Big Data Analysis and Metadata Standards for Earth System Models

Sébastien Denvil, Jean-Louis Dufresne, Marie-Alice Foujols, Nicolas Carenton, Mark Greenslade (IPSL)

Yann Meurdesoif, Arnaud Caubel, Jérôme Servonnat (LSCE/IPSL)

David Salas, Stéphane Sénési (CNRM/MétéoFrance)

Sophie Valcke (CERFACS), Julien Derouillat (MDLS), and Pascal Voury (IDRIS)

Outline

- **Convergence project**
- Next generation models / implications on write rate
- Where we are “environment control speaking”
- Where we go “environment control speaking”

Objectives

CONVERGENCE :
Project funded by french research agency (2014-2018)

- To develop a platform capable of running large ensembles of simulations with a suite of models
- To handle the complex and voluminous datasets generated
- To facilitate the evaluation and validation of the models and the use of higher resolution models.

Strategy

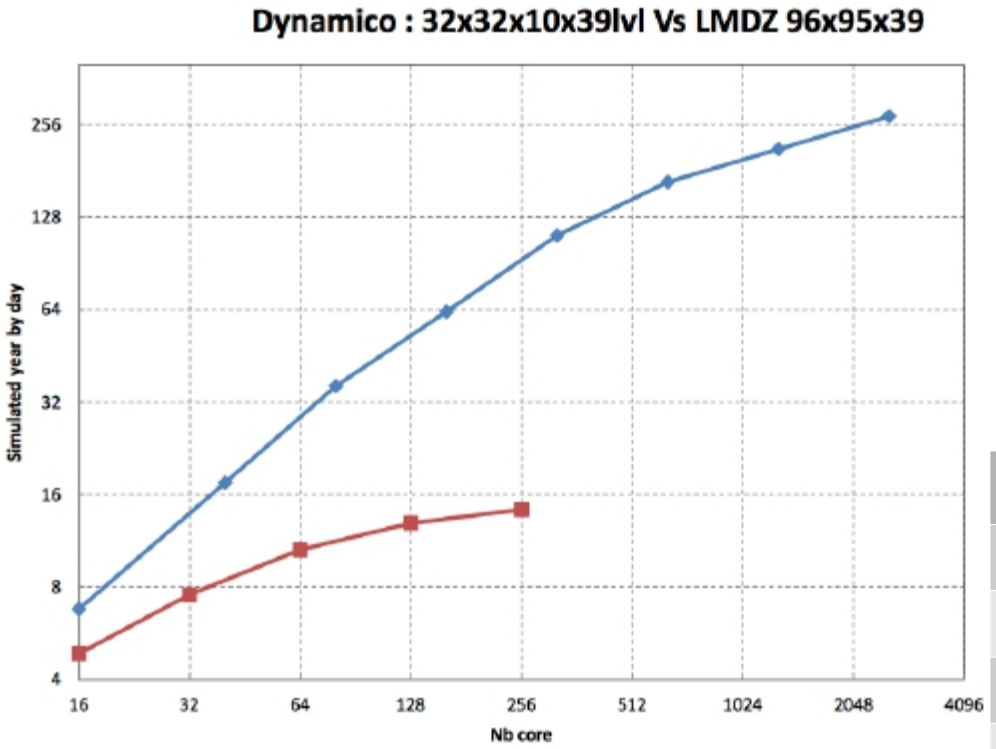
- The methodology consists in developing an ensemble of generic elements needed by French climate models
  - ensuring efficient and reliable execution of these models
  - managing large volume and variety of data
  - and allowing analysis and precise evaluation of the results
- Those generic elements will be open source and publicly available. The IPSL-CM and CNRM-CM climate models will make use of these elements that will constitute a national platform for climate modelling.

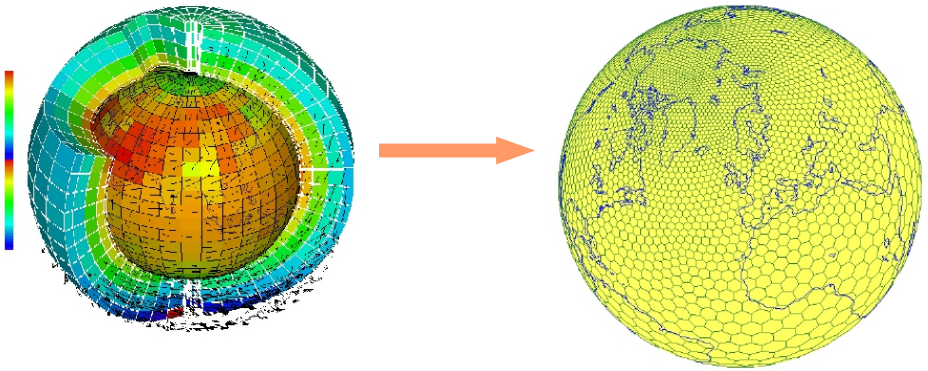
Institut Pierre Simon Laplace Sciences de l'environnement
METEO FRANCE Toujours un temps d'avance
CERFACS
MAISON DE LA SIMULATION
IDRIS
TGCC
INES Centre Informatique National de l'Enseignement Supérieur

Outline

- Convergence project
- **Next generation models / implications on write rate**
- Where we are “environment control speaking”
- Where we go “environment control speaking”

Next generation model performance





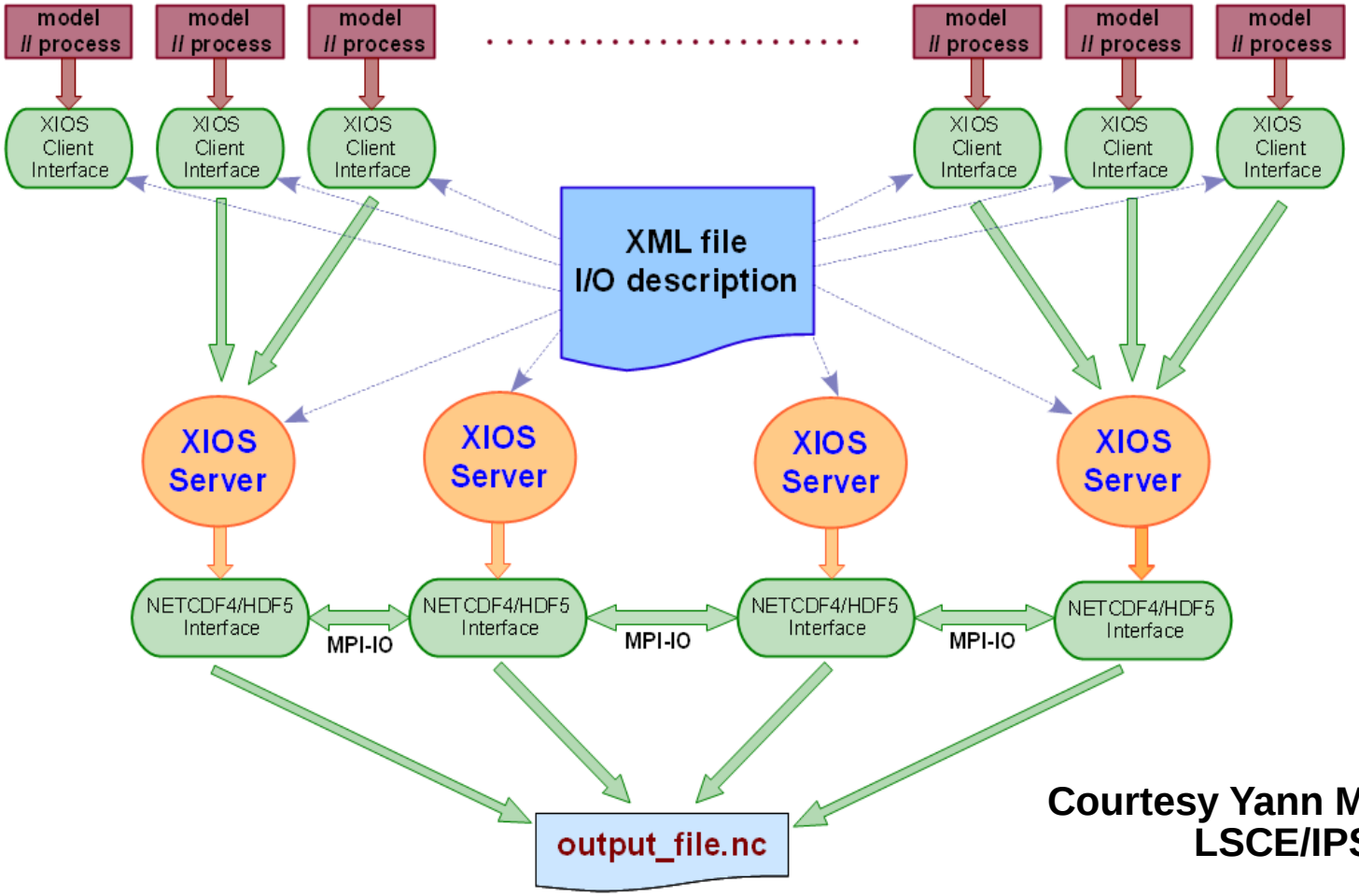
degree	cores	Year/day	Mh/century	
3	320	**110**	0,0077	*Measured*
1	1280	**20**	0,15	
1	5120	**55**	0,22	
½	5120	*10*	1,2	*Extrapolated*
½	11520	*18*	1,5	
½	20480	*28*	1,8	
¼	20480	*5*	10	
¼	46080	*8*	14	

Sciences de l'environnement — Institut Pierre Simon Laplace

Courtesy Thomas Dubos LMD/IPSL and Yann Meurdesoif LSCE/IPSL

Effective Input/Output strategy : XIOS

Objective : Having XIOS (XML IO Server) as our primary software to generate standardised data. Having a common piece of software to achieve this important task will have a lot of benefits on the long run (synergy speaking).



Courtesy Yann Meurdesoif
LSCE/IPSL

Institut Pierre Simon Laplace
Sciences de l'environnement

XIOS under extreme I/O case

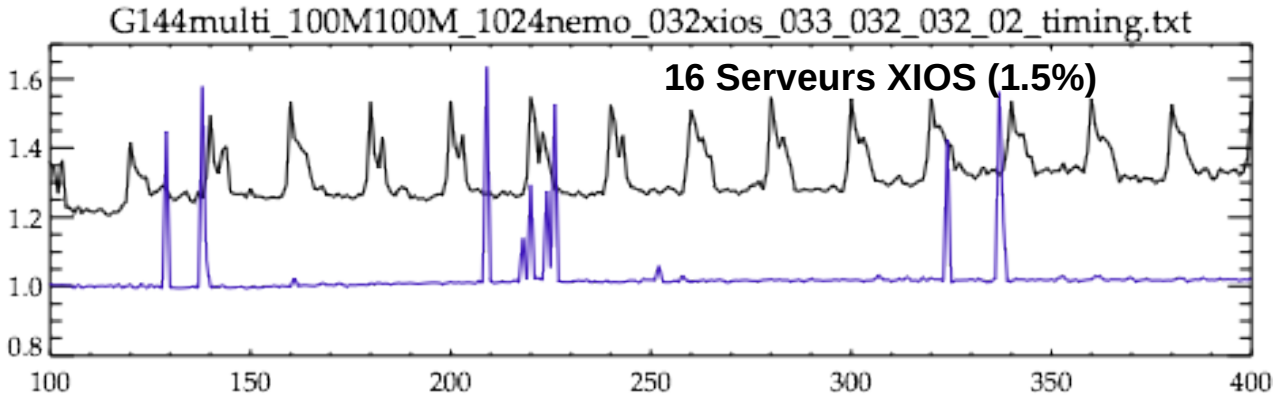
Configuration GYRE 1/12°
(4322x2882 grid points)

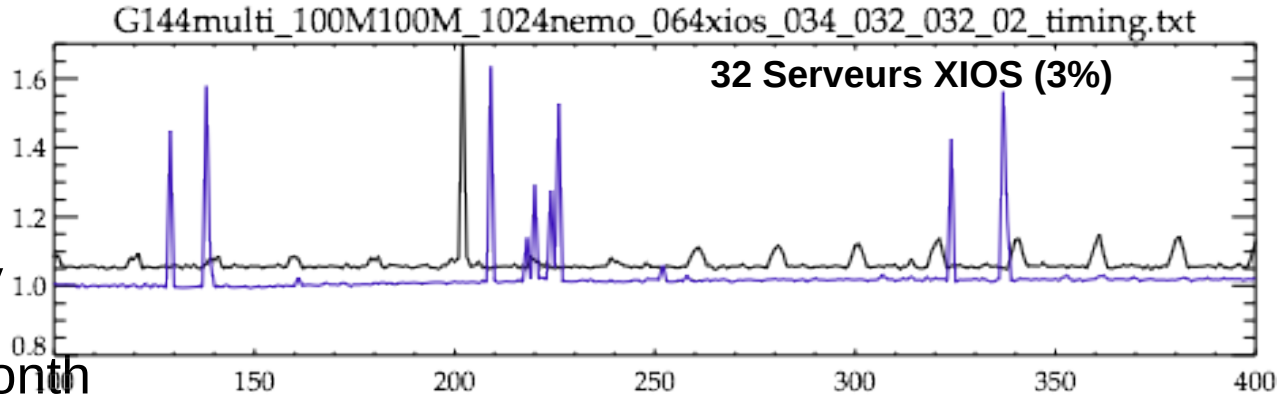
Time per iteration

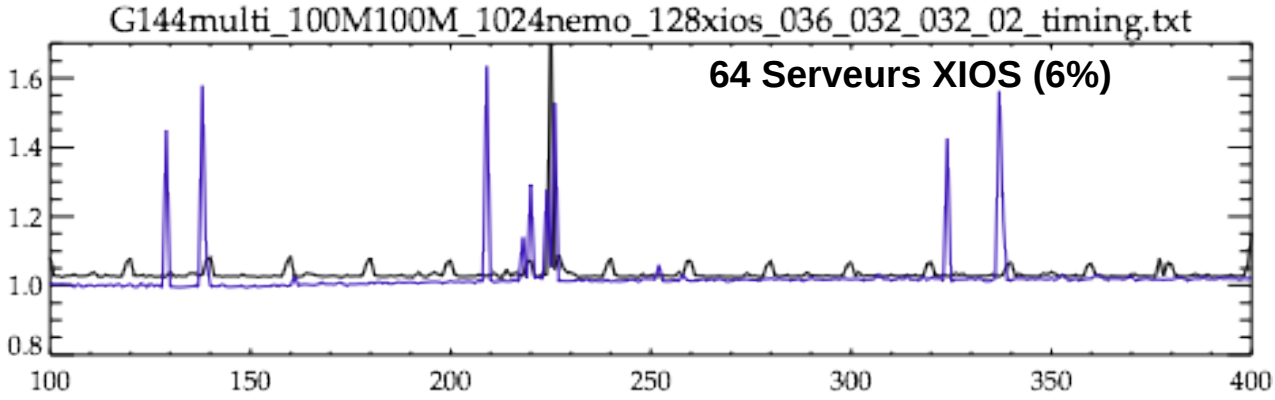
- **With Hourly Output**
- **Without Output**

246 Go within 400 seconds

- Equivalent to 51 To per day
- Equivalent to 1.5 Po per month







Courtesy Yann Meurdesoif (LSCE/IPSL) and Sébastien Masson (LOCEAN/IPSL)

Sciences de l'environnement
Institut Pierre Simon Laplace

To keep in mind

"the potential to interpret, compare and reuse climate information results is strongly related to the quality of their description"

But metadata alone won't get us there !

Computation useless if results cannot be stored/distributed/read

Sciences de l'environnement

Institut Pierre Simon Laplace

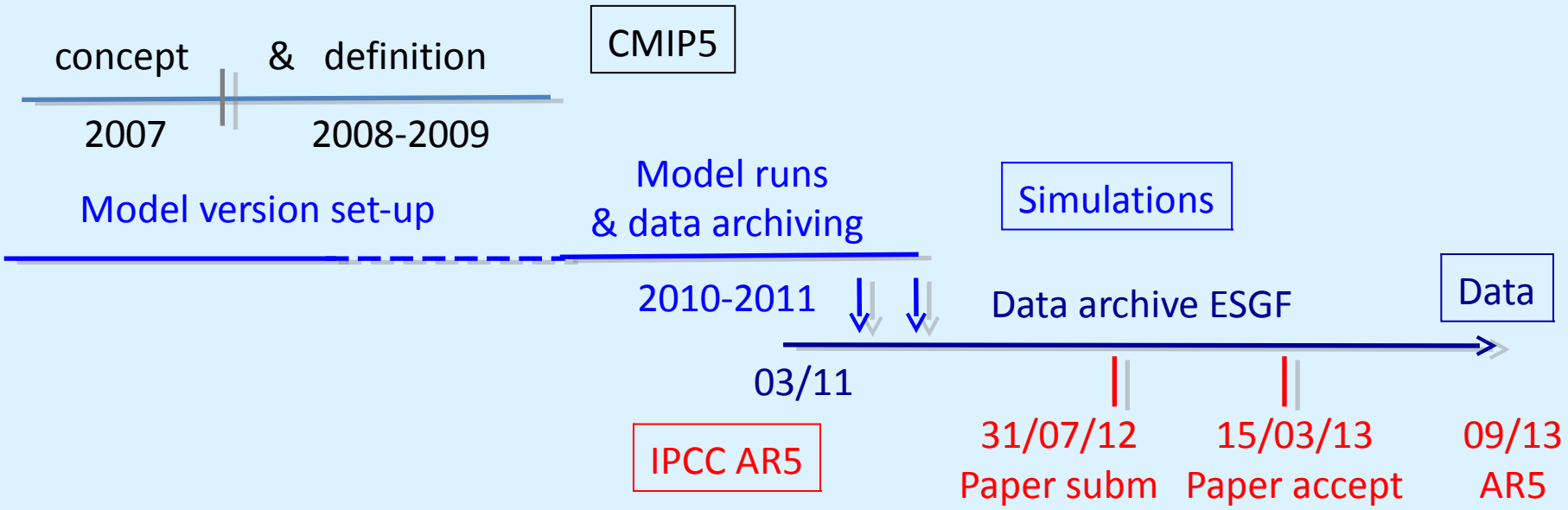
Outline

- Convergence project
- Next generation models / implications on write rate
- **Where we are "environment control speaking"**
- Where we go "environment control speaking"

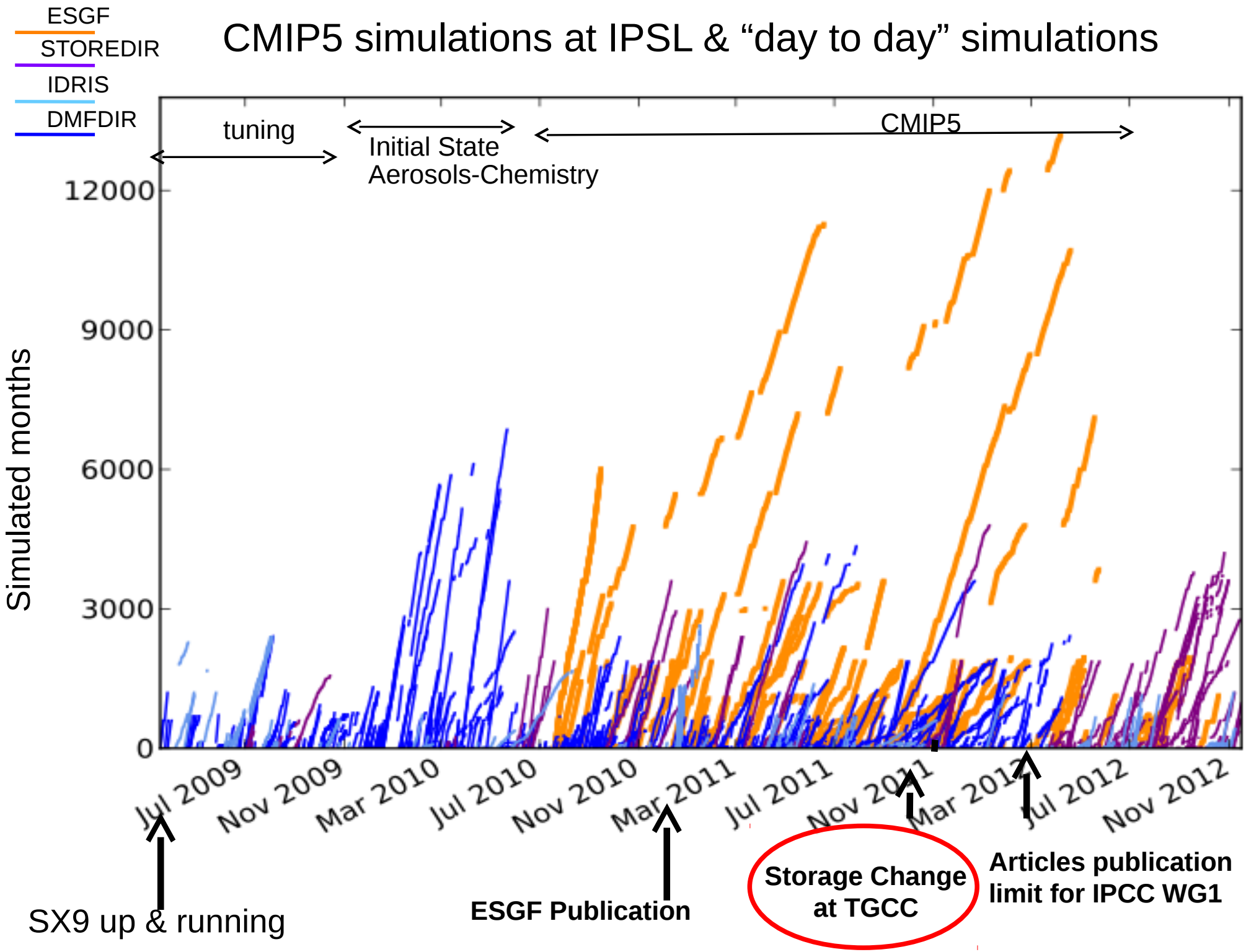
Coupled Model Intercomparison Project – CMIP5

International community under strong pressure

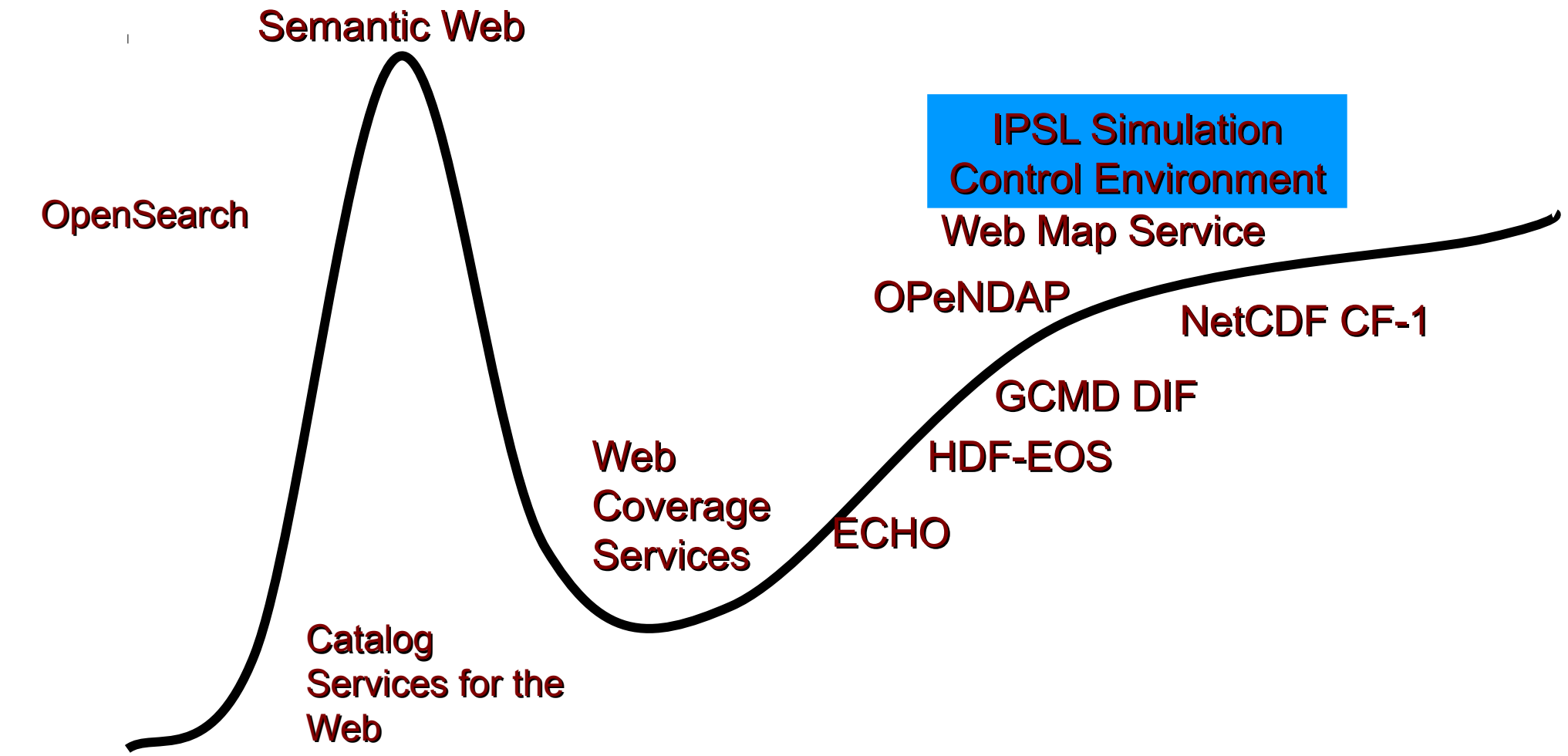
CMIP5/AR5 cycle



CMIP5 simulations at IPSL & “day to day” simulations

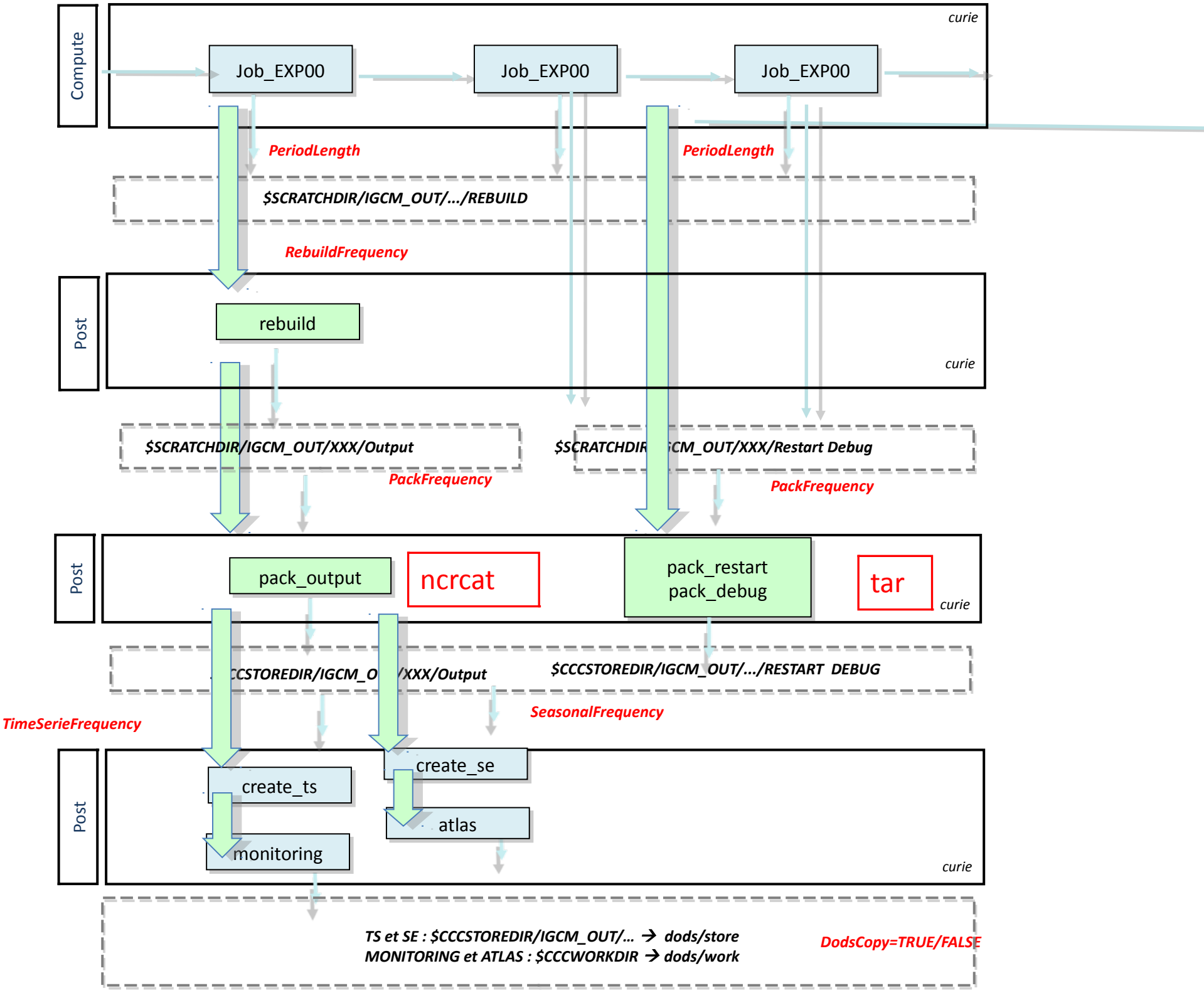


Hype .vs. Reality

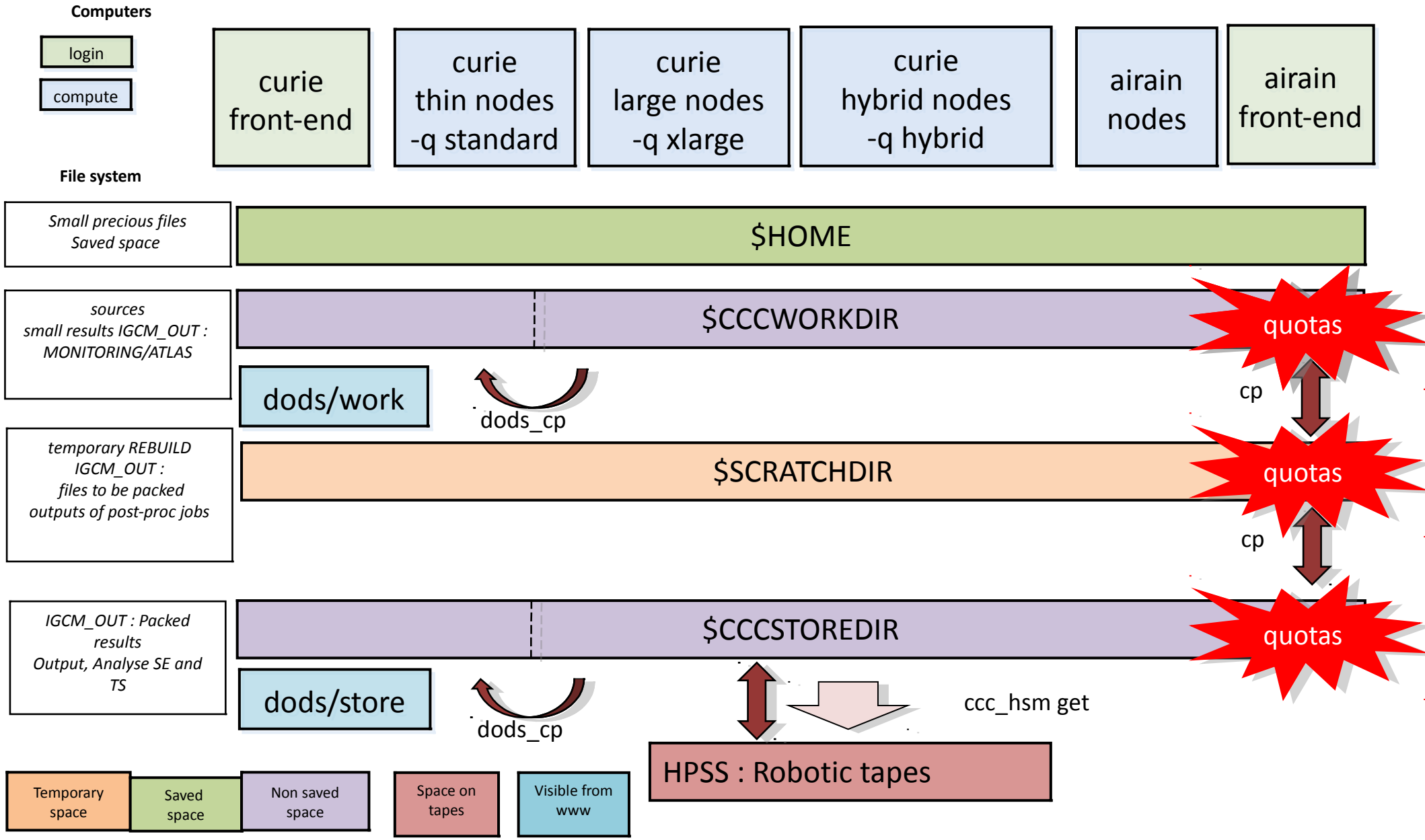


Institut Pierre Simon Laplace

TGCC


Compute
curie
Job_EXP00
Job_EXP00
Job_EXP00
PeriodLength
PeriodLength
$SCRATCHDIR/IGCM_OUT/.../REBUILD
RebuildFrequency
Post
rebuild
curie
$SCRATCHDIR/IGCM_OUT/XXX/Output
$SCRATCHDIR/IGCM_OUT/XXX/Restart Debug
PackFrequency
PackFrequency
Post
pack_output
ncrcat
pack_restart
pack_debug
tar
curie
$CCCSTOREDIR/IGCM_OUT/.../RESTART DEBUG
SeasonalFrequency
TimeSerieFrequency
Post
create_se
create_ts
atlas
monitoring
curie
TS et SE : $CCCSTOREDIR/IGCM_OUT/... → dods/store
MONITORING et ATLAS : $CCCWORKDIR → dods/work
DodsCopy=TRUE/FALSE

TGCC computers and file system in a nutshell



Profiling and performance

Type de job : create_se

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	860238	77.61	/Get
traitement	227933	20.56	/ncap2/ncrcat
exportation	20169	1.81	/Put_Out

Type de job : create_ts__2D

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	655963	62.45	/Get
traitement	366191	34.86	/cdo/ncatted/ncks/ncrcat
exportation	28200	2.68	/Put_Out

Type de job : create_ts__3D

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	125877	14.01	/Get
traitement	698877	77.82	/cdo/ncatted/ncks/ncrcat
exportation	73275	8.15	/Put_Out

Type de job : rebuild_fromWorkdir

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	16075079	45.57	/Get_Dir
traitement	17854634	50.61	/rebuild
exportation	1344607	3.81	/Put_Out

Sciences de l'environnement — Institut Pierre Simon Laplace

Percentage of different tasks per jobs type at TGCC

Profiling and performance

Action	nb de flux	minimum	maximum	moyenne	temps	depuis-vers
+ cdo	731	0.048828	24.002877	3.819191	259690	scratch-->scratch
+ Get_Dir	120	1.485950	30.715222	14.850255	16075079	scratch-->scratch
+ Get	33	0.157934	141.789306	79.400482	1641187	store-->scratch
+ Get	12	0.455728	1.813615	0.882582	891	work-->scratch
+ ncap2	15	5.815618	72.522759	33.651057	155106	scratch-->scratch
+ ncatted	389	0.067348	1008.697509	75.519026	12902	scratch-->scratch
+ ncks	731	0.032869	4.257812	1.505090	71500	scratch-->scratch
+ ncrcat	404	0.054252	161.906567	22.448468	793803	scratch-->scratch
+ Put_Out	1921	0.245659	279.044197	102.024970	1344607	scratch-->scratch
+ Put_Out	793	0.072337	296.996311	80.424637	121644	scratch-->store
+ rebuild	1921	0.000875	91.817505	14.815793	17854634	scratch-->scratch

Statistics for each elementary function on TGCC

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	17717157	46.22	/Get/Get_Dir
traitement	19147635	49.95	/cdo/ncap2/ncatted/ncks/ncrcat/rebuild
exportation	1466251	3.82	/Put_Out

Percentage of different tasks family at TGCC

Type action	Temps cumule	pourcentage	Actions correspondantes
importation	8042353	64.69	/Get/Get_Dir
traitement	2753828	22.15	/cdo/ncap2/ncatted/ncks/ncrcat/rebuild
exportation	1635210	13.15	/Put_Out

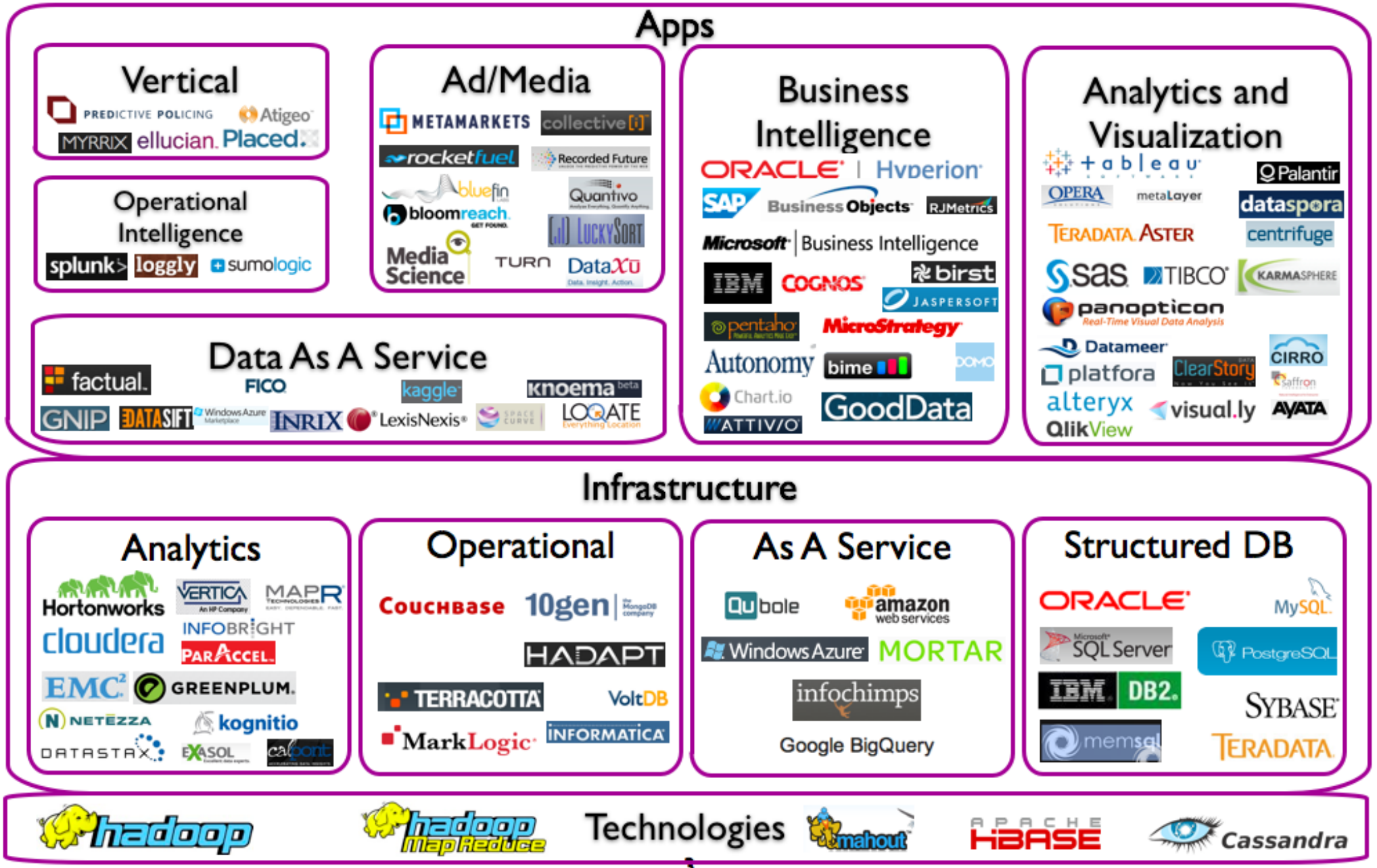
Percentage of different tasks family at IDRIS

Sciences de l'environnement
Institut Pierre Simon Laplace

Outline

- Convergence project
- Next generation models / implications on write rate
- Where we are “environment control speaking”
- **Where we go “environment control speaking”**

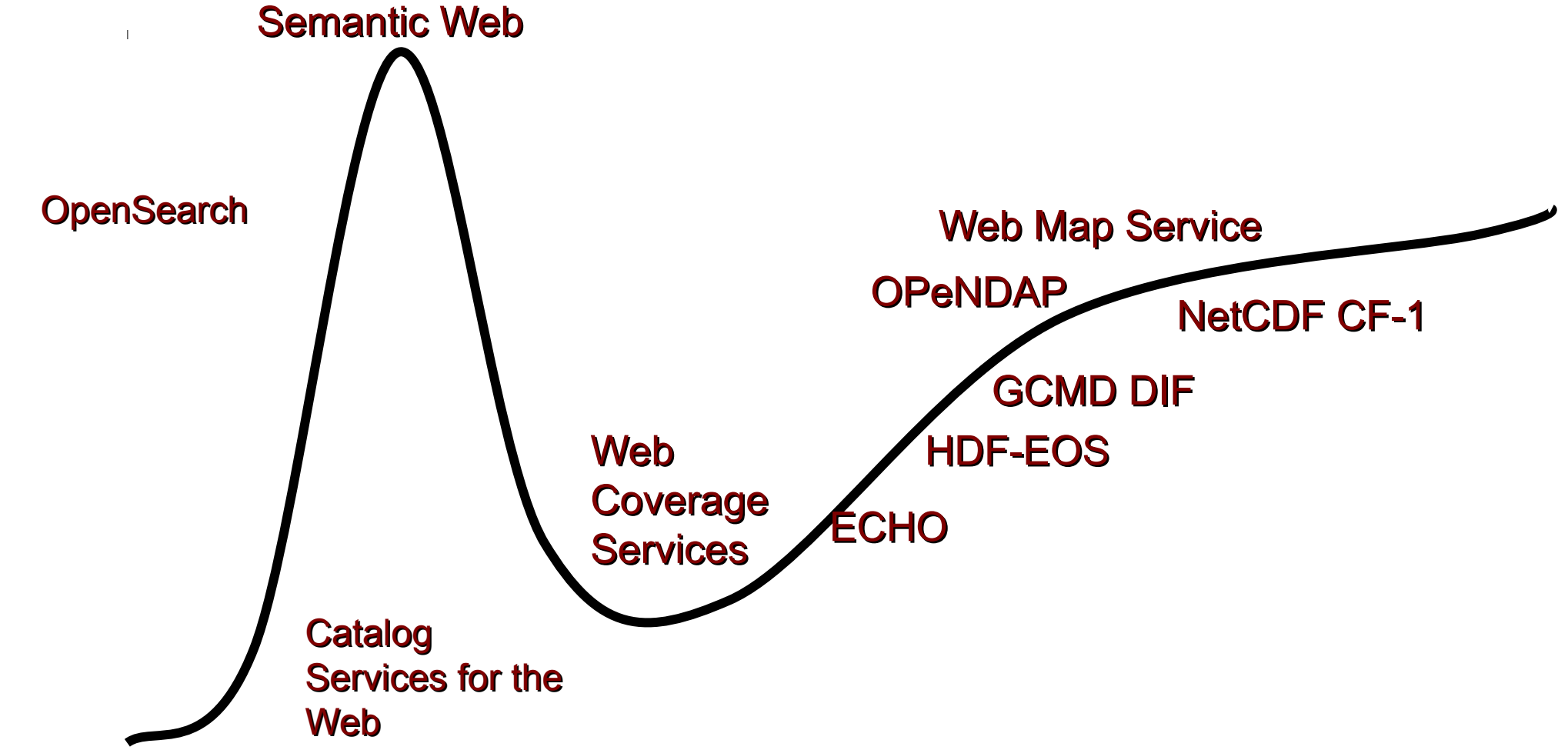
Big Data Landscape



dave@vcdave.com

bigdatalandcsape.com

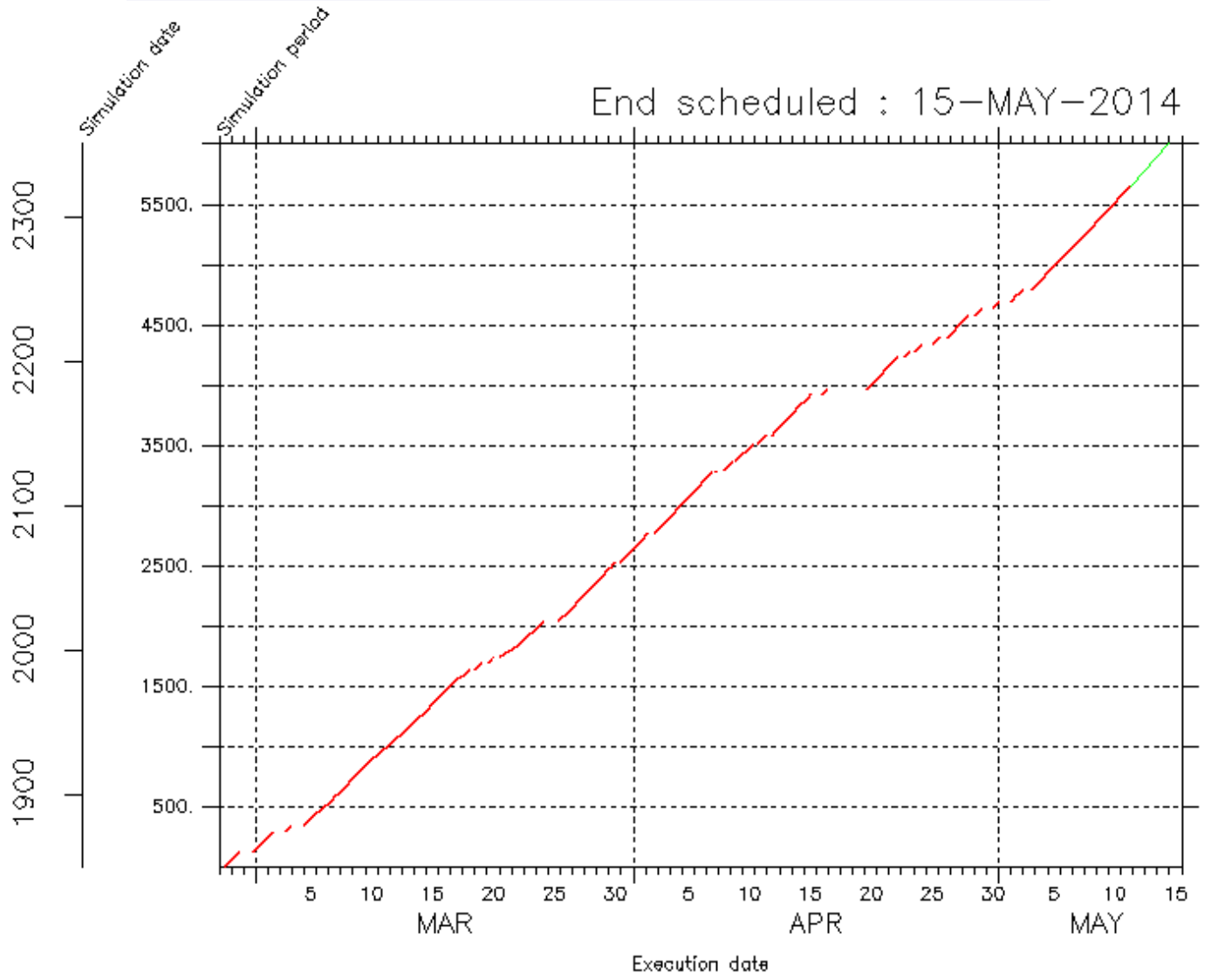
Hype .vs. Reality
Interoperability in Earth Sciences

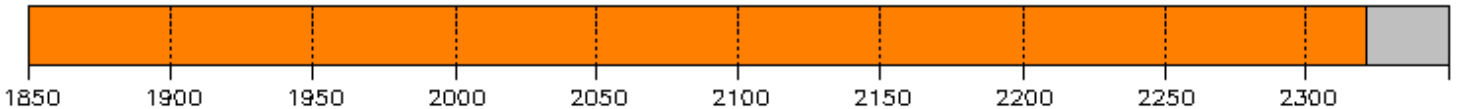


Sciences de l'environnement

Institut Pierre Simon Laplace

CM5AEH01 : 1850-2349





Institut Pierre Simon Laplace
Sciences de l'environnement

Why is it good to log « all around » ?

THEN...

Log files

```
[Sun Dec 21 09:17:09 2008] [error]
[Sun Dec 21 10:04:53 2008] [error]
[Sun Dec 21 10:45:50 2008] [error]
[Sun Dec 21 11:14:09 2008] [error]
[Sun Dec 21 12:26:04 2008] [error]
[Sun Dec 21 13:41:05 2008] [error]
[Sun Dec 21 14:37:16 2008] [error]
[Sun Dec 21 15:19:39 2008] [error]
[Sun Dec 21 15:26:05 2008] [error]
[Sun Dec 21 15:51:07 2008] [error]
```

NOW...

Operational intelligence

Message Queues

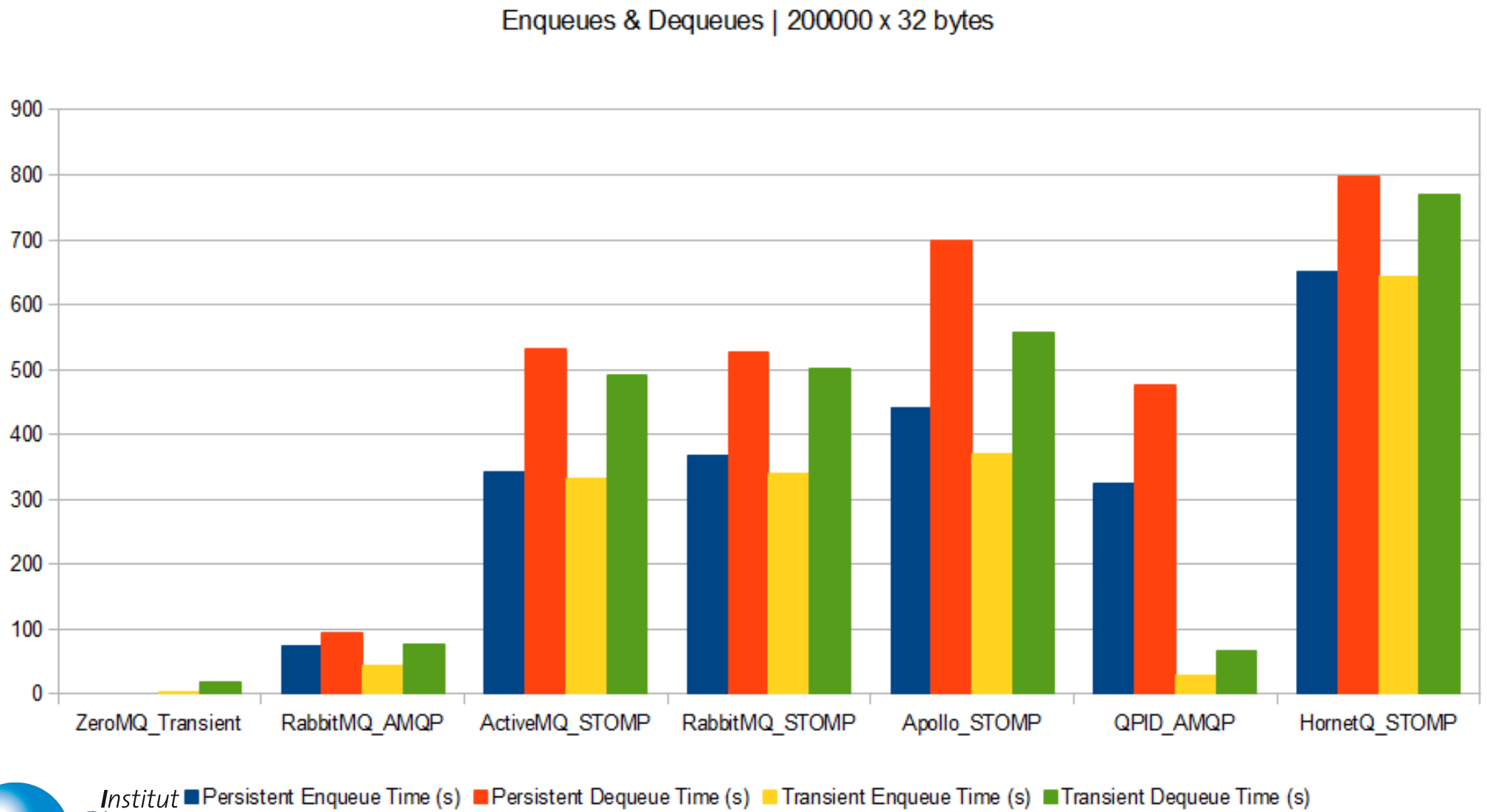
Rabbit MQ

http://www.rabbitmq.com/

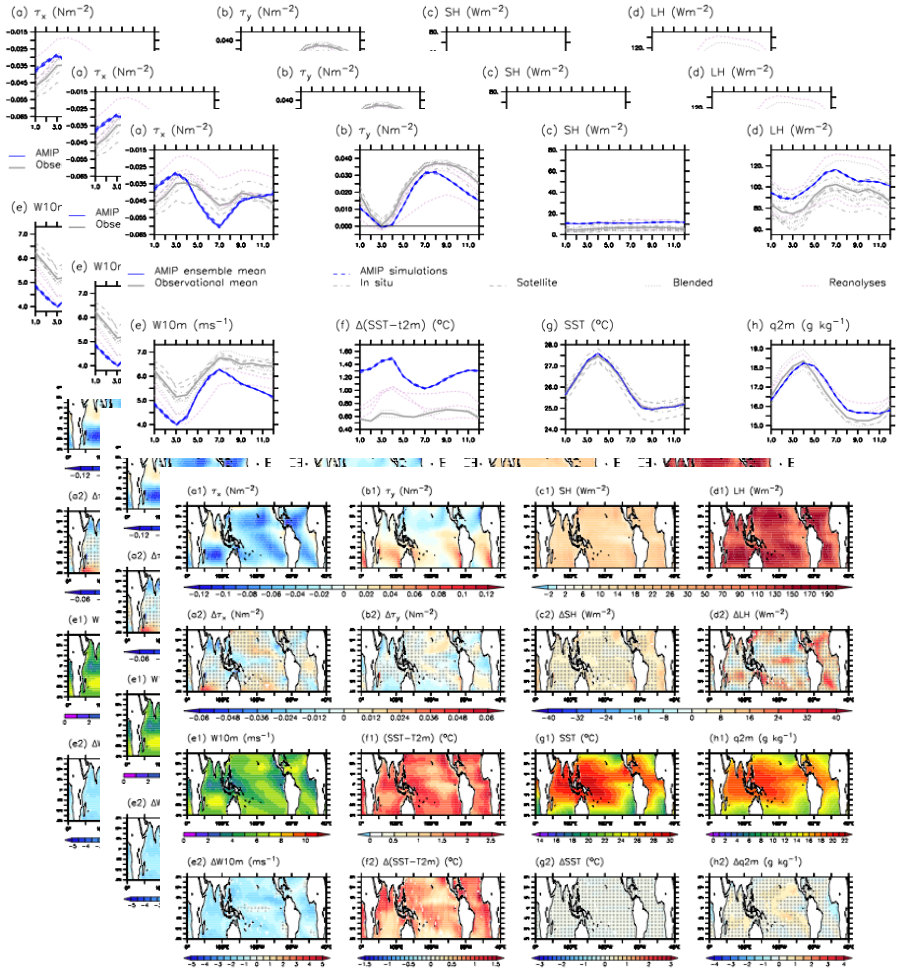
Durable Message Queues
AMQP : Advanced Message Queue Protocol
Open source message broker

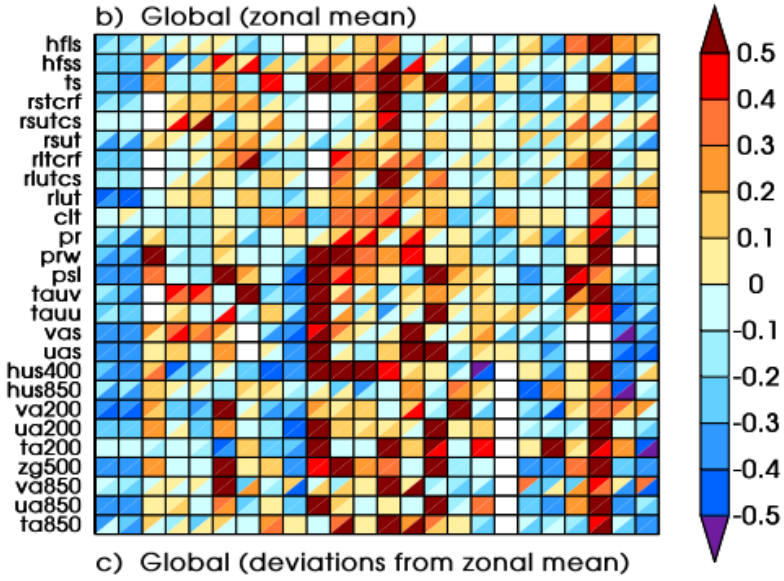
- Robust
- Powerful
- surprisingly simple to use

Performances



Synthesis is so important here also





Metrics Garden

Metrics Garden User Web Interface

Test Glecker like metrics on CMIP5 version of IPSL models

			Result															
		Variable	clt		hfls		hfss		pr		psl		rlds		rldscs		rlus	
		RegionName	Globe	NHEX	Globe	NHEX	Globe	NHEX	Globe	NHEX	Globe	NHEX	Globe	NHEX	Globe	NHEX	Globe	NH
Model	Experiment	SimName																
IPSL-CM5A-LR	historical	r1i1p1	-0.092	-0.118	+0.071	-0.006	-0.044	-0.024	+0.230	+0.241	+0.040	-0.020	+0.092	+0.072	+0.192	+0.092	-0.101	-0.
		r2i1p1	-0.098	-0.135	+0.055	-0.020	-0.062	-0.033	+0.213	+0.083	+0.039	+0.095	+0.026	-0.001	+0.124	+0.029	-0.113	-0.
		r3i1p1	-0.094	-0.126	+0.109	+0.010	-0.047	-0.035	+0.316	+0.238	+0.035	-0.033	+0.198	+0.155	+0.363	+0.230	-0.058	+0.
		r4i1p1	-0.090	-0.117	+0.036	-0.007	-0.071	-0.021	+0.252	+0.242	+0.001	-0.013	+0.136	+0.121	+0.217	+0.122	-0.089	+0.
		r5i1p1	-0.094	-0.115	+0.045	-0.038	-0.105	-0.072	+0.283	+0.197	+0.031	-0.019	+0.113	+0.034	+0.224	+0.056	-0.181	-0.
		r6i1p1	-0.097	-0.115	+0.053	+0.001	-0.087	-0.051	+0.370	+0.251	-0.041	-0.002	+0.116	+0.059	+0.221	+0.091	-0.057	-0.
IPSL-CM5A-MR	historical	r1i1p1	-0.122	-0.070	-0.331	-0.235	-0.167	-0.197	-0.537	-0.519	-0.214	-0.250	-0.409	-0.354	-0.510	-0.413	-0.142	-0.
		r2i1p1	-0.095	-0.030	-0.299	-0.220	-0.125	-0.170	-0.630	-0.593	-0.285	-0.245	-0.406	-0.343	-0.576	-0.383	-0.028	-0.
		r3i1p1	-0.097	-0.040	-0.370	-0.242	-0.125	-0.199	-0.597	-0.547	-0.303	-0.257	-0.433	-0.371	-0.628	-0.411	-0.052	-0.
IPSL-CM5B-LR	historical	r1i1p1	+0.878	+0.865	+0.630	+0.758	+0.833	+0.801	+0.098	+0.407	+0.697	+0.743	+0.567	+0.629	+0.372	+0.587	+0.819	+0.

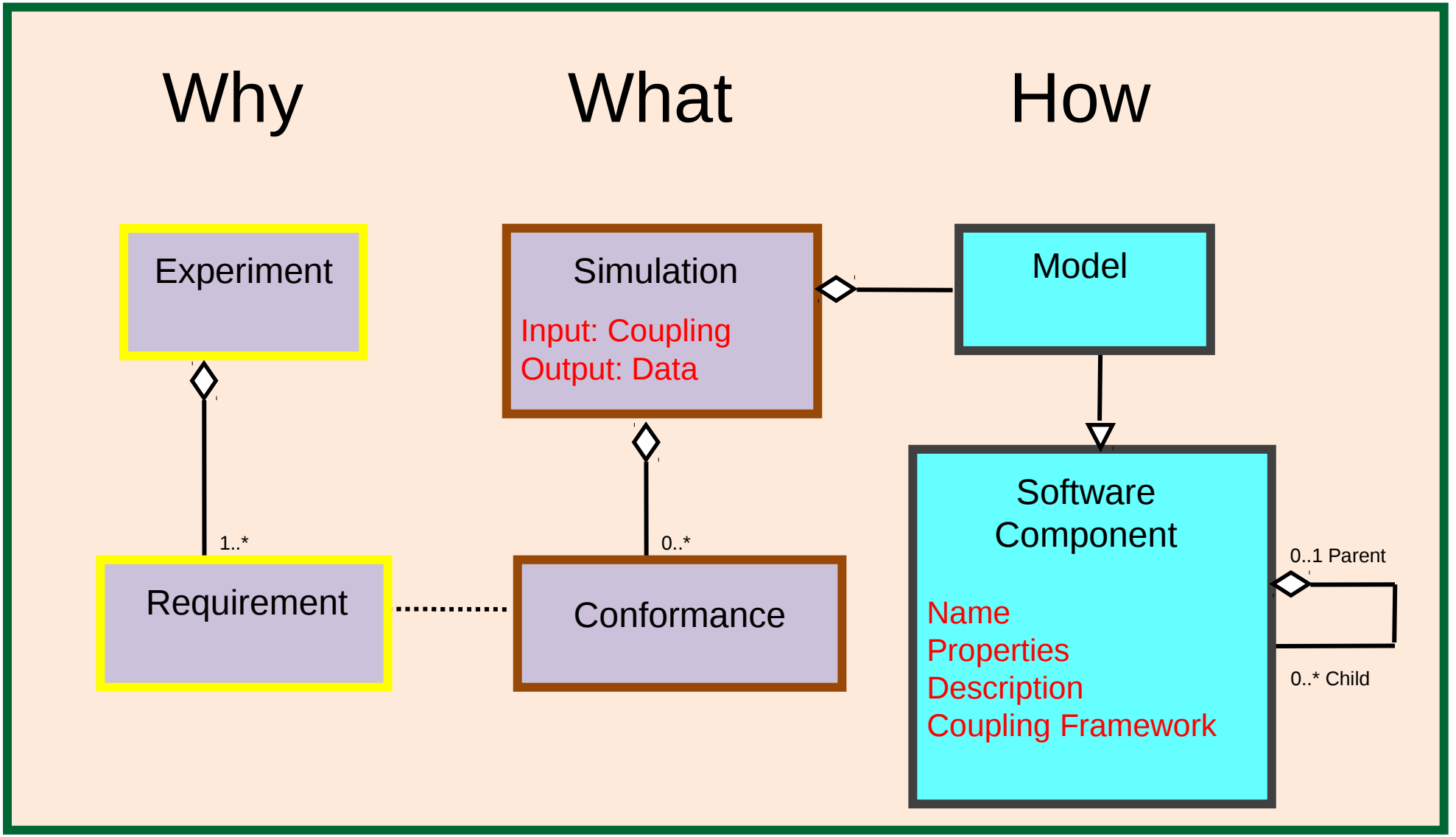
EU - IPSL, BADC, DKRZ
US - NOAA, NCAR, PCMDI

is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

es-doc
Earth System Documentation

A climate simulation

http://earthsystemcog.org/projects/es-doc-models/



Sciences de l'environnement
Institut Pierre Simon Laplace

es-doc
Earth System Documentation

is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

CIM

- The CIM is **intentionally very general**. It can be customized for particular user communities through the addition of specific Controlled Vocabularies.
- A Controlled Vocabulary **defines the content** that can be used within a CIM document. For example, in the case of climate models, the CIM schema (structure) allows a ModelComponent to have a child ModelComponent. And each of those components can have "types."
- A CV **is required** to list the permitted types. For example, the CMIP5 CV allows an "atmosphere" model to have a child "advection" model, but not a child "ocean" model. Thus, in order to be valid a CIM document must conform both to the CIM schema and to a particular set of CVs.

es-doc v0.9.0.0
Earth System Documentation

Project CMIP5 | Comparator Model Component Properties | Open

Step 1 : Select Model Component Properties

Help | Reset | Next

1. Select Models

All

- ACCESS1.0 view
- ACCESS1.3 view
- BCC-CSM1.1 view
- CFSV2-2011 view
- CMCC-CESM view
- CMCC-CM view
- CMCC-CMS view
- CNRM-CM5 view
- CSIRO-MK3.6.0 view
- EC-EARTH view
- GFDL-CM2P1 view
- GFDL-CM3 view
- GFDL-ESM2G view
- GFDL-ESM2M view
- GFDL-HIRAM-C180 view
- GFDL-HIRAM-C360 view
- GISS-E2-H view
- GISS-E2-H-CC view
- GISS-E2-R view
- GISS-E2-R-CC view
- GISS-E2CS-H view
- GISS-E2CS-R view
- HADCM3 view
- HADGEM2-A view
- HADGEM2-CC view

2. Select Components

∪ ∩

- *Aerosols*
  - Emission And Concentration
  - Model
  - Transport
- *Atmosphere*
  - Convection Cloud Turbulence
    - Cloud Scheme
    - Cloud Simulator
  - Dynamical Core
    - Advection
  - Orography And Waves
  - Radiation
  - Other
- *Atmospheric Chemistry*
  - Emission And Conc
  - Gas Phase Chemistry
  - Heterogen Chemistry
    - Stratospheric Heter Chem
    - Tropospheric Heter Chem
  - Photo Chemistry
  - Transport
- *Land Ice*
  - Glaciers
  - Sheet
    - Ice Sheet Dynamics
  - Shelves
  - Dynamics

3. Select Properties

All

- Aerosol Scheme
  - Bin Framework
  - Bin Species
  - Bulk Species
  - Framework
  - Modal Framework
  - Modal Species
  - Scheme Characteritics
  - Scheme Type
  - Species
- Coupling With
- Gas Phase Precursors
- ocean biogeochemical coupling
- Processes
- Standard Properties
  - Citations
    - Location
    - Title
  - Description
  - Long Name
  - PI Email Address
  - PI Name
  - Short Name
- vegetation model coupling

Conclusion

- Discussion are crucial but slow with general purpose HPC centers
- Making good use of the overall HPC center is not trivial
  - Critical for data intensive application like climate simulations
  - Offload I/O
- You have a great model / you need at least a good “pilot”
- New generation of tools, supervision is crucial
- Be in a position to make good decision from torrent of data
  - Turn data into information
- Several MQ Apps in developments to gather and make sense of all those metadata (performances, documentation)
- Be ready for CMIP6 to streamline “production phase”

Thank you for your attention

sebastien.denvil@ipsl.jussieu.fr