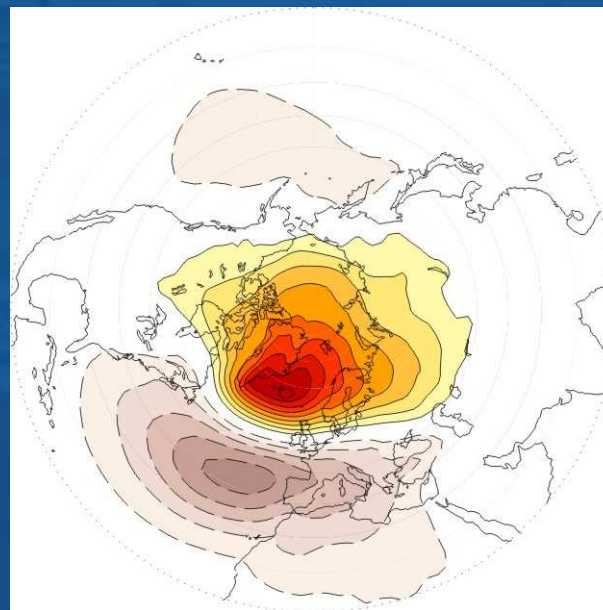


## On the hemispheric scale of the winter NAO



J. García-Serrano (BSC) and R. J. Haarsma (KNMI)

+

NCAR / A. de la Cámara, P. Hitchcock, I. R. Simpson

# On the hemispheric scale of the winter NAO

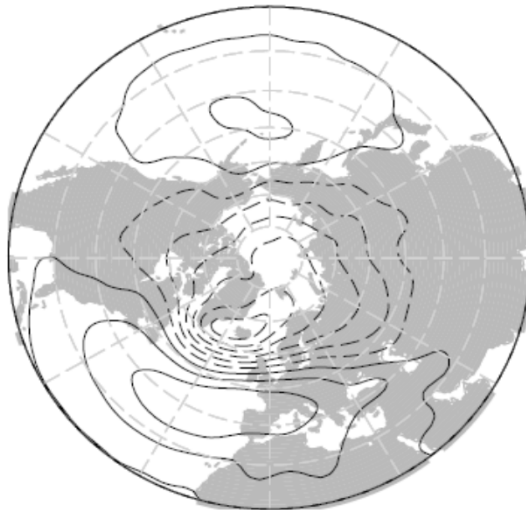


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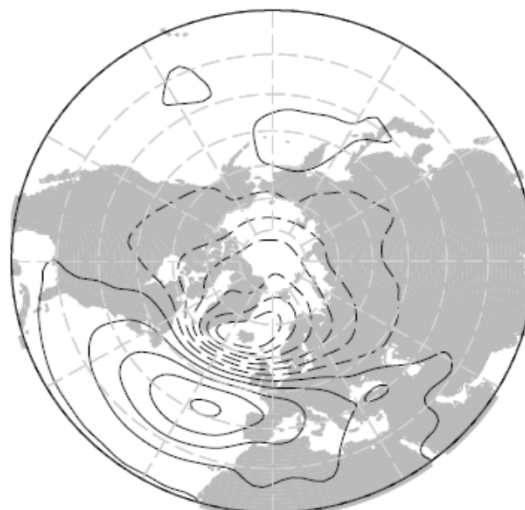
AO

NH



NAO

NH (Euro-Atlantic sector only)



(JFM, 1958-1999; Thompson et al. 2003)

# On the hemispheric scale of the winter NAO

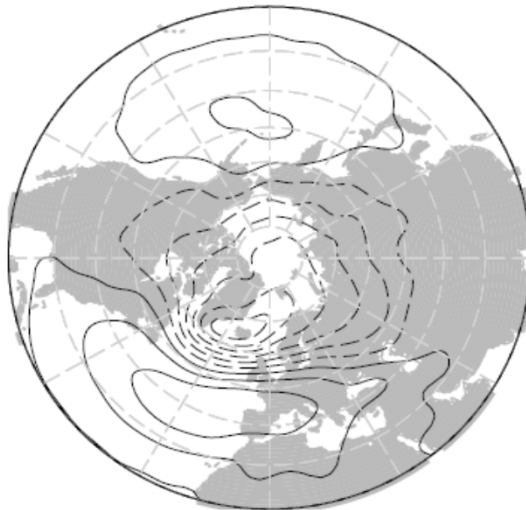


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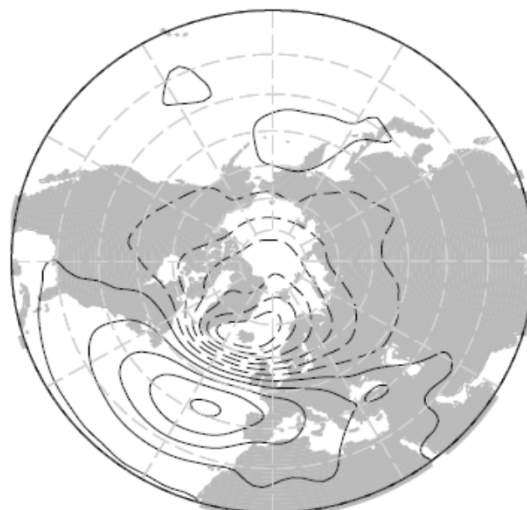
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NH



NAO

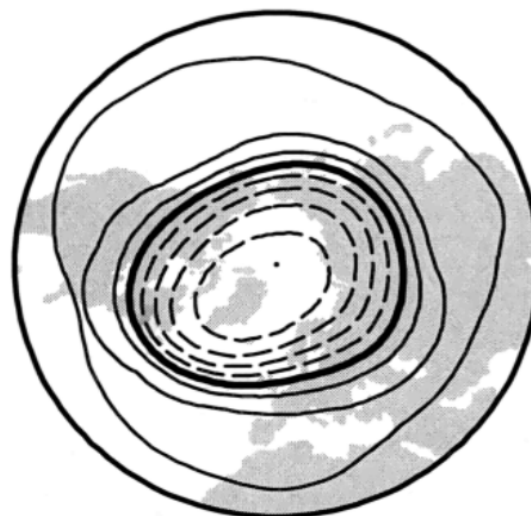
NH (Euro-Atlantic sector only)



(JFM, 1958-1999; Thompson et al. 2003)

NAM at 50hPa

(Z50; Deser 2000)



# On the hemispheric scale of the winter NAO

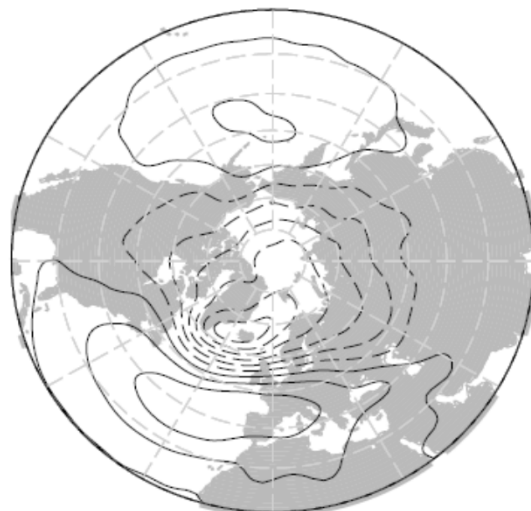


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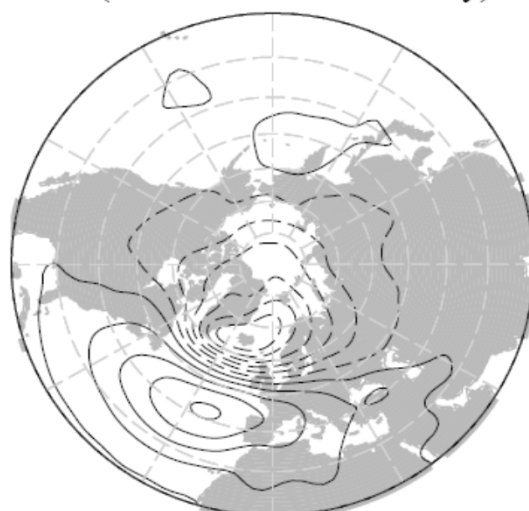
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NH



NAO

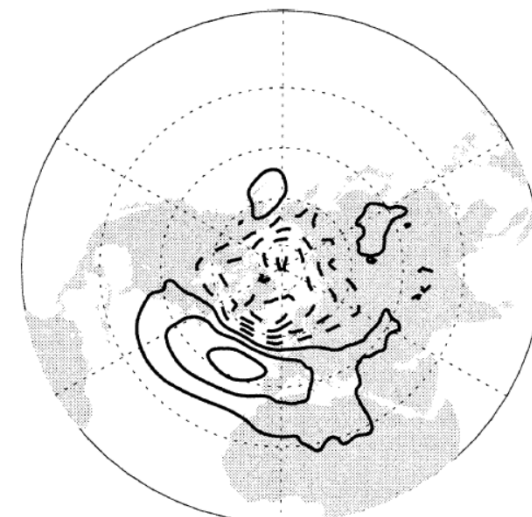
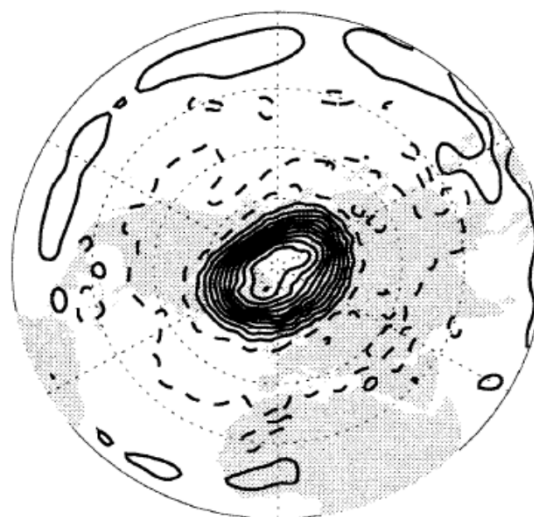
NH (Euro-Atlantic sector only)



(JFM, 1958-1999; Thompson et al. 2003)

SPV at 50hPa

(PV-500K ~20km  
Ambaum and Hoskins 2002)





# On the hemispheric scale of the winter NAO

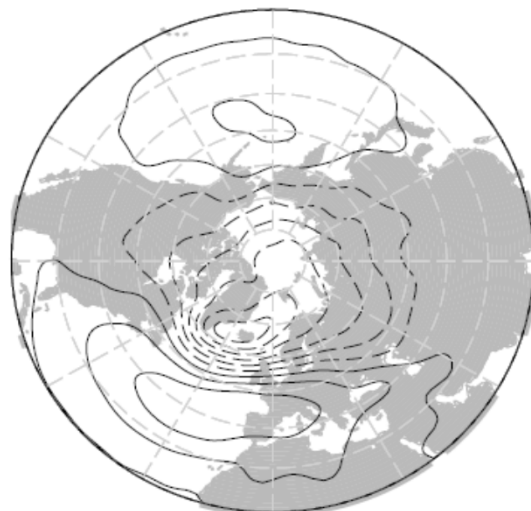


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AO

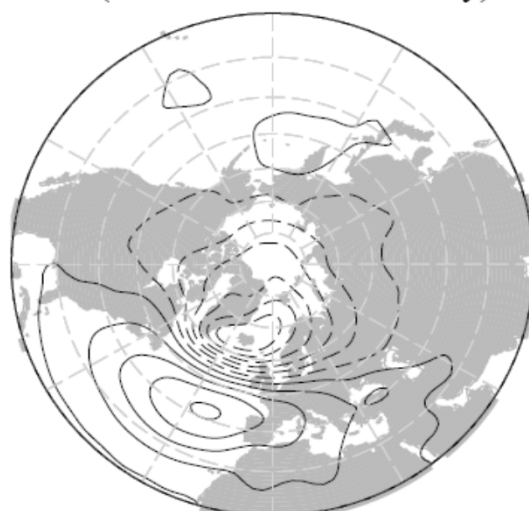
NH



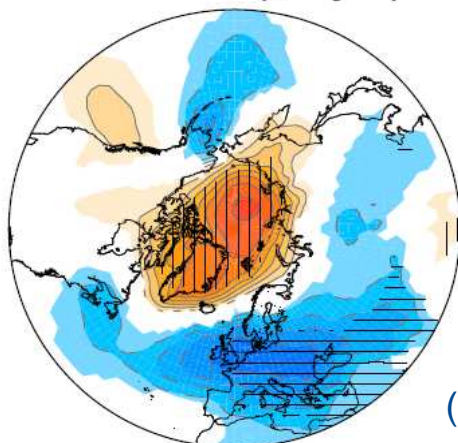
(JFM, 1958-1999; Thompson et al. 2003)

NAO

NH (Euro-Atlantic sector only)

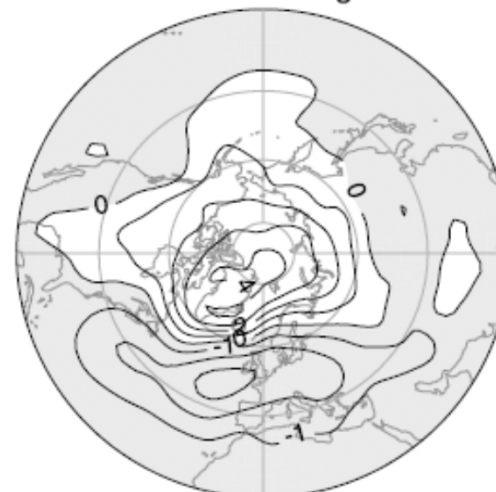


[5,35]-day period (Major)

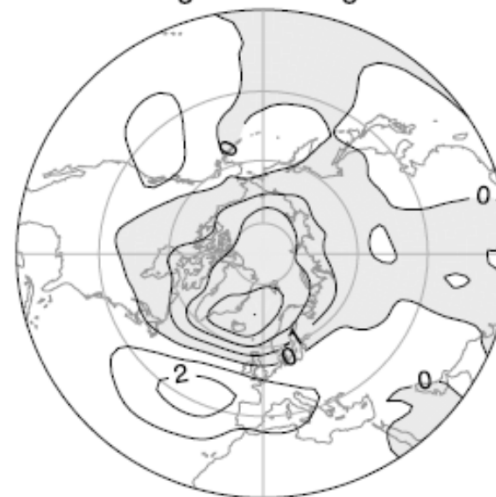


(SLP; Palmeiro et al. 2015)

a Weak Vortex Regimes



b Strong Vortex Regimes



(SLP; Baldwin and Dunkerton 2001)

# On the hemispheric scale of the winter NAO

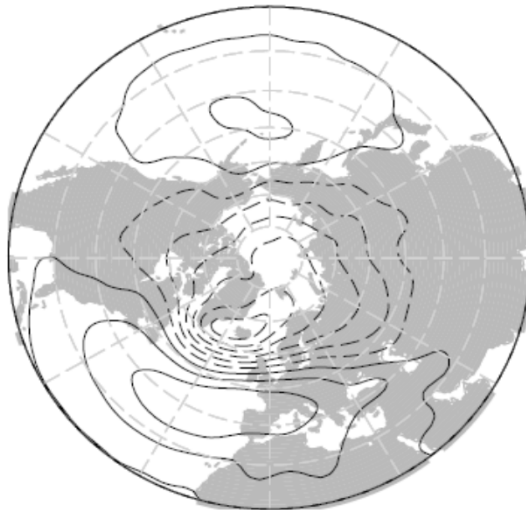


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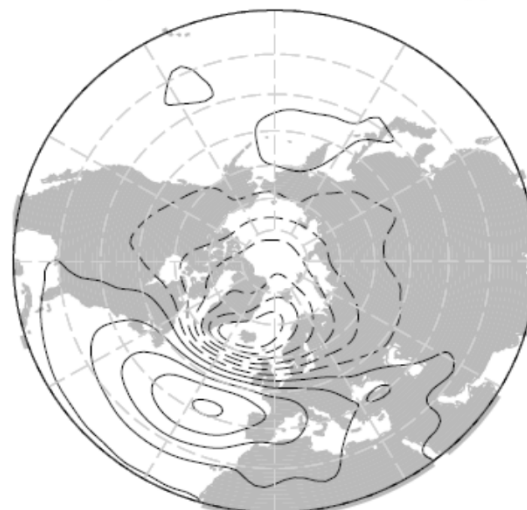
AO

NH

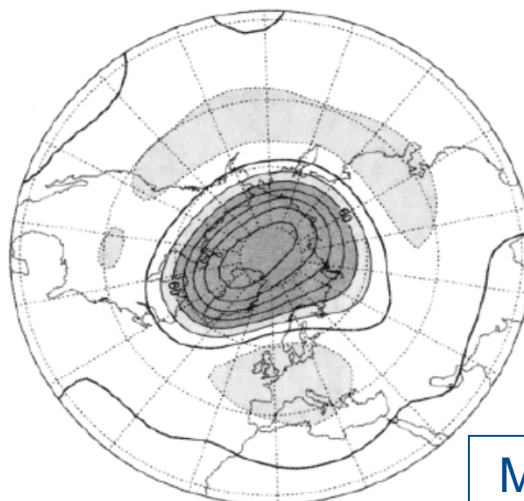


NAO

NH (Euro-Atlantic sector only)

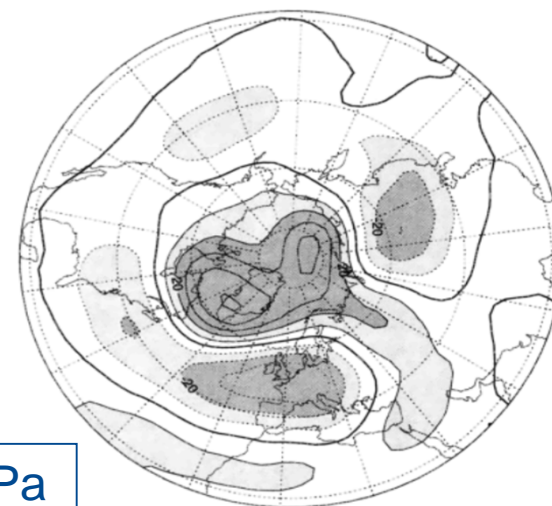


(JFM, 1958-1999; Thompson et al. 2003)



(Baldwin et al. 1994)

MCA 50hPa-500hPa



# On the hemispheric scale of the winter NAO

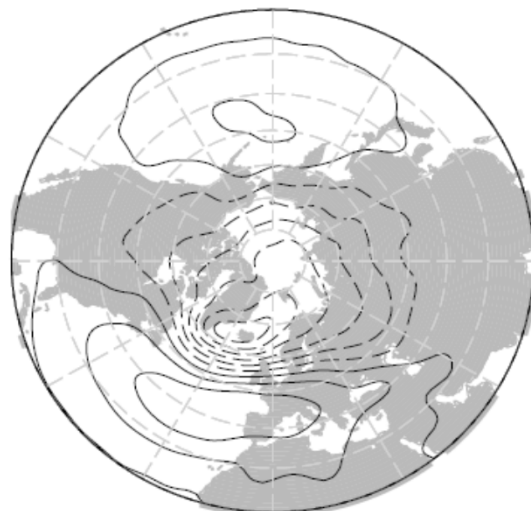


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AO

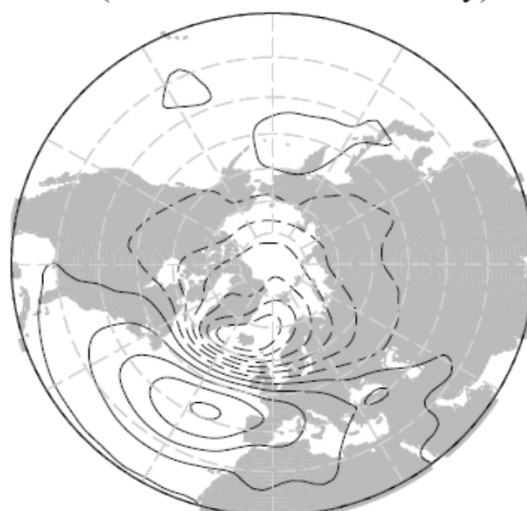
NH



(JFM, 1958-1999; Thompson et al. 2003)

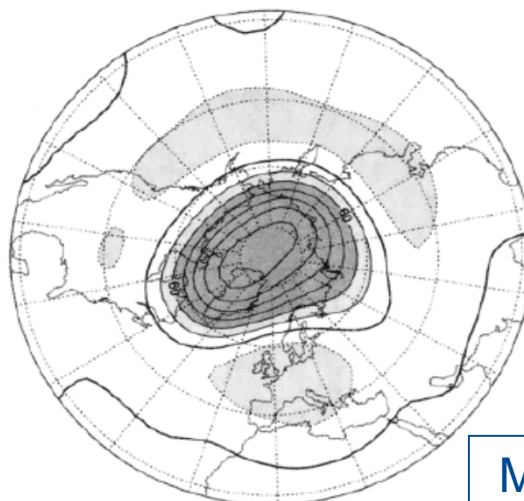
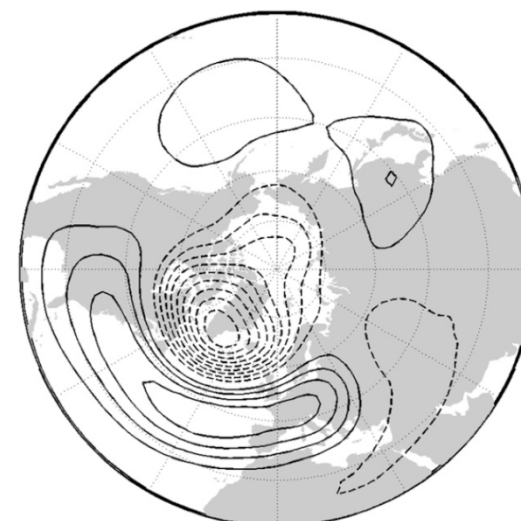
NAO

NH (Euro-Atlantic sector only)



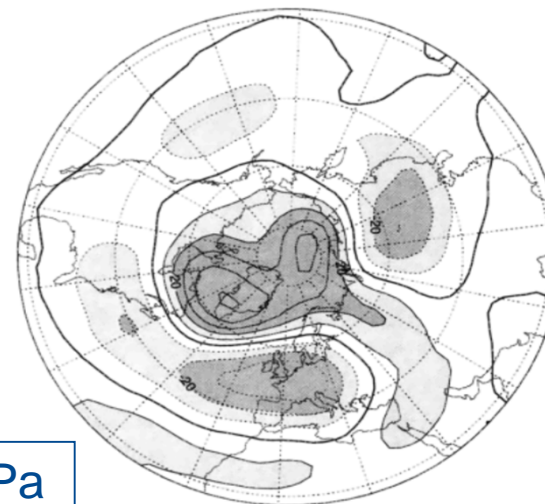
NAO at 500hPa

(Z500; Woollings et al. 2010)



(Baldwin et al. 1994)

MCA 50hPa-500hPa





# On the hemispheric scale of the winter NAO

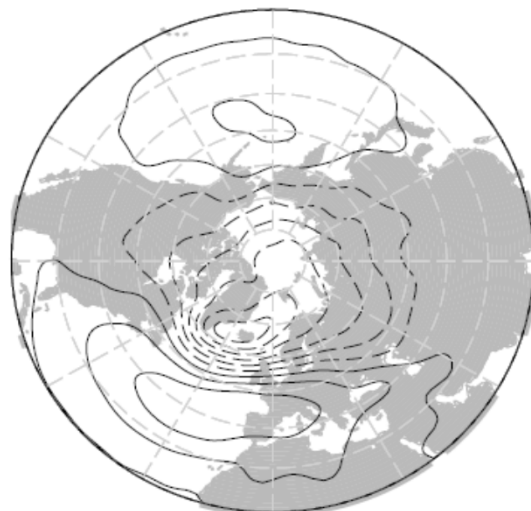


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AO

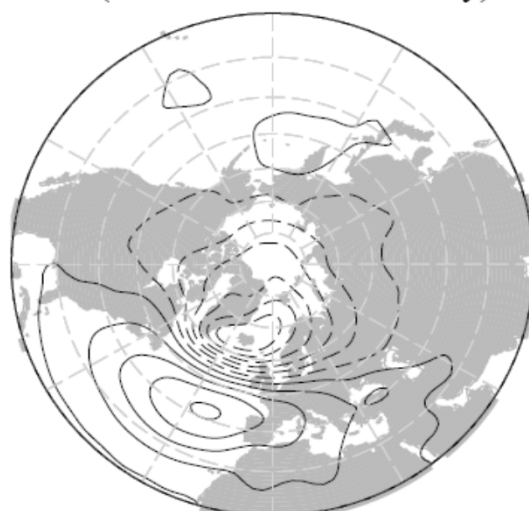
NH



(JFM, 1958-1999; Thompson et al. 2003)

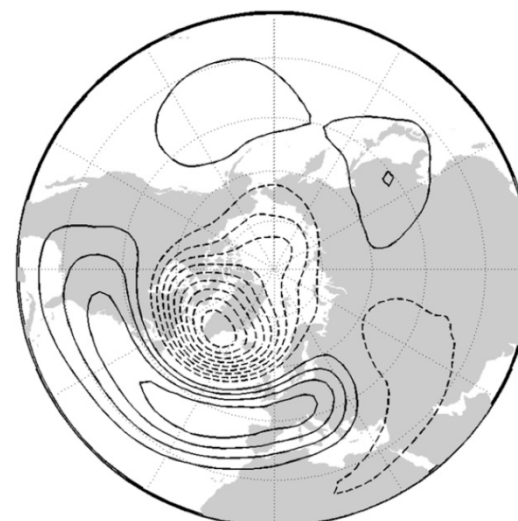
NAO

NH (Euro-Atlantic sector only)



NAO at 500hPa

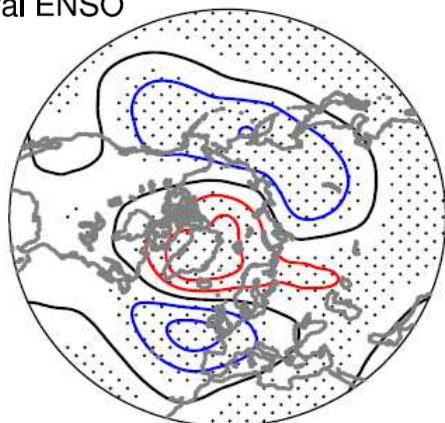
(Z500; Woollings et al. 2010)



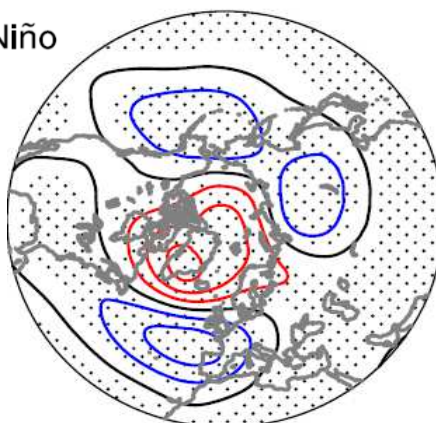
SSW-related Z500

(Polvani et al. 2017)

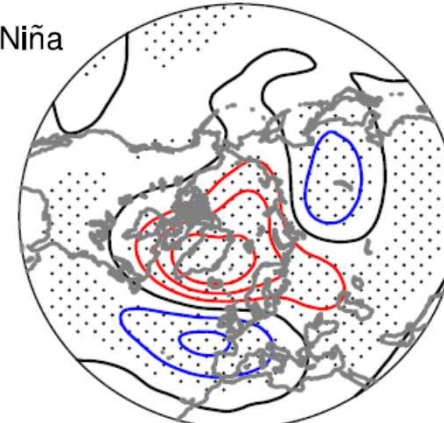
neutral ENSO



El Niño

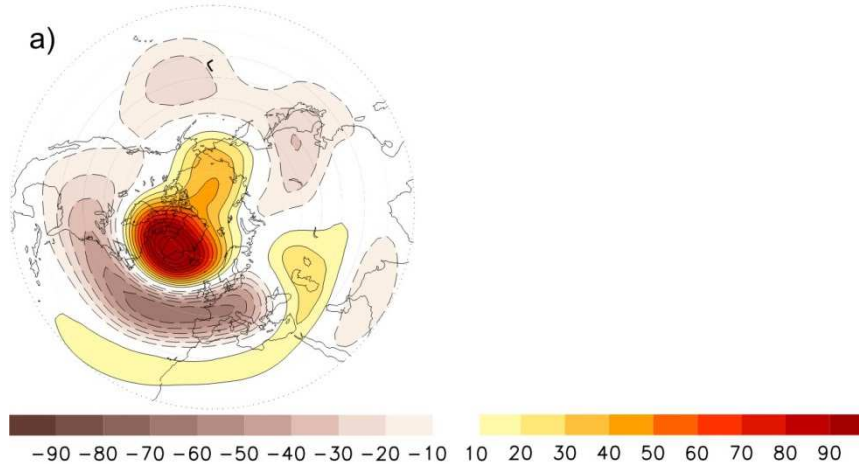


La Niña

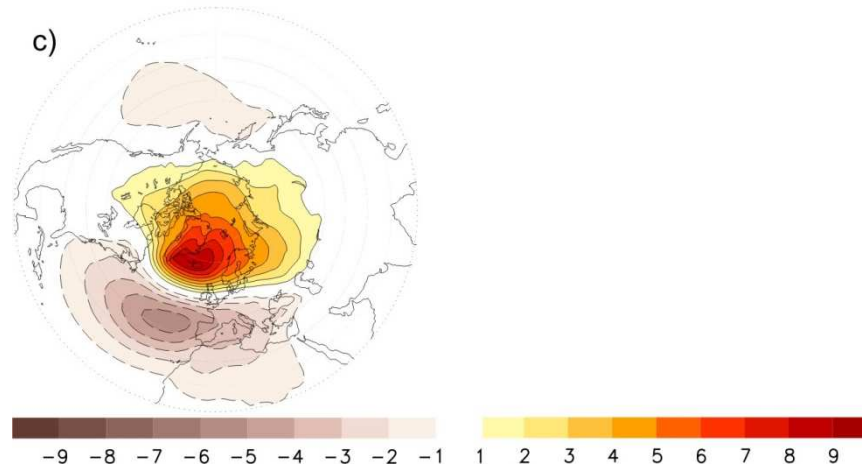




NAO x Z300 / ERA40 (JF)

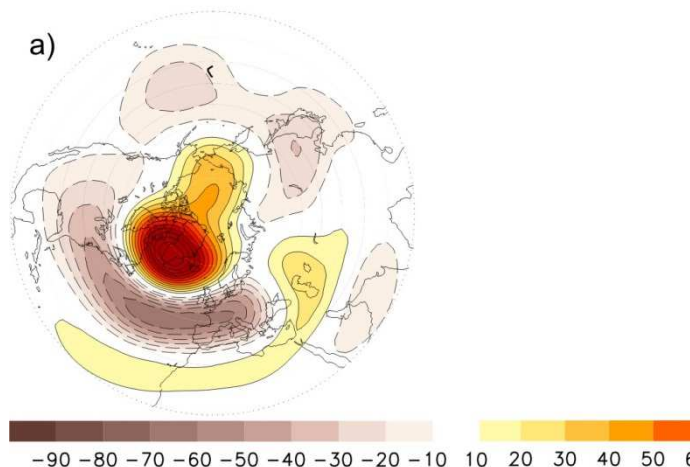


NAO x SLP / ERA40 (JF)

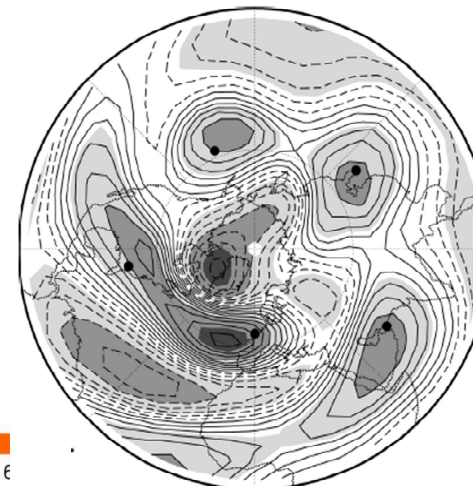


winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)

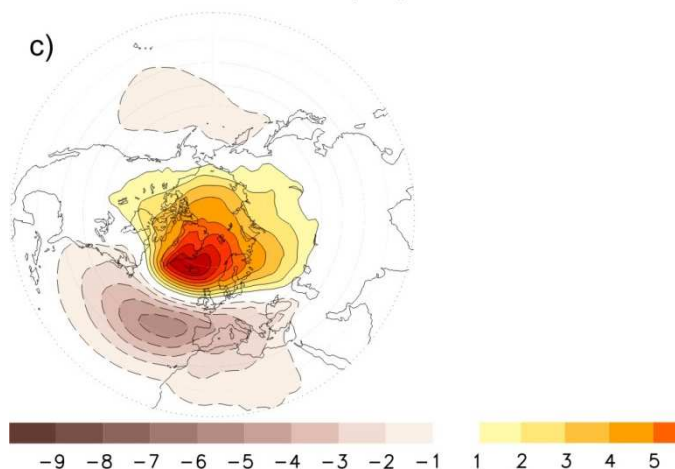
NAO x Z300 / ERA40 (JF)



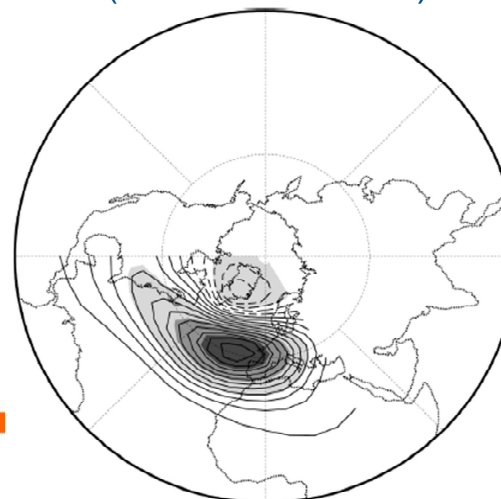
(NAO x PSI300)



NAO x SLP / ERA40 (JF)



(NAO from PSI850)



winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)

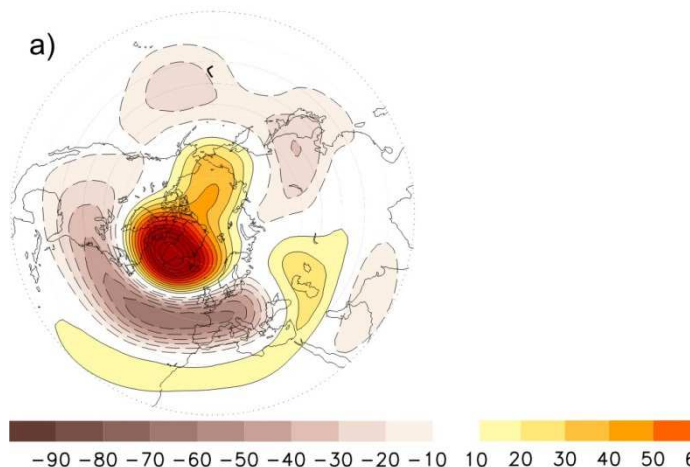
# On the hemispheric scale of the winter NAO



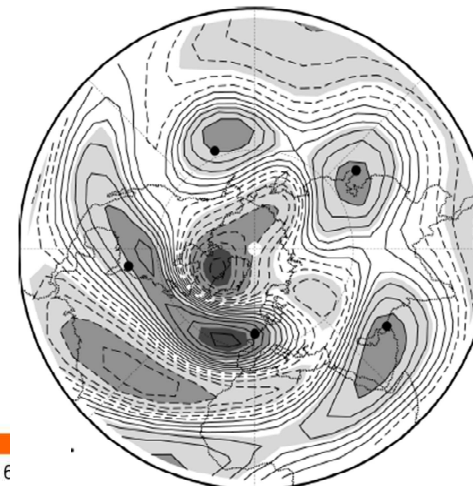
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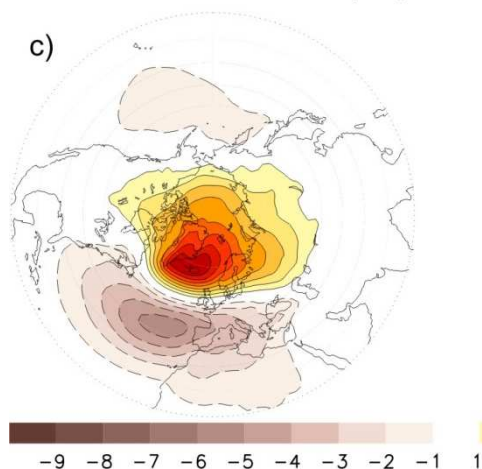
NAO x Z300 / ERA40 (JF)



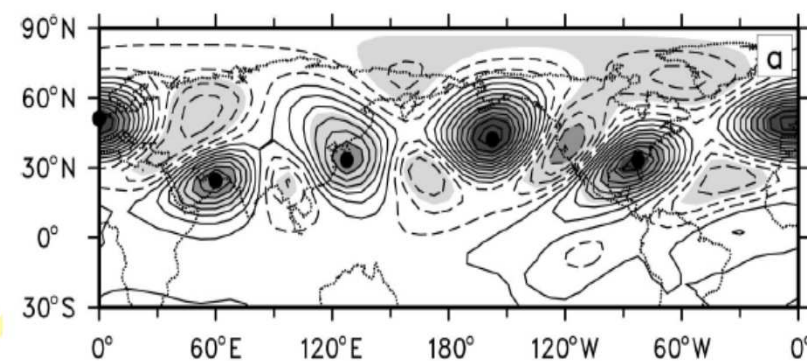
(NAO x PSI300)



NAO x SLP / ERA40 (JF)



(NAO x v300)



winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)

# On the hemispheric scale of the winter NAO

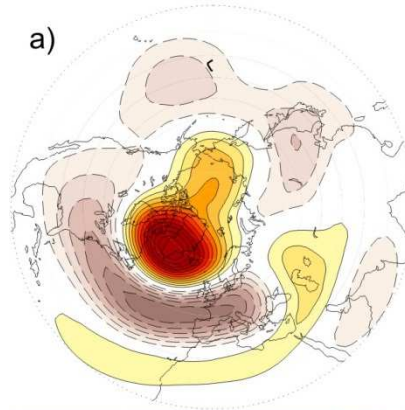


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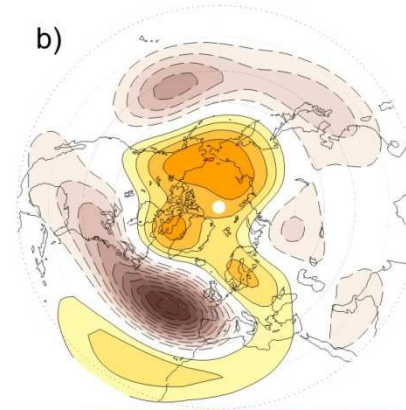
EXCELENCIA  
SEVERO  
OCHOA

NAO/CWP  
paradigm

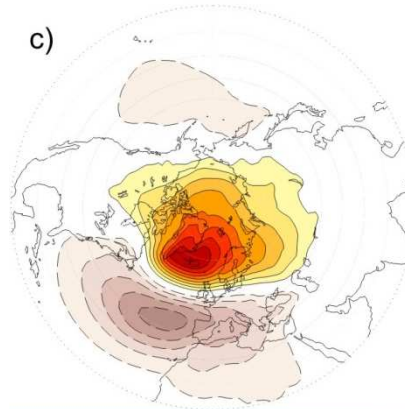
NAO x Z300 / ERA40 (JF)



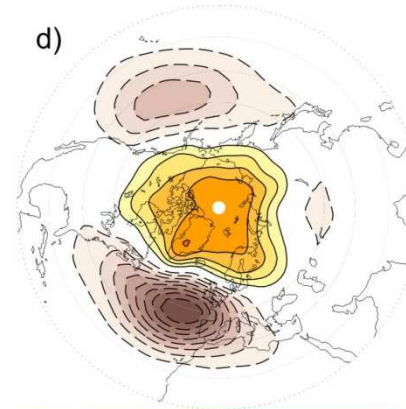
NAO x Z300 / SPEEDO (JF)



NAO x SLP / ERA40 (JF)



NAO x SLP / SPEEDO (JF)



winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)



# On the hemispheric scale of the winter NAO

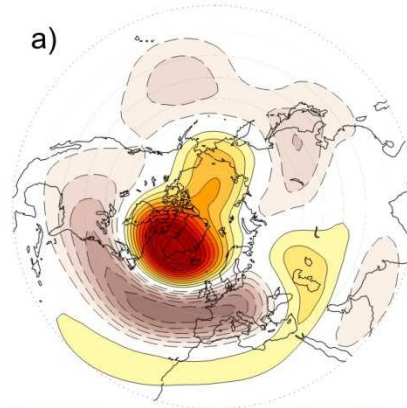


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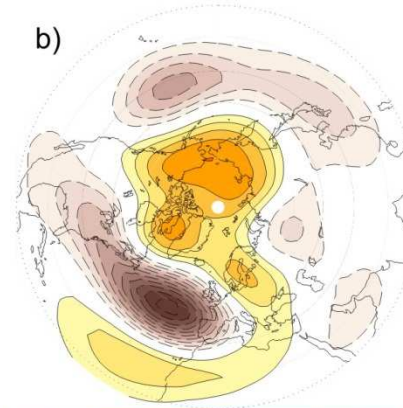


NAO/CWP  
paradigm

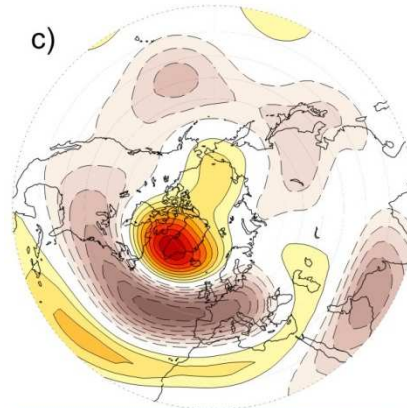
NAO x Z300 / ERA40 (JF)



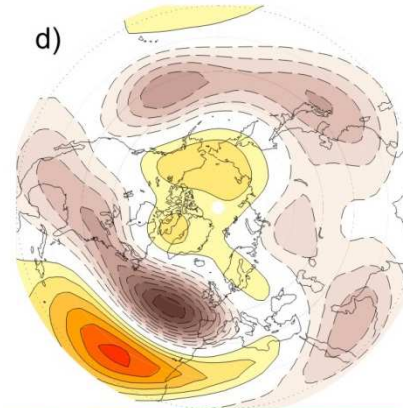
NAO x Z300 / SPEEDO (JF)



NAO x PSI300 / ERA40 (JF)



NAO x PSI300 / SPEEDO (JF)



winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)

# On the hemispheric scale of the winter NAO

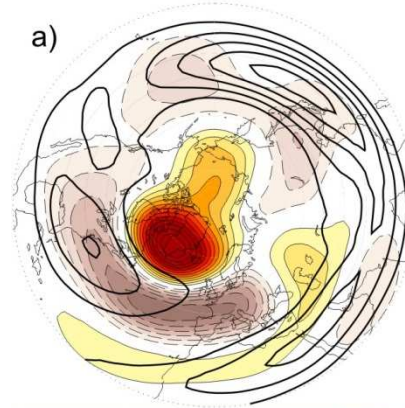


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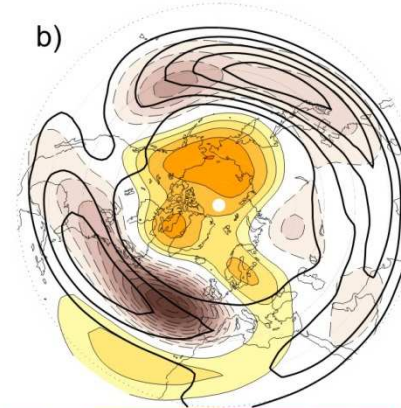
EXCELENCIA  
SEVERO  
OCHOA

NAO/CWP  
paradigm

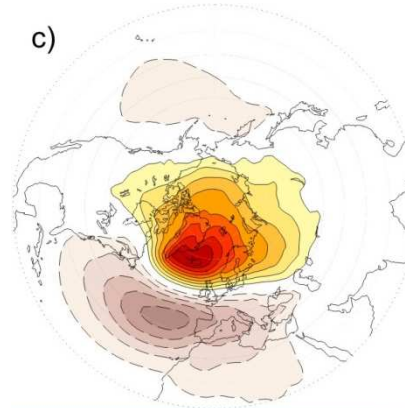
NAO x Z300 / ERA40 (JF)



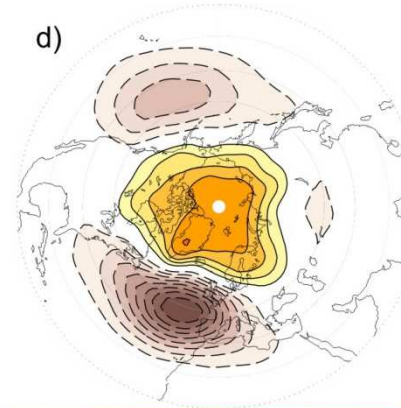
NAO x Z300 / SPEEDO (JF)



NAO x SLP / ERA40 (JF)



NAO x SLP / SPEEDO (JF)



winter NAO has a distinct global signature at upper-tropospheric levels  
(Branstator 2002)

SPEEDY (e.g. Haarsma and Hazeleger 2007)

intermediate complexity AGCM

no stratosphere

T30 (96 lon x 48 lat)

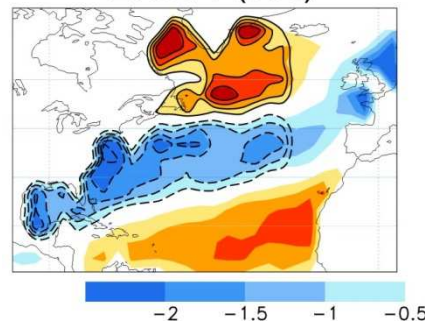
L7 (925, 850, 700, 500, 300, 200, 100)

200-member, 30-day long CTL + EXP (NAO+, NAO-)

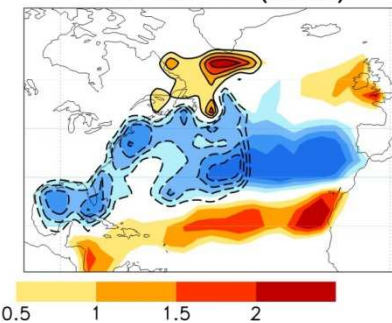
NAO/CWP  
paradigm

[ vs. *EC-EARTH3.2 T255L91* ]

e) boundary conditions  
ERSST (obs)



f) boundary conditions  
SPEEDO (mod)



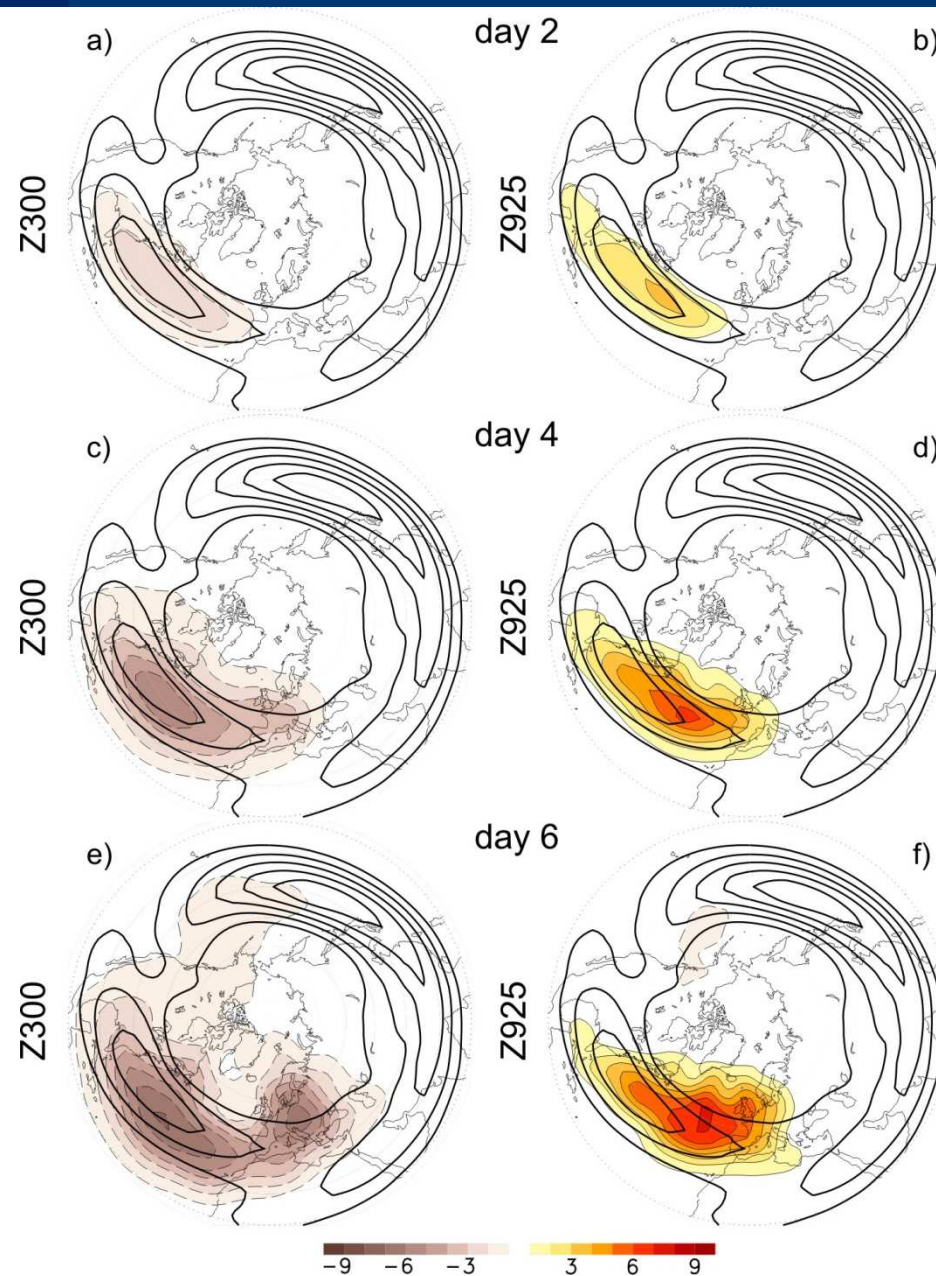


# On the hemispheric scale of the winter NAO



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EXCELENCIA  
SEVERO  
OCHOA



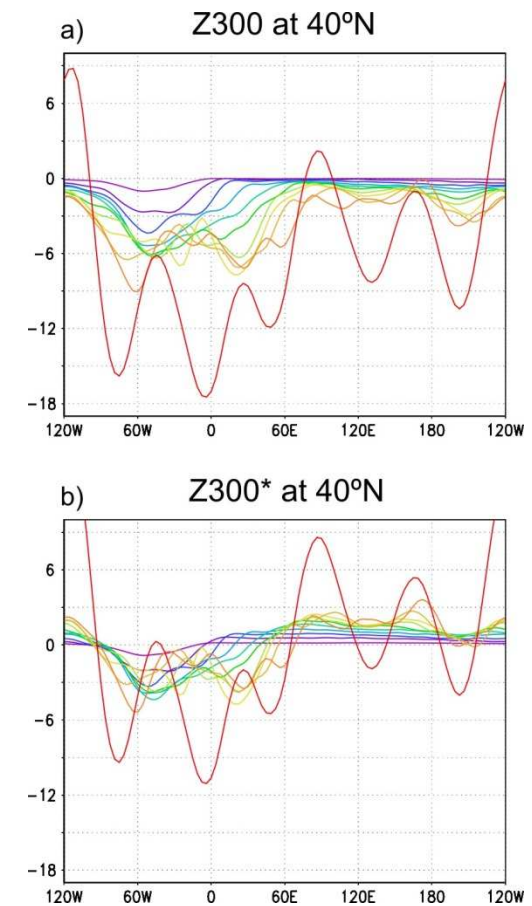
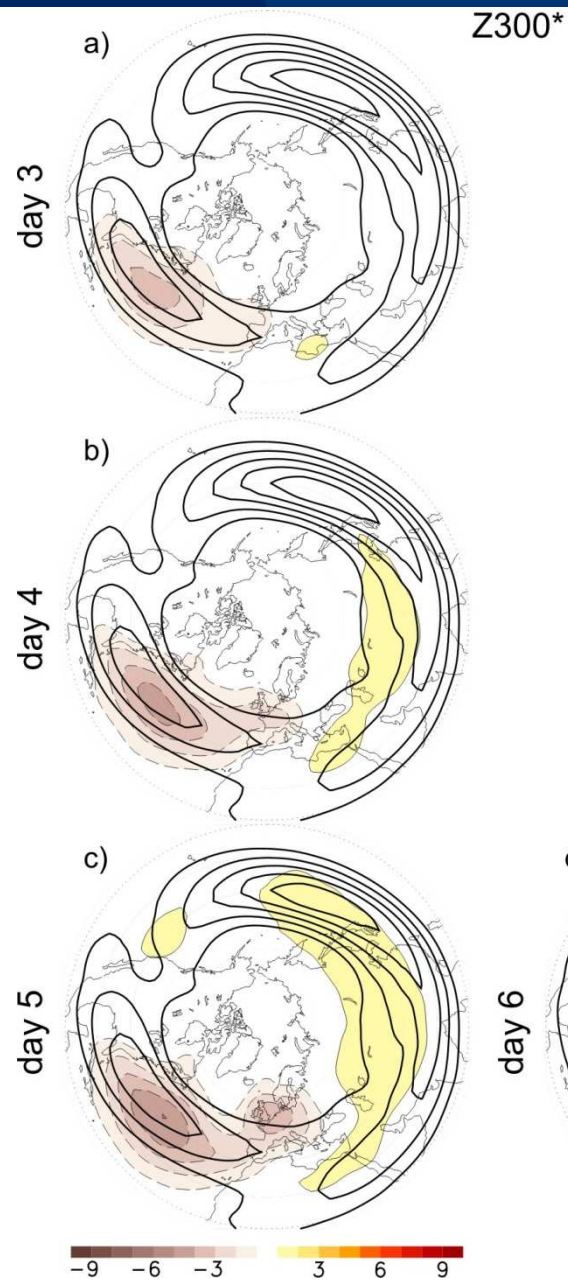


# On the hemispheric scale of the winter NAO



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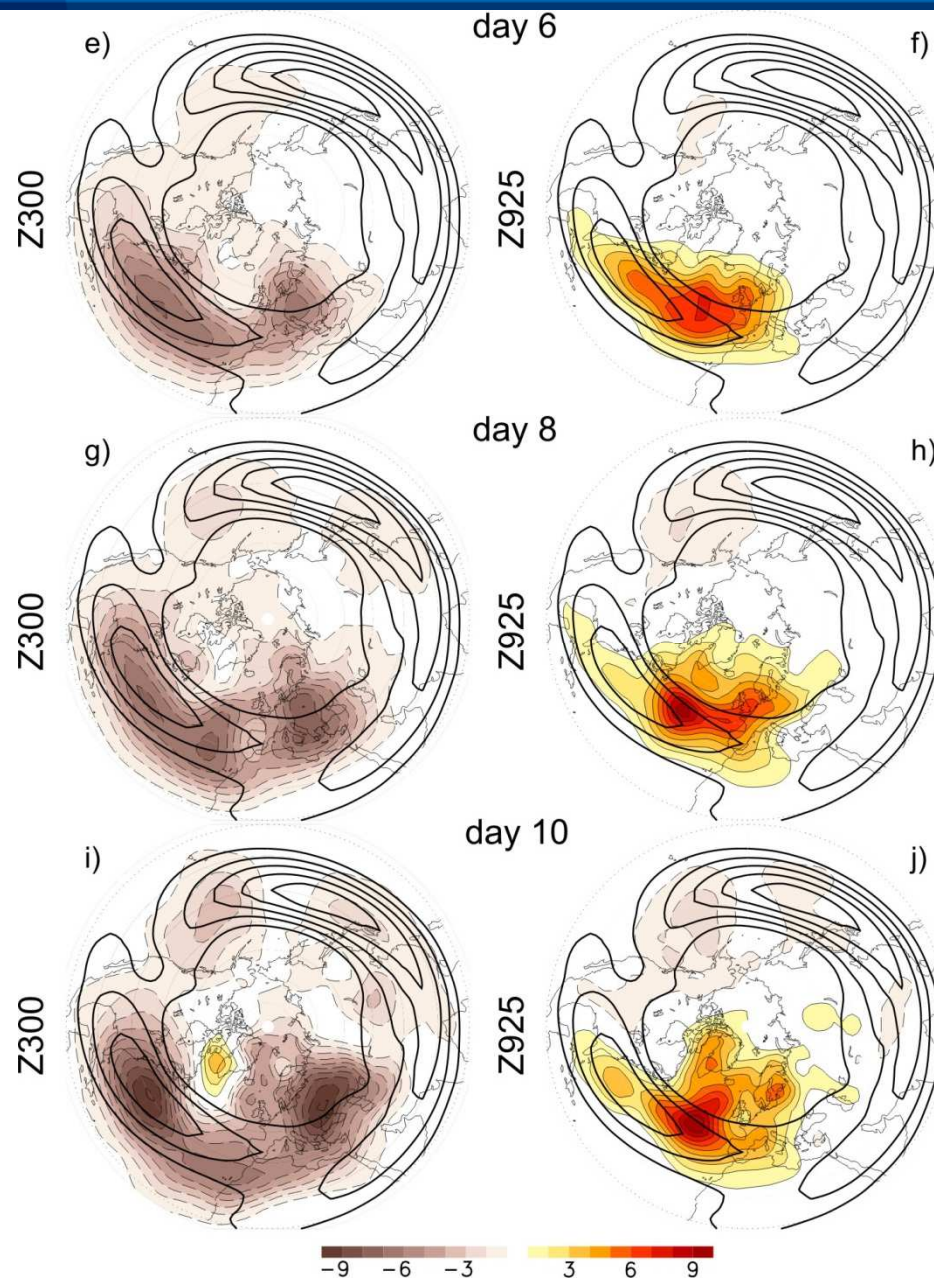
EXCELENCIA  
SEVERO  
OCHOA



# On the hemispheric scale of the winter NAO



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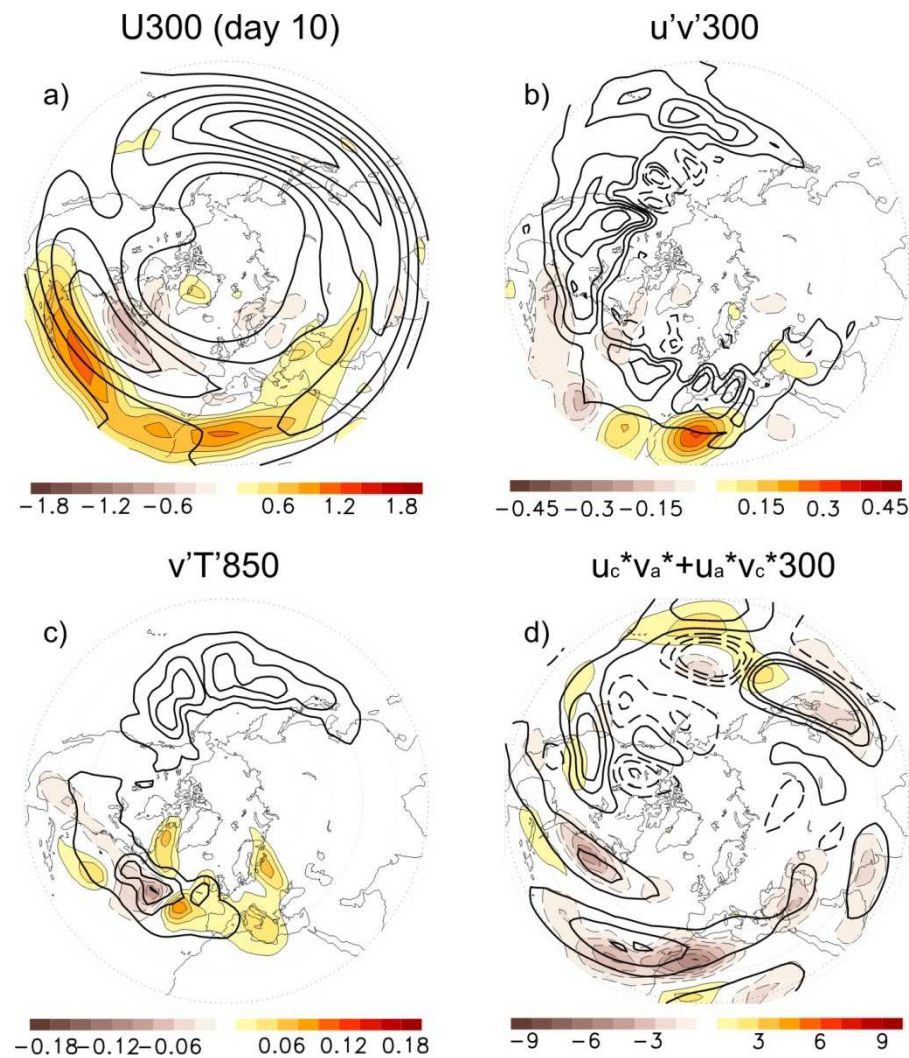


# On the hemispheric scale of the winter NAO



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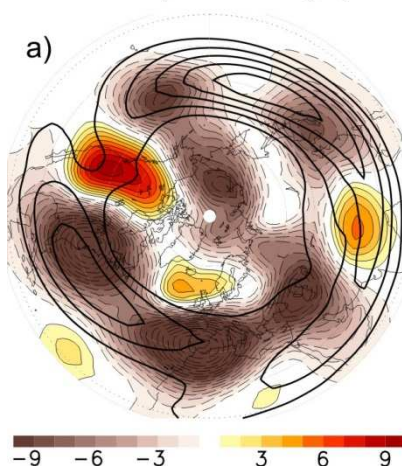
EXCELENCIA  
SEVERO  
OCHOA



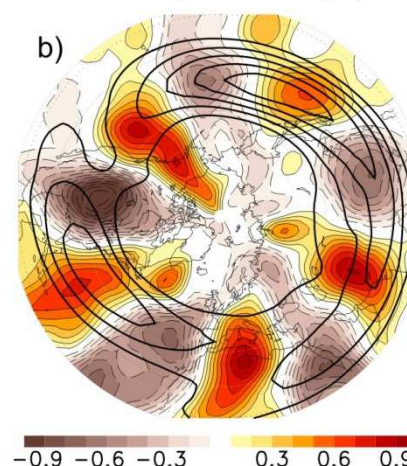
transient-eddy activity, zonal-eddy coupling



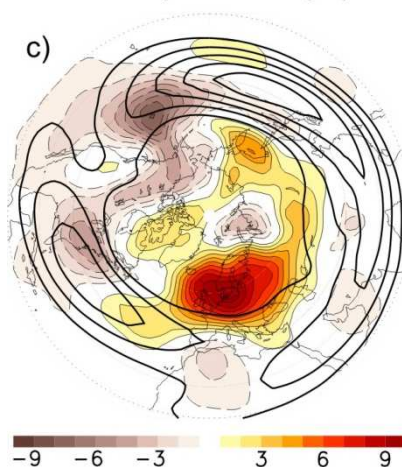
Z300 (15-30 days)



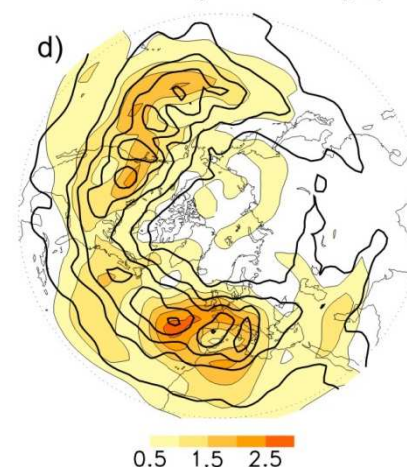
V300 (15-30 days)



Z925 (15-30 days)



PKE300 (15-30 days)



quasi-equilibrium, non-linear stage





## SUMMARY:

- the hemispheric signature of the NAO could be explained by tropospheric dynamics
- without the need of interaction with the stratosphere
- involving a Rossby wavetrain channelized into the westerly jets
- consistent with the CWP pattern at the upper troposphere

¿? why the predominance of wavenumber-5 in the CWP

¿? how annular dynamics in the stratosphere but non-annular in the troposphere



## SUMMARY:

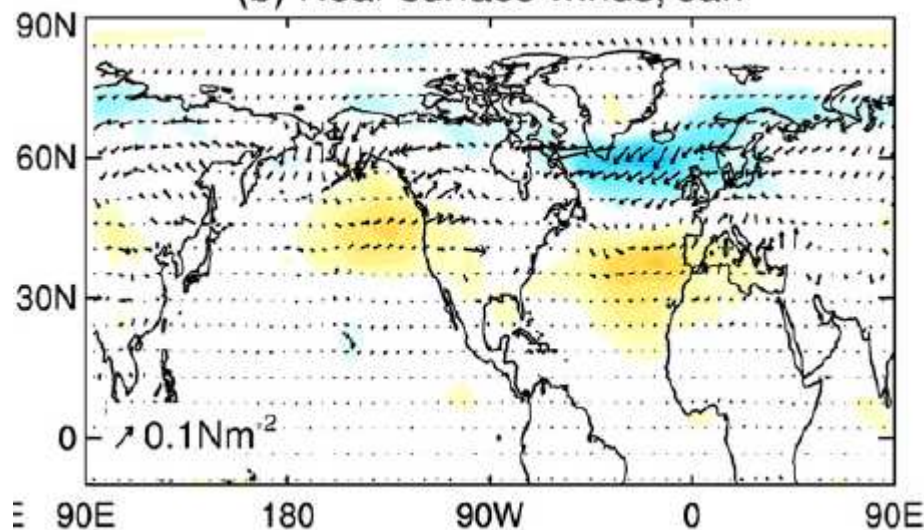
- the hemispheric signature of the NAO could be explained by tropospheric dynamics
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¿? what about a NAO-like response induced from the stratosphere

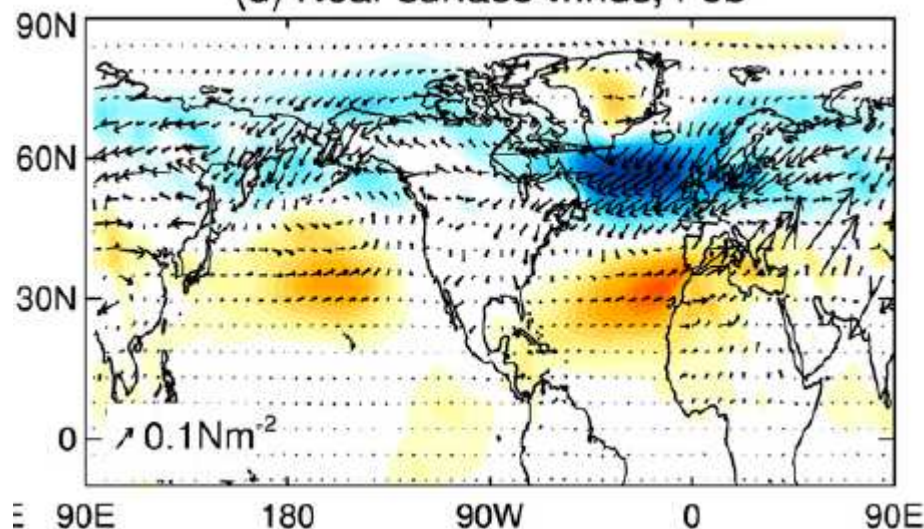
¿? does it also involve a CWP pattern in the troposphere

## SSWs - CTRL

(b) Near surface winds, Jan

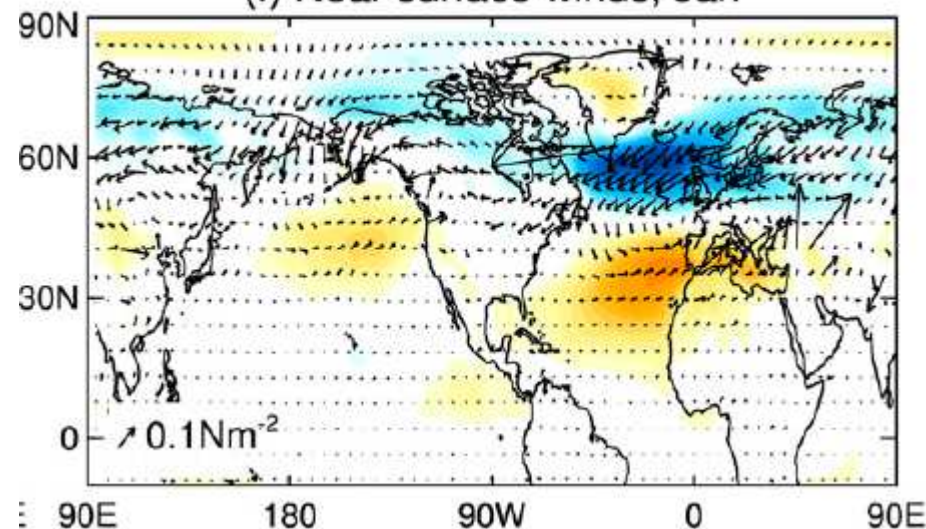


(d) Near surface winds, Feb

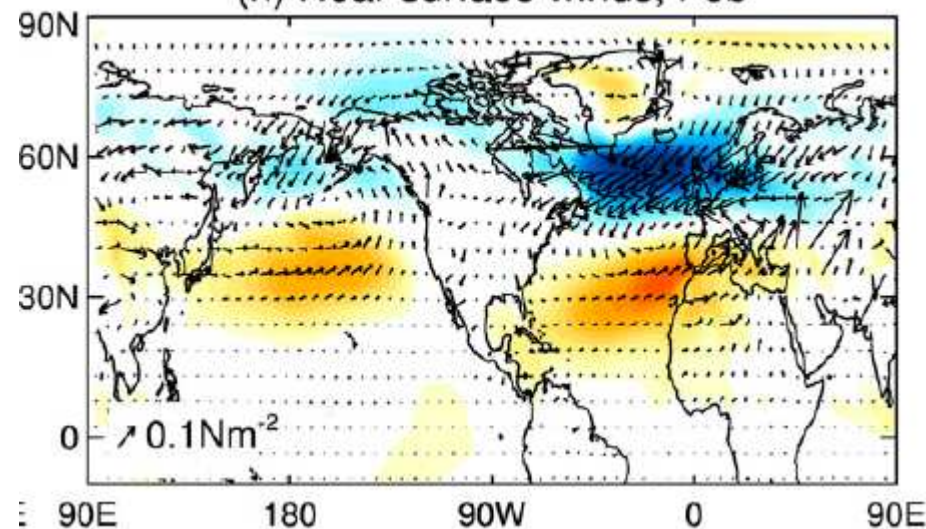


## SSWd - CTRL

(f) Near surface winds, Jan



(h) Near surface winds, Feb







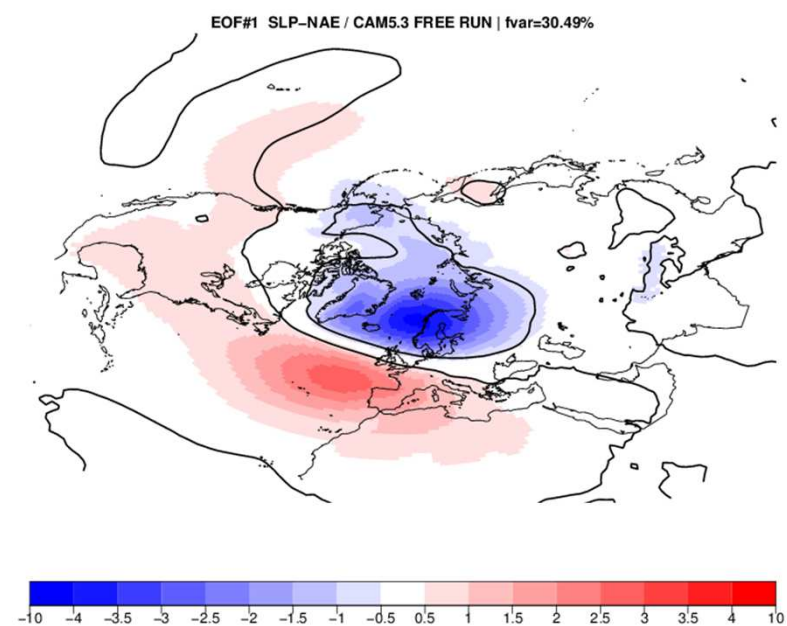
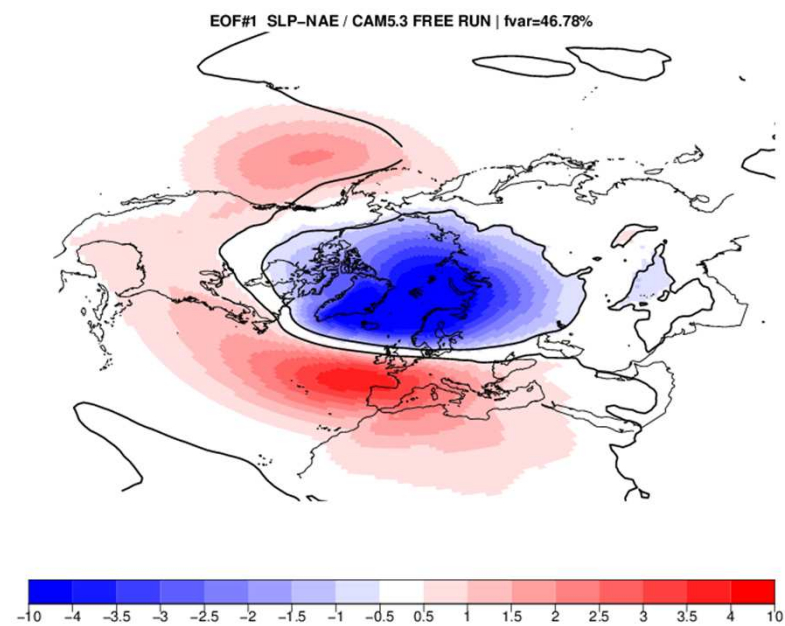
## SUMMARY:

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¿? what about a NAO-like response induced from the stratosphere

¿? does it also involve a CWP pattern in the troposphere





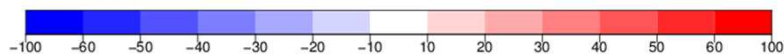
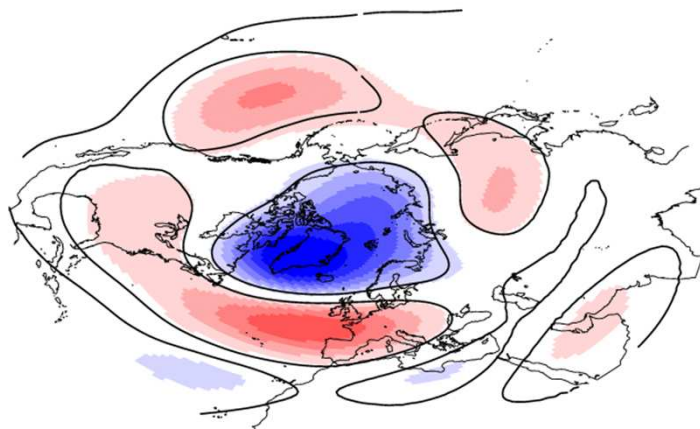
# NAO/CWP in CAM5.3



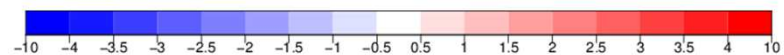
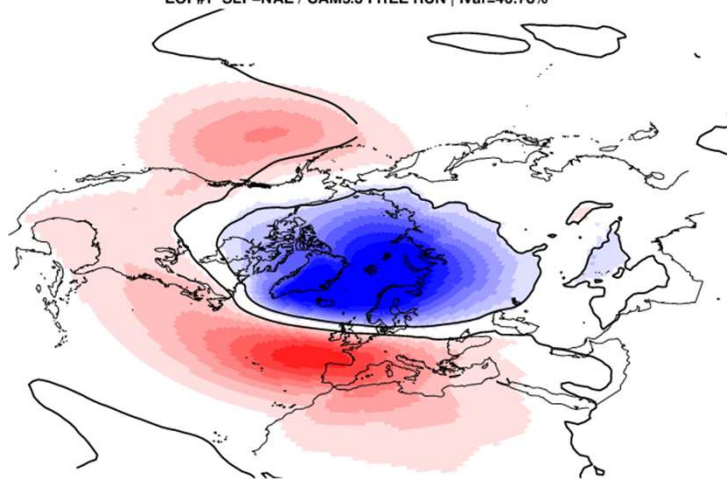
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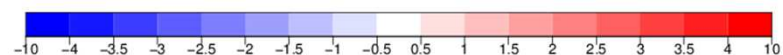
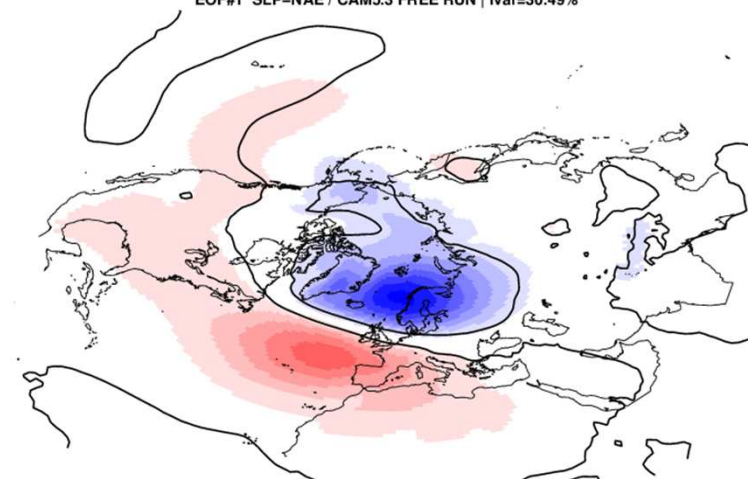
NAO x Z300 / CAM5.3 free (djf)



EOF#1 SLP-NAE / CAM5.3 FREE RUN | fvar=46.78%



EOF#1 SLP-NAE / CAM5.3 FREE RUN | fvar=30.49%



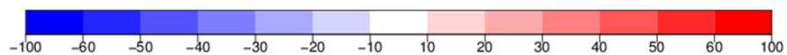
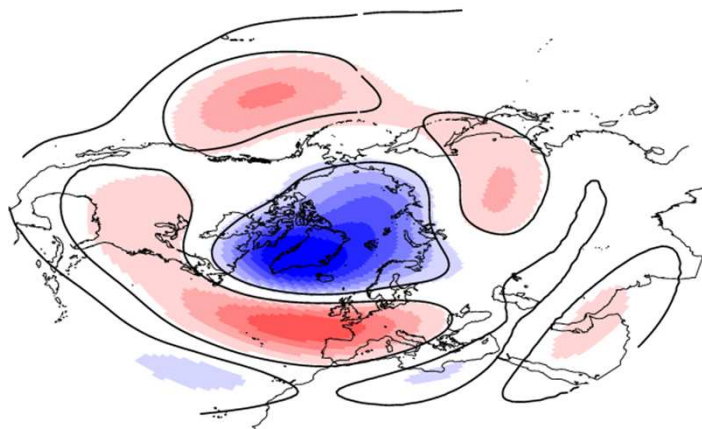
# NAO/CWP in CAM5.3



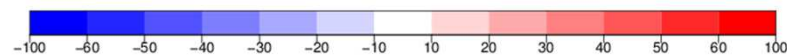
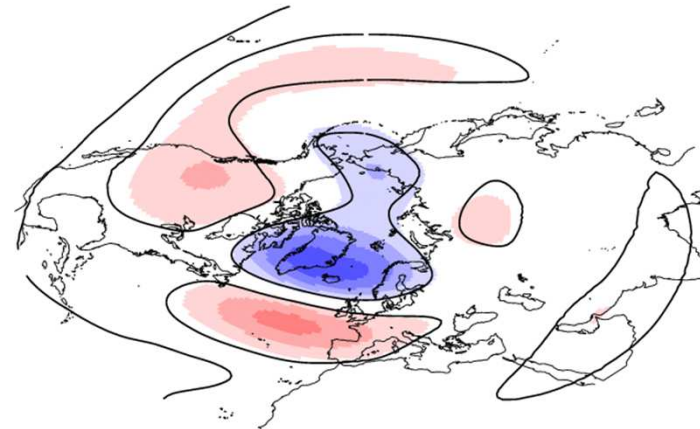
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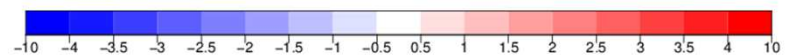
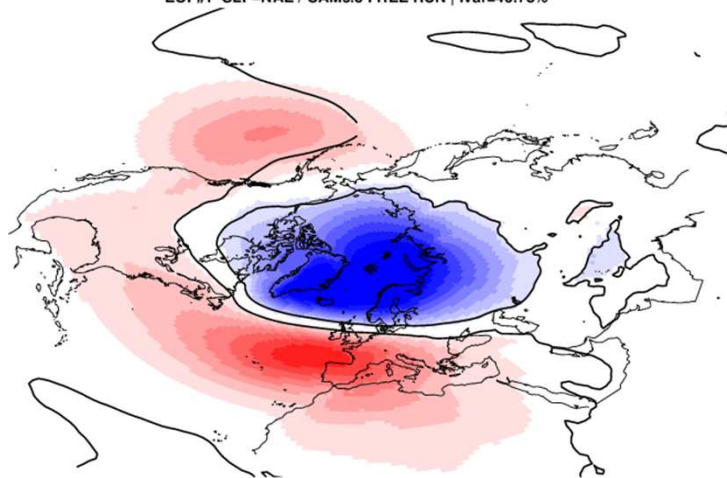
NAO x Z300 / CAM5.3 free (djf)



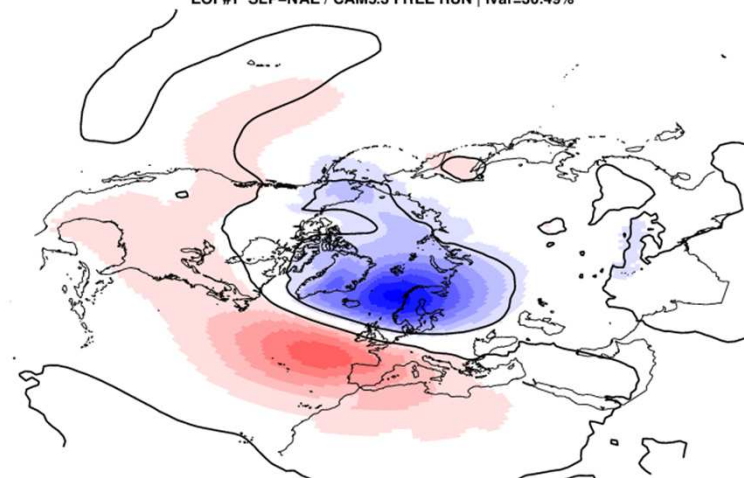
NAO x Z300 / CAM5.3 nudg (djf)



EOF#1 SLP-NAE / CAM5.3 FREE RUN | fvar=46.78%



EOF#1 SLP-NAE / CAM5.3 FREE RUN | fvar=30.49%





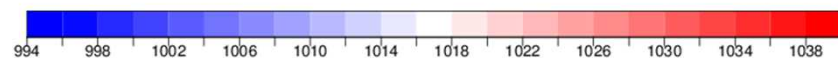
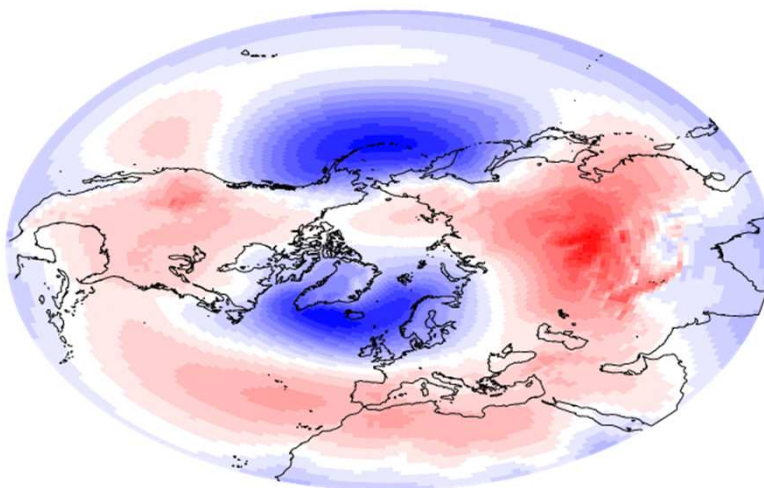
# NAO/CWP in CAM5.3



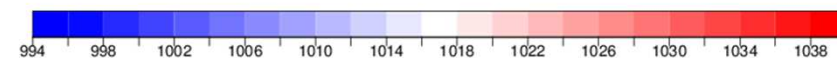
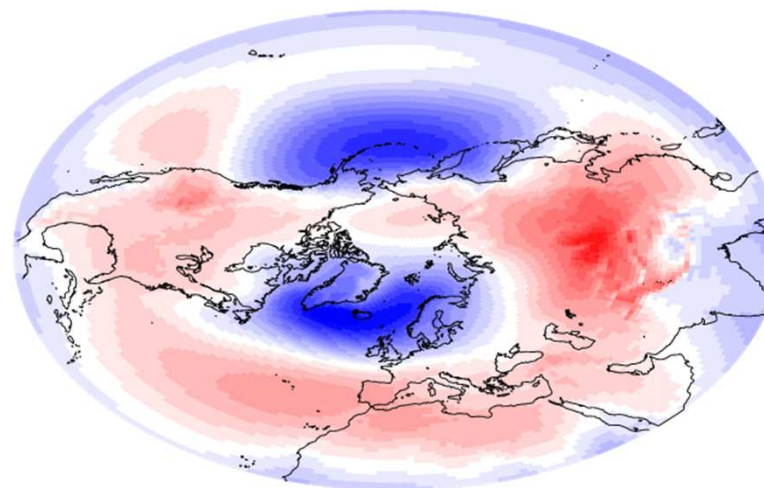
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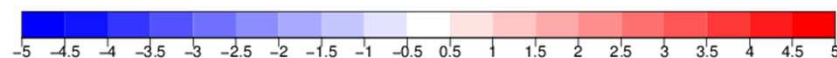
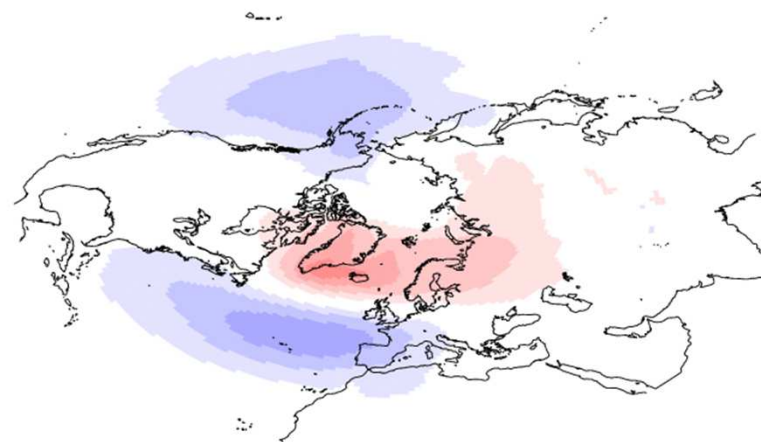
CAM5.3 FREE RUN | SLP climatology



CAM5.3 NUDG RUN | SLP climatology



CAM5.3 FREE-NUDG | SLP climatology



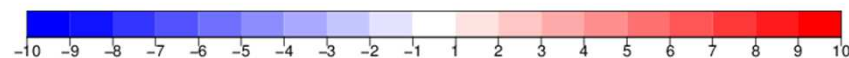
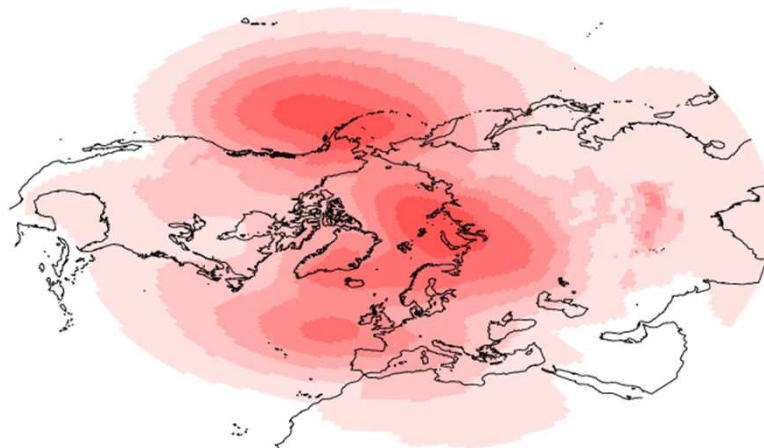
# NAO/CWP in CAM5.3



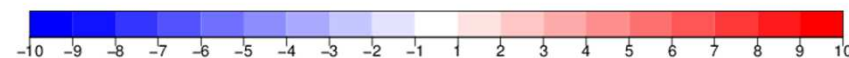
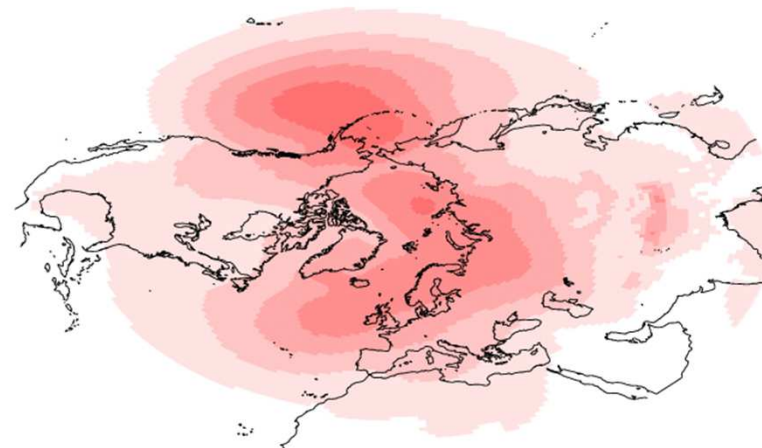
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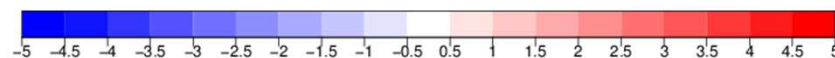
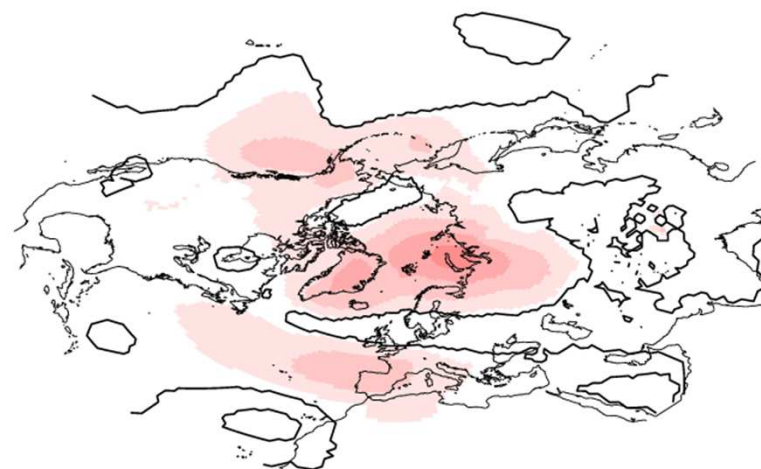
CAM5.3 FREE RUN | SLP std.dev



CAM5.3 NUDG RUN | SLP std.dev



CAM5.3 FREE-NUDG | SLP std.dev



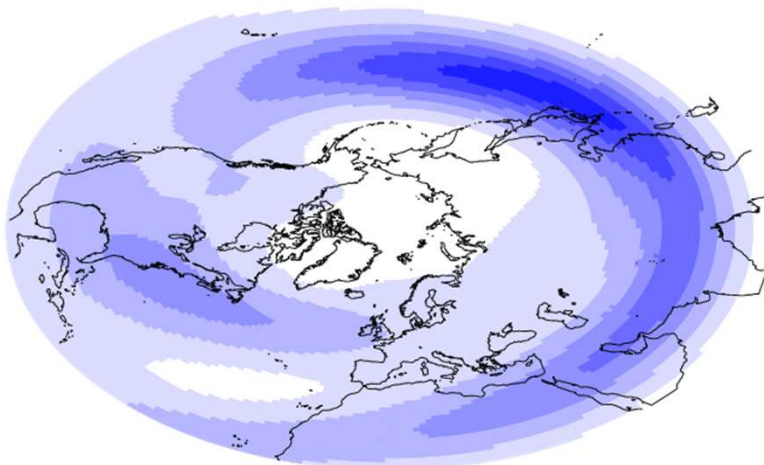
# NAO/CWP in CAM5.3



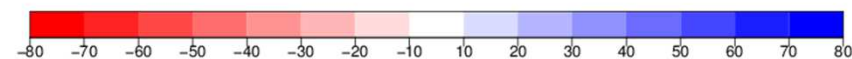
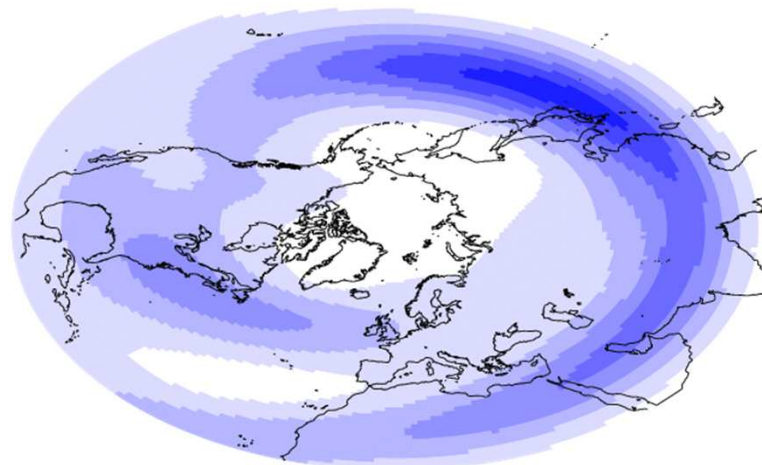
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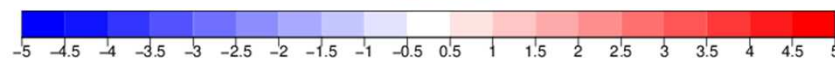
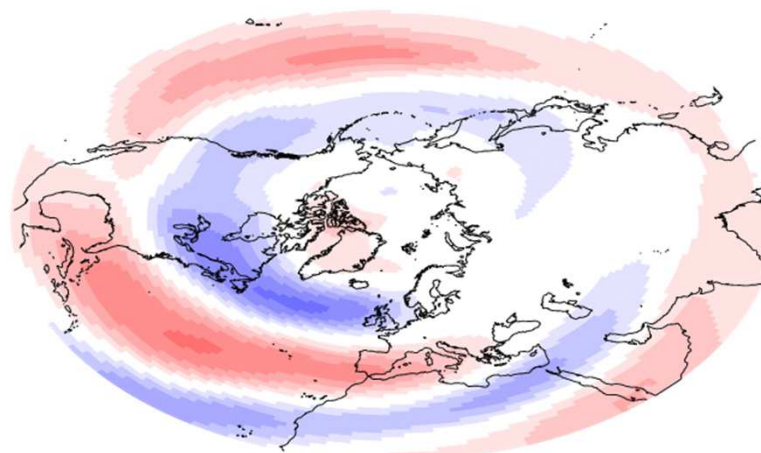
CAM5.3 FREE RUN | U300 climatology



CAM5.3 NUDG RUN | U300 climatology



CAM5.3 FREE-NUDG | U300 climatology





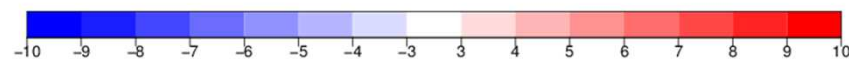
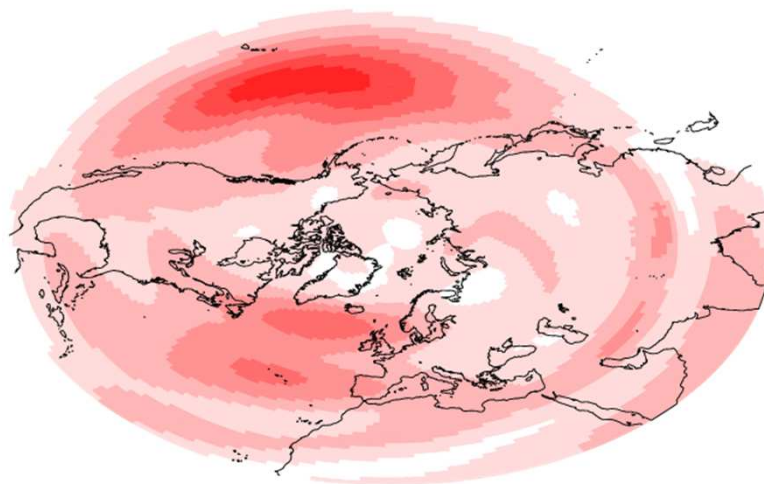
# NAO/CWP in CAM5.3



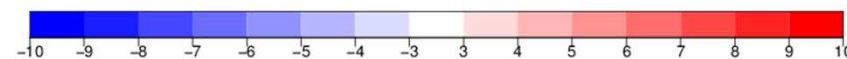
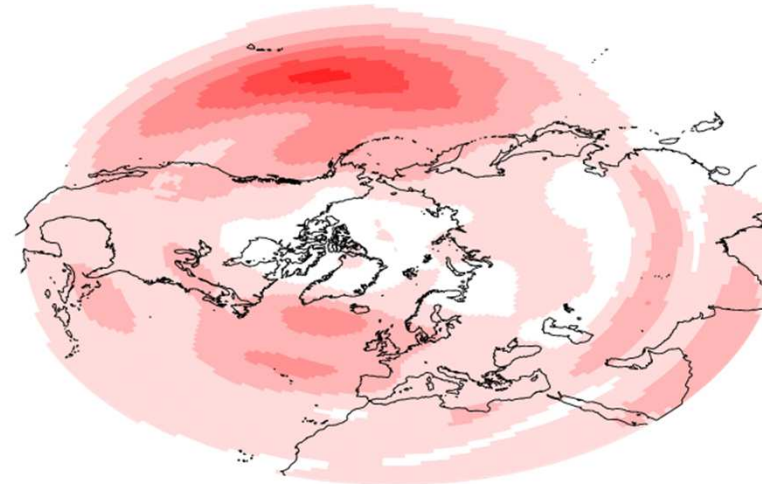
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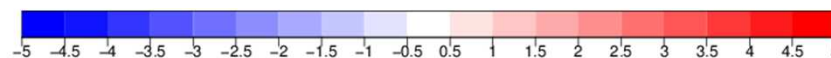
CAM5.3 FREE RUN | U300 std.dev



CAM5.3 NUDG RUN | U300 std.dev



CAM5.3 FREE-NUDG | U300 std.dev



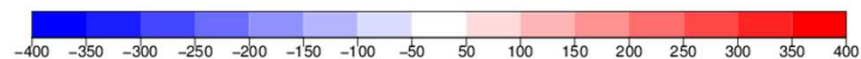
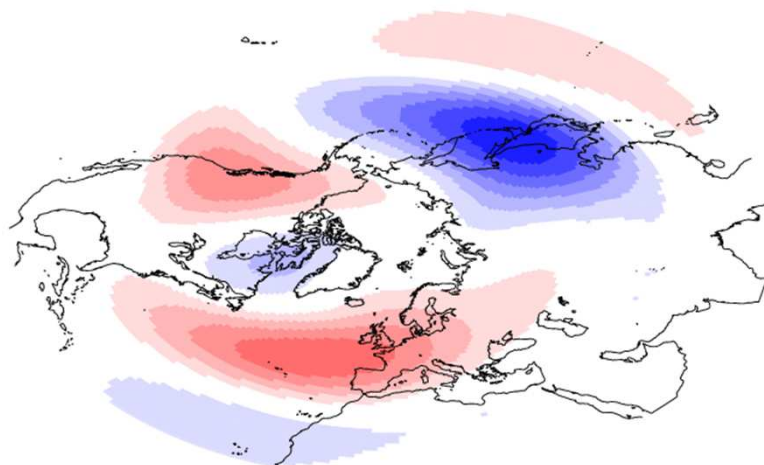
# NAO/CWP in CAM5.3



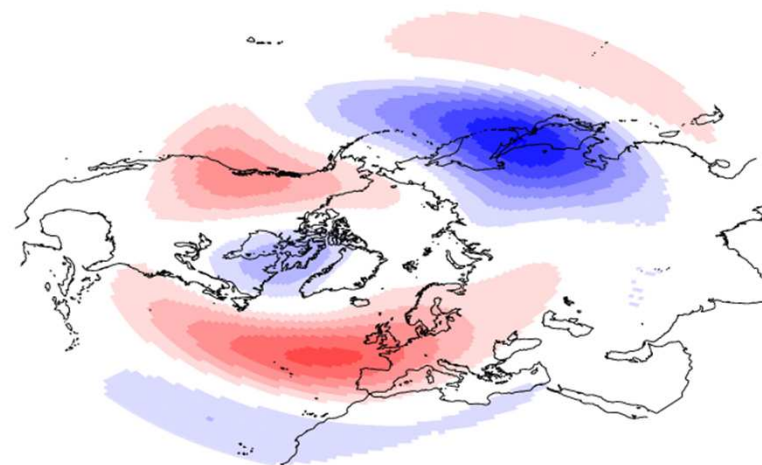
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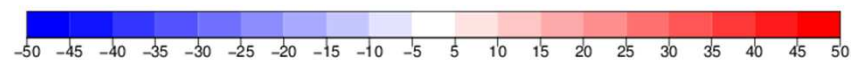
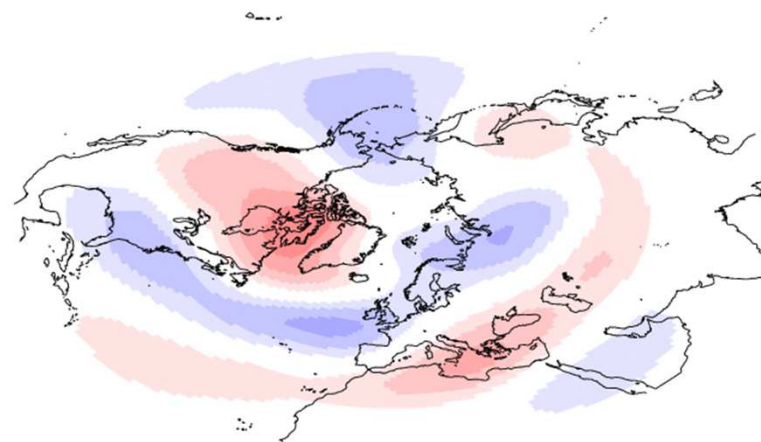
CAM5.3 FREE RUN | Z300° climatology



CAM5.3 NUDG RUN | Z300° climatology



CAM5.3 FREE-NUDG | Z300° climatology



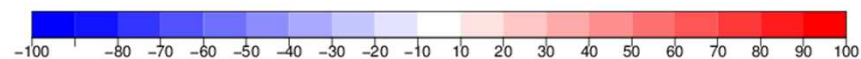
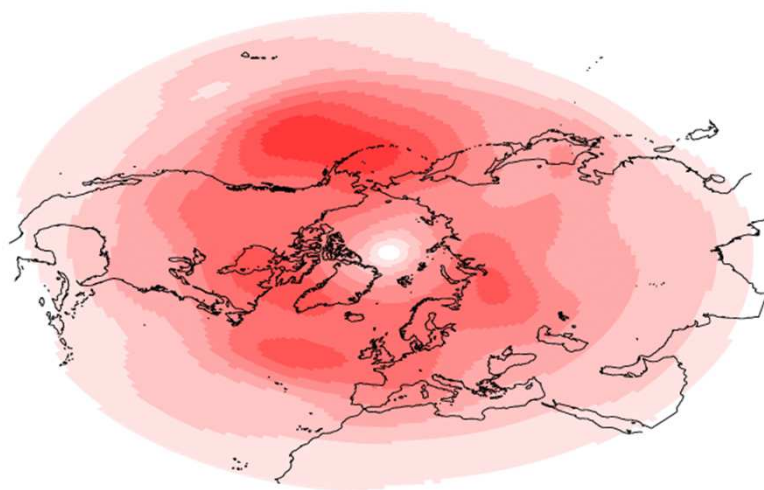
# NAO/CWP in CAM5.3



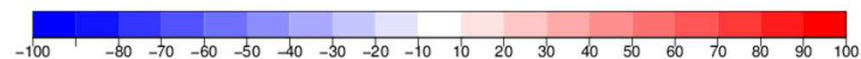
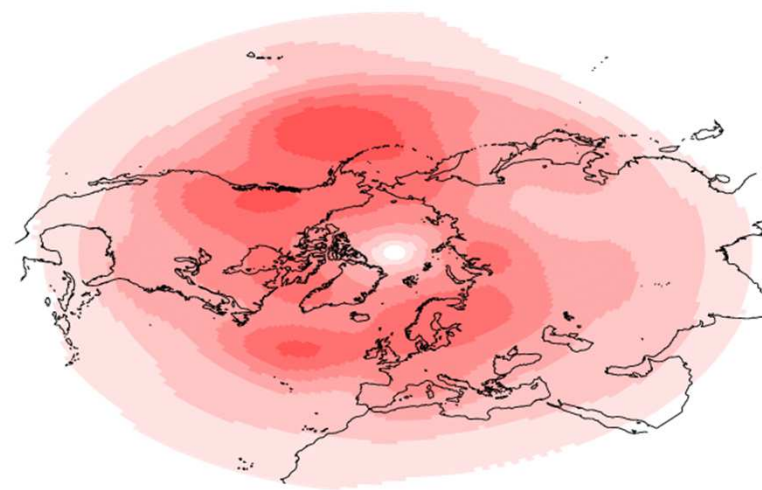
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EXCELENCIA  
SEVERO  
OCHOA

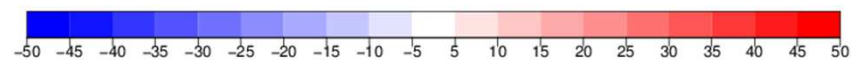
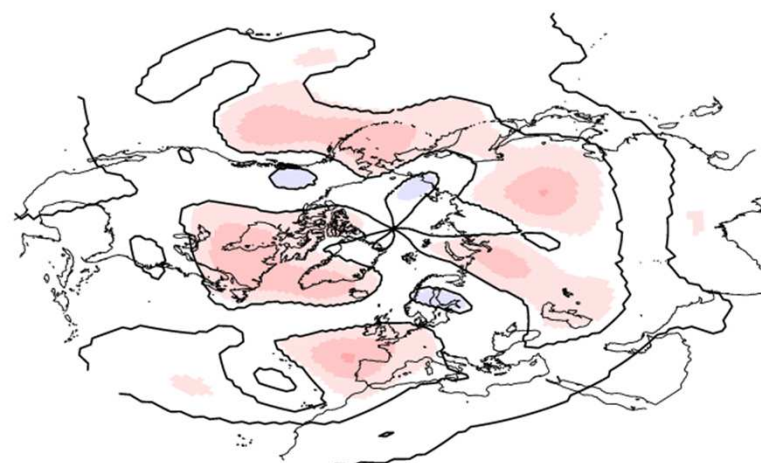
CAM5.3 FREE RUN | Z300\* std.dev



CAM5.3 NUDG RUN | Z300\* std.dev

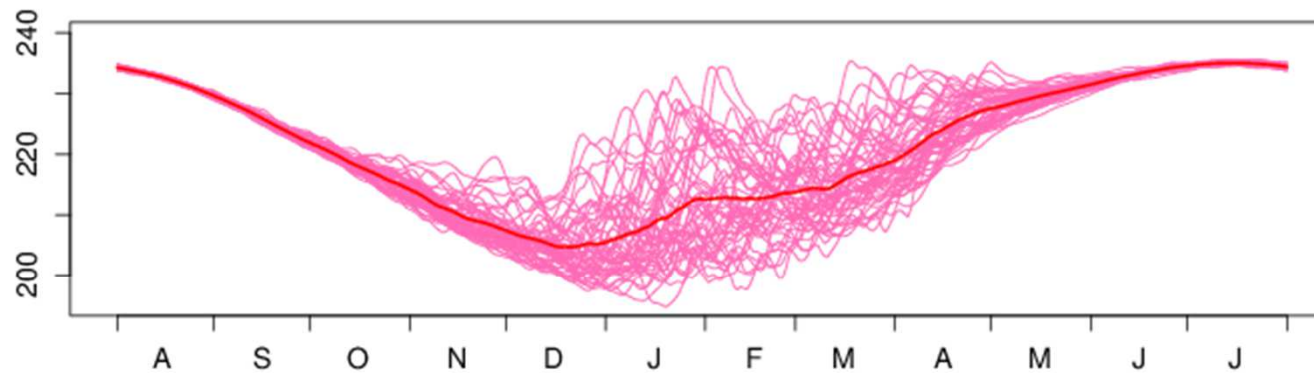


CAM5.3 FREE-NUDG | Z300\* std.dev

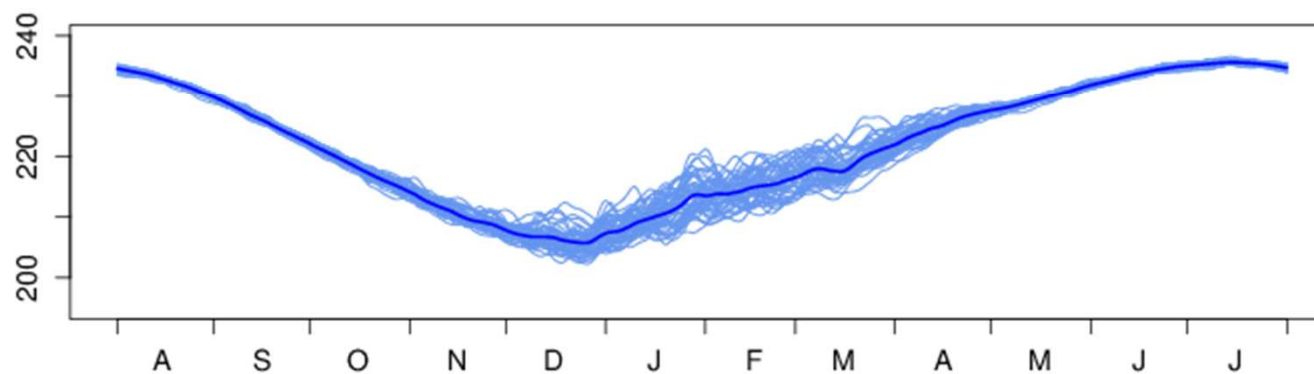




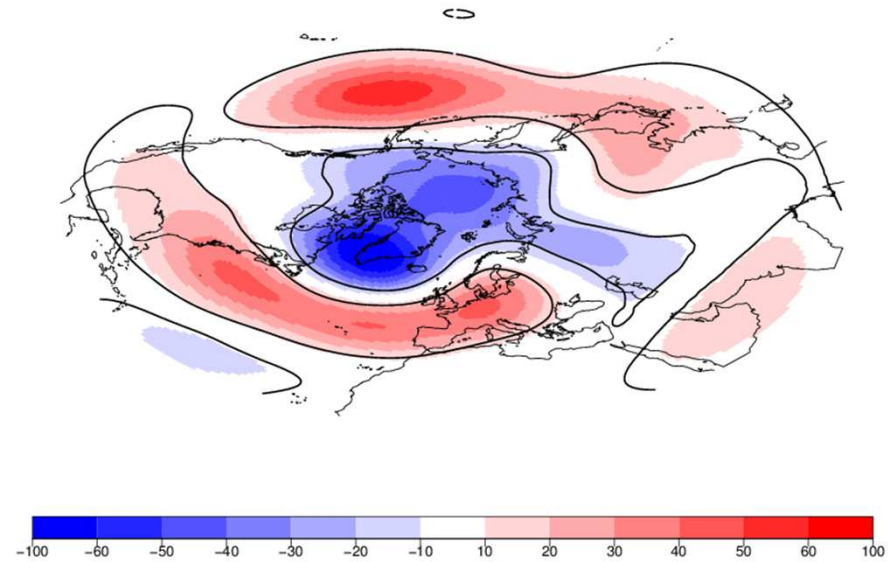
**{T@60N-90N}30hPa FREE RUN (a032)**



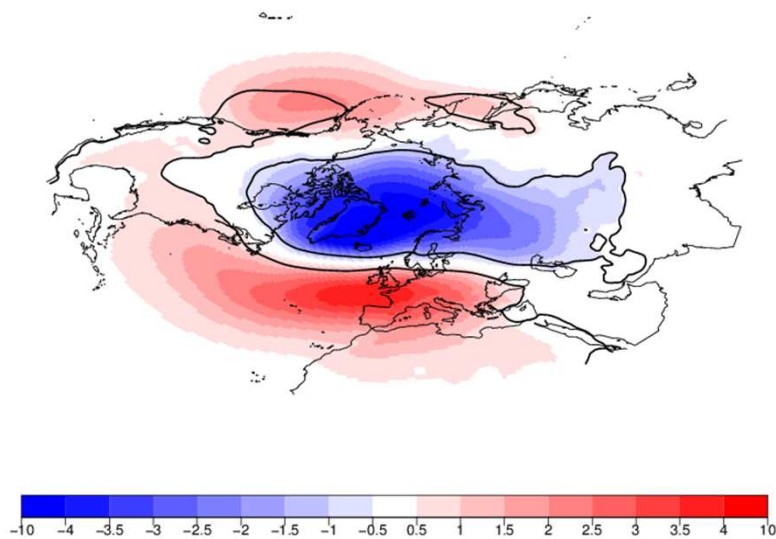
**{T@60N-90N}30hPa NUDGED RUN (a045)**



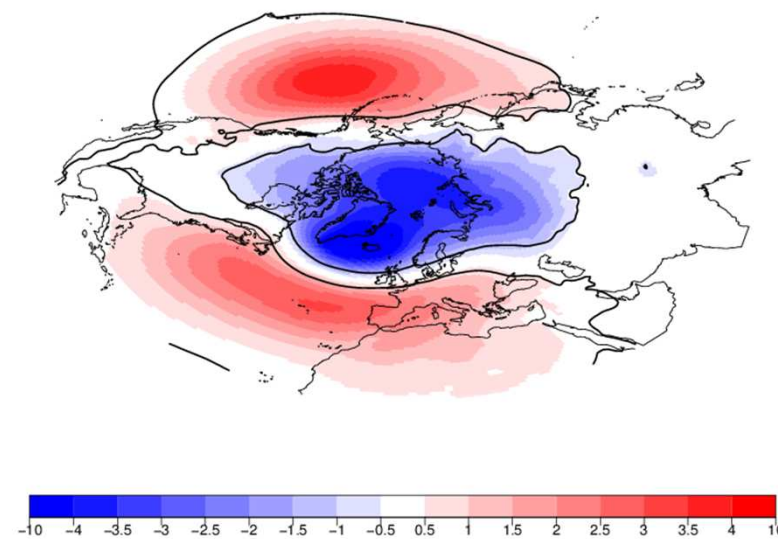
NAO x Z300 / NUDG (djf)



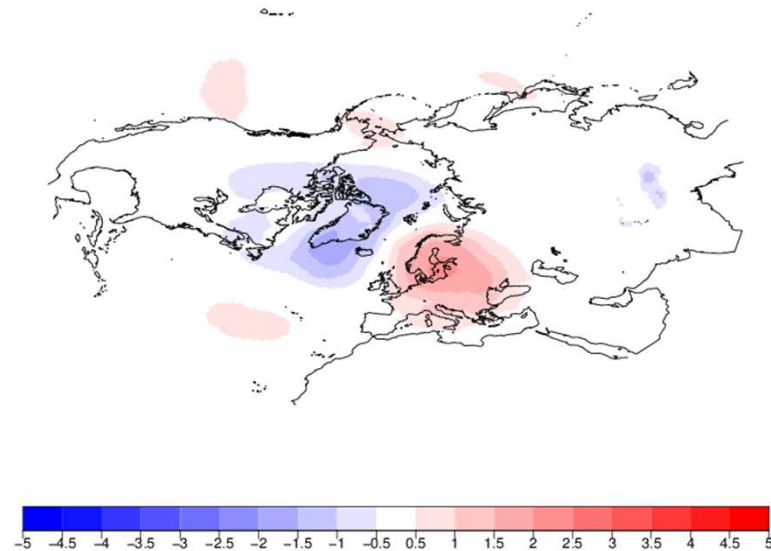
EOF#1 SLP-NAE FREE RUN | fvar=42.46% | season=12-14



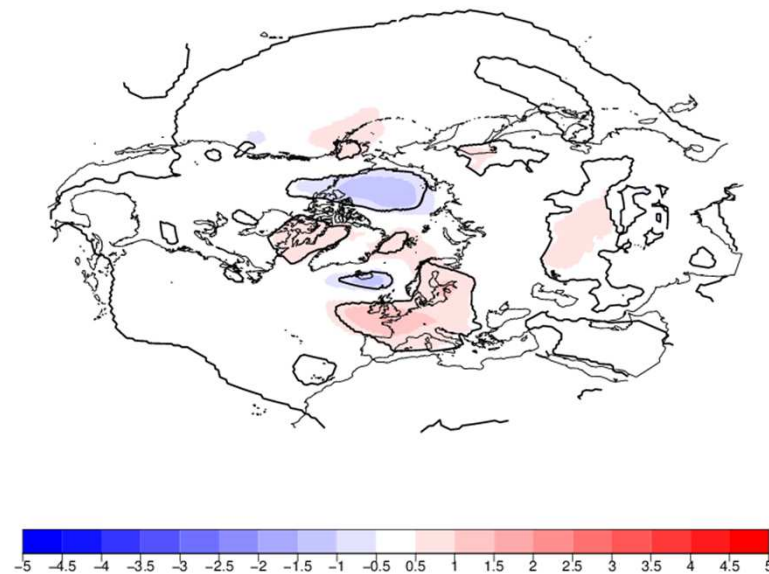
EOF#1 SLP-NAE NUDGED RUN | fvar=44.11% | season=12-14



EC-EARTH3.1 FREE-NUDG | SLP climatology



EC-EARTH3.1 FREE-NUDG | SLP std.dev







## SUMMARY:

- the hemispheric signature of the NAO could be explained by tropospheric dynamics
- without the need of interaction with the stratosphere
- involving a Rossby wavetrain channelized into the westerly jets
- consistent with the CWP pattern at the upper troposphere

¿? what about a NAO-like response induced from the stratosphere

¿? does it also involve a CWP pattern in the troposphere