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A Parallel Processing Algorithm for Gravity Inversion

N. Frasheri, Faculty of Information Technology, Polytechnic University of Tirana

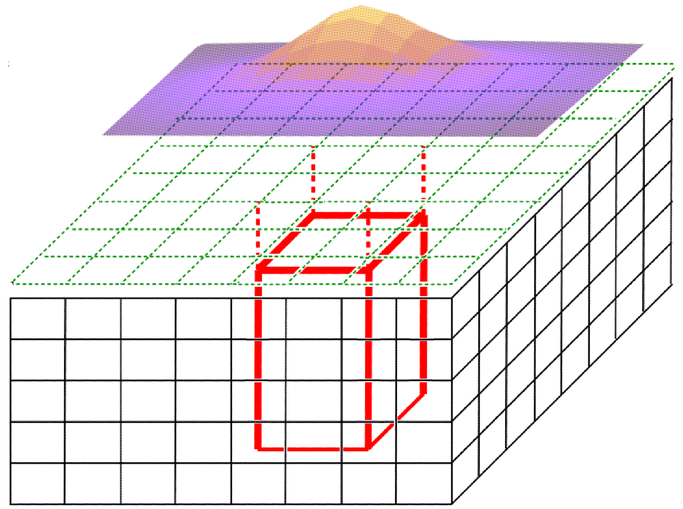
S. Bushati, Academy of Sciences of Albania

A. Frasheri, Faculty of Geology and Mining, Polytechnic University of Tirana

The Project HP-SEE

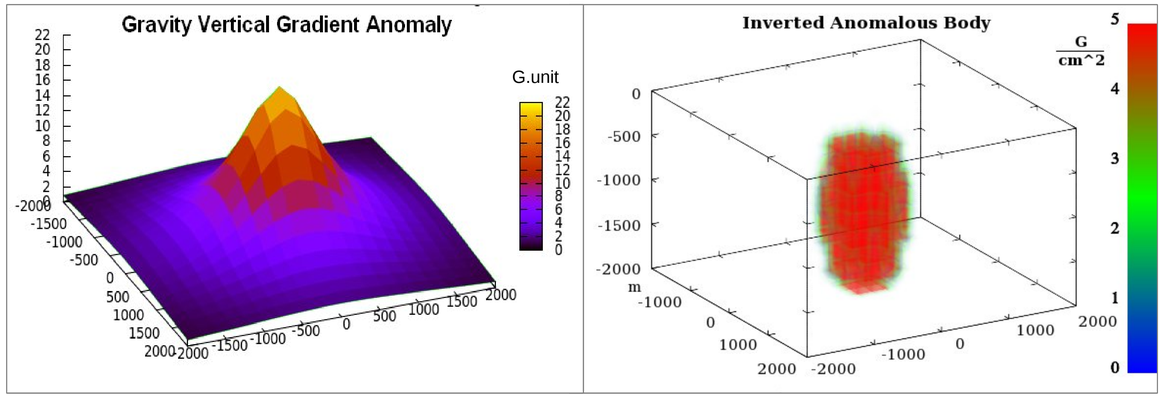
- FP7 Contract n°. RI-261499
- Web site: www.hp-see.eu
- Partners: GR, BU, RO, TR, HU, RS, AL, BA, MK, ME, MD, AR, GE, AZ
- Continuation of SEEREN & SEE-GRID
- In parallel with EGI and PRACE
- Goals: High Performance Computing in South-East Europe and Caucasus
- Application: Physics, Chemistry, Biology and GEANT connection (Caucasus)
- Albania: applications HMLCQD and GIM

- HMLCQD – Hadron Mass Lattice QCD
  - Dep. of Physics, University of Tirana
- GIM – Geophysics Inversion+Modeling
  - Faculty of IT, Polytechnic Univ. of Tirana
- Actual GIM: 3D Gravity Inversion

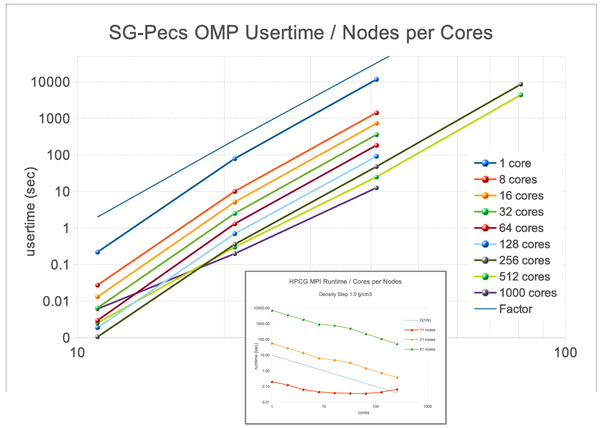


Gravity Inversion and Modeling

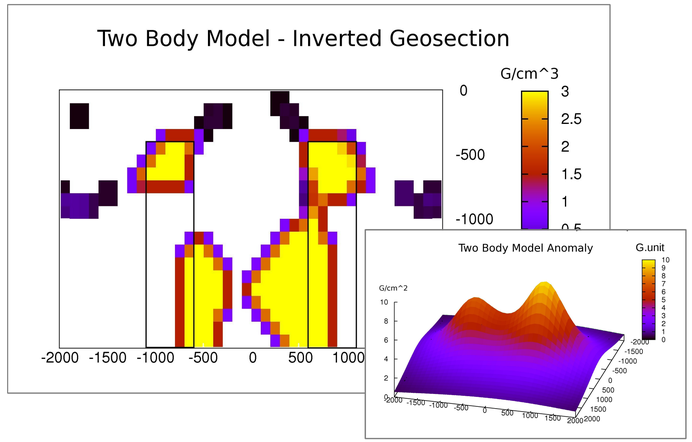
- Iterative approach modifying mass density of single 3D node in each step
- Parallelization with OpenMP and MPI
- Run in IICT-ACAD.BG and NIIFI.HU
  - Up to 1024 computing cores
- Single body model:



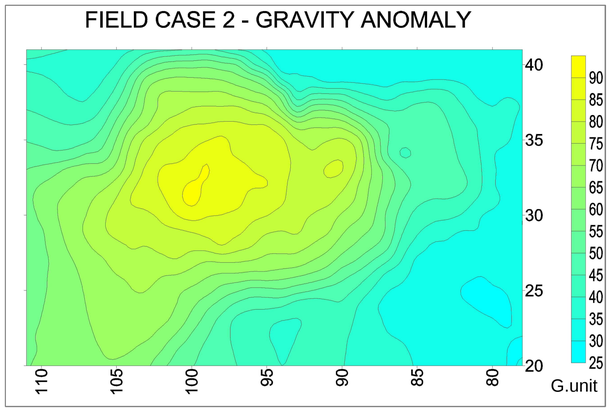
- Scalability:



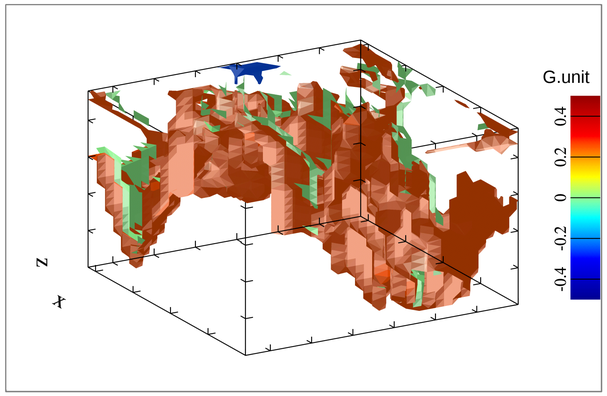
- Two body problem:



- Field case ...



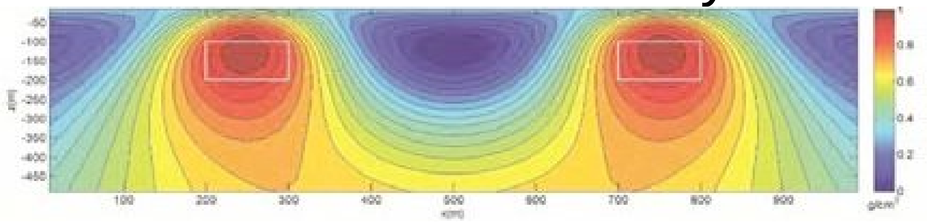
- ... and inversion



3D Gravity Inversion

- Ill – posed problem
  - Extrapolation from 2D into 3D
  - Typical example:

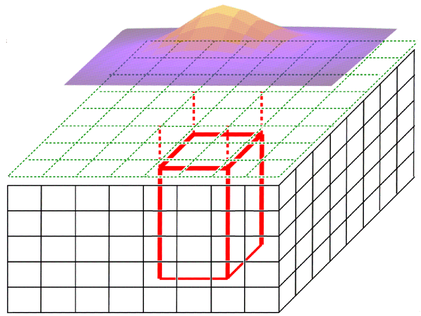
  Lack of contrast and false synclines



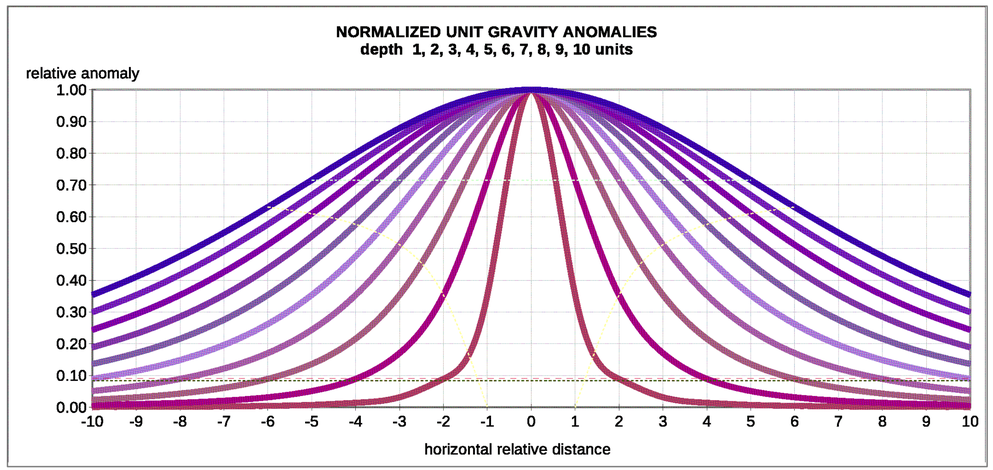
[Zhdanov et al, 2010, ISSN 1448-2177]

- Methodology in GIM
  - 3D array of cuboids
  - Iterative approach
  - Single cuboid in

  each step updated

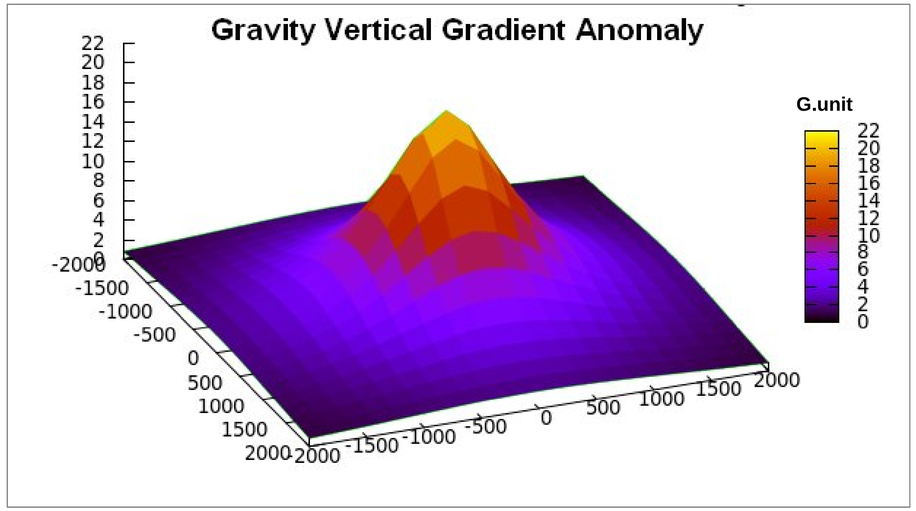


- Selection of cuboid (“3D node”) to update based on best least squares approximation of anomaly shape
  - Weighted least squares
  - Limited within a windows
  - Shape of node anomaly used for weighting and windows size:

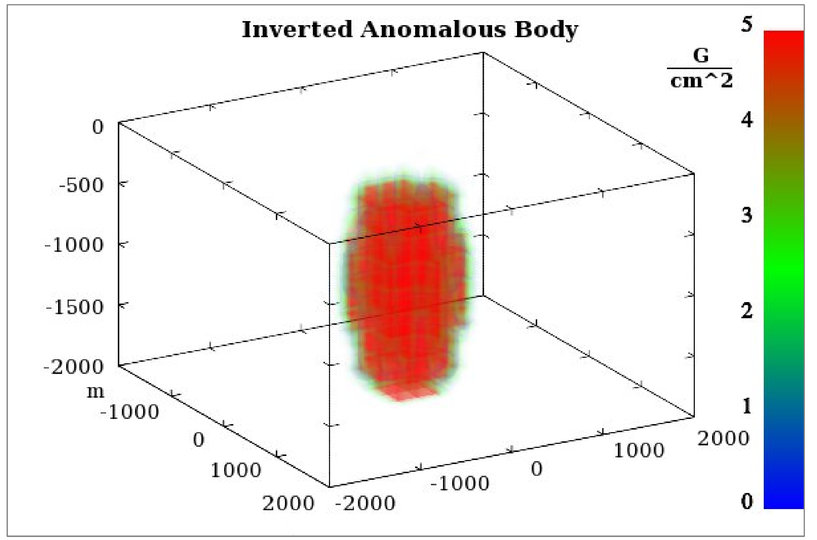


Single Body Model

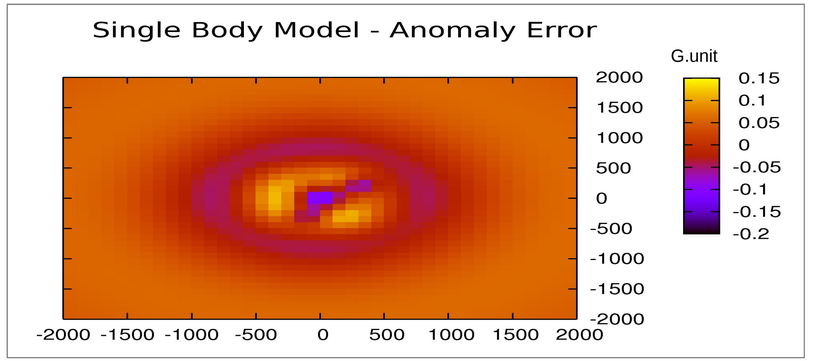
- Geosection 4000m*4000m*2000m
- Discretized up to 81x81x41 nodes
- Single prismatic body model for generation of anomaly and inversion
- Run in up to 1024 computing cores in IICT-ACAD.BG and NIIFI.HU



- Inversion

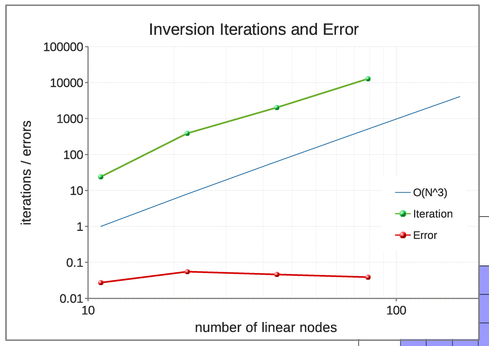


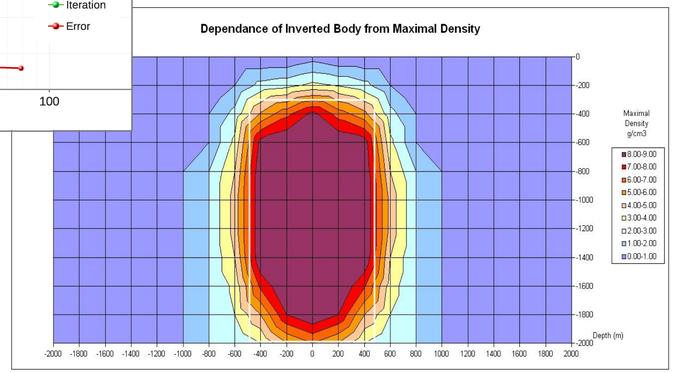
- Anomaly error



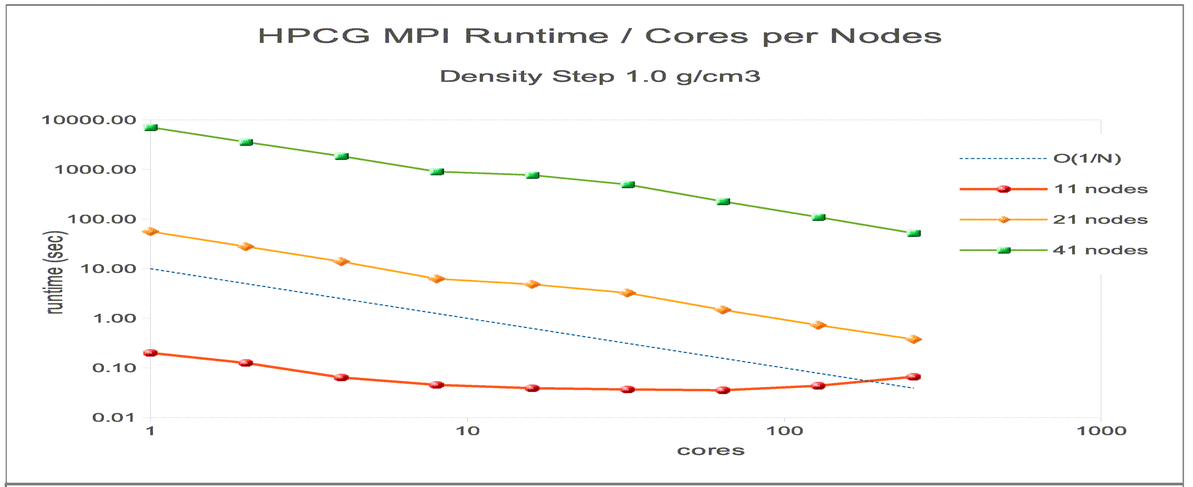
Computing Scalability

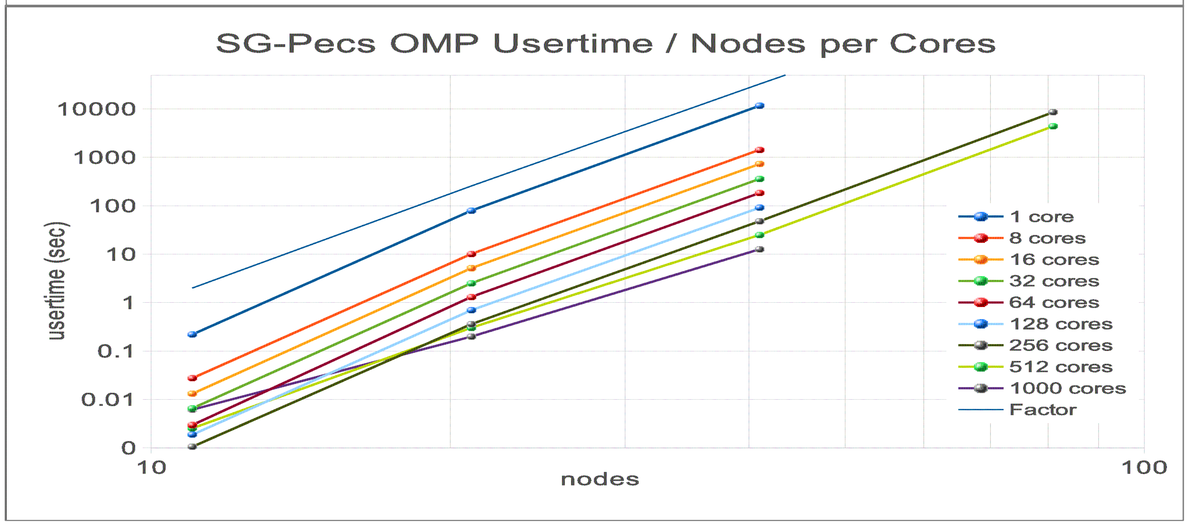
- Algorithm complexity
  - Dependence from number N of geosection edge nodes and maximal permitted mas density
  - Number of iterations O(N^3)
  - Computing runtime O(N^8)





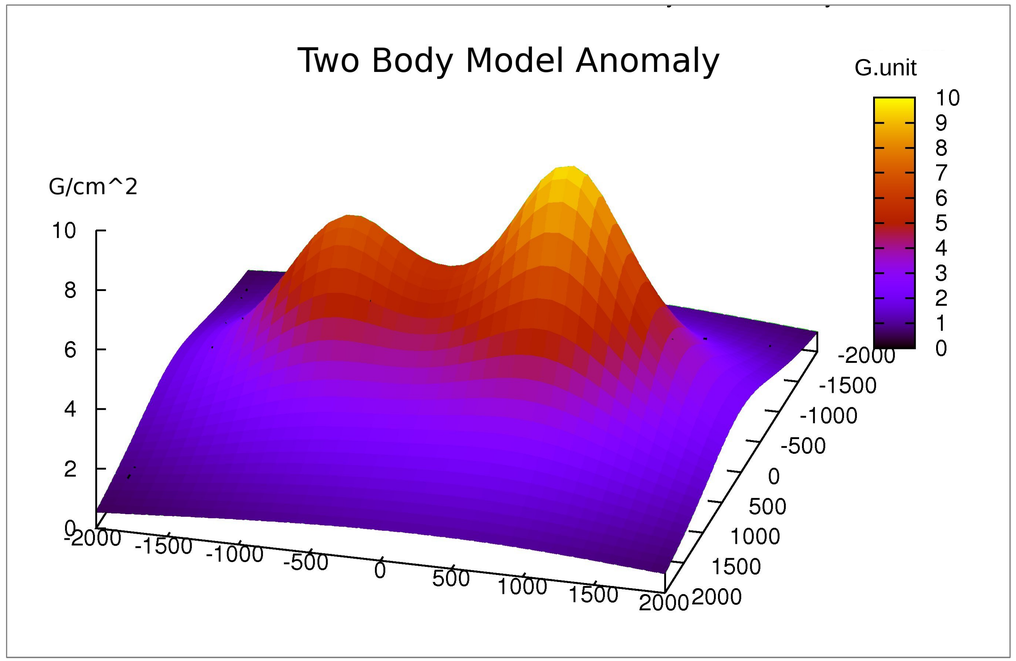
- Runtime scalability



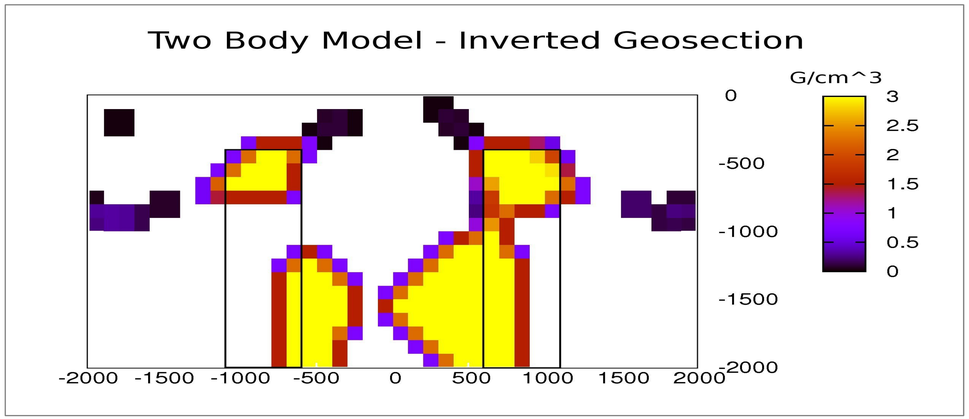


Two Body Problem

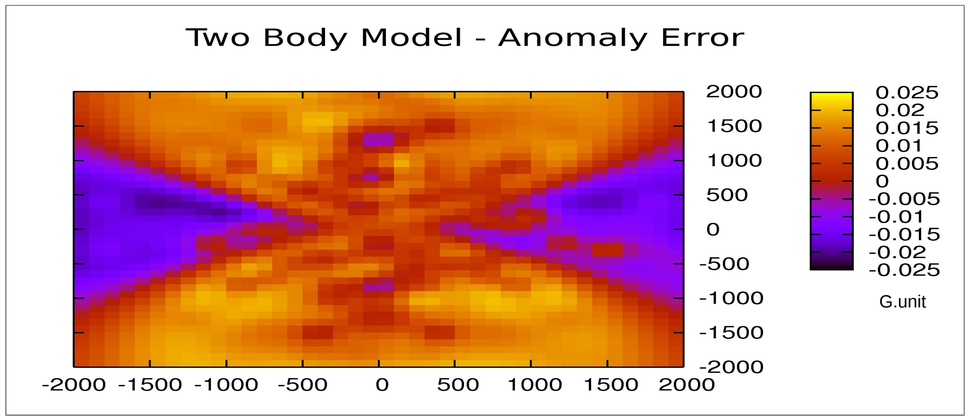
- Clear effect of ill – posed problem
- Two modal anomaly
- Bodies separation difficult in depth ...



- Inversion (central cross – section)

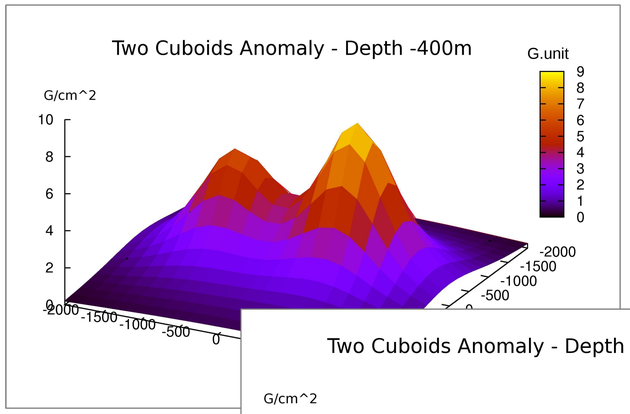


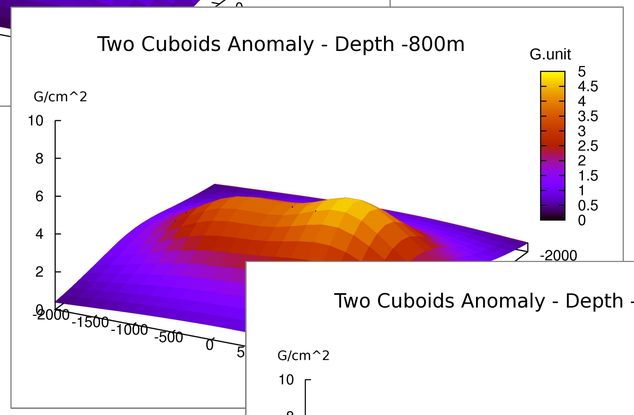
- Anomaly error

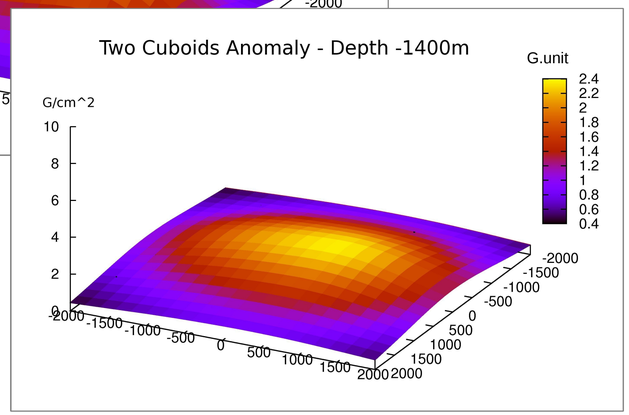


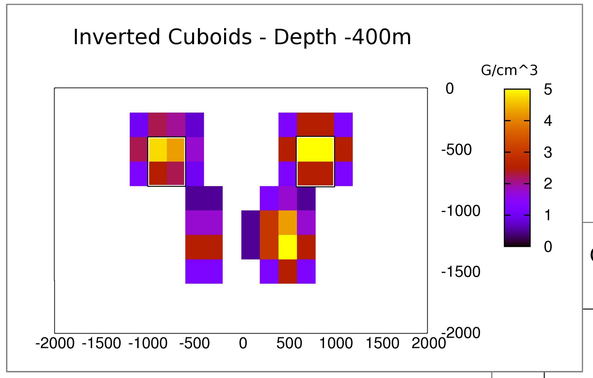
Two Bodies in Different Depths

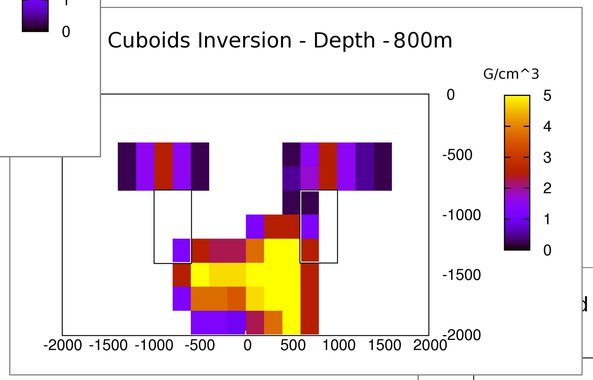
- Anomaly becomes uni–modal in depth
- Two bodies joined in depth
- Only shallow structures differentiate

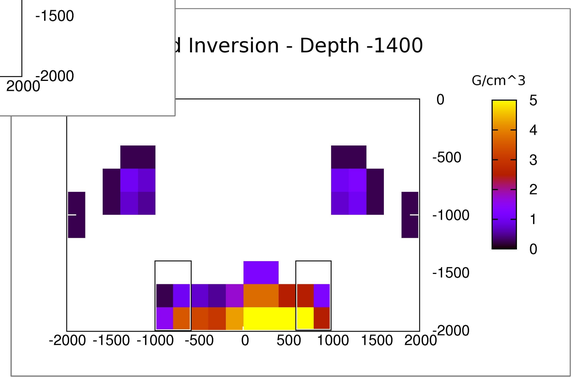






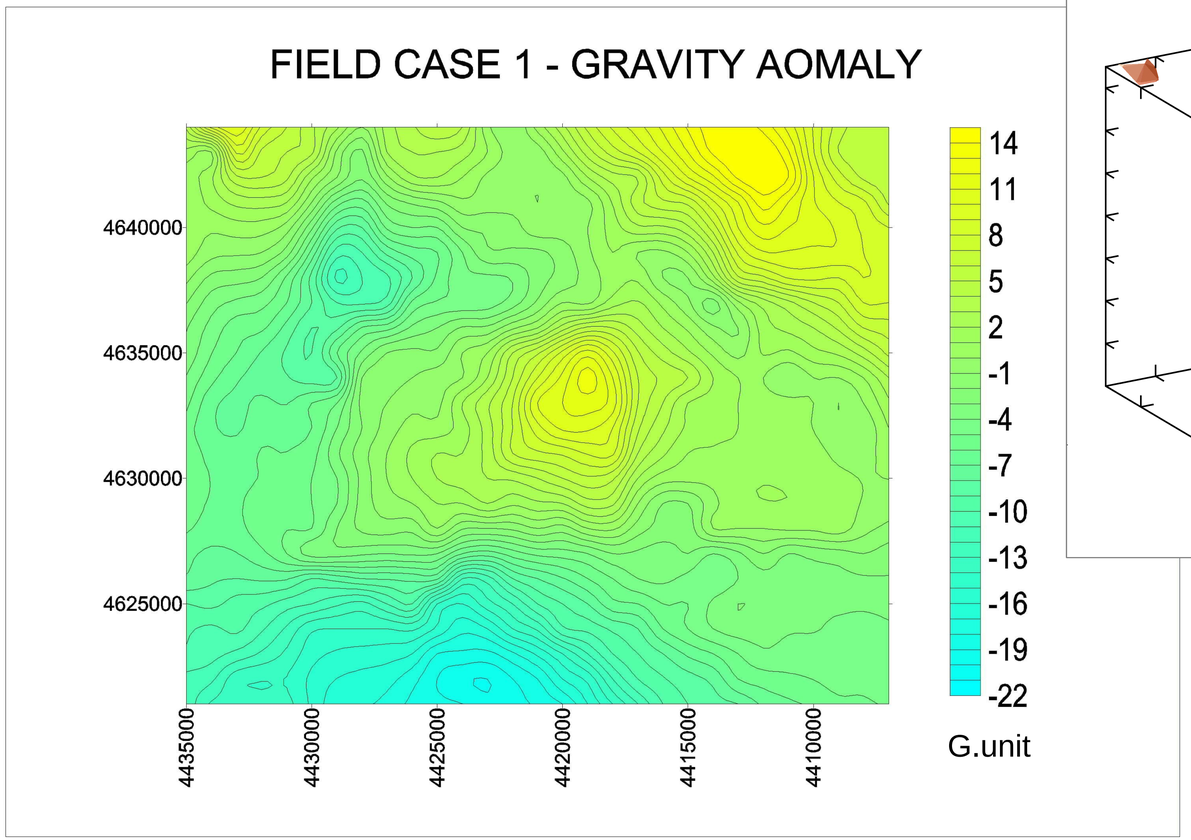


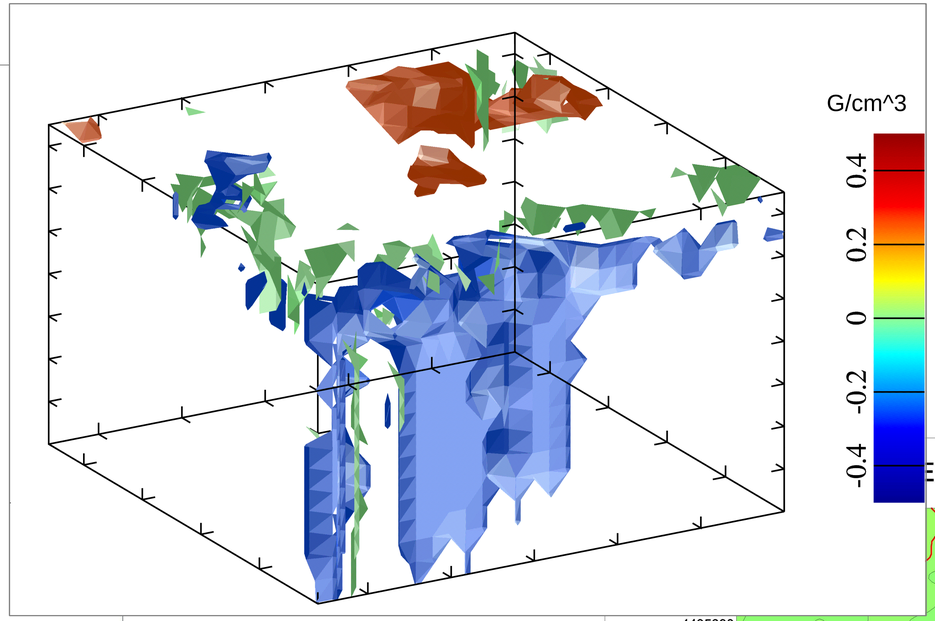


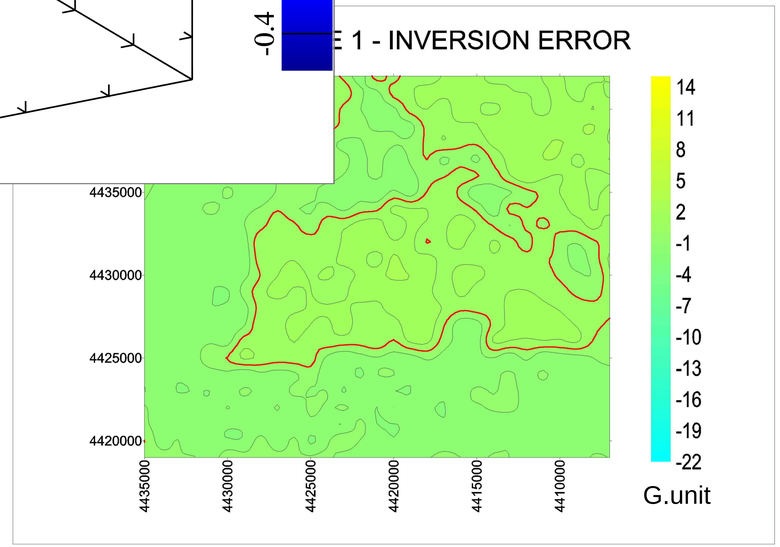


Field Case 1

- Gravity anomaly in Northern Albanides
- Inversion and Anomaly error

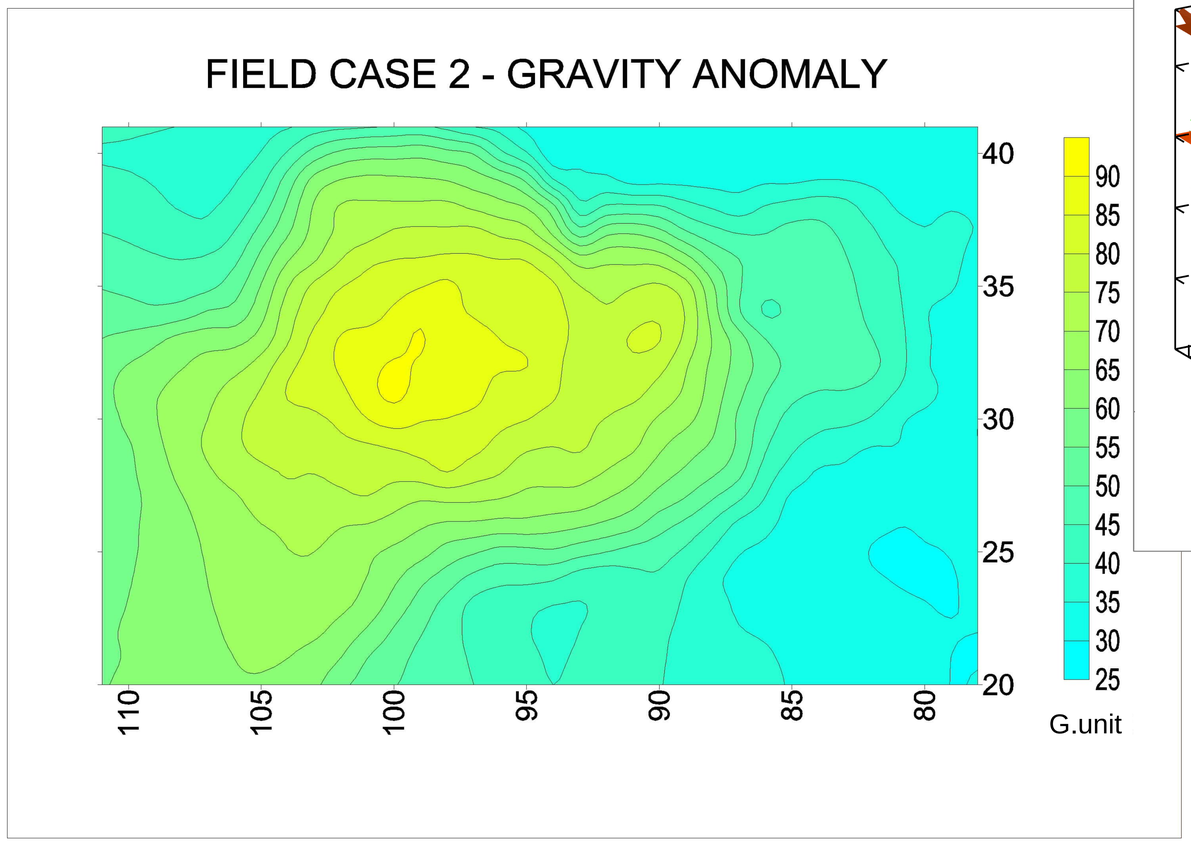


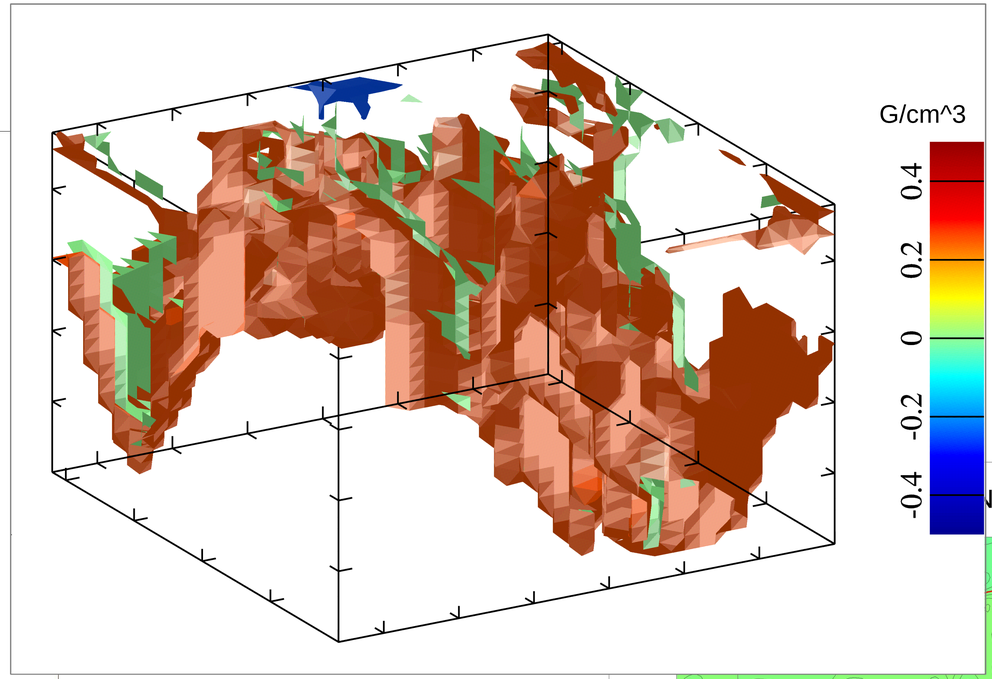


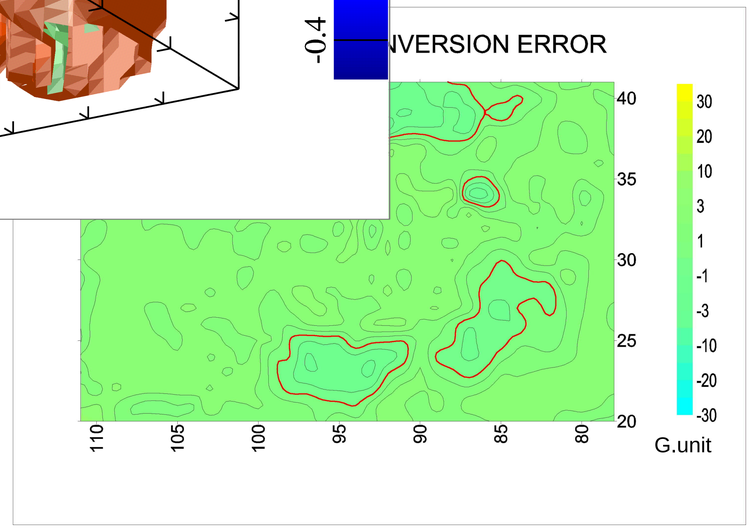


Field Case 2

- Bouguer anomaly in northern Albanides
- Inversion and Anomaly error





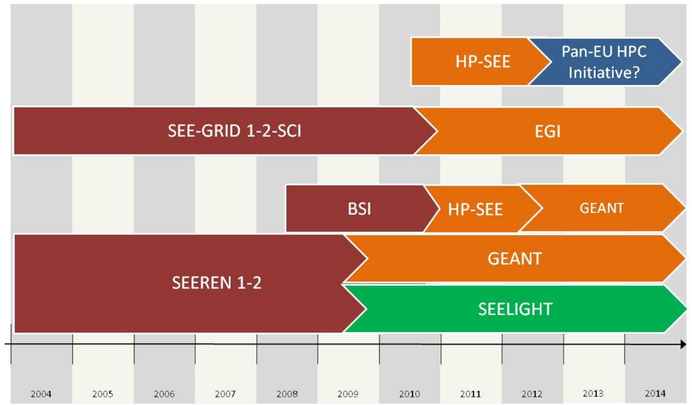


Conclusions for the Algorithm

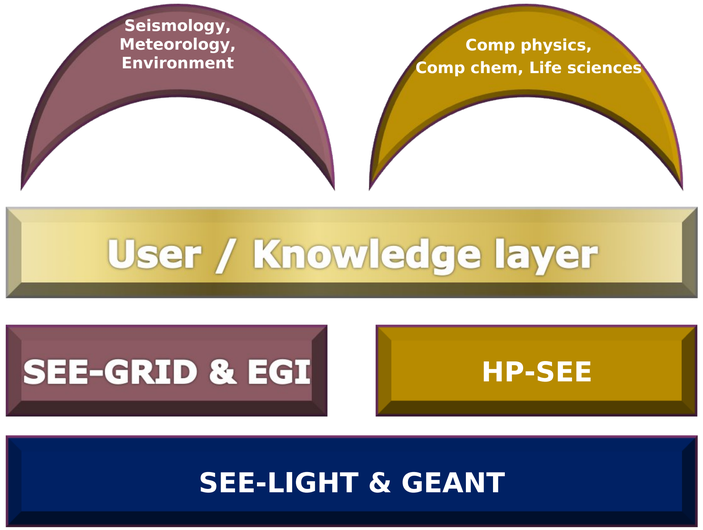
- Search global optimum through local improvement leading to local optimum
- Scalability of runtime in HPC is O(N^8) useful for models with modest resolution
- May be extended for regional magnetic inversion of massive bodies, difficult for cases with thin geological structures
- Sharp contrast of physical properties with surrounding rocks is achieved
- Being ill–posed problem leads to false merging of separate bodies in depth
- Easily deployed in widespread parallel platforms running MPI.
- Future work needed for migration in GPU platforms (desktop and parallel)
- Tests carried out searching the solution from 3D geosections with zero density.
- For the future ...
  - need for tests starting with non–zero geosections, and
  - combination with other optimizing methods

More on HP–SEE : Context and Objectives

- Context and Timeline



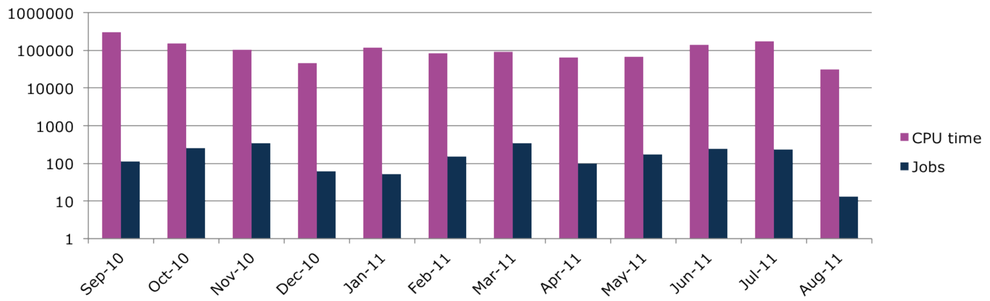
- Context and Model



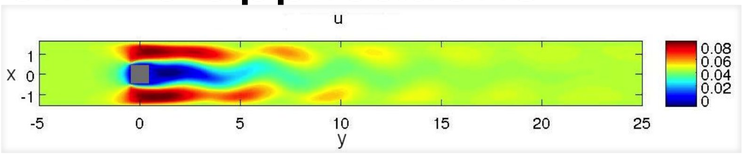
- Objective 1 – Empowering multi-disciplinary virtual research communities
- Objective 2 – Deploying integrated infrastructure for virtual research communities Including GEANT link to Southern Caucasus
- Objective 3 – Policy development and stimulating regional inclusion in pan-European HPC trends
- Objective 4 – Strengthening the regional and national human network

More on HP–SEE : Services and Achievements

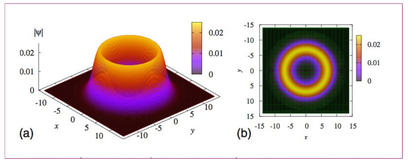
- Regional Operational Services
  - HPC centers in Bulgaria, FYROM, Hungary, Romania, Serbia
  - Cores 23624, Teraflops 115.26
  - Distributed operations services:
    - Resource Management System
    - ARC-LDAP service
    - Accounting System
    - Helpdesk & Monitoring
  - Sample of accounting data



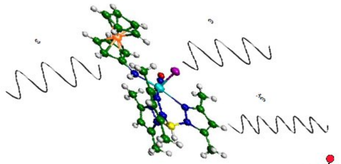
- Selected results from 26 applications
  - gas-microflows



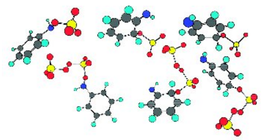
  - ultra–cold quantum gases



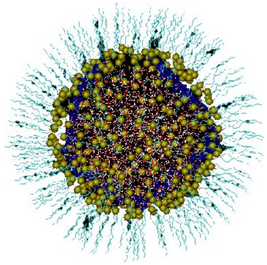
  - materials for photonics



  - quantum molecular mechanics



  - molecular dynamics simulation



  - more than 100 scientific communications

Thank You

Acknowledgments

This work makes use of results produced by the High-Performance Computing Infrastructure for South East Europe's Research Communities (HP-SEE), a project co-funded by the European Commission (under contract number 261499) through the Seventh Framework Programme. HP-SEE involves and addresses specific needs of a number of new multi-disciplinary international scientific communities (computational physics, computational chemistry, life sciences, etc.) and thus stimulates the use and expansion of the emerging new regional HPC infrastructure and its services. The work is supported by the HP Cluster Platform Express 7000 operated by the Institute of Information and Communication Technologies, Bulgarian Academy of Sciences in Sofia, Bulgaria and the SGE system of the NIIFI Supercomputing Center at University of Pécs, Hungary. Full information is available at http://www.hp-see.eu/.

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