Surprising Decrease in the Martian He Bulge during PEDE-2018 and Changes in Upper Atmospheric Circulation

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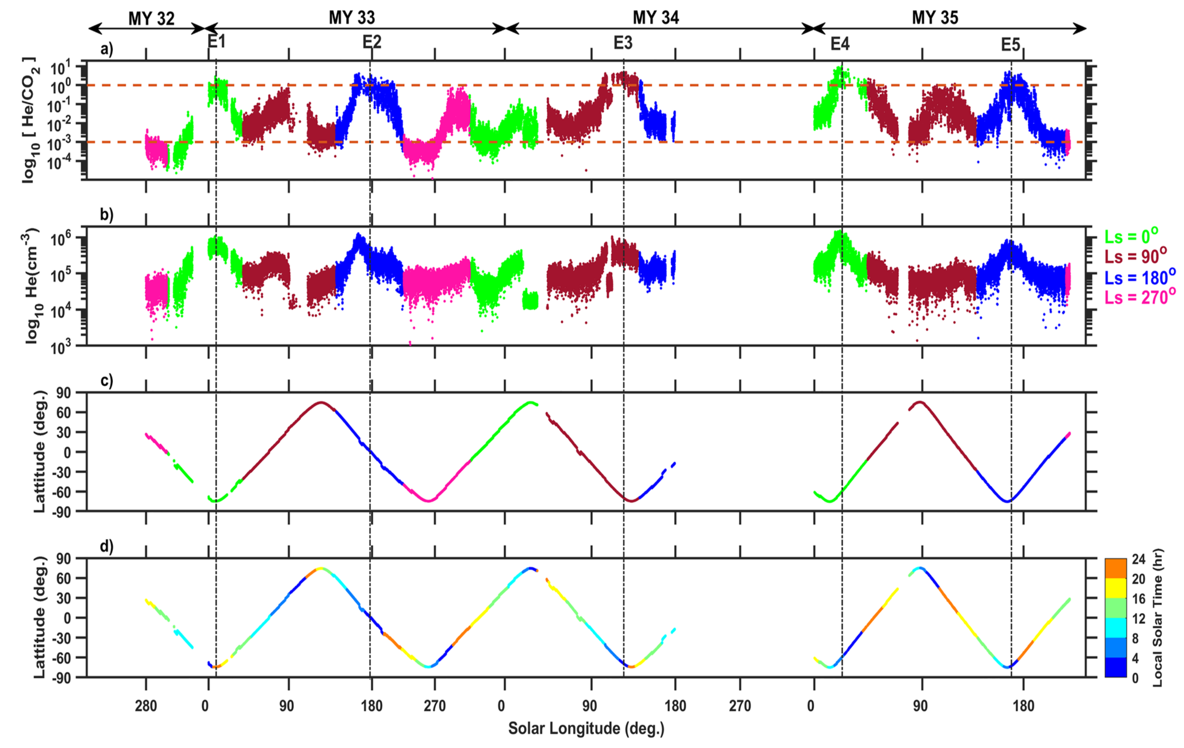
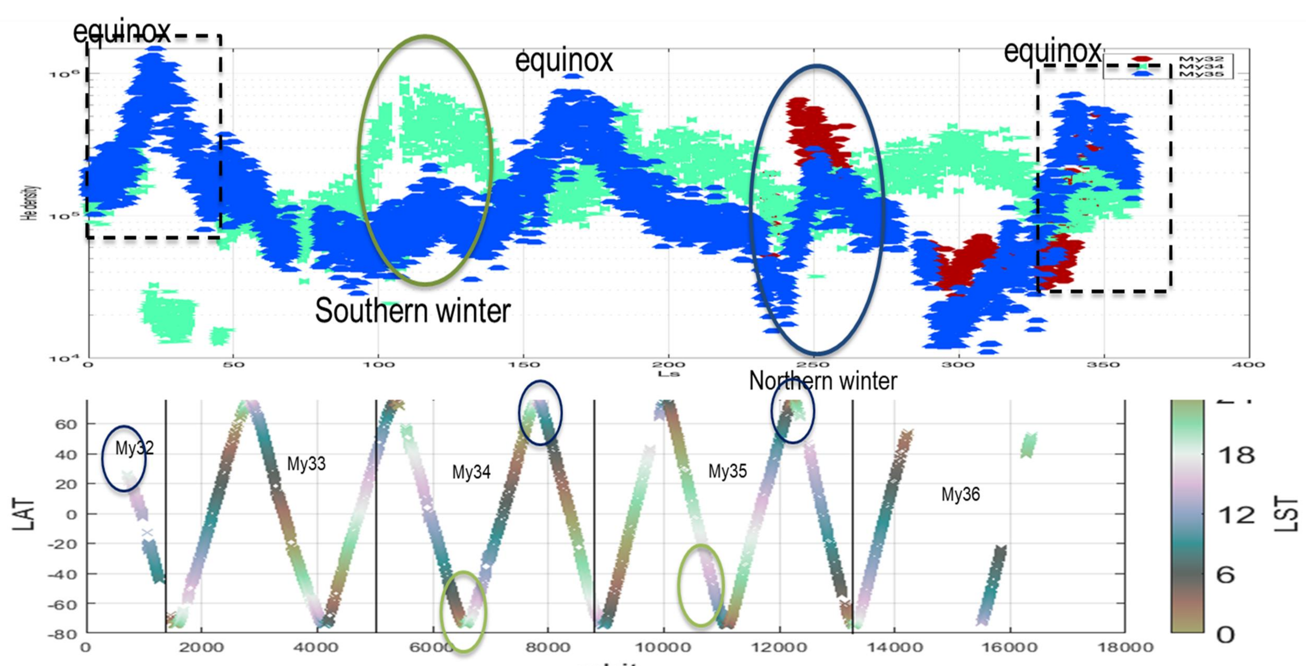
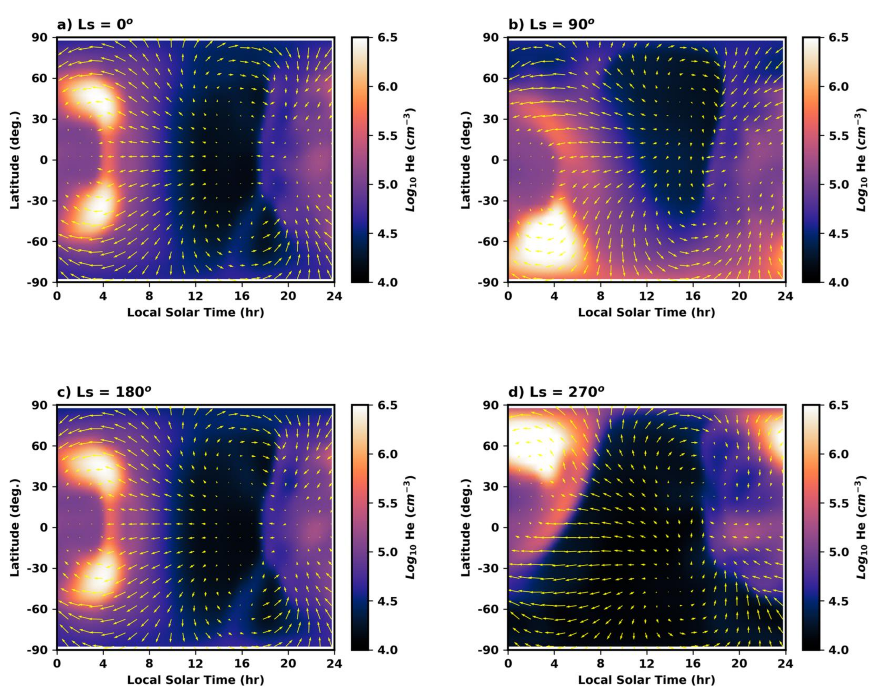
Introduction

Using the Neutral Gas and Ion Mass Spectrometer (NGIMS) on the Mars Atmosphere Volatile and Evolution spacecraft (MAVEN) we analyzed data from Mars Year (MY) 32, 34, and 35 to examine the He bulge during the northern winter solstice (Ls ~180-240) specifically focusing on the effects from the planet encircling dust event (PEDE-2018). He collects on the dawn/nightside winter polar hemisphere of the terrestrial planets (Earth, Mars, and Venus). The seasonal migration of the Martian He bulge has been observed and modeled (Elrod et al., 2017, Gupta et al., 2021). The MAVEN orbit precesses around Mars allowing for a variety of latitude and local time observations throughout the Martian year. MY32, 34 and 35 had the best possible opportunities to observe the He bulge during northern winter (Ls ~180-240). NGIMS observations during MY 32 and MY 35 revealed a He bulge on the nightside to dawn in alignment with modeling and previous publications. However, in MY 34, during the PEDE, the He bulge was not present indicating the PEDE directly impacted upper atmospheric circulation. Updates in modeling indicate changes in circulation and winds can cause He to shift further north and dawn-ward than MAVEN was able to observe. The temperature increases in the thermosphere on the nightside during the dust storm along with changes in gravity waves and eddy diffusion occurring during this event could account for this circulation change.



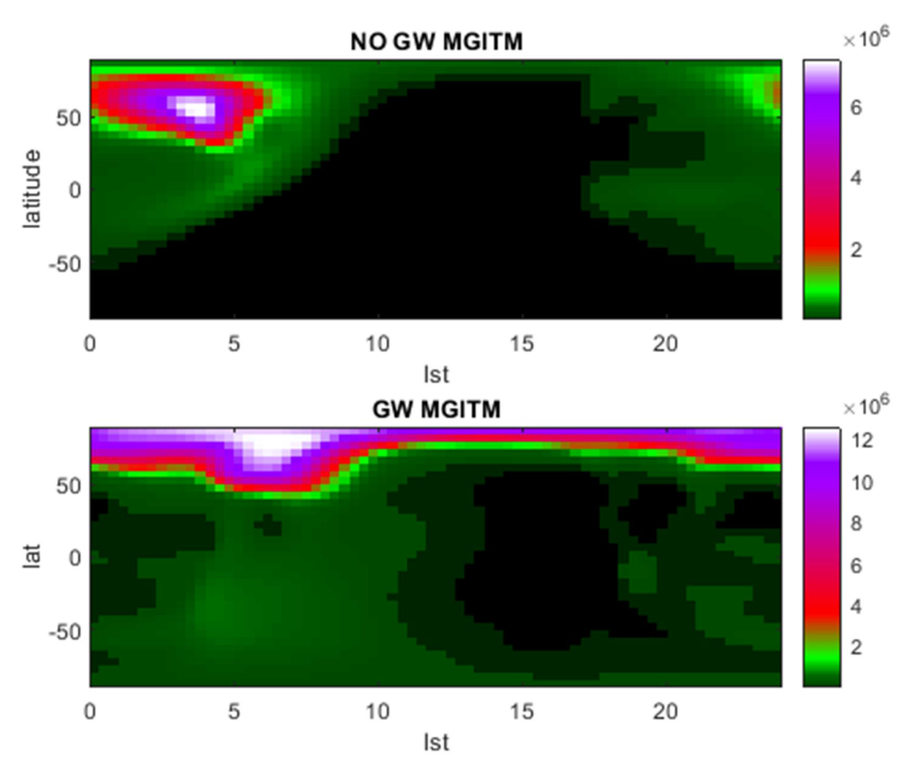
NGIMS He/CO2 data from MY32 – 35 (top), colors indicate different season (by Ls). Second panel is the He data, Third panel is the latitude, and the bottom panel is the latitude colored with local time rather than season.



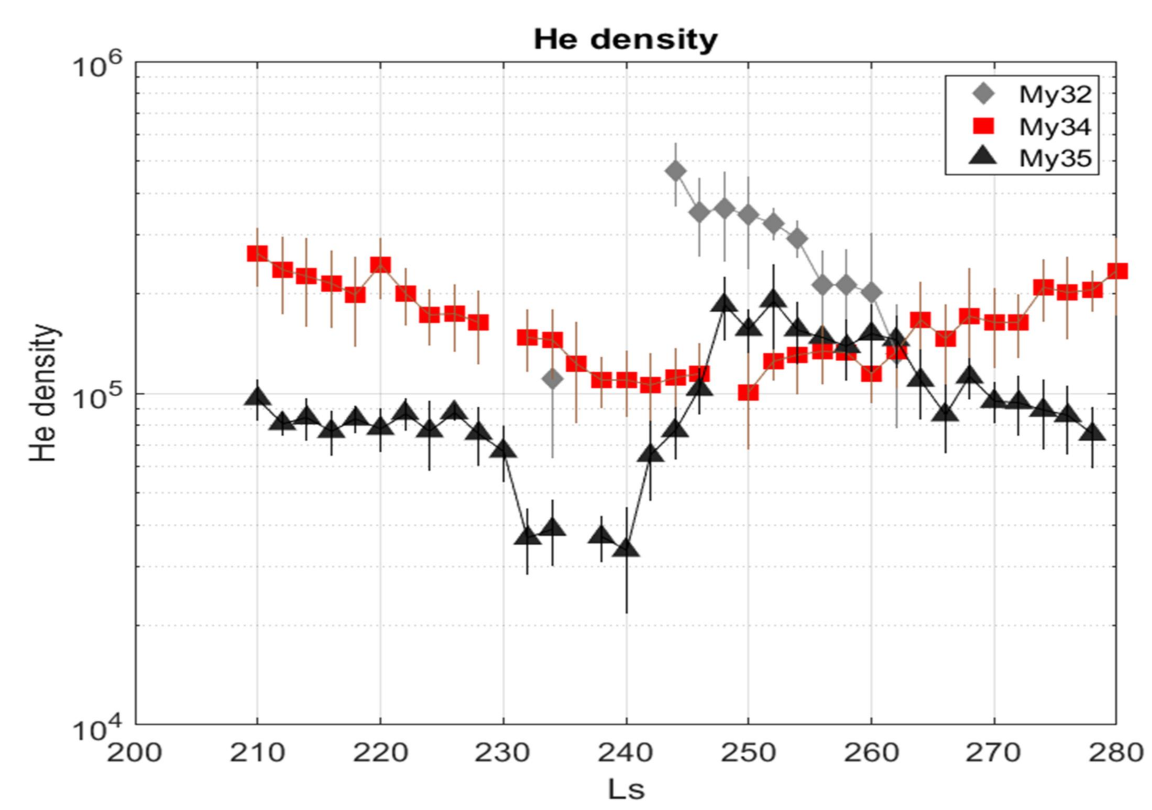


M-GITM model of He in the upper atmosphere at each season. Two left panels are during equinox Ls 0 (top) and 180 (bottom) and the right panels are during solstices Ls 90 (top) and 270 (bottom). These reflect the Martian atmosphere during non-dust storm conditions. Regional dust storms tend to form from Ls 190-360. Global Dust storms occur ~every # Martian Years (MY). The last observed global dust storm was in MY 34 (2018)

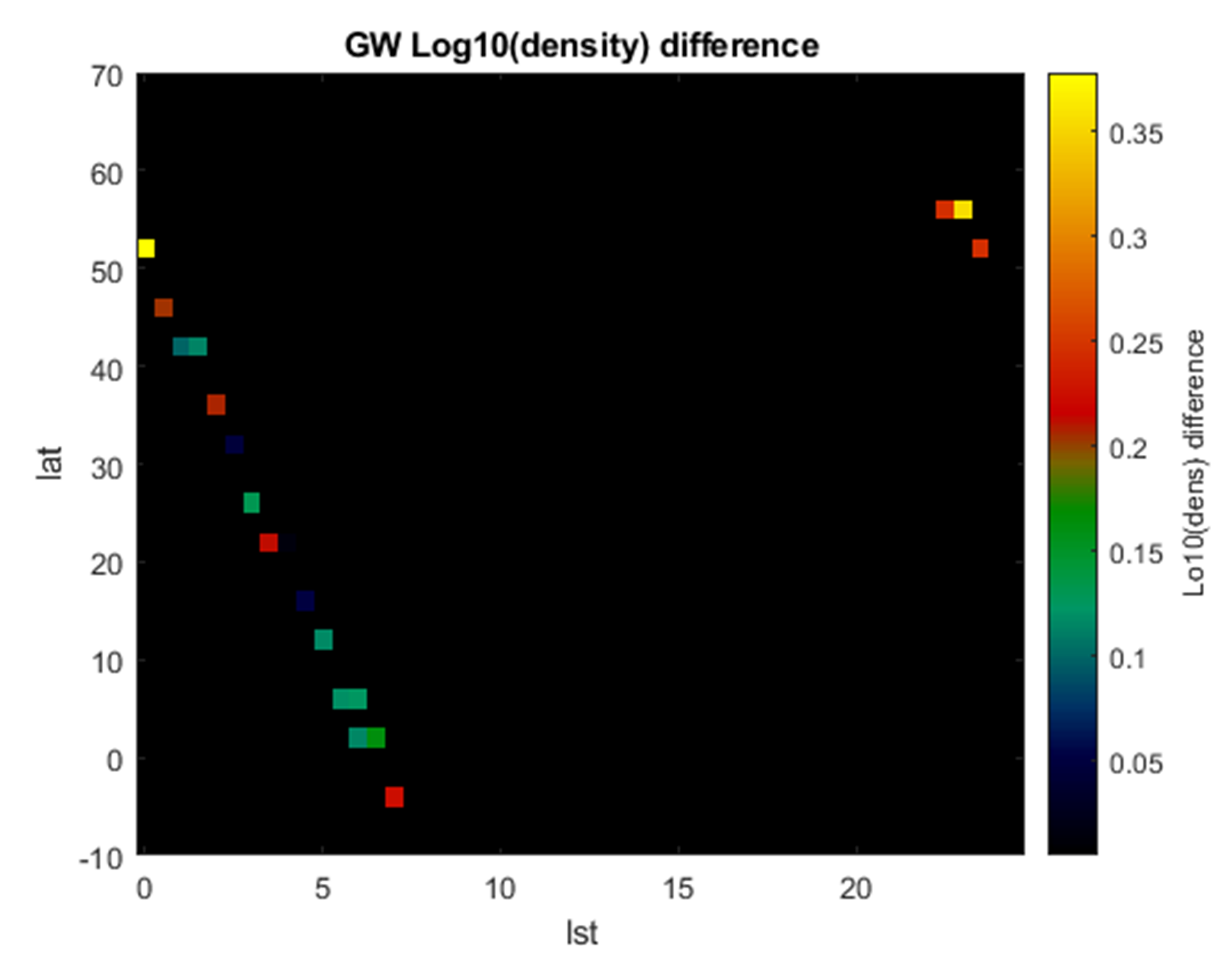
- NGIMS He data at 200km from MY 32, 34 and 35. These years were chosen because MAVEN was in NH during Ls 230-280 (Northern winter) only possible observations of the norther winter He bulge.
- It was observed in MY32 &MY35 but not MY34. The drop in the He density is due to the dust storm from Ls 200-240.

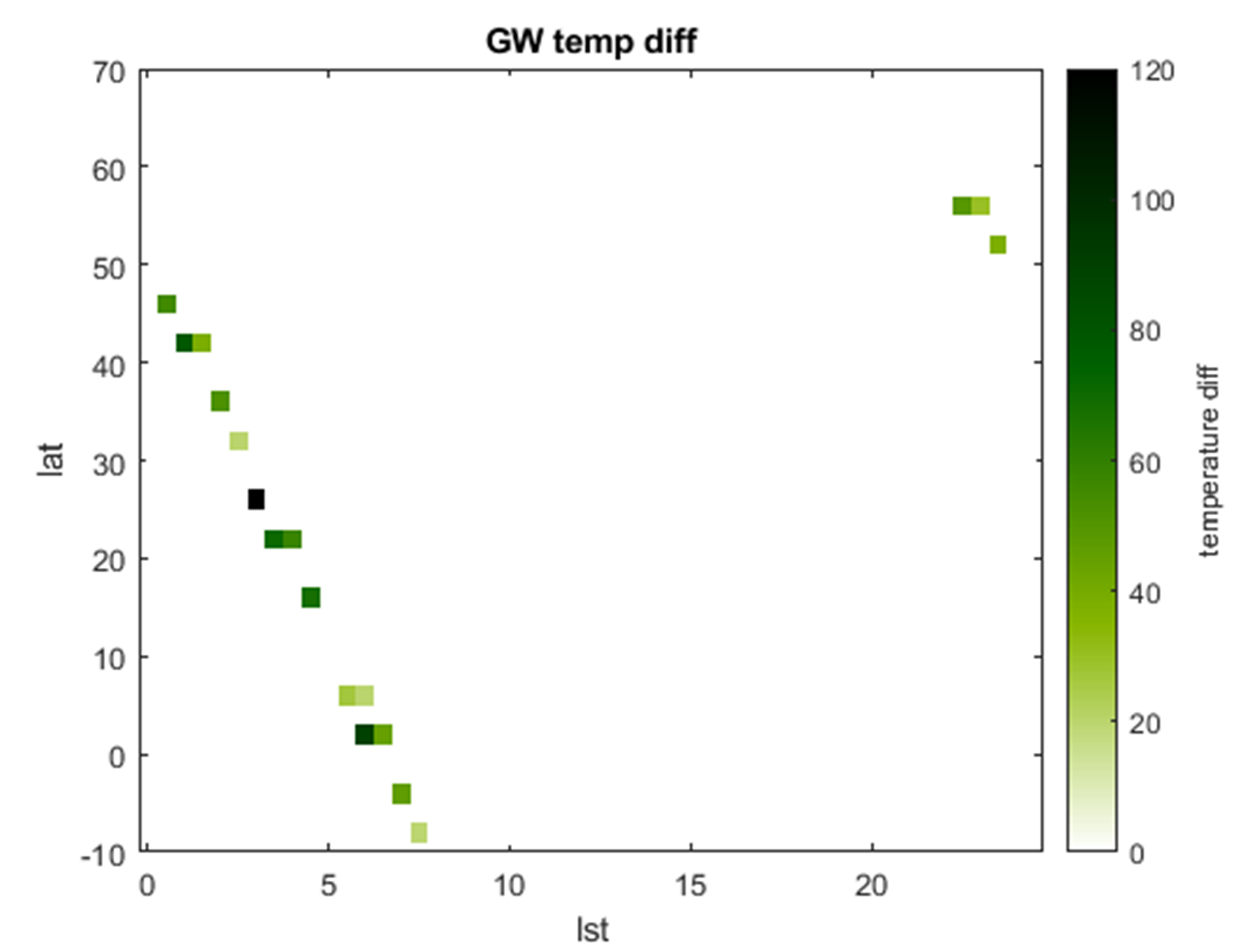


M-GITM model of He revised to account for circulation changes during the global dust storm. The top panel is without gravity waves and the bottom panel is with gravity waves. Note the substantial changes in the global circulation during the dust storm with the gravity waves. MAVEN moved from mid latitudes at LST ~ 6hr at the beginning of the storm, through >50º N latitude on LST ~22 hr by the end of the dust storm.



He density from MY34 (red) compared to MY 35 (black) and MY 32(grey) taken over a 10-orbit average from Ls 200-280. MY32 and MY 35 both exhibit the He bulge during the Northern winter on the night/dawn side as expected. The dip shown during MY34 indicates a significant disruption in the upper atmosphere circulation. This was during the global dust season.





MAVEN NGIMS data compared with the M-GITM model data. The model data has been binned to correspond with the NGIMS fly through during the dust storm from Ls 180-240 at 200km. The top panel is the difference in the log10(He dens). At the mid latitudes the gravity wave model matches well, but where the He was expected to be observed, above 50ºN latitude the model and data diverge significantly indicating that the He was not observed as expected. The lower panel is the temperature difference between the model and the NGIMS data. NGIMS observed significantly warmer temperatures during the dust storm that model results have been able to replicate thus far. Since He flows into the colder temperatures, this is one point of substantial interest to track down.

Conclusions

- Gravity waves significantly improved the Model – Data match (Gupta et al 2021)
  - Still mis-match in the data for the equinox data better match at the solstices.
  - NGIMS has higher He data than the model at the high latitudes, better match at the mid latitudes.
- Gravity waves may not be constant
  - PEDE show a good match at the beginning of the storm, bad match as the storm continues.
  - Polar and equatorial mismatch with He bulge may indicate different circulatory schemes needed for the different regions.
- Considering revision of eddy diffusion constant for polar region particularly during large scale dust storms. Could also be a factor during regional?? Still something to investigate further
  - He data is available even at higher altitudes and will be something that can be filled in for our data gaps along with Ar.
- As always restricted by location, and being in the right place at the right time.