

Earth System Sciences in the Times of Brilliant Technologies

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Overview

- Brilliant technologies
- Earth system sciences
- Cost/benefit considerations
- More brilliant technologies
- More science
- More threats

25 Years of German Climate Computing Centre (1987-2012)

First computer in 1987

- Control Data Cyber-205
 - 1 processor, 200 MFLOPS, 32 MB main memory
 - 2.5 GB hard drive, 100 GB tape library



“Blizzard” system 2009-2015

- IBM Power6
 - 8,500 processor cores, 158 TFLOPS, 20 TB main memory
 - 6 PB hard drives, 100 PB tape library



factor 1,000,000 in all components

July 1st: “Mistral” Put into Operation



bullx B700 DLC with
dual Intel E5-2680 Haswell@2.5 GHz



FatTree with FDR-14 Infiniband
3 Mellanox SX6536 core 648-port switches



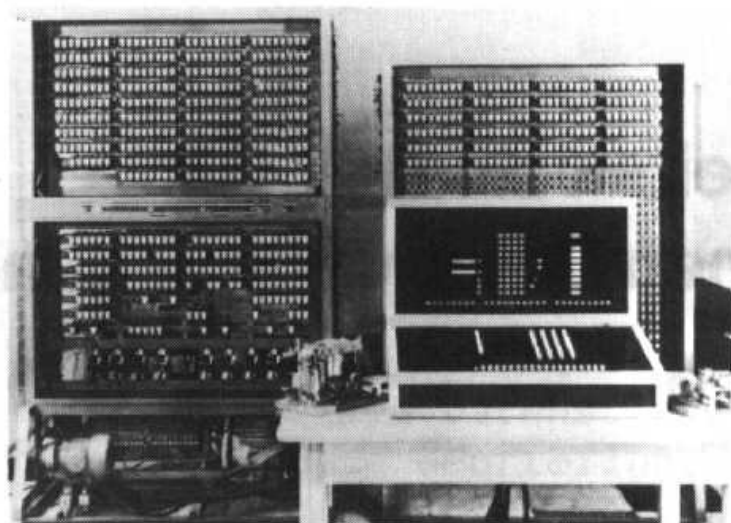
From “Blizzard” to “Mistral”

Measure	2009	2015	Factor
Performance (no accelerators)	150 TFLOPS	3 PFLOPS	20x
Main memory	20 TB	200+ TB	10x
Hard disk capacity	6 PB	50 PB	9x
Throughput memory to disk	30 GB/s	400 GB/s	13x
Tape library capacity (2015, 2020)	120 PB	390 PB	3x
Throughput disk to tape	10 GB/s	20 GB/s	2x
Power consumption	1.6 MW	1.4 MW	0.9x
Investment costs	€ 30M	€ 35M	1.2x

Brilliant Computer Technologies for 74 Years

First computer 1941: Zuses Z3
Performance 0.3 FLOPS

#1 computer 2015: Tianhe-2
Performance $34 \cdot 10^{15}$ FLOPS



Improvement factor 100,000,000,000,000,000 in 74 years

12.5 years 12.5 years 12.5 years 12.5 years 12.5 years

Madness has a Name: Exponential Growth



Performance growth in 74 years of computers $1 \cdot 10^{17}$

We are on which square? 58

When on square 64? 2022

Increase on check board $1 \cdot 10^{19}$

Driving Force: Semiconductor Technology

Semiconductor switches

- Transistor patented in 1925, used since 1945
- Smaller structures, different materials

The future

- When will this miniaturization end?
- „In the next five years“
(citation of my professor in elec. engineering in 1980 😊)
- „In the next ten years“ (Thomas Ludwig)

Next material for switching elements?

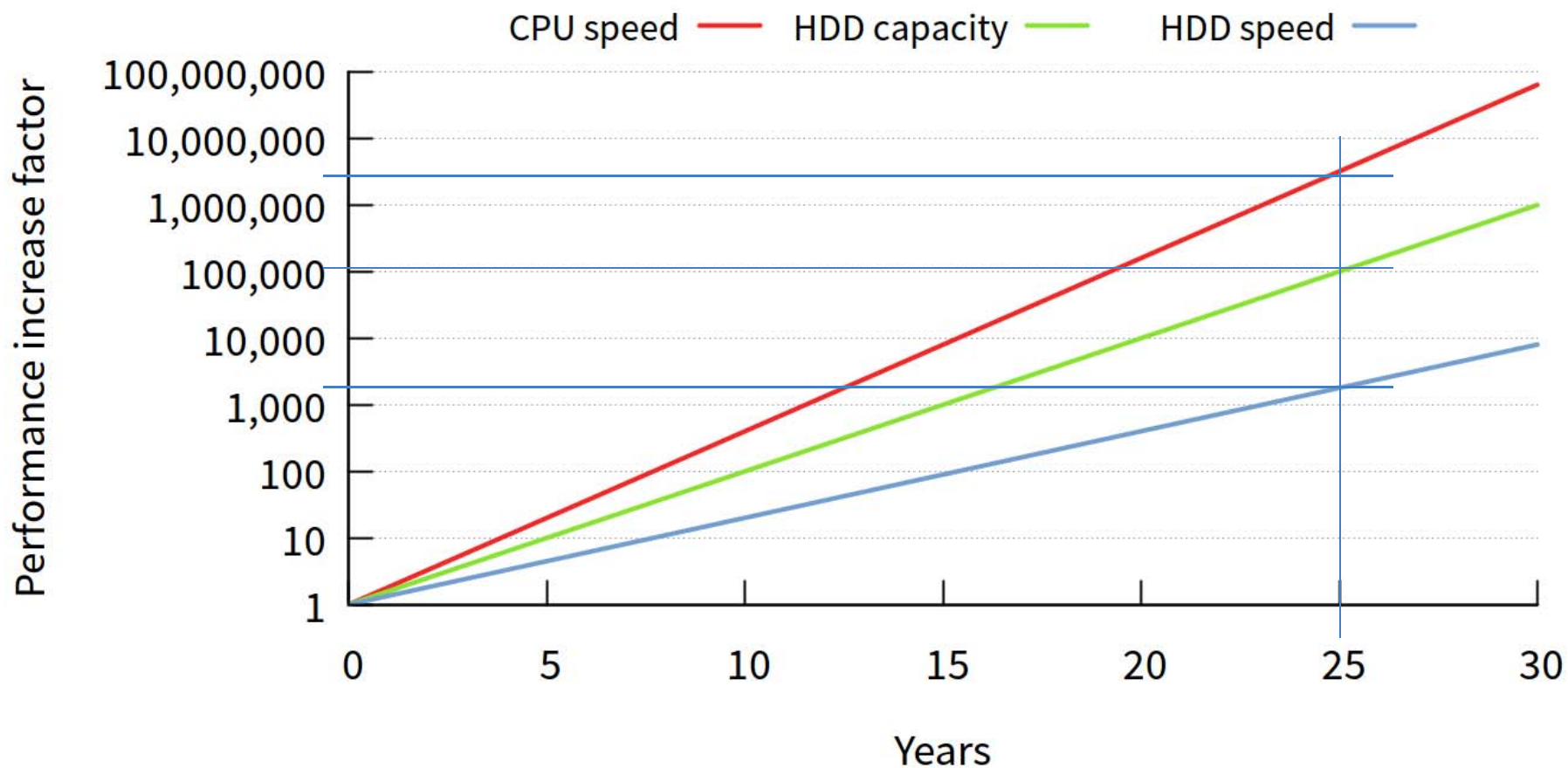
- Carbon nanotubes and/or graphene (+ semiconductors?)
really brilliant

Will there be further exponential increase in
computational power?

Yes.

However...

Technology Gap between Compute and I/O



Earth Sciences

There are so many of them...

We focus on computational earth sciences

- Weather
- Climate (atmosphere, ocean, bioshpere, cryoshpere, ...)
- Solid earth (earth quakes, tectonics, ...)
- ...

Earth Science Projects – Four Examples

- CMIP6
- HD(CP)²
- ESiWACE
- Met Office 's new HPC system

CMIP5 – Coupled Model Intercomparison Project

- Provides key input for the IPCC report
 - 5th AR, 2013
- ~20 modeling centers around the world
 - DKRZ being one of the biggest
- Produces 10s of PBytes of output data from ~60 experiments (“digital born data”)

Data are produced **without knowing all applications** beforehand and these data are stored and archived for **interdisciplinary utilization** by yet **unknown researchers**

CMIP5 Summary

- Status CMIP5 data archive (June 2013)
 - 1.8 PB for 59,000 data sets stored in 4.3 Mio Files in 23 ESGF data nodes
 - CMIP5 data is **about 50 times** CMIP3

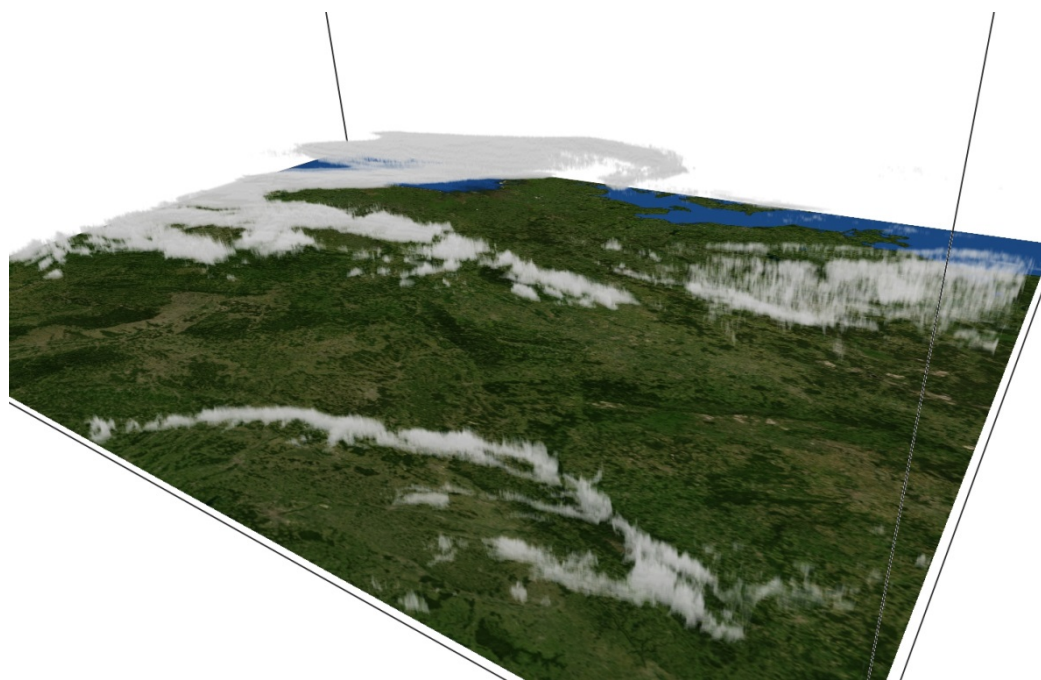
- Costs of CMIP5 at DKRZ
 - 20 M corehours in 2010/2011 = 1/3 annual capacity with IBM
 - Share of investments costs: € 1.6M
 - Share of electricity costs: € 0.6M
 - Share of tape costs: € 0.1M
 - Additional service staff: € 1.0 M

CMIP6 Data Volume Estimate

- Extrapolation to CMIP6 (2017-2019)
 - CMIP6 has a more complex experiment structure than CMIP5.
 - Expectations: more models, finer spatial resolution and larger ensembles
 - **Factor of 20:** 36 PB in 86 Mio Files
 - Potential DKRZ share: 3 PB on disk, 20 PB on tape
 - **Factor of 50:** 90 PB in 215 Mio Files

HD(CP)² – High Definition Clouds and Precipitation for Climate Prediction

- Model for Germany and Europe with 100 meter grid
- 22 million cells and 150 levels



ESiWACE



- The project ESiWACE has received funding (ca. €5M) from the European Union's Horizon 2020 research and innovation programme grant agreement *No 675191*.
- **Horizon2020 Work Programme 2014-2015, European research infrastructures**

Join weather and climate communities to provide support, training, services for efficient earth system modelling using HPC

Project Goals

ESiWACE will

- substantially **improve the efficiency and productivity** of numerical weather and climate simulation on high-performance computing platforms.
- **support the end-to-end workflow** of global Earth system modelling for weather and climate simulation in high performance computing environments.
- foster the **interaction between industry** and the weather and climate community on the exploitation of high-end computing systems, application codes and services.
- **increase competitiveness and growth of the European HPC industry.**

The European **weather and climate science community** will

- drive the **governance structure** that defines the services to be provided by ESiWACE.

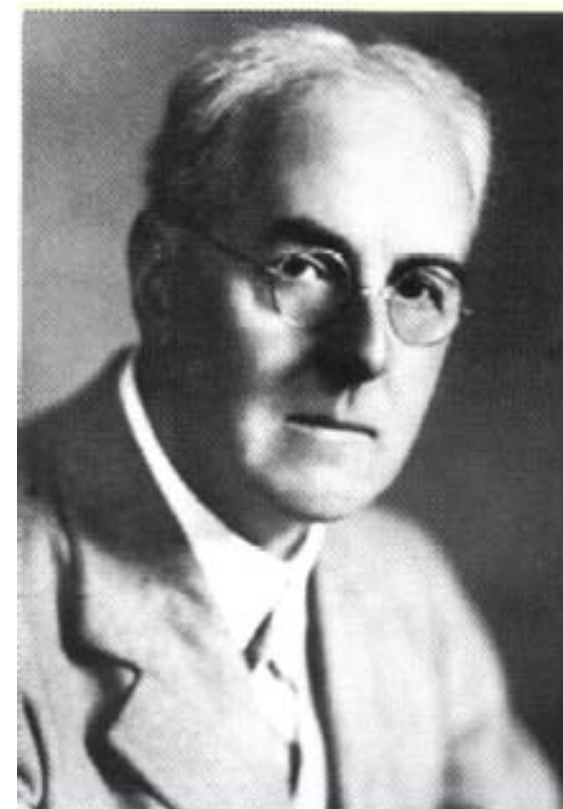
ESiWACE Partners

1	Deutsches Klimarechenzentrum GmbH COORDINATOR	DKRZ	Germany
2	European Centre for Medium-Range Weather Forecasts	ECMWF	United Kingdom
3	Centre National de la Recherche Scientifique	CNRS-IPSL	France
4	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. / Max-Planck-Institut für Meteorologie	MPG	Germany
5	Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique	CERFACS	France
6	Barcelona Supercomputing Center	BSC	Spain
7	Science and Technology Facilities Council	STFC	United Kingdom
8	Met Office	MetO	United Kingdom
9	The University of Reading	UREAD	United Kingdom
10	Sveriges meteorologiska och hydrologiska institut	SMHI	Sweden
11	National University of Ireland Galway (Irish Centre for High End Computing)	ICHEC	Ireland
12	Centro europeo-mediterraneo sui cambiamenti climatici scarl	CMCC	Italy
13	Deutscher Wetterdienst	DWD	Germany
14	Seagate Systems UK Limited	SEAGATE	United Kingdom
15	BULL SAS	BULL	France
16	Allinea Software Limited	ALLINEA	United Kingdom

Lewis Fry Richardson (1881-1953) – Cost/Benefit

In 1922 **Lewis Fry Richardson** publishes his book *Weather Prediction by Numerical Process*

Perhaps some day in the dim future it will be possible to advance computations faster than the weather advances and at a cost less than the saving to mankind due to the information gained



Lewis Fry Richardson

Met Office 's New HPC System

- €100M system in 2015-2017 from Cray
- Peak performance ca. 23 PFLOPS
- "The investment in the high-performance computing is for the benefit of the whole country. Our role as the National Met Service is vital in delivering significant economic benefits to the nation, providing a wide range of services to airlines, energy companies, retailers and many others." (Dan Williams)

Met Office 's New HPC System...

Rumors say:

- Met Office did a quantification on financial benefits of HPC
- As a consequence received this high funding

Refer to findings of IDC

- \$514 in revenue per dollar of HPC invested
- Expansive list of HPC success stories
- <http://insidehpc.com/2015/09/idc-presents-an-update-on-roi-with-hpc/>

More Brilliant Technologies...

Internet of things

- Sensors everywhere - thanks Apple!

Internet of humans

- Citizen Science = More Science

SCIENCE

TURN YOUR UMBRELLA INTO A MOBILE WEATHER STATION

I'M PINGING IN THE RAIN, JUST PINGING IN THE RAIN...

By Douglas Main Posted May 1, 2014



The umbrella prototype *Rolf Hut / Delft University of Technology*



A sensor measures raindrops hitting the umbrella's canvas, and transmits that data to a smartphone.

Oldweather

Old Weather: Our Weather's Past, the Climate's Future

Introduction

Help scientists recover Arctic and worldwide weather observations made by United States ships since the mid-19th century by transcribing ships' logs. These transcriptions will contribute to climate model projections and will improve our knowledge of past environmental conditions. Historians will use your work to track past ship movements and tell the stories of the people on board.



Follow vessels

Choose your voyage by joining a vessel



Digitise pages

Earn points on each ship. Every page counts



Get promoted

Work your way up from Cadet to Lieutenant and even become Captain

Project Statistics

Old Weather transcriptions so far

53%

OF THE LOGS COMPLETED

Arctic	PAGES DONE
📄 82,842	VOYAGES DONE
🚢 9	

More Threats

Citizen Science

- Enhances scientific process by human cognition
- Thus training neural networks in computers

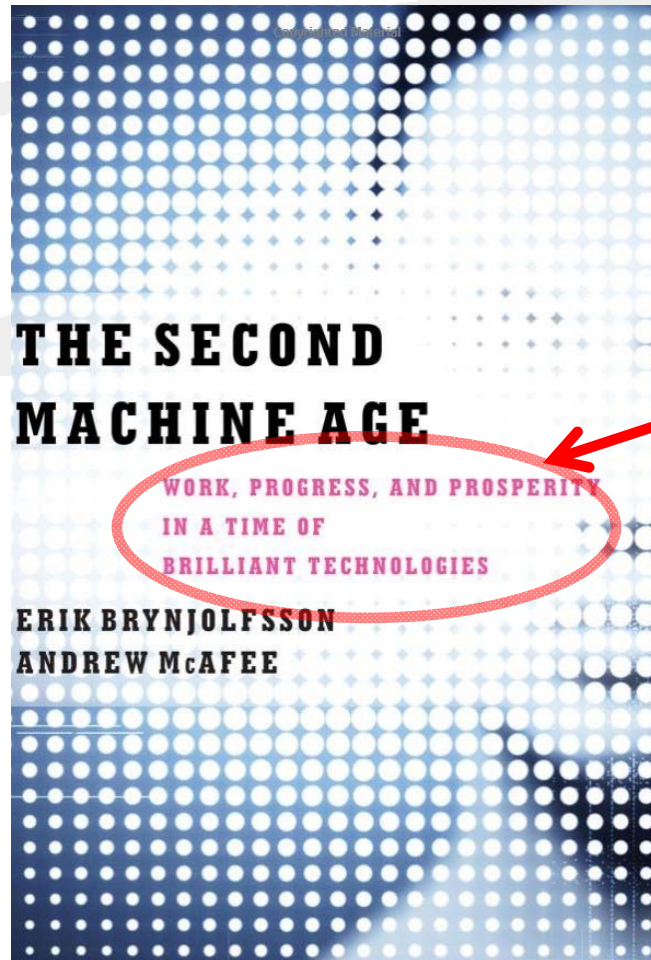
Wikipedia Authors

- Enters human knowledge into global data base
- Thus training concepts like IBM ´s Watson technology

More Threats...

It's all about algorithms...

- Machine learning
 - How to drive a car, a truck, a train...
- (Big data) data analytics
 - Numerical, visual, narrative

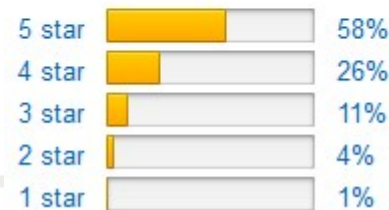


WORK, PROGRESS, AND PROSPERITY
IN A TIME OF
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Customer Reviews

★★★★☆ 402
4.4 out of 5 stars



The Washington Post

The Switch

Bill Gates on dangers of artificial intelligence: 'I don't understand why some people are not concerned'

A   0

By Peter Holley January 29 



Bill Gates joined Reddit for an AMA on Wednesday. (Tobias Schwarz/AFP/Getty Images)

Most Read Business

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- 2 A rollicking week in the markets is really a chance to clean up your act 
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- 4 America's growing love affair with the most wasteful thing to drink there is 

betanews

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Apple co-founder Steve Wozniak warns of the dangers of artificial intelligence



By David Curry | Published 5 months ago

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Technology

Stephen Hawking warns artificial intelligence could end mankind

By Rory Cellan-Jones
Technology correspondent

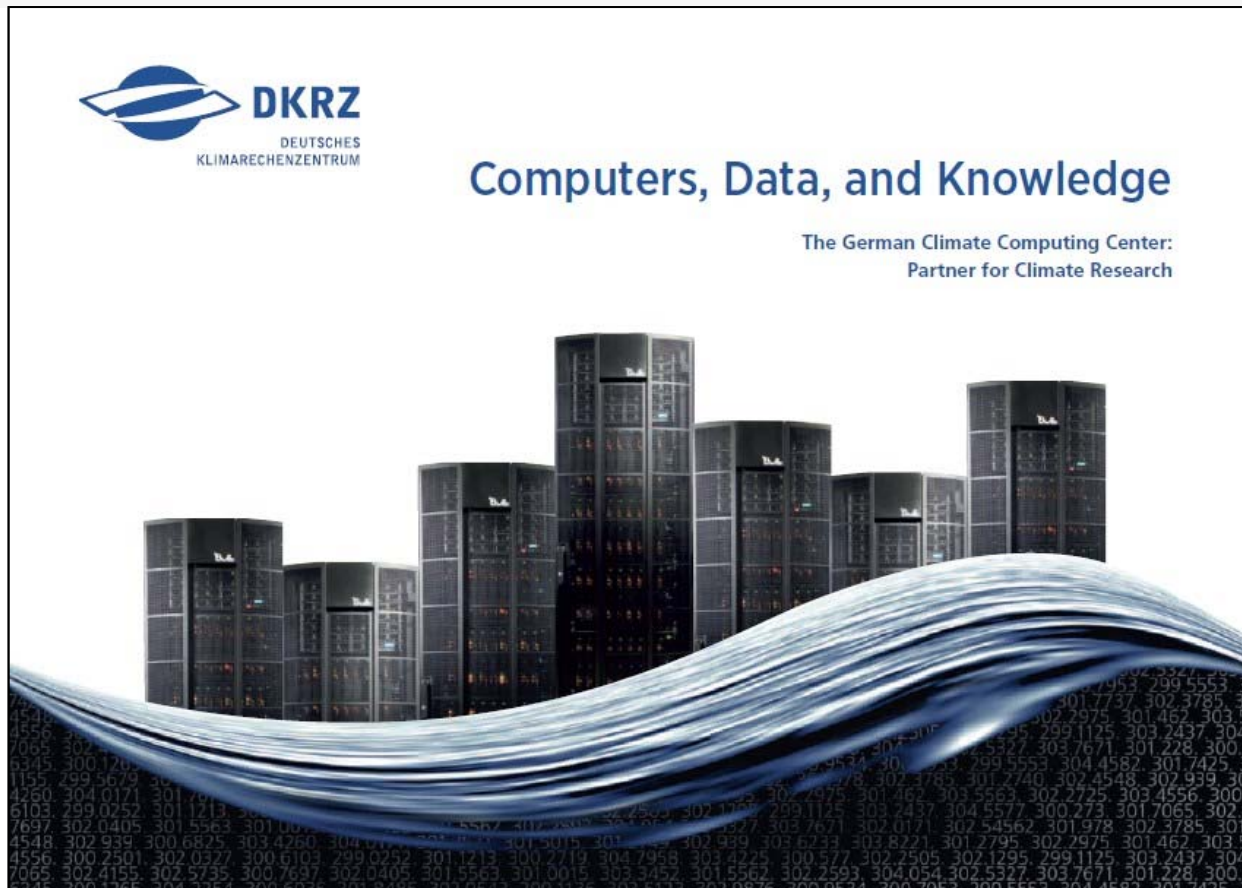
2 December 2014 | Technology | 1027



What is the bigger threat to mankind?

- ✓ Climate change?
- ✓ Progress in computer science?
- ✓ Ignorant politicians

October 2015



New brochure at
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