Effects of mean state of climate models on the response to prescribed forcing: Sensitivity experiments with the SPEEDY general circulation model.

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Introduction

State of the art General Circulation models show several issues in representing the extratropical circulation:

- The North Atlantic Storm Track is not well tilted.
- Tri-modality of the North Atlantic eddy-driven jet stream is absent.
- Responses to the same external forcing like Atlantic multidecadal variability(AMV), El Nino Southern oscillation(ENSO) are widely different.

Research question

“Is the response to external forcings of Atmospheric general circulation models (AGCM) affected by the mean state of the model?”

Methods

Simplified Parameterization primitivE-Equations DYnamics (SPEEDY)

- Primitive-Equations
- Hydrostatic
- Semi-implicit gravity waves
- T30 Spectral resolution (3.75 X 3.75 degree)
- 8 vertical levels

Methods

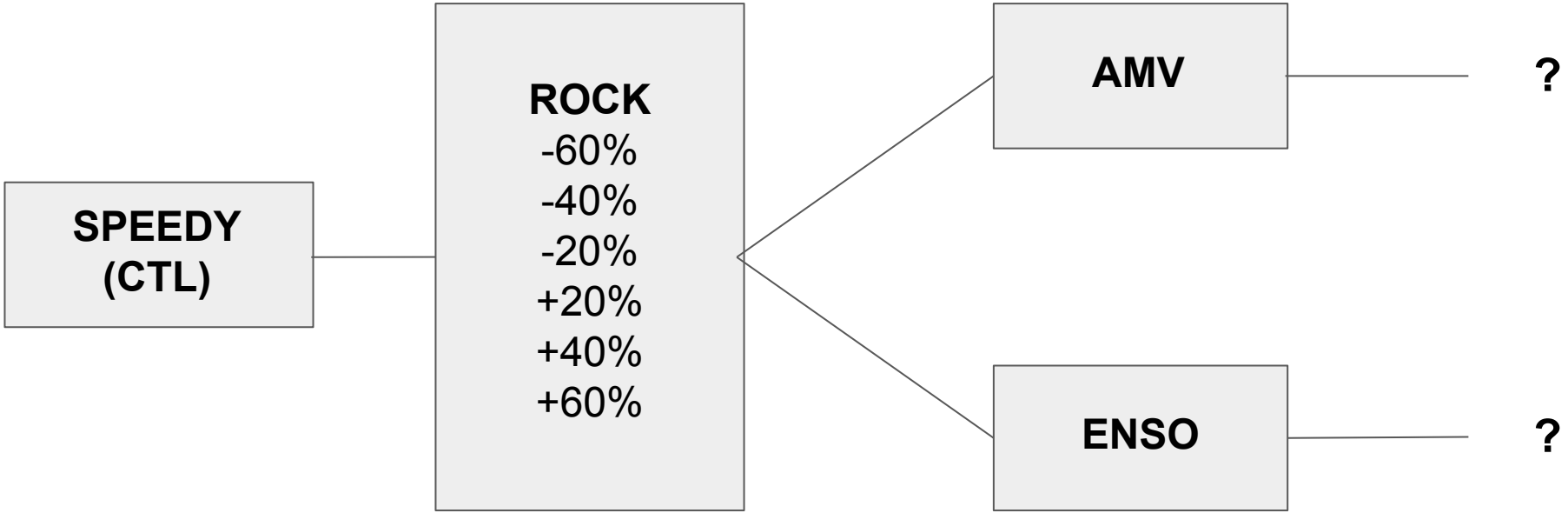
Several sensitivity experiment were performed using SPEEDY :

- A set of “different models” are obtained modifying the height of the Rocky Mountains (ROCK).

- External forcings (AMV, ENSO) are imposed in the ROCK and the control (CTL) experiments.

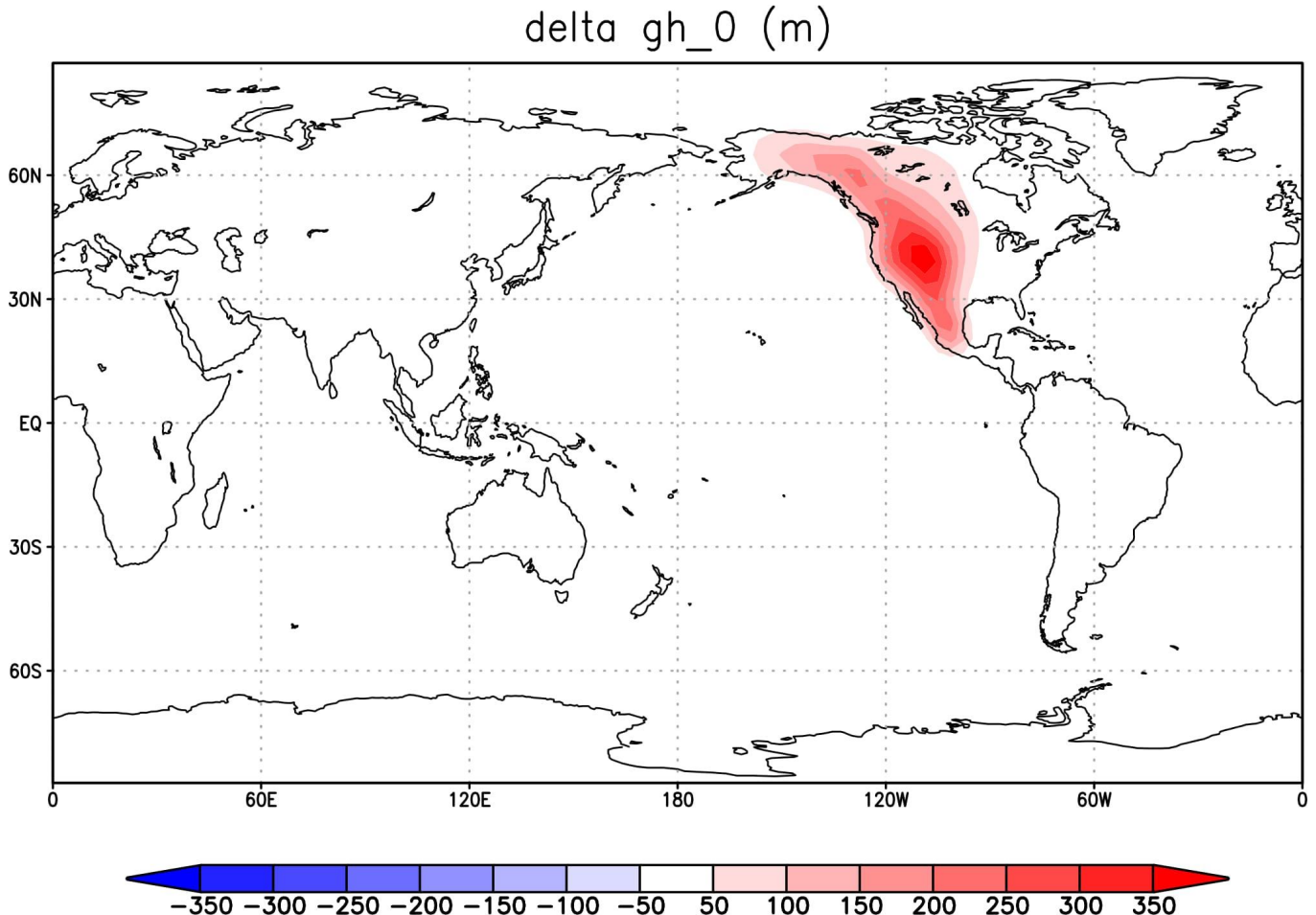
Methods

Several sensitivity experiment were performed using the following diagram



Methods

ROCK Experiment example: Geopotential height at the surface (m). Difference between the **+20%** experiment and the control run (CTL)



Changes in the mean state

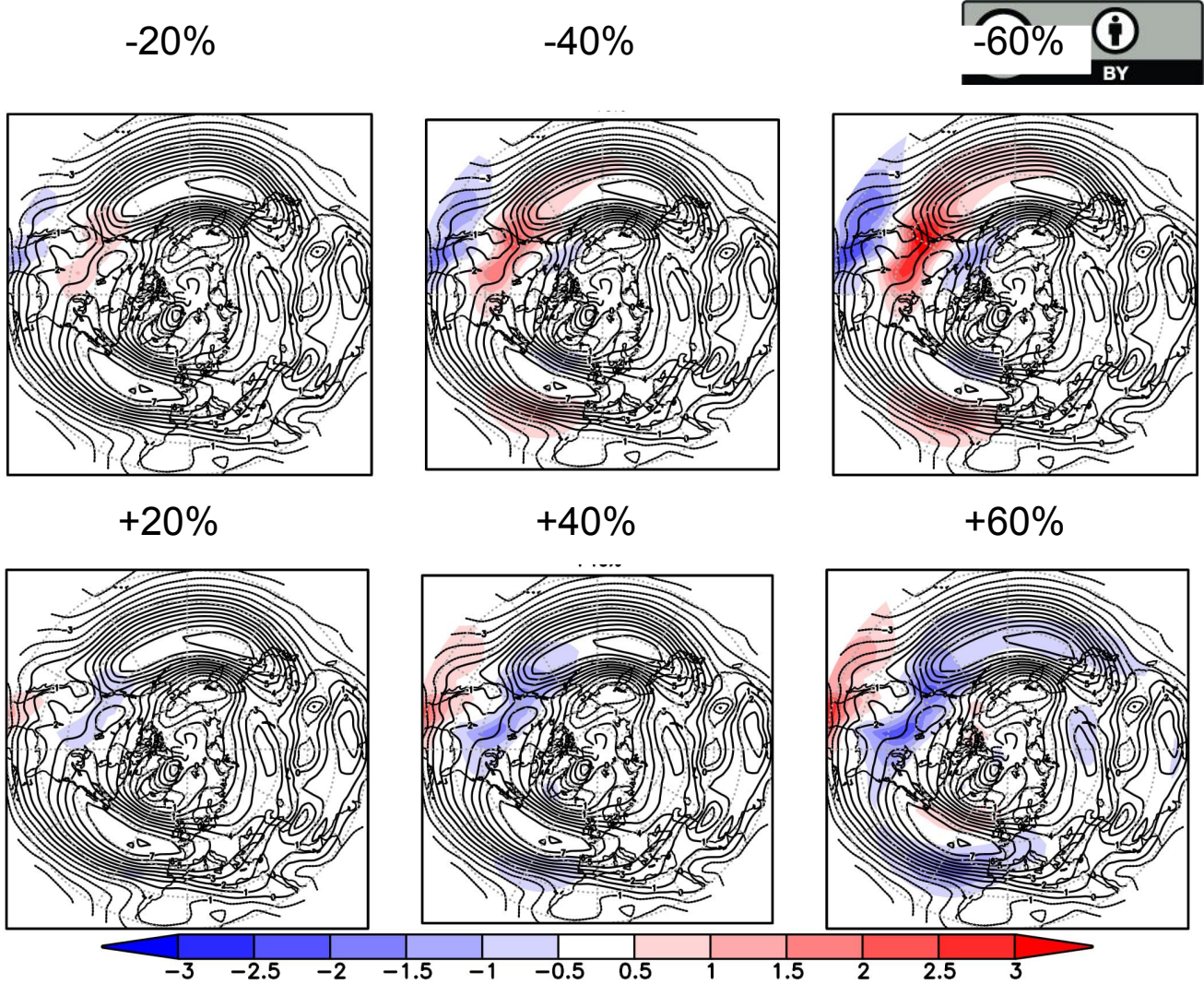
ROCK

ROCK

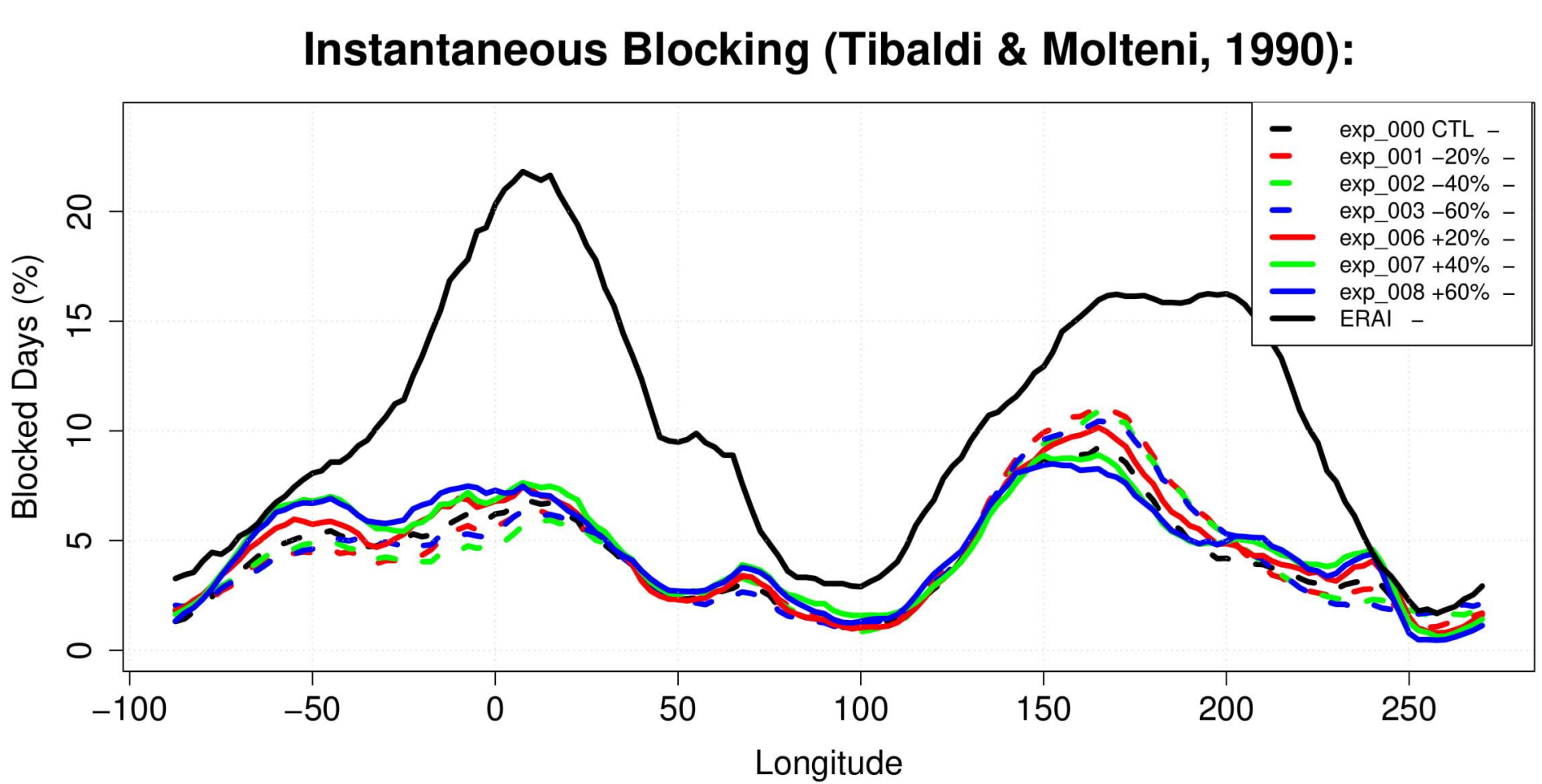
DJF U 850hPa (m/s).

Shades are the difference between the experiments and the CTL.

Contours are the CTL.



ROCK


Instantaneous Blocking (Tibaldi & Molteni, 1990):
Blocked Days (%)
0
5
10
15
20
−100
−50
0
50
100
150
200
250
Longitude
exp_000 CTL –
exp_001 –20% –
exp_002 –40% –
exp_003 –60% –
exp_006 +20% –
exp_007 +40% –
exp_008 +60% –
ERAI –

First conclusion

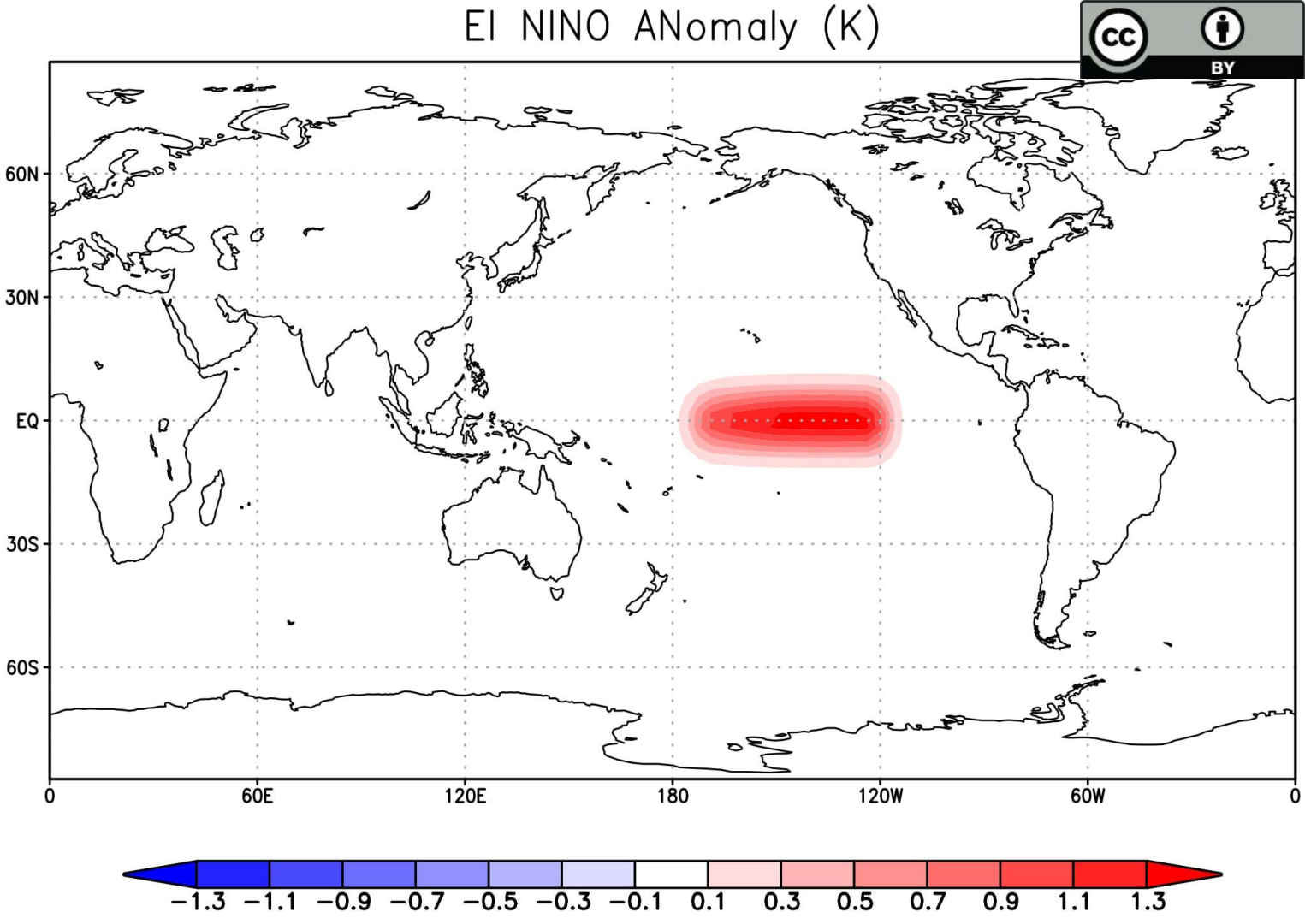
By modifying the orography of the Rocky Mountains it is possible to change the mean state of the model as shown with the ROCK experiments.

Idealised ENSO

ENSO

Idealised sea surface temperature **SST anomaly** for El Nino 3.4.

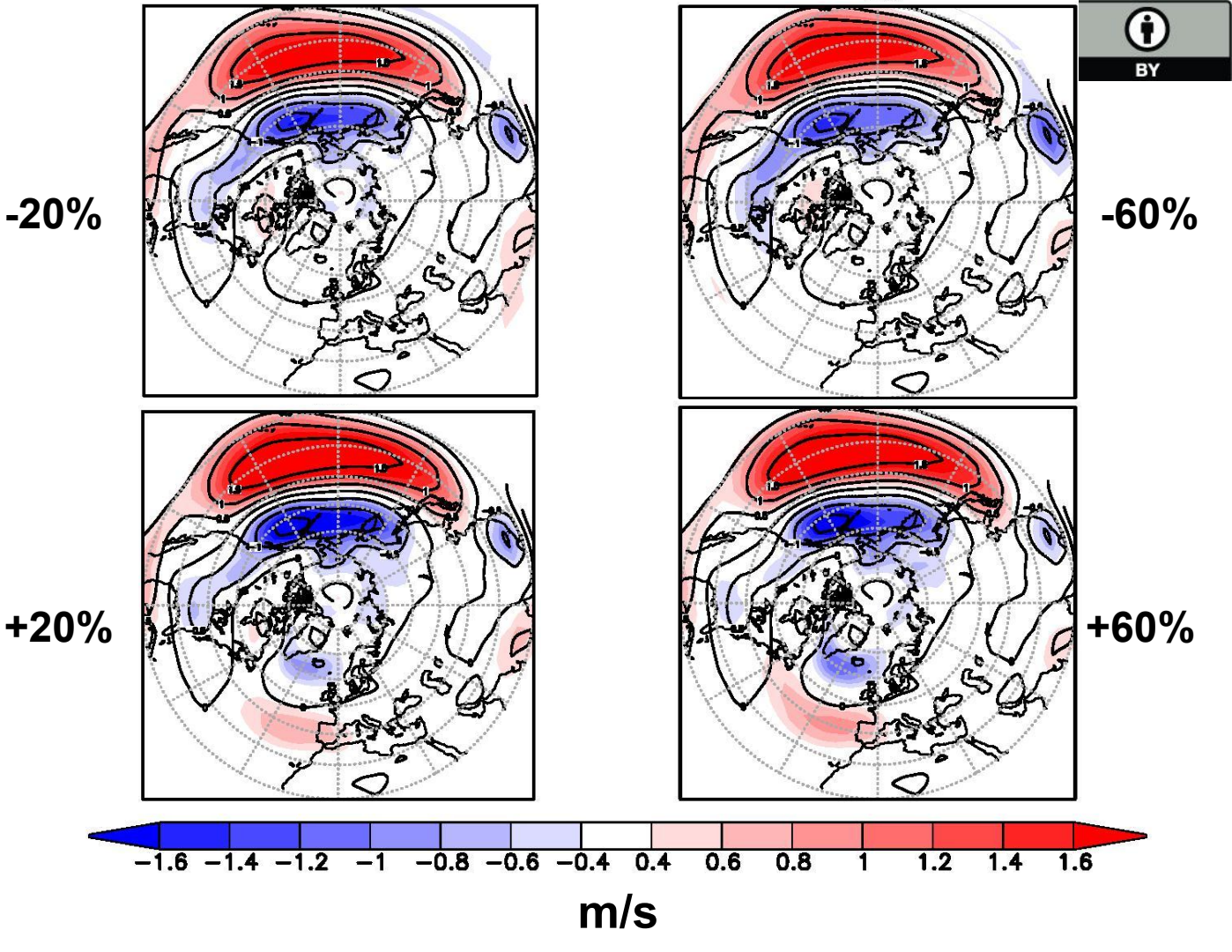
The anomaly is obtained from the NOAA daily SST anomalies data and making the composite of all the days with an El Nino index greater than 0.5.



ENSO

DJF U 850 hPa (m/s).
Shades are the difference between El Nino minus La Nina (**ΔENSO**) in the ROCK experiments.

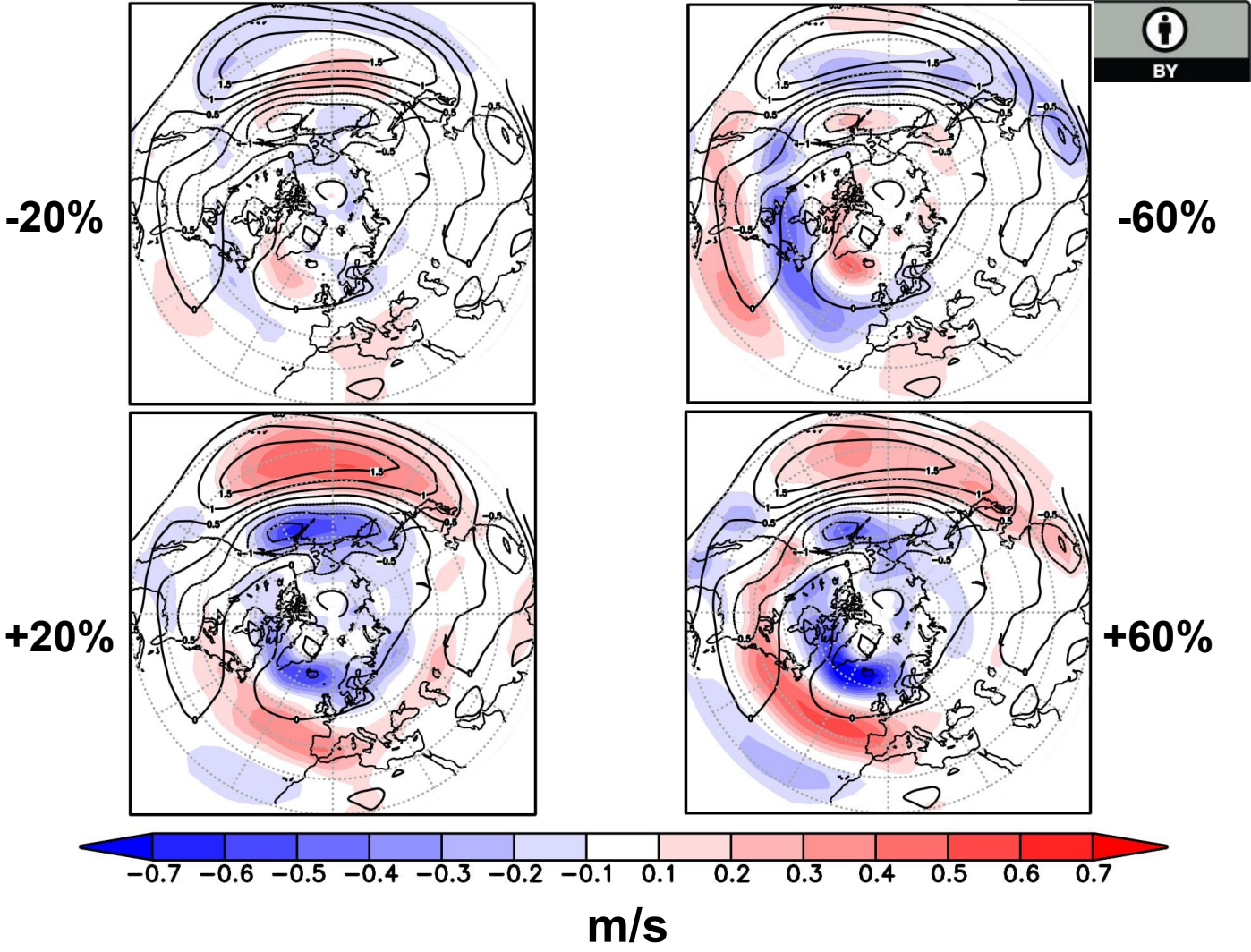
Contours are **ΔENSO** in the CTL.



ENSO

DJF U 850 hPa (m/s).
Shades are the difference between **ΔENSO** in the ROCK experiments and **ΔENSO** in the CTL.

Contours are **ΔENSO** in the CTL.



Second conclusion

The response to ENSO is affected by the mean state:

- ENSO experiments show that the response change the sign together with the modification of the orography.

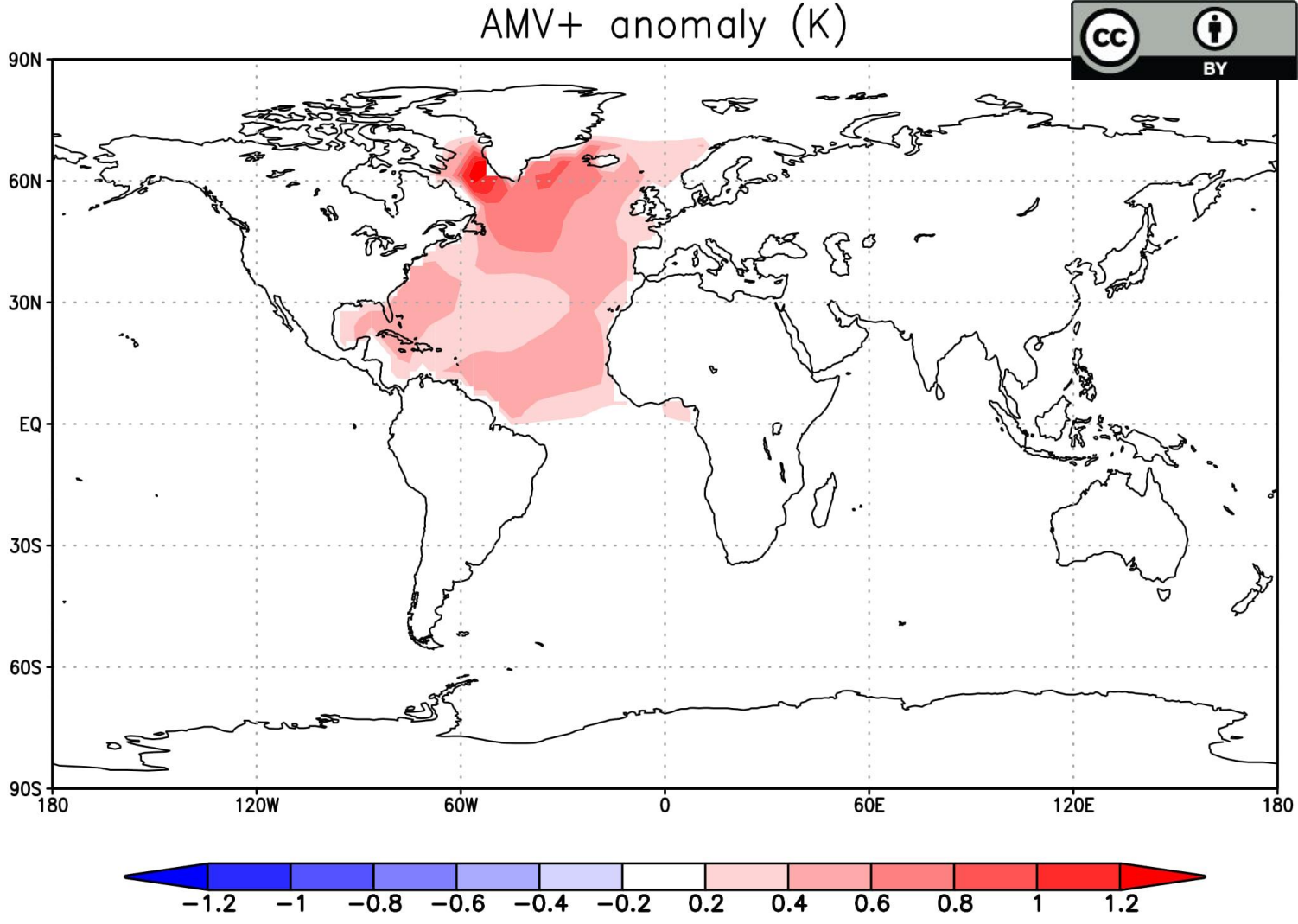
Response to the forcing

AMV

AMV

SST anomaly

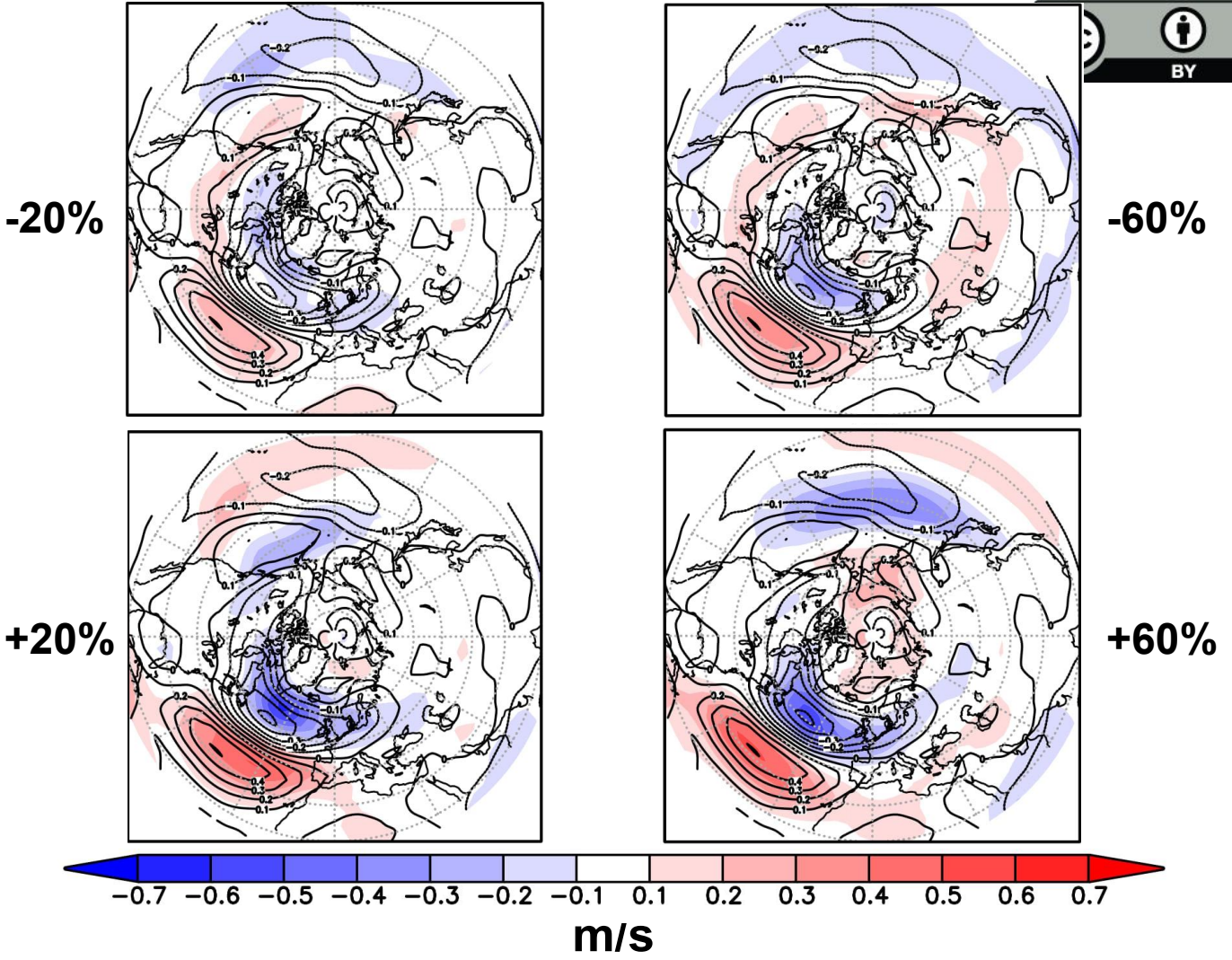
From the Decadal Climate Prediction Project (DCPP).



AMV

DJF U 850 hPa (m/s).
Shades are the difference between AMV+ minus AMV- (**ΔAMV**) in the ROCK experiments.

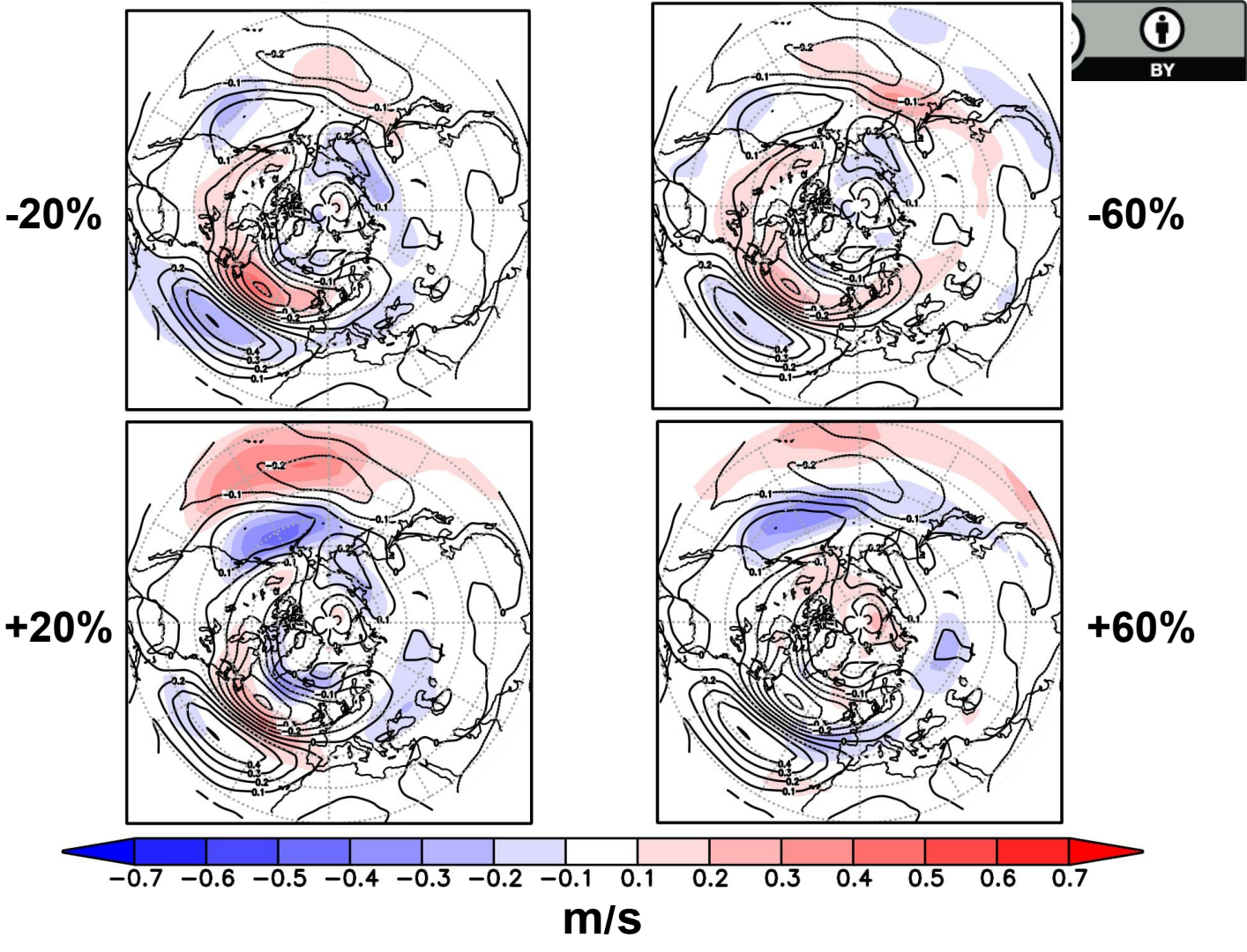
Contours are **ΔAMV** in the CTL.



AMV

DJF U 850 hPa (m/s).
Shades are the difference between **ΔAMV** in the ROCK experiments and **ΔAMV** in the CTL.

Contours are **ΔAMV** in the CTL.



Third conclusion

The response to AMV is affected by the mean state:

- AMV experiments show that the effect over the Pacific Ocean is larger with the increased orography while the effect over the North Atlantic is larger decreasing the orography.

Future steps

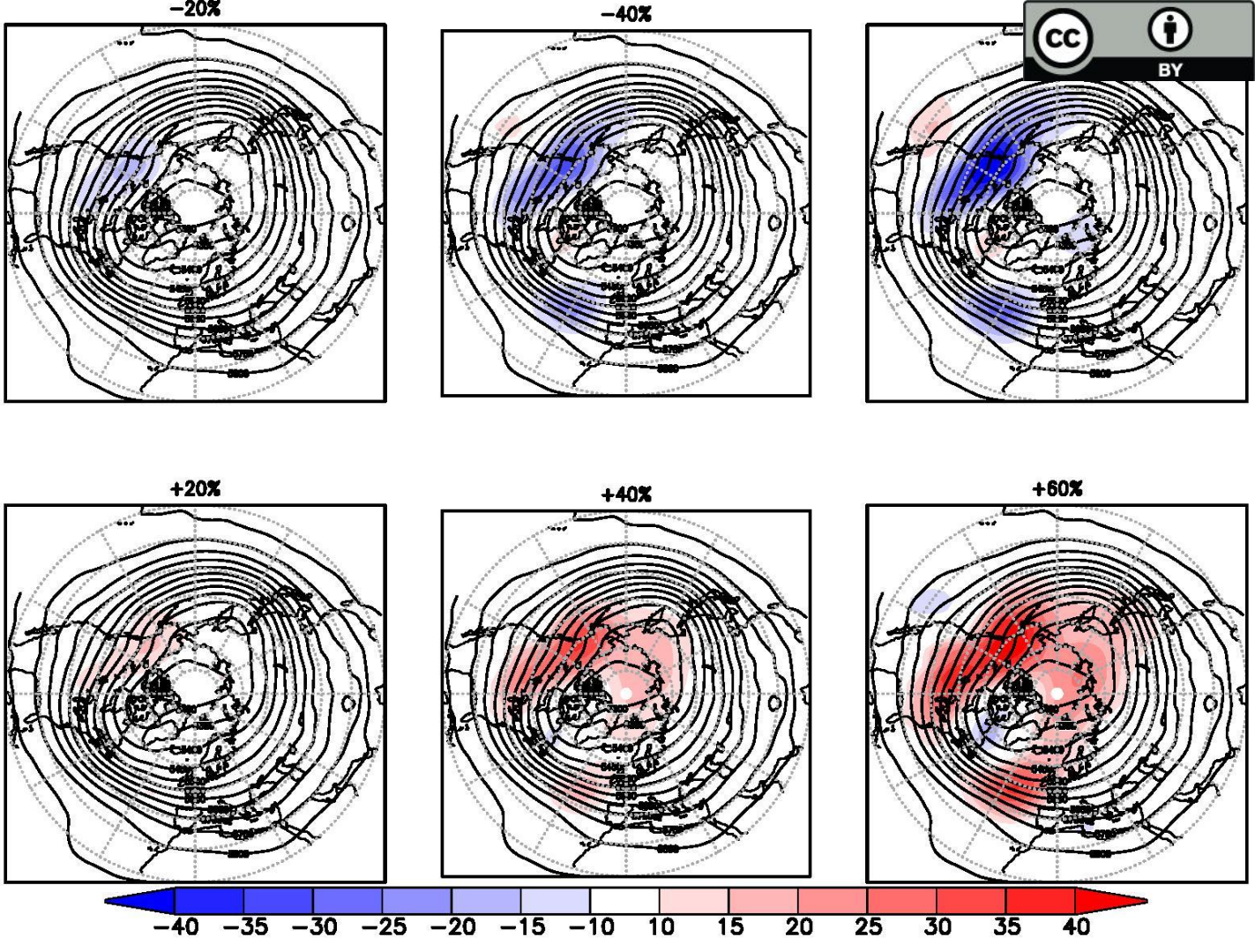
- Stronger external forcings, **doubling the anomalies**.
- A different approach to change the mean state. For example, modifying the **orographic drag coefficient**.

ROCK

DJF Z500 hPa (m).

Shades are the difference between the experiments and the CTL.

Contours are the CTL.

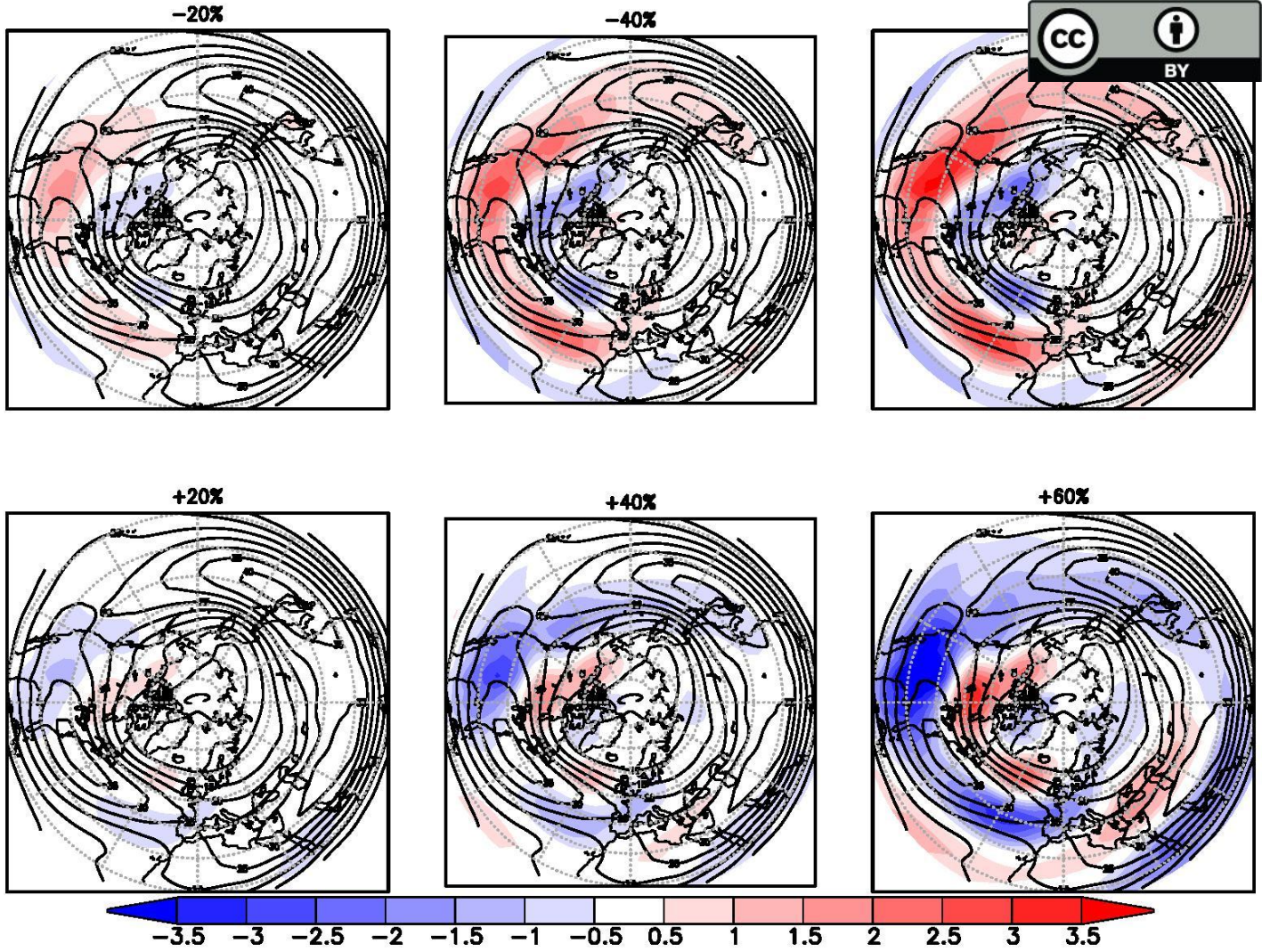


ROCK

DJF U 200 hPa (m/s).

Shades are the difference between the experiments and the CTL.

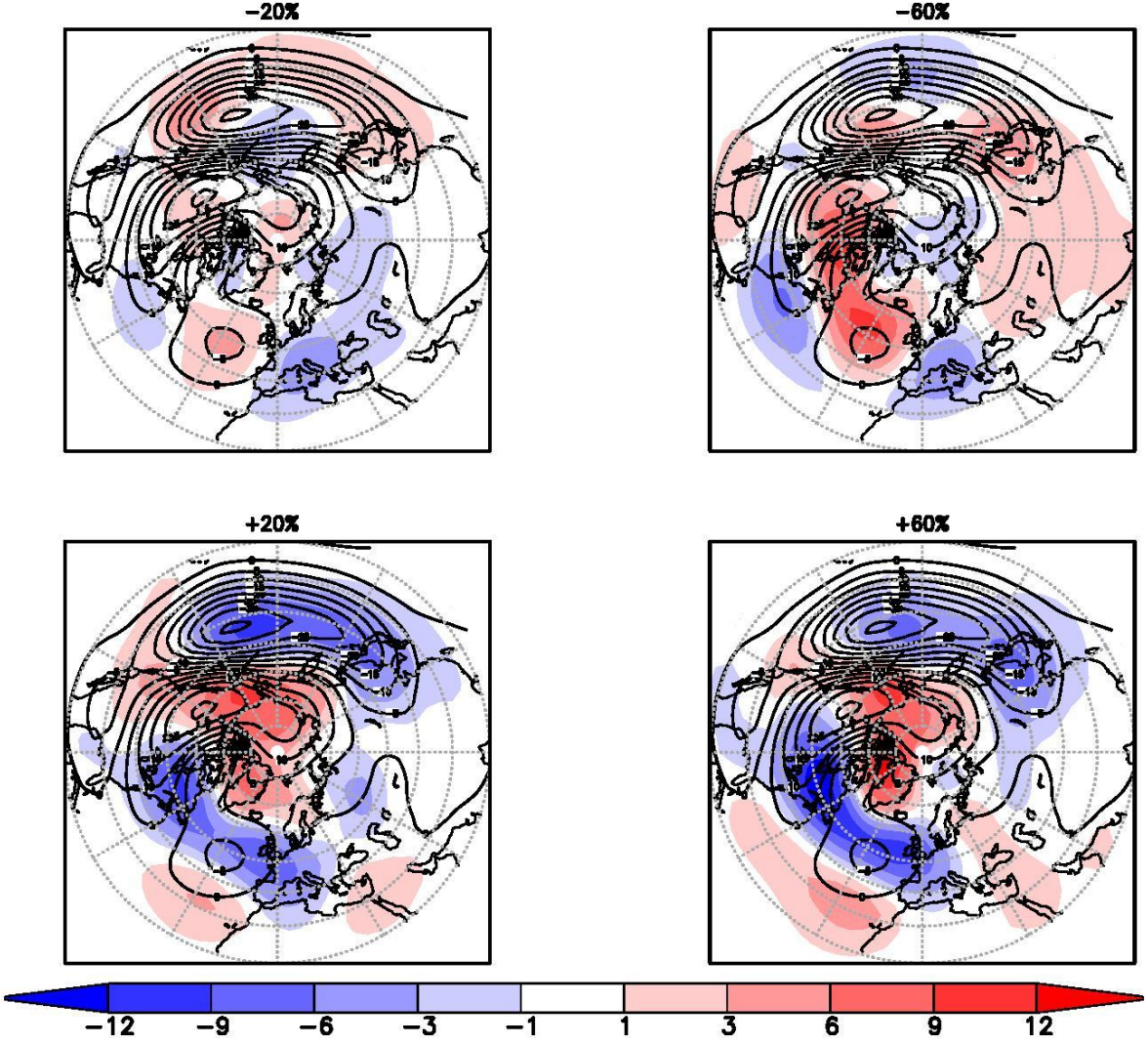
Contours are the CTL.



ENSO

DJF Z 500 hPa (m).
Shades are the difference between El Nino minus La Nina (**ΔENSO**) in the ROCK experiments.

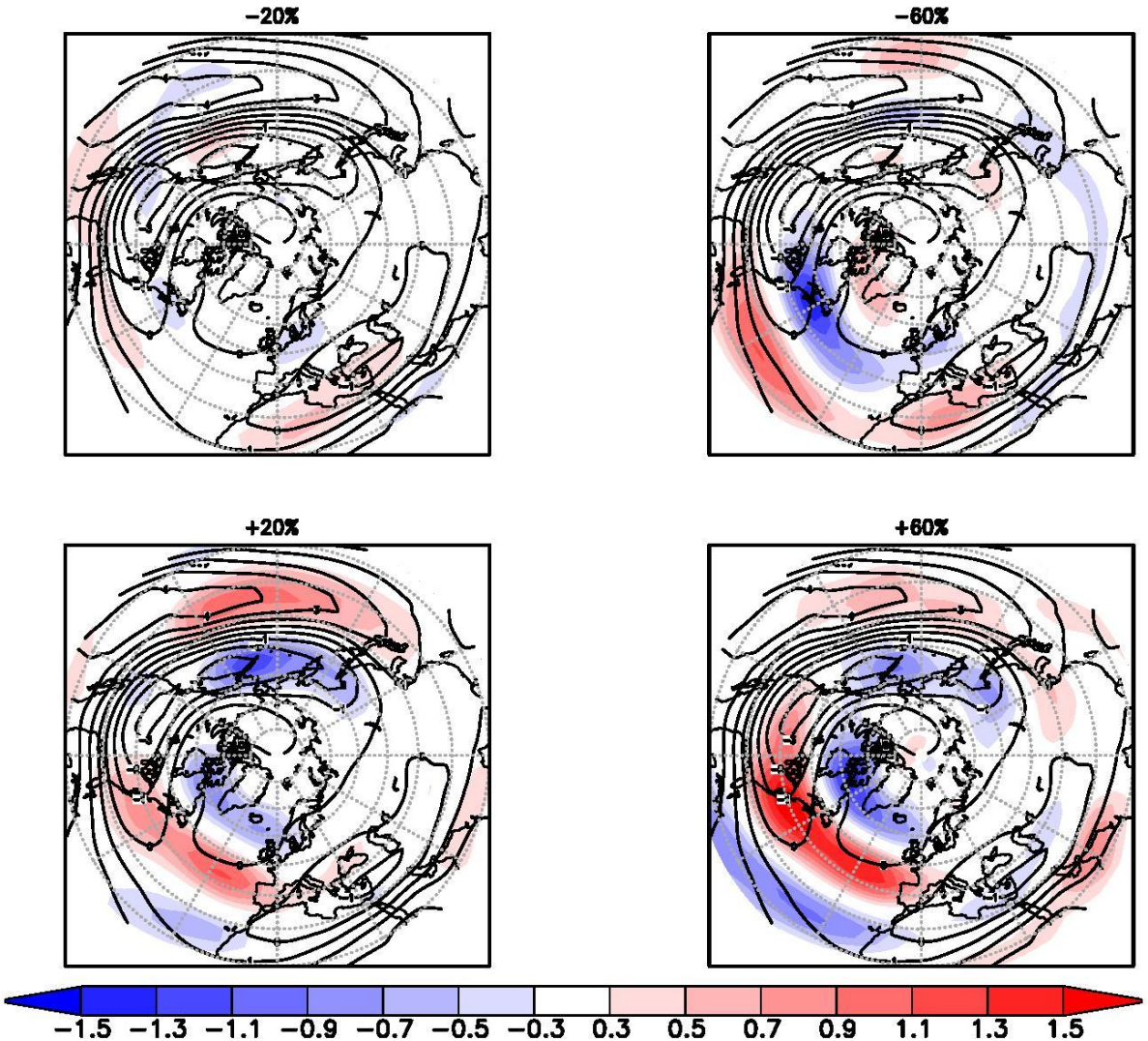
Contours are **ΔENSO** in the CTL.



ENSO

DJF U 200 hPa (m/s).
Shades are the difference between El Nino minus La Nina (**ΔENSO**) in the ROCK experiments.

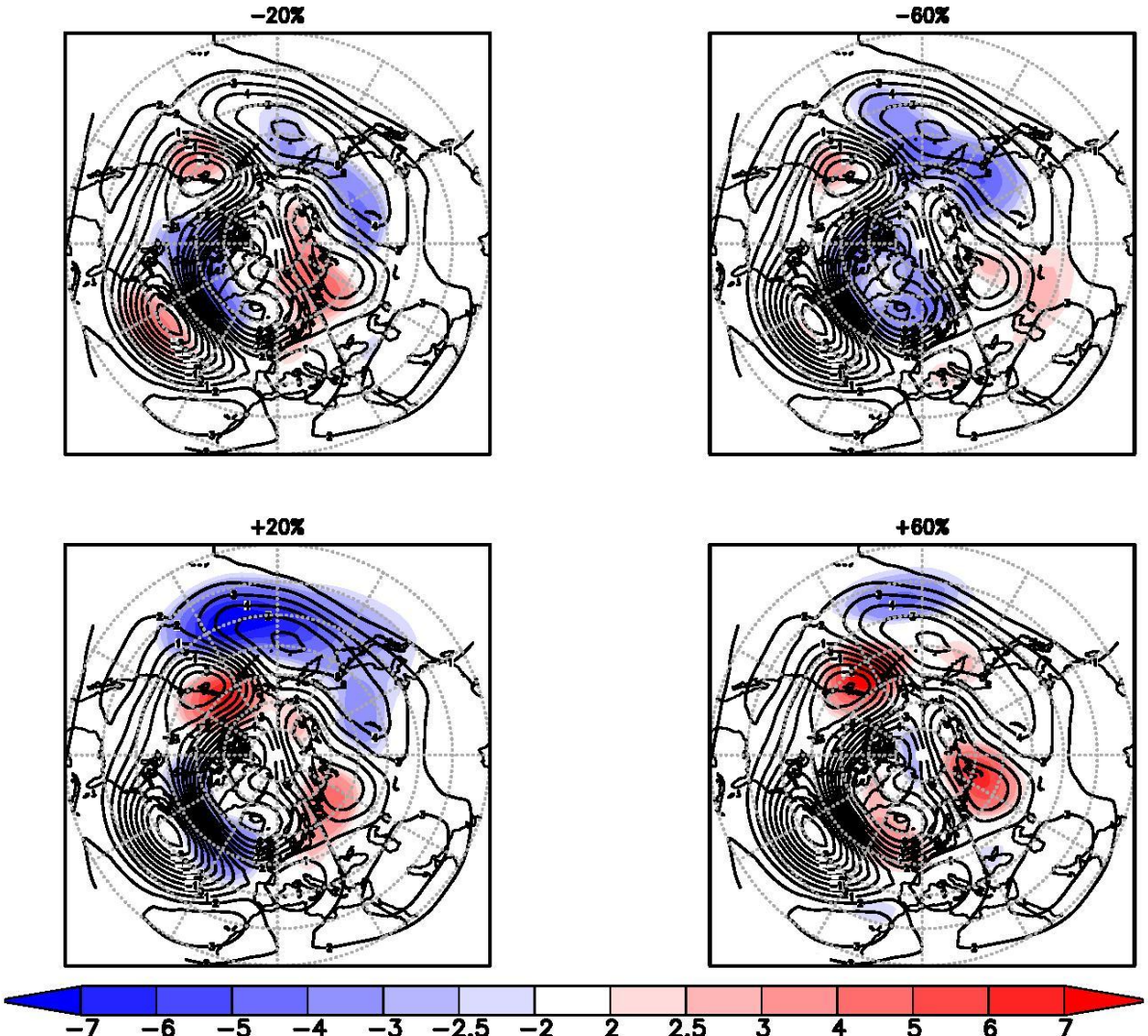
Contours are **ΔENSO** in the CTL.



AMV

DJF Z 500 hPa (m).
Shades are the difference between AMV+ minus AMV- (**ΔAMV**) in the ROCK experiments.

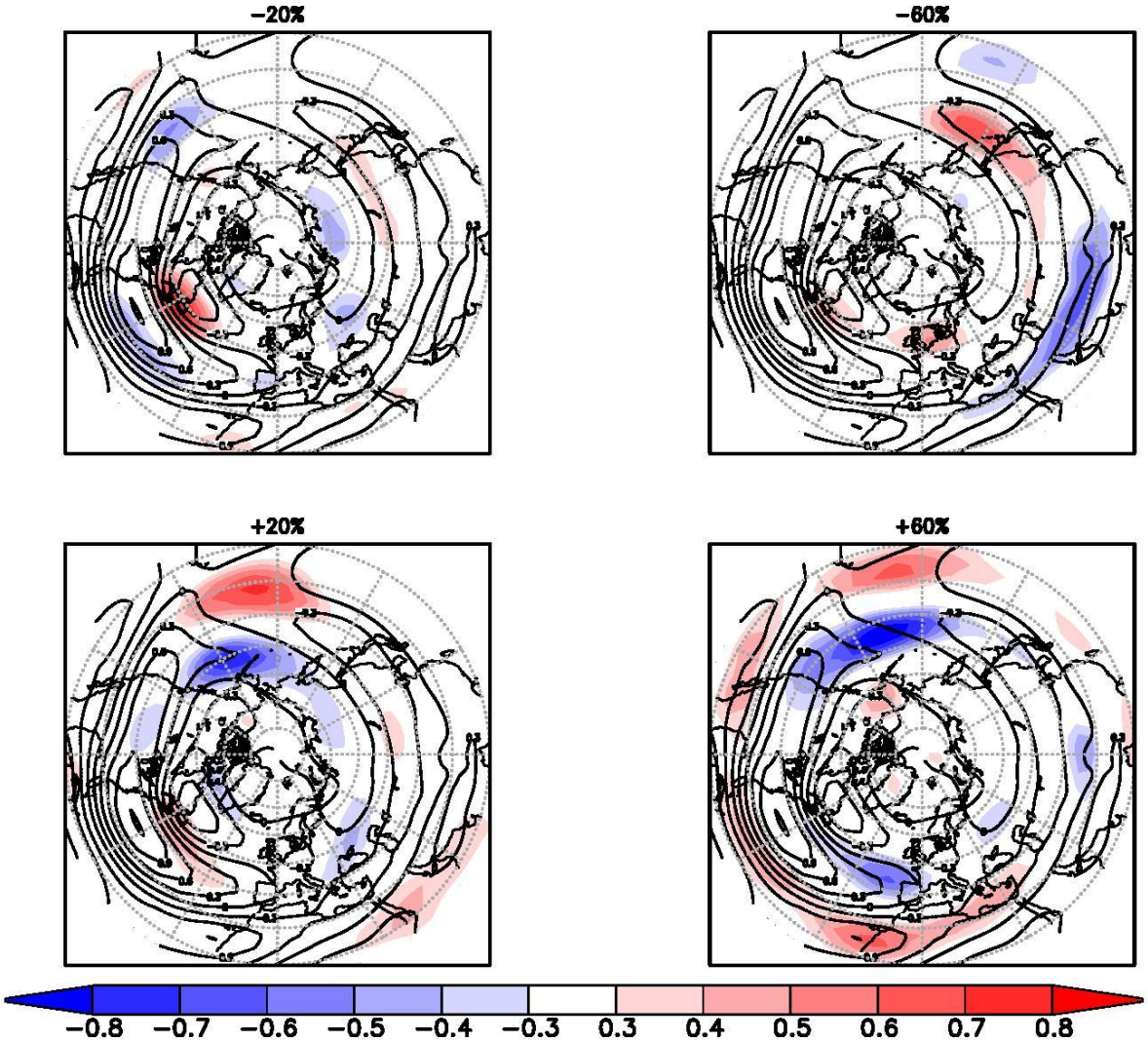
Contours are **ΔAMV** in the CTL.



AMV

DJF U 250 hPa (m/s).
Shades are the difference between AMV+ minus AMV- (**ΔAMV**) in the ROCK experiments.

Contours are **ΔAMV** in the CTL.



ROCK

DJF Geopotential Height isopleth for each **ROCK** experiments