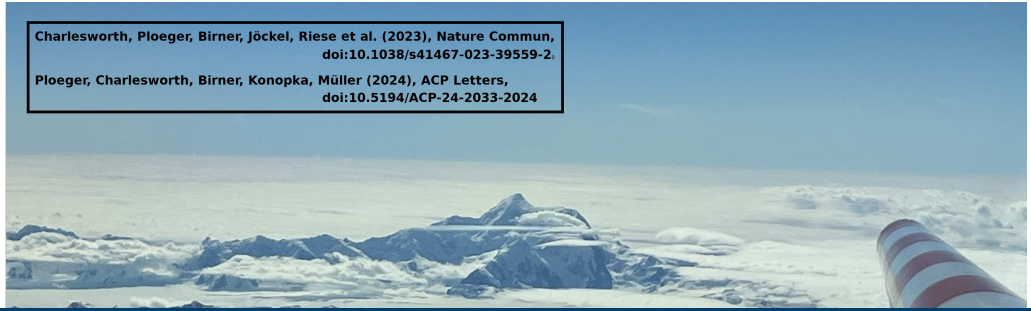

STRATOSPHERIC WATER VAPOR AFFECTING ATMOSPHERIC CIRCULATION

Felix Plöger, **P. Konopka**, Edward Charlesworth, T. Birner, R. Baihadzhaev, R. Müller, M. Riese et al.
Institute of Climate and Energy Systems, Stratosphere (ICE–4), Research Centre Jülich

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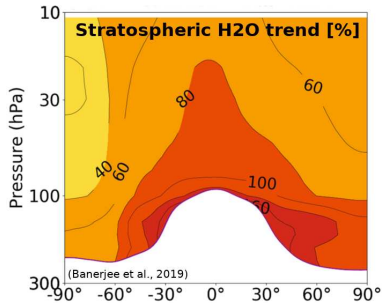
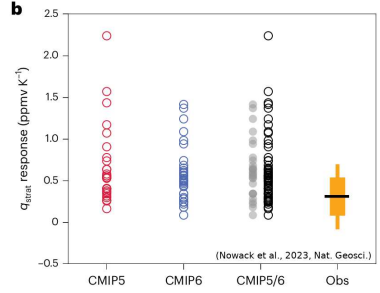
Why should we care about stratospheric water vapour?

- Stratospheric water vapor (SWV) increase in future climate causes positive climate feedback (Banerjee et al., 2019)
- Future SWV increases in models are not well constrained (Nowack et al., 2023)





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- Stratospheric water vapor (SWV) increase in future climate causes positive climate feedback (Banerjee et al., 2019)
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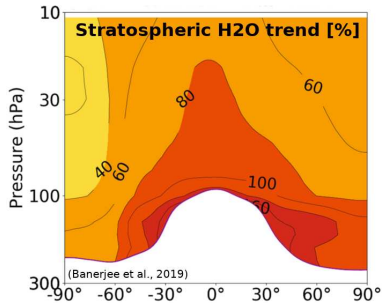
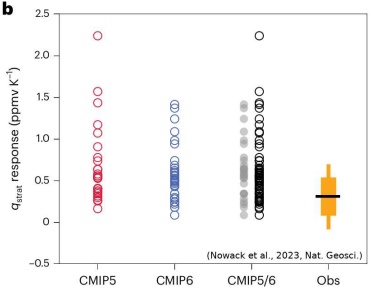
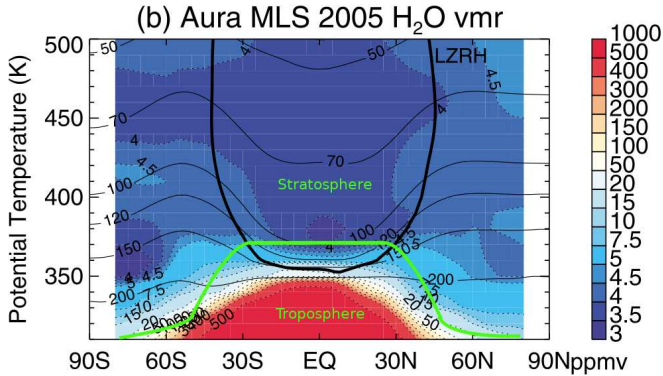
Questions for this talk:

1. How well is SWV represented in models?
2. What are the impacts of SWV increases on circulation? (Can a few ppm more water vapor shift jet streams and regional circulation systems?)





Challenge for global models



Need:

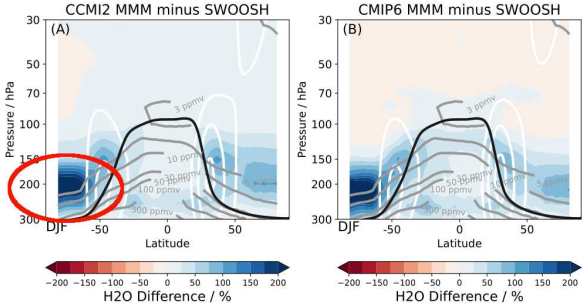
Model transport scheme with reduced numerical diffusion - to represent the steep H_2O gradients in UTLS

We use **EMAC–CLaMS**: Lagrangian transport in global climate model for SWV
(Charlesworth et al., 2023)

Stratospheric water vapor in climate models

Differences between climate model SWV and satellite observations show (Charlesworth et al., 2023):

- Large model moist bias in lowermost stratosphere (factor 2-3)
- Strongest biases occur in summer hemisphere



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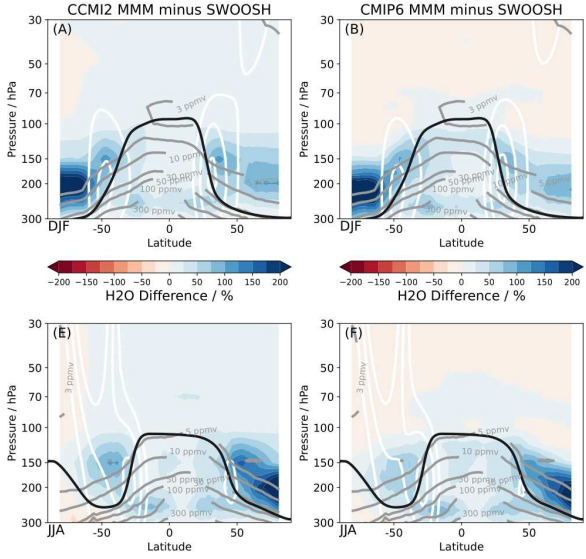
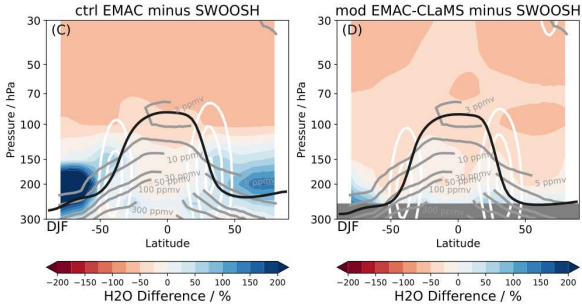


Model experiment

- 2 free-running EMAC climate model simulations
  (Charlesworth et al., 2023):
  - control
  - modified–Lagrangian
    (SWV with Lagrangian CLaMS transport)

- Lagrangian transport with reduced numerical diffusion causes more efficient sampling of cold tropopause



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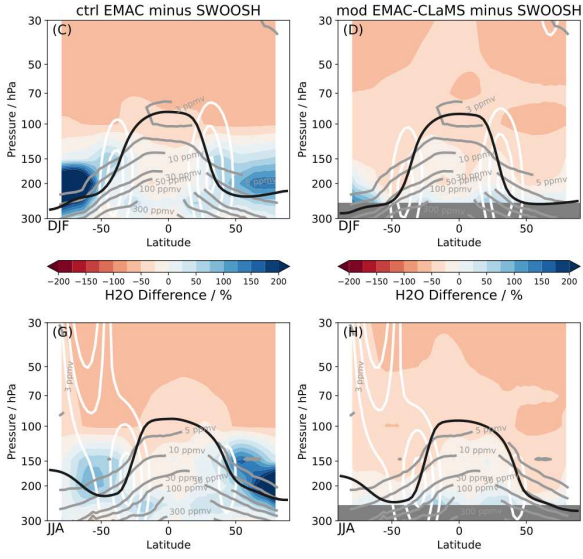
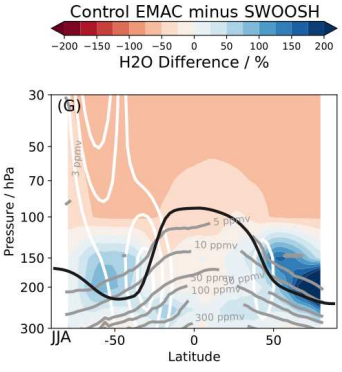
Lagrangian transport:

causes drier lowermost stratosphere and reduces the moist bias



Effects on atmospheric temperatures and circulation

- Deduce SWV effect on circulation from differencing control minus modified–Lagrangian simulations (Charlesworth et al., 2023).



SWV increase in lowermost stratosphere in control–EMAC

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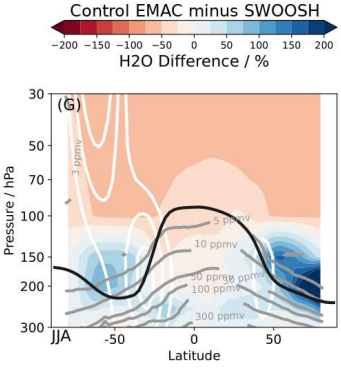

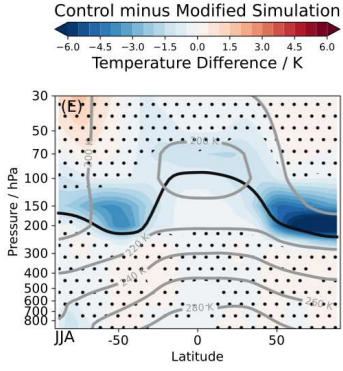

SWV increase in lowermost stratosphere in control–EMAC

⇒ causes **local cooling** & reduced temperatures

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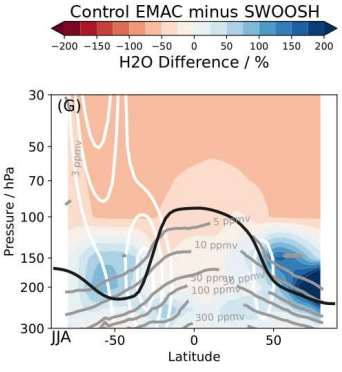
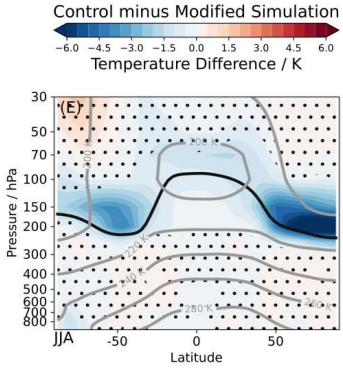
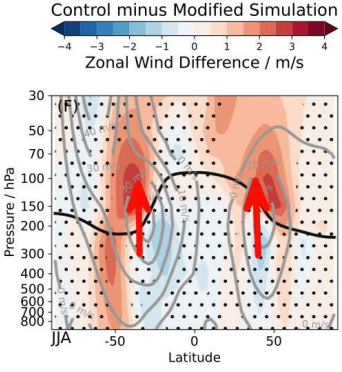




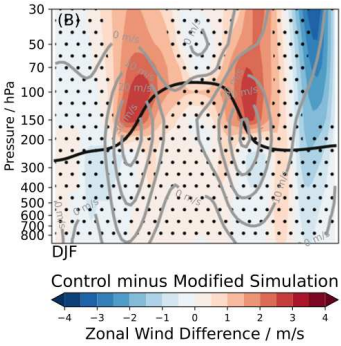


SWV increase in lowermost stratosphere in control–EMAC

⇒ causes **local cooling** & reduced temperatures

⇒ causes upward **shift** of **subtropical jets**

Effects on stratospheric circulation



Upward shift of subtropical jet streams

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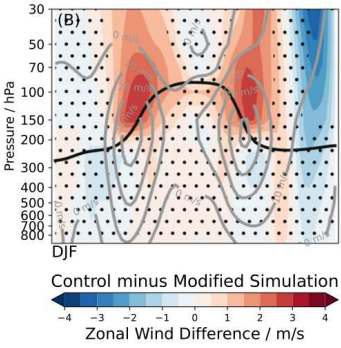
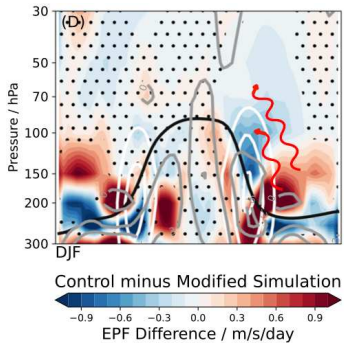
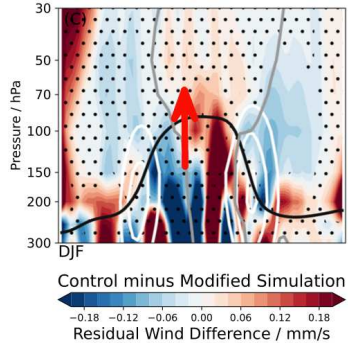
Effects on stratospheric circulation







Upward shift of subtropical jet streams

⇒ upward shift of critical layers & wave breaking

⇒ **increased** stratospheric **upwelling**

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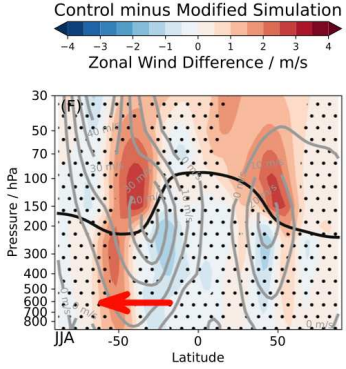
Impacts on near-surface winds

- Circulation impacts from SWV increase extend into troposphere (Charlesworth et al., 2023)
- **Poleward shift of eddy-driven jet**
- Strongest impacts in SH in JJA



Impacts on near-surface winds

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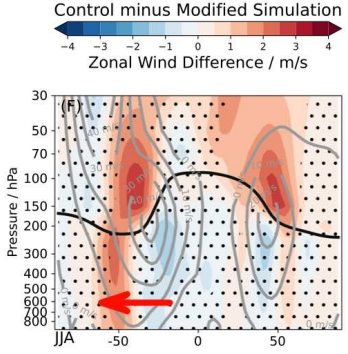
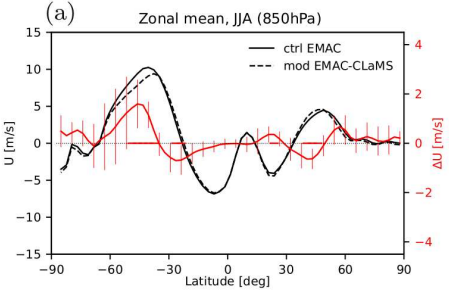
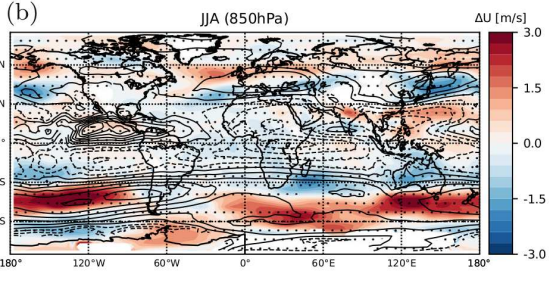
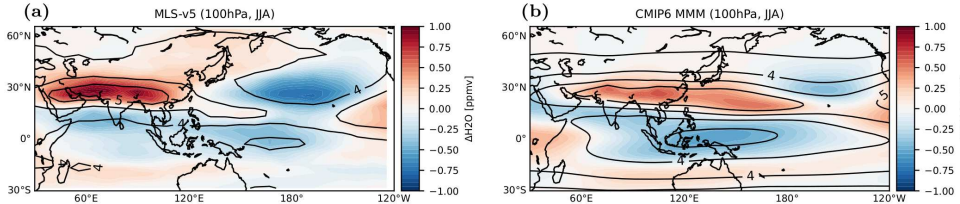
- Strongest impacts in SH in JJA
- Regional patterns:
  max. shift in Atlantic & Pacific







Regional model moist bias



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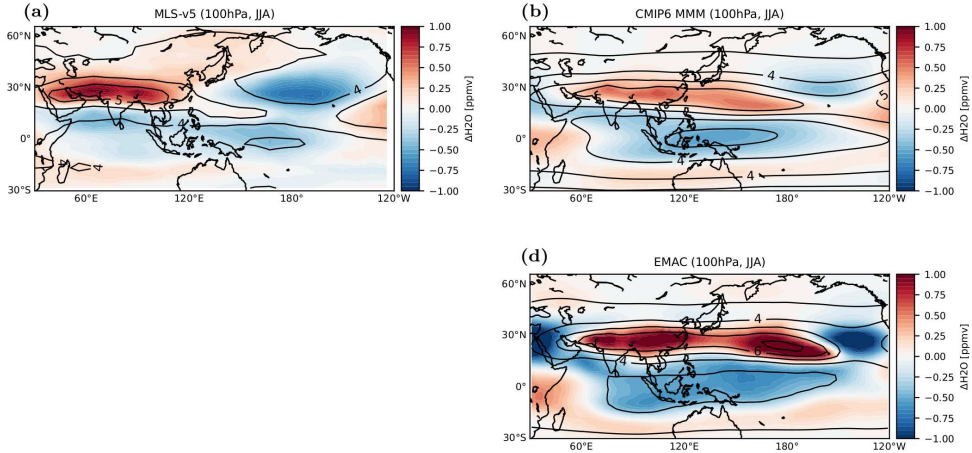

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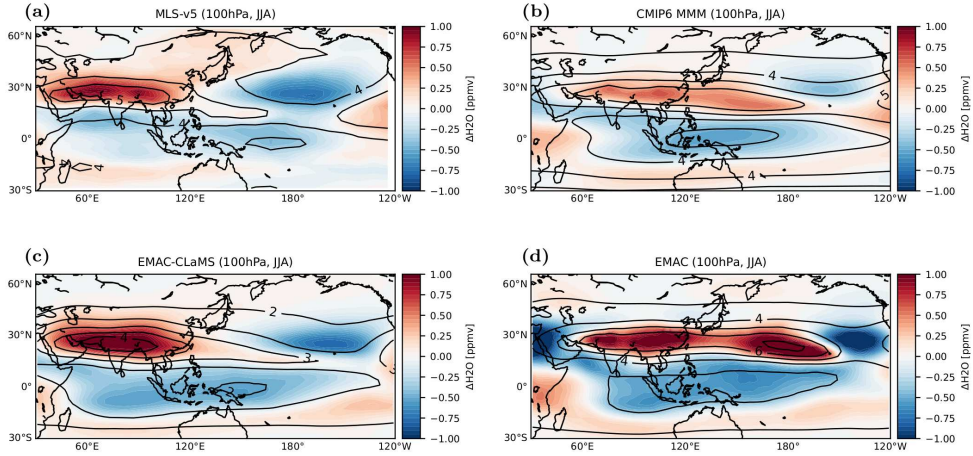

- Strongest model **moist bias in Pacific UTLS** in CMIP6 & EMAC (Ploeger et al., 2024, ACP Letters)
- Moist bias reduced with Lagrangian model simulations (EMAC-CLaMS)

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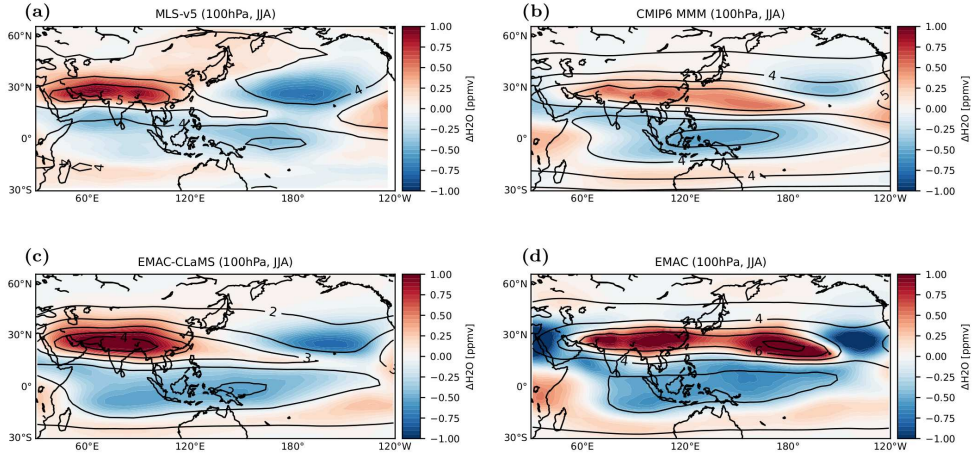

Estimate impacts on circulation...

... from differencing control EMAC vs. Lagrangian modified EMAC-CLaMS

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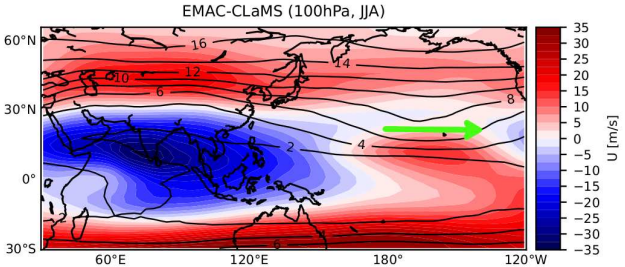
Impact on Pacific westerlies

- Prevalent westerlies in Pacific UTLS enable inter-hemispheric transport



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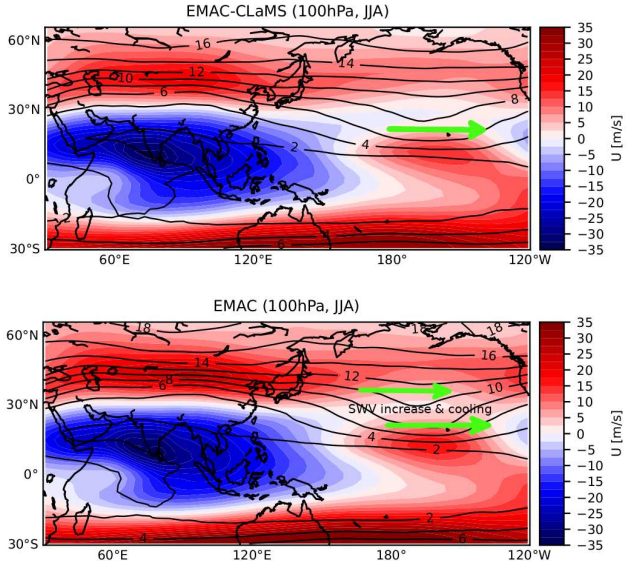

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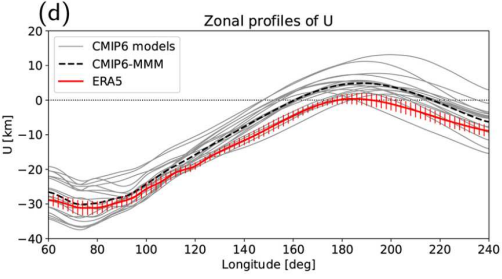
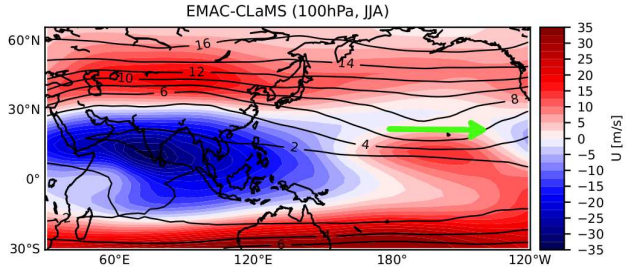
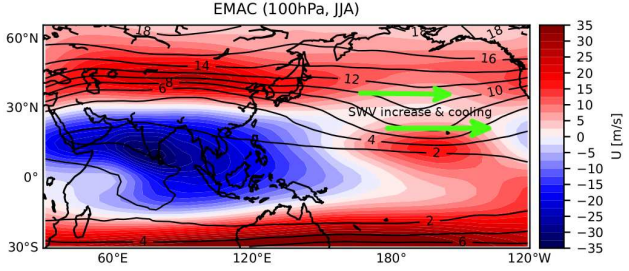
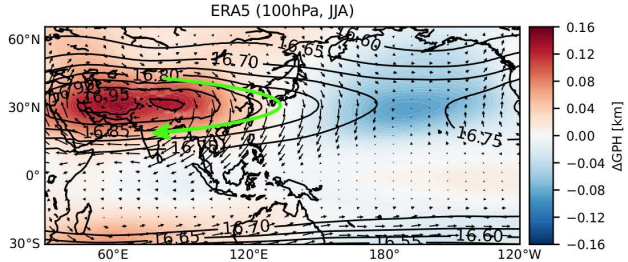






Impact on monsoon circulation

- Asian monsoon anticyclone in UTLS is main pathway for pollution



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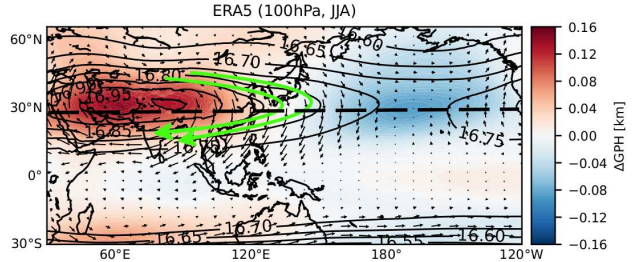

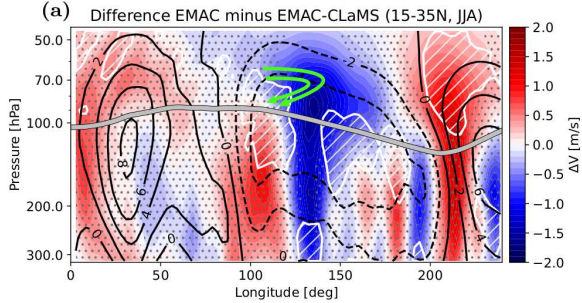

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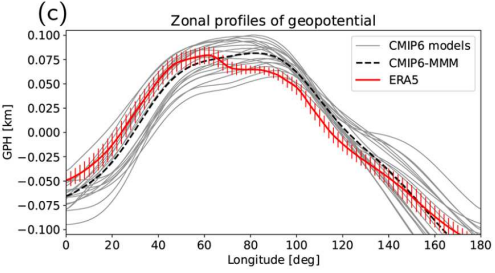

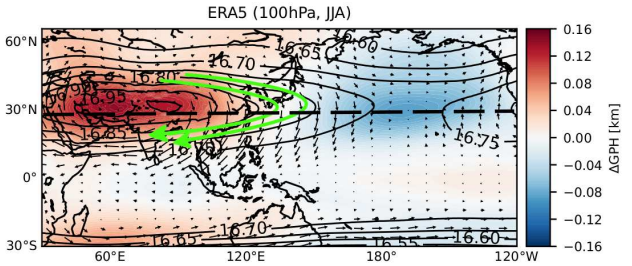

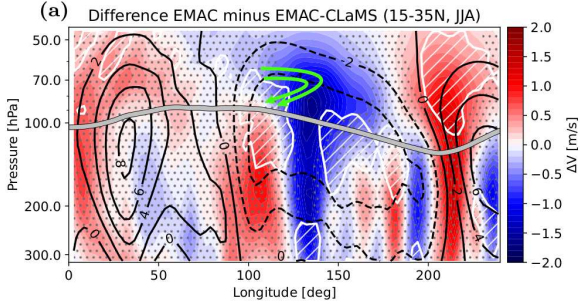

Conclusions

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Stratospheric water vapour - low concentrations but large impacts!

Improving stratospheric water vapour in models will likely improve simulated circulation in stratosphere and troposphere and climate and weather predictions

- Charlesworth et al., 2023, Nature Commun., doi:10.1038/s41467-023-39559-2
- Ploeger et al., 2024, ACP Letters, doi:10.5194/egusphere-2023-2196