The WRF4G Python Framework for regional climate simulations with WRF model

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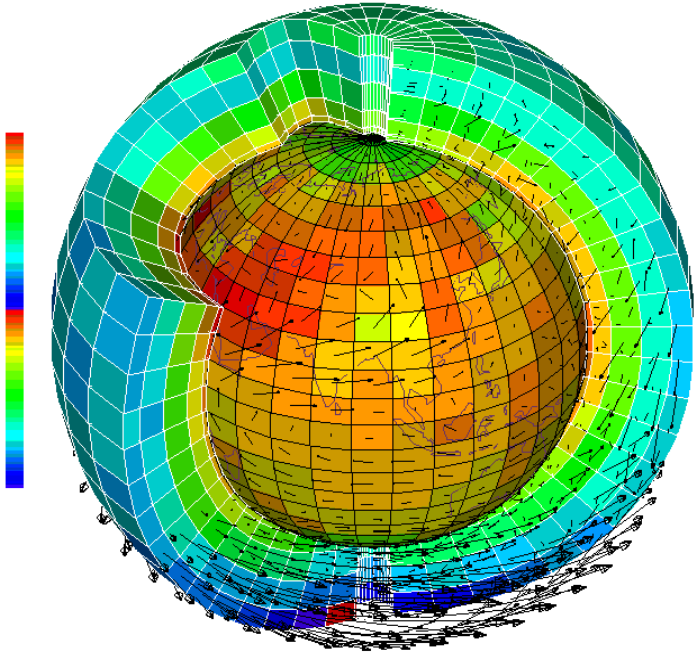
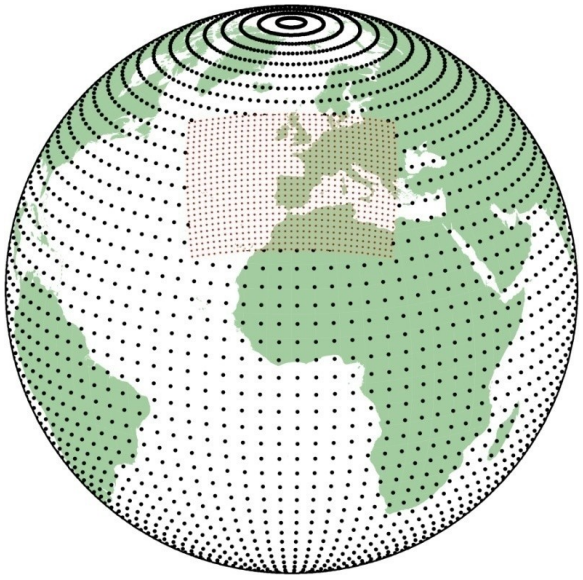
WRF4G Python Framework

WRF4G is a software framework developed in Python (75%) by the *Santander Meteorology Group*, which provides:

- Flexible WRF experiment **management**, **execution** and **monitoring**, and ...
- … run these experiments on **hybrid distributed computing infrastructures** (HDCI) concurrently in a **coherent** way.



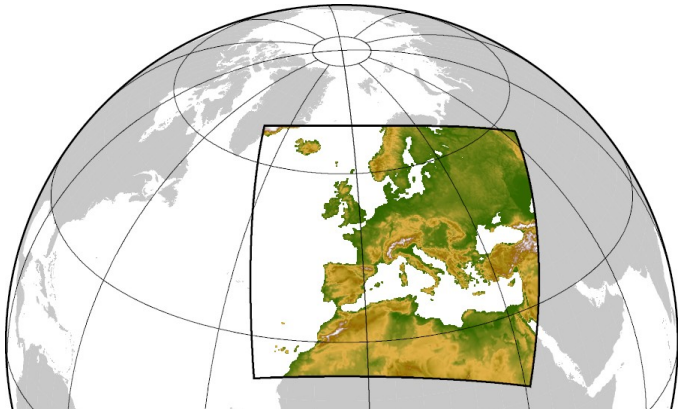


Crédit : Laurent Fairhead (LMD/CNRS)

WRF experimental setups

Reanalysis/Reforecasts/Hindcast

- High number (~10^4) of independent simulations
- High volume of output-data (>TB)
- Requires **scalability**

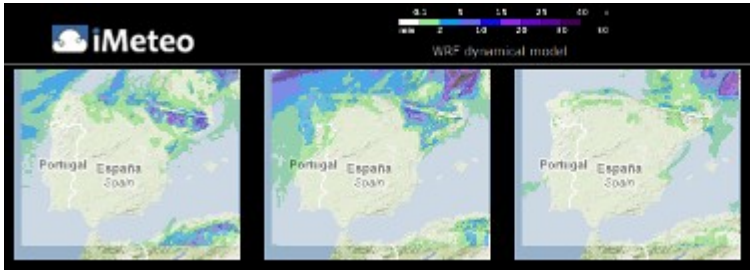


Regional climate simulation

- Long, continuous simulations; weeks of walltime
- High volume of output data (>TB)
- Recovering system for **simulation restart**

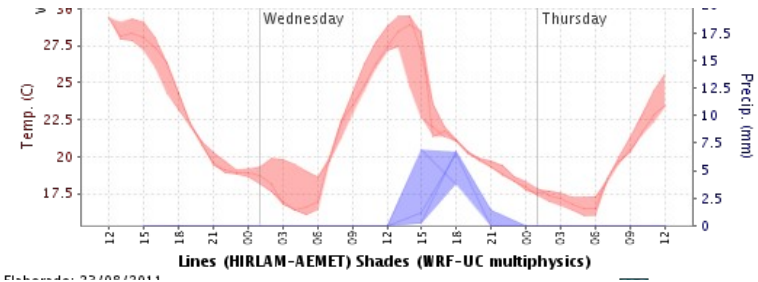
Weather Forecasting

- QoS and optimal resources: **deadline for delivery**

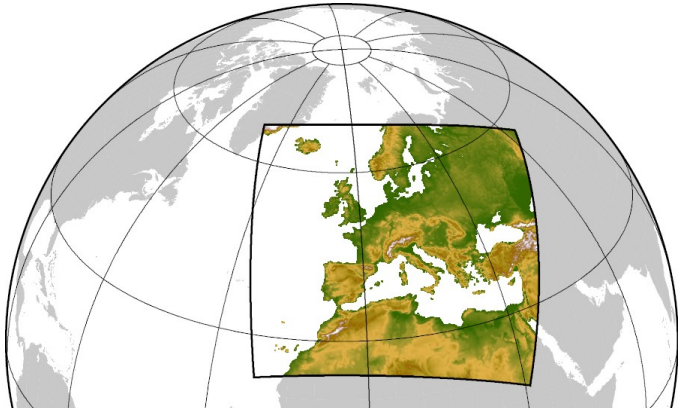


Sensitivity/ensemble studies

- Physical schemes, initial conditions and boundary conditions: uncertainty sampling
- Resource demanding experiments composed of many **independent simulations**



Examples: SantanderMetGroup



Reanalysis/Reforecasts/Hindcast

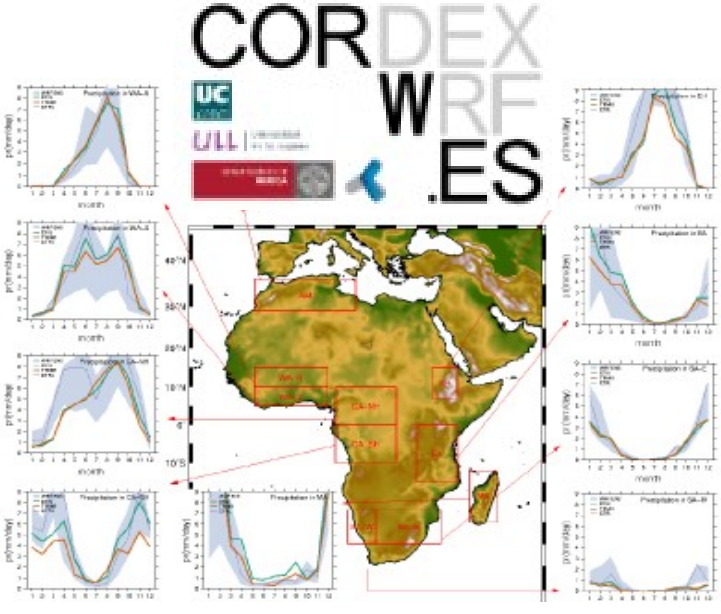
- SEAWIND project
- 21 years of daily reforecasts (36h each)
- 7,665 independent simulations

Regional climate simulation

- ESCENA & CORDEX projects: EUR, AFR and SAM
- 50 years (continuous run, 28-day restarts)
- 650 dependent simulations

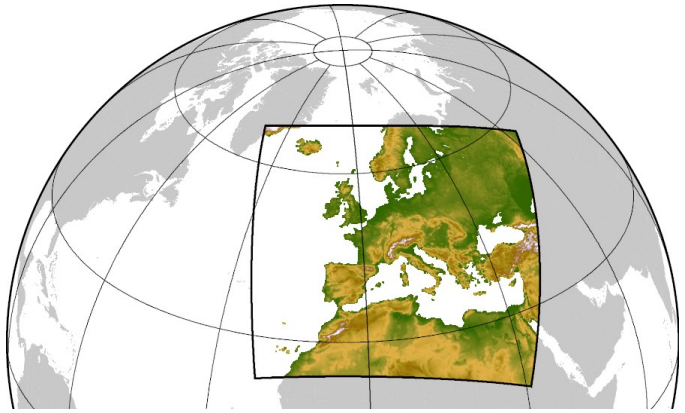
Sensitivity/ensemble studies

- CORWES project
- Physics sensitivity study for CORDEX-Africa
- 8-member ensemble of 5-year continuous simulations
- 8 independent groups of 65 dependent simulations



Benchmark

SEAWIND experiment set: past reforecasts of an improved wind field over Europe for off-shore wind farms.



- Characteristics of each experiment
  - 21 years of daily reforecasts (36h each)
  - 7,665 independent simulations
- Computation cost of each experiment
  - Working Node Architecture
    - CPU: Dual 8 Cores CPU
    - RAM Memory: 16 GB
  - Result
    - WALLTIME (MPI job) = 21 x 365 x 70' ~ **2 years**
    - Output = 21 x 365 x 17 GB ~ **130 TB**

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UNIVERSIDAD DE CANTABRIA

HDCI scenarios

Desktop/Laptop (UI)

- Limited computational power and storage
- **User interface** to other computer resources

Workstation

- Multi-core, shared memory, moderate storage
- Typically **ssh access**

Local group/institutional cluster

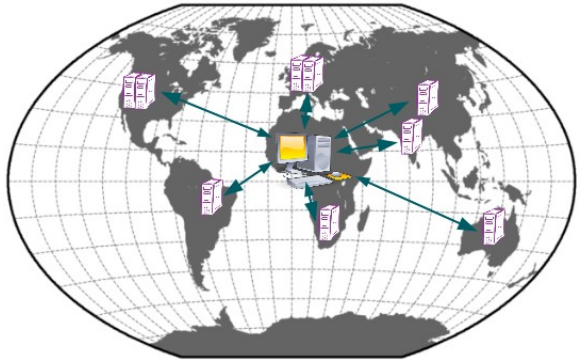
- Multi-node, distributed memory, large storage
- ssh access, **batch system** (PBS, SGE, ...) to submit jobs

Mainframe/HPC site

- **Different architectures** and memory configurations
- ssh or kerberos and token based security

Cloud/Grid infrastructures

- Geographically and temporal distributed and on-demand scalability.
- **Huge amount of potential computational power** and storage, which is not trivial to take advantage of it for weather & climate applications
- Distributed and federated authentication and authorization infrastructures



Statement of the problem

CARLOS

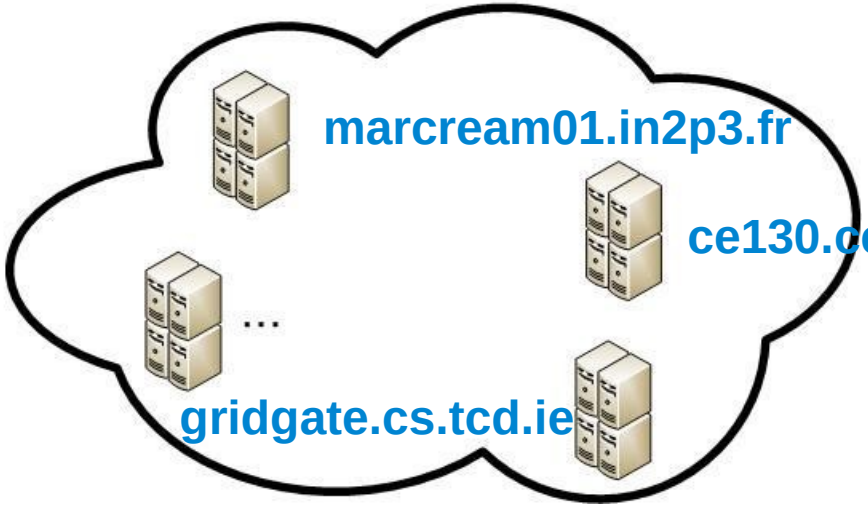
Statement of the problem

Workstation **Oceano**

CARLOS

PC
Blizzard

Supercomputer **Altamira**



Cloud/Grid

Statement of the problem

Workstation **Oceano**
UC

CARLOS

PC
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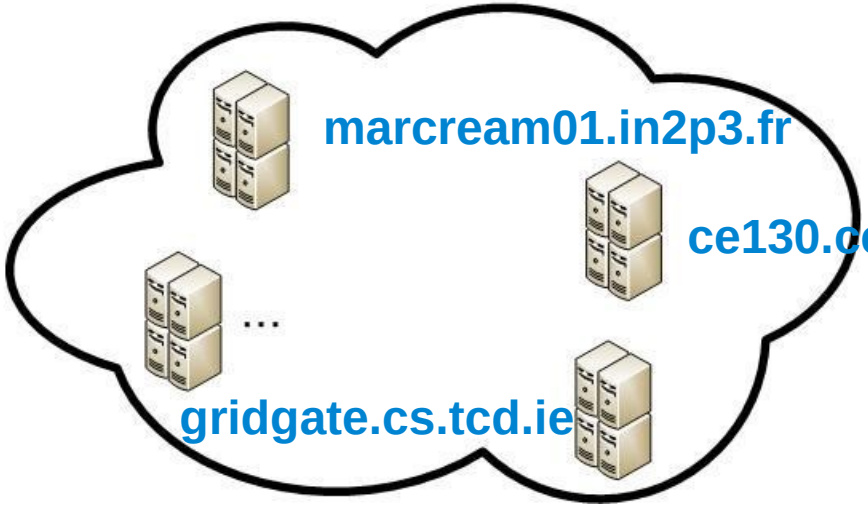
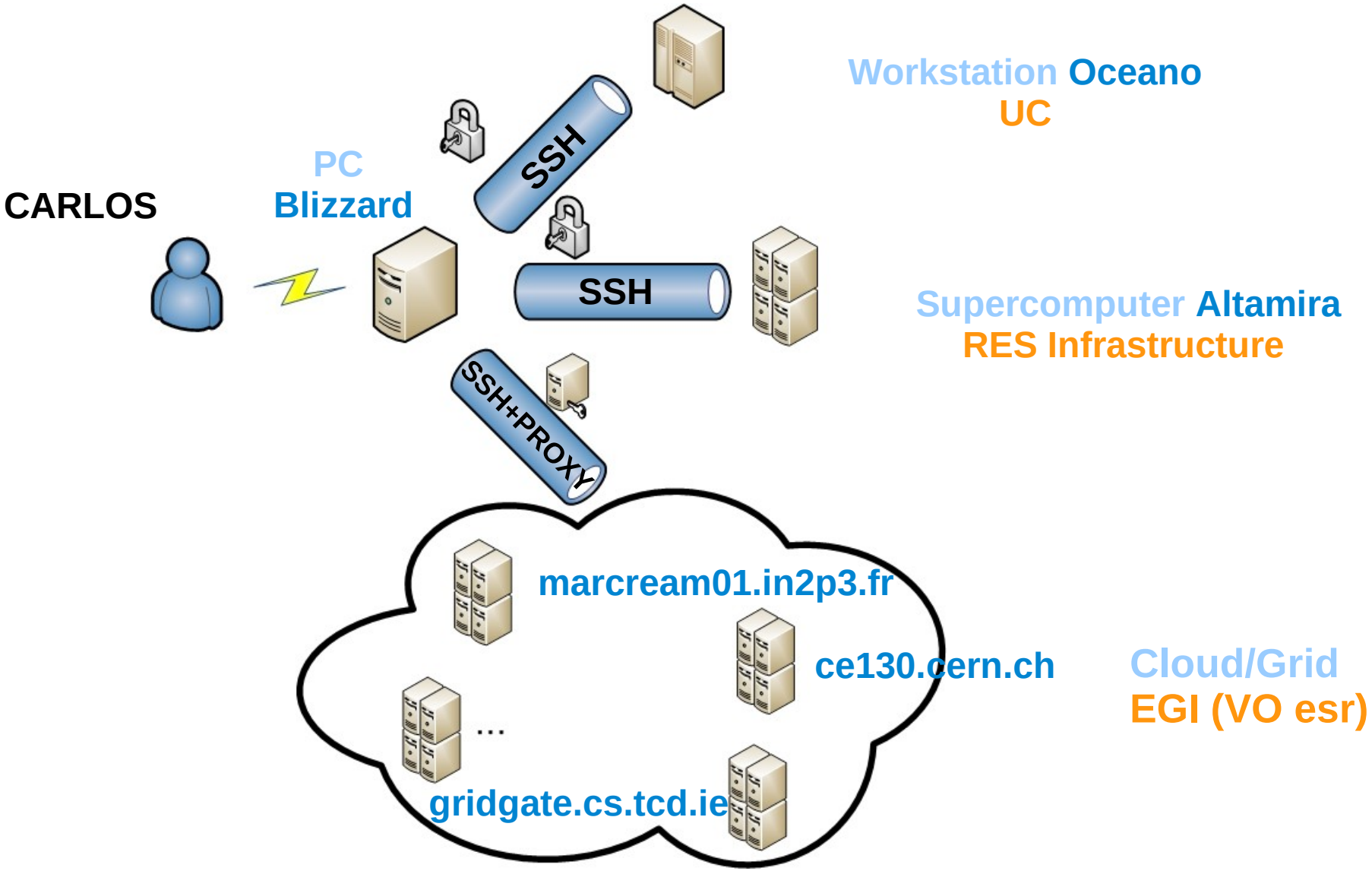
Supercomputer **Altamira**
RES Infrastructure



Cloud/Grid
EGI (VO esr)

Statement of the problem



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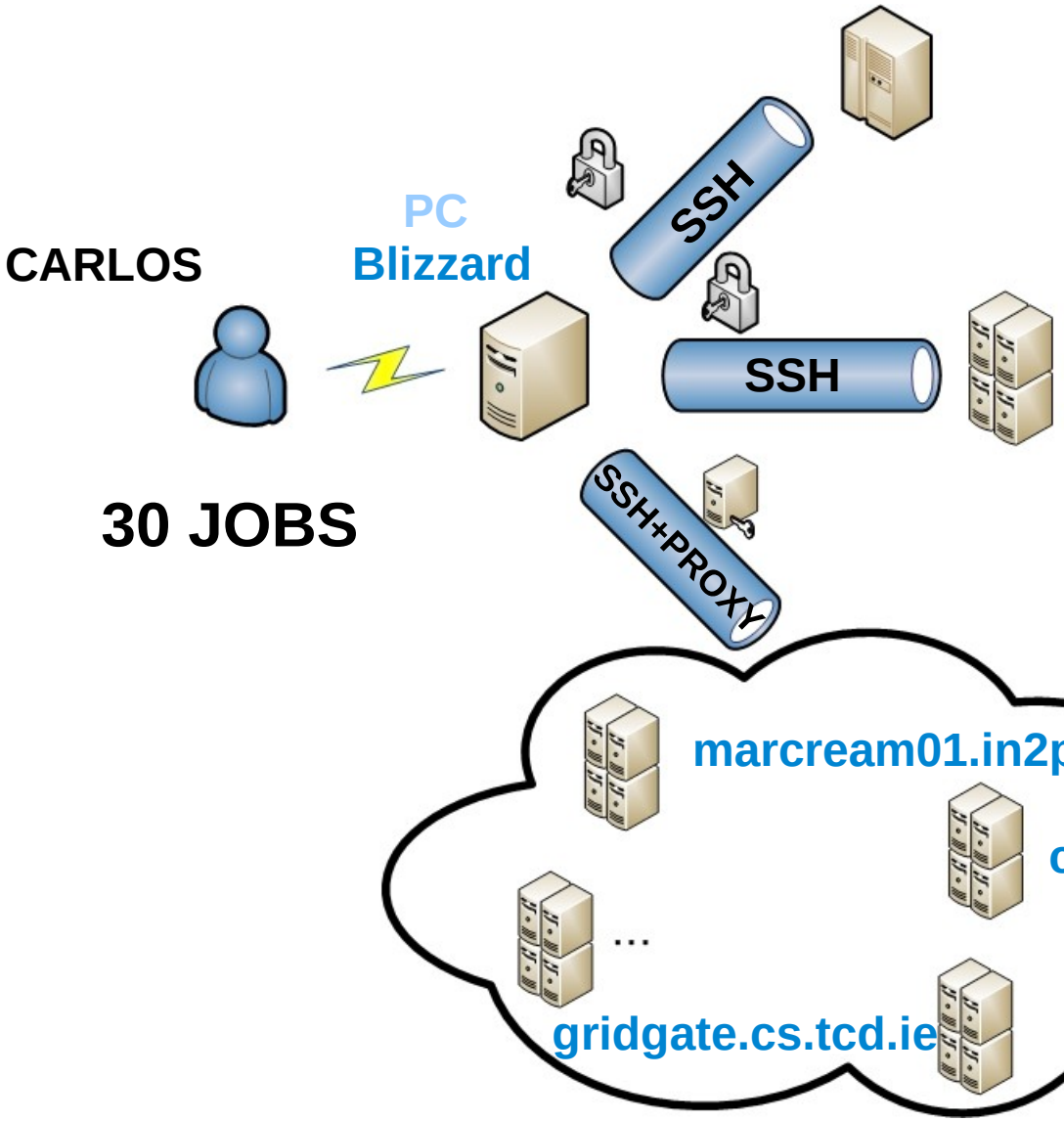


10 JOBS

Workstation **Oceano**
UC

10 JOBS

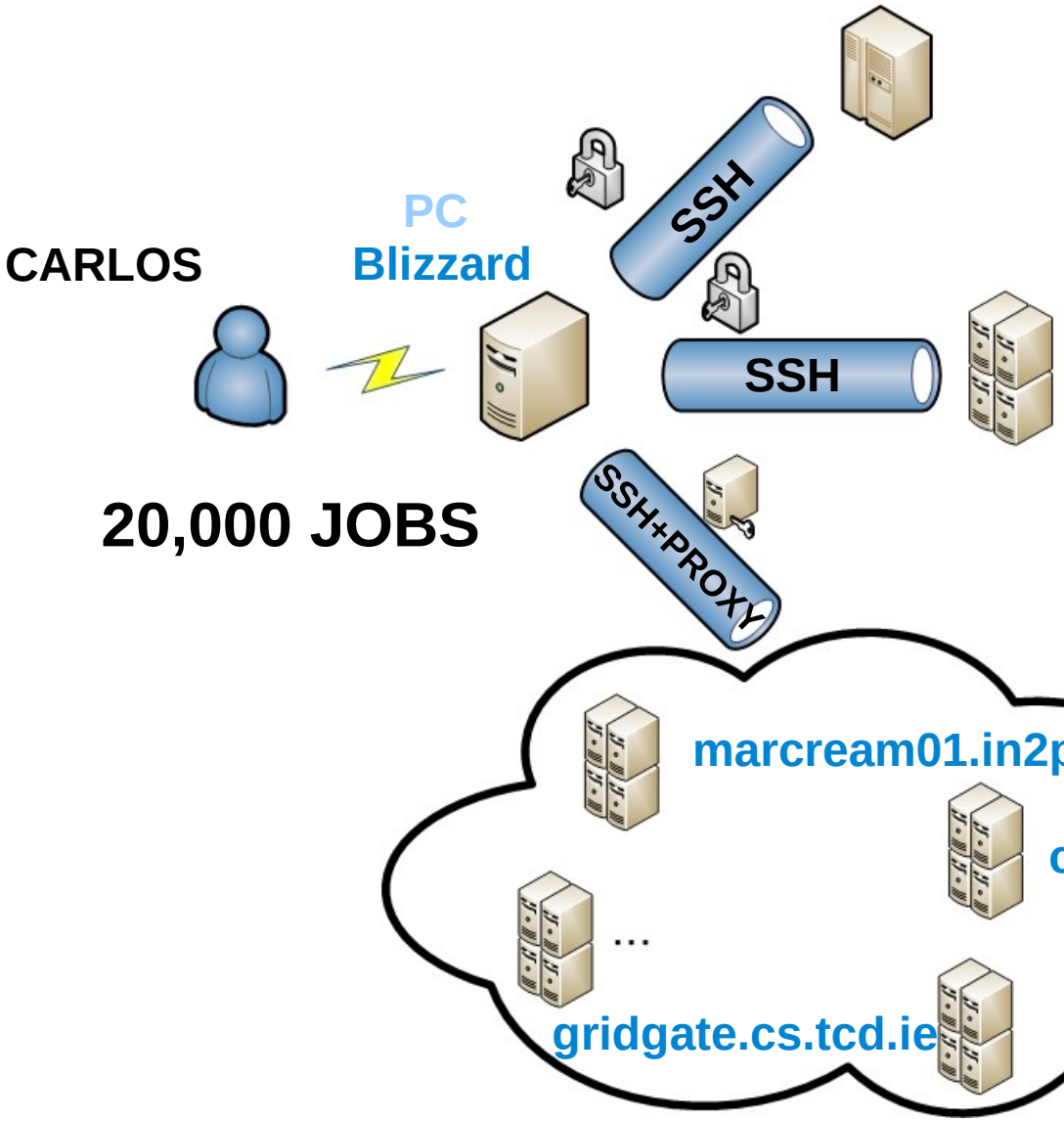
Supercomputer **Altamira**
RES Infrastructure

30 JOBS

10 JOBS

Cloud/Grid
EGI (VO esr)

Statement of the problem



? JOBS

Workstation **Oceano**
UC

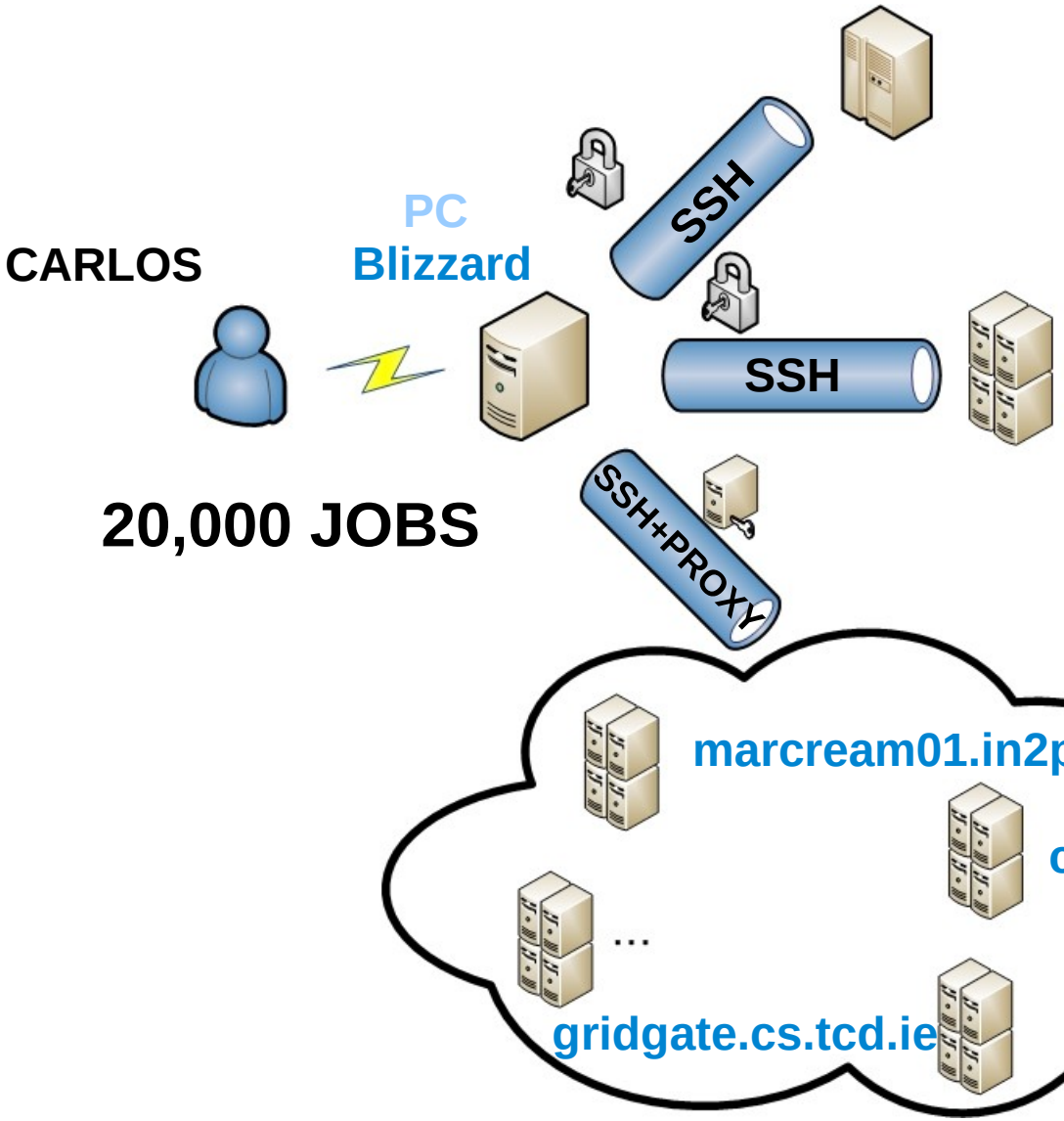
? JOBS

Supercomputer **Altamira**
RES Infrastructure

? JOBS

Cloud/Grid
EGI (VO esr)

Statement of the problem



? JOBS

Workstations **Oceano, Sea, ...**
UC

? JOBS

Supercomputer **Altamira, MN3, ...**
RES Infrastructure

? JOBS

Cloud/Grid
EGI (VO esr),
GISELA(VO prod.vo.eu-eela)

Requirements

- Uniform access to available resources
- Simple interface
- Robust and scalable
- Keep track of jobs
- Easy configuration
- Easy deployment and *batteries included*

WRF4G 2.0 Key features

- Written in **python.** Some bash scripts
- **Meta-scheduler** (DRM4G & GridWay)
- Advanced **CLI** with subcommands and **python API**:
  `$ wrf4g exp test submit`
- Dynamic management of **Hybrid-DCIs** (Grid, HPC,...)
- **Scalable** (~100,000 jobs)
- **Ready-to-run** (Linux). **WRF binaries** included. Some tools like nco, cdo OpenMPI stack.
- Simplification of **configuration files.** Easy experiment definition
- ORM abstraction layer for experiment's metadata management
- **Workflow execution** (other climate models such as CAM)
- **Identity management** (private/public keys and X509 tokens)

WRF4G Data Model

WRF4G splits a regular WRF simulation **experiment** into:

- **realizations**
  - A realization is a **independent WRF simulation**
- **chunks**
  - For convenience, a WRF realization are split into chunks. By definition, a chunk is a **dependent partial simulation** and requires the previous chunk to start.
  - Chunks depend on **computing resource limitations**: `WALLTIME, RESOURCE DISK QUOTA, ...`
  - Chunks allow to **customize** the size of the input files (boundary and initial conditions).

WRF4G Benefits

WRF4G helps to manage, execute and monitor of complex experiments using WRF simulations in HDCI providing a coherent access to computing and storage resources.

- It allows efficient use of HDCI resources without increasing complexity to the researchers.
- Its ability to add resources on-demand makes it ideal for solving work peaks or SLA with Cloud resources
- The meta-scheduling training and proper management of replicas are key to optimize the use of resources

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Large-scale climate simulations harnessing clusters, grid and cloud infrastructures

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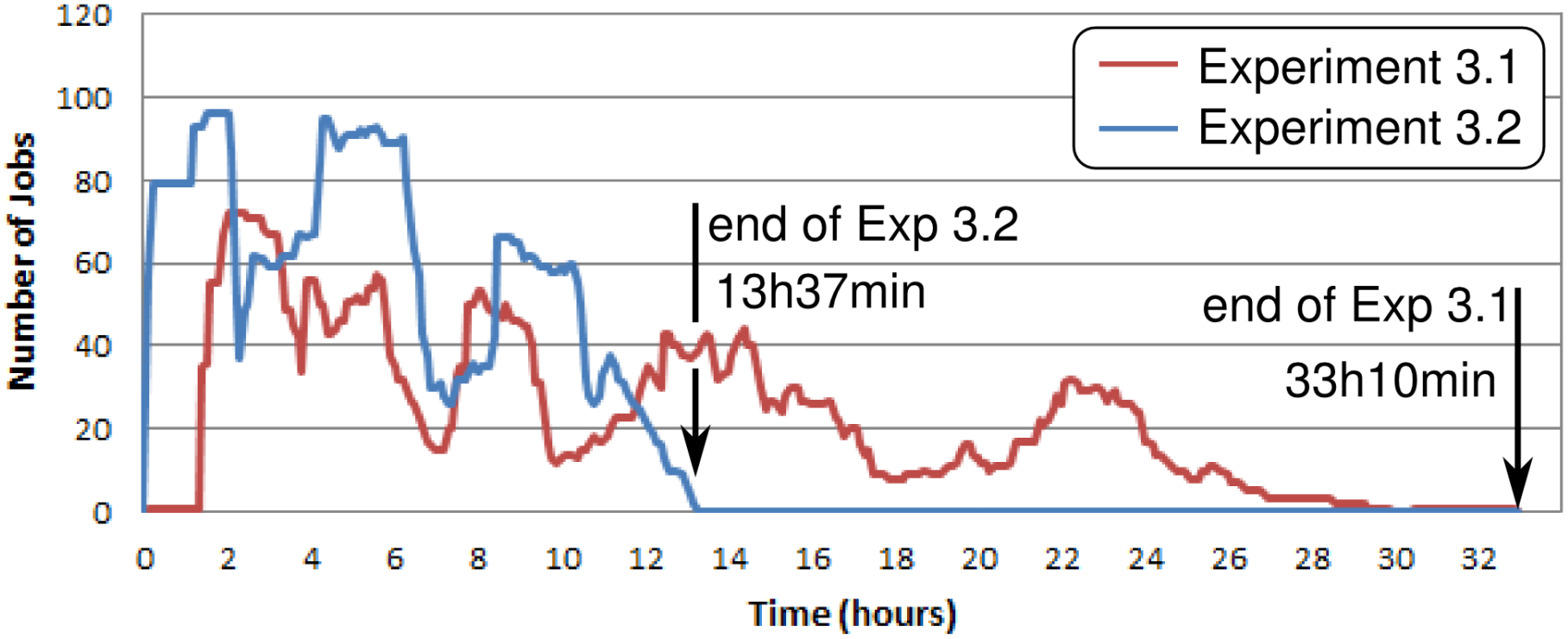

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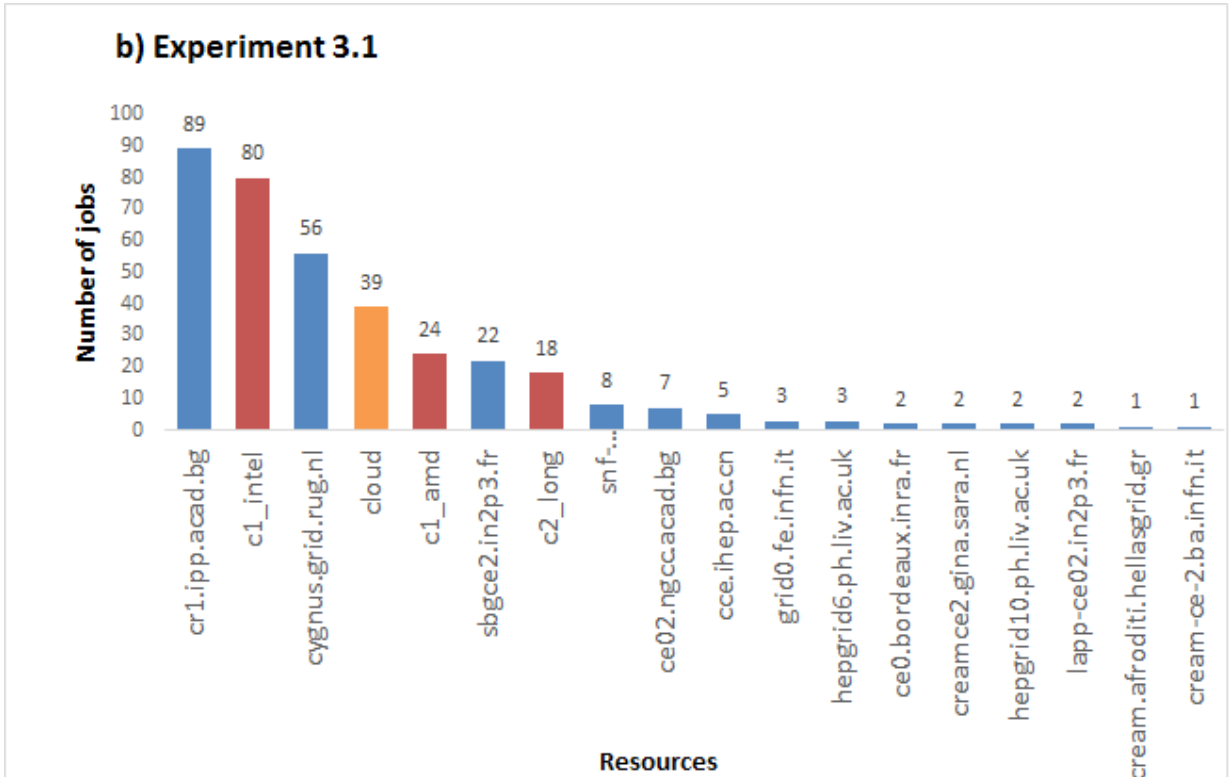
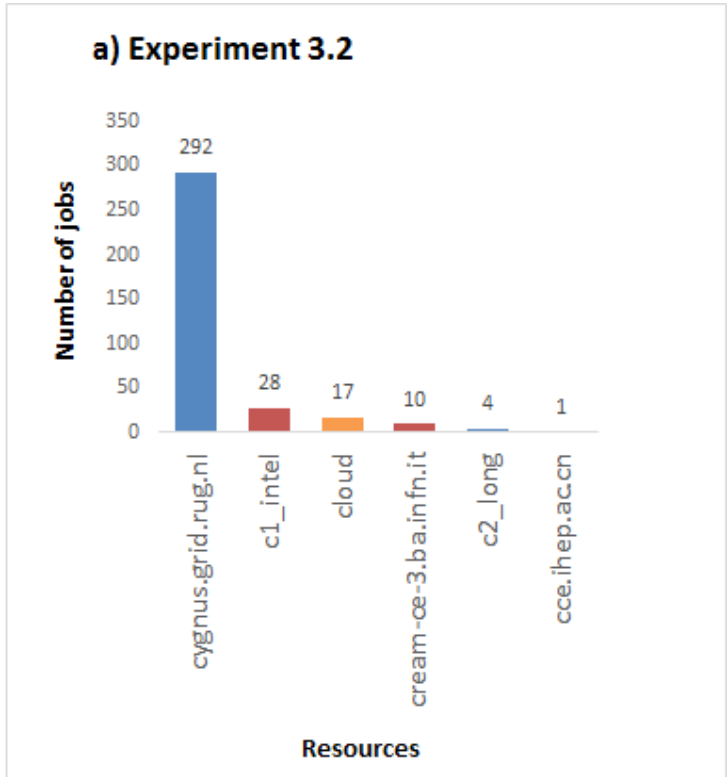




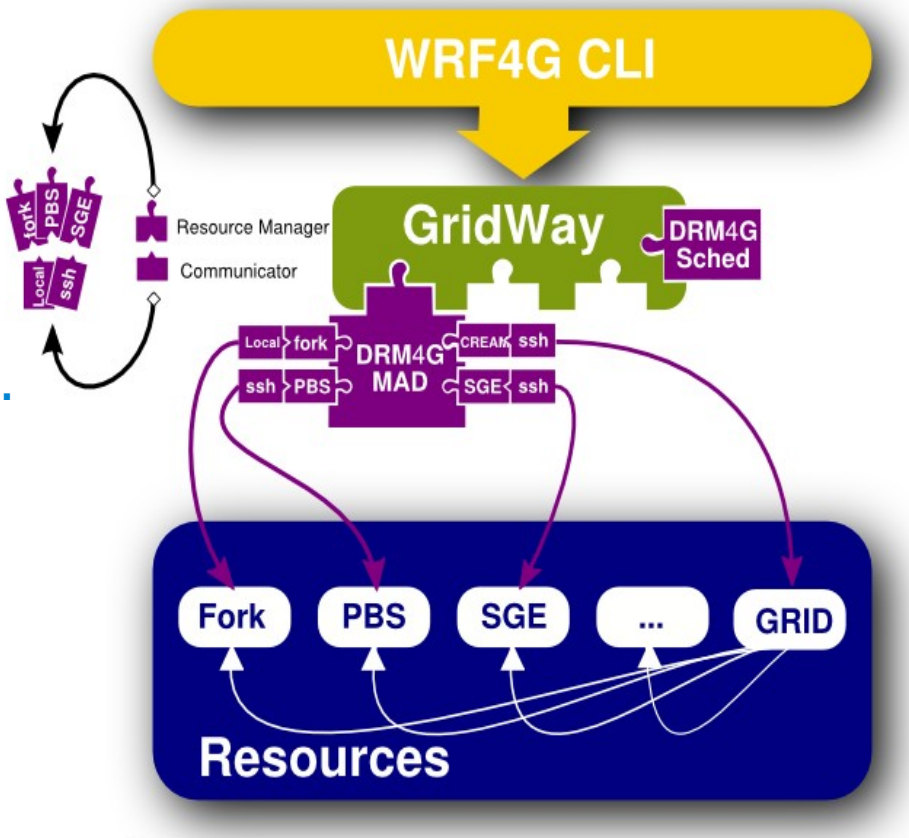
Meta-scheduler: DRM4G

- **CLI** offers users a command to submit, cancel, and monitor WRF simulations and configure resources.
- **GridWay core** is in charge of job execution and resource brokering.
- **Sched** is responsible for scheduling jobs.
- Middleware Access Driver (**MAD**)
  - Infrastructure Managers

    ROCCI, BOTO, APACHE CLOUD, ...
  - Resource Managers

    FORK, SGE, PBS SLURM, CREAM, GLOBUS, ...
  - Communicators Managers

    LOCAL, SSH, GSISSH, OPENID, ...



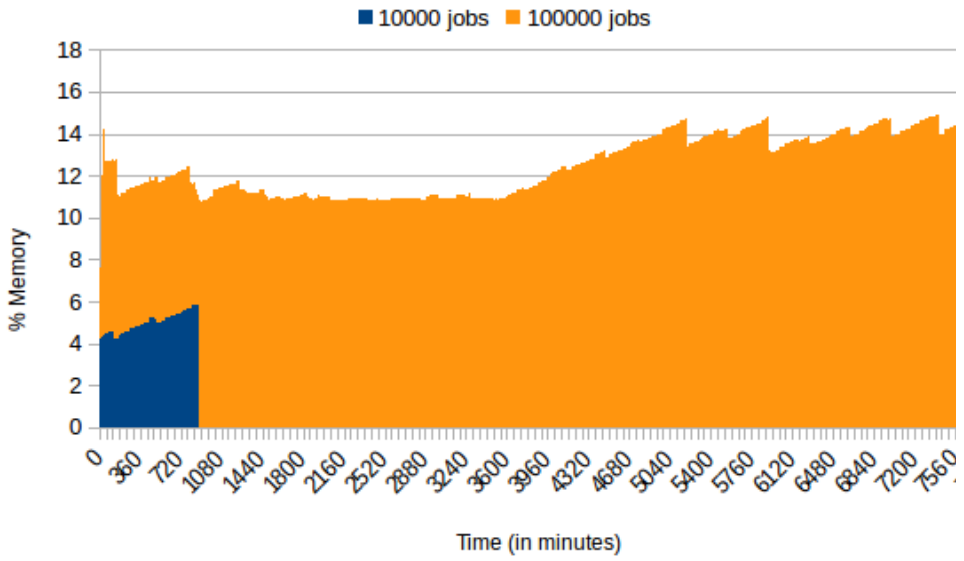
DRM4G Scalability

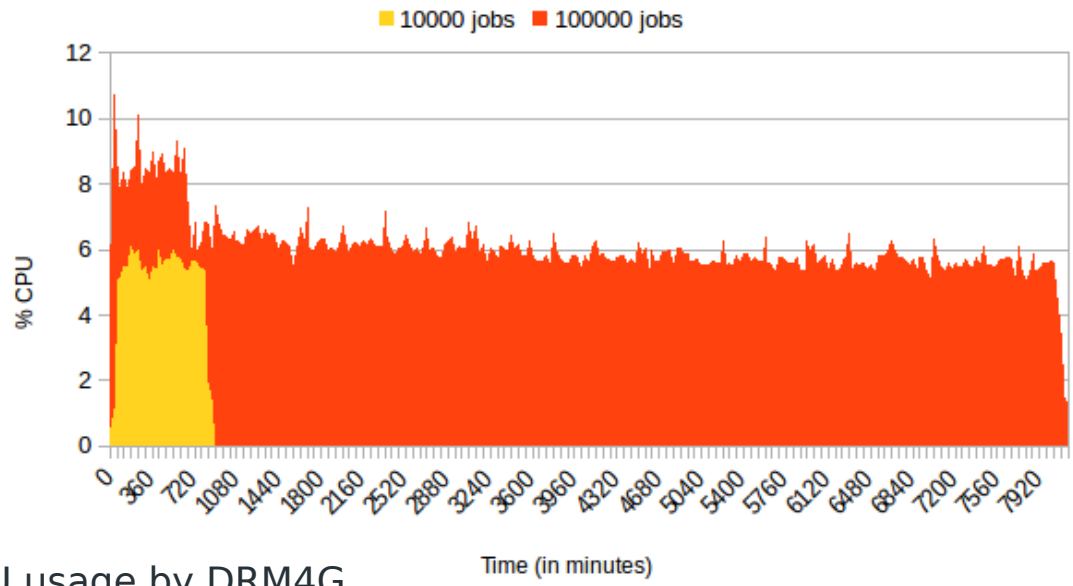
Scalability experiment on a laptop (Intel Core i5 at 1.9 Ghz and 8GB of RAM)

10K job experiment:

Meta-scheduler	Job assimilation	CPU	Memory
GridWay	4 minutes(blocking system)	~13%	~20% (400 MB)
DRM4G	75 seconds	~5%	~5% (100 MB)

100K job experiment:





Memory and CPU usage by DRM4G.

Download & deploy

```
$ wget https://meteo.unican.es/work/WRF4G/install.sh
$ bash ./install.sh
============================
WRF4G installation script
============================
--> Downloading wrf4g_x86_64_versions from ...

This script will install WRF4G version: 2.2.1

--> Downloading wrf4g-2.2.1-x86_64.tar.gz from ...
--> Unpacking wrf4g-2.2.1-x86_64.tar.gz in directory /home/user ...

====================================
Installation of WRF4G 2.2.1 is done!
====================================
In order to work with WRF4G you have to enable its
environment with the command:

    . /home/user/wrf4g/bin/wrf4g_init.sh

You need to run the above command on every new shell you
open before using WRF4G, but just once per session.
```

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=====
WRF4
=====
--> I

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Latest version:
https://meteo.unican.es/trac/wiki/WRF4G2.0

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You need to run the above command on every new shell you
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```

Starting

```
$ source ./wrf4g/bin/wrf4g_init.sh

$ wrf4g start
Starting DRM4G ...
  OK
Starting WRF4G_DB (MySQL) ...
  OK


$ wrf4g status
DRM4G is running
WRF4G_DB is running


$ wrf4g resource edit
```

Resource Configuration I

resources.conf

```
[altamira]
communicator       = ssh
username           = uc15003
frontend           = altamira1.ifca.es
private_key        = ~/.ssh/id_rsa
lrms               = slurm_res
max_jobs_running   = 40
max_jobs_in_queue = 50

[marenostrum]
communicator       = ssh
username           = ecm86048
frontend           = mn1.bsc.es
private_key        = ~/.ssh/id_dsa
lrms               = lsf
max_jobs_running   = 50
max_jobs_in_queue = 60
```

Resource Configuration II

resources.conf

```
[egi_esr]
communicator      = ssh
username          = carlos
frontend          = ui.macc.unican.es
private_key       = ~/.ssh/id_rsa
grid_cert         = ~/cert.p12
lrms              = cream
vo                = esr
```

Resource Configuration II

resources.conf

```
[CESNET_Metacloud]
enable          = true
communicator    = ssh
vm_communicator= op_ssh
private_key     = ~/.ssh/id_rsa
username        = user
vm_user         = drm4g_admin
frontend        = ui.meteo.unican.es
lrms            = rocci
cloud_provider = EGI FedCloud - CESNET-METACLOUD
myproxy_server = myproxy1.egee.cesnet.cz
flavour         = Medium
virtual_image   = Ubuntu-14.04
instances       = 1
volume          = 10
max_jobs_running = 5
```

Identity configuration

```
$ wrf4g identity altamira conf
--> Configuring private and public keys ...
    Enter passphrase for key '/uc15/uc15003/.ssh/id_rsa':
    Identity added: /uc15/uc15003/.ssh/id_rsa (/uc15/uc15003/.ssh/id_
    Adding 'id_rsa.pub' to 'authorized_keys' on 'altamira1.ifca.es'
    Lifetime set to 604800 seconds
```

Experiment preparation

```
$ wrf4g identity altamira conf
--> Configuring private and public keys ...
    Enter passphrase for key '/uc15/uc15003/.ssh/id_rsa':
    Identity added: /uc15/uc15003/.ssh/id_rsa (/uc15/uc15003/.ssh/id_
    Adding 'id_rsa.pub' to 'authorized_keys' on 'altamira1.ifca.es'
    Lifetime set to 604800 seconds

$ wrf4g exp test start –-template-exp=single

$ ls test
 experiment.wrf4g wrf4g_files

$ wrf4g exp test edit
```

Experiment configuration I

experiment.wrf4g

```
[DEFAULT]
# Experiment configuration
experiment_name  = test
# Simulation domain
max_dom          = 1
# Experiment time-specification
start_date       = 2011-08-28_12:00:00
end_date         = 2011-08-30_00:00:00
calendar         = standard
chunk_size_h     = 12
# Namelist
namelist_version = 3.3.1
# Running options
np               = 1
requirements     = ARCH = "x86_64"
```

Experiment configuration II

experiment.wrf4g

```
[resource:altamira]
AL_HOME          =/uc15/uc15003 #auxiliar variable
# Input data
domain_path     = %(AL_HOME)s/domains/Santander_50km
extdata_vtable = GFS
extdata_path    = %(AL_HOME)s/input/NCEP/GFS
extdata_interval      = 21600
extdata_preprocessor = default
# Output
output_path    = %(AL_HOME)s/output
postprocessor = SFC
# apps
app_bundles = netcdf | %(AL_HOME)s/netcdf/netcdf-4.1.1.tar.gz
              nco    | %(AL_HOME)s/nco/nco-4.0.9.tar.gz
              cdo    | %(AL_HOME)s/cdo/cdo-1.3.0.tar.gz
              wrf    | %(AL_HOME)s/WRF/WRFbin-3.3.1.tar.gz
              mpi    | %(AL_HOME)s/openmpi/openmpi-1.4.tar.gz
```

Experiment preparation and submission

```
$ wrf4g exp test create
Preparing namelist...
---> Single params run
---> Continuous run
   ---> cycle_chunks: test 2011-08-28_12:00:00 2011-08-30_00:00:00
         ---> chunks 1: test 2011-08-28_12:00:00 2011-08-29_00:00:00
         ---> chunks 2: test 2011-08-29_00:00:00 2011-08-29_12:00:00
         ---> chunks 3: test 2011-08-29_12:00:00 2011-08-30_00:00:00

$ wrf4g exp test submit
---> Submitting realization: test
    ---> Submitting chunk 1: 2011-08-28_12:00:00 2011-08-29_00:00:00
    ---> Submitting chunk 2: 2011-08-29_00:00:00 2011-08-29_12:00:00
    ---> Submitting chunk 3: 2011-08-29_12:00:00 2011-08-30_00:00:00
```

Monitoring

```
$ wrf4g exp test status
Realization  Stat Chunks   Host        Run.Sta       JID ext      %
test         W    1/3      altamira    Waiting         0   -   0.00

$ wrf4g exp test status
Realization  Stat Chunks   Host        Run.Sta       JID ext      %
test         R    1/3      altamira    Running         0   -   0.00

$ wrf4g exp test status
Realization  Stat Chunks   Host        Run.Sta       JID ext      %
test         S    3/3      altamira    Submitted       1   -  33.33

$ wrf4g exp test status
Realization  Stat Chunks   Host        Run.Sta       JID ext      %
test         R    3/3      altamira    Running         2   -  66.67

$ wrf4g exp test status
Realization  Stat Chunks   Host        Run.Sta       JID ext      %
test         D    3/3      altamira    Finished        2   0 100.00
```

Projects

INSIGNIA: Contribution to CORDEX Flagship Pilot Studies: regional climate downscaling and data publishing

CORDEX4CDS: Facilitate access to and manipulation of output of regional climate projections over Europe and boundary conditions from GCM simulations needed for future regional projections.

WRF4G: Adaptation of WRF Model to Grid Infrastructures and user-case for wind hindcast over Europe

The SCI-BUS project aims to ease the life of e-Scientists by creating a new science gateway customisation methodology based on the generic-purpose gUSE/WS-PGRADE portal family (WRF4SG)

Coordinated regional climate downscaling experiment using WRF: a contribution to the CORDEX initiative by the Spanish WRF community

CORDEX - Coordinated Regional Climate Downscaling Experiment: a WCRP-sponsored program to produce regional climate change scenarios globally

Publications

- M. Menendez, M. Garcia-Diez, L. Fita, J. Fernandez, F.J. Mendez and J.M. Gutierrez, "**High-resolution sea wind hindcasts over the Mediterranean area**", Clim. Dyn, vol. 42, n. 7-8, pp. 1857–1872, Apr. 2013.
- M. García-Díez, J. Fernández, L. Fita, and C. Yagüe, "**Seasonal dependence of WRF model biases and sensitivity to PBL schemes over Europe**," Q.J.R. Meteorol. Soc., vol. 139, no. 671, pp. 501–514, Jan. 2013.
- G. Nikulin, C. Jones, F. Giorgi, G. Asrar, M. Büchner, R. Cerezo-Mota, O. B. Christensen, M. Déqué, J. Fernandez, A. Hänsler, E. van Meijgaard, P. Samuelsson, M. B. Sylla, and L. Sushama, "**Precipitation Climatology in an Ensemble of CORDEX-Africa Regional Climate Simulations**," J. Climate, vol. 25, no. 18, pp. 6057–6078, Feb. 2012.
- R. Vautard, A. Gobiet, D. Jacob, M. Belda, A. Colette, M. Déqué, J. Fernández, M. García-Díez, K. Goergen, I. Güttler, T. Halenka, T. Karacostas, E. Katragkou, K. Keuler, S. Kotlarski, S. Mayer, E. van Meijgaard, G. Nikulin, M. Patarčić, J. Scinocca, S. Sobolowski, M. Suklitsch, C. Teichmann, K. Warrach-Sagi, V. Wulfmeyer, and P. Yiou, "**The simulation of European heat waves from an ensemble of regional climate models within the EURO-CORDEX project**," Clim Dyn, vol. 41, no. 9–10, pp. 2555–2575, Apr. 2013.

Remarks

- The WRF user community usually:
  - designs experiments where many or huge (!!) simulations are required
  - has access to hybrid distributed computer infrastructures for running simulations
- WRF4G focus on simplify the design, execution and monitoring of WRF on several computing resources as an coherent meta-computer.
- WRF4G is available under EUPL-1.1

Thank you!

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More info: “wrf4g” → I'm Feeling Lucky

Wiki: https://meteo.unican.es/trac/wiki/WRF4G2.0

Code: https://github.com/SantanderMetGroup/WRF4G

Job position: 2 years contract for a Python engineer in ESS software frameworks.

Let me know if you’re interested!!