Aspen Global Change Institute, June 14, 2017

Changes in mid-latitude atmospheric dynamics in the CESM Large Ensemble

What role AA compared to other processes in a warming climate?

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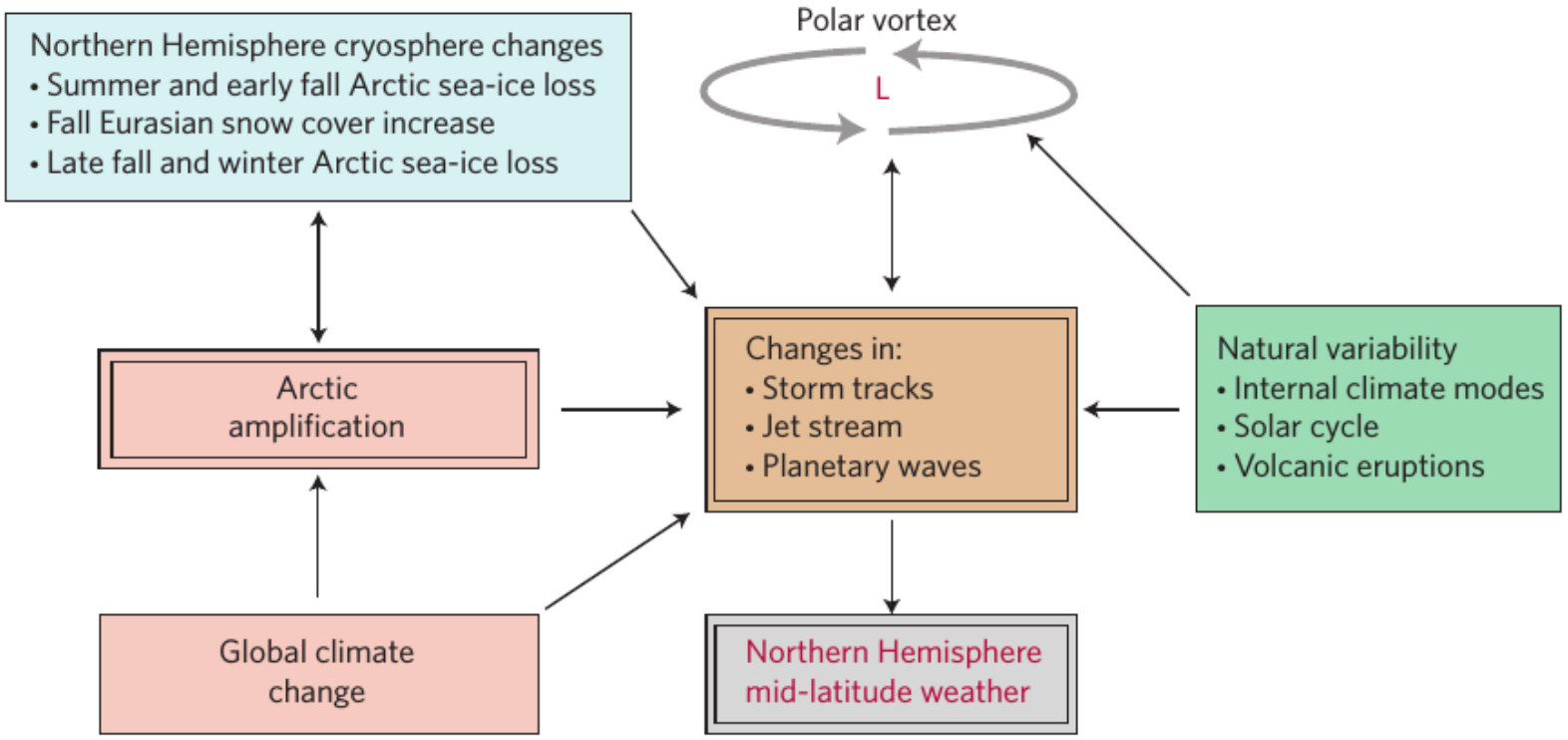
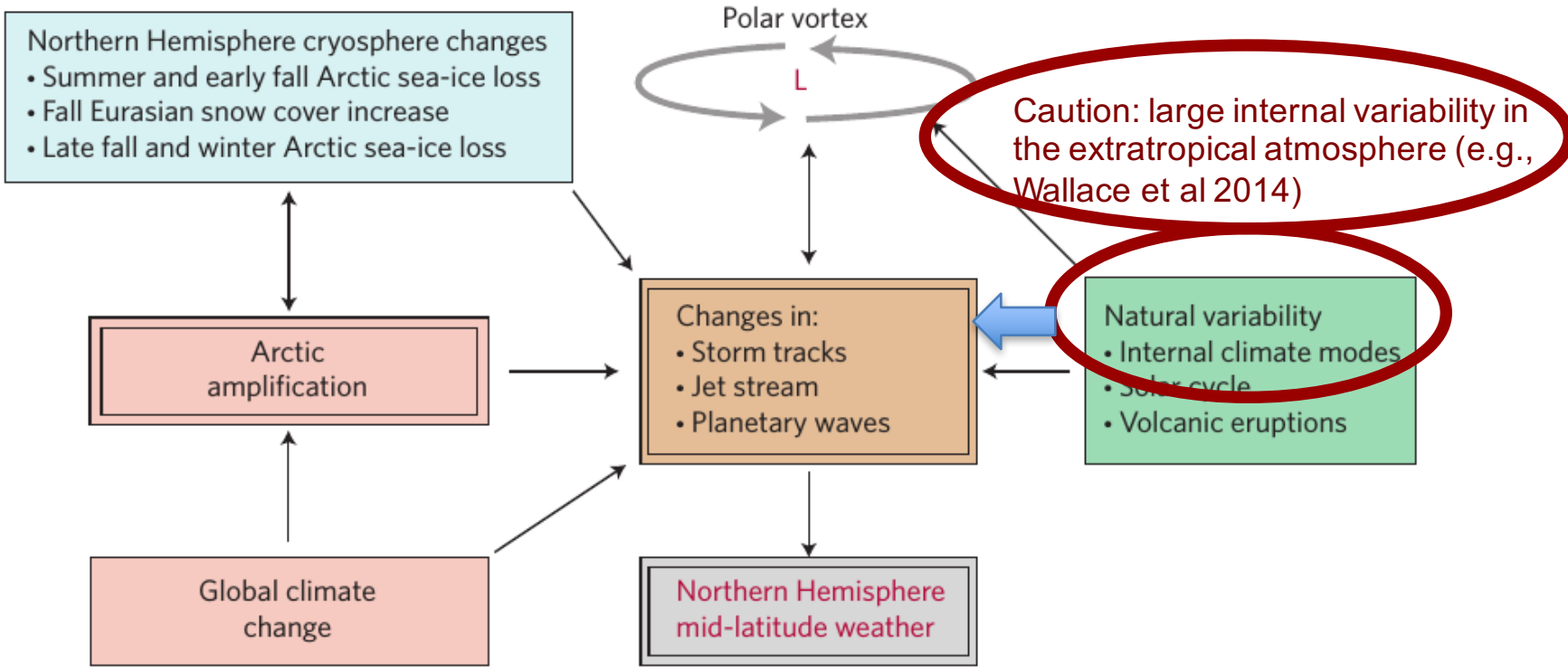
1. AA has been suggested as a driver of recent cooling trend in mid-latitudes, as well as responsible for increased jet stream meandering, blockings and associated extreme events (e.g., Cohen et al. 2014, Francis and Vavrus 2012, 2015). However, in observations, attribution of the recent trends to AA is debated and hampered by large internal variability (Barnes 2013, Screen and Simmonds 2013, Barnes and Screen 2015, Overland et al. 2015).



Cohen et al. (2014)

1. AA has been suggested as a driver of recent cooling trend in mid-latitudes, as well as responsible for increased jet stream meandering, blockings and associated extreme events (e.g., Cohen et al. 2014, Francis and Vavrus 2012, 2015). However, in observations, attribution of the recent trends to AA is debated and hampered by large internal variability (Barnes 2013, Screen and Simmonds 2013, Barnes and Screen 2015, Overland et al. 2015).



Cohen et al. (2014)

It is therefore attractive to use a large ensemble of simulations to increase the signal to noise ratio

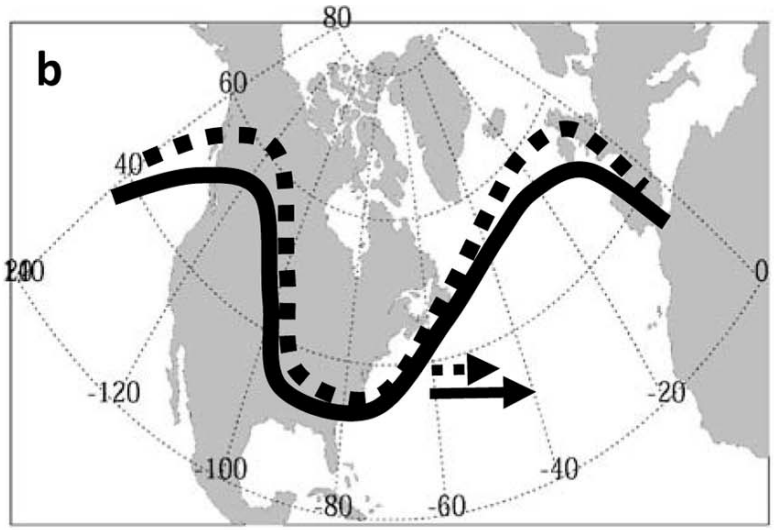
CESM large ensemble (CESM-LENS) from NCAR

40 members of fully coupled simulations

Run over 1920-2100

Historical forcing to 2005 thereafter following RCP8.5 anthropogenic emissions

An opportunity to investigate <u>robustly</u> how the mid-latitude climate responds to a strong Arctic sea ice decline

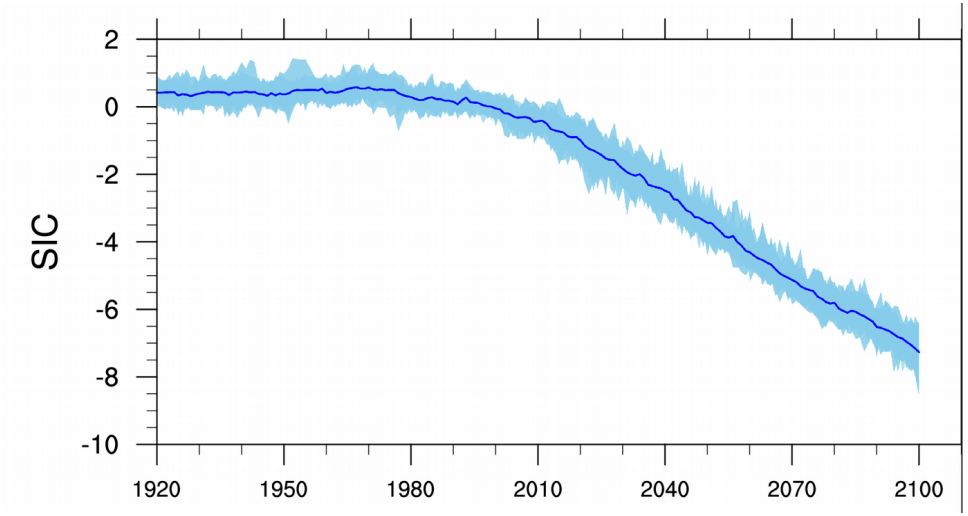


From Francis & Vavrus (2012):
"Evidence linking Arctic amplification to extreme weather in mid-latitudes"

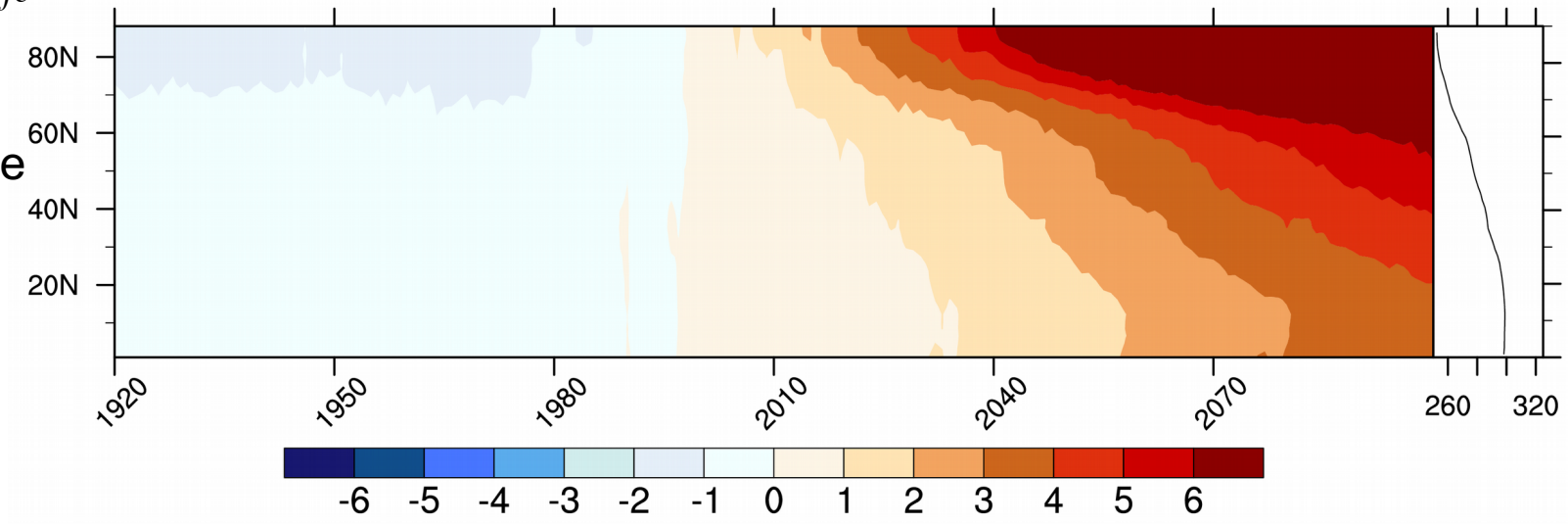
Evolution of zonal mean of ΔSIC and ΔT_{sfc} in LENS ensemble mean

40-member ensemble mean, anomalies relative to 1981-2010

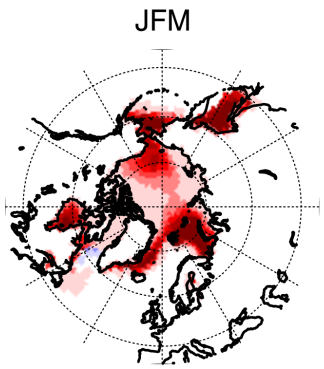
ΔSIC



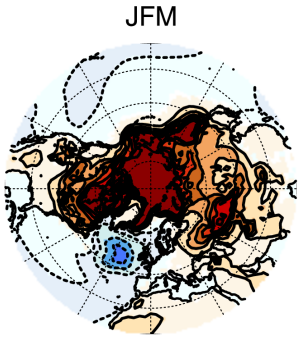
ΔT_{sfc}



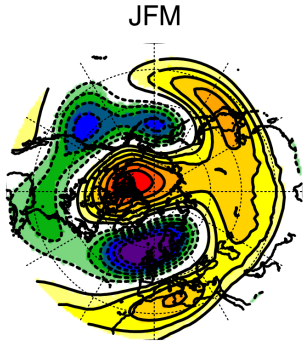
Ensemble mean changes in winter (JFM) between 2071-2100 and 1981-2010



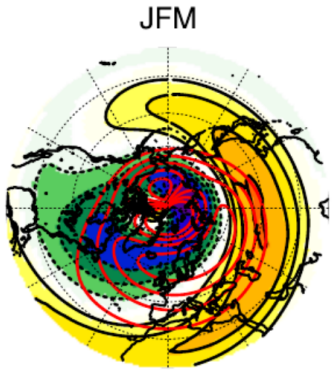
SIC (%)



T2m (K)

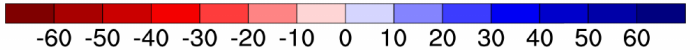


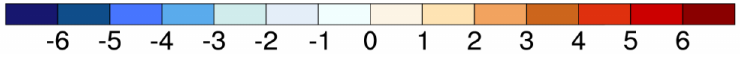
Z500 (m)

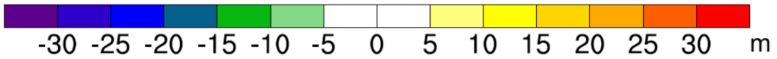


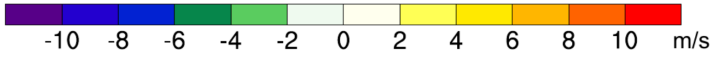
U_10hPa (m/s)

Subtract the global mean









Changes in zonal mean flow at 50N

Zonal Index: ZON

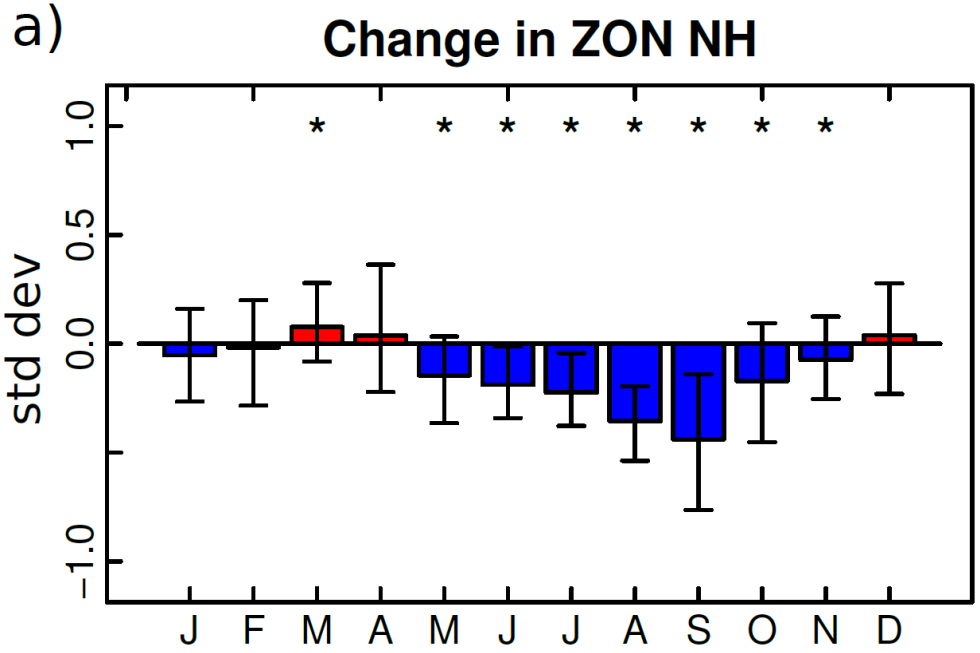
ZON = $Z500_{mid}$ - $Z500_{pol}$

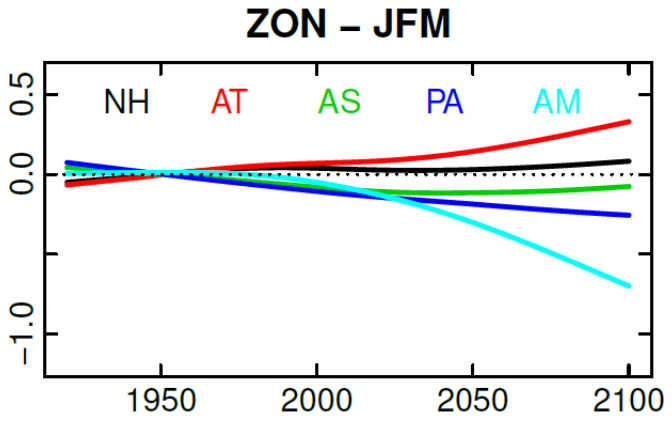
Changes in zonal mean flow at 50N

Zonal Index: ZON

ZON = $Z500_{mid}$ - $Z500_{pol}$

Change in zonal index at 50N in CESM-LENS





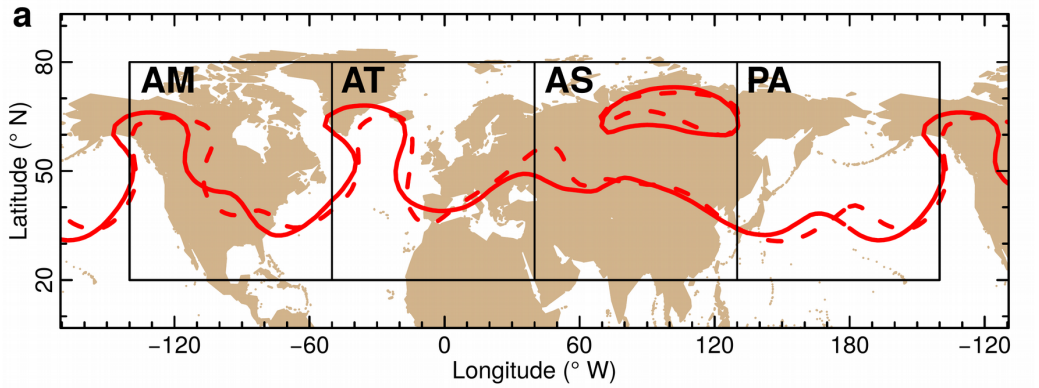
2071-2100 vs 1981-2010

Peings et al (2017)

Change in waviness at 50N

Sinuosity: SIN

length of the average Z500 isopleth within 30-70N



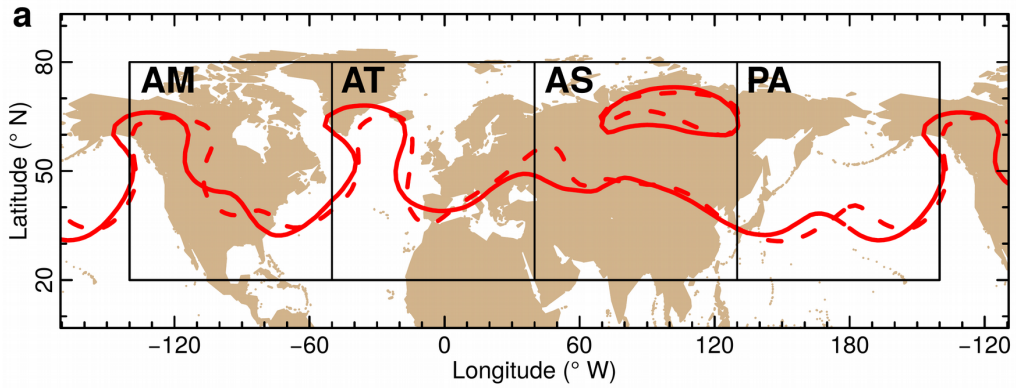
Similar to river sinuosity used in geomorphology

A straightforward metric to measure the waviness of the atmospheric circulation, or meanders in the mid-latitude jet stream, and how it responds to climate change

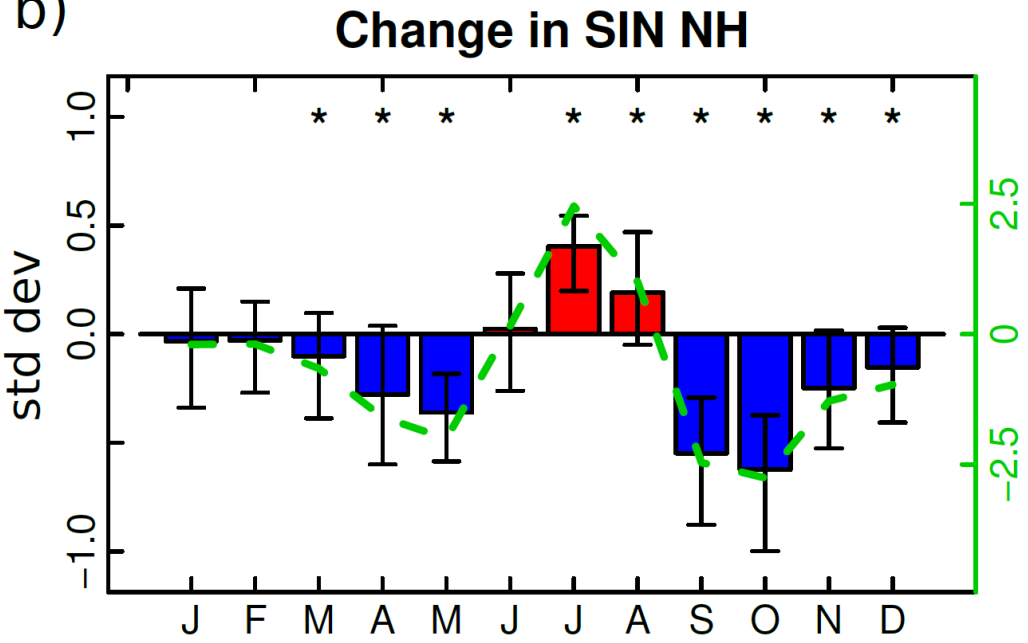
Change in waviness at 50N

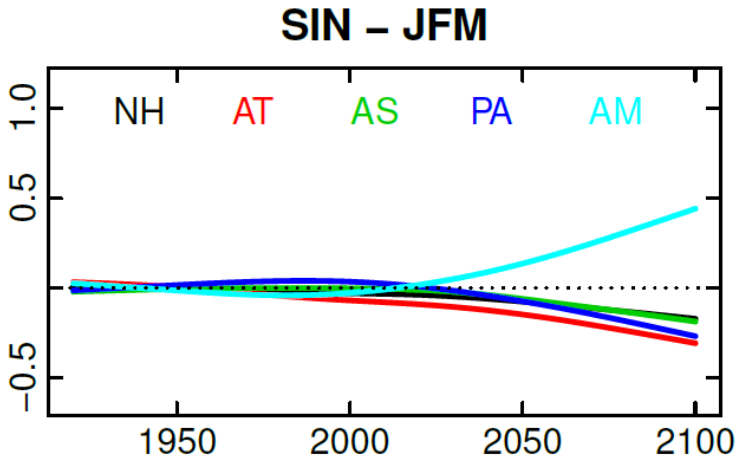
Sinuosity: SIN

length of the average Z500 isopleth within 30-70N



b)

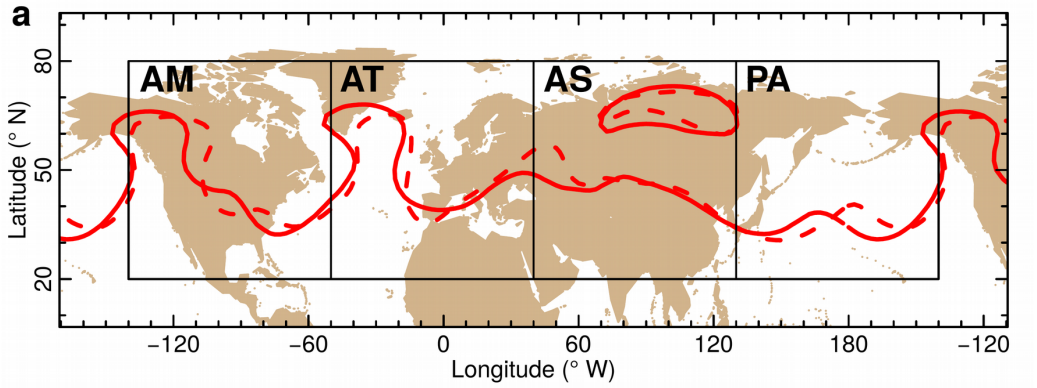




Peings et al (2017)

Change in waviness at 50N

Sinuosity



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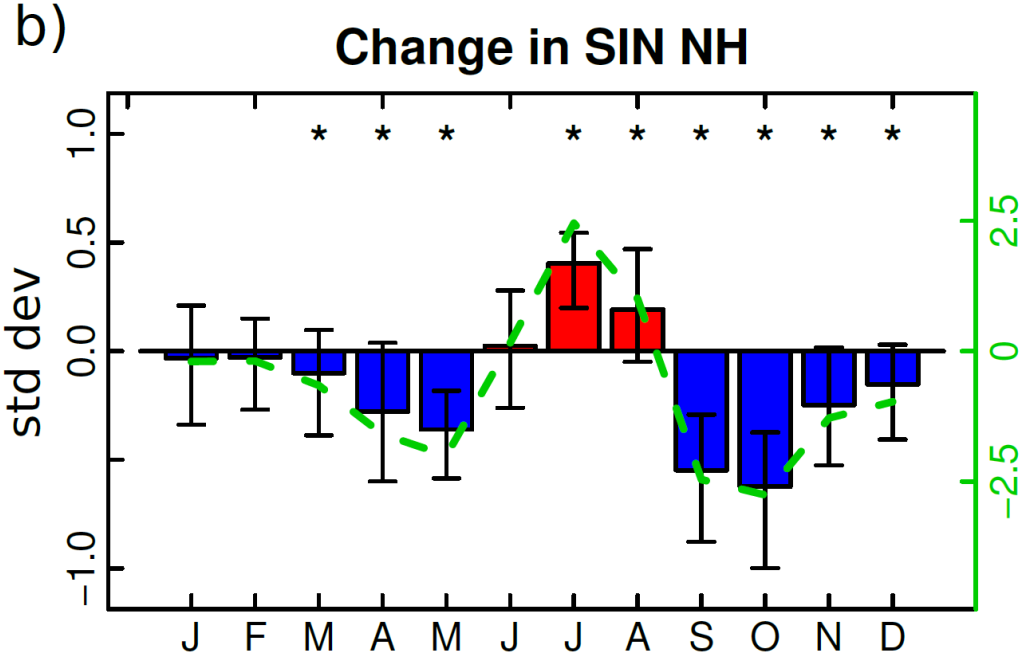
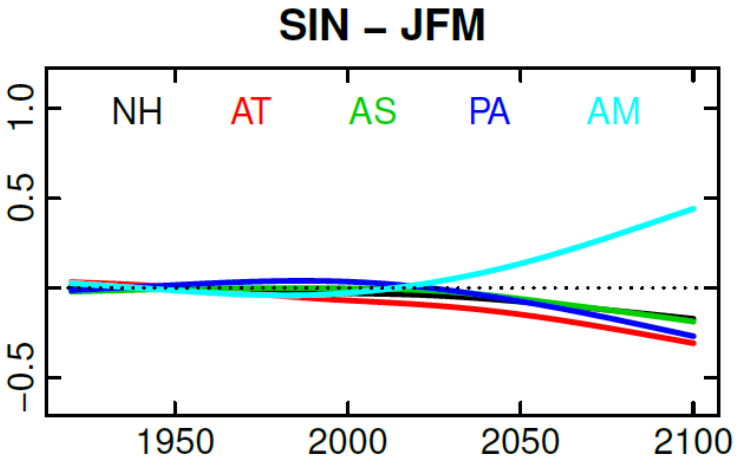
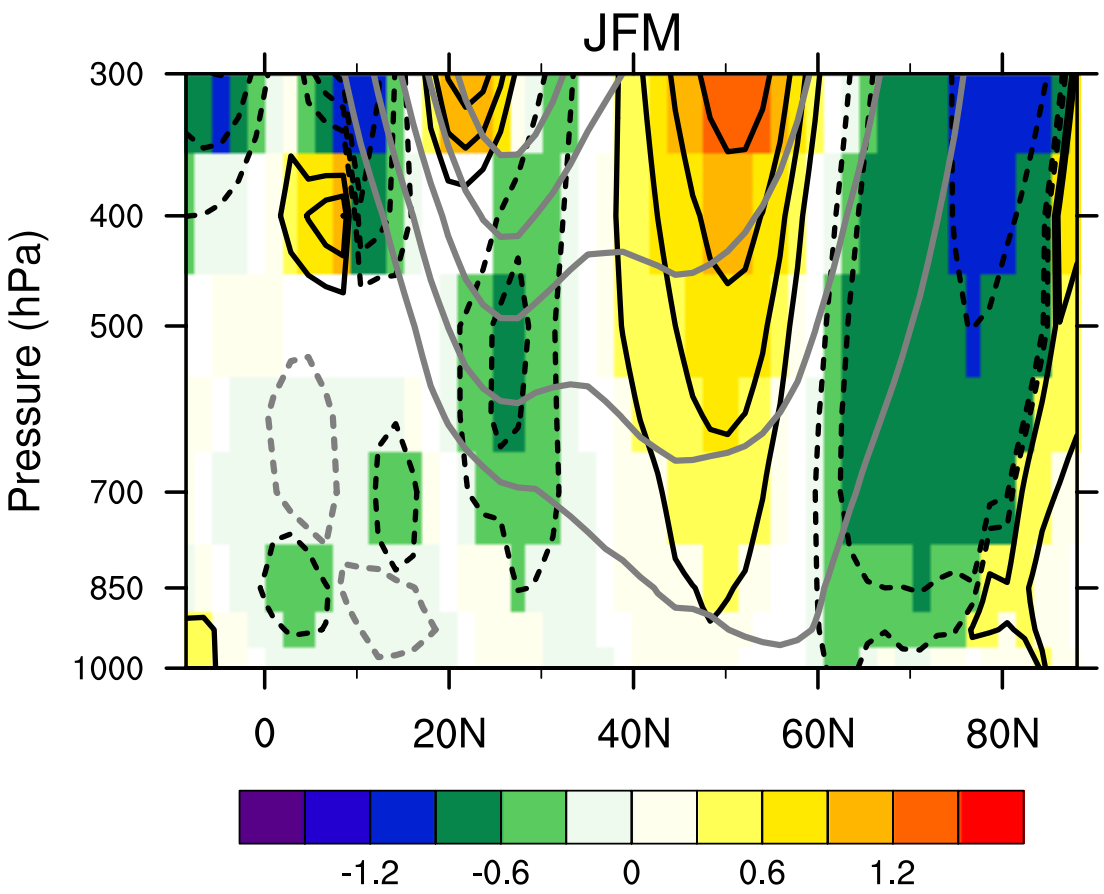




Does not support the "Francis & Vavrus hypothesis" except over AM

Changes in the eddy-driven jet stream

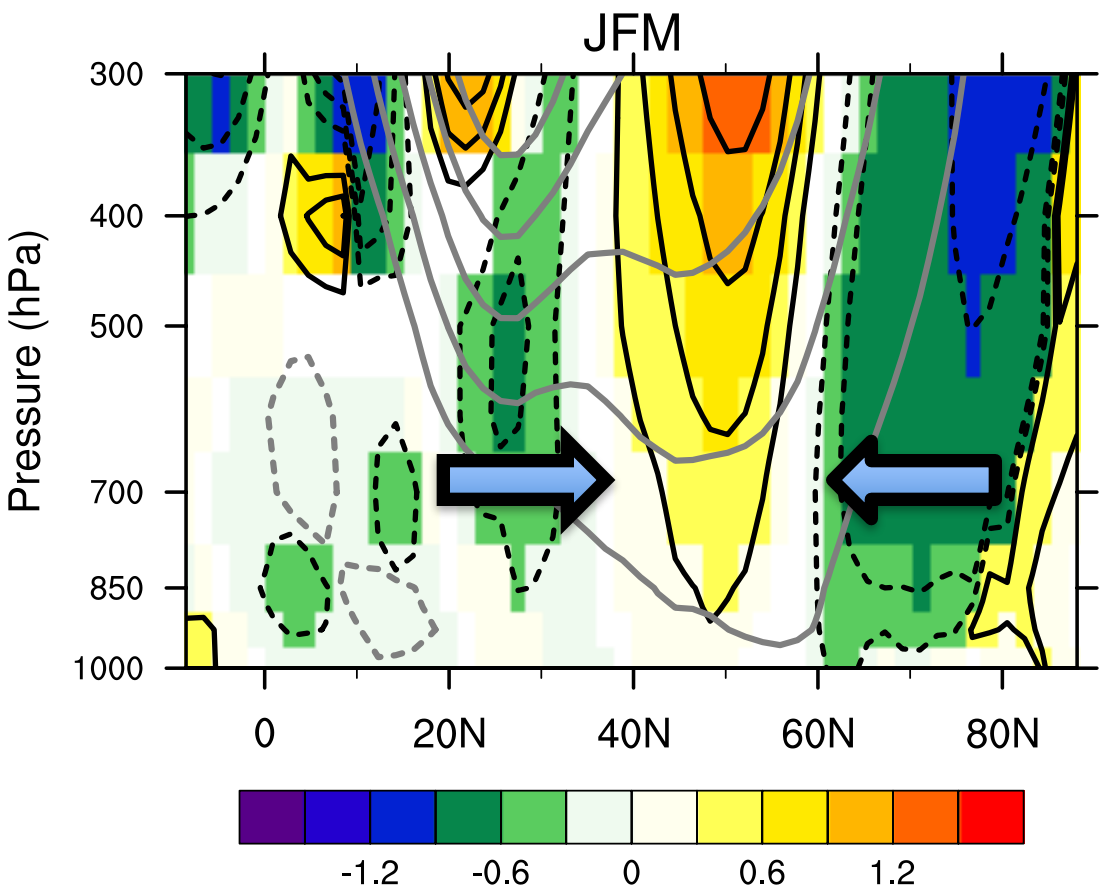
NH zonal mean



2071-2100 vs 1981-2010 pressure/latitude change in zonal mean zonal wind (m/s) in CESM-LENS. Gray contours represent climatology.

Changes in the eddy-driven jet stream

NH zonal mean



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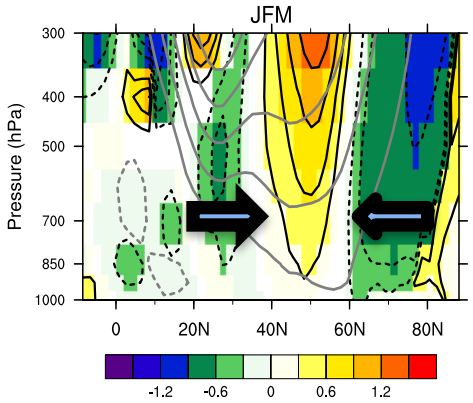
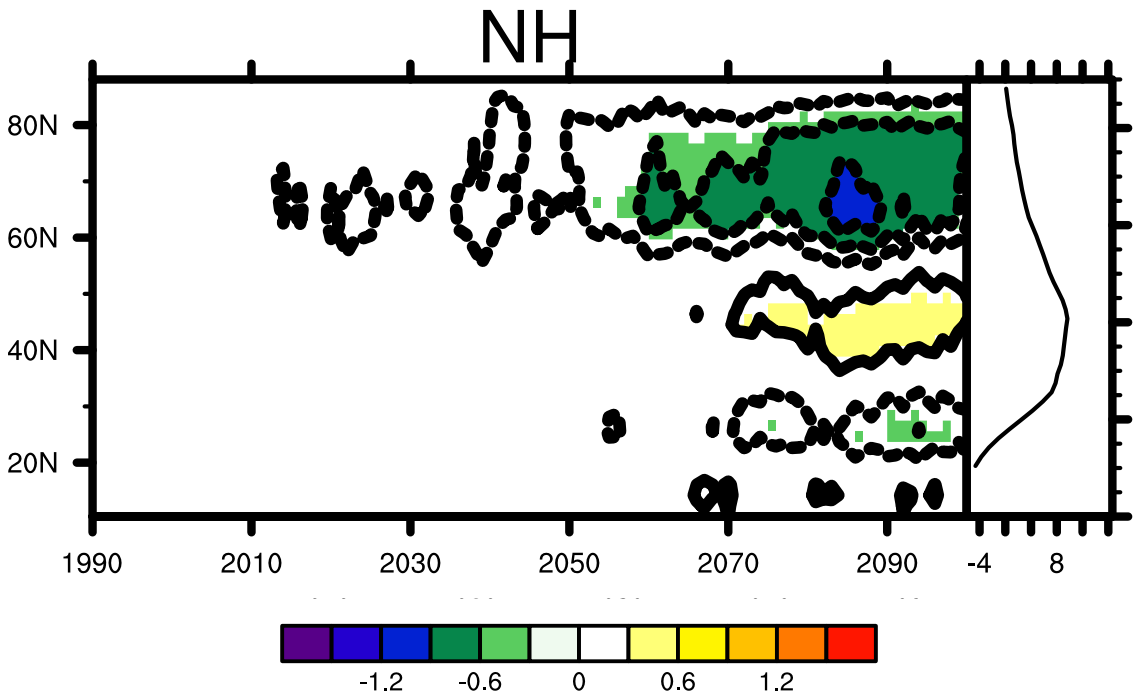
Changes in the eddy-driven jet stream (JFM)

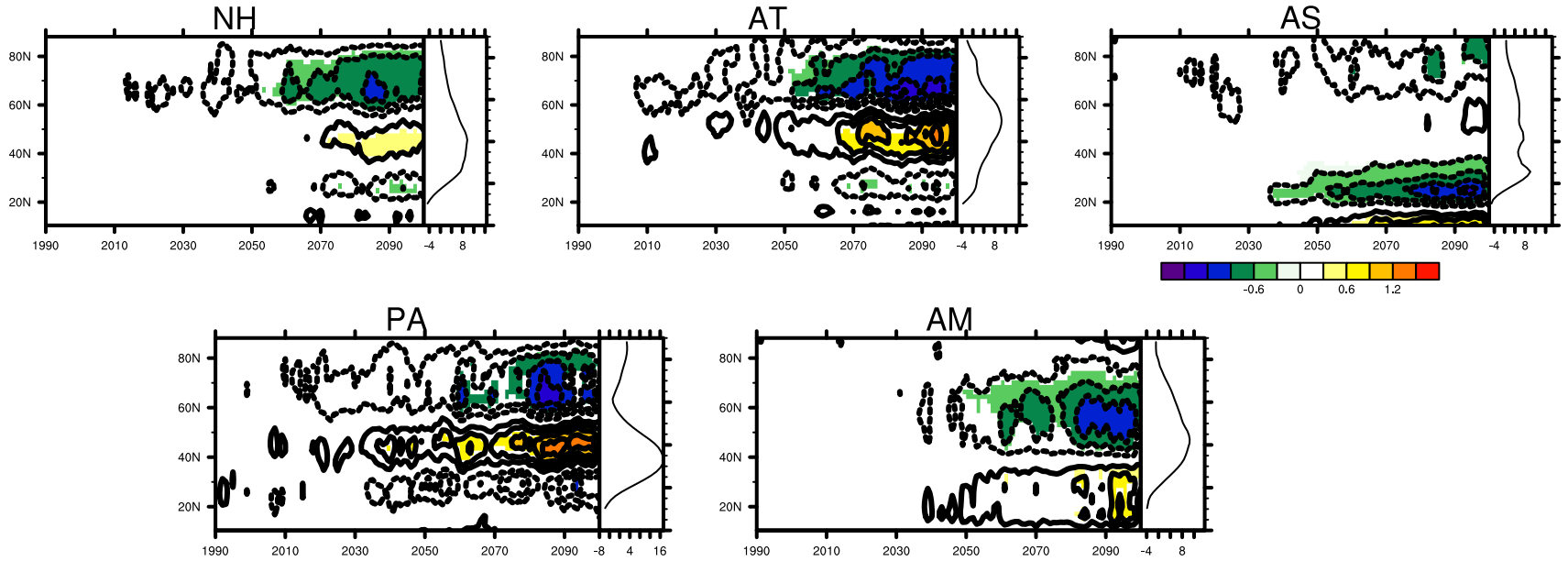




Latitude-time Hovmoller plots of anomalies in JFM zonal mean U700 (m/s) (relative to 1981-2010 climatology, shown in the right panel) in the NH. The 40-member ensemble mean is shown, with shading indicating anomalies that are significant at the 95% confidence level.

Changes in the eddy-driven jet stream (JFM)

Need to change lower panel

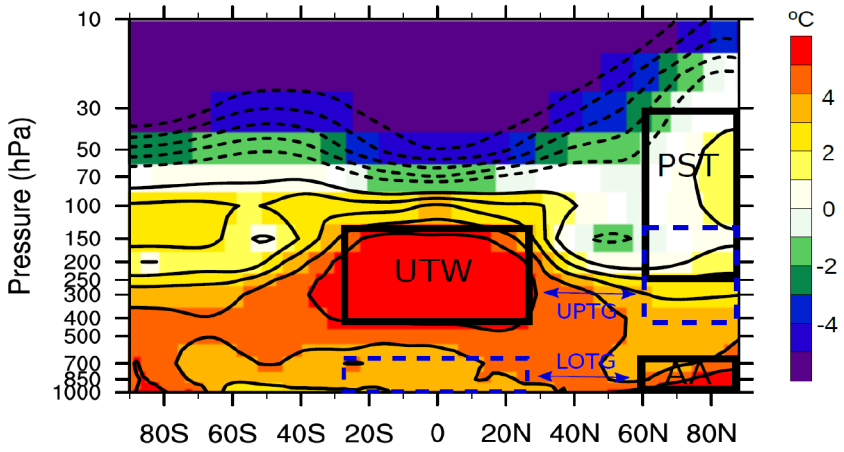


Latitude-time Hovmoller plots of anomalies in JFM zonal mean U700 (m/s) (relative to 1981-2010 climatology, shown in the right panels) for the different longitudinal sectors.

Narrowing and reinforcement of the Atlantic and Pacific jets at the end of the 21st century in CESM-LENS

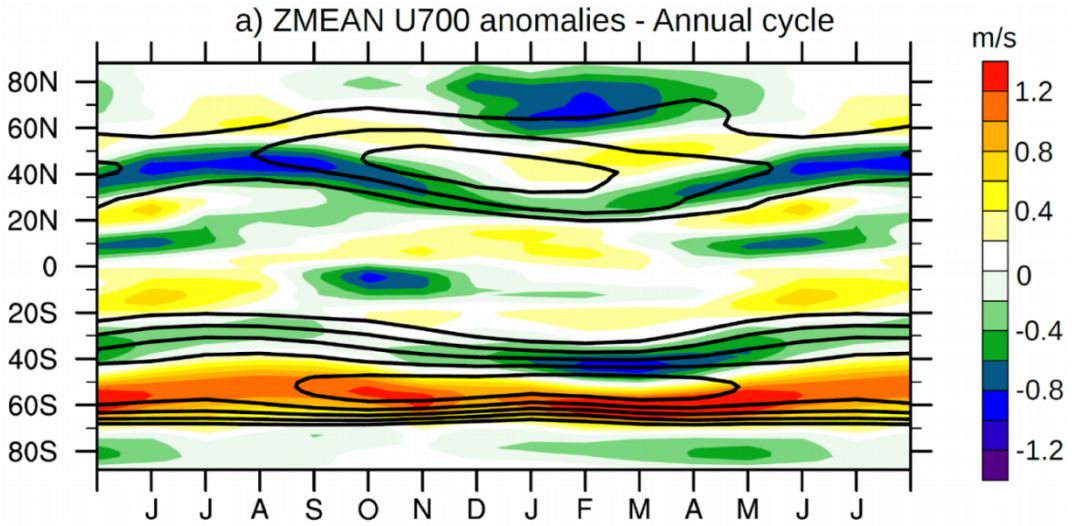
Changes in the eddy-driven jet stream

Change in zonal mean temperature (JFM), shown in pressure vs latitude cross-section



"Tug-of-war" between the Arctic warming and the tropical warming in the upper-troposphere, with opposite effects on each side of the jet

Change in zonal mean westerly winds in the lower troposphere as a function of month and latitude



Arctic Amplifications contributes to the **asymmetry between the Northern Hemisphere and the Southern Hemisphere,** where polar warming near the surface is missing.

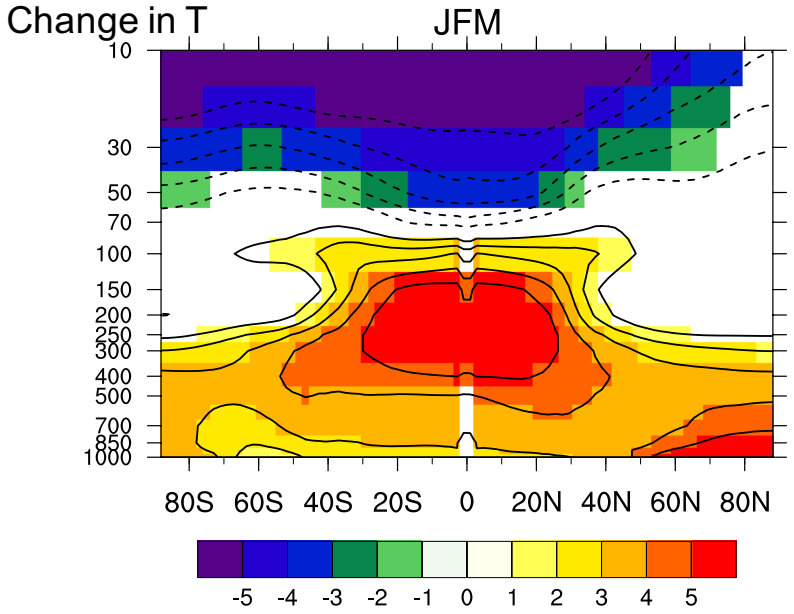
Peings et al (2017)

These results were obtained with 40 ensemble members of one climate model, the CESM

What happens in the CMIP5 ensemble mean?

Examine 36 ensemble members from 36 different models with different climate sensitivity etc.

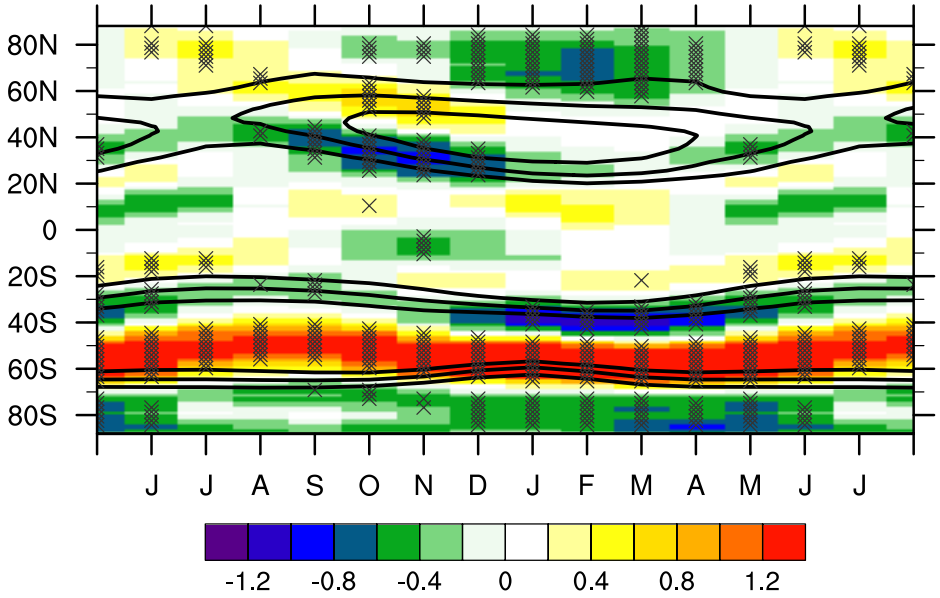
Changes in the eddy-driven jet stream from CMIP5



NH zonal average in winter

Still have the tug-of-war between the Arctic warming and the tropical upper-tropospheric warming.
No significant signal in PST

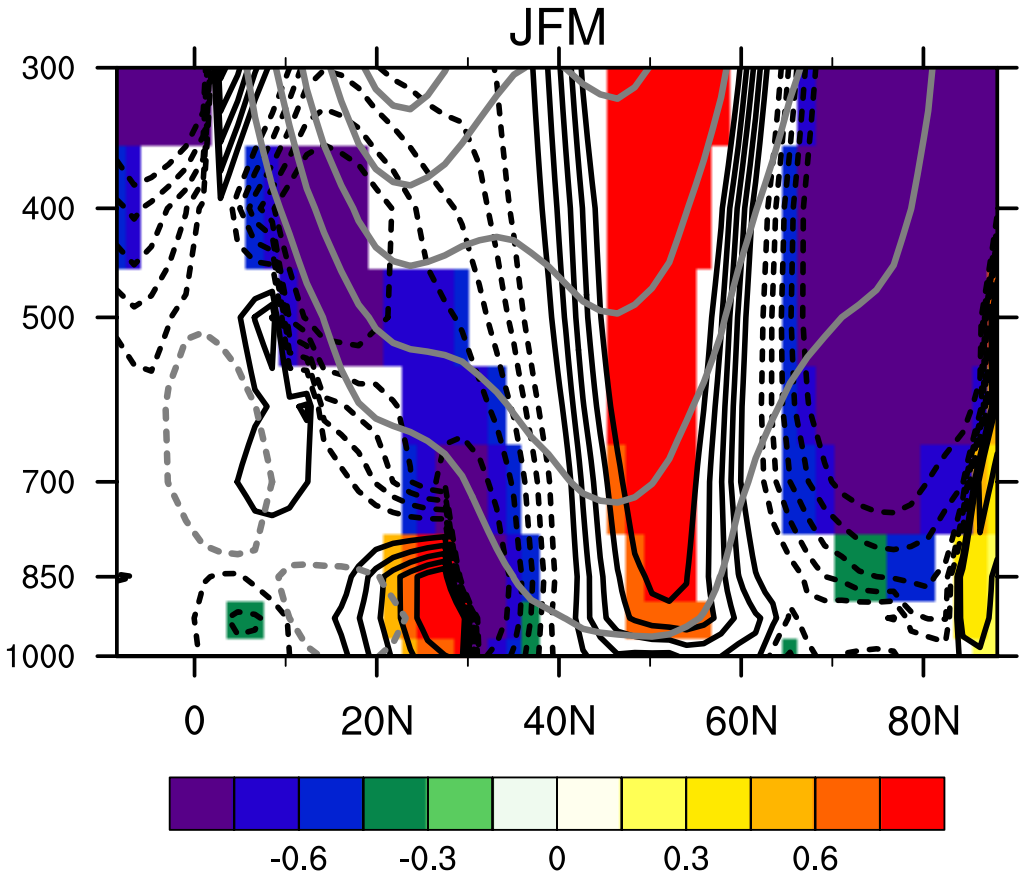
Change in zonal mean westerly winds at 700hPa as a function of month and latitude



The narrowing and reinforcement of the zonal mean jet still occurs, but it is **earlier** or in fall to early winter in the CMIP5 ensemble

Changes in the eddy-driven jet stream from CMIP5

Sector mean over North Atlantic



2065-2095 vs 1981-2010 pressure/latitude change in sector mean (Atlantic) zonal wind (m/s) in CMIP5. Gray contours represent climatology.

Changes in the eddy-driven jet stream from CMIP5

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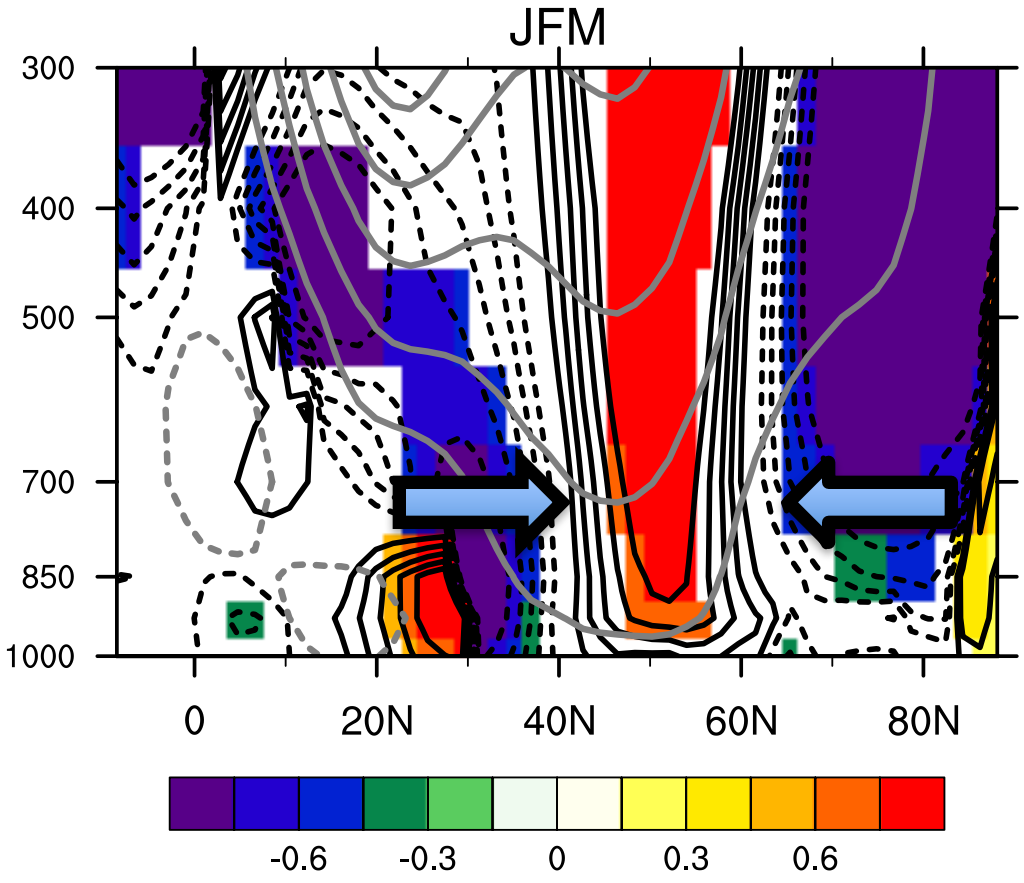
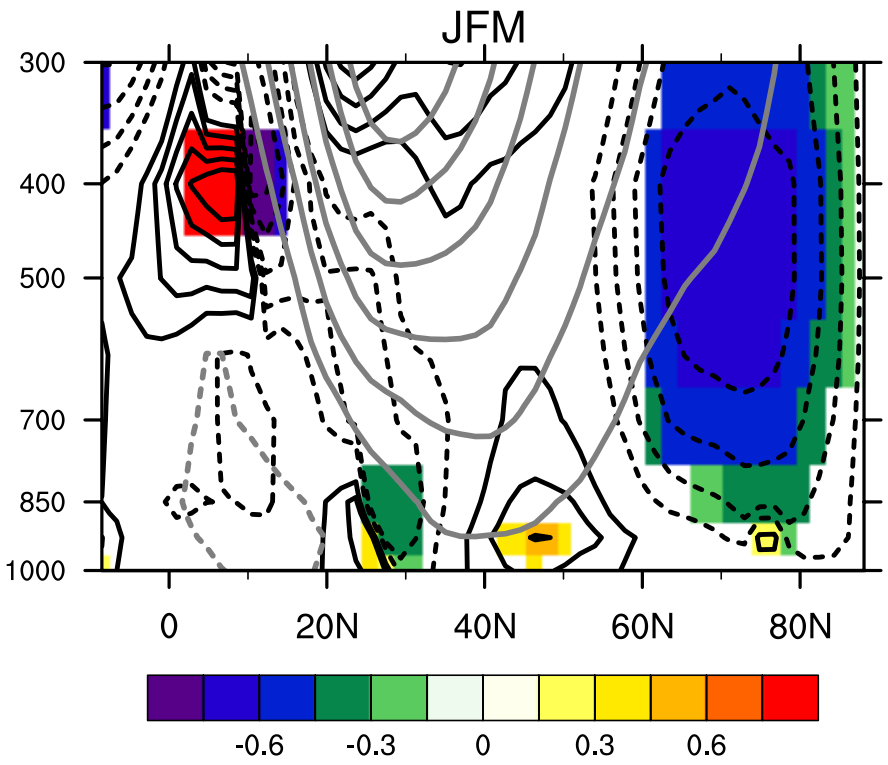


2065-2095 vs 1981-2010 pressure/latitude change in sector mean (Atlantic) zonal wind (m/s) in CMIP5. Gray contours represent climatology.

Changes in the eddy-driven jet stream from CMIP5

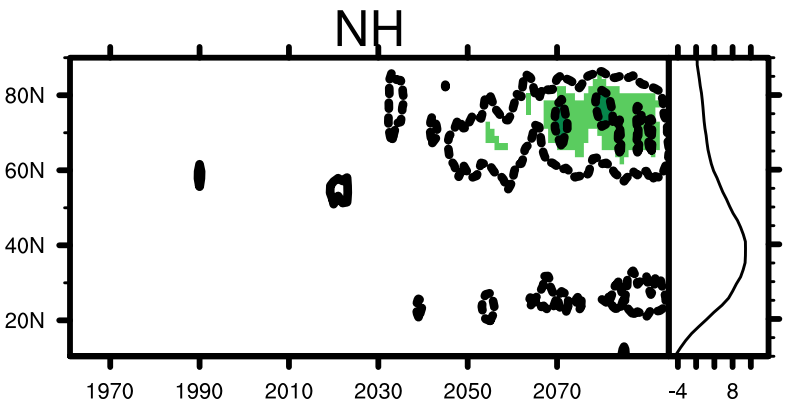
Zonal mean over NH in winter (JFM)



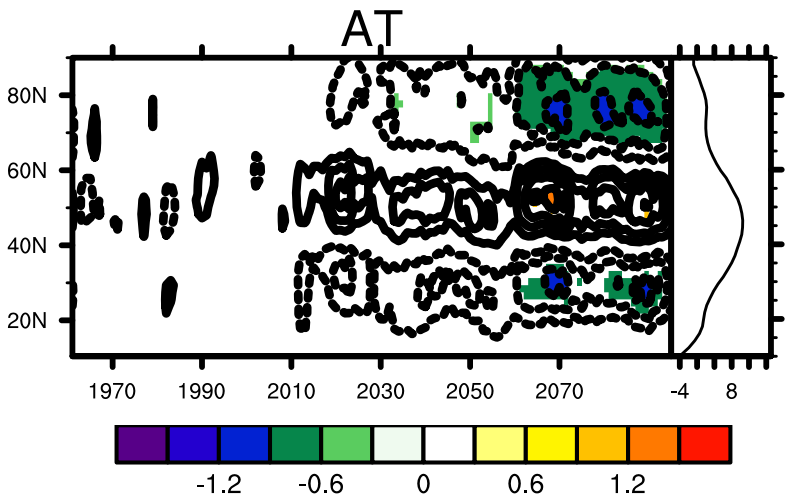
2065-2095 vs 1981-2010 pressure/latitude change in NH zonal-mean zonal wind (m/s) in winter (JFM) in CMIP5. Gray contours represent climatology.

Results from CMIP5 models

JFM anomalies of zonal mean U700



JFM anomalies of AT sector mean U700

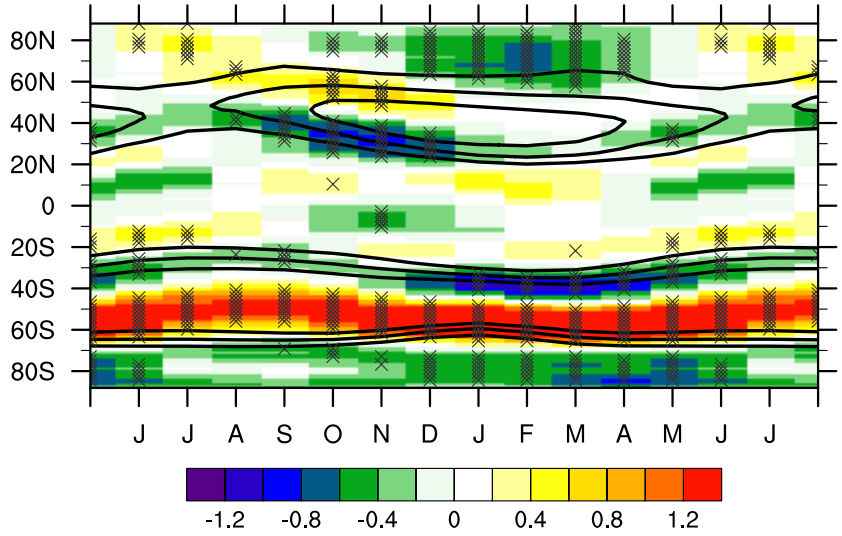


Ensemble mean of 36 CMIP5 models: latitude-time Hovmöller plots of anomalies in JFM zonal mean U700 (m/s) (relative to the 1981-2010 climatology, shown in the right panels), over the NH (left) and AT sector (right).

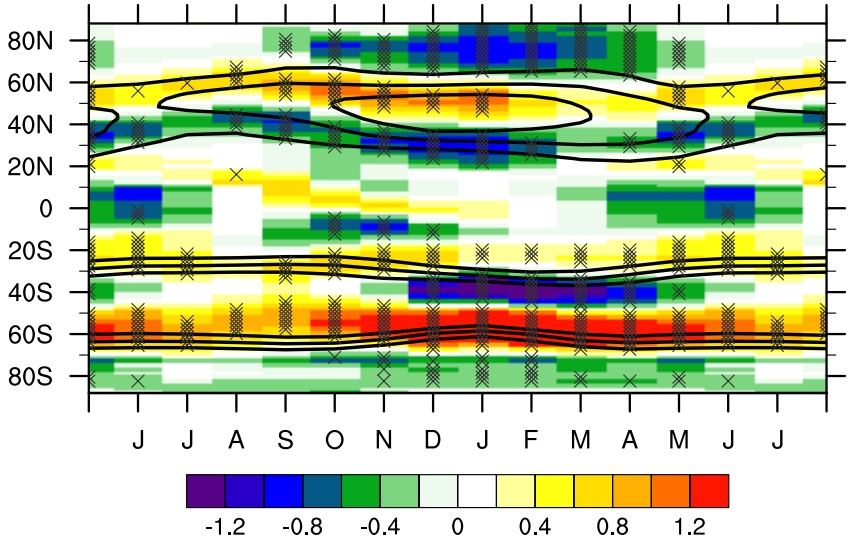
CMIP5 models also project a narrowing of the Atlantic eddy-driven jet in winter

Results from CMIP5 models

Change in zonal mean westerly winds at 700hPa as a function of month and latitude



NH



Atlantic sector

Conclusions

- CESM large ensemble has no significant change in NH Zonal Index at the end of the century. The response is sector dependent. Only the American sector shows a negative ZON response.
- SIN (sinuosity) is decreased over the NH in winter. Only over the American continent does SIN increase in winter.
- The response in the eddy driven jet is one of a narrowing and reinforcement of the zonal mean jet, primarily contributed to by the Atlantic and the Pacific sectors.
- Examined a 36 member ensemble of CMIP5 simulations. Also see the reinforcement and narrowing in the zonal mean jet, but it occurs earlier, or in late fall to early winter. Work in progress.

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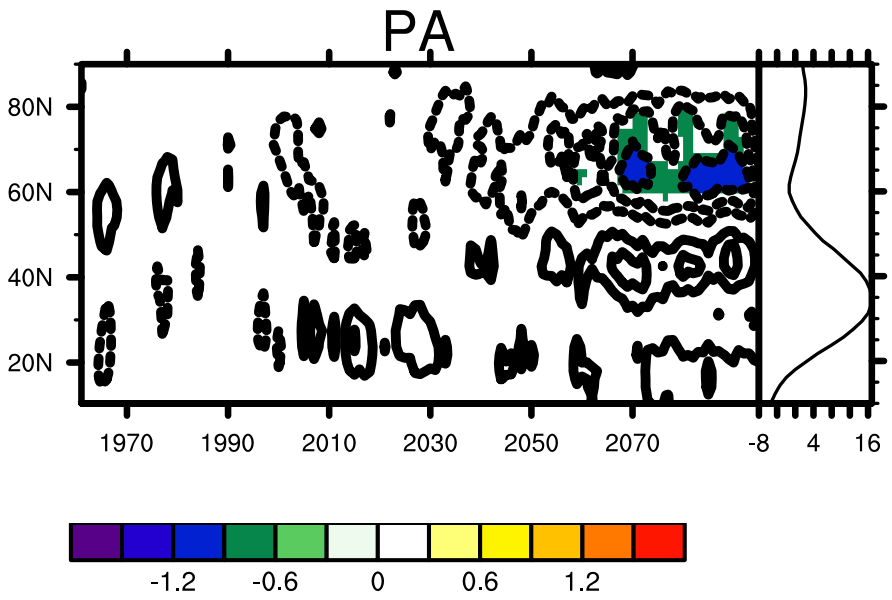
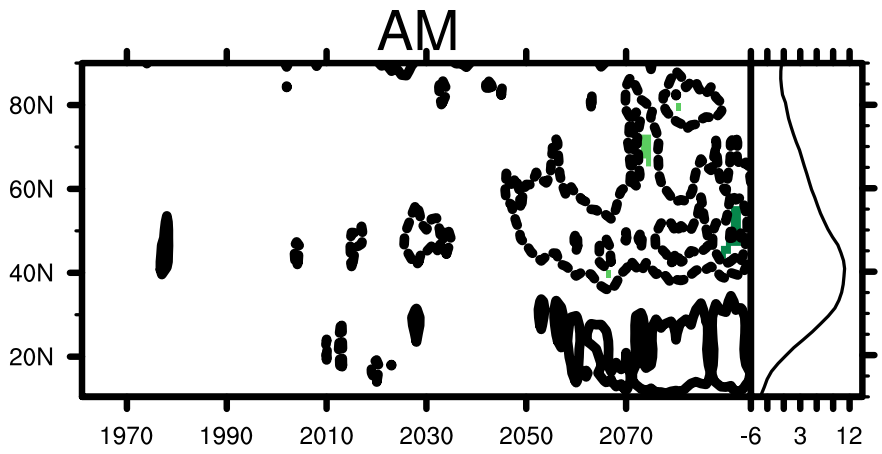
- Interested in hi-top forced experiments nudging to AA, UTW, PST one by one and in combination

CMIP5

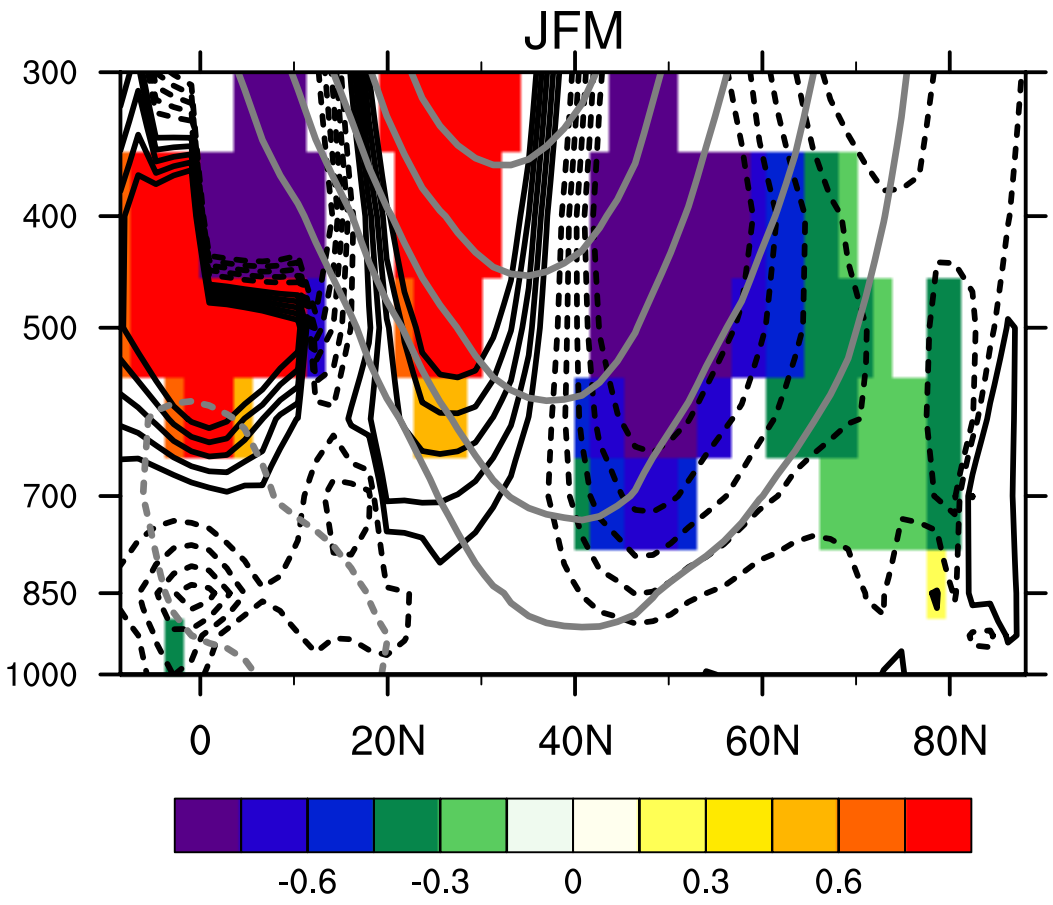

PA
80N
60N
40N
20N
1970
1990
2010
2030
2050
2070
-8
4
16
-1.2
-0.6
0
0.6
1.2

CMIP5



Changes in the eddy-driven jet stream from CMIP5

Sector mean over N America



2065-2095 vs 1981-2010 pressure/latitude change in zonal mean zonal wind (m/s) in CMIP5. Gray contours represent climatology.