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Exploring long-term satellite observations of global 3-D gravity wave characteristics in the stratosphere

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Note: Due to the online discussion format of EGU this year, this presentation has been summarised for quick reading.
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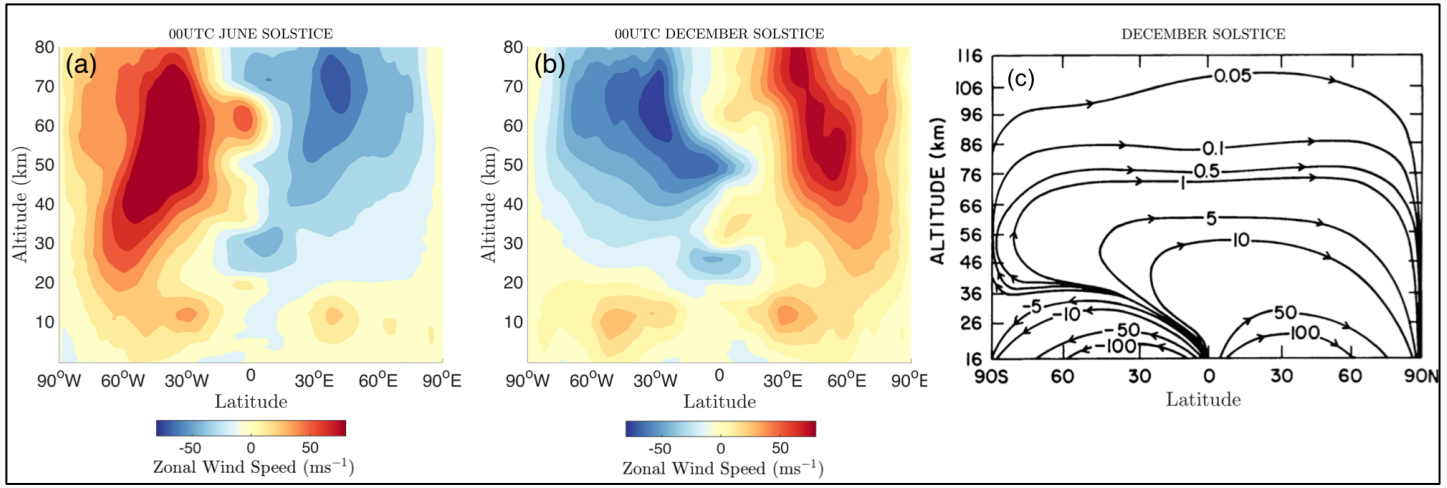
Introduction and Motivation

- **Gravity waves** (GWs) play a key role in **driving atmospheric circulations** through the transport and deposition of energy and momentum.
- In **global circulation models**, this momentum transport must be parameterized due to the relatively small size of GWs and their sources.
- But quantifying gravity wave **momentum transport** in observations is difficult because is requires **3-D wave observations**.
- Inaccurate, or incomplete representation of gravity waves in models can lead to **significant biases** (e.g., Butchart et al., 2011)

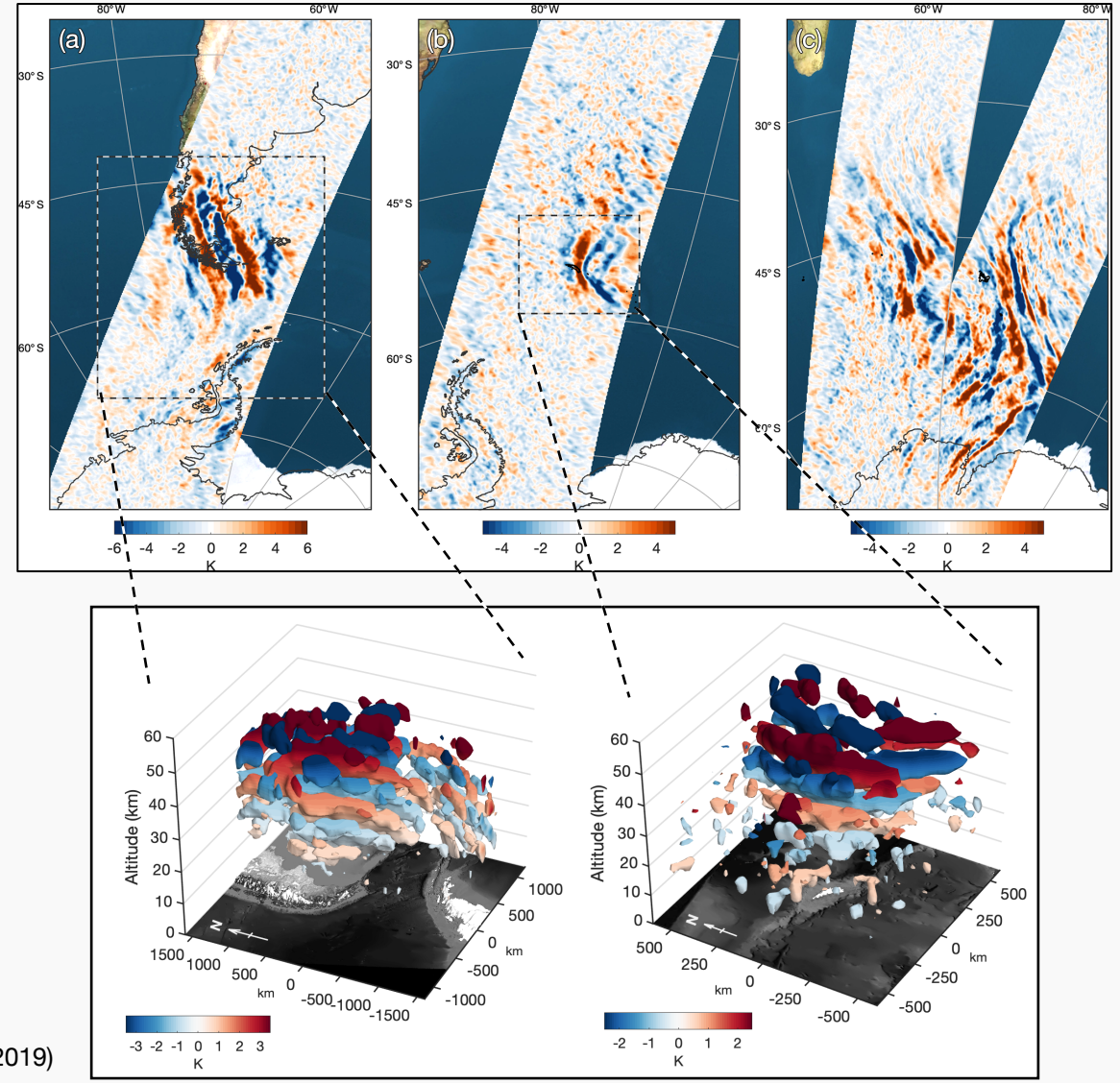


Gravity waves drive circulations that force the atmosphere into states away from radiative equilibrium (Brewer-Dobson Circulation, adapted from Garcia and Solomon (1983)).

Data and Methods

- Here we use **AIRS/Aqua 3-D satellite observations** to measure directional gravity wave **momentum flux** in the stratosphere for the period 2002-2019.

- The specialized AIRS retrieval of Hoffmann and Alexander (2009) provides global **3-D temperature measurements** between altitudes of around 20 to 40km.

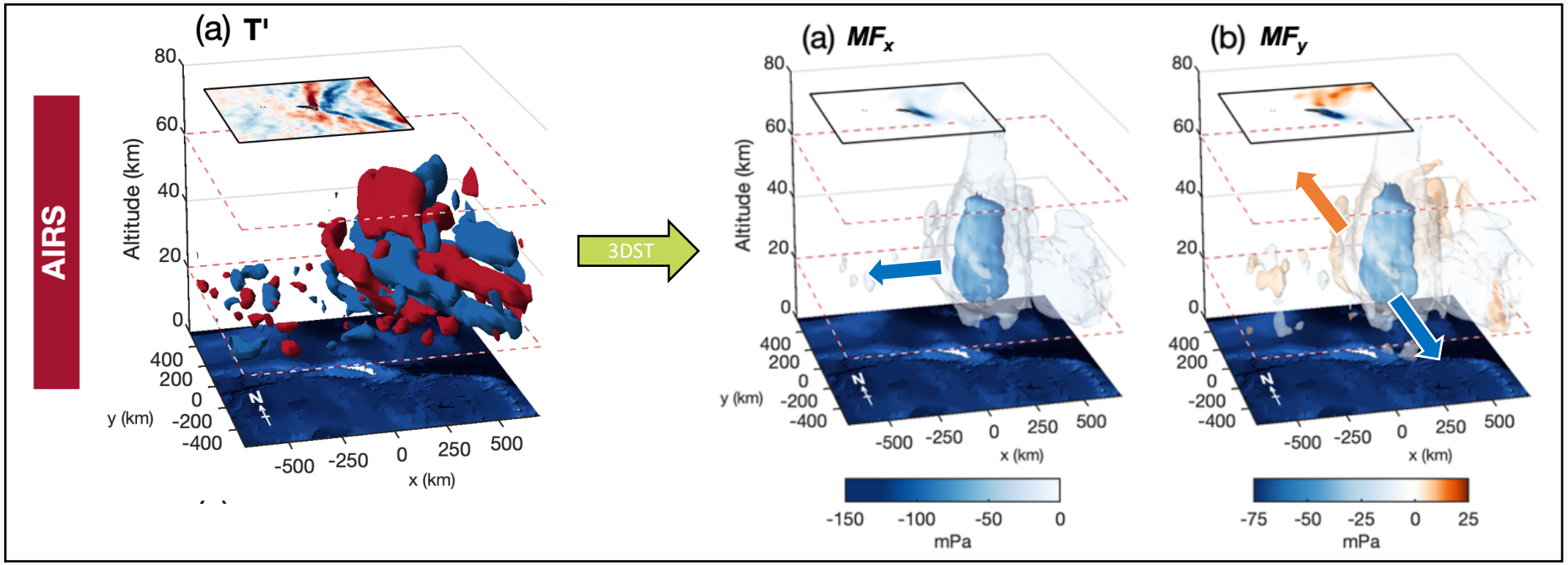


Hindley et al., (2019)

Data and Methods

- We use **3-D S-transform analysis** to measure gravity wave amplitudes, wavelengths and directions.

- From these measurements, we can compute the **directional gravity wave momentum fluxes** (GWMF) of stratospheric gravity waves globally.



Hindley et al., (2020, in prep)

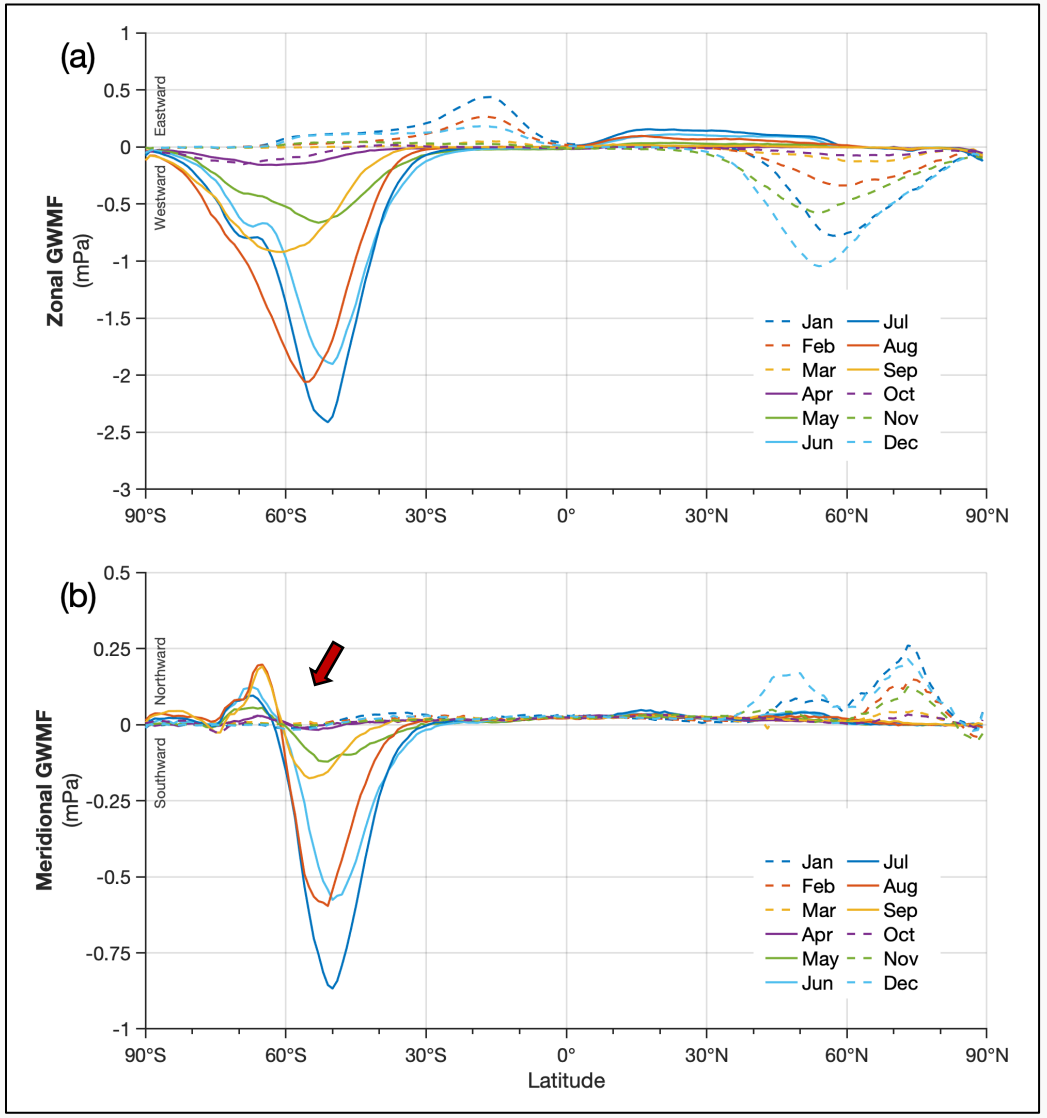
Results

- Monthly zonal-mean **directional gravity wave momentum fluxes** for the period 2002-2019 are computed. We find significant **asymmetry between hemispheres**, as seen in previous studies.

- In particular, an oblique **convergence of meridional momentum flux** towards latitudes of 60S is observed during winter months.

- This phenomenon is not seen in the northern hemisphere.

- **Key question: To what extent is this effect represented in global models, in either GW parameterisations or resolved waves?**



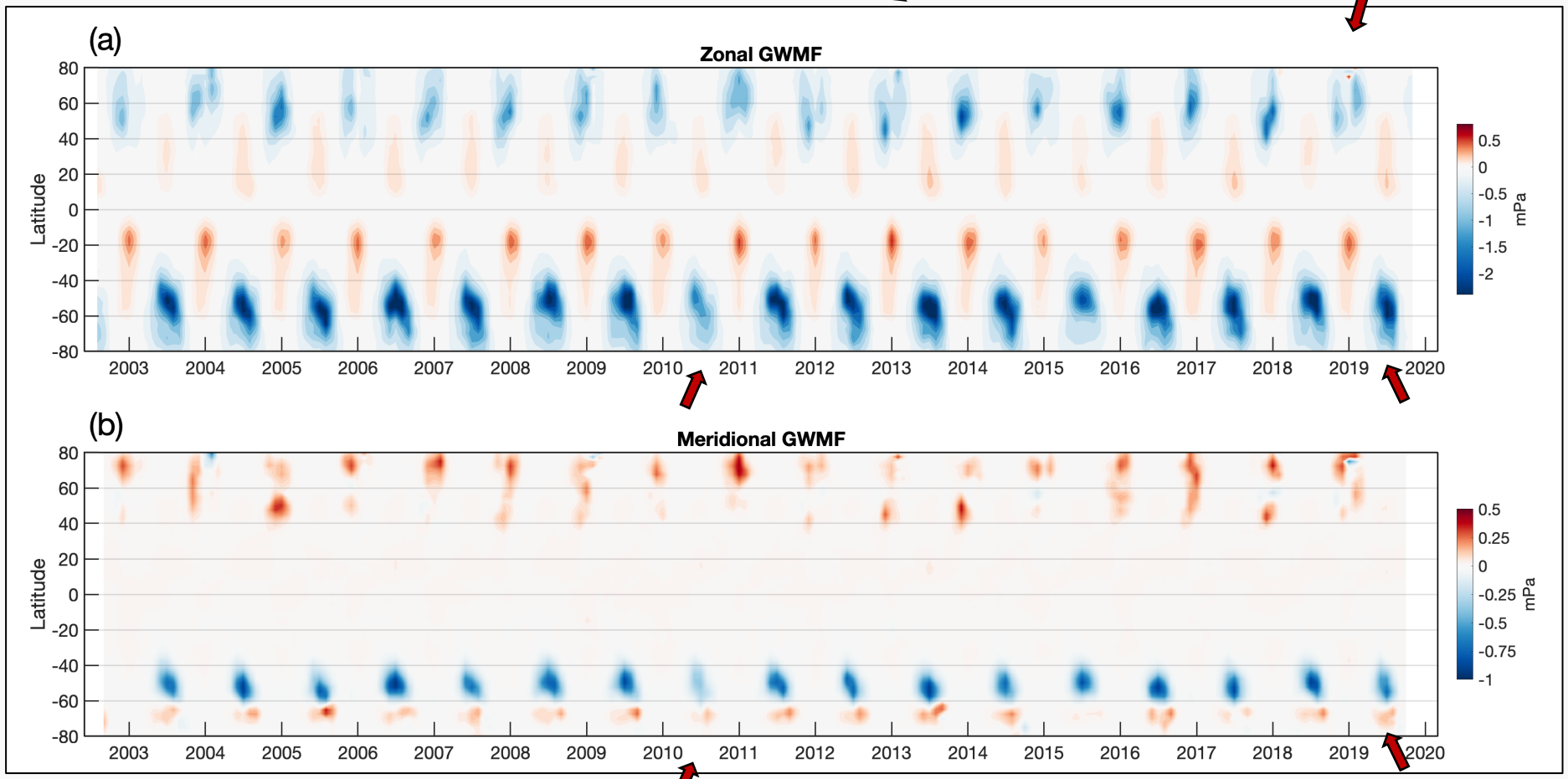
Hindley et al., (2020, in prep)

Results

- Long timeseries of **zonal-mean GWMF** indicate that this pattern is consistent each year, but variability is found to coincide with Sudden Stratospheric Warming (SSW) events in both hemispheres.

Hindley et al., (2020, in prep)

Irregular patterns in stratospheric GWMF in response to SSW events in the northern hemisphere



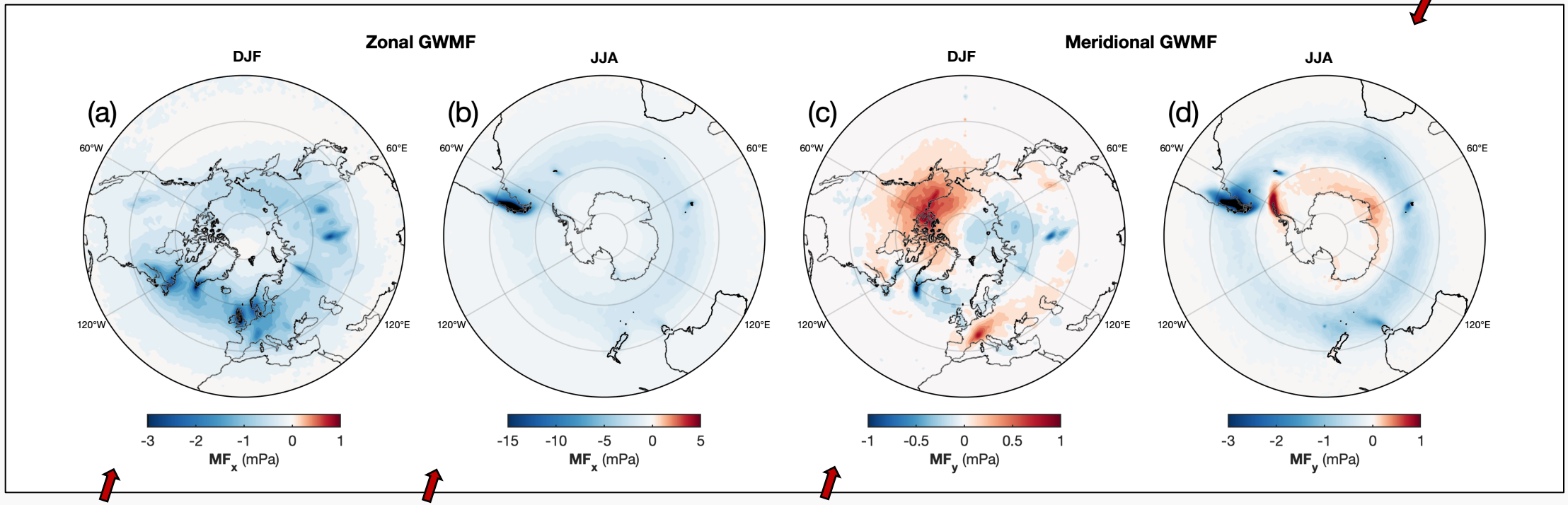
Reduced GWMF in the southern hemisphere during to the 2010 minor SSW in the SH...

... but less so in the 2019 southern SSW, likely because the warming occurred later in the season than in 2010.

Results

- Wintertime **sources of gravity wave momentum flux** in the stratosphere, particularly **orographic sources**, are well-defined in the long-timescale mean.

Meridional convergence towards 60S is is most significant over the southern Andes and Antarctic Peninsula



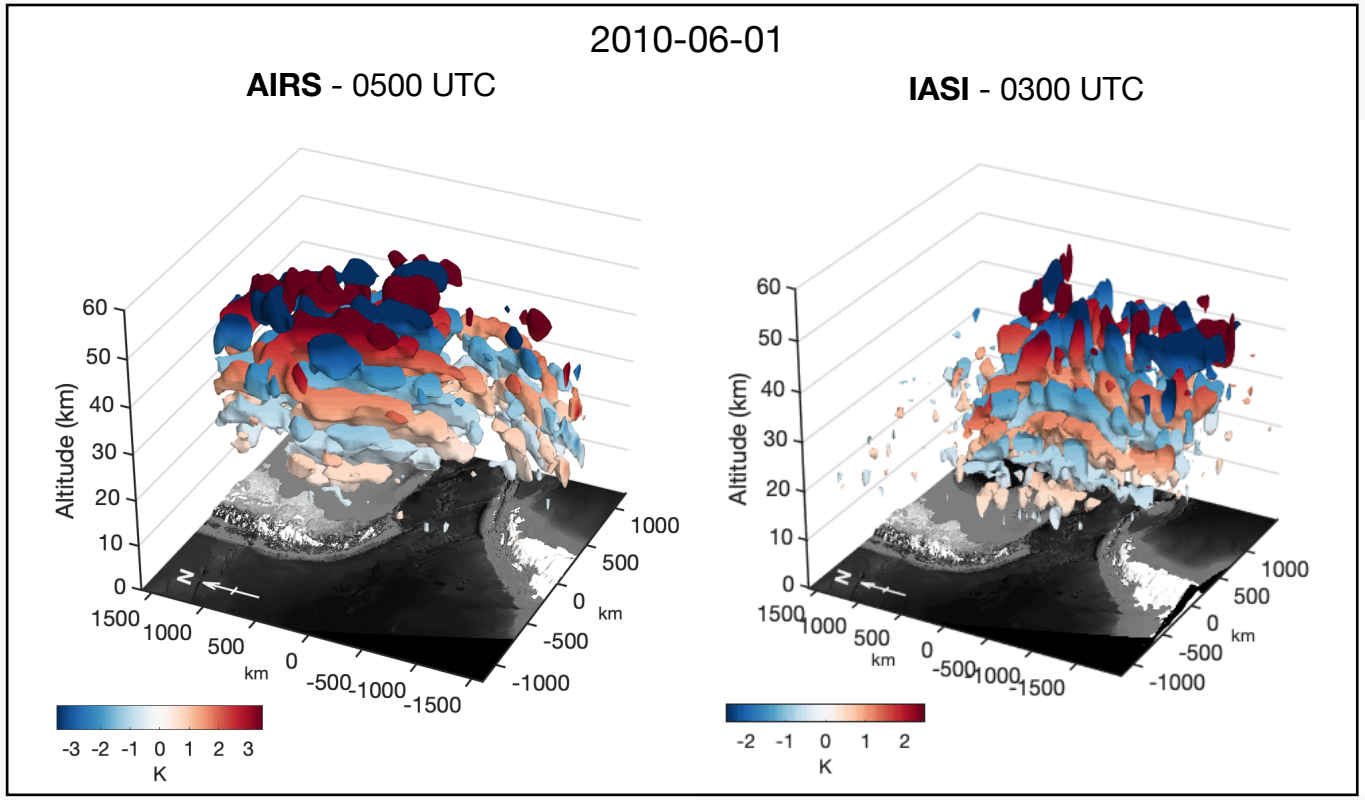
Orographic sources of **westward** GW momentum are well-defined in both hemispheres, but the **southern Andes** dominates the global picture due to the stronger winds in the southern polar vortex.

An interesting **longitudinal asymmetry** in meridional flux is seen in the northern hemisphere winter, but values are lower than in the southern hemisphere.

Hindley et al., (2020, in prep)

Future Steps

- A similar 3-D retrieval is being developed for the **IASI instruments** on board MetOp-A, B and C.
- This will provide **several times more global coverage** historically, and also ensure that such 3-D measurements can continue **into the future**.



Key Points and Conclusions

- **3-D satellite gravity wave observations** can provide global estimates of directional momentum fluxes needed to constrain global models.

- **Directional asymmetries** between hemispheres are found and quantified, most significantly a convergence of meridional flux towards 60S during winter that is not observed in the northern hemisphere.

Key questions:

- **How accurately is the directionality of GWMF represented in global circulation models, in either parameterisations or resolved waves?**

- **Should current model parameterisations be modified to account for this, or should model resolution be increased to try to resolve it directly?**

Thank you for reading, I hope you are enjoying EGU2020 Online!

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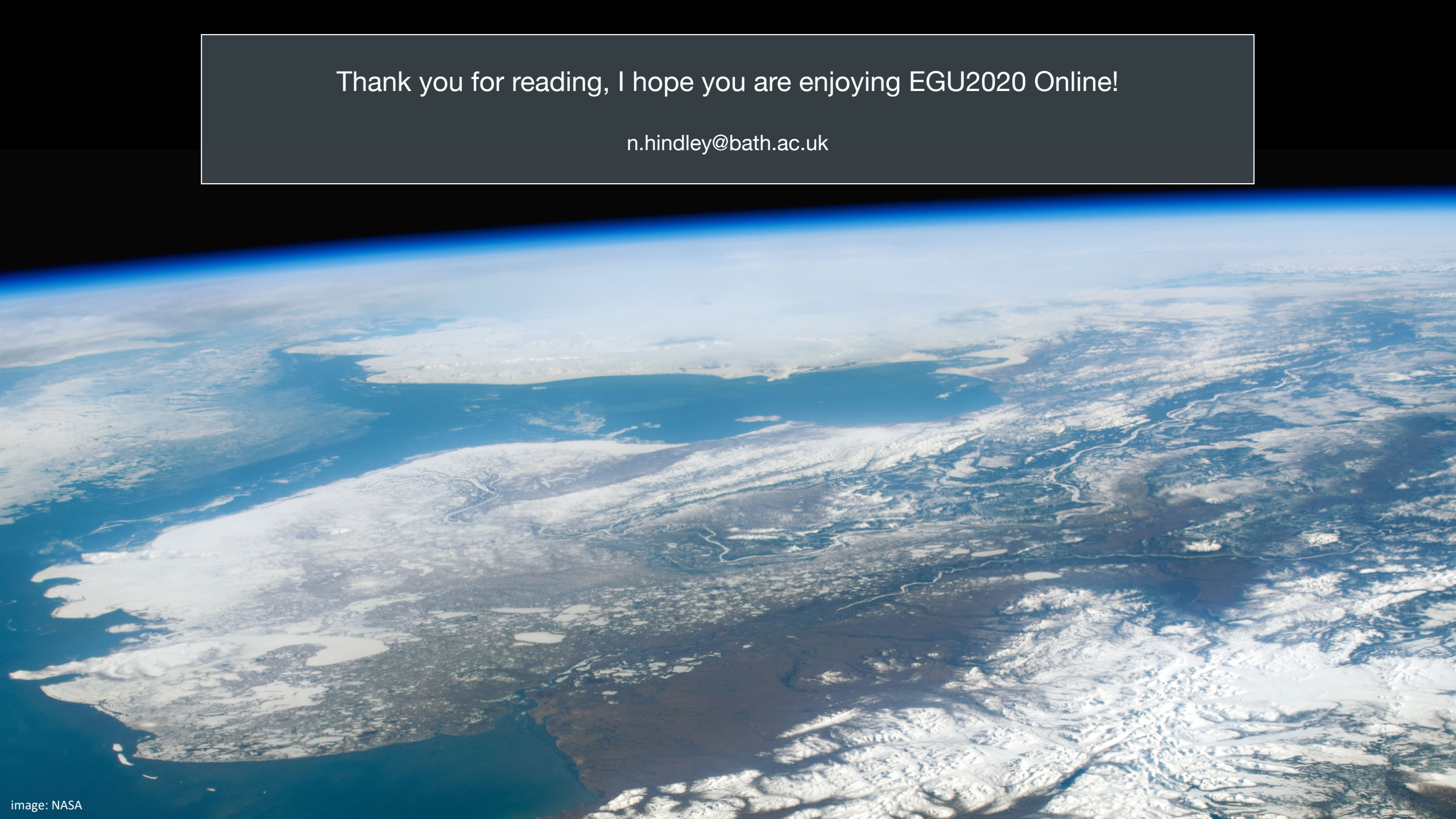

image: NASA