



ILMATIETEEN LAITOS  
METEOROLOGISKA INSTITUTET  
FINNISH METEOROLOGICAL INSTITUTE

# The response of ENSO high-latitude teleconnections to future dynamical and thermal changes

23/03/2022 Nicholas Tyrrell & Alexey Karpechko



# Question

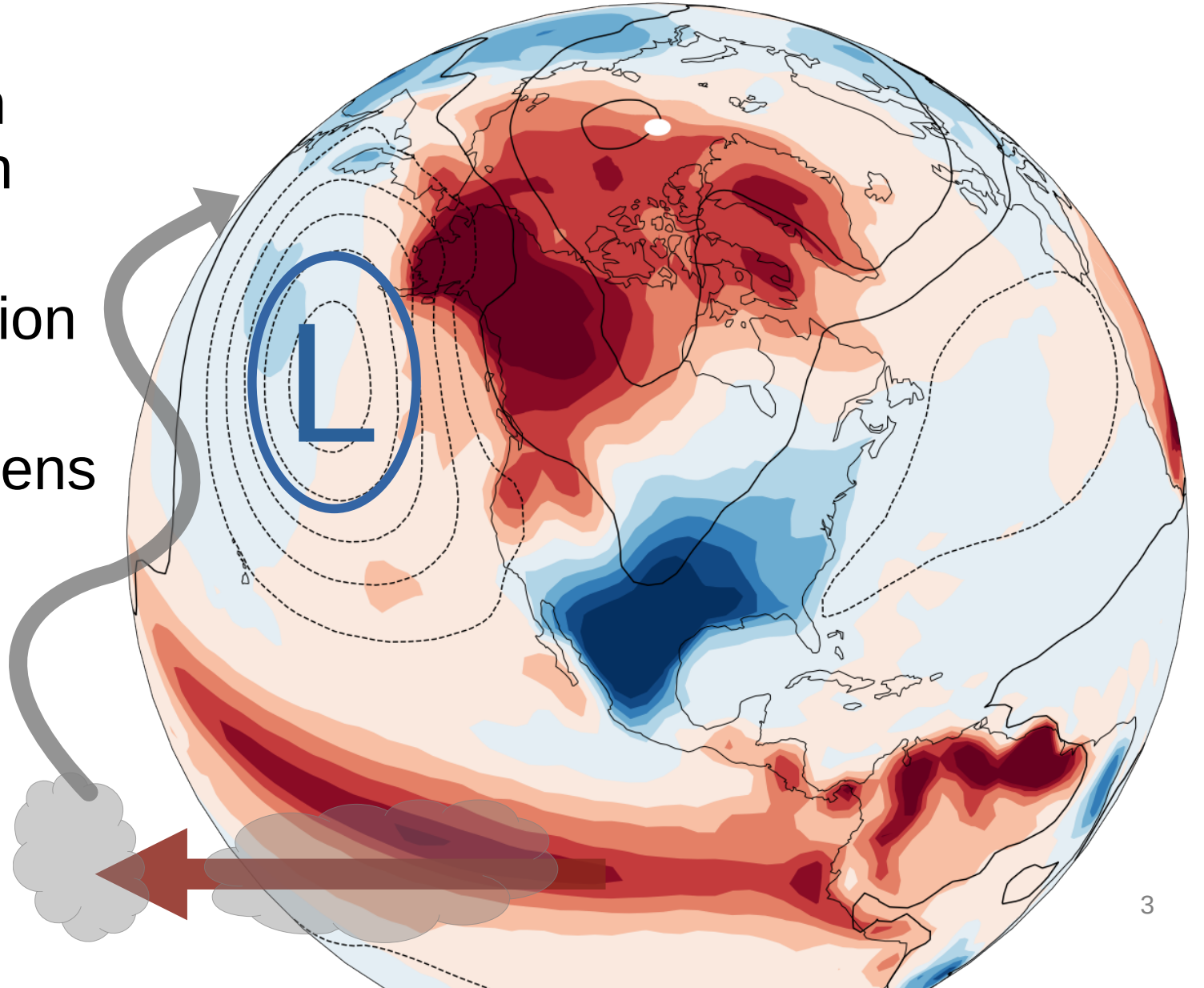
How will the future changes to temperature and winds affect the propagation and impact of teleconnections?

1. The ENSO Teleconnection
2. Nudging and tendency adjustment technique
3. ENSO teleconnection in the future climate



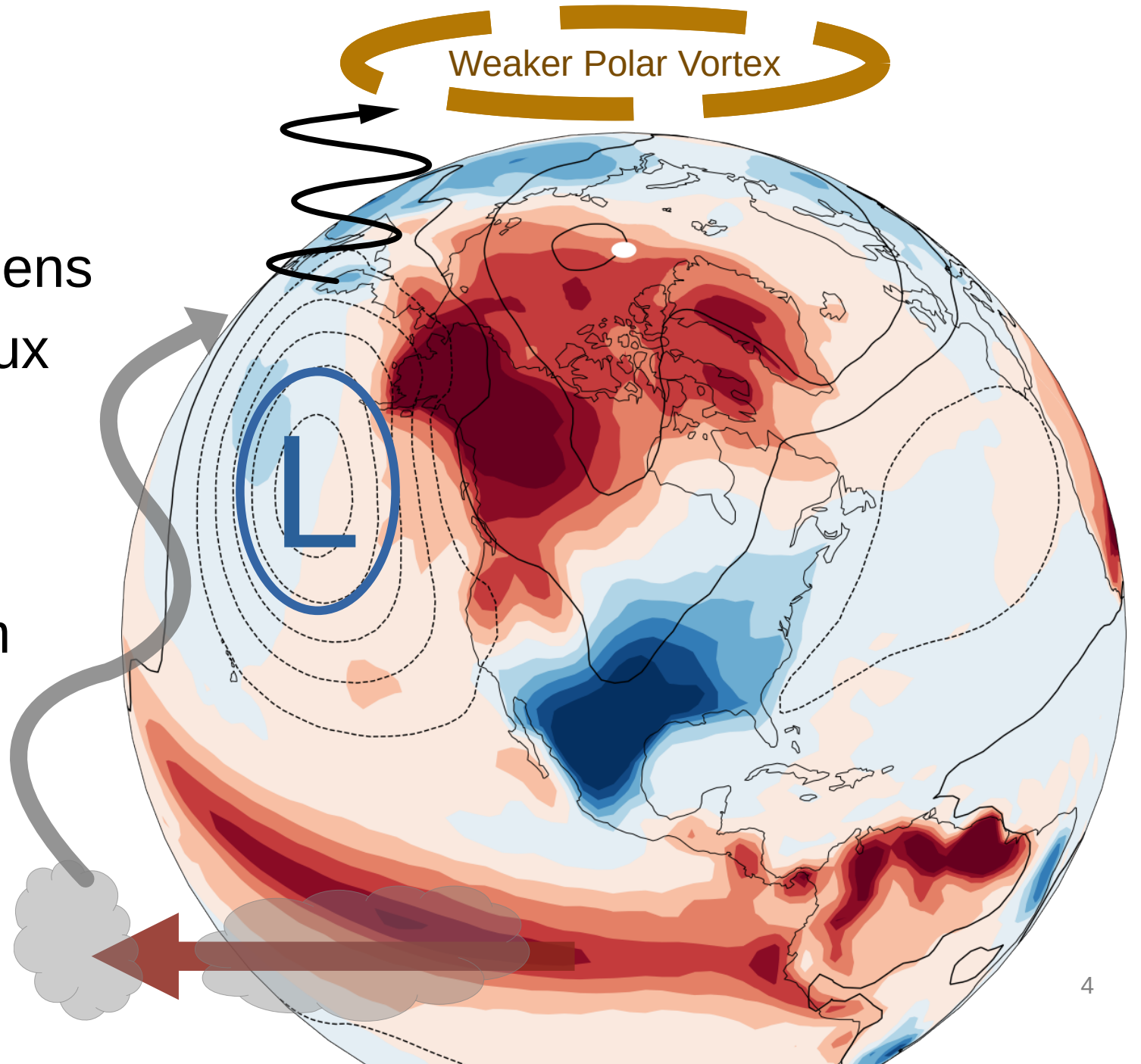
# El Niño teleconnection

- El Niño-Southern Oscillation causes anom. warm SSTs in the eastern Pacific
- Changes to tropical convection create Rossby waves
- Aleutian Low pressure deepens



# Stratospheric teleconnection

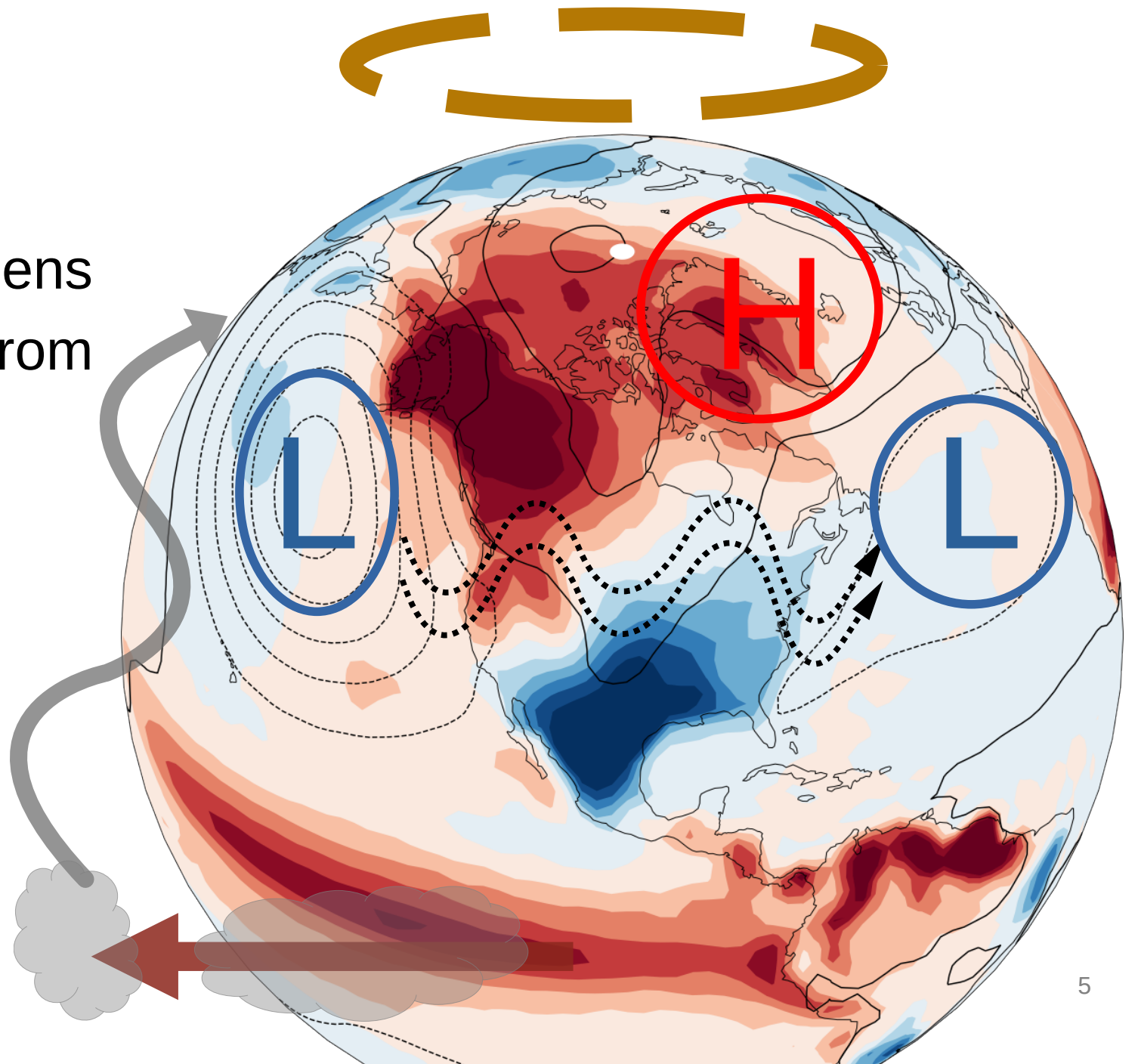
- Aleutian Low pressure deepens
- Increased planetary wave flux from troposphere to stratosphere
- Weakened polar vortex
- Downward propagation from stratosphere to troposphere





# Tropospheric teleconnection

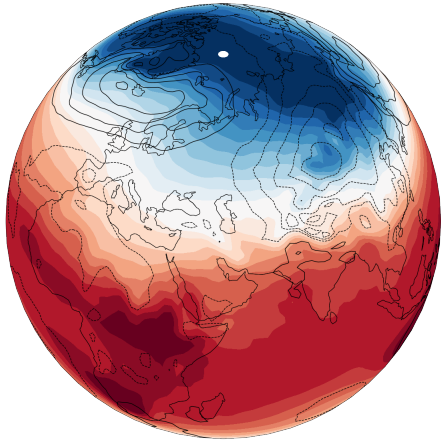
- Aleutian Low pressure deepens
- Increased transient eddies from Pacific to North Atlantic
- Negative NAO



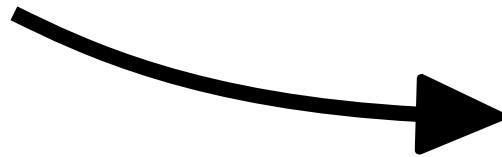
# Tendency adjustments to future climate

## - Step 1 of 2 -

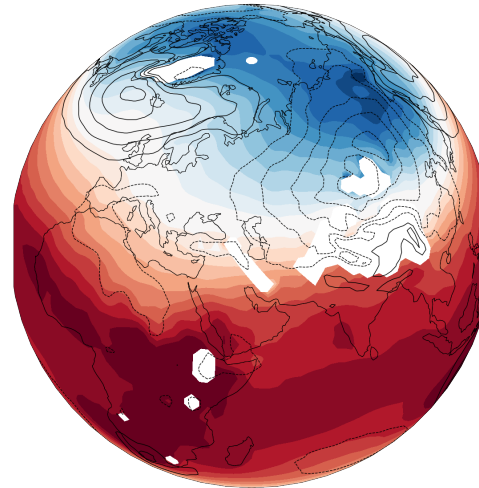
ECHAM6 AGCM.  
Present day forcings  
and SST/SIC



Nudge temperature,  
wind, pressure



MPI-ESM SSP585.  
CMIP6 high emission  
scenario  
2075-2094



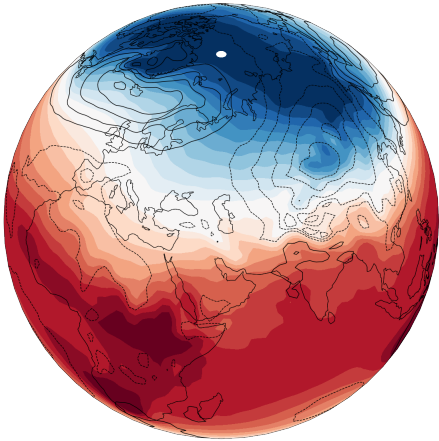
Record the nudging  
tendencies of  
temperature, winds,  
pressure. Create 12  
month climatology

*Model is tightly constrained  
to reference climate*

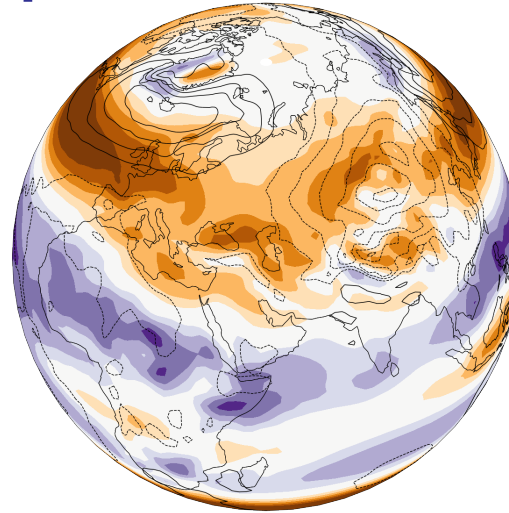
# Tendency adjustments to future climate

## - Step 2 of 2 -

ECHAM6 control.  
Present day forcings  
and SSTs

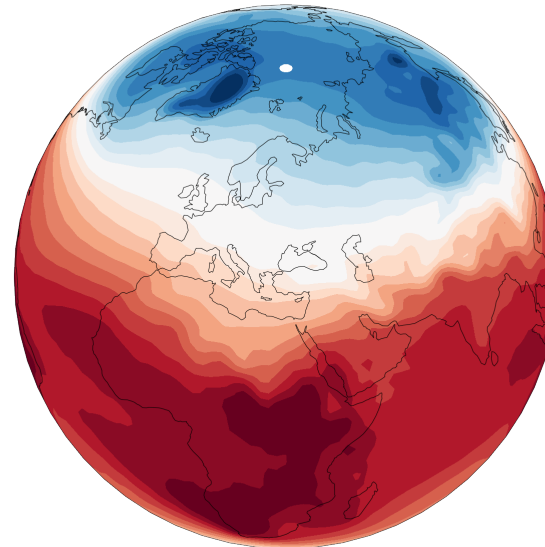


*Model can respond to  
perturbations,  
e.g. SST anomalies*



### Future Winds

Add climatology of wind and  
surface pressure nudging  
tendencies



### Future Temperature

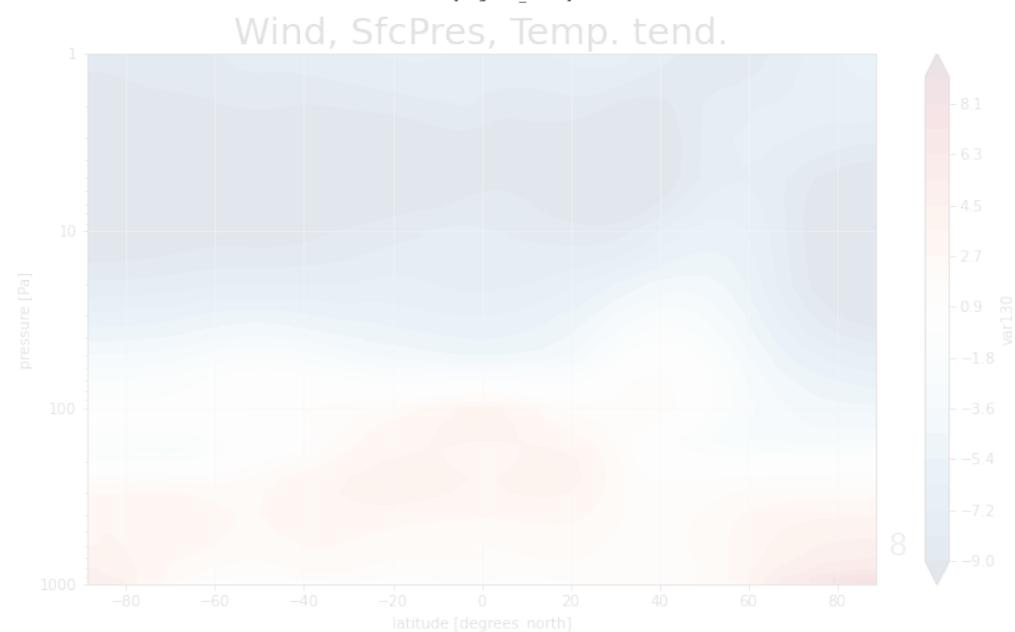
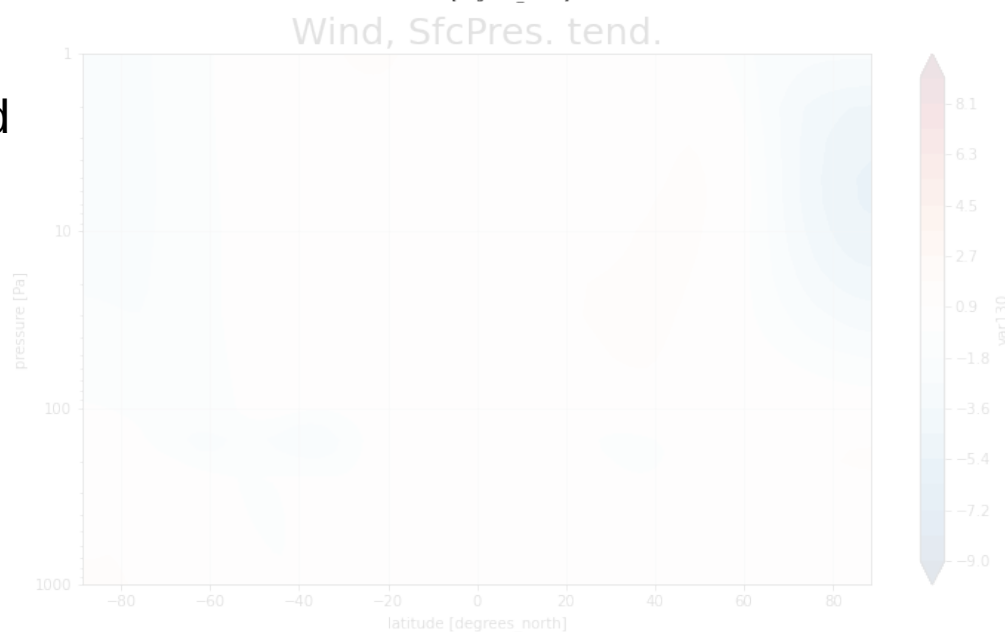
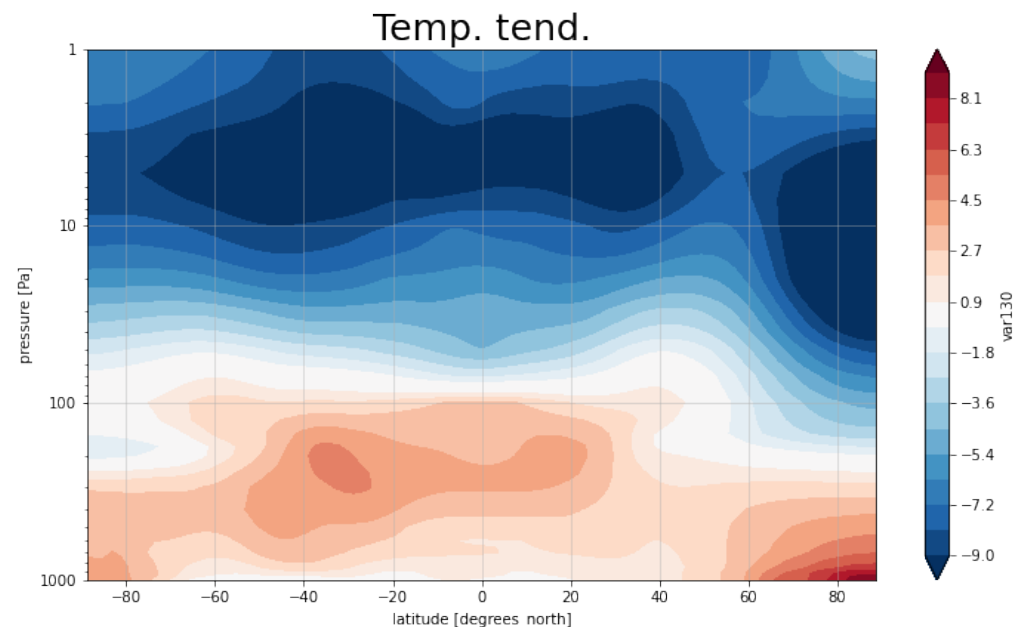
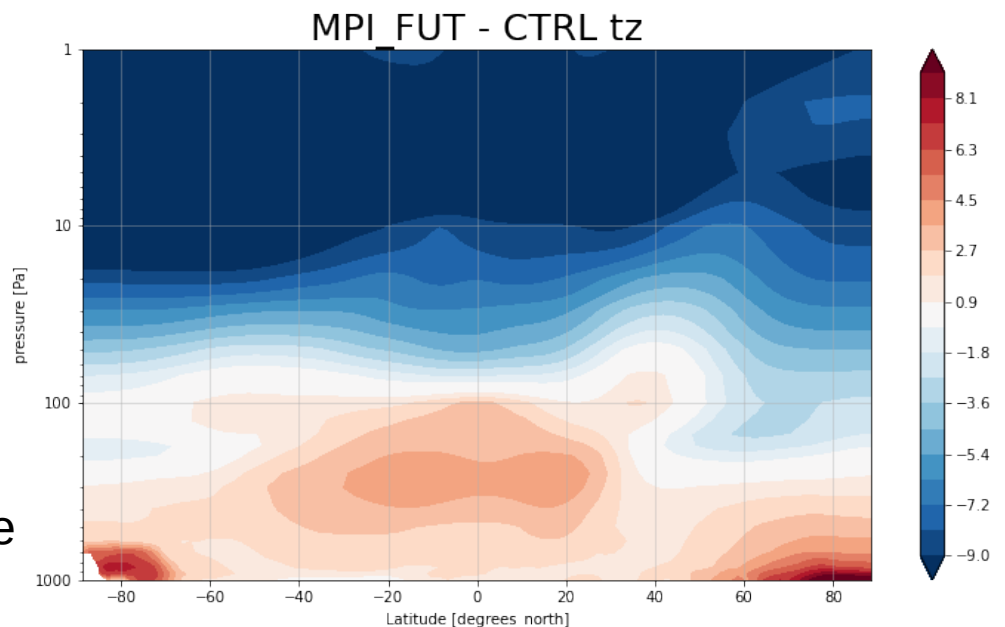
Add climatology of  
nudging temperature  
tendencies

# Recreating the future temperature

DJF zonal mean temperature anomalies from 100yr control run.

Tendency runs all 100 yrs.

- Future temperature tendencies recreate broad features
- Not as well defined



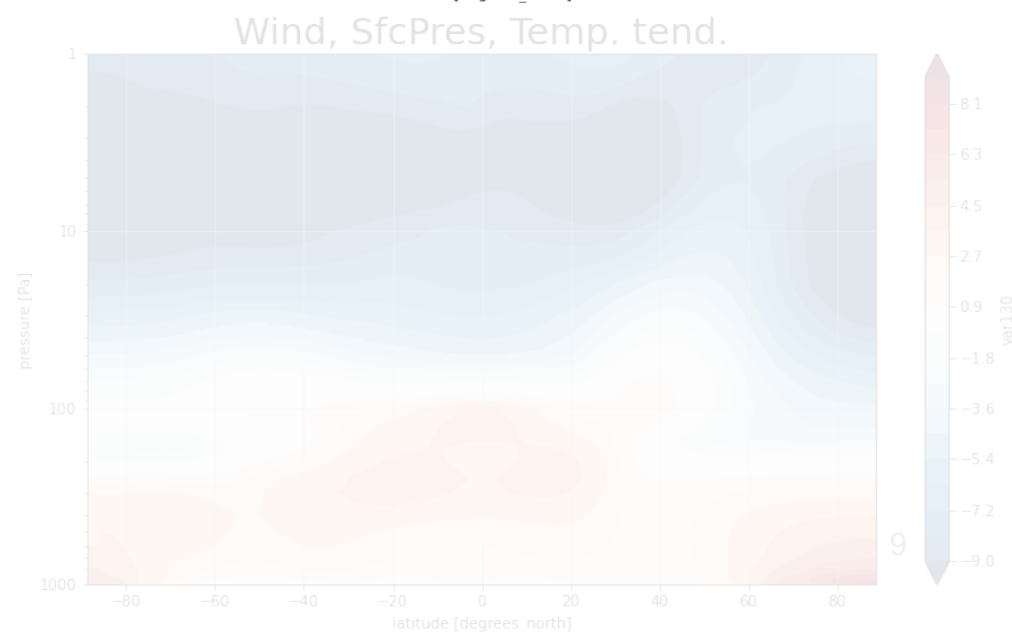
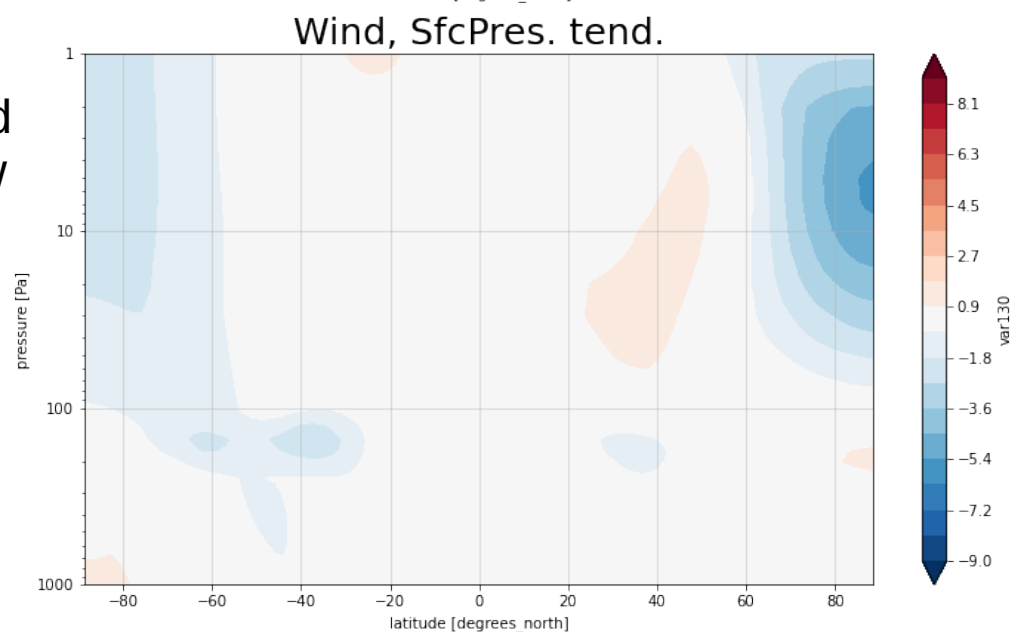
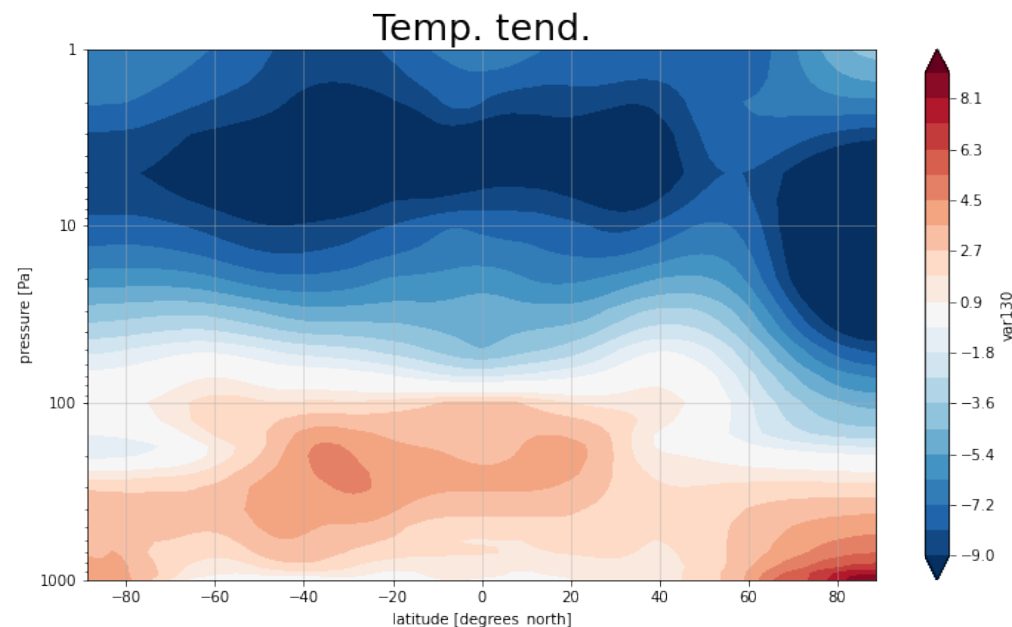
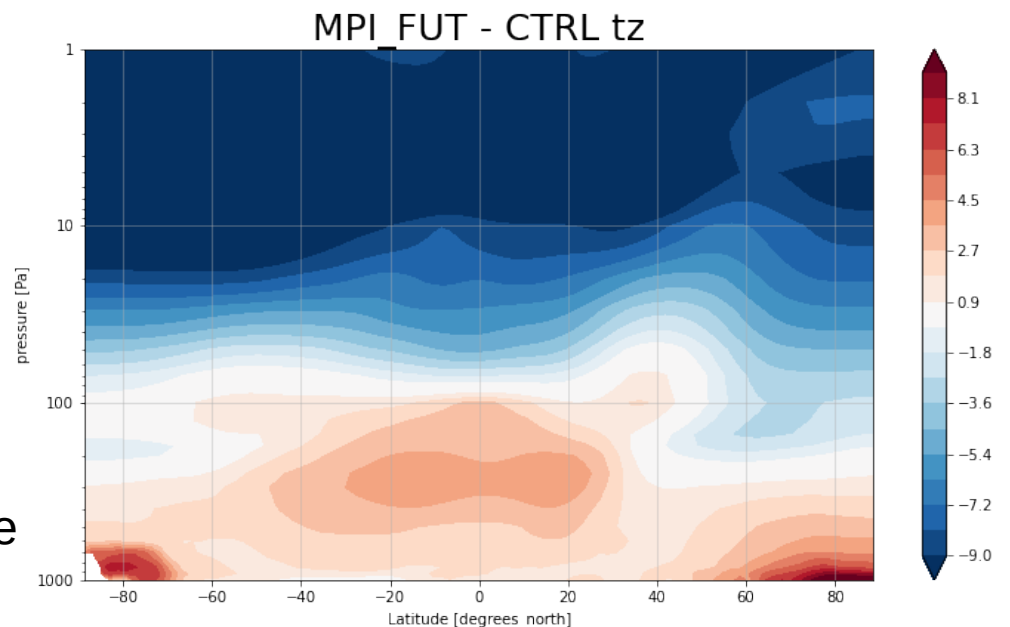


# Recreating the future temperature

DJF zonal mean temperature anomalies from 100yr control run.

Tendency runs all 100 yrs.

- Future temperature tendencies recreate broad features
- Not as well defined
- Future winds show polar vortex cooling

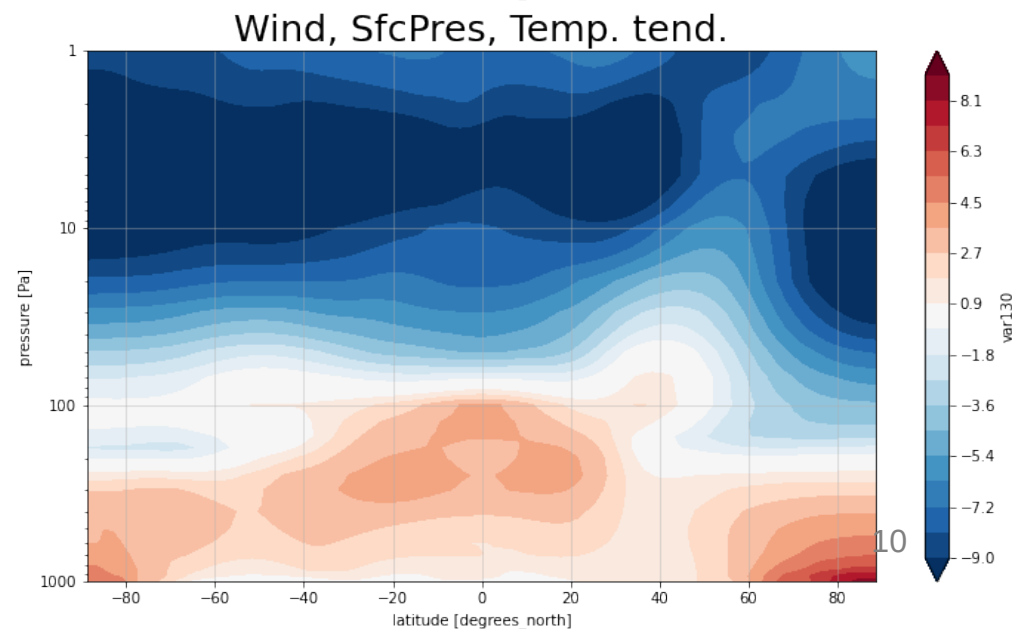
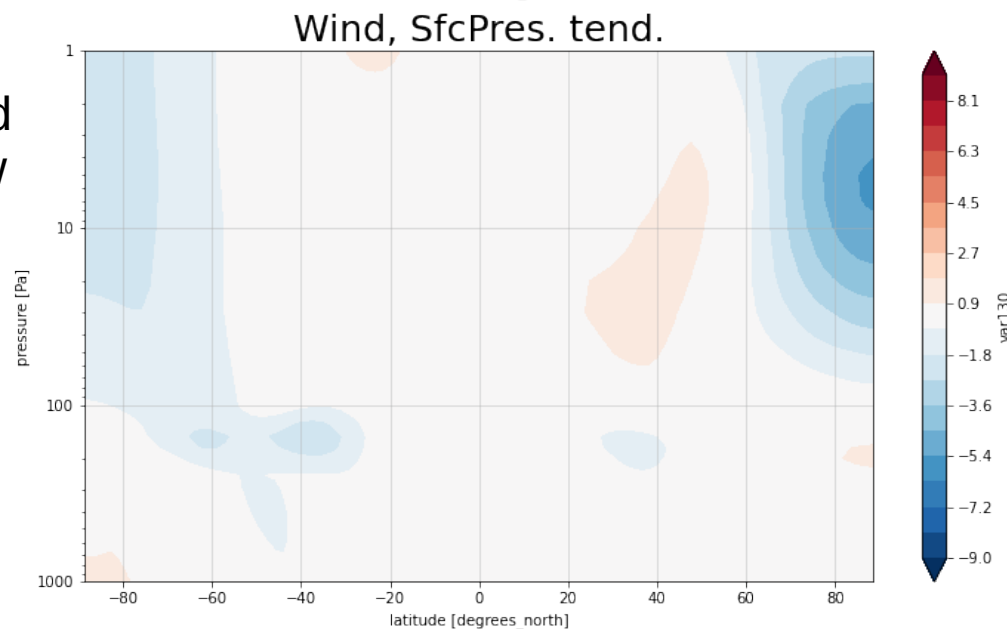
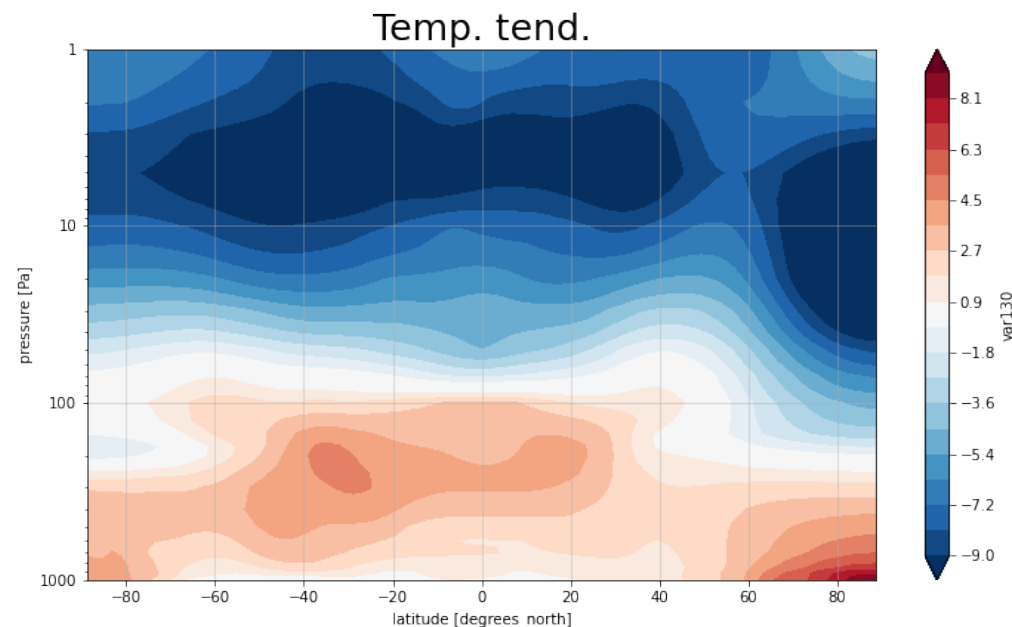
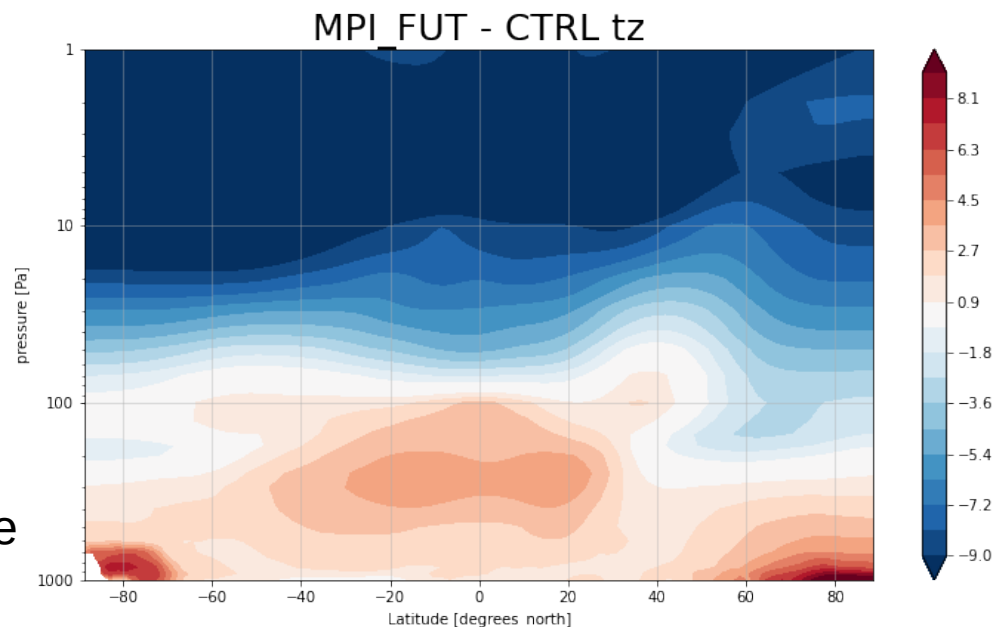


# Recreating the future temperature

DJF zonal mean temperature anomalies from 100yr control run.

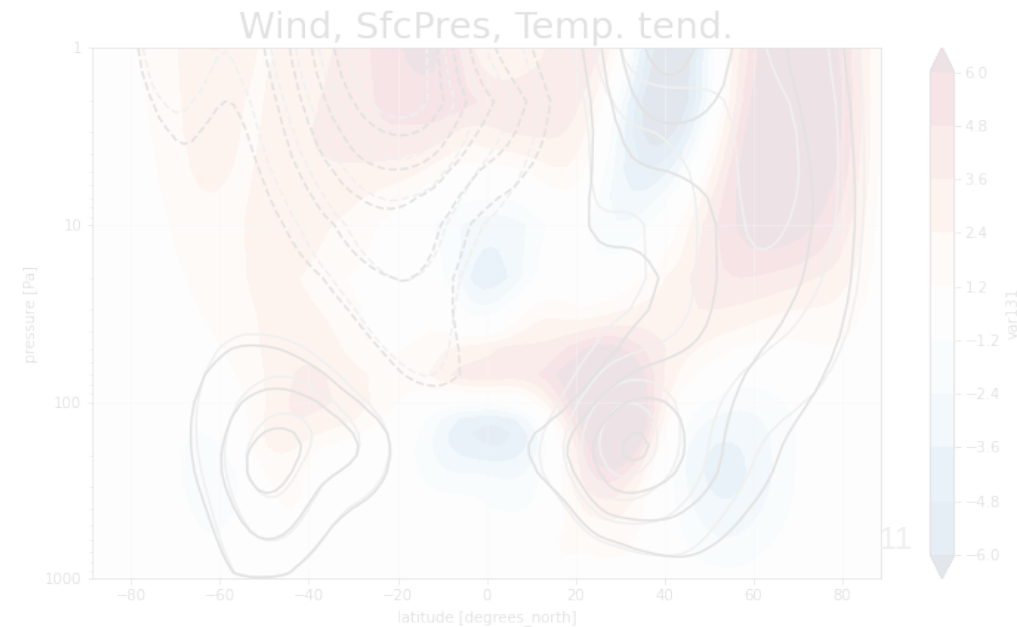
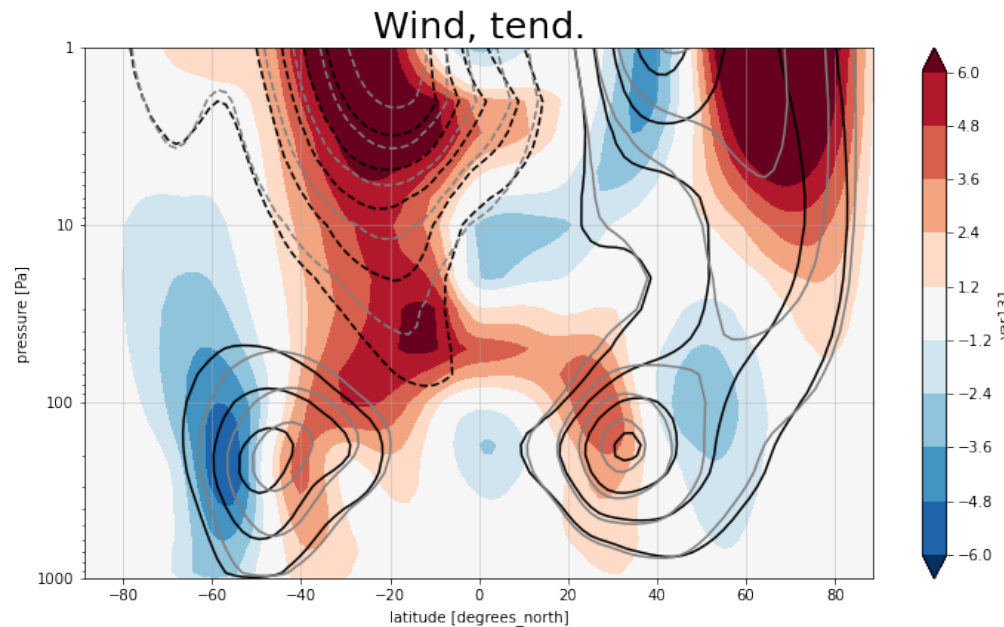
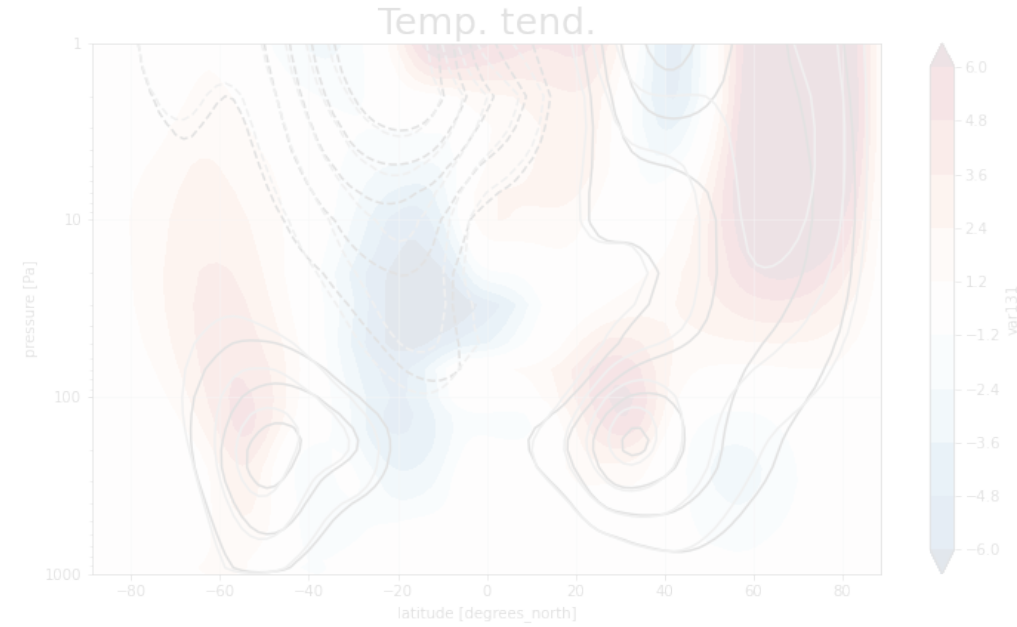
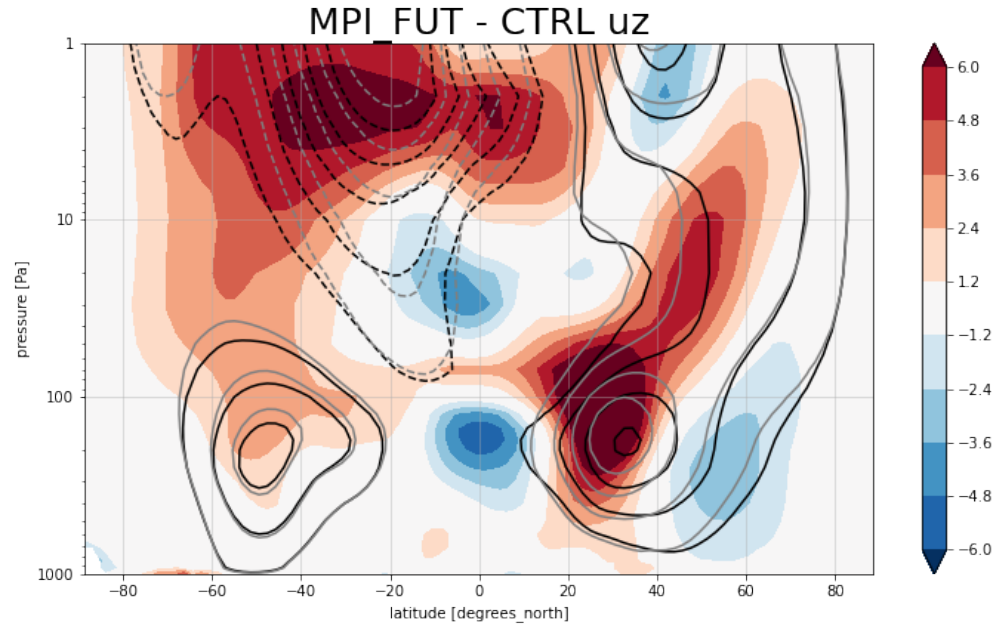
Tendency runs all 100 yrs.

- Future temperature tendencies recreate broad features
- Not as well defined
- Future winds show polar vortex cooling
- Future winds and temp. recreate features of MPI



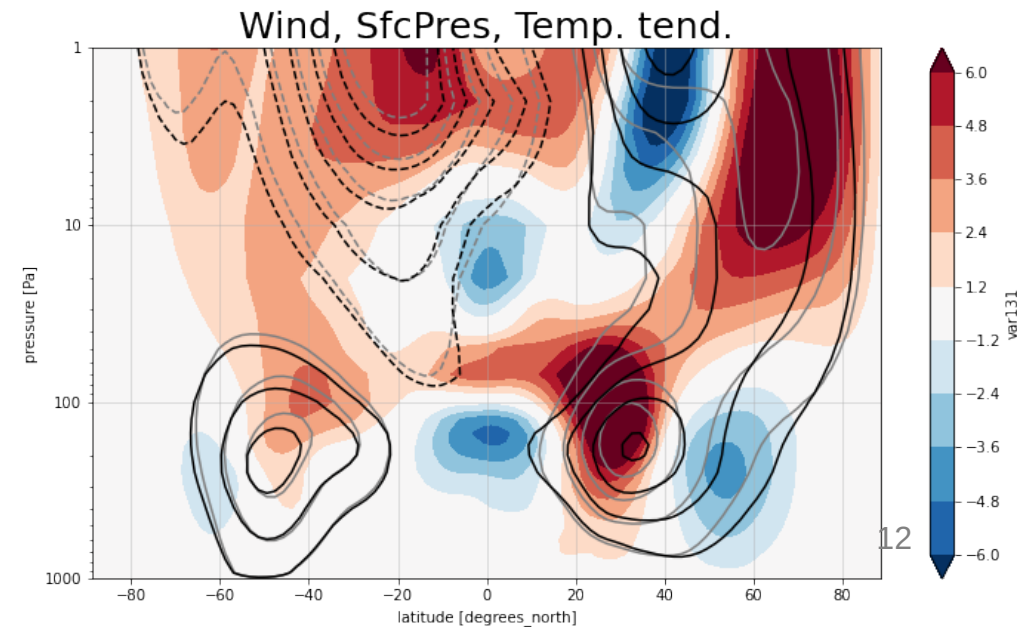
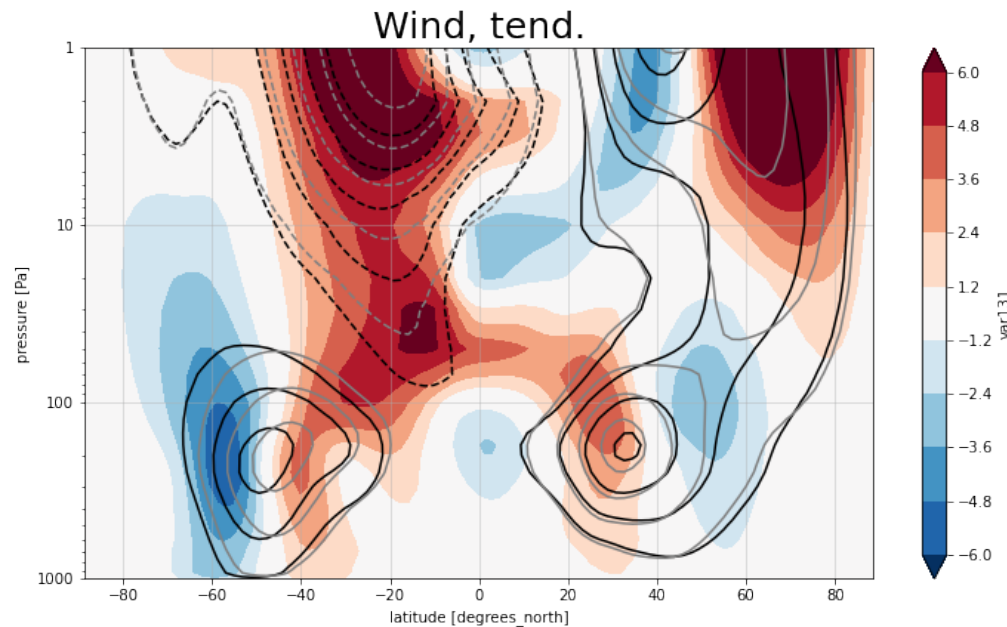
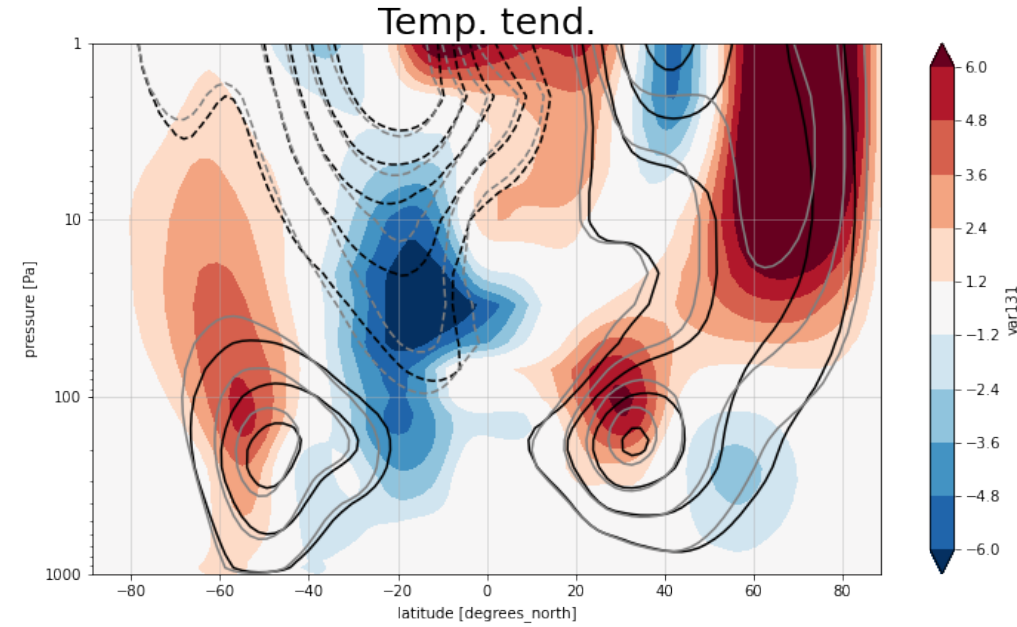
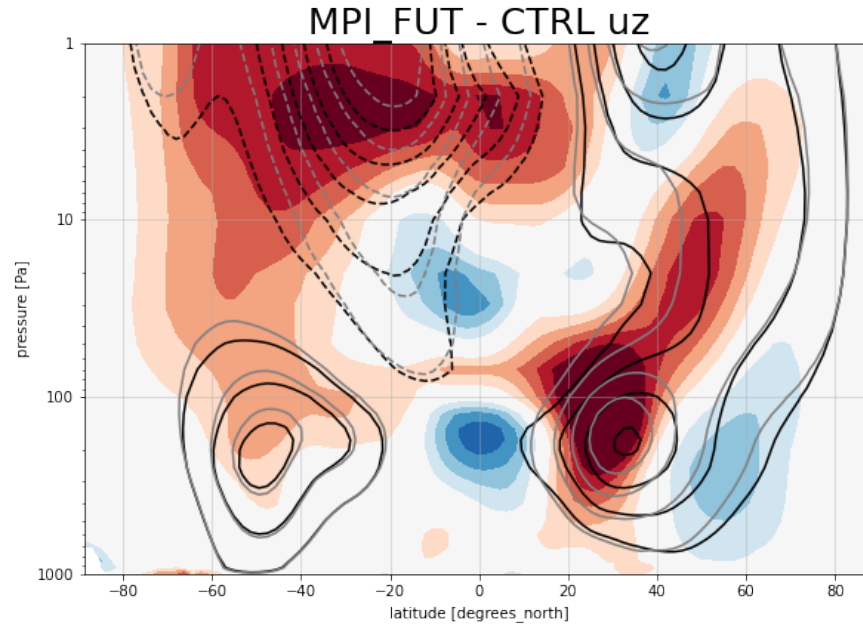
# Recreating the future winds

- Future wind tendencies show weaker jet shift
- Stronger vortex warming



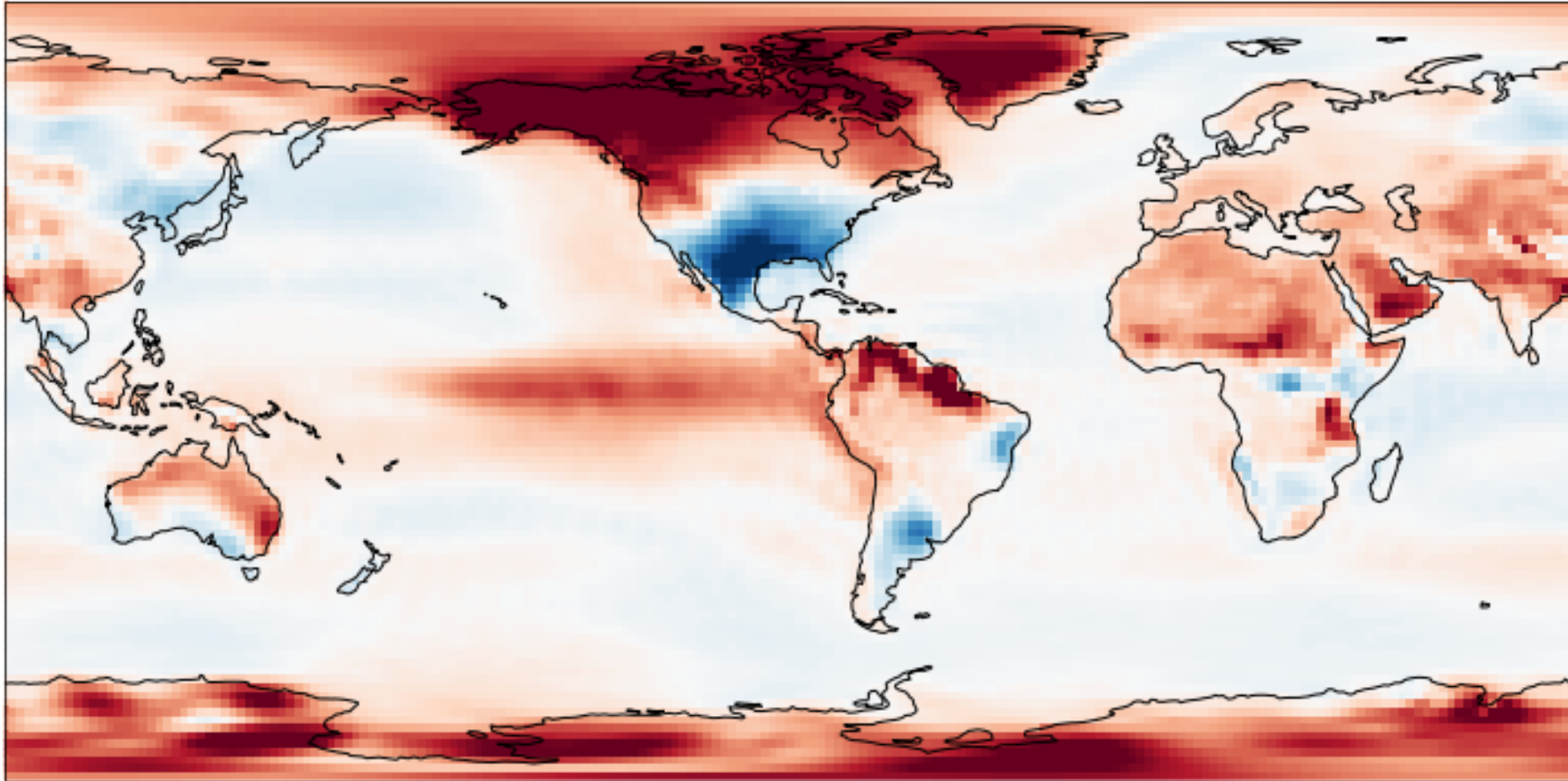
# Recreating the future winds

- Future wind tendencies show weaker jet shift
- Stronger vortex warming
- Future temperature also weaker jet shift and stronger vortex
- Combined closer to MPI for jet, too strong vortex



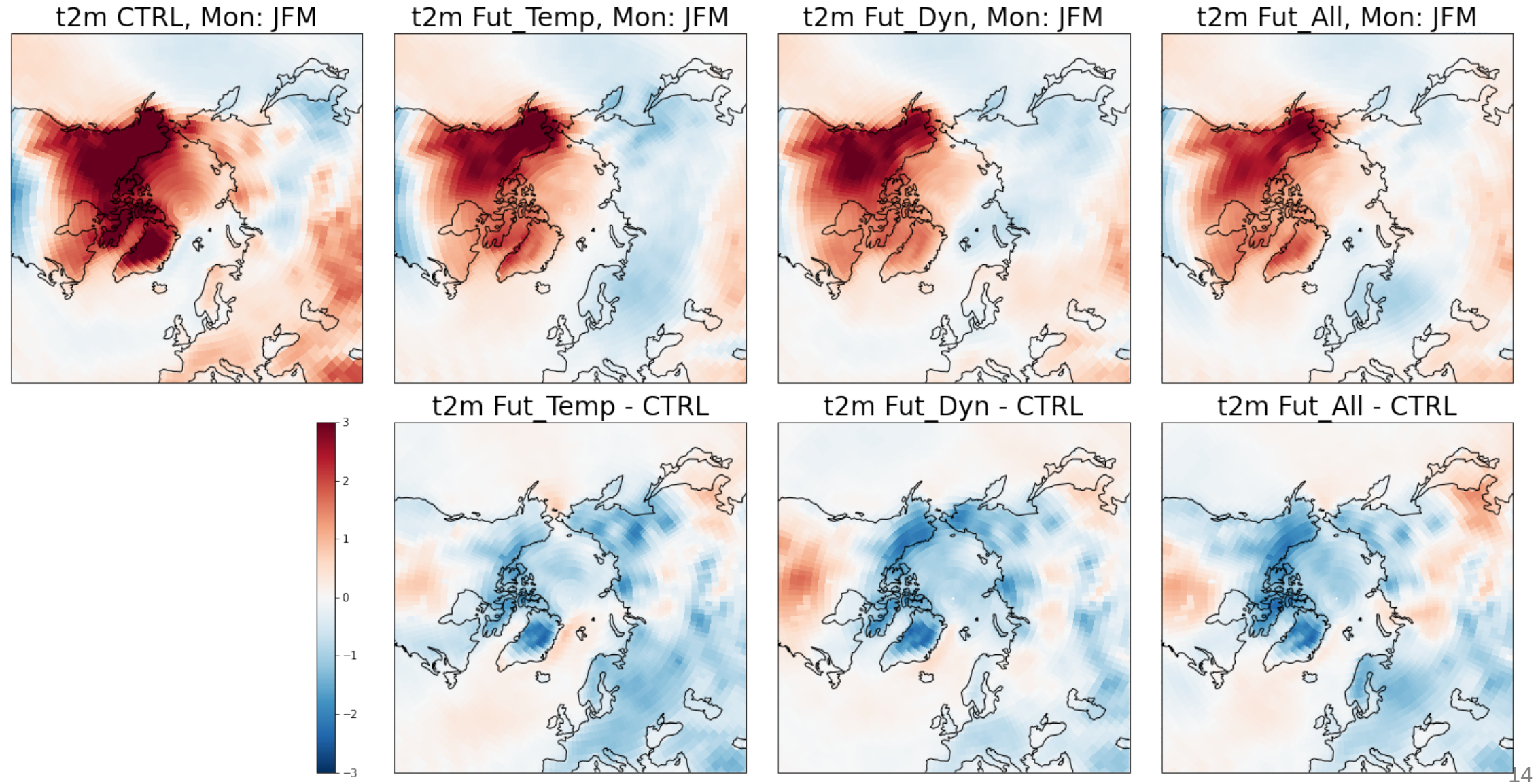
# El Nino SST experiments, 2m temp

El Nino anom, t2m, CTRL, Mon: JFM



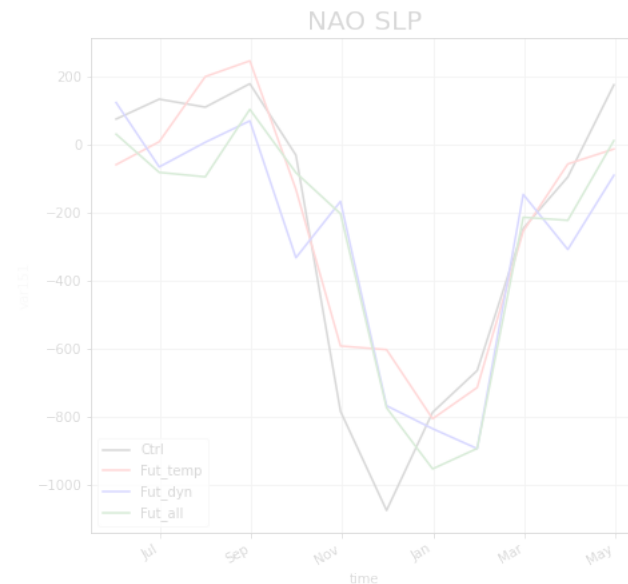
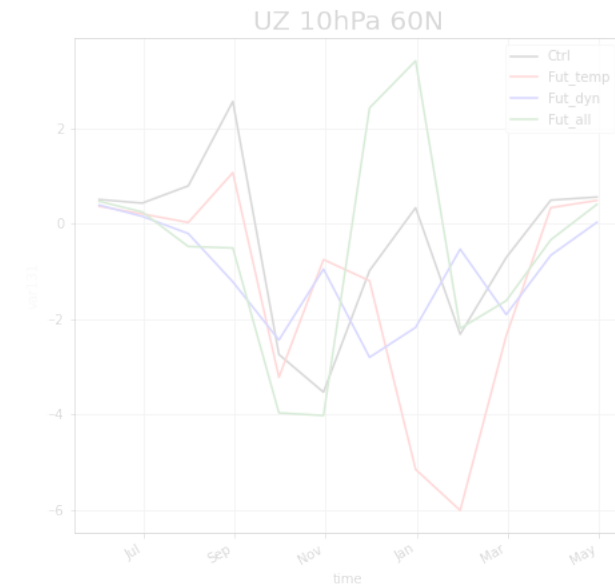
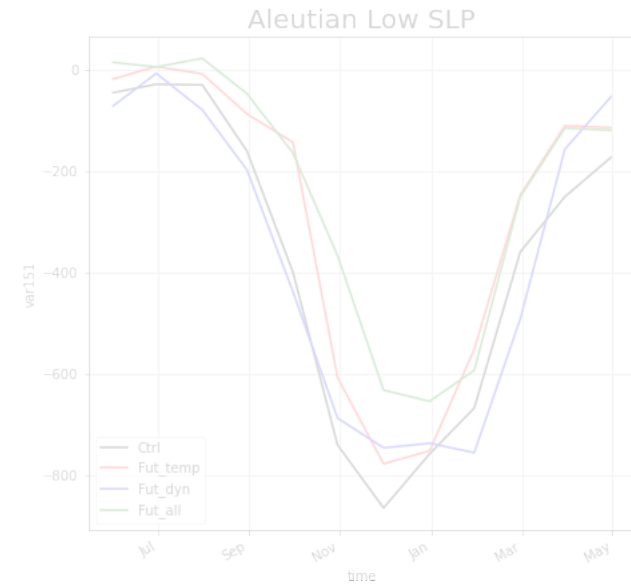
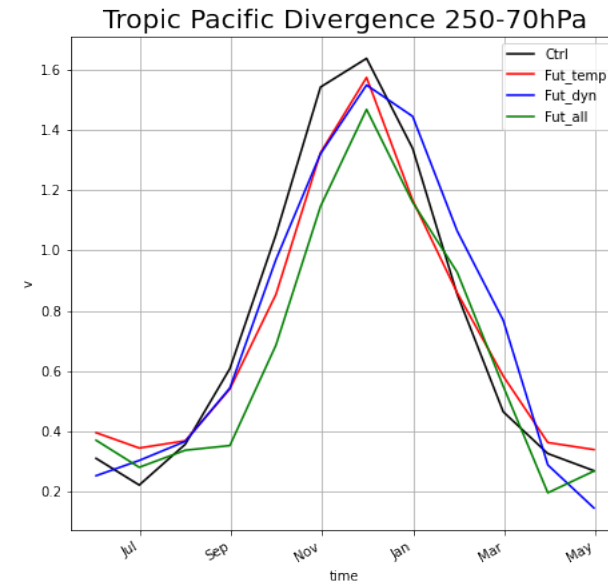
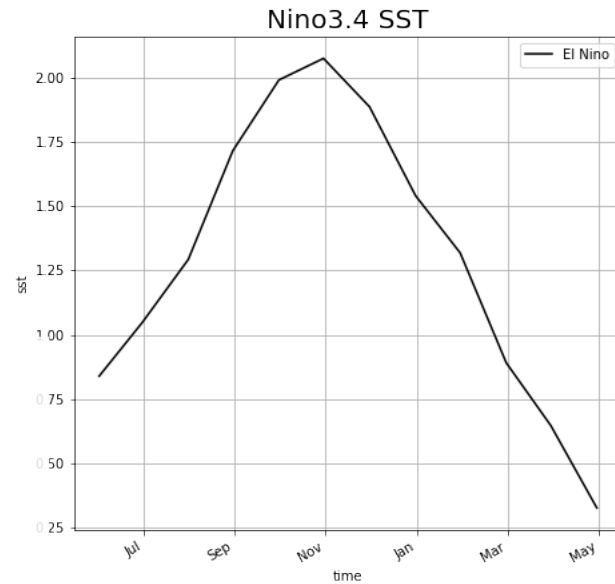


# Future experiments show less anom. warming in Arctic



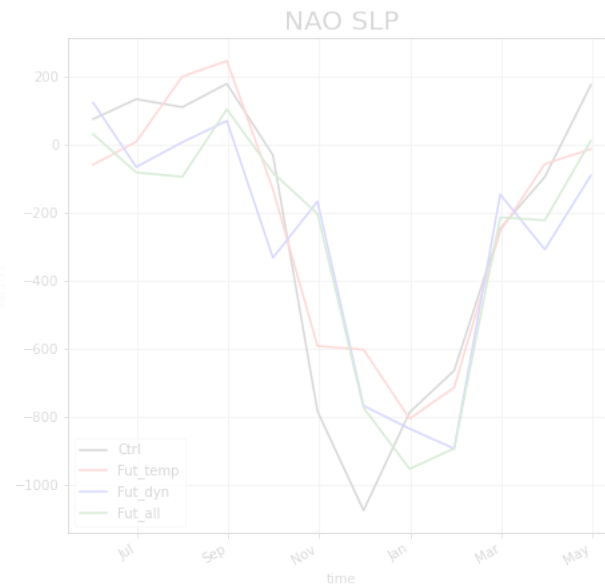
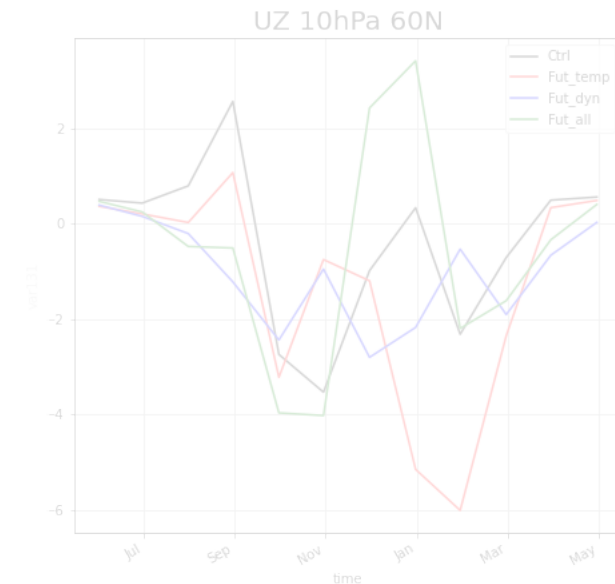
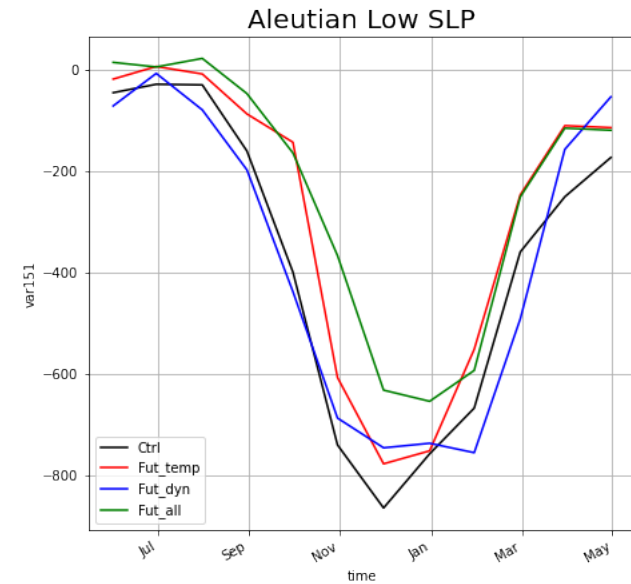
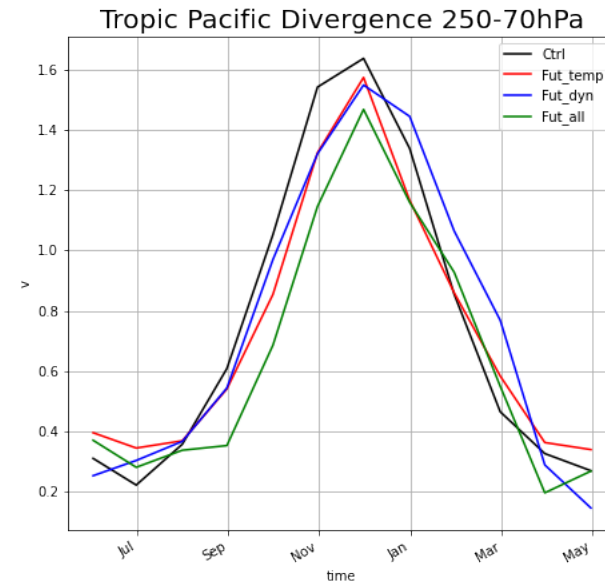
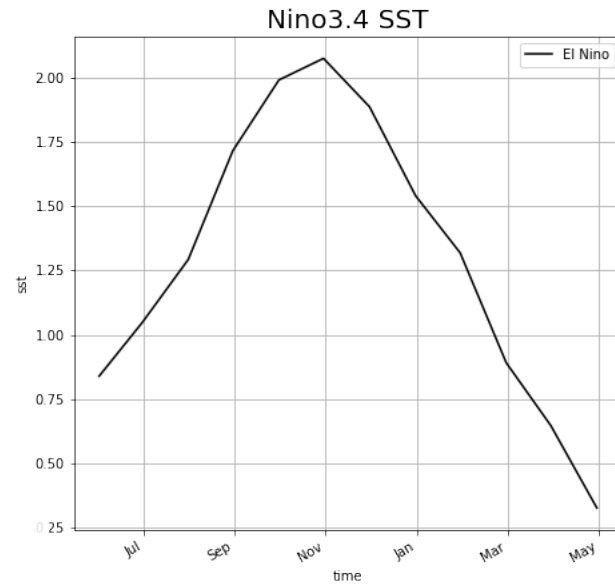
# ENSO teleconnection progression

- Tropical divergence as a measure of convection
- Reduced convection anomalies for future experiments
- Aleutian low response similar to tropical divergence
- Polar vortex response does not correlate well with Aleutian low
- Weakest NAO response for Fut-Temp, strongest for the CTRL run
- Doesn't correlate with polar vortex



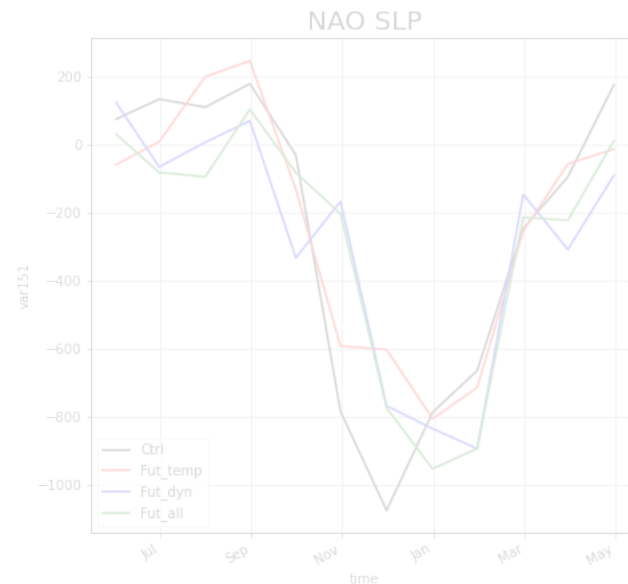
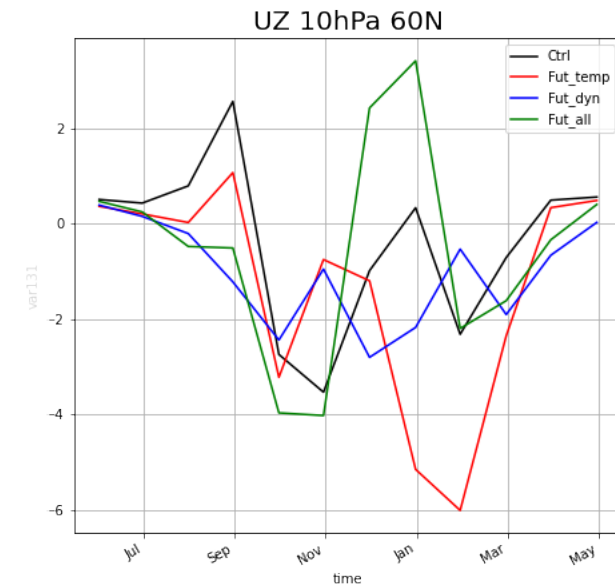
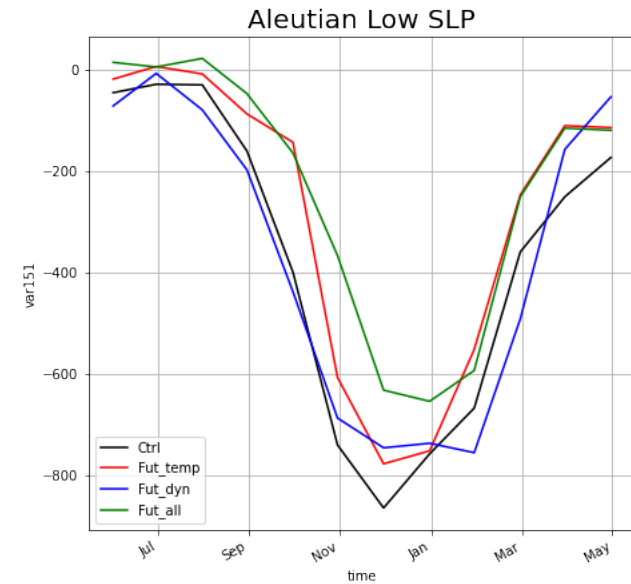
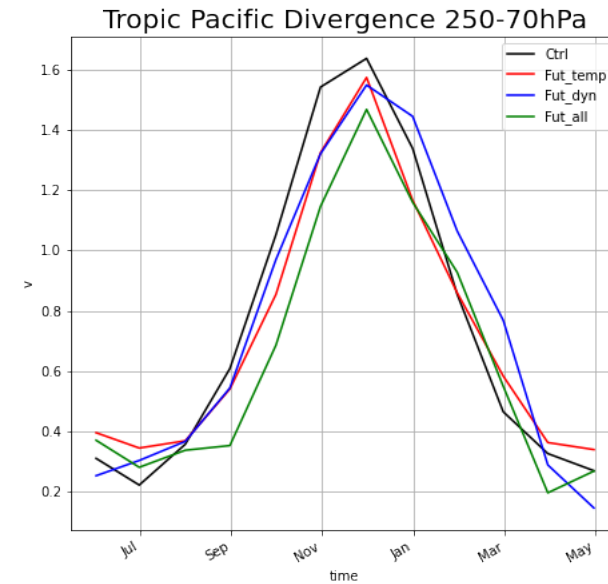
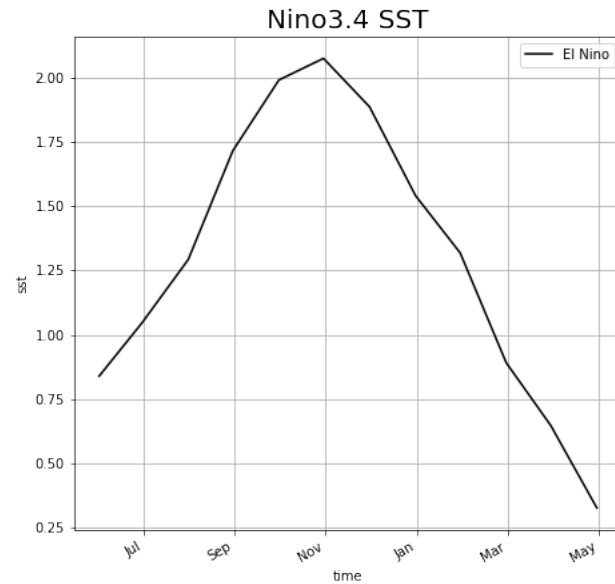
# ENSO teleconnection progression

- Tropical divergence as a measure of convection
- Reduced convection anomalies for future experiments
- Aleutian low response similar to tropical divergence
- Polar vortex response does not correlate well with Aleutian low
- Weakest NAO response for Fut-Temp, strongest for the CTRL run
- Doesn't correlate with polar vortex



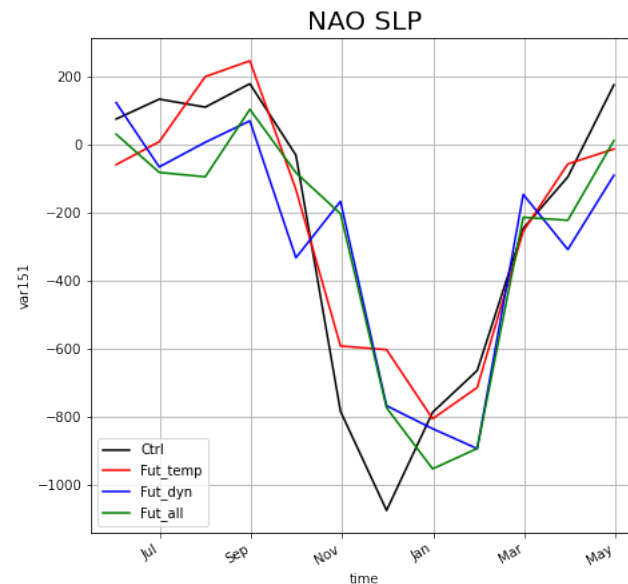
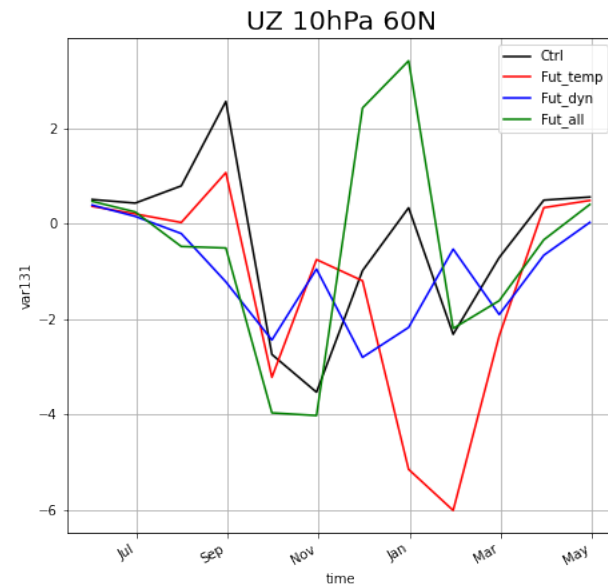
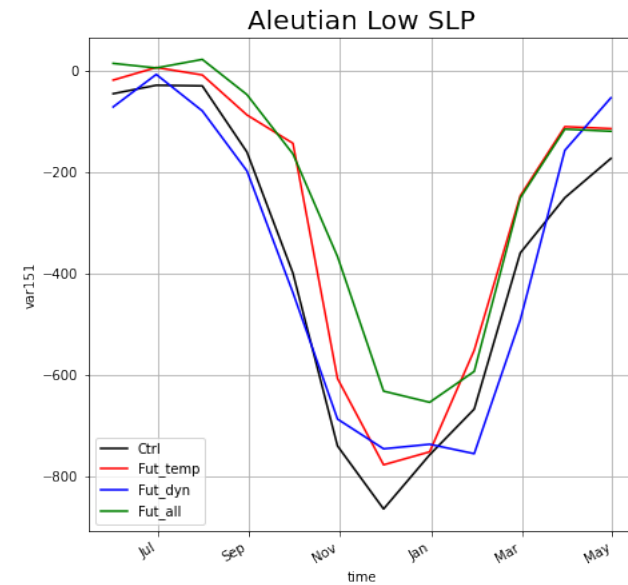
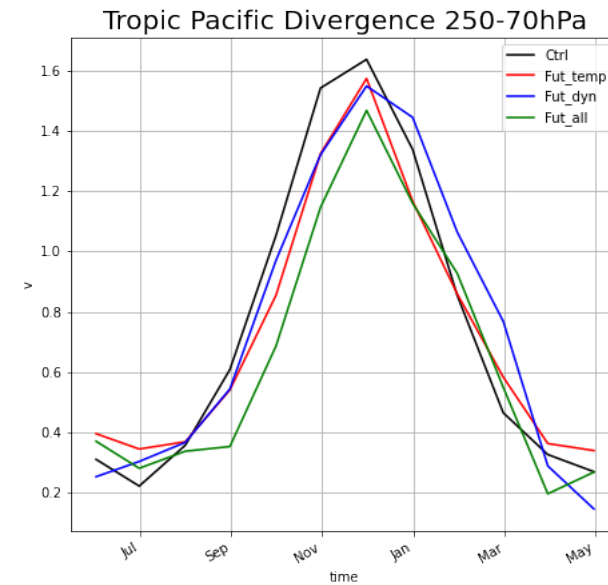
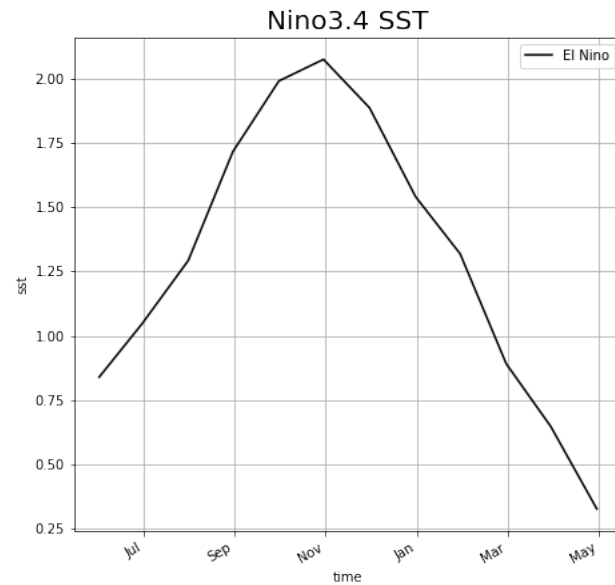
# ENSO teleconnection progression

- Tropical divergence as a measure of convection
- Reduced convection anomalies for future experiments
- Aleutian low response similar to tropical divergence
- Polar vortex response does not correlate well with Aleutian low
- Weakest NAO response for Fut-Temp, strongest for the CTRL run
- Doesn't correlate with polar vortex



# ENSO teleconnection progression

- Tropical divergence as a measure of convection
- Reduced convection anomalies for future experiments
- Aleutian low response similar to tropical divergence
- Polar vortex response does not correlate well with Aleutian low
- Weakest NAO response for Fut-Temp, strongest for the CTRL run
- Doesn't correlate with polar vortex



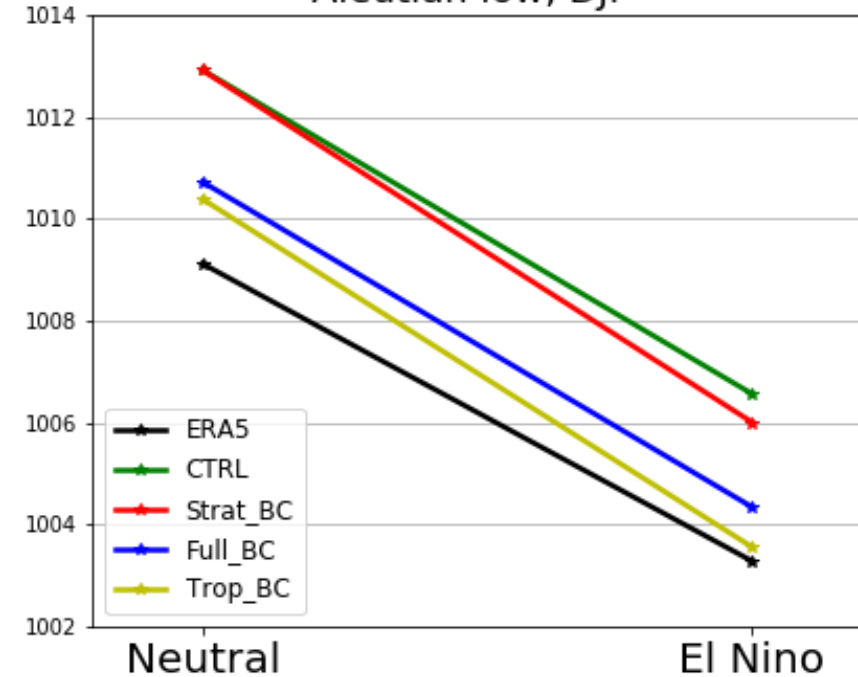


# Summary

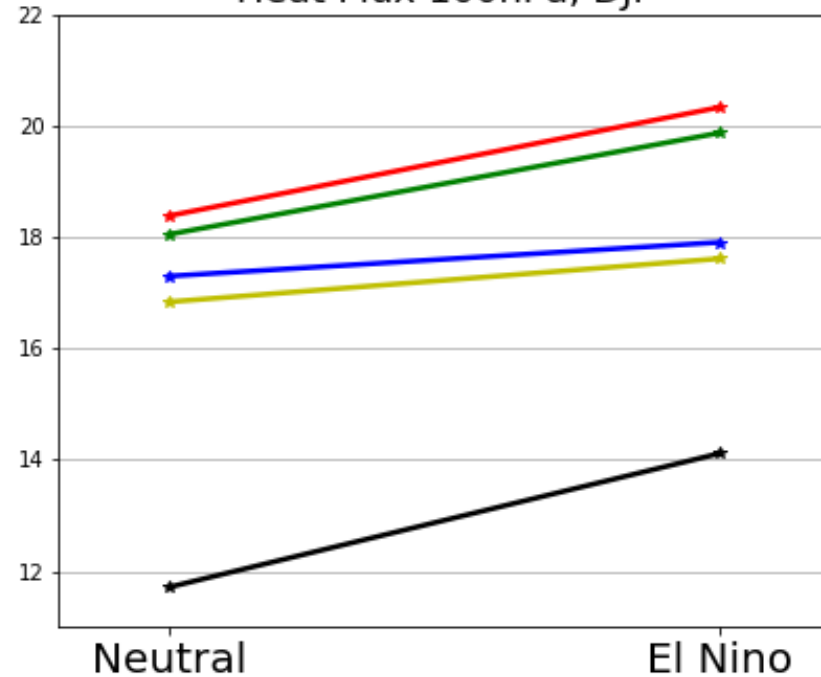
- For similar El Niño anomaly, extra-tropical teleconnections appear weaker
  - For our experiments due to smaller convective anomalies
  - Perhaps not that surprising or interesting...
- Different experiments?
  - Change to the tropical convective response of ENSO is only part of the question
  - More interesting to know the extra-tropical changes to the teleconnection, e.g.
    - Rossby wave/jet stream interaction
    - Polar vortex stratosphere-troposphere coupling in different climates
- Nudge to other models
  - Currently can only nudge to MPI-ESM
  - Apply the "Storyline" approach

# El Niño Bias Correction results

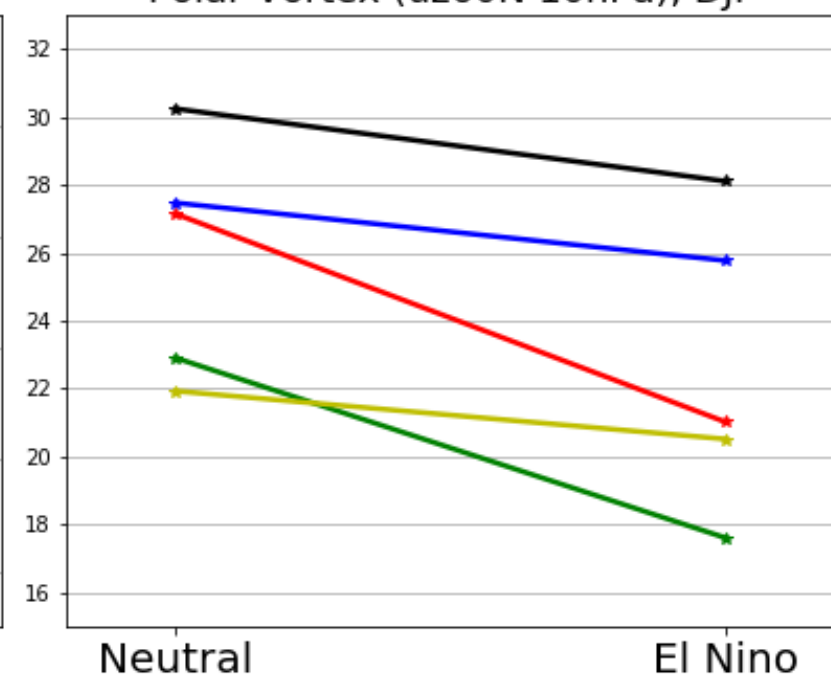
Aleutian low, DJF



Heat Flux 100hPa, DJF



Polar Vortex (uz60N 10hPa), DJF



- Biases in Aleutian Low do not affect response to El Niño
- Aleutian Low biases translate to differences in wave flux into stratosphere
- Biases in Polar Vortex do not affect anomalous response to wave flux



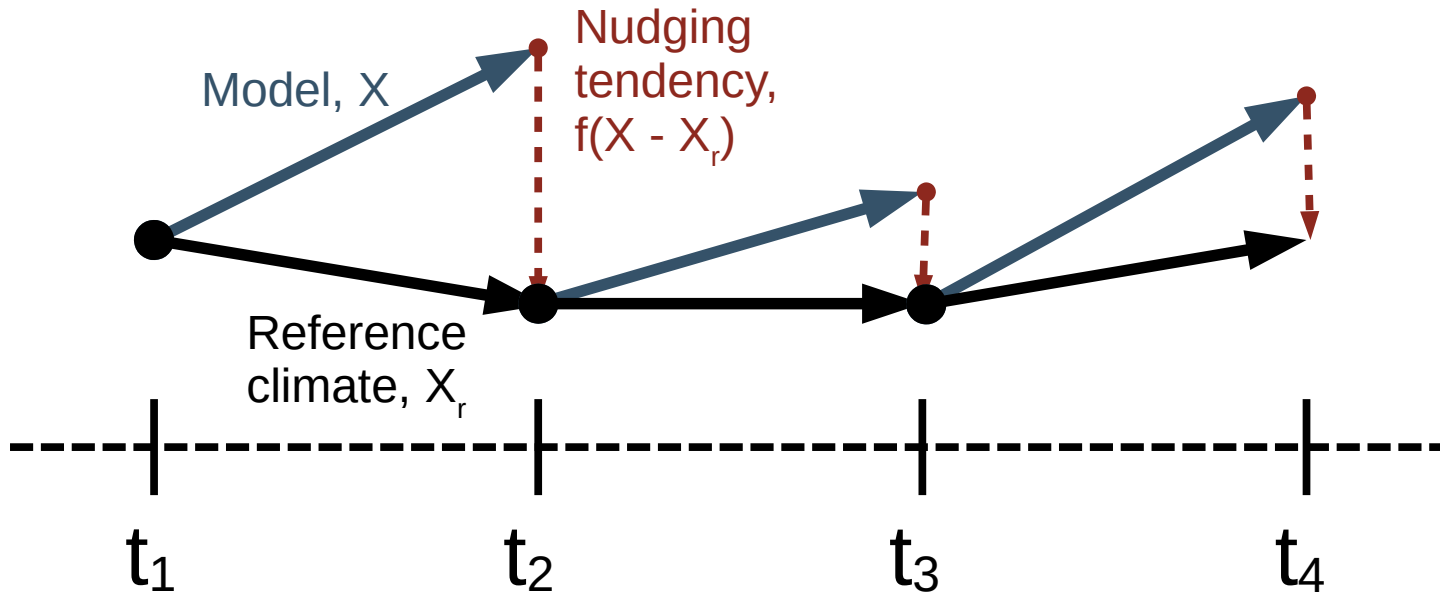
ILMATIETEEN LAITOS  
METEOROLOGISKA INSTITUTET  
FINNISH METEOROLOGICAL INSTITUTE

Thank you

05/18/2022 **Nicholas Tyrrell**

# Tendency Adjustment

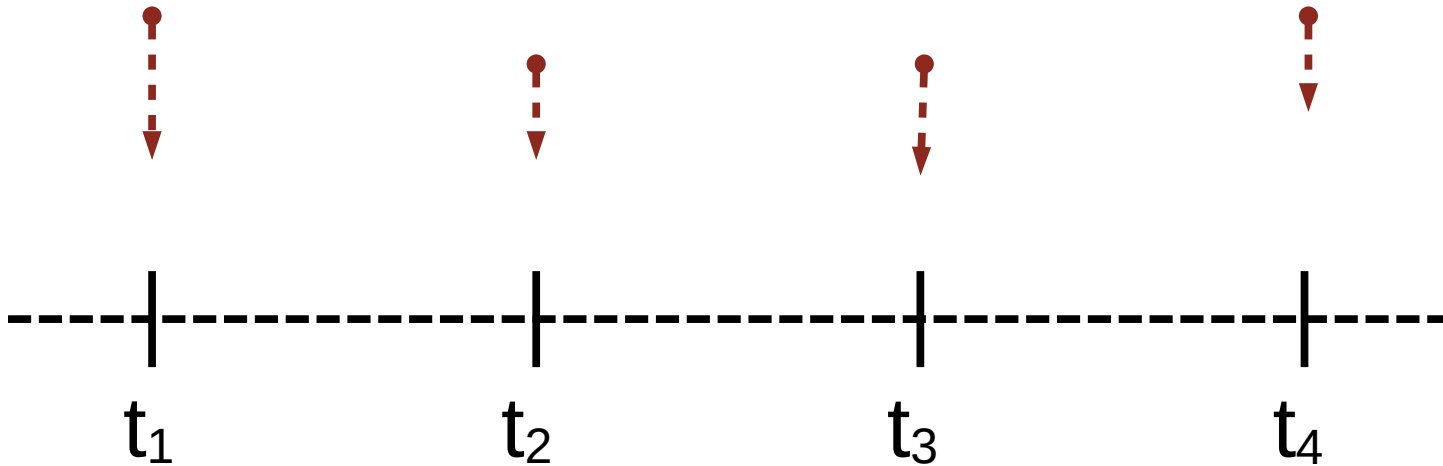
Temperature, winds, surface pressure



- Nudging step
  - Model is nudged towards future projection, 10-30 yrs
  - Correction depends on difference of model and obs.
- Tendencies collected
  - 12-month climatology of tendencies
  - Represents inherent model bias
- Tendency adjustment
  - Tendencies added at each step
  - Correction independent of model state

# Tendency Adjustment

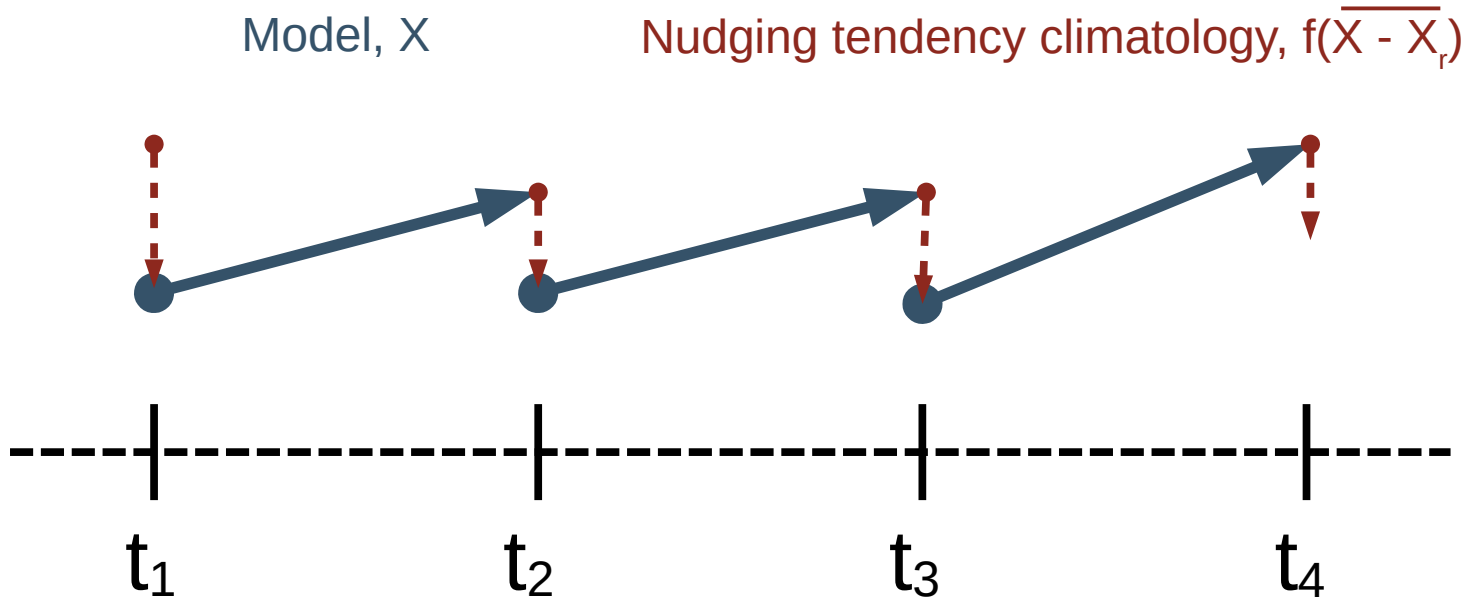
Nudging tendency climatology,  $f(\overline{X} - \overline{X}_r)$



- Nudging step
  - Model is nudged towards future projection, 10-30 yrs
  - Correction depends on difference of model and obs.
- Tendencies collected
  - 12-month climatology of tendencies
  - Represents inherent model bias
- Tendency adjustment
  - Tendencies added at each step
  - Correction independent of model state



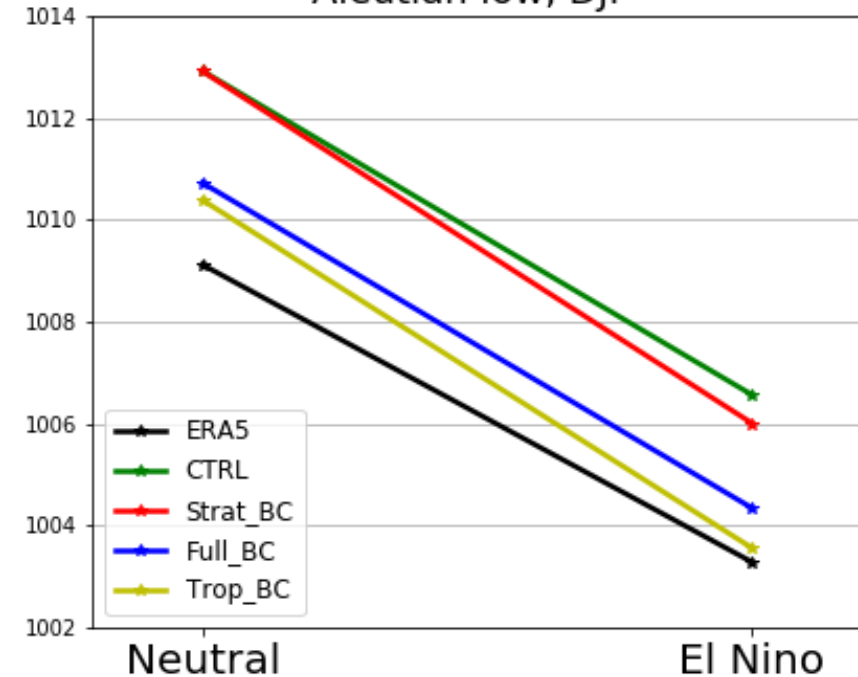
# Tendency Adjustment



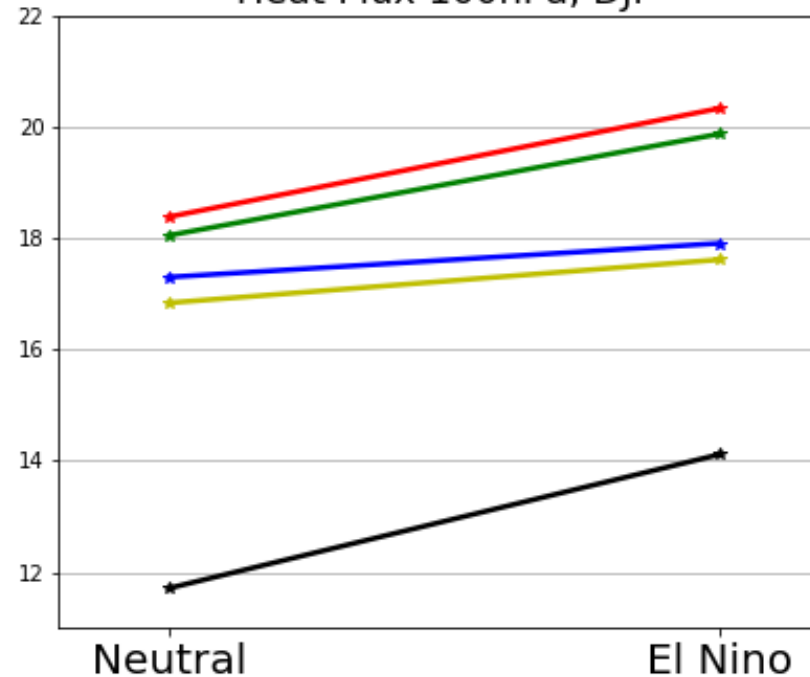
- Nudging step
  - Model is nudged towards future projection, 10-30 yrs
  - Correction depends on difference of model and obs.
- Tendencies collected
  - 12-month climatology of tendencies
  - Represents inherent model bias
- Tendency adjustment
  - Tendencies added at each step
  - Correction independent of model state

# El Niño Bias Correction key results

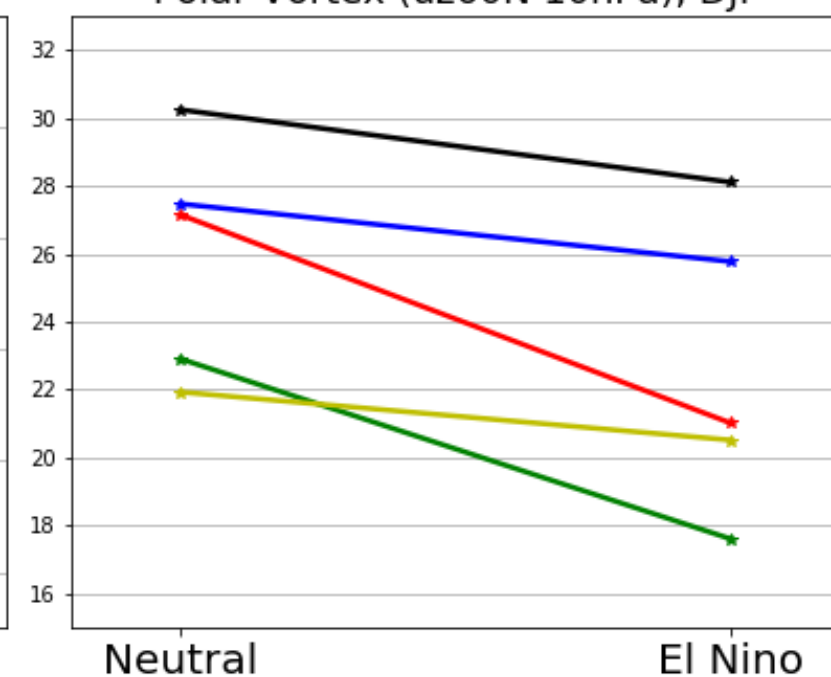
Aleutian low, DJF



Heat Flux 100hPa, DJF



Polar Vortex (uz60N 10hPa), DJF



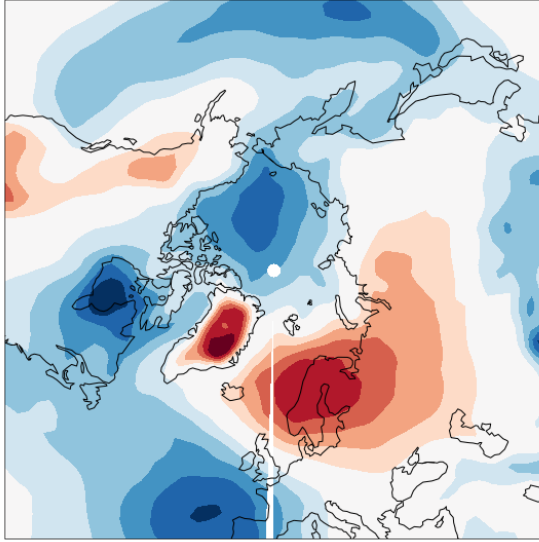
- Biases in Aleutian Low do not affect response to El Niño
- Aleutian Low biases translate to differences in wave flux into stratosphere
- Biases in Polar Vortex do not affect anomalous response to wave flux

# Tendency Adjustment Technique

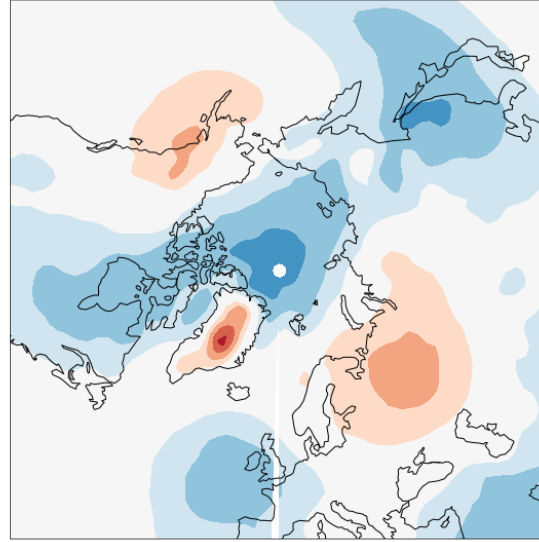
- ECHAM6 atmospheric model.
  - Resolution T63  $\approx$  180km, 46 levels, up to 0.01 hPa ( $\approx$  80km)
  - Spectral model, only features above  $\sim$ 500km are nudged
  - Nudged and corrected variables are temperature, divergence & vorticity (i.e. winds), surface pressure

# Recreating the future pressure

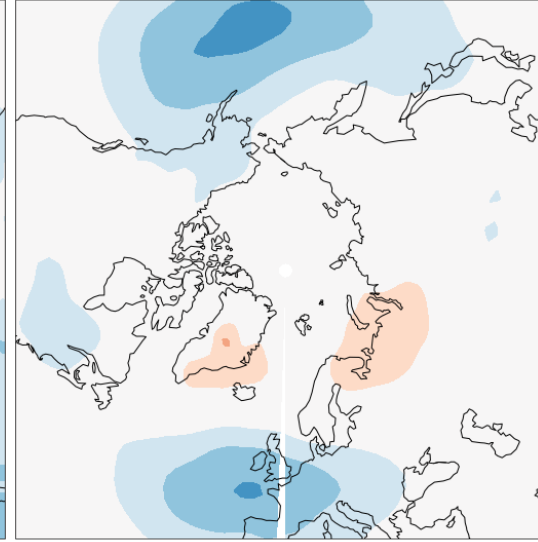
MPI\_FUT - CTRL slp



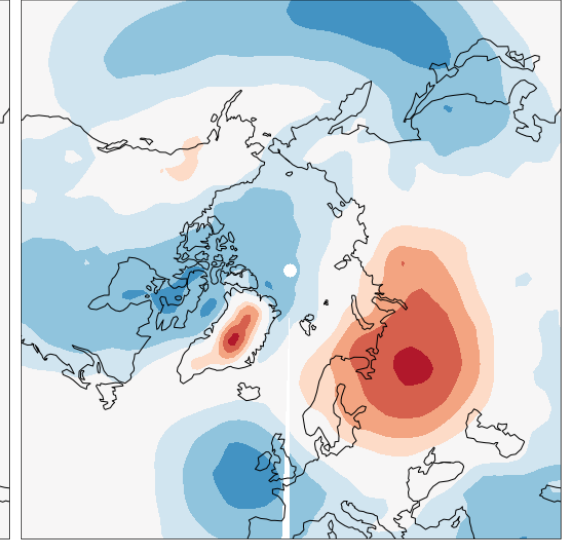
Temperature tend.



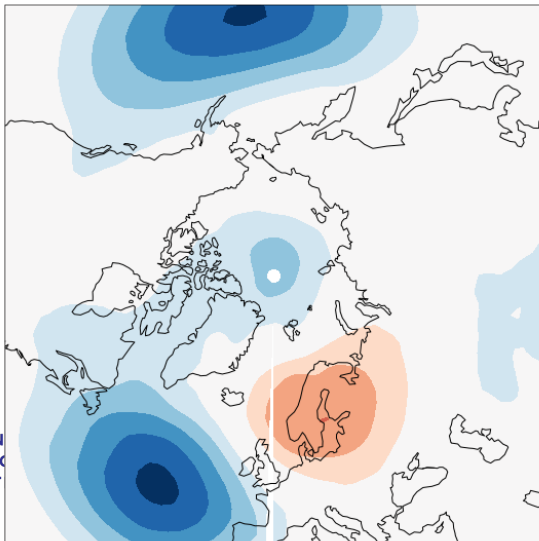
Surface Pressure tend.



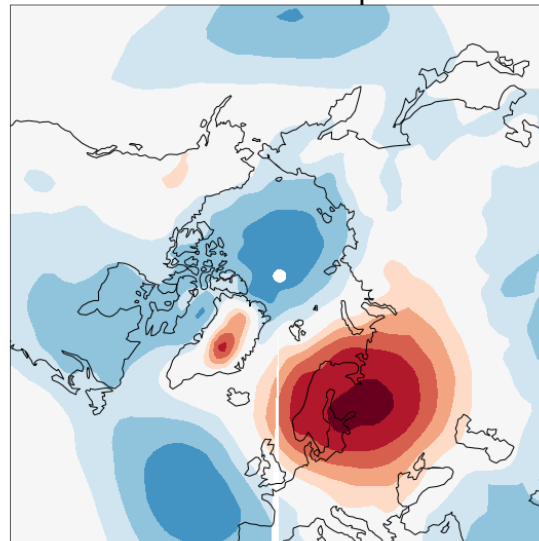
Temp. & Press.



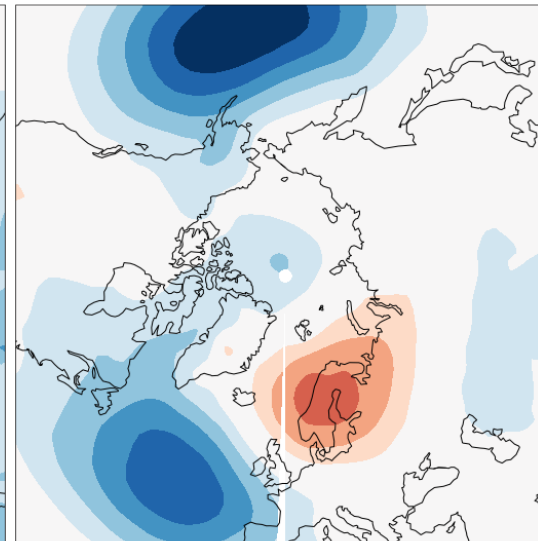
Wind tend.



Wind & Temp.



Wind & Pres.



Wind, Temp. & Pres.

