Session Notes

Session notes for “Plasma Structuring in the Polar Cap - Definition, Generation Mechanisms, and Properties of Polar Cap Patches” held during the 2024 CEDAR Workshop in San Diego, CA on June 12, 2024.

Presentations

Lindsay Goodwin

- Why do we care about plasma density irregularities?
- HF propagation diffraction based on density
- Both horizontal and vertical propagation
- What is a polar cap patch?
    - Plasma density enhancement in the polar cap
    - At least twice the background density
    - Traditional definition
- How do we make a patch?
    - Convection and MI coupling
    - Dense plasma is being pulled from the dayside into the nightside
    - Island of dense plasma moving into less dense plasma
    - TOI - chopped into patches? Or a poor resolution trail of patches?
    - Particle precipitation
    - PMAFs
    - Waves - drift from lower latitudes?
- Many ways to create plasma density enhancements that are twice the background
- What is the “background”; does it change based on instrument?
- Are “airglow patches” the same?
- Do simulations show preference for particular recommendations
- Does a TID become a patch by virtue of being in the polar cap? Does this make sense?
- Twice the density - does changing this based on the source mechanism make sense?
- Physics behind patches - very coupled system, but observations don’t provide complete measurements of all relevant regions (cusp, thermosphere, solar wind, ect)

Toshi Nishimura/Shasha Zou, Gareth Perry

- How do we determine if we are even in the polar cap?
- What is the appropriate enhancement?
- How to determine background, especially with limited measurements?
- Many ways to define patches with many different instruments
- Factor of 2 density enhancement is reasonably well accepted

- Definition of polar cap varies wildly in literature
- Sharpness of edge gradients varies
- Min and max patch sizes vary hugely depending on paper
- No consensus on how to define background
- Activity fill polar cap, mixing of polar cap and auroral oval
    - Often don't have localized precipitation information to correctly determine auroral oval
- Precipitation within the polar cap - "polar cap arc" - these are probably often called patches
- Depending on the data you use, how you process the data, what other information you have available, your definition of a patch can be vastly different
- Airglow emissions - sometimes agrees with density enhancements, sometimes not
    - If there's not enough recombination, probably won't see patches in airglow
- Patches in ISR
- Statistically, patches are colder than the surrounding region - indicates precipitation is NOT the primary sources?
- TEC - ratio between enhanced TED and background (tongue-to-background ratio TBR)
    - TBR of 1.3 or 1.4 may be an appropriate threshold
- TOI grouped together with plumes?
- SuperDARN - HF radar
    - Discrete regions of backscatter moving either polewards or equatorwards
    - GDI on the edge of patches is the presumed backscatter target
    - Hard to see patches moving broadside to the radar (don't see motion, but should still see backscatter)
- A lot of human bias involved in many of these detection techniques
- How do we study physics involving patches if we can't agree on how to define a patch?
- Patches are a vertically extended structure - altitude kind of depends on instrument
- High latitude TEC - integrating through highly oblique slides
    - Also limited number of measurements due to GPS orbital altitudes
- SuperDARN identification of patches
    - Flow channels? Patches? Could it be both?
    - Velocity structuring superposed with echoes
    - Can you tell the difference between patches and TIDs?
    - Don't get density measurements, get HF backscatter
- No reason to ONLY look at one dataset when it comes to patches
    - A lot of measurements are coincident
    - Maybe shouldn't do single-instrument studies of patches

Sharon Vadas

- Cross-polar propagation of Atmospheric Gravity Waves
- Filtering neutral wind is the diurnal tide
    - Rotates like a hose

    - GWs that reach the mid thermosphere oppose the diurnal tide
- Polar cap is not special - waves propagate here similar to anywhere else
- GW generated over Brazil
    - Modeled using convection model and TIME-GCM
    - GW at 150 km
    - Destructive/constructive interference in GW from different plumes
    - GW propagate up to 200 ish km?
    - This simulation only have waves propagate about 1000 km
    - When waves dissipate, they generate secondary gravity waves (concentric)
    - These go all the way up to 400 km
    - These waves travel all the way over Antarctica
    - Amplitudes 100% rho'/rho = definition of a patch (factor of 2)
    - Move 200-800 m/s
    - See these waves in MIGHTI data
- Polar Vortex
    - Primary waves break and dissipate
    - Secondary waves break and dissipate
    - Waves travel from Europe to Alaska
        - Midnight in Europe, noon in Alaska
        - Waves moving sunwards?? (southwards over Alaska)
    - 10-15% temperature perturbations
- None of this involves geomagnetic forcing
- Primaries waves from exit region of polar vortex
- At 200-300 km altitude, all wave activity is concentrated at poles
    - Waves criss-crossing and interacting with each other
    - Extremely strong neutral wind over the poles allows GWs to propagate to very high altitude
    - Confirmed with GOCE & CHAMP data
- Period of waves is under an hour, so ion drag should NOT impact the propagation
- GW propagate sunwards while classical patches propagate anti-sunwards
- Simulations have shown plenty of wave activity NOT considering mountain waves, just from auroral sources AND the opposite - would be interesting to run both for a common event

Shunrong Zhang

- Transpolar TIDs
- TID = 30% fluctuation (or 10% or 50%... also has a definition problem)
- How to derive TIDs?
    - Start with regional data over several hours
    - Get smooth background, then subtract to get fluctuations
    - Typically +/- 1 TECu (not strong enough to be "classical" patches)
- Mothers Day Storm - this approaches classical patches definition

- Patches evolving in time? Amplitude decreases
- Smaller structures near “large” classical patches
- Polar region - 60 degrees and above
- Over nightside, structure is propagating equatorwards
- Over dayside, structure is propagating polewards
    - These directions DO agree with “classical” patches
    - Still only about 20% enhancement
- During morning hours, westwards propagation
- During evening hours, eastwards propagation
    - This agrees with 2-cell convection
- These directional patterns are very consistent
- Eclipse event
    - Antisunwards AND eastwards component
- Dayside polar cap region is a hot region where TIDs may be generated?
- Observationally see many TIDs moving in similar directions as what we expect PCP
    - Often with much lower amplitudes, but not always
- Edge gradients?
- Maybe TIDs are smaller versions of patches?
- Ecitation of TIDs may move plasma up or down vertically (upwelling or downwelling)
- Propagation speeds may be similar to convection speed
    - 700-800 m/s
    - Are TIDs moving RELATIVE to plasma or WITH the plasma?
- GW due to cusp heating should propagate both polewards and equatorwards?
    - Except if damped due to the neutral wind direction
- Double background is a safe differentiator between “patches” and TIDs, which are much lower amplitude?

Roger Varney

- Modeling Polar Cap Structures
- GGS - coupled modeling framework
- Use of HIDRA (formerly IPWM) - brings in numerical methods from GAMERA; now allows VERY high resolution simulations
- Structures in the polar cap F-regions have corresponding structures in the ion outflow and classical polar wind
- Highly dynamic driving from GAMERA
- Lockwood and Carlson 1992 patch formation mechanism
    - Variable reconnection moves the x line back and forth and scoops out plasma
- Also temperature dependent precipitation
- Variable particle precipitation
- Mechanism denial mechanisms to determine what actually creates patches
- When you smooth out convection pattern, structures smooth dramatically and just get smoothe TOI across the entire polar cap

- Soft precipitation mostly impacts aurora on nightside, not the center of the polar cap so much
- Varying the chemistry also has minimal effect
- Most mesoscale structuring seems to be primarily due to variable convection
- Future work - coupling with a thermosphere model
- Is the twisted up tongue actually realistic?
    - A lot of observations show patches elongated in the E-W direction or transvers to the background convection
    - Twisted TOI in simulations are elongated in the wrong direction
- Are we missing something fundamental about how high latitude convection works at mesoscales?
- LC92 mechanism requires X-lines to move in way that is not reproduced by the model (not sure which is actually correct)
- Point-to-point comparison with an instrument is futile
- Need to determine typical fourier scales, typical wavelet scales to get useful statistical measures
    - Can you run GAMERA long enough to create meaningful statistics?
    - A week is feasible, months are less so
- Problem with chemistry mechanism
    - Highly dependent on temperature
    - In principle active, but likely not a major contribution
- Correlation studies between patch occurrence and By variations?
- Models do see PMAFs-like things, but probably don't have all the physics right to get all this quite right
    - Carlson 2012 paper argues that this mechanism isn't strong enough to get large amplitude patches
- Should "big" vs "little" (major vs minor enhancement that have more adverse effects) be a distinguishing factor between different categories of "patches"

Kasia Beser

- Patch detection Algorithm
- Any combination of parameters measured by SuperDARN that make patches "unique"
- Characterize patch without the density
- Clustering algorithm used to distinguish between different sources of backscatter
    - Used raytracing, determine probability of backscatter region
- Clustering on velocity, spectral width, SNR, and elevation
- Spectral width seems to be the main differentiator
- Automatic detention needed for statistical studies
- Single beam vs using adjacent beams together?

Discussion

Properties of Patches

- What are the properties of patches (e.g., generation mechanism, propagation and decay patterns)?
- How are these distinct from other density enhancements in the polar cap?

Definition of Patches

- How should we define polar cap patches?
- What is the density threshold to define a patch?
- How are the background density level and edges determined?
- How are density enhancements in the oval, polar cap arcs, and TIDs excluded?

Impact of Patches

- How do patches as observed from different modalities (e.g. ISR, TEC, in-situ, ASI and SuperDARN) compare to each other?
- What are the impacts of patches in the M-I-T system?
- What are the space weather effects of patches? What is their societal impact?

- Seasonal dependence - changes background, which changes how easy it is to get something twice the background
- Neutral wind is very important in stronger driving conditions
- Need processes in model that causes dramatic temperature enhancements - cusp in work in progress
- How do we get elongated patches?
- Are all mechanisms important?
- Large R1/R2 convection flow can cut TOI
- Are patches just GWs? Not large enough amplitude?
- For individual patches, the twice background is important but for statistical studies, may want to perturb this?
- Any constructive interactions between patches and TIDs?
- Plasma density is an integrator - tracer of complex convection history
- Do we not understand mesoscale convection?
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