WRF4G Intro

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L. Fita
M. García-Díez

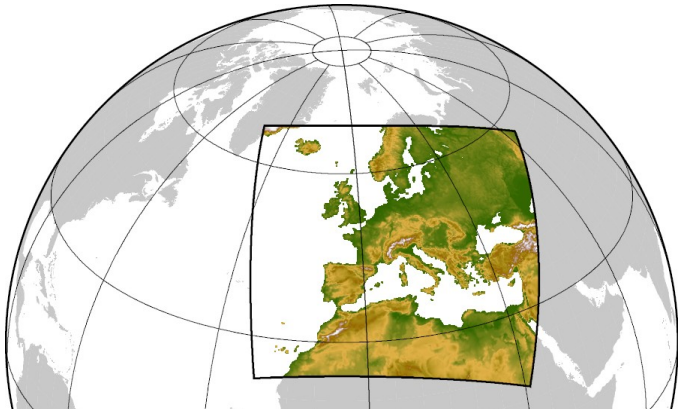
Outline

- Motivation
- WRF4G
  - Accessing distributed resources
  - Workflow
  - Experiment types
  - Side-products
  - Projects supporting WRF4G
- The Grid
  - Grid computing for meteo/climate apps
- Conclusions

WRF experimental setup scen.

Reanalysis/Reforecasts/Hindcast

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

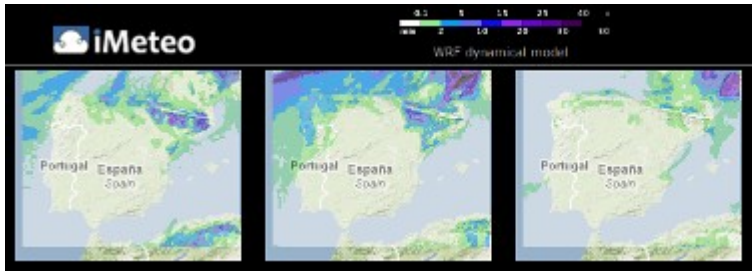


Regional climate simulation

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

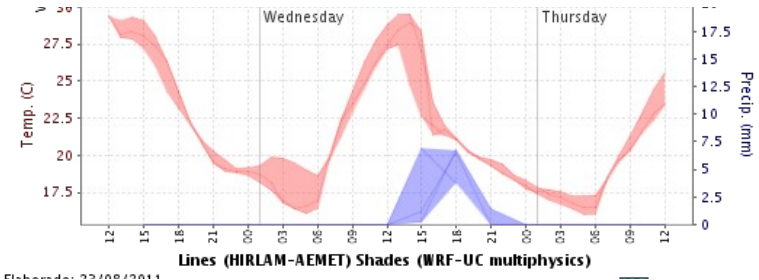
Weather Forecasting

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

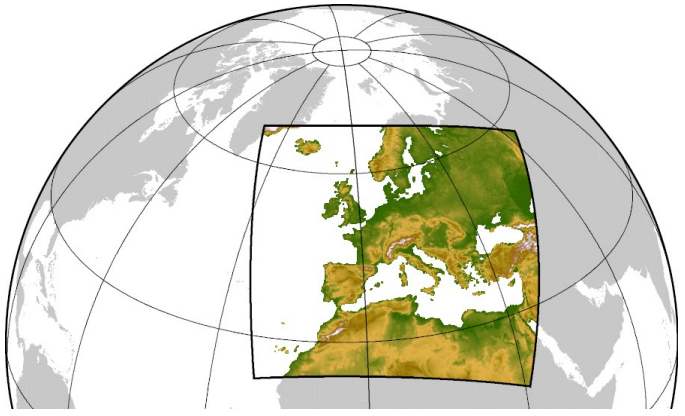


Sensitivity/ensemble studies

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



Examples: Santander MetGroup



Reanalysis/Reforecasts/Hindcast

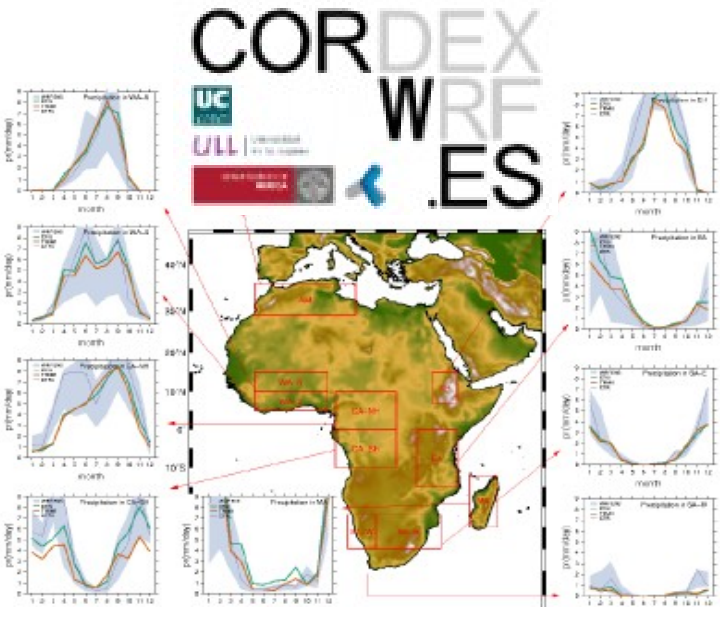
- SEAWIND project
- 21 years of daily reforecasts (36h each)
- 7,665 independent simulations

Regional climate simulation

- ESCENA project
- 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



Computer resource scenarios

Desktop/Laptop (UI)

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

Workstation

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

Local group/institutional cluster

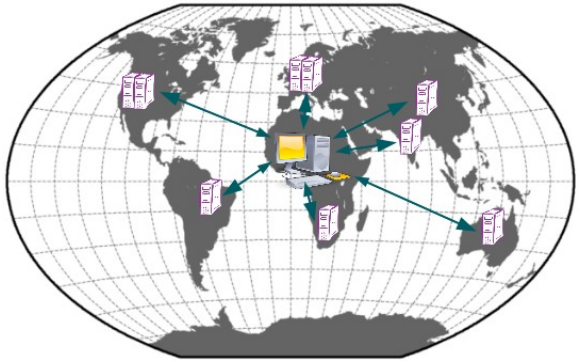
- Multi-node, distributed memory, large storage
- ssh access, **batch system** (PBS, SGE, ...) to submit jobs

Mainframe/HPC site

- **Different architectures** and memory arrangements
- ssh or higher security access

Grid infrastructure

- “Cluster of clusters”, geographycally distributed
- **Huge amount of computational power** and storage
  (not trivial to take advantage of it for meteo/climate apps)



WRF4G

WRF4G, developed by the Santander Meteorology Group, provides:

- Flexible WRF experiment **design**, **execution** and **monitoring**, and ...
- … the ability of running these experiments on different computing resources at the same time in a **transparent** way.

It is, currently, a set of **command line tool**s (Web interface planned)

WRF is **not installed in the host resources**. Binaries are transferred for each simulation.

The **output and log files are centralized** in a single repository

A broken experiment (due to a temporal failure of the resources) is **restarted by resubmitting the whole experiment**: only the unfinished simulations will be restarted from their last restart file

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The only **dependencies to be met** by the host are:

- python (usually present, no need to install)

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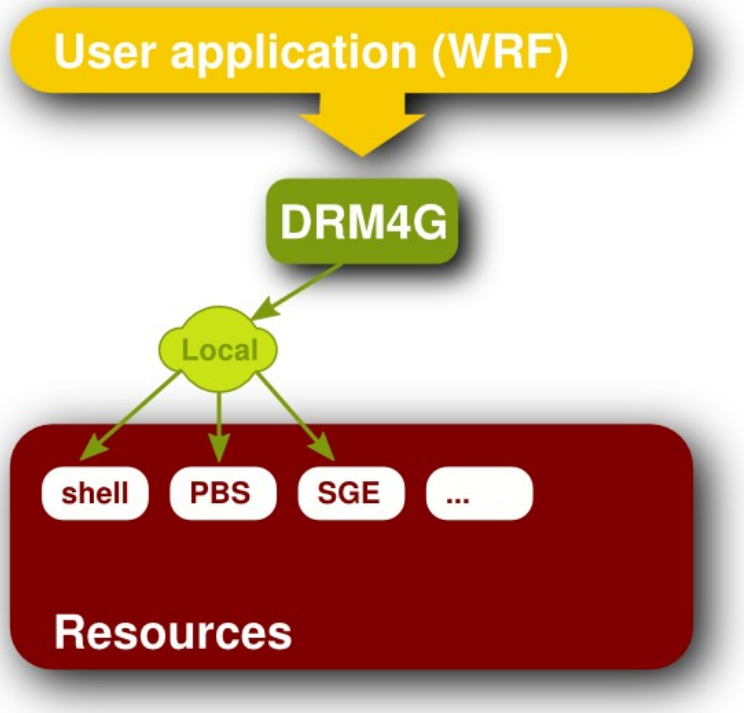
- … the ability of running these experiments on different computing resources at the same time in a **transparent** way.

Access to heterogeneous resources

DRM4G (Distributed Resource Manager) allows the user to merge different computing resources at hand in a transparent way:

Local resources (UI)



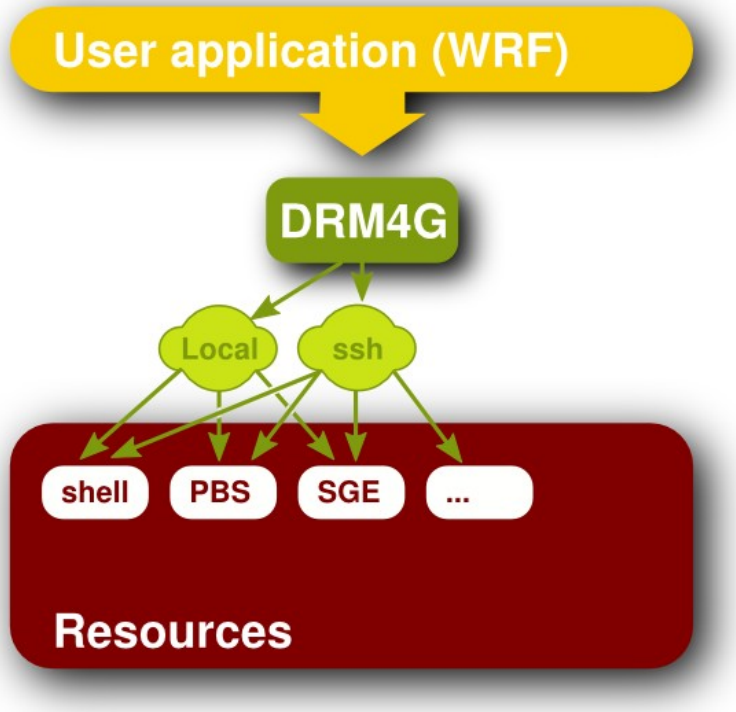
- Directly in a shell session
- Interacting with LRMS
  - PBS
  - SGE
  - SLURM
  - ...

Access to heterogeneous resources

DRM4G (Distributed Resource Manager) allows the user to merge different computing resources at hand in a transparent way:

Local resources (UI)

Remote resources (via ssh)



- Directly in a shell session
- Interacting with LRMS
  - PBS
  - SGE
  - SLURM
  - ...

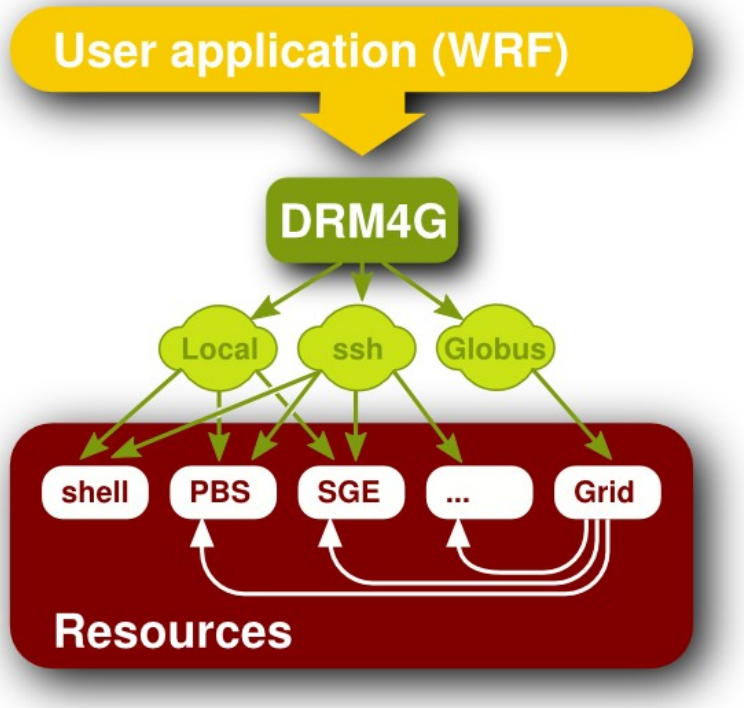
Access to heterogeneous resources

DRM4G (Distributed Resource Manager) allows the user to merge different computing resources at hand in a transparent way:

Local resources (UI)

Remote resources (via ssh)

Grid infrastructures (via Globus)



- Directly in a shell session
- Interacting with LRMS
  - PBS
  - SGE
  - SLURM
  - ...

Configuration files

wrf4gframework.conf

```
[Computing Resources]
mycomputer        local://localhost?
                    LRMS_TYPE=none;
                    NODECOUNT=1;

myworkstation     ssh://workstation.unican.es?
                    LRMS_TYPE=none;
                    NODECOUNT=16;

PBS_cluster       ssh://pbs.cluster.edu?
                    LRMS_TYPE=pbs;
                    QUEUE_NAME=long;
                    NODECOUNT=256;
SGE_cluster       ssh://sge.cluster.edu?
                    LRMS_TYPE=sge;
                    PROJECT=1.project;
                    NODECOUNT=256;
```

WRF4G

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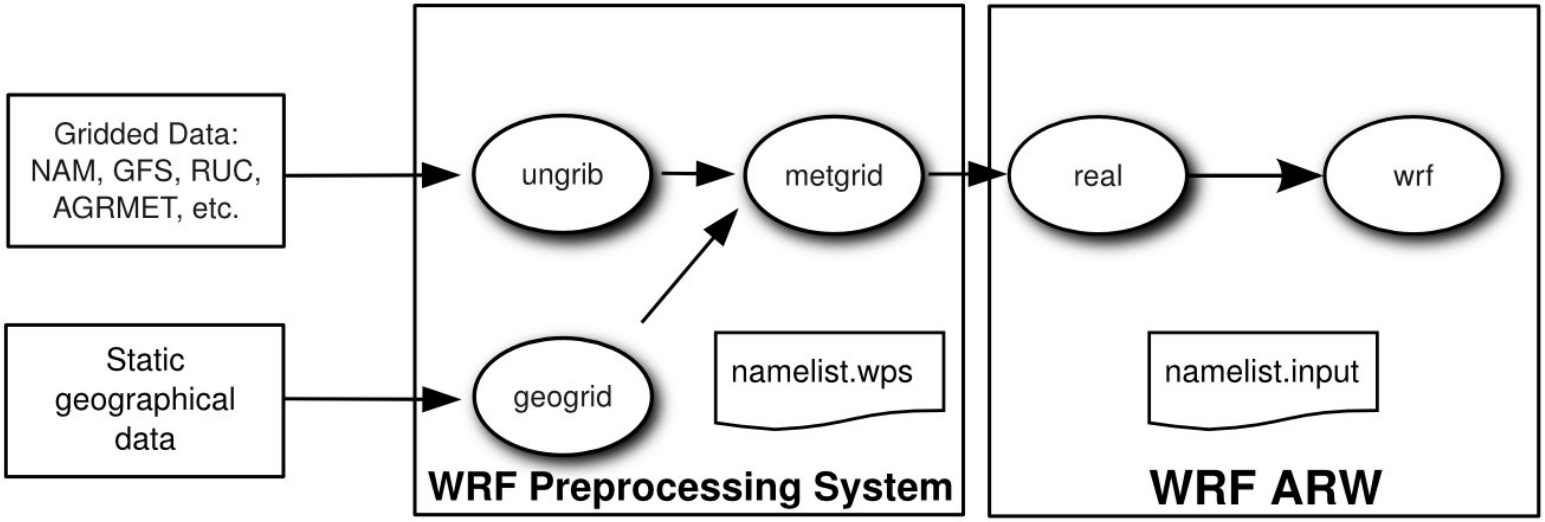
Gridded Data:
NAM, GFS, RUC,
AGRMET, etc.
Static
geographical
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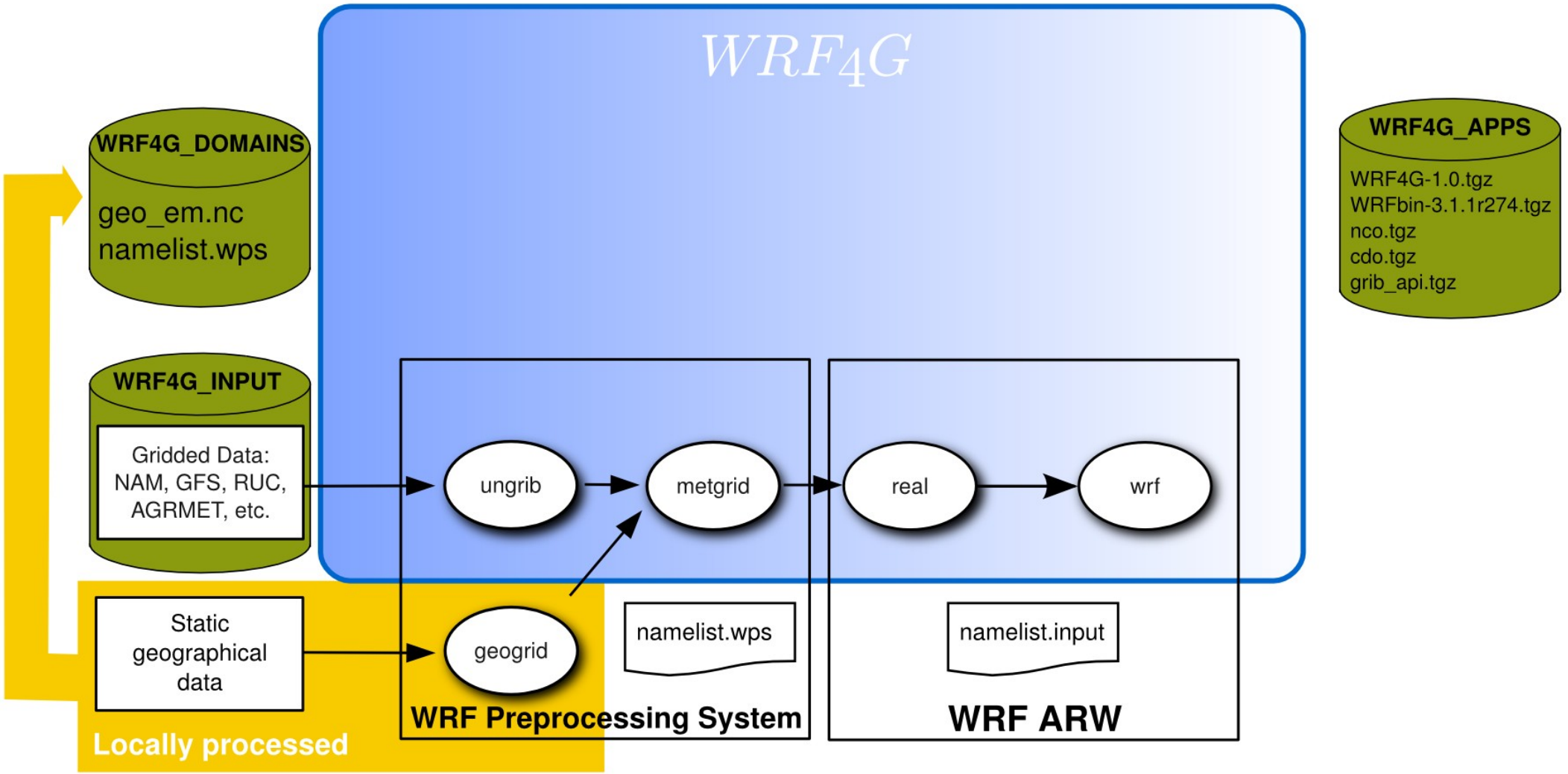
metgrid
geogrid
namelist.wps
WRF Preprocessing System
real
wrf
namelist.input
WRF ARW


WRF4G
WRF4G_DOMAINS
geo_em.nc
namelist.wps
WRF4G_APPS
WRF4G-1.0.tgz
WRFbin-3.1.1r274.tgz
nco.tgz
cdo.tgz
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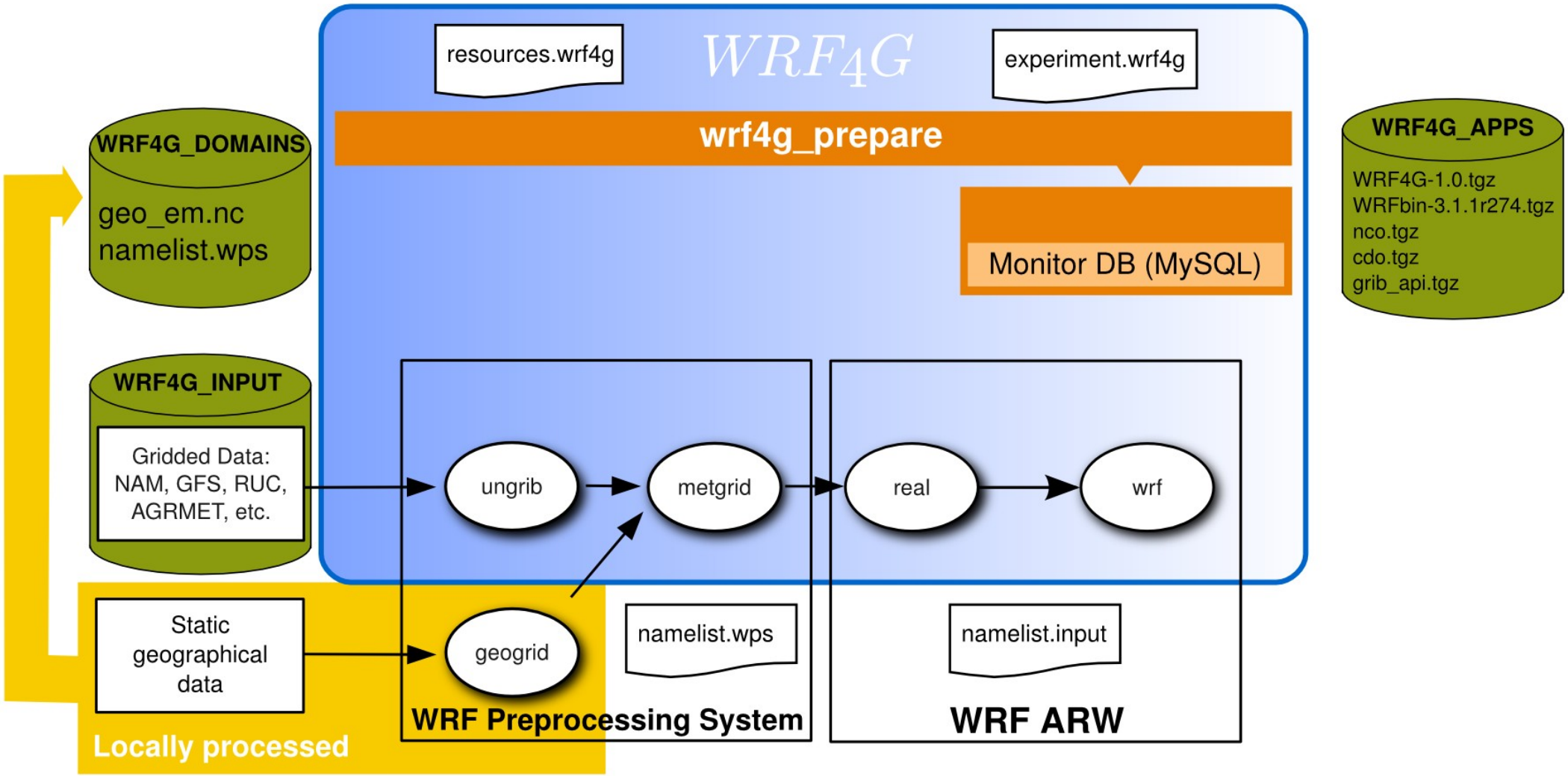
WRF Preprocessing System
WRF ARW
Locally processed


WRF4G
resources.wrf4g
experiment.wrf4g
wrf4g_prepare
Monitor DB (MySQL)
WRF4G_DOMAINS
geo_em.nc
namelist.wps
WRF4G_APPS
WRF4G-1.0.tgz
WRFbin-3.1.1r274.tgz
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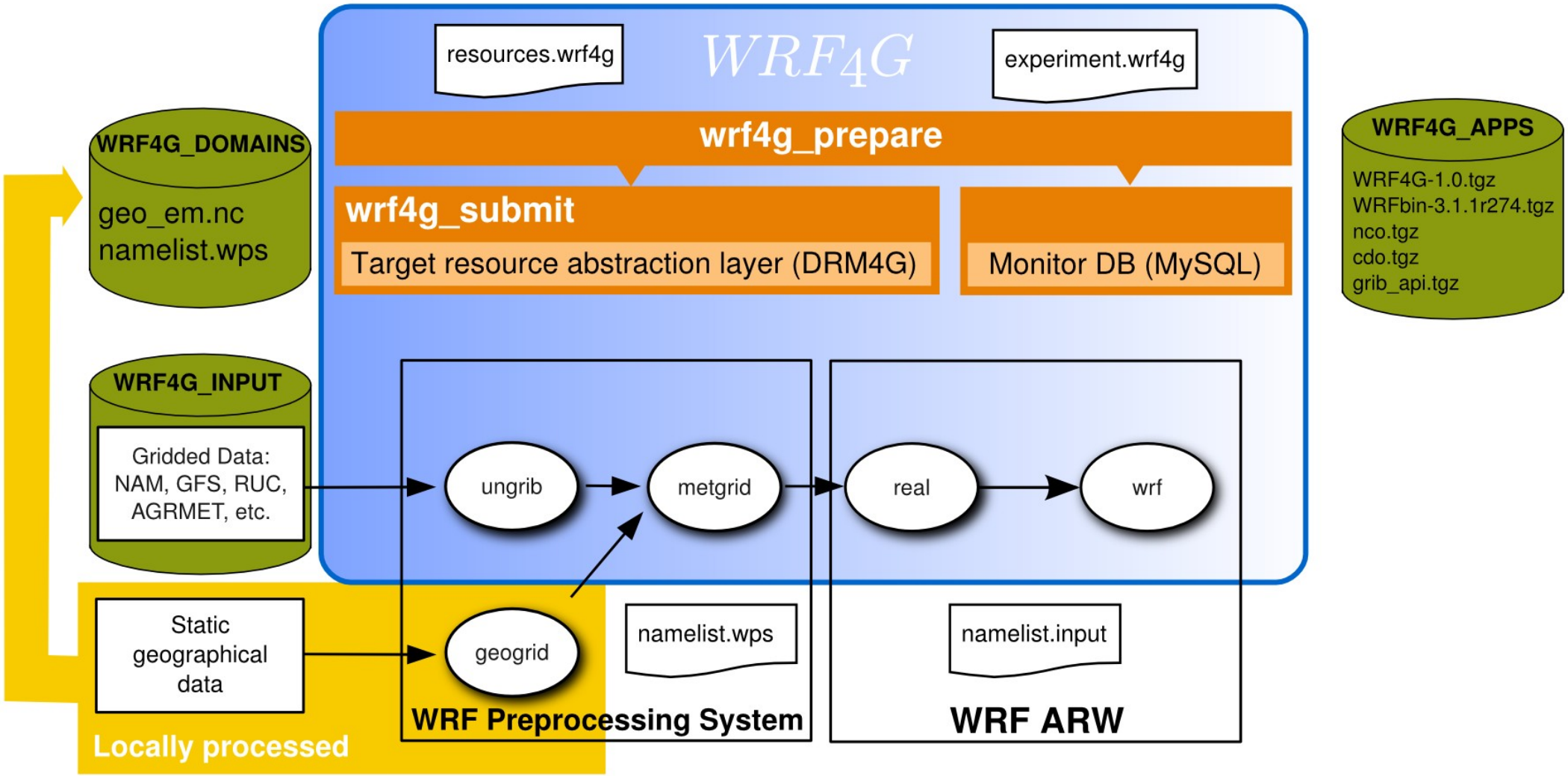
Locally processed


WRF4G
resources.wrf4g
experiment.wrf4g
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namelist.wps
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wrf4g_submit
Target resource abstraction layer (DRM4G)
Monitor DB (MySQL)
WRF4G_APPS
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WRFbin-3.1.1r274.tgz
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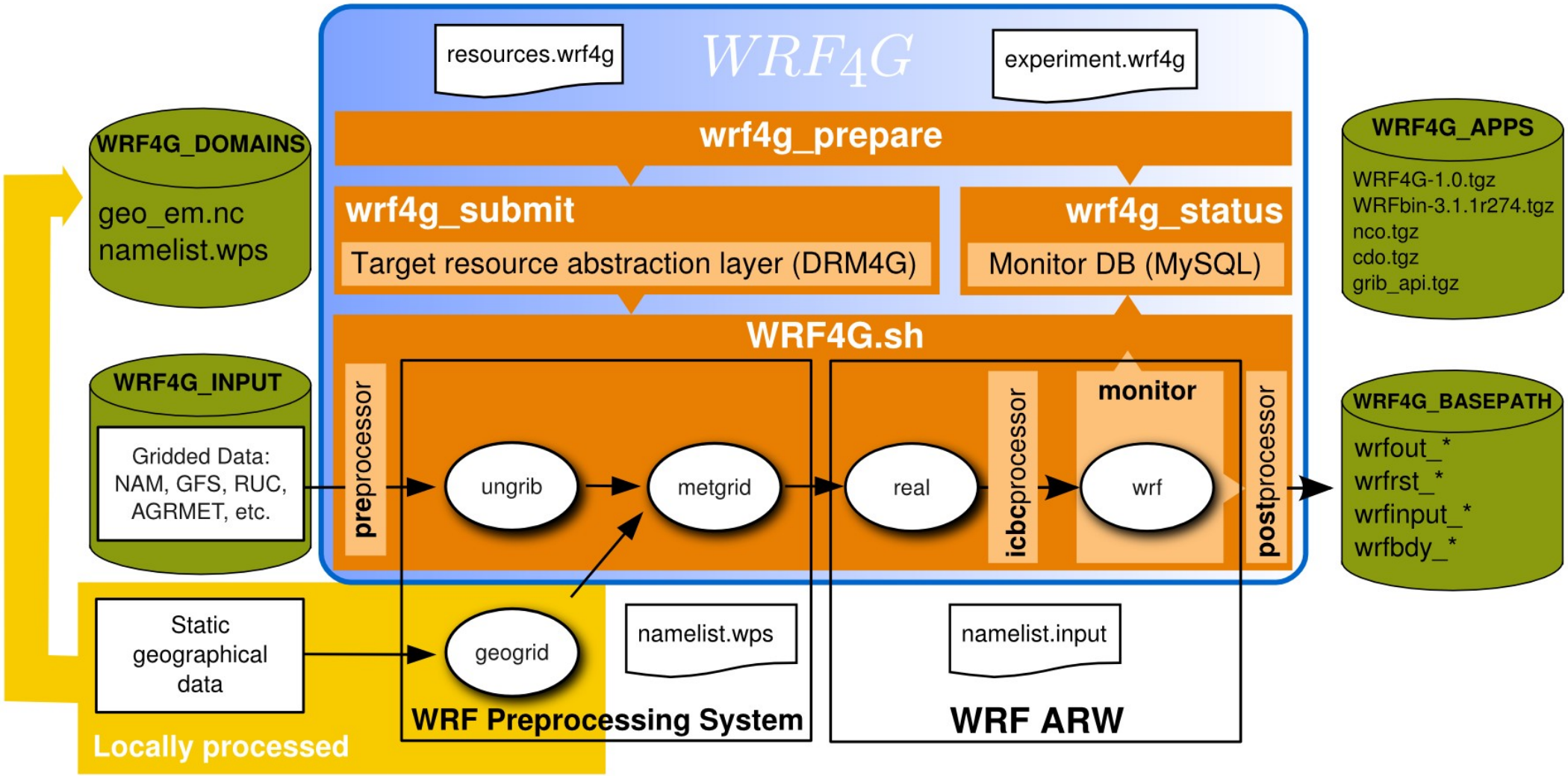
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postprocessor
WRF4G_BASEPATH
wrfout_*
wrfrst_*
wrfinput_*
wrfbdy_*
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WRF Preprocessing System
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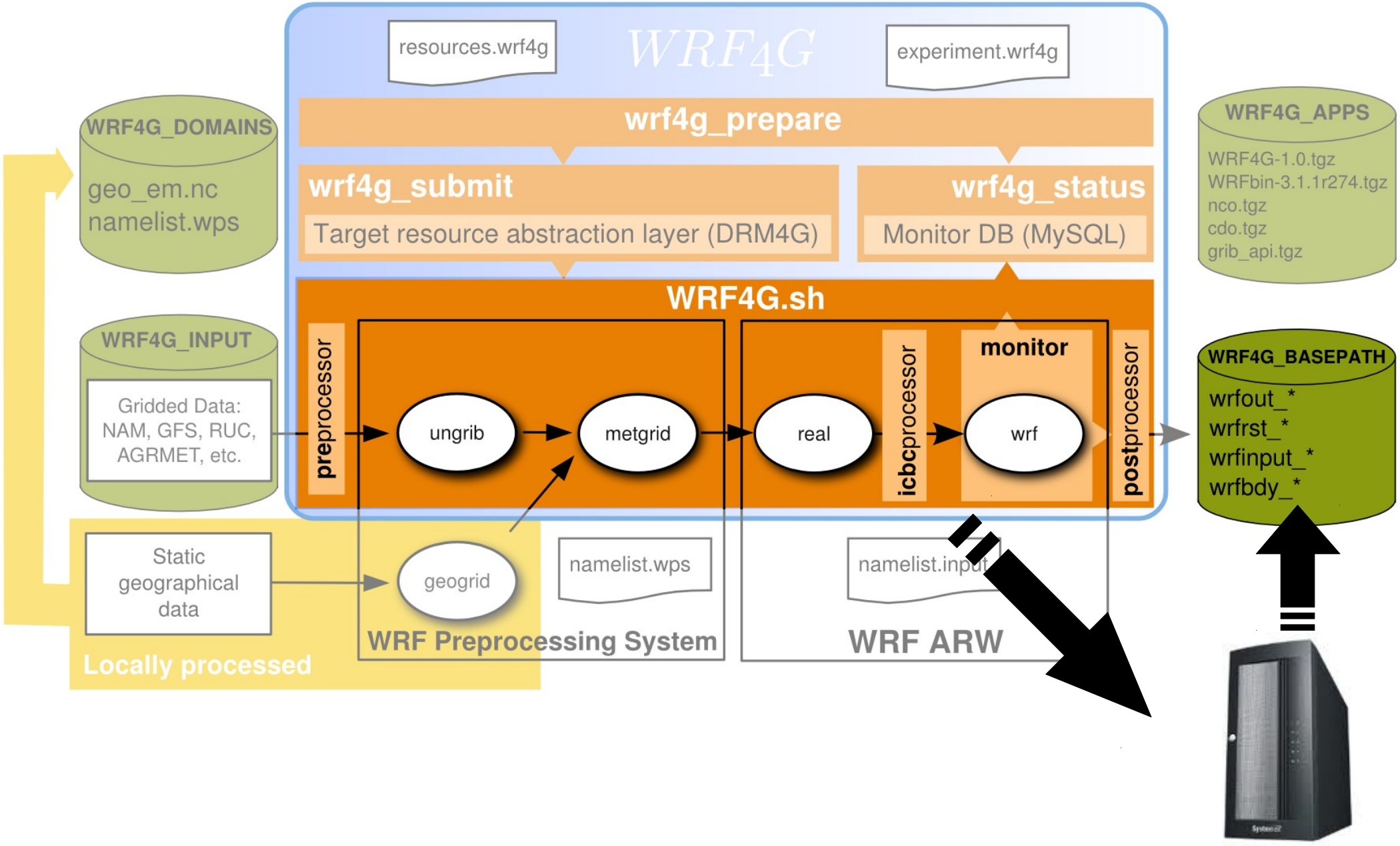
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namelist.input
WRF Preprocessing System
WRF ARW
Locally processed

Configuration files

wrf4gframework.conf | **resources.wrf4g**

```
# WRF4G version to use (packed scripts must be in $WRF4G_APPS)
WRF4G_VERSION="1.0"
# Name of the packed WRF binaries (the file must be in $WRF4G_APPS)
WRF_VERSION="3.1.1_r832INTEL_OMPI"


# Common path to save all output and log files
WRF4G_BASEPATH="/oceano/gmeteo/WORK/ASNA/WRF/experiments"
# Path to the preconfigured WRF domains
WRF4G_DOMAINPATH="/oceano/gmeteo/WORK/ASNA/WRF/domains"
# Path to the global data for the boundary and initial conditions
WRF4G_INPUT="/oceano/gmeteo/DATA"
# Path to the packed binaries (WRF4G script, WRF, cdo (preprocessor), ..)
WRF4G_APPS="/oceano/gmeteo/WORK/wrf4g/repository/apps"

# Number of parallel processors (cores) per simulation
NP=8
# Computer resources to use
RESOURCES="myworkstation,PBS_cluster"
# Fine tuning
ENVIRONMENT='MAXWALLTIME = 36000, MAXMEMORY = 1000'
```

Configuration files

wrf4gframework.conf | **resources.wrf4g**

```
# WRF4G version to use (packed scripts must be in $WRF4G_APPS)
WRF4G_VERSION="1.0"
# Name of the packed WRF binaries (the file must be in $WRF4G_APPS)
WRF_VERSION="3.1.1_r832INTEL_OMPI"


# Common path to save all output and log files
WRF4G_BASEPATH="rsync://my.storage.edu/path/to/WRF/experiments"
# Path to the preconfigured WRF domains
WRF4G_DOMAINPATH="rsync://other.computer.edu/path/to/WRF/domains"
# Path to the global data for the boundary and initial conditions
WRF4G_INPUT="rsync://other2.computer.edu/path/to/input/DATA"
# Path to the packed binaries (WRF4G script, WRF, cdo (preprocessor), ..)
WRF4G_APPS="rsync://other3.computer.edu/path/to/apps"

# Number of parallel processors (cores) per simulation
NP=8
# Computer resources to use
RESOURCES="myworkstation,PBS_cluster"
# Fine tuning
ENVIRONMENT='MAXWALLTIME = 36000, MAXMEMORY = 1000'
```

Configuration files

wrf4gframework.conf | resources.wrf4g | **experiment.wrf4g**

```
experiment_name = "MyExperiment"
domain_name = "Europe15km"
max_dom = 2

extdata_vtable = "ECMWF"    # Vtables must exist as Vtable.[input_extdata]
extdata_path = "${WRF4G_INPUT}/ECMWF/INTERIM"
extdata_interval = 21600    # Seconds between global analysis input times
extdata_preprocessor = "ECMWF"
postprocessor = "SEAWIND2"

start_date = "1989-01-01_06:00:00"
end_date = "2001-01-02_00:00:00"
chunk_size_h = 36

multiple_dates = 1
  simulation_interval_h = 24
  simulation_length_h = 1*chunk_size_h

multiple_parameters = 0
  multiparams_variables = "mp_physics,cu_physics,e_vert"
  multiparams_nitems = "${max_dom},${max_dom},${maxdom}"
  multiparams_combinations = "3,1,28 / 3,3,28 / 4,1,36 / 3,1,36"
  multiparams_labels = "WSM3_KF_L28/WSM3_GD_L28/WSM5_KF_L36/WSM3_KF_L36"

### Override namelist.input variables here ###
# Single valued:
NI_restart_interval = 2880 # minutes
NI_spec_bdy_width = 10
NI_spec_zone = 1
NI_relax_zone = 9
NI_sst_update__physics = 1
# One value per domain:
NIM_history_interval = 180,60  # minutes
NIM_frames_per_outfile = 4,12
# One value per domain; but all equal (provide a single value here):
NIN_e_vert                = 42
```

Boundary data

Experiment dates

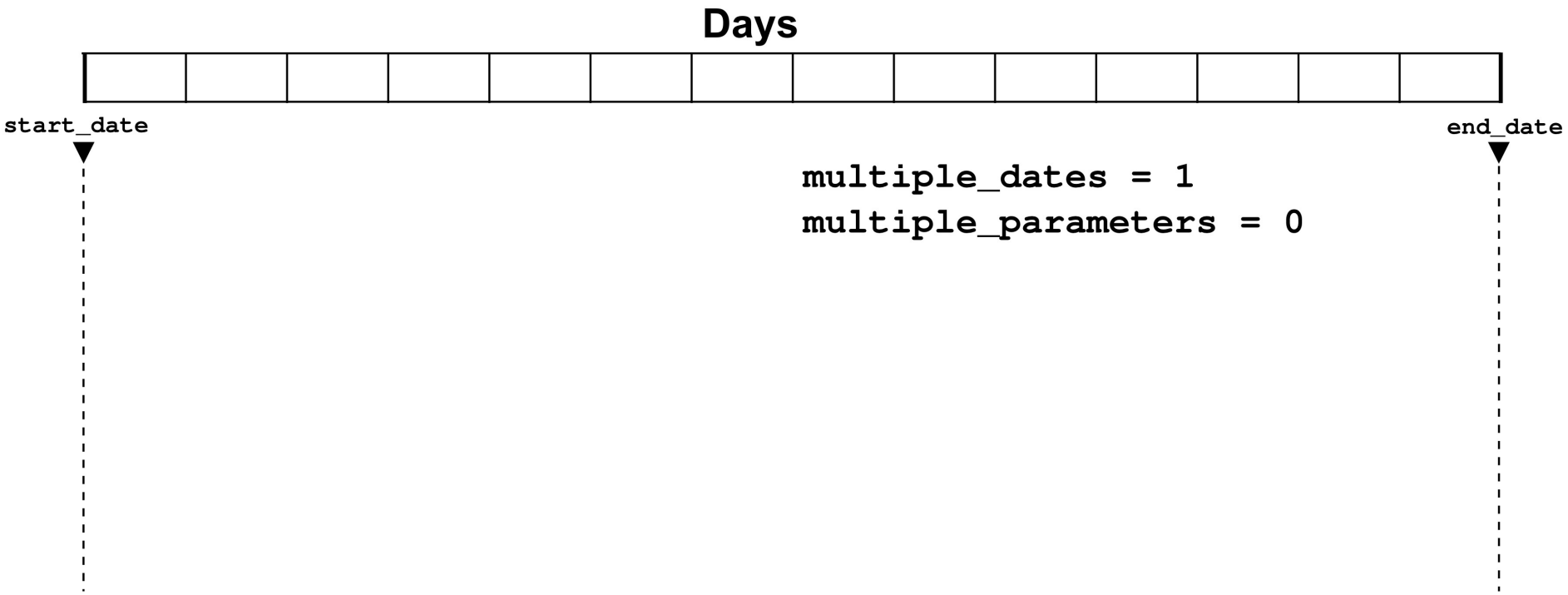
Multi-parameter experiment

namelist.input modifications

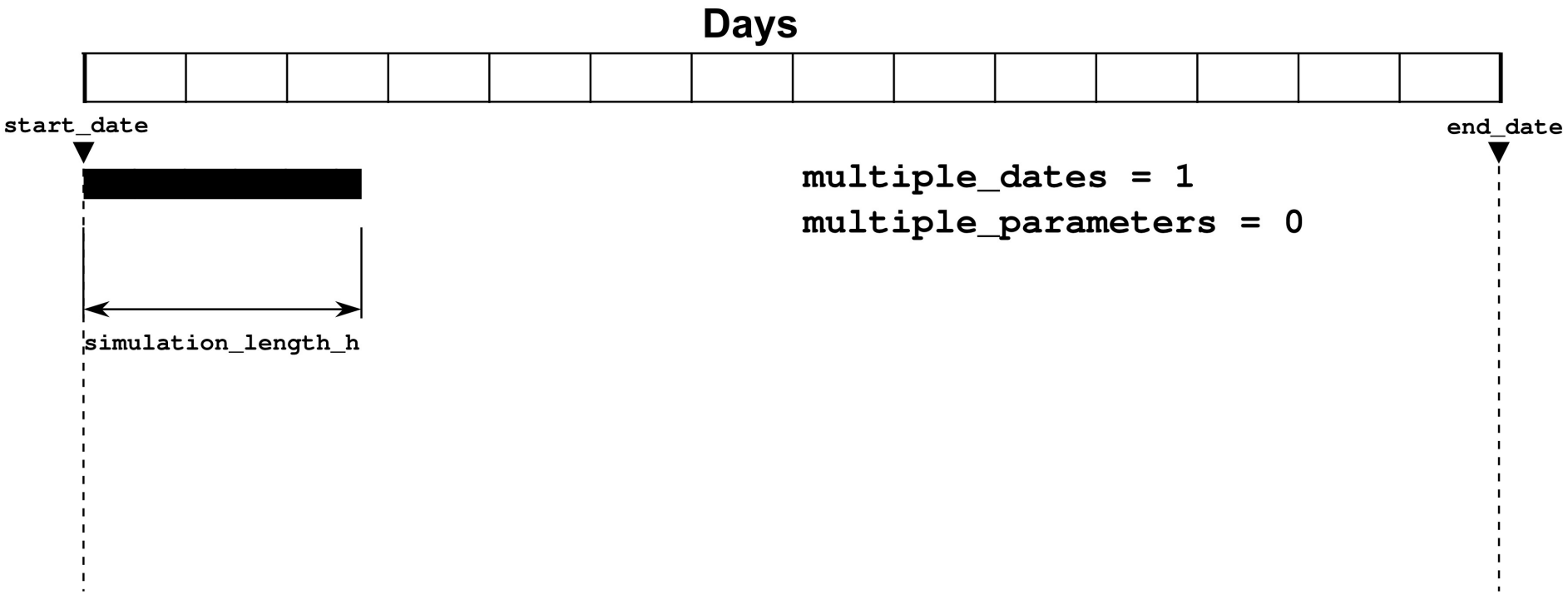
WRF4G framework

- WRF4G splits a regular WRF simulation **experiment** into:
  - **realizations**
    - A realization is any **independent WRF simulation**, which does not need as input the output (e.g. restart file) of another simulation.
  - **chunks**
    - For convenience, a WRF realization can be split into chunks. By definition, a chunk is a **dependent simulation** and requires the previous chunk to finish.
- Chunks are convenient to create WRF jobs finishing before the job is kicked out of a queue. Also, they allow fine tuning of the size of the input files.

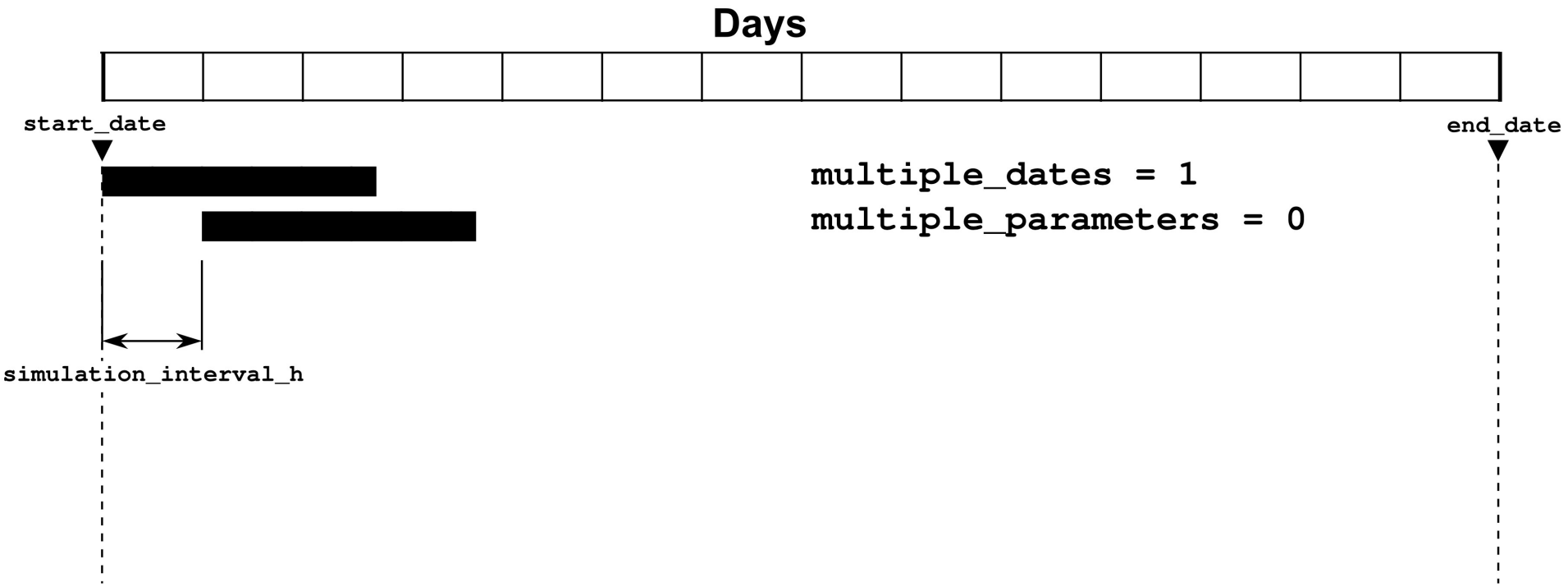
Experiment definition



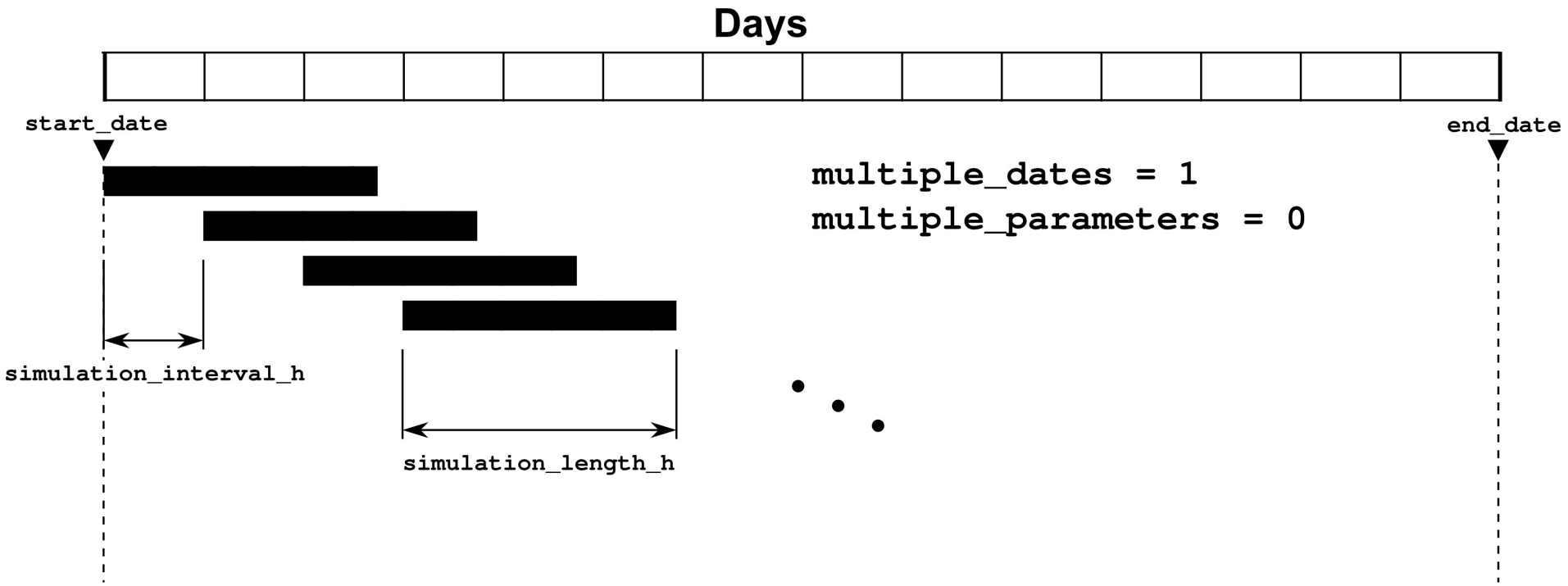
Experiment definition



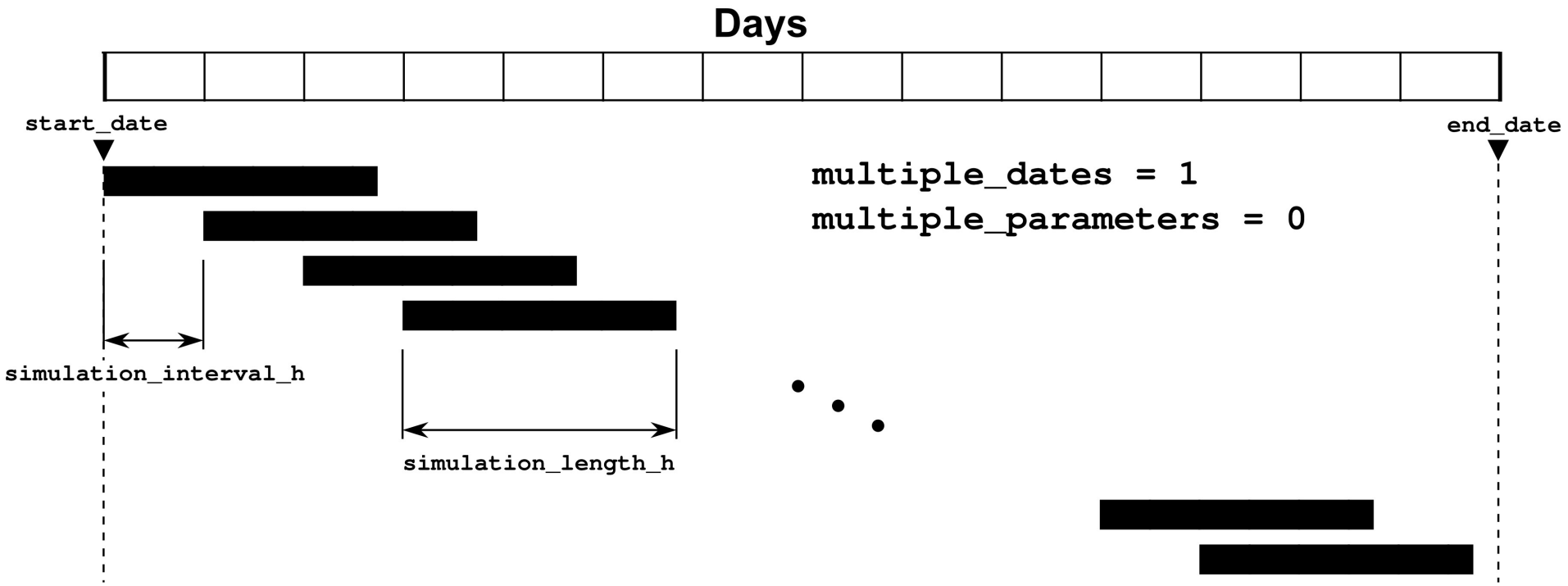
Experiment definition



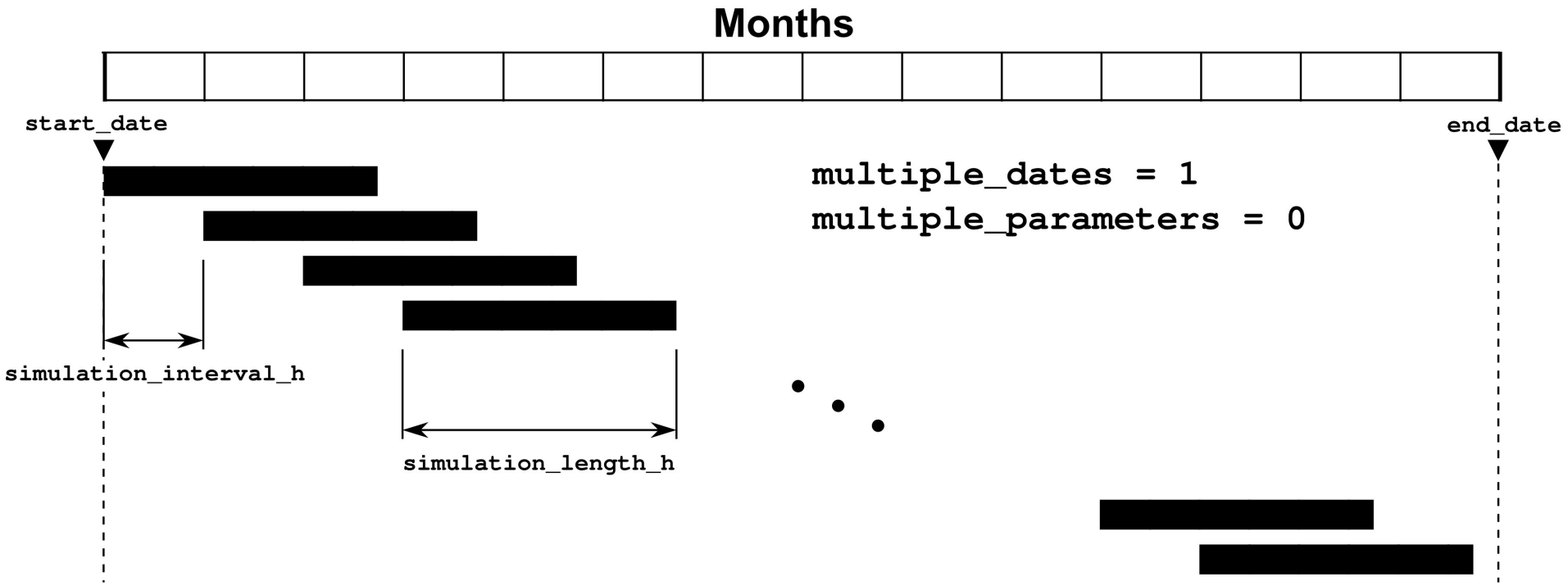
Experiment definition



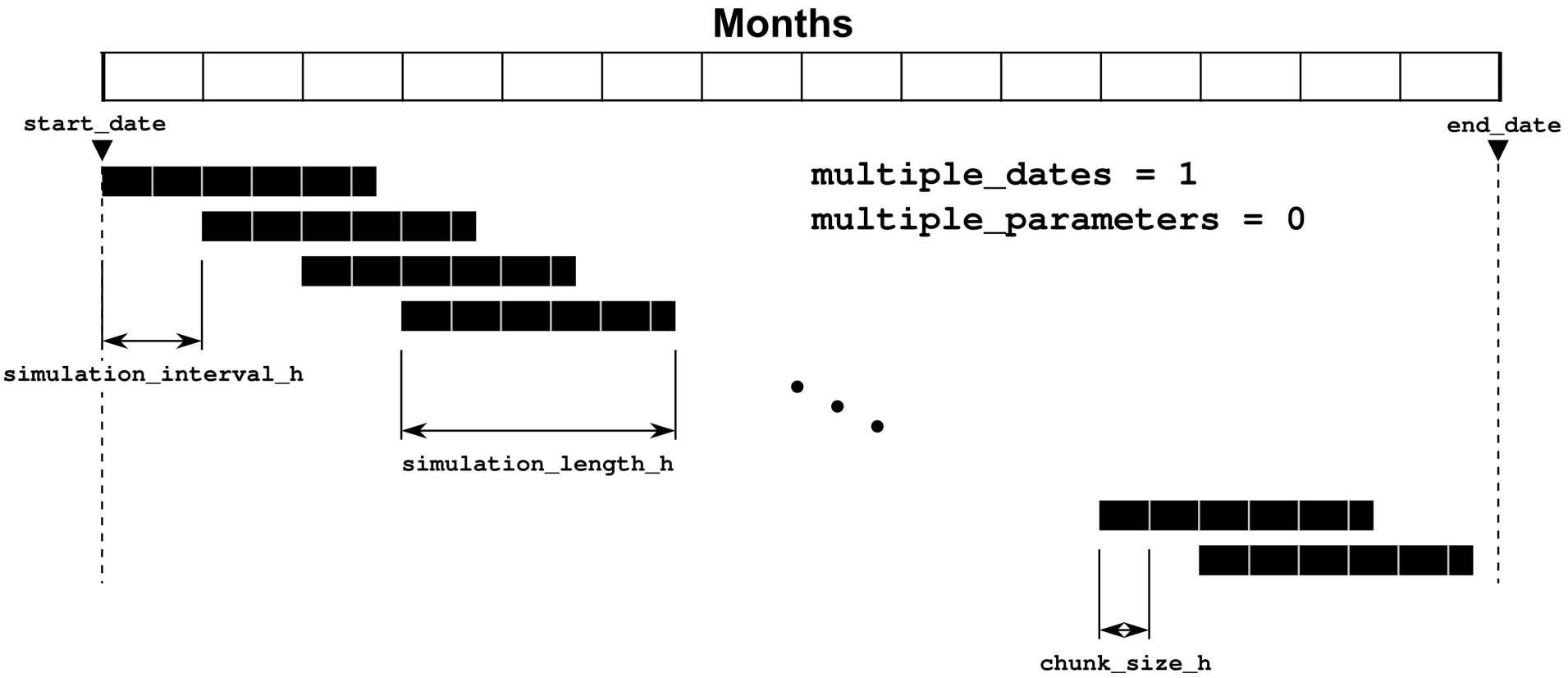
Experiment definition



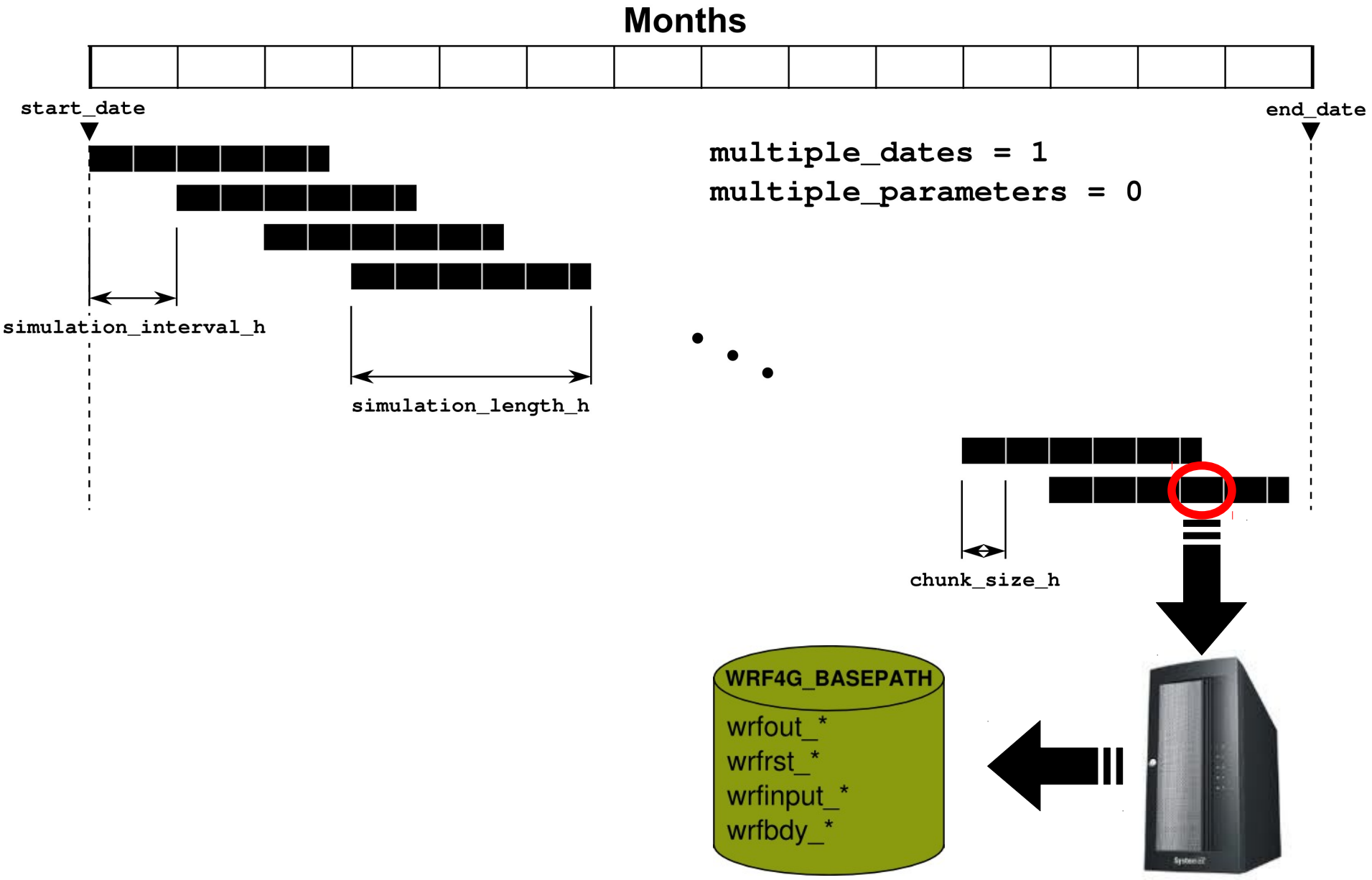
Experiment definition



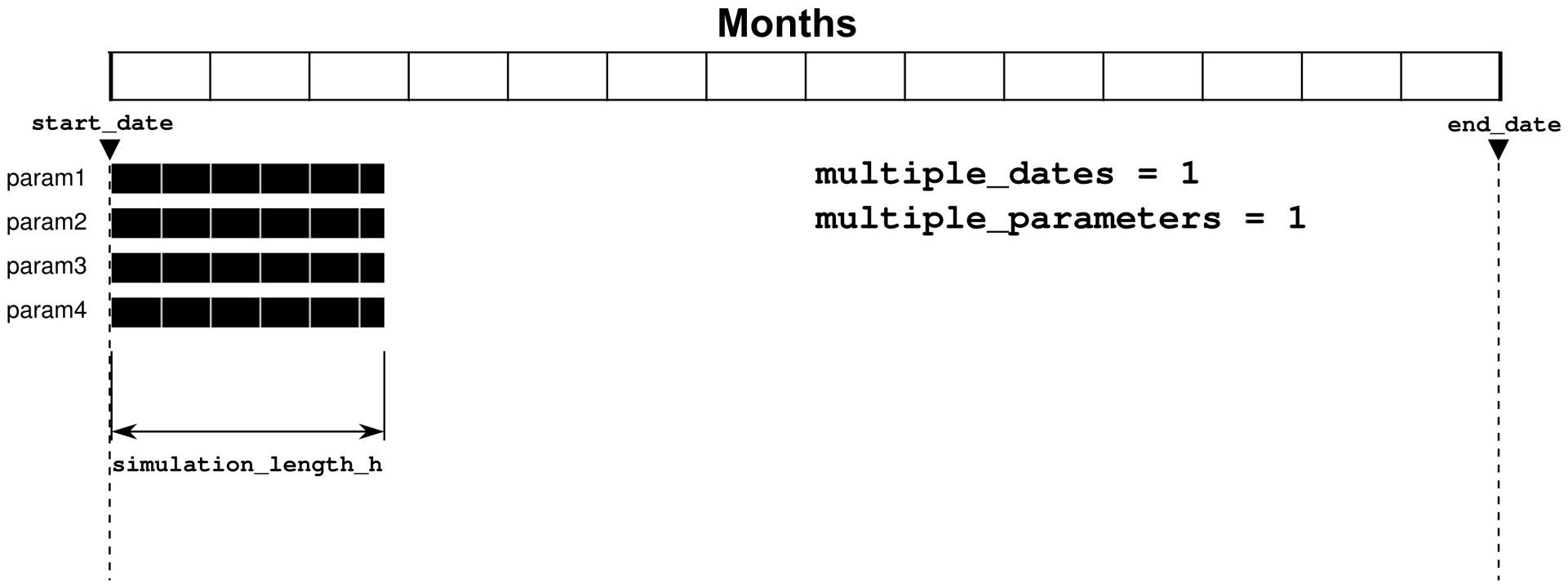
Experiment definition



Experiment definition



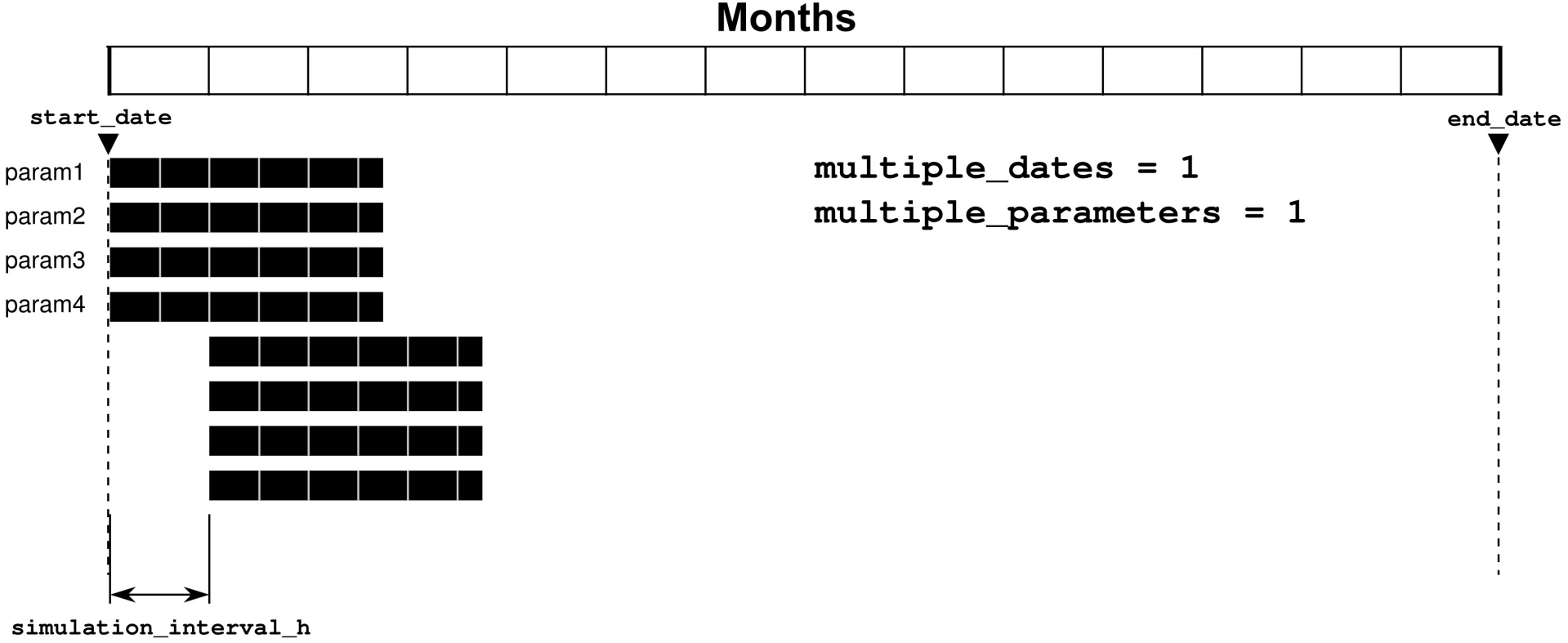
Multi-parameter & multi-date



Example:

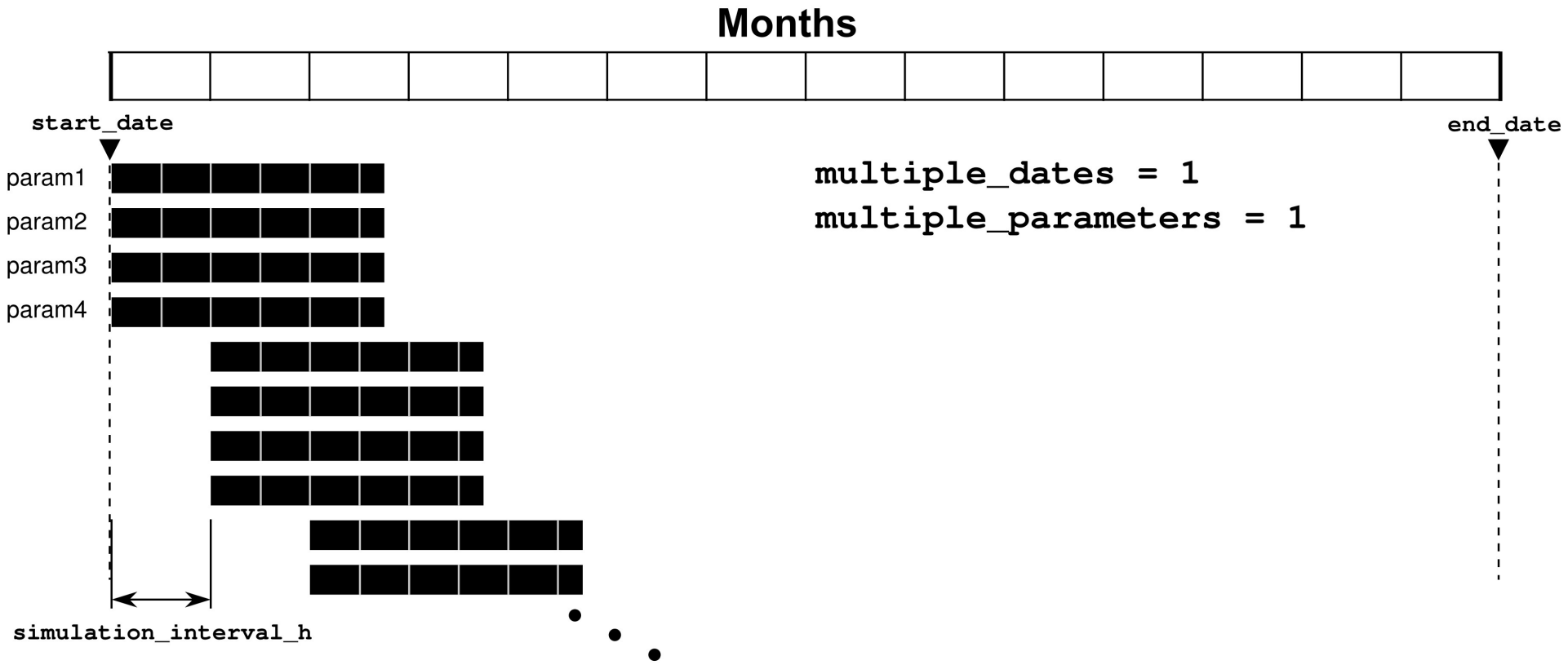
```
multiple_parameters = 1
  multiparams_variables = "mp_physics,cu_physics,e_vert"
  multiparams_nitems = "${max_dom},${max_dom},${maxdom}"
  multiparams_combinations = "3,1,28 / 3,3,28 / 4,1,36 / 3,1,36"
  multiparams_labels = "WSM3_KF_L28/WSM3_GD_L28/WSM5_KF_L36/WSM3_KF_L36"
```

Multi-parameter & multi-date



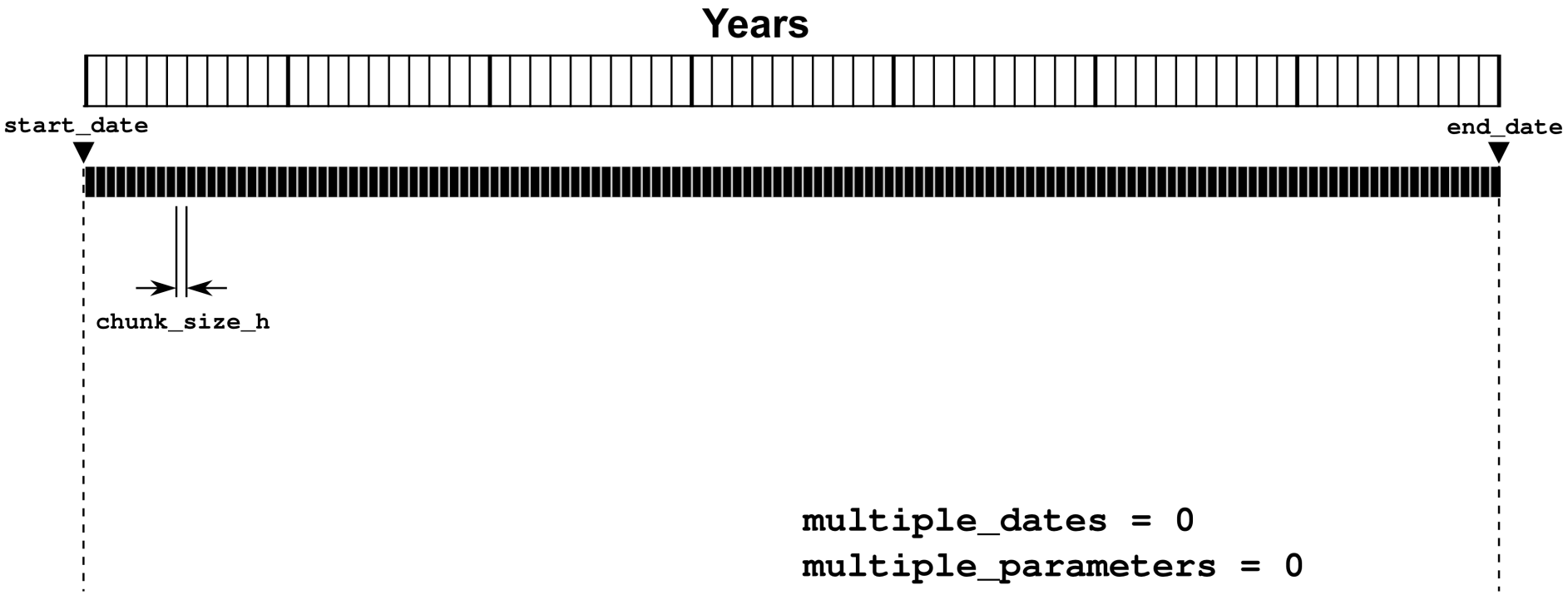

```
multiple_dates = 1
multiple_parameters = 1
```

Multi-parameter & multi-date

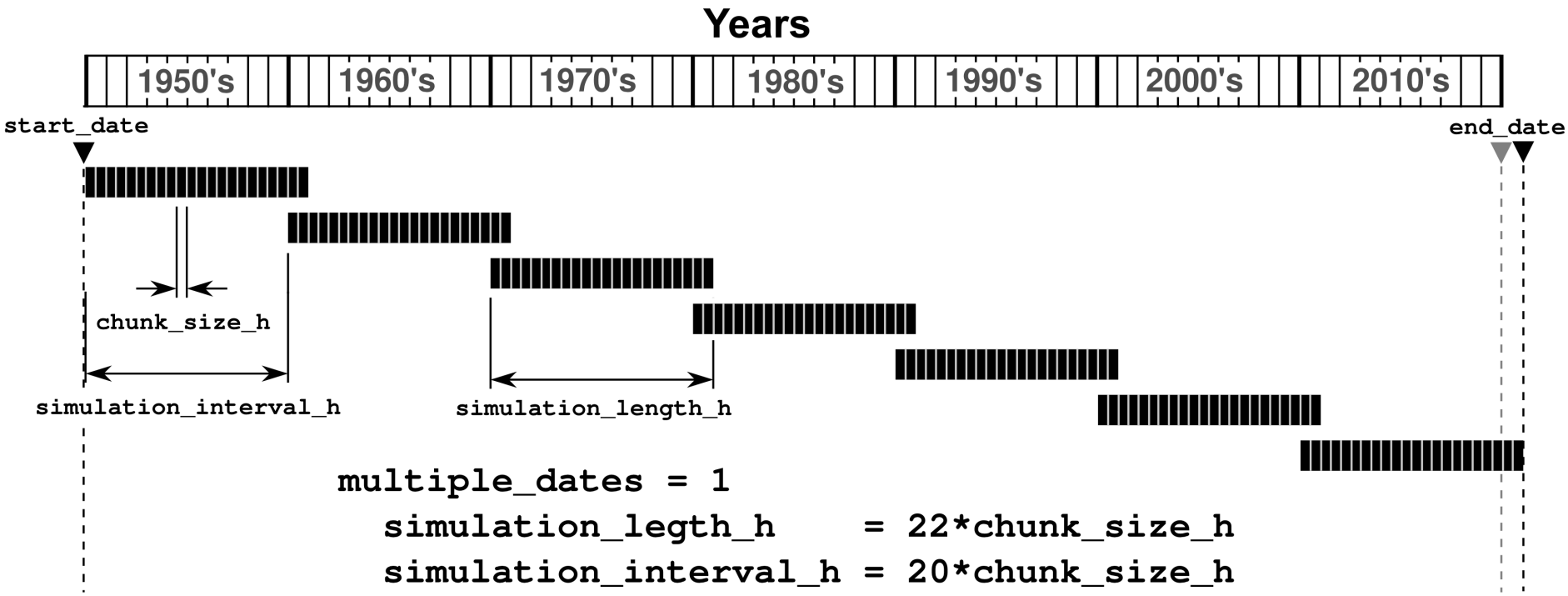



```
multiple_dates = 1
multiple_parameters = 1
```

Climate simulation (continuous)



Climate simulation (split)




```
multiple_dates = 1
  simulation_legth_h    = 22*chunk_size_h
  simulation_interval_h = 20*chunk_size_h
multiple_parameters = 0
```

Monitoring

```
Shell$ wrf4g_status -e example
Realization   GW Stat Chunks Comp.Res   WN        Run.Sta        ext   %
example__ph1  -    P  0/4    -          -         Prepared        - 0.00
example__ph2  -    P  0/4    -          -         Prepared        - 0.00
example__ph3  -    P  0/4    -          -         Prepared        - 0.00
example__ph4  -    P  0/4    -          -         Prepared        - 0.00
example__ph5  -    P  0/4    -          -         Prepared        - 0.00
```

Monitoring

```
Shell$ wrf4g_status -e example
Realization    GW Stat Chunks Comp.Res    WN         Run.Sta        ext    %
example__ph1   32    R  1/4    mycomputer legolas    metgrid         - 0.00
example__ph2   36    R  1/4    mycomputer legolas    Down. Bound.    - 0.00
example__ph3   40    W  1/4    -          -          Submitted       - 0.00
example__ph4   44    W  1/4    -          -          Submitted       - 0.00
example__ph5   48    W  1/4    -          -          Submitted       - 0.00
```

Monitoring

```
Shell$ wrf4g_status -e example
Realization    GW Stat Chunks Comp.Res    WN         Run.Sta       ext    %
example__ph1   32    R  1/4    mycomputer legolas    real           - 0.00
example__ph2   36    R  1/4    mycomputer legolas    metgrid        - 0.00
example__ph3   40    W  1/4    -          -          Submitted      - 0.00
example__ph4   44    W  1/4    -          -          Submitted      - 0.00
example__ph5   48    W  1/4    -          -          Submitted      - 0.00
```

Monitoring

```
Shell$ wrf4g_status -e example
Realization    GW Stat Chunks Comp.Res    WN         Run.Sta       ext    %
example__ph1   32    R  1/4    mycomputer legolas    WRF            - 0.00
example__ph2   36    R  1/4    mycomputer legolas    WRF            - 0.00
example__ph3   40    W  1/4    -          -          Submitted      - 0.00
example__ph4   44    W  1/4    -          -          Submitted      - 0.00
example__ph5   48    W  1/4    -          -          Submitted      - 0.00
```

Monitoring

```
Shell$ wrf4g_status -e example
Realization   GW Stat Chunks Comp.Res   WN        Run.Sta       ext    %
example__ph1  33   W  2/4    -          -         Submitted      - 25.00
example__ph2  37   W  2/4    -          -         Submitted      - 25.00
example__ph3  40   R  1/4    mycomputer legolas   WRF            - 10.37
example__ph4  44   R  1/4    mycomputer legolas   WRF            - 9.23
example__ph5  48   W  1/4    -          -         Submitted      - 0.00
```

Outline

- Motivation
- WRF4G
  - Accessing distributed resources
  - Workflow
  - Experiment types
  - Side-products
  - Projects supporting WRF4G
- The Grid
  - Grid computing for meteo/climate apps
- Conclusions

Useful tools developed

- vcp
  - Virtual copy
  - Provides transparent copy between any of:
    - local file
    - gridftp URL
    - ssh host (via rsync)
    - local link (as destination)
  - E.g:

```
vcp /local/file /other/local/path/
vcp /local/file rsync://remote.comp.edu/remote/path/
vcp rsync://remote.comp.edu/remote/path ln:/local/path  # (copies)
vcp /local/file ln:/other/local/path                    # (links)
vcp -r /local/dir gridftp://server:port/remote/path
vcp gridftp://srv1:port/rmt/file gridftp://srv2:port/other/file
```

Useful tools developed

- fortnml
  - Fortran namelist
  - Provides Fortran namelist manipulation from the command line along with some WRF namelist checks.
  - E.g:

```
fortnml -f namelist.input
fortnml --wrf -f namelist.input
fortnml -f namelist.input -s variable value
fortnml -f namelist.input -s variable value1 value2 value3 ...
fortnml -f namelist.input -s variable@record value
```

Projects supporting WRF4G

European commision (7FP):

EELA2: E-science grid facility for Europe and Latin America

Partners: 52 institutions in Latin America and Europe

Spanish Ministry of Science and Innovation:

WRF model port to Grid infrastructures and proof-of-concept for a high-resolution wind hindcast over Europe

Universidad de Cantabria

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

Partners: 3 Spanish universities and a supercomputing center

CORDEX WRF .ES

UC Universidad de Cantabria

ULL Universidad de La Laguna

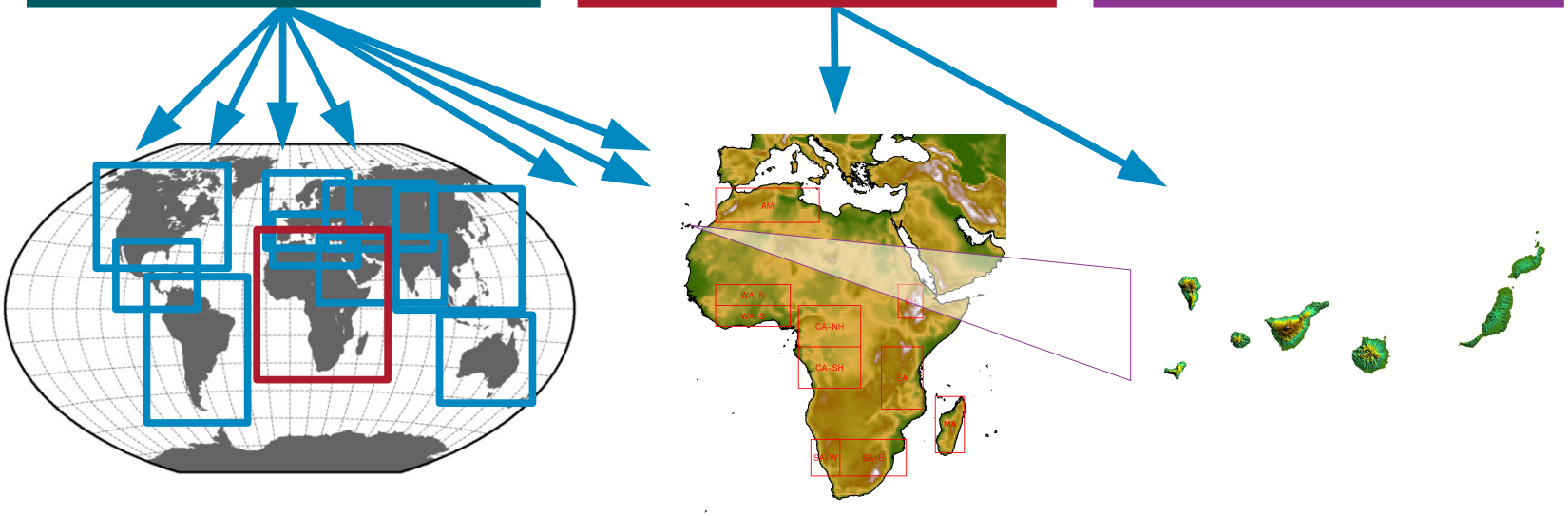
UNIVERSIDAD DE MURCIA

WRF

Grid computing

ROMS

Canary islands



WRF4G
CLWRF
Pre- & post-process tools

WRF modifications and tools

Coordination / dissemination

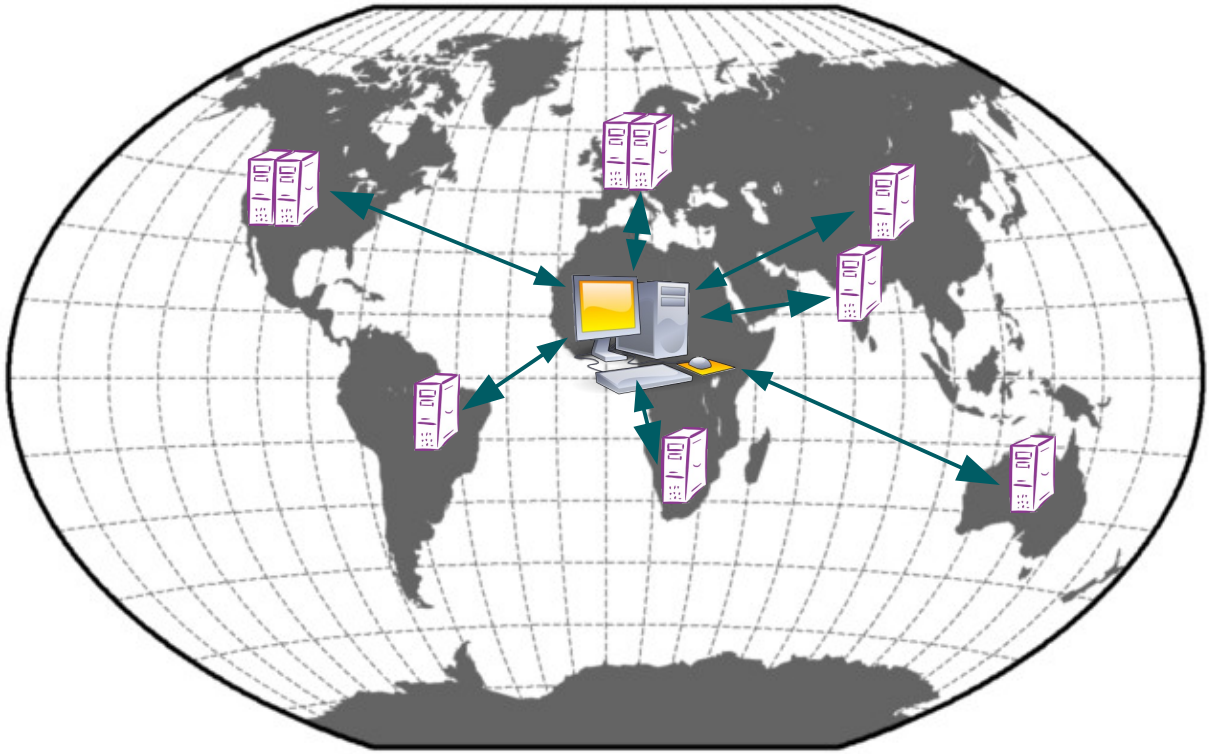
Grid computing

Grid computing is a computational paradigm taking advantage of **geographically distributed computer resources**.

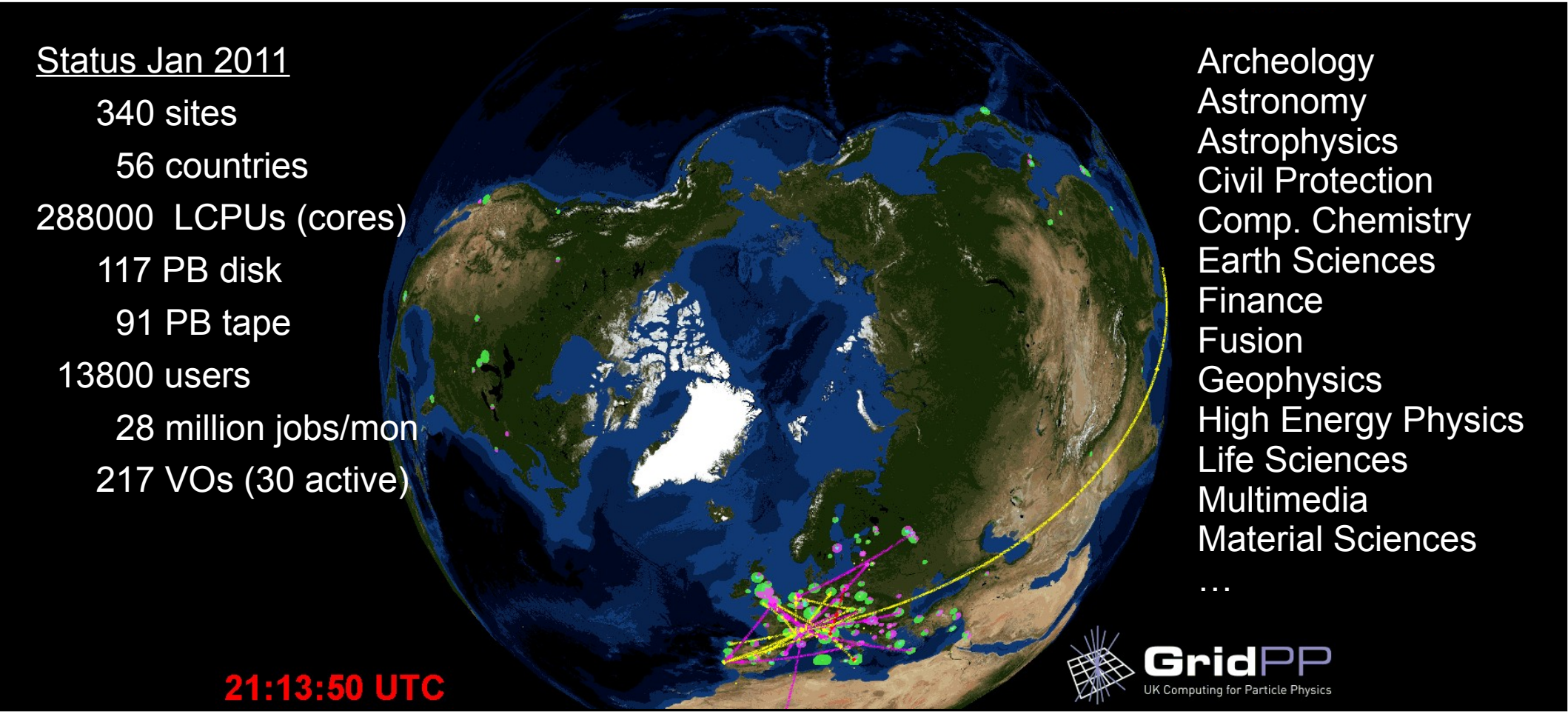
A software layer (middleware) provides **transparent access** to the distributed resources.

The access to the resources is **secure**

Users are organized in **virtual organizations**



Example: **EGI infrastructure**



Another example: **Earth System Grid** (only storage)

- Infraestructure shared between several NL in the US
- Holding the PCMDI CMIP3, CMIP5 and many other databases

Not trivial for climate ...

- Large input and output data transfer
- Long running times
- Very intensive: CPU and memory

  (requires parallel execution in order to finish in a reasonable time)

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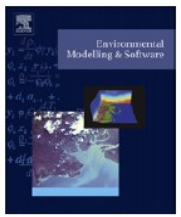


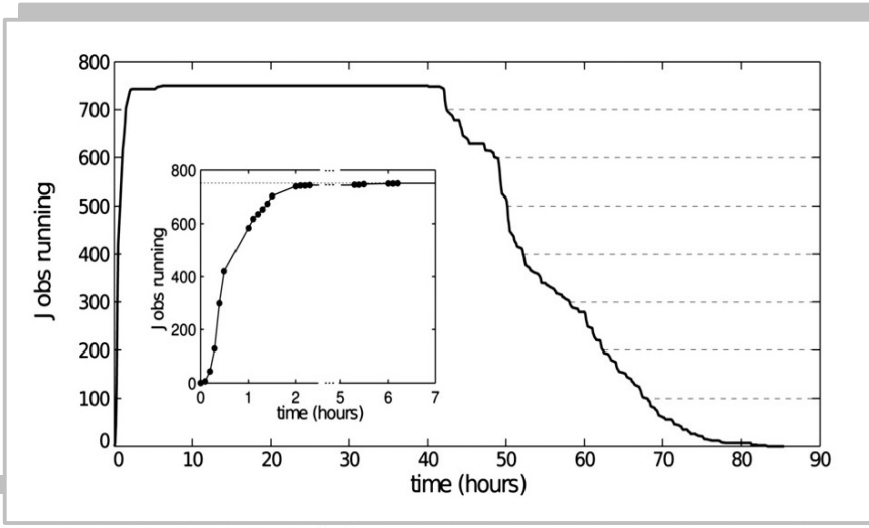
Featured Article

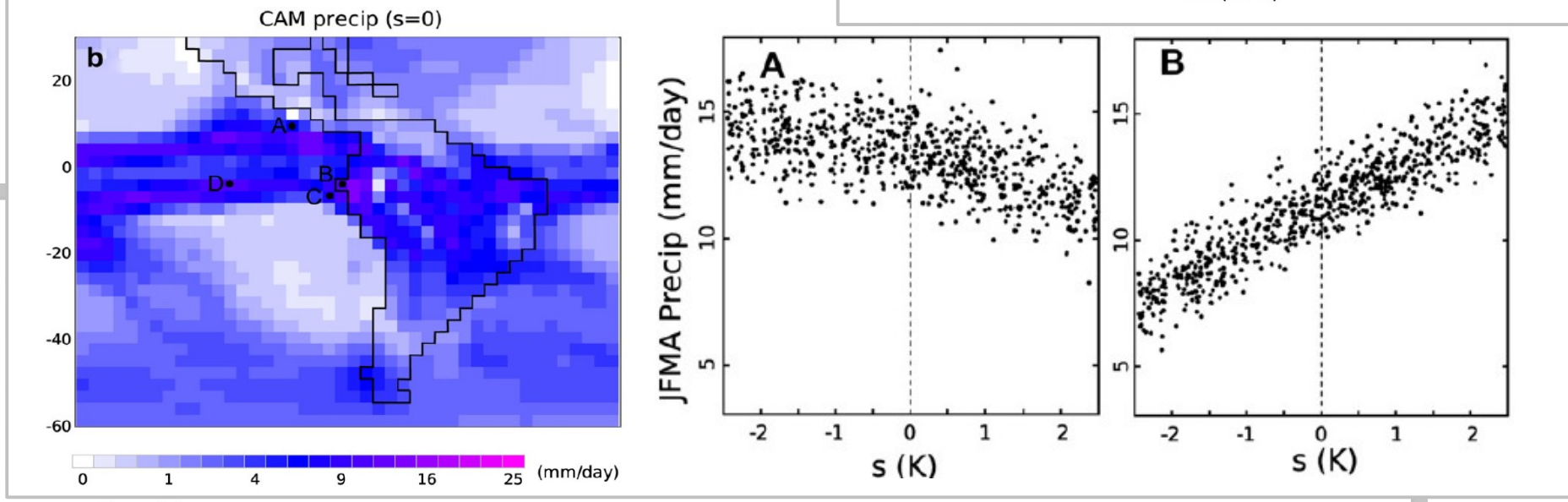
Benefits and requirements of grid computing for climate applications. An example with the community atmospheric model

V. Fernández-Quiruelas [a,*], J. Fernández [a], A.S. Cofiño [a], L. Fita [a], J.M. Gutiérrez [b]

… but still possible

More than 1000 years simulated with a global model (CAM, T62) in less than 4 days





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Conclusions

- The WRF user usually:
  - designs experiments where several (many?) simulations are required
  - has several computer resources available for her simulations
- WRF4G simplifies the design, execution and monitoring of WRF on several computer resources
- WRF4G is freely available for use...

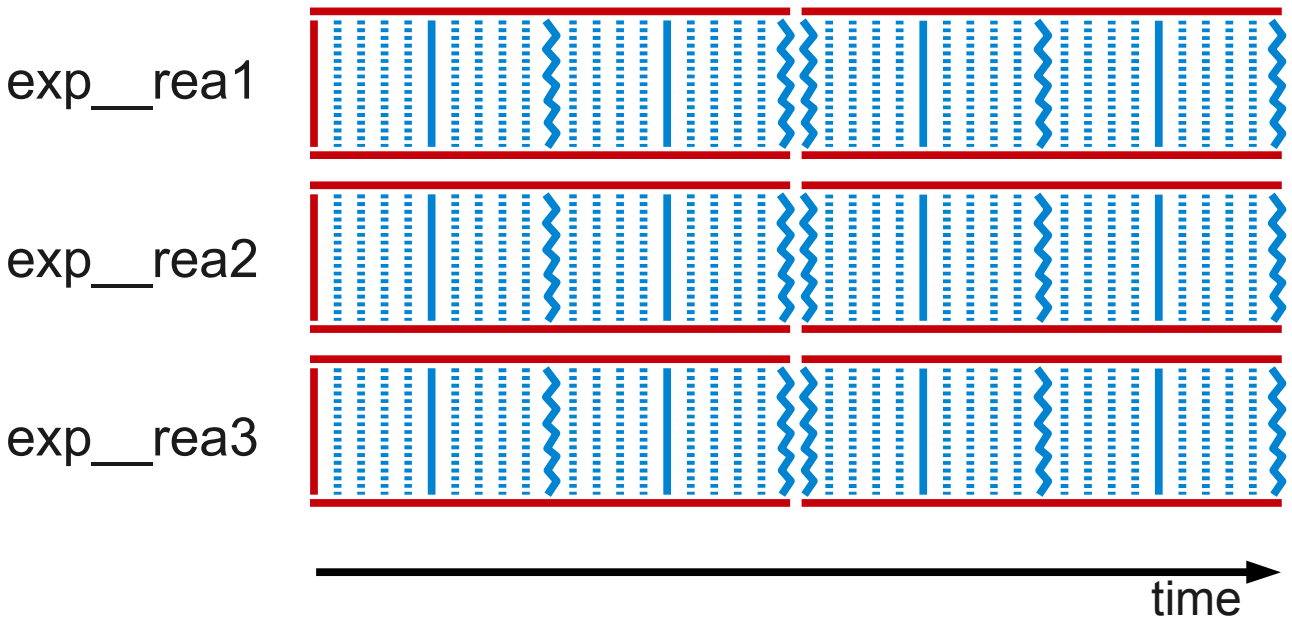
www.meteo.unican.es/software/wrf4g

Thank you!

Contact: jesus.fernandez@unican.es

More info: www.meteo.unican.es/software/wrf4g
(or just “wrf4g” → Google)

Three realizations split into two chunks each:



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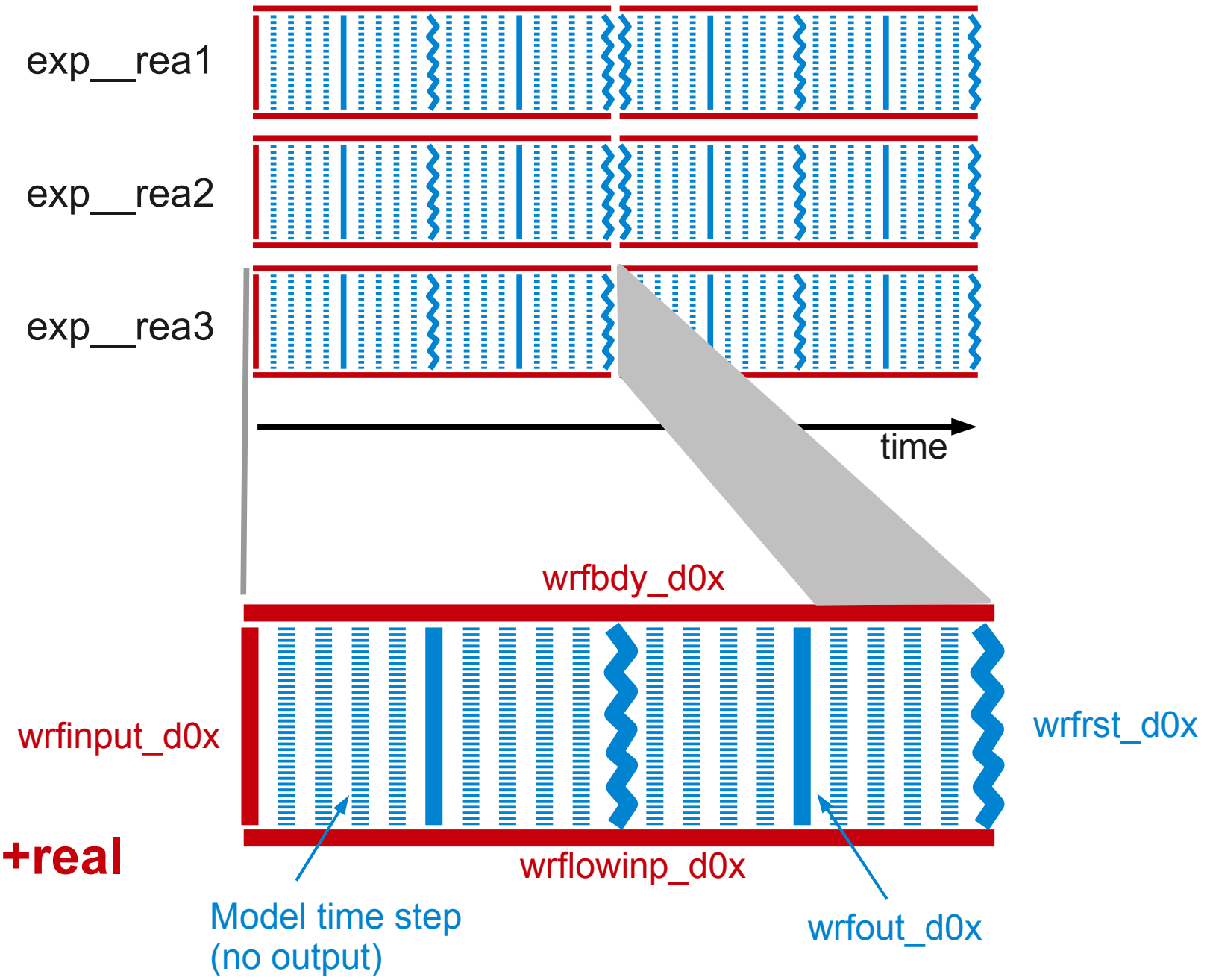
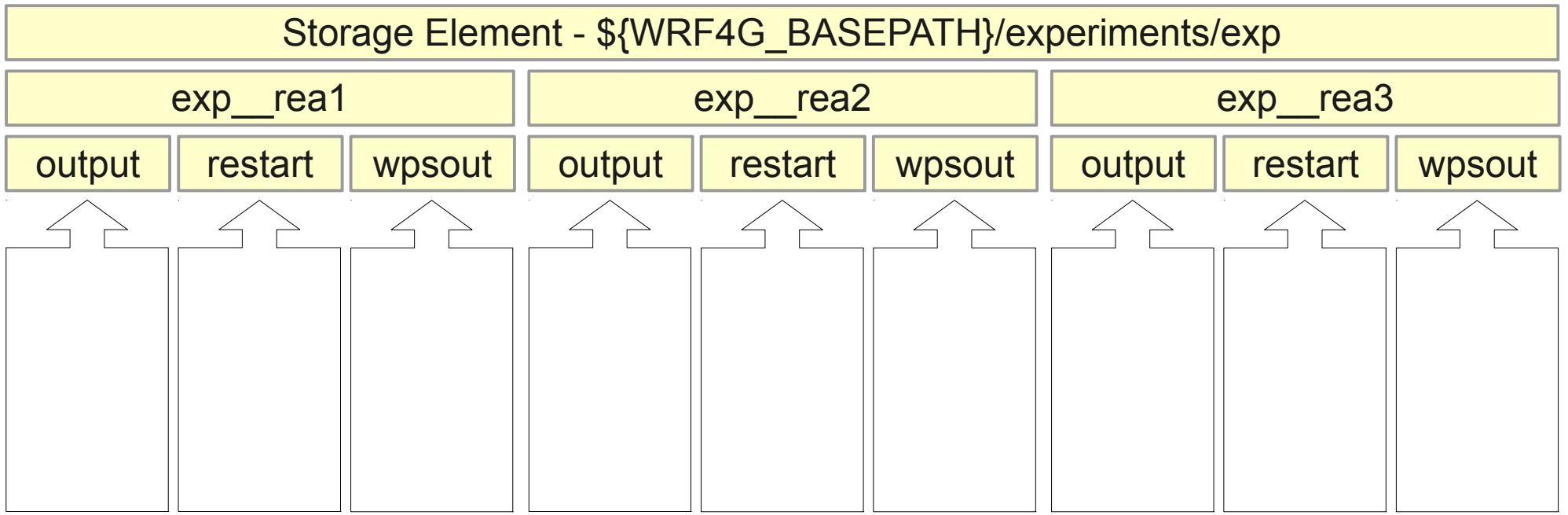


Three realizations split into two chunks each:

exp__rea1

exp__rea2

exp__rea3



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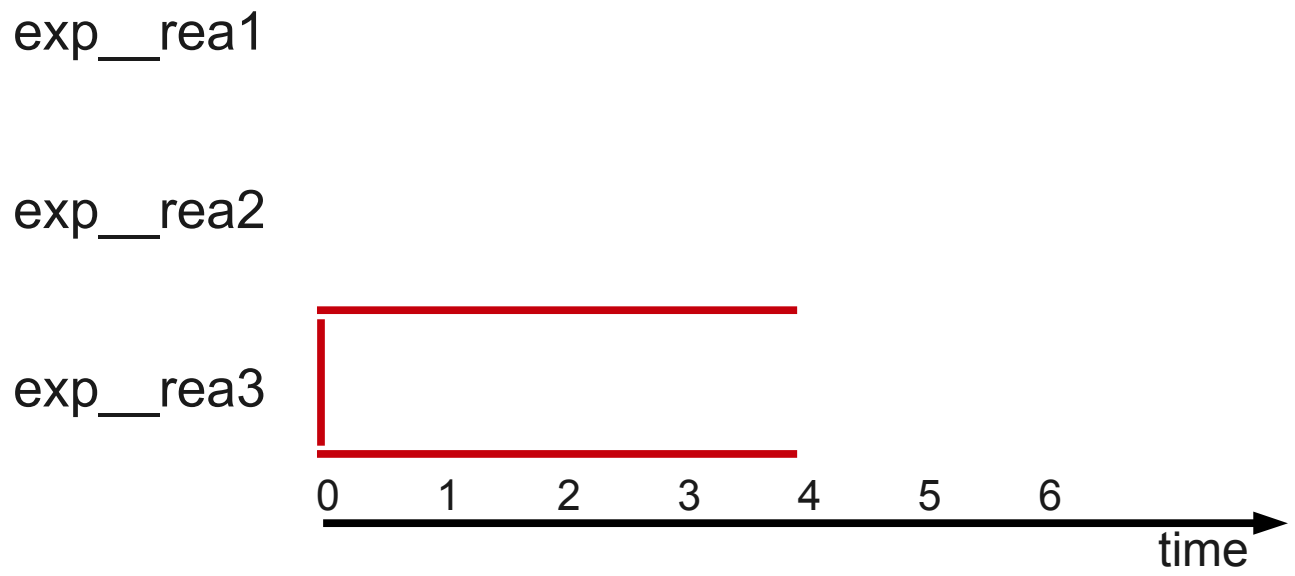

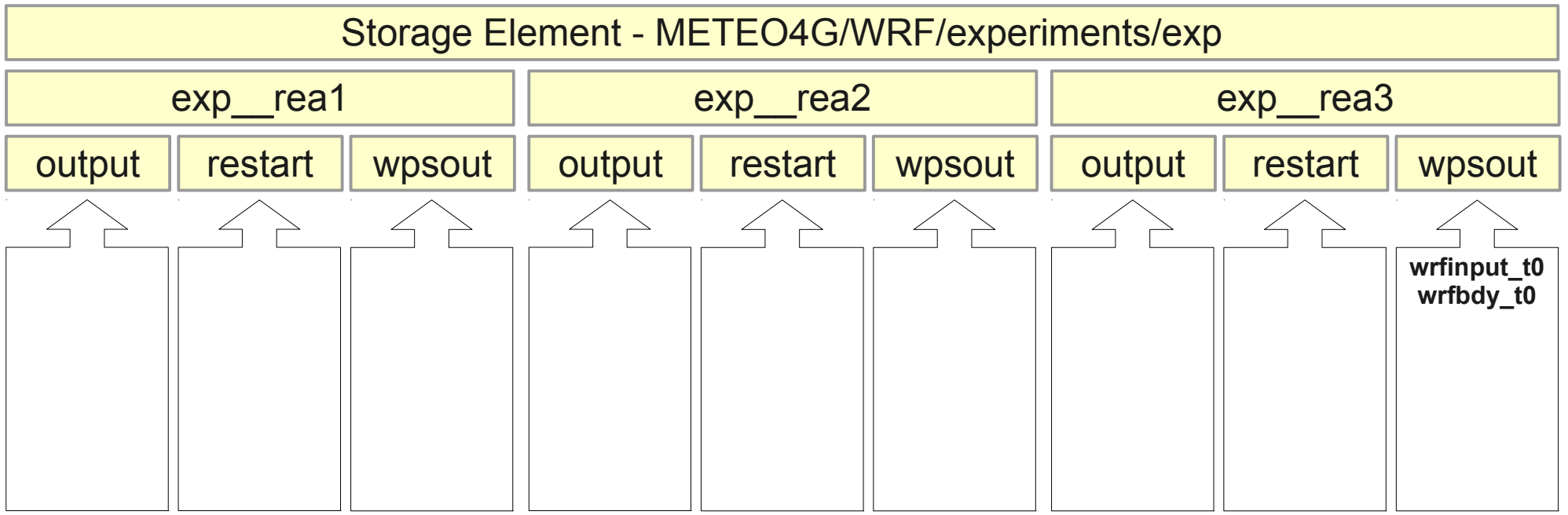

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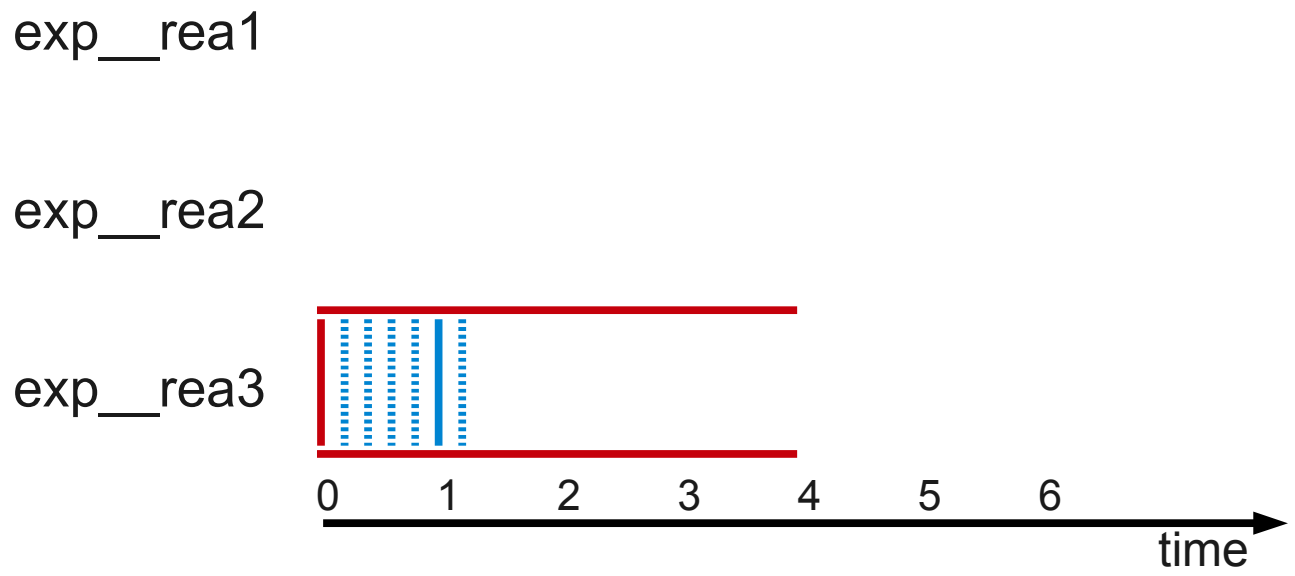

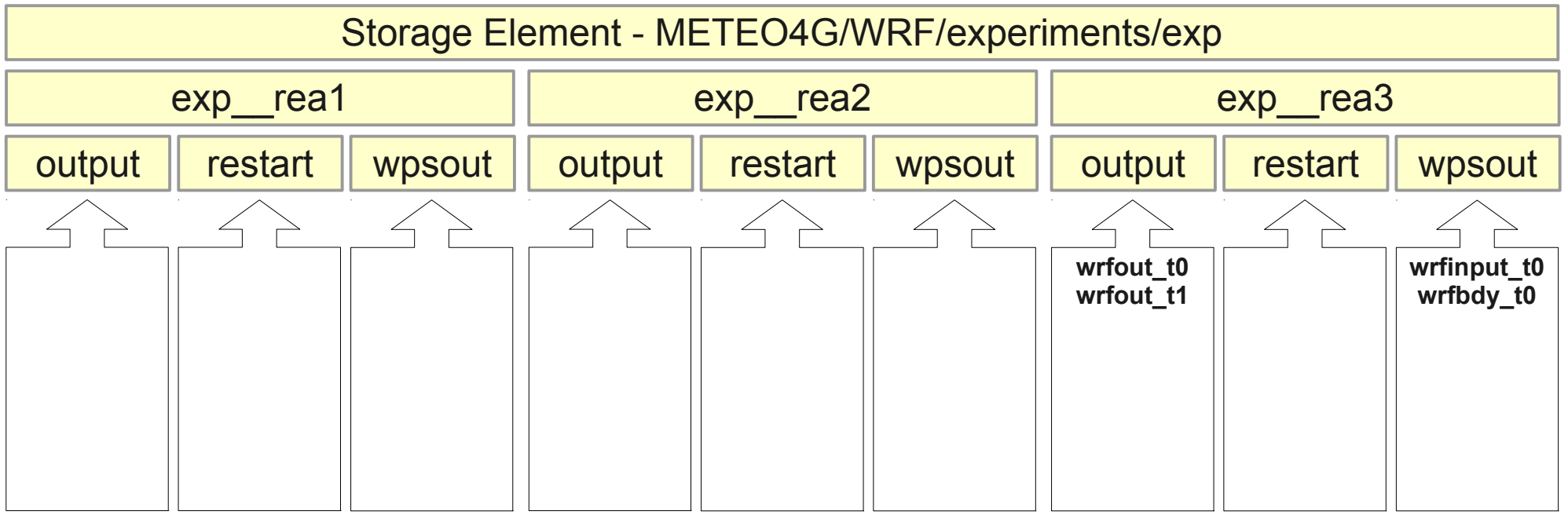

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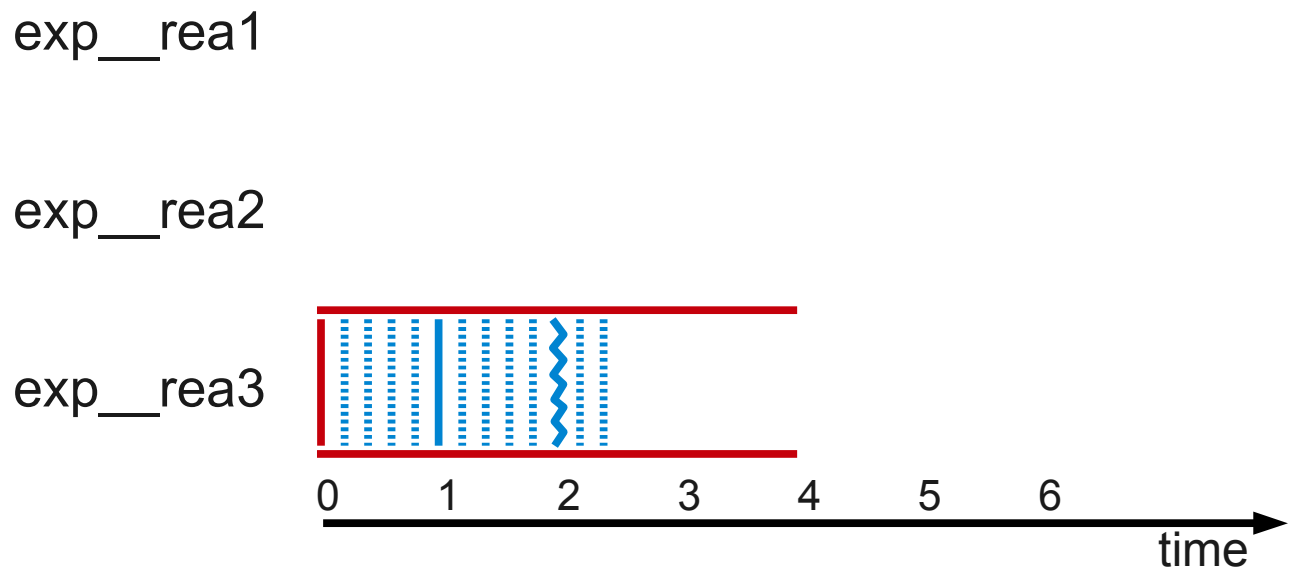

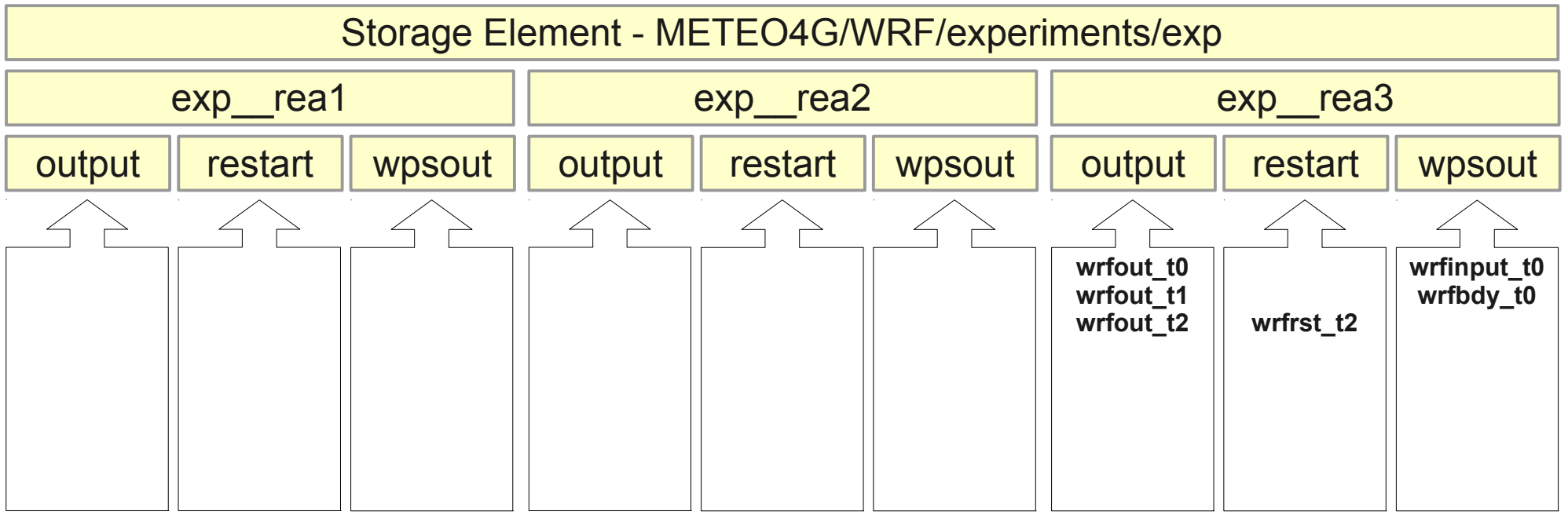

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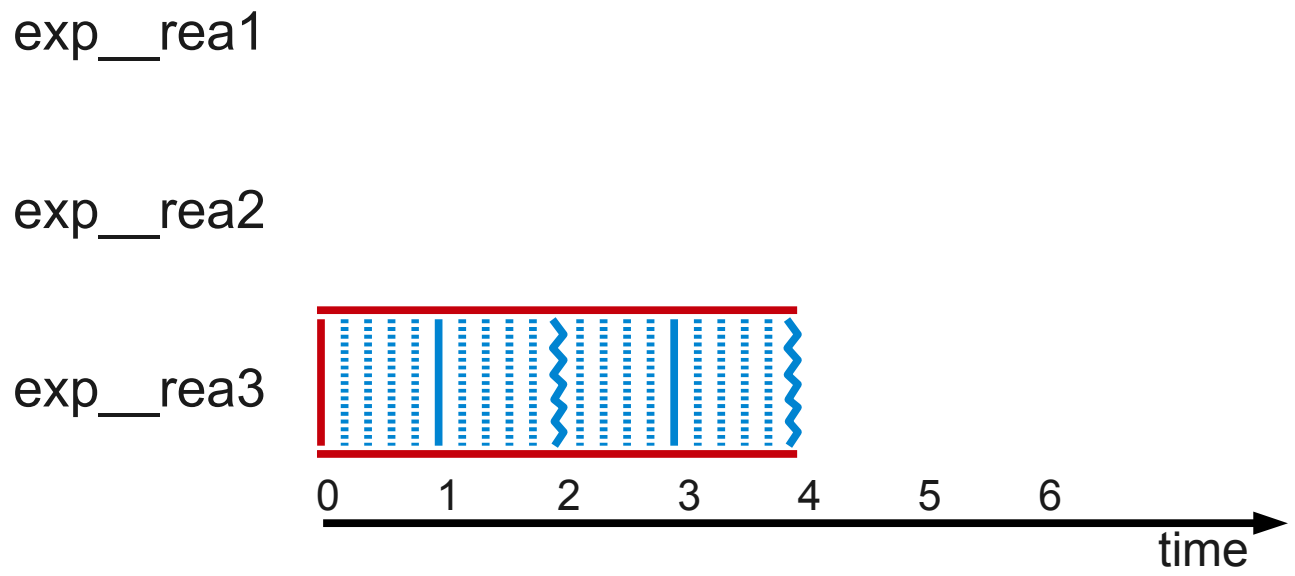

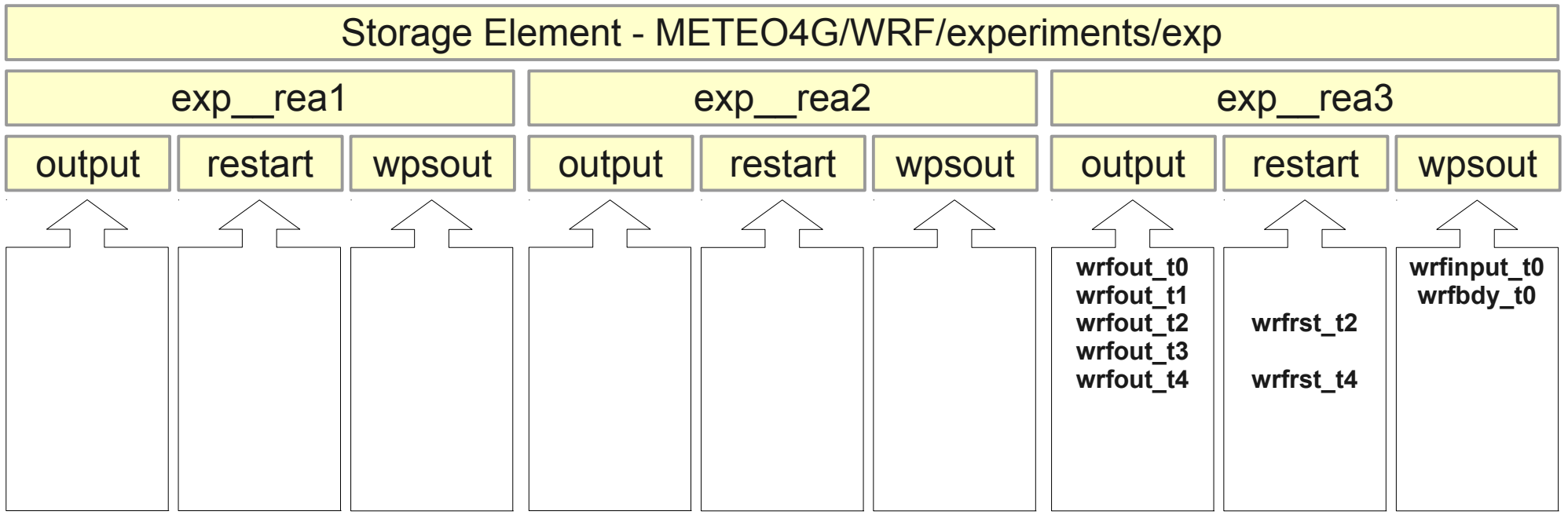

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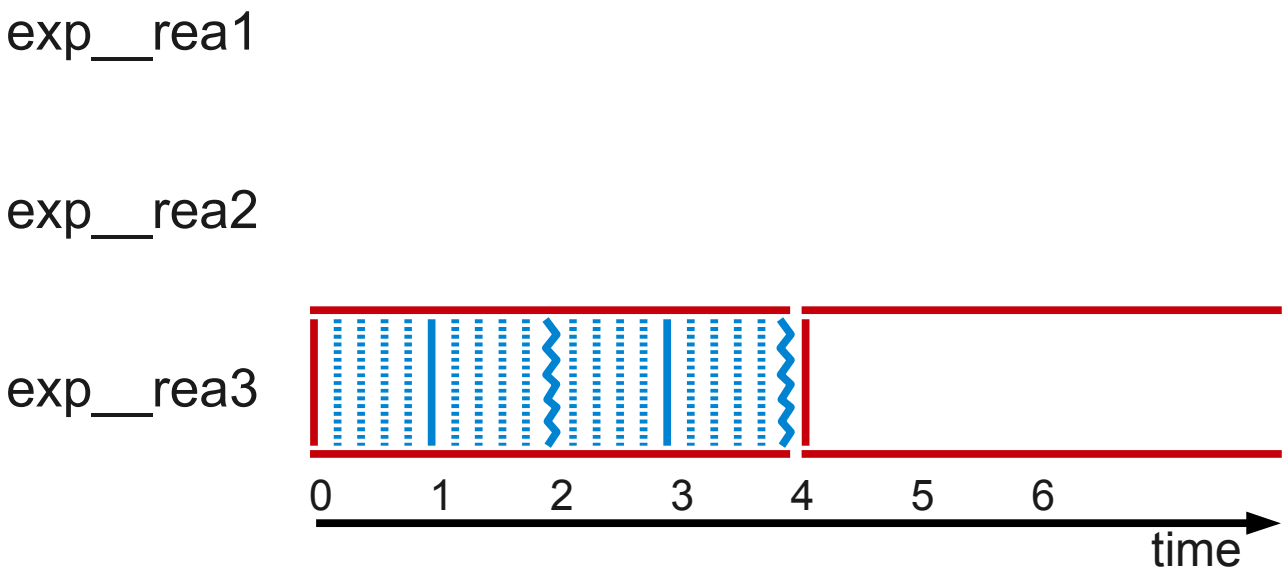

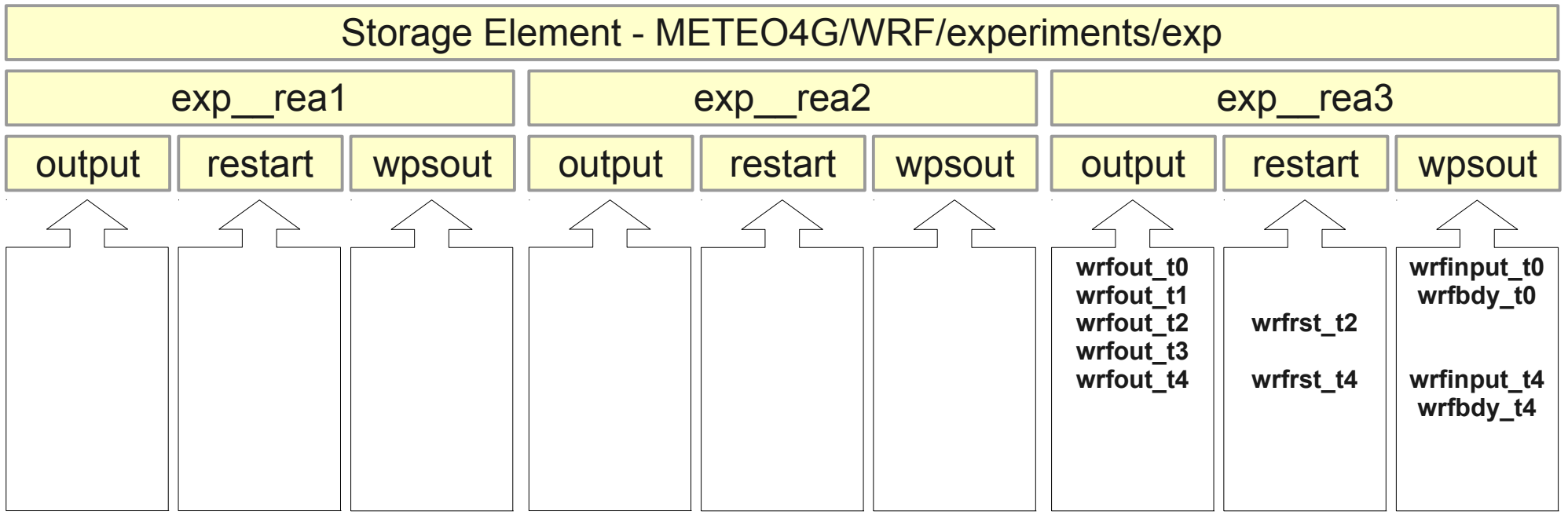

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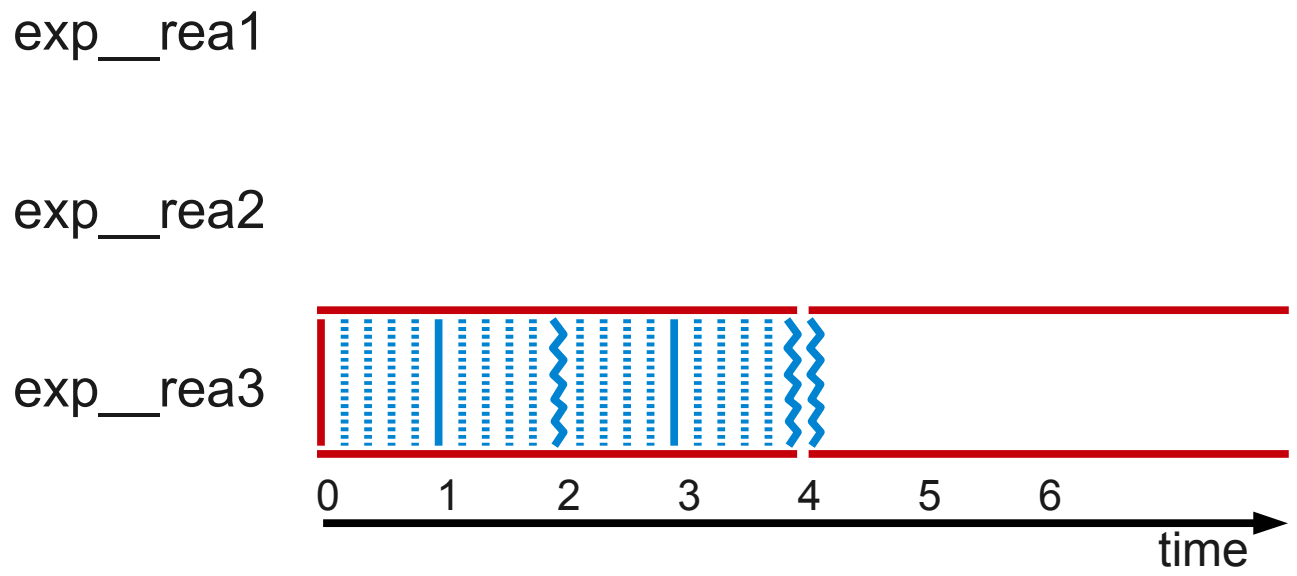

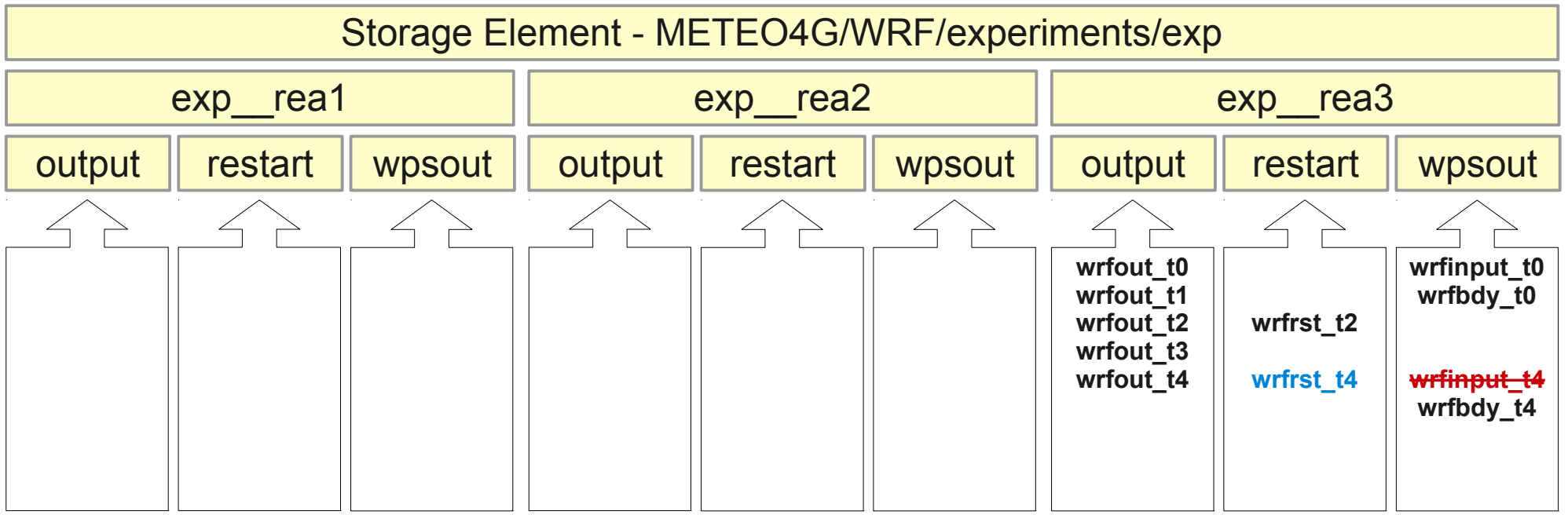

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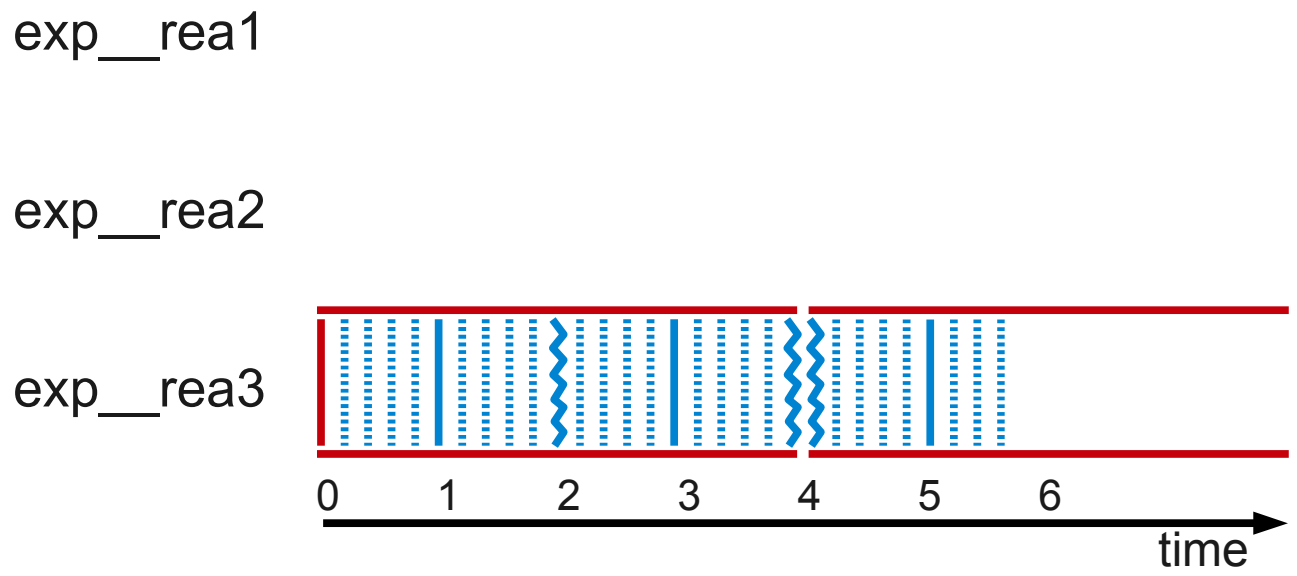

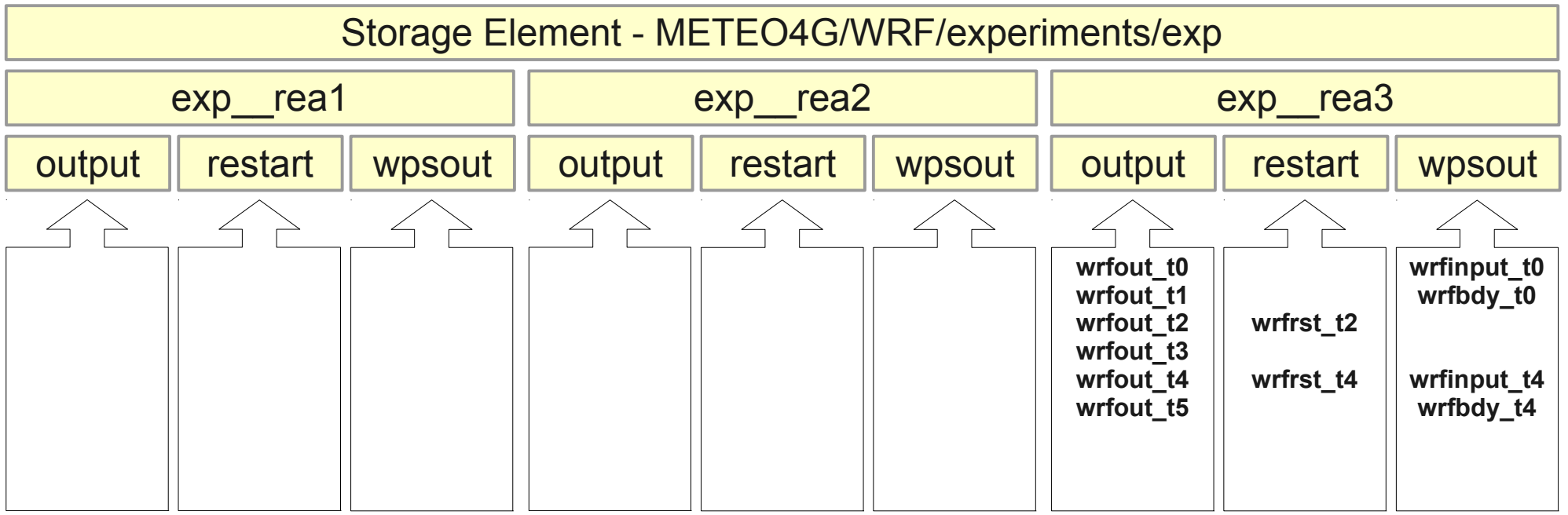

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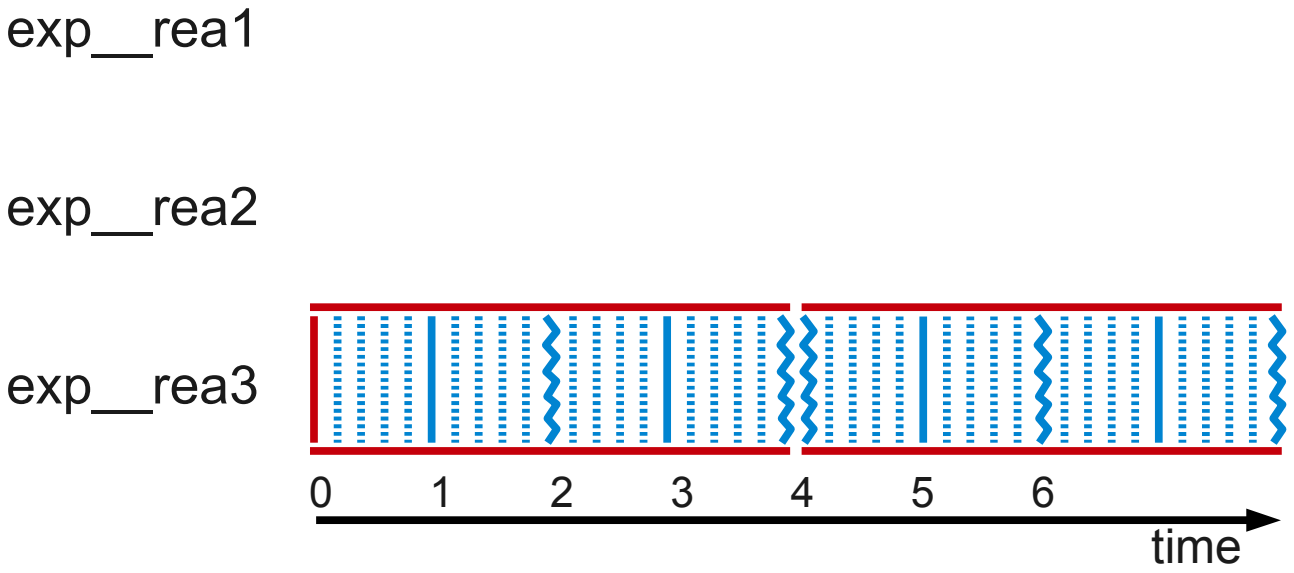

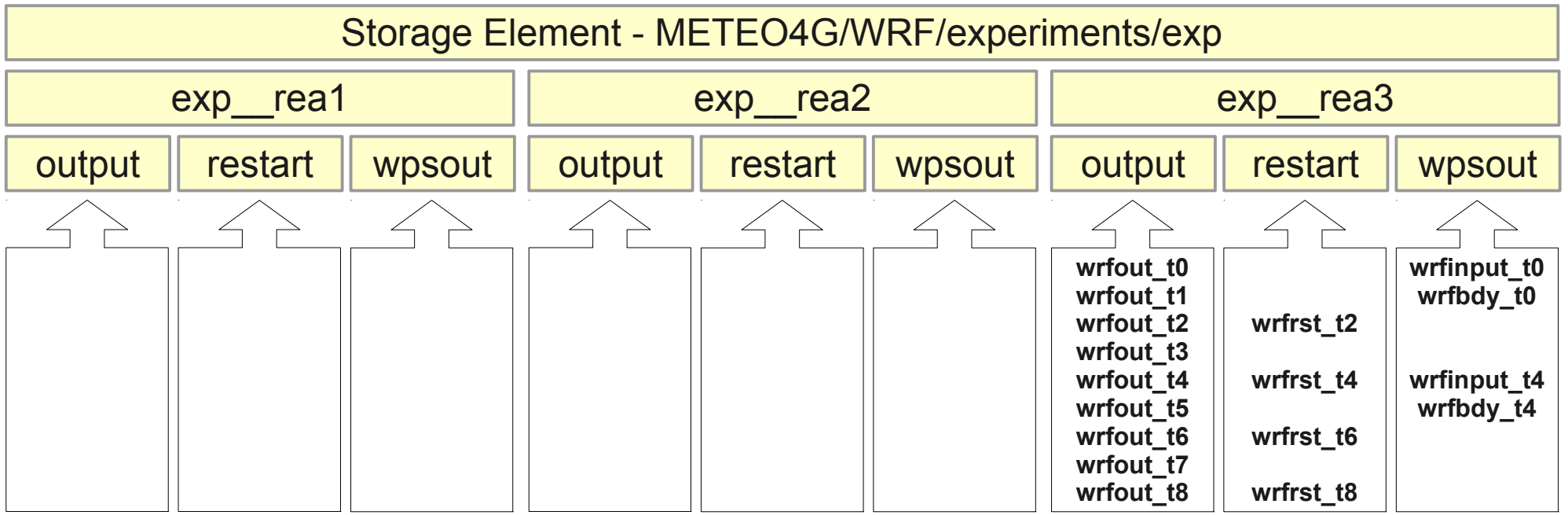

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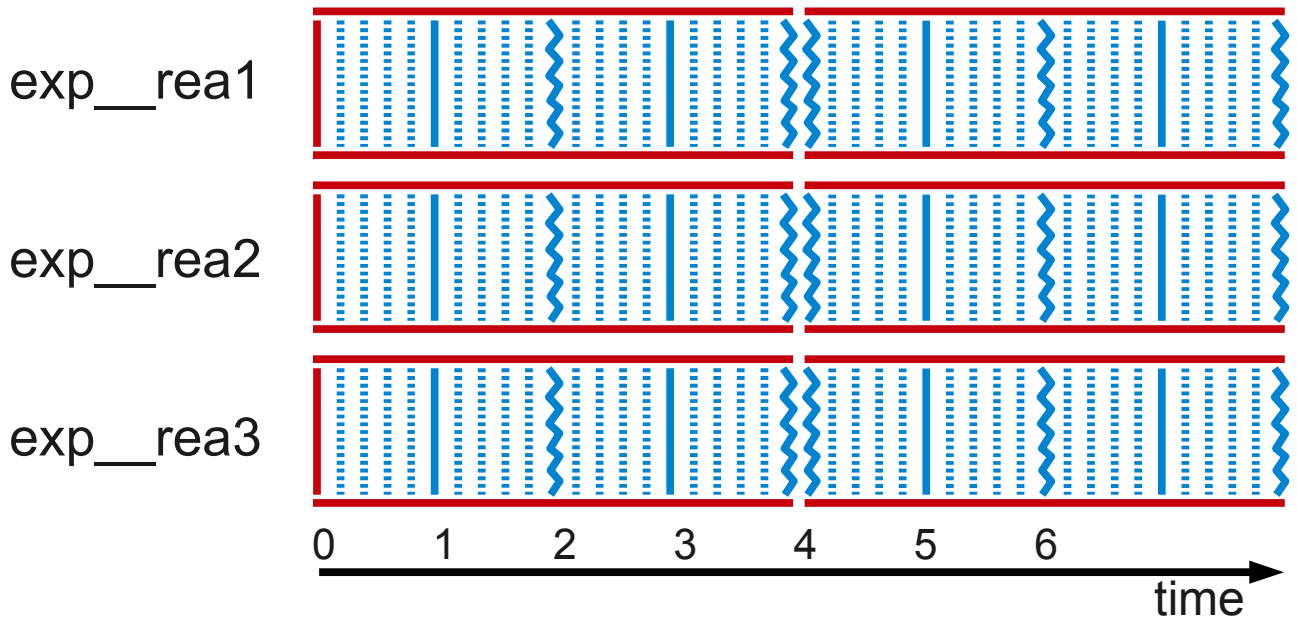

Storage Element - METEO4G/WRF/experiments/exp

exp__rea1			exp__rea2			exp__rea3		
output	restart	wpsout	output	restart	wpsout	output	restart	wpsout
wrfout_t0		wrfinput_t0	wrfout_t0		wrfinput_t0	wrfout_t0		wrfinput_t0
wrfout_t1		wrfbdy_t0	wrfout_t1		wrfbdy_t0	wrfout_t1		wrfbdy_t0
wrfout_t2	wrfrst_t2		wrfout_t2	wrfrst_t2		wrfout_t2	wrfrst_t2	
wrfout_t3			wrfout_t3			wrfout_t3		
wrfout_t4	wrfrst_t4	wrfinput_t4	wrfout_t4	wrfrst_t4	wrfinput_t4	wrfout_t4	wrfrst_t4	wrfinput_t4
wrfout_t5		wrfbdy_t4	wrfout_t5		wrfbdy_t4	wrfout_t5		wrfbdy_t4
wrfout_t6	wrfrst_t6		wrfout_t6	wrfrst_t6		wrfout_t6	wrfrst_t6	
wrfout_t7			wrfout_t7			wrfout_t7		
wrfout_t8	wrfrst_t8		wrfout_t8	wrfrst_t8		wrfout_t8	wrfrst_t8	