# Field-Aligned Potential Drops in an Ionospheric Streamer

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## Bubbles, Streamers and Our Model

- **Low-entropy bubbles** in the magnetosphere can form **ionospheric streamers** as their projections.
- Equatorward (earthward) current band east of streamer's (bubble's) center.
- Poleward (tailward) current band west of streamer's (bubble's) center.

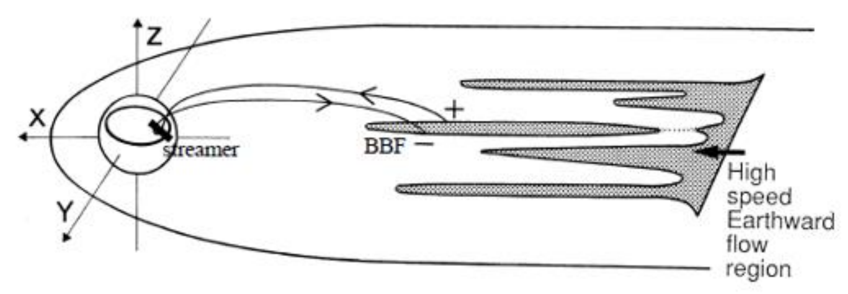



**Fig. 1.** Schematic sketch of BBF in the plasma sheet of the magnetotail, and their connection to auroral streamers in the ionosphere (from Sergeev et al., 2000, modified).

- Western current band involves electric field along magnetic field line into the ionosphere. Eastern band typically has no strong FAPD.

| Physical Feature | Bubble (M) | Streamer (I) |
|---|---|---|
| Width | $1-3\ R_E$ | 10 – 100 km |
| Speed | 300 – 400 km/s | 1 km/s |
| Electric Fields (Across) | 1 – 10 mV/m | 10 – 50 mV/m |
| Field-Aligned Currents | < 25 μA/m^2 | |
| FAPDs | 1 – 10 kV | |

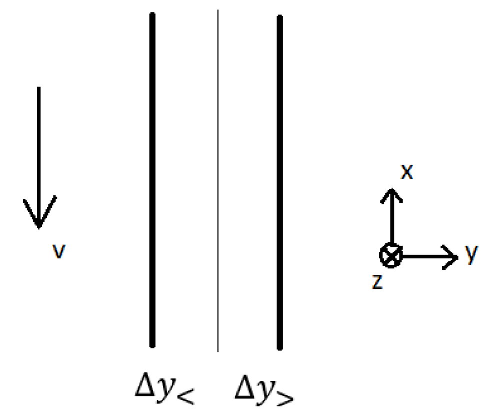



**Fig. 2.** Streamer Model Geometry

- The **streamer model** is zeroth-order and time-independent.
- We assume magnetic field points into the ionosphere. Streamer is aligned with the x-direction in ionosphere. It has width $d = \Delta y_< + \Delta y_>$. We ignore velocity outside of streamer. Hall conductance is neglected.
- We use the functions at the right to represent the entropy depletion, the eastern band **conductance enhancement** and the flux tube volume gradient.
- By design, $0 \le \eta \le 1$. Both $\Sigma_0$ and $\Sigma_a$ are assumed positive. The conductance takes its max value at $y = \Delta y_>/2$.
- We have allowed dawn-dusk streamer asymmetry.

$$(1)\quad K(y) = K_0 \begin{bmatrix} 1, & y \ge \Delta y_> \\ \dfrac{1-\eta\cos\left(\frac{\pi y}{\Delta y_>}\right)}{1+\eta}, & 0 \le y < \Delta y_> \\ \dfrac{1-\eta\cos\left(\frac{\pi y}{\Delta y_<}\right)}{1+\eta}, & -\Delta y_< \le y < 0 \\ 1, & y < -\Delta y_< \end{bmatrix}$$

$$(2)\quad \Sigma(y) = \Sigma_0 + \begin{bmatrix} \Sigma_a \sin\left(\pi \dfrac{y}{\Delta y_>}\right), & 0 \le y < \Delta y_> \\ 0, & elsewhere \end{bmatrix}$$

$$(3)\quad \frac{\nabla V}{V^\gamma} = S(-\hat{x}\cos\zeta + \hat{y}\sin\zeta)$$

- **Model Physics:**
- We use the MI coupling equation, which shows that a **field-aligned current** generated by the misalignment of entropy and flux tube volume gradients (**RHS**) results in an **ionospheric electric field** (**LHS**). This electric field is not along the field line:

$$(4)\quad \partial_y\left(\Sigma(y)\partial_y\Phi_i\right) = -J_\parallel = \frac{\hat{z}\cdot(\nabla K \times \nabla V)}{V^\gamma}$$

- In addition, we use a simple model for **field-aligned potential drops**, which is basically **Ohm's law** along a magnetic field line. This allows us to obtain the modified **electrostatic potential in the magnetosphere**:

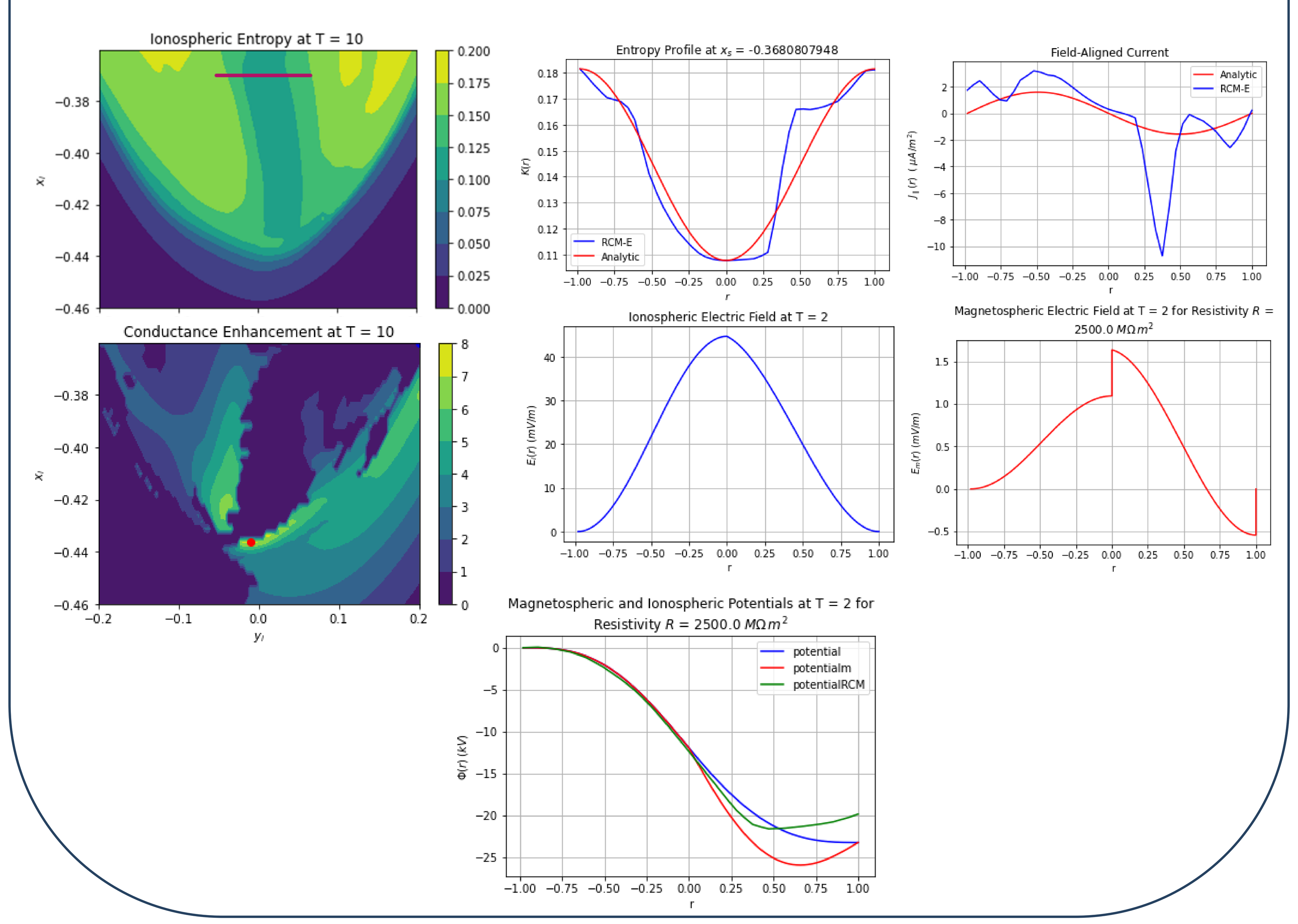
$$(5)\quad \Phi_m = \Phi_i + RJ_\parallel \begin{bmatrix} 1, & J_\parallel < 0 \\ 0, & J_\parallel > 0 \end{bmatrix}$$

## Procedure and RCM Results

- We take slices of the ionospheric streamer, and I use a code to fit the parameters and solve for the ionospheric and magnetospheric electric fields:
  1. Perform a run of RCM-E with a bubble injection.
  2. Pick a time after injection and a suitable slice across the streamer.
  3. Fit analytic model profiles for entropy, flux tube volume and conductance to slice profiles. Conductance enhancement uses the Robinson formula with average precipitation energies and energy fluxes computed using equations from *Wiltberger et al. 2009*.
  4. Check that profiles qualitatively match and have realistic magnitudes.
  5. Solve for potential drops and magnetospheric and ionospheric electric fields at a chosen field-aligned resistivity $R$.

## Results from One Bubble Injection

- The following example uses a bubble injection run of the RCM-E from *Yang et al. 2014*. The run proceeds in three stages:
  1. A 60-minute growth phase with a polar cap potential drop of $35\ kV$ and an average entropy $K = PV^\gamma$ of $\sim 0.16\ nPa * (R_E/nT)^{5/3}$ at the high-latitude midnight boundary.
  2. A 10-minute bubble injection centered at midnight with a local time width of 0.5 h. The entropy is reduced by 1/3 in the bubble, and there is a potential drop of $\sim 24\ kV$ ($\sim 4\ kV$ pre-injection).
  3. Returns the entropy and potential drops to pre-injection values.
- Along the red slice shown below, we fit the entropy and conductivity profiles, and the model generates FAPDs and flow reversals. I have shown a later moment in time of RCM so that you can see the streamer.




## Conclusions and Future Work

- We have used fitting to an RCM bubble injection run as input to a simple one-dimensional streamer model with field-aligned potential drops.
- The resulting FAPDs, cross-streamer electric fields, and equatorial bubble electric fields are all comparable to within an order-of-magnitude to existing observational constraints.
- The magnetospheric electric field, with FAPDs included, shows a pronounced field-reversal indicative of modified flows near the Birkeland currents which acceleration charged particles to precipitate from the magnetosphere into the ionosphere.
- In the future, we plan to perform a run of the RCM-E which includes the field-aligned potential drops to validate the model and see how the electric field and flow structures are modified in two dimensions.
- We will use parametrized bubble runs using observational constraints from magnetic reconnection in the magnetotail and streamers in the ionosphere to determine more realistic boundary conditions for bubble injections.
- We plan to integrate zeroth-order model features into global models to modify the flow patterns in the magnetosphere and improve MI coupling.

## References

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