Climate influence of autumnal Eurasian snow cover and its links with sea ice cover

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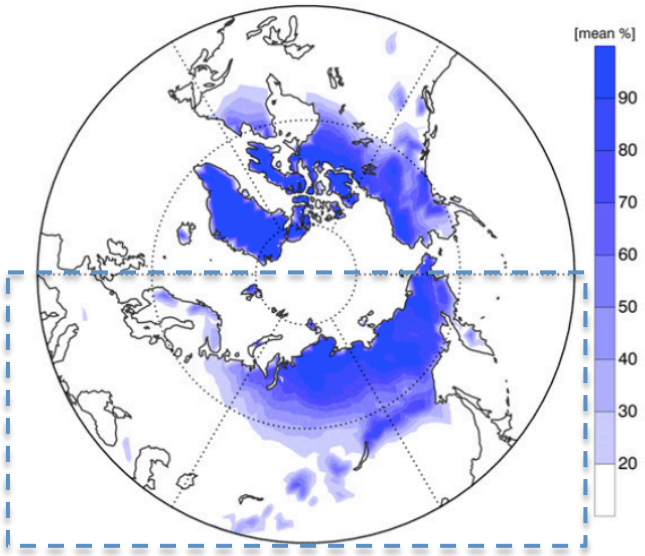
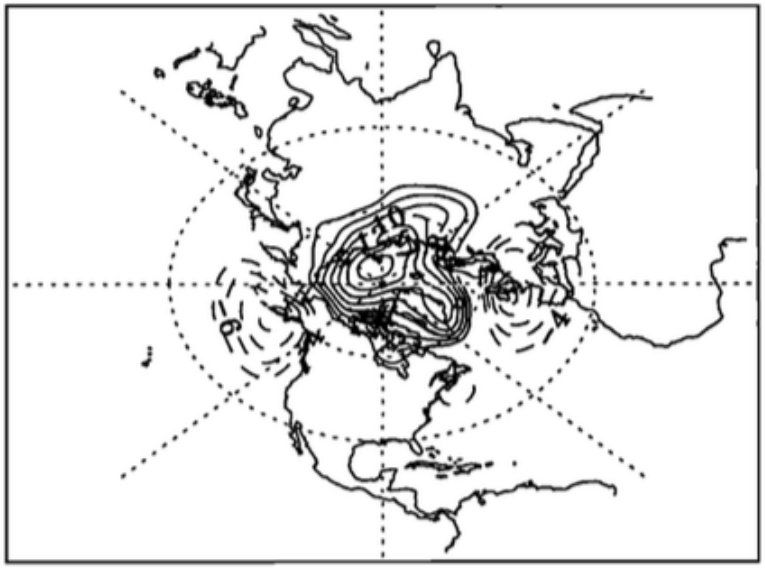
Interannual Eurasian snow cover influence

Mean snow cover in October (SCE)



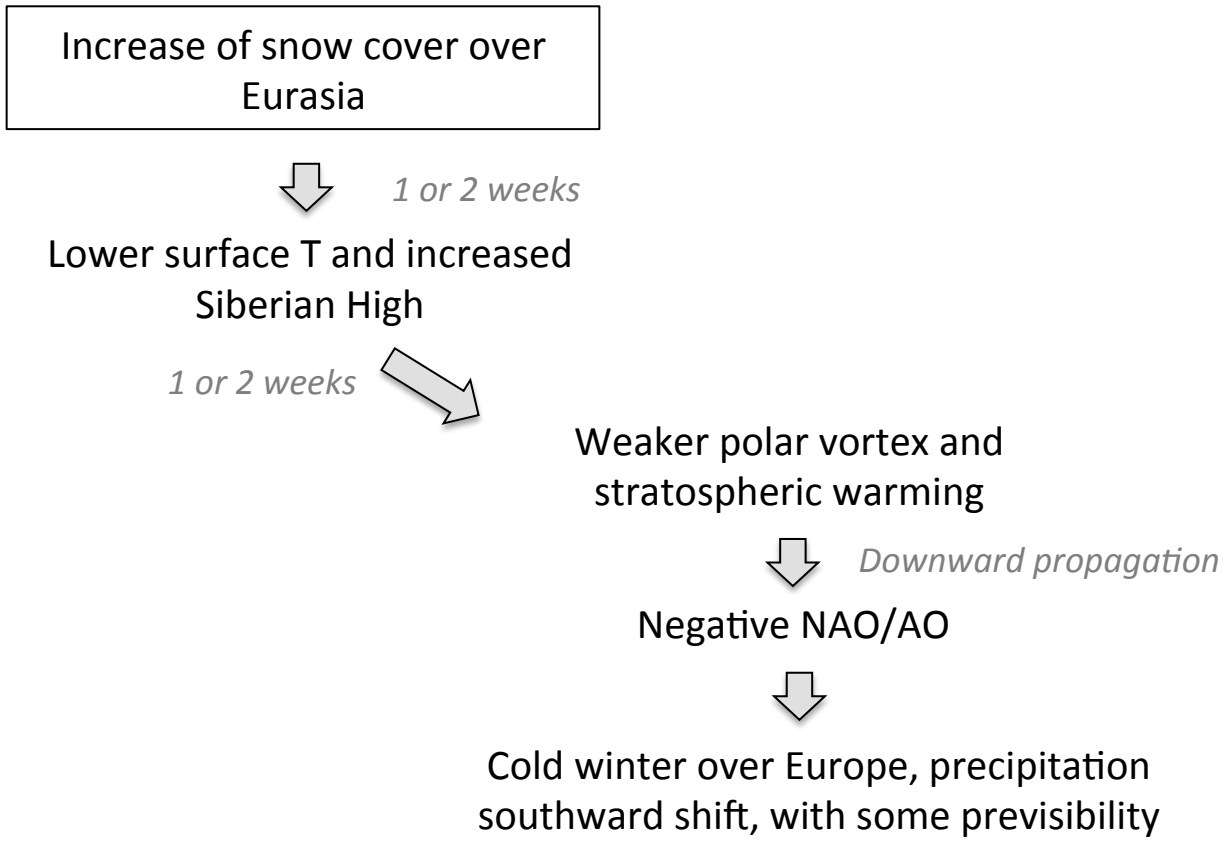
SLP DJF -> Difference high – low SCE



Cohen and Entekabhi, 1999

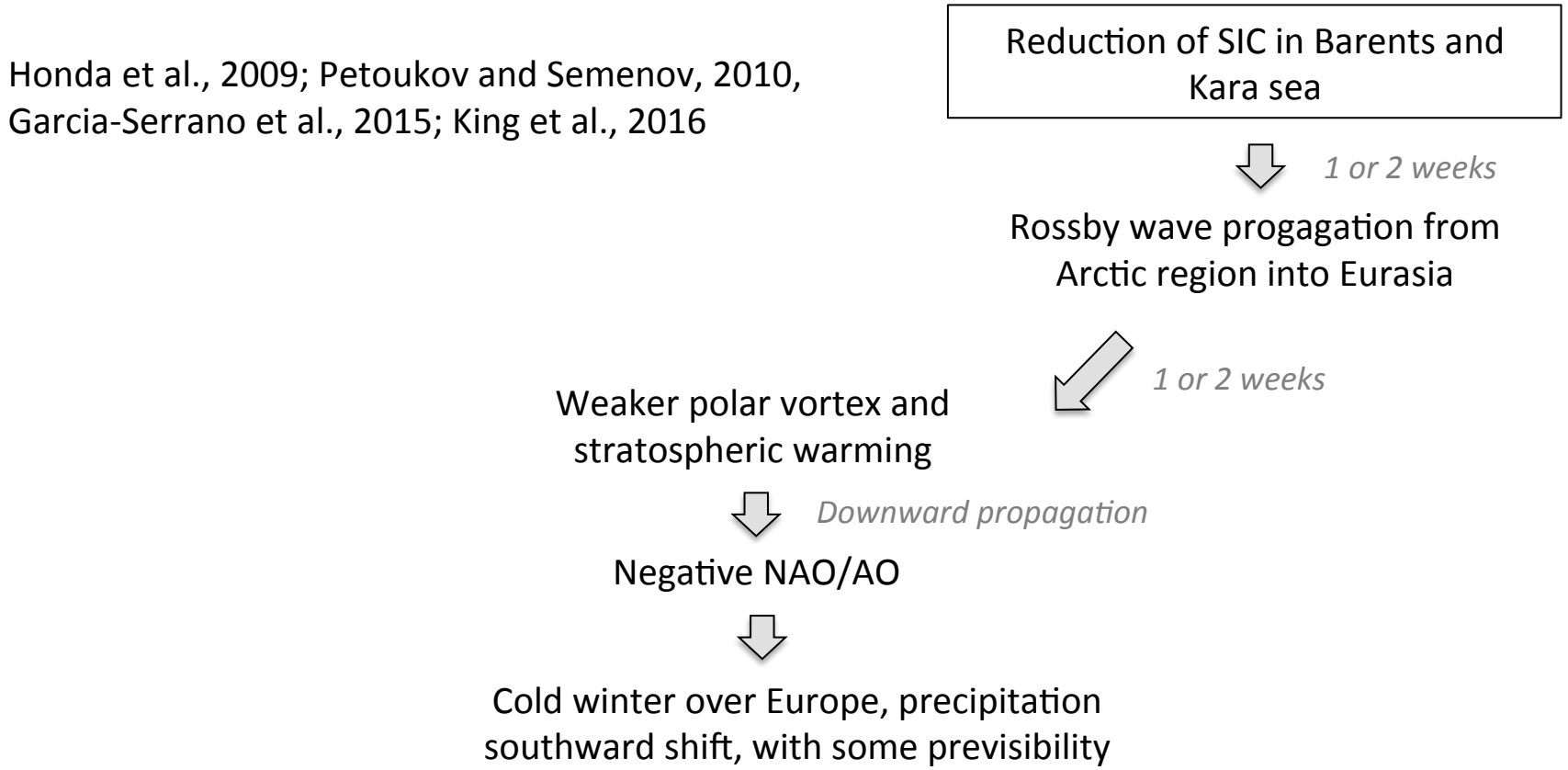
- Snow cover in SON and October received most attention (Cohen and Entekabhi, 1999; Cohen et al. 2014)
- Influence confirmed by sensitivity experiments using snow cover anomalies (Allen and Zender, 2011; Orsolini et al., 2013; Orsolini et al., 2016)

Processes related to Arctic surface state influence

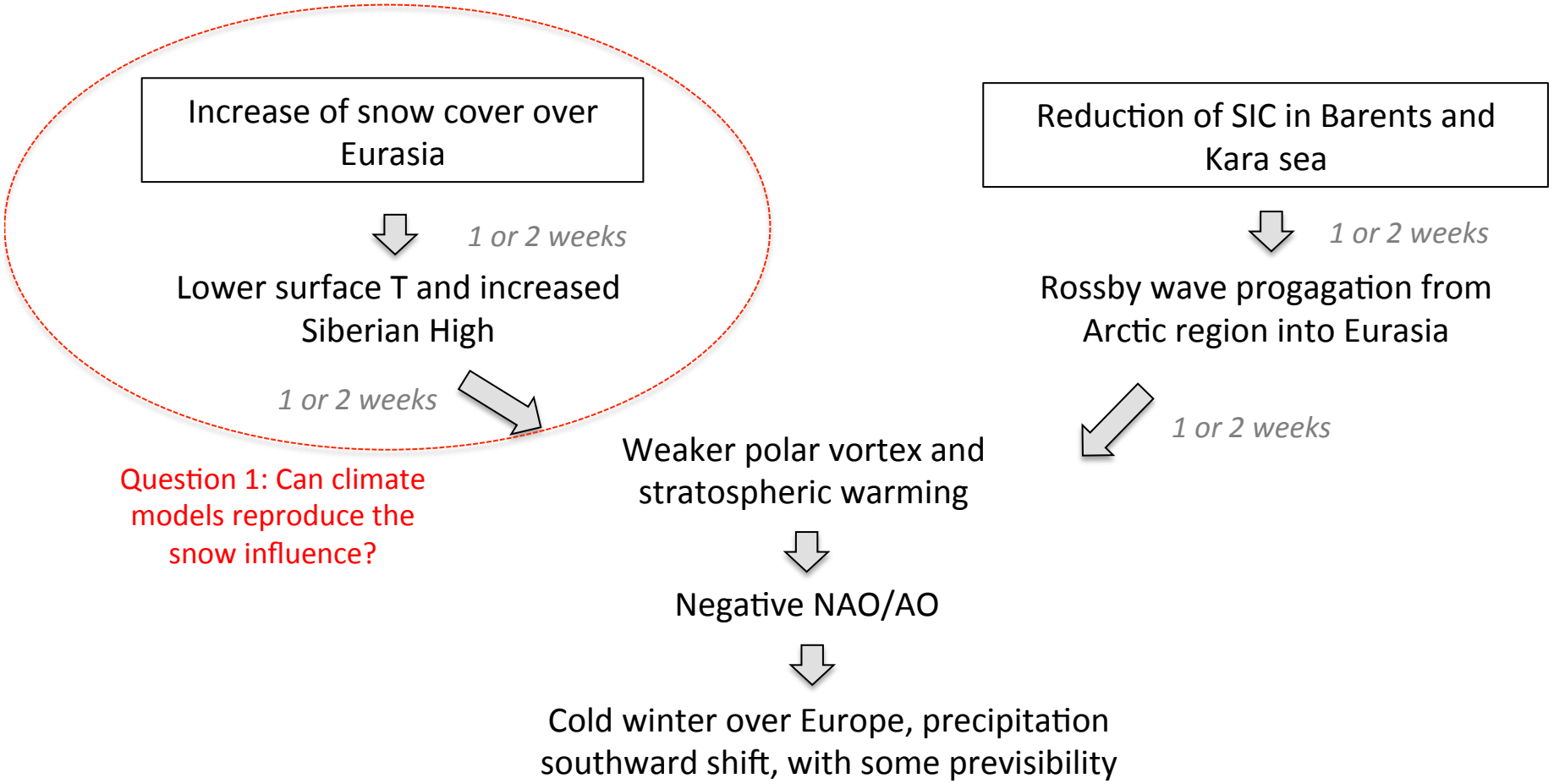


Processes related to Arctic surface state influence

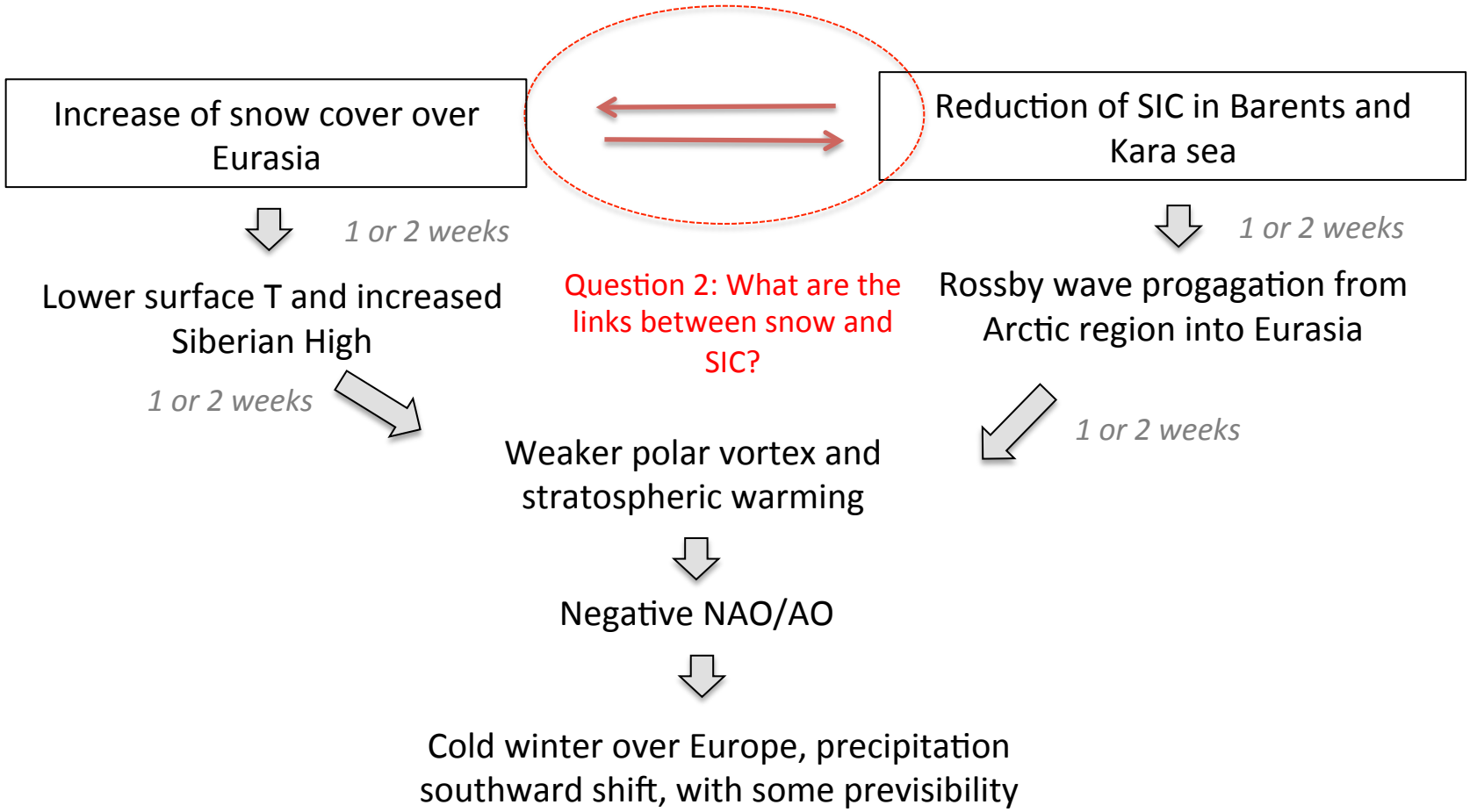
Honda et al., 2009; Petoukov and Semenov, 2010, Garcia-Serrano et al., 2015; King et al., 2016



Processes related to Arctic surface state influence



Processes related to Arctic surface state influence



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)

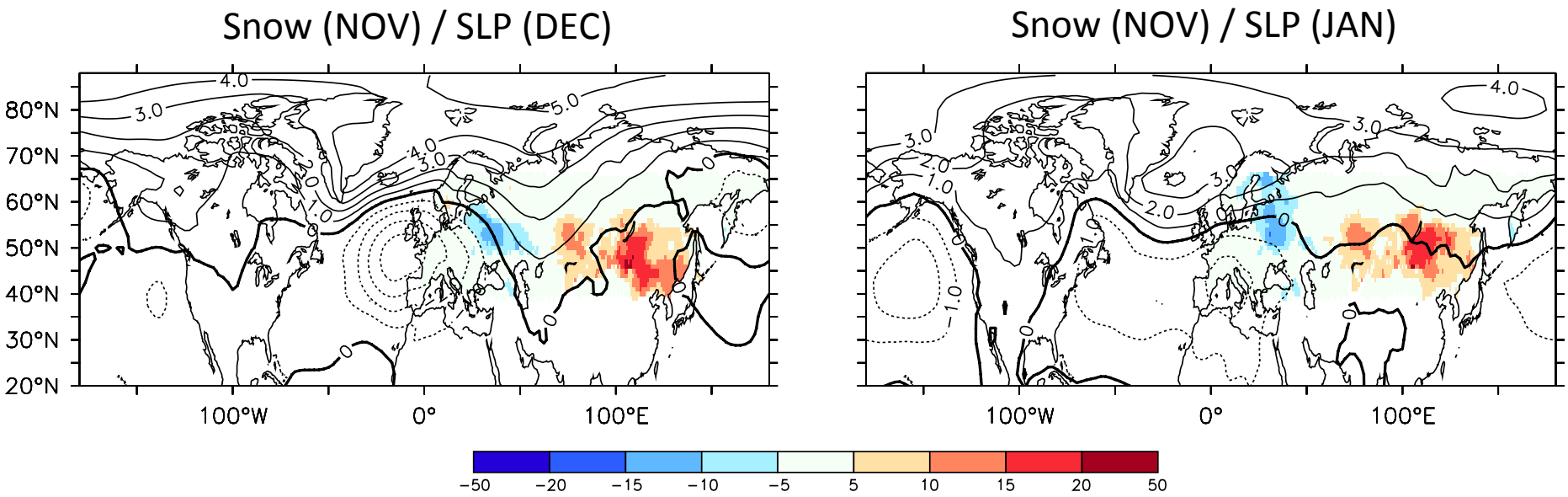
- Snow cover, sea ice concentration, and atmospheric variables from 12 CMIP5 ocean-atmosphere models, preindustrial simulations

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

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 SC (eigen value) using Monte Carlo,
- Part of ENSO teleconnection removed using regression onto 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,

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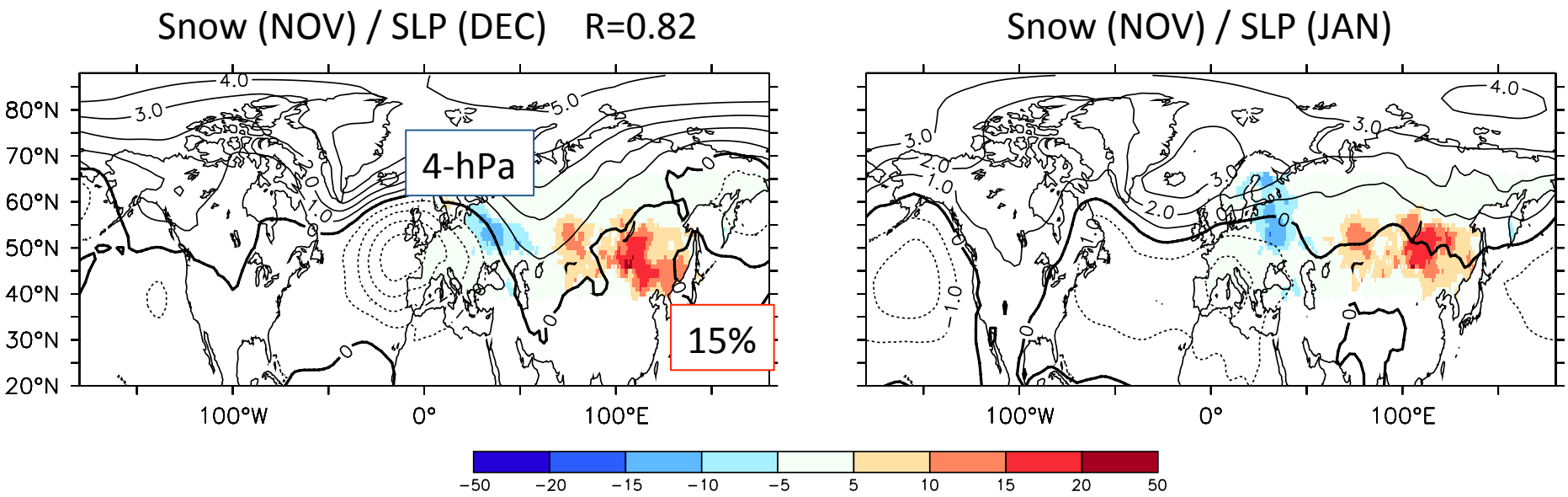
Homogeneous snow (colors, in %) and heterogeneous SLP (contours, in hPa)



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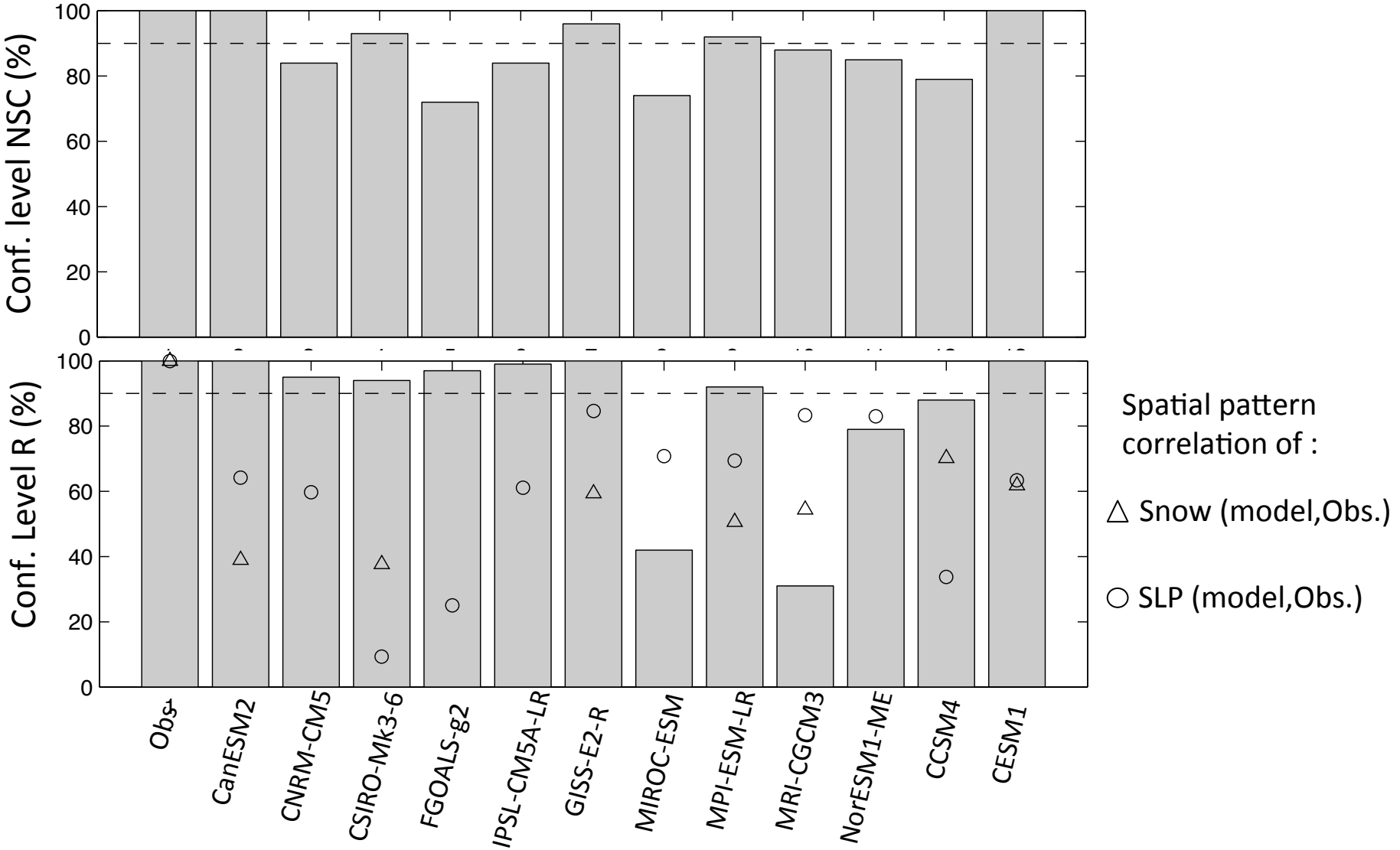
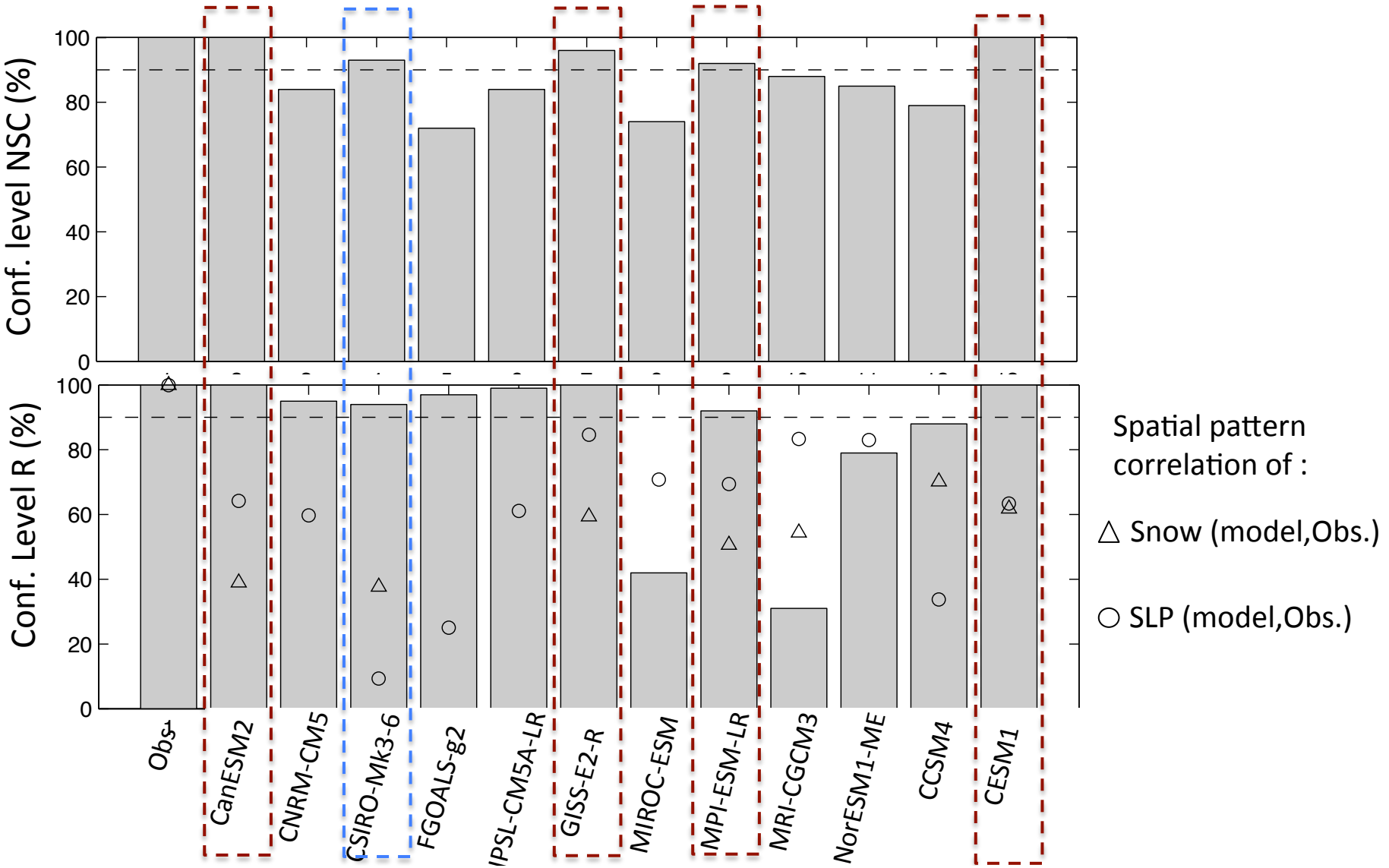
MCA Nov Snow / Dec SLP in CMIP5 models



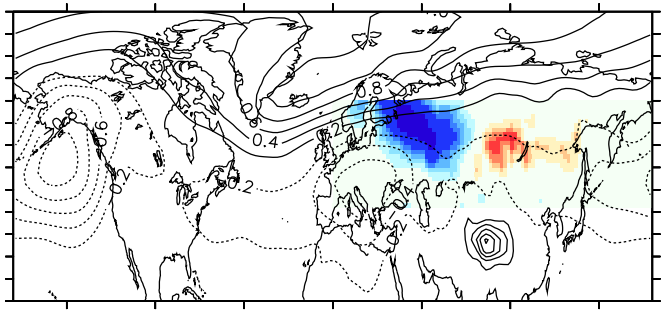
MCA Nov Snow / Dec SLP in CMIP5 models



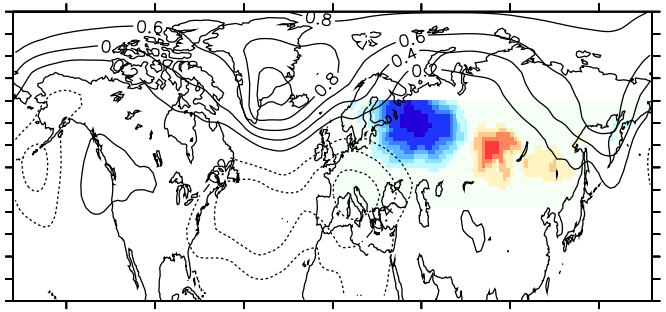
Snow influence in models

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

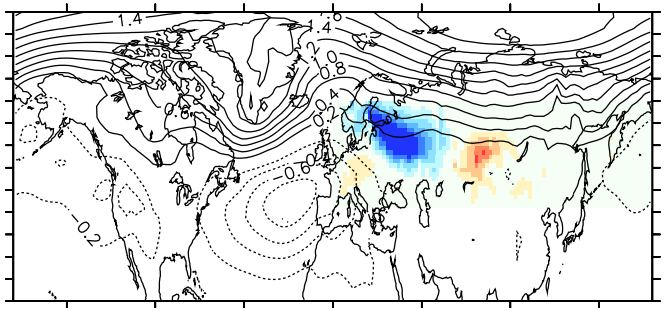
CanESM2



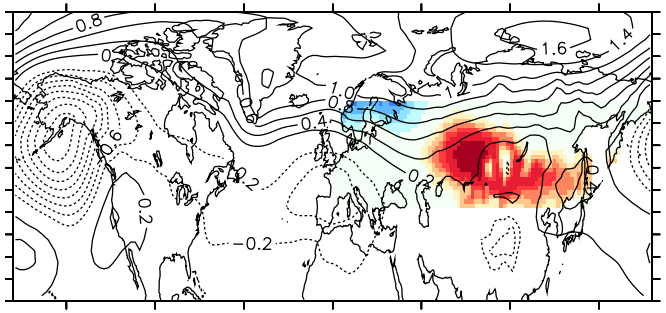
MPI-ESM-LR



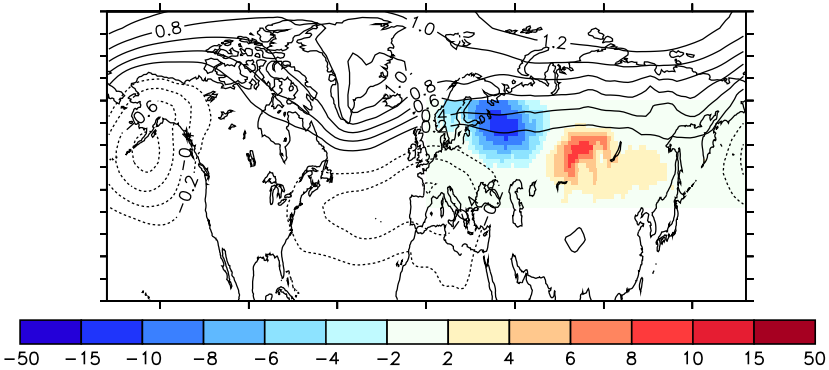
GISS-E2-R



CESM1



Mean of the 4 models

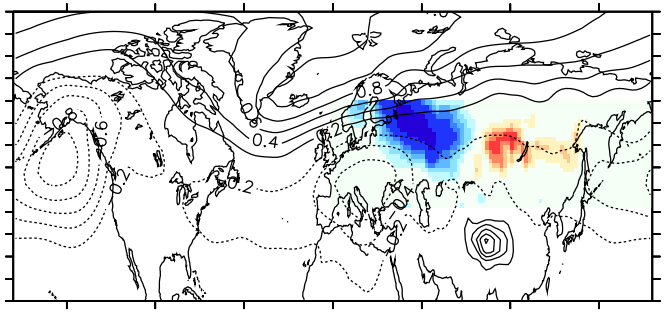


Links between Nov. Snow and Dec. SLP reproduced in these 4 models.

Snow influence in models

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

CanESM2



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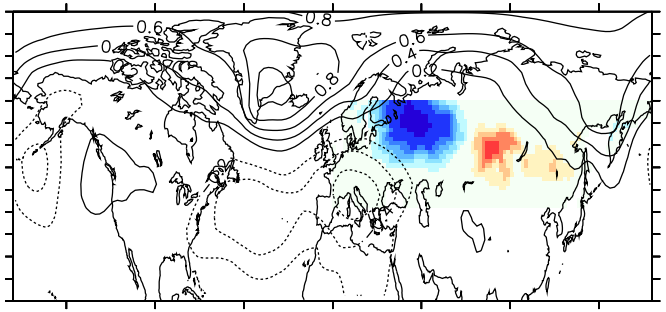
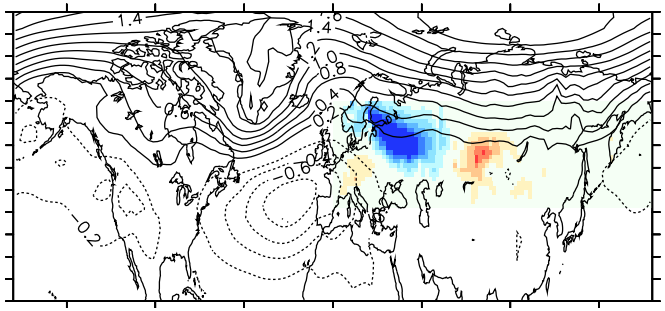


GISS-E2-R



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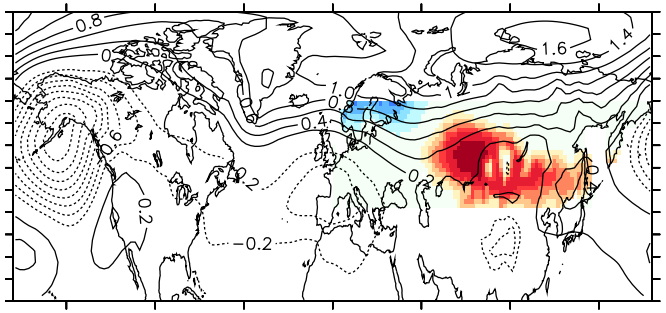
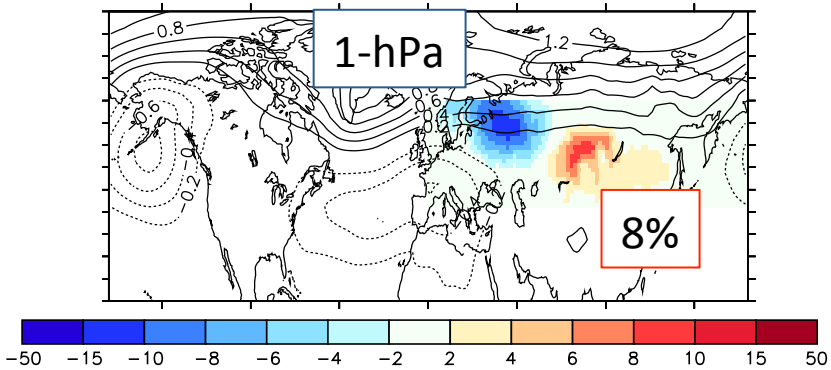


Mean of the 4 models R=0.17/0.27



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

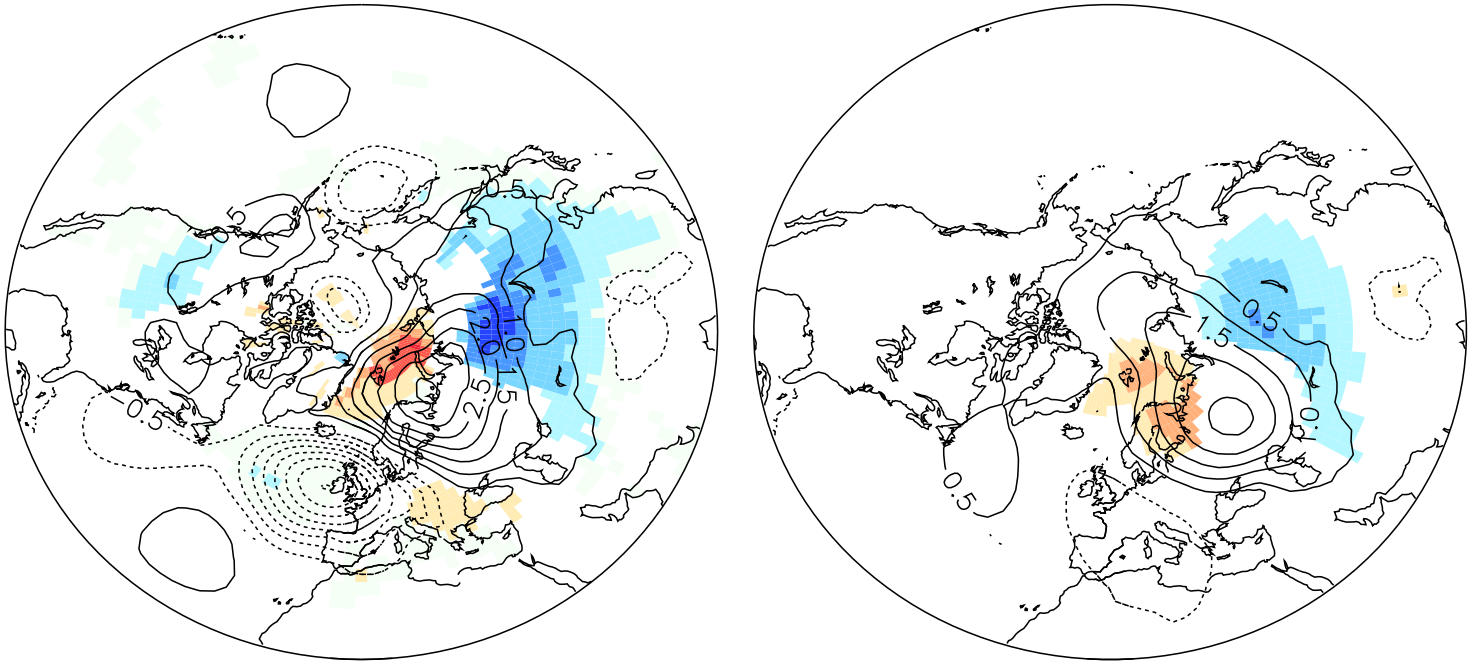
-> large underestimation

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

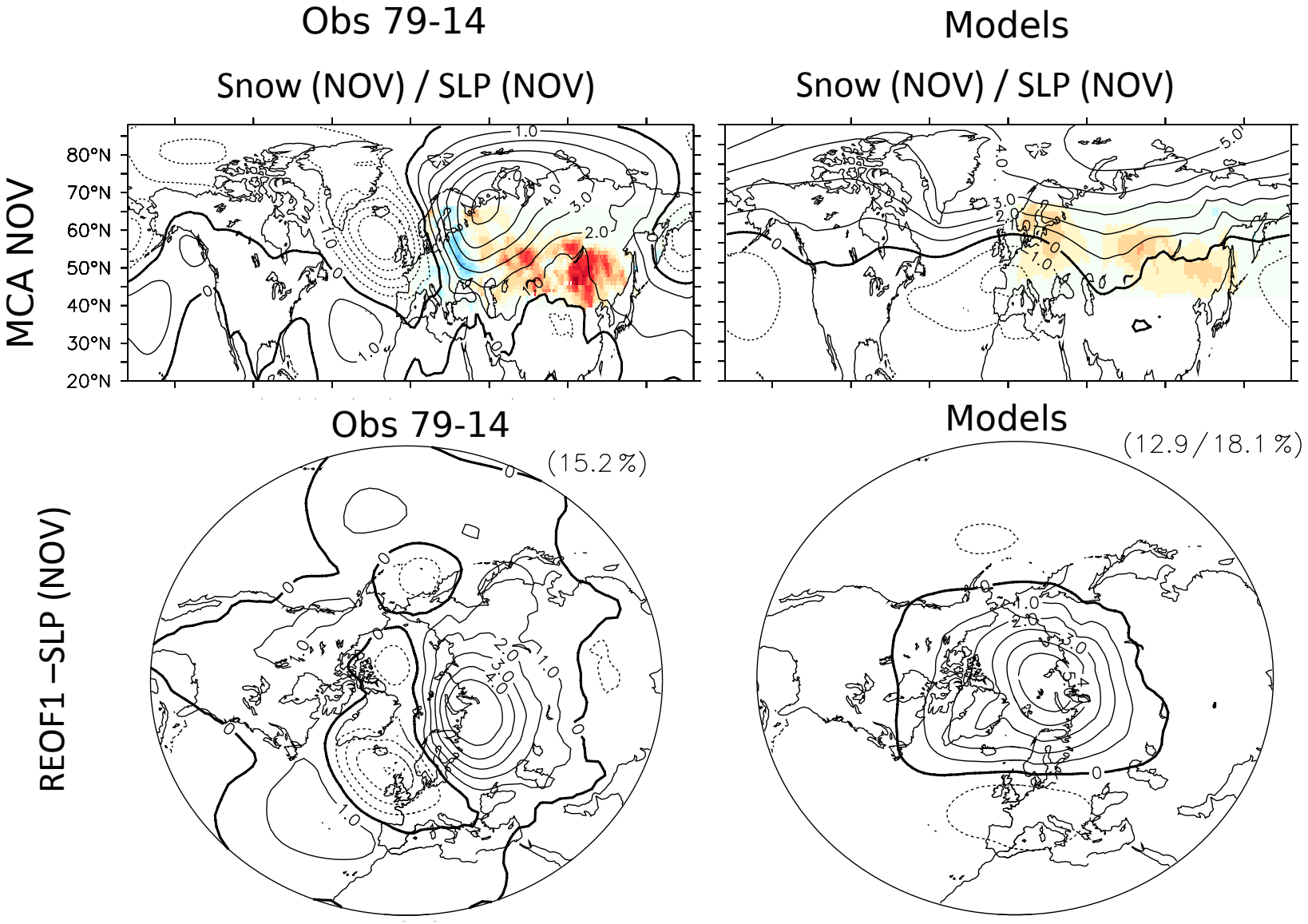
Obs. 79-14

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

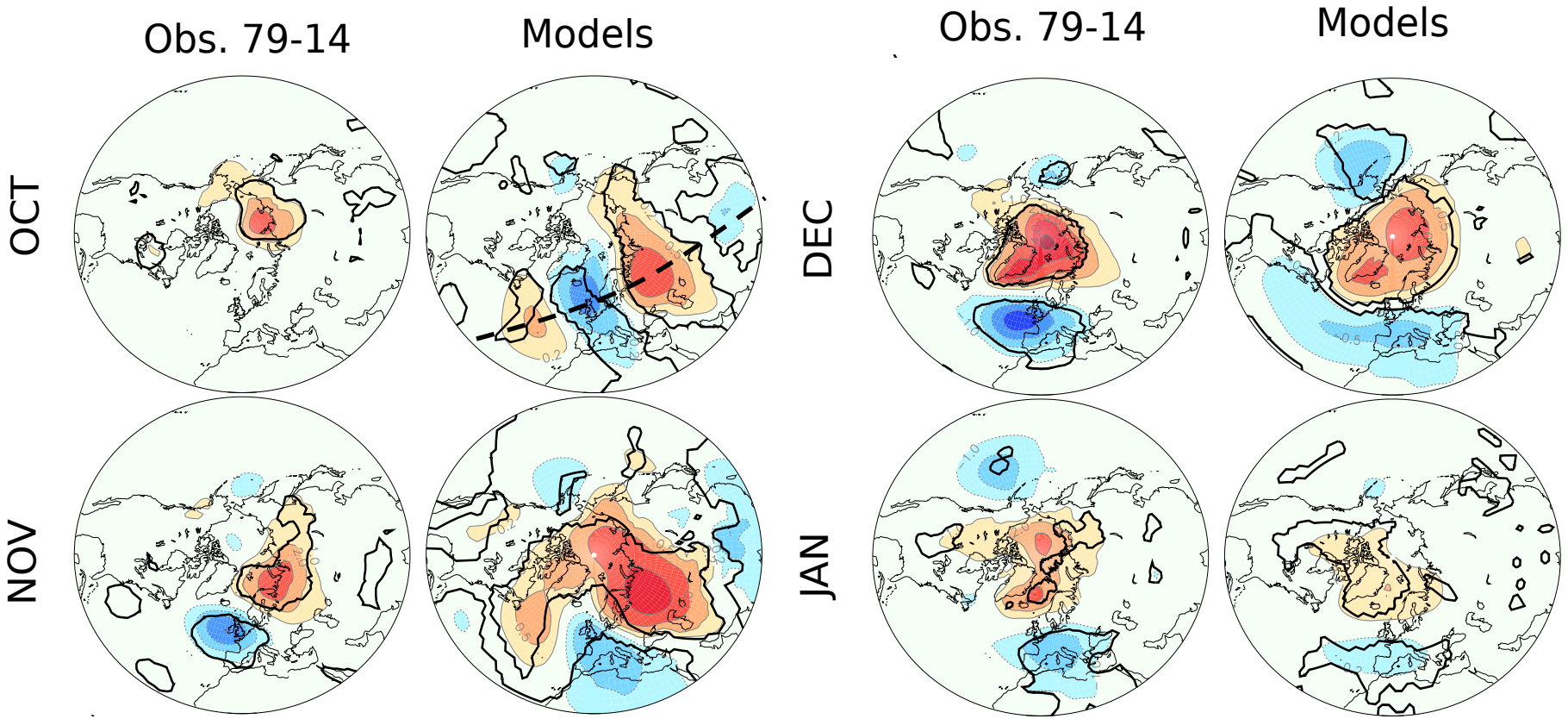


SCA pattern key for snow forcing

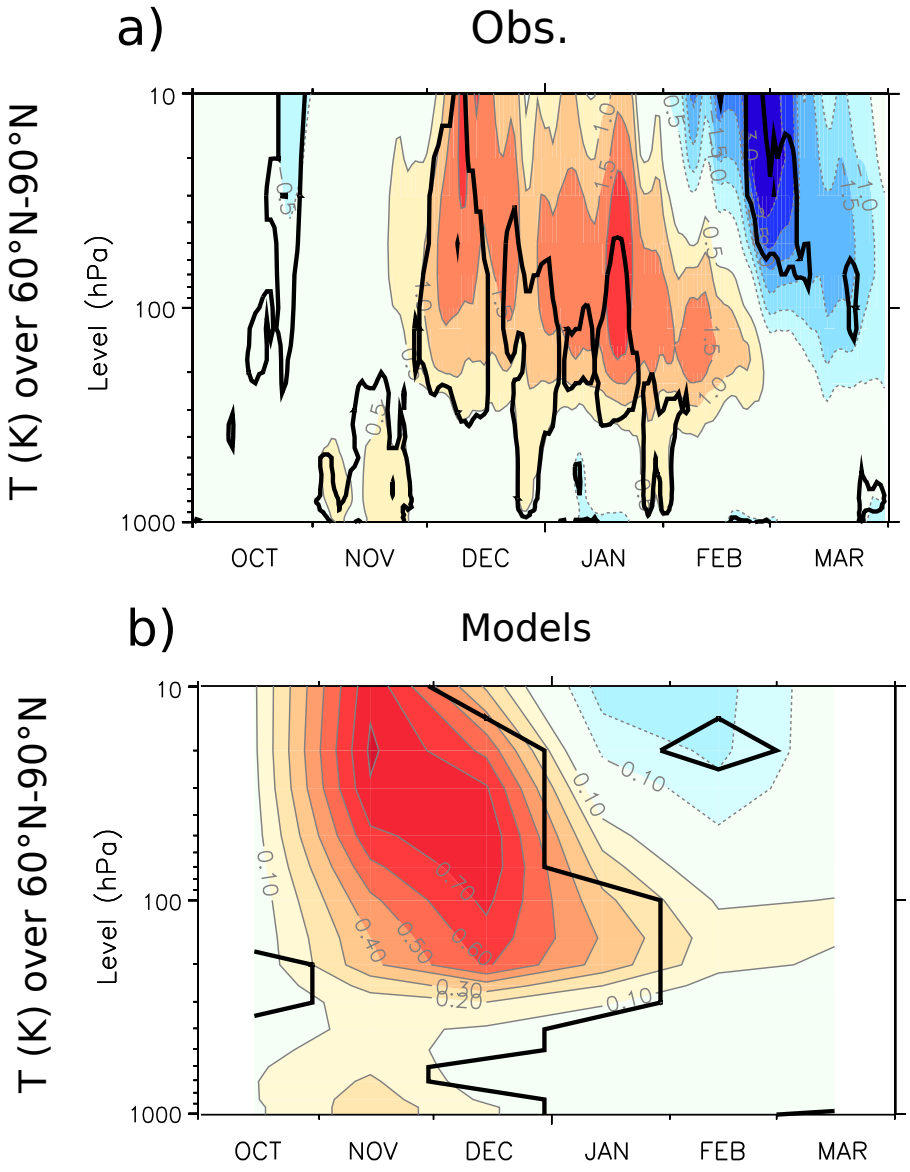
AO influence dominates in models

Tropospheric changes associated to snow dipole

SLP (in hPa) regression onto MCA snow time series



Downward propagation



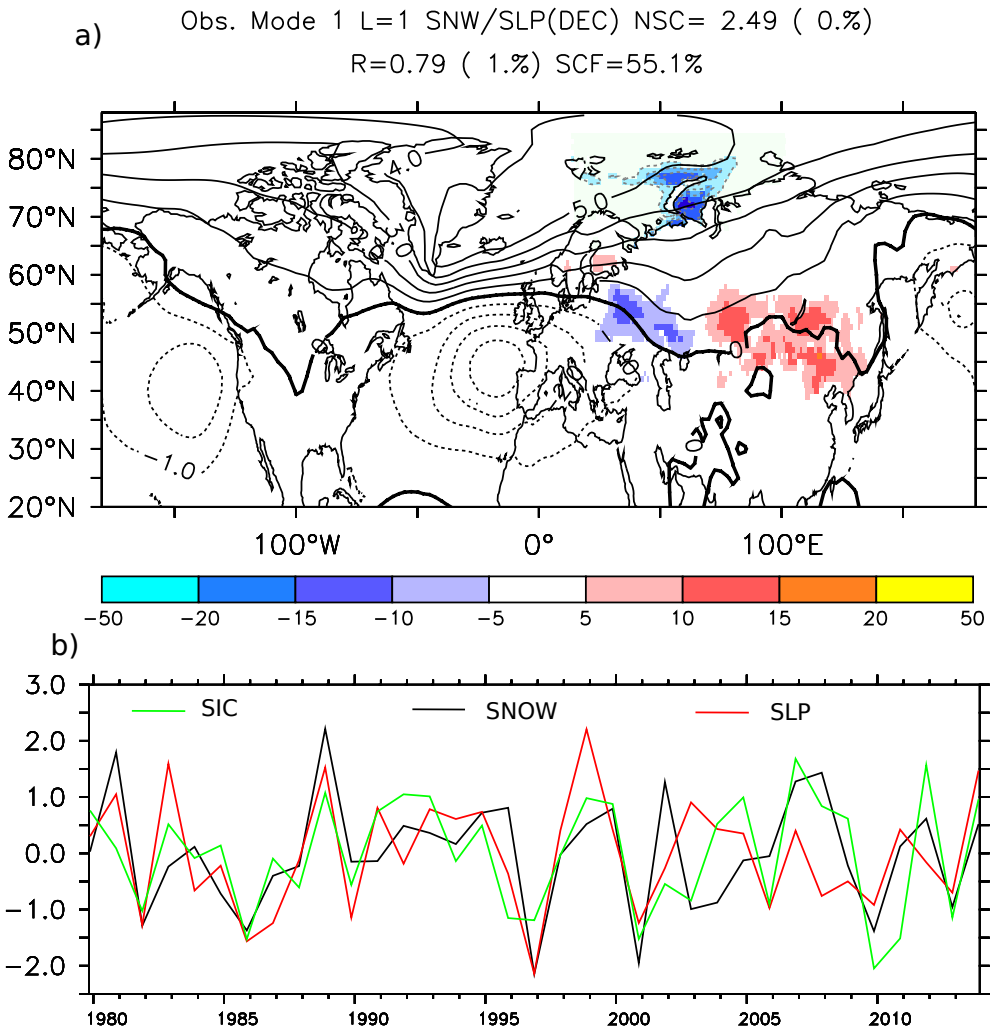
Methods:

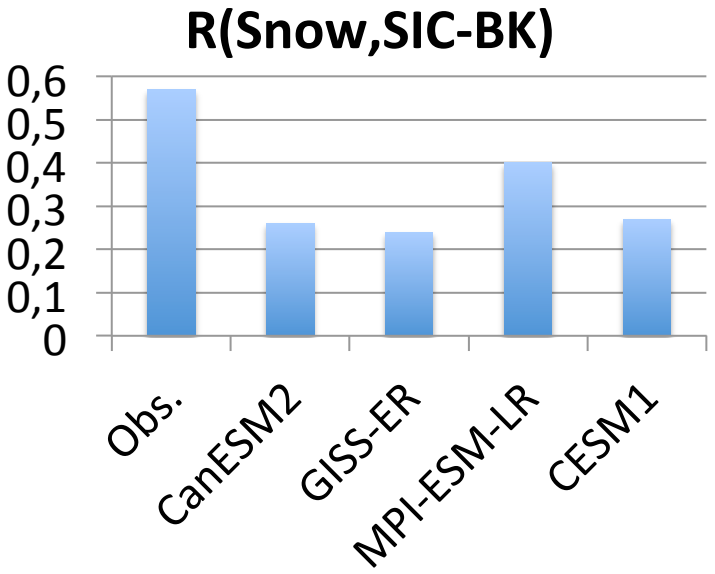
- Daily T over 60°N-90°N for obs.
- Monthly T over 60°N-90°N in Models

- Clear downward propagation in observatoins.
  -> especially in late Jan. or Feb.

- In models, no clear downward propagation.
  -> no influence in Jan. Or Feb.

Analysis with (Snow+SIC) Nov/SLP Dec



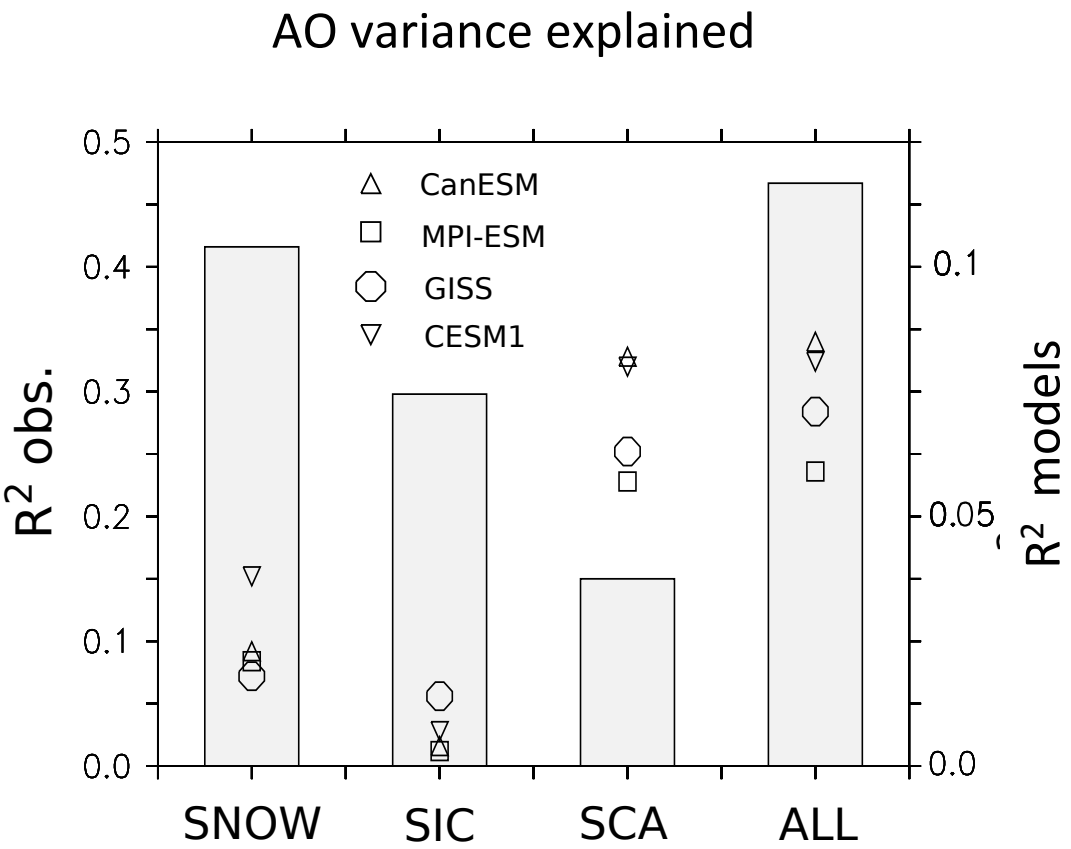


Conclusion : large association between snow and sea-ice that is underestimated in models

-> expected from SCA forcing

Regression analysis

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



- SIC and snow cover have comparable influence in observations.

  -> snow explains more variance

- In the selected models snow is dominant

- SCA does explain a lot of variance

  -> role of internal atm. process?

Conclusion

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

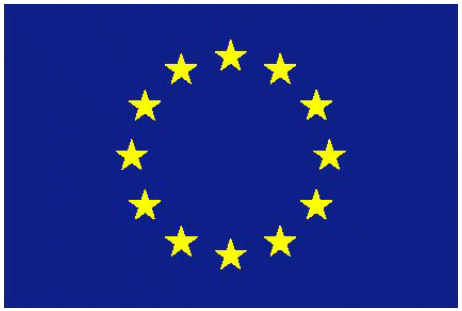
- The atmospheric pattern responsible for the dipolar snow anomalies is the Scandinavian Pattern (SCA) and is associated with sea ice concentration anomalies in the Barents/Kara Sea.

- 4 out of 12 CMIP5 models simulate an influence of snow similar to that observed, but it is underestimated:
  (1) due to insufficient strato./tropos. Coupling ?
  (2) due to underestimation of SCA (linked to blocking) ?
  (3) too small links between snow and Barents/Kara sea ice?

Questions/perspective:

- Strong links between the Snow cover, sea ice and SCA -> causality links need to be further investigated.

- In global warming condition, polar amplification: larger links between snow and sea ice through larger moisture flux, leading to a larger positive feedback?



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www.blue-action.eu/

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