VERTICAL WINDS, GRAVITY WAVES AND EQUATORIAL SPREAD F

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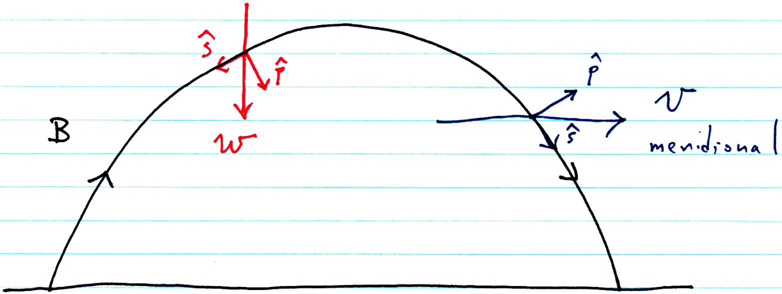
NEUTRAL WIND

- ionosphere models consider zonal (U) and meridional (V) winds
- zonal winds (U) drive vertical drifts (i.e., neutral wind dynamo) while meridional winds (V) push plasma along the geomagnetic field
- what about vertical neutral winds (W)?
- can be $\sim$ 50 m/s in auroral zone and $\sim$ 20 m/s in equatorial region (associated with gravity waves)
- latter point may be relevant to equatorial spread F

NEUTRAL WIND



ŝ : along B

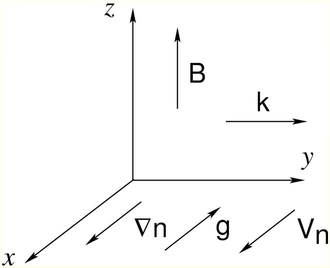
* p̂ : ⊥ to B

LINEAR THEORY

- use continuity and current conservation

$$\frac{c}{B}\delta E_y = i\omega L_n \frac{\delta n}{n_0}.$$

$$\delta J_y = \sigma_P(\delta E_y - \frac{B}{c}V_n) + \sigma_{Hi}\frac{B}{c}\frac{1}{\Omega_i}g$$



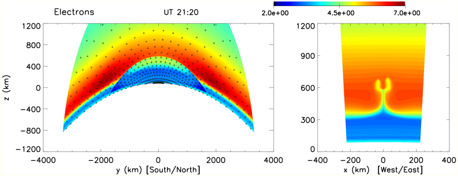
- linear growth rate

$$\gamma = \frac{g}{\nu_{in}L_n} - \frac{V_n}{L_n},$$

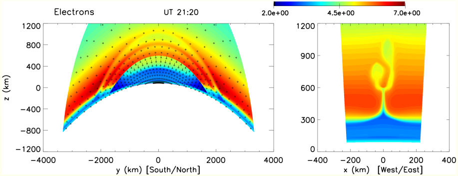
- $V_n > 0$ (upward): stabilizing
  $V_n < 0$ (downward): destabilizing

SAMI3/ESF MODEL

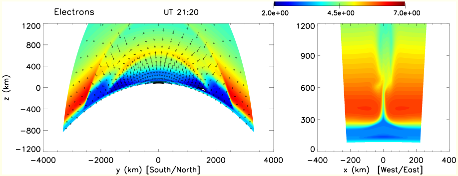
agrees with simple theory



$V_p = +20$ m/s



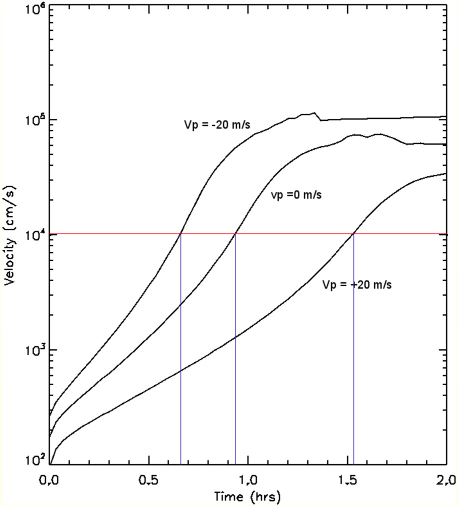
$V_p = 0$ m/s



$V_p = -20$ m/s

SAMI3/ESF MODEL

plot of maximum upward velocity



GRAVITY WAVES

high-frequency, deep atmosphere dispersion relation:

$$m^2 = k^2 \left(\frac{N^2}{\omega_i^2} - 1 \right) - \frac{1}{4H^2}$$

where

$k = 2\pi/\lambda_x$	λ_x: horizontal wavelength ($=$ 250 km)
$m = 2\pi/\lambda_z$	λ_z: vertical wavelength
$N = 2\pi/T_B$	T_B: buoyancy period ($=$ 600 sec)
$\omega_i = 2\pi/T_{GW}$	T_{GW}: intrinsic gravity wave period
H	H: scale height ($=$ 30 km)

GRAVITY WAVE EQUATION

$$u' = Au_0 \sin(kx + mz - \omega t) \qquad w' = -\alpha u'$$

with

$$\omega = kc = \omega_i + kU$$

$$A = (1 - \exp(-t/T_{GW})) \cos((x - x_o)(\pi/L_x))$$
$$\cos((y - y_o)(\pi/L_y)) \cos((z - z_o)(\pi/L_z))$$

and

$L_x = 500$ km, $L_y = 2000$ km, $L_z > 250$ km (integer depth in λ_z)

GRAVITY WAVES PARAMETERS

estimate vertical wavelengths and velocities

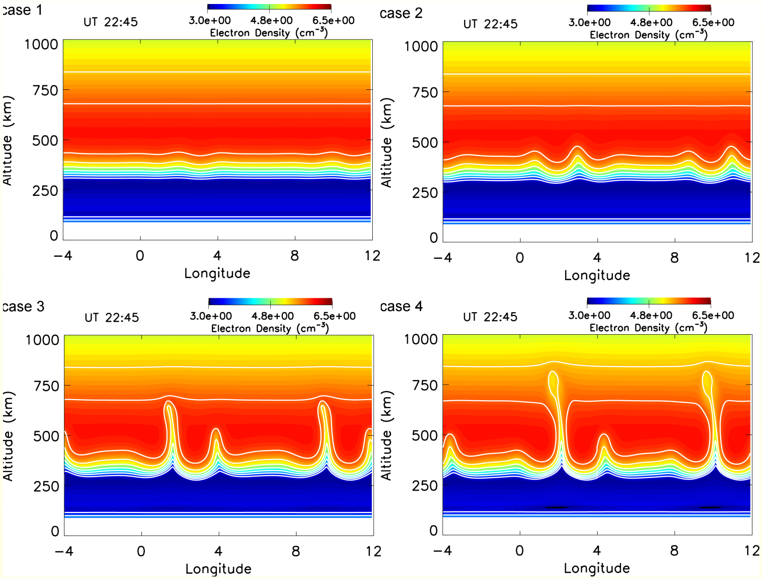
case	N/ω_i	T_{GW} (min)	λ_z (km)	c (m/s)	w'/u'
1	6	60	43	69	-0.17
2	3	30	90	139	-0.35
3	2	20	156	208	-0.60
4	1.5	15	278	278	-1.10

SAMI3/ESF simulations:

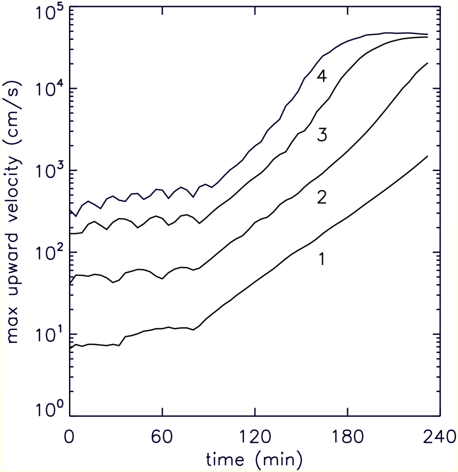
- uniform zonal wind (100 m/s)
- imposed wind perturbations (w'/u')
- centered at lat $=$ 10° and alt $=$ 250 km
- longitudinal width $= 8^\circ$ - grid $(nz, nf, nl) =$ (101,202,192)

SAMI3 RESULTS

contour plots of the 4 cases



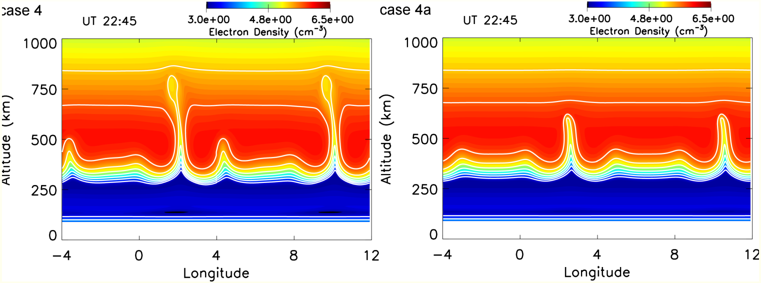
SAMI3 RESULTS



- onset time roughly the same for all cases
- initial perturbation largest for longest vertical wavelength case (i.e., shortest gw period)
- case 4: onset to saturation $\sim$ 60 min

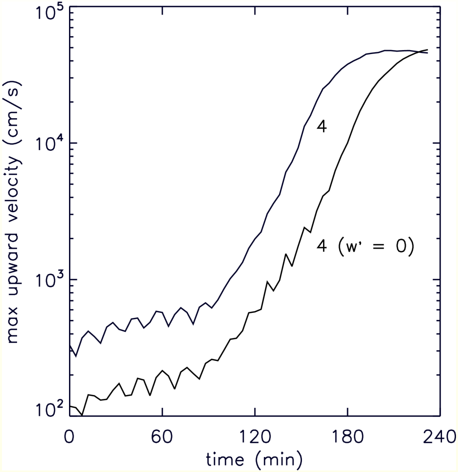
SAMI3 RESULTS

influence of w': case 4 with $w' \neq 0$ and $w' = 0$



SAMI3 RESULTS

influence of w': initial perturbation smaller with $w' = 0$



SUMMARY

- gravity waves can initiate ESF
- gw perturbation velocities u' and w' affect electrodynamics and generate density irregularities
- large vertical wavelength modes most effective (few hundred km)
- vertical wind w' can play a role: both destabilizing and stabilizing
- next step: incorporate realistic gravity waves from simulations into SAMI3/ESF