



# Determining the radiative and hydrologic controls on the diurnal air-temperature range using the thermodynamic limit of maximum power

By

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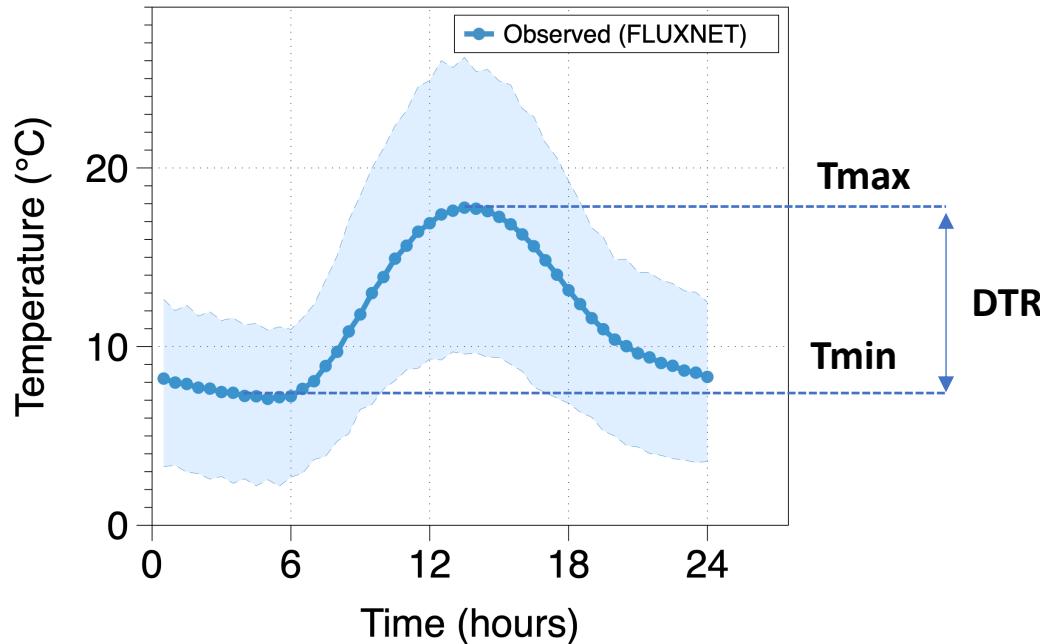
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Co-authors:

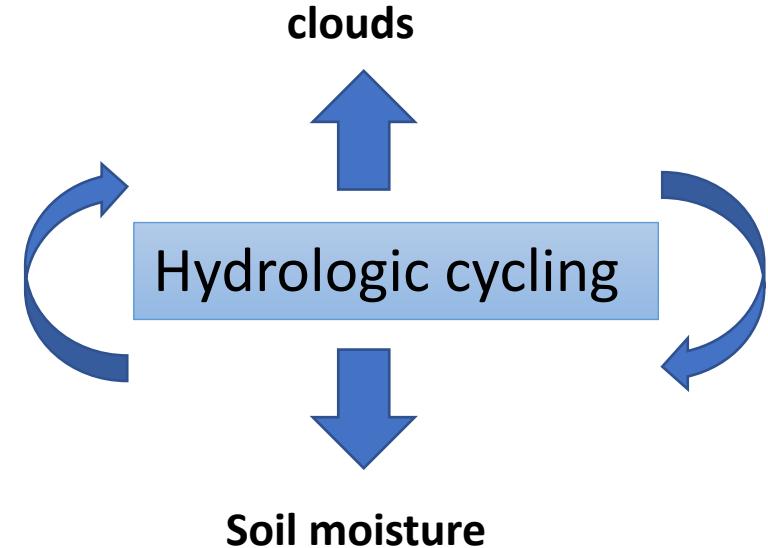
- **Kaighin McColl** (Harvard University)
- **Axel Kleidon** (Max Planck Institute for Biogeochemistry)



# What shapes the day to day variations in diurnal temperature range?



**Atmospheric controls**  
Radiation, heat storage changes

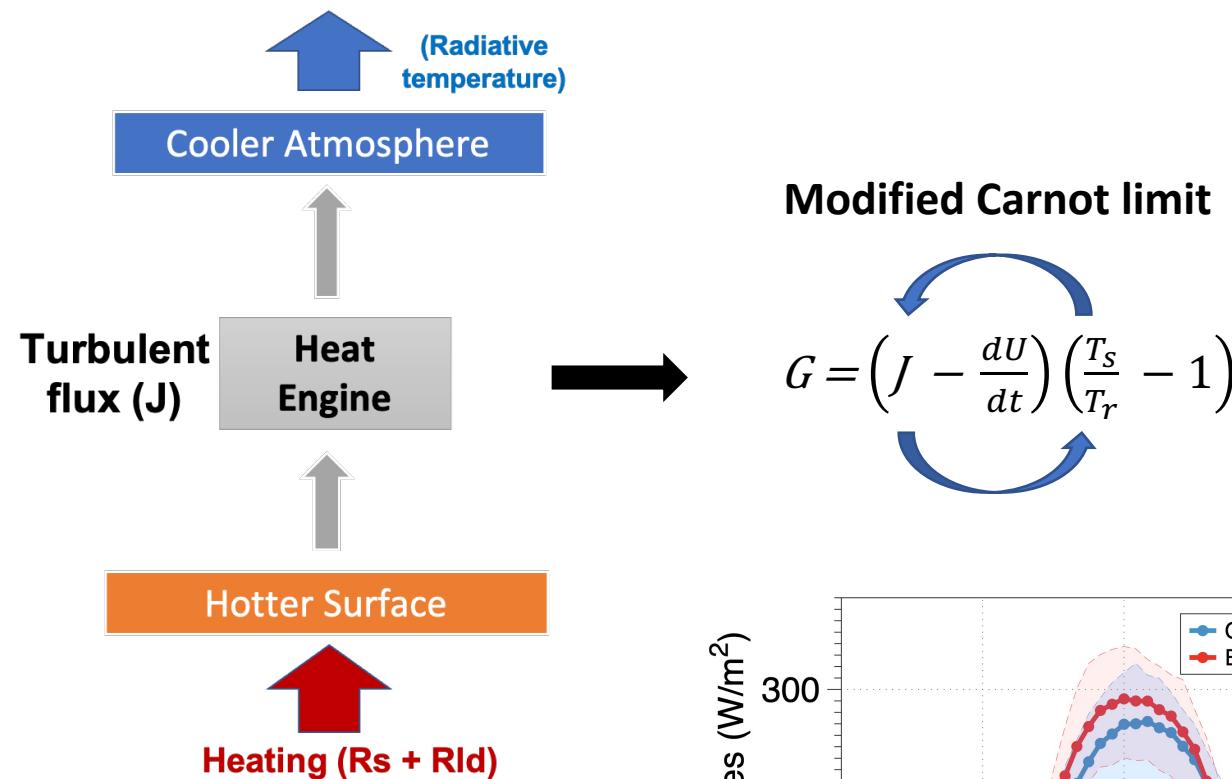


**Land – surface characteristics**  
Turbulent fluxes, albedo, land-cover

# Available constraints on surface – atmosphere exchange?

## 1. Surface energy balance

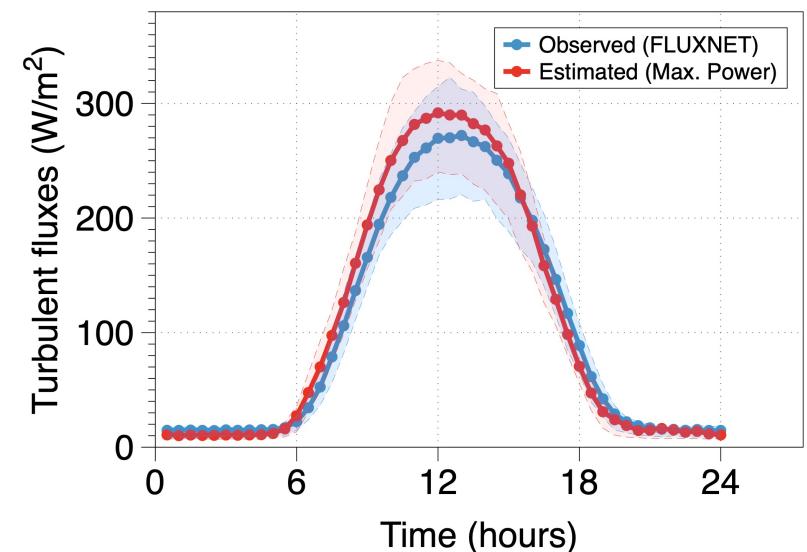
$$\Delta T_s = \frac{1}{K_r} (\underbrace{\Delta R_s + \Delta R_{ld}}_{\text{Radiative Heating}} - \underbrace{\Delta H - \Delta LE - G}_{\text{Turbulent Fluxes}})$$



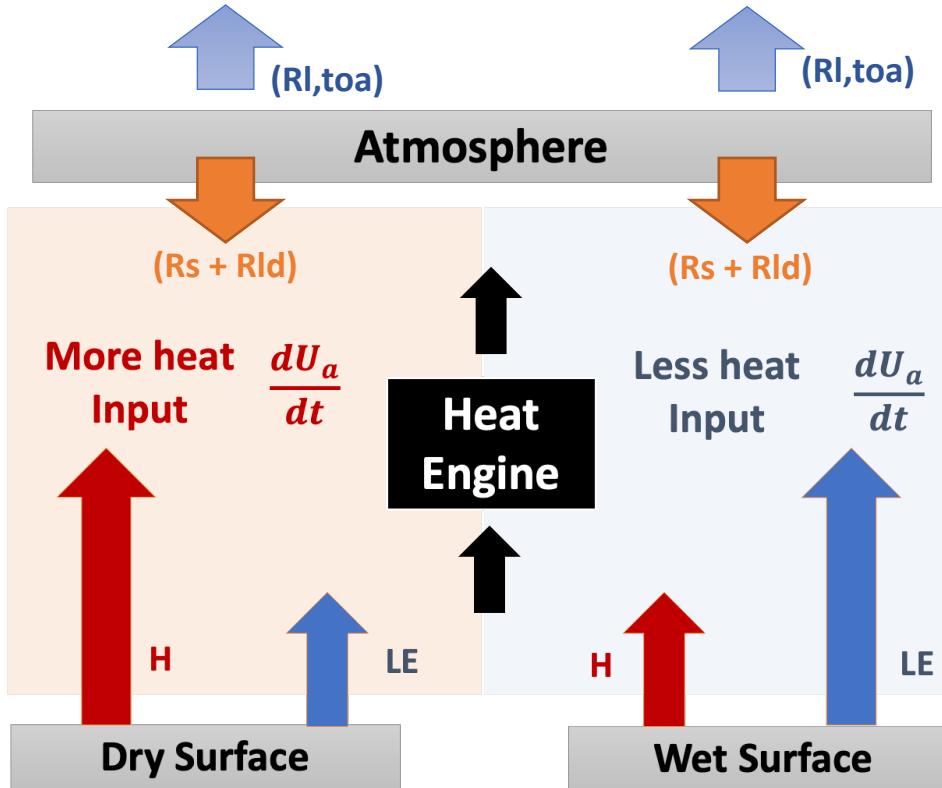
## 2. Maximum power constraint

### Entropy budget and work done

(Kleidon et al., 2013;2017;2018; Ghausi et al., (under review))



# Developing a simple model for DTR



## Concept:

The diurnal variation of air temperature reflects mostly the non latent heat input ( $\Delta U$ ) in the lower atmosphere.

$$\Delta U = \int (R_s - f_e J_{opt}) dt = \frac{1}{2} C_p \rho h \Delta T_a$$

## Estimated DTR

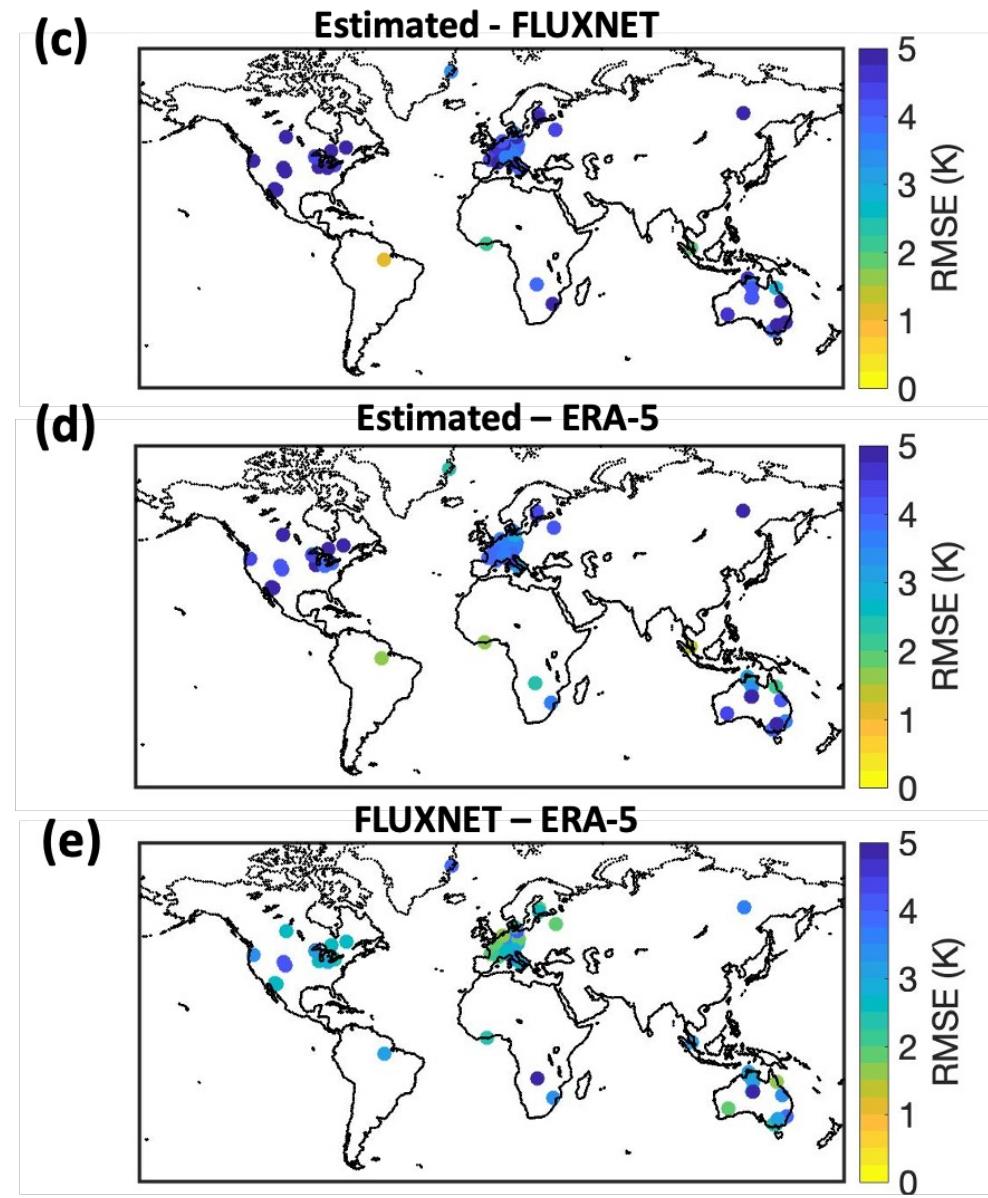
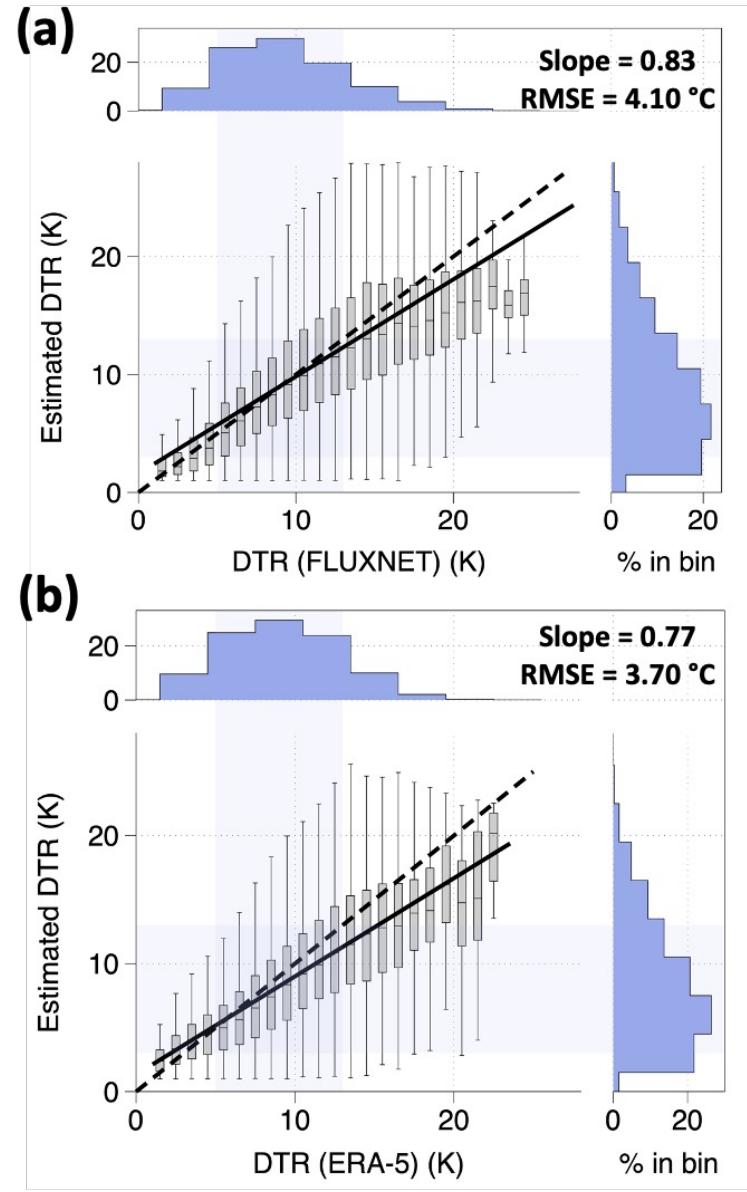
$$\Delta T_a = \frac{2}{C_p \rho h} \left( \left( \frac{2 - f_e}{2 + f_e} \right) R_s - \frac{f_e}{2 + f_e} R_{l,o} \right) \Delta t$$

$R_s$  : Solar absorption

$f_e$  : Evaporative fraction

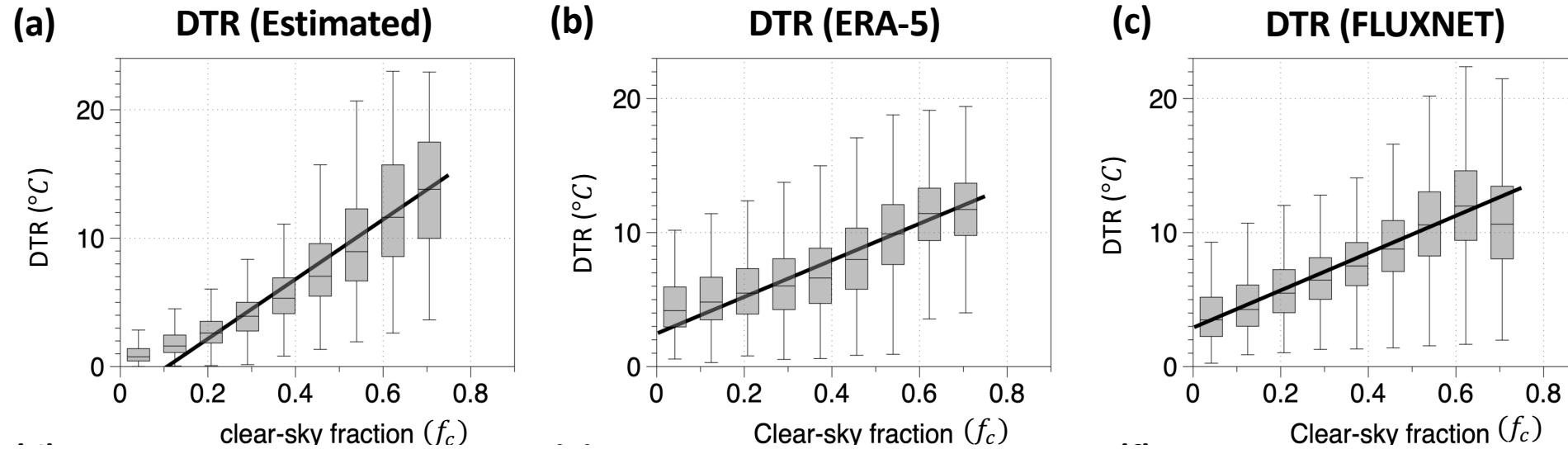
$h$  : Boundary layer height

$R_{l,o}$ : Grey atmosphere parameterization

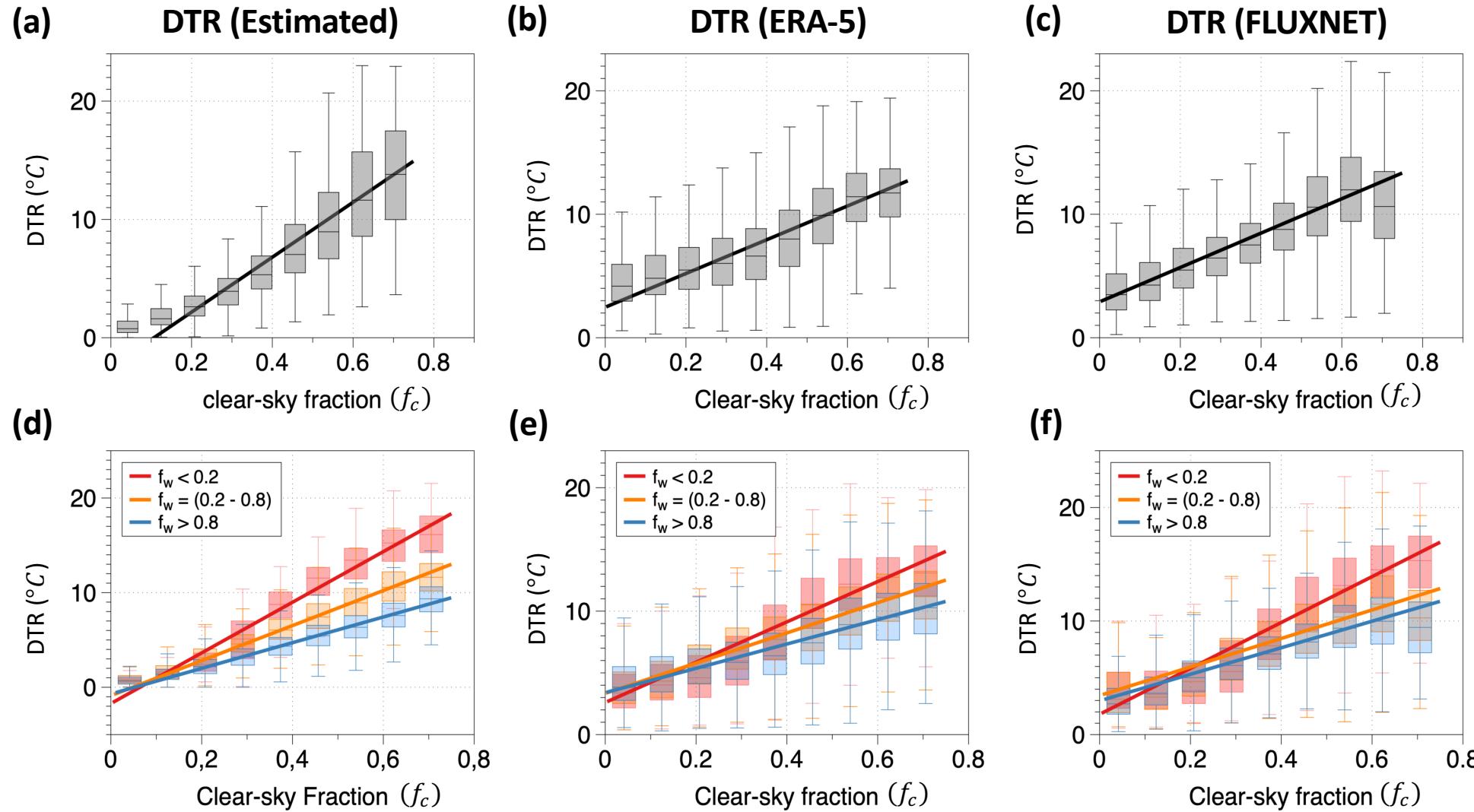


Works well!

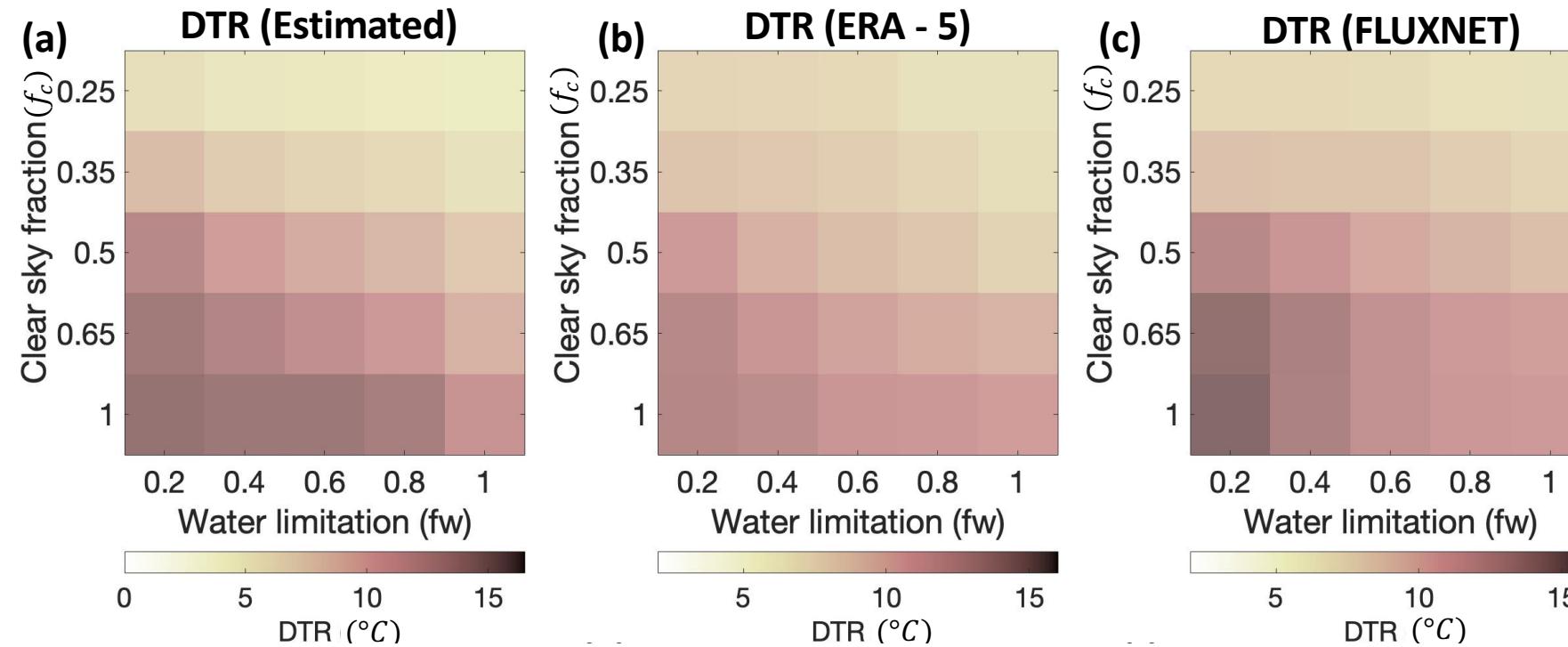
# DTR response to clouds and surface water availability



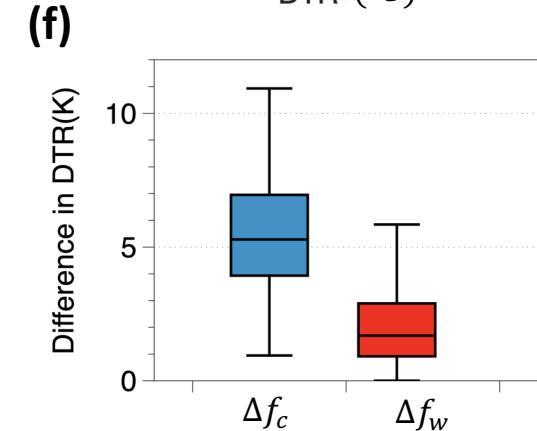
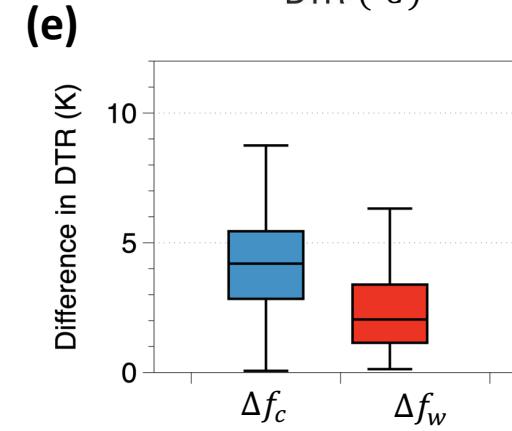
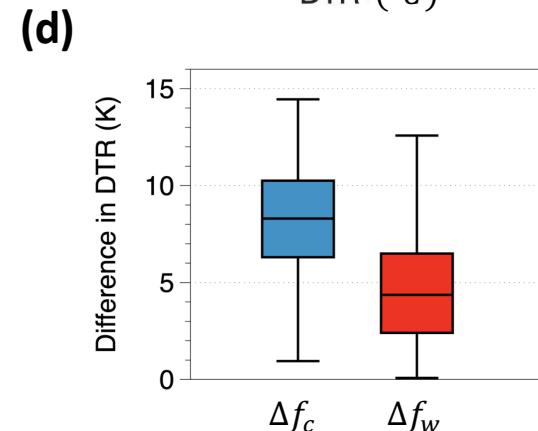
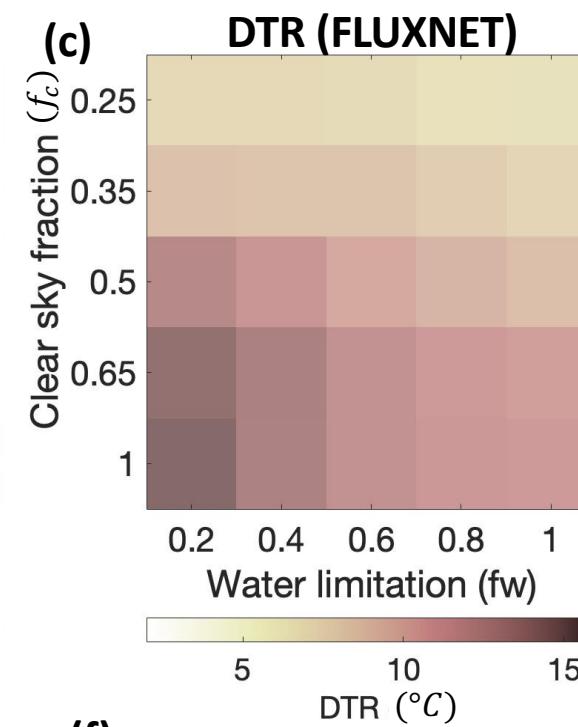
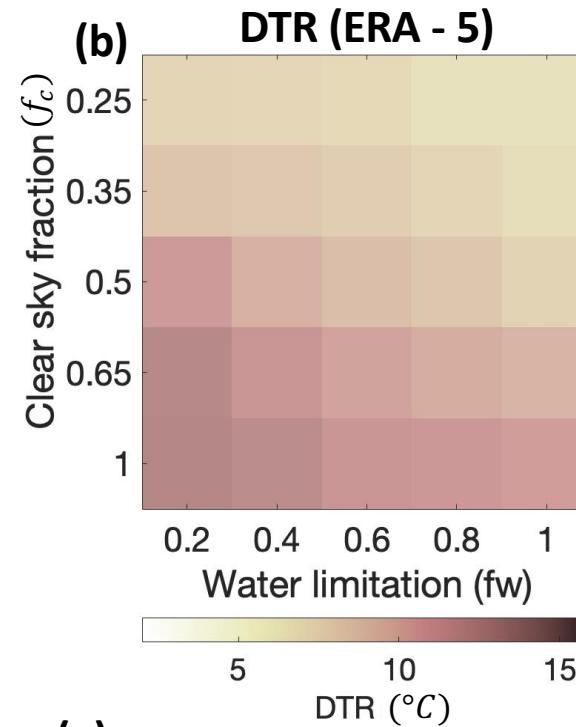
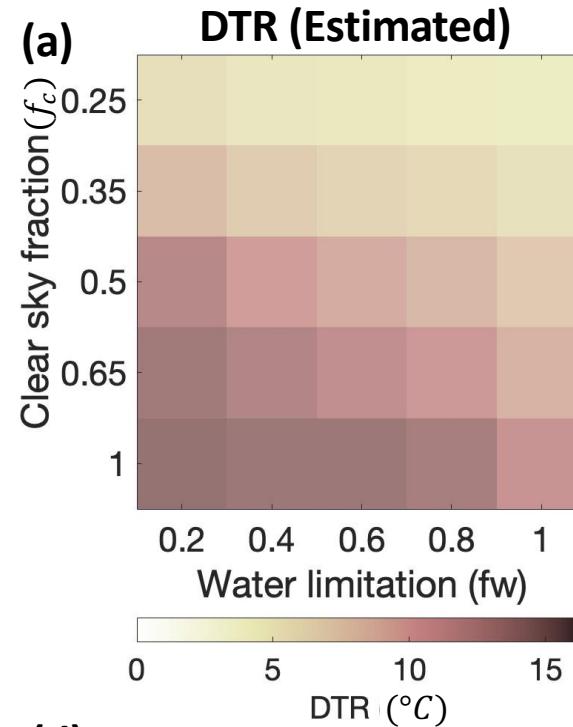
# DTR response to clouds and surface water availability



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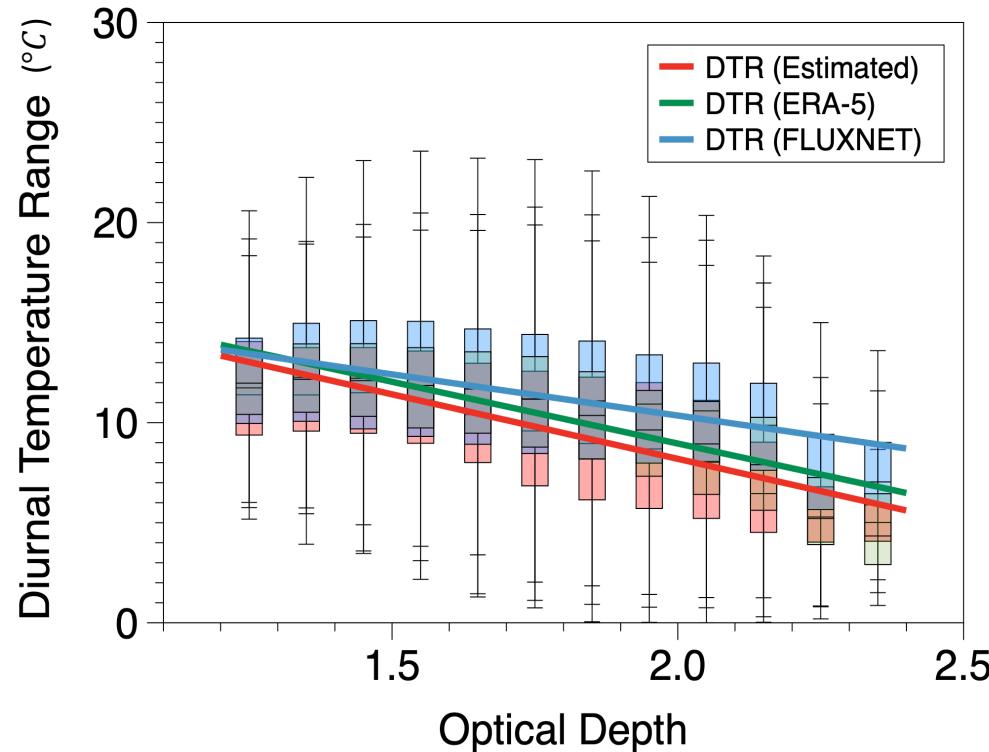


# DTR response to clouds and surface water availability

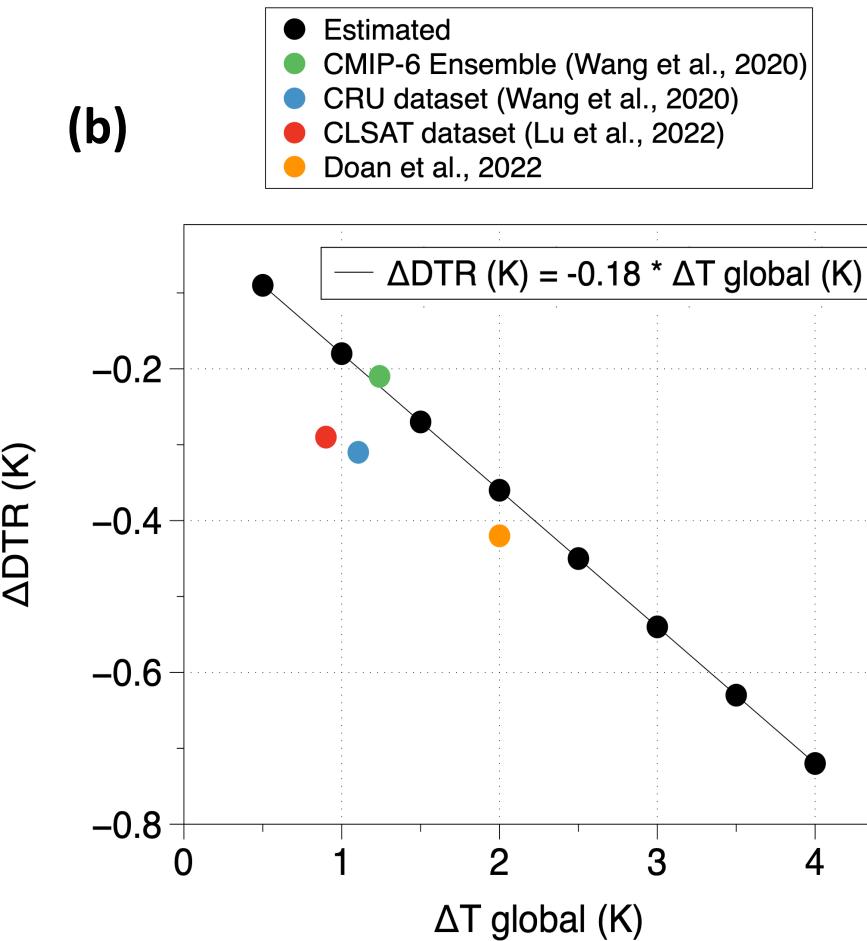


# Reponse of DTR to anthropogenic global warming

(a)



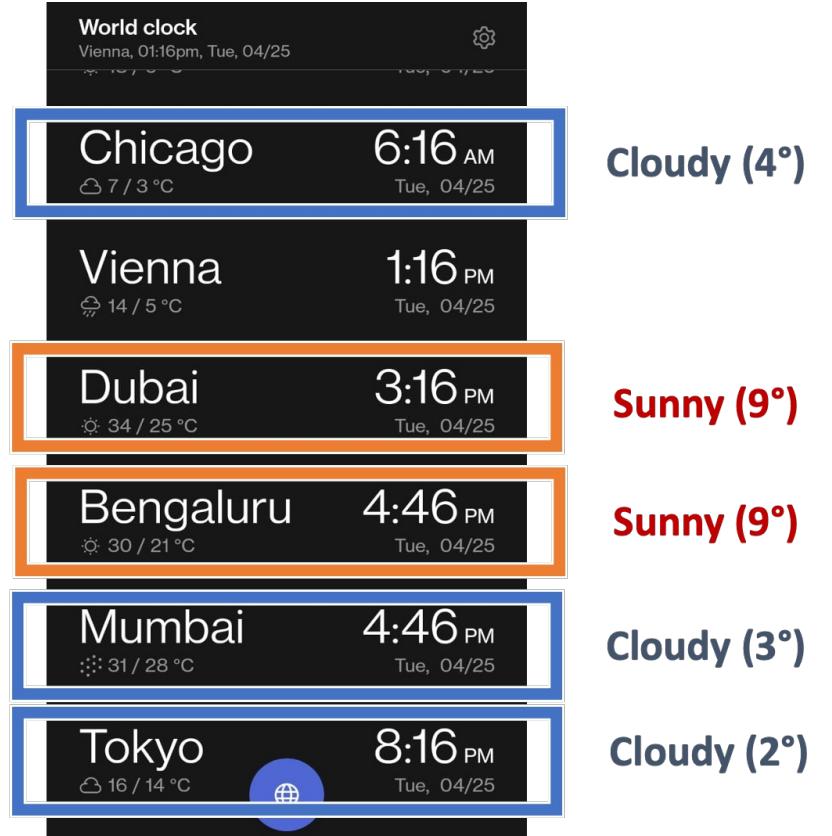
(b)



$$\frac{d(DTR)}{dT} = \frac{d(DTR)}{d\tau} \cdot \frac{d\tau}{dT}$$

# Summary

- DTR is strongly controlled by heat storage variations in the lower atmosphere
- DTR response to clouds and radiative forcings is modulated by land-surface characteristics with dry periods responding more strongly than wet periods
- Thermodynamics imposes a relevant constraint on surface-atmosphere exchange



Meet me during EGU for further discussion

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