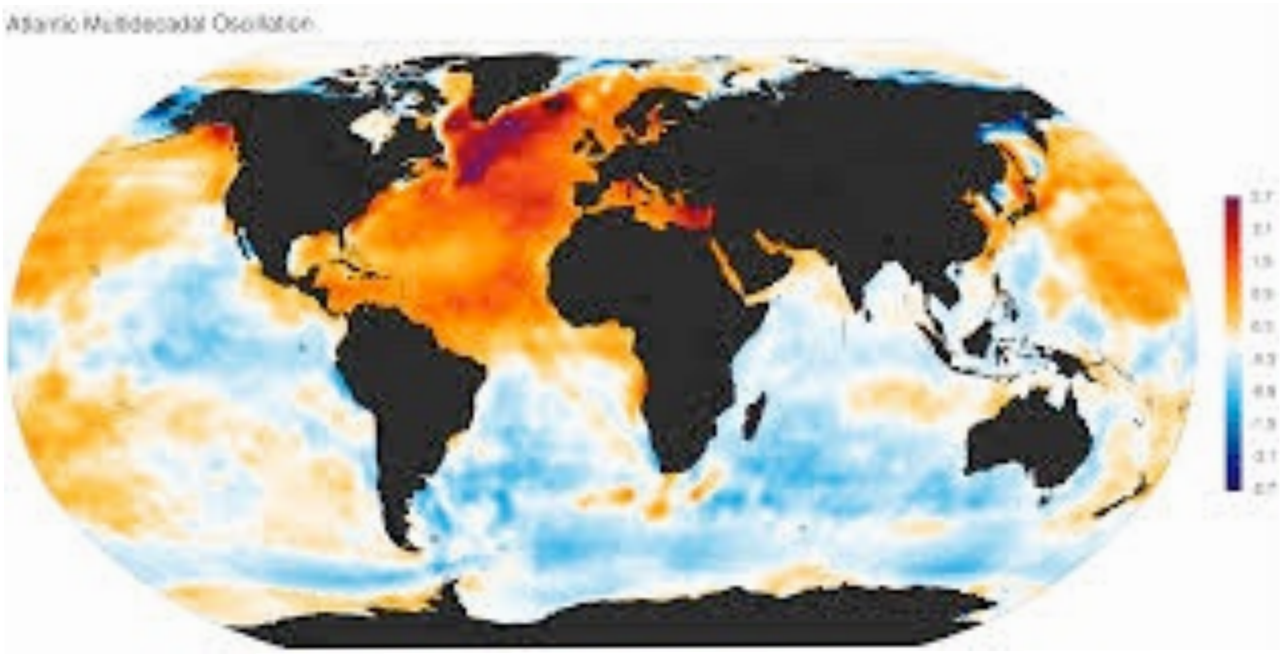
Decadal predictability associated with the AMOC

What are the climate impacts of the AMV?

Rym Msadek (CERFACS/CNRS and GFDL/NOAA)



Collaborators: Yohan Ruprich-Robert (Princeton U./GFDL), Tom Delworth (GFDL), Fred Castruccio (NCAR), Gokhan Danabasoglu (NCAR), Steve Yeager (NCAR)

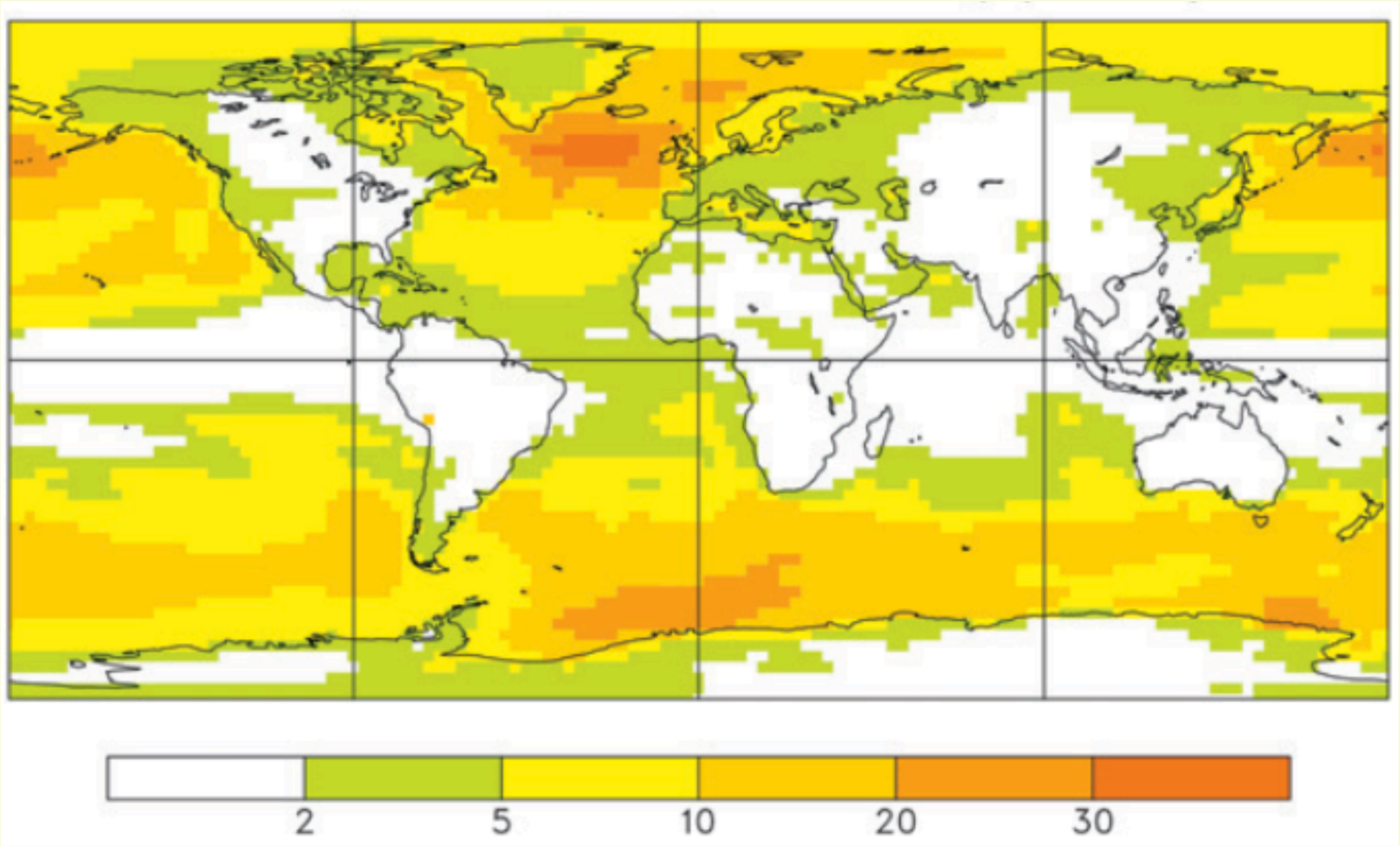
CLIVAR Workshop on Decadal Climate Variability and Predictability

ITCP- Trieste, November 16-20, 2015

Where should we expect decadal predictability?

Potential predictability variance fraction (Boer 2004)

CMIP3 models

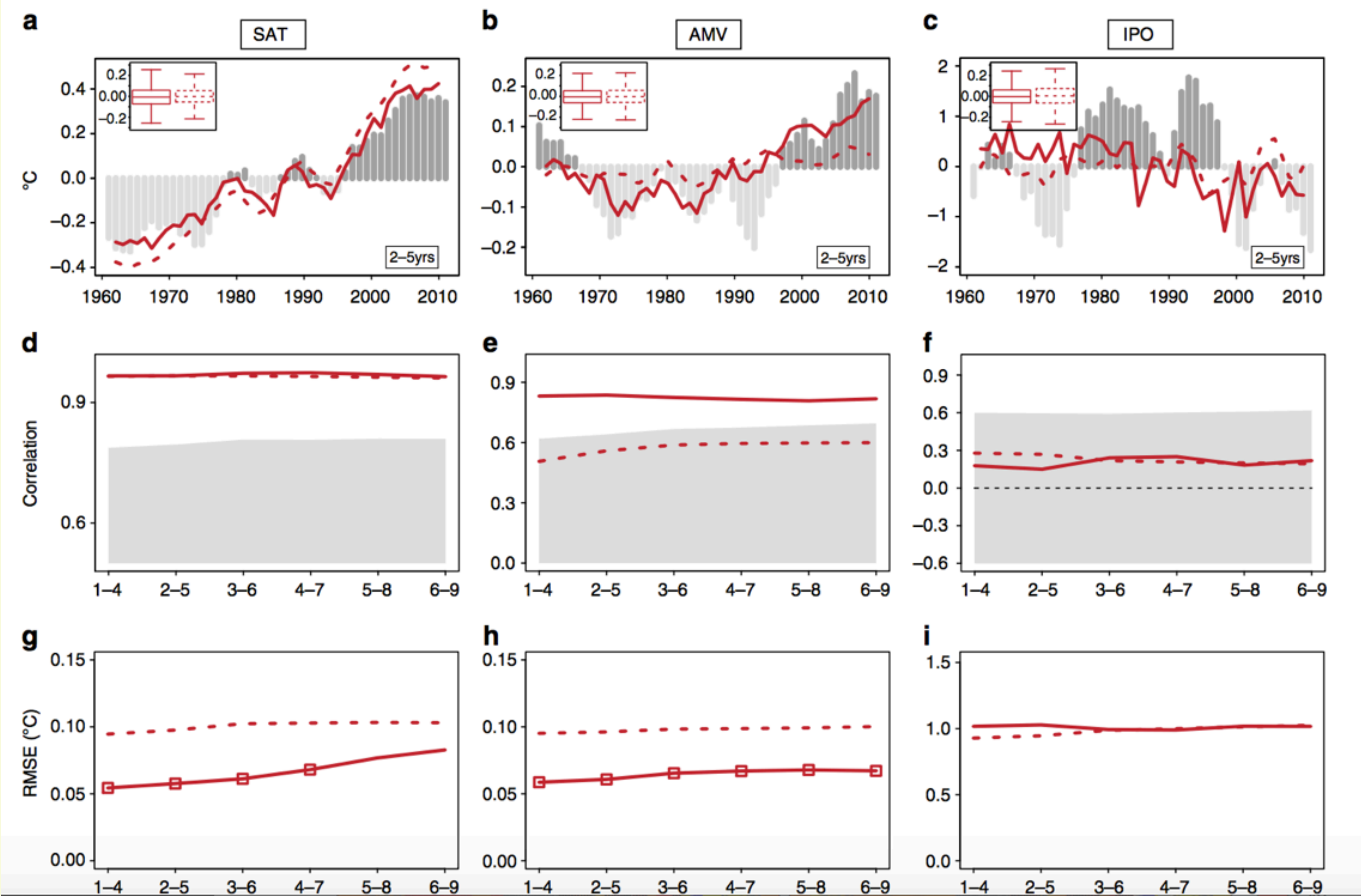


Boer (2012)
See also Ting et al. (2009), Terray (2012)

The North Atlantic, the North Pacific and the Southern Ocean regions are good candidates

Results from CMIP5 initialized decadal predictions

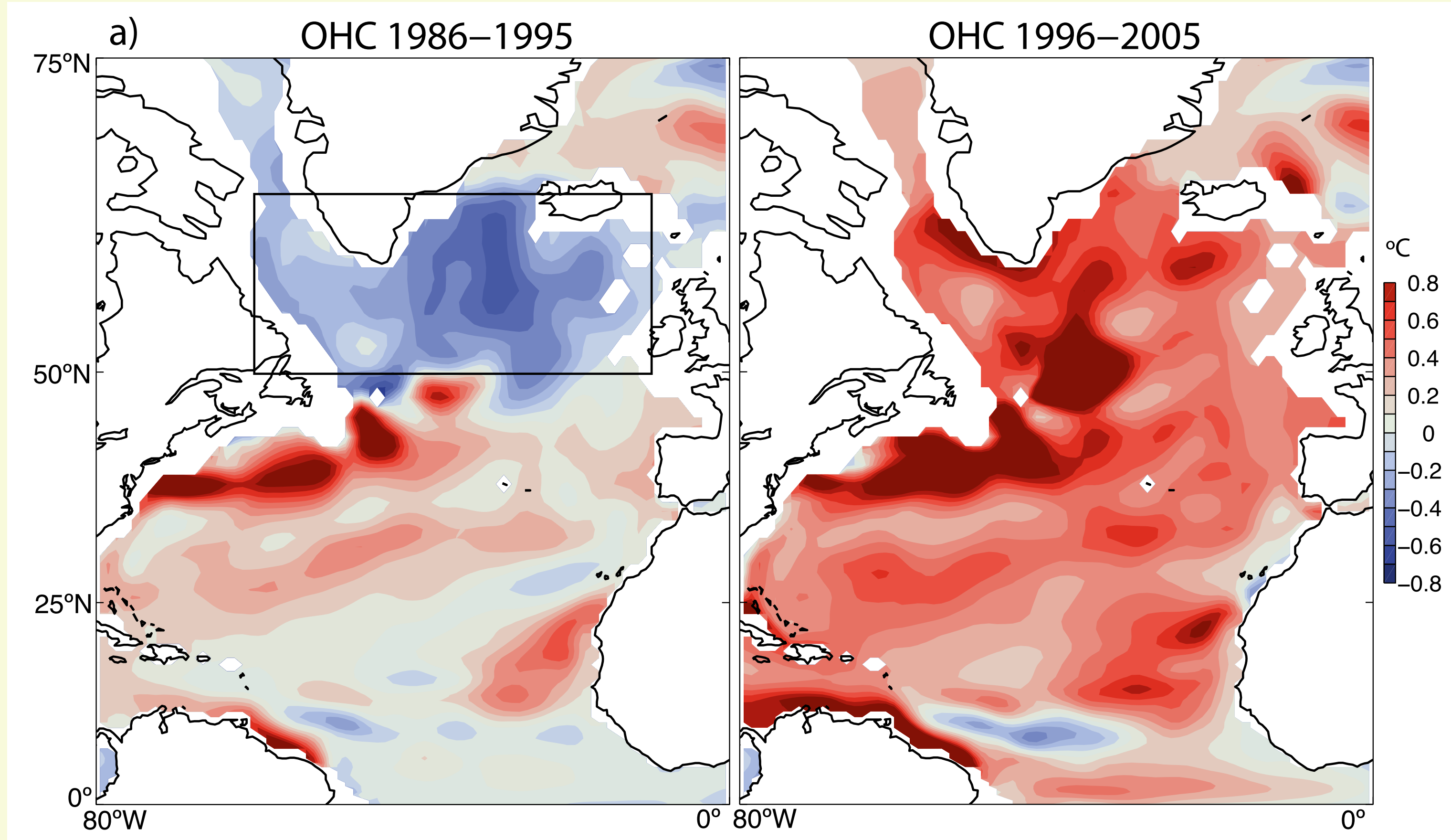
Doblas-Reyes et al. (2013)



See also Van Oldenborgh et al. (2011), Kim et al. (2012), Bellucci et al. (2015)

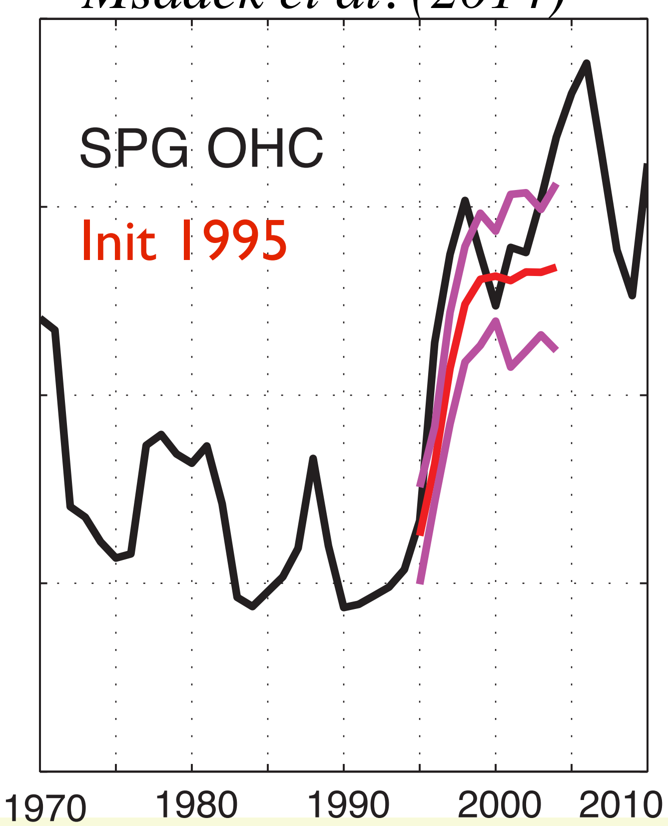
Skill associated with AMOC initialization

Observed warming of the North Atlantic SPG successfully predicted when AMOC is initialized



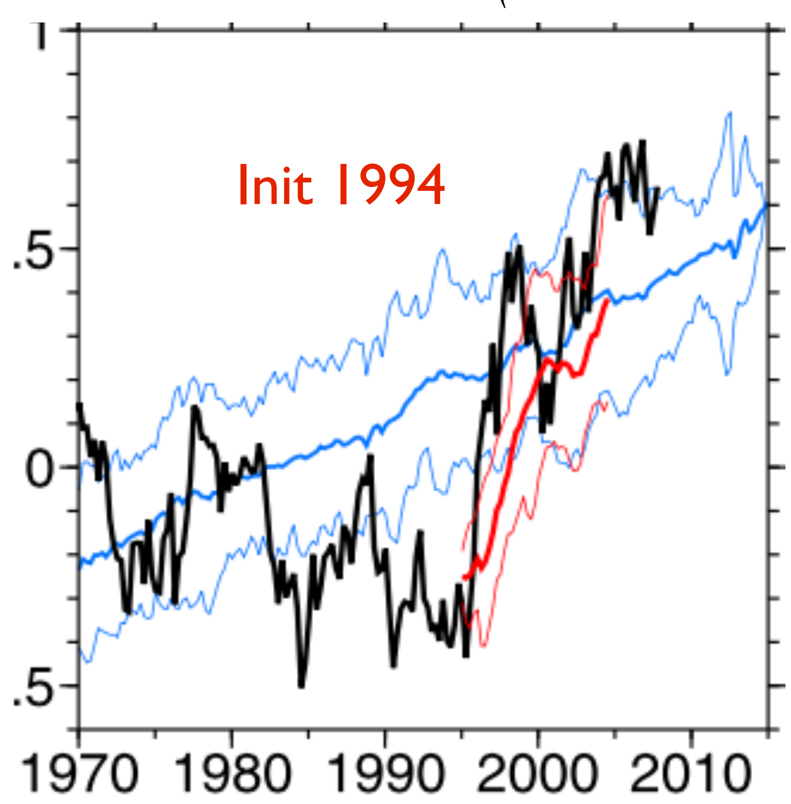
GFDL

Msadek et al. (2014)



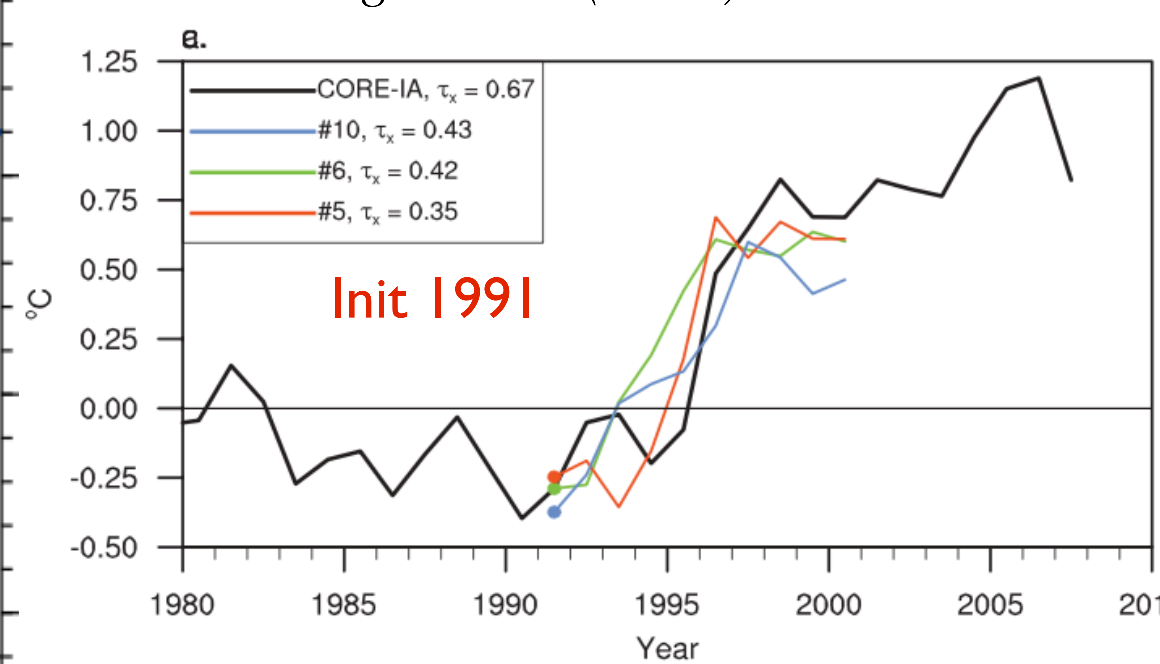
MetOffice

Robson et al. (2012

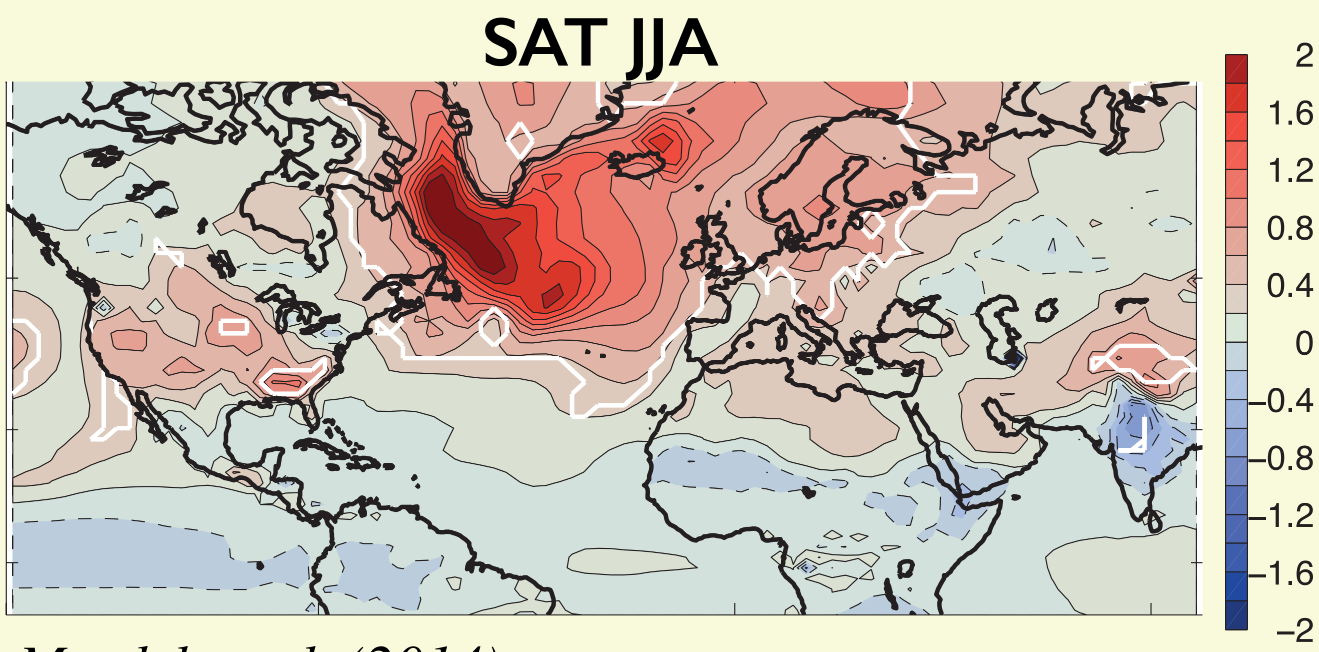


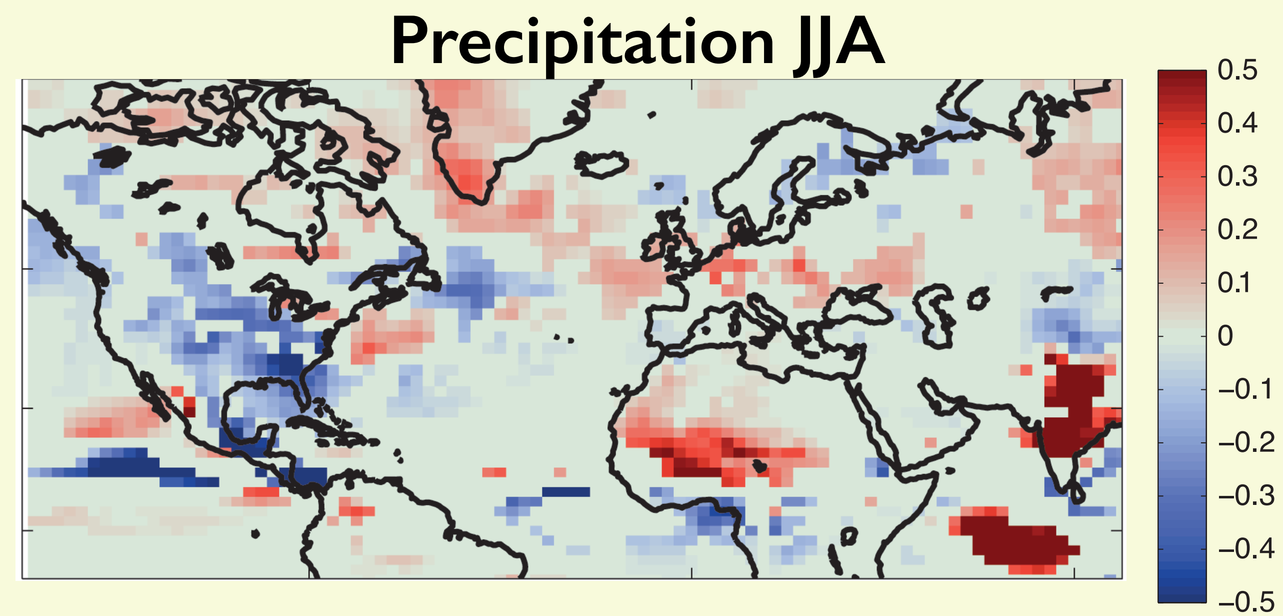
NCAR

Yeager et al. (2012)



Predicted climate anomalies following the mid-90s shift





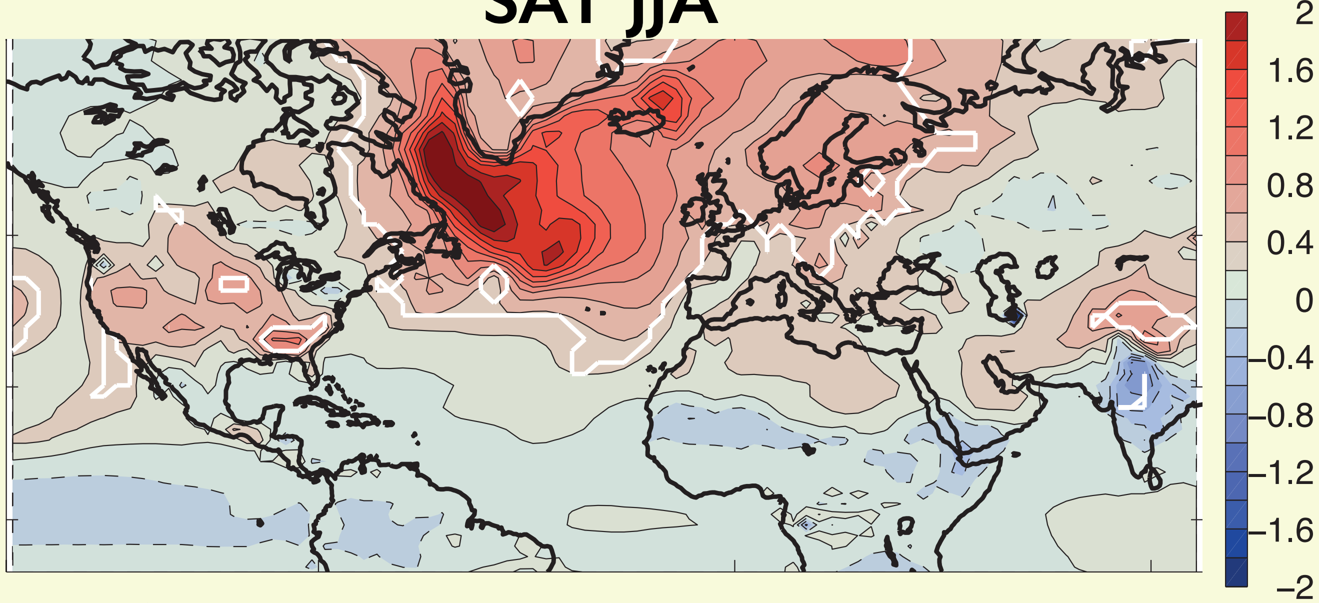
Msadek et al. (2014)

See also Robson et al. (2013)

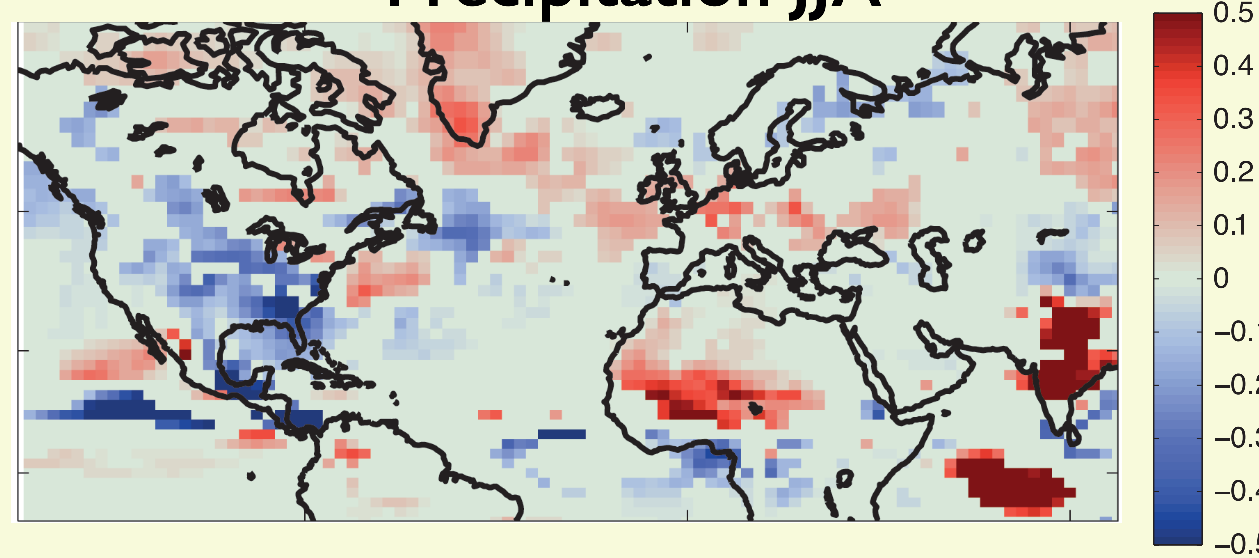
Climate impacts similar to those observed and simulated during a positive AMV *(e.g. Sutton and Hodson 2005)*

Predicted climate anomalies following the mid-90s shift

SAT JJA



Precipitation JJA



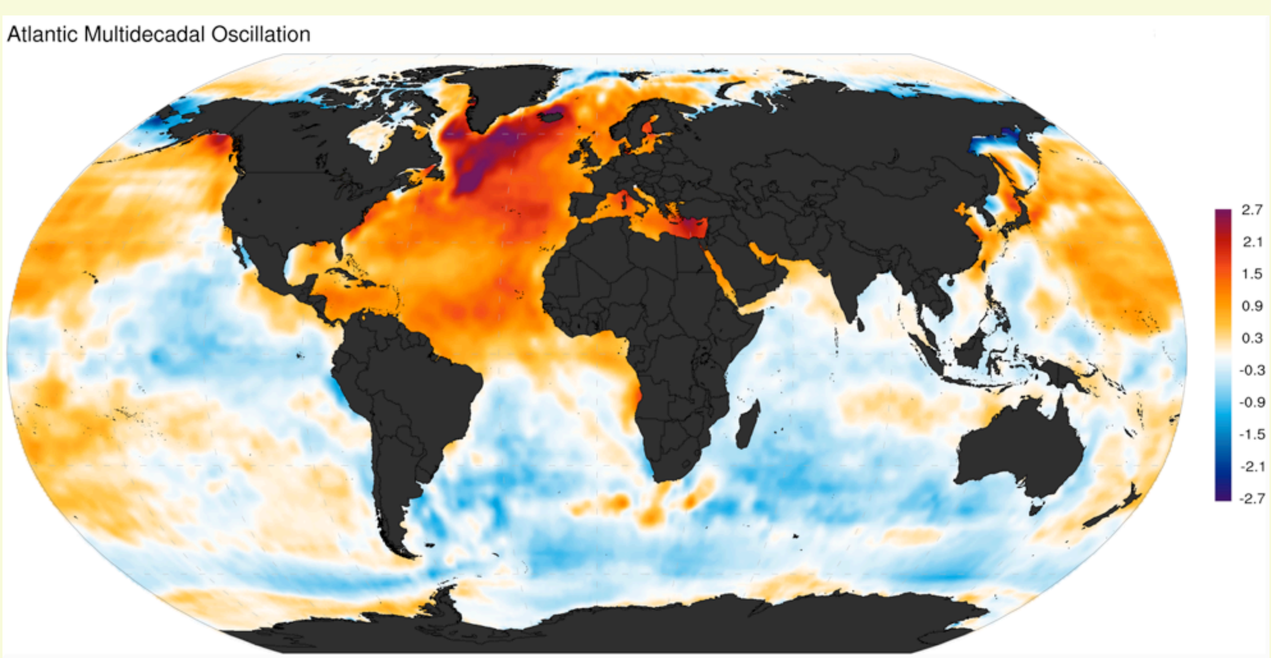
Msadek et al. (2014)

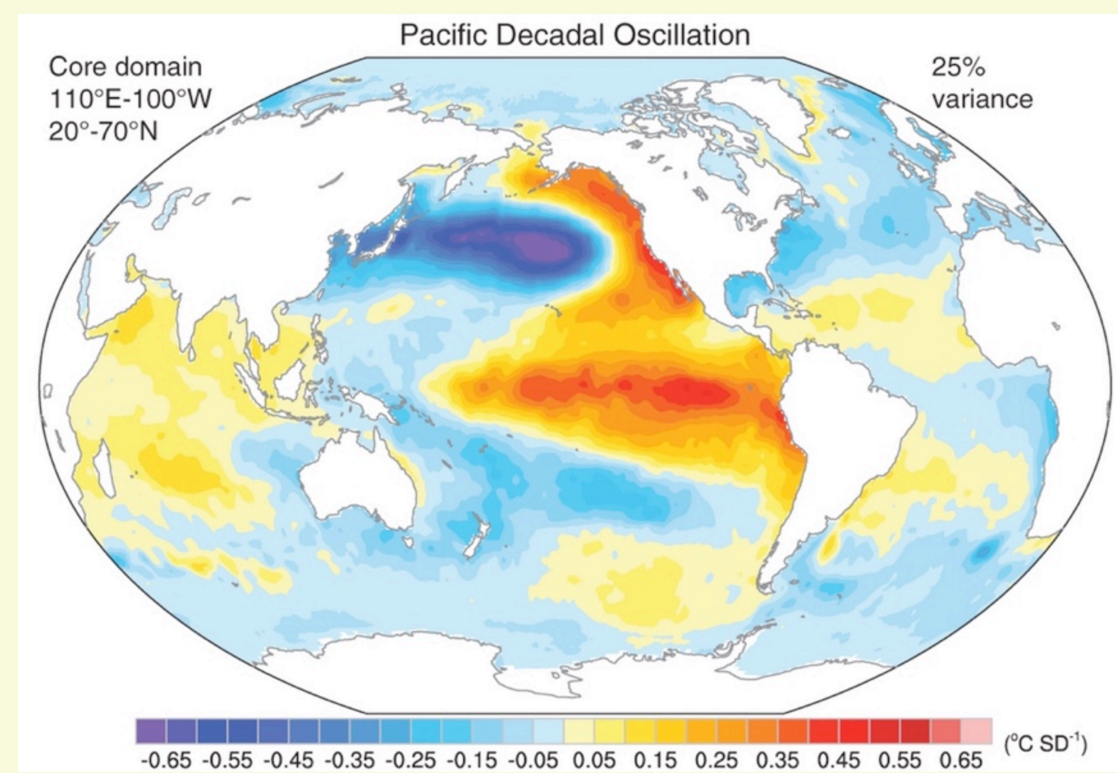
See also Robson et al. (2013)

Climate impacts similar to those observed and simulated during a positive AMV *(e.g. Sutton and Hodson 2005)*

Can we predict some of the Pacific decadal variability if we know the AMV?

Chikamoto et al. (2012), Meehl and Teng (2012), Mochizuki et al. (2010)





Outline

What would be the global climate anomalies if coupled models were able to properly simulate the AMV?

1-Global description of the AMV impacts during summer and winter

2-Pacific response to the AMV

3-Atlantic atmospheric response to the AMV

4-Conclusion and discussion

Experimental design: proposed for DCPP component C

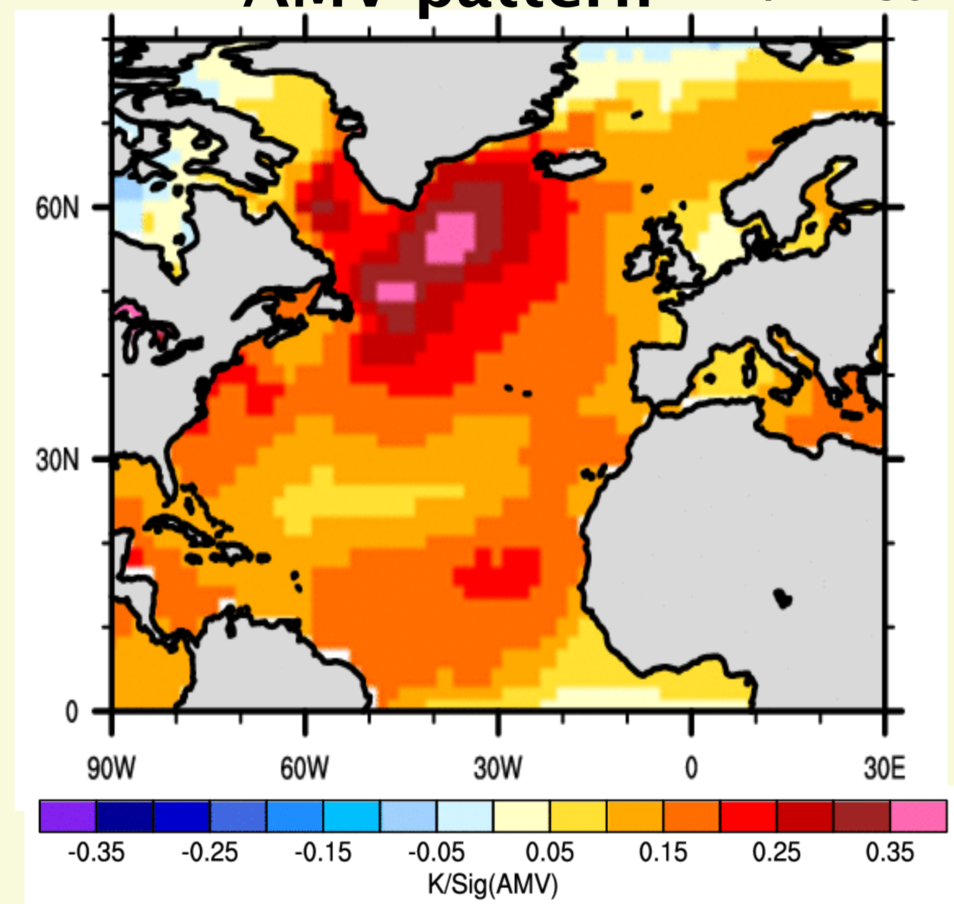
In a global coupled model, we restore the North Atlantic SST to the observed AMV pattern (1std)

Externally forced part of the AMV subtracted following Ting et al. (2009)

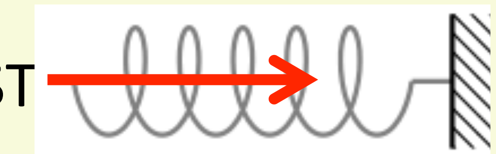
Restoring time scale= 100 W /m2/K

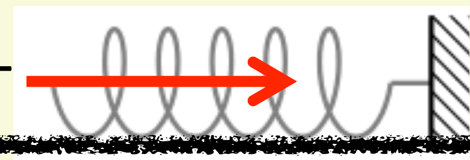
Ocean-atmosphere coupling allowed outside the Atlantic

AMV pattern +/- 1 std



AMV+ ensemble: daily North Atlantic SST  daily Climatology **+ AMV pattern**

AMV- ensemble: daily North Atlantic SST  daily Climatology **- AMV pattern**

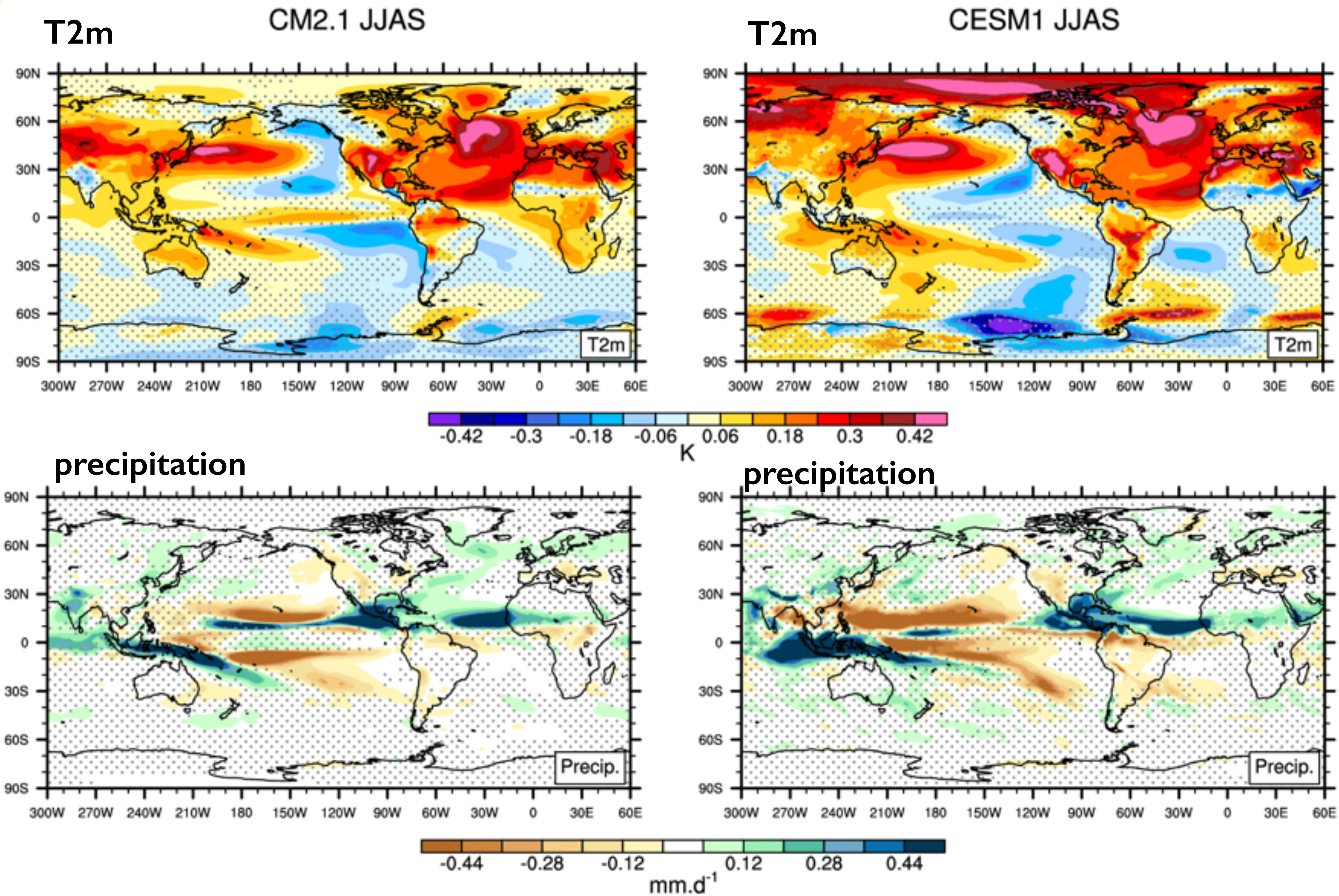
CTL ensemble: daily North Atlantic SST  daily Climatology

Two climate models

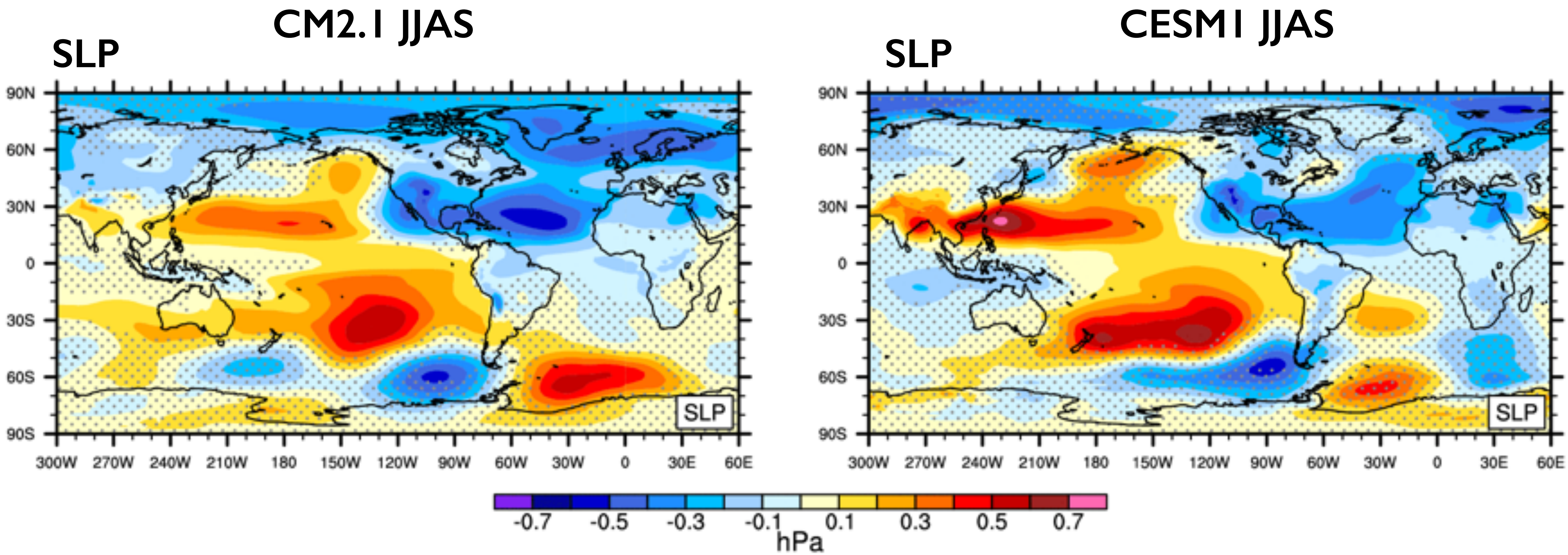
GFDL-CM2.1 (2° atm, 1° ocean) ***100 members***
NCAR-CESM1(1° atm, 1°ocean) ***30 members***

Response=
AMV+ minus AMV-
averaged over 10yr

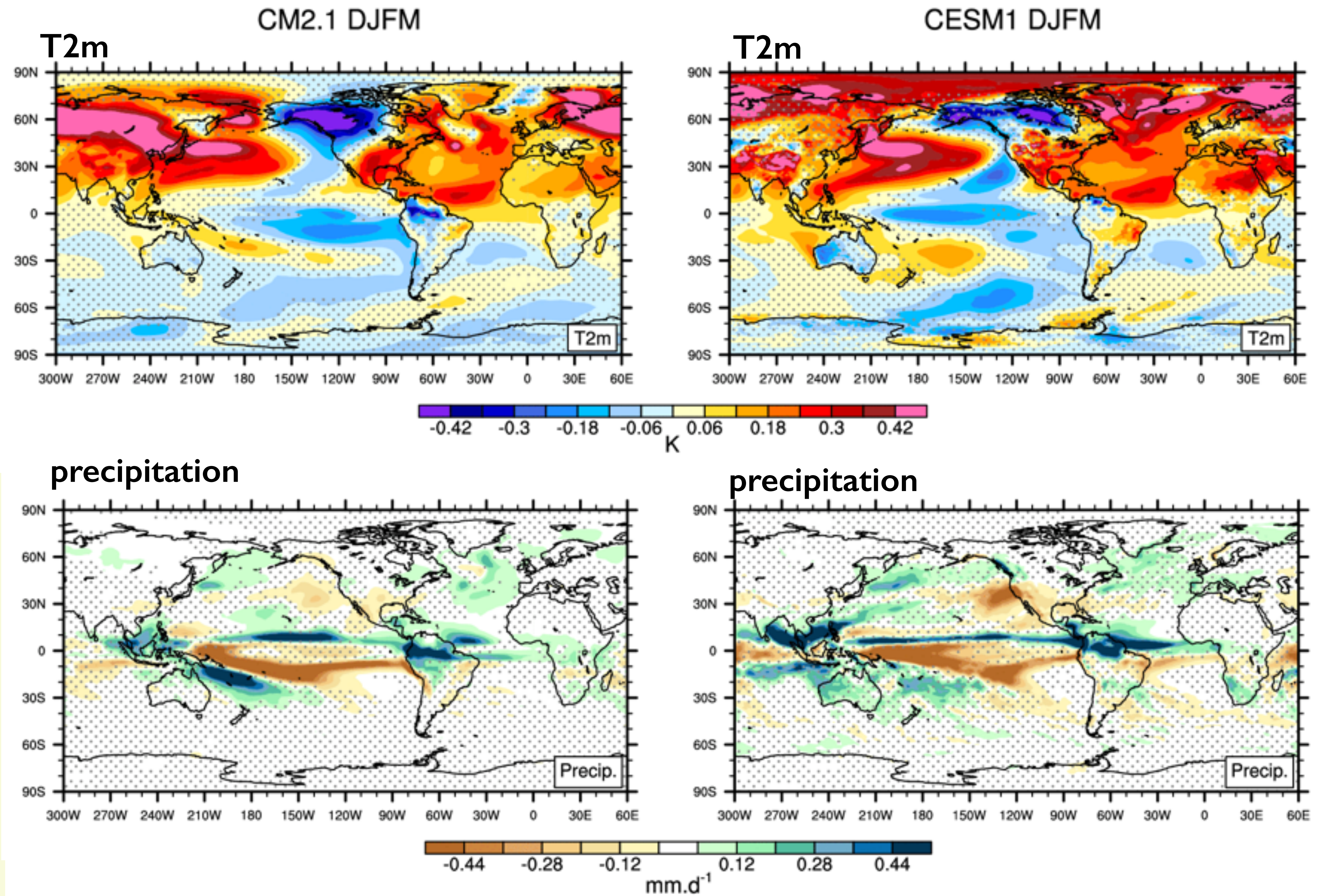
Results- Global impacts during summer



Results- Global impacts during summer



Results- Global impacts during winter



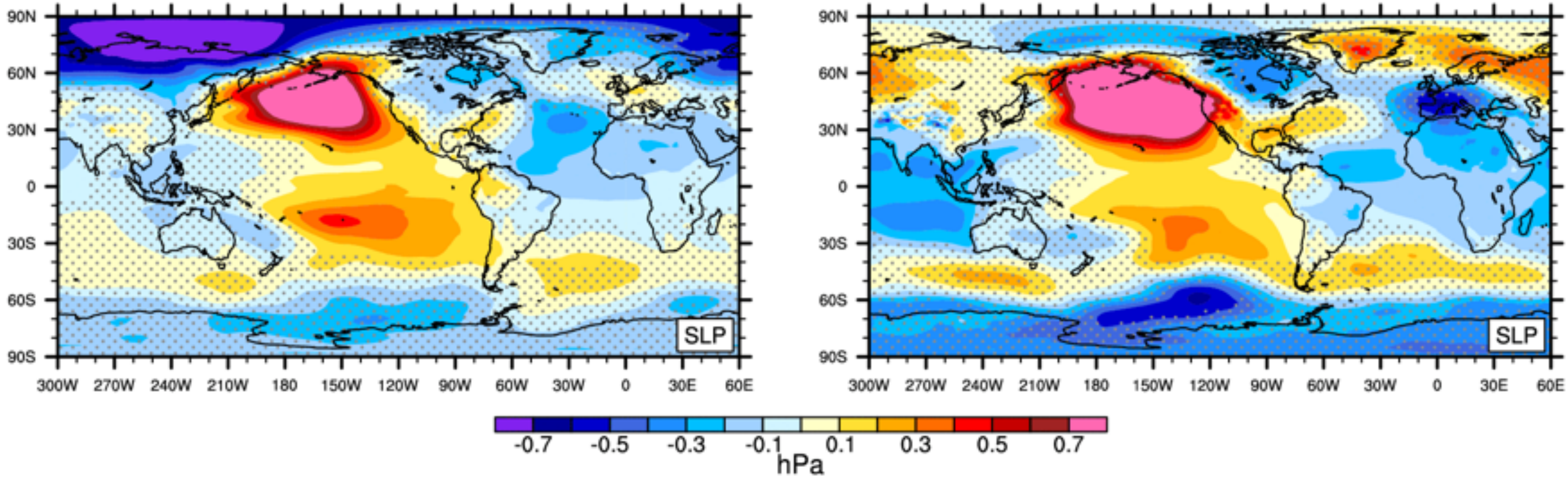
Results- Global impacts during winter

CM2.1 DJFM

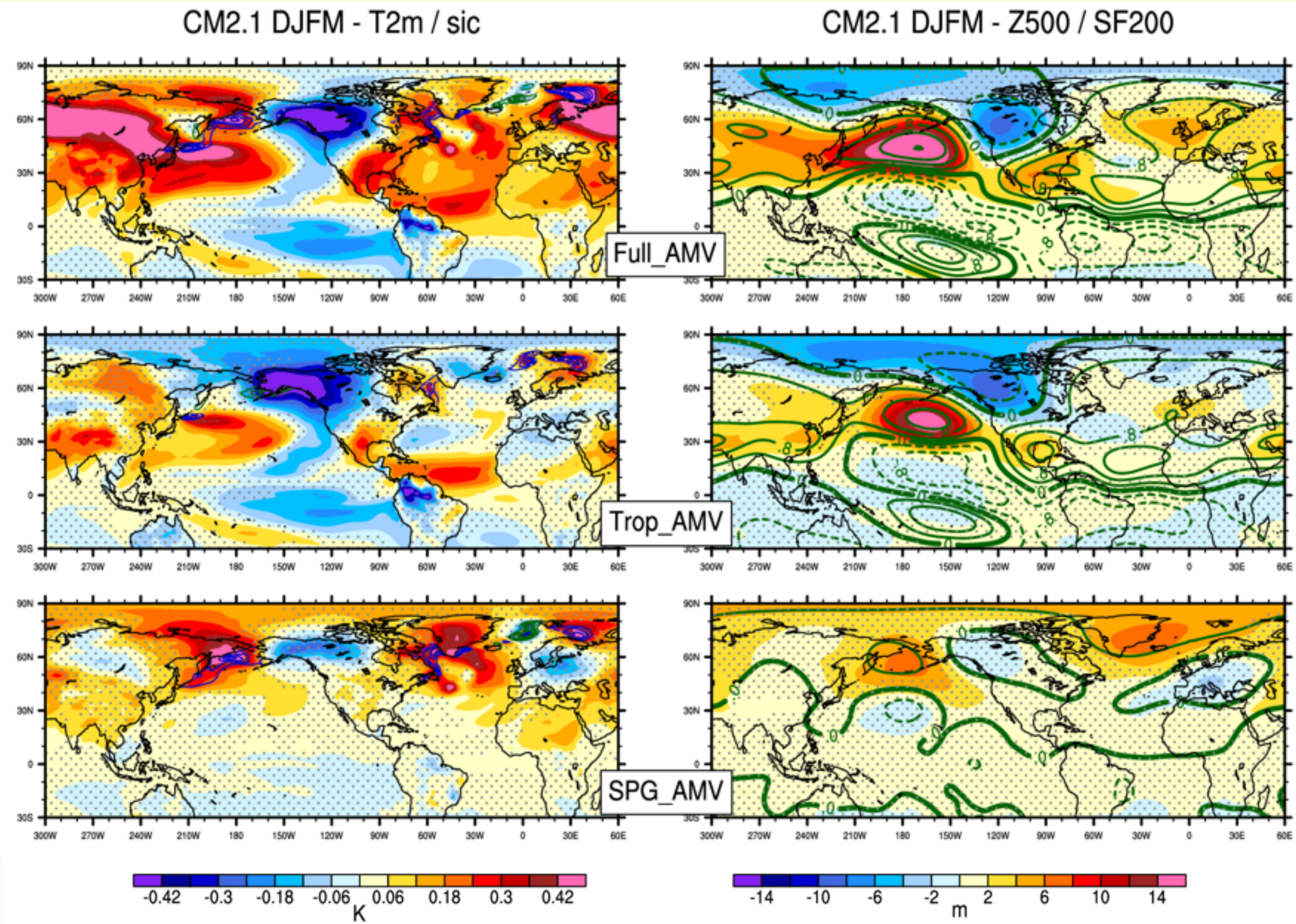
SLP

CESM1 DJFM

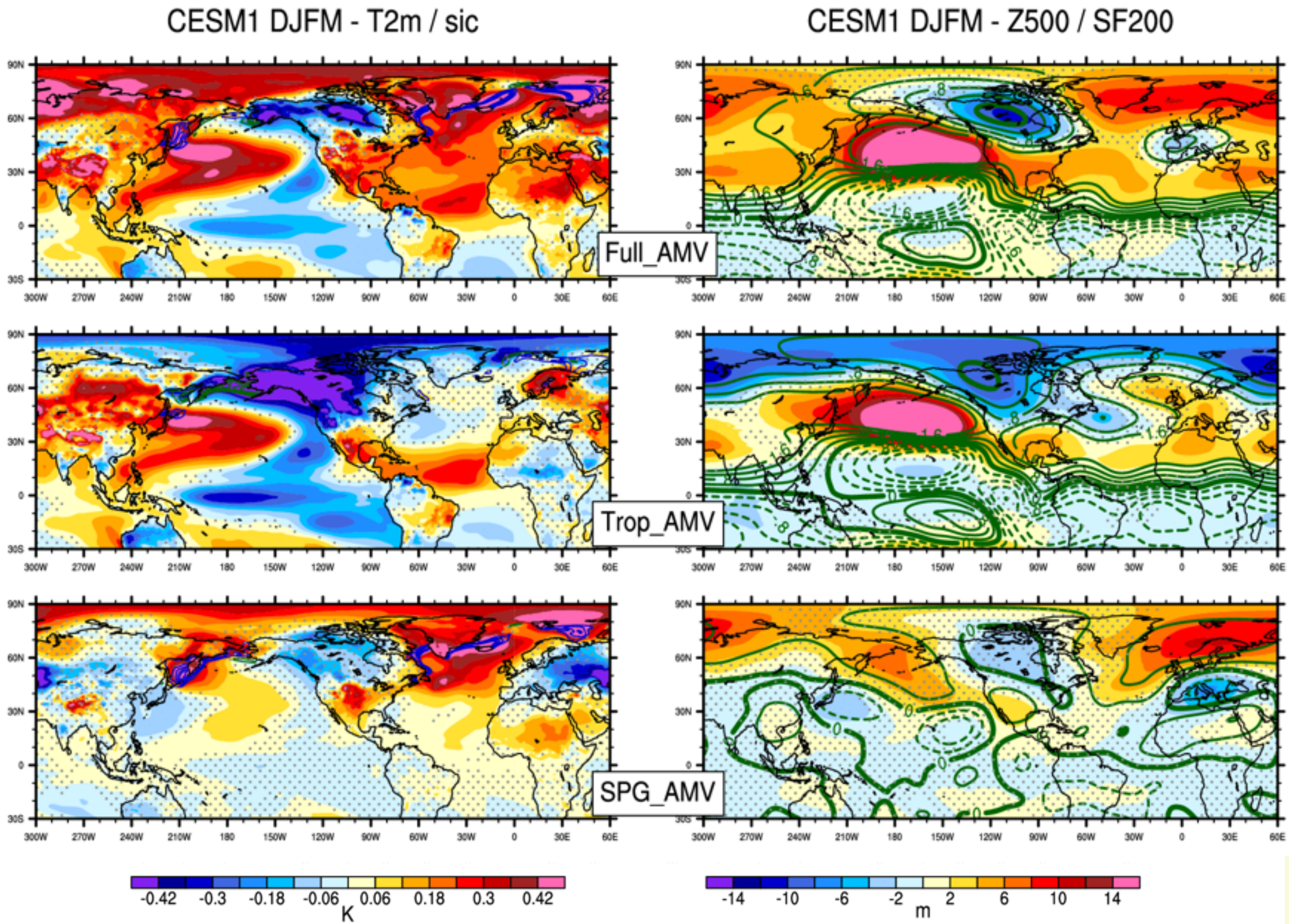
SLP



What drives the PDO-like anomalies?

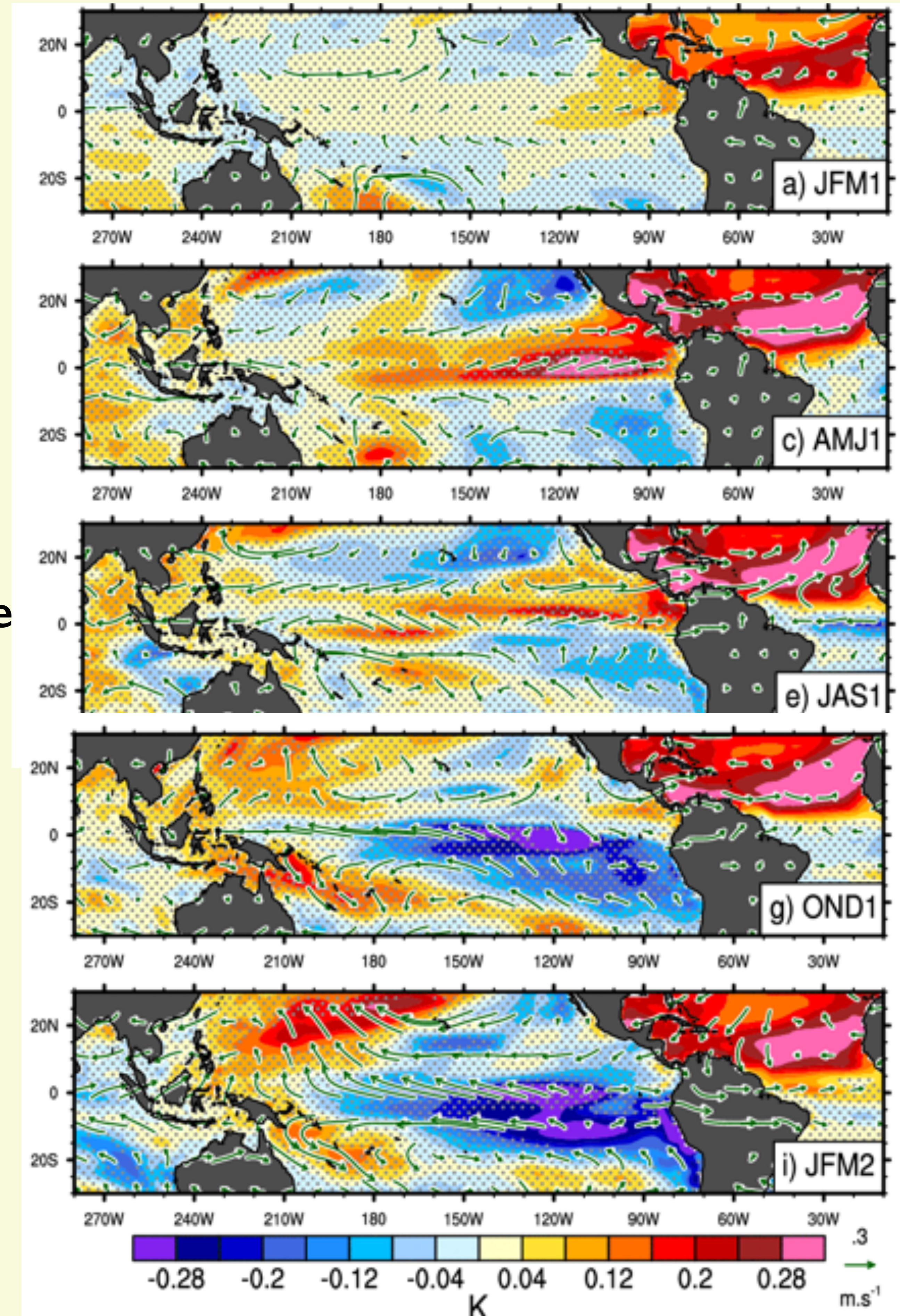


What drives the PDO-like anomalies?



Mechanism

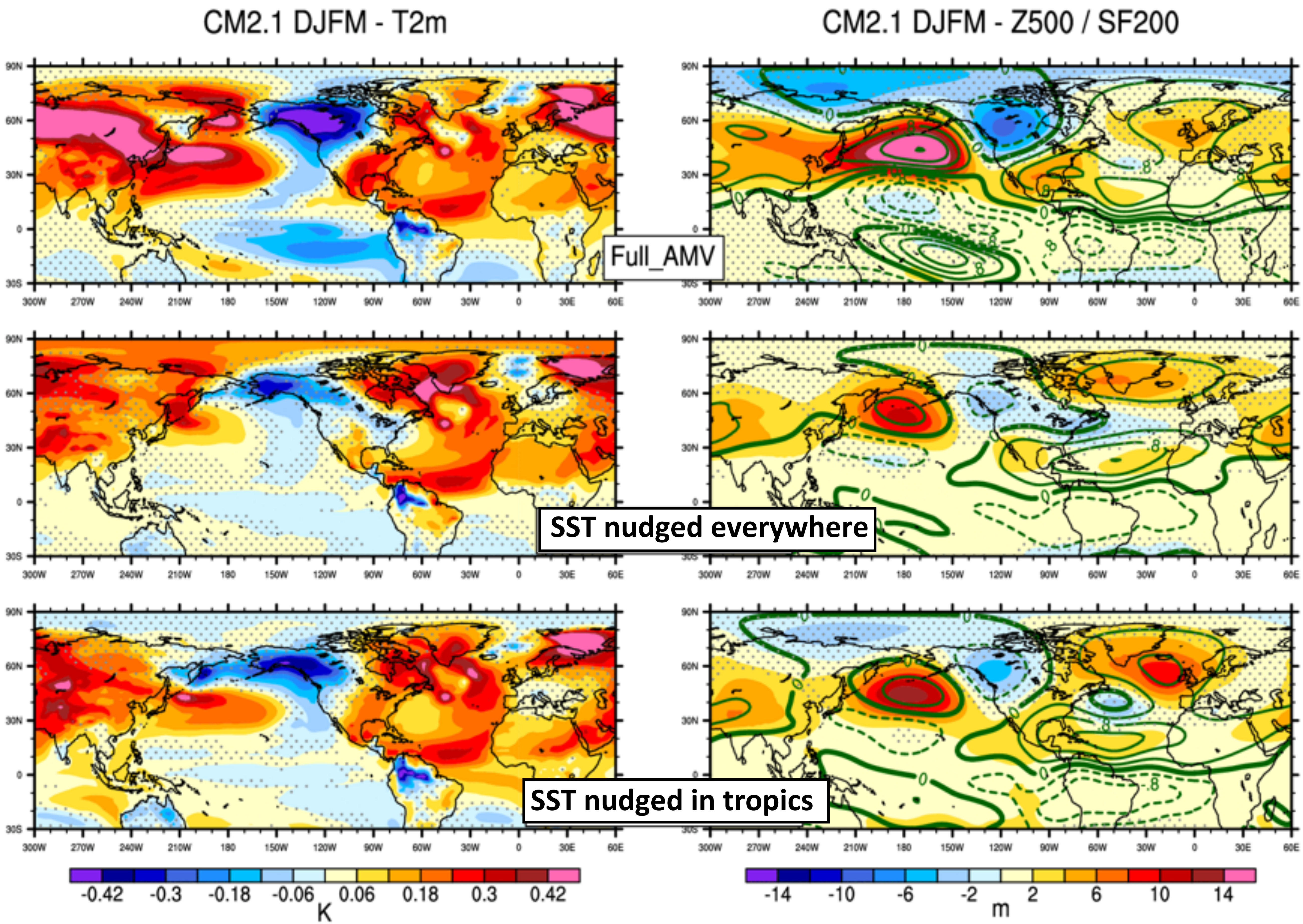
CM2.1 Full AMV
SST and UV @850mb



Enhanced Walker circulation drives a La-Niña like response

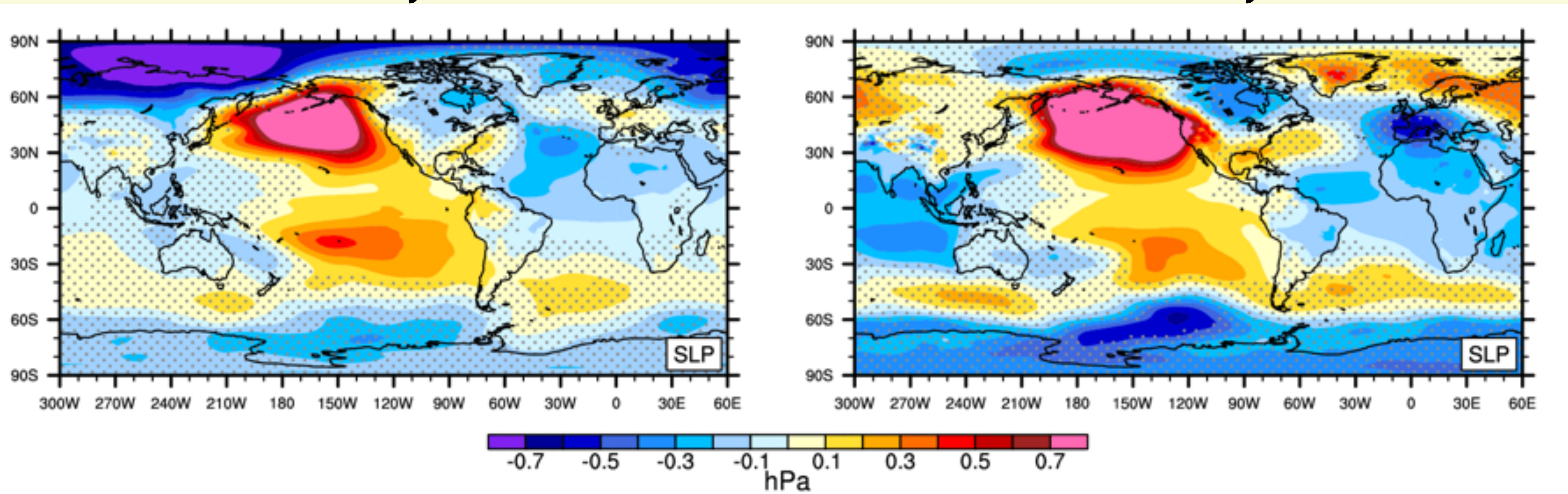
Consistent with McGregor et al. (2014), Kuscharski et al. (2015), Chikamoto et al. (2015), Li et al. (2015)

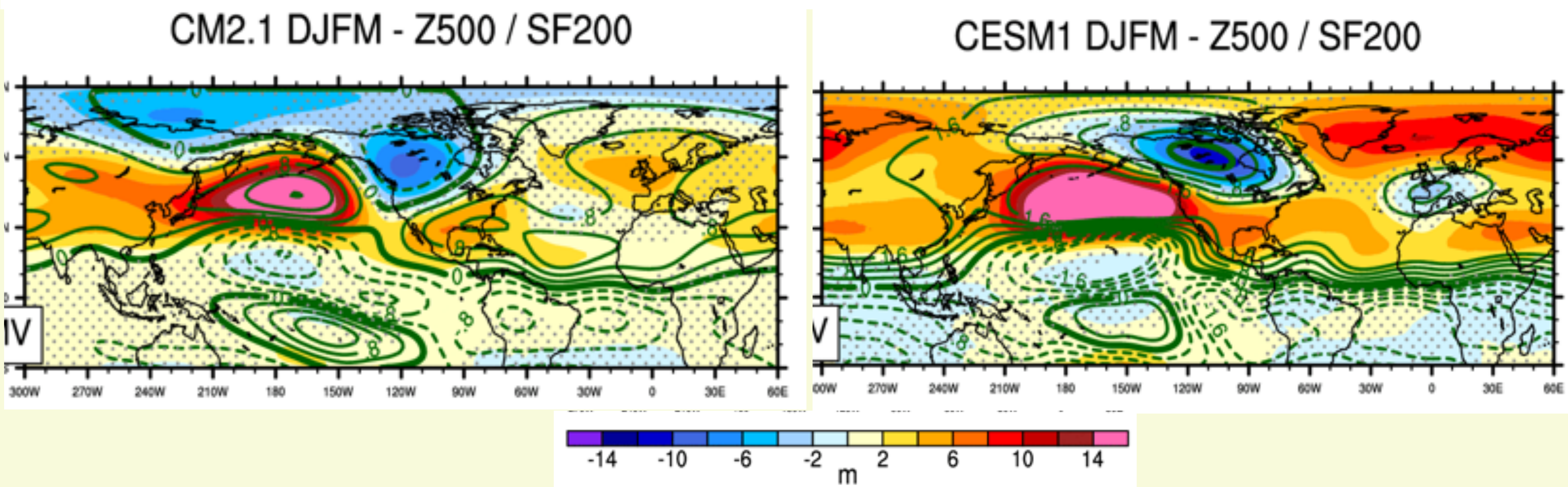
Do we need ocean-atmosphere coupling?



The North Atlantic response

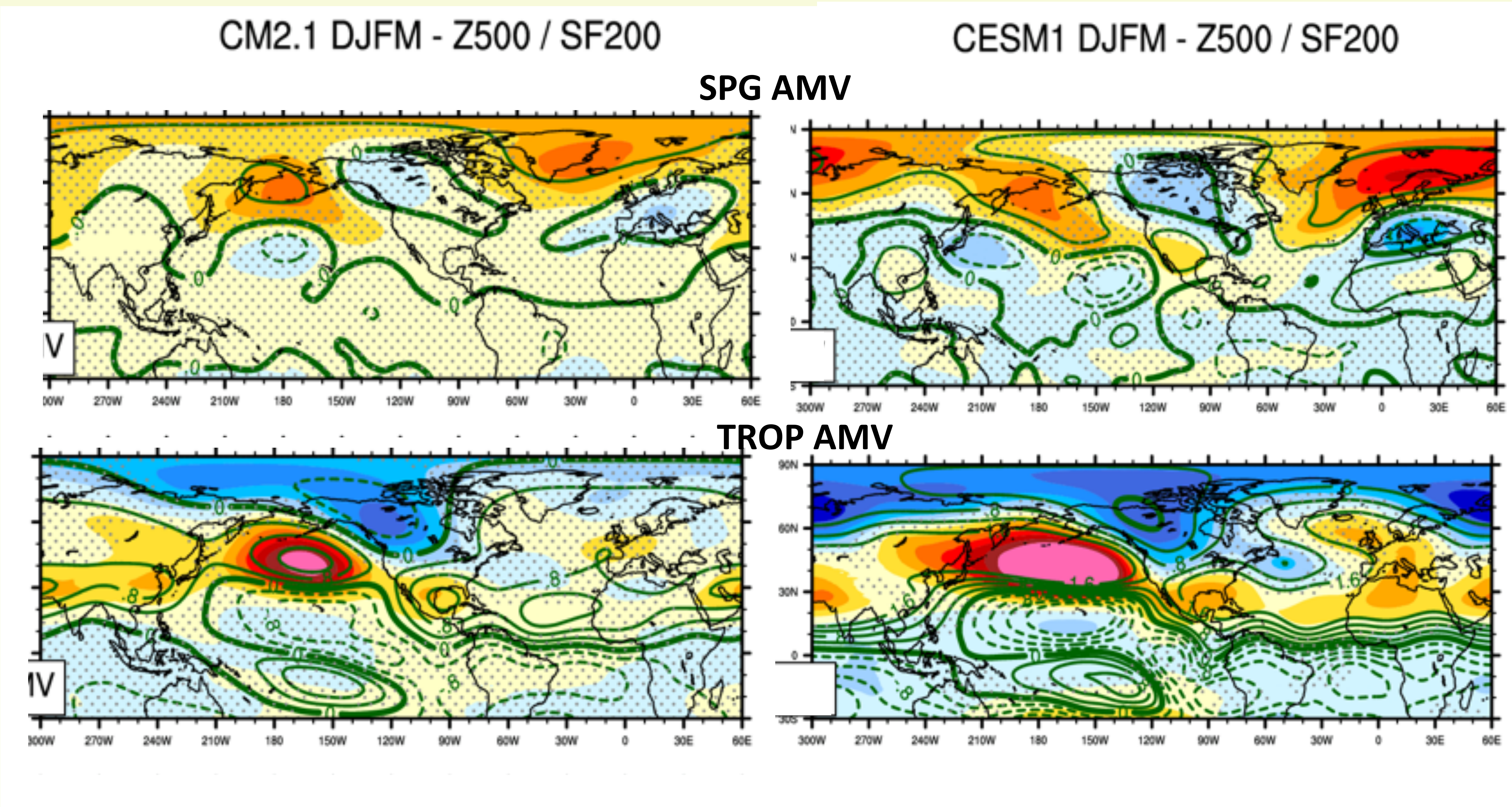
CM2.1 DJFM SLP **Full AMV** **CESM1 DJFM SLP**





Is the North Atlantic response "polluted" by teleconnections from the Pacific?

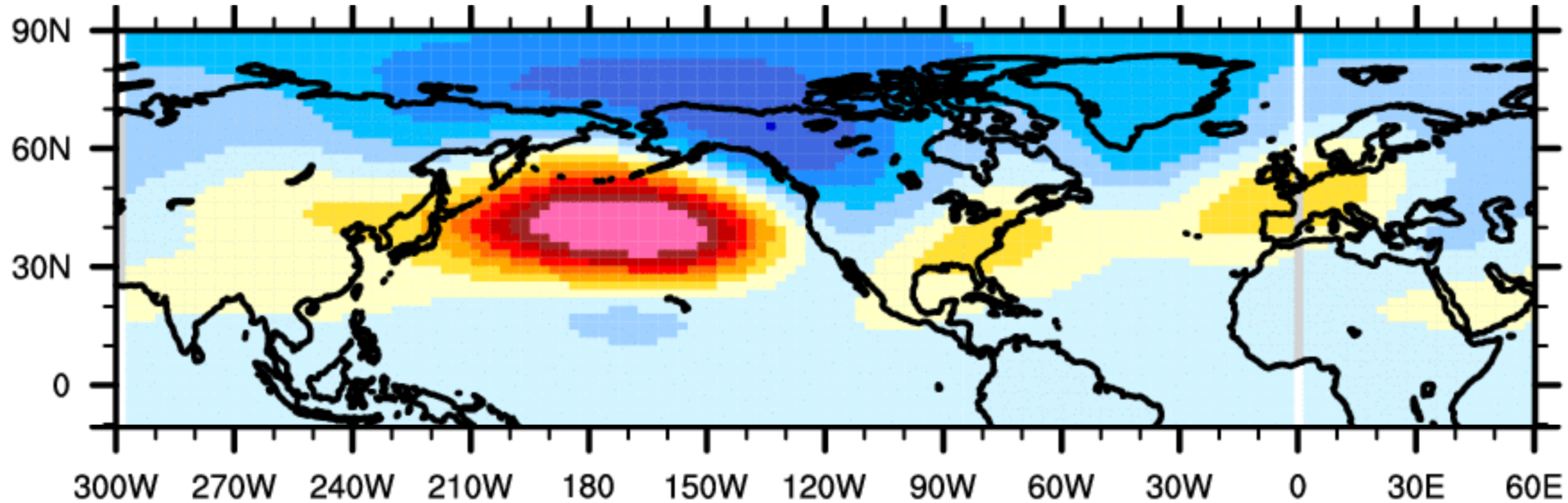
The North Atlantic response

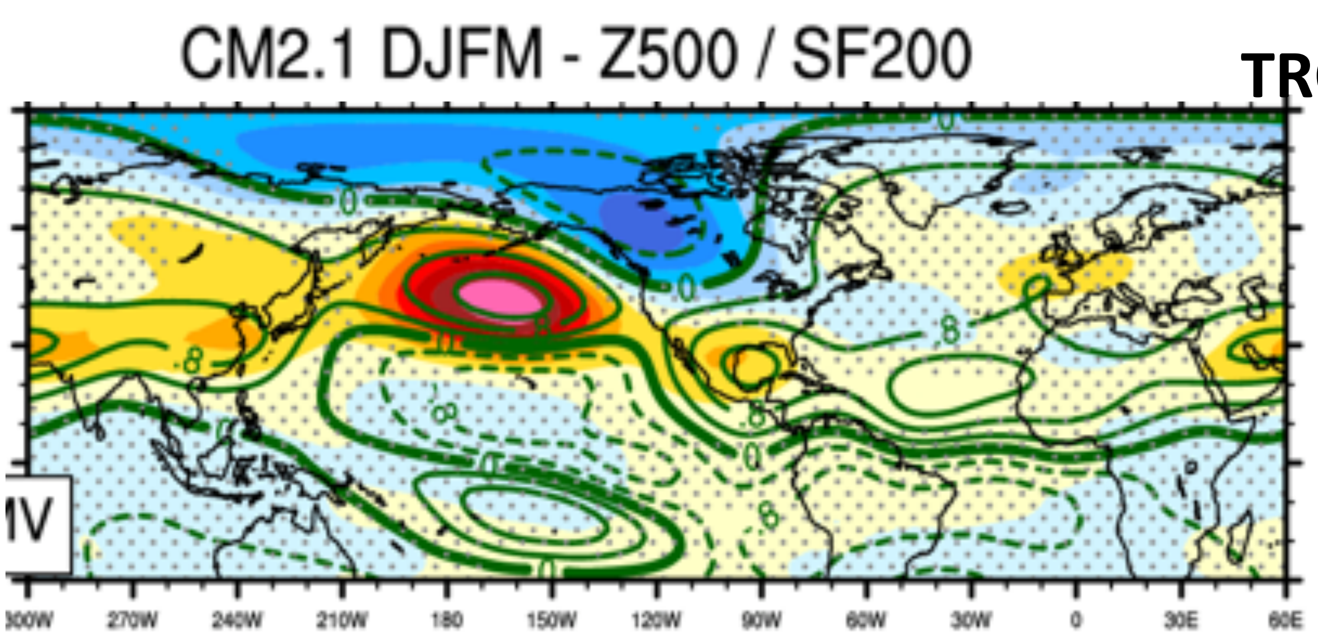


The contribution of the SPG and TROP are opposite

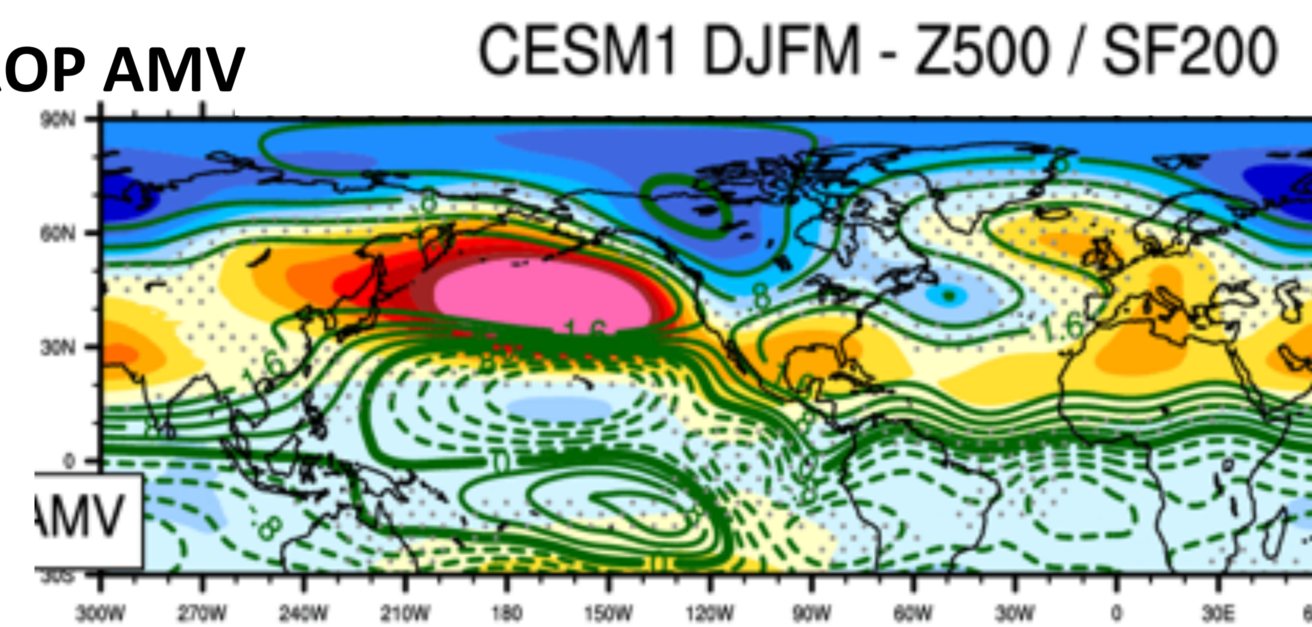
The North Atlantic response

Regression on Z500 on PDO index in CM2.1





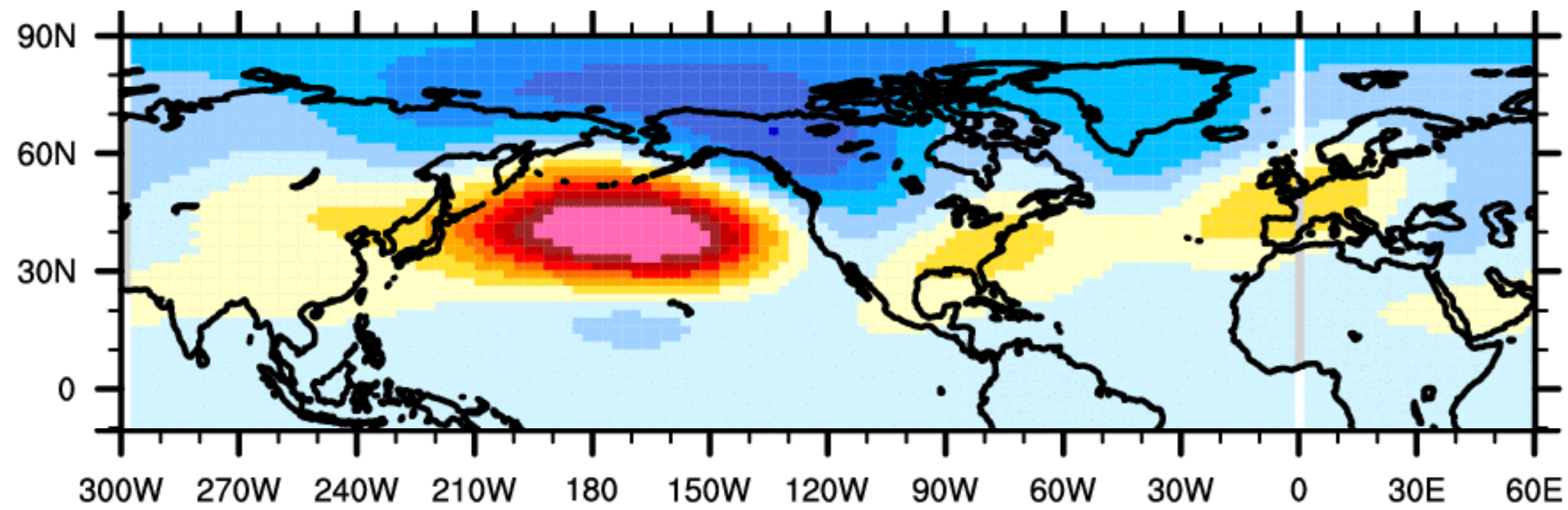
TROP AMV

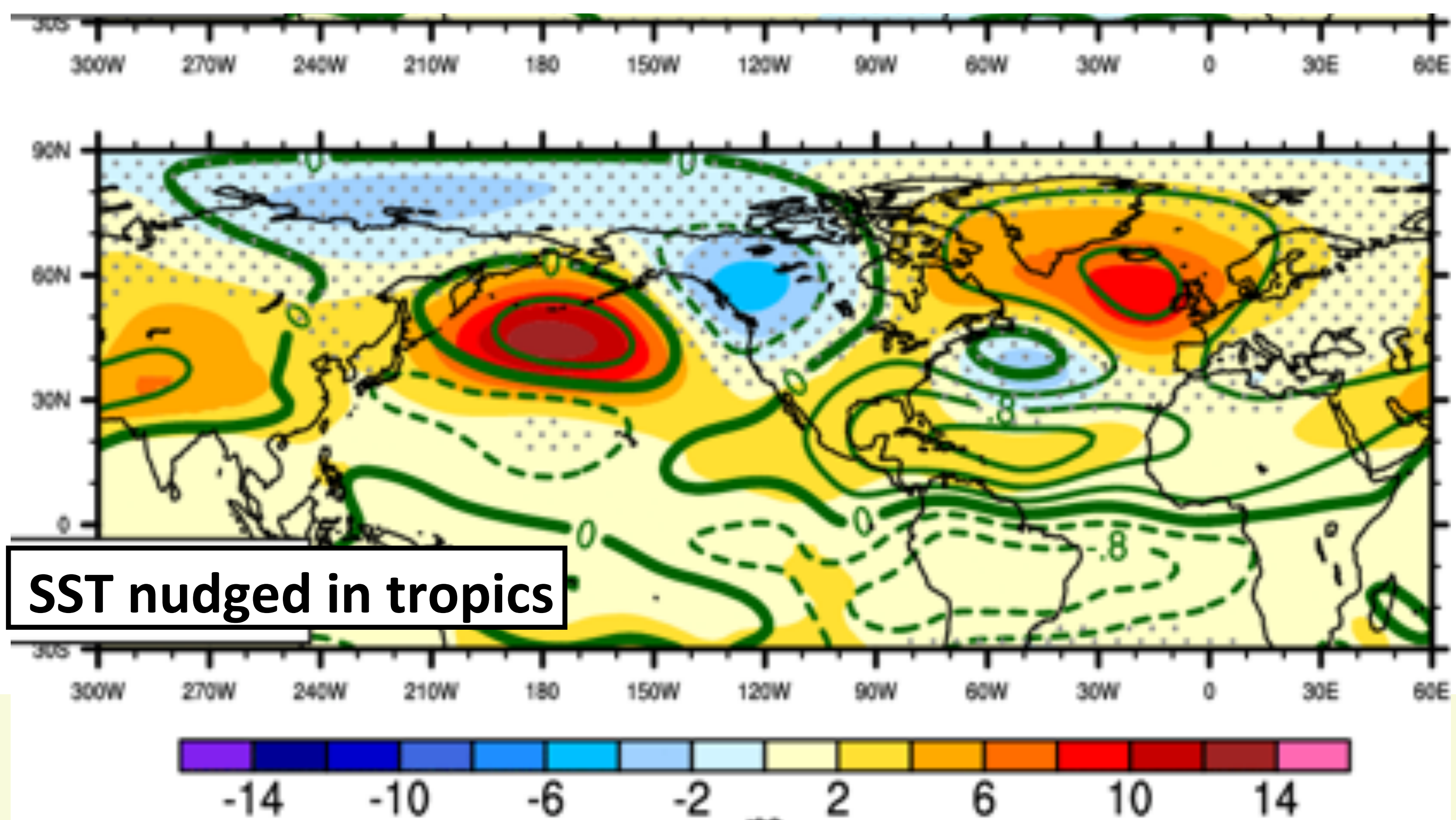


The PDO teleconnection over the North Atlantic projects onto a response that tends to weakens the direct response to SPG SST

The North Atlantic response

Regression on Z500 on PDO index in CM2.1

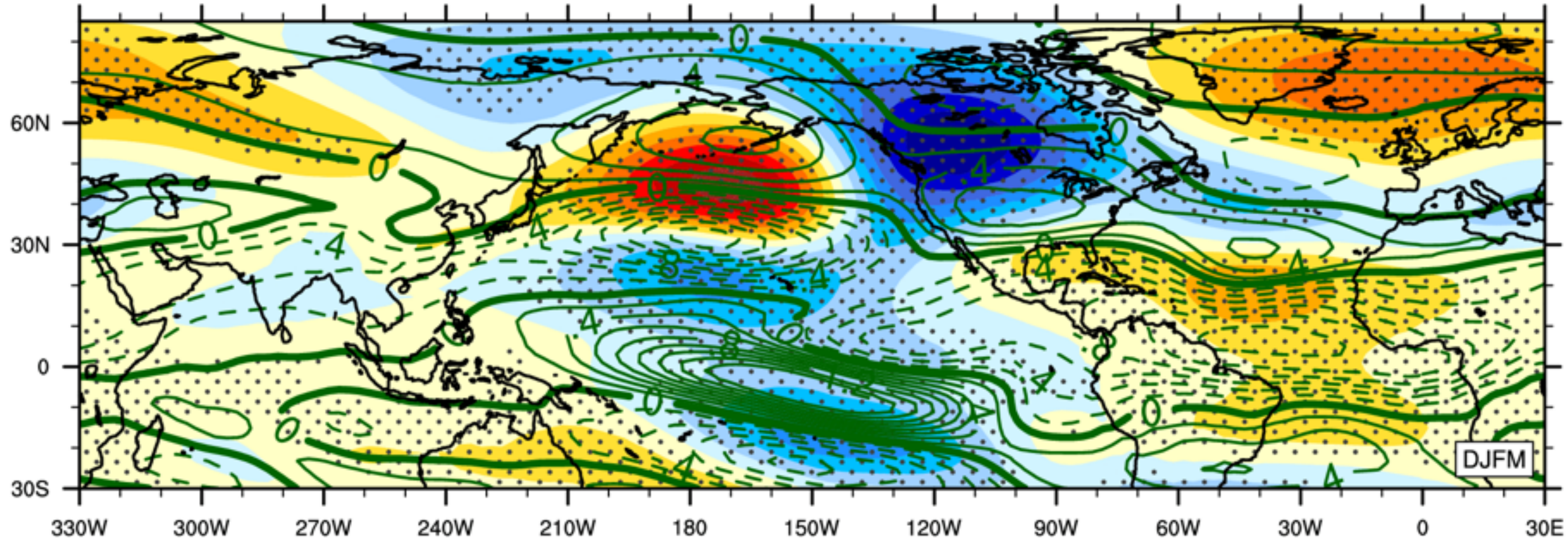




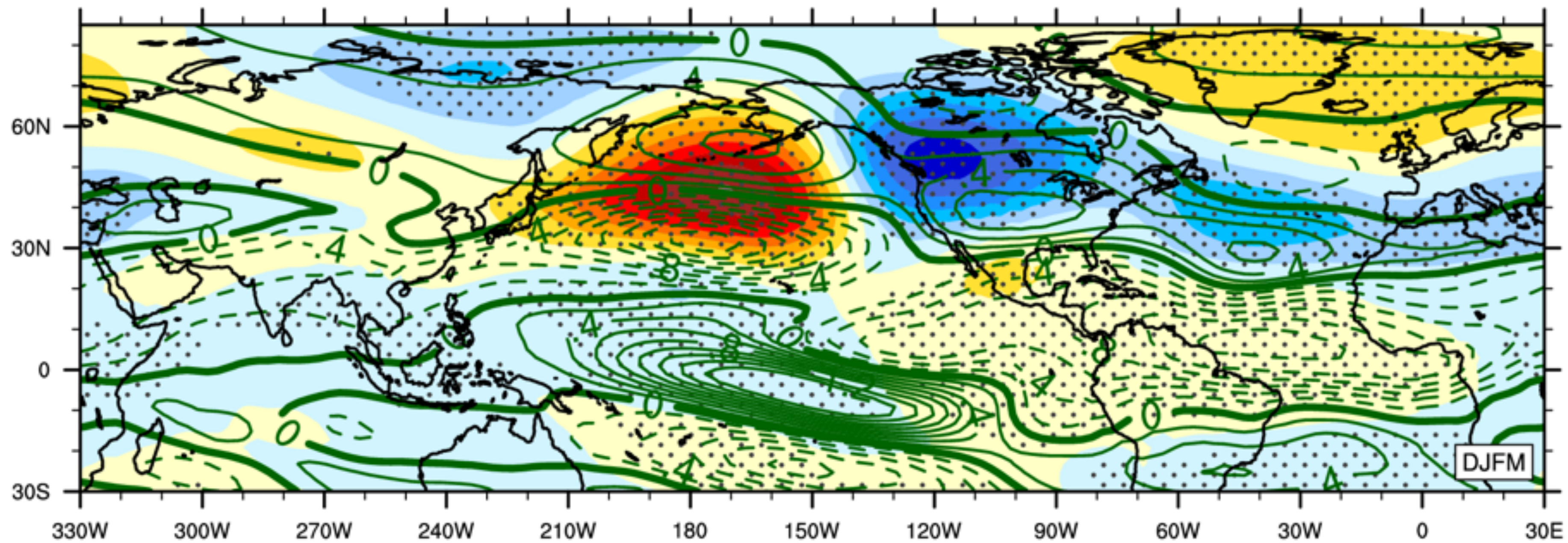
Mechanism of the North Atlantic response

DJFM CM2.1

Z200* and U200



Z500* and U200



Rossby wave train that originates in the tropics.

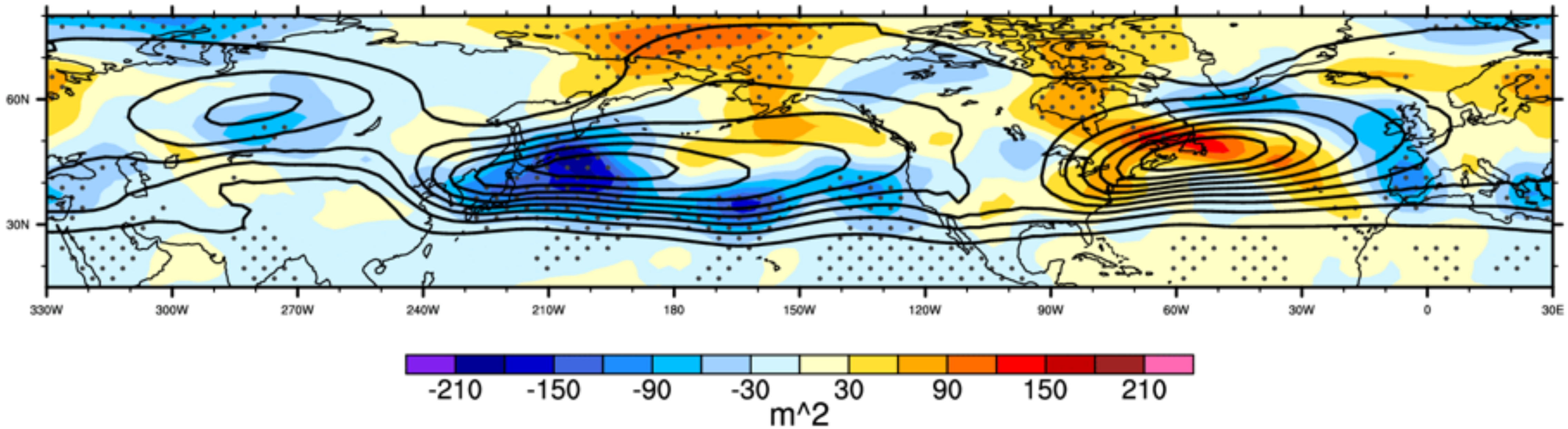
Barotropic response

Mechanism of the North Atlantic response

DJFM CM2.1

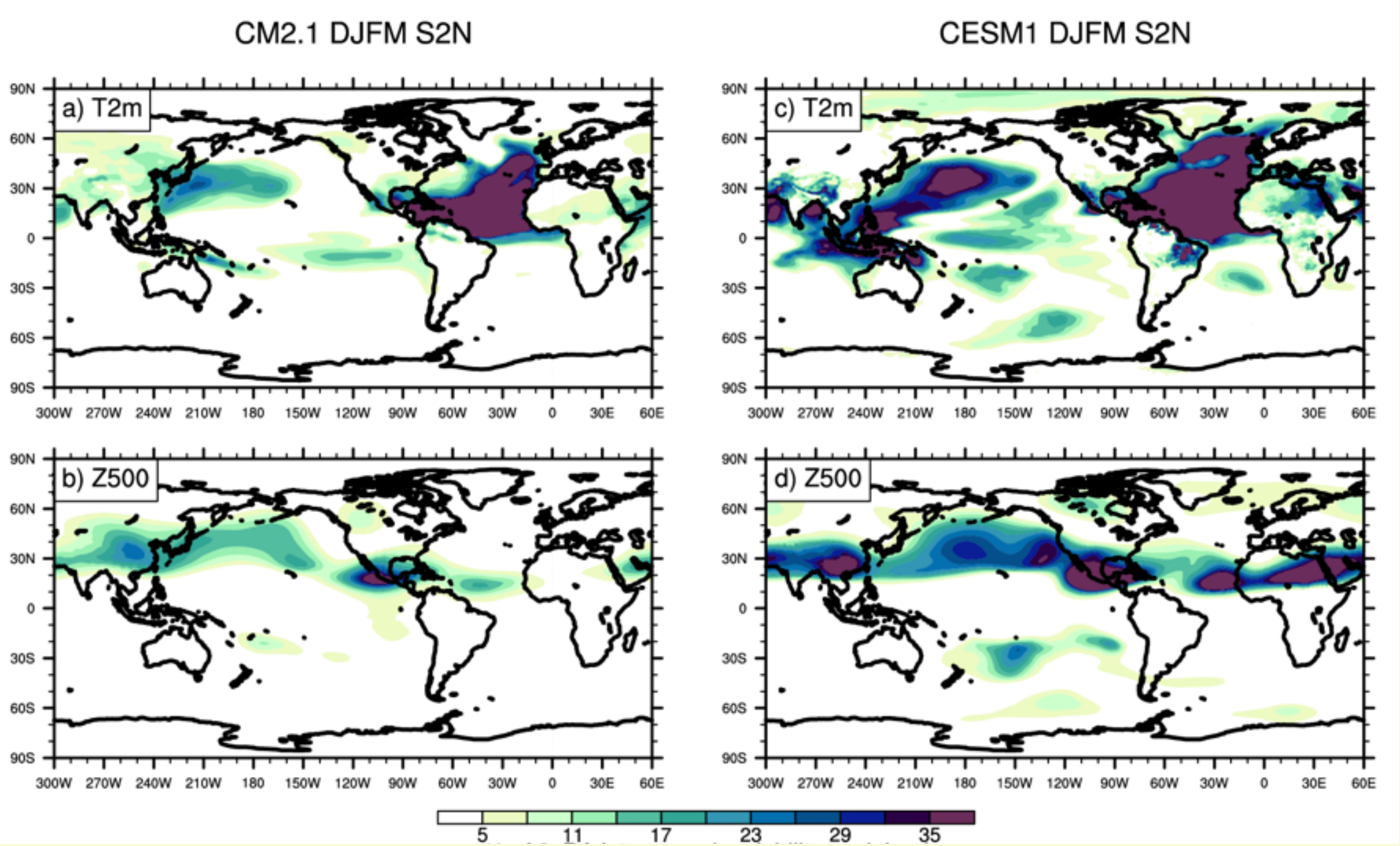
Changes in storm track activity in FULL AMV CM2.1

var[Z500' (2-8 days)]



Southward shift of the North Atlantic storm tracks

Signal to noise ratio



Fraction of decadal variance

About 20% of PDO/PNA variance explained by AMV in these experiments
Few land areas above 10% (nothing over Europe)

Conclusion

The AMV drives global impacts in temperature, precipitation and sea level pressure that are overall similar between the GFDL and NCAR models.

Over the Pacific, the observed AMV pattern drives a negative IPV-like response. The tropical Atlantic is the main driver of this teleconnection, with a mechanism involving changes in the Walker circulation consistent with *McGregor et al. (2014), Kucharski et al. (2015), Li et al. (2015).* The anomalies are reinforced by extratropical coupling.

The Atlantic warming yields an increased frequency of La Niña-like events and IPV-like events: possible modulation of the Pacific response by the AMV

The North Atlantic response to a positive AMV projects onto a shifted negative NAO and is mainly driven by the SPG, which is consistent with *Gastineau et al. (2012), Gastineau and Frankignoul (2015), Peings and Magnusdottir (2014, 2015), Omrani et al. (2014).*

The North Atlantic response is weakened by a teleconnection between the tropical Atlantic and the North Pacific. Might partly explain why it is hard to detect the signal in observations.
=> Tropical and extratropical anomalies must coincide to give a significant modulation of the NAO

Perspectives and challenges

Are these climatic impacts due to the AMOC? The AMOC has a weak SST signature in the tropical Atlantic: is it a model deficiency or a reality?

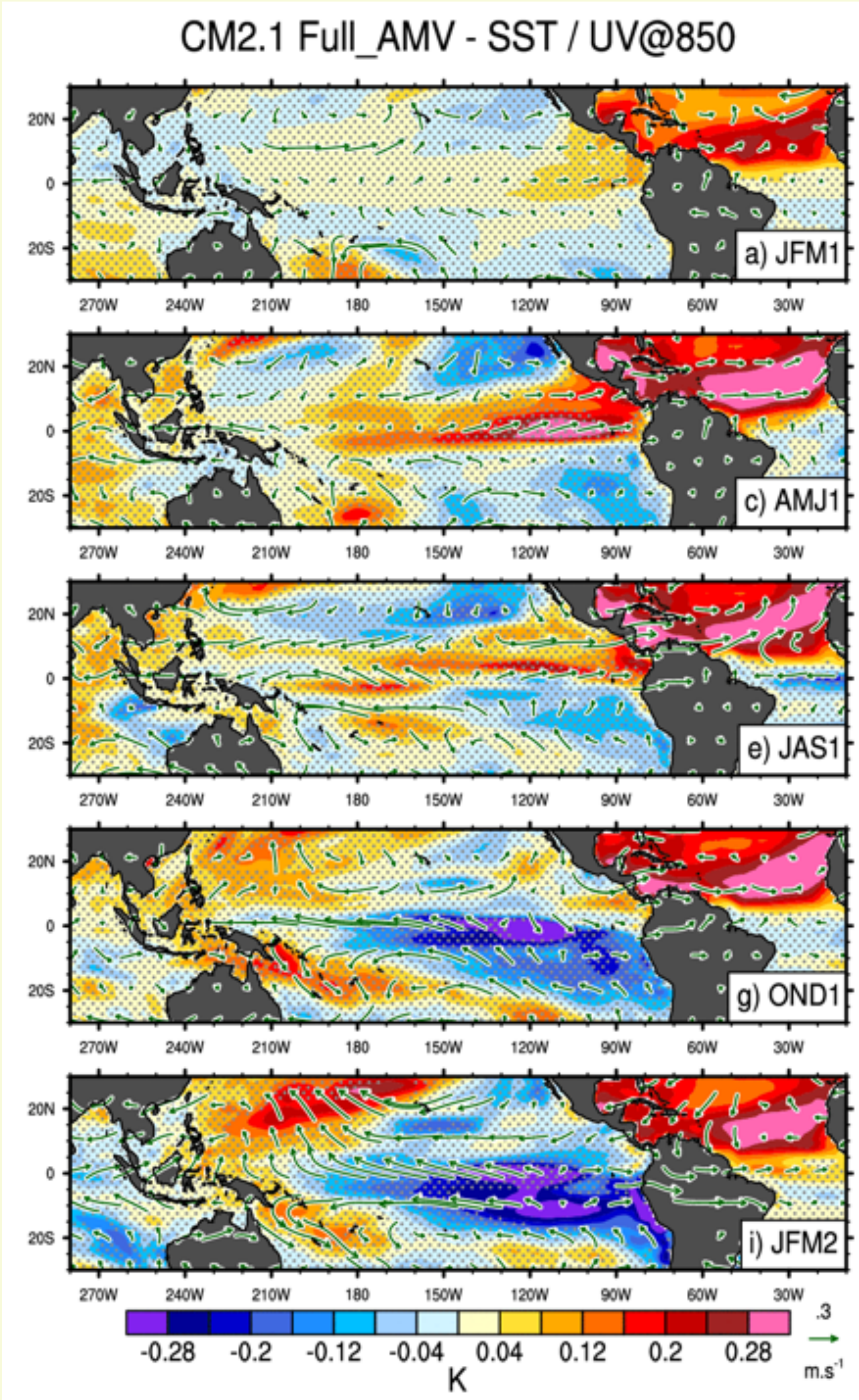
The tropical Atlantic appears to be key in the Pacific teleconnection: its bad representation in coupled models is problematic for decadal predictions

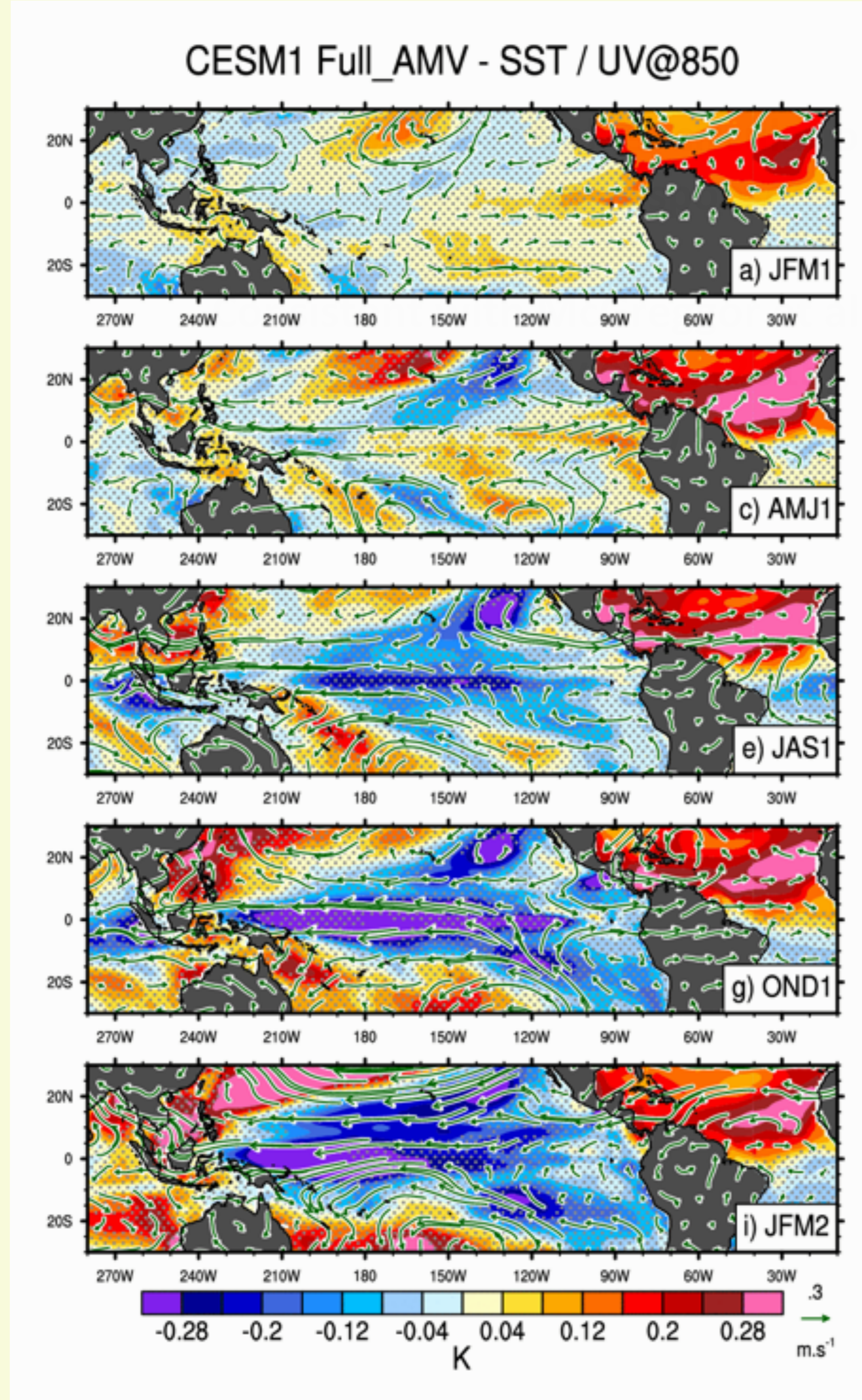
Weak signal to noise ratio and few impacts over land particularly over Europe. Similar results at high resolution. Too much noise?

Limitation of the protocol: drift in the North Atlantic because we use a constant restoring coefficient and we restore only to temperature. Ok for fixed AMV pattern but not for pacemaker experiments.
=> Need to restore SST and SSS and use a variable restoring coefficient (See Christophe Cassou's talk on Friday).

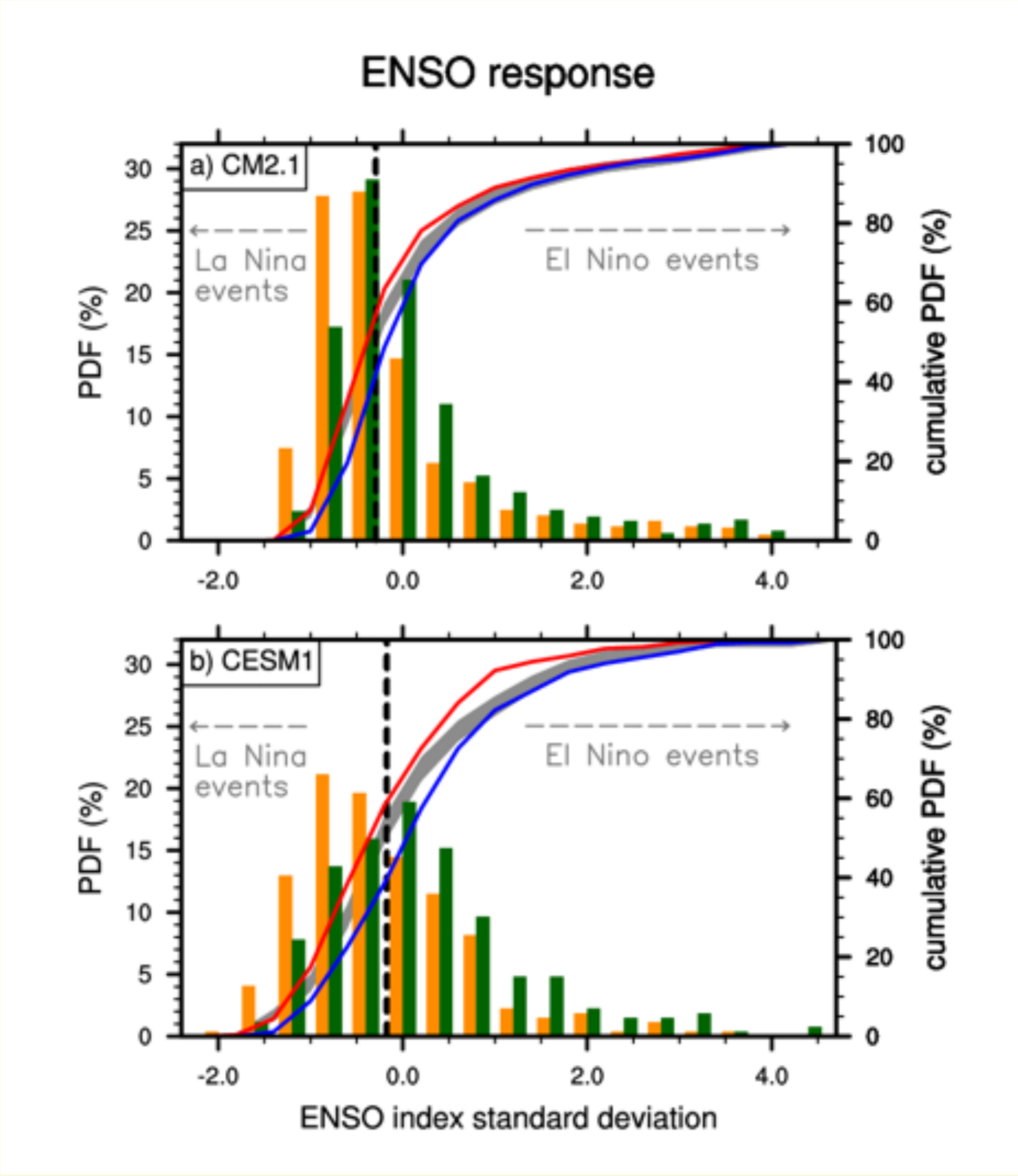
We have only investigated the Atlantic influence here. The Pacific has also a strong influence on the Atlantic. How do the two-way teleconnections add up and which ones are predictable?

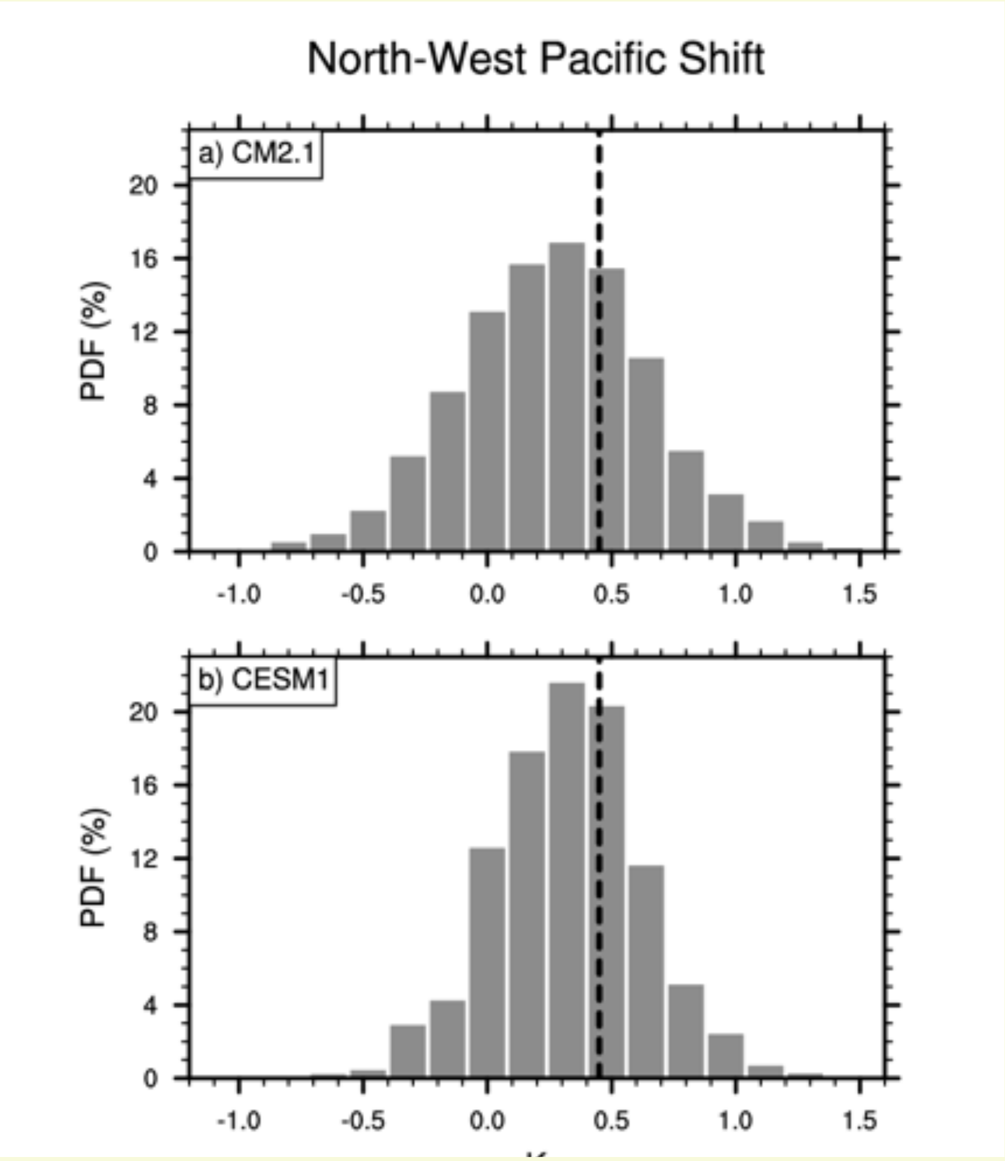
Mechanism


CM2.1 Full_AMV - SST / UV@850
a) JFM1
c) AMJ1
e) JAS1
g) OND1
i) JFM2
20N
0
20S
270W
240W
210W
180
150W
120W
90W
60W
30W
-0.28
-0.2
-0.12
-0.04
0.04
0.12
0.2
0.28
K
.3
m.s-1

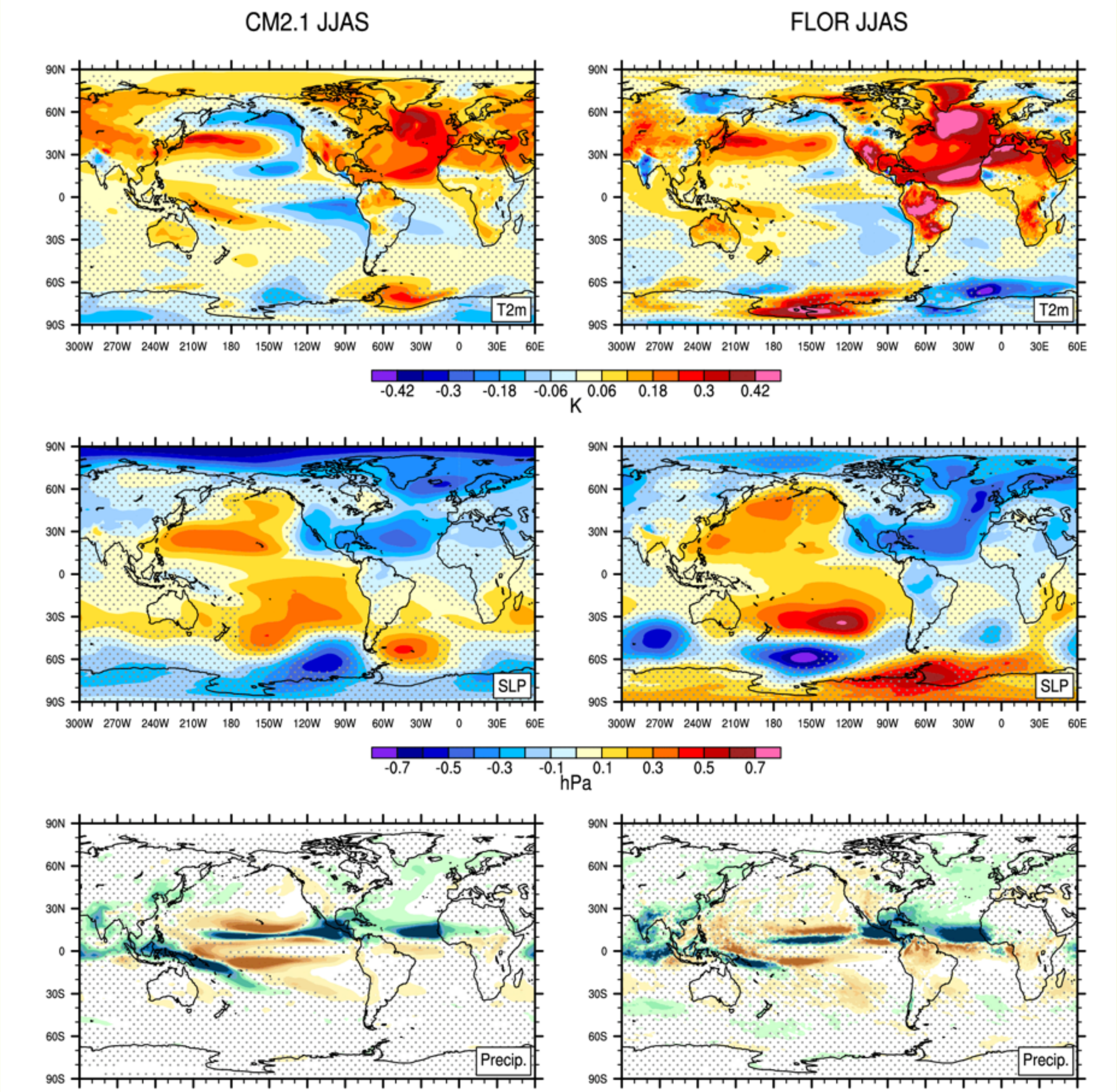

CESM1 Full_AMV - SST / UV@850
a) JFM1
c) AMJ1
e) JAS1
g) OND1
i) JFM2
20N
0
20S
270W
240W
210W
180
150W
120W
90W
60W
30W
-0.28
-0.2
-0.12
-0.04
0.04
0.12
0.2
0.28
K
.3
m.s-1

Modulation of ENSO

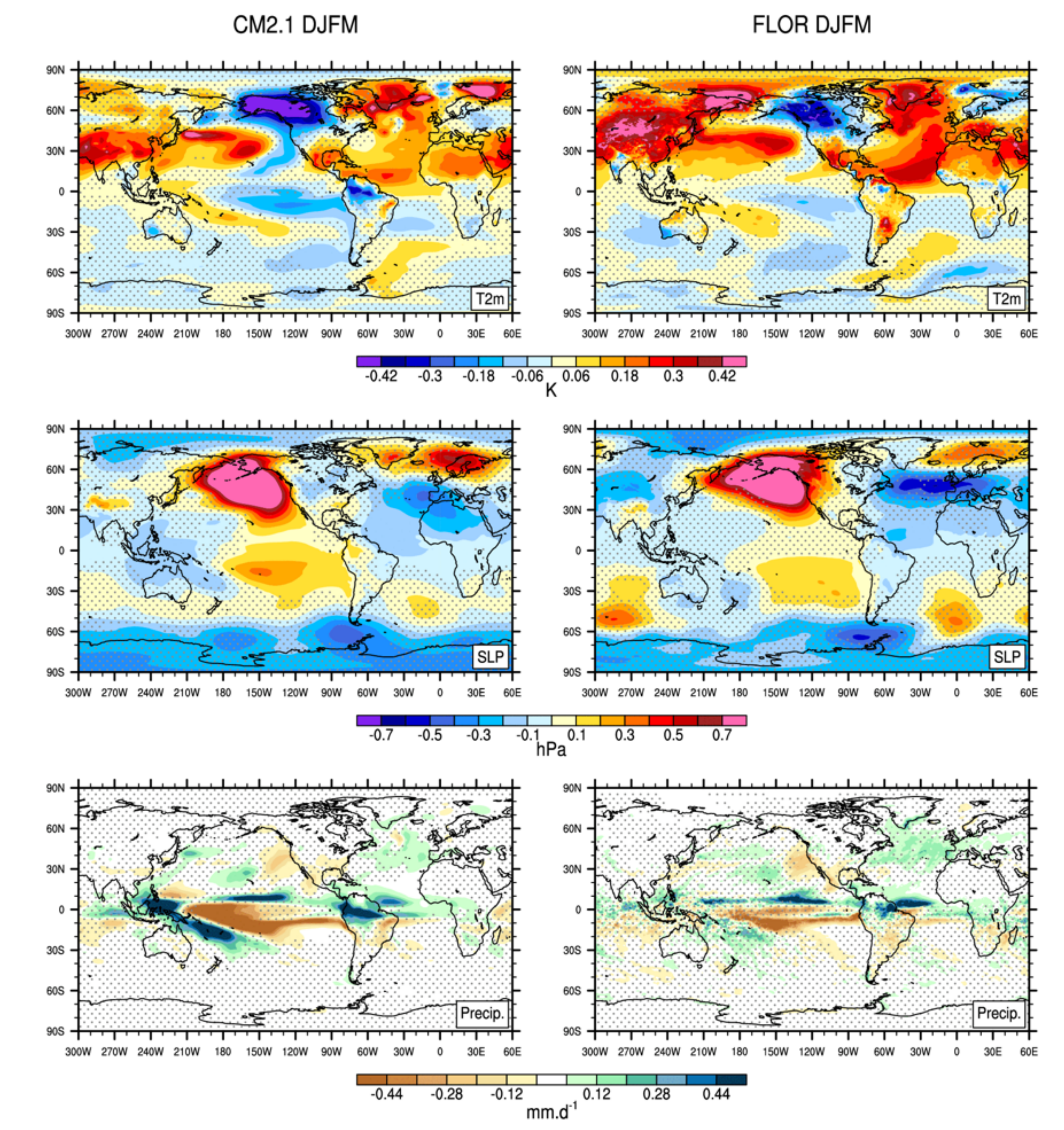




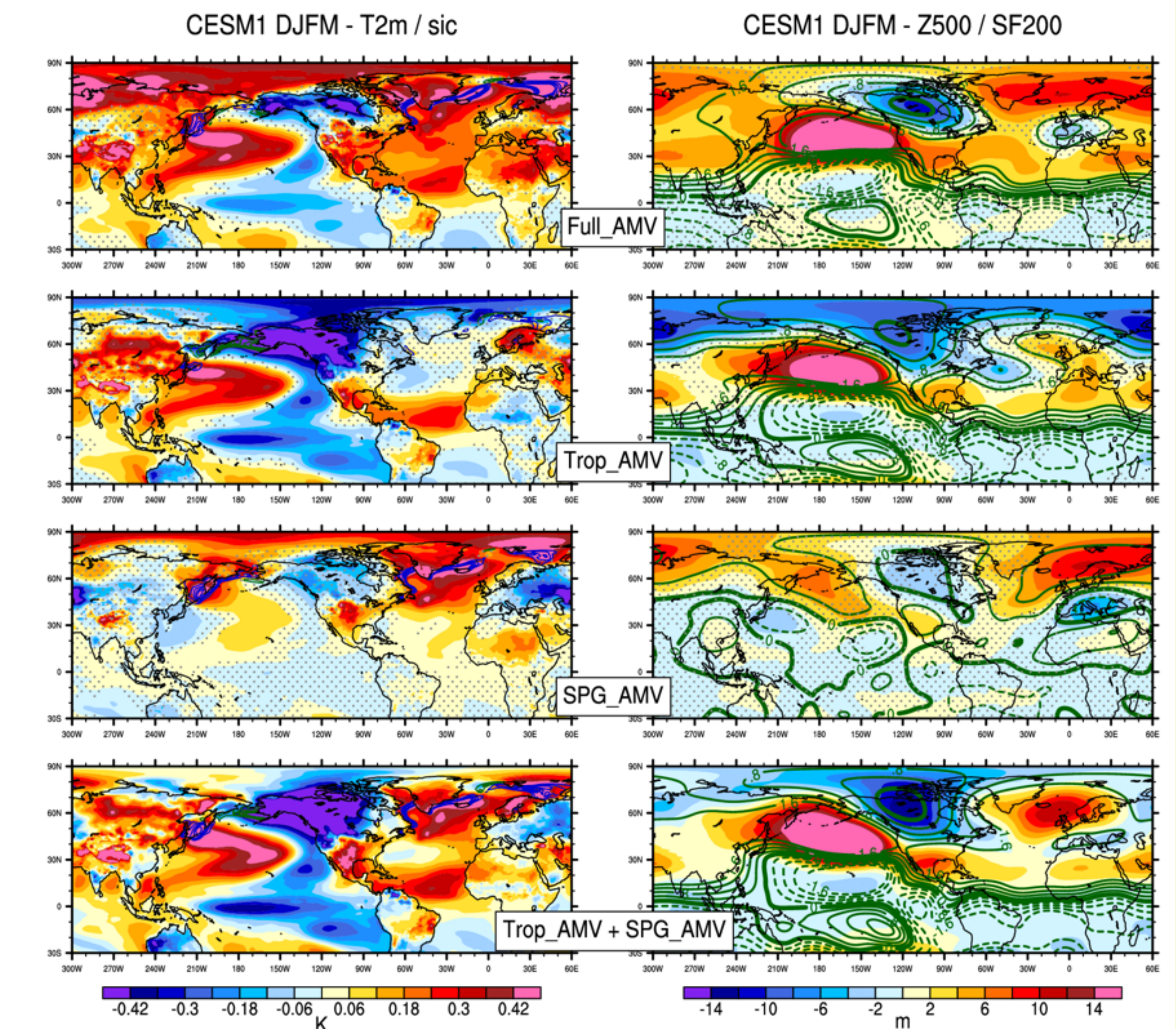
High-resolution response



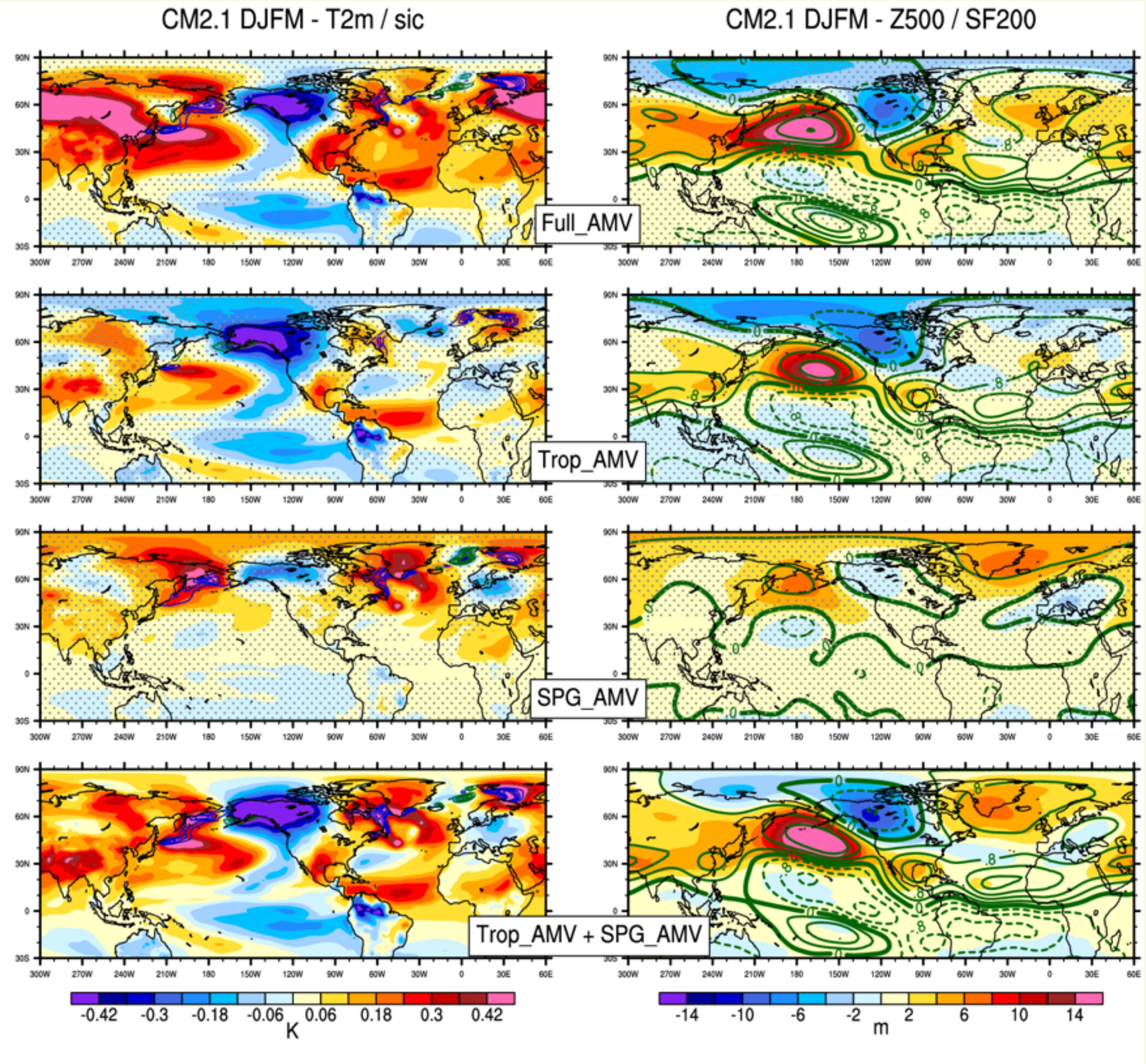
High-resolution response



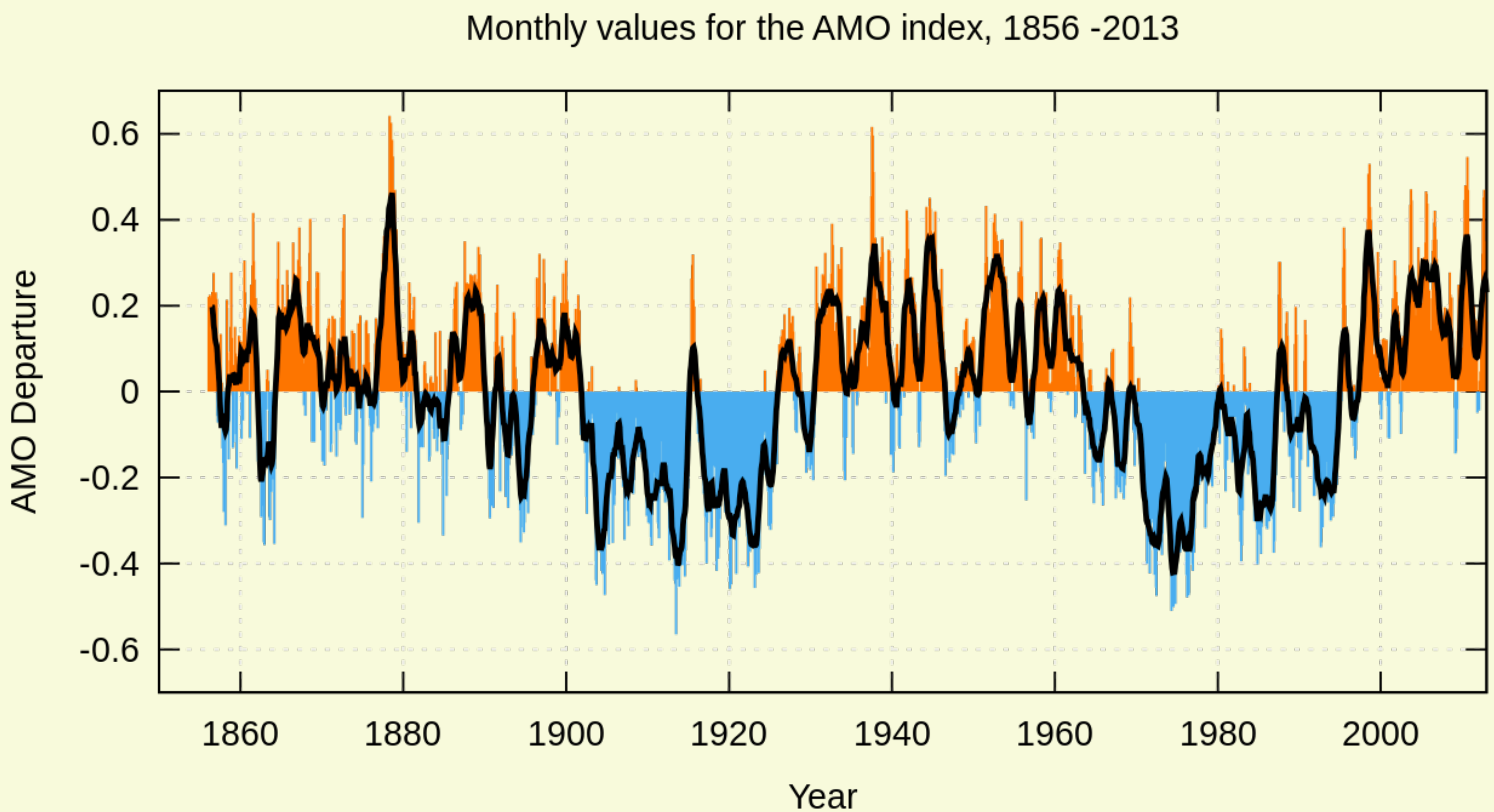
Sum of tropics and SPG contribution



Sum of tropics and SPG contribution



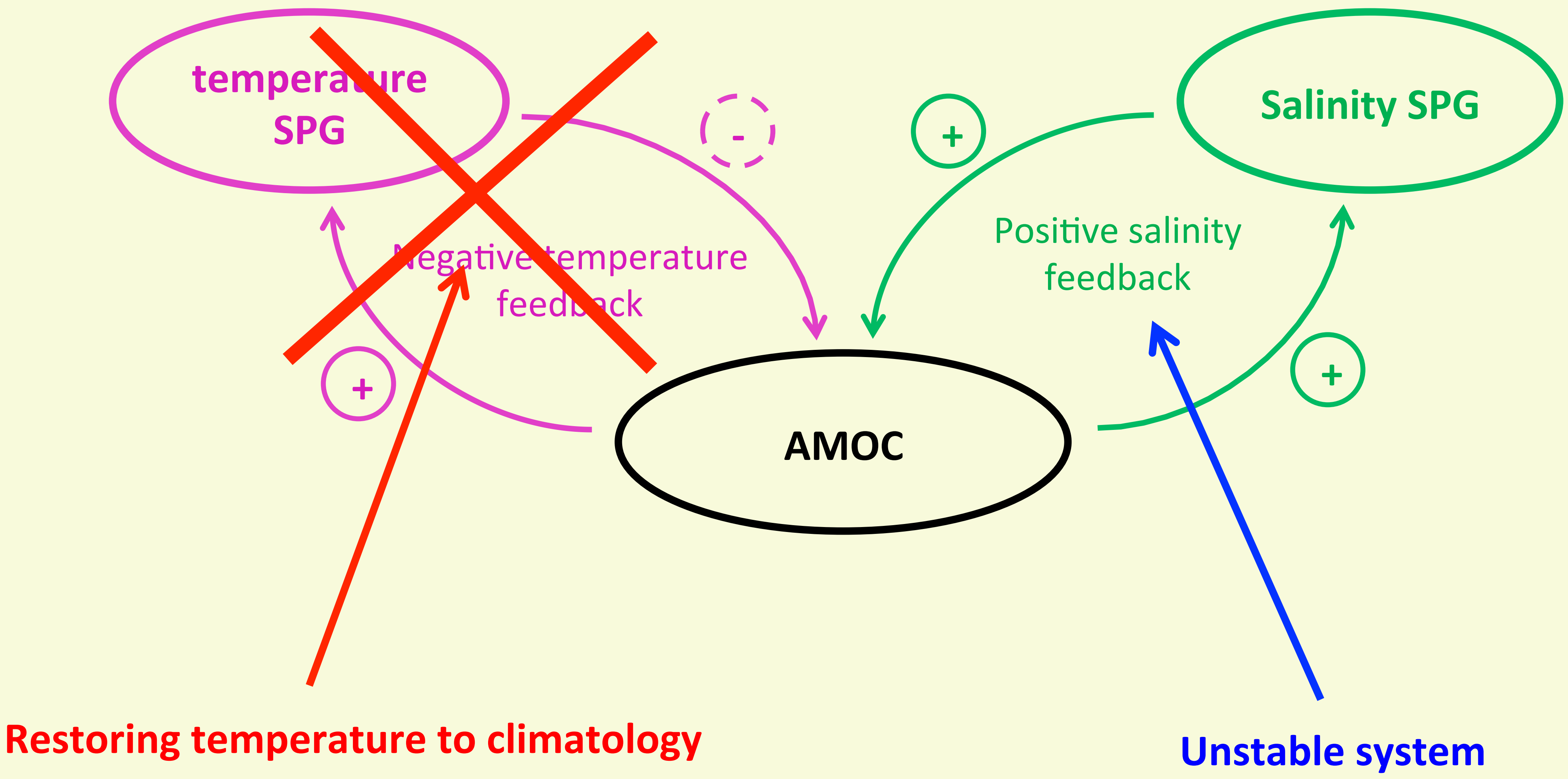
Why does it matter for DCPP component C?



In the pacemaker experiments, we need to impose a given sign for the AMV for more than 10 years.

The Atlantic subsurface drift can be communicated to other ocean basins

Why is there a drift?



Restoring SST only does not give consistent T/S relationship
We are not allowing temperature feedbacks
We favor weak AMOC states because it is easier to constrain a shallow mixed layer