

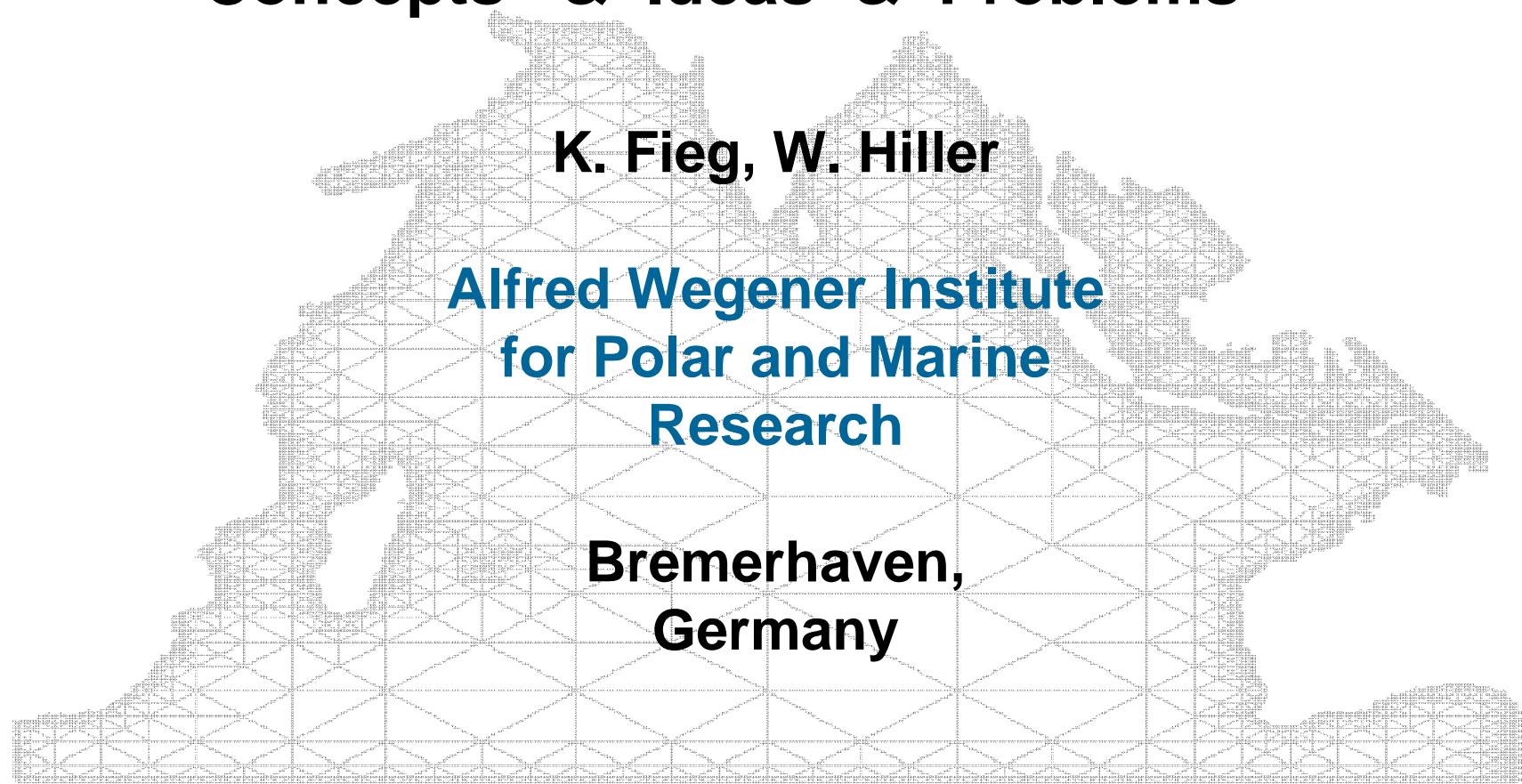
First Steps to include unstructured Grids to OASIS 4

Concepts & Ideas & Problems

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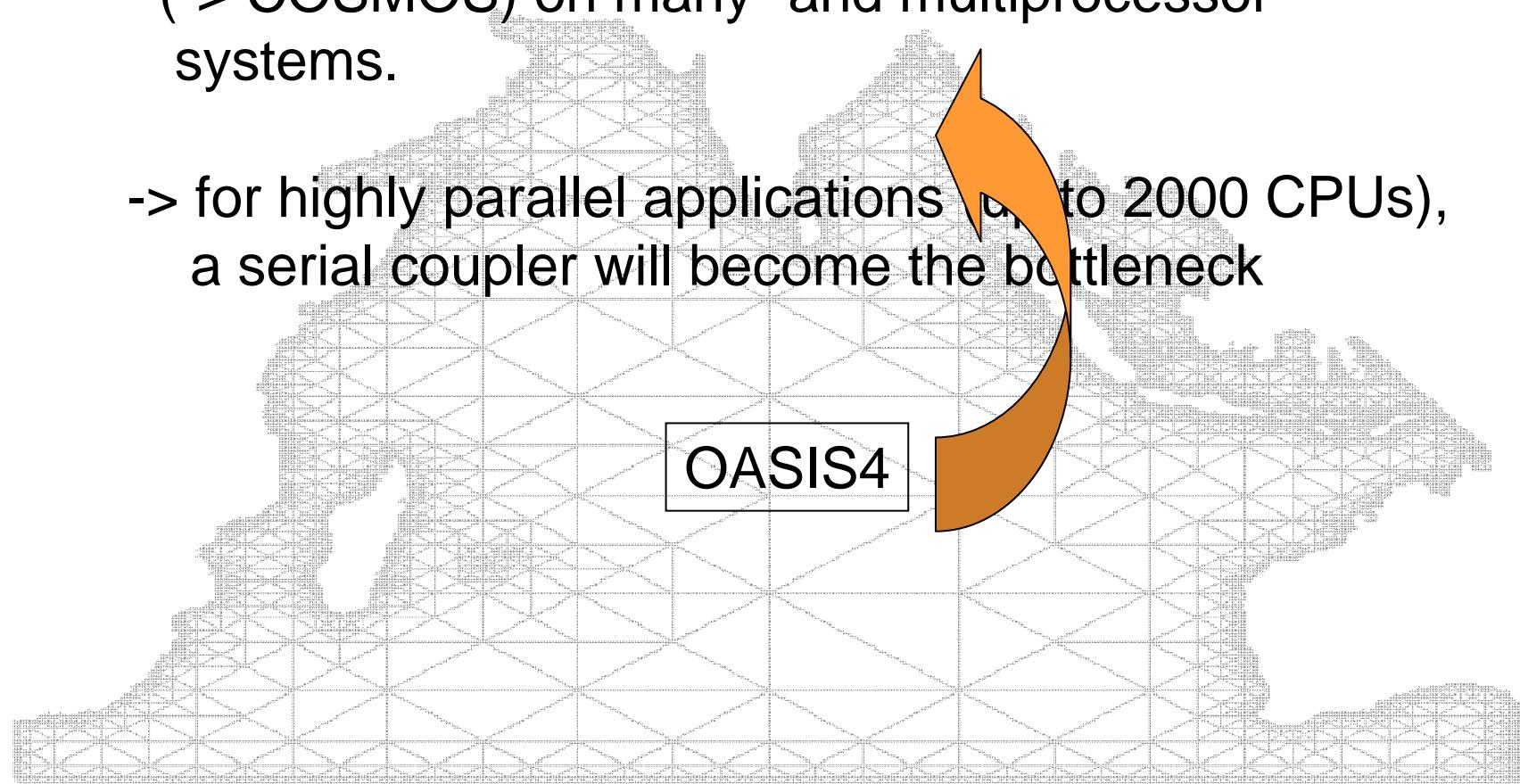
Bremerhaven,
Germany



ScalES - WP 3: Coupler

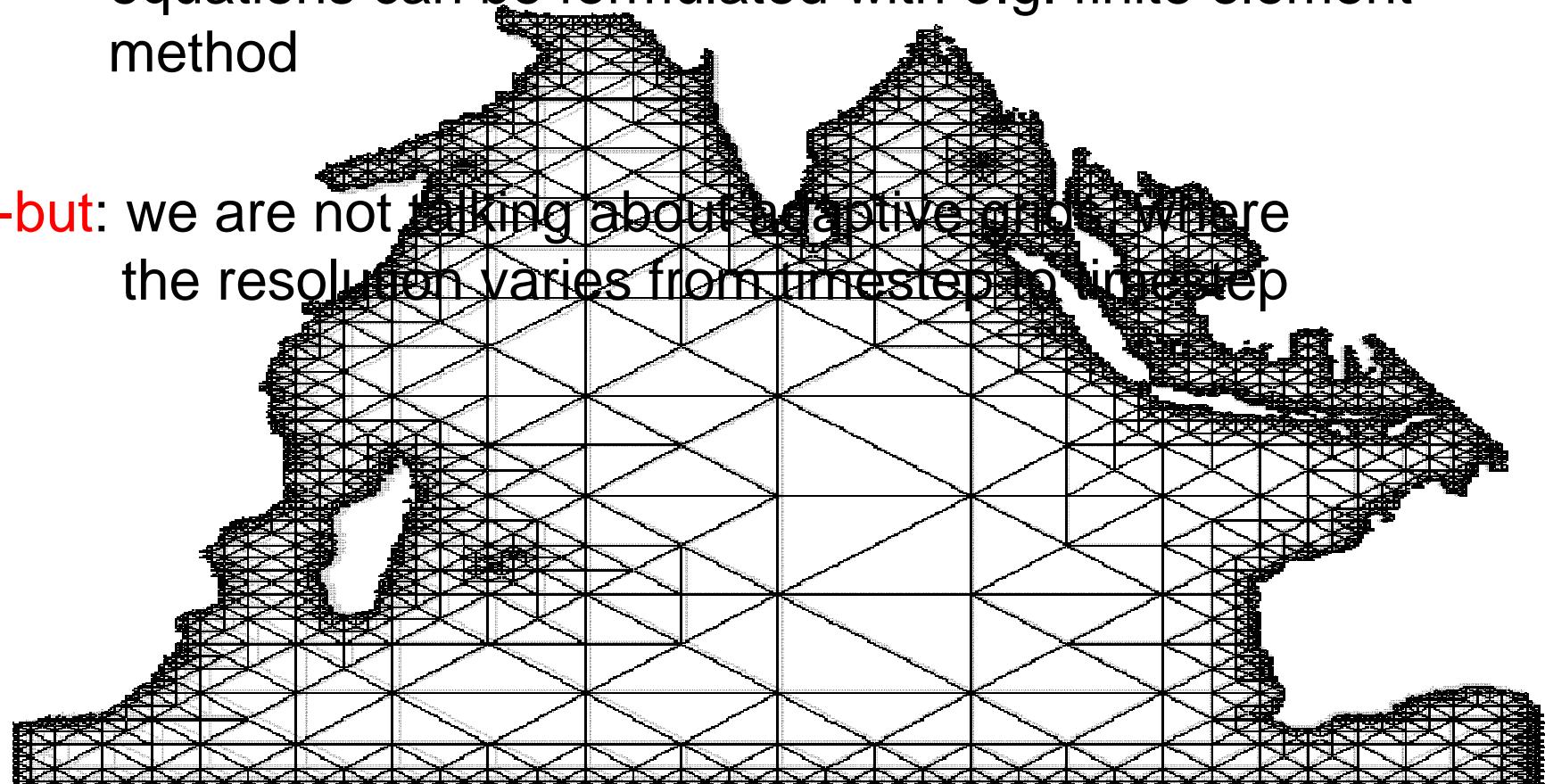
- BMBF funded project
- focus on technical part of coupling (not physical!)
- gives the possibility, to study scalability of ESMs
(-> COSMOS) on many- and multiprocessor systems.

-> for highly parallel applications (up to 2000 CPUs),
a serial coupler will become the bottleneck



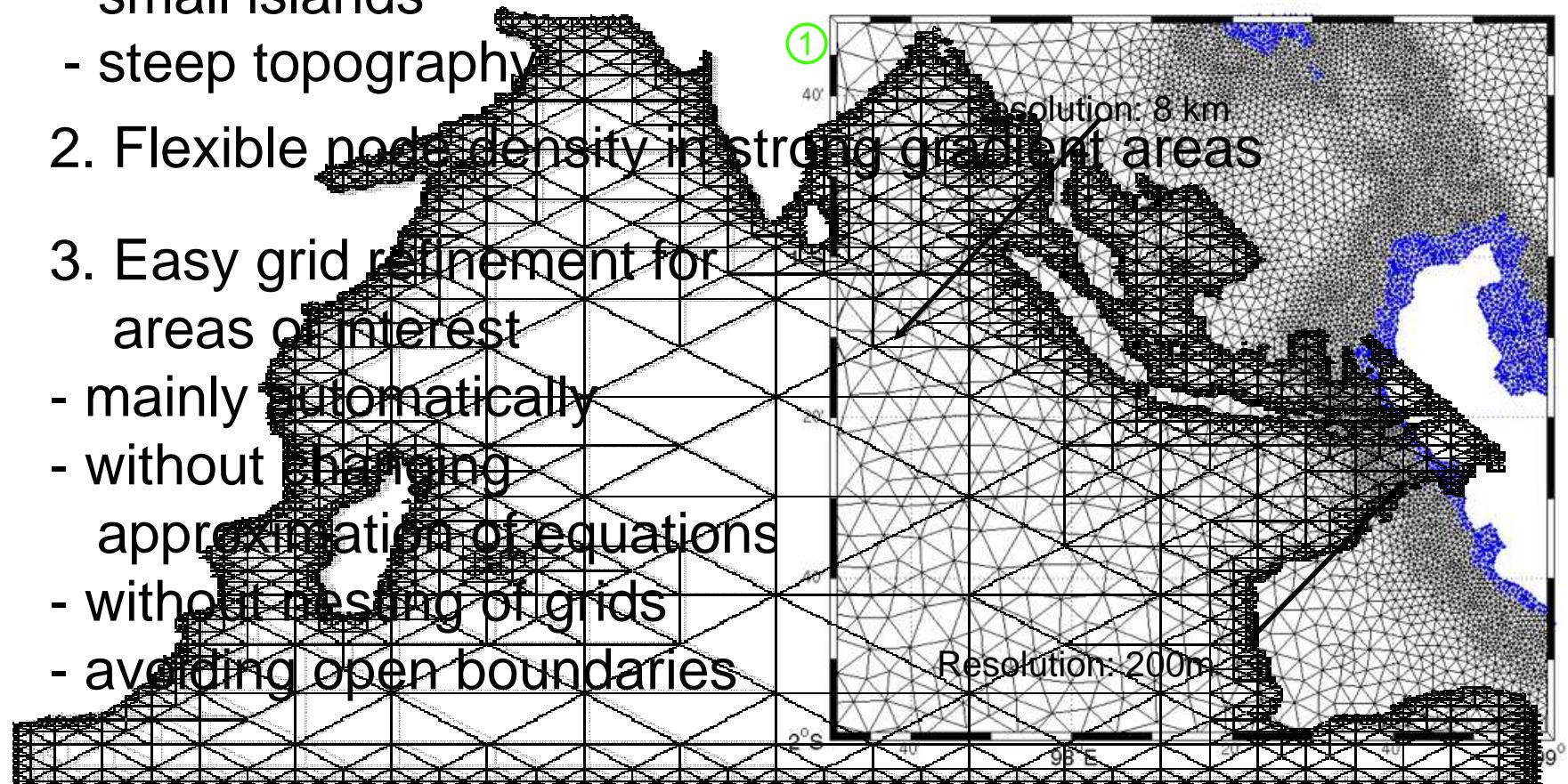
Some words about unstructured grids?

- not:** data streams, irregular in space and / or time
e.g. meteorological observations
- but:** large scale geographical grids, where the relevant equations can be formulated with e.g. finite element method
- but:** we are not talking about adaptive grids, where the resolution varies from timestep to timestep



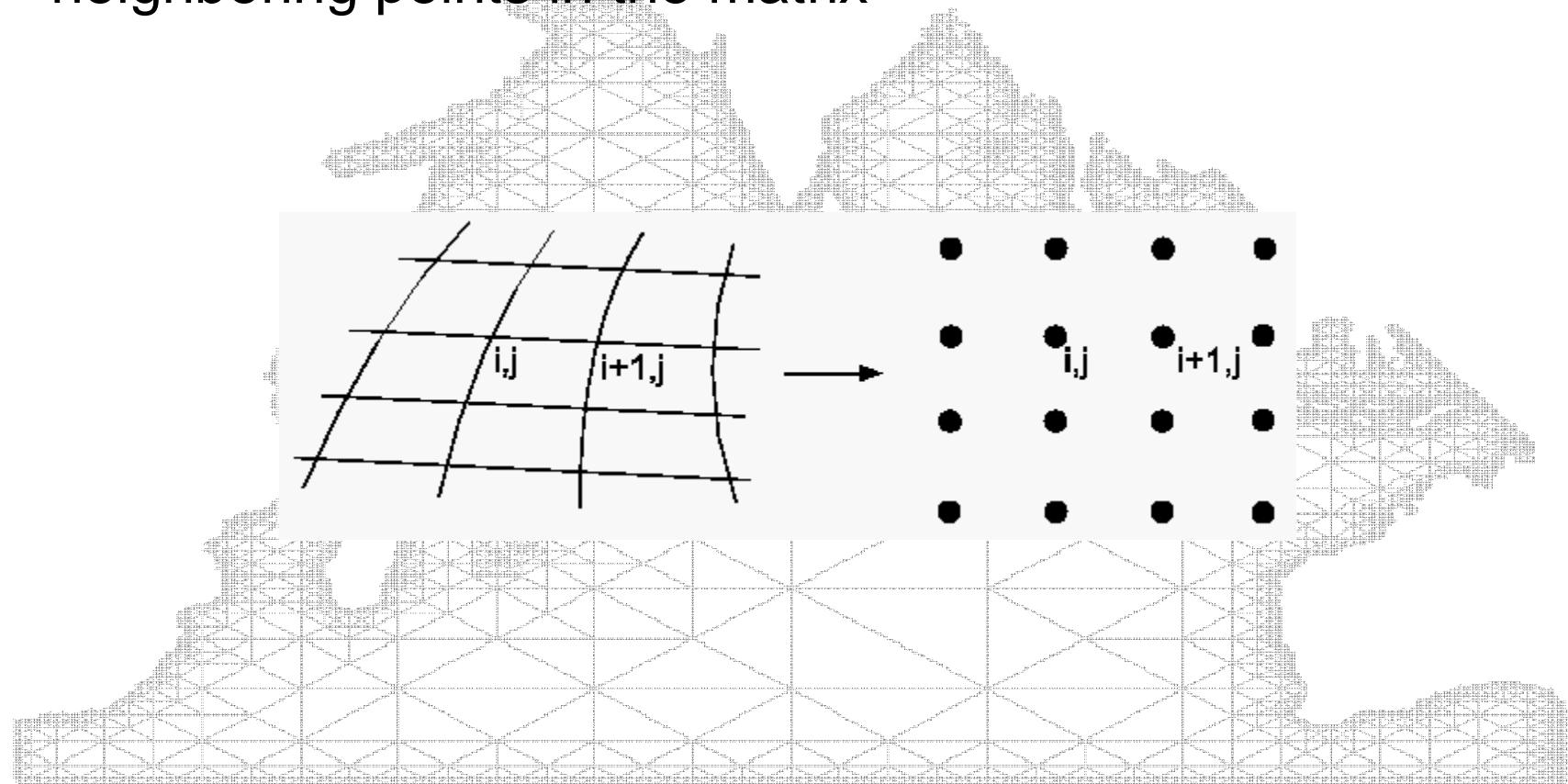
Advantages of unstructured grids

1. Easy handling of difficult geographical domains like
 - irregular coastlines
 - narrow straits
 - small islands
 - steep topography
2. Flexible node density in strong gradient areas
3. Easy grid refinement for areas of interest
 - mainly automatically
 - without changing approximation of equations
 - without nesting of grids
 - avoiding open boundaries



Disadvantages of unstructured grids:

Structured grids:
neighboring elements in the area (i,j) are
neighboring points in the matrix

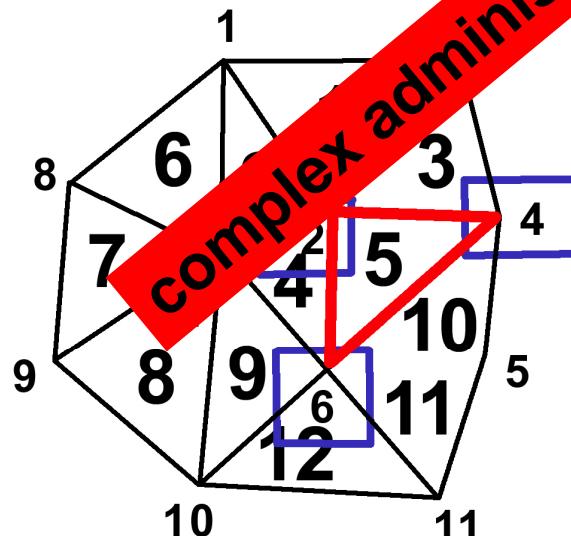


Disadvantages of unstructured grids:

Unstructured grids:

A „Connectivity Matrix“ describes the neighborhood of triangles.

Neighboring elements in the matrix are not necessarily neighboring points in the grid !

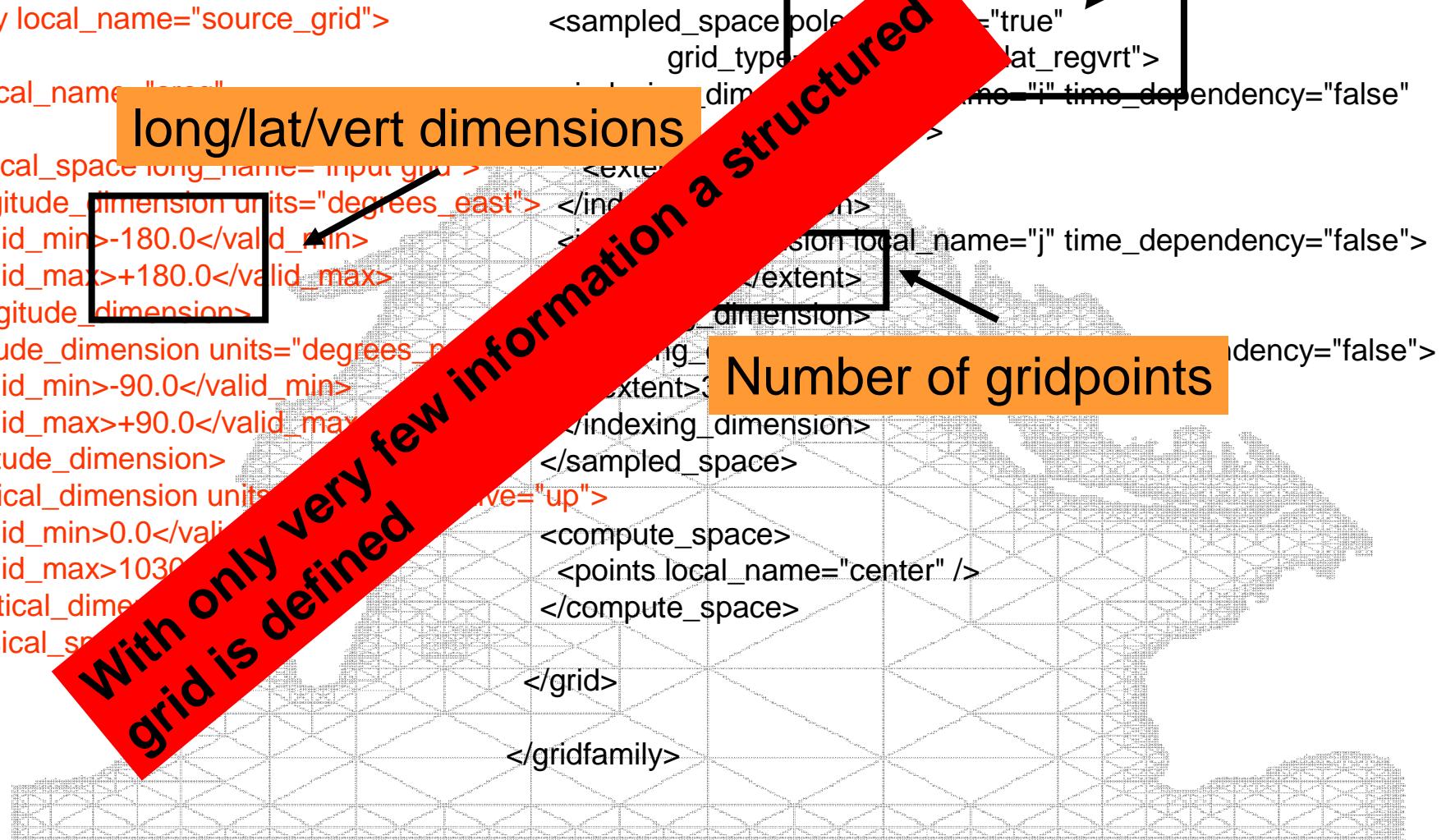


Connectivity Matrix

Element	Nodes	Nodes	Nodes
1	1	2	3
2	1	7	2
3	2	4	3
4	2	7	6
5	6	4	2
6	7	1	8
7	7	8	9

Technical problems

SMIOC: xml – file for a **regular** grid:



```
<gridfamily local_name="source_grid">
  <grid local_name="">
    <physical_space long_name="input_grid">
      <longitude_dimension units="degrees_east">
        <valid_min>-180.0</valid_min>
        <valid_max>+180.0</valid_max>
      </longitude_dimension>
      <latitude_dimension units="degrees_north">
        <valid_min>-90.0</valid_min>
        <valid_max>+90.0</valid_max>
      </latitude_dimension>
      <vertical_dimension units="sigma">
        <valid_min>0.0</valid_min>
        <valid_max>1030</valid_max>
      </vertical_dimension>
    </physical_space>
    <sampled_space pole="true" grid_type="lat_rect">
      <extents dimension="i">
        <extents dimension="j" local_name="j" time_dependency="false">
          <extents dimension="k" local_name="k" time_dependency="false">
            <extents dimension="l" local_name="l" time_dependency="false">
              <extents dimension="m" local_name="m" time_dependency="false">
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                              <extents dimension="u" local_name="u" time_dependency="false">
                                <extents dimension="v" local_name="v" time_dependency="false">
                                  <extents dimension="w" local_name="w" time_dependency="false">
                                    <extents dimension="x" local_name="x" time_dependency="false">
          </extents>
        </extents>
      </extents>
    </sampled_space>
    <compute_space>
      <points local_name="center" />
    </compute_space>
  </grid>
</gridfamily>
```

gridtype

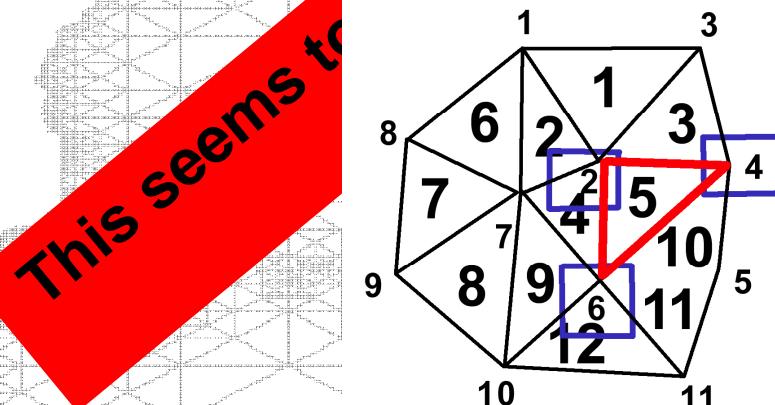
long/lat/vert dimensions

Number of gridpoints

With only very few information a structured grid is defined

Technical problems

Solution: additional files
OASIS4
many
(e.g. 1 line per
more information is needed
to make
the problem
describable an unstructured grid
OASIS4



Connectivity Matrix

Element	Nodes
1	1 2 3
2	1 7 2
3	2 4 3
4	2 7 6
5	6 4 2
6	7 1 8
7	7 8 9

technical problems

Like for the coupled models, structured grids have to be provided according to accepted standards.

- SCC (Specific Coupling Configuration)
- SMIOC (Specific Input Output Configuration)

...

Problem: up to now, there is no accepted standard for unstructured input (e.g. Balaji, Böttinger)

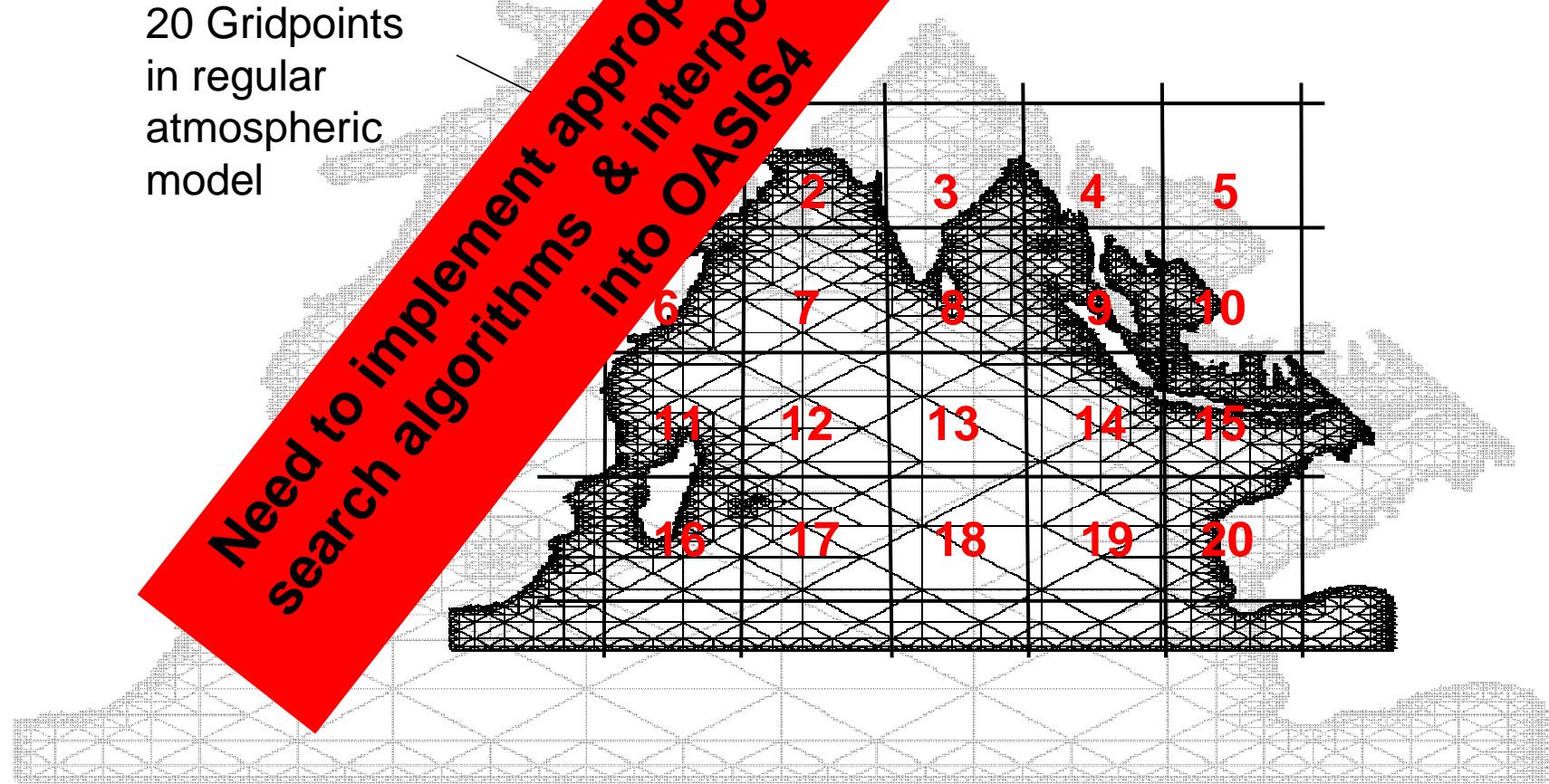
To Do: metadata standards for unstructured grids have to be defined (e.g. accepted metadata)

Technical problems

Ratio of source GP : target GP vary significantly

20 Gridpoints
in regular
atmospheric
model

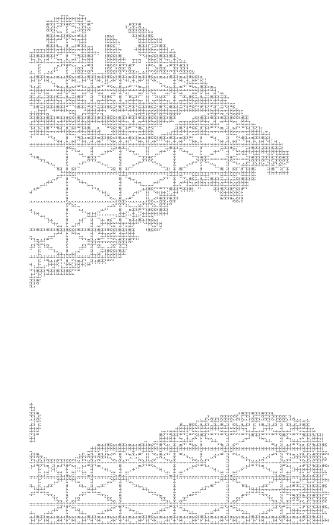
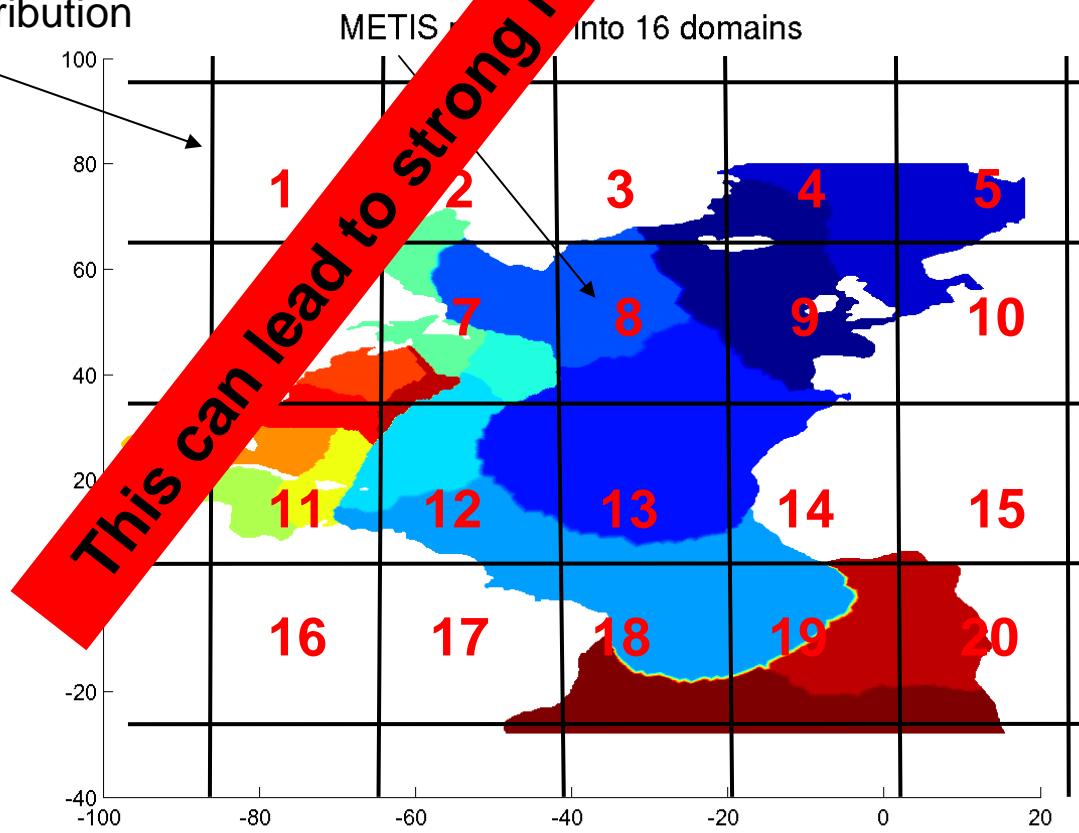
Need to implement appropriate, performant
search algorithms & interpolation schemes
into OASIS4



Technical problems

Ratio of source processes : target processes can vary significantly, mapping of non-rectangular grid geometry is complicated

Processor distribution
In regular atmospheric model



Physical problems

The coupling of unstructured grids was not tried yet for large scale climate model components

Strange and unpredictable things can happen!

Physical problems

Finding adequate resolution in time and space for coupling

Question: how can up- and down scaling of grid information from such different grids be realized in a way, that the relevant details don't get lost ?

Solution: the scientist has to take care for an intelligent model setup – an automatic transformation can lead to unwanted results.

Physical problems

mass conservation

coupling algorithm has to consider:

- non matching grid at land / ocean interface
- different element shapes ( / )

model drift

Coupled values calculated in one grid, passed over to the second and distributed there.

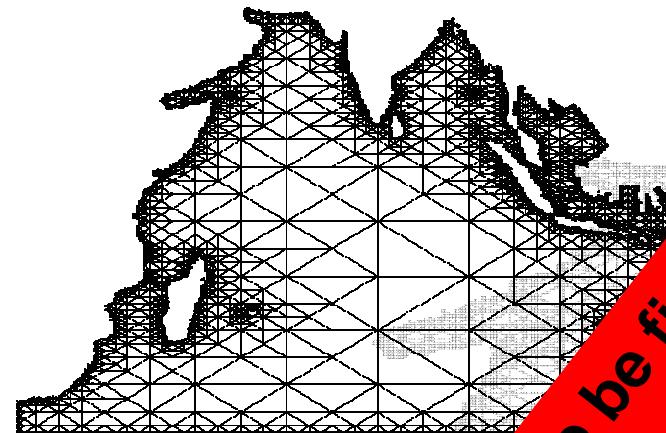
We have to deal with mainly the same problems, but in a more "extreme" way

My preliminary ToDo List

- metadata standards for unstructured grids have to be defined and discussed in the community
- a way to pass additional grid information to OASIS4 has to be discussed with the OASIS developer
- implementing performant search algorithms (e.g. CISL) into the OASIS4 code
- secure load balancing also for very unbalanced element distribution in the grids
- secure mass conservation also for coupling to strange element shapes
- find transformation routines appropriate for unstructured grids

First step: Coupling unstructured grid to intermediate structured grid

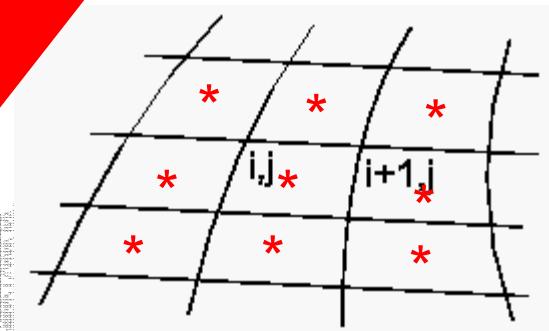
unstructured



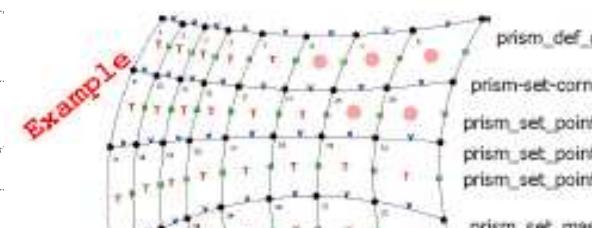
CCW
center
components

Promised to be finished until end of the year

structured intermediate grid with
“2nd order” resolution,
values cell centered



coupled via
OASIS4



Further steps: after interpolation to intermediate 2d lon / lat grid: direct coupling

- extending coupler interface to unstructured grids by amending unstructured grid nomenclatures
- extending existing xml communication structure of coupler to handle unstructured grids
- integration of additional mass conserving interpolation routines like „cell integrated interpolation scheme“ (e.g.CISL)
- testing different model setups
- secure portability by platform independency
- optimizing code for HPC

As a summary, coupling unstructured grids means:

- dealing with a similar class of problems as coupling structured grid
- the administration of the unstructured geometry requires an additional type of data structure
- special care in transformation, mass conservation and interpolation is needed to avoid model drift
- setting up a model run needs more manual interaction
- strong coordination work is needed to integrate unstructured grid concepts into existing coupler



Thank you