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Sensitivity of idealised baroclinic waves to different atmospheric temperature changes

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Introduction

- Most of the recent studies carried out with idealised baroclinic wave simulations have investigated the effect of atmospheric moisture on cyclone characteristics.
- It has not been documented comprehensively how idealised baroclinic waves respond to changed meridional temperature gradients.
- We investigated the response of extra-tropical cyclones to atmospheric temperature changes which are similar to those expected with climate change in the Northern Hemisphere: 1) uniform temperature increase, 2) decrease of the lower level meridional temperature gradient and 3) increase of the upper level temperature gradient.

Model set-up

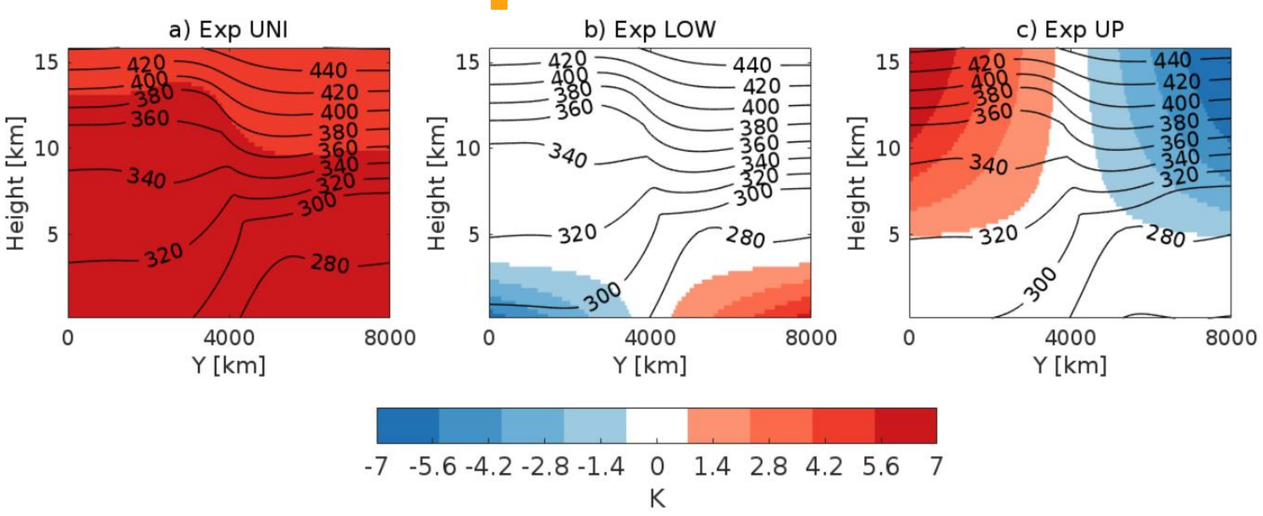

Figure 1. Initial zonal mean potential temperature (contours) and differences from the control run (shading) for a) Experiment UNI, b) Experiment LOW and c) Experiment UP.

- Weather Research and Forecast (WRF) model v. 3.8.1
- Idealized mode with periodic east-west boundaries
- 10 day simulations in a 5000 km (x) x 8000 km (y) x 16 (z) km domain
- Horizontal grid spacing Δx = 50 km
- Three sets of experiments + control run (CTRL) were performed:

1. **Experiment UNI**, increase of temperature uniformly by 6 K
2. **Experiment LOW**, decrease of meridional temperature gradient in the lower troposphere by 12 K
3. **Experiment UP**, increase of meridional temperature gradient in the upper troposphere by 12 K

- The experiments were conducted both in a **dry** and **moist** atmosphere

Results

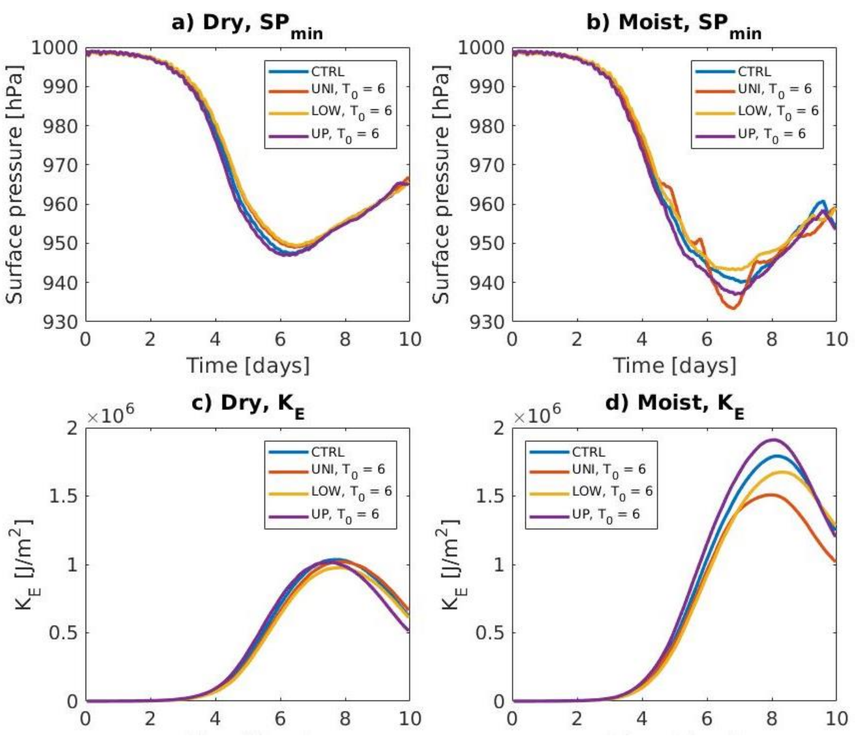

Figure 2. Time evolution of the minimum surface pressure in a) the dry experiments and b) the moist experiments, and eddy kinetic energy in c) the dry experiments and d) the moist experiments.

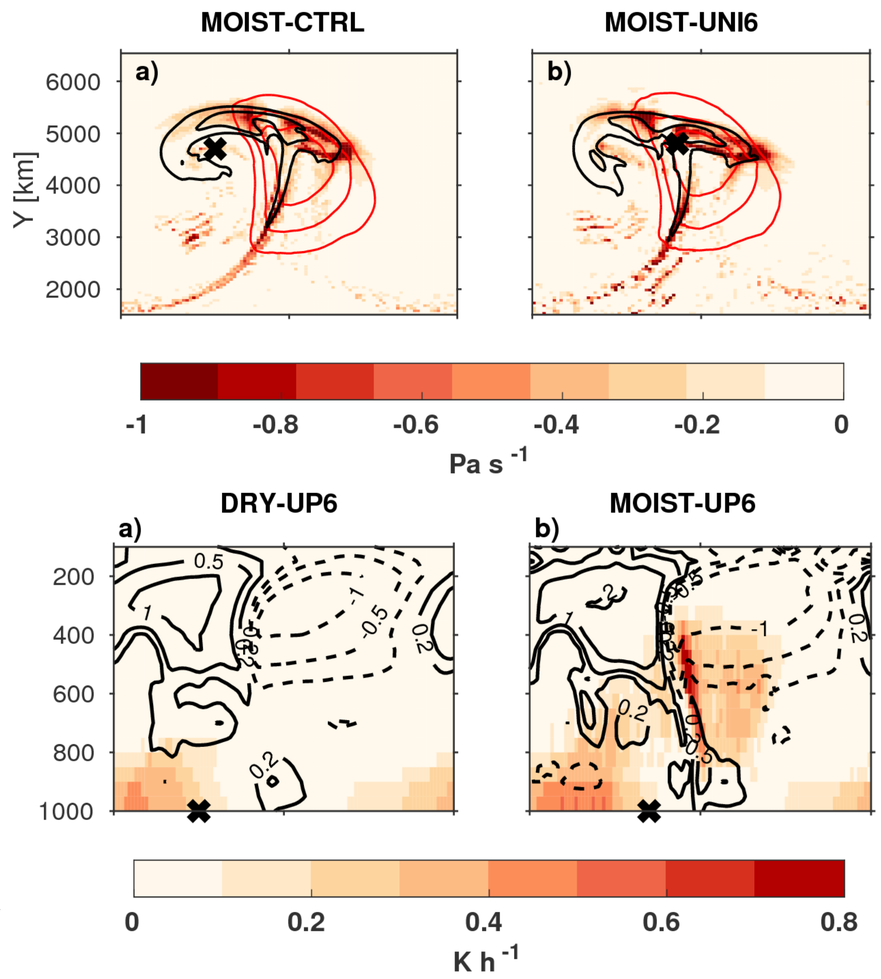

Figure 3. 500-900 hPa mean ω (colours), 500-900 hPa mean T* (red contours for 5, 9 and 13 K values) and 700-900 hPa Ertel PV (black contours for 1 and 2 PVU) for moist CTRL (left) and moist UNI6 (right) on day 6 of the simulations. The cross marks the location of the surface low.

Figure 4. Meridionally averaged cross sections of diabatic heating (colours) and Ertel PV* (contours) in dry UP6 (left) and MOIST-UP6 (right) on day 6 of the simulation. The cross marks the location of the surface low.

Conclusions

1. Exp UNI

- Increasing temperature and thus moisture in the atmosphere from typical present-day values induces deeper cyclones (Fig. 2b, red vs. blue) but with less eddy kinetic energy (EKE) (Fig. 2d, red vs. blue).
- The reduction of EKE with the warming can be traced to a more unfavorable phasing between ascent and buoyancy within the warm sector (Fig. 3, right vs. left).

2. Exp LOW

- The decrease of low-level temperature gradient is found to decrease the strength of the storm in a straightforward way: all the energy quantities explored in this study remain lower than in CTRL regardless if moisture is present in the simulation or not.

3. Exp UP

- In the dry atmosphere, increasing the upper level temperature gradient decreases EKE (Fig. 2c, purple vs. blue), whereas in the moist atmosphere EKE increases (Fig. 2d, purple vs. blue).
- In the moist case the diabatic heating enhances the interaction between upper- and low-level PV anomalies (Fig. 4), and hence helps the surface cyclone to exploit the increased upper level baroclinicity. As a result, EKE increases at larger meridional temperature gradients in the upper troposphere.

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