Name	Affiliation	Title, Authors, Abstract
Sophie Valcke	Cerfacs	Title: Latest developments of the OASIS3-MCT coupler for improved performance Authors: S. Valcke, L. Coquart, A. Craig, G. Jonville, E. Maisonnave, A. Piacentini Abstract: We will present the developments done in the OASIS3-MCT coupler during the last 24 months to improve its parallel efficiency. The most important improvements concern the communication scheme, which now uses the mapping weights to define the intermediate mapping decomposition and the hybrid OpenMP/MPI parallelisation introduced in the SCRIP library for the mapping weight calculation. Efforts were also spent to improve the initialisation with the update of the MCT library from version 2.8 to 2.10.beta1 and to introduce new options introduced in the global CONSERV operation. Finally, additional results obtained with IS-ENES2 coupling technology benchmark, either testing new options or running on Marconi KNL, will be shown.
Rocky Dunlap	NCAR	Title: Update on the Earth System Modeling Framework Authors: Abstract: This talk will give an update on the Earth System Modeling Framework (ESMF) since the last coupling workshop including major new features and developments in the 7.1 and 8.0 releases. In addition, I will present modeling applications using ESMF and the National Unified Operational Prediction Capability (NUOPC) interoperability layer, discuss successes and challenges with integration of the coupling technology into applications, and discuss connections between ESMF, workflows, and data assimilation systems.
Li Liu	Tsinghua University	Title: C-Coupler2: a flexible and user-friendly community coupler for model coupling and nesting Authors: Li Liu, Cheng Zhang, Ruizhe Li, Bin Wang, Guangwen Yang, Chao Sun, Xinzhu Yu, Hao Yu Abstract. The Chinese C-Coupler (Community Coupler) family aims primarily to develop coupled models for weather forecasting and climate simulation and prediction. It is targeted to serve various coupled models with flexibility, user-friendliness, and extensive coupling functions. C-Coupler2, the latest version, includes a series of new features in addition to those of C-Coupler1, including a common, flexible, and user-friendly coupling configuration interface that combines a set of application programming interfaces and a set of XML formatted configuration files, capability of coupling within one executable or the same subset of MPI (Message Passing Interface) processes, flexible and automatic coupling procedure generation for any subset of component models, dynamic 3-D coupling that enables convenient coupling of fields on 3-D grids with time-evolving vertical coordinate values, non-blocking data transfer, facilitation for model nesting, facilitation for increment coupling, adaptive restart capability and debugging capability. C-Coupler2 is publicly available (https://github.com/C-Coupler-Group/c-coupler-lib) and is ready for use to develop various coupled or nested models. It has passed a number of test cases involving model coupling and nesting, and with various MPI process layouts between component models, and has already been used in several real coupled models.
Moritz Hanke	German Climate Computing Center (Deutsches Klimarechenzentrum, DKRZ)	Title: Update on YAC and an introduction to ICON-ESM Authors: Moritz Hanke and René Redler Abstract: YAC (Yet Another Coupler) was first presented at the CW2013. Since then it has evolved into a fully functional coupling solution, which is actively being used. This presentation will give an update on the development in YAC to the last presentation. It will include some details on algorithmic and implementation details, which might distinguish it from other coupling software. Additionally, an overview on the interpolation methods implemented in YAC and the concept of the interpolation stack will be given. Being the main user of YAC, the presentation will include a short introduction to the ICON-ESM (ICON Earth system model).

Vijay Mahadevan	Argonne National Laboratory	Title: Couplers for E3SM: Comparisons between a fully online vs an offline-online remapping workflow Authors: Vijay S. Mahadevan, Iulian Grindeanu, Jason Sarich, Robert Jacob Abstract: Traditional coupled physics infrastructures for Climate models involve several steps in the simulation workflow to enable seamless transfer of information between components. The Model Coupling Toolkit (MCT) is one such software library that is used extensively in CIME and OASIS3-based climate models. Since MCT only handles the parallel data migration, and does not store any detailed information about the underlying component meshes, the remapping weights to transfer data is computed using an offline pre-processing step using tools such as ESMF-Regridder, SCRIP or TempestRemap. In this talk, we present details about our ongoing work to integrate the MOAB mesh database within CIME as used in E3SM, through interfaces to TempestRemap, in order to both compute the remapping weights during the actual simulation and to enable scalable data transfer between component pairs, with zero offline requirements. Such a modified workflow maximizes computational efficiency and increases scientific research productivity, without sacrificing discretization accuracy of field data being transferred. The MOAB library will interface to the HOMME SE atmosphere, MPAS FV ocean and FD land/river component models within E3SM and replace MCT's abstraction of field data transformation and migration between processes. We present some strong scaling results of this new MOAB-based coupler for some key cases, and provide a comparative analysis against the existing MCT-based coupler for remap operator application, and communication costs. Discussions on the ease of extending the MOAB coupler in the future to support a fully-distributed coupling strategy in order to minimize data replication that is inherent in a hub-spoke coupling model will also be presented.
Robert Oehmke	National Center for Atmospheric Research	Title: Earth System Modeling Framework Regridding Update Authors: Robert Oehmke, Ryan O'Kuinghttons, Peggy Li, Ben Koziol, and Gerhard Theurich Abstract: The Earth System Modeling Framework's parallel regridding capability is a versatile, mature, widely used, and scalable grid remapping tool based on an internal 3D finite element mesh engine. The ESMF regridding capability continues to be improved to address new scientific and computational requirements. In this talk I will first give a brief overview of the ESMF regridding system and its three primary interfaces: Fortran, Python, and command line applications. I will then report on new additions to the regridding system including extrapolation. I will also describe the status of the integration of the Mesh-Oriented datABase (MOAB) library into ESMF with the expected benefits of reducing maintenance costs and bringing in new functionality. Finally, I will describe additional regridding features expected to be included in the next ESMF release (8.1.0).
Nadine Wieters	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Title: esm-interface Authors: Nadine Wieters, Dirk Barbi Abstract: Within the Advanced Earth System Modelling Capacity (ESM) project, a goal is to develop a modular framework that allows for a flexible Earth System Model (ESM) configuration. One approach is to implement purpose build couplers in a more modular way. For this purpose, we developed the esm-interface library, in consideration of the following objectives: (i) To obtain a more modular ESM, that allows model components and model couplers to be exchangeable; and (ii) to account for a more flexible coupling configuration of an ESM setup. As a first application of the esm-interface library, we implemented it into the AWI Climate Model (AWI-CM) as an interface between the model components and the coupler. We will present the general idea of the esm-interface and it's implementation.
Inti Pelupessy	Netherlands eScience Center	Title: The Oceanographic Multipurpose Software Environment: introduction and applications. Authors: Inti Pelupessy(1), Ben van Werkhoven(1), Gijs van den Oord(1), Fredrik Jansson(2), Henk Dijkstra(3), Simon Portegies Zwart(4) 1) Netherlands eScience Center, 2) CWI, 3) IMAU, 4) Leiden Observatory Abstract: The Oceanographic Multipurpose Software Environment (OMUSE) is an open source framework for Oceanographic and other Earth system modelling applications developed in a collaboration between the Netherlands eScience Center and the IMAU (Utrecht) using coupling technology developed at Leiden Observatory (Leiden). OMUSE aims to provide a homogeneous environment for numerical simulation codes such that numerical experiments that combine different existing models representing different physics or spanning different physical scales can be easily designed. We will give a short introduction to the design of OMUSE. OMUSE is currently used, amongst others, in a project to to couple Large Eddy Simulation models with a global atmospheric circulation code and in a project that couples an eddy resolving ocean model with a fully implicit solver. We will present these applications in some detail and discuss the current development of OMUSE.

Thomas Reerink	Research Software Engineer at KNMI supporting the EC-Earth consortium	Title: Fast GCM - ice sheet model coupling software OBLIMAP 2.0, including on-line embeddable mapping routines. Authors: Thomas Reerink, Willem Jan van de Berg, Roderik van de Wal Abstract: We present the OBLIMAP package, which is able to map climate fields between a general circulation model (GCM) and an ice sheet model (ISM) in both directions by using optimal aligned oblique projections in order to minimize distortions. The curvature of the surfaces of the GCM and ISM grid differs, both grids may be irregularly spaced and the ratio of the grids is allowed to differ largely. OBLIMAP's stand-alone version is able to map data sets that differ in various aspects on the same ISM grid. Each grid may coincide either with the surface of a sphere, an ellipsoid or a flat plane, while the grid types might differ. Reprojection of, for example, ISM data sets is also facilitated. This is demonstrated by relevant applications concerning the major ice caps. As the stand-alone version applies also to the reverse mapping direction, it can be used as an off-line coupler. Besides, OBLIMAP 2.0 is an embeddable GCM–ISM coupler, suited for high-frequency on-line coupled experiments. OBLIMAP 2.0 contains a new fast scan method for structured grids as an alternative to the previous time-consuming grid search strategy, realizing a performance gain of several orders of magnitude and enabling the mapping of high-resolution data sets with a much larger number of grid nodes. Further, a highly flexible masked mapping option has been added to OBLIMAP 2.0. The limitations of the fast scan method with respect to unstructured and adaptive grids is discussed, together with a possible future parallel MPI implementation.
Uwe Fladrich	SMHI	Title: EC-Earth 4: Flexible coupling ESM components for practical use Authors: Uwe Fladrich (SMHI) & Jan Streffing (AWI) Abstract: During the development of the next generation EC-Earth model, flexible coupling of components and configuration management have been focal points. Due to the varying ESM configurations and versatile computational platforms, automatic generation of suited coupling information for OASIS and corresponding run-time scripts is crucial. Furthermore, modularisation of a thin application coupling layer (the Fortran CPLNG interface) has opened the opportunity to upstream-integration of CPLNG into OpenIFS, opening for a wider use of OASIS3-MCT in ESMs that use OpenIFS as the atmosphere component. An overview of the coupling architecture of EC-Earth 4 is presented as well as results of first practical tests.
Joakim Kjellsson	GEOMAR	Title: A mesoscale-resolving coupled climate model using OpenIFS and NEMO with grid refinement in the North Atlantic Authors: Joakim Kjellsson, Eric Maisonnave, Wonsun Park, Sebastian Wahl, Torge Martin Abstract: We present and discuss the technical and scientific results from using a coupled climate model with the AGRIF grid refinement tool. The model comprises OpenIFS global atmosphere at 25 km resolution, NEMO global ocean at 50 km resolution with AGRIF grid refinement to 10 km. The AGRIF grid covers the North Atlantic including the subpolar seas and some of the Mediterranean. Coupling between OpenIFS and NEMO + AGRIF is done via the OASIS3-MCT4.0 coupler. The increased horizontal resolution over the North Atlantic allows to fully resolve mesoscale ocean eddies in e.g. the Gulf Stream, which has clear impacts on the air-sea fluxes over the region. Model simulations with AGRIF grid refinement show reduced SST biases over the North Atlantic compared to simulations without any AGRIF grid refinement. Coupling OpenIFS directly to AGRIF also increases the variance in surface heat fluxes due to the sharper gradients in SST and sea-ice fraction. We also present ongoing modelling studies of climate variability and climate extremes with this high-resolution coupled model.
Tobias Bauer	Leibniz Institute for Tropospheric Research	Title: The two-way online-coupled model ICONGETM: Regridding strategy and capabilities provided by the X-Grid structure from ESMF Authors: Tobias Bauer, Knut Klingbeil, Peter Holtermann, Bernd Heinold, Hagen Radtke, Oswald Knoth Abstract: To understand the processes of local phenomena over the Baltic Sea such as Coastal Upwelling or Salinity Inversion, we are coupling an atmosphere and ocean model with the Earth System Modelling Framework (ESMF). For the atmospheric part the operational model of the German Weather Service (ICON) is utilized in a nested limited area mode. The General Estuarine Transport Model (GETM) has been chosen for the local ocean model. Within our framework, the flux data such as momentum, heat and radiation fluxes are interpolated from the unstructured triangular grid of ICON to the structured rectangular latitude longitude grid of GETM and vice versa. The interpolation routines as well as the X-Grid structure provided by ESMF are applied for the two-way coupling. The NUOPC Layer is used to control the work flow of the coupled model. This presentation will give an overview about the issues and their solutions of coupling an unstructured and a structured grid using the X-Grid. Furthermore, the details of the first model study of Coastal Upwelling events in the Baltic Sea are discussed.

Neil Barton	US Naval Research Laboratory	Title: Coupling in the Navy Earth System Prediction Capability (Navy-ESPC) global coupled model Authors: Neil Barton Abstract: The Navy Earth System Prediction Capability (Navy-ESPC) model is a global coupled atmosphere-ocean-sea ice prediction system that utilizes mature operational Navy models: Navy's Global Environmental Model (NAVGEM), Navy's HYbrid Coordinate Ocean Model (HYCOM), and the Los Alamos National Laboratory's sea ice (CICE) model for the atmosphere, ocean, and sea ice respectively. The goals of coupled model are to improve of short-term and long-term predictions, as well as an enhanced understanding of environmental interactions. In this talk, I will discuss the coupling in Navy-ESPC, and I will focus on the technical aspects. A particular unique aspect of Navy-ESPC is that the ocean model is at a much high resolution than the atmosphere model, and that the coastlines have slightly different definitions between these components. This creates difficulties during the interpolation of variables between the systems. A creep-fill algorithm has been developed for our unique interpolation, and parts of this routine have been recently implement into version 8 of Earth System Modeling Framework (ESMF).
Yun (Helen) He	Lawrence Berkeley National Laboratory	Title: Process and Thread Affinity with MPI/OpenMP The correct process and thread affinity for hybrid MPI/OpenMP programs is the basis for getting better performance. It is also essential for guiding further performance optimizations. Using common processors as examples for illustration, this talk will show the concept of NUMA, some tools to examine compute nodes architectures, and how optimal affinity is achieved and verified with OpenMP standard settings. Practical examples of essential MPI/OpenMP runtime settings when integrating with different compilers, MPI libraries, and batch schedulers are discussed.
Austin Ellis	Sandia National Lab	Title: Task Placement for E3SM to Reduce Communication on Current HPC Platforms Authors: J. Austin Ellis and Karen Devine Abstract: The aim of task placement is to reduce parallel applications' communication time by mapping MPI tasks to processing elements "nearby" in the network. E3SM's highly coupled climate simulation contains 7 component applications each with different communication patterns and intensities, and E3SM throughput is often communication bound. We propose a task placement algorithm that captures an MPI profile for a short duration then optimizes the task placement given an HPC network layout and allocation. This avoids extracting communication patterns directly from the component codes and coupler. We present new capabilities and algorithms developed inside the Zoltan2 package of the Trilinos Project that target both Dragonfly and Fat-tree networks. Performance tests are completed on the Theta machine at Argonne National Laboratory and Summit at Oak Ridge National Laboratory, which are Dragonfly and Fat-tree networks, respectively.
Guillaume Mercier	Bordeaux INP/ Inria	Title: HW topology management in Message-Passing based parallel applications. Authors: Guillaume Mercier Abstract: The Message Passing Interface is a more than 25 years standard that have proven to be a great success in parallel programming as it is massively used to code scientific applications. However, the advent of manycore/multicore processors in the landscape of parallel architectures has changed the state of things quite a bit and their hardware specifics have to be taken into account if one wants to exploit their full potential. In particular, this had lead to the rise of hybrid MPI + threads (e.g.,through OpenMP) applications. However, this calls for tailored pieces of software (e.g., hwloc) of for mechanisms directly available in the programming standards themselves. The main drawback of this approach is that such specialized software elements are more targeted at runtime systems/resource managers/MPI implementations developers than at the end users. Moreover, they are not standard strictly speaking, which hampers their acceptance. That is why relying on simpler mechanisms and abstractions available in programming standard might be a better choice for application development purposes. However, the MPI standard and its programming model are explicitly hardware-agnostic which is often interpretated as an impossibility to tackle hardware details. This issue is particularly relevent for coupled models applications which assemble various pieces of code (kernels) that exhibit different levels of MPI/OpenMP parallelization. In particular, an optimal usage of the underlying resources implies a careful mapping/binding of processing entities (processes, threads) onto the cores/hardware threads of the machine which can be difficult to achieve. In this talk, I will present what is currently available in MPI to accomodate for the exploitation of the current generation of complex architectures. I will show what does exist in the current version of the MPI standard, what is under discussion in the MPI Forum for the next versions but also what implementations are able to offer in this department.

Samuel K. Gutierrez	Los Alamos National Laboratory	Title: Adaptive Parallelism for Coupled, Hybrid Programs Authors: Samuel K. Gutierrez Abstract: Hybrid parallel programming models that combine message passing (MP) and shared-memory multithreading (MT) are becoming more popular, especially with applications requiring higher degrees of parallelism and scalability. Consequently, coupled parallel programs, those built via the integration of independently developed software libraries linked into a single application, increasingly comprise message-passing libraries with differing preferred degrees of threading, resulting in thread-level heterogeneity. Retroactively matching threading levels between independently developed and maintained libraries is difficult, and the challenge is exacerbated because contemporary middleware services provide only static scheduling policies over entire program executions, necessitating suboptimal over-subscribed or under-subscribed configurations. In coupled applications, a poorly configured component can lead to overall poor application performance, suboptimal resource utilization, and increased time-to-solution. So it is critical that each library execute in a manner consistent with its design and tuning for a particular system architecture and workload. In this talk, I present different ways to structure and execute coupled multithreaded message-passing (MT-MP) programs. I begin with an examination of contemporary approaches used to accommodate thread-level heterogeneity in coupled MT-MP programs. Here I discuss potential inefficiencies in how these programs are currently structured and executed in the high-performance computing domain. I then describe and evaluate a dynamic approach for accommodating thread-level heterogeneity. This approach enables full utilization of all available compute resources throughout an application's execution by providing programmable facilities with modest overheads to dynamically reconfigure runtime environments for compute phases with differing threading factors and affinities. Our performance results show that for a majority of the tested scientific workloads, our approach and corresponding open-source reference implementation render speedups greater than 50% over the static under-subscribed baseline.
Phil Jones	Los Alamos National Laboratory	Title: Task Parallel Runtimes and Algorithmic Improvements for Coupled Earth System Models Authors: Phil Jones and the CANGA team Abstract: Asynchronous Many Task Models have advantages for managing complexity, load-balancing and fault tolerance in coupled models. In addition, they permit a coupling of process models rather than large components. We will present some preliminary results from our exploration of these systems. In addition, we will describe some algorithmic improvements in both remapping of fields and in advancing a coupled system in time.
Mario Acosta	Barcelona Supercomputing Center	Title: Computational coupling cost evaluation: Challenges and solutions for the new generation of Earth System Models Authors: Mario Acosta, Sergi Palomas, Kim Serradell Abstract: Earth System Models (ESMs) can represent a variety of coupled components running independently on HPC systems at the same time as Multiple Program, Multiple Data (MPMD) applications. This work presents the computational performance analysis of CMIP6 configurations to provide the analysis per component but also as a coupled system, evaluating if the coupling calculations or waiting time among components could represent an overhead for the execution. Such analyses are required to reduce the cost of each component independently and as a whole, evaluating the load balance efficiency of the coupled system. The new ESMs are increasing the complexity and introducing more components working in parallel to simulate different processes such as atmosphere, ocean, biochemistry, vegetation, waves… Load-balancing of these coupled models using more than five components could be a new computational performance challenge for the ESM community that must be studied. A load balancing and affinity/binding distribution study will be presented in order to provide recommendations to minimize the idle-time in a range of OASIS-based coupled components covering irregular time steps, varied and wide range of component speeds and sequencing constraints. The results will differentiate load-balancing, component-interaction and single component issues, proposing an approach to recommend configurations (number of parallel resources per component) to reduce the load imbalance and the resources not used correctly.

Carsten Lemmen	Helmholtz-Zentrum Geesthacht	Title: Modular System for Shelves and Coasts (MOSSCO) -- Science applications, unstructured representations, and particle dynamics. Authors: Abstract: Coastal ecosystems are under multiple pressures ranging from Global Change to local anthropogenic influences. The sensitivity to those pressures is determined by internal coastal dynamics, which reflects a large bundle of physical, biogeochemical, ecological, or geological processes. At the very edge between ocean, atmosphere, and soil, coastal ecosystems form a central interface between Earth System compartments. Both scientific understanding of coastal ecosystems and a sustainable management of coast-related anthropogenic activities require an integrative approach. The Modular System for Shelves and Coasts (MOSSCO) helps to flexibly and modularly integrate process-based models into a larger regional Earth System context. We introduced the concept and first applications at the last two coupling technologies workshops. Here, we present results from published coupled MOSSCO applications that investigated the biota-mediated interaction of the seafloor and water column at the North Sea coast, and the anthropogenic pressures at this interface, e.g., offshore wind farming or microplastics. Since the last workshop, we have technically extended our coupling system to generically integrate unstructured grid models and point data, and we will demonstrate this capability for applications in the Elbe estuary and harbour complex, including novel models that describe suspended sediment dynamics with mixed organic/inorganic particle aggregation.
Aurore Voldoire	CNRM, Météo-France/CNRS	Title: Improving the river outflow coupling in a global climate model Authors: A. Voldoire, B. Ducharme Abstract: In global climate models, a growing attention is paid to the hydrology cycle. To properly close the water cycle between the continents and the ocean, the exchange of water mass from the river outlet to the ocean model has to be represented. In CNRM-CM, this coupling was represented rather crudely and a new method better conserving regional river outflows has been implemented. Traditionally when coupling fluxes fields, the basic idea is to provide a data on each unmasked target grid point. In the case of river outflow, the rationale is reversed since not all ocean target grid points will receive a value but it is necessary that all source grid points find a target on the ocean grid. To implement such a coupling using OASIS-MCT, we propose a method based on oasis interpolation weights but taking the reverse interpolation links. This method allows to conserve the river outflow locally and globally and could be implemented directly in OASIS-MCT. We also show the impacts of this improved coupling method on the climate simulated.
Tom Clune	NASA GSFC Global Modeling and Assimilation Office	Title: New Capabilities in MAPL Authors: Thomas Clune and Atanas Trayanov Abstract: MAPL is an ESMF-based coupling layer within the GEOS data assimilation system and continues to evolve in response to novel coupling requirements. New features include (1) a generic NUOPC wrapper which allows MAPL components to be used within a NUOPC-based application, (2) expansion of couplers to include connecting component-provided services, (3) exploiting recent ESMF advances to provide threading for column physics without direct OpenMP instrumentation, and (4) asynchronous input for demanding CTM configurations.
Hendrik Tolman	NOAA / NWS / Office of Science and Technology Integration	Title: The Unified Forecast System (UFS); using community modeling to improve operations at NOAA. Authors: Henrik L. Tolman and the UFS Team Abstract: In response to external reviews, NOAA is simplifying its so called Production Suite of operational weather and environmental models. The simplification is organized around the introduction of the Unified Forecast System (UFS). The UFS is a community based coupled environmental modeling system, that is shared between research and operations. After several years of planning for the UFS, the UFS is now becoming a tangible reality. The presentation will define what the UFS stands for, and how it is different from previous modeling approaches, in particular for NOAA. Practical progress on the UFS will be illustrated, including the first operational UFS implementation, code release and UFS support, a tentative plan for simplifying the Production Suite, and various coupled UFS prototype models. Finally, NOAA intends to accelerate the development of the UFS with the Environmental Prediction Innovation Center (EPIC), which will be the final topic of the presentation.

Mariana Vertenstein	National Center for Atmospheric Research	Title: CESM Authors: Abstract: A new coupling infrastructure based on ESMF/NUOPC will be the new coupling architecture for CESM and will replace the current CPL7 architecture. ESMF/NUOPC will provide significant advantages to the CESM community compared to the prior, aging and unsupported coupling infrastructure and will facilitate the CESM community in incorporating new science into the system. The new infrastructure called CMEPS (Community Mediator for Earth Prediction Systems) is being implemented in partnership with NCAR, NOAA/GFDL, NOAA/EMC and ESMF/NUOPC. The goal is to develop a highly flexible tool that can replicate all coupling functions currently used in CESM and to have it be the primary coupling infrastructure for the Community Earth System Model (CESM). In addition, CMEPS is will replicate key coupling functions used by NOAA/EMC and by the GFDL coupled model system. In addition to promoting more direct technology transfers from research to operational centers, the community mediator will enable controlled experimentation with different coupling science techniques. An overview of CMEPS along with its current status sill be presented.
Sylvie Malardel	Météo-France	Title: Ocean-Wave-Atmosphere coupling with SURFEX and OASIS for mesoscale simulations and numerical weather prediction of tropical cyclones Authors: Sylvie Malardel, Soline Bielli, Joris Pianezze, Cindy Lebeaupin-Brossier Abstract: At the Laboratoire de l'Atmosphère et des Cyclones (LACy), several research configurations of Ocean-Wave-Atmosphere coupled models are available for tropical cyclone research and NWP developements. For all configurations, the coupling between the Atmosphere, the Ocean and the Wave models is driven by the OASIS coupler (Cerfacs, CNRS) through the surface platform SURFEX (Météo-France and partners). The mesoscale atmospheric model Meso-NH or AROME, the oceanic model NEMO or CROCO and the wave model WW3 can then communicate across SURFEX with only minimal changes in the original code of each individual component of the coupled system. Currently, the preparation of the initial files and the lateral boundady coupling files for each of the component is a tedious task as it still uses the tools which have been developed for each component. The AROME-NEMO-WW3 configuration is running under the NWP suite tool VORTEX. In the future, the file preparation will be fully integrated into the VORTEX suite, ready for operational implementation. In this operational-like configuration, the atmospheric and wave files will direcly be derived from HRES IFS and the ocean files from MECATOR products at 1/12th of a degree. The system MESONH-CROCO-WW3 is a research tool which can be run at very high resolution with a large set of diagnostics. At LACy, it is used to study fine TC processes and to improve model physics. Improved parametrisations such as a surface scheme or microphysics scheme directly coupled with the wave model can then easily be transferred to the operational system AROME-NEMO-WW3. The physical consitency of the coupling between the different components of these coupled systems has still some known weaknesses, for example in term of drag between the wave model and the other components of the coupled system. They will be adressed in a near future. Simulations of recent TC with different configurations of coupled systems will be used to illustrate the large sensitivity of TC forecast intensity to O-W-A coupling.
Dan Copsey	Met Office	Title: The development of coupled NWP forecasting at the Met Office Authors: Dan Copsey, Tim Graham, Michael Vellinga, Chris Harris, Jean-Christophe Rioual Abstract: The Met Office plans to move coupled NWP with weakly coupled data assimilation for all of its operational global deterministic and ensemble atmosphere forecasts early in the next decade.. The system will be based on an atmosphere using the Unified Model, land surface using JULES, ocean using NEMO and sea ice using CICE. These models run in parallel using two executables (atmosphere+land and ocean+seaice) coupled every hour using OASIS3-MCT. In this talk we will present results from two test systems: 1) An operational resolution (10km atmosphere/ORCA025) model taking initial conditions from operational uncoupled atmosphere and ocean forecast systems. 2) A lower resolution (17km atmosphere/ORCA025) model using weakly coupled data assimilation. Results from both modes show improvements when compared to atmosphere only equivalents in verification statistics, tropical cyclone tracks and various other atmospheric phenomena. Future developments of the coupled NWP system will include increases to the ocean and atmosphere resolution, as well as using the new LFRic atmosphere model and SI3 sea ice model. It is essential that the system remains affordable on future HPC systems. We will outline how this is being addressed in the coupling part of the Met Office Next Generation Modelling Systems (NGMS) programme.

Lars Nerger	Alfred Wegener Institute	Title: Efficient Ensemble Data Assimilation for Earth System Models with the Parallel Data Assimilation Framework Authors: Lars Nerger, Qi Tang, Longjiang Mu, Dmitry Sidorenko Abstract: We discuss how to build an ensemble data assimilation system using a direct connection between a coupled Earth system model (ESM) and the ensemble data assimilation software PDAF (Parallel Data Assimilation Framework, http://pdaf.awi.de). The direct connection results in a data assimilation program with high flexibility, efficiency, and parallel scalability. For this we augment the source code of the coupled model by data assimilation routines and hence create an online-coupled assimilative model. This first modifies the coupled model to be able to simulate an ensemble. Using a combination of in-memory access and parallel communication with the Message Passing Interface (MPI) standard we can further add the analysis step of ensemble-based assimilation methods. Thus the assimilation of observations is computed without the need to stop and restart the whole coupled model system. Instead, the analysis step is performed in between time steps and is independent of the actual model coupler that couples the different model compartments. This strategy to build the assimilation system allows us to perform both weakly coupled (in-compartment) and strongly coupled (cross-compartment) assimilation. The assimilation frequency can be kept flexible, so that the assimilation of observations from different compartments of the ESM can be performed at different intervals. Further, the reading and writing of disk files is minimized. The resulting assimilative model can be run in the same way as the regular ESM, but with additional parameters controlling the assimilation and with a higher number of processors to simulate the ensemble. Using the example of the coupled climate model AWI-CM that contains the FESOM model for the ocean and sea ice and ECHAM6 for the atmosphere, both coupled through the OASIS-MCT coupler, we discuss the features of the online assimilation coupling strategy and the performance of the resulting assimilative model.
Phil Browne	ECMWF	Title: Coupling requirements for various flavours of coupled variational data assimilation at ECMWF Authors: Phil Browne, Marcin Chrust, Kristian Mogensen Abstract: ECMWF is pressing forward with its strategy to have an Earth system approach to numerical weather prediction. As part of this, ever more coupling is being introduced within the data assimilation systems as well as the forecast model. In this talk we will explain the various ocean-atmosphere coupling strategies which we adopt at ECMWF, from the operational weakly coupled approach that works at script level, to outer loop coupling which requires only forward model integrations to be coupled. The control layer for data assimilation at ECMWF will move towards an object oriented prediction system (OOPS) and so going forward we would like the ability to have more features and flexibility in our coupled data assimilation system. This means access to coupled model integrations, coupled tangent linear/adjoint models, and matrix-vector multiplications to a coupled control vector. The time stepping and coupling frequency of the coupled model shall be controlled by the OOPS control layer. We will give an overview of the features that we are missing which would facilitate ever stronger levels of coupling, and give an idea of what is low hanging fruit and what challenges we can foresee which do not have obvious practical solutions.
Sergey Skachko	Environment and Climate Change Canada, Meteorological Research Division	Title: Coupled atmosphere-ocean data assimilation system in the Canadian global prediction system. Authors: Sergey Skachko, Mark Buehner, Stéphane Laroche, Dorina Surcel-Colan and Greg Smith Abstract: A first prototype of a weakly coupled atmosphere-ocean data assimilation system was recently tested at Environment and Climatic Change Canada. The current system is built on four independent atmospheric, ocean, SST and sea-ice data assimilation components, where only the atmospheric and ocean data assimilations are weakly coupled, i.e. sharing common model background states from the coupled atmosphere-ocean model to compute two independent analyses. One of the key elements of this system is the current uncoupled daily SST analysis computed using the optimal interpolation (OI) method. This system estimates an SST that represents the “foundation” temperature, which is not affected by the diurnal cycle. Our goal in progressing towards strongly coupled data assimilation systems is to use the same data assimilation software as the atmospheric system to compute the SST analysis every 6h (instead of daily), i.e. the same frequency as the atmospheric analysis. To be more suitable for the assimilation of surface-sensitive atmospheric radiance observations, the new SST analysis should include a surface skin temperature that resolves the diurnal cycle in addition to the “foundation” temperature. This study presents these new SST analyses and compares them against the existing operational SST daily products.

Einar Olason	The Nansen Center, Bergen, Norway	Title: Coupling a moving-mesh to a fixed grid Authors: Einar Ólason(1), Laurent Brodeau(2), Claude Talandier(3), Pierre Rampal(1,4), Camille Lique(3) (1) Nansen Environmental and Remote Sensing Center, Bergen, Norway; (2) Ocean Next, Grenoble, France ; (3) Ifremer, Brest, France; (4) Now at IGE, Grenoble, France Abstract: We present the coupling of the neXtSIM sea-ice model and the NEMO ocean model, using the OASIS coupler. NeXtSIM is a new sea-ice model which uses a Lagrangian moving mesh to better preserve the simulated discontinuities in sea-ice properties. Coupling a moving-mesh model to one that uses a fixed grid presents us with a unique set of difficulties, the most important of which we will outline here. These difficulties include the need to recalculate interpolation weights as the mesh moves, and need to deal with a continuously changing spatial partitioning. We will present some preliminary solutions to these problems, as well as initial results of the coupled platform. The main challenge remaining is to improve computational performance, as some of the proposed solutions suffer from poor numerical performance, primarily in the form of poor numerical scalability.
Robin Smith	NCAS, University of Reading, UK	Title: Moving the boundaries: coupling interactive ice sheets in UKESM Authors: Robin Smith, Pierre Mathiot, Antony Siahaan and the UKESM core development team Abstract: Dependent on the state of the rest of the climate system, continental ice sheets melt, flow and significantly change their height and extent as a function of time, with corresponding changes in both regional and global-mean sea levels. Including ice sheets as fully interactive components of an Earth System model thus requires that the physical locations of the interfaces between atmosphere, land and ocean models be capable of being moved as a simulation proceeds. These locations are usually considered as a fixed part of the boundary condition for each model, and indeed many models are constructed in such a way as to make moving them impractical. We have developed the UK Earth System Model so that it can be be configured to include both the Greenland and Antarctic ice sheets as interactive components, and in this presentation I will describe how we approach the technical and scientific problems inherent in coupling the ice to our other climate components and allowing it to change shape.
Nagaraju Chilukoti	National Institute of Technology (NIT) Rourkela, India	Title: An assessment of potential climate impact during 1948- 2010 using historical land use land cover change maps Authors: Nagaraju Chilukoti, Irreversible Climate change research center, Yonsei University Abstract: Earlier studies of Land Use Land Cover Change (LULCC) normally used only a specified LULCC map with no interannual variations. In this study, using an Atmospheric General Circulation Model (AGCM) coupled with a land surface model, biophysical impacts of LULCC on global and regional climate are investigated by using a LULCC map which covers 63 years from 1948-2010 with interannual variation. A methodology has been developed to convert the LULCC fraction map with 1° resolution to the AGCM grid points in which only one dominant type is allowed. Comprehensive evaluations are conducted to ensure consistency of the trend of the original LULCC fraction change and the trend of the fraction of grid point changes over different regions. The model was integrated with a potential vegetation map (a control simulation) and the map with LULCC, in which a set of surface parameters such as leaf area index, albedo, and other soil and vegetation parameters were accordingly changed, from 1948 to 2010 with interannual variation. The results indicate that the simulation with the interannual LULCC map is able to reproduce better interannual variability of surface temperature and rainfall when compared to the control simulation. The LULCC causes global precipitation reduction, with the strongest significant signals over degraded regions such as West Africa, East Asia and South America, and some of these changes are consistent with observed regional anomalies for certain time periods. The LULCC causes reduction in net radiation and evapotranspiration, which leads to the changes in monsoon circulation and variation in magnitude and pattern of moisture flux convergence and subsequent reduction in precipitation. Meanwhile, LULCC enhances surface warming during the summer in the LULCC regions. Greatly reduced evapotranspiration leads to warm surface temperature during the summer season. In contradiction to the surface, upper troposphere temperatures are cool because of less latent heat released into the upper troposphere. This reduction in temperature decreases the temperature gradient, which leads to weaker circulation in LULCC regions.

Niels Drost	Netherlands eScience Center	Title: Coupling Hydrological models through eWaterCycle Authors: Niels Drost, Rolf Hut, Nick Van De Giesen, Ben van Werkhoven, Jerom P.M. Aerts, Jaro Camphuijsen, Inti Pelupessy, Berend Weel, Stefan Verhoeven, Ronald van Haren, Eric Hutton, Fakhereh Alidoost, Gijs van den Oord, Yifat Dzigan, Bouwe Andela, Peter Kalverla Abstract: The eWaterCycle platform is a fully Open-Source platform built specifically to advance the state of FAIR and Open Science in hydrological Modeling. eWaterCycle builds on web technology, notebooks and containers to offer an integrated modeling experimentation environment for scientists. It allows scientists to run any supported hydrological model with ease, including setup and pre-processing of all data required. The eWaterCycle platform uses Jupyter as the main interface for scientific work to ensure maximum flexibility. Common datasets such as ERA-Interim forcing data and observations for verification of model output quality are available for usage by the models. To make the system capable of running any hydrological model we use docker containers coupled through gRPC. As the main API, we use the Basic Model Interface (BMI). This allows us to support models in a multitude of languages. Our gRPC based system allows coupling of models, and running of multiple instances of the same model. Our system was designed to work with higher level interfaces such as PyMT, and we are currently integrating PyMT into our platform. During my talk I will give an overview of the different elements of the eWaterCycle platform, and zoom in on the coupling capabilities of our system.
Slavko Brdar	Research Center Juelich	Title: A New Atmosphere-Land Coupling in TerrSysMP: ICON and CLM3.5 Authors: Slavko Brdar (Juelich Supercomputing Centre, Juelich, Germany), Cunbo Han (KIT, Karlsruhe, Germany), Stefan Kollet (Research Centre Juelich, Juelich, Germany) Abstract: In this work we explain the coupling of ICON, the newest numerical model of German Met Office, and the land surface model Community Land Model (CLM) within our Terrestrial System Modeling Platform (TerrSysMP). With ICON in TerrSysMP we are able to perform high-resolution LES run over smaller areas where we study influence of soil moisture redistribution on atmospheric boundary layer. For that purpose we looked into correctness and performance of newly coupled code.
Prajeesh A G	Indian Institute of Tropical Meteorology, Pune, India	Title: Flux exchange and coupling in IITM-ESM Authors: Prajeesh A G, M. Singh, Sandeep N, Aditi Modi, Ayantika D.C., Swapna P, Krishnan R (Centre for Climate Change Research, Indian Institute of Tropical Meteorology (IITM), Pune) Abstract: The coupling in IITM-ESMv1, adapted from NCEP's CFSv2 suffered from two significant problems. Firstly, there was a large discrepancy in the flux exchange over the sea-ice and along coastal boundaries, which lead to a substantial error in the energy balance of the coupled system and significant biases in sea-ice simulations. Secondly, the ocean and atmospheric components were executed serially, i.e. a serial coupling sequence. In IITM-ESM version 2, implementation of fractional grids for computing surface fluxes solved a large part of the flux exchange discrepancy, leading to a better energy balance and sea-ice simulation. The implementation of a parallel coupling sequence in IITM-ESMv2 doubled the throughput of the model. The coupling in IITM-ESM happens in two steps, an intermediate coupler for gathering and redistributing fields from/to atmospheric processors to/from ocean processors and in the ocean processors the GFDL's FMS coupler does the regridding to/from ocean grids. There are challenges with the current implementation of intermediate coupler in handling parallel regridding and redistribution of coupling fields, flux computations on exchange grid, implicit coupling cycle etc. Recently, we have coupled MOM4p1 ocean component to a new atmospheric component of IITM-ESM entirely using the FMS coupler. The new atmospheric component in IITM-ESM is based on spectral transform method with a octahedral reduced Gaussian transform grid. Preliminary results from this effort will be presented.
Dirk Barbi	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Title: ESM-Tools - A tool for Earth System Modelling Authors: Nadine Wieters, Dirk Barbi, Paul Gierz, Luisa Cristini, Fatemeh Chegini Abstract: The ESM-TOOLS is a software developed to assist researchers and modelers in solving the challenges of obtaining and operating earth system models (ESM). The software provides a standard way of downloading, configuring, compiling and running modular ESMs on a variety of HPC systems. The user only needs to provide a short runscript of experiment specific definitions, while the ESM-TOOLS execute all the phases of a simulation in the correct order. A user-friendly API ensures that more experienced users have full control over each of these phases, and can easily add functionality. The software provides standard solutions to typical problems occurring within the workflow of model simulations, such as calendar operations, data post-processing and monitoring, sanity checks, sorting and archiving of output, and script-based coupling. The ESM-TOOLS, developed within the framework of the Helmholtz Association-funded project Advanced Earth System Model Capacity (ESM), supports four ocean models, three atmosphere models, two biogeochemistry models, an ice sheet model and an isostatic adjustment model. The new (3rd) version of the ESM-TOOLS which was released in October 2019, is re-coded in python and provides researchers with an even more user-friendly tool for earth system modeling.

Arnaud Caubel	IPSL	Title: CMIP6 at IPSL: a 4-year journey Authors: Abstract: The Institut Pierre Simon Laplace (IPSL, France) has been heavily involved in the sixth phase of the Coupled Model Intercomparison Project (CMIP6). The challenging CMIP6 protocol and Data Request (DR) have led to an intensive development phase of the IPSL Earth System Model and its associated data production workflow, an effort that started in 2015 and ended in 2018. During that time, 25 versions of the IPSL model were released and a revolutionary data workflow was implemented. That workflow combines (1) CNRM's DR2XML, which translates the massive CMIP6 DR into XIOS XML files (pre-processing step), with (2) IPSL's XIOS IO server which is integrated in the coupled model and produces finalized CMIP6 CF-compliant output files on the fly. Since March 2018, IPSL has made 850 simulations (55 000 model years), producing about 1 Pb of CMIP6 publication ready data files with no post-processing step. The publication of this enormous IPSL data set on CMIP6 database marks the completion of a 4-year scientific and technical journey.
Richard Hill	Met Office	Title: Coupled model control systems: Problems = Opportunities Authors: Richard Hill*, Mike Hobson*, Matthew Hambley*, Harry Shepherd*, Jean-Christophe Rioual*, Marc Stringer** (*Met Office, **NERC) Abstract: Historically, control systems for coupled models have evolved, at least at the Met Office, and no doubt elsewhere, from control systems originally aimed at and designed explicitly for running mature model codes on an individual component, stand-alone basis. Coupled model configuration and control has tended to be worked into these systems as something of an afterthought. As the Met Office prepares to meet the demands of the next generation of HPC architectures, we have the chance to re-design the supporting control systems and infrastructure used to manage coupled models. This opportunity to take a holistic approach to coupled model design and implementation, if addressed appropriately, has the potential to enhance and simplify the coupled model experience for users and developers. Here I aim to give a view of the planned work and progress made to date in preparing the next generation of coupled models at the Met Office, including highlighting potential improvements to the peripheral control mechanisms and model drivers.