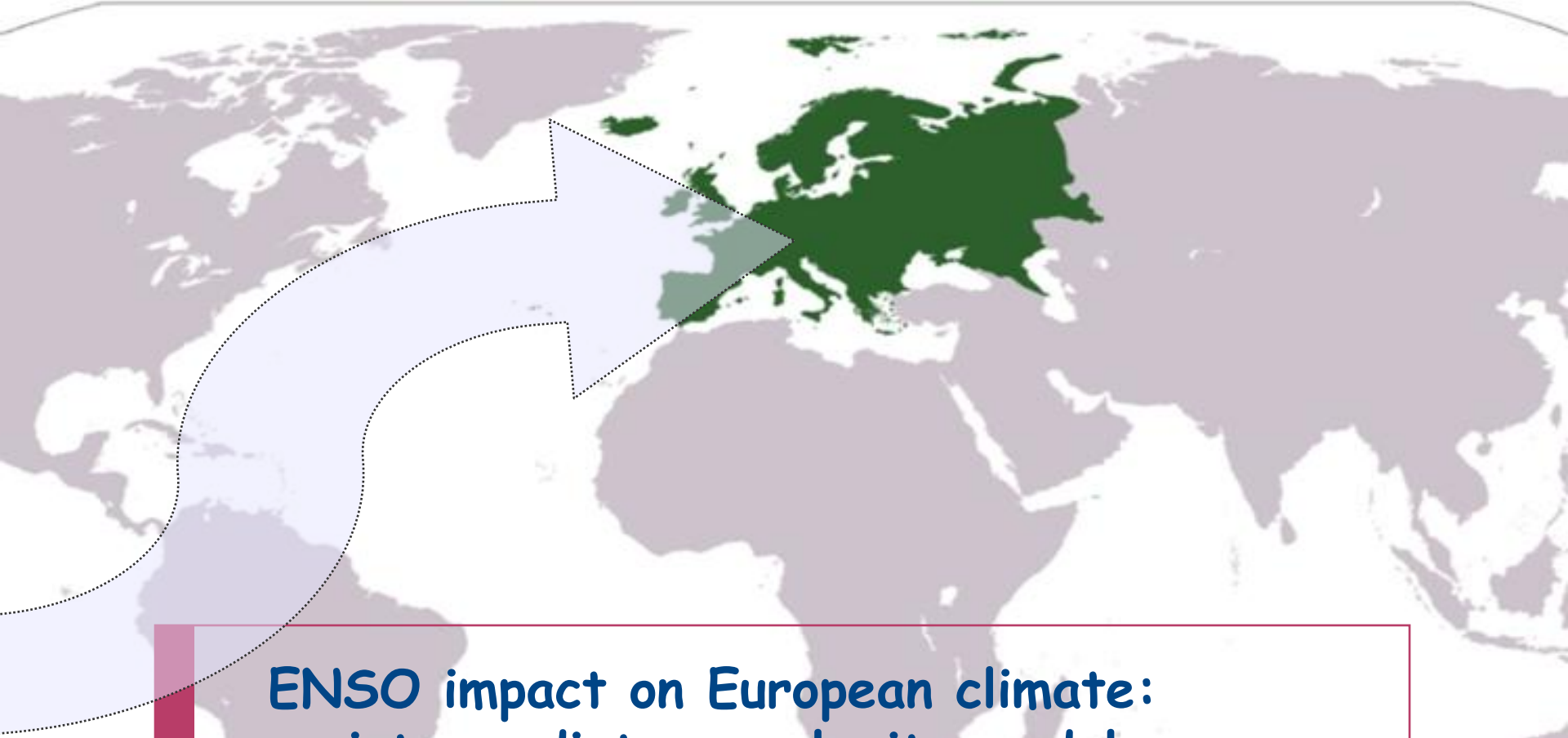


ENSO impact on European climate: an intermediate complexity model perspective

Ivana Herceg Bulić & Čedo Branković
Thanks to colaborators: Fred Kucharski, Bianca Mezzina, Paolo Ruggieri, Martin P. King

Andrija Mohorovičić Geophysical Institute, Zagreb, Croatia

ICTP Workshop on Teleconnections in the Present and Future Climate, Trieste, Italy, 24th - 28th October 2016

ENSO impact on North Atlantic European (NAE) region

El Niño-Southern Oscillation (ENSO): strong generator of climate variability around the globe

- influences tropics and mid-latitudes

- clear impact on North America and Australia

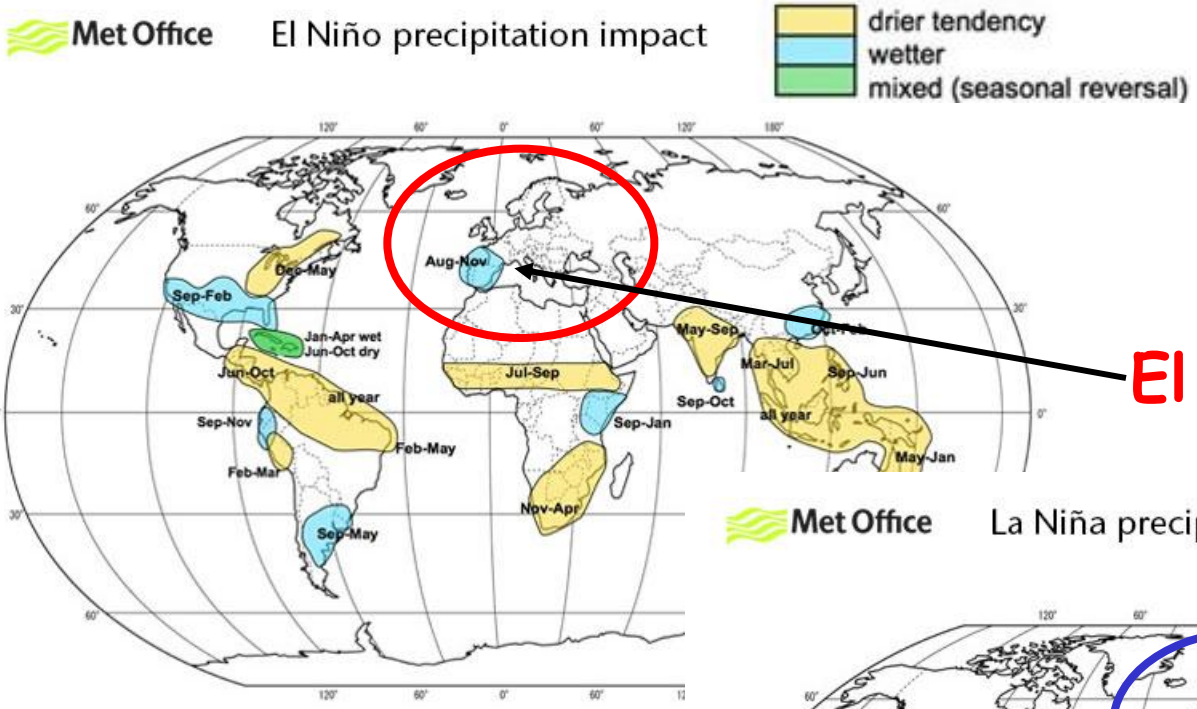
ENSO impact on NAE: difficult to asses

NAE sector:

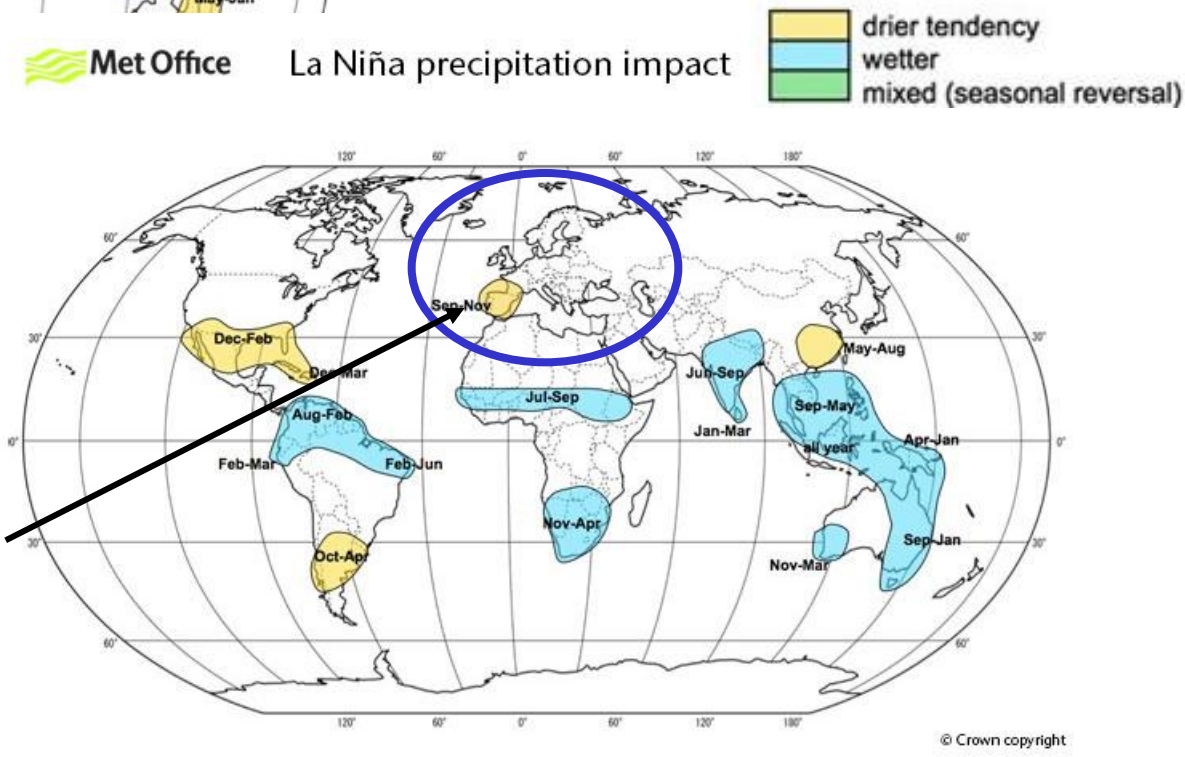
- large internal variability of the atmosphere may mask the response to ENSO (Kumar and Hoerling, 1997)
- influenced by other phenomenon such as NAO which is a major source of variability on the Northern Hemisphere (Hurrell and van Loon, 1997; Greatbatch, 2000)

- **Interactions with regional seasonal cycle, chaotic properties, complexity of feedbacks can mask ENSO signal over Europe**

Impact of ENSO on precipitation



El Niño

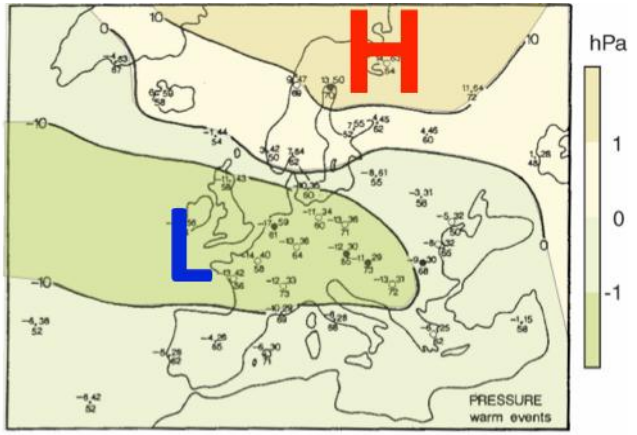


La Niña

Source: metoffice.gov.uk

ENSO impact on North Atlantic European (NAE) region

ENSO impact on North Atlantic European (NAE) region



Fraedrich and Müller [1992]

Observational and modelling studies: detectable ENSO signal in European climate (e.g. van Loon and Madden 1981, Fraedrich and Müller 1992, Oldenborgh et al. 2000, Brönnimann 2007, Nieves Lorenzo et al. 2010)

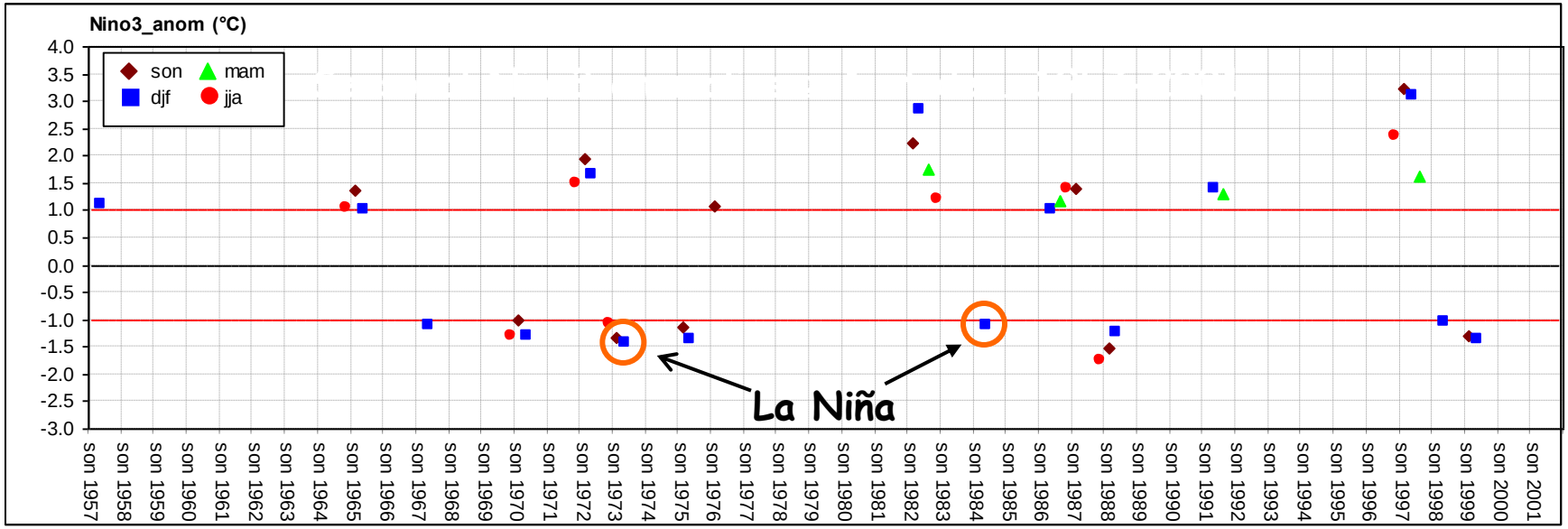
DJF season: warm (cold) ENSO events are related to a southward (northward) shift of the North Atlantic storm track (Fraedrich and Müller 1992)

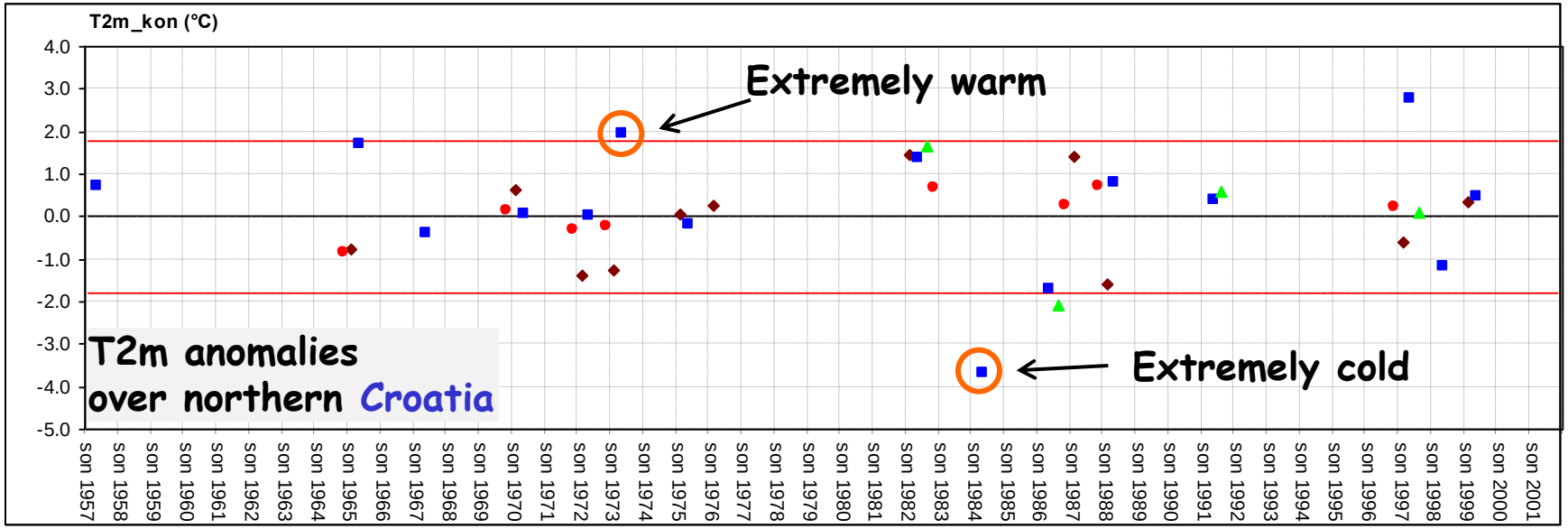
ENSO impact on NAE: seasonally and regionally dependent (Shaman 2014)

Lagged ENSO impact (e.g. Rodó et al. 1997, van Oldenborgh et al. 2000, Knippertz et al. 2003, Feddersen 2003, Nieves Lorenzo et al. 2010)

Regional impact of ENSO: sometimes controversial

Regional impact of ENSO: sometimes controversial





Author: Lidija Srnec (DHMZ)

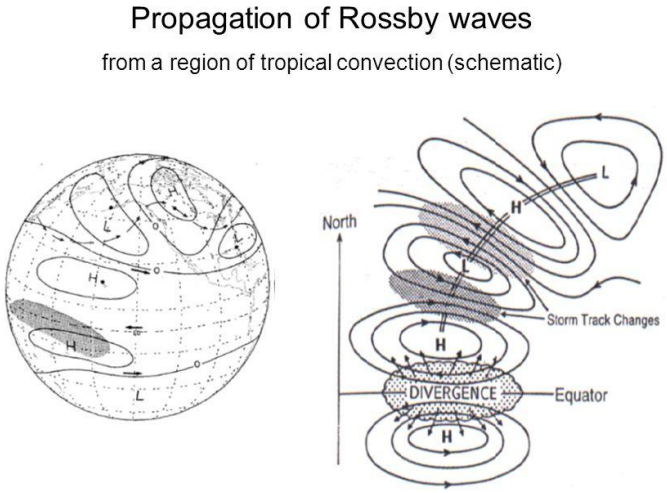
ENSO impact on NAE region – physical mechanisms and modelling

ENSO impact on NAE region – physical mechanisms and modelling

- **tropospheric pathway**: a barotropic Rossby wave train (Horel and Wallace 1981,Trenberth et al, 1998)
- **stratospheric link** between ENSO and European climate (e.g. Brönnimann 2004, 2007, Ineson and Scaife 2009, Butler et al. 2014)

Modelling point of view:

- numerical simulations of ENSO-NAE teleconnection: *AGCMs, AOGCMs* (Bengtsson et al., 1996; Grötzner et al., 2000; Kang et al., 2002)
- need of models with higher horizontal resolution (Merkel and Latif 2002)
- need of models with dynamically active stratosphere (Bell et al. 2009, Cagnazzo and Manzini 2009, Ineson and Scaife 2009)



Horel and Wallace (1981) *Trenberth et al. (1998)*

Modelling impact of ENSO on Europe
ICTP AGCM - Speedy

ICTP AGCM (SPEEDY) – **S**implified **P**arametrizations, primitiv**E**-Equation **DY**namics (Molteni, ClimDyn 2003)

An intermediate complexity model

T30L8 ~ 400 km (3.75°) → computational efficiency

The two model levels representing the lower stratosphere/upper troposphere are approximately located at 30 and 100 hPa

Speedy is successfully used in a number of studies dealing with various aspects of dynamical climatology (Kucharski et al. 2006, 2013)

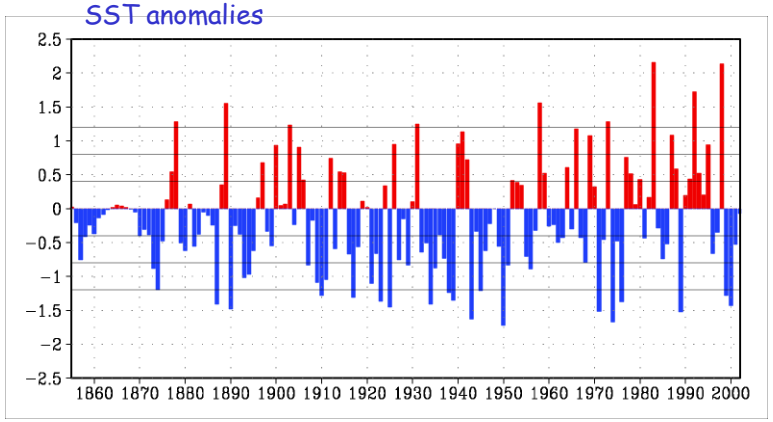
- ENSO influence on climate variability of North Atlantic-European region; teleconnections in a warmer climate, direct vs. indirect impact of elevated CO_2, wintertime ENSO impact on spring climate over the NAE, the role of North Atlantic in time delayed response to wintertime ENSO and NAO; the response of Speedy's stratosphere to ENSO forcing…

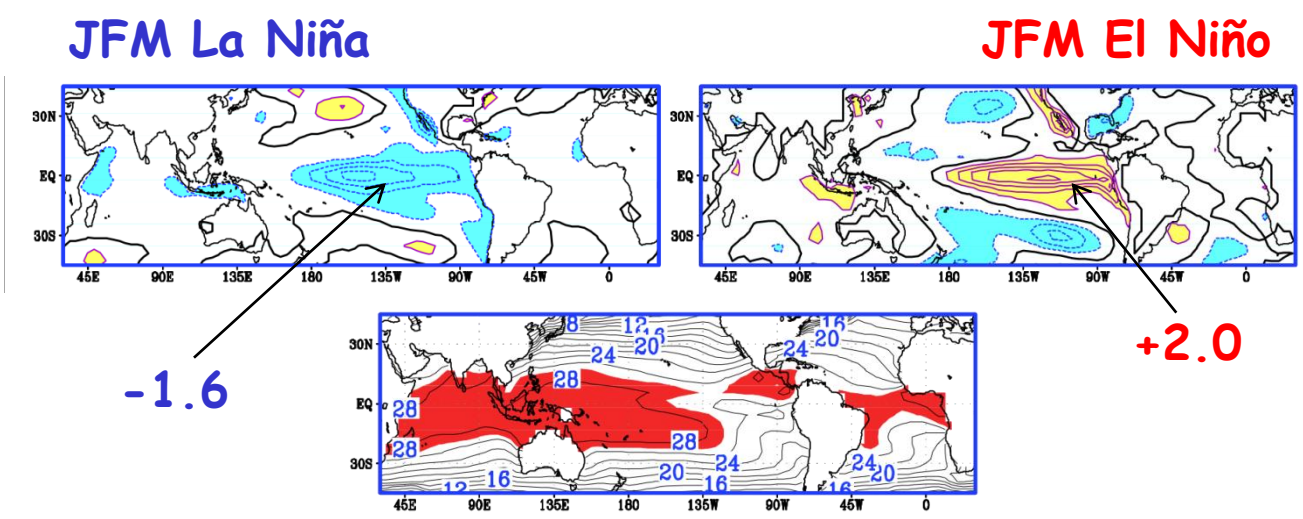
ENSO forcing of European climate

Herceg Bulić and Branković: ENSO forcing of the Northern Hemisphere climate in a large ensemble of model simulations based on a very long SST record, ClimDyn 2007.

ENSO impact on Europe:

- Speedy forced with observed SSTs
- **Composite analysis**:
  strong La Niña (18), strong El Niño (9)
- 35-member ensemble; 1854-2002
- Season analysed: **JFM**



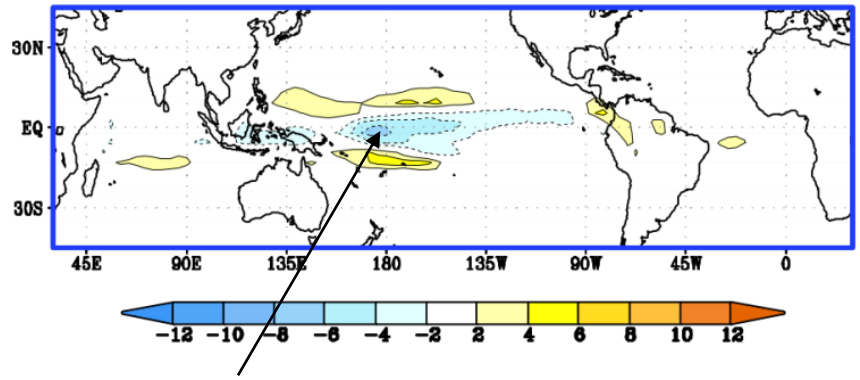


SPEEDY precipitation composites in the tropics

* Amplitude of JFM precipitation anomaly for La Niña is one half of that for El Niño, although amplitudes of SST anomalies are relatively similar

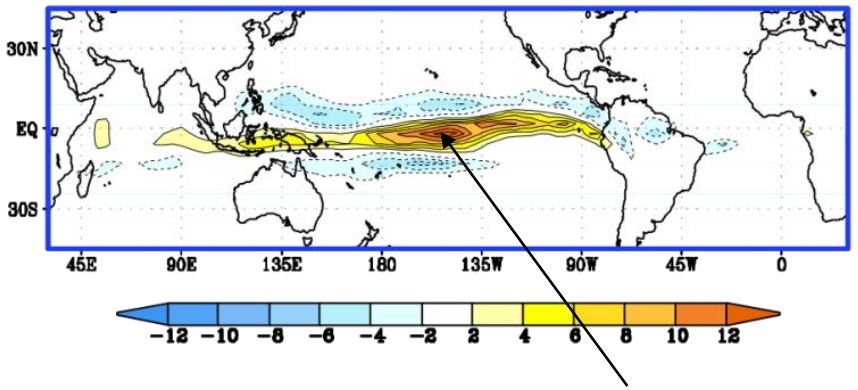
* Precipitation maxima shifted westward relative to maxima in SSTs

JFM La Niña

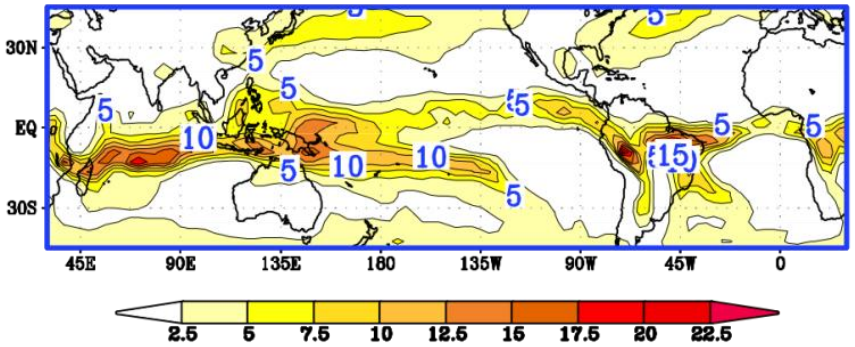


-7 mmday^{-1}

JFM El Niño

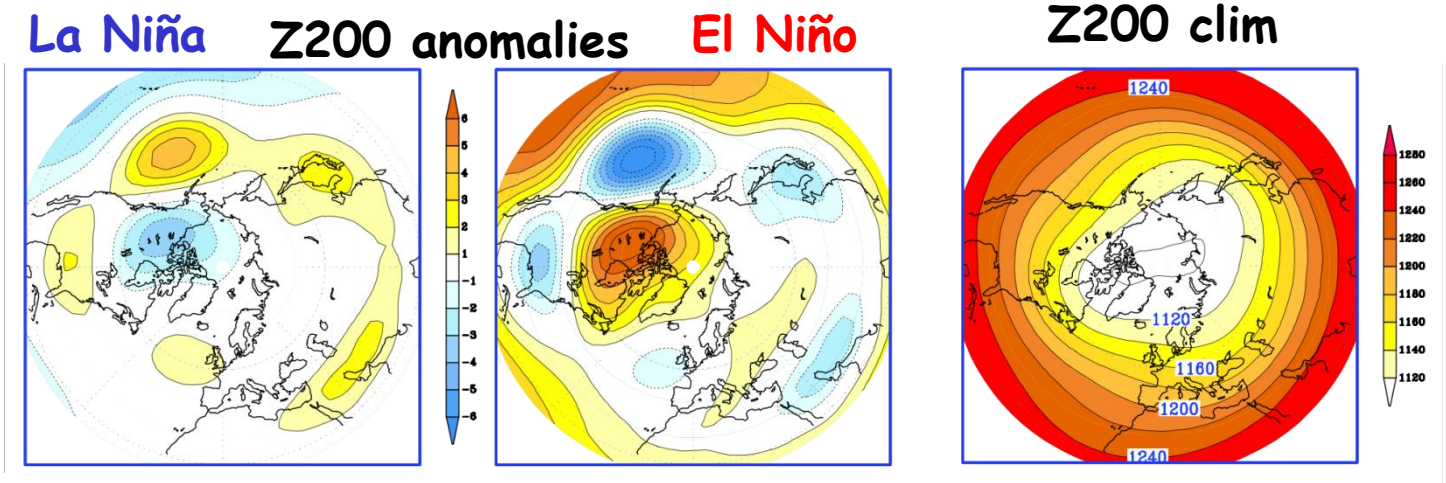


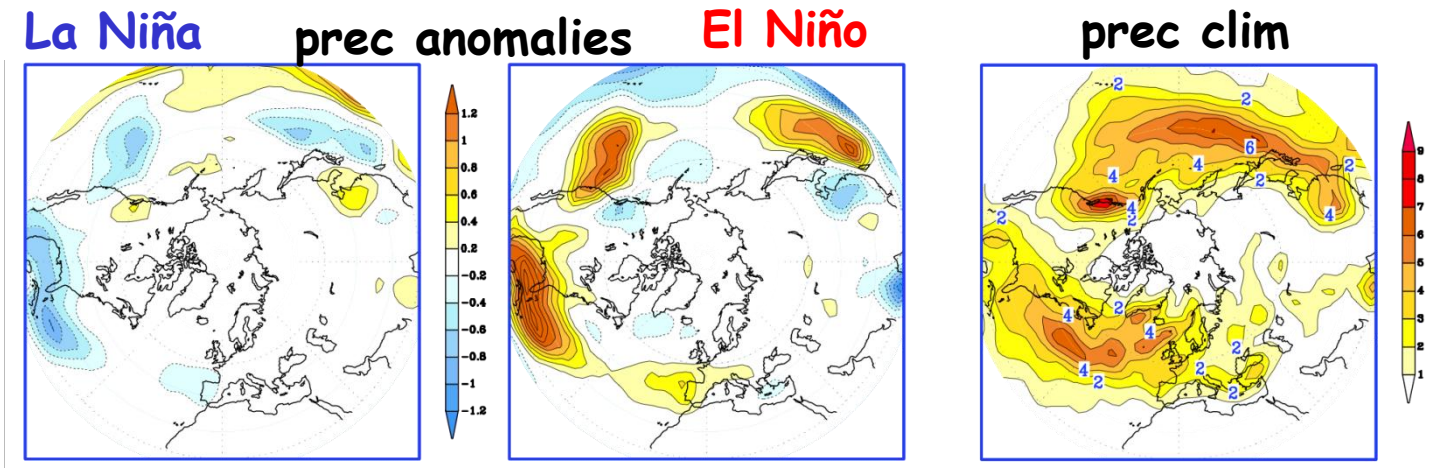
+14 mmday^{-1}



SPEEDY Northern Hemisphere composites

* Pacific anomalies stronger for warm than for cold composites; no shift between cold and warm phases despite shift in tropical prec.
* Strong symmetry in pattern and location (but not in amplitude) between composites of opposite polarity → too linear response to ENSO forcing

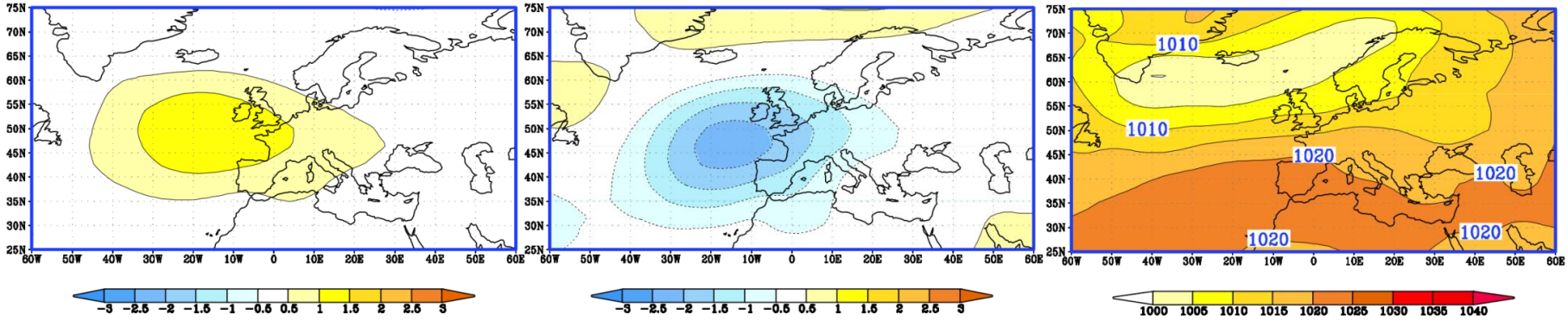




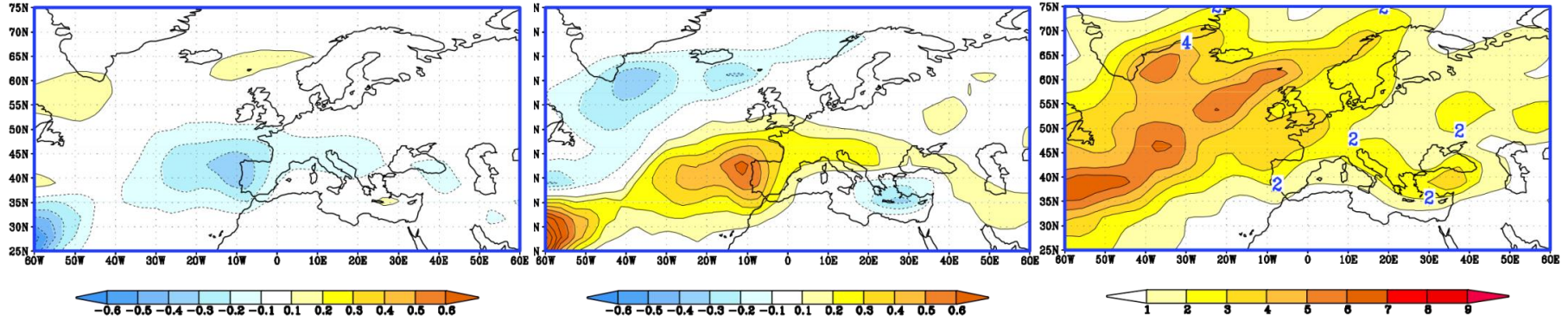
SPEEDY North Atlantic/Europe composites

* Signal for warm events stronger than that for cold events
* Model response insensitive to the strength of the Niño3.4 index
* Similarity with PNA region: spatial symmetry and amplitude asymmetry
* Good agreement with observations (Fraedrich and Müller 1992)

La Niña JFM MSLP anomalies El Niño MSLP climatology



La Niña JFM Precip anomalies El Niño Precip climatology



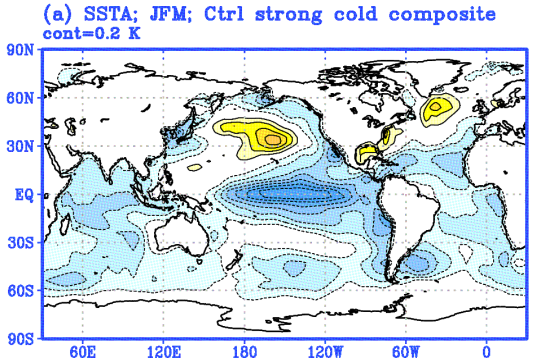
TroPac – SPEEDY experiment with SST forcing constrained to the tropical Pacific

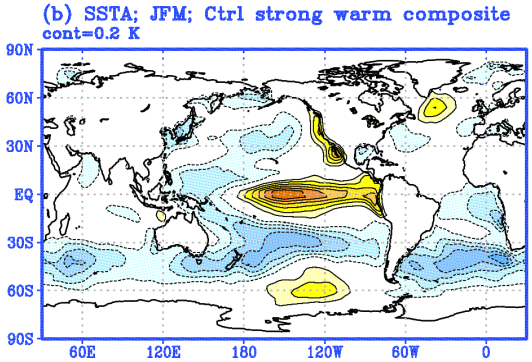
TroPac – SPEEDY experiment with SST forcing constrained to the tropical Pacific

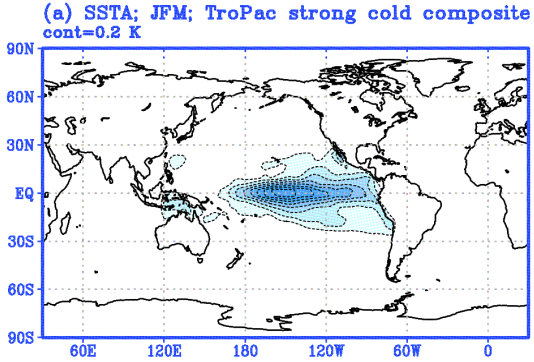
Ctrl: SST anomalies prescribed globally

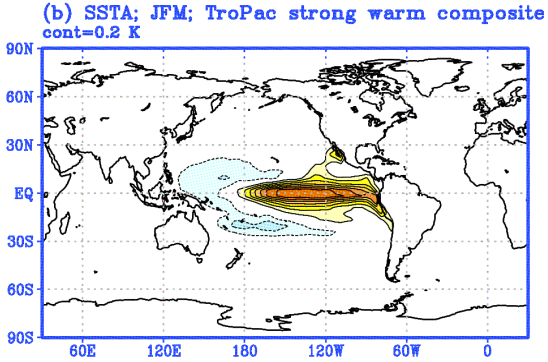
TroPac: SST anomalies constrained to the tropical Pacific; climatological SSTs elsewhere

La Niña JFM SSTA El Niño





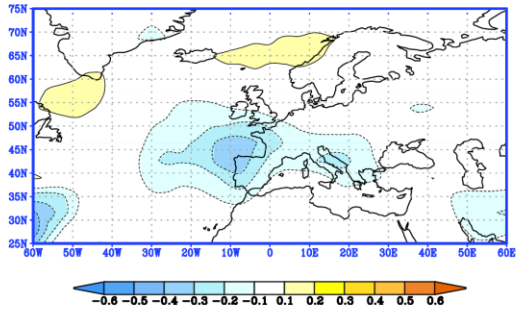




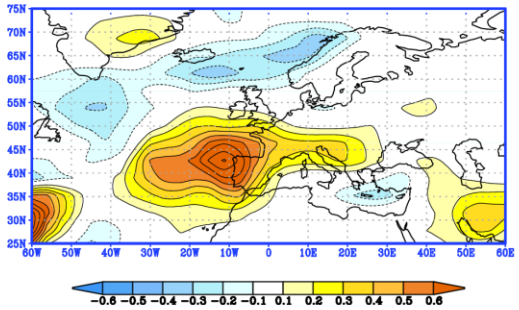
TroPac – SPEEDY experiment with SST forcing constrained to the tropical Pacific

La Niña — JFM prec. anomalies — El Niño

TroPac



TroPac



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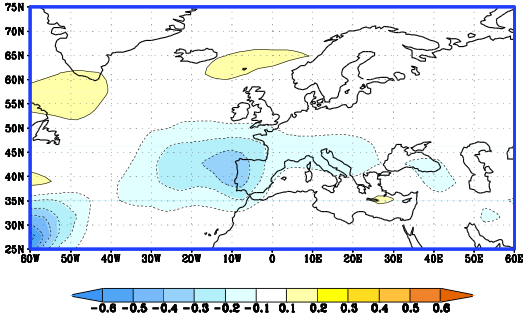

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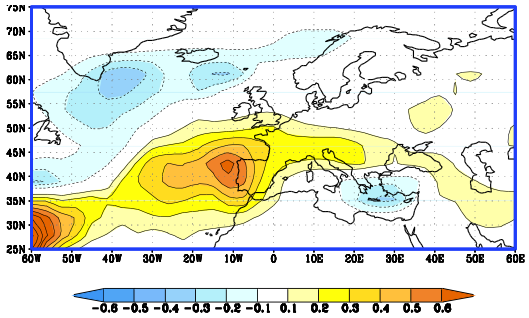


Spatial correlation TroPac-Ctrl	strong cold	strong warm
rr	0.94	0.88
GH200	0.80	0.90
p0	0.81	0.91
T850	0.91	0.80

Sumarry

- ENSO has an detectable impact on climate variability over the NAE region
- SPEEDY response: quite consistent with observations and other results
- JFM El Niño: cyclonic type of weather in winter, increased (decreased) precipitation over the northern (southern) Europe
- JFM La Niña: anticyclonic type of weather increased (decreased) precipitation over the northern (southern) Europe

ENSO impact in a **warmer** climate?

SPEEDY: ENSO impact on Europe in a warmer climate

CTRL experiment – current climate

CO_2 – an average value for 1961-1990 (**1xCO_2**)

SST climatology and anomalies: observed 1855-2002 (NOAA_ERSST_V2 data) + sea-ice (HadSSTI)

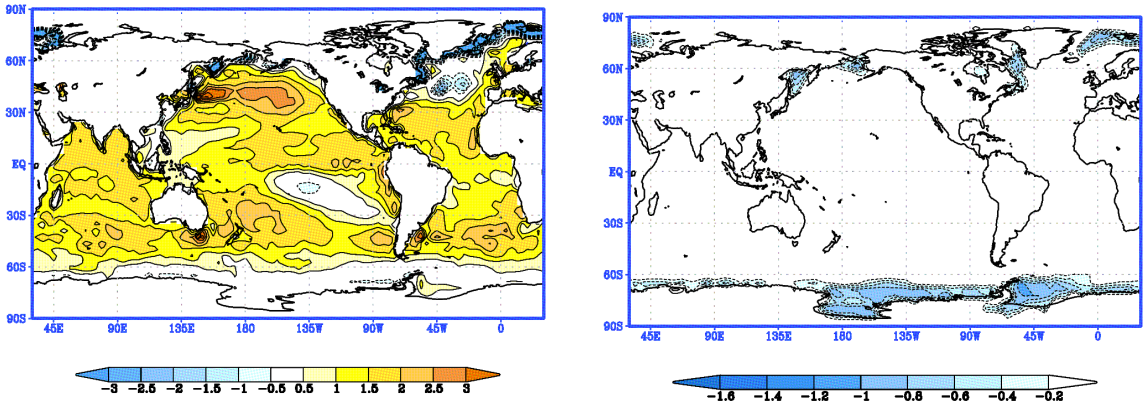
2xCO_2 experiment – warmer climate

CO_2 – doubled (**2xCO_2**)

SST climatology and sea-ice – simulated with HadCM3 for 2xCO_2 conditions

SST anomalies – same as in CTRL

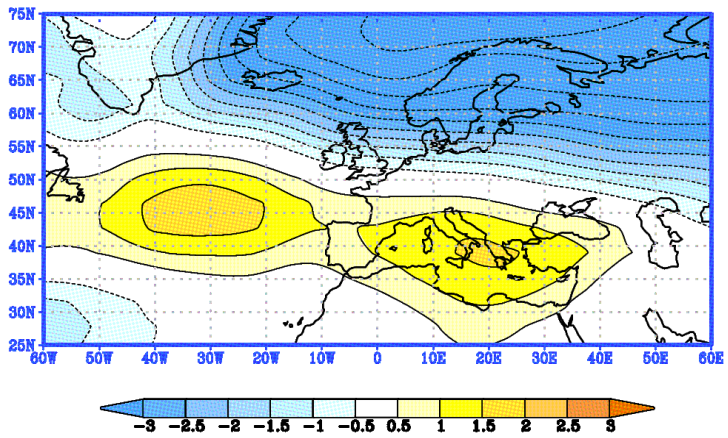
JFM SST clim | **2xCO_2-CTRL** | **JFM SICE clim**



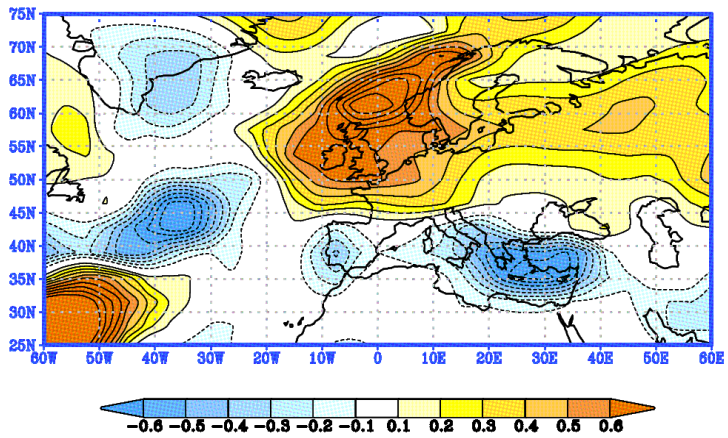
Herceg-Bulić, Branković and Kucharski:
Winter ENSO teleconnections in a warmer climate. ClimDyn 2012.

$2xCO_2$ - Ctrl climatology difference

JFM mslp

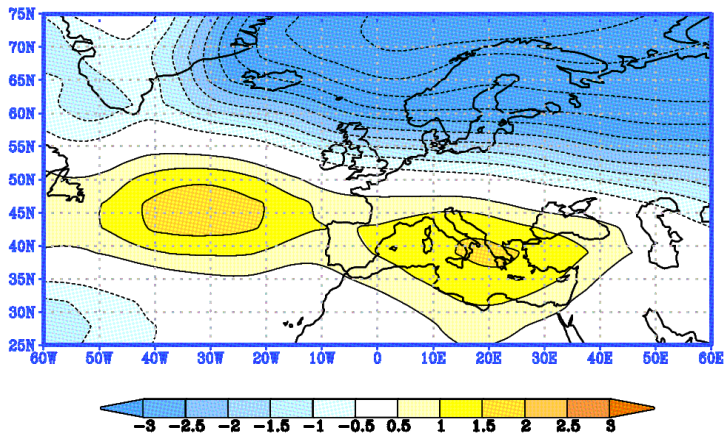


JFM prec

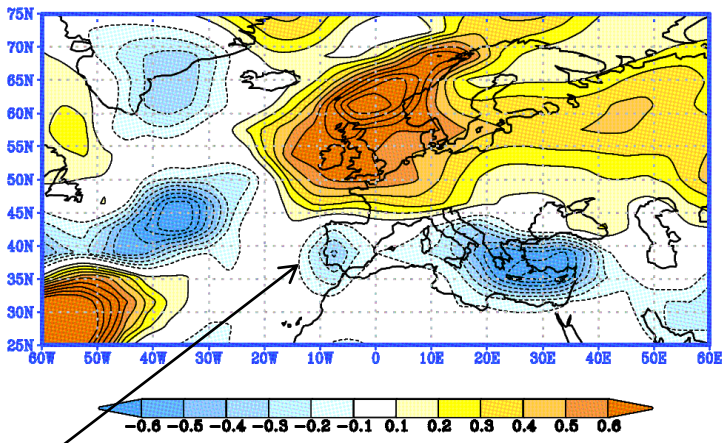


$2xCO_2$ - Ctrl climatology difference

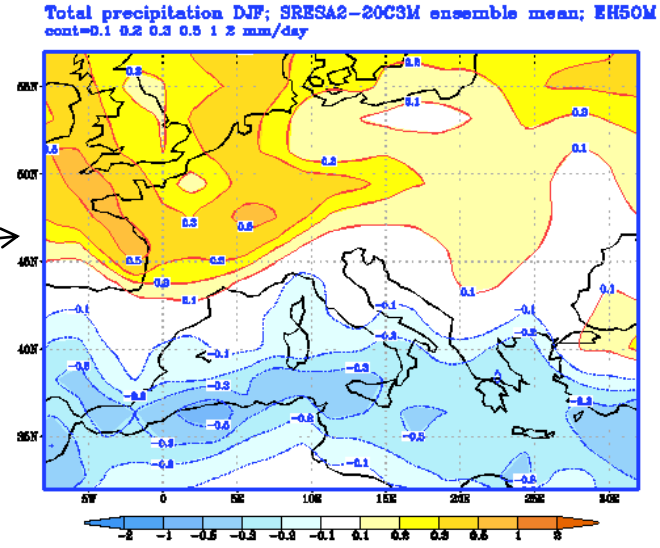
JFM mslp



JFM prec



Similar precipitation change to that obtained by EH5OM for SRESA2

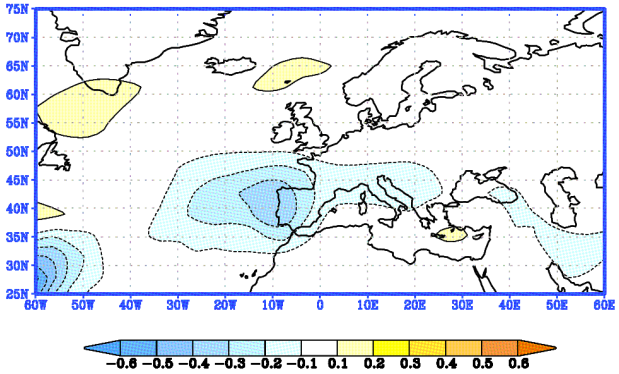


An assessment of global and regional climate change based on the EH5OM climate model ensemble
(Branković, Srnec and Patarčić, ClimChange 2010)

ENSO signature in a warmer climate – JFM precipitation

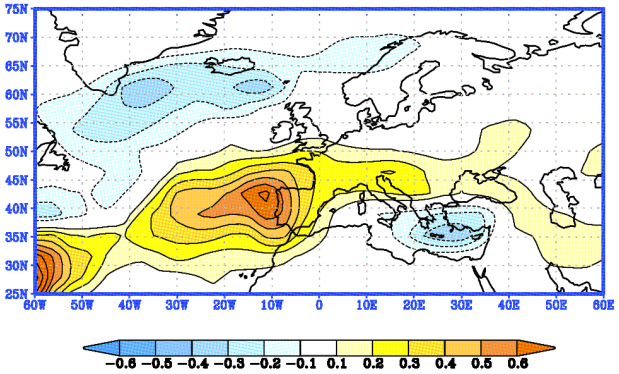
(a) Total precip; JFM; Ctrl strong cold composite

cont=0.1 mm/day



(b) Total precip; JFM; Ctrl strong warm composite

cont=0.1 mm/day



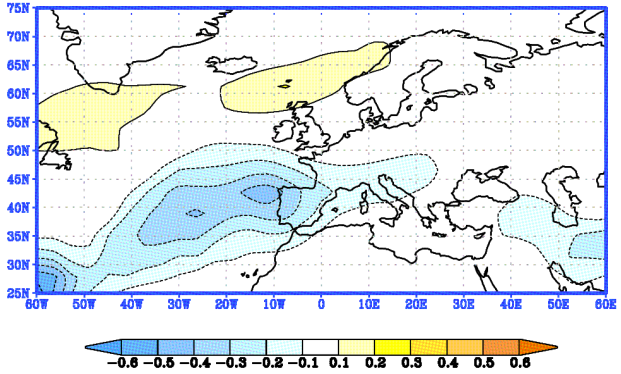
CTRL

La Niña

El Niño

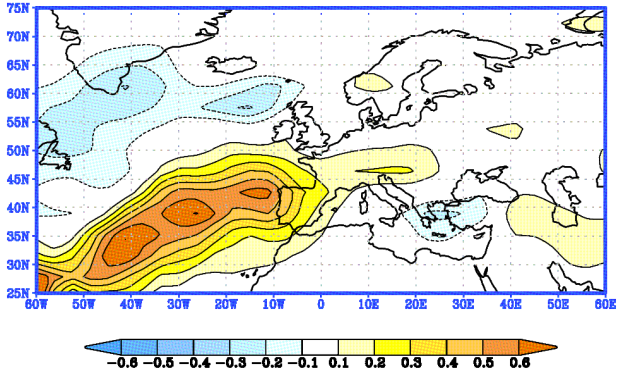
(a) Total precip; JFM; CO2x2 strong cold composite

cont=0.1 mm/day



(b) Total precip; JFM; CO2x2 strong warm composite

cont=0.1 mm/day



$2xCO_2$

ENSO signature in a warmer climate - JFM u200

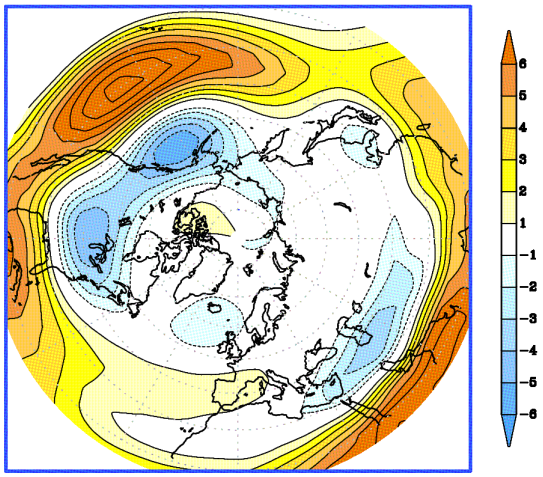
El Niño

La Niña

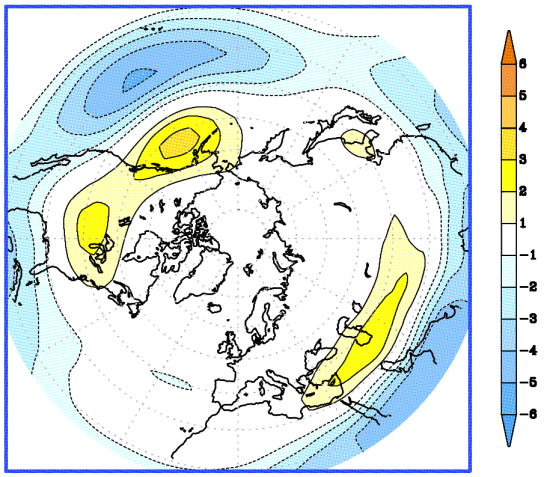
CTRL

$2xCO_2$

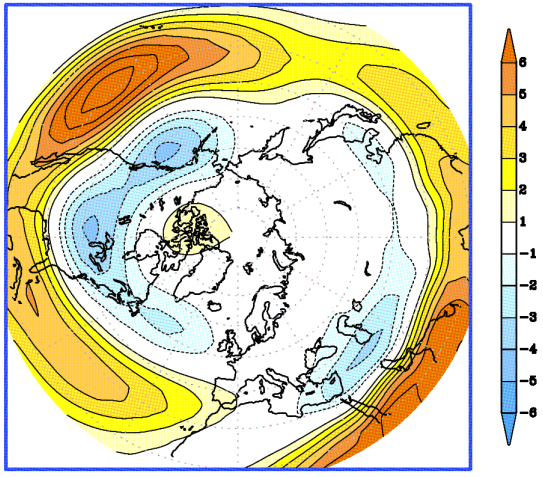
(a) u-wind 200; JFM; CTRL strong warm composite
cont=1.0 m/s



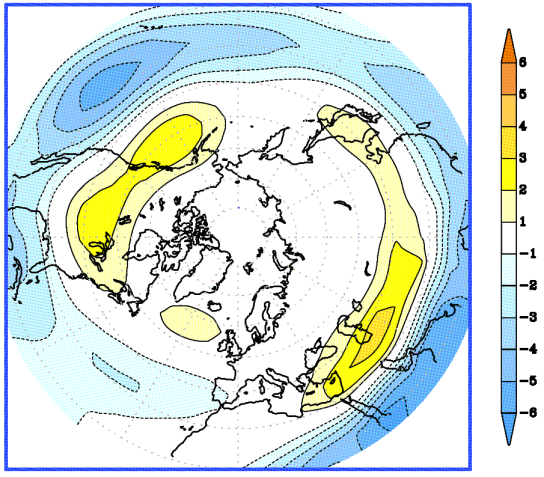
(b) u-wind 200; JFM; CTRL strong cold composite
cont=1.0 m/s



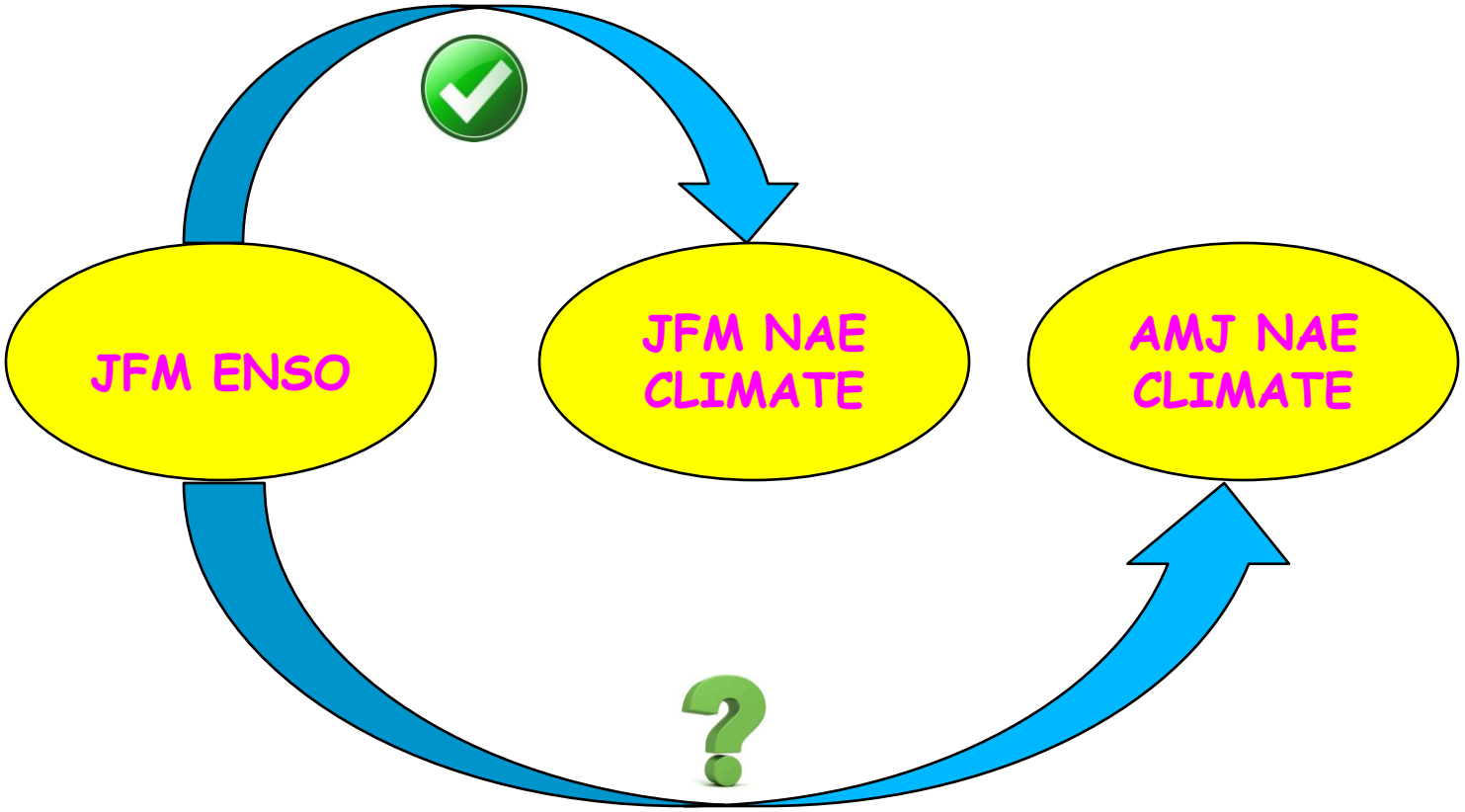
(c) u-wind 200; JFM; 2xCO2 strong warm composite
cont=1.0 m/s



(d) u-wind 200; JFM; 2xCO2 strong cold composite
cont=1.0 m/s



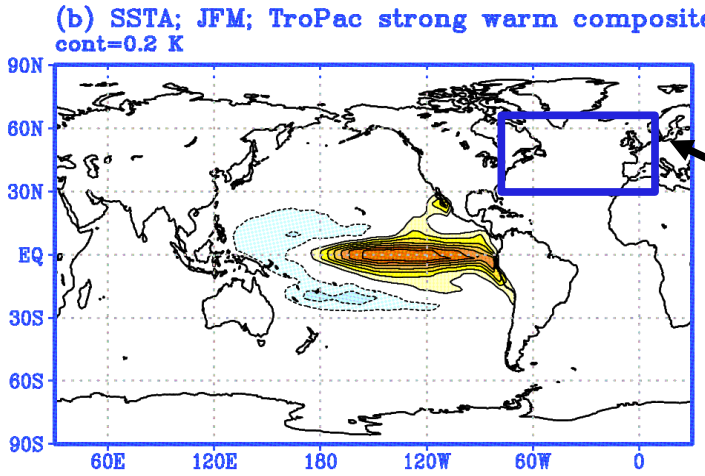
Delayed ENSO influence on NAE?



Delayed ENSO influence on NAE

Herceg-Bulić and Kucharski F: Delayed ENSO impact on spring precipitation over North/Atlantic European region. ClimDyn 2012.

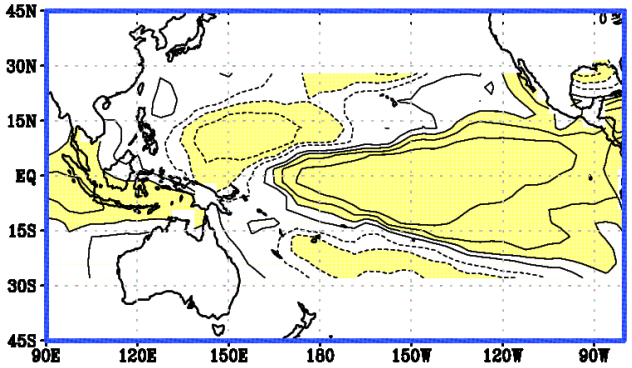
- **CTRL** experiment – observed SSTs 1854-2002 (NOAA_ERSST_V2 data)
- **MIX** experiment – observed SSTs in the tropical Pacific +climatological SSTs elsewhere + mixed slab ocean in North Atlantic



Slab mixed ocean layer in North Atlantic

Delayed ENSO influence on NAE

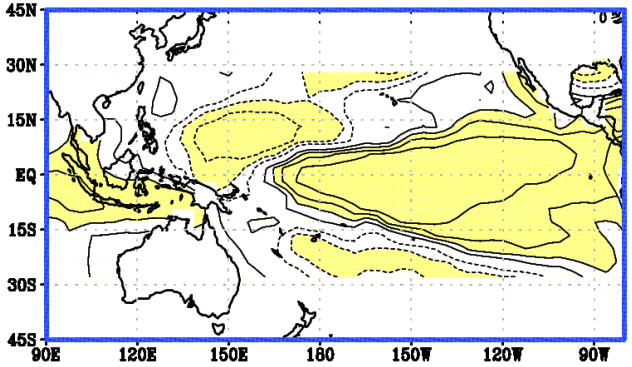
Correlation
PC1(**AMJ** NAE precipitation) –
JFM SSTA



AMJ precipitation variability is correlated with **JFM** SSTA in tropical Pacific

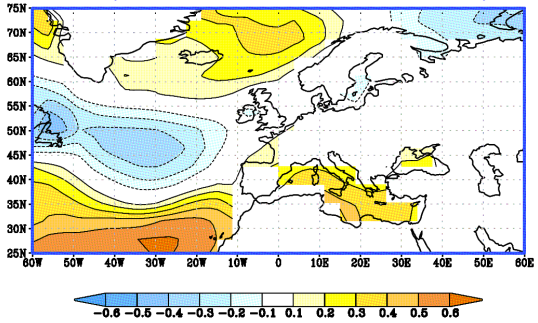
Delayed ENSO influence on NAE

Correlation
PC1(**AMJ** NAE precipitation) –
JFM SSTA

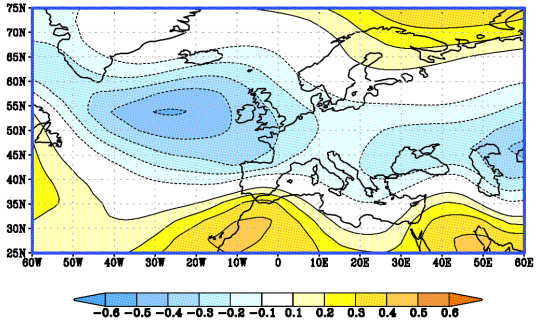


Correlation
JFM Niño3.4 – ***AMJ***
European climate

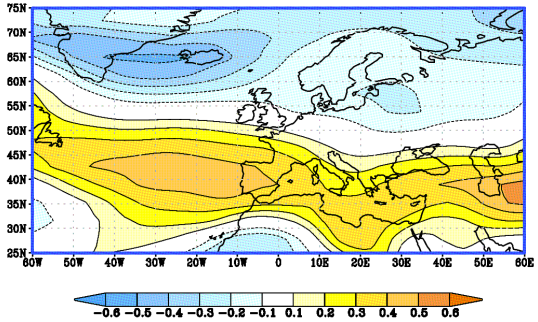
corr(JFM Niño3.4, AMJ SST MIX)



corr(JFM Niño3.4, AMJ SLP MIX)

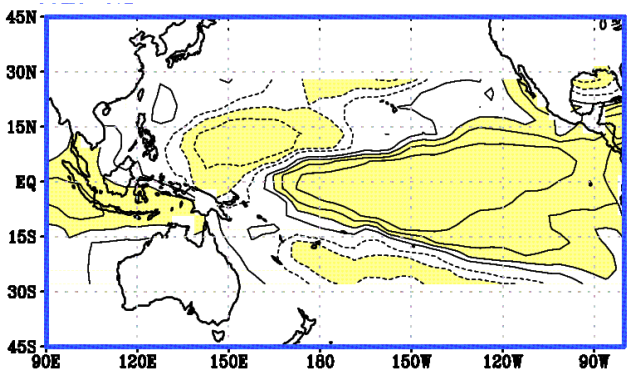


corr(JFM Niño3.4, AMJ u850)



Delayed ENSO influence on NAE

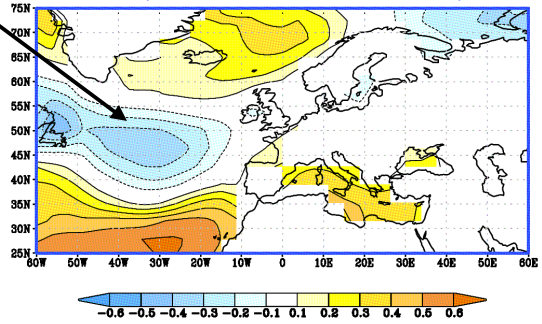
Correlation
PC1(***AMJ*** NAE precipitation) –
JFM SSTa (tropical Pacific)



NAE ***AMJ* precipitation** is
significantly correlated
with **JFM SSTA**
in the tropical Pacific

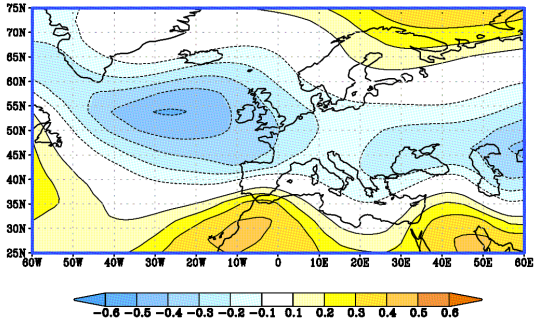
North Atlatic SSTs
as a link between
the wintertime ENSO and
springtime European climate

corr(JFM Niño3.4, AMJ SST)

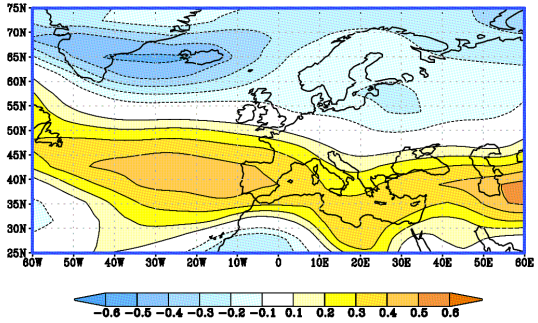


Correlation
JFM Niño3.4 – ***AMJ***
European climate
(MIX experiment)

corr(JFM Niño3.4, AMJ SLP)



corr(JFM Niño3.4, AMJ u850)



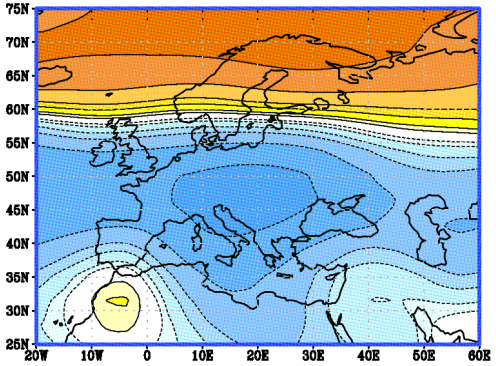
Delayed ENSO impact on SLP (modelled and observed)

AMJ SLP composites based on JFM Niño3.4 index

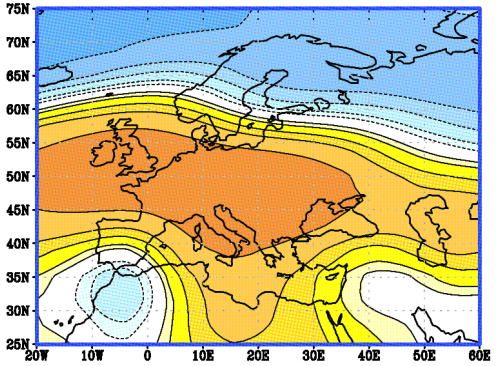
El Niño

La Niña

(c) MIX_winter_ENSO SLP; AMJ; warm composite
cont=−0.8 −0.5 −0.3 −0.2 −0.1 −0.05 0.05 0.1 0.2 0.3 0.5 0.8 hPa

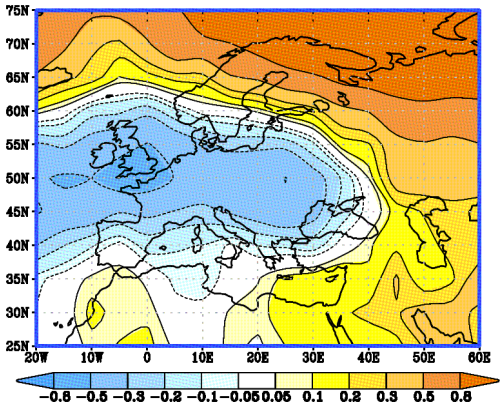


(d) MIX_winter_ENSO SLP; AMJ; cold composite
cont=−0.8 −0.5 −0.3 −0.2 −0.1 −0.05 0.05 0.1 0.2 0.3 0.5 0.8 hPa

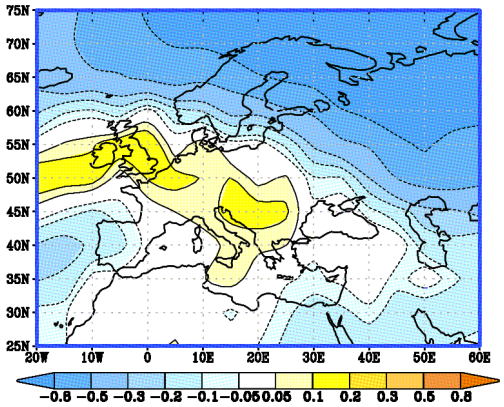


Speedy

(e) HadSLP SLP; AMJ; warm composite
cont=−0.8 −0.5 −0.3 −0.2 −0.1 −0.05 0.05 0.1 0.2 0.3 0.5 0.8 hPa



(f) HadSLP SLP; AMJ; cold composite
cont=−0.8 −0.5 −0.3 −0.2 −0.1 −0.05 0.05 0.1 0.2 0.3 0.5 0.8 hPa



OBS (HadSLP)

AMJ NAE climate

DELAYED ENSO INFLUENCE

JFM ENSO impact on
AMJ European climate
(with North Atlantic as a link)

MIX_winter_ENSO experiment

SST forcing in the tropical Pacific active only during the cold part of year
(**winter-to-spring** ENSO impact)

Mixed layer in North Atlantic

AMJ composites (based on JFM Niño3.4 index)

CONTEMPORANEOUS ENSO INFLUENCE

AMJ ENSO impact on
AMJ European climate
(due to SST persistence in the Tropical Pacific)

MIX_summer_ENSO experiment

SST forcing in the tropical Pacific active only during the warm part of year
(**spring-to-spring** ENSO impact)

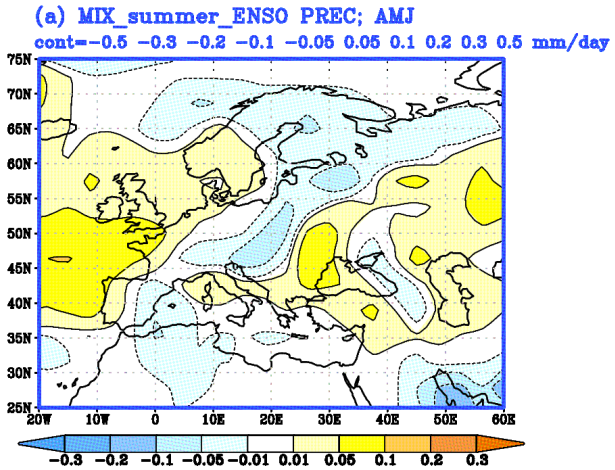
Mixed layer in North Atlantic

AMJ composites (based on JFM Niño3.4 index)

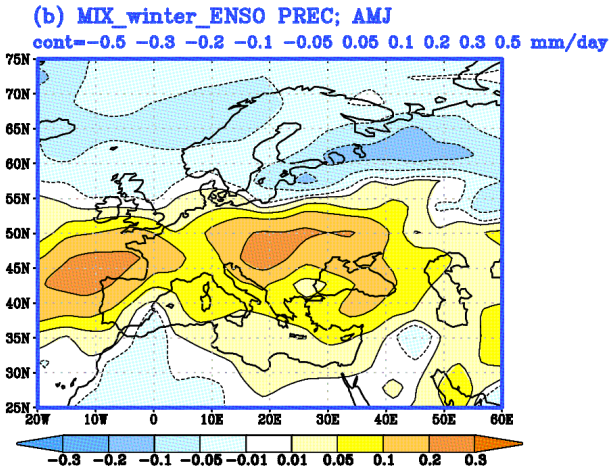
Delayed and contemporaneous ENSO influence

AMJ precipitation composites (based on JFM Niño3.4 index)

Tropical Pacific: SUMMER SSTs
NAtl: slab ocean
Contemporaneous ENSO effect
AMJ ENSO - AMJ PREC

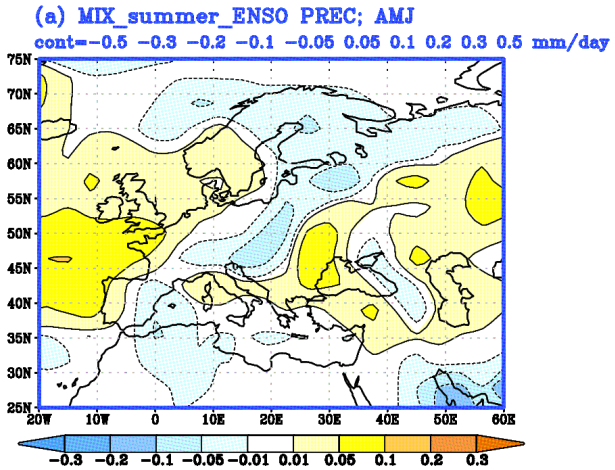


Tropical Pacific:WINTER SSTs
NAtl: slab ocean
Delayed ENSO effect
JFM ENSO - AMJ PREC

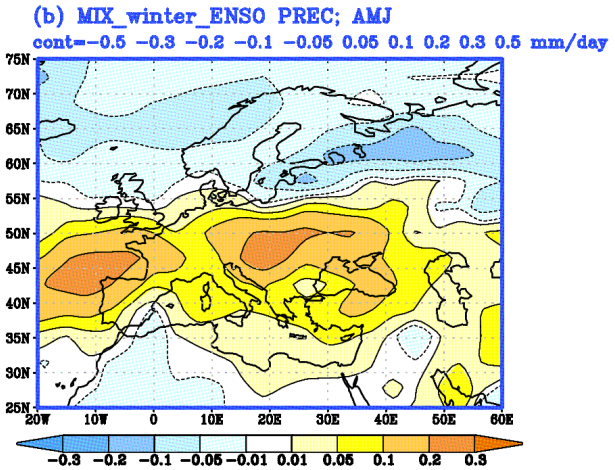


AMJ prec. may be affected with both JFM and AMJ ENSO

Tropical Pacific: SUMMER SSTs
NAtl: slab ocean
Contemporaneous ENSO effect
AMJ ENSO - AMJ PREC

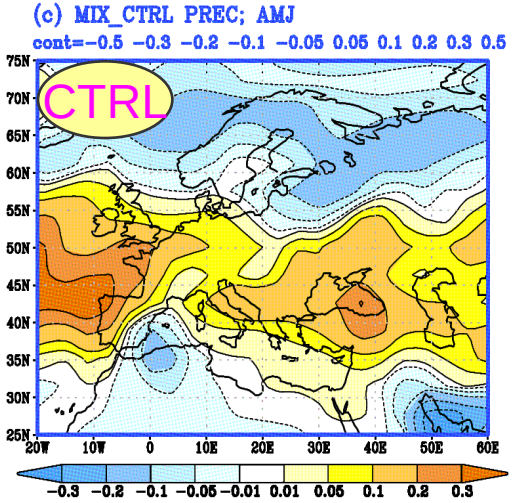


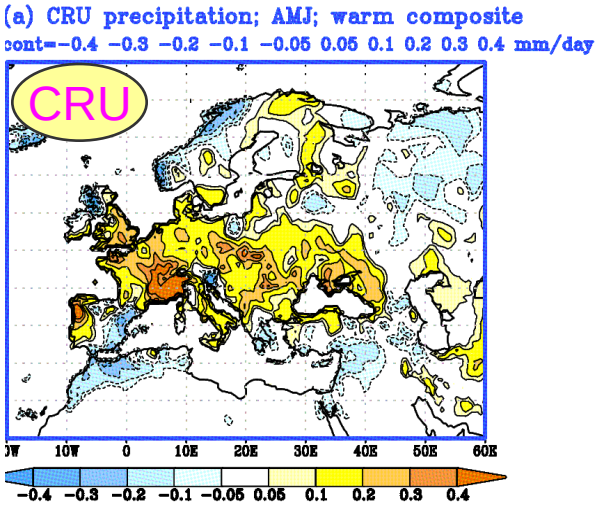
Tropical Pacific: WINTER SSTs
NAtl: slab ocean
Delayed ENSO effect
JFM ENSO - AMJ PREC



Global ocean: CONTINUOUS observed SSTs

Contemporaneous (AMJ-AMJ) and **delayed (JFM-AMJ)** ENSO effect on AMJ precipitation



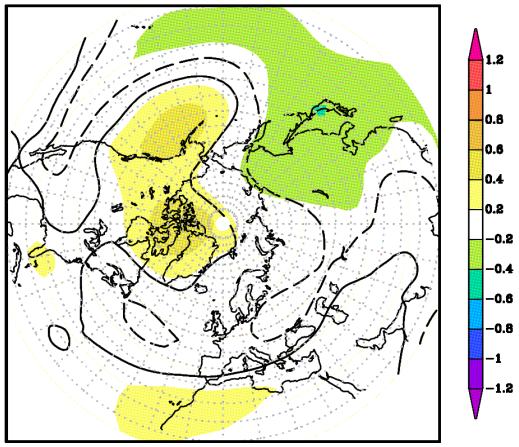


- **Speedy:** tropospheric and surface response to ENSO
- What is going on in the stratosphere?

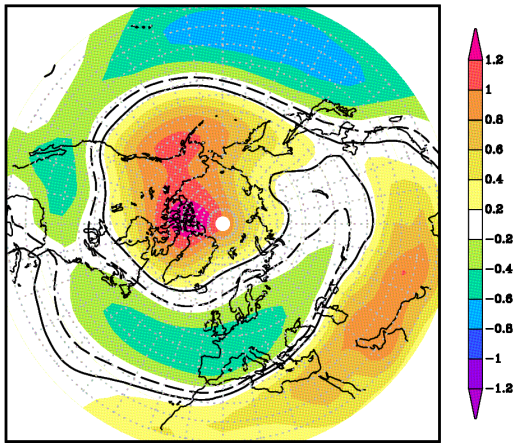
Speedy: Stratospheric response to JFM ENSO

T30 (El Niño-La Niña) composites

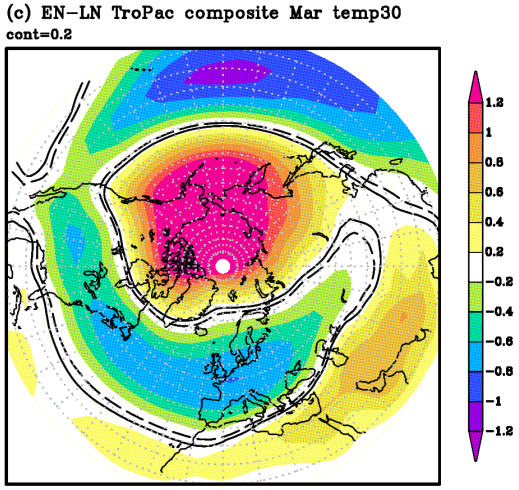
Jan



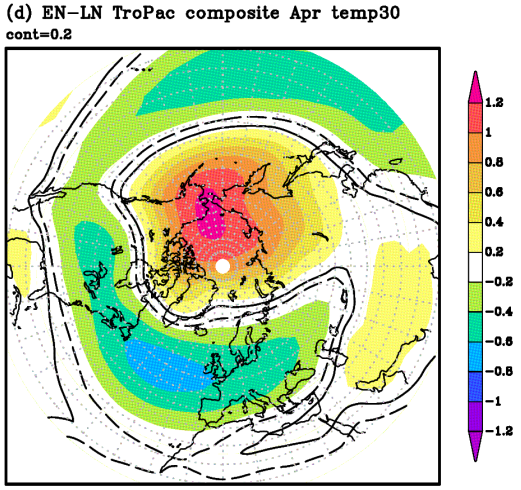
Feb



Mar



Apr

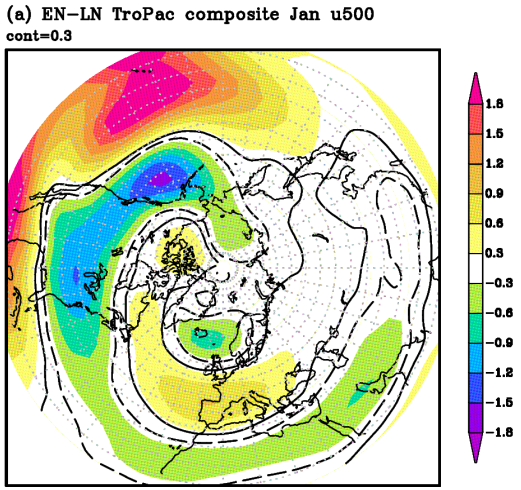


Herceg-Bulić et al.: Wintertime ENSO influence on late spring European climate: the stratospheric response and the role of North Atlantic SST.IntJClim (submitted)

Warming of the **polar stratosphere**

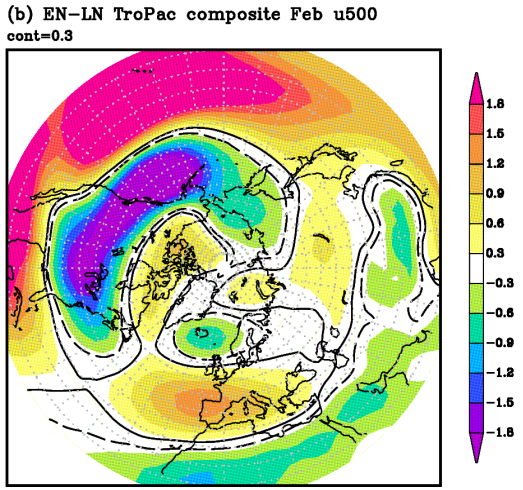
Speedy: Stratospheric response to JFM ENSO

u500



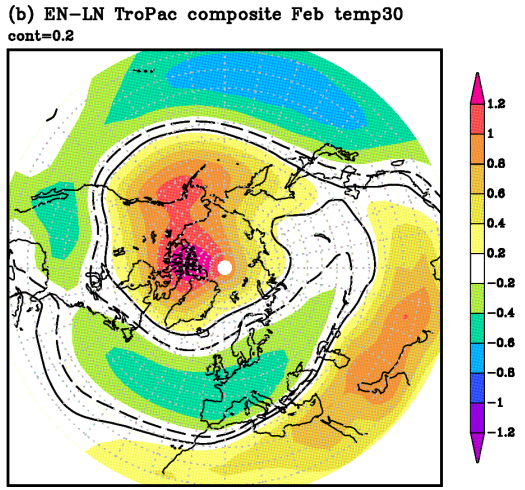
Jan

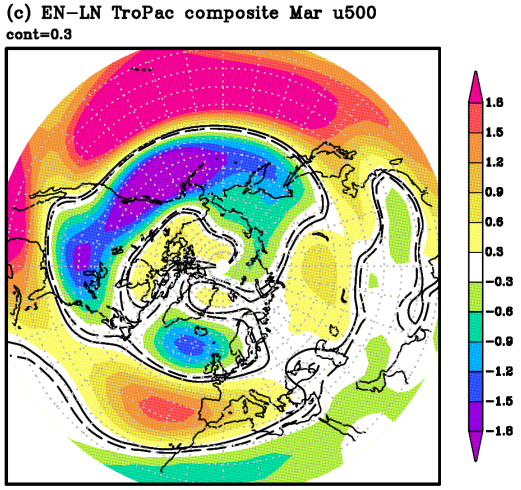
u500



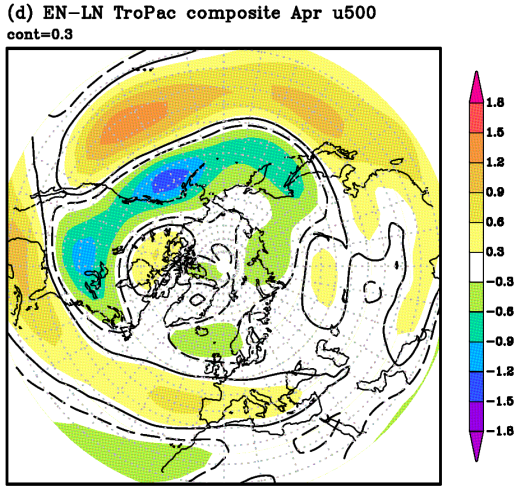
Feb

T30





Mar



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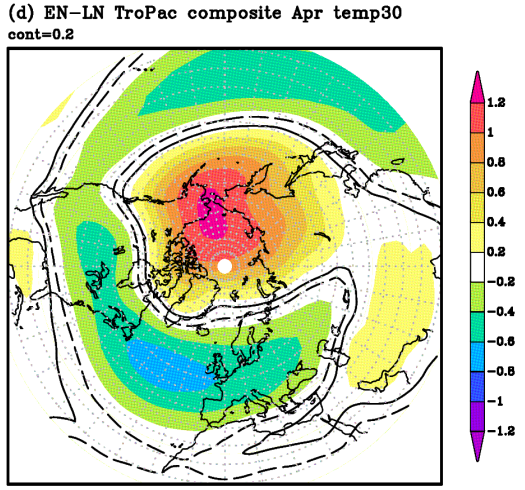


U500

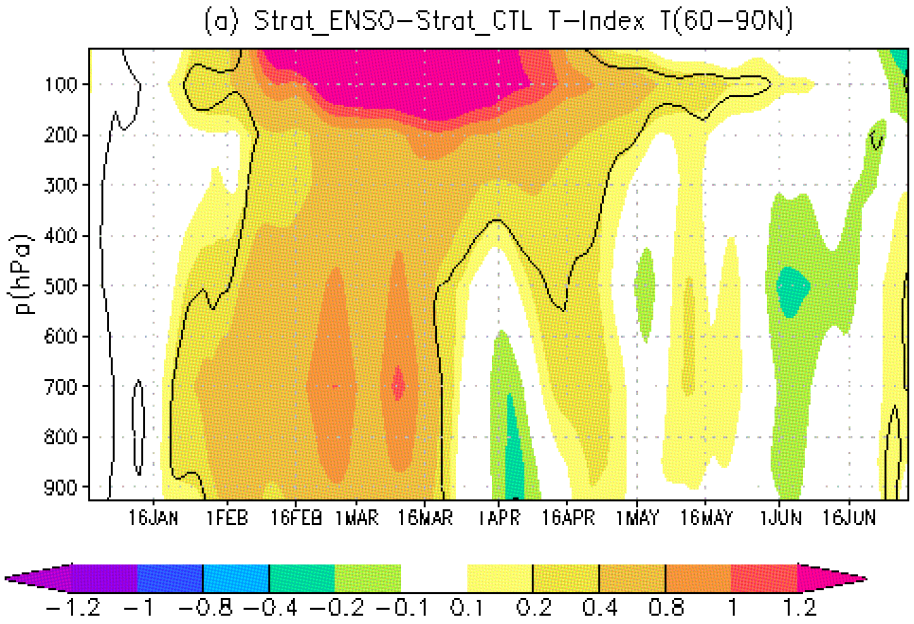
Northern Annular Mode

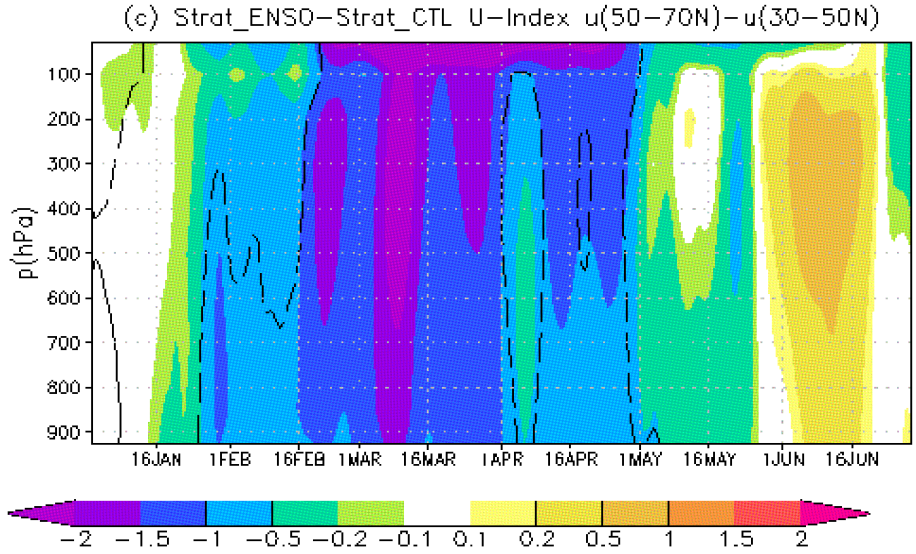
NAM

T30

Warming of the polar stratosphere

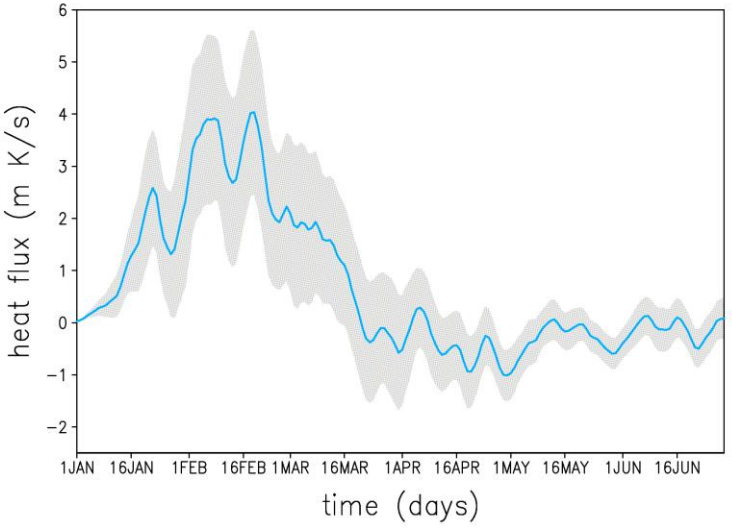
Speedy: Stratospheric response to idealized ENSO forcing





Idealised experiment Strat_ENSO:

- Daily data
- El Niño forcing in the tropical Pacific (constant from Jan to mid Feb, after that decreases linearly reaching zero at Mar16)
- No mixed layer
- TI = aveT(60-90°N)
- UI = aveU(50-70°N) - aveU(30-50°N)



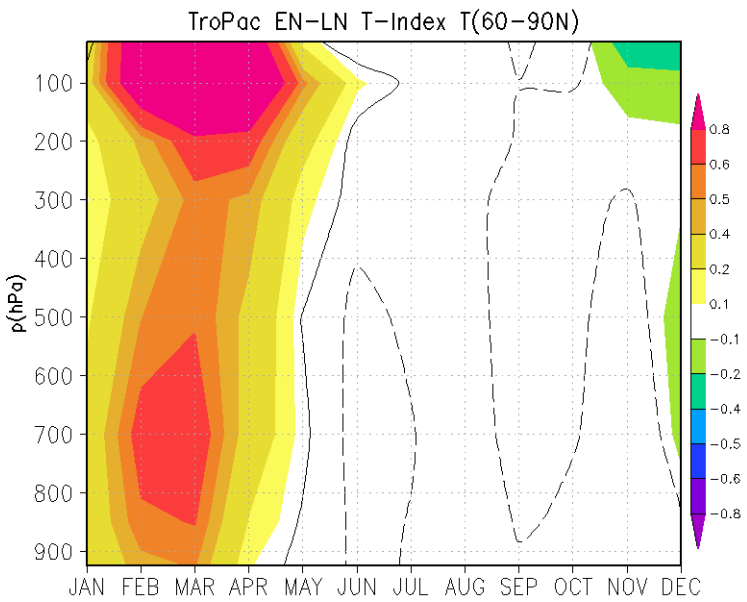
100-hPa daily meridional heat flux anomaly: increased incoming heat flux precedes the strongest polar warming

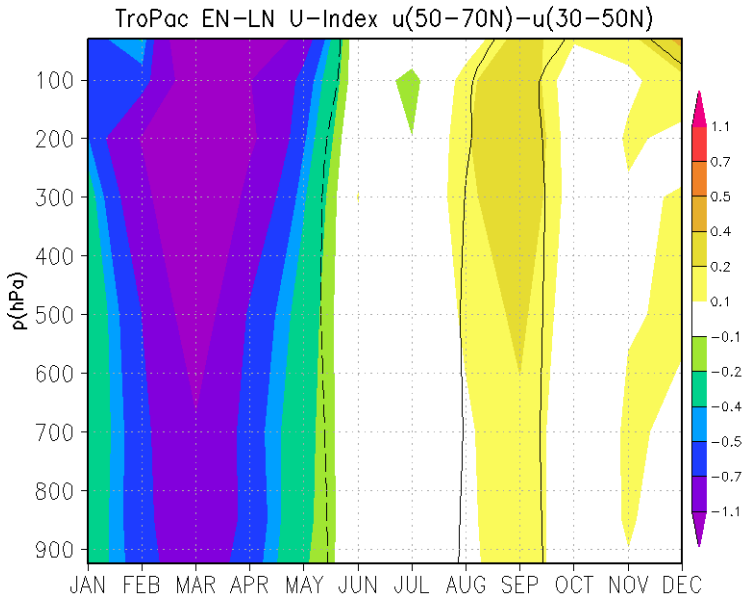
Contribution of the North Atlantic

TI =T(60-90°N)

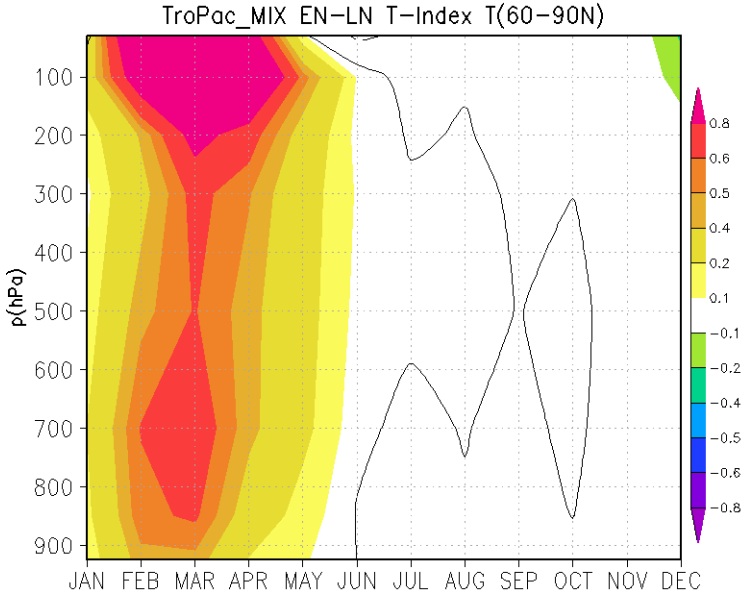
UI =U(50-70°N)-U(30-50°N)

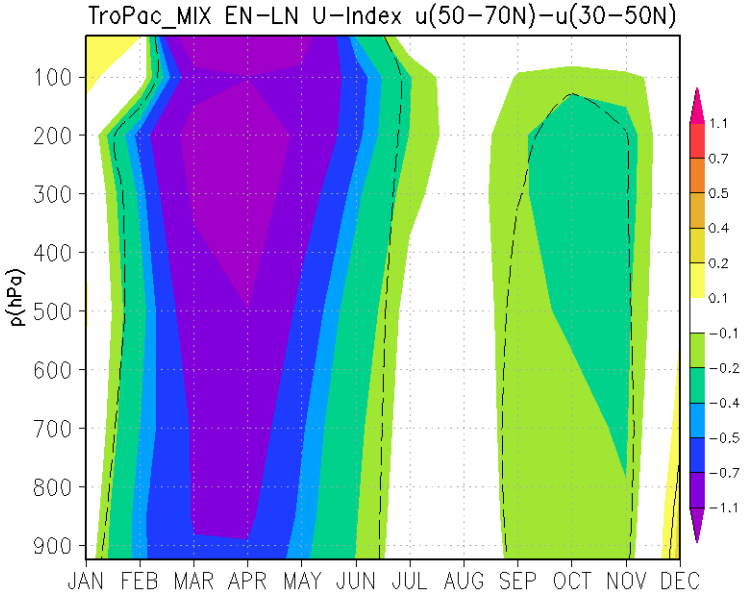
JFM ENSO forcing **NO** slab ocean





JFM ENSO forcing **WITH** slab ocean in North Atlantic

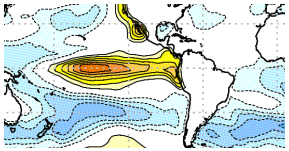




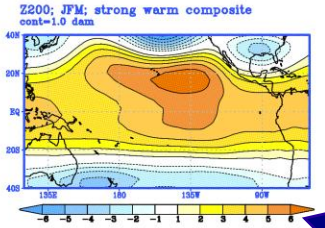
How does an ENSO impact on European climate looks like from the Speedy's perspective?

ENSO impact on European climate: Speedy perspective

Tropical Pacific **JFM**



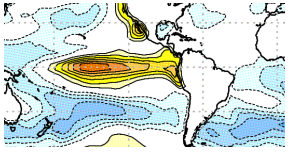
ENSO impact on European climate: Speedy perspective



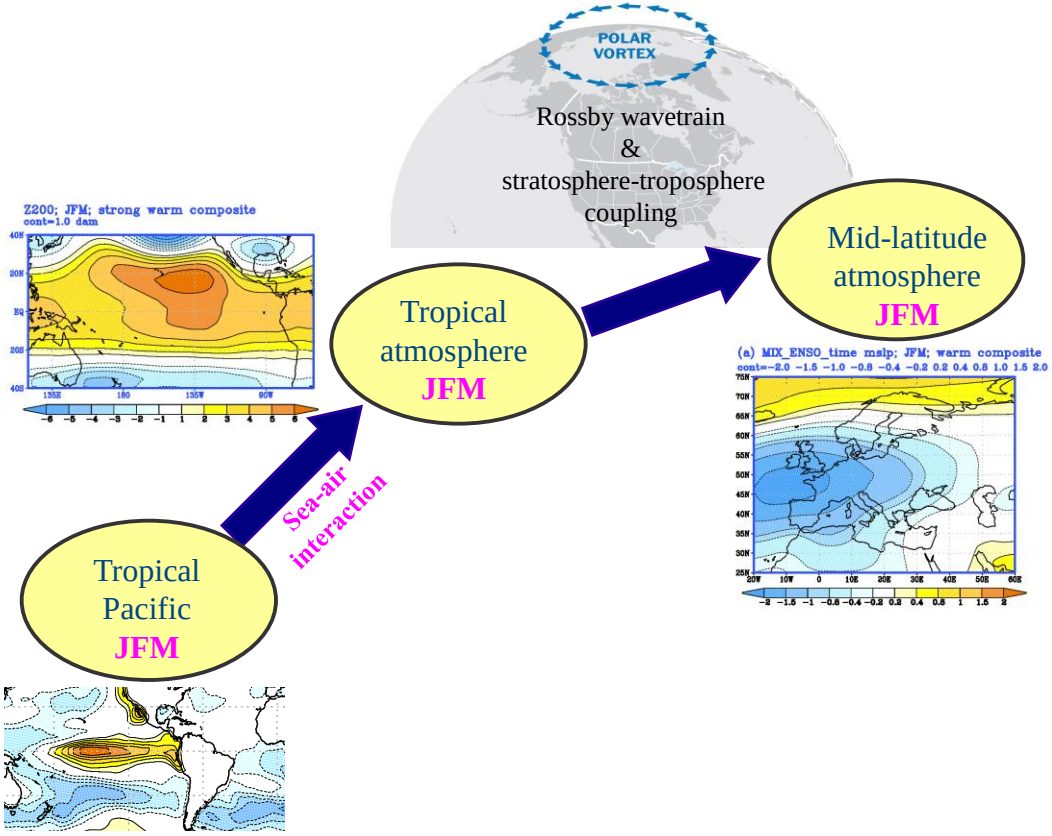
Tropical atmosphere **JFM**

Sea-air interaction

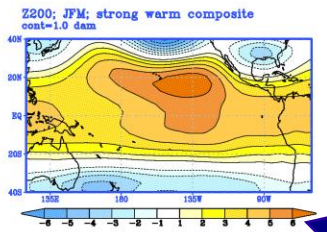
Tropical Pacific **JFM**



ENSO impact on European climate: Speedy perspective



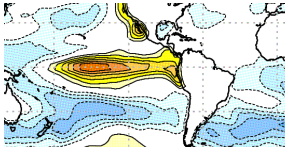
ENSO impact on European climate: Speedy model perspective

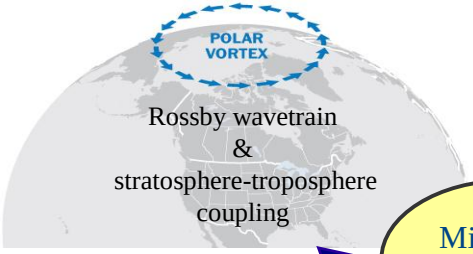


Tropical Pacific **JFM**

Sea-air interaction

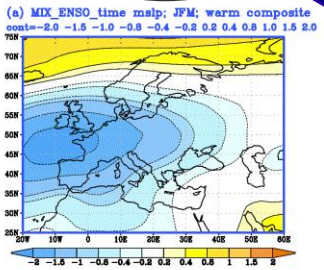
Tropical atmosphere **JFM**





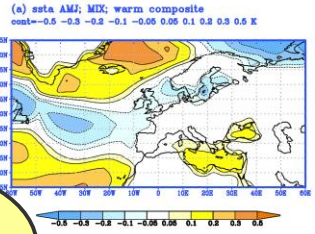
Rossby wavetrain & stratosphere-troposphere coupling

Mid-latitude atmosphere **JFM**

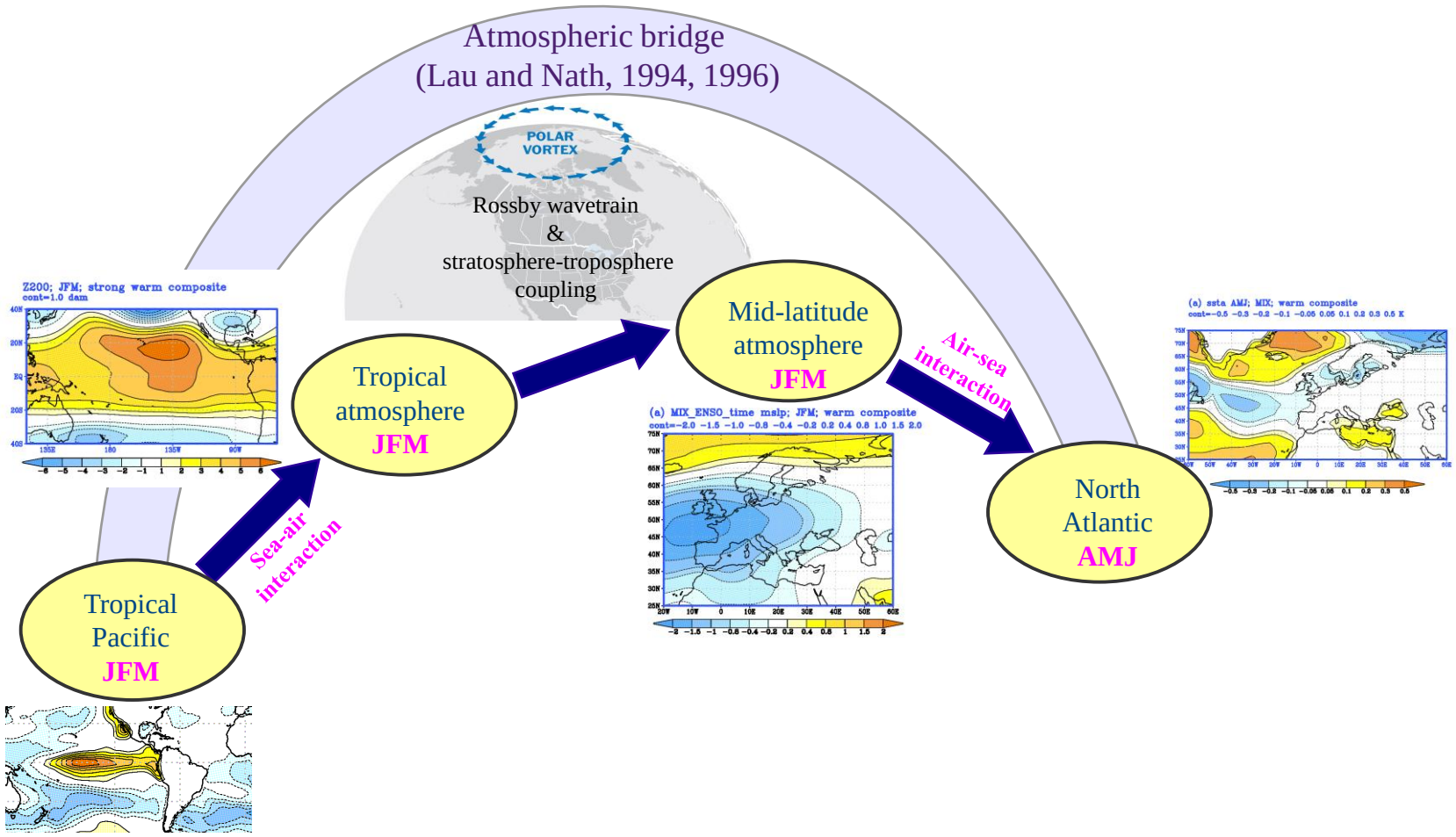


Air-sea interaction

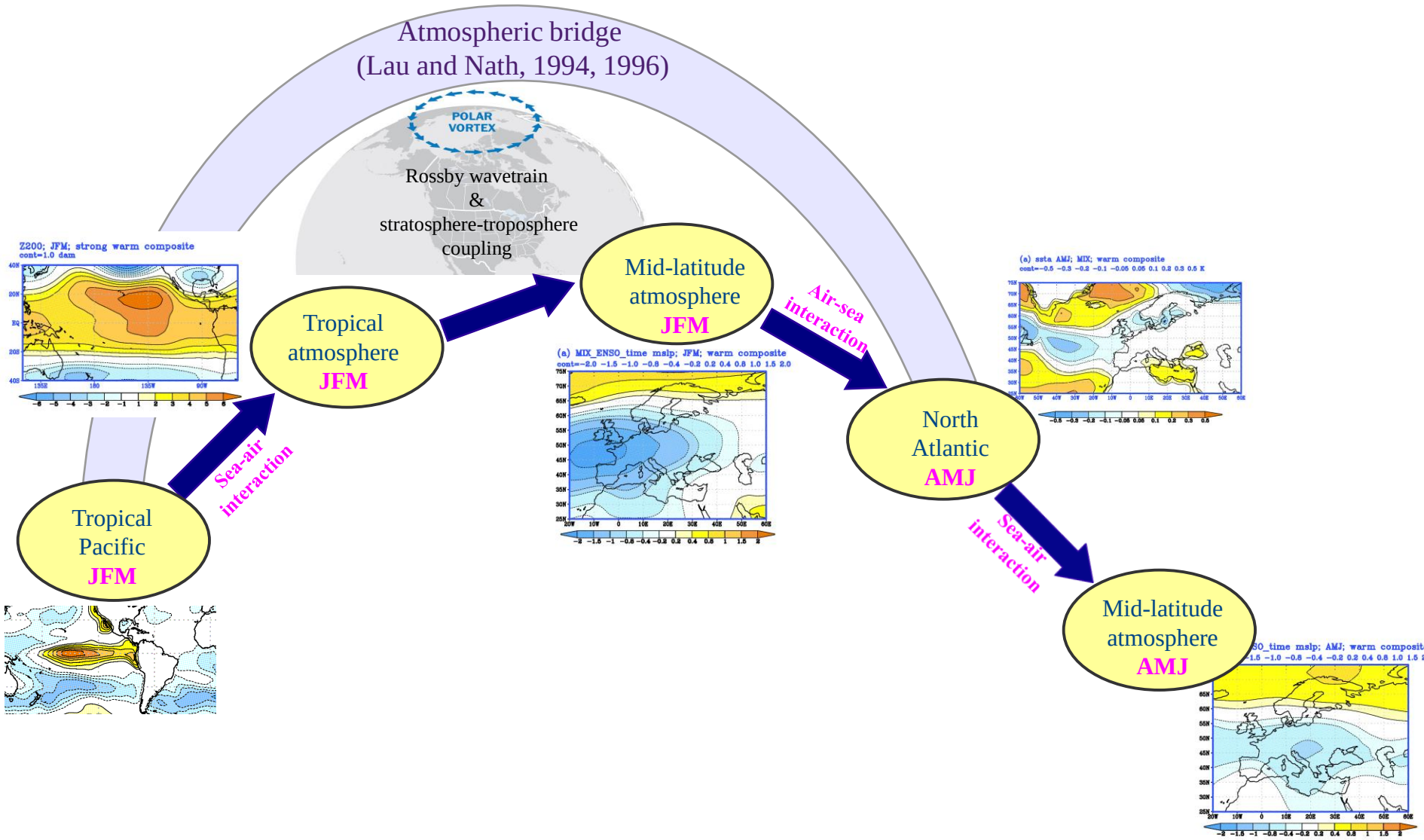
North Atlantic **AMJ**



ENSO impact on European climate: Speedy model perspective



ENSO impact on European climate: Speedy model perspective

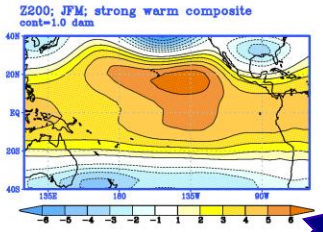


ENSO impact on European climate: Speedy model perspective

Atmospheric bridge
(Lau and Nath, 1994, 1996)

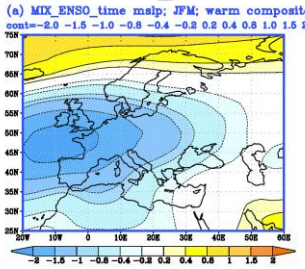
POLAR VORTEX

Rossby wavetrain
&
stratosphere-troposphere
coupling

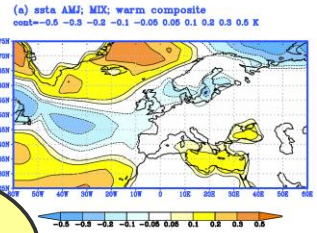


Tropical atmosphere **JFM**

Mid-latitude atmosphere **JFM**



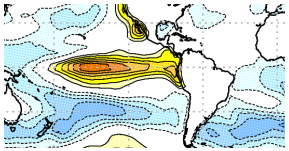
Air-sea interaction



North Atlantic **AMJ**

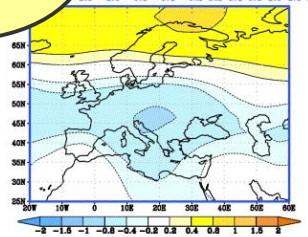
Sea-air interaction

Tropical Pacific **JFM**



Sea-air interaction

Mid-latitude atmosphere **AMJ**



Thanks!