GEM-CEDAR Day 2019

Transient ionospheric upflow driven by poleward moving auroral forms observed during the RENU2 sounding rocket campaign

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PMAFs are cool

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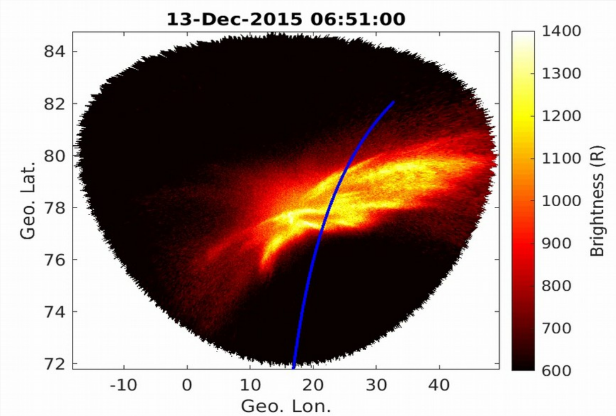
What is a PMAF?

PMAFs:

- Quasi-periodic sequence of poleward moving auroral forms
- Sequence have a repetition rate from 2-15 mins
- Typically associated with pulsed reconnection at the magnetopause
- Can be comprised of smaller sub-arc structures with spatial extents down to ~100m
- May directly impact ionospheric plasma escape due to highly transient soft particle precipitation

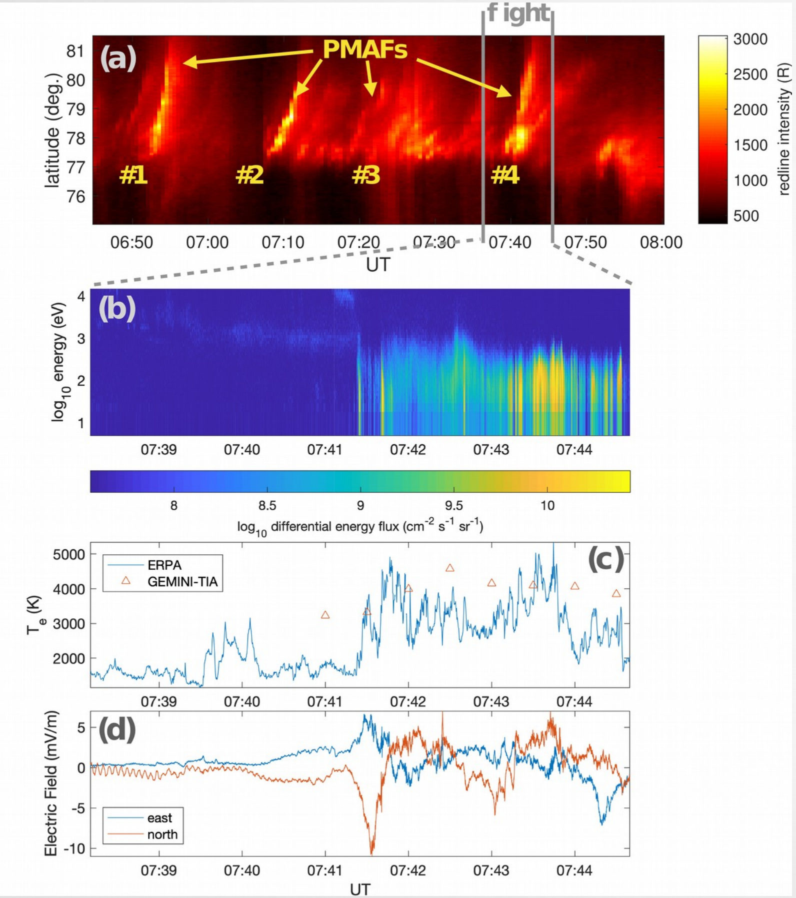
The variable dwell time of PMAFs, coupled with hysteresis, can create altitude, latitude, and temporal dependence in upflow responses.

The RENU2 sounding rocket was launched from the Andøya rocket range on December 13, 2015 at 7:34 UT into the fourth of a series of PMAFs.



PMAFs were observed from ~6:45 UT onwards through the time of flight by the University of Oslo all-sky imager at Longyearbyen (LYR) (http://tid.uio.no/plasma/aurora/).

From in situ measurements to model inputs…



Rocket flew through the fourth PMAF of the sequence:

Observed soft (<300 eV) particle precipitation

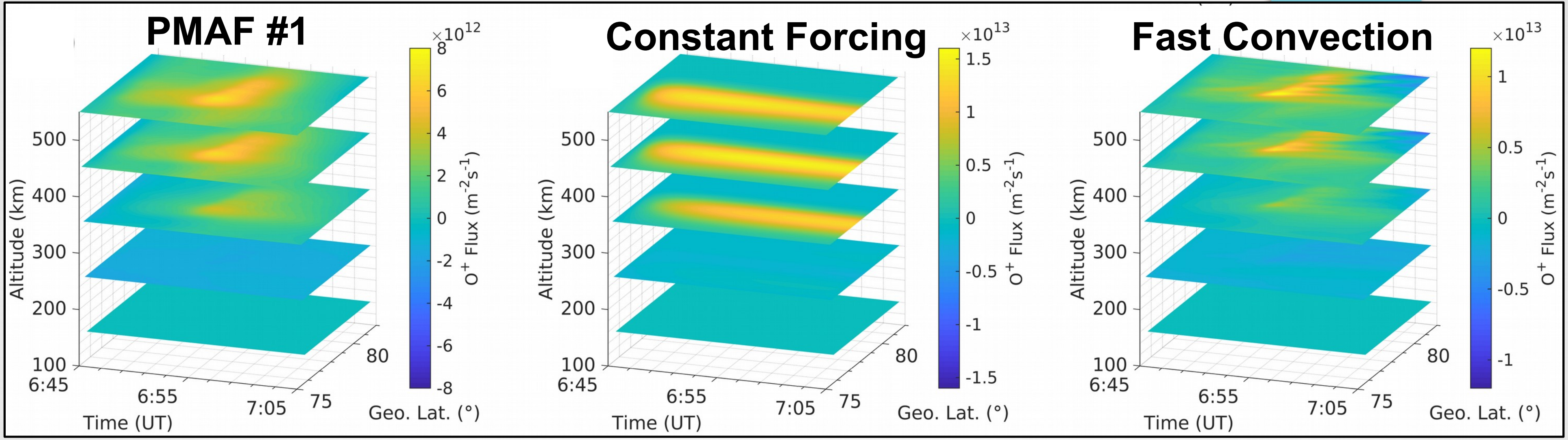
- Deposits energy at ≥ 200 km altitude
- Excites strong 630 nm emission
- Heats the ambient ionospheric electrons

DC electric field measurements

- Enhancement equatorward of the cusp/PMAF
- Unusually small and indicate PMAF was not locked into the slower background convection

2D multi-fluid ionospheric model, GEMINI-TIA, is driven with data-representative precipitation and DC electric field values to explore the local ionospheric effects of the PMAFs.

Effects of transient vs. steady forcing on low-altitude upflow



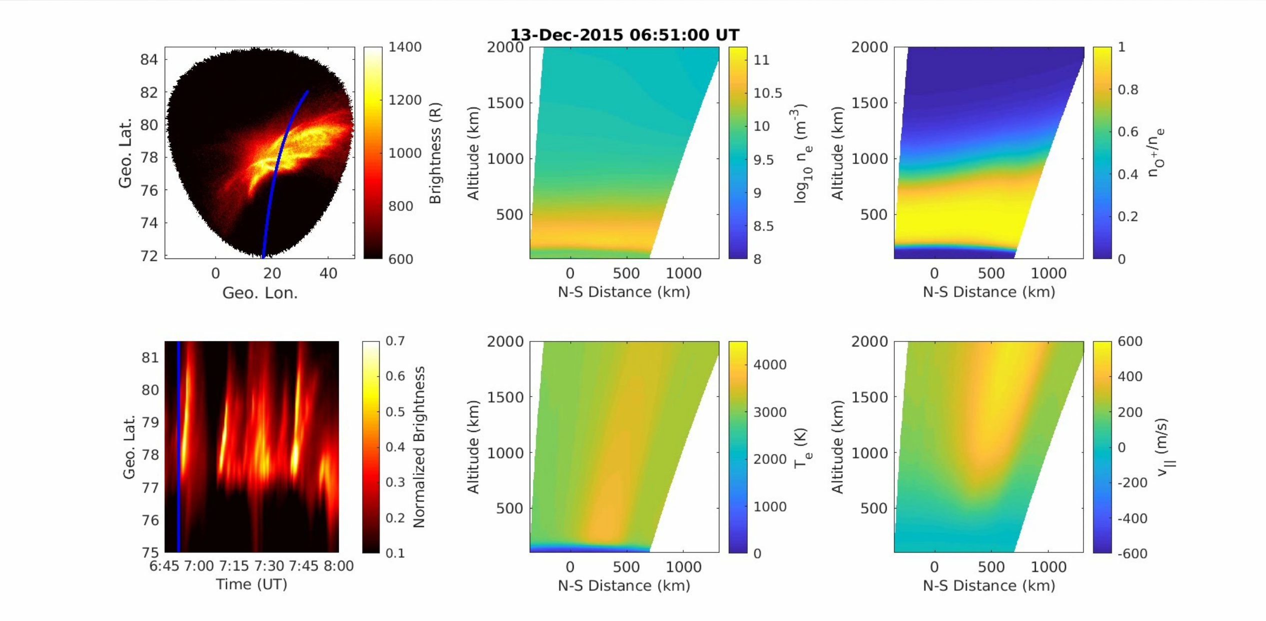
- *Brightness weighted* northward DCE (8 mV/m) and total energy flux (0.75 mW/m^2) with a constant characteristic energy (100 eV)
- Total O+ transport through 1000km is **1.9×10^{16}**

- *Constant* electron precipitation (total energy flux (0.75 mW/m^2) and characteristic energy (100 eV))
- Total O+ transport through 1000km is **3.3×10^{16}**

- PMAF #1 + eastward DCE (50 mV/m)
- Makes local background convection approx. equivalent to the PMAF speed (~1 km/s).
- Total O+ transport through 1000km is **3.0×10^{16}**

Using constant forcing, or a long duration “on-off” mechanism, to represent PMAFs, has the potential to over-estimate ionospheric responses.

Sequence of PMAFs



- Brightness keogram from along rocket trajectory
- Soft precipitation elevates electron temperature
- Results in a stronger ambipolar electric field
- Which enhances the _x005F_x005F_x000c_field-aligned upflow of plasma
- Cumulatively drive more O^+ to higher altitudes

PMAF motions, and changes in intensity, generate significant latitudinal differences

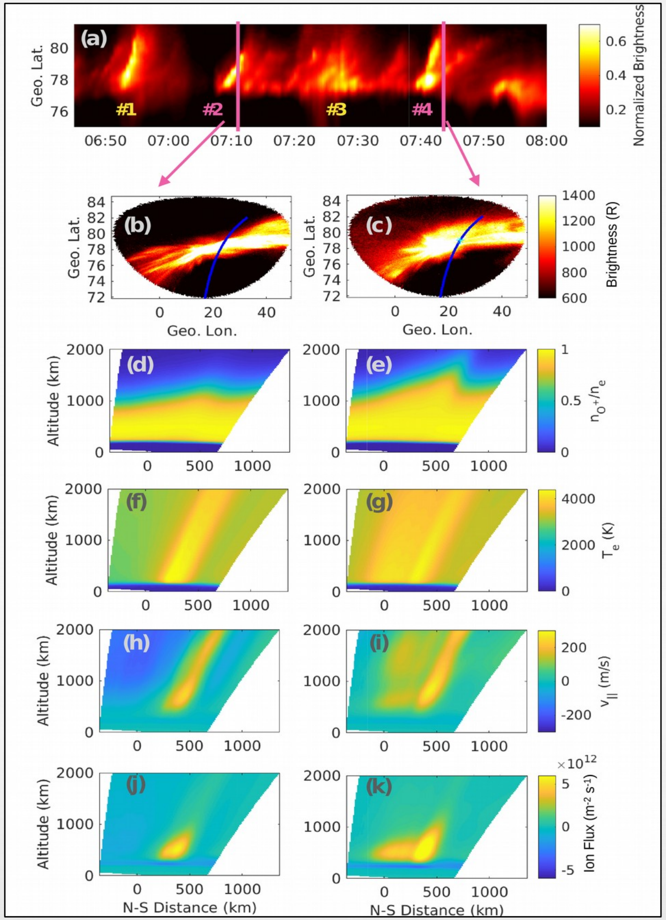
Sequence of PMAFs – two snapshot examples

PMAF motions, and changes in intensity, generate significant latitudinal differences.

For example…

<u>7:11:00 UT</u>

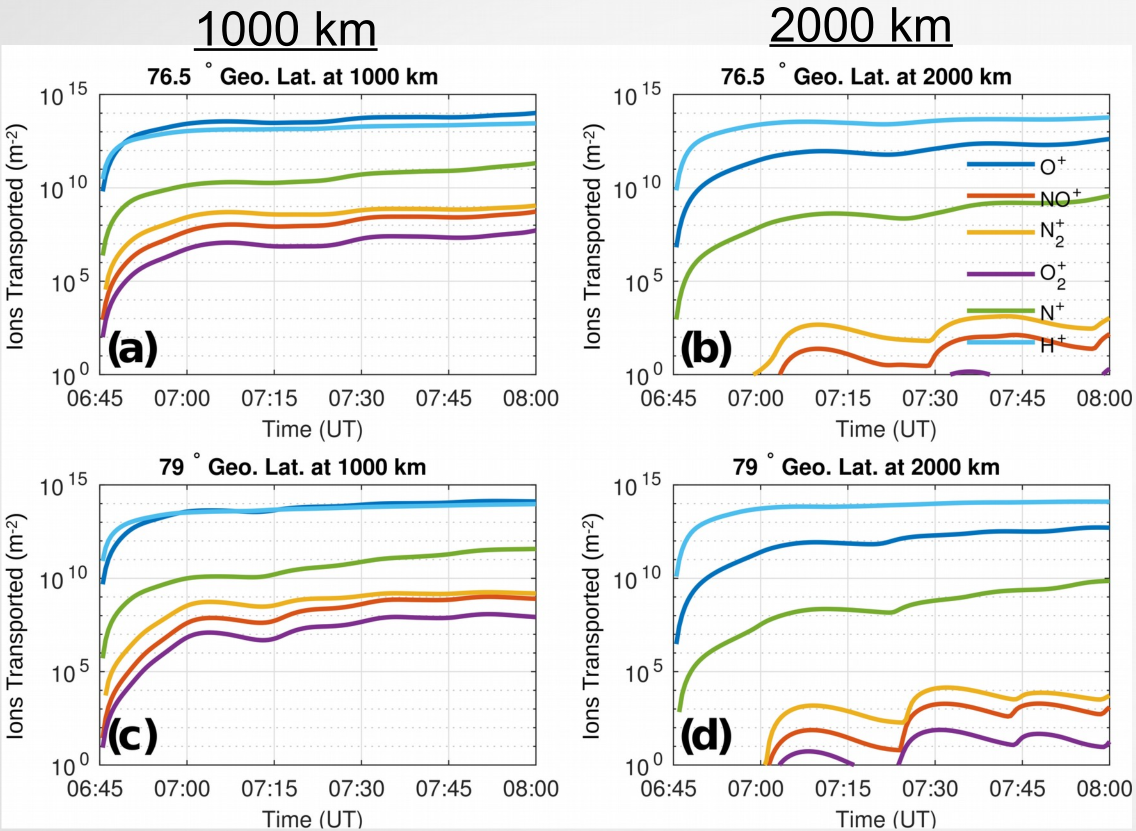
- Upflow at ~77-78°, due to auroral precipitation increasing electron temperatures
- Downflow at >79°, region has not been re-visited by PMAF
- PMAF dwell time in a region determines the amount of ion flux generated



<u>7:43:30 UT</u>

- Now upflow at >79 °
- The latitudinal extent of the PMAF motion has elevated electron temperatures over a broad region
- Effects of time history are evident:
  - ✓ A stronger part of the PMAF has just passed
  - ✓ Results in, cumulatively, more O^+ lofted to higher altitudes
  - ✓ Ion flux is larger

Upflow response time varies with ion specie



GEMINI-TIA has 6 ion species

Upflows take ~7 mins to reach 1000 km

Latitudinal dwell time variability of PMAFs impacts the ion flux generated

At 76.5°, PMAFs 1 and 3 have the greatest impact on the transport; PMAFs 2 and 4 do not provide significant precipitation this far south.

At 79°, all four PMAFs influence this region

There is a transport response time difference between the ion species at these altitudes.

The overall transition from downflow to upflow for all ion species occurs over a period of ~2 minutes and 30 seconds.

Conclusions

- PMAF auroral precipitation elevates electron densities and temperatures resulting in an enhanced ambipolar electric field which drives ion upflow

- The variable dwell time of the PMAFs in any given latitudinal region impacts the ion flux generated there at high altitudes.

- Using constant forcing, or a long duration “on-off” mechanism, to represent PMAFs, has the potential to over-estimate ionospheric responses.

- There is an ion species dependence in the response time where the heavier molecular ions are slower to respond. By the second PMAF, there is a 2 minute 30 second spread in response as downflows are driven to upflows.

- While soft electron precipitation is itself insufficient to accelerate ions to escape velocities, source populations available for higher-altitude energization processes are greatly increased.

- The transient nature of PMAFs may affect the conversion of upflow to outflow by secondary acceleration sources such as transverse ion acceleration.