Seasonal and Vertical Trends of Gravity Wave Potential Energy Density Measured by Lidar at McMurdo, Antarctica

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Background and Goals

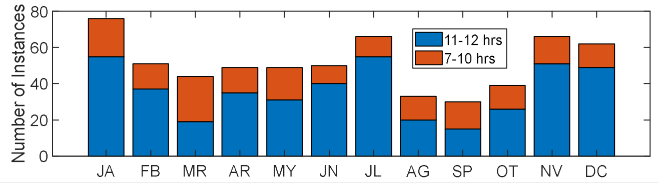
Since 2011, the Chu Lidar group has observed gravity waves (GW) in the middle-upper atmosphere over McMurdo, Antarctica, amassing thousands of hours of observations.

Potential Energy Density (Epm) is a measurement of the energy carried by a GW and can be used to assess its role in global transport. Knowing exactly how they play this role is crucial to modeling efforts.

Why study Antarctic gravity wave Epm with lidar?

- Lidar allows for high-time/alt resolution monitoring of GW.
- Using Epm to calculate wave drag can improve GW parametrization in GCMs, a known source of error.
- Observations of wave attenuation/growth will further our understanding of secondary wave generation, improving our picture of GW's role in vertical coupling.

Data and Run Length Distribution



Epm Calculation

This study utilizes the Interleaved Method (Gardner & Chu 2020).

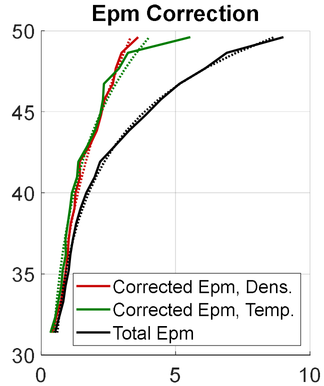
(1) Eq. 1 is the basic equation to find Epm.

(2) Eq. 2 shows the variance term relies on wave *and* noise-induced variance.

(3) Interleaved method: replace Var in (1) with the Covariance of samples derived from adjacent photon-count bins. Noncorrelation in the second term drives it towards zero.

The interleaved method is demonstrated on lidar data of both temperature and density, which generally agree ("Epm Correction").

- g: gravity
- N^2: Brunt–Väisäla Frequency
- $r(z,t)$: atmo. param. that varies with waves
- r': wave perturbation, Δr: noise perturbation
- r_A, r_B: atmo. params. from adjacent photon bins



Equations for Epm Calculation

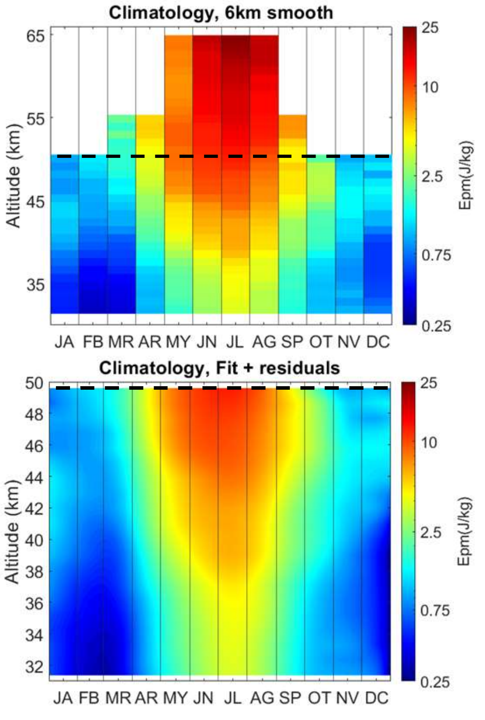
$$Epm_{Tot}(z) = \frac{1}{2}\frac{g^2}{N^2} Var[r(z,t)] \quad (1)$$

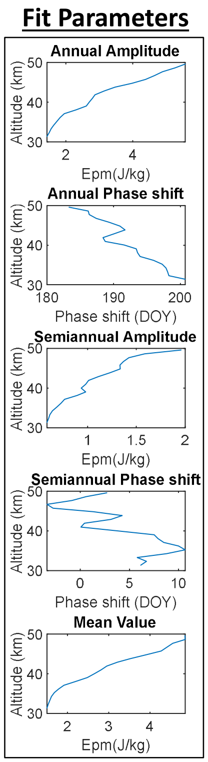
$$Var(r) = Var(r') + Var(\Delta r) \quad (2)$$

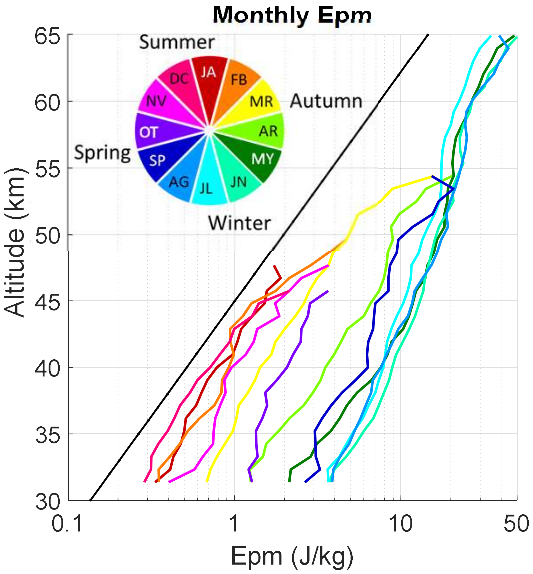
$$Cov(r_A, r_B) = Cov(r'_A, r'_B) + \quad (3)$$

~~$Cov(\Delta r_A, \Delta r_B)$~~

Epm Results







Processes and Conclusions

Process:

1. Climatology is developed from 10 years of monthly Epm averages with 6km moving median smoothing applied.
2. Fit is developed at each altitude for lowest 50km using equation (4) and subtracted from climatology. These residuals were smoothed by a 30-day FWHM Hamming window and added back to the fit (reincorporating a weak terannual signal).

$$A_0 + A_1 cos((\frac{2\pi}{365}(DOY - \phi_1)) + A_2 cos((\frac{2\pi}{365/2}(DOY - \phi_2))$$

3. A composite line plot is made ("Monthly Epm" showing each month's 6 km- smoothed median value over all the data.
4. Shown in black is the GW growth rate limit under nonattenuating conditions with no in-frame wave sources. The slope of this line can be used to compared against the Epm mean slopes to look for attenuation/energy addition.

Conclusions:

- The climatology confirms previously found results that wave energy is higher in the winter than the summer, with a max (min) in July (late February).
- The phase of these extrema shift earlier in DOY with altitude.
- Climatology is dominated by a strong annual phase, with a weak semiannual phase peaking in midsummer.
- Winter data appears to attenuate more strongly than summer, with summer showing little attenuation.
- No plots here show any wave sources within the range, as all the Epm growth rates here are equal or less than the limit.

Next Steps

- Further refine Epm derivation methods to concretely identify attenuation regions and establish their connection with secondary wave generation.
- Conduct similar study of mesosphere-lower-thermosphere region using metal measurements from the Fe Boltzmann and Na Doppler lidar.
- Establish vertical trends between the lower and upper regions from ~30km to ~110km to trace evolution of gravity waves.
- Derive wave drag values from the energy measurements here and apply them to improve GW parametrization in GCMs.