Joint GEM-CEDAR Workshop 2016
LTVM-01

Intermittency of Gravity Waves Momentum Flux in Airglow Imager Observations and Whole Atmosphere Community Climate Model (WACCM)

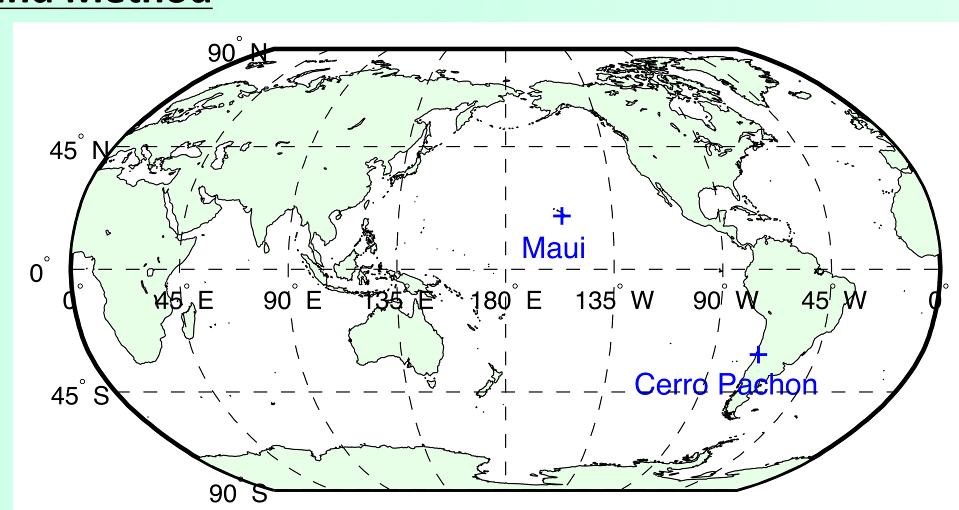
Bing Cao[1] and Alan Z. Liu[1]

1. Department of Physical Sciences, Embry-Riddle Aeronautical University

1. Introduction

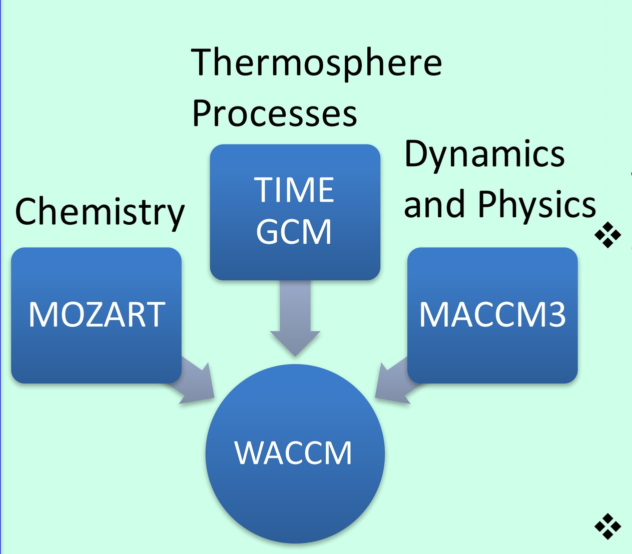
- Gravity waves with specific properties will not generally be occurring throughout the model area at all time, factors that can describe the spatial and/or temporal intermittency should be included in the model when GWs are parameterized. And this parameter is mostly tuned artificially and loosely constrained.
- In this work, multi-year airglow imager data and Whole Atmosphere Community Climate Model (WACCM) data are used to analyze the intermittent nature of gravity waves in the atmosphere. This goal is achieved by calculating and analyzing the **probability density functions** (pdfs) of gravity wave momentum-flux.
- Log-normal distribution is found in the pdfs derived from balloon, satellite, airglow imaging data and numerical simulations.
- Those rare but large waves are responsible for the intermittent nature of gravity waves and contribute a lot to the total momentum flux.
- Wave sources and background flow where the waves propagate through determine the observed intermittency.
- Comparing the intermittency of GWs from different sources can help further understand the effects of GW source parameterization on the statistical behaviors of GWs in the MLT.

2. Data and Method



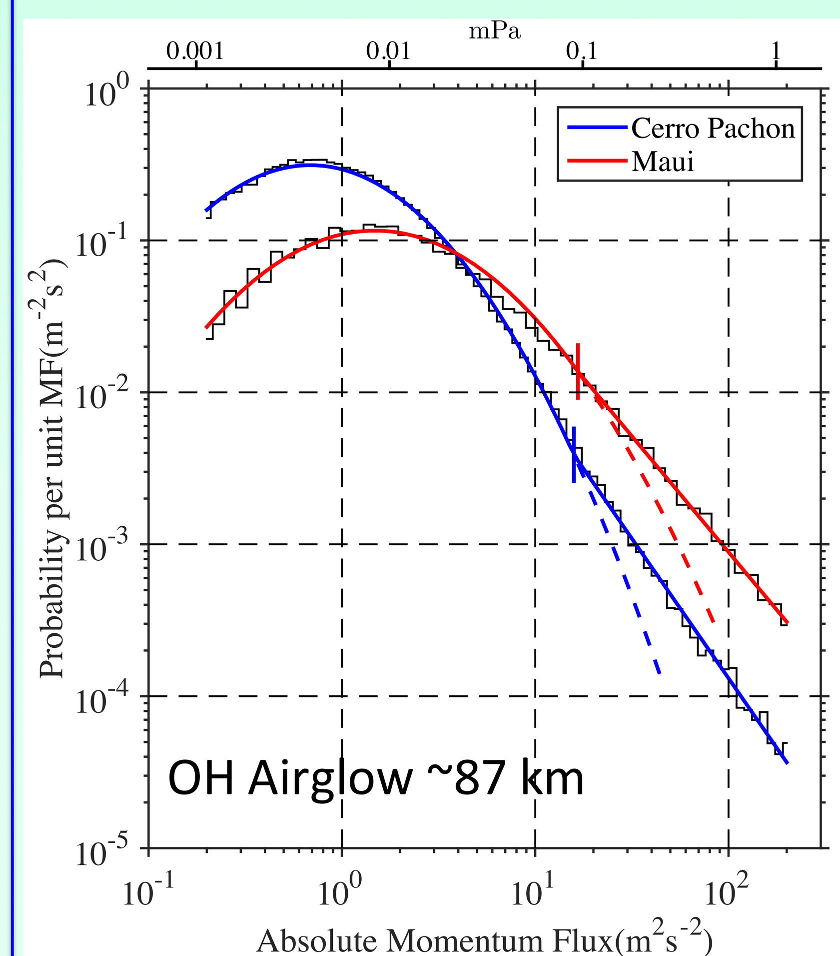
- University of Illinois at Urbana-Champaign (UIUC) OH airglow imager was deployed in Maui (20.7°N.156.3°W) from January 2002 to August 2007 and then relocated to Andes Lidar Observatory (Cerro Pachón, Chile, 30.0° S, 71.0° W) since September 2009.
- High-frequency quasi-monochromatic gravity waves are identified and wave parameters such as wavelength, period and momentum flux are derived from consecutive time-difference (TD) images.

Location	Start Date	End Date	Valid Days	Minimum Interval	Number of Measurements
Maui	2002/5/20	2007/6/13	639	6 min	19223
Cerro Phchón	2009/9/20	2014/1/13	347	3 min	60879



- The NCAR Whole Atmosphere Community Climate Model (WACCM) is a 'high-top' chemistry-climate model that covers the altitude range from the surface to the lower thermosphere (~140 km).
- A recent improvement in the GW source specification in WACCM is to replace the arbitrarily specified GW source spectrum with physically parameterized schemes for the convective source and the frontal source.
- By using the source-oriented GW parameterization in the WACCM, the wave generation becomes more realistic and self-consistent.

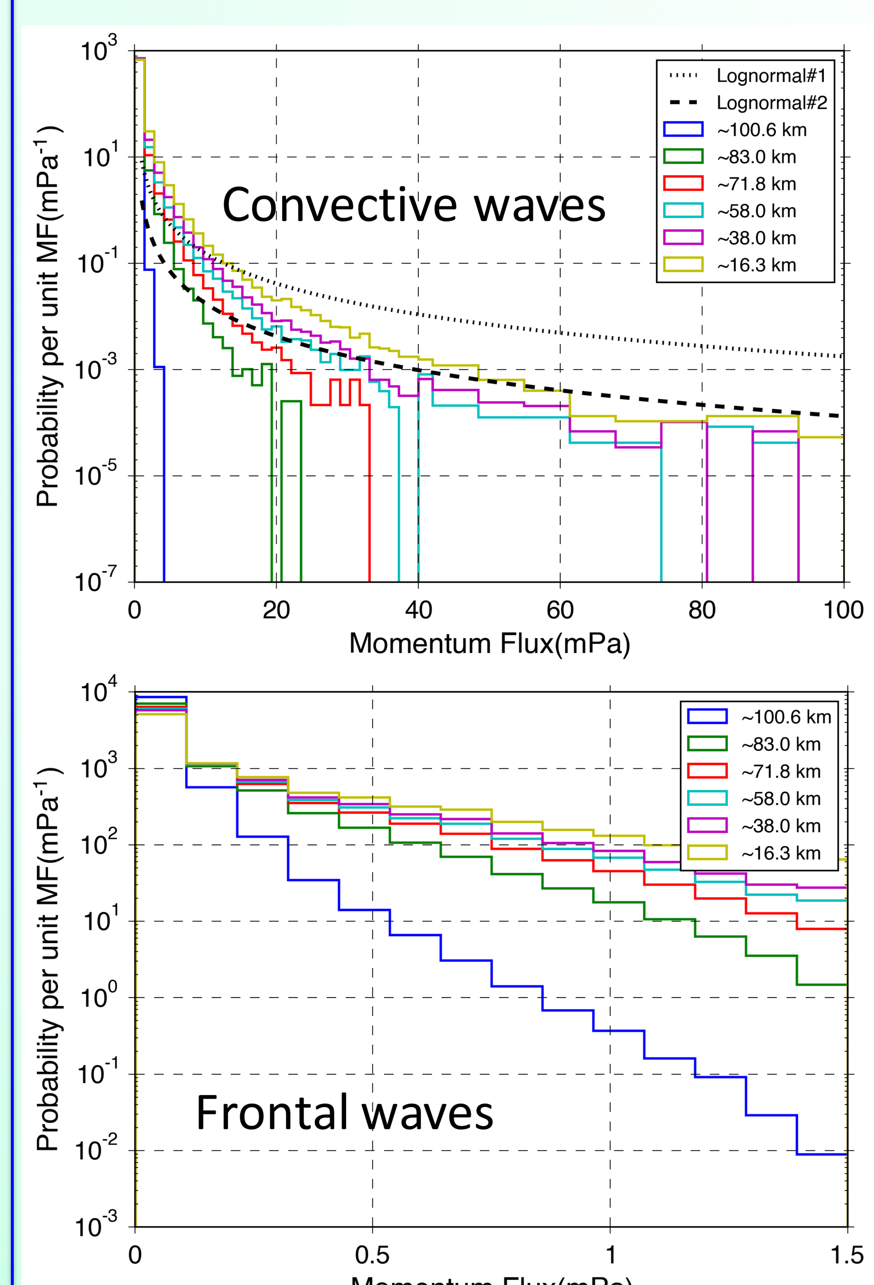
3.1 Results: Pdfs from Observations



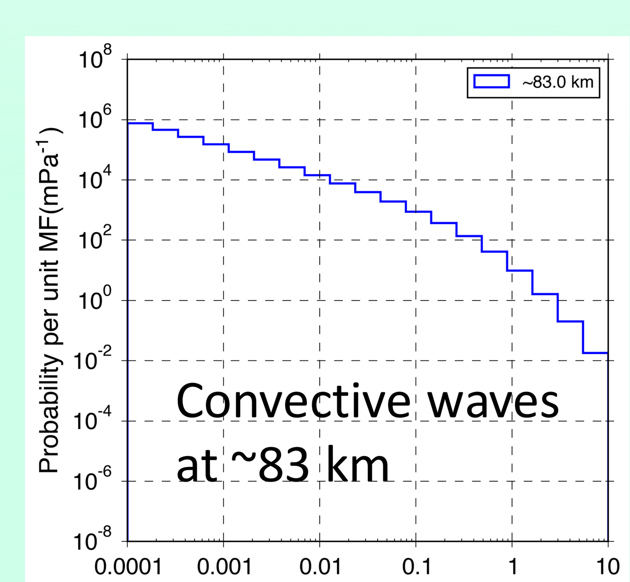
- Apparently equal width of each bin in the logarithm coordinate means wider bins (~10 m^2/s^2) in the larger end (200 m^2/s^2) of momentum flux and narrower bins (~0.1 m^2/s^2) in the smaller end (1 m^2/s^2).
- The pdfs from two sites show very similar distribution. There exists peaks around 1-2 m^2/s^2 and linear long tails in momentum flux larger than ~20 m^2/s^2.
- In pdfs, the left part (smaller magnitude) of the curves shows some symmetry and matches a parabola, which is not other thing but the **log-normal distribution** in the log-log coordinate.
- When momentum flux excesses 10~20 m^2/s^2, the pdfs derivate from parabola and board linear relation is clearly identified. This follows a **power-law distribution**.

3.2 Results: Pdfs from WACCM

- Similar pdfs are calculated for the gravity wave momentum flux data generated by running the SD-WACCM for a whole year with daily output frequency.

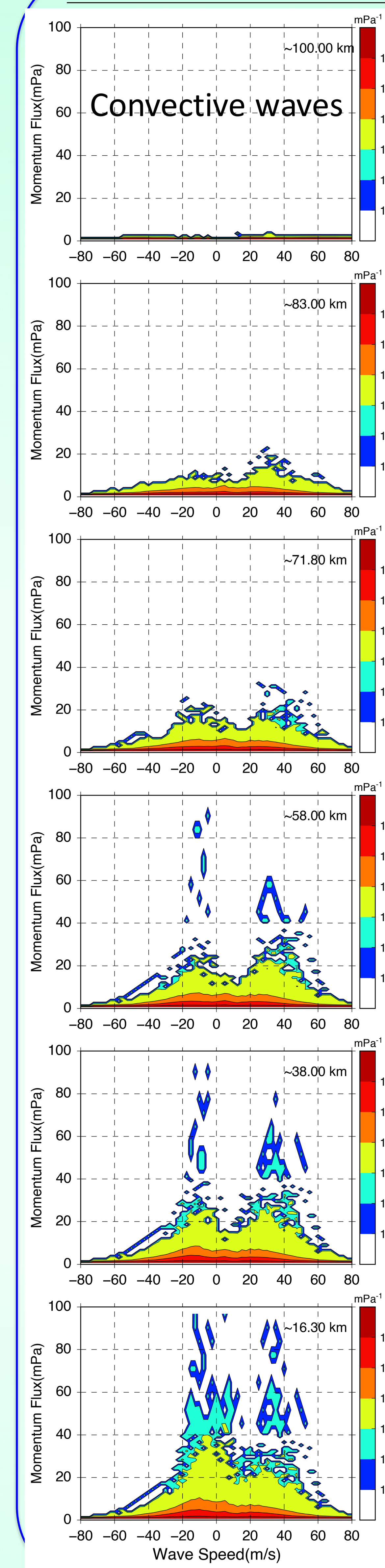


- Long tails (large but rare waves) still exists in the model. But all the pdfs seem to not follow the lognormal distribution.
- Convection-generated waves momentum flux reaches 100 mPa and long tails are clear in pdfs.*-
- Front-generated waves have momentum flux less than 1.5 mPa and pdfs tend to follow exponential distribution.
- With the increase of altitudes, more larger waves are filtered out from wave field; the shape of the pdfs becomes more sharp (concentrated near smaller waves).
- Compared with observational results, more small waves are included in the parameterization of gravity waves in model.

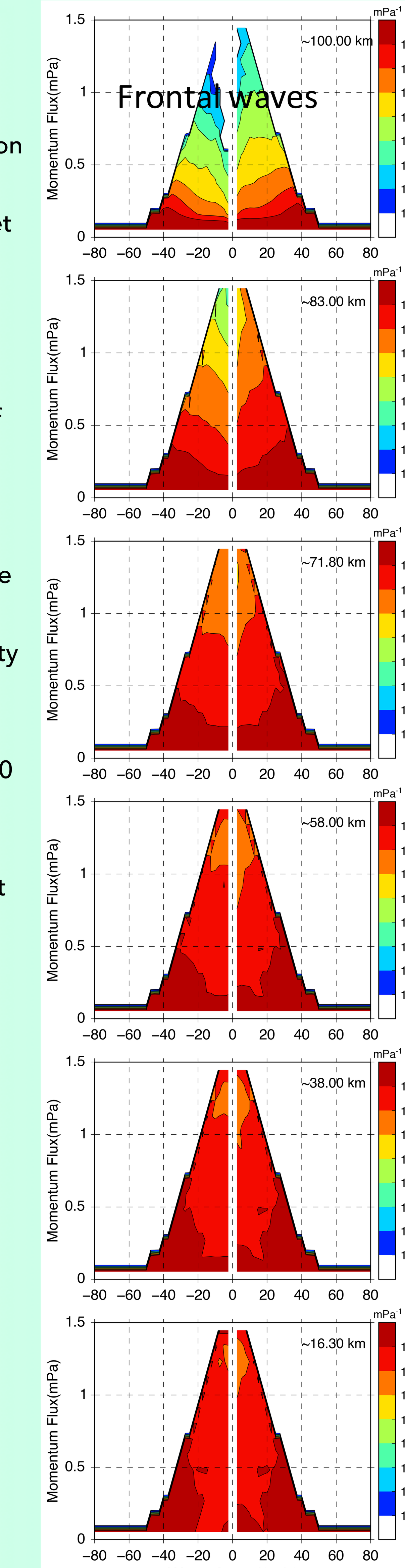


- In order to show the difference between model and observations, momentum flux near the mesopause (globally) is plotted.
- The order of magnitude is similar (~0.001-1 mPa) as observations but shape of pdf is different. More smaller waves exist in model.

3.3 Results: Pdfs w.r.t. Phase Speed



- In Lindzen's GW parameterization scheme, the wave phase speed determines where the waves get filtered out from the wave field.
- In WACCM, gravity waves are generated in the phase speed range of -80 m/s to 80 m/s. The pdfs are calculated for waves of same speed speed.
- At lower atmosphere (< 20 km), the probability distribution reflects the characteristics of the wave sources.
- For convective-generated gravity waves, the distribution is not symmetric in positive/negative phase speed, with peaks near 40 m/s and -20 m/s.
- For frontal-generated gravity waves, the distribution is almost symmetric with peaks near .
- As the increase of altitude, the pdfs of all wave components become more concentrated at smaller waves.



4. Discussion and Conclusion

- The statistical properties studied here are not limited to the traditional mean and standard deviations, rather on the detailed pdfs of GW properties and how they are affected by other factors.
- The pdfs show similar patterns in the observations of two different sites. Log-normal and power-law distribution are found in small and large momentum flux magnitudes, the transition between them is close.
- The observed intermittency is reproduced in WACCM to a certain extent. The pdfs derived from WACCM still show some lognormal-like shape with long tails in larger end, but do not satisfy the log-normal distribution fairly enough to be fitted and overestimate the smaller waves.
- The observed intermittency of gravity waves is believed to be related to the wave exciting sources as well as the background. Slight variations exist among the pdfs below ~60 km and pdfs start varying a lot above ~60 km, which indicate that the wave dissipation is strongest there.
- Limitation exists since wave is only launched along/against the source wind direction, which is oversimplified. Orographic-generated waves need to be studied.

Acknowledgements • This work is supported by NSF grants AGS-1115249 and AGS-1110199.

caob@my.erau.edu Bing Cao

CEDAR WORKSHOP, June 19-24, 2016