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.

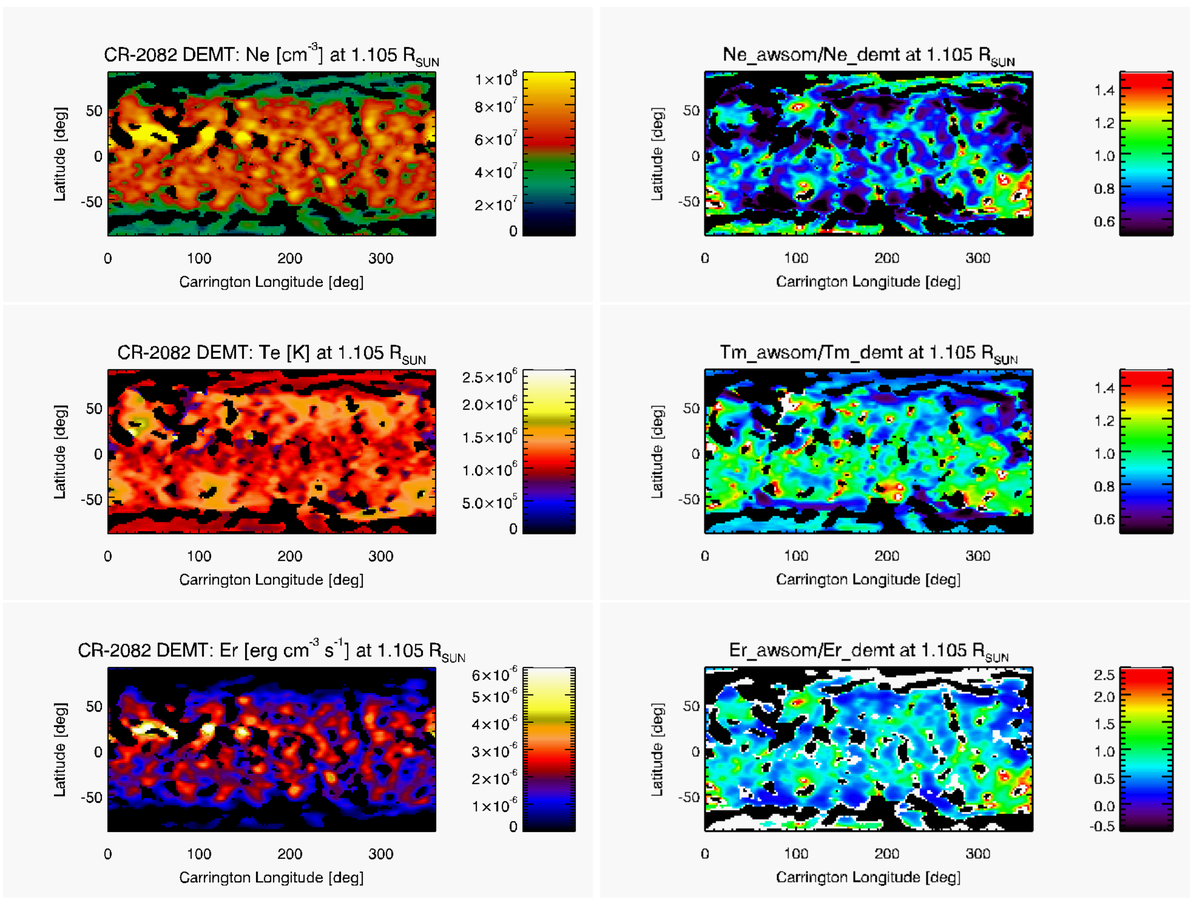
DEMT

DEMT technique allows calculation of the Local Differential Emission Measure (LDEM) in each voxel of the tomographic grid from series of EUV images taken during hafl of 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 the SDO spacecraft during CR-2208.

Alfvén Wave Solar Model (AWSoM)

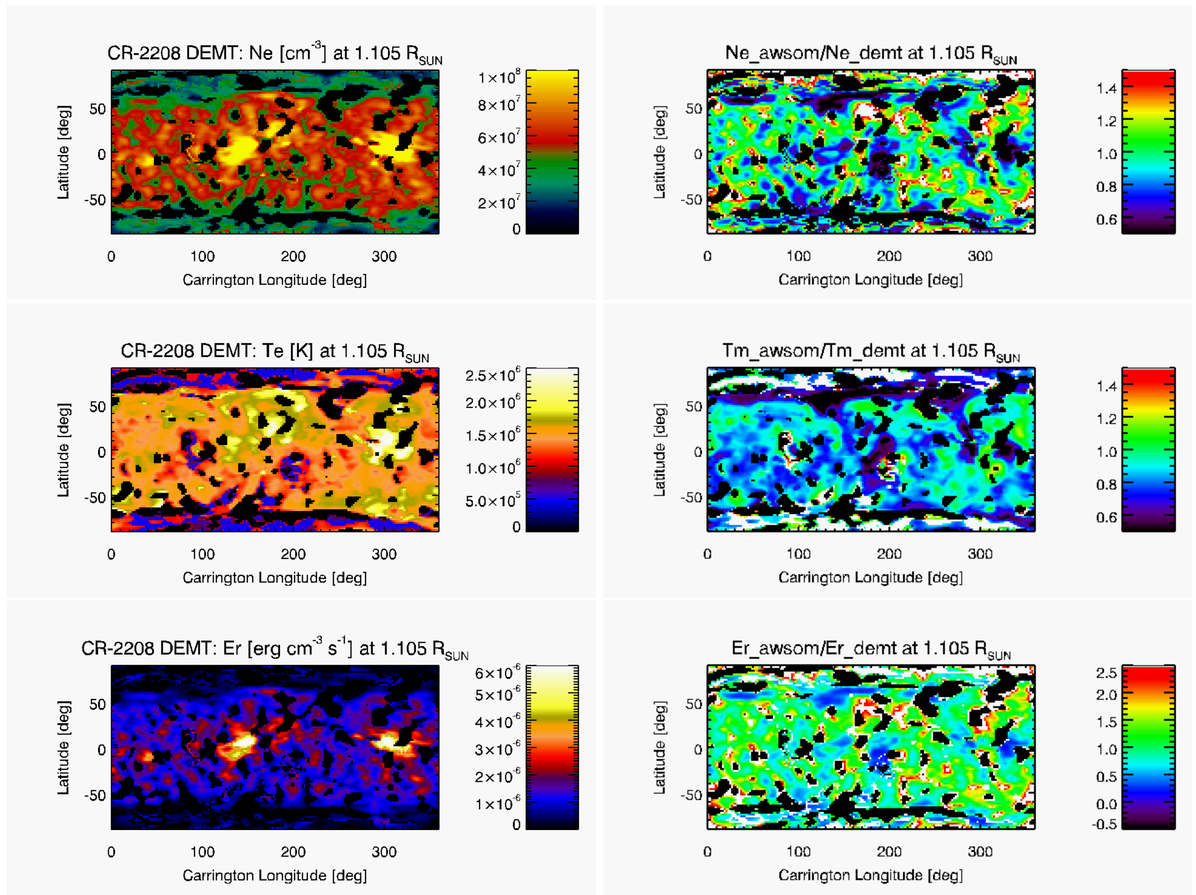
AWSoM is a global 3D MHD model of the solar chromosphere and corona driven by magnetogram data. At the coronal base, Alfvén waves are reflected and generate a turbulent cascade. The dissipation of this cascade contributes to the coronal heating. Taking into account the turbulence generated by low frequency 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.

Results for CR-2082



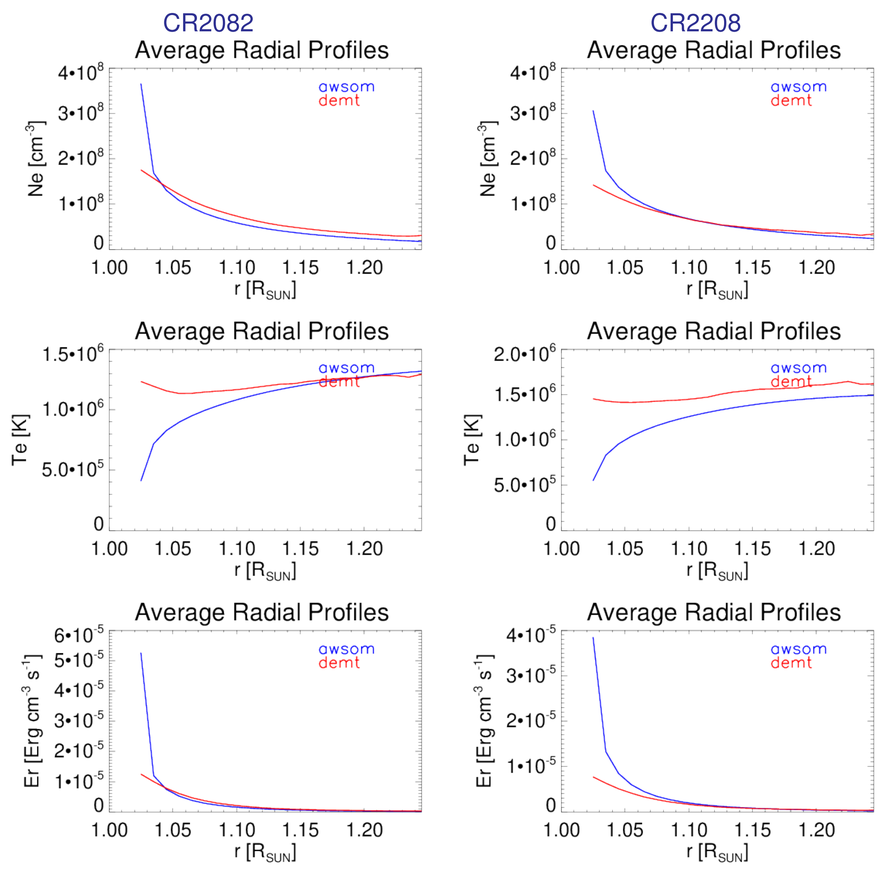
Carrington maps of several DEMT and AWSoM products at $1.105\,\mathrm{R}_\odot$ for CR-2082. **Left Panels:** electronic density, electronic temperature and radiative power. **Right Panels:** the ratio between AWSoM and DEMT of those quantities.

Results for CR-2208

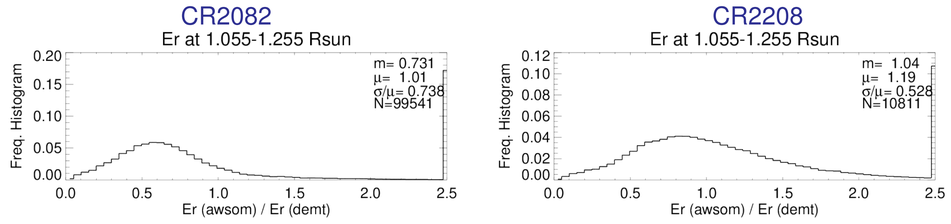


Same Carrington maps but for CR-2208.

Global Comparison as a Function of Height in Streamers



Radiative Flux in streamers



Histogram of the AWSoM-to-DEMT ratio of the radiative power, in the height range $1.05 - 1.26\,\mathrm{R}_\odot$.

Comments

- As in a previous analysis below $\sim 1.05\mathrm{R_{SUN}}$ 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 the AWSoM treatment of the extended Chromosphere/Corona transition.
- Above $\sim 1.05\mathrm{R_{SUN}}$ AWSoM tends to under-estimate (in both Streamers and CHs) $\mathrm{N_e}$ and $\mathrm{T_e}$ by $\lessapprox 20\%$
- Since Radiative power $\mathrm{E_r} \sim \mathrm{N_e}^2\mathrm{LF}$ and the LF is similarly treated by both models (using same version of CHIANTI), the AWSoM-to-DEMT ratio of the radiative power closely matches that of the $\mathrm{N_e}^2$.

Next Steps

- The DEMT electron density may require corrections due to the unknown [Fe] and the coronal irregularity factor. See the poster "Multi-Instrumental Tomography of the Solar Corona", by Frazin et al., in this same poster session.
- We will repeat the same type of analaysis for a rotation selected from the current solar minimum between Solar Cycles 24 and 25.
- A more detailed and precise analysis tracing the DEMT and AWSoM data along the magnetic lines will be carried out to validate AWSoM separately in specific coronal structures.