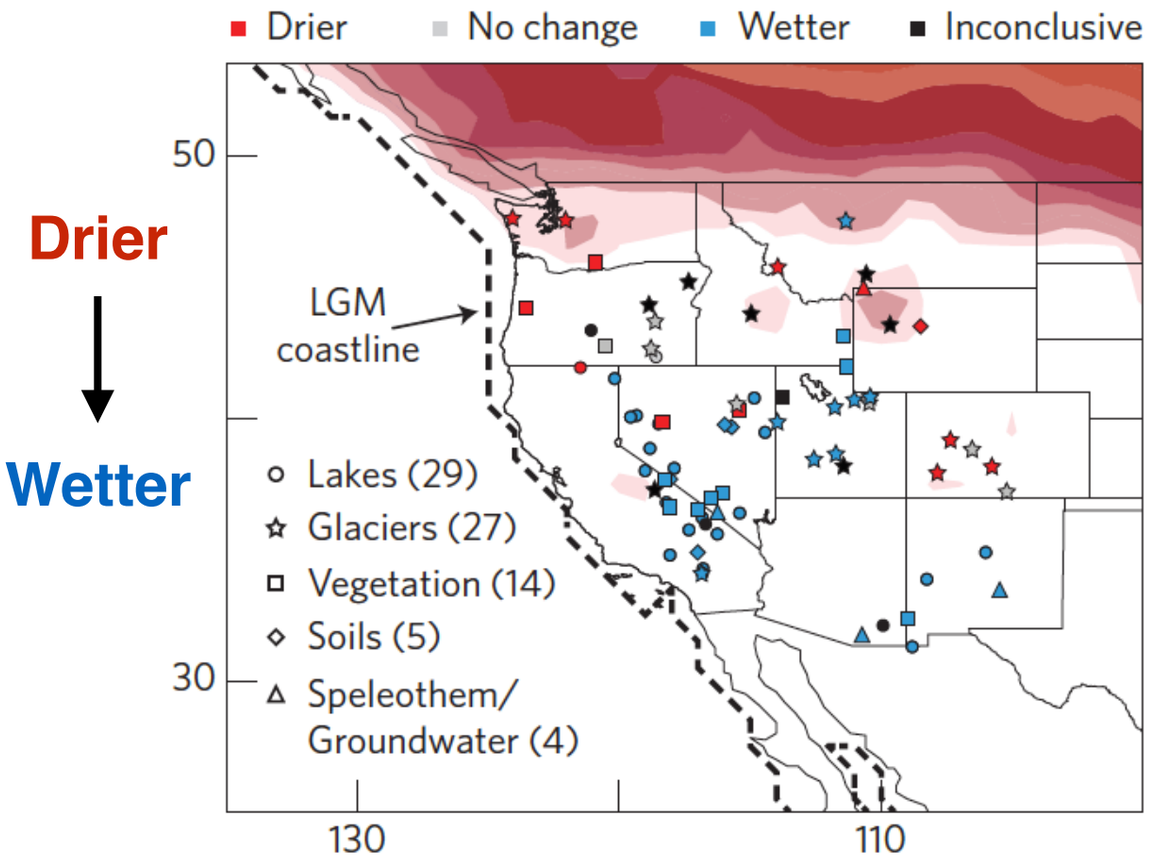
On the link between midlatitude wave guides, jet zonalisation, and equatorward shifted precipitation maximum at the Last Glacial Maximum

Marcus Lofverstrom
University of Arizona

PaleoWG winter meeting, NCAR, 2019

Data evidence of equatorward shifted precipitation at LGM

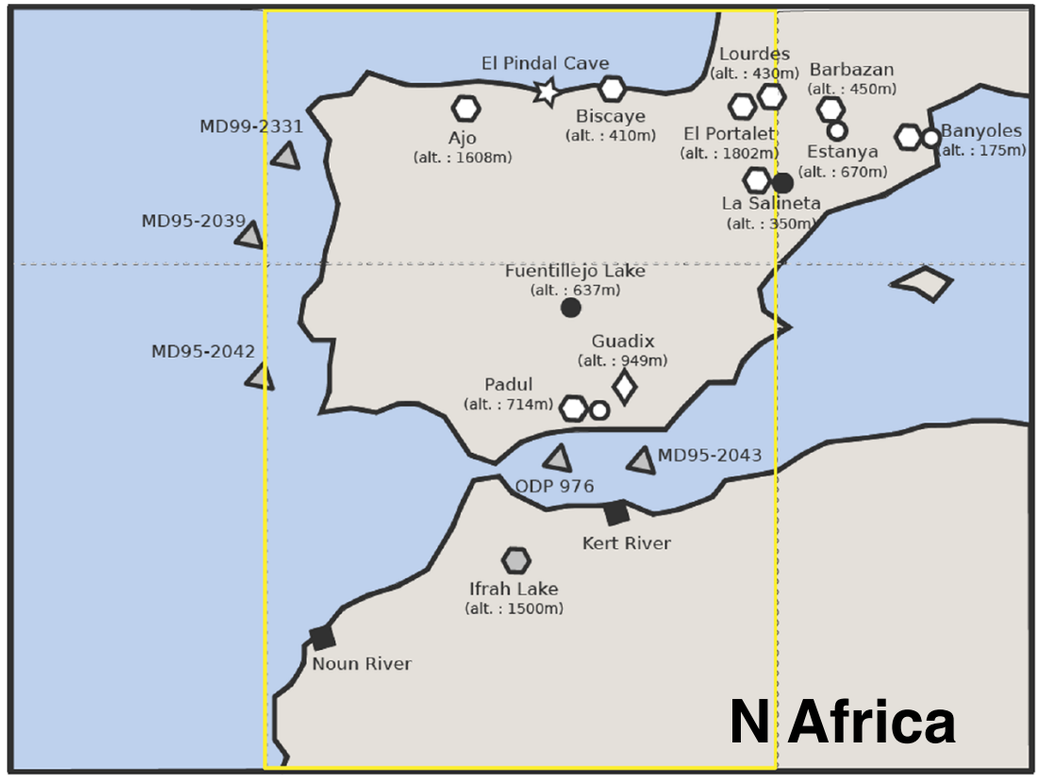
North America



Drier

Wetter

Iberia



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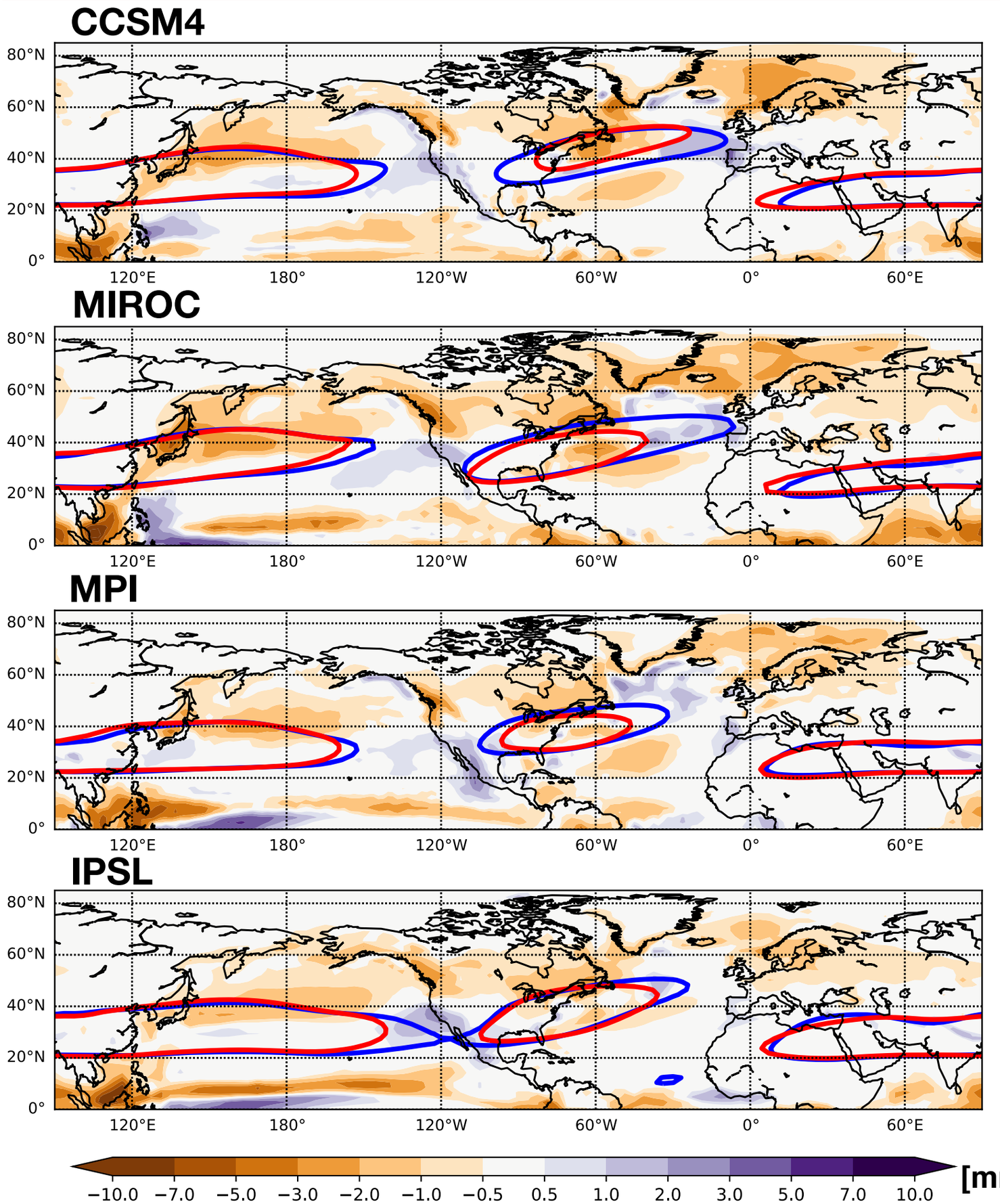
Oster et al. 2015

Beghin et al. 2015

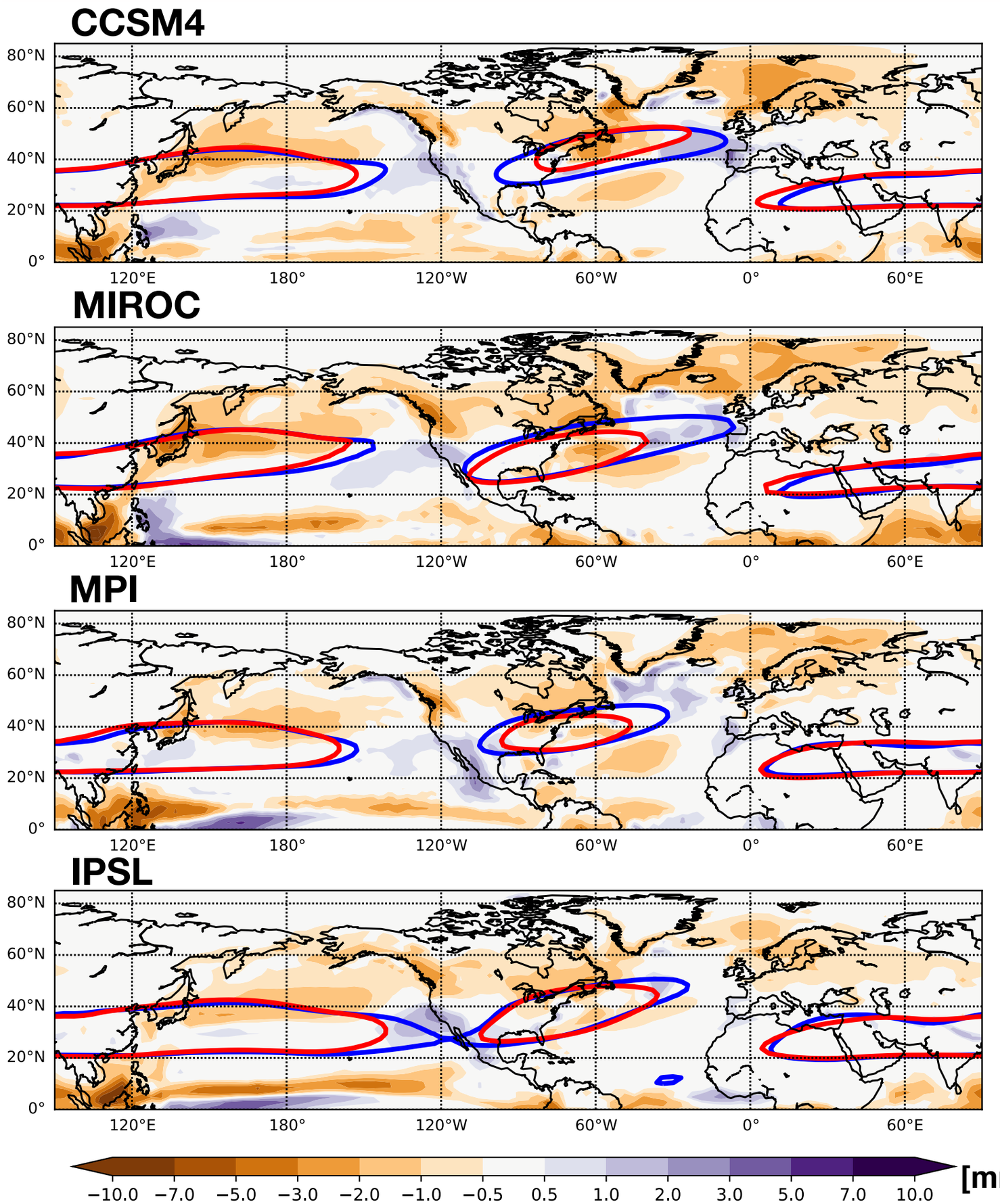
PMIP3 simulations — DJF climatologies



Lines:
250 hPa zonal wind
PI, **LGM**

Shading:
precipitation
LGM-PI

PMIP3 simulations — DJF climatologies



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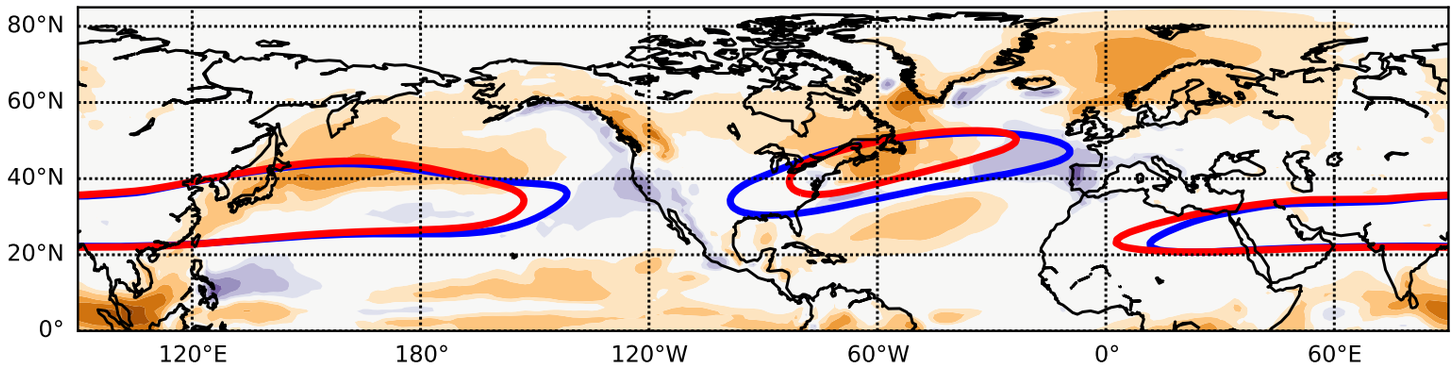
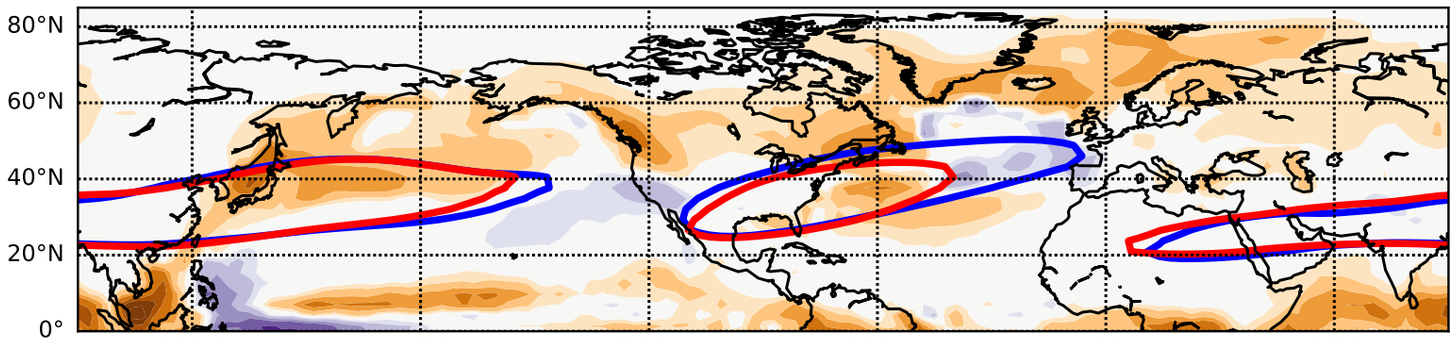
LGM jets:
- **Stronger than PI**
- **More zonal in some models**

PMIP3 simulations — DJF climatologies

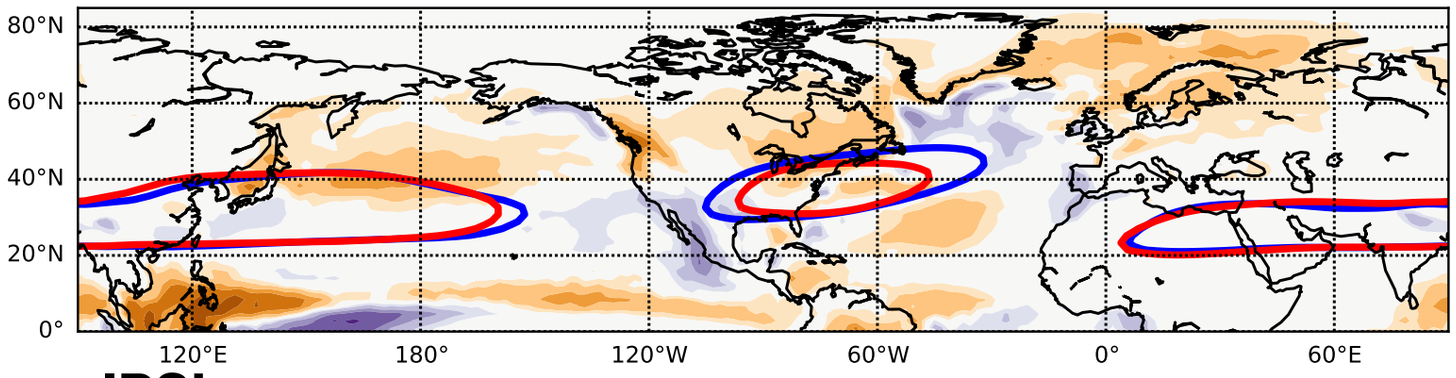
CCSM4



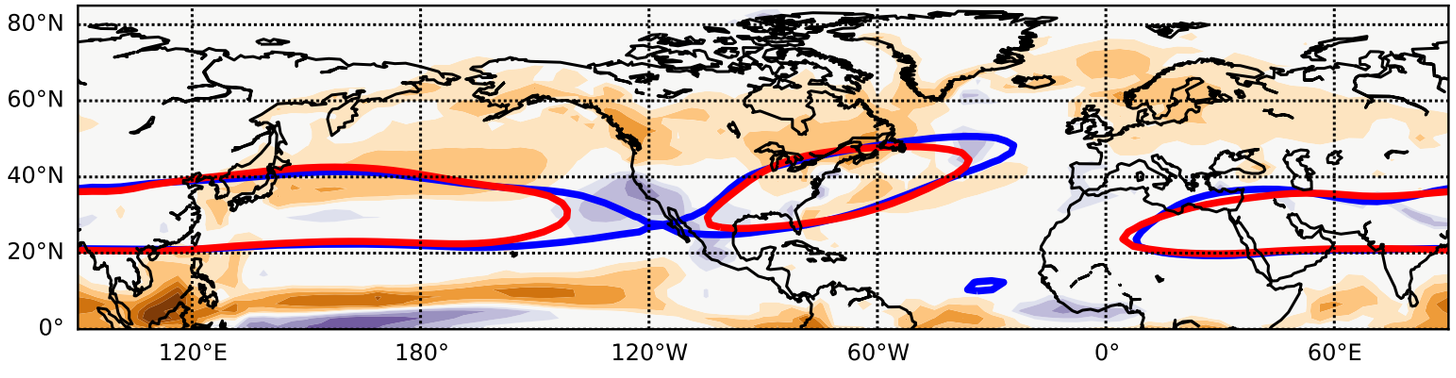
MIROC



MPI



IPSL



Drier ↓ Wetter

Lines:
250 hPa zonal wind
PI, LGM

Shading:
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LGM-PI

LGM jets:
- **Stronger than PI**
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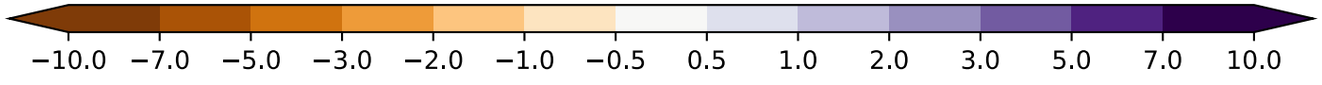
LGM precipitation:
- **Drier high latitudes**
- **SW US / Iberia wetter than PI**



Disclaimer: work in progress

Focus on the CCSM4 simulation from here on (Brady et al. 2013)

Broadly similar response in all models

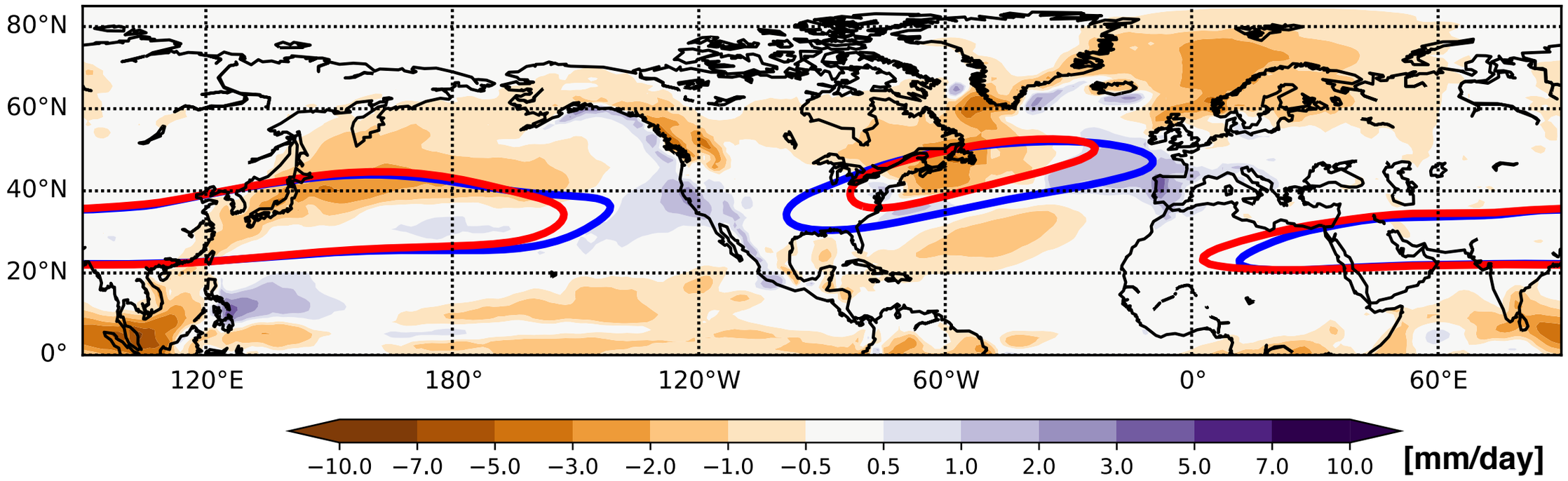
PMIP3 simulations vs. proxy data

100 yr climatologies

Shading:
precipitation
LGM-PI

Lines:
250 hPa zonal wind
PI, **LGM**

CCSM4



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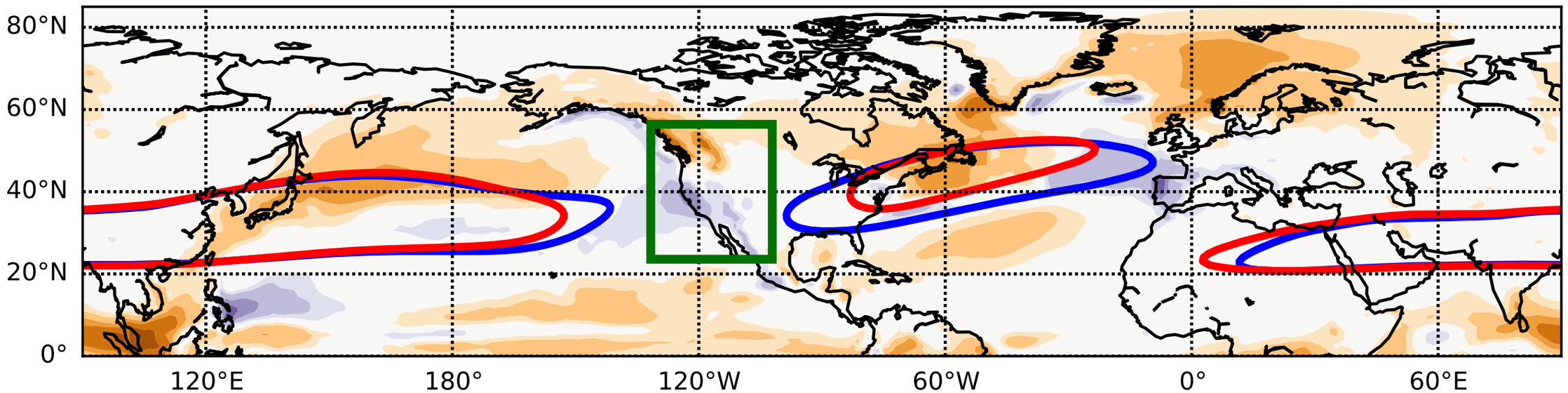
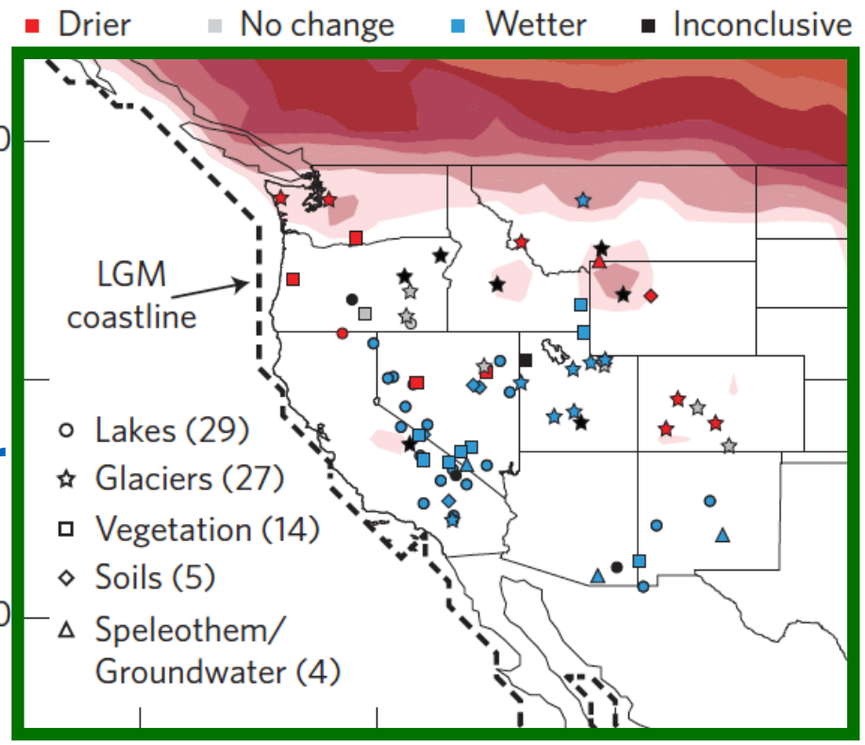


Drier ↓ **Wetter**

−10.0 −7.0 −5.0 −3.0 −2.0 −1.0 −0.5 0.5 1.0 2.0 3.0 5.0 7.0 10.0 **[mm/day]**



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Oster et al. 2015

Connection to atmospheric rivers?
Yup…

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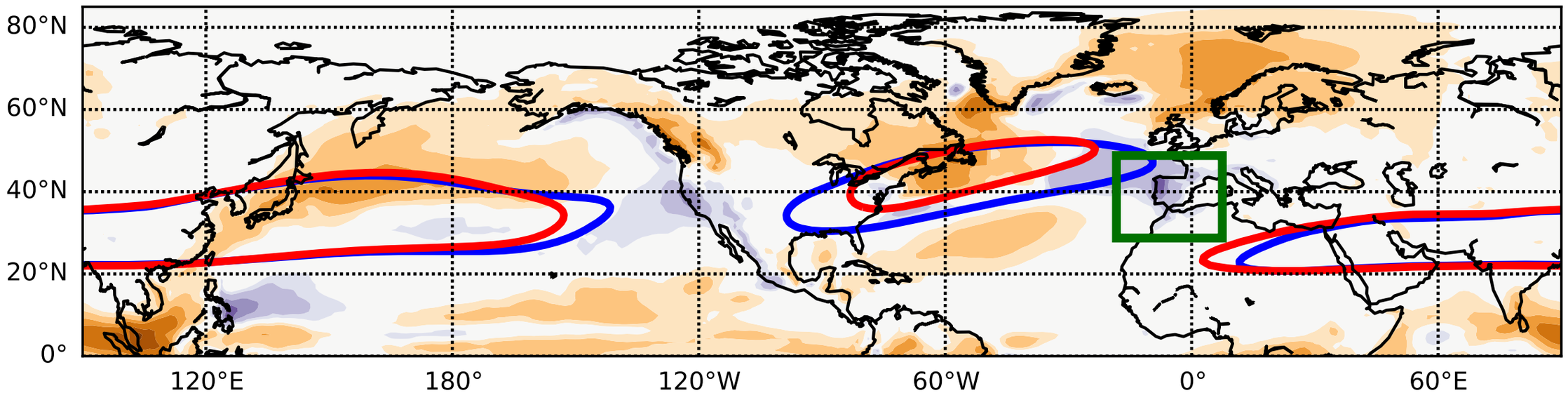

Drier

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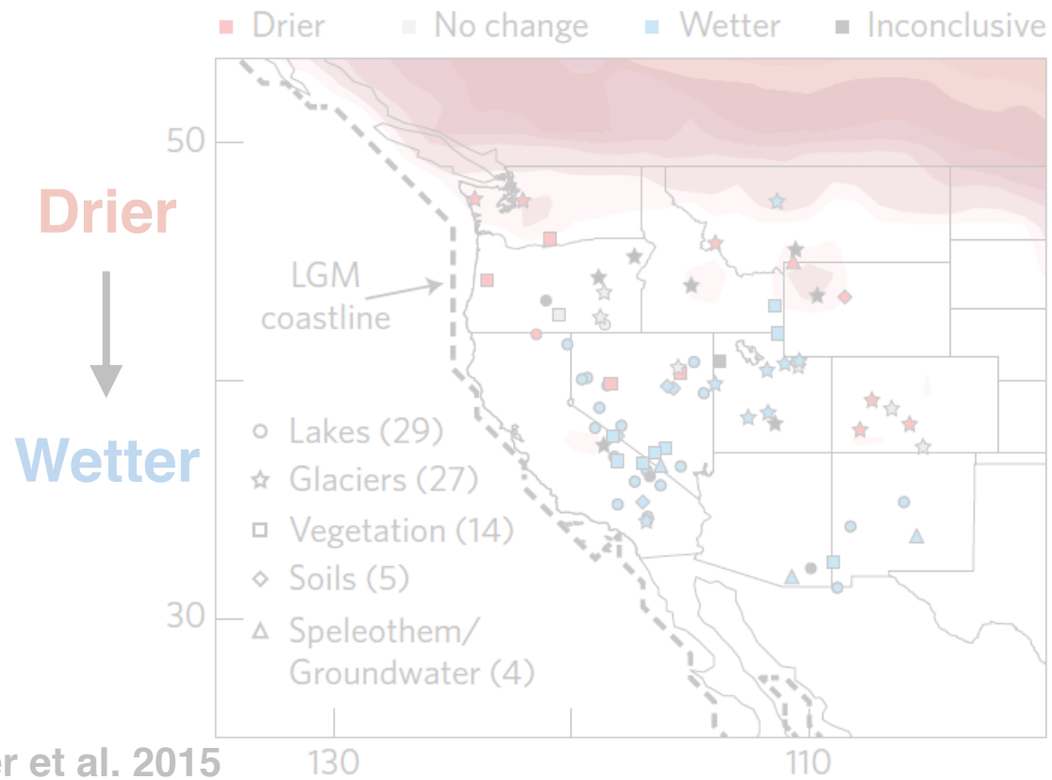
[mm/day]



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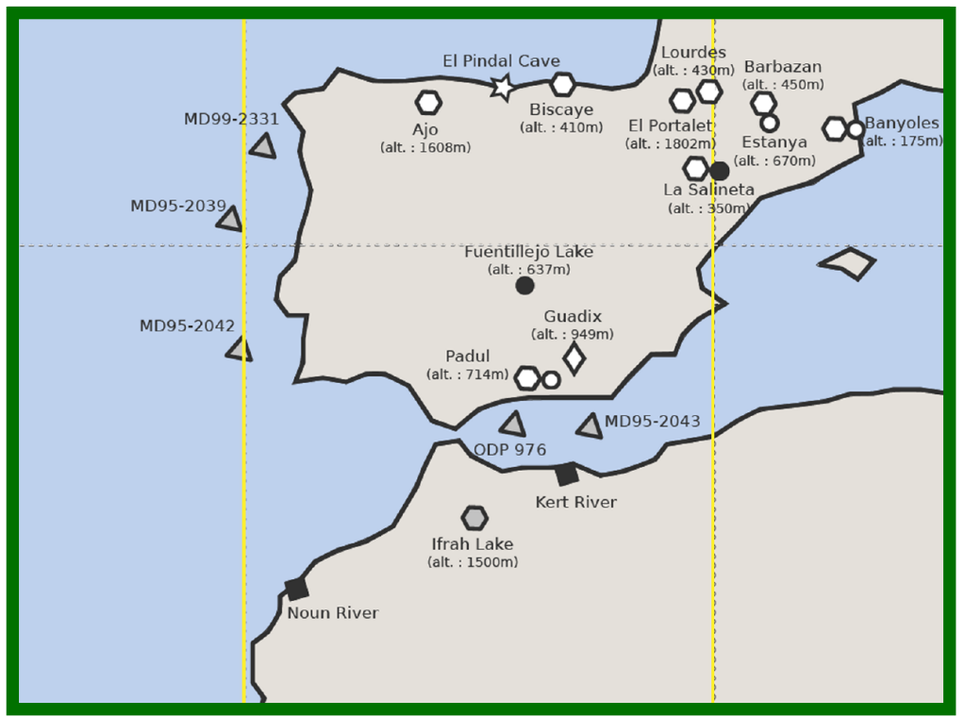

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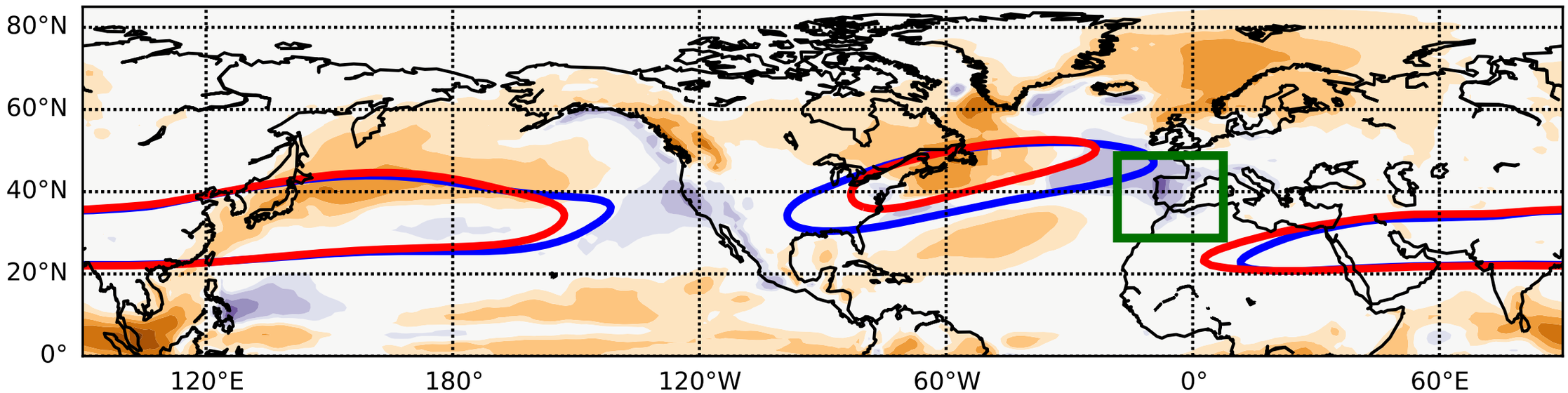

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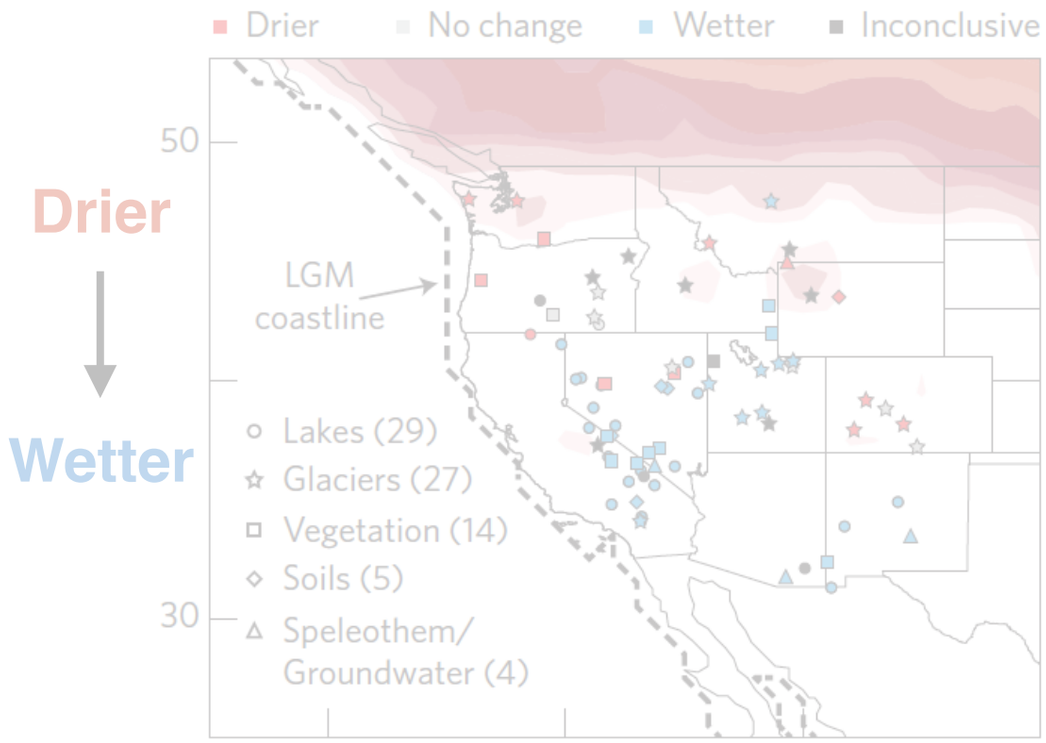

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CCSM4 climatology vs. EOF 1 of meridional wind

100 yr climatologies

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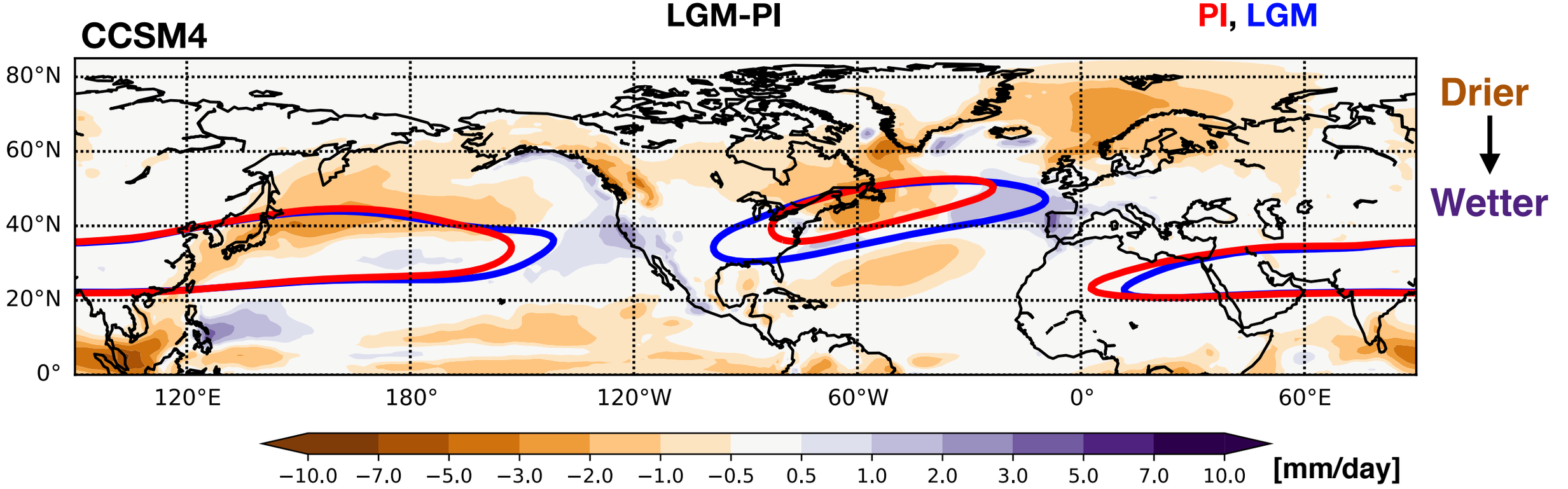

Question: Why are the precipitation maxima shifted at the LGM?

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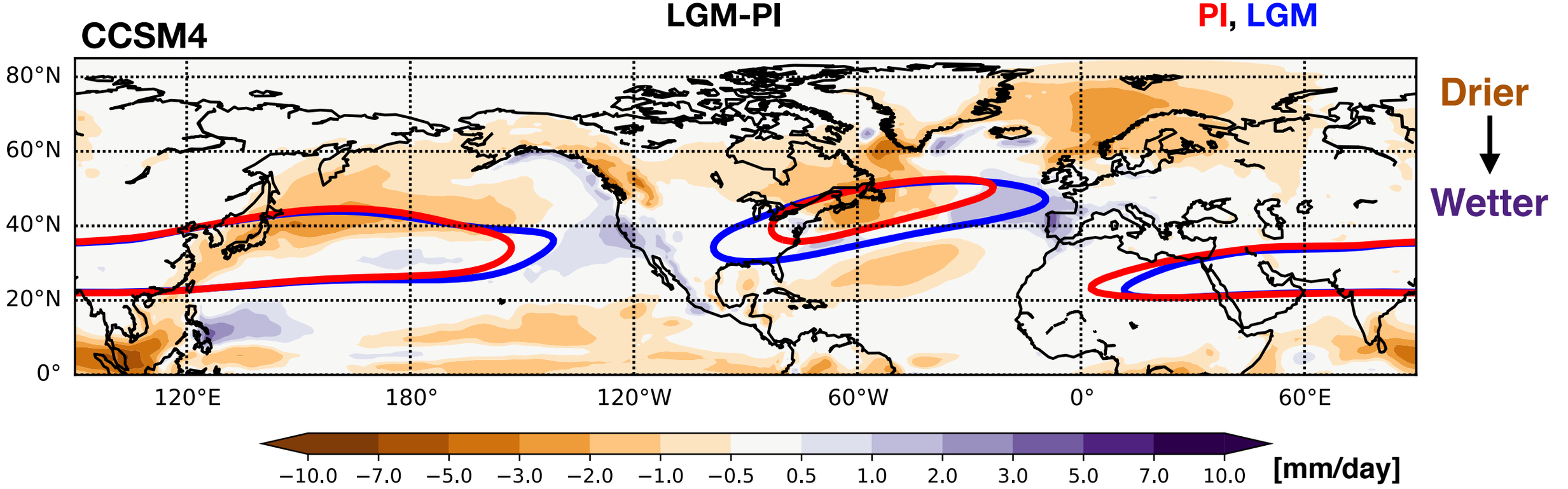


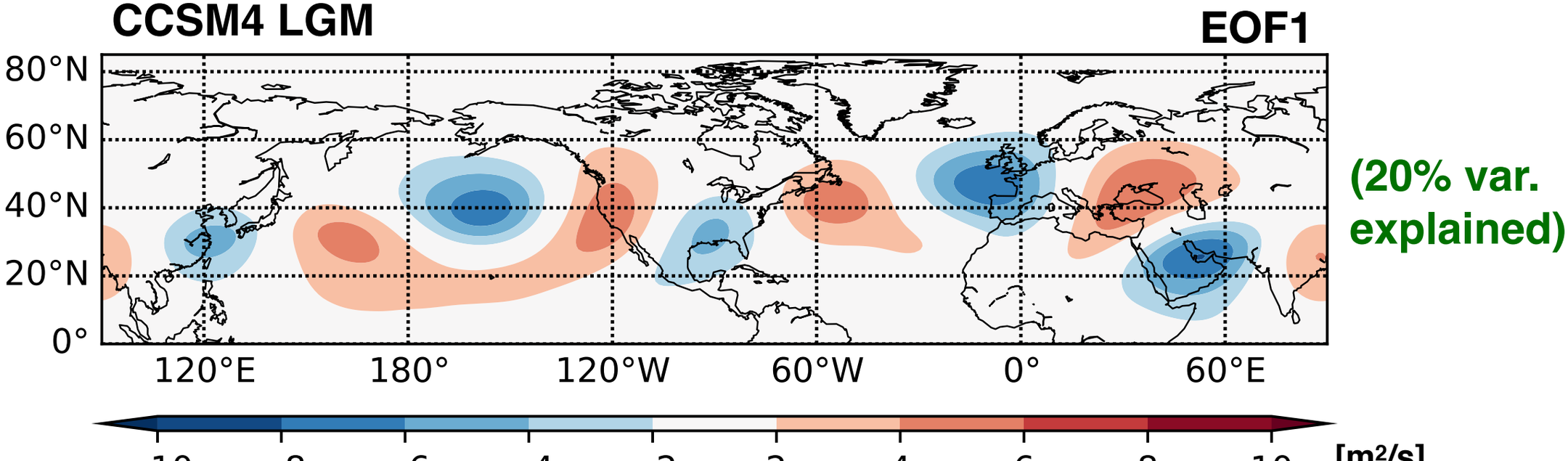
Question: Why are the precipitation maxima shifted at the LGM?

Realization:
Jet latitude is controlled by meridional wind

Analysis:
1: EOF analysis of meridional wind
2: Regression of fields onto EOF pattern

CCSM4 climatology vs. EOF 1 of meridional wind

Eddy streamfunction regressed onto EOF 1 of mer. wind



(20% var. explained)

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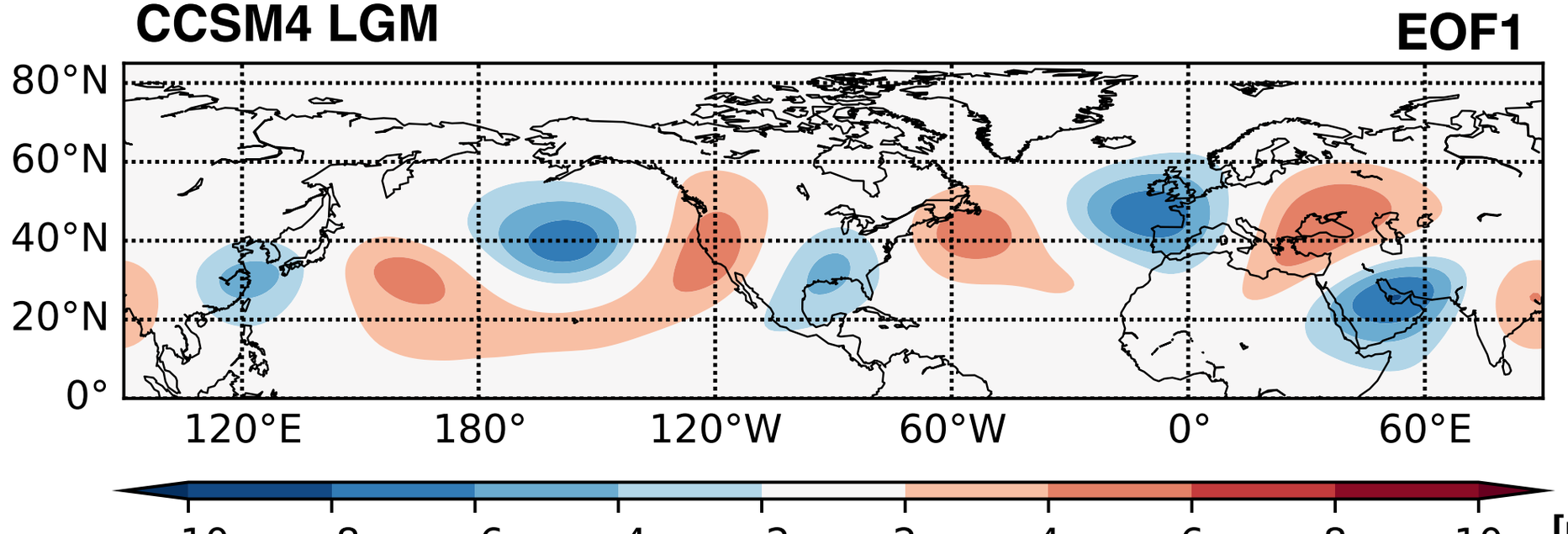

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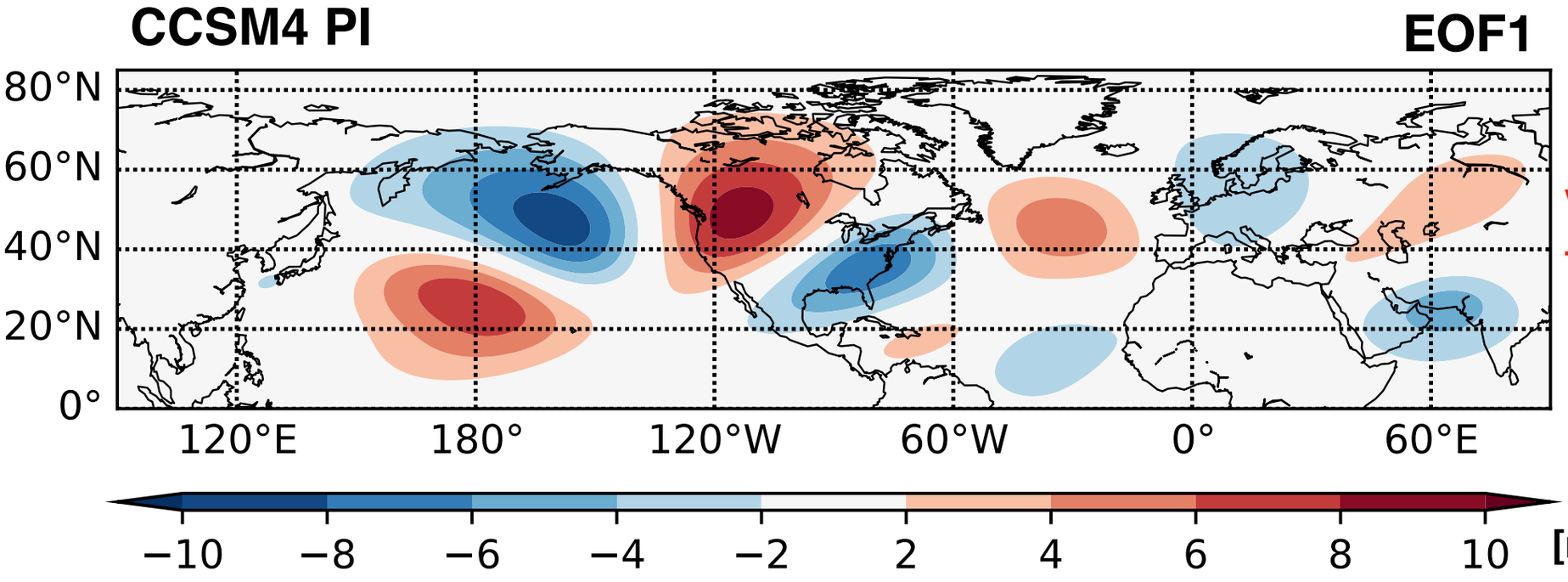
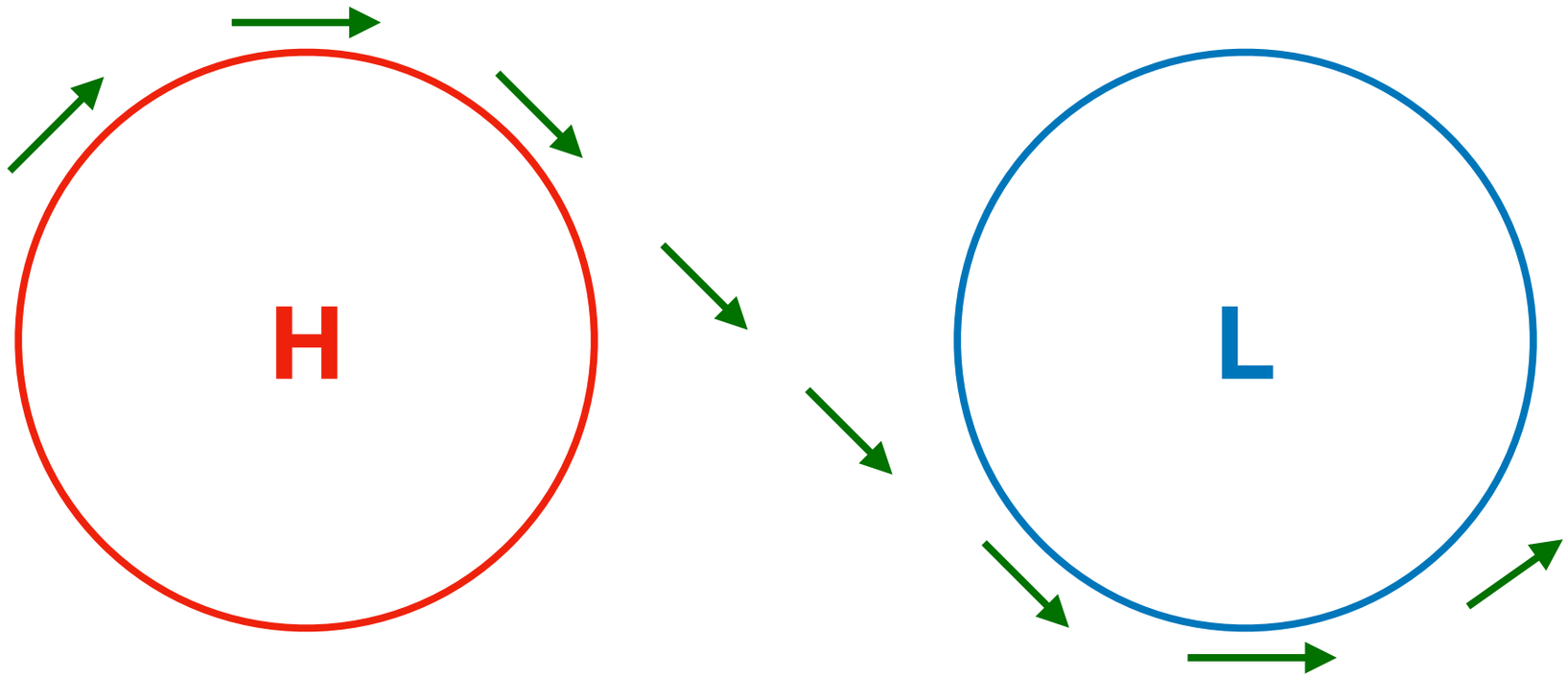


Very different from LGM case!

CCSM4 climatology vs. EOF 1 of meridional wind

What's the connection to the N Atlantic jet stream?

Wind around high- and low-pressure systems (Northern Hemisphere)



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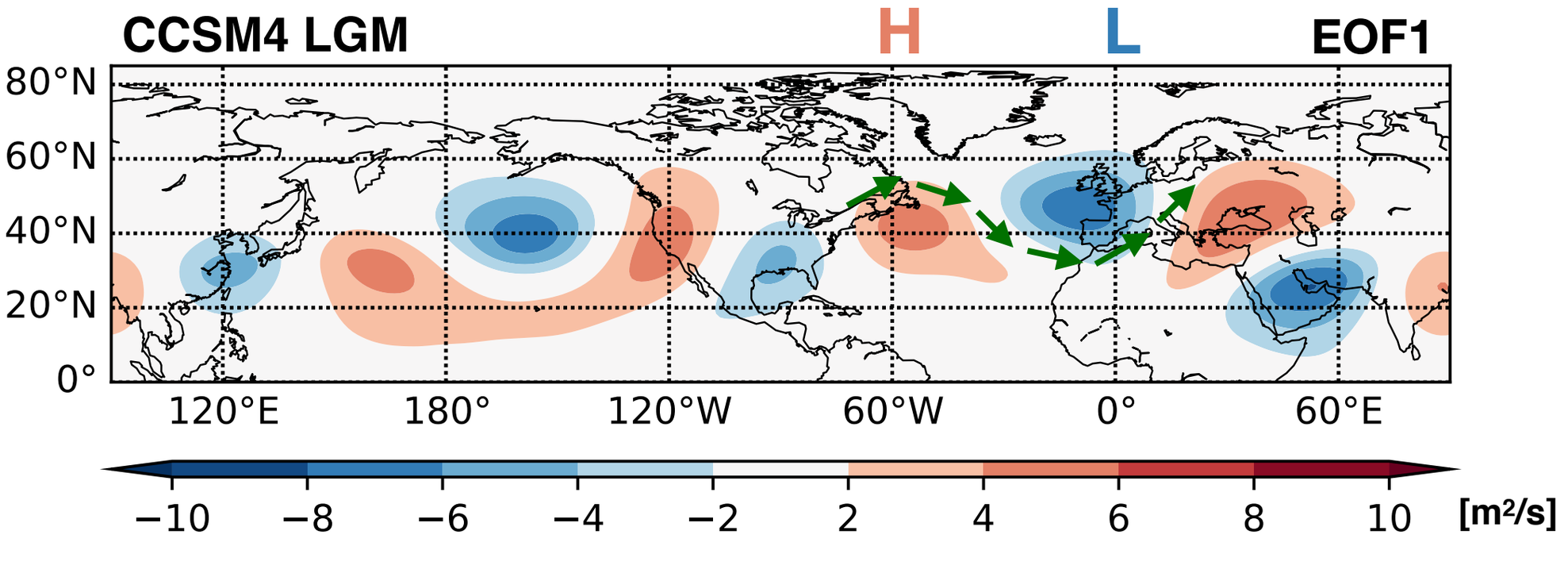
Eddy streamfunction regressed onto EOF 1 of mer. wind



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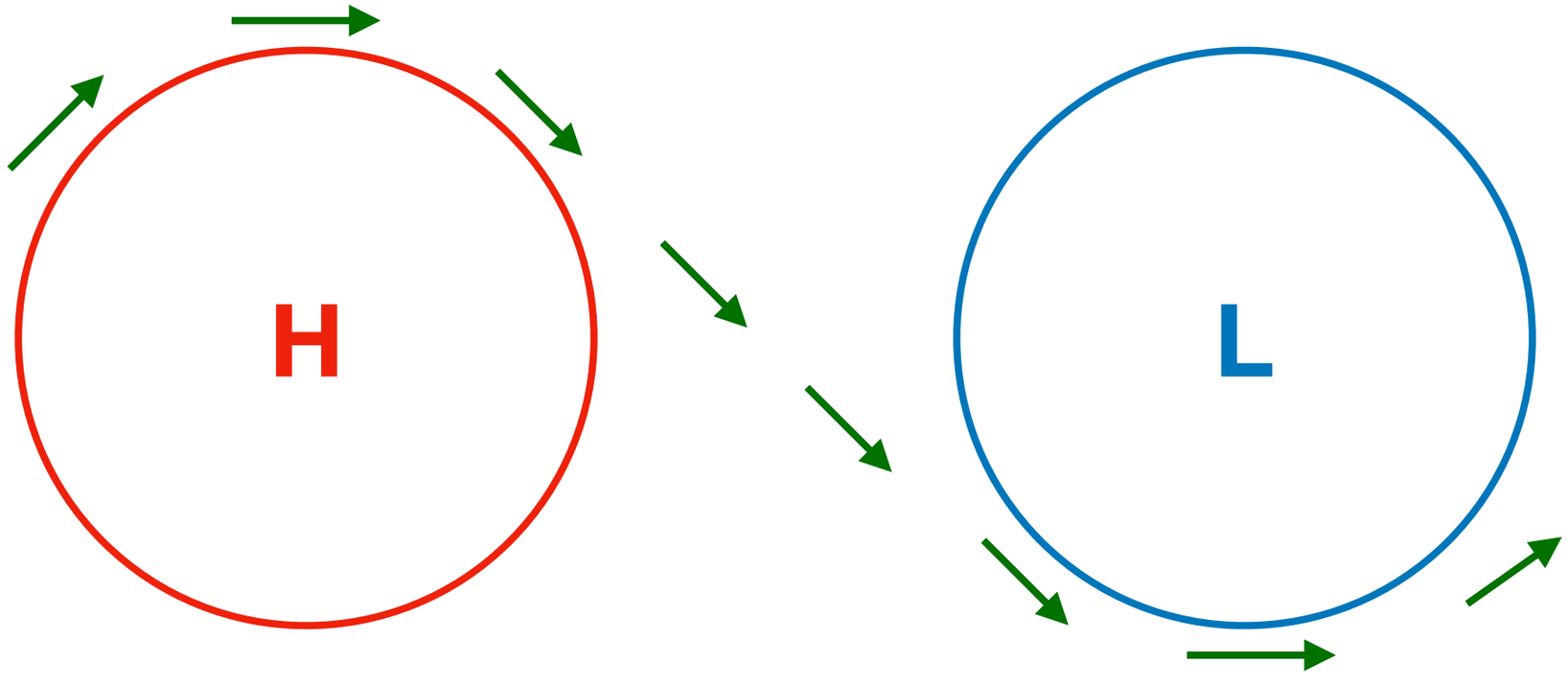
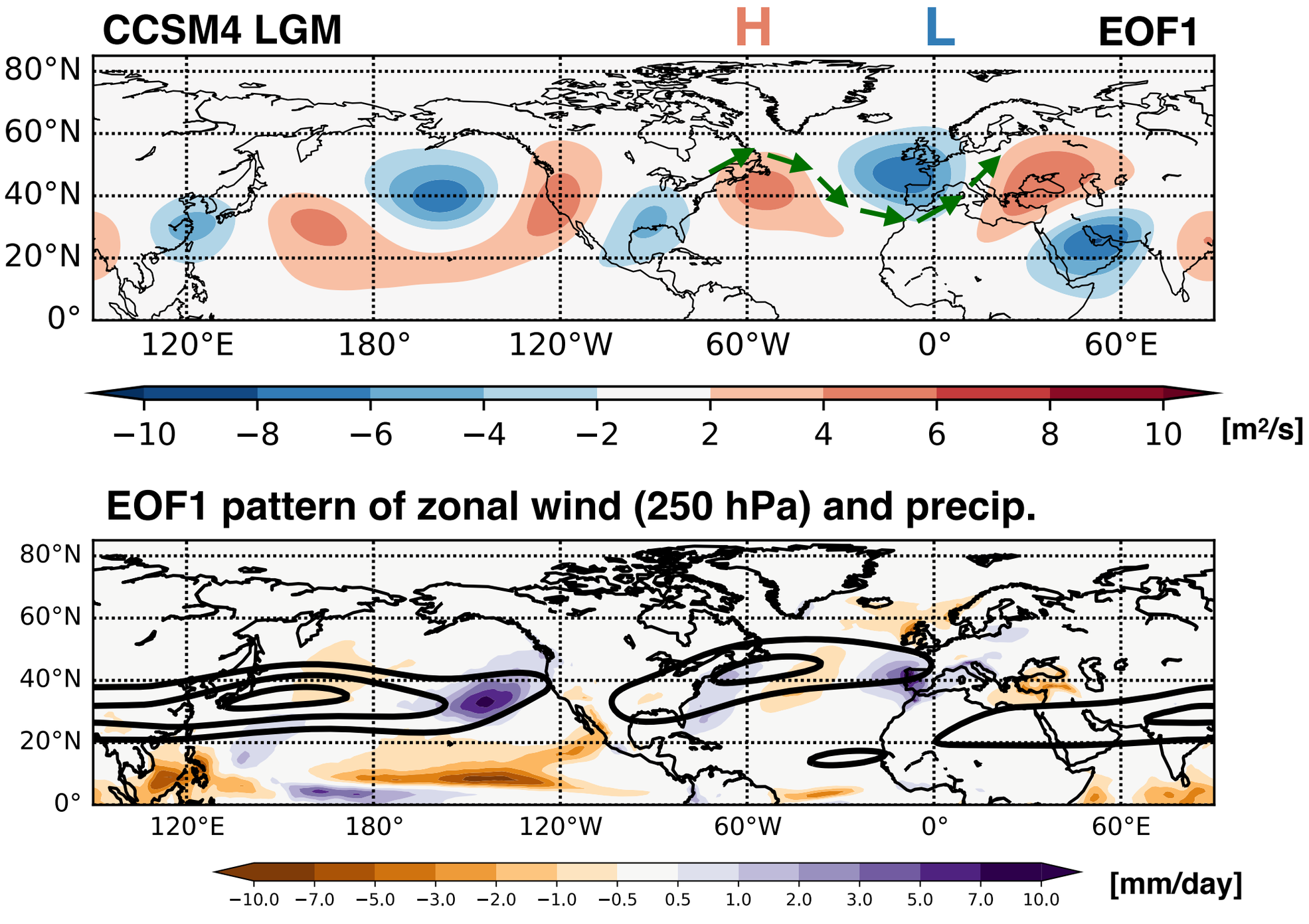


Quantifying LGM precipitation in Iberia

Eddy streamfunction regressed onto EOF 1 of mer. wind



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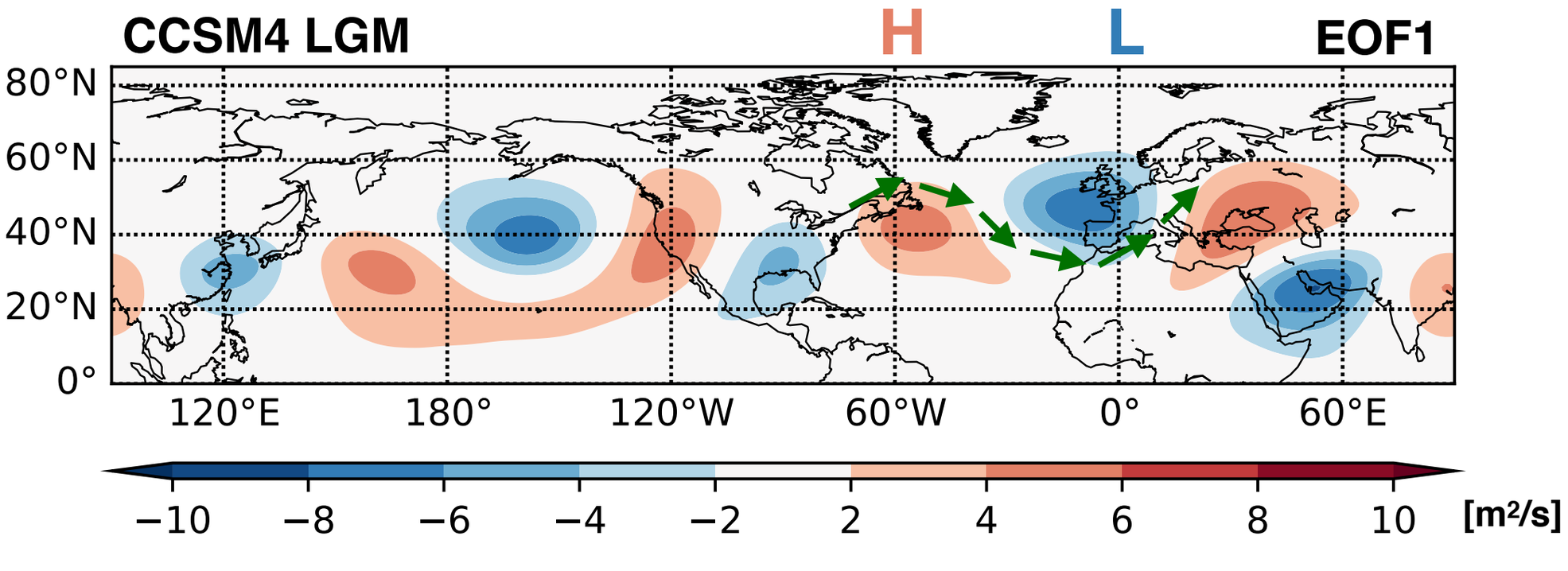
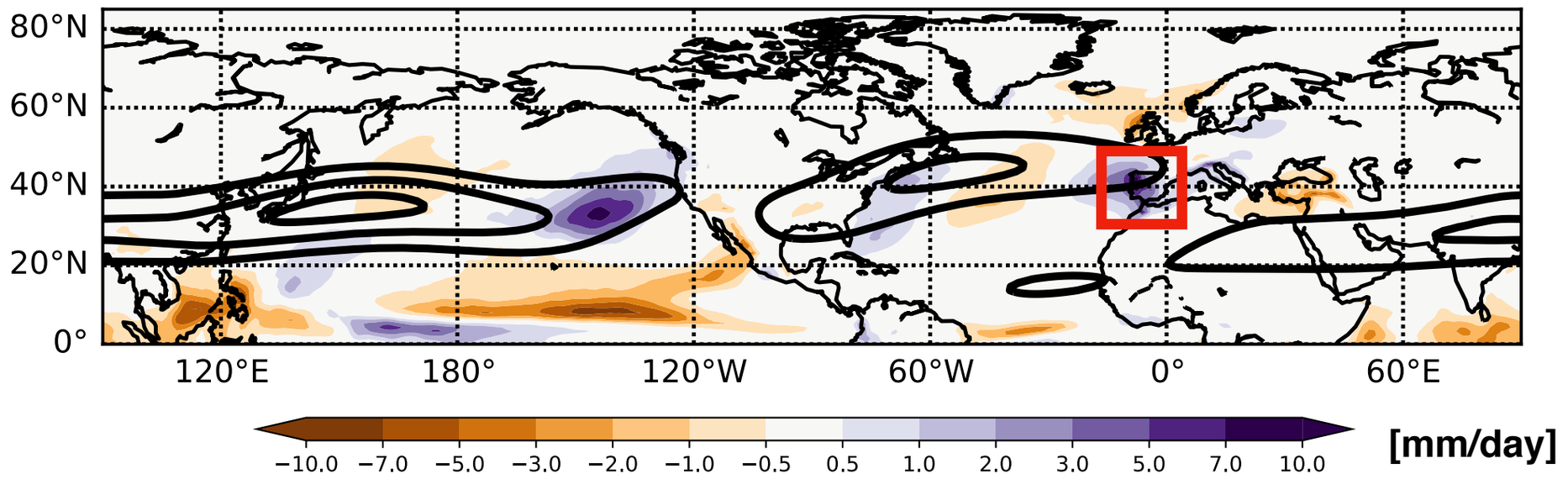


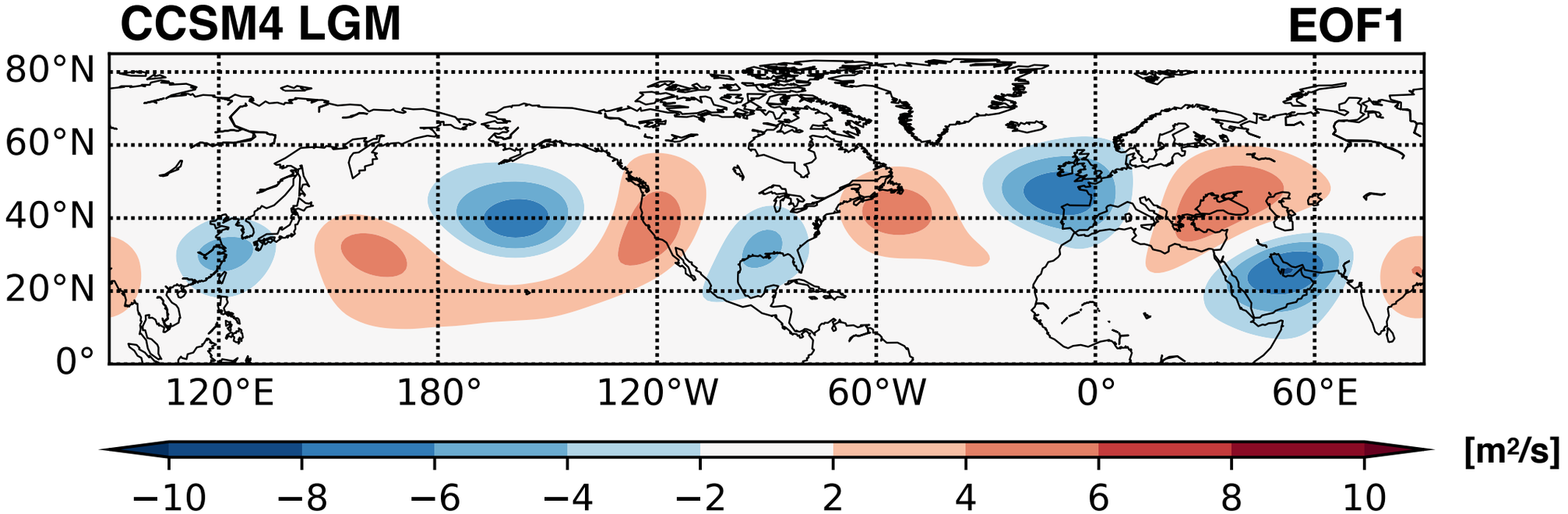
EOF1 pattern of zonal wind (250 hPa) and precip.



EOF 1 pattern accounts for 50-70% of total LGM winter precipitation in Iberia (derived from daily data)

Interpretation of LGM wave field

Eddy streamfunction regressed onto EOF 1 of mer. wind



Stationary wave number

$$K_s^2 \propto \frac{\beta - \partial_y \zeta}{U} = \frac{\beta_*}{U}$$

$$K_s^2 = K^2 \equiv k^2 + l^2$$

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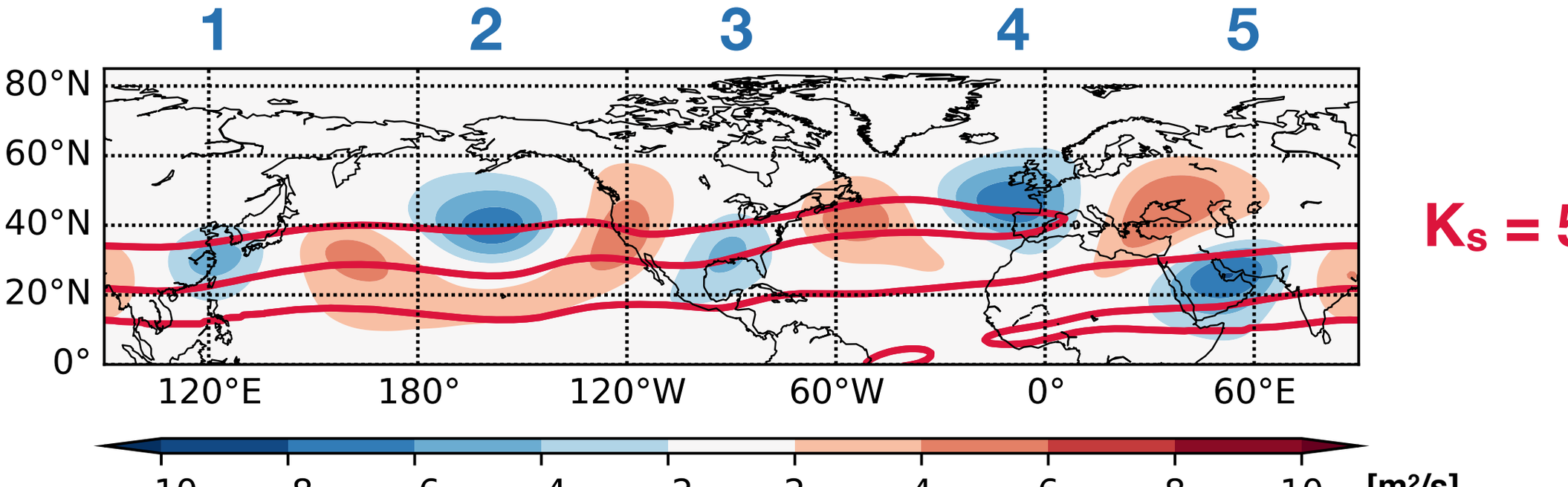

$K_s = 5$

Stationary wave number

$$K_s^2 \propto \frac{\beta - \partial_y \zeta}{U} = \frac{\beta_*}{U} \quad = 5$$

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Properties of wave field

$$\partial_y^2 \psi = \psi \left(K^2 - \beta_* / U\right)$$

$k < K_s$ **mer. propagation**

$k \geq K_s$ **mer. evanescence (wave guide)**

Conclusions

- Both proxy data and PMIP3 LGM simulations show comparatively wetter conditions in California and Iberia at the LGM (drier at higher latitudes)

- Leading EOF of mer. wind (LGM; ~20% var. explained) is a wave-number-5 wave-train in mid-latitudes (different from PI)

- Leading EOF is a zonal N Atlantic jet that brings precipitation to Iberia

- Leading EOF pattern accounts for 50-70% of total DJF precipitation in Iberia