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# Will tropical cyclones weaken in a cleaner environment?

## Composite perspective on ICON ensemble simulations with prescribed aerosols

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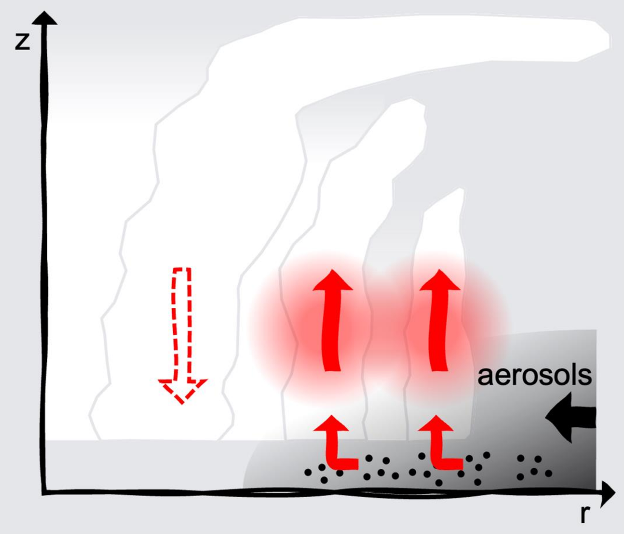
## Motivation

Projected decrease of anthropogenic aerosol emissions in the future.[1]

**Peripheric aerosol intrusion in TCs** [2-4]

- Rain band convection ↑
- Eyewall convection ↓
- Moist static energy ↓
- Broadening of circulation
- TC intensity ↓




How do TCs evolve in an overall **cleaner aerosol environment?**

## Take home messages

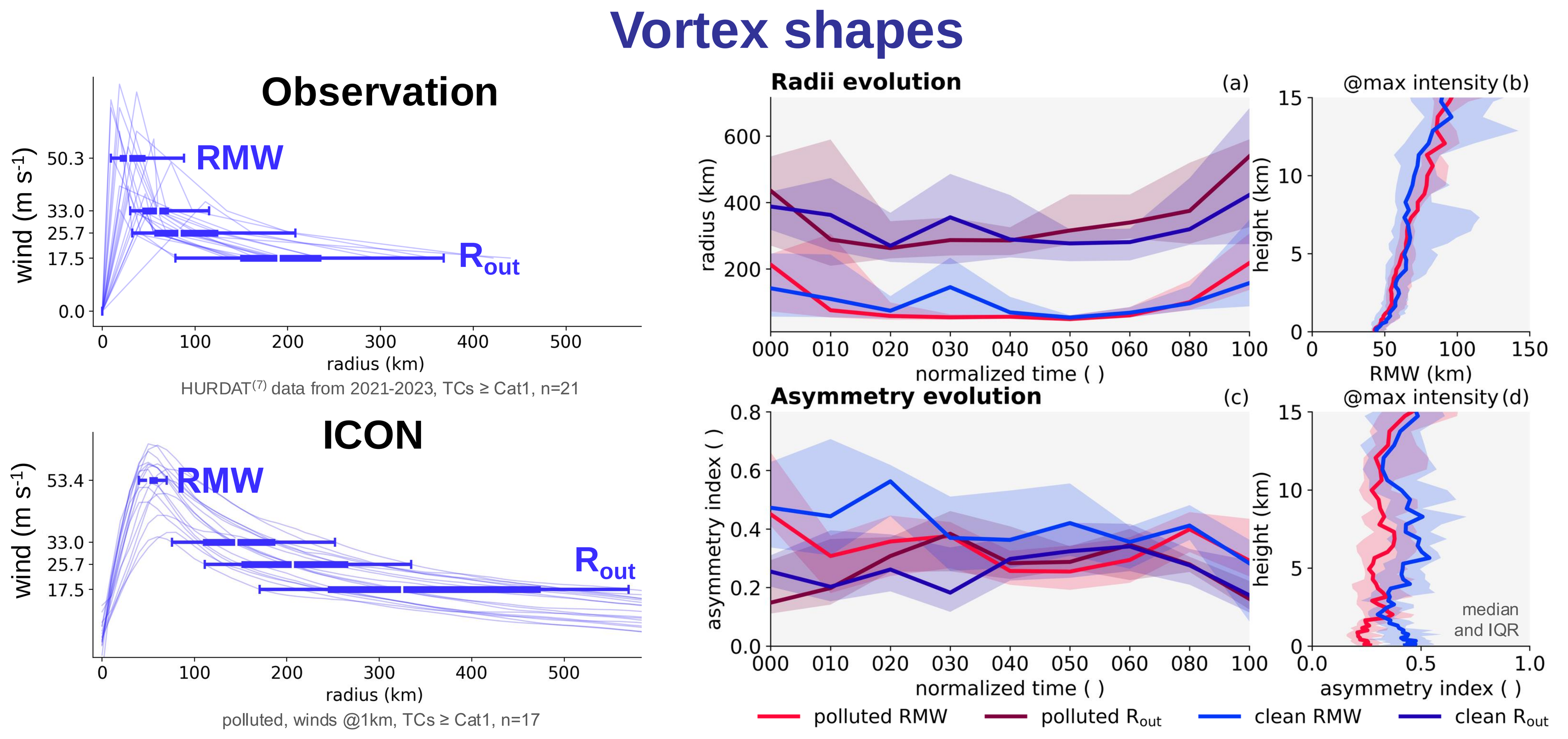
The symmetrisation and normalisation of TCs **reduce composite blurring**.

TCs become on average **weaker** in homogeneously cleaner aerosol conditions.

The weakening is likely caused by reduced cloud water in cleaner storms causing a **reduction in latent heat release**.

## Symmetrized-normalized composites

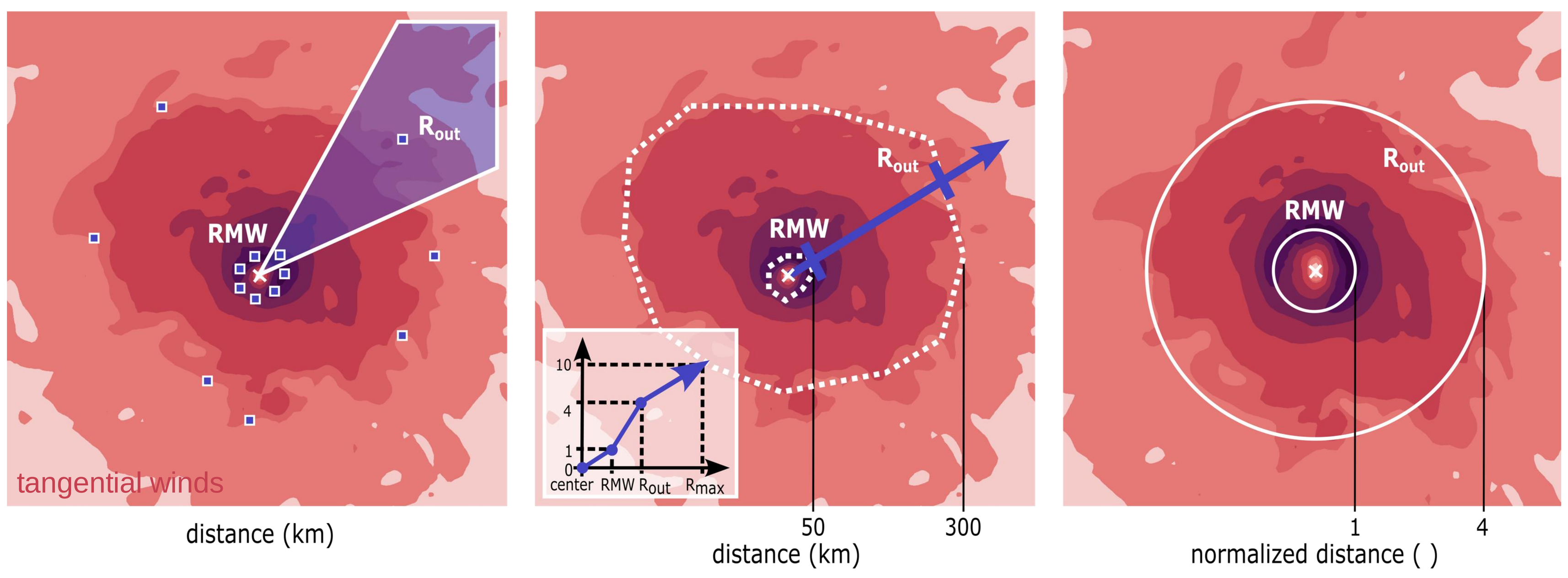
### Vortex shapes



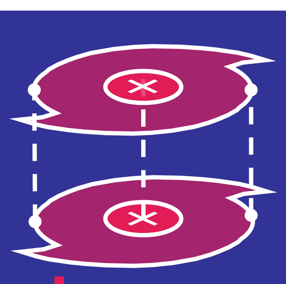

**Challenge:** Various vortex **sizes**, **tilts** and **asymmetry** smooths cyclone composite.

### Symmetrize and normalize TCs

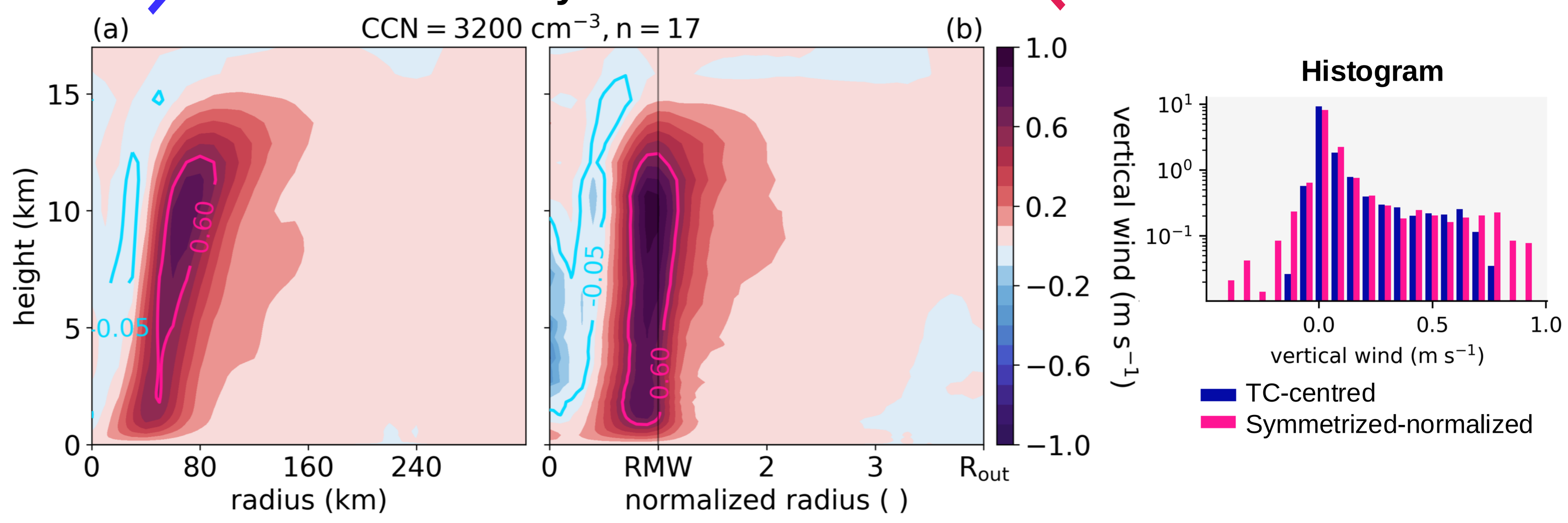
1. RMW & $R_{out}$ detection
2. Radius transformation
3. Symmetrized and normalized



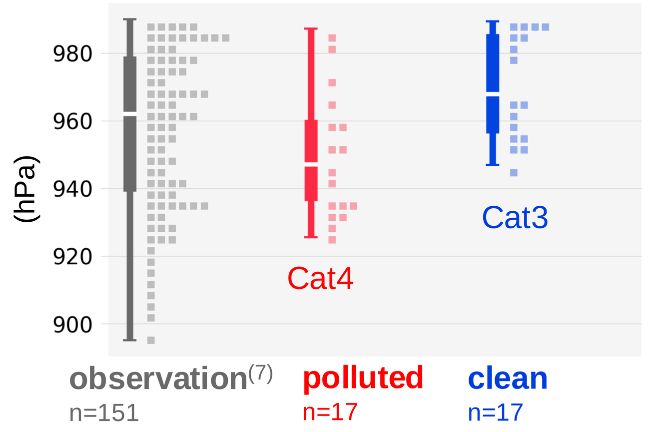

- ✓ Accounts for size, asymmetry and tilt
- ✓ Cyclone-relative interpretation
- ✓ Composite sharpening



TC-centred — Symmetrized-normalized



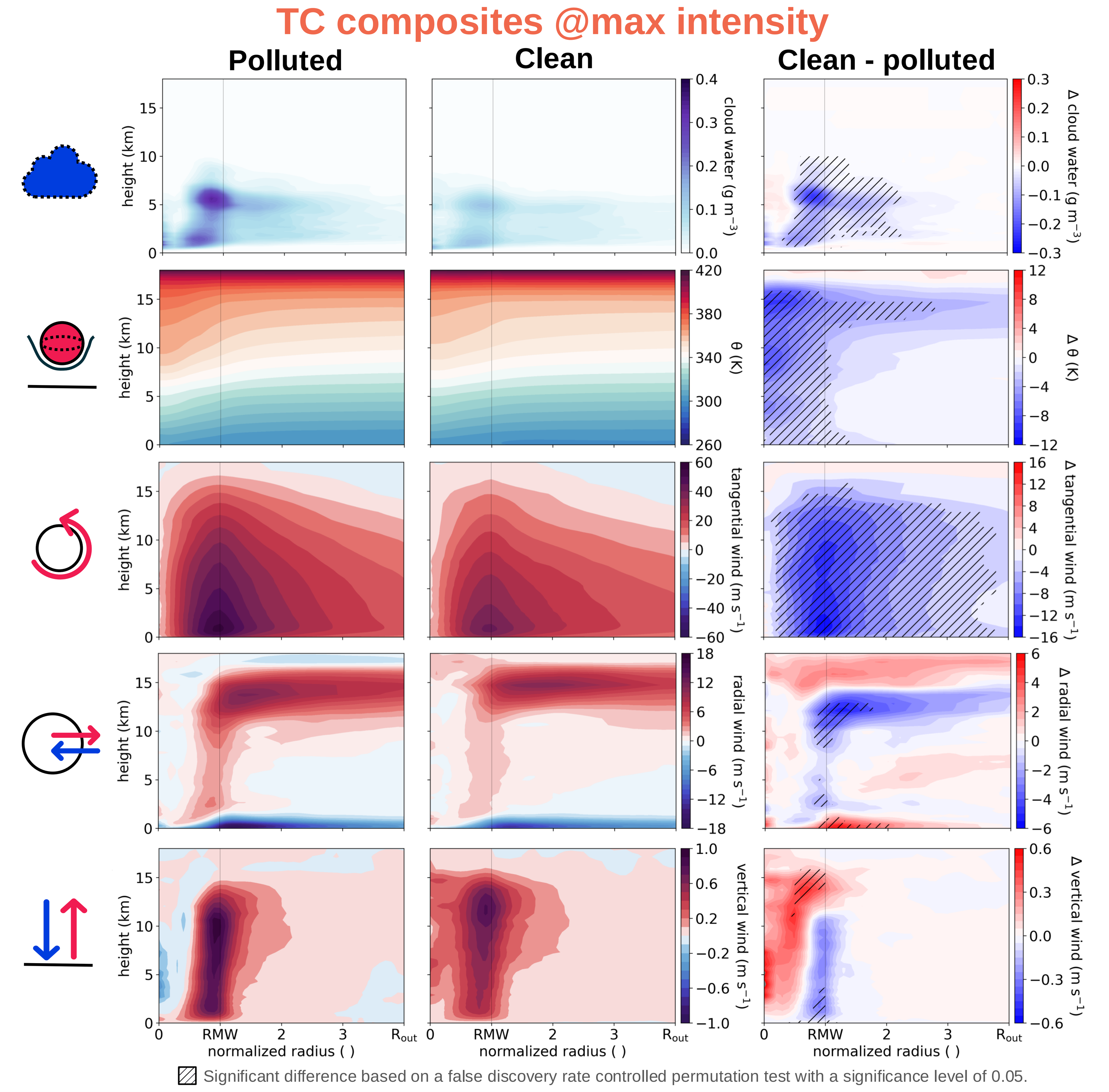

## CCN sensitivity




CCN ↓

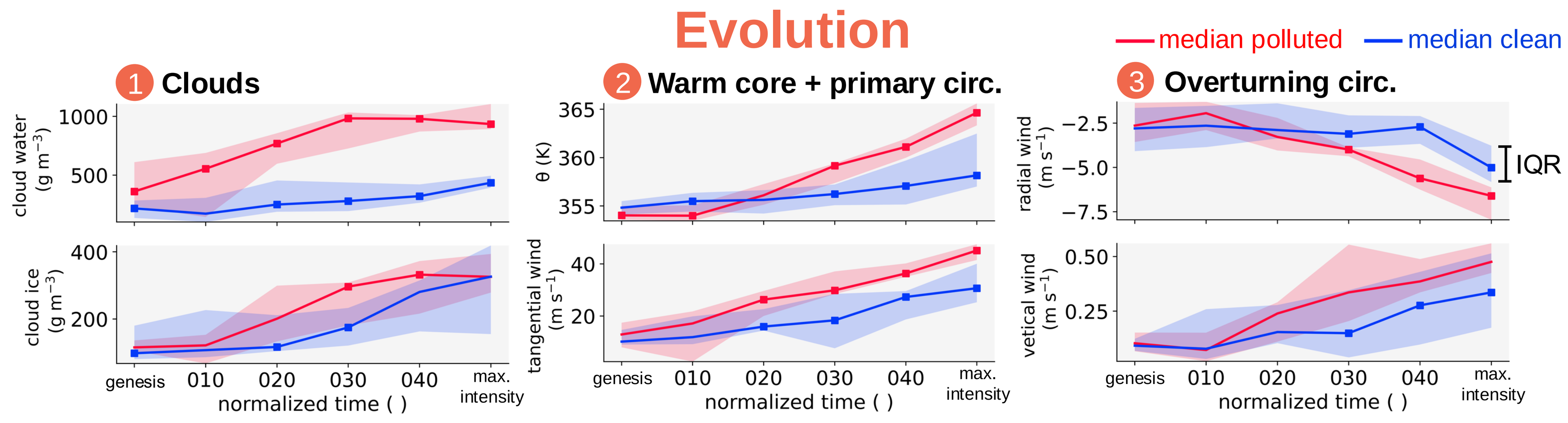
- → Droplet number ↓
- → Cloud water ↓
- → Latent heating ↓
- → Warm core ↓
- → Winds ↓
- → Inflow ↓
- → Updrafts ↓

### TC composites @max intensity




Significant difference based on a false discovery rate controlled permutation test with a significance level of 0.05.

### Evolution



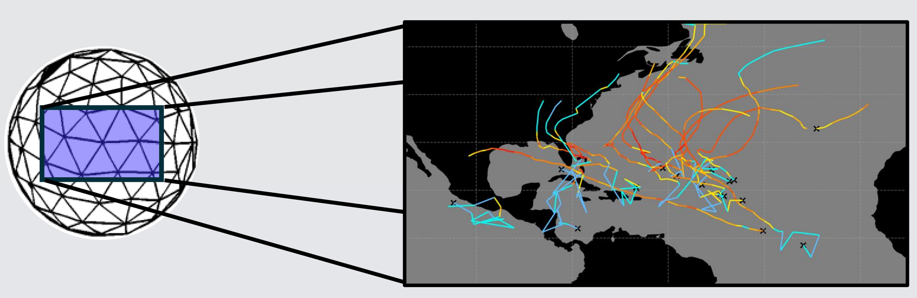

vertically integrated/averaged over low/mid or upper-levels, averaged within $r_{norm}$[0.5-1.5]

## Modelling

**1. ICON-NWP LAM**[5] ensemble simulations

polluted $3200\ cm^{-3}$

clean $100\ cm^{-3}$



**2. TC tracker**[6]

- ICON (ICOsahedral Non-hydrostatic)[5]
- NWP physics
- 13 km grid, 50 vertical levels
- Simulation August – September 2005
- IC and 6-hourly BC from ERA5
- 2-moment cloud microphysical scheme[8]

- Deep convection parametrisation turned off
- Homogeneously prescribed CCN
- Ensemble generation (3 members) by perturbing the moisture field

References

(1) Riahi et al. (2017). Global Environmental Change. https://doi.org/10.1016/j.gloenvcha.2016.05.009 (2) Lin et al. (2023). Atmospheric Chemistry and Physics. https://doi.org/10.5194/acp-23-13835-2023 (3) Wang et al. (2014). Nature Climate Change. https://doi.org/10.1038/nclimate2144 (4) Zhang et al. (2009). Geophysical Research Letters. https://doi.org/10.1029/2009GL037276 (5) Zängl, G. (2015). Quarterly Journal of the Royal Meteorological Society. https://doi.org/10.1002/qj.2378 (6) Enz et al. (2023). Geoscientific Model Development. https://doi.org/10.5194/gmd-16-5093-2023 (7) Landsea & Franklin (2013). Monthly Weather Review. https://doi.org/10.1175/MWR-D 12-00254.1 (8) Seifert & Beheng (2006). Meteorology and Atmospheric Physics.. https://doi.org/10.1007/s00703-005-0112-4 (9) Segal & Khain (2006). Journal of Geophysical Research: Atmospheres. https://doi.org/10.1029/2005JD006561

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