University of Reading

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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HadGEM3 on PRACE architectures

The UPSCALE team
(P.L. Vidale [PI], M. Roberts, *M. Mizielinski,* R. Schiemann, M.-E. Demory, J. Strachan)

S. Wilson, G. Lister, O. Darbyshire, T. Edwards

HadGEM3-A (N512, GA3.0) 30 APR 1987 05h UTC UPSCALE
Model and animation by the JWCRP High-Resolution Climate Modelling Team
http://ncas-climate.nerc.ac.uk/HRCM

Balancing computational demands

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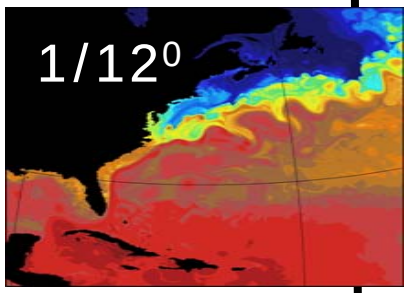
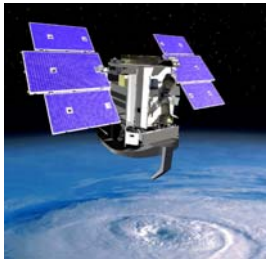
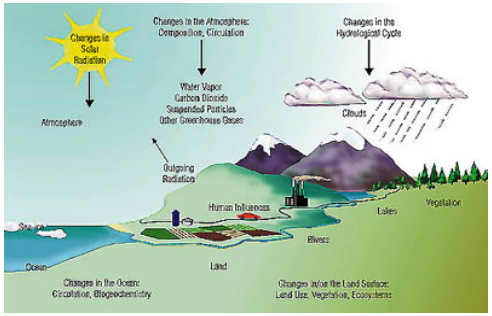


Earth Observation, Data Assimilation



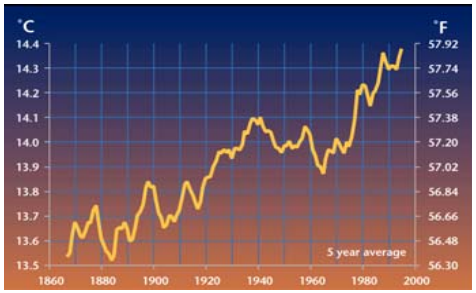


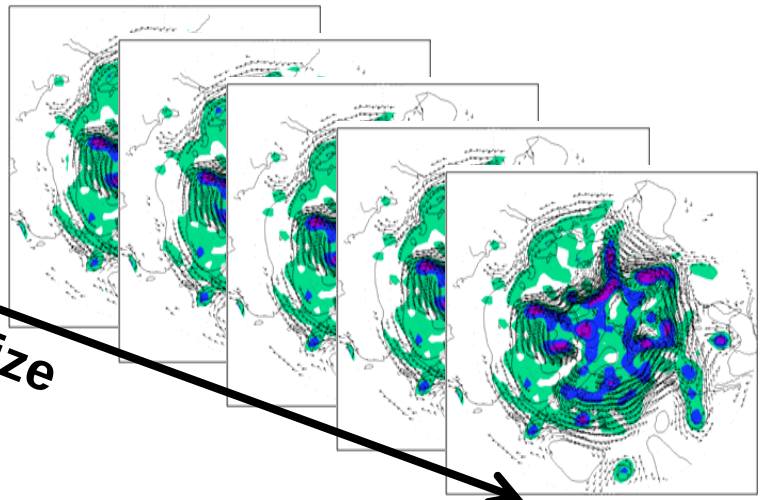
Resolution

Computing Resources

Complexity

Duration and/or Ensemble size





The range of temporal and spatial scales in the climate system

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Atmosphere

10s to hours/days

Cumulus

Heavy rain

Tornado

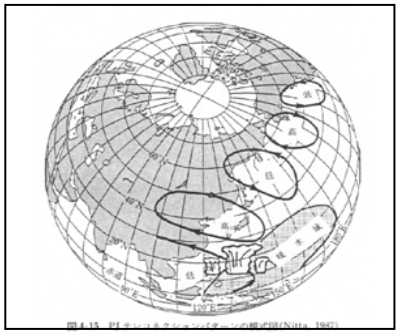
Days to weeks

Weather systems

Thousands of kilometres

Months to years to decades

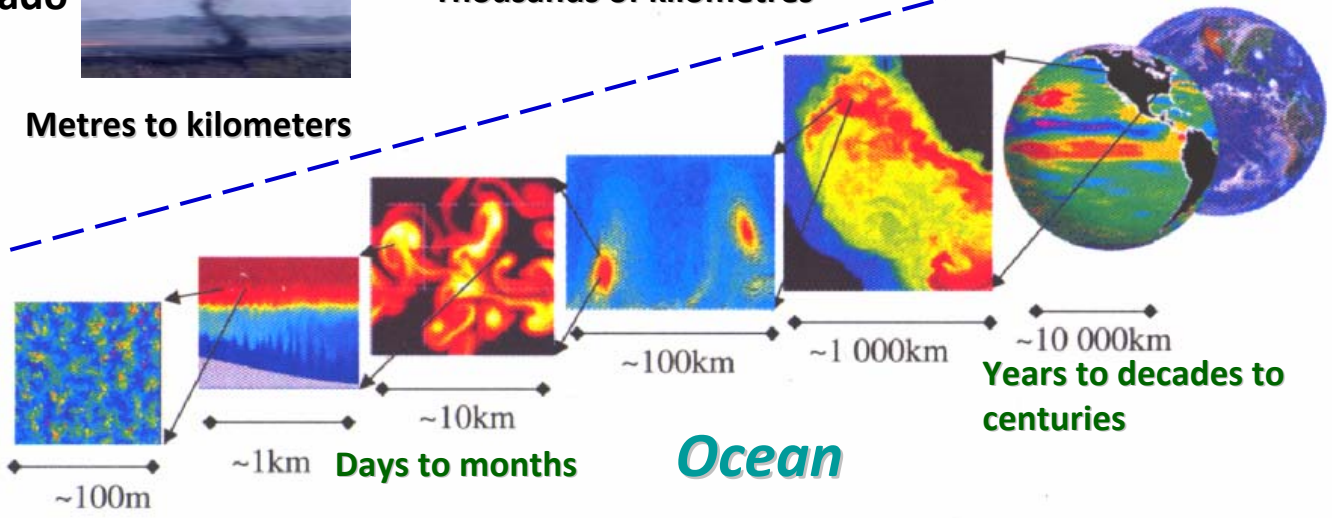
Teleconnections



[Nitta, 1987]

~ 10^4 kilometres

Metres to kilometers



Days to months

Years to decades to centuries

Ocean

How does a GCM work ?

slice the planet into boxes … and apply the laws of physics

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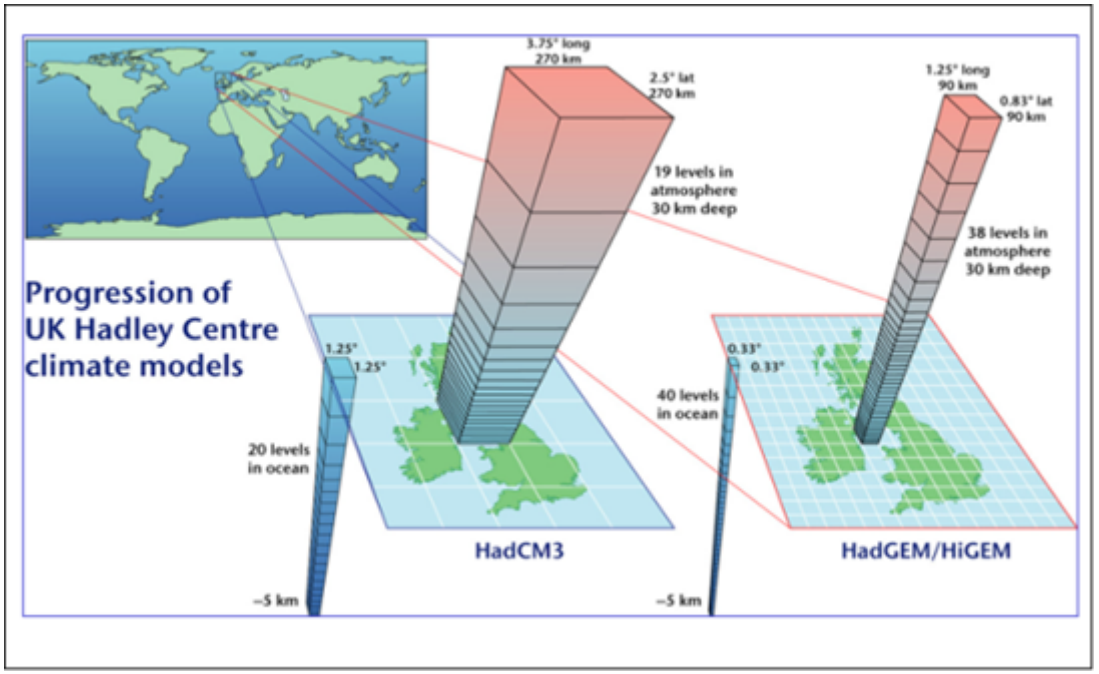

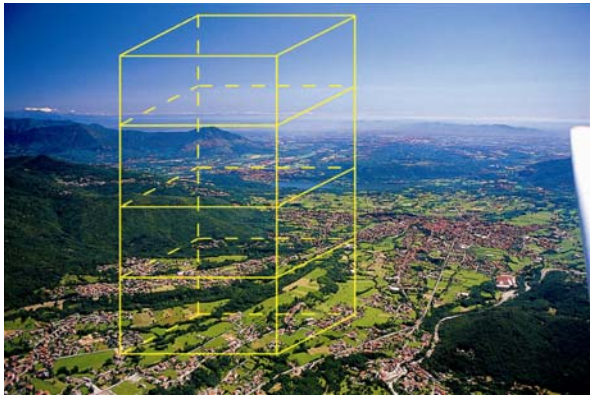

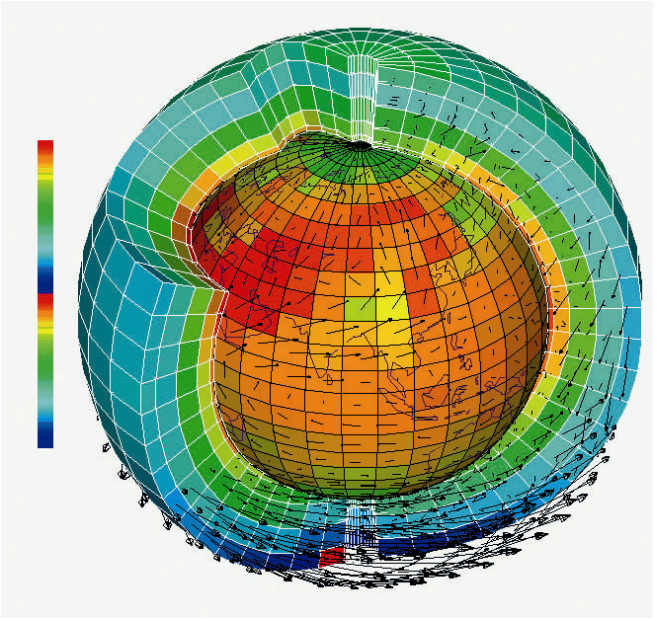

At every box location we compute radiation, winds, pressure, precipitation, temperature, using the laws of physics (gravitation, electromagnetism, thermodynamics, fluid dynamics, turbulence), chemistry, biology, ecology, etc.

To do all these computations with time steps in the range 5-30 minutes, for every single box for decades to centuries **we need significant computing resources**

Value of model resolution – orographic height

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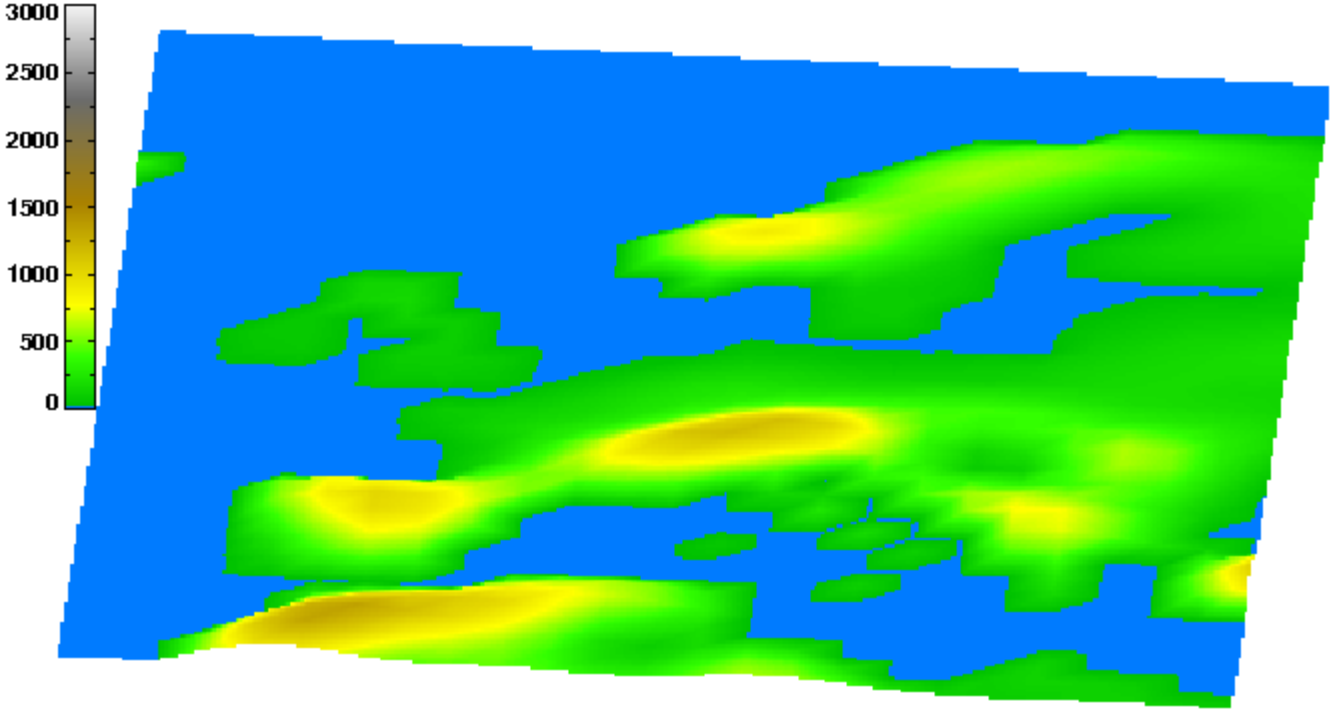

130km resolution

Value of model resolution – orographic height

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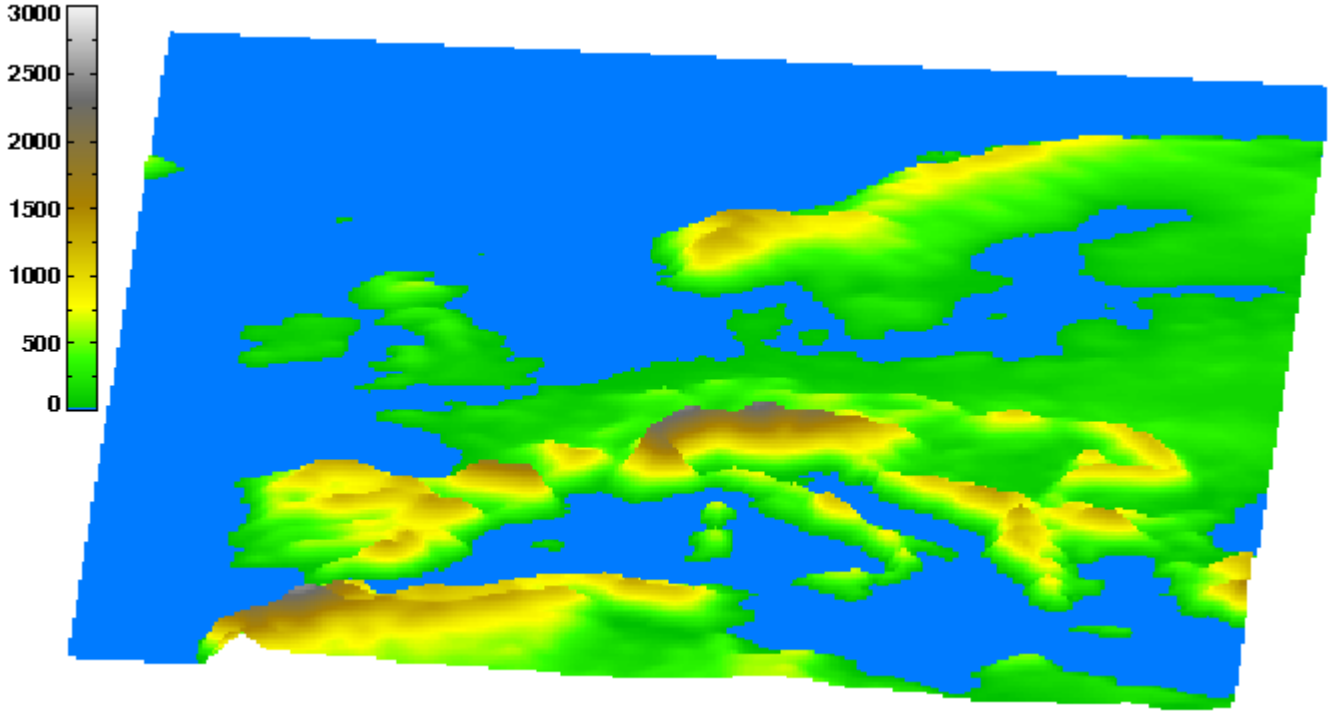

25km resolution
>80x cost

Value of model resolution – orographic height

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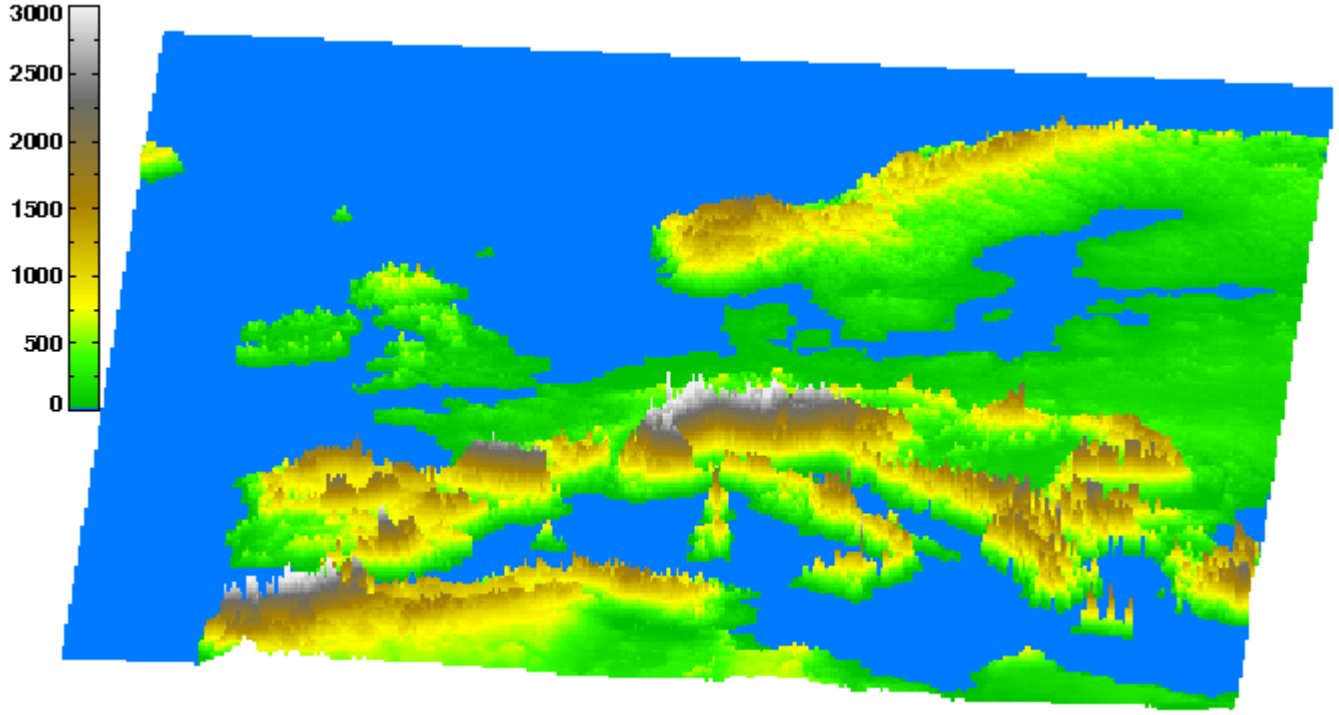
1.5km resolution >2500x cost



Heat-wave case studies

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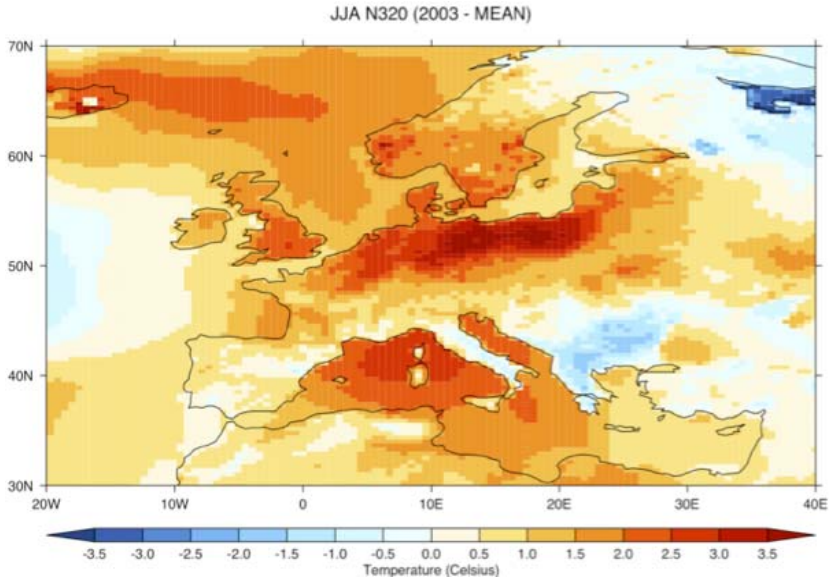
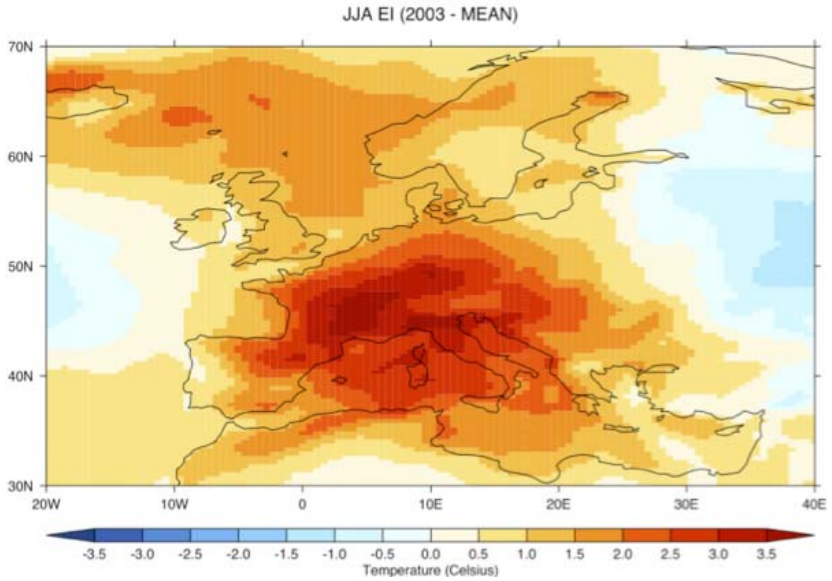
40km model JJA 2003

Surface temp anomaly



Observed JJA 2003:

Surface temperature anomaly



Similar magnitude anomalies not seen in lower resolution simulations – higher resolutions give enhanced capability for capturing extreme events

C. Van den Hoof, P. L. Vidale – University of Reading/NCAS-Climate

Tropical cyclone track density (transits per month)

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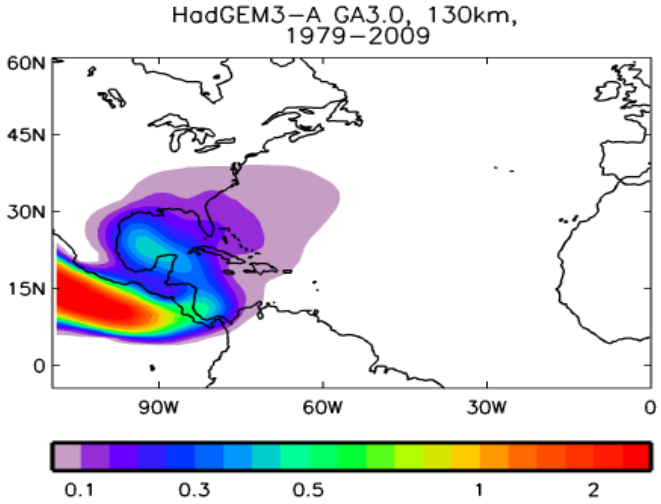

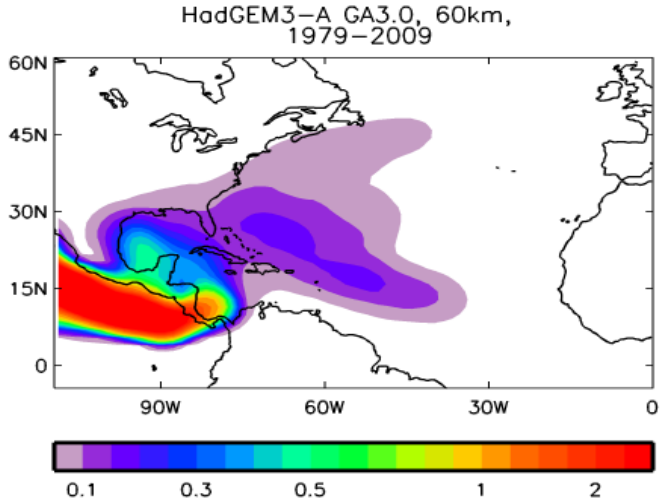

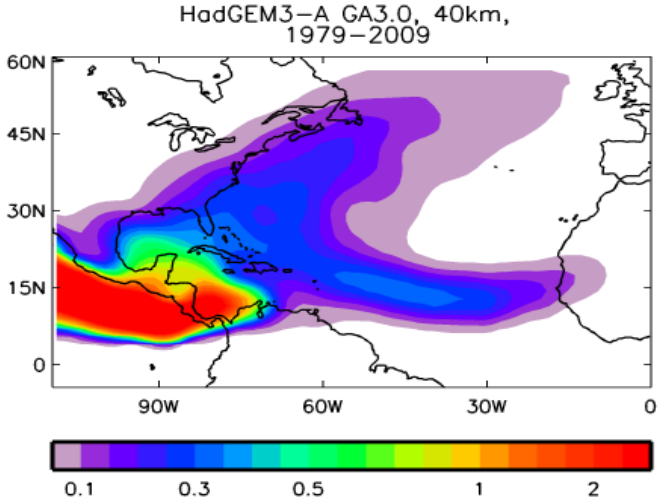

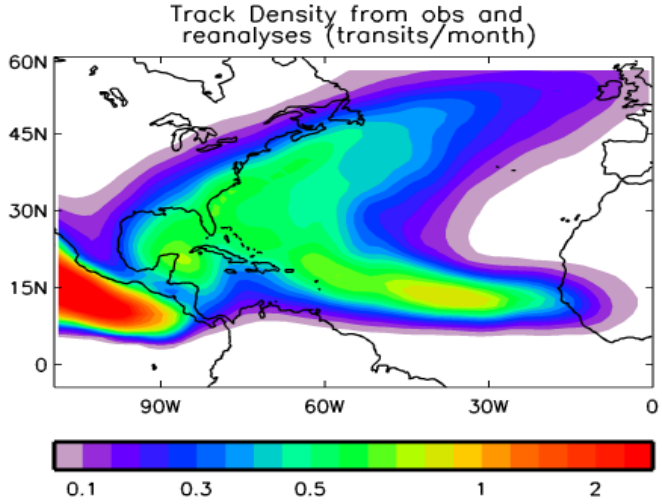

Tropical cyclone track density (transits per month)

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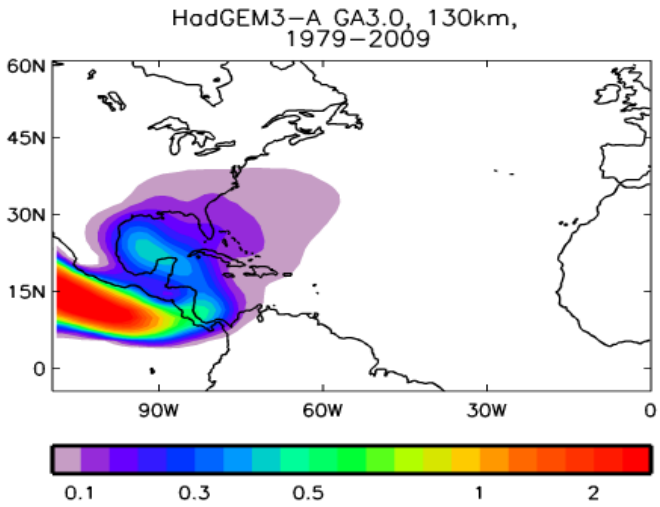

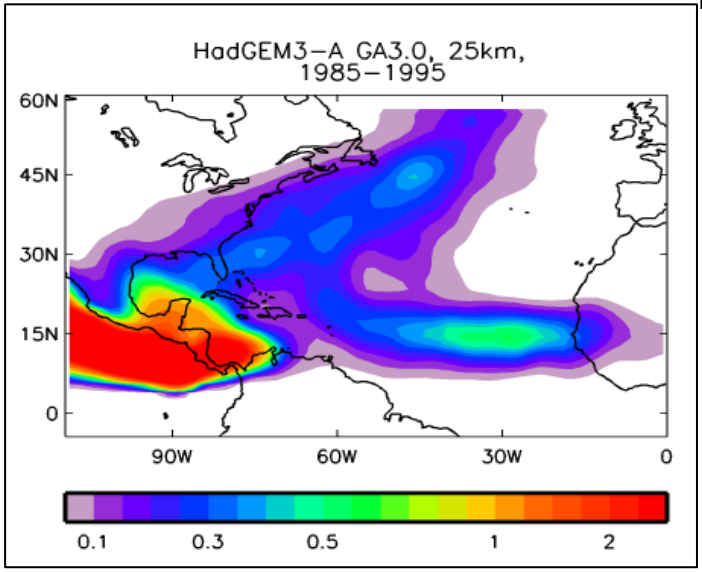

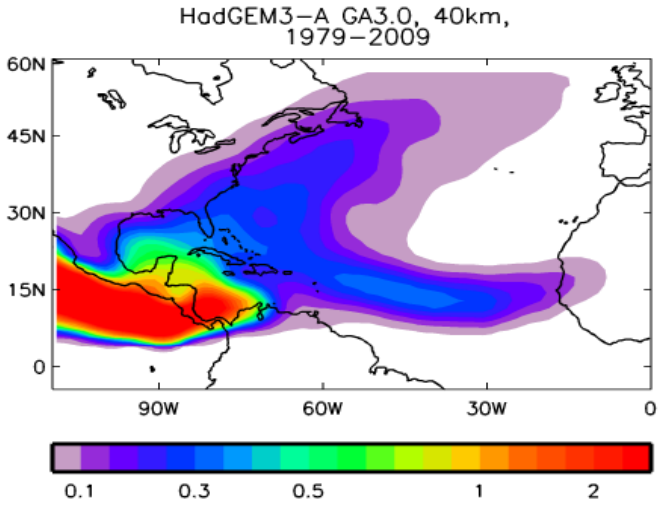

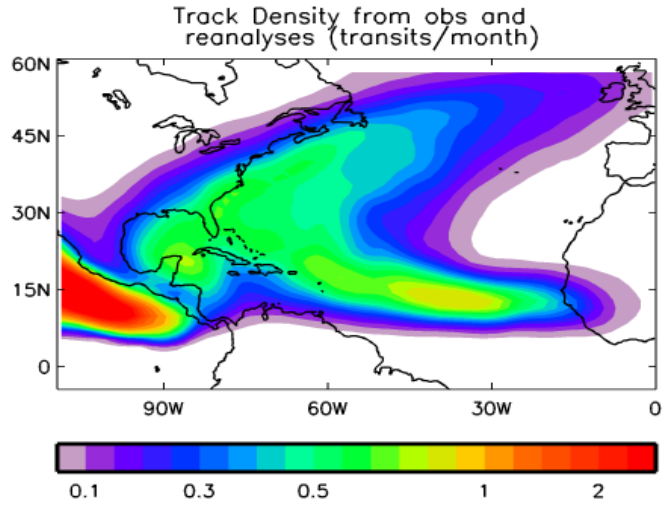

The UPSCALE project

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- Atmosphere only HadGEM3 climate model at same resolution as currently in use in weather forecasting
- 10 simulations, each 26 years long
  - 5 current climate (1985-2011)
  - 5 future climate “time-slice” (alter forcing data to look at climate change at end of 21st century)
- Ancillary data sets (short data sets of high temporal resolution data) plus extension to even higher resolution
- Running on Hermit @ HLRS through award of CPU time from PRACE
- Data set produced will be widely studied over next decade

Porting and Testing

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- Requirements
  - 350-400GB memory
  - Simulate minimum of 4-5 months per day
  - Bit reproducibility (weak requirement)
  - Model stability (minimise user intervention)
  - OpenMP and MPI
- Limited testing ability at this resolution
- Separate science and computing testing
- Spin-up

Testing by Tom Edwards @ Cray

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- Working array sizes (segment sizes) for radiation and diffusion routines
- Compiler optimisation levels on dynamics routines
- Processor & thread configuration (~100 tested)
- Lustre file system settings
- I/O server separation from computation

Testing by TE: Segment sizes

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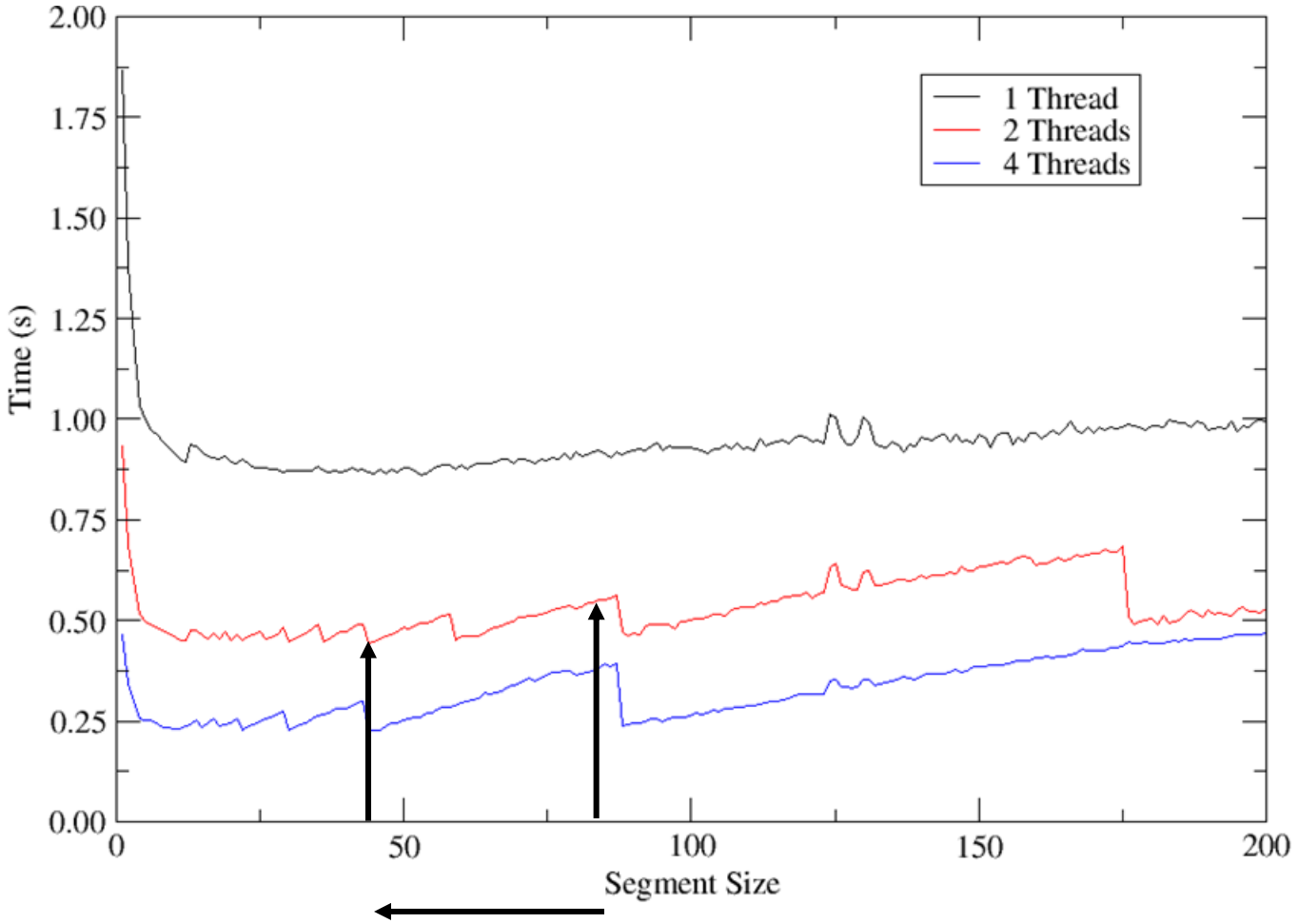
Long-wave segment size impact



25% improvement in radiation code cost (70% for 4 threads)

Testing by TE: IO server

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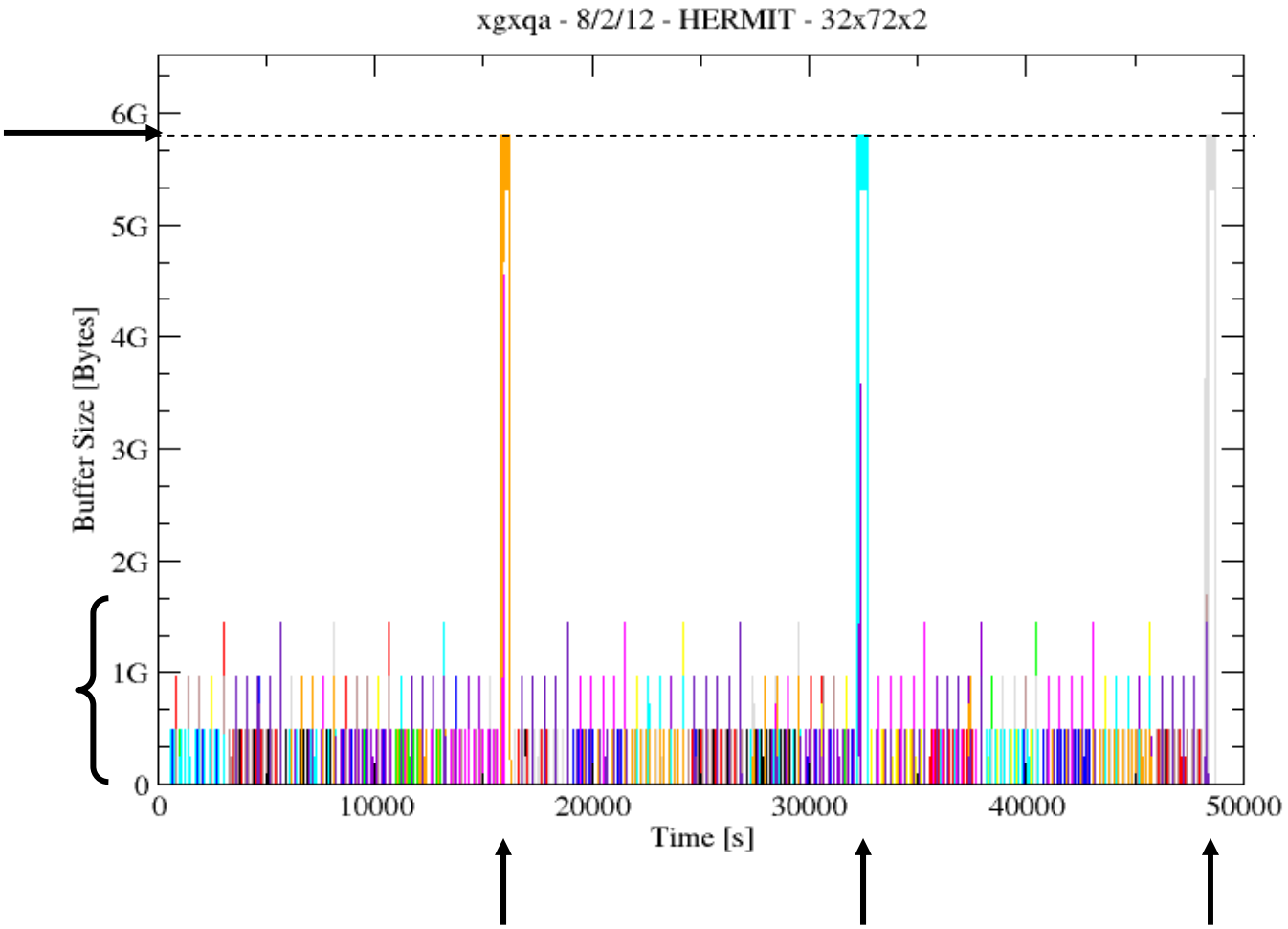
I/O server buffer size



Frequent, low level I/O; 3 hourly and daily data

Output of end of month data (~30GB) and 58GB restart dump

Scaling: Hector phase 2b
(Cray XE6, Magny-Cours)

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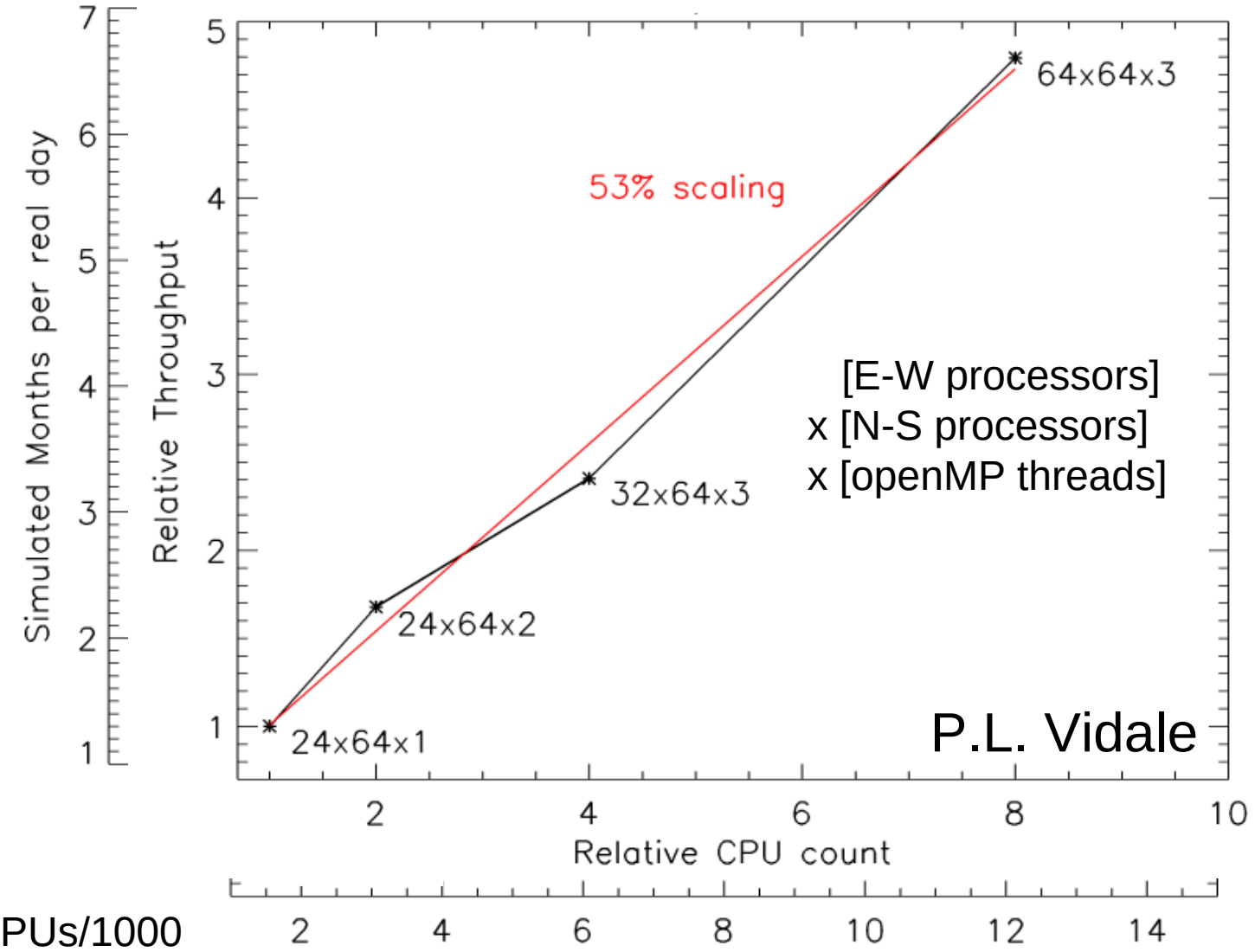

Scaling: Curie (Bull, Nehalem)

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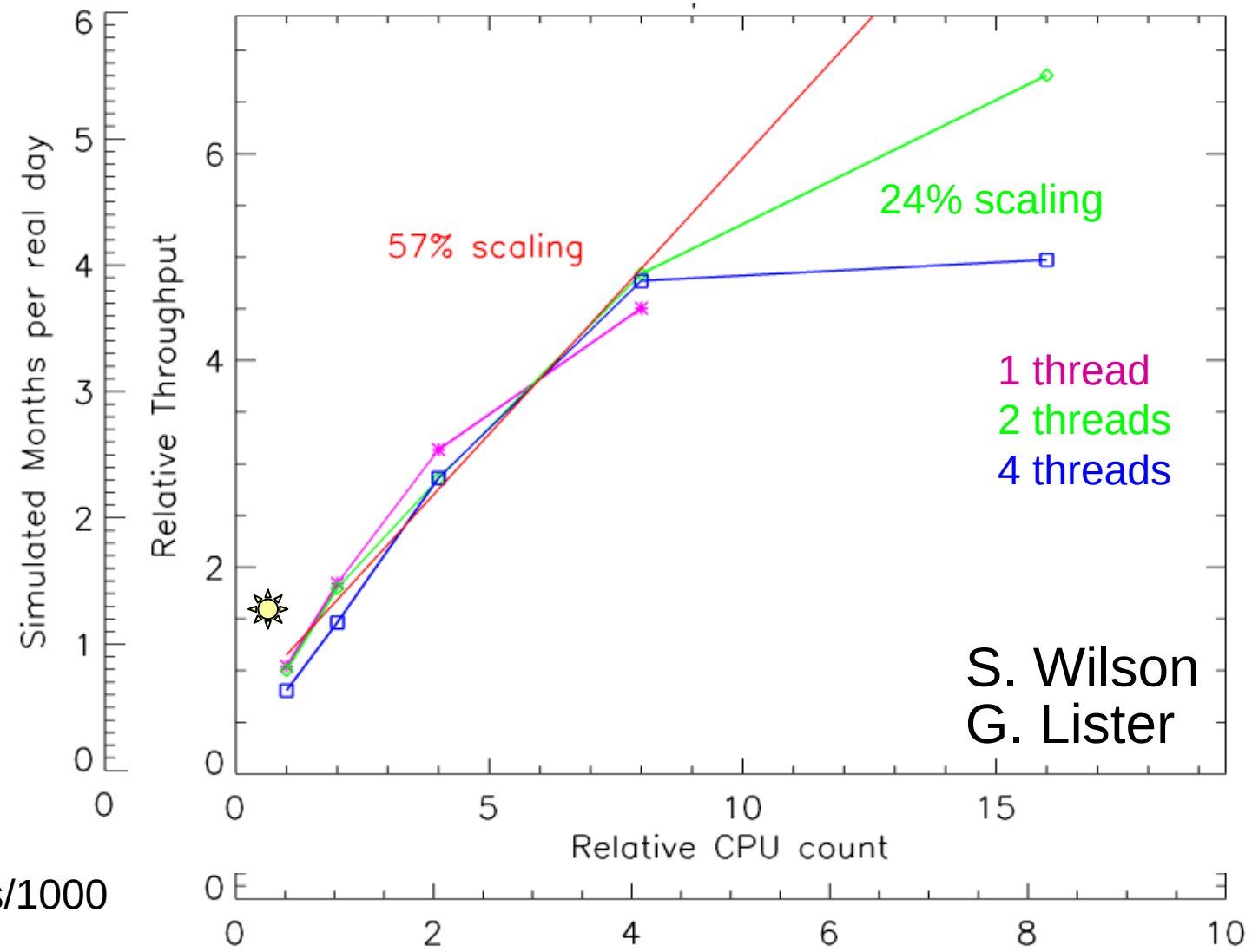

Scaling: Hermit (Cray XE6, Interlagos)

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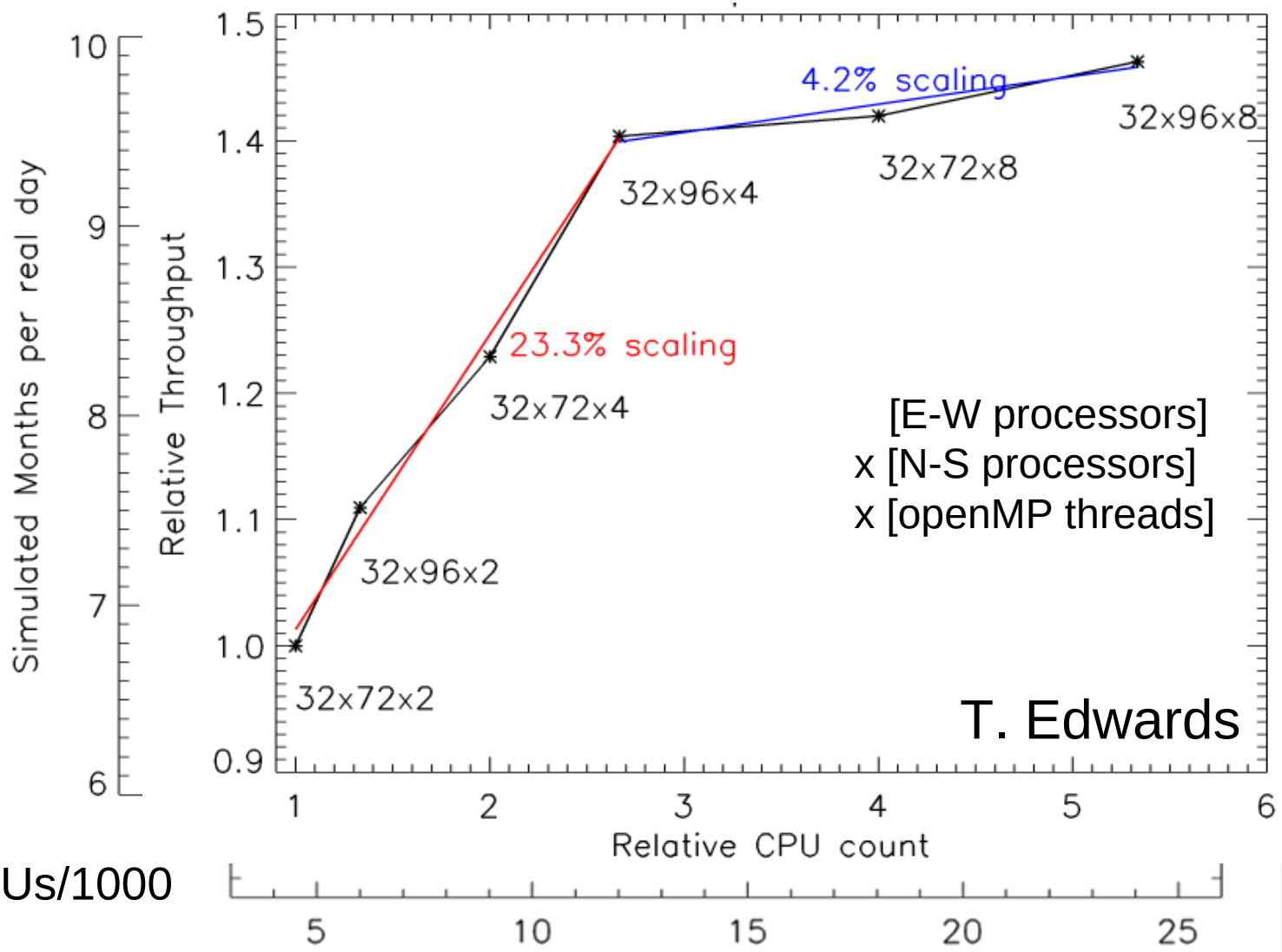
Excluding I/O



Data management

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- I/O server and optimisation gives us a model which runs 5-6 months per day
- Each model run produces around 1 TB every running day (up to 5 models running at once depending on stability/queues)
- Data format conversion and compression reduces this to ~380 GB/model/running day ∴ ~1-1.5TB to be transferred per day
- Project expected to produce 250-300 TB

Data management

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- Data management processes for
  - Filing of output data
  - Format conversion (and checking of)
  - Transfer to archive (rsync, gridFTP)
- Volume of data required to
  - Investigate short timescale (frequent data) processes, e.g. Indian monsoon
  - Investigate long timescale processes, e.g. glacier mass balance
  - Trace evolution of models to understand the physical processes driving behaviour
- Analysis of this data pushes limits of what our standard climate tools can do

Future work

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- Need a range of different models (e.g. EC Earth, ECHAM) to allow comparison
- New computational schemes enabling better scaling
- Coupled models (add the ocean)
- Earth System models (add atmospheric and ocean biogeochemistry)
- Higher resolution and convection resolving models