



Met Office

Computing Challenges for Weather and Climate Modelling at the Met Office

Paul Selwood

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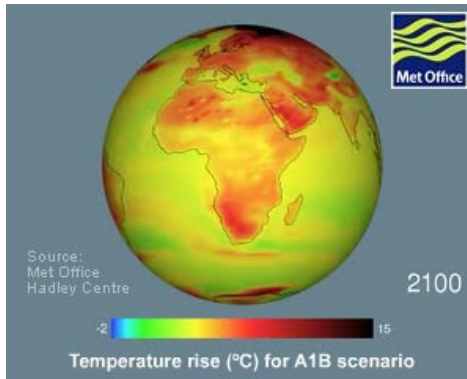
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Current Status

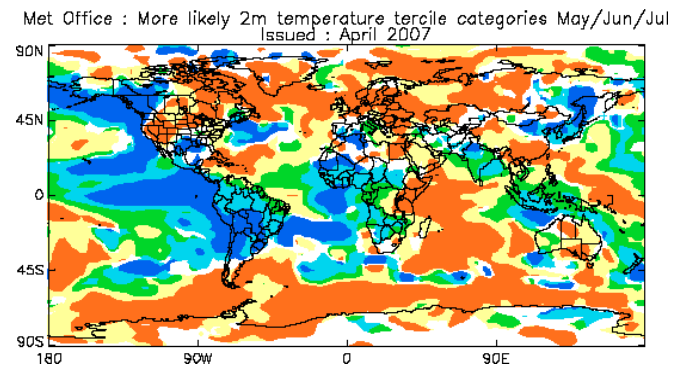


The Unified Model

- The same model formulation is used for all models from climate scale to mesoscale

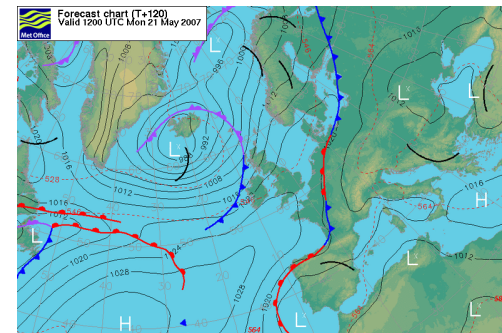


Climate modelling: input into IPCC reports
(Coupled Atmosphere-Ocean models)



Seasonal forecasting:
For commercial and
business customers

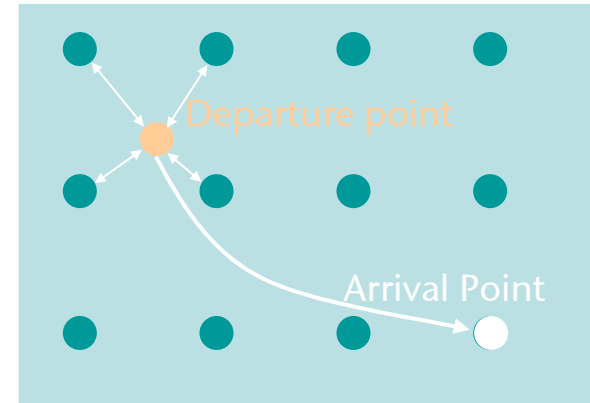
NWP:
Public Weather Service
WAFC, Commercial





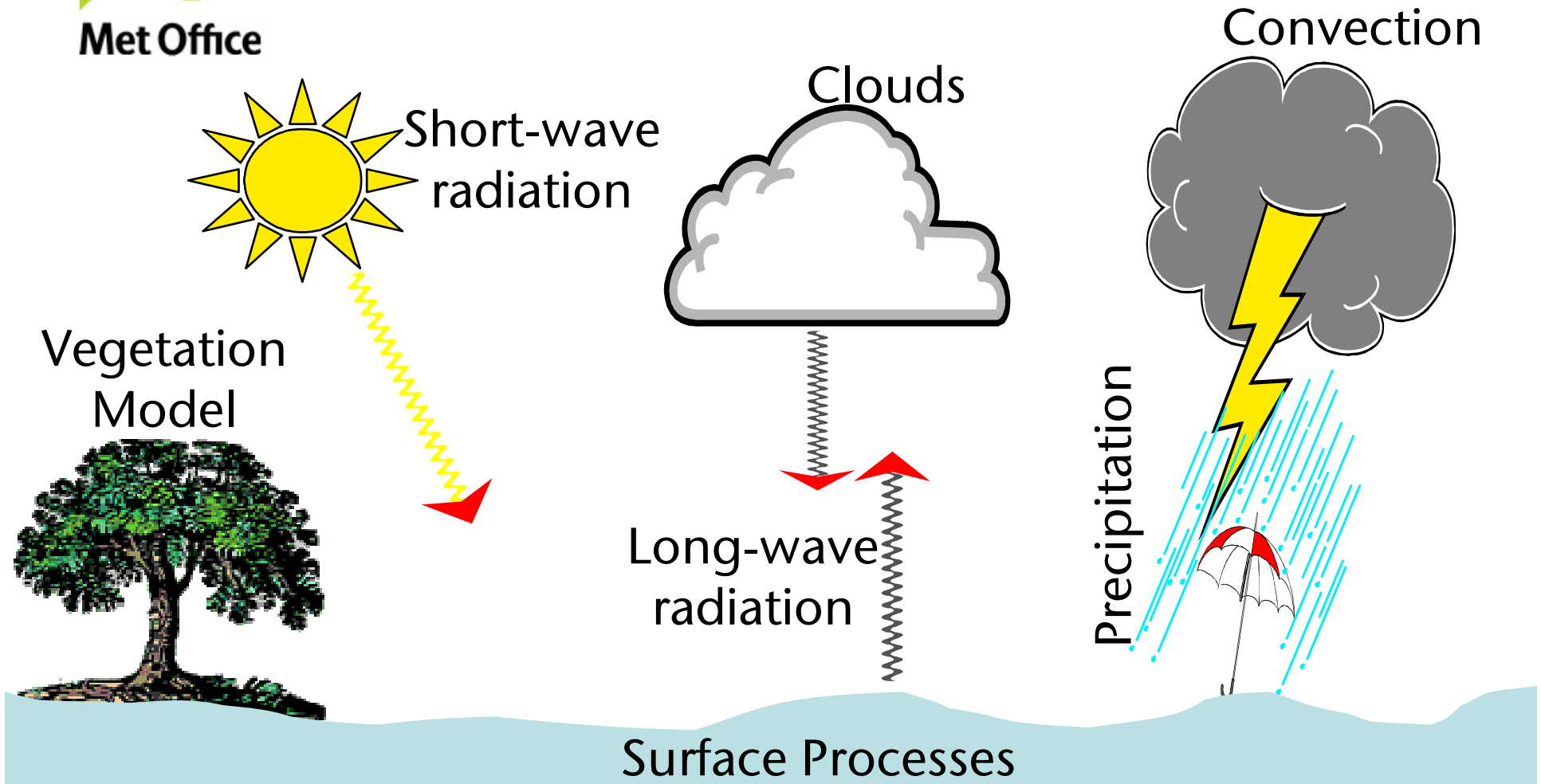
Dynamics – aka CFD

- Lat-Long Grid
- Advection
 - Semi-lagrangian scheme
 - Variable order interpolation
- Adjustment
 - Semi-implicit scheme
 - 3D Helmholtz equation
- Diffusion : Removing noise
 - Variable order





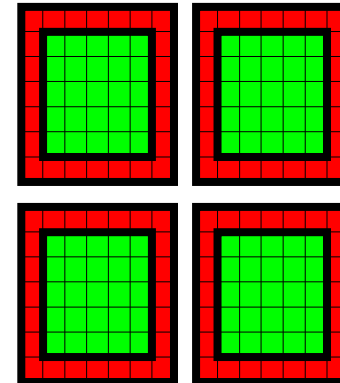
Physical Parameterizations





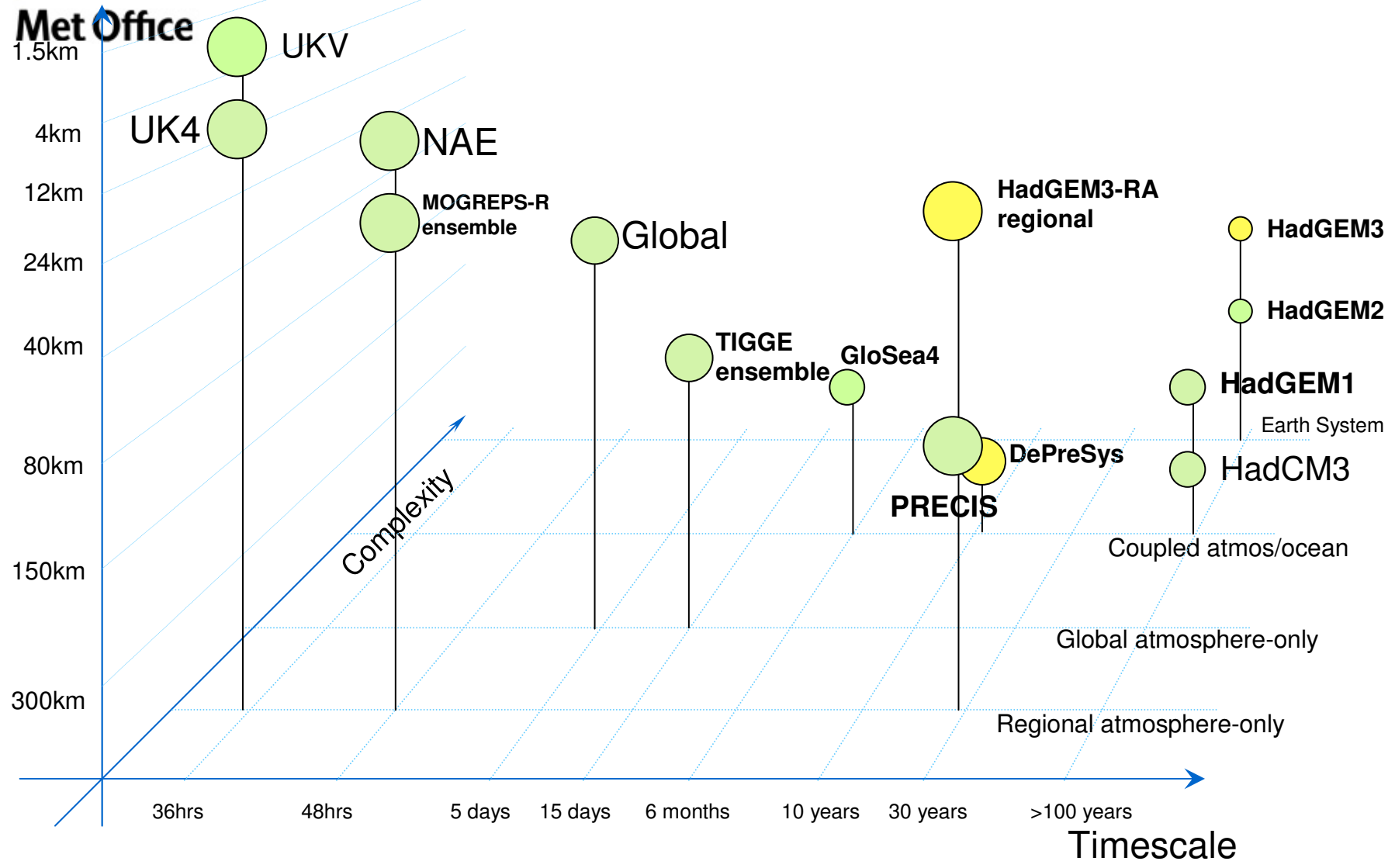
Parallel Implementation

- Regular, Static, Lat-Long Decomposition
- Mixed mode MPI/OpenMP
- Asynchronous I/O servers
- Communications on demand for advection
- Multiple halo sizes



Atmospheric grid length

In transition to Production
 Production system





Current Production schedule

IBM (Hall 1 and Hall 2) - OPERATIONAL NWP SUITE SCHEDULE - July 28th 2010

	Marine/AQUM 1n/2n	Global 24n ; QWENVER 4n	NAE/UK4 QY0Z 15n ; 044n	UKV 24n	CAMs QAVQC08 8/14n	EPS EGVEY 12/24f	ITALY 2n	IDS	Gloesa4 4n ; 2n	SSPS	UKPP	Non-Crit
00:00												
01:00		QJ18 0015 - 0105Z	QZ18 0015 - 0045Z									QH09 0030Z - 0100Z
02:00			QY00 0130 - 0210Z <i>Fallback QZ00</i>		QX18 0110 - 0140Z (from QG06) Q818 0135 - 0155Z (from QG06)	EG18 0110 - 0120Z	Q821 0110 - 0120Z					QH12 0135 - 0235Z
03:00	Q000 0230 - 0300Z	QG00 0240 - 0415Z <i>Fallback QZ00</i>	Q400 0305 - 0320Z	QY00 0210 - 0245Z (from QY00)								
04:00					Q400 0305 - 0400Z (from QG18)		Q800 0300 - 0320Z	Q200 0300 0305 Q200 0310 0315				
05:00	QM00 0415 - 0500Z	QY00 0415 - 0445Z	Q403 0420 - 0455Z (from QY00)	QY03 0420 - 0545Z (from QY00)	Q800 0415 - 0445Z (from QG18)							QH15 0430 - 0500Z
06:00	Q600 0520 - 0620Z	EN00 0515 - 0655Z			Q600 0520 - 0510Z (from QG18)							
07:00	Q000 0620 - 0700Z	QL00 0655 - 0745Z	Q200 0615 - 0845Z				Q808 0605 - 0620Z					QH18 0615 - 0645Z
08:00			QY06 0730 - 0810Z <i>Fallback QZ00</i>	QY06 0810 - 0845Z (from QY06)								
09:00	Q006 0830 - 0900Z	QG06 0845 - 0945Z	Q406 0830 - 0845Z		Q506 0850 - 0955Z (from QY06)							
TWS		<i>Fallback QY15</i>										
10:00	QL00 0955 - 1005Z		Q408 0930 - 1010Z (from QY06)	QY09 0930 - 1055Z (from QY06)								QH21 0900 - 0930Z



Met Office HPC

- 1989-2003 : Cray YMP,C90,T3E
- 2003-2008 : NEC SX6/8 ~5TFlop peak
- 2009-12 : IBM p575 Power6
 - o Operational from August 2009
 - o 145 TFlop peak capacity (7744 cores)
 - o 2 identical systems (2*106 node) for resilience plus small system (30 node) for Collaboration with UK Universities
- 2012-> : IBM Power 7
 - ~3 faster than Phase 1 measured by benchmark application speedup
 - At least 25000 cores with total Capacity approaching 1PFlop





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Scientific Drivers



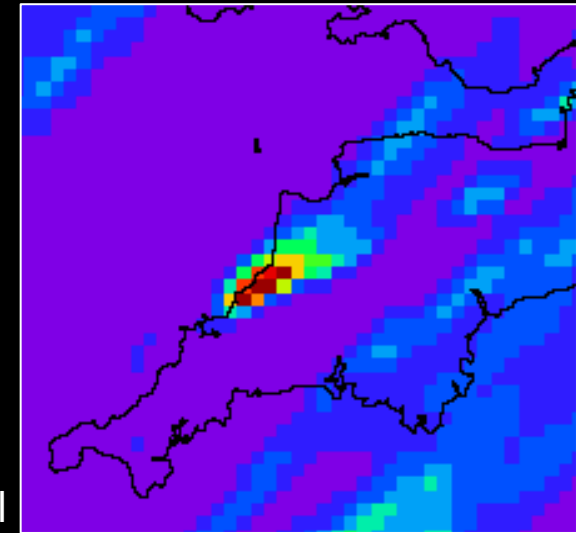
Timeliness is essential



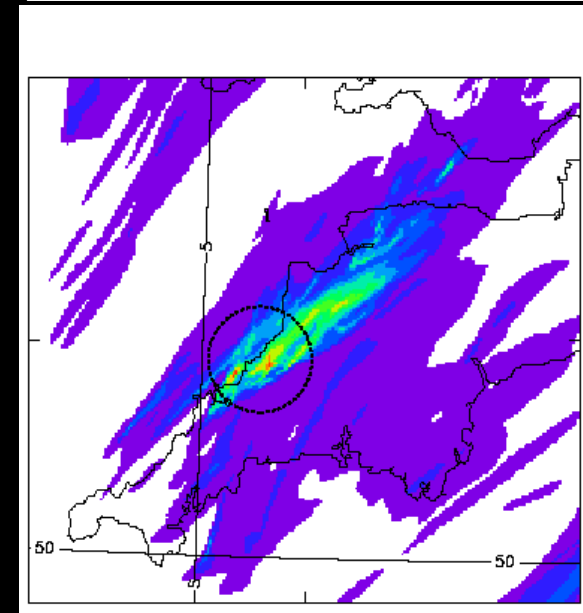
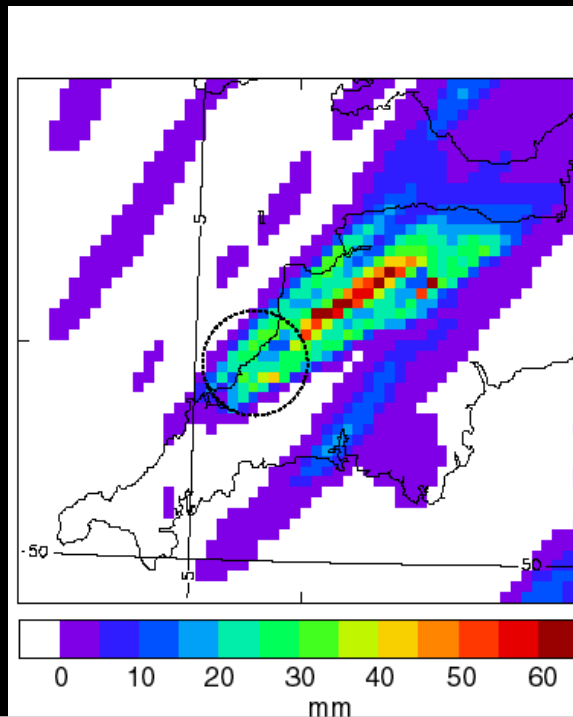
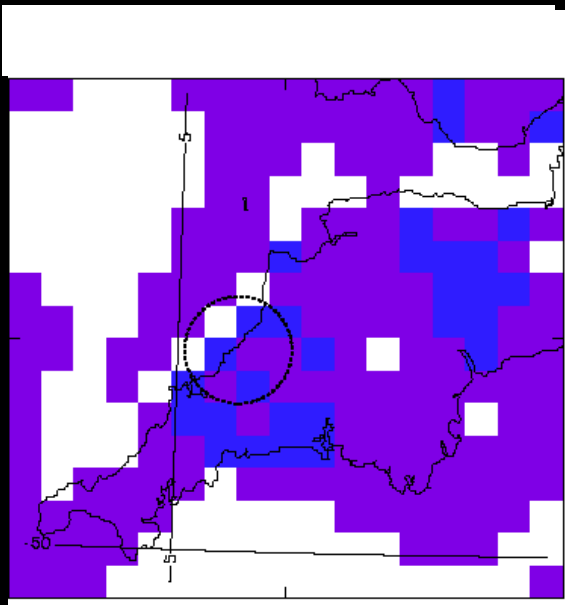
Resolution is important!



Boscastle storm:
forecast rainfall
accumulations for
16 August 2004,
12:00-18:00

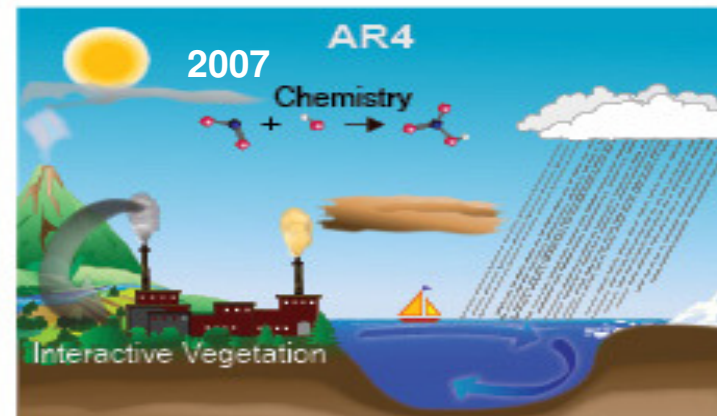
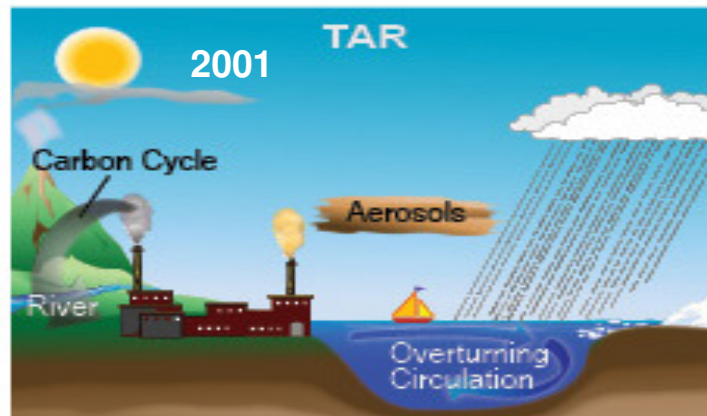
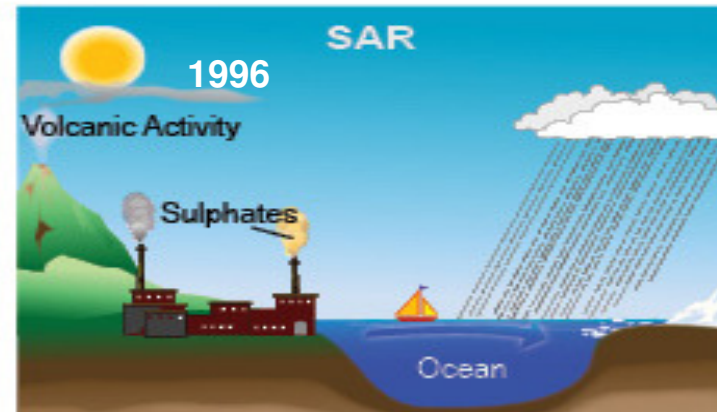


5km
radar
actual



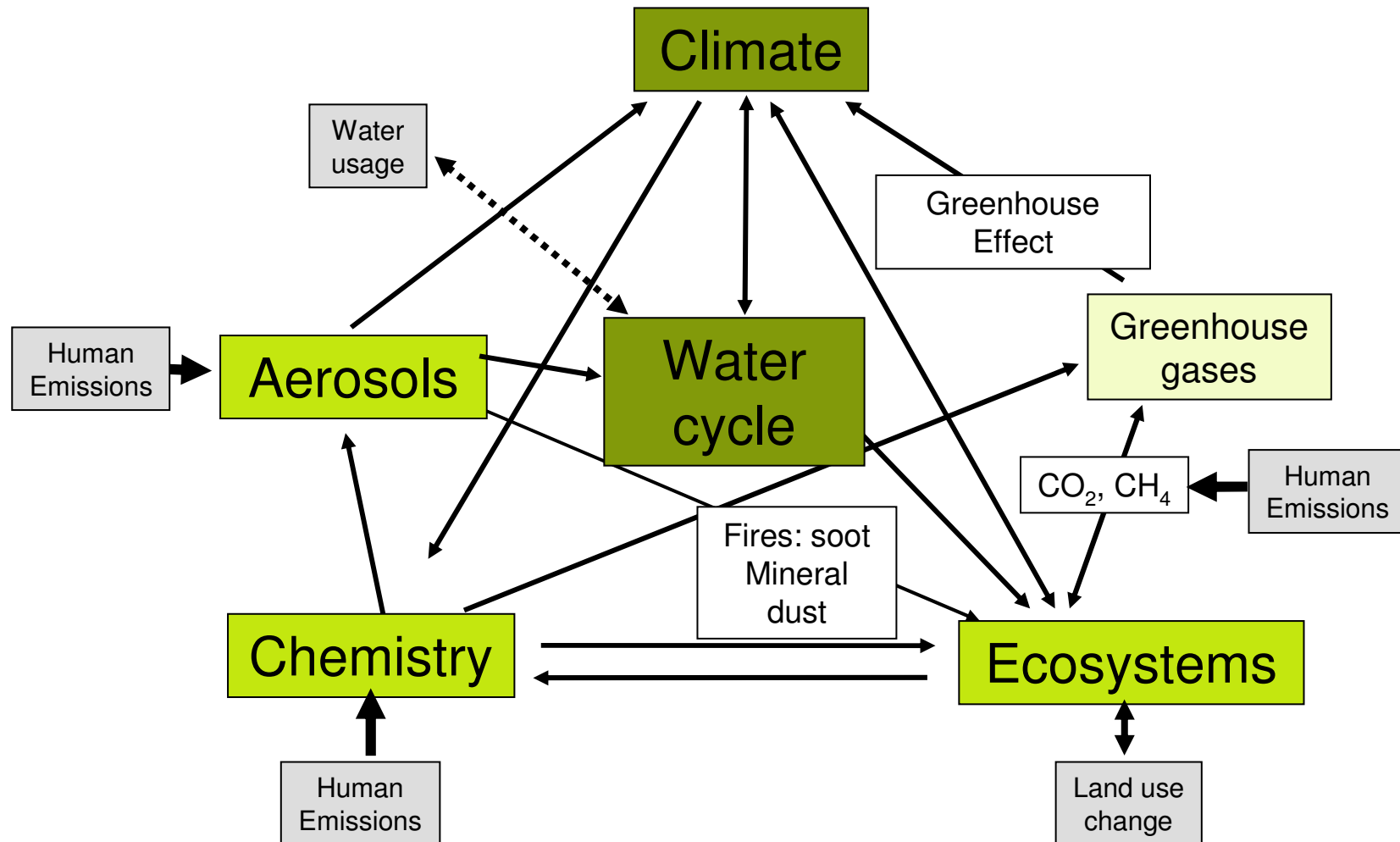


The World in Global Climate Models



(IPCC Timescales)

Toward the Earth-System Model





Future Climate Model Costs

	Atmosphere				Ocean			
Name	Res (km)	X	Y	Z	Res (deg)	Levels	Complexity	Cost Factor
HG2 N96-ES	135	192	145	38	1	40	2.5	1
HG3 N96-ES	135	192	145	85	1	40	2	2
HG3 N216	60	432	325	85	0.24	75	2	18
HG3 N216-ES	60	432	325	85	0.24	75	5	45
HG3 N320	40	640	481	85	0.084	75	2	196
HG3 N320-ES	40	640	481	85	0.084	75	5	489
HG3 N512	25	1024	769	85	0.084	75	2	293
HG3 N512-ES	25	1024	769	85	0.084	75	5	732
HG3 N512-ES+	25	1024	769	85	0.084	75	10	1463
HG3 1.5km-ES	1.5	17000	1280	200	0.084	75	10	406123



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Can We Scale?

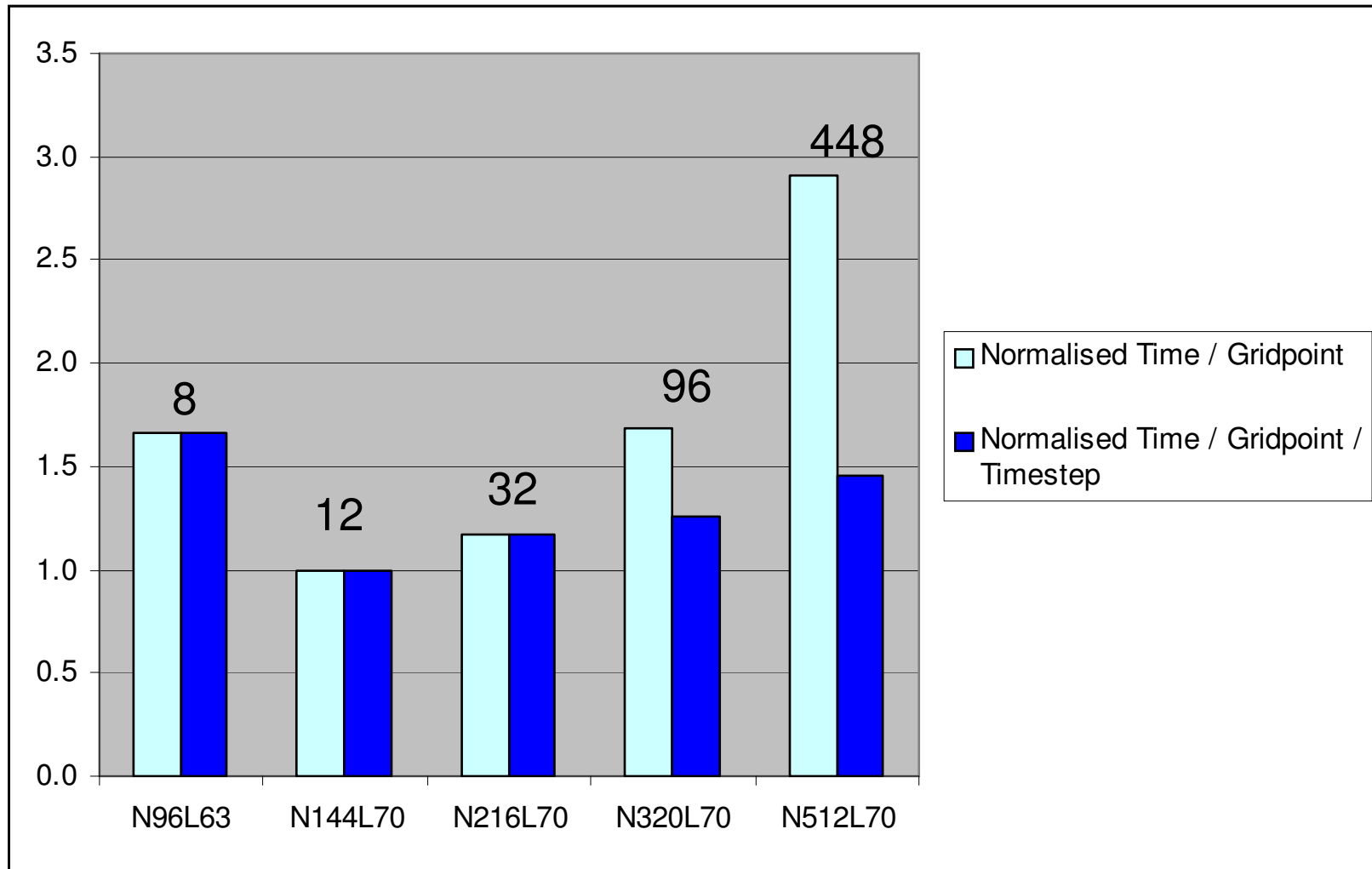


Is Weak Scalability Possible?

- Scalability challenge suggests resolution increase.
- Double resolution from M to $M/2$ km
- Grid-points increase by $O(n^2)$ in horizontal
- Grid-points increase by $O(n^2)$ in vertical
- Time-step will reduce
- Iteration count in solver will increase
- Scientists continue to add complexity to models

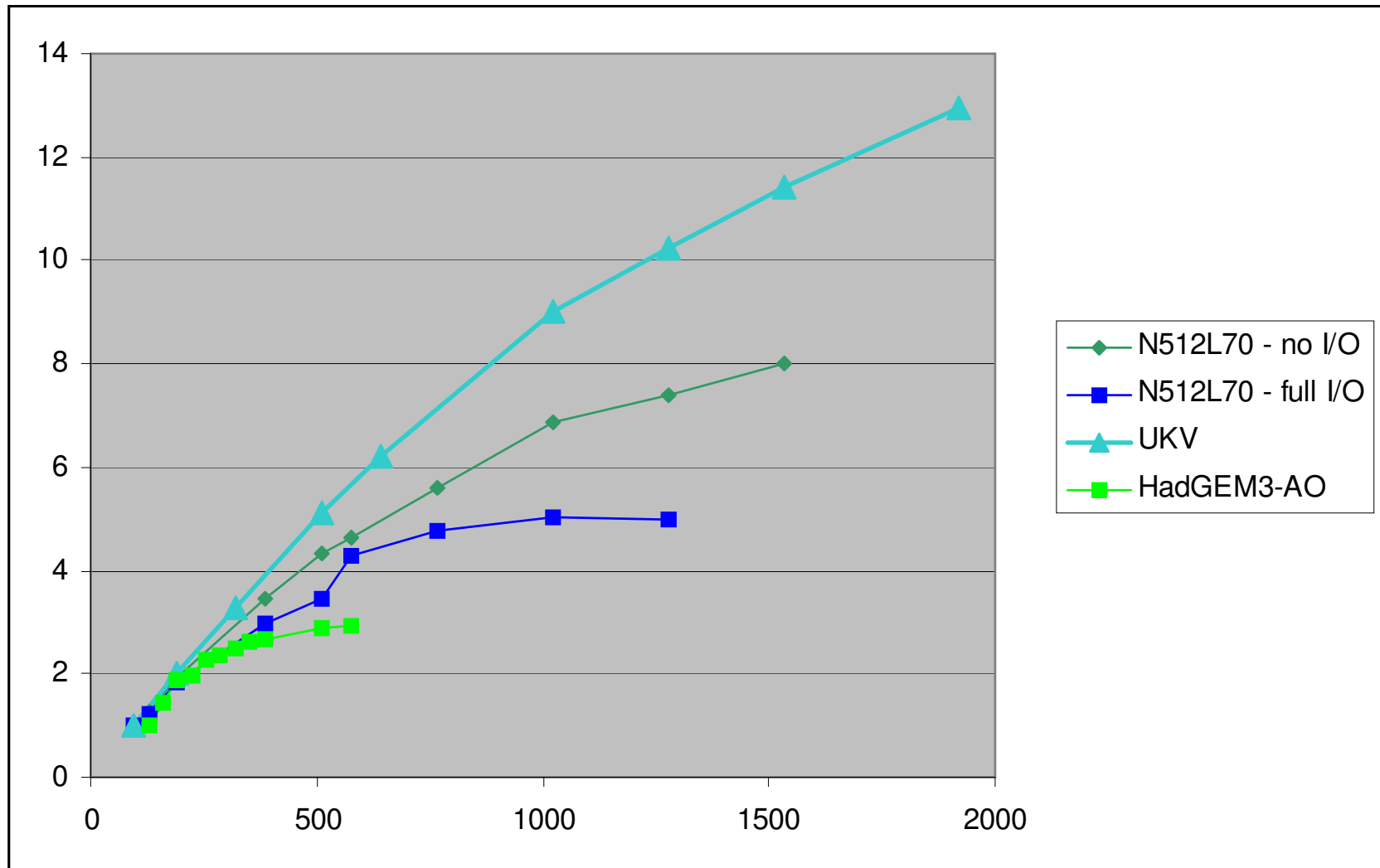


Global Model Weak Scalability





Strong Scaling – Mar 2010



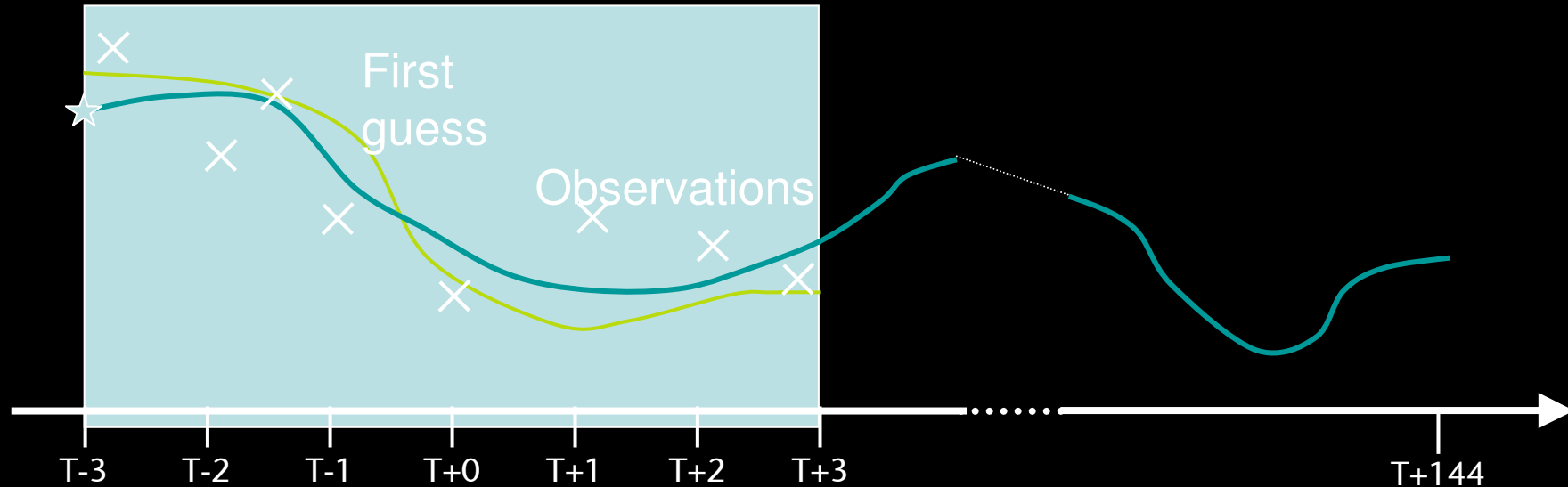


Global Model Dynamics Problems

- Lat-Long grid causes problems
- ADI preconditioner scales poorly
- Communication on demand in the advection is fairly costly and introduces imbalance
- Polar filtering is communication dominated and imbalanced
- Polar re-mapping in wind advection introduces load imbalance
- Constant pole requirement introduces communication



Data assimilation

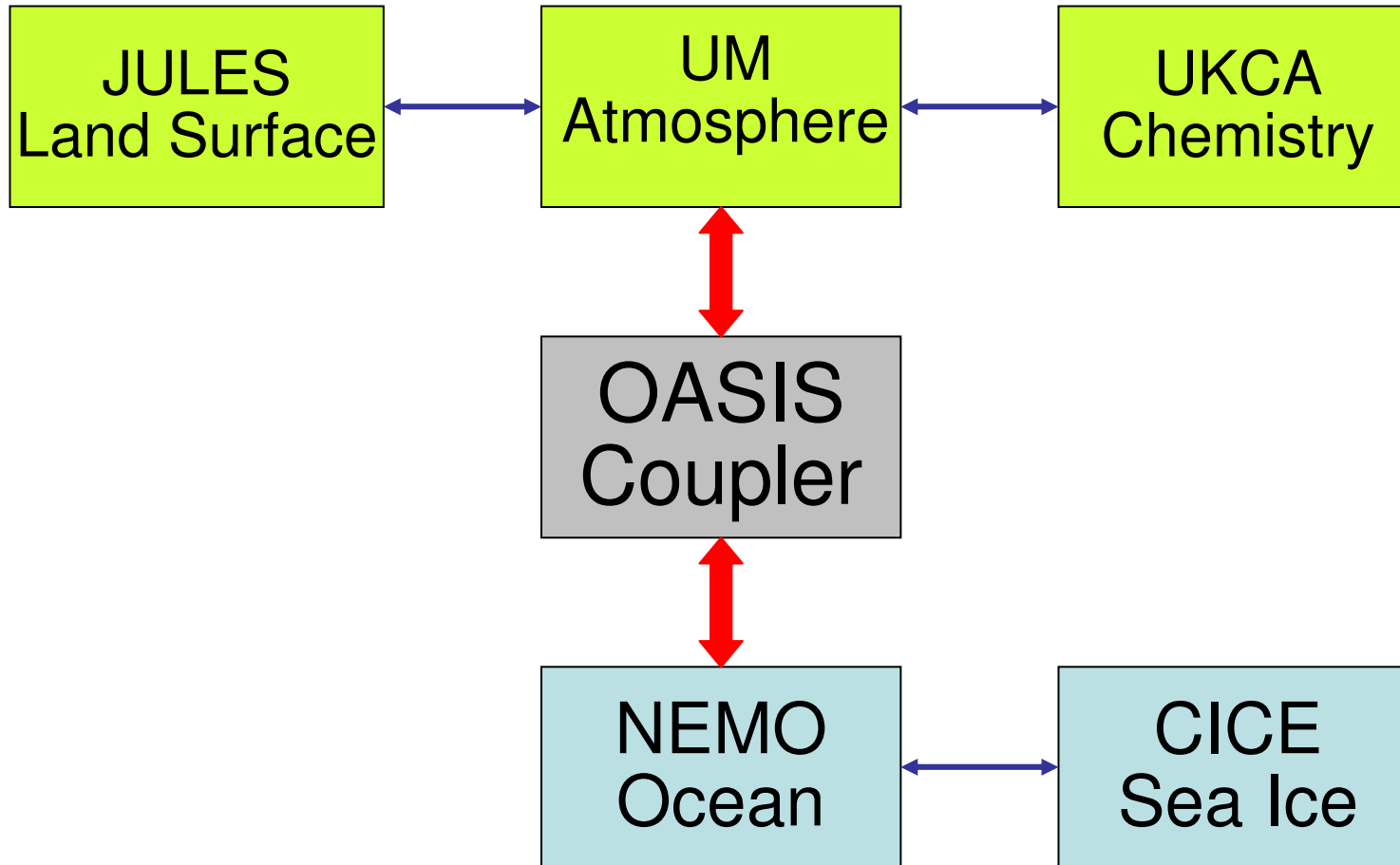


- The challenge:

To compute the model state from which the resulting forecast best matches the available observations



Earth System Model Components



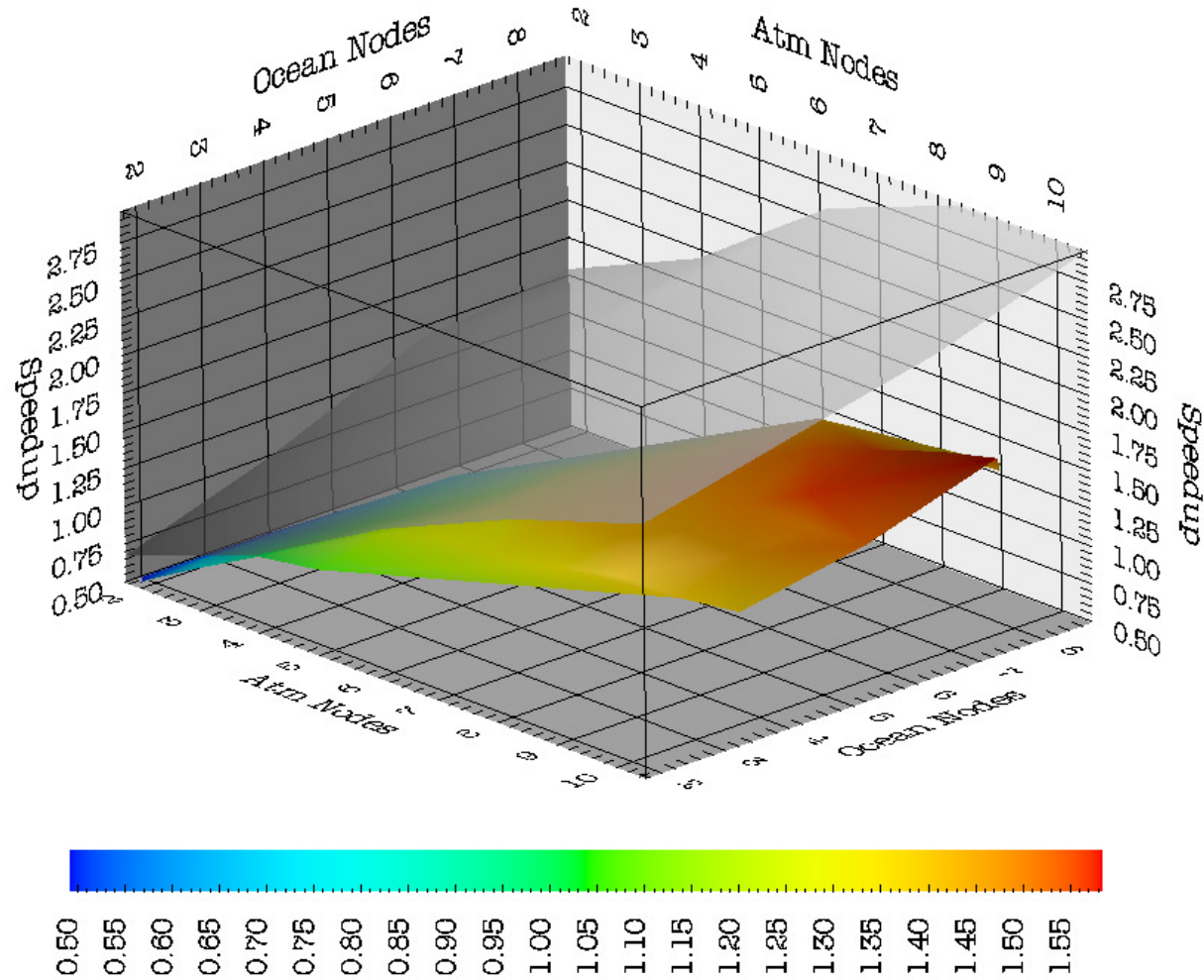


Load balancing and all that

- Component speed depends on
 - Cores given
 - Number of threads
- Coupled model speed
 - Only runs as fast as the slowest component
 - Don't want one component waiting for another
 - During optimisation work, constant need to rebalance.



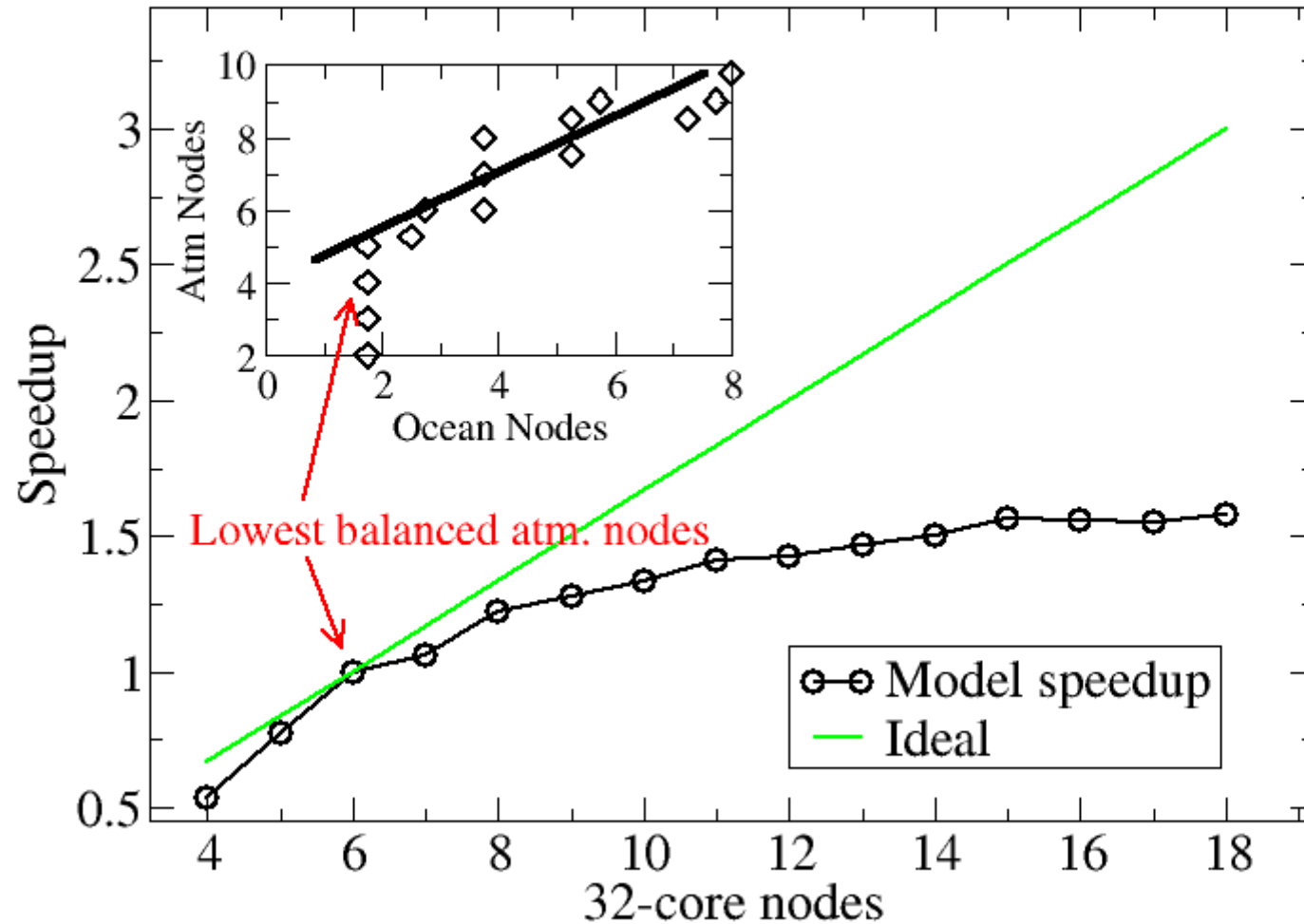
An extra dimension ...



Coupled model scaling

Scaling of HadGEM3-AO

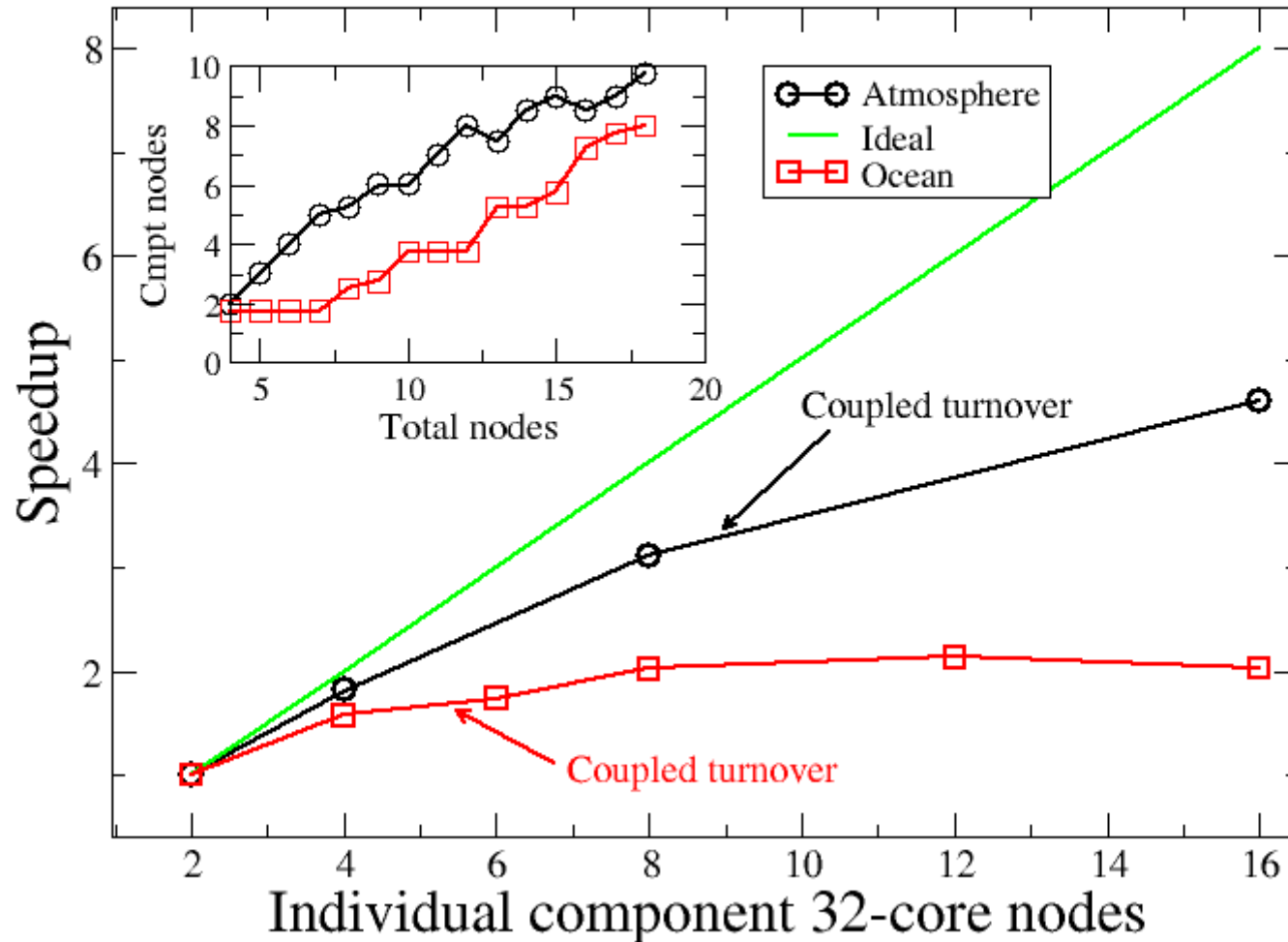
Top-performing Atm/Ocean balance, 8 coupling tasks



Individual components

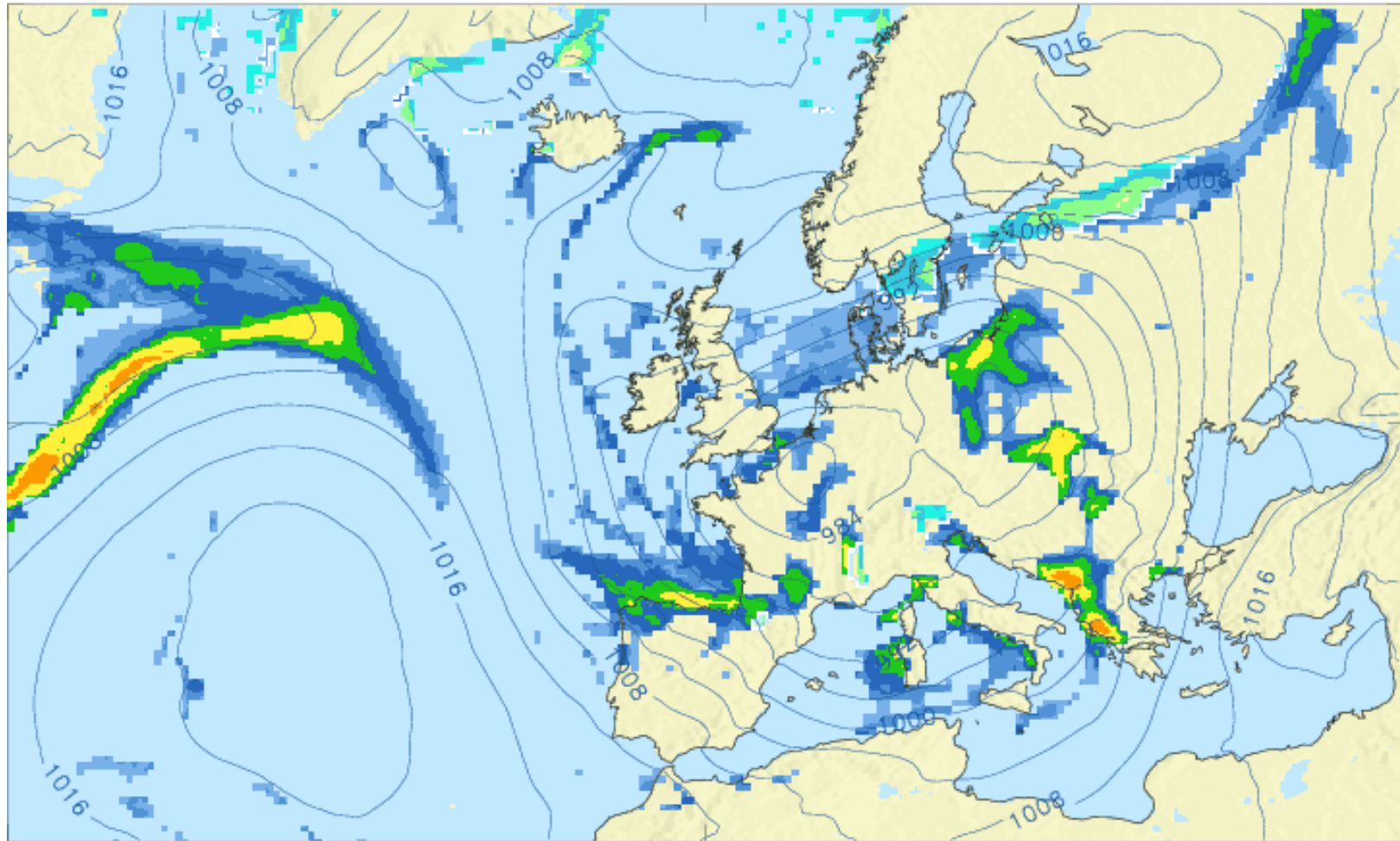
Scaling of Individual Model Components

Inset: nodes for individual cmpts vs. coupled model total



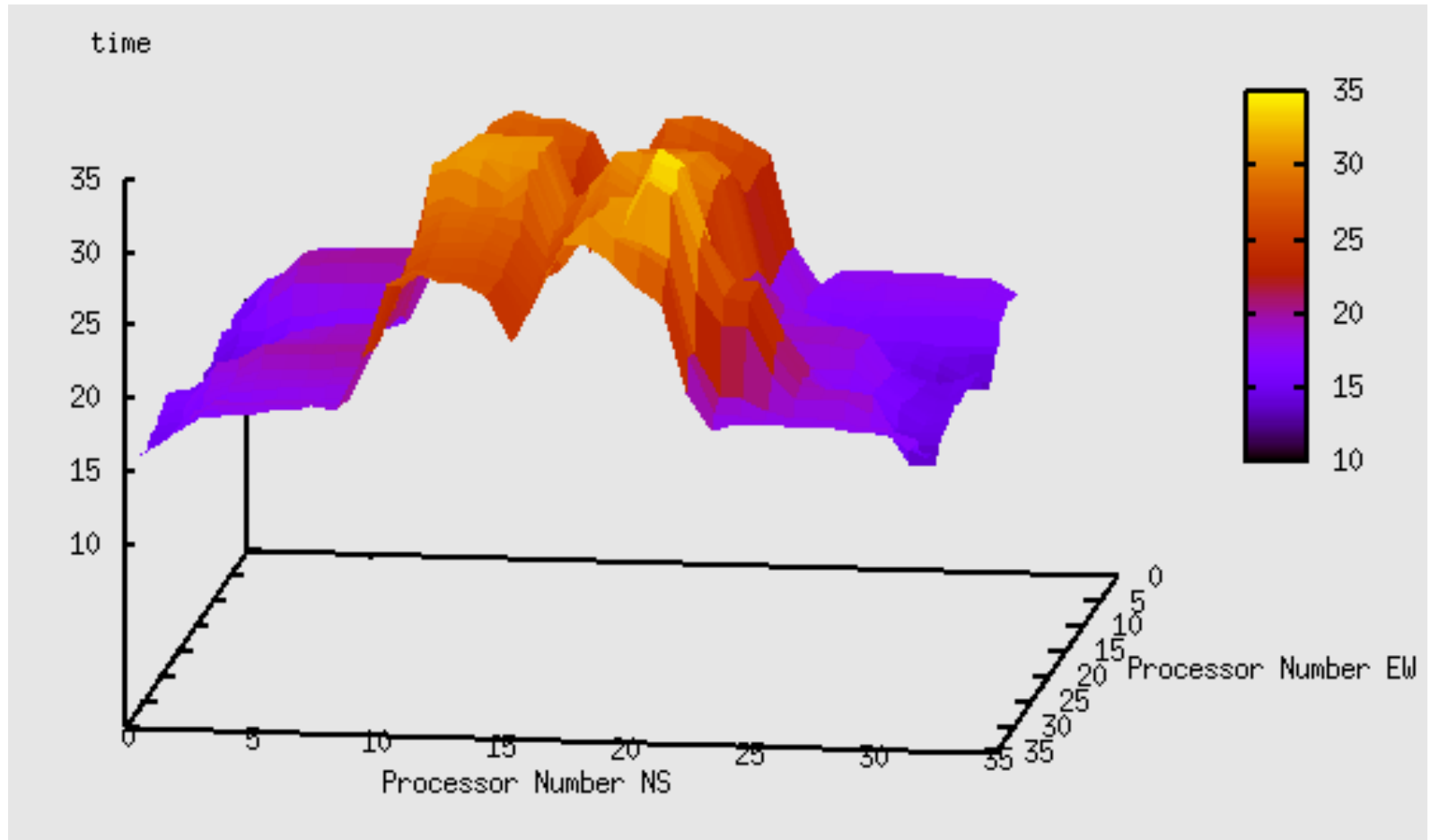


The world and its weather aren't uniform ...



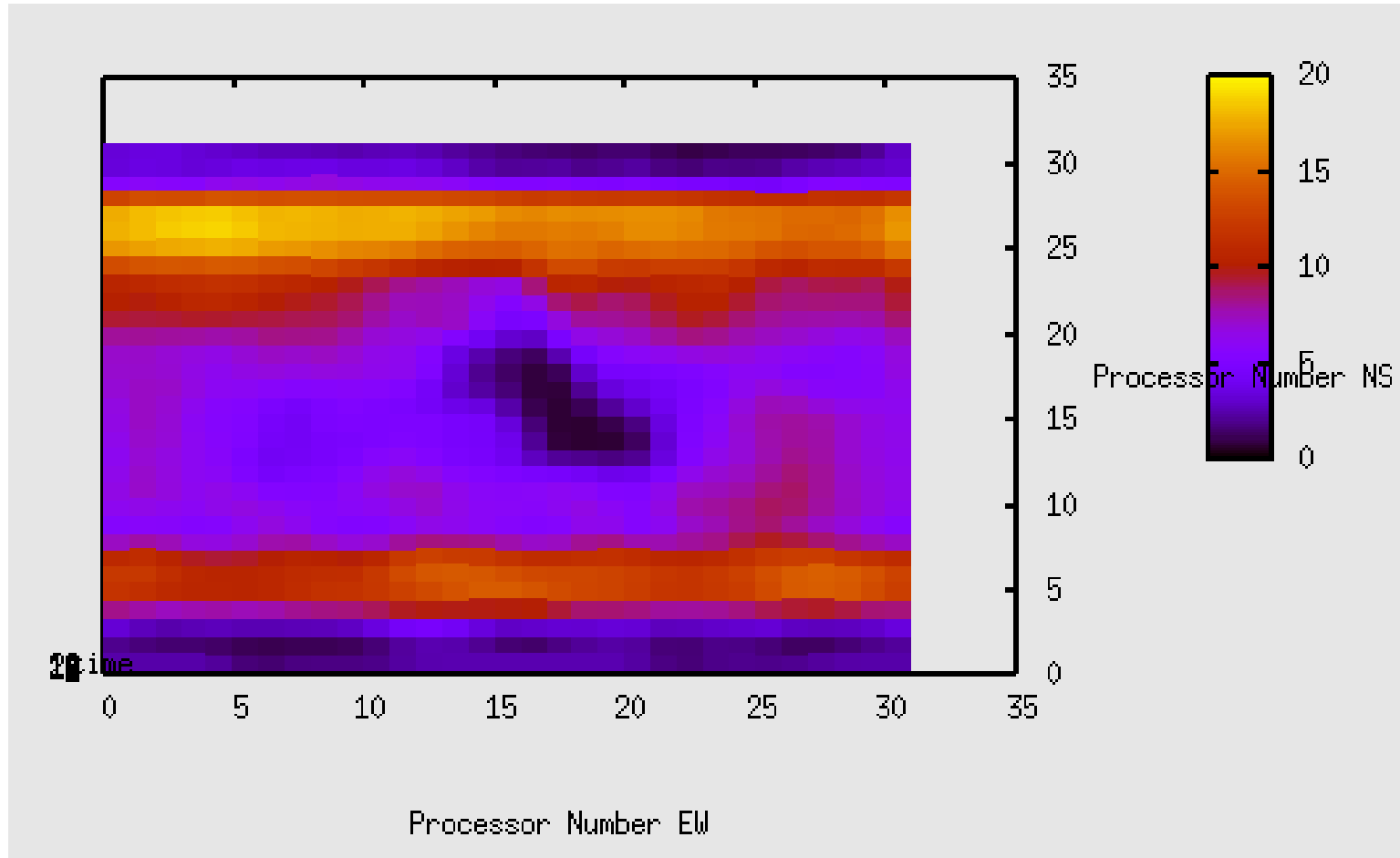


... so we get load imbalance in convection





... and in surface schemes



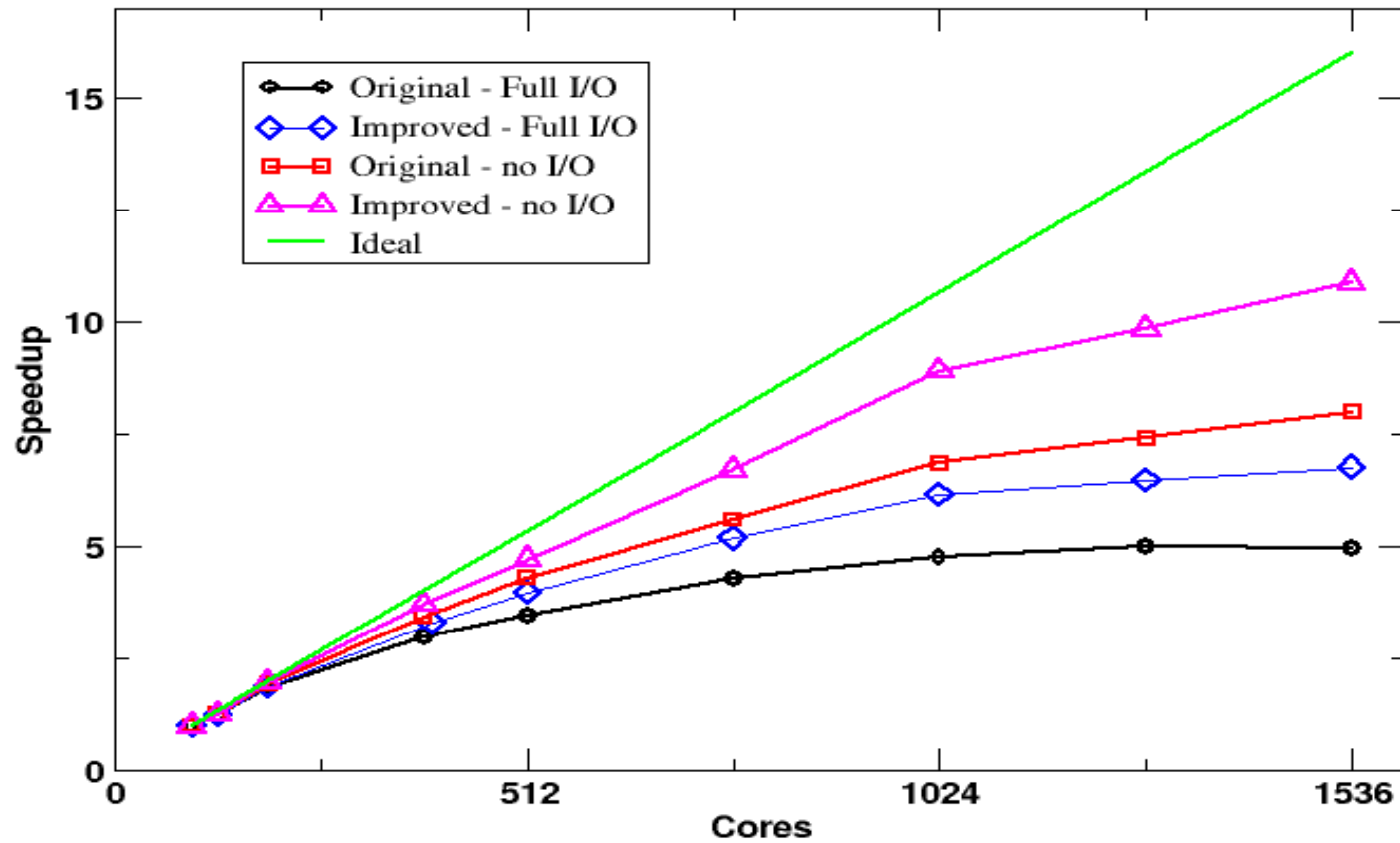


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What to do about it?



Conventional Optimisation





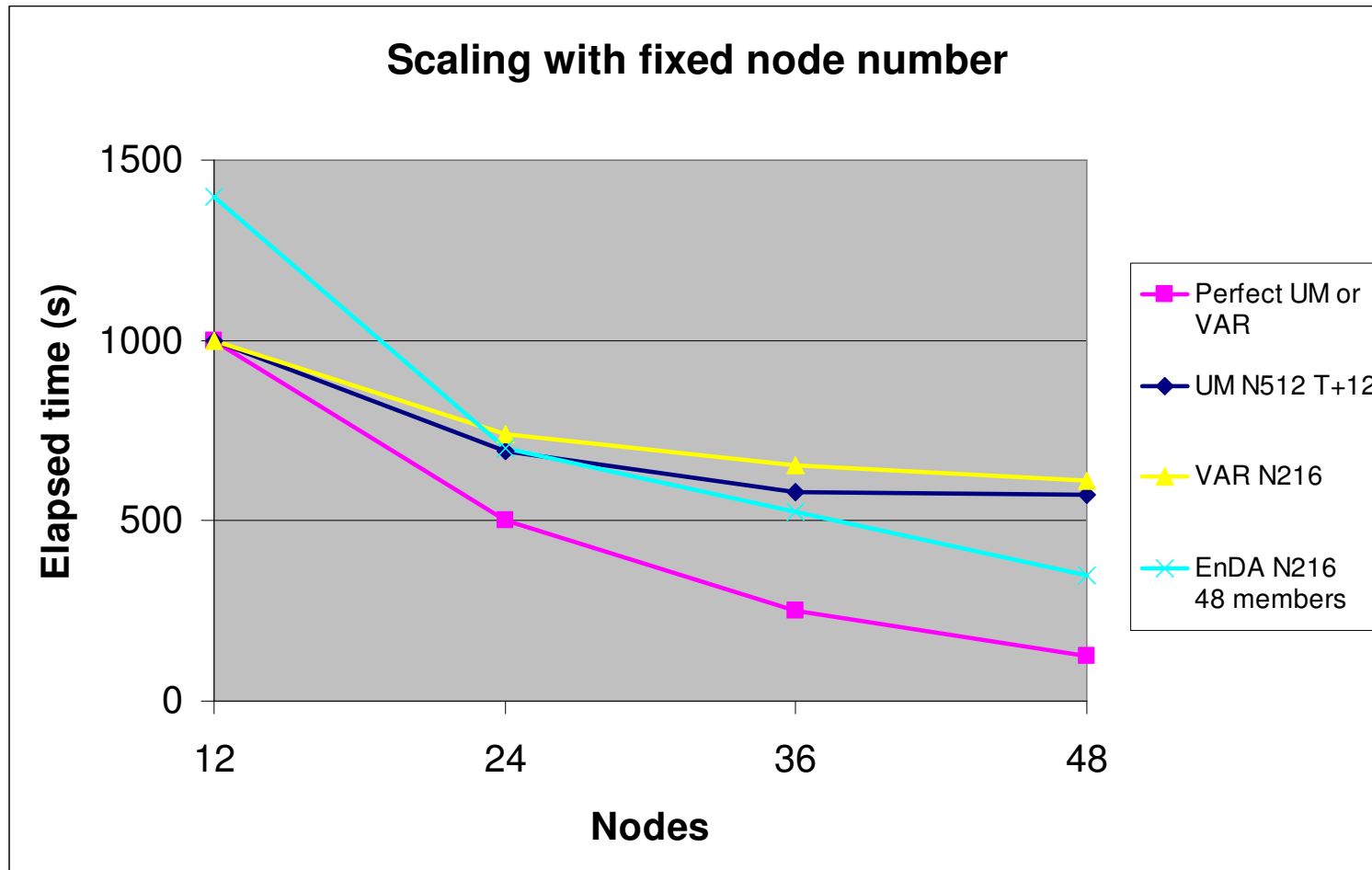
Rip it up and start again...

- Next Generation Weather and Climate Programme
- Collaboration with Hartree, Met Office and NERC
- Combine computer science and meteorology/climatology specialists
- Clean slate approach.

- EO has been put out and evaluations are starting.



VAR v EnDA (future scheme) with current IBM scaling

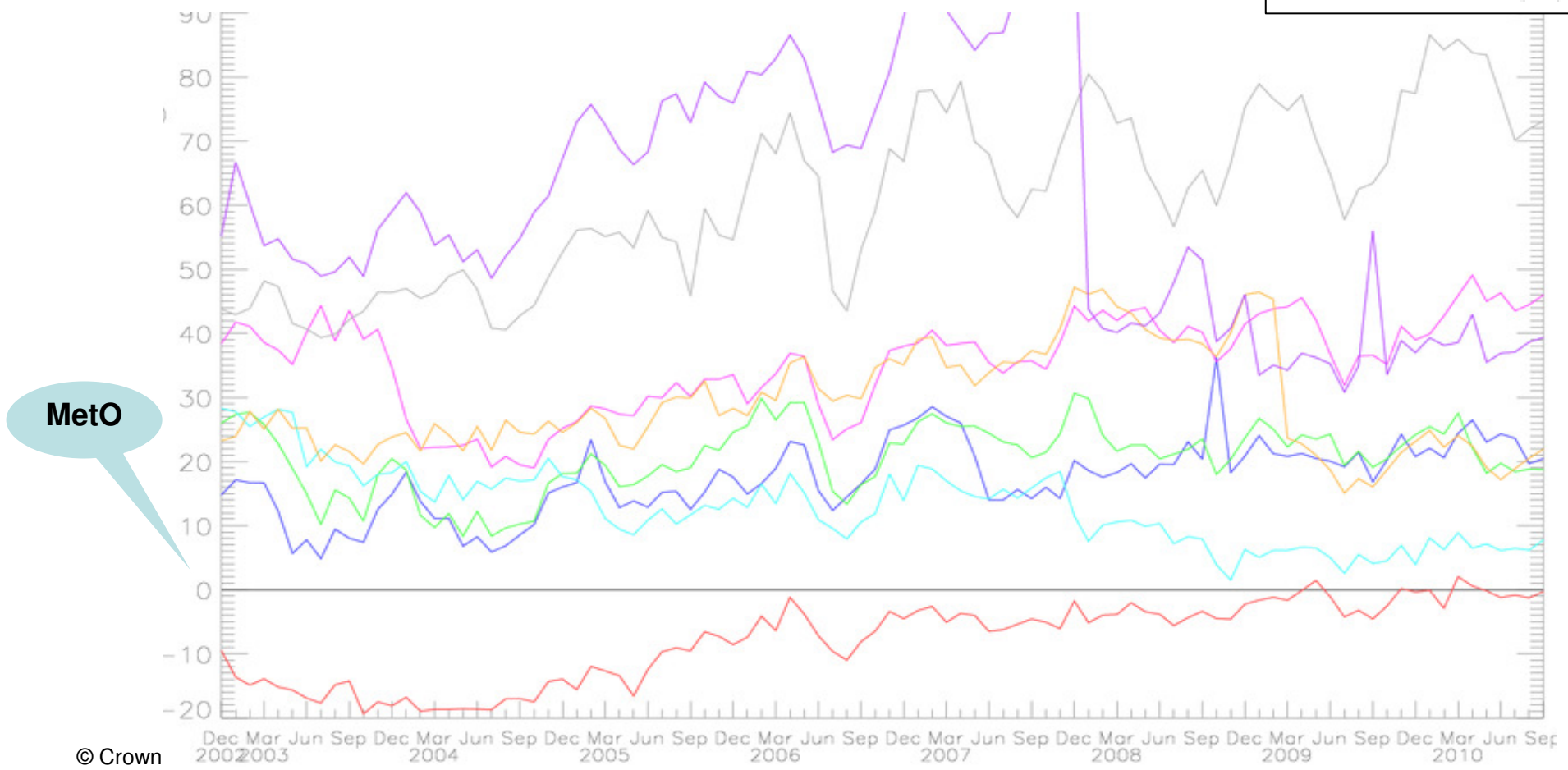




Global Model Comparison using NWP Index basket measure

% diff relative to Met Office

- ECMWF (EC)
- NCEP (US)
- MetFr (FR)
- DWD (GE)
- JMA (JA)
- CMC (CA)
- BoM (AU)
- NCMRWF (IN)





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Questions and answers