The European PRISM Initiative

&

the OASIS coupler

S. Valcke, CERFACS (France)
R. Budich, MPI –M (Germany)
M. Carter, UK MetOffice (UK)
M.-A. Foujols, IPSL (France)
E. Guilyardi, CNRS (France)
M. Lautenschalger, MPI-M&D (Germany)
R. Redler, NEC-CCRLE (Germany)
L. Steenman-Clark, CGAM (UK)
N. Wedi, ECMWF
Outline

• Part I - PRISM:
  • goals & benefits
  • FP5 project and the Support Initiative
  • organisation
  • the PRISM Areas of Expertise

• Part II - OASIS:
  • historical background
  • community today
  • the OASIS3 coupler
  • the OASIS4 coupler

• Conclusions - summary
PRISM: the goals

- Increase what Earth system modellers have in common
- Share development and support of these common tools and standards

Today

- Compiling + running env.
- Coupling & I/O
- Science
- MPI – LAPACK - …
- Fortran & C Compilers

Tomorrow

- Metadata
- Source management
PRISM: the benefits

- reduce the technical efforts of each research team
- facilitate assembling, running, and post-processing of ESMs based on state-of-the-art component models

Help climate modellers spend more time on science:

- promote key scientific diversity
- increase scientific collaboration
- stimulate computer manufacturer contribution
PRISM: FP5 project and Support Initiative

• 2001-2004: the PRISM EU project
  – a European project funded for 4.8 M€ by the EC
  – 22 partners

• 2005-2008: the PRISM Support Initiative:
  – 7 partners:
    France: CERFACS, CNRS
    Germany: MPI-M&D, NEC-CCRLE
    UK: CGAM, UK MetOffice
    ECMWF
  – 9 associate partners:
    CSC (Finland)
    IPSL, Météo-France (France)
    SMHI (Sweden)
    MPI-M (Germany)
    CRAY
    SUN
    SGI
    NEC-HPCE
PRISM: the Areas of Expertise

PRISM is organised around 5 “PRISM Areas of Expertise”:

• Organisation of related network of experts
• Promotion and, if needed, development of software tools for ESM
• Promotion of community standards
• Coordination with other international efforts

- Code coupling and I/O
- Integration and modelling environments
- Data processing, visualisation and management
- Meta-data
- Computing
PRISM: the organisation

PRISM Steering Board
CERFACS, CGAM, CNRS, ECMWF, MPI-M&D, UK MetOffice, NEC-CCRLE

PRISM SB Chair
P. Bougeault (ECMWF)

PRISM Coordinator(s)
E. Guilyardi (CNRS), S. Valcke (CERFACS)

PRISM Core Group
(7 people)

PRISM areas of expertise (PAEs)
- Code Coupling & I/O
- Integration & modelling environments
- Data processing, visualisation and management

- Meta data
- Computing

PUG chair
R. Budich (MPI)

PRISM User Group
**PAE Code Coupling and IO**  
**Leader: S. Valcke (CERFACS)**

- Development and support of OASIS3 and OASIS4 couplers
- Technology watch on coupling tools developed outside PRISM:
  - PALM coupler (CERFACS), BFG (U. of Manchester), CCSM (NCAR), ...
- Relations with projects involving code coupling:
  - UK Met Office FLUME project, US ESMF project, GENIE project, ACCESS

**PAE Integration & modelling environments**  
**Leader: M.Carter (MetOffice)**

- Source version control for software development
  - Subversion
- Code extraction and compilation
  - FCM (UK MetOffice), PRISM SCE (MPI M&I)
- Job configuration & running
  - prepIFS/prepOASIS4, SMS (ECMWF), PRISM SRE (MPI M&I)
**PRISM: the Areas of Expertise**

**PAE Data processing, visualisation and management**

*Leader: M. Lautenschlager (MPI-M&D)*

- Data processing, visualization, archiving and exchange for Earth system
  - NetCDF CF convention
  - CDO (MPI-M), CDAT (PCMDI)
  - CERA-2 data model (World Climate Data Centre, MPI-M&D)
  - MARS (ECMWF)

- Networking between geographically distributed archives

**PAE Computing**

*Leader: M.-A. Foujols (IPSL), R. Redler (NEC-CCRLE)*

- Keep computer vendors informed about climate community requirements
- Keep Earth system modellers informed about computing evolutions

- Computing aspects important for Earth system modelling:
  - File IO, algorithmic developments, portability (parallel and vector systems)
**PAE Meta-data**  
Leader: L. Steenman-Clark (CGAM)

*Meta-data: data about data, models, runs, ...*  
*... a hot topic in the last few years*

- exchange and use of data  
- interchangeability of Earth system models or modelling components

**forum to discuss, develop, and coordinate metadata issues:**

- **Numerical Model Metadata (U. of Reading):** numerical code bases, simulations  
- **CURATOR project (USA):** data, codes, simulations  
- **Numerical grid metadata (GFDL, USA):** grid  
- **netCDF CF convention (PCMDI and BADC):** climate and forecast data files  
- **OASIS4 metadata** coupling and IO interface  
- **UK Met Office FLUME project:** management of model configuration
End of Part I - PRISM
The OASIS coupler

What is a coupler?
A software tool that:
- exchanges (any) information between models with minimal interference in the codes
- transforms the coupling fields from the source model grid to the target mode grid
- contains no “science”; does not define the components

Why use a coupler?
- change as little as possible existing component models
- keep the modularity (model development, evolution)
- keep the flexibility to change one or more components
- use the coupler interpolation and regridding functionality

e.g. ocean-atmosphere: 2D coupling at the air-sea interface
OASIS: historical background

OASIS: developed since 1991 to couple existing GCMs

1991           2001
| ---  | --- PRISM |

OASIS 1 OASIS 2 OASIS 3 OASIS 4

OASIS 1, OASIS 2, OASIS 3:
• low resolution, low number of 2D fields, low coupling frequency:
  • flexibility very important, efficiency not so much!

OASIS 4:
• high resolution parallel models, massively parallel platforms, 3D fields
  • need to optimise and parallelise the coupler
OASIS: the community today

• CERFACS (France)
  ARPEGE4 - NEMO-LIM - TRIP
  ARPEGE3 - ORCA2-LIM

• Météo-France (France)
  ARPEGE4 - ORCA2
  ARPEGE media - OPAmed
  ARPEGE3 - OPA8.1-GELATO

• IPSL - LODYC, LMD, LSCE (France)
  LMDz - ORCA2-LIM
  LMDz - ORCA4

• MERCATOR (France)
  (for interpolation only)

• MPI - M&D (Germany)
  ECHAM5 - MPI-OM
  ECHAM5 - C-HOPE
  PUMA - C-HOPE
  EMAD - E-HOPE
  ECHAM5 - E-HOPE

• ECMWF
  - CTM (GEMS)
  IFS - ORCA2 (MERSEA)
  IFS
<table>
<thead>
<tr>
<th>Organization</th>
<th>Models and Components</th>
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<tbody>
<tr>
<td>IFM-GEOMAR (Germany)</td>
<td>ECHAM5 - NEMO (OPA9-LIM)</td>
</tr>
<tr>
<td>NCAS / U. Reading (UK)</td>
<td>ECHAM4 - ORCA2 HADAM3-ORCA2</td>
</tr>
<tr>
<td>SMHI (Sweden)</td>
<td>RCA(region.) – RCO(region.)</td>
</tr>
<tr>
<td>NERSC (Norway)</td>
<td>ARPEGE - MICOM</td>
</tr>
<tr>
<td>KNMI (Netherlands)</td>
<td>ECHAM5 - TM5/MPI-OM</td>
</tr>
<tr>
<td>INGV (Italy)</td>
<td>ECHAM5 – MPI-OM</td>
</tr>
<tr>
<td>ENEA (Italy)</td>
<td>MITgcm - REGgcm</td>
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<tr>
<td>JAMSTEC (Japan)</td>
<td>ECHAM5(T106) - ORCA ½ deg</td>
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<tr>
<td>IAP-CAS (China)</td>
<td>AGCM - LSM</td>
</tr>
<tr>
<td>BMRC (Australia)</td>
<td>BAM3–MOM2, BAM5–MOM2, TCLAPS-MOM</td>
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<tr>
<td>CSIRO (Australia)</td>
<td>Sea Ice code - MOM4</td>
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<tr>
<td>RPN-Environment Canada(Canada)</td>
<td>MEC - GOM</td>
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<td>UQAM (Canada)</td>
<td>GEM - RCO</td>
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<td>U. Mississippi (USA)</td>
<td>MM5 - HYCOM</td>
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<tr>
<td>IRI (USA)</td>
<td>ECHAM5 - MOM3</td>
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<tr>
<td>JPL (USA)</td>
<td>UCLA-QTTCM - Trident-Ind4-Atlantic</td>
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</tbody>
</table>
OASIS3 and OASIS4: Some key notes

- Developers: CERFACS, NEC CCRL/E, CNRS, SGI, NEC HPCE

- Public domain; open source license (LGPL)

- Programming language: Fortran 90 and C

- Public domain libraries:
  - external: MPI1 and/or MPI2; NetCDF/parallel NetCDF; libXML
  - included: GFDL mpp_io; LANL SCRIP
To use OASIS3 or OASIS4:

- Identify your component models
- Identify the coupling fields to be exchanged between those models
- Adapt your model i.e. insert calls to OASIS communication library (PSMILE)
- Choose the coupling parameters (source and target, frequency, fields transformations, etc.) and write the configuration file
- Compile OASIS and the components models linked with PSMILE
- Start OASIS and the models and let it manage the coupling exchanges
The OASIS3 coupler

• Coupler developed since more than 15 years in CERFACS
• Stable, well-debugged, but limited
• Last version: oasis3_2-5 delivered in September 2006
• User support provided but most development efforts go to OASIS4
• Platforms:
  • Fujitsu VPP5000, NEC SX5-6-8, Linux PC, IBM Power4, CRAY XD1, Compaq, SGI Origin, SGI O3400
**OASIS3: model adaptation**

**PRISM System Model Interface Library (PSMILE) API:**

- **Initialization:**
  
  ```
  call prism_init(...) 
  ```

- **Grid definition:**
  
  ```
  call prism_write_grid (...) 
  ```

- **Local partition definition:**
  
  ```
  call prism_def_partition (...) 
  ```

- **Coupling field declaration:**
  
  ```
  call prism_def_var (...) 
  ```

- **Coupling field exchange:**
  
  ```
  in model time stepping loop
  
  call prism_put (... , time, var_array. ...) 
  call prism_get (... , time, var_array, ...) 
  ```

- **user's defined source or target (end-point communication)**

- **sending or receiving at appropriate time only**

- **automatic averaging/accumulation if requested**

- **automatic writing of coupling restart file at end of run**
OASIS3: coupled model configuration

- In text file namcouple:
  - total run time
  - component models
  - number of coupling fields
  - for each exchange:
    - source and target names (end-point communication)
    - coupling or I/O period
    - transformations/interpolations
OASIS3: communication

PSMiLe based on MPI message passing

- Parallel communication between parallel models and interpolation process

- Direct communication between models with same grid and partitioning

- I/O functionality (switch between coupled and forced mode): GFDL mpp_io library
OASIS3: interpolations/transformations

- Separate sequential process
- Neighbourhood search
- Weight calculation
- Interpolation per se during the run

On 2D scalar or vector fields

- SCRIP 1.4 library, RPN Fast Scalar INTerpolator:
  - Nearest-neighbour interpolation
  - Bilinear interpolation
  - Bicubic interpolation
  - Conservative remapping

- Other spatial transformations: flux correction, merging, etc.
- General algebraic operations

On different types of grids: lat-lon, stretched or rotated (logically rectangular), gaussian reduced, unstructured
The OASIS4 coupler

• “New” coupler developed since ~ 2003

• Beta version available

• As flexible as OASIS3 but fully parallel and more efficient:
  • Parallel communication
  • Parallel interpolation based on NEC-CCRL/E multigrid algorithm
 Initialization:

\[
\text{call prism_init_comp (...)}
\]

Definition of grid (3D)

\[
\begin{align*}
\text{call prism_def_grid (...)} \\
\text{call prism_set_corners(...)}
\end{align*}
\]

Placement of scalar points and mask on the grid:

\[
\begin{align*}
\text{call prism_set_points (...)} \\
\text{call prism_set_mask (...)}
\end{align*}
\]
Example

prism_def_grid

prism-set-corners

prism_set_points

prism_set_points

prism_set_points

prism_set_mask
OASIS4: model adaptation (3/3)

• Coupling or I/O field declaration

```plaintext
call prism_def_var(...)```

• Coupling or I/O field sending and receiving:

  in model time stepping loop

```plaintext
call prism_put (var_id, date, date_bounds, var_array, info, ierr)
call prism_get (var_id, date, date_bounds, var_array, info, ierr)```

Depending on user’s specifications in SMIOC:

• user's defined source or target, component or file (end-point communication)
• coupling or I/O sending or receiving at appropriate times
• averaging/accumulation
XML (Extensive Markup Language) is a text format

An XML schema:
- defines the legal content of an XML file
- gives the possibility to check the validity of an XML file

Specific Coupling Configuration (SCC):
- start date and end date
- applications, components for each application
- host(s), number of processes per host, ranks for each component

For each component,
- a Specific Model Input and Output Configuration (SMIOC)
  - grid information: chosen resolution, …
  - coupling fields:
    - name, units, valid min max, numerical type, grid
    - input and/or output
    - source and/or target (component and/or file)
    - coupling or I/O dates
    - transformations/interpolations/combinations
Model interface library: PSMILE based on MPI1 or MPI2

- Parallel communication including repartitioning:
  - based on geographical description of the partitions
  - parallel calculation of communication patterns in source PSMILE

**OASIS4 communication (1/2)**

---

**Same grid, different decomposition**

- direct repartitioning

**Different grid and decomposition**

- interpolation in parallel Transformer

- one-to-one, one-to-many

- extraction of useful part of source field only
**OASIS4 communication (2/2)**

**Model interface library:** PSMILe based on MPI1 or MPI2

- **Parallel I/O (vector, bundles, vector bundles):** GFDL mpp_io + parNetCDF
• source time transformations (prism_put):
  • average, accumulation

• statistics

• local transformations:
  • addition/multiplication by scalar

• interpolation/regridding (3D):
  • 2D nearest-neighbour, bilinear, bicubic
  • 3D nearest-neighbour, trilinear

on different types of grids:
  • regular or irregular lat-lon
  • stretched and/or rotated (logically-rectangular)
  • Gaussian reduced
  • non-geographical
Current developments:
- 2D conservative remapping
- Parallel global search for the interpolation
- Transformer efficiency
- Full validation of current transformations

OASIS4 regularly tested and run with toy examples on:
- NEC SX6 and SX8 (NEC SX compilers)
- IBM Power4 (XL Fortran Compiler)
- PC-Linux (Portland Group Compiler Version 6.1)

Beta version OASIS4_0_2 available to beta tester groups:
- EU project GEMS: atmospheric dynamic and chemistry coupling
- SMHI: ocean-atmosphere regional coupling
- UK Met Office: global ocean-atmosphere coupling (currently prototyping)
- IFM-GEOMAR (Kiel) in pseudo-models to interpolate high-resolution fields.

Public version available in 2007
PRISM provides:

- network allowing ESM developers to share expertise and ideas
  (Code coupling and I/O, Integration and modelling environments, Data processing, visualisation and management, Computing, Meta-data)
- framework promoting common software tools for Earth system modelling
- some standard tools (OASIS, source management, compiling, …)
- visible entry point for international coordination (metadata)
- organisation for funding request (hard to get money for infrastructure)

PRISM current decentralized organisation (bottom-up approach):
- allows “best of breed” tools to naturally emerge
  relies on the developments done in the different partner groups

Interested groups are most welcome to join!

http://www.prism.enes.org
<table>
<thead>
<tr>
<th></th>
<th>OASIS3</th>
<th>OASIS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>stable, well tested</td>
<td>new, beta version under test</td>
</tr>
<tr>
<td>Model adaptation</td>
<td>Few OASIS3 PSMILe routines</td>
<td>Few OASIS4 PSMILe routines (more complex grid def)</td>
</tr>
<tr>
<td>Configuration of the</td>
<td>flexible; in an external text file (exchanges, frequency, transformations, …)</td>
<td>flexible; in external in XML files (exchanges, frequency, transformations, …)</td>
</tr>
<tr>
<td>coupled model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>partially parallel, one-to-one</td>
<td>fully parallel one-to-many</td>
</tr>
<tr>
<td>Interpolation</td>
<td>mono-process</td>
<td>fully parallel and efficient (multigrid algorithm)</td>
</tr>
<tr>
<td></td>
<td>2D nearest-neigh., bilinear, bicubic conservative remapping</td>
<td>3D nearest-neigh., bi/trilinear, bi/tricubic</td>
</tr>
</tbody>
</table>

The Australian Community Climate and Earth System Simulator (ACCESS)  
- Challenges & Opportunities, Melbourne, 28/11-01/12 2006
In conclusion for ACCESS

**Use of OASIS**

- Change as little as possible existing models
- Keep the modularity and the flexibility
- Use coupler interpolations
- Probably loose some efficiency

**Regarding PRISM: ACCESS**

- Shares PRISM philosophy
- Uses OASIS
- Uses Subversion and FCM
- Uses NetCDF CF convention
- Uses MARS

... so ...

ACCESS is already part of PRISM User Group!
The end
Application and component description (XML files):

For each application (code): one Application Description (AD):
  • possible number of processes
  • components included

For each component in the application:
  one Potential Model Input and Output Description (PMIOD)
    • component general characteristics: name, component simulated, …
    • grid information: domain, resolution(s), grid type, …
    • potential I/O or coupling variables:
      • local name, standard name
      • units, valid min and max
      • numerical type
      • associated grid and points
      • intent – input and/or output
The Australian Community Climate and Earth System Simulator (ACCESS) - Challenges & Opportunities, Melbourne, 28/11-01/12 2006

Grids supported by OASIS4

- Regridding, repartitioning, I/O:
  - Regular in lon, lat, vert ("Reglonlatvrt"): lon(i), lat(j), height(k)
  - Irregular in lon and lat, regular in the vert ("irrlonlat_regvrt"): lon(i,j), lat(i,j), height(k)
  - Irregular in lon, lat, and vert ("irrlonlatvrt") (not fully tested): lon(i,j,k), lat(i,j,k), height(i,j,k)
  - Gaussian Reduced in lon and lat, regular in the vert ("Gaussreduced_regvrt"): lon(nbr_pt_hor), lat(nbr_pt_hor), height(k)

- Repartitioning and I/O only:
  - "Non-geographical" fields
    - no geographical information attached
    - local partitions described in the global index space (prism_def_partition)

- I/O only:
  - Unstructured grids ("unstructlonlatvrt"): lon(npt_tot), lat(npt_tot), height(npt_tot)
What is an XML file?

→ Structured way of providing information
→ Hierarchy of elements and attributes
→ Structure of an XML file given by an XSD (schema) file

SCC.xsd
...
<x:s:element name="host">
  <xs:complexType>
    <xs:sequence>
      <xs:element name="nbr_procs"/>
    </xs:sequence>
    <xs:attribute name="local_name" type="xs:string" use="required"/>
  </xs:complexType>
</xs:element>
...
</xs:element>

SCC.xml
...
</host>
...
Parallel calculation of communication patterns in source PSMiLE

For each pair of source and target processes:

1/ Envelop exchange

2/ Detailed neighbourhood search

3/ EPIOS and EPIOT definition