Porting the UK Met Office's Unified Model to the Cray X1

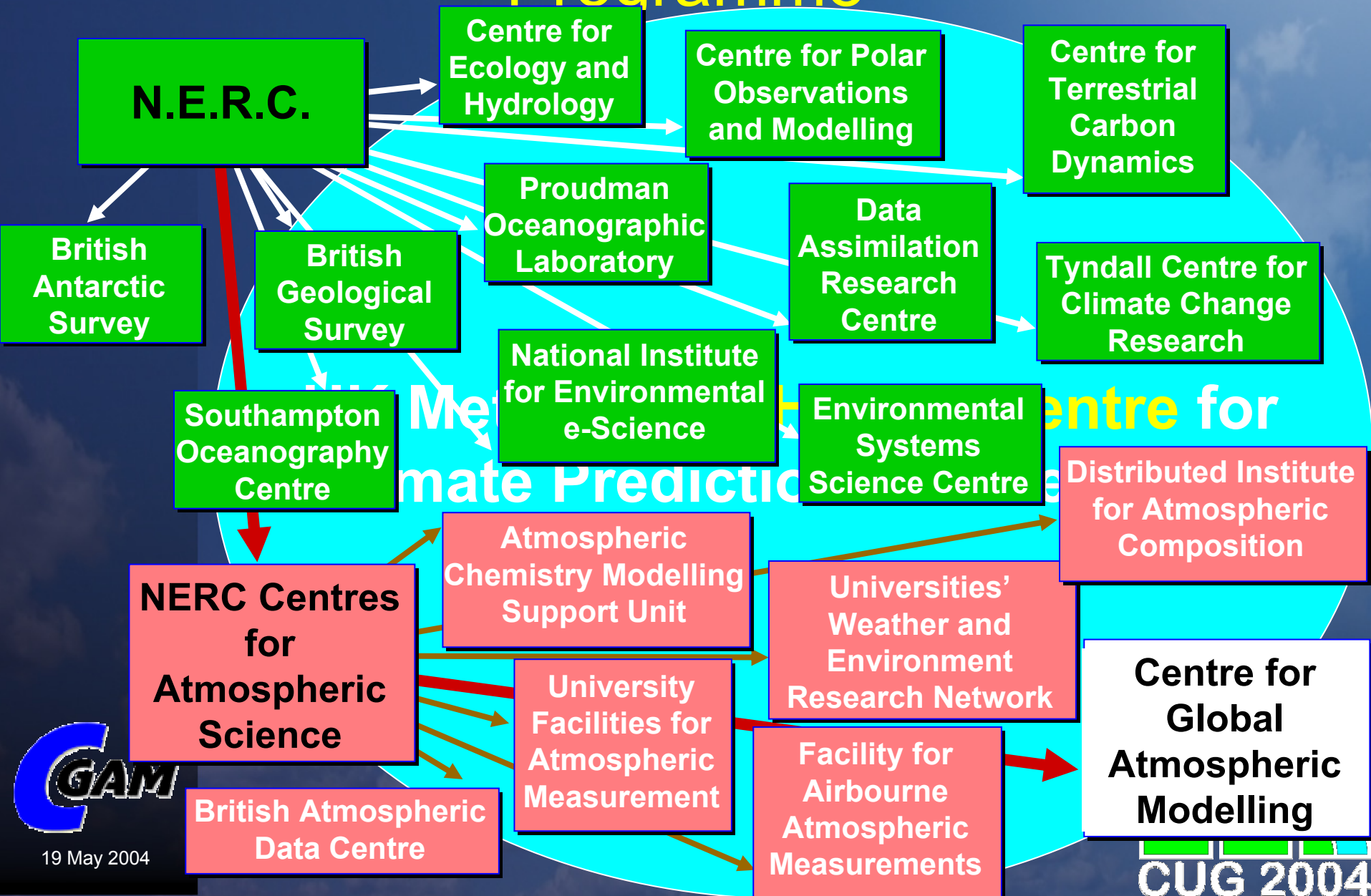
Paul Burton
Centre for Global Atmospheric Modelling,
University of Reading (UK)
Paul@met.rdg.ac.uk

Bob Carruthers
Cray UK
crjrc@cray.com

Overview

- About CGAM
- Computing Platforms
- The Met Office Unified Model
- Porting Results
  - Coupled Atmos/Ocean climate experiment
  - NWP Global Atmosphere Forecast
- Summary

CGAM's place in UK's Climate Research Programme



CGAM's Purpose

- Climate Science
  - UK Centre of expertise for climate science
  - Lead UK research in climate science
    - Understand and simulate the highly non-linear dynamics and feedbacks of the climate system
    - Earth System Modelling
    - From seasonal to 100's of years
    - Close links to Met Office's Hadley Centre
- Computational Science
  - Support for Met Office's Unified Model
  - Porting and optimisation
  - Development of new tools

Issues that CGAM Investigates

- Will there be an El Nino this year?
  - How severe will it be?
- Are we seeing increases in extreme weather events in the UK & elsewhere?
  - Extreme rainfall & flooding
  - Drought?
- Will the milder winters of the last decade continue?
- Can we reproduce and understand past abrupt changes in climate?

UK-HiGEM Project

- National “Grand Challenge” Programme for High Resolution Modelling of the Global Environment
- NERC in collaboration with UK Met Office’s Hadley Centre
- Develop high resolution version of HadGEM *(~ 1^0 atmosphere, $1/3^0$ ocean)*
- Better understanding and prediction of
  - Extreme events
  - Predictability
  - Feedbacks and interactions
  - Climate “surprises”
- Regional Impacts of climate change

Computer Systems available to CGAM

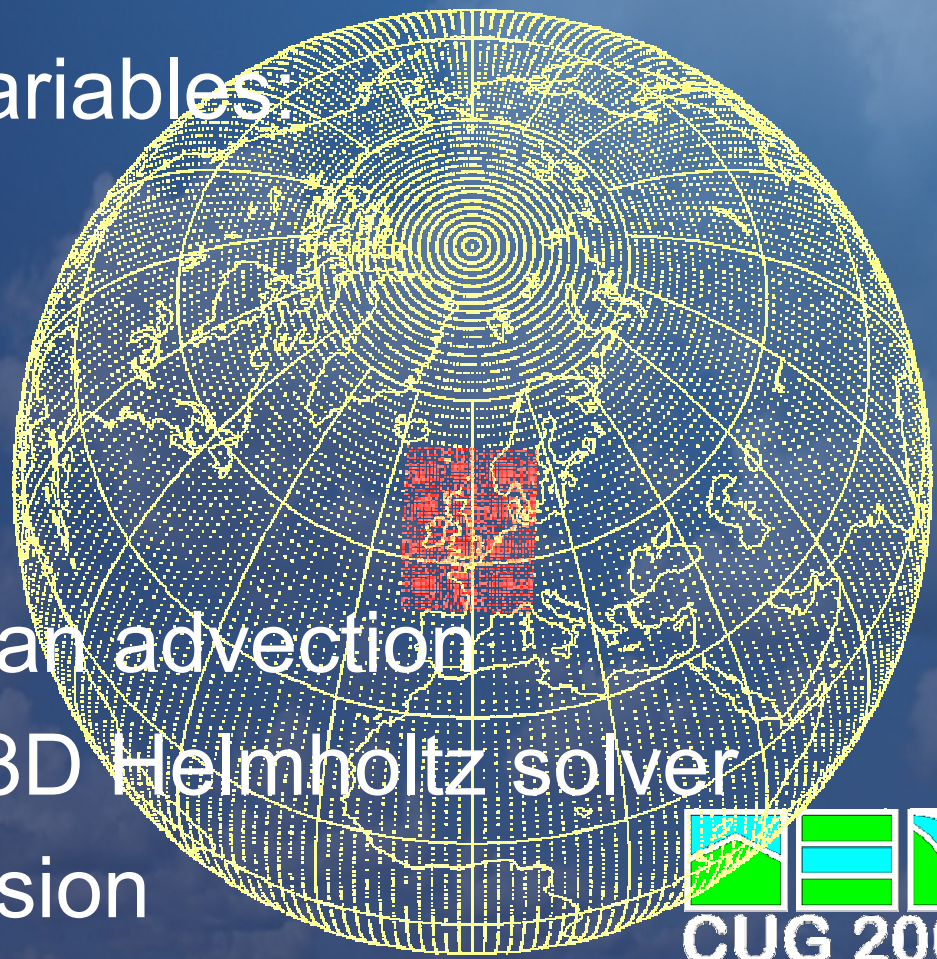
- CSAR (University of Manchester)
  - SGI Origin 3800 (512 CPU)
    - 0.4 Tf peak, 512 GB
  - SGI Altix Itanium2 (256 CPU)
    - 1.3 Tf peak, 384 GB
- HPCx (Daresbury / EPCC)
  - Phase1 : IBM p690/POWER4 (1280 CPU : 8 way LPAR)
    - 6.6 Tf peak, 1.28 TB
  - Phase2 : IBM p690+/POWER4+/Federation (1600 CPU : 32 way LPAR)
    - 10.8 Tf peak, 1.6 TB
- Earth Simulator, (JAMSTEC, Japan)
  - Similar to NEC SX6 (5120 CPU : 8 way node)
    - 40 Tf peak, 10TB
- UK Met Office (Exeter)
  - NEC SX6 (240 CPU : 8 way node)
    - 1.9 Tf peak, 1TB
- Cray
  - X1 @ Cray (3x16 SSP/4 MSP 800Mhz Production nodes)

The Unified Model

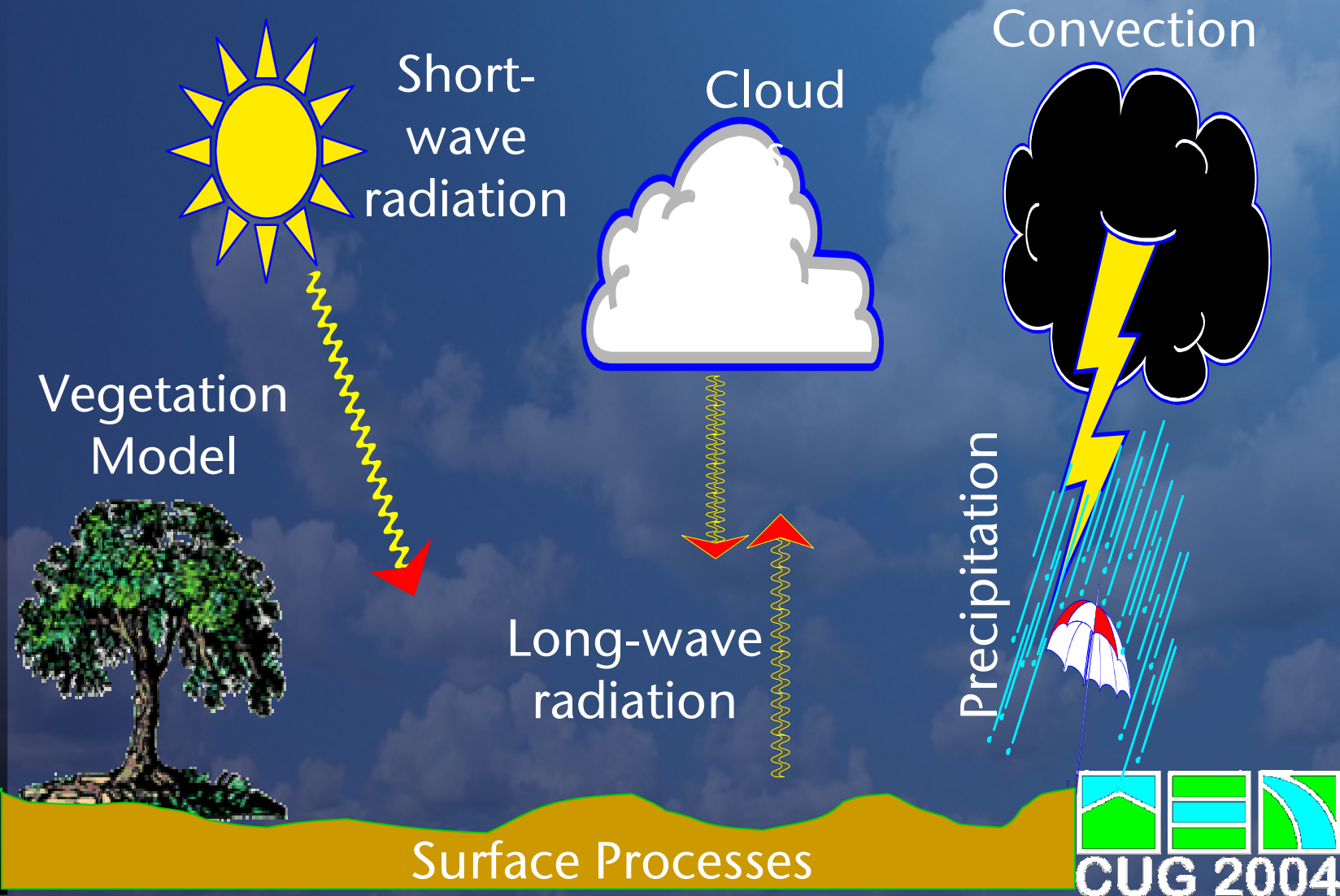
- Single code base and infrastructure
  - NWP : Global & Local Area
  - Climate : Coupled Atmosphere & Ocean
- Optional submodels (OASIS coupler)
- Powerful GUI
  - Configurable and tuneable science
  - Extensive diagnostic outputs
- Million lines of portable Fortran77/90 and C

Atmospheric Model

- Regular latitude/longitude grid
  - Definable vertical levels
- Main model variables:
  - Winds
  - Temperature
  - Moisture
  - Pressure
- Semi-lagrangian advection
- Semi-implicit 3D Helmholtz solver
- Targeted diffusion



Atmospheric Parameterizations



Ocean Model

- Linear free surface height
- 4^{th} order advection
- Conjugate gradient solver
- Parameterized Bottom Boundary Layer
- Coupled to atmosphere once a day
  - Conservative coupling
  - Coastal tiling scheme

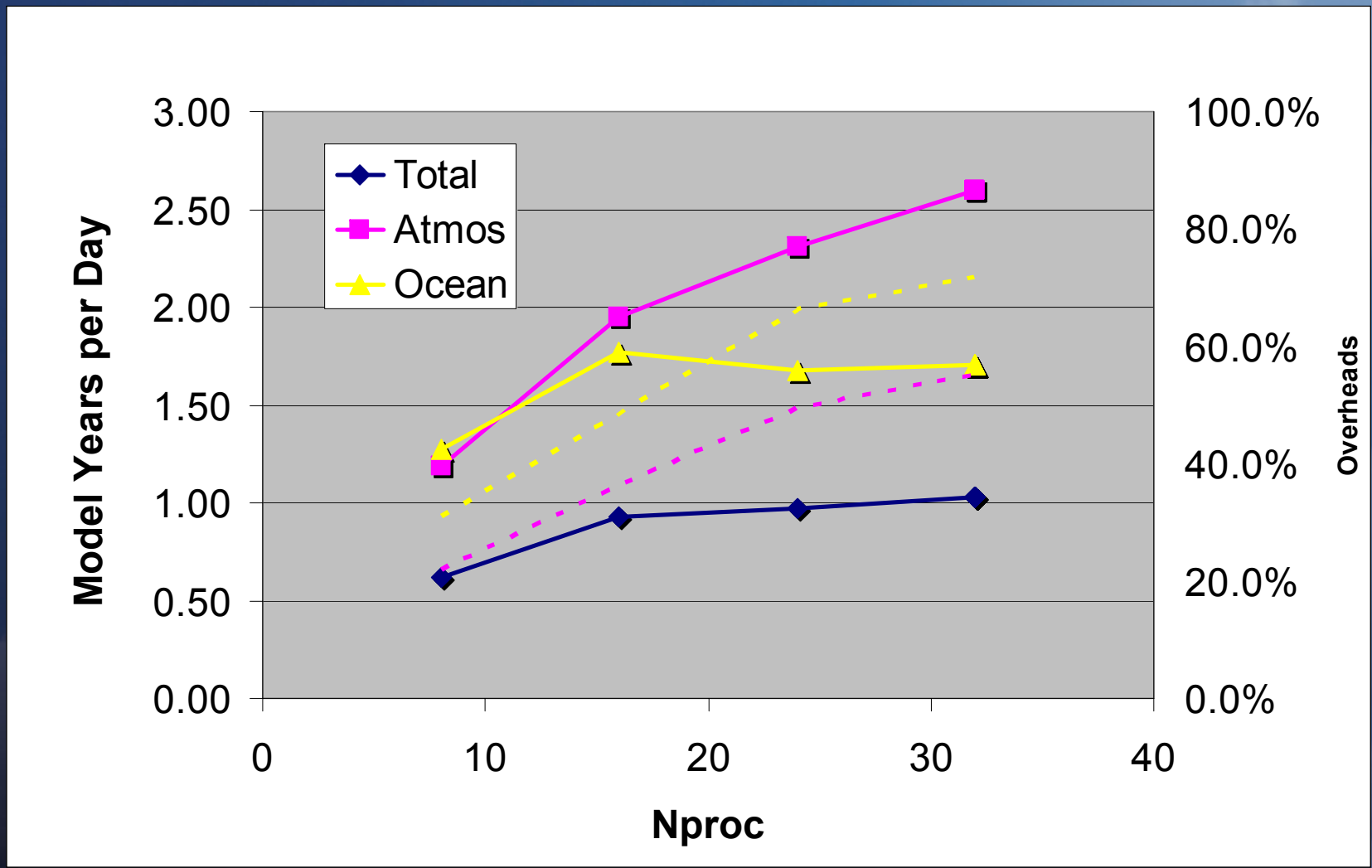
Parallelisation Aspects

- Domain Decomposition
  - Atmosphere : 2D Decomposition
  - Ocean : 1D Decomposition
- Parallelisation aimed at Cray T3E
- Message Passing
  - Portable Interface Library
    - GCOM / SHMEM
  - Some optional hand-coded SHMEM optimisations
- Characterised by short messages and plenty of barriers

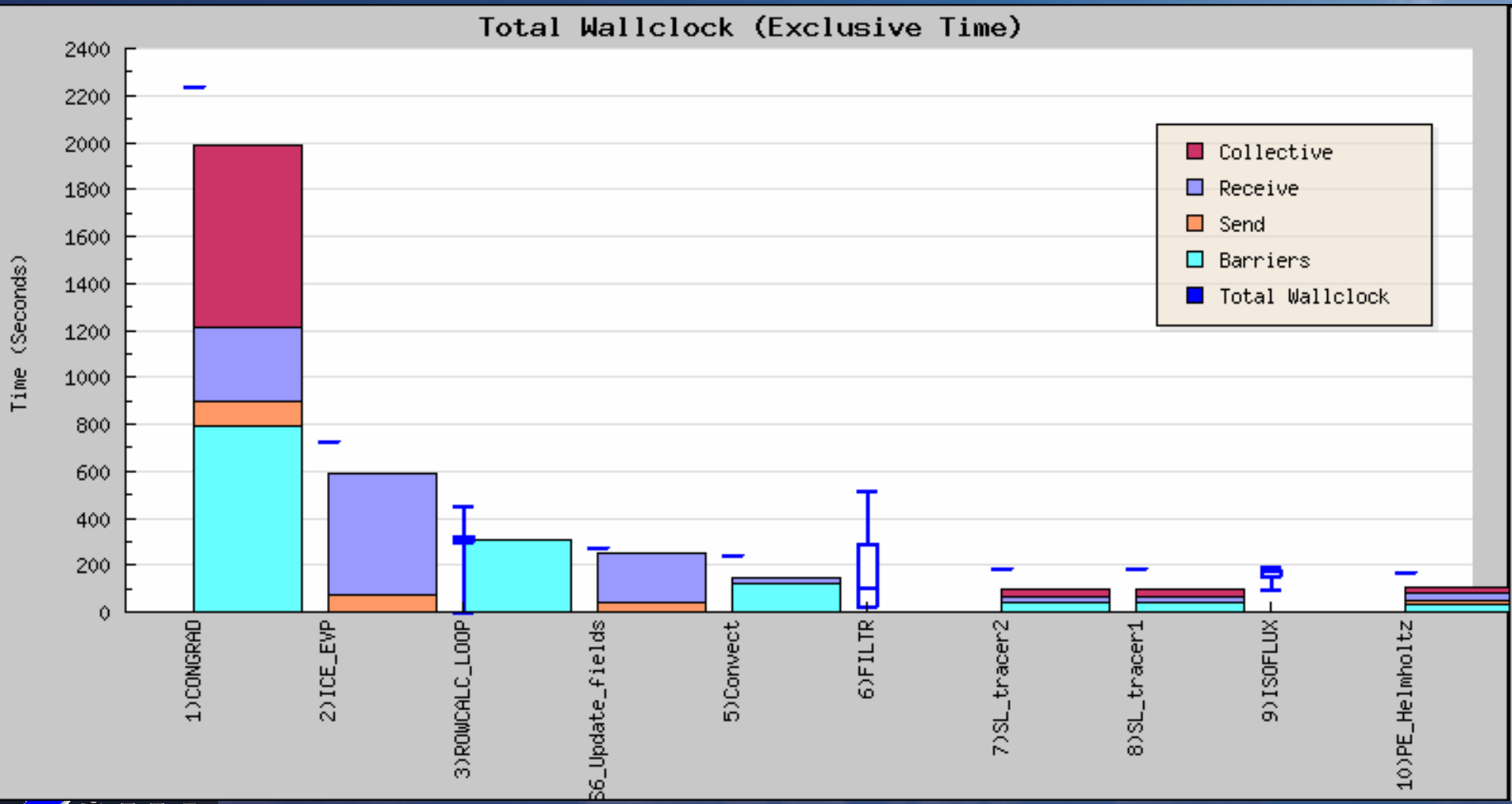
Coupled Model Porting Results

- Latest version of Hadley Centre's "HadGEM" configuration
  - Prototype for IPCC runs
- N48 (270km) atmosphere model 1º ocean model
- Developed on Cray T3E
  - Results are more or less basic port
    - IBM : -O3 –qstrict
    - SX6 : -Cvopt (basic vector & scalar opt)
    - X1 : -Oaggress,scalar3,vector2,stream0, nopattern,ssp,task0

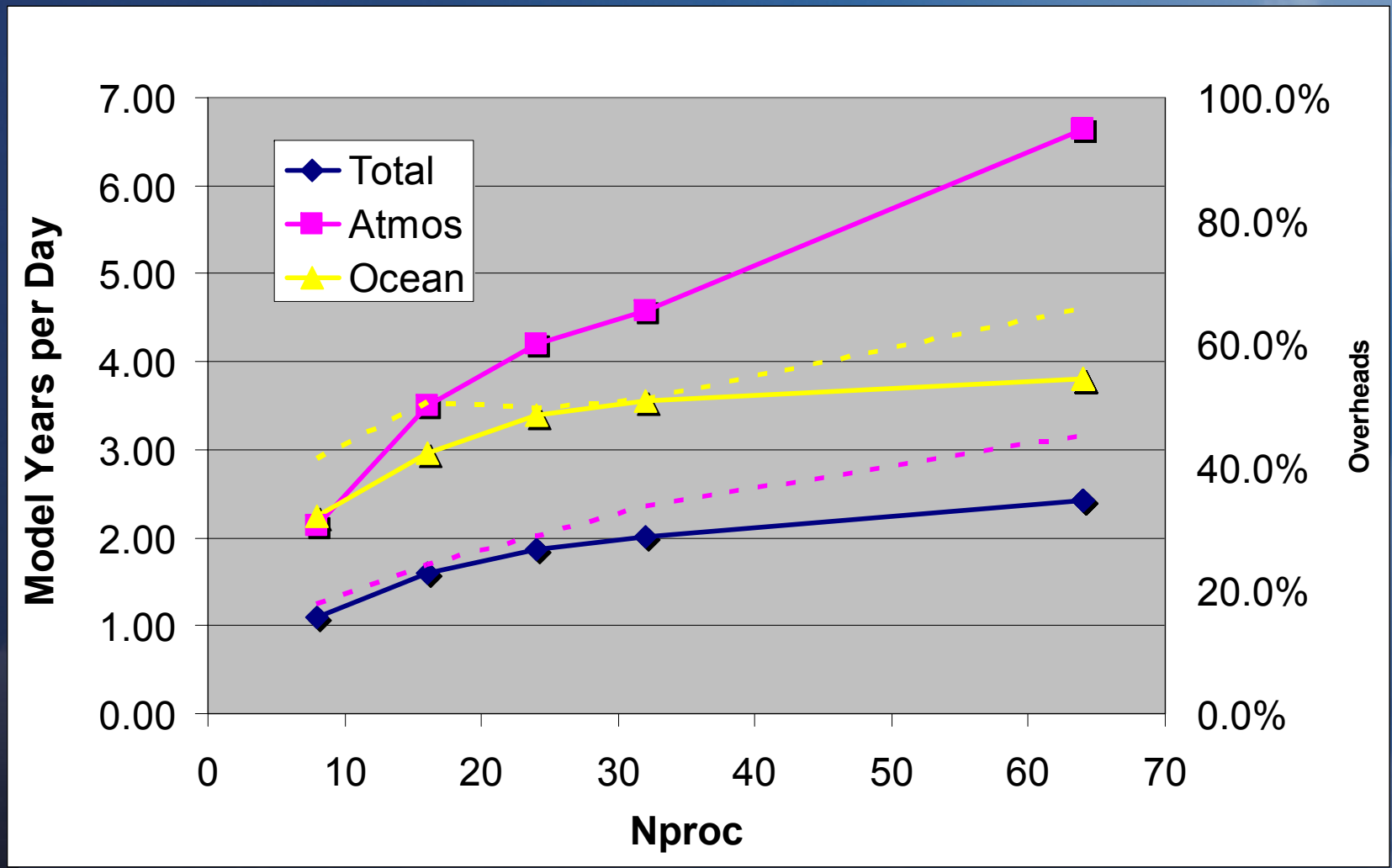
HPCx (IBM p690) : Phase 1



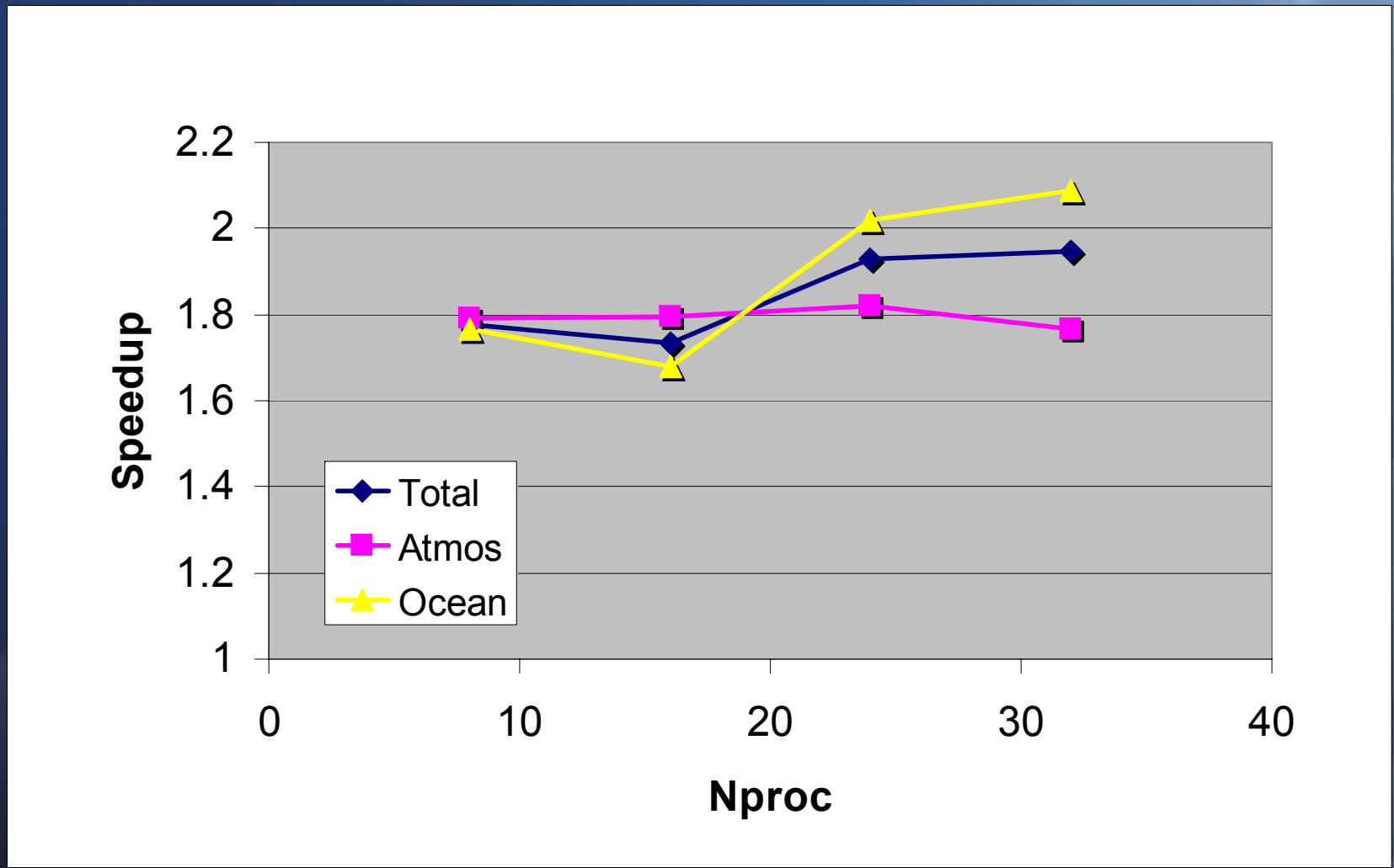
What's wrong with the Ocean Model?



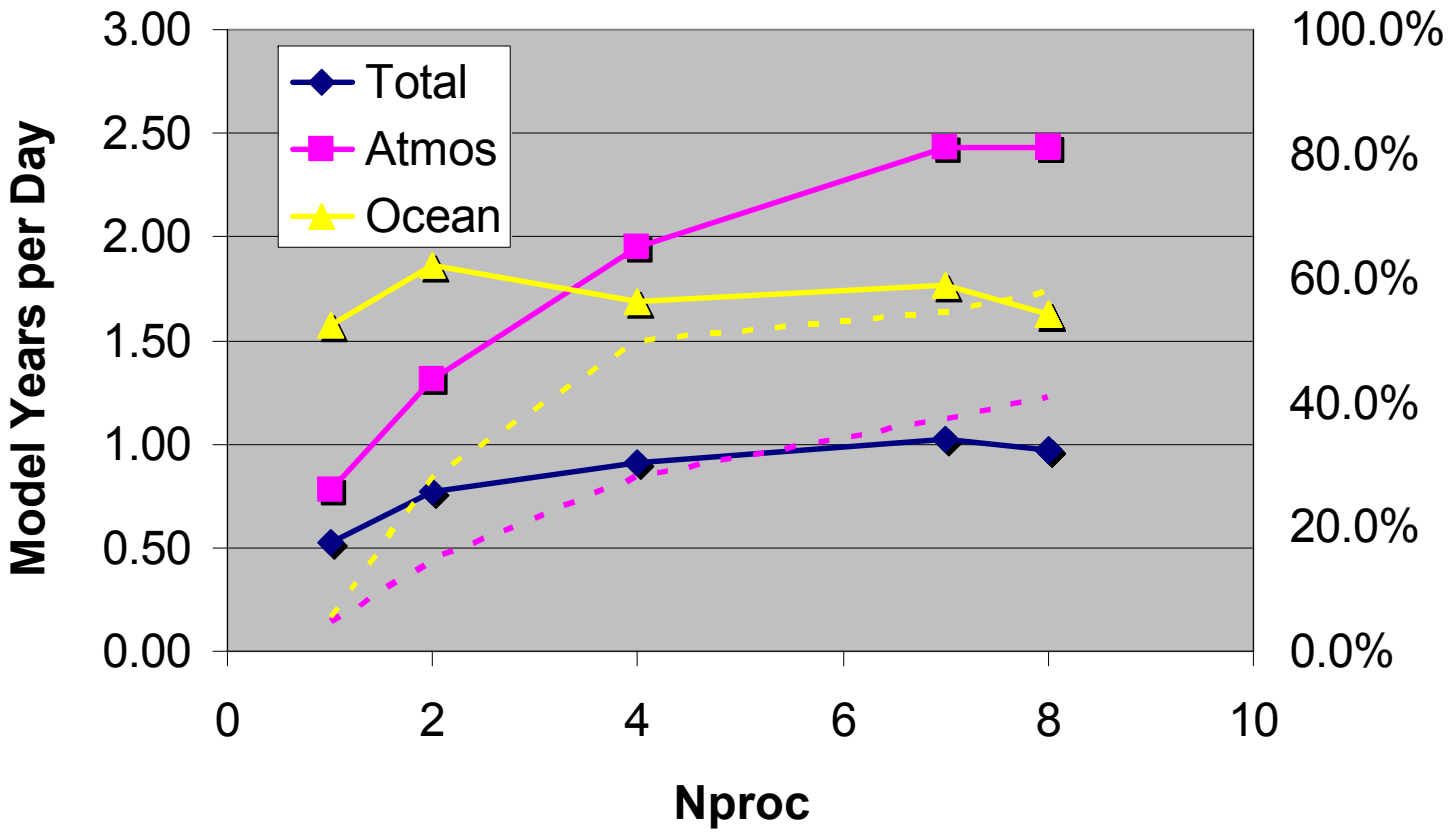
HPCx : Phase 2


Model Years per Day
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Total
Atmos
Ocean
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Overheads
0
10
20
30
40
50
60
70
Nproc

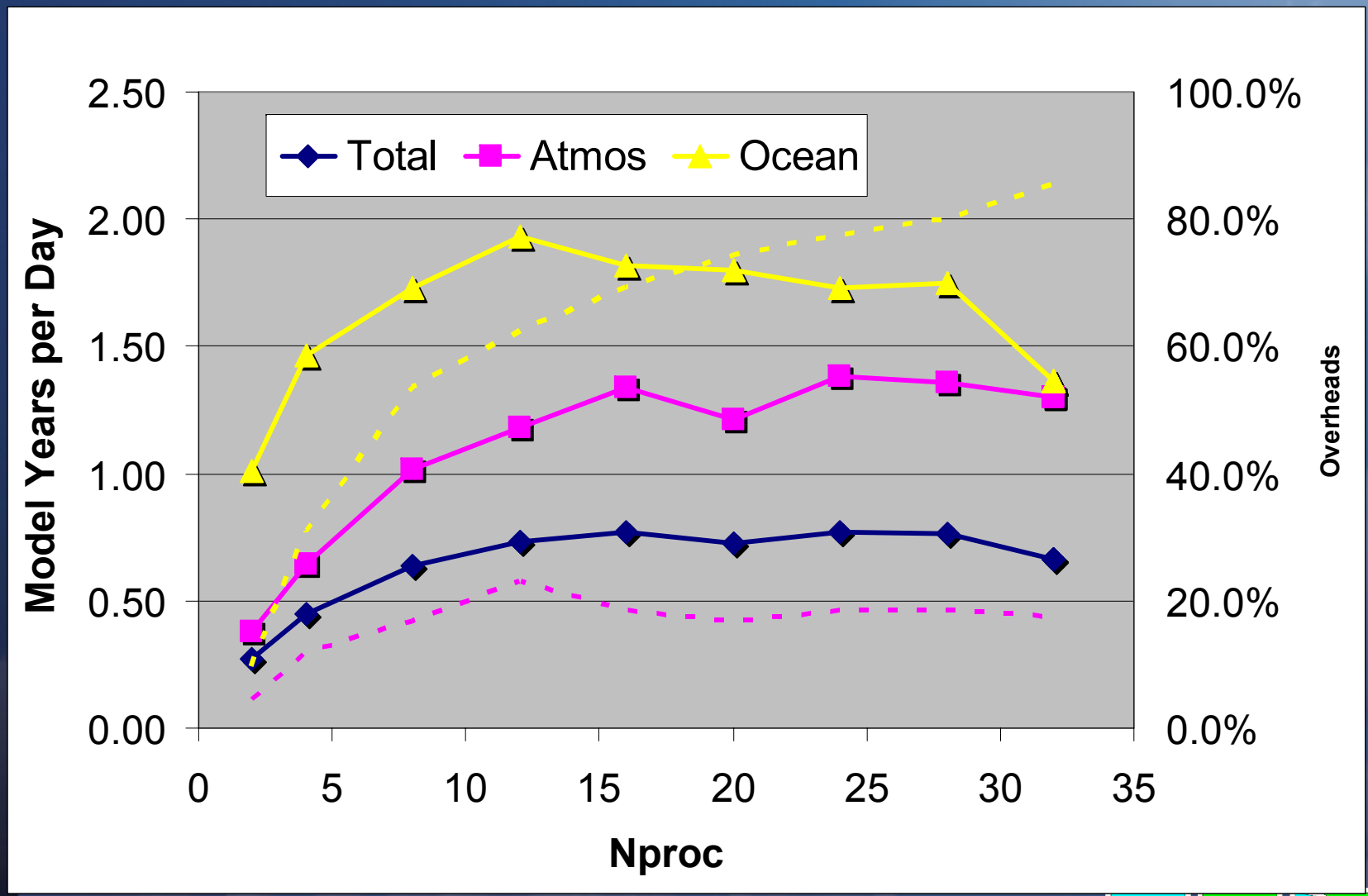
Performance Increase from Phase2



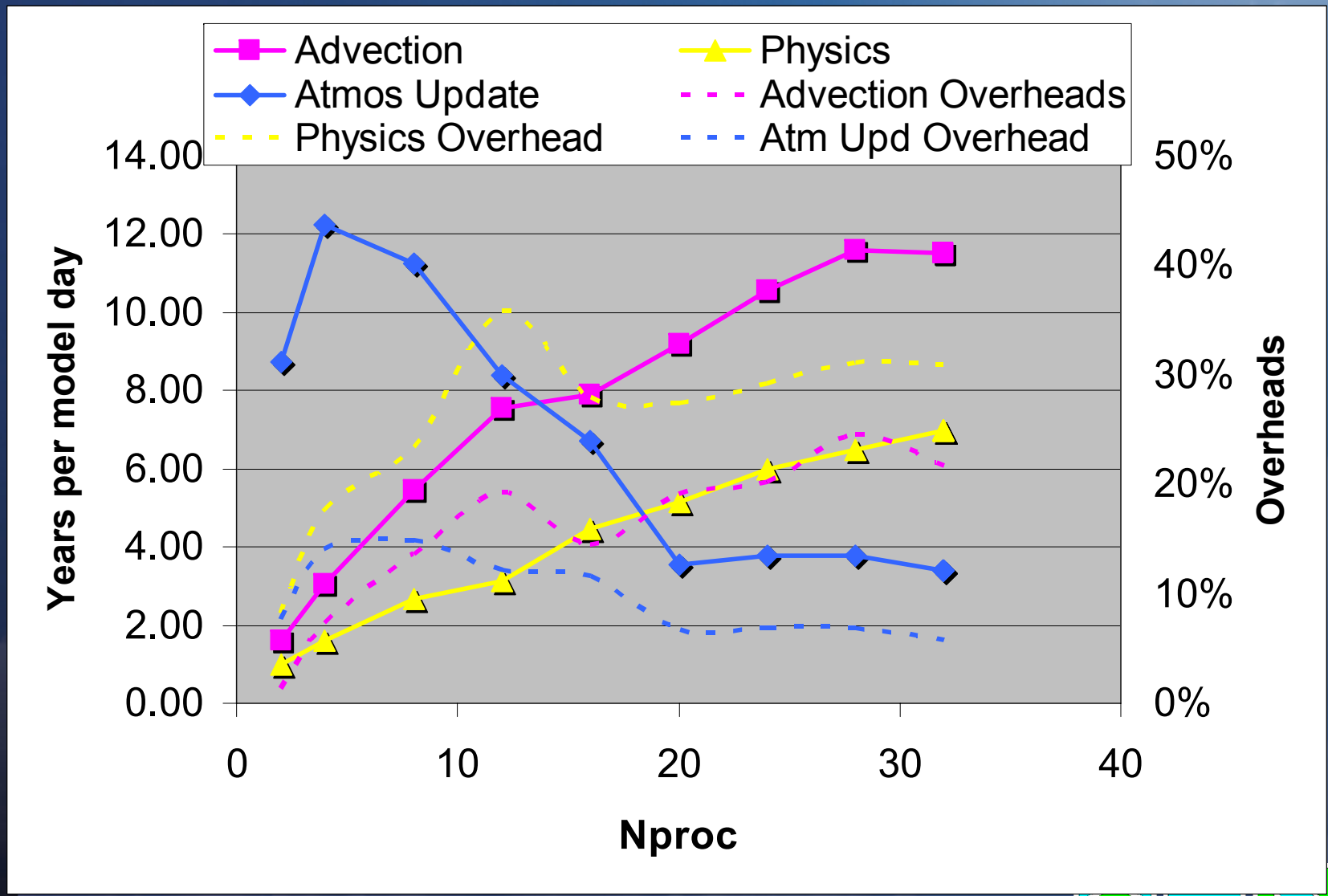
Met Office SX6



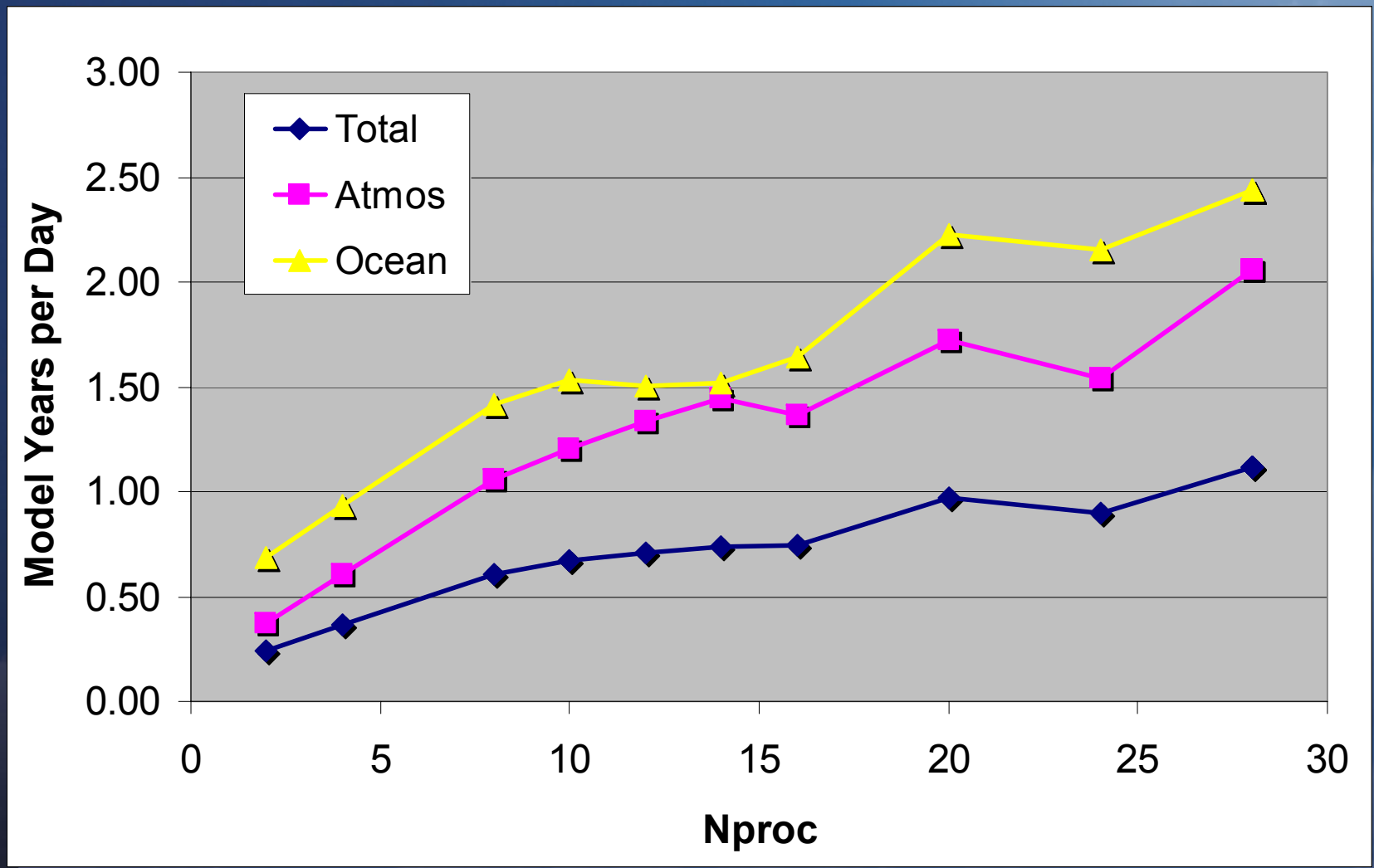
Cray X1


Total
Atmos
Ocean
Model Years per Day
Overheads
Nproc
2.50
2.00
1.50
1.00
0.50
0.00
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
0
5
10
15
20
25
30
35

Cray X1 : Atmosphere scaling



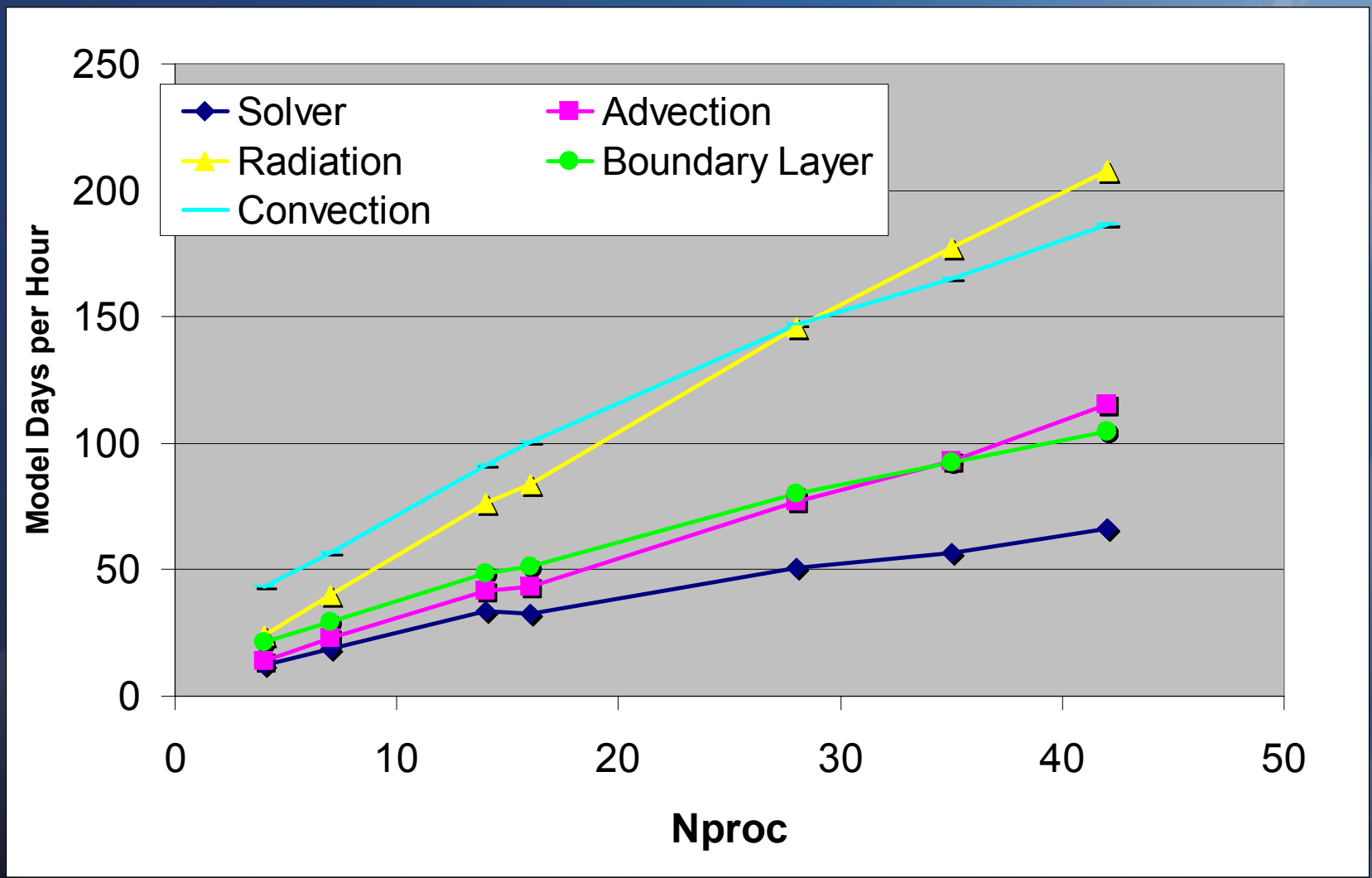
Cray X1 : SHMEM + Opt



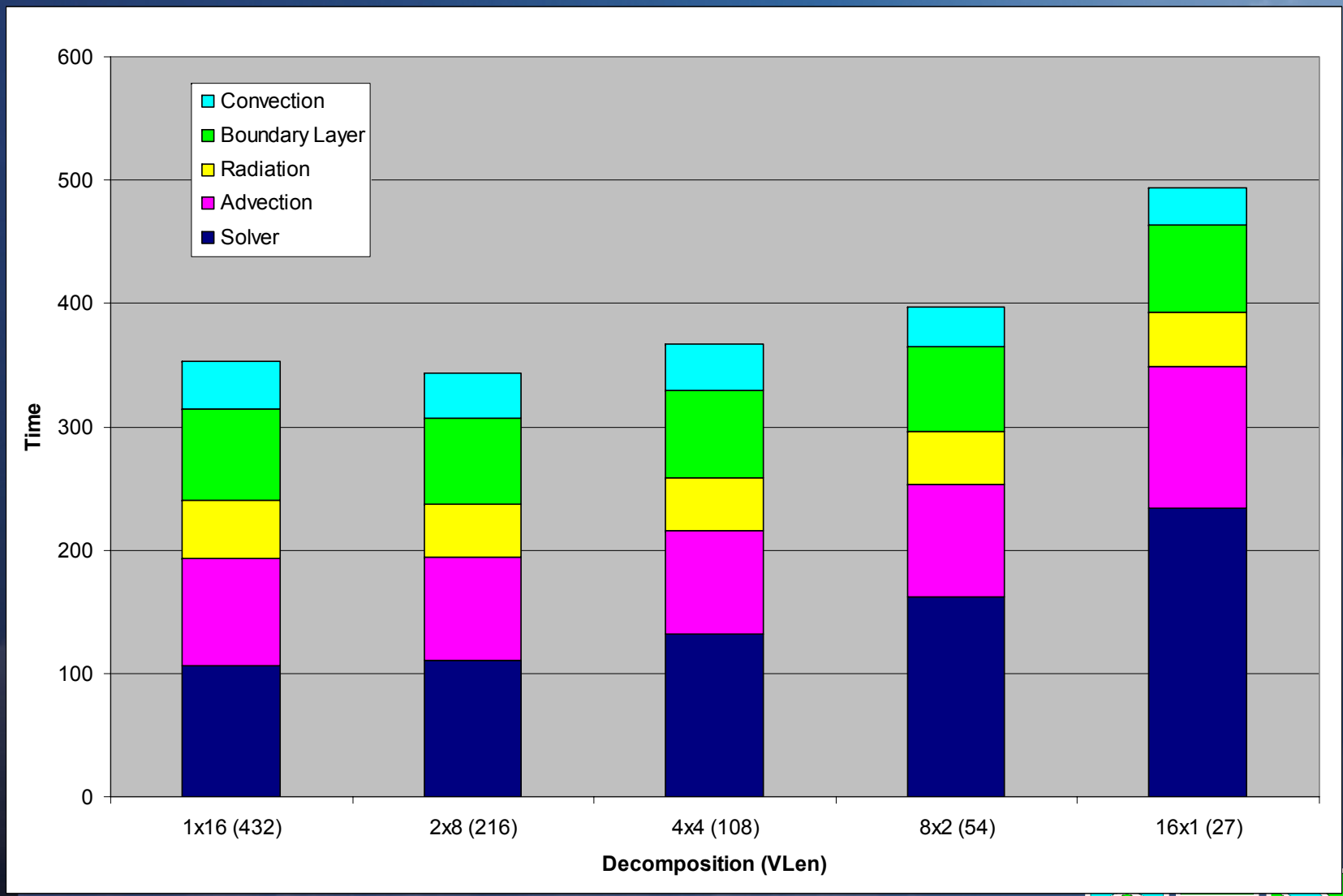
NWP Global Atmosphere Porting Results

- Latest version of Met Office's NWP configuration
  - In trial operational use on SX6
- N216 (60km) global atmosphere model
- Ported and optimised for SX6
  - Code changes for better vectorisation
  - Additional of compiler directives
  - Inlining
  - Optimisation of core communications (halo update)
  - -Chopt (highest vector and scalar optimisation)
    - Few routines compiled with -Cvsafe
- Cray X1 results are a basic port of T3E vn
  - Improvement of vectorisation for radiation and solver
  - Use SHMEM communications
  - -Oaggress,scalar3,vector2,stream0, nopattern,ssp,task0

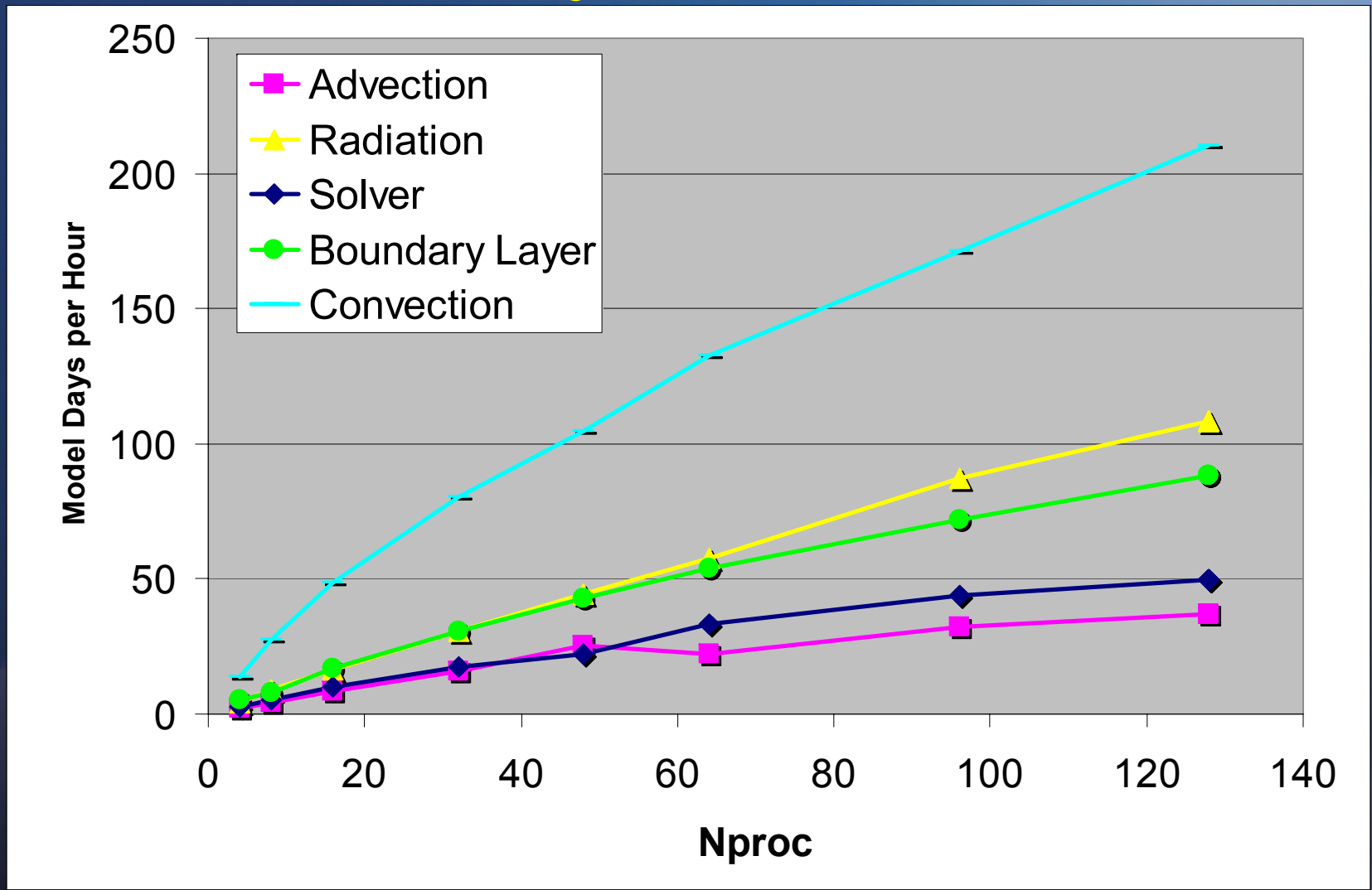
Met Office SX6



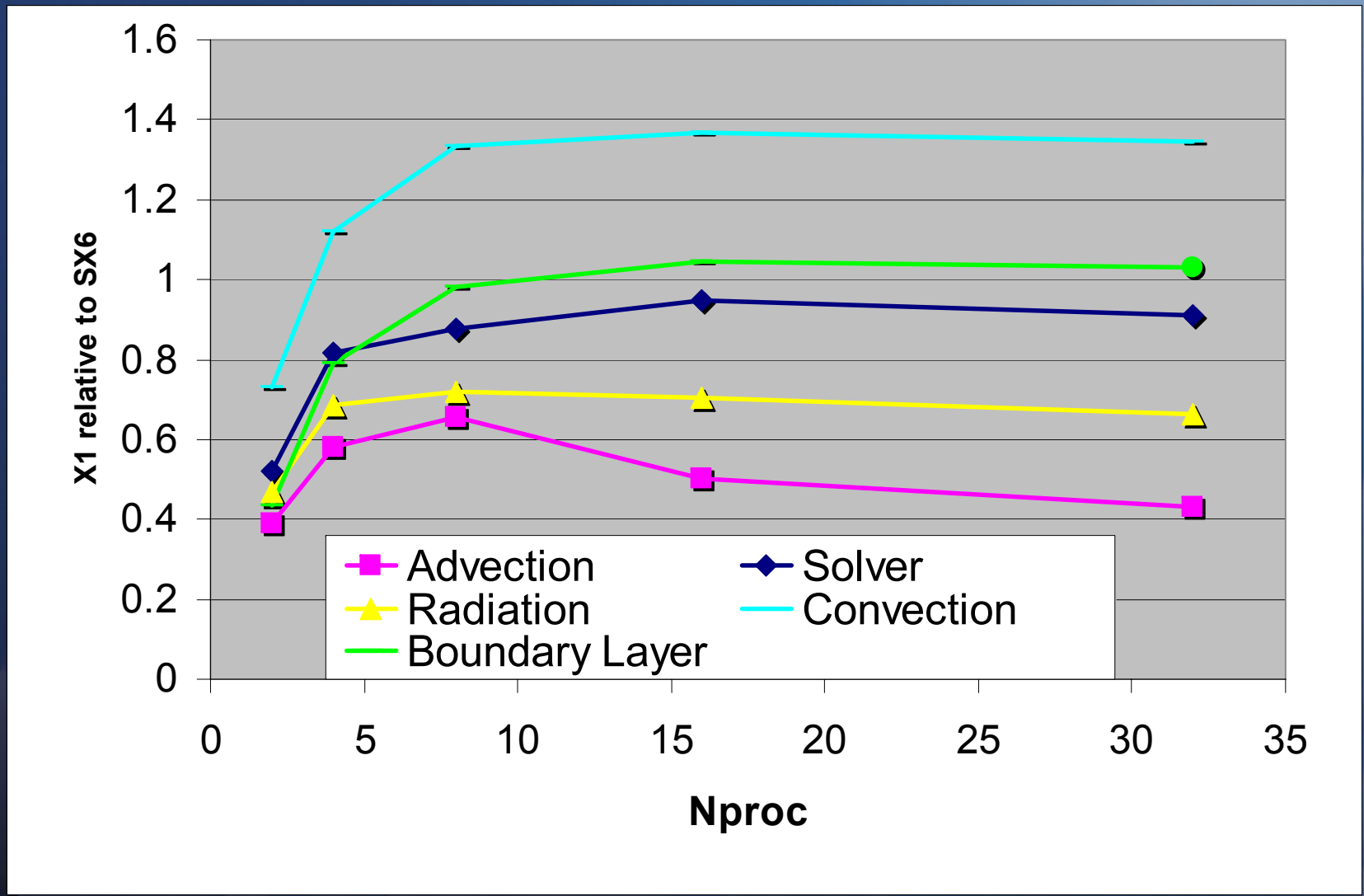
Decomposing along the vector (SX6)



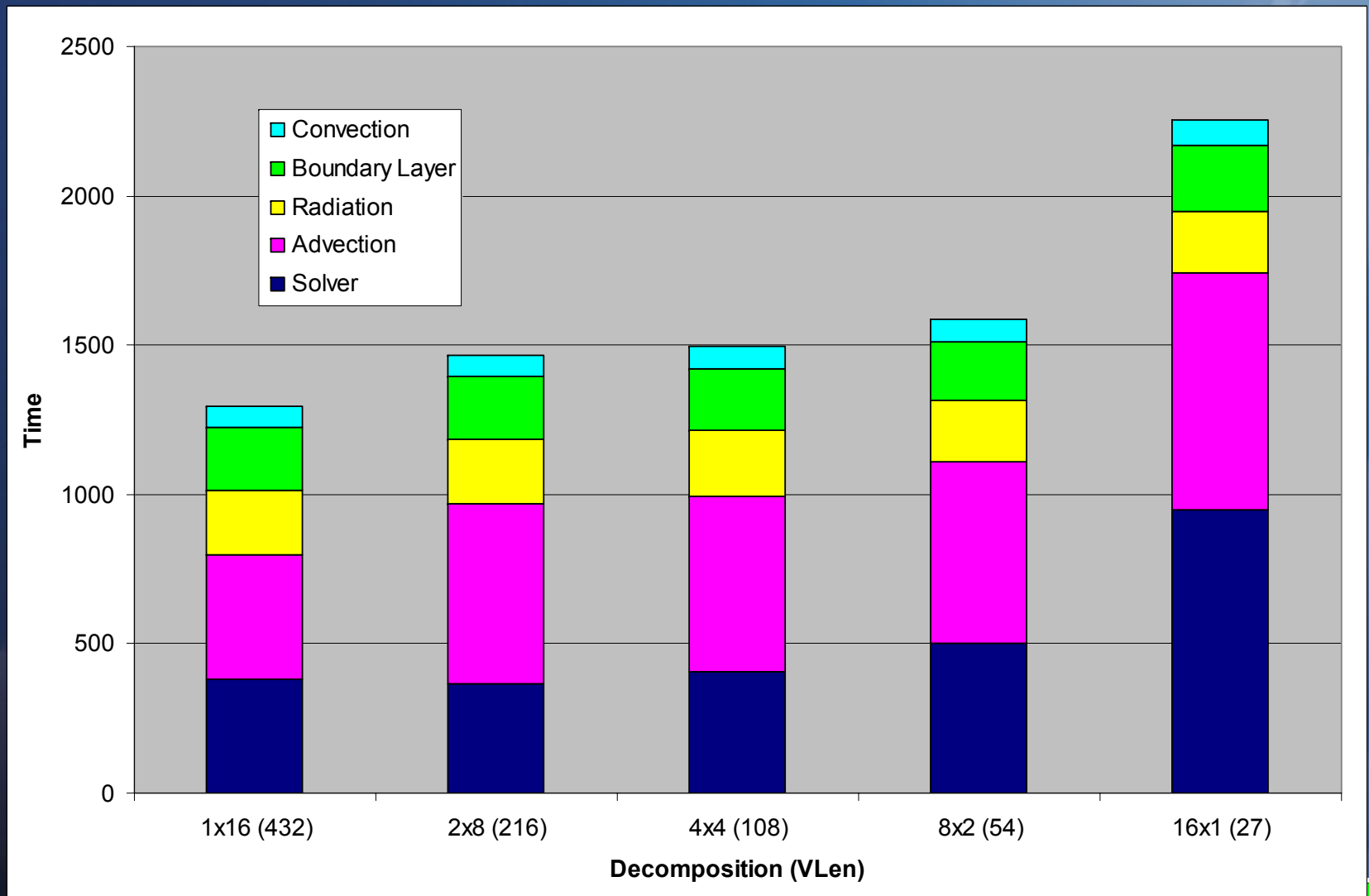
Cray X1


Advection
Radiation
Solver
Boundary Layer
Convection
Model Days per Hour
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Nproc

Relative to SX6



Decomposing along the vector (X1)



Conclusions

- Porting exercise relatively painless
- Early on in optimisation work
  - Early signs are promising
  - More work is obviously needed to reach desired performance
- #1 : Improve vectorisation
- #2 : Use MSPs to reduce decomposition effects?
- #3 : Use co-array Fortran