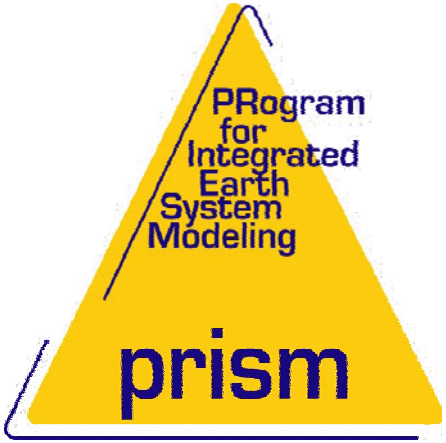
# The European PRISM Initiative
# &
# the OASIS coupler




*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*

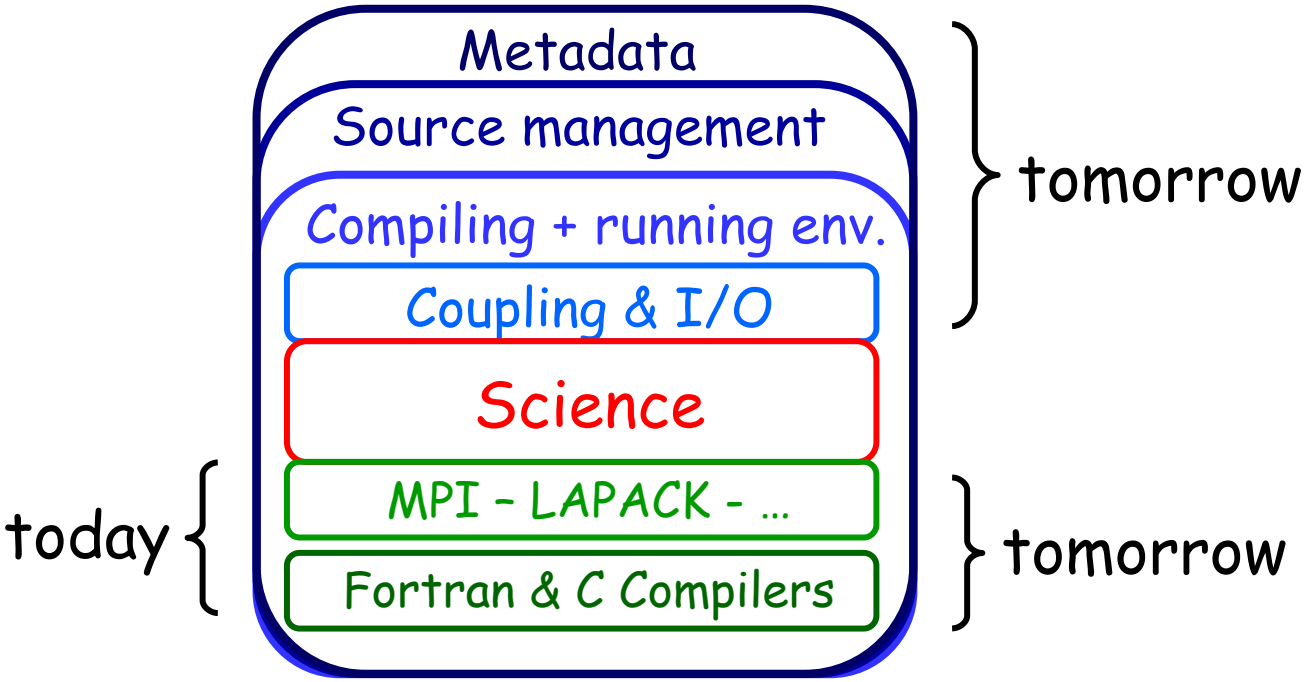
The Australian Community Climate and Earth System Simulator (ACCESS)
- Challenges & Opportunities, Melbourne, 28/11-01/12 2006

# 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



# 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** **UK: CGAM, UK MetOffice**
    **Germany: MPI-M&D, NEC-CCRLE** **ECMWF**
  - 9 associate partners:

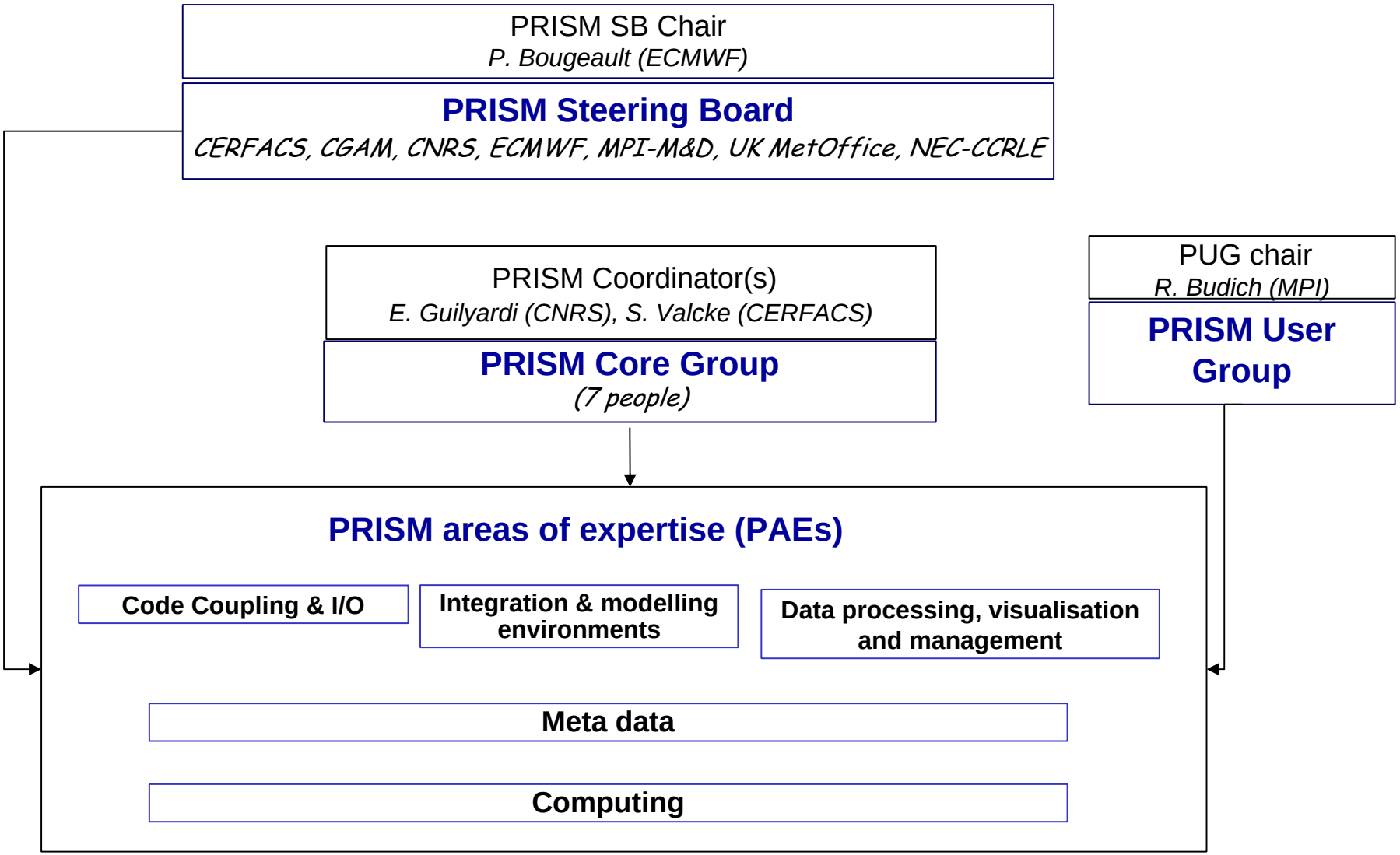
    **CSC (Finland)** **IPSL, Météo-France (France)** **SMHI (Sweden)**
    **MPI-M (Germany)** **CRAY** **SUN** **SGI** **NEC-HPCE**

# 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: the Areas of Expertise

## 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&D)
- job configuration & running
  - prepIFS/prepOASIS4, SMS (ECMWF), PRISM SRE (MPI M&D)

# 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)

# PRISM: the Areas of Expertise

## 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:

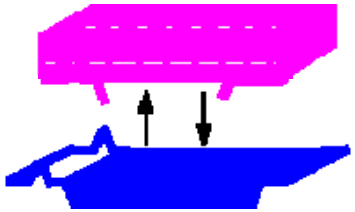
| | |
|---|---|
| • Numerical Model Metadata (U. of Reading): | numerical code bases, simulations |
| • CURATOR project (USA) : | data, codes, simulations |
| • Numerical grid metadata (GFDL, USA): | grid |
| • netCDF CF convention (PCMDI and BADC): | climate and forecast data files |
| • OASIS4 metadata | 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 | → | OASIS3→ |
| | → | OASIS4 → |

OASIS1, OASIS2, OASIS3:

- low resolution, low number of 2D fields, low coupling frequency:
  - ➔flexibility very important, efficiency not so much!

OASIS4:

- high resolution parallel models, massively parallel platforms, 3D fields
  - ➔need to optimise and parallelise the coupler

# OASIS: the community today

- **CERFACS** (France)
  - ARPEGE3 - ORCA2-LIM
  - ARPEGE4 - NEMO-LIM - TRIP
- **METEO-FRANCE** (France)
  - ARPEGE4 - ORCA2
  - ARPEGE3 - OPA8.1-GELATO
  - ARPEGE medias - OPAmed
- **IPSL- LODYC, LMD, LSCE** (France)
  - LMDz - ORCA2LIM
  - 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**
  - IFS - CTM (GEMS)
  - IFS - ORCA2 (MERSEA)


# OASIS: the community today

| | |
|---|---|
| •IFM-GEOMAR (Germany) | ECHAM5 - NEMO (OPA9-LIM) |
| •NCAS / U. Reading (UK) | ECHAM4 - ORCA2 HADAM3-ORCA2 |
| •SMHI (Sweden) | RCA(region.) – RCO(region.) |
| •NERSC (Norway) | ARPEGE - MICOM |
| •KNMI (Netherlands) | ECHAM5 - TM5/MPI-OM |
| •INGV (Italy) | ECHAM5 – MPI-OM |
| •ENEA (Italy) | MITgcm - REGgcm |
| •JAMSTEC (Japan) | ECHAM5(T106) - ORCA ½ deg |
| •IAP-CAS (China) | AGCM - LSM |
| •BMRC (Australia) | BAM3-MOM2, BAM5-MOM2, TCLAPS-MOM |
| •CSIRO (Australia) | Sea Ice code - MOM4 |
| •RPN-Environment Canada (Canada) | MEC - GOM |
| •UQAM (Canada) | GEM - RCO |
| •U. Mississippi (USA) | MM5 - HYCOM |
| •IRI (USA) | ECHAM5 - MOM3 |
| •JPL (USA) | UCLA-QTCM - Trident-Ind4-Atlantic |

# OASIS3 and OASIS4: Some key notes

- Developers: CERFACS, NEC CCRLE, 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

# OASIS3 and OASIS4: Some key notes

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

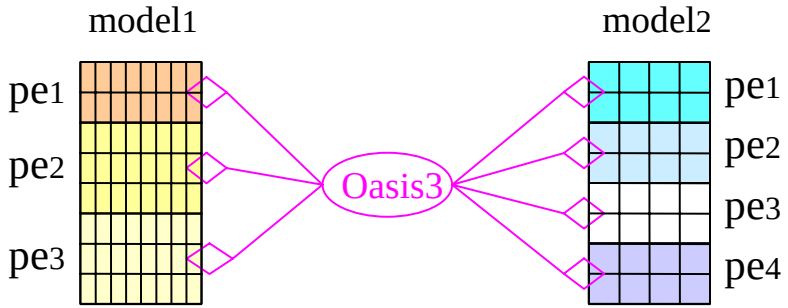
# OASIS3: coupled model configuration

- 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

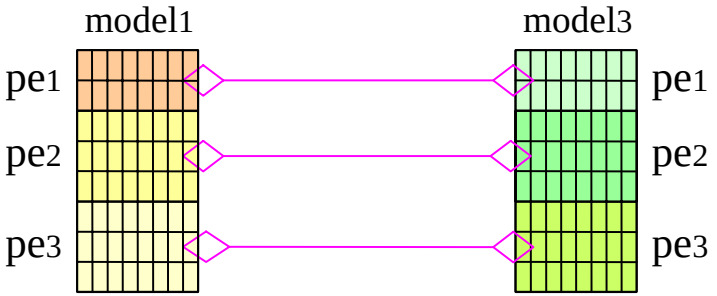
# OASIS3: communication

PSMILe based on MPI message passing

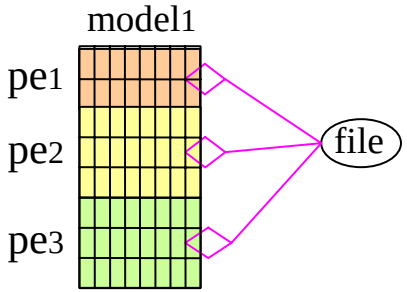
- Parallel communication between parallel models and interpolation process




- Direct communication between models with same grid and partitioning

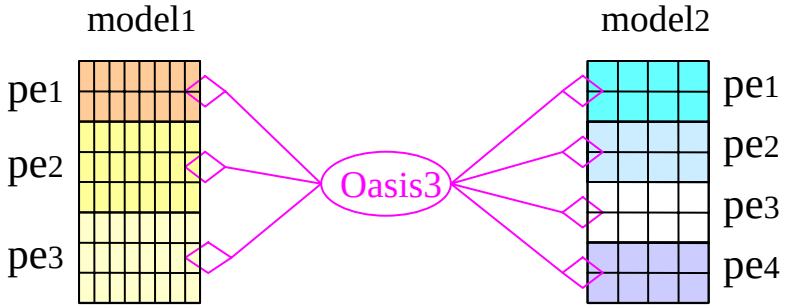



- I/O functionality (switch between coupled and forced mode): GFDL mpp_io library

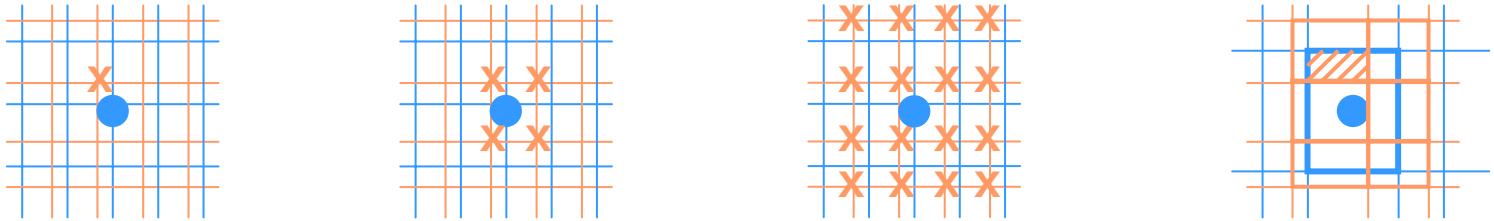


# OASIS3: interpolations/transformations

- separate sequential process (Oasis3)
  - ✓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-CCRLE multigrid algorithm

# OASIS4: model adaptation (1/3)

- Initialization:

```
call prism_init_comp (...)
```

- Definition of grid (3D)

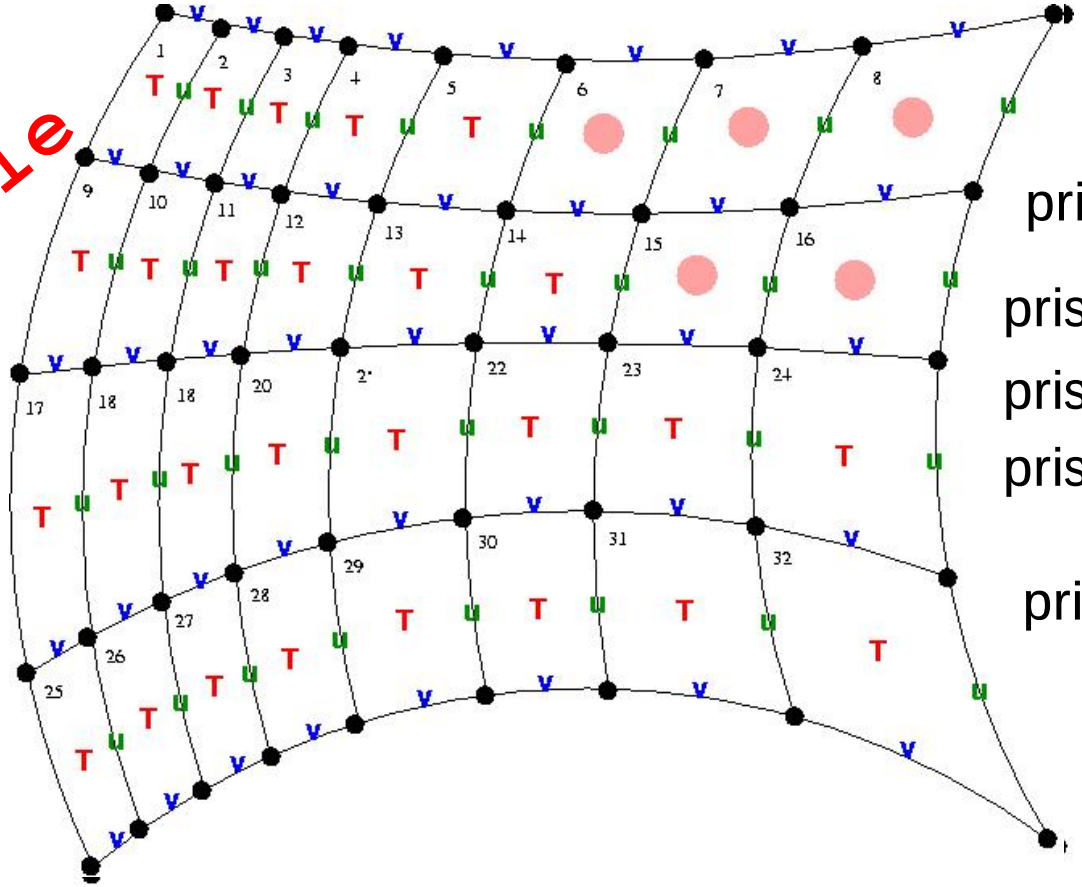
```
call prism_def_grid (...)
call prism_set_corners(...)
```

- Placement of scalar points and mask on the grid:

```
call prism_set_points (...)
call prism_set_mask (...)
```

# OASIS4: model adaptation (2/3)

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**

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

- **Coupling or I/O field sending and receiving:**
  - in model time stepping loop

```
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

# OASIS4: coupled model configuration

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

➢ a **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,**

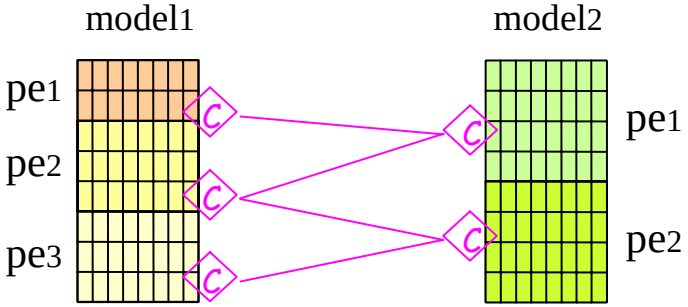
**a Specific Model Input and Output Configuration (SMIOC)**

- 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

# OASIS4 communication (1/2)

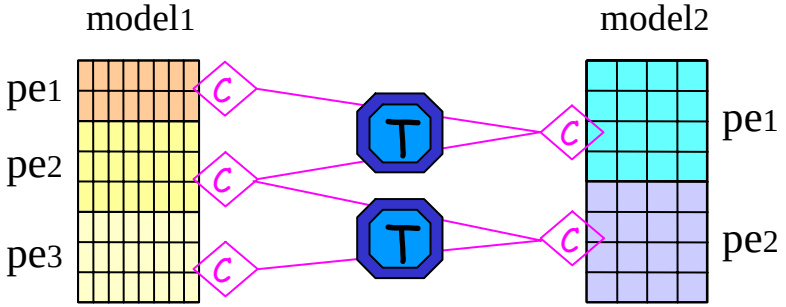
Model interface library: PSMILe based on MPI1 or MPI2

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




Same grid, different decomposition

- direct repartitioning




Different grid and decomposition

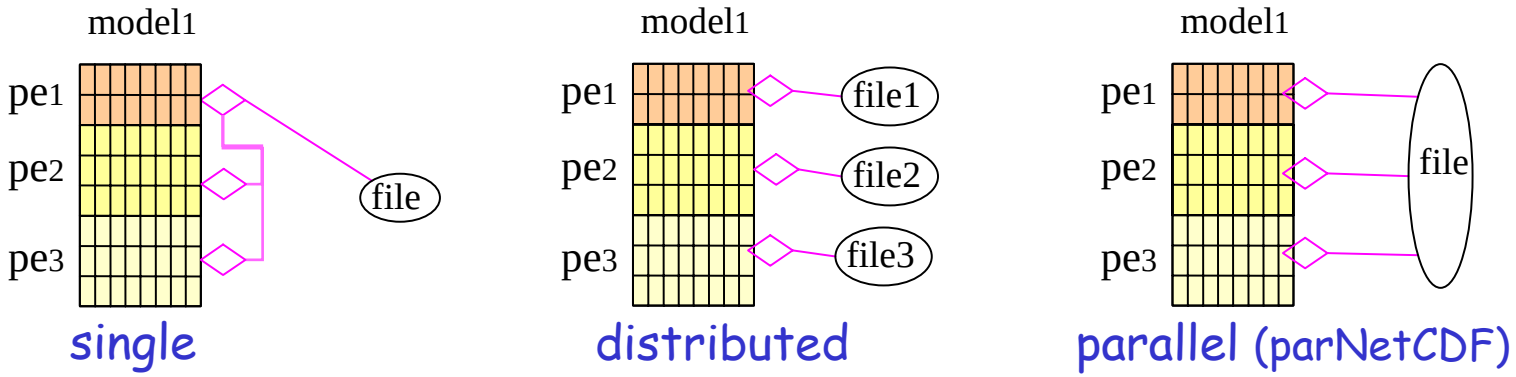
- interpolation in parallel Transformer

- 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



# OASIS4 regridding/transformations

- 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

# OASIS4: developments & perspectives

- 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

# Part I – PRISM: summary

- 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 !

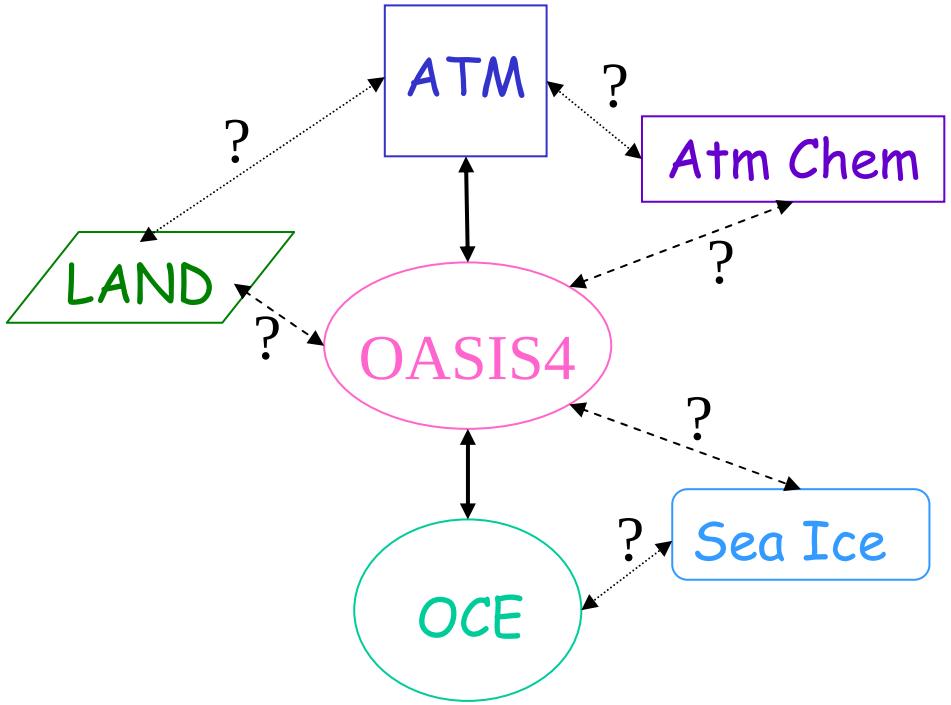
  http://www.prism.enes.org

# Part II - OASIS3 & OASIS4 summary

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

# 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

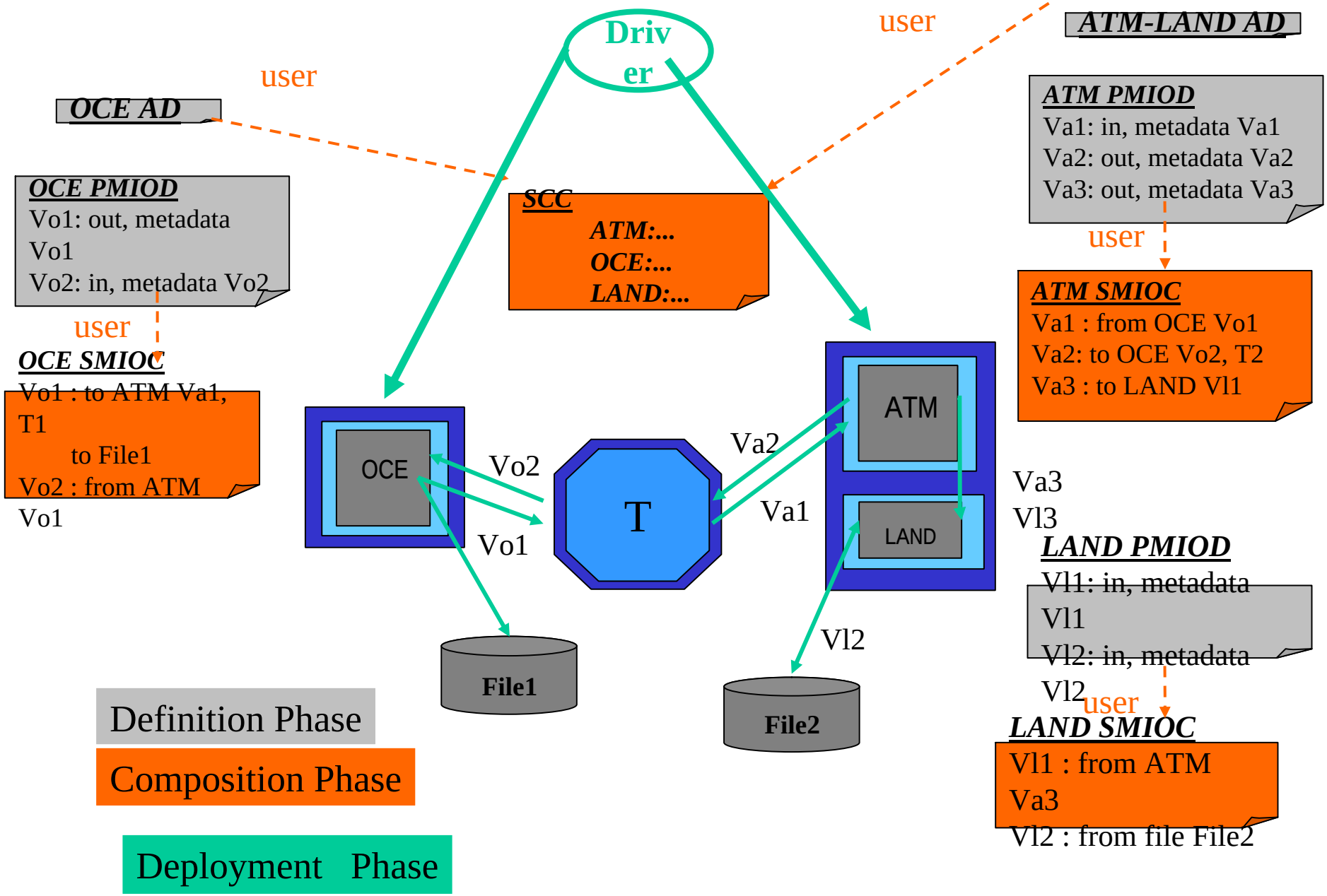
# OASIS4: component model description

## 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


Driv
er
user
OCE AD
OCE PMIOD
Vo1: out, metadata
Vo1
Vo2: in, metadata Vo2
user
OCE SMIOC
Vo1 : to ATM Va1,
T1
to File1
Vo2 : from ATM
Vo1
SCC
ATM:...
OCE:...
LAND:...
user
ATM-LAND AD
ATM PMIOD
Va1: in, metadata Va1
Va2: out, metadata Va2
Va3: out, metadata Va3
user
ATM SMIOC
Va1 : from OCE Vo1
Va2: to OCE Vo2, T2
Va3 : to LAND Vl1
OCE
T
ATM
LAND
Vo2
Vo1
Va2
Va1
Va3
Vl3
Vl2
File1
File2
LAND PMIOD
Vl1: in, metadata
Vl1
Vl2: in, metadata
Vl2
user
LAND SMIOC
Vl1 : from ATM
Va3
Vl2 : from file File2
Definition Phase
Composition Phase
Deployment Phase

# 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**

```
…
<xs: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 name=“nbr_procs“
 type="xs:integer“ />
```

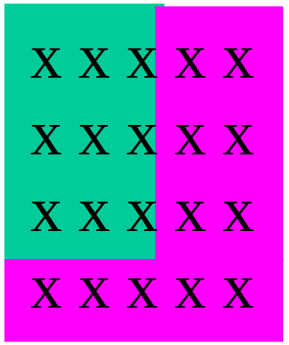
**SCC.xml**

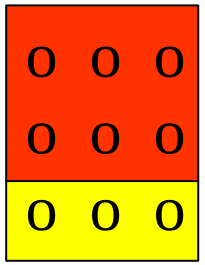
```
…
 <host   local_name="host1">
       <nbr_procs>2</nbr_procs>
  </host>
…
```

# Oasis4: communication (2/3)

## 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