(0-0’25’’)
Good afternoon everyone! My name is Shuang Xu. I’m a graduate student from Atmospheric Science major. Here I would like to present you a brief introduction about thermospheric Traveling Atmospheric Disturbances observed by GOCE and CHAMP satellites. Also, many thanks to my advisors Dr. Yue, Dr. Vadas and Dr. Russell.

(0’25’’-1’00’’)
Firstly, let me introduce you a little bit background if you are not familiar with atmosphere structure and those 2 satellites. The thermosphere is more than 85 km from the ground surface. As shown here, thermosphere is above the red dashed line. Most of ionosphere is in this region as well. The altitude of GOCE and CHAMP satellites were 270 km and 300－450 km respectively.

(1’00’’-2’10’’)
For thermospheric Traveling Atmospheric Disturbances, most of them are atmospheric gravity waves, or AGWs. Just like ripples across water surface when a tossed stone disturbs the water surface, gravity waves are born when air masses are pushed up or down. In atmosphere, gravity waves are not excited by stone, but much more powerful things, such as a thunderstorm, or when strong wind climb over a mountain range. The restoration force of gravity wave is gravity, or buoyancy if it’s more correct. That’s why they got their name “Gravity waves”. Please not to be confused with “Gravitational waves”. They have nothing to do with buoyancy.

The figure here is showing gravity wave propagation in lower atmosphere, generated by a thunderstorm. The horizontal scale of their impacts, as you can see is about 2000 km, so it’s actually quite regional for atmosphere.

(2’10’’-2’45’’)
By the time they reach the higher level, however, their impacts can be huge because the air density in upper atmosphere is extremely thin. The two movies here show two different wind fields at earth surface and at 90 km altitude respectively. We can clearly see the strong effects of gravity waves in the upper atmosphere.

(2’45’’-3’45)
Although there are many indirect ways – I mean remote sensing methods - to observe TADs, the observation quality - such as accuracy and resolution - are usually low, because thermosphere is too far and the air density is too low. The best way to observe those disturbances is by flying within them. GOCE and CHAMP were two of several satellite missions flew through thermosphere. GOCE and CHAMP carried highly accurate accelerometers, so they can derive air drag force and air density of its surroundings along satellite track. For example, in 2011, the GOCE observed density perturbation with amplitude more than 10%. Those perturbation are gravity waves caused by Tohoku tsunami, directly propagated from sea surface to thermosphere.

(3’45’’-4’30’’)
So, in our study, we process the GOCE and CHAMP air density perturbations, in a way similar to what people have done to find the waves caused by Tsunami. However, we are not satisfied with just a case study like that, we process all of the GOCE density observation and get the climatological results. Firstly, we apply FFT analysis to decompose the satellite data. We sort all the components into 3 λ_track ranges. The λ_track here means the horizontal wavelength along satellite track.

(4’30’’-5’30’’)
In step 2, we use Kp index. The Kp index quantifies the level of overall global geomagnetic activities. For example, the higher Kp index, the more Aurora activities we can see. After step 1, we divide the density perturbations into 3 λ_track ranges by FFT. In step 2, since Kp index and density along track data are both time-dependent, we classify the 3 groups of density perturbations components by their corresponding Kp levels.

By the way, all the processing steps aforementioned for GOCE density data was applied to CHAMP data as well.

(5’30’’-8'00")
After step 1 and step 2, we gridded those filtered waves in 5 by 5 degree longitude-latitude bins, and calculate the standard deviation of data in each bin. The result here shows the distribution of STDDEV of TADs at 3 Kp levels and all the 3 λ_track ranges. In subfigure (a) at upper left panel and lower left panel (which is south polar view map), we can see that **for small- scale TADs when Kp is near 0, the hotspots over Southern Andes are clearly seen**. In subfigure (b) and (c), for middle and large-scale TADs when Kp is near 0, some hotspots are still over Southern Andes region, although they are weaker and more diffusive comparing to subfigure (a). Also, there are TAD hotspots around south pole.

You may ask why we are exciting about this observation. Well, for a long time, scientists assumed (but not fully confirmed) that **the TAD hotspots around south pole during “quiet time”** are mainly caused by the remnant of geomagnetic activities. However, in this figure, we see that this hotspot is actually **still** obvious when Kp is near zero, which strongly suggest that those waves are mainly sourced from lower atmosphere instead of geomagnetic activities in upper atmosphere.

One more conclusion we can make is for numerical models. Since in conventional global circulation models, gravity waves are parameterized and launched in the troposphere or stratosphere, and the hot spot GWs over the Southern Andes in the quiet-time winter thermosphere cannot be successfully derived by those conventional model, we also suggest that those TADs are likely secondary or tertiary (or higher-order) gravity waves.

For the interest of time, I won’t introduce you the CHAMP results, but generally they also support the conclusions I made in the previous page.

That’s all I have for today, and I appreciate your attention.