A Global View of Stratopause Gravity Waves Derived from AIM/CIPS

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Science Questions:

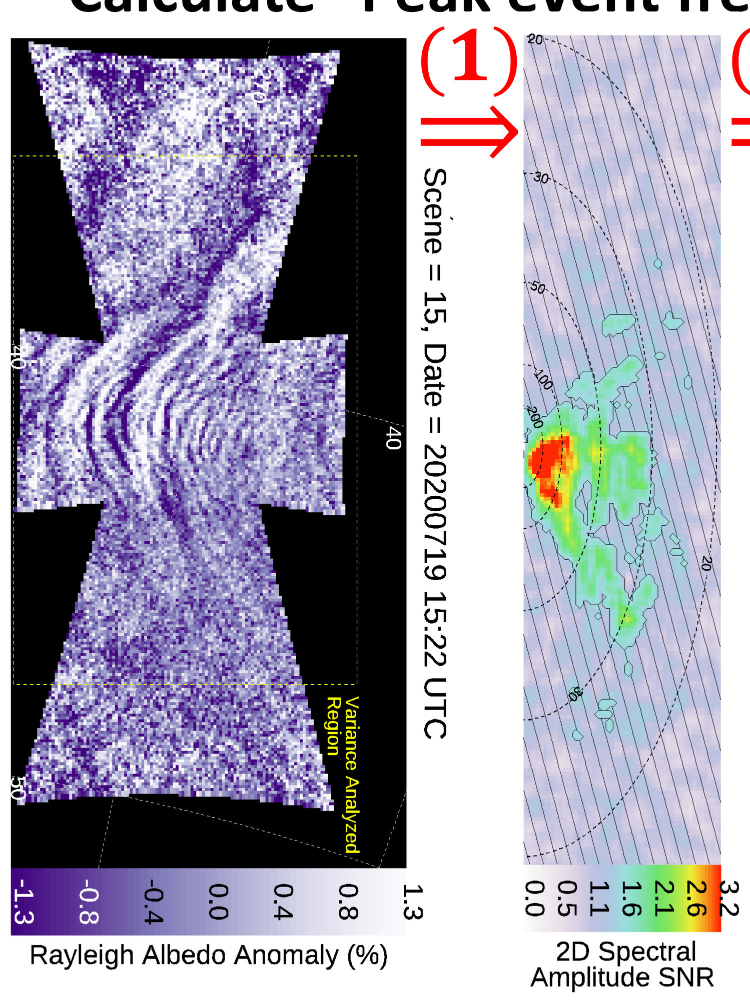
- What is the morphology of gravity waves (GWs) in the upper stratosphere?
- How do the GWs vary and what are the sources?
- What is the role of stratospheric GWs in coupling of atmospheric regions?

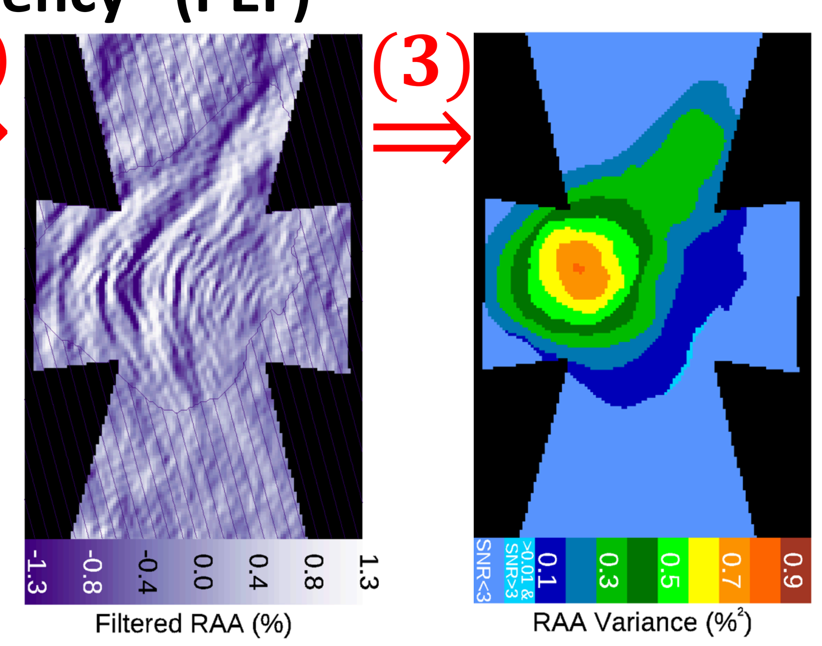
1. Introduction

- First near-global maps of GW activity near **50–55 km altitude** from NASA Aeronomy of Ice in the Mesosphere (AIM) Cloud Imaging and Particle Size (CIPS) instrument
- GWs inferred from variances of **Rayleigh Albedo Anomaly (RAA)** variances of Rayleigh scattering @ 265 nm.
- Comparisons to GW hotspots near **30-40 km altitude** inferred from **Atmospheric Infrared Sounder (AIRS) brightness temperature perturbation (BTP)** @ 4.3 µm are presented

2. Methodology

- **Calculate "Peak event frequency" (PEF)**





(1) Apply 2D FFT to each "scene", filter out the insignificant region (<median noise, line filled part).
(2) Reconstruction after filtering.
(3) Calculate neighborhood variance σ^2 over each pixel.

- **Definition of PEF**

$$\sigma_T^2(\theta) = \sigma^2(\theta) + \boldsymbol{n}\times\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left[\sigma^2(\theta_i)-\sigma^2(\theta)\right]^2}$$

i.e., Threshold(θ)=AVG(θ)+ $\boldsymbol{n}$×USSD(θ).

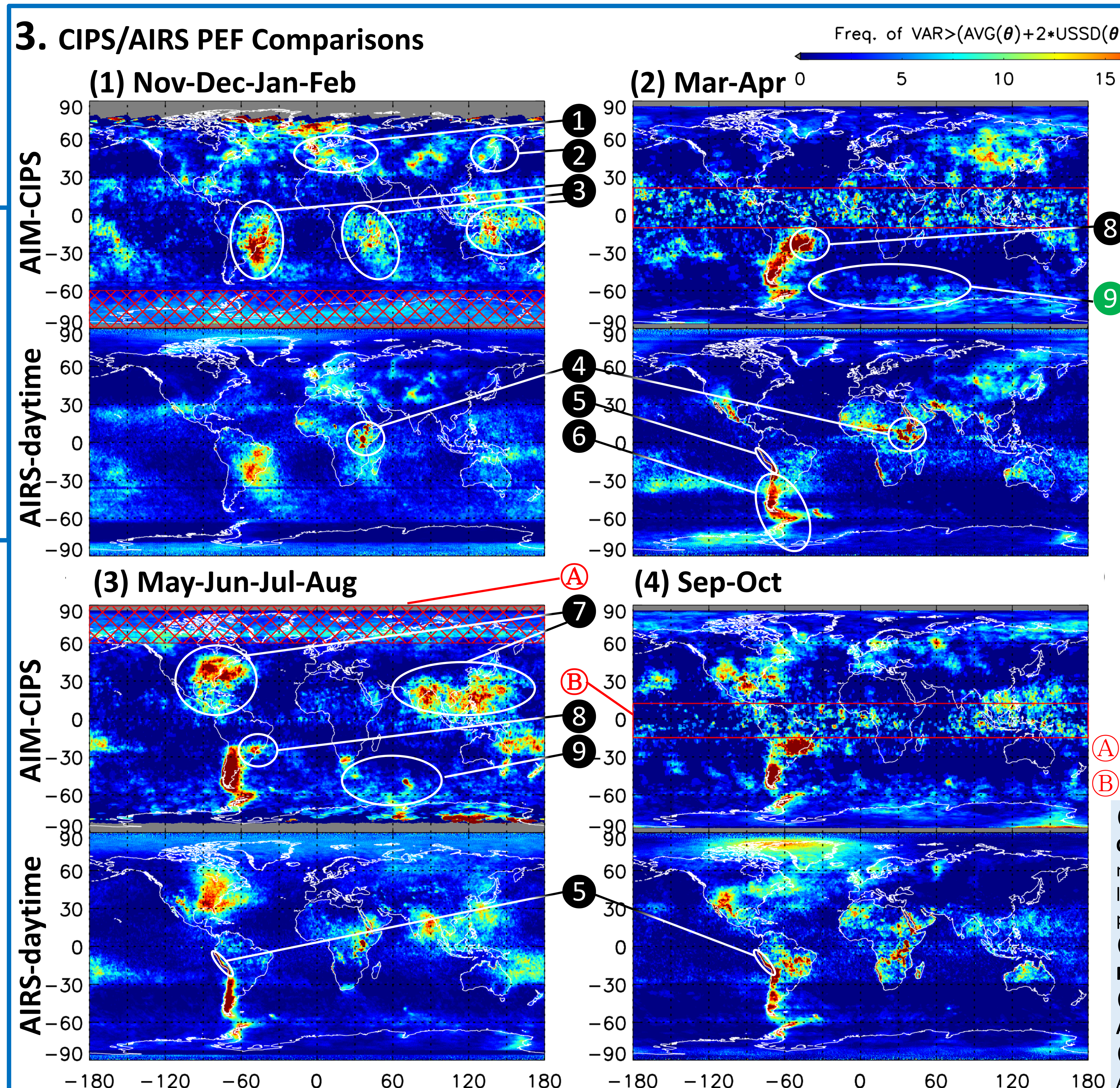
(factor $\boldsymbol{n} = 2$ in this study, $\boldsymbol{\theta}$ means latitude)

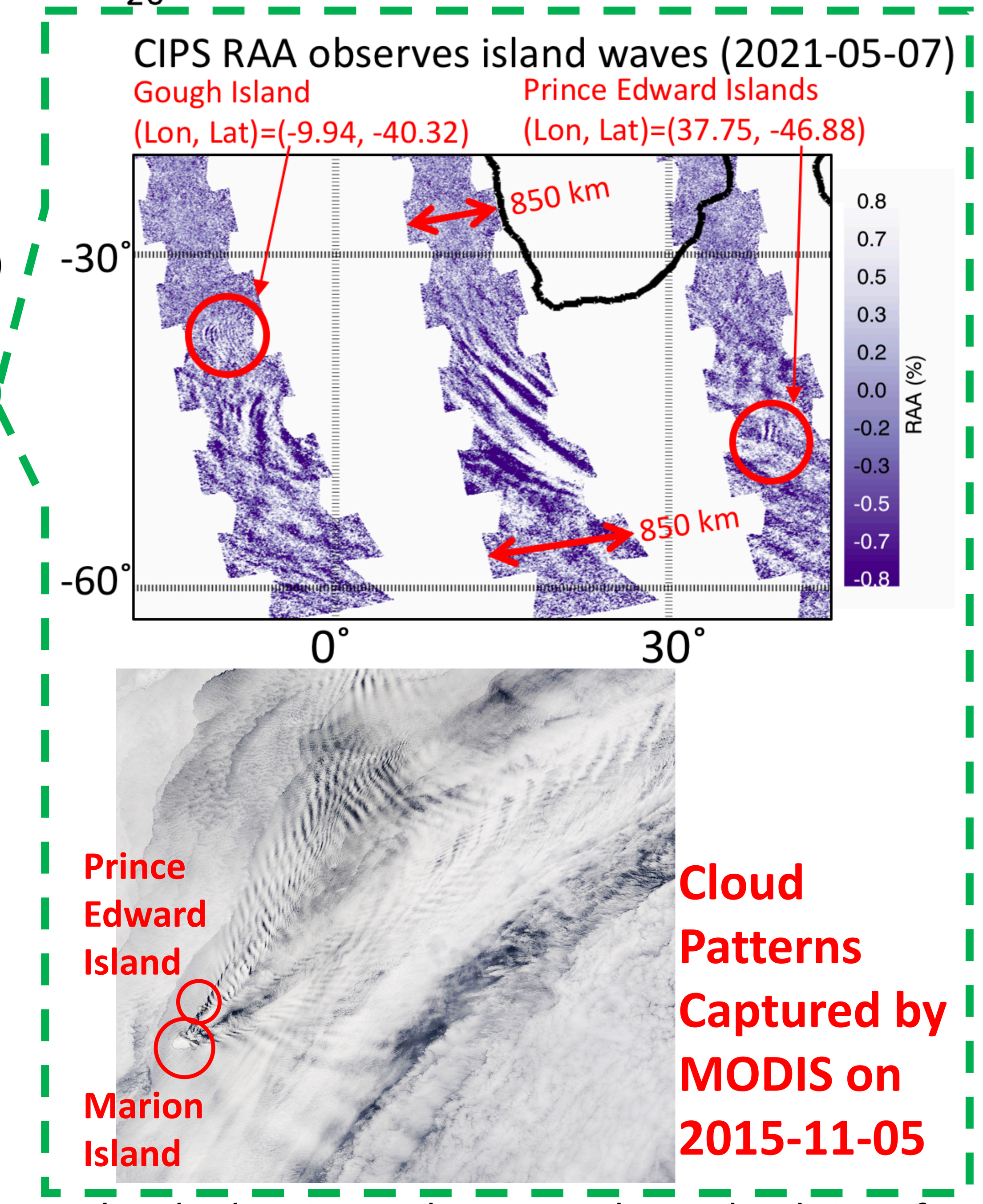
$$\left[\begin{array}{c}\textit{The PEF in each}\\ \textit{map grid cell (unit: \%)}\end{array}\right] = \left[\frac{\textit{\# pixel that exceed threshold } \sigma_T^2}{\textit{total \# pixel in the grid cell}}\right]$$

- **Compare CIPS and AIRS**

➢ Observation time of **CIPS**: 2019 Nov ~ 2021 Oct (2 years); of **AIRS**: 2019 Aug ~2021 Sep (w/o 2020 Aug–Sep, 2 years)
➢ Horizontal Resolution: **CIPS** 7.5 km; **AIRS** 14-40 km
➢ Local time: **CIPS** 9:00-11:30; **AIRS** 13:30
➢ GW altitude: **CIPS** 50-55 km; **AIRS** 30-40 km
➢ Map grid resolution: 0.5°x0.5°

3. CIPS/AIRS PEF Comparisons

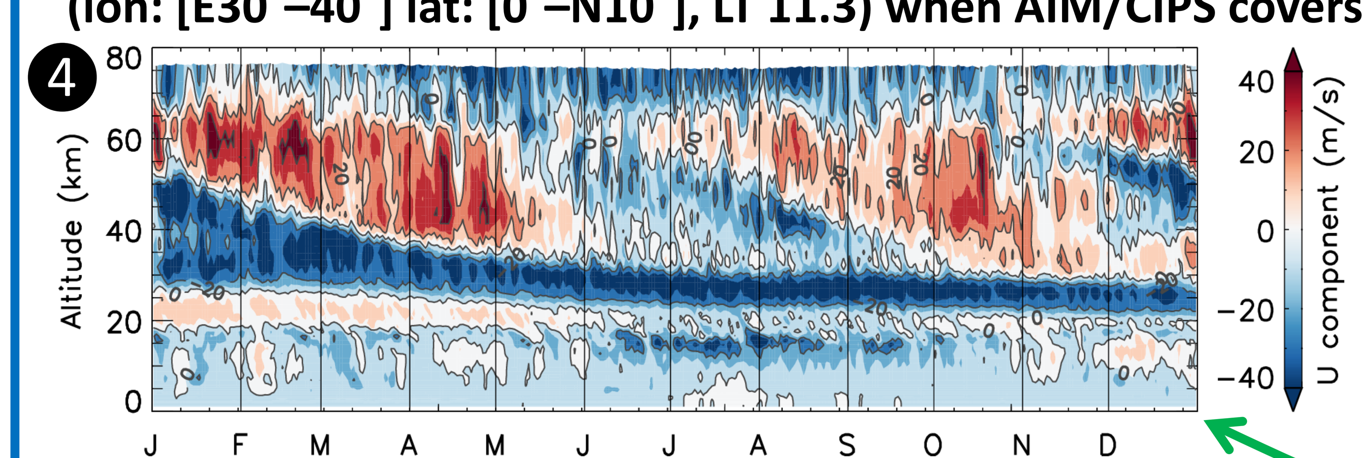




Ⓐ Cross hatched region: polar mesospheric clouds interfere

Ⓑ Noise-like pattern: missing "scenes" due to satellite yaw

MERRA2 mean U over East Africa region at UT 9.0 during 2021 (lon: [E30°–40°] lat: [0°–N10°], LT 11.3) when AIM/CIPS covers



❶ GW hotspots over **Europe** due to orography.

❷ Hotspot over **Northeast Asia** observed by AIM-CIPS, the reason is still under investigation.

❸ A pronounce **"three peak feature"** in mid-latitude regions, strongly correlated with convection.

❹ Intensive GW hotspots observed by AIRS over **East Africa** during both solstitial seasons, but not in AIM-CIPS. The possible reason: filtering effect due to the horizontal wind shift in stratosphere.

❺ Strong hotspot observed by AIRS **along Pacific coast along Cordillera Occidental Mountains (Peru and northern Chile)**, but not in CIPS. A possible reason: the orographic waves are relatively large in scale, but CIPS orbit strips are too thin to identify wave patterns confidently.

❻ Well-known hotspot over **Southern Andes and Antarctic Peninsula**, orographic feature related to the polar jet.

❼ Large hotspots are observed over **North America and East Asia** due to convection activities.

❽ A **persistent hotspot** is observed by CIPS over **South Brazil**. AIRS also observes waves there but does not show pronounced hotspot in seasonal climatology because the "PEF" along Pacific coast nearby (❺) is much higher.

❾ Highlight of CIPS: Due to high horizontal resolution, AIM/CIPS is good at capturing the small scale island waves. This benefit also can be shown in CIPS variance climatology. Tiny wave troughs and peaks clearly relative to two islands are easily to discern in the top-right corner figure. **This is very important since the cumulative effect of gravity waves from isolated islands in the Southern Ocean could be significant for the circulation of the middle and upper atmosphere.** Here AIM-CIPS shows a strong ability to quantify small scale waves.

4. Summary

1) These results are the first to show satellite-based GW activity near altitudes of 50–55 km throughout both the northern and southern hemispheres in all seasons.
2) The CIPS RAA variance seasonal maps of GW activity near 50-55 km altitude show many of the same hotspots observed near 30-40 km in the AIRS 4.3-µm brightness temperature variances. Both CIPS and AIRS detect convectively-generated waves and non-convectively-generated waves (e.g., orographic waves or waves that are generated by the polar vortex).
3) AIM/CIPS instrument has an outstanding horizontal resolution ability, which is especially good at observing small scale waves (e.g., island waves). This ability can be effectively used to quantify the event frequency/physical influence over atmosphere circulation via small scale waves.
4) Further investigation is being applied to better interpret differences between the climatological results obtained by AIRS and CIPS.

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