

The Data Deluge in High-Resolution Climate and Weather Simulation

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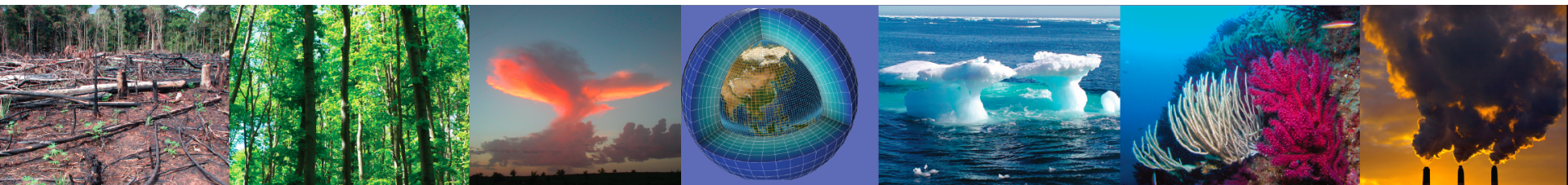
Bryan Lawrence, Christian Pagé, Joachim Biercamp
(NCAS/UREAD, CERFACS, DKRZ)

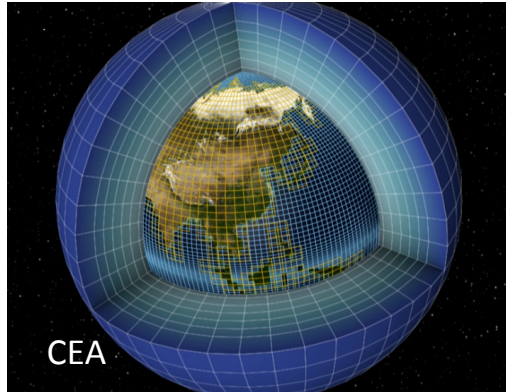


esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER
AND CLIMATE IN EUROPE

www.esiwace.eu

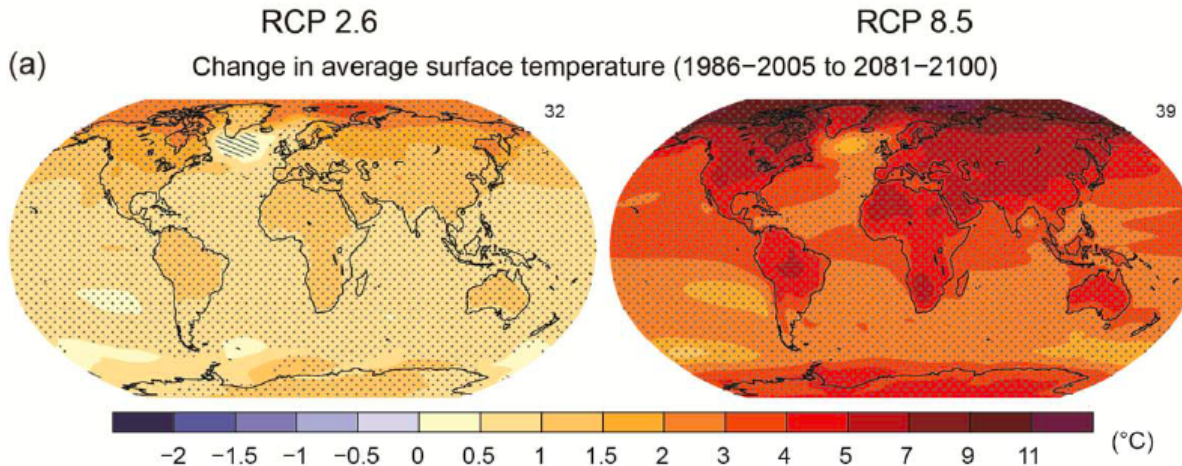
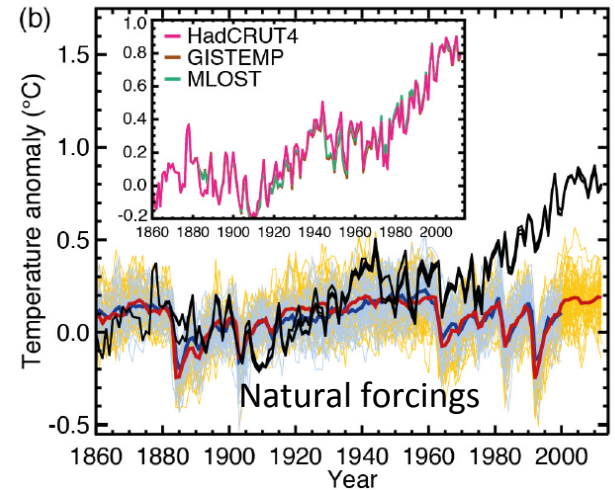
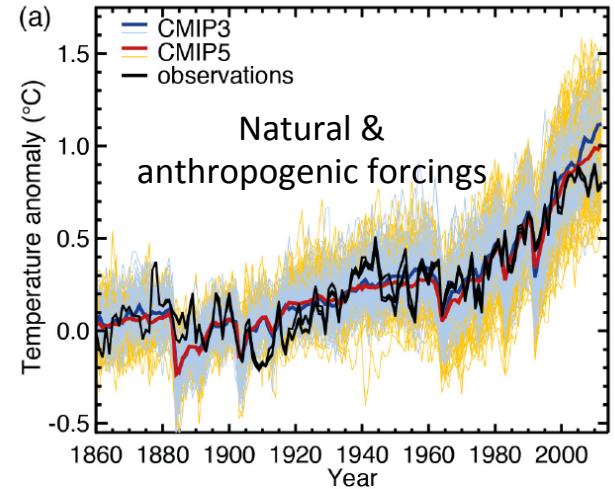
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**Understand
& Predict
Climate / Weather**

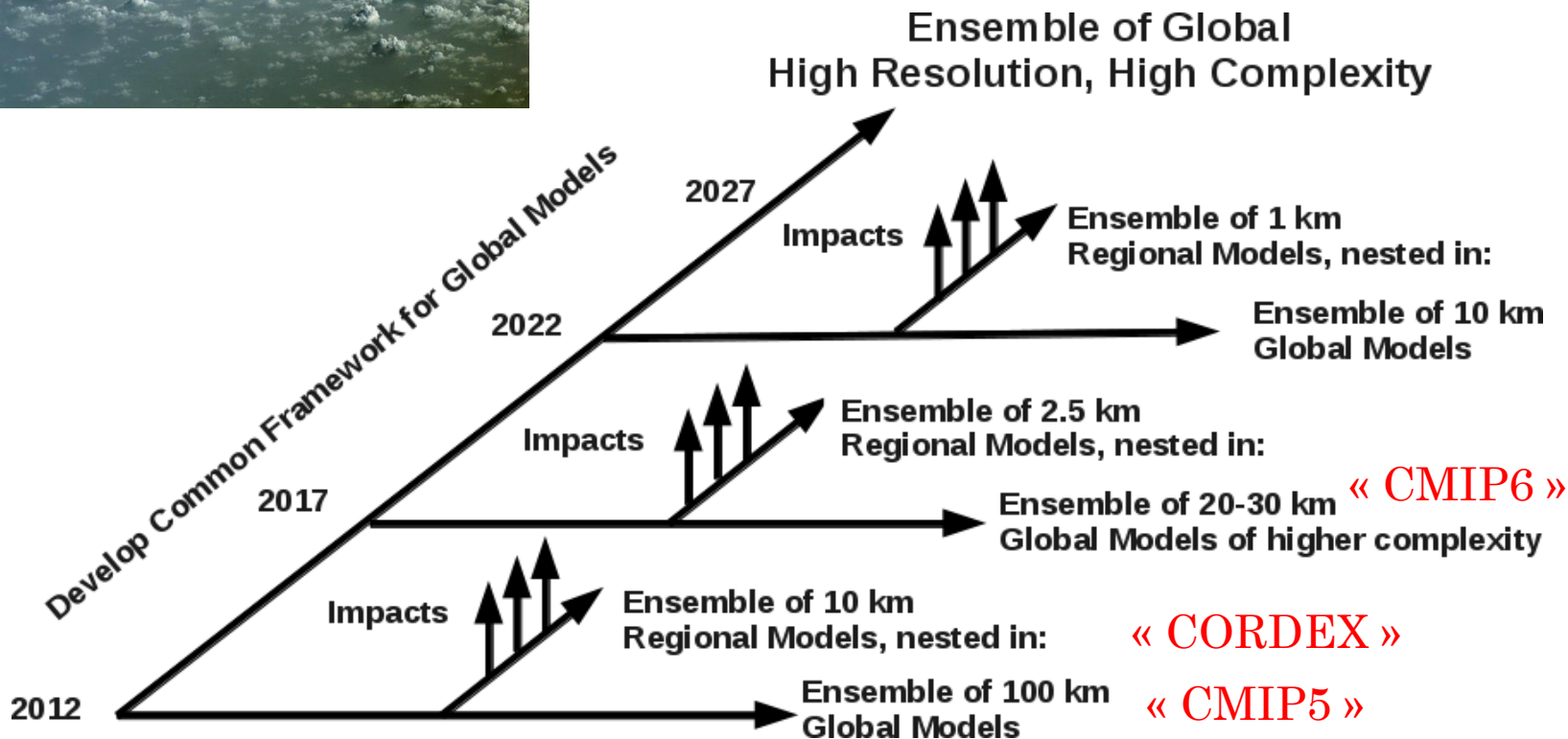
IPCC (20013)



<http://enes.org/>

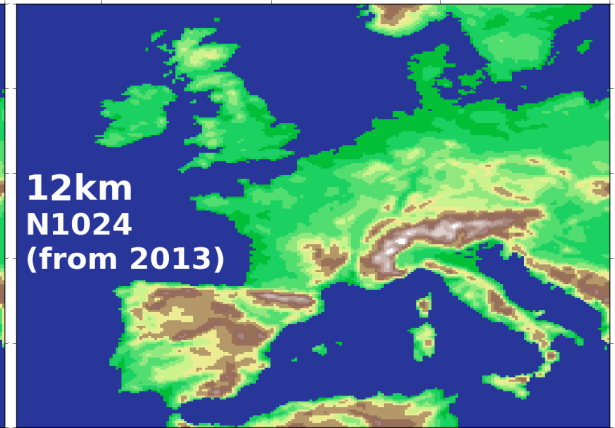
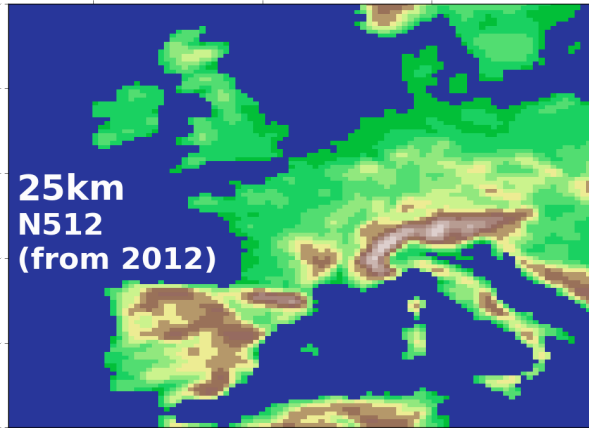
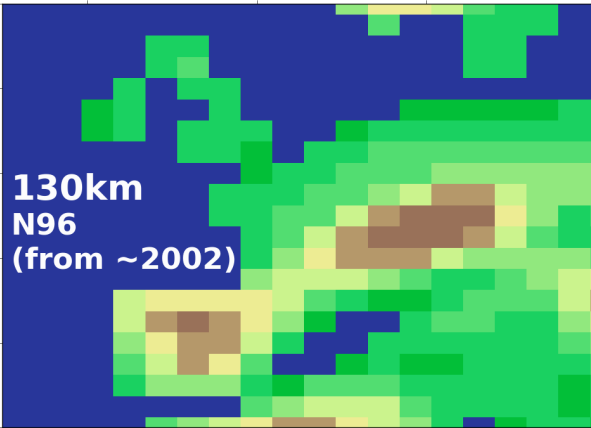


A grand challenge :
Towards ≈ 1 km scale for atmosphere
resolving deep convective clouds
in global climate models

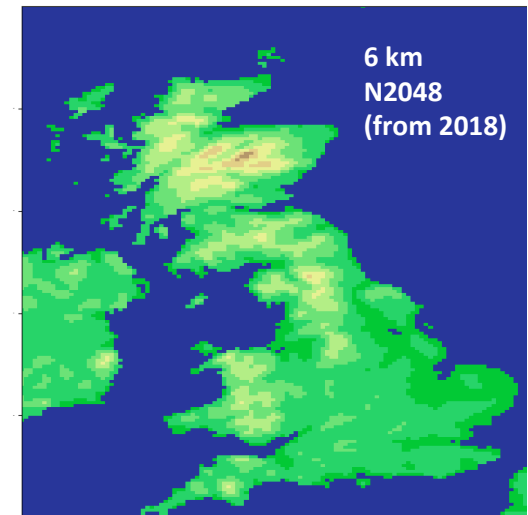




High Resolution



- With time, simulation “**resolutions**” are increasing
- ... but we are also producing more “**ensembles**”, and **complexity** is increasing too ...
- ... more numbers are being calculated, and more numbers are being stored, for later analysis and use!

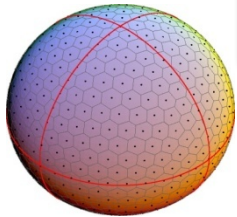


(All these pictures are from
global climate models!)

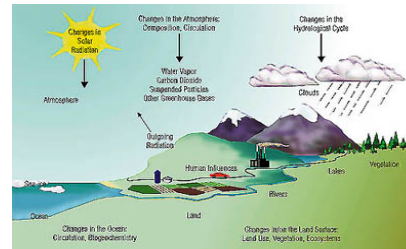
Needs for HPC

And more data outputs

$\times 3 \approx \times 27$
 $\times 100 \approx \times 10^6$



EO,
Data Assim.

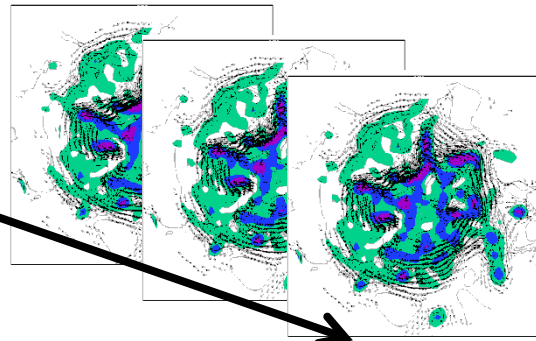
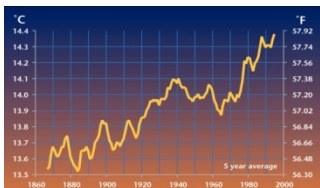
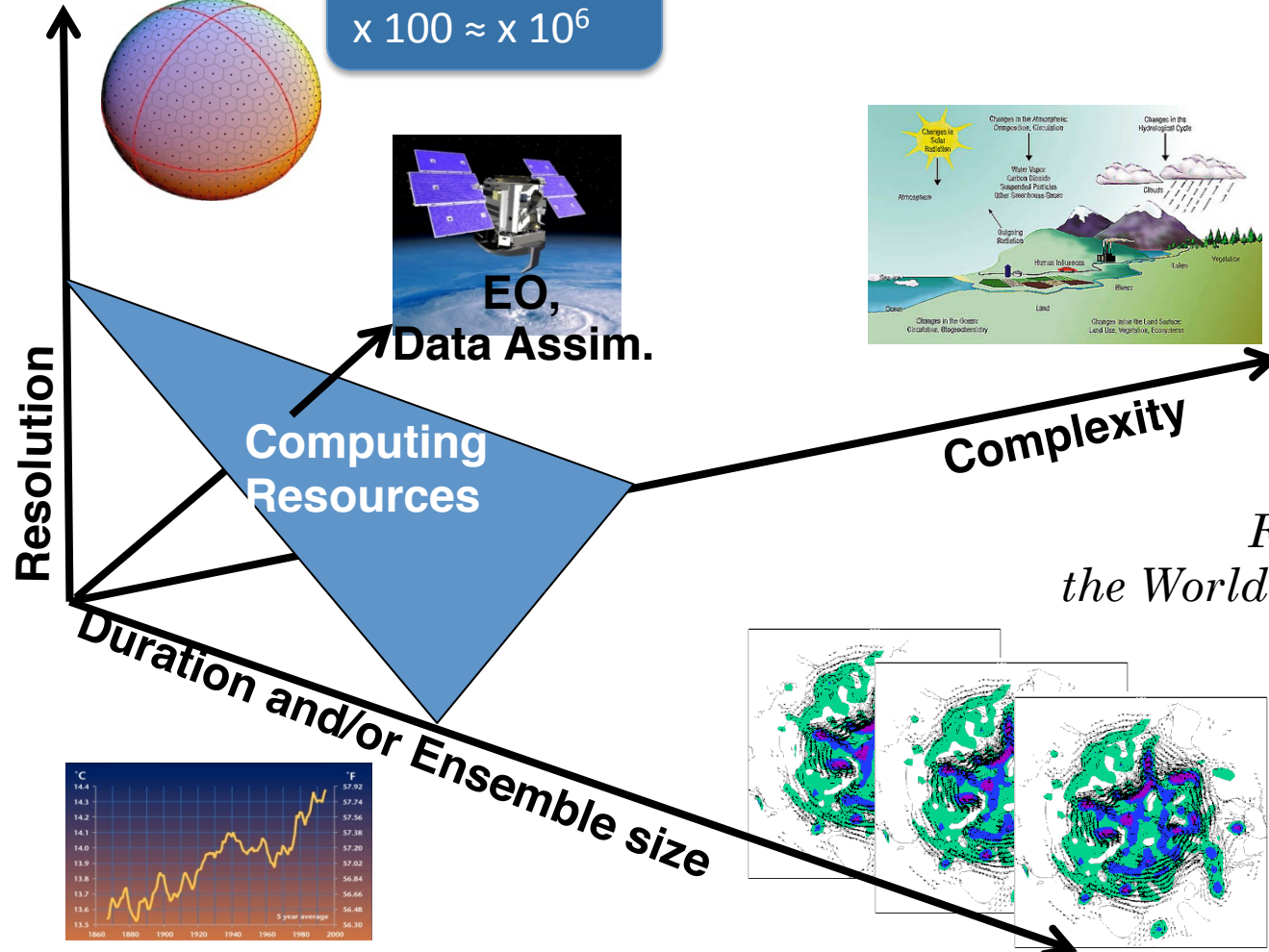


$\times 5-10$

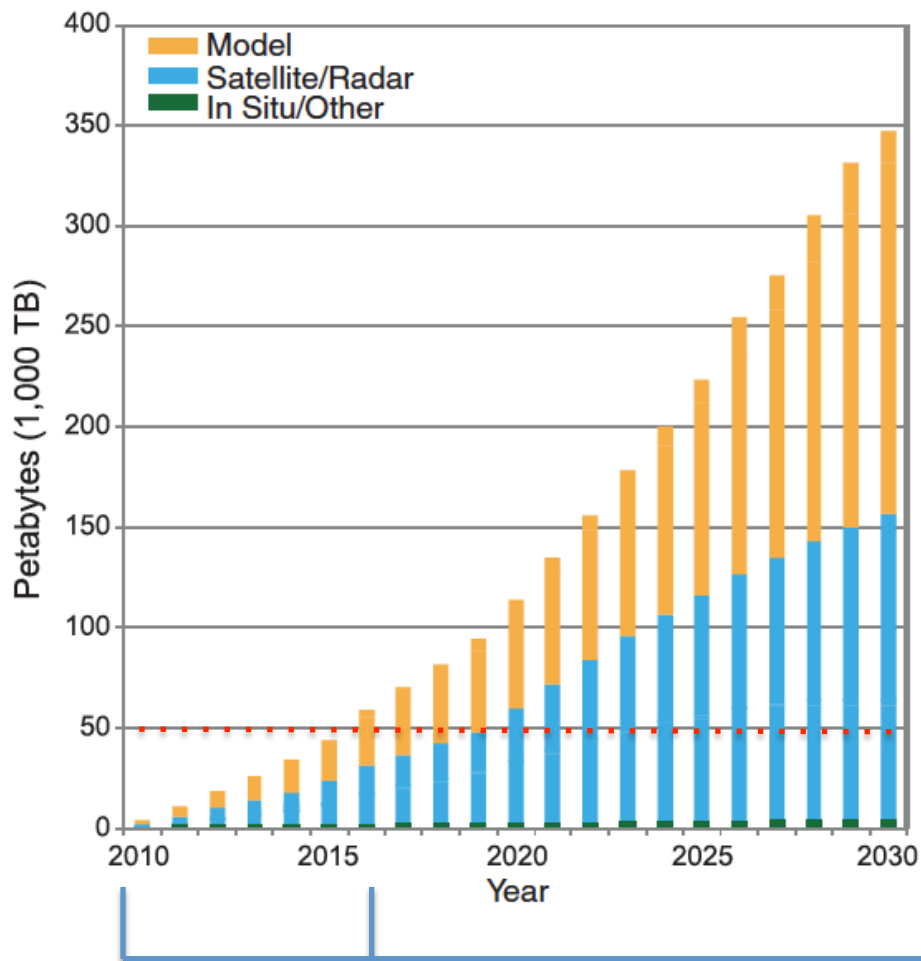
*From Jim Kinter,
the World Modelling Summit, 2008*

ensemble: $\times 10$

duration: $\times 10-100$

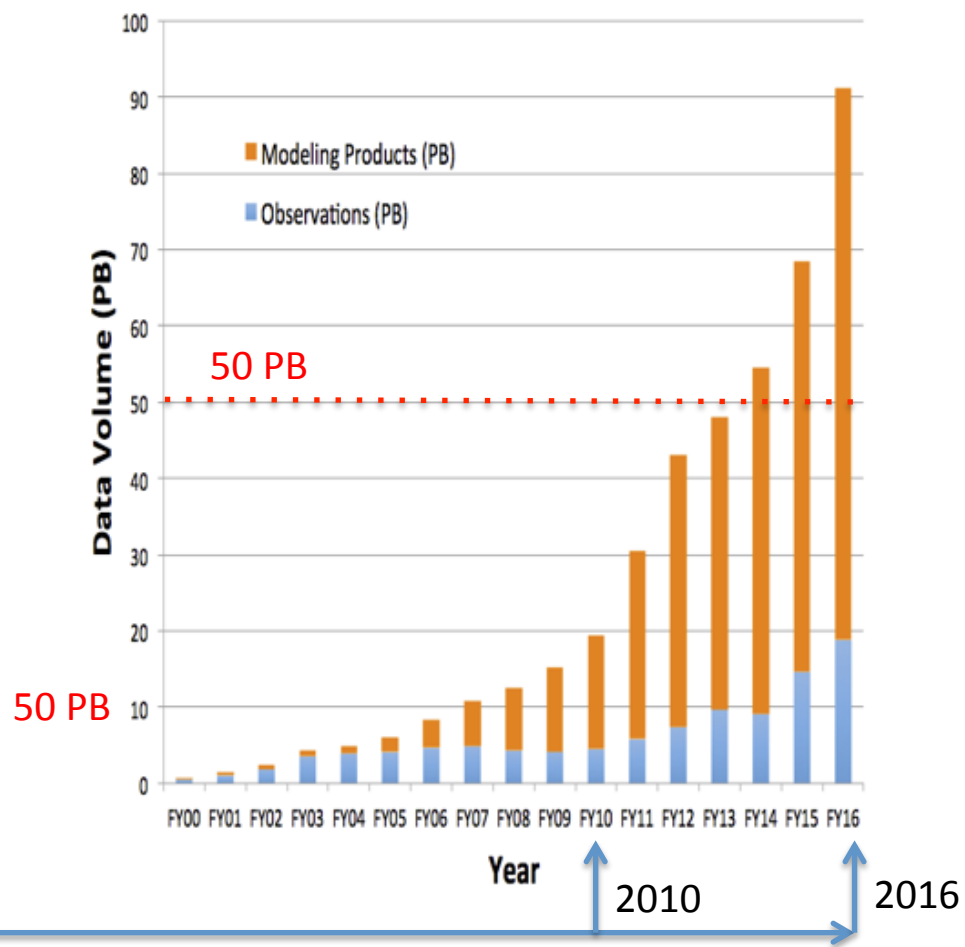


Overpeck et al. (Science 2011)



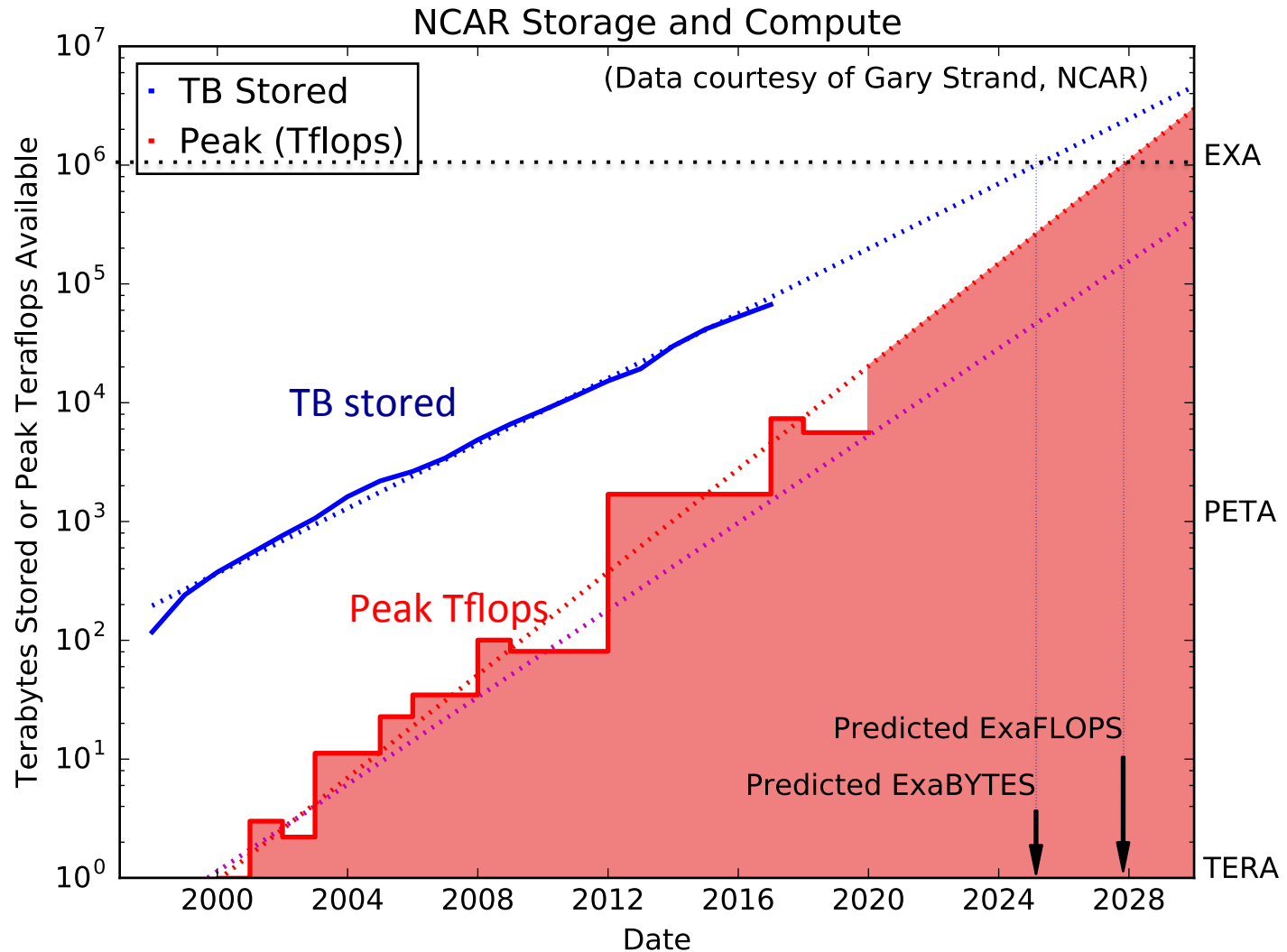
Tsengdar Lee, Icas17

NASA Earth Science Data Growth





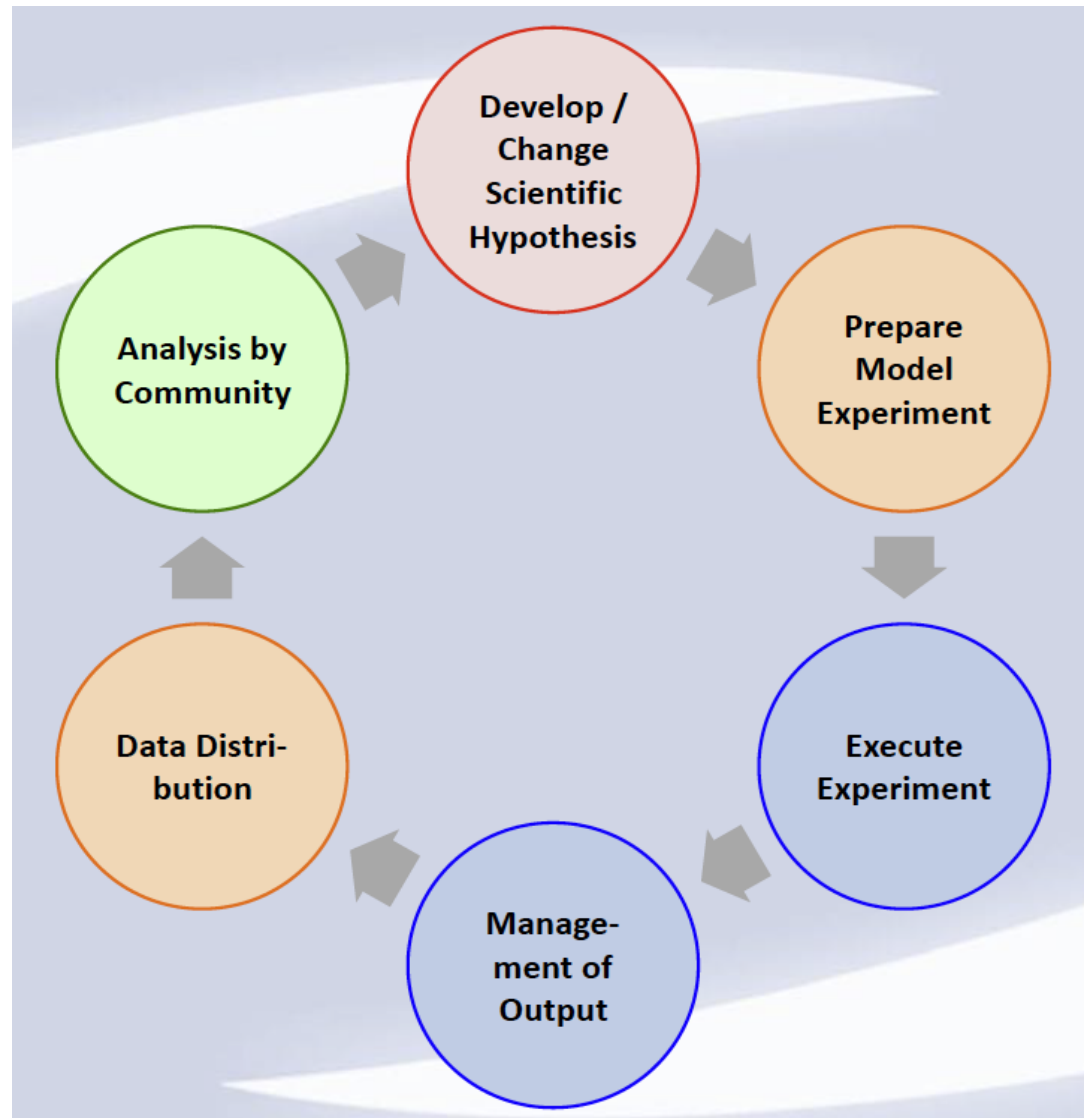
Scale and Growth: Continual Evolution





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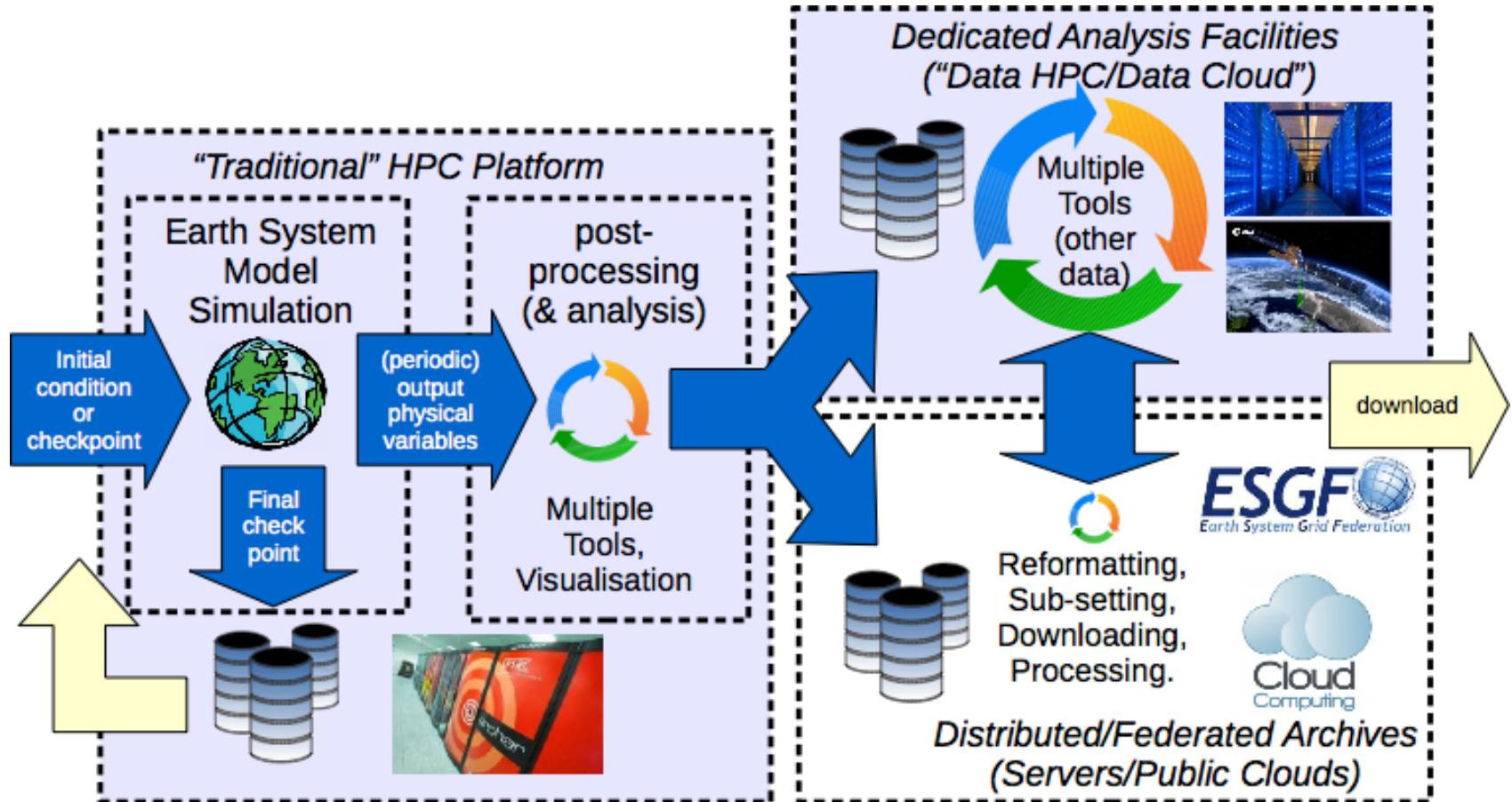
Workflow



Final Report, 2017



Multiple Types of Storage & Data Interaction



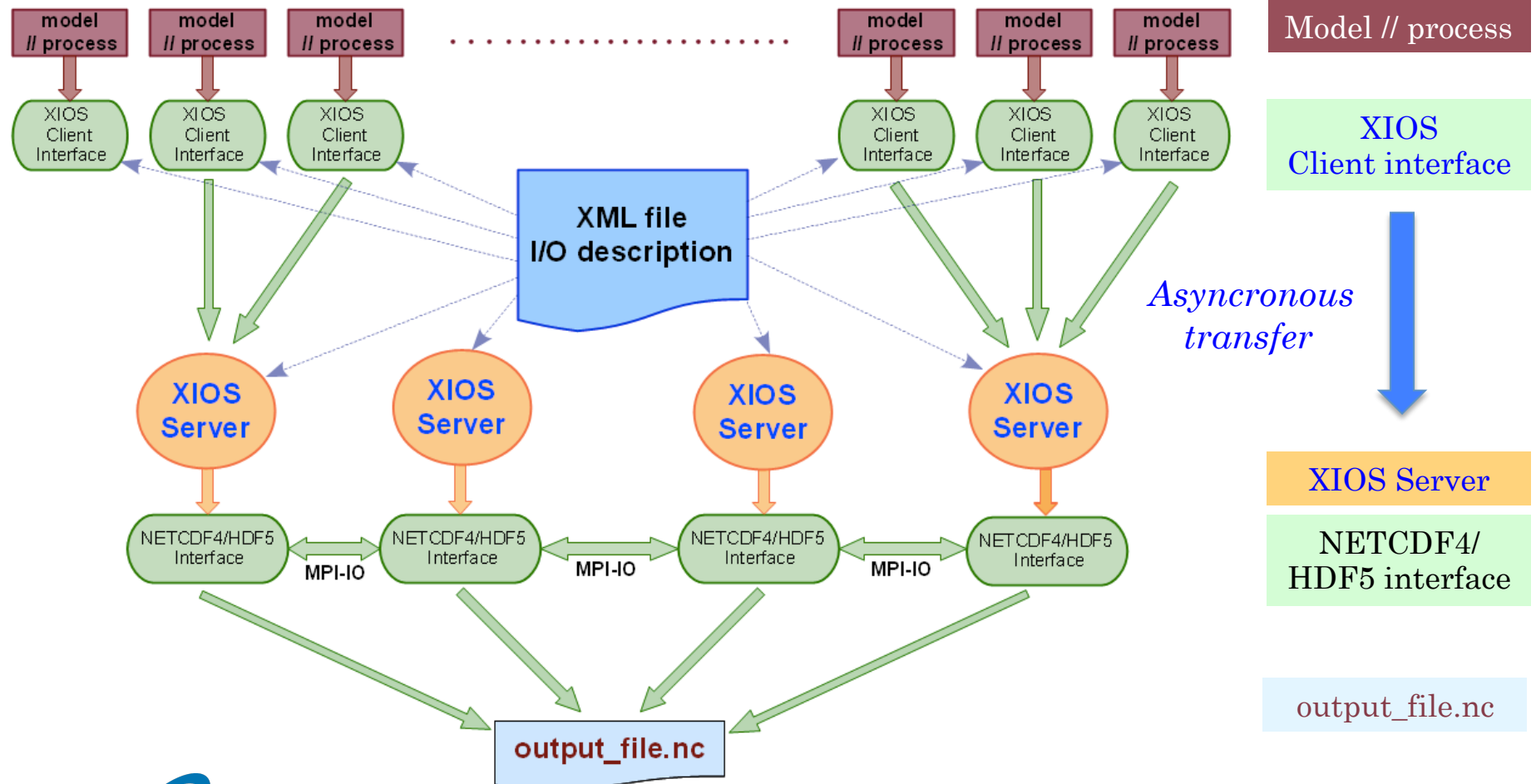
Multiple Roles, at least:

Model Developer, Model Tinkerer, Expert Data Analyst, Service Provider, Data User





(1) Management of output





Example : JASMIN - Bringing Compute to the Data

<http://jasmin.ac.uk>

LOTUS

Optimised
High
Performance
Data Analysis
Environment

**Community
Cloud**

Customisable

(with high
performance route
to archive)

**CEDA
Data
Services**

Remote access
to archive &
catalogues.
Download etc

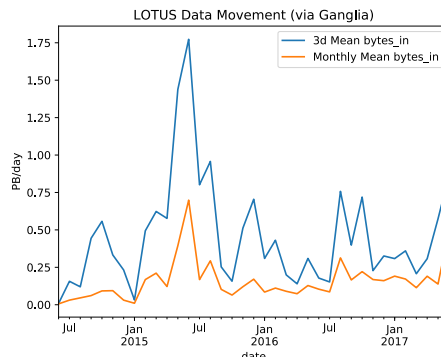
**CEDA
Archives**

JASMIN – Data Intensive Computer
Storage, Compute and Network Fabric
Batch Compute, Private Cloud, Disk, Tape

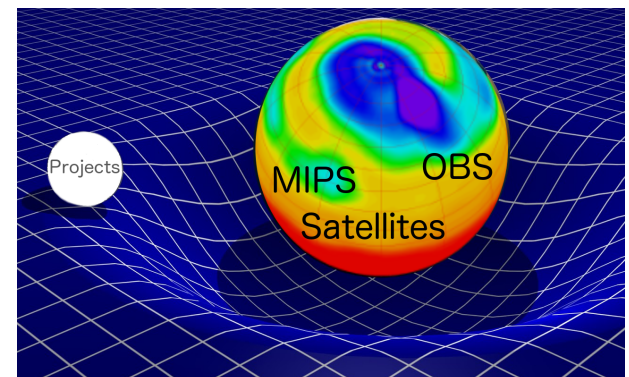


- 5 PB of CURATED POSIX archive data (and growing, with 10 PB expected in next 2 years).
- 6 PB of USER POSIX data on disk (and growing, with rapid growth expected as UK environmental science will no longer buy HPC with large local analysis disk, data from ARCHER, NEXCS, MONSOON, PRACE all expected to flow to JASMIN)!
- Lots of EPHEMERAL POSIX data (many PB more, comes and goes, need space for analysis!)

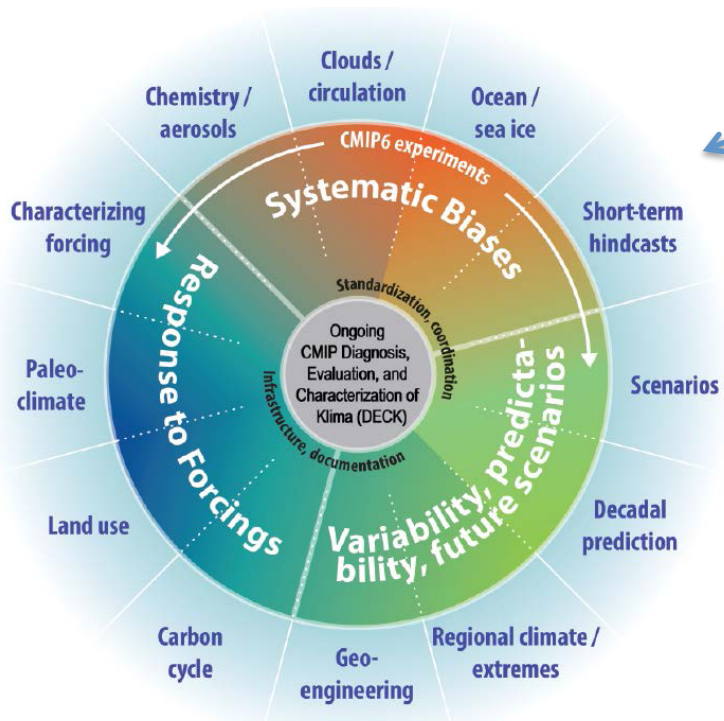
Moving PB
per day in and
out of LOTUS
(the batch
cluster):



The importance
of data gravity;
when you have
data, more data
comes to you!



(3) Distributed Archives Model data distribution



CMIP5 – o(2) PB from modelling centres

CMIP6 – expected to be o(30+) PB

Managing and distributing the data via the Earth System Grid Federation (ESGF).

Includes tools for publication, cataloguing, documentation, and both download and replication.

Meehl et al. (2014)



14 000 Registered Users





Issues:

- **Cost:** Disk prices not falling as fast as they used to.
- **Behaviour:** Larger groups sharing data for longer, which means *data is “hot” for longer*.
- **Performance:** Traditional (POSIX) disk not performant at scale.
- **Software:** Little software for our domain which can exploit “OBJECT store” disk (hard to use the public cloud.)
- **Tape:** Tape remains important, particularly for *large amounts of “cold” data*.



Community Action: ESIWACE “Exploitability” work package:

1. Better understanding of costs and performance of existing and near-term storage technologies.
2. New “**Earth System Middleware**” prototype
 - Provides an interface between the commonly used HDF library and storage which addresses both the performance of POSIX and the usability of object stores.
3. New “**Semantic Storage Library**” prototype:
 - Python library that uses a “weather/climate” abstraction (CF-NetCDF data model) to allow one “file” to be stored across tiers of, e.g. POSIX disk, OBJECT store, and TAPE.



Three domains of interest to weather and climate community:

- New Fabric and infrastructure (private/public cloud)
 - Exploiting virtualisation to provide flexible and elastic services. Not suitable for large scale simulation, but big role to play in analysis (e.g. JASMIN).
 - Large scale use will depend on addressing usability of object stores.
- New compute paradigms **emerging** (in our community)
 - New ways of arranging data and scheduling compute across hardware (e.g. HADOOP, SPARK) – *not used*
 - Some small scale experiments reported in the literature. DASK experiments underway at the UK Met Office (<http://www.informaticslab.co.uk/>)
- New ways of exploiting algorithms **emerging** (in our community).
 - e.g. using machine learning to identifying patterns in data, something we've done for decades, but with new and (possibly) better tools.
 - Experiments comparing traditional methods to new methods are underway (e.g. at LLNL in the US) to evaluate potential.
 - Possible use for Quality Control of data (e.g. unusual field) or Parameterisations (e.g. optimal parameters)



- Data are a key component of climate and weather modelling
- Exabytes will be reached before exaflops !

Facing the EXA era, 3 challenges:

- Reduce the amount of data: on-the-fly analyses, sampling issue
- Better methods to write data and manage and use storage
- Data science: Better algorithms to extract and exploit

Just startingTowards a revolution!