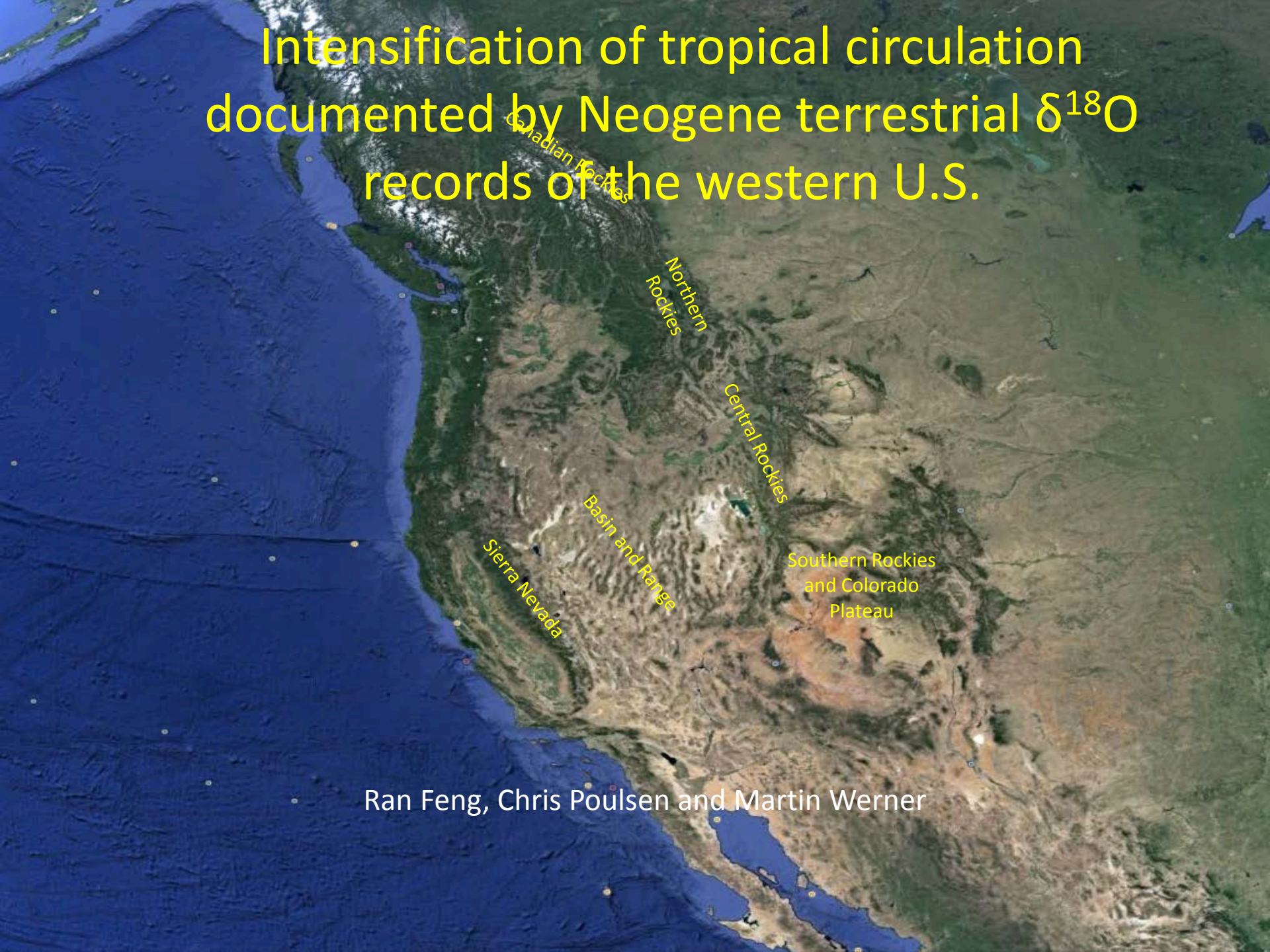
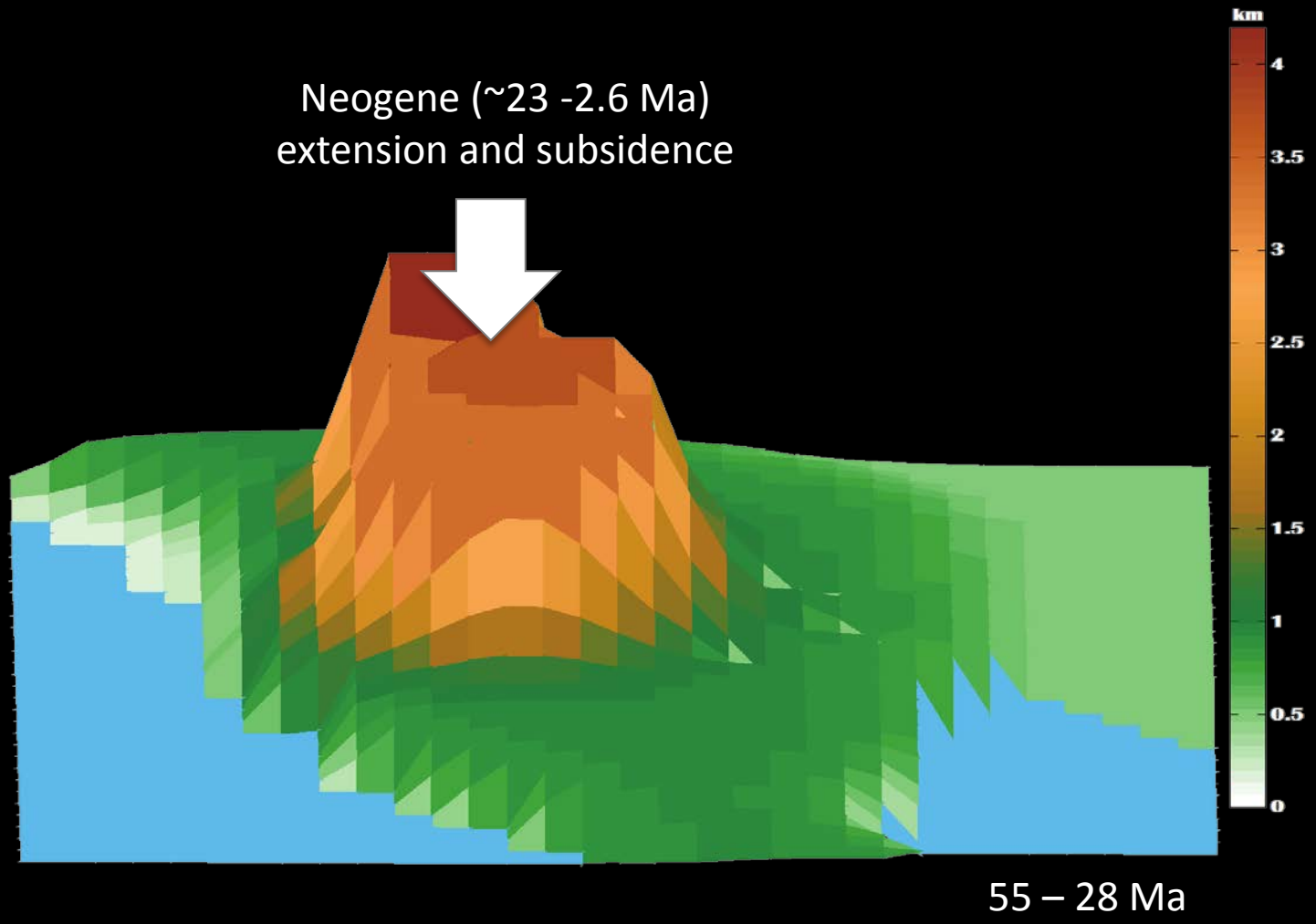
Intensification of tropical circulation documented by Neogene terrestrial $\delta^{18}O$ records of the western U.S.



Ran Feng, Chris Poulsen and Martin Werner

What might this area look like in the past?



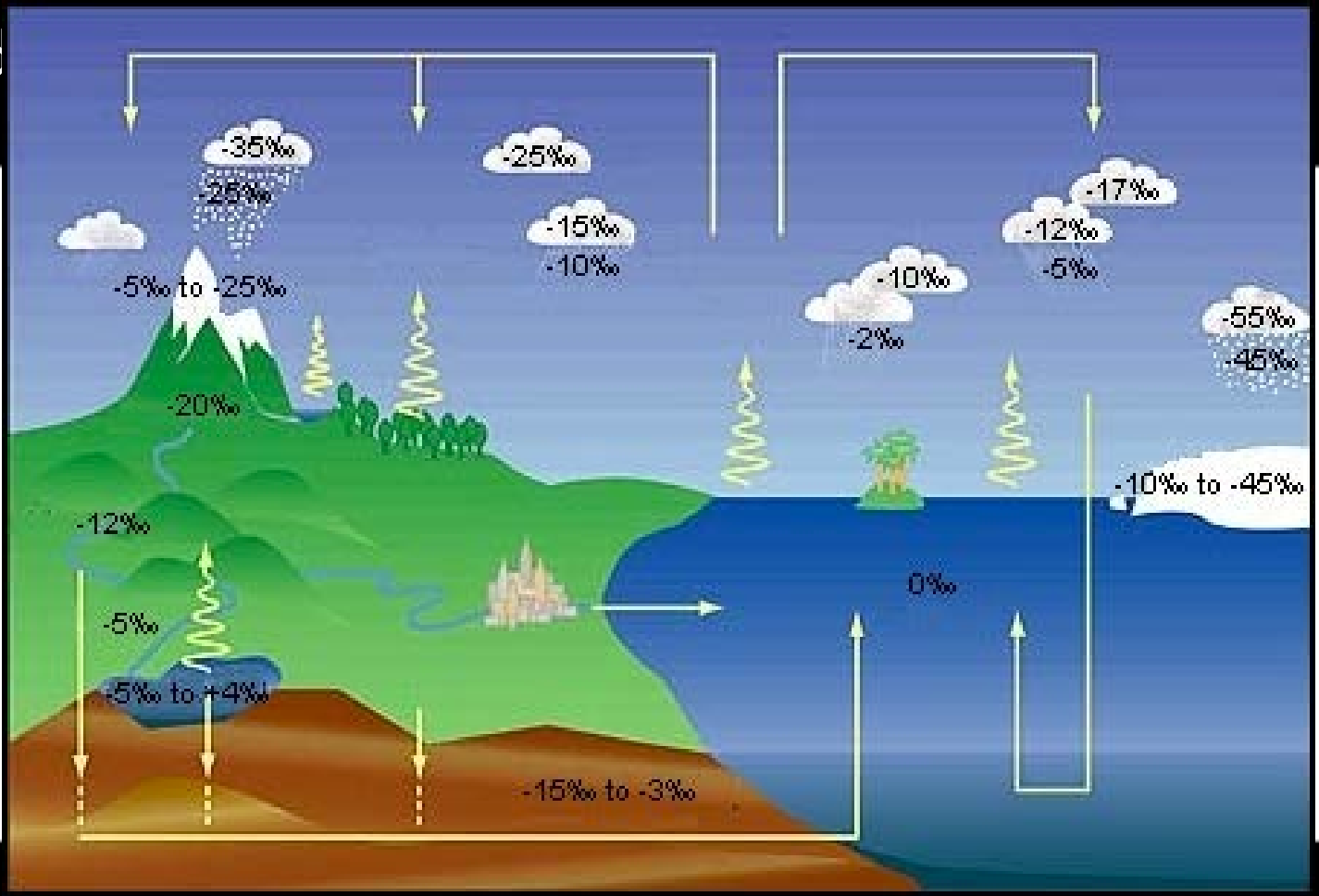
Stable isotope (O^{18}) compositions

- Stable isotope (O^{18}) compositions of authigenic minerals and organic materials
- Mineral O^{18} composition
  - proxies for the surface water and precipitation O^{18}

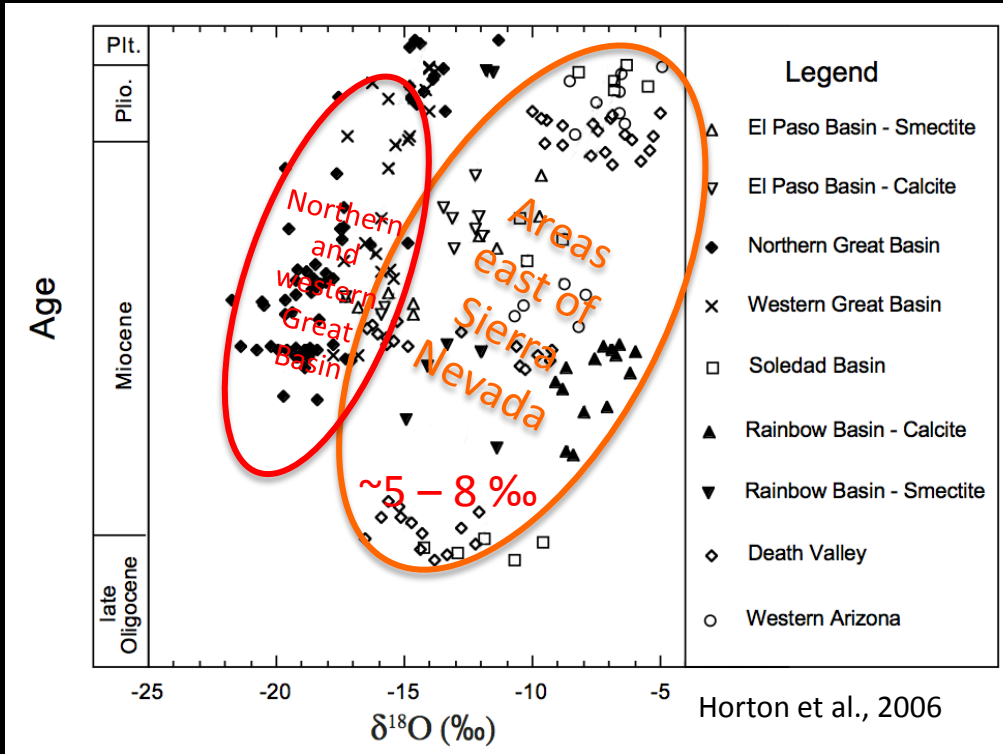
- δ notation:
  - $\delta = (R - Rstd)/Rstd*1000$, $R = O^{18}/O^{16}$

How do we interpret elevations from proxy $\delta^{18}O$?

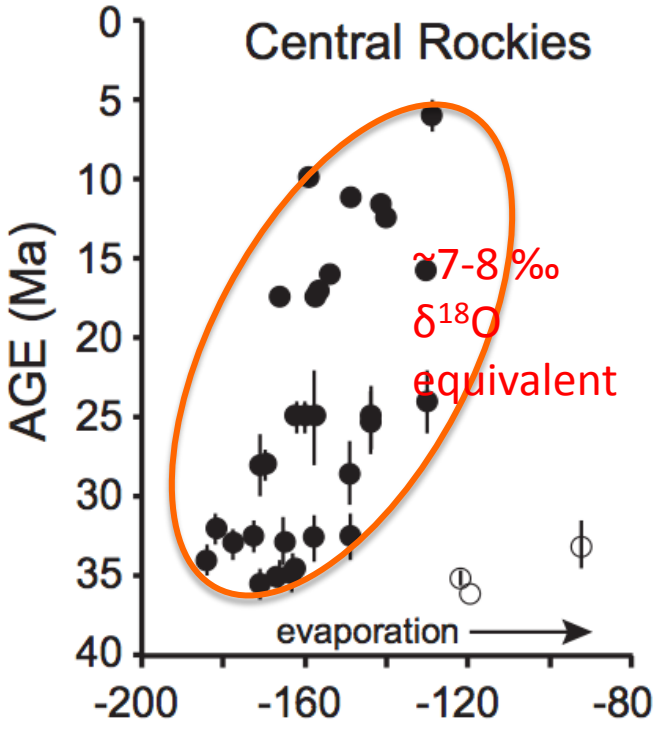
- d



Surprising enrichment pattern of Neogene isotope records



Horton et al., 2006



Neogene Environmental changes

- Increasing equator-to-pole temperature gradient
  - lowering CO_2 level (2 x PI CO_2 to PI CO_2) (Zhang et al., 2014)
  - high latitude glaciation (early Neogene reconstructions from Herold et al., 2008)
  - increasing meridional SST gradient (Goldner et al., 2014)
- Increasing tropical Pacific zonal SST gradient (Zhang et al., 2014)
- Grassland expansion (Strömberg, 2011)
- Geographic and topographic changes (outside the western U.S.) (Herold et al., 2008)

Experiment setup

- ECHAM5-JSBACH-wiso: isotope tracking in both atmosphere and land model (Werner et al., 2011; Haese et al., 2013)
  - T63 resolution (~2°)
- Boundary conditions designed to test regional responses to four different aspects of Neogene climate changes (ΔC):
  - $\Delta C = C((\Delta T_{meridional})_{mod}, (\Delta T_{zonal}, Gc, Vc)_{mod,} R)$
    $- C((\Delta T_{meridional})_{early\ Neogene}, (\Delta T_{zonal}, Gc, Vc)_{mod}, R);$

    $\Delta T_{meridional}$: meridional SST gradient, CO_2, icesheets

    ΔT_{zonal},: zonal Pacific SST gradient

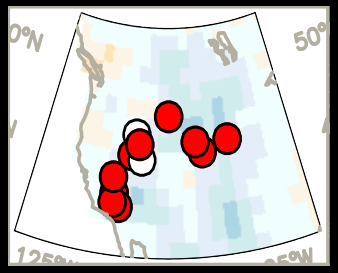
    Gc: geographic and topographic changes

    Vc: vegetation changes (Grassland expansion)

Responses of $\delta^{18}O$

Increasing equator-to-pole temperature gradient

Increasing east-west tropical Pacific SST gradient



Geographic and topographic reconfiguration

Grassland expansion

✔

ment

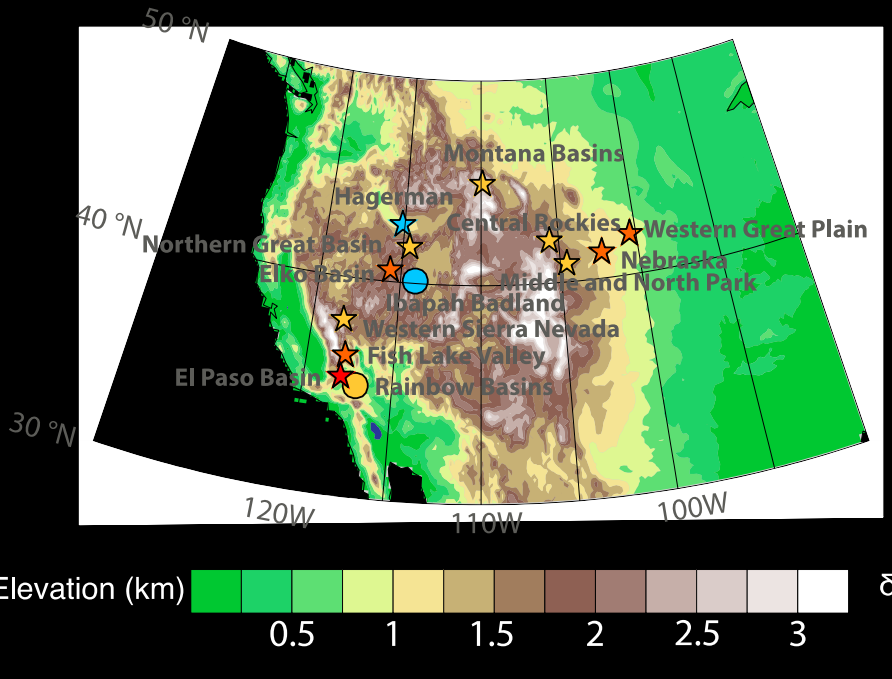
opposite direction, proxy depletion

-5 -3 -1 1 3 5

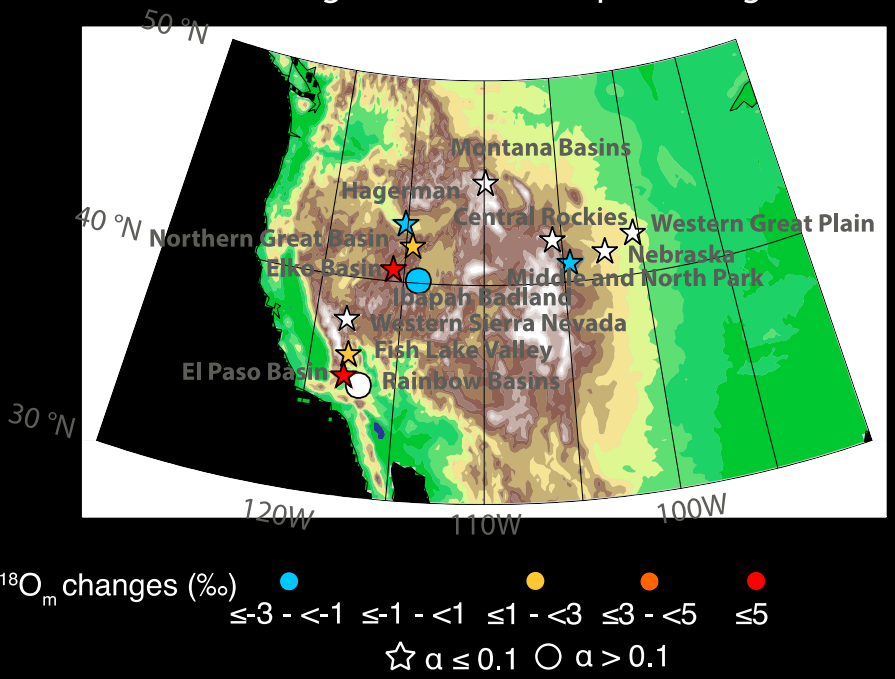
- Enrichment pattern in response to increasing equator-to-pole temperature gradient matches the proxy enrichment pattern at most locations.

Comparison with proxy data

Proxy Neogene isotopic changes



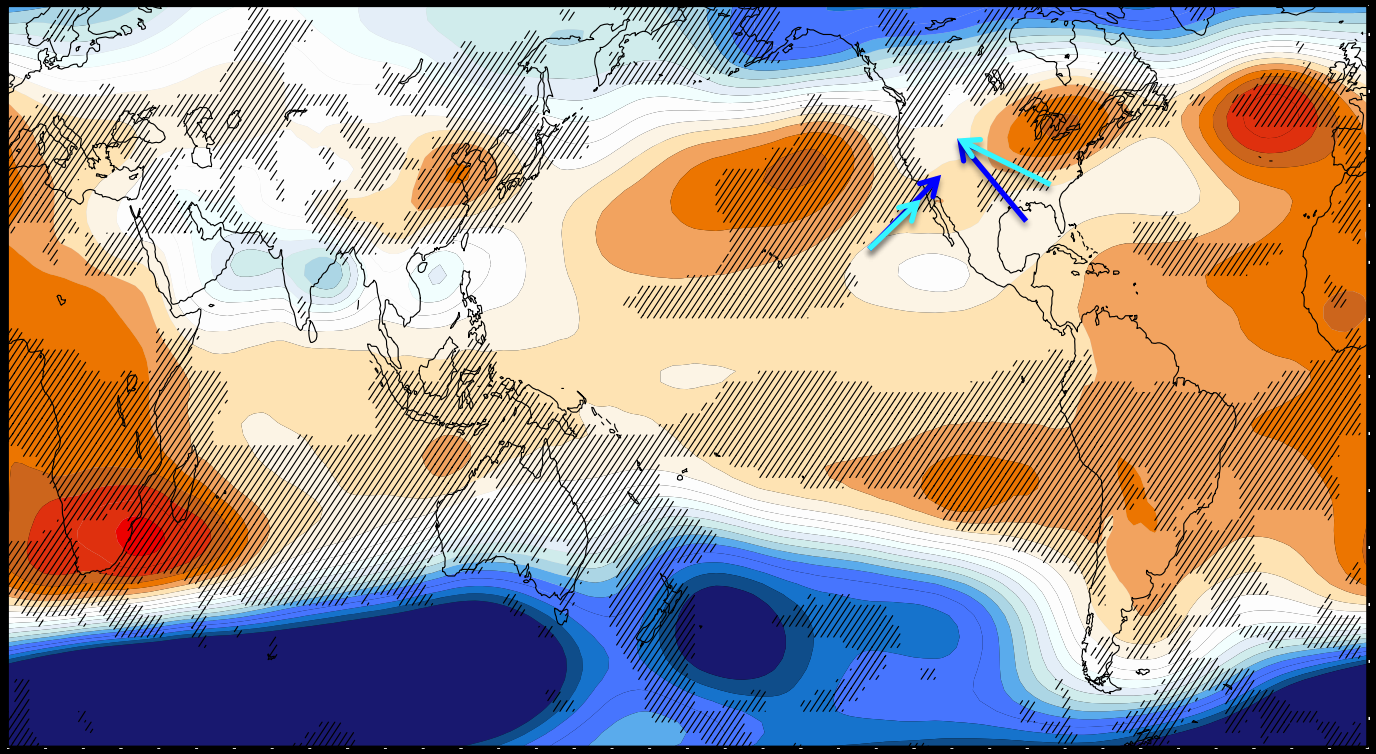
isotopic changes after removing ^{18}O-responses to increasing meridional temperature gradient



- The proxy enrichment across the central Rockies and northern Great Basin can mostly be explained as $\delta^{18}O$ responses to Neogene strengthening of the equator-to-pole temperature gradient.

Global responses of soil water $\delta^{18}O$

Responses of geopotential height and vertical pressure velocity 700 hPa

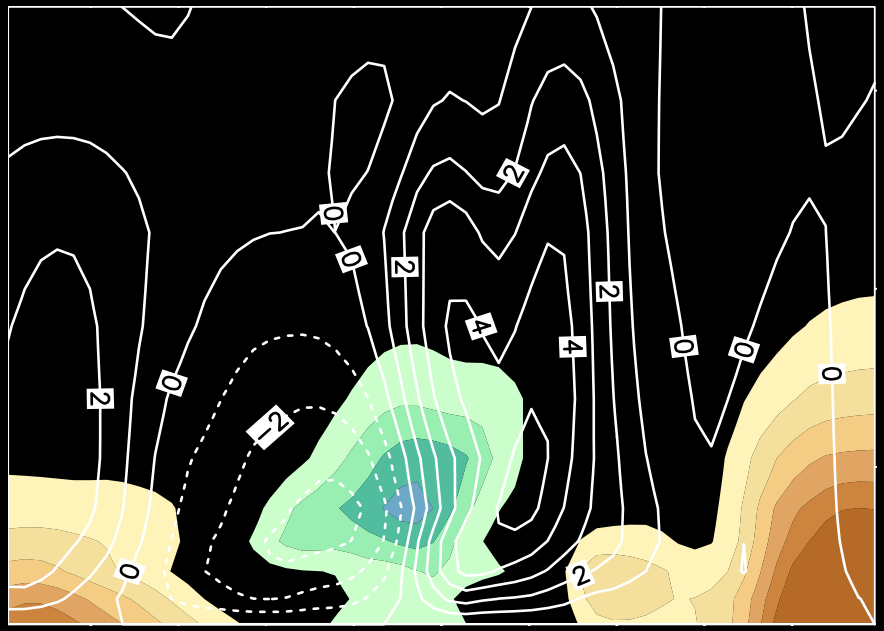


t changes (m)

Enhanced subsidence

Strengthened Hadley circulation

Summer Hadley circulation responses



erturning mass flux (10^{10} kg/s)

- Strengthen of the Hadley circulation by increasing equator-to-pole temperature gradient through enhanced tropical convergence and moist convection

Conclusions and implications

- Neogene terrestrial $\delta^{18}O$ records from the Sierra Nevada and Central Rockies may have recorded long-term intensification of Hadley circulation.
- Stable isotope records have the potential to be used to reconstruct past circulation changes with the help of isotope-enabled climate models

Questions?