CMIP6: On the energy cost of data production, data transfer and data storage

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Simulated years, Data produced, Core-hours spent

CMIP6 experiments Institutions/Models	SY sent to ESGF	Total SY including preparatory runs	SY (%) (ESGF/total)	Data sent to ESGF (PB)	Total data produced (PB) including preparatory runs	Data (%) (ESGF/total)	CH (Mh) for SY sent to ESGF	Total CH (Mh) including preparatory runs	CH (%) (ESGF/total)
EC-Earth	28105	38854	72.3	0.8	1.405	56,9	31.3	46,5	67.3
CNRM-CERFACS	47000	110000	42.7	0.8	2.48	32.2	160	365	43,8
IPSL	75000	165000	45.5	1.8	7.6	23.7	150	320	46.9
CMCC	965	1926	50.1	0.27	1.46	18.5	1.99	4.34	45.8
UKMO	59000	117764	50.1	1.2	13.96	8.6	683	1491	45.8
NERC	640	1277	50.1	0.46	2.49	18.5	55.50	121.2	45.8
NCC-NORESM2	34443	68749	50.1	0.32	1.1	29.1	27.23	80	34.0
MPI	24175	35000	69.1	1.92	10.38	18.5	16.31	35.61	45.8
DKRZ	1276	1321	96.6	0.29	1.57	18.5	5.52	5.90	93,6
	270604	539891	50.1 %	7.86	42.445	18.5 %	1131	2470	45.8 %
CMIP5	93000		?	1.05	6.9+	15.2%	46.8		?

Some groups have no records for some numbers. Missing numbers, as shown in red, are then estimated from the ratios computed from the other groups

They are still a few discrepencies between numbers for different centers, work in progress !

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	270604	539891	50.1 %	7.86	42.445	18.5 %	1131	2470	45.8 %
CMIP5	93000		?	1.05	6.9+	15.2%	46.8		?

A few general remarks:
- the number of simulated years finally sent to ESGF is approximately half of the total number of SY run by the groups, due to tuning runs, aborted ones, … This ratio also applies, quite understandably, to core hours;
- however, a bit less than 20% of the total amont of produced data have been sent to the ESGF archive, a ratio lower than the one applying to SY: this would likely mean that some data, although of scientific value, have been kept at the group level for more specific analysis ?

With respect to the preceeding CMIP5 exercise (for which some numbers were not collected at the time):
- the number of ESGF SY has been multiplied by at least 3, maybe up to 6: one more group, more members in the ensemble simulations, …
- the amount of ESGF data been multiplied by almost 8: larger number of SY, but also increased resolution of simulations;
- the number of core-hours has been multiplied by at least 20 (and maybe up to 50), corresponding for a significant part to the increased resolution of the simulations

Energy spent for producing the simulations

CMIP6 experiments Institutions/Models	SY sent to ESGF	Total SY including preparatory runs	SY (%) (ESGF/total)	Data sent to ESGF (PB)	Total data produced (PB) including preparatory runs	Data (%) (ESGF/total)	CH (Mh) for SY sent to ESGF	Total CH (Mh) including preparatory runs	CH (%) (ESGF/total)	Energy (J)
EC-Earth	28105	38854	72.3	0.8	1.405	56,9	31.3	46,5	67.3	1.24E+12
CNRM-CERFACS	47000	110000	42.7	0.8	2.48	32.2	160	365	43,8	6.18E+12
IPSL	75000	165000	45.5	1.8	7.6	23.7	150	320	46.9	8.72E+12
CMCC	965	1926	50.1	0.27	1.46	18.5	1.99	4.34	45.8	1.61E+12
UKMO	59000	117764	50.1	1.2	13.96	8.6	683	1491	45.8	2.67E+13
NERC	640	1277	50.1	0.46	2.49	18.5	55.50	121.2	45.8	2.17E+12
NCC-NORESM2	34443	68749	50.1	0.32	1.1	29.1	27.23	80	34.0	1.69E+12
MPI	24175	35000	69.1	1.92	10.38	18.5	16.31	35.61	45.8	7.1E+11
DKRZ	1276	1321	96.6	0.29	1.57	18.5	5.52	5.90	93,6	4.09E+11
	270604	539891	50.1 %	7.86	42.445	18.5 %	1131	2470	45.8 %	4.94E+13
CMIP5	93000		?	1.05	6.9+	15.2%	46.8		?	?

Total of 510^{13} J or 13,700 MWh ,

corresponding approximately to the production of a 1,000 MW power plant during half a day

Energy consumption for transfering the data

A simple question «***What is the energy cost of transfering data, expressed in J/GB or kWh/GB ?***» with no answer !

General estimations range from a few Wh/GB, when based on the energy cost of a few devices (*e.g.*, routers) to a few kWh/GB, when estimated macroscopically from the Web

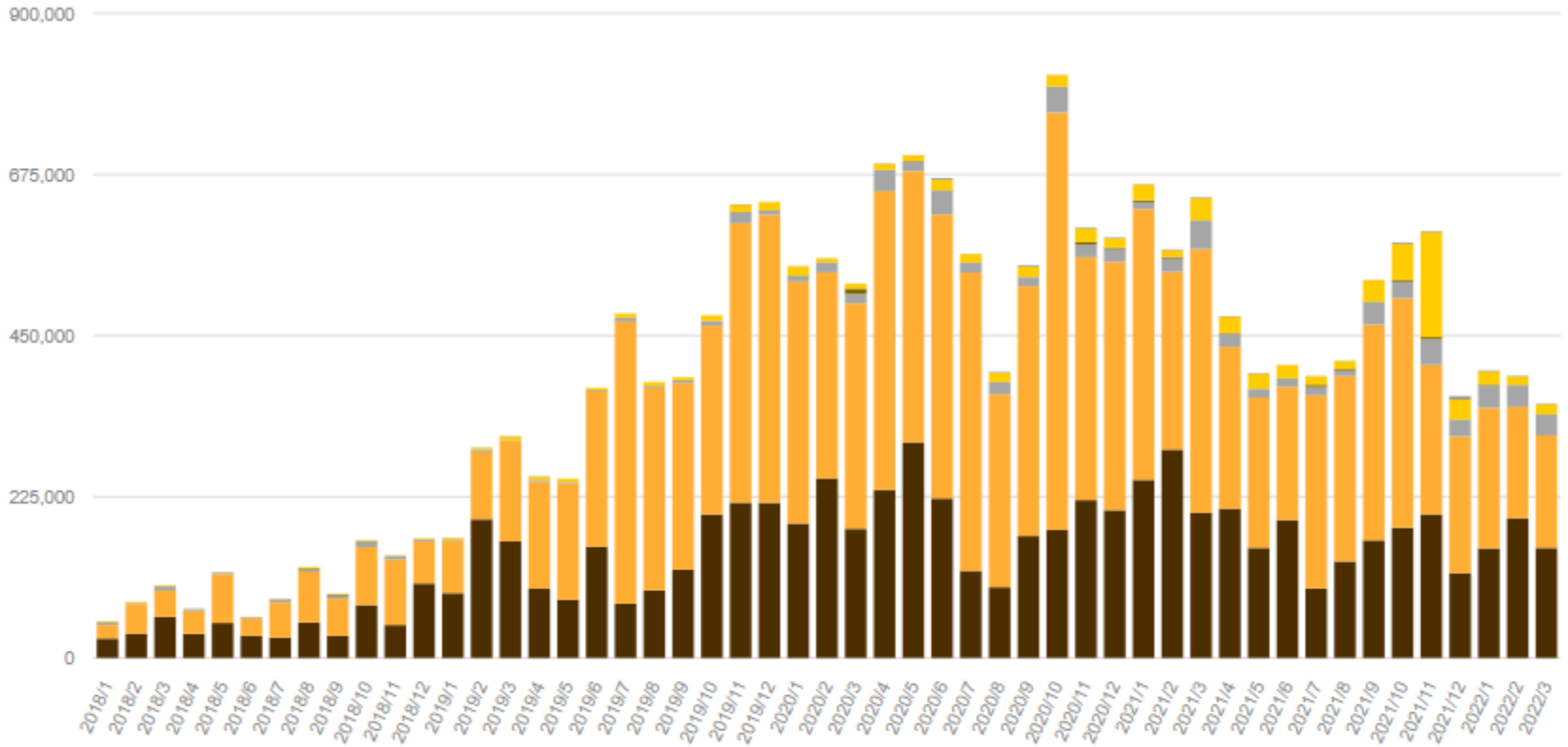
Only one (?) more-relevant paper (Aslan *et al.*, 2017):

For 2015 : 60 Wh/GB, with expected halving every second year (more efficient equipements)

Two phases: (1) groups feeding the ESGF archive (2018?), 8 PB

(2) users (European) downloading data for analysis

Energy consumption for transfering the data



200TB per month over 3+ years (2019-2021), total 8 PB

Energy consumption for transferring the data

Feeding the ESGF archive: 8 PB at 30 Wh/GB (2018)

= 240 MWh

Downloading from the ESGF archive: 8 PB at 15 Wh/GB (2019-2021)

= 120 MWh

Total for data transfer: ~ **500 MWh**

Many caviats:

- the download number above (8 PB) could be multiplied by 2+ if one considers that it should include downloads of European data by non-European users and the other way around ?

- there are also uncertainties about the feeding number above (8PB), which could be somewhat overestimated as some groups have shorter access to ESGF

- the final number may be underestimated, as the macroscopic estimate would lead to a number larger by almost 2 orders-of-magnitude !

- the energy cost depends on the way the data are transferred (small *vs.* large packets), number of devices on the way (routers, …), either old or new, ...

Energy consumption for storing the data

Estimates from both JASMIN (thanks Bryan) and BSC (thanks Mario and Pierre-Antoine) are consistent with a cost of a few MWh/PB$_x$year (3 to 20)

Hypothesis: 8 PB stored locally for 3 years at each of the 8 centers

Amounting to a total of 600-4,000 MWh

i.e. **a few hundreds to a few thousands of MWh**

Summary and follow-on

Our «best» estimate (orders of magnitude): Production of simulations: ~ 10,000 MWh
Transfer of data: ~ 1,000 MWh
Storage of data: ~ 1,000 MWh

What remains to be done

At the HPC-TF level:

- Double-check all numbers (*e.g.* CMCC for energy,…)
- Include specific cost of storage for all centers
- Transform into carbon footprint (country dependant)

For the IT community at large

- Provide numbers, rather than estimates and rules-of-thumb, for data transfer