Snow Cover and Sea-Ice Impacts and their Links in coordinated experiments

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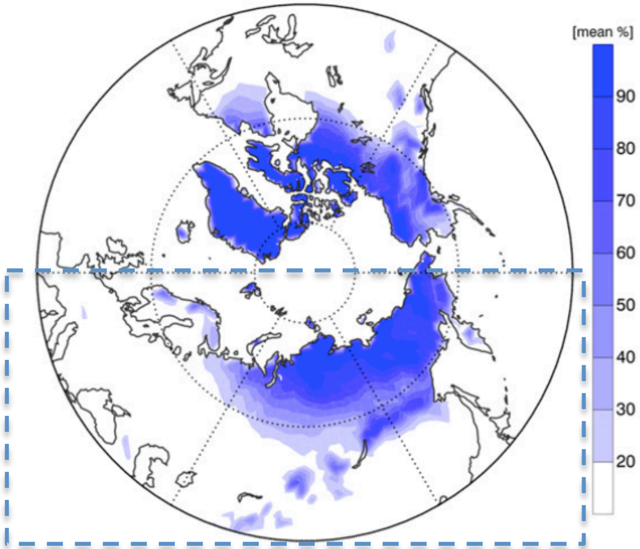
Gastineau, G., J. García-Serrano, and C. Frankignoul. The influence of autumnal Eurasian snow cover on climate and its link with Arctic sea ice cover. *J. Clim.* (2017): 7599-7619.

BLUE ACTION

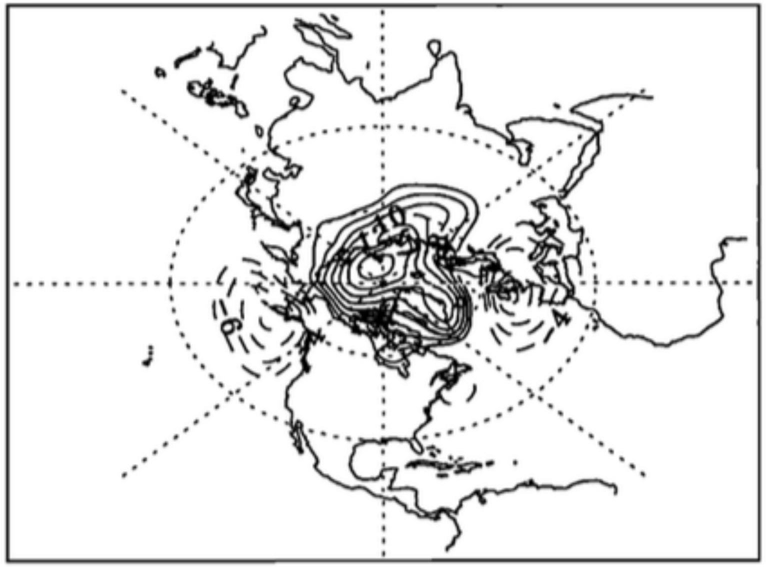
The research leading to these results received funding from the H2020 project Blue-Action under grant agreement 727852.

Interannual Eurasian snow cover influence

Mean snow cover in October (SCE)



SLP DJF -> Difference high – low SCE



Cohen and Entekabhi, 1999

- Snow cover in SON and October received most attention (Cohen and Entekabhi, 1999; Cohen et al. 2014)
- Influence confirmed by sensitivity experiments using snow cover anomalies (Allen and Zender, 2011; Orsolini et al., 2013; Orsolini et al., 2016)

Processes related to Arctic surface state influence

Increase of snow cover over Eurasia

1 or 2 weeks

Lower surface T and increased Siberian High

1 or 2 weeks

Weaker polar vortex and stratospheric warming

Downward propagation

Negative NAO/AO

Cold winter over Europe, precipitation southward shift, with some previsibility

Processes related to Arctic surface state influence

Honda et al., 2009; Petoukov and Semenov, 2010, Garcia-Serrano et al., 2015; King et al., 2016

Reduction of SIC in Barents and Kara sea

1 or 2 weeks

Rossby wave progagation from Arctic region into Eurasia

1 or 2 weeks

Weaker polar vortex and stratospheric warming

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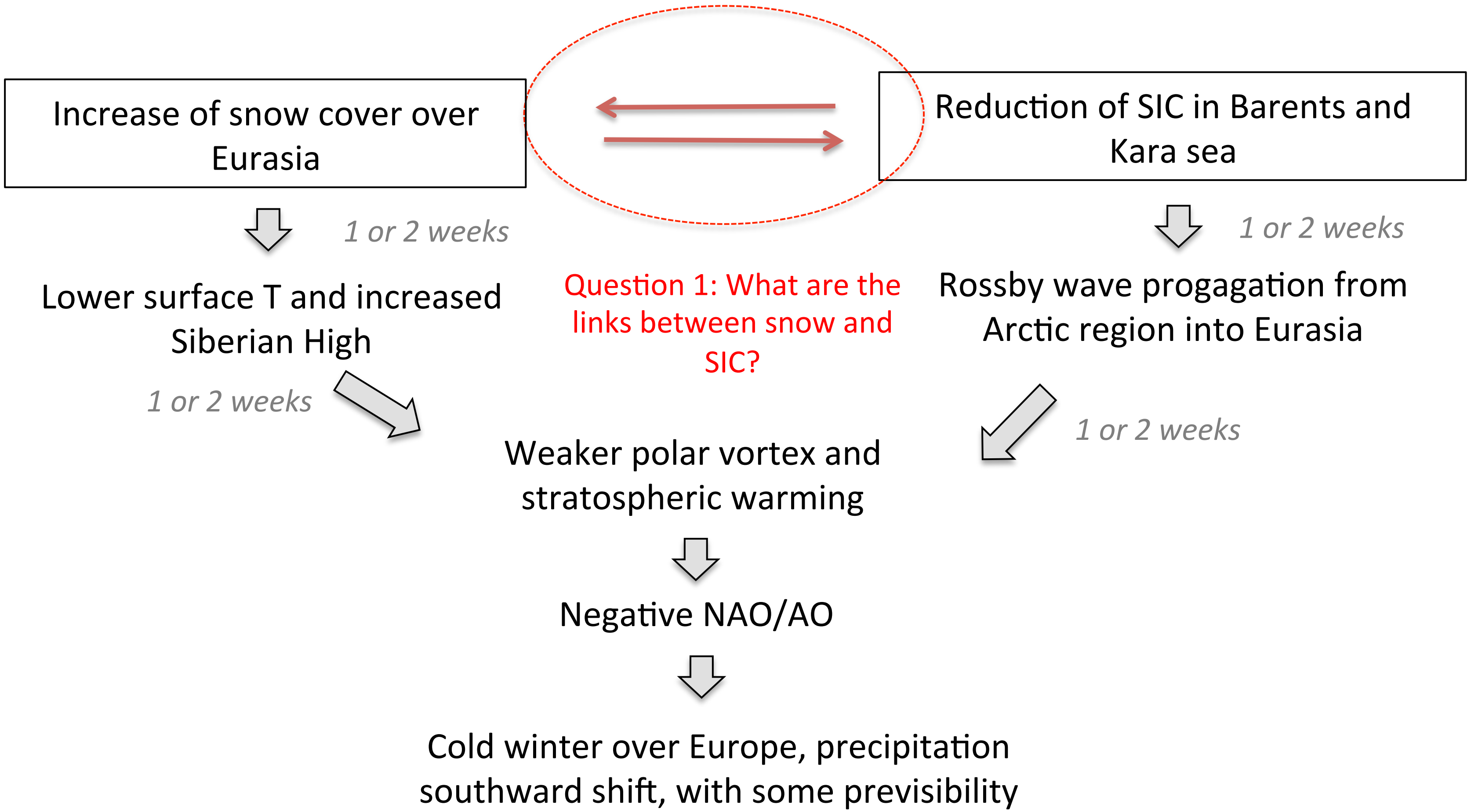
Cold winter over Europe, precipitation southward shift, with some previsibility

Processes related to Arctic surface state influence



Processes related to Arctic surface state influence

Increase of snow cover over Eurasia

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Weaker polar vortex and stratospheric warming

Question 2: Which forcing is the most important?

Negative NAO/AO

Cold winter over Europe, precipitation southward shift, with some previsibility

Data and methods

Datasets:

- Observation 1979-2014 from : (1) ERA-Interim
  (2) NOAA/NSIDC passive microwave sea ice concentration
  (3) NOAA/NCDC snow cover (Comiso, 2012)

- Snow cover, sea ice concentration, and atmospheric variables from 12 CMIP5 ocean-atmosphere models, preindustrial simulations

Group	Model	length (year)
CCCma	CanESM2	995
CNRM-CERFACS	CNRM-CM5	850
CSIRO-QCCCE	CSIRO-Mk3-6-0	500
LASG-CESS	FGOALS-g2	700
MIROC	MIROC-ESM	630
MPI-M	MPI-ESM-LR	1000
MRI	MRI-CGCM3	500
NASA-GISS	GISS-E2-R	550
NCAR	CCSM4	600
NCC	NorESM1-ME	250
NSF-DOE-NCAR	CESM1-BGC	500
IPSL	IPSL-CM5A-LR	1000

Data and methods

- Snow cover and SLP from the 6 atmosphere-only models GREENICE simulations of 1982-2014 :
  - EXP1 : SST and SIC vary
  - EXP2 : SST clim, SIC vary

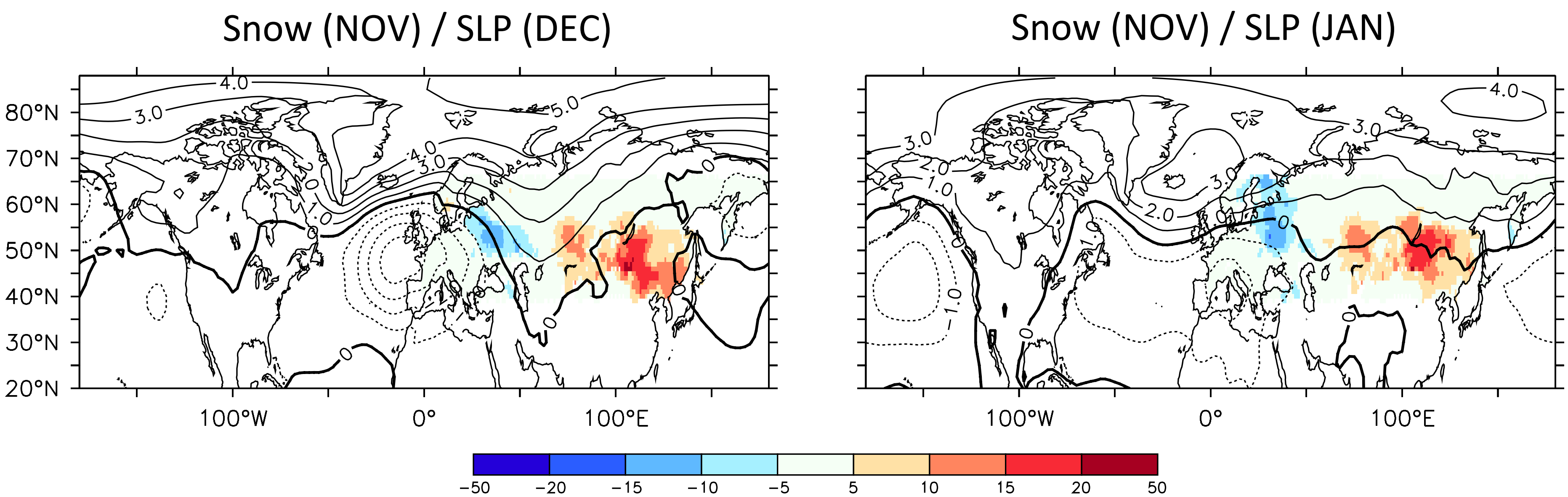
Group	Model	Number of members
SHMI	IFS	20
IAP	IAP4	10
IPSL	LMDZOR	40
UoB	CAM4	20
UoB	WACCM	20
HU	AFES3.1	30

Methods :

- A quadratic trend is removed from all data,
- Maximum Covariance Analysis (MCA) between snow cover and atmospheric sea-level pressure,
- Level of significance of R (correlation) and NSC (scaled eigen value) using Monte Carlo,
- For CMPI5 and observation, part of ENSO teleconnection removed using regression on the first PC of the Pacific ocean.

Snow influence in observations

Homogeneous snow (colors, in %) and heterogeneous SLP (contours, in hPa)



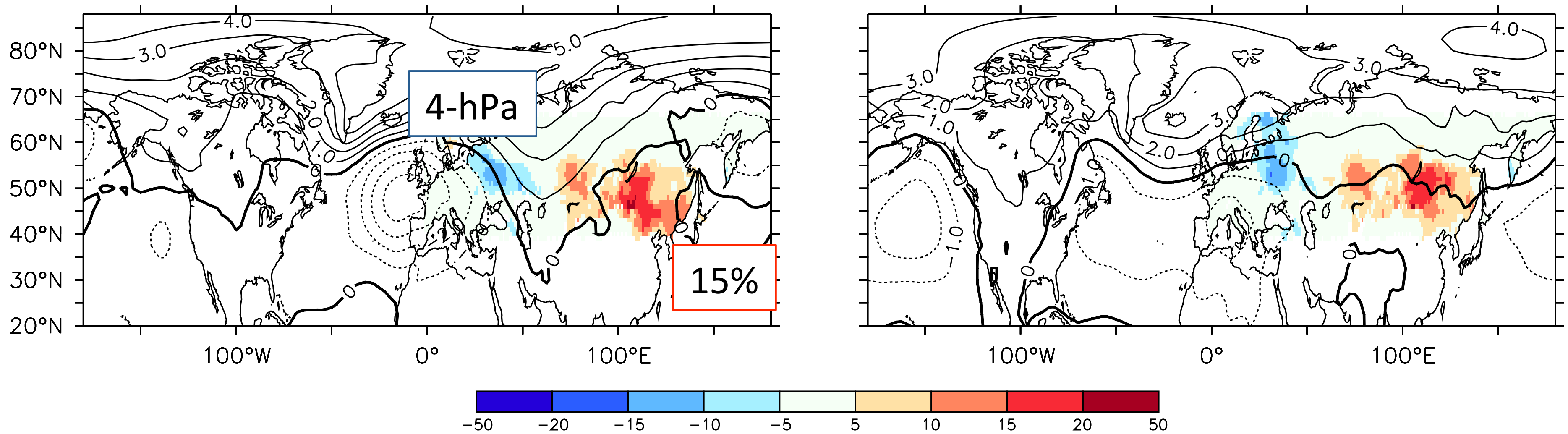
- MCA statistics only show statistical significance with p-values < 5% for Snow in November and SLP in December/Januaray

- The snow cover pattern that influence most the AO is a dipole,

Snow influence in observations

Homogeneous snow (colors, in %) and heterogeneous SLP (contours, in hPa)

Snow (NOV) / SLP (DEC) R=0.82 Snow (NOV) / SLP (JAN)



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Snow influence in CMIP5 models

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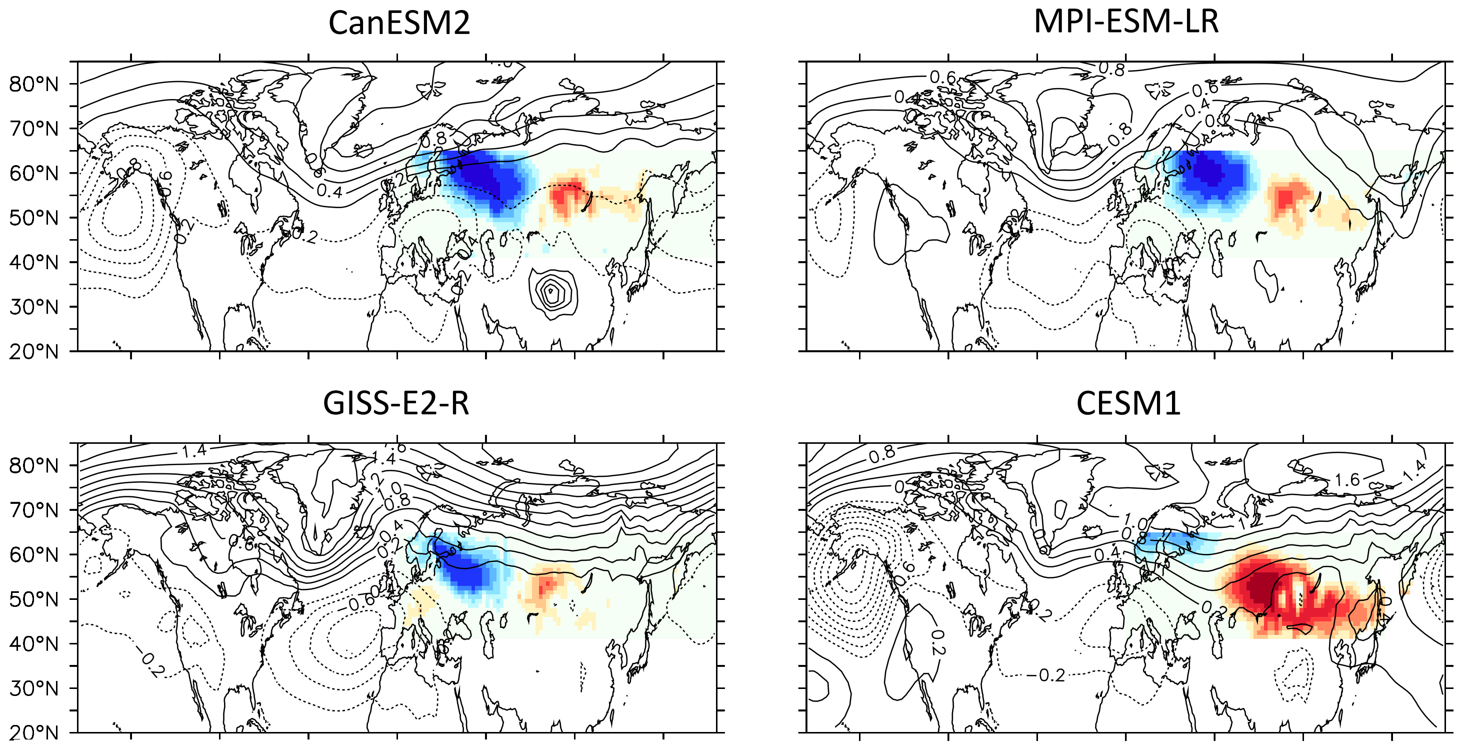

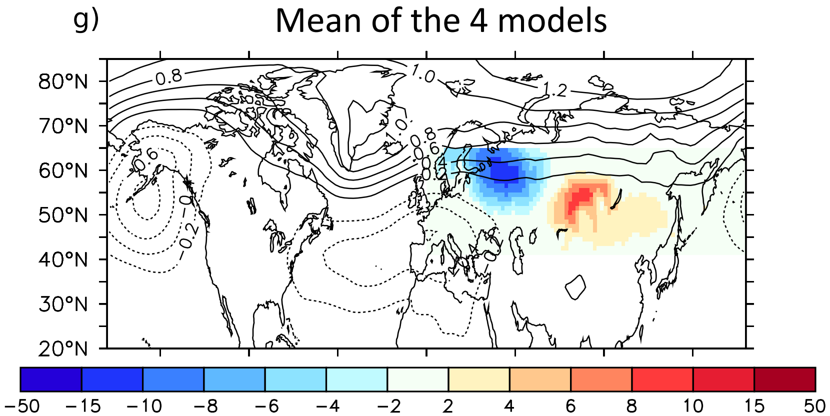

Links between Nov. Snow and Dec. SLP reproduced in these 4 models.

Snow influence in CMIP5 models

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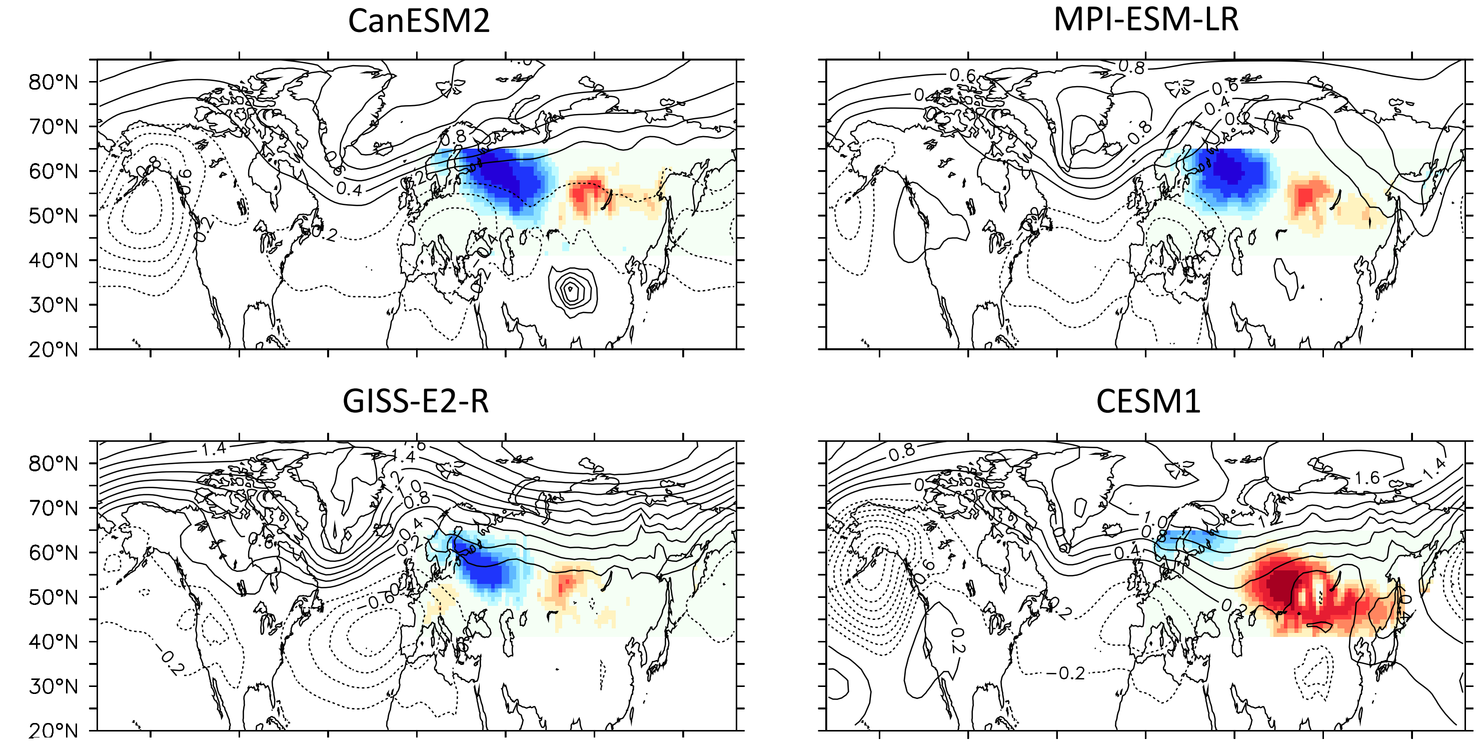
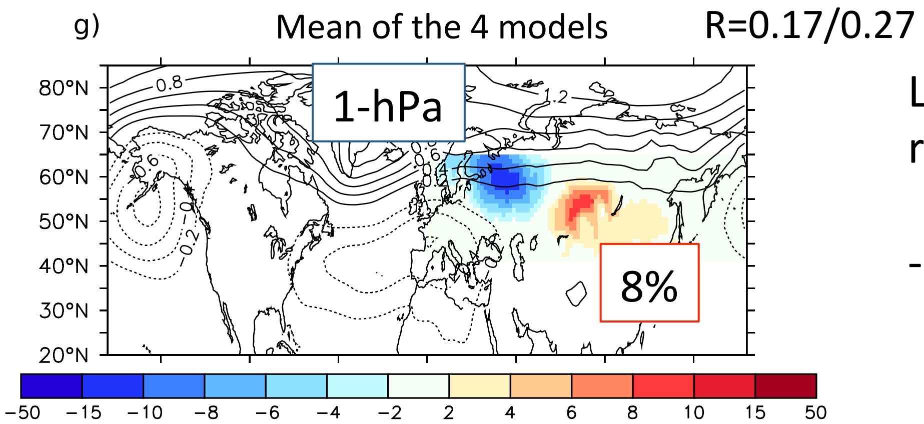


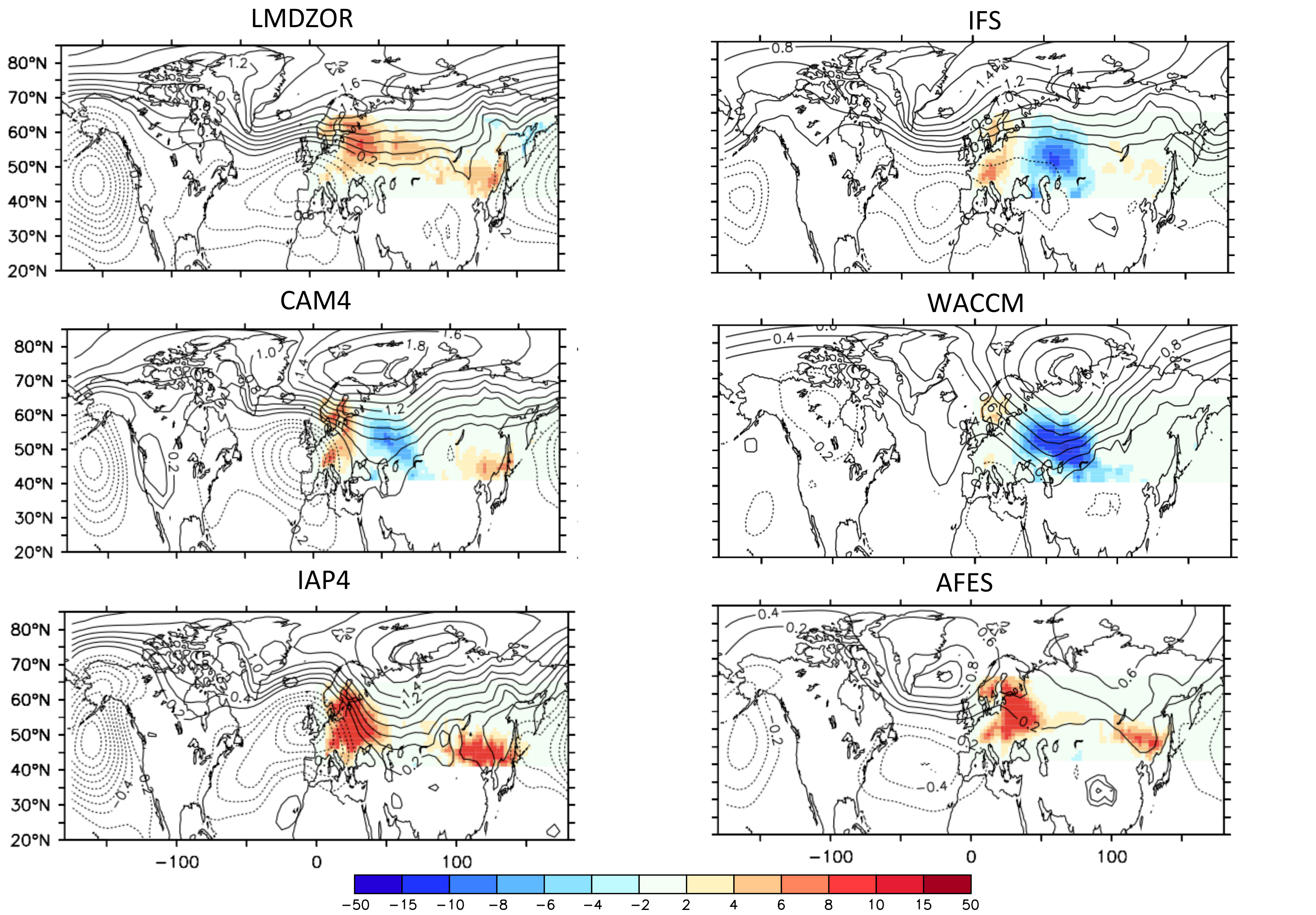


Links between Nov. Snow and Dec. SLP reproduced in these 4 models.

-> large underestimation

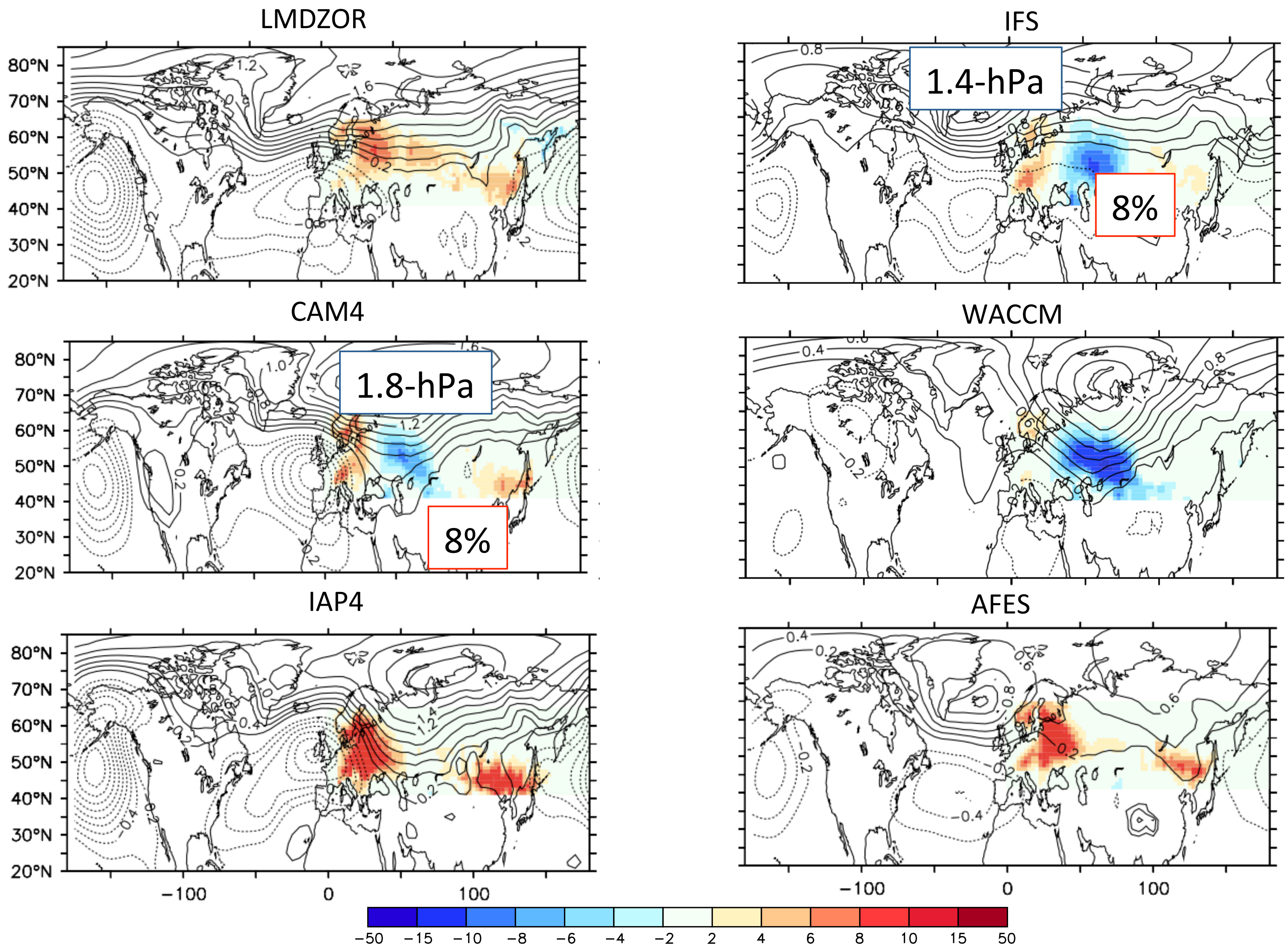
Snow influence in EXP1 GREENICE

Homogeneous Nov. snow (colors, in %) and heterogeneous Dec SLP (contours, in hPa)

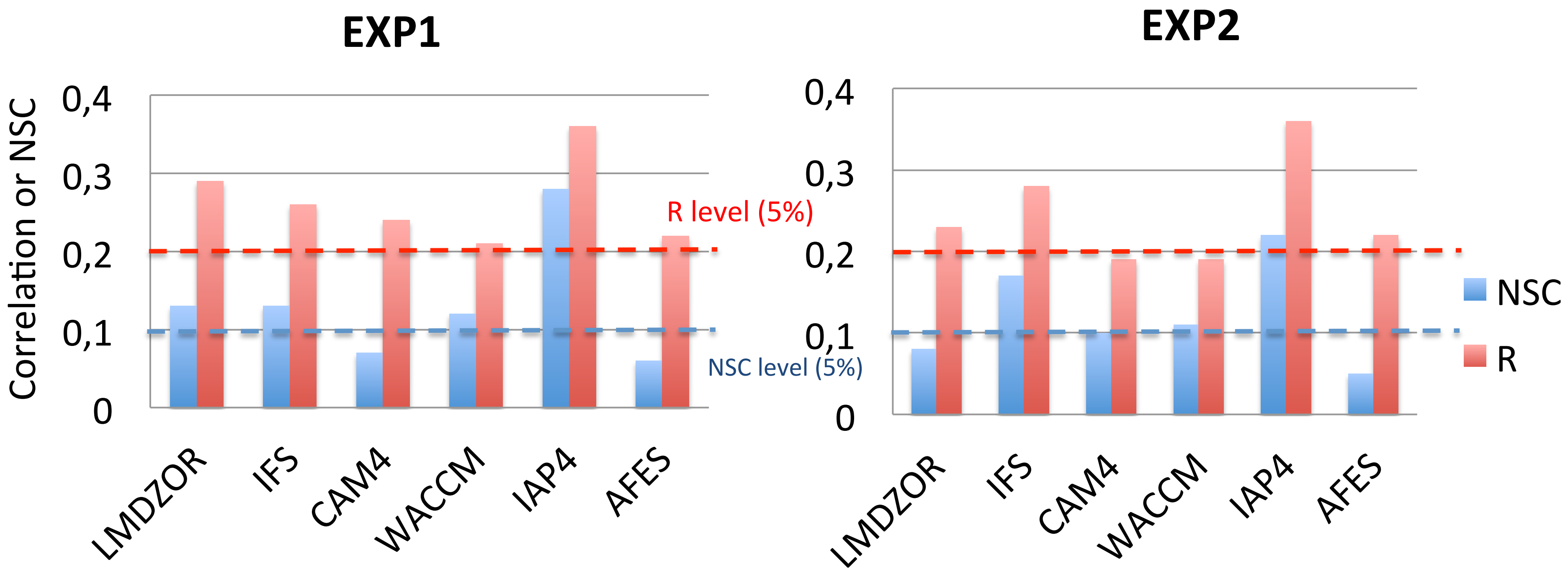


Snow influence in EXP1 GREENICE

Homogeneous Nov. snow (colors, in %) and heterogeneous Dec SLP (contours, in hPa)



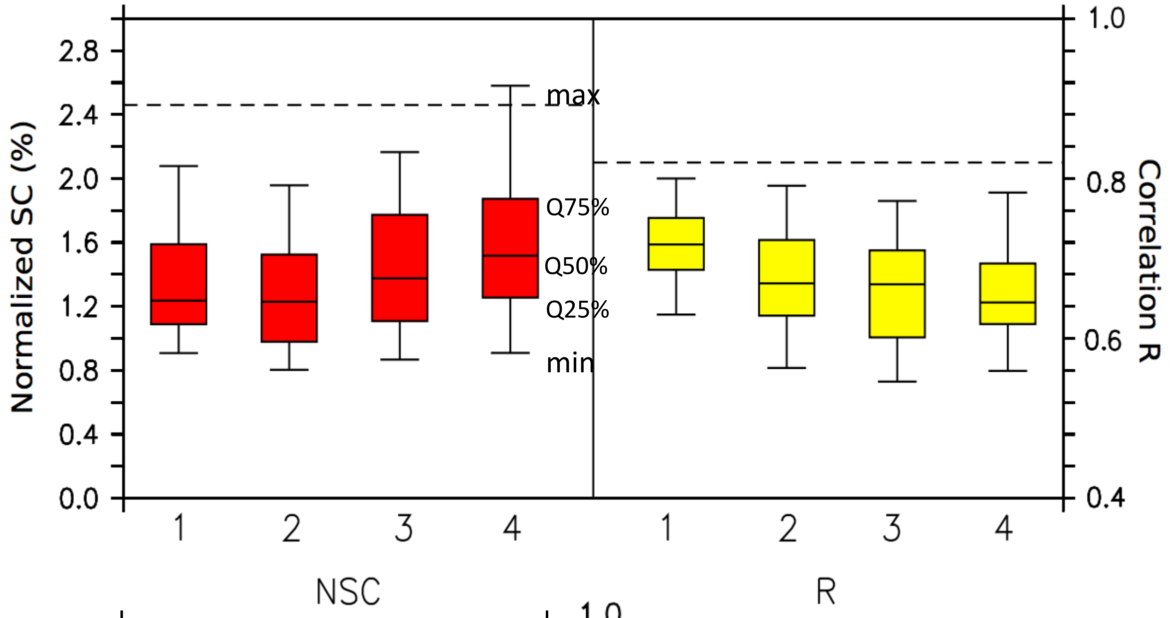
Statistics of MCA modes in GREENICE simulations



<u>Summary</u> :

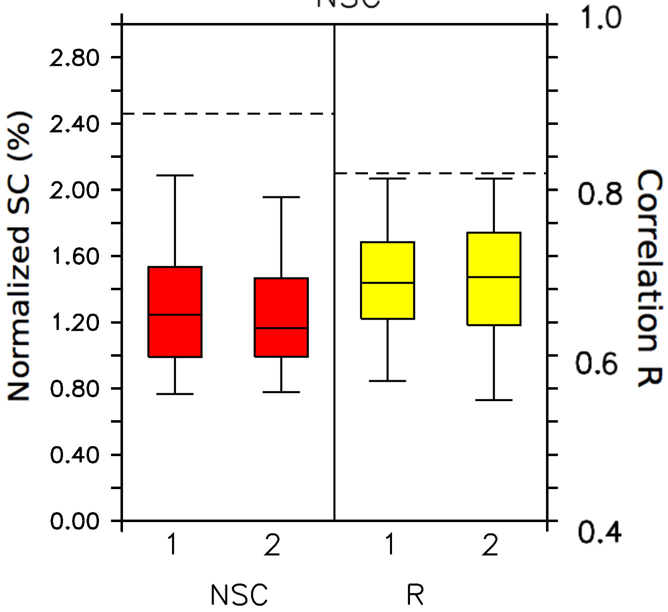
- The November snow cover anomalies lead significant SLP anomalies in December in most models. But the snow dipole is not the dominant mode.
- EXP1 and EXP2 show similar covariability patterns.

Internal atmospheric variability?



The CMIP5 control runs were divided into 36-yr periods.

Model :
1. CanESM2
2. MPI-ESM
3. GISS-E2-R
4. CESM1



Same analysis for all GREENICE simulations:

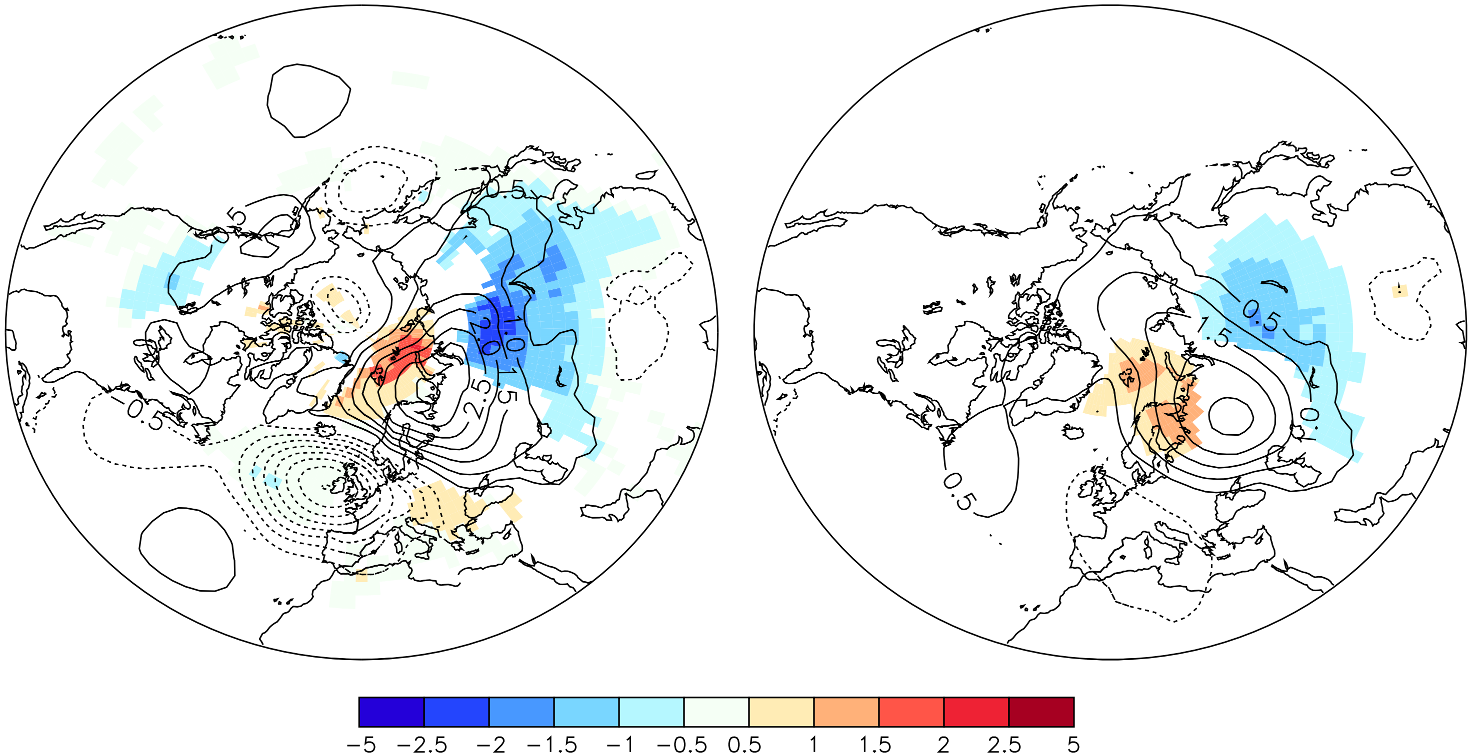
Ensemble :
1. EXP1
2. EXP2

Summary : internal atmospheric variability cannot explain the underestimation of R and NSC

Origin of snow dipolar anomalies

Air temperature at 2m (in K, color) and SLP (in hPa, contour) in Nov., regression onto MCA snow time series

Obs. 79-14 | CMIP5 Models



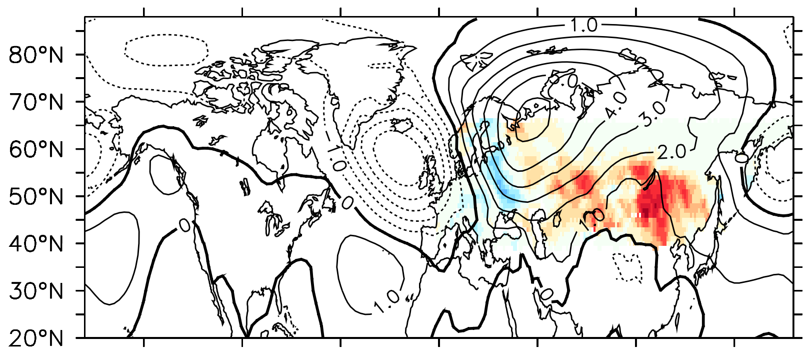
Atmospheric pattern :
- Scandinavian Pattern (SCA) – Bueh and Nakamura (2007),
- Eurasian pattern type 1 – Barnston and Livesey (1987),
- Russian pattern – Smoliak and Wallace (2015)

Atmospheric forcing of snow cover

MCA NOV

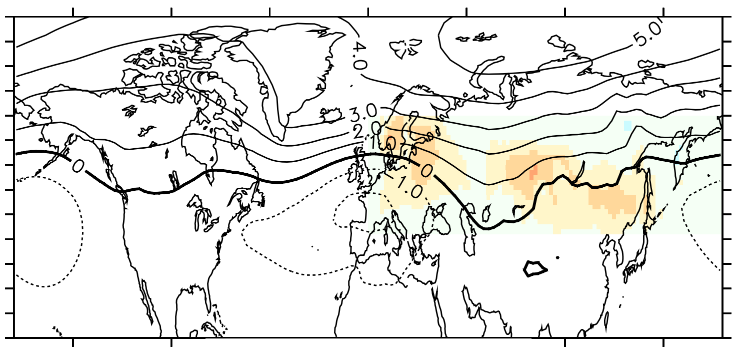
Obs 79-14

Snow (NOV) / SLP (NOV)



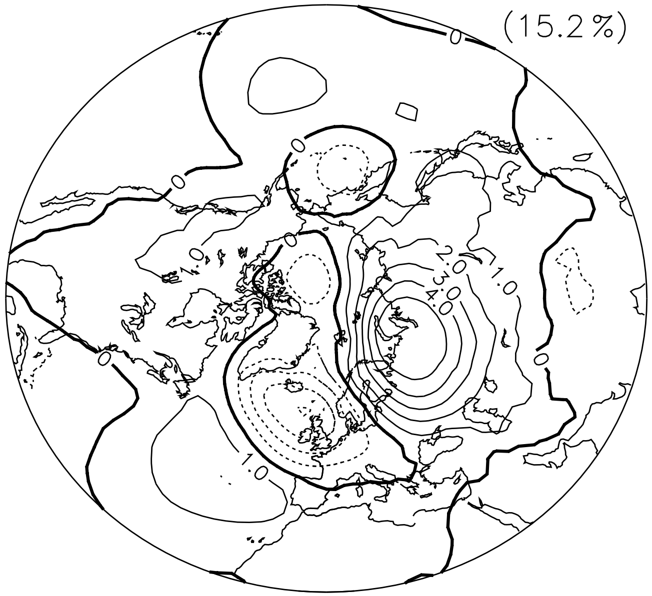
CMIP5 Models

Snow (NOV) / SLP (NOV)

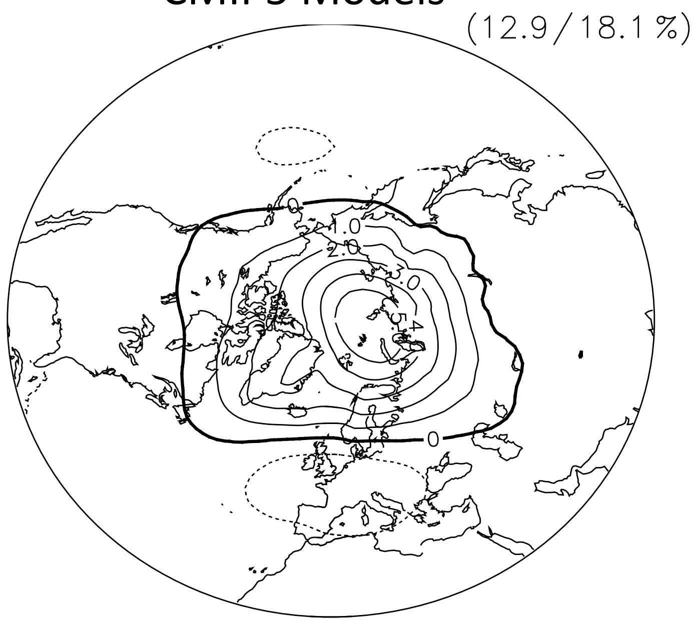


REOF1 –SLP (NOV)

Obs 79-14



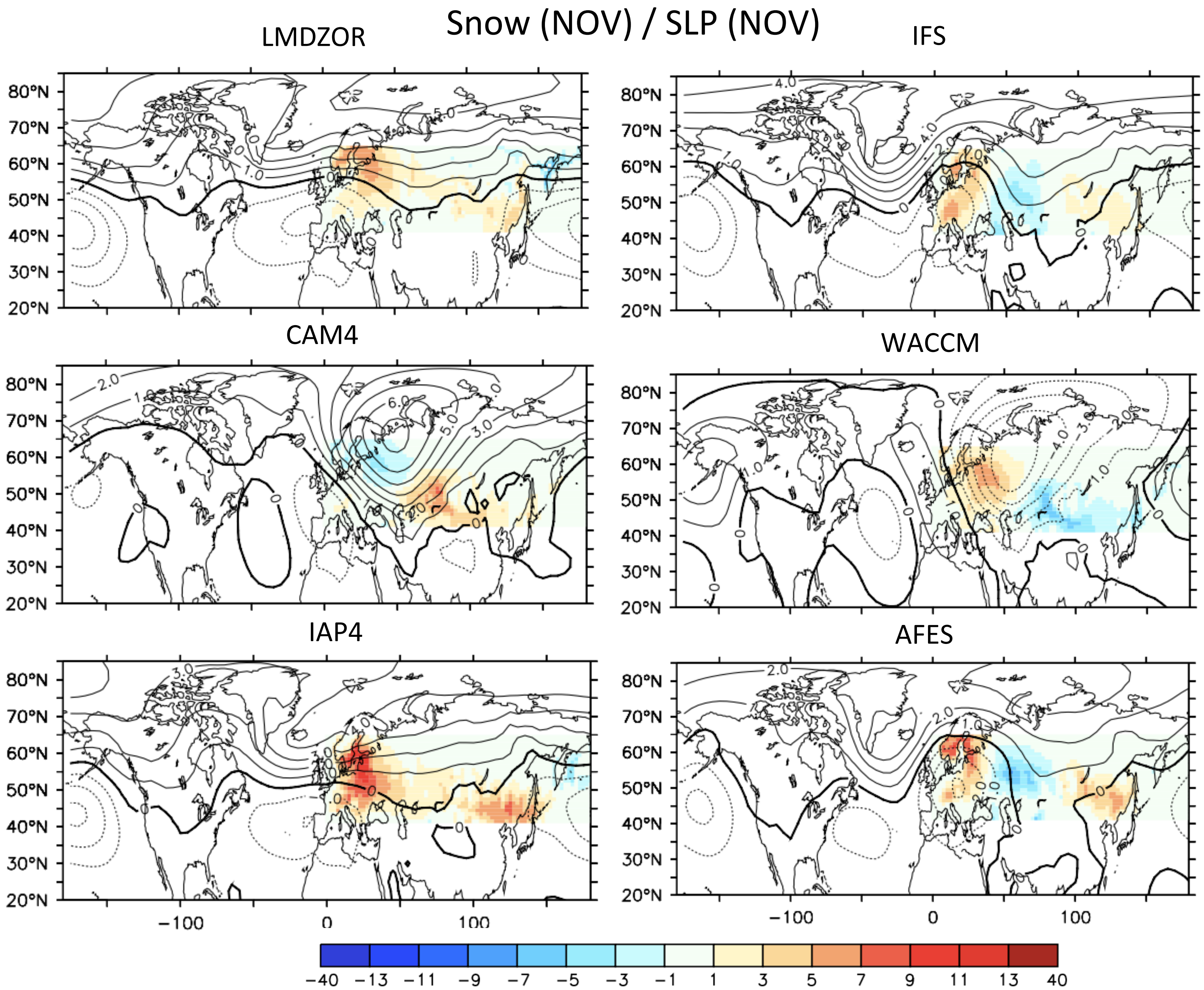
CMIP5 Models



SCA pattern key for snow forcing

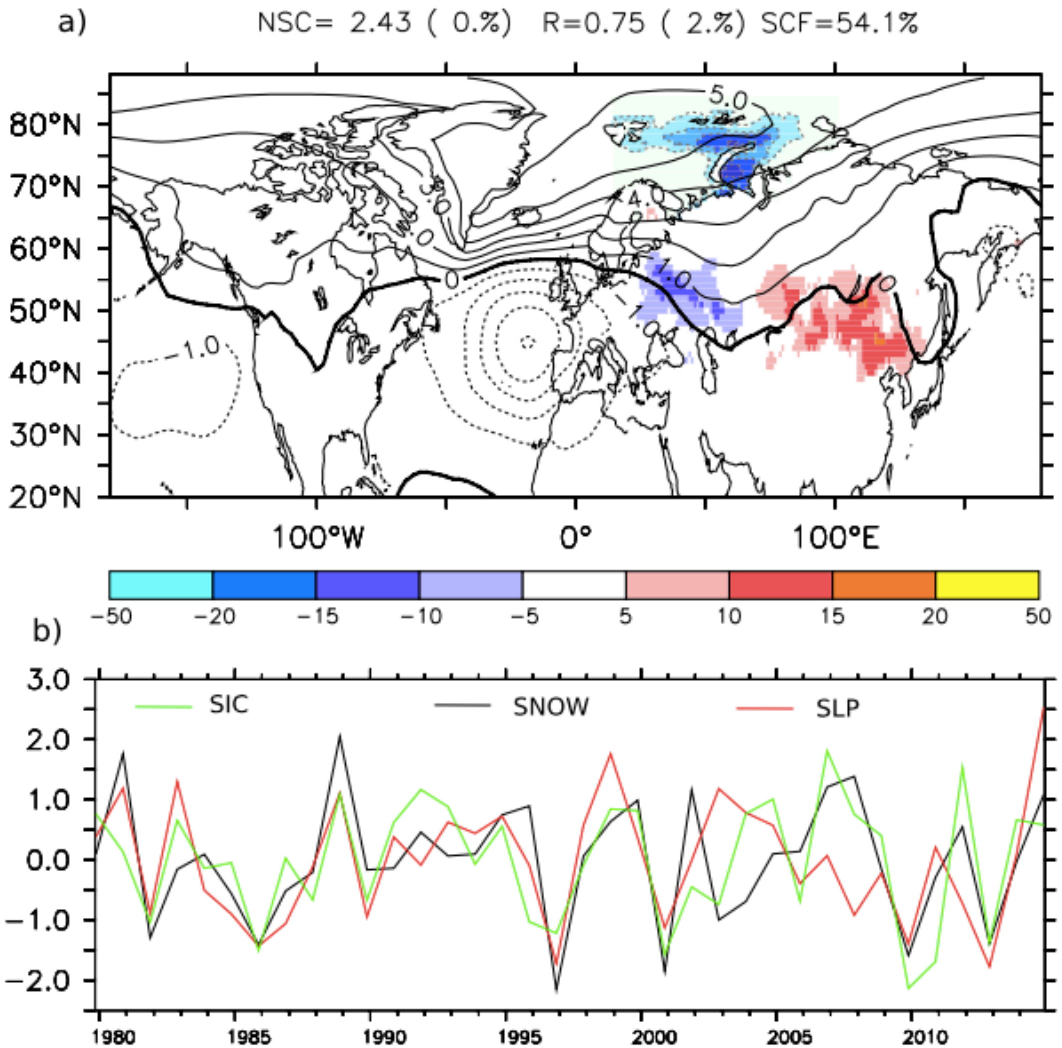
AO influence dominates in models

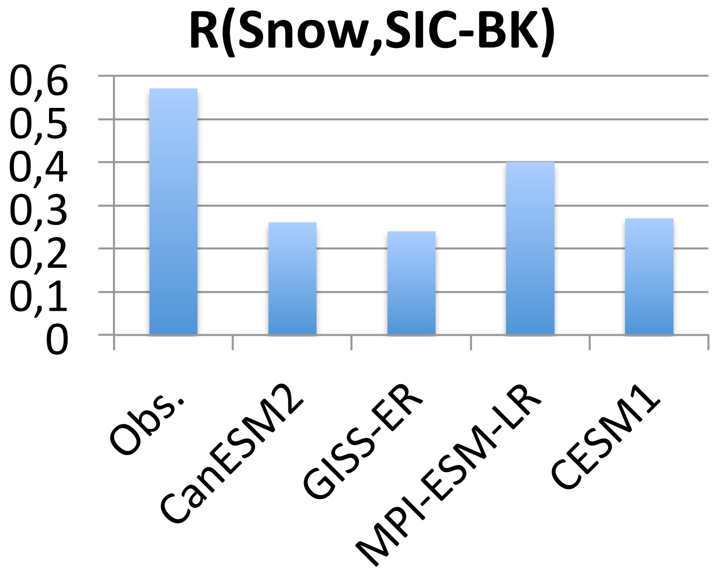
Atmospheric forcing in GREENICE EXP1



Analysis with (Snow+SIC) Nov/SLP Dec

Homogeneous Nov. Snow + SIC (colors, in %) and heterogeneous Dec SLP (contours, in hPa)



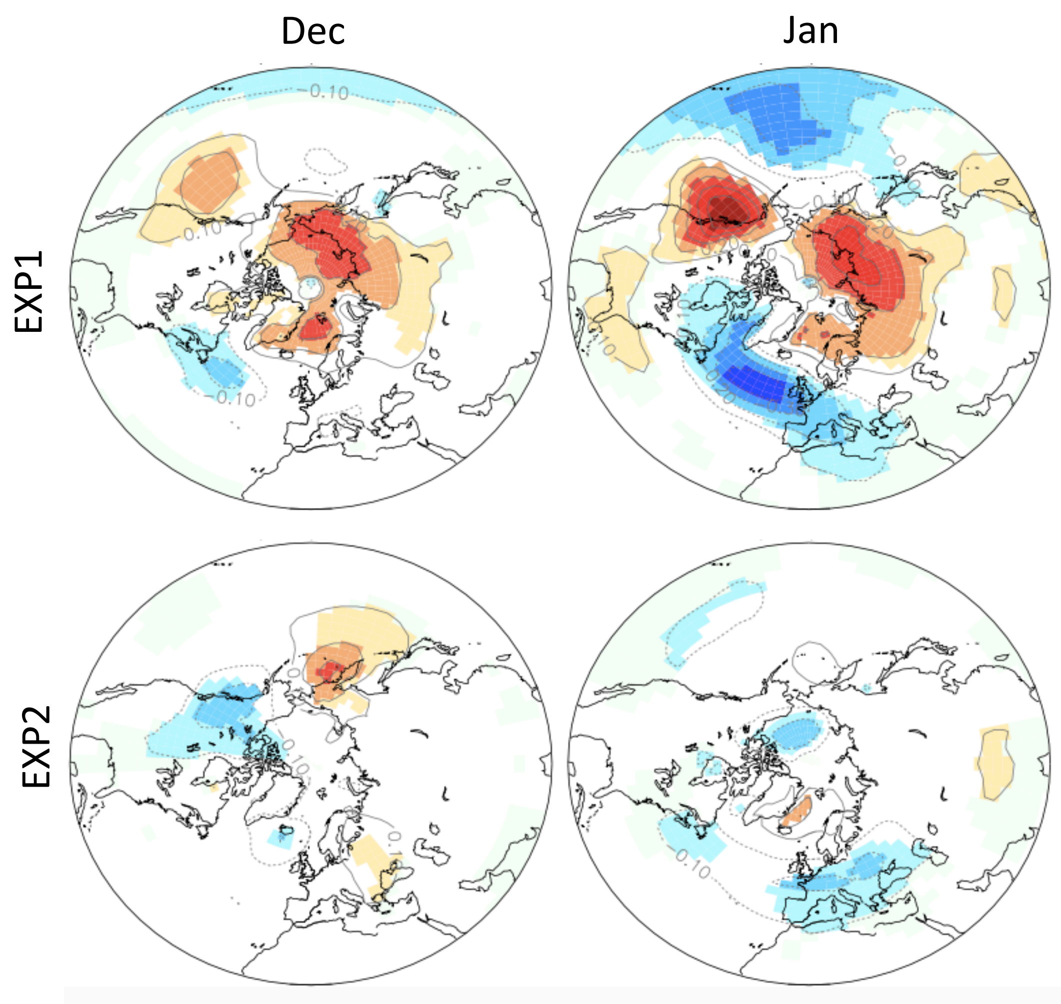


<u>Conclusion</u> : large association between snow and sea-ice that is underestimated in CMIP5 models

-> expected from SCA forcing

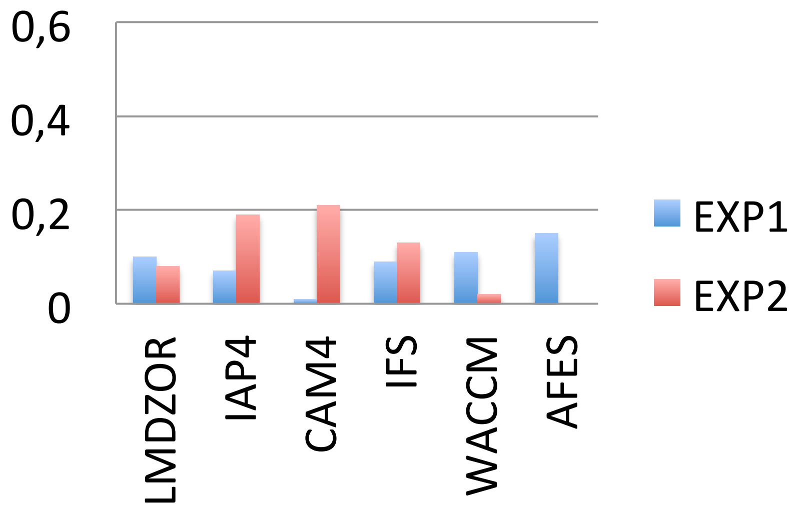
Influence of sea ice Barents/Kara

Regression of SLP (hPa) onto SIC B/K in GREENICE



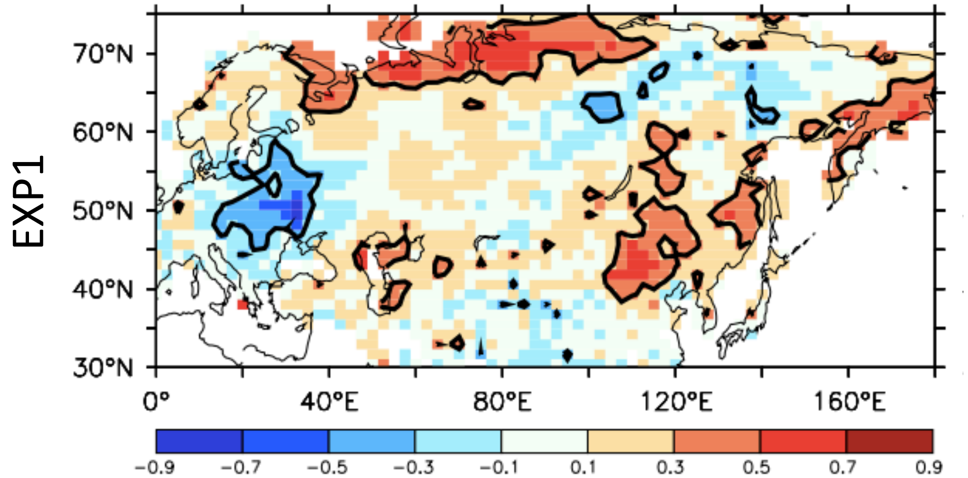
- Regression of SLP in each member, then averaged across members and models.
- Only weak impacts of SIC B/K
- No link between snow/SIC

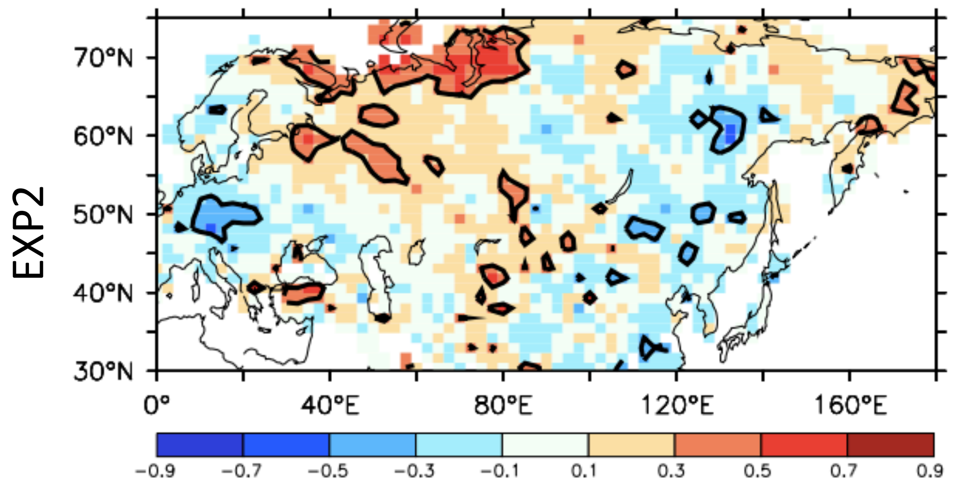
Correlation SIC / Snow



Influence of SIC and SST onto continental snow cover

Correlation snow cover OBS vs GREENICE
Multi-model Mean



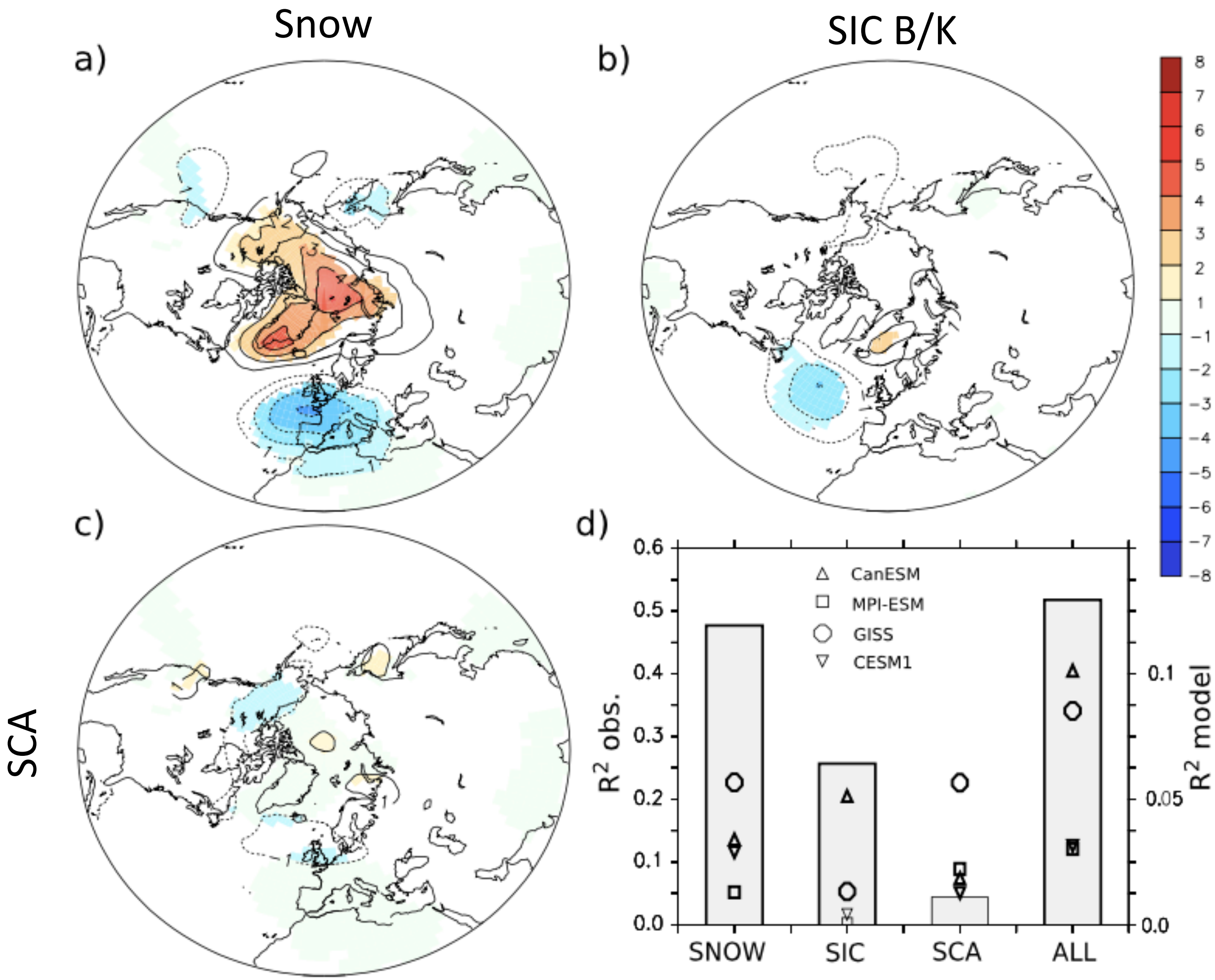


The correlation between model and observed snow cover show :

- Influence of SST anomalies onto snow cover large over eastern Siberia and Pacific sector.
- Influence of SIC anomalies onto snow cover limited to the surrounding of Barents and Kara Seas.

Regression analysis

Model : α (Snow_Dipole) + β (SIC_BK) + γ (SCA) = SLP



- Both in observation and the selected CMIP5 models snow is dominant
- SCA does explain a lot of variance in models

Conclusion

- Dipolar snow cover anomalies are found to have a large influence in November.

- Some CMIP5 and GREENICE models simulate an influence of snow similar to that observed, but it is underestimated:

    (1) due to insufficient strato./tropos. Coupling ?

    (2) due to poor simulation internal atmospheric variability (SCA) ?

- The atmospheric pattern responsible for the dipolar snow anomalies is the Scandinavian Pattern (SCA) and is associated with sea ice concentration anomalies in the Barents/Kara Sea,

- The SIC and snow cover dipole are not correlated in the GREENICE simulation and the Barents/Kara sea-ice atmospheric signature is weak.

  -> consistent with an snow cover dipole having the main driving by internal atmospheric variability

The research leading to these results has received funding from the H2020 project Blue-Action, under grant agreement n.727852. www.blue-action.eu/