National Aeronautics and Space Administration

Solar Atmospheric Dynamics from Doppler & Magnetic Imaging

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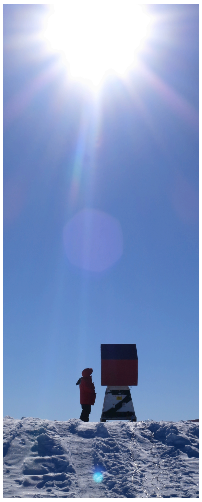
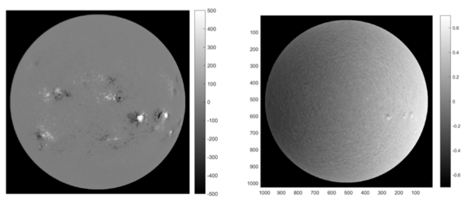
Program: Strategic



Observations from the South Pole

Line-of-sight magnetic field (L) and velocity (R) at two heights in the solar atmosphere



The MOTH-II observatory's instruments measure the Doppler shift and circular polarization (proportional to the line-of-sight magnetic field) in two solar absorption lines (Na 589nm & K 770nm) formed at different altitudes in the Sun's atmosphere, allowing us to view velocity and magnetic fields in 3-dimensions.

Project Objectives:

The main objective of this research is to detect and characterize waves in the solar atmosphere, with focus on gravity waves. Gravity waves have been detected but not well characterized. They can be recognized in processed Doppler data by the unusual property that their group and phase velocities are orthogonal, so they appear to be traveling in opposite directions in the line of sight velocity.

The main objective of this year's R&TD research was to carry out the analysis needed to identify various wave modes in the sun's atmosphere exploiting data collected during two solar observing runs made at the south pole using the Magneto Optical Filters at Two Heights (MOTH) experiment. While it was not our primary aim, we found that our data set allowed us to map the coustic cutoff frequency in the sun' atmosphere, key variable in the proceses that heat the solar chrmosphere.

Benefits to NASA and JPL

This research is part of a broader strategy to exploit recent successes in Space Physics instrument technology development at JPL (in partnership with collaborators at Georgia State University, and the University of Hawaii). This strategy is intended to develop a scientific track record using data from these recently developed instruments, that addresses important science questions in Heliophysics and Planetary Science.

The study of gravtiy waves is challenging, but could potentially uncover an important mechanism for energy and momentum transfer in the solar atmosphere. Insights into the spatial variability of the acoustic cutoff frequency, reported here, have important consequences for solar atmospheric heating

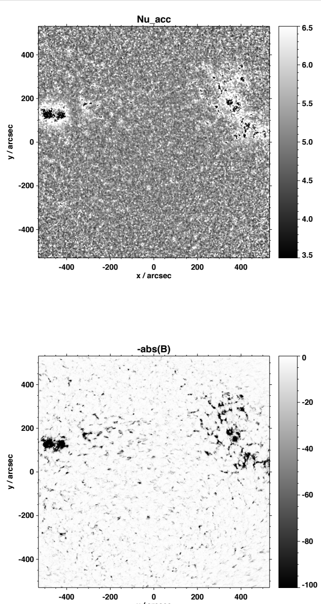


Figure 1) upper panel map of the acoustic cutoff frequency, lower panel the unsigned magnetic field from HMI.

FY18/19 Results:

Solar Doppler imaging data collected by the Magneto-Optical filter at Two Heights (MOTH-II) instrument (K 770nm and Na 589nm channels) in 2017, were reduced and calibrated, and coaligned with Doppler images from the Solar Dynamics Observatory's Heliospheric Magnetic Imager (HMI). MOTH-II and HMI data were spatially binned to yield an effective pixel size of 1.27 arcsec, and the 5 s cadence MOTH-II data were averaged to match the 45 s cadence HMI data. HMI data can be resolved into two velocity fields, separated in height by ≈50km, do the resulting high quality data set enables the analysis of the line-of-sight velocity field at four heights in the solar atmosphere.

This year's research has concentrated on using travel time analysis to map the propagation of waves from the sun's photosphere up into the chromosphere. These acoustic waves are generated by turbulent convection below the photosphere and can carry significant energy into the chromosphere, producing mechanical heating by shock formation. Whether or not acoustic waves can propagate in a stratified medium such as the solar atmosphere is determined by the acoustic cut-off frequency of the atmosphere. Waves with frequencies below the cut-off frequency are evanescent (i.e., non-propagating) while waves with frequencies above the cut-off can freely propagate.

Figure 1) shows a map of the acoustic cutoff frequency over a1000 arcsec square, centered on the solar disk, compared to a map of the line-of-sight magnetic field measured by HMI. The upper panel in figure 1) shows significant variability n the acoustic cutoff frequency across the map, which is aligned with regions of higher magnetic field in the lower panel. Two effects stand out – where the field is highest the cutoff frequency is depressed, allowing lower frequency waves to propagate freely and deposit energy in the chromosphere, and around these high field regions are brighter halos, which appear to be downward propagating waves above the acoustic cutoff frequency.

While there have been some studies of the variation in acoustic cutoff frequency with height in the atmosphere, to the best of our knowledge, this is the first study showing how the cut-off frequency varies spatially in latitude and longitude.

In addition to its importance in identifying regions of enhanced wave propagation, variations in the acoustic cutoff frequency have been shown to be a main contributor to local helioseismology travel-time shift measurements, which severely limit our ability to study changes the structure beneath sunspots as they evolve. The ability to map the acoustic cutoff my provide a correction to the travel time shift, enabling a deeper understanding of the development of magnetic active regions on the sun.

Publications:

Jefferies, S. J., Fleck, B., Murphy, N., Berilli, F., "Observed local dispersion relations for magneto-acoustic-gravity waves in the Sun's atmosphere: Mapping the acoustic cut-off frequency", *ApJ Letters* AAS18865R1: Accepted for Publication 2019

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