Research Opportunities at GMU: Planetary Atmospheres and Ionospheres

Code 675 PHaSER Faculty Liaison

GEORGE MASON UNIVERSITY

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Erdal Yiğit, George Mason University; GSFC, NASA

PHaSER Open House – 18 September 2024, Wednesday

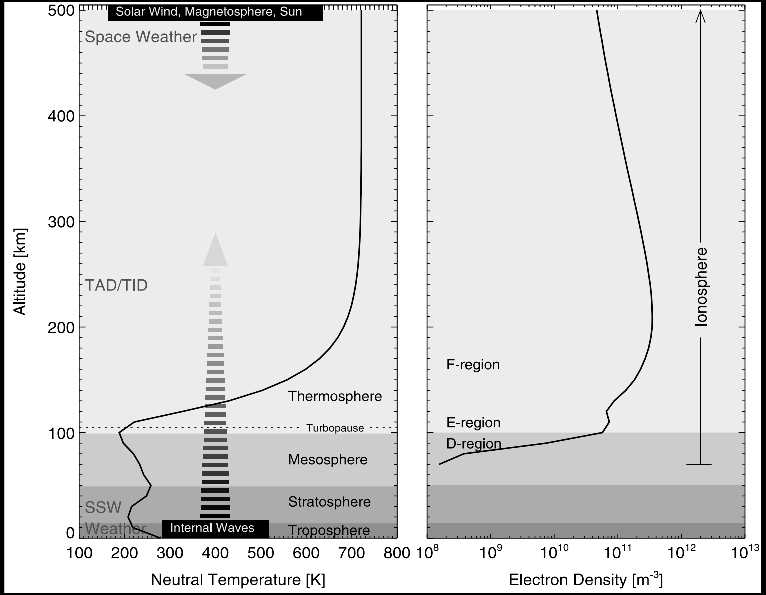
NASA GSFC

Research Activities and Interests

Vertical coupling in planetary atmospheres and ionospheres?

About me:

- Professor of Physics, George Mason University
- Faculty liaison – 675
- PhD in Physics, UCL, UK
- BSc in Physics, Jacobs University Bremen, Germany
- Vertical coupling in Planetary Atmospheres
  - General circulation modeling
  - Satellite observations
  - GIGI project: “Studying the mean and variable structure of the upper atmosphere using GOLD and ICON”



(Yiğit and Medvedev, 2015, ASR)

- Selected topics:
  - Gravity waves, solar tides, sudden warmings, escape, ice clouds, magnetic storms, hurricanes, wave-mean flow interactions, dust storms, transport of water.

Numerical modeling tools

CMAT2 (Coupled Middle Atmosphere Thermosphere General Circulation Model-2)

- Three-dimensional atmosphere model, extending from the lower atmosphere (15 km) to the upper thermosphere (250-500 km) (Yiğit et al. 2009, JGR).
- Empirical ionosphere and high-latitude inputs
- Subgrid-scale gravity waves parameterized by the whole atmosphere GW parameterization

Martian General Circulation Model

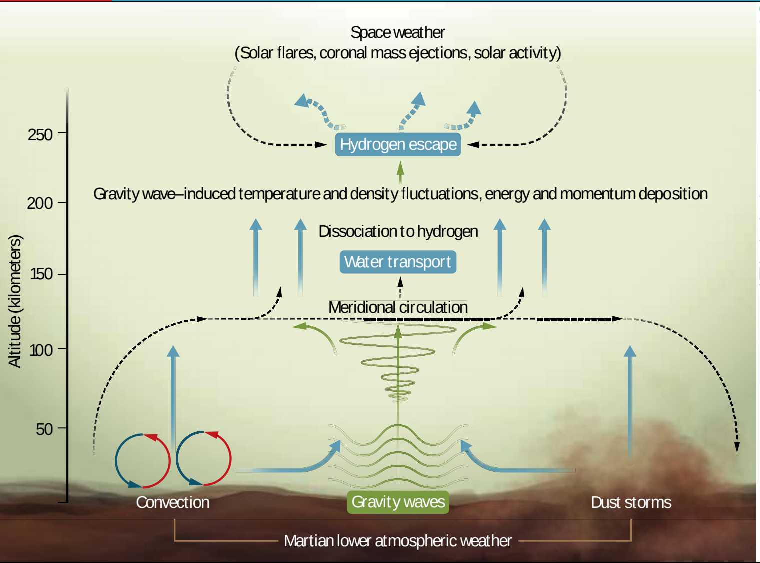
- Surface to ~160 km Martian GCM
- Water transport
- Subgrid-scale gravity waves

Whole atmosphere GW Parameterization

(Yiğit et al. 2008, JGR).

- Vertical evolution of lower atmospheric GW activity (vertical flux of GW horizontal momentum) self-consistently accounting for the effects of wave dissipation
- GW-induced acceleration/deceleration, heating/cooling, mixing
- Higher-order wave generation.

Gravity waves, dusts storms and water escape



nature geoscience

Review Article

https://doi.org/10.1038/s41561-022-01118-7

Coupling and interactions across the Martian whole atmosphere system

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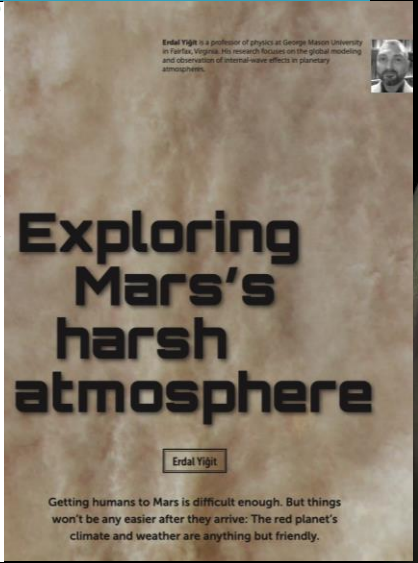
Check for updates

Erdal Yiğit

The Martian surface environment today is cold and dry, but evidence suggests the planet may have hosted more habitable conditions in the past. Open questions about the evolution of the Martian atmosphere and climate motivate much Mars exploration and science. Recent global-scale observations of the Martian atmosphere combined with models reveal intriguing connections between the lower and upper atmospheres. Here we review the role of atmospheric waves, dust storms and atmospheric loss and discuss how these processes are coupled within the Martian whole atmosphere system. Atmospheric gravity (buoyancy) waves are globally present at all altitudes. The effects of planet-encircling dust storms in the lower atmosphere propagate to the upper atmosphere. The Martian hydrological cycle in which water is exchanged between the surface and atmosphere is coupled to dynamical and radiative processes operating across atmospheric layers. The thermal escape of atomic hydrogen to space, which is thought to be the primary mechanism for the long-term loss of water on Mars, is influenced by atmospheric waves and dust storms. Understanding the coupling among atmospheric waves, dust storms and atmospheric loss processes, and thus a unified understanding of the Martian whole atmosphere system, is essential to understand past and current climate on Mars.



Yiğit (2021), Martian water escape and internal waves, Science, vol 374, Issue 6573

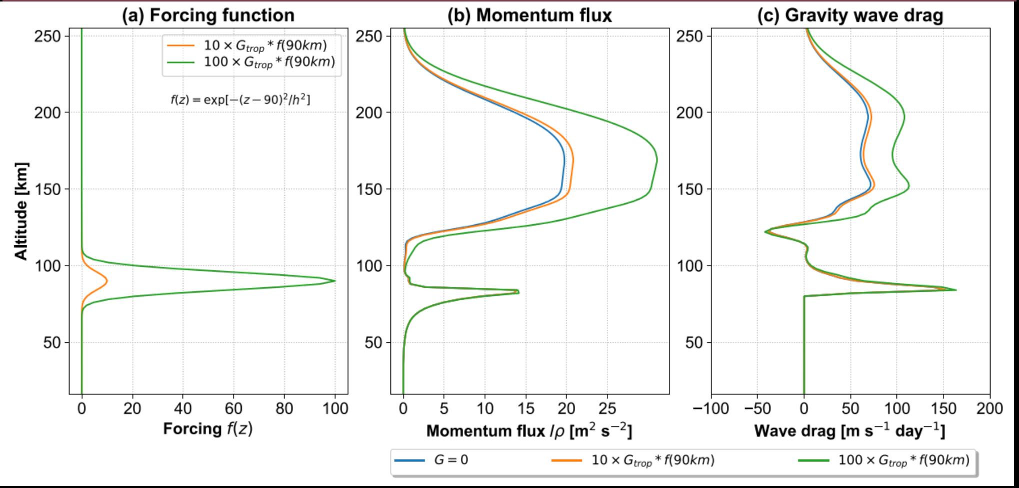
Yiğit (2023) Nat. Geoscience

Yiğit (July 2024) Physics Today

- GW-induced vertical coupling between the lower and upper atmosphere on Mars could have played an important role in the long-term evolution of Martian water and climate.

Vertically localized sources (secondary waves) vs primary waves

- What is the relative importance of secondary gravity waves?



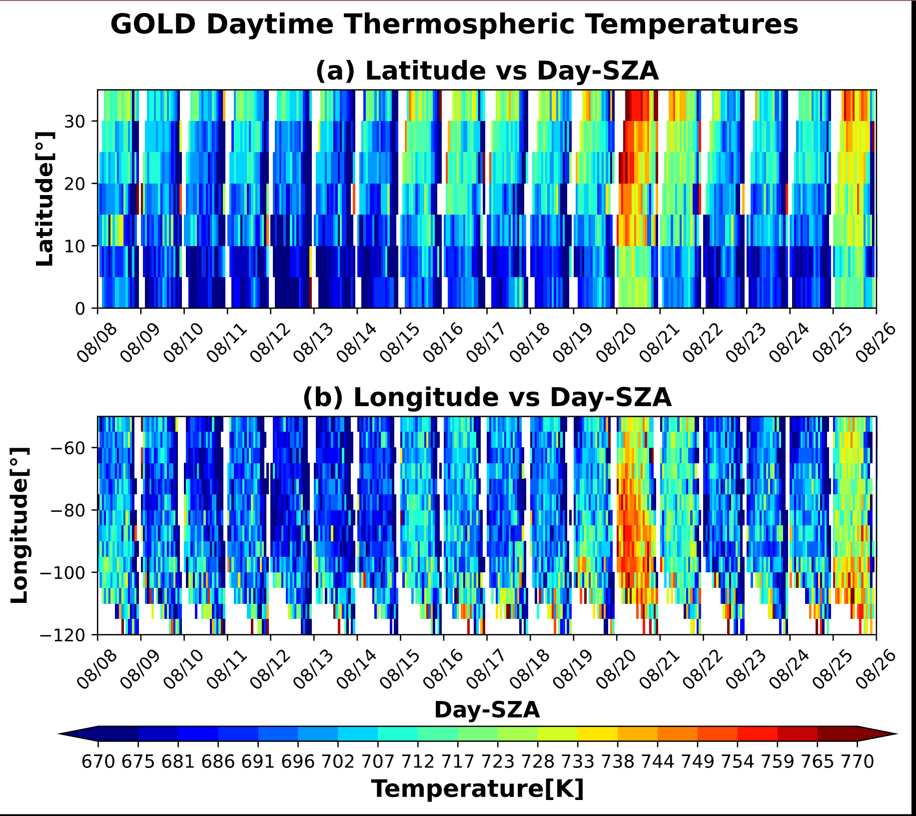
- Source centered around 90 km, just above the local maximum of the mesospheric GW breaking (Medvedev, Klaassen, Yiğit, 2023, JGR-S).
- Assume localized sources generate same spectrum of GWs

- Test forcing amplitude one and two orders of magnitude larger than the characteristic strength in the troposphere
  - $10 \times G_{trop}$ contributes virtually nothing in the thermosphere
  - $100 \times G_{trop}$ adds ~50% to the tropospheric contribution
  - → air in the mesosphere is very thin, and to produce a noticeable change in the thermosphere, sources there must be unusually strong compared to the troposphere.

- The dynamical effect of secondary GWs in the thermosphere is negligible compared to that of the primary GWs generated in the troposphere.

Thermospheric temperature variations induced by Hurricane Grace

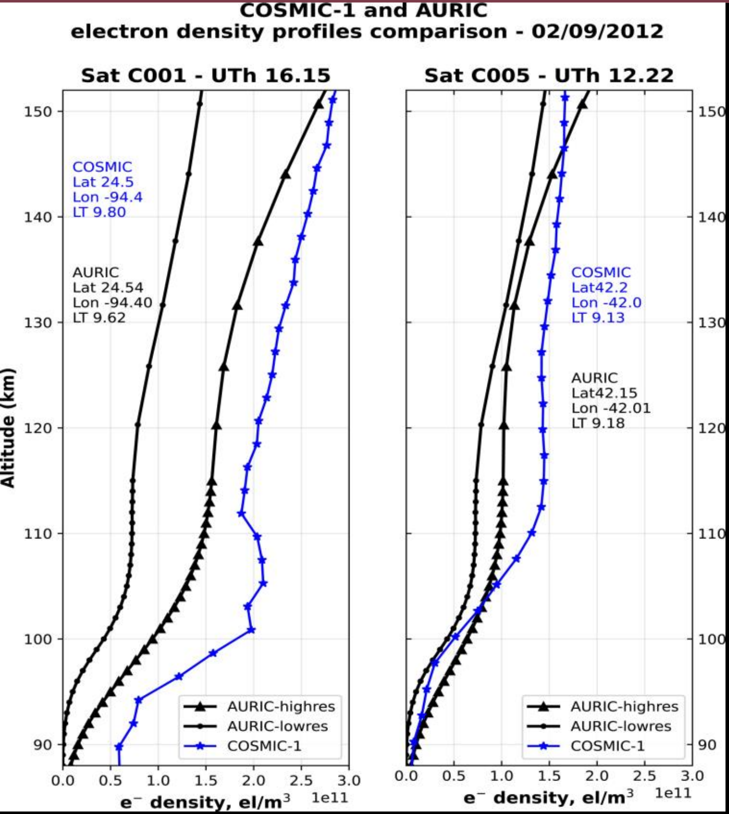
How did Hurricane Grace affect thermospheric temperatures?



- Examining the extent of hurricane-induced thermal perturbations in the upper atmosphere
- GOLD satellite observations, focusing on temperatures around 150 km altitude
- Substantial warming (>50 K) observed during hurricane's rapid intensification, indicating strong thermodynamic coupling (Gann and Yiğit, 2024, JGR-S, submitted)

- Daytime thermospheric temperatures binned by day and solar zenith angle

How do high-resolution cross sections influence low-latitude ionospheric electron density and photoelectron flux?



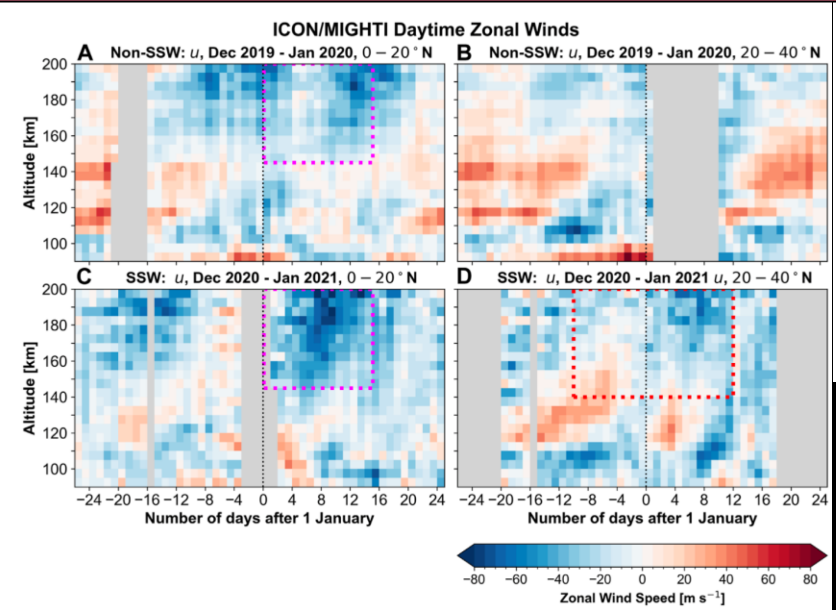
Comparison between COSMIC-1 GPS radio occultation (RO) with AURIC

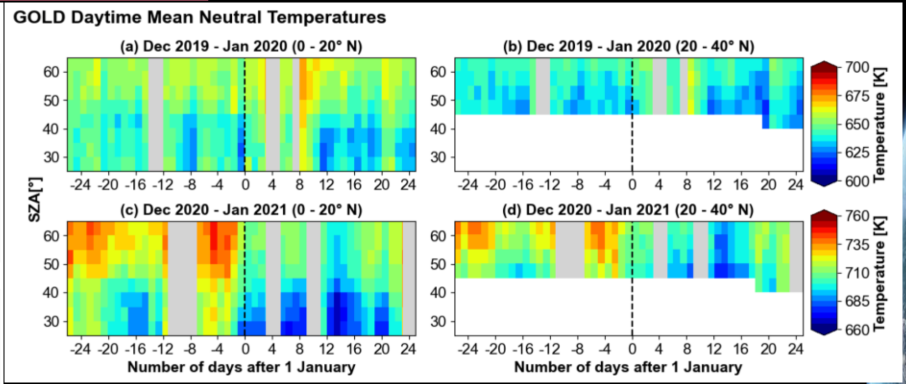
Validation of E-Region Model Electron Density Profiles With AURIC Utilizing High-Resolution Cross Sections

- Atmospheric Ultraviolet Radiance Integrated Code (AURIC) simulations are updated utilizing high-resolution photoionization and photoabsorption cross sections and scaled solar spectra.
- Multi-instrument observations have been used to compare electron density profiles with AURIC E-region high-resolution modeling efforts.
- Main results:
  - New high-resolution calculations show improvement in the E-region electron density calculation by producing more ionization. **(Sakib et al., 2023; JGR-S)**
- Future Work:
  - A comparison of photoelectron flux energy spectrum between satellite data and updated AURIC in different solar conditions.

Observation of coupling with ICON and GOLD during SSWs

- What are the impacts of SSWs on the upper atmosphere?



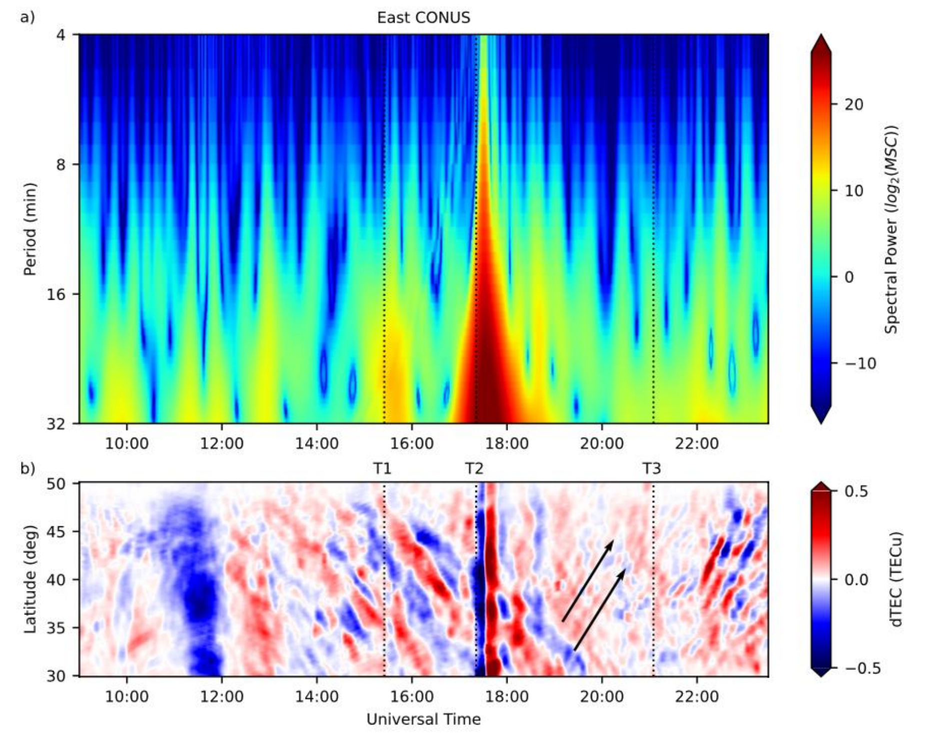


- 2020/2021 SSW: Changes in circulation and temperature at low-latitudes in the thermosphere
  - Up to 50 K cooling (partially due to the changing solar radiation)
  - Zonal winds become more westward

(Yiğit et al., 2024, FASS)

TI response to solar flares and gravity waves

- How does transient changes of solar radiation affect TI and GWs?



- dTEC from GNSS-TEC
- Response of the upper atmosphere to transient changes in solar radiation, focusing on GWs caused by solar flares, and daily solar terminator passages.
- Initial results of a solar flare case study indicate a longitudinal response depending on the geomagnetic field geometry (Sarp, Yiğit, Kilcik, 2024, Space Weather, accepted)

- a) Wavelet Coherence results for a specific region
  b) Keogram analysis for the same region
  Solar Terminator around 1200 UT
  Solar Flare at 1721 UT

Summary

- Current research activity
  - Hurricanes
  - Gravity wave effects in the whole atmosphere region (Mars, Earth)
  - Photoelectron flux, electron density, and cross-sections
  - Solar flare effects on the TI
  - Observation of vertical coupling with GOLD/ICON
  - Connection between dust storms, gravity waves, and water escape on Mars

- If you are interested in working with students, contact me or any other faculty liaison