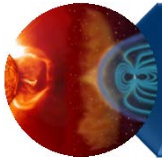
Height-resolved energy exchange rates in the ionosphere

Lei Cai, Anita Aikio, Tuomo Nygren, and Ritva Kuula
lei.cai@oulu.fi
Department of Physics
University of Oulu

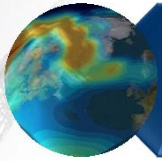
Content



Background

Methods

Energy Transfer Rate Profile



Conclusion

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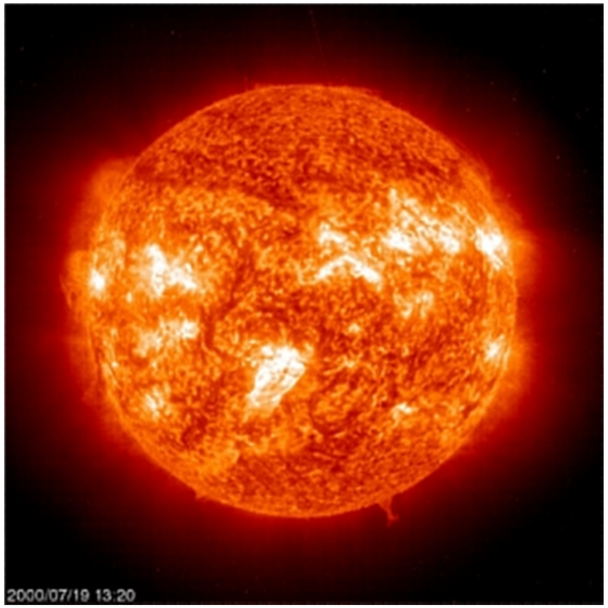
Energy Input from the Sun

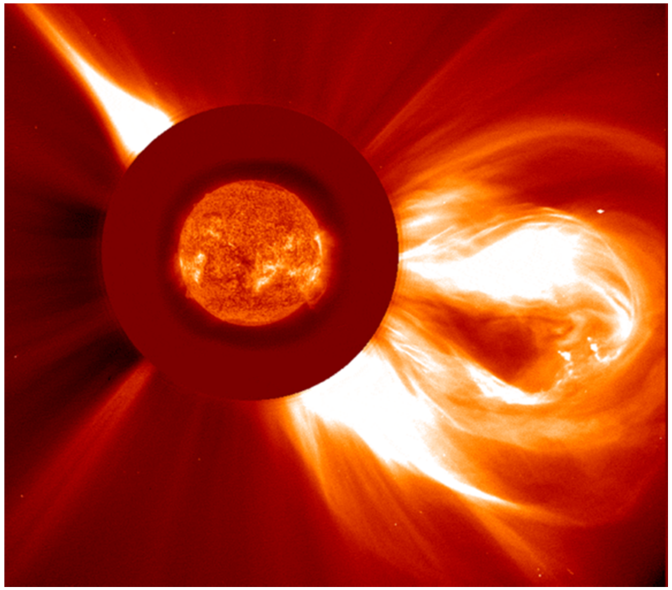
- Solar radiation
  - Soft X-ray, EUV, UV



Energy Input from the Sun

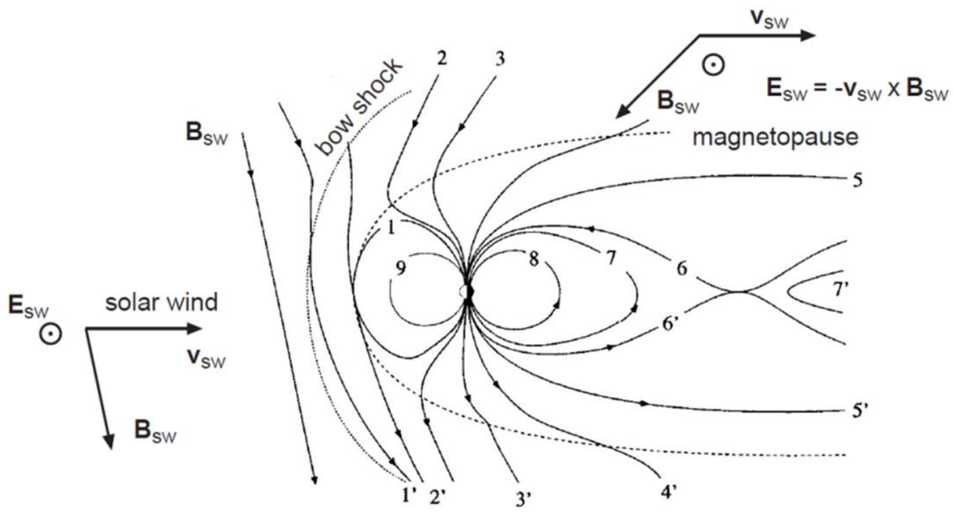
- Solar radiation
  - Soft X-ray, EUV, UV

- Energetic particles precipittaion
  - CME, SEP



Energy Input from the Sun

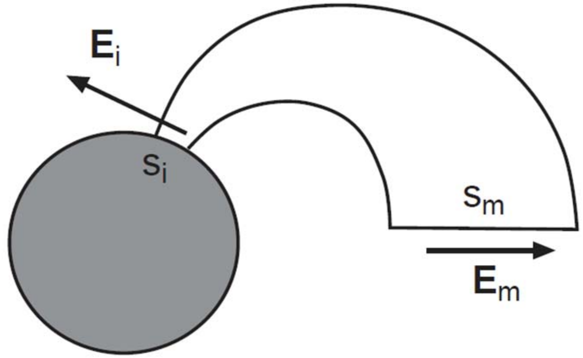
- Solar radiatio
- Energetic part
  precipittaion
- Electromagnetic
  energy injection

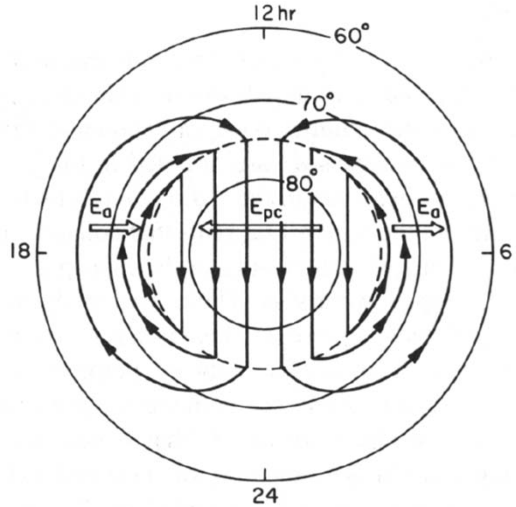


Magnetospheric convection during
southward IMF

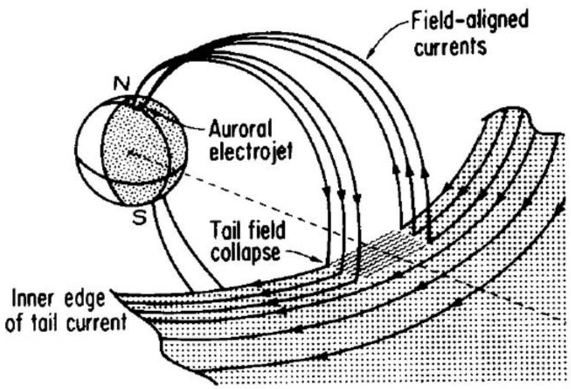
Electromagnetic (EM) Energy Mapping

$$s_i E_i = s_m E_m$$



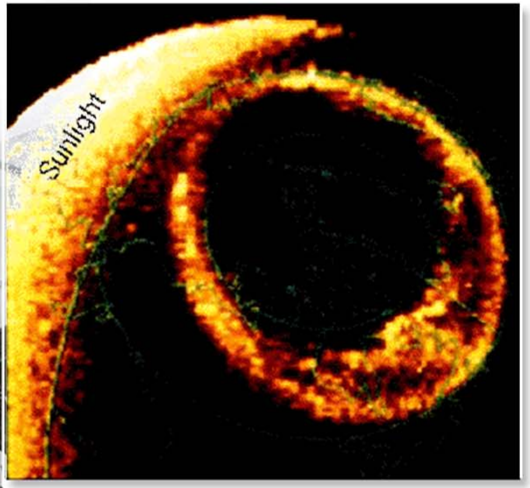


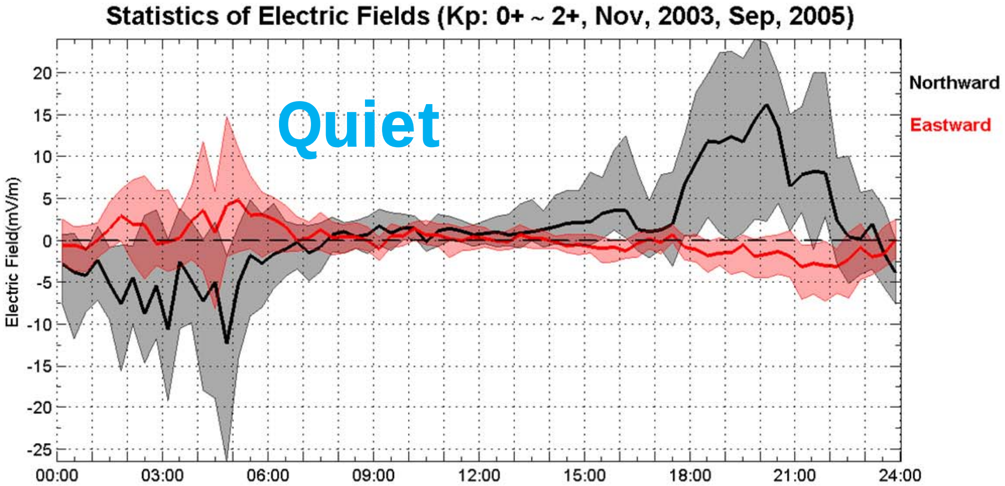
Plasma convection in the northern high latitude ionosphere and associated convection electric elds.

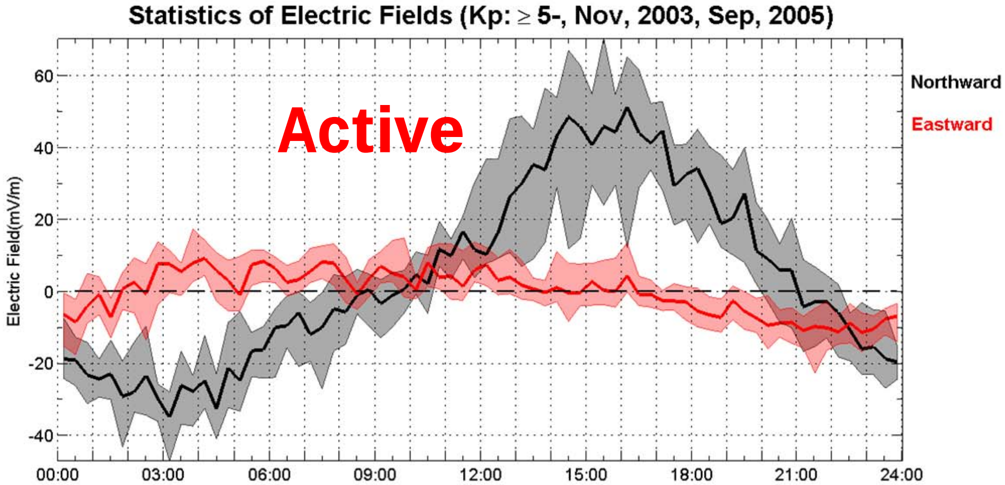


Dipole Field-Aligned Current Model of Substorm Expansion

EM Energy Injection in Auroral Oval



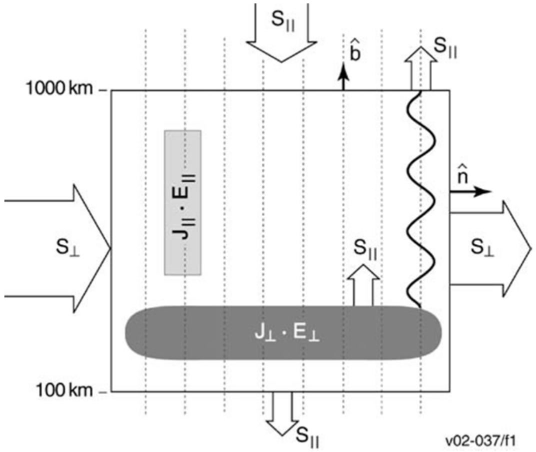




Energy Exchange in the Ionosphere

Poynting's theorem

Energy exchange



Electromagnetic (EM) energy exchange under steady state

$$\nabla \cdot \mathbf{S} + \mathbf{j} \cdot \mathbf{E} = 0$$

$$\underline{\mathbf{j} \cdot \mathbf{E}} = \underline{\mathbf{j} \cdot \mathbf{E}'} + \underline{\mathbf{u} \cdot (\mathbf{j} \times \mathbf{B})}$$

q_{EM}, EM energy exchange rate

q_m, neutral mechanical energy rate

q_J, ion-neutral frictional heating (sometime called *Joule heating*) rate

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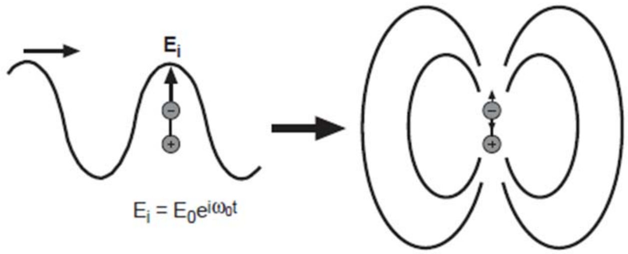
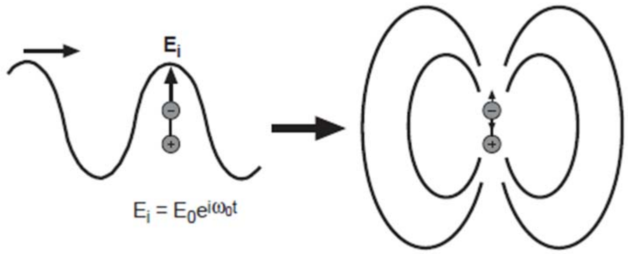
EISCAT Incoherent Scatter Radar



The mechanism of Thomson scattering in terms of dipole radiation of an oscillating electron.

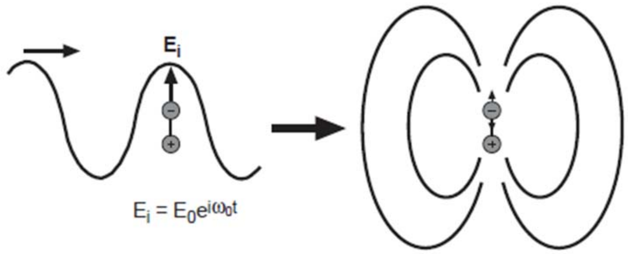
EISCAT Incoherent Scatter Radar



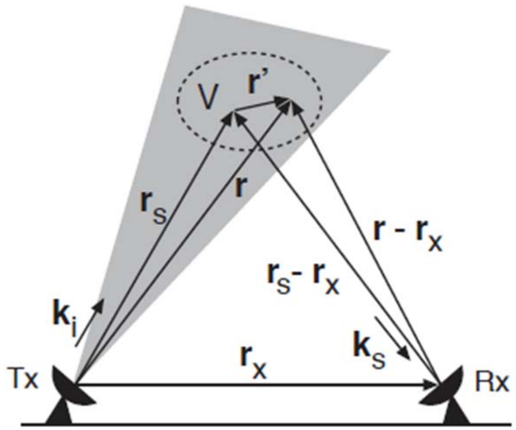
The mechanism of Thomson scattering in terms of dipole radiation of an oscillating electron.

Arecibo: 300 m. Too large plate.

EISCAT Scientific Association



The mechanism of Thomson scattering in terms of dipole radiation of an oscillating electron.

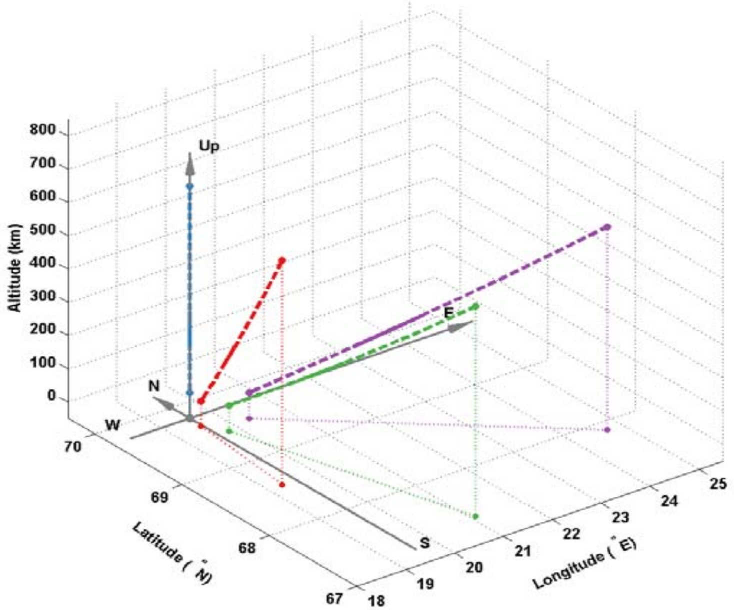


Arecibo: 300 m. Too large plate.

Smaller one. Three radar systems in Northern Scandinavia.

EISCAT CP2 experiments inTromsø

Four beam directions.



- **25-day** data from September 6 to September 30 in 2005.
- **9-day** data from November 11 to November 19 in 2003.
- The data in 2003 is supplemented for active conditions.

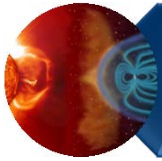
What are calculated?

$$
\begin{cases}
q_E = \sigma_P \cdot \mathbf{E}^2 \\
q_J = \mathbf{j} \cdot (\mathbf{E} + \mathbf{u} \times \mathbf{B}) \\
q_m = \mathbf{u} \cdot (\mathbf{j} \times \mathbf{B}) \\
q_{EM} = q_J + q_m
\end{cases}
$$

Goals

- To study the height-resolved energy exchange rate, Joule heating rate, and mechanical energy rate in the E region.
- To illuminate the geomagnetic activity and MLT dependences of the altitude profile for each energy rate through a statistical study.
- To understand how the neutral wind affects the dissipation of electromagnetic energy input from the magnetosphere.

Content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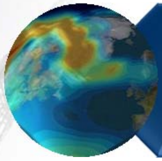
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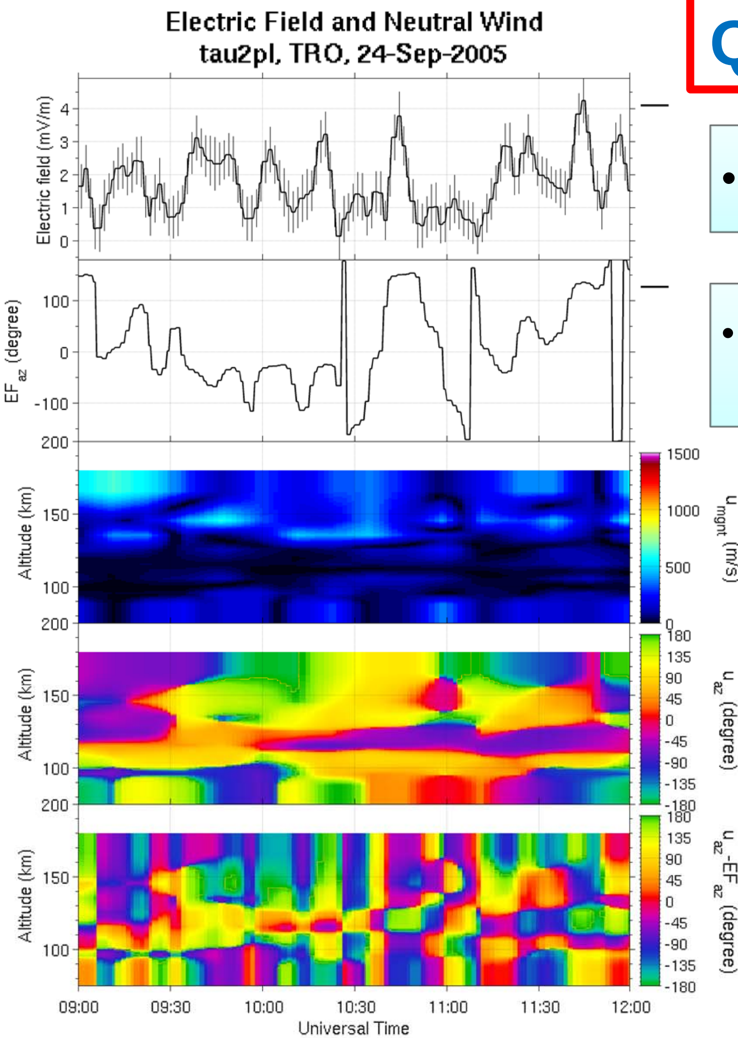


Quiet daytime

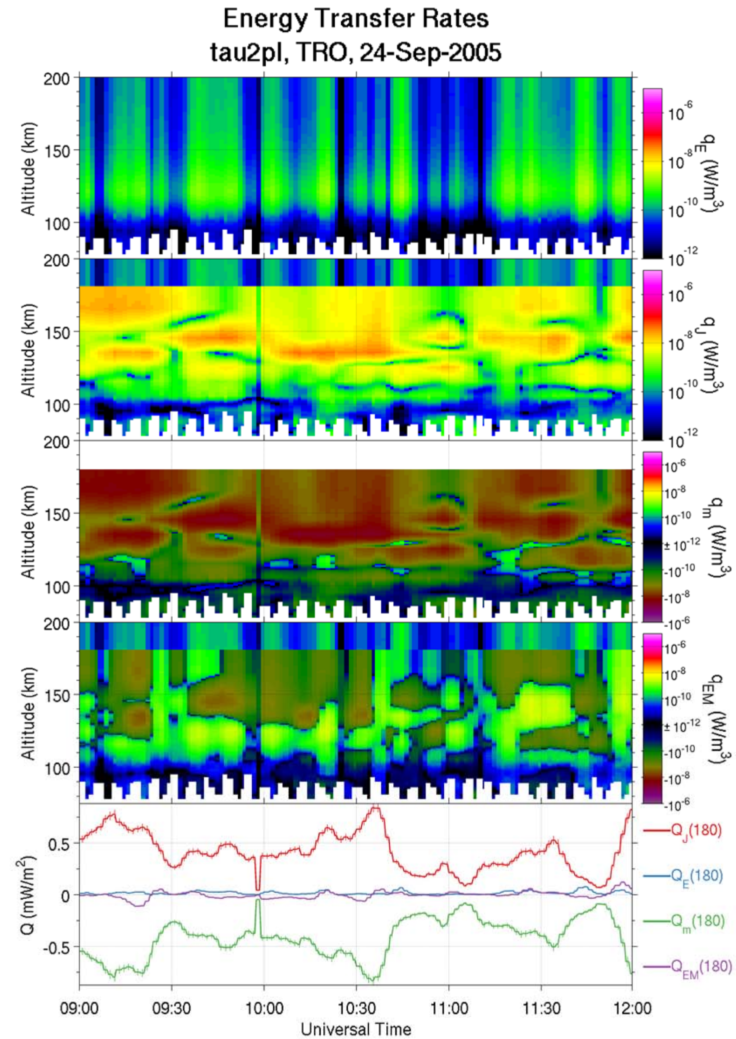
- $q_E \propto E^2\,,\; q_E \propto \sigma_P$.

- q_J: structured in altitude.

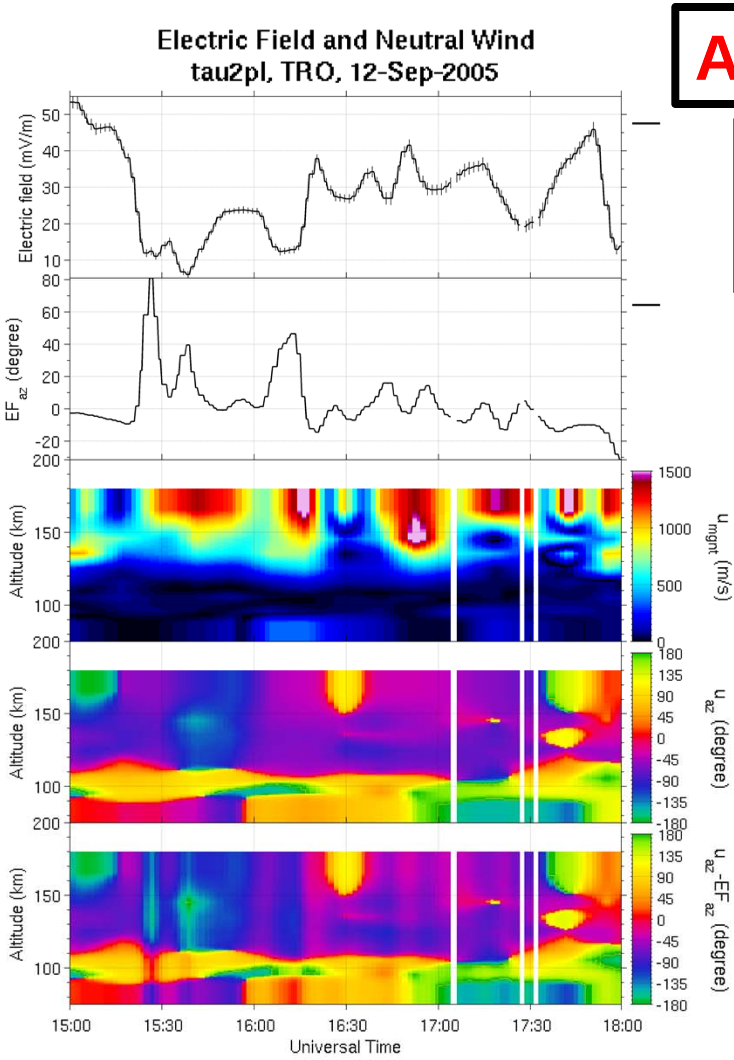
- q_m: structured, mainly negative.
- Neutral wind is making work.

- q_{EM}: small positive and negative values.

- Height-integrated values, $Q_J \sim |Q_m|$.



- During the studied daytime, EM energy input/output is very small.
- Winds are making work, which is dissipated as Joule heating.



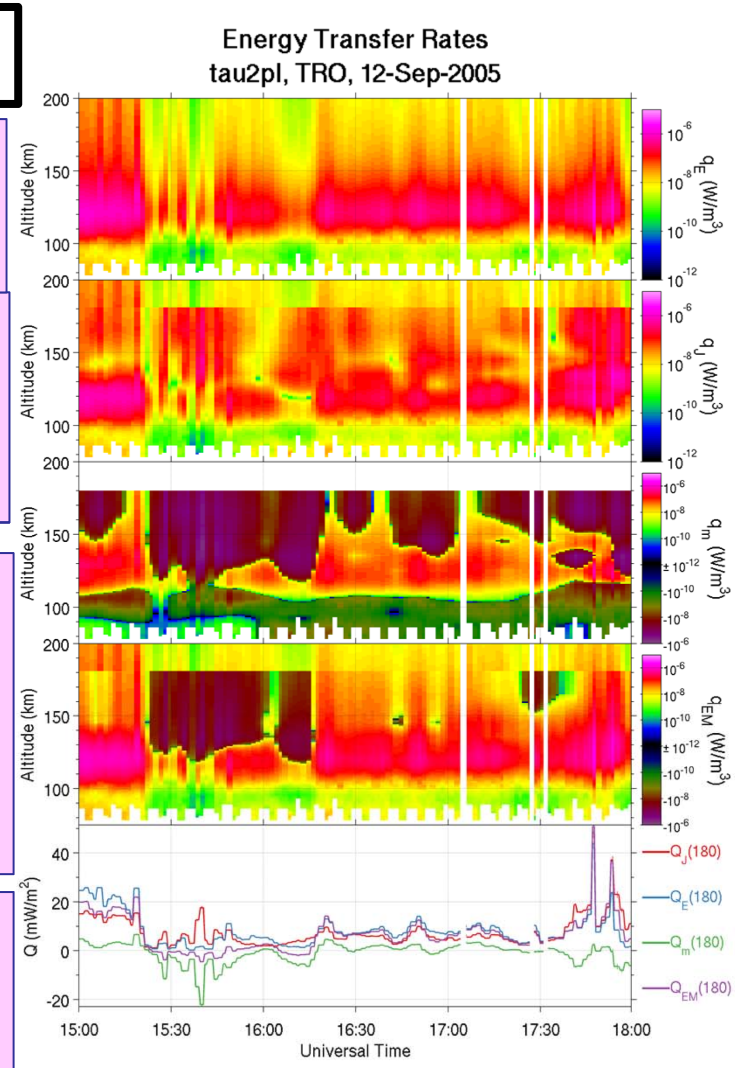
Active daytime

- $q_E \propto E^2$, $q_E \propto \sigma_P$.

- q_J resembles q_E.
- Some structuring at high altitudes due to winds.

- q_m: negative at high altitudes; positive at low altitudes.
- Positive enhancement expands to higher altitudes with larger electric field.

- q_{EM}: mostly positive and large.
- Negative regions at higher altitudes.



- **Strong EM energy input from the magnetosphere**
- **Winds make work at highest altitudes, but are a loader in E region ($q_m > 0$);**
- **Mostly, both EM energy input and neutral winds contribute to Joule heating;**

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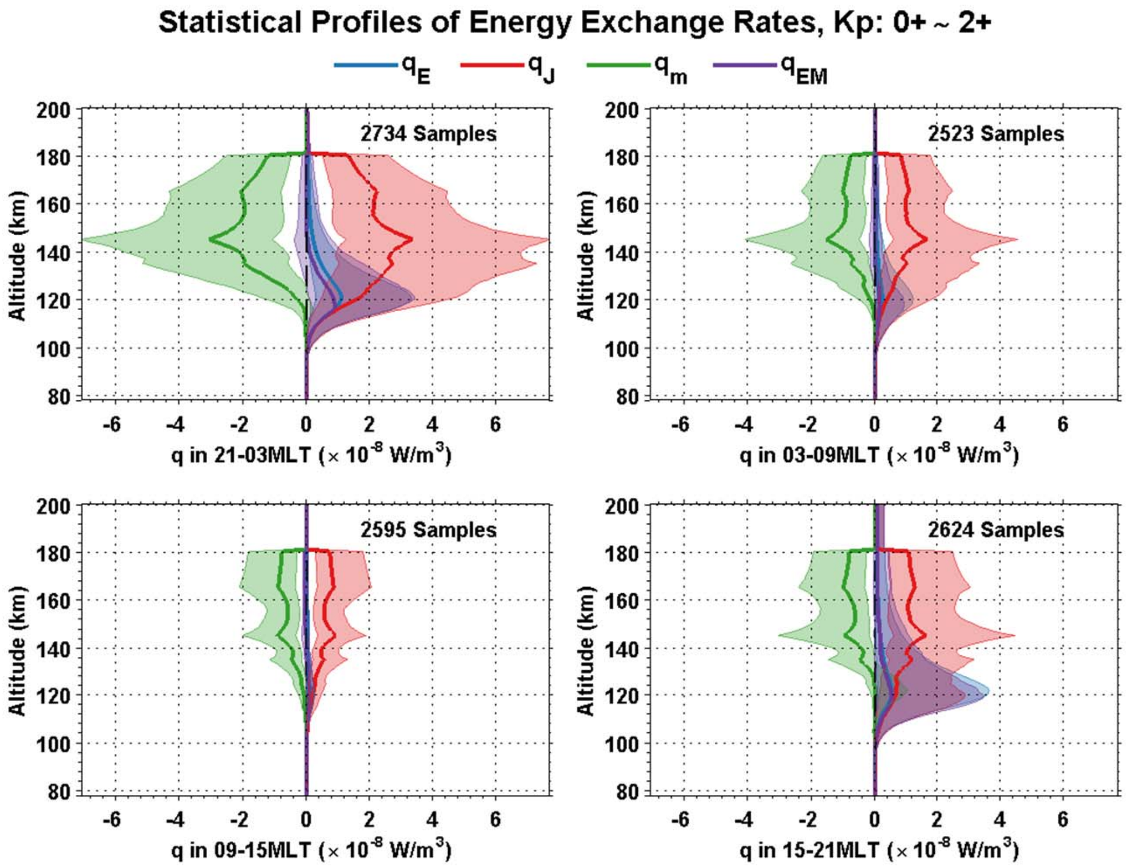
OULUN YLIOPISTO

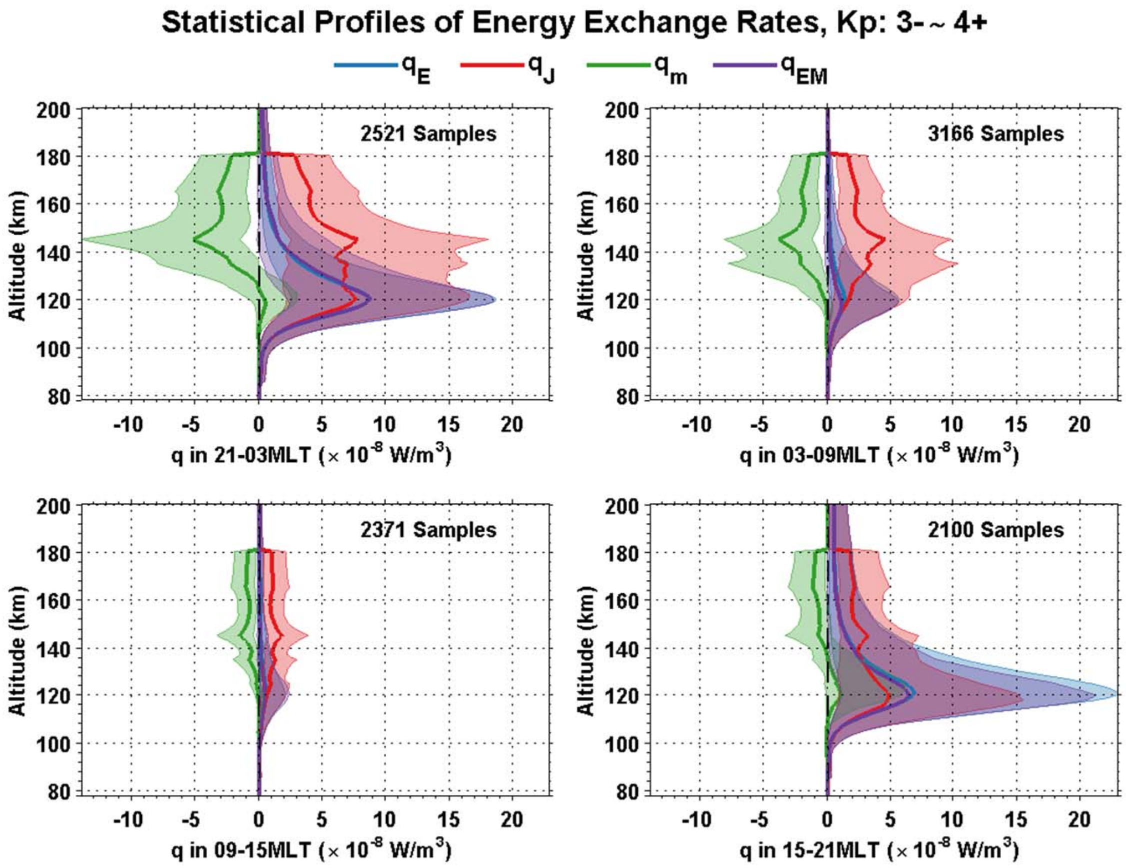
Statistical Study



Low activity

- Neutral wind is the main source of height-integrated Joule heating in all MLT sectors.
- Neutral wind is the main source of Joule heating above 125 km.
- Strongest enhancements of EM energy input and Joule heating rate are in the midnight sector. The peak height of q_J is about 145 km, and that of q_{EM} is bout 120 km.
- The dissipation of EM energy takes place between 100 km and 140 km.

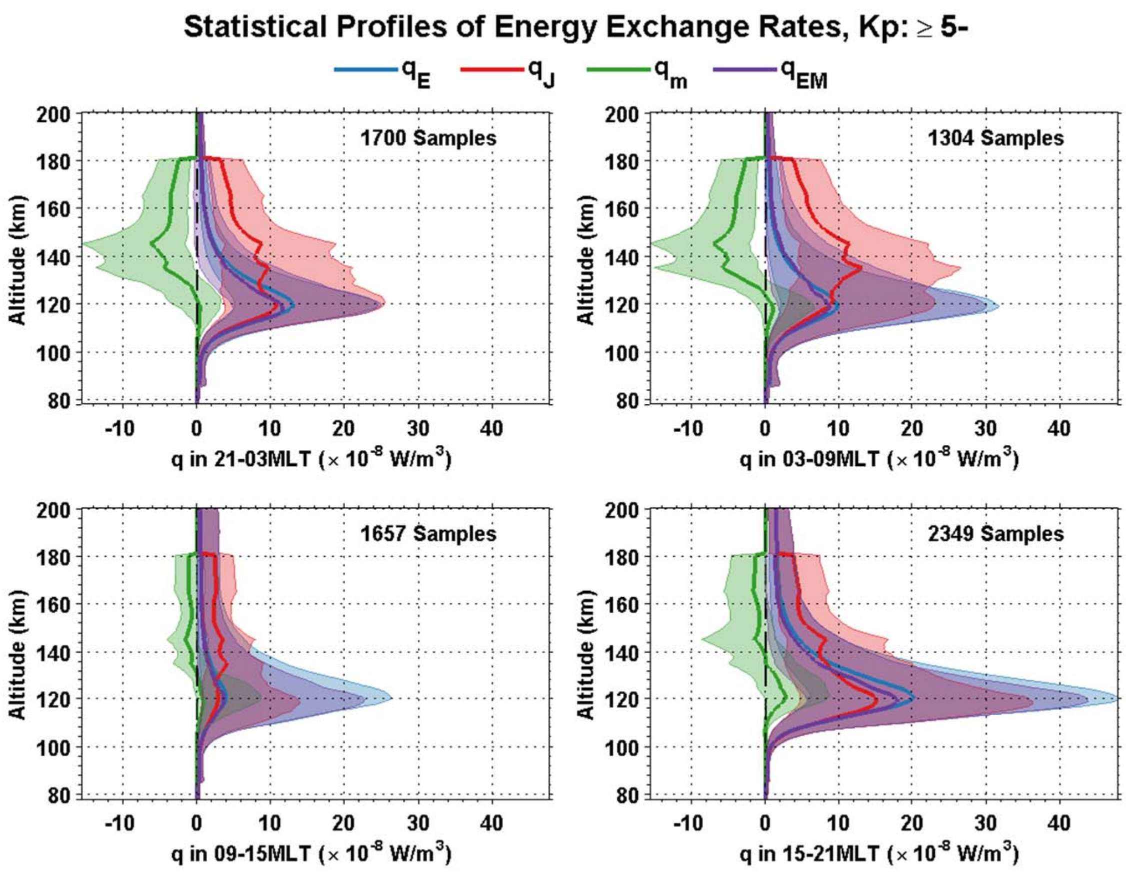
Statistical Study



Median activity

- In the evening and midnight sectors, EM energy dissipation is the main source of height-integrated Joule heating.
- In the evening and midnight sectors, EM energy goes also to neutral wind at altitudes between about 110 and 130 km.
- Neutral wind is the main source of Joule heating above ~ 150 km in the evening sector, and above ~ 130 km at other MLT sectors.
- Maximum q_J and q_{EM} take place in the midnight sector.

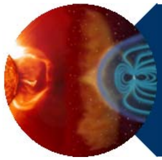
Statistical Study



High activity

- EM energy dissipation is the main source of height-- integrated Joule heating in all other MLT sectors except the morning sector.
- Some EM energy goes to neutral winds at all MLT sectors, but the strongest transfer takes place in the evening sector between 110-140 km altitude.
- Maximum q_J and q_{EM} take place in the evening sector

Content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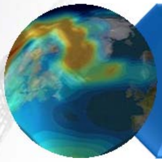
Conclusion

Conclusion

- **Neutral winds are the main source of Joule heating under quiet conditions, while EM energy dissipation dominates on Joule heating under active conditions.**
- **Neutral winds affect the altitude distribution of Joule heating especially at high altitudes.**
- **EM energy dissipation enhances with increasing geomagnetic activity. The maxima takes place at 120 km.**
- **Mainly, EM energy dissipates on Joule heating. However, some EM energy goes to neutral winds at the altitudes between about 115 and 140 km under active conditions.**

Thank you!