The Equatorial Electrojet

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Outline

- Introduction to the equatorial ionosphere and the equatorial electrojet (EEJ)
- Attempts to model the EEJ
- Plasma instabilities in the EEJ
- Climatology of EEJ
- Future EEJ research

The Ionosphere

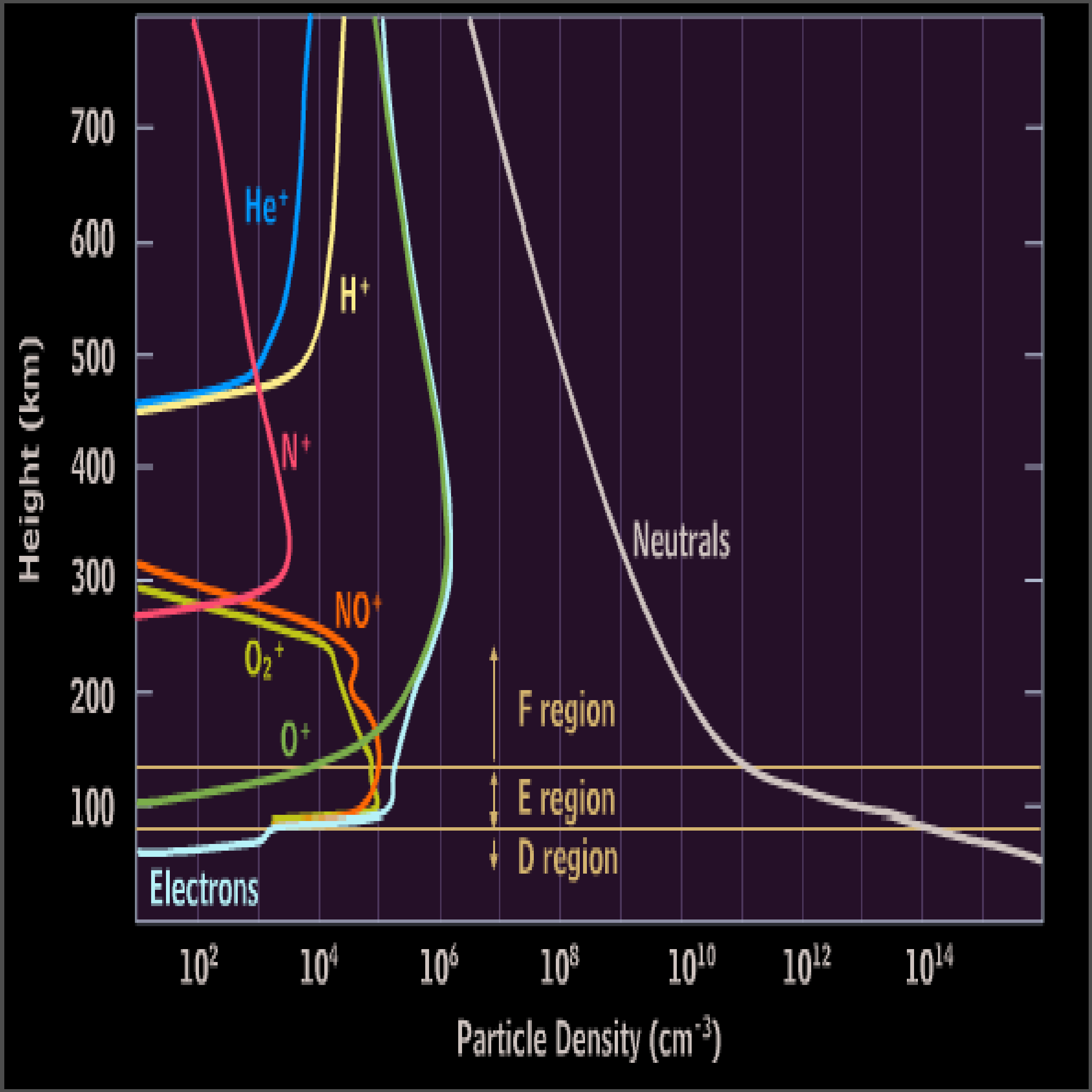
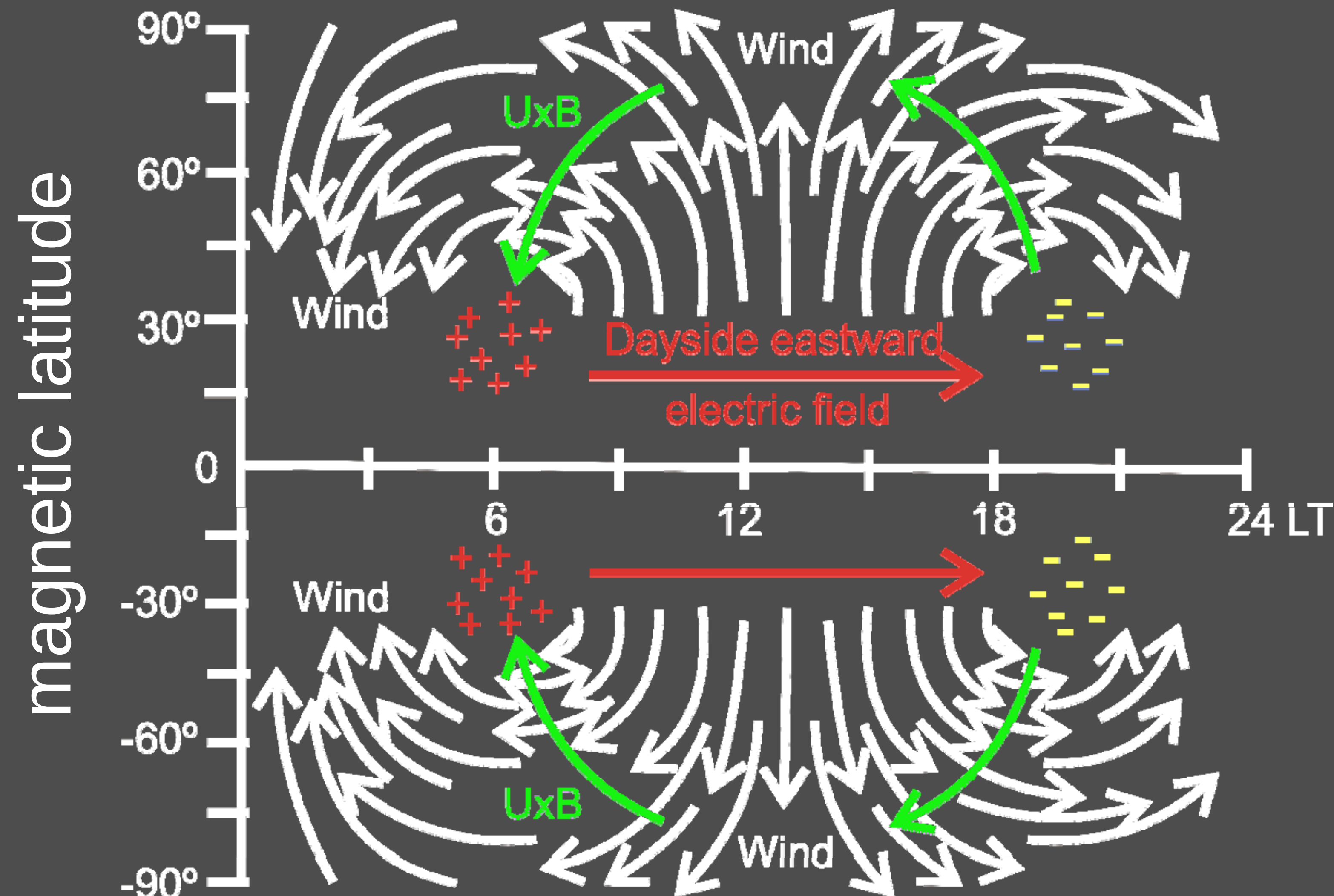
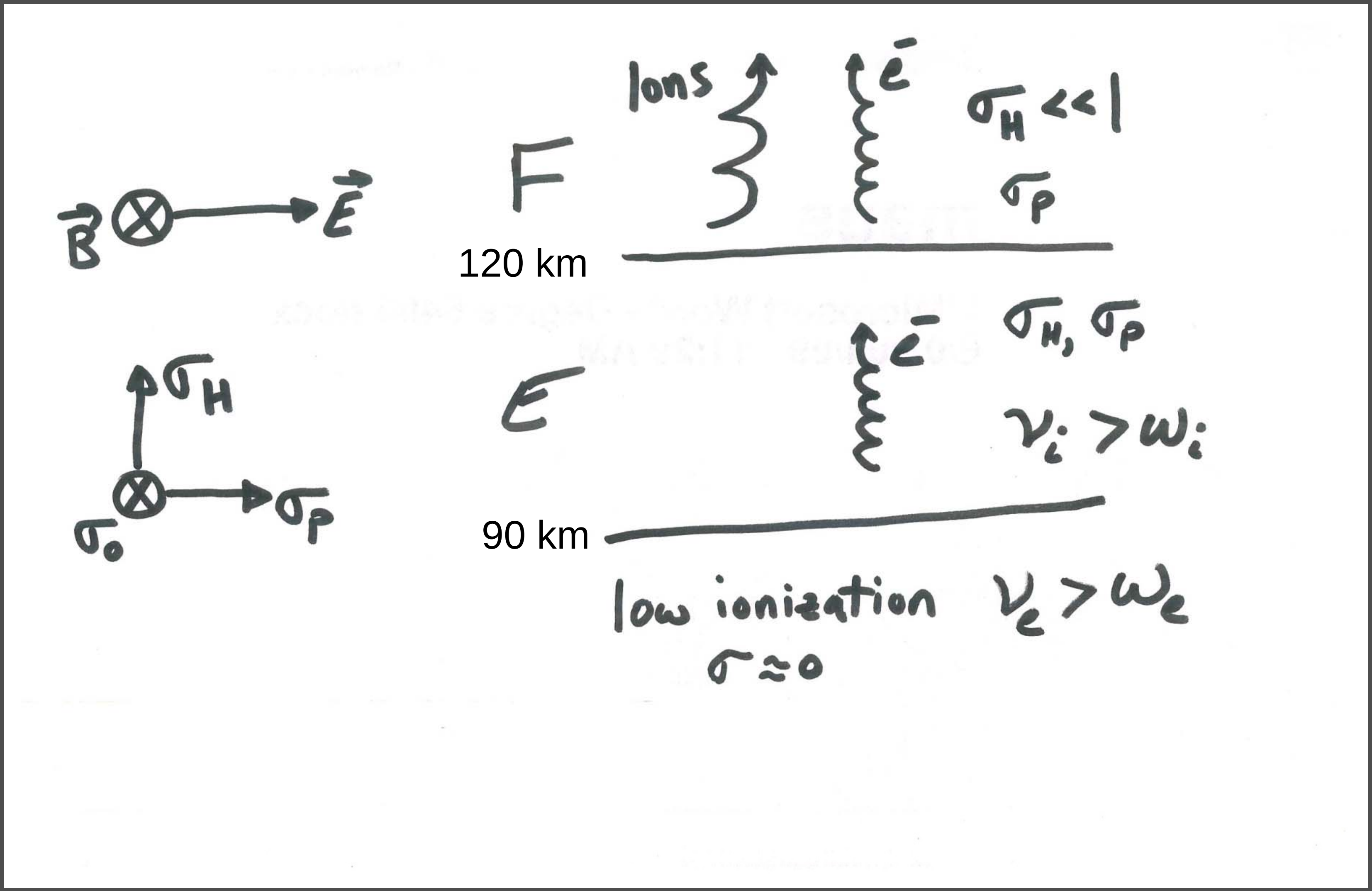


Image courtesy of http://www.windows.ucar.edu

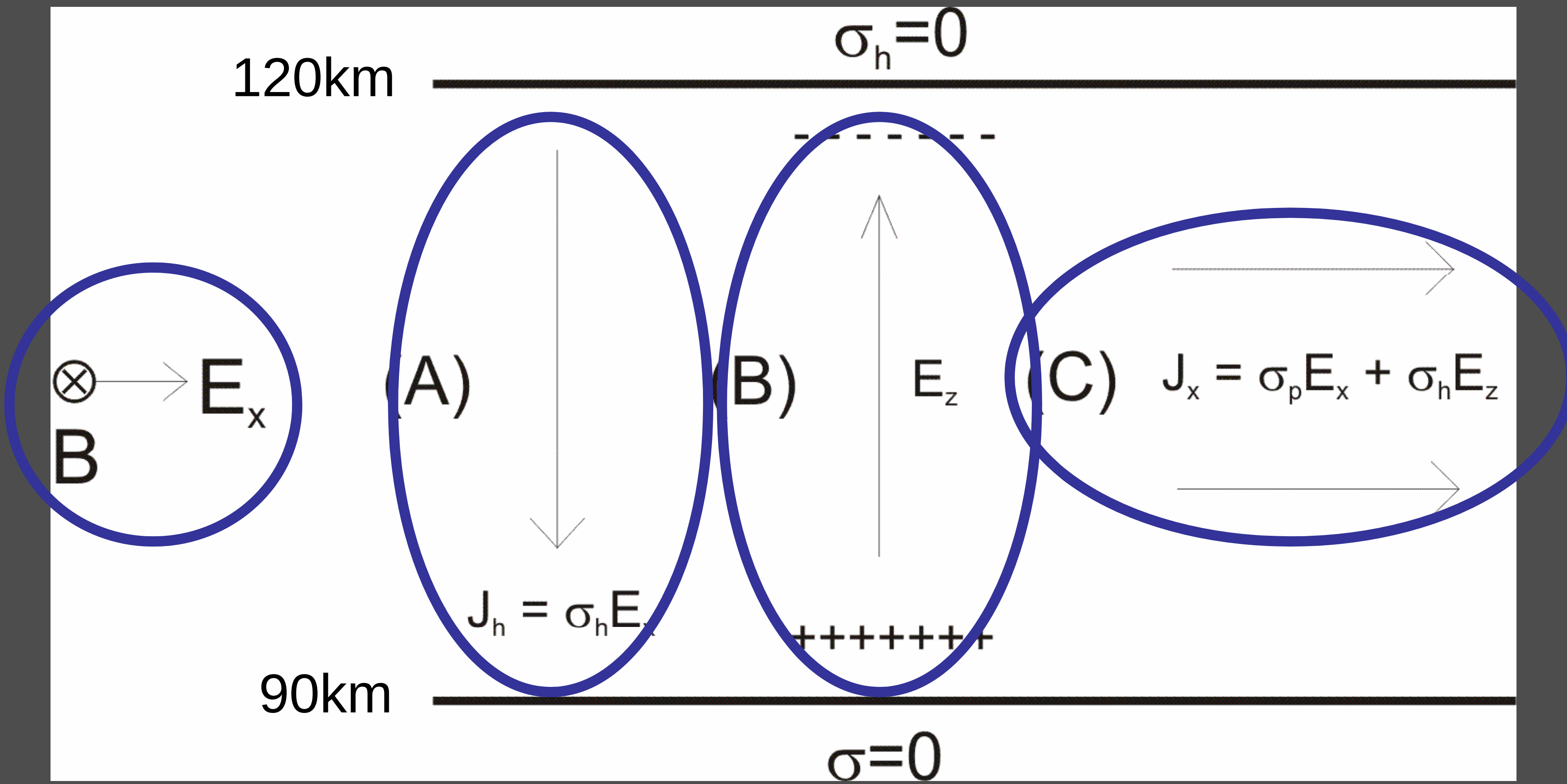
The Eastward Electric Field



Ionospheric Conductivities



The Equatorial Electrojet



Low collision frequency: $\mathbf{V} = \mathbf{E}\mathrm{x}\mathbf{B}/B^2$

Early studies of the EEJ

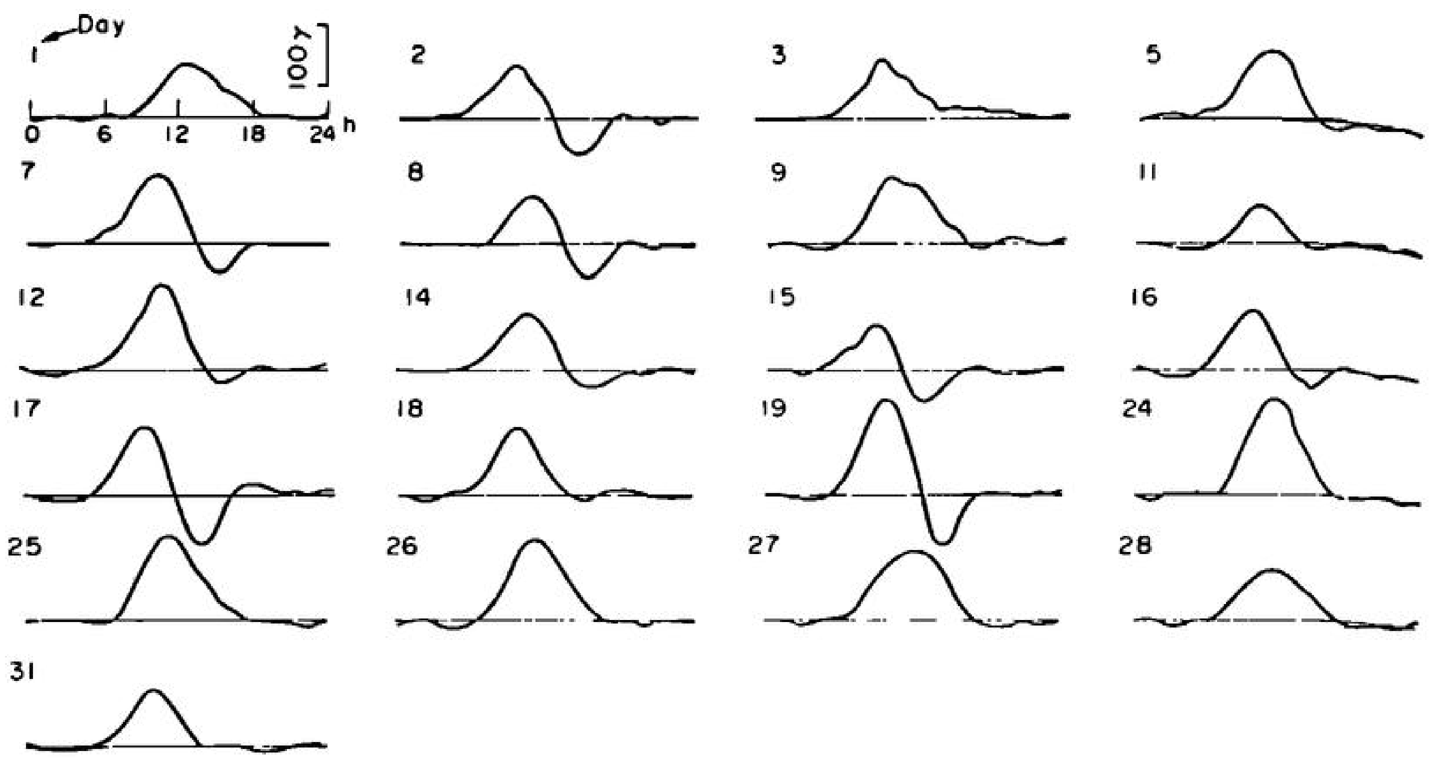


Fig. 4. S_R variations in *H* at Huancayo for quiet days during the month of January 1923 (Figure is from *Mayaud* [1977]. Reprinted by permission of Pergamon Press.)

Modeling the EEJ

Modeling the EEJ current

$$\nabla \times \mathbf{E} = 0$$

$$\mathbf{J} = \underline{\sigma}(\mathbf{E} + \mathbf{u} \times \mathbf{B})$$

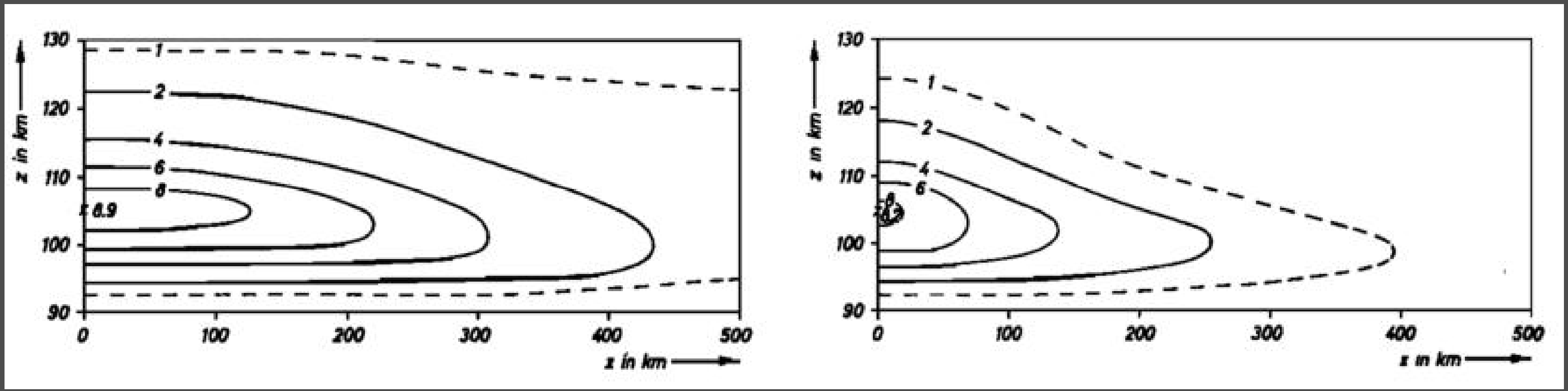
Conductivity is represented by an anisotropic tensor

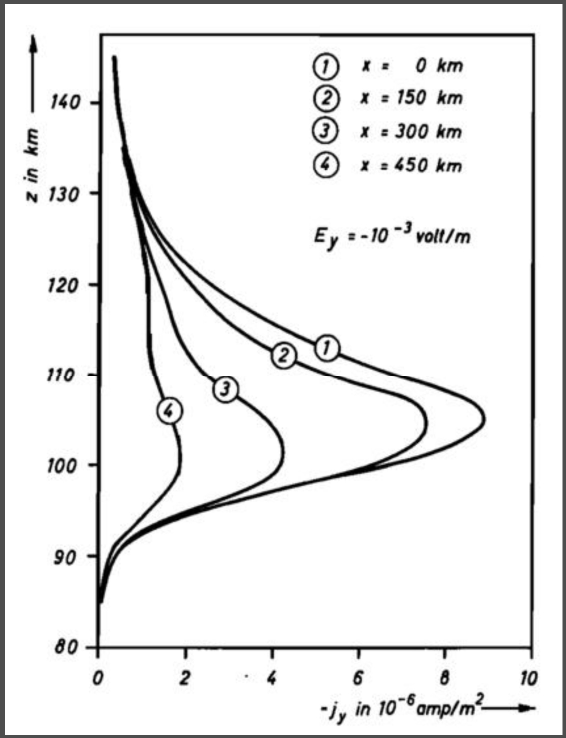
σ_0 = conductivity in magnetic field direction

σ_P = Pederson conductivity perpendicular to magnetic field and in plane of electric and magnetic fields

σ_H = Hall conductivity (3rd coordinate direction) which is vertical at the equator.

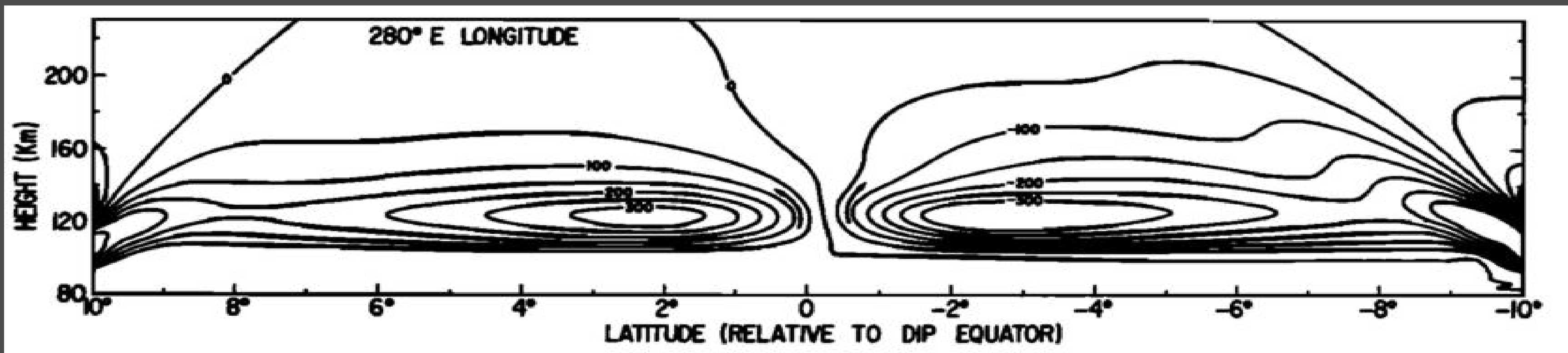
Theoretical Models





- Untiedt, JGR (1967)
- Electric field only (no winds)
- Meridional current flow important for self consistent model

Theoretical Models



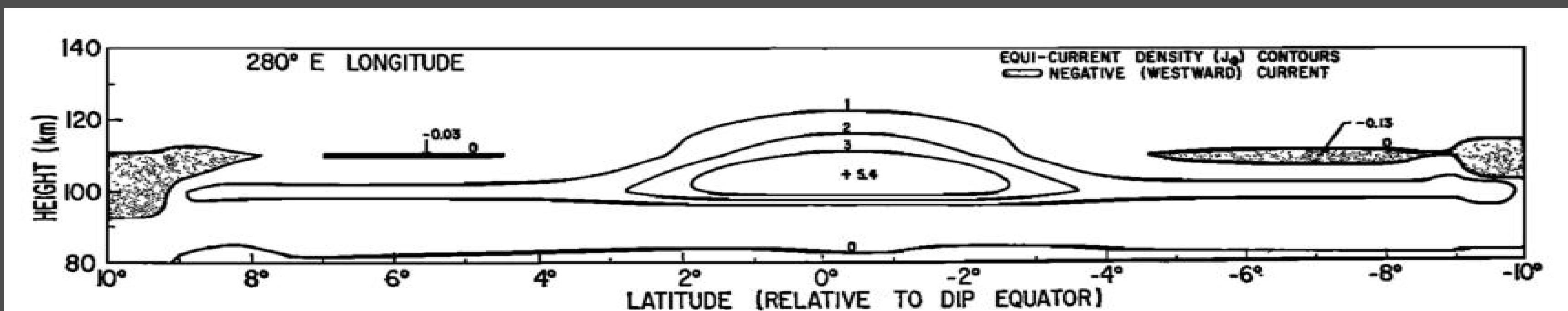
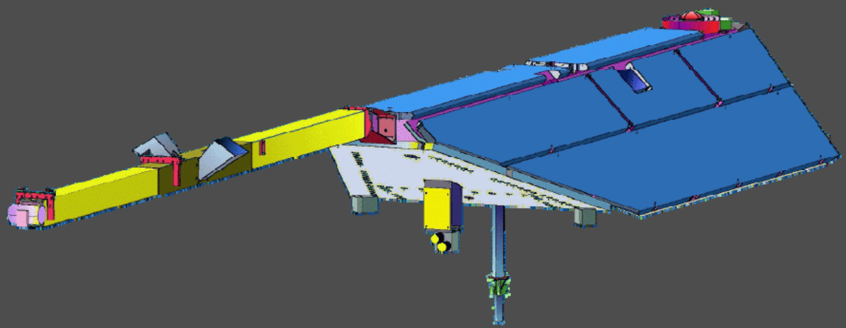


Fig. 2. The eastward current density, j_ϕ, for longitude 280°E: in units of 10^{-5} amp/m^2. The driving electric field, $E_{\phi 0} = 2.4 \times 10^{-3}$ volt/m. The shaded areas represent reversed, westward currents.

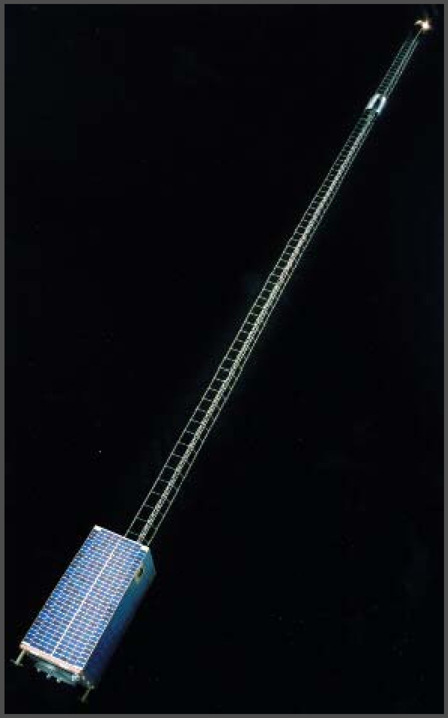
- Sugiura and Poros, JGR (1969)
- Electric field only (no winds)
- More realistic boundary conditions than Untiedt – more accurate modeling of the meridional current system
- Studied current flow at different longitudes (using different conductivity profiles) and found significant differences
- Found westward currents a few degrees off the dip equator

Satellite Data for Modelling



CHAMP (since 2000)

- 450 km altitude, descending
- Drifts rapidly in local time



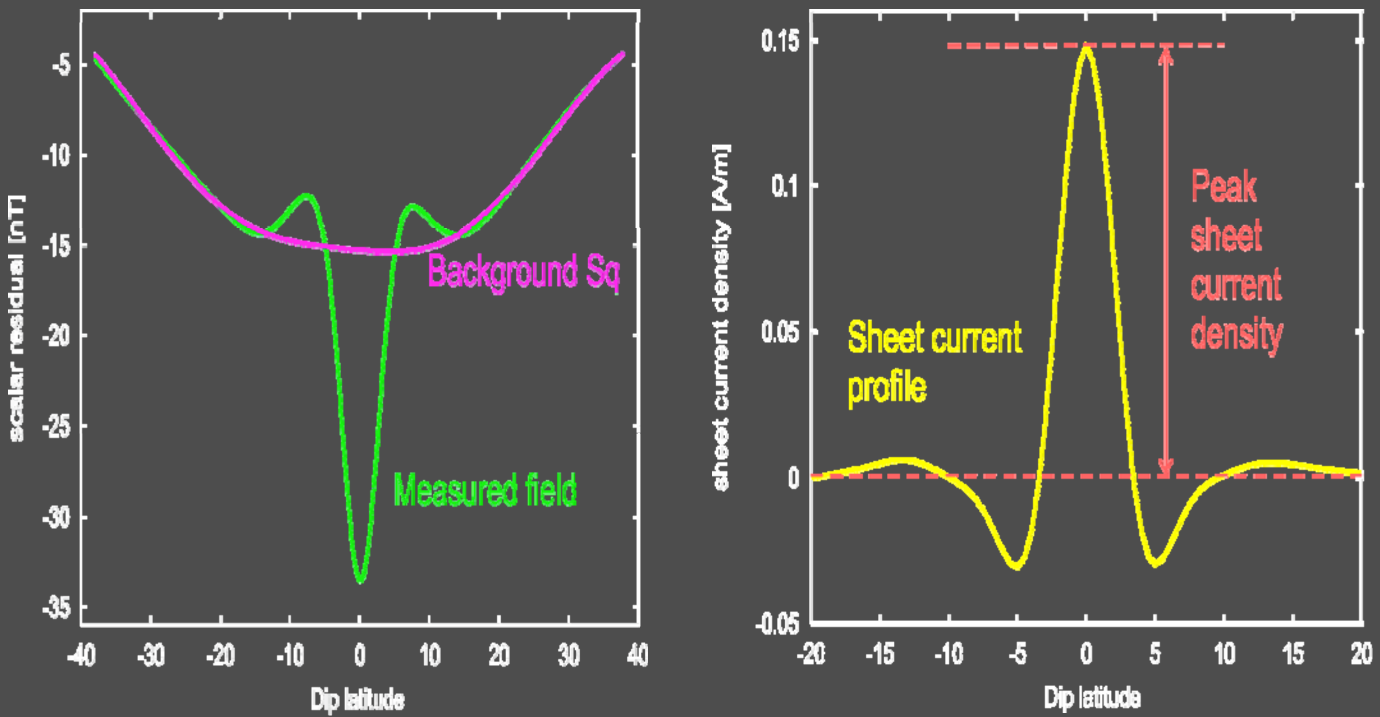
Oersted (since 1999)

- 600 – 800 km altitude
- Drifts slowly in local time

SAC-C (2000-2004)

- 700 km altitude
- Sun-sync noon-midnight orbit

EEJ Current Density Inversion

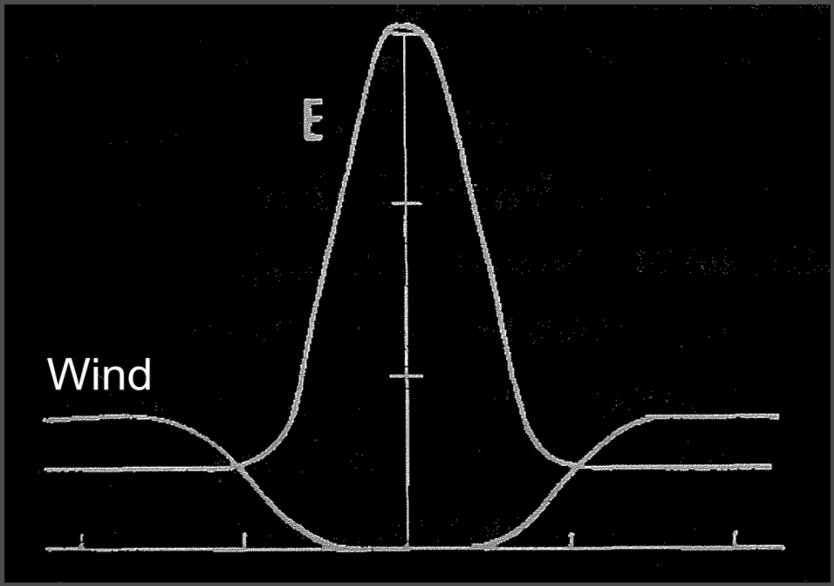


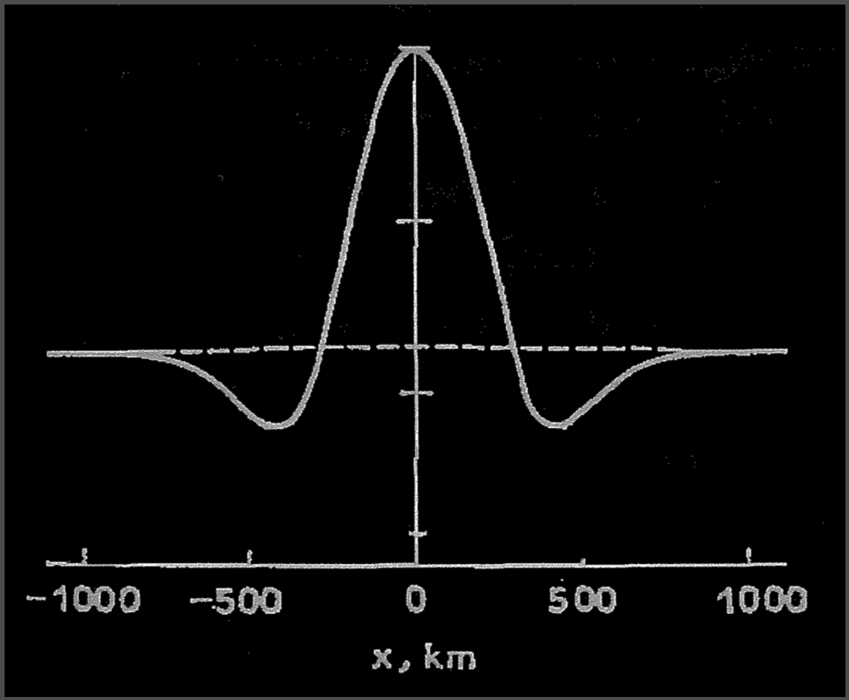
- EEJ latitude profiles at all local times, longitudes and seasons
- EEJ peak current aligns with the dip equator
- Very high day-to-day variation in current strength
- Width of EEJ is constant for a given longitude
- Significant longitudinal dependence of current density

Luehr et al, JGR 109, 2004

Effect of eastward electric field + westward wind

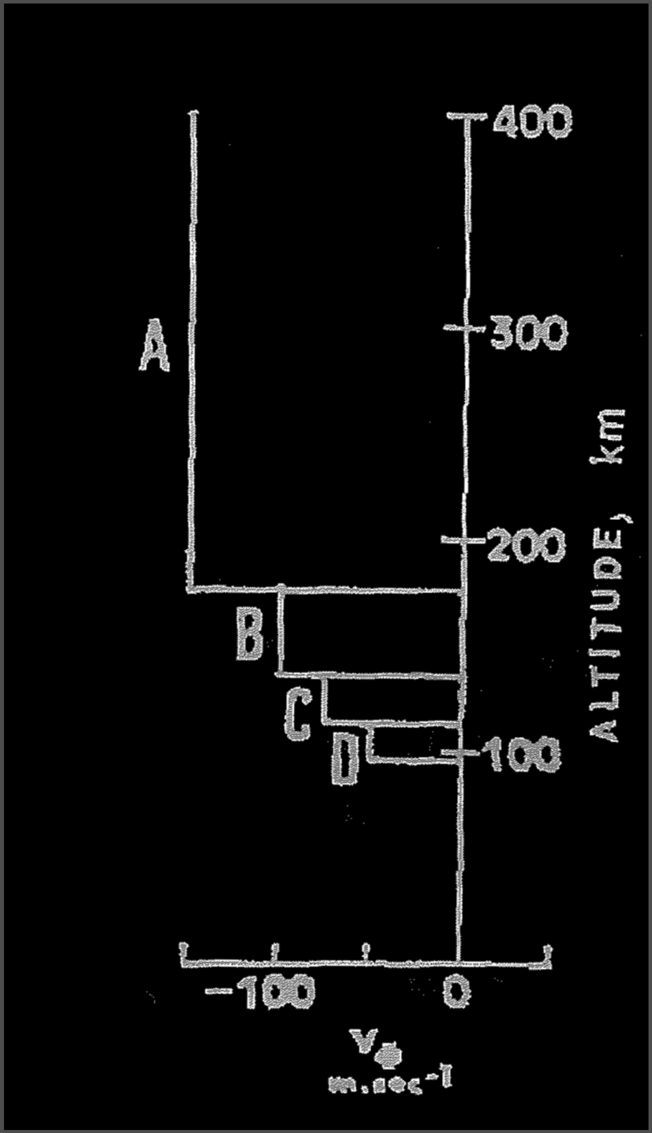
Sum of electric field and wind effects



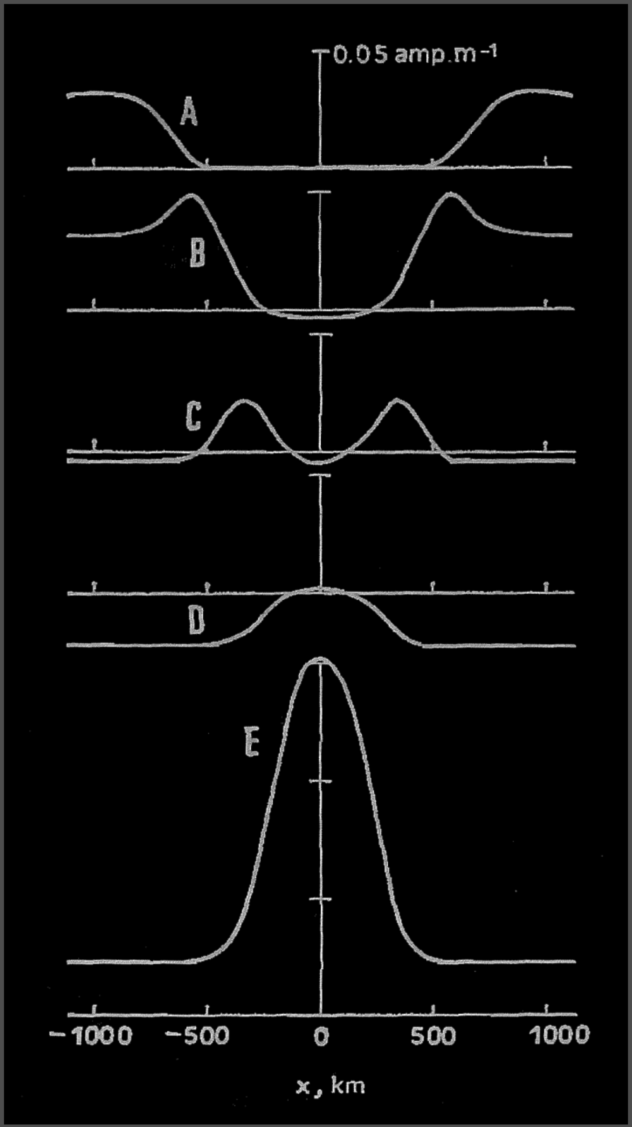


Fambitakoye, Mayaud and Richmond (1976)

Westward wind

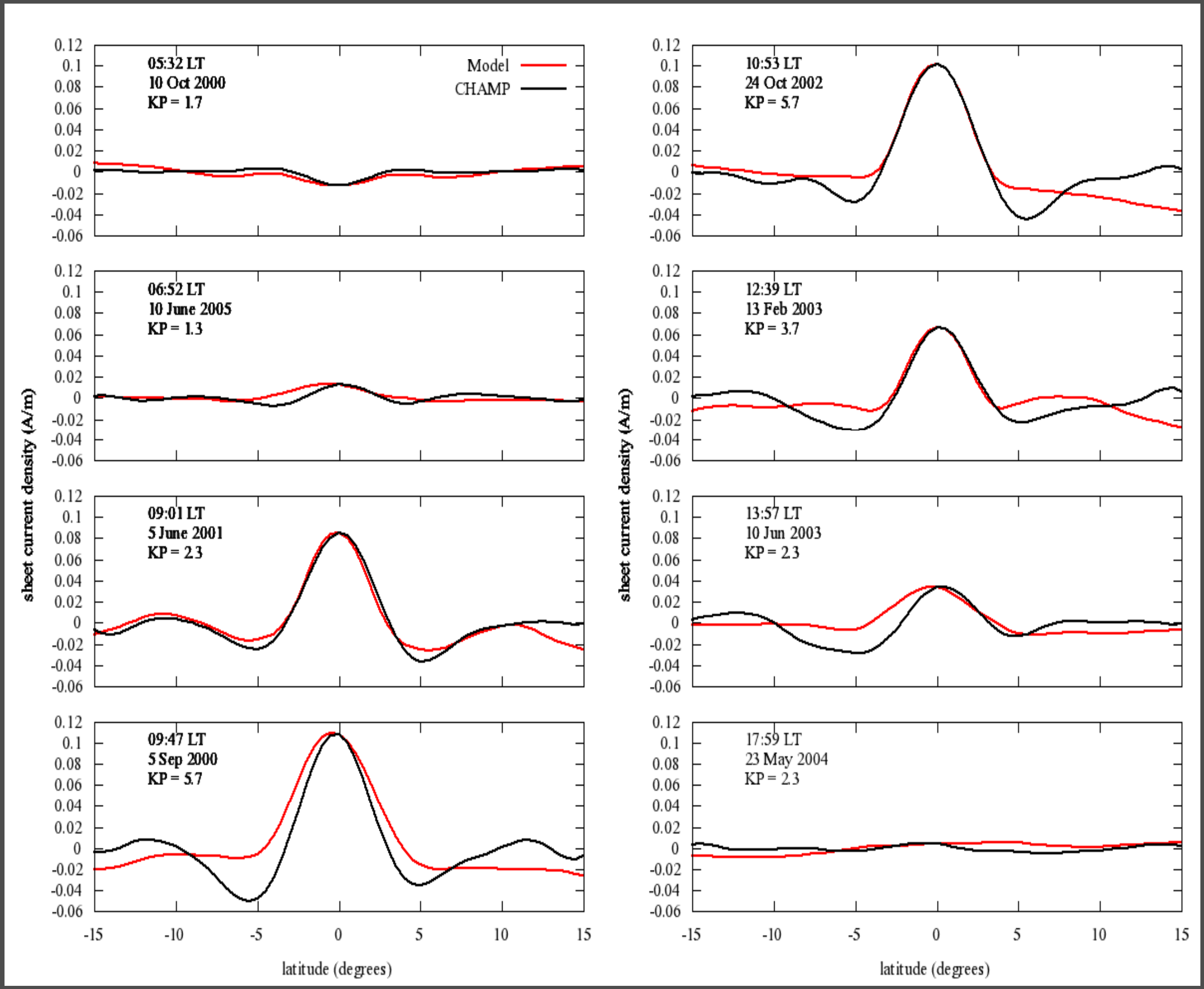


Eastward current



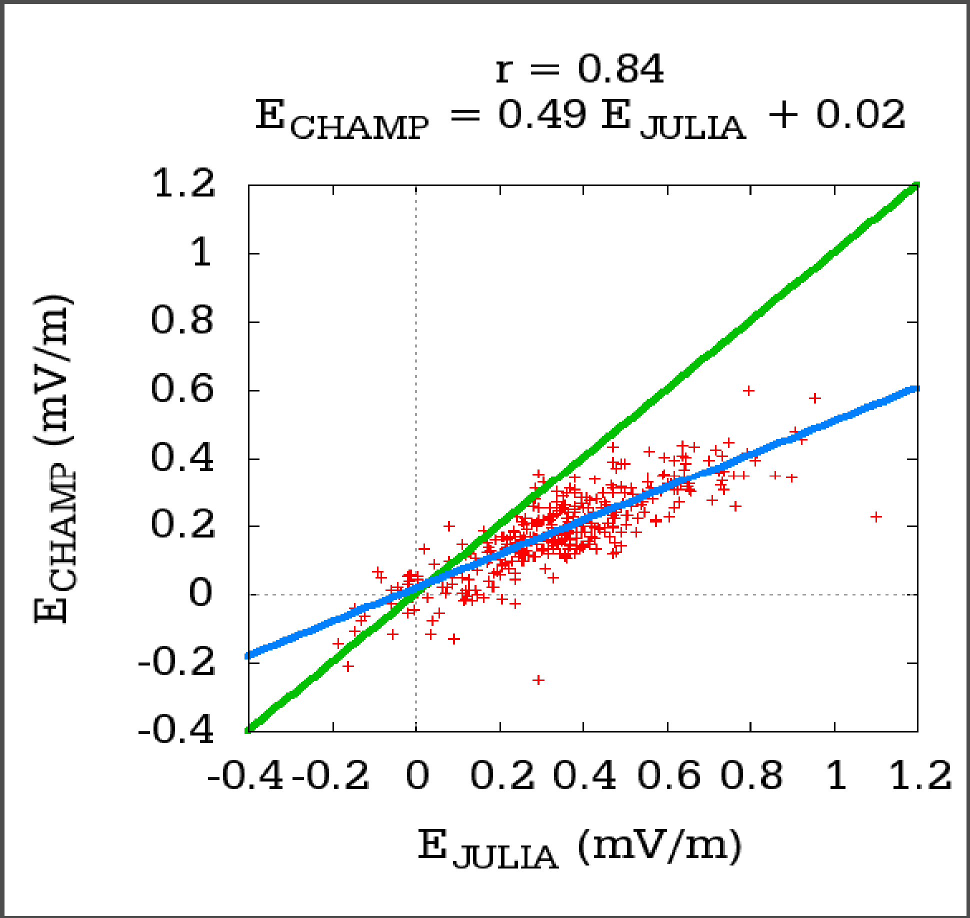
Fambitakoye, Mayaud and Richmond (1976)

Individual CHAMP Profiles allow computation of EEF



Alken and Maus, JASTP, 2009

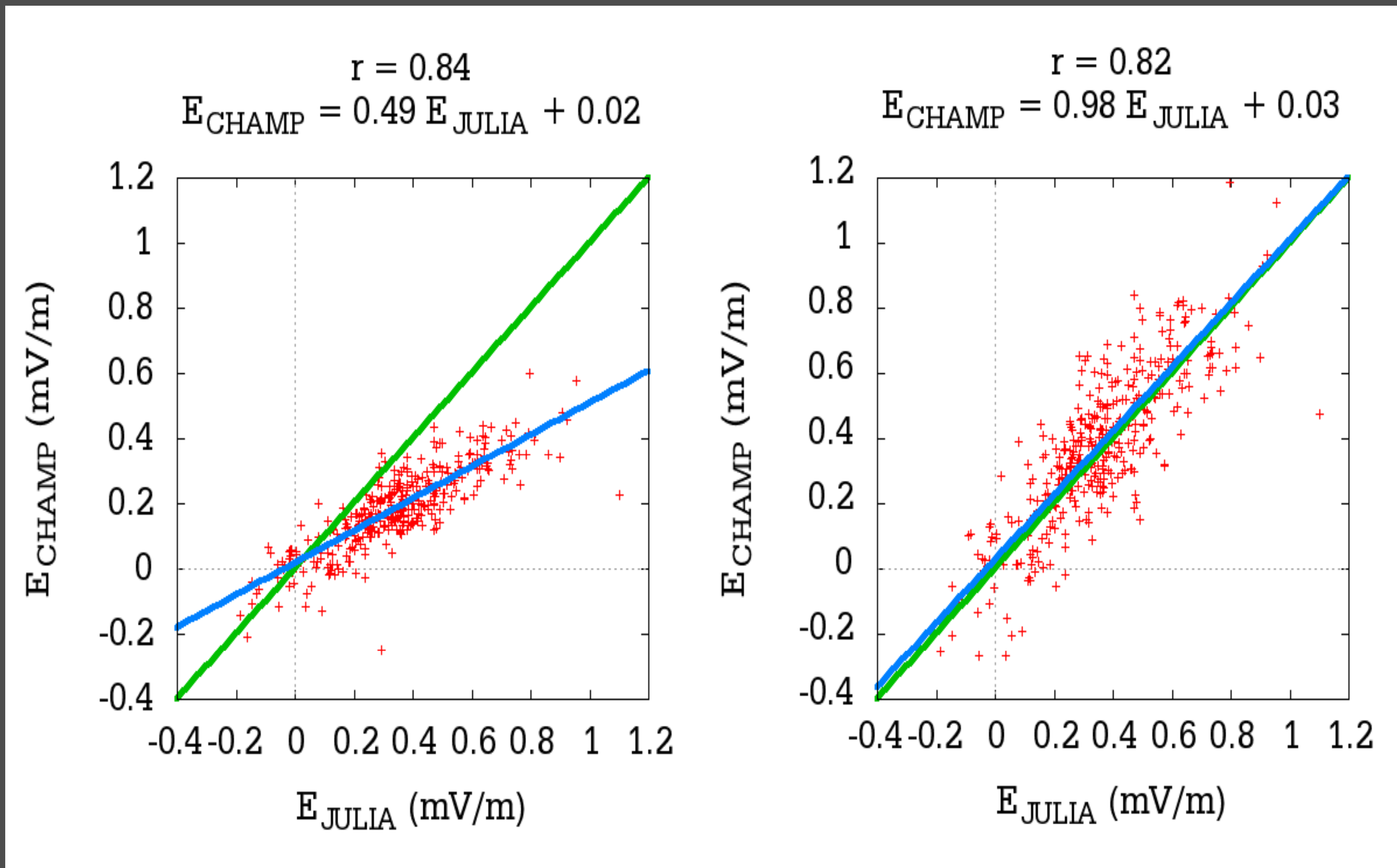
Correlation with JULIA Electric fields



CHAMP profiles within +/- 10 degrees of JULIA radar

Gagnepain, Crochet, Richmond, "Comparison of equatorial electrojet models", JATP, 39, 1977

Correlation with JULIA Electric fields, all KP



rms error 0.14 mV/m

with $4\upsilon_e$ correction

CHAMP profiles within +/- 10 degrees of JULIA radar

Gagnepain, Crochet, Richmond, “Comparison of equatorial electrojet models”, JATP, 39, 1977

Plasma Instabilities in the EEJ

Instability Dispersion Relation

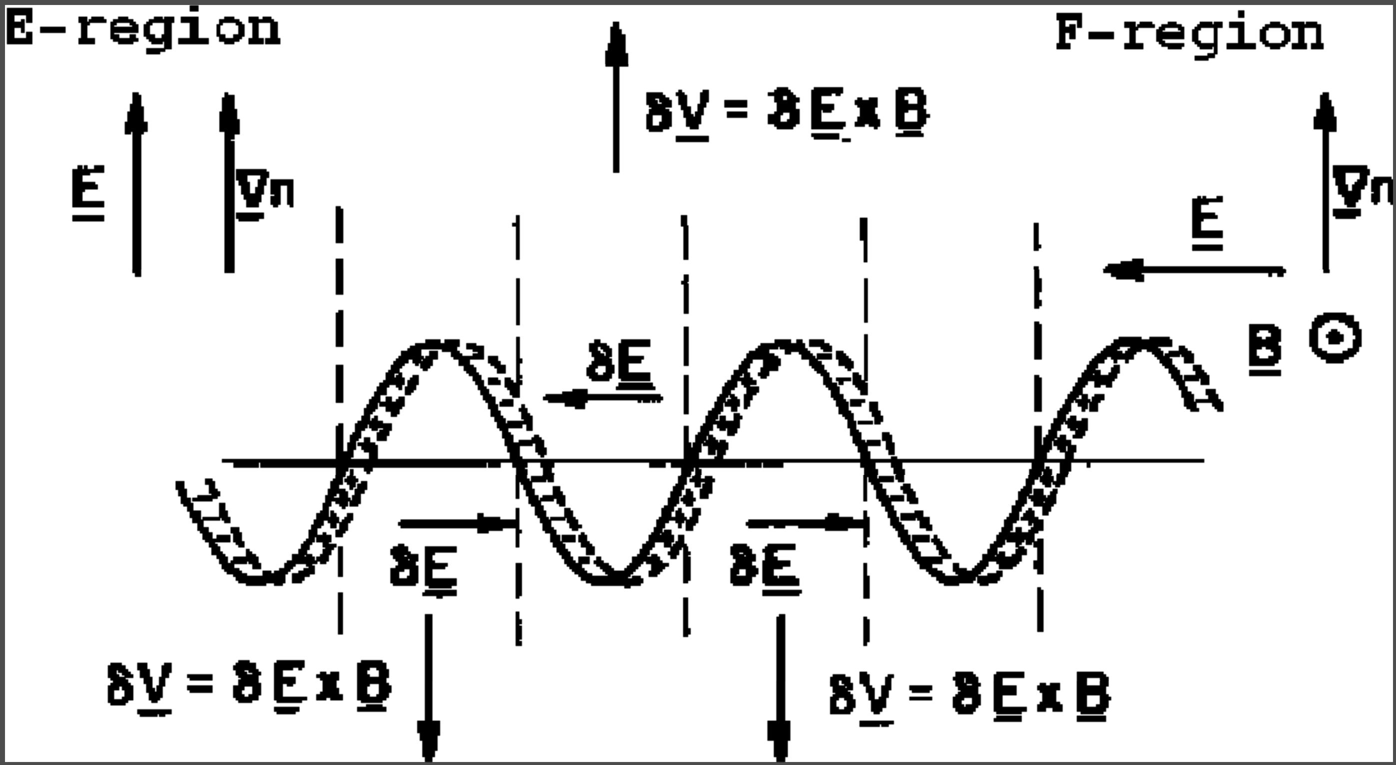
$$\omega = \omega_k + i\gamma_k$$

$$\omega_k = \frac{\vec{k} \cdot \vec{V}_d}{1+\psi}$$

$$\gamma_k = \frac{\psi}{(1+\psi)\nu_i}\left(\omega_k^2 - k^2 C_s^2\right) + \frac{\nu_i}{\Omega_i}\frac{\omega_k k_{west}}{N\left(dN/dh\right)^{-1} k^2} - 2\alpha N$$

Two-stream Gradient drift

Gradient Drift Instability

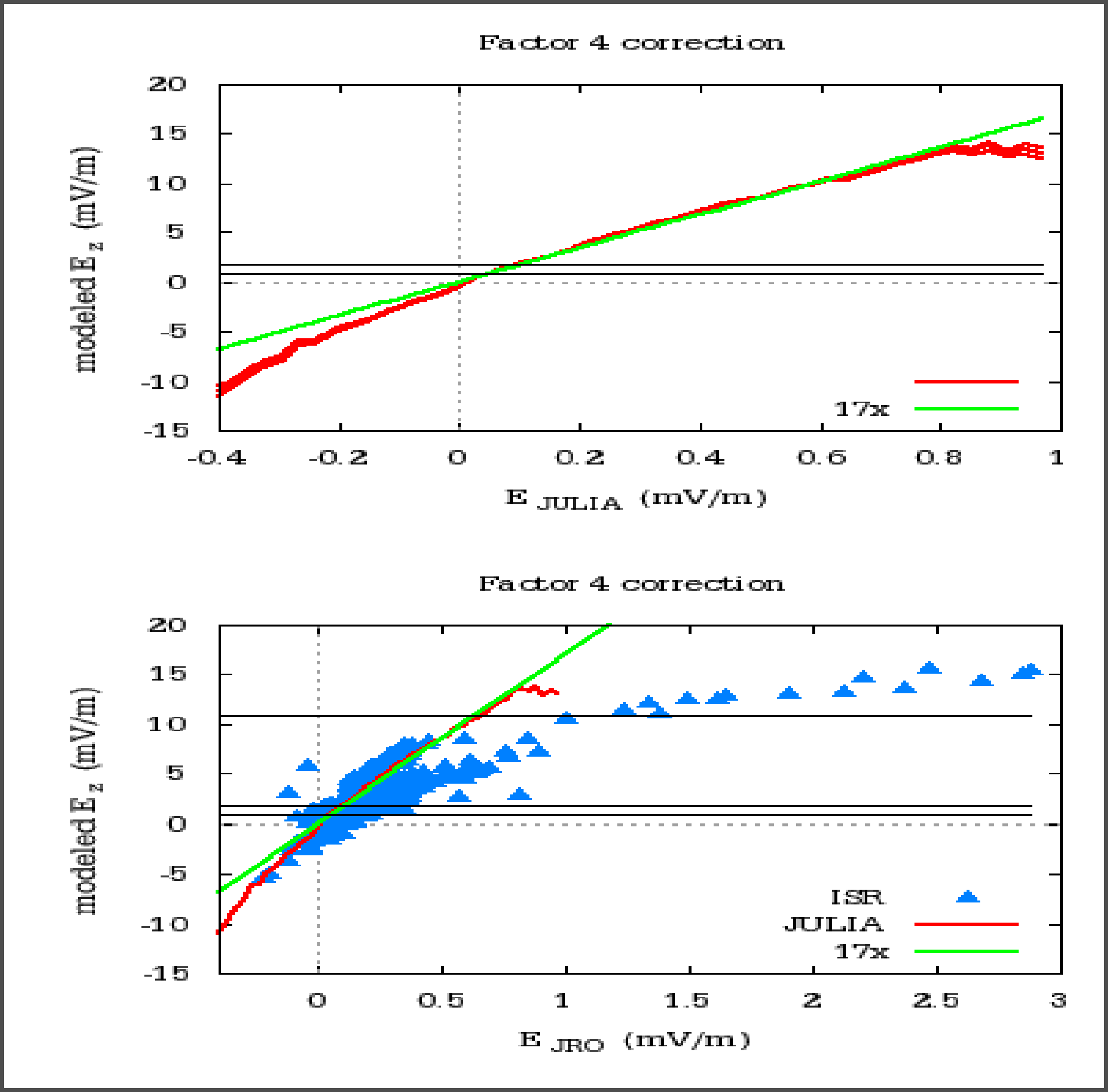


Instabilities in the EEJ

Linear Instability theory for typical EEJ conditions:

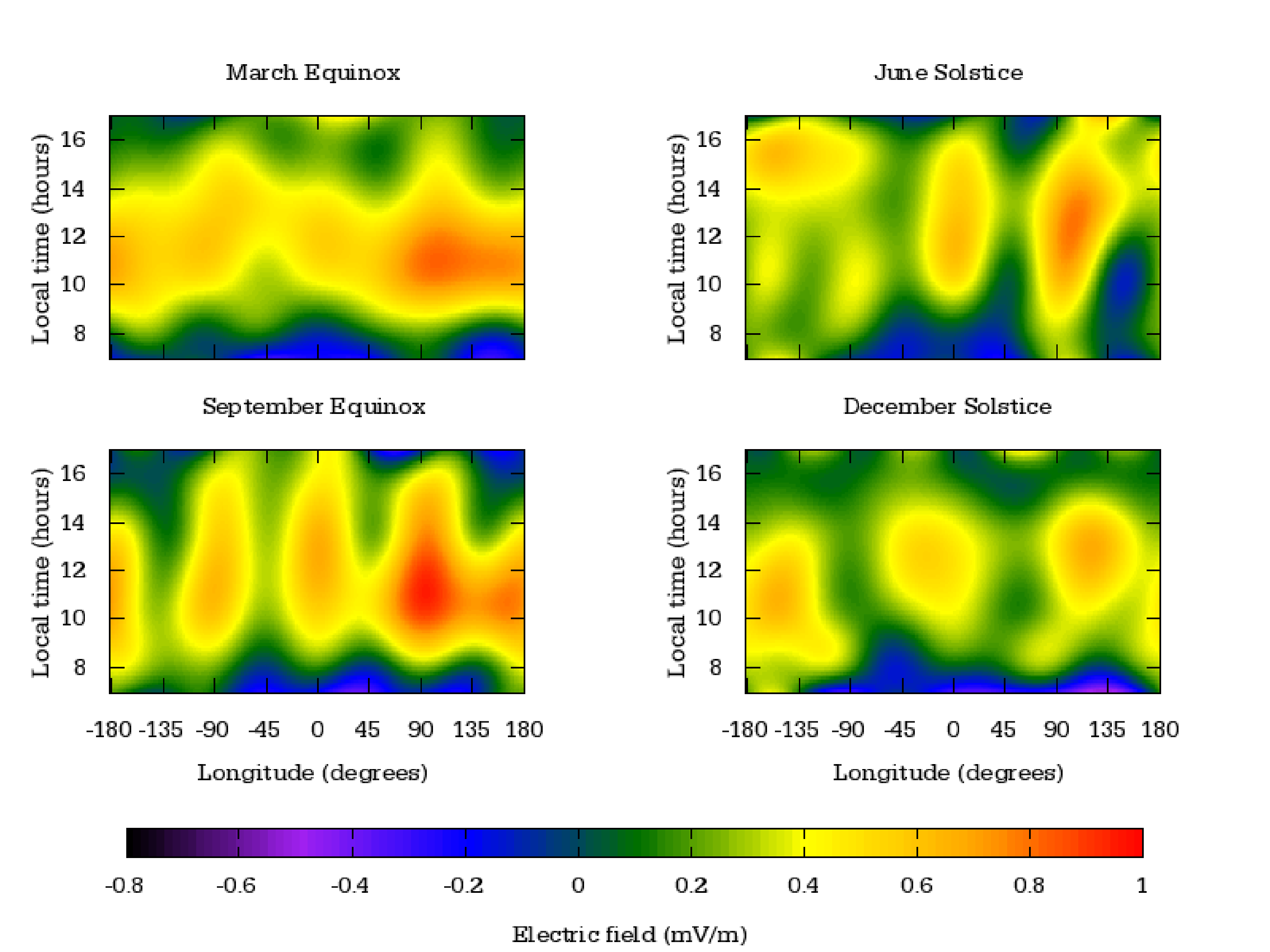
Gradient drift
Ez ~ 0.8 – 1.7 mV/m

Two-stream:
Ez ~ 11 mV/m



P. Alken and S. Maus. Relationship between the ionospheric eastward electric field and the equatorial electrojet. Geophys. Res. Lett. , 37:L04104, 2010. doi: 10.1029/2009GL041989

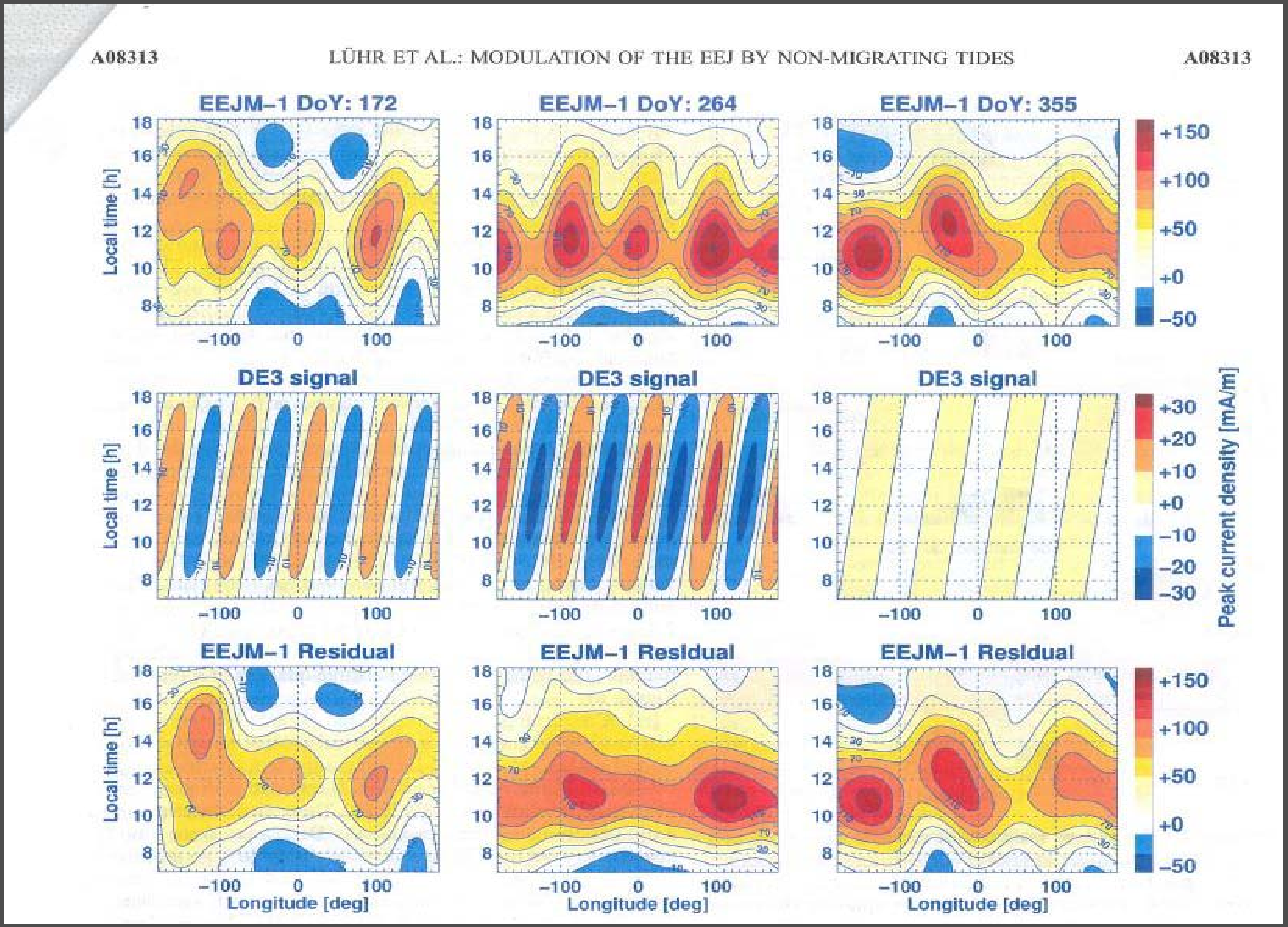
Climatology of EEJ



Alken and Maus, JASTP, 2010

Wave-4 Structure

Which tidal harmonic is responsible for the wave-4 structure in the EEJ?



Lühr et al, JGR, 2008.

Future EEJ Research

- Wave-4 studies: determine all tides present in the EEJ for different local times, seasons, longitudes, etc; Improve wind models to include these tides for more accurate modeling of the EEJ
- Instabilities in the EEJ: is the factor-4 correction valid at all longitudes? Is it possible to directly include instability effects in the modeling to avoid using fudge-factors?
- Return currents: how exactly does the EEJ current close?

Relevant Publications

Forbes, J. M. (1981), The equatorial electrojet, Rev. Geophys., 19, 469– 504

Onwumechili, C. A. (1997), The Equatorial Electrojet, Gordon and Breach, Newark, N. J.

Heelis, R.A.,2004.Electrodynamics in the low and middle latitude ionosphere: a tutorial. J. Atmos. Sol. Terr. Phys. 66, 825–838

Kelley,M.C.,1989.The Earth's Ionosphere: Plasma Physics and Electrodynamics. Academic Press Inc., San Diego

Fejer, B. G., and M. C. Kelley (1980), Ionospheric irregularities, Rev. Geophys., 18, 401–454