Atmospheric modeling: introduction, some applications and computational demands

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Outline

- Presentation
- Introduction
- Models in BSC
- Running Models
- Examples of work
  - Parallelizing
  - Optimizing
  - Bechmarking
- Further directions

Presentation

- Made my education in FIB.
- Finished on 2005.
- Then working in different places.
- And two years ago, I went to the BSC and started to work on Earth Sciences Dpt.

Introduction

- Atmospheric Model: Mathematical Models with dynamic equations

- We need computers to solve these equations

- Before getting this nice picture, we need to follow a *"forecast chain"*.

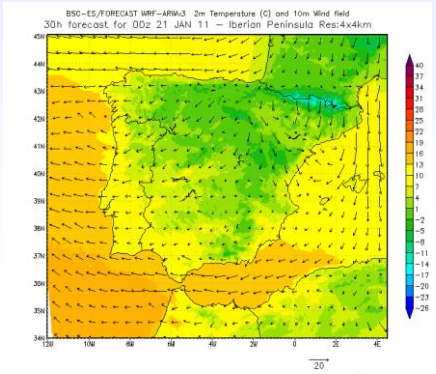
- Today we will explain this from the IT point of view.

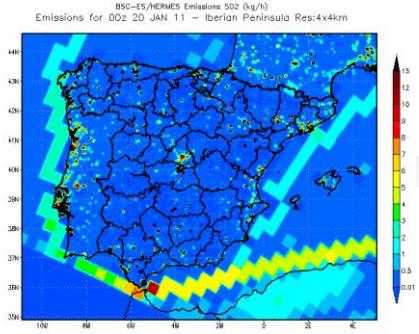
Models in ES-BSC

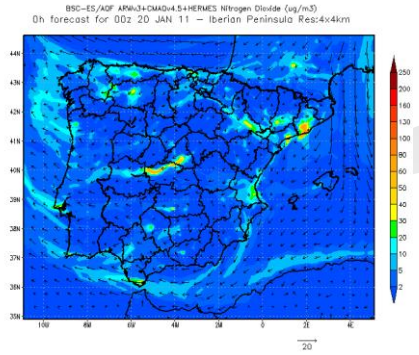
- **Meteorological Modeling**
  - ***WRF: Weather Research Forecasting***
    - **Fortran Code**
    - **MPI, OpenMP and CUDA**

- **Emissions**
  - **HERMES: High-Elective Resolution Modelling Emissions System**
    - **C Code**
    - **Not parallel**

- **Air Quality Forecasting**
  - ***CMAQ: Community Multiscale Air Quality***
    - **Fortran Code**
    - **MPI**



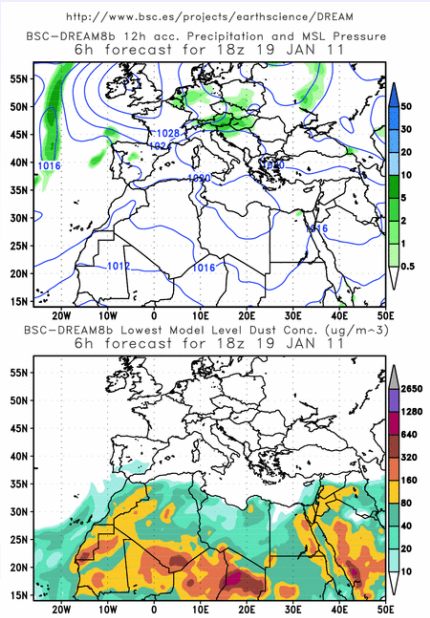


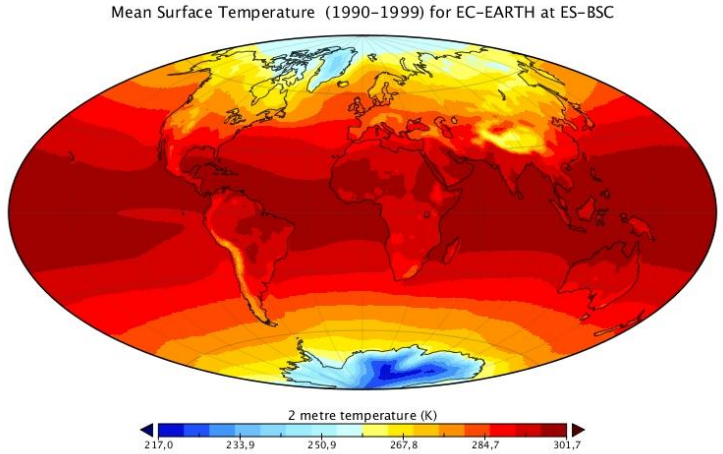


Models in ES-BSC

- Mineral Dust Modeling
  - *BSC-DREAM8b: Dust REgional Atmospheric Model*
  - Fortran Code
  - Not parallel

- Climate Change
  - *EC-EARTH*
  - Fortran, C
  - MPI, OpenMP





Computational Demands

- Which domains are we simulating ¿?
  - Barcelona
  - Catalunya
  - Spain
  - World

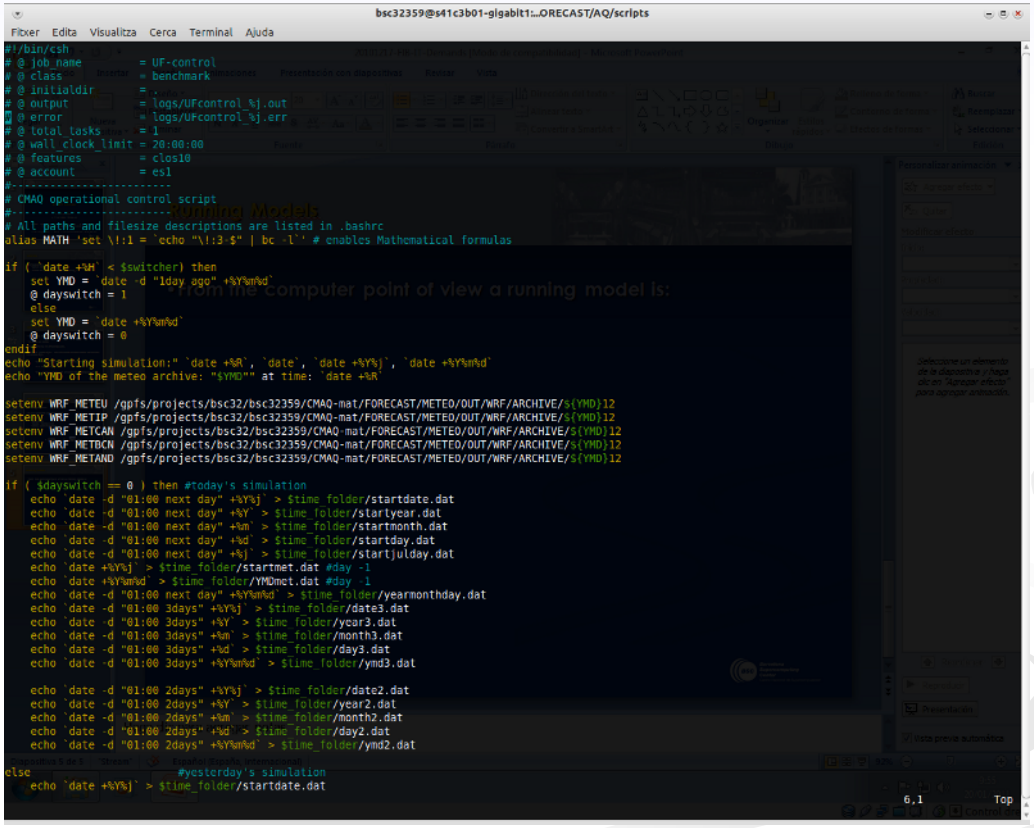
- Which resolution ¿?
  - 1 km^2 4 km^2 12 km^2 50 km^2

- Increasing this parameters, increases the system constraints
  - Computation Needs (CPU's, Memory Bandwith…)
  - Data Storage

- Define this parameters in function of your hardware and time to serve forecast.

Running Models

- From the computer point of view a running model is:

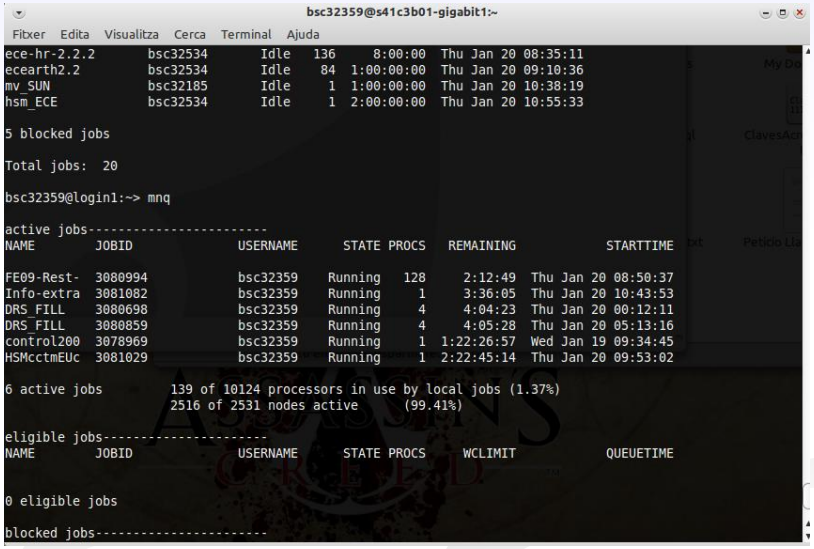


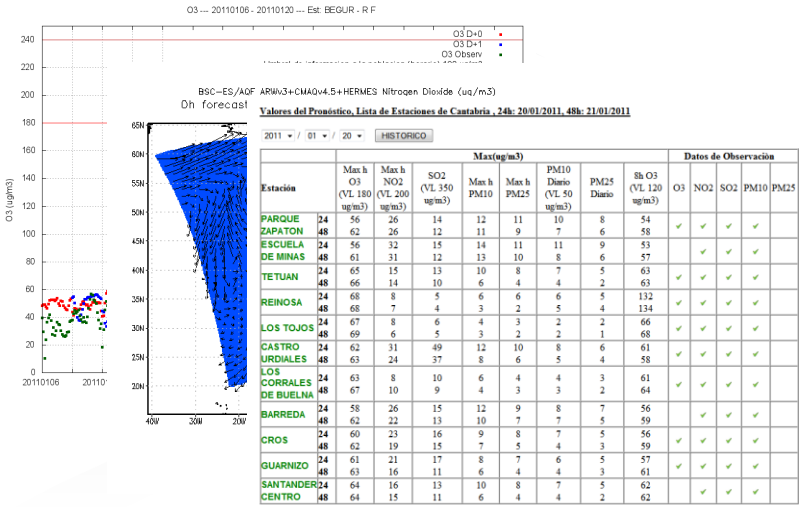
A LARGE SCRIPT

Only the main control has more than1600 lines.

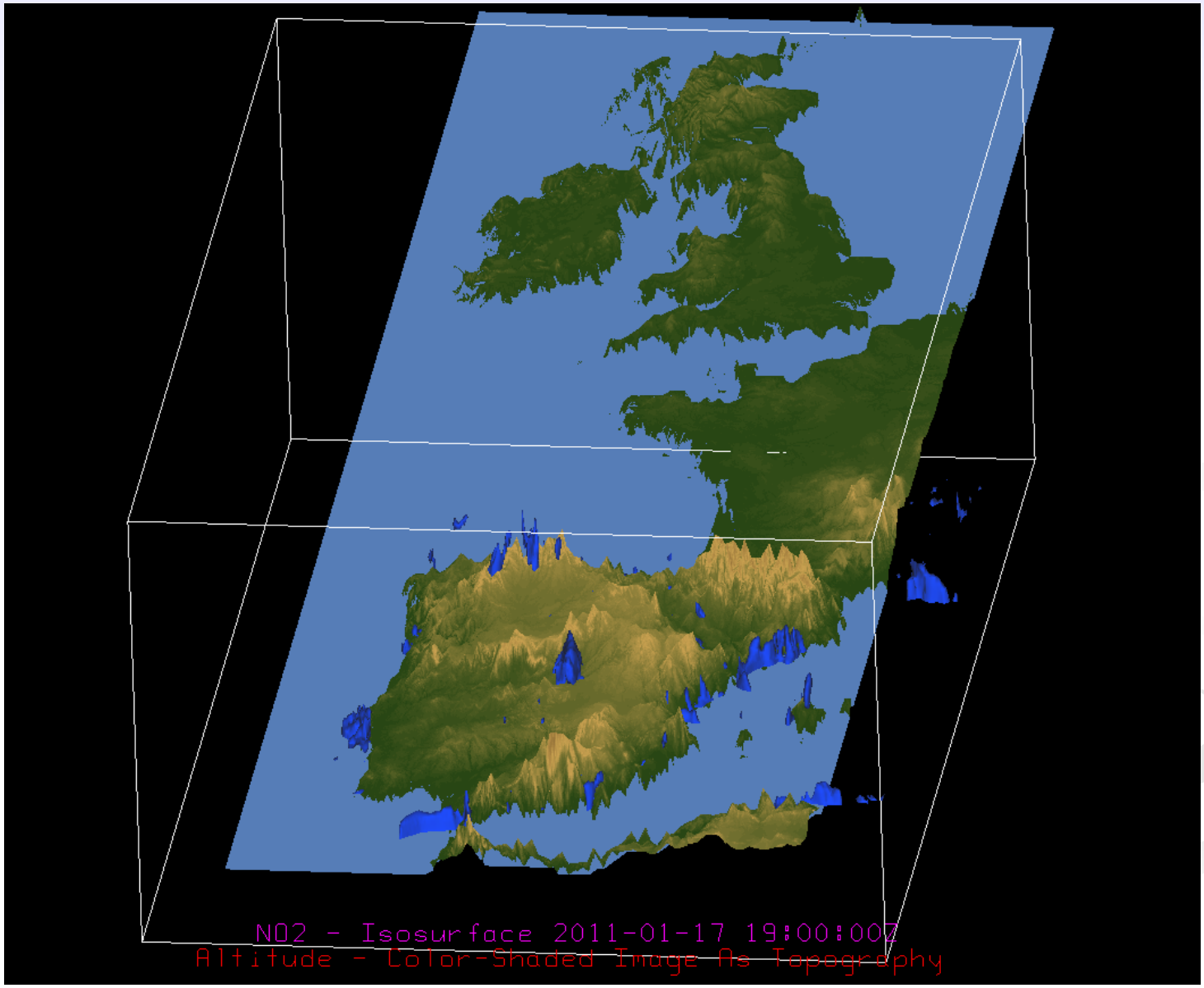
Three principal steps

- Getting initial data and boundary conditions
  - Via FTP
  - From other institutions
- Running Models
  - Intensive calculations
- Publishing results
  - Maps
  - Plots
  - KMZ
  - Data to analyze…





Or even 3D…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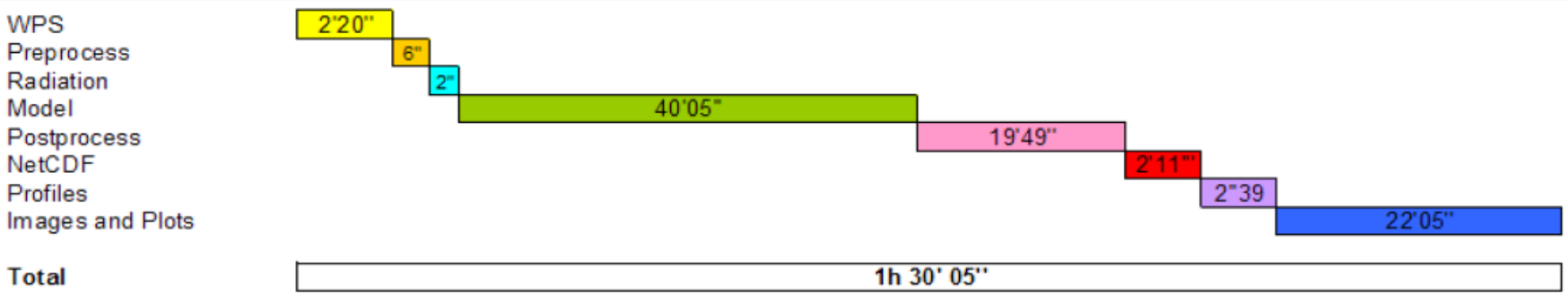
Altitude - Color-Shaded Image As Topography

Challenges of the IT

- Assuring daily execution on the model
  - Crash recovery
  - Monitoring the Model
  - Assuring transfers
- Timing the execution
  - Results have to be on time
- Data Storage
  - Huge size of data
  - Storing and cleaning
- Helping researchers in modeling/running/optimization
- And many more...

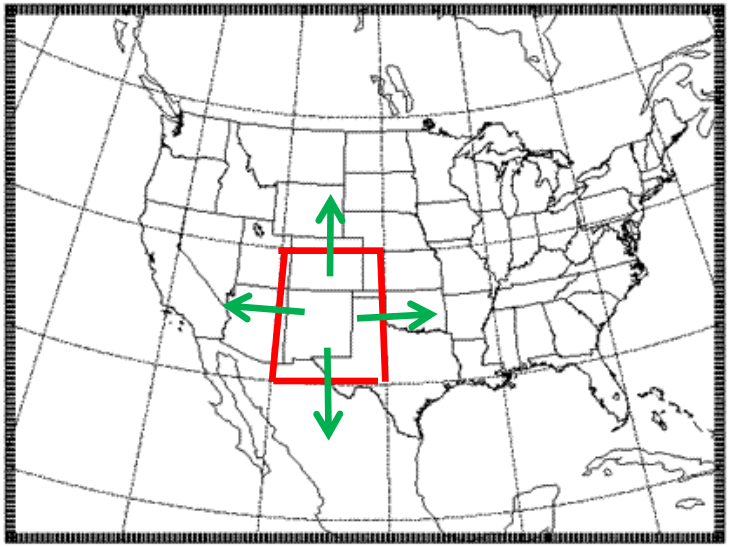
Example: Model Chronogram BSC-DREAM8b



- Different steps involving different executables, data…
- Many failures points
- Data transfers
- Fixed time to run

Parallelizing Atmospheric Models

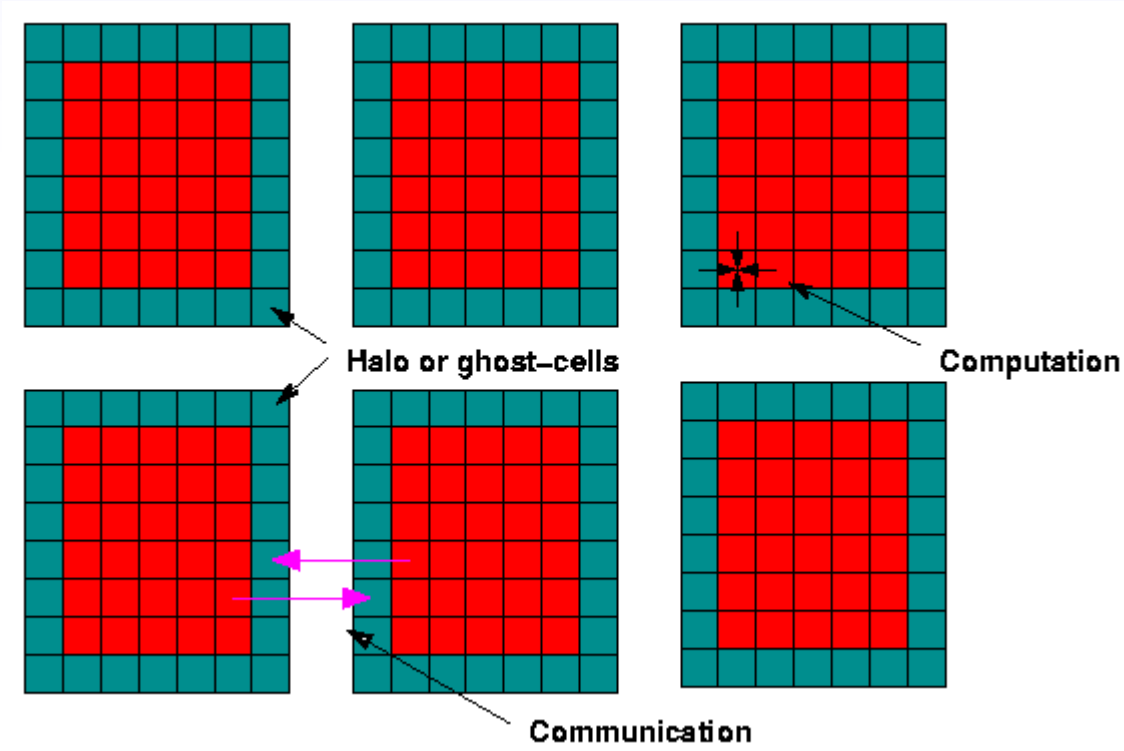
- We need to be able to run this models in Multi-core architectures.
- What's the way to do it ¿?
  - Model domain is decomposed in patches
  - Patch: portion of the model domain allocated to a distributed memory node.



Patch

MPI Communication with neighbours

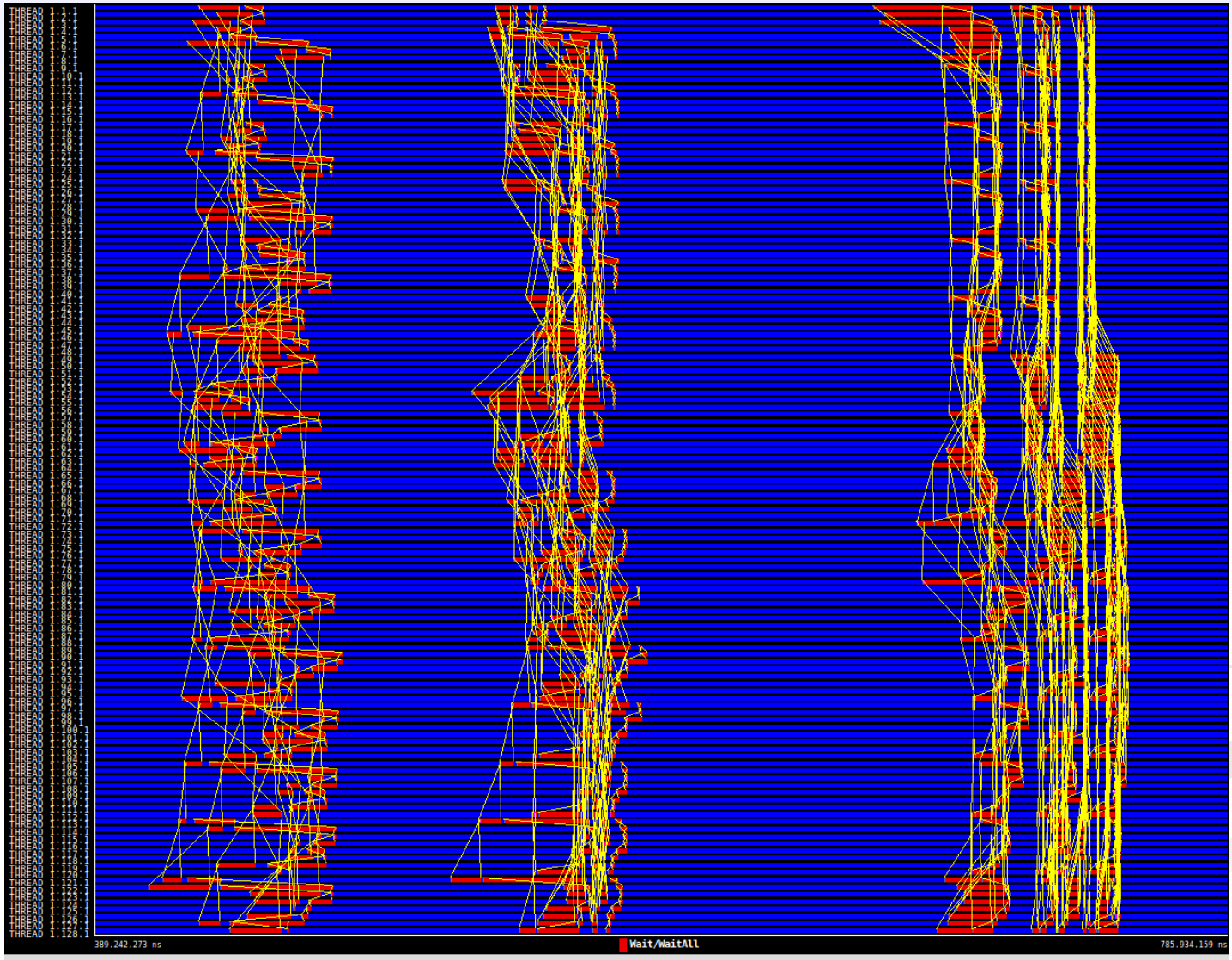
Parallelizing Atmospheric Models



Optimizing Applications

- Multicore applications
- Applications sometimes not scalling correctly.
- We need to find the causes and correct it.
- But how to do it, in a 128 Cores Run ¿?
- These optimizations are highly hardware dependent.
- Also, compiler optimizations.
  - Which flags are the best for our machine ¿?
  - Do I have accurate results ¿?

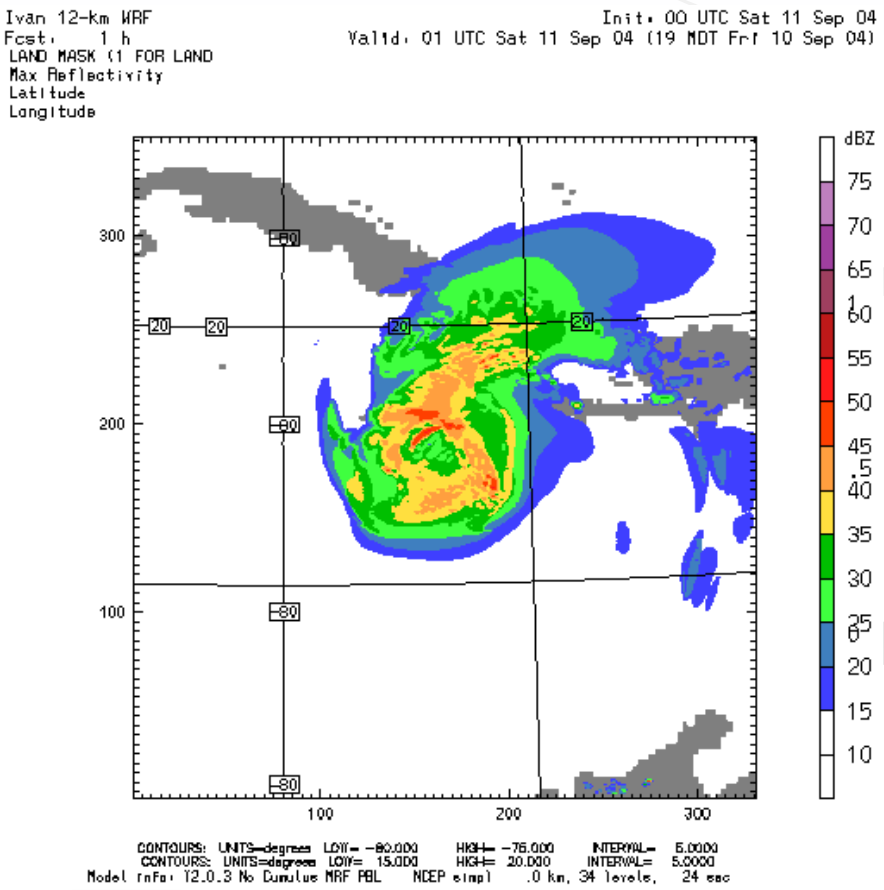
Optimizing Applications



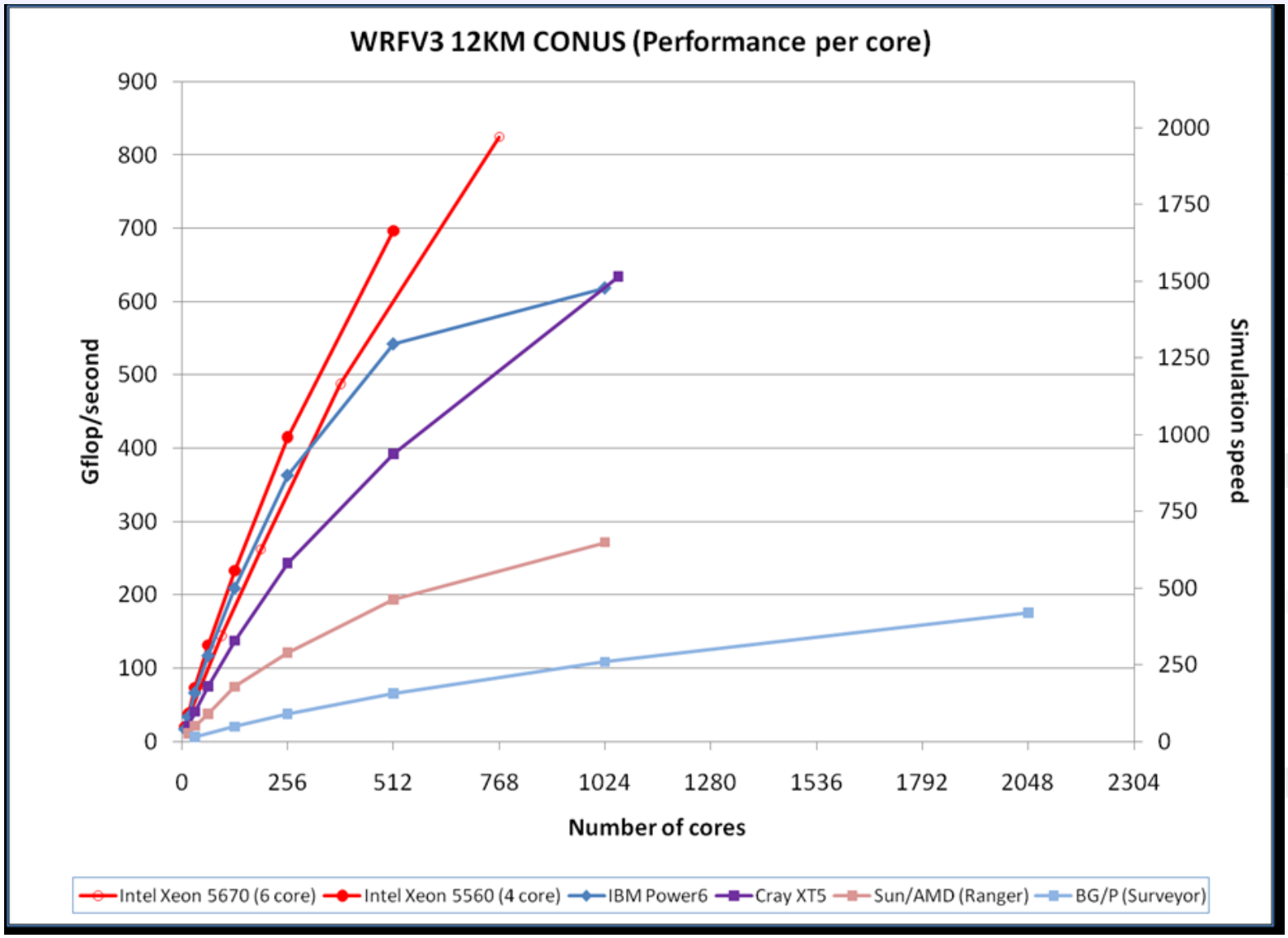
- Idle
- Running
- Not created
- Waiting a message
- Bloking Send
- Thd. Synchr.
- Test/Probe
- Sched. and Fork/Join
- Wait/WaitAll
- Blocked
- Inmediate Send
- Inmediate Receive
- I/O
- Group Communication
- Tracing Disabled
- Others
- Send Receive

Benchmarking

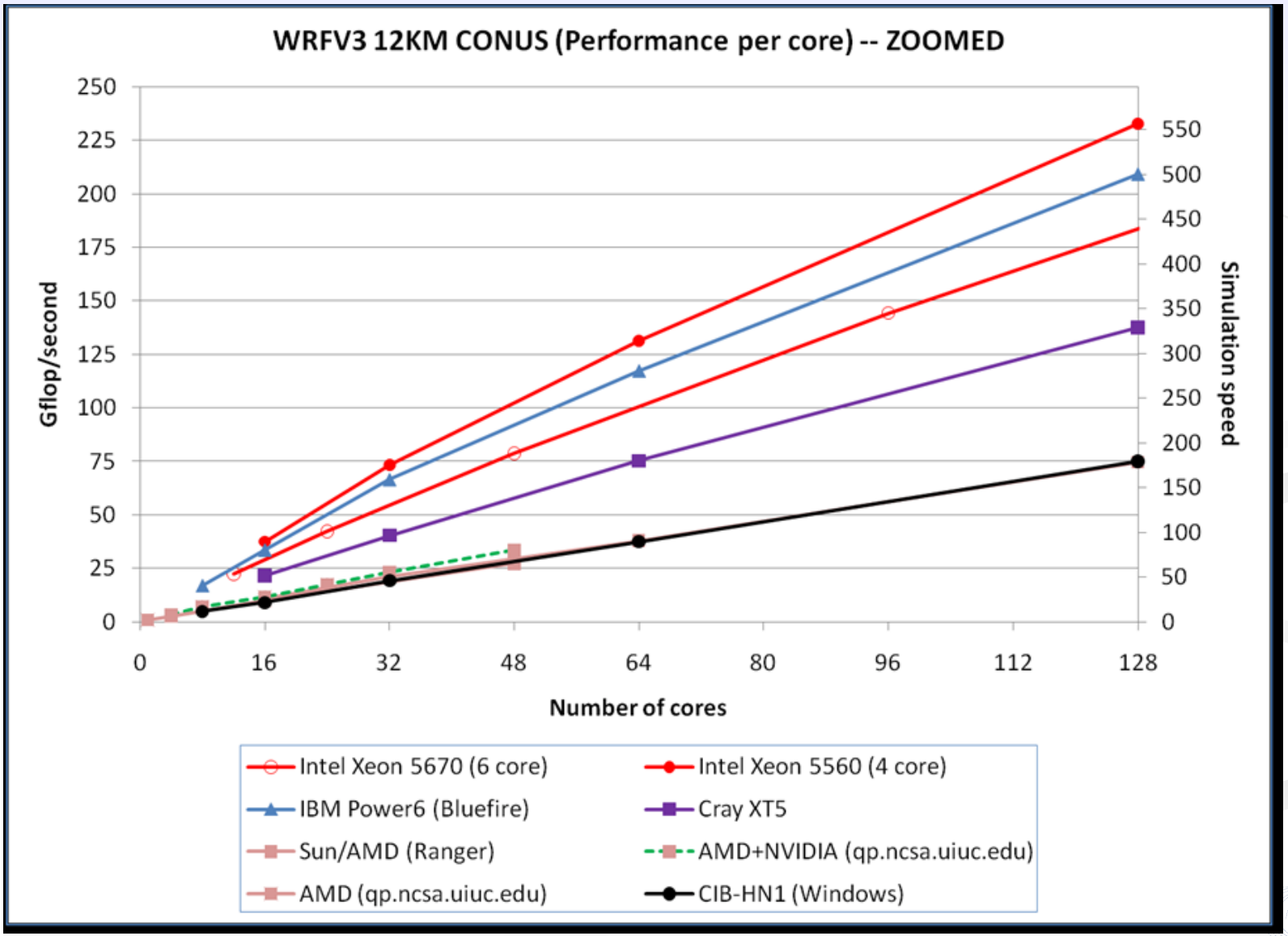
- Compare our execution with other architectures.
- Test cases are defined:
  - Cases with intense activity
- We want to evaluate:
  - Execution time (speed) in our architecture.



Benchmarking



Benchmarking



Further Directions

- Petascale supercomputers to Earth Sciences
- GAEA: The Fastest Supercomputer for Earth Sciences
- In June 2010, installation concluded for a 260-teraflop Cray XT6 system with 2,576 AMD “Magny-Cours” 12-core, 2.1 GHz processors.
- In June 2011, a 720-teraflop Cray XE6 system will be added to Gaea. It will employ the next-generation AMD Interlagos 16-core processor.

Further Directions

- Using GPU's on Earth Sciences
  - Graphics processing units are highly parallel, multi-threaded, many-core processors with a very high computational power and memory bandwidth.
  - Porting code to this new technology.
  - WRF Community started last year (1% code translated can give 20% of speedup).

GRÀCIES !