GRAVITY WAVE SEEDING OF EQUATORIAL SPREAD F

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ISSUES

- day-to-day variability of equatorial spread F (ESF) is not understood
- one suggestion is seeding (or lack of seeding)
- possible seeding mechanisms
  - vertically-sheared plasma flows
  - collisional shear instability
  - sporadic E layers
  - traveling ionospheric disturbances
  - gravity waves
- investigate last seed using NRL model SAMI3/ESF

PLASMA DYNAMICS

- ion velocity

$$\frac{\partial \mathbf{V}_i}{\partial t} + \mathbf{V}_i \cdot \nabla \mathbf{V}_i = -\frac{1}{\rho_i} \nabla \mathbf{P}_i + \frac{e}{m_i} \mathbf{E} + \frac{e}{m_i c} \mathbf{V}_i \times \mathbf{B} + \mathbf{g}$$

$$-\nu_{in} (\mathbf{V}_i - \mathbf{V_n}) - \sum_j \nu_{ij} (\mathbf{V}_i - \mathbf{V}_j)$$

- gravity wave wind perturbations affect
  - perpendicular motion through E (potential eqn)
  - parallel motion via $\nu_{in} V_n$
- impact on E most important for ESF triggering

- analytical expressions for gravity wave winds
- numerical data for gravity wave winds

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)	perturb
$\omega_i = 2\pi/T_{GW}$	T_{GW}: intrinsic gravity wave period	
H	H: scale height (= 30 km)	

zonal and vertical drifts

$$u' = A u_0 \sin(kx + mz - \omega t) \qquad w' = -\alpha u'$$

GRAVITY WAVES PARAMETERS

estimate vertical wavelengths and velocities

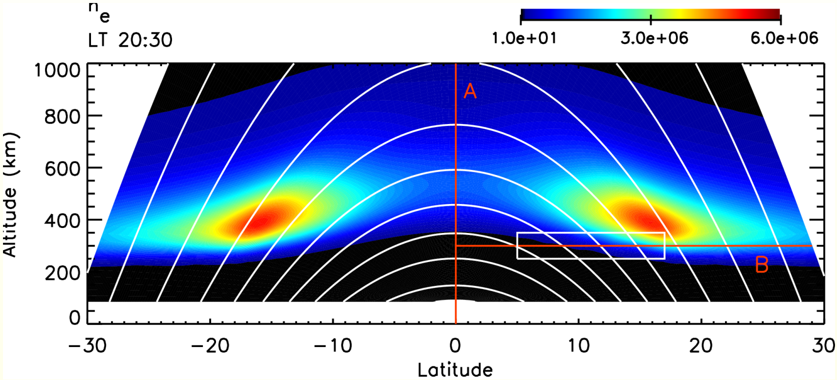
case	N/ω_i	T_{GW} (min)	λ_z (km)	c (m/s)	w'/u'
1	6	60	43	69	-0.17
2	3	30	90	139	-0.35
3	2	20	156	208	-0.60
4	1.5	15	278	278	-1.10

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)

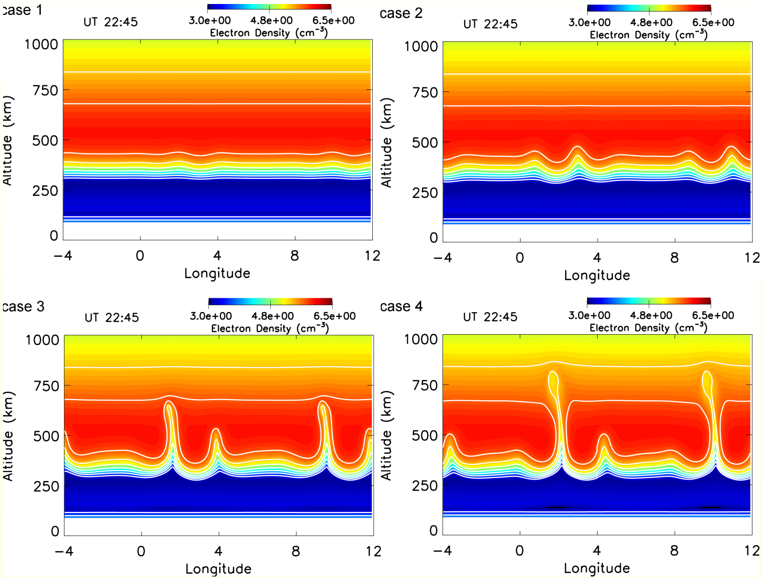
PERTURBED REGION

analytical wave model



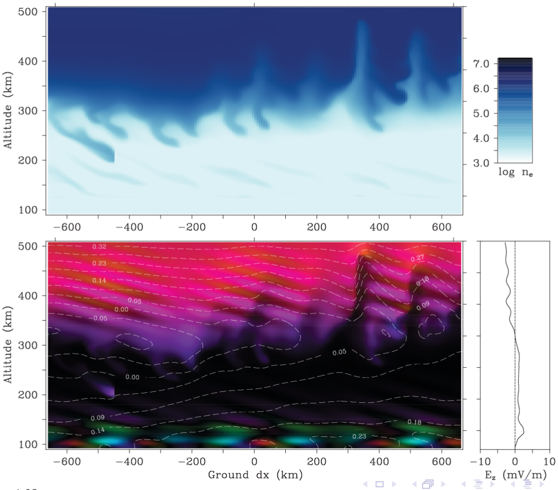
SAMI3 RESULTS

contour plots of the 4 cases

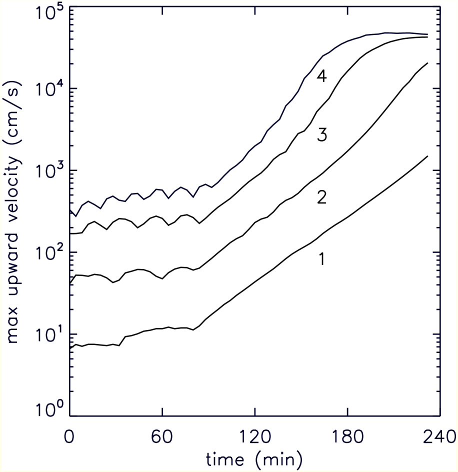


HYSELL RESULTS

λ_x=250 km, T = 60 min., λ_z = 43 km, u' = 100 m/s

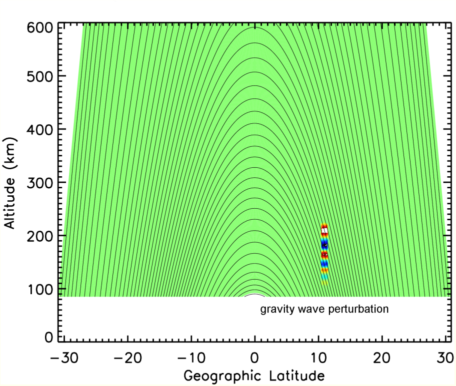


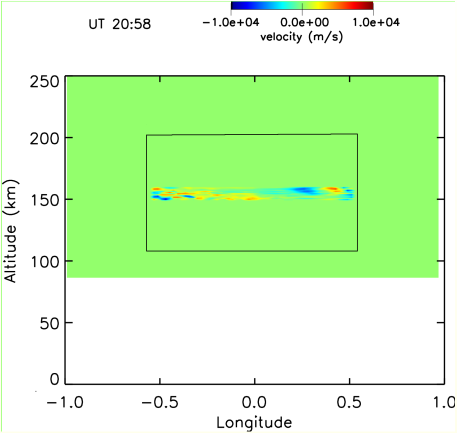
SAMI3 RESULTS



- 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

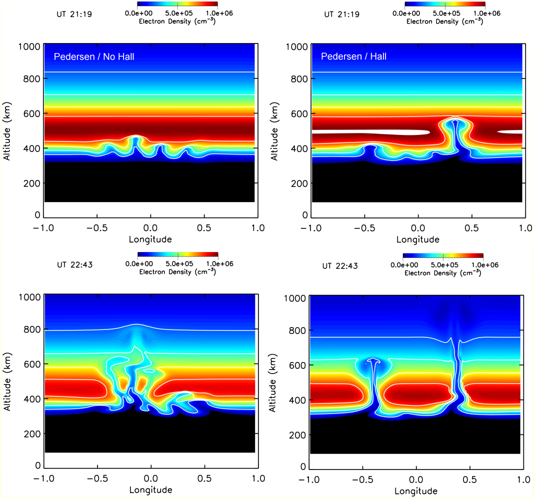
NUMERICAL WAVE DATA





SAMI3 RESULTS

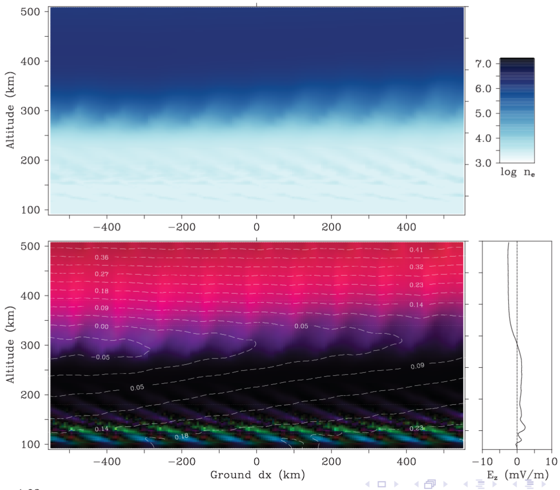
no hall and hall



HYSELL RESULTS

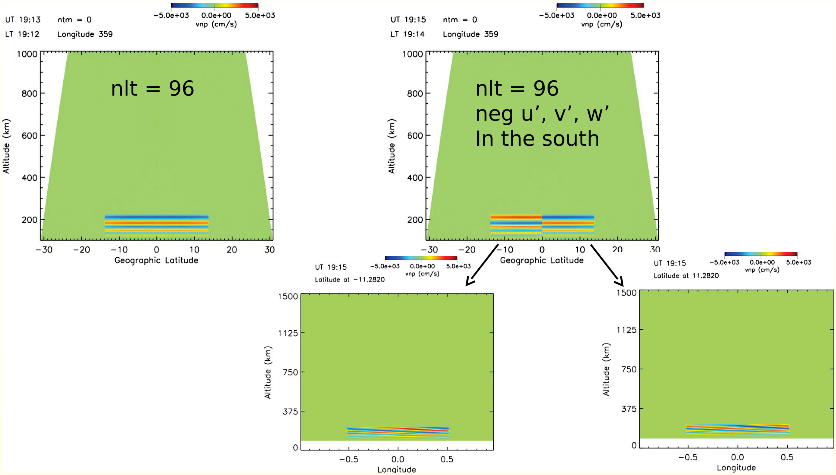
3D electrodynamics code (after 60 min)

perpendicular plane, +60 min.



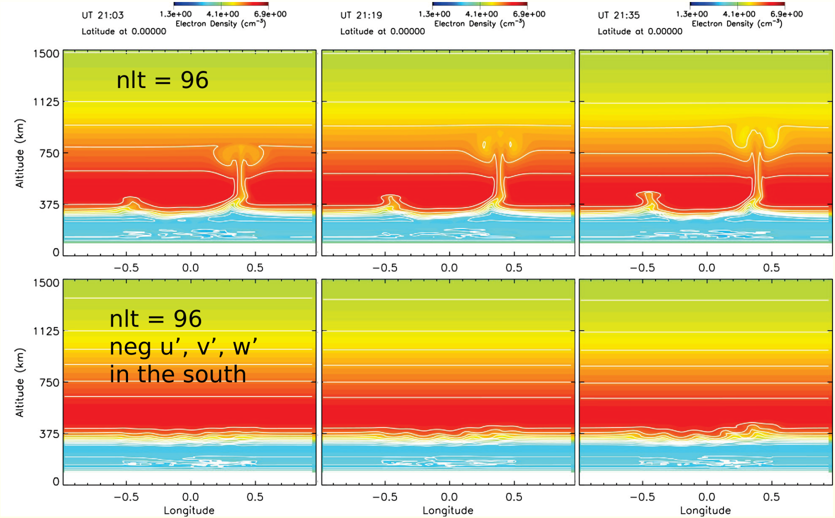
NUMERICAL WAVE DATA

in-phase and out-of-phase in conjugate hemisphere



NUMERICAL WAVE DATA

in-phase: 'normal' growth rate – out-of-phase: reduced growth rate



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)
- location and phase of gravity waves relevant
- do not need gravity waves at 200 - 400 km to be effective waves at 100 - 200 km can affect electrodynamics (dynamo) to initiate spread F