# Recent activities and developments in ENES

Reinhard Budich, MPI for Meteorology

# Max-Planck-Institut für Meteorologie

Located in Hamburg, Germany
Part of
➜ Max-Planck-Society, ~80 institutes world wide
Founded in 1975
Fundamental Research
Climate Research
About 250 researchers and staff
Three departments: Atmosphere, Land, Ocean
➜ Directors: Stevens, Claussen, Marotzke
➜ Part of CMIPn/IPCC ARn
➜ Mainly numerical climate modeling
Recently added: Scientific Computing Lab

➜ Klima-Campus partner
Largest shareholder of German Climate Computing Centre DKRZ

# MPI für Meteorologie

The Max Planck Institute for Meteorology (MPI-M) is

**dedicated to fundamental climate research**.

Among the **tools** used are **advanced numerical models** that simulate the dynamics of the **atmosphere**, the **ocean**, the **cryosphere** and the **biosphere**, and their **interactions**.

MPI-M has developed a series of comprehensive Earth System Models, based on the **ECHAM** and **MPIOM** atmosphere and ocean general circulation models, which are made available to the scientific community in Europe and elsewhere.
Today **MPI-ESM1** (ECHAM6/MPIOM2, used for the CMIP5 experiments) are supported, while a new model **MPI-ESM2** is developed.
**MPI-ESM2** abandons the spectral representation of the dynamics and switches to finite differences on icosahedral, i.e. unstructured grids. It is based upon the **ICON** model developed jointly with the German weather service DWD and uses the same software structure for both the atmosphere and the ocean. The physics of the model are transferred from ECHAM and MPI-OM to **ICONatm** and **ICONoce**, resp..

MPI-M has also developed the climate data operators (**CDO**), a toolbox for the processing of climate modelling data in different formats. It contains an I/O layer called **CDI**, which have recently been partly parallelized.

The MPI-M is is a core partner in the European Network for Earth System Modelling ENES www.enes.org.

# The Scene

Last Presentation in 2012

– CMIP5 just ceased

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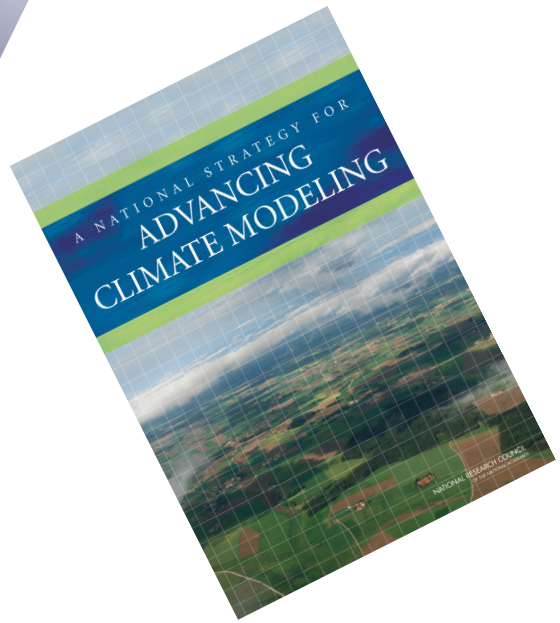

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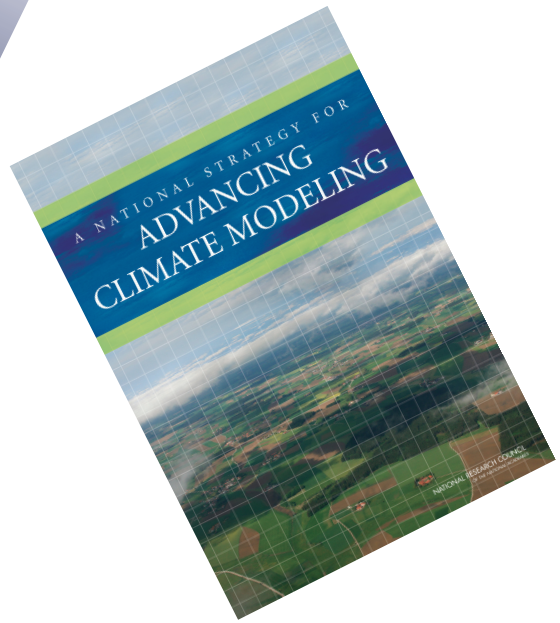

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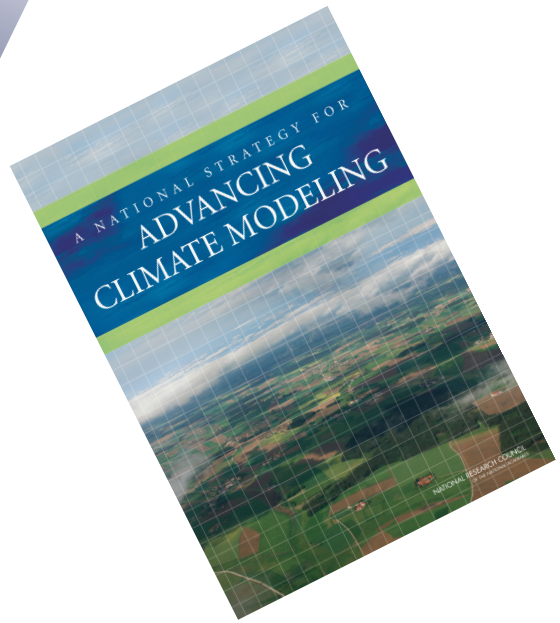

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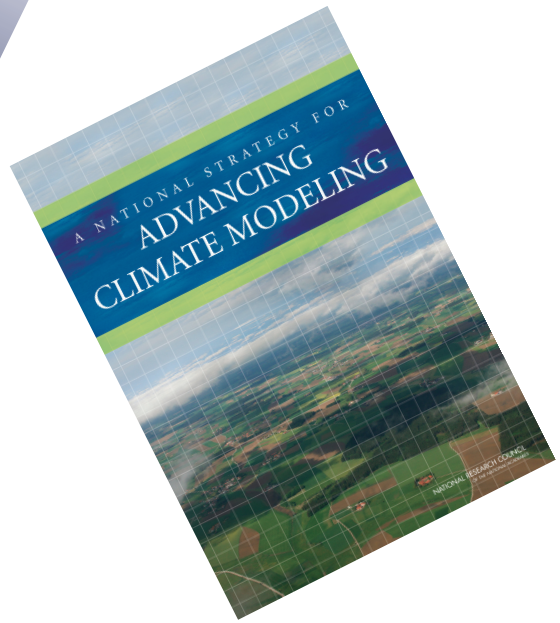

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  - CMIP6
  - Horizon 2020

# My Main Conclusions 2012

- Key drivers:
  + Science and Society
  – Computing HW
- Models need:
  + Competition in science
  + Common software IS
  + Increased resolution
  + Consideration of the complete line from NWP to ESM
- Modelers need
  + Education
  + Exchange
  + Reward
- Users need
  + Easy access to the data
  + Assistance in interpretation

# European Network for Earth System Modelling

# The European Network for Earth System Modelling ENES: Current Activities

- ★ Intro and Motivation
- ★ Brief History
- ★ Scientific projects
- ★ Infrastructures in Earth System Modelling
  - – Report on ISENES(1)
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# ENES: History

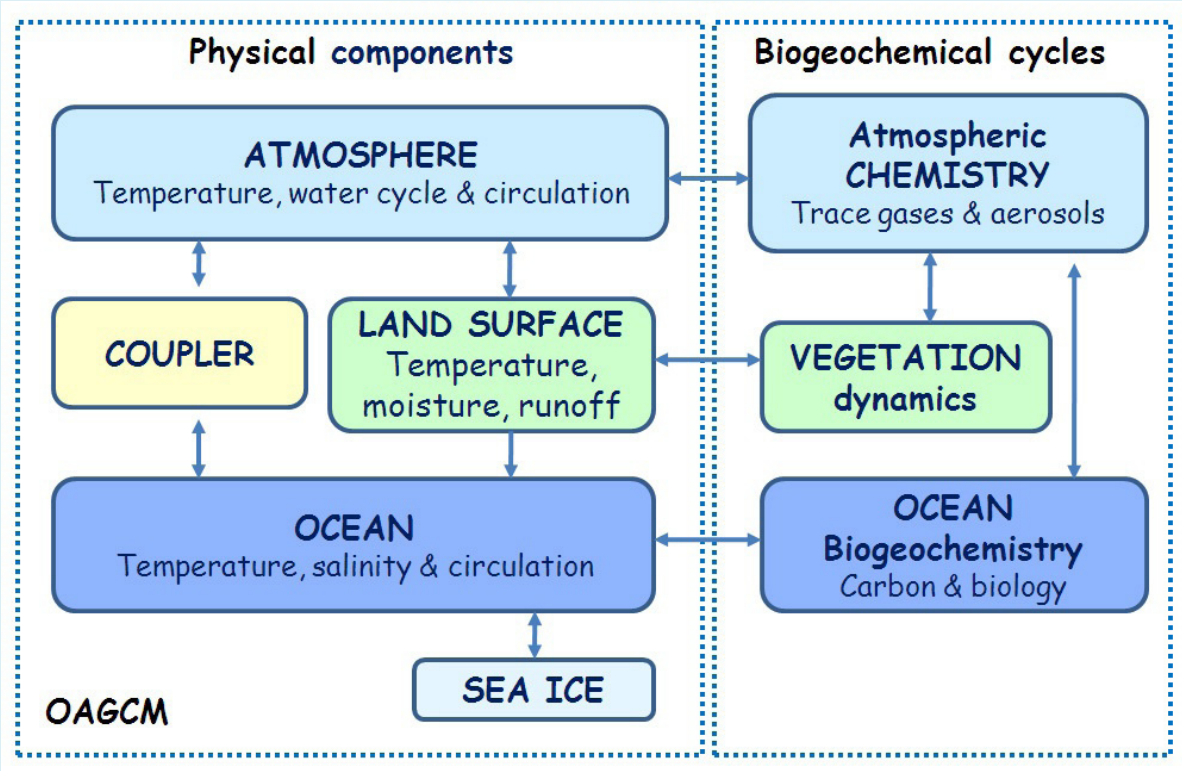
- ★ Euroclivar Recommendation 1998:
  - – “a better integration of the European modelling effort with respect to human potential, hardware and software”
- ★ In 2001 Guy Brasseur helped to found ENES
- ★ Scientific Board
  - – S. Joussaume, J.C. André, S. Belcher, J. Biercamp, R. Budich, B. Lawrence, J. Marotzke,, T. Palmer, A. Navarra,
- ★ Today about 50 partners
- ★ Main focus : Discuss strategy to accelerate progress in climate/Earth System modelling and understanding

Map and dots not to scale!

# ENES

European Network for Earth System modelling

## Earth System Models

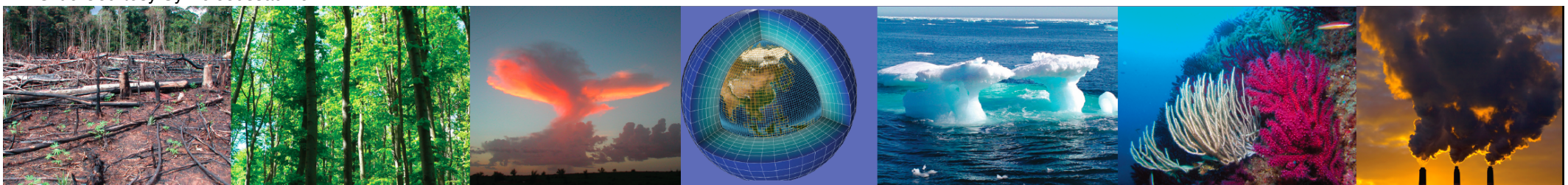



**7 global European Earth System Models (CMIP5):**

- **EC-EARTH**
- **IPSLCM5**
- **CNRM-Cerfacs**
- **COSMOS**
- **C-ESM**
- **HadGEM2**
- **NorESM**

**Several regional models (CORDEX)**

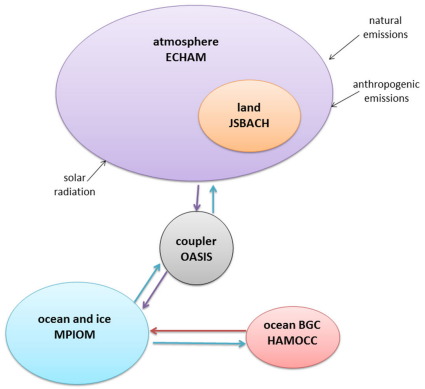
Slide Courtesy Sylvie Joussaume



Courtesy Kaitlin Alexander, Steve Easterbrook, see http://climatesight.files.wordpress.com/2011/08/poster.pdf

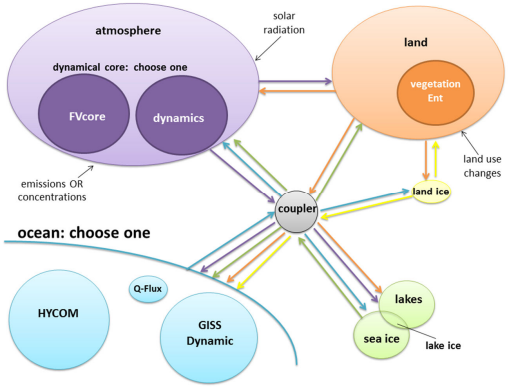
## COSMOS 1.2.1

Max-Planck-Institut für Meteorologie, Germany



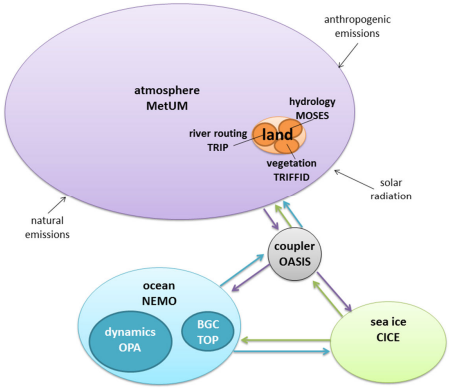

## Model E June 17, 2011 revision

NASA Goddard Institute for Space Studies, USA



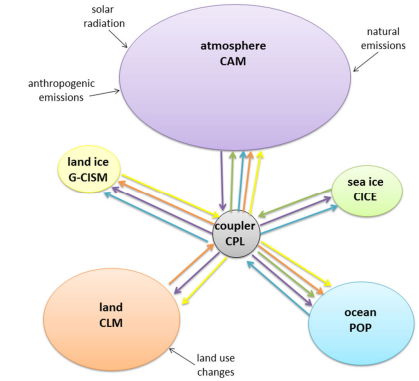

## HadGEM3 August 3, 2009 revision

Met Office, UK



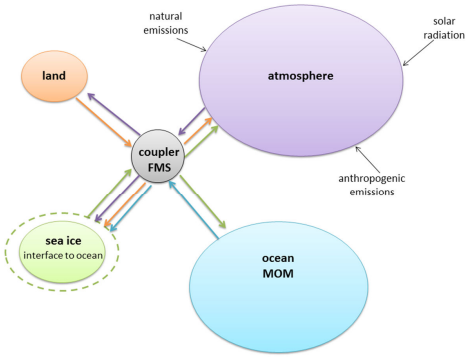

## CESM 1.0.3

National Center for Atmospheric Research, USA



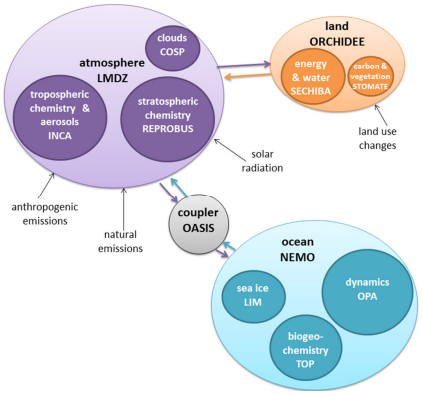

## GFDL Climate Model 2.1 (coupled to MOM 4.1)

Geophysical Fluid Dynamics Laboratory, USA



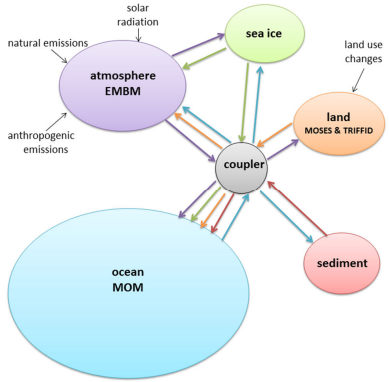

## IPSL Climate Model 5A

Institut Pierre Simon Laplace, France




## UVic Earth System Climate Model 2.9

University of Victoria, Canada




## Key to Diagrams

Each component of the climate system has been assigned a colour:
atmosphere ocean land sea ice land ice sediment

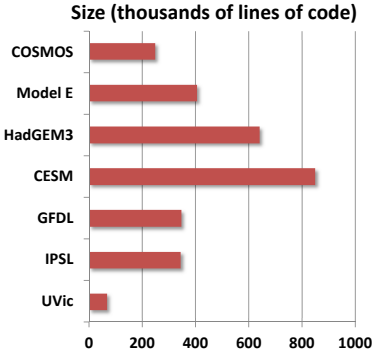
Model code for a component is represented with a bubble. Fluxes are represented with arrows, in a colour showing where they originated.

Couplers are grey. Components can pass fluxes either directly to each other or through the coupler.

The area of a bubble represents the size of its code base, relative to other components in the same model.

A smaller bubble within a larger one represents a small, highly encapsulated model of a system (eg, clouds) that is used by the component.

Radiative forcings are passed to components with plain arrows.




Generated using David A. Wheeler's "SLOCCount".

## What is a Climate Model?

We don't have access to multiple Earths for the purpose of experimentation. Instead, scientists have developed global climate models (GCMs): large pieces of software that simulate the climate system, and how it might react to agents of climate change. In this study, we compared and contrasted the software architecture of seven GCMs from Canada, the United States, and Europe.

## Common Features

**Infrastructure code** (shell scripts and Perl) configures, builds, and runs the model. **Scientific code** (FORTRAN and some C) consists of calculations to simulate the climate system.

**Cells** (3D, ~100 km wide) are created by laying a grid over the Earth's surface and atmosphere. **Time steps** indicate how often calculations are performed (typically minutes to hours).

**Dynamics** calculations resolve fluid dynamics from first principles. **Physics** calculations are parameterizations: approximations for complex or small-scale processes.

## Component-Based Software Engineering (CBSE)

A climate model is really a *collection* of models (components) for the atmosphere, land, etc. They are highly encapsulated, for stand-alone use as well as a mix-and-match approach that facilitates code sharing. CBSE pools resources, creating high-quality components that are used by many GCMs.

Components are modified when they are passed between institutions, to suit new GCMs. These modifications are encouraged by code sharing practices. Virtually anyone can get access to GCM source code, but only the core development team can modify the master copy.

A drawback of CBSE is the fact that the real world is not encapsulated. Relationships between sea ice and the ocean are particularly difficult to represent. Here are some examples of the different approaches taken:

- **CESM**: Sea ice is separate to the ocean, with a transient boundary.
- **IPSL:** Sea ice is a sub-component of the ocean.
- **GFDL:** Sea ice is an interface to the ocean. All fluxes to and from the ocean pass through "sea ice", even if no ice is actually present.

# ENES: Principles

Partners from Academia, Research Institutions and Industry have signed an agreement to:

- Help in the **development** and evaluation of state-of-the-art climate and Earth system models,
- Facilitate focused model **intercomparisons** in order to assess and improve these models,
- Encourage **exchanges** of software and model results, and
- Help in the development of high performance computing **facilities** dedicated to long high-resolution multi-model ensemble integrations.

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3 infrastructure issues

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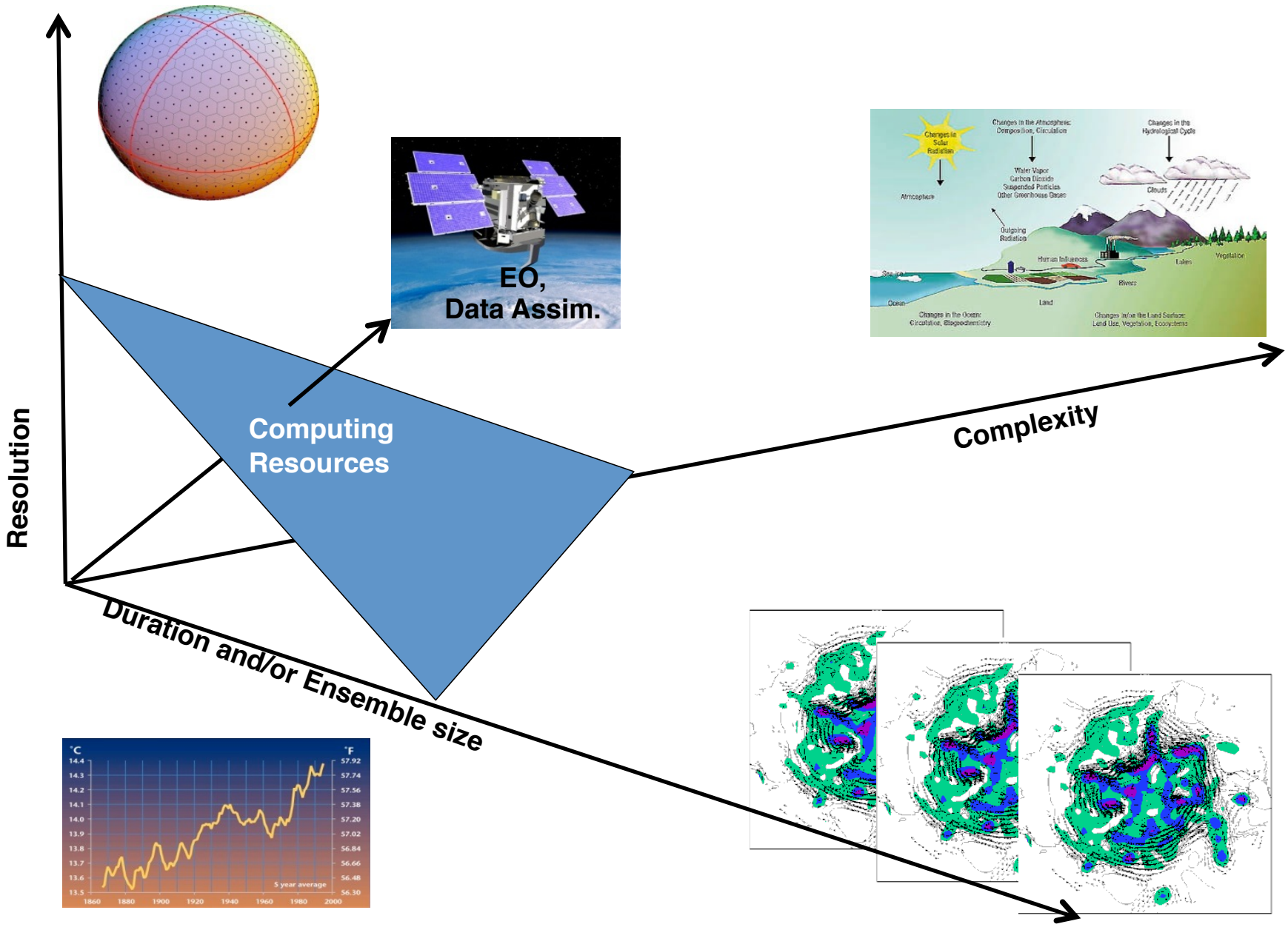
# ENES Projects

- ★ FP5
  - PRISM
- ★ FP6
  - ENSEMBLES
- ★ FP7
  - METAFOR, COMBINE, EUCLIPSE, EMBRACE, SPECS

- ★ H2020
  - ★ Advanced Earth-system models, Call SC5-01-2014

# ENES: Current Science Projects

- 3 Projects in Call „Advanced Earth-system models“
  - **Crescendo**
    - Improve the representation of key biogeochemical, biophysical and aerosol processes and feedbacks in the 7 European ESMs
    - Colin Jones, ULeeds
  - **Impulse**
    - Clouds, Circulation and Climate Sensitivity as one of the six grand challenge problems
    - PI: A.P. Siebesma, KNMI
  - **Primavera**
    - To develop a new generation of advanced and well-evaluated high-resolution global climate models, capable of simulating and predicting regional climate with unprecedented fidelity
    - PI: Pier Luigi Vidale, URead




Jim Kinter, Modelling Summit 2008

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# IS-ENES

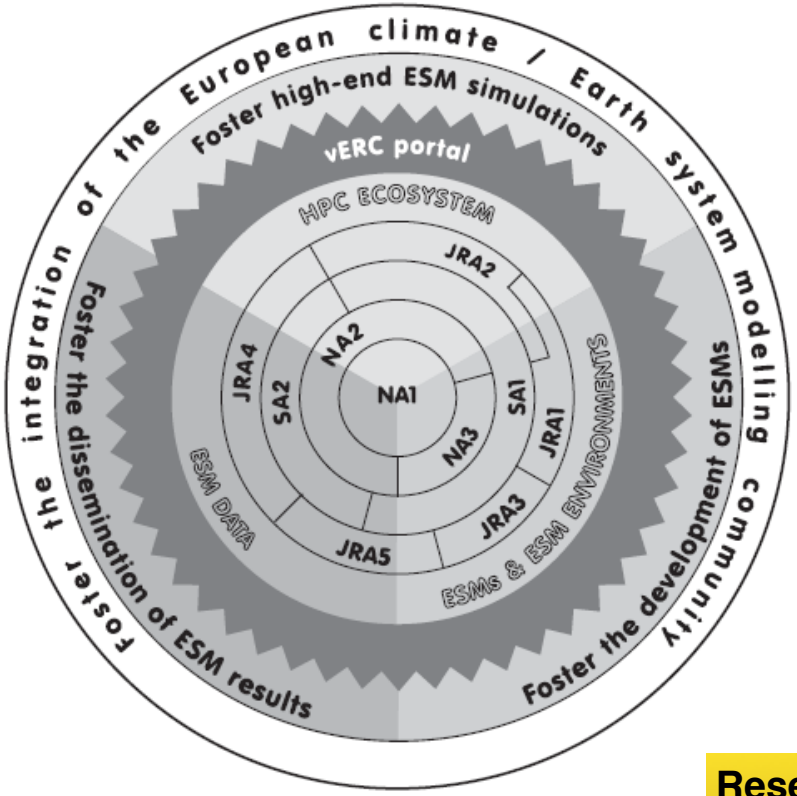
- ★ Report on ISENES (1)
  - ★ Major goals
  - ★ Major achievements
  - ★ What was left to do?

# IS-ENES1: Goals

March 2009- Feb 2013 (7.6 M€), 18 partners

**Networking Activities**
**WP2/NA1**: Establishing the Future ENES Strategy
**WP3/NA2**: The Virtual Earth System Resource Centre
**WP4/NA3**: Strengthening the European Network on Earth System Modelling

**Networking:**
- Strategy
- Portal for collaboration
- Educational activities




**Service Activities**
**WP5/SA1**: Access to the European Network of geographically distributed ESM Resources
**WP6/SA2**: Access to the European Network of geographically distributed ESM data archives

**Services on:**
- HPC
- Data

**Joint Research Activities**
**WP7/JRA1:** Earth System Models, Tools and Environments: Development and Integration
**WP8/JRA2**: European ESM: Performance Enhancement
**WP9/JRA3:** ESM: Evaluation: An Infrastructure
**WP10/JRA4**: ESM Data: Enhancement of Management Protocols and SW Infrastructures
**WP11/JRA5**:Bridging Climate Research Data and the NEeds of the Impact Community

**Research:**
- Performance enhancements
- Environments and Tools
- Meta-data and usability of data

# IS-ENES1: Achievements

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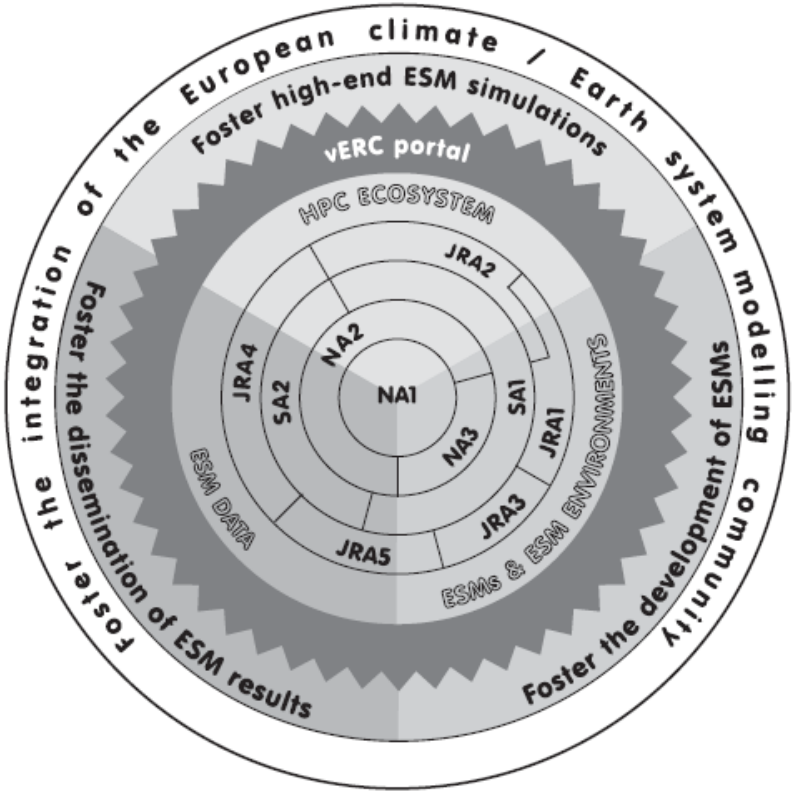


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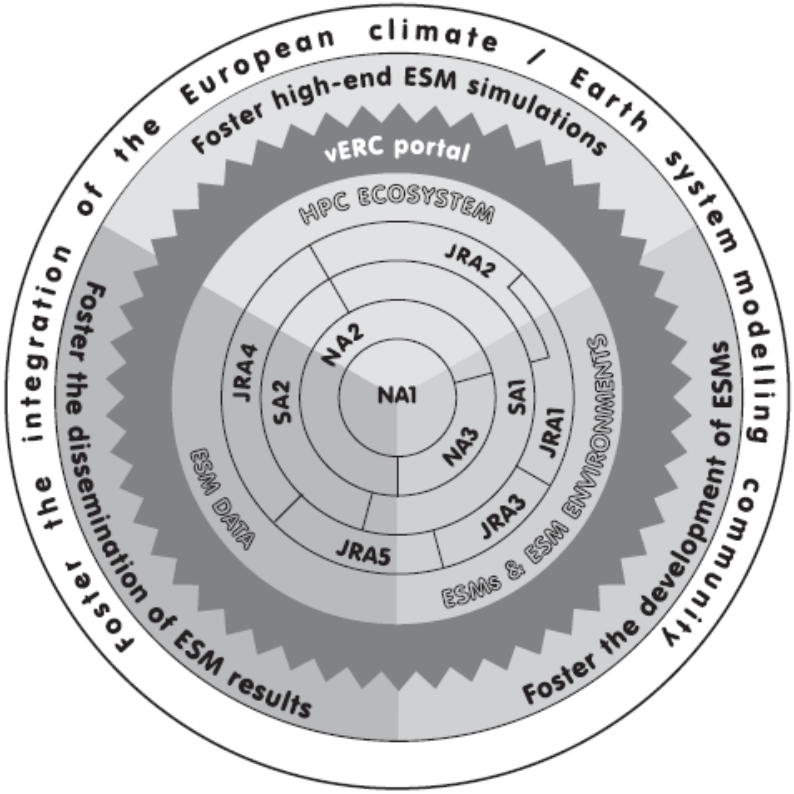


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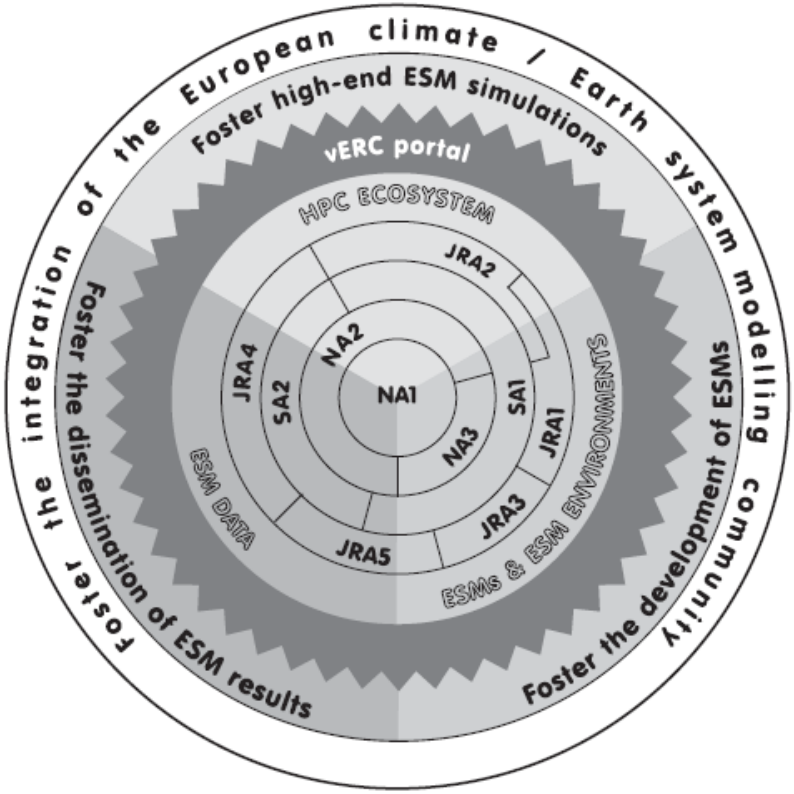


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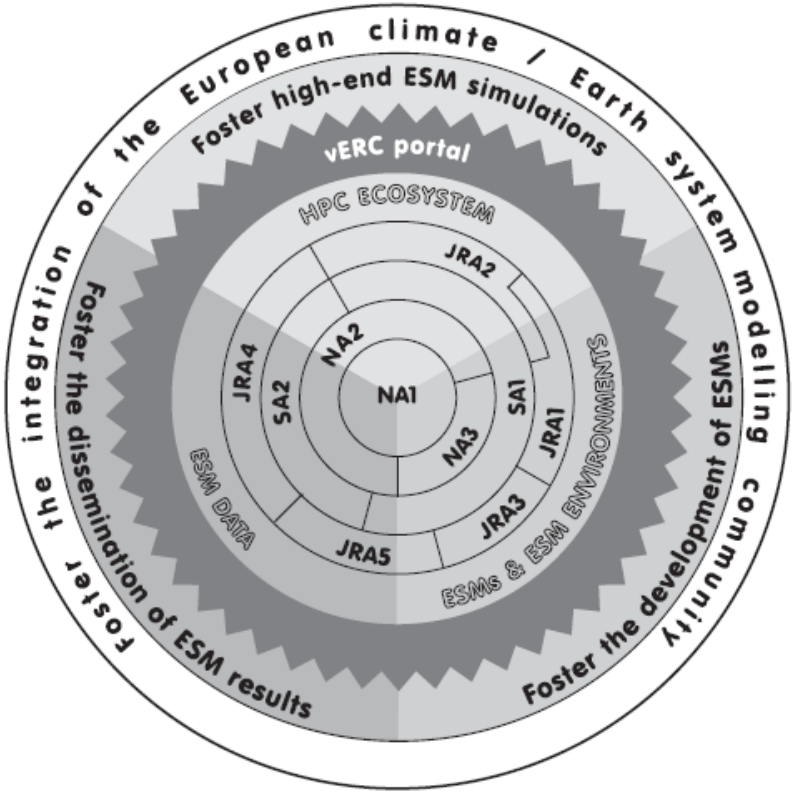


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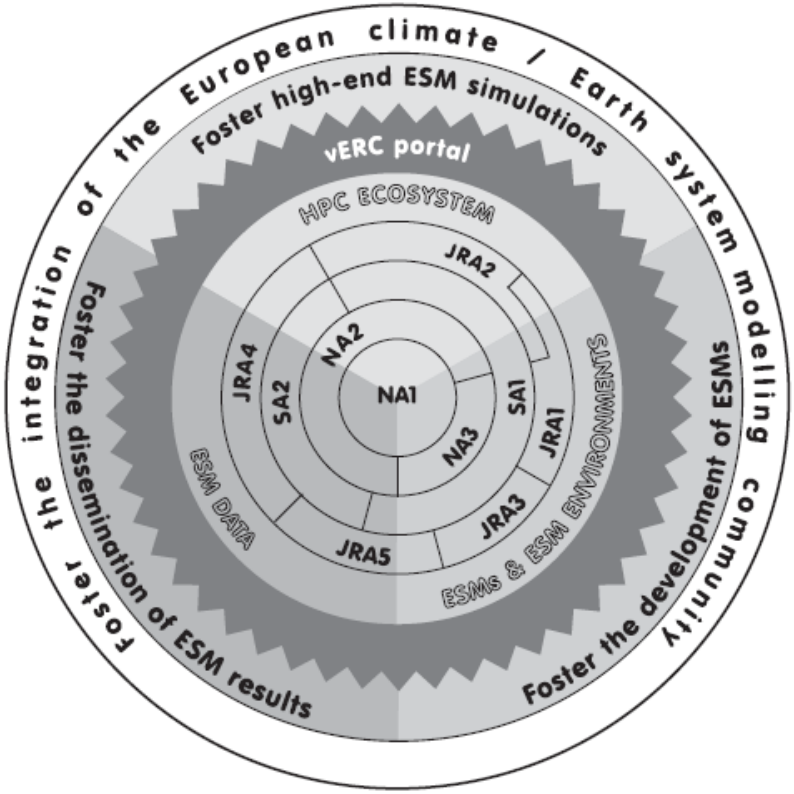



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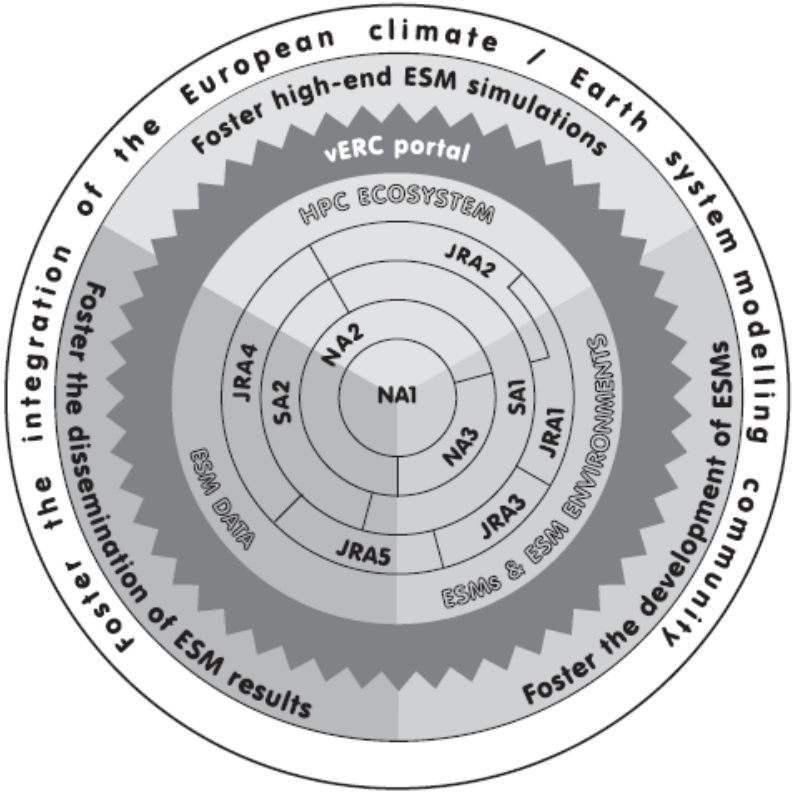



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PRACE

ESGF Earth System Grid Federation

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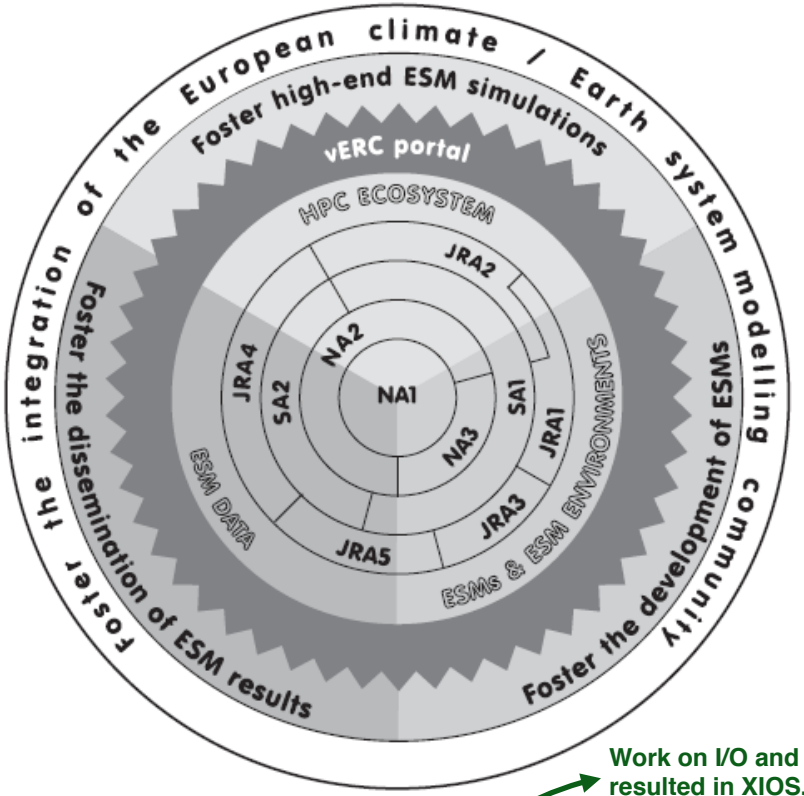



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Work on I/O and coupling resulted in XIOS, parCDI and OASIS3-MCT

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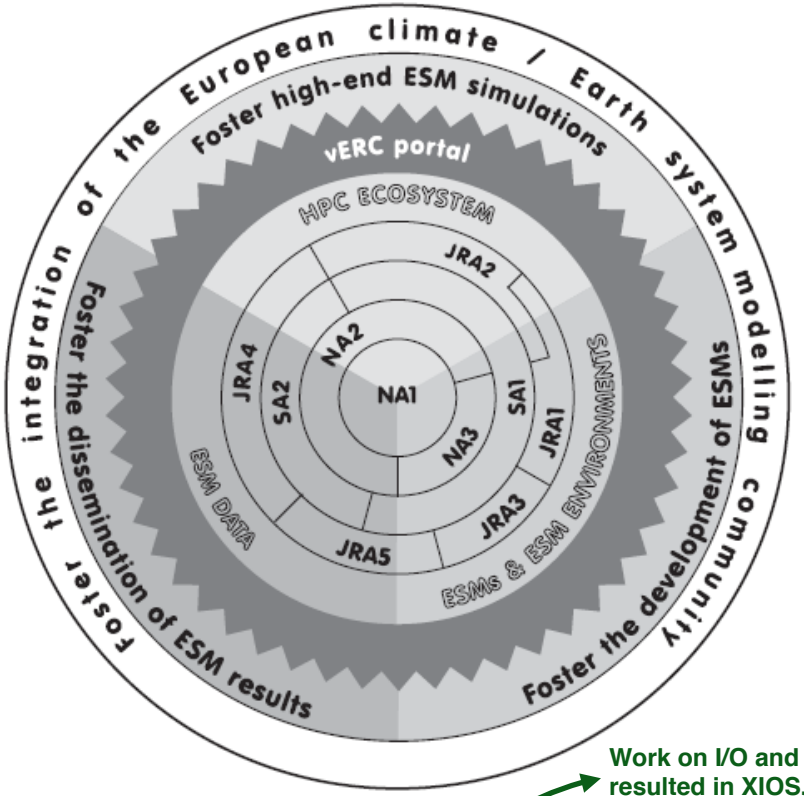
- **WP3/NA2**: The Virtual Earth System Resource Centre
- **WP4/NA3**: Strengthening the European Network on Earth System Modelling





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PRACE

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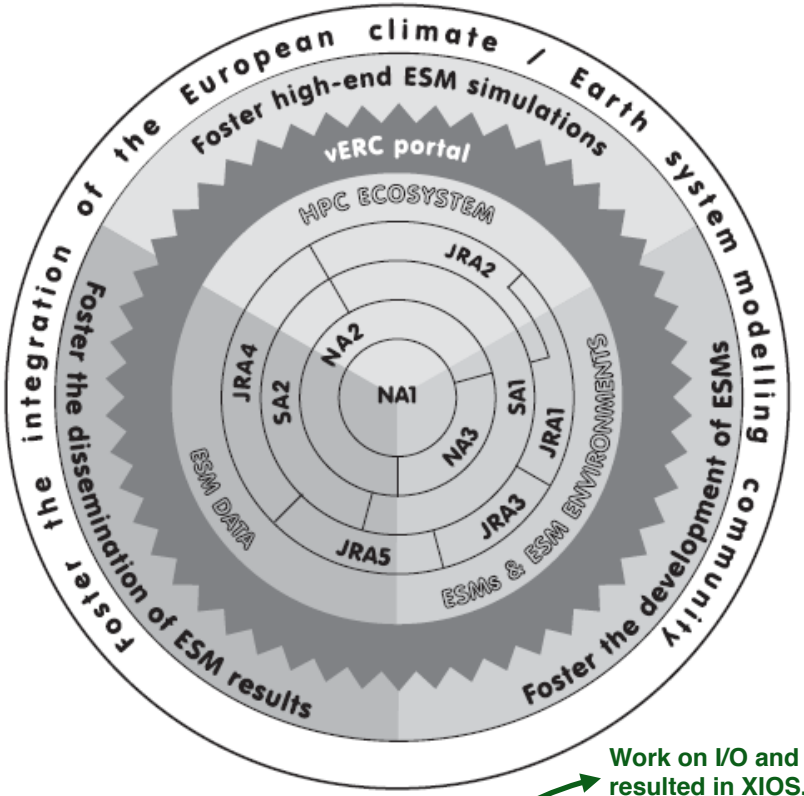


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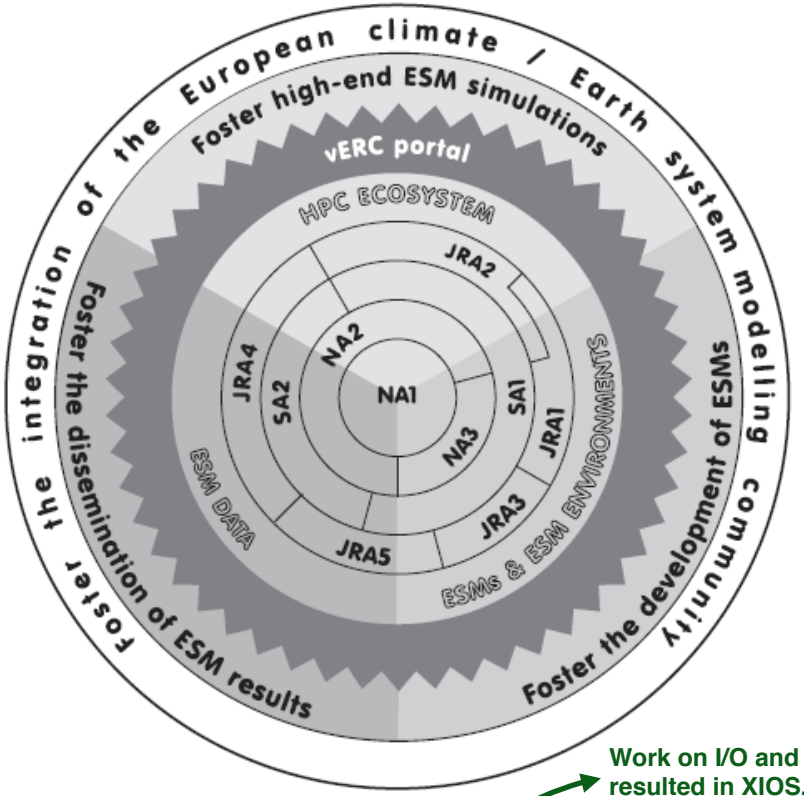



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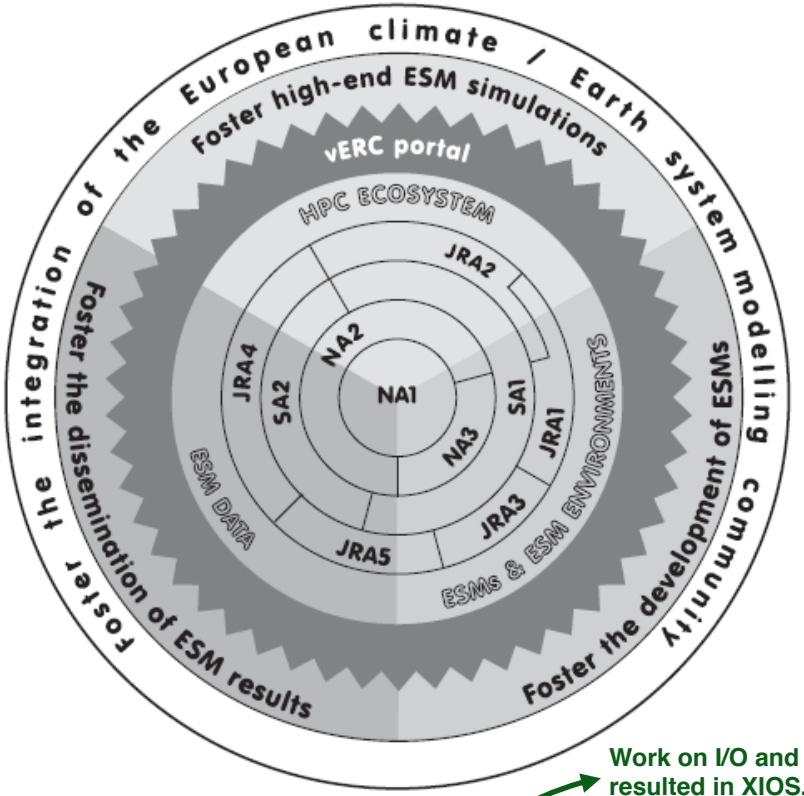



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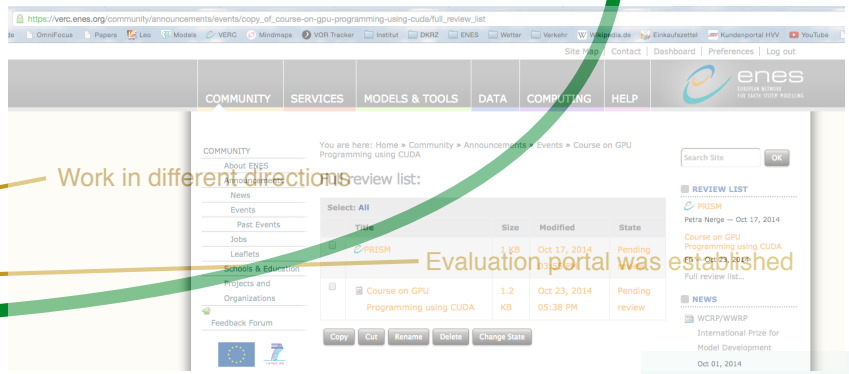


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Max-Planck-Institut für Meteorologie

# IS-ENES1: What was left to do?

Issues:

- PrACE:
  - Improve access
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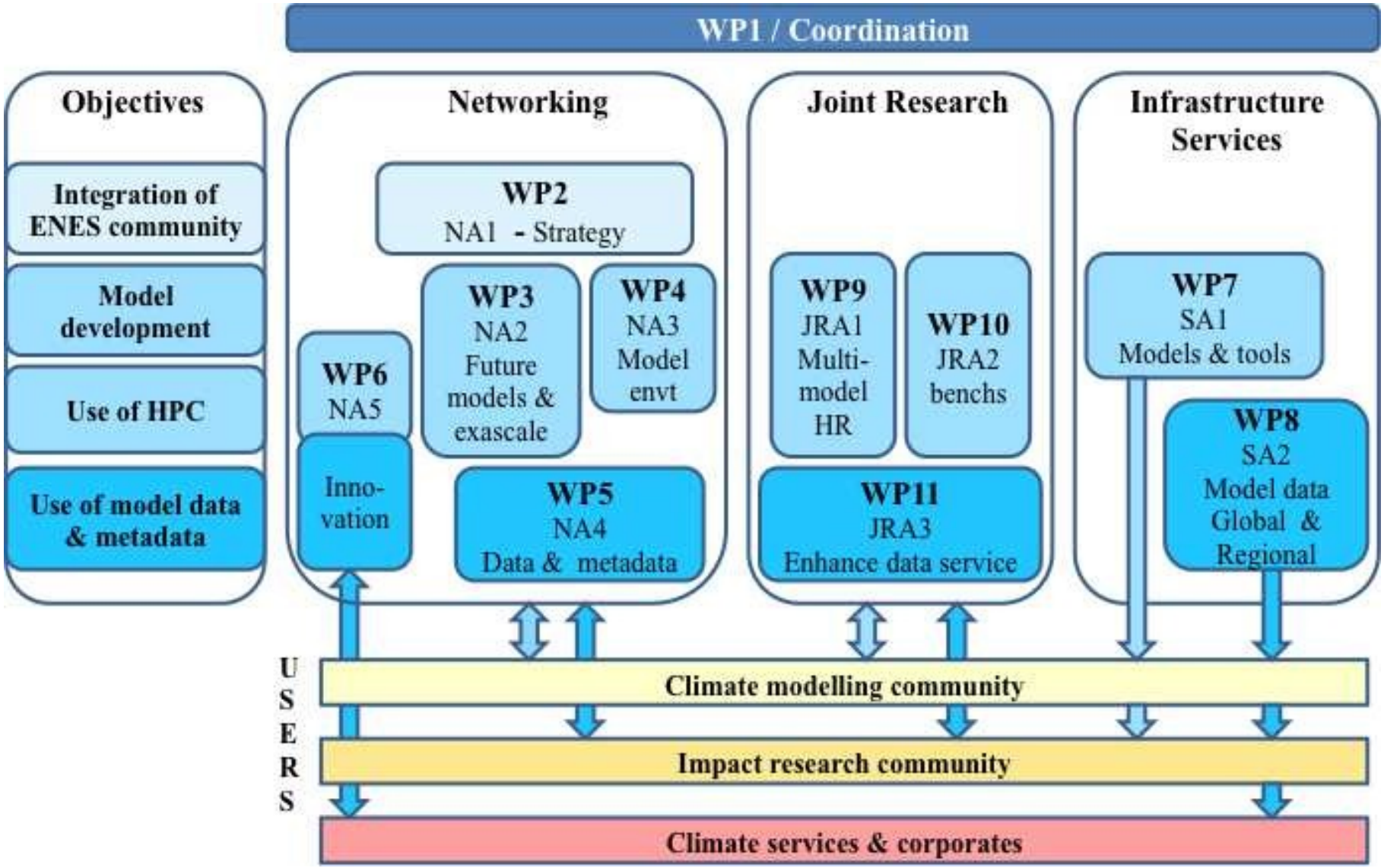
- Services to impact community

# IS-ENES2: Goals

Apr 2013- March 2017 (8 M€), 23 partners



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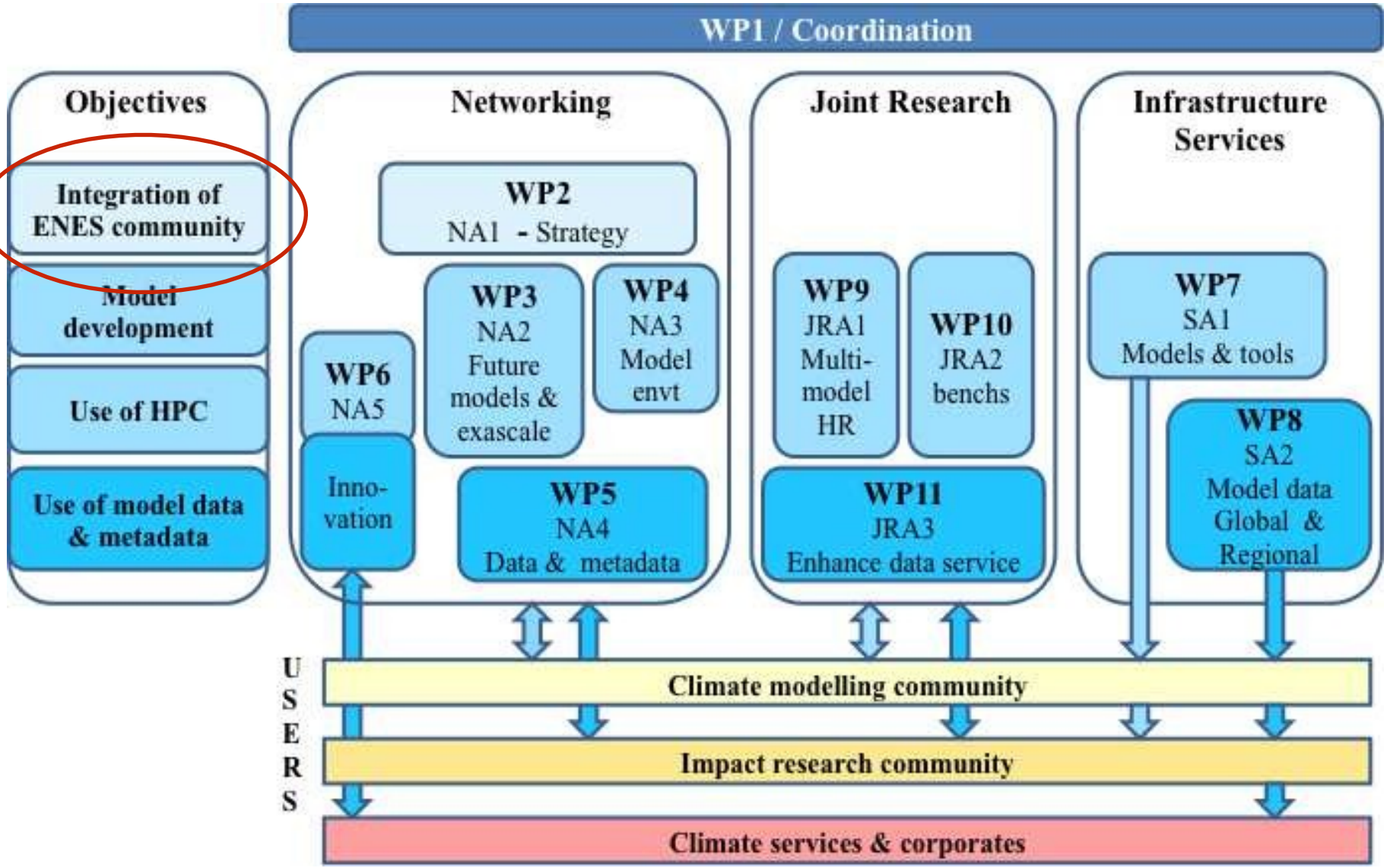

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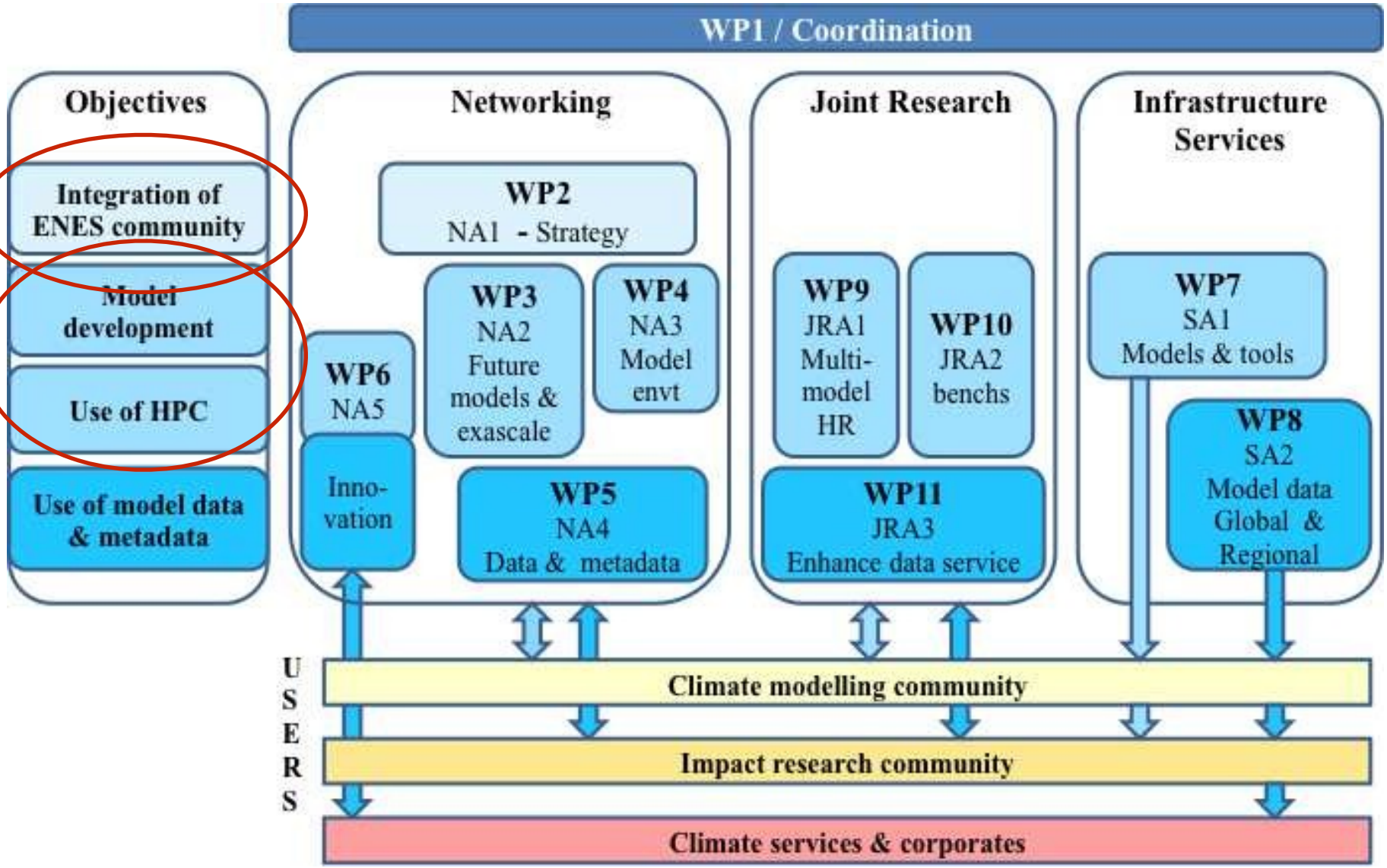

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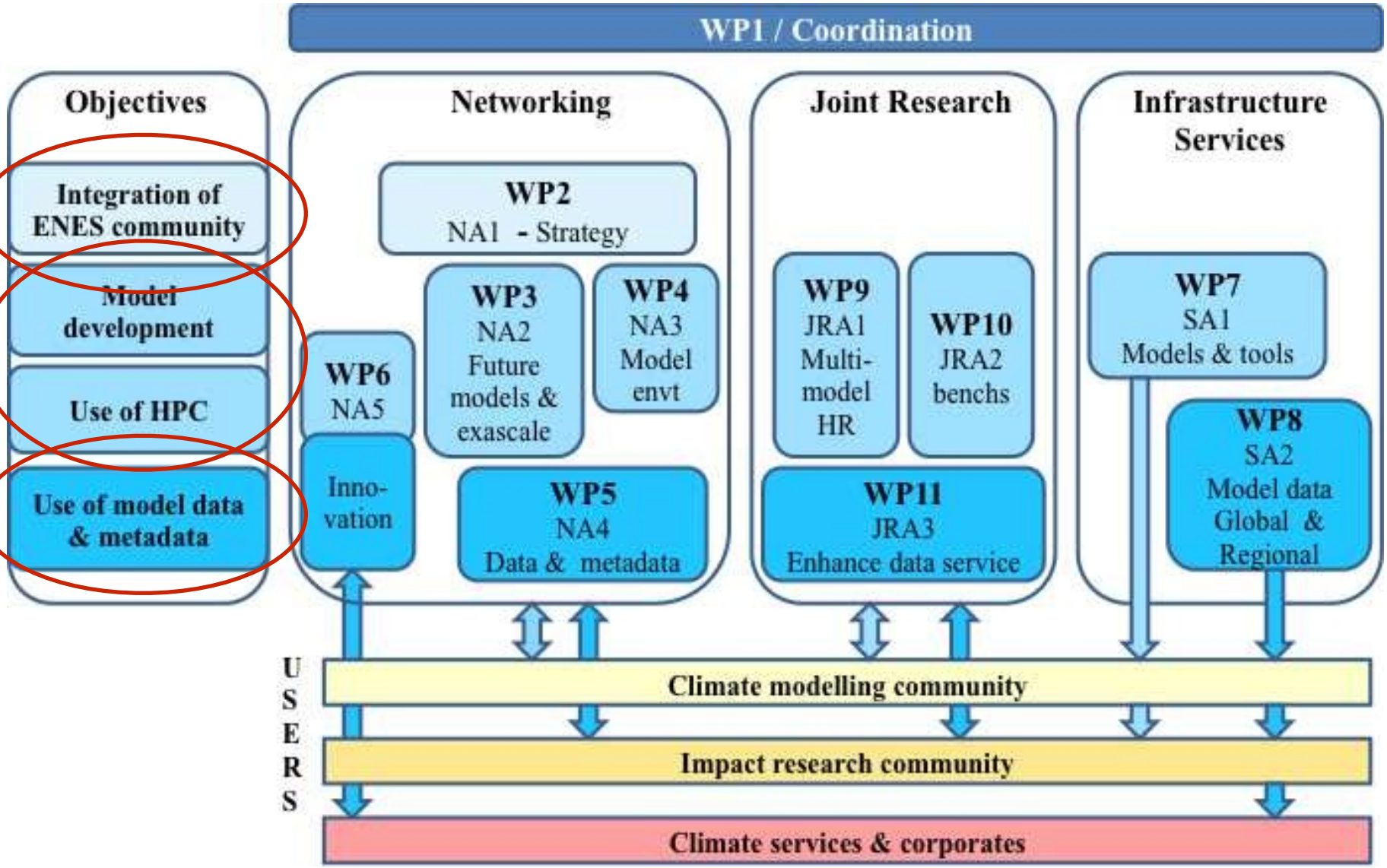

# IS-ENES2: Achievements

★ Next slides from 1st ISENES“ GW in Barcelona, Spain, June 2014; Courtesy Sylvie Joussaume

# IS-ENES2 activities

## Foster the integration of the European ESM community

*Foster interactions, synergies and common strategies*

NA1
With all WP

**ENES Infrastructure Strategy :**

- Infrastructure for model evaluation
- Mid-term update 2016

**Community building**:

- Training school on ESM (2nd and 3rd schools)
- ENES portal (cont.)

- **Strengthen governance:**
  - ENES Scientific Officer : Francesca Guglielmo 01/07/2014
  - Organisation of ENES (ENES Board& task forces)
  - Governance on common software

Courtesy Sylvie Joussaume

# IS-ENES2 activities

## Enhance the development of ESMs

*Accelerate progress/ Foster common developments/ Share expertise*

**Service on models and model environment:**

- Model documentation (CIM CMIP5)
- Service on tools and components: OASIS, CDO & NEMO
- Service on models :

  Level 1 (information on models) & Level 2 (codes)

SA1

**Towards next generation models:**

- Common radiation (Euclipse)
- Code/software convergence
- NEMO Kernels

NA2

NA3

**Sharing best practices for model environments**

- Configuration management, workflow ….

Courtesy Sylvie Joussaume

# IS-ENES2 activities

## Support high-end simulations

*Ensure efficient access and execution of ESMs on HPC*

**Networking on high-performance computing (HPC):** NA1

- HPC Task Force, Common strategy, interface with PRACE RI
- Technology tracking for exascale NA2

**Improve model performance on HPC**: JRA1

- I/O, coupler, post-processing, running ensembles
- Performance analyses

**Prepare future high-end experiments** (SPECS) JRA1

- Ensemble High-Resolution

**Develop coupled benchmarks** JRA2

Innovation: **Interactions with ICT & vendors** NA5

Courtesy Sylvie Joussaume

# IS-ENES2 activities

## Facilitate the dissemination of ESM simulation results

*Ease use of model results fro climate research & for climate impact research*

**Service around model results** — SA2
- CMIP5 & CORDEX
- Service to providers (data nodes) & users

**Develop more efficient tools for ESGF** — JRA3

**Metadata**
- upgrades & interoperability

**Services for climate impacts** — NA4, JRA3
- Tools, downscaling, indices

**Societal innovation**: — NA5
- to corporates (coll Climate KIC)
- to climate services centers (coll CSC)

Courtesy Sylvie Joussaume

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Brainstorming meetings on "issues left" identified three major issues

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# The European Network for Earth System Modelling ENES: Current Activities

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    - CoE
- ★ Conclusions


*From Leonardo Flores Añover & Aniyan Varghese*

- HPC strategy combining three elements:

*a.* Computer Science: towards **exascale** HPC;

*A special FET initiative focussing on the next generations of exascale computing as a key horizontal enabler for advanced modelling, simulation and big-data applications*

[HPC in Future and Emerging Technologies (**FET**)]

*b.* Providing **access** to the best supercomputing facilities and services for both industry and academia*;*

*PRACE - world-class HPC infrastructure for the best research*

*[HPC in **e-infrastructures**]*

*c.* Achieving excellence in HPC **applications**;

***Centres of Excellence*** *for scientific/industrial HPC applications in (new) domains that are most important for Europe*

[HPC in e-infrastructures]

- complemented with training, education and skills development in HPC

**(a) and (c) will be implemented in the context of the HPC Public-Private Partnership**

# FET =
# Future and Emerging Technologies

New activity of the EC in H2020

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Future and Emerging Technologies go beyond what is known! Visionary thinking can open up promising avenues towards powerful new technologies.

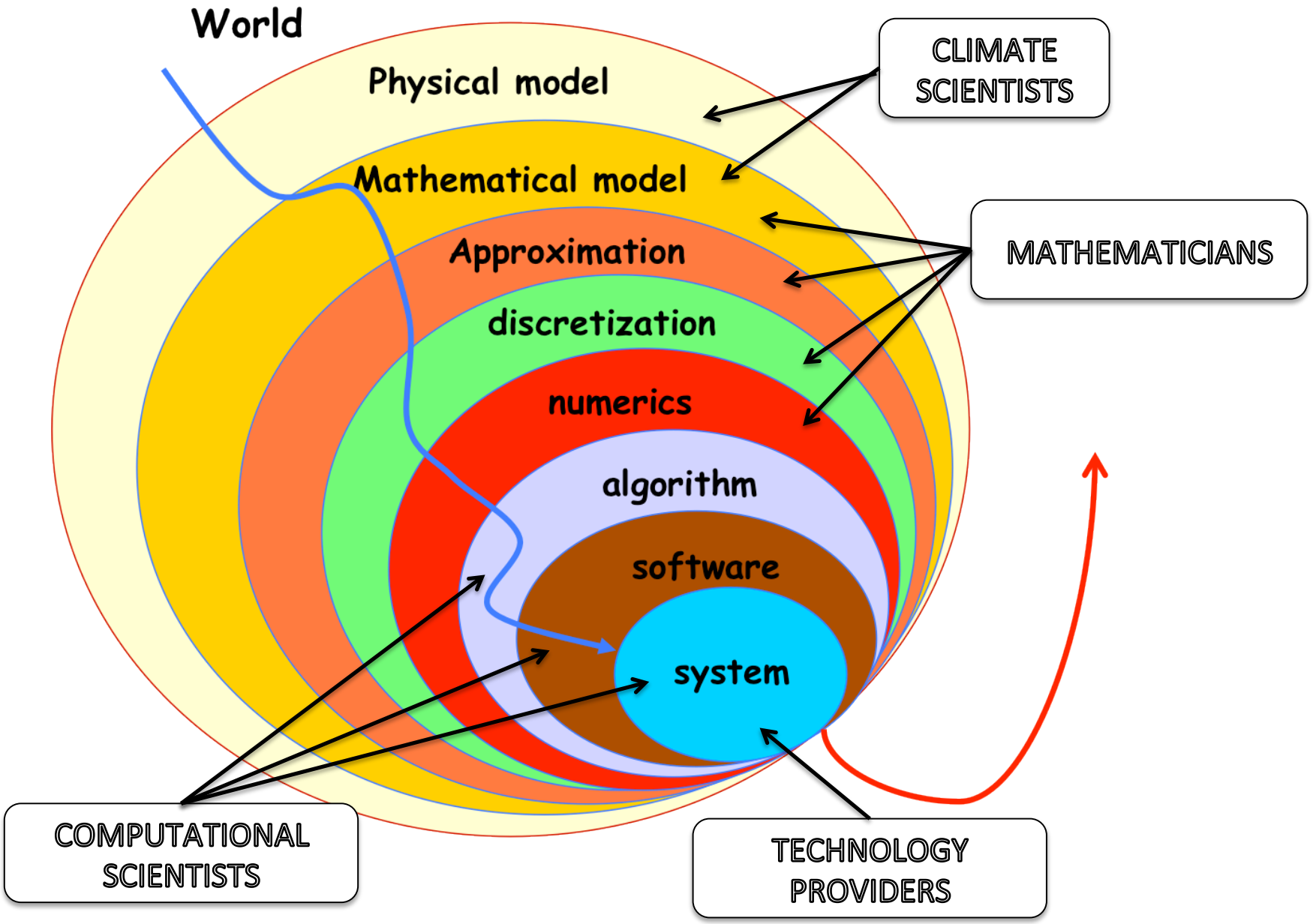
# FET: Future and Emerging Technologies

H2020 Call: FET-HPC1-2014

## Chance Proposal

- The CHANCE project aims at exploiting new mathematical and algorithmic approaches for existing or emerging applications on extreme scale systems
- The co-design approach will be used to optimize NEMO for exascale architectures
- Climate scientists, computational scientists, mathematicians and technology providers will work together, each focusing on the specific layers of the optimization chain

PI: Giovanni Aloisio, CMCC

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… is a complicated process

# Strategic issues for IS-ENES

**Earth's climate system modelling European research infrastructure**

**"CliM-ERI"**

Discussion on Friday

## Objectives

Accelerate progress in climate science &
Facilitate use of model results by a large range of user communities
(from research to climate services)

## Contour

**Climate models and environment tools / Computing (HPC) ecosystem / Data bases**

- Support the realisation of the WCRP international coordinated numerical experiments: CMIP & CORDEX cycles
- Provide access to model data/metadata (WCRP model data infrastructure)
- R&D : software development for models and data – issues on HPC and big data

**Human resources & computing/storage facilities**

**Proposal for the ESFRI roadmap update (end of 2014)**

Endorsed by JPI Climate (May 2014)

Slide Courtesy Sylvie Joussaume

# CoE =
# Centre of Excellence

- ★ Excellence in HPC applications
- ★ User-driven
- ★ Integrate HPC and data
- ★ Multi-disciplinarry
- ★ Co-locate
  - ★ domain and HPC system, software and algorithms
- ★ Distributed
- ★ Sustainable

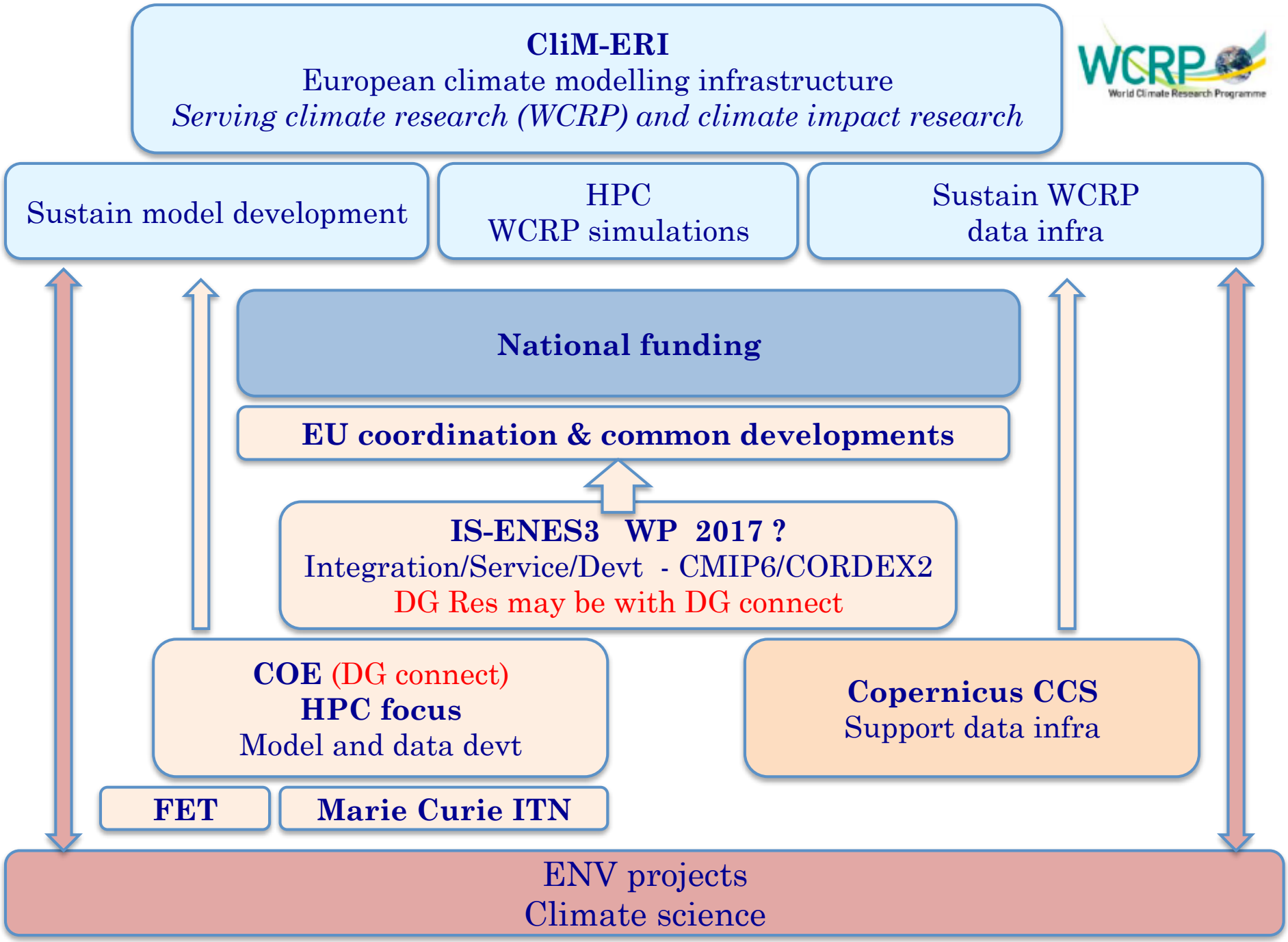
- ★ Dead Line 14.01.2015 for 8-10 prototypes
  - ★ 4-5 M€ each

- ★ Focus: Solve short-term issues with a service target

# ENES CoE (name tbd)

- 3 Topics
  - Scalability
    - Models
    - Model Development
  - Usability
    - Environments and workflows
    - Tools
  - Exploitability
    - Data
- PI
  Joachim Biercamp, DKRZ

- Major Issue:
  - Solve short term issues
  - Lay the ground for tackling the burning long-term problems
  - Establish the relevant services
  - Governance
    - To select right topics in order to focus
    - Integrate NWP and ESM

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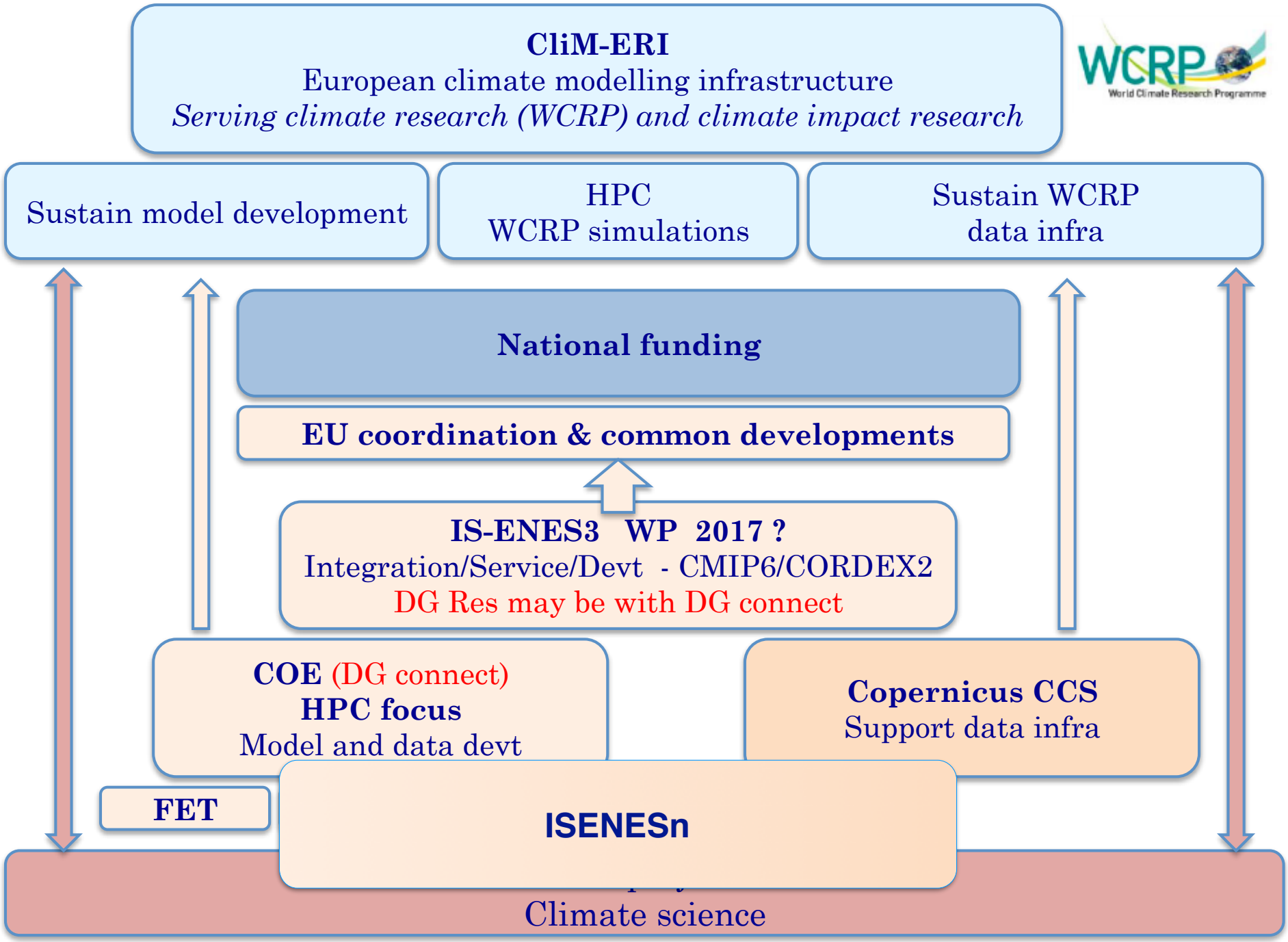


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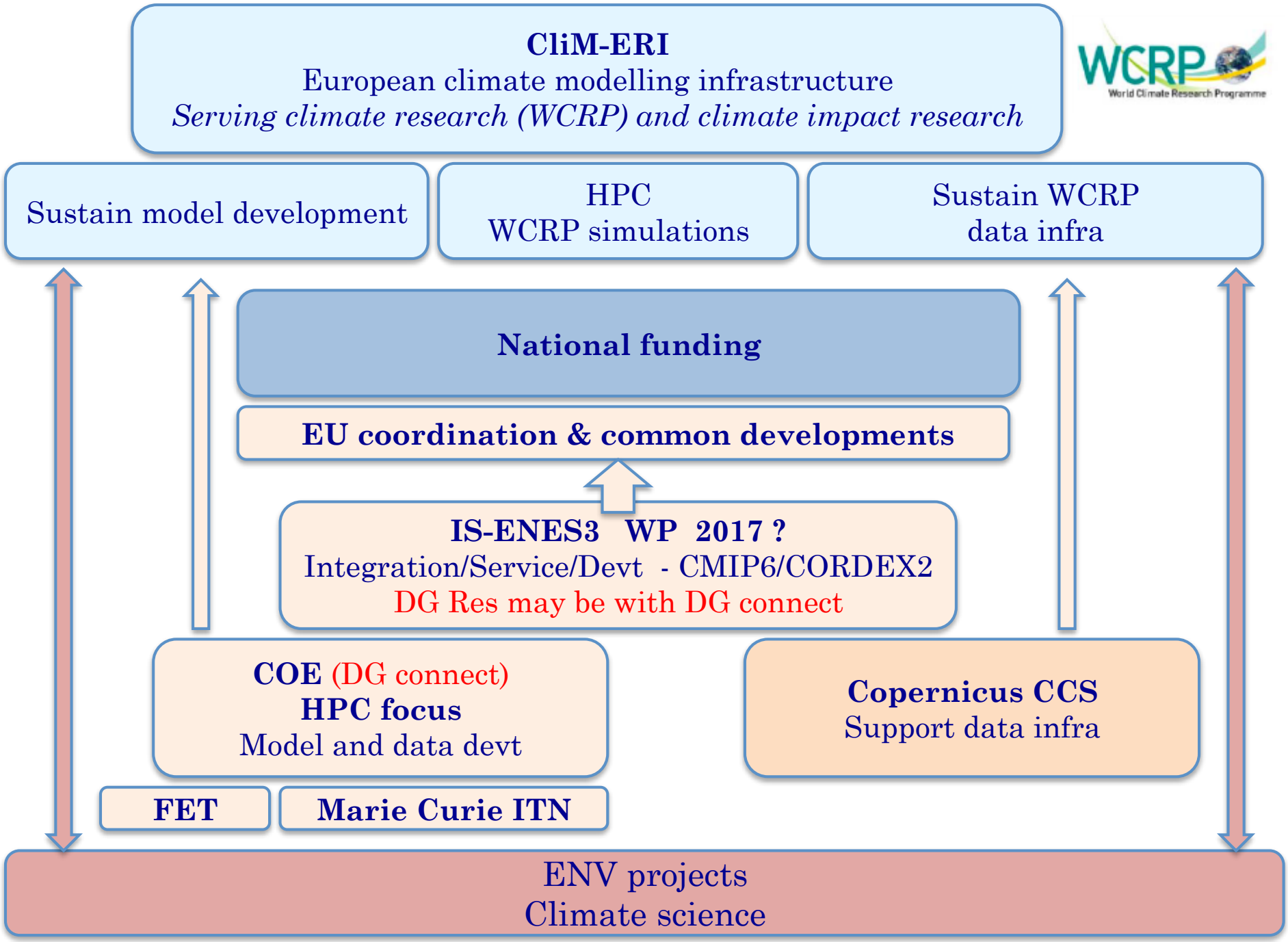


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# My Main Conclusions 2012

- Key drivers:
  + Science and Society
  – Computing HW
- Models need:
  + Competition in science
  + Common software IS
  + Increased resolution
  + Consideration of the complete line from NWP to ESM
- Modelers need
  + Education
  + Exchange
  + Reward
- Users need
  + Easy access to the data
  + Assistance in interpretation

# Conclusions

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We need to stabilize and improve ENES structures

We need to consider where NWP and/or operational oceanography and climate modeling can interact and cooperate more intensely?

COE leading this way….

Thank you


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