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Linking midlatitude transient eddy moist static energy transport and extratropical cyclones

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Background

In midlatitudes, the largest contribution to poleward atmospheric energy transport occurs on the timescale of weather systems, which are also referred to as transient eddies (TE).

Moisture plays a two-fold role: transport of latent heat contributes to the overall energy transport, while latent heat release is known to intensify and prolong individual extratropical cyclones.

The increase in specific humidity with climate change and its non-linear effect on cyclone development adds to the need of understanding how extratropical cyclones transport energy.

Research questions

How do individual cyclones contribute to the zonal mean energy transport (Figure 1)?

What is the relationship between meridional latent heat flux convergence and cyclone intensification?

Energy flux and cyclone data

- First results are based on ERA5 data for DJF Northern Hemisphere during 1981-2021.*
- TE moist static energy (MSE) flux $v'm'$ is computed from high-pass filtered[1] meridional wind v and MSE $m=c_pT+Lq+\phi$. Vertical integrals assume constant surface pressure.
- Cyclones are tracked using hourly sea level pressure (SLP).

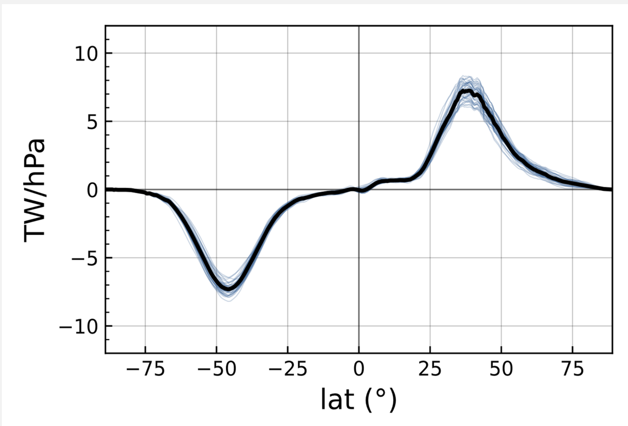

Figure 1: Climatology of zonally integrated $v'm'$ at 850hPa (black). Individual years are shown in blue.

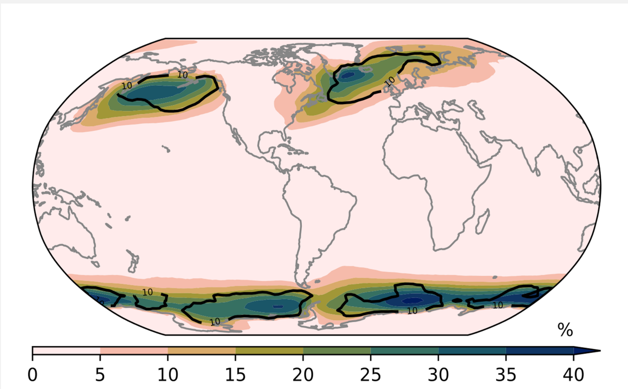

Figure 2: Climatological cyclone frequency (shading) and standard deviation (contour).

* Data for other seasons and regions are available and presented conclusions do not depend thereon.

Cyclones and MSE fluxes

First results

Before addressing how cyclones contribute to the zonal mean energy flux, we inspect how TE MSE fluxes evolve during cyclone lifetime:

- Fluxes tend to peak during cyclone intensification, before reaching mature stage (Figure 3).
- Composites show that poleward flux is pronounced in the warm sector[1] and stronger in deeper cyclones (Figure 4).

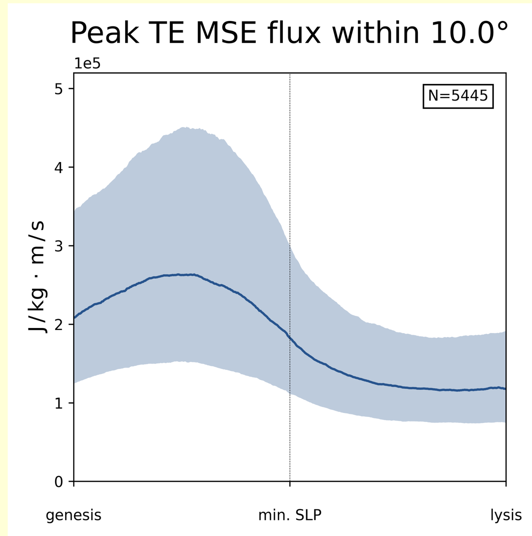

Figure 3: Evolution of 850hPa near-center **MSE flux** during normalized cyclone lifetime.

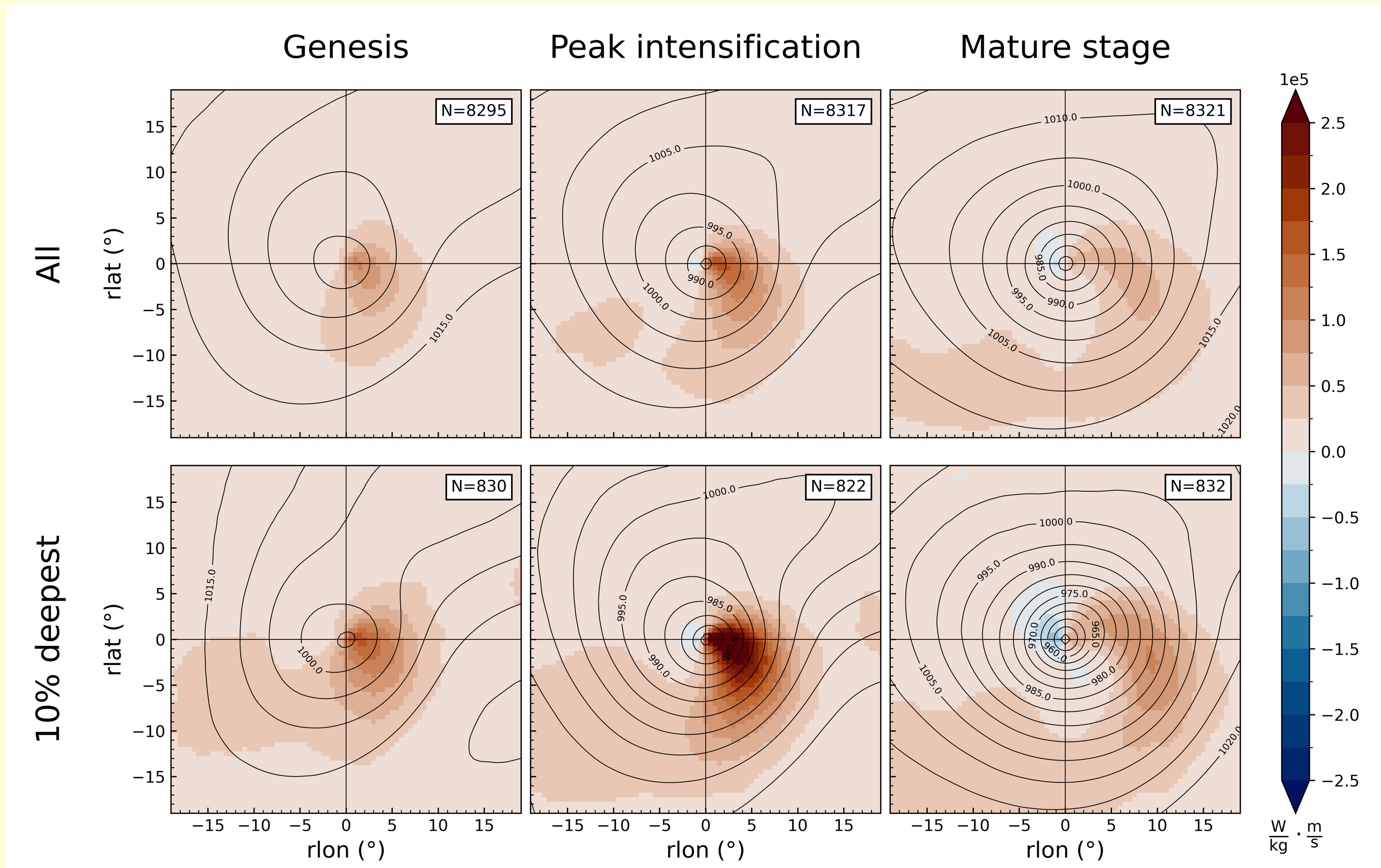

Figure 4: Cyclone composites of 850hPa meridional **TE MSE flux** (shading) and **SLP** (contours) during cyclone intensification.

Next steps

To explain how individual cyclones contribute to the zonal mean, we identify and track events of high TE MSE flux (Figure 5).

This allows to link the variability of energy fluxes (Figure 1) with the variability of cyclone characteristics (Figure 2).

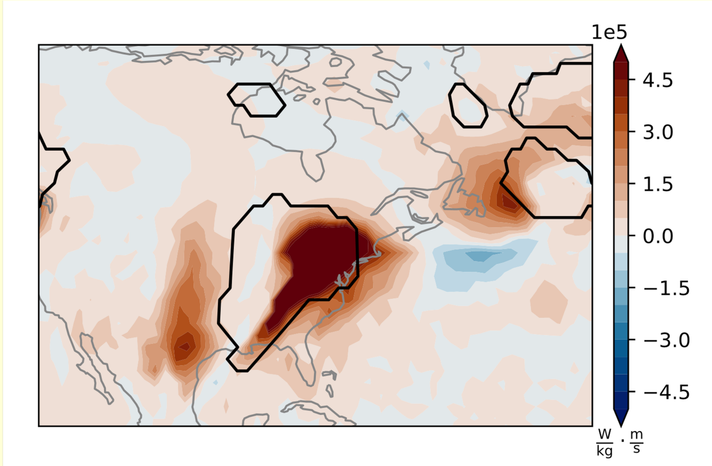

Figure 5: Snapshot of 850hPa **TE MSE** flux (shading) and **surface cyclones** (contours).

References

1. Messori, G., and A. Czaja: On the sporadic nature of meridional heat transport by transient eddies. Quarterly Journal of the Royal Meteorological Society, 139, 999–1008, doi:10.1002/qj.2011 (2013).
2. Shaw, T. A., Barpanda, P., & Donohoe, A.: A Moist Static Energy Framework for Zonal-Mean Storm-Track Intensity, Journal of the Atmospheric Sciences, 75(6), 1979-1994 (2018).
3. Sinclair, V. A., Rantanen, M., Haapanala, P., Räisänen, J., and Järvinen, H.: The characteristics and structure of extra-tropical cyclones in a warmer climate, Weather Climate Dynamics, 1, 1–25, https://doi.org/10.5194/wcd-1-1-2020, (2020).

Latent heating and moisture convergence

First results

Composites in Figure 6 reveal:

- The meridional convergence of TE latent heat flux peaks poleward and downstream of maximum precipitation by 1-2°.
- The latitude of zero TE moisture flux divergence (and TE MSE flux divergence, not shown) matches with the cyclone center[2].

A priori not surprising; zonal and low-frequent flux convergence are not included.

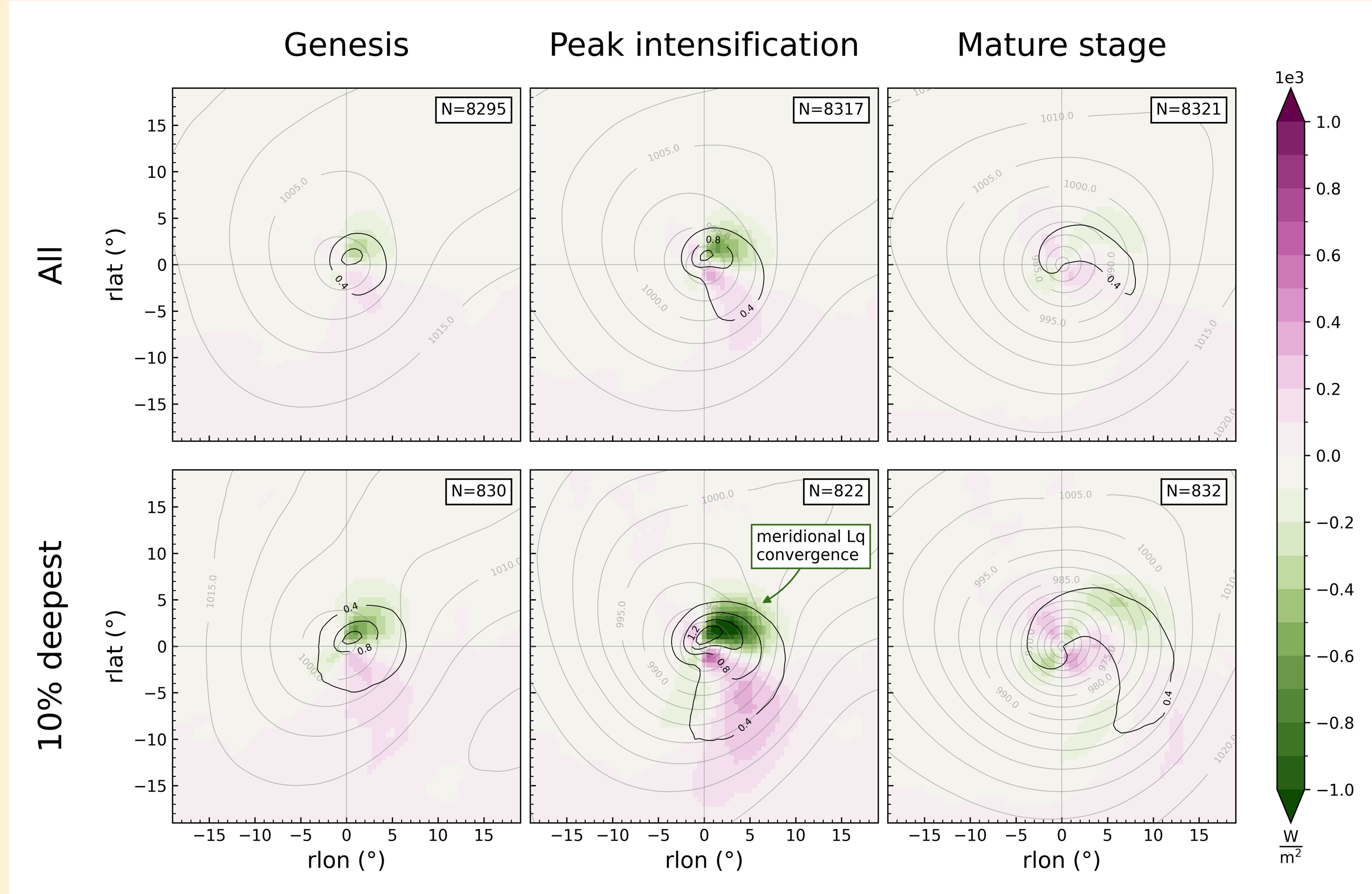

Figure 6: Vertically integrated meridional **TE *Lq* flux divergence** (shading) and **precipitation** (black contours) as in Figure 4. **SLP** is here shown with transparent grey contours.

Follow-up research

Open question: Is high TE moisture flux convergence only linked to cyclone intensity, or is it also linked to intensification (e.g., inferred from potential vorticity changes)?

General Outlook

By combining results from both research questions, we aim to diagnose the effect of increasing moisture under global warming on cyclone characteristics[3].

The methods will be applied to:

- an ICON aquaplanet ensemble featuring zonally symmetric sea surface temperatures of a reference and a warmed climate
- a 5-member CESM SSP3.7-0 ensemble spanning 1980-2100