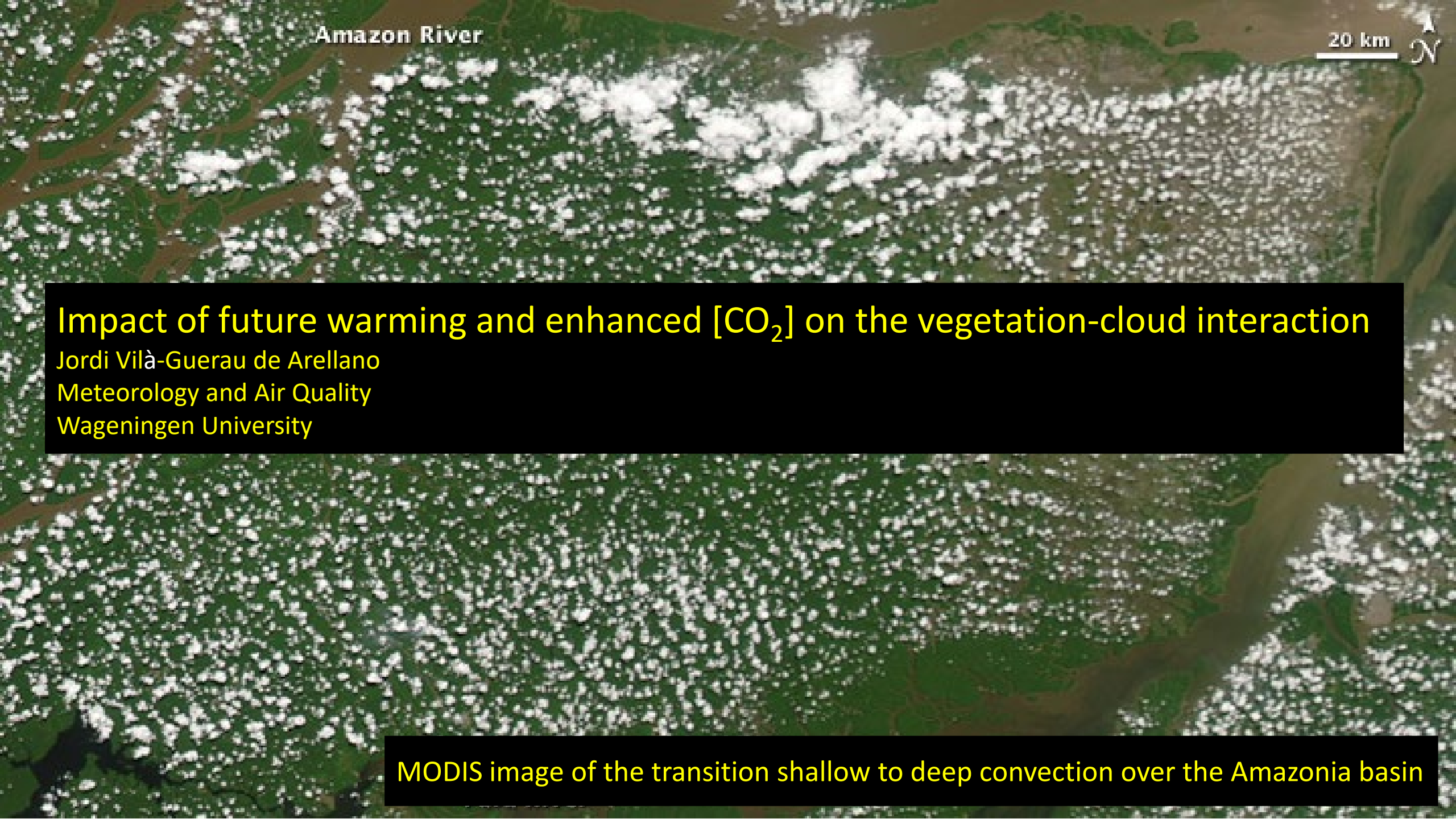

Impact of future warming and enhanced [CO_2] on the vegetation-cloud interaction

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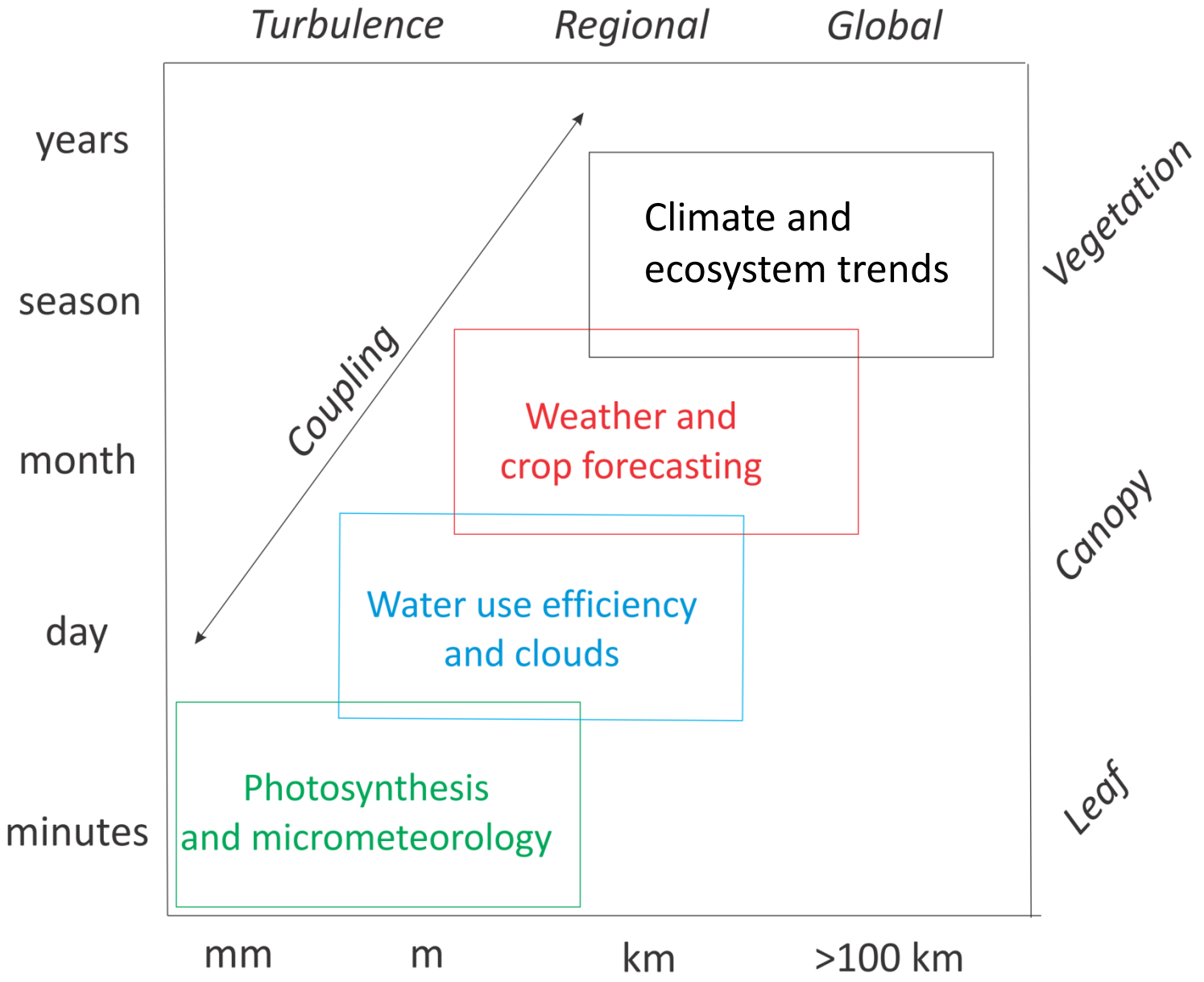
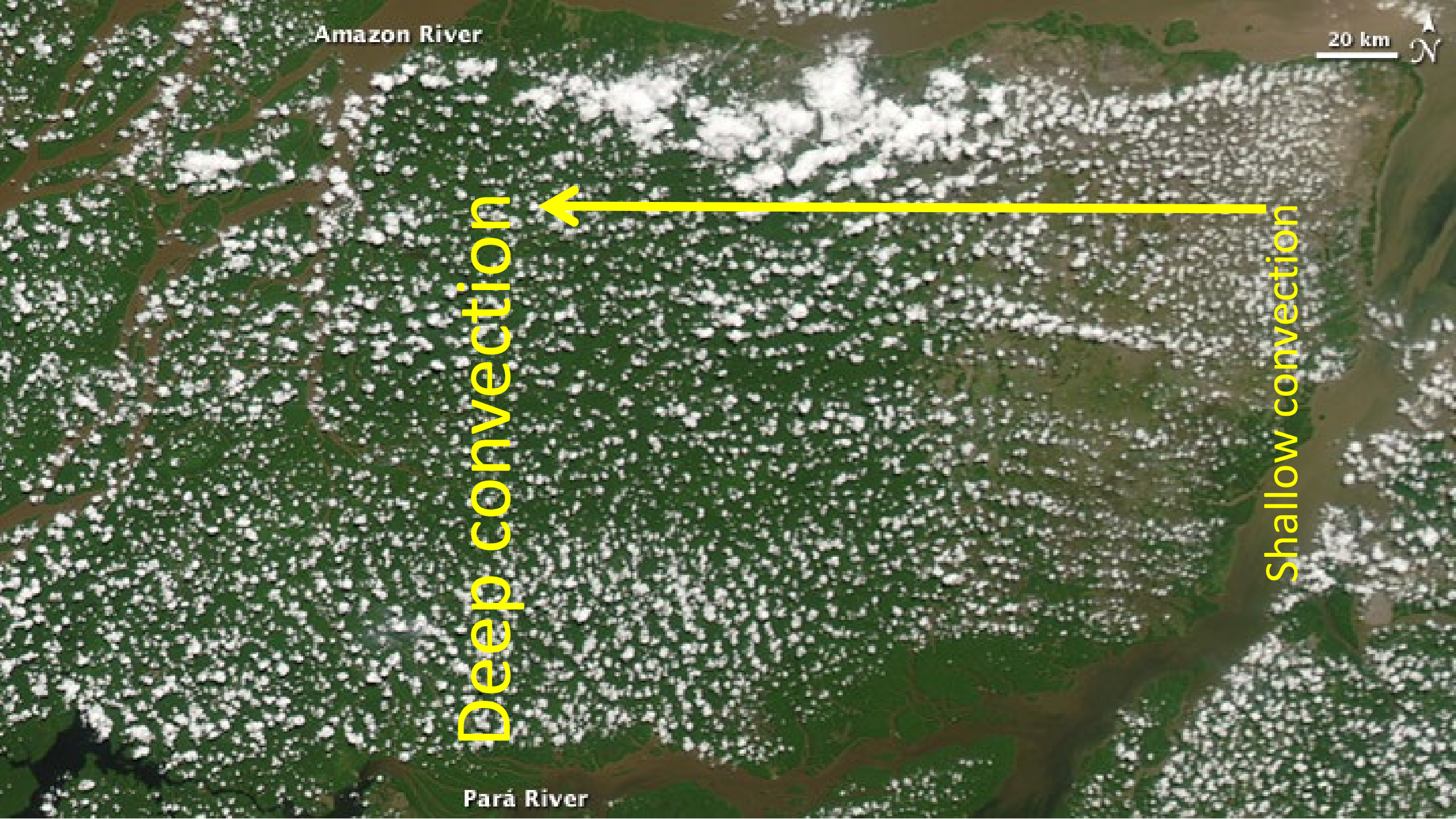
Meteorology and Air Quality
Wageningen University

MODIS image of the transition shallow to deep convection over the Amazonia basin

Multi-scale water and carbon cycle interactions




Amazon River
20 km
N
Deep convection
Shallow convection
Pará River

How do warmer and enhanced CO_2 conditions control and influence the partition of the heat/moisture/carbon dioxide turbulent fluxes and cloud cycling?

And what are the positive and negative effects?

Contrasting effects in the vegetation-cloud system

Atmosphere with CO_2-enhancement

↓

Stoma closes

Enhancement stomatal resistance

↓

Less evaporation

↙ ↘

$WUE = \frac{NEE}{ET}$ increases

$EF = \frac{ET}{ET + SH}$ decreases

Warmer atmosphere

↓

Atmosphere has higher capacity in taking water vapor

↓

More evaporation

↙ ↘

$WUE = \frac{NEE}{ET}$ decreases

$EF = \frac{ET}{ET + SH}$ increases

Research strategy

- Explicit calculation of the canopy-atmosphere interaction

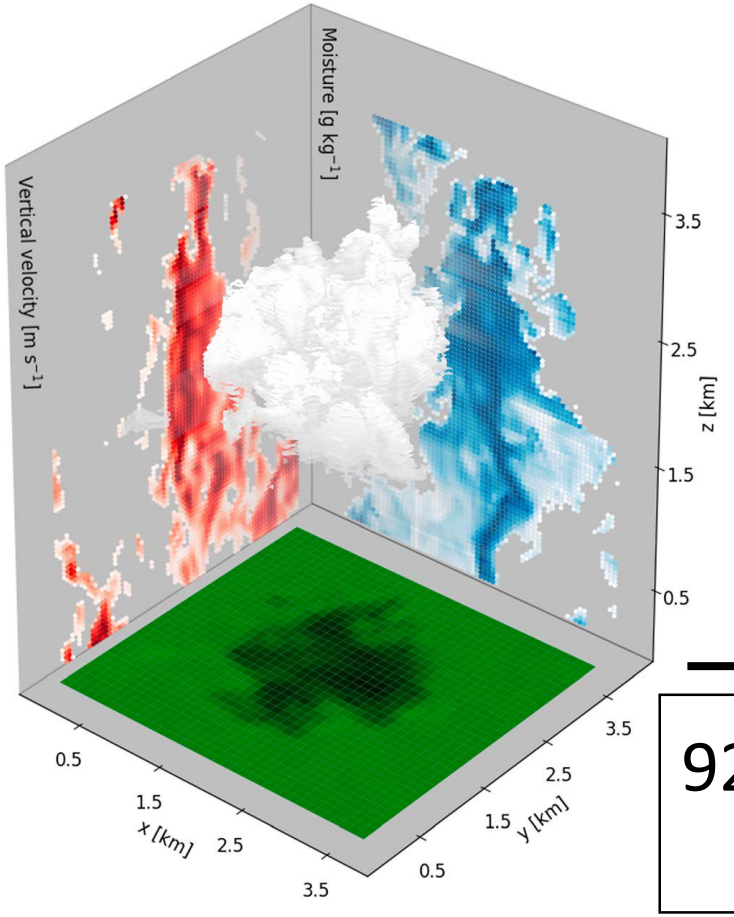
⇒ Large-eddy simulation (systematic experiments)

- Case constrained by observations taken during the dry season at the Amazonia basin

⇒ Comprehensive validation with observations (Vilà-Guerau de Arellano et al., 2020)

- Present and future numerical experiments (4 experiments):
  - ⇒ Current situation (observational based)
  - ⇒ Enhanced CO_2 (200 ppb)
  - ⇒ Warmer atmosphere (Temperature increase by 2 K)
  - ⇒ Future (combined enhanced CO_2 and warmer climate)

Explicit calculation of clouds and their perturbation at the surface (large-eddy simulation)



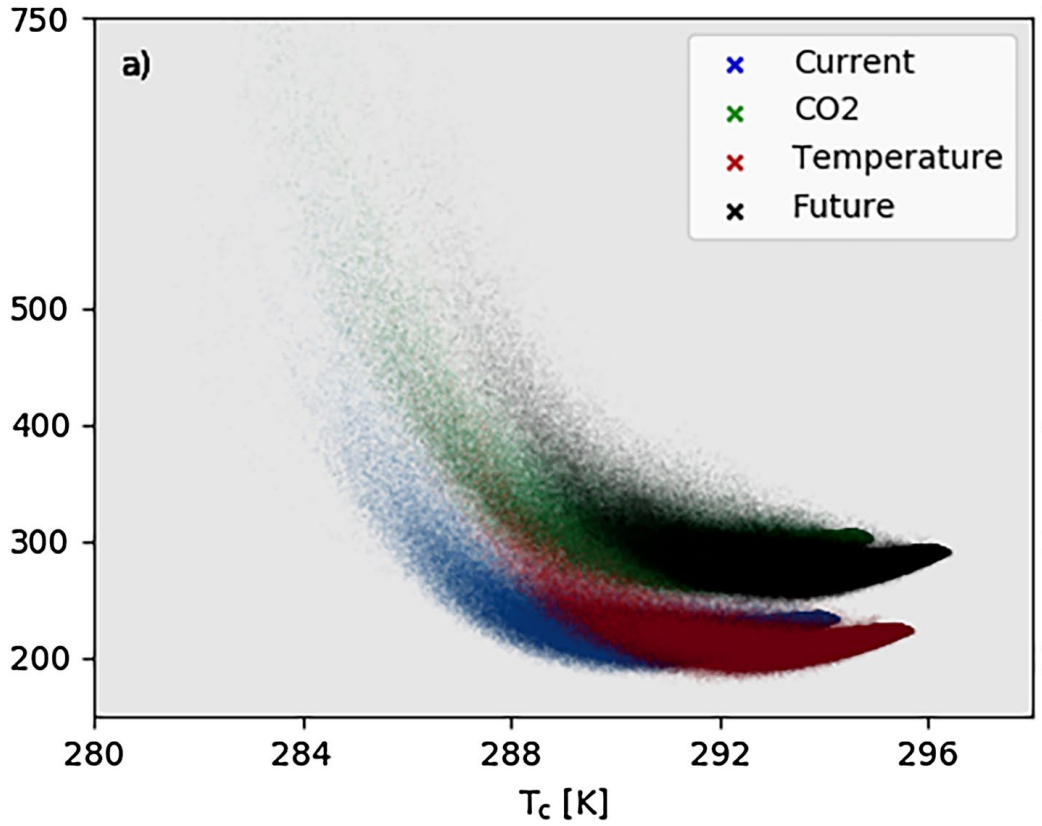
921.600 Surface Points at 14:00

1 virtual observation
- every 50 x 50 m^2
- every second

Closed

Open

Stomatal aperture r_c [s m^{-1}]

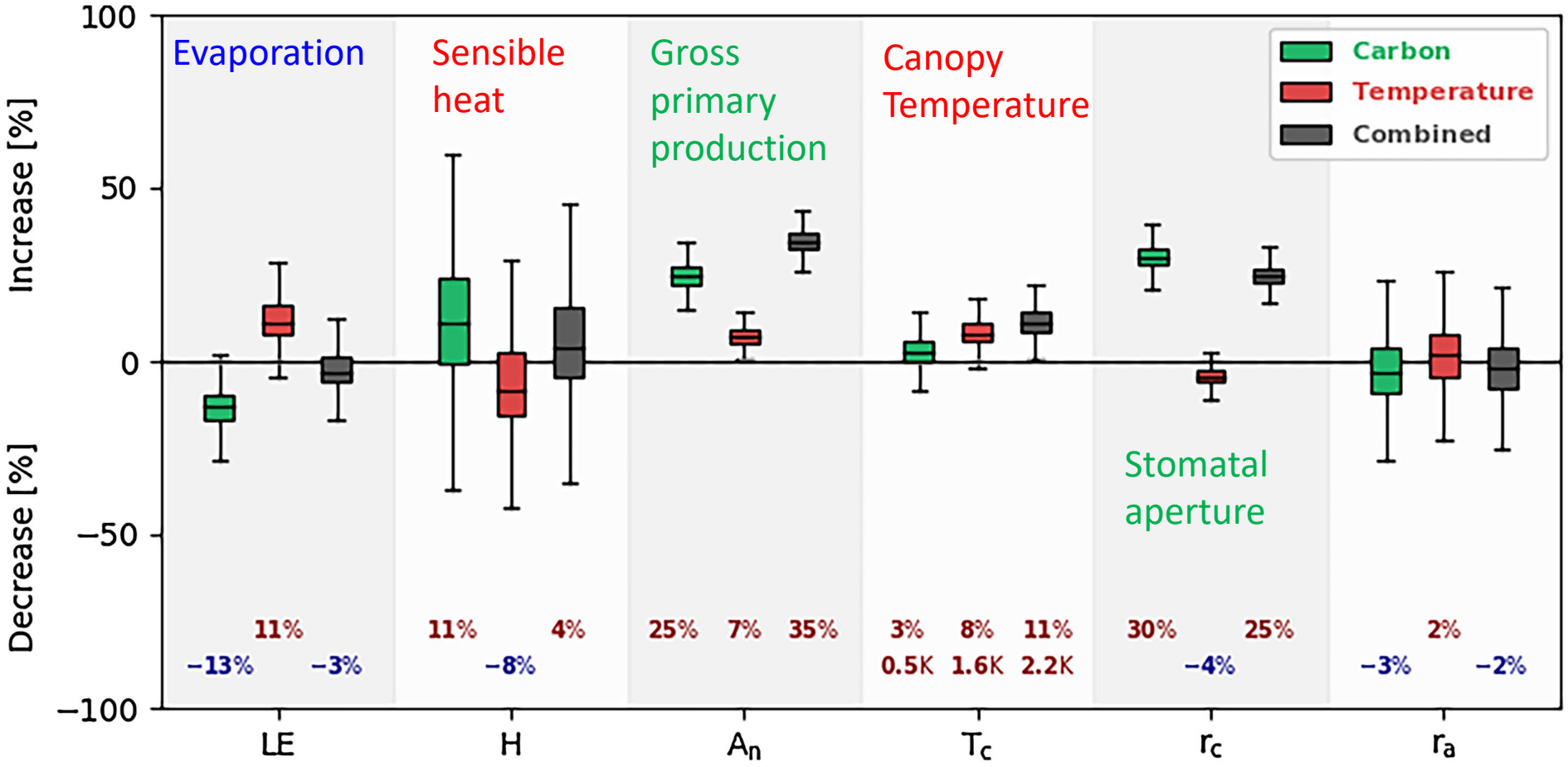


Temperature canopy

Optimal T canopy 298 K

What is the impact of the current and future conditions on
the surface turbulent fluxes controlled by the rainforest?

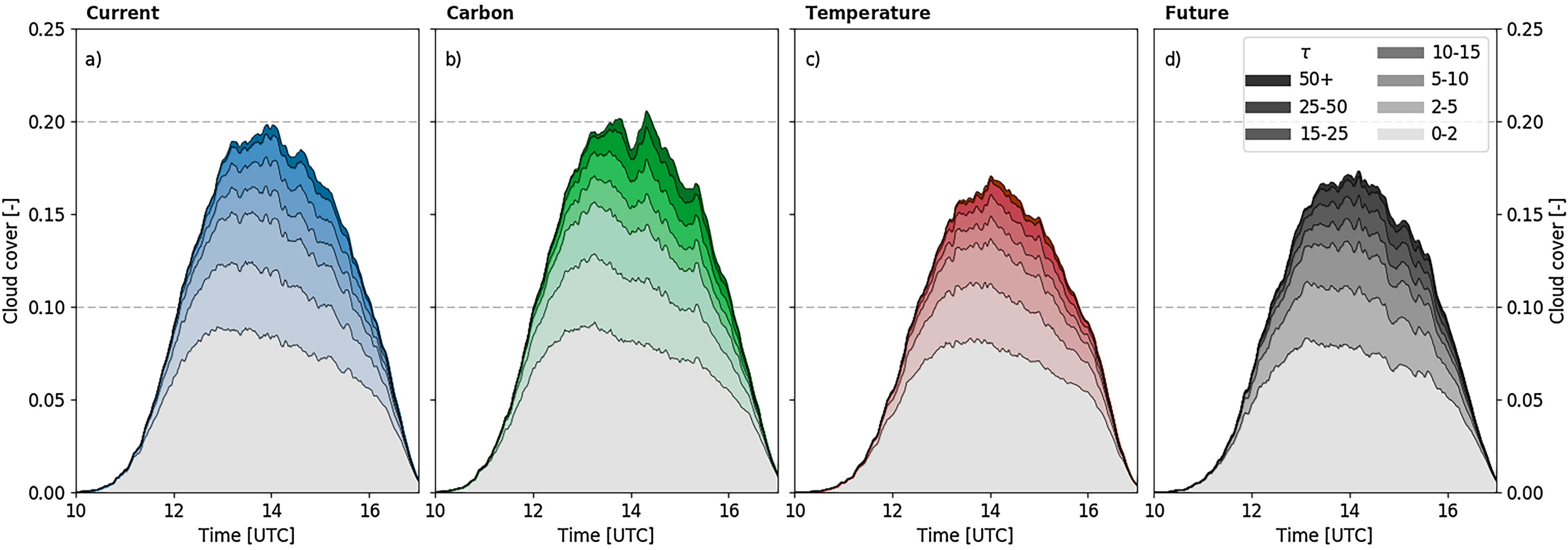
Decreased or increase surface variables compared to current conditions



- Non-linear effects depending on the turbulent flux
- The combined enhanced carbon and warmer temperatures yields to an **offset** for LE and SH and an **enhancement** for (An=GPP)

How these differences in the surface turbulent fluxes influence cloud cycling?

Evolution cloud cover as a function of cloud optical depth



- Under future conditions: Lower cloud covers and thinner clouds

(cloud optical depth equal to 18.6 Current versus 16.3 Future)

Conclusions

- *Surface perspective*: Under future conditions of enhanced CO_2 and warming climate:

⇒ Evaporation and sensible heat flux are offset be the 2 conditions
⇒ Photosynthesis is enhanced associated to stoma closure

} Disruption partitioning of surface fluxes

- *Cloud perspective:* Dominant higher temperatures leads to:

⇒ Higher limit free convection and a thicker transition layer
⇒ More forced or passive closure, less cloud cover and thinner

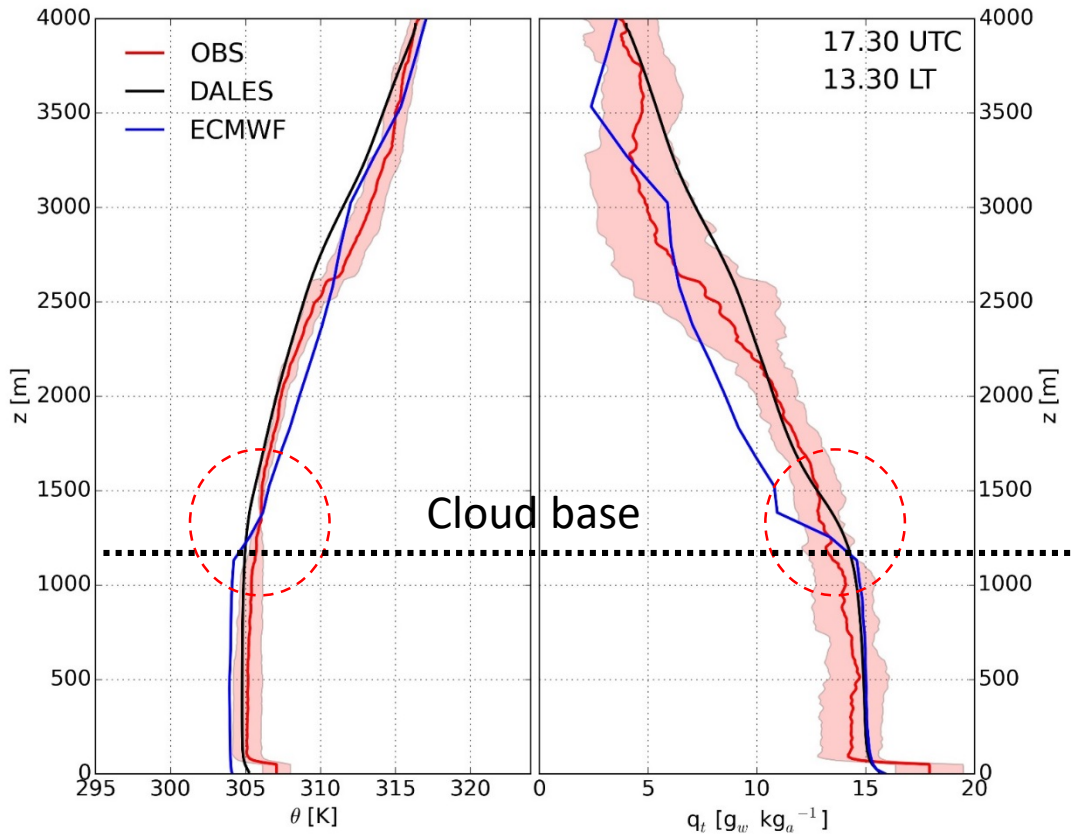
} Perturbation cloud diurnal cycling

- Need to include explicitly non-linear effects of plant physiology in

⇒ Numerical weather prediction
⇒ Carbon-climate regional models

Complete information at:
Sikma et al. (2019) Journal of Geophysical Research – Atmosphere
https://doi.org/10.1029/2019JD030717

Moistening and destabilization above cloud base



- Thermodynamic profiles follow typical vertical structure shallow convection
- Reduce moistening and destabilization above cloud base by ECMWF-IFS
- Dependence on the partitioning of surface turbulent fluxes
- Impact on triggering deep convection

More complete information: Vilà-Guerau de Arellano et al. (JAMES, 2020)