ENSO and NAO influence on climate variability in Europe

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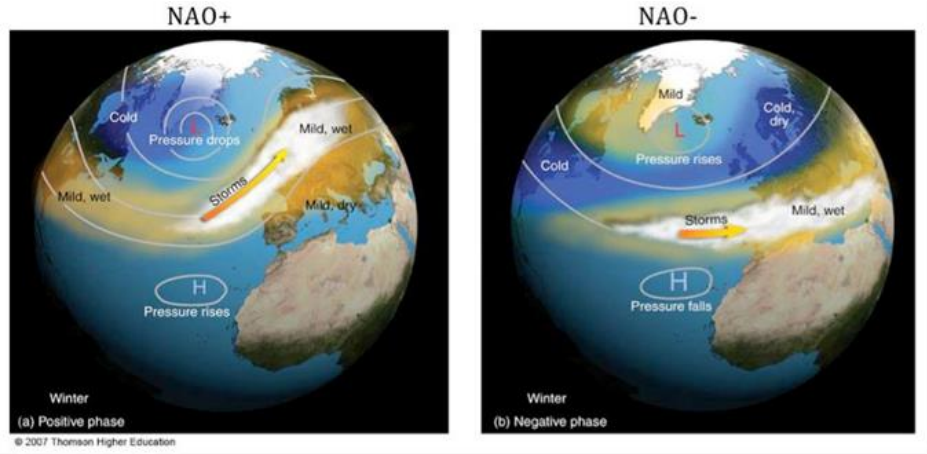
Hrvatsko meteorološko društvo

Meteorološki izazovi 6

NAO

North Atlantic Oscillation

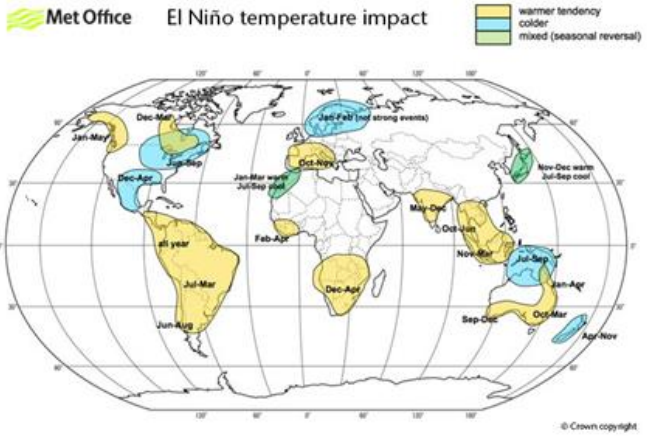
- **NAO**: the 1st EOF of MSLP or Z500
- Internal mode of atmospheric variability
- Dominant mode of variability on a range of time scales over the NAE region
- European seasonal weather is strongly affected by NAO

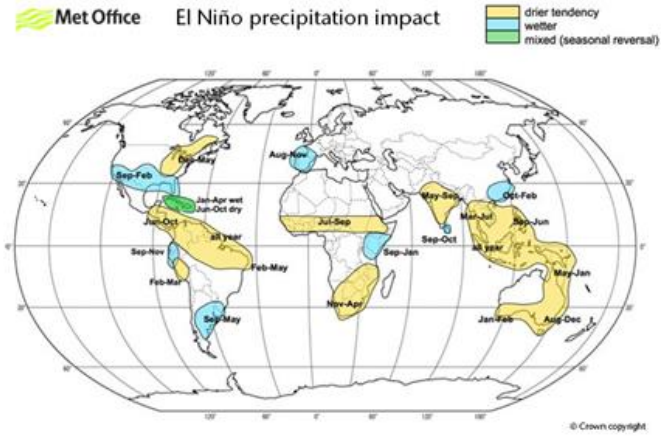


ENSO

El Niño Southern Oscillation

- **ENSO impact** on North Atlantic/European region (**NAE**) – difficult to asses; **incomplete dynamical understanding** → large internal variability of the atmosphere; impact of other phenomena (i.e. NAO; Hurrell and van Loon, 1997; Greatbatch, 2000), seasonal dependence of ENSO response (Brönnimann 2007), nonlinearity and non-stationarity in time (Pozo-Vázquez et al. 2015)
- Interactions with regional seasonal cycle, chaotic properties, complexity of feedbacks can mask ENSO signal over Europe

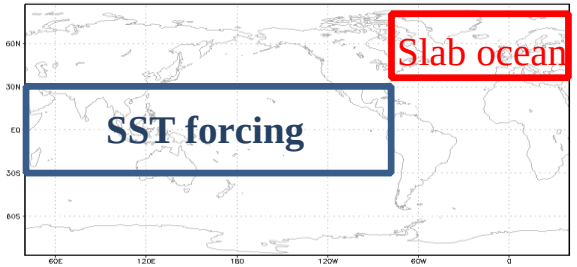




ENSO signature in SPEEDY model
→ Experimental design

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**



- **NAO index:** PC1 of JFM MSLP over the North Atlantic/European region (NAOI)
- **ENSO index:** area averaged JFM SSTs in Nino3.4 region (NINO3.4)
- **Observed 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

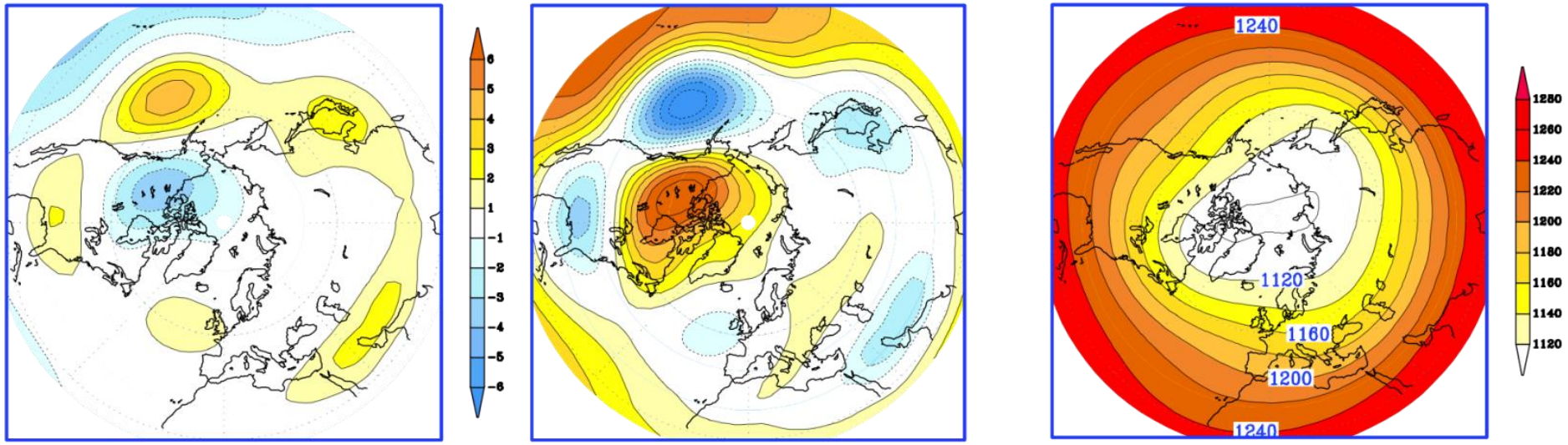
  SST: **NOAA_ERSST_V2** data (provided by NOAA/OAR/ESRL PSD, USA)

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

SPEEDY NH composites (CTRL)

La Niña **Z200 anomalies** **El Niño** **Z200 clim**

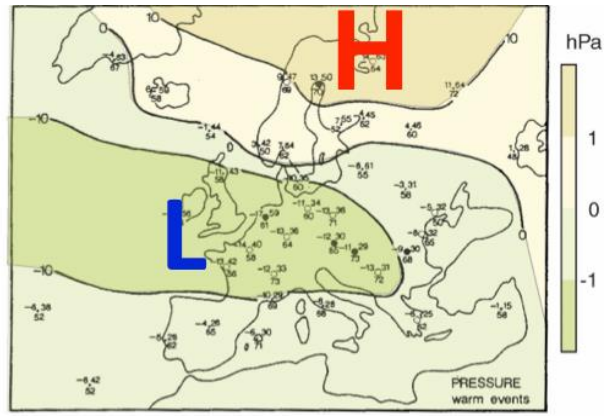
JFM



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 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 and modelling studies (e.g. Fraedrich, Tellus 1994; Brönnimann, RevGeophys 2007)
- **NAE:** Generally, **El Niño → cyclonic** type of weather

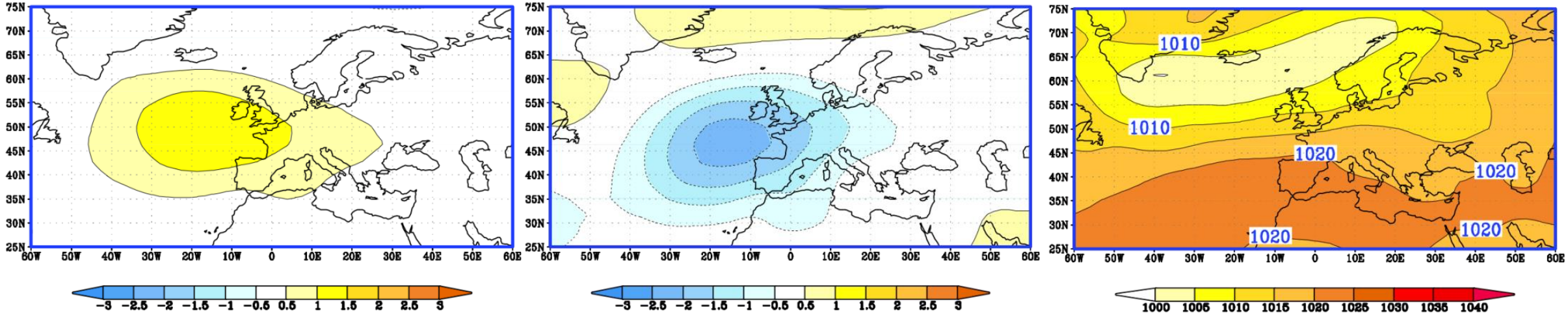
  La Niña → anticyclonic type of weather



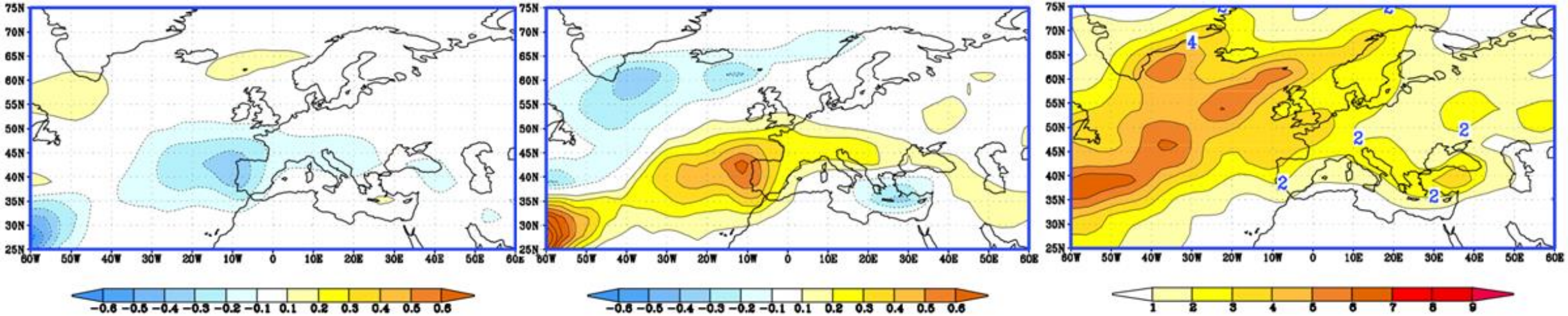
Fraedrich and Müller [1992]

SPEEDY NAE composites (CTRL)

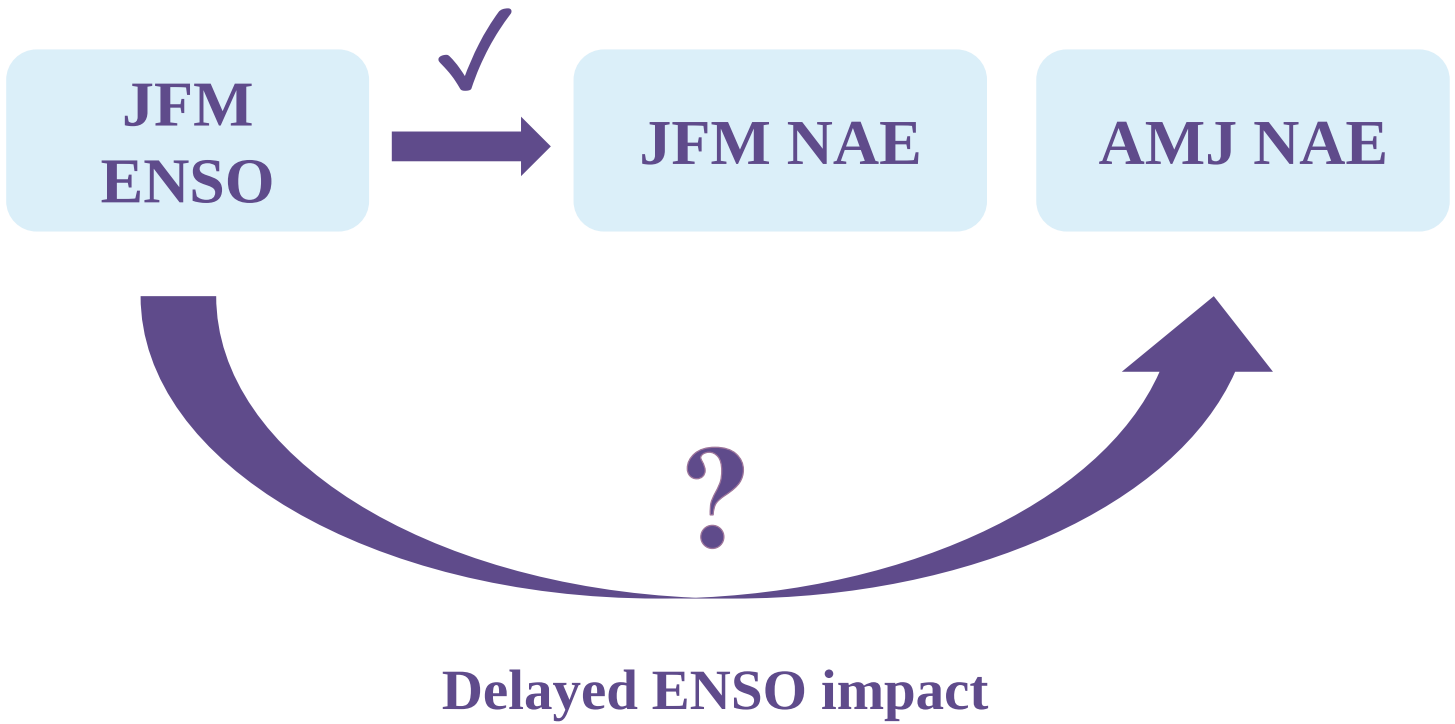
La Niña — JFM MSLP anomalies — El Niño — MSLP climatology



La Niña — JFM Precip anomalies — El Niño — Precip climatology



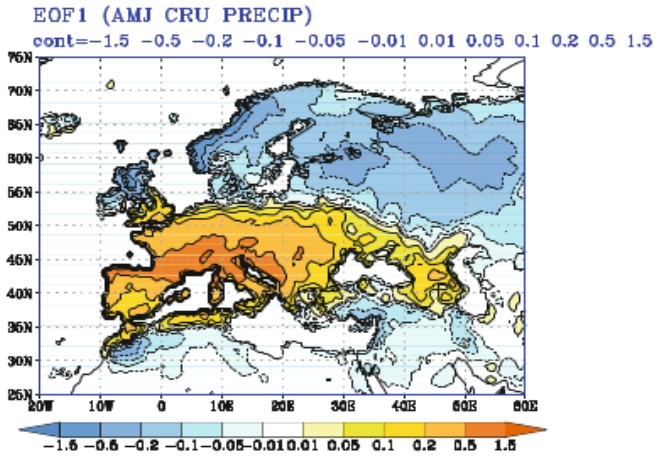
Delayed ENSO impact on NAE region



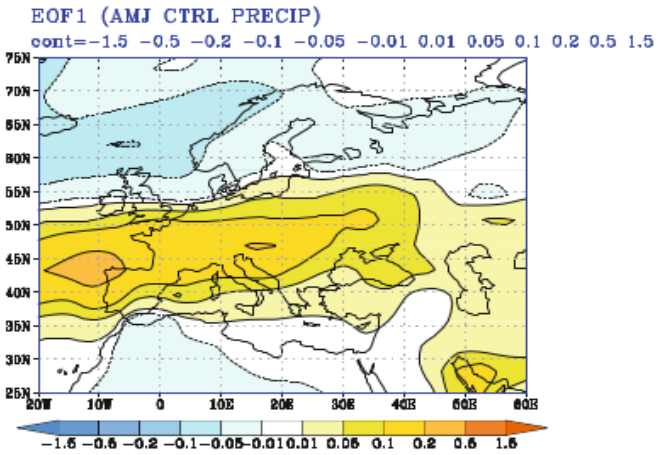
Delayed ENSO impact on NAE region

EOF1 (AMJ precipitation)

CRU



SPEEDY



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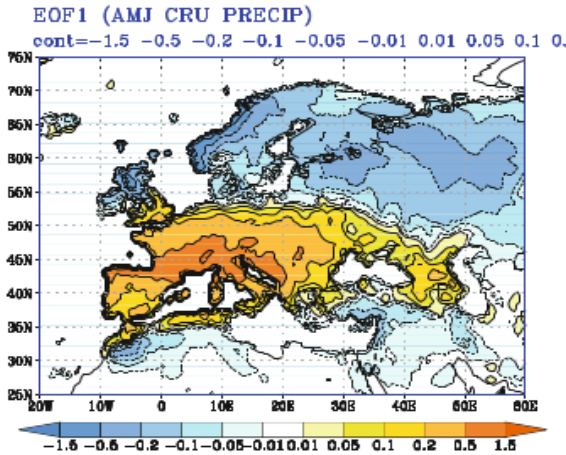
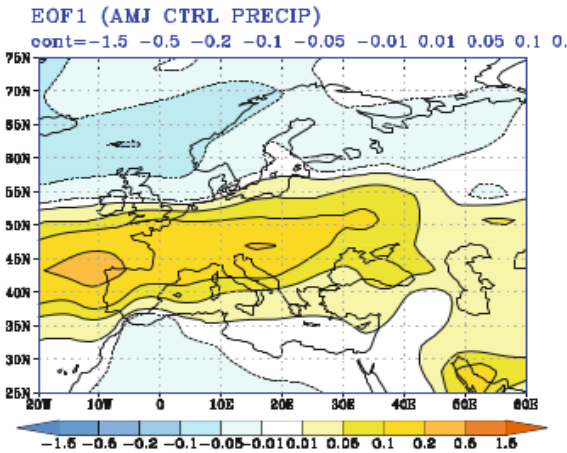
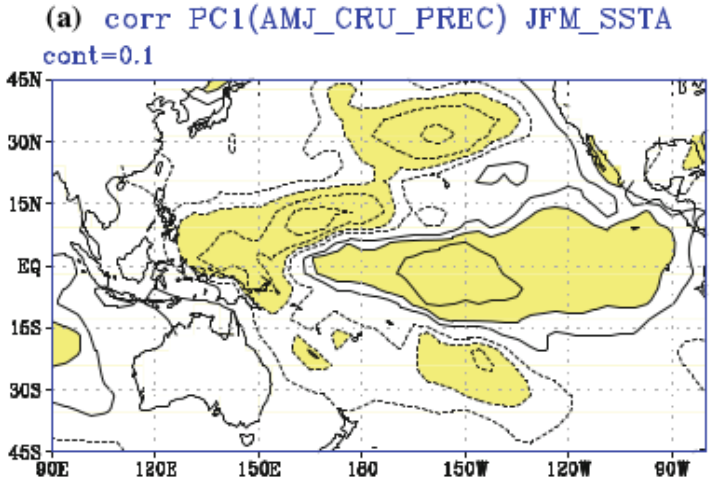


SPEEDY



Correlation PC1 AMJ precipitation - SSTA

CRU



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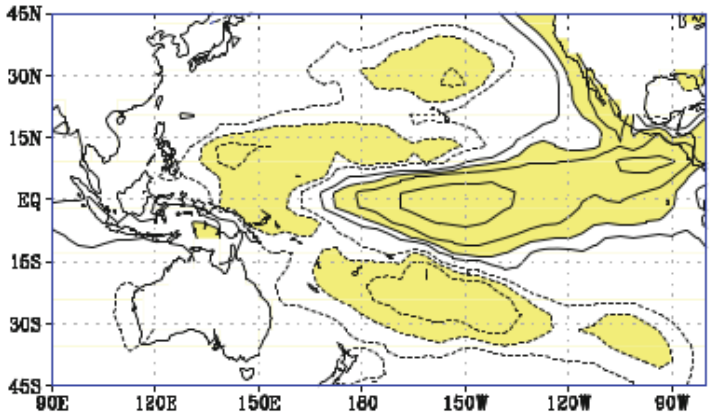
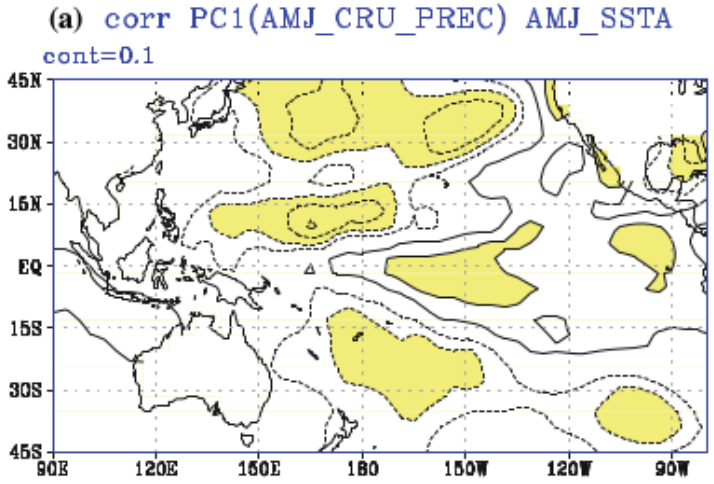
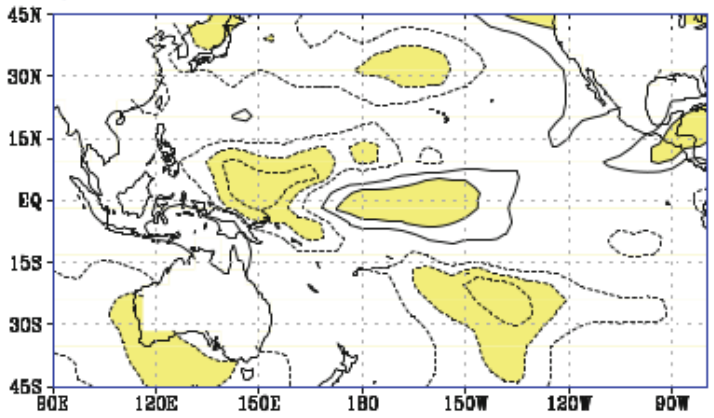


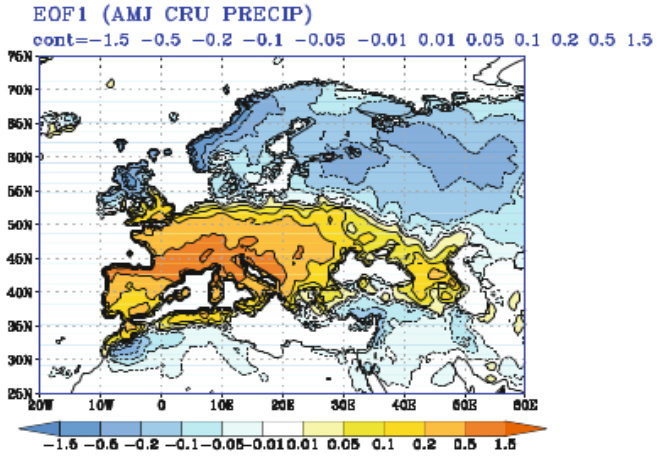




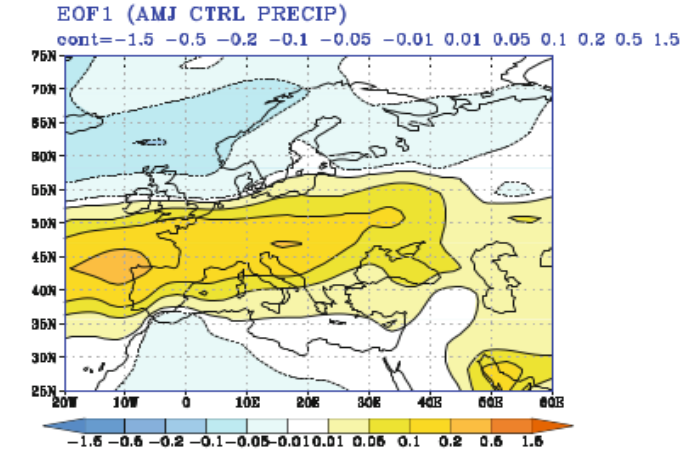
Delayed ENSO impact on NAE region

EOF1 (AMJ precipitation)

CRU



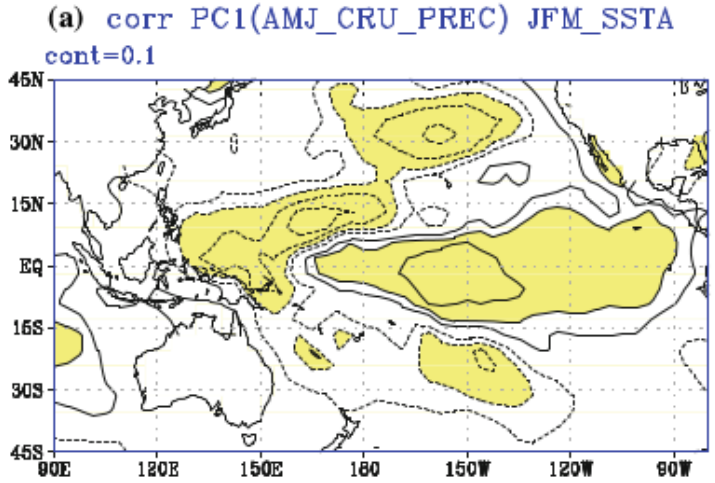
SPEEDY

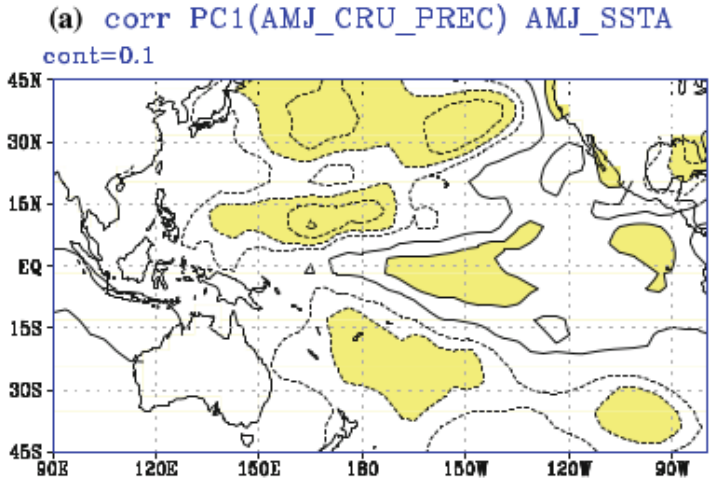


AMJ NAE precipitation variability is correlated with JFM SSTs in tropical Pacific and projects onto the El Niño pattern!

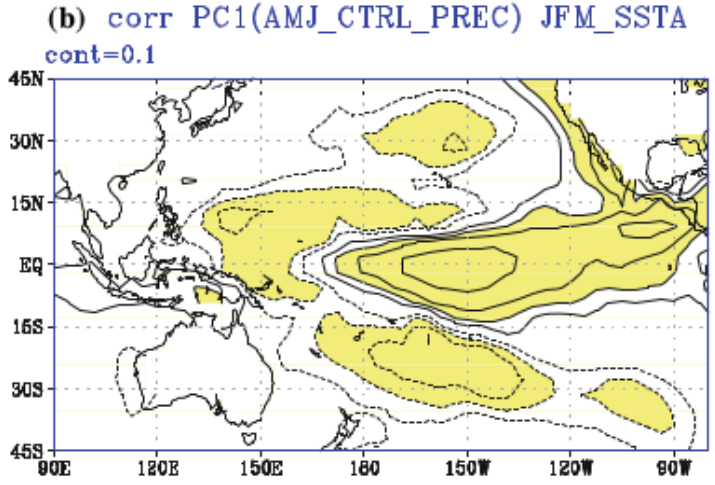
Correlation PC1 AMJ precipitation - SSTA

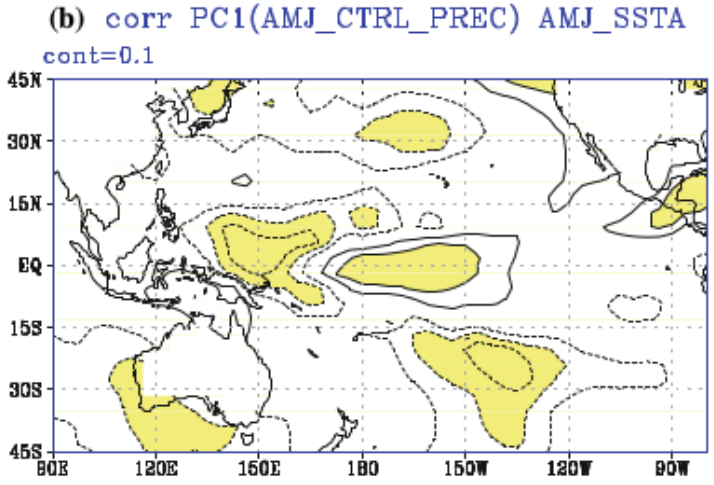
CRU





SPEEDY





MIX winter ENSO experiment

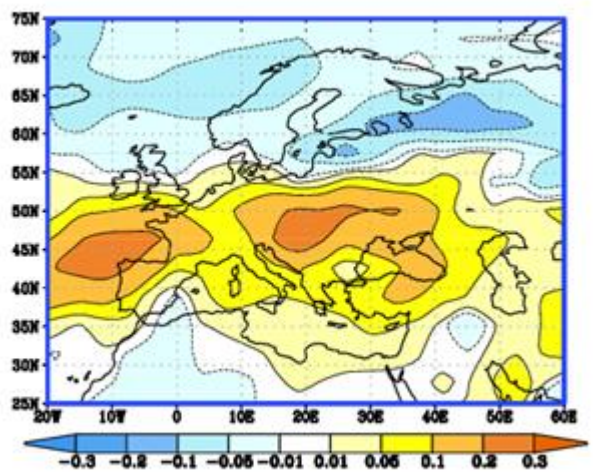
ENSO forcing restricted to winter (Oct – Mar)

~~contemporaneous AMJ SST~~

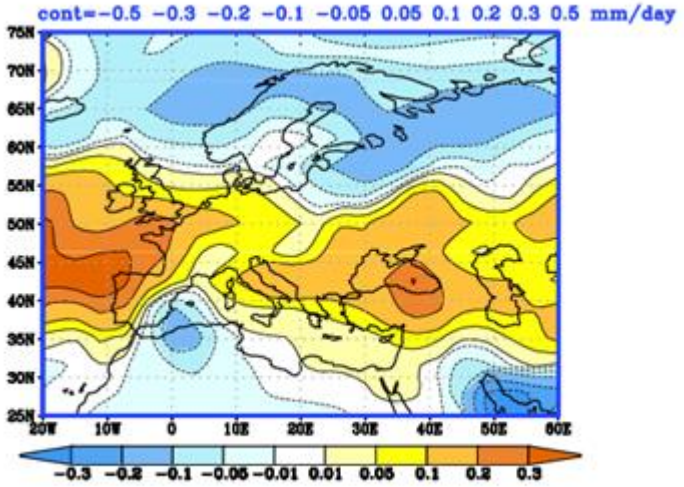
Tropical Pacific SST → **AMJ NAE**

JFM SST delayed

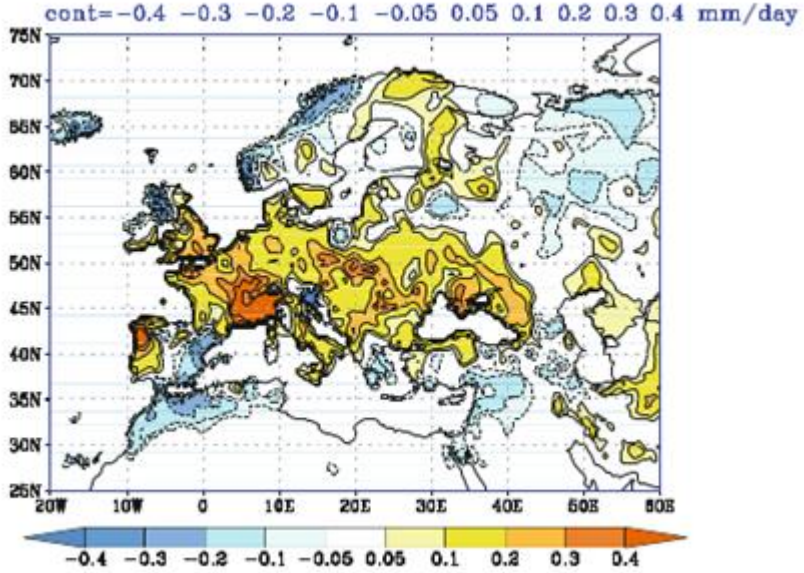
MIX winter ENSO AMJ prec



CTRL AMJ prec



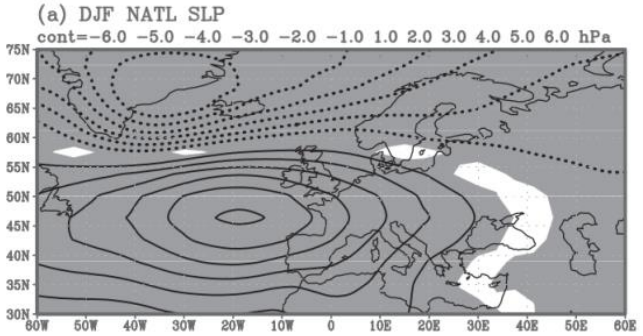
CRU AMJ prec

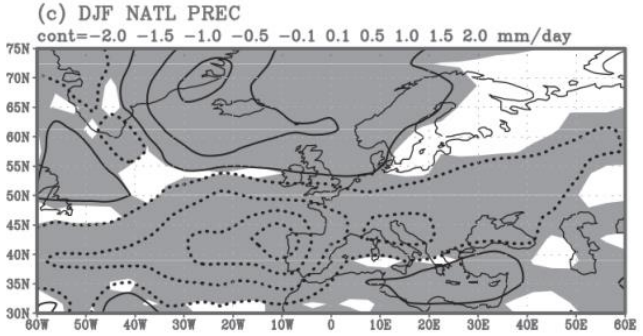


NAO signature in SPEEDY

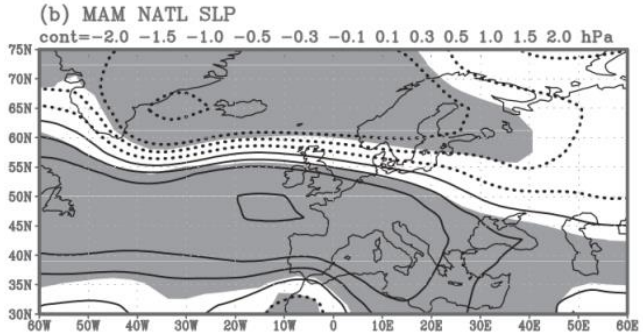
Seasonal persistence

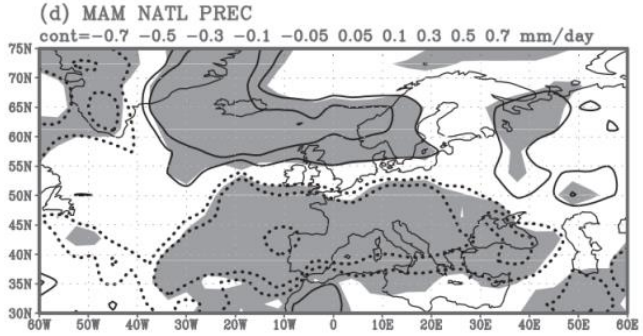
DJF





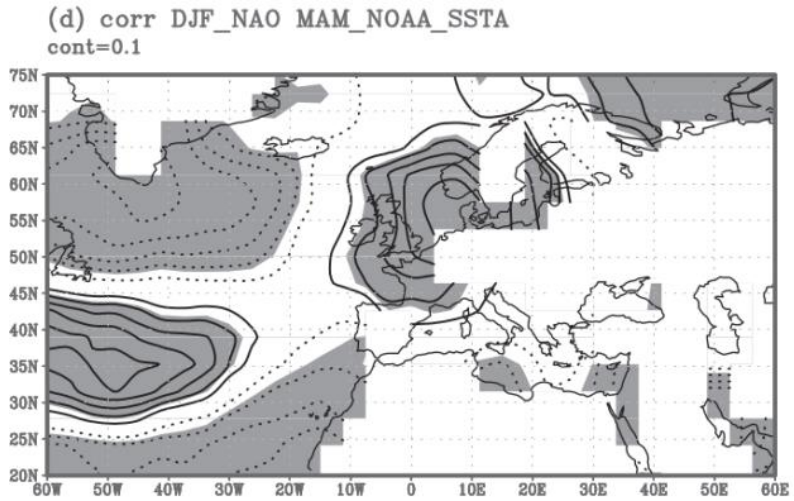
MAM





North Atlantic as a link between the wintertime NAO and the following spring climate

Herceg Bulić and Kucharski (JClim 2014)



Signal and noise in an ensemble of numerical simulations

A realization = Signal + Noise

- Ensemble means define the "climate signal"
- Deviations from the ensemble mean define the noise

Signal: $\sigma_s^2 = \frac{1}{M}\sum_{j=1}^{M}(\bar{x}_j - \bar{\bar{x}})^2$

$\bar{x}_j$: ensemble mean

$\bar{\bar{x}}$: climatological mean of ensemble mean

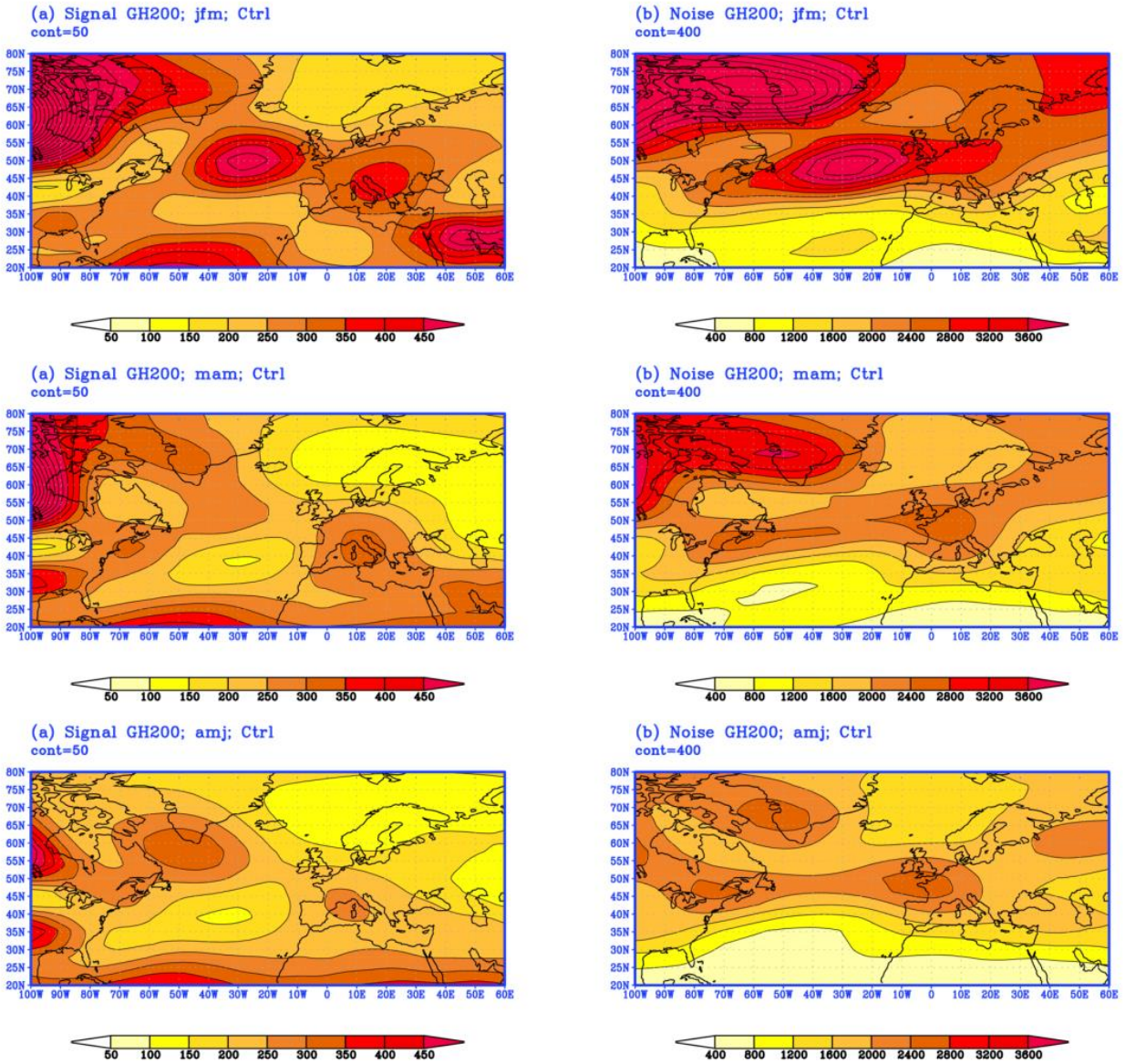
Noise: $\sigma_n^2 = \frac{1}{M}\sum_{j=1}^{M}\left[\frac{1}{N}\sum_{i=1}^{N}(x_{i,j} - \bar{x}_j)^2\right]$

SPEEDY:

M – number of years (**156**)

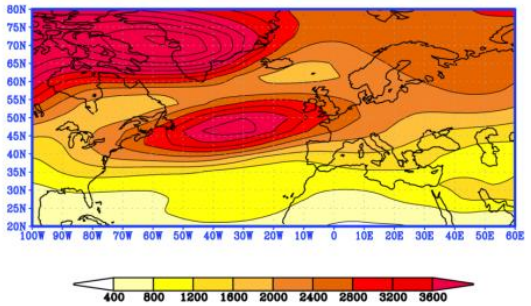
N – number of ensemble memebers (**35**)

SPEEDY

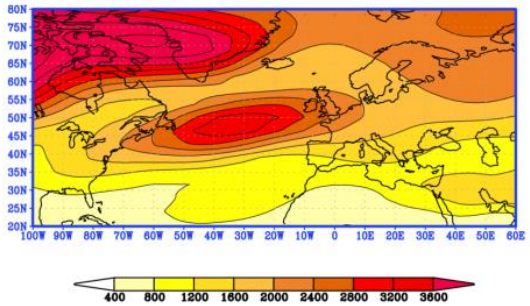


ENSO signal and noise in SPEEDY

(a) ElNino signal GH200; JFM
cont=400



(b) Strong ElNino signal GH200; JFM
cont=400



(c) LaNina signal GH200; JFM
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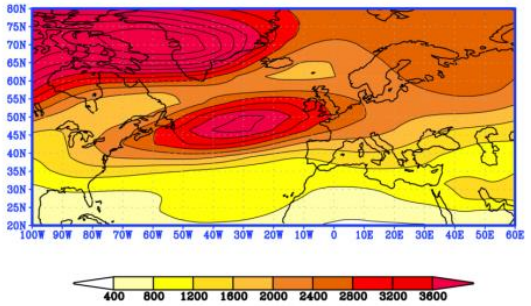

(d) Strong LaNina signal GH200; JFM
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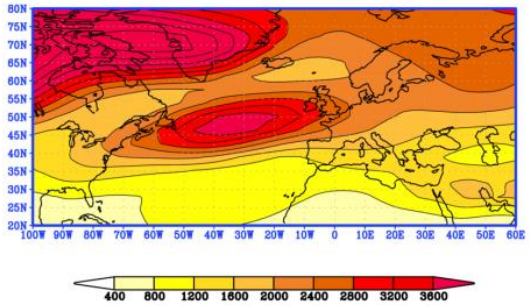

(e) ENSO signal GH200; JFM
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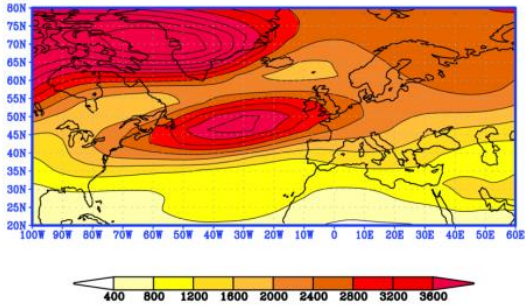

ENSO signal and noise in SPEEDY

(a) ElNino signal GH200; JFM
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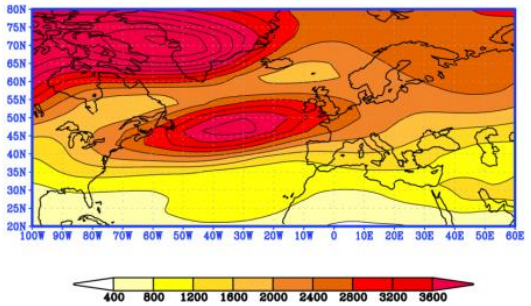

(b) Strong ElNino signal GH200; JFM
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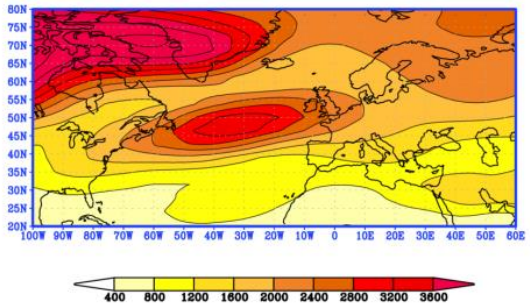

(c) LaNina signal GH200; JFM
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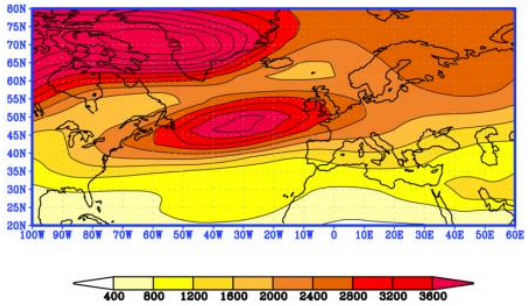

(d) Strong LaNina signal GH200; JFM
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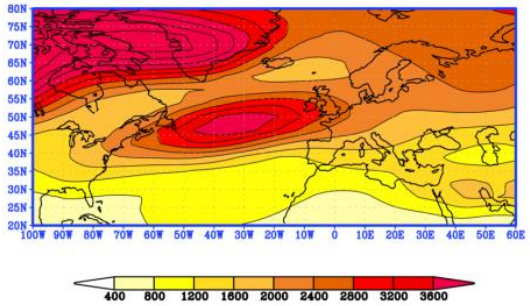

(e) ENSO signal GH200; JFM
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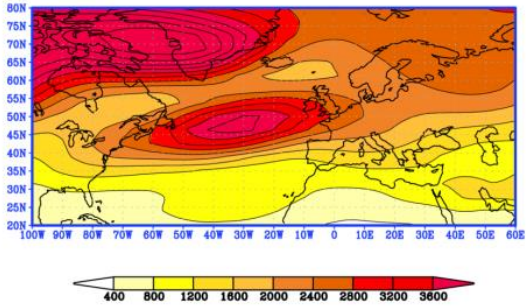

(e) ENSO noise GH200; JFM
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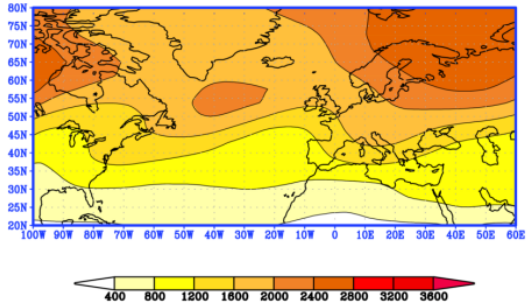
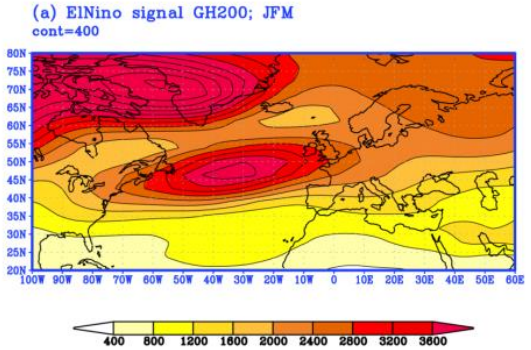
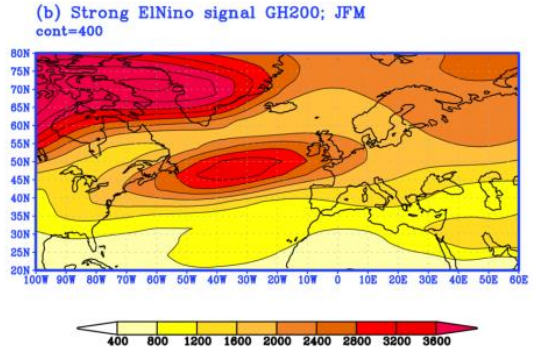
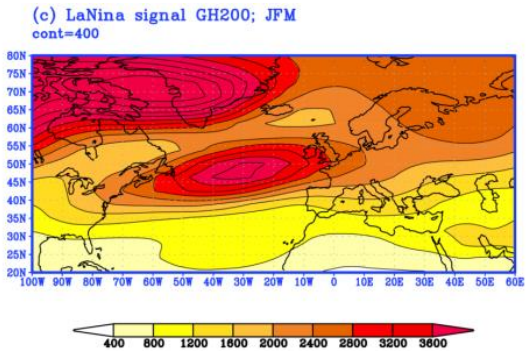
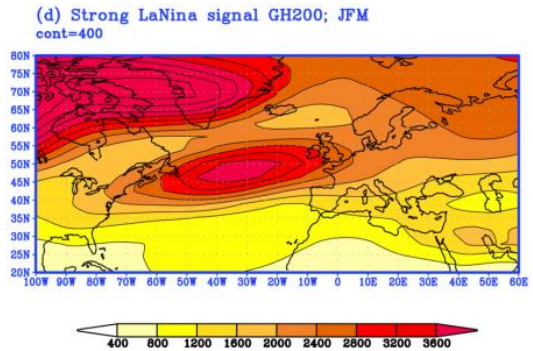


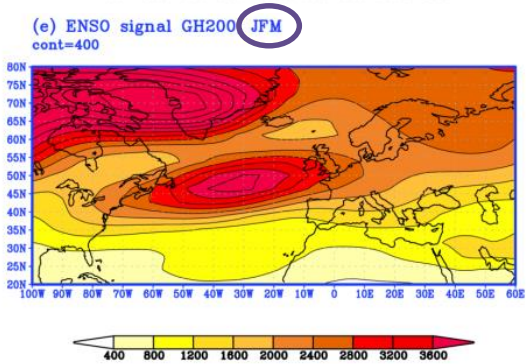
ENSO signal and noise in SPEEDY

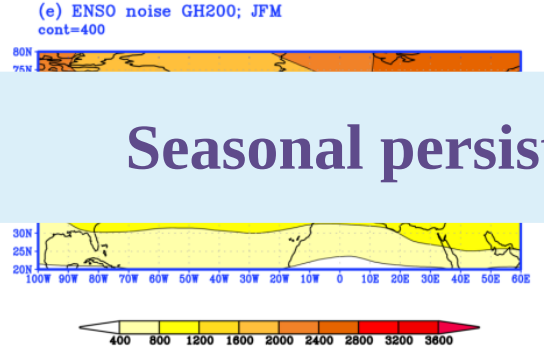




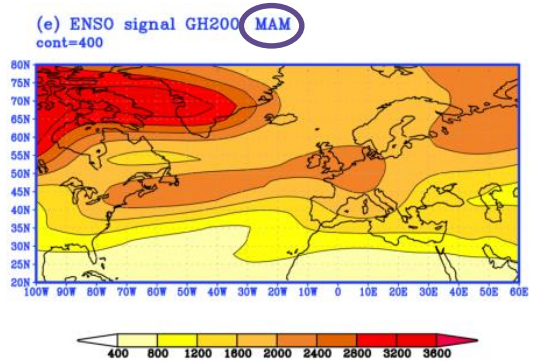


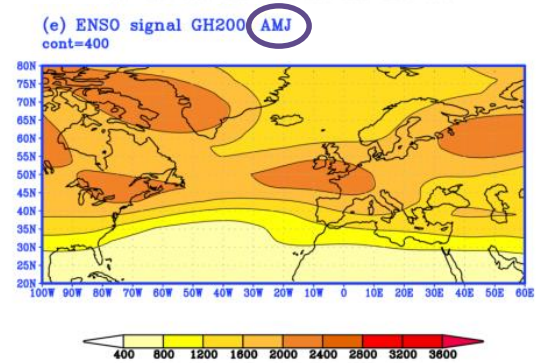






Seasonal persistence





Conclusion

- **NAE** region is affected by **ENSO** and **NAO**
- **NAO**: dominant influence
- **ENSO**: weak but detectable signal
- Delayed ENSO and NAO impact
  WINTER → SPRING
- **North Atlantic:** enables seasonal persistence
- **NAE region**
  - signal << noise
  - ENSO related signal > noise
  - seasonal persistence of the ENSO signal

Future?

- Is it possible to distinguish ENSO from NAO signal?
- Seasonal persistence of the signal (spring, summer…)
- The strength of seasonal ENSO signal
- Signal-to-noise ratio
- Possibility of implications for seasonal predictions