Rice Convection Model:

Present, Near Future, and Role of CCMC

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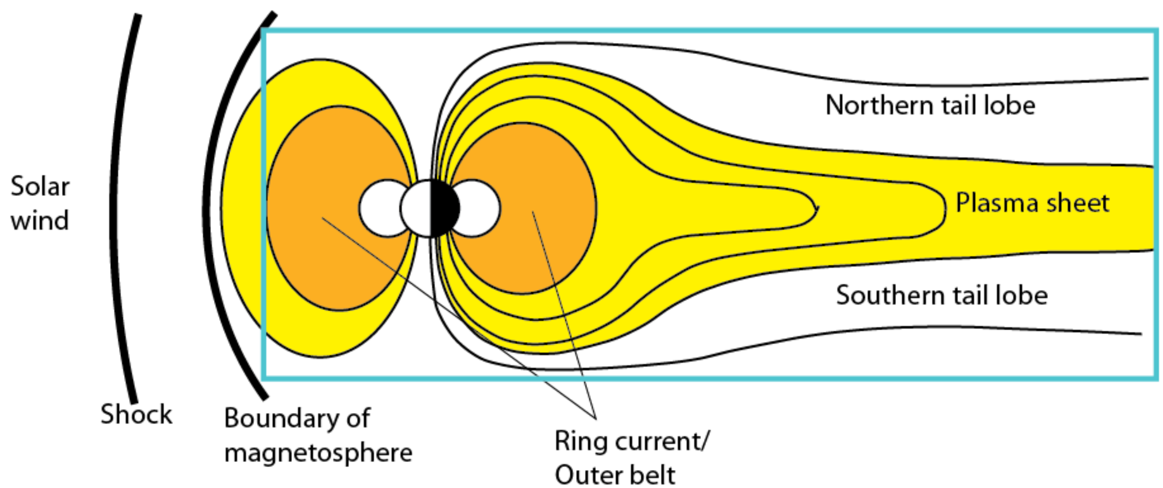


RCM: Drift Physics + Ionospheric Convection

RCM solves special form of guiding-center Vlasov equation for isotropic distribution function of hot plasma in the inner magnetosphere:

$$\left(\frac{\partial}{\partial t} + \frac{\vec{B} \times \vec{\nabla}\left(q\Phi' + \lambda V^{-2/3}\right)}{qB^2} \cdot \nabla \right) f(\lambda, \vec{x}, t) = S_{IonoOutflow} - L_{cex} - L_{precip}$$

$$\nabla \cdot \left(-\hat{\Sigma} \cdot \nabla\Phi \right) = \frac{\hat{\mathbf{b}} \cdot \vec{\nabla} V \times \vec{\nabla} P}{B}$$

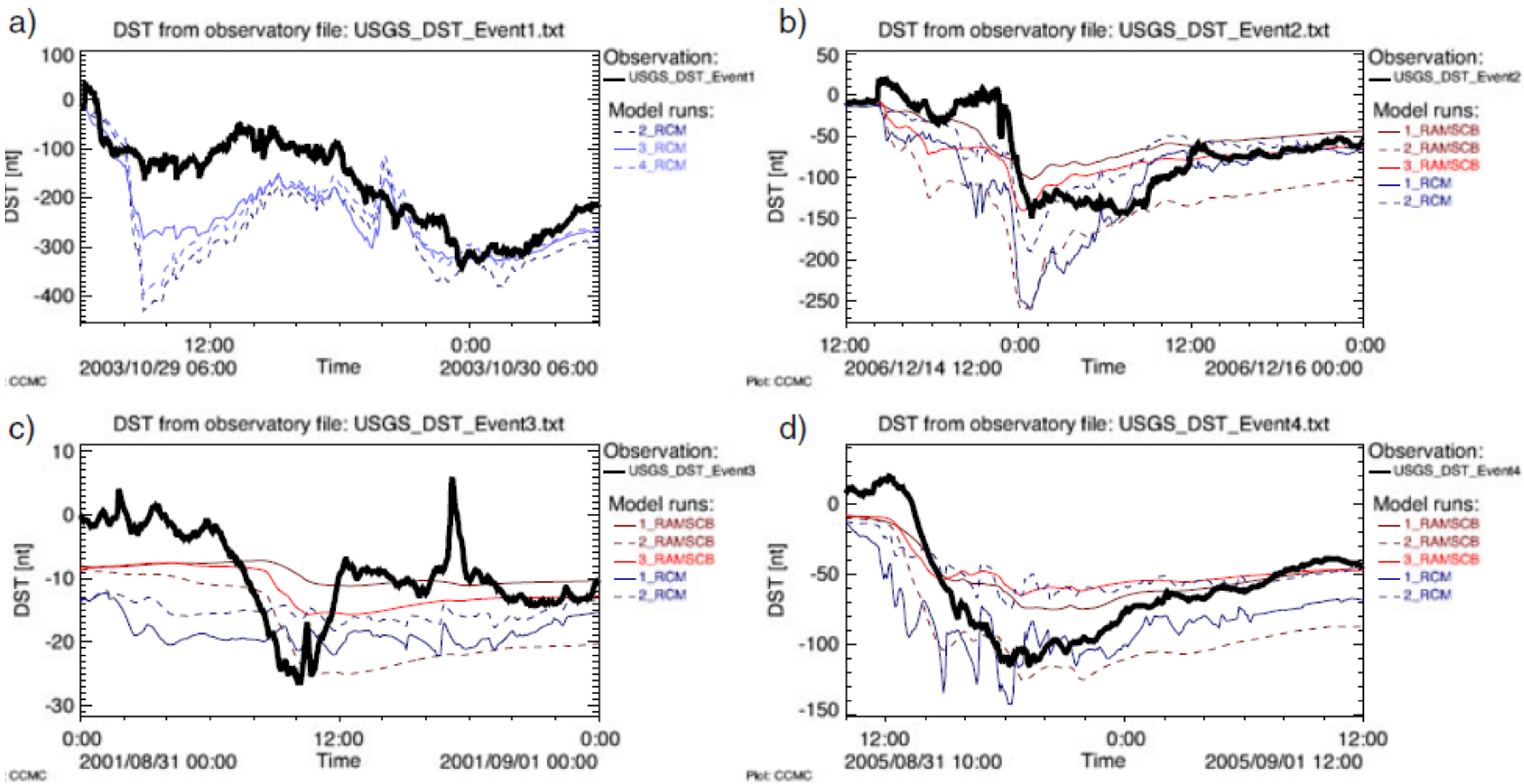
Magnetic field and boundary condition on PSD *f:*

- prescribed with empirical models (**standalone RCM**)
- provided by global MHD codes (coupled MHD-RCM: **SWMF with RCM)**.

Rice Convection Model at CCMC

- RCM as part of SWMF: has been at CCMC almost since beginning of time
- Standalone RCM
  - Installed at CCMC last year (December 2013)
  - Available for runs on request for event simulations
  - Driven by empirical magnetic field and plasma sheet model
  - Output: convection E, $J_{||}$, Σ, moments of *f*, PV^{γ} , auroral precipitation, plasmaspheric density.
- Advantages of running standalone RCM:
  - Parametric studies, varying various processes
  - More rapid development, adding new physics.

Dst Challenge: RCM results

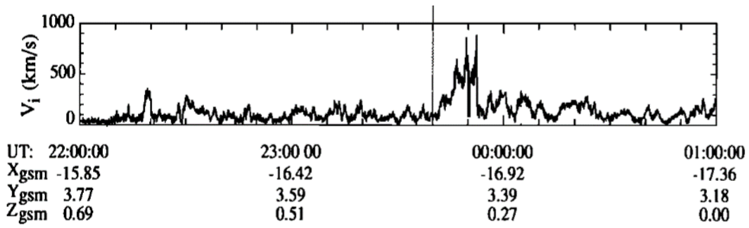


- Rastätter, L., et al. (2013), Geospace environment modeling 2008–2009 challenge: *D*st index, *Space Weather*, *11*, 187–205, doi:10.1002/swe.20036.

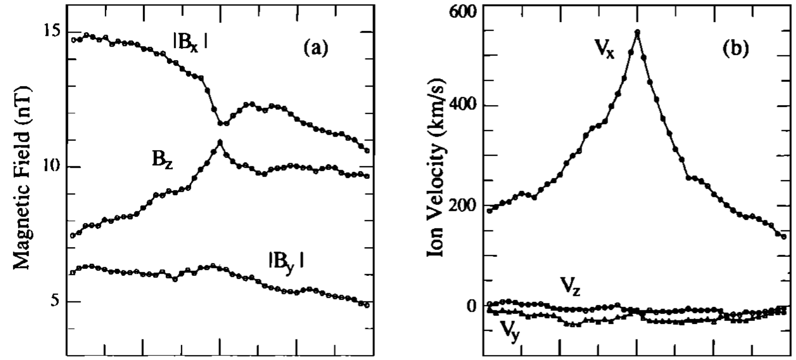
(Some) RCM Inputs

Magnetic field	*Tsyganenko* B-field models driven by solar wind data as background. Fit measured **B** for modeled event using Grad-Shafranov corrections
Particle initial condition	*Spence and Kivelson* [1993] empirical pressure distribution
Particle DF at high-L boundary	Basic *P* and *n* from *Tsyganenko and Mukai* [2003], $T_e/T_i \sim 1/7$ [*Baumjohann et al*., 1989], ion composition estimated from [*Young et al*., [1982].
Potential at high-L boundary	PCP estimated from DMSP ion-drift meter observations or from solar wind data and *Boyle et al*. [1997]. Weimer (2005) potential pattern
Ionospheric conductance	IRI-90 for quiet-time conductance + auroral enhancement based on *Robinson et al*. [1987] formula and RCM-computed precipitation.

Magnetospheric Convection: It is Mesoscale



(*Angelopoulos et al*., 1992)

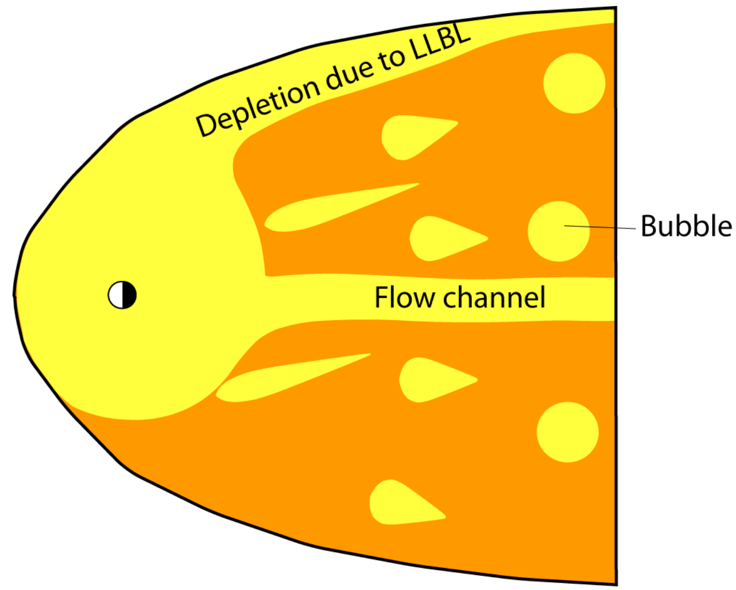


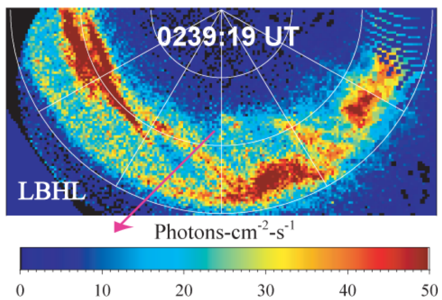
(1 minute tic marks)

- It was discovered in the early 1990's [*Baumjohann et al*., *JGR*, *95*, 3801, 1990; *Angelopoulos et al*., *JGR, 97*, 4027, 1992] that, though the average earthward flow velocity was only a few km/s, **a large fraction of the earthward flow came in brief flow bursts with velocities of 100s of km/s, which occurred in periods called "bursty bulk flows".**
- Flow bursts tend to have enhanced B_z and decreased $|B_x|$. Field lines more dipolar.
- Earthward of about 20 R_E, bursty bulk flows are almost entirely earthward.
- Cluster measurements suggest that flow bursts have dawn-dusk dimension ~ 2-3 R_E [*Nakamura et al*., *GRL*, *31*, L09804, 2004].

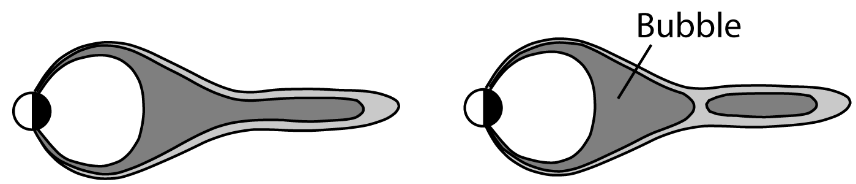
Ionospheric Signatures of Mesoscale Convection

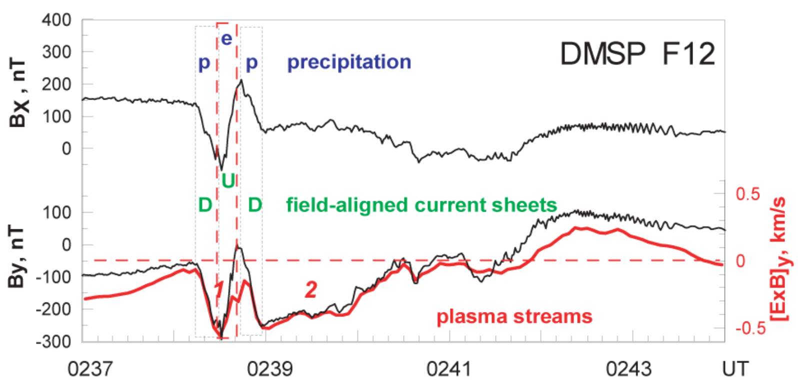
Auroral streamers in the ionosphere seem to be associated with BBFs in the plasma sheet (e.g., *Zesta et al.* [*JGR*, *111*, A05201, 2006]). Figure below adapted from *Sergeev et al*. [*AG*, *22*, 537, 2004]





Polar Ultraviolet Imager





The mesoscale BBF/auroral-streamer phenomenon (time scale of minutes, a few R_E width) doesn't fit within the picture of quasi-steady earthward convection.

New Physics in RCM (current work)

- Goal is to create new version of RCM that includes effects of inertial drifts in an approximate way.
- Global MHD codes compute Birkeland currents that include both pressure-driven and inertial currents, but lack sufficient resolution at the inner boundary to resolve adequately auroral zone M-I coupling.
- RCM has high-resolution (also grid is field-aligned).
- For standalone RCM, we make 3 simplified assumptions:
  - pressure is isotropic and therefore constant along magnetic field lines,
  - there is instantaneous communication between equat. plane and ionosphere
  - all of a flux tube's mass is assumed to be concentrated in the equatorial plane (purposes of calculating the effect of inertia only)
- Re-derive the equation for Birkeland current
- This approach provides a generalized form of coupling to MHD

Including effects of inertial drifts in RCM

- Current conservation if Birkeland currents are pressure-driven only:

$$\nabla \cdot \left(-\Sigma_p \nabla \Phi \right) = J_{\|}, \text{ where } \frac{\hat{\mathbf{b}} \cdot \vec{\nabla} V \times \vec{\nabla} P}{B}$$

- Conservation of current at the ionosphere when inertial contribution to Birkeland currents is added leads to the following elliptical equation that must be solved for the time rate of change of the potential:

$$\boldsymbol{\theta} \frac{\partial \Phi}{\partial t} = -\frac{\nabla_i \cdot \left(\overleftrightarrow{\Sigma}(t) \cdot \nabla_i \Phi(t) \right)}{B_i} - \frac{\nabla_i V \times \nabla_i p \cdot \hat{b}}{B_i} - \frac{\partial \mathbf{x}_e}{\partial \beta} \cdot \frac{\partial}{\partial \alpha} \left(\rho V \mathbf{Q} \right) + \frac{\partial \mathbf{x}_e}{\partial \alpha} \cdot \frac{\partial}{\partial \beta} \left(\rho V \mathbf{Q} \right)$$

$$\boldsymbol{\theta} = \frac{\partial}{\partial \alpha_i} \left(\sigma_{ij} \frac{\partial}{\partial \alpha_j} \right) \text{ where } \sigma = \rho V \begin{pmatrix} \left(\partial \mathbf{x}_e / \partial \beta \right)^2 & -\left(\partial \mathbf{x}_e / \partial \alpha \right) \cdot \left(\partial \mathbf{x}_e / \partial \beta \right) \\ -\left(\partial \mathbf{x}_e / \partial \alpha \right) \cdot \left(\partial \mathbf{x}_e / \partial \beta \right) & \left(\partial \mathbf{x}_e / \partial \alpha \right)^2 \end{pmatrix}$$

- Work in progress. Potentially better way to couple with global MHD codes.

Collaboration with CCMC

- Support for code installation and visualization from CCMC (L. Rastätter, M. Kuznetsova) has been terrific.
- We would like to increase available options for running standalone RCM for RoR, visualization improvements.
- CCMC-organized and/or CCMC-assisted "challenges" (GEM challenge, CEDAR-GEM) are very effective (but not easy).
- Constructive suggestions:
  - **Who model users are and what do they do?** [Can RoR form have mandatory box of "purpose" that is automatically emailed to model developers?]
  - **How to provide extra/alternative access to the CCMC runs?** [Access CCMC runs with extra criteria? VMR support?]
  - **Value of placing models at CCMC?** [Can NASA and NSF mandate (in AO's) that proposals comment on use of models at CCMC?]

Summary

- RCM at CCMC has two roles:
  - A component of global geospace model (SWMF)
  - Standalone version for runs on request: a simpler and faster way to run events for just inner magnetosphere, allows parametric studies, faster development
- New physics in RCM: Effects of inertial drifts
  - Relax assumption of quasi-static slow-flow approximation
  - Simulations of mesoscale convection with high spatial resolution
- Suggestions to CCMC:
  - Improve user to modeler feedback
  - More flexible access to the runs database
  - Advocate more formal acknowledgement of CCMC in NASA- and NSF-funded research