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# EOF-based analysis of atmospheric flow regimes in NorESM1-M

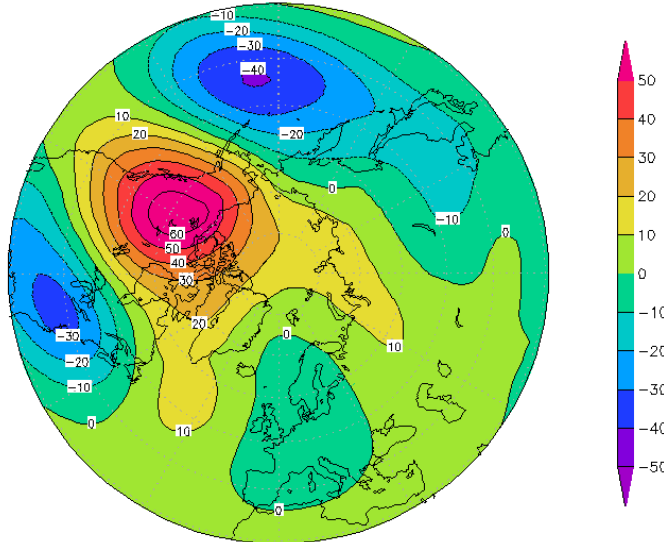
CMIP5 historical ensembles [1850-2005]  
Black Carbon simulations



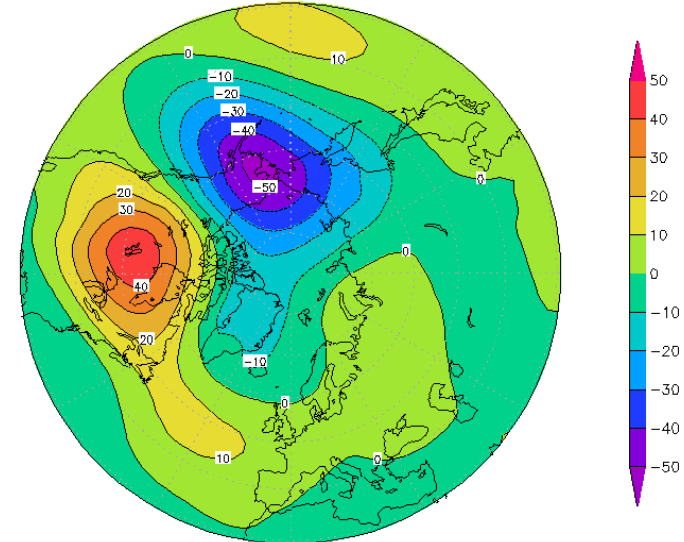
*Trond Iversen, UiO/met.no*  
*Øyvind Seland, met.no*  
*Ivar Seierstad, met.no*  
*Alf Kirkevåg, met.no*  
*Terje K. Berntsen, UiO*

# CMIP5; 3 ensembles Z500 [year 1850-2005]. 906 months, DJFM

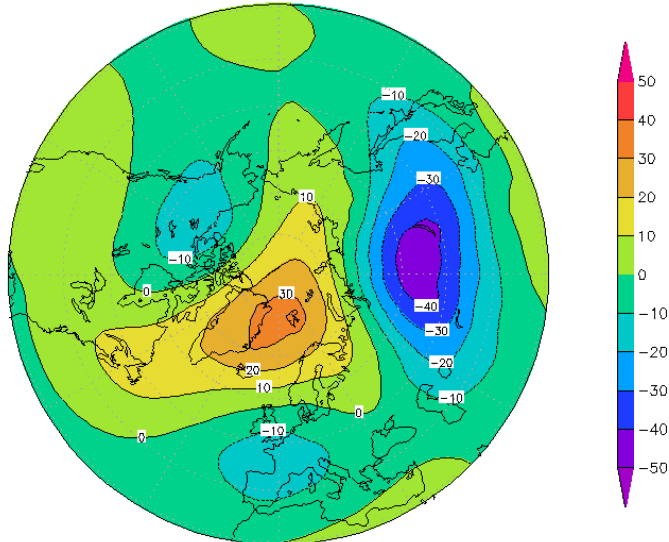
EOF1 [CMIP5 hist. ens.] 18.73 %



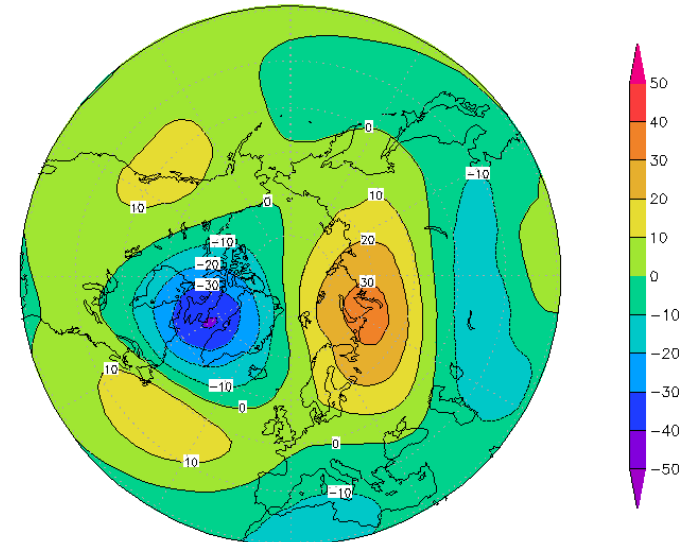
EOF2 [CMIP5 hist.ens.] 12.86 %



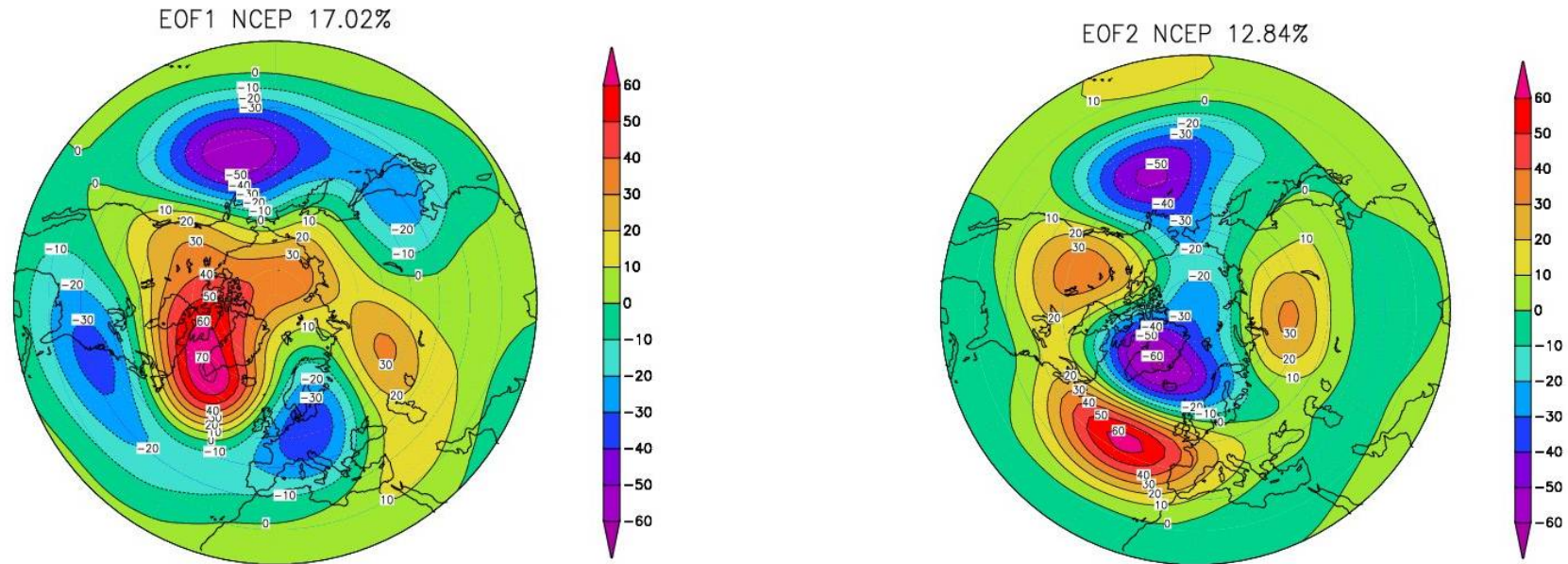
EOF3 [CMIP5 hist. ens.] 9.95 %



EOF4 [CMIP5 hist. ens.] 7.55 %



# NCEP reanalysis [year 1954/5-1997/8], 176 months, DJFM



## Rotation:

REOF1 = EOF1+EOF3  $\langle \text{REOF1}, \text{EOF1\_NCEP} \rangle = \max$

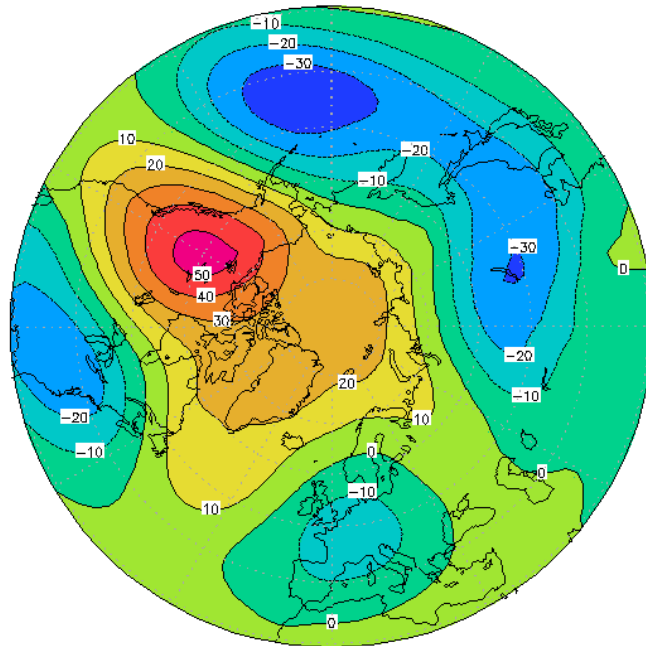
REOF2 = EOF2+EOF4  $\langle \text{REOF2}, \text{EOF2\_NCEP} \rangle = \max$

$$\text{EOF1}_{\text{NCEP\_PROJ}} = \frac{\text{EOF1}_{\text{NCEP}} \cdot \text{EOF1}}{\text{EOF1} \cdot \text{EOF1}} \cdot \text{EOF1} + \frac{\text{EOF1}_{\text{NCEP}} \cdot \text{EOF3}}{\text{EOF3} \cdot \text{EOF3}} \cdot \text{EOF3} \quad \text{REOF1} = \frac{\text{EOF1}_{\text{NCEP\_PROJ}}}{\|\text{EOF1}_{\text{NCEP\_PROJ}}\|}$$

# Rotated phase space **CMIP5** ensembles [1852-2003]

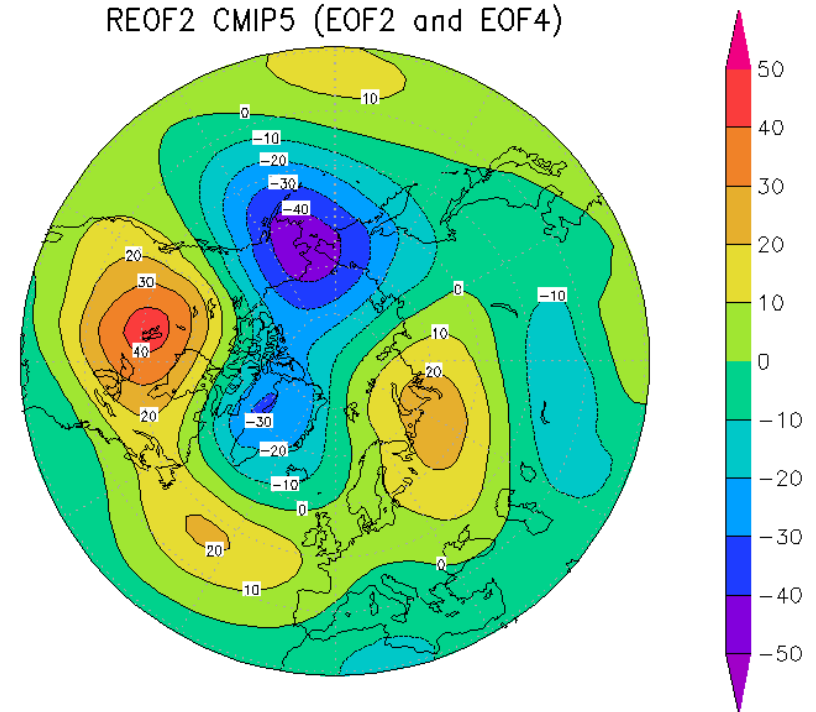
## REOF1

REOF1 CMIP5 (EOF1 and EOF3)

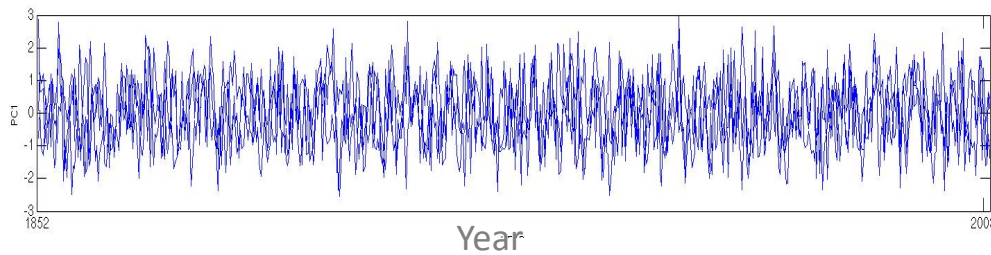


## REOF2

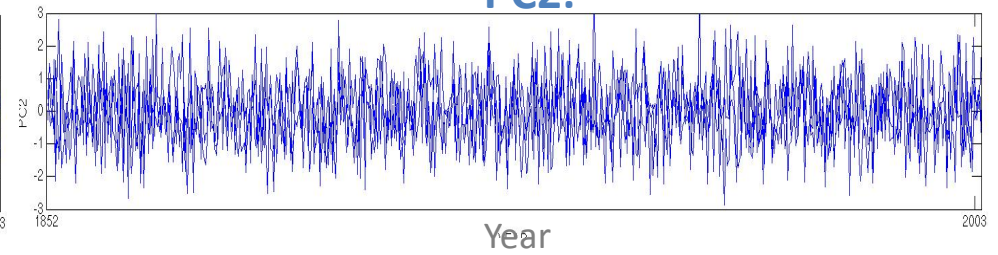
REOF2 CMIP5 (EOF2 and EOF4)



## PC1:



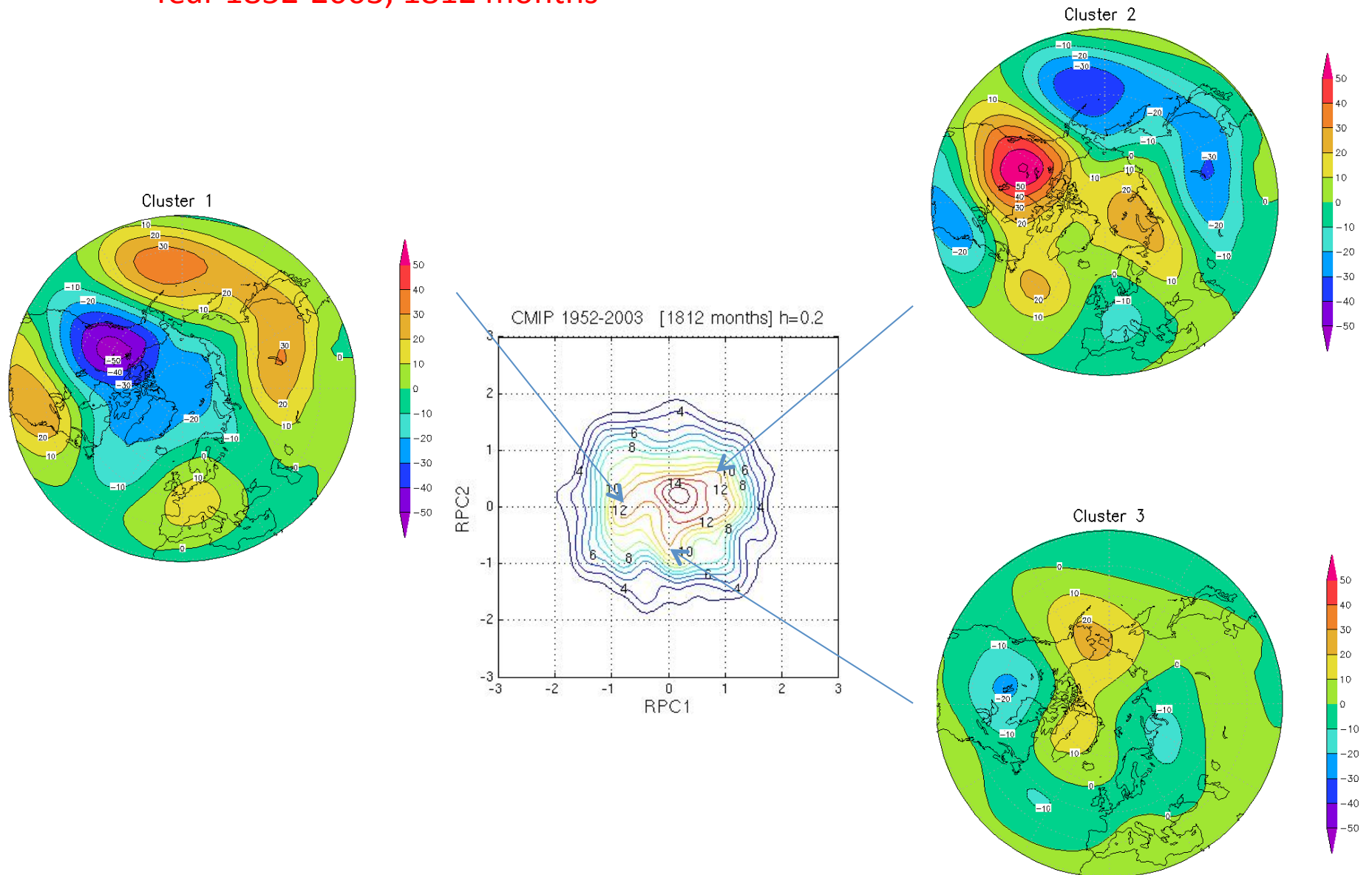
## PC2:



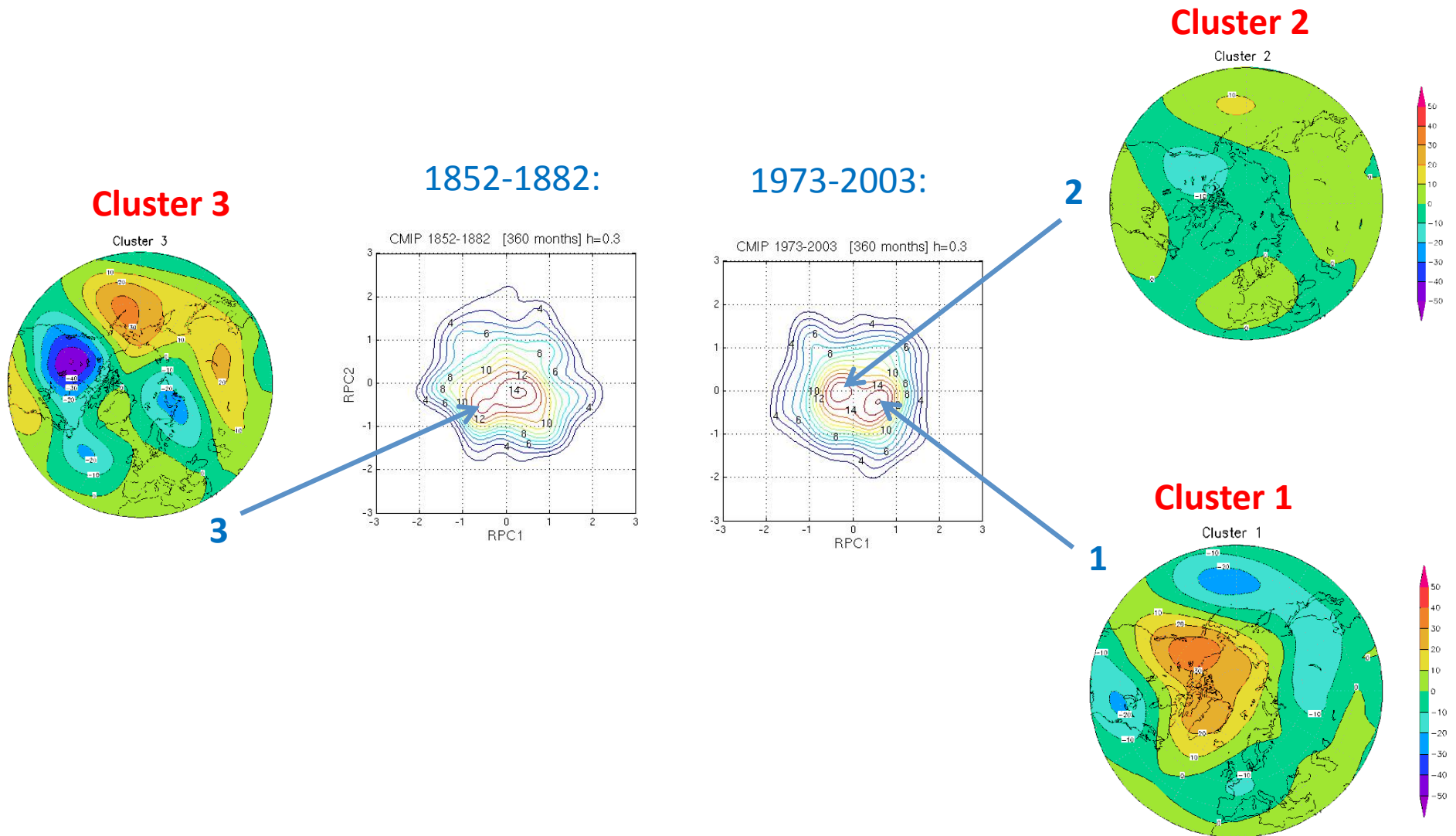


# Cluster analysis: Kernel Density Estimation Method

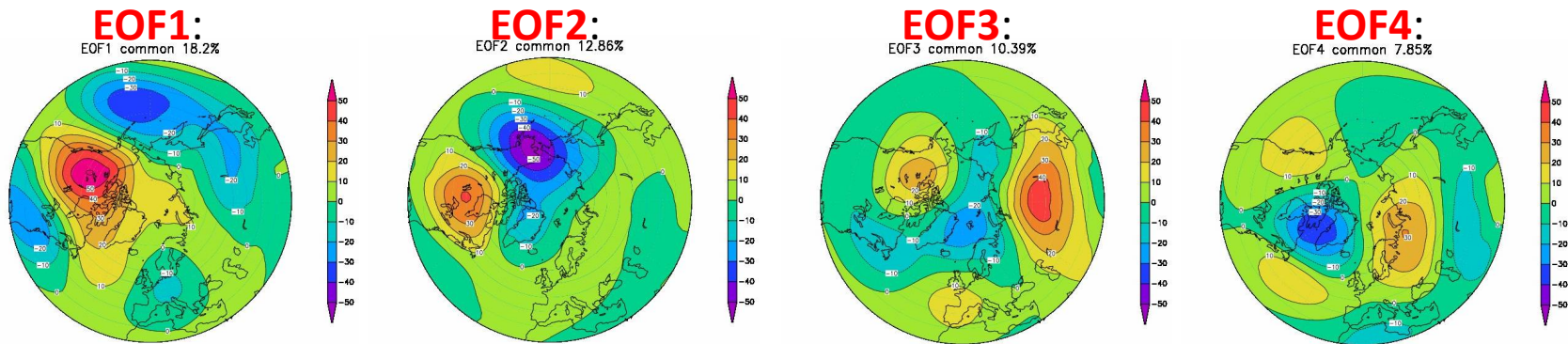
Year 1852-2003, 1812 months



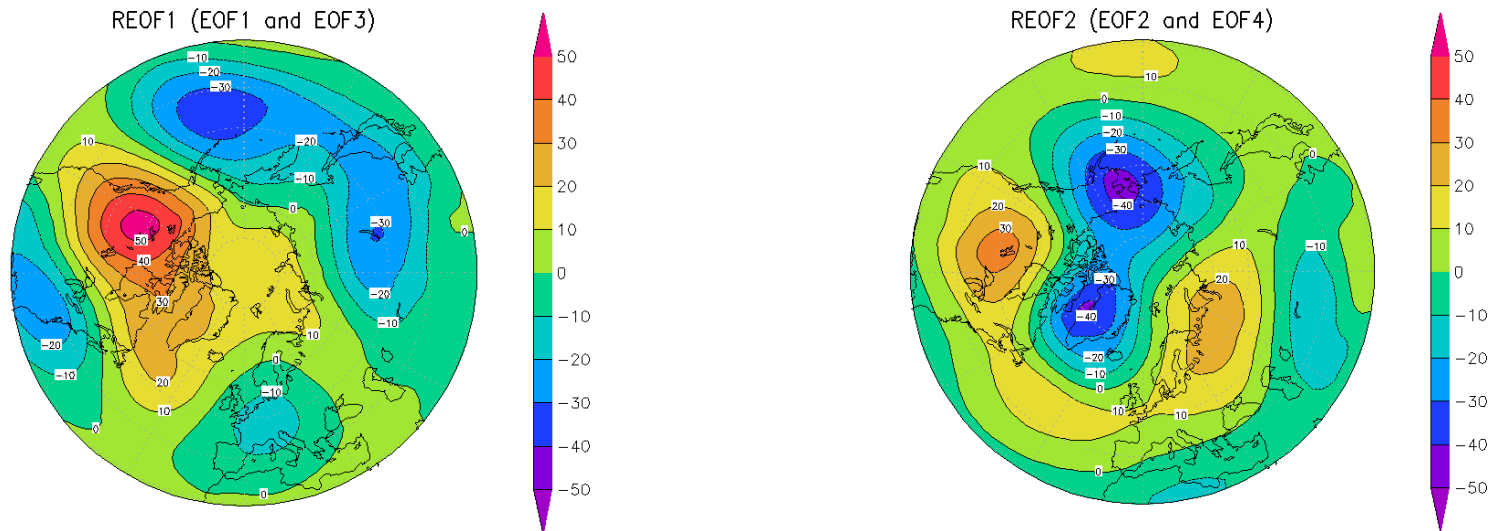
# Cluster analysis: Differences between first and last 30 years?



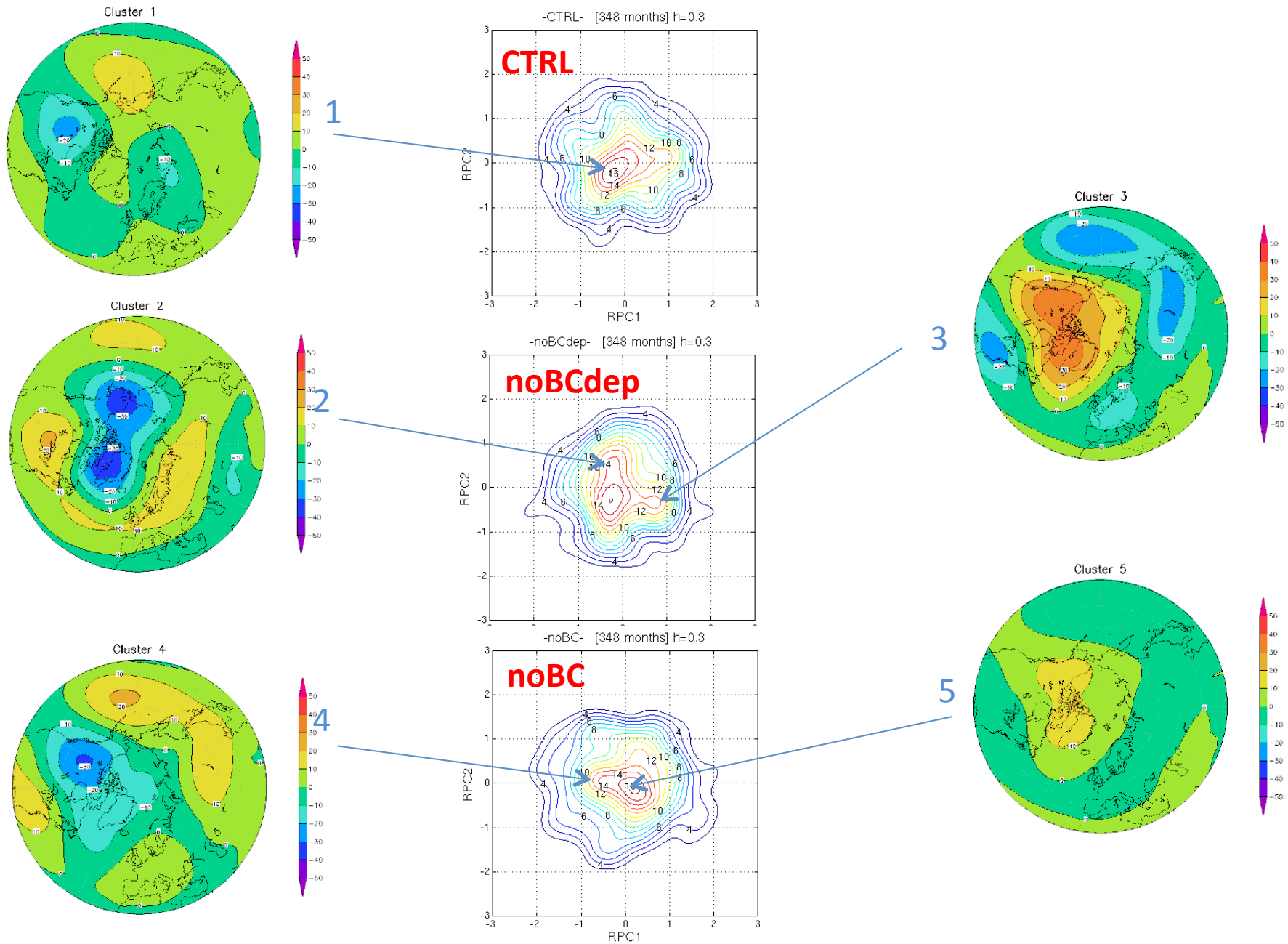
# CTRL, BC dep. and no BC runs [year 118-205]. 783 months, DJFM



## Rotated phase space:



# Cluster analysis: difference between the 3 simulations?





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# Sensitivity studies in NorESM1-M

Does it matter where the forcing comes from?



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*Øyvind Seland, met.no*  
*Alf Kirkevåg, met.no*  
*Jean-Francois Lamarque, NCAR*  
*Jen Kay, NCAR*

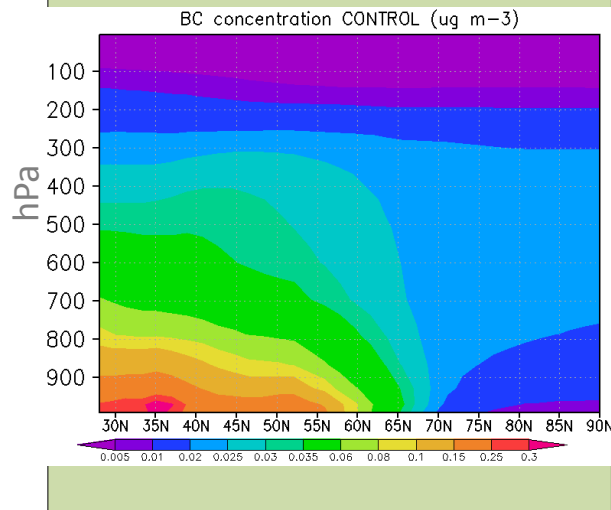
Earthclim meeting 2011 Bergen

# Applying forcing from Black Carbon in two different latitude bands

## Experimental setup:

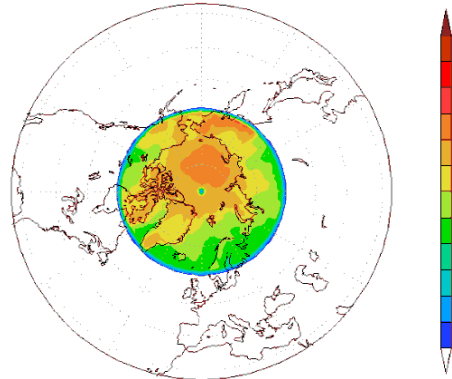
Black carbon concentrations are **multiplied by 10** in 2 different latitude bands;

- **the Arctic** (60N-90N)
- **the mid-latitudes** (28N-60N) .

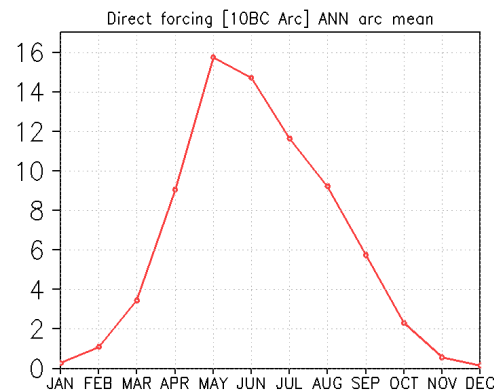


## 10xBC Arctic: 'donut hole forcing'

Direct forcing TOA [ $\text{W/m}^2$ ] -10xBC Arctic-

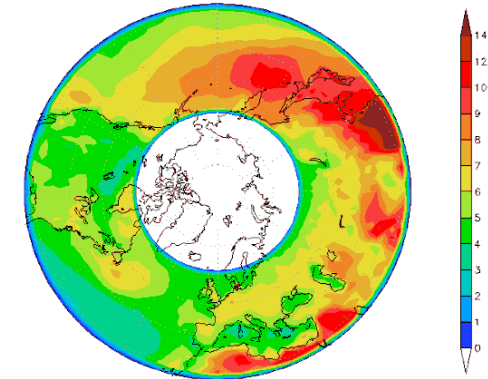


Local mean:  **$6.16 \text{ W m}^{-2}$**   
Global mean:  **$0.41 \text{ W m}^{-2}$**

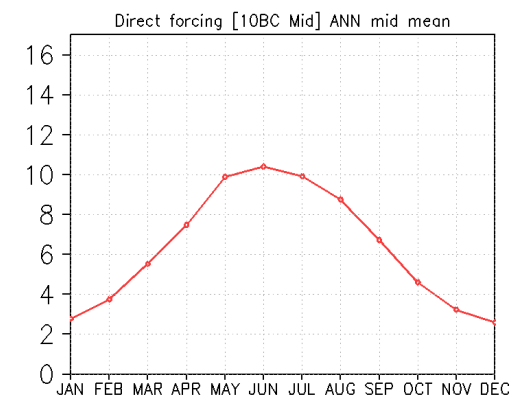


## 10xBC Mid lat: 'donut forcing'

Direct forcing TOA [ $\text{W/m}^2$ ] -10xBC Mid lat-



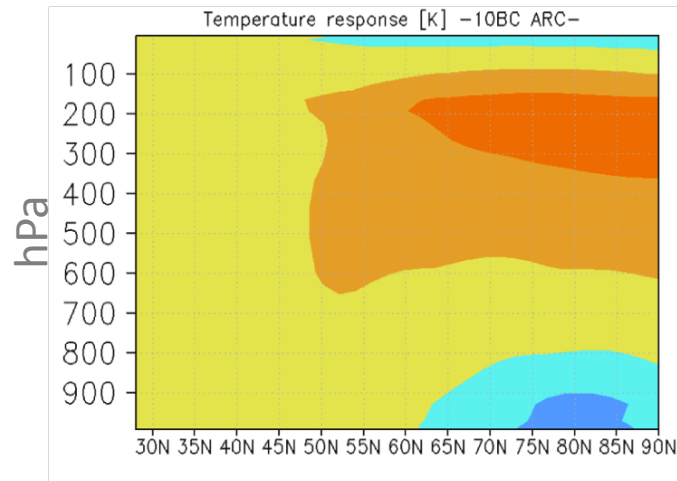
Local mean:  **$6.30 \text{ W m}^{-2}$**   
Global mean:  **$1.26 \text{ W m}^{-2}$**



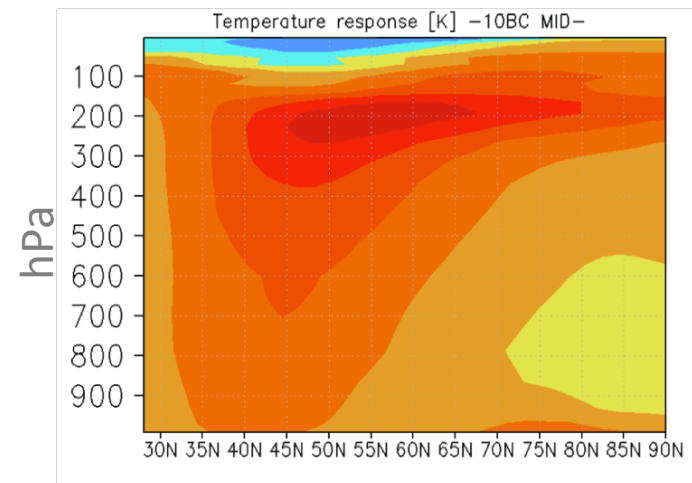
# Temperature response in the Arctic

Zonal  
annual  
average:

Donut hole forcing:



Donut forcing:



Arctic  
seasonal  
average:

