Thermodynamics of the Inner Solar Corona: A Tomographic Validation Study of the AWSoM Model

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Abstract

To advance the understanding of the physics of the solar corona, magnetohydrodynamic (MHD) three-dimensional (3D) models need to be validated with observations. To that end, differential emission measure tomography (DEMT) provides global 3D maps of the electron density and temperature in the inner corona (1.0-1.25 Rsun). In combination with models of the coronal magnetic field, it allows estimating the energy input flux required at the coronal base to maintain thermodynamically stable coronal structures. Hence, the DEMT analysis can be useful to tune up the model's Alfven wave amplitudes and dissipation rates. Here, a DEMT validation study of the latest version of the Alfvén Wave Solar Model (AWSoM) of the Space Weather Modeling Framework (SWMF) is reported. The analysis is carried out for Carrington rotations selected from the previous solar minimum and the current declining phase of solar cycle 24. The capability of the model to reproduce the tomographic products is discussed, and the need for improvements in the model is evaluated.

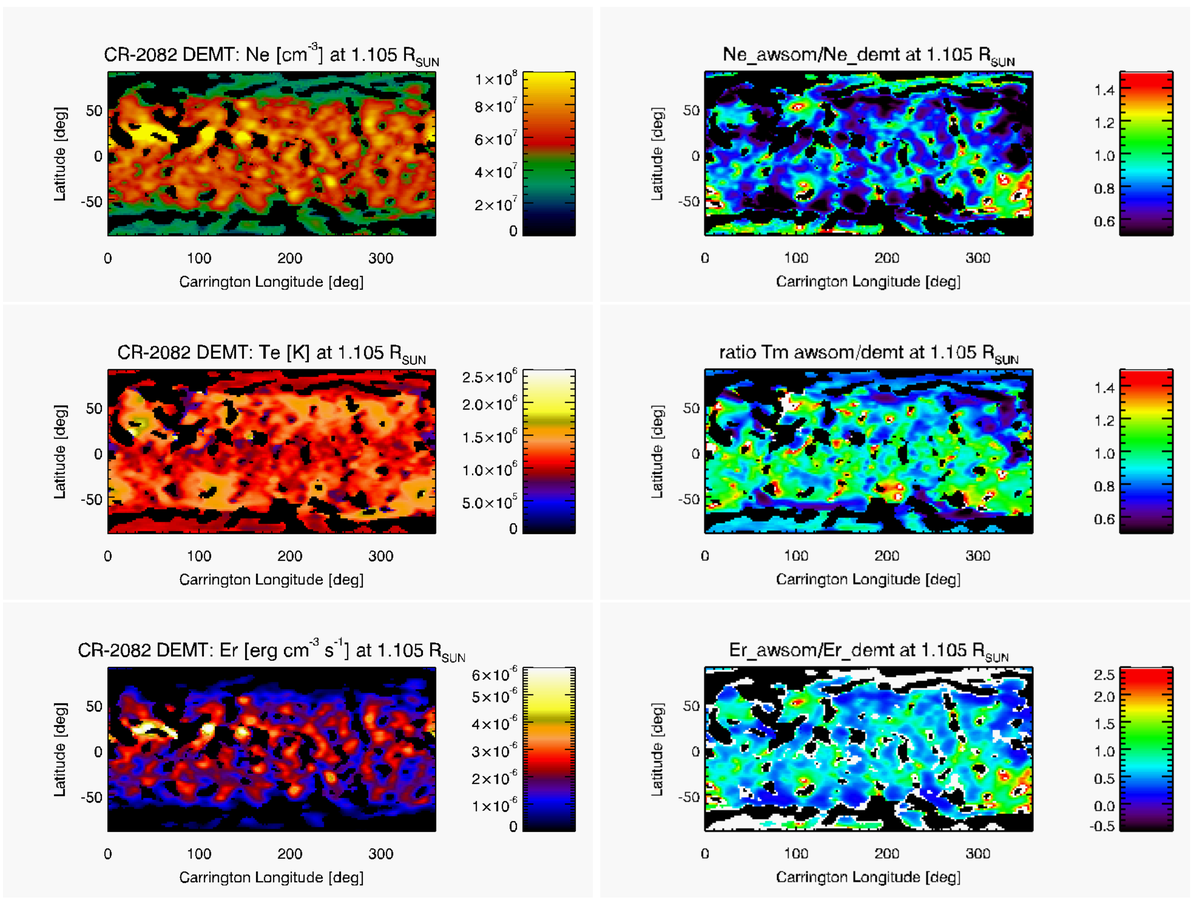
DEMT Technique

DEMT technique calculates the Local Differential Emission Measure (LDEM) in each 3D volume element from series of EUV images taken during a solar rotation. By computing LDEM moments, 3D distributions of electronic density and temperature can be obtained. In this work DEMT was applied to EUV (Extreme Ultraviolet) images taken by the Extreme Ultraviolet Imager (EUVI) instrument on board the STEREO-B spacecraft during Carrington Rotation (CR)-2082 and by Atmospheric Imaging Assembly (AIA) instrument on board SDO during CR-2208.

Alfvén Wave Solar Model (AWSoM)

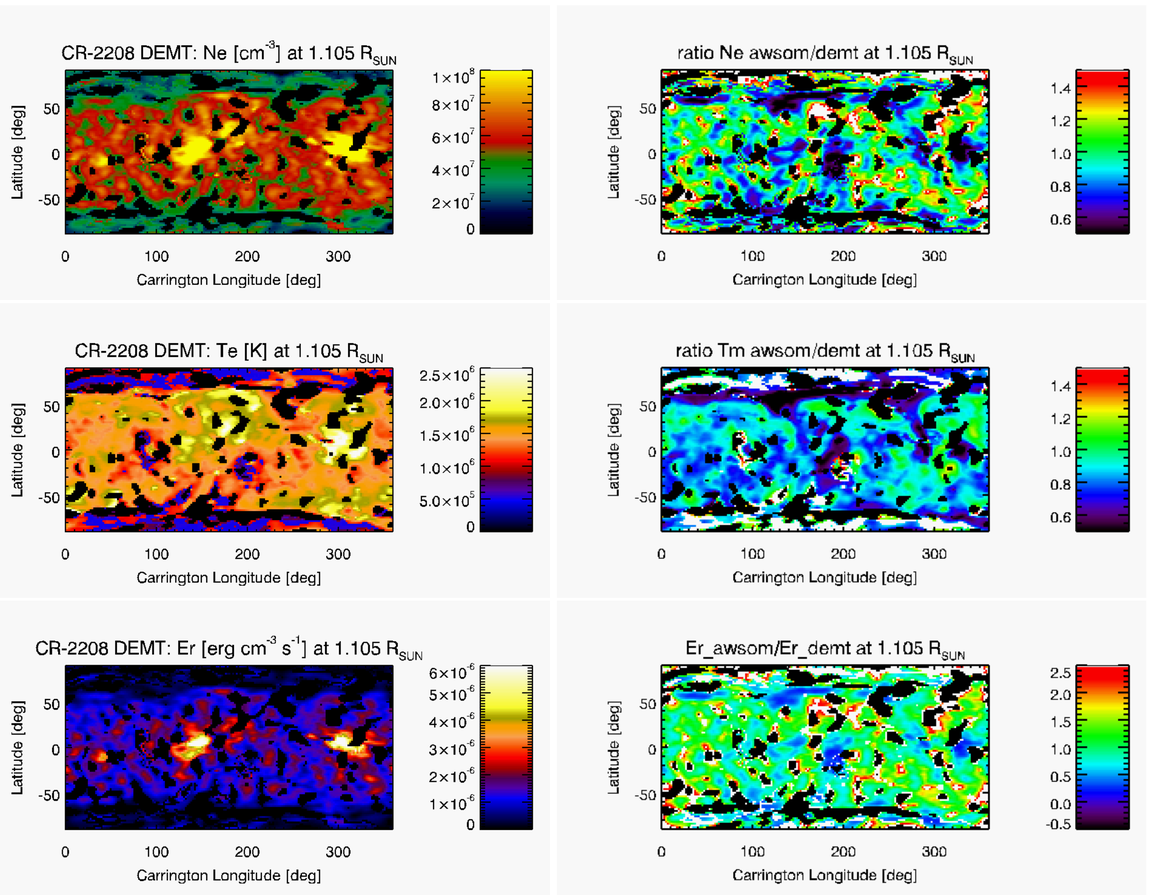
AWSoM is a global 3D MHD model of the solar chromosphere and corona driven by magnetogram data. At the coronal base, Alfvén waves are reflected and generate a turbulent cascade. The dissipation of this cascade contributes to the coronal heating. Taking into account the turbulence generated by low frequency Alfvén waves, the model solves MHD equations and obtains 3D distributions of electronic density and temperature, together with many other physical quantities. In this work we perform a steady-state simulation of CR-2082 and CR-2208 using synoptic magnetograms from the Michelson Doppler Imager (MDI) instrument on board the SoHO spacecraft.

CR-2082



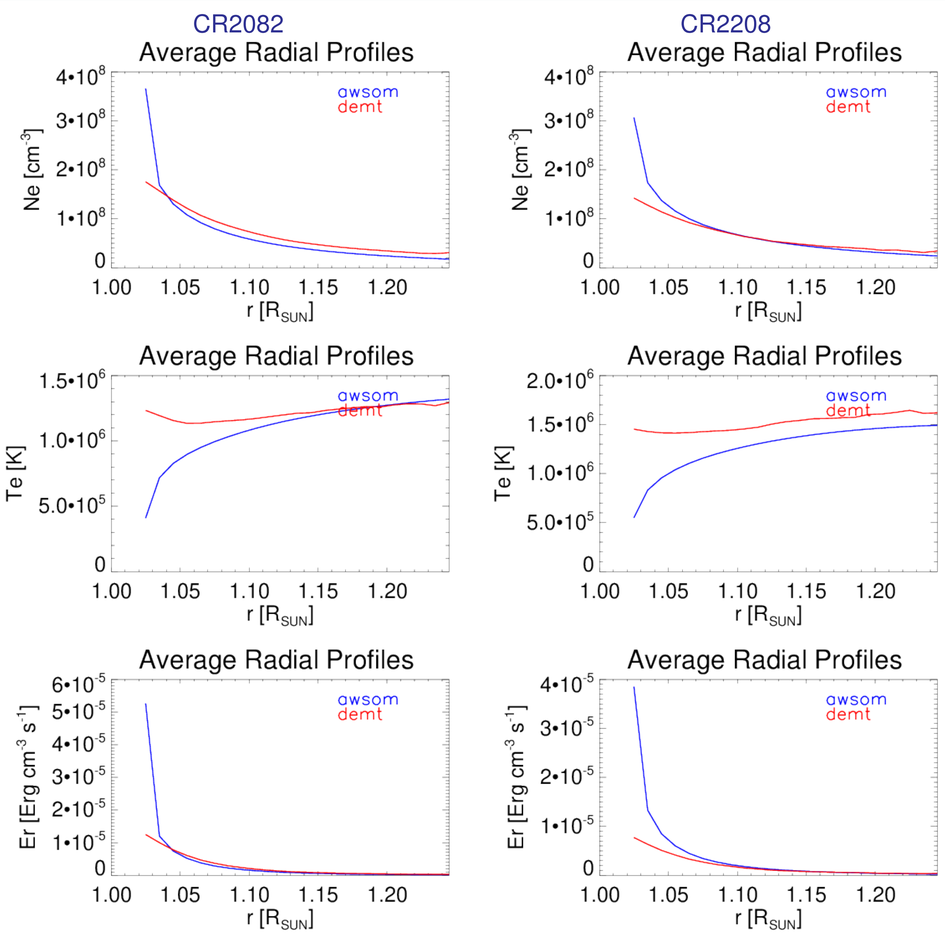
Carrington maps at $1.105\,\mathrm{R}_\odot$ of CR-2082. At the left the Electronic density, electronic temperature and radiaty power and at the right the ratio between AWSoM and DEMT of those cuantities.

CR-2208

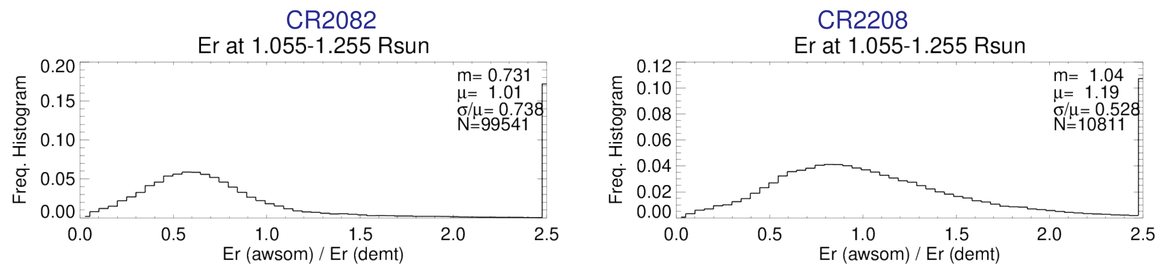


Same Carrington maps but for CR-2208.

Global Comparison as a Function of Height: Streamer



Radiative Flux in streamer



Statistic of the ratio of the radiaty power above the end of the extended transition region.

Comments

- A previous work showed that below $\sim 1.05\mathrm{R}_{\mathrm{SUN}}$ (in both Streamers and CHs): the electron temperatures of AWSoM are a factor ~ 2 smaller than those observed with DEMT, while the electron densities are a factor $\sim 2-5$ large. this lack of agreement is related to its treatment of the extended Chromosphere/Corona transition.
- Above $\sim 1.05\mathrm{R}_{\mathrm{SUN}}$ AWSoM tend to under-estimate $\mathrm{N_e}$ and $\mathrm{T_e} \sim 20\%$
- The structure of the streamer is dominated by down loops which are not modeled by AWSoM.
- Since Radiative power $\mathrm{E_r} \sim {\mathrm{N_e}}^2\mathrm{LF}$ and the behavior is the same as $\mathrm{N_e}$ then the radiative loss function is the same.

Next steps

- ${\mathrm{N_e}}^{DEMT}$ need to be corrected by the irregularity factor (check the poster "Multi-Instrumental Tomography of the Solar Corona" (by Alberto Vásquez) in this same session.)
- We will analyze a newer rotation closer to the solar minima.
- A more detailed and precise analysis tracing the DEMT and AWSoM data along the magnetic lines will be carry on.