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Ground based optical estimates of electron precipitation energetics in the auroral zone

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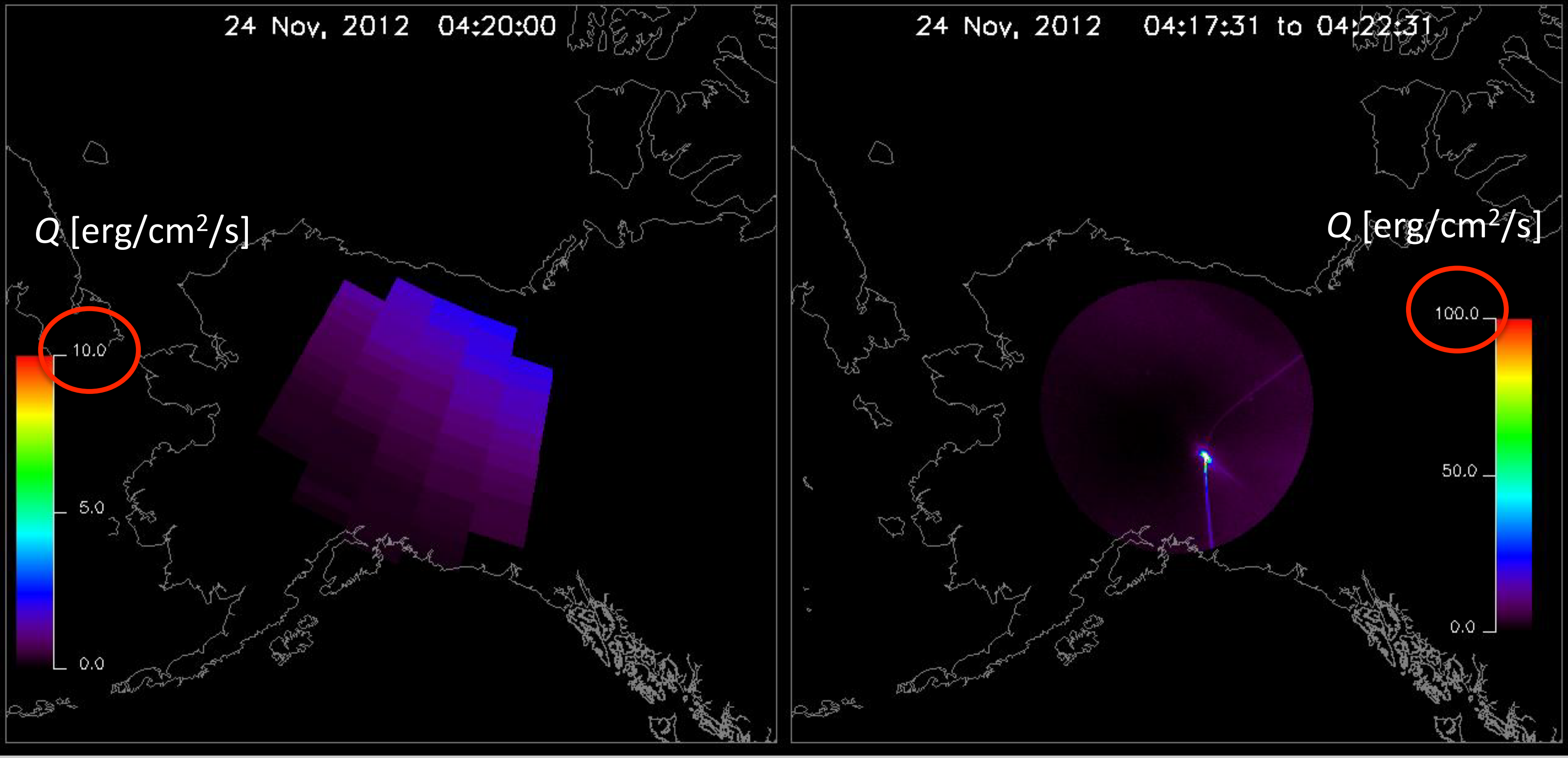
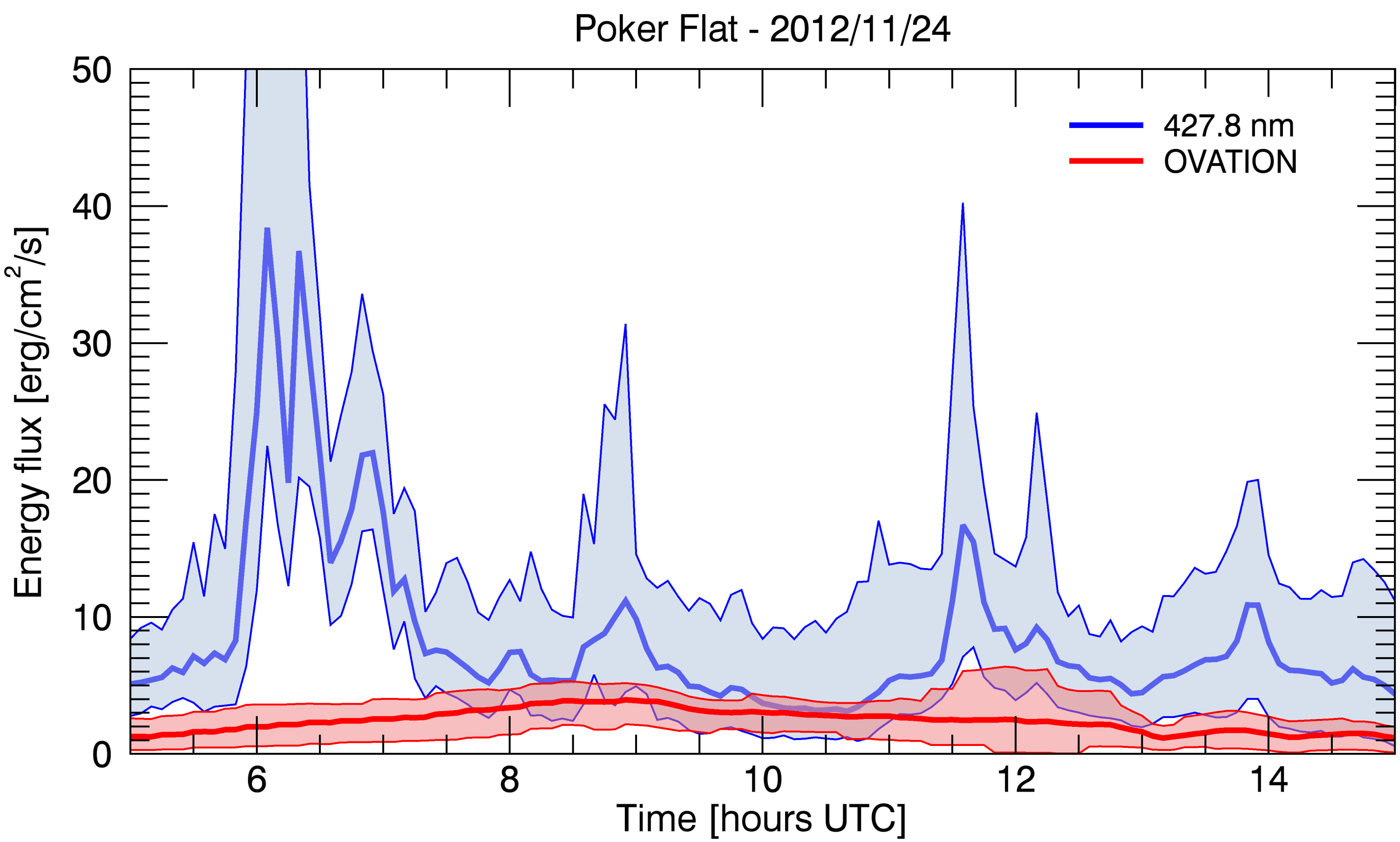
Hampton, MTSSP – 21 April, 2015

Ovation Comparison



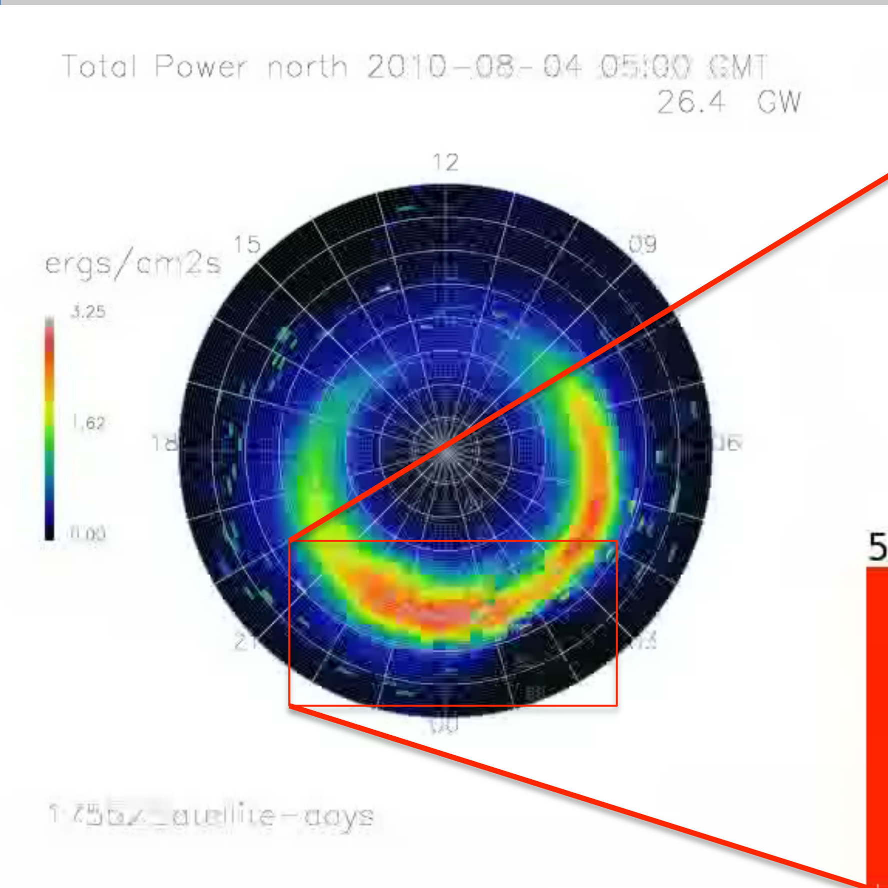
Note the factor of 10 in scale

Regional Energy

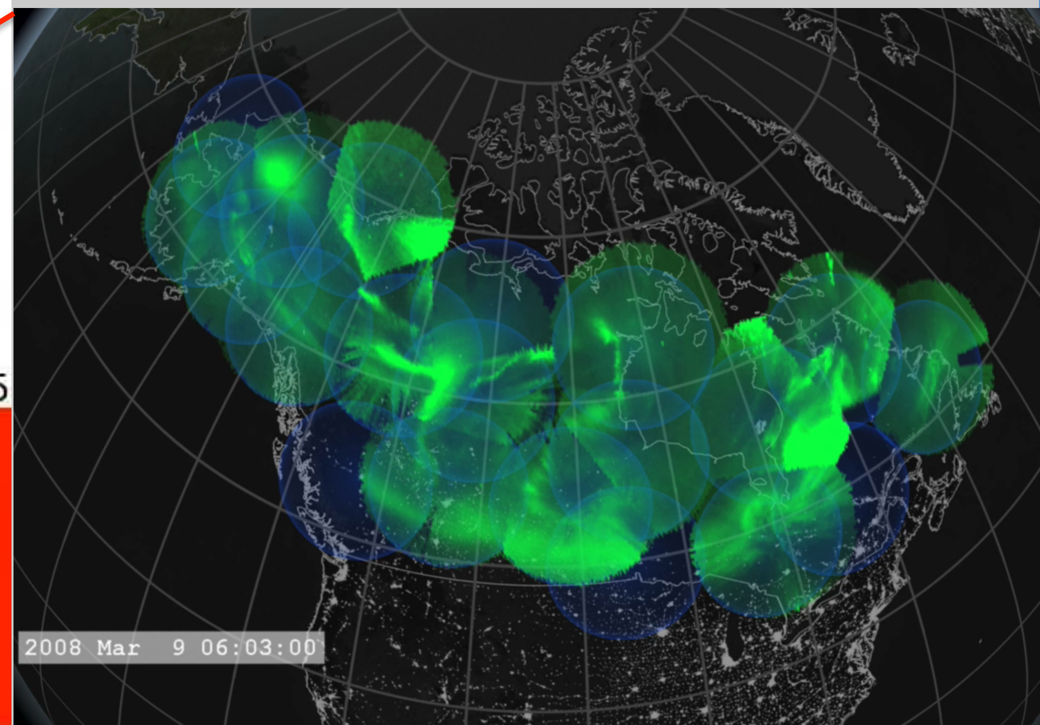


Aurora Precipitation Input into ITM Models

Ovation Prime Model



THEMIS ASI array



Global assimilative models do not capture the complexity of auroral structure and dynamics

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Methods to determine e-precipitation parameters

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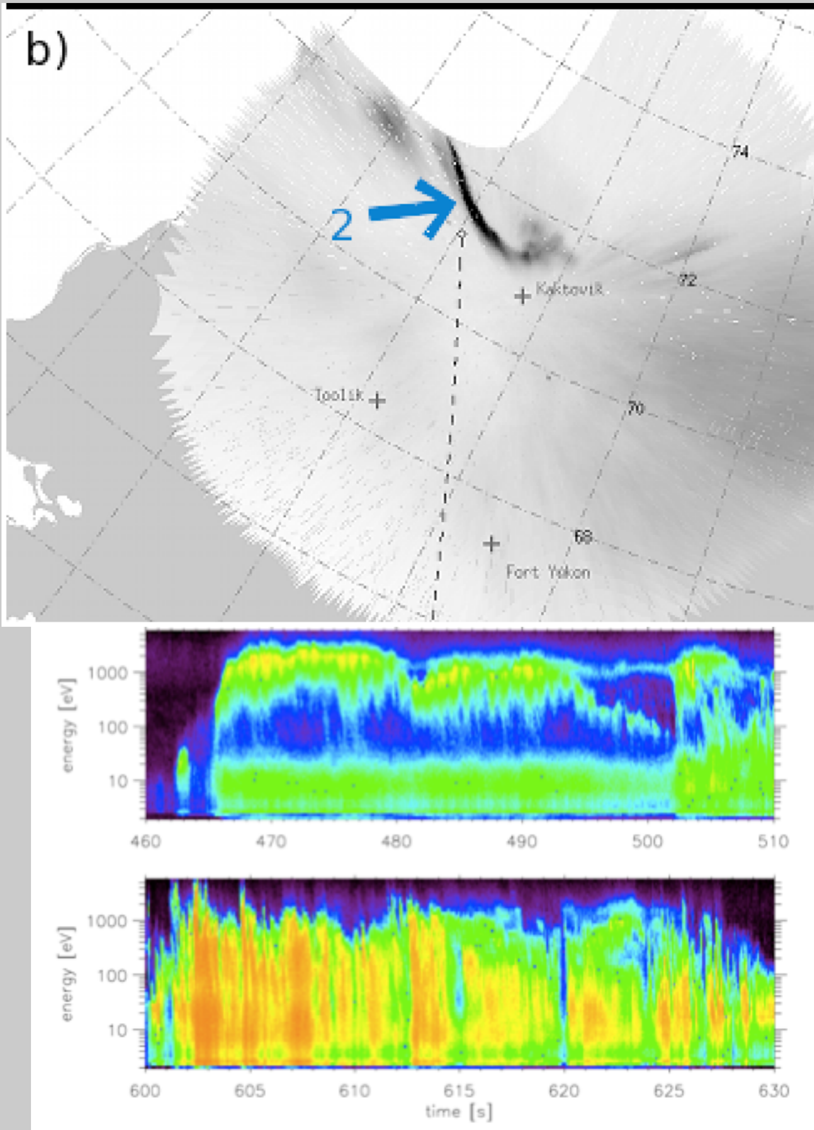
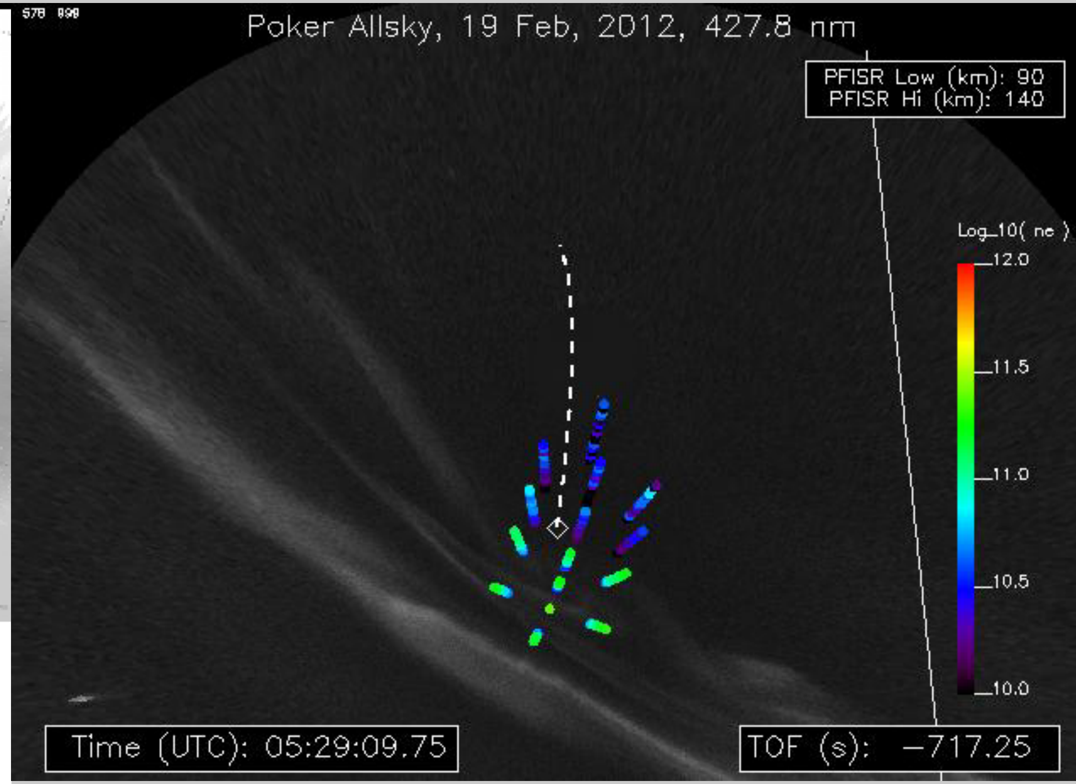
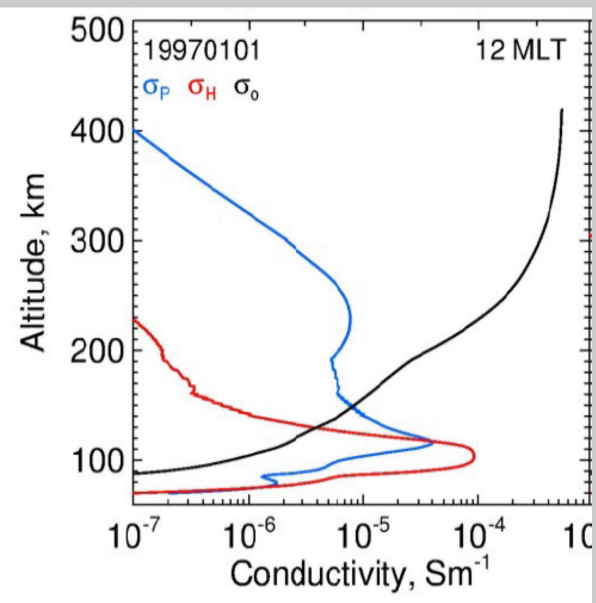
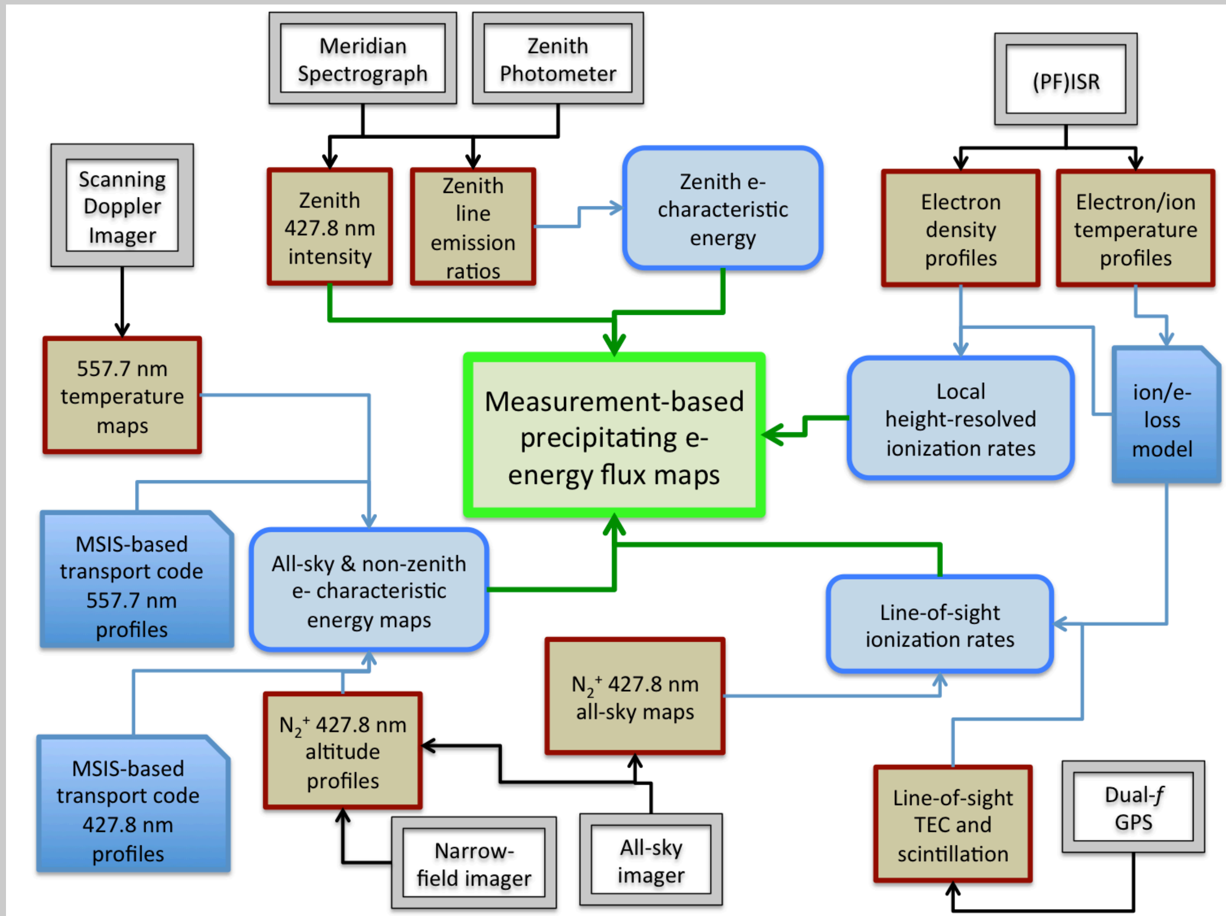




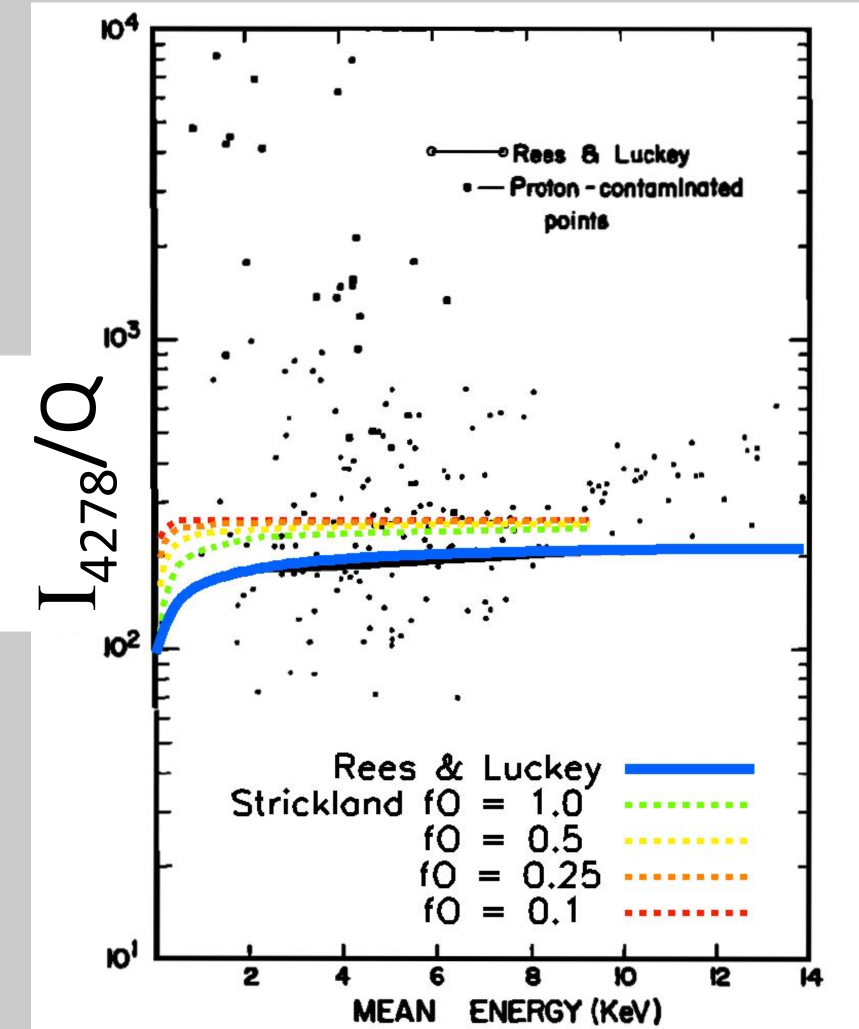
How to estimate the input? (Ground-based)

Two parameters needed:
Energy flux (erg/cm²/s)
Average energy per e- (eV)
[= 2 x characteristic energy for a maxwellian]





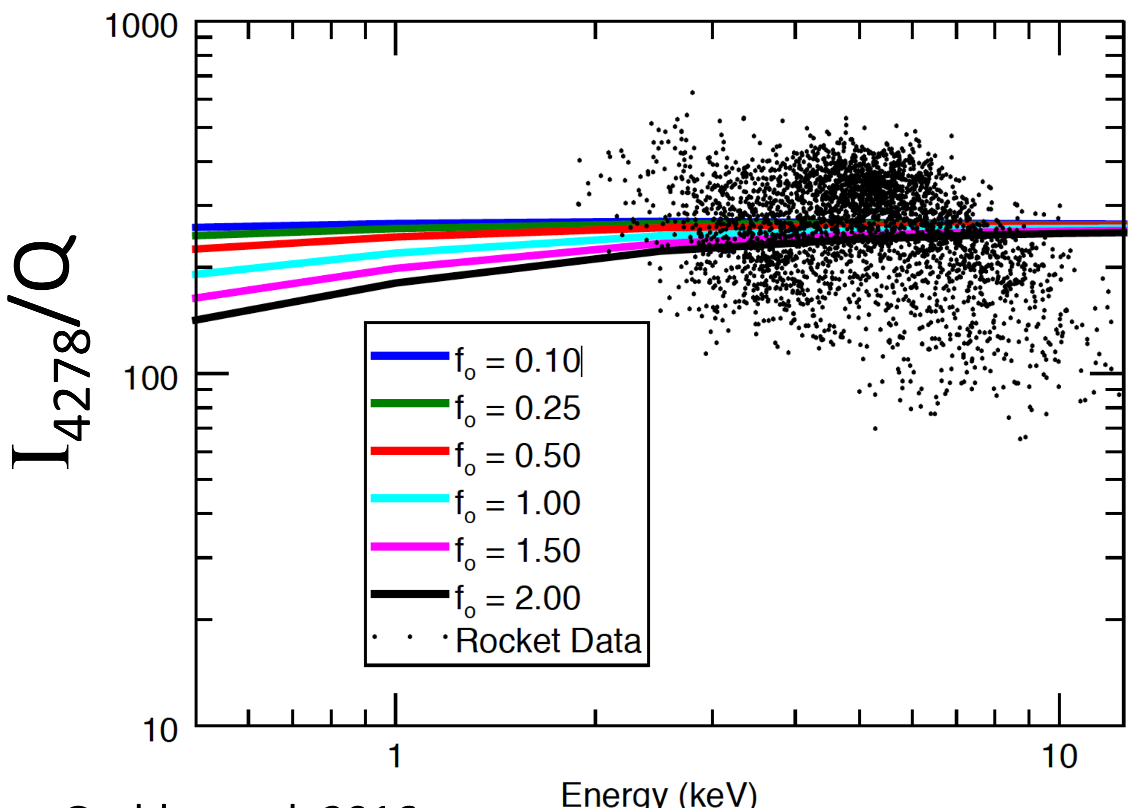
427.8 nm intensity ∝ energy flux (multiple researchers)



For a given intensity (I_{4278}) and characteristic energy (α), calculate the total energy flux in erg cm^{-2} sec^{-1}

Both models (Rees & Luckey, and Strickland et al.) and measurements (Kasting & Hays) show that the ratio is consistently 200 to 250 (+/- quite a bit for the measurements) for anything above 1 keV.

Energy Flux vs Blue line
(Hot off the presses)



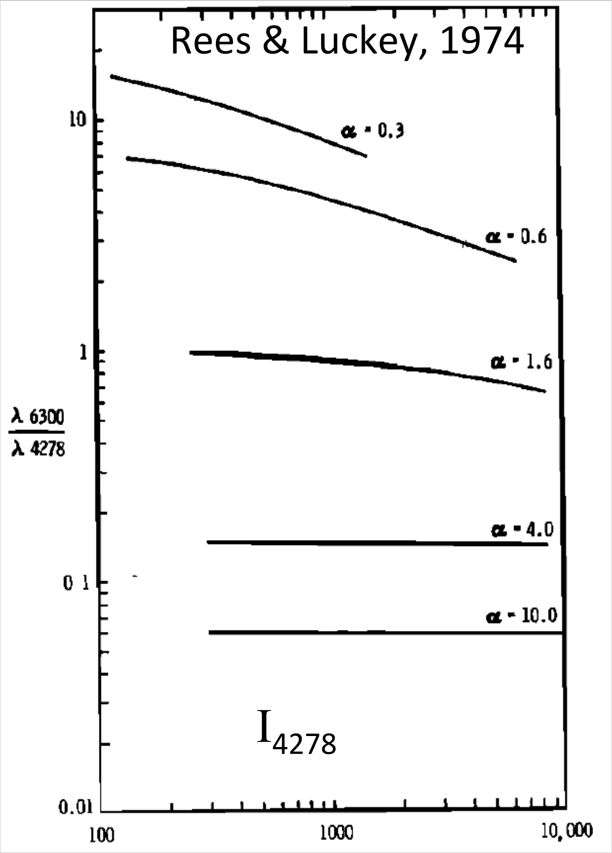
Grubbs et al, 2016

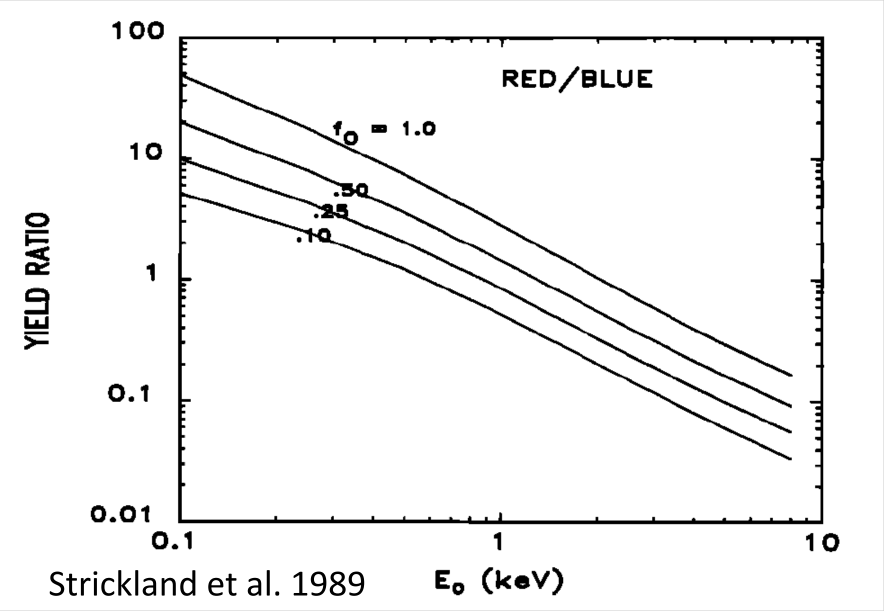
From the GREECE rocket campaign:

- High resolution, multi-spectral ground-based imaging and on-board e- detection.
- Particle detector data integrated for average energy <E> and total energy flux.
- 427.8 nm is measured at the rocket footpoint.
- Model is B3C (Strickland)

Ratios (2)

Ratios of key wavelengths vs. average energy have been modeled

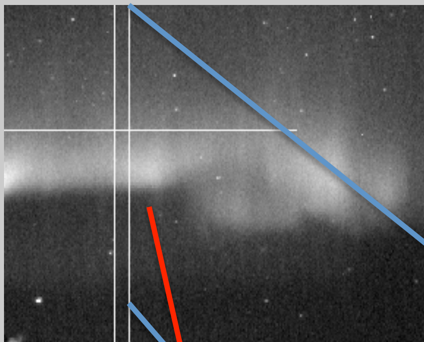




- This only works for ratios of emissions from the ENTIRE arc!
  - Oblique views will results in incorrect energy estimates.
- **Regional coverage requires a large number individual observing sites**

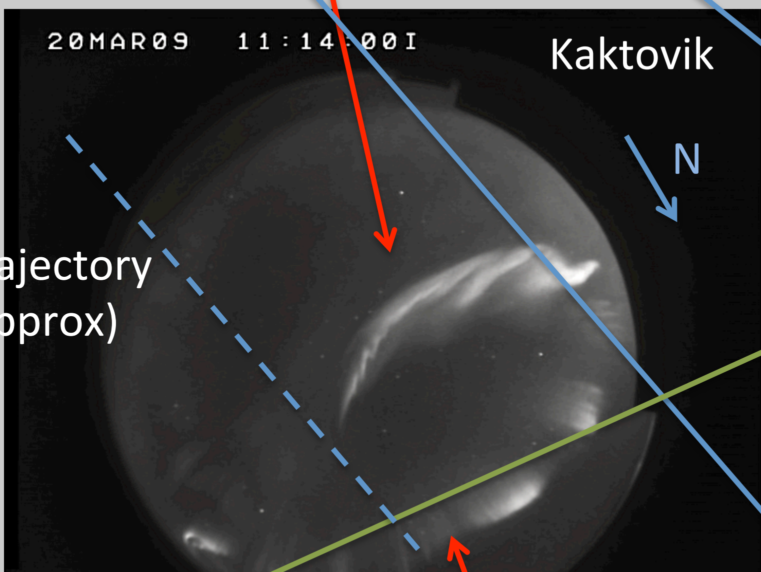
Altitude Profiles
CASCADES-2

Toolik

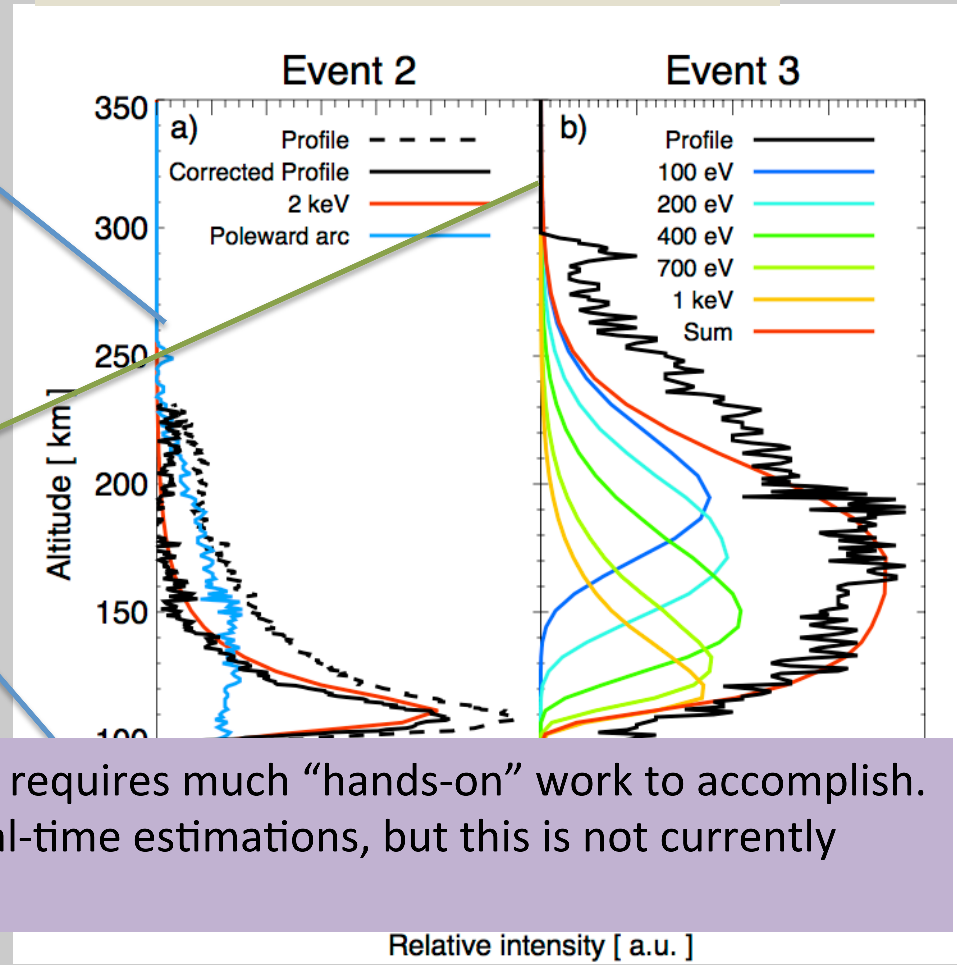


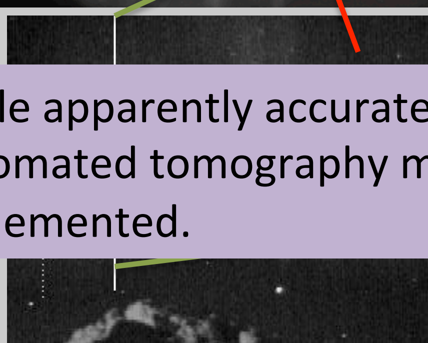
Event 2

Use an electron transport code to calculate expected profiles [Lummerzheim & Lilensten, 1994]



Trajectory (approx)





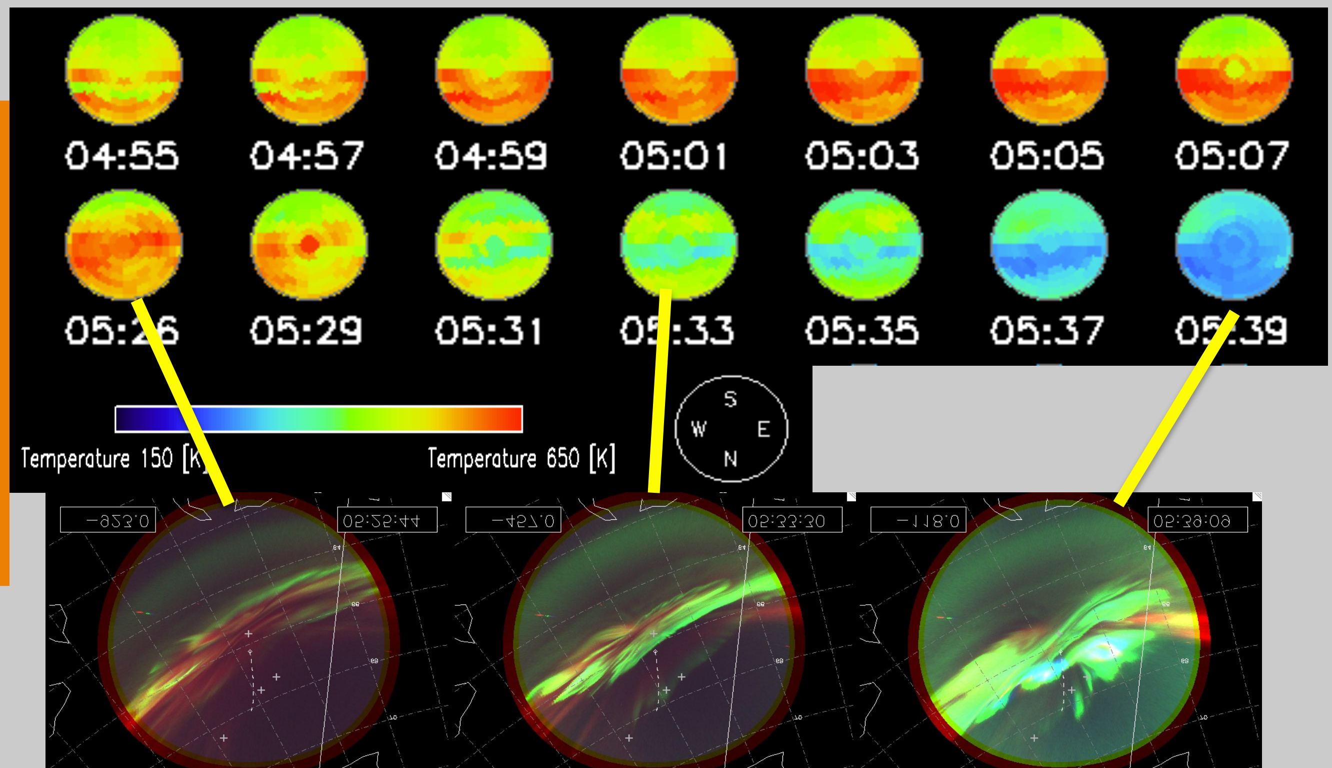
Too

While apparently accurate, this method requires much "hands-on" work to accomplish. Automated tomography may enable real-time estimations, but this is not currently implemented.

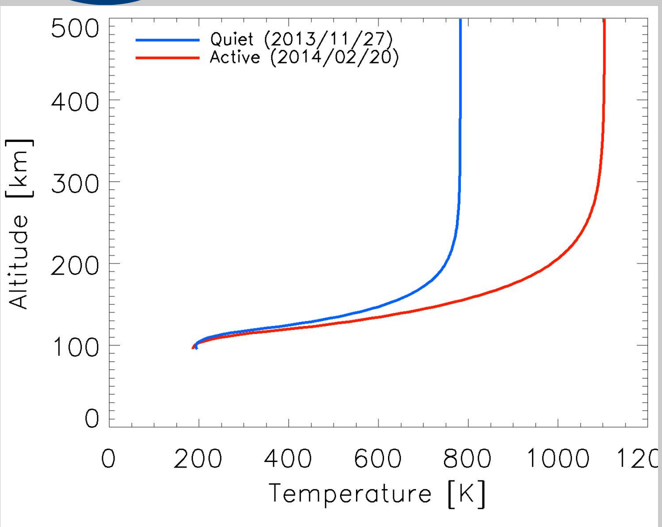
Scanning Doppler Imager (SDI) Temperature Maps

- A standard product of the SDI is emission temperature of 557.7 nm emission in 115 zones
- Rapid temperature changes are regularly seen associated with auroral e- precipitation
- Not a function of heating – result of change in peak emission altitude & strong thermospheric gradients

We exploit this to estimate the characteristic energy of the precipitation.



Convert Temperature to Characteristic Energy



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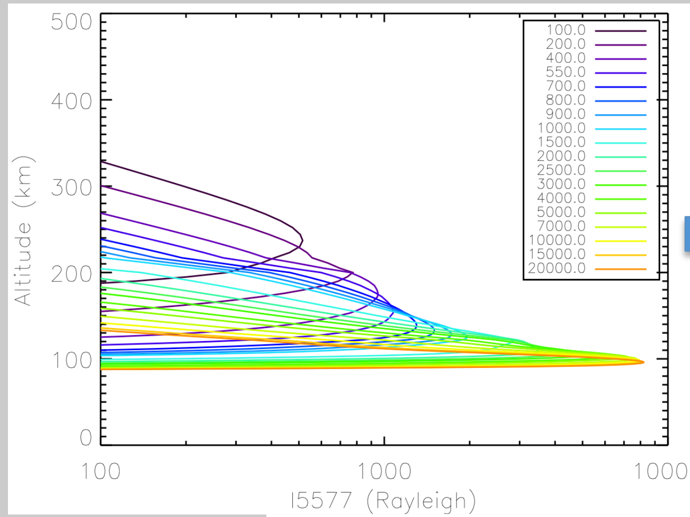
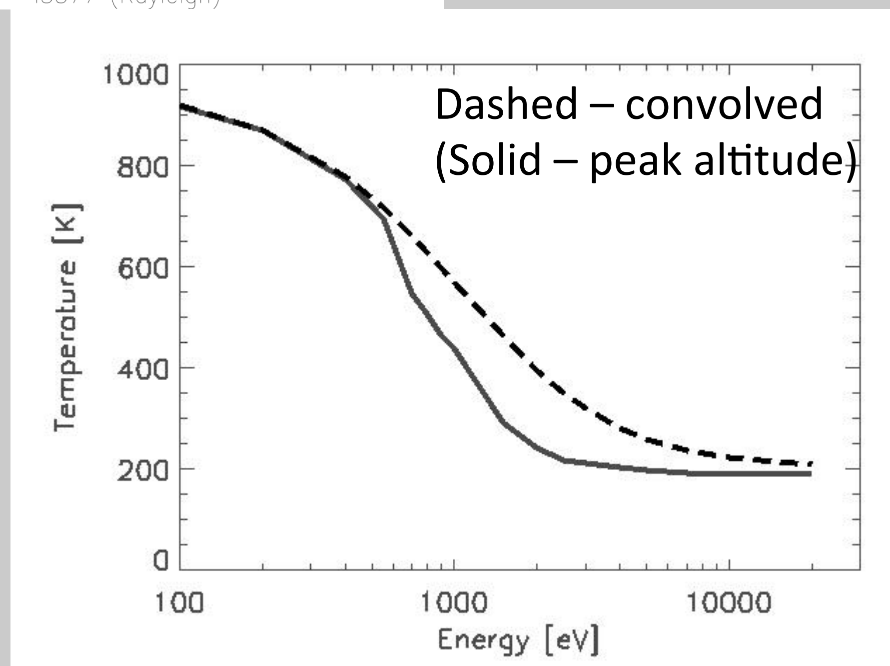




Convolve the MSIS temperature profile with green-line emission altitude profiles for several energies from GLOW to get the effective temperature as measured by the SDI for each

Putting it all together

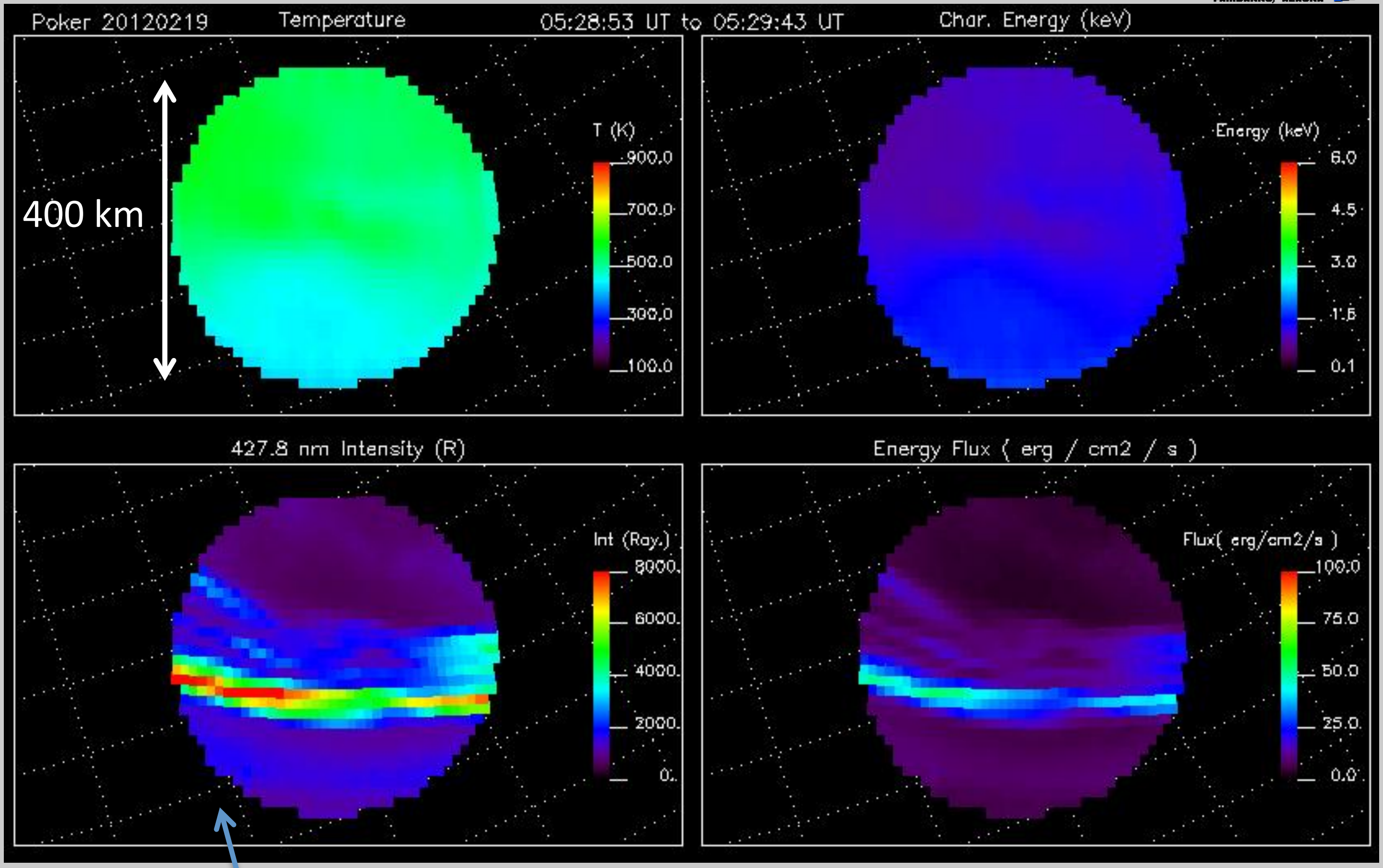
Use 20 km cells

Interpolate SDI temperature data onto the grid

Convert T to E0

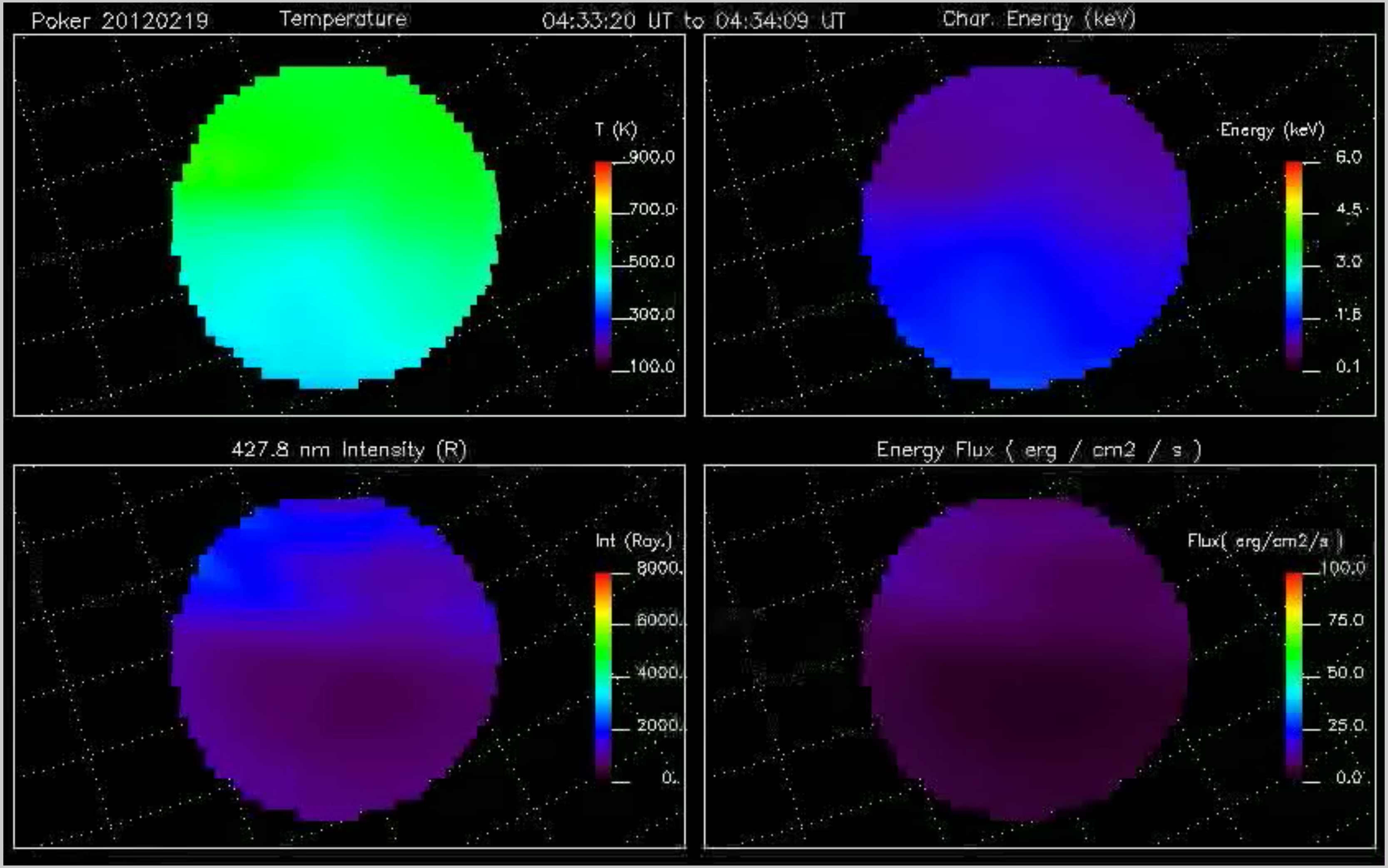
Re-bin 427.8 nm emission onto grid and average over SDI integration time

Convert to Q based on I_{4278}/Q relation

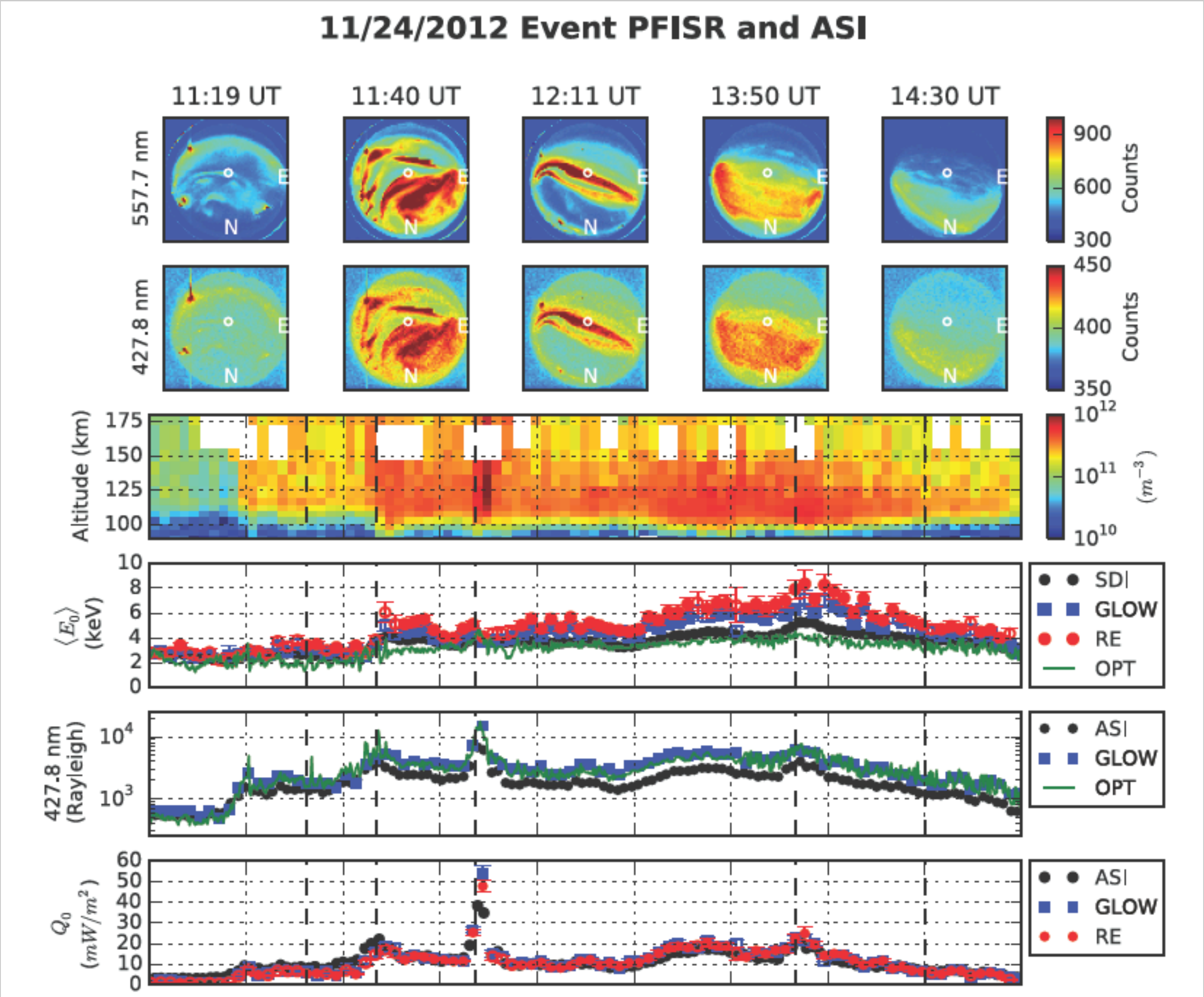


Geographic grid

Examining Dynamics



Comparison to PFISR data at zenith



Kaeppler et al. 2015

The fine print

- Assumes Maxwellian distribution
  - Not all aurora is Maxwellian
- Uses I_{4278}/Q in oblique views
  - Cell size is approximately the emission altitude profile width for energetic particles
- Strongly dependent on MSIS, which does not always do well during active (rapidly changing) conditions and SDI temperature measurement errors
- Conversion is only as good as the imager calibration
- Method underestimates the characteristic energy compared to PFISR analysis, but matches photometer results quite well
- Strongly E-region (“high” energy) centric.
  - Need a similar method for low energy => F-region

Moving ahead

- Use other instruments and methods to *validate* and ***train*** the method
  - PFISR [✓], zenith emission ratio[✓], ***satellite overpasses, off-zenith determinations***
- Better implementation of MSIS[✓] and transport codes [in progress]
- Use other transport models[✓] or GREECE [✓] rocket results for determining flux
- Figure out how to do something similar for low energy precipitation that affects the F-region
- Multi-SDI/ASI implementation
- Combine with SuperDARN data (Bristow, 2015)
- Lead to an empirical model of auroral energy deposition with realistic timing and dynamics?

Multi-SDI possibilities