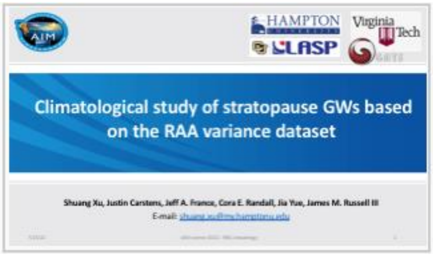
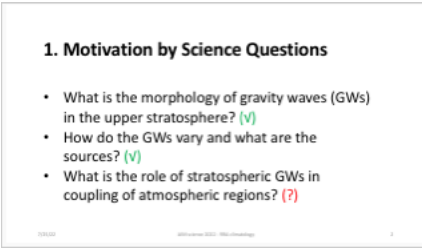
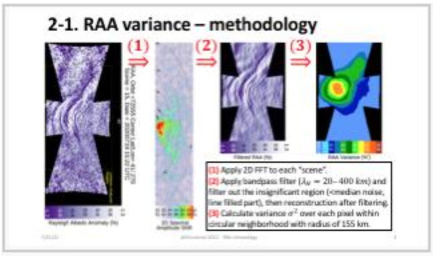
This is the script of AIM science meeting (2022, VT), 30-min oral presentation about RAA climatology study. PPT filename: **20220720_aim_science.pptx**



Good morning everyone, my name is Shuang Xu. It's my pleasure to introduce my work based on the RAA dataset obtained by CIPS instrument. It is still a very immature study right now especially for the discussion part, so any comments are welcomed.

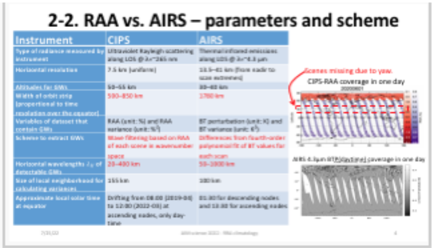


This study is driven by 3 basic science questions: *1. What is the morphology of gravity waves (GWs) in the upper stratosphere? 2. How do the GWs vary and what are the sources?* The answer for the first 2 questions are straightforward to be answered, because **very soon** I will show you the RAA climatology results, which show the spatial and temporal variability of GWs at stratopause. However, the 3rd - *What is the role of stratospheric GWs in coupling of atmospheric regions?* – this is a very big question. A short version answer is that the stratopause is the gateway to mesosphere, ionosphere, thermosphere system, so the stratopause GWs have an impact on the circulation of the upper atmosphere. But for more specific aspect, for example, what would RAA show if there is a certain extreme event happens, or how the RAA climatology would change as the global climate is changing, those are some questions I cannot answer right now.



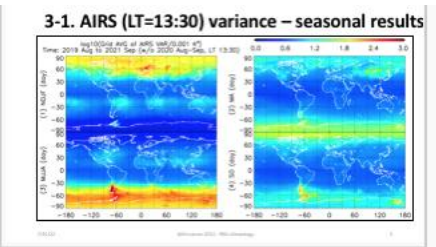
2-1

This page shows the schematic steps to derive the RAA variance dataset and this is the material that we will use for climatology study. Firstly, we apply a forward FFT over each scene, and then we apply a bandpass filter and also filter out the noise region with small amplitudes in wavenumber space. Then in the third step we calculate the variance over each pixel within circular neighborhood with radius of 155 km. This part has been introduced by Justin yesterday intensively, so I won't introduce this anymore. But just for your information that pixels with variance SNR less than 3 are zeroed in climatological study.



2-2

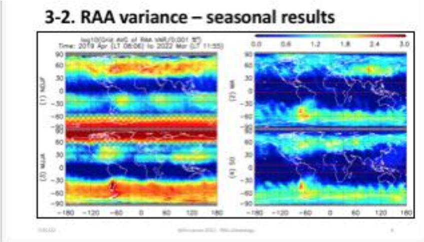
One more motivation behind making RAA variance dataset is that the AIRS team has published their gravity wave variance dataset for many years. The AIRS variance dataset and corresponding climatology study in 2013 successfully shown seasonal and global change of GWs in stratosphere. So, we want to compare whether CIPS as a very different instrument would see the same or different things about GWs at stratopause. Here are the parameters that are used for CIPS team and AIRS team to generate their own variance dataset. I won't go through line by line, but some are very important to keep in mind for understanding the RAA climatology study. For example, the RAA orbit strip is only 500–850 km wide, which is only about 1/3 of the width of AIRS orbit strip. Because the orbit strip broadness is proportional to the low-latitude time resolution in satellite remote sensing, it also means that AIM needs about 3 times of accumulative observation time to achieve climatology study with quality equivalent to AIRS. That is a very important reason to extend the AIRS mission lifetime. One more important difference between the 2 variance datasets is the scheme method to extract gravity waves: we use wave filtering in wavenumber space, while AIRS team uses the differences from fourth-order polynomial fit to define GWs. After investigation, we think this makes RAA variance dataset has higher signal to noise ratio than AIRS, not to mention that RAA has higher resolution and focus at smaller horizontal scale perturbations. All of the parameters in this table are responsible with different degree for the differences in RAA and AIRS climatology results.



3-1

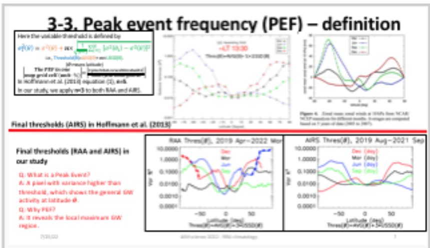
Now we can have a look and compare the seasonal climatological results. This is the AIRS brightness temperature variance distribution based on 2 years of data. There is a strong stratospheric wave activity in mid- and high-latitudes related to polar vortex. In summer hemisphere, there is a three-peak structure related to deep convections.

During equinox season, the stratospheric variability is much weaker because it is a transition state between summer and winter season.



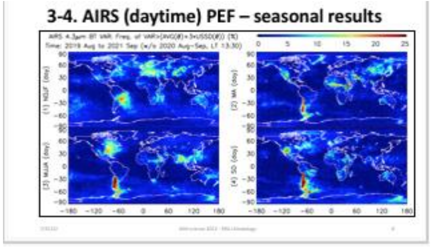
3-2

Then here is RAA variance seasonal results for stratopause GWs. The cross-hatched region denotes the PMC contaminated region for GW variance retrieval. The red box in the low latitudes denotes the yaw region. Generally speaking, compare to the AIRS, the RAA qualitatively shows the same pattern of distribution. However, in the equinox season, there is orbital shade which is due to poor time resolution of CIPS. To get climatology results equivalent to AIRS in the last page, we'd better have 6 years of RAA observation, but here we only have 3 years of RAA input here. Although compare to AIRS, the RAA seems to have a stronger contrast in color, it doesn't mean very much because AIRS and RAA target at different altitude and they also have different units, so it is not an apple-to-apple comparison.



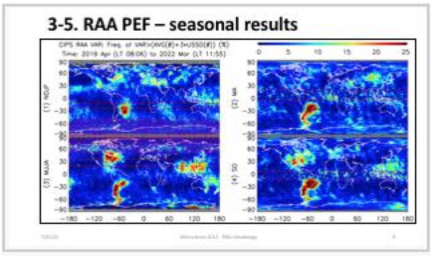
3-3

In order to make an apple-to-apple comparison, we calculate the "Peak event frequencies" or "PEF" of each map grid cell and each season. The PEF shows the relative wave activity of one location compare to other locations at the same latitude. This method is used in Hoffmann's 2013 paper about AIRS climatology, and we adopted this method because it intuitively shows the location of a gravity wave hotspot where waves happened more frequently than other places at the same latitude. Here are the details: The two figures in the upper panel shows the final threshold that Hoffmann paper derived based on AIRS data from 2003 to 2007. A pixel with variance higher than threshold can be called "peak event". In the threshold definition equation, AVG is the average variance at latitude θ, USSD is the unbiased sample standard deviation of variances at latitude θ, and "n" is an empirically defined factor. In Hoffmann's 2013 paper, the final threshold derived from AIRS dataset shows the general GW activity at different latitude. In our study, we also derive the threshold for AIRS and RAA. As shown in the lower panel, the threshold of RAA and AIRS for data in our study is very similar to Hoffmann's figure, except for the RAA variance data contaminated by PMCs in polar region.



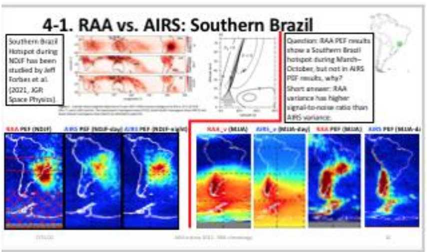
3-4

Here is the seasonal peak event frequency distribution based on the AIRS dataset. Regardless the different factor of threshold definition and color bar difference, this result is almost identical to Dr. Hoffmann's 2013 paper. The hotspot of source regions due to convection and orography are clearly seen. For example, from November to February, there are hotspot over southern Brazil due to convection and hotspot over Europe due to flow over mountains; From May to August, there are hotspots over East US due to strong convection events and southern Andes due to orography.



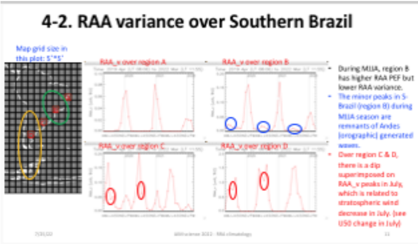
3-5

Now, here are the RAA peak event frequency results. Generally, the important hotspots found in AIRS in the last slides are also found in RAA climatology. However, they are similar, not the same. For example, the RAA sees a persistent hotspot over Southern Brazil, but during May-June-July-August season, it is not very obvious in the AIRS.



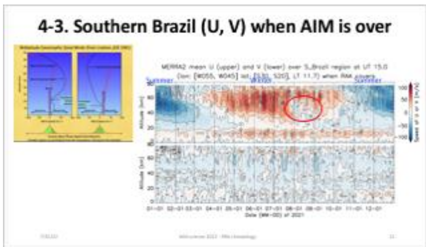
4-1

To make the specific problem about Southern Brazil hotspot more clear, I sort all of the results in a new page. The left part of the page is the Southern Brazil hotspot observed by RAA and AIRS during southern summer. This hotspot has been studied by Dr. Jeff Forbes and his main point is that this is caused by convective source over rainforest region, and those GWs would propagate upward and southward toward the middle atmosphere westward jet core. This hotspot is not observed by AIRS in southern winter, which is OK, because the middle atmosphere is dominant by eastward jet during southern winter, not westward jet. But it is unexpected that the RAA PEF observed this S-Brazil hotspot, although much weaker.



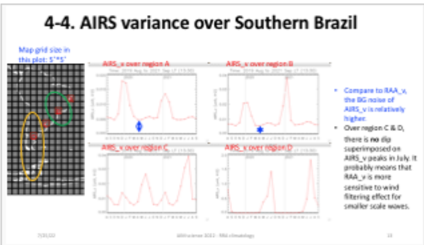
4-2

To investigate the possible source of S-Brazil hotspot, I did a simple test. I plotted the monthly mean RAA variance of map grid A B C D along time axis. You can see that from region A to region D, the RAA variance peaks change from southern summer season to southern winter season, because the green circle is dominant by convective source, and orange circle is dominant by much stronger orographic source. While region A and C are at the periphery sides. Therefore, for S-Brazil, we can say that GWs at this S-Brazil region during MJJA (or non-monsoon seasons) are NOT purely convection generated. It is a composition effect of rainforest convection-generated GWs and jet over Andes mountain-generated GWs. The first type of GWs has a minimum during MJJA season, while the second type of GWs reaches their maximum simultaneously. It's also interesting that, over region C & D, there is a dip superimposed on RAA variance data peaks in July, which is related to stratospheric wind decrease in July. It means that the RAA is very sensitive to change of GWs due to wave filtering effect.



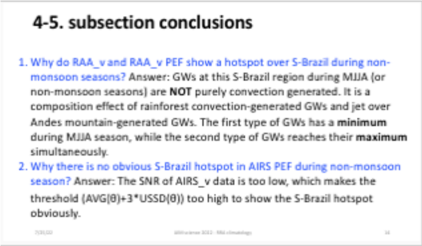
4-3

This is the figure that shows the zonal wind decreasing around stratopause in July.



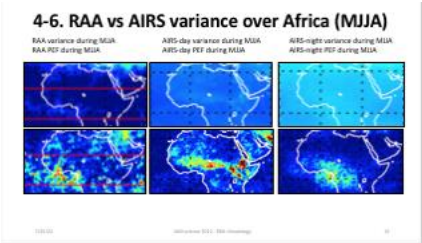
4-4

Here are the monthly AIRS variance for the same 4 regions. You can see that the bottoms of the curves are much higher away from the bottom, which means the AIRS data has lower signal-to-noise ratio.



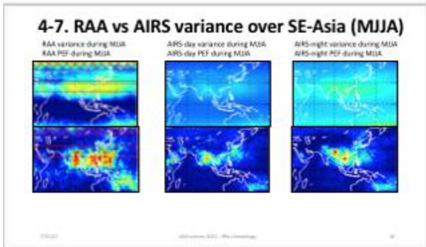
4-5

I will passs these subsection conclusions because I've already mentioned them just now.



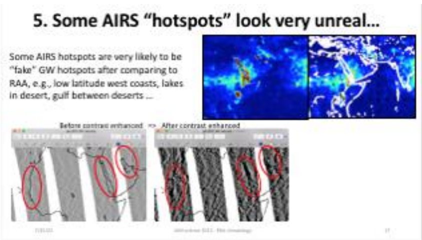
4-6

Alright, these are more comparisons of RAA climatology over some regions of interest. Here is the African rainforest hotspot.



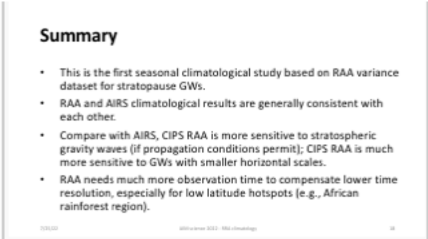
4-7

This is the southeast Asia.



5

Here is the last interesting thing I want to share. When we were investigating the possible source of hotspots appear in AIRS but not in RAA, we found that a lot of them are caused by high AIRS variance due to systematic brightness temperature sudden change at boundaries between desert and water in low latitudes. The brightness temperature is usually lower at the water side than the desert side. I don't know the possible reason but I'm pretty sure those hotspots reported by Hoffmann's 2013 paper have little to do with real waves in stratosphere.



Alright, I will stop here and please comment if you have any. Thanks!

Summary

- *This is the first seasonal climatological study based on RAA variance dataset for stratopause GWs.*
- *RAA and AIRS climatological results are generally consistent with each other.*
- *Compare with AIRS, CIPS RAA is more sensitive to stratospheric gravity waves (if propagation conditions permit); CIPS RAA is much more sensitive to GWs with smaller horizontal scales.*
- *RAA needs much more observation time to compensate lower time resolution, especially for low latitude hotspots (e.g., African rainforest region).*