European Big Data Value Forum
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The Data Deluge in High-Resolution Climate and Weather Simulation

Sylvie Joussaume
CNRS, IPSL
Bryan Lawrence, Christian Pagé, Joachim Biercamp
(NCAS/UREAD, CERFACS, DKRZ)

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CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

www.esiwace.eu

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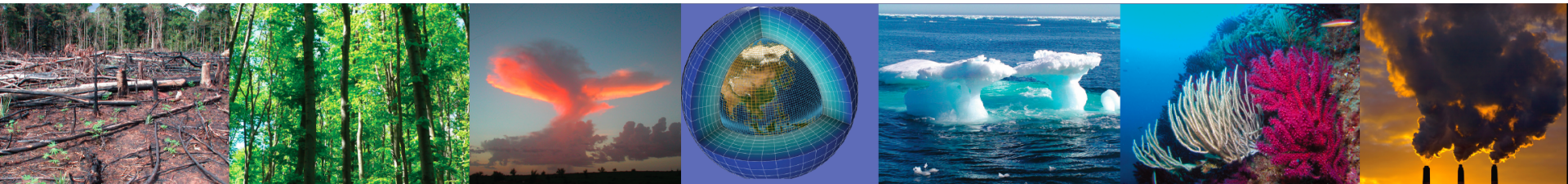

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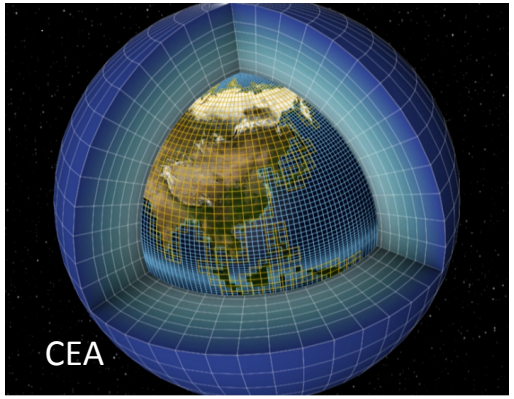
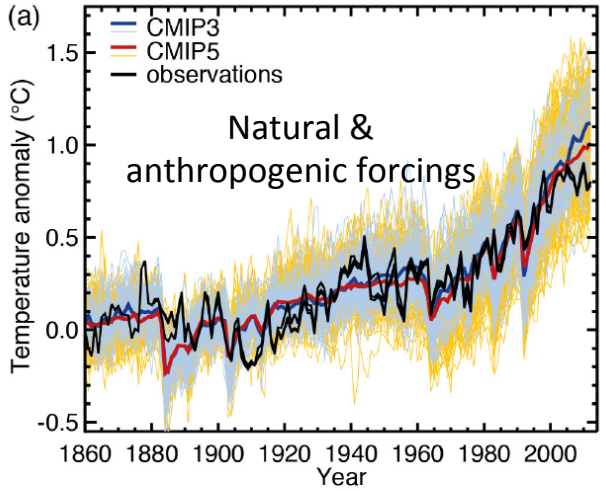
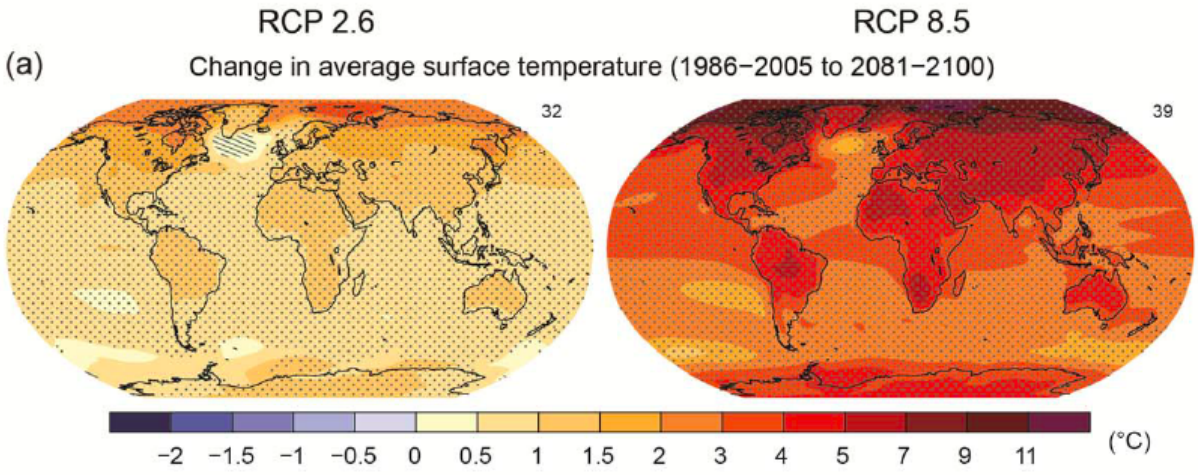
Climate and Weather Simulation

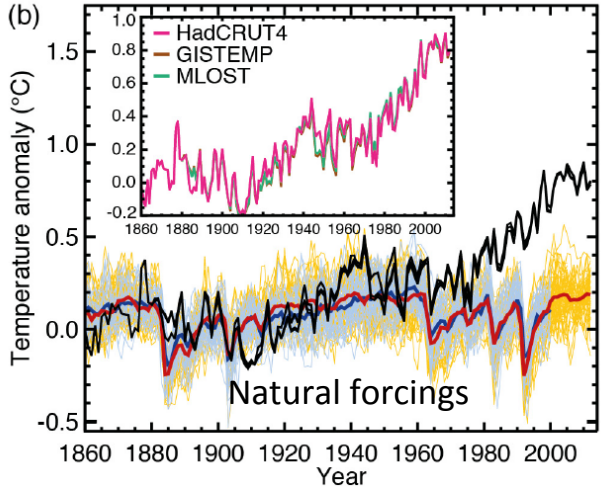


Understand
& Predict
Climate / Weather



IPCC (20013)





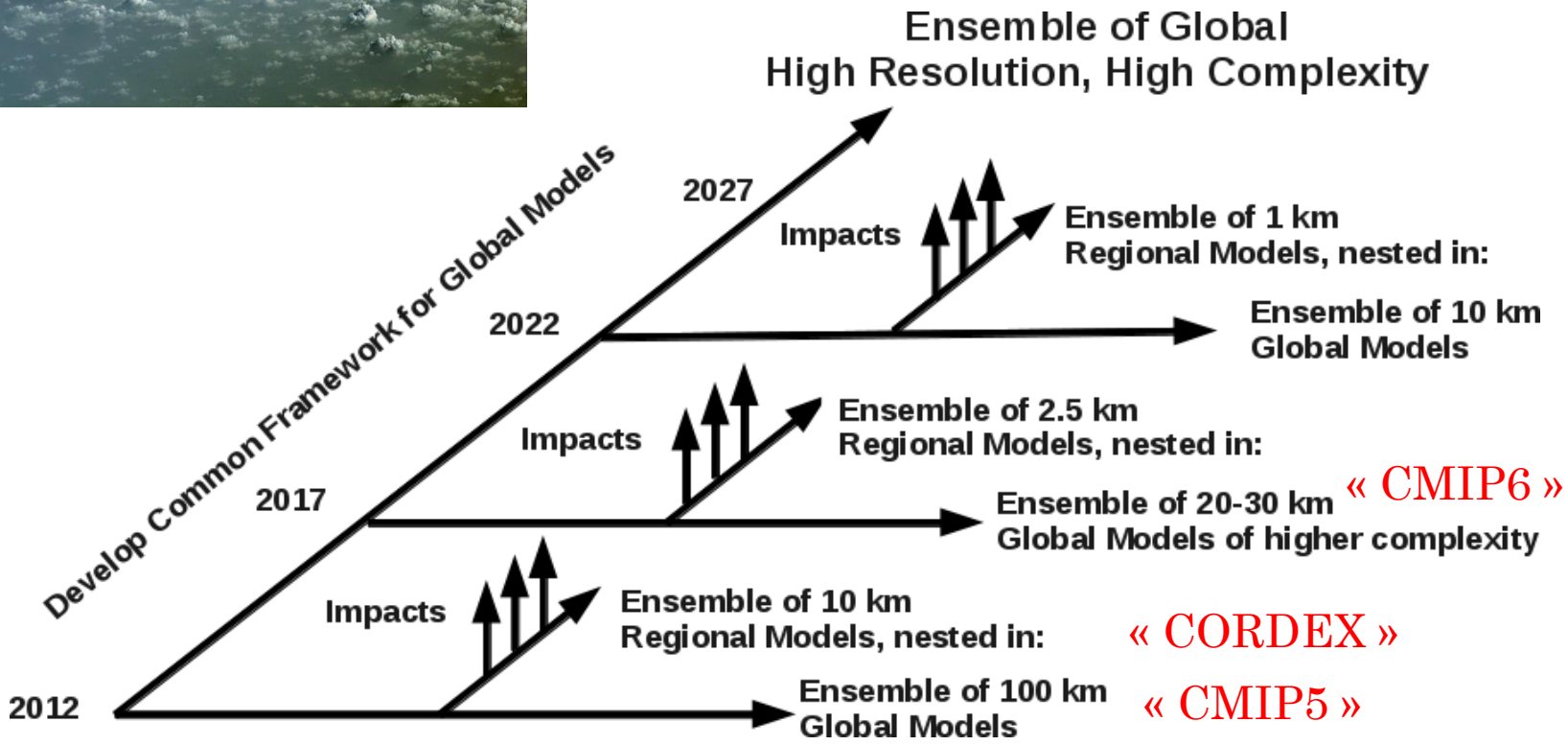
ENES Infrastructure Strategy Roadmap

Mitchell et al., 2012

enes
EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

http://enes.org/

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



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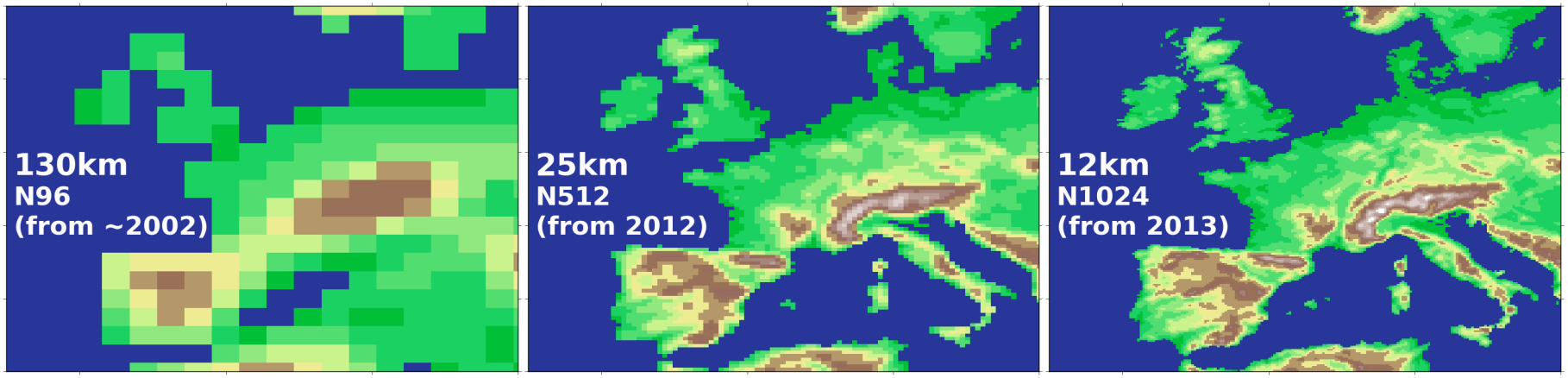
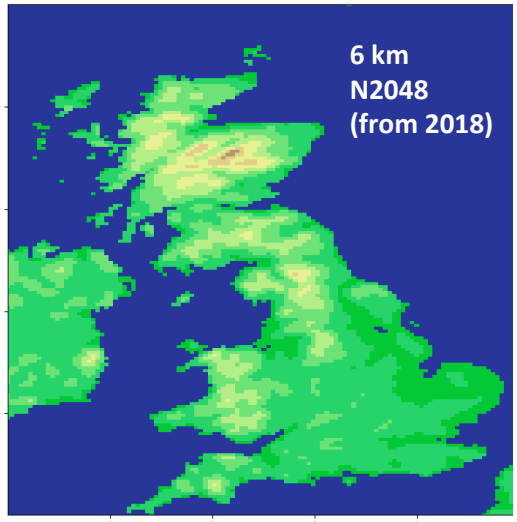
High Resolution



- 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!)

ENES Infrastructure Strategy Roadmap

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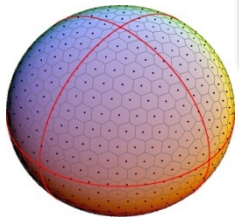
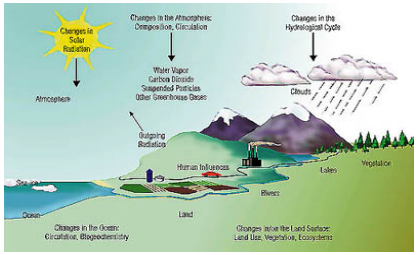
EUROPEAN NETWORK
FOR EARTH SYSTEM MODELLING

Needs for HPC

x 3 ≈ x 27
x 100 ≈ x 10^6



EO,
Data Assim.



And more data outputs

x 5-10

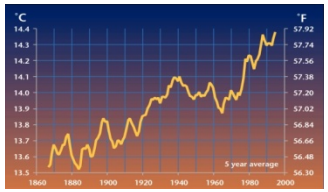
Resolution

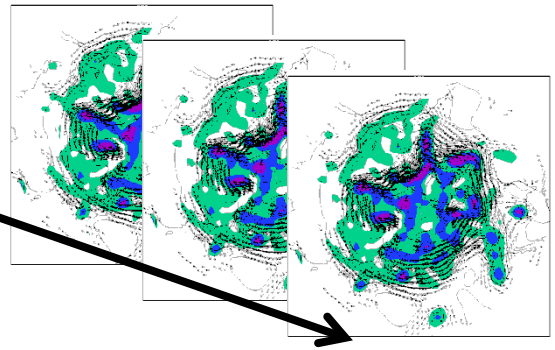
Computing Resources

Complexity

Duration and/or Ensemble size

From Jim Kinter,
the World Modelling Summit, 2008



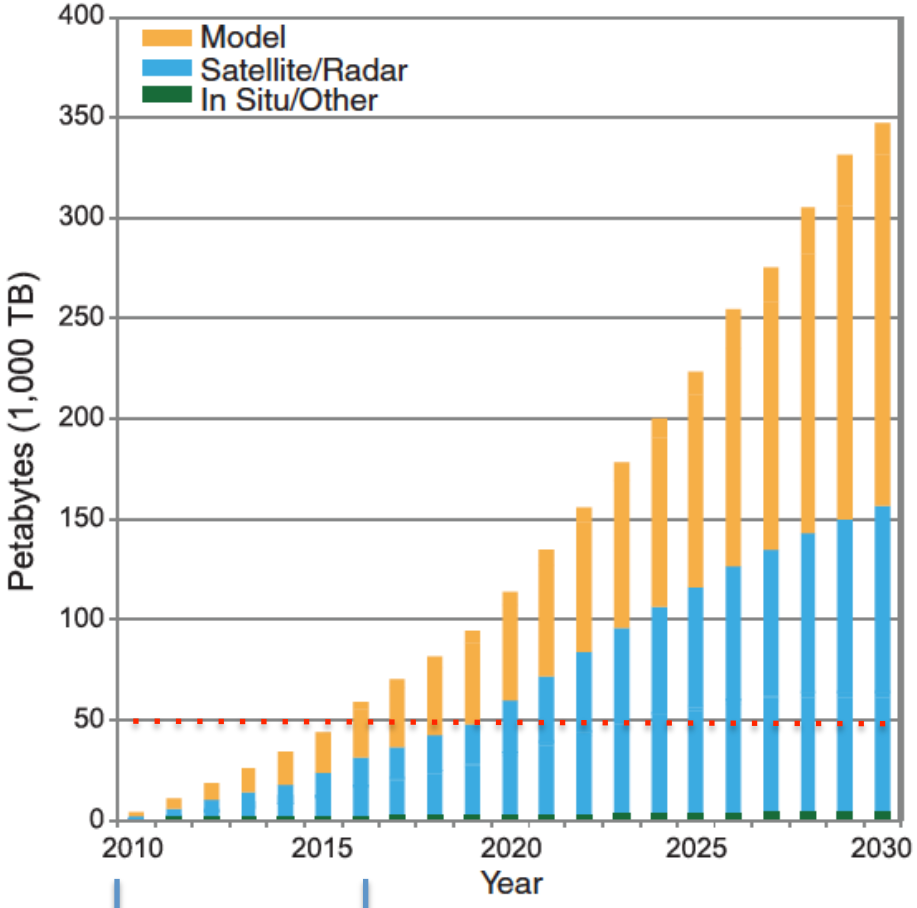


ensemble: x 10

duration: x 10-100

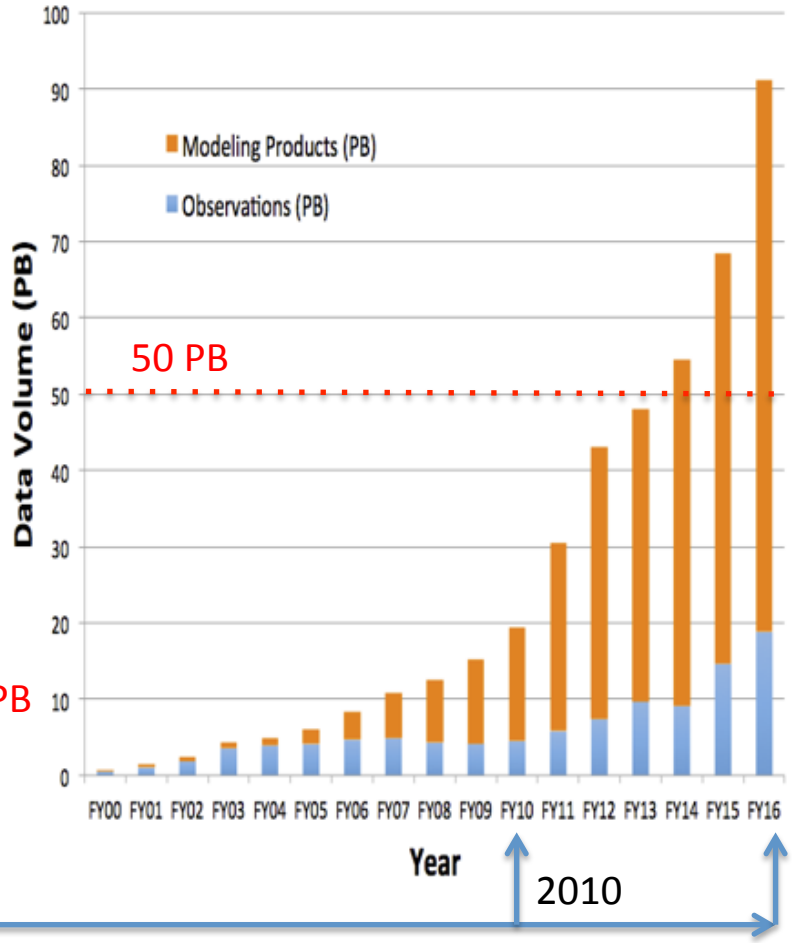
Increase of model data

Overpeck et al. (Science 2011)



50 PB

Tsengdar Lee, Icas17



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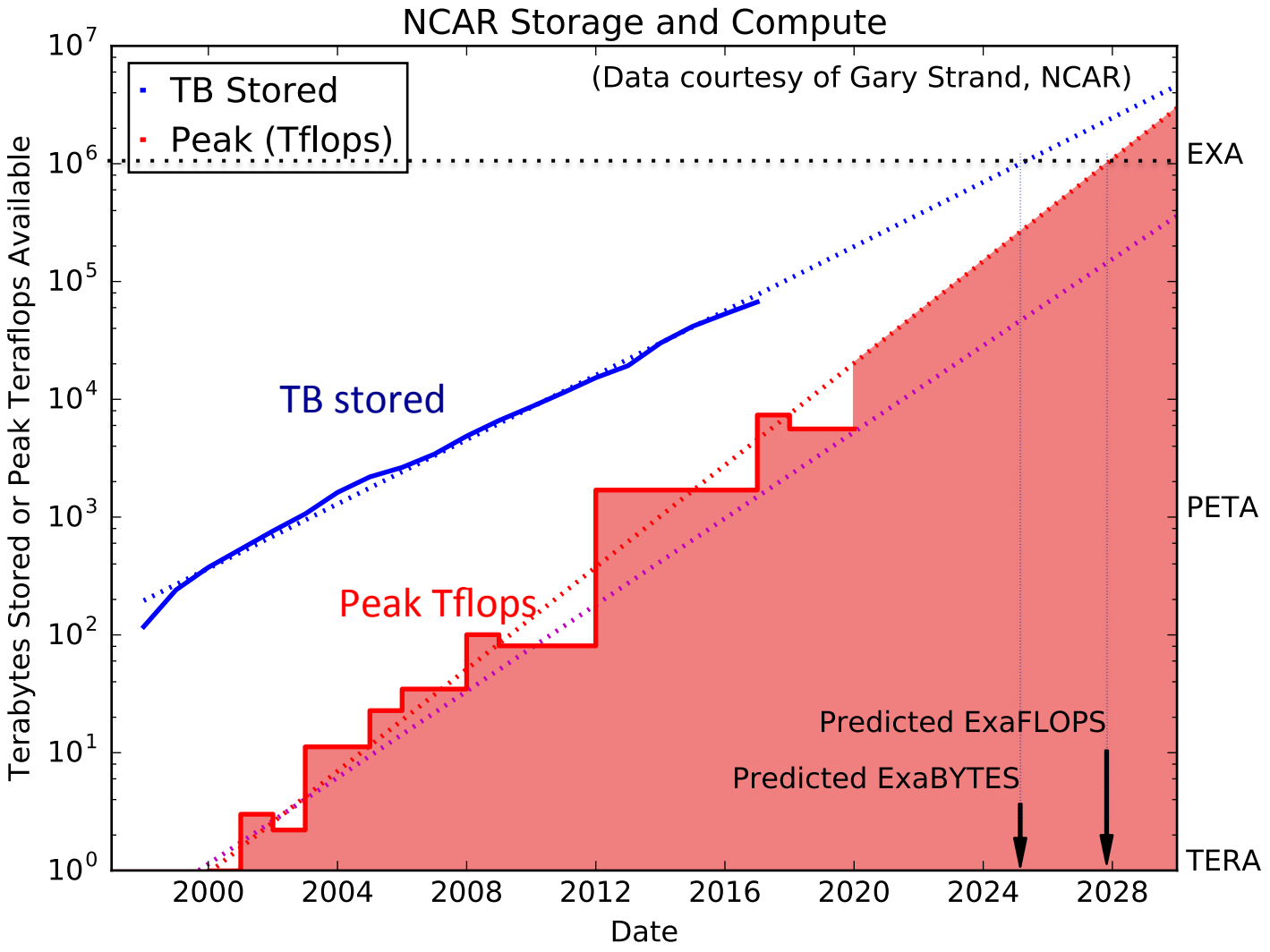
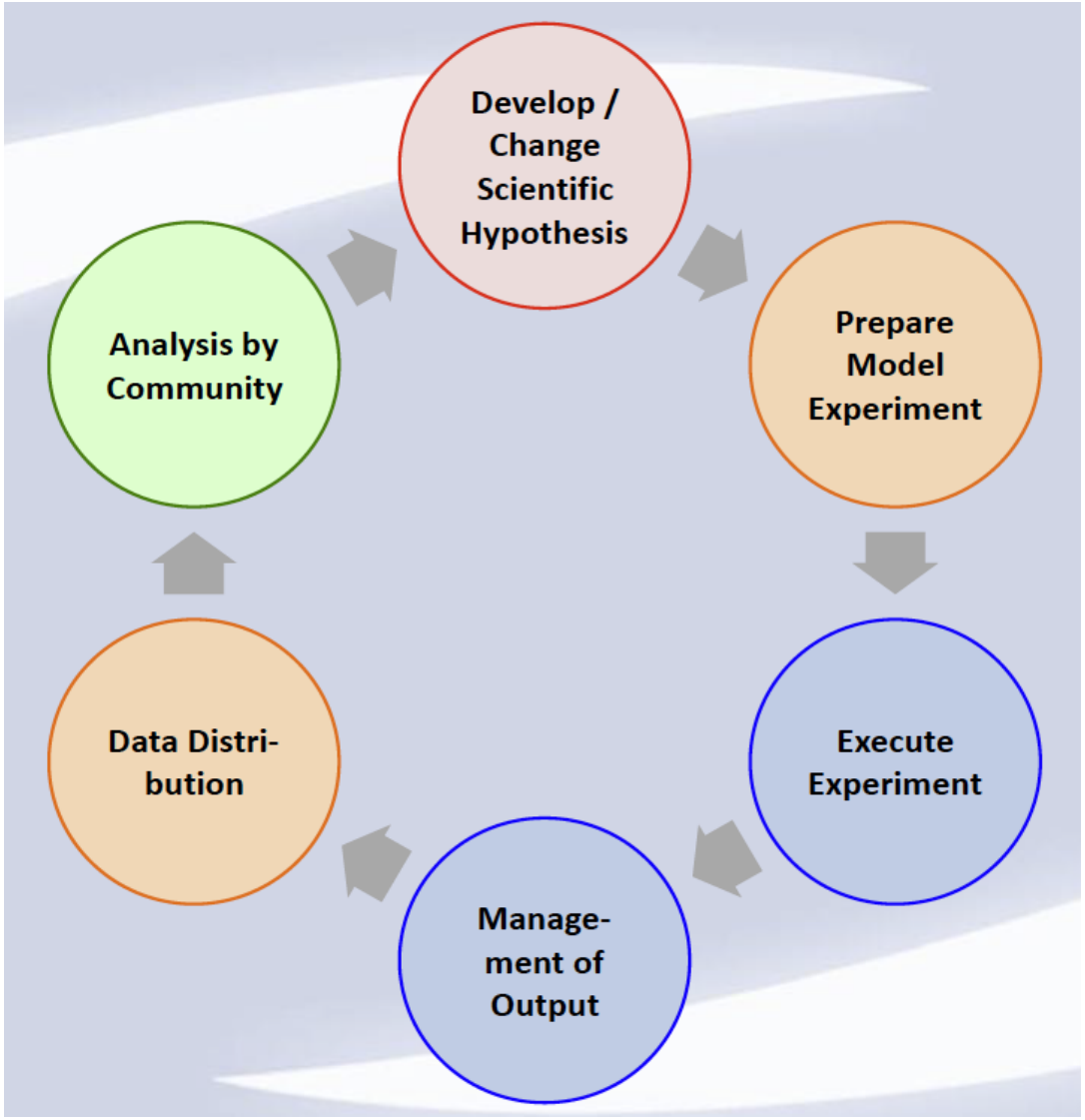
Scale and Growth: Continual Evolution



Workflow



Final Report, 2017

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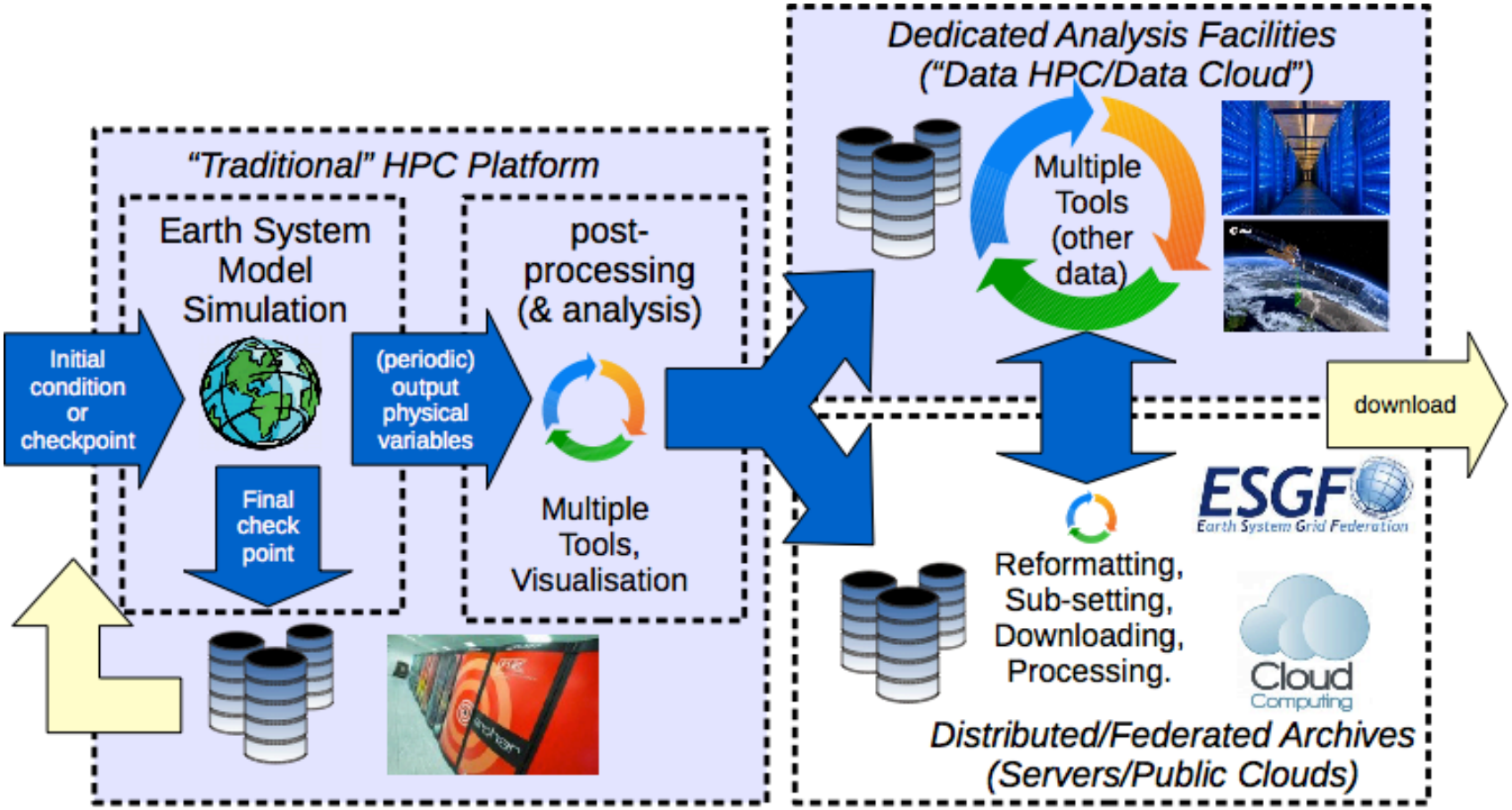
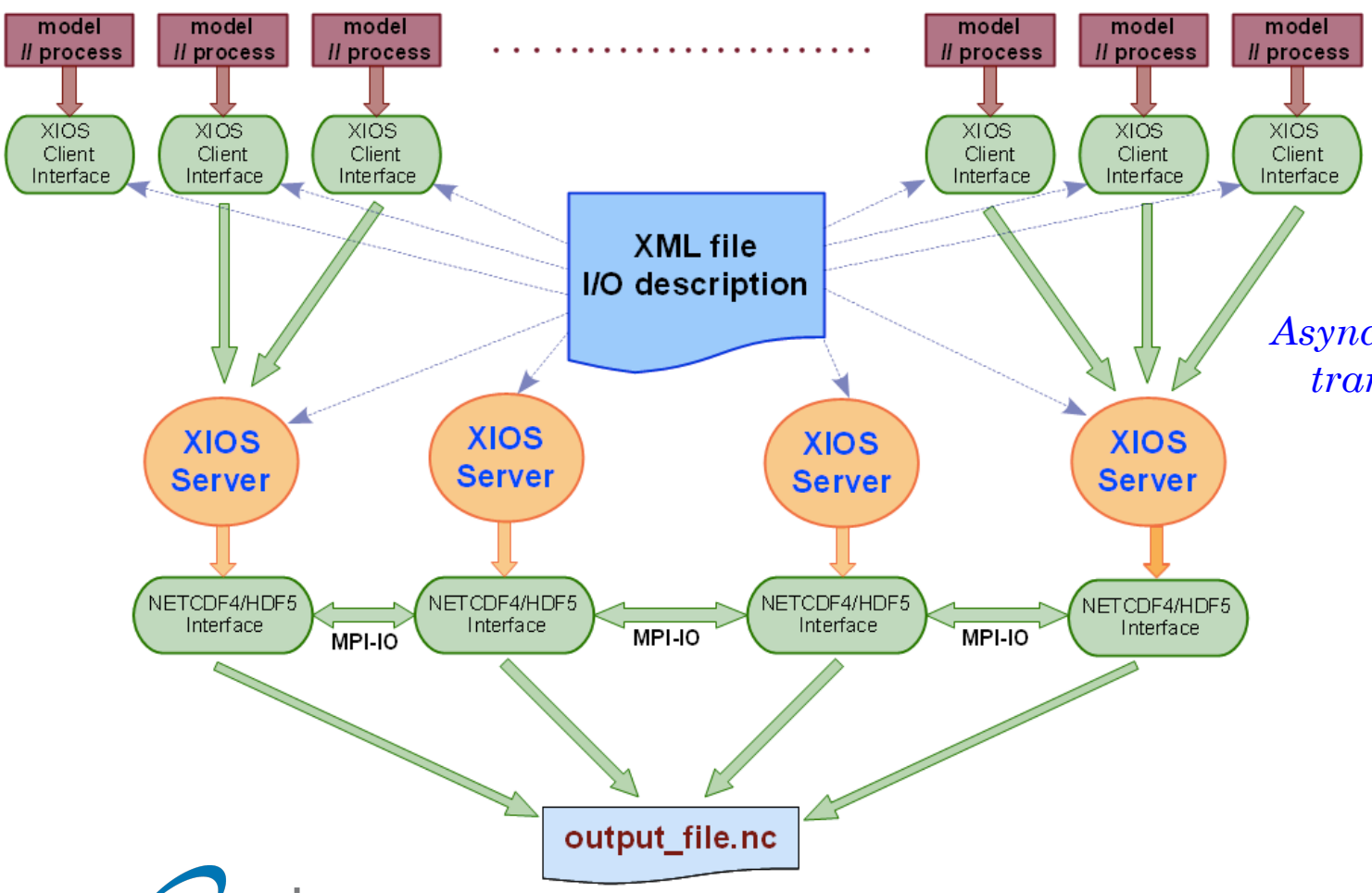
Multiple Types of Storage & Data Interaction



Multiple Roles, at least:
Model Developer, Model Tinkerer, Expert Data Analyst, Service Provider, Data User

(1) Management of output



Model // process

XIOS Client interface

Asyncronous transfer

XIOS Server

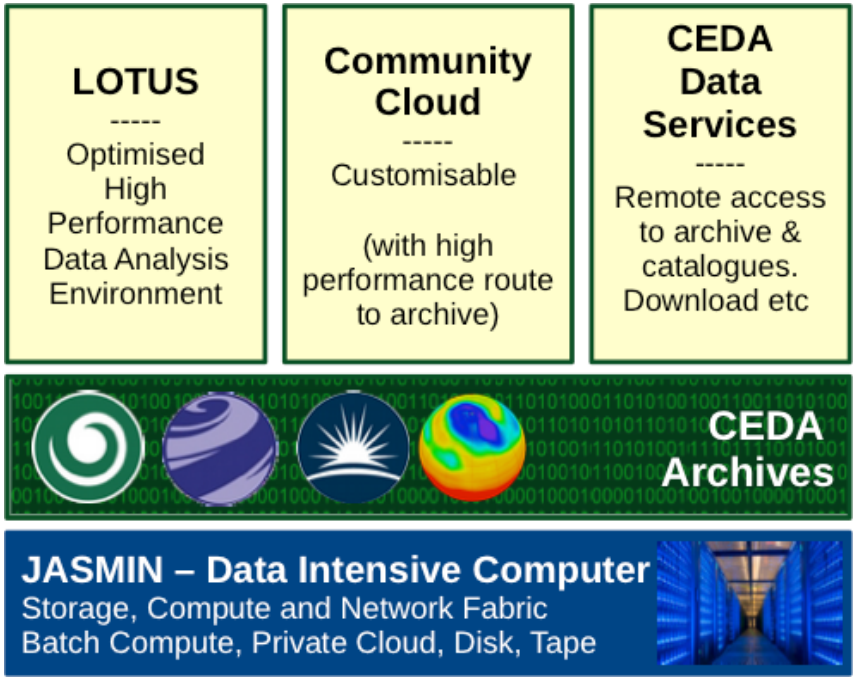
NETCDF4/ HDF5 interface

output_file.nc

(2) Dedicated Analysis Facilities

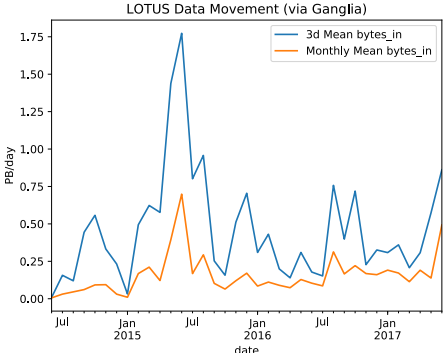
Example : JASMIN - Bringing Compute to the Data

http://jasmin.ac.uk

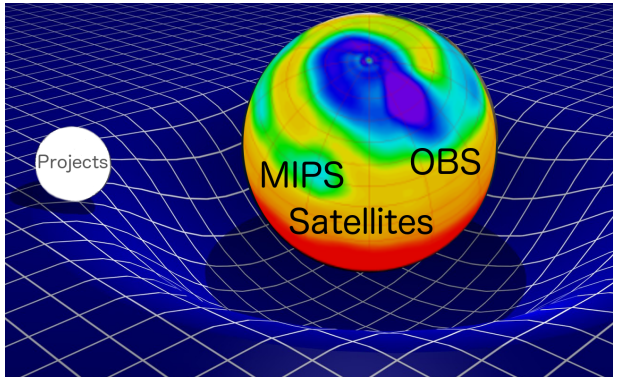


- 5 PB of CURATED POSIX archive data (and growing, with 10 PB expected in next 2 years).
- 6 PB of USER POSIX data on disk (and growing, with rapid growth expected as UK environmental science will no longer buy HPC with large local analysis disk, data from ARCHER, NEXCS, MONSOON, PRACE all expected to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

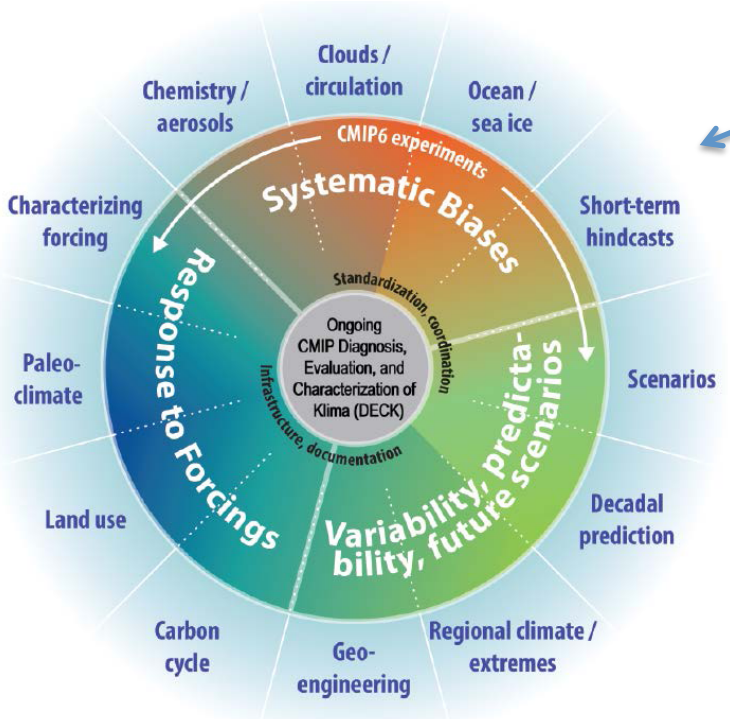
Moving PB per day in and out of LOTUS (the batch cluster):



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



(3) Distributed Archives
Model data distribution



Meehl et al. (2014)

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.

14 000 Registered Users

Storage issues & Actions arising

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.

Cloud computing and Big Data

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 or 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)

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Conclusions

- 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 starting ….Towards a revolution!