Current Continuity in Auroral System Science

* ABSTRACT
* BACKGROUND AND MOTIVATION
  + The MI coupling scene, what’s local?
    - Wolf 1974 (IM coupling: large scale, 2 magnetopause generator region – 3 magnetic field lines – 4 ionospheric conductivity)
      * Briefly explain the large scale convection?
      * Magnetopause: place where the solar wind touches the magnetosphere, this makes some generator/demand/driver of current/flow/electric field
      * Conducting magnetic field lines connect magnetopause to ionosphere
      * Vasyliunas 1970 - Know magnetospheric electric field >> assume we know source plasma (ring + sheet) + non-adiabatic precip >> compute particles distribution, get pressure tensor, MHD momentum, ehhhh some creation of birkeland currents
    - Cowley 2000 (ionospheric flow and currents – Dungey – cusp currents to IMF)
      * Explain birkeland currents
      * These bikeland currents must be balanced in the collisional ionosphere via perpendicular currents.
    - Lysak 1985 (joules dissipation implies generation in magnetosphere, whether current driven or potential driven changes scale sizes, “highly structured”, “narrow sheets” i.e. local, down to auroral arc scales)
      * Acceleration region along with Pedersen currents (joule heating) dissipate energy (j.E>0) which must be balanced by plasmaspheric generator j.E<0.
      * Satellite data have shown this large scale description of current closure embeds much more structured currents (DE, Swarm, champ, more?)
  + The I of MI coupling: Generator: current vs potential
    - Lysak 1985 (see discussion and conclusions)
      * Lysak describes natural scale length depends on pure voltage or pure current generator
  + Okay, M and I are coupled (through Alfven reflections, E parallel somehow), now what
    - Parallel E, seyler 1990 discussion
    - Talk about how accel is formed, but then Electrostatics
    - Evans 1974 (Inverted V precipitation)
      * This creates complex conductivity in ionosphere
    - Some figure that shows global MI coupling zoomed down to Ionospheric picture with U potentials and all that
  + Derivation of ionospheric cc equation
    - We’ve talked current j, potential, E, how do they relate? Ionospheric conductivity, ohms law
    - Kelley 2009, chap 8, brekke 1989
    - Fang 2010 (impact ionization changes conductances)
    - Relatively well posed up to here for sheetlike arcs
    - Work on that last figure showing where this 2d map of current exists, or point out on that last figure
  + Why 3d modelling now?
    - Zettergren 2012, 2015? (Straggling recombination time hysteresis)
    - Goertz 1979 (basic 2d model of MI coupling Pedersen wave damping? idk)
    - Mallinckrodt 1985 (2d ionosphere models, current loops)
    - Amm 2008 (what 3d models will show)
    - Fujii 2011 (cowling channel)
    - Marghitu 2012 (coupling of FAC to hall current or FAC blockage)
      * This is an incomplete picture, piecing together discrete arcs with limited data
    - Hard to find what the ionosphere will “choose” to respond with. What’s physical?
* THESIS STATEMENT
  + The aim of this thesis is to find physical, self-consistent solutions to the ionospheric current continuity equation using state-of-the-art ionospheric 3D modelling to provide insight into the role the ionosphere plays in IM coupling for less idealized auroral events.
  + In particular, knowing the portions of FAC closed by Pedersen currents, which produce collisional Joule heating, versus Hall currents, which are non-dissipative \citep{amm2008,clayton2021}, gives insight into the extent to which the ionosphere acts as a load to a magnetospheric generator \citep{wygant2000}.
* APPROACH AND METHODOLOGY
  + GEMINI 3d modelling
    - Zettergren et al (general what it do)
  + Drive gemini with 2d maps
    - Talk about developing potential maps from flow maps, reconstructor
    - Figure of input maps + cut to loading bar
  + Base maps on in-situ + GBO data
    - Example of alex data
    - Wu 2020 (superposed epoch analysis of current sheets and brightness + alfvenic)
  + Create catalogue of parameterized stereotypical flow/current/precip combinations and introduce along-arc structure to investigate nonsheetlikeness to drive gemini
  + Systematically build on those cases, change parameters, and compare outputs (J path, flow, ne)
  + Visualize simulations in 3d
  + Add to GEMINI: Electrostatic induction module
    - How will this help thesis: it will more accurately depict dynamics of 10s of seconds, alfvenic timescales, no feedback however
    - Ask matt how to approach
      * Need full perp ion momentum (for wave dynamics). Used to be simple force balance
      * Need full electron momentum, used to be v\_i-v\_e=J only
      * Get J from v\_i-v\_e
      * Get B from curlB=J and get E from curlE=dB/dt (previously divJ=0 with E=-gradphi)
    - Lotko 2004 (inductive coupling)
    - Seyler 1990 (more on parallel E in generator region using oblique alfven waves)
  + Add to GEMINI: Energy bookkeeping, address cowling channel, pointing
    - How this will help thesis: Can use pointing constraint to back out what the physical solution might be (why not just start with this then? Seems like it answer thesis… not as easy as it sounds)
    - Fujii 2011
    - Richmond 2010
    - Richmond 2010 (pointing theorem in ionosphere)
    - Wygant 2000 (polar UVI + alfven)
* SCIENCE STUDIES
  + Straight
    - Baseline case, boring but needed
    - One fac driven
    - One flow driven
    - Should be the same
  + Bend
    - Does minor along-arc structure alone do interesting stuff to current closure?
  + Bend moving (bend moving westward at ~ km/s)
    - Does recombination time introduces across-arc gradients changing current path?
  + Sharc
    - How will current close if sheet is not infinite? With and without precip. What about at the surgehead
  + Loading bar
    - What happens when precip moves through current sheet?
  + Precipitation depth
    - Move from Pedersen to hall layer sequentially. What happens to current closure?
  + 100 s precip turn on
    - See gradual change in current closure based on precipitation
  + Current versus potential driven
    - Not sure how to approach this?
  + 3d figures of current flow ne for loading bar and wts
  + Closure:
    - How will these studies address the thesis
* GOALS
  + Task list
    - Get more accurate inverted-V precip for gemini
    - Short paper on reconstruction algorithm?
    - Paper on wts + loading bar?
  + Schedule
    - By end of 2022
      * Settle on precip close to inverted v
      * Run baseline, loading bar, wts, and precip depth runs
      * Cedar poster
      * Investigate Alex/Maia stats
      * Improve upon existing studies and determine where to go from there
      * Short Reconstruction paper?
    - 2022-2023
      * AGU
      * Cedar
      * Paper on what’s been found so far
    - 2023-2024
      * AGU
      * Cedar
  + The team:
    - Maia
    - Byron
    - Maeve
    - Alex
    - Matt
    - Kristina

