Wintertime ENSO Impact on Spring European Climate

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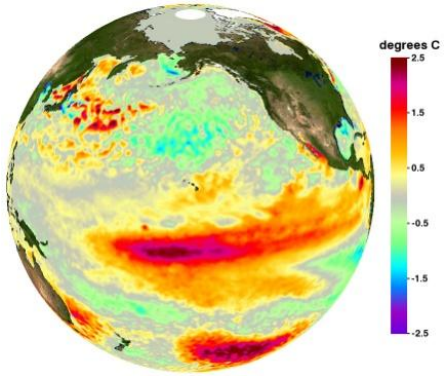
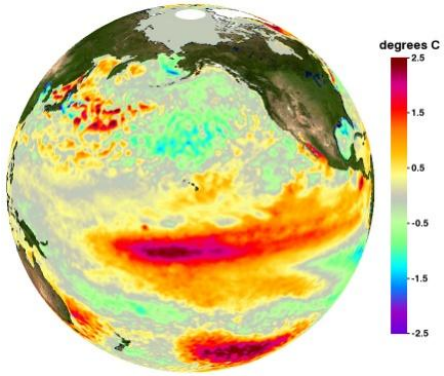
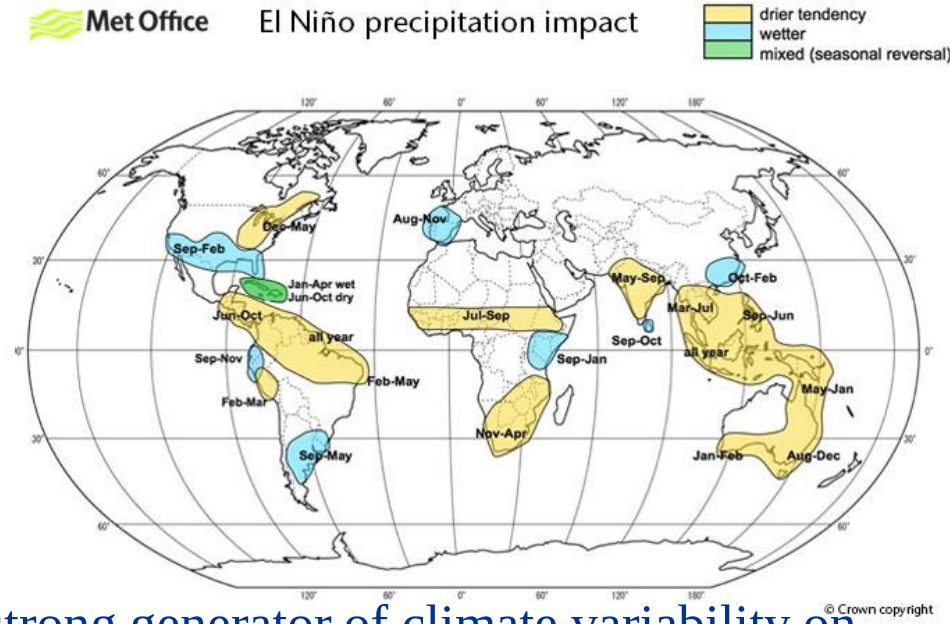
Outline



- Introduction (winter ENSO forcing)
- Motivation
- Experimental design
- Results (delayed ENSO impact)
- Conclusion (physical mechanism)

Introduction

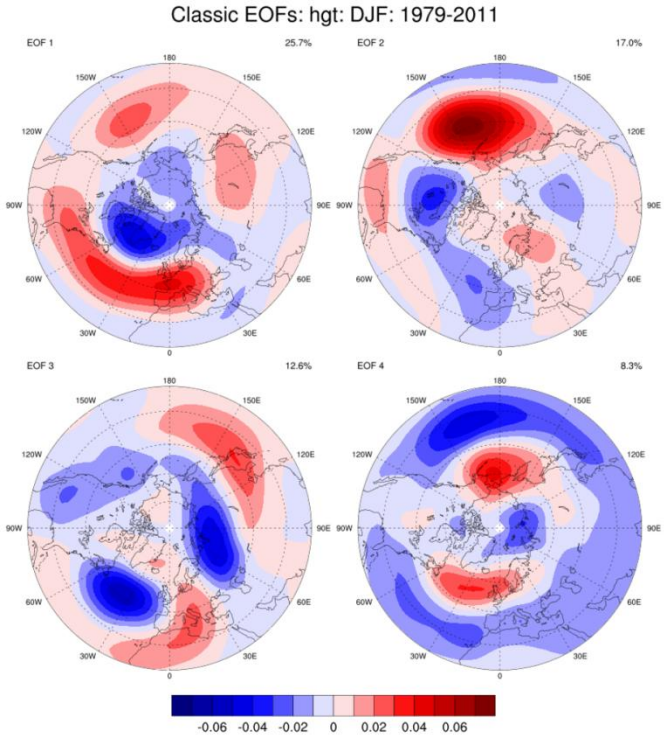




- SST anomalies in tropical oceans – strong generator of climate variability on Earth
- SST anomalies in tropical Pacific associated with ENSO – affect both tropical and extratropical atmosphere
- Impact on midlatitudes – *tropical extratropical-teleconnections* – Rossby wave propagation (+ wave-mean interactions), stratosphere-trosposhere coupling
- ENSO impact on Pacific-North American (PNA) region and Australia – clear impact
- ENSO impact on North Atlantic/European region (NAE) – difficult to asses; incomplete dynamical understanding

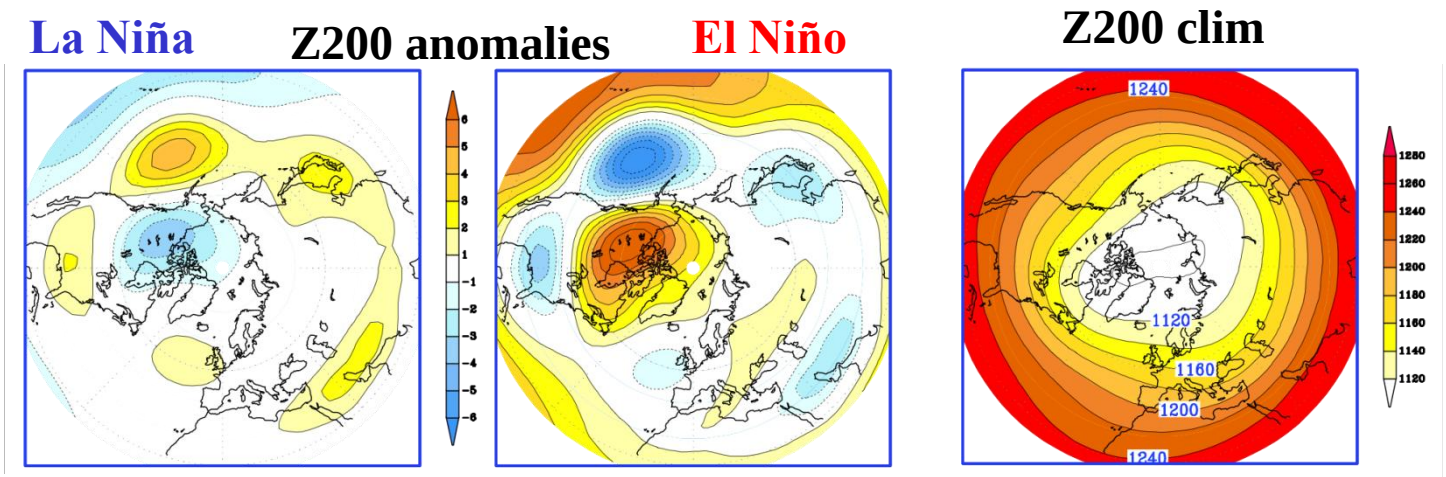
Introduction

North Atlantic-European region



- 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

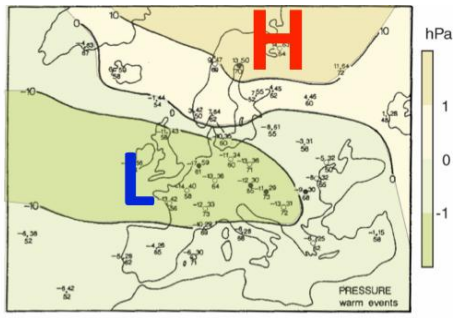
Introduction: Winter ENSO forcing



Herceg Bulić and Branković (ClimDyn 2007); Herceg Bulić, Branković and Kucharski (ClimDyn 2011):

- **SPEEDY:** Symmetrical **ENSO signal** in the **winter (JFM)** climate anomalies over the **PNA** region (PNA pattern) in Z200 anomalies as well as in other atmospheric variables (precipitation, temperature, mslp …)
- **Weak** but detectable winter **ENSO signal** over the **NAE** region (in line with some previous observational as well modelling studies; e.g. Fraedrich, Tellus 1994; Brönnimann, RevGeophys 2007)
- **NAE:** Generally, El Niño ⇒ cyclonic type of weather

  La Niña ⇒ anticyclonic type of weather



Fraedrich and Müller [1992]

Motivation

NAE region:

- **Concurrent** (JFM → JFM) + **time-delayed ENSO effect** (e.g. Rodó et.al. ClimDyn 1997; Kiladis and Dias JClim 1989; van Oldenborg et.al. IntJClimatol 2000, Herceg Bulić and Kucharski ClimDyn 2012, Herceg Bulić at al. IntJClimatol 2017)
- **Spring precipitation anomaly** sometimes may be **even stronger than that in winter** – possible time-lagged teleconnection
- Progress in understanding, observing and modelling ENSO – has resulted in **skillful dynamical ENSO predictions** up to two seasons in advance (e.g. Barnston et al. BAMS 2012, Infanti and Kirtman ClimDyn 2016, Gonzales and Goddard Climdyn 2016)
- Improved understanding of dynamical mechanisms of tropical-extratropical teleconnections – **a physical basis for seasonal climate prediction over North America and Euroasia** (Scaife et al. GeopysResLett 2014, Dunstone et al. NatureGeosci 2016) → possible application for seasonal predictions

Experimental design

- Time period: 1901 – 2002

- **Observational data:**

  Precipitation: Climatic Research Unit (**CRU**) gridded monthly dataset (0.5°×0.5°)

  Sea-level pressure: **HadSLP** re-analysis (5°×5°); provided by Hadley Centre, UK

  SST: **NOAA_ERSST_V2** data (provided by NOAA/OAR/ESRL PSD, USA)

  Sea-ice climatology: HadISST (Hadley Centre, UK)

Experimental design

Modeled data: experiments based on ensembles of numerical simulations by ICTP AGCM **(SPEEDY; T30L8)**

1. **CTRL**: 20-member ensemble; simulations forced with observed global monthly SST anomalies

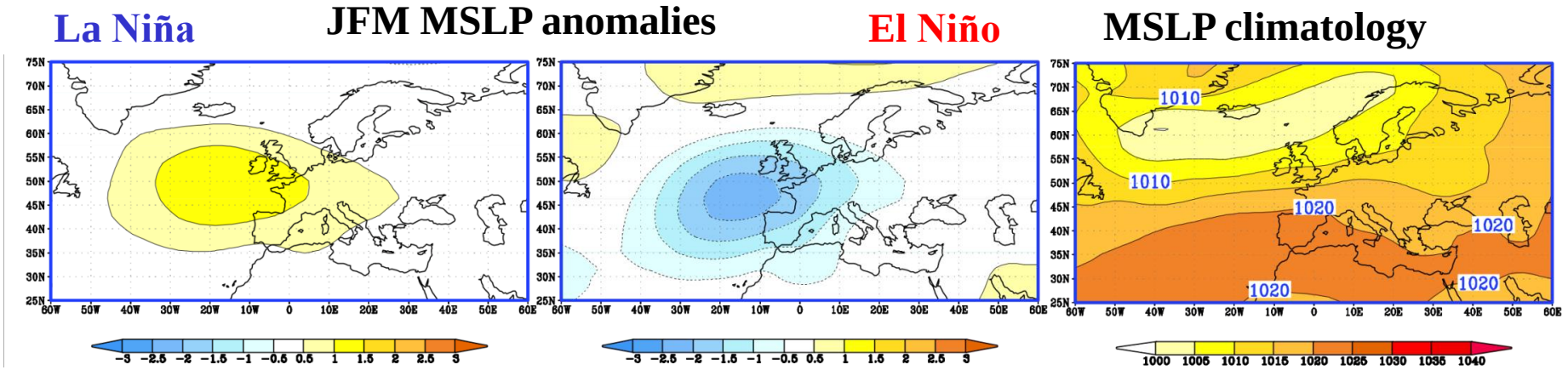
2. **MIX**: 10-member ensemble, SPEEDY coupled with a passive *slab ocean* layer in the *North Atlantic* + observed global monthly SST anomalies in the Indo-Pacific tropical basin

3. **MIX_winter_ENSO** experiment: same as the MIX experiment, but with SST forcing in the Indo-Pacific basin during **October - March**

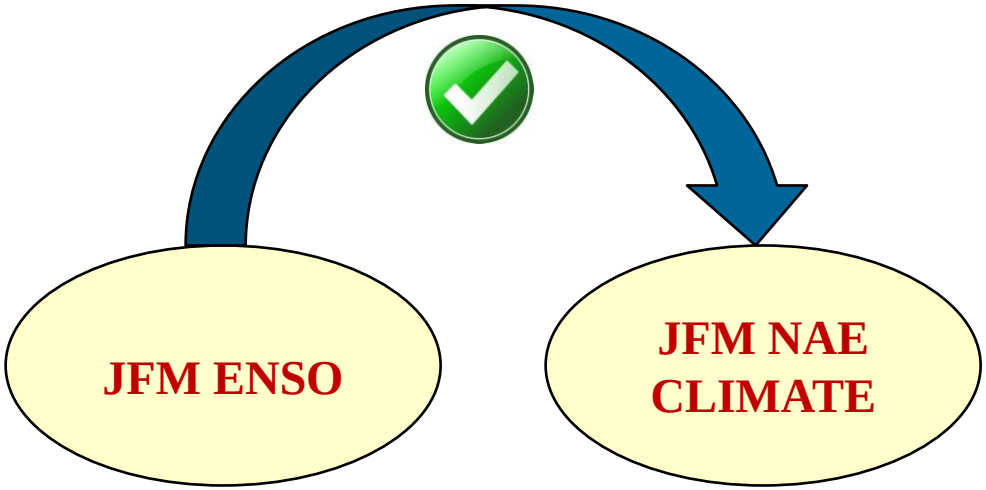
4. **MIX_summer_ENSO** experiment: same as the MIX experiment, but with SST forcing in the Indo-Pacific basin during **April - September**

Results: SPEEDY NAE composites

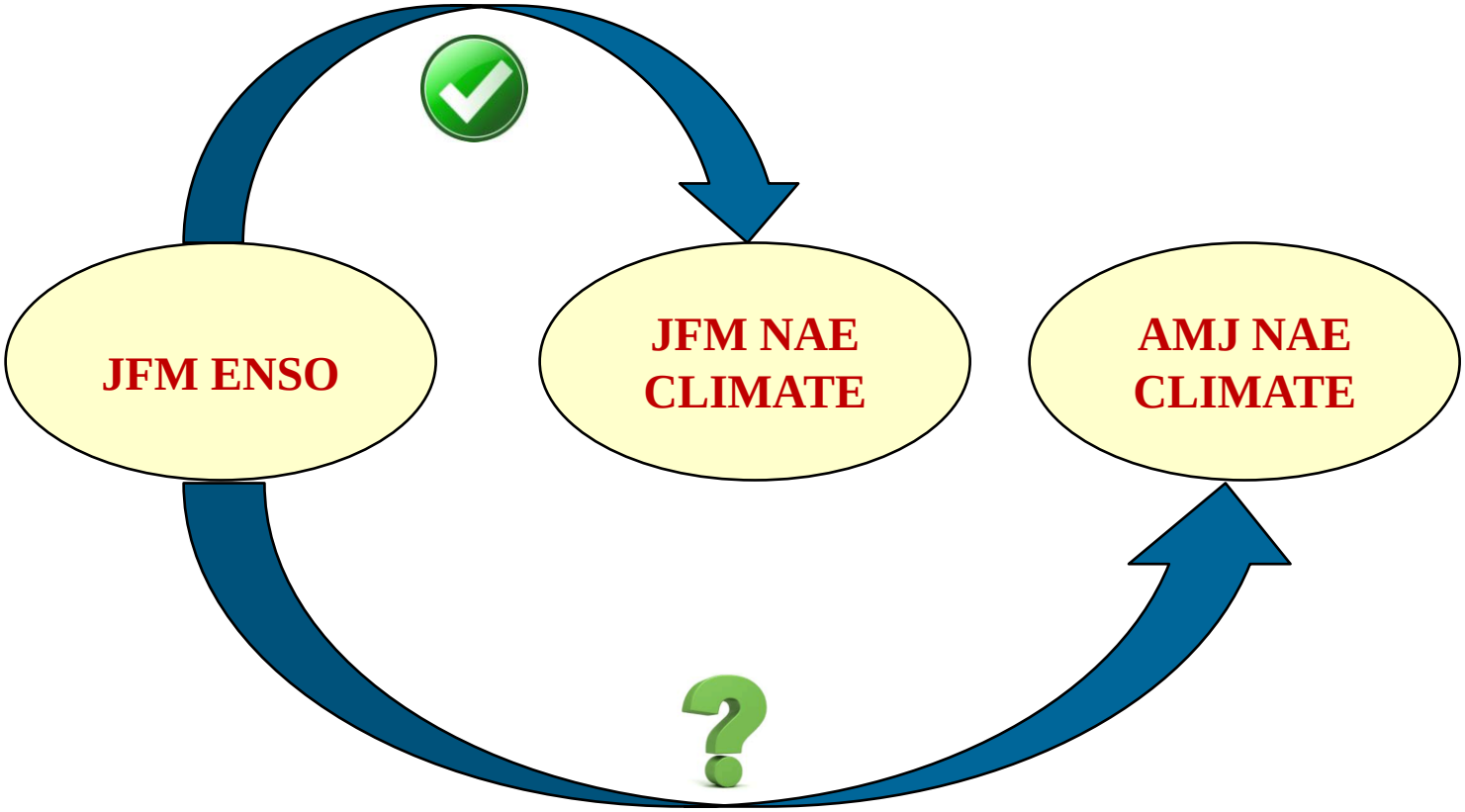
- Signal for warm events stronger than that for cold events
- Model response insensitive to the strength of the Niño3.4 index



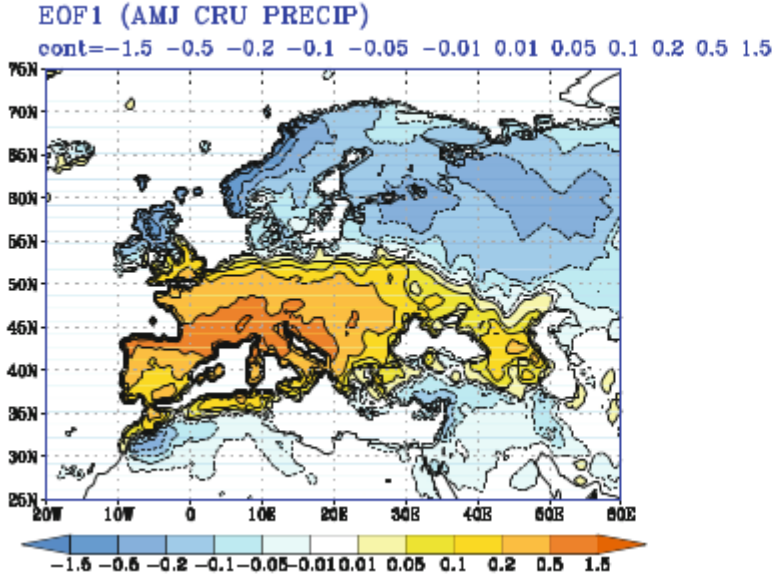
Concurrent ENSO influence on NAE

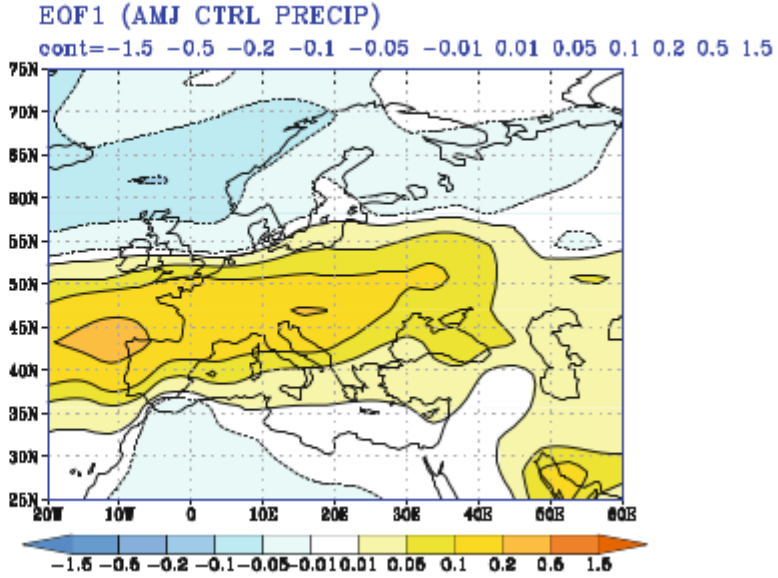


Delayed ENSO influence on NAE?

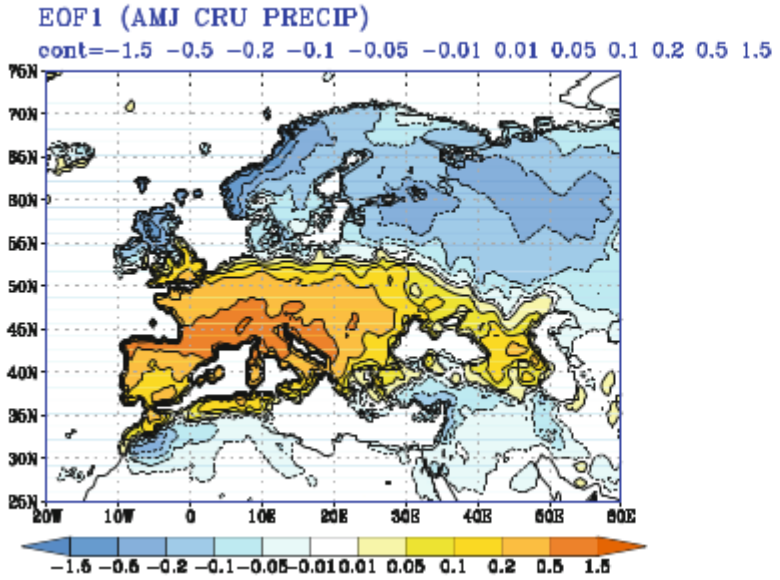


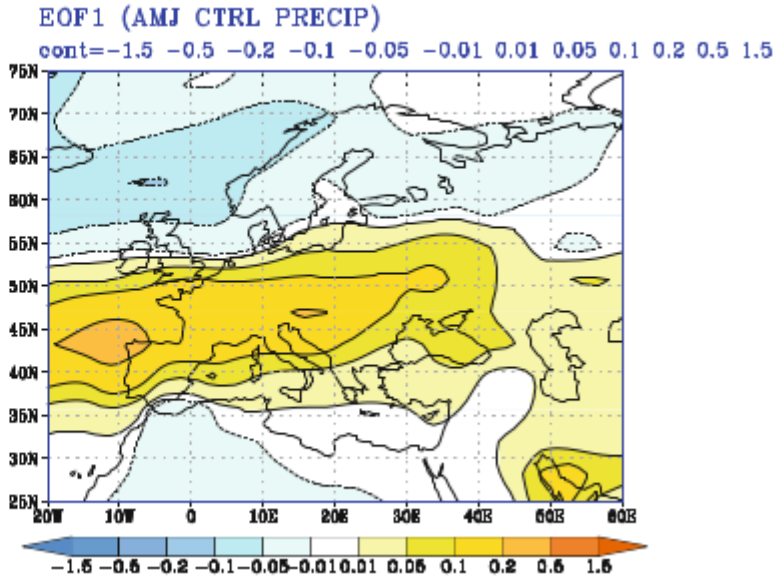
Results: EOF1 of AMJ precipitation





Results: EOF1 of AMJ precipitation





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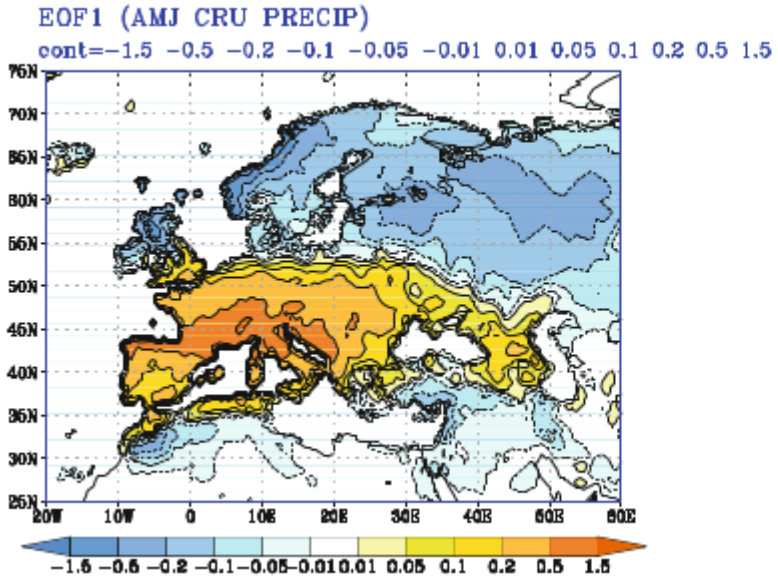
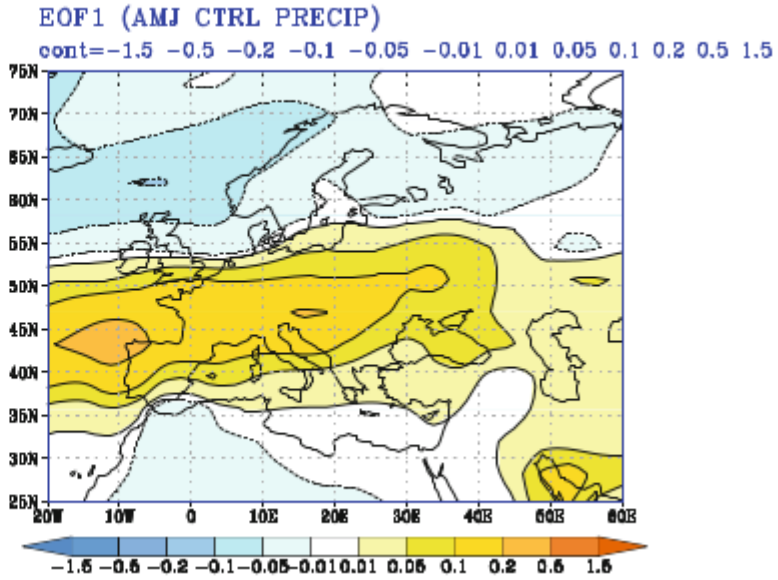




Tropcal Pacific SST

contemporaneous
AMJ - AMJ

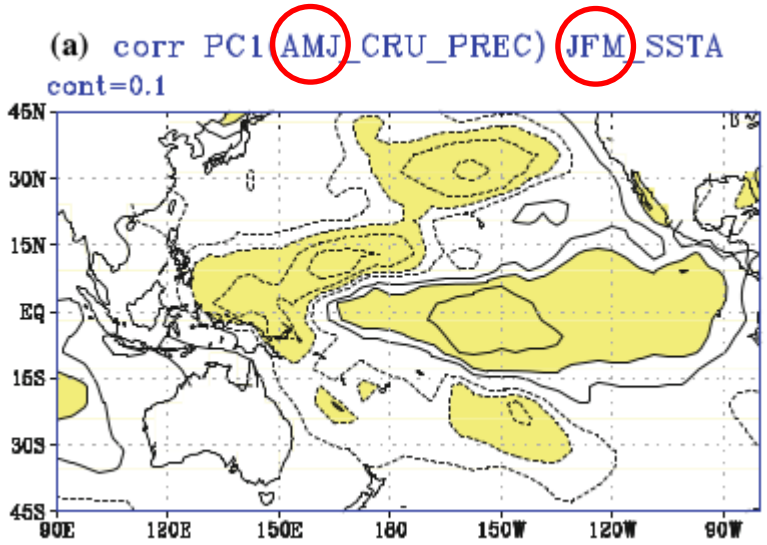
JFM – AMJ
delayed

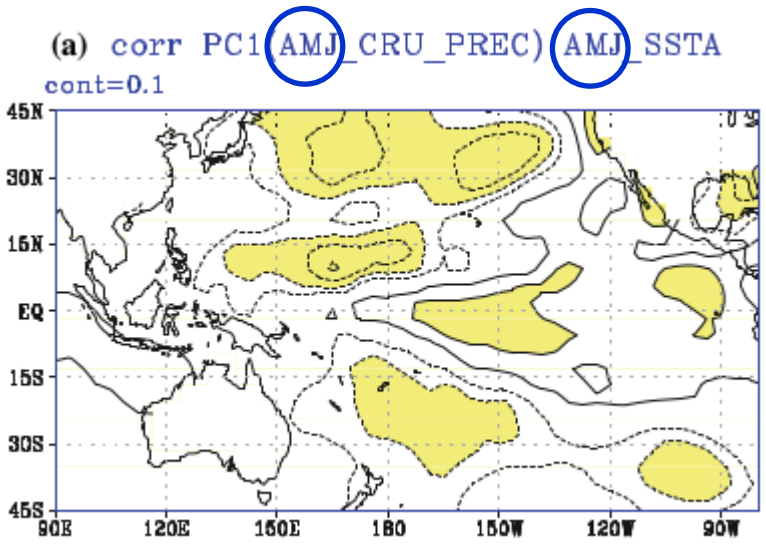
AMJ NAE precipitation

Delayed ENSO influence on NAE?

Correlation PC1 AMJ precipitation - SSTA

CRU

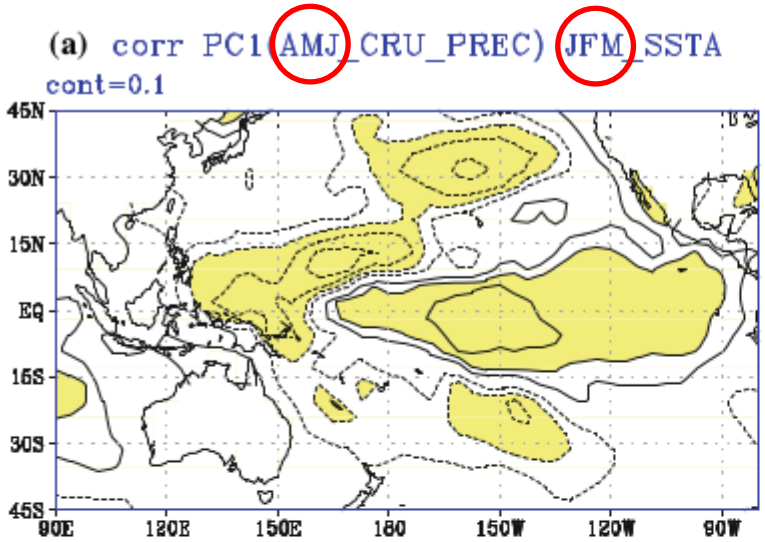


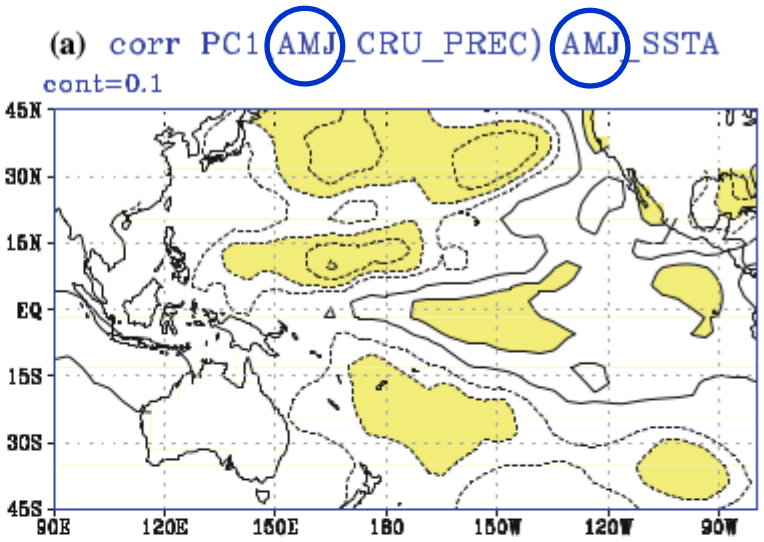


Delayed ENSO influence on NAE?

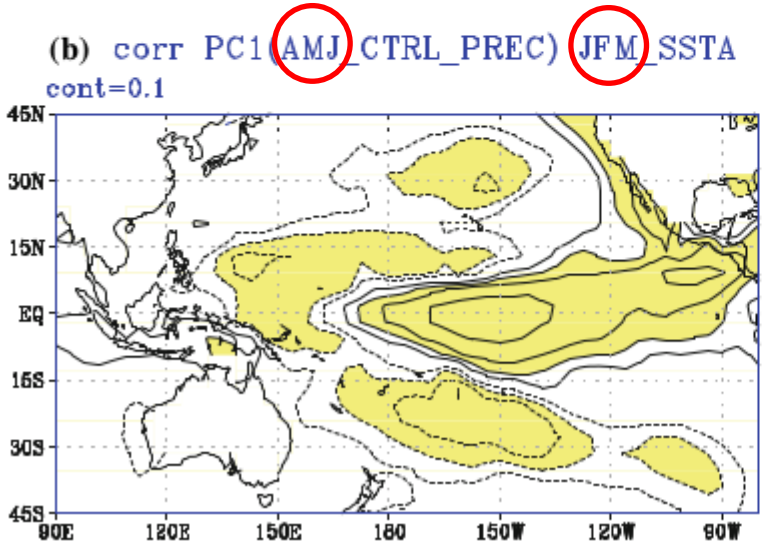
Correlation PC1 AMJ precipitation - SSTA

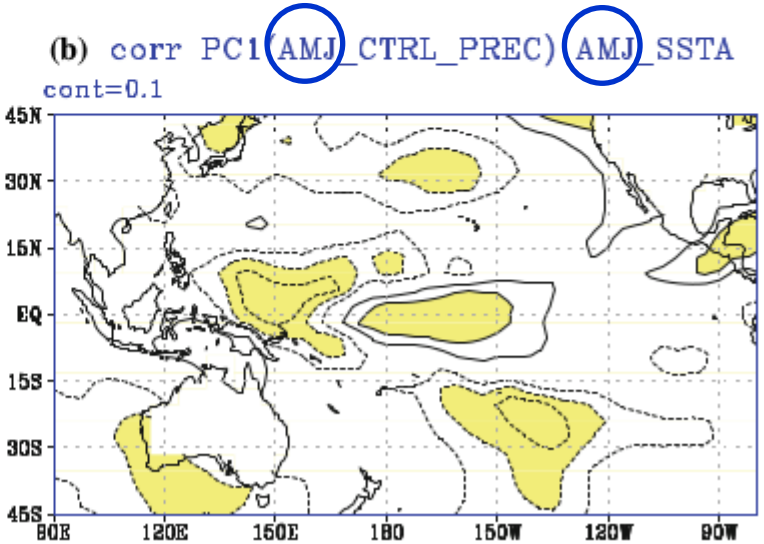
CRU





SPEEDY





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

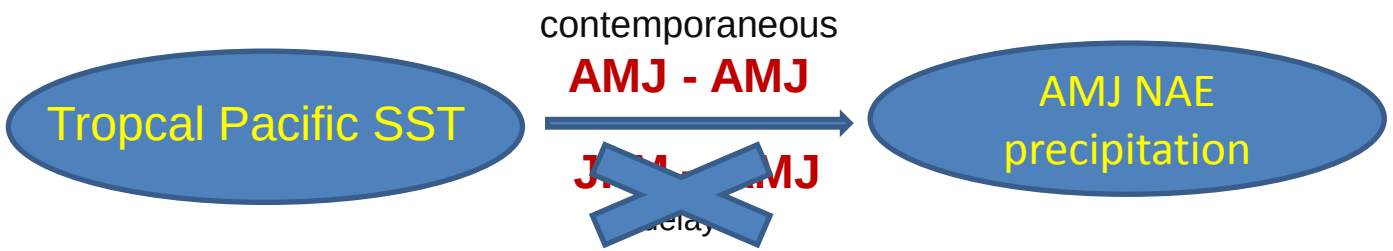

Tropcal Pacific SST
contemporaneous
AMJ - AMJ
JFM – AMJ
delayed
AMJ NAE
precipitation

MIX winter ENSO experiment

ENSO forcing restricted to the **winter (Oct – Mar)**

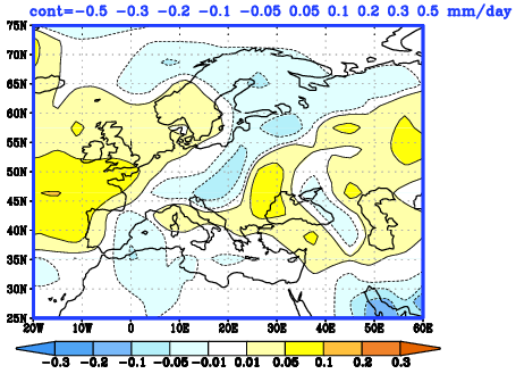
MIX summer ENSO experiment

ENSO forcing restricted to the **summer (Apr – Sep)**

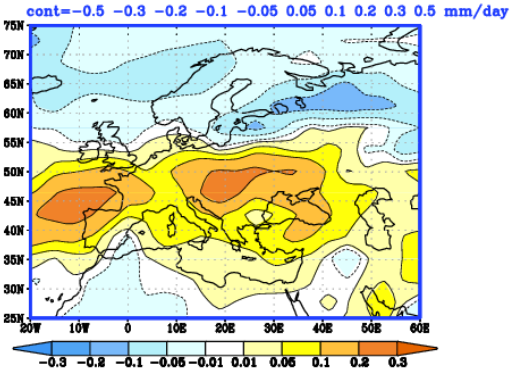


Results: AMJ precipitation composites

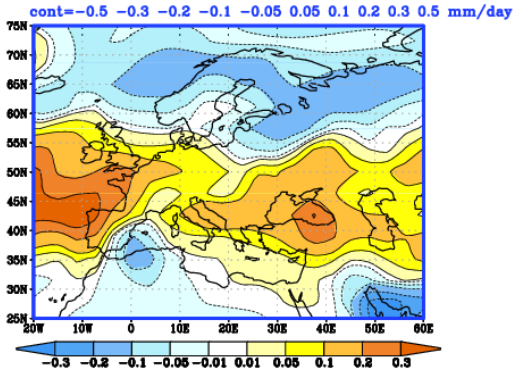
MIX summer ENSO AMJ prec



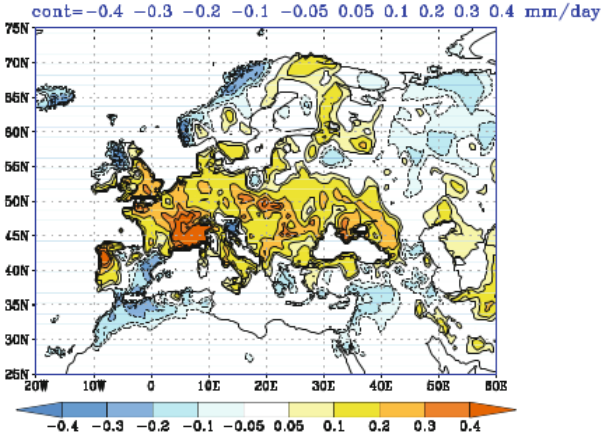
MIX winter ENSO AMJ prec



CTRL AMJ prec



CRU AMJ prec



A physical mechanism of time delayed ENSO impact on NAE?

- CRU and MIX_winter_ENSO precipitation data have demonstrated (similar) time delayed response to winter ENSO
- MIX_winter_ENSO & MIX_summer_ENSO : a seasonal persistence of ENSO as a potential explanation is excluded
- Rossby wave propagation mechanism can not explain winter-spring teleconnection
- Some intermediary physical mechanism / slower component of the climate system is expected to be involved → the role of North Atlantic

(a) corr PC1(JFM_Nino3.4_SST) AMJ_SST_MIX_winter_ENSO
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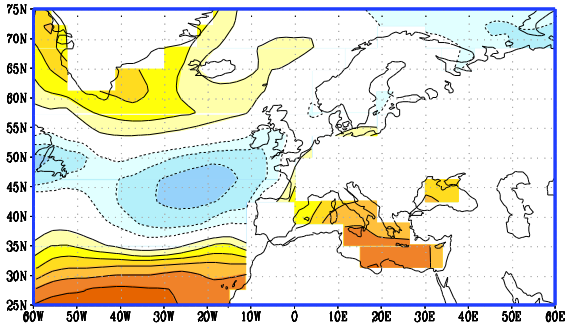

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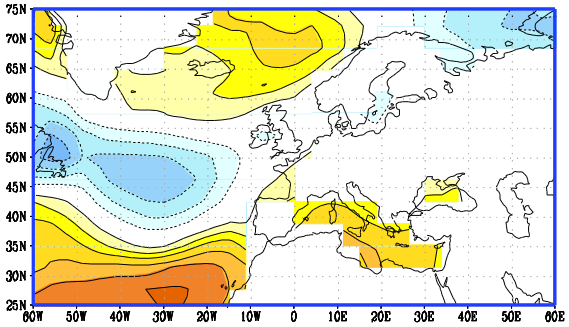

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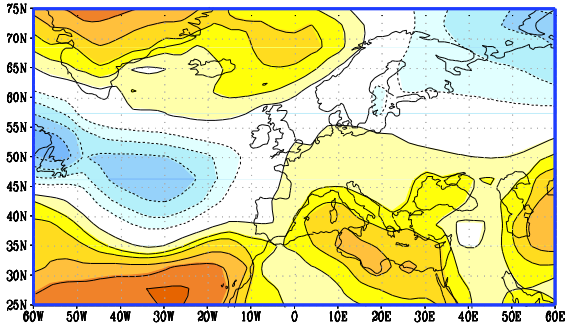

(d) corr PC1(JFM_Nino3.4_SST) AMJ_T850_MIX
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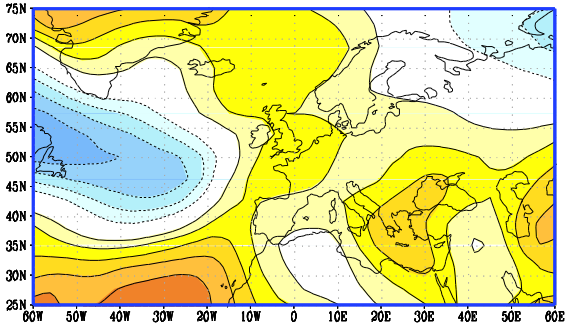

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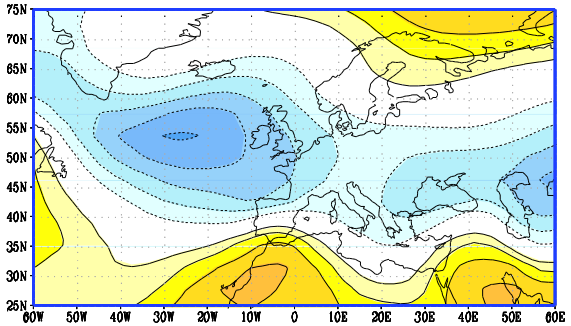

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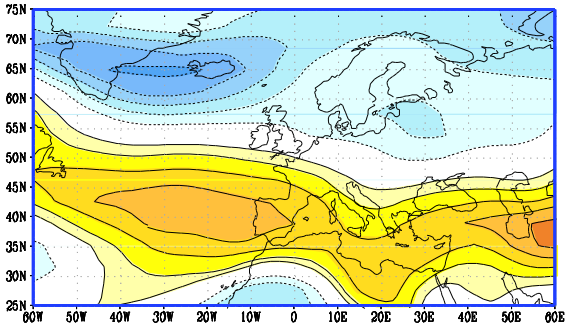

(a) corr PC1(JFM_Nino3.4_SST) AMJ_SST_MIX_winter_ENSO
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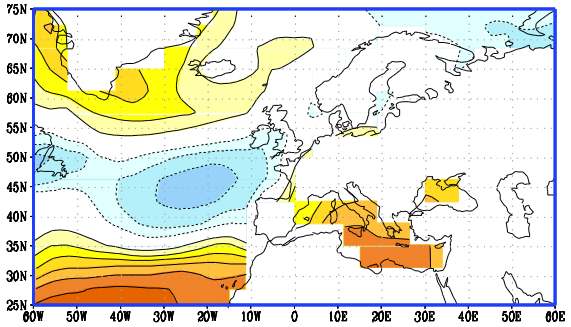

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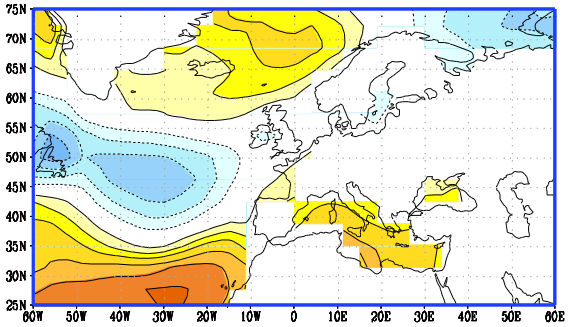

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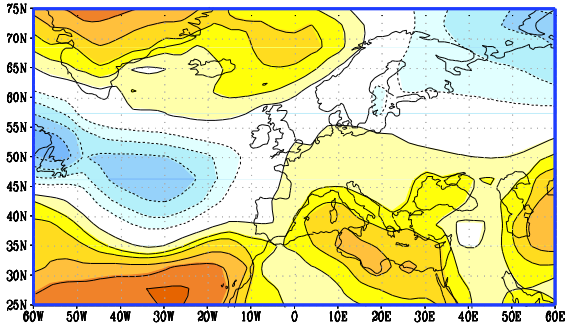

(d) corr PC1(JFM_Nino3.4_SST) AMJ_T850_MIX
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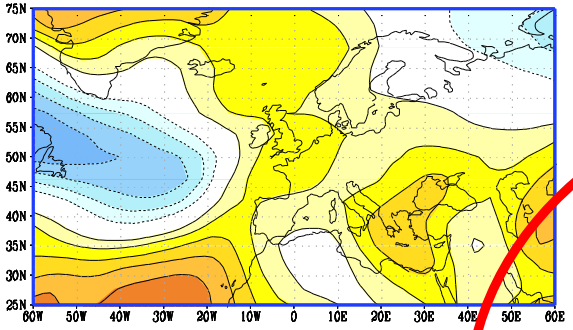

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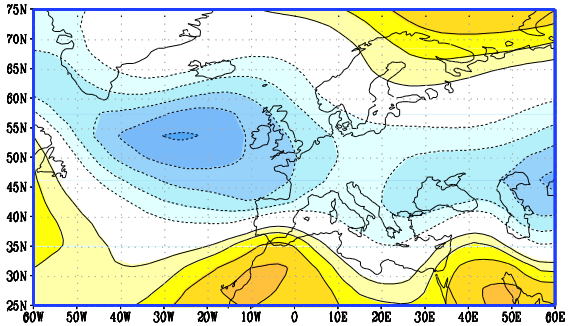

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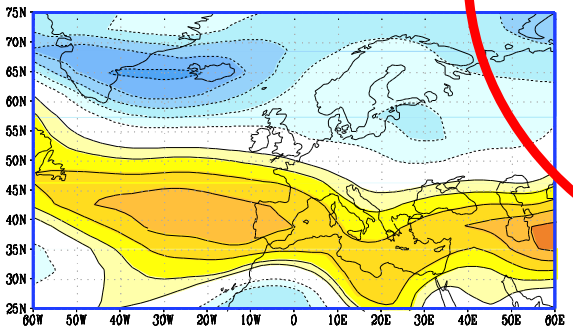
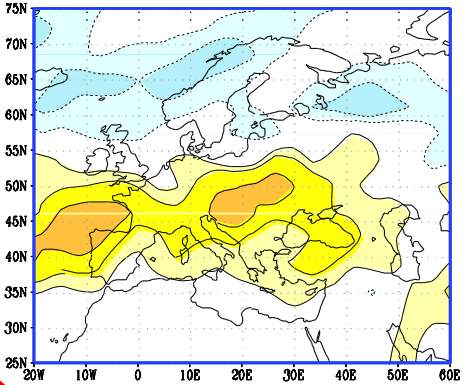


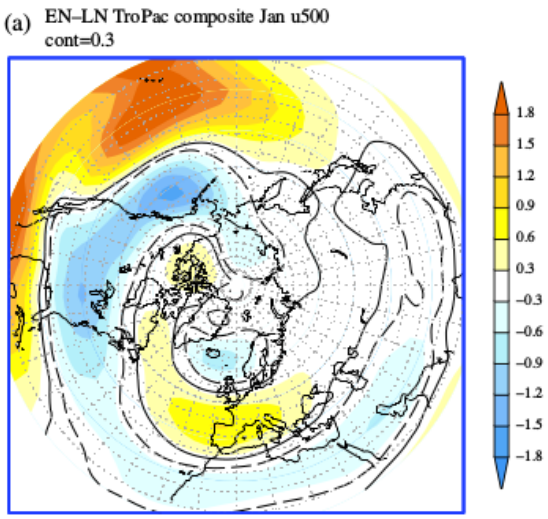
(e) MIX_winter_ENSO PREC; AMJ; warm composite
cont=-0.4 -0.3 -0.2 -0.1 -0.05 0.05 0.1 0.2 0.3 0.4 mm/day

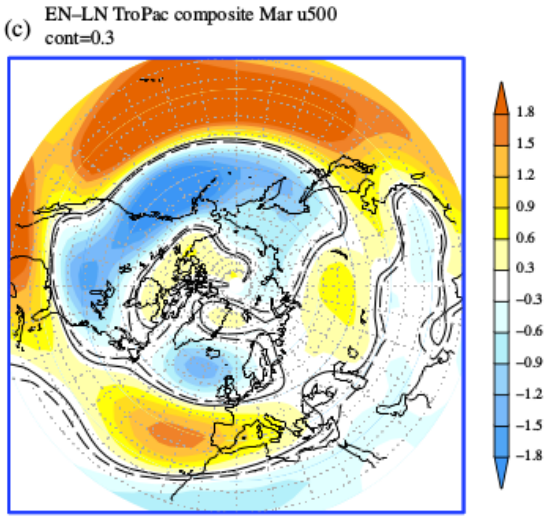


What is going on in the Speedy's stratosphere?

What is going on in the Speedy's stratosphere?

u500





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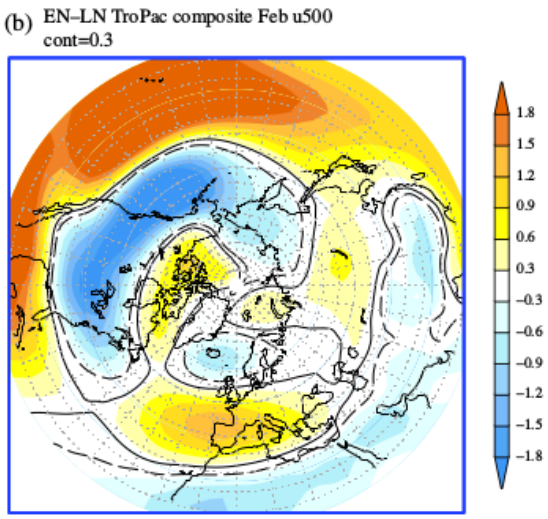
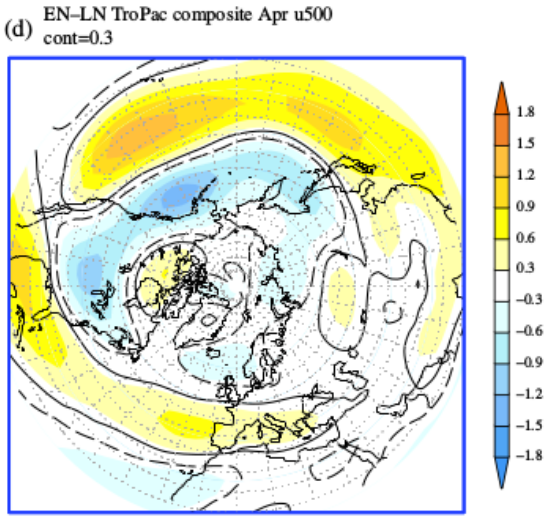
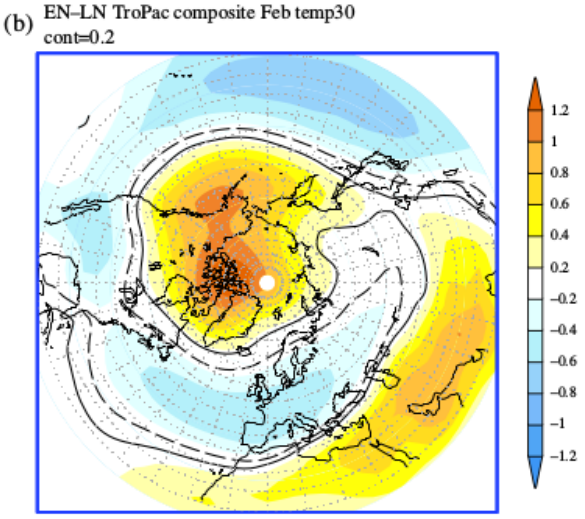
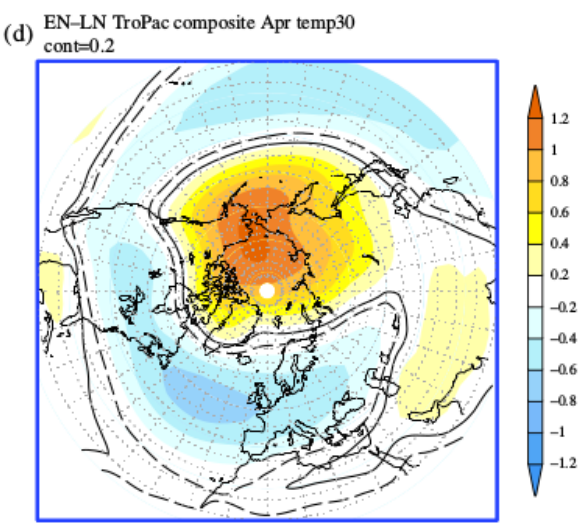




T30





U500

Northern Annular Mode

NAM

T30

El Nino: Warming of the polar stratosphere

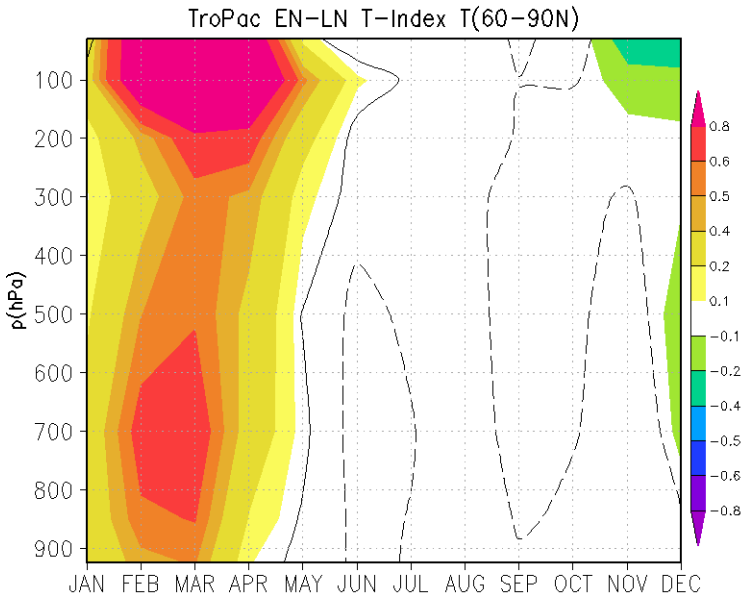
Contribution of the North Atlantic + stratosphere

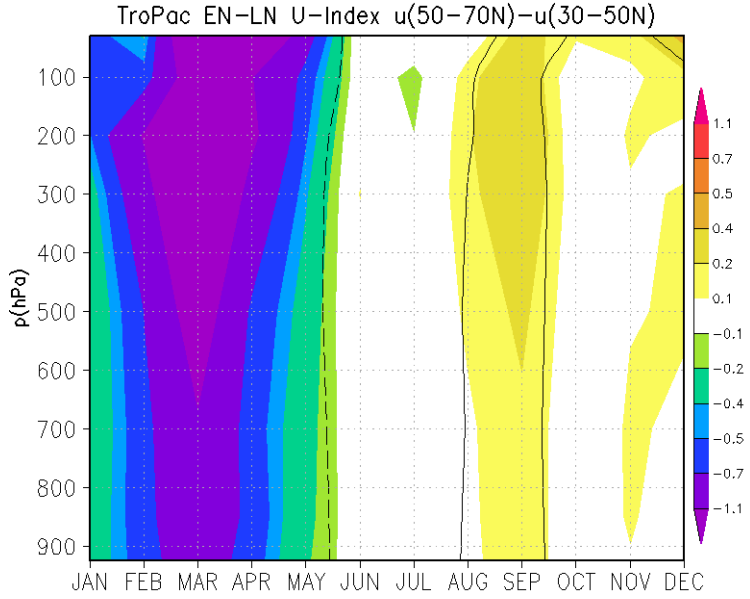
TI =T(60-90°N)

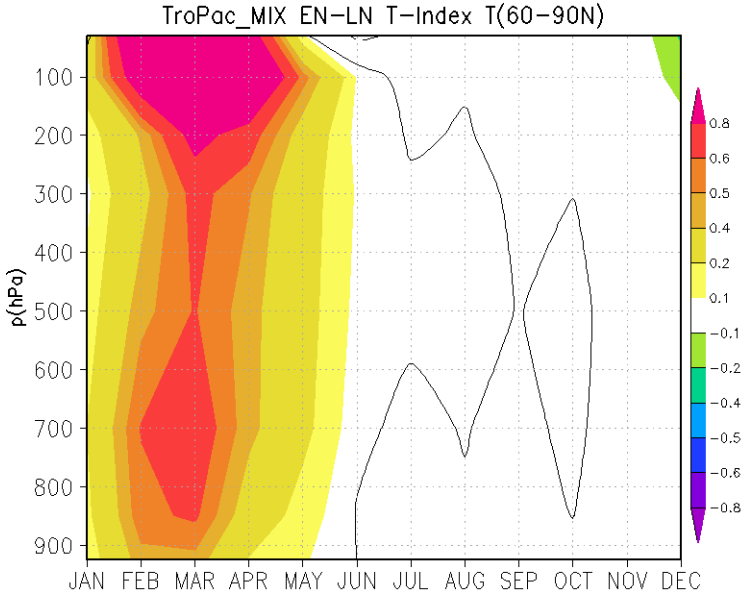
UI =U(50-70°N)-U(30-50°N)

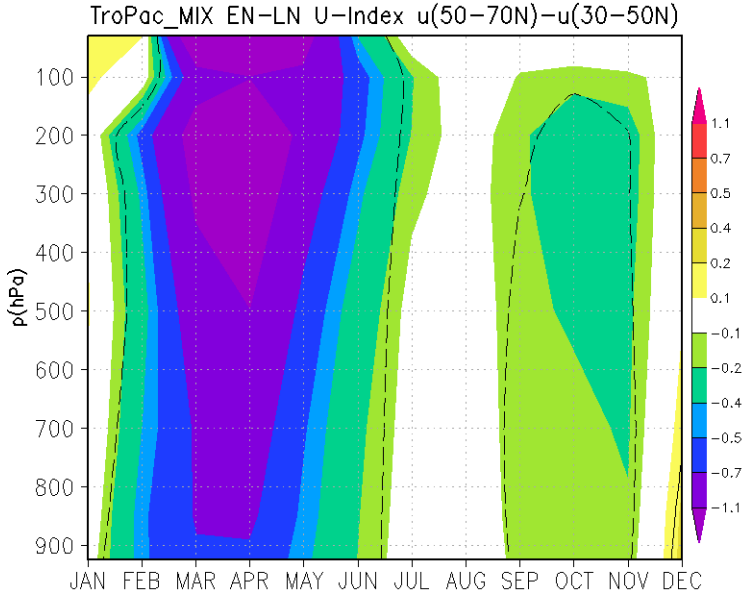
JFM ENSO forcing **NO slab ocean**

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

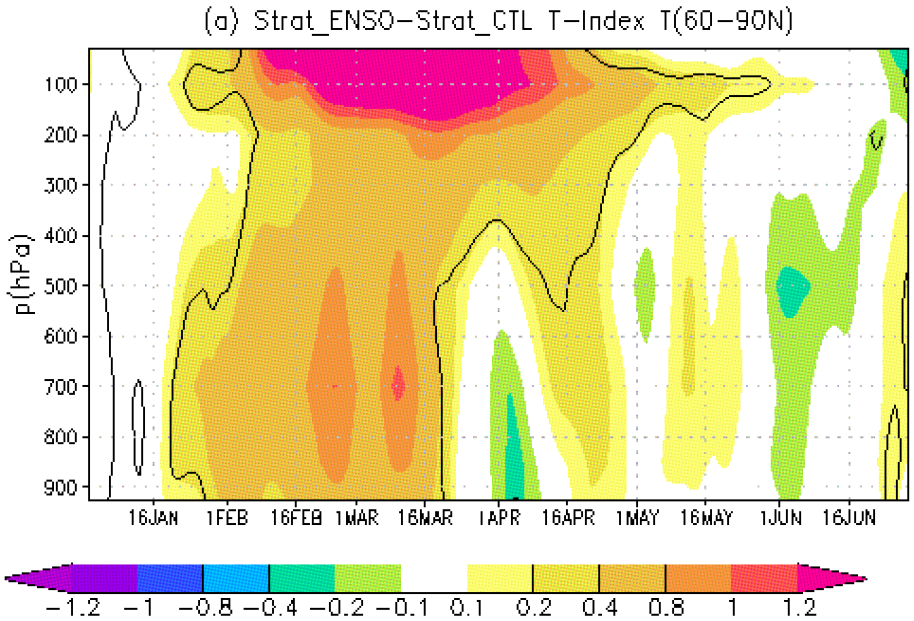


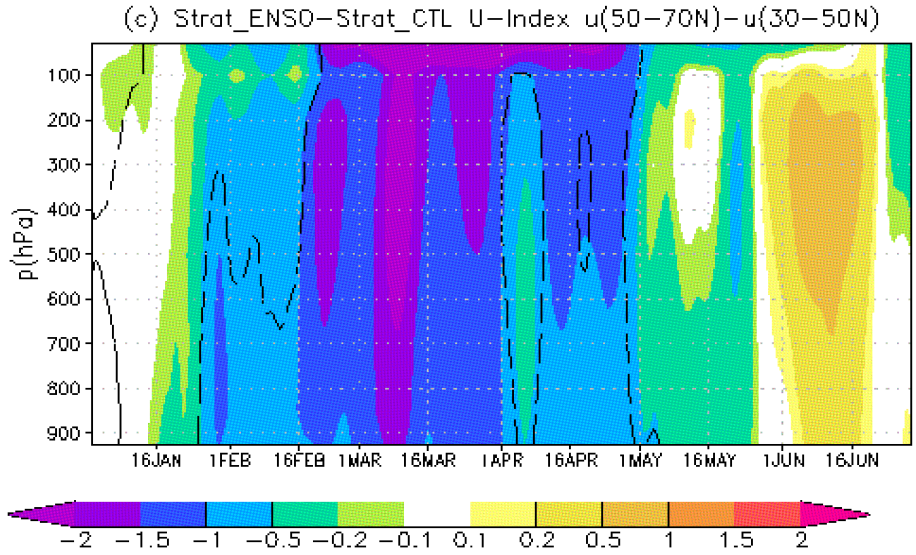






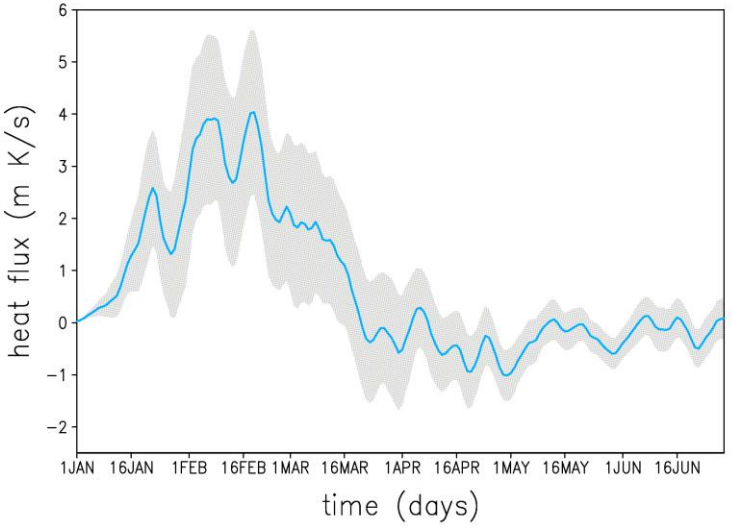
Speedy: Stratospheric response to idealized ENSO forcing





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 = T(60-90ºN)
- UI = U(50-70ºN) - U(30-50ºN)

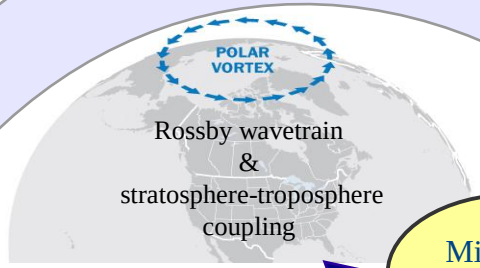


100-hPa daily meridional heat flux anomaly: increased incoming heat flux precedes the strongest polar warming

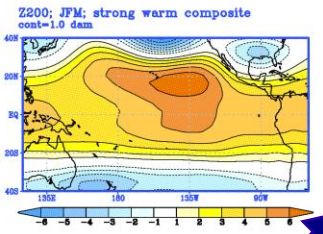
Conclusion: ENSO impact on NAE from the Speedy's perspective

Conclusion:
ENSO impact on NAE from the Speedy's perspective

Atmospheric bridge
(Lau and Nath, 1994, 1996)



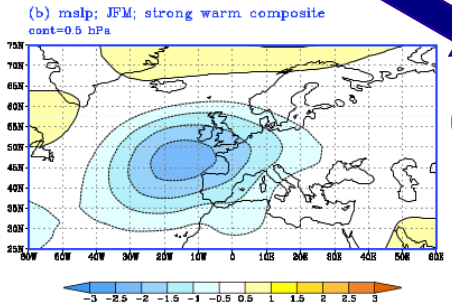
Rossby wavetrain
&
stratosphere-troposphere
coupling



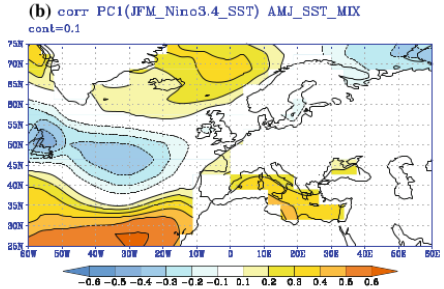
Tropical
atmosphere
JFM

Mid-latitude
atmosphere
JFM

Air-sea
interaction



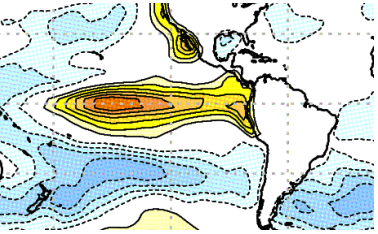
North
Atlantic
AMJ



Sea-air
interaction

Tropical
Pacific
JFM

Sea-air
interaction



Mid-latitude
atmosphere
AMJ