On the transition from 3D to 2D transport equations for a study of the long-term cosmic-ray intensity variations in the heliosphere

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Main topics

- **Motivation:** To solve 2D instead of 3D TPE is easier and more logical, but what is the exact 2D TPE?
- **Theory**: The reduction of 3D to 2D TPE; The source term (Q) of 2D TPE; The 3D and 2D drift velocities.
- **Calculations**: Calculated from 3D TPE Q1 for 2007.II, T=1 GeV; Comparison of Q1 with Tdr and with estimated Q2.

Theory

- **3D TPE, average it over the longitude and get from it the 2D equation for the phase density averaged over the longitude.**
- **This 2D TPE has the source term, which we calculate (Q1) solving 3D TPE for the case when the only longitude dependent factor is the polarity of HMF ($\mathcal{F}$)**

$$\nabla(\mathcal{K}\nabla\mathcal{U}) - \vec{\mathcal{V}}^{sw*}\cdot\nabla\mathcal{U} - \vec{\mathcal{V}}^{dr}\cdot\nabla\mathcal{U} + \frac{\mathcal{D}V}{3}p\frac{\partial\mathcal{U}}{\partial p} = 0.$$

$$\mathcal{U} = U + u$$

$$U = \langle\mathcal{U}\rangle_\varphi$$

$$\nabla(K\nabla U) - \vec{V}^{sw}\cdot\nabla U - \vec{V}^{dr}\cdot\nabla U + \frac{DV}{3}p\frac{\partial U}{\partial p} + Q = 0$$

$$Q = -\left\langle \vec{v}^{dr}\cdot\nabla u\right\rangle_\varphi$$

$$\vec{\mathcal{V}}^{dr} = \vec{V}^{dr} + \vec{v}^{dr}$$

$$\vec{\mathcal{V}}^{dr,reg} = C^{dr}_{scat}\cdot\frac{pv}{3q}\cdot\mathcal{F}\left[\nabla\times\frac{\vec{B}^m}{B^2}\right]$$

$$\vec{\mathcal{V}}^{dr,cs} = C^{dr}_{scat}\cdot\frac{pv}{3q}\cdot\left[\nabla\mathcal{F}\times\frac{\vec{B}^m}{B^2}\right]$$

$$F = \langle\mathcal{F}\rangle_\varphi,$$

$$\vec{V}^{dr,reg} = C^{dr}_{scat}\cdot\frac{pv}{3q}\cdot F\left[\nabla\times\frac{\vec{B}^m}{B^2}\right],$$

$$\vec{V}^{dr,cs} = C^{dr}_{scat}\cdot\frac{pv}{3q}\cdot\left[\langle\nabla\mathcal{F}\rangle_\varphi\times\frac{\vec{B}^m}{B^2}\right]$$

Numerical Calculations

Fig. 1 illustrates the structure of the r, θ and φ parts of the calculated source term (Q1) due to the regular and cs-drifts.

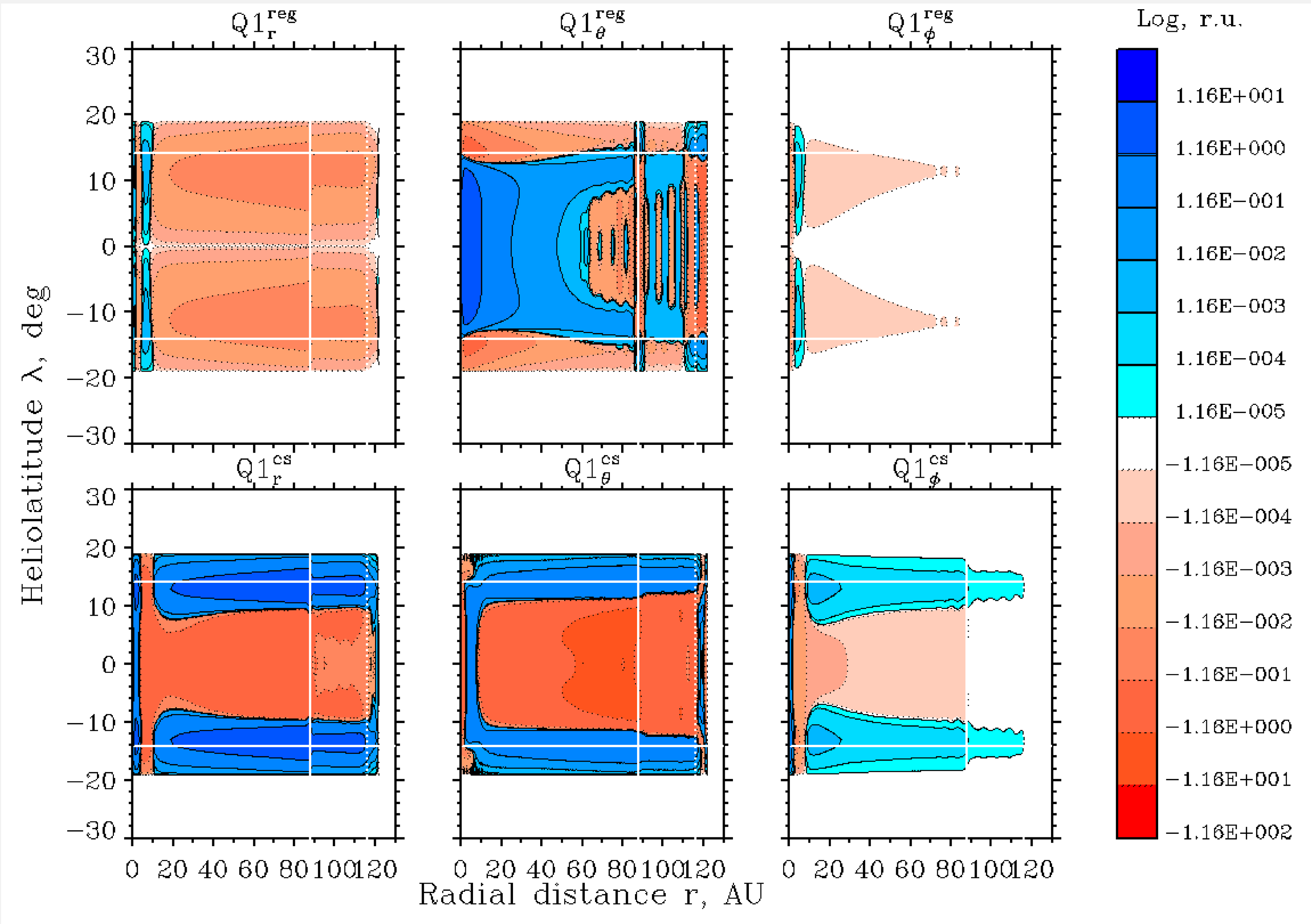

Fig. 1

Fig. 2 shows the structure of the r and θ parts of the drift term of 2D TPE due to the regular and cs-drifts.

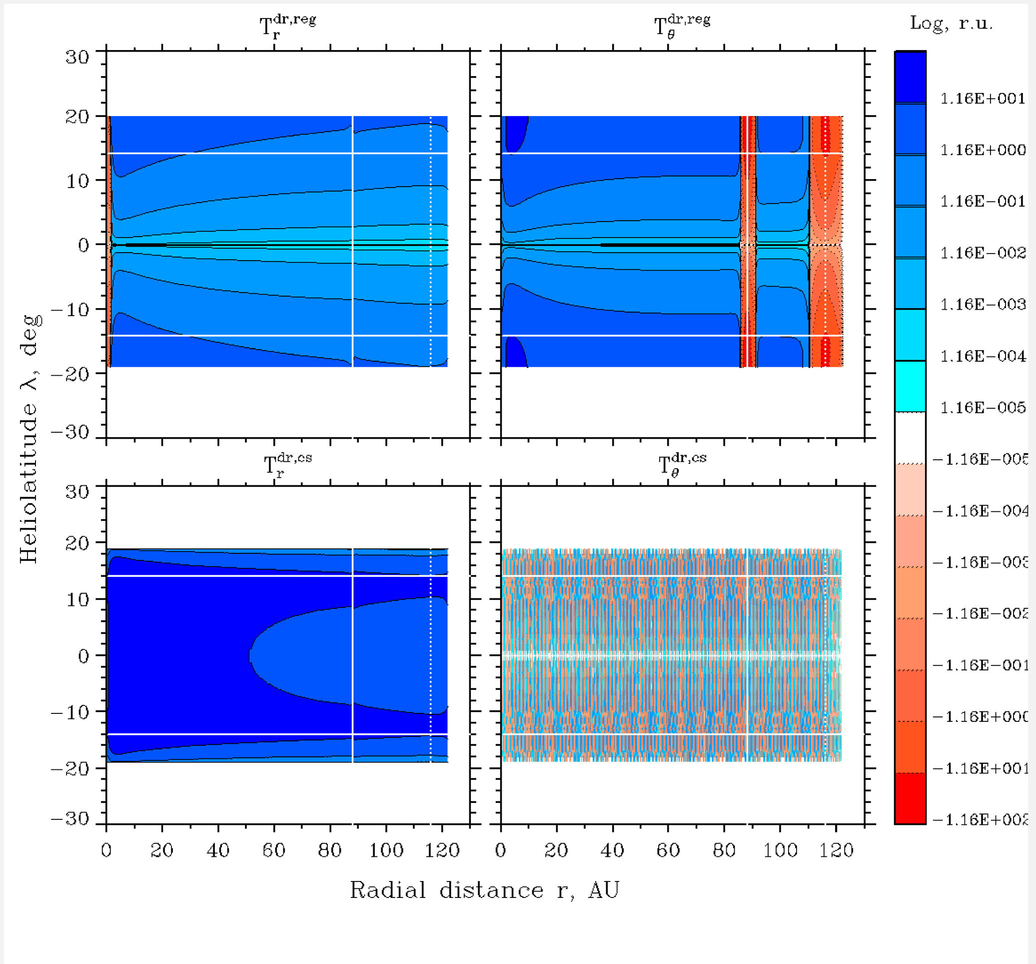

Fig. 2

Fig. 3 shows the structure of the r and θ parts of the estimated source term (Q2) due to the regular and cs-drifts.

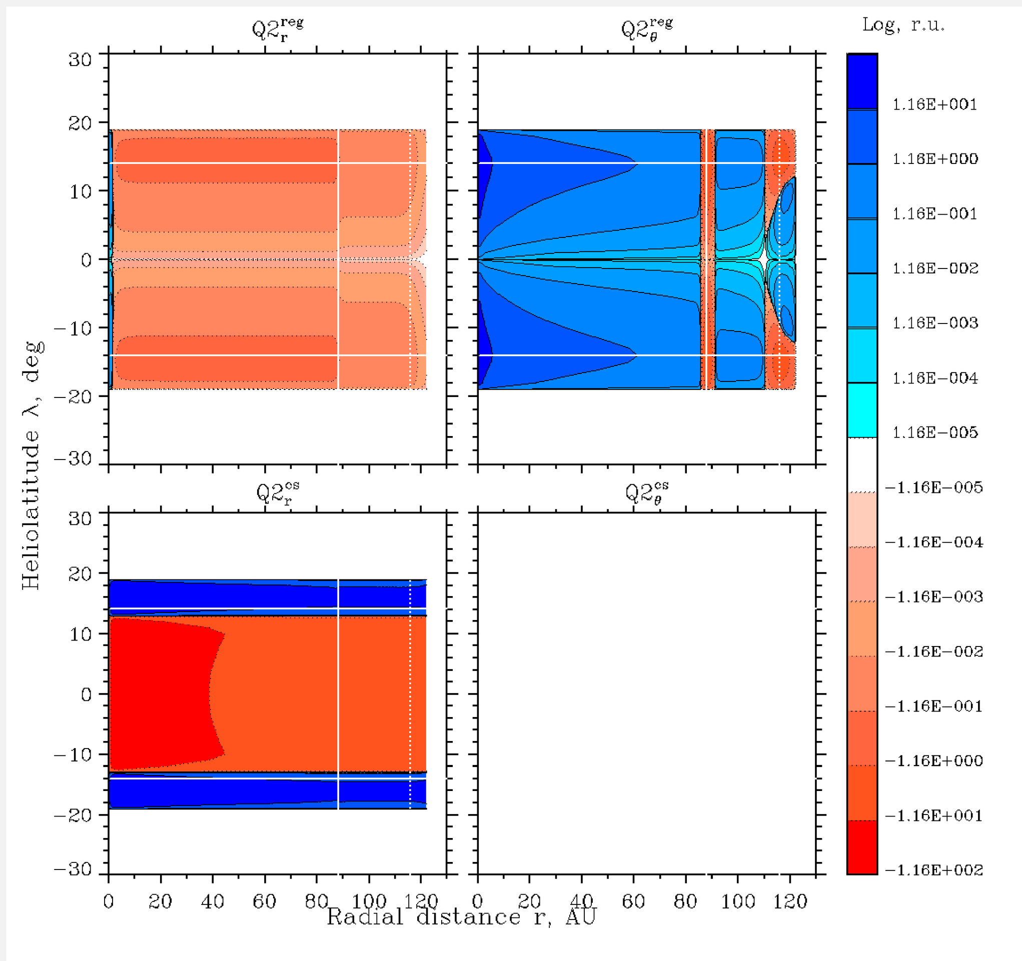

Fig. 3

Conclusions

The structure of the calculated source term of the exact 2D TPE reduced from the 3D TPE steady-state in the frame rotating with the Sun for the simple case of the HMF polarity as the only longitude dependent heliospheric factor is rather complex and on the whole should result in some reduction of drift effects in the solar modulation of GCRs.

A detailed analysis is needed for more precise conclusions since the contribution of the source term is different for different parts of the drift term (for different components of the drift velocity caused by both the regular and the current sheet drifts) and for different energies.

On the whole, the structure of the source term of the exact 2D TPE, estimated earlier without solving the 3D TPE, differs from its structure calculated using the solutions of the 3D TPE, although there are similar features. further efforts to estimate the source term more properly.

Although these calculations assist us in estimating the source term properly, further study and improvement are required.

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