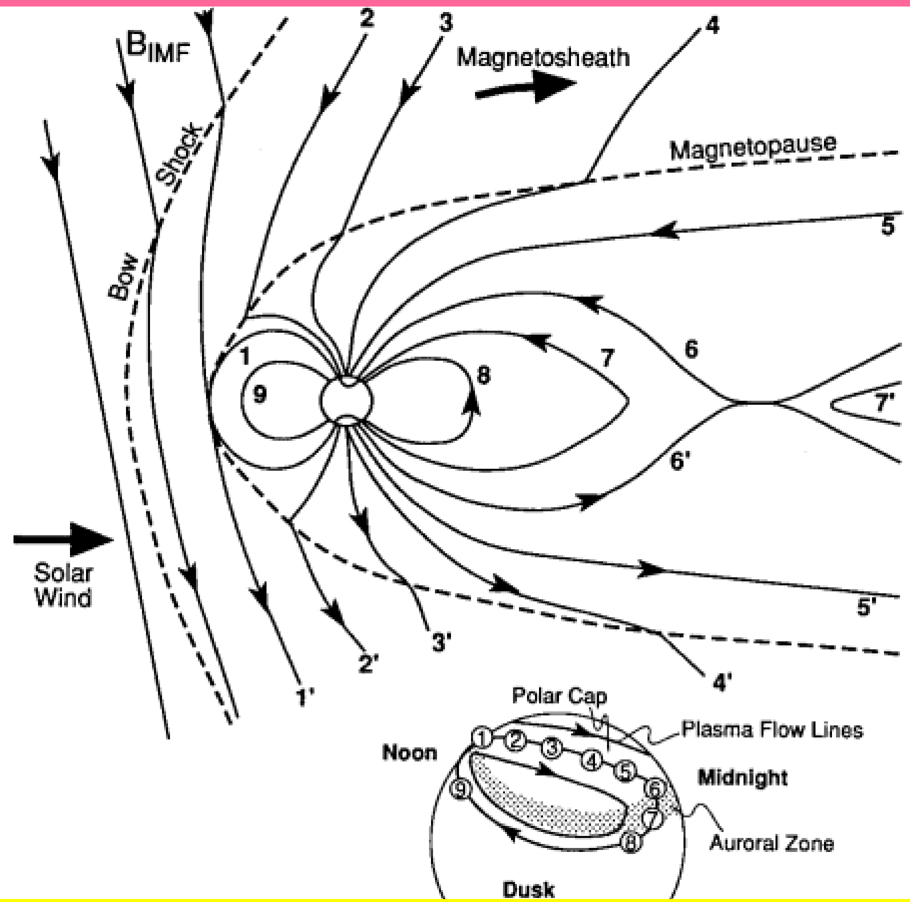
磁気圏対流駆動機構
The driver of the magnetosphere convection



S. Fujita, Meteorological College

Three defects of the Dungey convection model

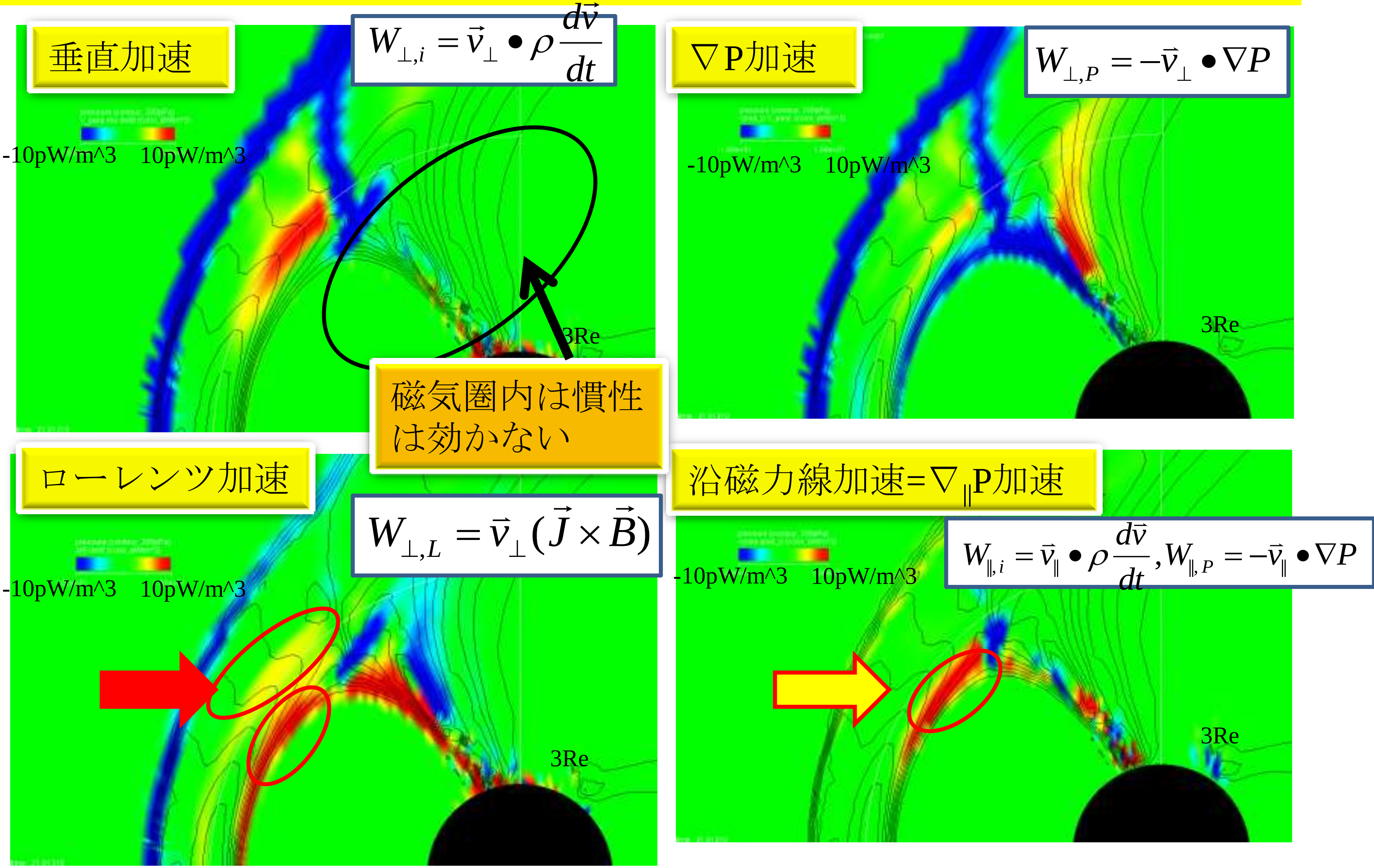
1. **Dungey convection model naturally invokes the inertial force and plasma acceleration in the magnetosphere.**

2. **Dungey convection model does not consider the three-dimensional topology of the magnetic field merging.**
   - Combination between the null-separator structure and the dynamics of the plasmas (solar wind $B_z<0$, $B_y\neq0$)

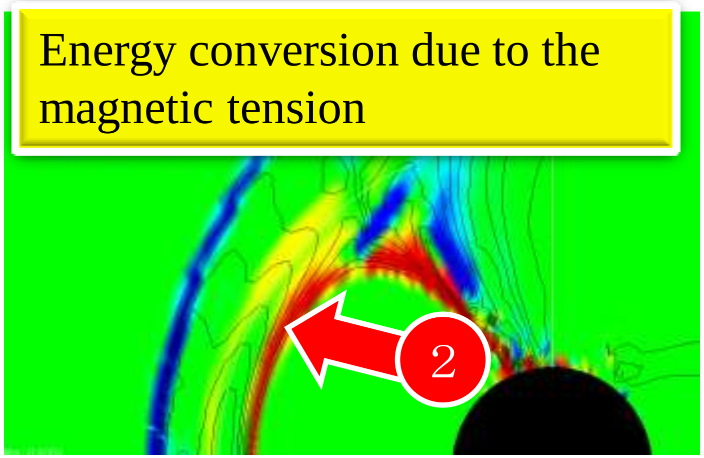
3. **Dungey convection model does not consider energy convection in the magnetosphere.**
   - The plasma bulk flow transports kinetic and internal energy. However, Dungey convection model considers only the field-perpendicular flow. $\Rightarrow$ a new view of the dynamo process
   - Magnetospheric energy circulation is identified. This convection has a peculiar feature compared with the ordinary convection like the atmospheric global circulation.

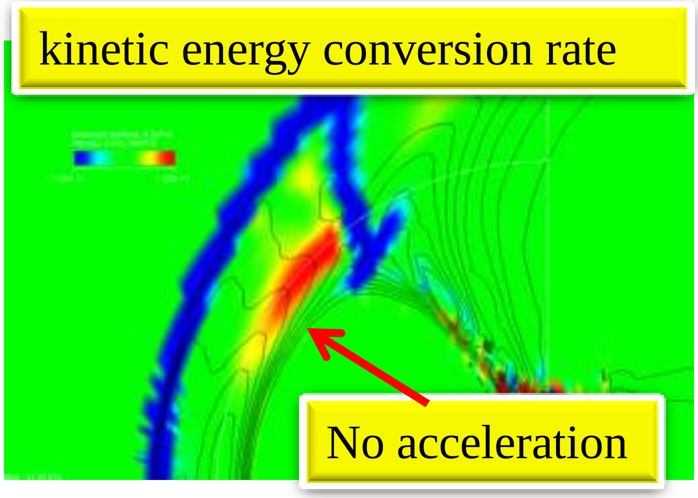
各エネルギー変換率の分布（南IMF）

（黒コンターは圧力分布）

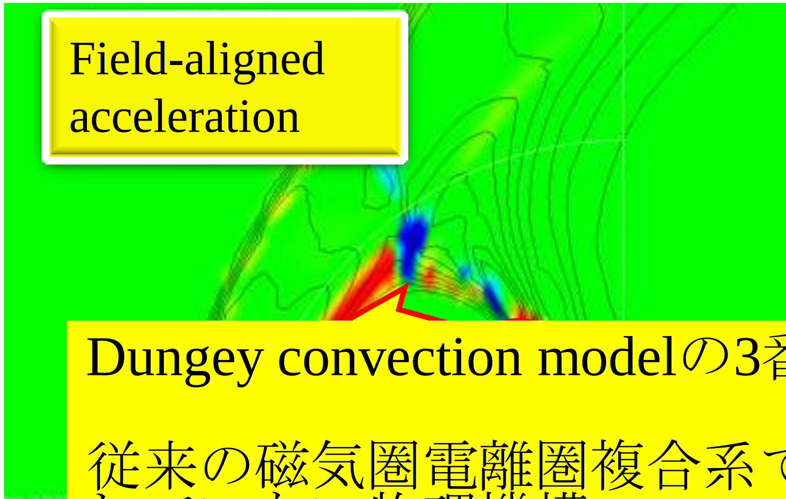


Transport of EM energy to the C-F current region



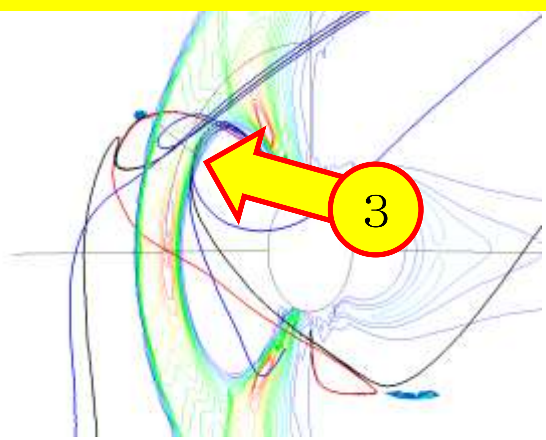


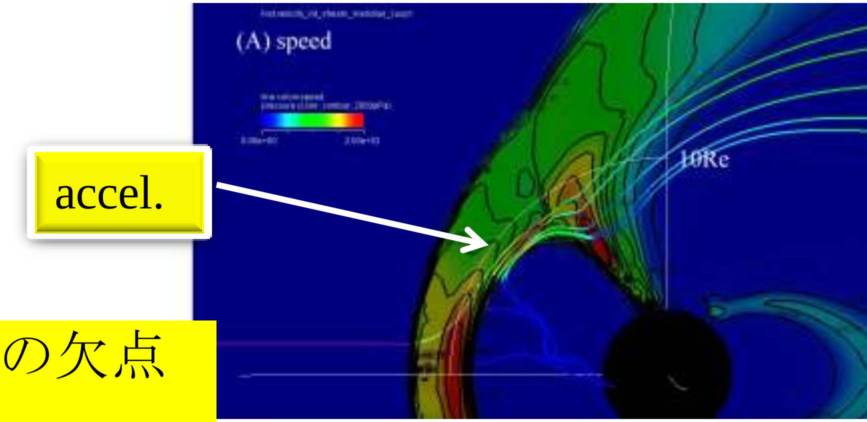
Plasmas are transported into the cusp along the field lines



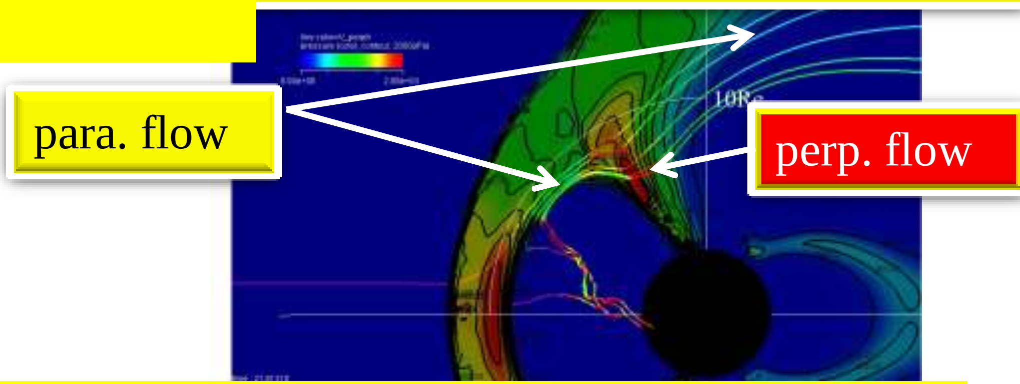
Dungey convection modelの3番目の欠点

従来の磁気圏電離圏複合系では考慮されていない物理機構



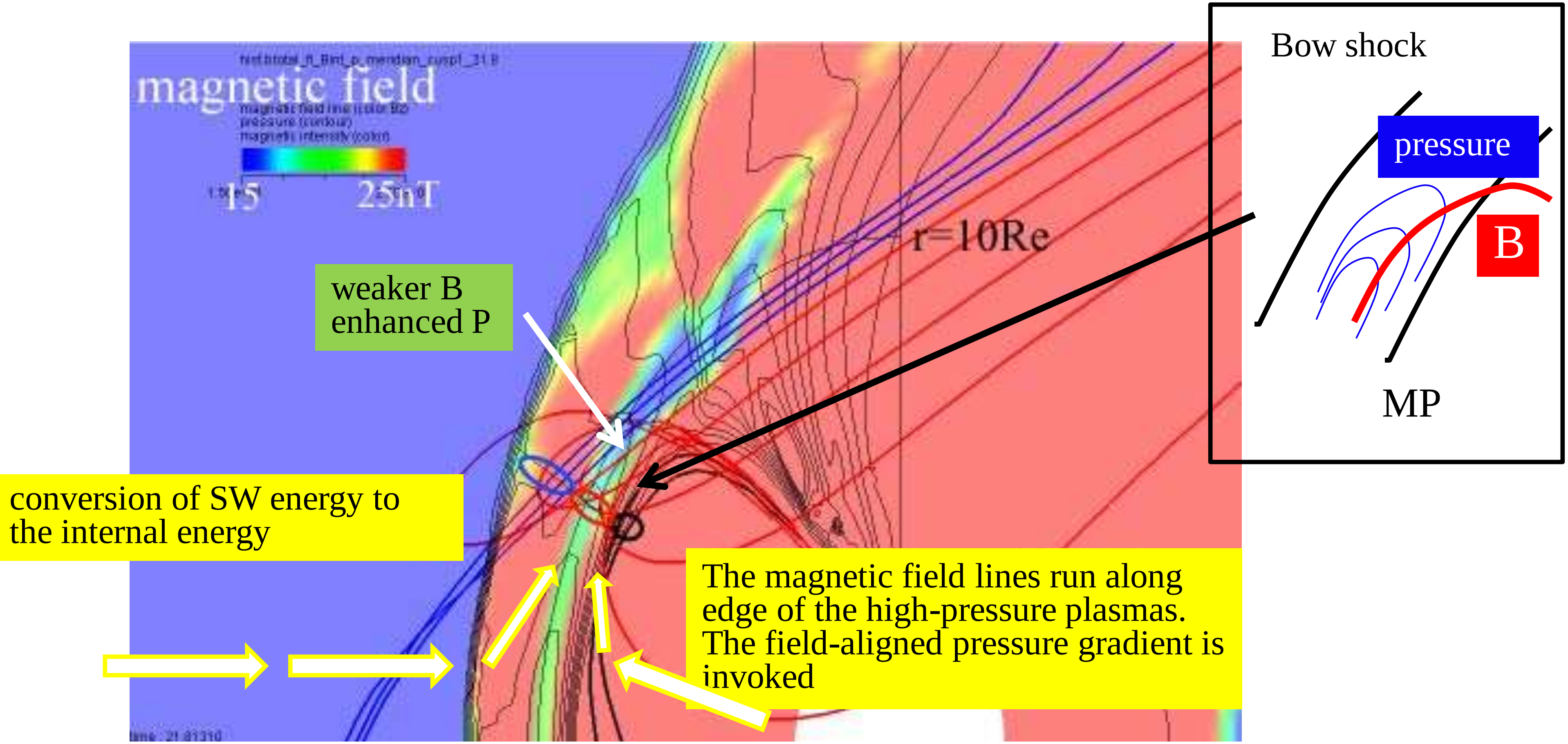


vind and magnetospheric plasmas entry



- Supply plasmas into the cusp
- Negative E*J (dynamo) in the mantle due to the slow mode expansion fan
- Positive E*J (load) in the lower-latitude side of the cusp due to plasma compression

Field-aligned acceleration



Plasma bulk flowの重要性

- 磁気圏プラズマ対流は磁力線に垂直な方向のフローであるので、従来バルクフローは重要視されていない。しかし・・・
  - カスプーマントル域ではプラズマが磁力線に沿って加速され磁気圏に入り込んでいる。
  - プラズマの力学エネルギーおよび熱エネルギーのフラックスはバルクフローに沿って運ばれる。

⇒エネルギーの議論をするにはbulk flowが不可欠。

Dynamo equation from energetic balance

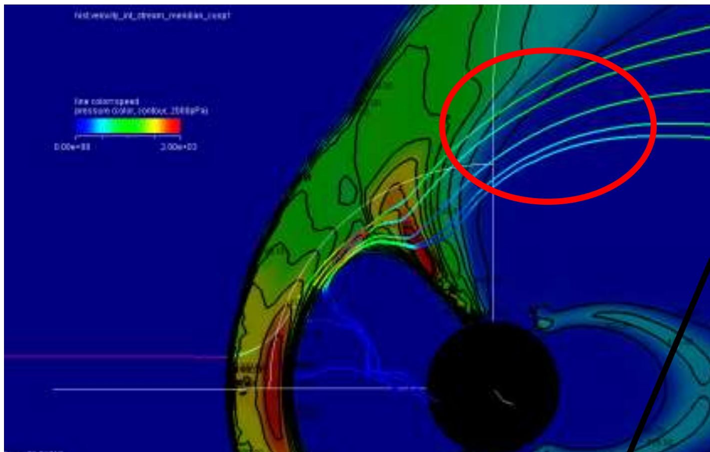
$$(\vec{v}\nabla)P + \gamma P(\nabla\vec{v}) \approx 0$$

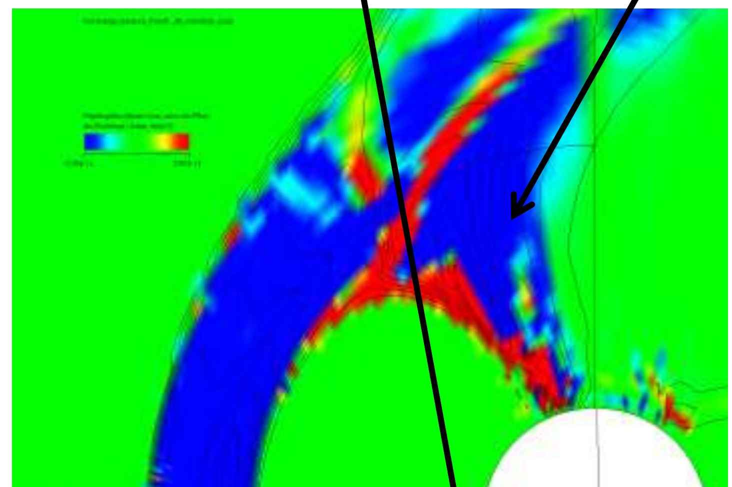
$$\vec{E}\bullet\vec{J}_{\perp} \approx (\vec{v}_{\perp}\nabla)P \approx -(\vec{v}_{\parallel}\nabla)P - \gamma P(\nabla\vec{v})$$

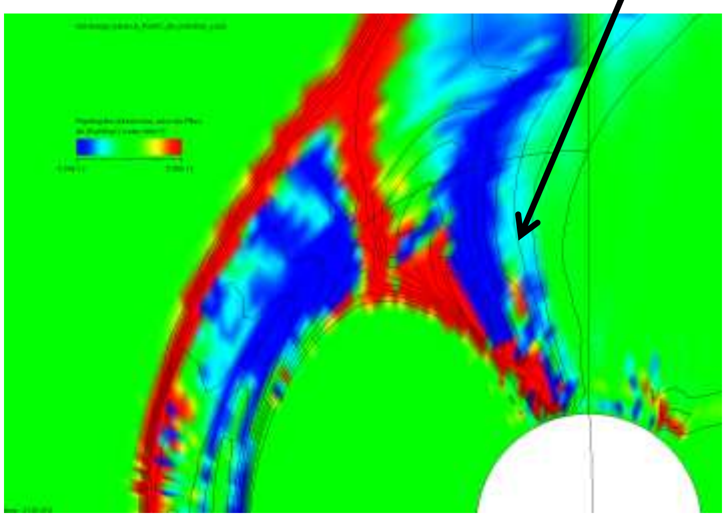
- 力バランスの式を連続の式とエネルギーの式（断熱過程）で書き直す。
- 非圧縮性から、slow mode expansion fanも現れる

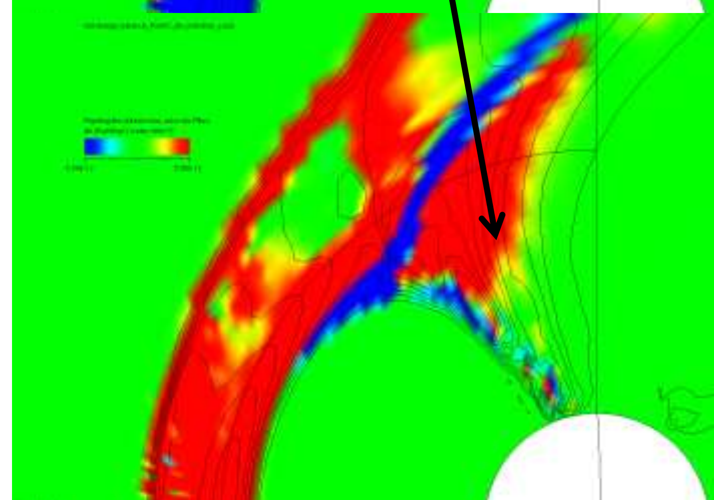
Plasma bulk flow and dynamo activity

$$\vec{E}\bullet\vec{J} \approx (\vec{v}_\perp \nabla_\perp)P = -(\vec{v}_\parallel \nabla_\parallel)P - \gamma P(\nabla\vec{v}), \quad -\gamma P(\nabla\vec{v}) = -\gamma P(\nabla_\perp \vec{v}_\perp) - \gamma P(\nabla_\parallel \vec{v}_\parallel)$$

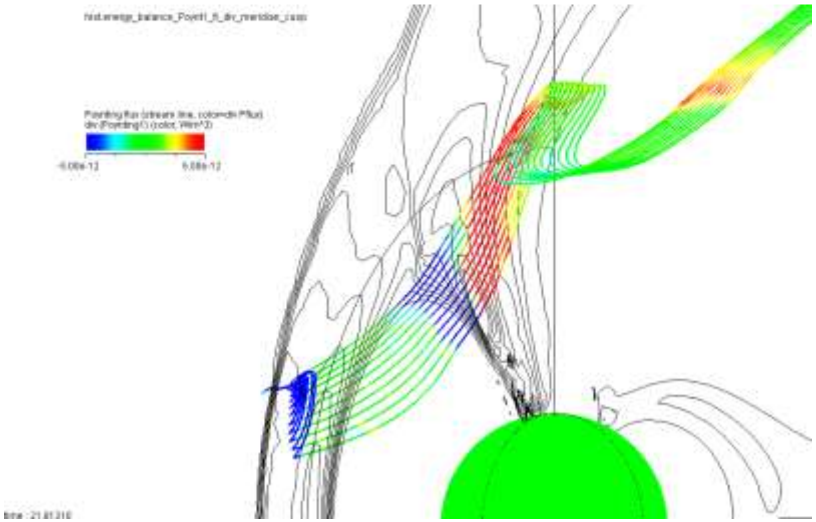


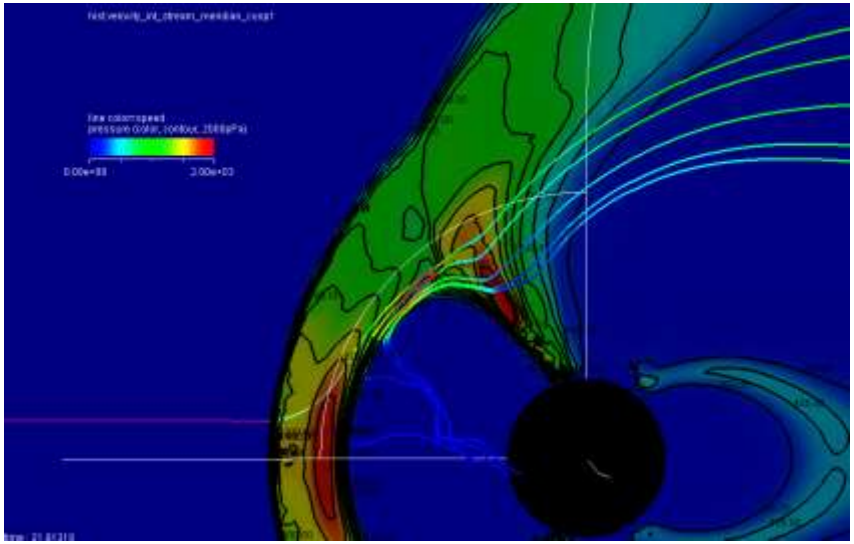


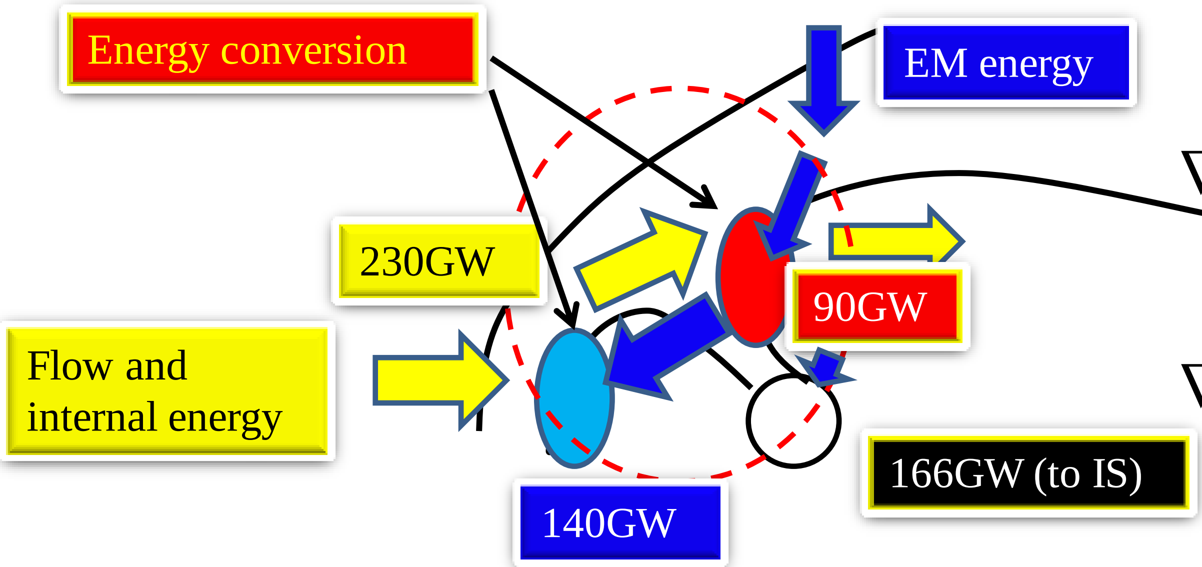




Magnetospheric energy convection



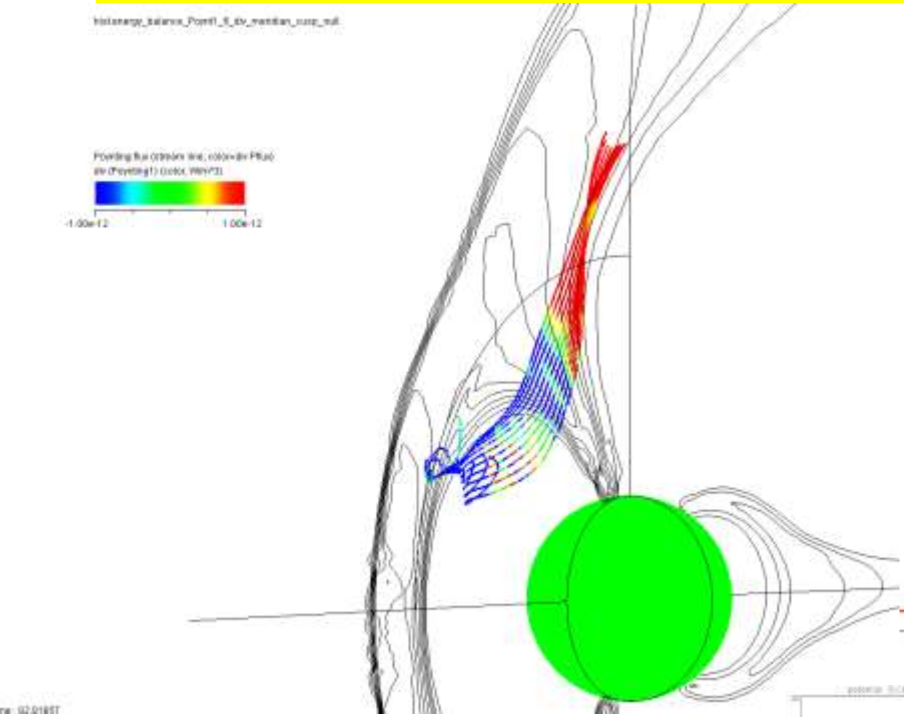


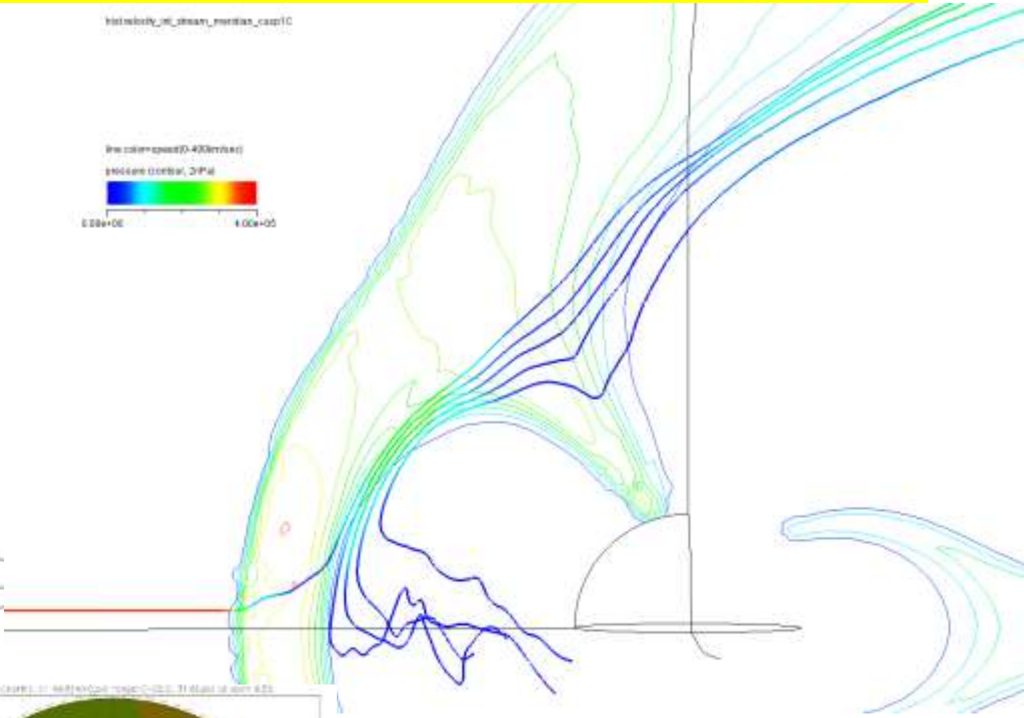


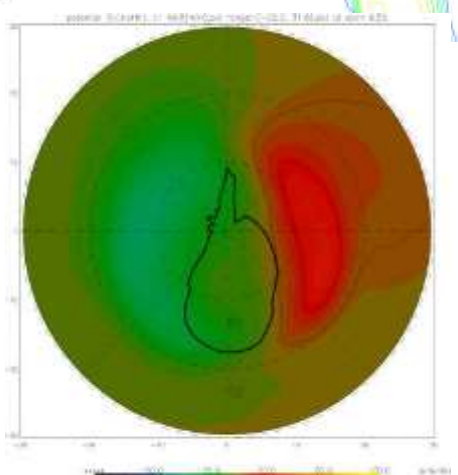
$$\nabla\left[\vec{v}\frac{\rho v^2}{2}+\frac{\gamma}{\gamma-1}\vec{v}P\right]\approx\vec{E}\bullet\vec{J}$$

$$\nabla\left[\frac{\vec{E}\times\vec{B}}{\mu_0}\right]\approx-\vec{E}\bullet\vec{J}$$

SW without IMF







Atmospheric convection and magnetospheric convection

$$U_a = \frac{\rho v^2}{2} + \frac{P}{\gamma - 1} + \rho\Phi$$

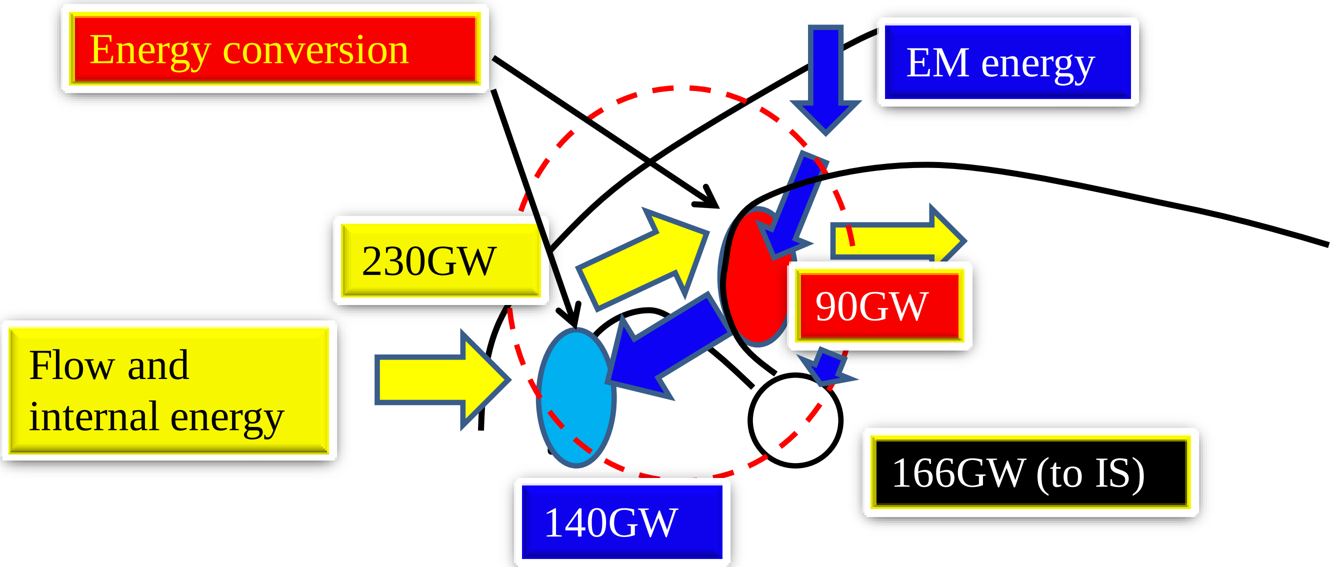
$$\frac{\partial U_a}{\partial t} + \nabla\left[\left(\frac{\rho v^2}{2} + \frac{\gamma}{\gamma - 1}P + \rho\Phi\right)\vec{v}\right] = -\rho\vec{v}\left[\vec{\Omega}\times(\vec{\Omega}\times\hat{r})\right]$$

$$U_m = \frac{\rho v^2}{2} + \frac{P}{\gamma - 1} + \frac{B^2}{2\mu_0}$$

$$\frac{\partial U_m}{\partial t} + \nabla\left[\left(\frac{\rho v^2}{2} + \frac{\gamma}{\gamma - 1}P\right)\vec{v} + \frac{\vec{E}\times\vec{B}}{\mu_0}\right] = 0$$

まとめ

- 磁気圏エネルギー対流
  - 電磁エネルギーと運動エネルギー・熱エネルギーの交換という磁気圏エネルギー対流が定義できる。 （plasmasheetにも同様のものがある⇒substormに関与）



おわり