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# Doubly-shadowed regions in lunar polar craters: hydrogen accumulation in the presence of recursive plasma wakes

# (Recursive plasma wakes make a volatile splash)

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# Why study the lunar polar plasma environment?

Direct relevance to (a subset of) the primary science questions of the DREAM Institute:

- What is the ***evolution of volatiles*** including water ice at the lunar surface, especially in the very cold polar regions?
- Where and when is ***lunar surface charging*** the most intense?
- How will ***human outposts and activities*** affect this fragile environment (and vice versa)?

**DREAM = Dynamic Response of the Environment at the Moon**

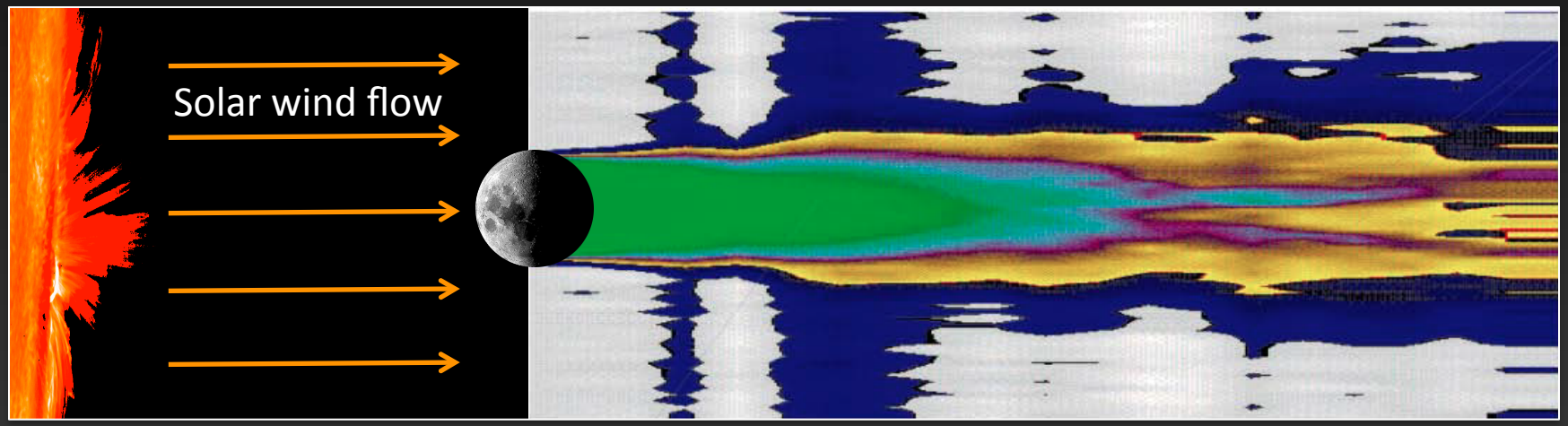
# Solar wind-volatile connection?

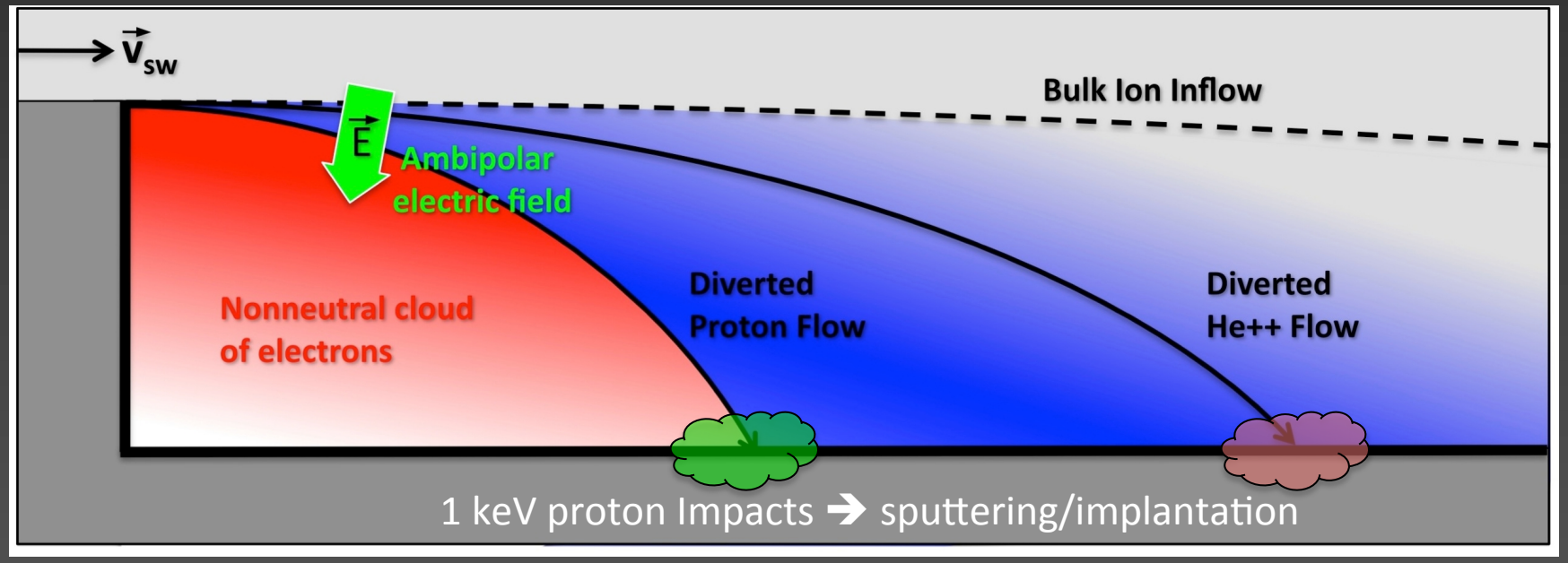
- Diviner suggested PSRs cold enough to trap water ice
  [Paige et al. 2010]
- LAMP revealed low-concentration frost in some PSRs
  [Gladstone et al. 2012]
- Mini-RF signatures consistent with ice in some pol. crat.
  [Neish et al. 2011, Spudis et al. 2010]
- LCROSS plume revealed volatile-rich surface composition [Colaprete et al. 2010, Gladstone et al. 2010]

- No clear connection between properties of individual craters and inferred volatile concentrations
  - ***Topographically-modulated plasma physics component?***

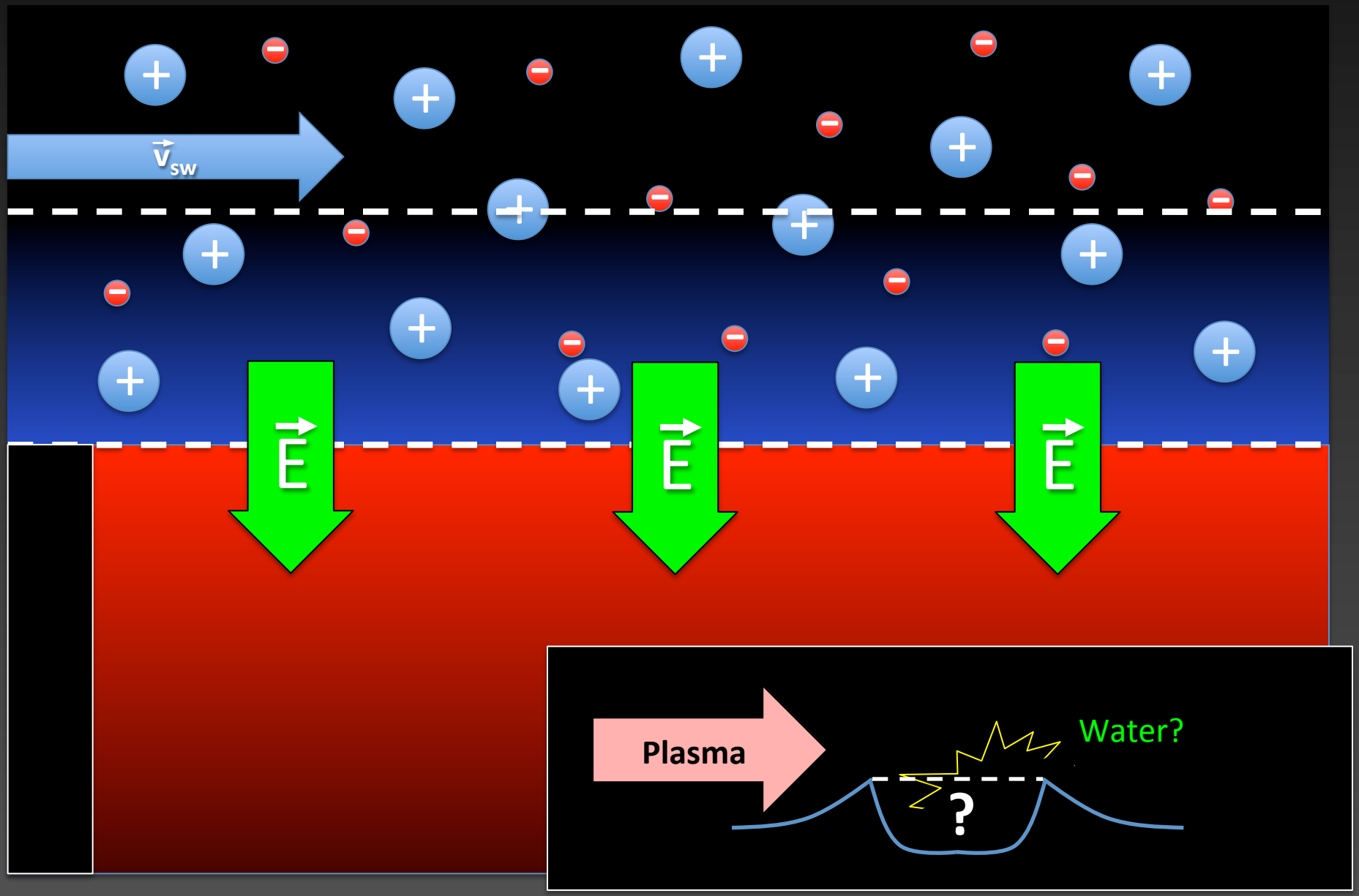
# Lunar Crater Wakes: Global Analogy

**Simulation data from Farrell et al. (1998)**

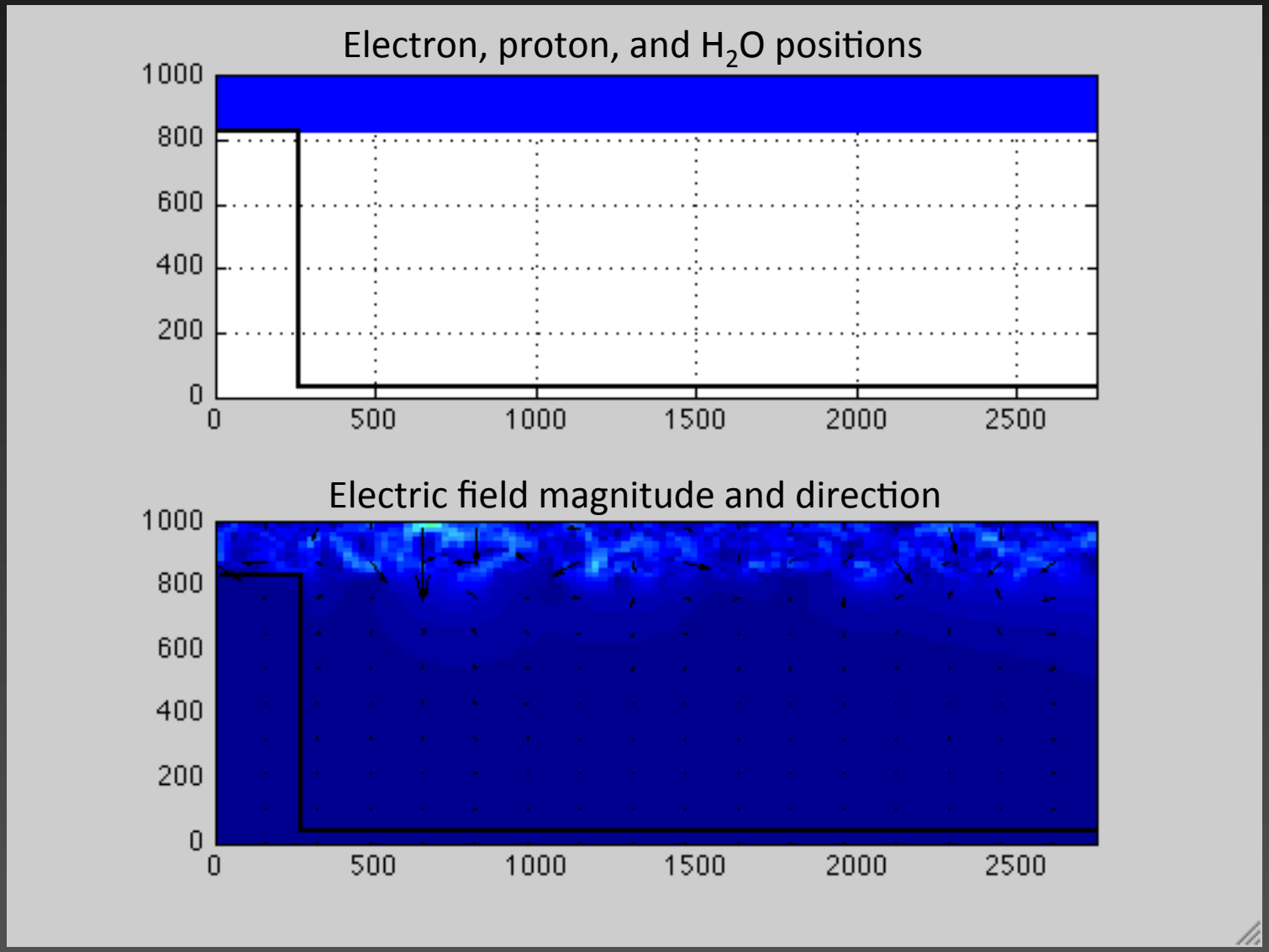


# Expectation: Plasma Expansion into Vacuum



# Plasma simulations allow detailed studies of crater wakes

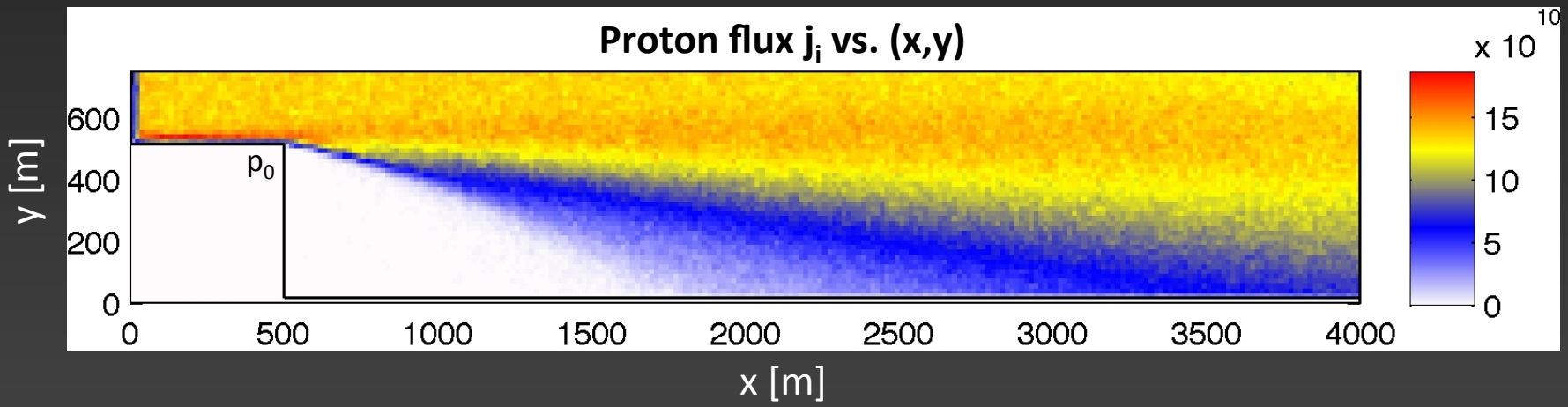


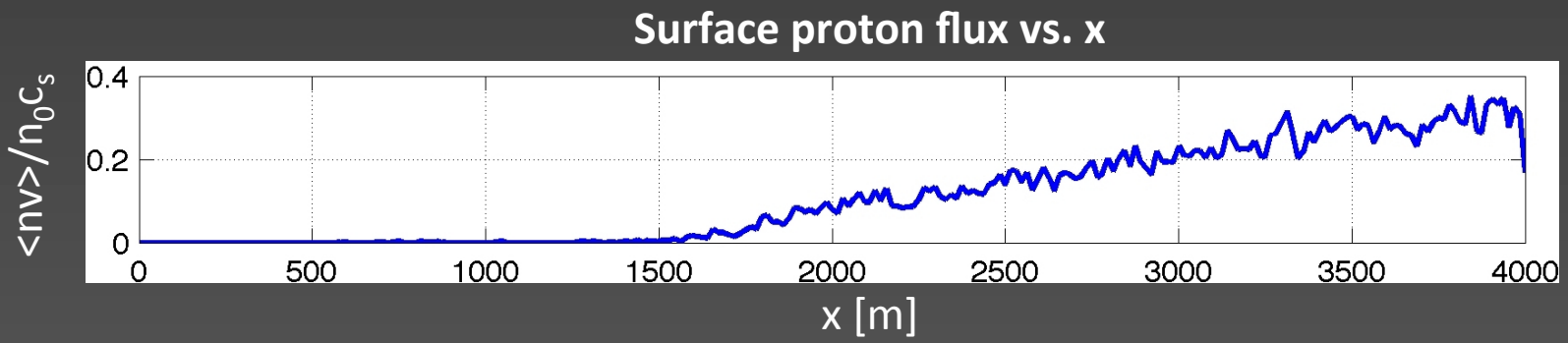
# Basic theory/simulation comparison

- Wake structure is captured by a single parameter – the point of occultation is critical

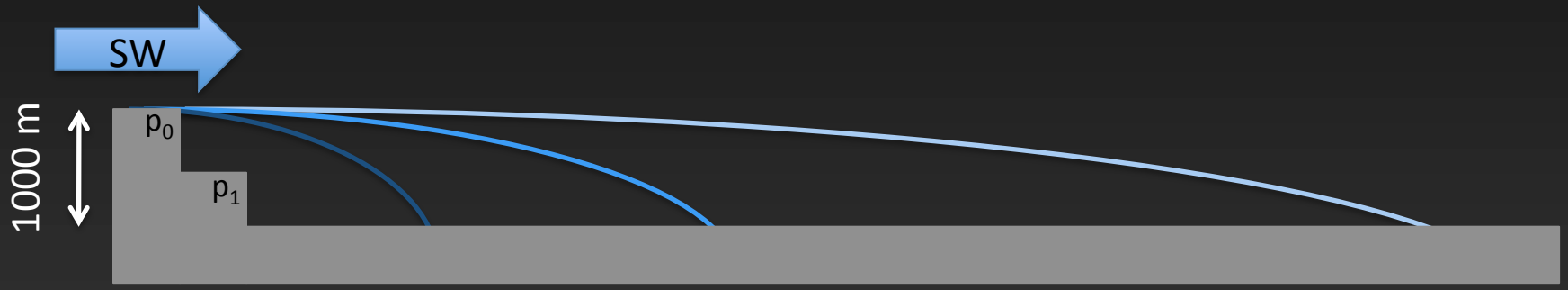
$$\xi(x,y) = \frac{v_{sw}}{c_s}\frac{(h_{cr}-y)}{(x-x_{cr})}$$

$$j_i(x,y) \sim (1+\xi)\exp(-\xi)$$

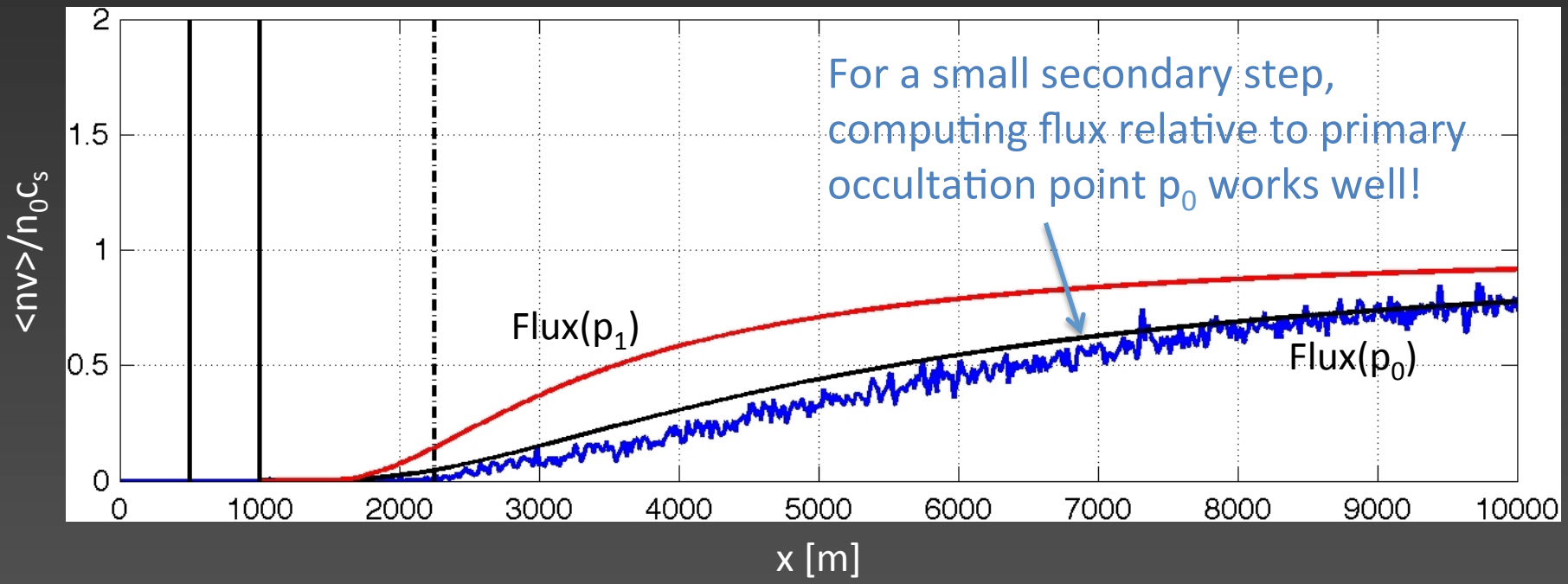


# Results for a double step crater

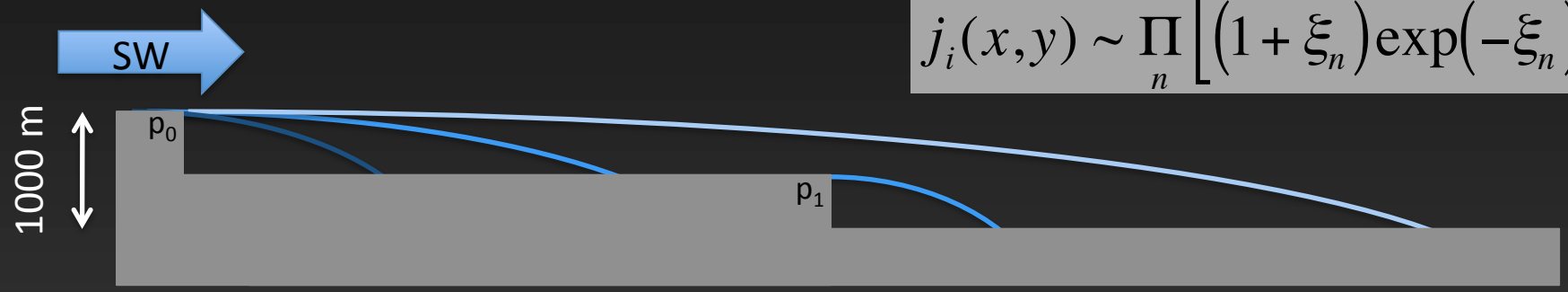



**Surface proton flux vs. x**

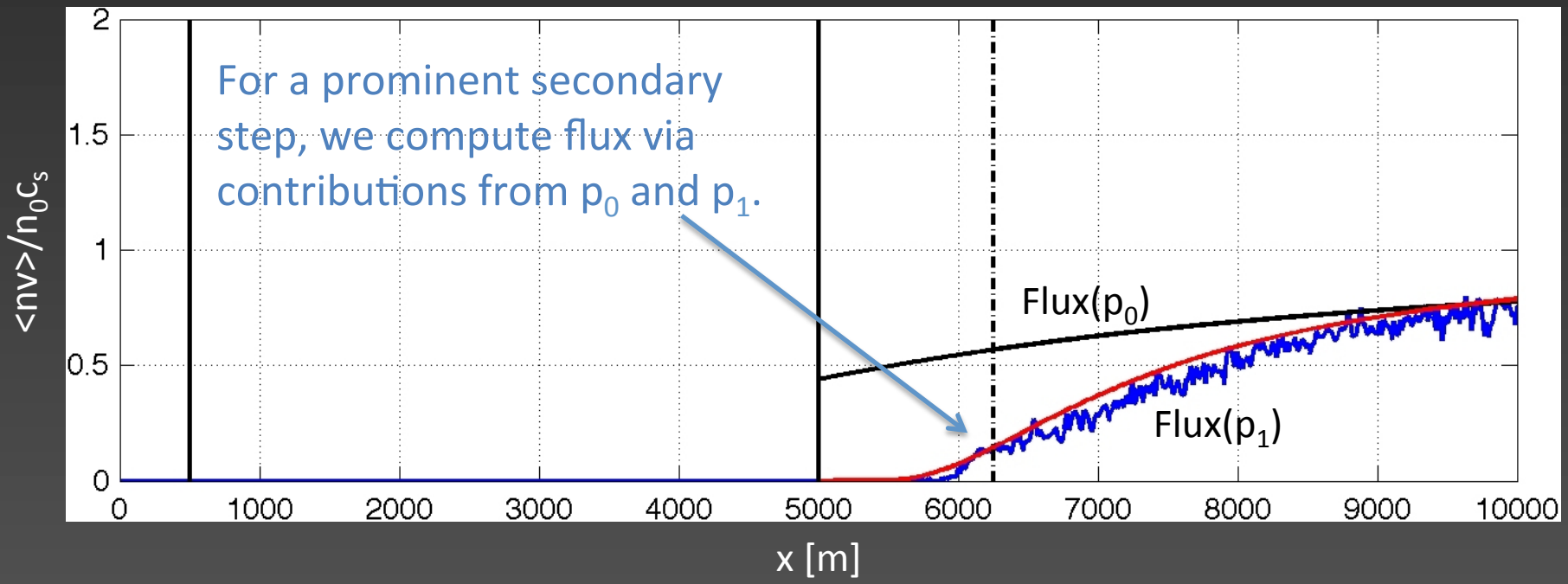


# Results for a double step crater

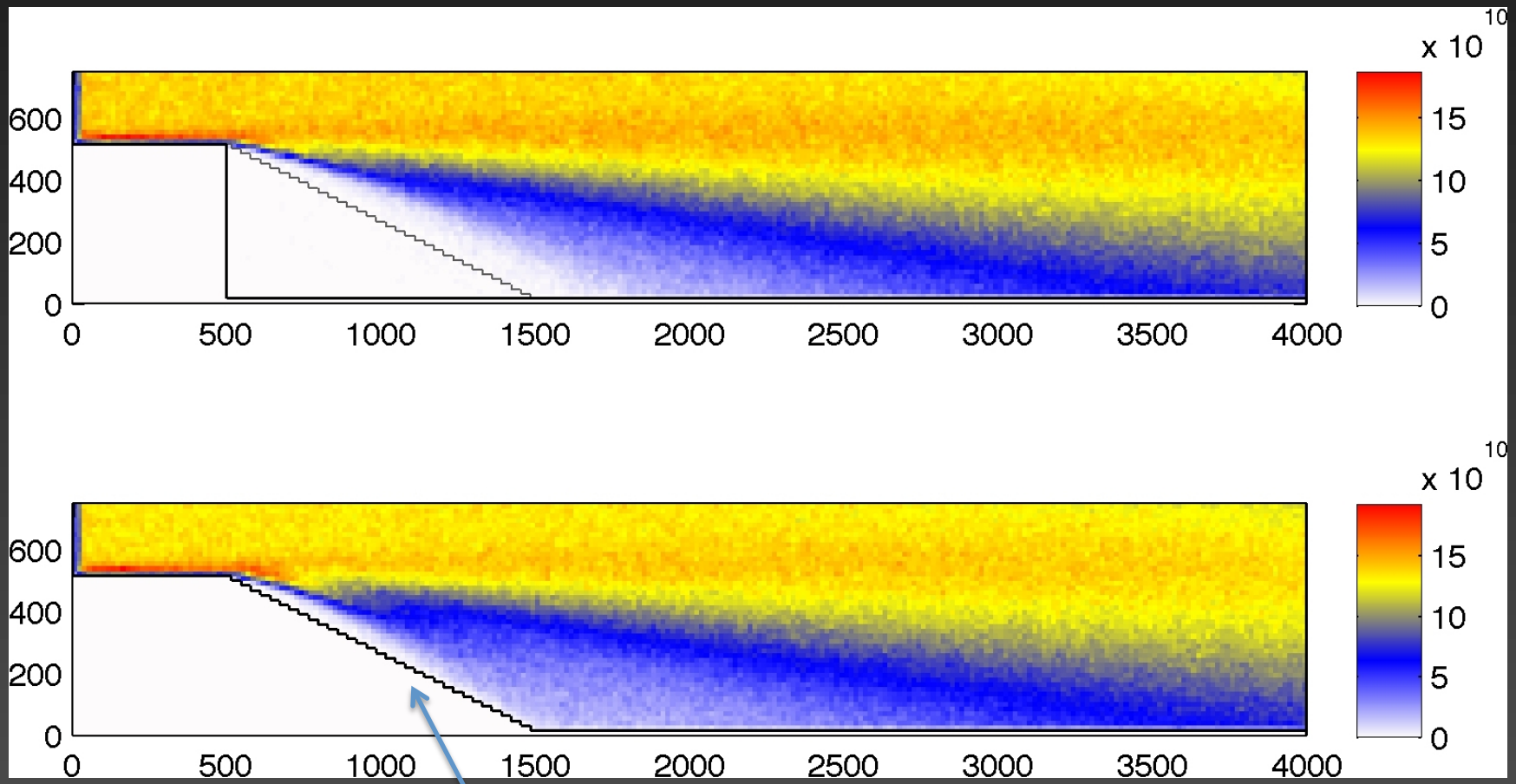
$$j_i(x,y) \sim \prod_n \left[ \left(1+\xi_n\right) \exp\left(-\xi_n\right) \right]$$




**Surface proton flux vs. x**



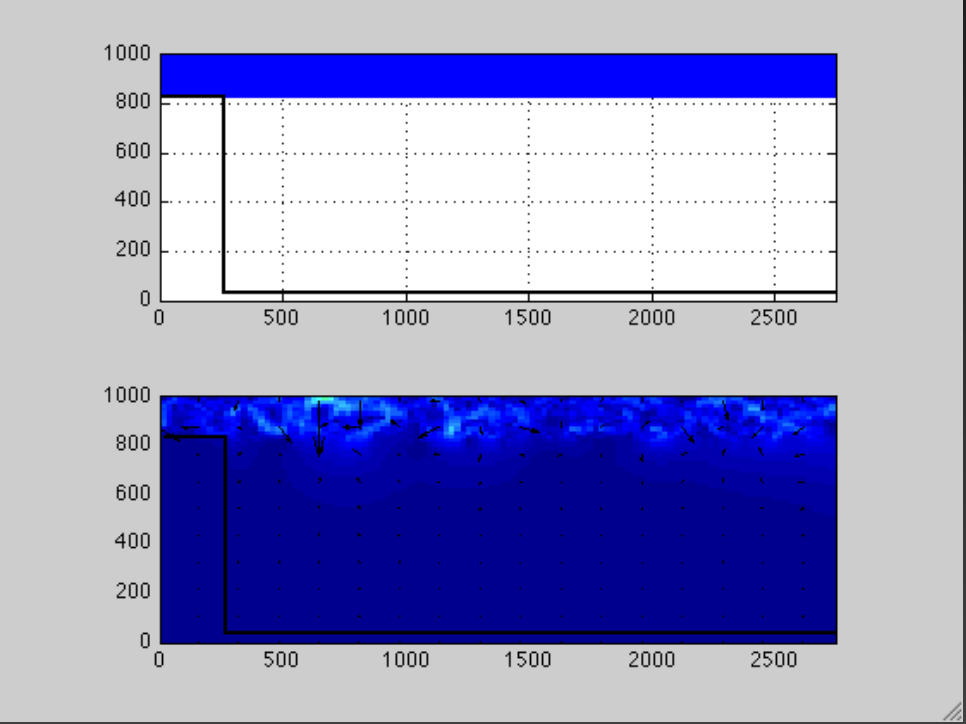
# Surface charging draws protons in




Surface electric field (not shown) enhances ion flux to inclined surface

# Conclusions

- **Solar wind ions do get into polar craters!**
- We can directly model 2D ion inflow near complex km-scale topography … plus a virtually limitless variety of sputtering products
- Simulation + theory combo will predict polar maps of water sputtering & proton implantation




Is there a unique, topographically-modulated plasma/volatile connection that could explain the observed polar water concentrations?