Last Glacial Maximum atmospheric lapse rates: a model-data study on the American Cordillera case

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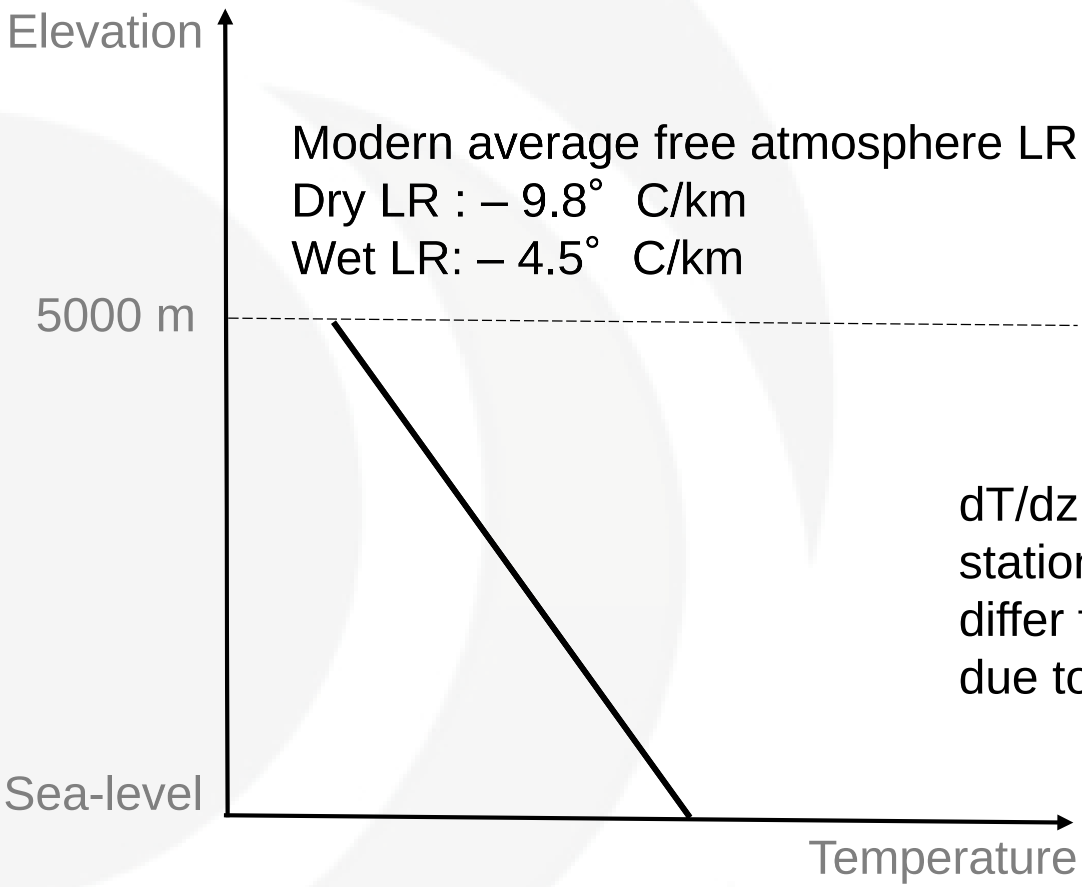
Topic: atmospheric lapse rate(s)

Temperature generally cools with increasing height

=> characterization: lapse rate (LR) = dT/dz

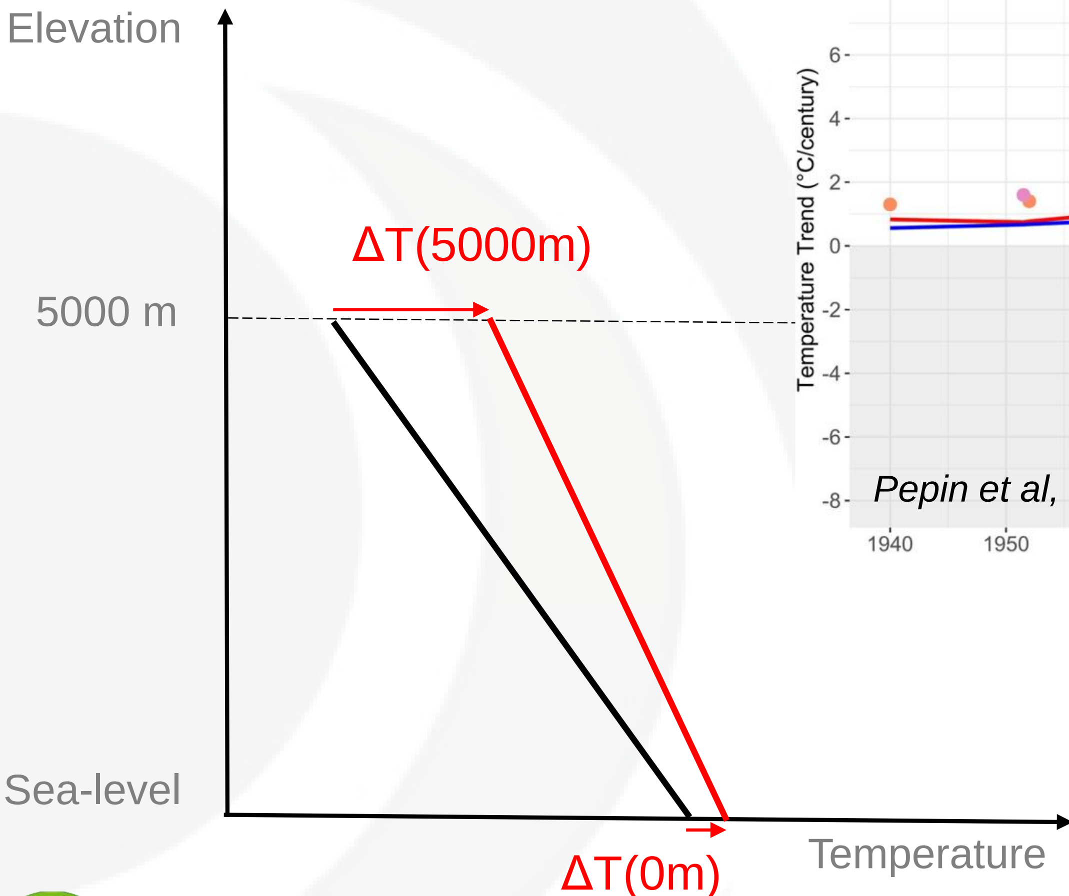
Modern average free atmosphere LR : – 6.5° C/km
Dry LR : – 9.8° C/km
Wet LR: – 4.5° C/km

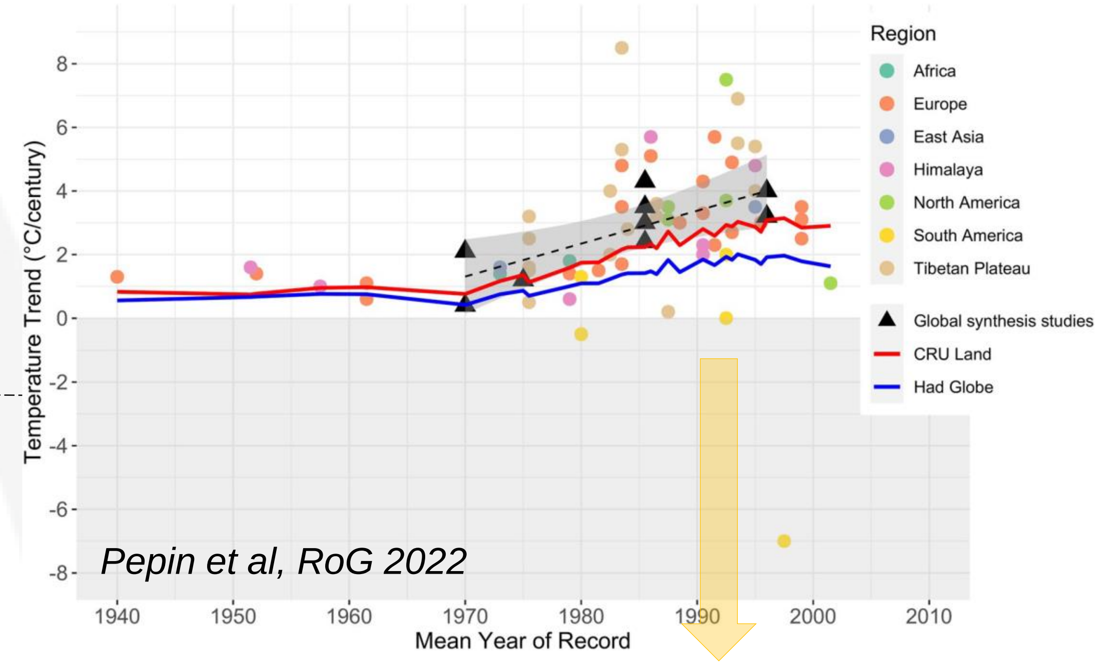


dT/dz computed from surface weather stations along mountain slopes can differ from the free atmosphere LR due to local feedbacks/phenomena

Topic: elevation-dependent warming

Observed temperature trends over mountains suggest amplified warming compared to global values





However, large spread of values, even within same mountain range

Need for studying changes in EDW and related processes

Processes involved in elevation-dependent warming

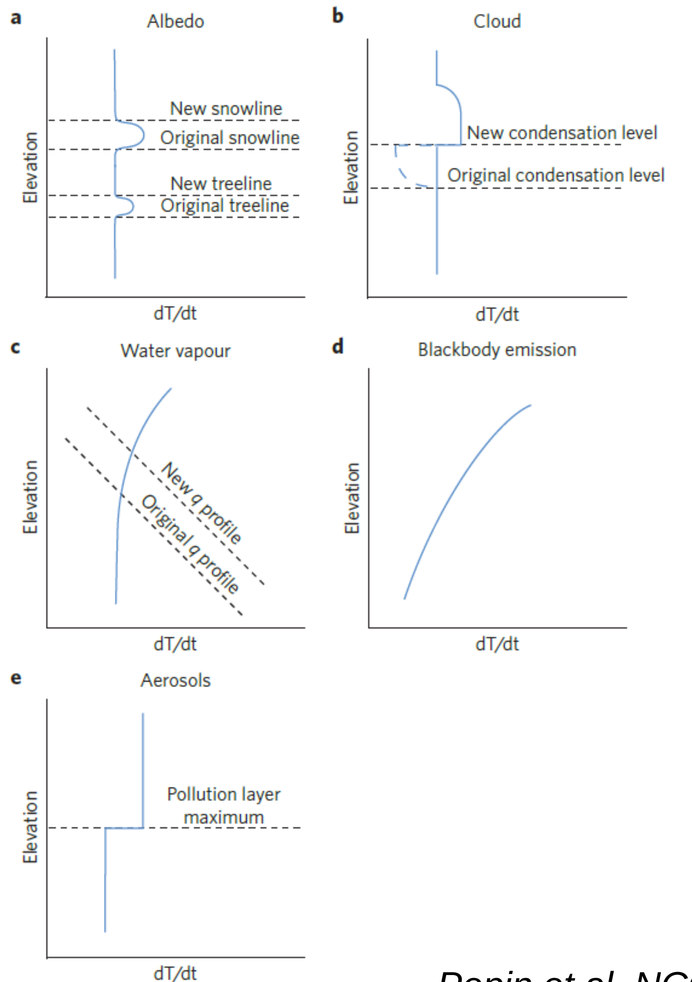
Moist adiabatic lapse rate
(esp relevant for the tropics)
depends on temperature:

$$\Gamma_m = g \frac{1 + \frac{L_v r_v}{RT}}{c_{pd} + \frac{L_v^2 r_v \epsilon}{RT^2}},$$

($\Gamma = - dT/dz$)

$\Rightarrow$ for a warming,
| LR | is decreasing
ΔT is amplified with height

Other processes

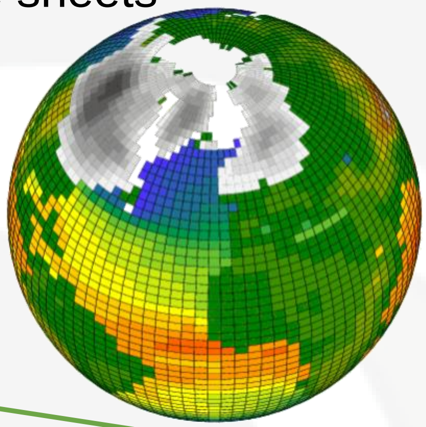


Pepin et al, NCC 2015

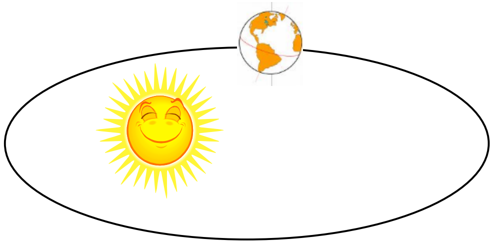
Looking back: warming since the Last Glacial Maximum

The Last Glacial Maximum, ~21000 years ago

Ice sheets



Lower GHG concentrations:
$[CO2]_{atm}$ = 190 ppm

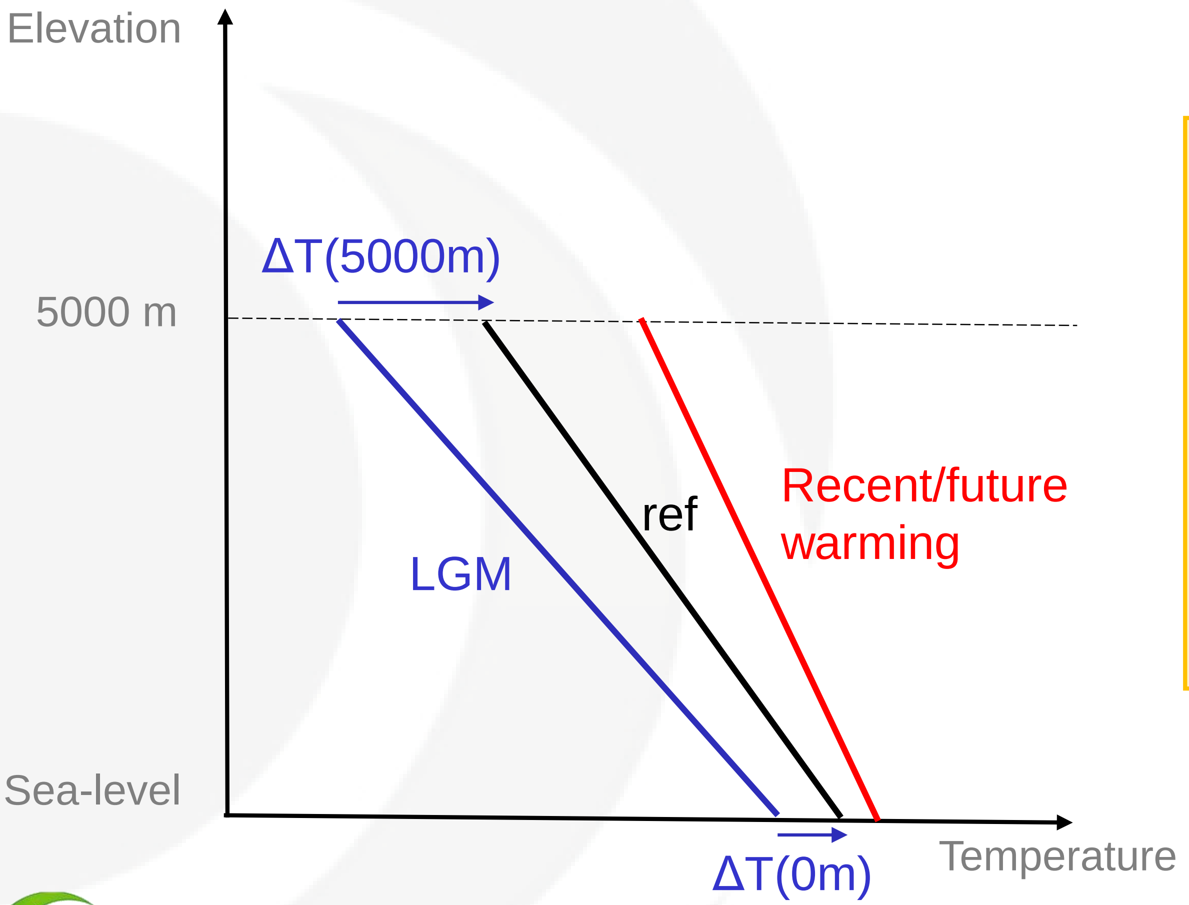


Astronomical parameters:
=> Changes in insolation

A colder, drier climate
=> 4-7° C warming from LGM to modern

Target for climate modelling experiments
(cf. Paleoclimate Modelling Intercomparison Project)

Focus: elevation-dependent warming since the LGM



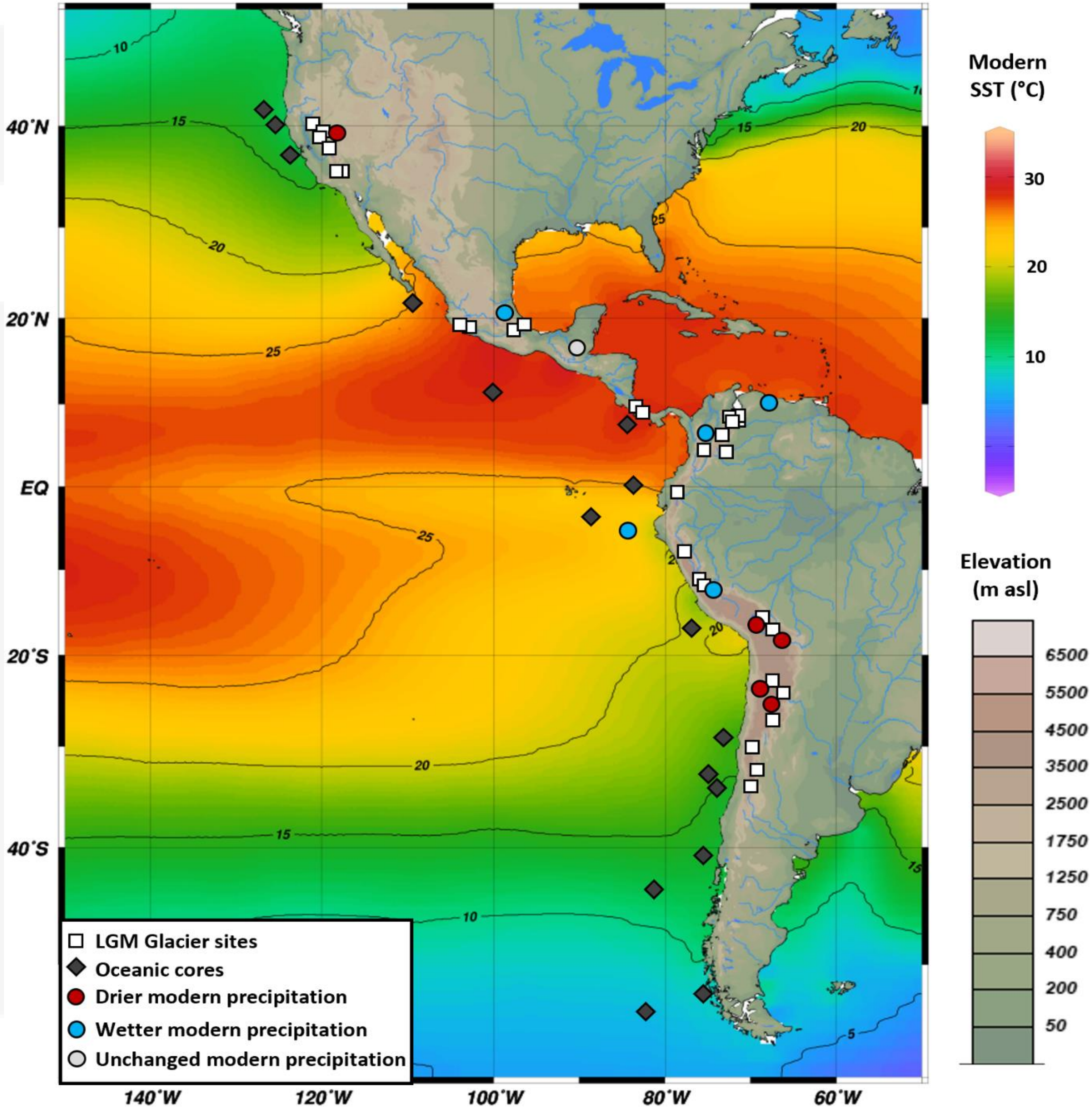
Work presented here

Reconstructions of high altitude + sea level temperatures

Comparison to IPSLCM5A2 climate model results

Discussion on processes based on the RCE model *konrad* (Kluft et al., JCl 2019

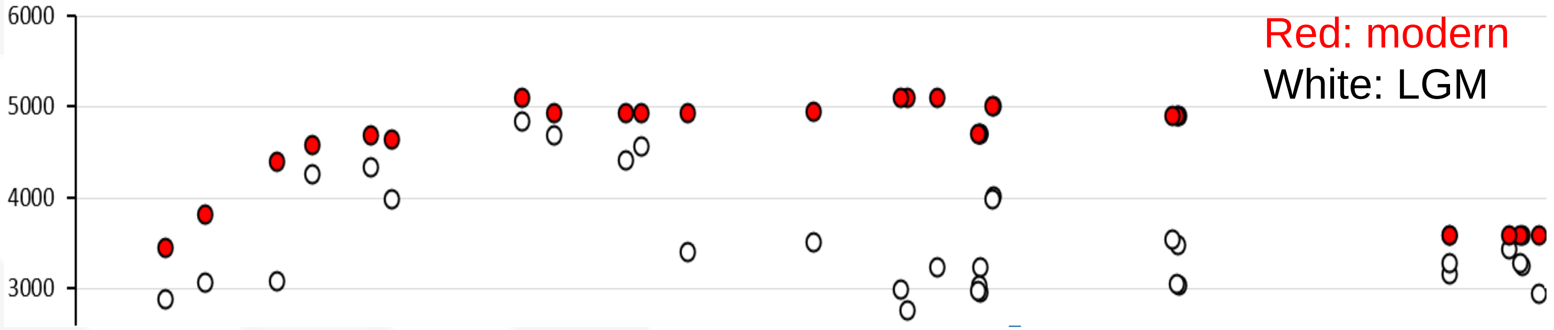
Study area: American cordillera



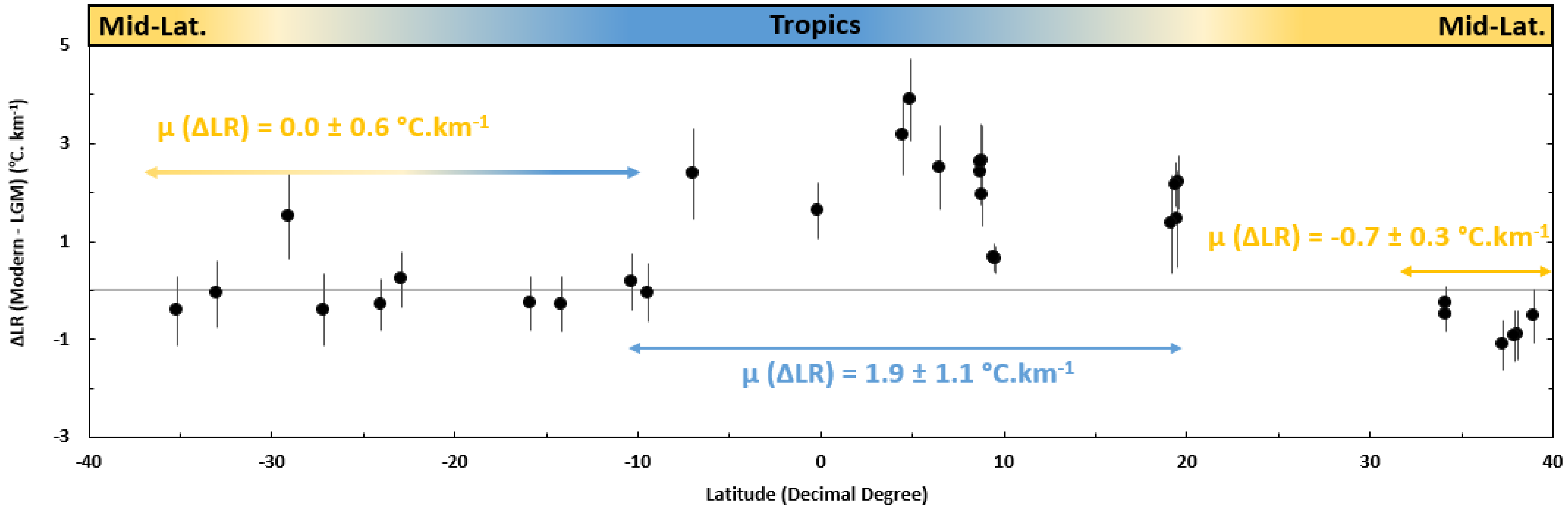
- 34 glacier sites, dated with cosmogenic nuclides
- 15 ocean cores from the East Pacific close to the American coast, with SST reconstructions based on alkenones
- 31 continental sites with precipitation reconstructions (from lake levels, packrat middens, pollen)

Altitude of the 0° C isotherm, SSTs and lapse rate

Altitude of the 0° C isotherm

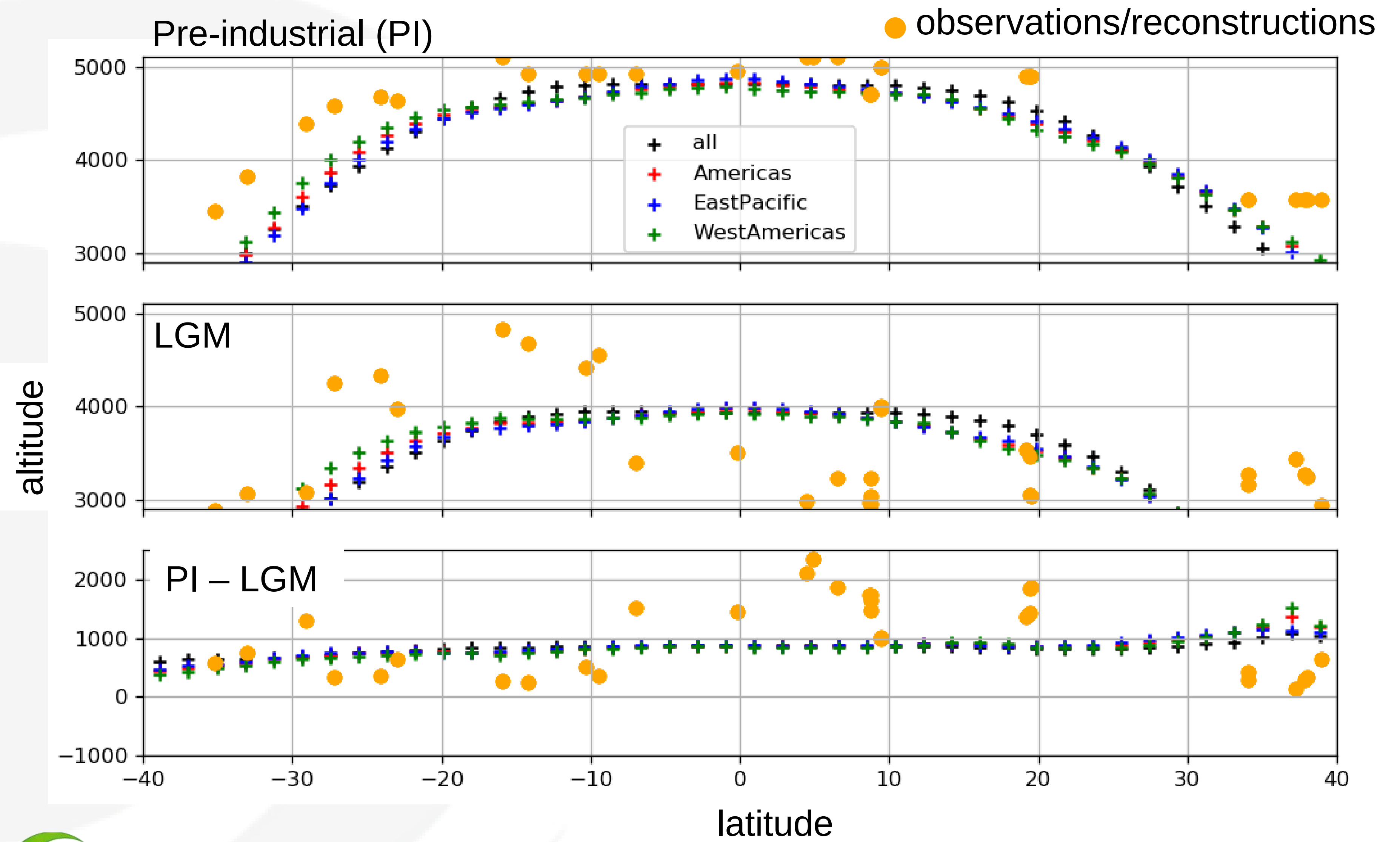


Together with SST changes ➔ estimate of changes in LR = dT/dz

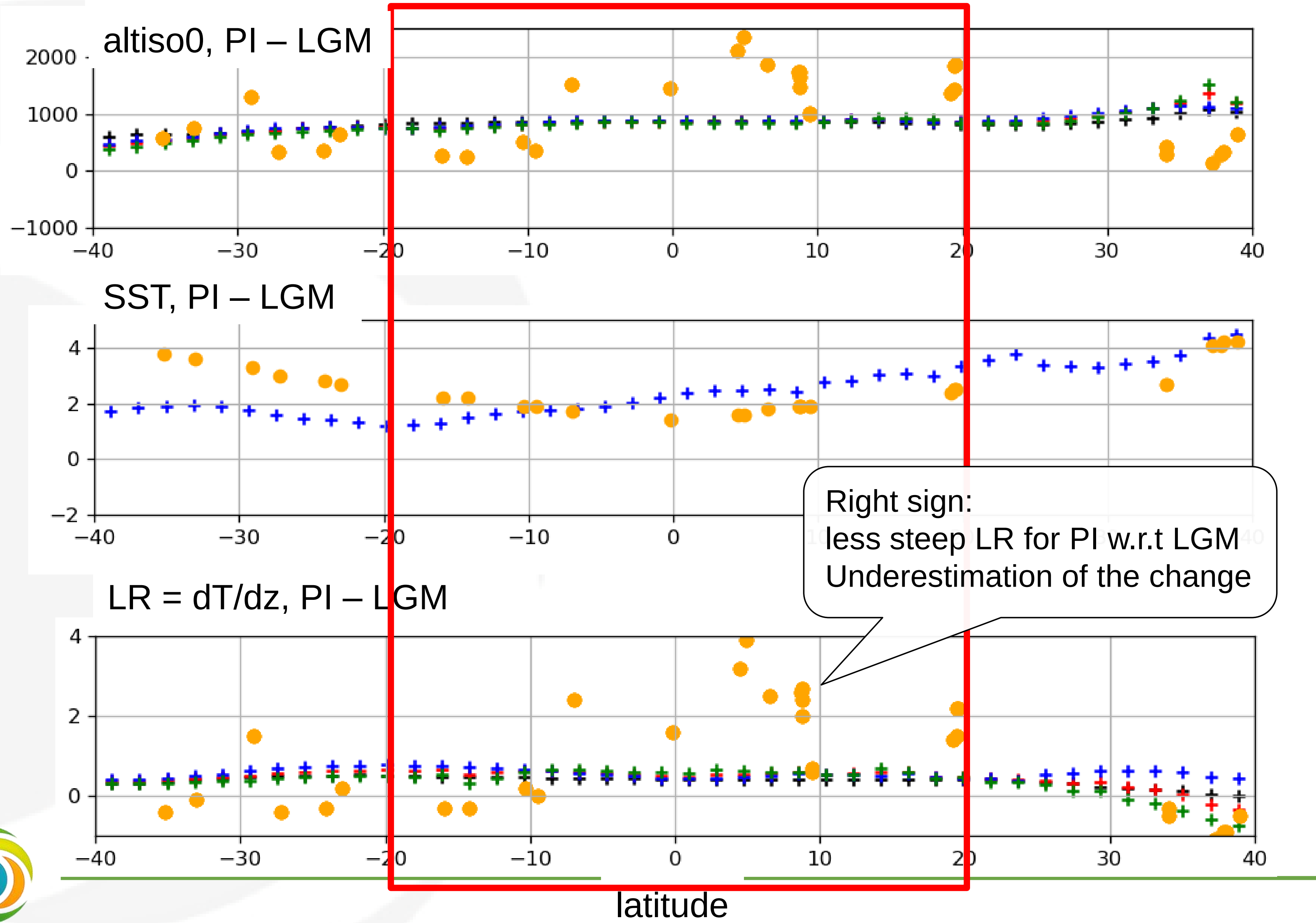


➔ From LGM to PI, LR is less steep in the tropics

IPSLCM5A2 model results: altitude of the 0° C isotherm



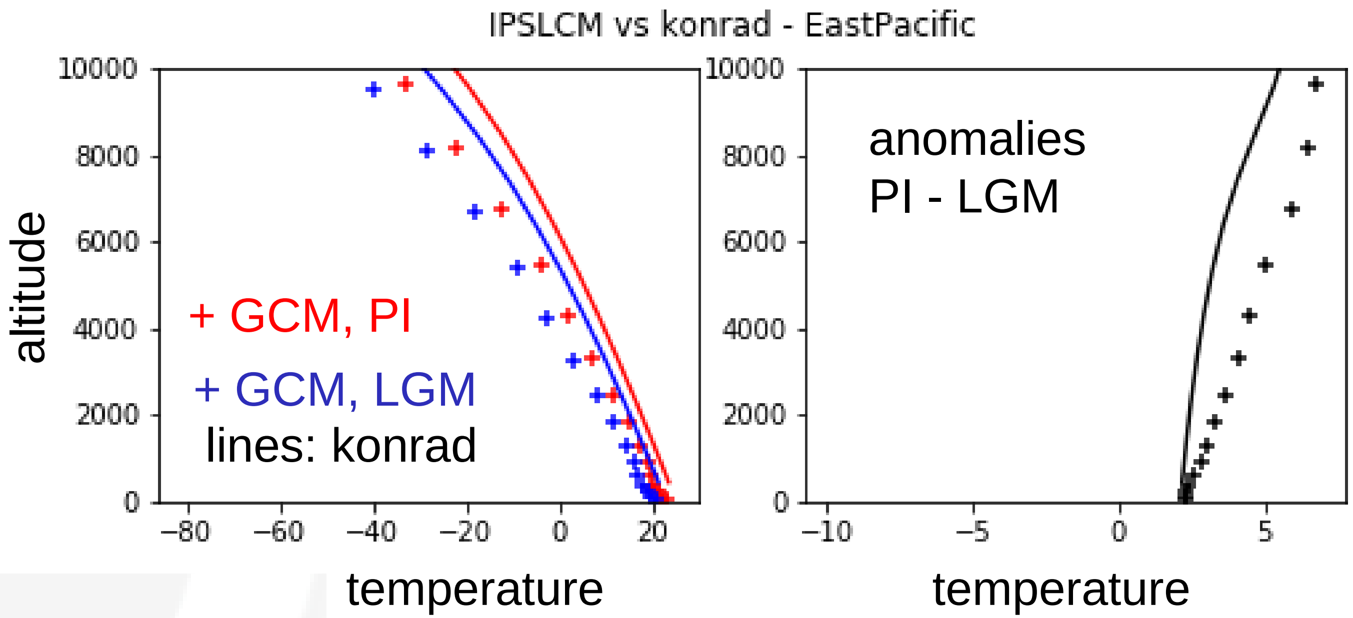
IPSLCM5A2 model results:
altitude of 0° C isotherm, SSTs, lapse rates



Processes

#1 moist adiabatic lapse rate ?

Use the radiative convective equilibrium model *konrad*
to compute temperature response to changes in SSTs, CO_2 and humidity

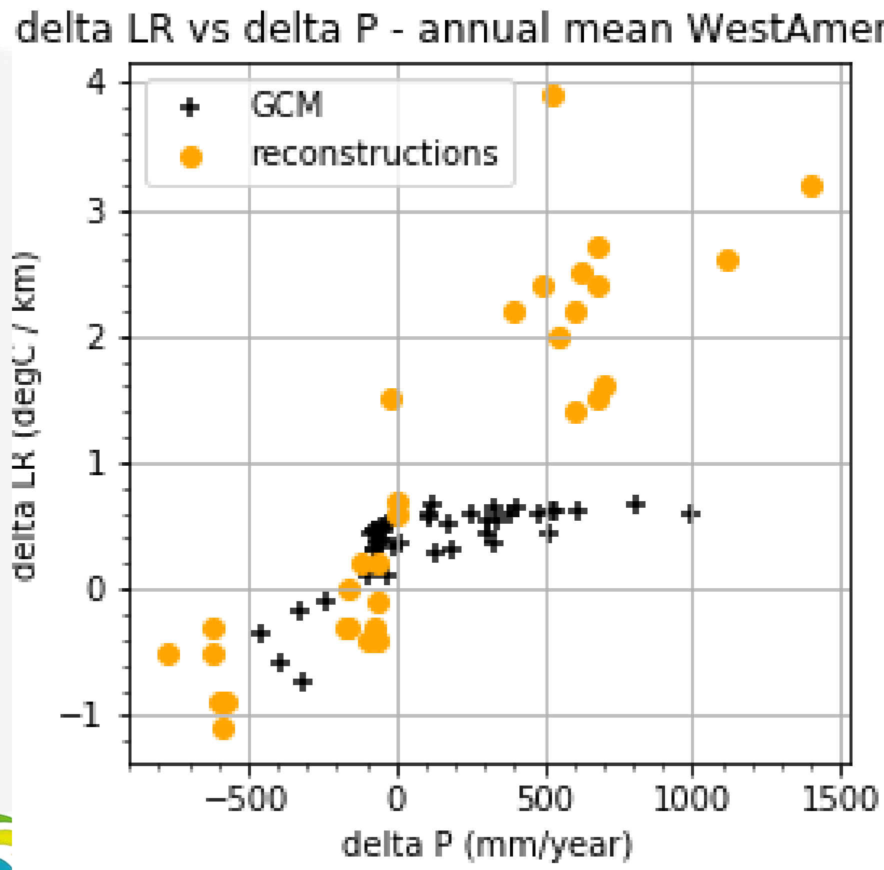


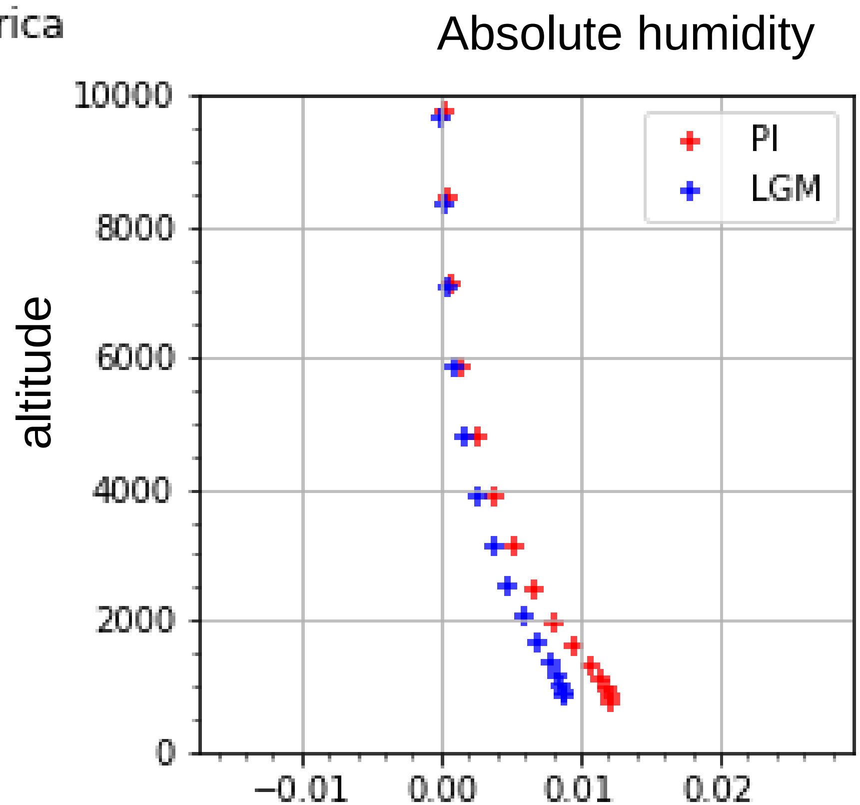
- ➔ Right sign, amplitude too small
- ➔ Boundary layer not represented…

Processes

#2 relationship with humidity ?

Relationship between ΔLR and Δprecip, in the reconstructions and in the model





Summary and perspectives

- Warming since the LGM: reconstructions show an amplification with elevation
- IPSLCM5A2 results in agreement on the sign, but underestimate its amplitude
- Processes involve moist adiabat changes, but not only

Ways forward:

- Compare to other model results (PMIP!)
- Compare processes for Future – PI warming and for PI – LGM warming
- Increase model resolution to better represent orography
- Study impact of other processes !

Thank you for your attention!