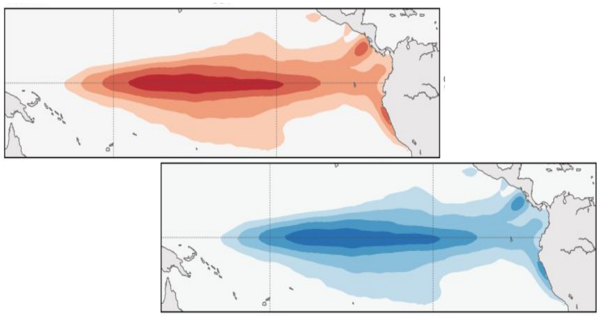
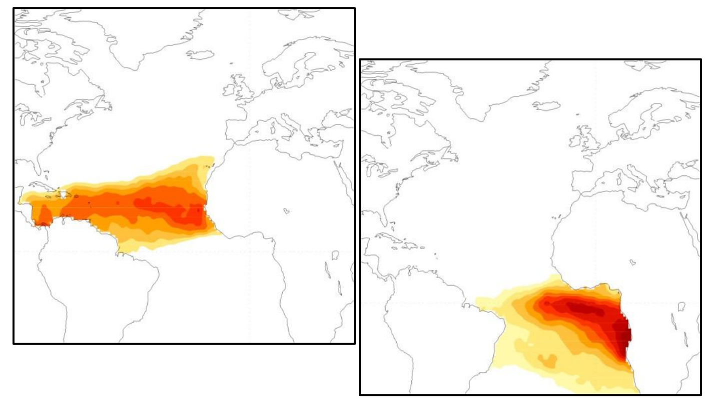
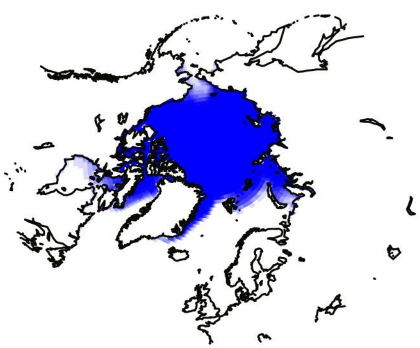
METEO-UB

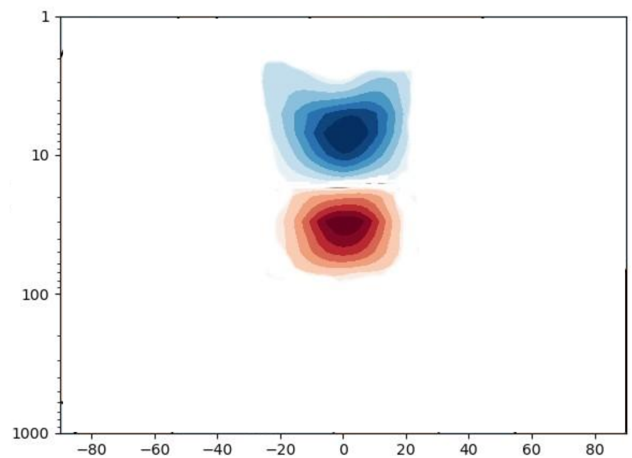
UNIVERSITAT DE BARCELONA

Additional sources of seasonal predictability









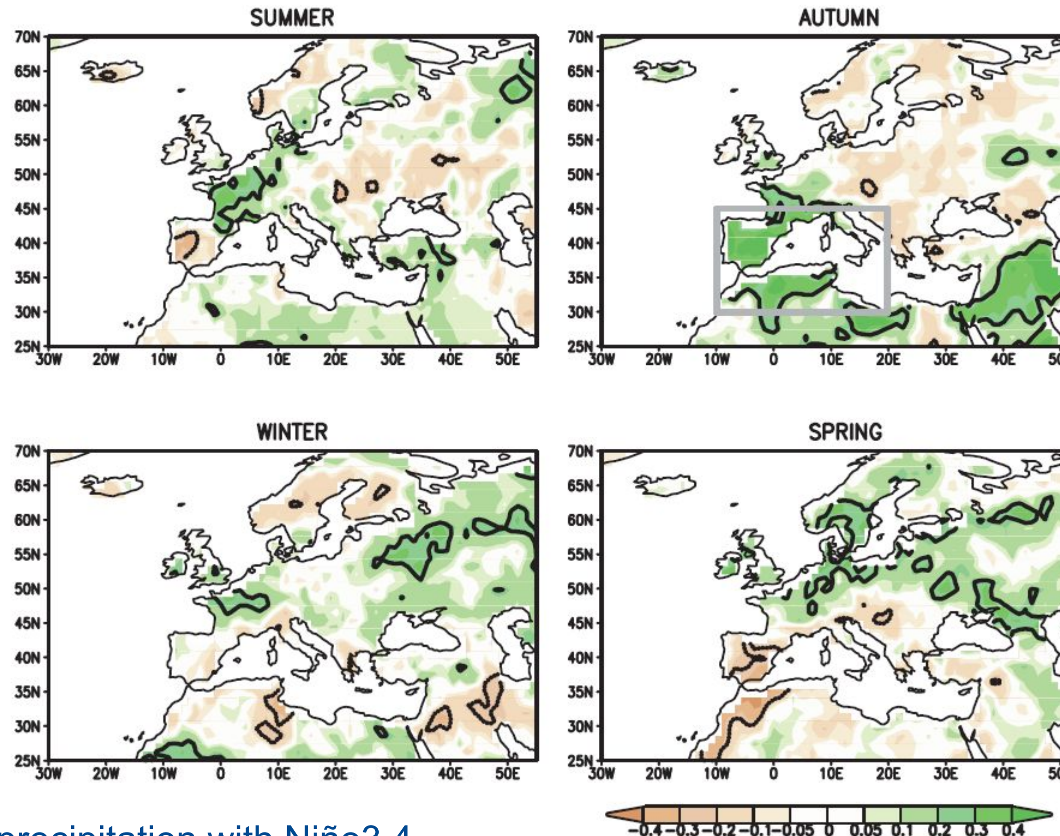
Javier García-Serrano

Group of Meteorology
(METEO-UB)

ENSO

ENSO is the leading mode of climate variability on seasonal-to-interannual timescales

ENSO is the most important source of predictability at seasonal timescale
[e.g. Doblas-Reyes et al. 2013]

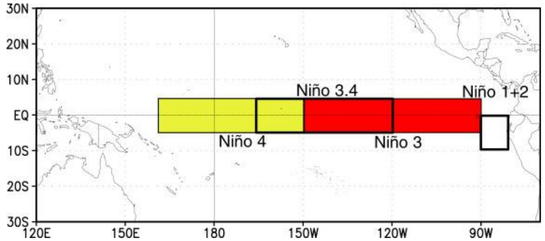


correlation maps of precipitation with Niño3.4
[Mariotti et al. 2002]

METEO-UB

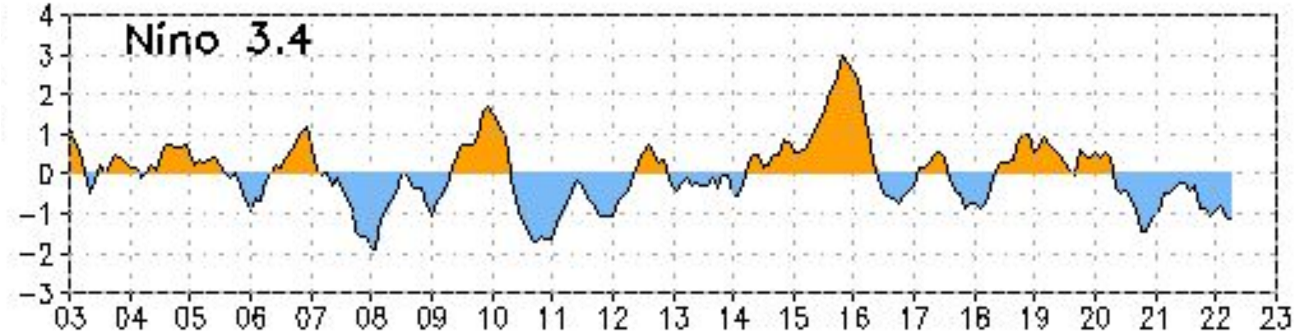
ENSO

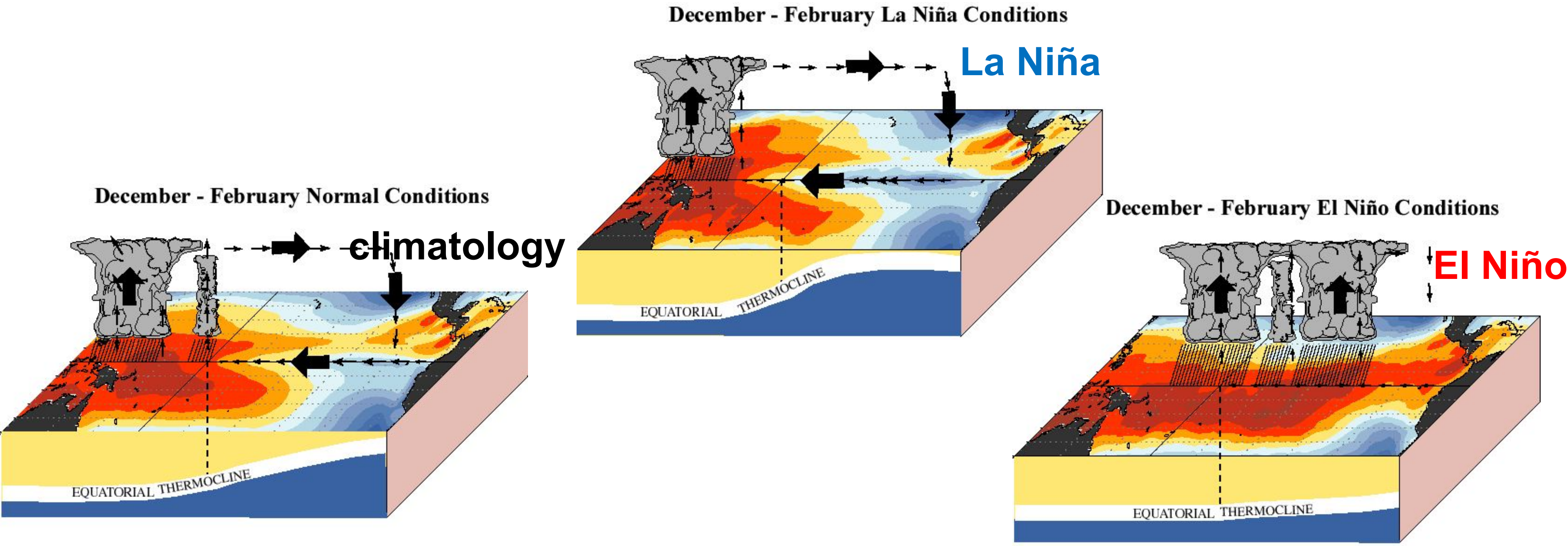
UNIVERSITAT DE BARCELONA



[www.cpc.ncep.noaa.gov]

SST anomaly up to April 2022



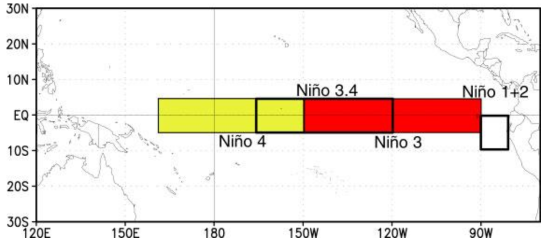


key process in ENSO: “positive” ocean-atmosphere (Bjerknes) feedback

METEO-UB

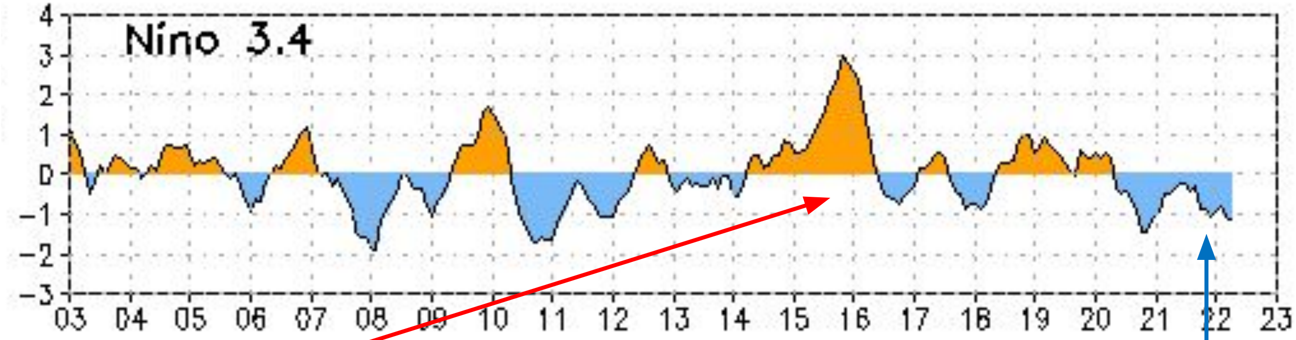
ENSO

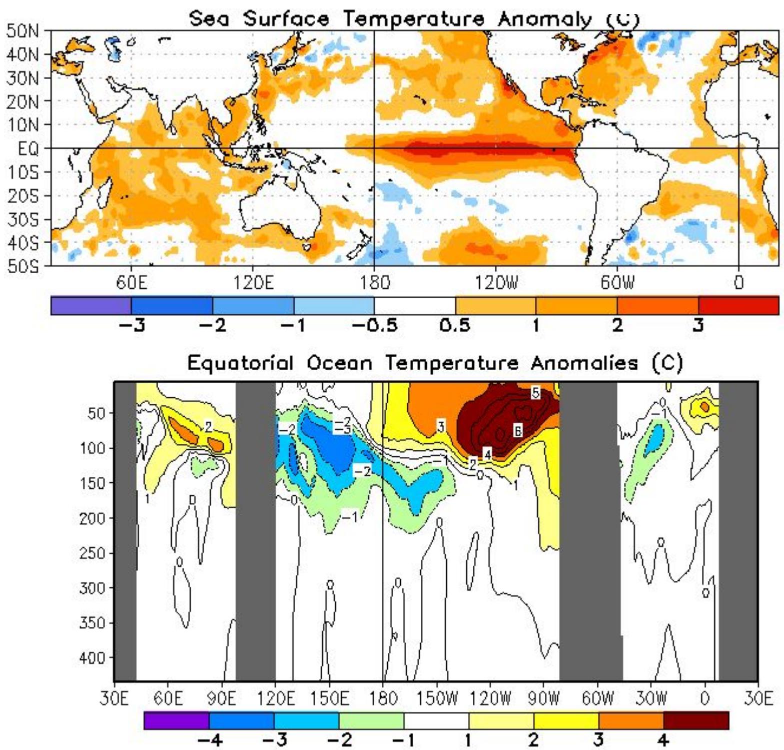
UNIVERSITAT DE BARCELONA



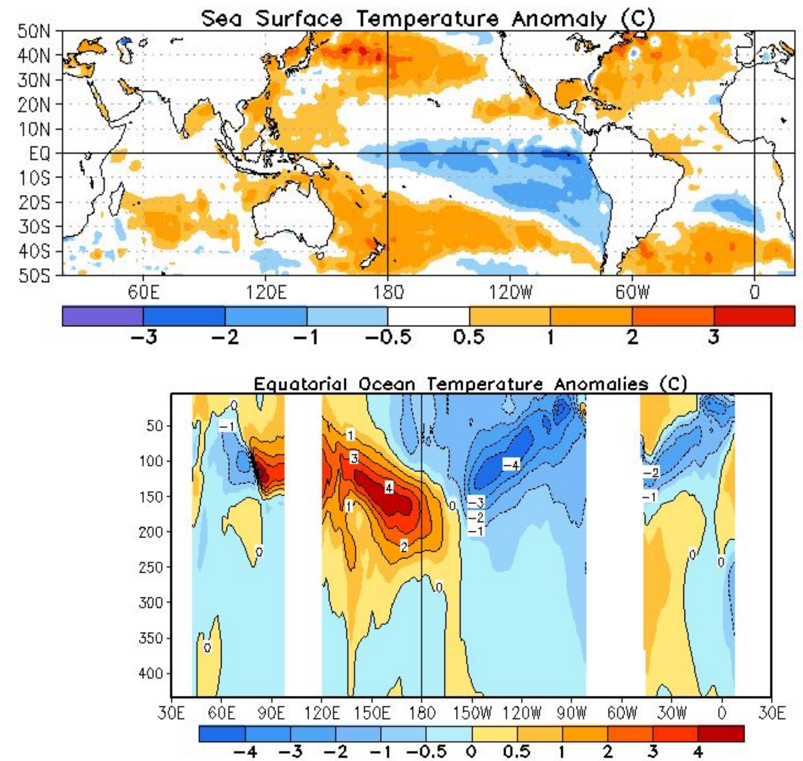
[www.cpc.ncep.noaa.gov]

SST anomaly up to April 2022





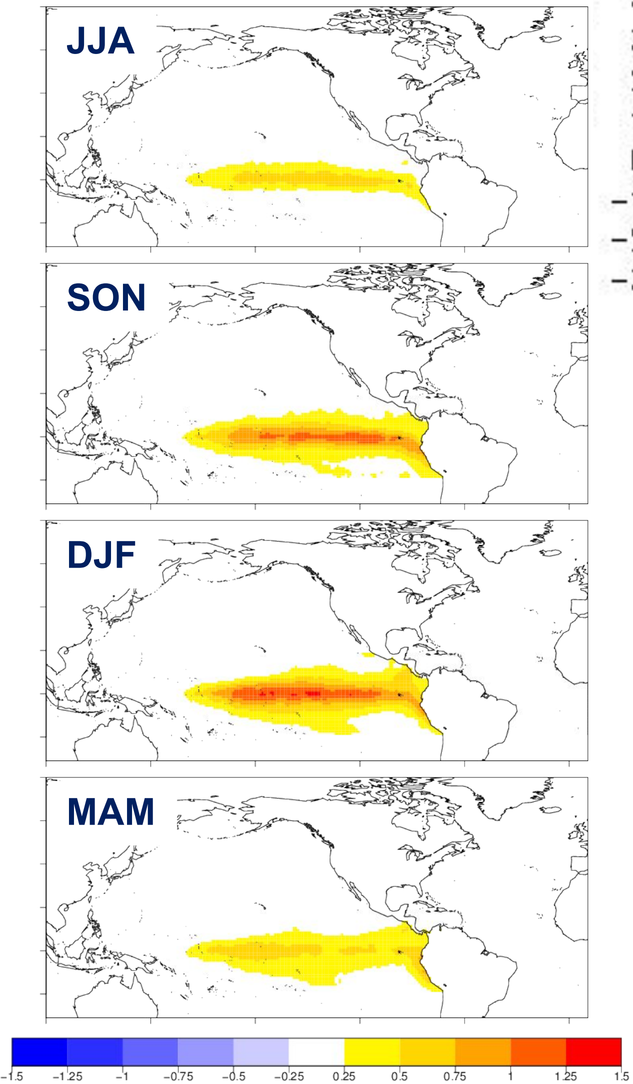
Dec 2015



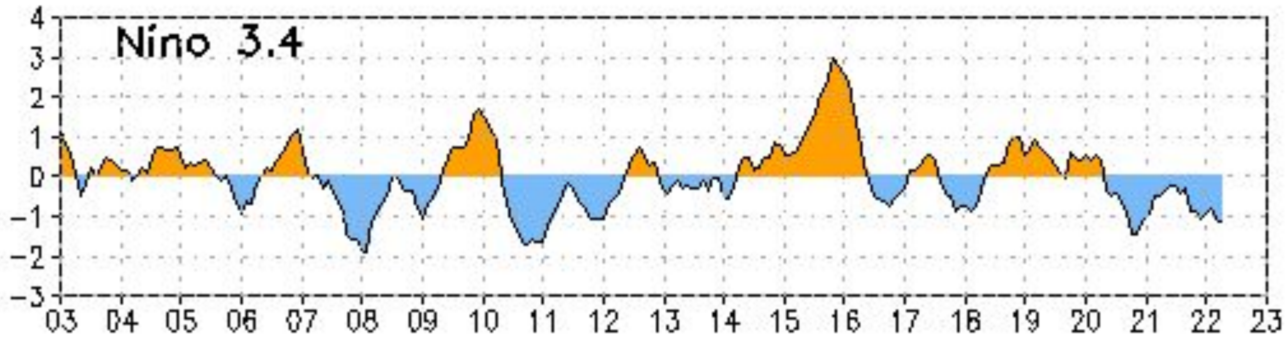
Dec 2021

ENSO

ENSO cycle



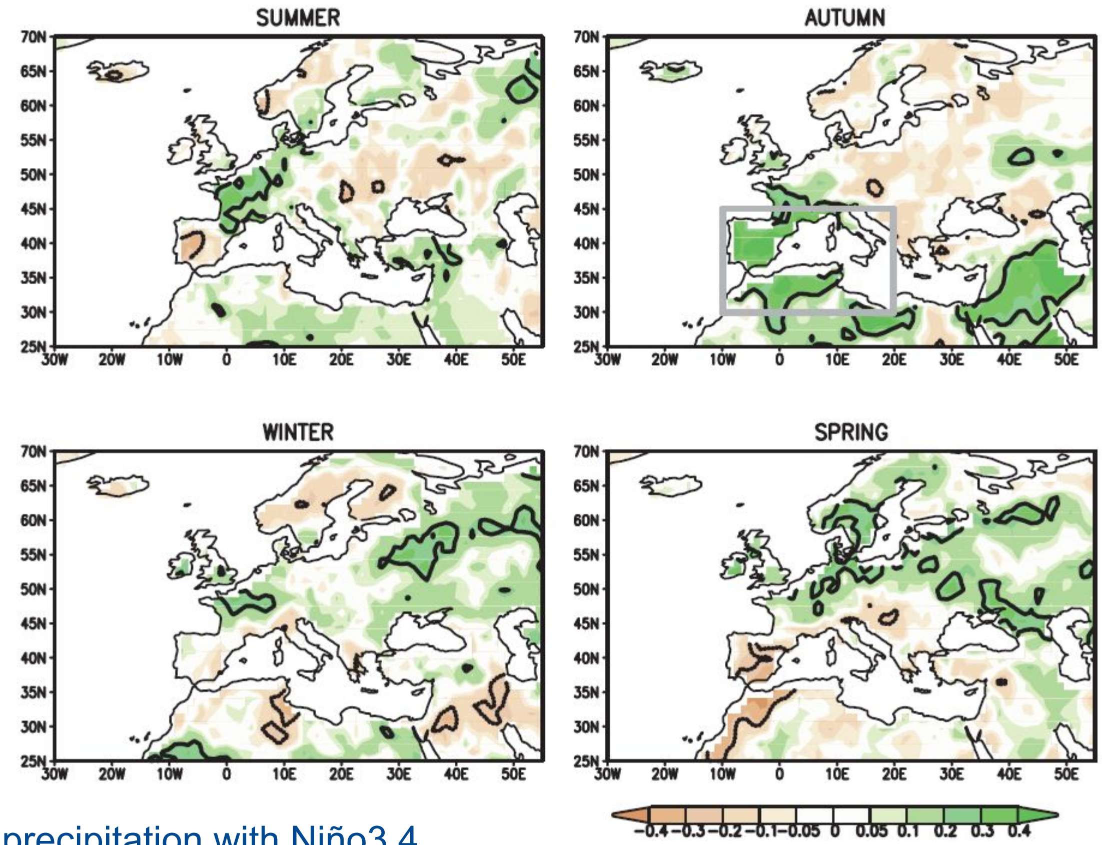
SST anomaly up to April 2022



ENSO

ENSO is the leading mode of climate variability on seasonal-to-interannual timescales

ENSO is the most important source of predictability at seasonal timescale
[e.g. Doblas-Reyes et al. 2013]

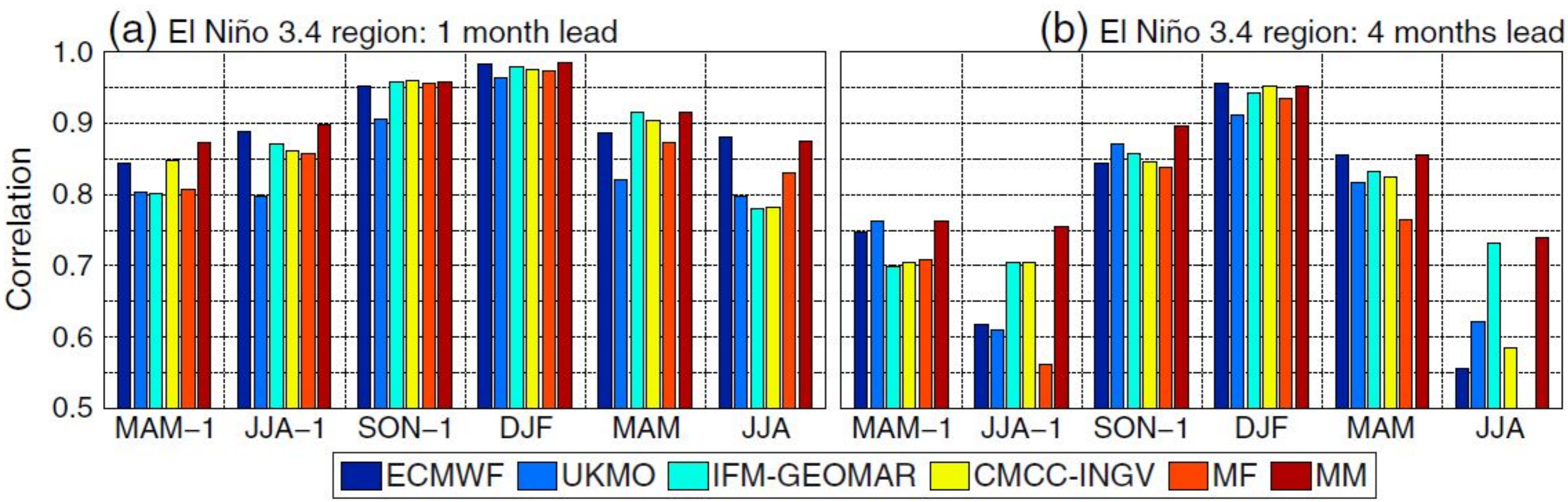


correlation maps of precipitation with Niño3.4
[Mariotti et al. 2002]

ENSO

ENSO is the leading mode of climate variability on seasonal-to-interannual timescales

ENSO is the most important source of predictability at seasonal timescale
[e.g. Doblas-Reyes et al. 2013]

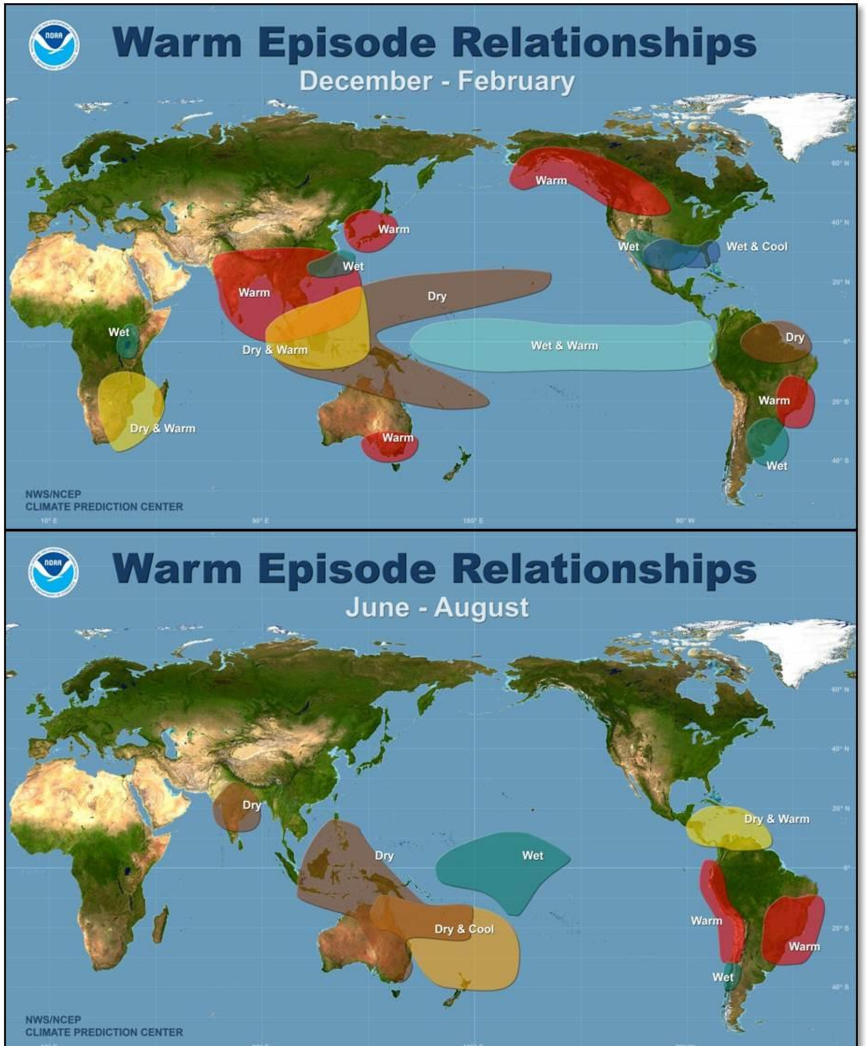


correlation skill of Niño3.4 in ENSEMBLES
[Manzanas et al. 2014]

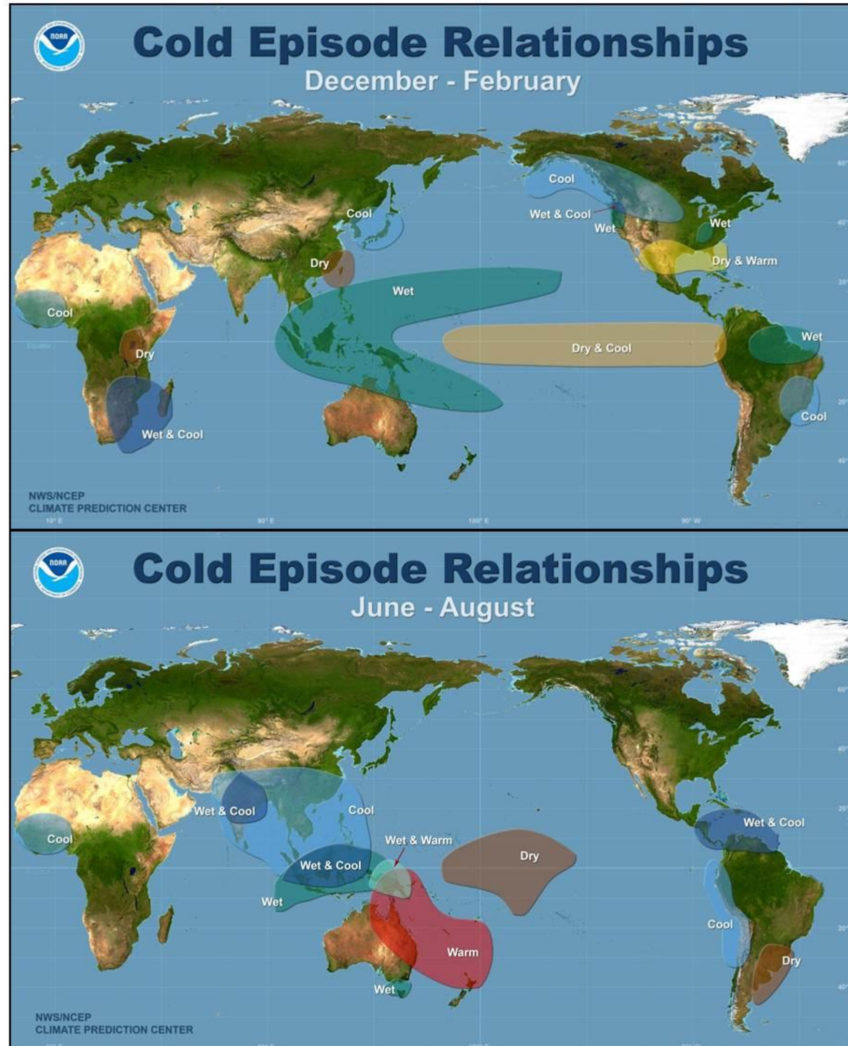
ENSO teleconnections

UNIVERSITAT DE BARCELONA

El Niño impacts

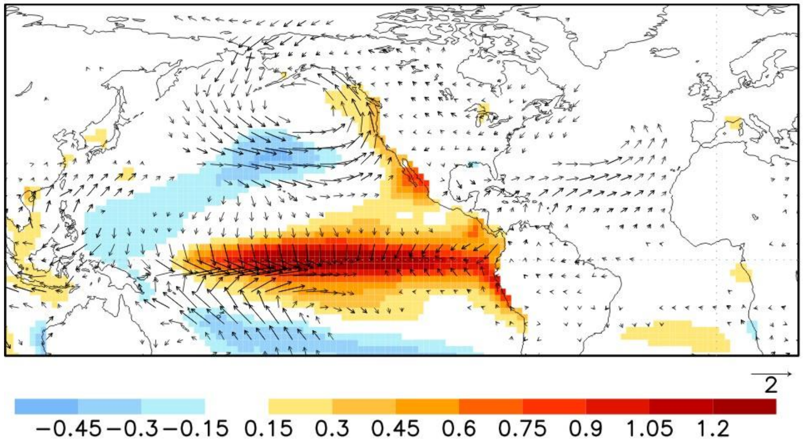


La Niña impacts

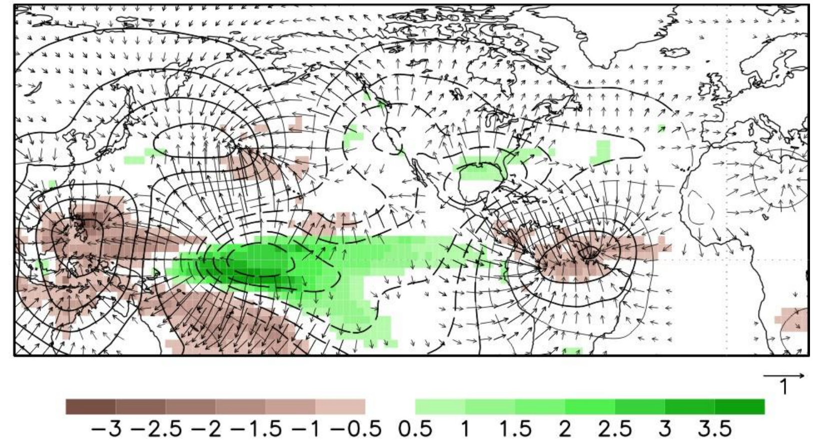


ENSO teleconnections

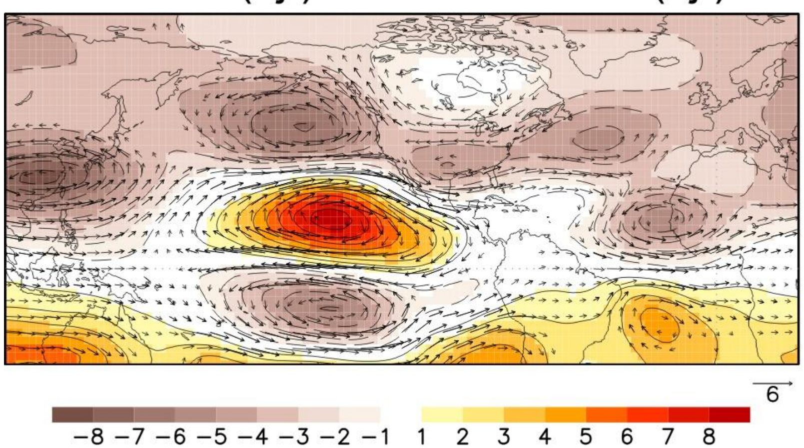
Niño3.4 (djf) x SST/wind-10m (djf)



Niño3.4 (djf) x GPCP/divergent-200 (djf)



Niño3.4 (djf) x rotational-200 (djf)



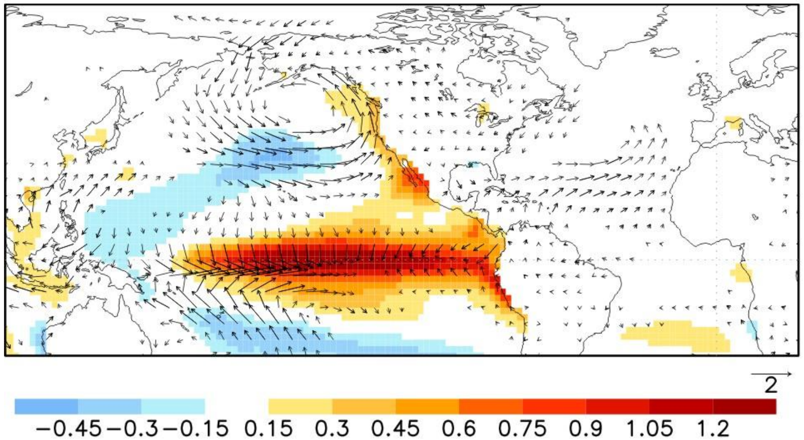
[García-Serrano et al. 2017]

ENSO teleconnections

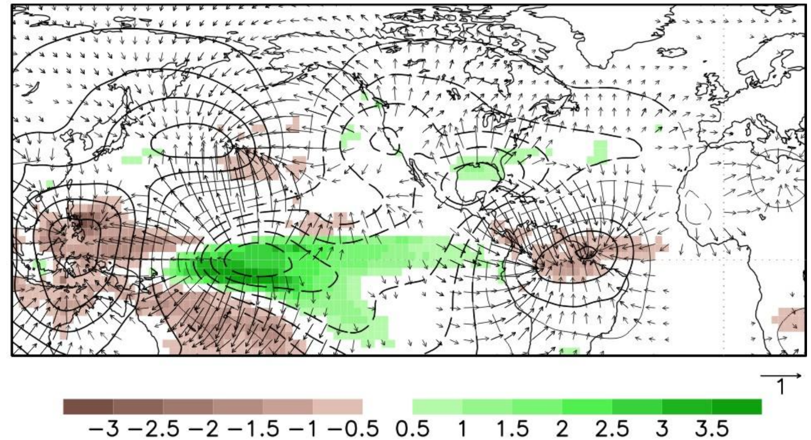
influence of the tropical Pacific
in remote regions

ENSO teleconnections

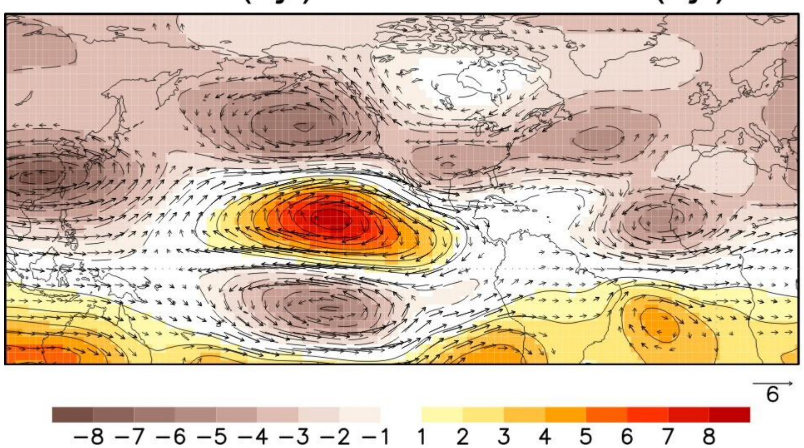
Niño3.4 (djf) x SST/wind-10m (djf)



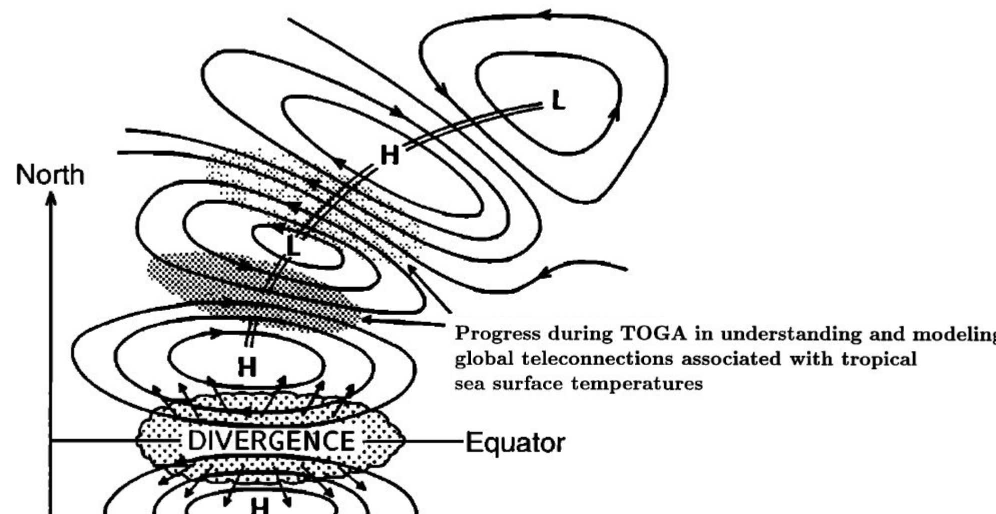
Niño3.4 (djf) x GPCP/divergent-200 (djf)



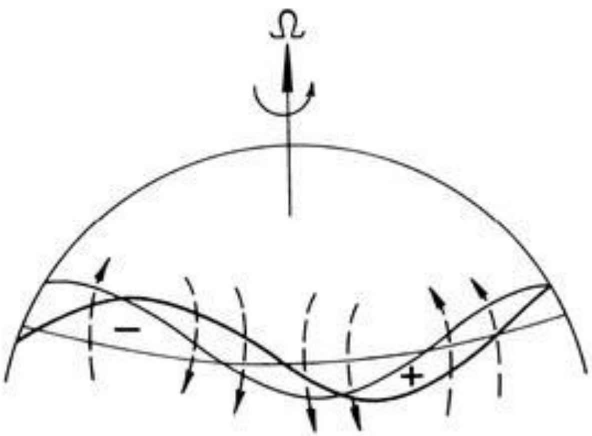
Niño3.4 (djf) x rotational-200 (djf)

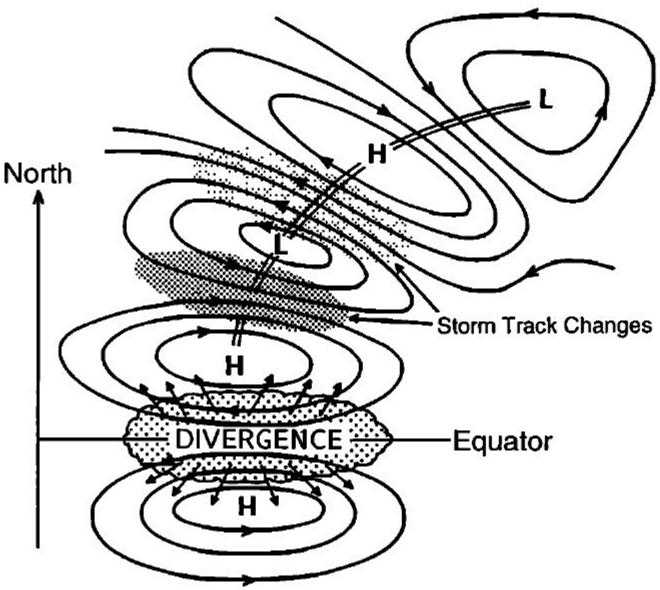


[García-Serrano et al. 2017]



Trenberth et al. (1998)





Rossby wave

$$\boxed{\zeta + f = cte}$$

planetary vorticity / Coriolis parameter

$$f = 2\Omega sin\varphi$$

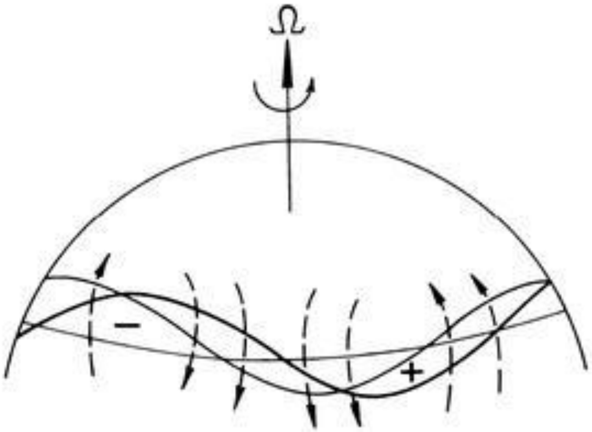
relative vorticity (local)

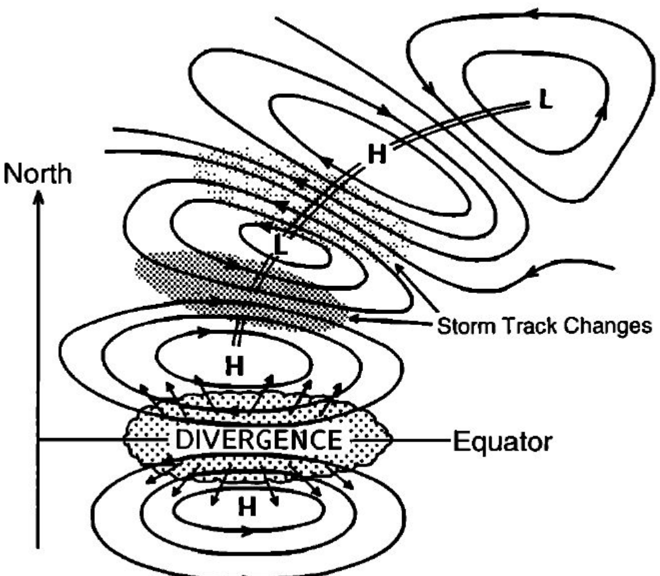
$$\zeta = \vec{k}\cdot(\nabla\times\vec{v}) = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Barotropic Vorticity Equation

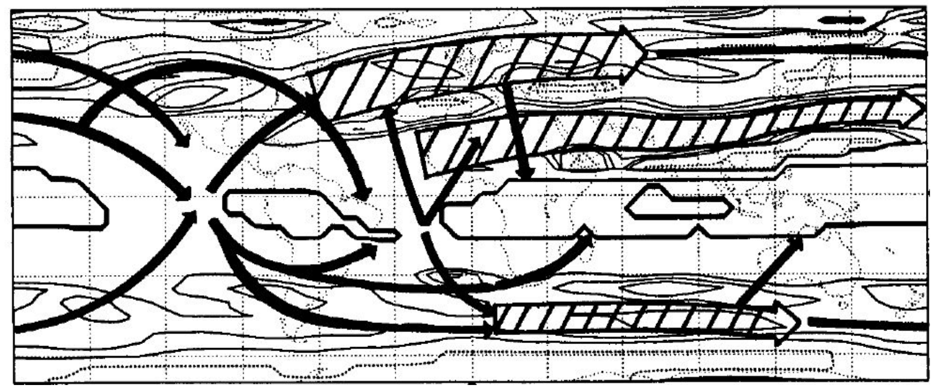
$$\underbrace{\frac{d}{dt}(\zeta + f)}_{\text{propagation}} + \underbrace{\cancel{(\zeta + f)\nabla\cdot\vec{v}}}_{\text{source}} = 0$$

teleconnections

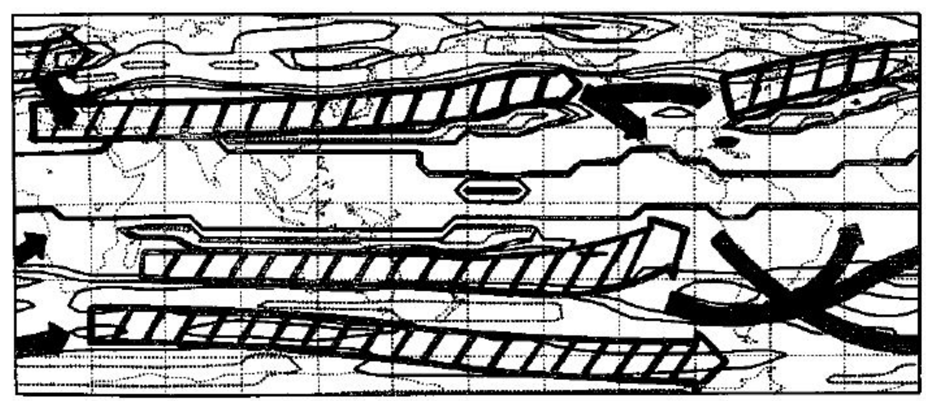




WINTER *Hoskins & Ambrizzi (1993)*



SUMMER *Ambrizzi et al. (1995)*

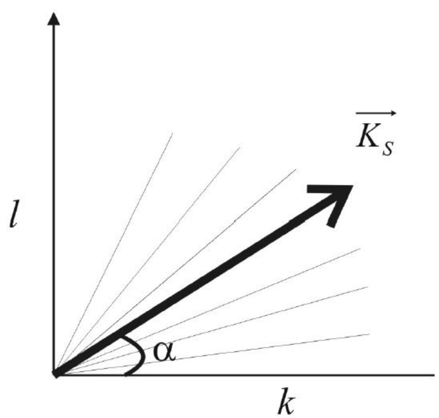


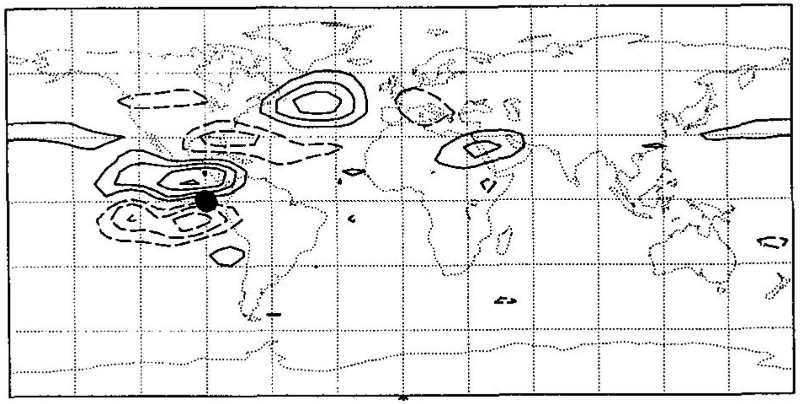
teleconnections propagate anomalies

<u>depend on the background flow!!</u>

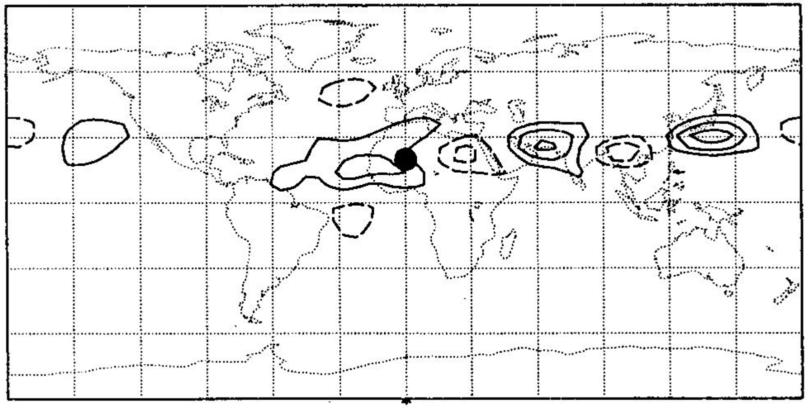
teleconnections

$$\cos\alpha = \frac{k}{K_S} = k\sqrt{\frac{U}{\beta - \frac{\partial^2 U}{\partial y^2}}}$$





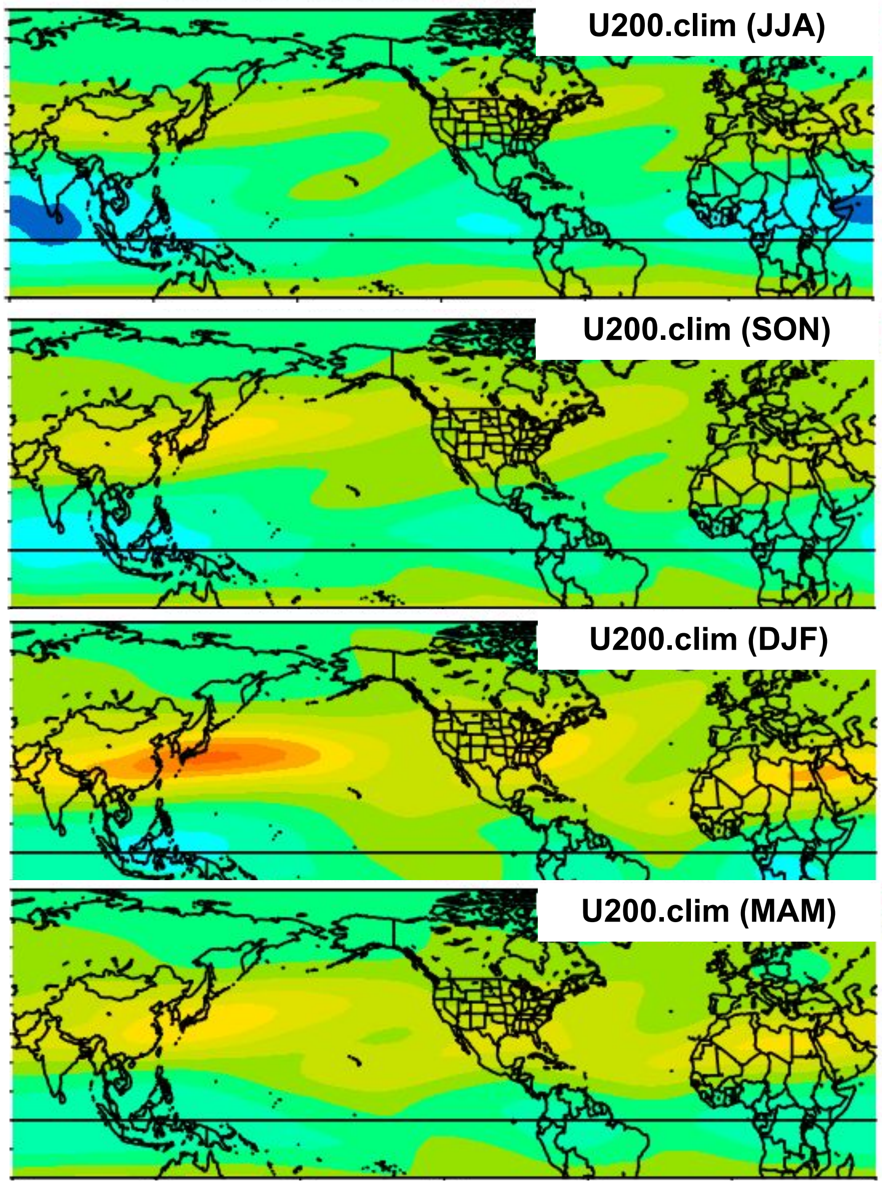
Hoskins & Ambrizzi (1993)

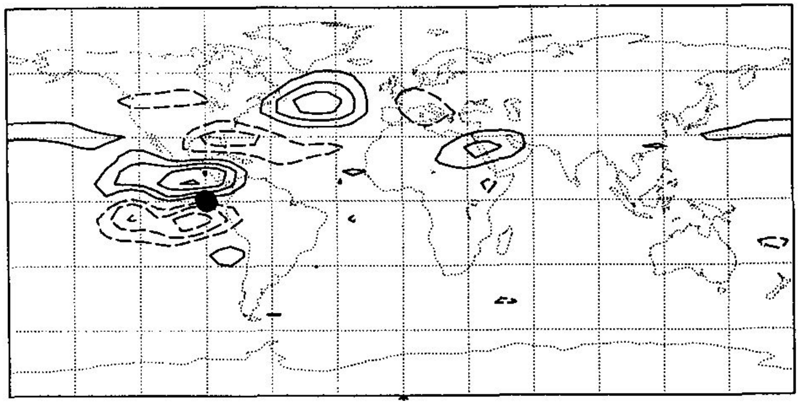


teleconnections propagate anomalies

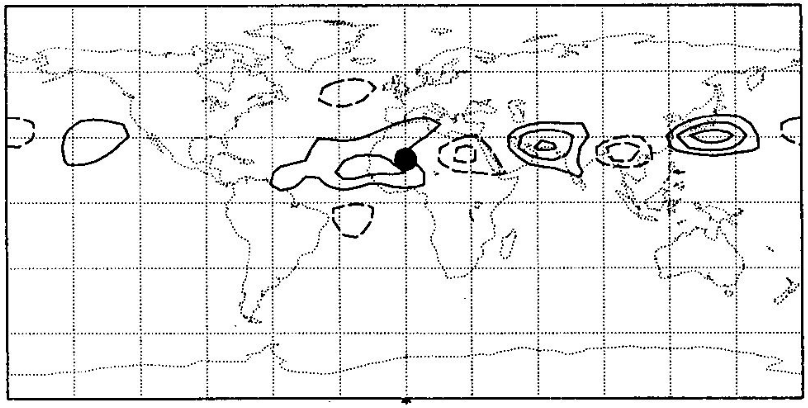
depend on the background flow!!

teleconnections





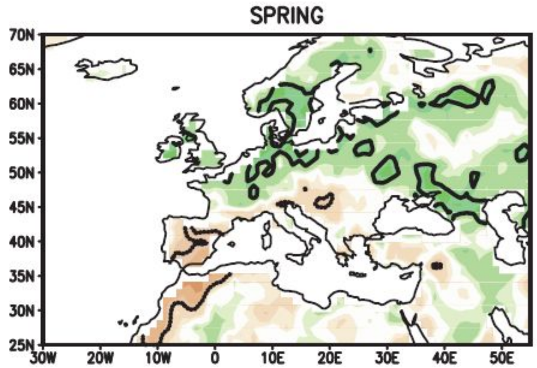
Hoskins & Ambrizzi (1993)



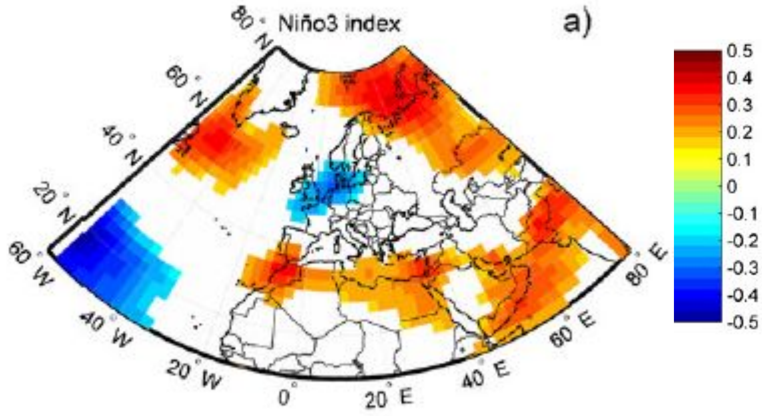
teleconnections propagate anomalies

depend on the background flow!!

ENSO

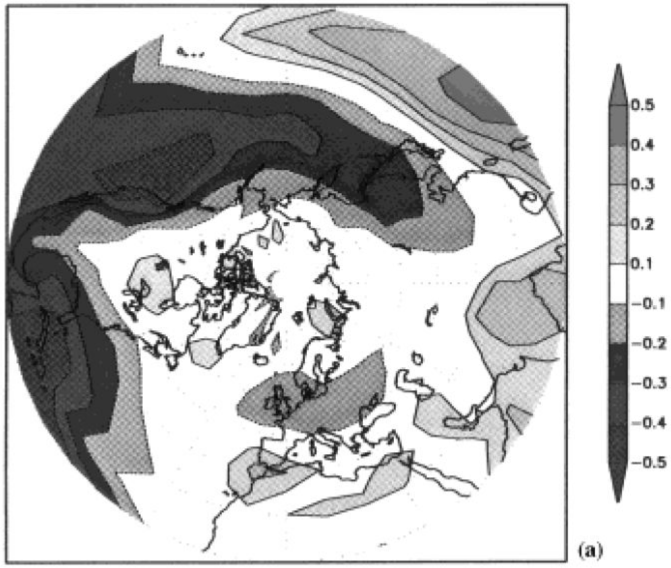


correlation map of precipitation with Niño3.4
[Mariotti et al. 2002]



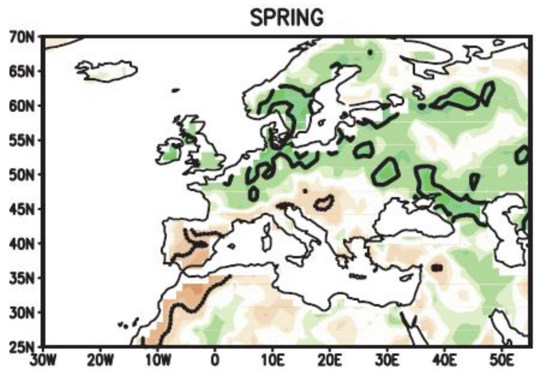
correlation map of MAM-SLP with DJF-Niño3
[Lorenzo et al. 2011]

SPRING



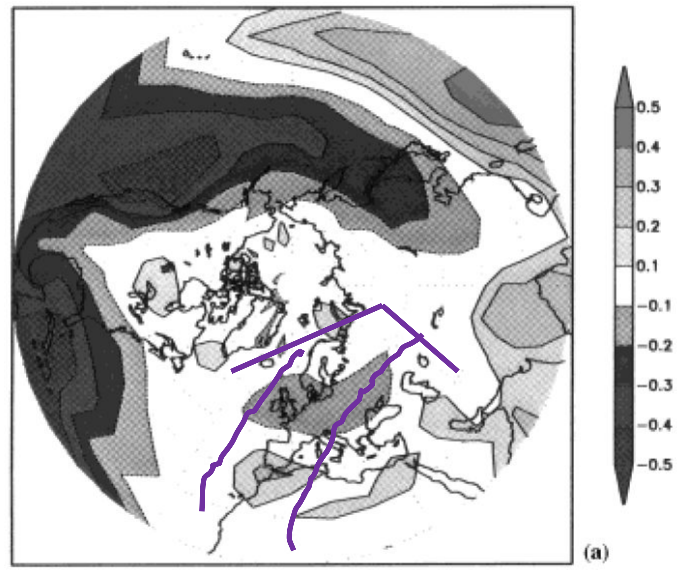
correlation map of SLP with Niño3 (in MAM)
[van Oldenborgh et al. 2000]

ENSO

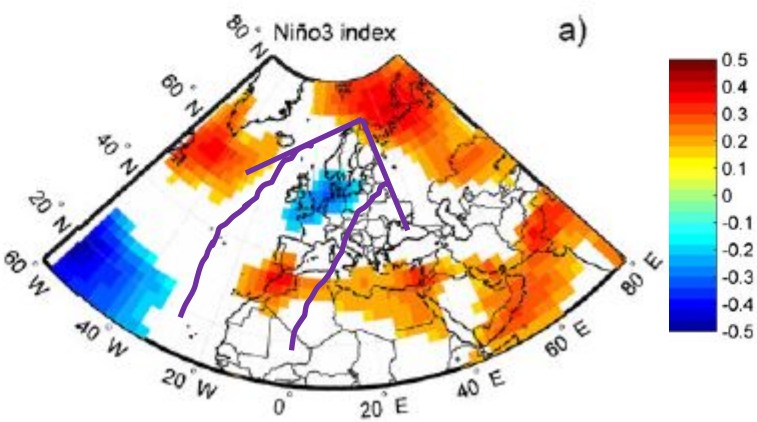


correlation map of precipitation with Niño3.4
[Mariotti et al. 2002]

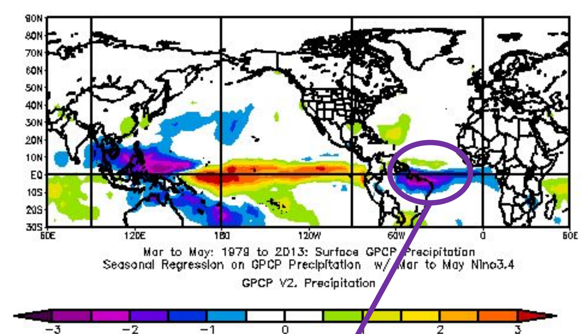
SPRING



correlation map of SLP with Niño3 (in MAM)
[van Oldenborgh et al. 2000]



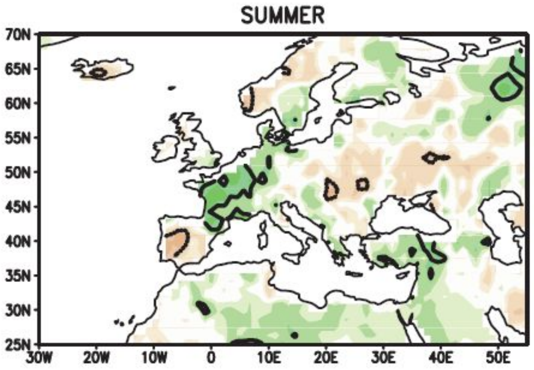
correlation map of MAM-SLP with DJF-Niño3
[Lorenzo et al. 2011]



secondary Rossby wave source [García-Serrano et al. 2017]

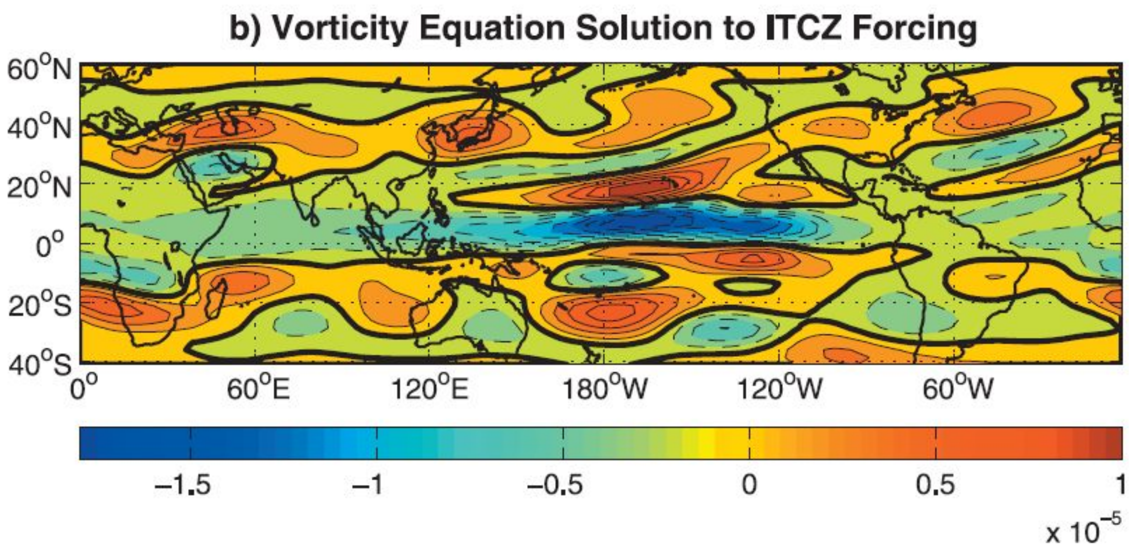
ENSO

SUMMER



correlation map of precipitation with Niño3.4

[Mariotti et al. 2002]

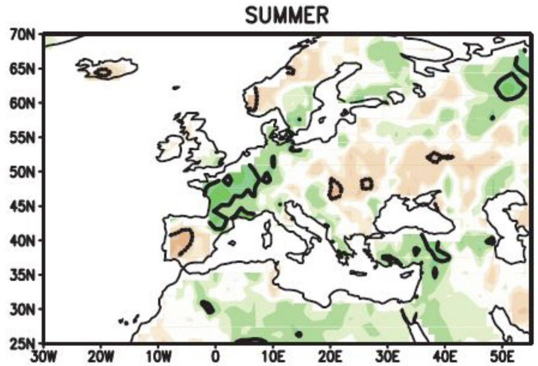


resembling El Niño-La Niña composite (JAS)

[Shaman and Tziperman 2007]

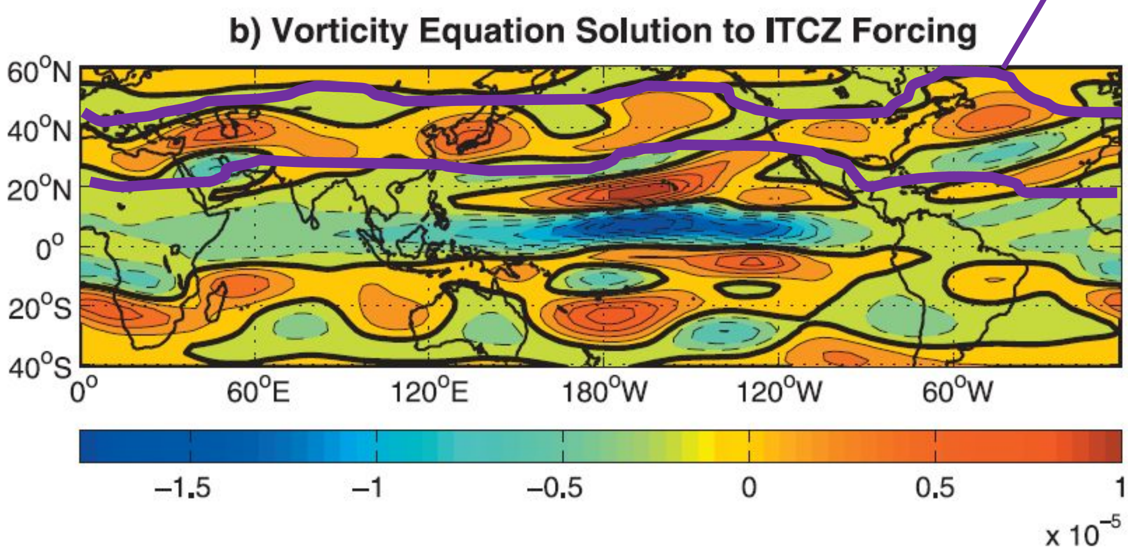
ENSO

SUMMER



correlation map of precipitation with Niño3.4
[Mariotti et al. 2002]

waveguided, zonally-propagating Rossby wavetrain

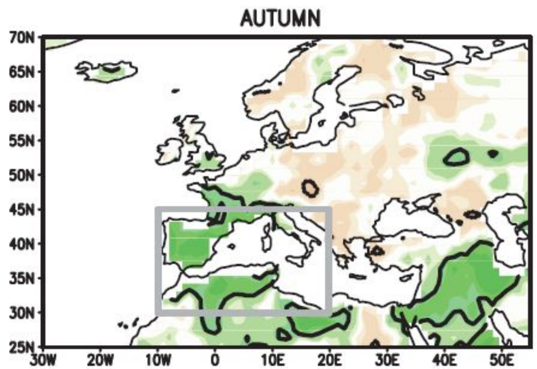


resembling El Niño-La Niña composite (JAS)
[Shaman and Tziperman 2007]

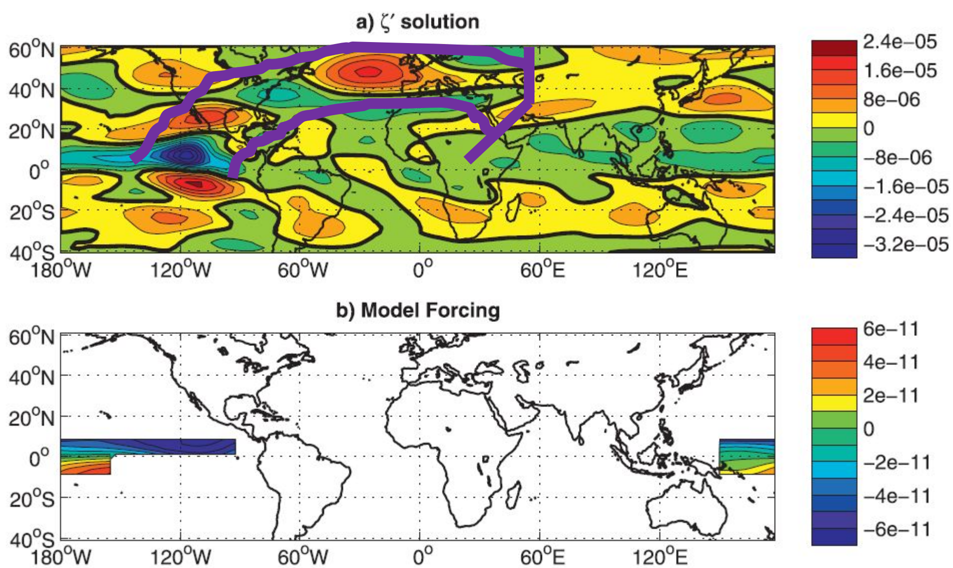
METEO-UB

ENSO

UNIVERSITAT DE BARCELONA

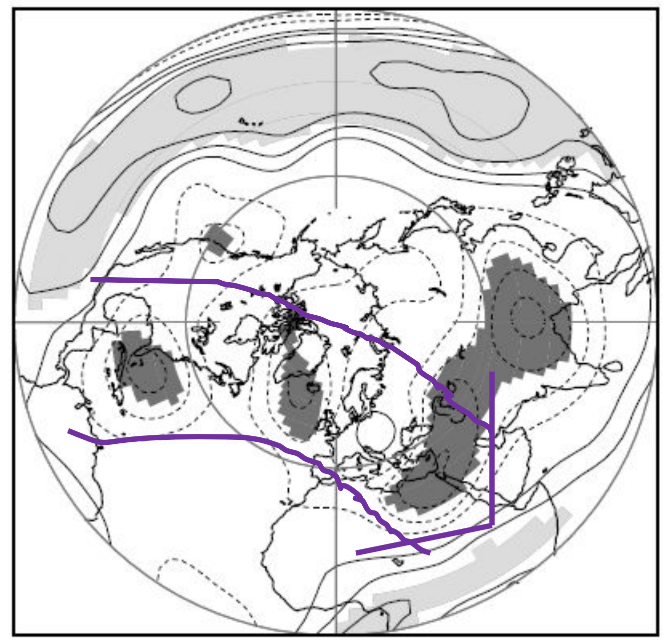


correlation map of precipitation with Niño3.4
[Mariotti et al. 2002]



[Shaman and Tziperman 2011]

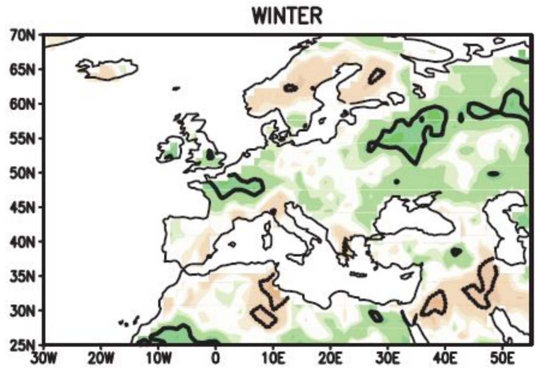
AUTUMN



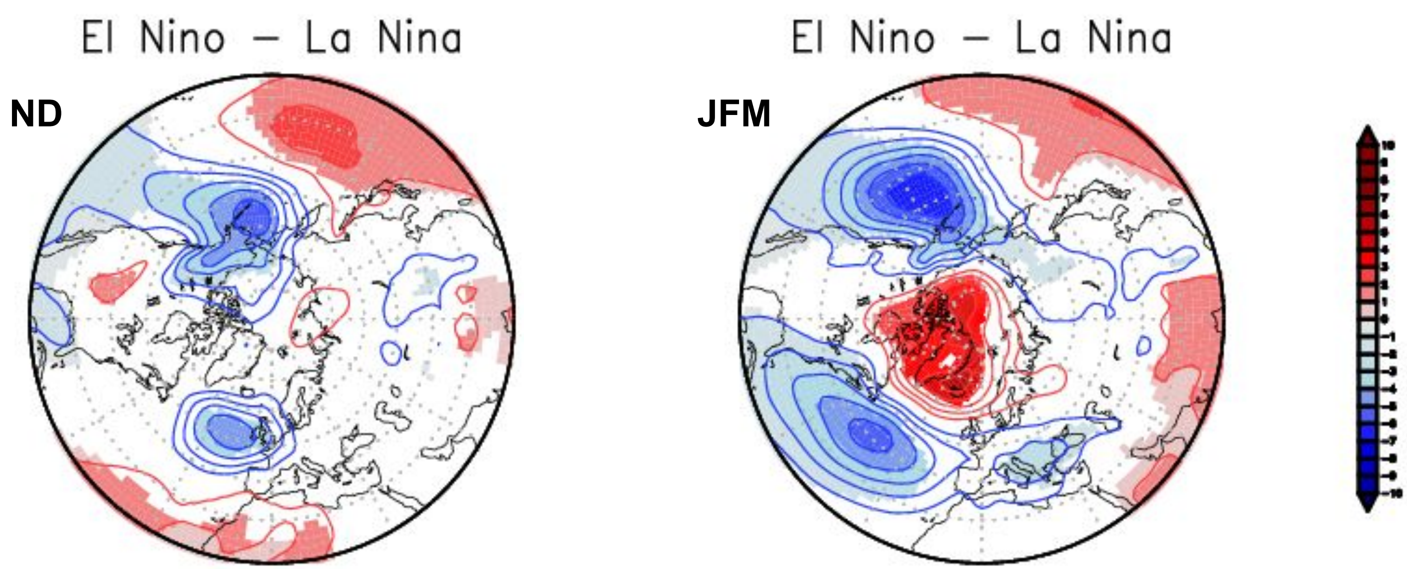
composite of PSI200 linked to El Niño
[Mariotti et al. 2005]

ENSO

WINTER



correlation map of precipitation with Niño3.4
[Mariotti et al. 2002]

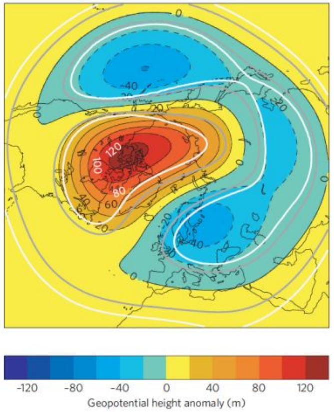


strong intra-seasonal modulation: early-winter (ND) vs mid/late-winter (JFM)
[Moron and Gouirand 2003; Gouirand et al. 2007; King et al. 2018; Ayarzagüena et al. 2018]

ENSO

Z50 (lower stratosphere)

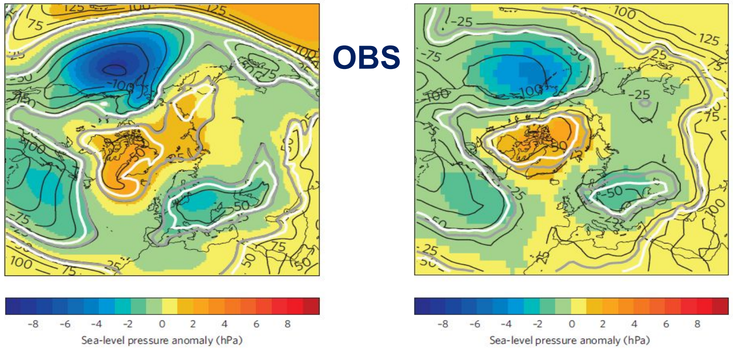
weakened polar vortex
[Ineson and Scaife 2009]



WINTER

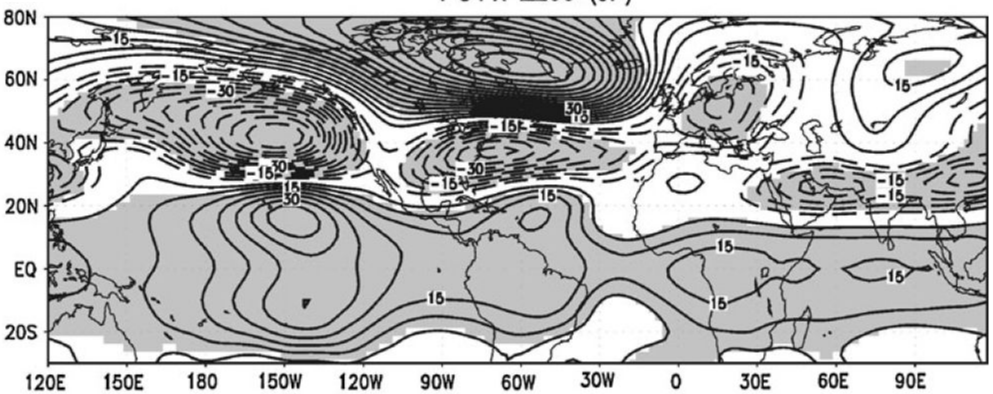
MOD

OBS

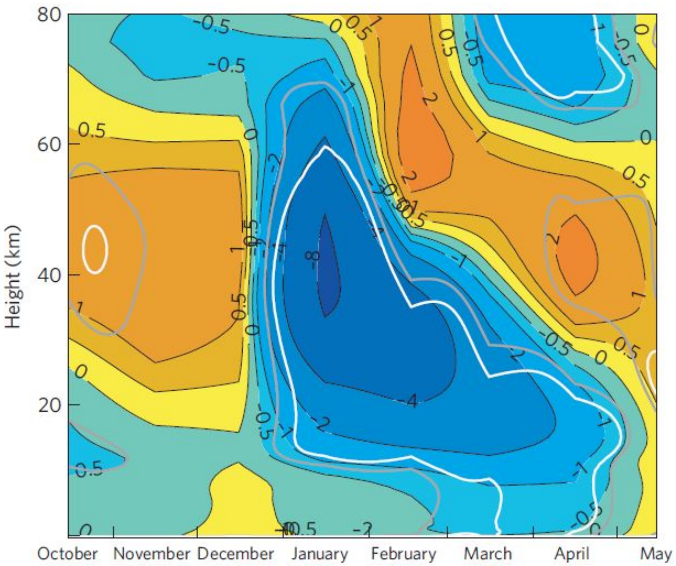


canonical signature in JFM [Ineson and Scaife 2009]

PC1 x Z200 (JF)



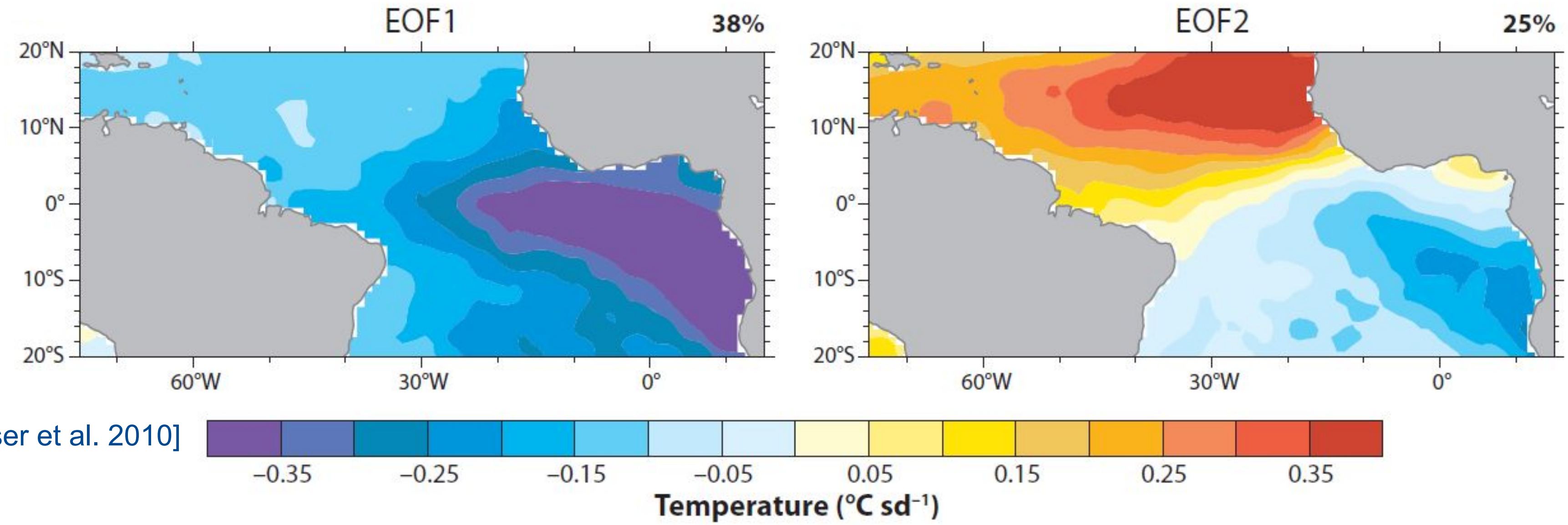
tropospheric pathway
[García-Serrano et al. 2011b; Mezzina et al. 2020, 2022]



stratosphere as feedback for persistence
[Cagnazzo and Manzini 2009]

stratospheric pathway
[Ineson and Scaife 2009; Bell et al. 2009]

TA
V



[Deser et al. 2010]

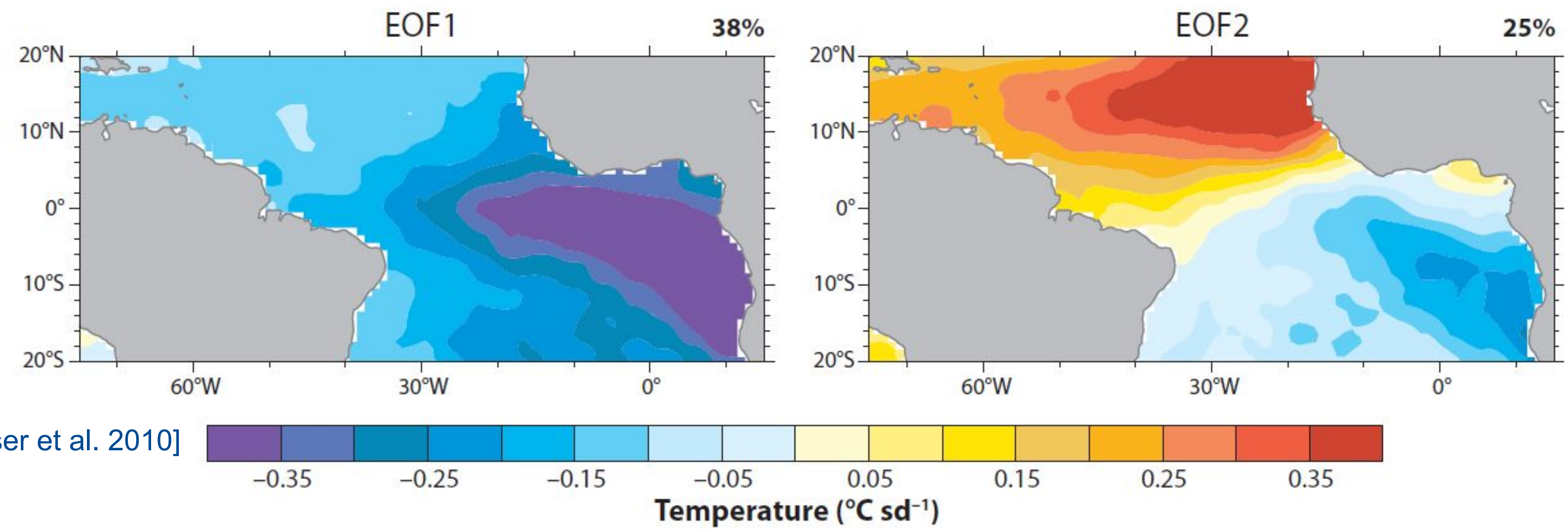
Tropical Atlantic Variability (TAV)

SST variability coupled to deep convection (ITCZ) in the tropical Atlantic

METEO-UB

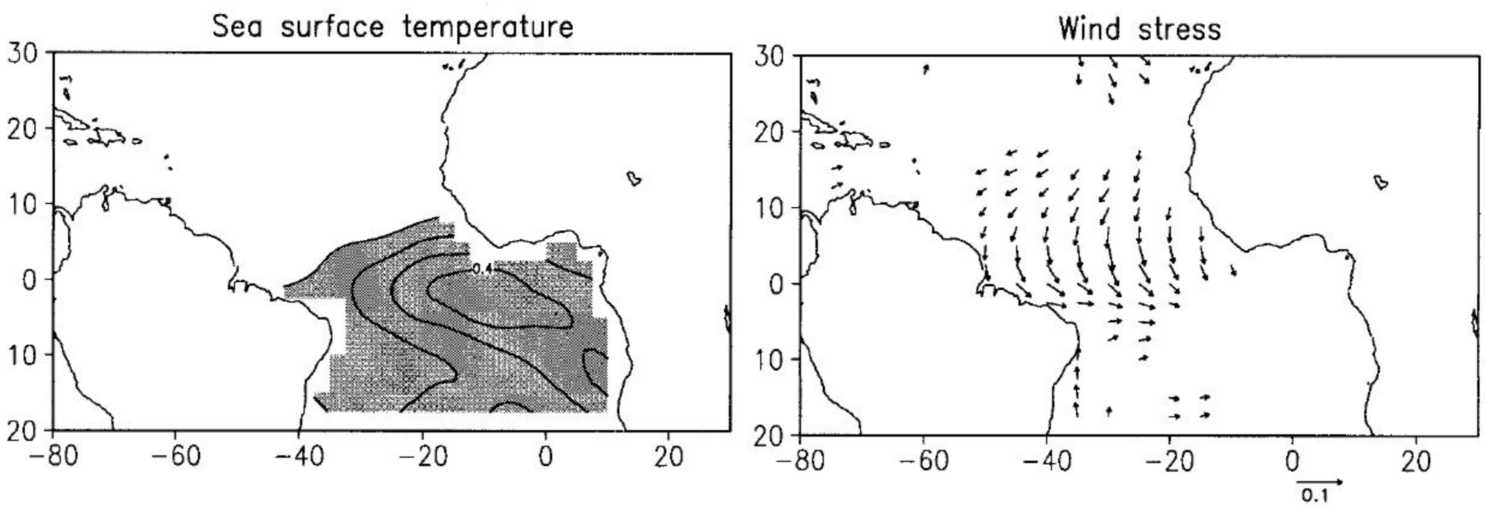
TA
V

UNIVERSITAT DE BARCELONA



[Deser et al. 2010]

Atlantic Niño (ATLN)



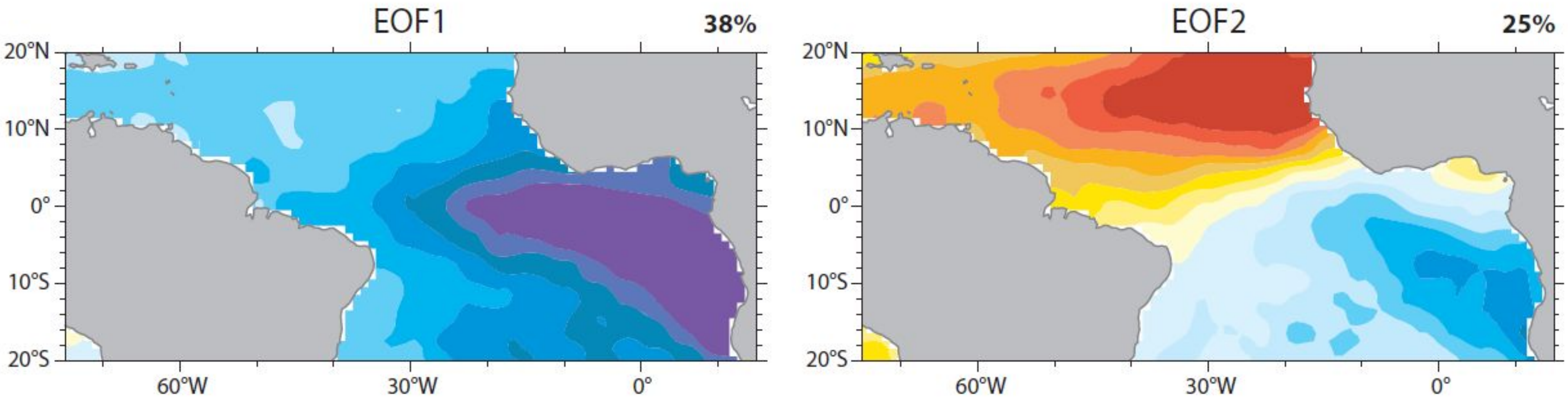
Bjerknes feedback

[Ruíz-Barradas et al. 2000]

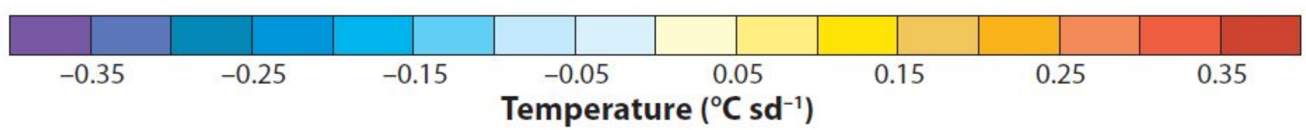
METEO-UB

TA
V

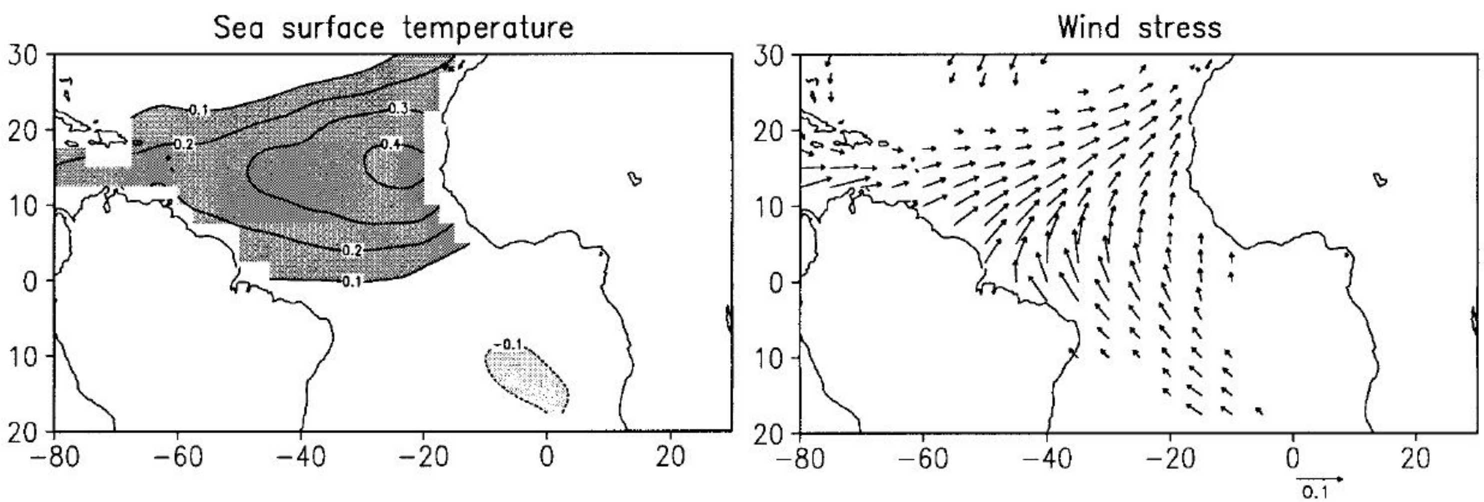
UNIVERSITAT DE BARCELONA



[Deser et al. 2010]



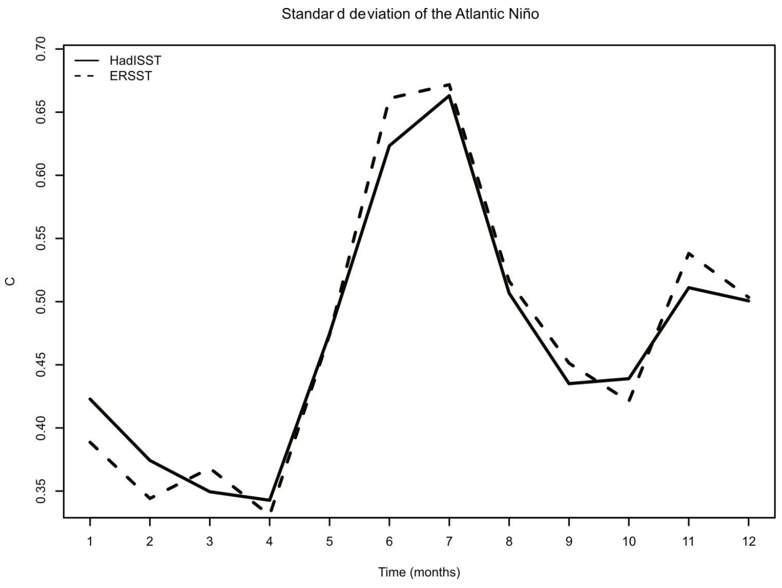
Subtropical North Atlantic (SNA)

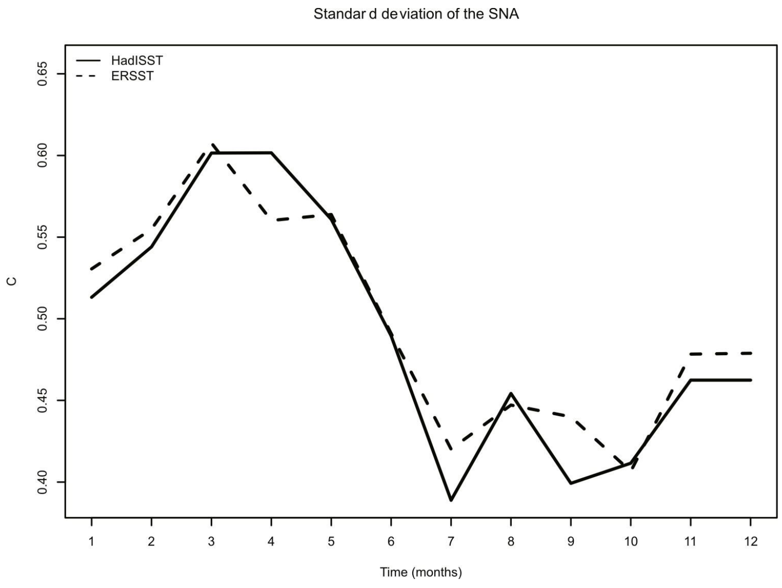


WES feedback

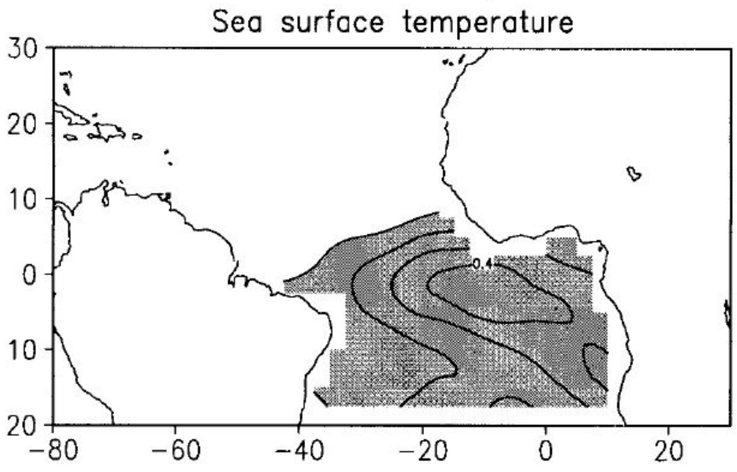
[Ruíz-Barradas et al. 2000]

TA
V

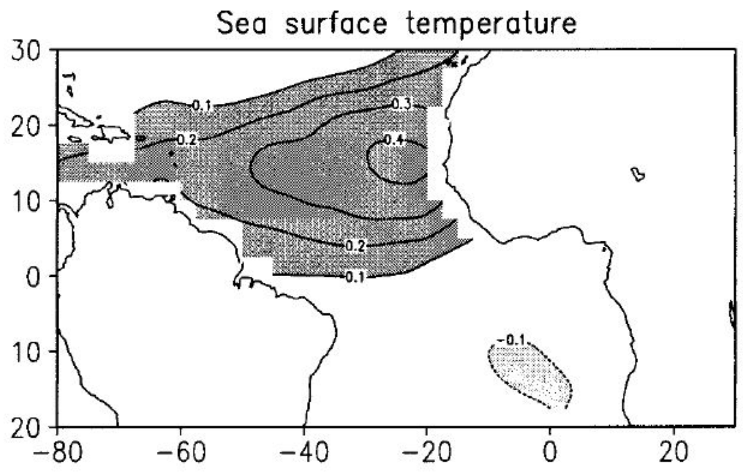




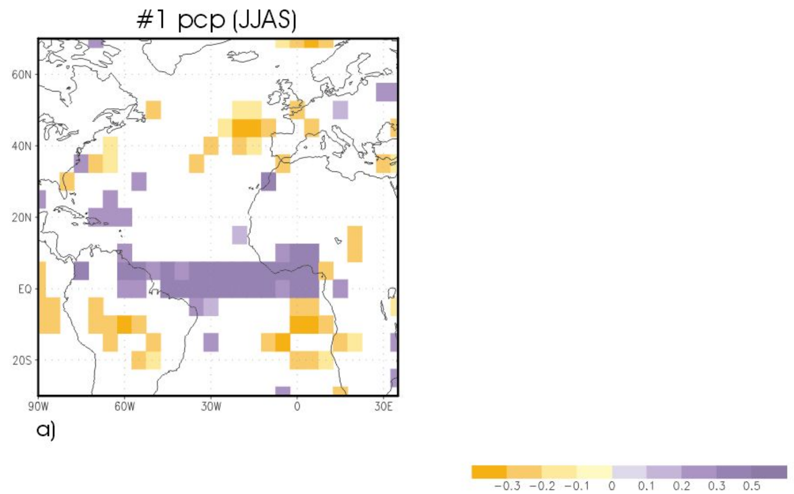
Atlantic Niño (ATLN)

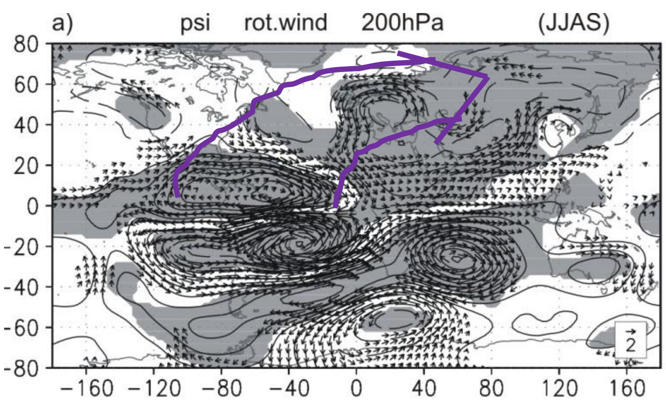


Subtropical North Atlantic (SNA)



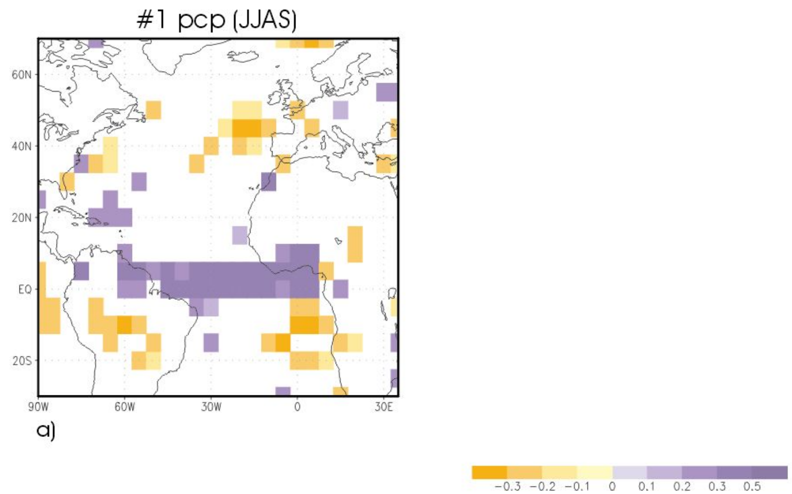
Atlantic Niño (ATLN)

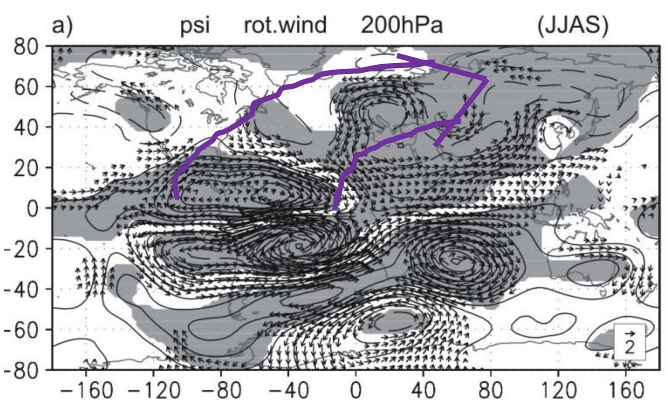


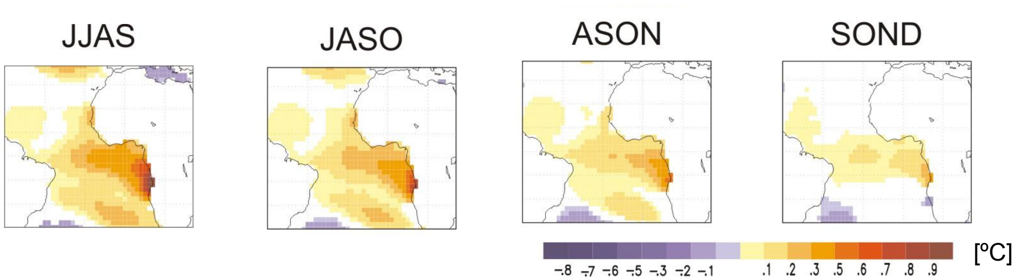


[García-Serrano et al. 2008, 2011a]

Atlantic Niño (ATLN)

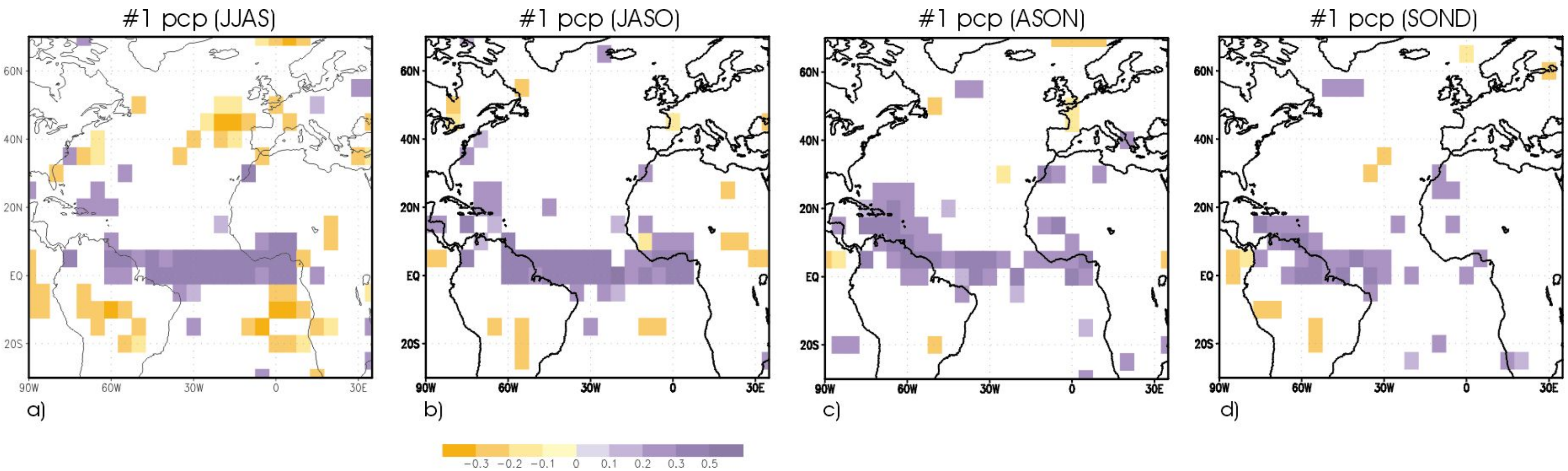


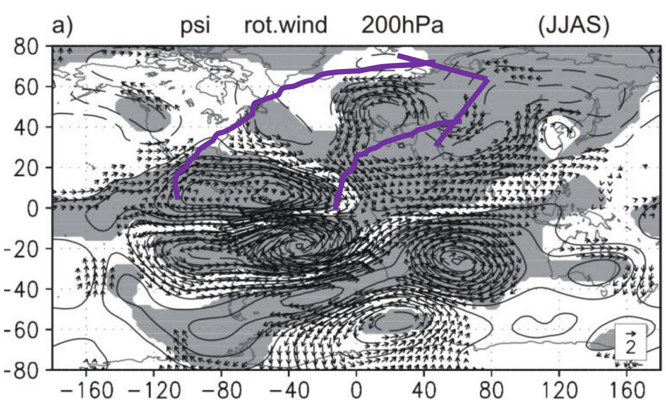


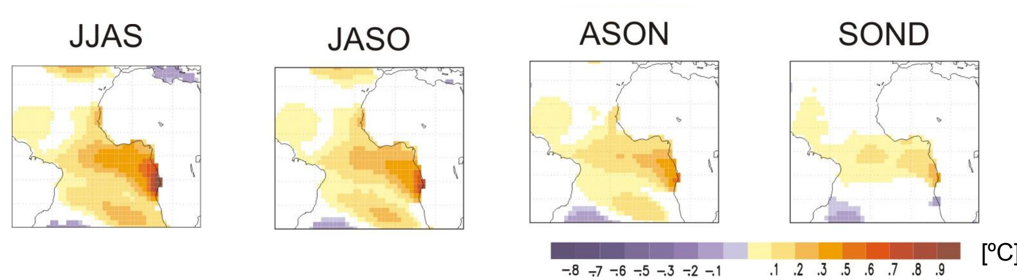


[García-Serrano et al. 2008, 2011a]

Atlantic Niño (ATLN)

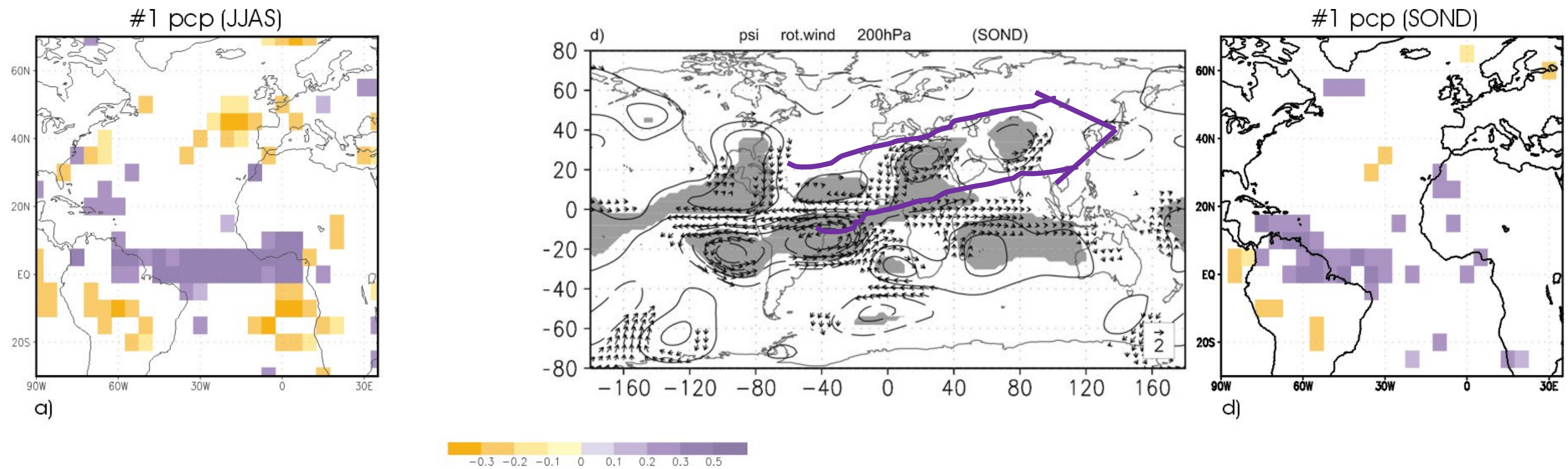


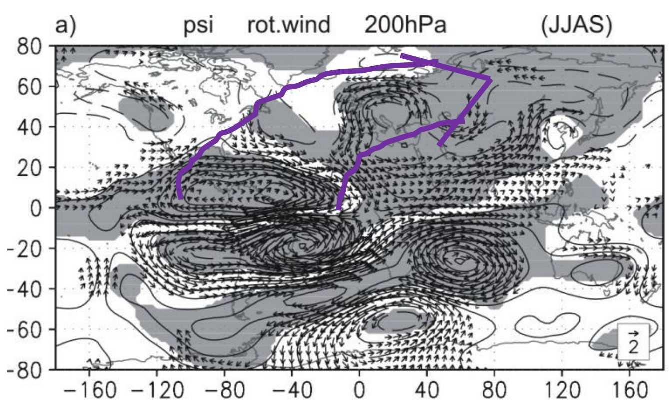


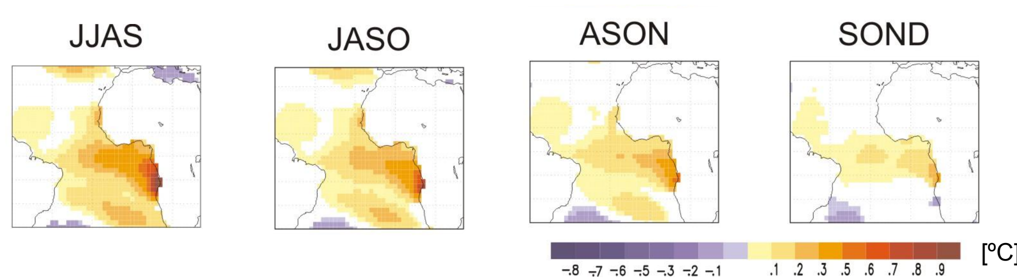


[García-Serrano et al. 2008, 2011a]

Atlantic Niño (ATLN)

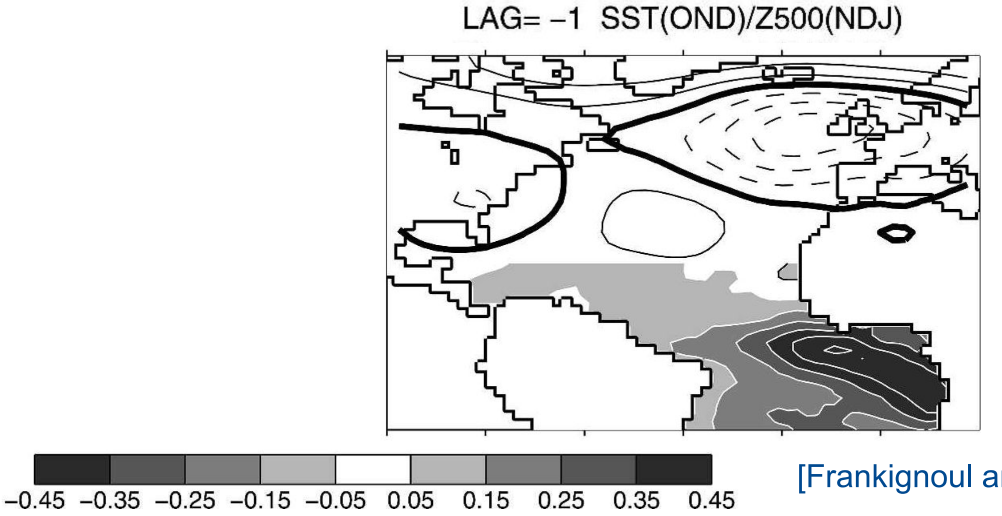






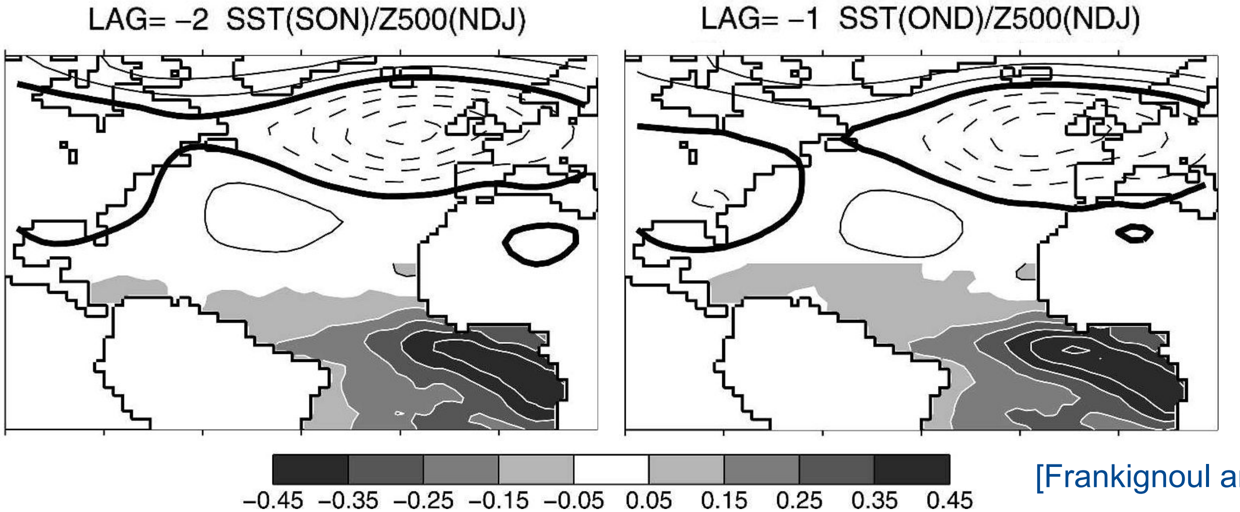
[García-Serrano et al. 2008, 2011a]

Atlantic Niño (ATLN)



[Frankignoul and Kestenare 2005]

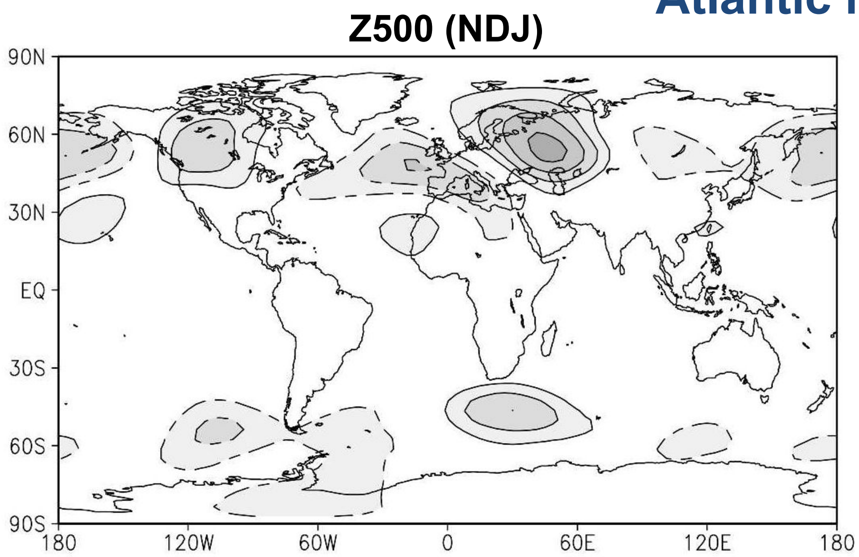
Atlantic Niño (ATLN)



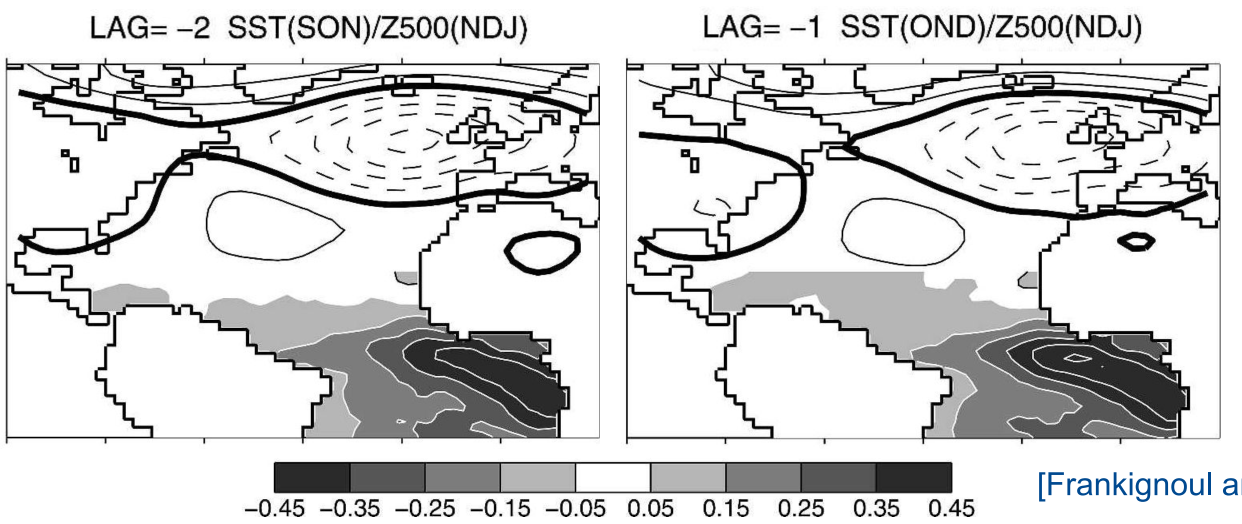
[Frankignoul and Kestenare 2005]

atmospheric response

Atlantic Niño (ATLN)



[Haarsma and Wazeleger 2007]

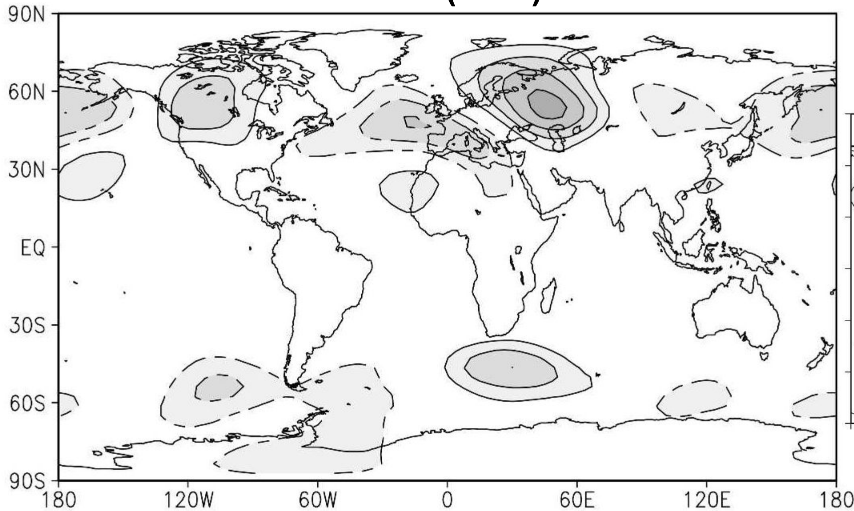


[Frankignoul and Kestenare 2005]

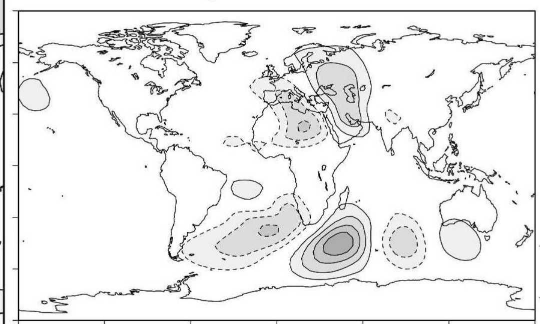
Atlantic Niño (ATLN)

atmospheric response

Z500 (NDJ)

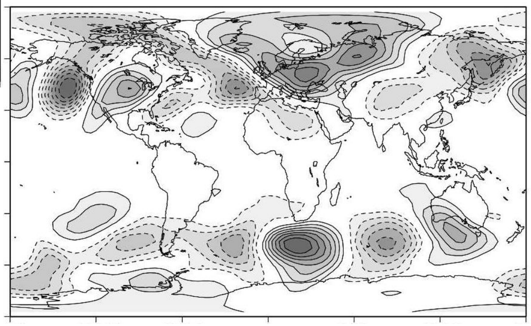


day 6–10



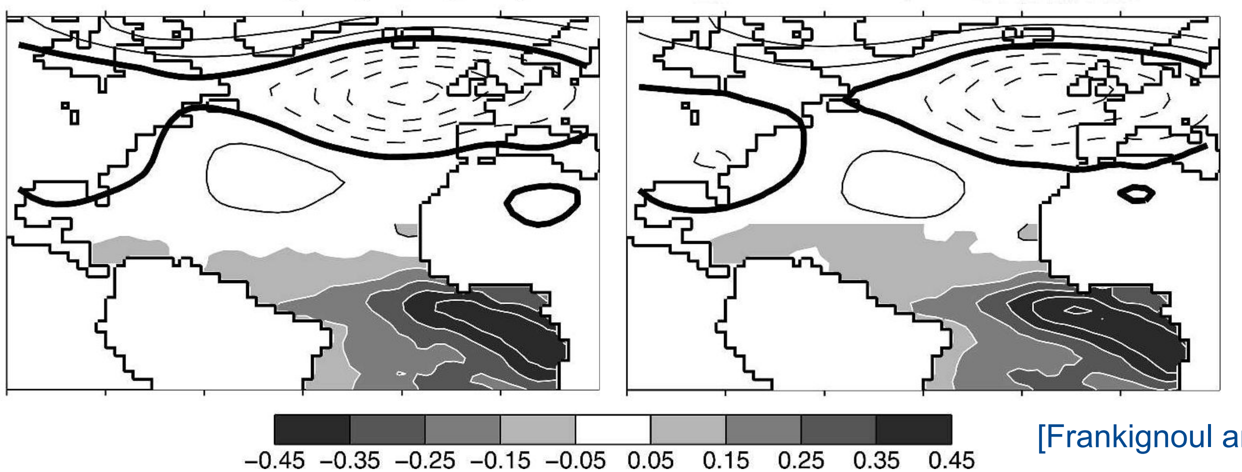
[Haarsma and Wazeleger 2007]

day 26–30



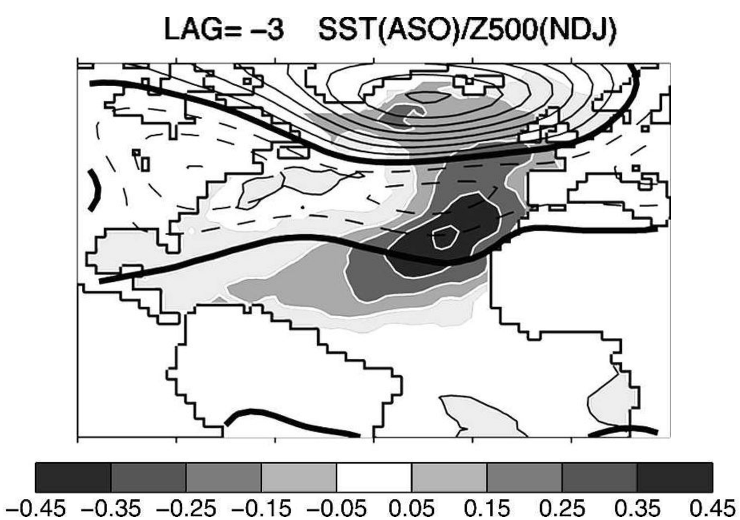
LAG= –2 SST(SON)/Z500(NDJ)

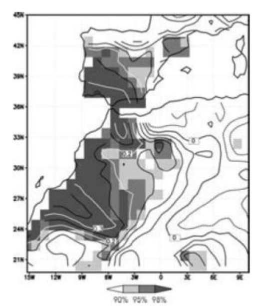
LAG= –1 SST(OND)/Z500(NDJ)

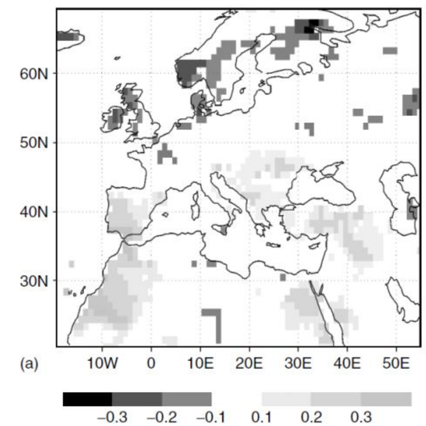


[Frankignoul and Kestenare 2005]

Subtropical North Atlantic (SNA)



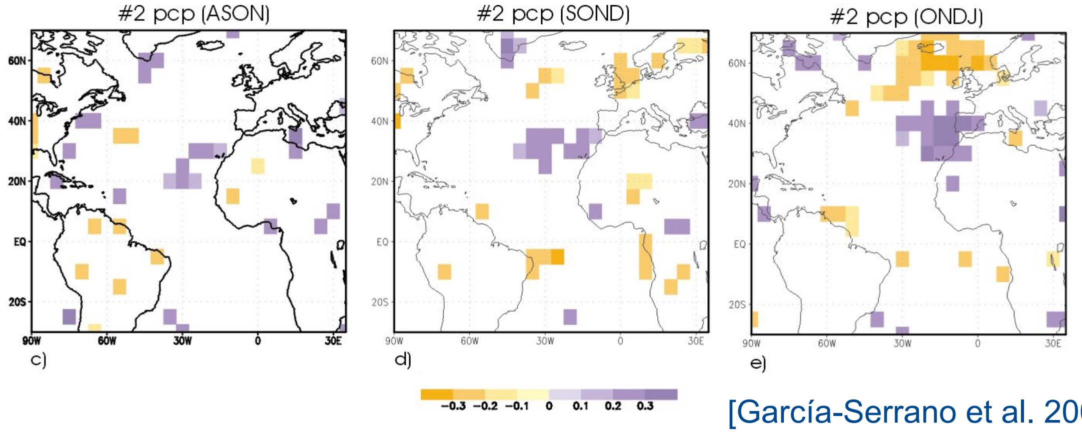




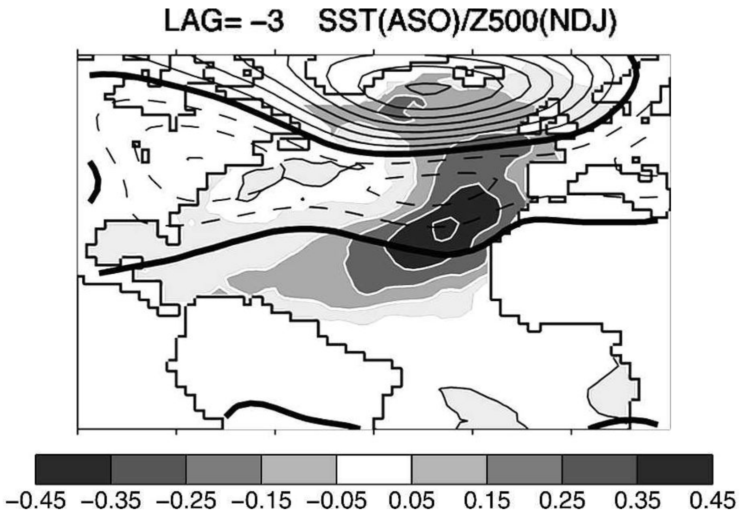
[Rodríguez-Fonseca and Castro 2002; Rodríguez-Fonseca et al. 2006]

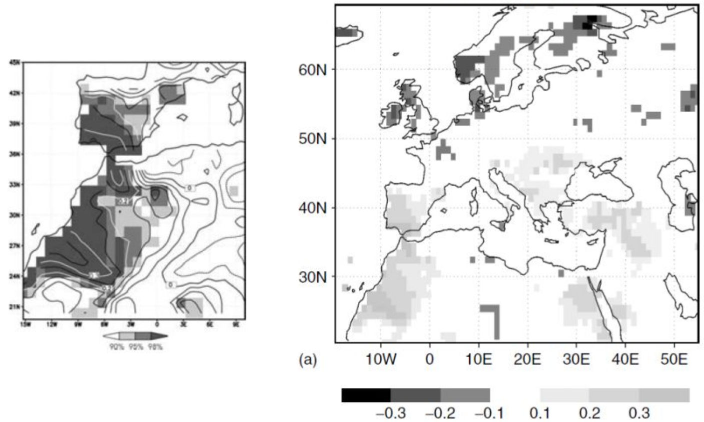
[Frankignoul and Kestenare 2005]

Subtropical North Atlantic (SNA)



[García-Serrano et al. 2008]

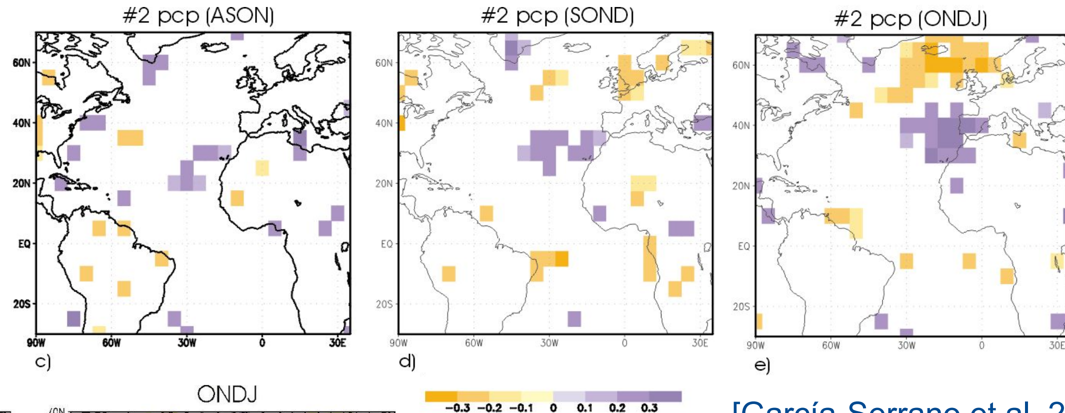




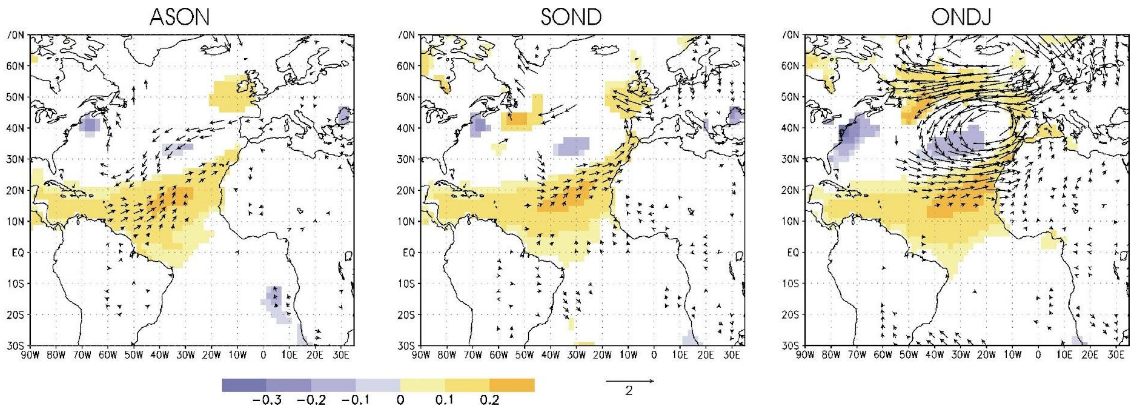
[Rodríguez-Fonseca and Castro 2002; Rodríguez-Fonseca et al. 2006]

[Frankignoul and Kestenare 2005]

Subtropical North Atlantic (SNA)

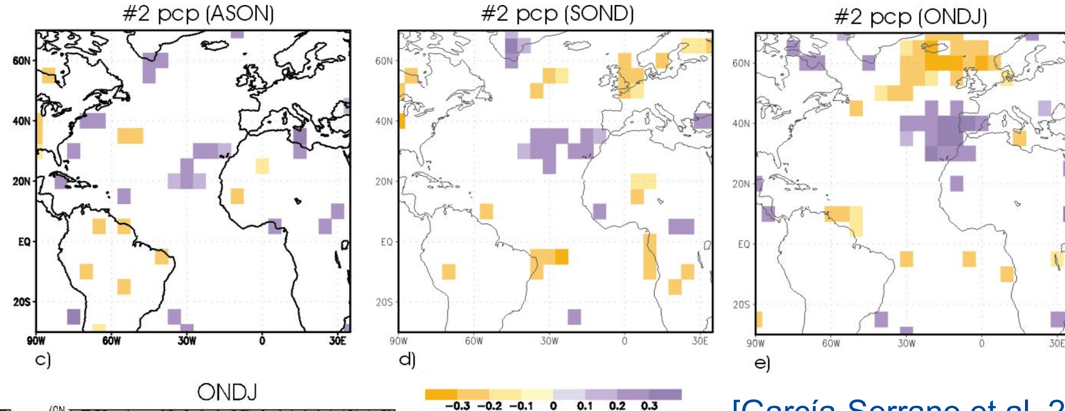


[García-Serrano et al. 2008]

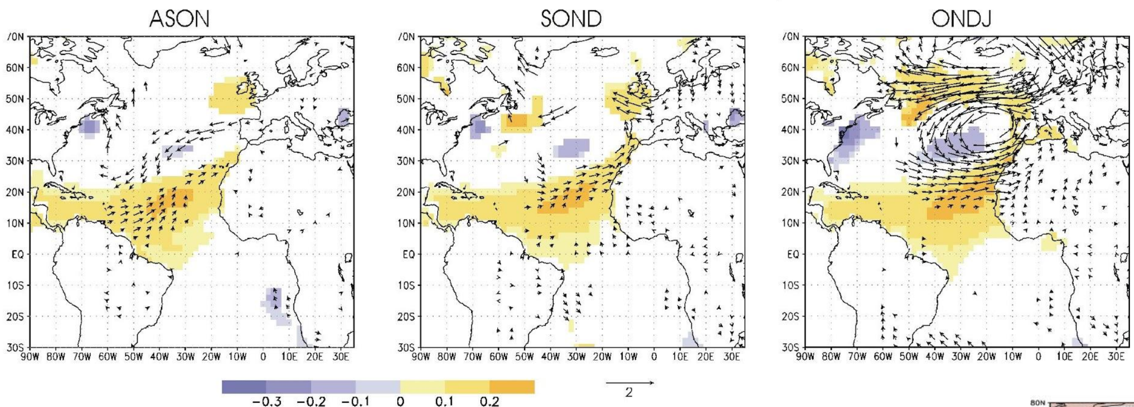


SST, wind.925

Subtropical North Atlantic (SNA)

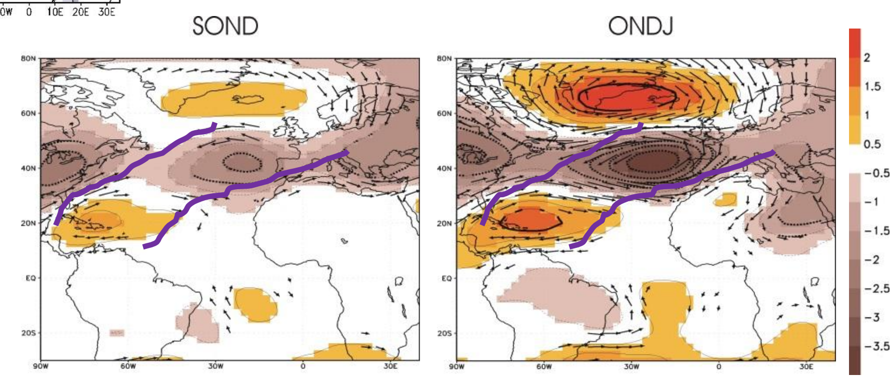


[García-Serrano et al. 2008]



SST, wind.925

PSI200, rot.wind

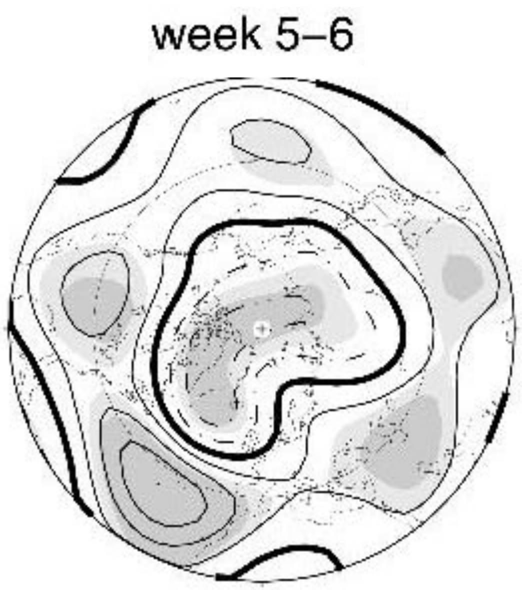


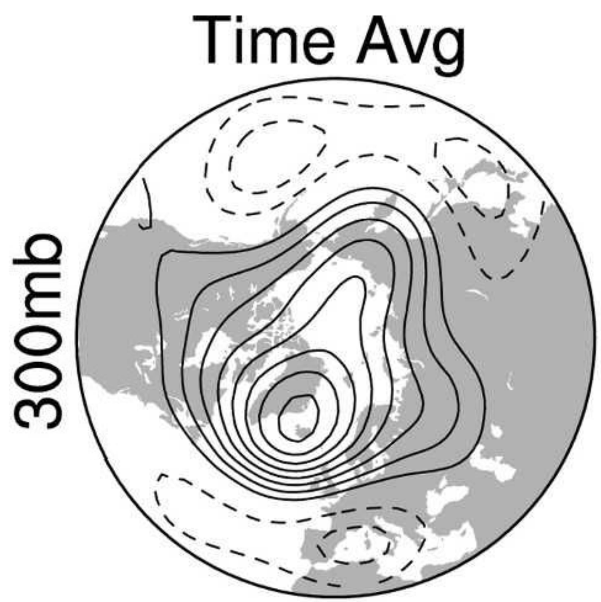
METEO-UB

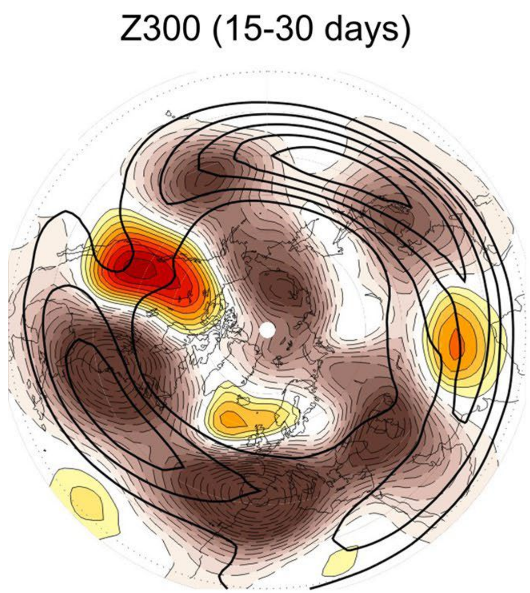
NAO

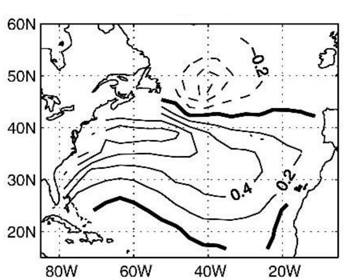
UNIVERSITAT DE BARCELONA

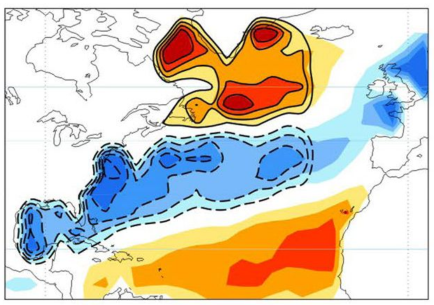
NAO coupling to the ocean (North Atlantic) persistence/predictability











[Ferreira and Frankignoul 2005]

[Deser et al. 2007]

[García-Serrano and Haarsma 2016]

Arctic sea-ice

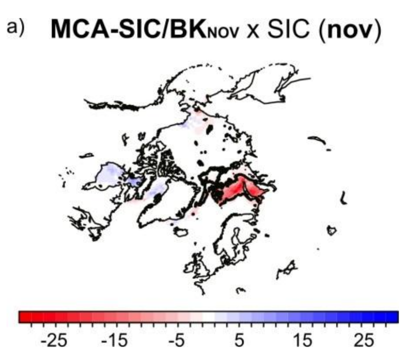
METEO-UB

UNIVERSITAT DE BARCELONA

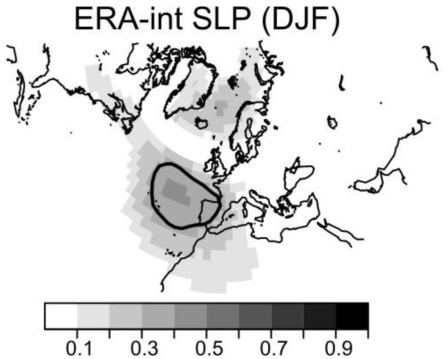
Barents-Kara sea-ice concentration in autumn (**NOV**)

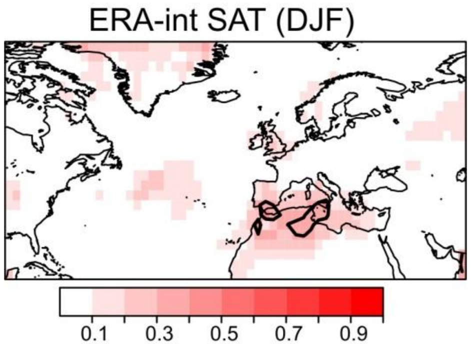
[García-Serrano et al. 2015; King et al. 2015; Koenigk et al. 2015]

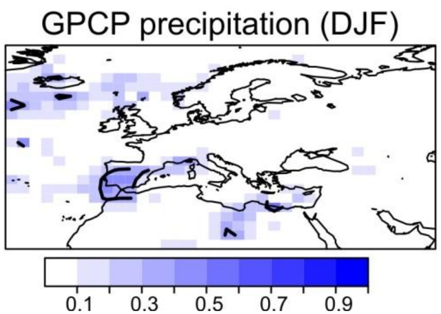
[Scaife et al. 2014; Dunstone et al. 2016]



[García-Serrano et al. 2015, 2017]





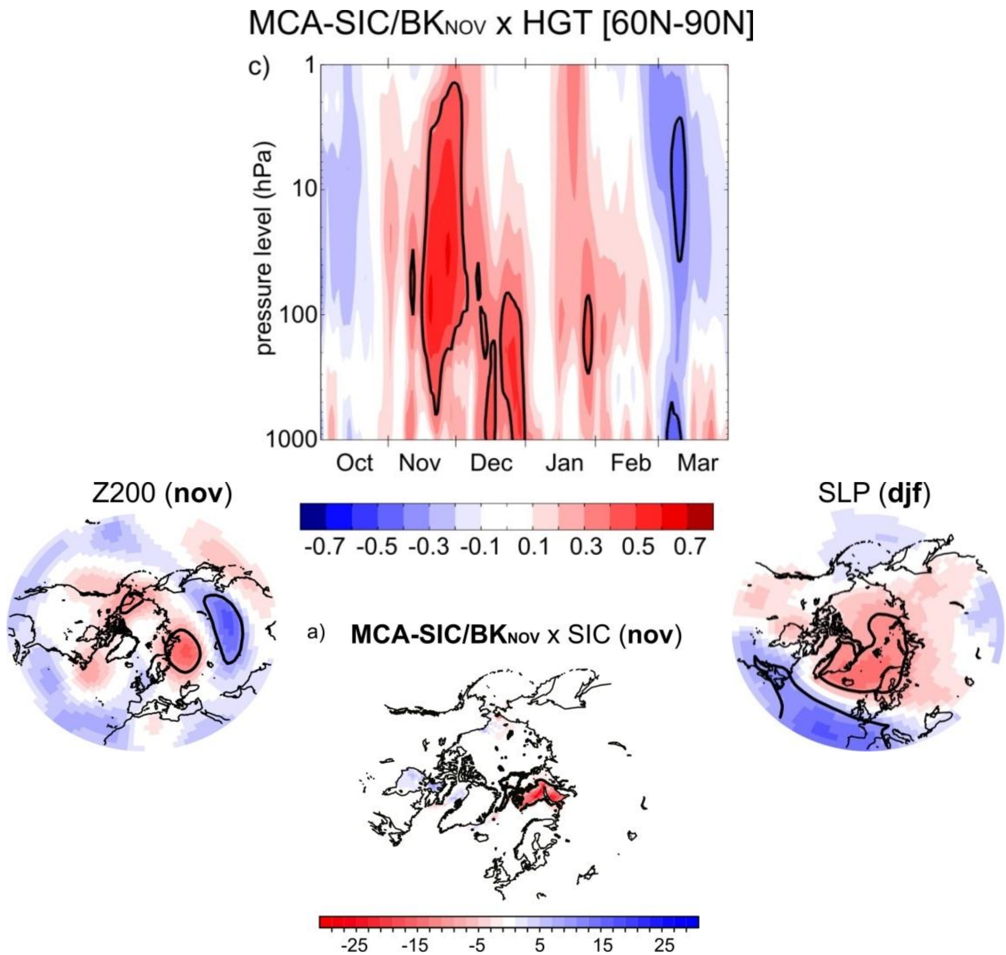


empirical prediction skill

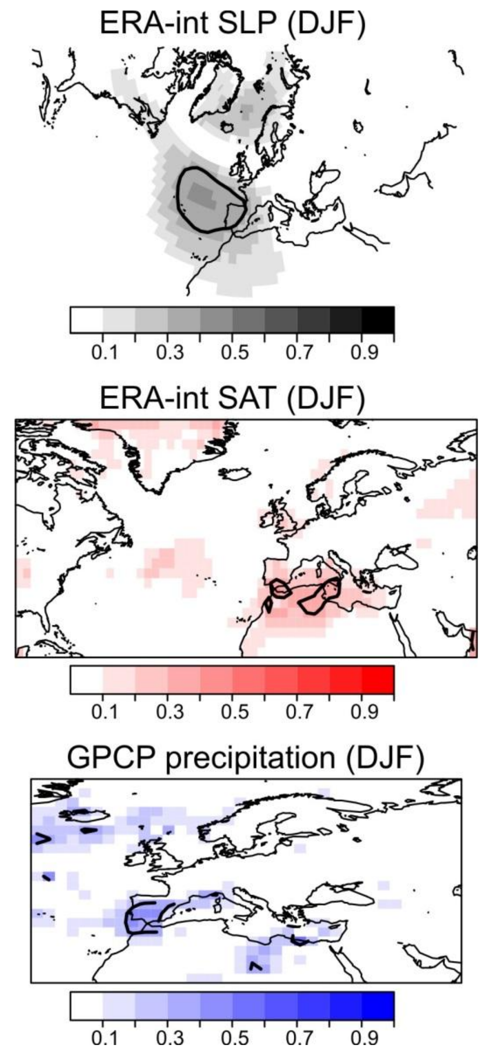
[García-Serrano et al. 2015]

Arctic sea-ice

Barents-Kara sea-ice concentration in autumn (**NOV**)
[García-Serrano et al. 2015; King et al. 2015; Koenigk et al. 2015]
[Scaife et al. 2014; Dunstone et al. 2016]



[García-Serrano et al. 2015, 2017]

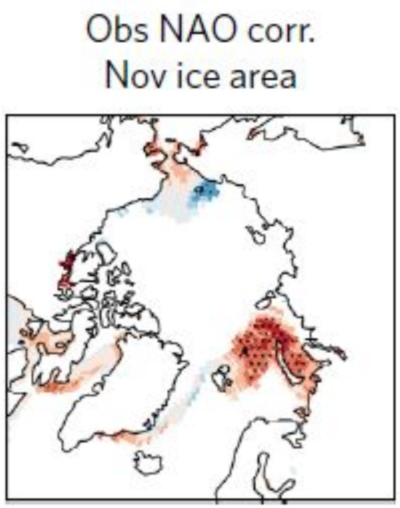


empirical prediction skill
[García-Serrano et al. 2015]

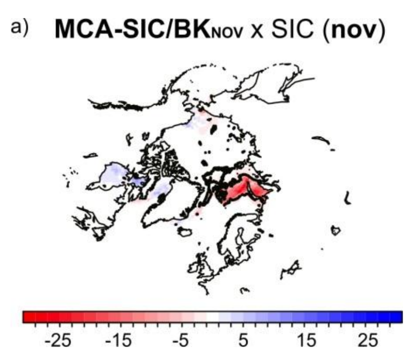
Arctic sea-ice

Barents-Kara sea-ice concentration in autumn (NOV)

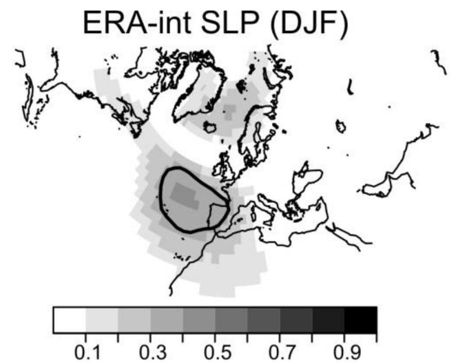
[García-Serrano et al. 2015; King et al. 2015; Koenigk et al. 2015]
[Scaife et al. 2014; Dunstone et al. 2016]

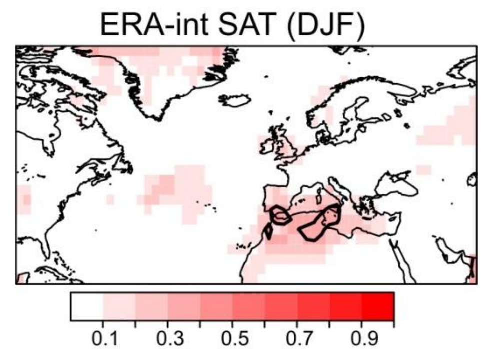


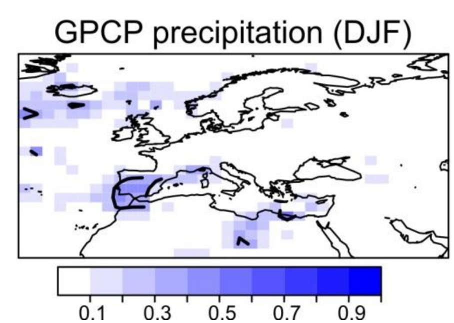
[Dunstone et al. 2016]



[García-Serrano et al. 2015, 2017]







empirical prediction skill
[García-Serrano et al. 2015]

METEO-UB

Arctic sea-ice

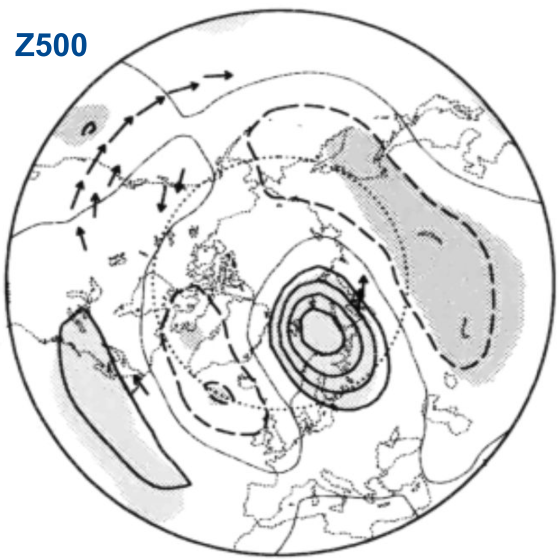
UNIVERSITAT DE BARCELONA

what precedes the winter NAO NAO precursors

November

wave-like anomalies over Eurasia coupled
to troposphere-stratosphere variability

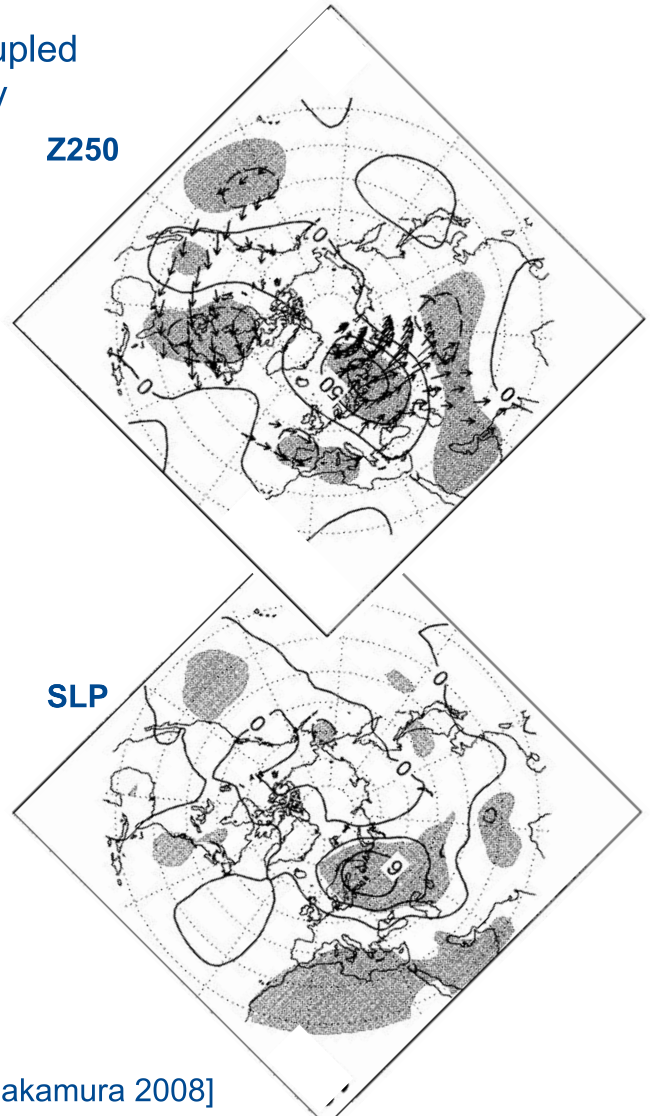
Z500



[Kuroda and Kodera 1999]

Z250

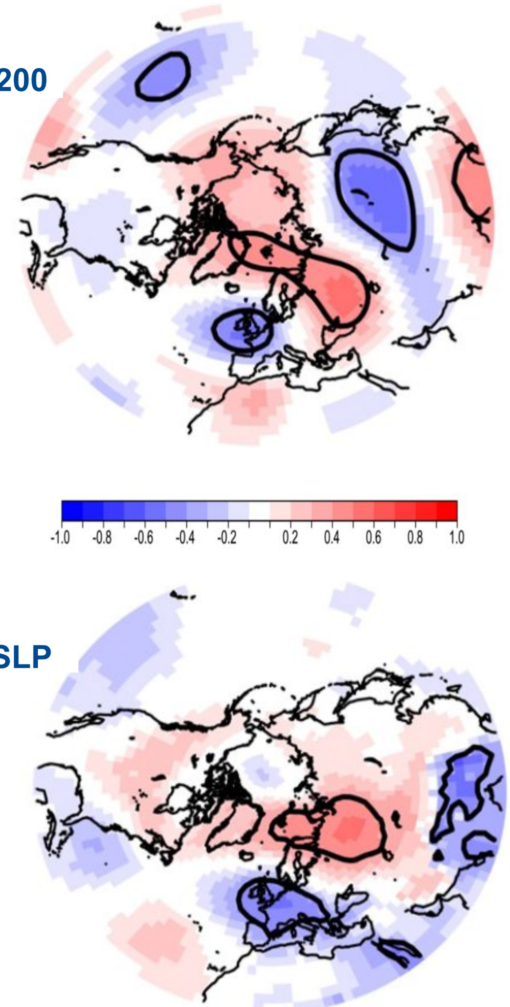
SLP



[Takaya and Nakamura 2008]

Z200

SLP



[García-Serrano et al. 2015]

METEO-UB

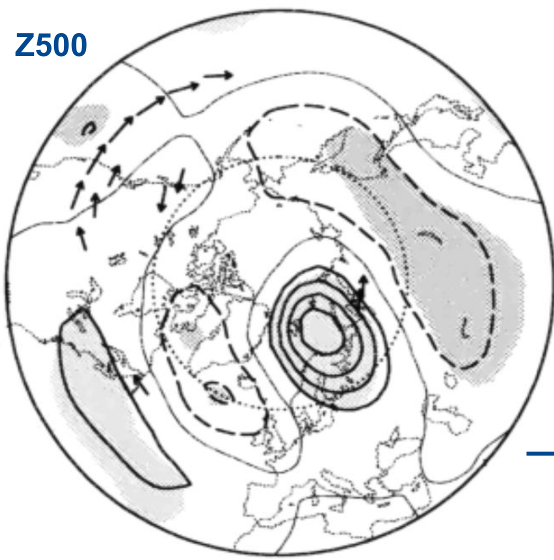
Arctic sea-ice

what precedes the winter NAO □ NAO precursors

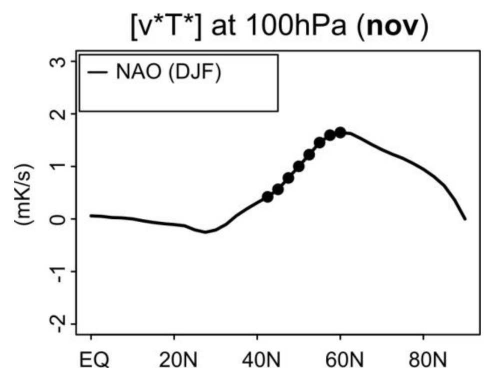
November

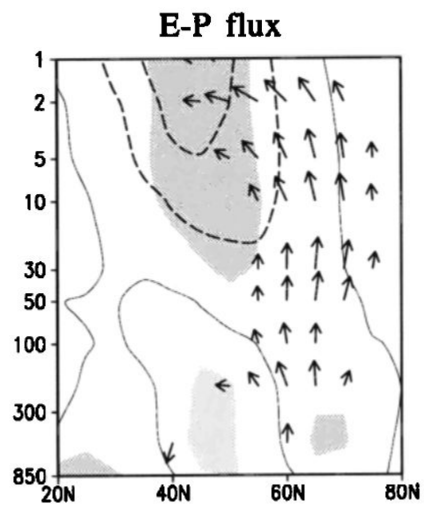
wave-like anomalies over Eurasia coupled to troposphere-stratosphere variability

Z500

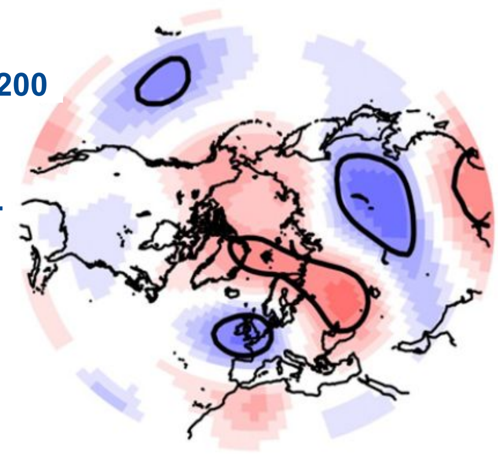


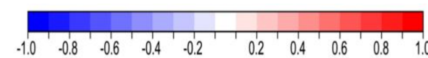
[Kuroda and Kodera 1999]



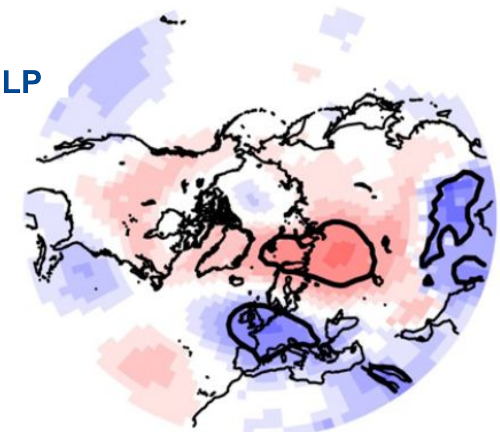


Z200





SLP



[García-Serrano et al. 2015]

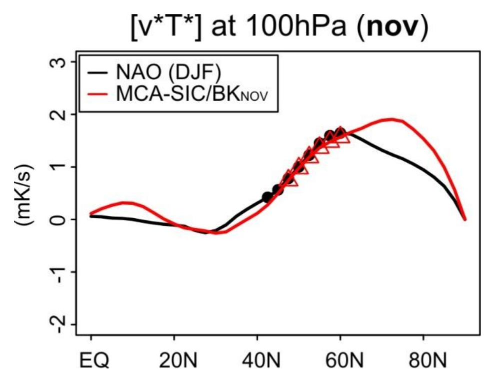
METEO-UB

Arctic sea-ice

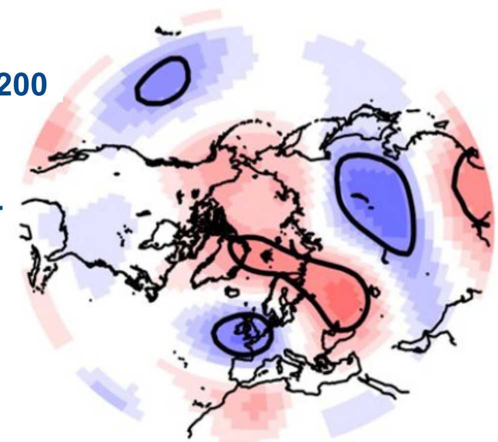
what precedes the winter NAO □ NAO precursors

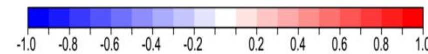
November

wave-like anomalies over Eurasia coupled to troposphere-stratosphere variability

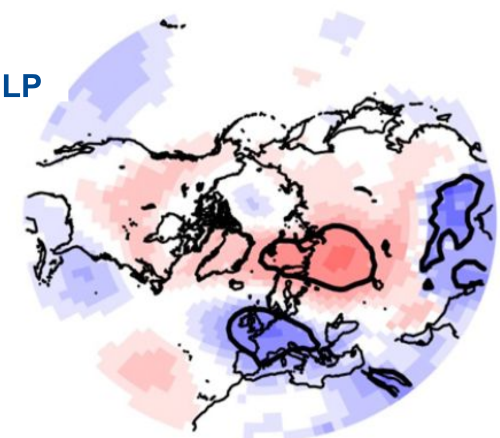


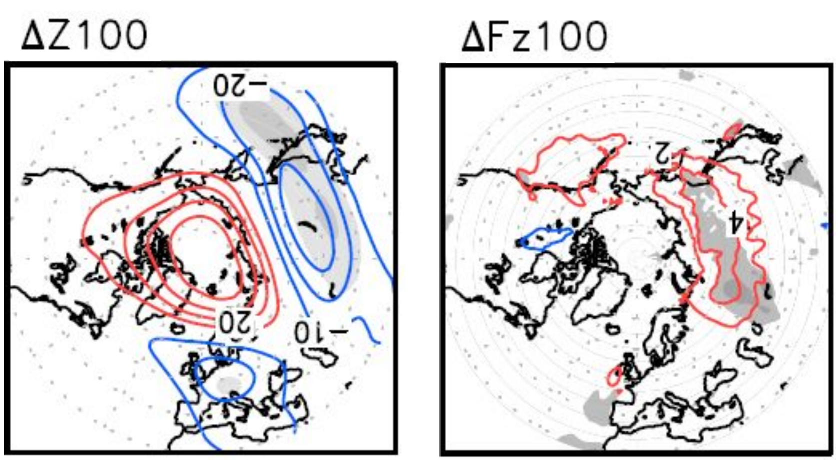
Z200





SLP

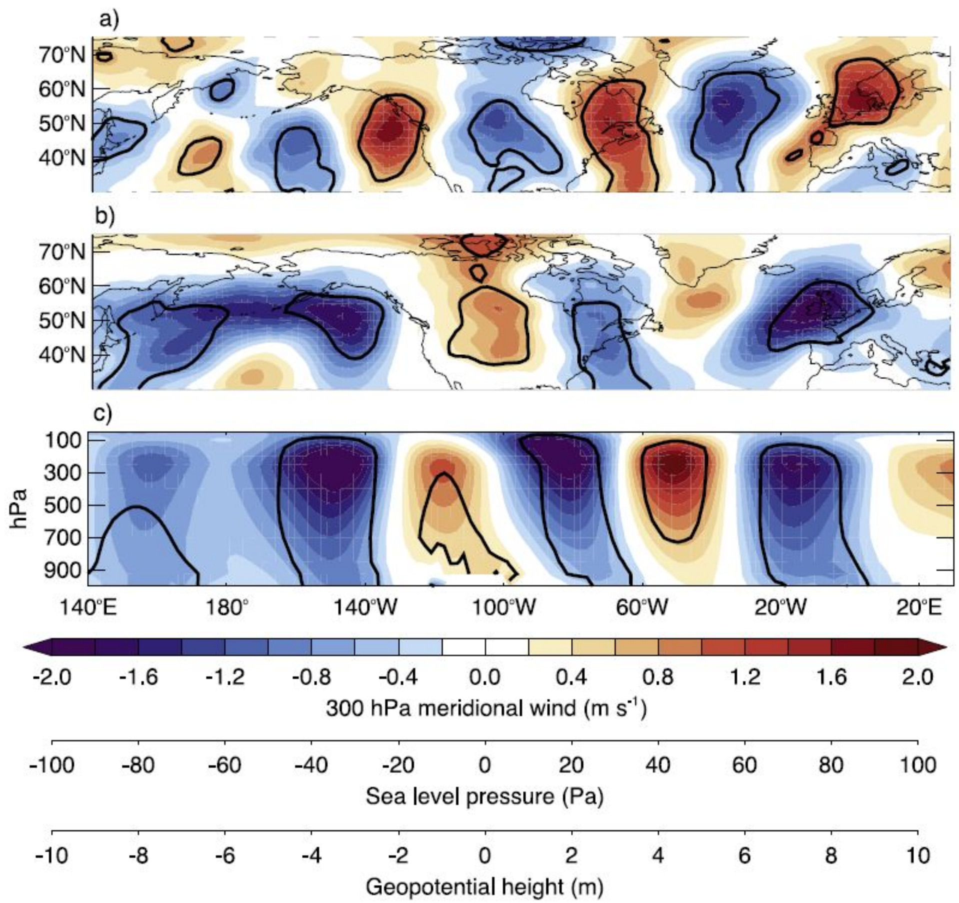




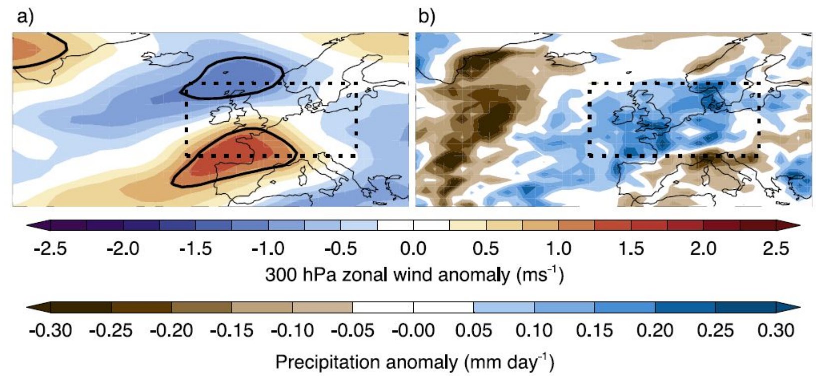
[Nakamura et al. 2016]

[García-Serrano et al. 2015]

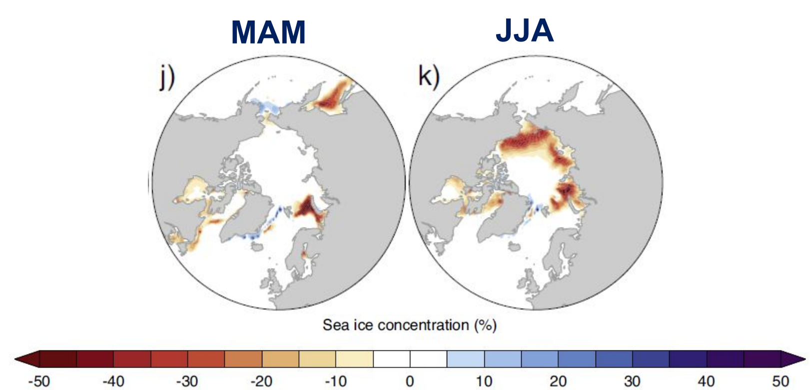
Arctic sea-ice



SUMMER



sea-ice reduction linked to weakening of the North Atlantic westerly-jet

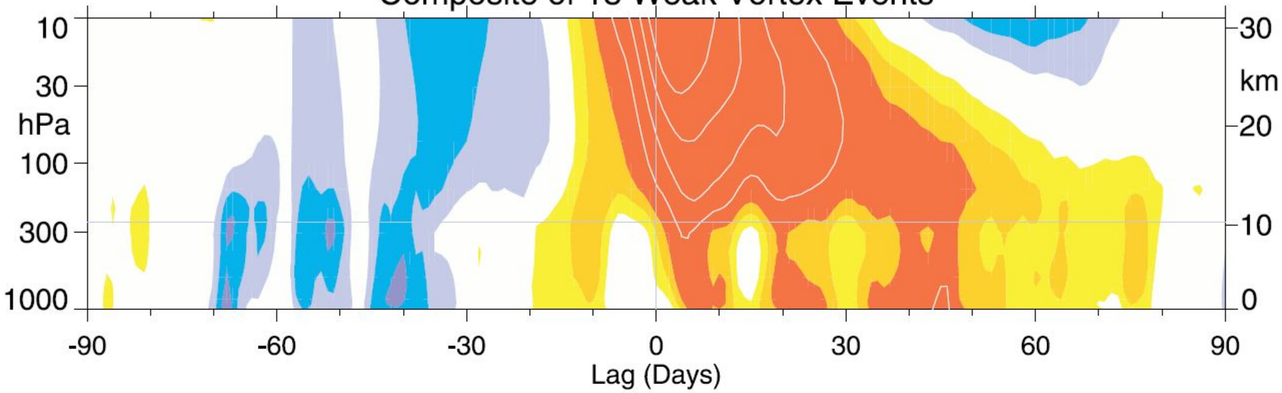


Arctic sea-ice is also a precursor for summer atmospheric circulation and rainfall anomalies over Europe
[Screen 2013]

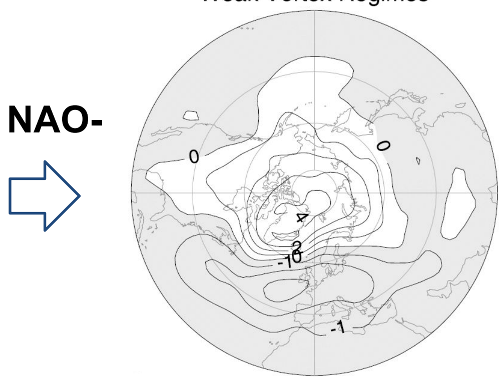
stratosphere (SSWs)

NAO coupling to the stratosphere predictability

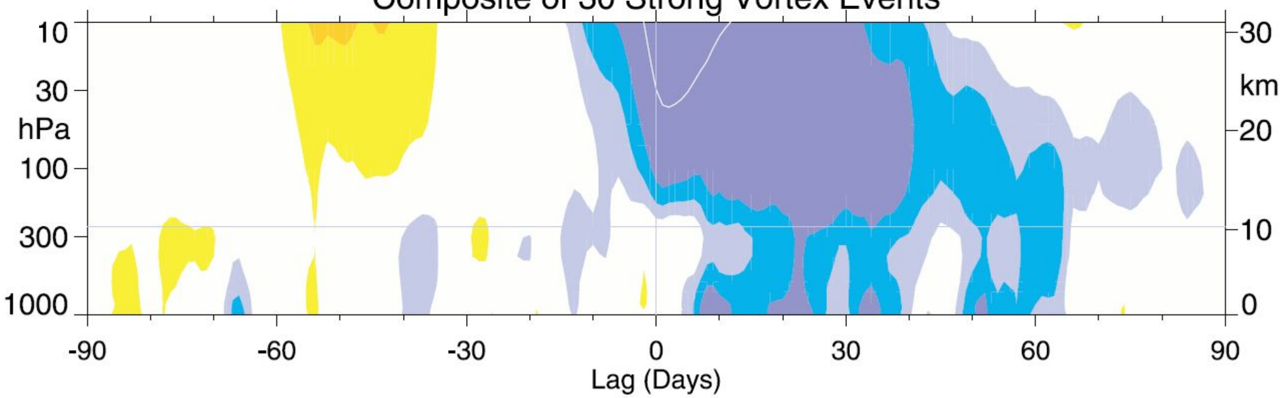
Composite of 18 Weak Vortex Events



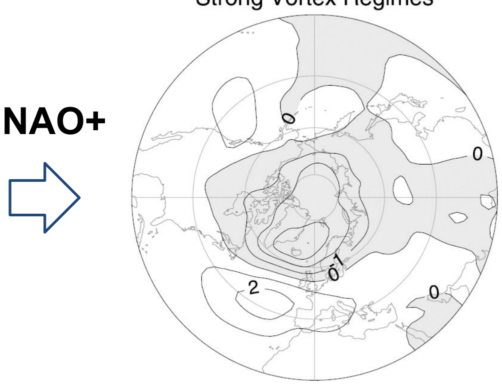
Weak Vortex Regimes



Composite of 30 Strong Vortex Events



Strong Vortex Regimes



[Baldwin and Dunkerton 2002]

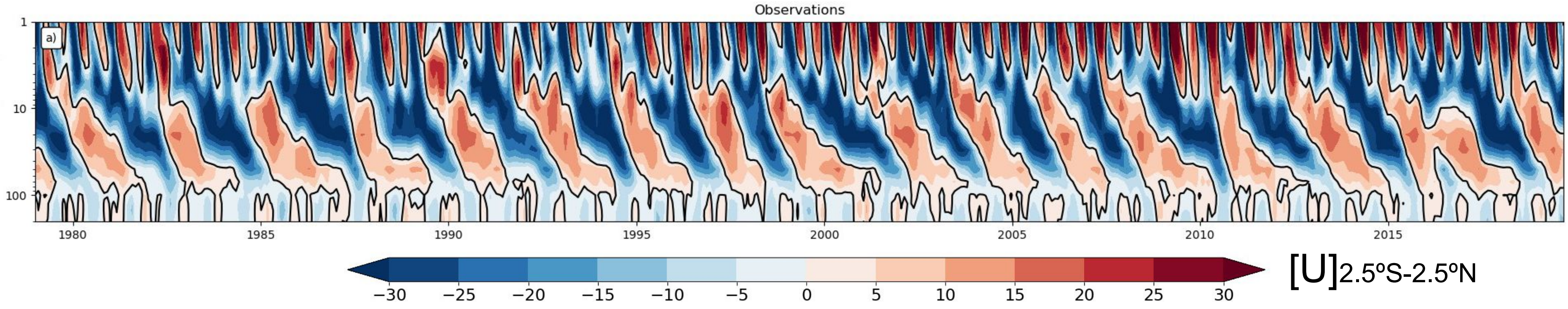
METEO-UB

QBO

UNIVERSITAT DE BARCELONA

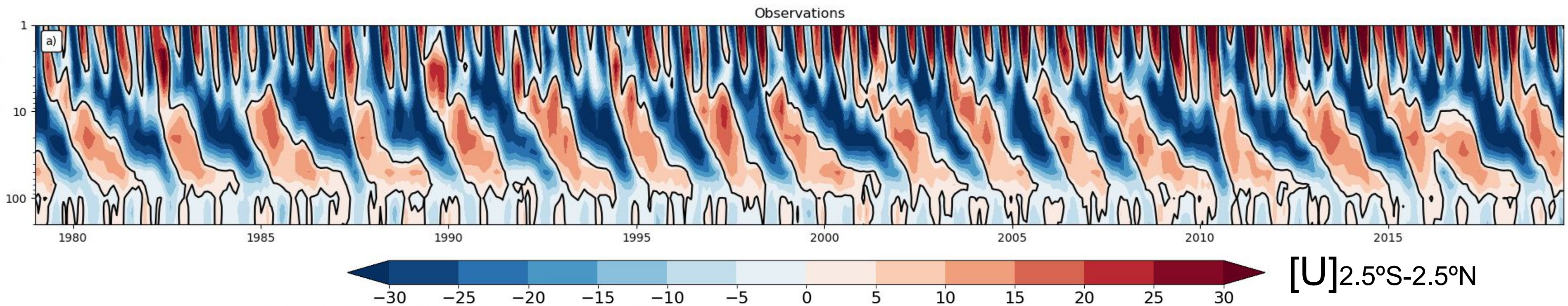
Quasi-Biennial Oscillation (QBO)

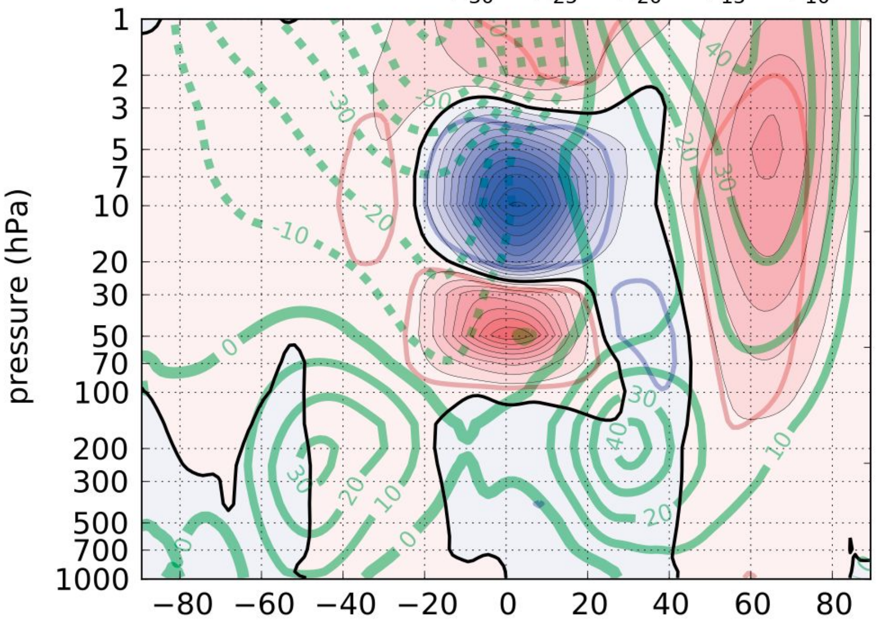
leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds



Quasi-Biennial Oscillation (QBO)

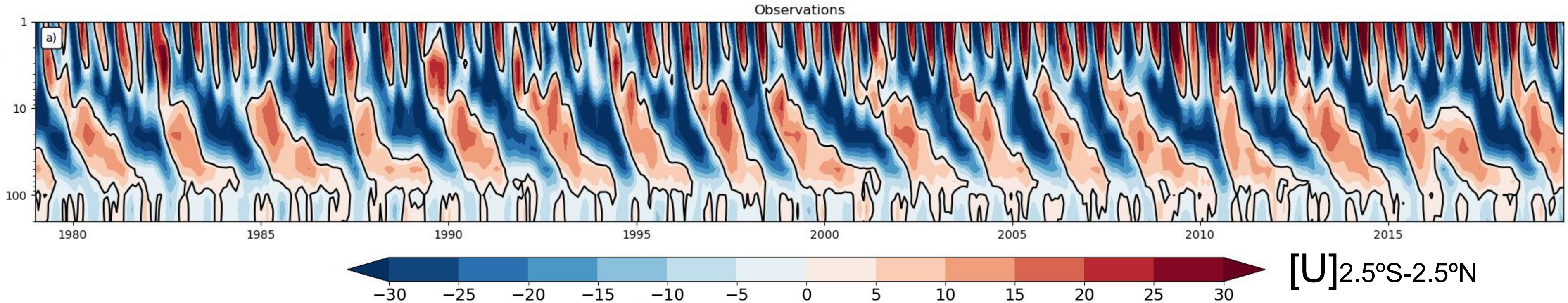
leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds

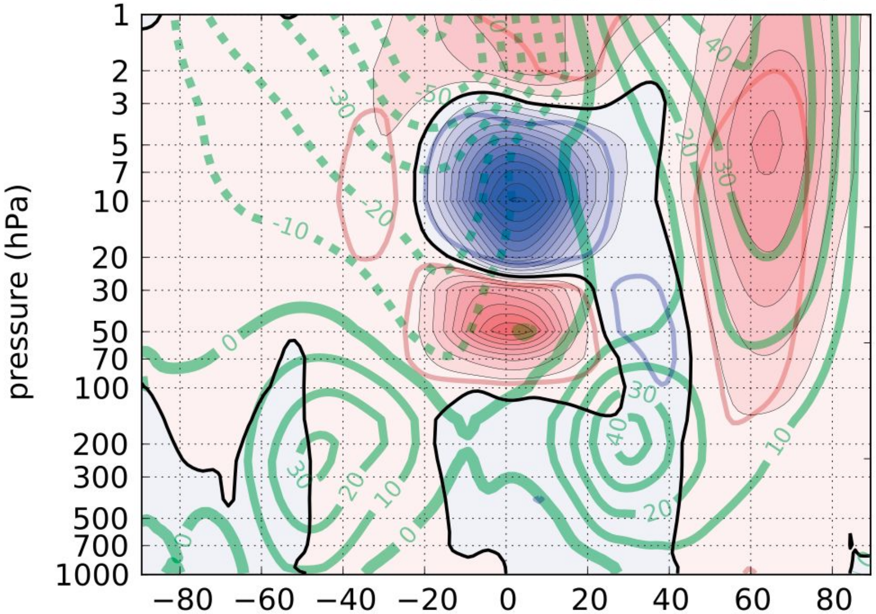




Quasi-Biennial Oscillation (QBO)

leading mode of interannual variability in the tropical stratosphere, characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds



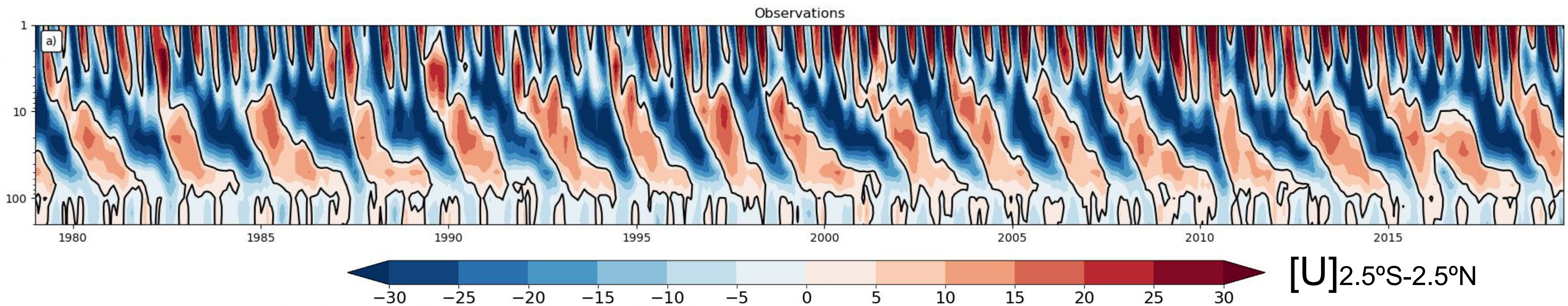


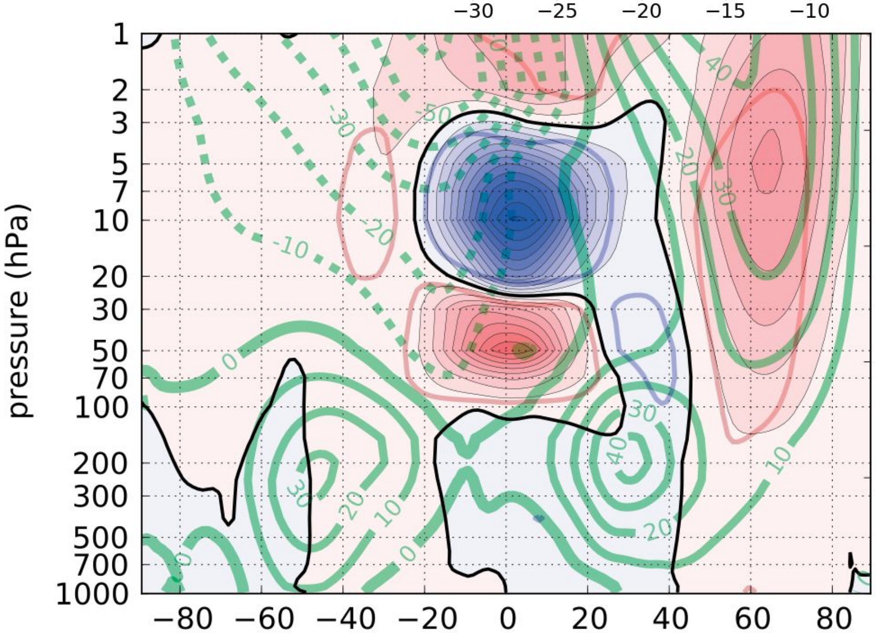
Holton-Tan effect (1980)

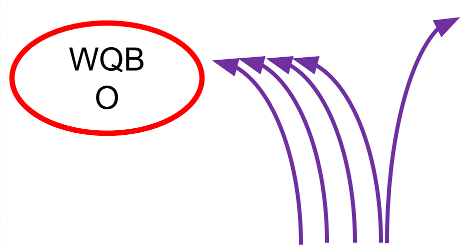
QBO

Quasi-Biennial Oscillation (QBO)

leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds





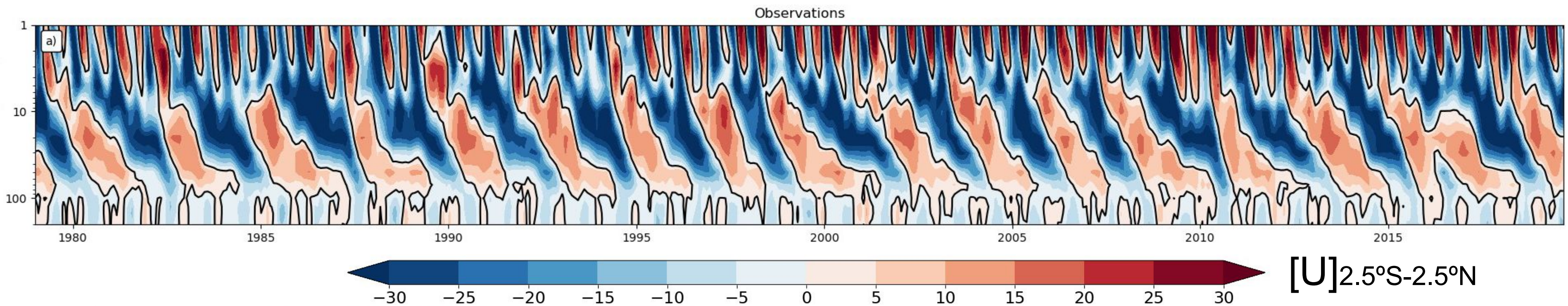


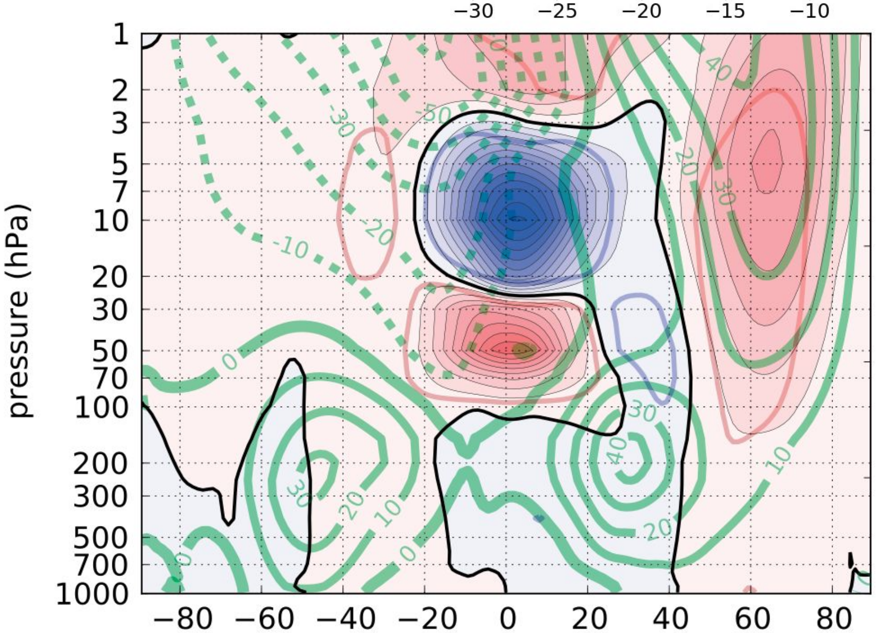
Holton-Tan effect (1980)

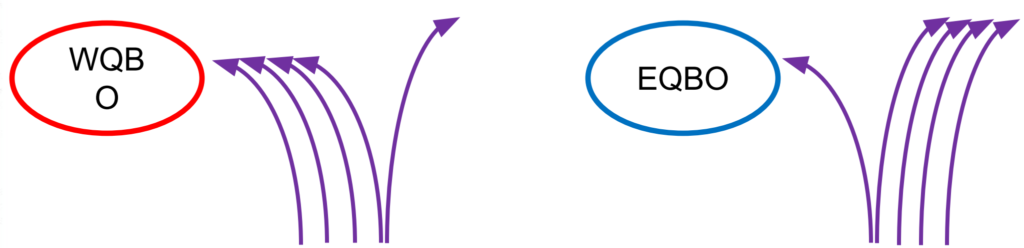
QBO

Quasi-Biennial Oscillation (QBO)

leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds



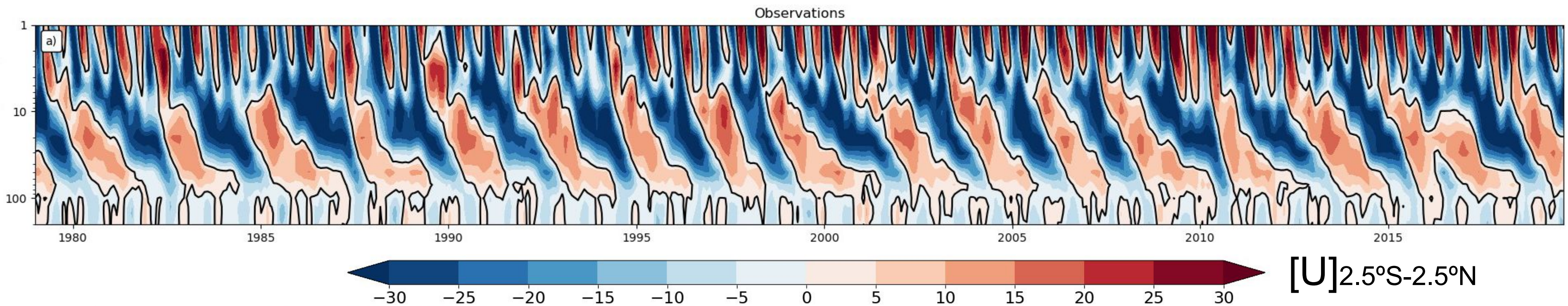


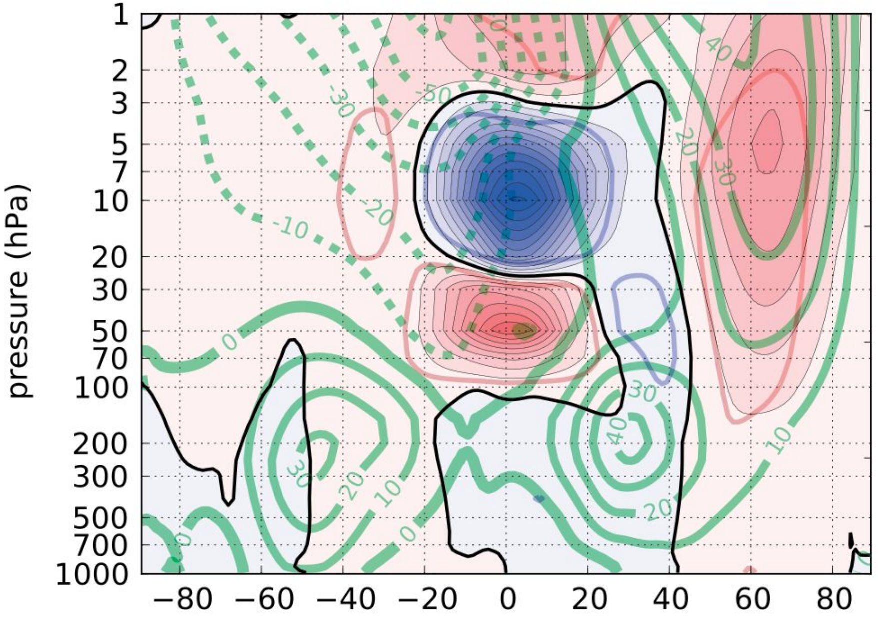


Holton-Tan effect (1980)

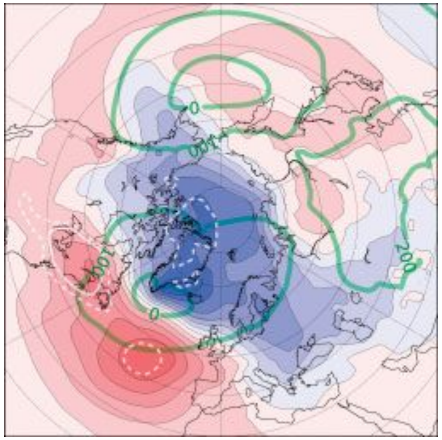
Quasi-Biennial Oscillation (QBO)

leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds





winter SLP (WQBO-EQBO)

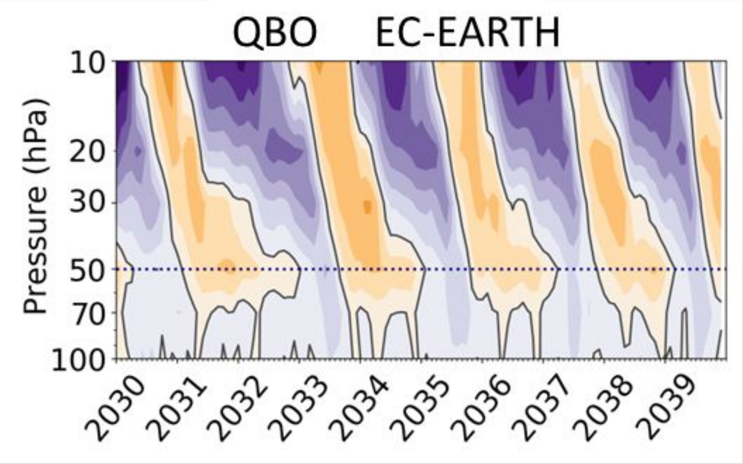


Holton-Tan effect (1980)

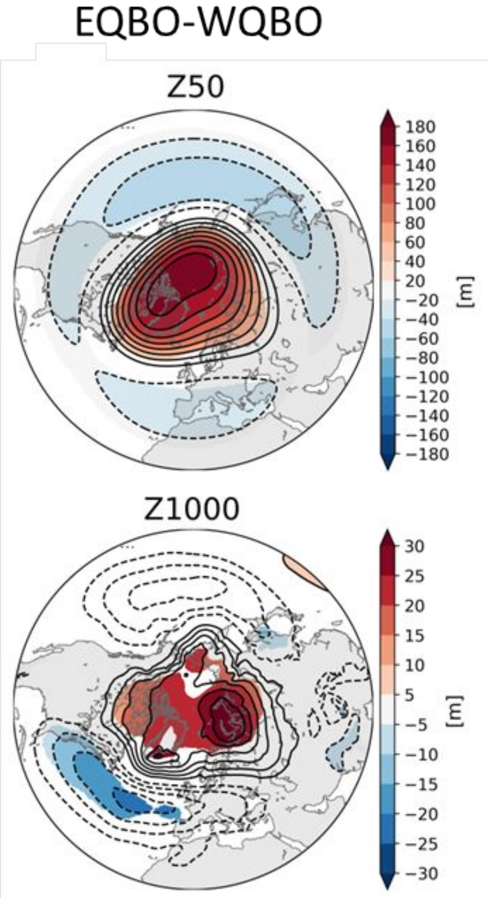
Quasi-Biennial Oscillation (QBO)

leading mode of interannual variability in the tropical stratosphere,
characterized by alternating, descending easterly (EQBO) and westerly (WQBO) winds

EC-EARTH: T255 (~80km), L91 (top 0.01hPa)



[Palmeiro et al. 2020]



Additional sources of seasonal predictability

SUMMARY:

- ENSO is the most important source of predictability at seasonal timescale…

- …other oceanic basins may also provide predictability (e.g. Atlantic, Indian)

- …other forcings may play a larger role in seasons when ENSO signal is weak

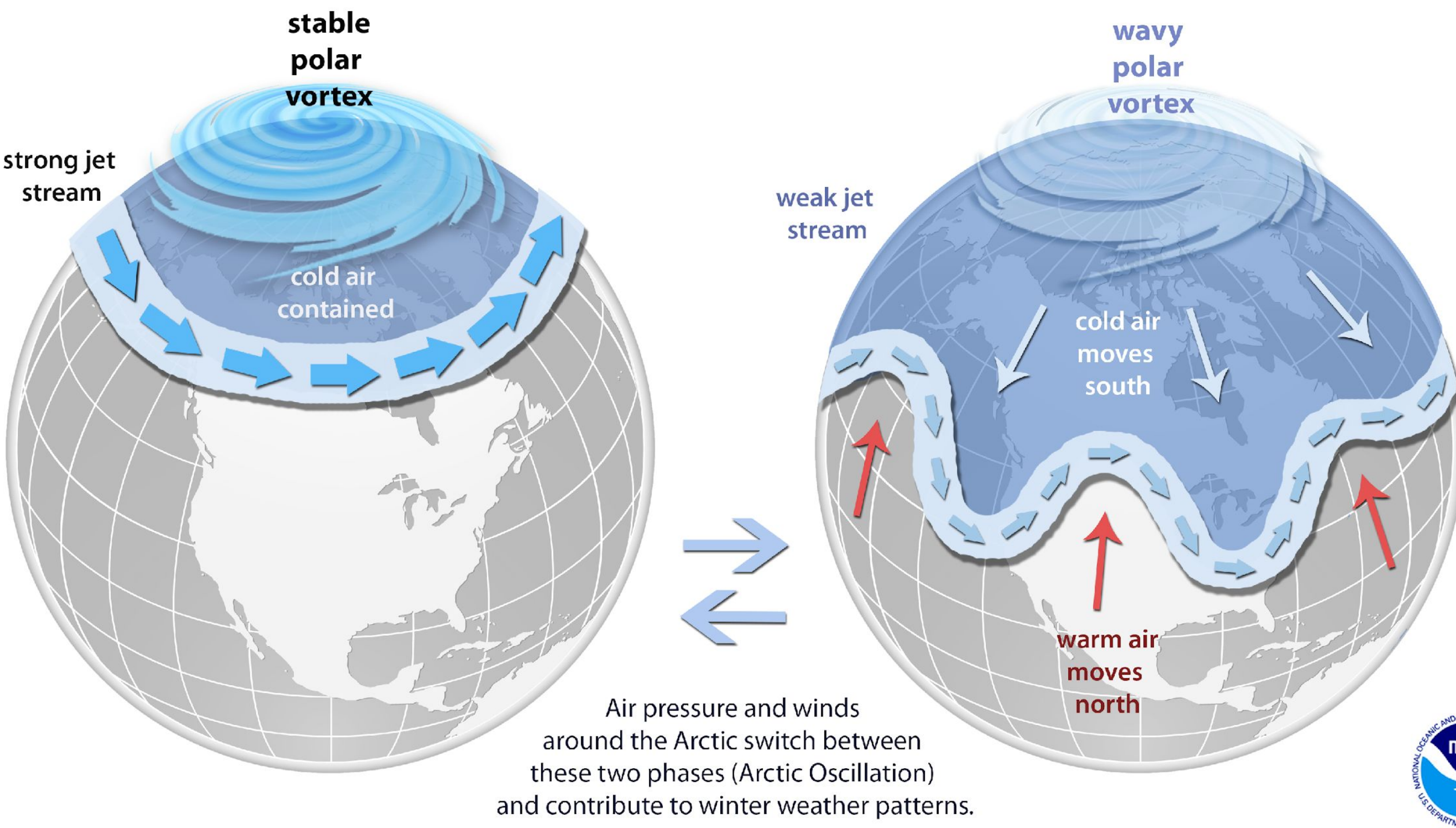
- …other atmospheric phenomena might be important (e.g. QBO; MJO)

□ dynamical forecast systems require a proper representation of the stratosphere

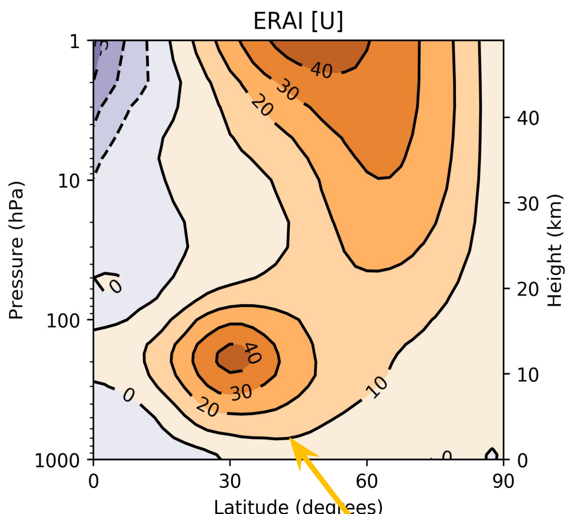
□ there is room for comprehensively improving empirical prediction models

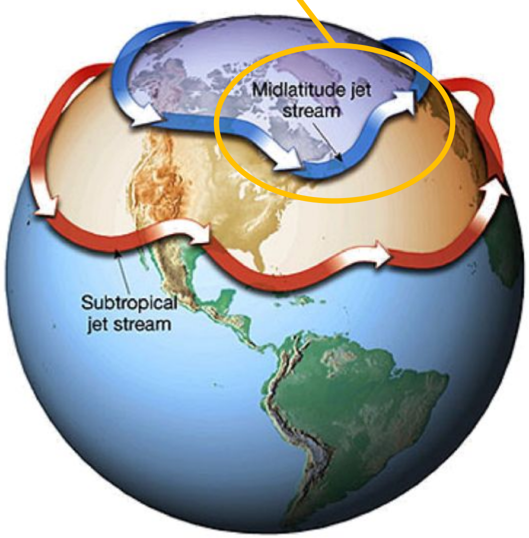
NAO

NAO coupling to the stratosphere persistence

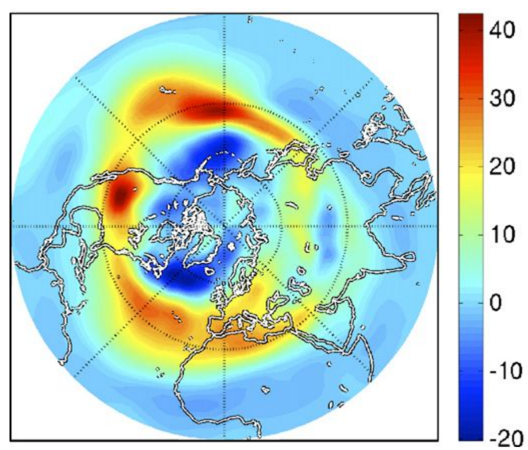


NAO coupling to the stratosphere □ persistence

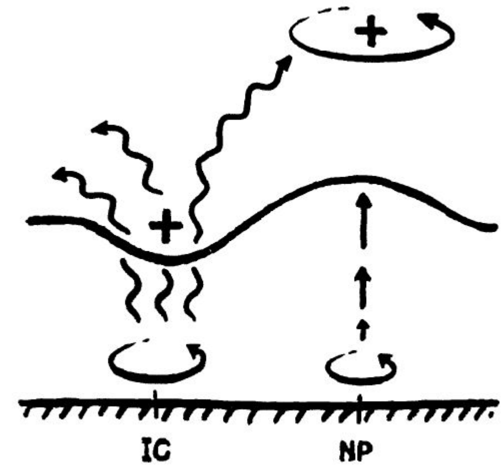


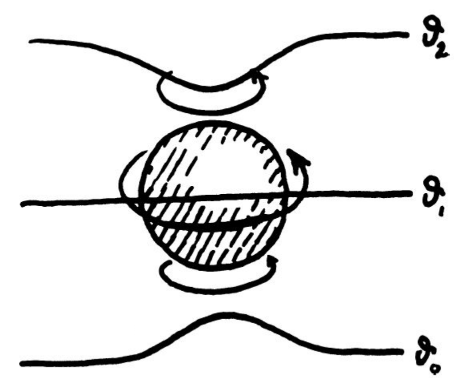


North Atlantic jet strongly coupled with the stratospheric polar vortex



eddy momentum flux: *u’v’*





Ambaum & Hoskins (2002)

METEO-UB

NAO

UNIVERSITAT DE BARCELONA

NAO coupling to the ocean (North Atlantic) □ persistence