Alfvén Dynamics in High-Latitude IT Heating

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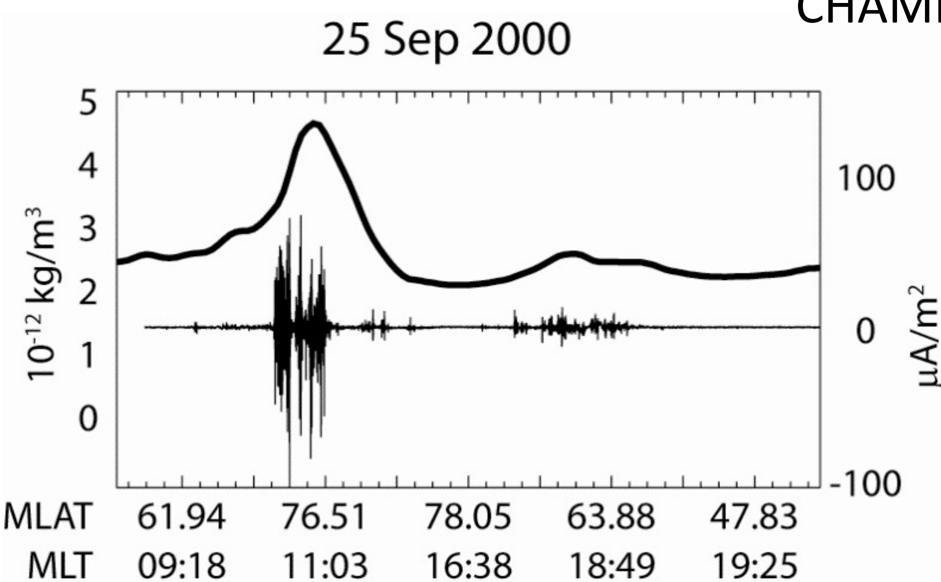
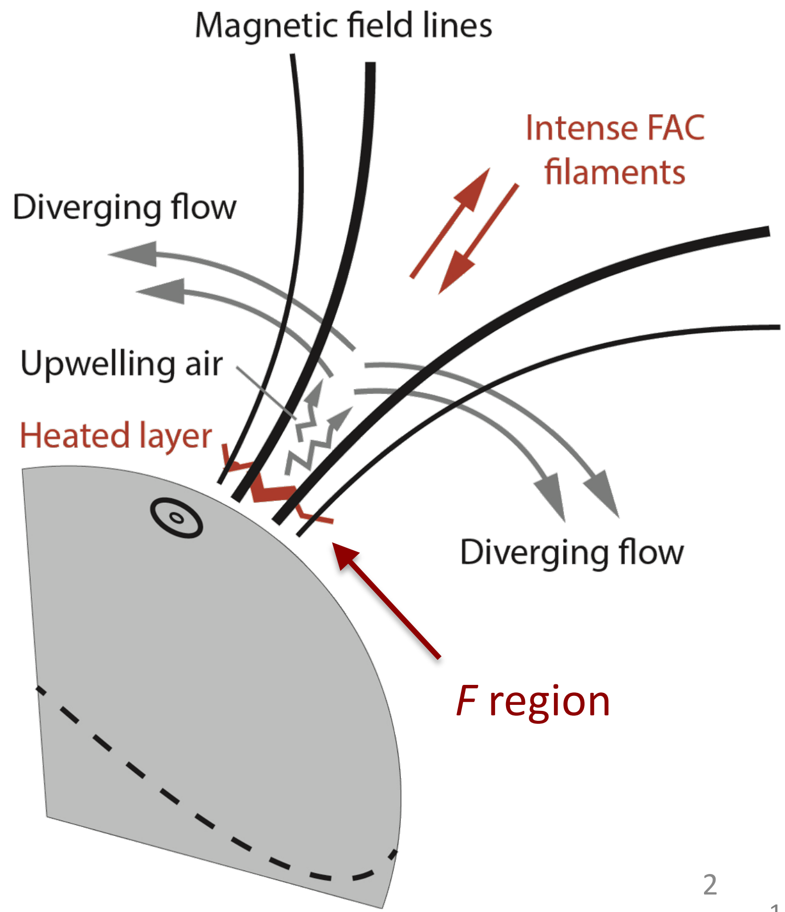
CHAMP



Geomagnetic cusp

Lühr et al. 2004



Wave impedance measured in the *F*-region by DE-2

Altitude 312 km

MLT 7.1 – 9.4 hrs

MLAT 75.5° - 81.6°

Findings

- $\lambda_\perp > 16$ km

  Quasi-static

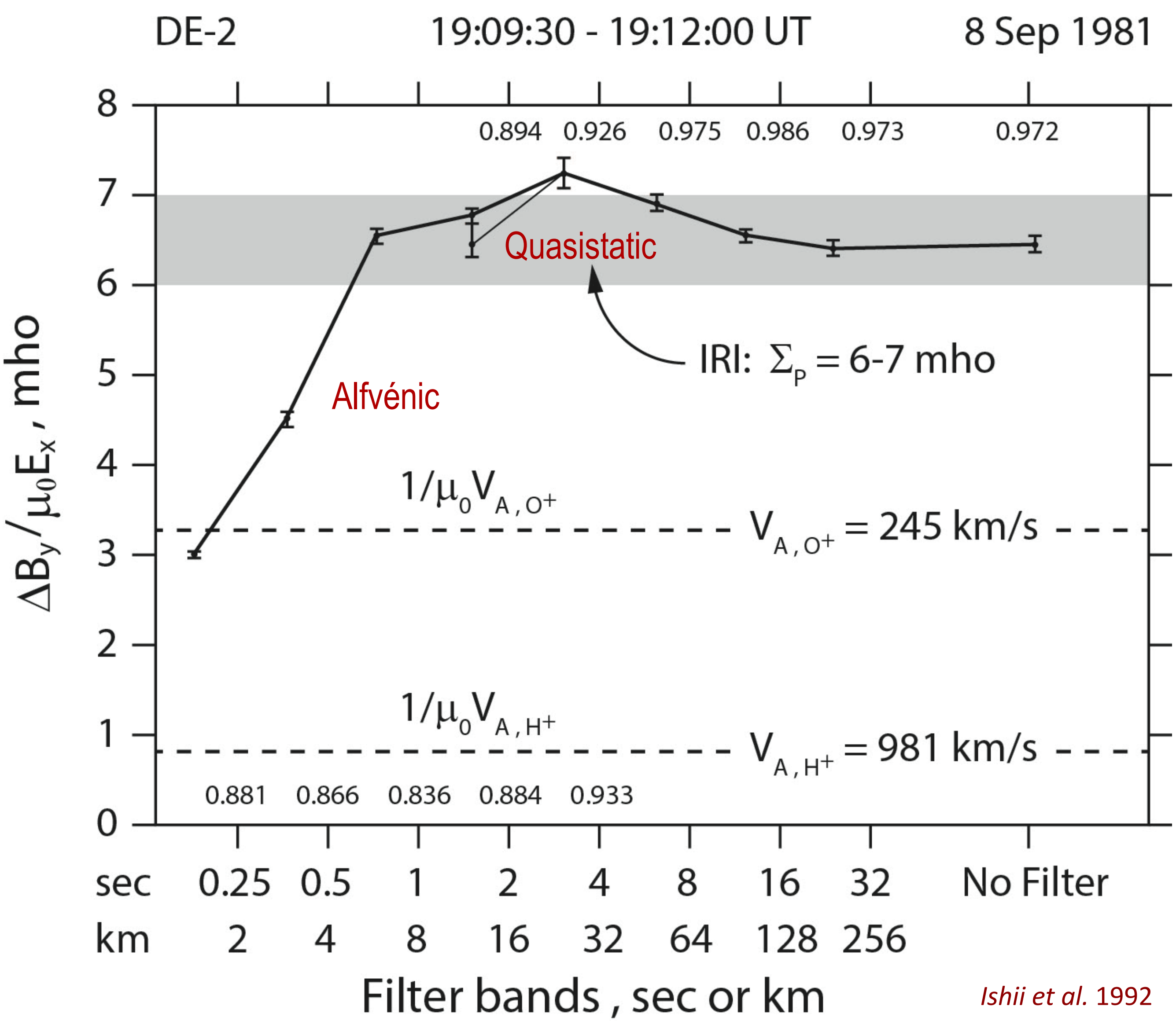
- $\lambda_\perp < 16$ km

  Alfvénic

  AND/OR

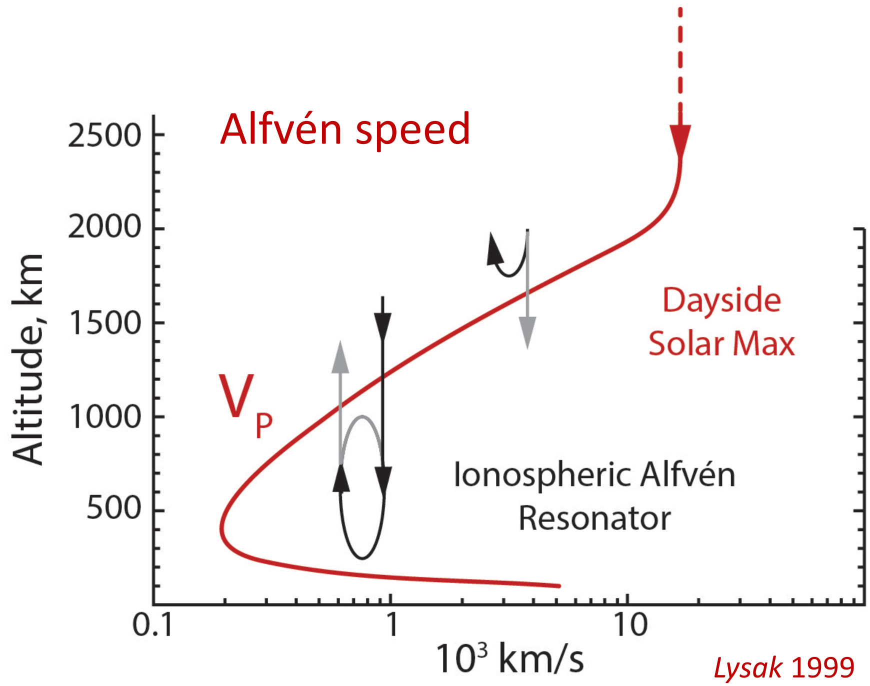
  Quasi-static with finite $\sigma_{||}$ at smallest scales

Forget et al. 1991



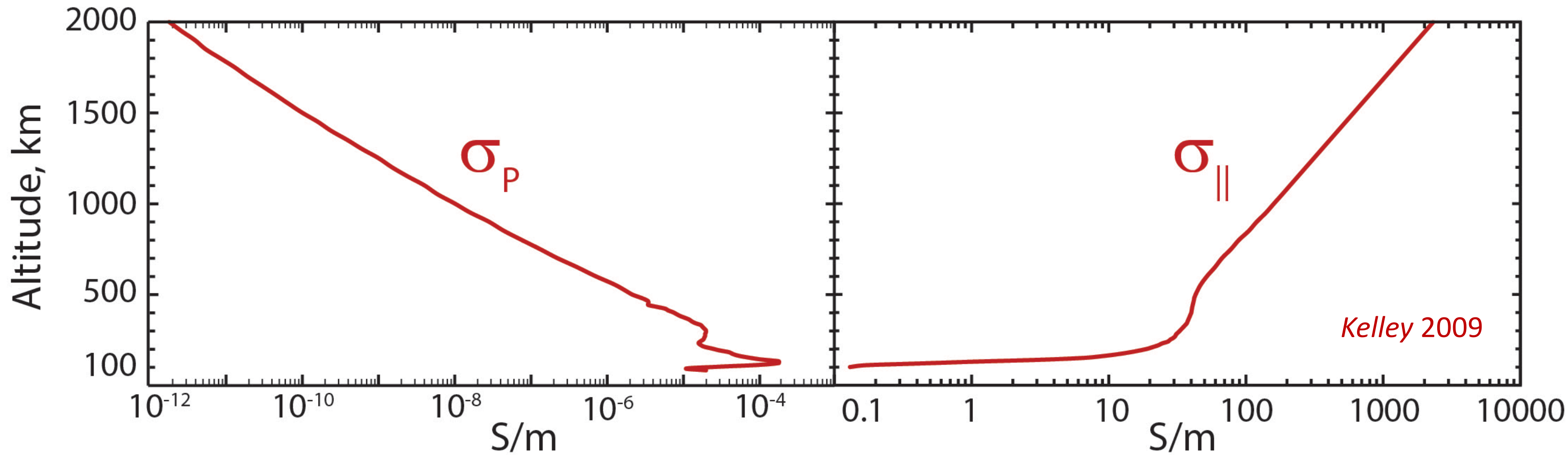
Ishii et al. 1992

Ionospheric profiles for Aflvén wave propagation

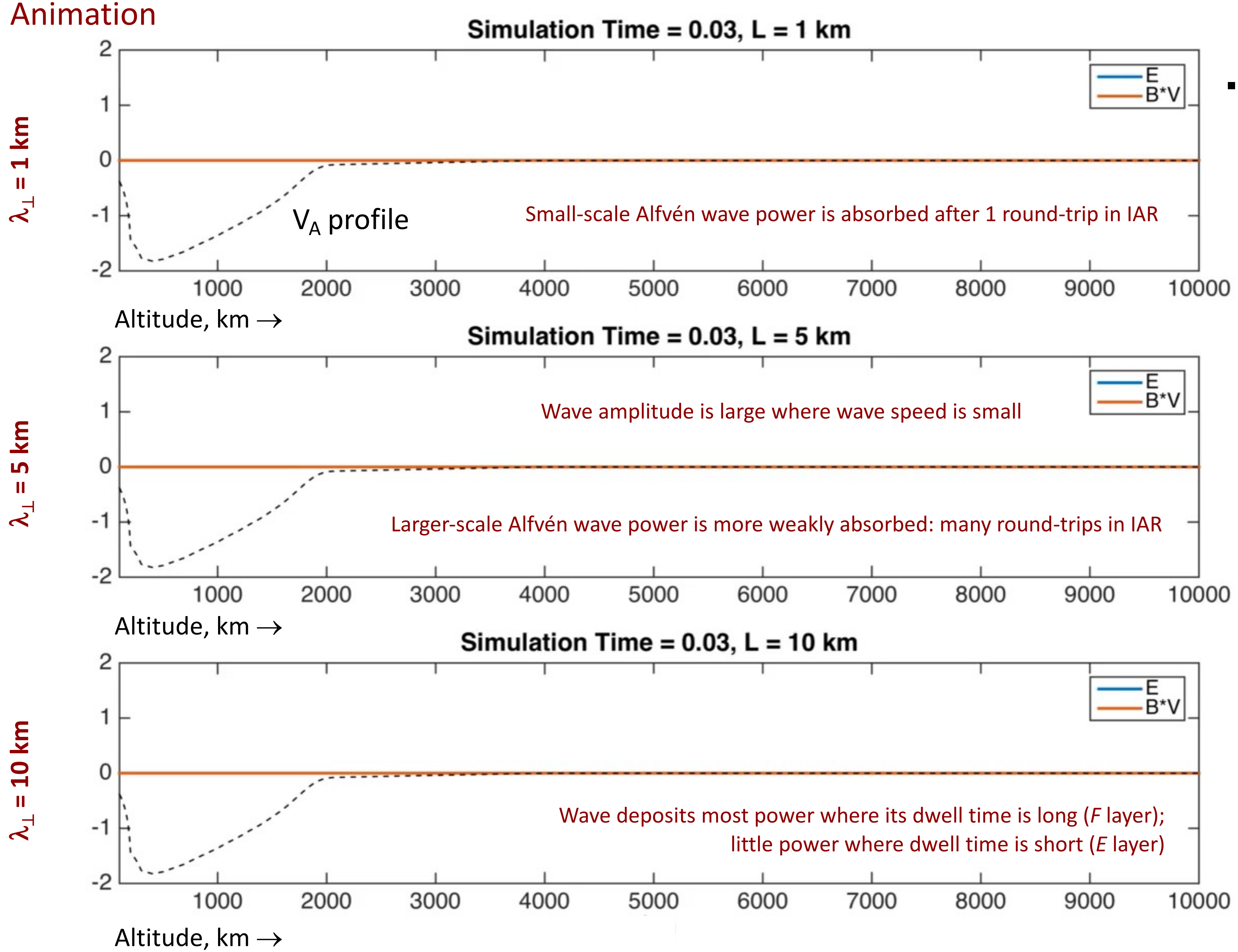


Alfvén wave propagation in a height-resolved ionosphere (*Lysak*, 1999)

- Alfvén wave is launched from 30000 km
- Driven for ½ wave period: 0.5 s
- Reflected power is removed by an absorbing layer at 10000 km



Animation


Simulation Time = 0.03, L = 1 km
E
B*V
V_A profile
Small-scale Alfvén wave power is absorbed after 1 round-trip in IAR
λ⊥ = 1 km
Altitude, km →
Simulation Time = 0.03, L = 5 km
Wave amplitude is large where wave speed is small
Larger-scale Alfvén wave power is more weakly absorbed: many round-trips in IAR
λ⊥ = 5 km
Altitude, km →
Simulation Time = 0.03, L = 10 km
Wave deposits most power where its dwell time is long (F layer);
little power where dwell time is short (E layer)
λ⊥ = 10 km
Altitude, km →

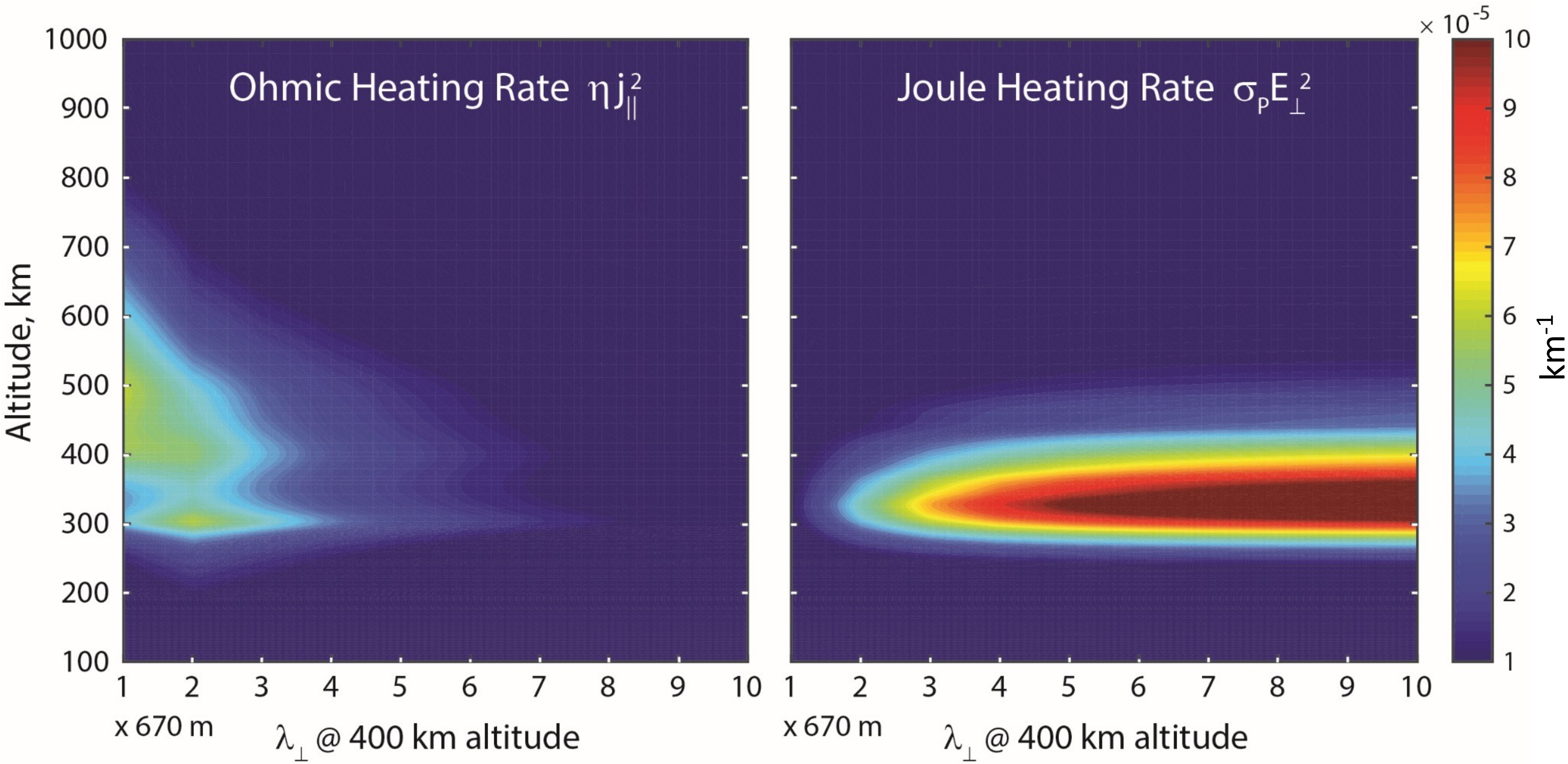
Normalized Alfvénic Heating Rates

Integrated, normalized heating rates

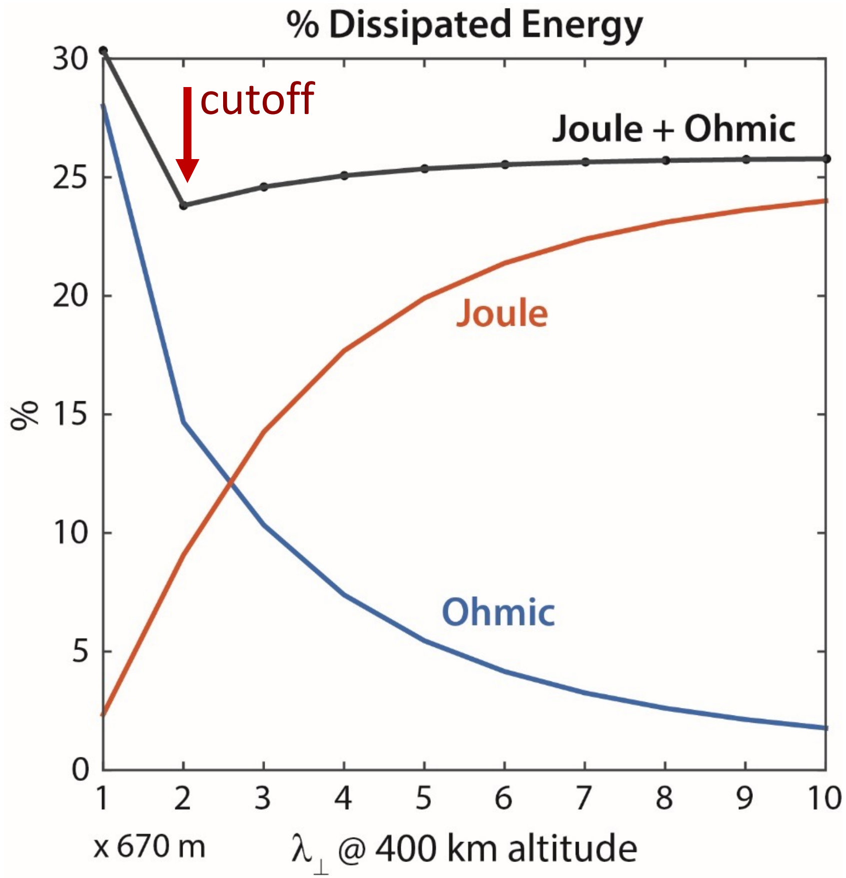
$$\tau_w = 0.5 \text{ s} \;,\; L = \lambda_\perp$$

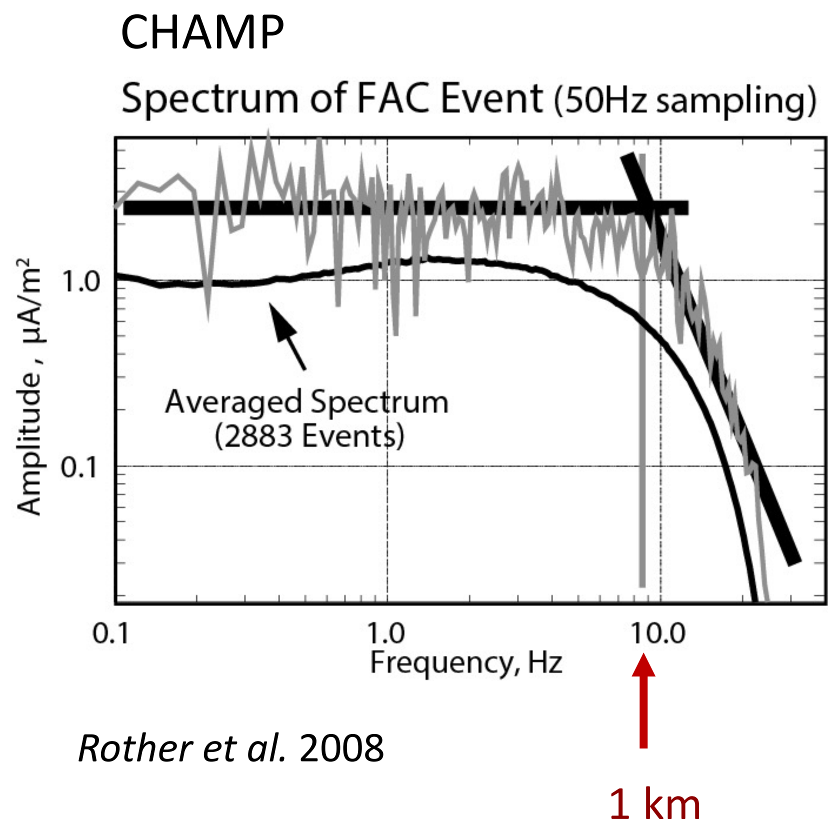
$$\int_0^{t_\infty} dt \int_0^{L} dx \, W_H \Bigg/ \boxed{\int_0^{\tau_w} dt \int_0^{L} dx \, S_\parallel}$$

constant



Reflected and Absorbed Alfvénic Power

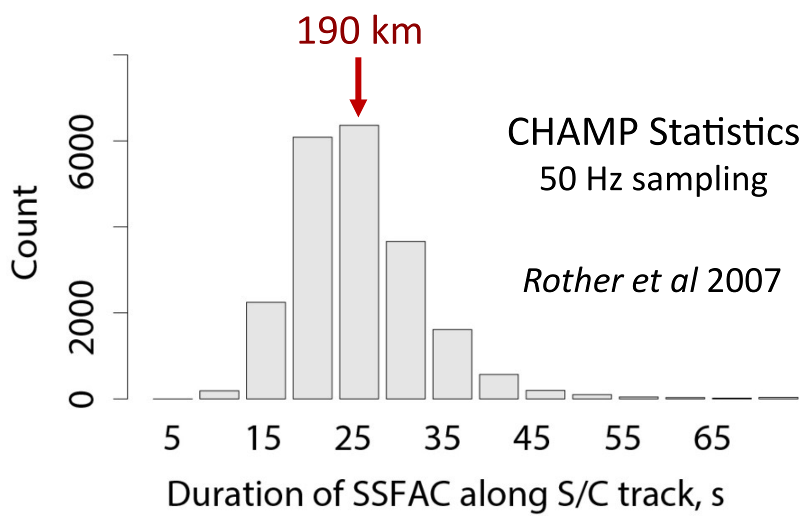




Rother et al. 2008

≈ 1 km "cutoff" wavelength of CHAMP small-scale, field-aligned currents

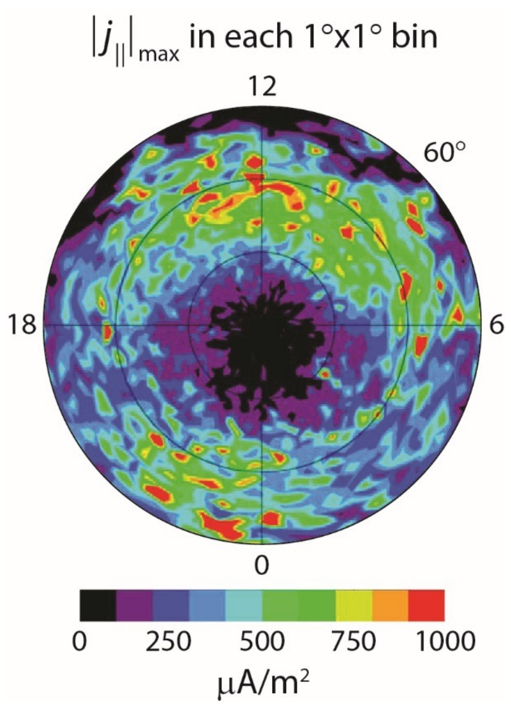
Cumulative Heating from Impulsive Alfvénic Energy Deposition



CHAMP Statistics
50 Hz sampling

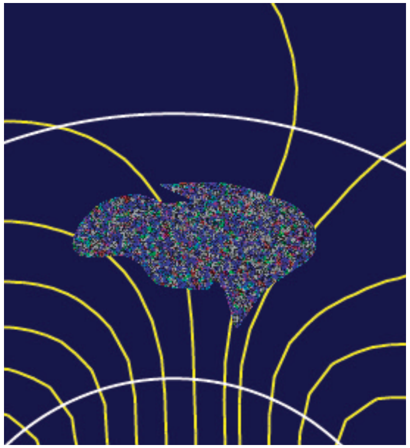
Rother et al 2007

Ørsted Statistics
25 -100 Hz sampling



Neubert and Christiansen 2003

Stochastic heating in cusp



- Alfvén power in: $\langle S_{||} \rangle \approx 1$ mW/m²
- Neutral wind: u_n = 200 m/s
- Width of heating region: 200 km
- Duty cycle: 50% intermittency
- *F*-region heating: **2×10^{-8} W/m³**

Comparable to
Zhang et al. (2015)
Brinkman et al. (2016)

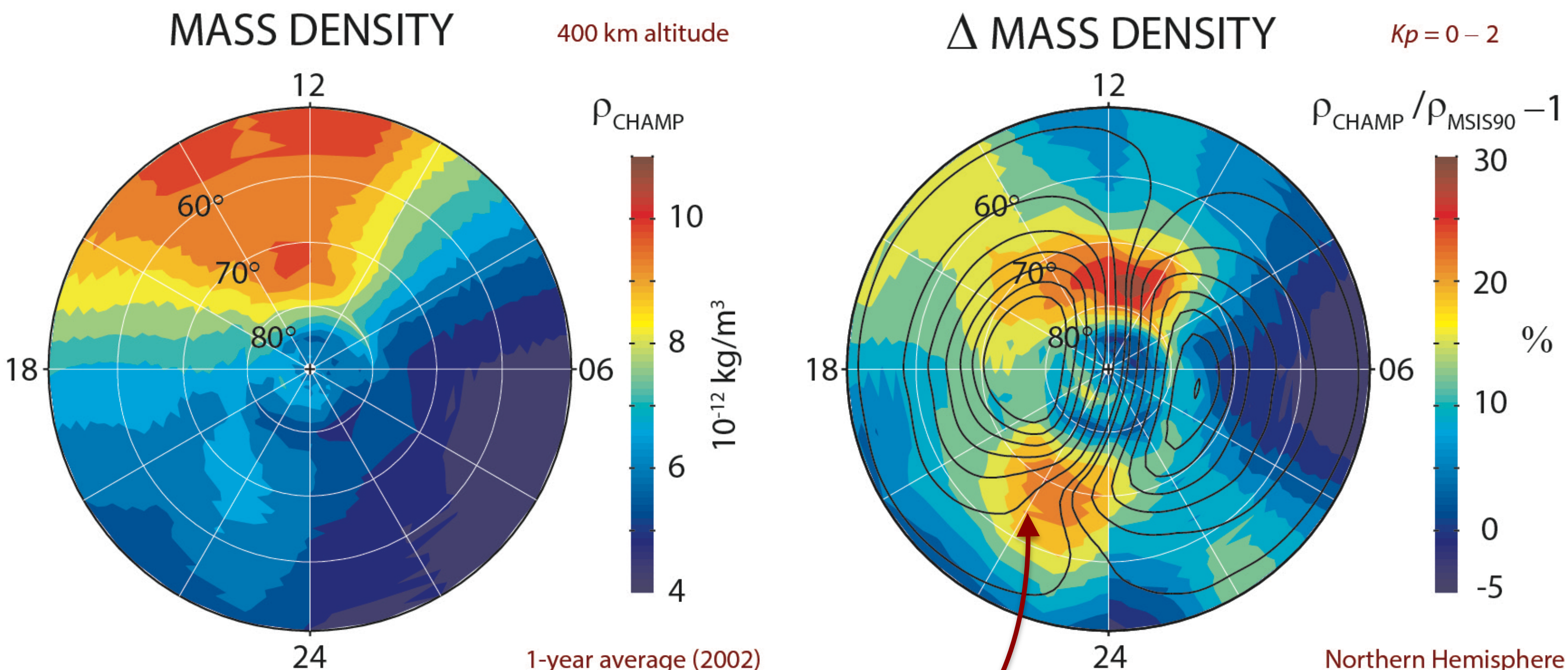
Effects of soft precipitation on σ_P have not been included

Thermospheric density anomalies at 400 km altitude

CHAMP

Geomagnetic coordinates

Liu et al. 2005



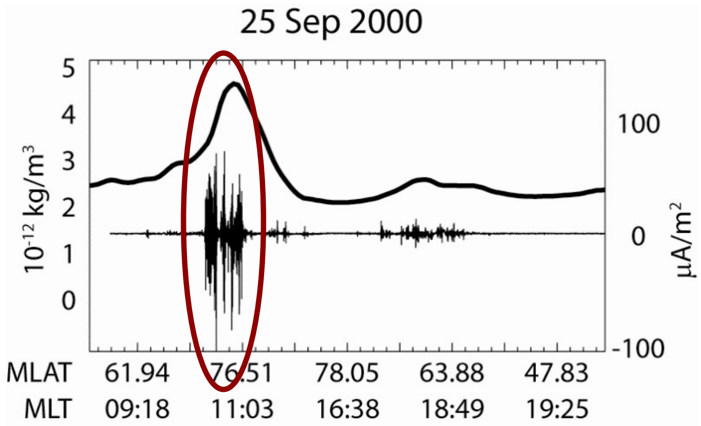
Global simulation (LFM) model streamlines

⇒ Anomalies straddle dayside (cusp) and nightside convection throats

⇒ Anomalies are strongly controlled by magnetic geometry

Effects of dynamic (Alfvénic) SSFACs during anomalies

Lühr et al. 2004 ++



CHAMP | 400 km altitude

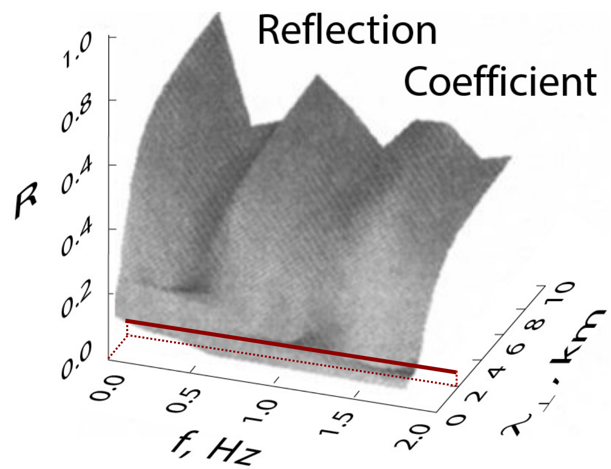
Alfvénic field-aligned currents are prevalent in the cusp region.

How does energy deposition by Alfvénic SSFACs differ from that of quasi-static SSFACs?

Ionospheric reflection of small-scale Alfvén waves

Kilometer-scale (in $\lambda_\perp$) *waves are almost fully absorbed.*

Larger scale waves are reflected and trapped.



Lessard and Knudsen 2001