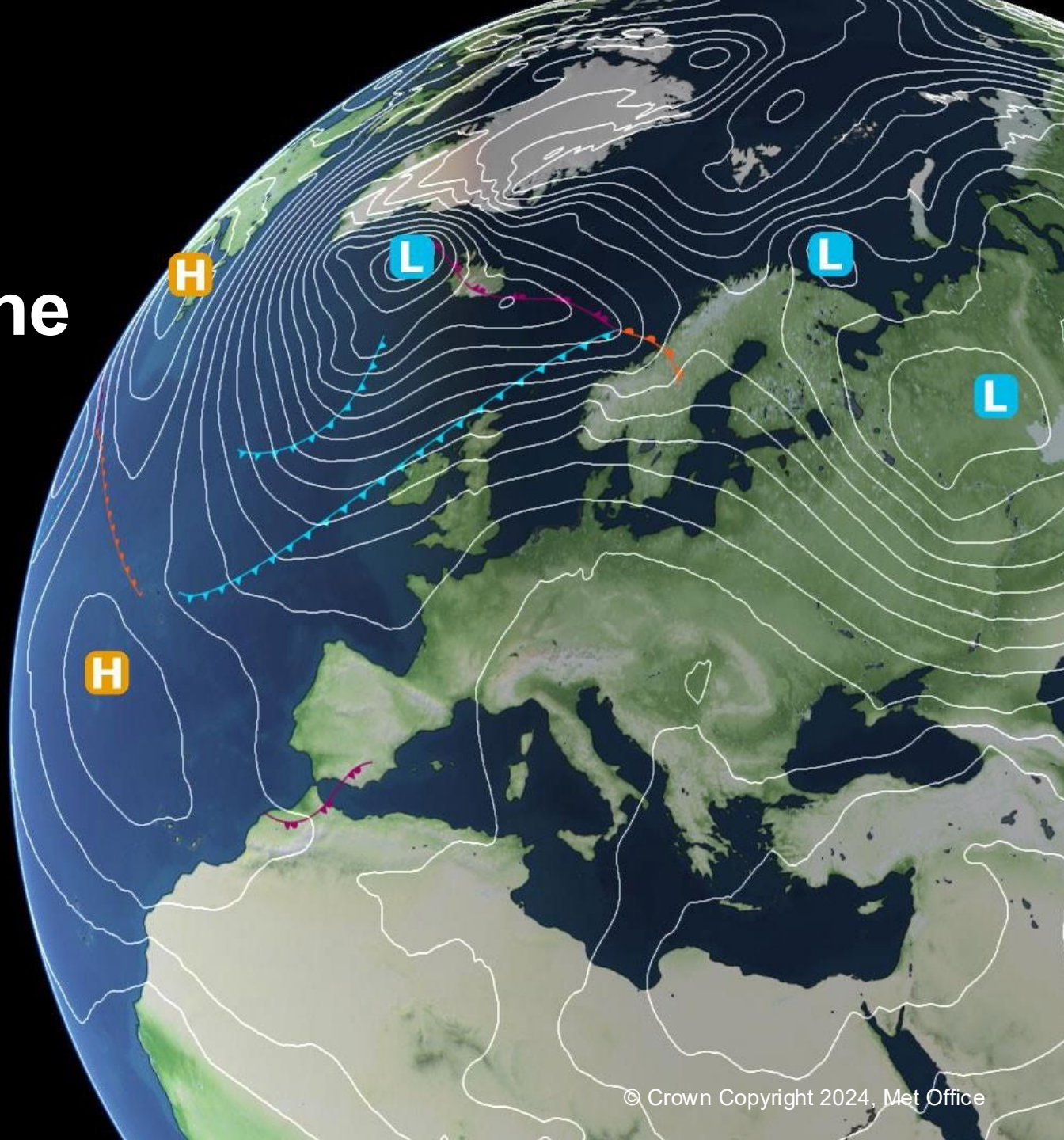
Met Office
Hadley Centre

Multidecadal Pacific Circulation Changes in the Large Ensemble Single Forcing Runs

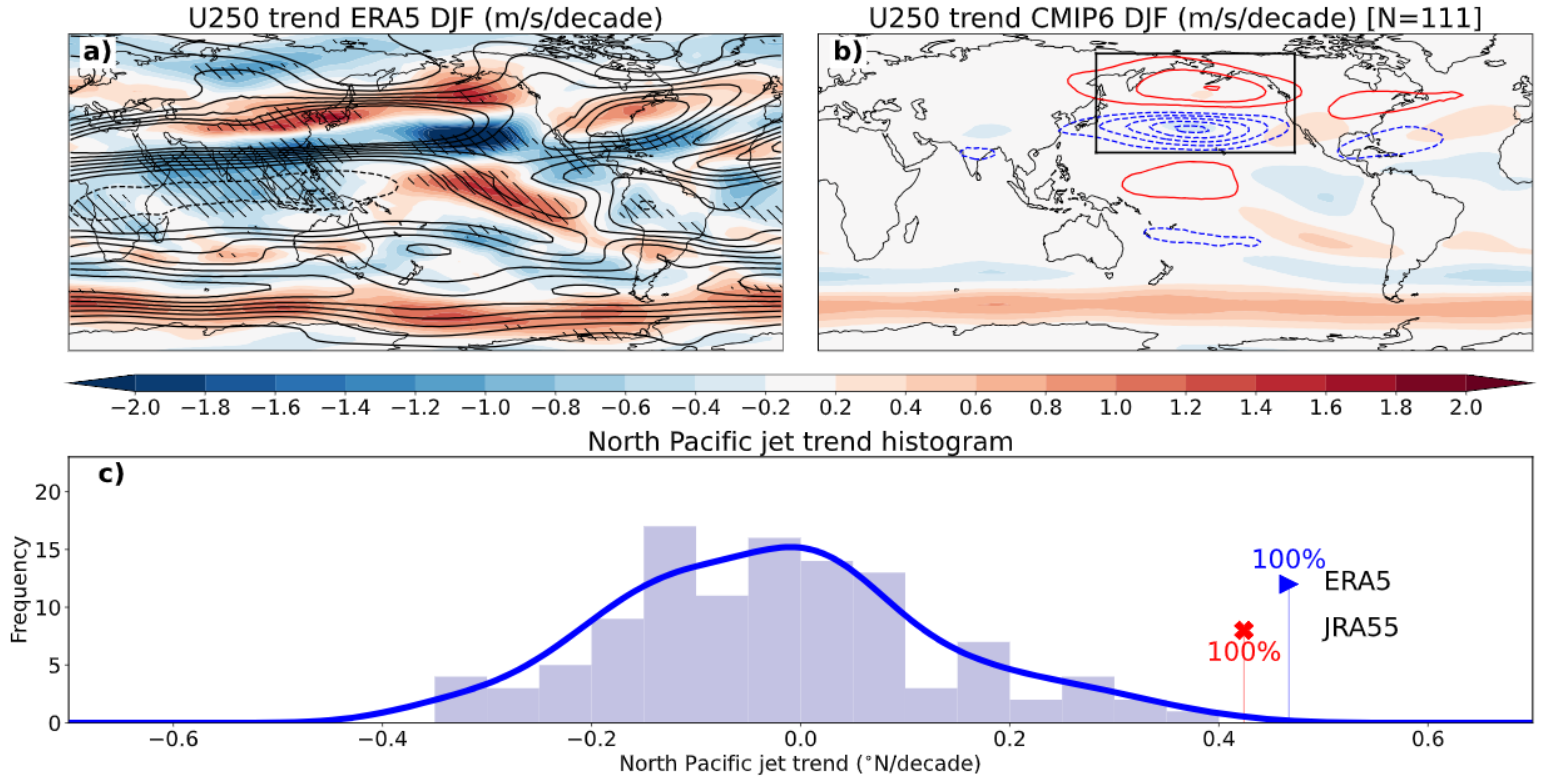
Melissa Seabrook, Doug Smith, Ted Shepherd, Buwen Dong, Nick Dunstone

Met Office/Reading University



Met Office
Hadley Centre

- Trends in Pacific Jet (1979–2023)
- CMIP6 range is outside of observations.
- Increasing number of examples (Blackport&Fyfe 2022, etc)
- Must be some error in model internal variability or forced response
- Focus on forced response by using large ensembles

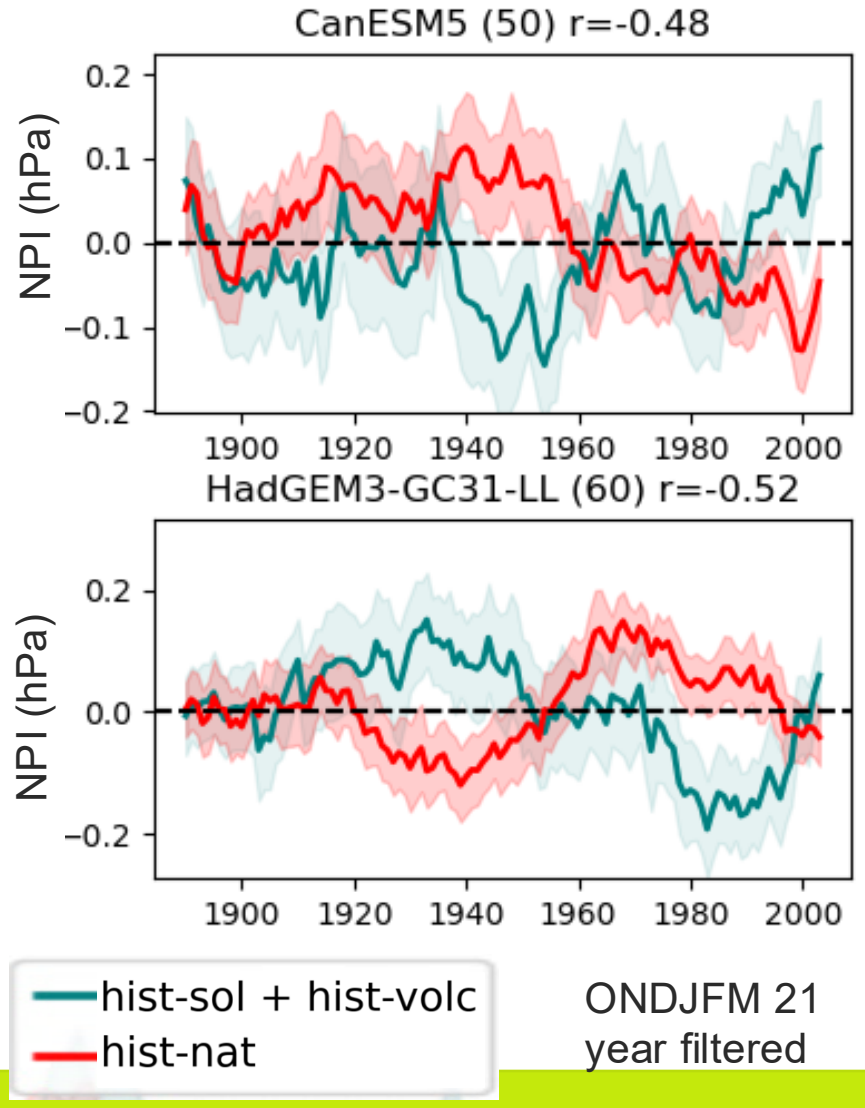


Patterson et al 2025

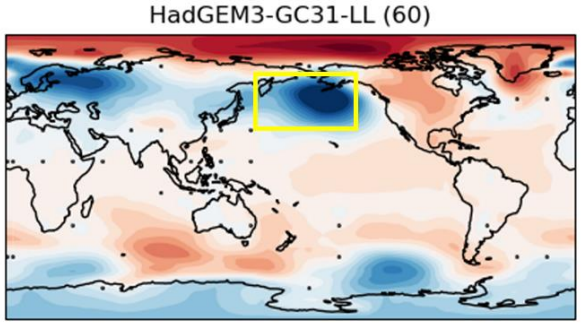
Large Ensemble Single Forcing (LESFMIP) experiments

- Hist-sol
- Hist-volc
- Hist-nat
- Hist-aer
- Hist-GHG
- Historical (all forcings)

Aleutian Low Variability (NPI) in natural forcing runs



ONDJFM 21 year filtered

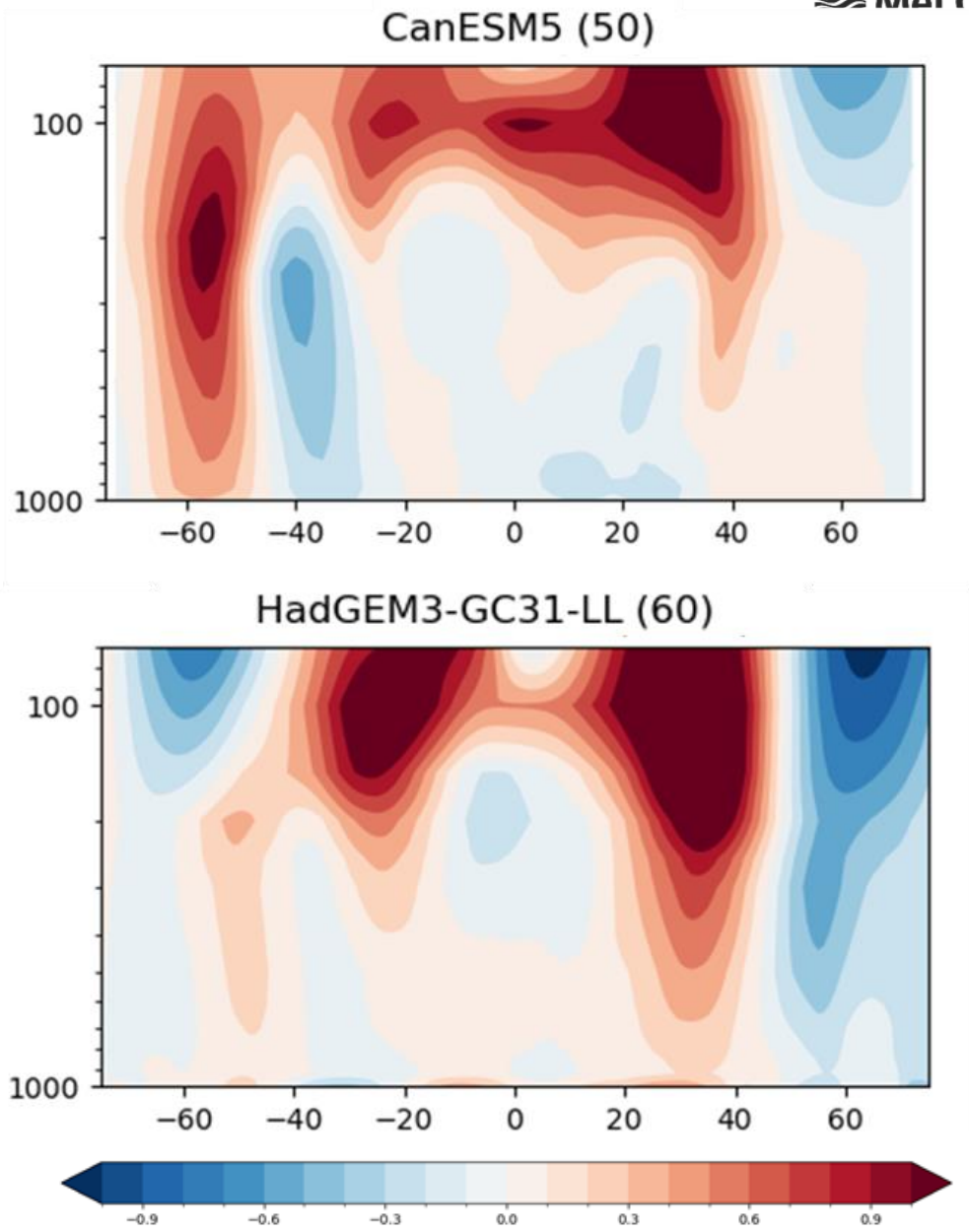


- Opposite responses!
- Solar and volcanoes don't add up to the natural forcing!
- Pacific Jet latitude and Aleutian Low are closely related
- Here focus on opposite model responses

Model Differences in the Aleutian Low/ Pacific Jet Response

- Regressions against Earth Energy Imbalance Index in the natural forcings experiments

- CanESM5 poleward shift
- HadGEM3 equatorward shift



Pacific mean zonal wind (m/s)

Multiple Linear Regression on Pacific Jet

hist-volc	r^2 (EEI index, SPV, surface pole temp, 200hPa equatorial temp, 100hPa WV)
CANESM5	0.33
HadGEM3-GC31-LL	0.43
MIROC6	0.31
MPI-ESM1-2-LR	0.34

21 year means

- Used Multiple Linear Regression to predict Pacific Jet Latitude

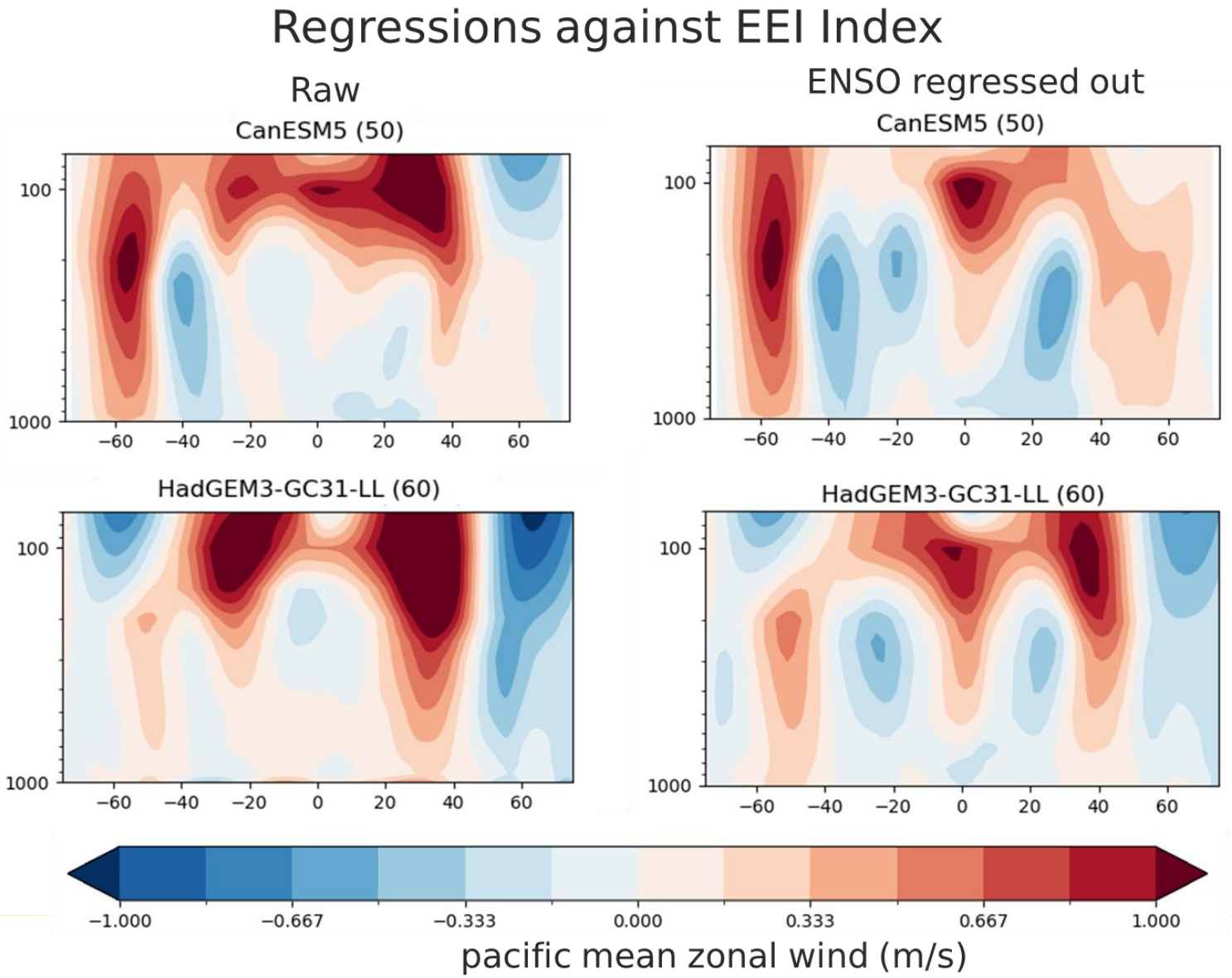
Multiple Linear Regression on Pacific Jet

hist-volc	r^2 (EEI index, SPV, surface pole temp, 200hPa equatorial temp, 100hPa WV)	r^2 (EEI index, SPV, surface pole temp, 200hPa equatorial temp, 100hPa WV, **NINO3.4**)
CANESM5	0.33	0.88
HadGEM3-GC31-LL	0.43	0.93
MIROC6	0.31	0.74
MPI-ESM1-2-LR	0.34	0.77

21 year means

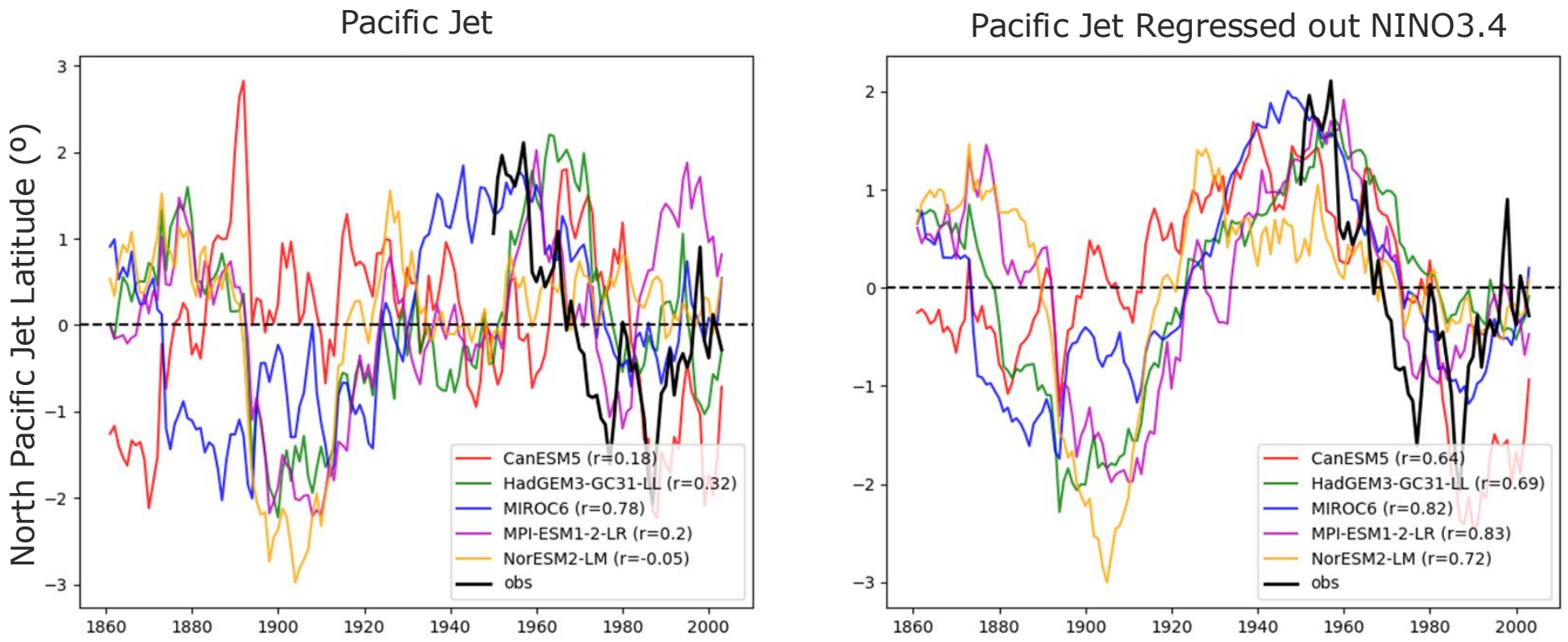
- Used Multiple Linear Regression to predict Pacific Jet Latitude
- Much more variance explained when NINO3.4 is included

Regressing out ENSO Variability (hist-nat)



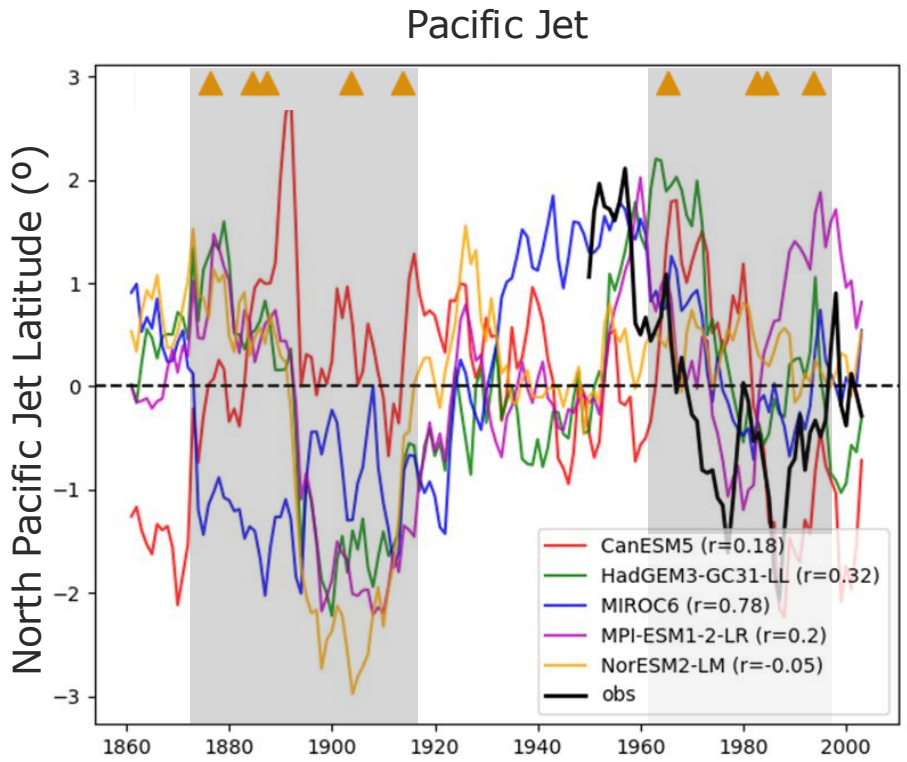
- Regress out interannual NINO3.4 from each ensemble member (unpredictable noise)
- Models now similar

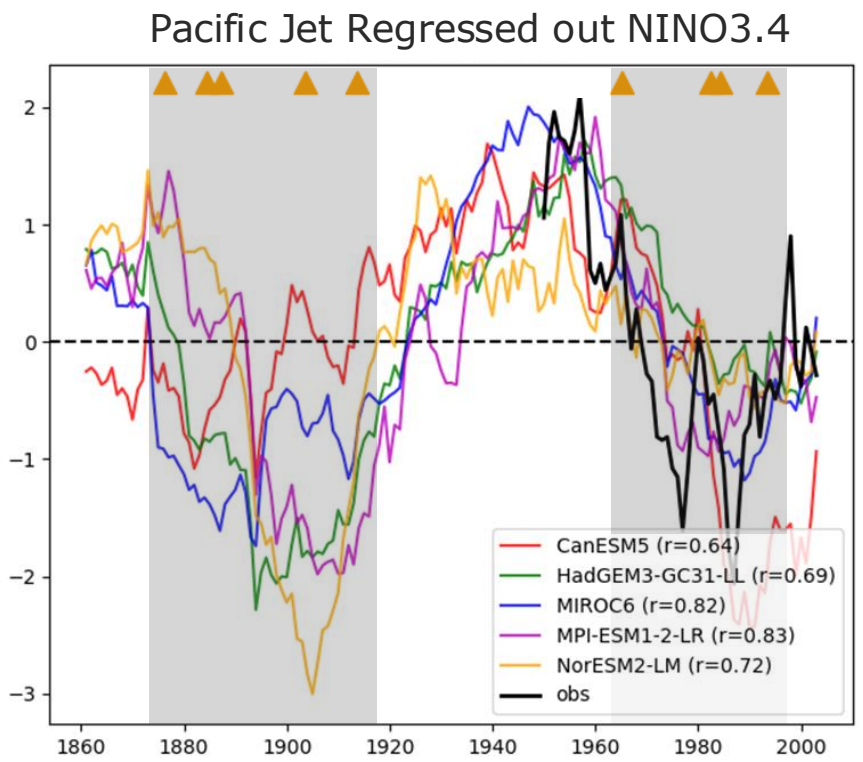
hist-nat Pacific Jet Regressed ENSO



- **Before regressing out ENSO**: Large model spread
- **After regressing out ENSO**: More model agreement

hist-nat Pacific Jet Regressed ENSO

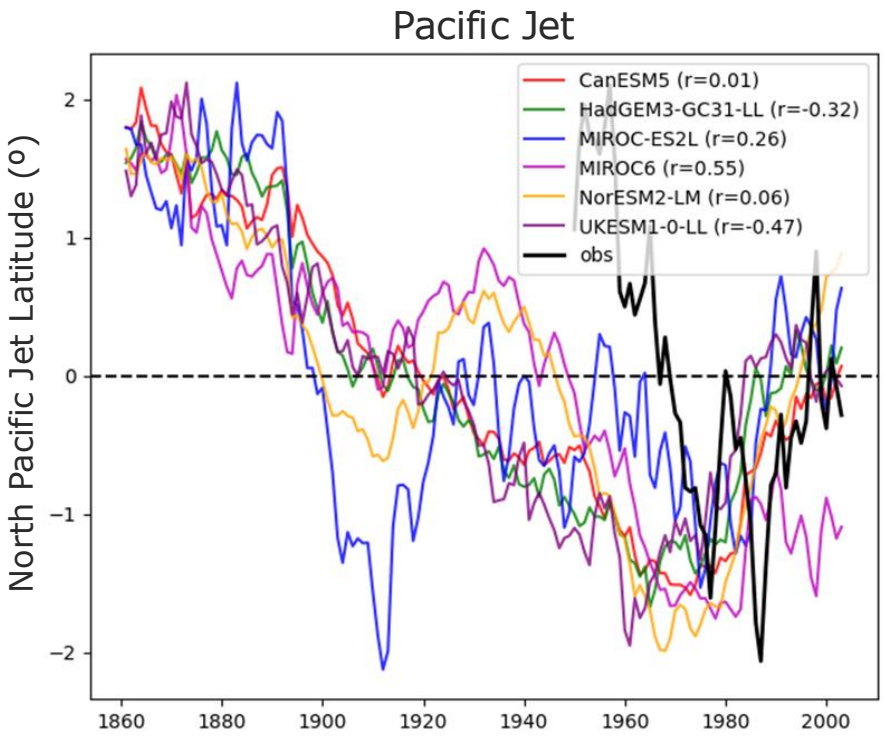


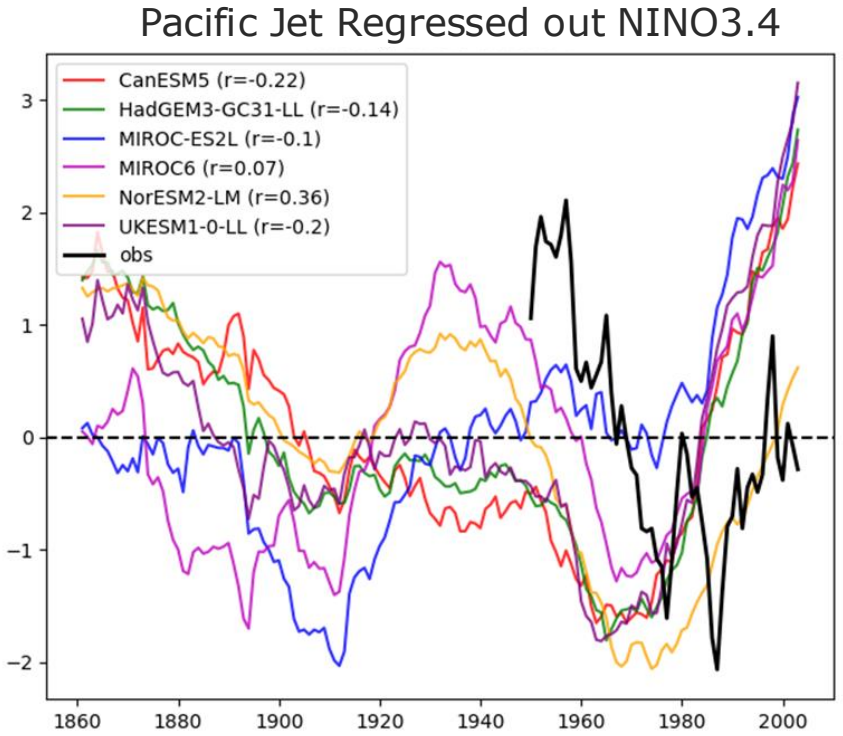


- **Before regressing out ENSO**: Large model spread
- **After regressing out ENSO**: More model agreement
- Volcanically forced signal, agreement with observations

Historical Pacific Jet Regressed ENSO

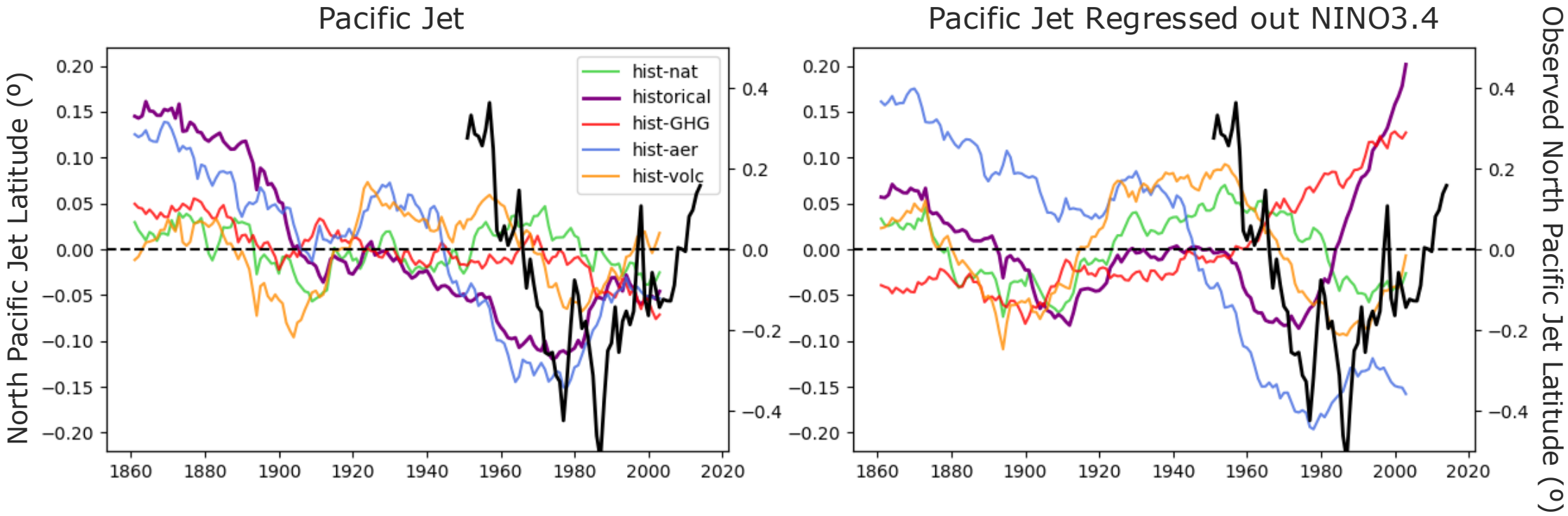
historical





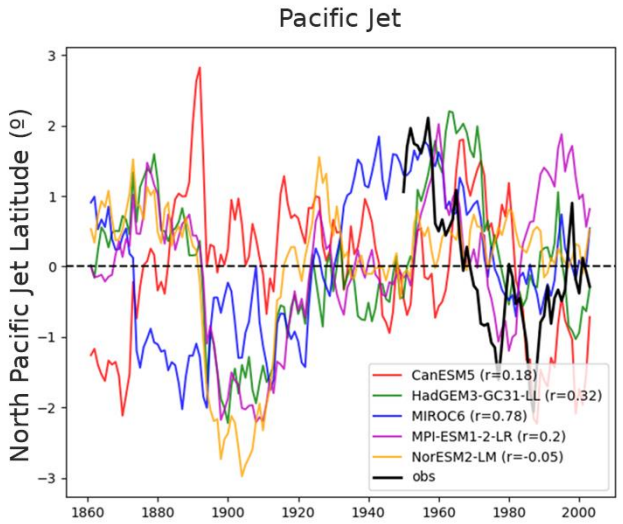
- Not as clear for historical
- Regressing out ENSO produces large increase after 1980, not seen in observations

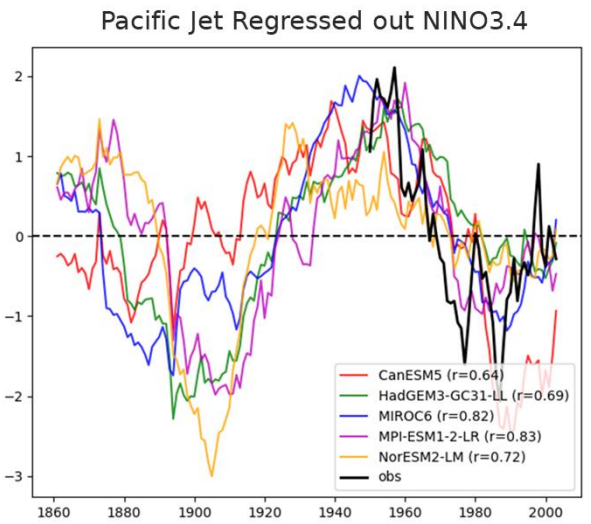
Regressing ENSO in all single forcings



- Clearly see the hist-nat response is being driven by volcanoes
- Uptick in historical is not evident in either aerosol or GHG

Summary



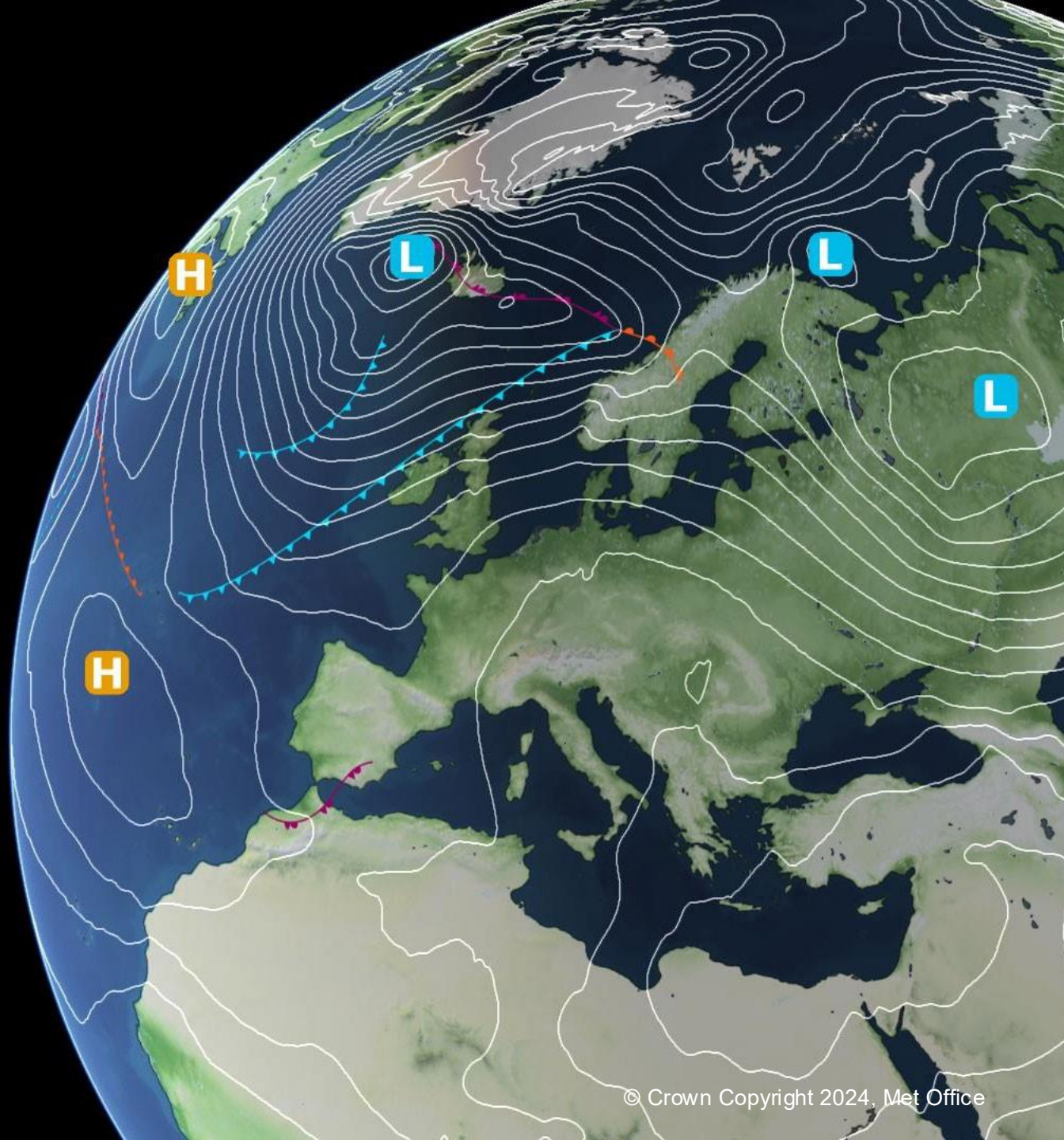


- Models can have **opposite** responses to the same forcings!
- Aim is to understand differences and correct for them
- Regressing out ENSO from hist-nat makes the models agree
- This reveals a volcanically forced signal in agreement with observations
- Uncertainty in the equatorial pacific is important in the model jet response but perhaps not in the real world
- It is an ongoing puzzle why this approach does not work in the historical (all forcings) simulations

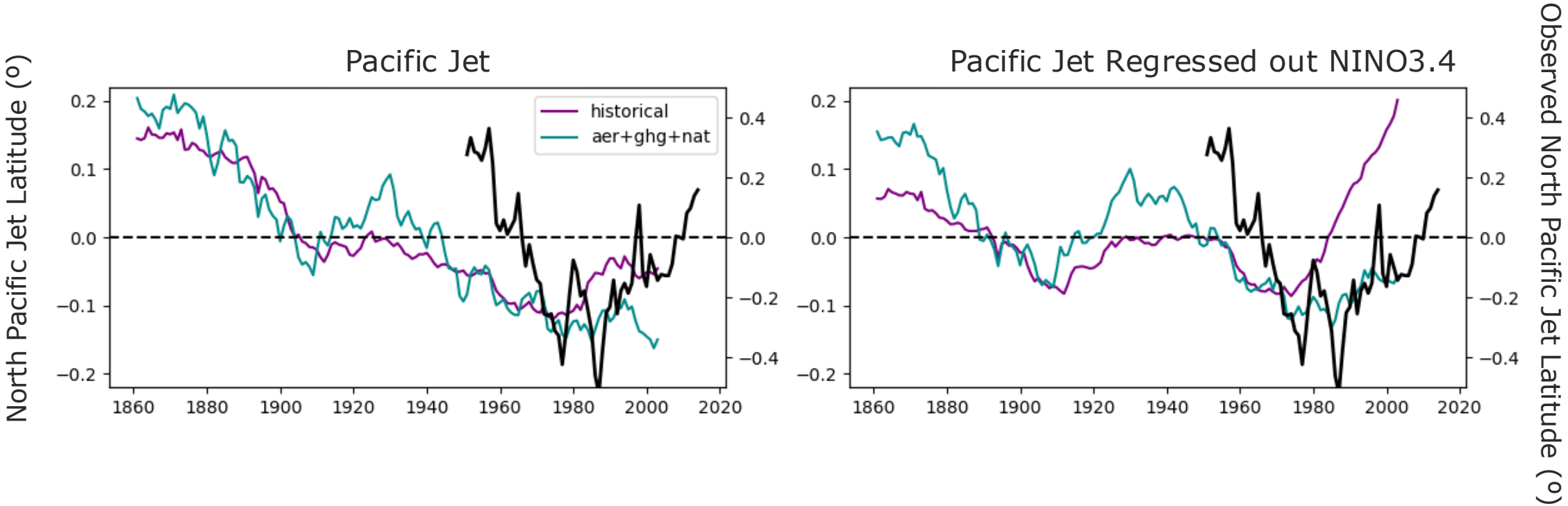
Met Office
Hadley Centre

Thanks for listening

Any questions?



Non additivity in responses



- After regressing out ENSO experiments do not linearly add up
- Although there is an increase from 1980-present day in the addition of the single forcing runs, this does not fully explain the uptick in the historical runs
- CAVEAT: not same ensmeble members
- Make lines thicker

Met Office Hadley Centre

Regressing out NINO3.4 Index

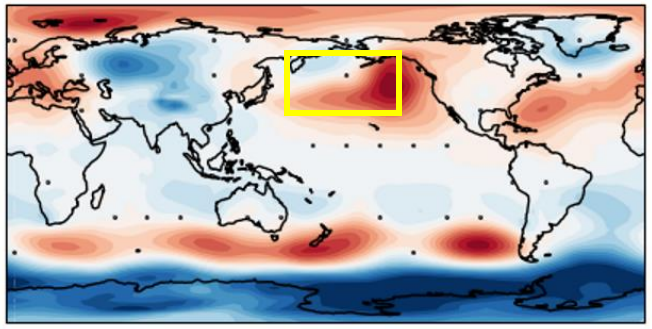
Tried MLR and identified a key need to include ENSO

Regressions against EEI Index

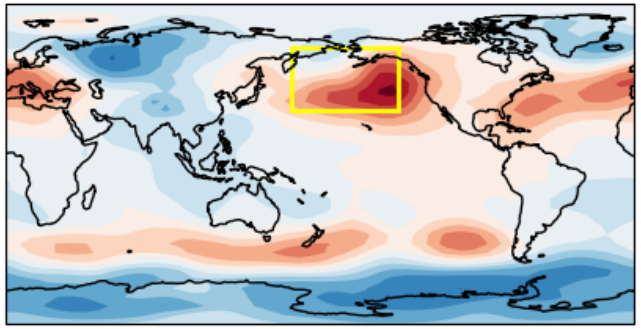
Raw

ENSO regressed out

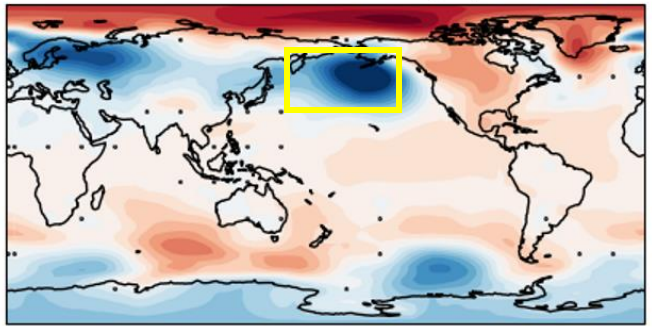
CanESM5 (50)



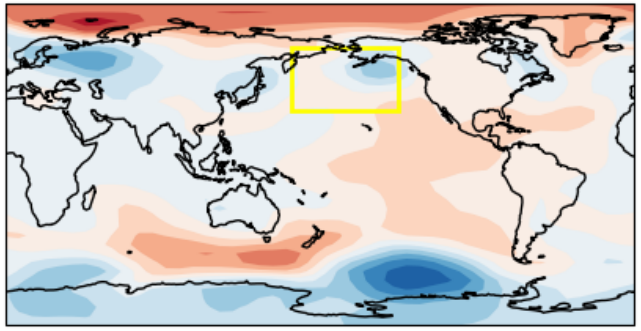
CanESM5 (50)

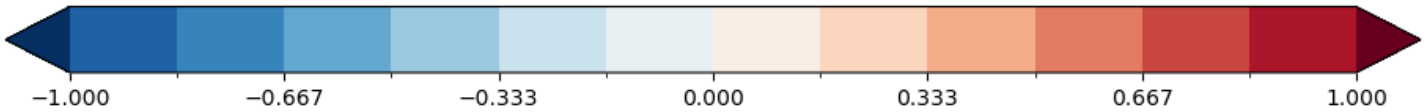


HadGEM3-GC31-LL (60)



HadGEM3-GC31-LL (60)





mean sea level pressure (hPa)