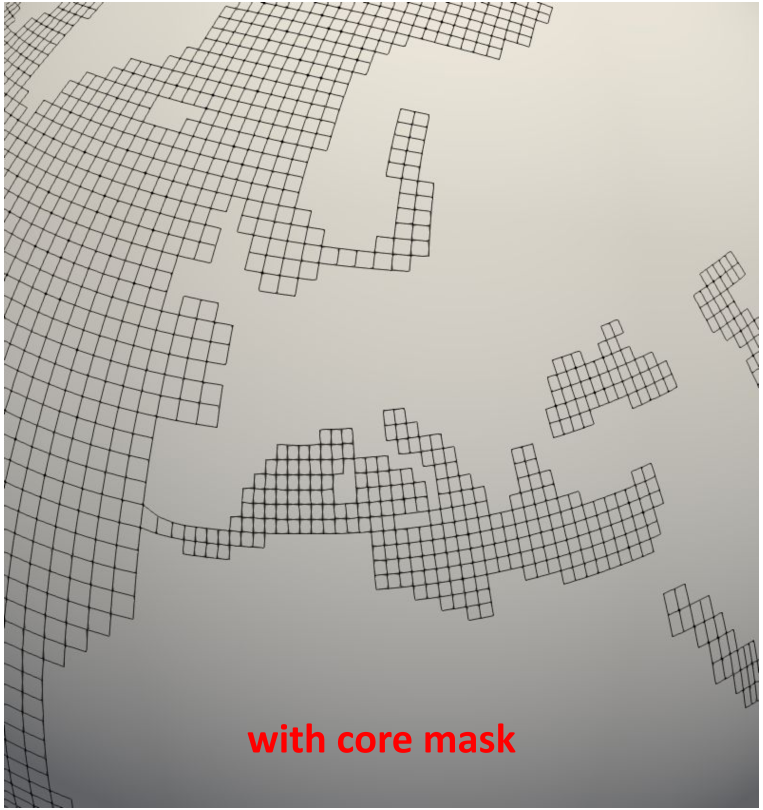
- Masks types
- Configuration files
- Definition of couples
- Synchronisation of definitions
- Querying of definitions

Masks types

Core mask	Field mask
defined per grid	defined per points or per field
masked out cells/vertices/edges are completely ignored by YAC	mask out cells/vertices/edges are ignored in the weight computation
used to mask out degenerated and duplicated cells/vertices/edges	used to mask out cells/vertices/edges that have no valid data assigned to them (e.g. halos) or that should not receive data

Core mask example





Field mask application

- In atmo/ocean coupling
  - deactivate land points in global atmo grid
- Halos
  - deactivate halos for outgoing fields
    → send only valid data
  - activate halos for ingoing fields
    → no halo update required after coupling

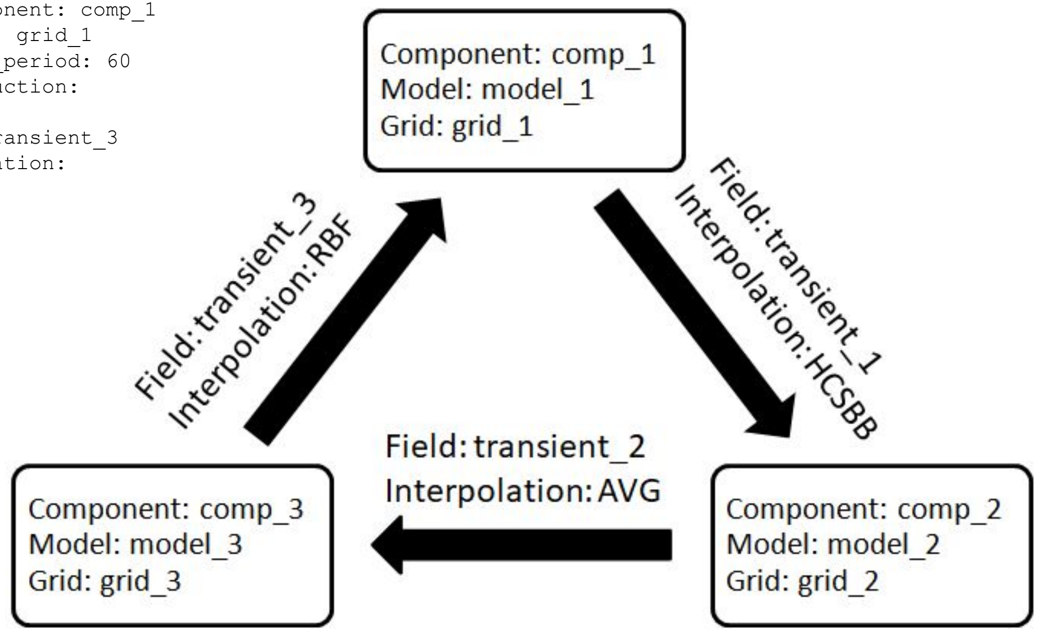
Configuration files

- Contains information about
  - (optional) start- and end date of the run
  - (optional) calendar to be used
  - which fields are supposed to be coupled
  - what interpolation is supposed to be used
  - at which frequency the coupling is supposed to be executed
- Have to be read in by at least one process
- One or more configuration files can be read by arbitrary processes
- Full support of YAML Version 1.2
- Documentation at:

  https://yac.gitlab-pages.dkrz.de/YAC-dev/dd/dfa/yaml_file.html

Configuration files example

```yaml
start_date: 2008-03-09T16:05:07
end_date: 2008-03-10T16:05:07
timestep_unit: second
calendar: proleptic-gregorian
coupling:
# comp_1 -> comp_2
  - src_component: comp_1
    src_grid: grid_1
    tgt_component: comp_2
    tgt_grid: grid_2
    coupling_period: 60
    time_reduction: accumulate
    field: transient_1
    interpolation:
      - bernstein_bezier
# comp_2 -> comp_3
  - src_component: comp_2
    src_grid: grid_2
    tgt_component: comp_3
    tgt_grid: grid_3
    coupling_period: 60
    time_reduction: accumulate
    field: transient_2
    interpolation:
      - average
# comp_3 -> comp_1
  - src_component: comp_3
    src_grid: grid_3
    tgt_component: comp_1
    tgt_grid: grid_1
    coupling_period: 60
    time_reduction:
accumulate
    field: transient_3
    interpolation:
      - rbf
```



Configuration files example

```yaml
definitions:
  - &time_config
    src_lag: 1
    tgt_lag: 1
    coupling_period: 3600
  - &config_model
    <<: *time_config
    time_reduction: none
    interpolation:
      - nnn
      - fixed:
         user_value: -999.0
  - &config_io
    <<: *time_config
    time_reduction: accumulate
    interpolation:
      - conservative:
         enforced_conservation: false
         normalisation: fracarea
         partial_coverage: false
      - fixed:
         user_value: -999.0
```

```yaml
start_date: 2008-03-09T16:05:07
end_date: 2008-03-10T16:05:07
timestep_unit: second
calendar: proleptic-gregorian
coupling:
  - src_component: dummy_atmosphere
    src_grid: dummy_atmosphere_grid
    tgt_component: dummy_ocean
    tgt_grid: dummy_ocean_grid
    <<: *config_model
    field: [surface_downward_eastward_stress,
            surface_downward_northward_stress,
            surface_fresh_water_flux,
            surface_temperature,
            total_heat_flux,
            atmosphere_sea_ice_bundle]
  - src_component: dummy_ocean
    src_grid: dummy_ocean_grid
    tgt_component: dummy_atmosphere
    tgt_grid: dummy_atmosphere_grid
    <<: *config_model
    field: [sea_surface_temperature,
            eastward_sea_water_velocity,
            northward_sea_water_velocity,
            ocean_sea_ice_bundle]
```

Definition of couples

- Couples can be defined in definition phase by
  - reading of configuration file
  - call to user interface routine `yac_fdef_couple`

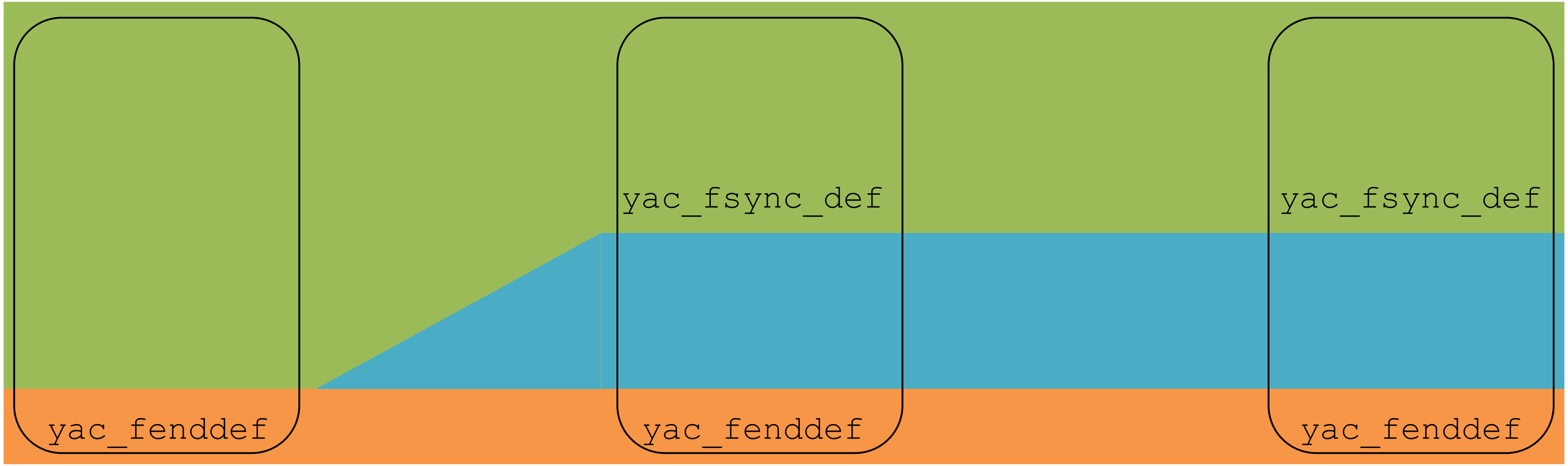
Definition of couples via user interface

```
subroutine yac_fdef_couple (                          &
  src_comp_name, src_grid_name, src_field_name, &
  tgt_comp_name, tgt_grid_name, tgt_field_name, &
  coupling_timestep, time_unit, time_reduction, &
  interp_stack_config_id, src_lag, tgt_lag,      &
  weight_file, mapping_side, scale_factor,       &
  scale_summand, src_mask_names, tgt_mask_name )

! *: optional arguments
```

Synchronisation of definitions

Definition phase (grids, fields, and couples)



Querying of definitions

- YAC internally keeps global configuration information about all components, grids, and fields on each process
- Each processes can query about this information
- Examples:
  - Is component “atmo” defined
  - Has component “ocean” defined field “sea_surface_temperature”
  - What is the collection size of field “total_heat_flux” on component “atmo”

End

- Questions?
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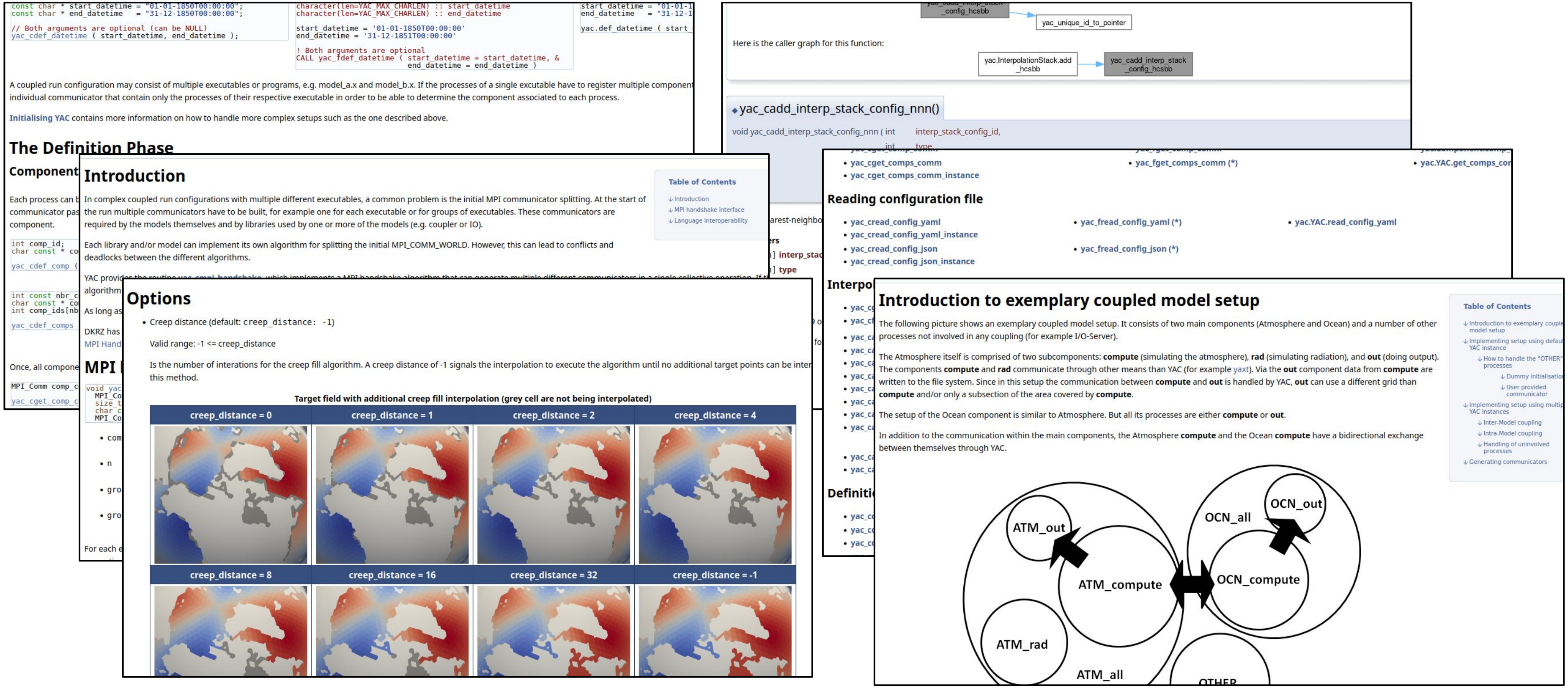
  - E. Kritsikis, M. Aechtner, Y. Meurdesoif, and T. Dubos: Conservative interpolation between general spherical meshes, Geosci. Model Dev., 10, 425–431, https://doi.org/10.5194/gmd-10-425-2017, 2017
  - Xiaoyu Liu, Larry L. Schumaker, Hybrid Bézier patches on sphere-like surfaces, Journal of Computational and Applied Mathematics, Volume 73, Issues 1–2, 1996, Pages 157-172, ISSN 0377-0427, https://doi.org/10.1016/0377-0427(96)00041-6

YAC in OASIS

- OASIS3-MCT 6.0 planned for end 2024
  - contains optional online weight computation by YAC

Documentation



Initial MPI communicator splitting

- initials communicator splitting is done by YAC using an MPI handshake algorithm
  - https://gitlab.dkrz.de/dkrz-sw/mpi-handshake
- processes not using YAC can take part in this splitting by using this algorithm, which is independent from YAC