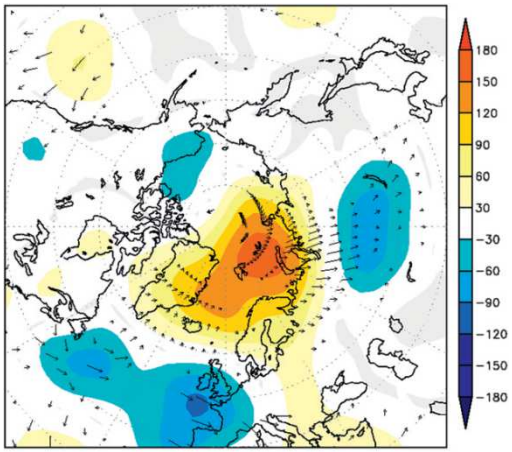
Predictability of the Euro-Atlantic climate from Arctic sea-ice variability

J. García-Serrano (LOCEAN/IPSL, **BSC**), C. Frankignoul (LOCEAN/IPSL)

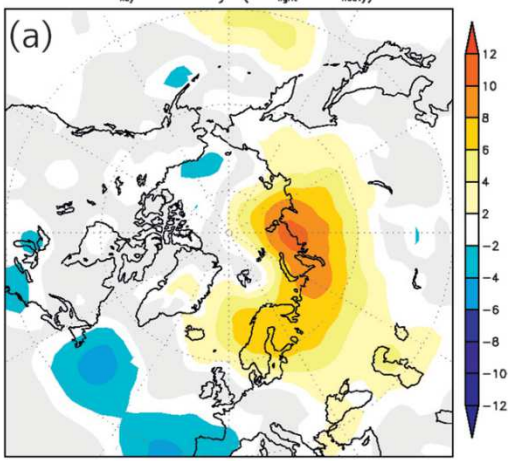
with contributions/feedback: [OBS] G. Gastineau (LOCEAN/IPSL), A. de la Cámara (LMD/IPSL, NCAR)
[MOD] A. Arribas (MetOffice), Y. Gao (NERSC/BCCR), V. Guemas (BSC, CNRM), M. P. King (URC/BCCR), D. Matei (MPI-M), R. Msadek (GFDL, CERFACS), W. Park (GEOMAR), E. Sanchez-Gomez (CERFACS)

M-CLIX workshop, 5-7 Oct 2015

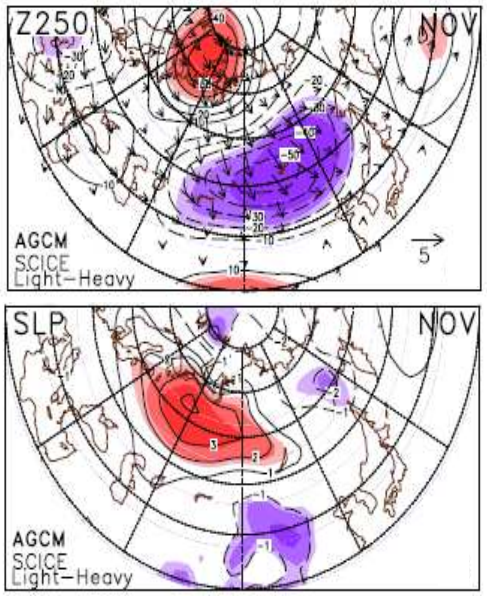
Z250 / WAF (DJF)



SLP_{key} anomaly ($Ice_{light} - Ice_{heavy}$)



Inoue et al. (2012, GRL)

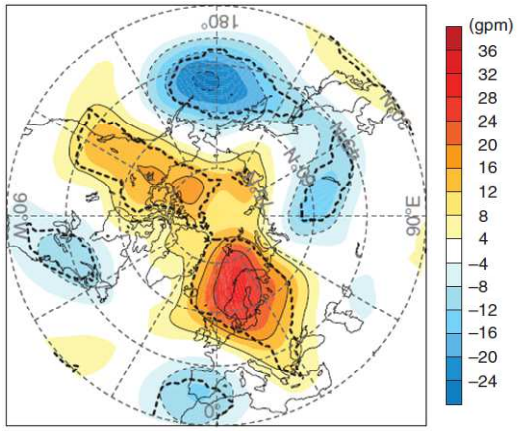


Honda et al. (2009, GRL)

might be non-linear to SIC reduction!

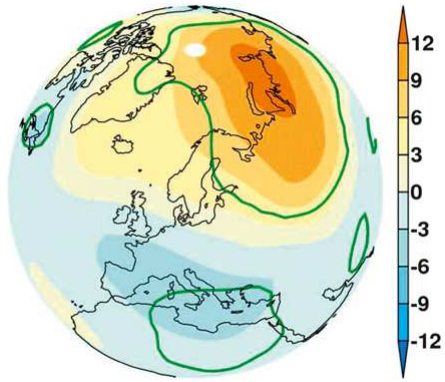
Petoukhov and Semenov (2010, JGR)

ΔZ500 for ND, CAM5



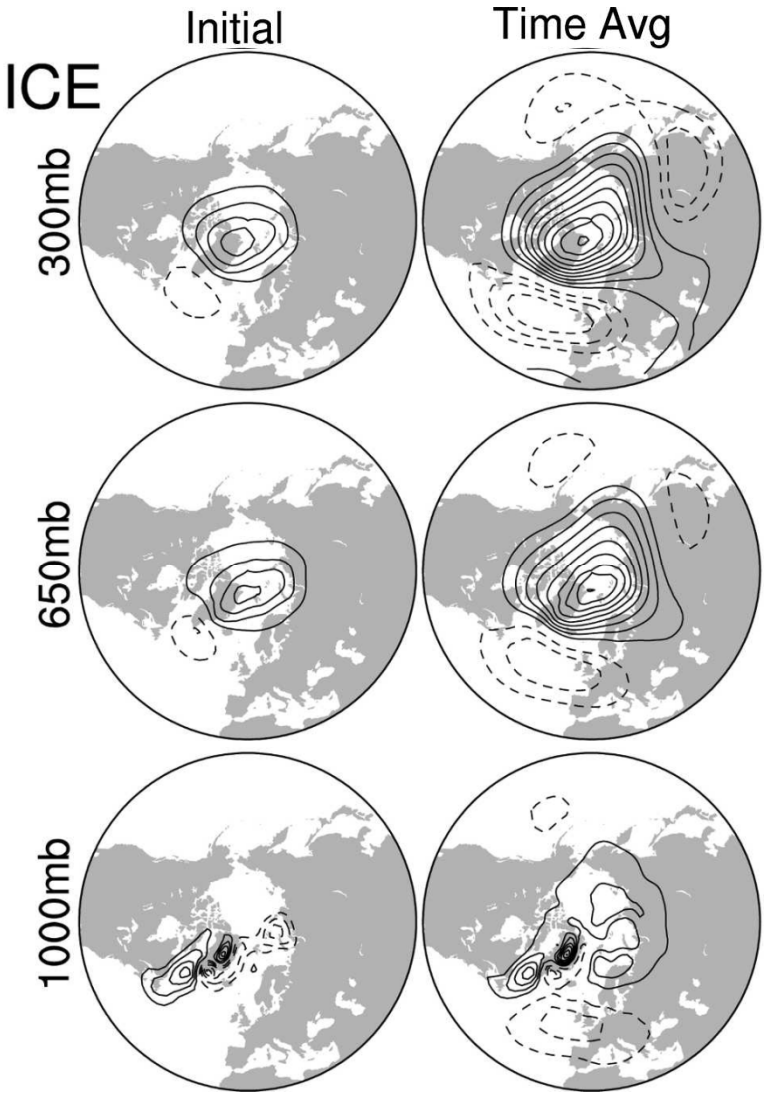
Kim et al. (2014, Nat.Comms)

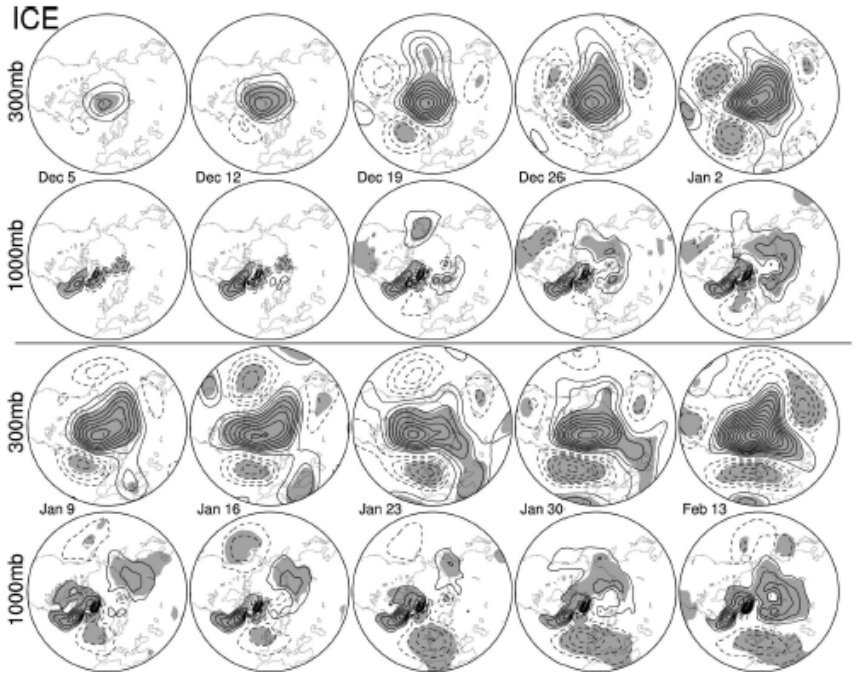
SLP JAN [CAM]



Grassi et al. (2013, JCLIM)

RECENT REVIEWS: Bader et al. 2011; Cohen et al. 2014; Vihma 2014; Walsh 2014; Gao et al. 2015; Overland et al. 2015

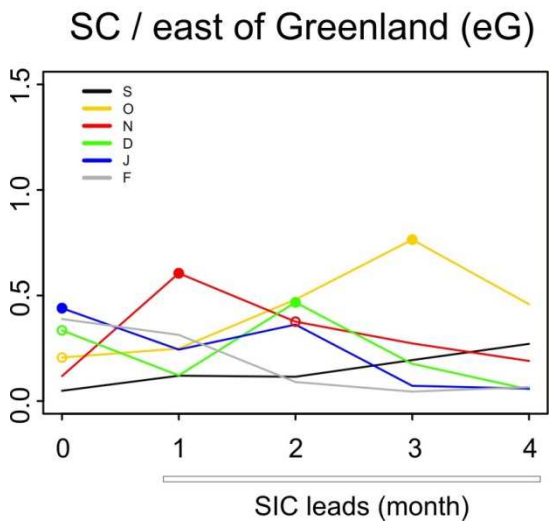




the equilibrium response to SIC reduction over G-B Seas, which projects on the negative NAO, is reached in about two months

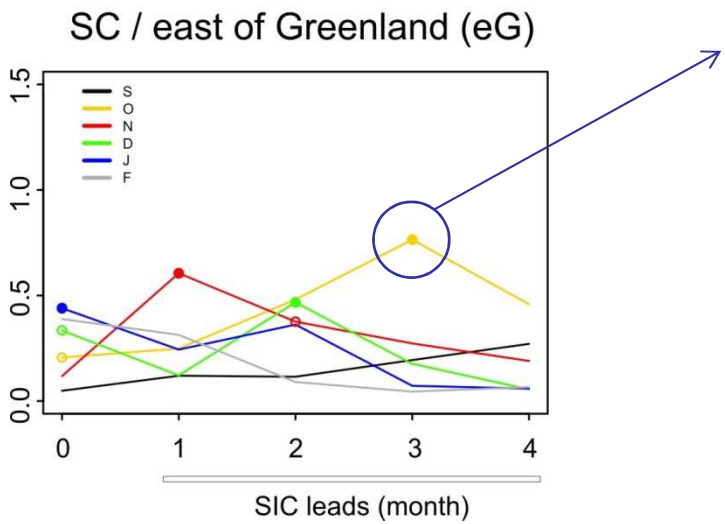
Deser et al. (2007, JCLIM)

HadISST



- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

HadISST



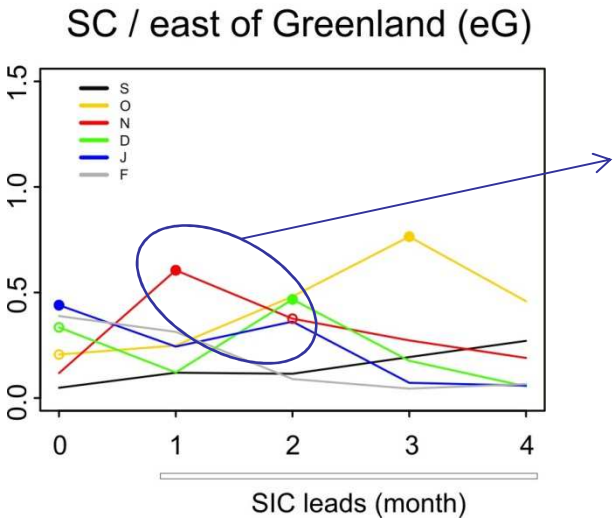
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

might be linked to winter blocking over Eurasia

Mori et al. 2014 (Nat.Geosci); García-Serrano et al. (2015, JCLIM)

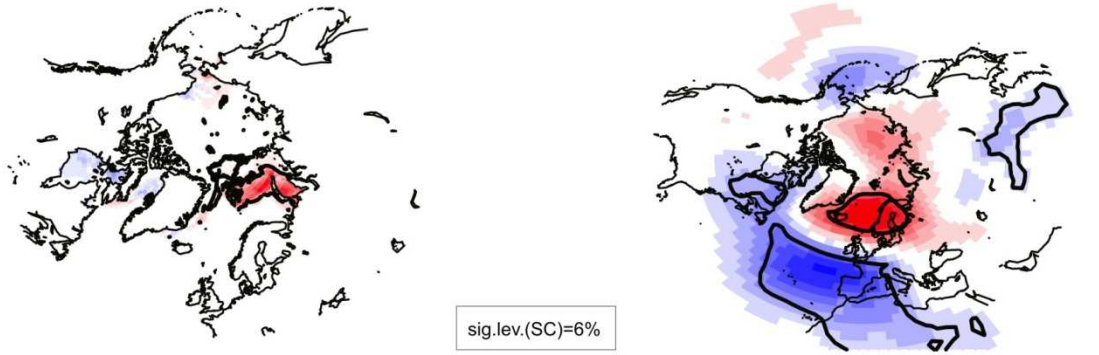
but the lead-time is longer than the expected atmospheric response time to SIC forcing

HadISST



a) **MCA-SIC/eG$_{NOV}$ x SIC (nov)**

b) **MCA-SIC/eG$_{NOV}$ x SLP (jan)**

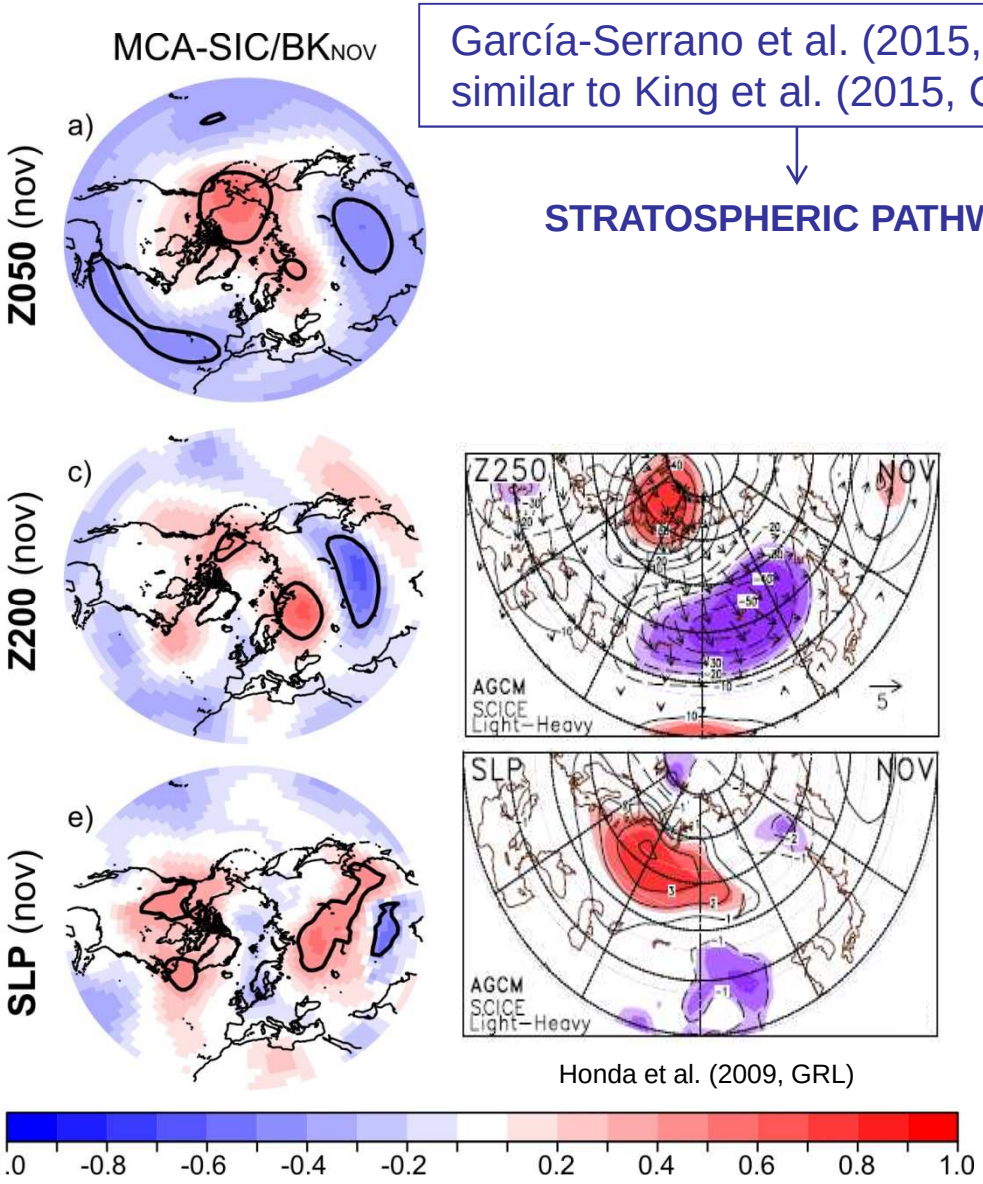


- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

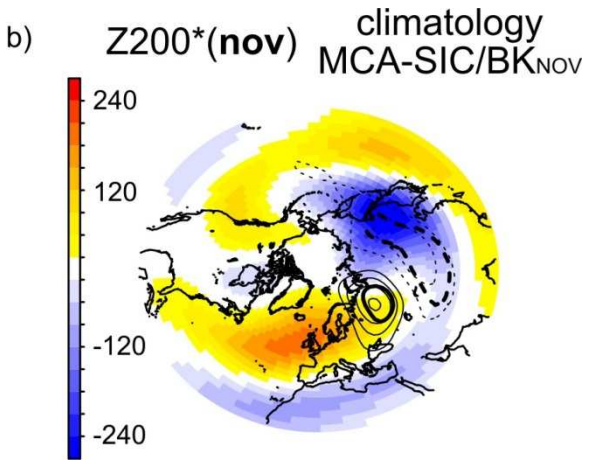
García-Serrano et al. (2015, JCLIM); similar to King et al. (2015, ClimDyn)

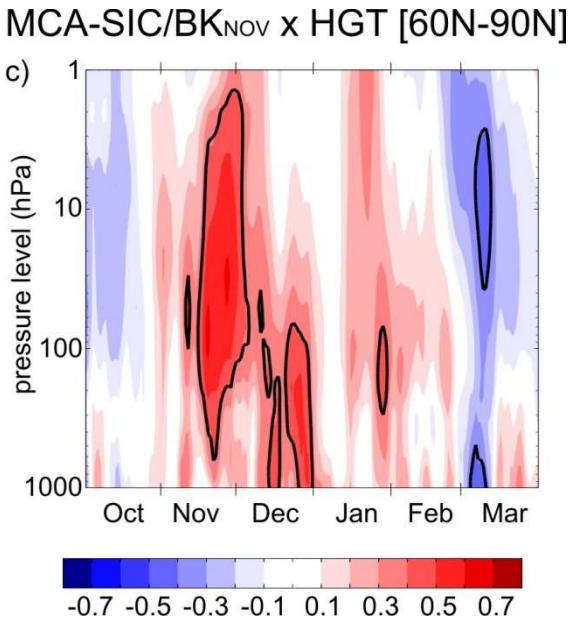
↓

STRATOSPHERIC PATHWAY



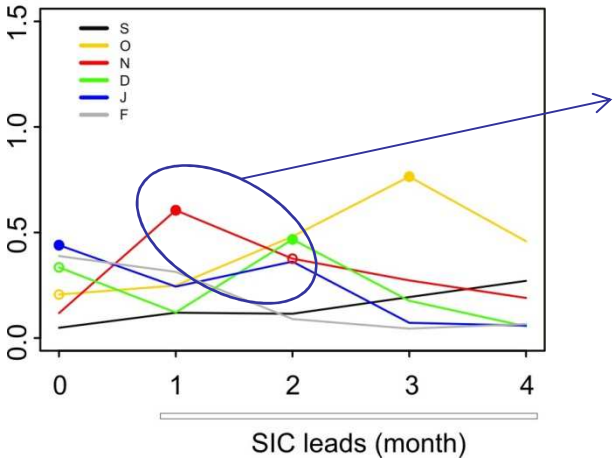
Honda et al. (2009, GRL)





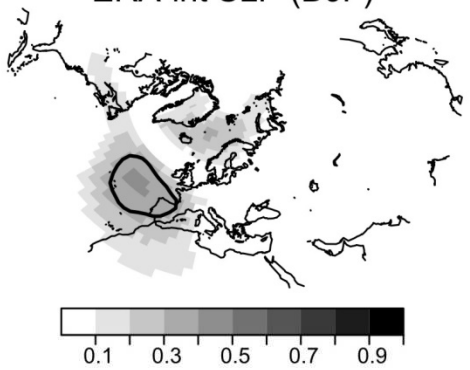
HadISST

SC / east of Greenland (eG)

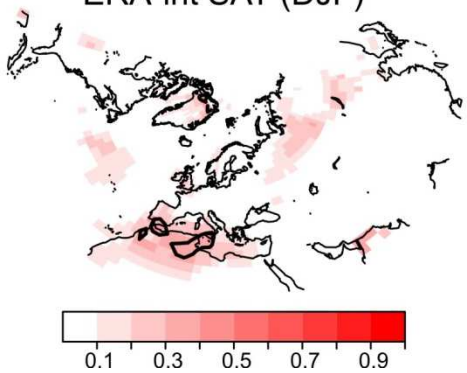


predicted by **SIC/BK$_{NOV}$**

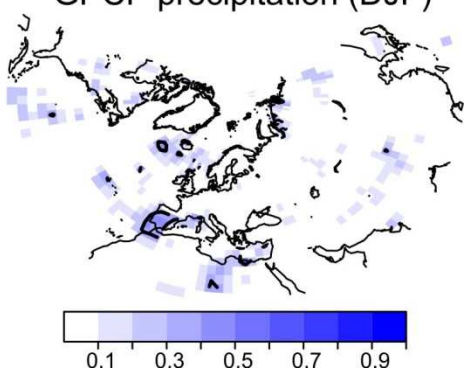
ERA-int SLP (DJF)



ERA-int SAT (DJF)



GPCP precipitation (DJF)

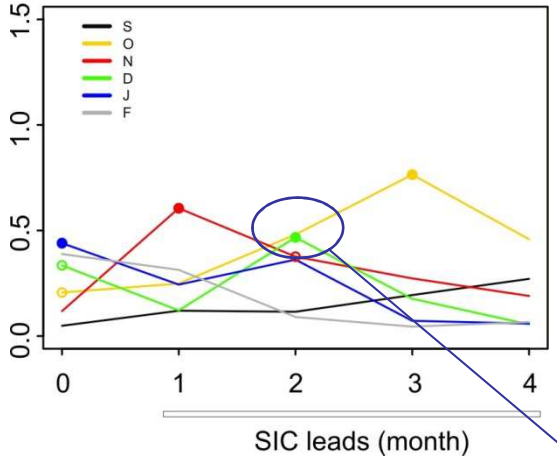


- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

García-Serrano et al. (2015, JCLIM); in agreement with Scaife et al. (2014, GRL) and Koenigk et al. (2015, ClimDyn)

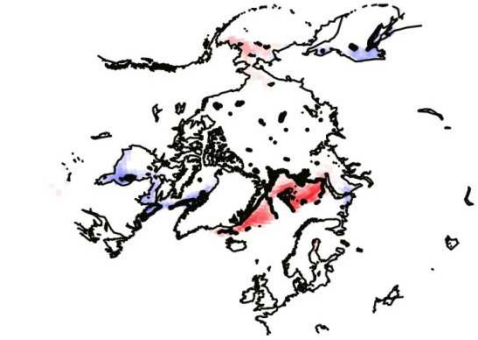
HadISST

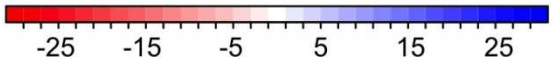
SC / east of Greenland (eG)



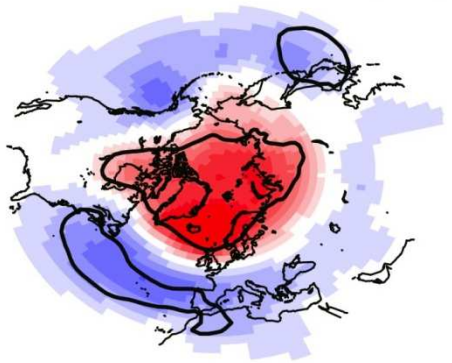
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

c) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

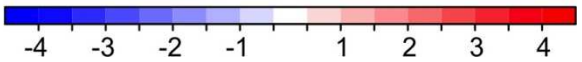


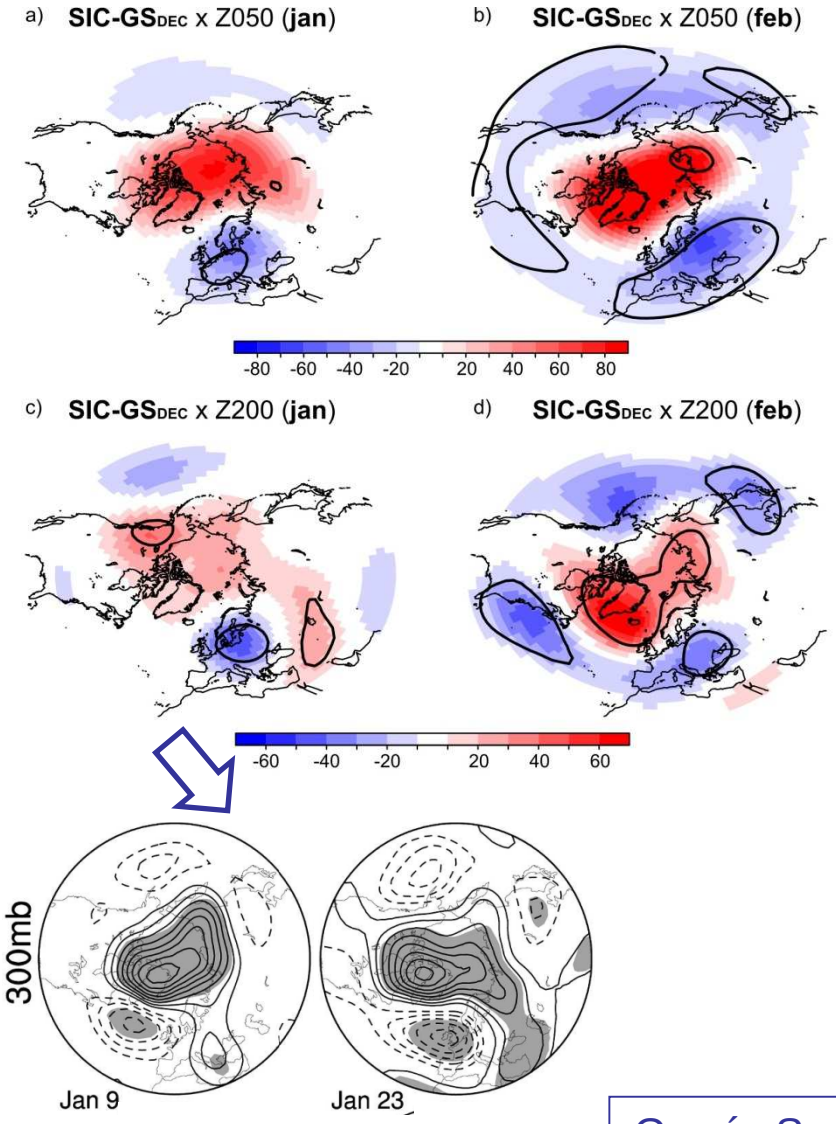


d) **MCA-SIC/eG$_{DEC}$** x SLP (**feb**)



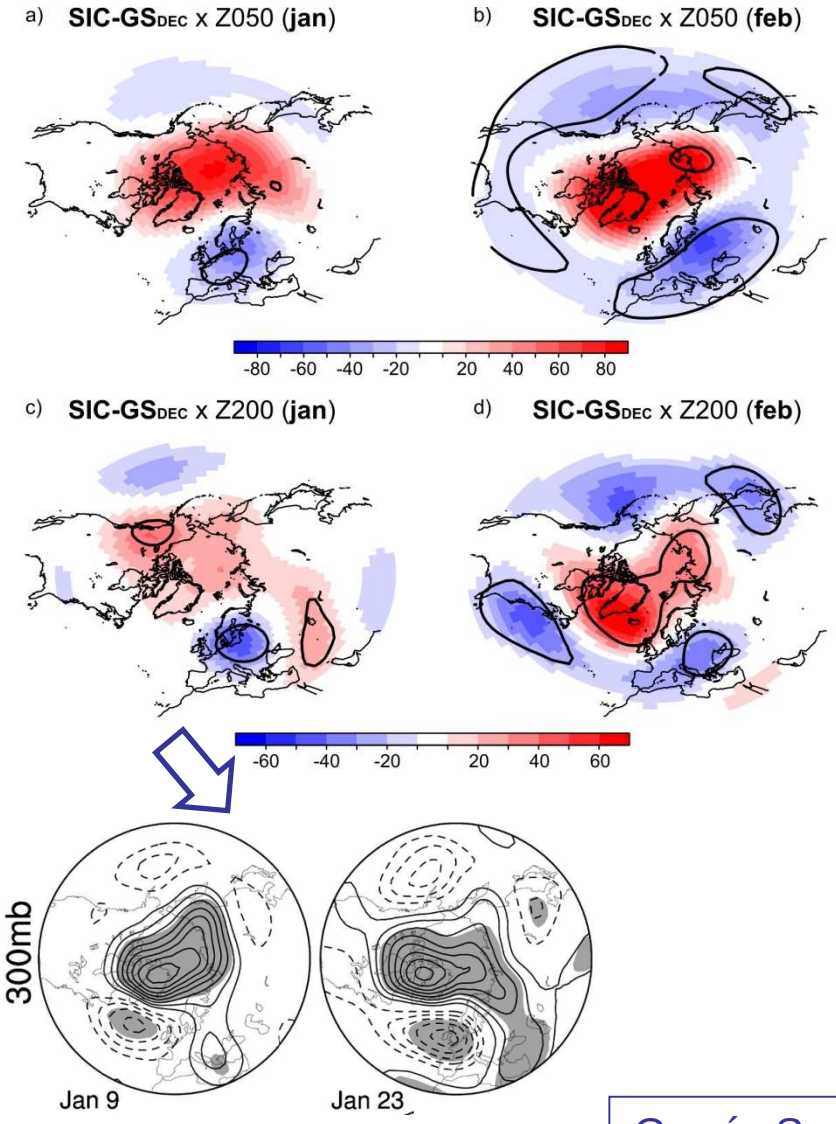
sig.lev.(SC)=0%



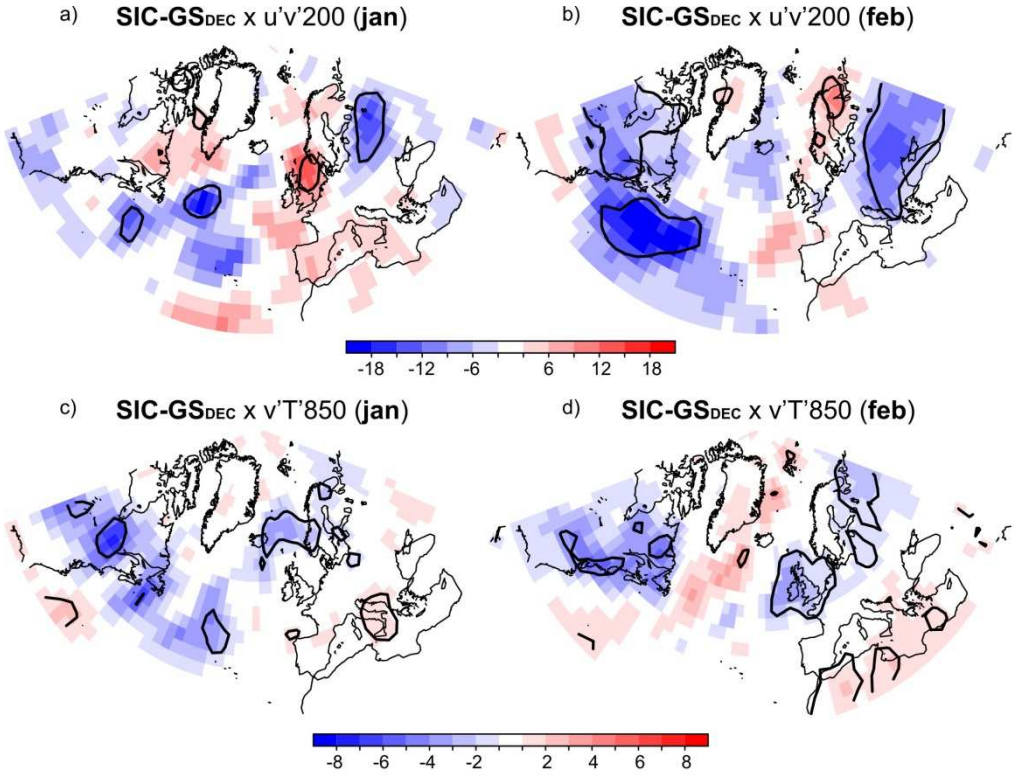


Deser et al. (2007, JCLIM)

García-Serrano and Frankignoul (2015, ClimDyn – under review)



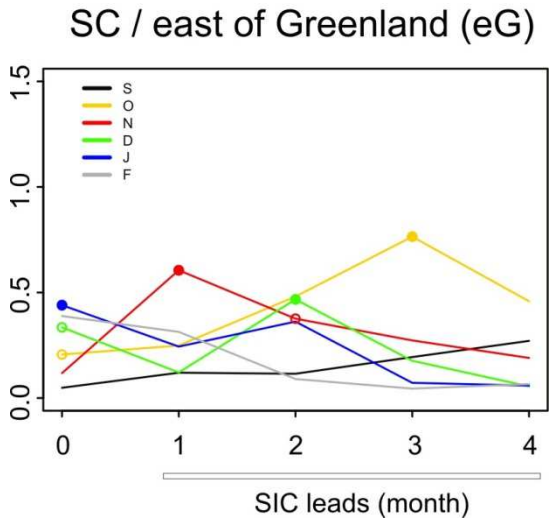
Deser et al. (2007, JCLIM)



TROPOSPHERIC DYNAMICS

García-Serrano and Frankignoul (2015, ClimDyn – under review)

HadISST



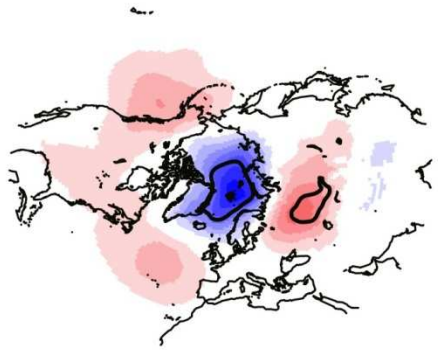
- detrended, monthly anomalies;
period 1979-2013;
target – cold season (Sep-to-Feb)

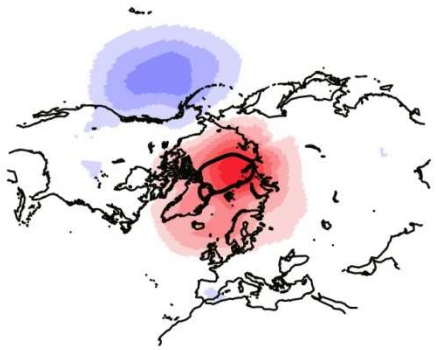
- **CMIP5**: no multi-model, each model individually;
CCSM4 (5mb), CNRM-CM5 (10mb), EC-EARTH2.3 (3mb), GFDL-CM2.1 (10mb), HadGEM2-ES (4mb), IPSL-CM5A-LR (3mb), MPI-ESM-MR (3mb), NorESM1-M (3mb) - HISTORICAL RUNS

CCSM

a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)

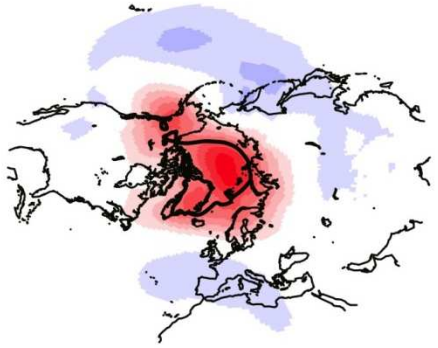
b) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)



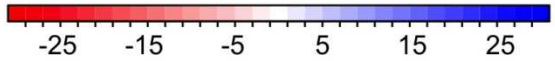


c) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

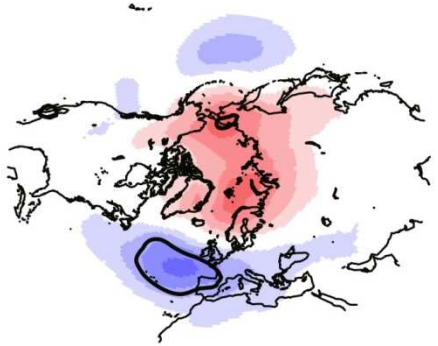
d) **MCA-SIC/eG$_{DEC}$** x SLP (**feb**)

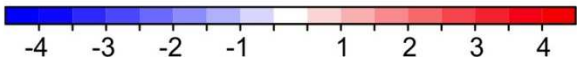


sig.lev.(SC)=5%

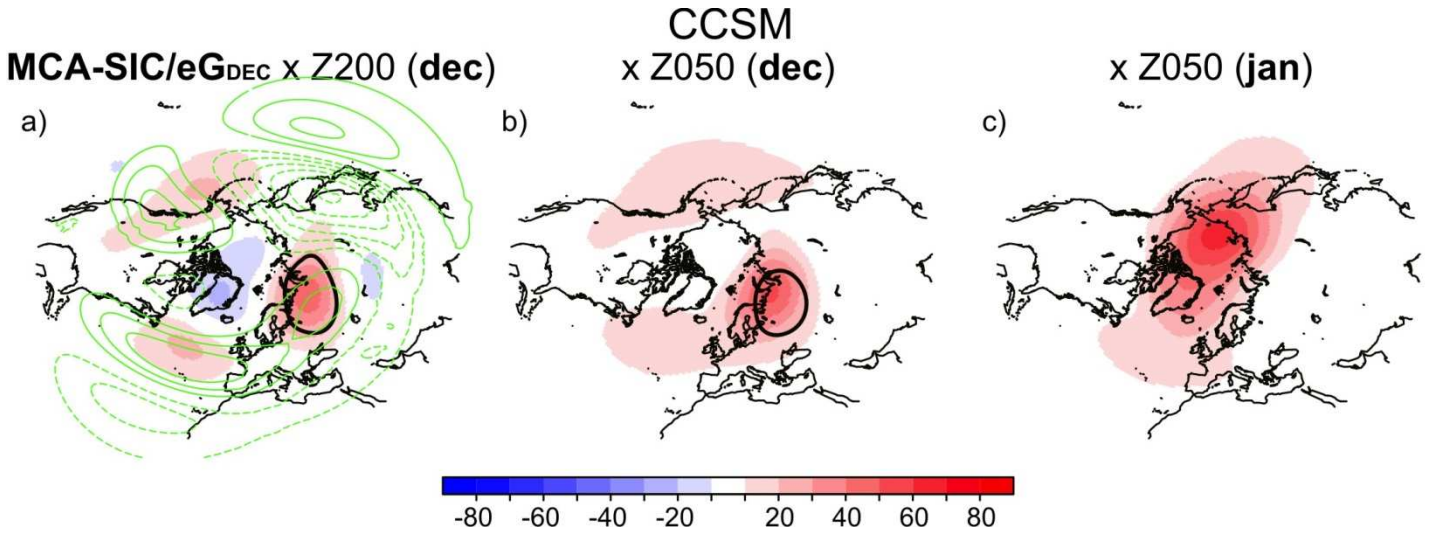


e) **MCA-SIC/eG$_{DEC}$** x SLP (**mar**)





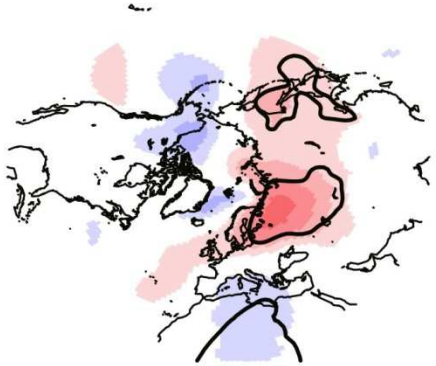
- eG **Dec** / SLP **Feb**: resembles the observed MCA mode (with 2-month lag); SLP anomalies over Polar Cap change sign from Dec to Jan, and amplify into Feb (statistical significance as well); lagged SLP anomalies over North Atlantic become stronger in Mar (also Z200), likely eddy-driven



- eG **Dec** / SLP **Feb**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP). there is no clear weakening of the polar vortex in Dec (Z050), and in Jan it's not significant; it becomes significant in Feb (not shown), once the AO-like anomaly is established in the troposphere (Jan-Feb), suggesting that tropospheric dynamics is key in driving the lagged anomalies whereas the stratosphere acts as positive feedback (e.g. Ambaum and Hoskins 2002)

CNRM

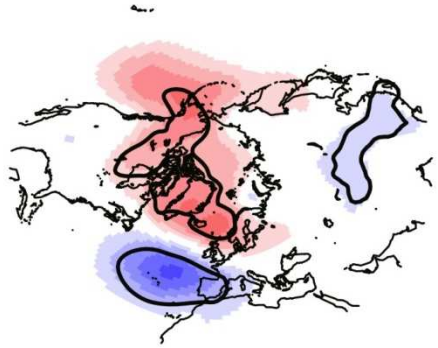
a) **MCA-SIC/eG$_{DEC}$** x SLP (**dec**)

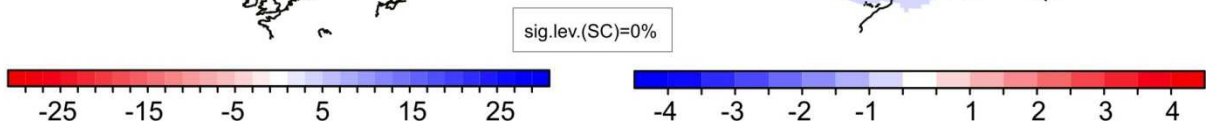


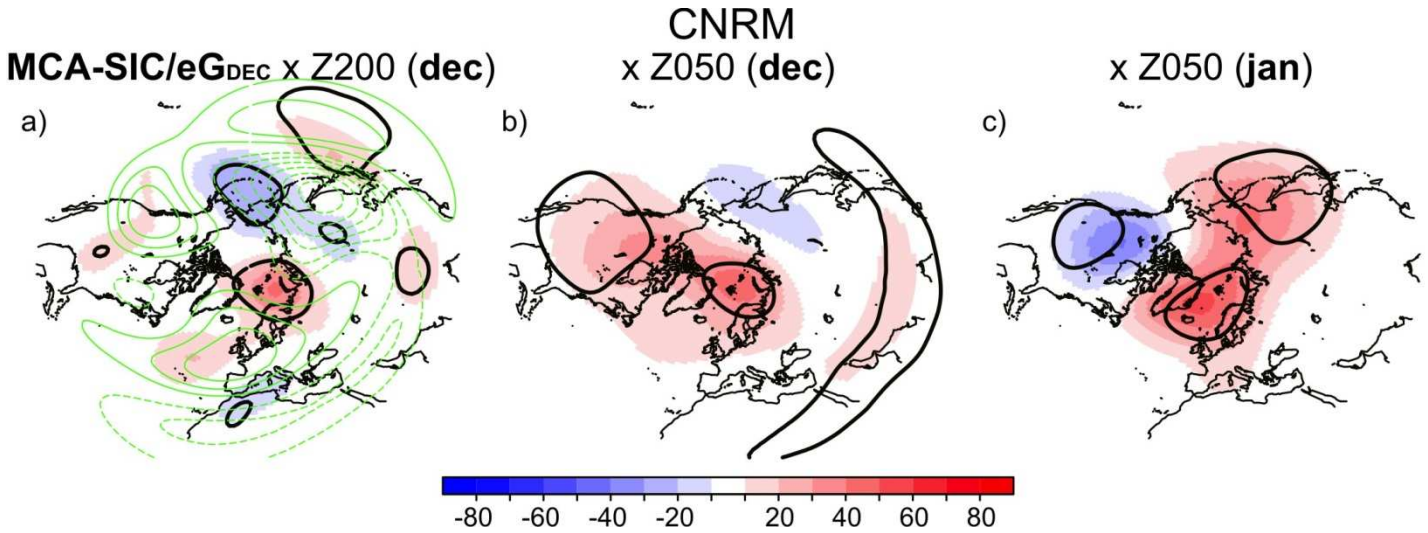
- <u>eG</u> **Dec** / SLP **Jan**: resembles the observed MCA mode with SIC in Nov (with 1-month lag), but different timing (Dec->Jan vs Nov->Dec); it yields anomalous anticyclone over Siberia preceding the negative NAO-like pattern

b) **MCA-SIC/eG$_{DEC}$** x SIC (**dec**)

c) **MCA-SIC/eG$_{DEC}$** x SLP (**jan**)



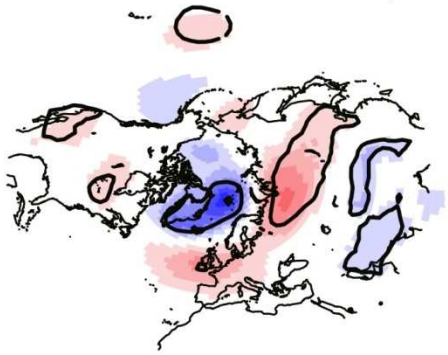




- eG **Dec** / SLP **Jan**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP); Z200 anomalies show some downstream extension, with negative anomalies over eastern Eurasia-western North Pacific (as shown in observations). there is a weakening of the polar vortex in Dec (Z050), projecting on a wavenumber-2 structure, preceding the establishment of the negative NAO-like patter at surface (in Jan), suggesting that a stratospheric pathway could act as driving mechanism

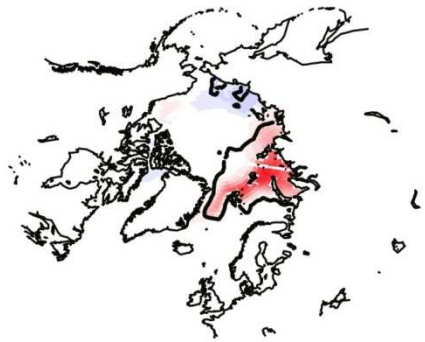
GFDL

a) **MCA-SIC/eG$_{OCT}$ x SLP (oct)**

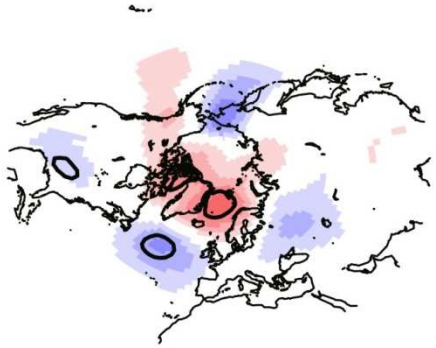


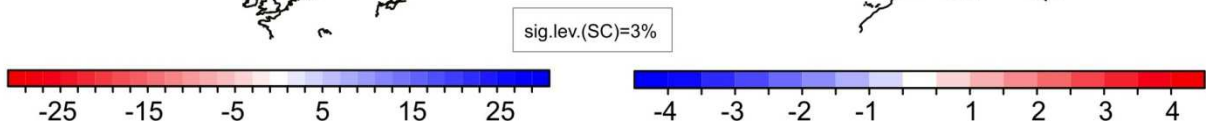
- eG **Oct** / SLP **Nov**: it resembles the observed MCA with SIC in Nov (1-month lag towards negative NAO-like), but different timing – prior to obs (Oct->Nov vs Nov->Dec) vs CNRM and EC-EARTH showing 1-month delay; it also shows anomalous anticyclone over Siberia

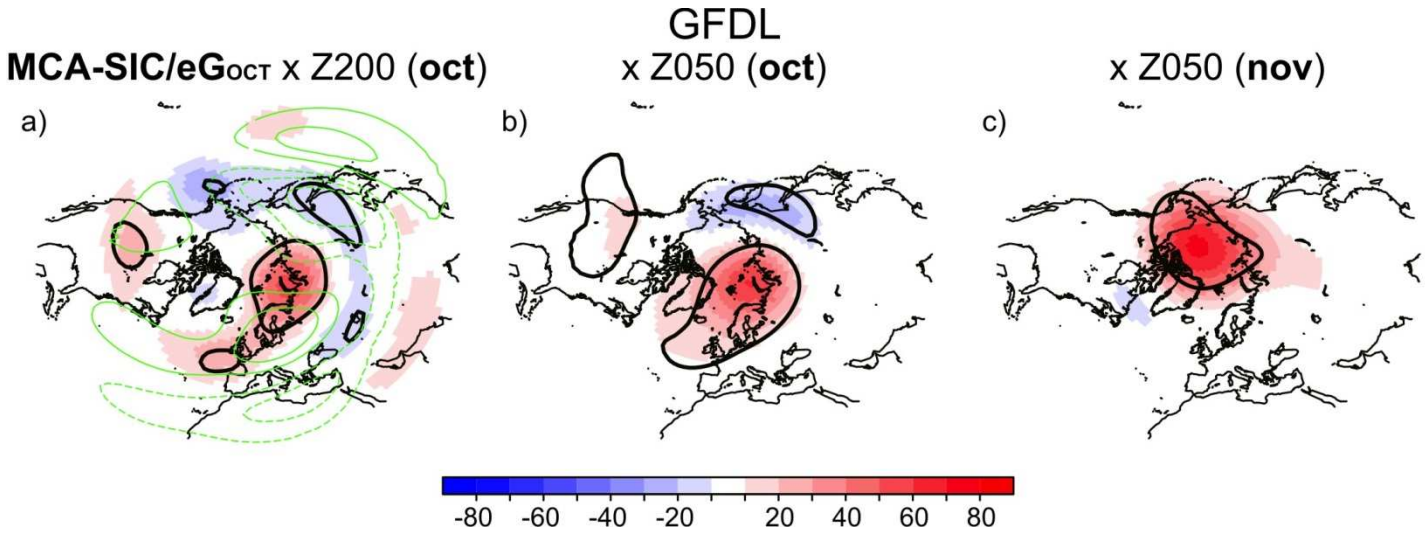
b) **MCA-SIC/eG$_{OCT}$ x SIC (oct)**



c) **MCA-SIC/eG$_{OCT}$ x SLP (nov)**

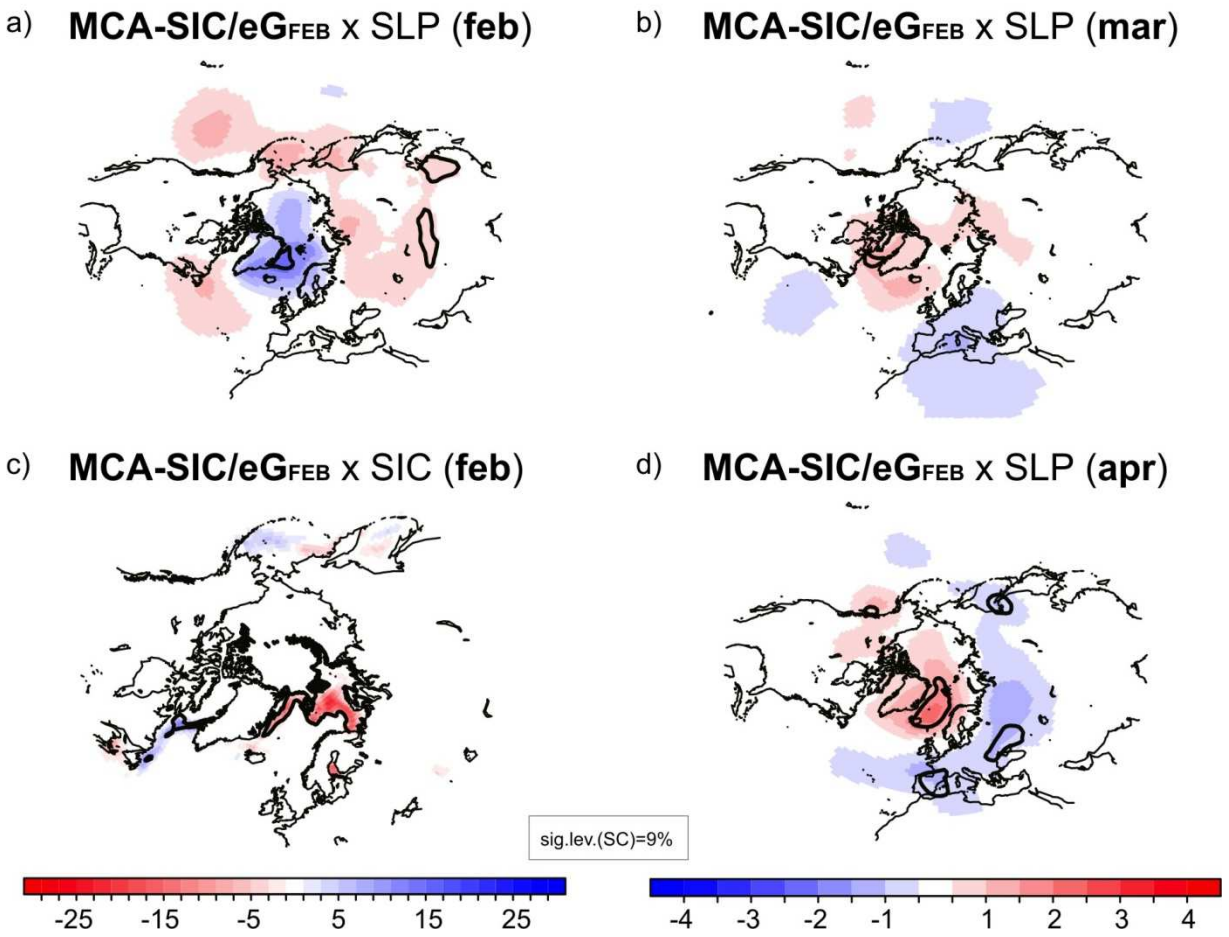




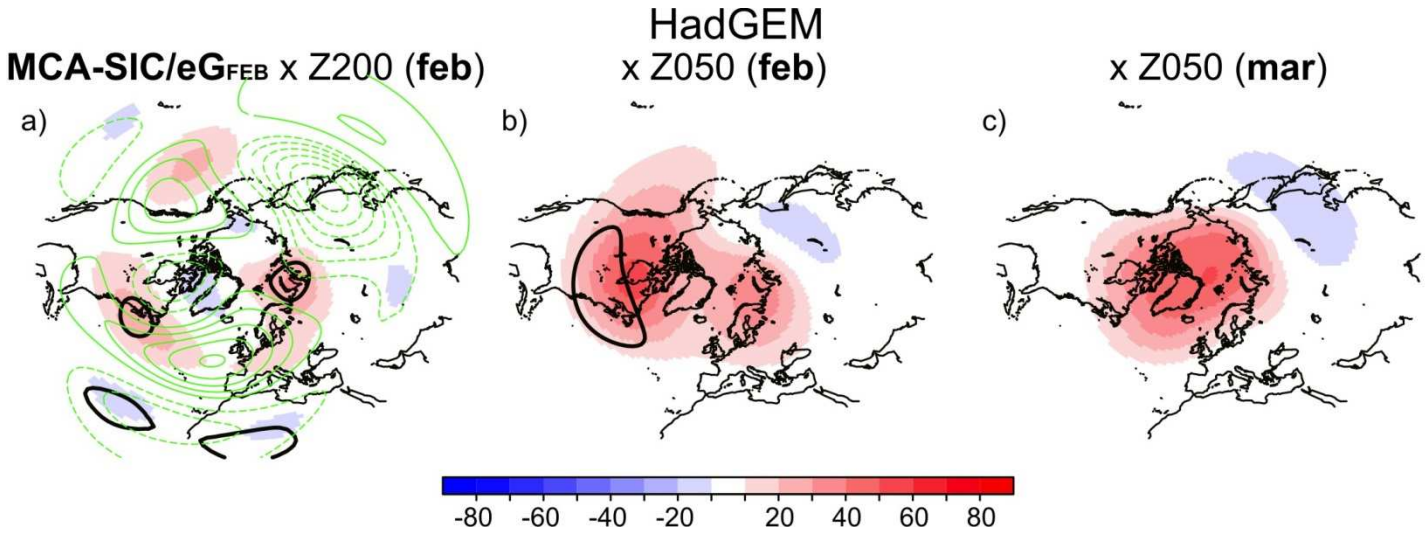


- eG **Oct** / SLP **Nov**: the anomalous anticyclone over northern Siberia (Z200) shows some baroclinicity (cf. SLP), consistent with direct linear response to SIC reduction. there is also an apparent downstream propagation of anomalies. the weakening of the polar vortex in Oct (Z050), preceding the establishment of the negative NAO-like patter at surface (in Nov), is quite barotropic - projecting on a mixture of wavenumber-2 structure and vortex displacement. in Jan, the weakening remains. these results suggest an active role of the stratosphere in driving the lagged negative NAO-like pattern. NOTE: the polar vortex is probably developing at this time (Oct-Nov)

HadGEM



- eG **Feb** / SLP **Apr**: resembles observations with SIC in Dec (2-month lag), with SIC reduction over Greenland-Barents Seas followed by negative NAO-like pattern; in Mar (b) the circulation anomalies already show a negative NAO signature, but not significant – likely eddy-feedback



- eG **Feb** / SLP **Apr**: anomalous anticyclone over northern Siberia (Z200) consistent with direct linear response to SIC reduction (see SLP). there is no clear weakening of the polar vortex in Feb (Z050) – barotropic anomaly over USA, and in Mar it's not significant; it becomes significant in Apr (not shown), once the NAO-like anomaly is established in the troposphere, suggesting that tropospheric dynamics is key in driving the lagged anomalies / eddy-driven

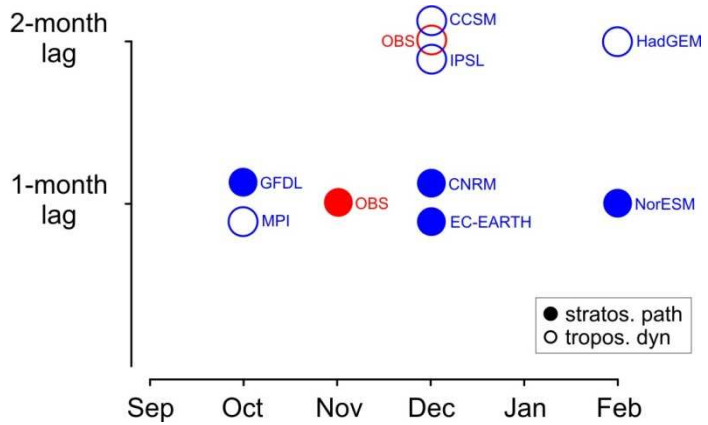
SUMMARY

- CMIP5 models analysed here show a significant link with sea-ice reduction over the eastern Arctic (Greenland-Barents-Kara Seas) followed by a negative NAO-like pattern

- If the simulated relationship takes *one month* – the results suggest (in general) that a stratospheric pathway could be at play [in observations, this is shown for SIC in Nov]

- If the simulated relationship takes *two months* – the results suggest (in general) that tropospheric dynamics is dominant [in observations, this is shown for SIC in Dec]

- Sea-ice information should be incorporated in seasonal forecast systems



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