IS-ENES2

3rd PERIODIC REPORT
Core Report

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Name, title and organisation of the scientific representative of the project's coordinator:
Sylvie JOUSSAUME
Directeur de Recherche
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)
CNRS – Institut Pierre Simon Laplace – Laboratoire des Sciences du Climat et de l'Environnement

Tel: + 33 1 69 08 56 74
Fax: + 33 1 69 08 30 73
Email: sylvie.joussaume@lsce.ipsl.fr

Project website address: https://is.enes.org

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Introduction to IS-ENES2

Project abstract

IS-ENES2 is the second phase project of the distributed e-infrastructure of models, model data and metadata of the European Network for Earth System Modelling (ENES). This network gathers together the European modelling community working on understanding and predicting climate variability and change. ENES organizes and supports European contributions to international experiments used in assessments of the Intergovernmental Panel on Climate Change. This activity provides the predictions on which EU mitigation and adaptation policies are built.

IS-ENES2 further integrates the European climate modelling community, stimulates common developments of software for models and their environments, fosters the execution and exploitation of high-end simulations and supports the dissemination of model results to the climate research and impact communities. IS-ENES2 implements the ENES strategy published in 2012 by: extending its services on data from global to regional climate models, supporting metadata developments based on the FP7 METAFOR project, easing access to climate projections for studies on climate impact and preparing common high-resolution modelling experiments for the large European computing facilities. IS-ENES2 also underpins the community's efforts to prepare for the challenge of future exascale architectures.

IS-ENES2 combines expertise in climate modelling, computational science, data management and climate impacts. The central point of entry to IS-ENES2 services, the ENES Portal, integrates information on the European climate models and provides access to models and software environments needed to run and exploit model simulations, as well as to simulation data, metadata and processing utilities. Joint research activities improve the efficient use of high-performance computers and enhance services on models and data. Networking activities increase the cohesion of the European ESM community and advance a coordinated European Network for Earth System modelling.

As per its DoW, IS-ENES2 has delivered four main objectives (in brackets relevant work packages and type of activity, see figure 1)**:**

- **To foster the integration of the European Climate and Earth system modelling community** by strengthening the ENES governance, further developing its strategy, especially with regards to model evaluation and model developments, stimulating interactions between global and regional climate modelling communities, and developing training (WP2/NA1 and other WPs)
- **To enhance the development of Earth System Models for the understanding of climate variability and change** by networking on future model developments required to improve model quality and use of future computing architectures, by stimulating common software developments and by providing a service on models and tools (WP3/NA2, WP4/NA3 and WP7/SA1)

- **To support high-end simulations enabling us to better understand and predict climate variations and change** by preparing for future exascale computing architectures (WP3/NA2), by preparing multi-model high resolution common experiments on the European PRACE high-performance computer facilities (WP9/JRA1), and by stimulating collaboration with ICT companies (WP6/NA5 & WP10/JRA2)
- **To facilitate the application of Earth system model simulations to better predict and understand the climate system and climate change impacts on society** by enhancing the dissemination of model results from both global and regional model experiments (WP8/SA2), by developing an interface dedicated to the climate impact community and improving the quality of information on simulations through metadata developments and guidance to users (WP5/NA4 & WP11/JRA3) and by enhancing interaction between the climate modelling activity and users from companies and the emerging climate services (WP6/NA5).

IS-ENES2 has served the needs of the climate modelling community as well as the needs of communities using model results to study the impacts of climate change and develop climate services.

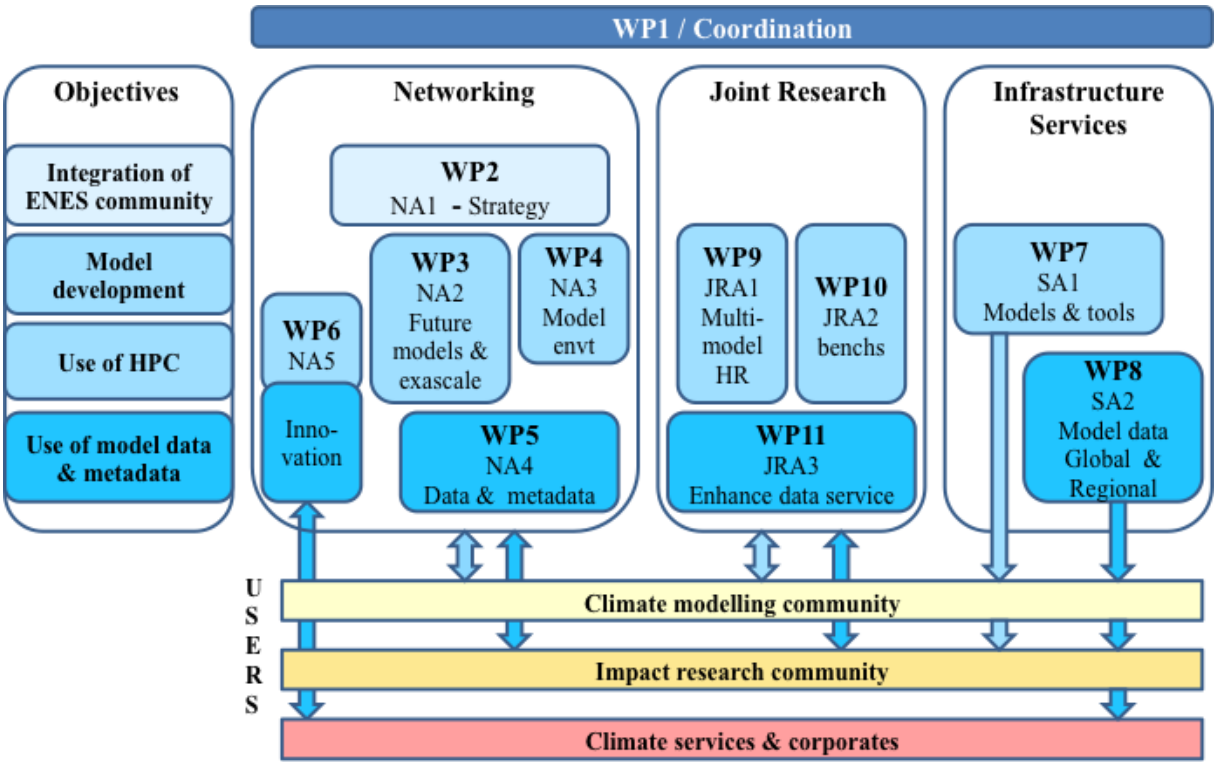

Fig.1: Organisation of IS-ENES (type of activities, thematic grouping into Work Packages) with respect to the project's objectives and relations with user communities.

Project objectives for the period

The third and last period of IS-ENES2 has been devoted to the following main objectives:

Sustain and enhance service activities on models and on model data:

- On models and tools (WP7/SA1): continue the service on models and tools and improve the service through new releases.
- On model data and metadata (WP8/SA2): integrate new services for the regional metadata repository, provide access to results of a larger number of CORDEX experiments for Europe and Africa, continue and further improve the help desk services for data users (CMIP5 and CORDEX) and data node providers, and deploy more services on the climate4impact portal.

Develop network activity with a specific focus on:

- Strategy issues: elaborate the mid-term update of the ENES infrastructure strategy, revisiting recommendations from the ENES infrastructure strategy 2012-2022 in the context of 2017 state of the art, achievements and challenges (WP2/NA1)
- Community building: further develop and maintain the ENES portal and hold the 3rd ENES summer school (WP2/NA1)
- Strengthen the networking around radiation code and cloud simulator software (WP3/NA2)
- Exploitation of the community expertise in software environment tools for climate modellers, such as configuration management, workflow and metadata capture (WP4/NA3)
- Prepare models for future HPC architectures: with work on model performance through the analyses of computational issues at exascale in atmosphere and ocean codes and code convergence (WP3/NA2), with technology tracking on exascale (WP3/NA2) and by collaborating with ICT industry (WP6/NA5)
- Data and metadata standards (WP5/NA4): collaborate at a global scale to finalise CMIP6 specifications and standards, coordinating the related ES-DOC international effort, organise community review, refine requirements for quality control of data, and extend the Common Information Model (CIM) used for metadata to regionally downscaled model results (WP6/NA5)
- Network with a range of users from the climate impact community as well as climate service providers (WP5/NA4 and WP6/NA5)

Develop joint research activity with a specific focus on:

- High-end experiments (WP9/JRA1): test a multi-model, multi-member high resolution experiment prototype, improve performance through coupler and I/O, improve workflow tools for multi-model simulations
- Benchmarking (WP10/JRA2): finalize the ENES benchmark on coupling technologies, run it on 3 platforms to demonstrate the versatility of this benchmarking environment and make it available to the community
- Improving data services (WP11/JRA3): maintain and improve software tools for the international Earth System Grid Federation (ESGF) model results data base, maintain and develop software tools for the metadata Common Information Model (CIM), develop the CMIP6 documentation software infrastructure (ES-DOC), enhance climate4impact portal functions and on developing monitoring tools for ESGF.

Main results for the third period

Results presented in the following descriptions of each work package (WP) activity show that the project has achieved its main objectives. Headline achievements of IS-ENES2 during its third period, described according to the project main objectives, are:

To foster the integration of the European Climate and Earth system modelling community

- Through discussion at the dedicated strategy workshop and at the final General Assembly, a mid-term update of the ENES infrastructure strategy 2012-2022 has been prepared, updating main recommendations in the context of 2017. (WP2/NA1)
- The Third ENES summer school further confirmed the importance of training on European climate models with hands-on (WP2/NA1).
- IS-ENES2 co-sponsored with the Princeton University Cooperative Institute for Climate Science the 4th international Workshop on "Coupling Technologies for Earth System Models" (WP4/NA3).
- IS-ENES has been well integrated in the international activities in support to ESGF, CORDEX and the preparation of CMIP6. This has happened through representatives among the international ESGF governance members, at the Steering, Executive and working teams levels, and participation of IS-ENES partners within the WGCM Infrastructure Panel to prepare guidelines for CMIP6 (WP2/NA1, WP5/NA4, WP11/JRA3).
- The ENES data task force has started investigation the national support to CMIP6 in order to sustain activities beyond the end of IS-ENES2 project (WP2/NA1).
- Integration of the climate community around HPC has been reinforced within the collaboration the ESiWACE center of Excellence. A common workshop was organised and meetings with vendors investigated the specific needs for ESM as well as gave a view on possible future collaboration (WP2/NA1, WP6/NA5 with other WP on HPC).

To enhance the development of Earth System Models for the understanding of climate variability and change

- The prototypal implementation of the common radiation tool has been finalised and integrated into more than one model, and networking in IS-ENES2 contributed to improvements of the CFMIP Observation Simulator Package (COSP) (WP3/NA2)
- The configuration management best practice guide, in response to the mid-term review, was established and provides a clear message on the topic. The last workshop on workflow and metadata capture (WP4/NA3) showed the value of direct exchange amongst the community, interaction amongst colleagues was intensively fostered (WP4/NA3).
- An international workshop has been organized in order to exchange information about the development coding strategies needed to exploit next generation architectures (WP3/NA2).
- The technology tracking activity has been continued through the investigation of new parallel approaches to improve the performance portability of climate models at large computational scales and through the exploration of potential of emerging low-power heterogeneous processors and heterogeneous scheduling and portable performance (WP3/NA2)
- A first version of an ENES coupling technology benchmark was developed (WP10/JRA2). Stand-alone components running on 4 different grids and coupled test-cases based on components running on the regular latitude-longitude grid and using five different coupling technologies

developed in Europe and USA are publicly available. As a proof of concept, these coupled test cases were run in different configurations on three different HPC platforms (WP10/JRA2).

- Services on models and environment tools (WP7/SA1) have been continued.

To support high-end simulations enabling us to better understand and predict climate variations and change

- A suite of benchmarks for coupled models has been developed, tested and made available from web. They are meant to interact with vendors and should be used to test new HPC systems. (WP10/JRA2).
- A series of talks with European and international hardware vendors has been organised. It has been the opportunity to present the benchmarks and discuss how future generation (Exascale) hardware would possibly influence the strategy of building and using the next generation Earth System Models (ESM) (WP6/NA5).
- The Multi-Member Multi-Model High-Resolution (M4HR) demonstrator has been implemented, including improvements on coupler, IO server workflow performed during the project. Results show a higher level of coordination and integration for coordinated experiments than at the start of the project (WP9/JRA1).
- Through the HPC task force, a project has been prepared and proposed to PRACE to perform high-end experiments within CMIP6, however, it was not successful showing the limits of PRACE for internationally coordinated experiments (WP2/NA1 and WP9/JRA1).

To facilitate the application of Earth system model simulations to better predict and understand the climate system and climate change impacts on society

- IS-ENES2 teams have continued to play a critical role in developing ESGF data nodes for CORDEX results for the Euro-CORDEX and Africa-CORDEX domains as well as for CORDEX Empirical Statistical Dowscaling data (CORDEX-ESD) (WP11/JRA4 and WP8/SA2).
- IS-ENES2 has supported ESGF developments in preparation of CMIP6 on several aspects, such as installation, quality control, persistent identifiers and monitoring (WP11/JRA3). Thanks to the technology and expertise developed within IS-ENES2, IS-ENES2 partners are engaged in providing access to climate projections using ESGF to the Copernicus Climate Change Service.
- IS-ENES2 has also a major contribution to the development of the metadata services, standards and interfaces elaborated within ES-DOC in collaboration with US (WP11/JRA3). An updated version of the CIM (v2.0) has been developed for CMIP6, improved tools and services to access CIM have been implemented (WP11/JRA3), tools for automatic metadata capture developed and support for modelling groups CMIP6 documentation put in place (WP5/NA4). The networking activities have been influential in steering the development of metadata technologies that will make the provision of meta-data for CMIP6 more efficient (WP4/NA3). Thanks to IS-ENES2, Europe is and remains a key player in defining international standards for climate modelling and in developing the associated tools.
- The climate4impact portal, aiming to ease access to ESGF model data for the climate impact community, has been further developed enhance and improve the interface to access to downscaled information and to compute climate indices (WP11/JRA3 and WP5/NA4).

Work progress and achievements during the period

Main results and assessment of deviations/difficulties and next steps beyond IS-ENES2.

	Positive aspects	*Deviations* / next steps beyond IS-ENES2
Integration NA1	**Governance:** The data and HPC task forces are instrumental to ENES infrastructure governance.	*A revision of the MOU has been postponed to better account for further discussions on the development of a sustainable research infrastructure.*
	Plans for a sustainable infrastructure (not initially planned): Key role of IS-ENES to support CMIP further emphasized, complemented by ESIWACE on the preparation of models for exascale computers. Importance of a sustainable ENES data infrastructure for the development of Copernicus climate change service.	Plans for sustainability to be further discussed after the end of IS-ENES2. Agreement to continue to collaborate for CMIP6.
	Foresight: mid-term update of the ENES infrastructure strategy provided.	
	ENES portal: uptodate final version	To be continued with minimum updates for CMIP6 on models and data.
MODELS And Environment tools NA2, NA3 SA1, JRA2	**Service on climate model**: continued level 1 and level 2 services on climate models. Positive feedbacks from internal reviews	
	Continued services on OASIS, NEMO and CDO	
	Best practice guide **on model configuration management tools**	
	Networking on common radiation code and diagnostics: radiation tool available and implemented in one other model. European collaboration on COSP contribution to CMIP6.	Advertise on radiation tool for further use by other models.
	Coupling technologies First ENES coupling technology benchmark available, already used with 5 different coupling technologies and advertised at the 4th international Workshop on Coupling Technologies for Earth System Models	Pursue this community effort by extending the benchmark tests to other coupling characteristics; organize the dissemination of the results on the ENES portal.

HPC NA1, NA2, NA5, JRA1, JRA2	**Improved performance of codes:** inclusion of OASIS3-MCT, I/O servers. Analyses of performance key bottlenecks for NEMO.	
	Preparation of high-end experiments Demonstrator of Multi-model Multi-member experiments.	
	Preparation of a common PRACE proposal for high-end experiments within CMIP6	*Has been delayed due to delayed PRACE2.* Has not been evaluated successfully but cannot be postponed due to CMIP6 timeline.
	Dedicated meetings with vendors for climate modelling.	Collaboration with vendors to be further developed in ESIWACE
Data and metadata NA4, NA5 SA2 JRA3	**ESGF:** Strong involvement of European experts in ESGF development and preparation of CMIP6 within the WIP.	To be continued with coordination ensured by the data TF IS-ENES partners to implement an ESGF datanode for Copernicus C3S. Involvement in EOSC pilot
	CORDEX data nodes: Key role of IS-ENES2 in implementing CORDEX data in ESGF, also for CORDEX ESD and in South Africa	
	ES-DOC / Metadata standard: update of CIM in preparation of CMIP6, complete end-to-end workflow design and development including automated tools for model, experiments, conformance, performance, etc.. documentation. White paper published and community review organised. Extended standards for downscaled information.	Core activity of WGCM/WIP, overseen by ES-DOC. Support from Copernicus and H2020 climate modelling projects planned
	Climate4impact portal and platform: implementation of further services. Master class trainings on portal use.	

WP2/NA1 ENES strategy

Work Package Number	*WP2/NA1*		Start Date or Starting Event					Month 1	
Work Package Title	**ENES strategy**								
Activity Type	*COORD*								
Participant Number	**1**	**6**	**10**	**5**	**3**	**4**	**14**	**22**	**9**
Participant Short Name	**CNRS-IPSL**	**MetO**	**MPG**	**UREAD-NCAS**	**CERFACS**	**DKRZ**	**UIB**	**DLR**	**KNMI**

Summary of progress of the work package:

WP2/NA1 aims at strengthening the integration of the ENES community. It includes three levels of action: strengthening the governance of ENES, further developing the ENES strategy and supporting community building.

Task 1: ENES governance

ENES governance

In the course of RP3 the activity of WP1 covered several infrastructure aspects, in particular –but not only- those related to the upcoming CMIP6, while discussing and elaborating strategies for the future of the infrastructure. The governance strongly involved the ENES HPC and Data Task Forces as well as the ENES Scientific Officer. These task forces play an important role in the governance as described in D2.1.

- The HPC Task Force (HPCTF) organized, jointly with the Centre of Excellence ESiWACE, the 4th ENES HPC workshop. The workshop benefitted from input from the NWP community that has many shared challenges, It tackled issues such as the European HPC ecosystem, innovative new developments on key issues such as new dynamical cores, IO servers, high-resolution models, and new paradigms concerning languages, standards, and next-generation models in preparation for Exascale computing. The openness to representatives of NWP was furthermore reinforced as part of ESIWACE by the appointment of Peter Bauer from ECMWF and Oliver Fuhrer, from Meteo-Swiss, as new members of the HPCTF. Moreover, the HPCTF collected information on HPC and storage requirements for CMIP6 and helped prepare the HiPRACE proposal for CMIP6 high-resolution model experiments on PRACE. Work on identifying current and anticipating future needs in terms of HPC was instrumental to the preparation of a document updating of the HPC strategy (MS2.5), eventually contributing to the update of the strategy for the whole infrastructure for the next 10 years. To complement this information, the document "Use of HPC facilities for European climate science: feedback from the CMIP5 experience" was also finalized and published as an appendix to the HPC strategy. The HPC-TF also follows and coordinates ENES activities with respect to European initiatives in HPC (ETP4HPC and Extreme-scale demonstrators, EXDCI...).

- The ENES Data Task Force (DataTF) also worked in preparation of CMIP6: calculated resources (storage, human resources, tasks) allocation and contributed contribution to terms of reference for Tier1 and Tier 2 ESGF systems. Ongoing initiatives, such as Copernicus and EOSC, also demanded coordination of efforts and contribution. The Task Force also worked on the organization required for the data infrastructure when IS-ENES2 support will cease. The DataTF also contributed in updating the ENES strategy for the infrastructure.

- The activities of the ENES Scientific Officer covered the liaison with several on-going projects such as ENVRIplus, ESIWACE, Climateurope, WGCM Infrastructure Panel and the contribution to overall governance and update of foresight.

The discussion on governance of IS-ENES software, initiated at the last IS-ENES2 General Assembly, was summarized in a document going through the different governance structures in place, analyzing available and applicable governance models, and finally issuing some guidelines and considerations of what forms effective governance for various types of software at various stages of shared use (D2.5).

Further steps toward IS-ENES sustainability were made: a foresight workshop (MS2.4) proposed a multi-lateral agreement around the data infrastructure as a solution, to grant the infrastructure its needed long-term dimension. The issue was further discussed at the General Assembly.

International governance:

- IS-ENES participates to the international ESGF governance. The 6th ESGF F2F meeting was an opportunity to share expectations on ESGF by each of its 5 stakeholders. IS-ENES2 also contributed to the Executive level as is reported in WP11/JRA3.
- IS-ENES continues to participate in the activities of the WGCM Infrastructure Panel (WIP) to design the requirements for CMIP6 (see WP5/NA4 and WP11/JRA3)
- IS-ENES is represented in the Board of European Environmental Research Infrastructures (BEERI) created in the frame of the European project ENVRIplus.

Task 2: European Climate Community Strategy

During RP3, the white paper on ESM evaluation needs and infrastructure has been finalised and published in the peer-reviewed literature following a series of international discussions (D2.3). It then contributed to discussions on the update of the strategy.

In view of the mid-term update of the ENES infrastructure strategy, a foresight workshop was held in Reading 25-27 October 2016 (MS2.4). This led to a first draft of the strategy document, and discussions on main recommendations further discussed at General Assembly. The mid-term update of the strategy (D2.6), as circulated in April 2017, analyses drivers and infrastructure components in the context of 2017 and partially reformulates, accordingly, the previous recommendations, complementing them with guidance on scientific evaluation of models and on how to organisationally tackle the sustainability challenge.

Task 3: Climate modelling community building

Summer School

The 3rd European Earth System and Climate Modelling school took place in Helsinki in June 2016, 9-21 (D 2.4). It was organised by UREAD-NACS, MPG and BSC and gathered 28 students. Three models were setup, run, and inter-compared. Participants were very satisfied by the school providing insightful recommendations for the next school.

ENES Portal

Following its major upgrade as of June-September 2015, the ENES portal (http://enes.org) is being maintained and regularly updated. Its future and sustainability beyond IS-ENES2 have been discussed and solutions and work toward the implementation of the chosen solution has started.

Significant results:

Task 1:

- 4th ENES HPC workshop in collaboration with ESiWACE (Toulouse, 6-7 April 2016)
- Update of the ENES strategy for HPC (MS2.5)
- Update of ENES governance rules (D2.1)

- Analysis of governance of shared software (D2.5)
- Participation to the international governance of ESGF and the WIP

Task 2:

- D.2.3 led to the peer-reviewed paper: *Eyring, V., P.J. Gleckler, C. Heinze, R. J. Stouffer, K. E. Taylor, V. Balaji, E. Guilyardi, S. Joussaume, S. Kindermann, B. N. Lawrence, G. A. Meehl, M. Righi, and Dean N. Williams, 2016, Towards improved and more routine Earth system model evaluation in CMIP, Earth System Dynamics, 7, 813–830, www.earth-syst-dynam.net/7/813/2016/doi:10.5194/esd-7-813-2016*
- Discussion within IS-ENES2 contributed to a multi-author review paper manuscript to be submitted to *Reviews of Geophysics* in May 2017 (invitation to do so was received): *"Climate feedbacks in the Earth system and their evaluation"(by C. Heinze, V. Eyring, P. Friedlingstein, C. Jones, Y. Balkanski, W. J. Collins, T. Fichefet, S. Gao, D. Ivanova, W. Knorr, R. Knutti, A. Loew, M. Ponater, M. G. Schultz, M. Schulz, P. Siebesma, J. Teixeira, G. Tselioudis, and M. Vancoppenolle)*
- Update of the ENES infrastructure strategy (D2.6), based on discussions at the foresight update workshop (MS2.4)

Task 3:

- 3rd ENES Summer School held in June 2016 (D2.4)
- D2.7 on ENES portal, documenting the final status of the portal

Deviations from Annex I (DoW):

D2.1, although initially planned to present a revision of the full ENES governance, D2.1 presents the terms of reference of the two ENES Task Forces on Data and HPC, which are central to the governance of the ENES Infrastructure.

Reasons for failing to achieve critical objectives and/or not being on schedule

A revision of the ENES MOU has been postponed to better account for further discussions on the development of a sustainable research infrastructure.

Use of resources:

CNRS-IPSL, 13.03 pm, co-leads WP2. CNRS-IPSL with the ENES scientific officer chairs the ENES Board and is involved in the international governance and in the HPC and Data Task Forces.

MetO, 0.4 pm, participates to the HPC task force, the ENES Board and prepared governance rules for common software and review of the updated HPC strategy,

MPG, 3 pm, participates to the HPC task force, the ENES Board and contributed to the 3rd ENES summer school.

UREAD-NCAS, 2.21 pm, leads WP2**,** participates to the HPC and Data Task Forces and the ENES Board. UREAD-NCAS is involved in the international governance for ESGF, ES-DOC as well as WIP. It led the 3rd ENES summer school and organized the foresight workshop

CERFACS, 1 pm, leads the HPC Task Force and collaborates on preparing the governance on software. It organized the 4th ENES HPC workshop (in collaboration with ESiWACE).

DKRZ, 3.3 pm, is in charge of maintaining and upgrading the ENES Portal. DKRZ is also involved in the HPC and Data Task Forces. DKRZ coordinates the Centre of Excellence in applications of HPC on climate and weather modelling.

UiB, 4.5 pm, has contributed to the elaboration of the white paper on model evaluation infrastructure strategy and organized the initial workshop leading to it. Further, UiB took the lead in a multi-author manuscript "Climate feedbacks in the Earth system and their evaluation".

DLR, 4.09 pm, led the paper on infrastructural needs for model evaluation. V. Eyring as chair of the CMIP Panel ensures an international dimension to this activity and its insertion in the preparation of CMIP6.

KNMI, 0 pm, has not contributed to RP3. KNMI initially planned to co-lead the strategy update, could not due to staff change, but contributed as a participant to discussions.

Corrective actions: none

WP3/NA2 Towards next generation models

Work Package Number	*WP3/NA2*		Start Date or Starting Event					Month 1	
Work Package Title	**Towards next generation models**								
Activity Type	*COORD*								
Participant Number	**4**	**10**	**5**	**2**	**1**	**12**	**7**	**16**	**6**
Participant Short Name	**CMCC**	**MPG**	**UREAD -NCAS**	**DKRZ**	**CNRS -IPSL**	**UNIMAN**	**STFC**	**BSC**	**MetO**

Summary of progress of the work package:

WP3/NA2 is devoted to prepare the climate modelling community for the exascale computing era and better connect those working on climate model development by sharing best practices and methods, by establishing code convergence where useful and feasible, and by developing common understanding of divergent codes.

The third period led to finalize the prototypal implementation of the common radiation tool and the integration into more than one atmospheric model. Activities on COSP have been continued: IS-ENES has contributed to the optimisation of the current stable version and to the testing of the next major release.
The report on programming languages of the main European ESMs has been finalized, as well as the EC-EARTH performance analysis. As regards computational code convergence, an international workshop has been organized in order to exchange information about the development coding strategies needed to exploit next generation architectures. NEMO and ICON models have been considered as key test cases and some performance optimization strategies have been analysed and collected in a re-design document.
The technology tracking activity has been continued through the investigation of new parallel approaches to improve the performance portability of climate models at large computational scales and through the exploration of potential of emerging low-power heterogeneous processors and heterogeneous scheduling and portable performance.

Details for each task:

Task 1: Building a community using common radiation tools

Task 1 is devoted to putting in place a community working on developing a common radiation library, as well as developing and extending the existing community work on optimising the observation system simulators.
During the last period, the ICON radiative code has been implemented as standalone code module. It can be used as shared library and integrated to C/C++ and Python code. The code has been integrated into the atmospheric model LMDZ and tested successfully.
The CFMIP Observation Simulation Package COPSv1.4.1 has been tested and released. It includes two additional diagnostics requested by CMIP6. The activity on COSP allowed contributing to the CFMIP paper in GMD, which includes a COSP section (Webb et al, GMD, in press). The development of COSP2 has been started: two models have been chosen to implement a beta version of COSP2 (UM and MIROC). An international workshop on COSP Network Support and Optimisation has been organized in Paris in February 2017 (**MS3.6**). The main outcomes of the workshop have been reported in the deliverable **D3.3** "Report on common radiation tools".

Task 2: Developing convergent model codes

Task 2 is devoted to the code convergence. During the last period, the document on the analysis of NEMO re-design strategies needed to efficiently exploit the new architectures, has been extended to the ICON model and the added **D3.4** "Report on NEMO and ICON models re-design" has been delivered.
The international workshop "Crossing the Chasm" was organized in Reading in October 2016 (**MS33** and **MS3.5**). The workshop exploited the possibility of input from major European activities, such as innovative new techniques like domain specific languages to optimize parts of the model stack in a machine-independent way. The main outcomes of the workshop have been reported in the deliverable **D3.2** "Crossing the Chasm: How to code weather and climate models for next generation computers?". Moreover, the analysis of the programming languages used by the European and non-European ESMs has been updated and reported in a working document (see task2 significant results), as well as the analysis of EC-EARTH using BSC DIMEMAS simulator.

Task 3: Technology tracking

Task 3 is devoted to the technology tracking and to the analysis of new parallel approaches at large computational scale.
During the last period, the application of the novel PSyKAl (Parallel System, Kernel, Algorithm) approach to the NEMO ocean model has been investigated. The kernel extracted from the NEMO code as part of the WP10 benchmark suite has been used to test the "separation of concerns" approach. Two versions of the kernel have been developed: the sequential version of the original code and the PSyKAl version. The activity aimed at evaluating pros and cons of the 'separation of concerns' approach in NEMO development with a focus on the code complexity/readability as well as on performance portability. The PSyKAl original approach should be partially revised to match the natural scientists requirements in terms of code readability. Some feasible solutions have been identified and are under discussion with the NEMO developer team. The document "Application of the PSyKAl approach to the NEMO ocean model (analysis of feasibility)" summarizes the activity and the main outcomes.
Finally, potential of emerging low-power heterogeneous processors (where memory is shared between CPUs and GPUs, as opposed to traditional systems where the GPU is accessed over, for example, PCI Express) and heterogeneous scheduling and portable performance have been explored.

Significant results:

Task 1:

- Implementation of the ICON radiative code as standalone code module; integration and testing within the LMDZ model
- Contribution to testing and release of COSP v1.4.1
- Contribution to the CFMIP paper in GMD, which includes a COSP section
- International workshop on COSP Network Support and Optimisation held in Paris on 27-28 February 2017 (MS3.6)
- Delivery of D3.3 "Report on common radiation tools"

Task 2:

- Update of the document "Earth System Models programming languages" (https://portal.enes.org/ISENES2/documents/na2-working-documents/programming-languages/view)
- Delivery of the document "Simulation-based performance analysis of EC-Earth 3.2.0 using Dimemas" (https://portal.enes.org/ISENES2/documents/na2-working-documents/simulation-based-performance-analysis-of-ec2010earth-3-2-0-using-dimemas/view)
- International workshop "Crossing the chasm" (joined milestone: MS3.3 and M35)

- Delivery of D3.2 "Crossing the Chasm: How to code weather and climate models for next generation computers?"
- Delivery of D3.4 "Report on NEMO and ICON models re-design"

Task 3:

- Analysis on the application of the novel PSyKAl (Parallel System, Kernel, Algorithm) approach to the NEMO ocean model. The code example is available at https://github.com/arporter/NEMO-DSL. The document "Application of the PSyKAl approach to the NEMO ocean model (analysis of feasibility)" has been delivered (https://portal.enes.org/ISENES2/documents/na2-working-documents/application-of-the-psykal-approach-to-the-nemo-ocean-model/view).
- Exploration of potential of emerging low-power heterogeneous processors (including with shared CPU-GPU memory), heterogeneous scheduling and portable performance

Deviations from Annex I (DoW):

The "Workshop on European Radiative Transfer Library" (**MS3.4)** has been replaced by smaller working meetings and workshops of opportunities. This was in part due to delays in development due to recruitment difficulties but proved to be useful in the period of development since it made it easier to reach a larger development community.

The milestone **MS3.3** "Workshop on Model Structure, Code Evaluation" has been delayed, amalgamated with the "Workshop on Convergence" (**MS3.5**) and renamed as "Crossing the Chasm" workshop. This has been to take advantage of other activities going on in Europe, in particular to be timed to exploit the possibility of input from major European activities.

The deliverable **D3.2** "Report on strategies for developing convergent model codes" has been delayed to follow the "Crossing the Chasm" workshop. D3.2 has been renamed as "Crossing the Chasm: How to code weather and climate models for next generation computers?". This better emphasizes its content but is still highly linked to the initial issue since we need to converge on common libraries and tools to cross the chasm between current computing hardware and the expected next generation.

Additional activities:
The deliverable **D3.4** "Report on NEMO and ICON models re-design" has been added as result of both the analyses of the models computational performance and the technology tracking activity.

Testing the PSyKAl approach to NEMO ocean model has been added thanks to some internal reallocation funds.

Reasons for failing to achieve critical objectives and/or not being on schedule

Use of resources:

CMCC: 2.28 pm, leads the WP by participating to project meetings and by scheduling the activities. In task 2.2 CMCC contributed to the deliverable D3.4. Finally, in task 3.2 CMCC, in collaboration with STFC, investigated the application of the novel PSyKAl approach to the NEMO ocean model development and evaluated the impact of this approach on code complexity/readability as well as on performance portability. The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.

MPG: 10 pm, implemented the ICON radiative code as standalone code module. The source code has been substantially reduced in size, its readability has been much improved, so that the cost of further developments will constantly decrease. MPG delivered D3.3.

UREAD-NCAS: 5.82 pm, organised the "Crossing the Chasm" workshop, and has prepared the "Crossing the Chasm" deliverable, which reports on current activities and provides recommendations for the future. Additional work on documenting model codes using the ES-DOC mechanism was also carried out, work that will, in a future alteration, allow the decoration of model codes with ES-DOC compliant markup. Some of this work was presented at the Lisbon IS-ENES2 joint workshop on workflows and metadata generation.

DKRZ: 1.22 pm, carried out performance analysis of the fast evolving ICON model code, as part of Task 2. DKRZ also developed and implemented solutions for the elimination of detected performance bottlenecks. DKRZ contributed to the additional deliverable D3.4 and to the program of the "Crossing the Chasm" workshop.

CNRS-IPSL: 7.78 pm, contributed to test the use of the new radiative transfer library within the LMDZ atmospheric model. The test was positive which allows continuing the development of this library. CNRS-IPSL organized and hosted the COSP Network Support and Optimisation in February 2017 (Milestone MS3.6)**,** and delivered D3.3 on "Report on common radiation tools"

UNIMAN: 5 pm, focussed on exploring the potential of emerging low-power heterogeneous processors. Techniques to characterise workload and power/energy use of applications has also been undertaken and a paper on this work is in preparation.

STFC: 2.35 pm, have also collaborated with CMCC to look at the feasibility of using the PSyKAl approach to the NEMO ocean model. A new API, more suitable for pre-existing codes, has been designed and these results have been presented to the NEMO HPC team and will be presented to the NEMO development team.

BSC: 1.71 pm, has produced the technical memorandum "Simulation-based performance analysis of EC-Earth 3.2.0 using Dimemas". To produce this document, some developments on BSC tools have been done, released in the webpage of BSC tools.

MetO: 3.3 pm, has contributed to the following activities: definition of the COSP CMIP6/CFMIP3 data request, documented in Webb et al. (2017); organisation of the IS-ENES international workshop on COSP (MS3.6); development of COSP v2.0. Also preparation for and attendance at the Crossing the Chasm workshop.

Corrective actions: *None.*

WP4/NA3 Earth System Modelling Environments

Work Package Number	*WP4/NA3*		Start Date or Starting Event				Month 1
Work Package Title	Earth System Modelling Environments						
Activity Type	*COORD*						
Participant Number	1	2	3	4	6	10	22
Participant Short Name	CNRS-IPSL	DKRZ	CERFACS	CMCC	MetO	MPG	UiB

Summary of progress of the work package:

Earth System Modelers need a rich environment of tools to support their modeling activity, and a lot of knowledge on how to select and use these tools. This concerns Workflow, post- processing, configuration management, meta-data management and coupling tools.

Technical and human resources are scarce, so more risky approaches to this with potential efficiency gains are avoided, developments are targeted at local problems, and tools. Networking lowers the barriers to use common software solutions for such tools. This work package provided opportunities to study and evaluate solutions by sharing experiences with software tools of colleagues at other international modelling centers through workshops and meetings. It facilitated best practices and software sharing by supporting software evaluations leading to well prepared, in depth workshops allowing partners to understand the opportunities for shared software solutions.

Details for each task:

Task 1: Workflow solutions, including seasonal to decadal climate prediction systems

The final workshop on workflow solutions (**MS4.7**) was planned and took place coincident with the metadata capture final workshop (which led to deliverable D4.4) see Task 3.

In RP1, a first workshop identified issues with workflows (WF) in ESM, looked at solutions from NWP and other realms, and attempted to provide views on possible ways into the future. In RP3, a second workshop also included discussions on post processing solutions in use in the community and how they are integrated into workflows. Furthermore, in depth discussions on CMIP6 WF-solutions and employment of meta-schedulers were held, including hands-on training sessions for the Cylc and Autosubmit meta-schedulers. Development priorities for the Cylc workflow tool under the ESiWACE CoE where presented and agreed. Both the training exercises and the presentation of real-life successes with Cylc and Autosubmit will encourage interest in shared software solutions in the wider community. By combining this workshop with the needs for the ESiWACE centre of excellence, we were able to reach a wider audience for both projects.

Task 2: Configuration Management Tools

The "Configuration Management Best Practice Guide" was delivered out of a virtual workshop on configuration management (**MS4.5**) in response to the comments in the mid-term review asking for outputs of this type.

Different configuration management systems are in use at various ESM sites, FCM (Flexible Configuration Management) system developed at the Met Office being one of the most prominent. The networking activity shared experiences with such systems at two workshops organised by the Met Office. Also, support of a community evaluation at different sites where the Met Office

supported the migration of model code to FCM was supplied. In this RP, evaluations were collected in a second, virtual workshop, which produced a community driven "Configuration Management Best Practice Guide[1]" with input from in excess of 30 institutions worldwide. This new approach was driven by requests made in the mid-term review and a virtual workshop was found to be a very effective approach to developing such a resource for the community. The main result is the document itself which can act as a reference within the community. The contents will help groups, especially those with less experience, to implement robust Configuration Management and will alert people to the range of tools and methodologies used in the community. An important bi-product from the exercise of writing this document is the level of engagements that was received from the participants. This was well beyond that expected by the lead author and is clearly the result of considerable thought and analysis which has its own lasting value.

Task 3: Meta-data creation and usage

The final workshop on meta-data capture was planned and took place leading to deliverable **D4.4**.

With two workshops organised by DKRZ, one in RP1 and one in RP3, this networking activity promoted the sharing of experiences and designs in the emerging area of providing rich meta-data to describe ESM experiment sets. This is achieved by building meta-data capture into the heart of the ESM experiment process and driving meta-data provision exercises. Additionally, the readout of metadata from file headers is enhanced by furnishing them with more and richer meta data, as well as with links to further information.

Task 4: Governance of a community coupler

The main results have been achieved in the previous two periods. The governance of the OASIS coupler (D4.3) served for the discussions in WP2 on software governance. The "Fourth Workshop on Coupling Technologies for Earth System Models" continuing the series started under IS-ENES1 in Toulouse in 2010 and pursued in Boulder in 2013 and in Manchester in 2015 under IS-ENES2 was held in Princeton (USA), supported in part by IS-ENES2 funding, although this was not initially planned. It was an opportunity to discuss the latest developments and applications of coupling technologies for Earth System Models (ESMs) of the international community.

Significant results:

Task 1:

- **MS4.7** Final workshop on workflow solutions, has been held in Lisbon (Portugal) from September 27 to 29, 2016.

Task 2:

- The "configuration management best practice guide" was produced out of a virtual workshop (MS4.5). It is available on the ENES portal.

Task 3:

- The **MS4.6** Final workshop on meta-data generation during experiments has been merged with MS4.7, in September 2016 (initially due April 2016), for practical reasons and to allow the largest audience possible.
- **D4.4** Meta-data Capture Final Workshop Report, delivered in Feb 2017.

Task 4:

- 4th Workshop on Coupling technologies for Earth System Models, has been held in Princeton, March 20-22, 2017 gathering about sixty researchers and engineers from nine different

countries in North America, Europe and Asia.
(see https://www.earthsystemcog.org/projects/cw2017)

Deviations from Annex I (DoW): none

Use of resources:

CMCC: **4.06 pm,** contributed to state of the art analysis about workflow solutions suitable for numerical climate change experiments. Specific solutions like Kepler and Ophidia have been analysed and evaluated for multi-model climate experiments. (The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.)

CERFACS: 0.7 pm, finalized the terms of the OASIS coupler governance that will be launched in June 2017.

DKRZ: **1.03 pm**, organized the IS-ENES "Joint final IS-ENES2 workshop on Workflow Solutions in Earth System Modelling and Meta-Data Generation during Experiments" (MS4.6 and MS4.7) including preparation and subsequent finishing work.

MetO: 1.1 pm, Lead the development of the Configuration Management best practice guide; prepared and attended at the last workflow workshop, including preparation and delivery of a hands-on Cylc tutorial. Reviewed documents.

UiB: 0 pm claimed; Prepared and attended at the workflow workshops, gave 2 presentations about the Norwegian workflow solutions for high-resolution modeling and data handling.

CNRS-IPSL: 0 pm claimed**.** Prepared and attended workshops.

Corrective actions: *None.*

WP5/NA4 Data Networking

Work Package Number	*WP5/NA4*		Start Date or Starting Event				Month 1
Work Package Title	Data Networking						
Activity Type	*COORD*						
Participant Number	1	2	3	4	7	8	9	11
Participant Short Name	CNRS-IPSL	DKRZ	CERFACS	CMCC	STFC	SMHI	KNMI	CSAG
Participant Number	12	14	17	19	21			
Participant Short Name	UNI-MAN	WU	UC	DMI	MF-CNRM			

Summary of progress of the work package:

Data Management requires significant resources, and collaboration at the European and international levels is essential to ensure proper data access to users. This implies, notably, quality control, metadata standards and interoperability, access protocols, user interface for data access and processing.

The activity in this work package has supported the networking activities required to develop the software infrastructure for documenting CMIP6, under the banner of ES-DOC and in interaction with the modeling community within the Working Group on Coupled Models Infrastructure Panel (WIP). This workpackage was successful in providing recommendations on data access protocols and quality control requirements based on consultations. Significant work took place to create and develop an international collaboration aimed at refining/defining metadata standards for climate indices and indicators. This work is necessary to be able to incorporate those datasets into existing portals and technology, as they require standards to enable automation. European and International collaboration continued to be very active on building the underlying infrastructure of data dissemination to the climate change impact communities. It also included implementing user requirements gathered in the first periods of IS-ENES2.

Details for each task:

Task 1: Core data services

In order to gather the different data access requirements, two consultation actions have been performed in previous periods with results laid down in MS5.2 (*Consultation on data access protocols*) and MS5.3 (*Consultation on quality control requirements*). These consultations led to **D5.3** *"Report on basic data access protocols and data quality control"* which focuses on the need for standardisation of ESM data among data providers. D5.3 reviews existing standards and provides recommendations for the implementation of standards.

Task 2: Meta-data, interoperability and standardisation

Work has been continuing on Metadata standards and Data Reference Standards (DRS) for climate indices and indicators. This work, initiated by the FP7-CLIPC project, has been done in collaboration with IS-ENES2, where people from both projects were very active in the workshops. Following the end of the FP7-CLIPC project, IS-ENES2 has taken over all the work related to these new standards. A final workshop within the IS-ENES2 project was organized to deal with pending issues, as well as

with the end of the IS-ENES2 project as this activity is no longer funded after the end of IS-ENES2 and CLIPC.
IS-ENES2 has also contributed to the definition of vocabularies in two important areas. For CMIP6 this work delivered the Data Request and documentation within ES-DOC, while for the CORDEX the primary outcome was the Data Reference Syntax (**D5.4**). NA4 also contributed to the international coordination of ES-DOC.

Task 3: Requirements for the impact user communities

Collaboration and discussions continued to be strong, regarding both the underlying architecture as well as the climate4impact portal interface itself, with FP7-CLIPC, FP7-SPECS, FP7-EUPORIAS projects, as well as with the ESGF Compute Working Team (CWT) and ESGF-IDEA (KNMI), and the H2020-EUDAT2020 project. Work within the ESGF Working Teams was sometimes limited because only a few PMs were available, but those were quite productive to have a tighter integration of climate4impact with the ESGF infrastructure, especially with the future ESGF computing nodes.
CSAG has undertaken a Climate Portals review, user experience analysis, and feature/characteristics comparison of portals including the climate4impact portal and the CSAG CIP (Climate Information Platform) portal. The results have been developed into a paper currently accepted to WIREs Climate Change. CMCC has validated the requirements on the monitoring system for the impact user community, which has been identified in the previous periods. A specific section on this topic has been also provided in the **D5.2.**

Significant results

Task 1:
- Deliverable **D5.3** "Report on basic data access protocols and data quality control" has been delivered. D5.3 recommends an open license (license "CC by") which is more open than the result of WIP white paper ("CC by-sa") and which is in agreement with outcomes of the RDA meeting in Denver (2016-09) (more open or even no license like CC0).
- Completion of the CMIP6 Data Request .
- DKRZ quality control tool has been applied to bias-adjusted datasets from several institutes ahead of final publications under WRCP-endorsed ESGF project CORDEX-Adjust.

Task 2
- **D5.4** "report on metadata controlled vocabulary extensions" has been delivered.
- Joint action on Metadata Standards for climate indices/indicators with CLIPC, with documents describing the new standards. Further dissemination was done.
- Preparation of the proposal for the extension of the CORDEX DRS to Empirical Statistical Downscaling.

Task 3
- **D5.2** "Assessment of impact communities requirements" has provided input for further improvements of the climate4impact portal. Many of those improvements have been implemented after being prioritised, while others were postponed for later.
- Extensive dissemination activities at the European and International levels (linked to WP11/JRA3 Tasks).
- Continuous user requirements and feedbacks gathering for the climate4impact platform and portal.

Deviations from Annex I (DoW) : None

Reasons for failing to achieve critical objectives and/or not being on schedule: None.

Use of resources:

STFC, 20.5 pm used (23 PM total project). Finalisation of ES-DOC experiment specifications (collected at tabulated information in spreadsheets and exported to ES-DOC); contributions to the International Climate Network Working Group (icnwg.llnl.gov); preparation of the CMIP6 Data Request.

CERFACS, 1.9 pm used (18 PM total project). Dissemination of climate4impact platform in international conferences. Organisation and development of new Metadata standards for climate indices. Continued collaboration with ESGF Compute Working Team, as well as with EUDAT2020.

CSAG, 4.9 pm used (14 PM total project). Climate Portals review, user experience analysis, and evaluation activity and paper publication. On-going engagement with Metadata and DRS activities focused on the CORDEX-ESD (Empirical Statistical Downscaling) metadata and DRS standards.

DKRZ, 3.11 pm used (12 PM total project). Updating of MS5.2 and MS5.3 from earlier reporting periods (RP1 and RP2). Integration of MS5.2 and MS5.3. Writing of D5.3. Finalizing, reviewing of D5.3.

SMHI, 5.83 pm used (9 PM total project). Quality control and publication of bias-adjusted data from several institutes. Organisation and development of new/extended metadata standards for climate indices, including co-organisation of technical workshops. Contacts and interaction with other projects and international organisations regarding metadata requirements and standards for climate indices focussing user requirements. Contribution to dissemination activities.

KNMI, 1.28 pm used (8 PM total project). Dissemination of climate4impact platform in international conferences. Organisation, participation and development of new Metadata standards for climate indices. Continued collaboration with ESGF Compute Working Team. Assisted in organizing classroom exercises at WU to help students and knowledge purveyors understand how to use climate4impact.

WU, 4.02 pm used (8 PM total project). Contribution to Climate4impact portal coding sprints activities such as updates and expanding of user guidance and documentation pages, popup help messages, facets definitions, coding, analysing portal access, using statistics and increase accessibility of the portal through improved keywords.

UC, 3 pm used (6 PM total project): Proposal for a new Metadata standard for Empirical Statistical Downscaling. Interactions with other international initiatives like EUPORIAS and SPECS.

CMCC, 3.83 pm used (4 PM total project). Validation of the requirements from the impact user community identified in the previous periods and regarding the data usage metrics. Contribution to the deliverable D5.2. The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.

CNRS-IPSL, 0 pm used in this period (3 PM total project), although has participated within the international WIP and ES-DOC committees to the preparation of metadata for CMIP6.

MF-CNRM, 0.15 pm used (3 PM total project). Participation to the project Final General Assembly and dissemination of information on WP5 activities (Climate4impact web portal) towards French actors of climate services

UNIMAN, 0 pm used (2 PM total project), no activity in WP5 during this period

DMI, 0 pm used (2 PM total project). Work has been completed before RP3. Nothing to be reported.

Corrective actions: *None.*

WP6/NA5 Innovating on climate modelling

Work Package Number	*WP6/NA5*		Start Date or Starting Event				Month 1
Work Package Title	**Innovating on climate modelling**						
Activity Type	*COORD for NA5*						
Participant Number	**1**	**2**	**3**	**4**	**5**	**7**	**8**	**14**
Participant Short Name	**CNRS-IPSL**	**DKRZ**	**CERFACS**	**CMCC**	**UREAD-NCAS**	**STFC**	**SMHI**	**WU**

Summary of progress of the work package:

This work package is addressing two groups of external users. The first is the ICT industry, where the aim is to improve collaboration and create a culture of co-design aiming to facilitate efficient use of future computer architectures and systems for climate models.

This work package also aims to reinforce relations with providers of climate services in order to stimulate innovation in this field and better use results from IS-ENES2. Activities in this part of the WP have been affected by the launch of the Copernicus Climate Change Service. The FP7 Copernicus CLIP-C project (2014-2016) aimed at integrating model results (from IS-ENES2) with observational datasets for a large range of users in the context of climate services and overlapped with initial task 3 objectives. The same is true for a new Copernicus C3S project called SWICCA (Service for Water Indicators in Climate Change Adaptation), which was initiated in November 2015. IS-ENES2 WP6's objective was to seek collaboration with evolving European climate services policies and projects. It was therefore decided to adjust task 2 and 3 activities, and benefit from collaboration with both projects.

Details for each task:

Task 1: Facilitate innovation through collaboration with ICT companies

During RP3, IS-ENES2 community initiated a series of talks with European and international hardware vendors. The goal was to understand, how future generation (Exascale) hardware would possibly influence the strategy of building and using the next generation Earth System Models (ESM). Outcomes and conclusions drawn from the interaction – together with findings from a workshop that took place in RP2 (April 2014) - were summarized in **D6.4**.

Task 2: Facilitate innovation through the transfer of climate knowledge to consultancies and corporates

The masterclass course on the use of climate data for adaptation strategies (using the climat4impact portal) was developed and tested in earlier reporting periods. The master class aims at training SMEs and larger companies using CMIP5 and CORDEX data on the application in different decision maker's contexts, assuming the need for climate data use in such contexts is growing. Company representatives, following the master class, enhance their capacity and skills to apply climate model data in a correct way and to assess the possibilities, limitations and uncertainties of data. The master class has an interactive character with dialogues between providers and users on real life decision-making contexts. The exchanges are based on case studies provided by participating companies. During RP3, two master classes have been given in collaboration with the SWICCA project. The training has been given to a total number of approximately 150 interested students, company

representatives and consultants between 2015-2017.

Task 3: Facilitate societal innovation

IS-ENES2 representatives have made contributions on the use of climate model data for climate services in several IS-ENES2-Copernicus workshops and results have been used for the production of **D6.2** (*Report on needs for climate services*). The deliverable was completed at the end of 2016.
Work on requirements for the impact user community was continued in collaboration with WP5 and in the frame of the development of the climate4Impact portal by developing and introducing new case study storylines (on seasonal forecasts) and the introduction of hydrological indicators.

Significant results:

Task1:

- **D6.4** sums up the findings of the interactions with vendors in RP2 and RP3. The main conclusion with the most practical implications for the daily work is that most Earth System Model codes as they are in use today will not be able to efficiently leverage the potential performance gain of next generation HPC systems, so refactoring and rewriting of codes has to be considered**.**

Task 2:

- In RP3 the master class was given twice in collaboration with the Copernicus SWICCA project to consultants and SME representatives: in April 2016 (15 representatives from consultancy and business) and in March 2017 (22 participants from consultancies and business). See http://www.wur.nl/en/newsarticle/Climate-Services-Training-successfully-held.htm. The April 2016 master class course presentations were published on the SWICCA website as tutorials: http://swicca.climate.copernicus.eu/information-videos/#close (see figure). The master class training was also integrated in a master course on consultancy training at Wageningen University. This course was given twice during RP3 for 67 students
- An entrepreneurship session (**MS6.5**) took place at the 3rd ENES summer school given by a finnish industrial company ENIRAM working to reduce fuel consumption for ships.

Task 3:

- **D6.2** Report on needs for climate services was finalized.

Figure: screenshot SWICCA tutorials on internet, these presentations are taken from the IS-ENES2 WP6 task 2 master class curriculum

Deviations from Annex I (DoW) None.

Reasons for failing to achieve critical objectives and/or not being on schedule
none

Use of resources:

CNRS-IPSL, 2.58 pm, contributed in Task 3 to the production of D6.2.

DKRZ: 2.4 pm was used for organising the series of vendor talks (Task1) and compiling the deliverable D6.4.

CERFACS, 0 pm, no activity is reported during this period.

CMCC, 0 pm, no work was planned and no resources used in RP3

UREAD-NCAS, 0 pm, no activity is reported during this period.

STFC 0 pm, no activity is reported during this period.

SMHI 1.14 pm. Lead of deliverable 6.2 production.

WU, 4.02 pm Organisation and further refinements of master class trainings. Four trainings given in RP3. Contributions (from the climate service community perspective, to the climate4 impacts portal. Contribution to D6.2 production. Coordination activities for task 2 and 3.

Corrective actions: none

WP7/SA1: The European Network of geographically distributed services on Earth System models, component models and tools

Work Package Number	***WP7/SA1***		**Start Date or Starting Event**			**Month 1**	
Work Package Title	**The European Network of geographically distributed services on Earth System models, component models and tools**						
Activity Type	*SUPP*						
Participant Number	**3**	**1**	**8**	**9**	**21**	**6**	**22**
Participant Short Name	**CERFACS**	**CNRS-IPSL**	**SMHI**	**KNMI**	**MF-CNRM**	**MetO**	**UiB**
Participant Number	**10**	**4**	**23**	**2**			
Participant Short Name	**MPG**	**CMCC**	**met.no**	**DKRZ**			

Summary of progress of the work package:

During the third period, level 1 services were continued on all European ESMs as well as level 2 services on EC-Earth and on the Unified Model. Services on NEMO ocean model and OASIS and CDO tools were offered as planned, and new versions of these software model and tools were released. The milestone MS7.6 "*2nd review report on the ENES Earth System Model Resources*", originally planned for mo36, was delivered at mo44 and was very positive. The other milestone due during RP3 MS7.7 "*Documentation of the reference and sensitivity experiments based on the activation of LIM3 in ORCA025*" was delivered on time at mo48.

Details for each task:

Task 1: Managing the ENES Earth System Model Resources

During the third period of the project, mails with the ENES portal manager and with the different ESMs groups were exchanged to ensure that the ESM portal pages were kept up-to-date. Interactions with Dr K. Puri (ACCESS, AU) also took place so to facilitate the production of the 2nd review report on the ENES Earth System Model Resources.

Task 2: Services on European ESMs

During the third period, all services on Earth System models were offered as planned:

1. **Level 1 services on all European ESMs** (see also point 7. below)

Statistics on portal hits for the ESMs pages and detail per ESM are available at https://verc.enes.org/awstats/awstats.pl?config=esm. These statistics, started in August 2014, cover the second and third reporting periods. They show that the **number of accesses to the ESMs pages has significantly increased during the third period**. The number of unique visitors, number of visits, and hits have increased over the third period compared to the April 2015-March 2016 period respectively from 10144 to 13391 (32%), 20196 to 27036 (34%), 68599 to 78902 (15%). They also show that people from all over the world access the ESMs pages, with a maximum of people from the USA. Finally one can notice a sensible difference between the different ESMs, with e.g the UK MetOffice HadGEM2 pages being viewed 7155 times in 2016 while the CNRM-Cerfacs CNRM-CM5 pages were accessed only 2620 times.

Overall, these records show that IS-ENES2 portal is being accessed by users from all over world with

an increasing number of visits, confirming that the portal is found to be useful by users.

2. Level 2 services on EC-Earth and on Met Office HadGEM2, HadGEM3 and ESM families:

For EC-Earth:

- 2 versions released (3.2.1 and 3.2.2)
- 45 new users registered (219 in total)
- 137 new issues reported - 81 issues closed
- 35 new or updated wiki pages
- 107 forum messages posted
- Source code change sets: 964

For Met Office HadGEM2, HadGEM3 and ESM families

General support

- Maintaining support pages on TWiki collaboration platforms
- Writing and distribution of a newsletter
- Support for common diagnostic/analysis tools (Iris, AutoAssess)
- Development of Cube Browser (python package to plot and explore your Iris cube)

In-person user support:

- HadGEM3 installation support
- UKESM porting and installation support for all the associated systems
- UM User Workshop (150 attendees in 2016)
- UM User Tutorial (17 participants from 9 organisations in 2016)
- Bespoke on-site training for
  - Korean Meteorological Administration (South Korea, 30 participants in 2016)
  - National Institute of Meteorological Sciences (South Korea, 25 part. in 2016)
  - National Centre for Medium Range Weather Forecasting (India, 45 part. In 2016)

Task 3: Services on NEMO ocean model component (installation 8) (CNRS-IPSL)

NEMO services are organised around the existing web site[2], accessible from the ENES portal. The organisation of NEMO CDE (Collaborative Development Environment) was completely revisited to ensure more stability and security in a user-friendly environment. Through this web service, complete and regularly-updated information is available so that users can access: the NEMO code reference distributed under free license and its history (using Subversion server); reference manuals; user guides; publications; forums, meetings announcement and news; a ticketing system for developments.

During the last 12 months, services around NEMO have ensured:

- 2000 changes of the NEMO source code
- 65 tickets opened (for developments or bug fixes), and 45 bugs fixed
- 150 edits of the wiki pages (documentation, description of on-going work)
- around 100 mails sent to answer questions (user support).

Overall, NEMO is currently used in 240 projects in 27 countries (14 in Europe, 13 elsewhere) with more than 1400 registered users. The following numbers (covering the last 12 months) also illustrate the use and size of NEMO community:

- Number of logins in use on NEMO web site: 1544
- Downloads of NEMO: 1363 for the 3_6_STABLE reference, 581 for the trunk (shared version in development)

The main service around NEMO, although not officially covered in IS-ENES2, is the sustained development of the reference version of NEMO. During the past 12 months, a large part of the

[2] http://www.nemo-ocean.eu/

work focused on the finalization of NEMO 3_6_STABLE release for CMIP6. Indeed, NEMO is the ocean component model used in 5 of the 7 European ESMs (CNRM-CERFACS, CMCC, EC_EARTH, IPSL, Met-Office Hadley Centre) participating to CMIP6.

In the framework of IS-ENES2, the NEMO System Team contributed to this effort by helping the community to build and share expertise on the configurations in play for CMIP6, i.e. eORCA1_LIM3_PISCES 1°, and eORCA024_LIM3_PISCES ¼° global configurations. In particular, the NEMO System Team has:

- set up the forge project (shaconemo, https://forge.ipsl.jussieu.fr/shaconemo/wiki) to offer a reliable tool to share information, expertise and progress through wiki pages and ticketing system. The shaconemo project has for now 80 registered users, all directly related to use of NEMO in CMIP6;
- organised regular workshops (in person and by videoconference) allowing the different groups to confront their experiences and enhance the search for optimal solutions:
  - Workshop NEMO in CMIP6 - 19 January 2017 - Grenoble Workshop
  - Workshop NEMO in CMIP6 - 14 September 2016 by videoconference
  - Workshop NEMO in CMIP6 - 28 29 January 2016 – Grenoble;
- provided guidance on choices of inputs (cpp keys, namelists, …)

The core of the service activities during the past year has therefore clearly been to facilitate the community sharing of experience and expertise. The number of releases of eORCA1_LIM3_PISCES configurations, i.e. 10 in the past year, clearly demonstrates the usefulness of this service for the community.

The KPIs have the following values for the 4 last 6-month periods, i.e. 04-09/2015, 10/2015-03/2016, 04-09/2016, 10/2016-03/2017

- Number of downloads for NEMO: 1235, 1112, 3001, 1110
- Number of discussions and mails exchanged for NEMO: 60, 80, 240, 100
- Number of tickets opened/closed for NEMO 107/106, 219/215, 50/30, 55/43

Finally, the milestone **MS7.7** (mo 48) "*Documentation of the reference and sensitivity experiments based on the activation of LIM3 in ORCA025*" has been delivered although there have been changes in the community priorities (i.e. a focus on the lower resolution eORCA1 global 1° configuration in a first step). The complete eORCA025 configuration is now set up and available with documentation; first sensitivity experiments were produced and presented to the community and are now available on the shaconemo forge project.

Task 4: Services on ESM tools

All these services are available since the beginning of the project.

OASIS (installation 9) (CNRS-IPSL, CERFACS)

During the third period of 12 months, services around OASIS have consisted in:

- Maintaining the most up-to-date sources and documentation available on the Subversion server: 231 change sets registered (respectively 558 and 549 for the first and second 18-month period).
- Distributing them to the climate modelling community through the OASIS web site (https://verc.enes.org/oasis) accessible through the ENES portal (see the KPI below).
- Updating the Redmine development tickets, see https://inle.cerfacs.fr/projects/oasis3-mct :41 updates (respectively 219, 475 for the first and second 18-month period).
- Active user support was also provided mainly through mail exchanges and few phone conversations (see the KPI below).
- Following and updating OASIS forum conversations (see the KPI below).

These services helped users on specific issues and provided guidance on how to use the software on

specific platforms and in particular configurations.

The KPIs have the following values for the 4 last 6-month periods, i.e. 04-09/2015, 10/2015-03/2016, 04-09/2016, 10/2016-03/2017

- Number of downloads for OASIS: 106, 68, 56, 22
- Number of discussions and mails exchanged for OASIS: 118, 113, 196, 121
- Number of tickets opened/closed for OASIS: 5/3, 4/4, 5/3, 3/8

CDO (installation 10) (DKRZ)

As during the first and second periods, services included running the CDO helpdesk and webserver set up, accessible via the ENES portal. In particular, up-to-date documentation, FAQ, and help form are accessible through the ENES portal. One new version CDO 1.8.0 was released during the period.

The KPIs have the following values for the 4 last 6-month periods, i.e. 04-09/2015, 10/2015-03/2016, 04-09/2016, 10/2016-03/2017

- Number of downloads for CDO: 6374, 5700, 6000, 3400
- Number of discussions and mails exchanged for CDO: 550, 324, 503, 444
- Number of tickets opened/closed for CDO: 72/18, 0/46, 31/37, 45/47

Significant results:

The two WP milestones of the period were delivered (see the specific reports):

- **MS7.6** "2nd review report on the ENES Earth System Model Resources" was delivered at mo44, by Dr K. Puri (ACCESS, AU) and was very positive. In particular, it was noted in the report that: "(i) all the links [to the ESM CIM documentation] now work, (ii) contacts listed for the ESMs are current, (iii) all contacts approached for the second review responded and provided requested information, (iv) the major point about the visibility of IS-ENES2 among potential European users is being followed up and release of the IS-ENES2 newsletter at regular intervals is a welcome development."

Nevertheless, two paths for improvement were suggested:

- Reduce the number of steps to get to a desired page (e.g. to download model data or to find the appropriate model contact), as this may discourage the user.
- Increase the visibility of IS-ENES2 among potential European users. The number of users that contacted the service providers directly through the IS-ENES2 portal (around 10) is rather low. Suggestions were made to address this problem:
  - have a session at EGU or a similar meeting dedicated to showcasing IS-ENES2 with demonstrations, case studies, presentations by European modelling groups, etc. ;
  - write an article about IS-ENES2 in a reputable journal (e.g. BAMS) ;
  - further develop the IS-ENES2 newsletter to increase the visibility of the project.

- **MS7.7** "Documentation of the reference and sensitivity experiments based on the activation of LIM3 in ORCA025" due at mo 48 was completed.

Deviations from Annex I (DoW) :
MS7.6 originally due mo36 had been already delayed by 6 months (see previous period report). It was finally delivered at mo 44 but this did not have any impact on other tasks.

Reasons for failing to achieve critical objectives and/or not being on schedule :
For M7.6, the delay of 8 months was linked to the fact that we considered that the 2nd periodic report should be used, among other material, as an input by the reviewers to produce their report.

Use of resources:

CERFACS: 0.1 pm, has coordinated the WP7/SA1 (task 1) and has provided services on OASIS.

- Operation costs for the third reporting period: **3 092 €**
- Percentage of the operation costs charged to the project: **20%**
- Access cost charged to the project for the third reporting period: **618 €**

CNRS-IPSL is the main provider of services on NEMO, is involved in services on OASIS and has provided level1 services on IPSL-CM5 although does not request access cost during this period.

SMHI does not request access cost, although has provided level1 and level2 services on EC-Earth.

KNMI does not request access cost for RP3

MF-CNRM does not request access cost, although has provided level1 services on CNRM-CM5.

MetO has provided level2 services on Unified Model and HadGEM2

- Operation costs for the third reporting period: **44 965€**
- Percentage of the operation costs charged to the project: **20%**
- Access cost charged to the project for the third reporting period: **8 992.98 €**

UiB does not request access cost, although has provided level1 services on NorESM

MPG does not request access cost, although has provided level1 services on MPI-ESM and services on CDO.

CMCC does not request access cost, although has provided level1 services on CMCC-CESM

Met.No does not request access cost, although has provided level1 services on NorESM

Corrective actions: none

WP8/SA2 ENES Climate Data Services

Work Package Number	*WP8/SA2*		Start Date or Starting Event			Month 1
Work Package Title	ENES Climate Data Services					
Activity Type	*SUPP*					
Participant Number	1	2	7	9	15	19
Participant Short Name	IPSL	DKRZ	STFC	KNMI	LIU	DMI

Summary of progress of the work package:

Details for each task:

Task 1: Core Data services

After the security breach of ESGF and the need for a revised software, European datanodes have been re-established and data from CMIP5 and CORDEX been exchanged (Figure 1)

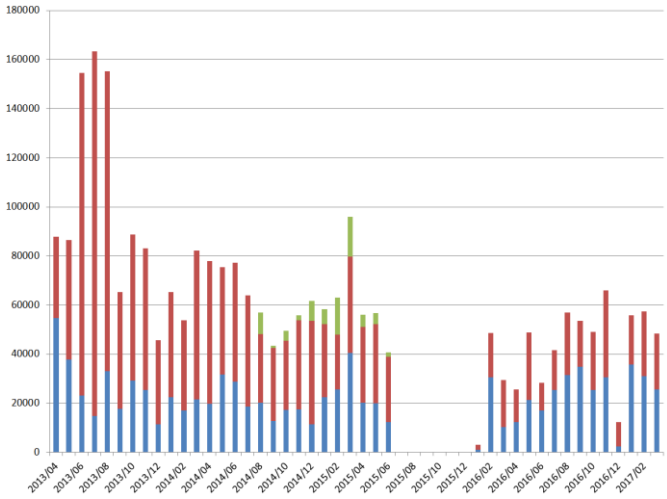

Figure 1: Data volume downloaded from European ESGF datanodes for CMIP, CORDEX and some smaller projects. In blue amount of data downloaded by European users, in red from other institutions. In green data downloaded fromWDCC.

1.1 User support:

In the reporting period, support for ESGF users has been improved further. A replacement for first-level support staff in case of an absence has been introduced. As a consequence, response times do not show dominant peaks as in past years, see diagram below.

The number of queries did not reach the high numbers from before the ESGF downtime (June 2015 – January 2016) again because of a much more stable ESGF; data nodes malfunctioning for months do not exist anymore. This is in turn a consequence of a far better organized admin support. A new intersurface and maybe the improved self-help pages have had an effect too. The ratio of email threads with involvement of IS-ENES2 staff is very high.

The ESGF self-help pages, which are mainly maintained by IS-ENES2, have completely been moved to CoG, the new ESGF surface. Since CoG is also the new surface for all ESGF portals (index nodes), self-help pages and ESGF portals have a uniform look-and-feel now. Unlike the old Github pages, CoG allows images. This new feature has intensively been used for inserting screenshots. Additionally, two new tutorials about authorization and OPeNDAP have been added to the ESGF/CoG help. The tutorial about ESGF wget download scripts has completely been revised. The

FAQ has been revised and extended too. The OPeNDAP tutorial is also in the ENES portal.

1.2 CORDEX support:
DMI hosts an ESGF data node for CORDEX data and receives and serves 0.44-degree CORDEX data for data providers without an own ESGF node (Hungary, Belgium, Netherlands, Canada). For these institutes, test data have been delivered for which a quality control with the DKRZ Quality Control programme (developed in WP11/JRA3) was run and advices to the respective groups were given. In collaboration with DKRZ and SMHI, DMI takes care of the name registration for Regional Climate Models in the CORDEX project as a whole. DKRZ receives and hosts the EUR-11 0.11-degree CORDEX data (German groups, Croatia, Belgium). Here, too, Quality Control and user interaction were conducted.

1.3 Service for Quality Control and low level data access:
DKRZ gave support for the installation of ESGF data and index nodes, as well as for ESGF data publication at DMI, ICHEC, KNMI, CMCC, DLR, PIK und NCI. DKRZ also supports various European ESGF data nodes by acting as their index node and/or identity provider – this is the case for DMI, ICHEC, KNMI, CMCC, DLR, and PIK.

Task 2: Meta-data Services

For Task 2, software developed within WP11/JRA3 and ES-DOC, had to be documented and integrated into the workflows. This comprises e.g. web services as a cdf2cim converter and tools for cim-search, -publishing, and –url-rewriting. In preparation for CMIP6 model specializations for ocean, sea ice & atmosphere were developed and CMIP6 MIPs & Experiments documentation published. User frontends were created for comparison of CIM records, and for search, for viewing, and for errata display. The full CMIP6 documentation workflow was established including a development roadmap. All this was discussed at the regular transatlantic phone conferences of ES-DOC which publicises its activities on a newly created WordPress website.

Task 3: Enhanced Data and Information Access

3.1 ENES Data Portals:
The ENES portal: The focus of the self-help pages for end users in the ENES portal is an introductory instruction, mainly for beginners, and project-specific information whereas ESGF self-help pages, hosted at the CoG ESGF portals are more comprehensive in the technical sense but contain less information concerning CMIP5 and CORDEX. Links have been inserted pointing from the ENES portal to ESGF/CoG help and vice versa.
The Climate for Impact Portal (C4I) had a remarkable increase of users: from 500 in 2013, to 1000 in 2014, to 1600 unique visitors in 2016 on average per month. The new search interface to ESGF now is operational as well as convert and subset web services. Climate indicator processing and data of statistical downscaling have been integrated. The Copernicus oriented Clip-C portal decided to use the web services of C4I. As user support the help web pages were supplemented by a *Getting started* section.
To make CORDEX regional climate data available for the European community, about 50 TBytes were stored and made accessible at DKRZ. The whole amount of CORDEX data on European ESGF data nodes at the end of IS-ENES2 project is 61.1 Terabytes (67.5 TB including data nodes outside Europe). The affiliation of permanent identifiers (DOI) is going on. These are mainly EUR-11 data and AFR-44, additionally smaller amounts of data from the Arctic, South American, and Western Asia regions.

3.2 Support
The improvement of ESGF support has taken effect. In the ESGF 2016 User Survey, a poll among data providers (8%), data consumers (63%) or both (29%), user support and distributed global search were the only two ESGF components rated as most useful.

Nevertheless, documentation was rated as most difficult in the same survey. Indeed, among the ESGF/CoG tutorials are many which describe editing of CoG pages and administration of CoG groups, themes irrelevant for ESGF users. Especially ESGF beginners might additionally have the problem to find the right self-help page among the ESGF tutorials since ESGF help is more comprehensive and beginners have to find and read several tutorials. The best information for beginners is in the ENES portal. Therefore, a guidepost with clearly visible links to the relevant pages in the ENES portal was inserted in the ESGF/CoG overview page https://www.earthsystemcog.org/projects/cog/tutorials_web.

Altogether, self-help pages seem to be more frequently read by users than in former years. Many users refer to them in their queries to the user support mailing list. Alongside, IS-ENES support via mailing list and the links to the ENES portal have increased the visibility of IS-ENES. The most important ENES DATA pages are frequently visited

Statistics of user support: IS-ENES contribution to ESGF support

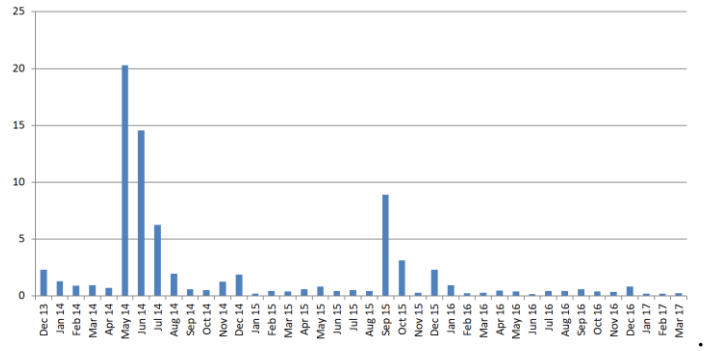

Figure 2: Mean response times or ESGF user support in days

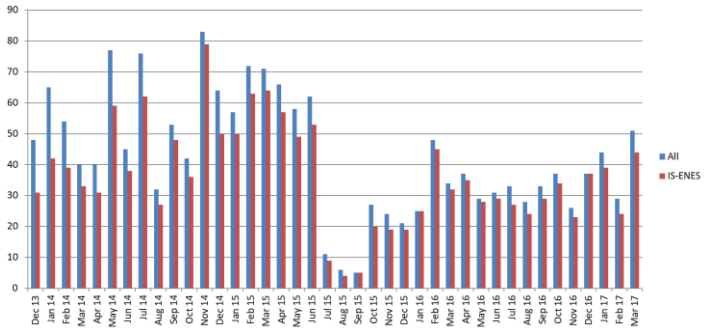

Figure 3: Number of email threads in sum and with IS-ENES contribution

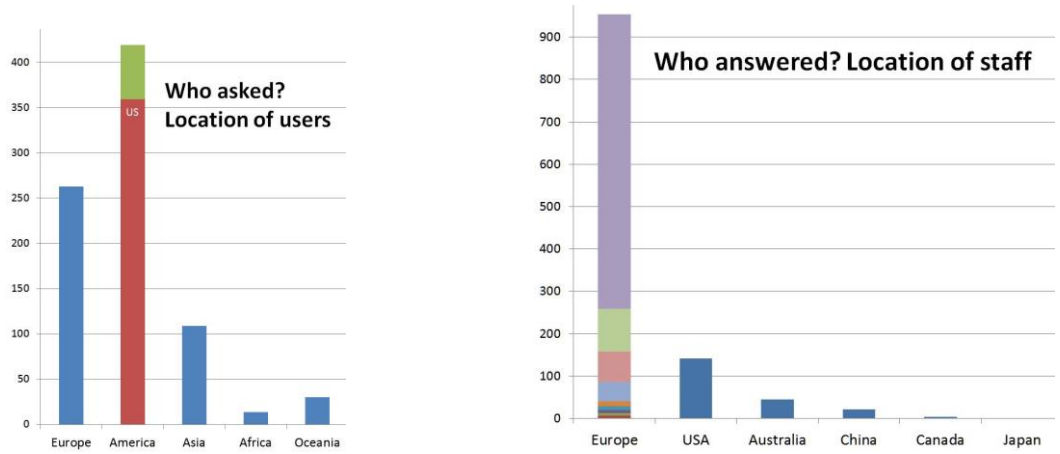

Figure 4: Origin of the questions (left) and of the answers (right)

3.3 Outreach:
The ESGF F2F meeting in December 2016, was an opportunity to advertise on the service and make the work visible to the global ESGF community.

3.4 Review:
The most important ENES DATA pages have again been reviewed. The recommendation of the reviewer, an introduction of help information for which purpose ESGF and for which Climate4impact should be chosen, has been integrated: page https://verc.enes.org/data/data-metadata-service has been extended by a guidepost. The recommendations concerning the climate4impact portal were communicated to KNMI and taken into account for further development. Recommendations on the ESGF user surface were forwarded to our partners in the US. They were implemented by DKRZ as far as they were related to help texts and documentation.

Significant results:

MS8.7 (M36) "2nd Review Report on the ENES Climate Data Infrastructure":
The most important ENES Data pages have again been reviewed, this time by an internal reviewer from DKRZ since the review committee of the first review could not overtake the second review. Besides the review report, the milestone contains a description of the arrangements performed in answering to the review.

Deviations from Annex I (DoW):

MS 8.7: *2nd review report on the ENES Climate Data Infrastructure*
Initially, this MS had a deadline of M36. It had to be delayed as the selected external reviewers for the 2nd report did not answer to mails. We had to engage an internal reviewer instead. The MS was finished on 2017-02-16 (M47).

Reasons for failing to achieve critical objectives and/or not being on schedule
-- none in WP 8 --

Use of resources:

DKRZ, The work on user and data node (DN) support including DN statistics and maintenance of IS-ENES data website went on as well as data storage in long term CMIP archive, including quality checks, and affiliation of a Digital Object Identifier (DOI). In these fields preparations were taken for the CMIP6 project, too.

- Operation costs for the third reporting period: **839 764 €**
- Percentage of the operation costs charged to the project: **11.8 %**
- Access cost charged to the project for the third reporting period: **99 368 €**

STFC, ongoing development of the CIM data model in cooperation with our US partners in the ES-DOC collaboration, regular bimonthly phone conferences for governance. User and data node support which includes running the CIM portal for user access.

- Operation costs for the third reporting period: **921 733 €**
- Percentage of the operation costs charged to the project: **15.9 %**
- Access cost charged to the project for the third reporting period: **146 195 €**

CNRS-IPSL has provided user and data node support, including software deployment and installation support; es-doc.org and associated services have been continued as well as the quality control on CIM content. The monitoring tool of the es-doc services has been enhanced.

- Operation costs for the third reporting period: **121 553 €**
- Percentage of the operation costs charged to the project: **20%**
- Access cost charged to the project for the third reporting period: **26 012€**

LIU has provided CORDEX user and data node support by operating ESGF CORDEX attribute service and answering many CORDEX related questions; work on ESGF development.

- Operation costs for the third reporting period: **15 033 €**
- Percentage of the operation costs charged to the project: **20%**
- Access cost charged to the project for the third reporting period: **3 217€**

DMI, ongoing CORDEX user and data node support. DMI has maintained and operated the DMIESGF index node as well as a data node. .

- Operation costs for the third reporting period: **125 222 €**
- Percentage of the operation costs charged to the project: **20%**
- Access cost charged to the project for the third reporting period: **25 044€**

KNMI, does not request access cost, although has worked on Climate4Impact including ongoing user support and statistics. Improvement of performance and of the search interface went on; here user feedback was included. The Web Processing Service was enhanced Together with the ClipC project, a workshop for interested parties was held in Wageningen to get user feedback and for dissemination of portals as Climate4Impact. The API documentation was further designed and completed.

Corrective actions: none

WP9/JRA1: Multi model, multi member high resolution Earth System Models

Work Package Number	*WP9/JRA1*		Start Date or Starting Event			Month 1	
Work Package Title	Multi-model, multi-member high resolution Earth System Models						
Activity Type	*RTD*						
Participant Number	8	3	1	2	4	10	6
Participant Short Name	SMHI	CERFACS	CNRS-IPSL	DKRZ	CMCC	MPG	MetO
Participant Number	9	21	23	18	5	20	16
Participant Short Name	KNMI	MF	met.no	DLR	UREAD-NCAS	IC3	BSC

Summary of progress of the work package:

The main focus of JRA1 in RP3 was on the integration and assessment of performance improvements, made earlier in the project, for the various ESM components and workflow steps. This has lead to more efficient ESM components, whole ESMs, and, finally, to the implementation of the Multi-Member Multi-Model High-Resolution (M4HR) demonstrator as the overarching objective of this work package. Even though not all of the individual performance enhancements could be made available for each ESM or component, the level of coordination and integration between components and models has clearly improved with respect to the beginning of the project. This is proven by the coordinated component upgrades for the coupler and I/O components, the coordinated performance analysis for I/O servers, the integration of ESMs into common workflow tools, and, finally, the implementation of the M4HR demonstrator, providing a proof-of-concept for coordinated high-resolution simulations.

Details for each task:

Task 1: M4HR experiment definition, implementation, and analysis

A multi-model multi-member high-resolution (M4HR) demonstrator has been set up and tested. Compared to initial plans, it has been limited to two ESMs in order to adapt to available computing resources, allowing however, to provide a reliable proof of concept. The M4HR demonstrator was implemented on a common computing platform (MareNostrum3, BSC), using the latest available versions of two ESMs (ARPEGE5-NEMO and EC-Earth3), and controlled by a common workflow management system developed in task 4 (Autosubmit). Computational performance of the two M4HR demonstrator models, as well as other JRA1 ESMs outside of the demonstrator, has been measured and documented (**D9.6**), making use of the performance metrics earlier developed in the WP (D9.1 and published in Balaji et al, 2017).

Task 2: Performance analysis of HR ESM after OASIS updates

The evaluation of computing performances lead to discussions with the aim to precisely assess what "performances" meant in this context, particularly regarding to coupling. Balaji et al (2017) proposes a standard set of metrics and describes the corresponding methods to simply obtain them. The LUCIA tool (developed during IS-ENES1 and now distributed with the OASIS reference version) helps to reduce load imbalance of our coupled systems. Load imbalance is reduced below 15% in any model of the M4HR demonstrator (D9.2).

Task 3: Development and performance analysis of I/O subsystems

Development of I/O servers has continued under RP3 and JRA1 ESMs have been updated to more recent versions (e.g. EC-Earth and ARPEGE-Climat to XIOS2). The computational performance of

CDI-pio and XIOS has been analysed under conditions that match real production requirements. CDI-pio was evaluated with the atmospheric model ECHAM6 and XIOS with the atmospheric model ARPEGE-Climat and the ocean model NEMO. Both CDI-pio and XIOS2 I/O libraries proved their capacity to efficiently manage high-resolution model output (**D9.4**).

Task 4: Performance analysis of post-processing

The CDO system for post-processing operations has been further developed and new versions have been released. The performance of disk transfer rates during "read and write" operations has been analysed (**D9.5**) to identify bottlenecks in the post-processing workflow step. The analysis confirmed that the CDO system is capable to efficiently transfer large amounts of data.

Task 5: Job control for M4HR experiments

A common submission and job control environment, based on Autosubmit, has been set up for the M4HR demonstrator developed in task 1. Based on this environment, M4HR experiments have been monitored on the common computational resource (MareNostrum3) and a user guide for the set-up has been produced (included in **D9.6**). A general-purpose wrapper has been included in Autosubmit, packing multi-member simulations into a single executable with suitable job control (part of **MS9.9**).

Significant results:

Task 1

- Design, implementation, analysis, and documentation of a coordinated multi-member coupled climate simulation demonstrator at high resolution (M4HR), using JRA1 HR ESMs (**D9.6**)
- Computational performance of JRA1 ESMs (ARPEGE-NEMO, EC-Earth, CESM-NEMO, HadGEM-GC, NorESM) measured using the CPMIP metrics (D9.1 and disseminated article) and documented as part of **D9.6**.

Task 2

- Reduction of load imbalance due to coupling in the M4HR demonstrator (**D9.2**)

Task 3

- HR ESM upgrades to the new I/O server version XIOS2 released in RP2
- Coordinated assessment of CDI-pio and XIOS shows compatibility, suitability, and reasonable performance for JRA1 ESMs (**D9.4)**

Task 4

- CDO performance analysis (**D9.5**) reveals no bottlenecks in the transfer of large amounts of data from/to disks
- New CDO version released (version 1.8 in 10/2016 plus minor versions)

Task 5

- User guide for Autosubmit configuration of M4HR created (D9.6)
- Autosubmit released to ENES community through GNU license (**MS9.9**)

Deviations from Annex I (DoW)

D9.4: Originally it was foreseen to compare the two IO servers CDI-pio and XIOS in the same climate model. However, after further consideration, no model needed to implement the two IO servers and it was too much work for just testing performance. Nevertheless, a coordinated indirect comparison of the I/O server performance in HR context has been carried out.

D9.6: Due to limited computing resources, the scope of M4HR has been changed from an ensemble of four different climate models to a demonstrator with two models. D9.6 delivers a M4HR demonstrator implementation and the corresponding performance analysis. Changes and motivation are detailed in the deliverable document.

Reasons for failing to achieve critical objectives and/or not being on schedule

Use of resources:

CNRS-IPSL 1.63 pm, contributed to the XIOS development in order to provide full support for data output and post-processing for CMIP6, avoiding costly post-processing phases at the end of simulations (to be used by IPSL and CNRM models). The XIOS team implemented and consolidated a lot of new functions in the XIOS internal workflow to be compliant with CMIP6 data request: horizontal remapping, vertical interpolation in pressure levels, spatial reduction, time series management, etc. The NEMO consortium will also benefit from these enhancements.

DKRZ: 2.38 pm, evaluated performance of the CDI-pio I/O library implemented in the ECHAM6 model for a range of different model resolutions (D9.4). Furthermore, systematic analysis of the CDI-pio performance using the 'pio_write' test and synthetic benchmark program (part of the CDI-pio package) has been carried out. In particular, the influence of ROMIO hints on the effective data write rate and performance scalability with respect to the number of I/O servers for different MPI implementations have been analysed.

CERFACS: 3.6 pm. As WP co-leader, CERFACS coordination was required to implement the M4HR demonstrator and write the final deliverable documentations. We also contributed to prepare a CPMIP (Computing Performances Intercomparison Project) relying on CMIP6 experiments.

CMCC: 3.51 pm, contributed to D9.6 by providing the performance analysis on the IBM iDataPlex DX360M4 cluster of the CMCC very high resolution fully coupled general circulation model, based on a 1/4 degree configuration in both atmospheric and ocean component. The coupled model components performance has been measured according to the set of the CPMIP metrics. The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.

UREAD-NCAS, 4.02 pm, have been developing cf-python (http://cfpython.bitbucket.org/) as a means of performing model analysis. In particular, methods have been and continue to be developed in CF-Python for doing spherical and cartesian regridding conservatively, bilinearly, and with nearest neighbour interpolation based on the high-performance Earth System Modelling Framework (ESMF) re-gridding library. UREAD has put in place a framework for parallelising select cf-python functionality, in particular working towards parallelising the collapse method.

MetO: 0 pm, No work was planned and no resources used in RP3**.**

SMHI: 5.43 pm, contributed to task 1 by porting EC-Earth 3.2 to MareNostrum3 and performing initial performance analysis prior to the M4HR demonstrator. Support was given to the integration of EC-Earth into the Autosubmit environment (partly task 5) and part of the M4HR test runs where performed. SMHI contributed to the M4HR documentation in D9.6. Test runs for various coupling configurations for improved performance where performed with EC-Earth 3.2 (task 2). SMHI contributed to the design and documentation of the CDO performance analysis (D9.5, task 4).

KNMI: 0 pm, No work was planned and no resources used in RP3.

MPG: 0 pm, No work was planned and no resources used in RP3.

BSC: 1.9 pm, contributed to task 1 by giving support to the integration of ARPEGE5-NEMO into the Autosubmit environment of the M4HR demonstrator and part of the M4HR test runs where performed. BSC contributed to the M4HR documentation in D9.6. BSC released Autosbumit 3.7.7 to

the ENES community through the GNU/GPL3 license (MS99, task 5).

DLR: 1.41 pm. In Task 3.2, the MESSy CHANNEL plug-in module interfacing CDI-PIO has been further developed and tested.

MF-CNRM: 0 pm, No work was planned and no resources used in RP3.

met.no: 9 pm, performed testing for an optimum number distribution of core distribution for various resolutions of NorESM and reported numbers for CPMIP. Testing a structure for running an automated multi-member ensemble of NorESM. As an aftermath of the preparatory access work on PrACE computers reported in RP2, we have tried to be involved in the set-up of our application for HighResMIP. This has been harder than expected.

Corrective actions: Adaptation of objectives for D9.4 and D9.6, leading to results well in line with overall objectives of the WP

WP10/JRA2 Performance benchmarks for coupled climate models

Work Package Number	*WP10/JRA2*		Start Date or Starting Event			Month 1		
Work Package Title	Performance benchmarks for coupled climate models							
Activity Type	*RTD*							
Participant Number	1	2	3	4	6	7	10	12	15
Participant Short Name	CNRS-IPSL	DKRZ	CERFACS	CMCC	MetO	STFC	MPG	UNIMAN	LiU

Summary of progress of the work package:

The main objectives of the JRA2 activities within the IS-ENES2 project is to assemble a set of benchmarks based on real Earth System Model (ESM) codes used in European climate research as well as to collect and make available key performance data for these benchmarks on different HPC systems. During the third reporting period, the work on further development and extension of the ENES Benchmark Suite has been continued. Currently, the suite includes seven application benchmarks of different complexity and a coupling technologies benchmark based on five different coupling technology software packages. The available benchmarks are:

- CMCC-CM2 (ESM)
- EC-EARTH (ESM)
- IPSLCM (ESM)
- MPI-ESM1 (ESM)
- ICON (uncoupled atmospheric model component of MPI-ESM2)
- NEMO tracer advection kernel
- ICON communication kernel
- Coupling technologies benchmark

The benchmarks documentation and performance reference for model benchmarks and kernels are provided at https://redmine.dkrz.de/projects/enes-benchmark-suite.
The community coupling technology benchmark is available on the ENES portal at https://portal.enes.org/computing/performance/benchmarks. It contains stand-alone components and coupled test cases examining five different coupling technologies (i.e. OASIS3-MCT, OpenPALM, ESMF, MCT-only and YAC) in a standardised benchmarking environment.

Links to the documentation and performance reference data of the prepared benchmarks are collected in the ENES Portal at https://portal.enes.org/computing/performance/benchmarks that acts as a central entry point for the dissemination of information and services to the Earth system modelling community.

Details for each task:

Task1: Framework and benchmarking guide

Task 1 is devoted to the development of a technical and organisational framework to set up, run, distribute, and evaluate benchmarks. As already reported, this task has been accomplished in the earlier project phase to prepare a basis for the activities within Task 2 and Task 3. Among others, relevant performance metrics were identified and the SCT library for low-overhead time measurements of benchmark runs was developed.

Task 2: Suite of base benchmarks

Task 2 covers activities aimed at the development of climate application benchmarks and collection of key performance data on different HPC platforms. As the last year of the IS-ENES2 project coincided with the final preparatory phase for CMIP6, much effort has been put into the advancement of the computational and scientific performance of ESMs that are included in the ENES benchmark suite.

- CMCC continued the work on improving the CMCC-CM2 ESM, dealing with computational aspects (model tuning and the fixing of a few detected bugs) and scientific model development toward the finalization of the version that will be used in CMIP6, which has been frozen in March 2017.
- CNRS-IPSL used agile methods to produce the IPSLCM6A-LR model, which will be used for CMIP6 at CNRS-IPSL. Eight different versions have been produced during the last 15 months. For each version, performance has been checked and optimised. Performance gains were achieved due to time steps changes, different organisations of MPI/OpenMP decomposition, optimized compiler options, etc. CNRS-IPSL worked together with a supercomputer expert team to figure out the optimal choice of compiler, OS and runtime environment settings to achieve the best performance with an MPMD/MPI/OpenMP model. Furthermore, CNRS-IPSL has set up the very low resolution IPSLCM6_rc0 benchmark for systematic check of production systems at 3 different centres (TGCC, IDRIS and locally). The results are available at http://webservices.ipsl.jussieu.fr/trusting/.
- LiU carried out an in-depth performance evaluation of the EC-Earth 3.2beta model, which is a pre-release of the CMIP6 version. Different performance aspects have been systematically analysed and compared for the Intel and Cray compilers.
- DKRZ and MPG jointly worked on the development, update, documentation, and performance analysis of the new ICON APE benchmark and ICON communication kernel.

Task 3: Evaluation of coupling strategies

Task 3 focuses on the evaluation of the performance of different coupling technologies implemented in the current ESMs. For this purpose a standard benchmarking environment has been set up. It contains four stand-alone components running on four different grid types and well-defined coupled configurations, or test cases, assembled from the standalone components. Today, five coupled configurations running on the regular latitude-longitude grid with 100x100 (LR), 1000x1000 (HR) and 3000x3000 (VHR) grid points and using either the OASIS3-MCT, OpenPALM, ESMF, MCT-only or YAC coupling technologies are publicly available at bitbucket.org. The available test cases have been benchmarked on three different HPC systems (i) Occigen, Bullx at CINES in France, (ii) Cray XC40 at the UK MetOffice and (iii) the Broadwell partition of Marconi at CINECA in Italy using up to O(10000) cores. Detailed benchmark description and first results of the performance measurements are presented in the deliverable **D10.3**, primarily demonstrating the versatility of this benchmarking environment. However, more work is needed to interpret them before any firm conclusions could be drawn on the relative performance of the coupling technologies used.

Significant results:

Task 2:

- Further advancement of the ENES Benchmark Suite:
  - Benchmark versions of four coupled ESMs partially updated and made available
  - Completely revised ICON APE benchmark released
  - Extraction of the ICON communication kernel
- Performance analysis of the updated benchmarks on accessible HPC systems
- Update of benchmark documentation and performance data at https://redmine.dkrz.de/projects/enes-benchmark-suite.
- Results are published in the deliverable **D10.4** "Report on the suite of base benchmarks and

analysis of performance on available platforms"

Task 3:

- First version of the community coupling technologies benchmark released
- Benchmarking of the available coupled test cases on three different HPC systems
- Publication of deliverable **D10.3** "Report on benchmark suite for evaluation of coupling strategies"

Deviations from Annex I (DoW):

Reasons for failing to achieve critical objectives and/or not being on schedule:
None

Use of resources:

CNRS-IPSL: 0.5 pm, made systematic and regular use of the IPSLCM6_rc0 benchmark to check production systems at three centres (TGCC, IDRIS and locally) with a very low resolution (http://webservices.ipsl.jussieu.fr/trusting/). CNRS-IPSL used agile methods to produce the IPSLCM6A-LR model, which will be used for CMIP6. Regular tests of compilers especially Intel compiler have been performed. Our objective is to have the same version on different computer centres (TGCC, IDRIS, locally). Different compiler optimisations have been tested to increase performance and we noticed an improvement of 20%. Work with supercomputers expert team to figure out the optimal choice of compiler, OS and runtime environment settings to achieve the best performance with an MPMD/MPI/OpenMP model.

DKRZ: 7.71 pm, leads the WP10/JRA2 by participating in project meetings, telephone conferences, and by coordinating the work package activities. It maintains the Redmine Project Management Tool used for documentation and dissemination of ENES benchmarks and corresponding performance data (https://redmine.dkrz.de/projects/enes-benchmark-suite) and publishes the corresponding information in the ENES Portal (https://portal.enes.org/computing/performance/benchmarks). DKRZ and MPG jointly developed the revised version of the atmospheric model benchmark ICON APE and ICON communication kernel as well as provided instructions on execution and evaluation of these benchmarks, and results of performance analysis. For the community coupling technology benchmark DKRZ implemented coupled test-cases with YAC.

CERFACS: 3.1 pm, led the development of the ENES coupling technologies benchmark, implemented the test-cases with the OASIS3-MCT and OpenPALM couplers and performed the runs on the Bullx Occigen at CINES in Montpellier. CERFACS also wrote the deliverable D10.3 "Report on benchmark suite for evaluation of coupling strategies"

CMCC: 8.25 pm, continued work on the improvement of the ESM from both a computational and scientific perspective. The former includes further model tuning and the fixing of few bugs discovered. The latter includes the work toward the finalization of the version that will be used in CMIP6 (CMCC-CM2), which has been frozen in March 2017. CMCC also contributed to D10.4 "Report on the suite of base benchmarks and analysis of performance on available platforms". (The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.)

MetO: 1.2 pm, contributed to the development of the ENES coupling technologies benchmark, including implementation of the cubed-sphere-mesh benchmark and, in collaboration with STFC, the regular latitude-longitude benchmark. The benchmark codes were run on the Met Office Cray XC40

and the Met Office contributed to the writing of deliverable 10.3.

MPG: 0 pm, contributed to the development of the atmospheric model benchmark ICON APE and ICON communication kernel. No personnel cost is charged to the project in RP3.

STFC: 3.71 pm, contributed to the development and release of the ENES coupling technologies benchmark, implemented the ESMF implementation of the regular latitude-longitude benchmark in collaboration with the Met Office, integrated the dl-timer timer library, ran the benchmarks on the Broadwell partition of Marconi at CINECA in Italy, contributed to the writing of deliverable 10.3 and set up and managed the benchmark repository.

UNIMAN: 6 pm, worked on the Coupling Technologies Benchmarking, in particularly developing and supporting the initial evaluation of the MCT versions of the benchmark cases and contributed to the production of deliverable D10.3.

LiU: 1.99 pm, worked on improving the documentation of EC-Earth benchmarks, and completion of the EC-Earth performance analysis on the Beskow Cray XC40 system at PDC. LiU also contributed to D10.4 "Report on the suite of base benchmarks and analysis of performance on available platforms".

Corrective actions: None

WP11/JRA3 Developing software infrastructure for data archive services

Work Package Number	***WP11/JRA3***			**Start Date or Starting Event**				**Month 19**	
Work Package Title	**Developing software infrastructure for data archive services**								
Activity Type	*RTD*								
Participant Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Participant Short Name	**CNRS-IPSL**	**DKRZ**	**CER FACS**	**CMCC**	**UREAD**	**MetO**	**STFC**	**SMHI**	**KNMI**
Participant Number	**10**	**13**	**15**	**17**	**19**				
Participant Short Name	**CSAG**	**INHGA**	**LiU**	**UC**	**DMI**				

Summary of progress of the work package:

WP11/JRA3 aims to enhance the existing data archives services of WP8/SA2. After the major overhaul of the core data services, further developments have contributed to create a robust new service package ready for the challenge of CMIP6. The meta-data services have created a comprehensive documentation framework and service infrastructure and a detailed plan for implementation. The services for down-stream users provided by the climate4impact portal have been significantly extended. A dashboard to monitor usage of the distributed system has been put in place, ready to monitor usage of the CMIP6 archive.

Details for each task:

Task 1: Core data service software development

The core data service package has been upgraded in many areas and subjected to extensive testing. Support information has been migrated to the new CoG system and support for Frequently-asked-questions pages has been improved. The quality control software has been adapted for CMIP6 and integrated into a web processing environment. Quality control support for data uploaded by providers to a server at DMI has been provided. Support for resolvable persistent identifiers has been developed. This system allows users to access current information about every data file, using a link embedded in the file. The underlying system from handle.net, implemented with help from EUDAT, is designed to ensure robustness of the service and persistence of the information records. An ESGF node for CORDEX data has been tested and deployed in S. Africa: the first ESGF node in Africa.The installation process has been improved with an automated system and unit tests. Further details of IS-ENES2 contributions to the ESGF software stack are given in **D11.5**.

Task 2: Meta-data Services Package

As part of IS-ENES2 contribution to ES-DOC, a new documentation system has been configured and deployed for CMIP6 (**D11.4**) This includes tools for capturing and harvesting documentation of climate models and simulation. The simulation documentation will predominantly be compiled automatically on the basis of metadata that is present in published files. Crucially, data providers will be able to update the documentation if modifications are required, reducing the need to update data files for minor metadata adjustments. Files will contain a link to the meta-data records (the link is also constructed automatically from descriptive meta-data in the files). Climate model documentation will be gathered from modelling centres. The new documentation system includes improved support for

data citation. An extension for statistically downscaled data has been added.

Task 3: Data access services for climate impacts

The climate4impacts.eu portal has been enhanced with more processing services and an improved user interface (**D11.6**) after a review of main objectives and services (**MS11.8**). The processing services can be accessed through "wizards" guiding users through the construction of a processing request, or through the underlying Web Processing Services (for experts and remote systems). A number of processing functions sit behind the wizards, including the icclim package, discussed further below, which provides a comprehensive range of climate statistics. Extensions to downstream connectivity have been advanced by deploying a prototype workflow through which the processing service delegates processing to remote ESGF processing nodes. Upstream connectivity has been extended by implementing services through the CSAG Climate Information Platform (http://cip.csag.uct.ac.za/webclient2/app/). Content has been enhanced with new downscaled data products and new use cases based on previous work in Denmark.
In association with the work on new data products, the ICCLIM diagnostics package has been enhanced. It now implements the full range of statistics defined by the Expert Team on Climate Change Detection and Indices (ETCCDI - https://www.wcrp-climate.org/unifying-themes/unifying-themes-observations/data-etccdi), and has implemented features to improve memory and network efficiency.

Task 4: Federated archive system monitoring (FASM)

During the RP3, the software module for the federation of the statistics, the 'ESGF dashboard" (FASM-N component) has been completed A brand new dashboard GUI has been implemented (the FASM-D component). A new package, named dashboard REST API module has been implemented to programmatically provide access to the data usage metrics (esgf-stats-api).
The implementation of the data warehouse back-end with project specific metrics (inferred from the index node) regarding Obs4MIPS, CORDEX, and CMIP5 has been completed. The support for fine-grain metrics (by dataset, time frequency, variable, experiment, model, realm, institute) is available in the final release of the dashboard. A complete report about the activity performed in this task has been presented in **D11.3**.
The software modules (FASM-N and FASM-D) developed during the project have been tested on several sites (DKRZ, NASA/JPL, LLNL), finalised and delivered to the ESGF Release Team for their inclusion into the ESGF Release. CMCC setup and chaired the ESGF-Dashboard Working Team chaired to discuss (on a weekly basis) about the progress and planning of the activities regarding the data usage and monitoring system.

Significant results:

Task 1

- D11.5, Report on Core Data Services, Version 2, describes the major contribution made by IS-ENES2 to the global archiving system run by ESGF.
- Installation logs for ESGF nodes are available at https://github.com/snic-nsc/esgf-install-logs

Task 2

- Significant improvements on the definition of the new Metadata and DRS Standards for climate indices and indicators. Documents hosted on github: https://github.com/cerfacs-globc/impact-indicators
- D11.4 presents the new CMIP6 documentation, also available from http://es-doc.org/cmip6

Task 3

- D11.6, Report on Derived Data Products in climate4impact, describes significant

improvements in:

- The range of products provided – now the full set of indices defined by ETCCDI;
- The efficiency of the processing service through advanced caching;
- Documentation and layout of the portal.
- Substantial improvements on the user experience

- **MS11.8** « Review climate4impact services and objectives »

Task 4

- A new web interface has been developed, available at CMCC at http://esgf-ui.cmcc.it:8080/esgf-dashboard-ui.
- **D11.3** Report on Service Monitoring and Dashboard, finalised February, 2017.

Deviations from Annex I (DoW) : ***No deviations***

Reasons for failing to achieve critical objectives and/or not being on schedule
All critical objectives achieved

Use of resources:

CNRS-IPSL, 4 pm, served as ESGF Release manager, worked on introducing automated installation mechanism in the ESGF installer procedure; Developed a test suite for the ESGF installer software. CNRS-IPSL further developed the synda command line tool, which supports bulk movement (archive to archive/archive to user) of ESGF data (https://github.com/Prodiguer/synda/). CNRS-IPSL also implemented errata services for the ESGF hosted datasets and coordinated work presented in D11.4.

DKRZ, 6 pm, extended the data node service package with the possibility to publish and assign Persistent Identifiers (PIDs), contributed improved of version control to esgprep tool and supported FAQ pages update / move support pages to COG. DKRZ integrated processing services into the birdhouse WPS Processing system and integrated Quality Assurance tools into the WPS framework. DKRZ also adapted the DKRZ-QA tool for CMIP6. DKRZ worked on metadata collection and generation tools to support data citation and early data citation based on DOIs, especially to support CMIP6.

CERFACS, 2.1 pm, added more Processing Services to the climate4impacts.eu portal (C4I); developed ICCLIM (http://icclim.readthedocs.io/en/latest/) to support C4I Use Cases; Organized C4I Coding Sprint with KNMI.

CMCC, 5.64 pm, has developed the software packages for the monitoring of ESGF, the ESGF dashboard, including the user interfaces, usage statistics and visualisation. The number of person months is higher than initially planned because figures with a lower monthly rate have been employed.

UREAD-NCAS, 0.25 pm, has developed the tools for metadata capture from model documentation and documentation of simulations.

MetO, 0 pm claimed**.** Following release of the demonstration software for the metadata database-to-CIM generator in the previous period, the remaining activity in task 2 was the feedback of the lessons learned in the development of this software to the ES-DOC infrastructure activity. This has led to rationalisation of the metadata requirement information to be downloaded by modelling groups and to resolving a number of issues concerning the pyesdoc API with the ES-DOC development team.

STFC, 6.59 pm, developed services and infrastructure in readiness to manage CMIP6. STFC CEDA developed an automated workflow for data archival and publication (in link with MetO). STFC CEDA developed a test suite for the ESGF-Publisher software package, and extensions for the Data Reference Syntax (DRS) to manage datasets beyond the normal remit of ESGF. STFC CEDA developed and maintained the esgf-pyclient python client library for interfacing with ESGF search API (see: http://esgf-pyclient.readthedocs.io), integrated OAuth2.0 for user delegation in the ESGF software stack.

SMHI, 2.89 pm, prepared, produced, evaluated CORDEX downscaled products (A Bias-Correction Intercomparison Project, BCIP, contribution).

KNMI, 11.19 pm, further developed the climate4impact portal: documentation updates, addition of web processing services, improvement of search and download functions, prototyping web processing services calling the prototype ESGF computing node processing. Organised C4I coding sprint meetings with CERFACS. Dissemination of results and participation to the ESGF F2F meetings.

CSAG, 6 pm, has tested an ESGF node and prepared CORDEX-ESD experiment data (Task 1). CSAG continued the development of the statistical downscaling metadata standards for CORDEX-ESD (Task 2). CSAG implemented a prototype access to ESGF data (or C4I services) into the CSAG CIP platform to provide point based time series analysis in real time (Task 3).

INGHA, 8.98 pm, finalized the Lower Danube River Basin case studies: selection of representative climate simulations, assessment of potential climate change impact on the hydrological regime at local scale, for a selected medium size River Basin (using SAC-SMA conceptual hydrological model), and at regional scale using a robust hydrological events modelling approach (based on fuzzy logic system), contribution to D11.6.

LiU, 2.46 pm, worked on the new ESGF node manager, the automated deployment system for ESGF and has been the manager for the ESGF 2.2 and 2.4 releases.

UC, 3 pm, dissemination of the integration of the Downscaling Portal with the climate4impact platform. Participation in project meetings and telcos. Generation and publication for the CORDEX-Adjust data and metadata

DMI, 3.95 pm, assisted providers of CORDEX data to the DMI datanode with quality control; DMI has been inviting groups without their own datanode to use the server cordexesg.dmi.dk. DMI worked on implementing a real use case as an example in the climate4impact.eu help section, using specific index calculations, which were made for a county in Denmark, and which is now being emulated with the tools available in climate4impact.eu.

Corrective actions: None

Project Management Report

During the third reporting period, the Coordinator, with the assistance of the European Project Manager, ensured the management tasks such as the day to day management, the organization of meetings, the communication between the European Commission and the Beneficiaries, the management of the budget and the dissemination of the information related to the project.

The Coordinator, helped by the European Project Manager, also ensured the scientific coordination of the project as described in the Annex I of the Grant Agreement.

At last, the Management Team coordinated the reporting of the project from the beginning of February 2017 until the end of May 2017.

Overall Management and scientific coordination of the Project

The Final General Assembly:

The IS-ENES2 Final General Assembly (**MS1.5**) was hosted by CNRS-IPSL and held in Paris from the 16th to the 18th January 2017. It enabled to look back on what has been performed in the course of the project, to discuss the next steps and to prepare final reporting.

Most Beneficiaries were represented with 56 participants from 20 partners. Unfortunately CSAG, DLR and IC3 were unable to attend.

The main objective of this final GA was to obtain a clear view of project achievements in order to best prepare the final report. In that sense, a topical approach was decided and talks were results-focused instead of following traditional WP description. This required strong upfront preparation with different WP teams. Usual reporting work by WP was still prepared and circulated before the General Assembly.

The first day of the meeting gave an overview of IS-ENES2 activities through dedicated thematic sessions following the project main orientations, and divided into two main areas of expertise, models/HPC on the one hand and data/metadata on the other hand.

The next day was divided into a breakout group session in the morning, including topical discussions such as governance on software, and an afternoon session with all partners, dedicated to the preparation of the upcoming future. Presentations were made on IS-ENES2 related on-going projects such as CLIPC and ESIWACE and a discussion was held on the update of the ENES foresight.

The last day of the final GA set the focus on how to sustain activities after the end of IS-ENES2, through discussions related to ENES governance and the common banner between ENES and IS-ENES2.

Before the closure of the meeting, a debriefing of the breakout group sessions and a general discussion helped to better define the procedure and planning of IS-ENES2 final reporting.

Presentations given during the final General Assembly can be found at:

https://portal.enes.org/ISENES2/events/is-enes2-final-general-assembly

Management and scientific coordination of the Project:

The management and the scientific coordination of IS-ENES2 have been ensured by the Executive Board, composed by the work packages Leaders/Co-leaders and the Management Team.

The Coordinator, helped by the European Project Manager, has organised and chaired 5 teleconferences and one face-to-face meeting at the final General Assembly, gathering the Executive

Board. These teleconferences usually include a first part dedicated to the debriefing of work packages by the WPLs, followed by one or various sessions dealing with consortium management issues such as general information on the project, organisation of meetings, announcement of meetings of general interest for the project and the community, as well as on strategic issues such as the international governance of ESGF, the preparation of a long-term infrastructure for IS-ENES and the synergies between IS-ENES2 and the Centre of Excellence on HPC for Climate and Weather, ESiWACE.

The role of the Management Team was to disseminate information on the project, to be sure that Work Package Leaders respected the work plan and the timeline of IS-ENES2, and to propose corrective actions if necessary

Communication

Project Website (http://is.enes.org/):

The IS-ENES2 dedicated website (http://is.enes.org/) was set up by DKRZ (Beneficiary 2), and CNRS-IPSL (Beneficiary 1). It was launched in July 2014.The content management system used is Plone. It uses the same domain name as the first phase of IS-ENES, which archive has been added as a new folder.

The website presents the project, its aims and objectives and gives a short description of each work package. It also provides the list of beneficiaries with a short description. A section of the website is dedicated to the project management and provides some information on the organizational structure of the Consortium.

The IS-ENES2 website also provides access to resources such as the model and data services (link to the ENES portal, central point of entry to these services). Visitors can find news about the project and information about the IS-ENES2 meetings on the Event page, regularly updated.

The "documents" folder offers the possibility to visitors to download documents related to the project, such as deliverables and milestones that are also regularly uploaded. At last the folder "Internal" provides information about how to access the collaboration area.

Project Newsletter:

A newsletter has been elaborated by the European Project Manager, with contributions from the ENES Scientific Officer, and started in January 2015. When possible it was sent monthly. Due to technical problems it has stopped for a few months but launched again in July 2016 with longer coverage. It provides information on IS-ENES2 results as well as other issues related to climate modelling infrastructure. It was sent to 150 people.

Dissemination on work done within IS-ENES2 by the partners

During the third reporting period the Coordinator, work package Leaders and Partners have given talks, participated to poster sessions and have published papers related to work done within IS-ENES2. Please find below the list of dissemination material about the project for this period:

Publications

2016

Eyring, V., Gleckler P.J., Heinze C., Stouffer R. J., Taylor K. E., Balaji V., Guilyardi E., Joussaume S., Kindermann S., Lawrence B. N., Meehl G. A., Righi M., and Williams D. N, Towards improved and more routine Earth system model evaluation in CMIP, Earth System Dynamics, 7, 813–830, 2016, **doi:10.5194/esd-7-813-2016**

Williams D., Balaji V., Cinquini L., Denvil S., Duffy D., Evans B., Ferraro R., Hansen R.,

Lautenschlager M., Trenham C., A global repository for planet-sized experiments and observations, *Bull. Amer. Meteor. Soc.*, 803-816, May 2016, **DOI:10.1175/BAMS-D-15-00132.1**

Hewitt, H. T., M. J. Roberts, P. Hyder, S. E. Belcher, R. Bourdalie-Badie, D. Copsey, A. Coward, C. Guiavarch, C. Harris, R. Hill, J. Hirschi, G. Madec, M. Mizielinski, E. Neininger, A. New, J. Rae, J.-C. Rioual, B. Sinha, D. Storkey, A. Shelly, L. Thorpe, and R. A. Wood, The impact of resolving the Rossby radius at mid-latitudes in the ocean: results from a high-resolution version of the Met Office GC2 coupled model, *Geosci. Model Dev.*, 9, 3655-3670. 2016, **doi:10.5194/gmd-9-3655-2016**

Roberts, M. J., H. T. Hewitt, P. Hyder, D. Ferreira, S. A. Josey, M. Mizielinski, and A. Shelly, Impact of ocean resolution on coupled air-sea fluxes and large-scale climate, *Geophys. Res. Lett.*, 43, 2016, **doi:10.1002/2016GL070559**

Kern, B. and Jöckel, P.: A diagnostic interface for the ICOsahedral Non-hydrostatic (ICON) modelling framework based on the Modular Earth Submodel System (MESSy v2.50), *Geosci. Model Dev.*, 9, 3639-3654, 2016, **doi:10.5194/gmd-9-3639-2016**

Williams D., Lautenschlager M., Cinquini L., Denvil S., Juckes M., Ferraro R., Duffy D., DeLuca C., Balaji V., Evans B., Trenham C., ESGF Implementation Plan v1.0, PCMDI, Lawrence Livermore National laboratory, May 4, 2016

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Balaji, V., Maisonnave, E., Zadeh, N., Lawrence, B. N., Biercamp, J., Fladrich, U., Aloisio, G., Benson, R., Caubel, A., Durachta, J., Foujols, M.-A., Lister, G., Mocavero, S., Underwood, S., and Wright, G., CPMIP: measurements of real computational performance of Earth system models in CMIP6, *Geosci. Model Dev.*, 10, 19-34, 2017, **doi:10.5194/gmd-10-19-2017**

Webb et al., The Cloud Feedback Model Intercomparison Project (CFMIP) contribution to CMIP6, *Geosci. Model Dev.*, 10, 359-384, 2017, **DOI:10.5194/gmd-2016-70**

Heinze C., Eyring V., Friedlingstein P., Jones C., Balkanski Y., Collins W. J., Fichefet T., Gao S., Ivanova D., Knorr W., Knutti R., Loew A., Ponater M., Schultz M. G., Schulz M., Siebesma P., Teixeira J., Tselioudis G., and Vancoppenolle M., Climate feedbacks in the Earth system and their evaluation, ***Submitted*** *to Reviews of Geophysics* May 22 2017

Manubens-Gil D., J. Vegas-Regidor, C. Prodhomme, O. Mula-Valls and F. J. Doblas-Reyes, Seamless management of ensemble climate prediction experiments on HPC platforms, *HPCS 2016 Conference*, pp. 895-900, Innsbruck, Australia, 18-22 July 2016, **doi: 10.1109 / HPCSim.2016.7568429**

Orals, posters and flyers communications

Orals

Guglielmo F., et al., ENES the European Network for Earth System modeling and its infrastructure project IS-ENES, *EGU 2016*, Vienna, Austria, 17-22 April 2016

Valcke S., Code coupling for climate modeling, *CEMRACS 2016 Summer School*, Marseille, France, 18th July – 26th August 2016

Joussaume S., IS-ENES, *Seminar at PCMDI*, Livermore, USA, 30 August 2016

Valcke S., OASIS3-MCT, a coupling software for climate modeling, *International Fall School on Terrestrial Modeling and High-Performance Scientific Computing*, Bonn, Germany, 10-14 October 2016

Joussaume S., Linking climate modeling research infrastructure and climate services, *ClimatEurope Webinar*, 16 November 2016

Joussaume S., Guglielmo F., IS-ENES, *3rd ENVRI week session on linking research infrastructures with Copernicus*, Prague, Czech Republic, 16 November 2016

Guglielmo F., Joussaume S., IS-ENES, 3rd *ENVRI week PICO session on research infrastructures*, Prague, Czech Republic, 14-18 November 2016

Joussaume S., Data model intercomparison projects: the experience from climate experiments CMIP, *Belmont Forum workshop on e-infrastructure exemplars*, Paris, France, 28-29 November 2016

Denvil S., Earth System Grid Federation, *Belmont Forum workshop on e-infrastructure exemplars*, Paris, France, 28-29 November 2016

Joussaume S., European Network for Earth System modeling Data Infrastructure, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Rathmann T., ESGF support working team – Progress update & future roadmap, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Hollweg H-D., QA-DKRZ: the Annotation Model, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Ben Nasser A., Greenslade M., ES-DOC and ES-DOC Services, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Plieger M. et al, Recent Climate4impact Developments: Provenance in Processing and Connection to the CLIPC Portal, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

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Denvil S., Synda (synchro-data), *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Valcke, S., First results from the IS-ENES2 coupling technology benchmark, *Fourth Workshop on Coupling Technologies for Earth System Models*, Princeton, USA, 20-22 March 2017

Mocavero S., Towards KNL the NEMO ocean model case study, *KNL Workshop*, CINECA, Italy, 22-23 March 2017

Joussaume S., European Infrastructure for climate modeling, *First ClimatEurope Festival*, Valencia, Spain, 4-7 April 2017

Parinet M., Guglielmo F., Joussaume S., IS-ENES2 Project Management, Lessons Learned, *EGU 2017*, Vienna, Austria

Joussaume S., Guglielmo F., IS-ENES2, *ENVRIPlus Booth, EGU 2017*, Vienna, Austria, 23–28 April 2017

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Posters

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Plieger M. et al, The Climate4Impact Portal, *ESGF F2F meeting*, Washington DC, USA, 5-9 December 2016

Greenslade M. et al., ES-DOC and ES-DOC Services, *ESGF F2F meeting*, Washington DC, Washington DC, 5-9 December 2016

Plieger M., de Vreede E., ADAGUC open source visualization in climate4impact using OGC standards**,** *ESGF F2F meeting*, Washington DC, 5-9 December 2016

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Greenslade M., Documenting CMIP6 with ES-DOC, *EGU 2017*, Vienna, Austria, 23–28 April 2017, http://meetingorganizer.copernicus.org/EGU2017/EGU2017-14769.pdf

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Stockhause M. and Lautenschlager M., CMIP6 Citation Services and the Data Services of the IPCC Data Distribution Centre for AR6, *EGU 2017*, Vienna, Austria, 23–28 April 2017, http://meetingorganizer.copernicus.org/EGU2017/EGU2017-4325.pdf

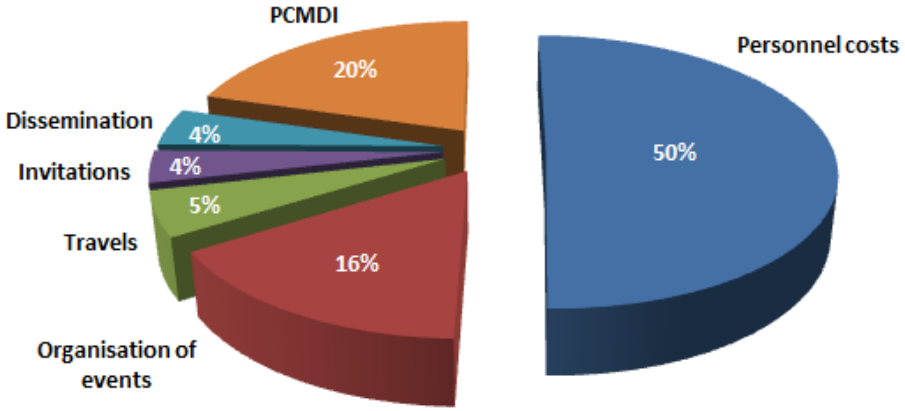
Parinet M., Guglielmo F., Joussaume S., IS-ENES project management, lessons learned, *EGU 2017*, Vienna, Austria, 23–28 April 2017

Flyers

Autosubmit: a versatile tool to manage weather and climate experiments in diverse supercomputing environments

IS-ENES2 flyer presenting the project

WP1 use of resources



Staff efforts:

CNRS-IPSL (Beneficiary 1) devoted 14.72 person months (PMs) for the management of the project. The Coordinator spent *2.72* PMs on the overall management and scientific coordination of the project for the final 12 months. The European project manager, paid by IS-ENES2, spent *12* PMs in order to assist the coordinator in their tasks.

Staff efforts amounting to 72 513.59€ represent *50*% of the total direct costs for the third period.

Organisation of events:

16% of the total direct costs amounting to 22 649.7€ were spent in order to organise events such as the IS-ENES2 Second and Final General Assemblies. Due to delays of reimbursement procedure, costs related to the organisation of IS-ENES2 Second General Assembly were affected to period 3, although the meeting took place within period 2, as planned in the DoW.

The Second GA cost was 8 740.75€ and the Final GA cost was 12 950.87€.

Support was also granted to the organisation of thematic workshops by partners such as the Workshop on ESM Valtool organised by our partner DLR in Munich, or two workshops related to NEMO.

Travels:

5% of the total direct costs amounting to7 629.2€ was devoted to travels essentially to attend IS-ENES2 meetings, but also to participate to external events to promote the project. In that framework, the European project manager presented IS-ENES2 as a case study to the 2016 European Geosciences Union General Assembly in Vienna in May 2017.

Invitations:

Invitations of expert scientists from the community amounts to 5 458.05€, representing *4*% of the total direct costs spent during the third period. We have invited expert scientists to the Second and Final General Assemblies and we supported the attendance of experts to thematic workshops such as the ESM Valtool workshop mentioned above.

Dissemination

In the second period, 6 299.14€ (4% of WP1 direct costs) were spent on dissemination activities. This includes supporting the mission of Christian Pagé (CERFACS) for his presentation on the climate4impact plateform to the American Society 96th Annual Meeting and the provision of IS-ENES2 notebooks, flyers, USB sticks and other communication material circulated during IS-ENES2 meetings.

Affiliated partners (USA)

A budget of 55 k€ was initially planned for collaboration with the USA.

During the third period:

- 10th April - 1st May 2016, 1515€ were spent to support the travel of Eric Guilyardi (CNRS-IPSL) to PCMDI to set the base of the ES-DOC model documentation process for CMIP6 with Karl Taylor and Paul Durack. This paved the way for the IS-ENES2 deliverable D11.4 on Formal CMIP6 documentation (WP11). However the related costs are not claimed to the project.
- 27th August-24th September 2016, 5 902.19€ were spent to support Sylvie Joussaume's (CNRS-IPSL) collaboration with NCAR and PCMDI. It allowed investigating the state of the art in climate modelling of the NCAR US community model, especially in terms of software and environment tools for CMIP6, as well as discussing ESGF plans and collaboration with PCMDI for CMIP6. This travel was in support of WP1 coordination and WP2 strategy issues.
- 12th September - 30th October 2016, 6 059.45€ were spent to support Jerome Servonnat's (CNRS-IPSL) collaboration with PCMDI on CMIP6 evaluation infrastructure related to the PCDMI metrics package. This travel was in support to WP2 task on evaluation infrastructure strategy.
- 5-7th December 2016, 2 373.25€ were spent to support Axel Lauer's (DLR) collaboration with PCMDI on infrastructure for model evaluation for CMIP6. This travel was in support to WP2 task on evaluation infrastructure strategy.
- 21st October -11th December 2016, 3 450.82€ were spent to support Alessandra Nuzzo's (CMCC) collaboration with PCMDI on the development of the dashboard. This travel was in support to WP11 task on ESGF monitoring.

List of Project Meetings

Date	Meeting	Venue
06-07/04/2016	4th ENES HPC Workshop	Toulouse, France
08-09/06/2016	IS-ENES2 ESGF-CMIP6 preparation and Data-TF meeting	Paris, France
09-21/06/2016	Third European Earth System and Climate Modeling School: 3rd E2SCMS	Helsinki, Finland
20-22/06/2016	IS-ENES2 climate4impact portal coding sprint	De Bilt, Netherlands
27-29/09/2016	Final workshop on meta-data generation during experiments	Lisbon, Portugal
27-29/09/2016	Final workshop on workflow solutions	Lisbon, Portugal
17/10/2016	2nd CLIPC/IS-ENES2 Workshop on Metadata/DRS for climate indices	Brussels, Belgium
24-25 /10/2016	Crossing the Chasm: Towards common Software Infrastructure for Earth System Model development	Reading, UK
25-27/10/2016	ENES community meeting on Earth System Modelling Infrastructure Strategy	Reading, UK
08-10/11/2016	ES-DOC coding sprint	Reading, UK
15-16/11/2016	2nd Technical ESMValTool Workshop	Munich, Germany
30/11/2016 to 12/01/2017	Workshop on innovation in HPC for climate models (several sessions)	Hamburg, Germany
16-18 /01/2017	IS-ENES2 Final General Assembly	Paris, France
19/01/2017	Workshop on NEMO in CMIP6	Grenoble, France
31/01/2017 to 02/02/2017	IS-ENES2 NEMO sea ice working group: designing a strategy for sea ice development in NEMO	Paris, France
27-28 /02/2017	Workshop on COSP Network Support and Optimisation	Paris, France
14-15/03/2017	3rd IS-ENES2 Workshop on Metadata for Climate Indices	De Bilt, Netherlands
20-22/03/2017	Fourth Workshop on Coupling Technologies for Earth System Models	Princeton, USA

Use of Staff Effort per Beneficiary during the third reporting period

In the column Description of Work (DoW) we highlighted in red the new number of PMs agreed after the two rounds of reallocations (see RP2 report).

WP	WP1			WP2			WP3			WP4			WP5			WP6			WP7			WP8			WP9			WP10			WP11			Total per Beneficiary		
	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3	DoW	RP1 + RP2	RP3
CNRS	54	36,2	14,7	29	23	13	12	2,19	7,78	4	4,4	0	3	4,8	0	5	2,13	2,58	0	0	0	0	0	0	19	16,1	1,63	11	10	0,5	27	14,7	4	164	114	44
DKRZ	0	0	0	12	8,2	3,3	9	3	1,22	7	7,4	1,03	12	5,1	3,11	4	1,4	2,4	0	0	0	0	0	0	12	5,3	2,38	18	10	7,71	23	20	6	97	60	27
CERFACS	0	0	0	2	2,5	0,6	0	0	0	13	11,9	0,7	18	19,3	1,9	2	1	0	4	2,9	0,1	0	0	0	25	21,7	3,6	9	4,7	3,1	24	18,9	2,1	97	83	12
CMCC	0	0	0	0	0	0	15	20,8	2,28	3	0	4,06	4	0,79	3,83	2	4,55	0	0	0	0	0	0	0	4	2,96	3,51	12	10,3	8,25	21	29	5,64	61	68	28
UREAD	0	0	0	8	6,2	2,21	12	5,8	5,82	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	16	7,1	4,02	0	0	0	21	8,8	10,3	59	28	22
MetO	0	0	0	2	0,7	0,4	12	9,6	3,3	12	7,2	1,1	0	0	0	0	0	0	0	0	0	0	0	0	13	14,5	0,3	11	8	1,2	6	4,3	0	56	44	6,3
STFC	0	0	0	0	0	0	4	2,79	2,35	0	0	0	23	5,67	20,5	2	0,4	0	0	0	0	0	0	0	0	0	0	5	1	3,71	18	21,6	6,59	52	31	33
SMHI	0	0	0	0	0	0	0	0	0	0	0	0	9	2,68	5,83	3	2,27	1,14	0	0	0	0	0	0	19	13,1	6,43	0	0	0	8	4,26	2,89	39	22	16
KNMI	0	0	0	2	0,3	0	0	0	0	0	0	0	8	4,38	1,28	0	0	0	0	0	0	0	0	0	5	2,3	0	0	0	0	20	16	11,2	35	23	12
MPG	0	0	0	3	0	3	14	4	10	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	3	3	0	0	0	0	34	21	13
CSAG	0	0	0	0	0	0	0	0	0	0	0	0	10	7,21	4,9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	6,52	6	21	14	11
UNIMAN	0	0	0	0	0	0	3	9	5	0	0	0	2	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4,5	6	0	0	0	12	15	11
INHGA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	13,8	8,98	15	14	9
WU	0	0	0	0	0	0	0	0	0	0	0	0	8	6,94	4,02	8	2,77	4,02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	9,7	8
LiU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4,79	1,99	7	7,31	2,46	13	12	4,5
BSC	0	0	0	0	0	0	12	10,5	1,71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2,92	1,9	0	0	0	0	0	0	16	13	3,6
UC	0	0	0	0	0	0	0	0	0	0	0	0	6	8,25	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	27,5	3	18	36	6
DLR	0	0	0	6	2,56	4,09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1,95	1,41	0	0	0	0	0	0	10	4,5	5,5
DMI	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4,78	3,95	9	6,8	4
IC3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	12,9	0	0	0	0	0	0	0	11	13	0
MF-CNRM	0	0	0	0	0	0	0	0	0	0	0	0	3	1,99	0,15	0	0	0	0	0	0	0	0	0	5	5,41	0	0	0	0	0	0	0	8	7,4	0,2
UiB	0	0	0	6	4	4,5	0	0	0	3	1,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5,6	4,5
met.no	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	6	2,8	9	0	0	0	0	0	0	6	2,8	9
TOTAL	54	36	15	70	47	31	93	68	39	48	38	6,9	108	71	49	28	15	10	4	2,9	0,1	0	0	0	151	117	34	82	56	32	220	197	73	858	649	291
REMAIN	3,06			-8,626			-14,12			2,65			-11,12			3,34			1			0			-0,28			-6,78			-50,498			-81,374		
% of Use	94%			112%			115%			94%			110%			88%			75%			n/a			100%			108%			123%			109%		

Analysis of overall budget

At the end of RP2, the General Assembly has agreed some internal reallocations. In the table below the new budget allocated at the end of RP2 is named "New budget after reallocations". The table also presents the total costs requested by each partner at the end of RP3 and summarizes the associated person-months.

Overall analysis:

Requested costs at the end of RP3 reach a total of 7 946 898,28 € versus an EC allocation of 7 999 941,63 €. The difference is less than 1% of the total budget.
In person-months, the total reaches 939 PMs to be compared to 858 initially planned, i.e. +9%. As described below, this is mainly due to some lower personnel costs than initially estimated, but remains quite close to the initial value.
The justified costs and PMs per partner show however some deviations.

Deviations in terms of budget

Most differences (18/23) are within ± 15% (over / under) of the new budget after RP2.

Those are mainly due to:

- Higher personnel costs (CNRS, DKRZ, CERFACS), leading to a slight overspending
- Lower personnel costs, in particular associated with more junior staff (STFC, INHGA, UNIMAN), associated generally with more time spent by younger researchers
- Over spending in travels, in particular associated with the international dimension of the activity on ESGF and ESDOC (e.g. CNRS in WP11, SMHI)
- Under spending in travel and/or workshops: e.g. MetO organised virtually the second planned workshop on configuration management, in order to get a wider overview for the best practice guide, MPG managed to spend a bit less for the two training schools than planned, WU organised master classes at a lower cost, CSAG from South Africa could join meetings as much as expected, DLR could not participate to some of the general assemblies, UiB also had less travel than expected for the evaluation strategy.
- Under spending in personnel cost: KNMI both used less NA pms due to staff change and shifted PMs from NA to JRA with more technical focus and reduced costs.
- Difficulties with service justifications: DMI has delivered a service on data but encountered difficulties to justify all costs.
- No deviation (CMCC, BSC), even if in the case of CMCC personnel costs were lower, compensated by higher PMs.

Deviations over 15%:

- **LiU** has delivered a service on data but encountered difficulties to justify all costs, leaving an under spending of -20%. Besides, JRA budget was spent as planned although lower personnel costs related to research activities were compensated by a higher number of pms.
- **UREAD** has under spent their allocation by - 26%: this is due to both lower personnel costs in NAs but also less PMs in WP9/JRA1. This latter is a deviation, which is explained in JRA1 RP3 report. Due to lack of PRACE resources, it has indeed been decided lately to develop a demonstrator. This did not allow UREAD to participate due to an overlap with the PRIMAVERA project started after the launch of IS-ENES2.
- **MF-CNRM,** has over spent their allocation by +29%, due to higher personnel costs associated with permanent staff. MF-CNRM has however, the second lowest allocation.

- **UC** has over spent their allocation by +49%. As planned at the RP2 General Assembly, UC has been charged to develop an ESGF datanode for empirical statistical downscaling data. This requested an important amount of work in particular with regards to setting data and metadata standards. UC has been allocated extra PMs and budget at the end of RP2 but costs were still underestimated. This is justified by the amount of work.
- **Met.no** has over spent their allocation by +27%. As described in WP9/JRA1, they encountered some difficulties in setting a high-resolution version of their climate model, which requested more manpower.

It is noteworthy, however, that these differences in budget have not affected the achievement of IS-ENES2 main objectives as described in RP3 and previous periodic reports. The RP2 reallocation has even permitted more work to be done, for example on CORDEX statistical downscaling data (WP11/JRA3), on testing a new approach for the NEMO code (WP3/NA2). More work could also be done on preparing for CMIP6, which could not yet be planned when IS-ENES2 was proposed.

The total justified costs exhibit some differences compared to the new budget allocated after RP2. But since differences remain minor or reasonably well justified and since the total budget requested is lower than the maximum EC contribution, the General Assembly, contacted by email, has accepted these changes compared to initial estimates.

	Costs					PMs			
	Initial budget	New budget after reallocations	Total Budget requested	New budget minus Requested	Requested / New budget	Planned in Dow	New allocation agreed by GA	Total used	Used / New allocation
CNRS-IPSL	1 640 452,53	1 637 156,53	1 709 155,04	-71 998,51	104%	158	164	157,86	96%
DKRZ	1 172 847,31	1 122 987,32	1 172 778,10	-49 790,78	104%	106	97	87,55	90%
CERFACS	509 332,60	537 043,60	564 852,61	-27 809,01	105%	97	97	95	98%
CMCC	521 395,00	531 025,00	530 298,61	726,39	100%	60	61	95,99	157%
UREAD	621 330,57	557 130,57	410 716,82	146 413,75	74%	59	59	50,2	85%
MetO	332 023,12	332 023,12	313 961,45	18 061,67	95%	56	56	50,6	90%
STFC	716 323,86	724 513,75	736 215,87	-11 702,23	102%	51	52	64,58	124%
SMHI	368 747,00	368 747,00	374 590,72	-5 843,72	102%	39	39	38,62	99%
KNMI	369 944,23	369 944,23	348 511,73	21 432,50	94%	35	35	35,434	101%
MPG	345 869,50	410 069,50	391 867,20	18 202,30	96%	34	34	34	100%
CSAG	148 914,00	117 134,00	101 884,30	15 249,70	87%	29	21	24,63	117%
UNIMAN	108 385,36	110 590,36	109 835,76	754,60	99%	12	12	26	217%
INHGA	44 843,70	44 843,70	40 838,31	4 004,95	91%	15	15	22,79	152%
WU	173 973,44	173 973,44	149 824,87	24 148,57	86%	16	16	17,75	111%
LiU	207 646,29	207 646,29	166 977,50	40 668,79	80%	13	13	16,55	127%
BSC	77 967,00	77 967,00	78 226,63	-259,63	100%	16	16	17	106%
UC	81 200,00	118 400,00	176 942,94	-58 542,94	149%	12	18	41,75	232%
DLR	82 808,16	82 808,16	77 874,73	4 933,43	94%	10	10	10,01	100%
DMI	160 039,17	160 039,17	155 722,87	4 316,30	97%	9	9	10,73	119%
IC3	57 420,00	57 420,00	56 942,44	477,56	99%	11	11	12,92	117%
MF-CNRM	53 351,79	53 351,79	68 834,73	-15 482,94	129%	8	8	7,55	94%
UiB	122 729,00	122 729,00	105 702,23	17 026,77	86%	9	9	10,06	112%
Met.no	82 398,00	82 398,00	104 342,83	-21 944,83	127%	6	6	11,8	197%
Total	**7 999 941,63**	**7 999 941,53**	**7 946 898,28**	**53 042,70**	**99%**	861	858	939,37	109%

Cooperation with other projects/programmes

European Projects

ClimatEurope is a coordination action gathering Earth system modelling and climate services in Europe, including aspects related with infrastructures. CNRS-IPSL represents IS-ENES2 in the consortium. http://www.climateurope.eu/

CLIPC: Climate Information portal for Copernicus is an FP7 precursor project for Copernicus. CLIPC has integrated data from IS_ENES2 to observation and results from impact studies. CLIPC has also used the technology developed for the climate4impact portal to develop its own data portal. http://www.clipc.eu/

COST VALUE: VALUE is n European COST Action on "Validating and Integrating Downscaling Methods for Climate Change Research ». Collaboration has been established with IS-ENES2 on metadata standards and the publication of data on ESGF. http://www.value-cost.eu/

CP4CDS and CORDEX4CDS: are two Copernicus C3S projects preparing ESGF datanodes for global and regional projections respectively. It is based on IS-ENES2 expertise

ENVRIPlus: ENVRIPlus is a Horizon 2020 project bringing together Environmental and Earth System Research Infrastructures, projects and networks together with technical specialist partners to create a more coherent, interdisciplinary and interoperable cluster of Environmental Research Infrastructures across Europe. IS-ENES2 is represented in ENVRIPlus by CNRS-IPSL and DKRZ and collaborates on data/metadata aspects and on strategy.

ESIWACE: is a H2020 Centre of Excellence in Simulation for Weather and Climate. IS-ENES2 has paved the way to this project, which aims at preparing climate models for future exascale computers. https://www.esiwace.eu/

EUDAT: ENES community is represented in EUDAT through IS-ENES2 partners (DKRZ, MPG and CERFACS). A strong link is established with issues such as metadata and data citation. IS-ENES2 has continued collaboration with EUDAT2020 including STFC in the collaboration. DKRZ represents the ENES community within the EUDAT consortium agreement.

INDIGO data-cloud (https://www.indigo-datacloud.eu/) is a H2020 project which aims at developing a data and computing platform targeting scientific communities. CMCC develops an applications for Earth System modelling based on ESGF, in strong link with IS-ENES2. See for example :
Fiore S., Large-Scale Data Analytics Workflow Support for Climate Change Experiments, ESGF F2F meeting, Washington DC, USA, 5-9 December 2016
https://esgf.llnl.gov/media/2016-F2F/7-12-2016/community_software/F2F-2016-INDIGO.pdf

PRIMAVERA: is a H2020 project on high-resolution climate modelling in Europe. IS-ENES2 has supported preparation of high-end experiments on PRACE. https://www.primavera-h2020.eu/

SPECS: IS-ENES2 has collaborated with the FP7 SPECS project on seasonal to decadal climate predictions for climate services. Indeed, SPECS provides its model results on ESGF. SPECS benefits from IS-ENES2 experience to install data nodes on ESGF through STFC, from provider support and access to software tools. http://www.specs-fp7.eu

SWICCA: "Service for water indicators in climate change adaptation", is a Copernicus Climate Change Service Project run by SMHI to provide data for climate impact assessments. http://swicca.climate.copernicus.eu. IS-ENES2 has provided master classes for SWICCA.

International programmes

WCRP: IS-ENES2 is strongly linked to WCRP activity in climate modelling. It supports the European contribution to the data infrastructure ESGF for international global and regional climate model experiments. A MoU is under preparation to recognise the role of IS-ENES2 in the implementation of CORDEX results on ESGF. Several partners of IS-ENES2 participate to the newly established Infrastructure Panel (WIP).

ESGF: Earth System Grid Federation is the international database for climate model results. Thanks to IS-ENES and IS-ENES2, European partners have acquired a strong role in ESGF software maintenance and development and are responsible for some activities. International governance is under discussion with DoE.

ES-DOC: Earth System Documentation is an international collaboration led by US on metadata standard for climate models. IS-ENES2 partners play a key role in the development of metadata software and standard. .

RDA: ENES is represented in the international Research Data Alliance by Michael Lautenschlager. This allows linking our activities with RDA.

Annex: Acronyms

CDO: Climate Data Operators (http://www.mpimet.mpg.de/cdo) - collection of about 100 functions developed by the MPG for handling and analyzing data produced by a variety of climate and NWP models - e.g. for file operations, simple statistics, or the calculation of climate indices. The code is used by around 150 groups (220 users) world-wide, including some of the project partners, calling the CDO around 200000 times per day.

CF: Climate and Forecast Metadata Convention (http://cf-pcmdi.llnl.gov/) - International standard for model data files format.

CIM: Common Information Model - The FP7 METAFOR project has developed this standard.

CLIMATE4IMPACT: ENES Portal for Climate Impact Communities (http://climate4impact.eu) developed within IS-ENES and IS-ENES2 to ease access to model data for the climate impact research communities

CMIP5/6: Coupled Model Intercomparison Project Phase 5/6, under the auspices of WCRP to prepare IPCC AR5/6 **(**http://cmip-pcmdi.llnl.gov/cmip5/**)**

COPERNICUS C3S: European initiative for the implementation of information services dealing with environment and security (previous Global Monitoring for Environment and Security) (http://www.copernicus.eu). C3S is the Copernicus Climate Change Service.

CORDEX: "Coordinated Regional downscaling Experiments" under WCRP auspices (http://wcrp.ipsl.jussieu.fr/SF_RCD_CORDEX.html).

CORDEX-ESD: stands for the regional data obtained from Experimental Statistical Downscaling http://www.cordex.org/index.php?option=com_content&view=article&id=222&Itemid=714

COSP: Cloud Observing System Package (http://cfmip.metoffice.com/COSP.html) has been developed to simulate cloud satellite observed parameters from climate model data in order to allow a more direct comparison with satellite data. It is available from MetO.

EEA: European Environment Agency (http://www.eea.europa.eu)

ENES: European Network for Earth System Modelling (http://www.enes.org) - A consortium of European institutions aiming at helping the development of use of ESMs for climate and Earth System studies.

EPM: IS-ENES European Project Manager

ES-DOC: Earth System Documentation (http://es-doc.org) is an international collaboration led by US on metadata standard for climate models.

ESGF: Earth System Grid Federation (http://www.earthsystemgrid.org/) is an international collaboration with a current focus on serving the WCRP CMIP project and supporting climate and environmental science in general. The ESGF grew out of the larger GO-ESSP community.

ESM(s): Earth System Model(s). These models are developed to simulate the climate system in its full complexity, i.e. atmosphere, ocean and land which are the basic components included in climate models together with biogeochemical cycles, i.e., carbon cycle, vegetation, aerosol and chemistry processes.

ESMF: Earth System Modelling Framework (http://www.esmf.ucar.edu/)- Devoted to define standards in the designing of climate model components for easier exchange and coupling, US-led

EUDAT: FP7 project "European Data Infrastructure" (http://www.eudat.eu/) launched on Oct 1rst 2011, aims at providing a pan-European solution to the challenge of data proliferation in Europe's scientific and research communities. MPG and Cerfacs represent ENES in this consortium

Exascale: for exascale computing, refers to computing power corresponding to 10^{18} operations per second. It is thousand times more powerful than present top computing facilities. It is expected to be available around 2018.

HPC: High Performance Computing

I/O: Input/Output is the generic process of exchanging data during a simulation, either as input to the model or as output of model simulations

ICON: is a new dynamical core project run by MPG and Deutscher Wetter Dienst based on icosaedral grids for atmosphere and ocean global models **(**http://icon.enes.org/**)**

ICT: Information & Communication Technology

IPCC: Intergovernmental Panel on Climate Change (http://www.ipcc.ch) - Provides regular scientific assessments reports (AR) on climate change issue under the auspices of UNEP and ICSU. The last one is the AR4 produced in 2007; the next one is AR5 to be issued in 2013

IS-ENES (or IS-ENES1): Infra**S**tructure for the **E**uropean **N**etwork for **E**arth **S**ystem Modelling, first phase**; FP7 project (**http://is.enes.org **)**

LIM: Louvain-la-Neuve sea ice model **(**http://www.astr.ucl.ac.be/index.php?page=LIM Description**)** – A Sea Ice Model

METAFOR: Common Metadata for Climate Modelling Digital repositories (http://ncas-cms.nerc.ac.uk/METAFOR/) - FP7 infrastructure project under ENES, which focuses on developing common standards for data and model information exchange that will be implemented in IS-ENES.

NCAR: National Center for Atmospheric Research in Boulder, USA (http://www.ncar.ucar.edu/)

NEMO: Nucleus for European Modelling of the Ocean (http://www.locean-ipsl.upmc.fr/NEMO/) - State-of-the-art modelling framework including 3 components: an ocean general circulation model (OPA), a sea-ice model (LIM) and a biogeochemistry model (TOP); NEMO is interfaced with all European atmospheric models via the OASIS coupler.

netCDF: network Common Data Form (http://www.unidata.ucar.edu/software/netcdf/) - A set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data

NOAA: National Oceanographic and Atmospheric Organisation, USA (http://www.noaa.gov/)

OASIS: Ocean Atmosphere Sea Ice and Soil coupler (http://www.cerfacs.fr/globc/software/oasis/) – A software component allowing synchronized exchanges of coupling information between numerical codes representing different components of the climate system.

Obs4MIP: Observations for Model Intercomparisons Project is an activity to make observational products more accessible on ESGF for climate model intercomparisons (https://www.earthsystemcog.org/projects/obs4mips/).

PCMDI: Program for Climate Model diagnosis and Intercomparison, (http://www-pcmdi.llnl.gov/) at Lawrence Livermore National Laboratory (USA) has the responsibility for supporting modelling studies CMIP5.

PRACE: Partnership for Advanced Computing in Europe (http://www.prace-project.eu/) - An FP7 infrastructure project devoted to prepare the implementation of world-class high-performance computers in Europe.

SPECS: new Environment FP7 project "**S**easonal-to-decadal climate **P**rediction for the improvement of **E**uropean **C**limate **S**ervices » (2012-2016)

WCRP: World Climate Research Programme (http://www.wmo.ch/pages/prog/wcrp)

WIP: WGCM Infrastructure Panel (https://www.earthsystemcog.org/projects/wip/)

WGCM: Working Group on Coupled Models (http://www.clivar.org/organization/ wgcm/wgcm.php) - Under WCRP defines the international strategy for climate model evaluation and simulations for IPCC reports

XML: Extensible Markup Language