The impact of changes of atmospheric water mass on tropical cyclone intensification in ICON-A

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① BACKGROUND

Changes in atmospheric water content are the main driver of atmospheric mass variations (Trenberth et al., 1987; Trenberth & Smith, 2005). In the atmosphere model ICON-A, however, the **total atmospheric mass is conserved**. Thus, precipitation and evaporation do not affect surface pressure and atmospheric dynamics. This study investigates the impact of the precipitation mass sink / evaporation mass source on the evolution of an idealised tropical cyclone.

② METHODS

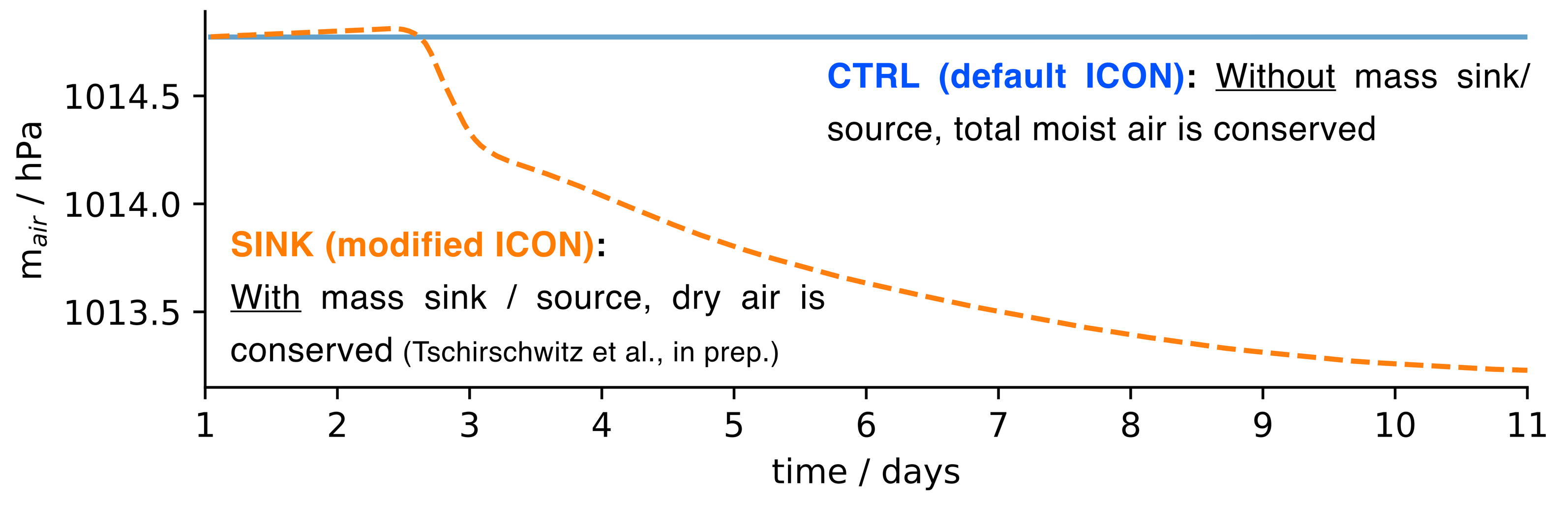

Fig. 1: Globally averaged pressure exerted by total air mass, for CTRL (blue solid line) and SINK (orange dashed line).

- Resolution: 10 km (R2B8) with 90 vertical levels
- ICON-Sapphire physics (Giorgetta et al., 2022): microphysics (single-moment), radiation, vertical diffusion

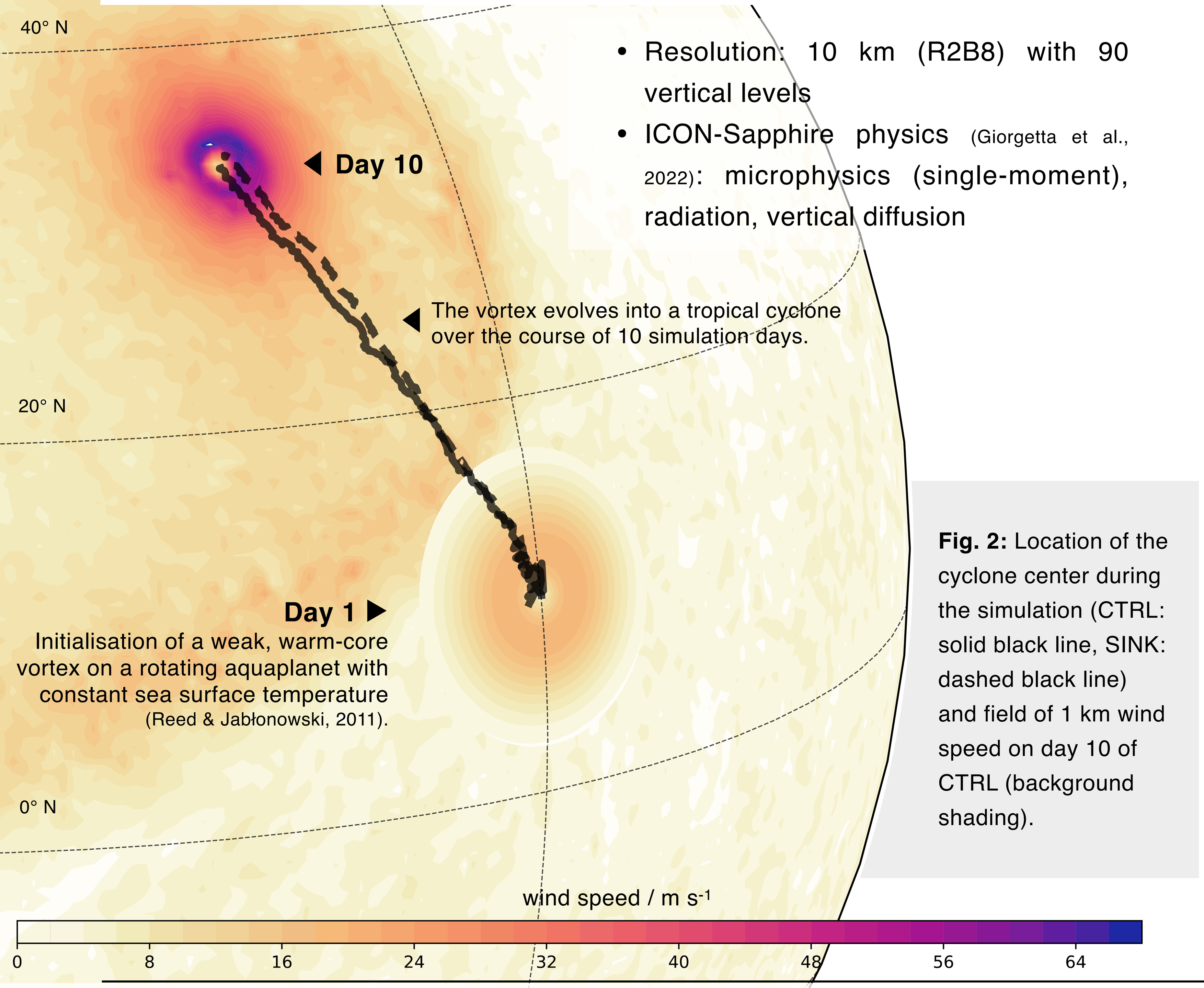

Fig. 2: Location of the cyclone center during the simulation (CTRL: solid black line, SINK: dashed black line) and field of 1 km wind speed on day 10 of CTRL (background shading).

CONCLUSION

- Including a simple precipitation mass sink / evaporation mass source into the ICON-A model results in a **stronger tropical cyclone**, characterised by a decrease in minimum surface pressure and an increase in maximum wind speed (Fig. 3). This confirms results from previous studies of the precipitation mass sink (Qiu et al., 1993; Lackmann & Yablonsky, 2004).
- The azimuthally averaged profile of pressure differences between the two simulations shows **lowered pressure particularly around the center of the cyclone**, compared to the control simulation (Fig. 4). This could facilitate the **transport of moisture towards the tropical cyclone** and provide it with more energy.

③ RESULTS

The tropical cyclone is strengthening when considering changes in atmosphere mass.

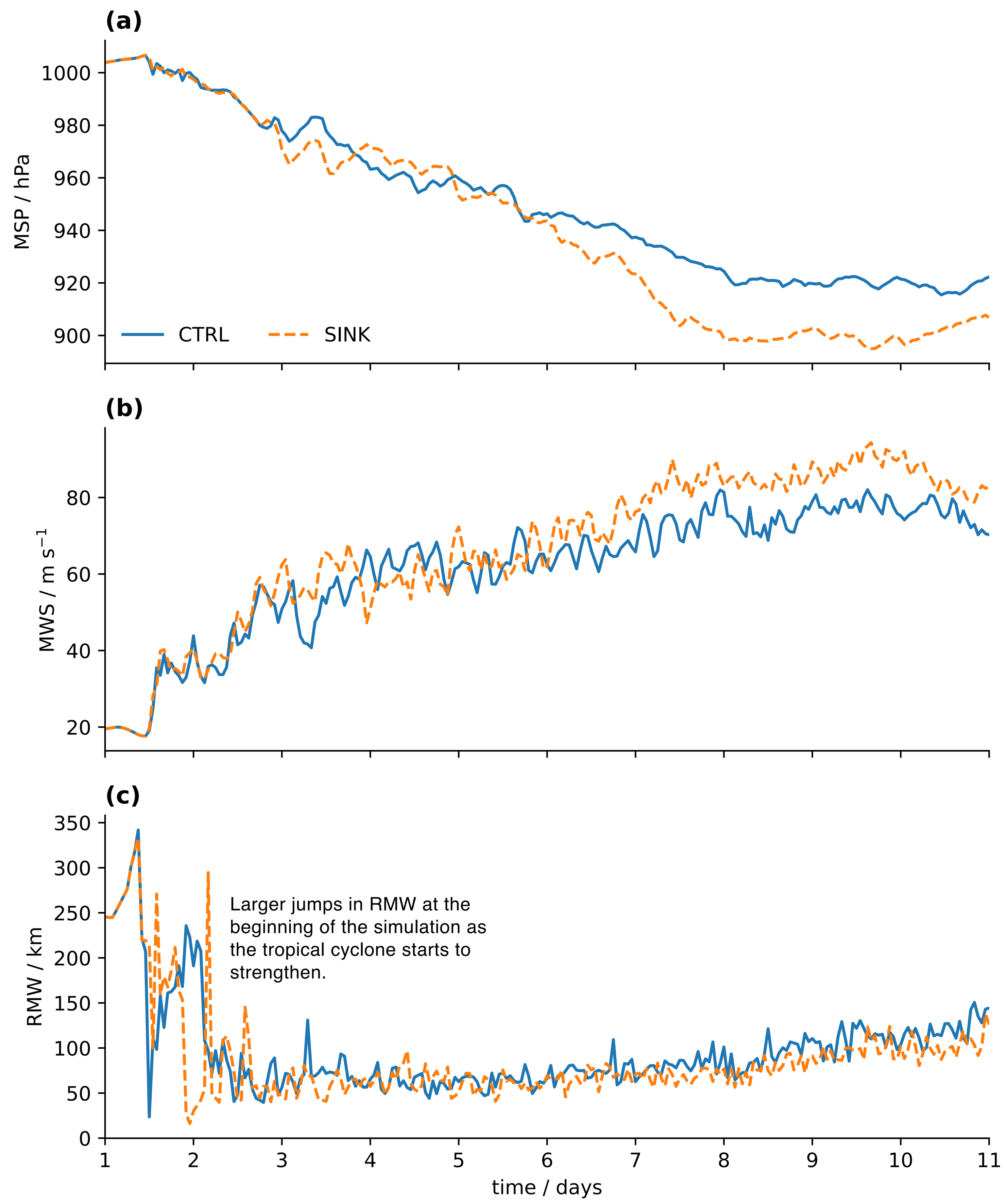

Fig. 3: (a) Minimum surface pressure (MSP), **(b)** maximum wind speed (MWS) at 1 km, **(c)** radius of maximum wind (RMW), from hourly model output.

Why?

↓ **Decrease in pressure** around cyclone center due to precipitation.

↑ **Increased moisture transport** into the tropical cyclone which fuels the tropical cyclone.

↑ **Strengthening** of the tropical cyclone.

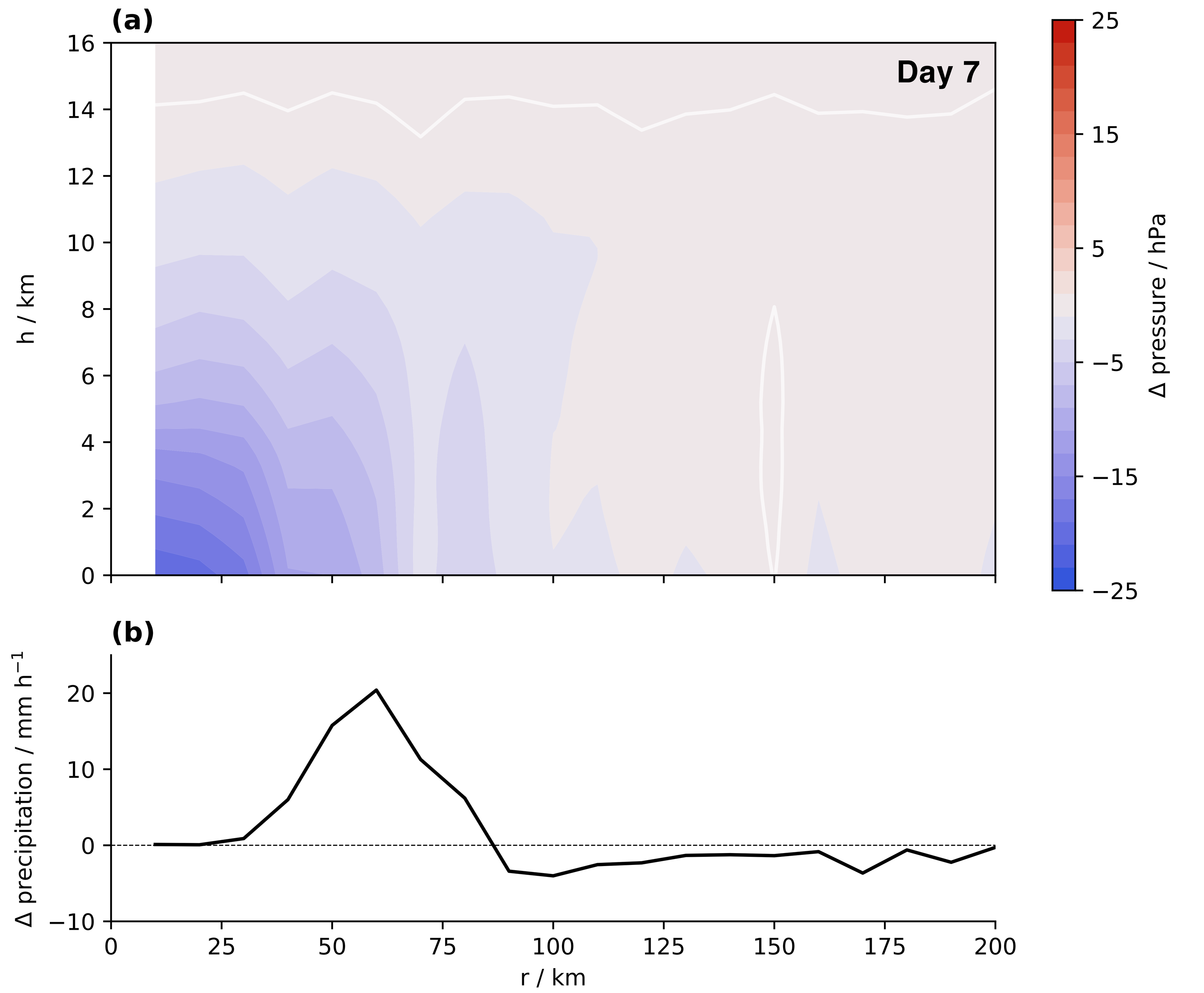

Fig. 4: (a) Azimuthally averaged profile of pressure differences at full model levels, and **(b)** azimuthally averaged difference in surface precipitation rate (SINK-CTRL), averaged over day 7. The white line in (a) denotes Δpressure = 0.

References

Giorgetta et al. (2022). The ICON-A model for direct QBO simulations on GPUs (version icon-cscs:baf28a514). *GMD*, 15, https://doi.org/10.5194/gmd-15-6985-2022

Lackmann, G. M., & Yablonsky, R. M. (2004). The importance of the precipitation mass sink in tropical cyclones and other heavily precipitating systems. *JAS*, *61*(14), 1674–1692. https://doi.org/10.1175/1520-0469(2004)061<1674:TIOTPM>2.0.CO;2

Reed, K. A., & Jablonowski, C. (2011). An analytic vortex initialization technique for idealized tropical cyclone studies in AGCMs. *MWR*, *139*(2), 689–710. https://doi.org/10.1175/2010MWR3488.1

Qiu, C.-J., Bao, J.-W., & Xu, Q. (1993). Is the mass sink due to precipitation negligible? *MWR*, *121*(3), 853–857. https://doi.org/10.1175/1520-0493(1993)121<0853:ITMSDT>2.0.CO;2

Trenberth, K. E., Christy, J. R., & Olson, J. G. (1987). Global atmospheric mass, surface pressure, and water vapor variations. *JGR: Atmospheres*, *92*(D12), 14815–14826. https://doi.org/10.1029/JD092iD12p14815

Trenberth, K. E., & Smith, L. (2005). The mass of the atmosphere: A constraint on global analyses. *JCLI*, *18*(6), 864–875. https://doi.org/10.1175/JCLI-3299.1

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