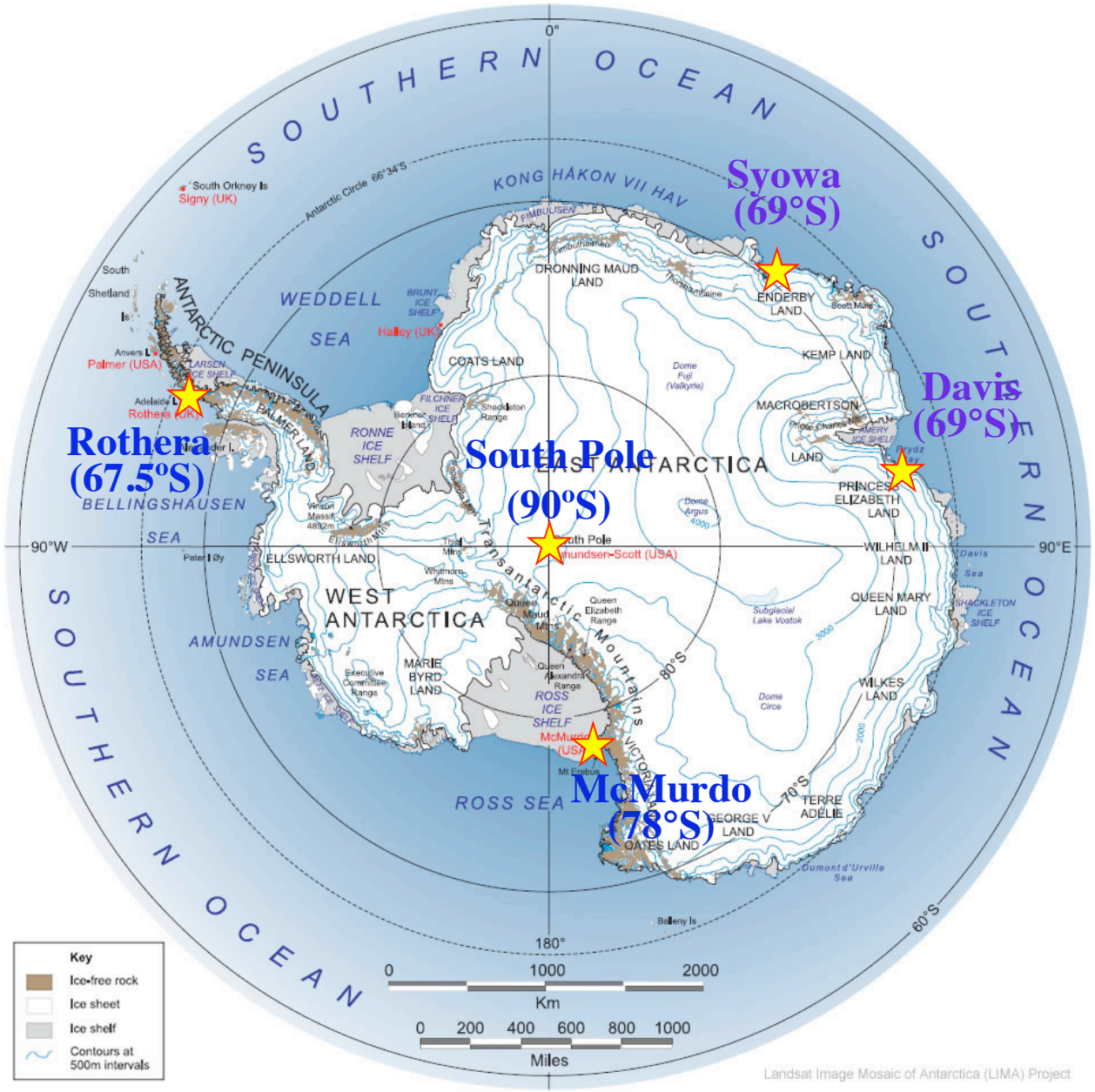
AGU Chapman Conference @ Honolulu, Feb. 28th, 2011

Characteristics of Gravity Waves in the Lower Atmosphere and Their Long-Term Variations at the South Pole and McMurdo

Zhibin Yu[1], Xinzhao Chu[1], Adrian McDonald[2], Chester S. Gardner[3], and Chihoko Yamashita[1,4]

[1]University of Colorado at Boulder
[2]University of Canterbury
[3]University of Illinois at Urbana-Champaign
[4]National Center for Atmospheric Research

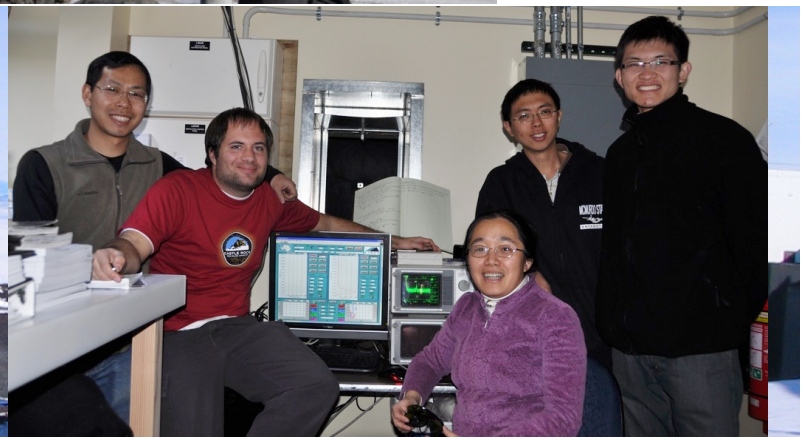
South Pole and McMurdo (78°S), Antarctica



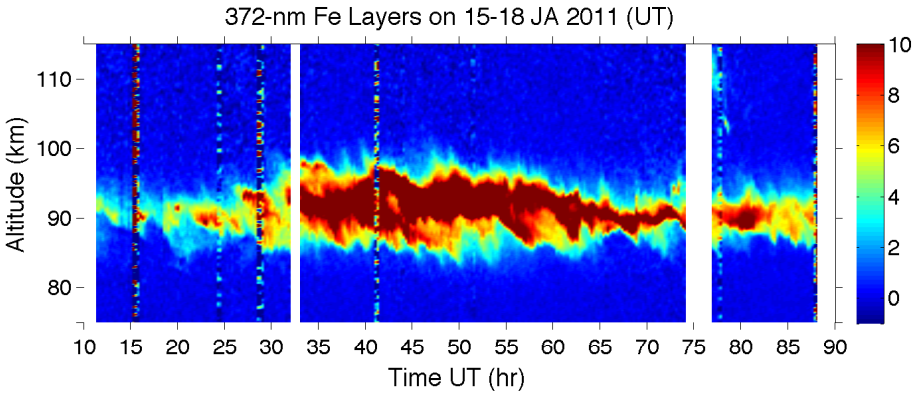
McMurdo Lidar Campaign (since Dec 2010)

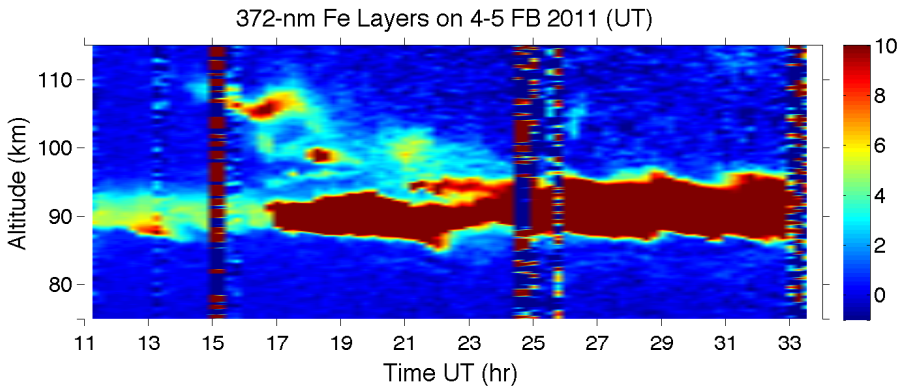


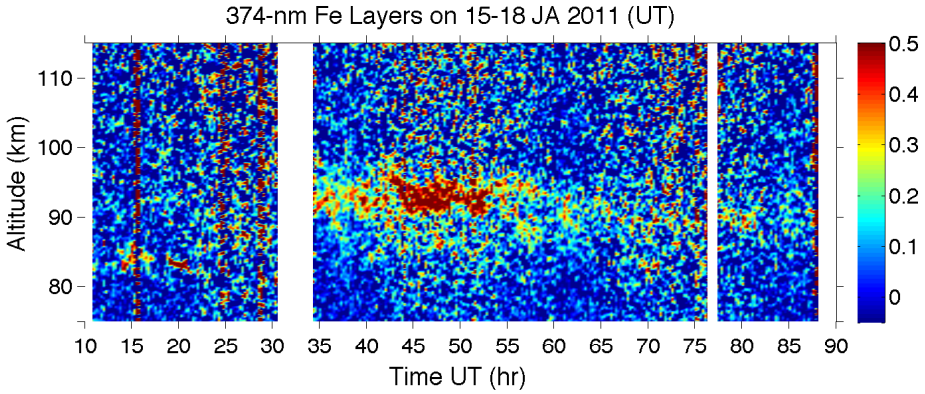


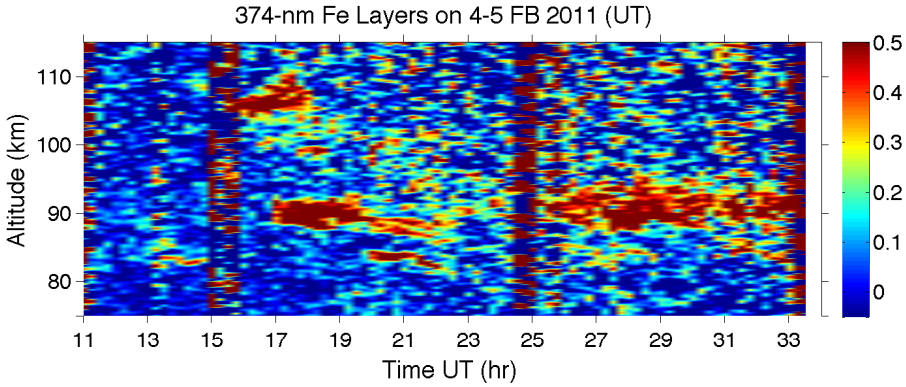


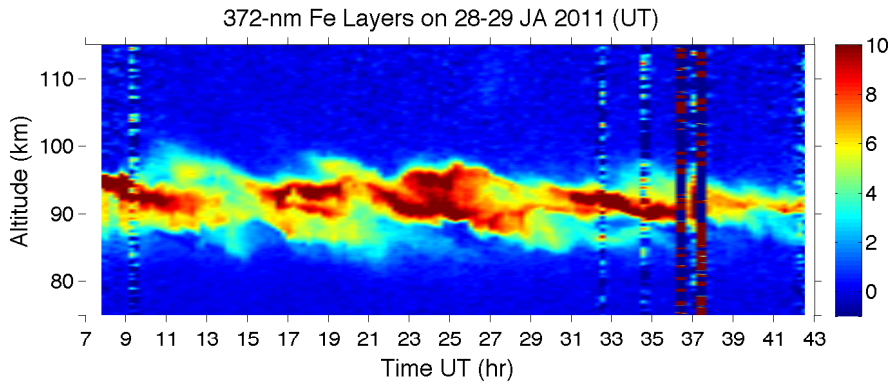
First Season Data – Exciting Results!

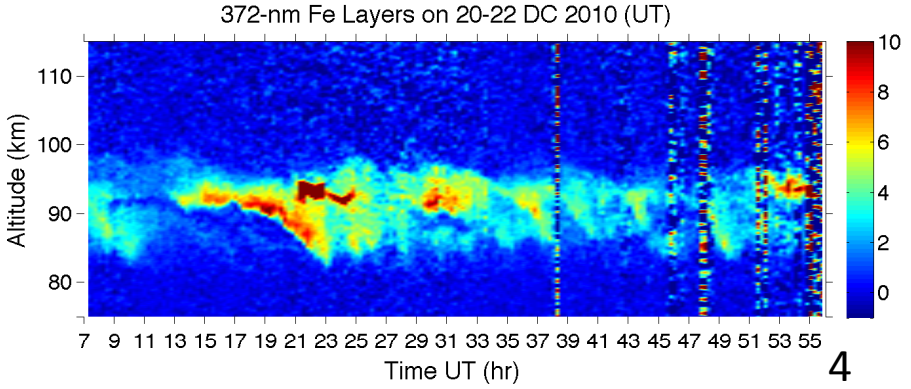












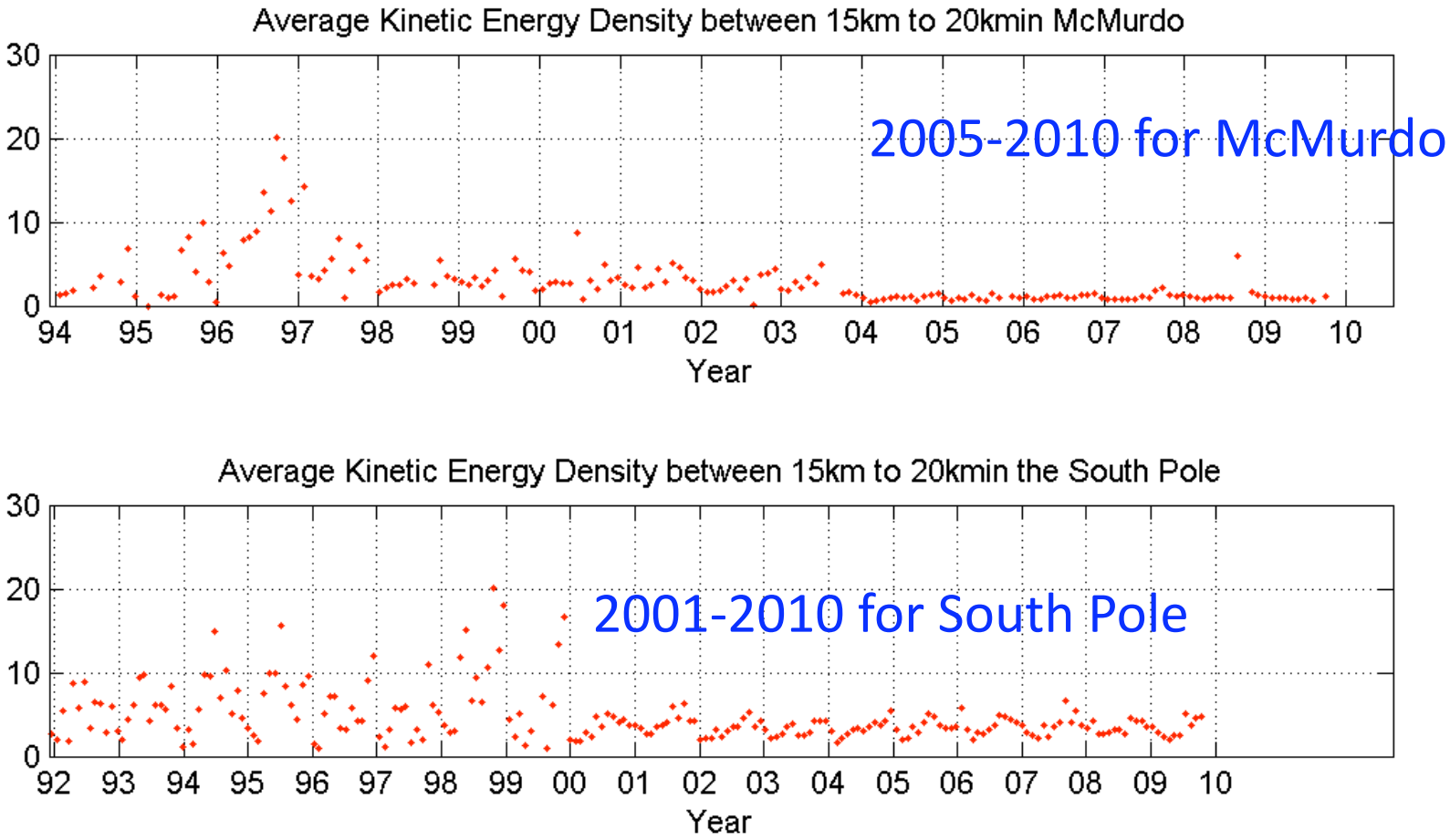
McMurdo Winter-Over Scientist



Zhibin Yu – PhD Student of CU-Boulder

1st Winter-over Scientist at McMurdo, Antarctica in the last 22 years

Balloon Radiosonde Data – Quality vs. Year



The much larger kinetic energy density before 2000 is likely due to the old tracking technique which was not as accurate as the GPS technology employed since 2000.

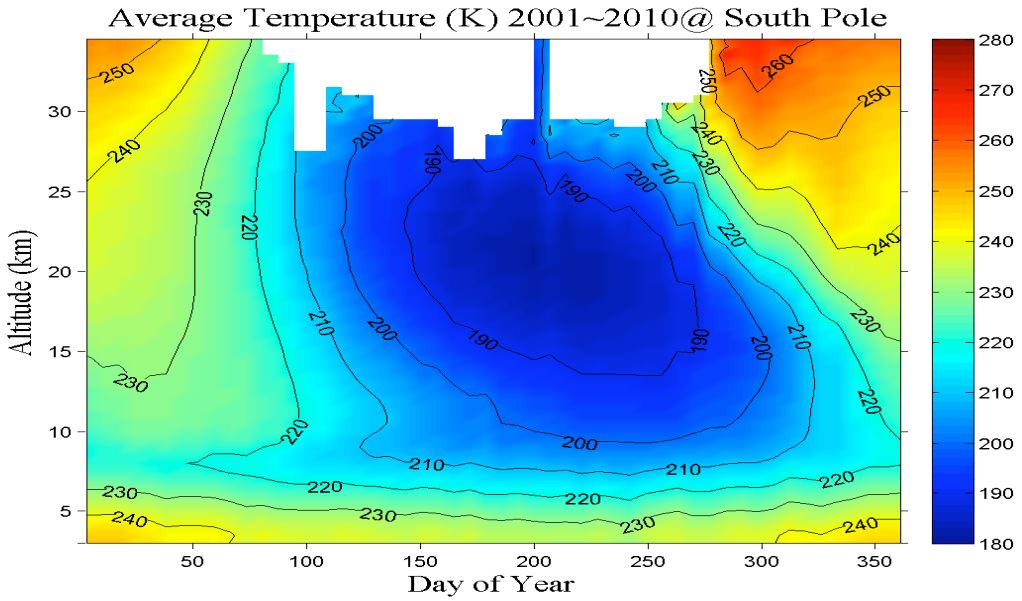
Background - Mean Temperature @ SP & MCM

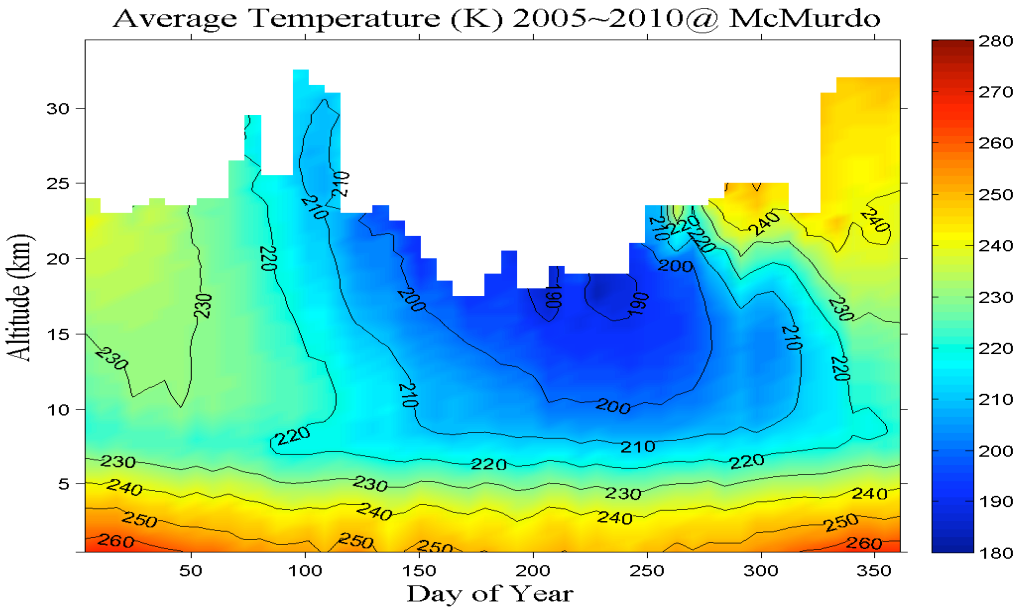
Radiosonde data used –

(2001-2010) for South Pole

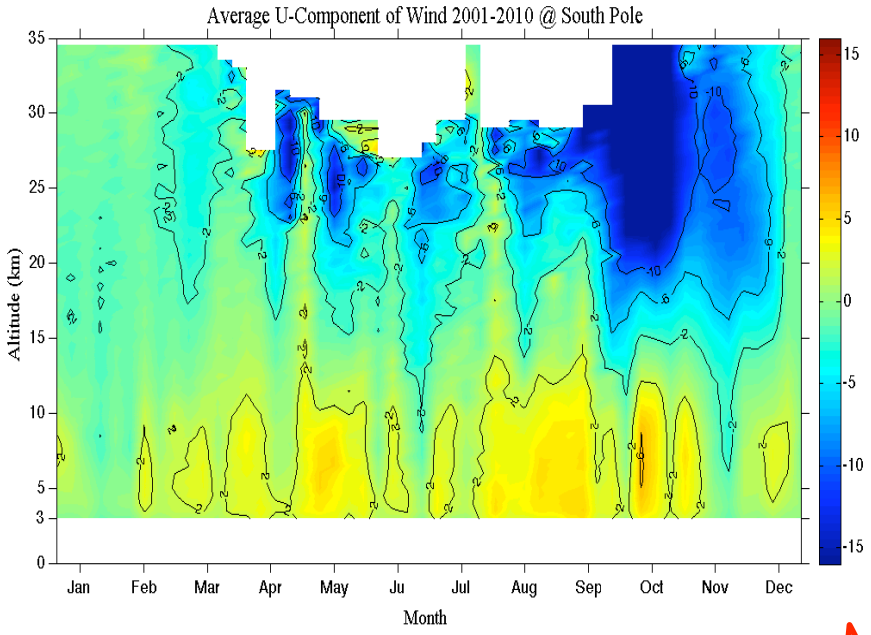
(2005-2010) for McMurdo

Binning raw data to a
1 week X 500 m grid, and
then take means.

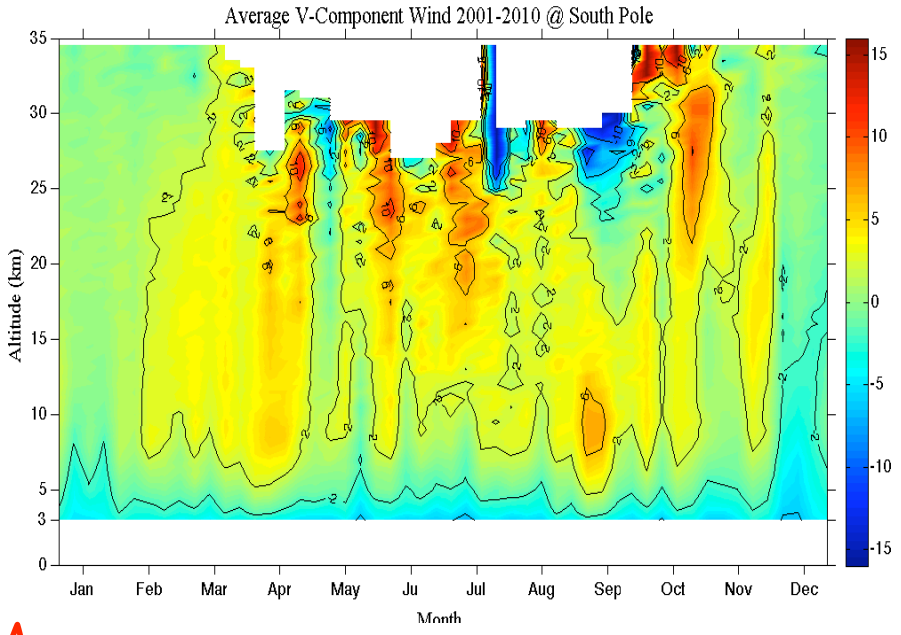




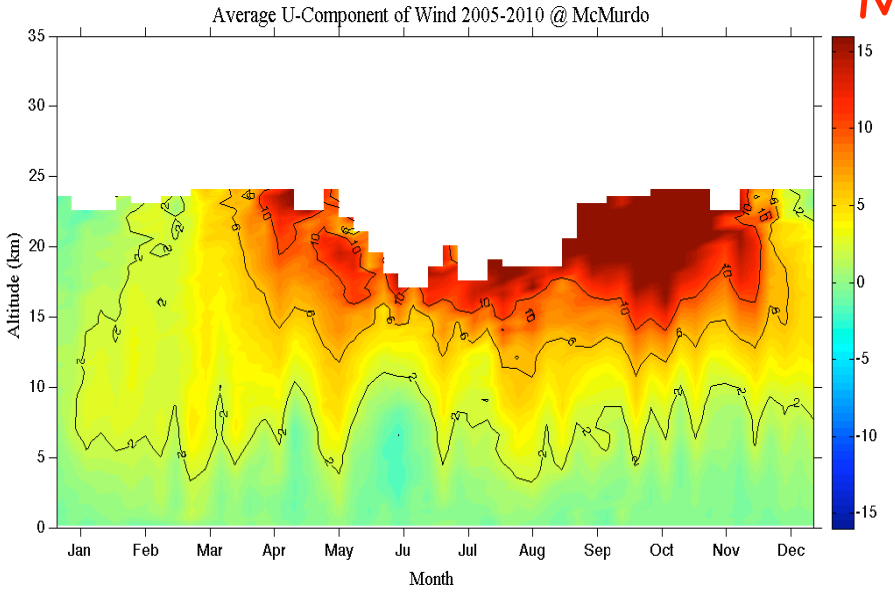
Mean Wind at South Pole and McMurdo

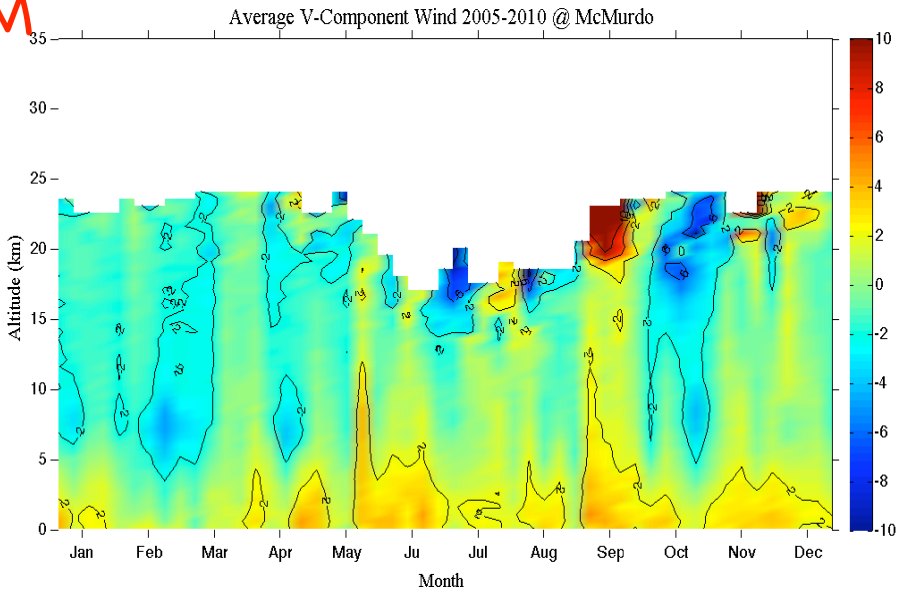


SP



MCM





Gravity Wave Energy Densities & Ratio

Data Analysis methods followed [Pfenninger et al., JGR, 1999] and [Allen and Vincent, JGR, 1995].

The potential energy density (PED) and kinetic energy density (KED), computed by Eq. 1, are obtained from the temperature and wind perturbations.

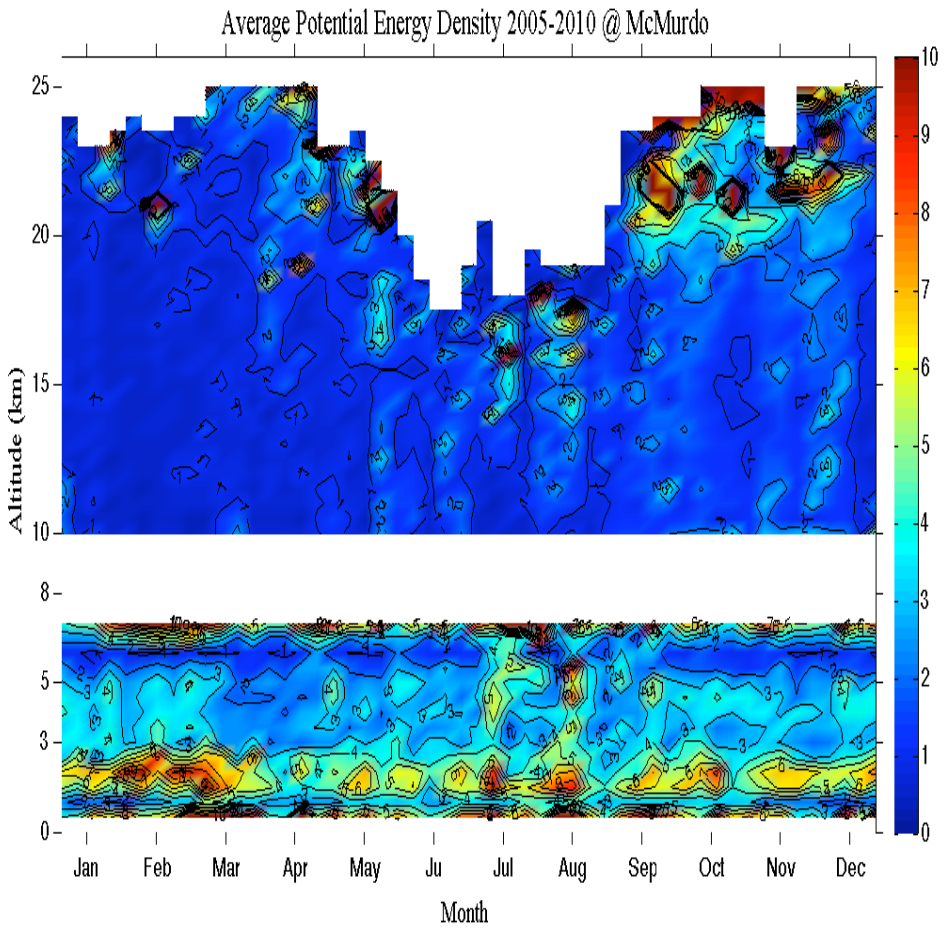
Eq. 1
$$\begin{cases} PE = \dfrac{g^2 \overline{\left(T' / T_0\right)^2}}{2N_0^2} \\ KE = \dfrac{1}{2}\left(\overline{u'^2} + \overline{v'^2}\right) \end{cases}$$

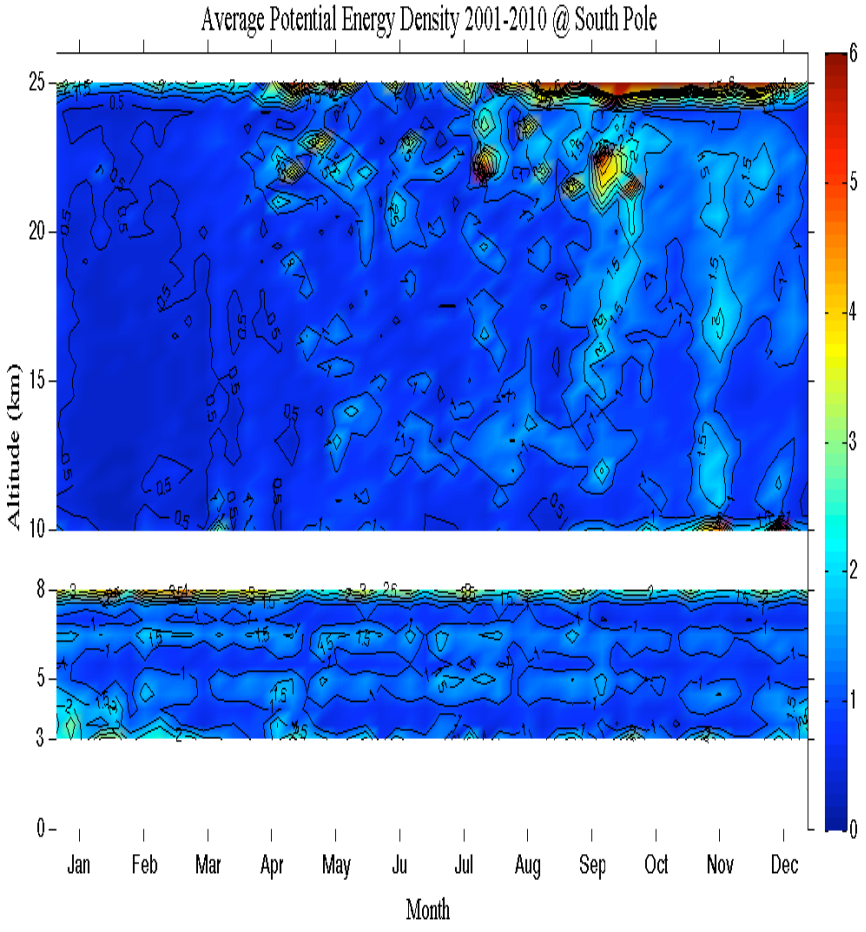
Where g is gravity acceleration constant , N_0 is the buoyancy frequency, T_0 is background temperature, T' is temperature perturbation, u' and v' are the zonal and meridional wind perturbations.

Eq. 2
$$N_0^2 = g \frac{\partial \ln \overline{\theta}}{\partial z}$$

Where g is gravity acceleration constant , $\overline{\theta}$ is the mean potential temperature.

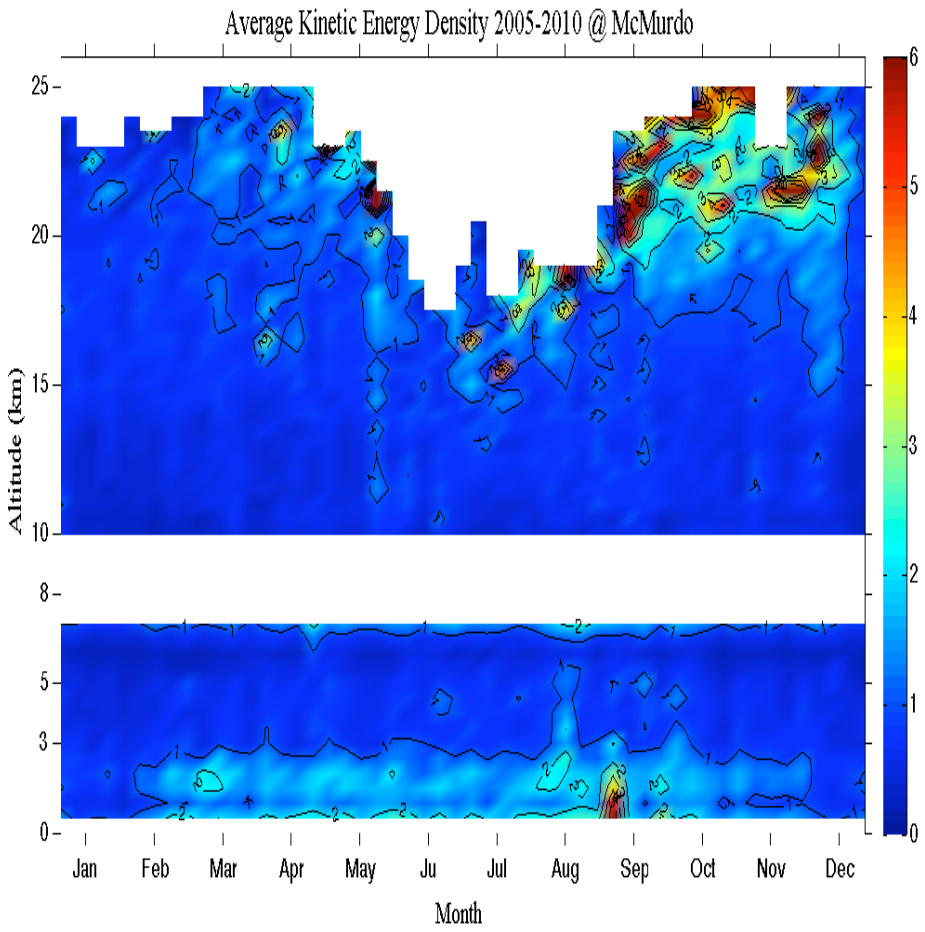
Comparison of Potential Energy Density

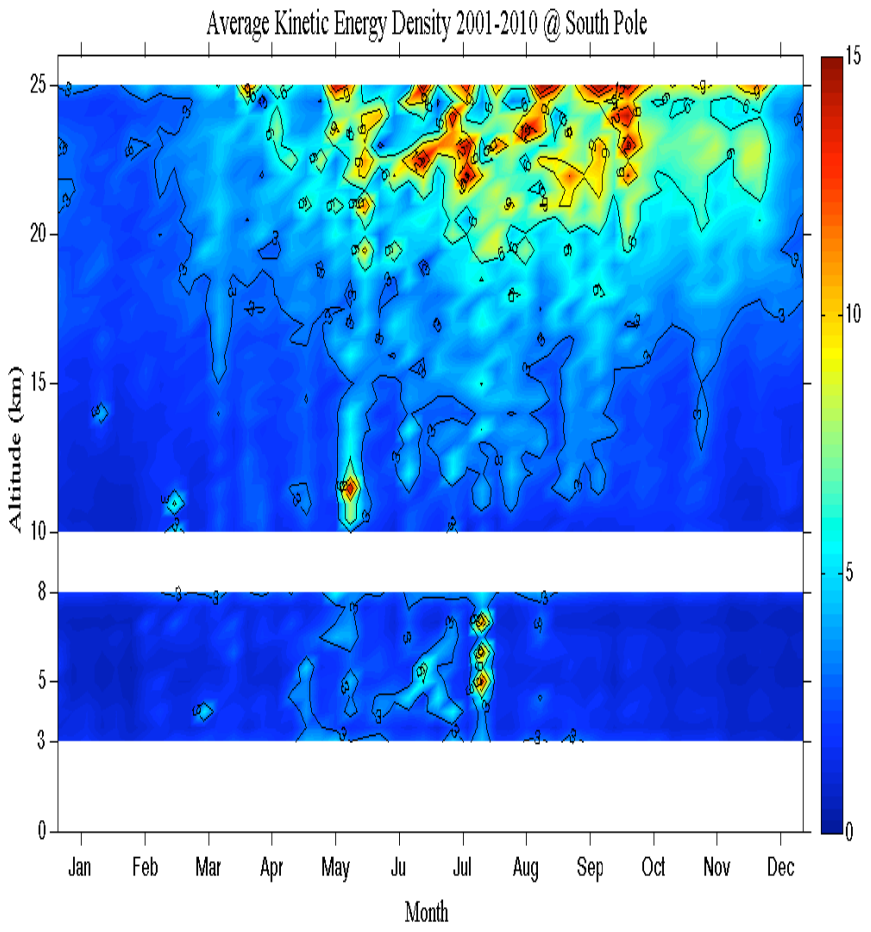




Strato & Tropo E_p: McMurdo > South Pole

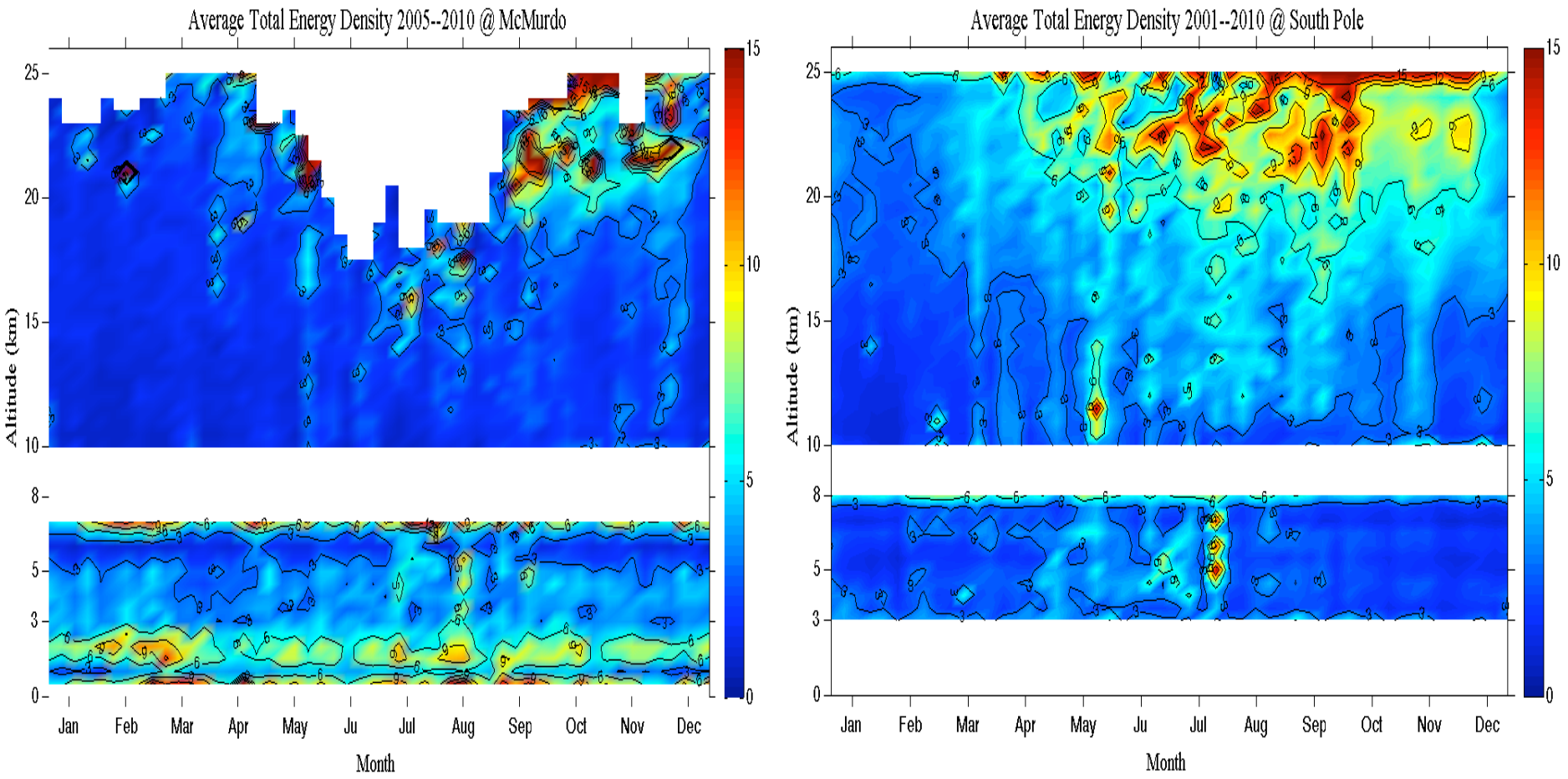
Comparison of Kinetic Energy Density





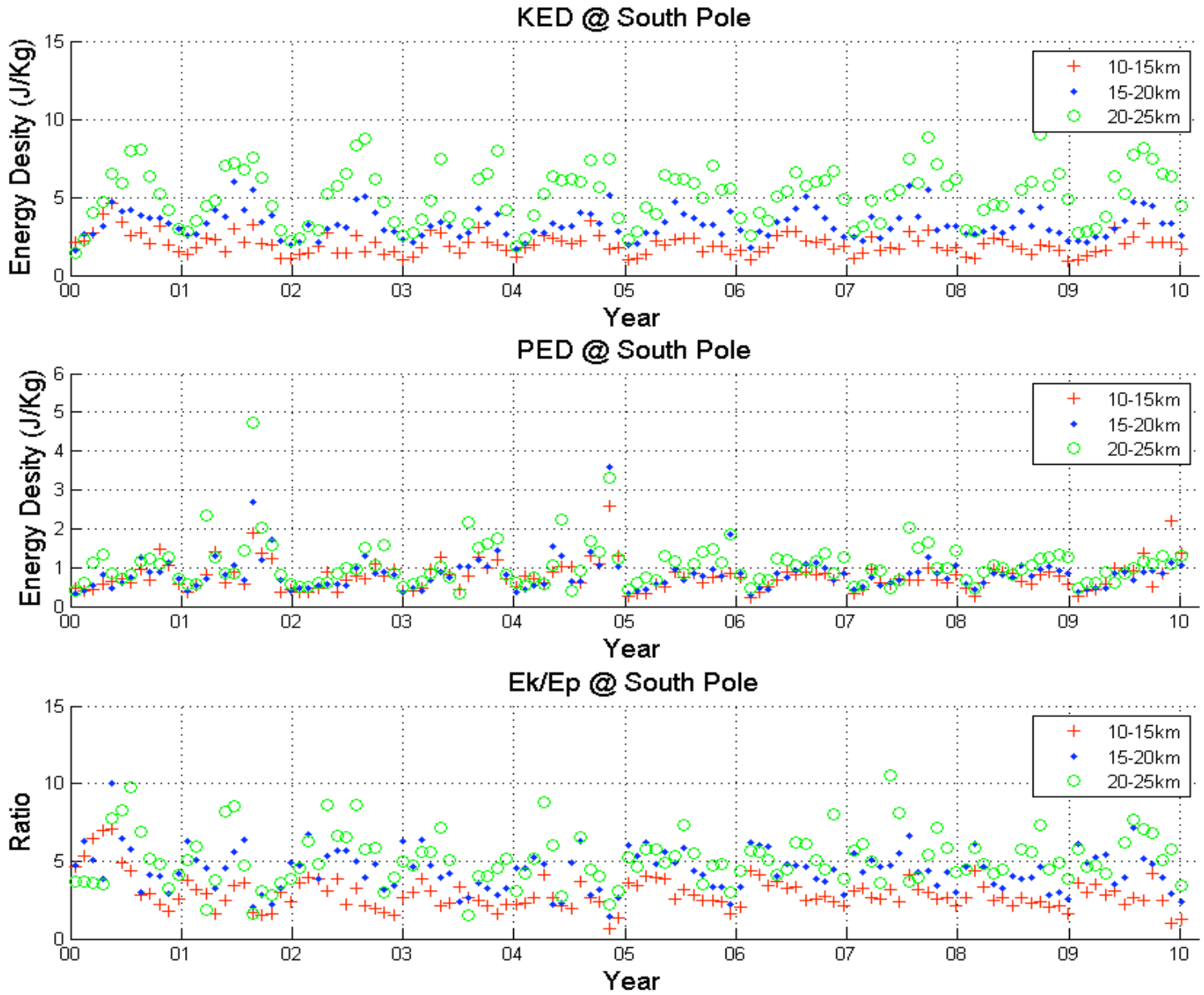
Stratosphere E_k: McMurdo < South Pole

Comparison of Total Energy Density

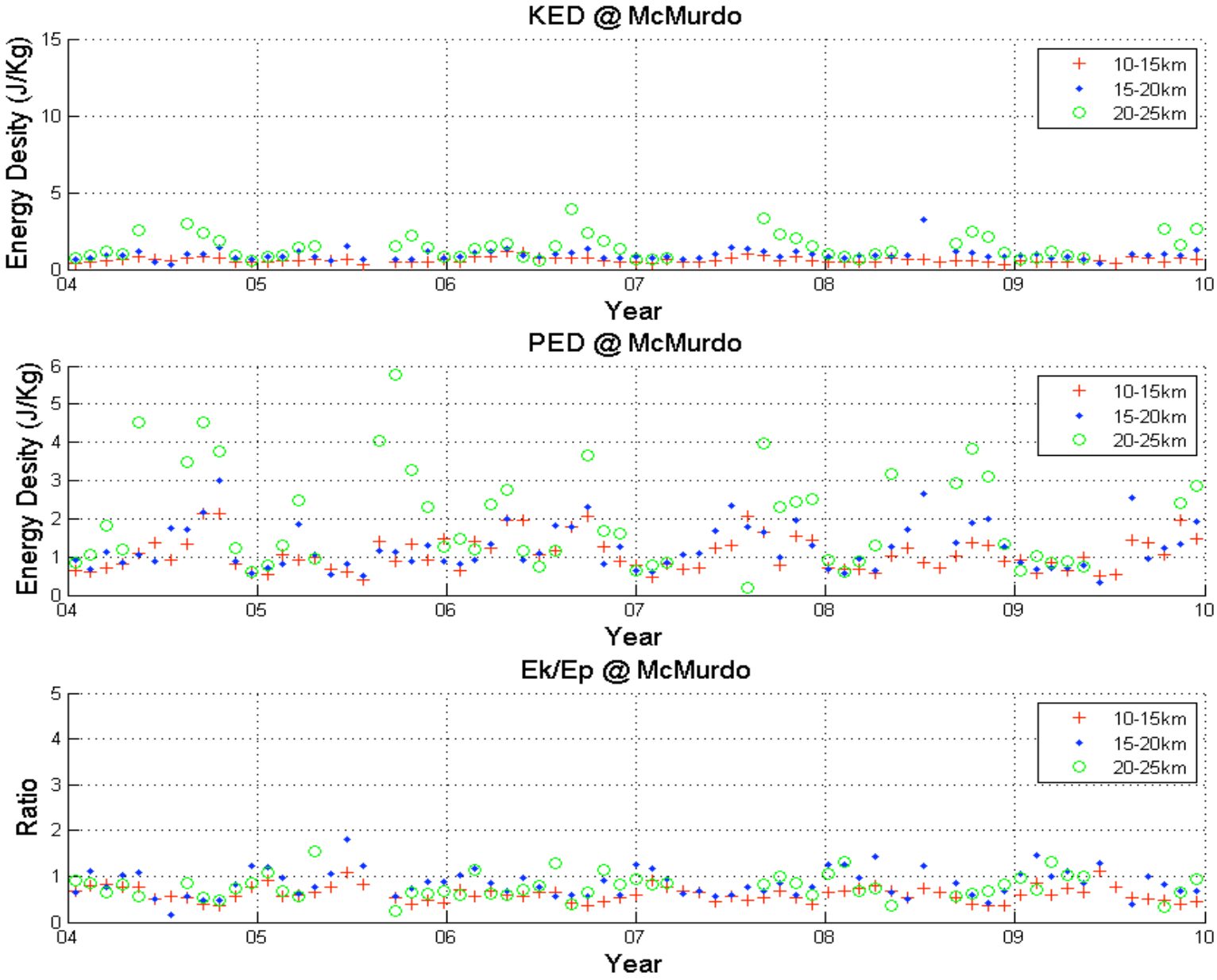


Stratosphere E_{total}: McMurdo < South Pole

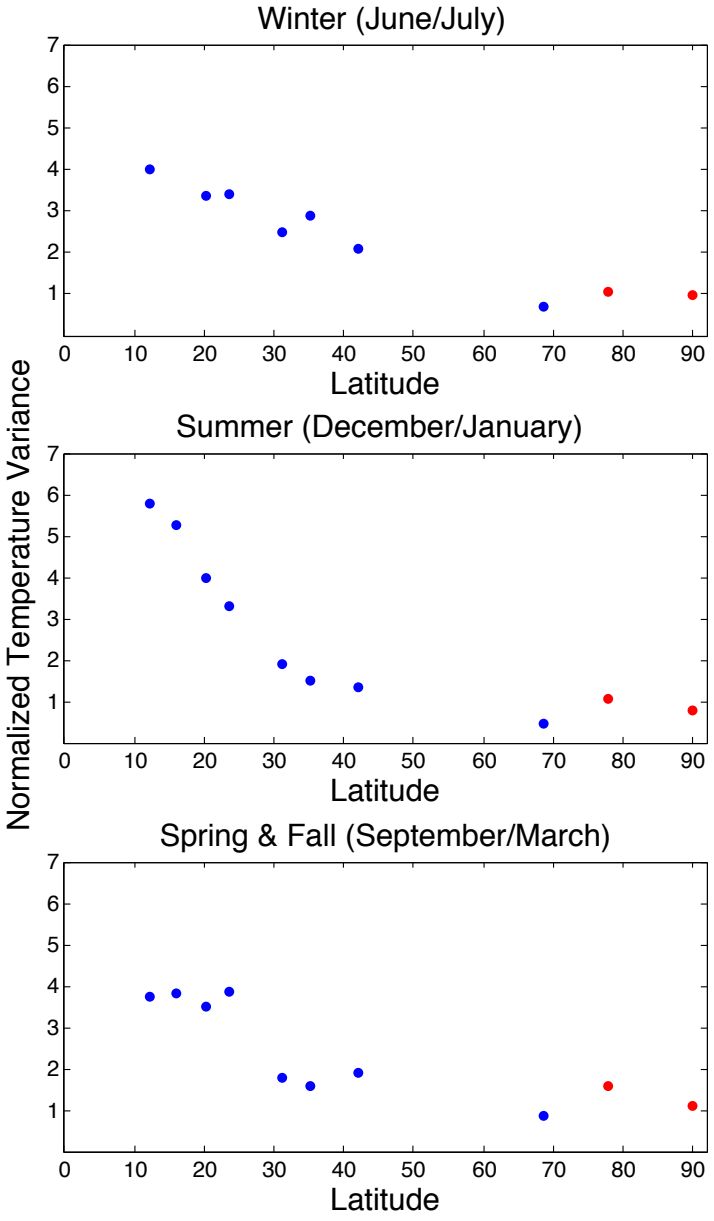
South Pole: E_K, E_P, and E_K/E_P (2001-2010)

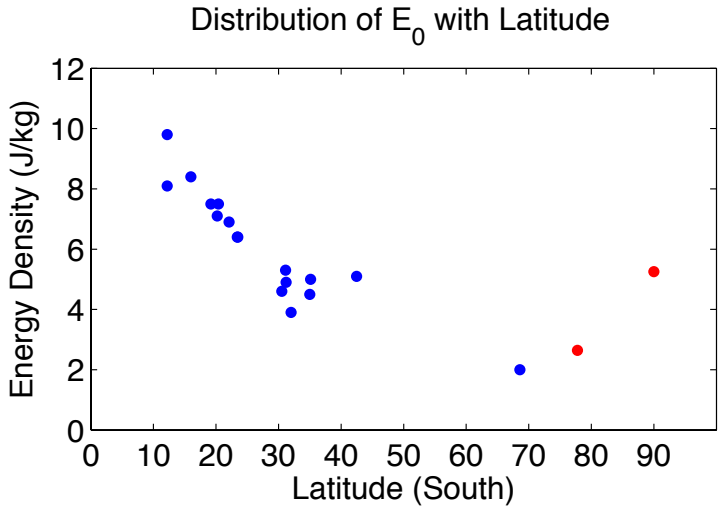


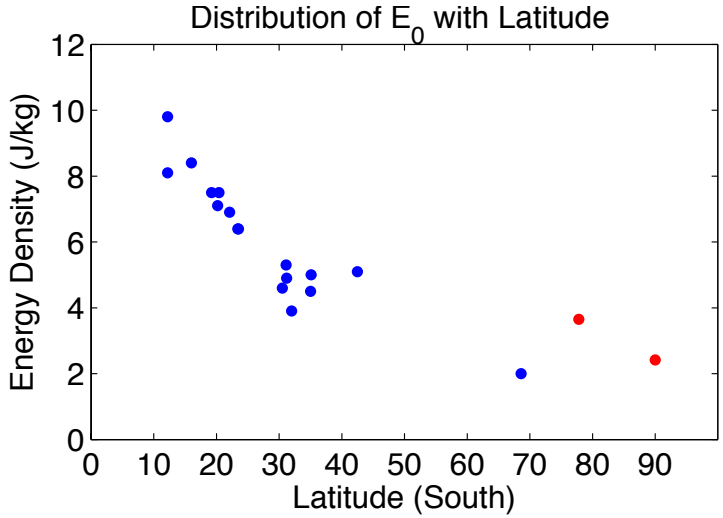
McMurdo: E_K, E_P, and E_K/E_P (2005-2010)



Latitudinal Dependence of GW Energy Density



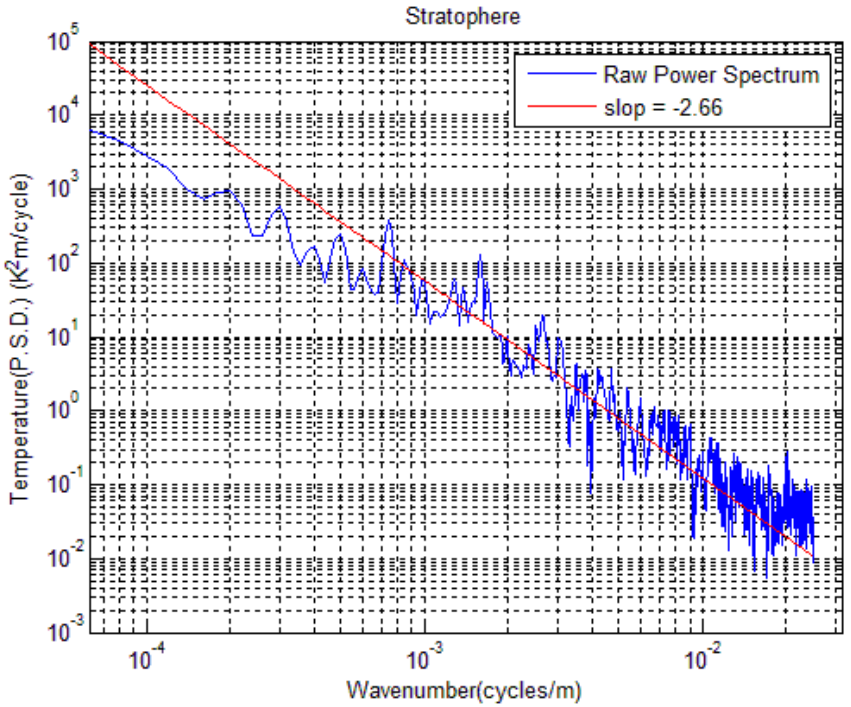




Yearly-mean GW total energy density vs. latitude (17.0 to 24.0 km). Blue points are taken from [*Allen and Vincent, 1995*].

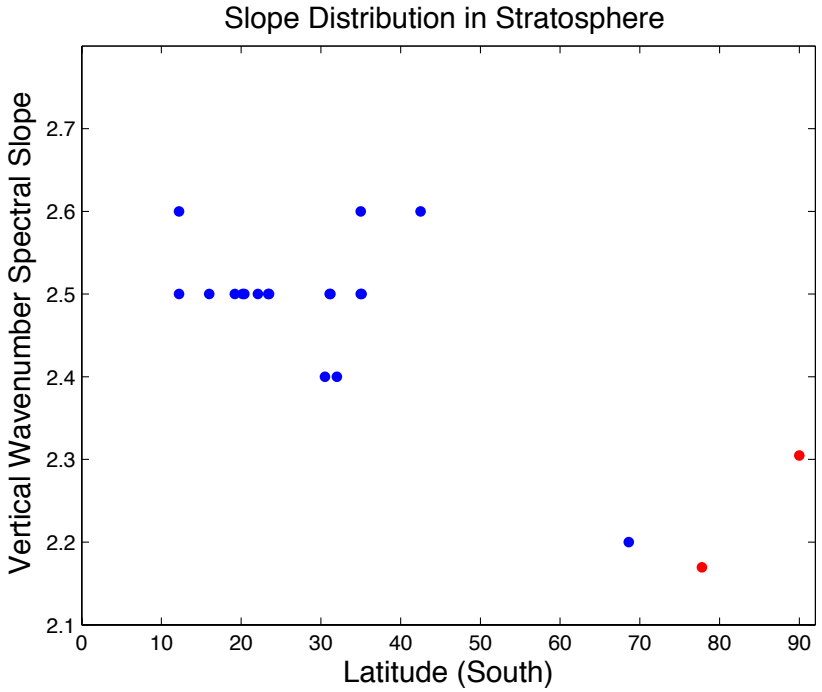
Vertical Wavenumber Spectra of Temperature Perturbations

- The vertical wavenumber spectrum indicates the characteristics of the distribution of gravity wave energy as a function of vertical wavelength.
- The South Pole radiosonde data have a relatively large vertical extent, usually reaching above 30 km in the austral summer. High-resolution temperature data at the South Pole span over 18 years.
- The spectral analysis techniques are based on the methodology described in [*Dewan and Grossbard, 2000*].



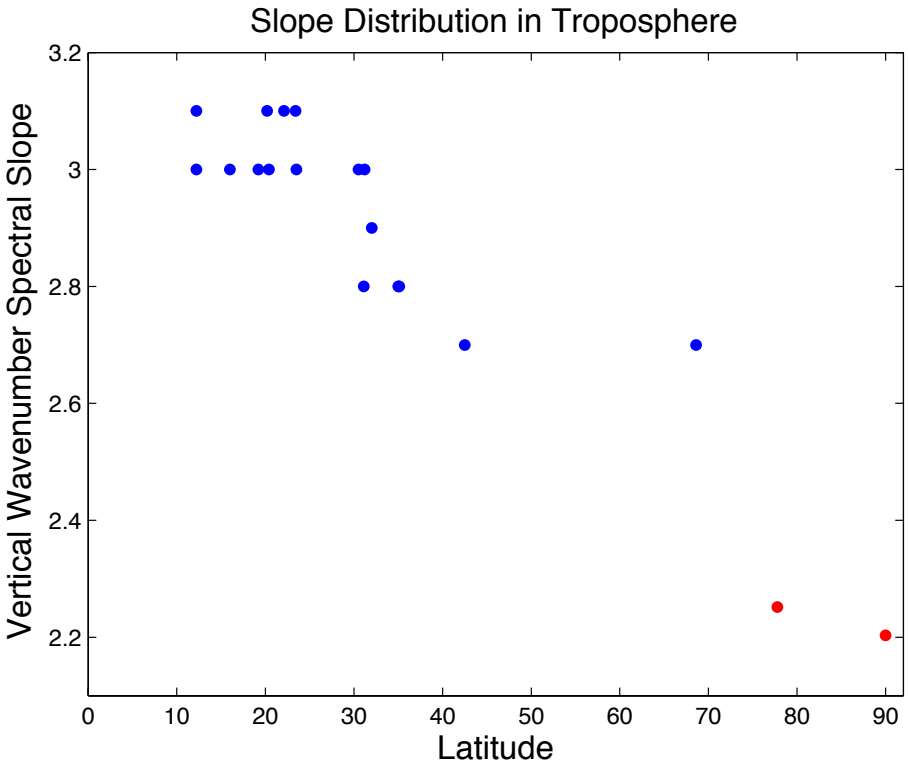
Sample power spectrum in stratosphere over the South Pole on Jan. 4th, 1993. The red line is linear fitting to the raw power spectrum in log scale.

Latitudinal Dependence of Vertical Wavenumber Spectral Slope of Temperature Perturbation

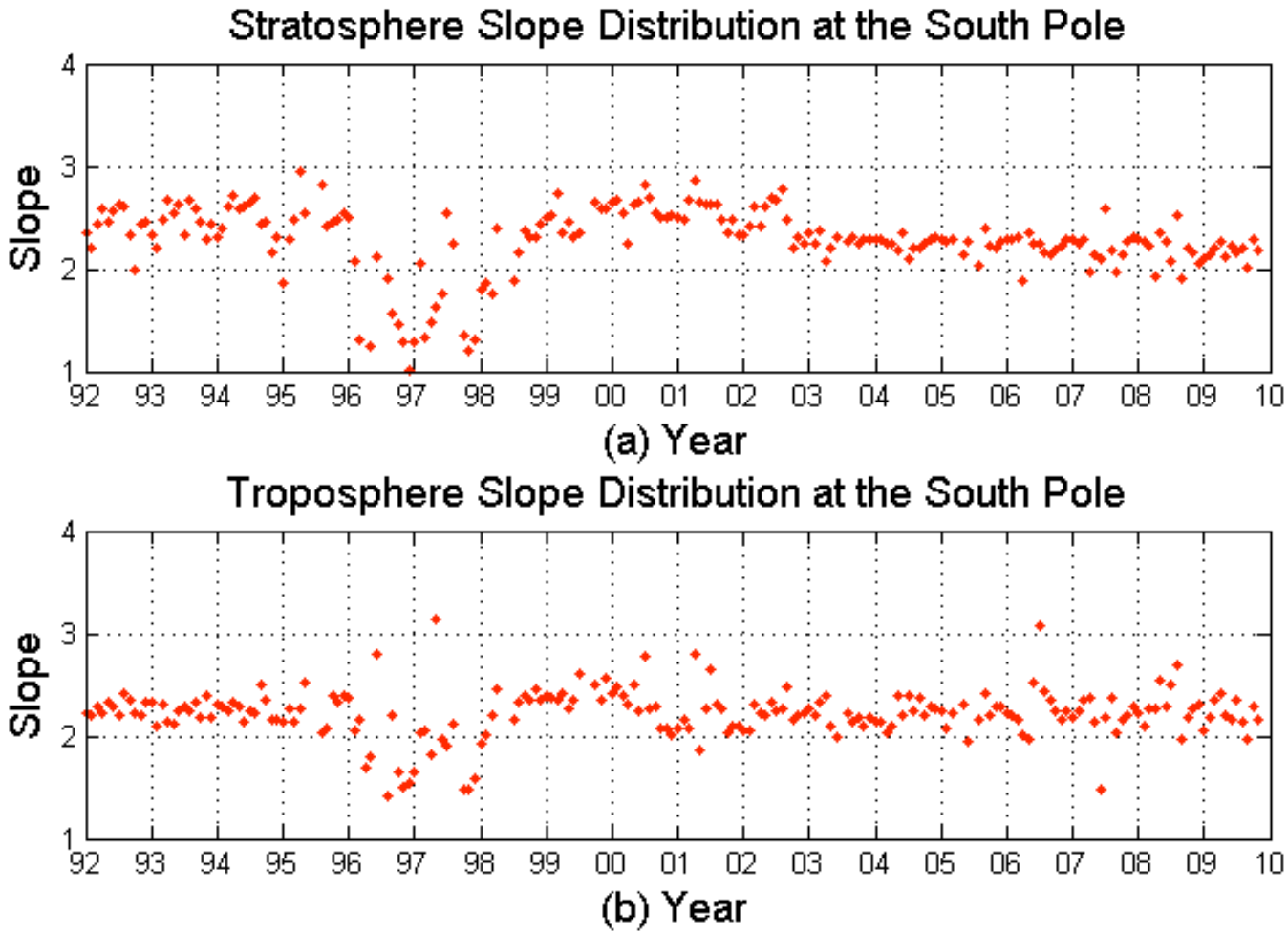


The mean slopes in stratosphere over McMurdo and the South Pole are much smaller than the theoretical value of -3 predicted by theoretical models, and smaller than the low and middle latitude regions [*Allen and Vincent, 1995*].

In our definition, stratosphere at the South Pole is above 10 km, and the troposphere is from 3 km to 8 km above the sea level.

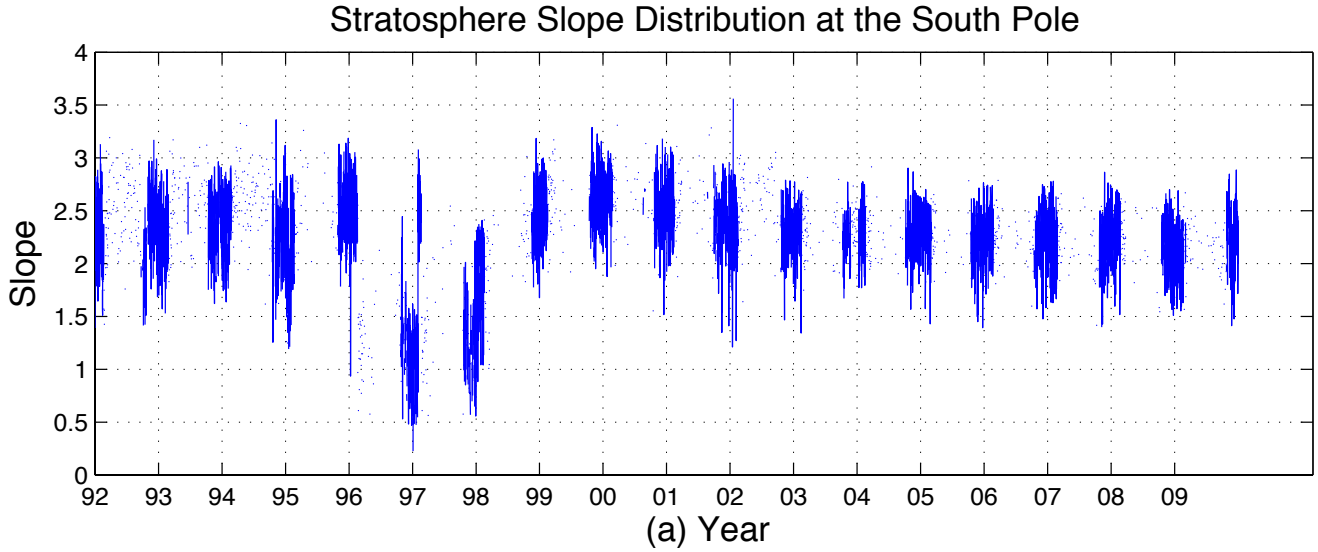


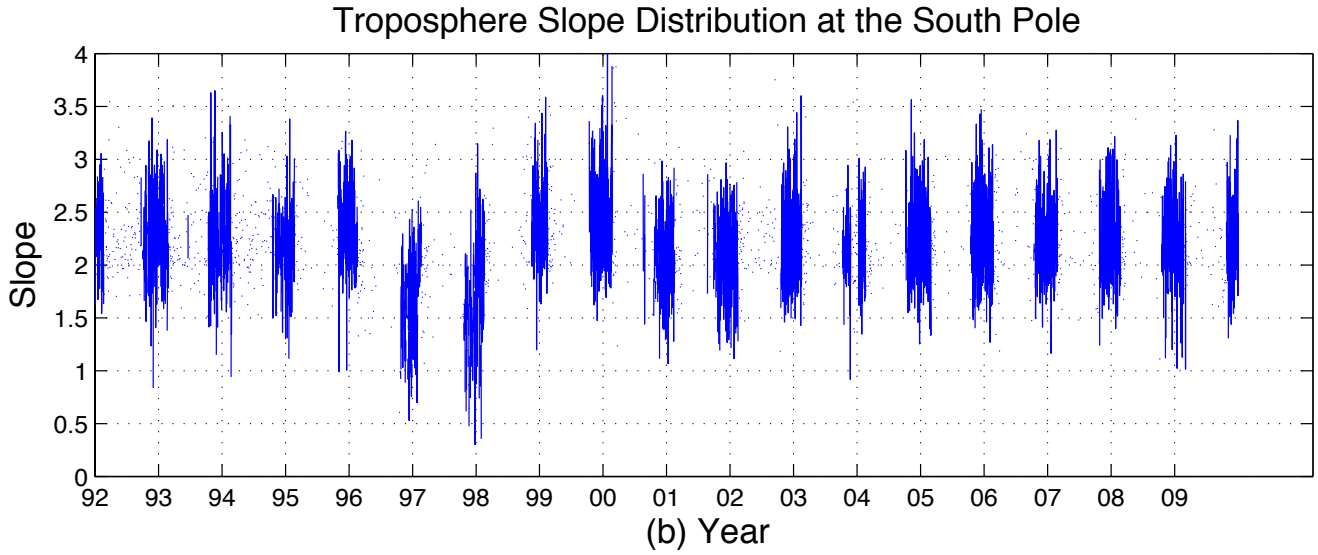
Long-term variations of vertical wavenumber spectral slope of temperature perturbation



Monthly mean slopes in troposphere and stratosphere from 1993 to 2010

South Pole long-term variations of spectral slopes





Individual profile slopes in troposphere and stratosphere from 1993 to 2010

Summary and Discussion

1. The ratio of Ek/Ep is location dependent, and quite different from linear GW model expectation (between 5/3 to 2).

-- Does this indicate the different propagation angles of GW at McM and S. Pole? A hypothesis is

$$\phi_{el} = \tan^{-1}(\sqrt{(w')^2/[(u')^2 + (v')^2]}) \qquad \phi_{el} = \tan^{-1}(w_{rms}/\sqrt{u_{rms}^2 + v_{rms}^2})$$

2. GW energy density is latitudinal dependent, decreasing with increasing latitude
3. The slope of vertical wavenumber spectra of temperature perturbation is not fixed to -3 (linear GW model), but has a tendency of decreasing with increasing latitude.
4. There may be long-term variations of the slope of the vertical wavenumber spectra of temperature, but not too sure.
5. No obvious long-term trend in gravity wave kinetic and potential energy density as well as the ratio of Ek/Ep.