WAVE COUPLING IN THE ATMOSPHERES OF EARTH, MARS AND VENUS: A COMPARATIVE PLANETARY PERSPECTIVE

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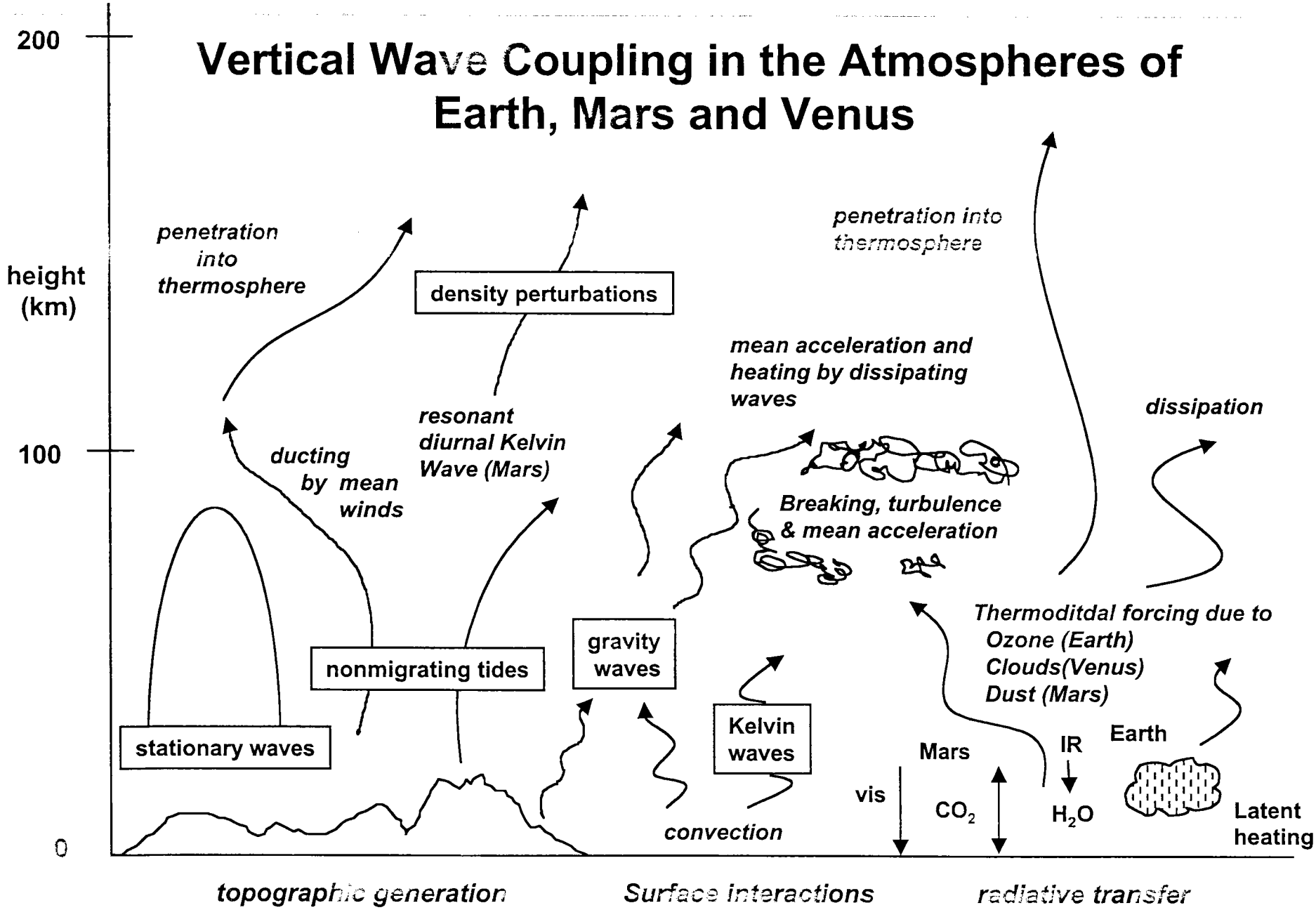
- Dynamic similarities exist between Earth, Mars and Venus
- Gravity waves and tides are especially prevalent in the atmospheres of the terrestrial planets
- Dissipating waves influence the mean thermal and wind structures of planetary atmospheres
- For Earth and Mars, topographic influences extend into the thermosphere
- Synergy of comparative planetary studies

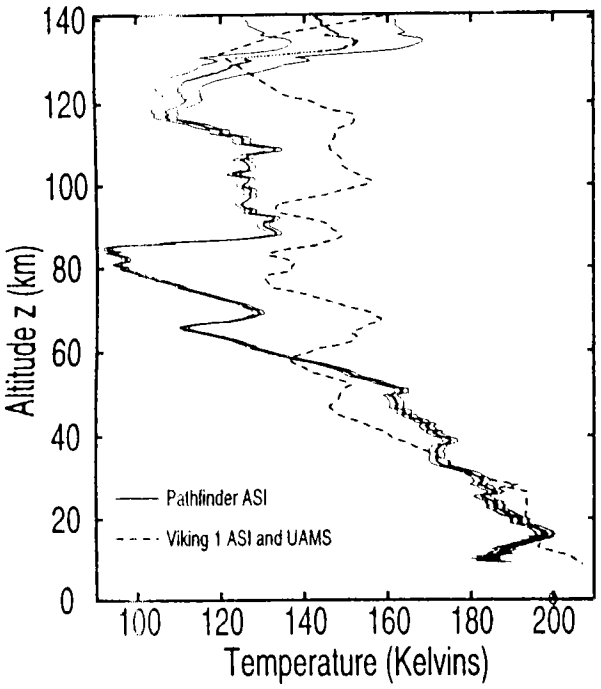
Vertical Wave Coupling in the Atmospheres of Earth, Mars and Venus



Gravity Waves in Terrestrial Planetary Atmospheres

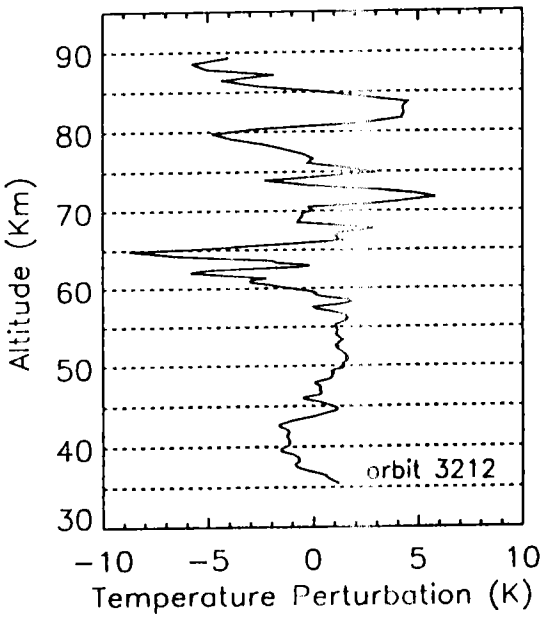
Mars Probes

Magalhaes et al., 1999



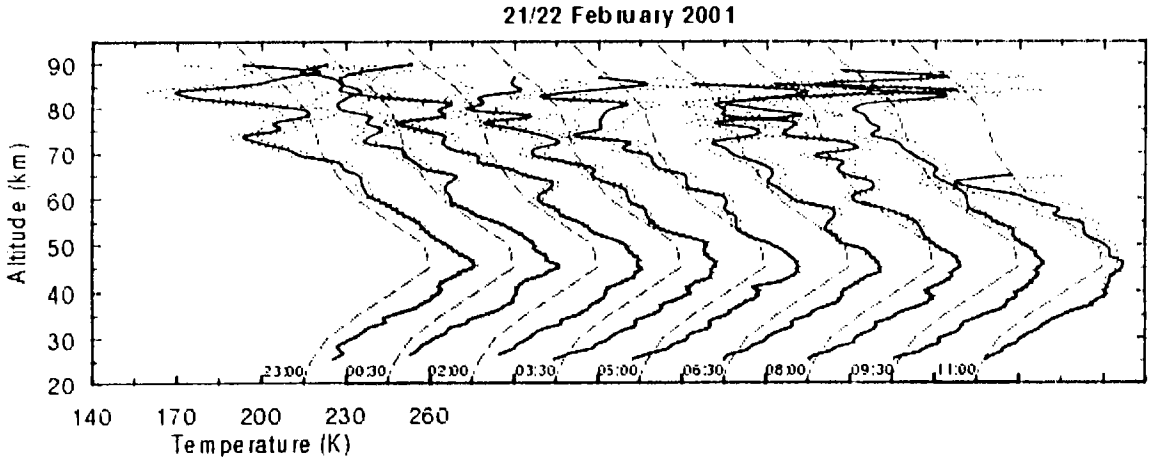
Venus Magellan Occultation

Hinson & Jenkins, 1995



Earth - Haystack Firepond Lidar

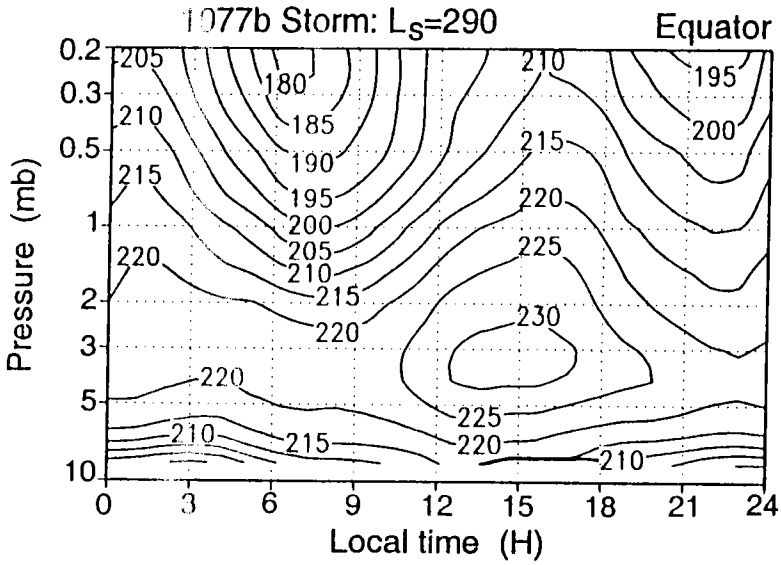
Duck et al., 2001



Thermal Tides in Terrestrial Planetary Atmospheres

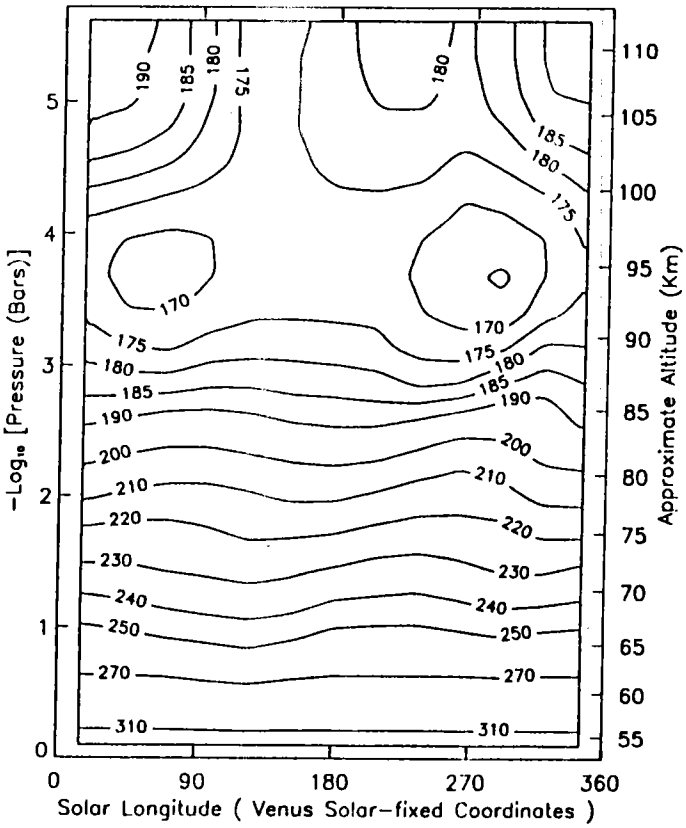
Mars GFDL GCM

Wilson & Richardson, 2000



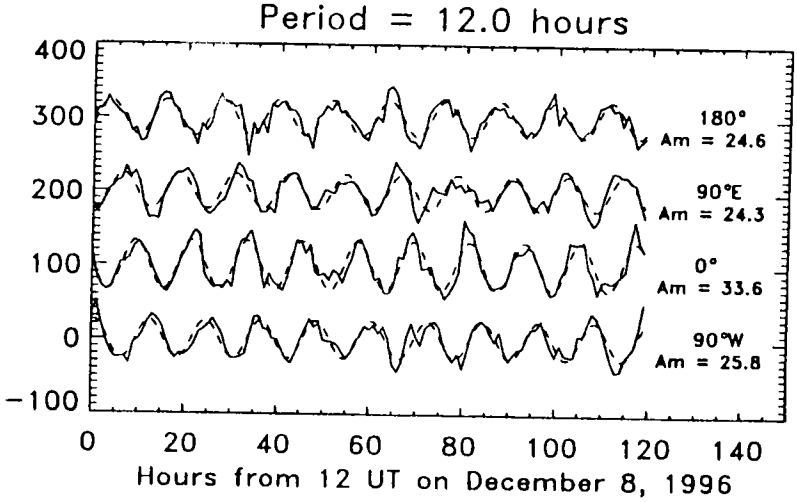
Pioneer Venus OIR

Schofield & Taylor, 1983



South Pole Meteor Radar

Forbes et al., 1995



Dissipating waves influence the mean thermal and wind structures of planetary atmospheres

$$\frac{\partial \overline{u}}{\partial t} + \text{nonlinear terms} + 2\Omega\cos\theta\overline{v} = \text{dissipative terms} + \overline{F}_u$$

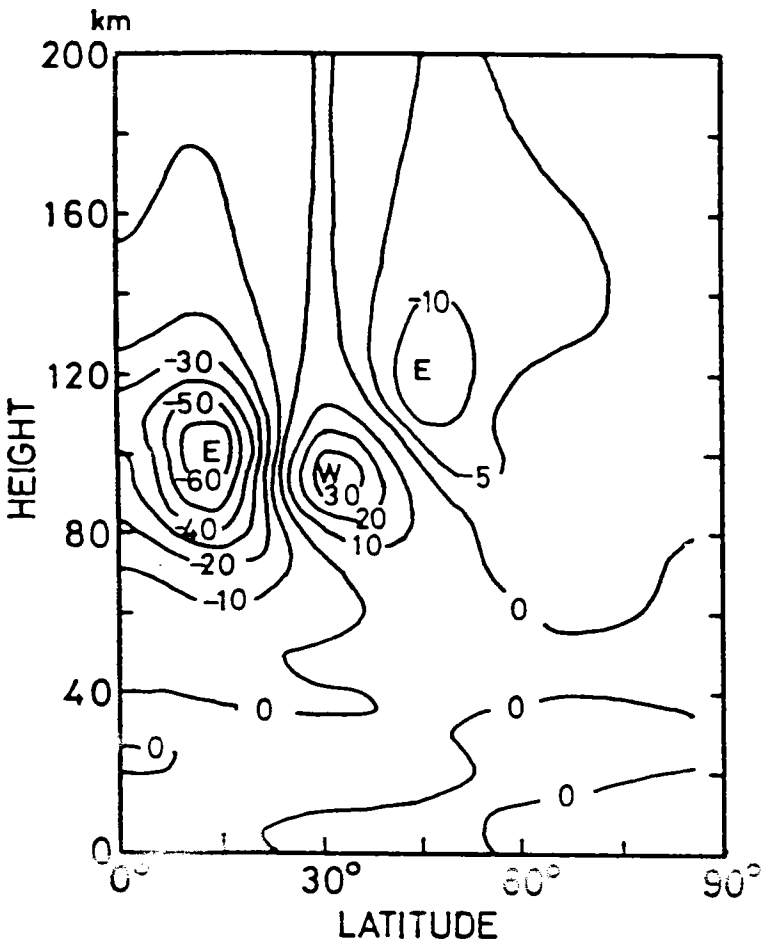
where

$$\overline{F}_u = -\frac{1}{a}\frac{\partial \overline{u'v'}}{\partial \theta} - \frac{2\cot\theta}{a}\overline{u'v'} - \frac{1}{p}\frac{\partial p\overline{u'w'}}{\partial z}$$

Zonal Mean Winds Due to Dissipation of Thermal Tides: Diurnal

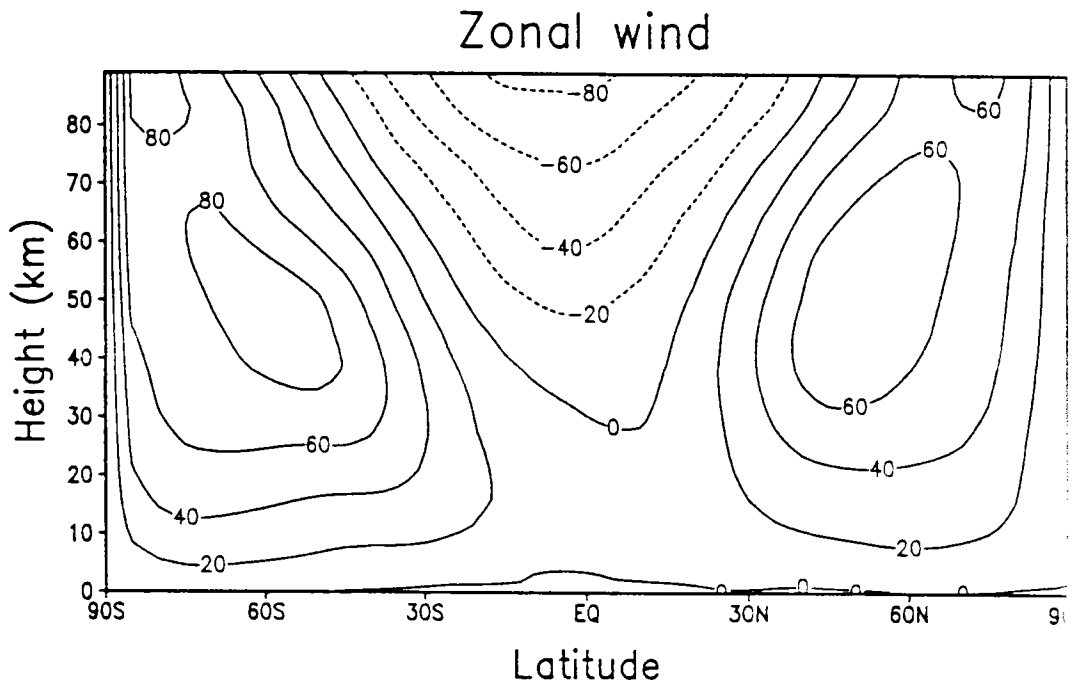
Earth

Miyahara, 1981



Mars

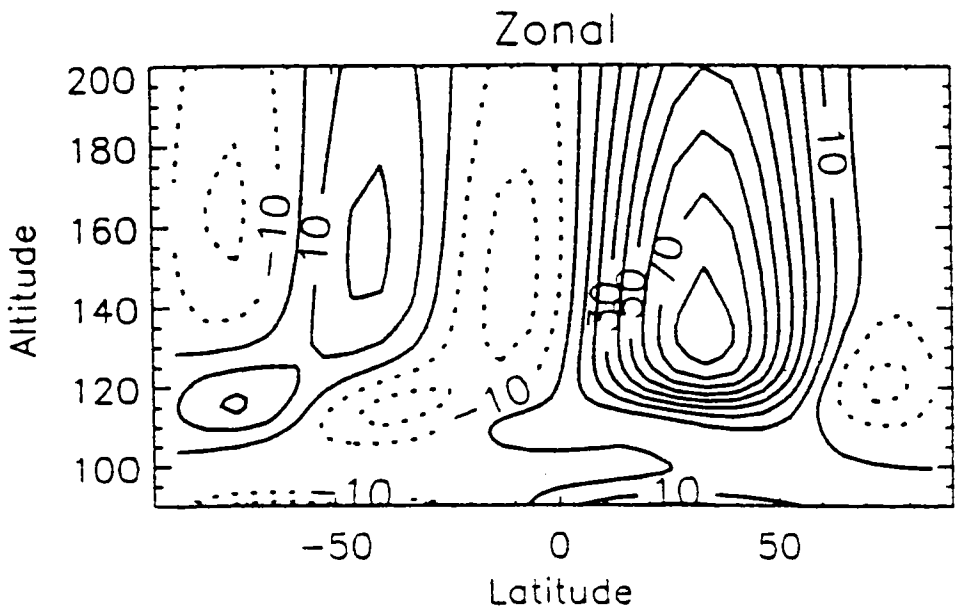
Forget et al., 1999



Zonal Mean Winds Due to Dissipation of Thermal Tides: Semidiurnal

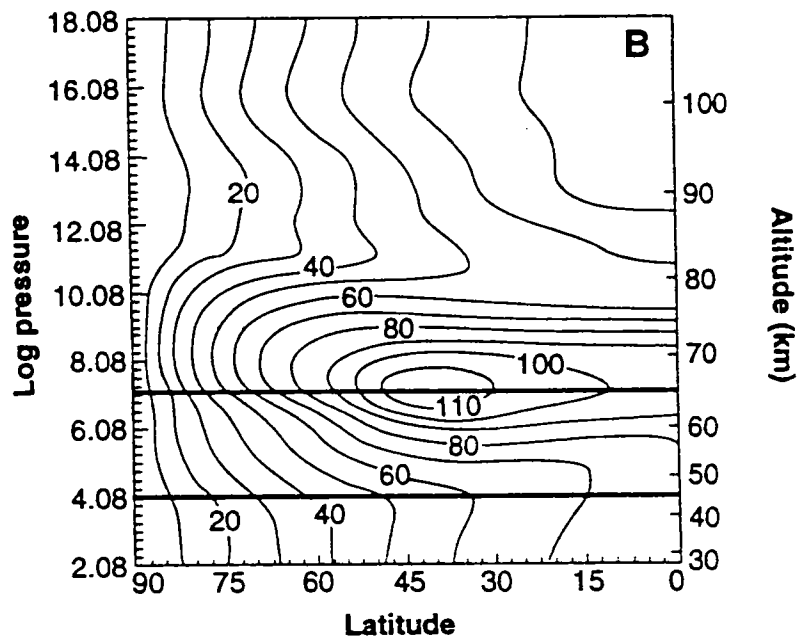
Earth

Angelats I Coll & Forbes, 1999

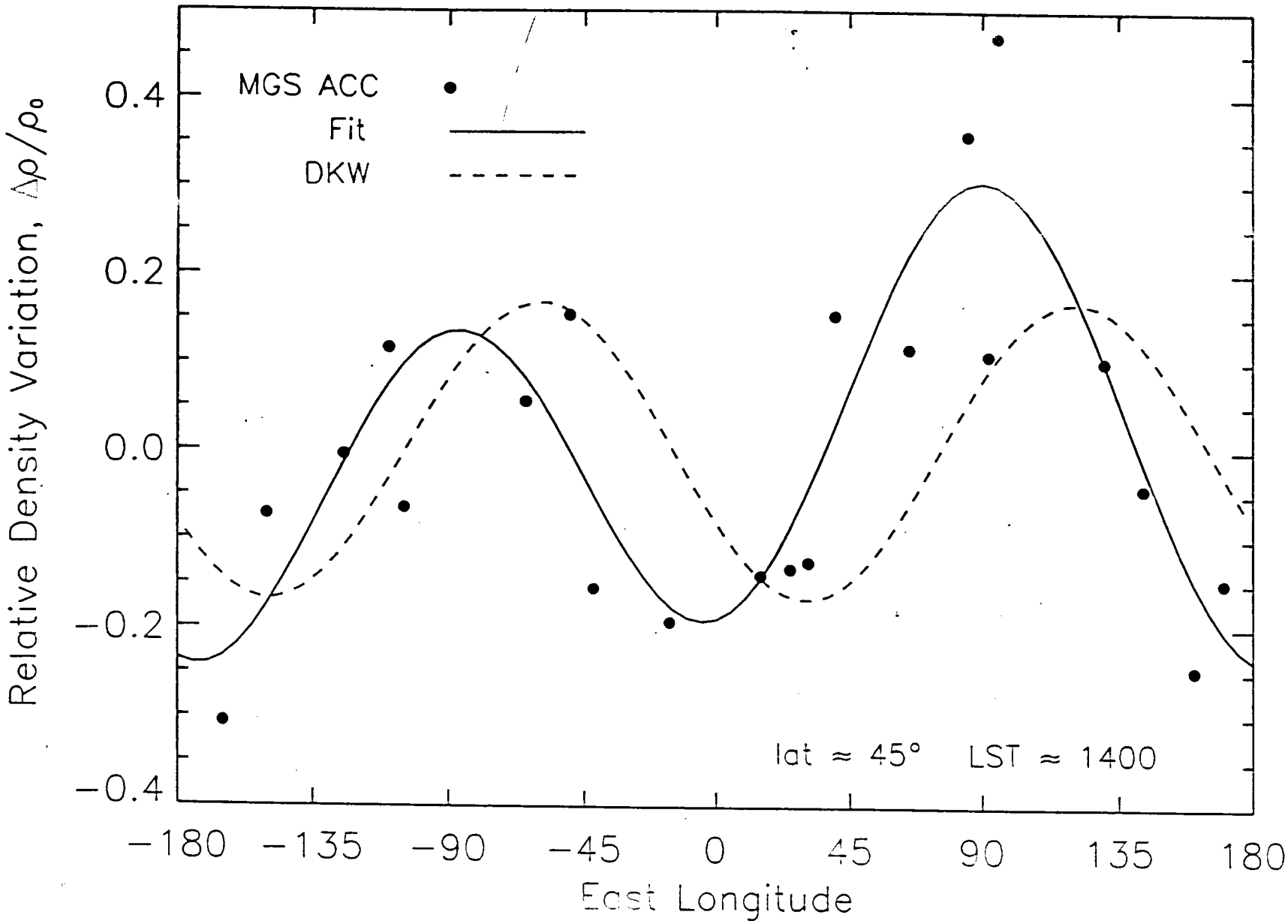


Venus

Newman & Leovy, 1992

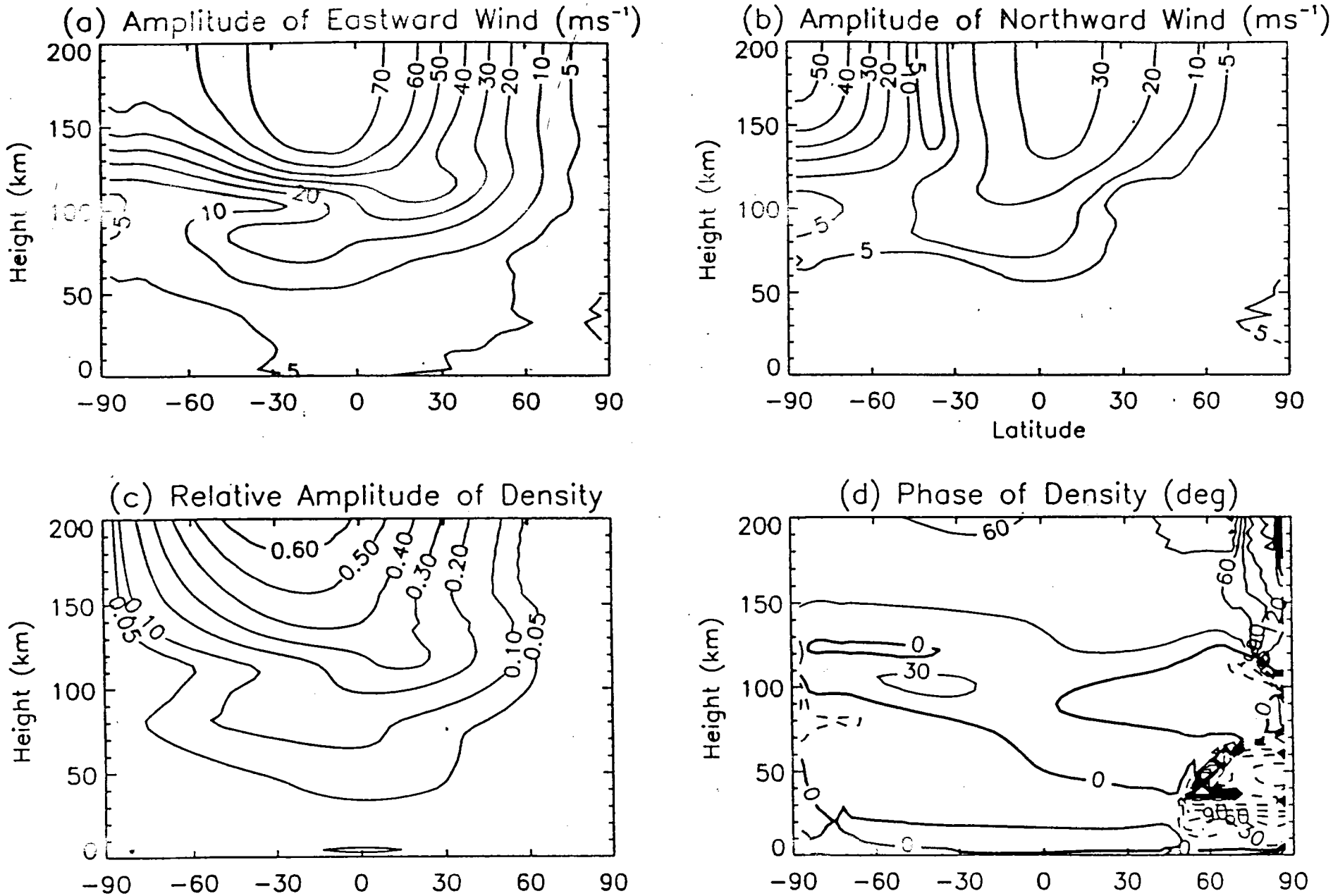


Mars Global Surveyor Accelerometer Measurement, Phase I Aerobraking
Mars GSWM Diurnal Kelvin Wave [Forbes and Hagan, 2000]

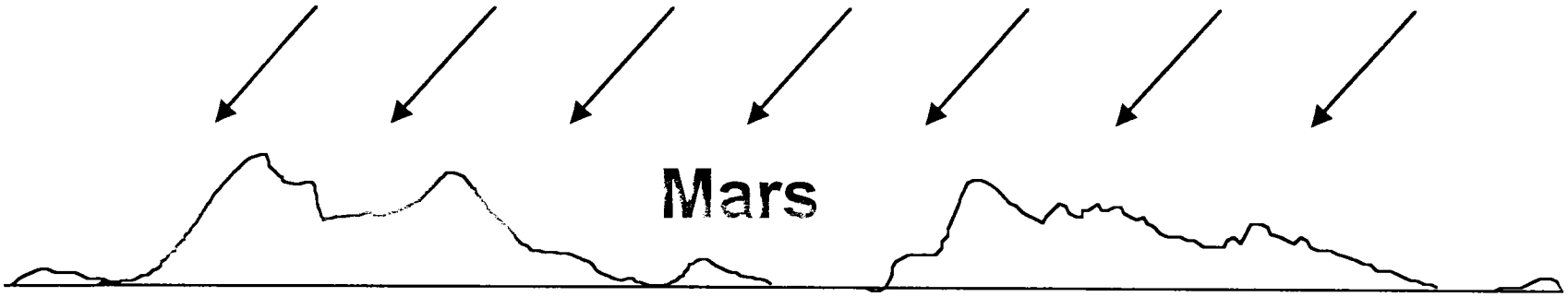


Mars GSWM Tidal Simulation

Period =−1.0 sols, S = 1, Ls = 270, idust = 0, eddy = 1



Westward migrating solar radiation interacting with s = 2 topography



$$\cos(\Omega t + \lambda)\cos 2\lambda \;\text{--->}\; \cos(\Omega t + 3\lambda) + \cos(\Omega t - \lambda)$$

solar radiation

topography

westward propagating s=3

eastward propagating s=1

Similarly,

westward propagating s=4

standing s=0

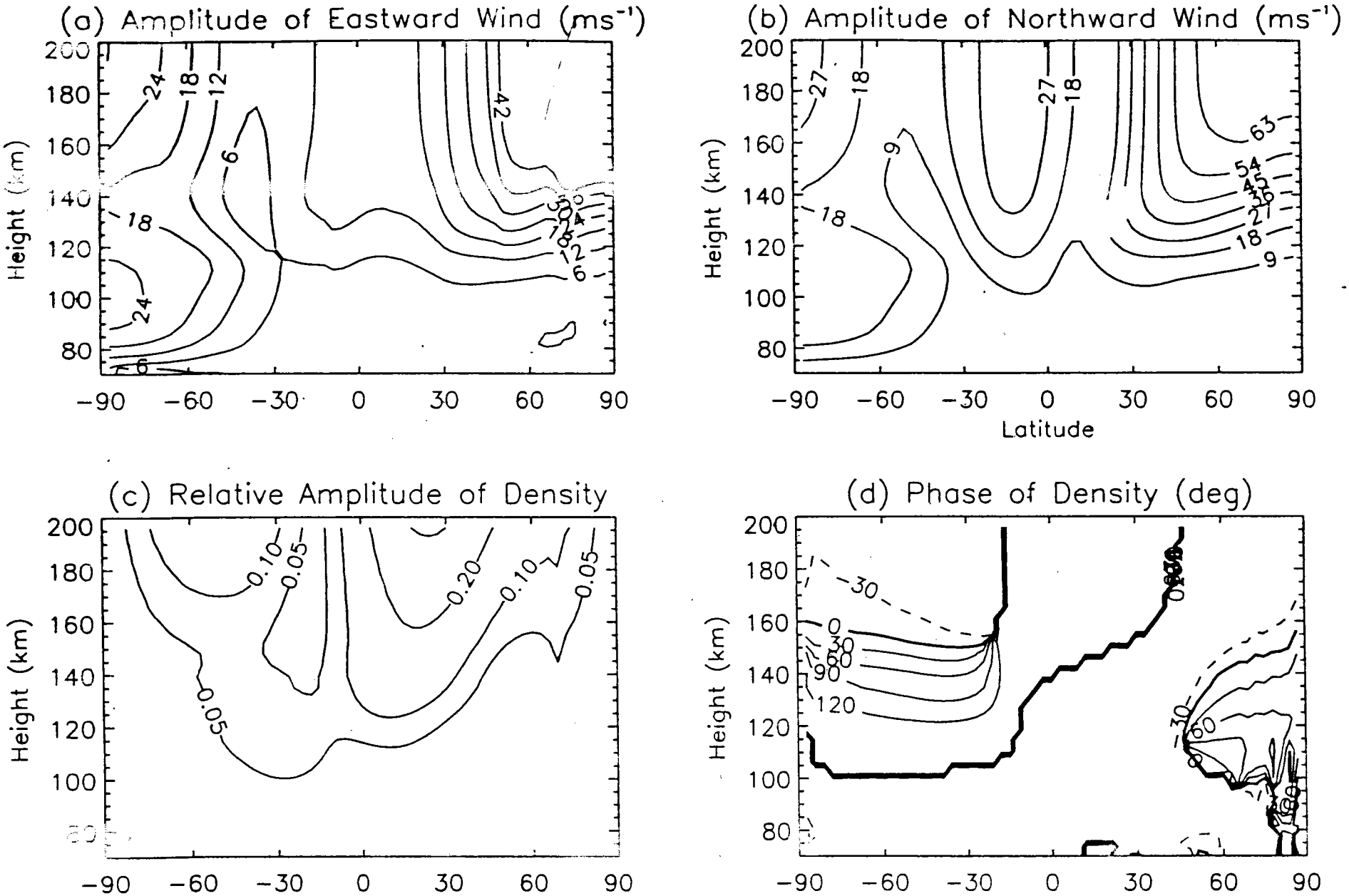
$$\cos(2\Omega t + 2\lambda)\cos 2\lambda \;\text{--->}\; \cos(2\Omega t + 4\lambda) + \cos(2\Omega t)$$

solar radiation

topography

Mars GSWM Tidal Simulation

Period =0.50 sols, S = 1, Ls = 270, idust = 0, eddy = 1



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Simulations of Diurnal Tides due to Tropospheric Heating from the NCEP/NCAR Reanalysis Project

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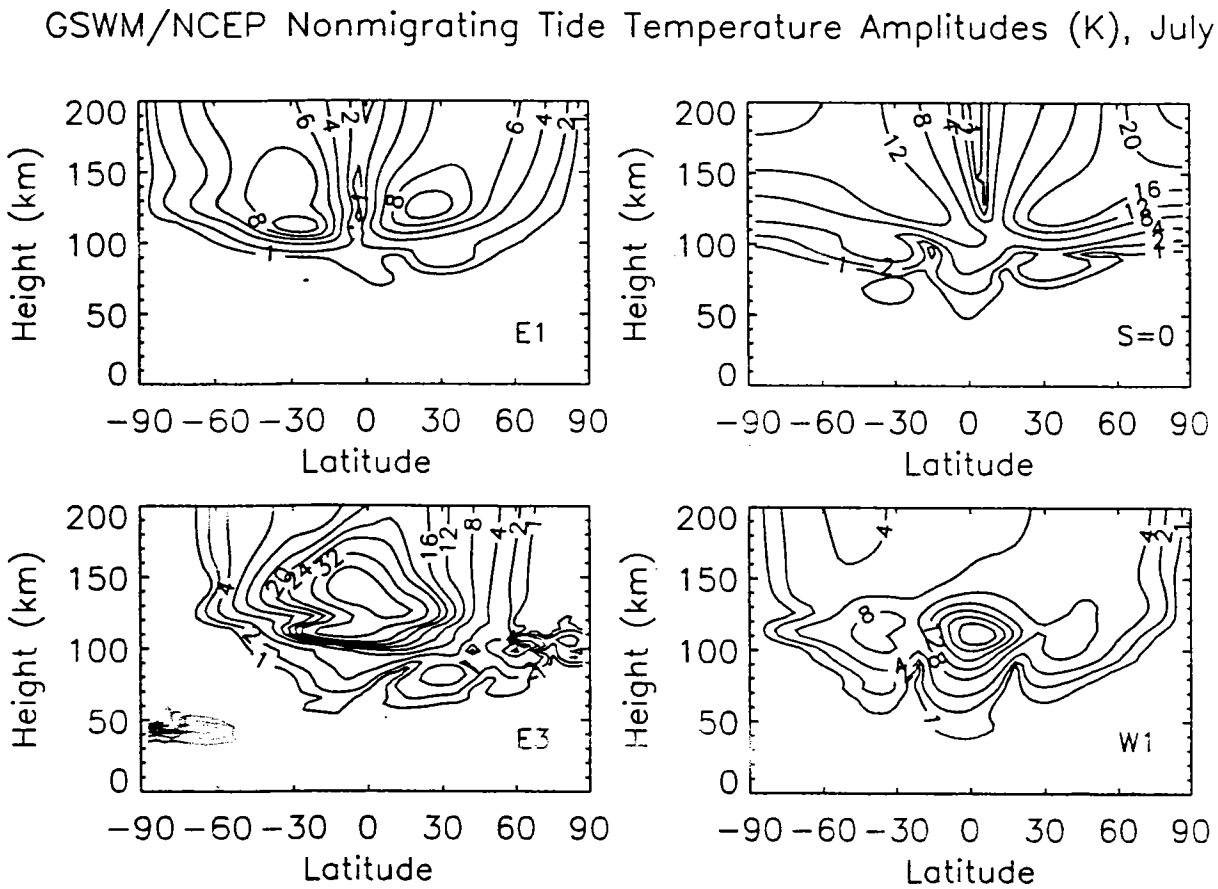

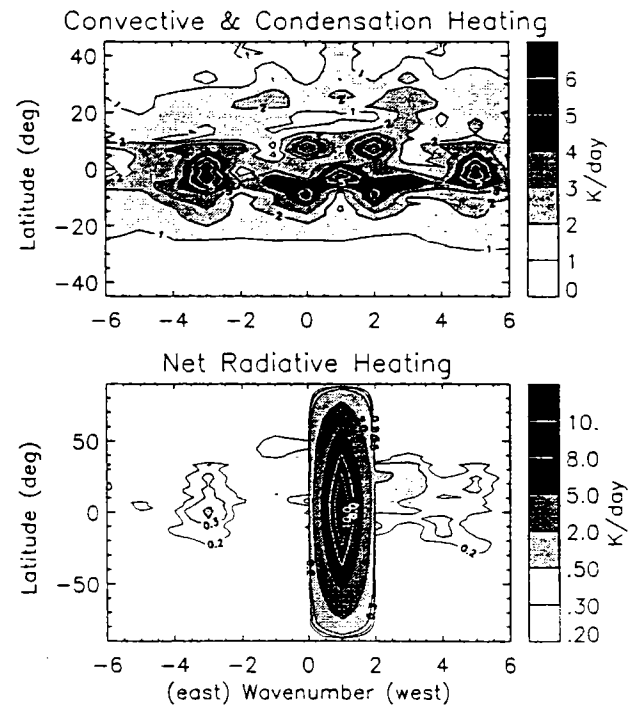

CONCLUSIONS

- Dynamic similarities exist between Earth, Mars and Venus
- Gravity waves and tides are especially prevalent in the atmospheres of the terrestrial planets
- Dissipating waves influence the mean thermal and wind structures of planetary atmospheres
- For Earth and Mars, topographic influences extend into the thermosphere

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- A comparative planetary approach is synergistic