Calculation of Electric Field Strength (E_y) in the Ionospheric F-region

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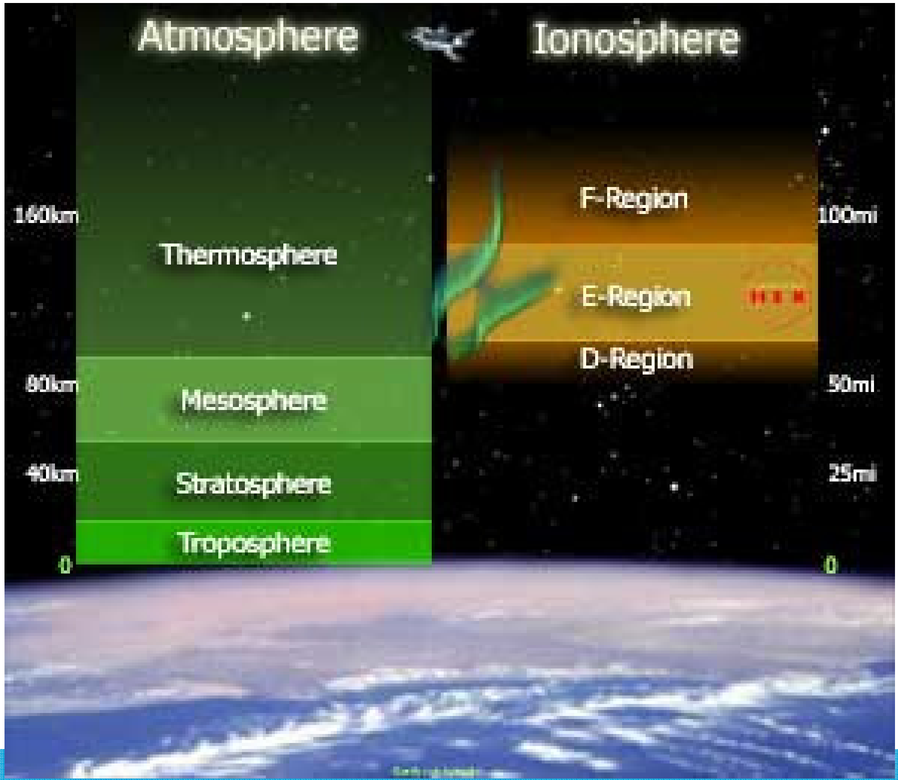
WHAT IS THE IONOSPHERE?

- The atmosphere above ~70km that is partially ionized by ultraviolet radiation from the sun
    - This region of partially ionized gas extends upwards to high altitudes where it merges with the magnetosphere
- Discovered in the early 1900s in connection with long distance radio transmissions
    - Scientists postulated, and later proved, that long distance radio communication was possible due to reflection off of an ionized region in the atmosphere



OVERVIEW OF THE IONOSPHERE

Structure of ionosphere continuously changing

- Varies with day/night, seasons, latitude and solar activity

Essential features are usually identifiable

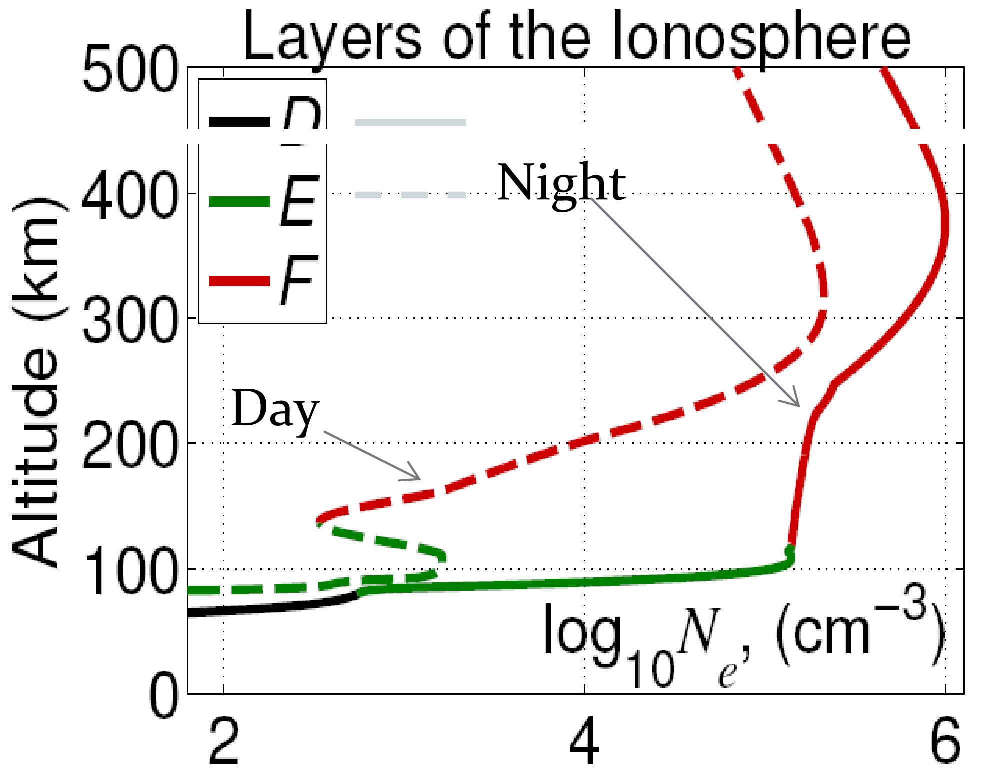
Ionosphere divided into layers, according to electron density and altitude

- D Layer (or D Region)
- E Layer
- F Layer

Several reasons for distinct layers

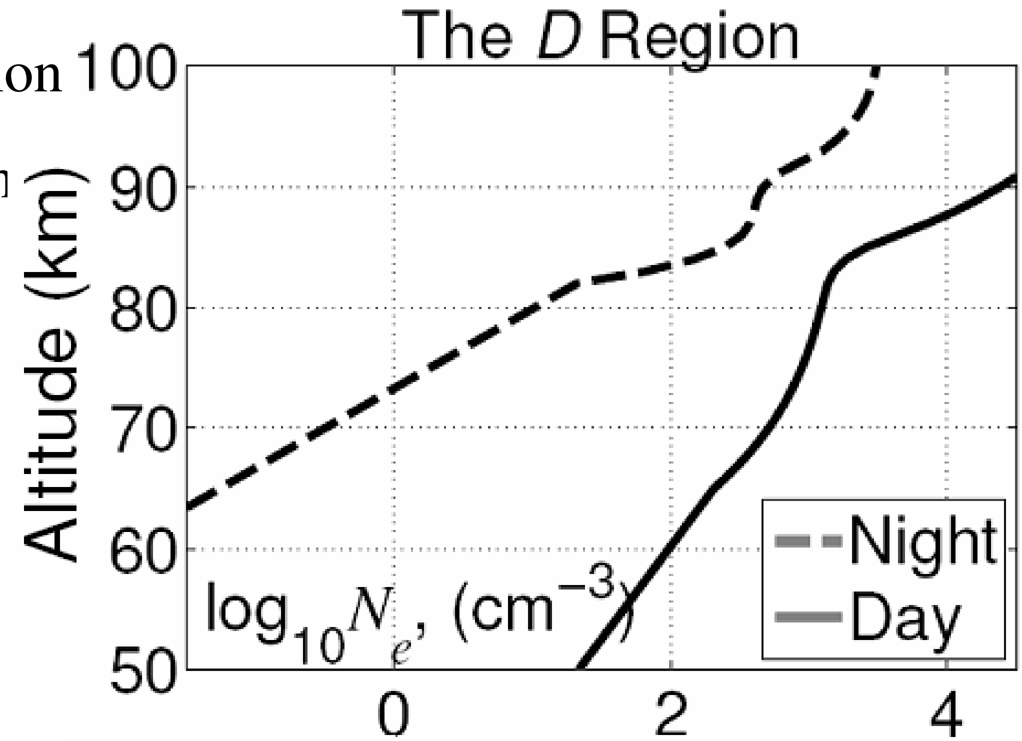
- Solar spectrum energy deposited at various altitudes depending on absorption of atmosphere
- Physics of recombination depends on density of atmosphere (which changes with altitude)

Composition of atmosphere changes with height



ELECTRON DENSITY

- ***To derive electron density of a layer:***
  - Combine electron losses with production
  - Rate of loss of electrons per unit volum is proportional to n_e^2
- ***In equilibrium*** $q = \alpha n_e^2$
- $n_e = (n_e)_{max} \exp\{0.5\,(1 - y - \exp(-y))\}$
- $y = \dfrac{h - h_m}{H}$

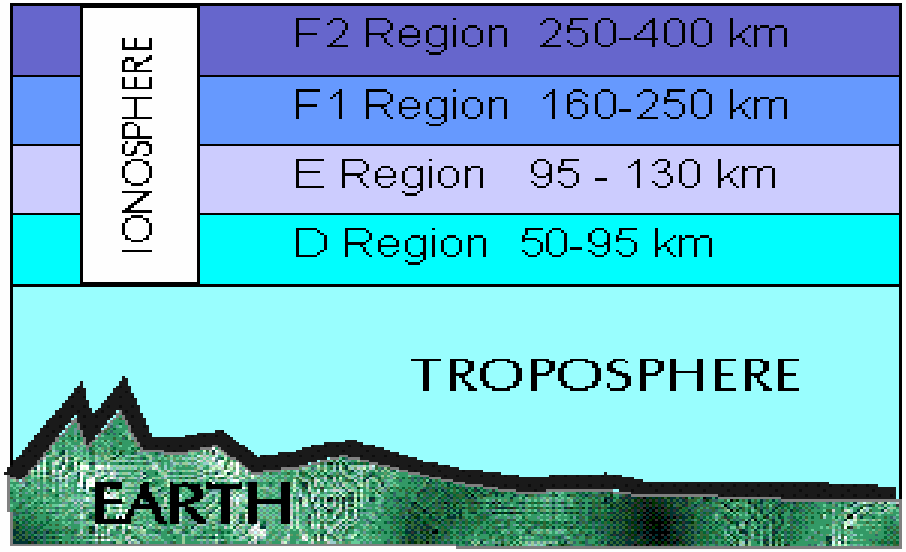


- H is scale height: vertical distance over which pressure of atmosphere decreases by factor of e

Why is Study of the Ionosphere important?

- *It affects all aspects of radio wave propagation on earth, and any planet with an atmosphere*
- *Knowledge of how radio waves propagate in plasmas is essential for understanding what's being received on an AWESOME setup*
- *It is an important tool in understanding how the sun affects the earth's environment*

we have examined conductivity tensor for the cold and warm plasma the accepted conditions in ionospheric plasma and compared the magnitudes of the elements of conductivity tensor.



ionosphere

The approximation of WKB in ionospheric plasma for one dimension electric field

According to WKB approximation, it is assumed that a plane electromagnetic wave has become "of frequency ω, propagation along z-axes and the polarized along y-axes" in any medium. If the refractive index of medium is n and change to z-direction (n(z)), the electric field component of plane wave propagating z-direction is given by

$$E_y(z,t) \equiv E_y(z)\exp(-i\omega t)$$

From Maxwell equations; a differential equation for electric field $E_y(z)$ is obtained as follow

$$\frac{d^2 E_y}{dz^2} + k_0^2 n^2 E_y = 0$$

after the approximations included with respect to WKB solution

$$E_y \cong E_0\, n^{-1/2} \exp\left(\pm i k_0 \int^z n\, dz\right)$$

The refractive index for ordinary wave in ionospheric plasma,

$$n_o^2 = 1 - \frac{X}{1+Z^2} + iZ\frac{X}{1+Z^2}$$

For case without collision in ionosphere

$$n_o^2 = 1 - X$$

If Z≠o,

⇓

$n^2=(\mu+i\chi)^2=M+iN$

From here, electric field strength

$$E_y \cong E_0\, n^{-1/2} \exp\left(\pm i k_0 \int^{z} n\,dz\right) \quad (Z=0)$$

$$E_y \cong E_0 (\mu+i\chi)^{-1/2} \exp\left(\pm i k_0 \int^{z} (\mu+i\chi)\,dz\right) \quad (Z\neq 0)$$

$$\mu^2 = \frac{1}{2}\left[\left(M^2+N^2\right)^{1/2} + M\right]$$

$$\chi^2 = \frac{1}{2}\left[\left(M^2+N^2\right)^{1/2} - M\right]$$

μ: the part propagating wave and χ: Attenuation factor

Conclusions

The electric field strength (E_y), the refractive index (both collisional and collision-free) and the attenuation factor were calculated at geographic coordinates of (39.13°N; 38.14°E, f≈14 MHz) by using with both local time and altitude for the year 1990 (Maximum sunspot number).

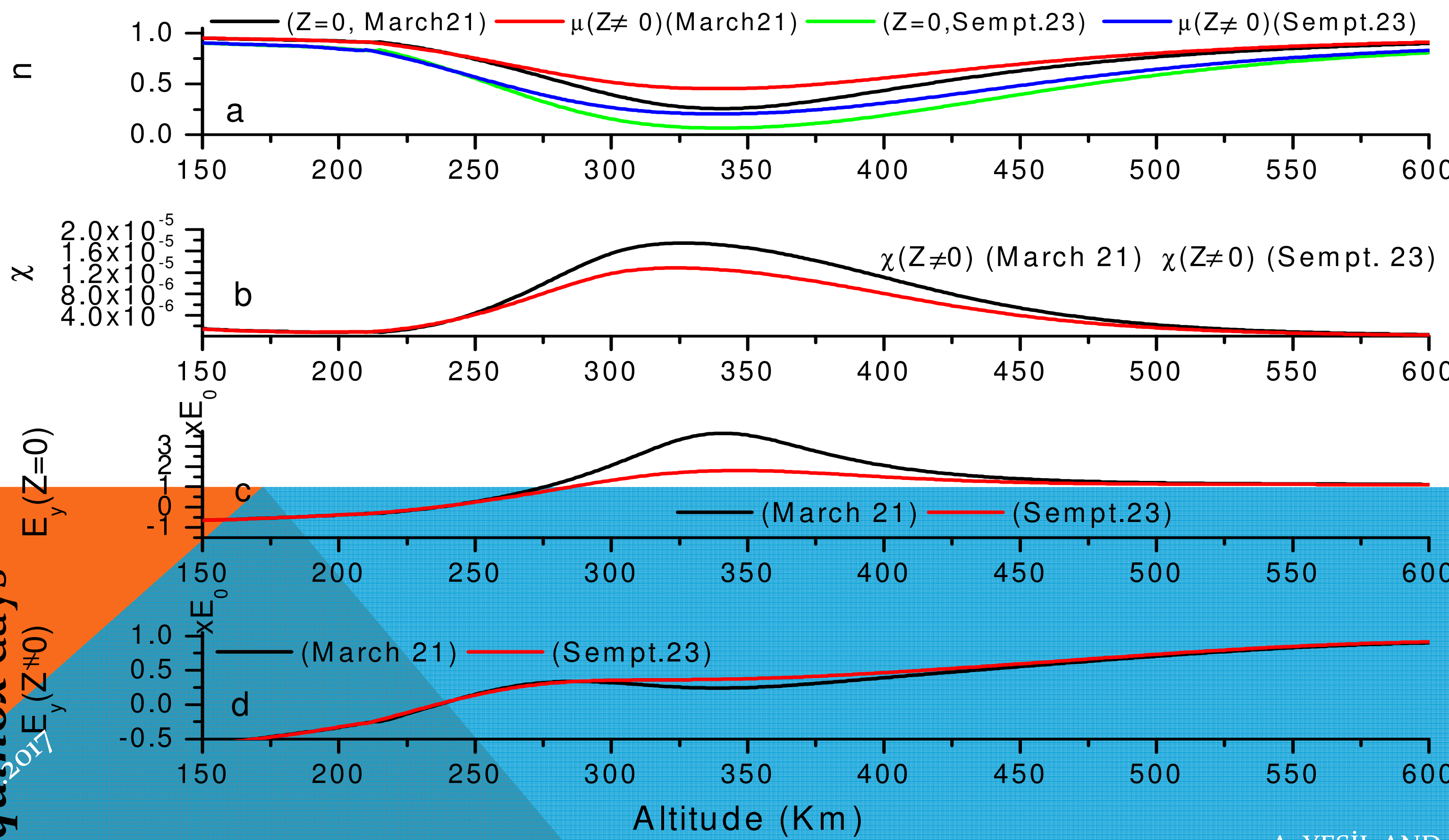


Figure 1. *a, b, c, d. The change of n, χ, E_y (Z=0) and E_y (Z≠0) with altitude for* equinox days

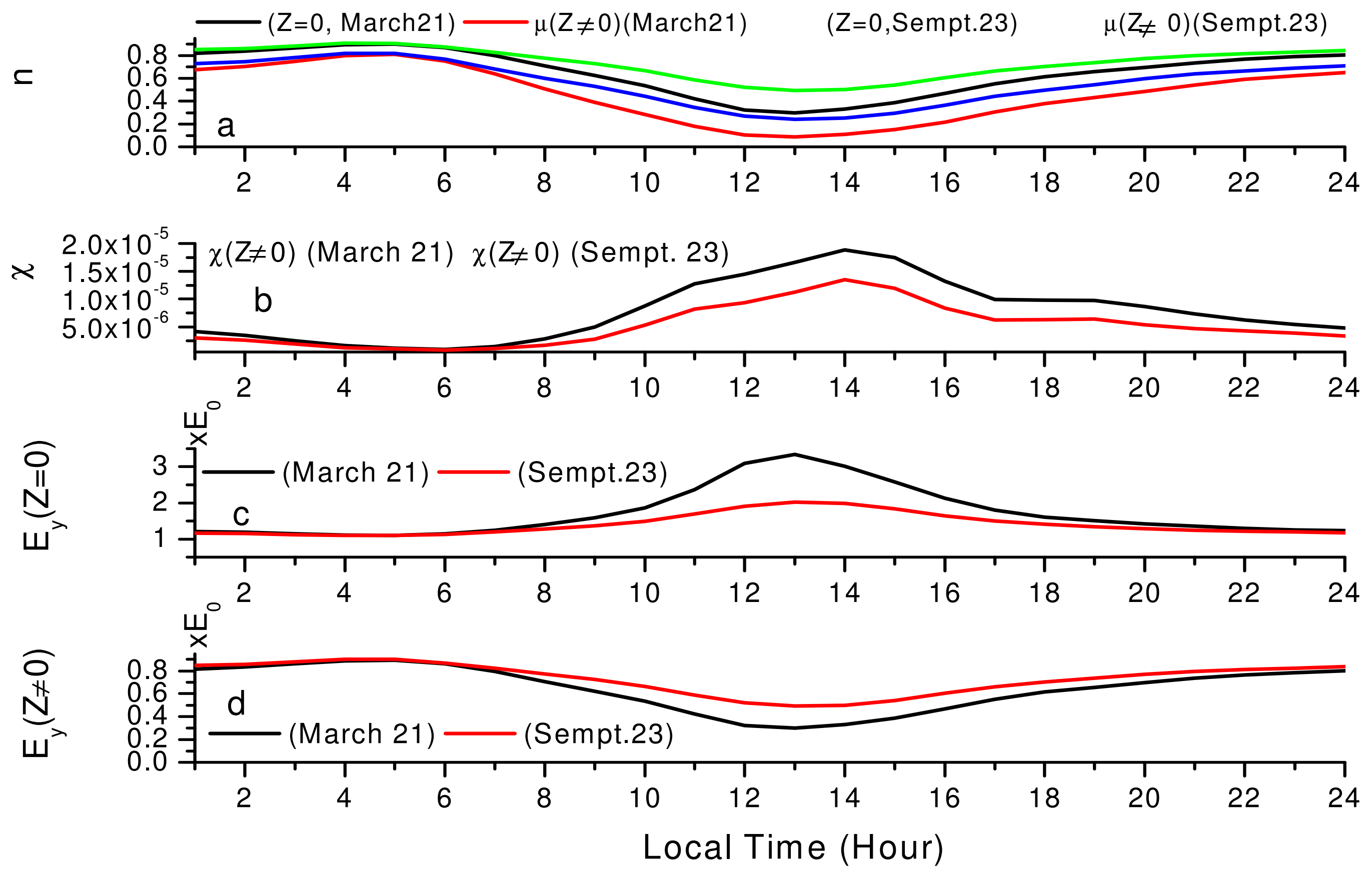


Figure 2. a, b, c, d. The change of n, χ, E_y (Z=0) and E_y (Z≠0) with local time for equinox

The magnitudes of electric field strength (E_y) are negative below 240 km, and above this altitude, it is positive for both $Z=0$ and $Z\neq0$. Actually, this height has a critic importance. So, the heights below 240 km are stop-band, and above this height, there is the pass-band for the used wave (ω). When $Z\neq0$, the electric field strength decreases remarkably for two seasons and for local time and altitude. It could be interpreted that energy is transferred from wave to ionospheric plasma. If particle collisions cannot be calculated, the values of Ey are bigger on March 21st than on September 23rd in contrast to $Z\neq0$. It could be a result of seasonal anomaly.

Thank you so much for listening me