SPACEINN WP4 Helioseismology
Deliverable D4.9
Report on local helioseismology working group meeting #1

Coordinated by the Max-Planck-Institut für Sonnensystemforschung (MPG)

The first SPACEINN local helioseismology working group meeting was held on 5 November 2013 (telecon).

Participants for the discussion (15 people):

MPG: A. C. Birch, R. Burston, R. Cameron, L. Gizon (Chair), E. Papini, J. Schou, H. Shunker, K. Nagashima (Minutes), **KIS:** M. Roth, G. Baumann, R. Salhab, **IAC:** E. Khomenko , **CEA:** A. S. Brun, **NWRA:** T. Felipe, **HAO:** M. Rempel

Purpose of the meeting:

To identify and collect simulation codes/results to make available to the helioseismology community through the web site.

Meeting agenda:

Time (UTC+1)	Session Titles	Session Goals
Morning Sessions		
9:00-9:30	1. Spherical-shell simulations of magnetoconvection (and rising flux?)	Which datasets $\xi(r,\theta,\phi,t)$ could be made available? What for?
9:30-10:00	2. Numerical simulations of linear waves/modes in complex media	Make available codes and useful datasets. What needs improvement
Evening Sessions		
16:30-17:00	3. Synthetic global-mode observations and observational & instrumental effects	What effects matter and should be included in models?
17:00-17:30	4. Box simulations of compressible magnetoconvection	Make available useful (small) datasets.

Summary of the sessions:

Session 1. Spherical-shell simulations of magnetoconvection

Main goal: What datasets could be made available? What for?

We identified three anelastic simulations and one simulation with reduced sound speed:

MHD codes	contact person	Properties, Reference
ASH (Anelastic Spherical Harmonic) **simulation**	A.S. Brun (CEA) Any of Sacha Brun's 2-D or 3-D data are available on demand, HD or MHD.	3D anelastic HD and MHD simulations based on spherical harmonics decomposition for horizontal part. Shell up to 0.98 Rsun, full sphere (r=0) now possible. **References:** ● Miesch et al. 2000 ● Brun & Toomre 2002 ● Brun, Miesch & Toomre 2004: MHD version of ASH more relevant ref) ● Jouve & Brun 2009: flux emergence in fully developed convection zone ● Pinto & Brun 2013: flux emergence in magnetized (dynamo) fully developped convection zone ● Jouve, Aulanier, Brun 2013: flux emergence of omega loops ● Nelson et al. 2011, 2013a, b: self-consistent magnetic wreaths and omega-loop generation in dynamo
		What we need to think to implement dynamics to the simulations (Suggested by A.S. Brun): ● Latitudinal dependence of emergence properties (timing, strength ...) ● Radial (temporal evolution as it emerges) dependence of emerging structure (is tilt already present at 10 Mm below the surface for instance?) ● Correlate flux to MC flow perturbations (as in Svanda et al. 2008)
MagIC	Wicht (MPG) Availability: To be confirmed.	Stellar simulation developed by planetary people **References:** ● Wicht 2002 Physics of the Earth and Planetary Interios 132, 281-302 ● Gastine and Wicht 2012 Icarus 219 428-442
MHD EULAG	Charbonneau (Universite de Montreal) Availability: To be confirmed.	Global MHD simulation of convection zone (Anelastic simulation). **Reference:** ● e.g. Cossette, Charbonneau, Smolarkiewicz 2013, ApJL 777 L29

AMaTeRAS (AMR Magnetohydrodynamics code for Technique of RSS for Astro- and Solar physics)	H. Hotta (Univ. Tokyo), M. Rempel (HAO) Availability: Contact them if you need data.	With reduced sound speed. (This has acoustic modes!) Not to the pole, up to 0.99Rsun, lmax~500, spherical shell, some months? **Reference:** ● Hotta et al. 2012 A&A Vol. 539 A30

Session 2. Numerical Simulations of linear waves/modes in complex media

The available codes and datasets are listed below:

SPARC and Glass

SPARC: linear HD, plane-parallel geometry

Glass: HD, 3D spherical geometry - full sphere

Contact person: S. Hanasoge, E. Papini (MPG)

Reference: http://www.mps.mpg.de/projects/seismo/sparc/

Availability: SPARC codes can be downloaded from the website

SLiM code (Semi-spectral Linear MHD code)

Simulation of wave propagation through an inhomogeneous, magnetised solar atmosphere

Contact person: R.Cameron, H. Schunker (MPG)

Reference: http://www.mps.mpg.de/projects/seismo/SpaceInn/MODEL/SLiM.html

Cameron et al. 2007 AN vol. 328, p.313

Availability: older version is available on the web. For newer version, ask Cameron for details.

IAC MHD Mancha code (current version)

2.5D/3D magnetohydrodynamical code with hyper diffusion algorithms and Cartesian grid written in Fortran 90 (see below for details).

Contact person: Felipe(NWRA), Khomenko(IAC)

Reference: http://www.iac.es/proyecto/spia/

Felipe, T., Khomenko, E., Collados, M., ApJ, 2010, Vol. 719, p. 357.

Availability: Contact the persons above.

The IAC MHD Mancha code is developed by T. Felipe, E. Khomenko and M. Collados at the Instituto de Astrofísica de Canarias. The current working version of the code is 2.5D/3D magnetohydrodynamical code with hyper diffusion algorithms and Cartesian grid written in Fortran 90 (2.5D means that all vector quantities are in three dimensions, while the derivatives are only done in two dimensions). The code evolves in time non-linear perturbations to a given MHS equilibrium. Spatial discretization is based on a six-order center-difference scheme. The numerical solution of the system is advanced in time using an explicit fourth-order Runge-Kutta scheme. The boundary condition for waves includes a Perfectly Matching Layer (Berenger 1994) allowing to avoid spurious reflections from the boundaries. The code is fully MPI-parallelized using the distributed memory concept (domain decomposition). The Mancha code has been fully tested and extensively used on PowerPC 4 machines like MareNostrum/BSC. It reaches good scalability up to a high number of CPUs (e.g., 512 CPUs), if not including radiative transfer aspects. It is proprietary code. Descriptions of this code can be found in research article Felipe et al. 2010 (ApJ).

IAC MHD Mancha code (new version)

(see below for details)

Contact person: Felipe(NWRA), Khomenko(IAC)

Reference: http://www.iac.es/proyecto/spia/

Availability: Newer version available at the webapge within 1 year

The newer version of this code (currently under development) includes the treatment of non-ideal plasma effects by means of generalized Ohm's low, as well as calculation of radiative energy exchange term solving Radiative Transfer Equation. It solves quasi-MHD equations with some additional terms in the energy and induction equation that appear as a consequence of the presence of a large amount of neutral atoms in the solar atmosphere. Apart from the classical Ohmic term those additional terms are: Ambipolar diffusion term, Hall term and Biermann battery term. The neutral fraction is evolved in the code by means of Saha equation assuming instantaneous ionization equilibrium between the species. Such description is appropriate in the limit of strong collision coupling between the species. The description of the this non-MHD version of the code can be found in: Khomenko, E., Collados., M. The Astrophysical Journal, Volume 747, Issue 2, article id. 87. Currently, adaptive mesh refinement is being introduced in the code (PARAMESH package). They plan to make this version generally available at our web page within one year, approximately.

SAC code

Contact person: Sheffield group?

Reference: Shelyag et al. 2008 A&A Vol. 486, p.655, Shelyag et al. 2009 Vol. 501, p.735

Pencil code

Reference: http://pencil-code.nordita.org/

Availability: open, extendable code

Artificial helisoseismology data by Thomas Hartlep

Numerical simulations of helioseismic oscillations in a 3D full sphere Sun.

Several datasets with different setups are available.

Contact person: Thomas Hartlep

Reference: http://sun.stanford.edu/~thartlep/Site/Artificial_Data/Artificial_Data.html

Availability: Datasets are downloadable from the website

Artificial helisoseismology data by Konstantin Parchevsky

3Dsimulation of acoustic waves in the solar upper convection zone.

Need to check the status.

Contact person: Konstantin Parchevsky

Reference: e.g., Parchevsky & Kosovichev 2007 ApJ Vol. 666, p.547

Session 3. Synthetic global-mode observations and observational effects

Main goal: Survey of general interest. What effects matter and should be included in models?

Observational effects identified

1. Point spread functions
2. Wavelength filters
3. Map scale and remapping
4. Line formation heights, phase changes with height as a function of center to limb distance

Proposed solution: Artificial Dopplergrams

Simulate observations including all instrumental effects and mode physics

Session 4. Box simulations of compressible magnetoconvection

Main goal: Select and make available useful datasets

We listed up the box simulations and checked their properties as well as availability.

Code	Description (data size, property etc.)	Notes	Reference, data availability, and any comments
MURaM	http://www.mps.mpg.de/projects/solar-mhd/muram_site/index.html What is already available @MPG: ● Lots of snapshots ● shorter time series (smaller box, 1-2hr, high-cadence) Mathias's data examples: ● 50Mm wide,16Mm deep, 24-48hr ● Sunspot data: 75Mm wide, 9Mm deep, 24hr ● Another sunspot data: 100Mm wide, 18Mm deep, 60hr ● QS data: 100Mm wide, 18Mm deep, 30hr ● Biggest data: 200Mm wide, 50Mm deep, 10days? w/ 192km resolution	for helioseismology study, - full resolution needed? (300km in horizontal, 100km in vertical) - longer time series needed (usually only limited slices are saved)	**Reference:** Vögler et al 2005 A&A Vol. 429 p. 335. Datasets will be open on the website. Currently no well-prepared documents for users.
STAGGER	http://steinr.pa.msu.edu/~bob/data.html ● Some datacubes are available online. ● Datacubes available @MPG: 96Mm x 96 Mm x 20Mm, ~5hr (calculation itself in total ~24hr), Quiet Sun (but with weak magnetic field)	Need to clarify boundary condition issue...?	**References:** e.g., Stein et al. 2009 AIPC Vol. 1094, p.764 Stein et al. 2009 ASPC Vol. 416, p.421 Stein 2012 LRSP Vol.9 no.4 The newest datacube has no updated reference?

Bifrost (Oslo)	Stellar atmosphere simulation from the convection zone to the upper atmosphere (corona). Included non LTE Small box region.	Not yet used for helioseismology analyses? Mainly used for spicules or chromosphere studies.	**References:** Gudikson et al. 2011, A&A Vol. 531, p.154
CO5BOLD	http://www.astro.uu.se/~bf/co5bold_main.html 3D radiative hydrodynamics simulations for several temperature stars, including 5700K stars (Sun). Typical property: 5Mm (horizontal), 2Mm (vertical), up to ~0.5Mm above the surface		**References:** Nutto, Steiner, Roth 2012 A&A Vol. 542, L30 Freytag et al. 2012 JCoPH Vol.231, p.919
Student in Yokoyama-san's group in Univ. Tokyo	large-scale convection, cartesian (quite impressive)	not yet published (Contact person: Mr. H. Iijima in Dr. Yokoyama's group in Univ. Tokyo)	
Pencil Code	http://pencil-code.nordita.org/ radiative transfer is also implemented.		Codes are open to public. To know the know-how it takes time though.

Outcome of the meeting

Following the discussions we made at this meeting, the selected data sets were made available under the 'Simulated Data' webpage in the SPACEINN local helioseismology website: http://www.mps.mpg.de/projects/seismo/SpaceInn/SimData/index.html .
(See Deliverable D4.8)