

Coopérations internationales, simulations climatiques et masse d'informations

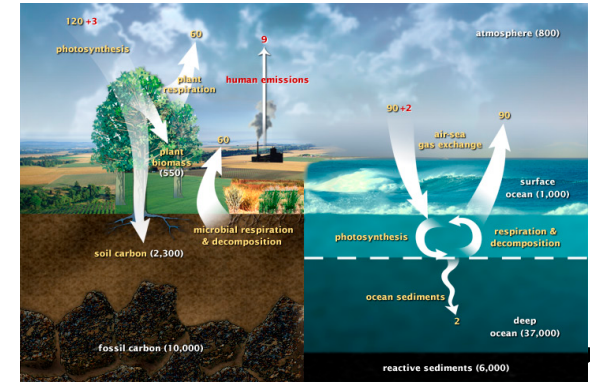
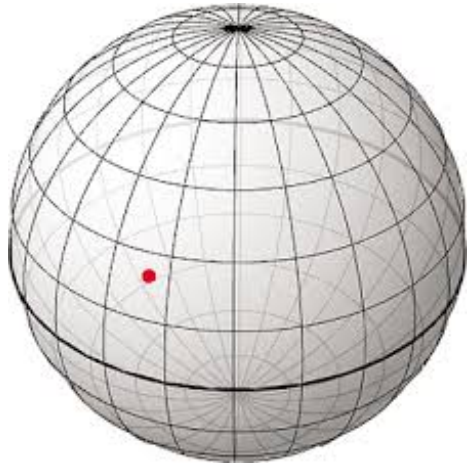
Sous titres:

Les “challenges” en termes d'accessibilité et d'usage

Sébastien Denvil (IPSL/CNRS)

Outline

- Motivation
 - Drowning in data, with more to come.
- CMIP5 as an example of the current technology
 - Different views; institutional, federated, subsetted
 - Have we hit the limit for downloading?
 - Metadata infrastructure
- The future
 - Taking the computing to the data
 - Taking the computing and the data to the data
 - Scaling to the future requires standards and conformance



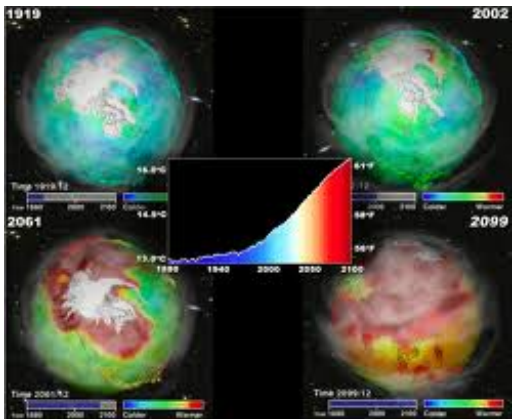
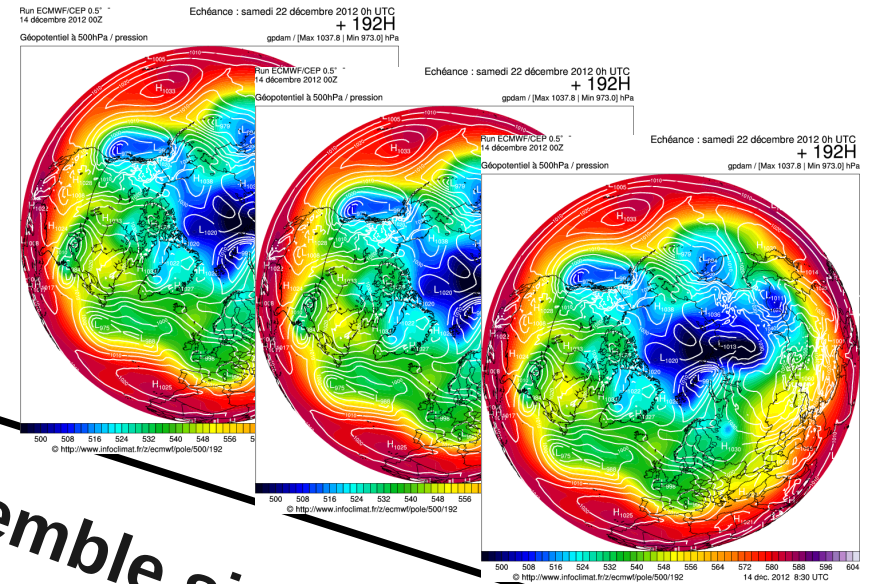
Earth Observations

Complexity

Resolution

Enhanced computing resources produce MORE DATA

Duration and ensemble size



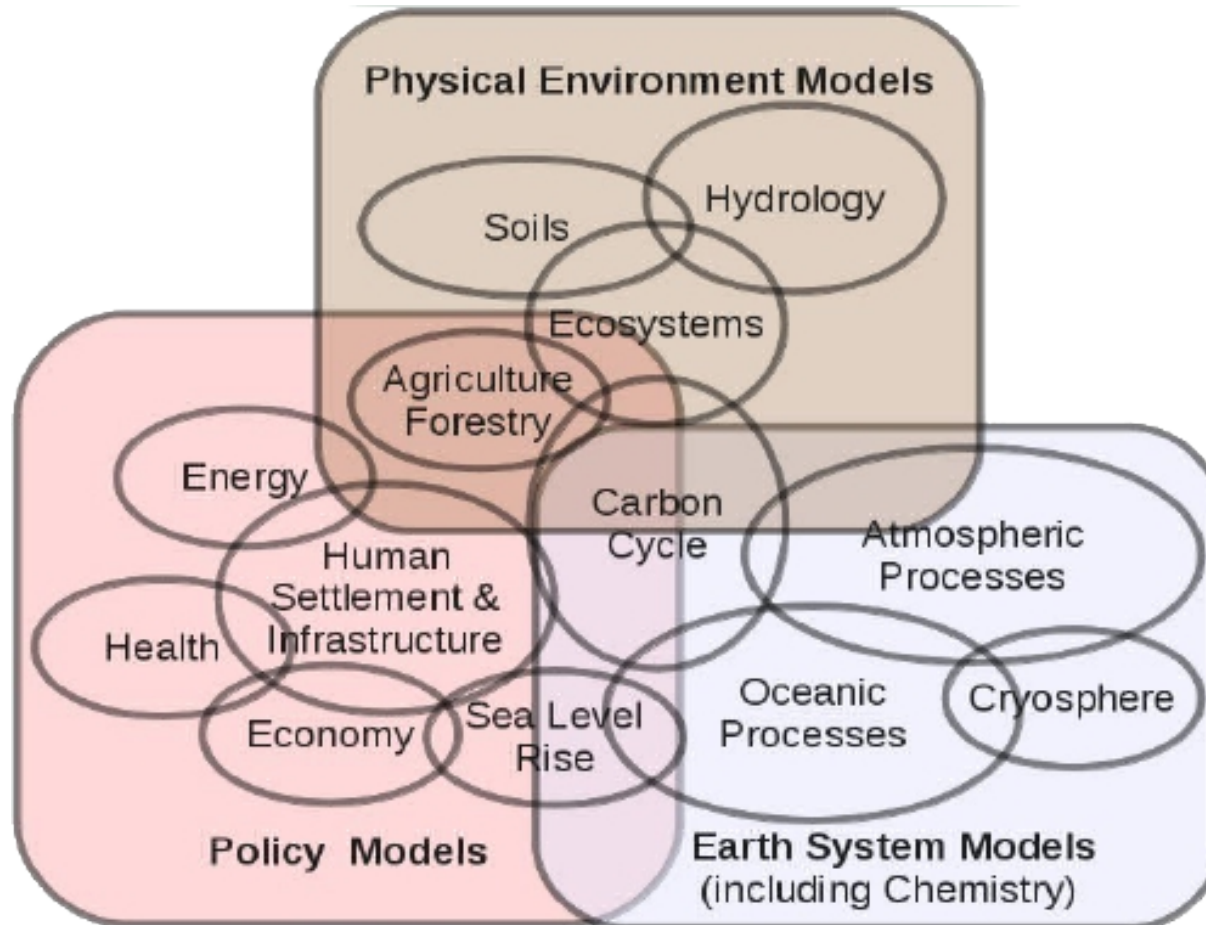
To keep in mind

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

Computation useless if results cannot be stored/distributed/read



Many, many processes, many, many communities !



Interconnected communities, all needing access to (some) of the data!

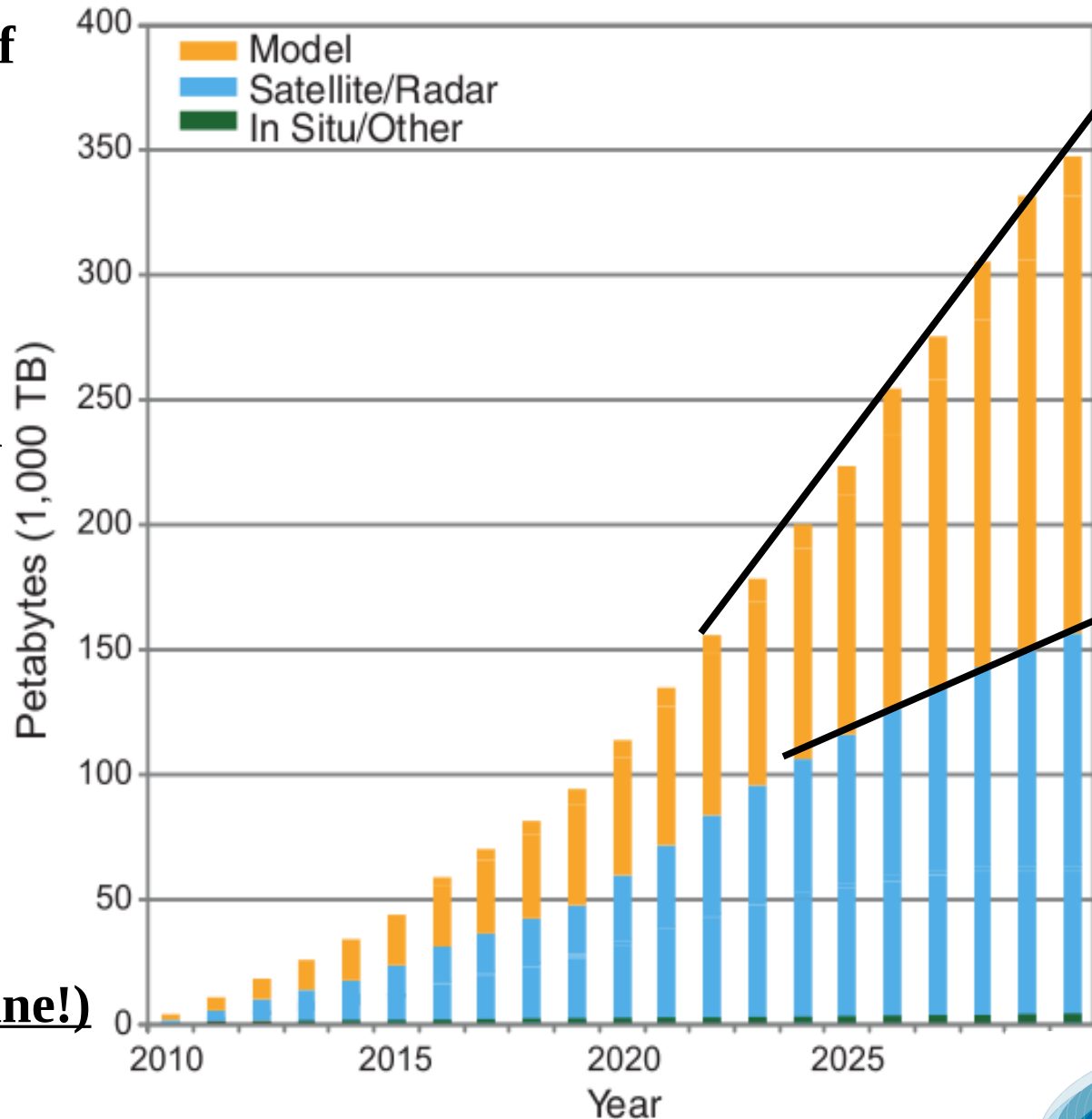
IPCC AR5 variable counts

	1 hour	3 hour	6 hour	daily	month	annual	totals
aerosol	0	0	0	0	81	0	81
atmosphere	75	101	9	86	184	0	455
land	0	3	0	2	59	0	64
land ice	0	0	0	2	13	0	15
ocean	0	1	0	3	116	0	120
biogeochemistry	0	0	0	0	88	71	159
sea ice	0	0	0	4	47	0	51
totals	75	105	9	97	588	71	945

Overpeck et al. Science 2011;331:700-702

Fig. 2 The volume of worldwide climate data is expanding rapidly, creating challenges for both physical archiving and sharing, as well as for ease of access and finding what's needed, particularly if you are not a climate scientist.

(Their words, not mine!)



We might want to write more data

Another way of looking at this:

CMIP5 output at the IPSL was about 3TB / day in average (2 years).

We wanted to have pick writing at 6 TB/day sometime.

Actually can't write at full model capacity every day.

- We had to stop simulations from time to time to be able to cope with data production !
- **Archive and network were the real constraints! Already!**

& that's before considering users, usability etc.

Now we know that archive and network are constraints, let's turn to accessibility, affordability, and usability.

A one slide guide to CMIP5 from a data perspective

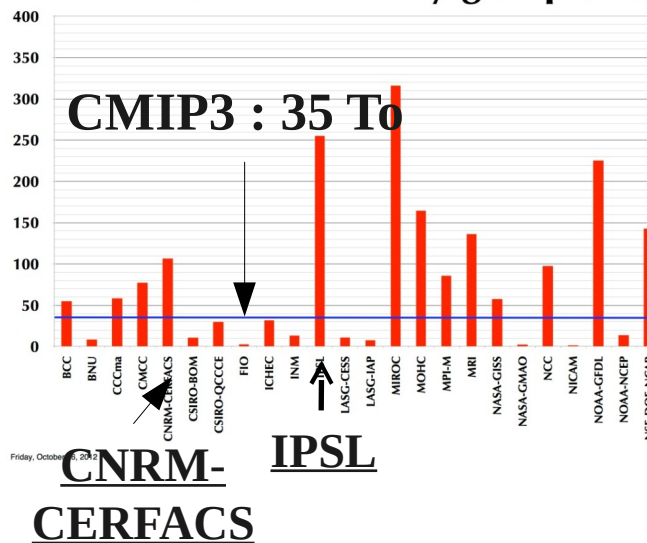
Fifth Climate Model Intercomparison Project (CMIP5)

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finished early 2010!
Actual Timing?
Years late.

101 experiments
61 model variants
59,000 datasets!
4.5 million files
2 PB in global archive.
Unknown PB locally!

CMIP5 data volumes by group (TB)



PCMDI-led,
Community developed
(GO-ESSP)
s/w infrastructure for
data delivery:
**Earth System Grid
Federation**

“Without substantial research effort into new methods of storage, data dissemination, data semantics, and visualization, all aimed at bringing analysis and computation to the data, **rather than trying to download the data** and perform analysis locally, it is likely that the data might become frustratingly inaccessible to users”

A National Strategy for Advancing Climate Modeling, 2012

Why did they think that?

Semantic Analysis: “substantial research effort” “new methods”
“computation to data” “rather than trying to download”
“frustratingly inaccessible” (to whom?)

...and it's going to get worse,
... more computing ...

« Nor any I should clone » ?

You can buy disk, but, can you populate it?

Network bandwidth limits what we can write (e.g. CMIP5)

Network bandwidth limits what we can deliver for download

- IPSL currently 1 Gb/s
- (Theoretical maximum: 10.5 TB/day. Practical Maximum ~ 0.3 peak)
- It'll go faster (Gilder's Law), fast enough ?

You can buy disk, but, can you afford it?

Decadal Expectations:

Kryder and Kim 2009

Storage Capacity	$\sim o(x100)$
Cost/TB	$\sim o(/100)$
Energy/TB	$\sim o(/10)$
...	
Energy Cost/TB	$\sim o(x10)$

For us (about 1 PB in 2014) at constant funding, we could afford 27 PB (disk) in 2024.

We're not at constant funding. Yet. Are you?

Coming back to National Academy

Analysis !

“substantial research effort”
“new methods”
“computation to data”
“rather than trying to download”
“frustratingly inaccessible” (to whom?)

Download ?

→ What?
(There is a lot of data, how do I choose?)
→ How?
(Where to? How do I make it go fast, multiple files, fault tolerant?)

Computation to Data

Nice idea, but
→ data in multiple places.
→ distributed analysis
→ distributed analysis environments

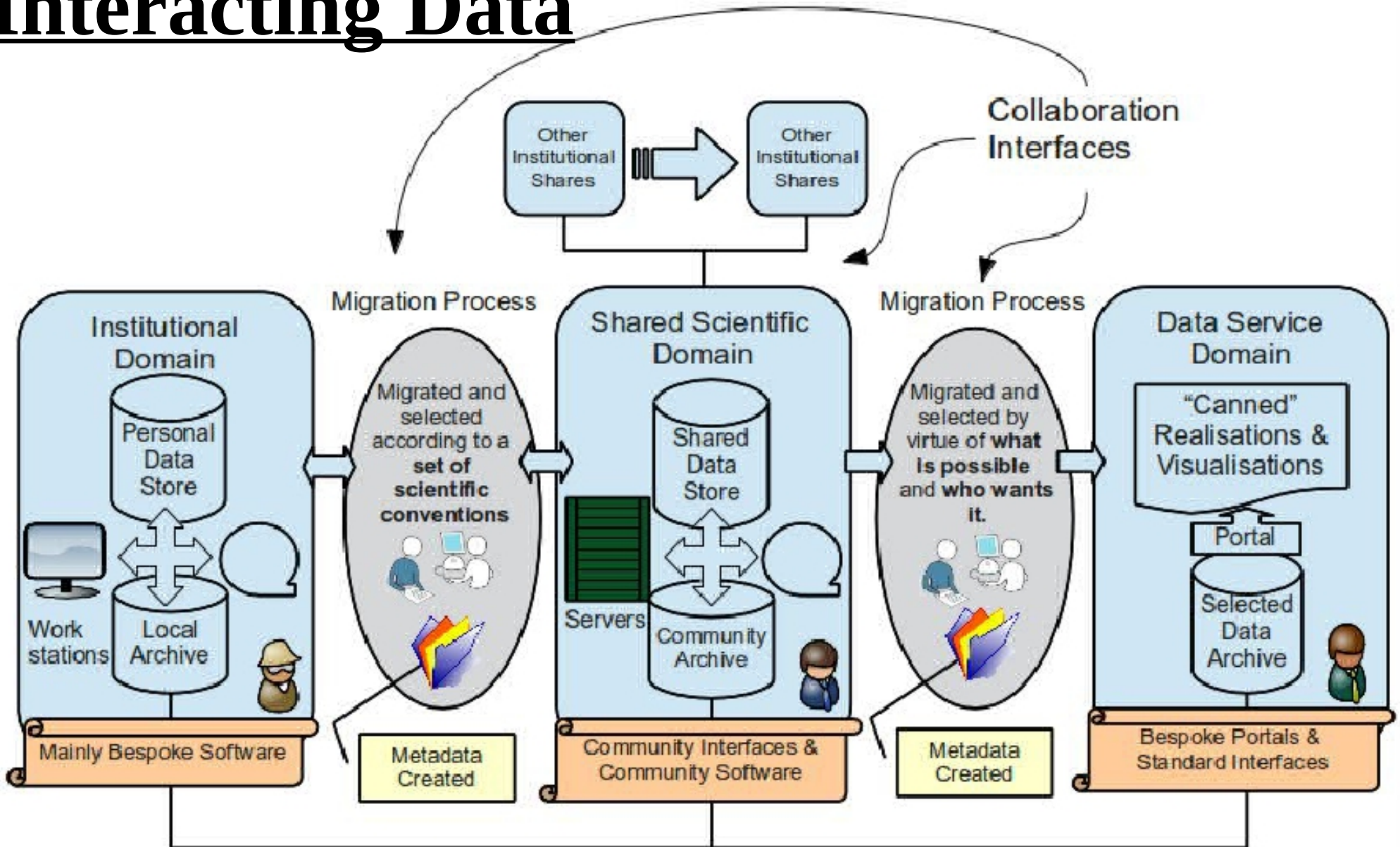
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New methods/research effort

→ What?
– Multiple activities
– ES-DOC
→ How & Computation to Data?
– Avoid duplication?
– EXARCH
– CICLAD

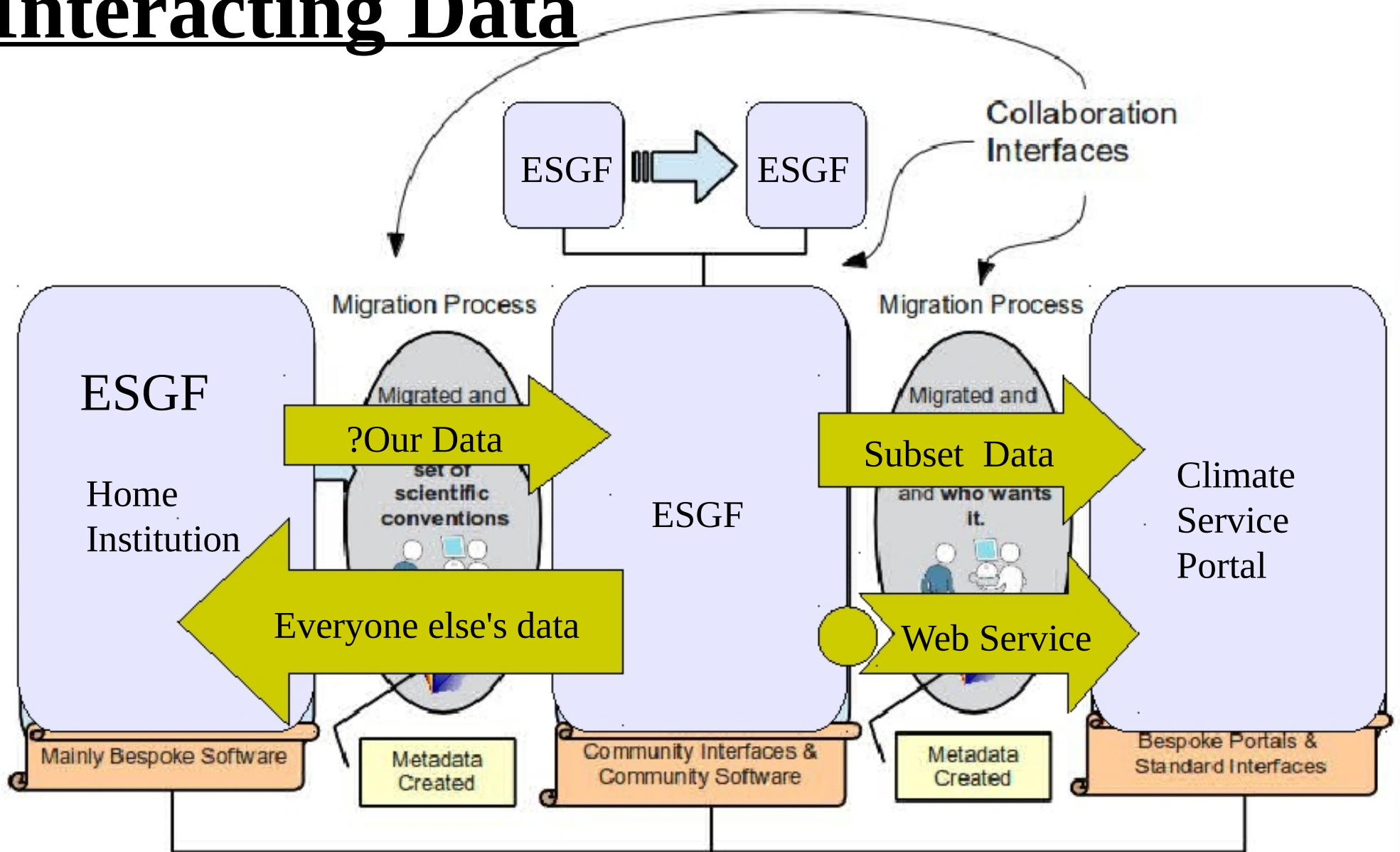
... how we interact with data ...

Interacting Data



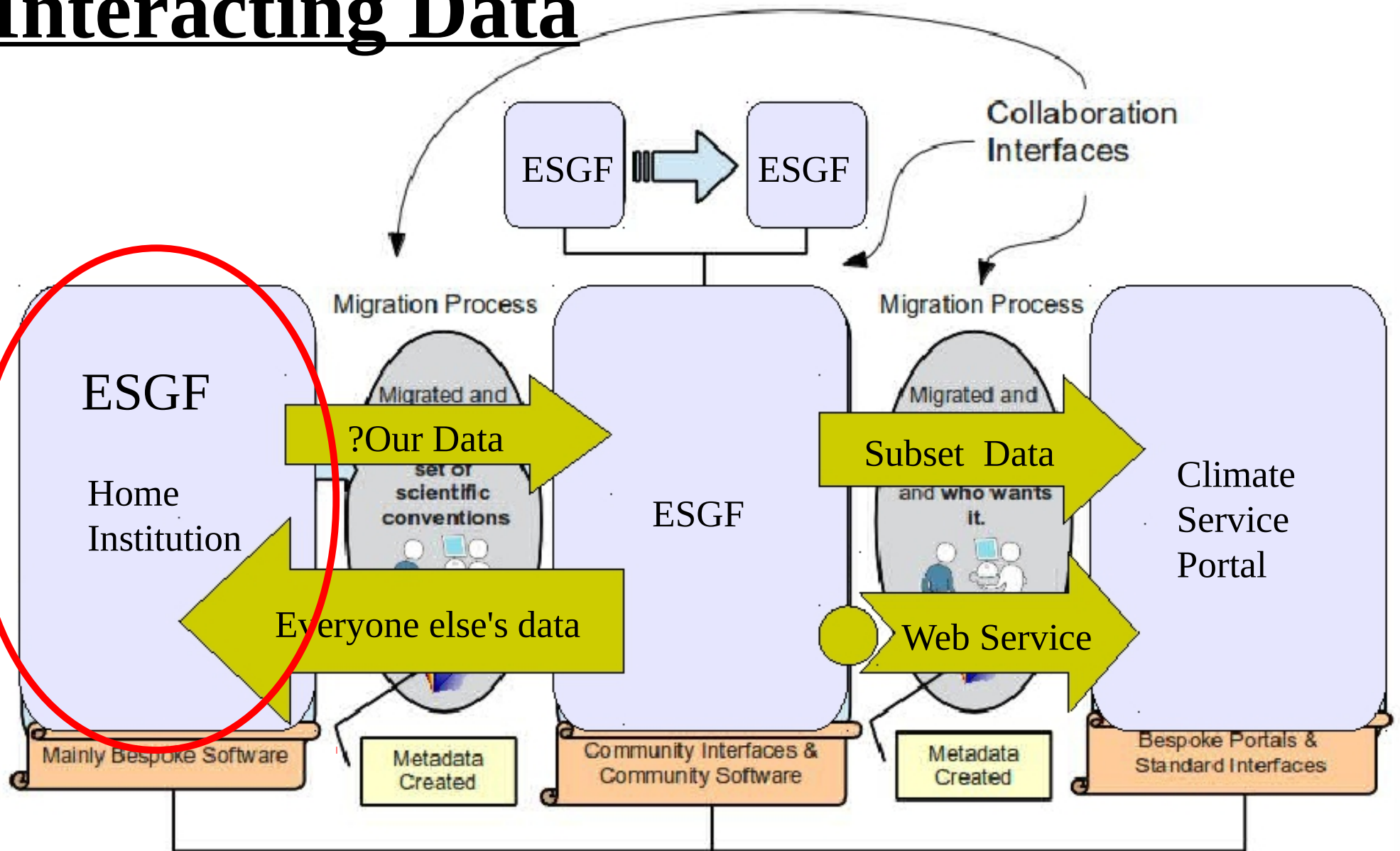
Often this is or could be (locally) the same physical archive.
(but different individuals may or may not be responsible)

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My/Your Data Environment

At your home institution, you:

→ Have (some) control over your software environment

- Favourite packages, e.g. IDL
- Familiar Linux

→ Can buy/arrange more storage / compute on varying time-scales ... can optimise ...

→ Are responsible for deleting / preserving your own data

→ Are likely to be duplicating data others have already downloaded *in your own institution* ... let alone within a larger collaboration.

We all like control!

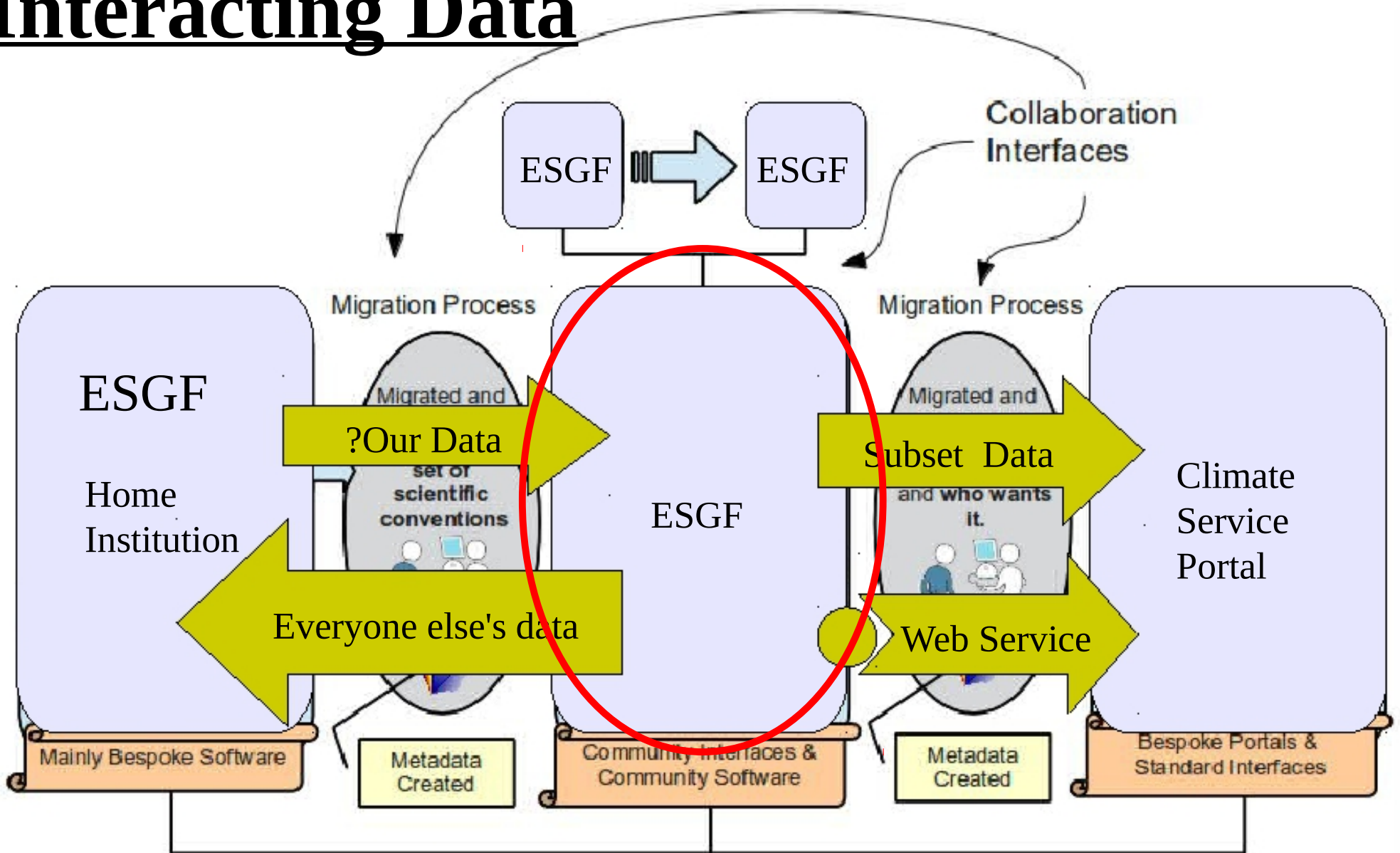
We all like the (illusion?) that we can scale our resources as necessary.

We all lose/destroy/duplicate data.

Most of us do our HPC remotely.

Some of us do our analysis remotely. Why not more of us?

Interacting Data



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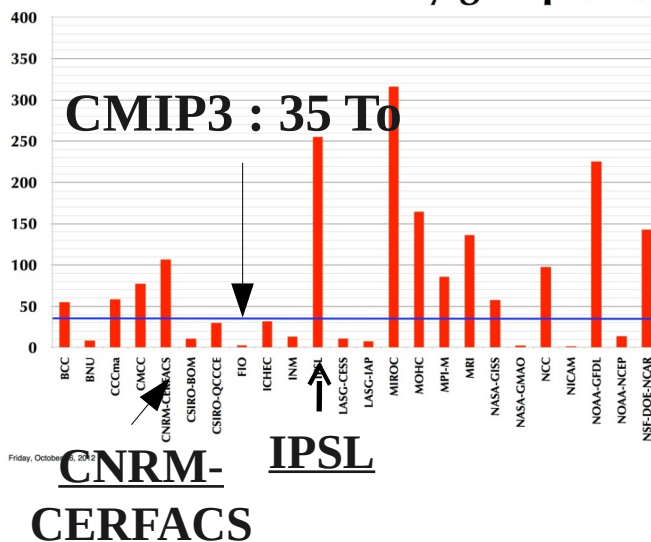
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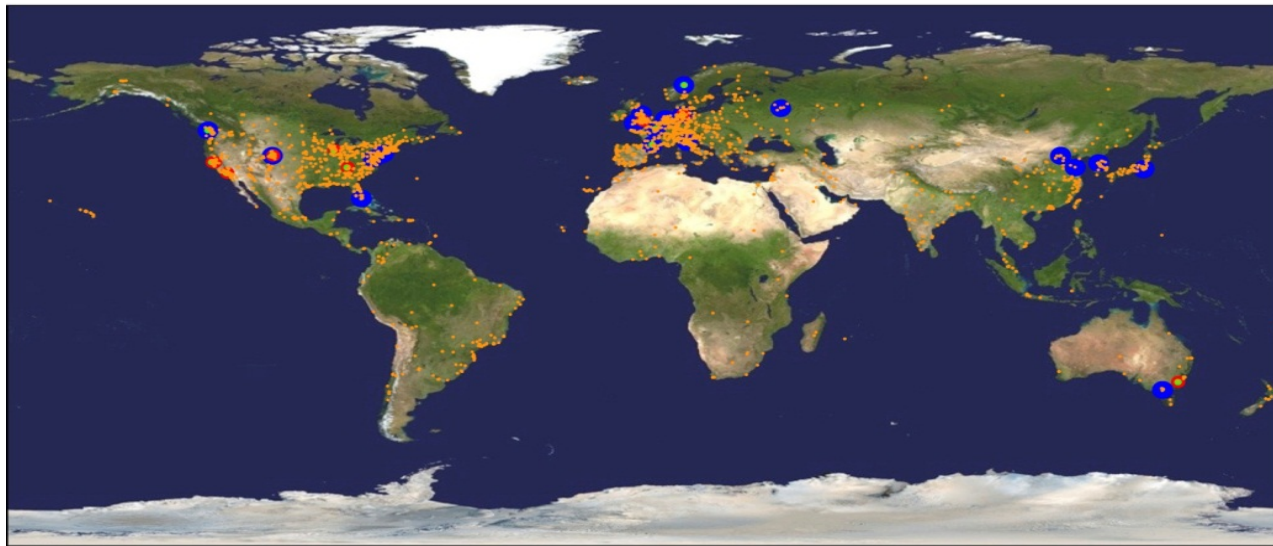
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Worldwide distributed system

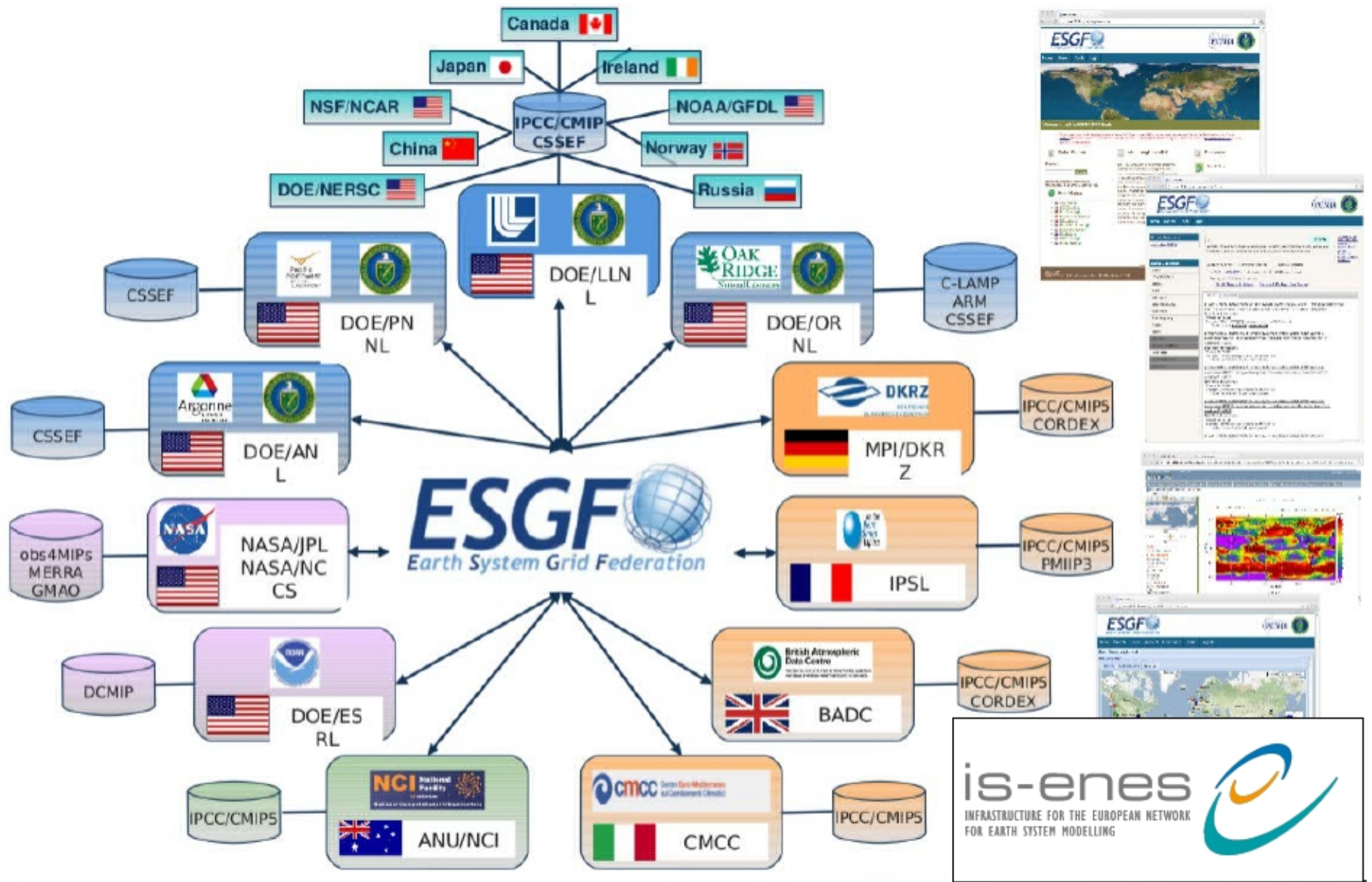
The **Earth System Grid Federation (ESGF)** is a multi-agency, international collaboration of persons and institutions working together to build an open source software infrastructure for the management and analysis of Earth Science data on a global scale

- Software development and project management: ANL, ANU, **BADC**, **CMCC**, **DKRZ**, ESRL, GFDL, GSFC, JPL, **IPSL**, ORNL, LLNL (lead), PMEL, ...
- Operations: tens of data centers across Asia, Australia, Europe and North America

IPCC AR5 distribution



Worldwide distributed system



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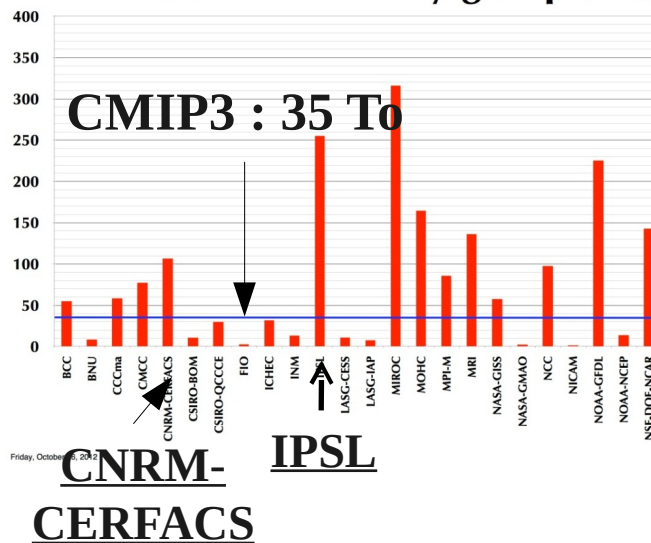
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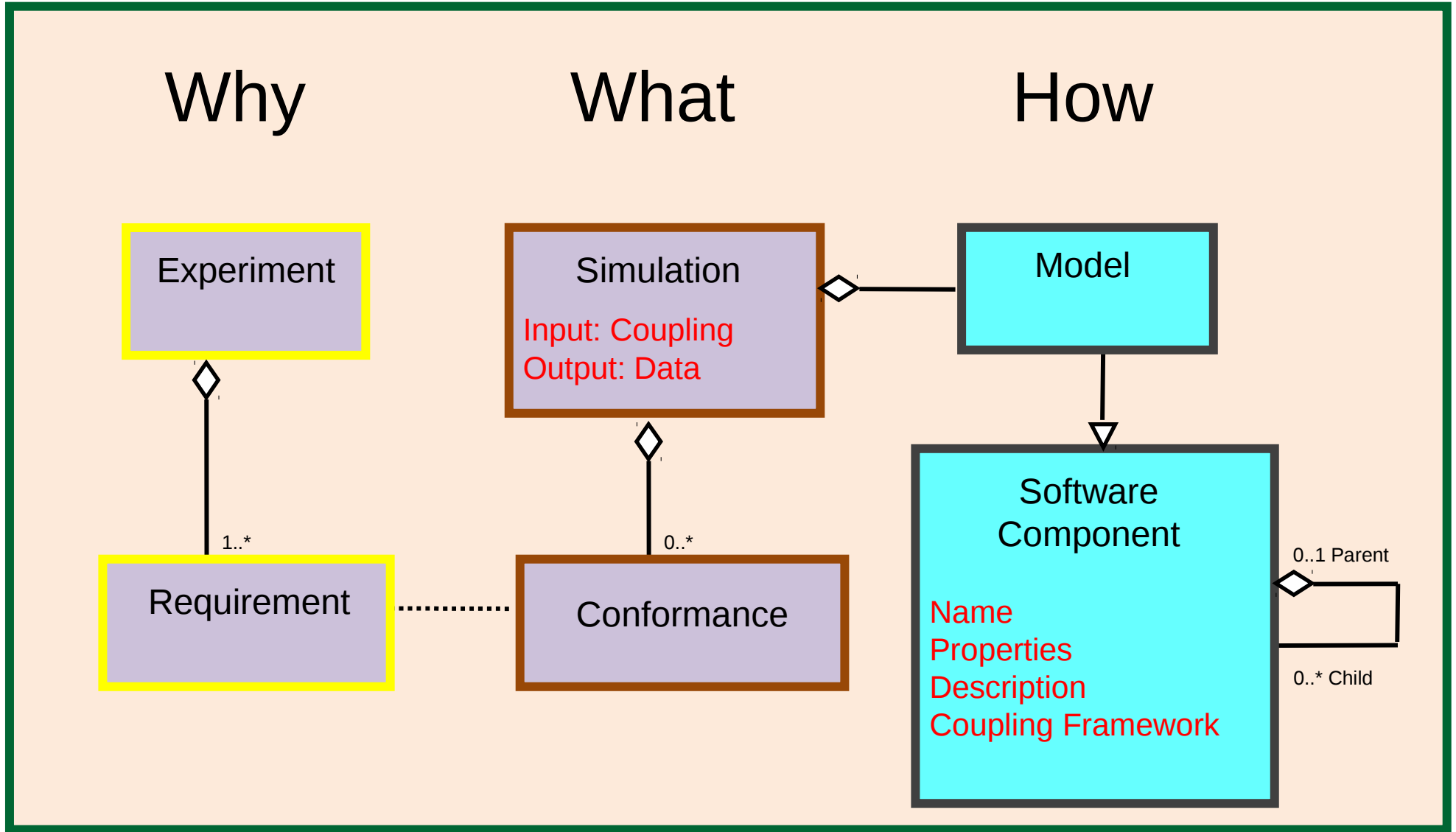
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A climate simulation

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



CMIP5 – Browse Metadata

Earth System Documentation - Viewer | CMIP5 Model - gfdl-hiram-c180 (v2)

CMIP5 Model - gfdl-hiram-c180

Model Experiment

Overview Citations Contacts **Components**

- Atmosphere
 - Convection Cloud Turbulence
 - Cloud Scheme
 - Dynamical Core
 - Advection
 - Orography & Waves
 - Radiation
- Land Surface**
 - Albedo
 - Energy Balance
 - Lakes
 - RiverRouting
 - Snow
 - Soil
 - Heat Treatment
 - Hydrology
 - Vegetation

Land Surface

Properties

- Basic Approximations : Physics - Full 1D Vertical Soil And Heat With Parameterized Ground Water,rivers And Lakes; Vegetation - Princeton Scheme
- Conservation Of Properties > Water Storage Method : Other
- Conservation Of Properties > Water Treatment : Storage
- Coupling With Atmosphere : Implicit
- Genealogy : Other
- Land Cover Types : Bare Soil
- Land Cover Types : Ice
- Land Cover Types : Lake
- Land Cover Types : Other
- Land Cover Types : Vegetated
- List Of Prognostic Variables : Canopy Skin Temperature
- List Of Prognostic Variables : Canopy Snow Content
- List Of Prognostic Variables : Canopy Water Content
- List Of Prognostic Variables : Other
- List Of Prognostic Variables : River Water Storage
- List Of Prognostic Variables : Snow Mass
- List Of Prognostic Variables : Snow Water Content
- List Of Prognostic Variables : Soil Ice Content
- List Of Prognostic Variables : Soil Moisture
- List Of Prognostic Variables : Soil Temperature
- List Of Prognostic Variables : Surface Skin Temperature
- Tiling : Common To All LS Subcomponents
- Tiling Method : Dynamic
- Time Stepping Framework > Method : Use Atmosphere Time Step

Earth System Documentation - Viewer (v0.8.7.1) CMIP5 Model - gfdl-hiram-c180 (v2)

ES-DOC

“Common Information Model”
Javascript plugin linking data to
remote documentation

CMIP5 - Comparing and contrasting



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-GS	view

2. Select Components

u n

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	●
Sea Ice	●

3. Select Properties

All

Aerosol Scheme
Bin Framework
Bin Species
Bulk Species
Framework
Modal Framework
Modal Species
Scheme Characteristics
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

CMIP archive (aka disk) Metadata

Two levels: the way we bundle the files (the layout on disk), and the content of the files (the layout of metadata) within them!

The Layout:

Directory Reference Syntax (DRS)

Key to supporting tools which manage the (millions of files), and provide services. Key to a RESTful API ...

The Files

Constrained CF (Climate Model Output Rewriter, CMOR, and tables).

- Define layout *in* files: so tools can manipulate the file contents.

- key role for netCDF climate forecast conventions **and** additional (project) metadata requirements. That get just the bundle « you »

... it's all about supporting automation!
Key to usability!

So we've just seen how ESGF works, how much of that will apply at exascale?

New methods/research effort

→ Computation to Data?

Avoid duplication?

EXARCH

CICLAD

ExArch

G8 funded research project aiming at 10 years horizon:

ExArch: Climate analytics on distributed exascale data archives.

STFC (NCAS), UCLA, U. Toronto, DKRZ, Princeton U., IPSL, CMCC

Web processing services

Query syntax

Common information model

Processing operators and quality control

Scientific diagnostics

EO data for model evaluation

Grid computing

“Bring the computing to the data”

→ need faith in the data (QC)

→ need to know what the data is (metadata)

→ exploit existing operators (tooling)

Requires

coordination

between data

repositories ...

High Performance Data (HPD) Analysis Environment

Mutualized

Jointly *delivered* by

→ IPSL laboratories.

Joint *users* (initially):

→ IPSL community

Joint *users* (target):

→ French Academic community

Analysis capabilities

Environmental Data

Compute Service

Web Service Provision for :

→ Climate Science

→ Earth Observation

→ Environmental studies

Access services to ESGF System

Users don't have to find, download,
and keep up to date the data they need

CMIP5, CORDEX

Reanalysis,

Obs4MIPs

PMIP

...



Big DATA Platform

Collaboration Environment

→ Access to Curated Archive.

→ Large shared “Group Work Spaces”

→ climate analysis enabled system

→ + 1 PB of high performance disk
coupled to hundreds of cores
configured for analysis

Summary

- We might find the path to exascale is constrained by storage as much as by compute!
- Collaboration depends on metadata, with many different levels involved.
- The dependency on metadata will only grow as the scale of our archives increase.
- We will need not only to move computation to data, but aggregate our data collections
 - which requires dedicated “HPD” platforms like CICLAD
- It is likely that those who cannot conform to shared standards will (should) be left working on their own, unable to enter their data into federated and shared systems.