

Clouds in decade-long convection-resolving climate simulations over Europe

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Clouds in convection-resolving climate simulations

Clouds

- **Major source** of uncertainties in climate simulations
- **Causes:** **parameterizations**, **coarse** grid resolution

Convection-resolving climate simulations

- **Resolved** deep convection
- **Finer** grid resolution

Studies so far

- **Many on precipitation**
(*e.g. Kendon et al., 2014; Ban et al., 2014, ...*)
- **Clouds?**



Research questions

1. **Added value** of convection-resolving climate simulations for the representation of clouds?
2. **Impact of climate warming** on clouds in the convection-resolving and parameterizing approaches?

→ **Focus on European summer**

Convection-resolving climate simulations over Europe

MODEL & SETUP

- RCM **COSMO**, **GPU** version (*Fuhrer et al., 2014*)
- Run on Piz Daint (CSCS, Lugano CH)
- **10-year-long** climate simulations over Europe
- **Convection-**
 - **resolving: 2 km** (0.02°), 1536x1536 x 60 grid points
 - **parameterizing: 12 km** (0.11°), 355x355 x 60 grid points

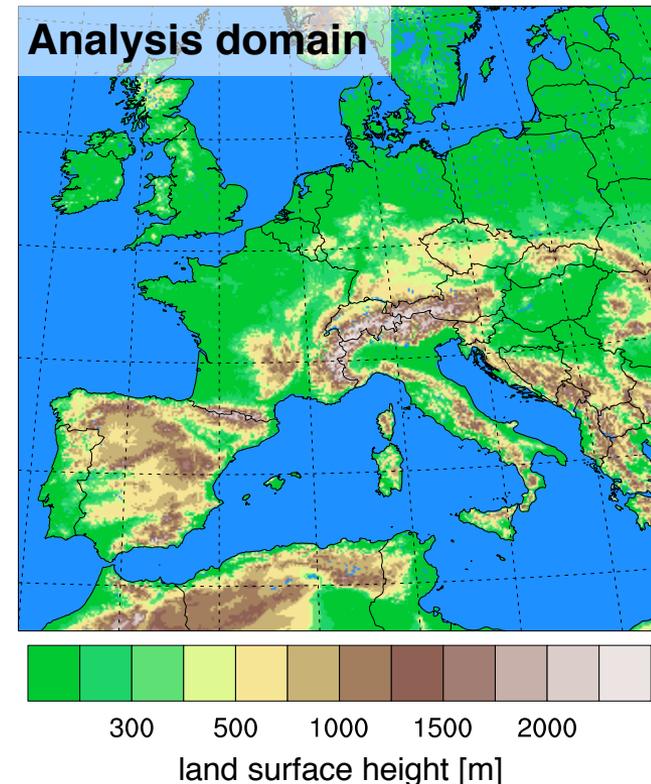
SIMULATIONS

Present climate (CTRL) - 1999-2008 (*Leutwyler et al., 2017*)

- **Boundary Conditions:** ERA-Interim → 12 km → 2 km

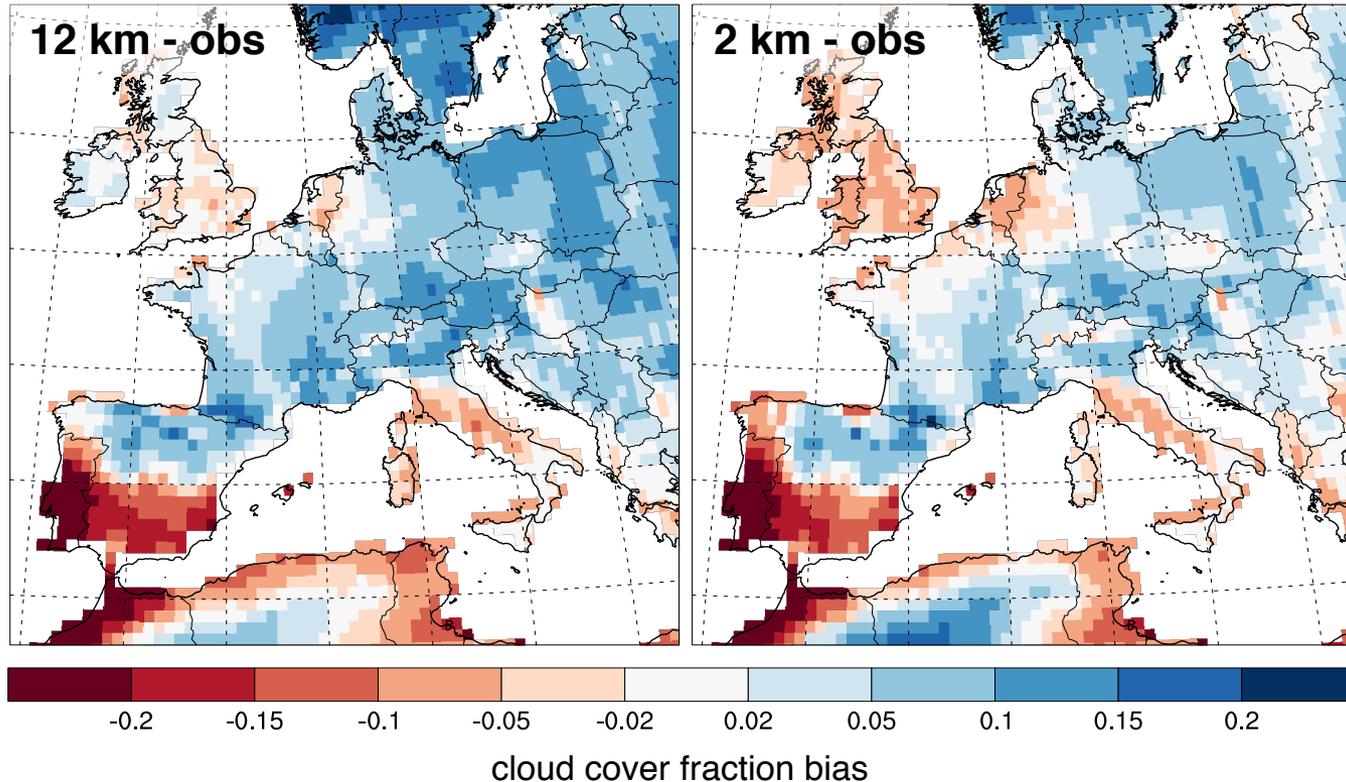
Future climate: Pseudo-Global Warming (PGW) experiment - 2079-2088

- **BC:** ERA-Interim + Climate change signal from GCM (*Liu et al., 2016, Kröner et al., 2016*)
- **Changes due to:**
 - Large-scale atmospheric **warming & moistening**
 - Slowly-varying **circulation** changes



Total cloud cover fraction (summer)

→ Comparison with CRU observations – 1999-2008



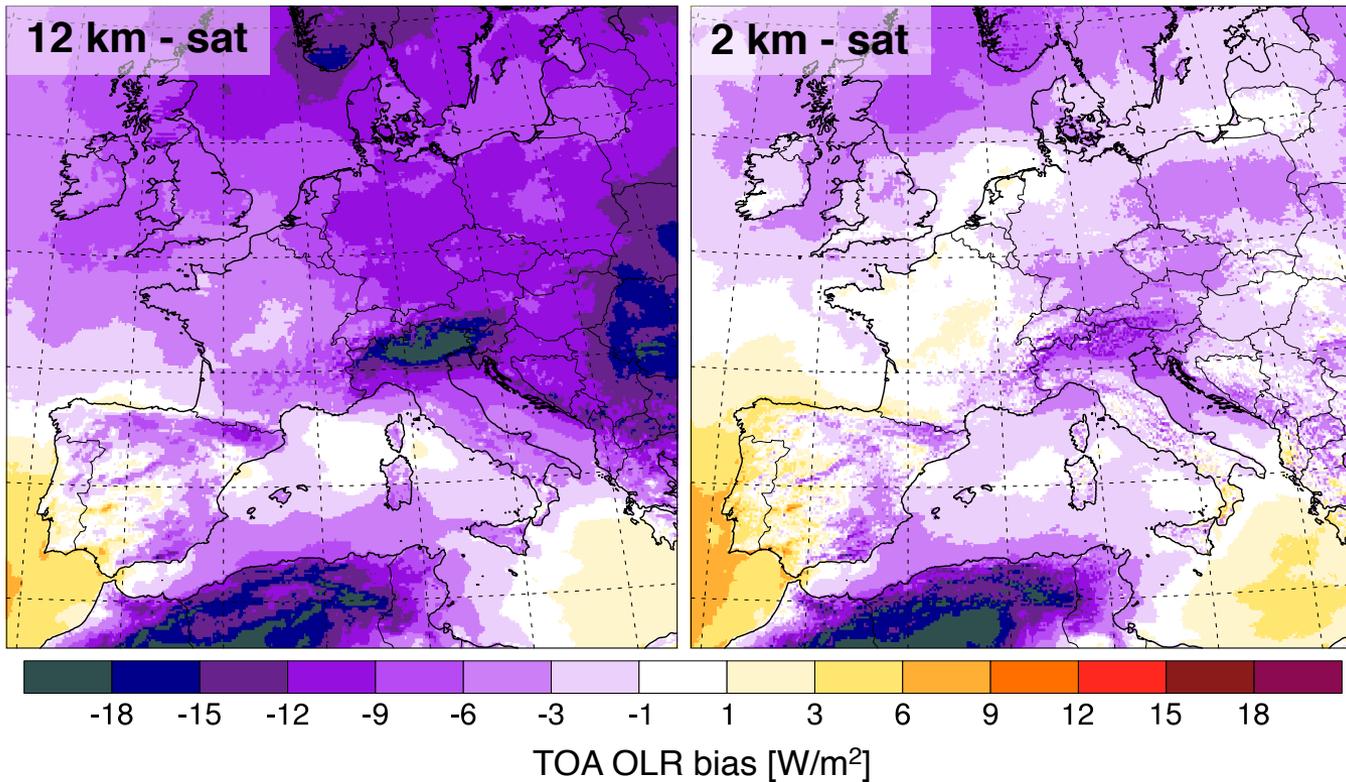
CRU Observations

- (Harris et al., 2014)
- 0.5° x 0.5°
- Land-only

- **Overestimation** of the modelled total cloud cover (*consistent with e.g. Jäger et al., 2008*)
- 2 km: slightly **reduced bias**

TOA Outgoing Longwave Radiation (summer)

→ Comparison with TOA GERB/SEVIRI satellite data – 2004-2008

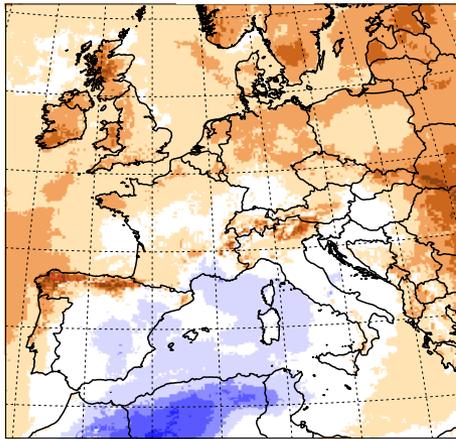


- GERB/SEVIRI data**
- (Clerbaux et al., 2017)
 - $0.05^\circ \times 0.05^\circ$
 - Uncertainty: $< 0.5\%$

- **Overestimation of high cloud amount**
- **2 km: reduced bias** compared to 12 km

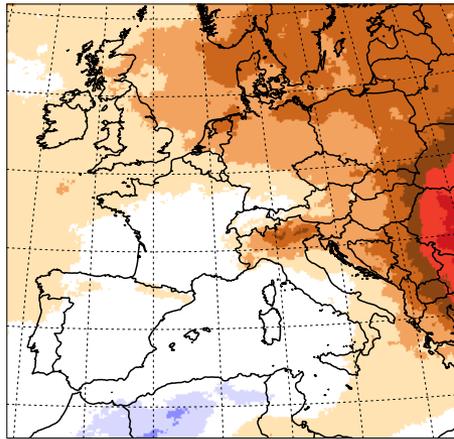
Clouds – Model comparison in the present climate

Total



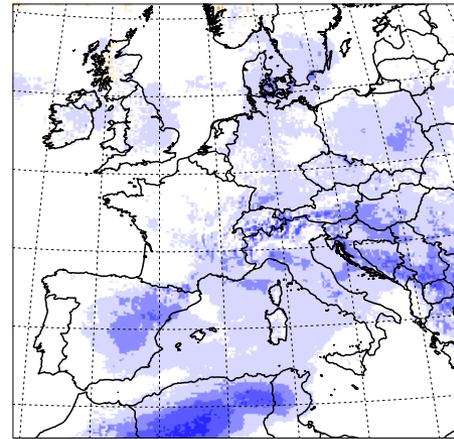
High-level

400 hPa < ...



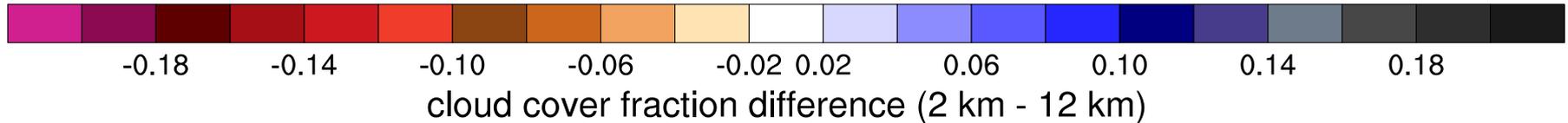
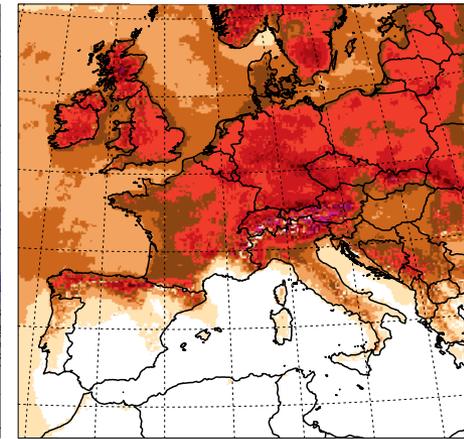
Mid-level

800 hPa < ... < 400 hPa



Low-level

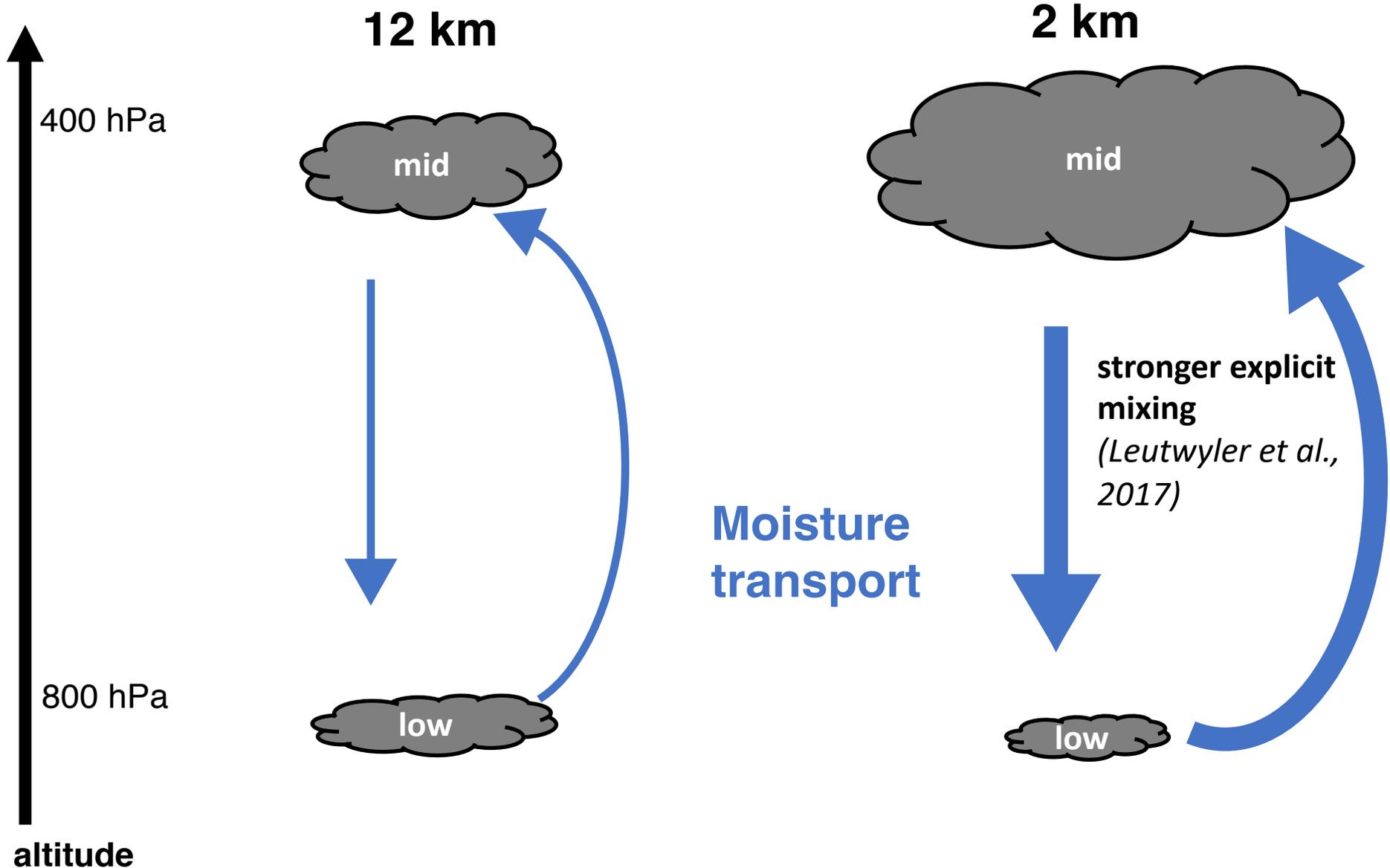
... < 800 hPa



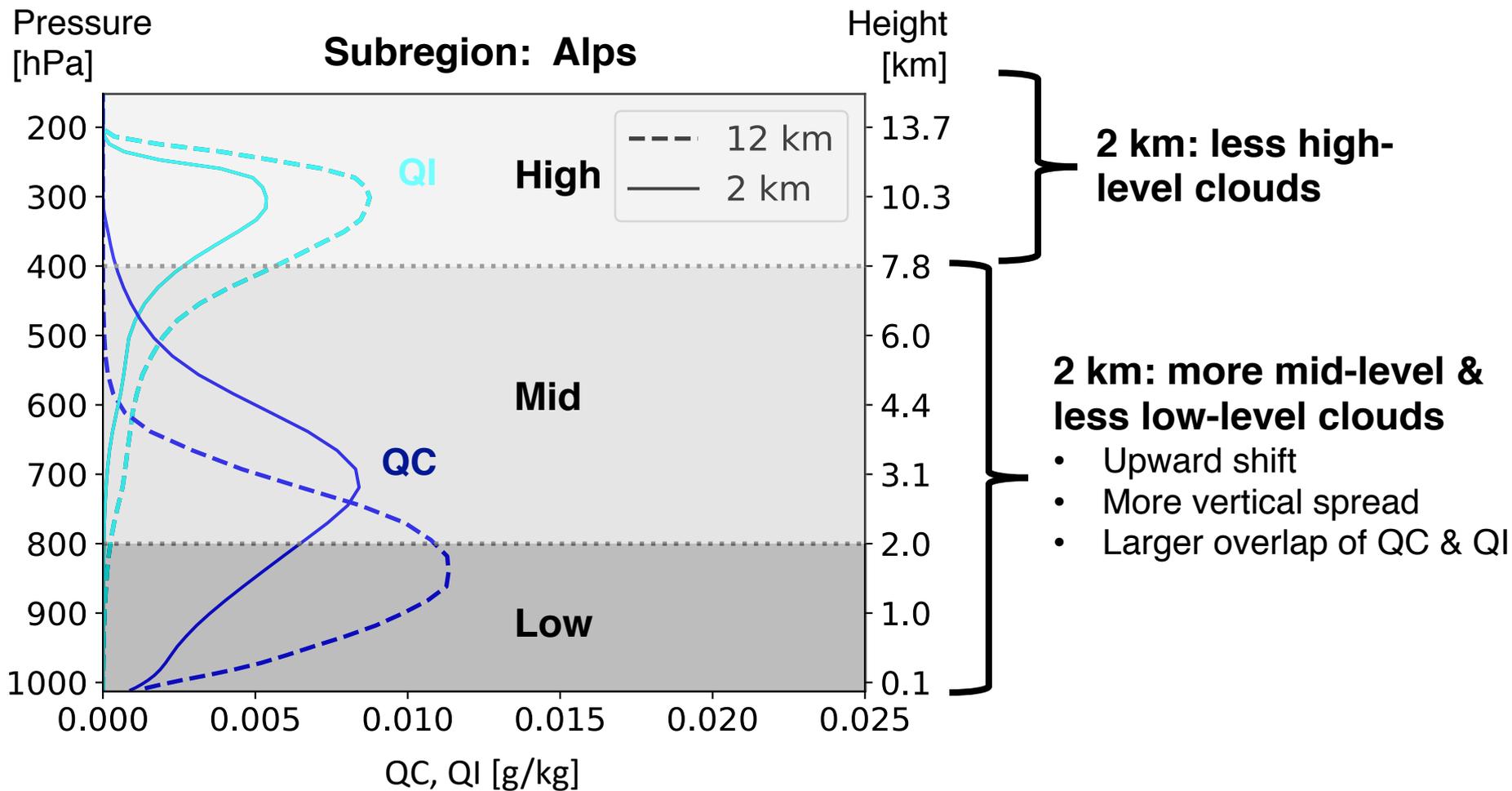
- **High-level:** reduced cover → reduced bias
- **Mid-level:** enhanced cover → reduced bias (*Böhme et al., 2011; Keller et al., 2015*)

→ Reason for model differences?

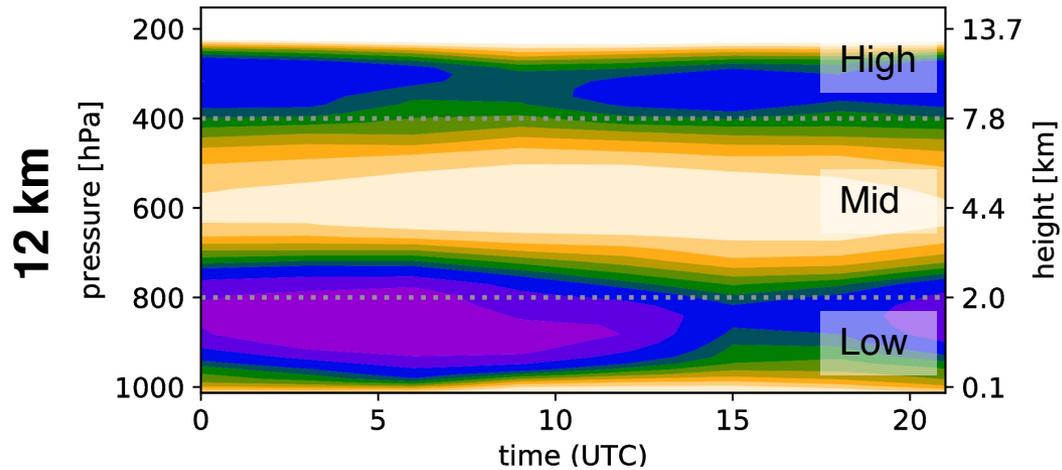
Mixing of tropospheric moisture



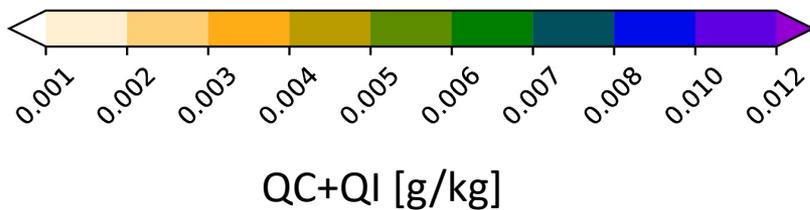
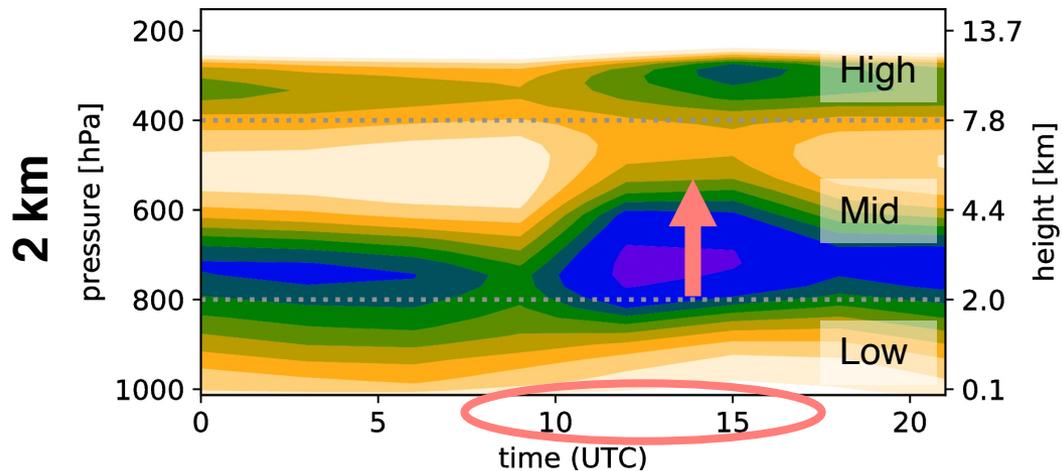
Cloud liquid (QC) and ice (QI) contents (summer 2006)



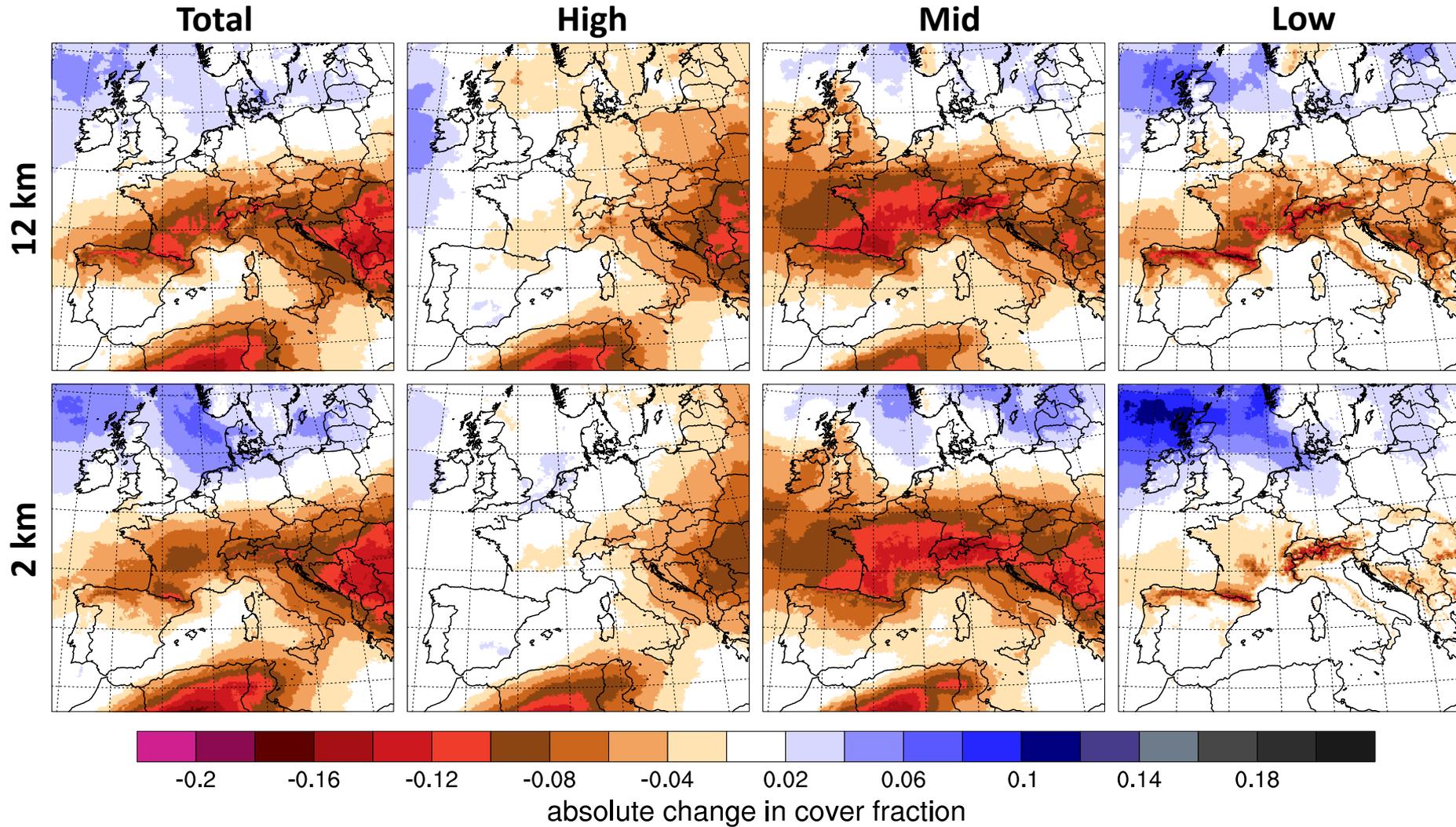
Diurnal evolution of QC + QI (Alps, summer 2006)



→ Improved diurnal cycle
of clouds in 2 km
(**timing & deepening**)

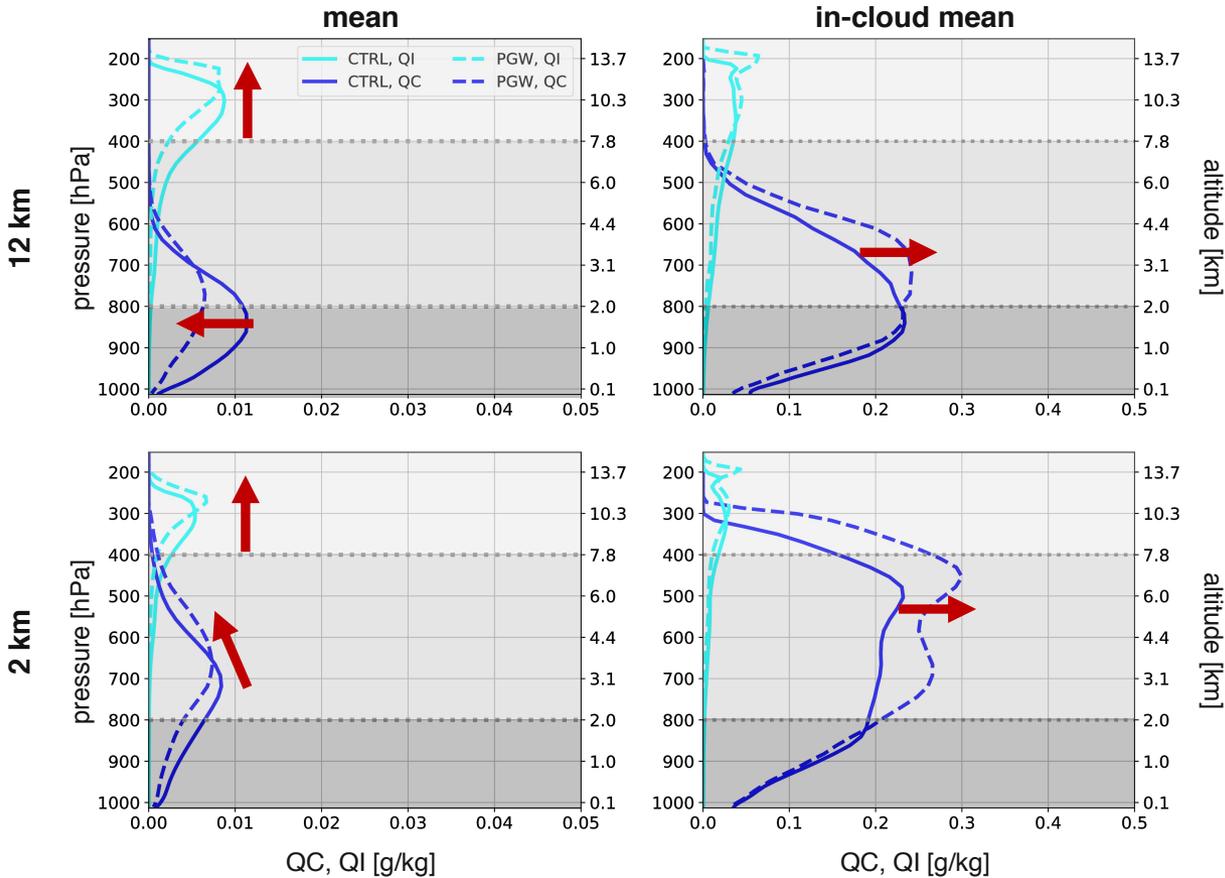
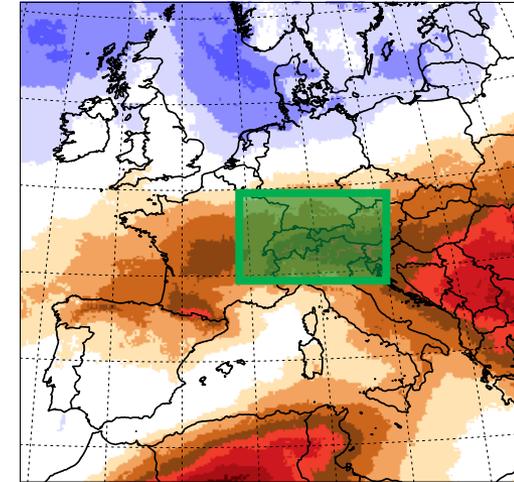


Cloud changes in a warmer climate



Changes in cloud liquid (QC) and ice (QI) contents

→ Present (2006) vs. warmer (2086, PGW) climate

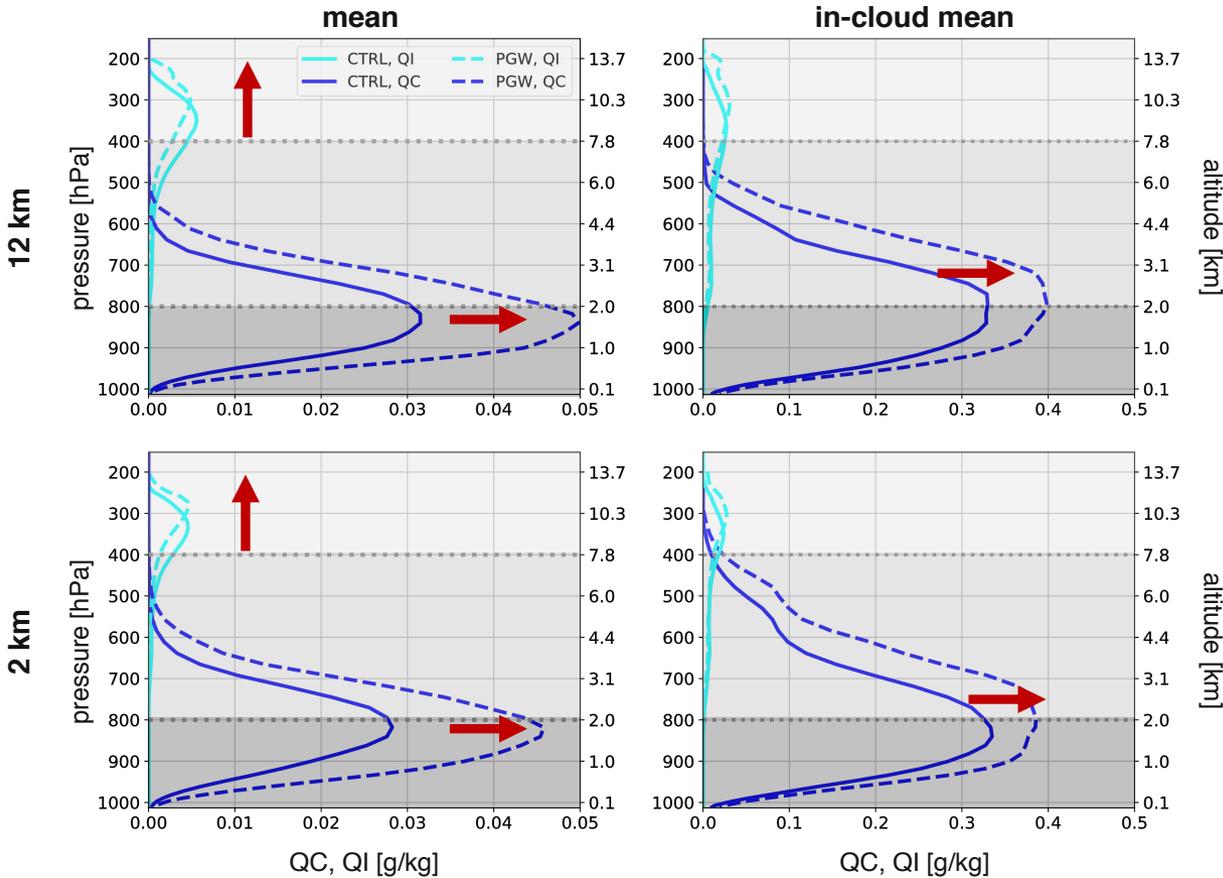
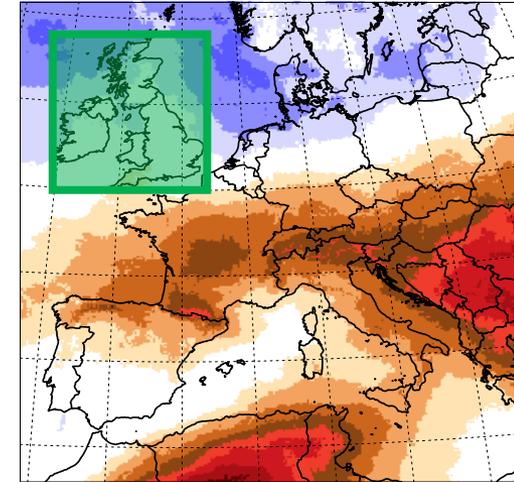


- Increased cloud top height
- Reduced cloud liquid water
- Cloud thickening

➤ Positive feedback on surface warming?

Changes in cloud liquid (QC) and ice (QI) contents

→ Present (2006) vs. warmer (2086, PGW) climate



- Increased cloud top height
- Increased cloud liquid water
- Cloud thickening

➤ **Negative feedback on surface warming?**

Conclusion

→ Clouds in convection-resolving climate simulations

1. Added value in the present climate

- **Reduced biases** in the cloud amount & TOA radiation budget
- **Enhanced** boundary layer and tropospheric **mixing**
- Improved **diurnal cycle**

2. Impact of climate warming (PGW experiment)

- **Consistent cloud changes** between the convection-resolving & convection-parameterizing approaches
- **Upward shift** of high-cloud top height
- **Increased in-cloud** water
- **Reduction of mid- & low cloud amount**
 - 12 km: reduction of water content
 - 2 km: upward shift