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International collaboration - Global Oscillation Network Group (GONG)

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Abstract. Global Oscillation Network Group (GONG) is a community based International programme to study the solar interior through the use of the technique of helioseismology. The GONG programme was initiated at the National Solar Observatory, Tucson with the support of the National Science Foundation, USA. Helioseismology requires nearly continuous 24-hour observations of solar surface oscillations. After a thorough site evaluation of 15 potential sites distributed almost evenly around the globe, six sites were selected for installation of identical GONG instruments. This network of 6 stations has started operating since October 1995.

1. Introduction

The discovery of propagating sound waves in the Sun, with periods of about 5 minute has provided a marvellous new tool to infer Sun's internal structure and dynamics. This new approach to study the solar interior is called 'helioseismology'. Prior to the advent of helioseismology, our understanding of some of the most important process in Astrophysics was limited to indirect inferences from theories, that tried matching computer models with global solar properties: radius, luminosity, mass composition and presumed age. Helioseismology provides far more stringent tests of stellar structure and evolution theory.

Convection noise excites millions of distinct mode of oscillation which are emitted from the Sun's surface. These waves are trapped in resonant cavities, bounded on the outside by the solar surface and on the inside by refraction due to the increasing temperature with depth. The frequency of these resonant waves depends on their propagation speed and cavity depth. The large number of modes, with different cavity depths allows us to construct extremely narrow probes of temperature, chemical composition and motions at different levels, from just below the surface down to the very core of the Sun.

Accurate measurement of wide range of frequencies will permit both forward and inverse deductions of the Sun's internal structure. For example, the comparison of oscillation frequencies predicted from Solar models with those actual observations has yielded more accurate measurement of helium abundance in the Sun. Similarly, measurements of rotationally induced mode frequency splitting will permit the inference of the internal rotational profile in both

radius and latitude. Observations of mode frequencies in local areas will permit the measurement of subsurface flow structure, as well as permit inferences about the internal structure of magnetic features, such as sunspots and active regions.

The major obstacle in utilising this exciting new tool is the interruption in the observations imposed by the day and night cycle at a single observatory, which introduces a fundamental uncertainty in the determination of the periods of waves, as well as creating background noise that hides all but the strongest oscillations. This limitation can be over come by several ways. Observations from Earth's south pole have provided very useful, week long observations... However there is a little prospect for extending this significantly. Observations have recently started from SOHO spacecraft located at the lagrangian point L1 with Solar Oscillations Imager (SOI-MDI), Variability Irradiance and Gravity Oscillations (VIRGO), Global Oscillation at Low Frequency (GOLF) experiments. While these spacecraft experiments enjoy atmospheric distortion free continuous imaging of the Sun, the satellite communication's bandwidth and short life span spacecraft limit their usefulness to a large extent.

The Global Oscillation Network Group (GONG), sponsored by the National Science Foundation, USA, and operated by the National Solar Observatory, Tucson, has chosen Earth based network approach to conduct a detailed helioseismic study of the solar interior. Earlier to this effort, there were several networks such as the Nice group's IRIS, Birmingham group's BISON and Henry Hill's - Arizona's Network. Recently, Taiwanese Oscillation Network TONG has also started. Both IRIS and BISON experiments aimed towards oscillations with low-Is and used Sun as star. GONG and TONG use 2-D solar image for high-1 values up to 250 and 1000 respectively. To create an optimum network of 6-sites, the GONG project conducted detail site evaluation program for more than 5 years. Out of the 15 sites, as shown in Figure 1, the following six sites have been finally selected for the network, in view of the maximum duty cycle and longitude coverage. Udaipur Solar Observatory (India); Teide (Tenerife), ; Cerro Tololo, Chile; Big Bear, California; Mauna Loa, Hawaii; and Learmonth, W. Australia.

From the operation of the full GONG network of 6 sites, duty cycle of better than 93% has been achieved. The whole network has started operating since October, 1995.

2. GONG Instrument

The GONG instrument consists of a computer controlled periscope, with brings the Sun-light trough 100mm aperture objective into a 'shipping container', converted to a sophisticated laboratory. The solar beam passes through a 'Fourier tachometer', working on the principle of phase - shift interferometer. This instrument makes precise measurements of the Doppler shifts of the absorption line. The solar image is focused on a 256×242 pixel CCD camera, yielding a 8×8 arc second resolution on the Sun. A Dopplergram in the NiI line at 6768A is made every minute, while a longitudinal magnetogram taken every hour. On an average, 1.8 sites observe concurrently, so that average total data from the whole network is about 1 gigabyte per day. The data is collected on exabyte tapes and reduced and archived at the GONG headquarters in Tucson, at nearly same overall rate as they are collected. The images are processed, filtered, calibrated and converted to Doppler velocity, modulation (approximately

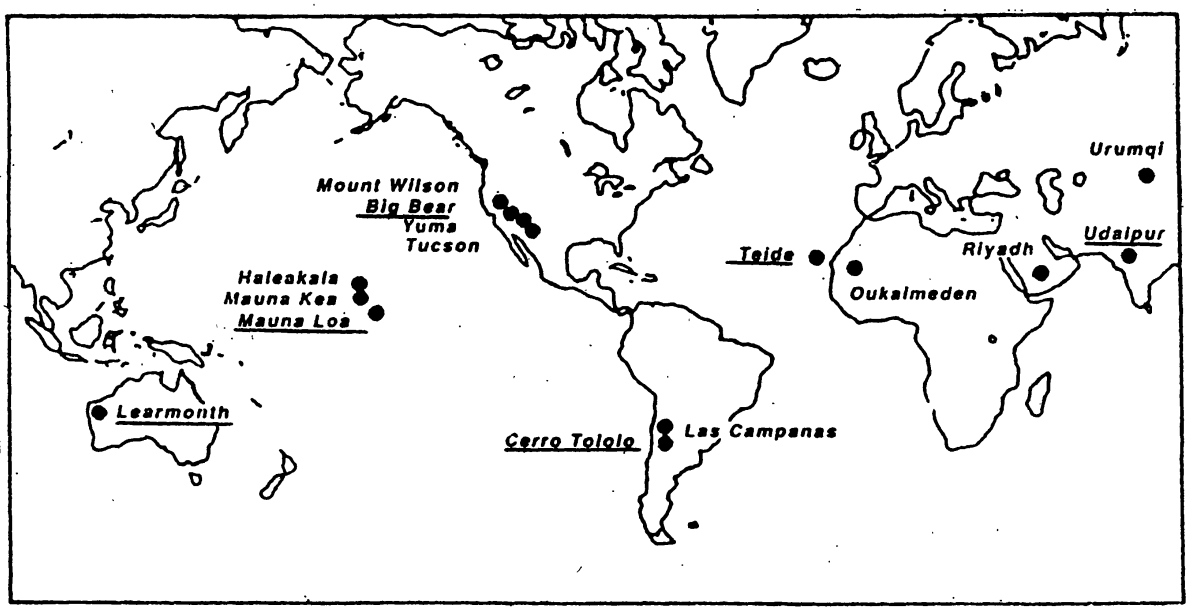

Figure 1. World map showing all the 15 sites initially selected for site survey. The underlined 6 sites are the final GONG sites

line strength) and total intensity images. The spherical harmonic decomposition of each remaped image is estimated up to l=250, thereby sampling all of the globally resonant modes. Time series of mode amplitudes obtained simultaneously at different sites are corrected and combined and the power spectra are computed. Finally, the frequencies, amplitude, and line widths of peaks in the power spectra are estimated. These parameters are then used to infer the solar internal conditions.

3. International collaboration

The intricacies of helioseismology requires substantial amount of data analysis, and theoretical research. To carry out the merging of data from different sites, mode analysis, inversion methods or forward problem, equation of state, interior dynamics, requires world wide participation. For this purpose 7 teams of scientists have been formed to encourage participation by a broad community. These teams are: 1. Data reduction and Analysis team, 2. Inversion team, 3. Solar internal model team, 4. Nearly Steady flow and magnetic fields team, 5. Low frequency team, 6. Mode physics, 7. Magnetic field team.

4. GONG membership

The general management policy of GONG is to encourage membership by a broad community. It is assumed that scientists will become members of GONG in order to contribute to the success of the project. Because of the participation in the development of tool, the GONG members will naturally have access to the data, analysis and interpretation tools. GONG data

is available to any qualified investigator whose proposal has been accepted. However, active membership in a GONG Scientific Team encourages early access to the data and the collaborative scientific analysis that the teams are undertaking. Application for the membership in GONG should contain the following information: Name institution and Title, a brief description of the scientific objectives of the proposal, brief description of the activity to be contributed, the level of effort that would be committed, resources that are or would be available, potential collaborators and a brief bibliography of relevant publications.

A GONG Newsletter provides status reports on all aspects of the project and related helioseismic science. Information on the status of the Project, the scientific investigations, as well as access to the data is available on WWW server whose URL is www. gong. naoa.edu.

5. Publication

The highlight of the first results of GONG has been recently published in the special issue of Science (31 May 1966). In addition to an introductory article and one describing the Project, five of the scientific teams presented their first results using the GONG data. There are policy guidelines for publication of GONG results by the members and the GONG data users. These are given in GONG Newsletter.

6. Data Product

The Data Management and Analysis Centre (DMAC) at NSO-GONG, operates a Data Storage and Distribution System (DSDS) for users of GONG data products. Nearly 200 data products are generated by DMAC, which could be made available to the GONG members. To obtain these data products, an application form has to be submitted to Dr. John Leibacher, project GONG NSO, P.O. Box No. 26732, Tucson AZ 85726-6732, USA. A USER'S GUIDE has been prepared by Dr. Jim Pintar, DMAC Manager, which gives the procedure for assessing the data products.