IS-ENES – WP 4

D4.6 - ESM revised documentation following the full CIM metadata.

Abstract:

The full description of the 6 Europeans ESM involved in IS-ENES and also participating to the 5th Coupled Model Intercomparison Project (CMIP5) is available from the ENES portal. This description follows the Common Information Model (CIM) metadata standard. The current deliverable also includes the D4.2 "ESM documentation following a subset of CIM metadata" deliverable as it was decided to merge these two deliverables.

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Executive Summary

The complete description of all European Earth System Models (ESMs) involved in IS-ENES and participating to the 5th Coupled Model Intercomparison Project (CMIP5) is now available through the ENES portal. The ESMs described are CMCC-ESM, CNRM-CM5, EC-Earth, HadCM3 and HadGEM2-ES, IPSL-CM5 and MPI-ESM[1]. This description follows the Common Information Model (CIM) standard proposed by the EU METAFOR project and endorsed by the Working Group on Coupled Modelling (WGCM) of the World Meteorological Organization (WMO).

To provide this description, each ESM group filled out a questionnaire produced by the METAFOR project. This CMIP5 questionnaire is currently a bespoke web application written in Python that offers to the user different forms to provide information about the different parts of his ESM (e.g. scientific description of the ESM components and sub-components, the coupling fields exchanged between the different components, the data used as initial or boundary input, the responsible parties, the references, etc.). The questionnaire produces a CIM-compliant document that is harvested in the METAFOR repository. The ESM CIM description is then directly available from the ENES portal on the ESM page, thanks to a link to the METAFOR CIM viewer. The ESM description is also automatically available on the Earth System Grid (ESG) gateway.

The work done fulfils the D4.6 deliverable “ESM revised documentation following the full CIM metadata” into which the D4.2 deliverable “ESM documentation following a subset of CIM metadata” originally due at month 18 was merged. In fact, as providing the full ESM CIM description by filling the CMIP5 questionnaire is a mandatory step for all ESMs groups publishing CMIP5 data, the IS-ENES project partners felt that the production of the intermediate step represented by D4.2 was not justified.

[1] Formerly known as COSMOS-Model

1. INTRODUCTION

The likely evolution of climate linked to natural and anthropogenic causes needs to be further understood in order to define proper mitigation and adaptation strategies. The Earth climate results from complex interactions between its different components and due to the complexity of the system, theoretical and experimental studies are necessarily limited. Therefore, Earth System Models (ESMs) assembling numerical representations of the different climate components (e.g. the ocean including its biogeochemistry, the atmosphere with its chemistry and aerosol microphysics, the sea-ice, the land and its vegetation) represent today essential tools to assess the climate system over a wide range of space and time scales. However, ESMs are sophisticated systems usually developed by large teams of scientists and IT experts. In order to do proper science or to define effective strategies to mitigate climate change and deal with its impact on society, researchers and experts from multiple disciplines need to access, together with the data produced by ESMs, indications on the suitability of the data for their purpose. In particular, a detailed and standard-compliant documentation of the ESMs is therefore essential for the proper use of the ESMs and the full exploitation of their results.

IS-ENES is committed to establishing standardized information about existing ESMs in Europe. To reach this objective, the documentation and users guides of all European ESM existing prior to IS-ENES were first assembled (see deliverable D4.1). As a next step, the ESM developer groups had to provide a more standard description of their ESM following the Common Information Model (CIM) developed in the METAFOR EU project. A two-step approach was first planned with deliverable D4.2 “ESM documentation following a subset of CIM metadata”, originally due at month 18, and deliverable D4.6 “ESM revised documentation following the full CIM metadata”, due at month 36.

However, after the production of D4.1, it soon became clear that all European ESM groups had anyway to provide the full standard CIM description (metadata) of their simulations and models before the end of 2011 as this was considered an essential step for all ESMs groups participating to the 5th Coupled Model Intercomparison Project (CMIP5). The EU project METAFOR was charged by the Working Group on Coupled Modelling (WGCM) of the World Meteorological Organization (WMO) to define such standard metadata and to develop the tool to gather the information from the different ESM groups. This is how METAFOR developed the Common Information Model (CIM) standard. Version 1.5 of the CIM is used for CMIP5 and the relevant information is harvested though an on-line questionnaire that produces CIM-compliant documents harvested in the METAFOR repository. METAFOR also develop a CIM viewer, which allows a user-friendly visual access to the CIM information. Defining appropriate links to the CIM viewer, the full ESMs CIM description is now available through the ENES portal ESM pages and both deliverables D4.2 and D4.6 are therefore fulfilled.

In this document, we start with a description of the CIM 1.5 metadata standard. The next section provides information on the CMIP5 questionnaire. The list of European ESMs for which the CIM description is available through the ENES portal is then provided and we finally conclude with a brief analysis of the benefits and drawbacks of the whole approach.

2. THE COMMON INFORMATION MODEL

The Common Information Model is a formal model of a searchable description of the climate modelling process. It includes descriptions of the experiments being undertaken, the simulations being run in support of these experiments, the software models and tools being used to implement the simulations and the data required and generated by the software. Callaghan et al 2010 provides a detailed description of the CIM elaboration process, which is also available upon request as a METAFOR deliverable (see D2.5 at http://metaforclimate.eu/trac/wiki/deliverables).

The construction of CIM 1.5 was based on two steps, like the previous CIM versions. The first step consist in defining the normative UML (Universal Modelling Language) model known as the "conceptual model" (CONCIM) and the second step is to derive an "application schema" (APPCIM), currently an XSD XML Schema (see http://www.w3.org/TR/xmlschema-0/). This construction is illustrated in Figure 1. By separating formulation and implementation of the CIM and by using UML to express the CIM conceptual model (CONCIM), discussions about the CIM can focus on the climate modelling concepts and the relationship between these concepts, while the application structure of the model (APPCIM) can be expressed independently after CONCIM completion. Although the application of the CIM within METAFOR is expressed in XML, it is expected that other non-XML schemas will be developed in different user communities. With this construction, as long as all the communities agree upon the conceptual schemas through a robust governance mechanism, interoperability can be maintained.

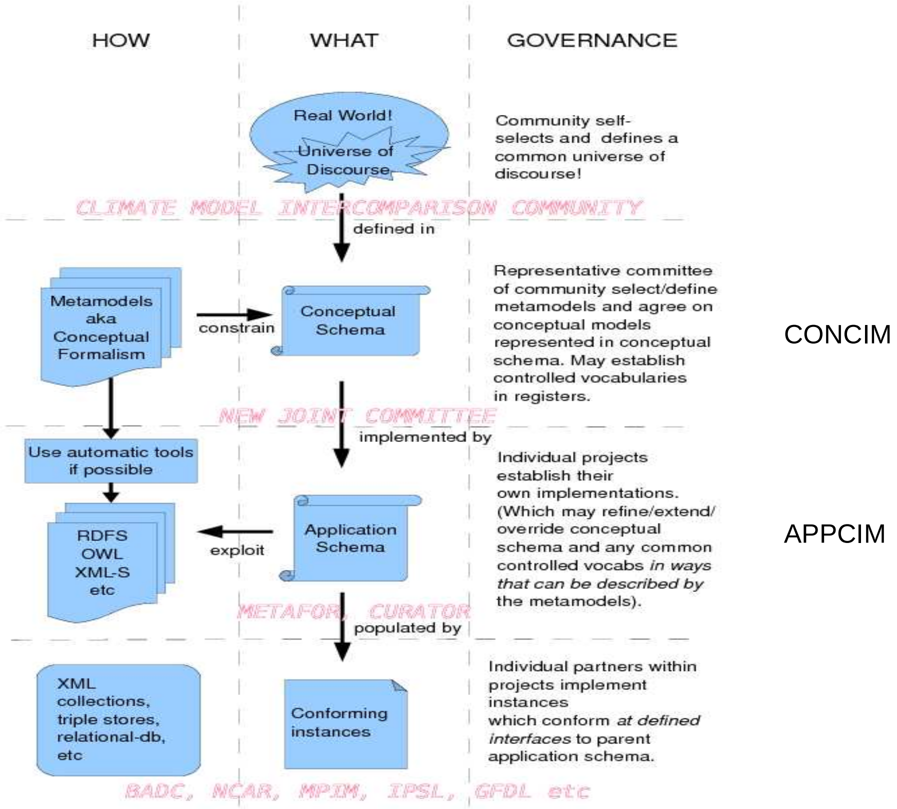

Figure 1. A representation of the CIM construction with the conceptual schema (CONCIM) and the application schema (APPCIM).

The CIM is divided into a number of packages to separate different aspects of the complex climate modelling process. This division has been retained throughout the CIM development. The packages are:

- Activity: specifies the simulation design including requirements and description of how simulations conform to these requirements.
- Software: specifies all the software components forming the ESM used in the modelling process.
- Data: describes the data used as input and generated as output from the climate modelling process.
- Grids: provides a complete description of the horizontal and vertical discretisation of modelling elements; may refer e.g. to grids that output data is mapped onto or grids that software adheres to.
- Shared: contains those elements that are used in many different packages.
- Quality: contains elements used to express diverse quality metrics for CIM metadata or the artefacts that metadata describes.

In addition, many concepts from existing ISO standards, particularly the Geographic Markup Language (GML, see http://www.opengeospatial.org/standards/gml) 19136 series, are referred to from within the CIM. Figure 2 illustrates the UML view of the software package.

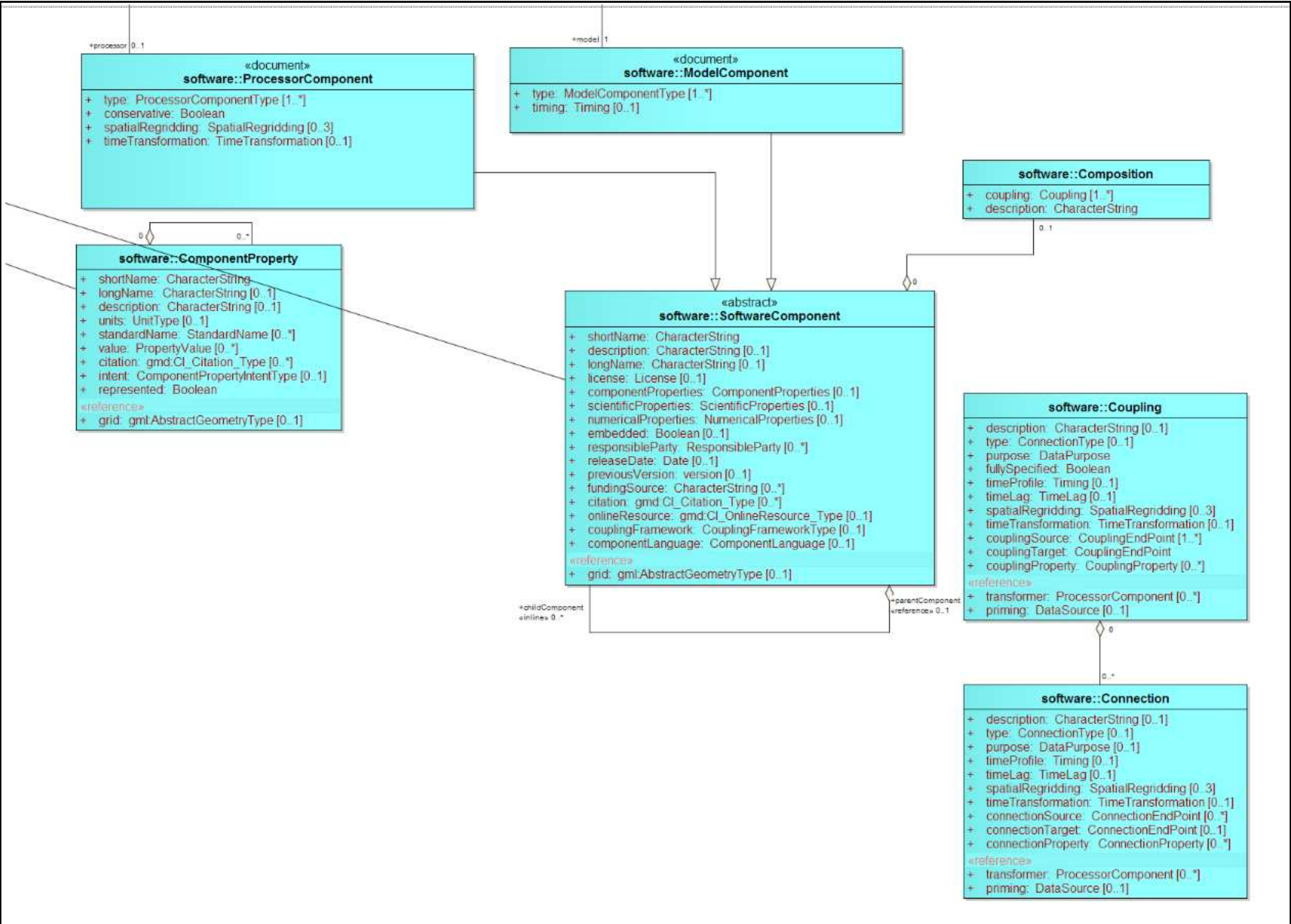

Figure 2 – UML representation of the CIM software package

The CIM itself provides a fairly generic structure and can be supplemented by particular Controlled Vocabularies (CVs), which provide constraints for the contents of the CIM. For example, within the software package, there is the concept of a model component with child components. A CV paired with the CIM could therefore specify “atmosphere” as a component with “radiation” and “advection” as child components. The terms “atmosphere”, “radiation” and “advection” are part of the atmosphere modelling community Controlled Vocabulary, which constrains the generic concept of CIM model component. Thus a CIM “conforming instance” as shown at the lower level in Figure 1 can be validated with respect to a CIM application schema and a particular CV.

Mindmaps were developed to define all the CV needed to describe climate models. METAFOR spent a great deal of time and effort working with climate scientists - especially those participating in CMIP5 - to create an appropriate set of mindmaps. In fact, one reason why mindmaps were chosen as a format for storing controlled vocabularies was that it is both visually intuitive and able to be modified in real-time in response to discussions with scientists. As an example, Figure 3 shows the mindmap for the ocean component. The mindmaps are used to configure the CMIP5 questionnaire (described in more detail in the next section) that is presented to users and that, ultimately, generate CIM instances.

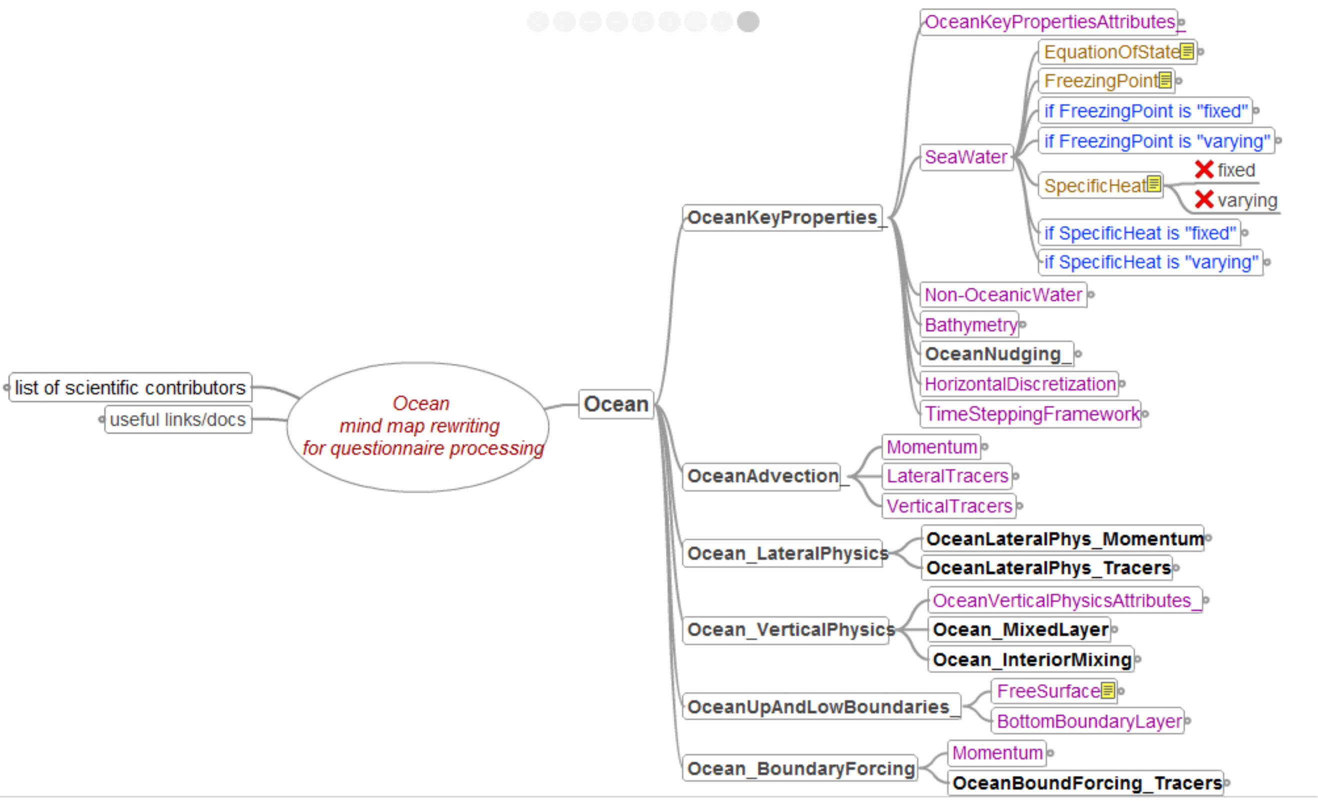

Figure 3 – An example mindmap, here for the ocean model component

Controlled vocabularies provide standardized description elements (metadata) here for climate model algorithms. The standardisation of metadata is the key concept for inter-comparison of climate model algorithms. The same argument is valid for variable names and the climate model data inter-comparison.

In summary, what we call here the “ESM CIM documentation” corresponds to the software part of XML instances conforming to the METAFOR CIM schema (i.e. one particular APPCIM) constrained by Controlled Vocabulary defined for CMIP5. The “ESM CIM documentation” provides a searchable description of the climate model algorithms. But more generally, the term “CIM” can also be used to refer to the overall concept or “information model” from which CIM implementations are constructed.

3. THE CMIP5 QUESTIONNAIRE

The CMIP5 Questionnaire is a bespoke web application written in the Python (http://www.python.org/) scripting language. The METAFOR CIM schema and Controlled Vocabulary (CV) heavily influenced the structure of the application. The questionnaire allows users to fill in all parts necessary for describing a climate numerical model (the software), climate simulations done with the software, climate data used as initial or boundary input or produced as output, references, involved parties, etc.

The questionnaire is available at http://q.cmip5.ceda.ac.uk/. Once logged in, there is a start page for each participating institute. The view for CNRM-CM5 is shown at Figure 4. All parts of the questionnaire where input is possible or necessary are available as links from this start page. As can be seen on Figure 4, the three main steps are:

- Platform: create at least one computing platform where the model ran.
- Grid: create at least one grid used by a model or corresponding to some data
- Model: create at least one model developed at that institute and used to produce data
- Files, References, Parties: Describe the files, references and parties associated with the model
- Simulations: Add simulations produced by a model using a grid and running on a computing platform.

The 'Model' part of the questionnaire describes all aspects of climate models and their underlying software. This is the part of the questionnaire filled in with higher priority by IS-ENES ESM groups so to produce the CIM description of their ESMs and accordingly the merged D4.2 - D4.6 deliverables.

As introduced above, the "Model" part of the questionnaire is derived from the CMIP5 CV mindmaps, which has been collected, collated and defined by METAFOR from discussion with the broad modelling community. Thus the questionnaire represents the modeller's view of the CMIP5 modelling domain. The questionnaire has questions about 500 different model parameters across all the 8 CMIP5 modelling "realms" (Atmosphere, Aerosols, Chemistry, Ocean Bio-geo-chemistry, Sea Ice, Land Surface and Land Ice). The questionnaire poses questions to the CMIP5 modeller and the responses are constrained by the CV. The "Model" main page for CNRM-CM5 is illustrated at Figure 5, while Figure 6 shows part of the questionnaire page on the OceanKeyProperties, corresponding to part of the mindmap illustrated on Figure 3.

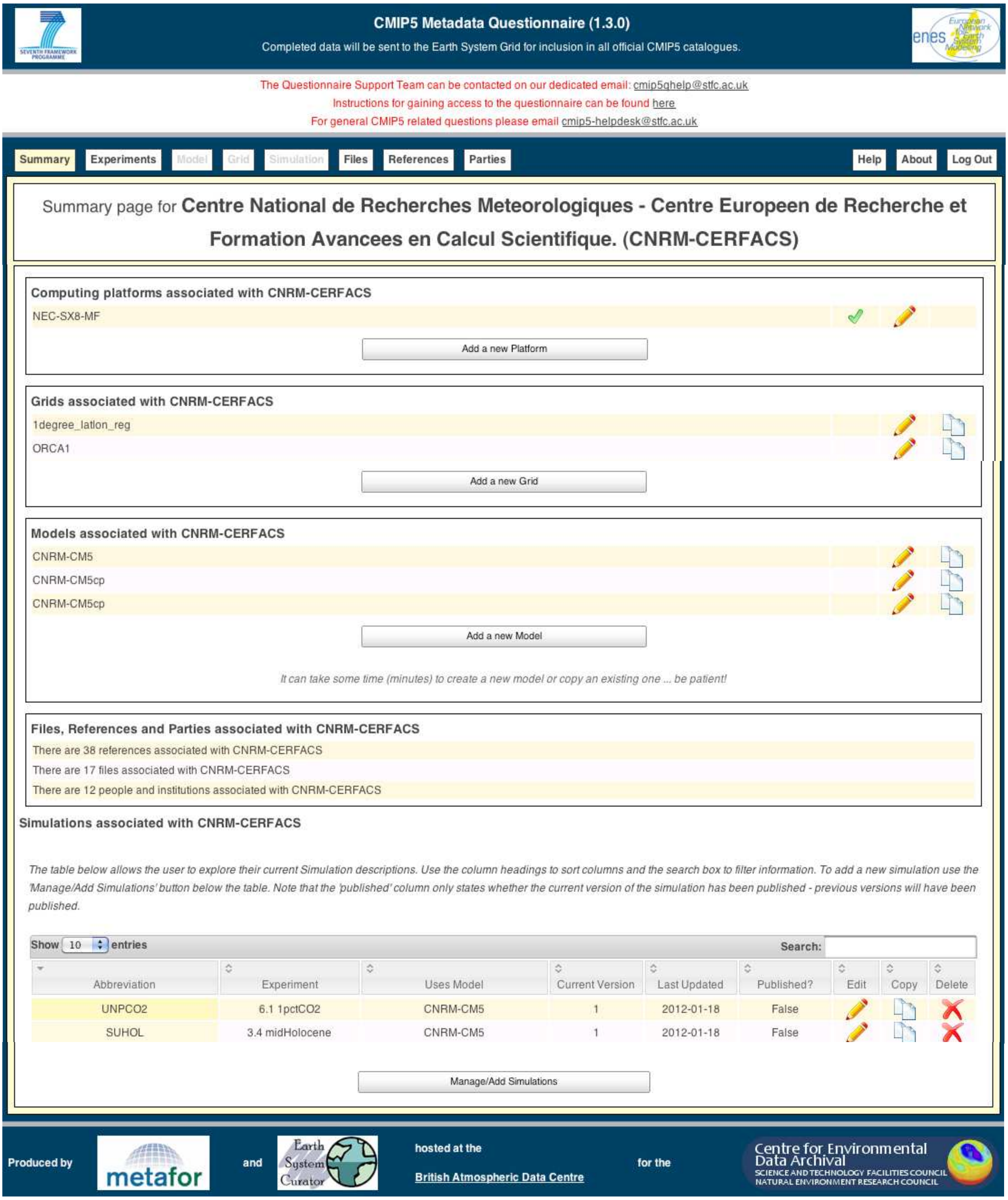

Figure 4 - Example of CMIP5 Questionnaire main page for CNRM-CM5

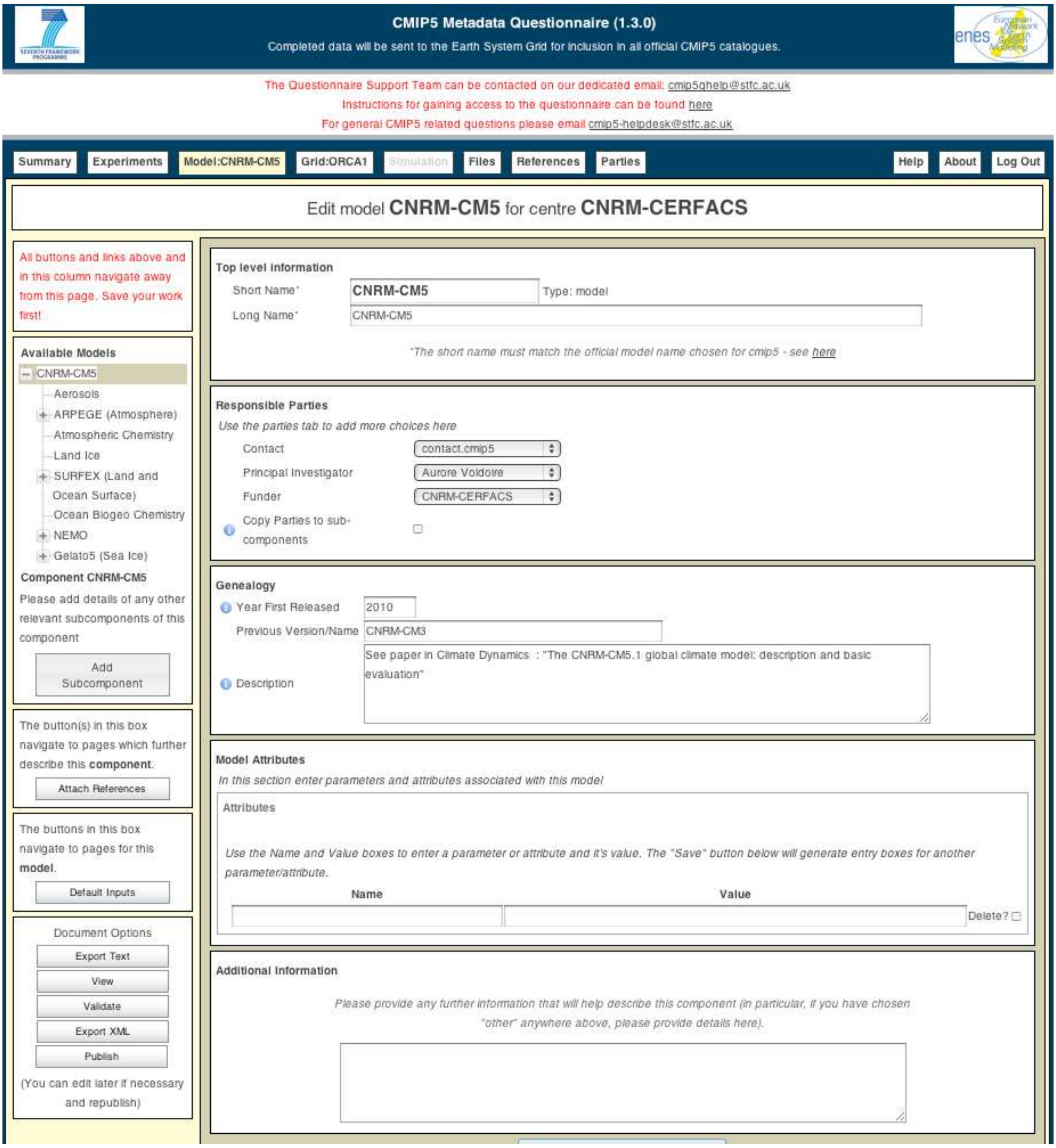

Figure 5 - CMIP5 Questionnaire “Model” main page for CNRM-CM5

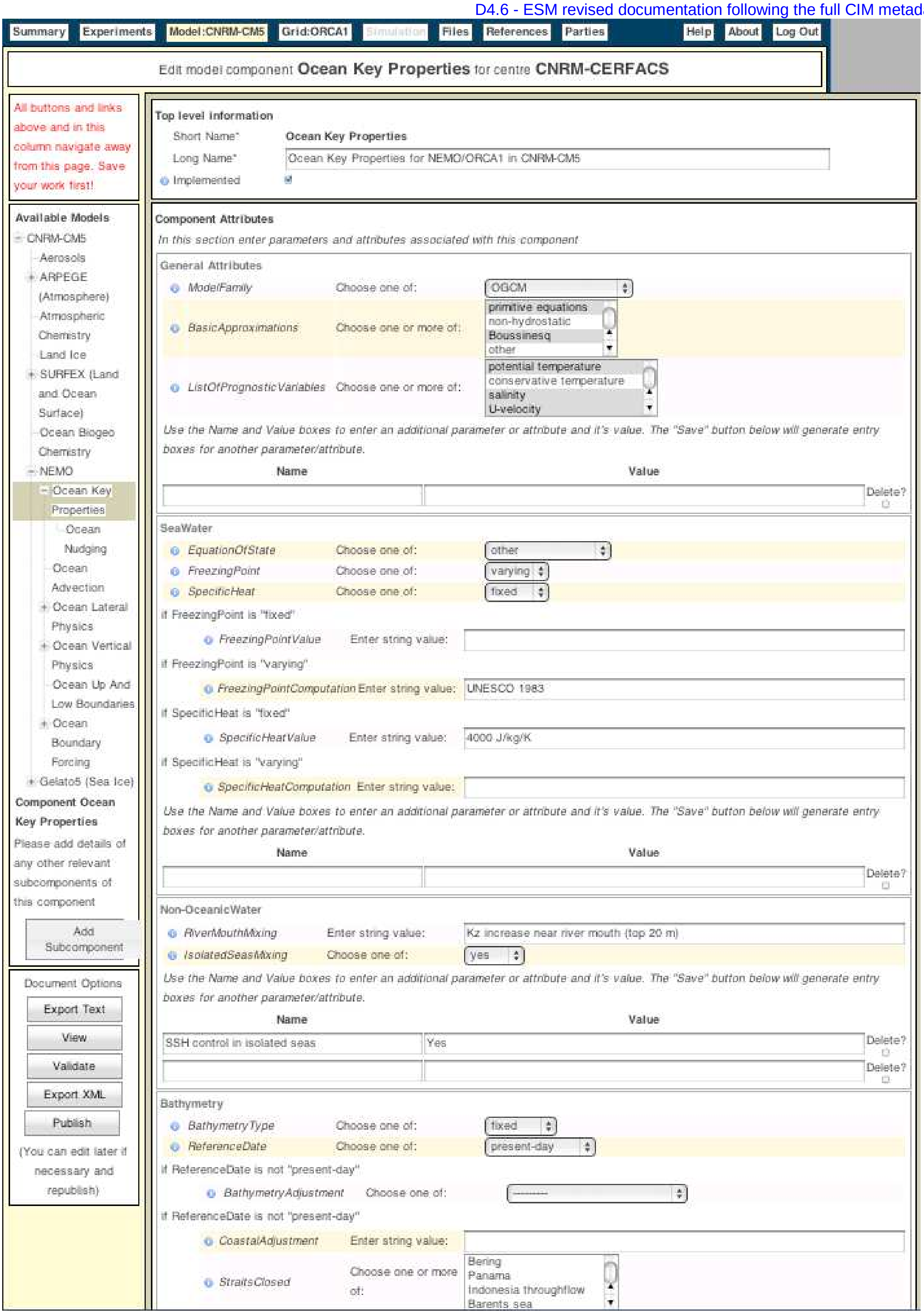

Figure 6 - CMIP5 Questionnaire “OceanKeyProperties” page for NEMO ocean model in CNRM-CM5

4. EUROPEAN ESMS DESCRIBED WITH THE CIM

Different versions of the 6 European ESMs involved in IS-ENES and participating to CMIP5 were described using the CMIP5 questionnaire and these model descriptions are harvested in the METAFOR CIM repository (see http://es-doc.org/site/public/repository) and viewable thanks to the METAFOR CIM viewer. The described models are CMCC-ESM, CNRM-CM5, EC-Earth, HadCM3 and HadGEM2-ES, IPSL-CM5 and MPI-ESM.

4.1. CMCC

Three different versions of CMCC ESM are used at CMCC for CMIP5. They are all based on the OPA8.2 ocean model, using the ORCA2 configuration (182x149 grid points) with 31 vertical levels and including LIM for the sea-ice, coupled by OASIS3 to the atmosphere model ECHAM5. On ENES portal, information on CMCC ESM as well as links to the CIM description of its different versions are available at https://enes.org/models/earthsystem-models/c-esm. The three versions of CMCC-ESM are:

- CMCC-CM (Scoccimarro et al 2011) is the "standard" CMCC climate model used for CMIP5 pre-industrial simulations, decadal simulations and centennial projections. In CMCC-CM, ECHAM5 is run with a horizontal triangular truncation T159 (480x240 grid points) and 31 vertical levels.
- CMCC-CMS is very close to CMCC-CM except that the atmosphere model runs at higher resolution to resolve the stratosphere with a horizontal triangular truncation T63 with 95 vertical levels.
- In CMCC-ESM (Vichi et al 2011), a lower resolution is used for ECHAM5, i.e. a horizontal triangular truncation T31 (96x48 grid points) with 19 vertical levels but the processes related to the biological and geochemical parts of the carbon cycle are represented by SILVA for the land and vegetation (interfaced directly in ECHAM5) and by PELAGOS for the ocean biogeochemistry (interfaced directly in OPA).

4.2. CNRM-CM5

CNRM-CM5 , assembled by Météo-France and CERFACS, is used in CMIP5 for the decadal and the long-term simulations (Voldoire 2011). CNRM-CM5 is composed of 3 codes: the atmospheric component ARPEGE-Climat 5.1 (including the surface module SURFEX), the ocean NEMO V3.2 (interfaced with the sea-ice module GELATO), and the runoff routing model TRIP. The atmospheric spectral model operates on a T127 triangular truncation with 31 vertical levels. NEMO uses the ORCA1 configuration (362x292=105704 grid points) with 42 levels vertically. TRIP is used for river routing and has a 1^0x1^0 resolution.

On ENES portal, information on CNRM-CM5 and a link to its CIM description are available at https://enes.org/models/earthsystem-models/cnrm-cm5

4.3. IPSL-CM5

IPSL-CM5 (Dufresne et al 2012) is developed by IPSL and includes 5 component models representing the Earth System climate and its carbon cycle: LMDz (atmosphere), NEMO (ocean, oceanic biogeochemistry and sea-ice), ORCHIDEE (continental surfaces and vegetation), INCA (atmospheric tropospheric chemistry) and Reprobus (atmospheric stratospheric chemistry). INCA, Reprobus and ORCHIDEE are directly included in LMDz that is coupled to NEMO through OASIS3. In CMIP5, three different versions of IPSL-CM5 are used that differ by the atmospheric model with two different sets of parameterization, LMDZ5A and LMDZ5B, and two horizontal resolution (96x95 L39) and (144x144 L39) while NEMO is always used in the ORCA2 configuration (148x182 grid points horizontally) with 30 levels vertically. The coupling configuration is the same in the three versions.

On ENES portal, information on IPSL-CM5 as well as links to the CIM description of its different versions are available at https://enes.org/models/earthsystem-models/ipslesm .

4.4. EC-EARTH V2.3

The EC-Earth model is a state-of-the-art earth system model based on ECMWFs Seasonal Forecasting System. Different partners in the consortium further develop the baseline model into an Earth System Model used for different climate studies and CMIP5 in particular. Currently, the EC-Earth consortium consists of 25 academic institutions and meteorological services from 10 countries in Europe. EC-Earth component models are IFS for the atmosphere, including the land and vegetation HTESSEL component, and NEMO for the ocean including the LIM2 sea-ice model. In EC-Earth V2.3 used for CMIP5 (Hazeleger et all, 2011), IFS version used is cycle 31r1 and runs with horizontal triangular truncation of T159 (i.e. with 35718 grid points in the horizontal for the reduced Gaussian grid) and 62 vertical levels; NEMO uses the ORCA1 configuration with 362x292 grid points horizontally and 42 vertical levels.

On ENES portal, information on EC-EARTHv2.3 as well as links to the CIM description of its different versions are available at https://enes.org/models/earthsystem-models/ec-earth .

4.5. HADGEM2

HadGEM2 stands for the Hadley Centre Global Environment Model version 2. The HadGEM2 family includes an atmosphere-only version (HadGEM2-A), coupled atmosphere-ocean configuration, with or without a vertical extension in the atmosphere to include a well-resolved stratosphere, (HadGEM2-ES) and an coupled configuration that includes dynamic vegetation, ocean biology and atmospheric chemistry (HadGEM2-CC). The standard atmospheric component has 38 levels extending to ~40km height, with a horizontal resolution of 1.25 degrees of latitude by 1.875 degrees of longitude, which produces a global grid of 192 x 145 grid cells. This is equivalent to a surface resolution of about 208 km x 139 km at the Equator, reducing to 120 km x 139 km at 55 degrees of latitude. A vertically extended version, with 60 levels extending to 85km height, is also used for investigating stratospheric processes and their influence on global climate. The oceanic component utilizes a latitude-longitude grid with a longitudinal resolution of 1 degree, and latitudinal resolution of 1 degree between the poles and 30 degrees North/South, from which it increases smoothly to one third of a degree at the equator, giving 360 x 216 grid points in total, and 40 unevenly spaced levels in the vertical (a resolution of 10m near the surface).

On ENES portal, information on HADGEM2 as well as link to the CIM description of HadGEM-A, HadGEM2-ES and HadGEM2-CC are available at https://enes.org/models/earthsystem-models/hadgem2-es . As an example, the main page of the CIM view for HadGEM2-ES is shown at Figure 7.

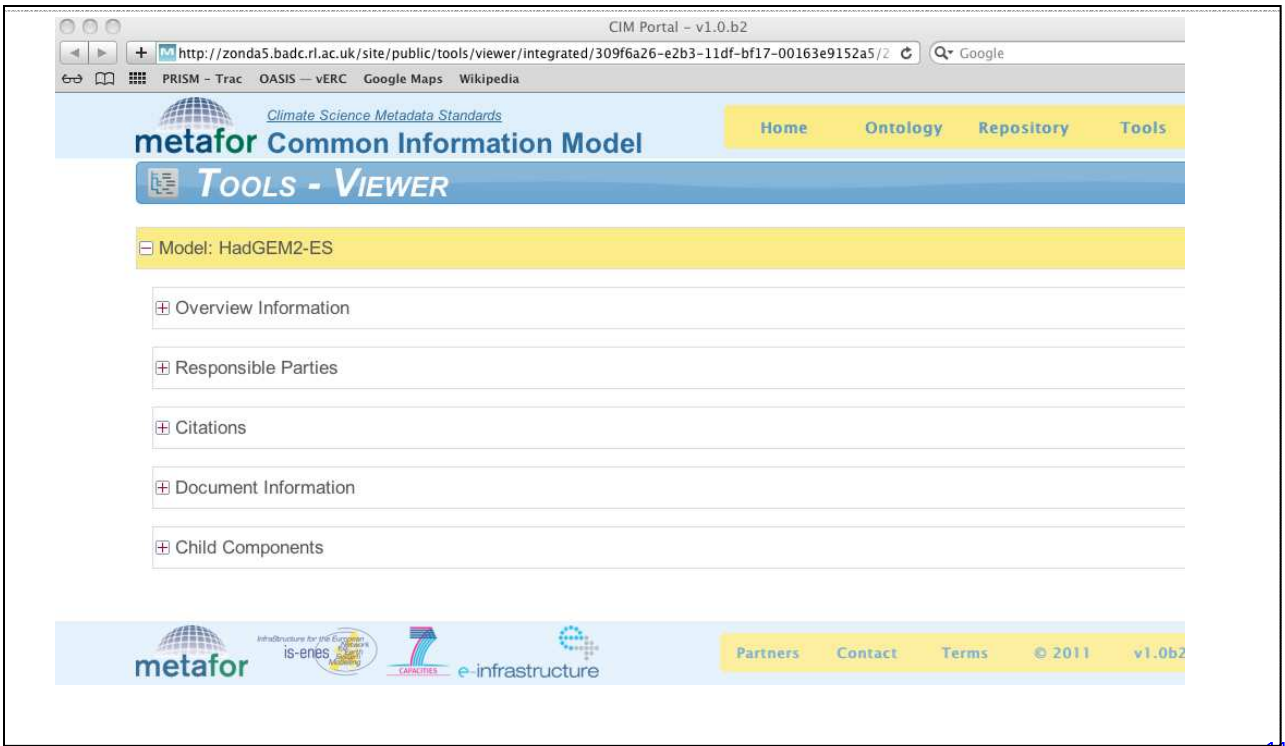

Figure 7 – CIM view main page for HadGEM2

4.6. MPI-ESM

In MPI-ESM, the atmospheric circulation model ECHAM6, including the dynamical land vegetation model JSBACH, is coupled via OASIS3 to the ocean and sea ice model MPI-OM, that also includes the marine biogeochemistry model HAMOCC.

Different resolution versions of MPI-ESM are used for CMIP5. In MPI-ESM-MR (middle resolution) and MPI-ESM-LR (low resolution), a dynamic feedback of vegetation and land use is fully included, land cover change data are included from external files, and orbital parameters are calculated at every radiation time step; this is not the case for the third version of the model, MPI-ESM-P, which is used for paleoclimatic simulations. Regarding the resolution, MPI-ESM-P and MPI-ESM-LR use the same configuration. Also, all 3 versions use a spherical harmonic truncation T63 in ECHAM and 40 vertical levels in MPI-OM. In MPI-ESM-MR and MPI-ESM-LR (or MPI-ESM-P), ECHAM5 is run using with 95 and 47 vertical levels respectively and the MPI-OM tripolar ocean grid has an approximate horizontal resolution of 0.4 and 1.5 degree respectively.

On ENES portal, information on MPI-ESM as well as links to the CIM description of its different versions are available at https://enes.org/models/earthsystem-models/cosmos .

5. CONCLUSION

A detailed description of the 6 European ESMs using the Common Information Model (CIM) metadata standard proposed by the EU project METAFOR is now available via the ESM pages on the ENES portal. By exploring the CIM documentation of the individual ESMs, one can find detailed and standardized (and thus easily comparable) information on these climate models. This fulfils merged deliverables D4.2 "ESM documentation following a subset of CIM metadata" and D4.6 "ESM revised documentation following the full CIM metadata".

Producing the CIM description of European ESMs was strongly favoured by the fact that this is considered a mandatory step for the publication of climate data within the 5th Coupled Model Intercomparison Project (CMIP5) that will form the scientific basis of the next Intergovernemental Panel on Climate Change (IPCC) report. In fact, it has been possible to produce this standard description thanks to the infrastructure developed by METAFOR, i.e. the CIM itself, but also the Controlled Vocabulary that constraints it for climate modelling, the on-line questionnaire that produces CIM-compliant documents harvested in a CIM repository, and the CIM viewer used to visualise the resulting information. The work realized by the METAFOR to support and facilitate the process for the modelling groups was huge. Nevertheless, filling up the questionnaire proved to be a very demanding and laborious task, which in many cases mobilized a whole set of experts, each one mastering one aspect of the coupled system. In this sense, IS-ENES funding devoted to producing a standard description of European ESMs was very much welcomed even if all the groups had to spend additional internal resources to achieve the task. Producing standard ESM CIM description was also a mandatory step for the participation to CMIP5, which was therefore a strong incentive. Therefore, even if every one agrees that producing standard ESM description is an essential step for the climate modelling community, it can be questioned if it would have been realistic to target this production outside the realization of a so important must-participate international exercise.

Even if the CMIP5 CIM repository is not yet fully complete, first experiences with the already existing CIM climate model and experiment descriptions are positive and the CIM concept is well accepted. The climate community realises that more valuable information is available for CMIP5 than for all previous CMIPs. Requirements are formulated to use the CMIP5 data management structure including the CIM description also for other modelling projects like CORDEX or PMIP. But the question is now how the maintenance of CIM and specifically of the related Control Vocabularies can be organised in the post METAFOR period. Addressing this issue is necessary in order to transform the CMIP5 pilot implementation of the CIM metadata environment into an operational service for the climate community.

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