Origin and Development of Medium-Scale Traveling Ionospheric Disturbances

E. S. Miller and E. R. Talaat

APL

Geospace and Earth Science Group
Johns Hopkins University Applied Physics Laboratory

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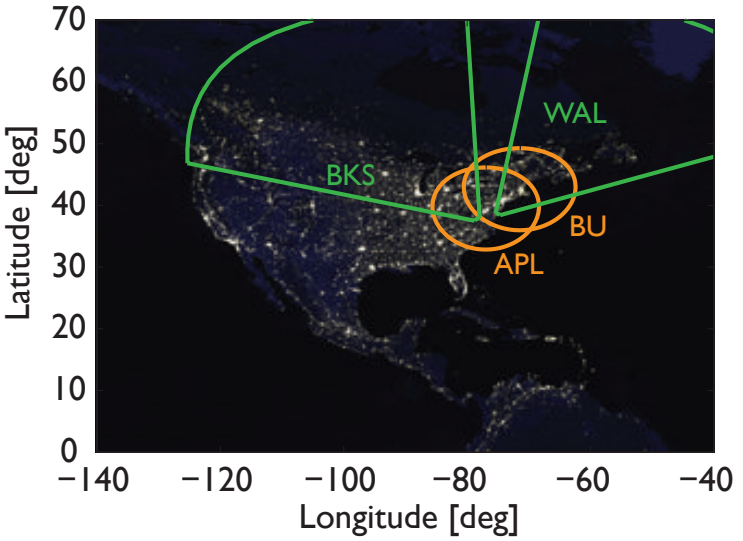
Science Question and Approach

Oddly enough...

What is the origin of medium-scale traveling ionospheric disturbances (MSTIDs)?

Approach...

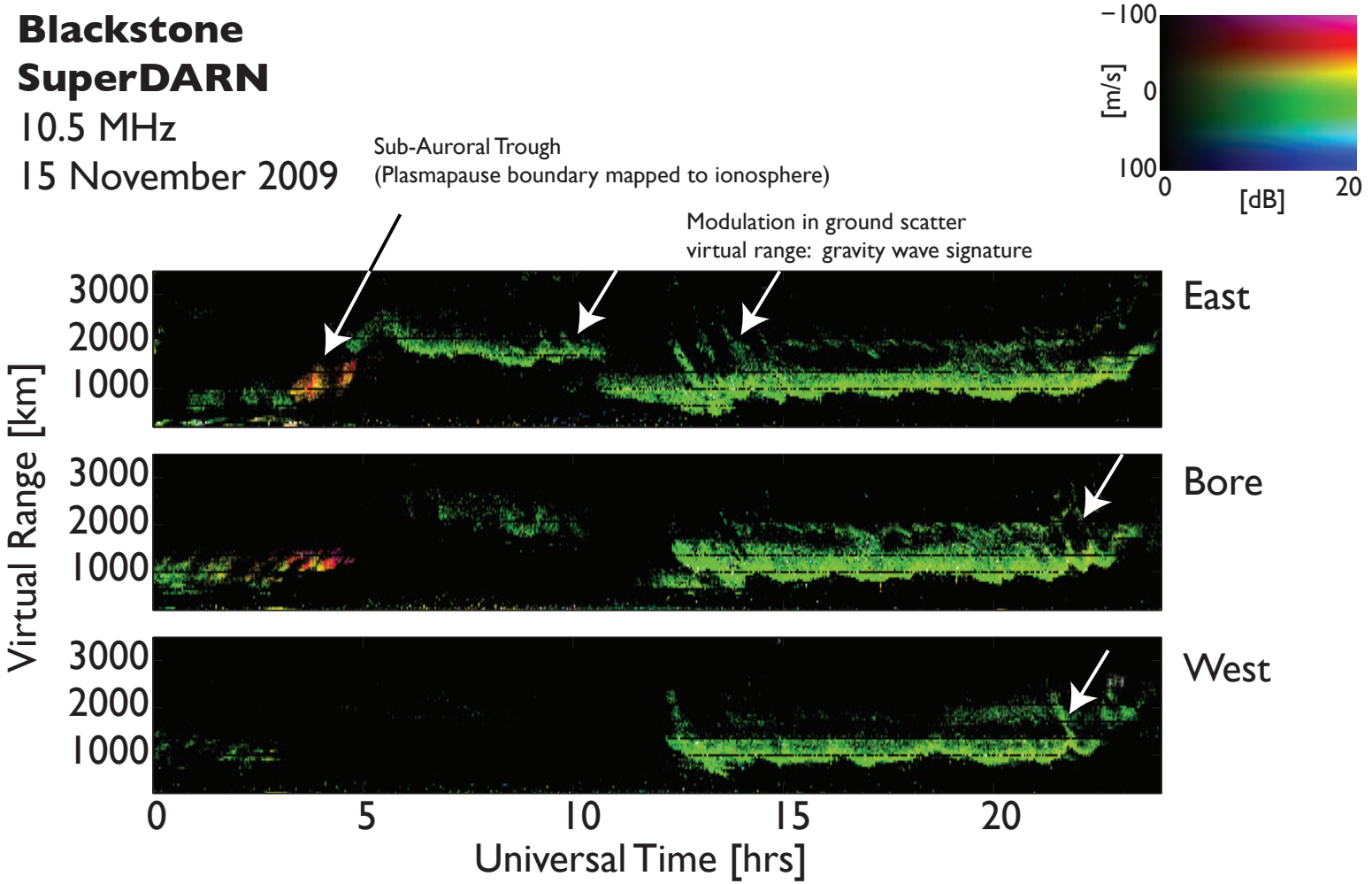
Investigate *E*-*F* coupling, gravity waves through airglow imaging and middle-latitude SuperDARN HF radar measurements.



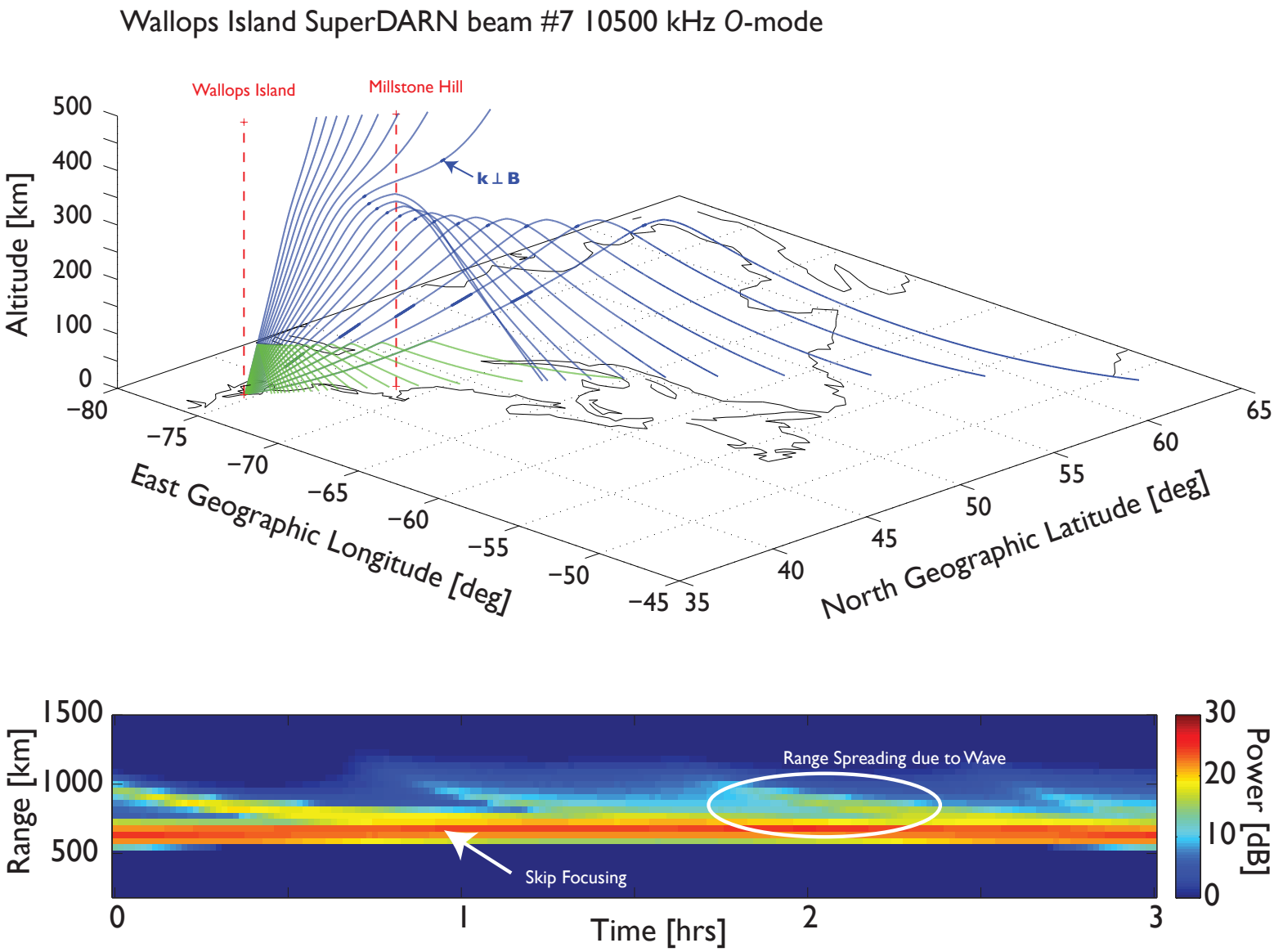
Introduction

- MSTID—Medium-Scale Traveling Ionospheric Disturbances
- $\lambda \sim 100$'s km, $v_p \sim 100$ m/s (in westward-equatorward direction, about 45 degrees from magnetic meridian)
- A night-time phenomenon, have been shown to appear in conjugate hemispheres.
- Observed at middle-, tropical-, and low-latitudes in airglow, HF Doppler, ISR, etc.
- Often contain FAI $\rightarrow$ coherent-scatter HF/VHF observations.
- Origin remains an open scientific question:
  - Originally attributed to atmospheric gravity waves (e.g., *Hines*, and others).
  - Now, plasma instability (Perkins, *E*-*F* coupled) is gaining acceptance (e.g., *Behnke, Tsunoda, Cosgrove, Yokoyama*).

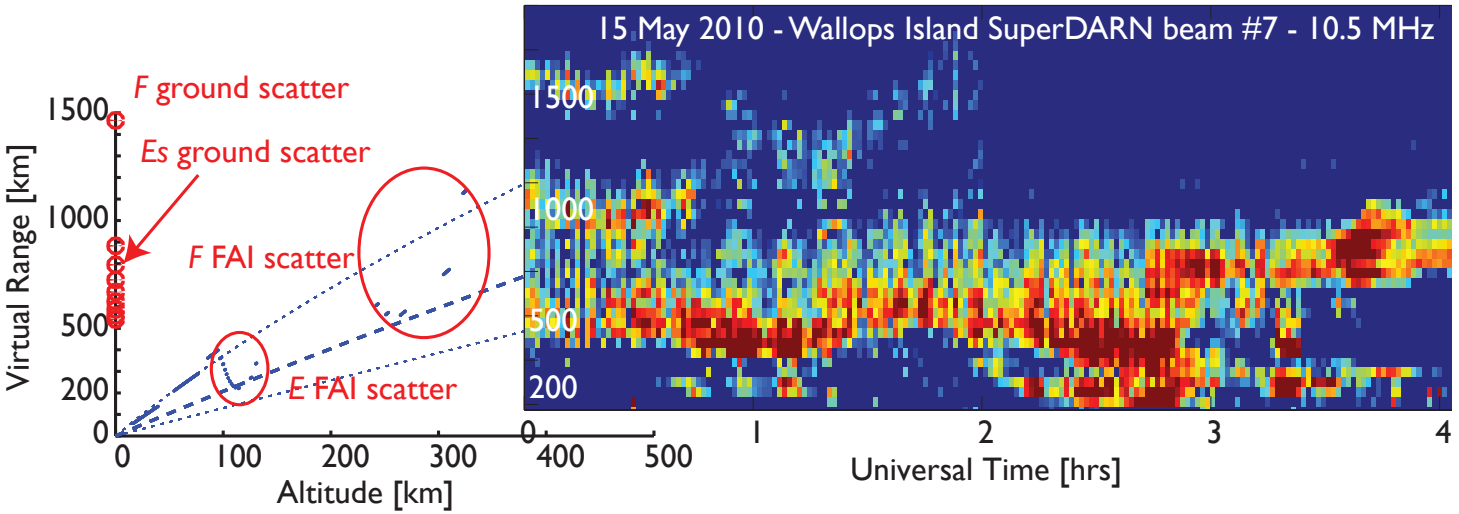
Gravity Waves: Skip Focusing



Gravity Waves: Skip Focusing

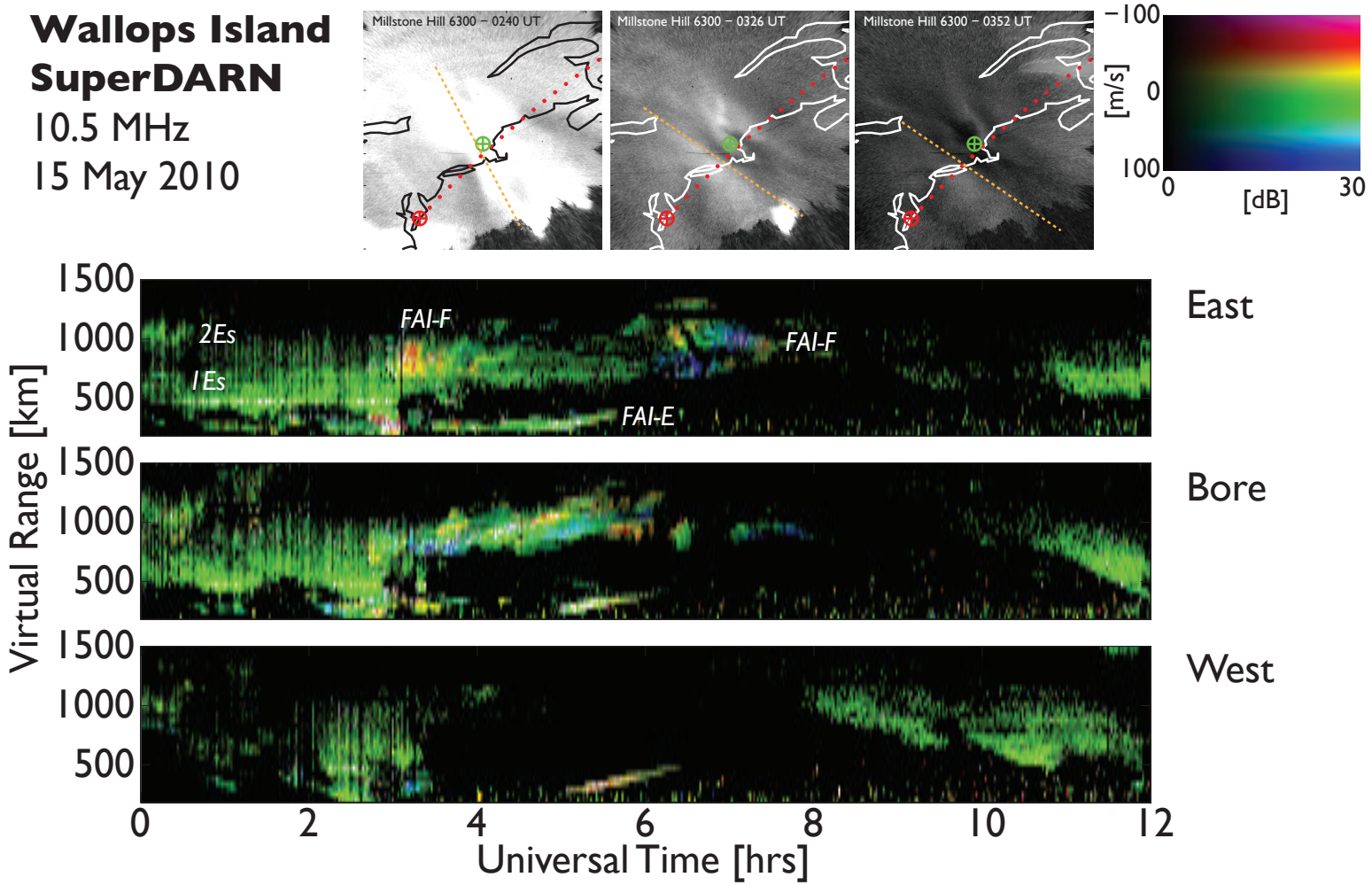


FAI Bands

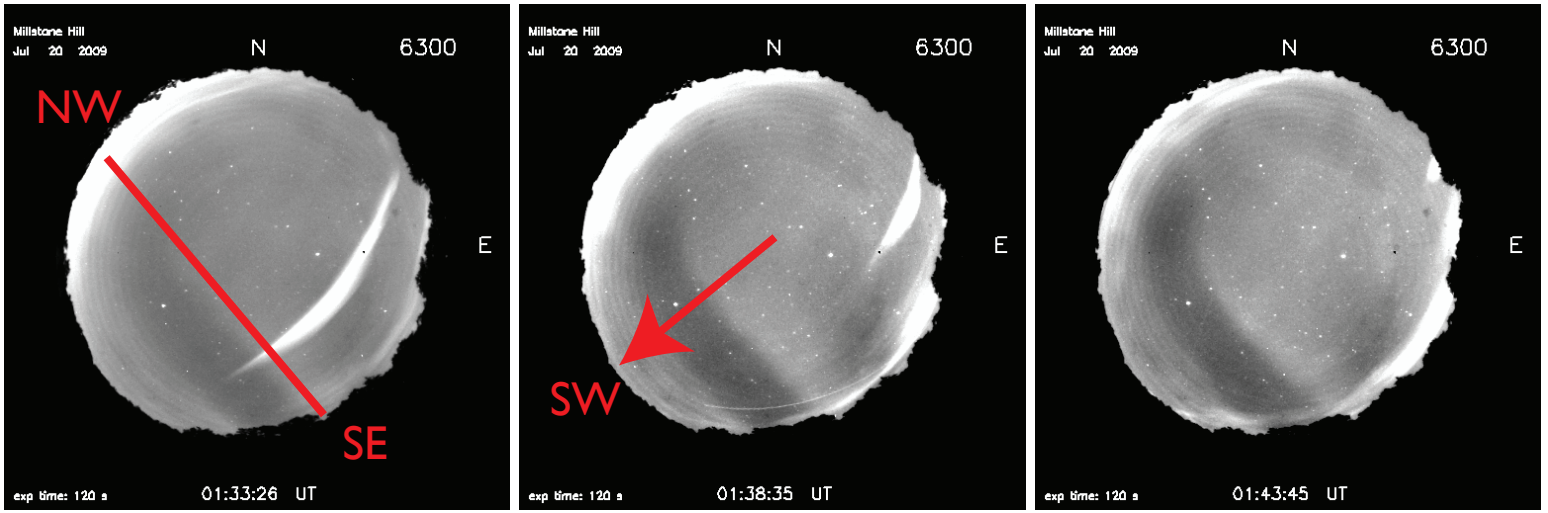


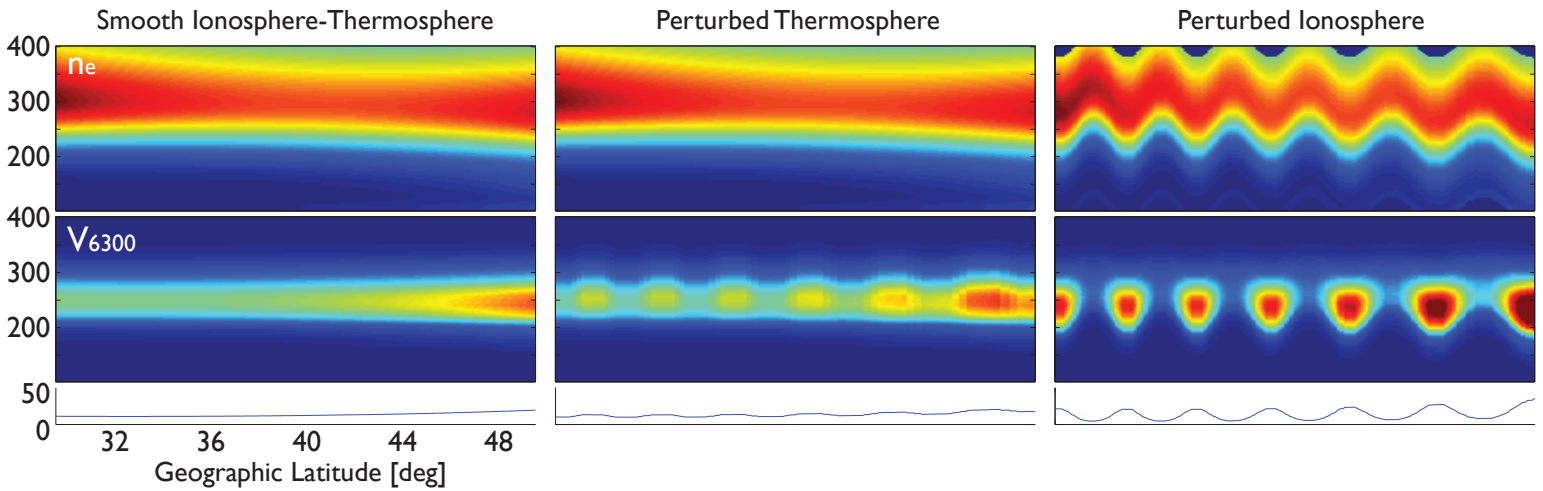
- Refraction matters with SuperDARN, especially in the *F*-region.
- Employ a raytracing code to identify loci of perpendicularity to $\mathbf{B}$ $\rightarrow$ ranges from which FAI is expected.

FAI Bands

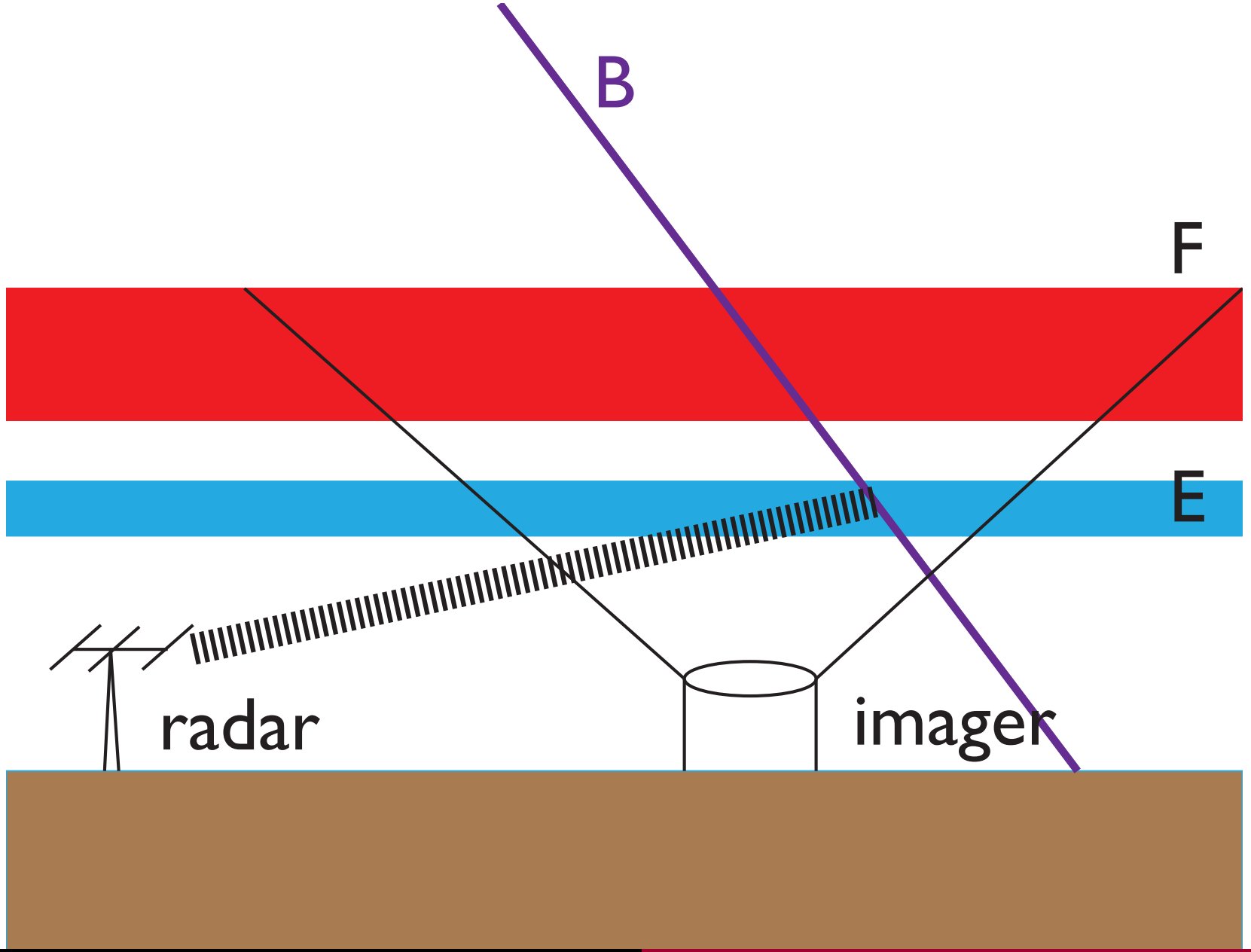

Wallops Island
SuperDARN
10.5 MHz
15 May 2010
Millstone Hill 6300 – 0240 UT
Millstone Hill 6300 – 0326 UT
Millstone Hill 6300 – 0352 UT
−100
0
100
[m/s]
0
30
[dB]
2Es
1Es
FAI-F
FAI-F
FAI-E
East
Bore
West
Virtual Range [km]
1500
1000
500
0
2
4
6
8
10
12
Universal Time [hrs]

Airglow (630-nm) Signature





Combined Airglow and Radar



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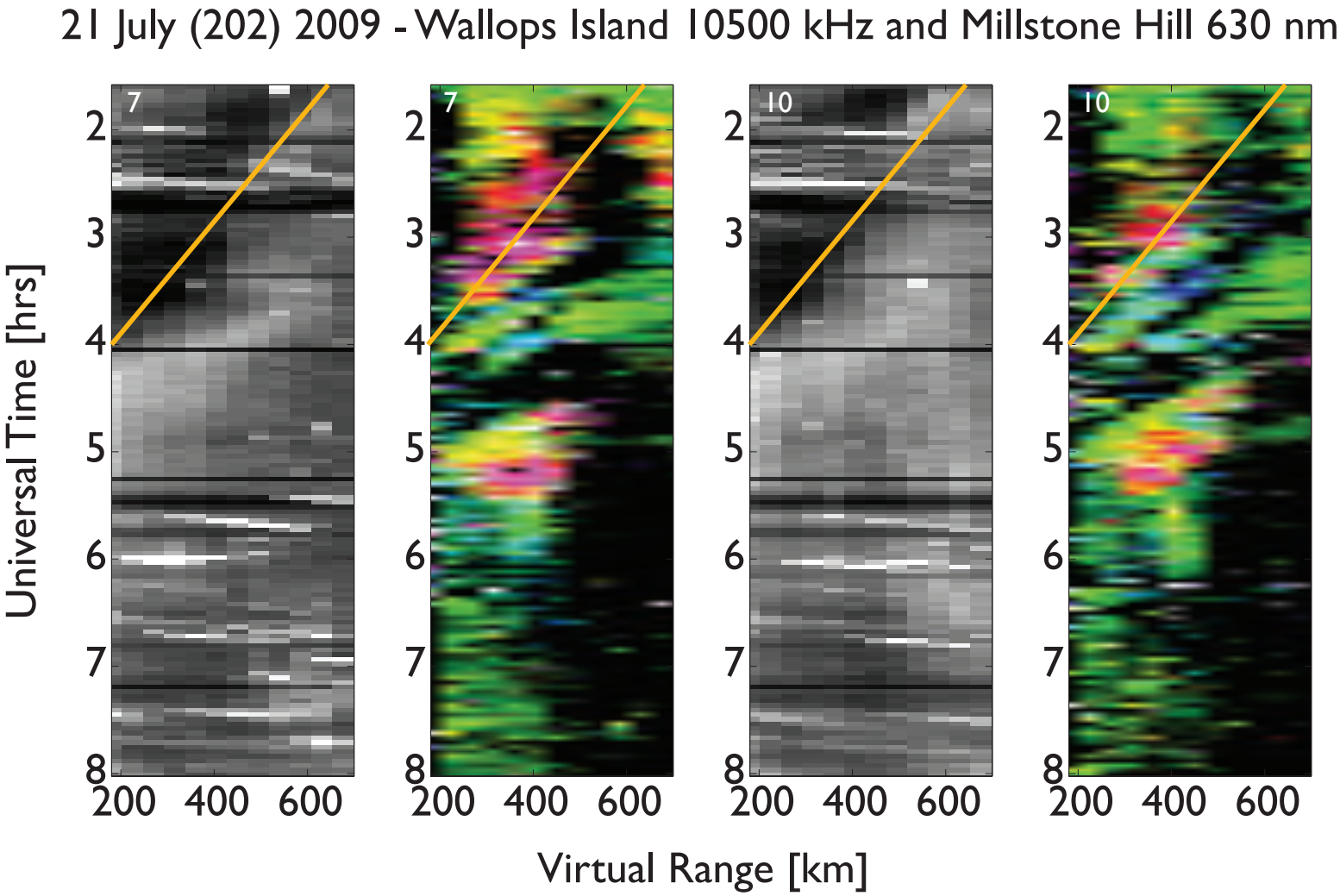

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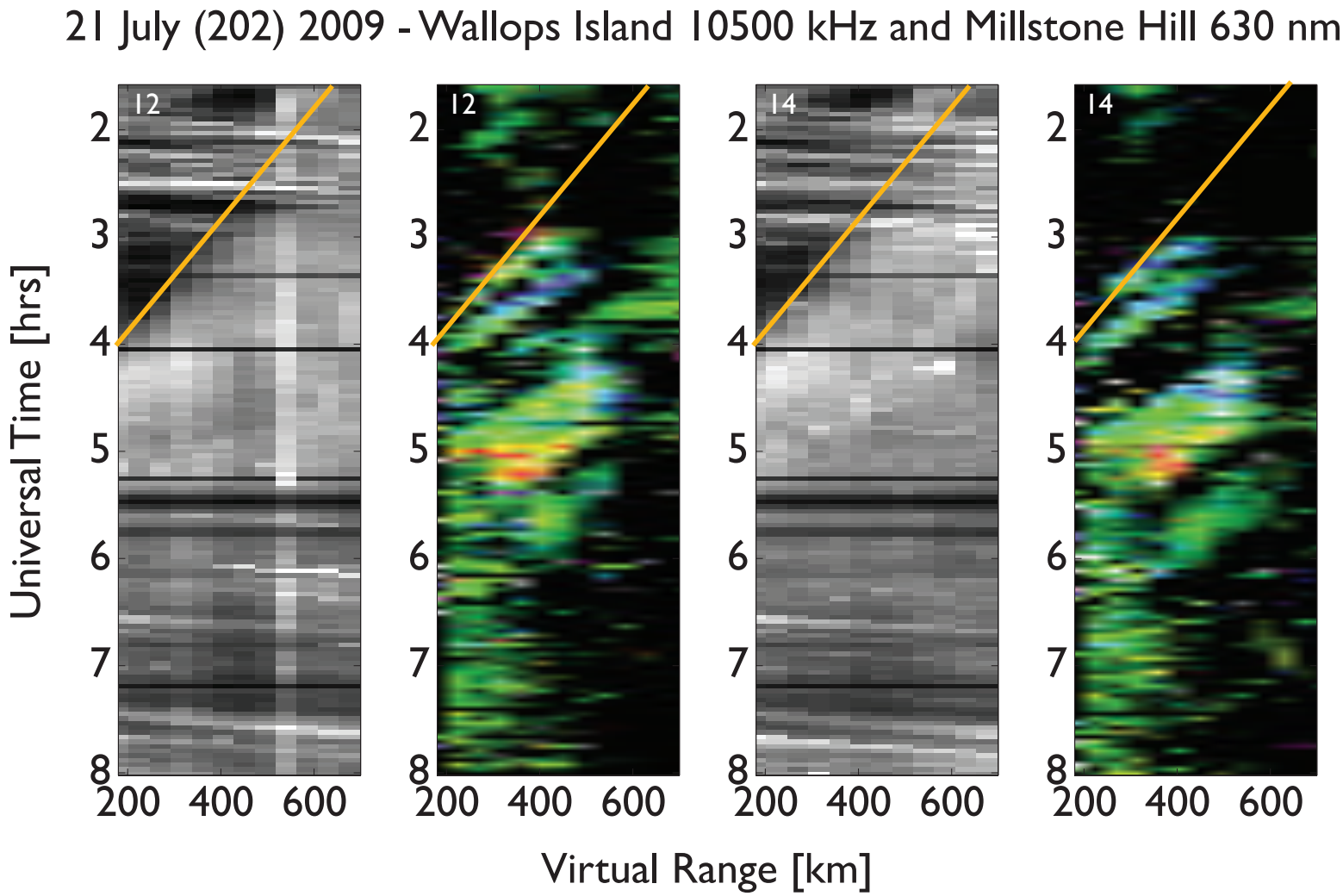
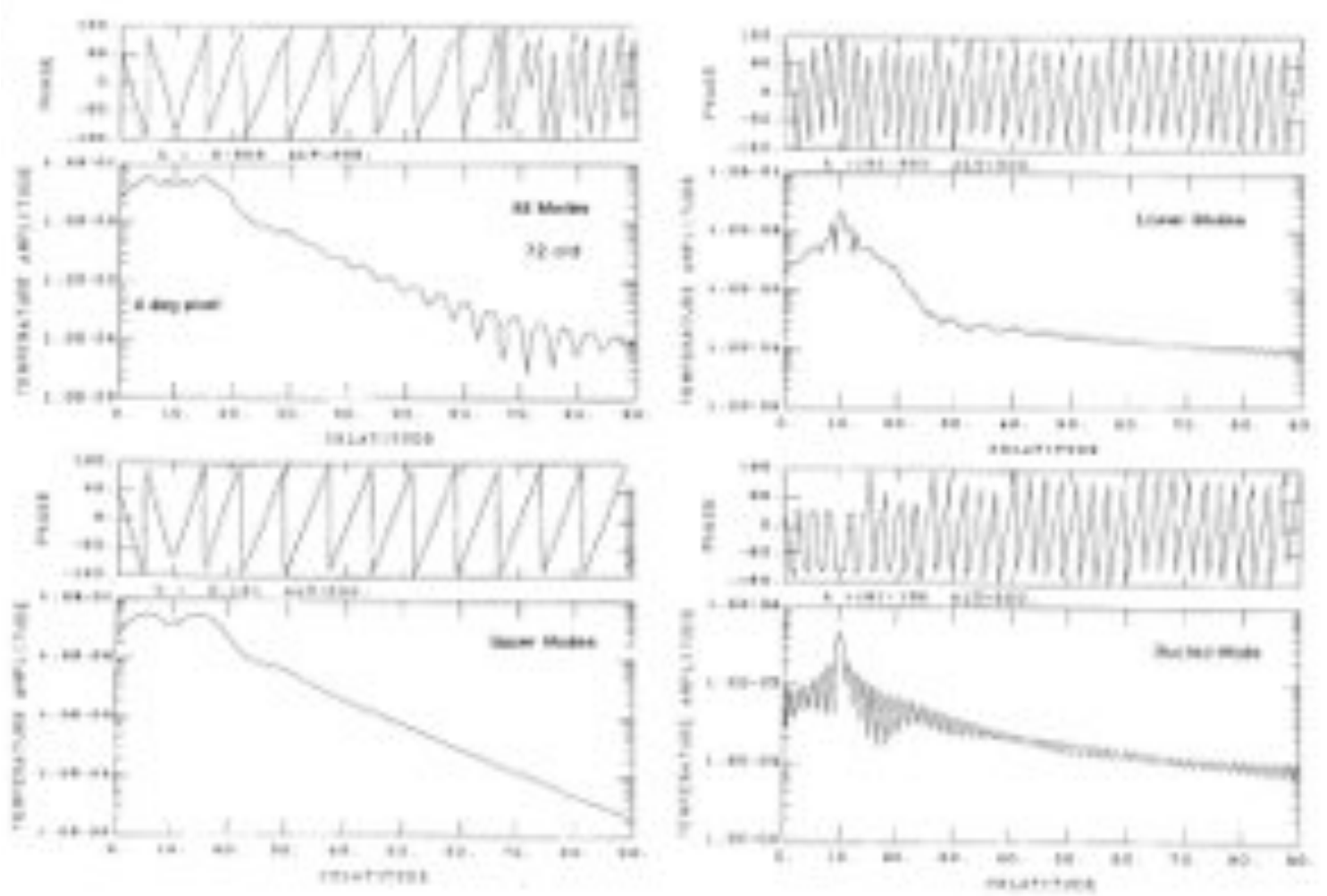


Discussion

- Coupling does exist between *E*- and *F*-region structure.
- Look to initial motivating interest in MSTIDs—their appearance near/at the geomagnetic equator during deep solar minimum (*E. Miller, et al*, 2009, *Makela, et al*, 2010).
- *Kelley*, 2011, revisited *C. Miller*, 1997 (no relation): MSTIDs are gravity waves that experience minimum Joule damping from their interaction with the ionosphere.
- These suggest that Perkins instability is less likely.
  - Perkins instability invalid at equator, Perkins simulations sensitive to initial conditions.
  - Gravity wave explanation requires gravity waves that propagate (nearly) horizontally for $>$ 500 km (movie).

TFGWM Modal Dissipation at 300 km

Auroral source; "ducted" mode experiences less ($10^{1.5}$ vs $10^{2.5}$ in $\Delta T/T$) damping than upper/lower modes; 20-min period.

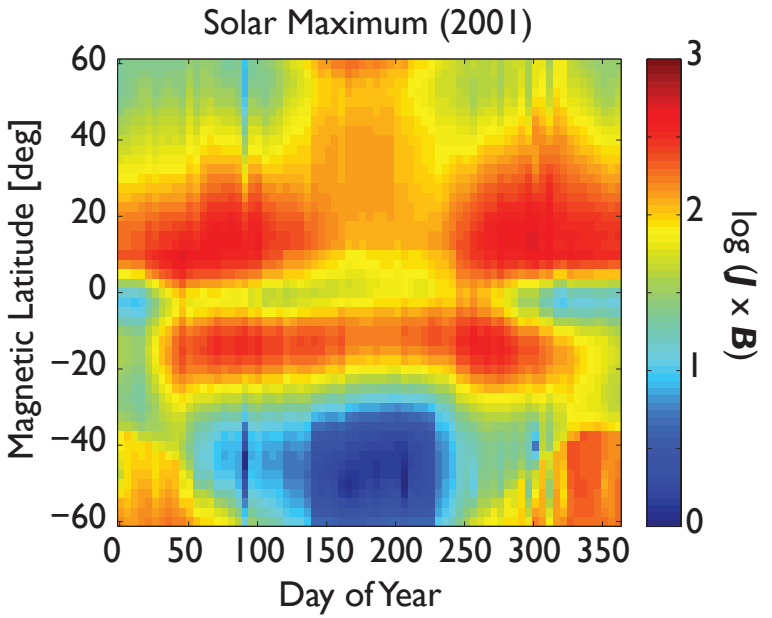


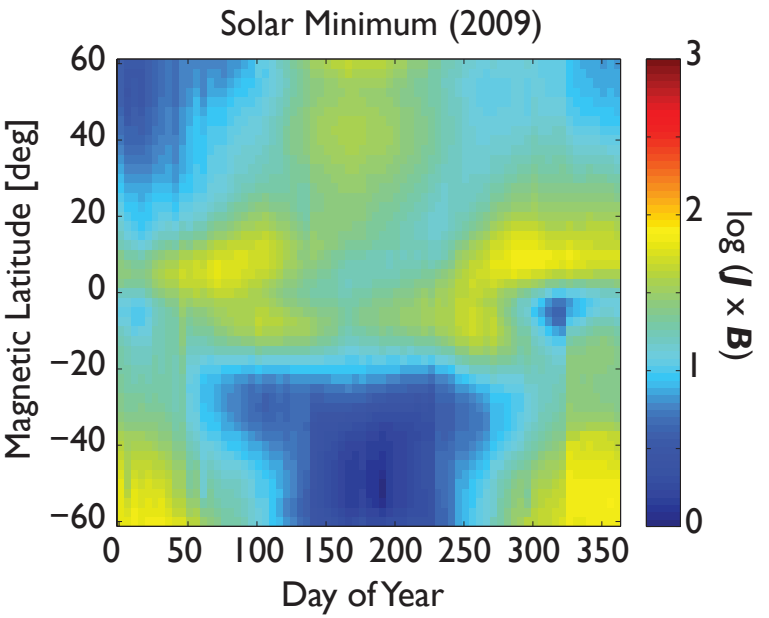
After *Mayr, et al*, 1984.

Local Joule Damping Study

- Does decrease in Joule damping explain propagation of MSTIDs to the equator at solar minimum?
- Devise a crude model of $\mathbf{J} \times \mathbf{B}$
  - Local conductivity tensor computed from IRI 2007, NRLMSISE-00.
  - Dynamo from wind perturbation of 100 m/s rotated 45° from $\mathbf{B}$ (preferred direction).
  - Background wind from HWM07.
  - Consider along magnetic meridian of CTIO (0.4°) over $\pm 60°$ invariant latitude over entire year.
  - Around midnight local time.

Local Joule Damping Study





- There is still a modest amount of Joule damping at solar minimum.
- MSTIDs have an anecdotal proclivity for appearing on days (of year) 15–35 at CTIO.
- Background wind field seems to have an effect, but have not yet rigorously modeled.

Summary

- **Concept:** Although AGWs in the thermosphere *interact* with the ionospheric plasma, a special class of structure is *enhanced* by plasma-neutral coupling.
  - Given the data, this explanation is compelling, but also difficult to prove.
  - See my MSTID-"plasma blob" connection talk on Friday.
- MSTIDs are an important manifestation of coupling between
  - ionosphere and thermosphere (and possibly below)
  - high, middle, and low latitudes
- Role of E_s layers still not fully-quantified: demand a non-local Joule damping model?
- Does "ducted" gravity wave mode predicted by the Mayr model actually exist? There are many more modern works to consider.