Do water isotopes in Asian ice cores record past precipitation changes?

Camille Risi

LMD/IPSL/CNRS

with thanks to: Sandrine Bony, You He, Valérie Masson-Delmotte

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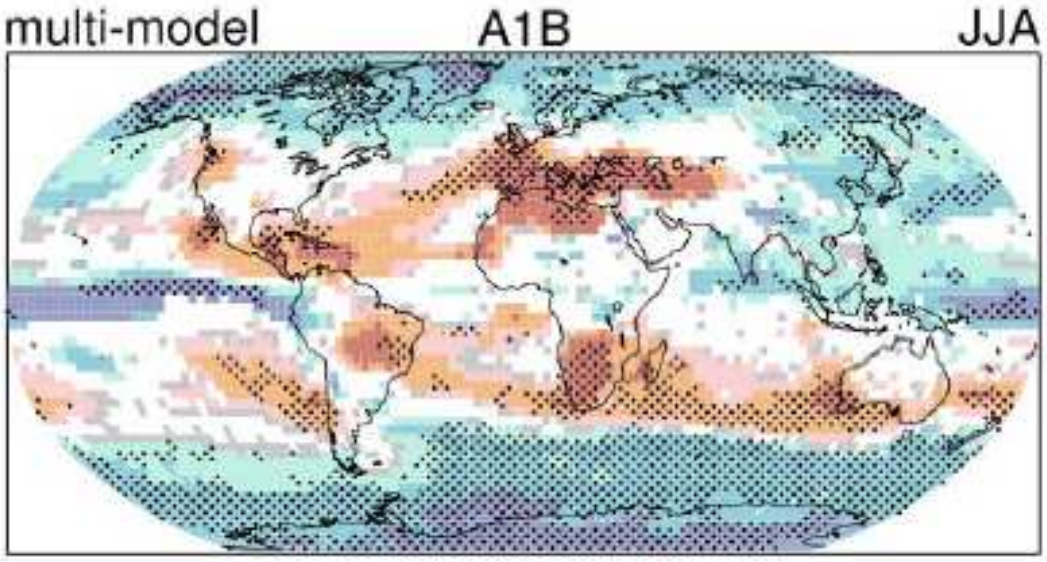
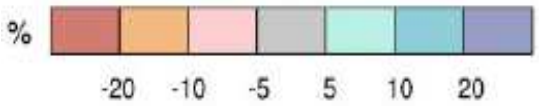
Spread in precipitation projections





precipitation change by 2100 (%)

<2/3 agree on sign

>90% agree on sign

CMIP3 models

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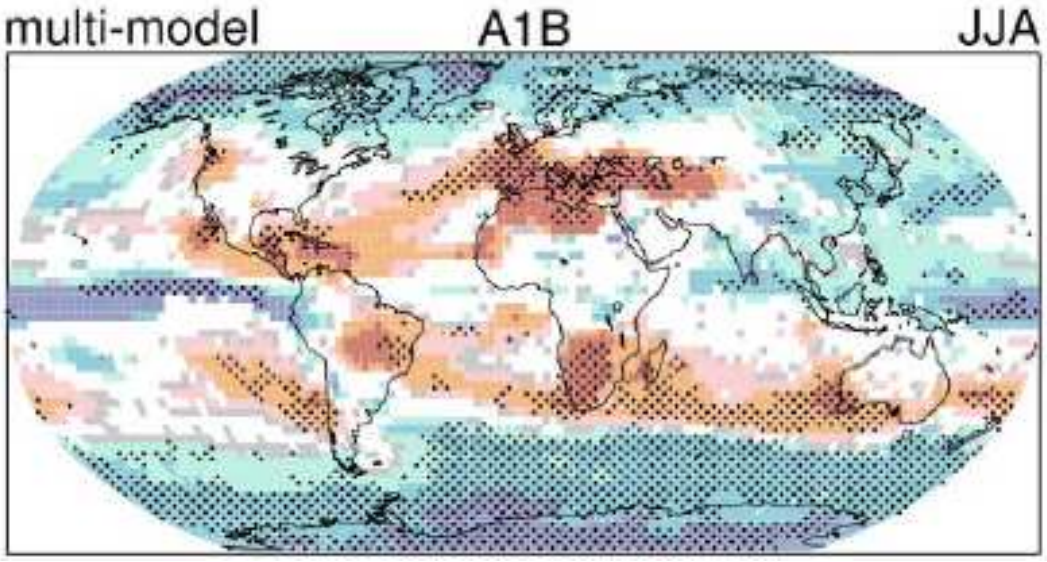

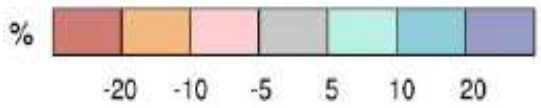

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Can we assess the credibility of future precip projections of tropical precip using past changes?

1. if a model is better for the past, is it better for the future?

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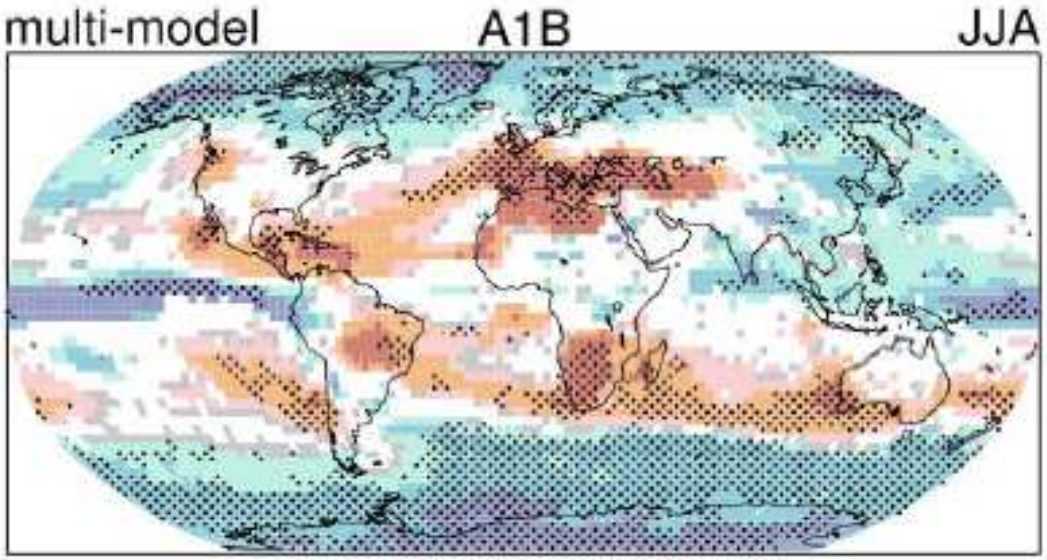

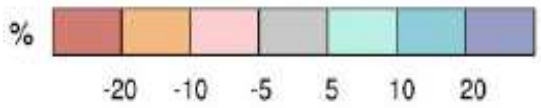

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CMIP3 models

Can we assess the credibility of future precip projections of tropical precip using past changes?

1. if a model is better for the past, is it better for the future?
2. Proxies of past precipitation changes?
   - Precip $\delta^{18}O$ archives (ice cores, speleothems)?

What does tropical $\delta^{18}O$ record?

Interpretations in the litterature:

- Thompson et al 2000 $\rightarrow$ proxy for temperature
- Vuille et al 2005, Pausata et al 2011 $\rightarrow$ proxy for monsoon intensity, upstream precipitation

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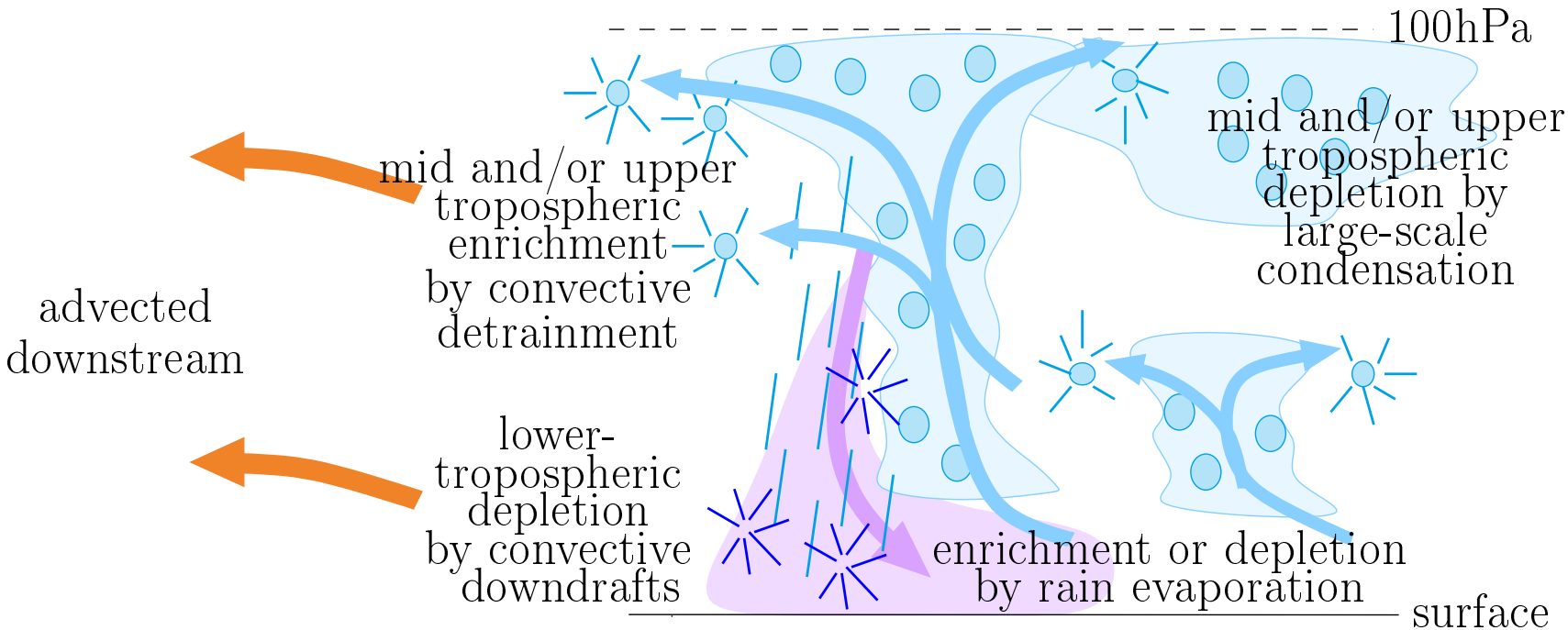
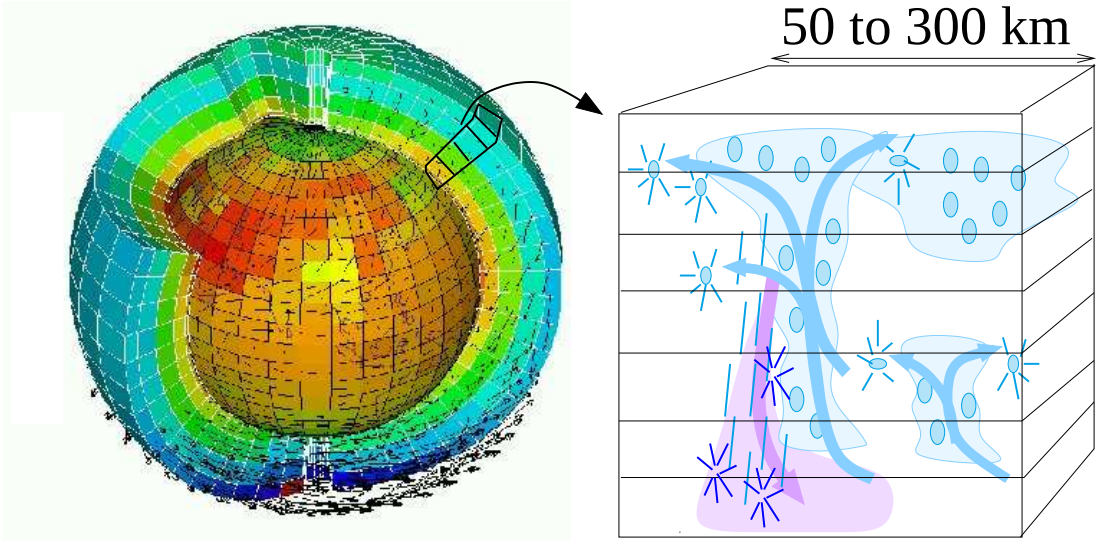
Expected effect of convection: Risi et al 2008, 2010:



LMDZ-iso simulations



- LMDZ general circulation model with isotopes (Risi et al 2010)

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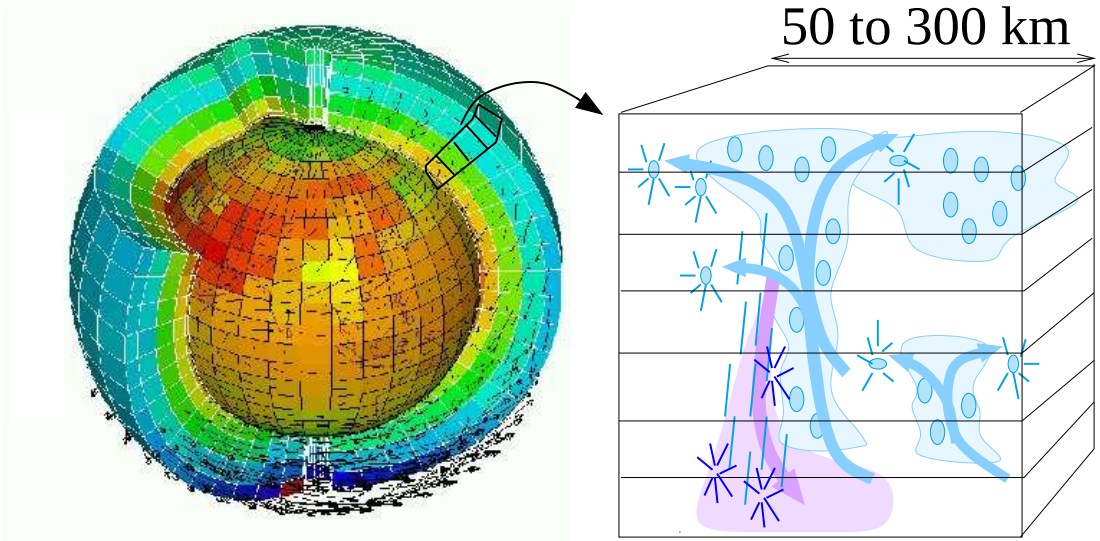

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- simulations of 11 different climates: LGM with different SSTs, MH , 2x and 4x CO2 with different SSTs, last interglacial
  - paleo relationships between $\delta^{18}O$ and climate?

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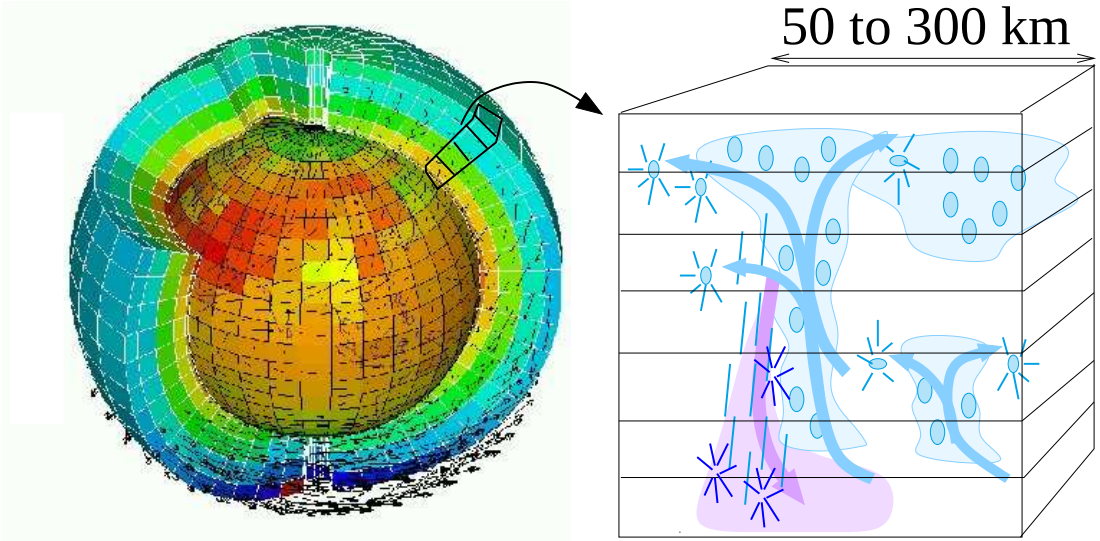

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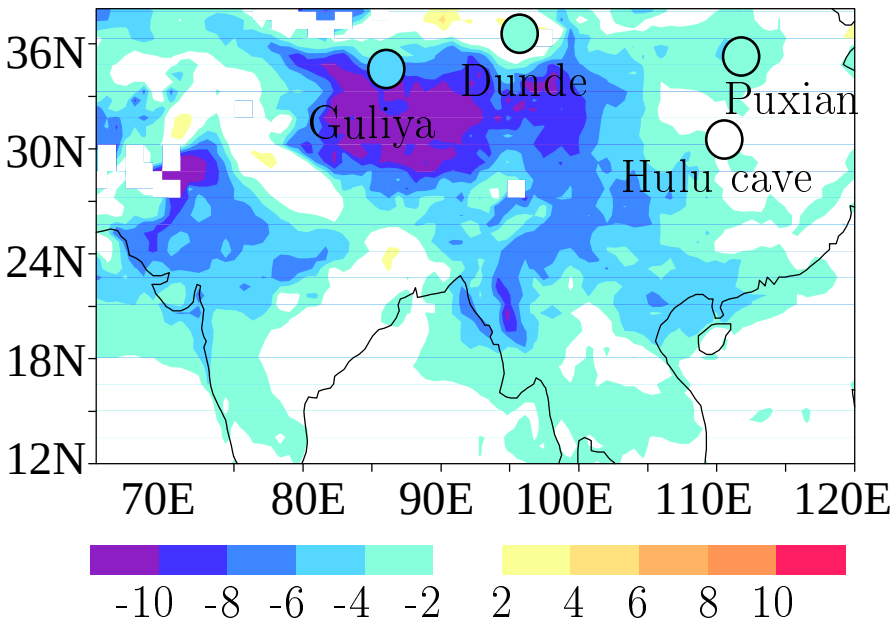
- simulations of 11 different climates: LGM with different SSTs, MH , 2x and 4x CO2 with different SSTs, last interglacial
  - paleo relationships between $\delta^{18}O$ and climate?
- sensitivity tests to model physics and resolution (including 50km zoom)
  - robustness of simulated relationships?

Evaluation for LGM and MH

Last Glacial Maximum

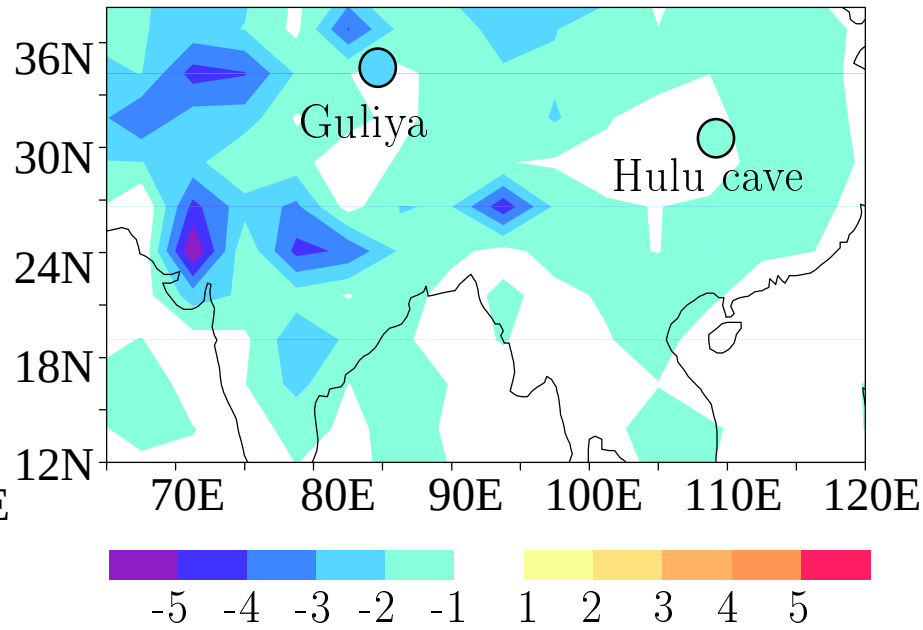


$\Delta\delta^{18}O$ (‰)

(sea water corrected)

LMDZ 50km resolution

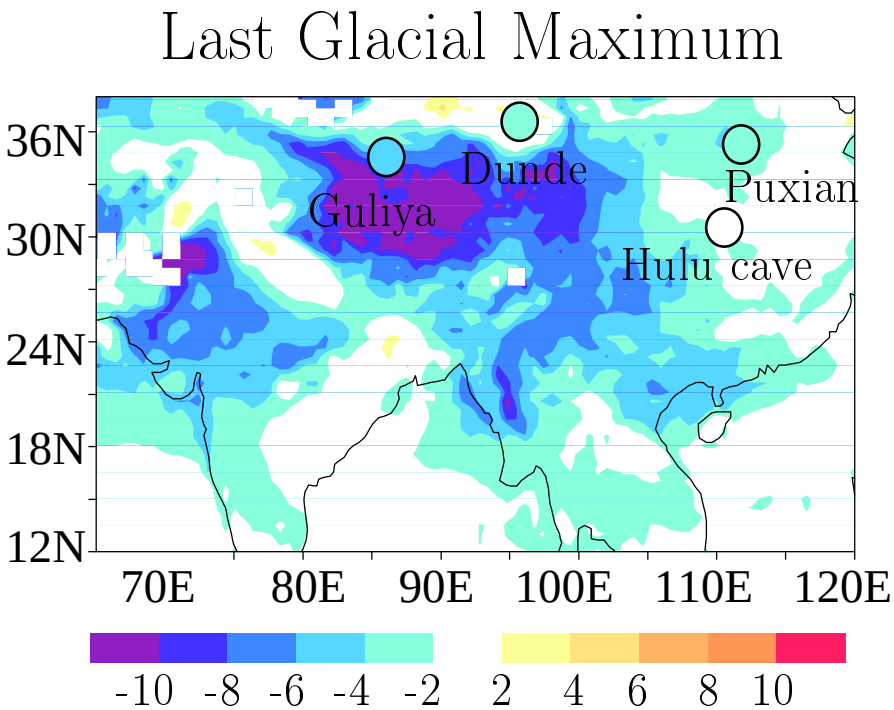
Mid Holocene

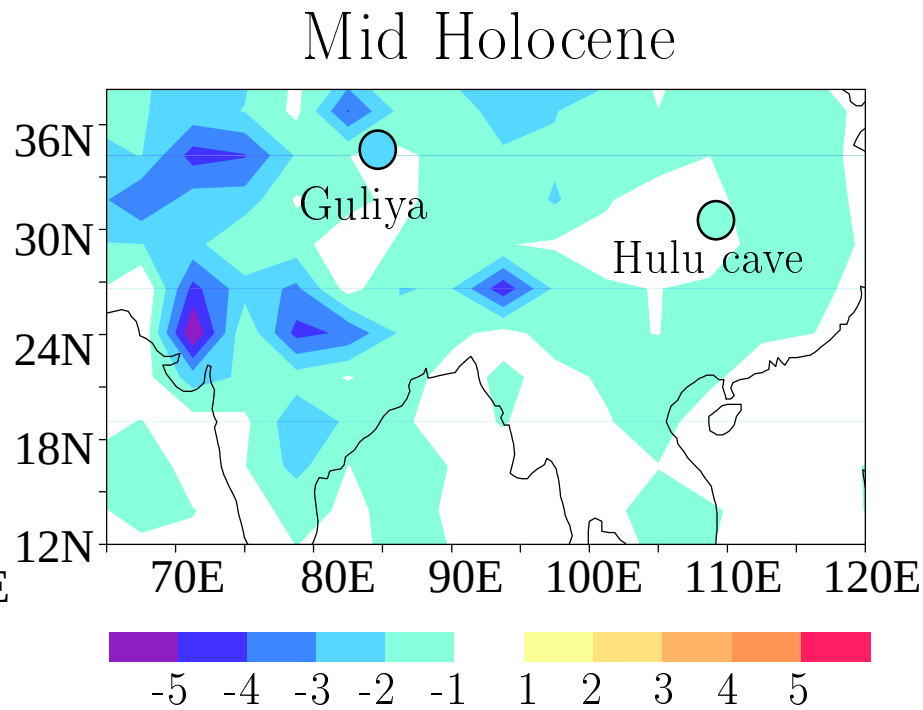


$\Delta\delta^{18}O$ (‰)

LMDZ control

Evaluation for LGM and MH





- LMDZ captures LGM and MH observed depletion

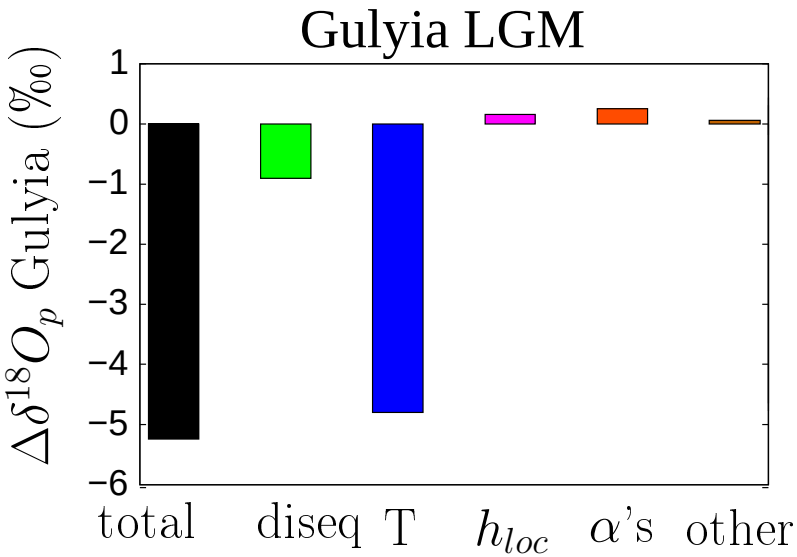
Causes of $\delta^{18}O$ changes?

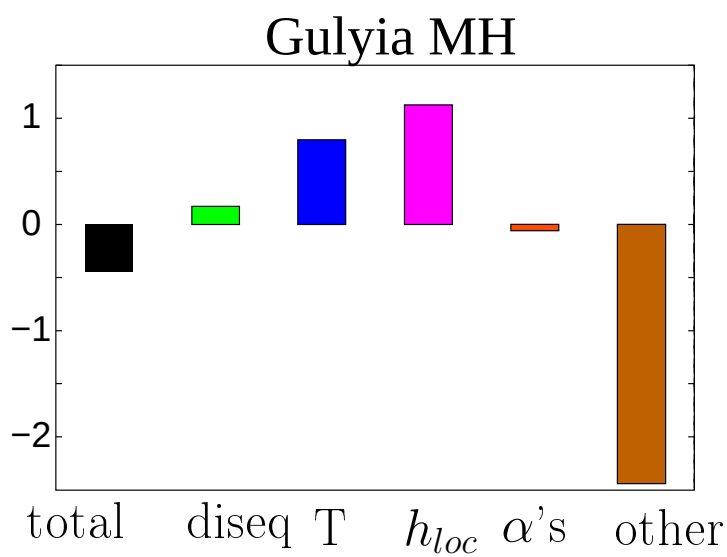
$$R_p = R_v + (R_p - \alpha_{loc} \cdot R_v) + (\alpha_{loc} \cdot R_v - R_v)$$

vap-cond diseq

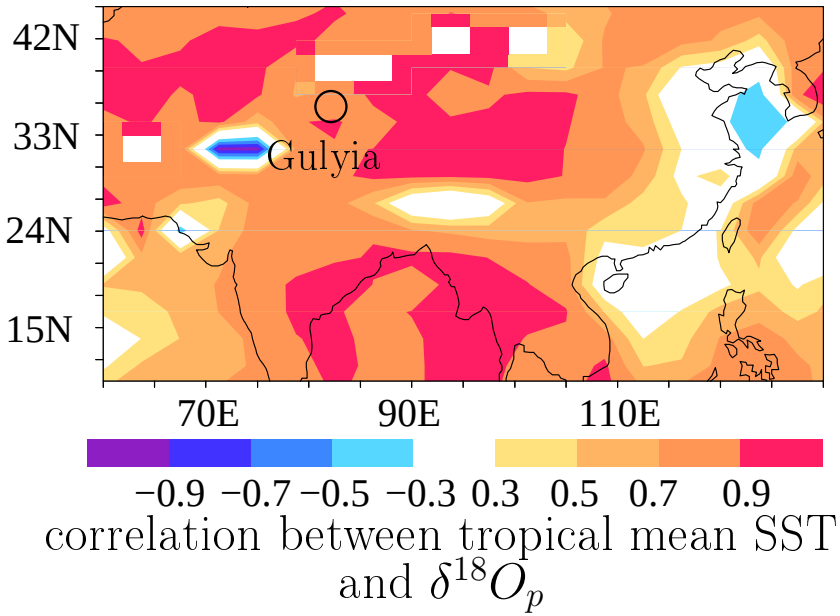
$$R_v = \frac{R_{oce}/\alpha_i}{\alpha_K \cdot (1-h_i)+h_i} \cdot \left(\frac{h_{loc} \cdot q_s(T_{loc})}{q_s(T_i)}\right)^{\alpha_{loc}-1} + \text{residual}$$

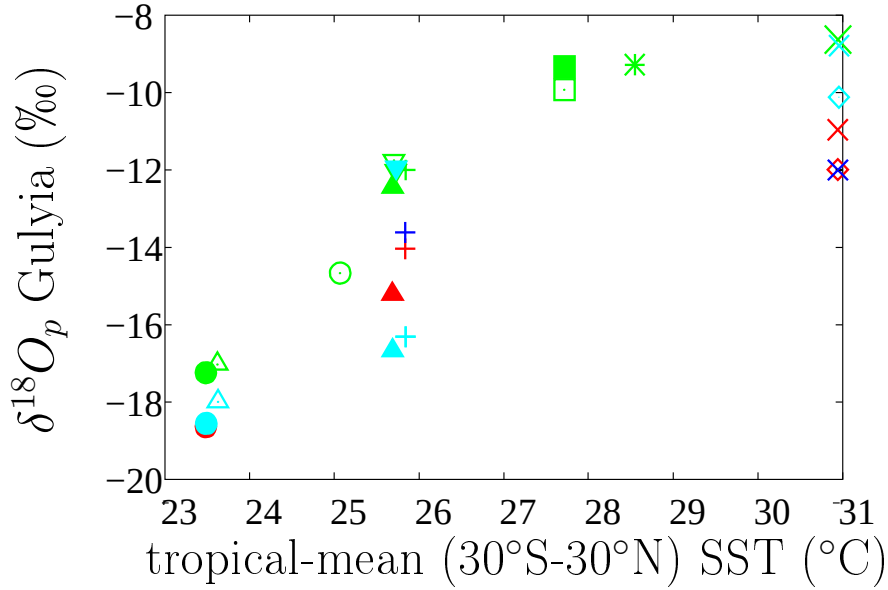
initial vapor | distillation | e.g. upstream convection





Is $\delta^{18}O$ a proxy for temperature?





Climates:
- + present−day
- × 4xCO2 IPSL
- ✳ 2xCO2 IPSL
- □ 2xCO2 ECHAM
- ■ 2xCO2 MIROChi
- ○ LGM climap
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Model versions
- control
- less diffusion
- more detrainment
- less condensation
- 50 km resolution

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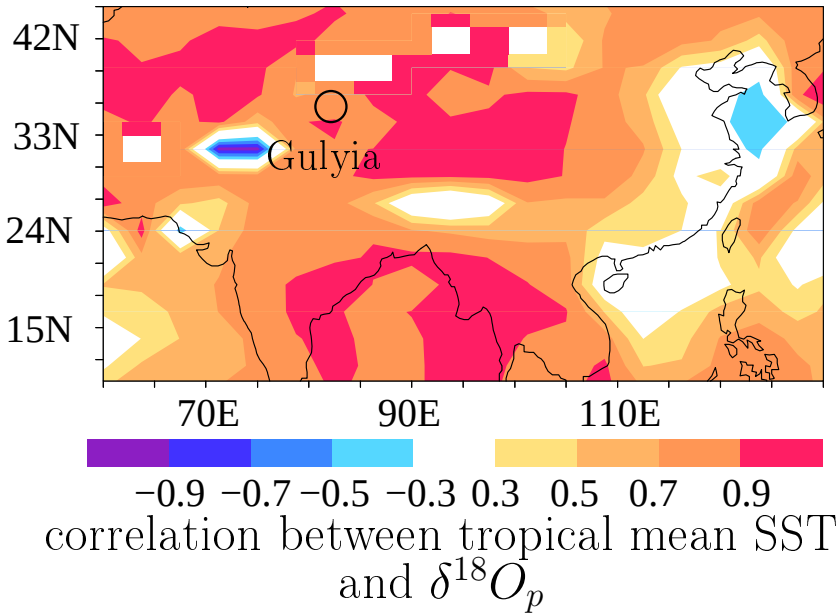

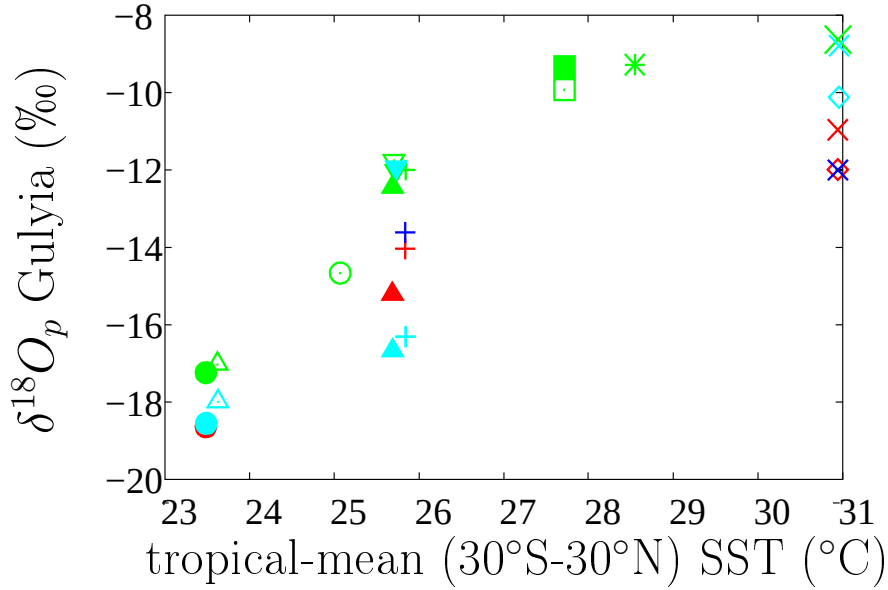

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Model versions
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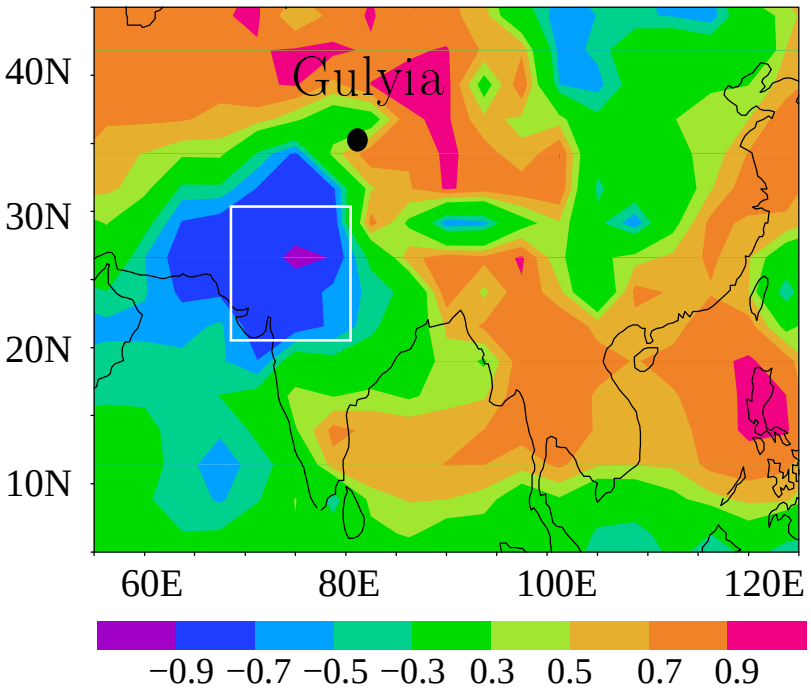
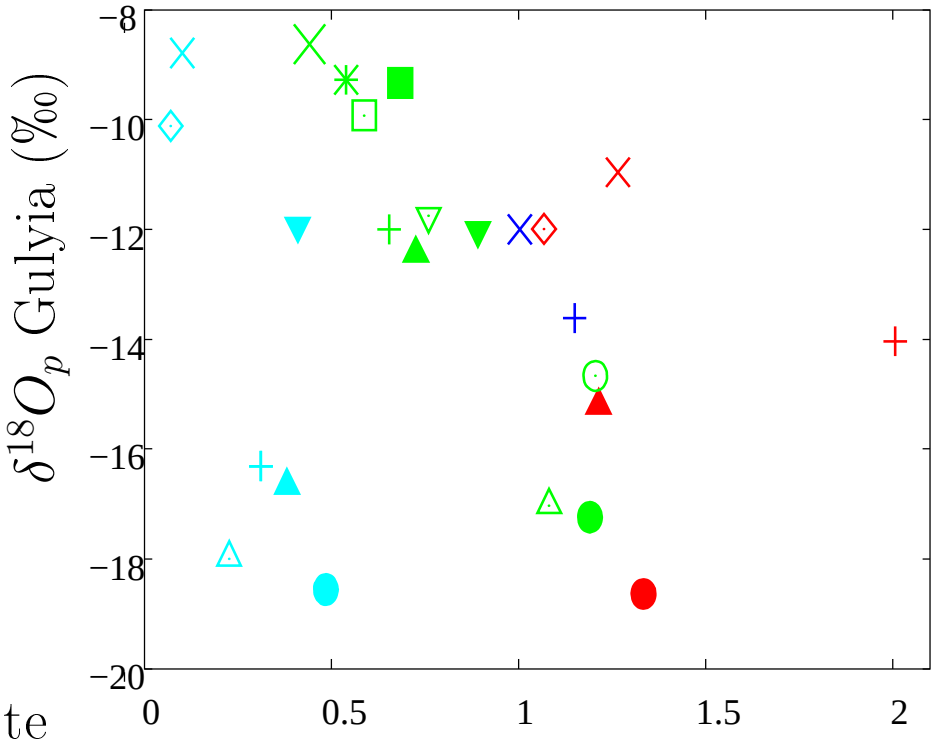
- temperature = significant control at paleo time scales
- robust to model physics

Is $\delta^{18}O$ a proxy for precipitation?

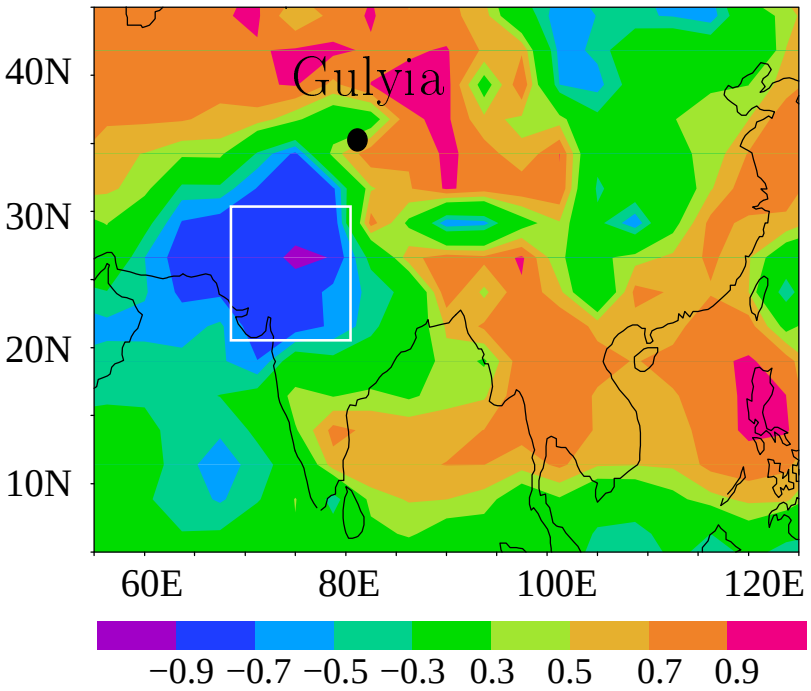


correlation between $\delta^{18}O_p$ at site and precipitation around



box-averaged precipitation (mm/d)

Is $\delta^{18}O$ a proxy for precipitation?



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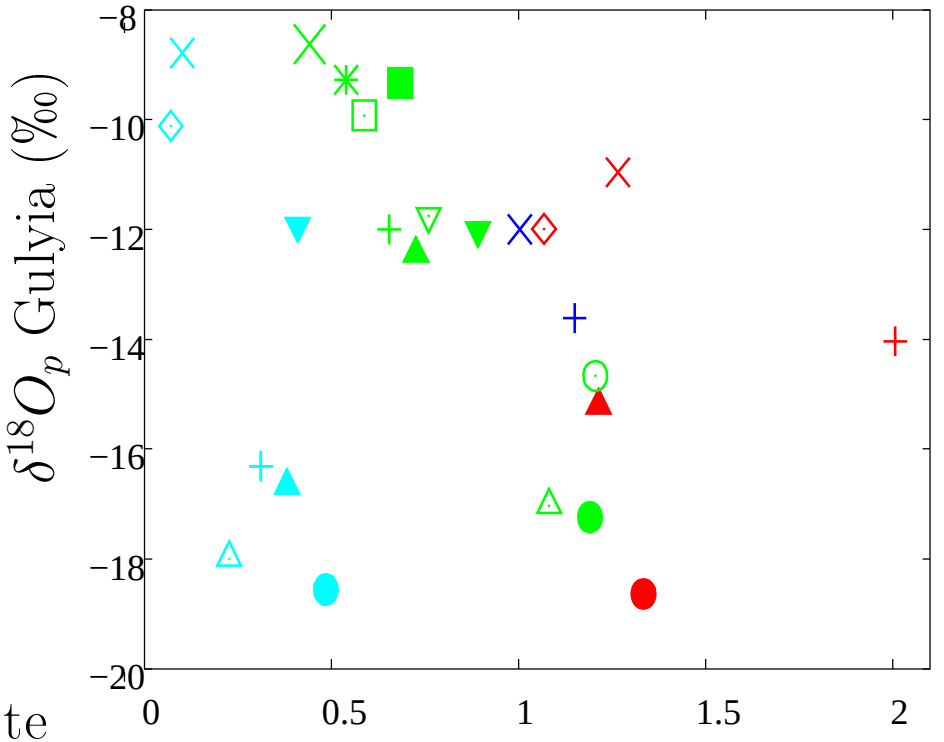
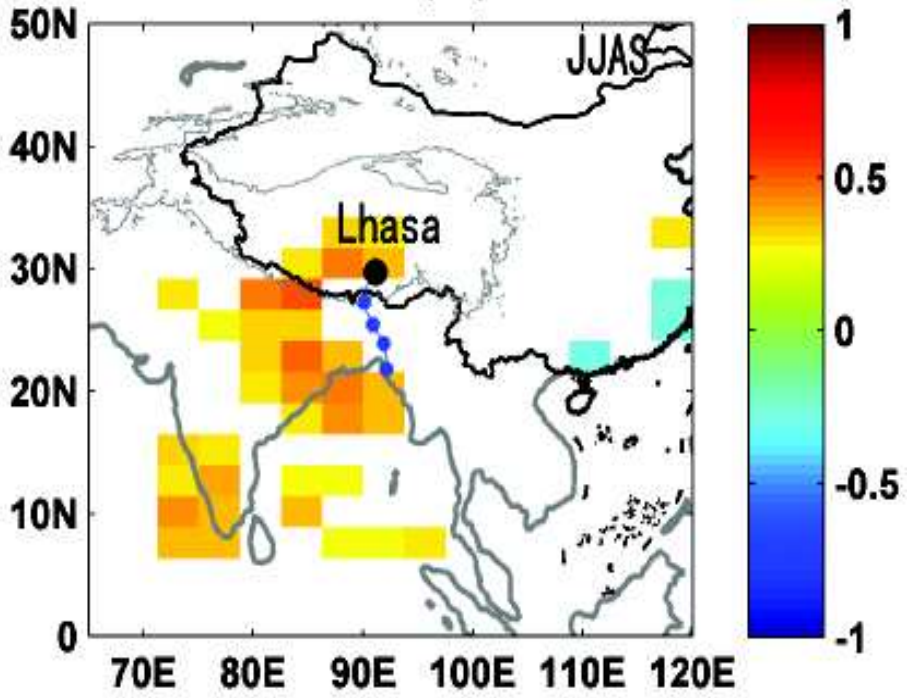


- Upstream precipitation plays a role at paleo time scales
- Sensitive to the model physics

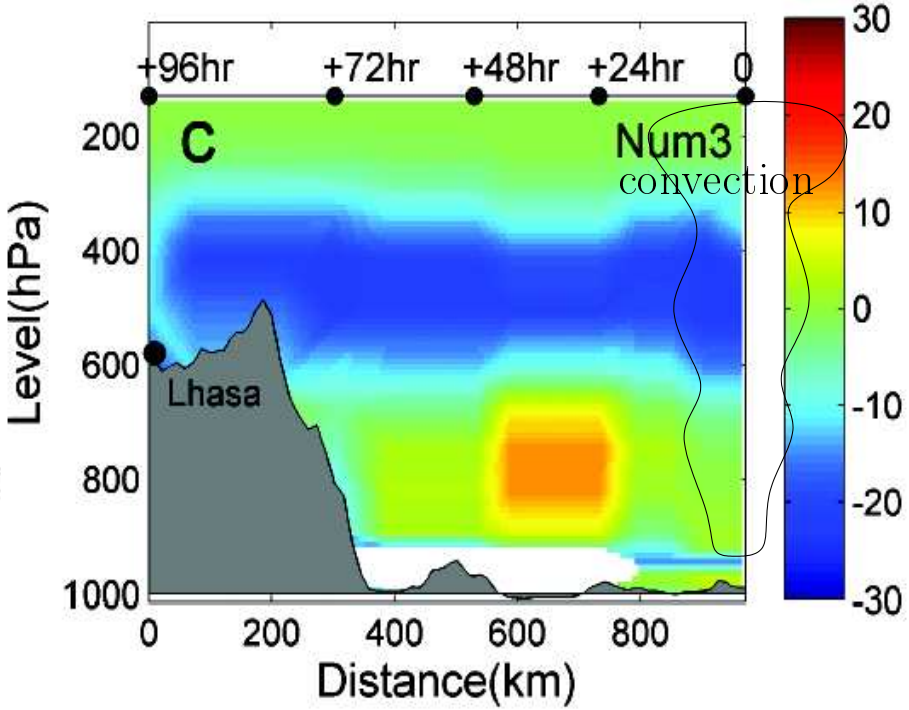
Process study using satellite observations

- You He's PhD thesis: use of TES data

daily correlation between δD at 400hPa at Lhassa and OLR around in JJAS



δD composite anomalies (‰) along trajectories to Lhassa when OLR is low 4 days before



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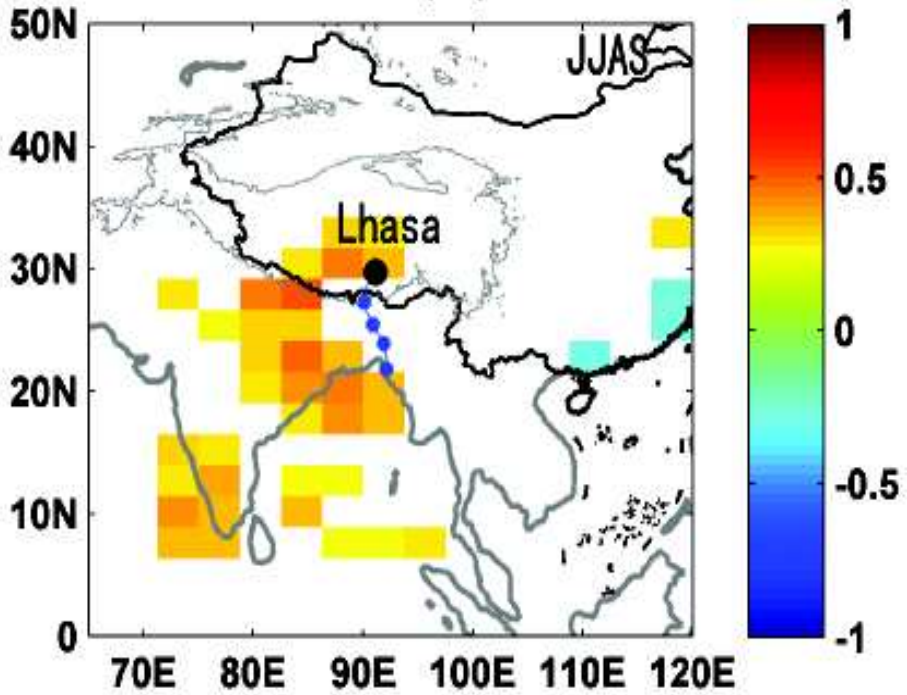

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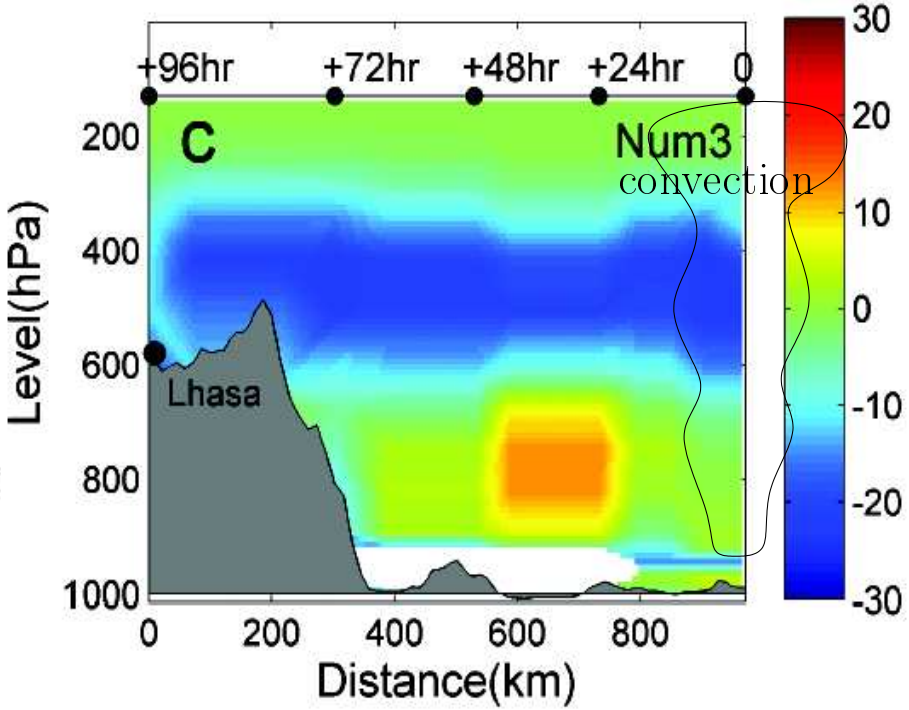
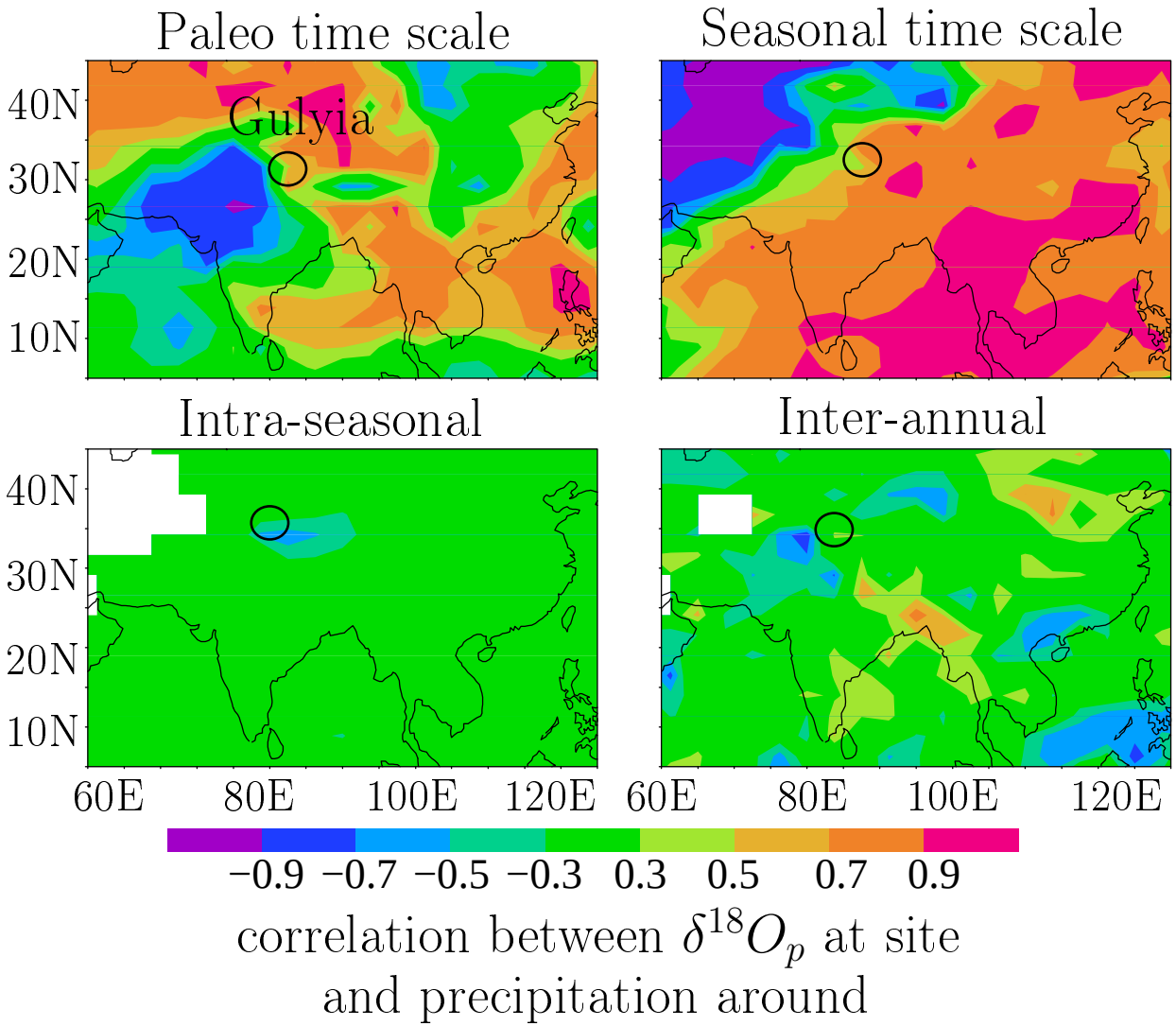


- convection in India depletes mid-tropospheric vapor
- depleted anomaly is transported downstream to Lhassa

Does this apply to paleo scales?

Can we use present-day observations to better understand processes controlling paleo $\delta^{18}O$ and evaluate them in models?



Conclusion

- LMDZ can reproduce several aspects of past $\delta^{18}O$ changes
- At paleo time-scales and especially during LGM, temperature is a major control
- At paleo time-scales and especially during MH, relationship with upstream precip but sensitive to the model physics
- Surface and satellite data can help understand processes controlling $\delta^{18}O$ at daily time scale $\Rightarrow$ role of convection
- But relationship between precip and $\delta^{18}O$ depends on time scale

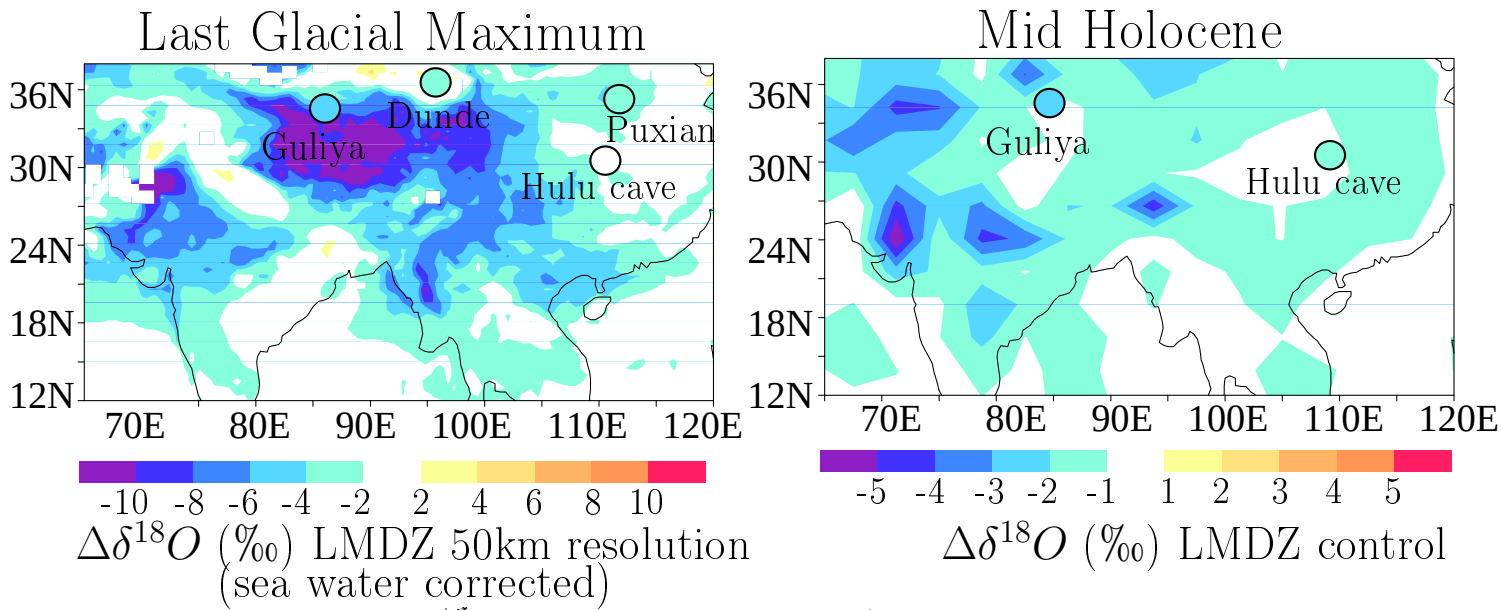
Perspectives

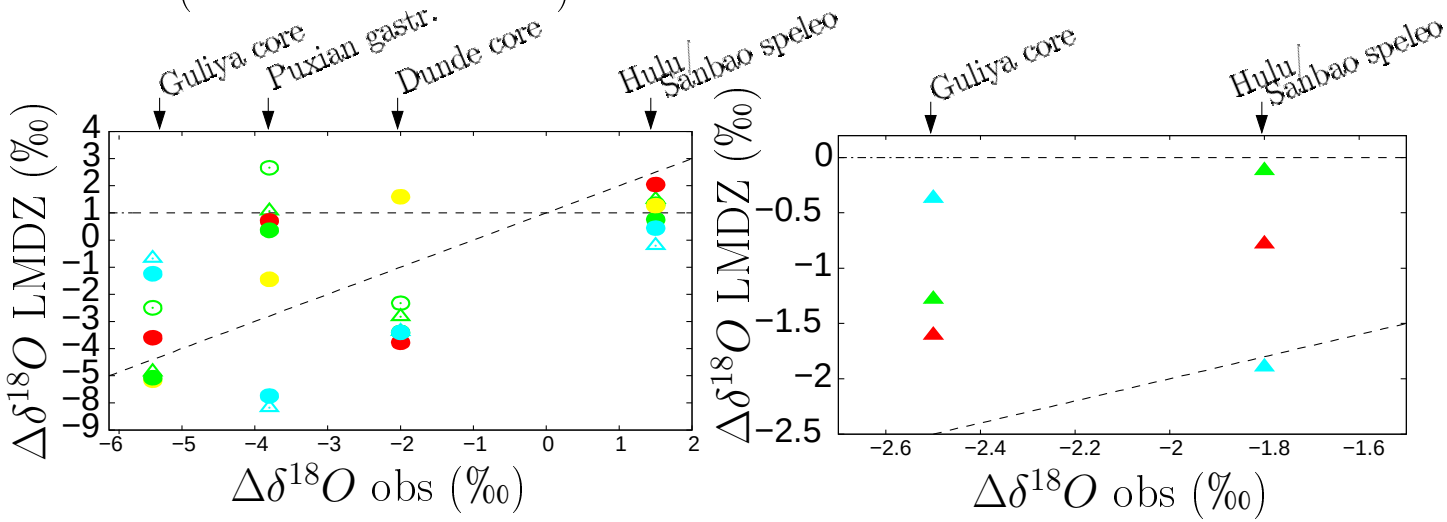
- Better evaluate climate-$\delta^{18}O$ relationships:
  - More data synthesis needed for paleo $\delta^{18}O$ to evaluate models
  - are some sensitivity tests more realistic at daily time scales?
  - do we expect them to be more realistic for paleo time scales?
  - compare with other models
- can we use $\delta^{18}O$ records to better constrain future precip changes?
  - common behavior in past and future periods?
  - common precip changes mechanisms for past and future?

  $\Rightarrow$ investigation using past and future simulations in CMIP5

Appendix

Evaluation for LGM and MH





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Past/future precip changes in CMIP5