ENSO and NAO influence on climate variability in Europe

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**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 assess; **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
ENS0 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 anomalies

**JFM**

- **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

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

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

JFM ENSO → JFM NAE → AMJ NAE

Delayed ENSO impact
Delayed ENSO impact on NAE region

EOF1 (AMJ precipitation)

EOF1 (AMJ CRU PRECIP)

EOF1 (AMJ CTRL PRECIP)
Delayed ENSO impact on NAE region

EOF1 (AMJ precipitation)

Correlation PC1 AMJ precipitation - SSTA
Delayed ENSO impact on NAE region

EOF1 (AMJ precipitation)

Correlation PC1 AMJ precipitation - SSTA

AMJ NAE precipitation variability is correlated with JFM SSTs in tropical Pacific and projects onto the El Niño pattern!
MIX winter ENSO experiment
ENSO forcing restricted to winter (Oct – Mar)

**Tropical Pacific SST** → **AMJ NAE**

**JFM SST delayed**

**MIX winter ENSO AMJ prec**

**CTRL AMJ prec**

**CRU AMJ prec**

cont=-0.4 -0.3 -0.2 -0.1 -0.05 0.05 0.1 0.2 0.3 0.4 mm/day
North Atlantic as a link between the wintertime NAO and the following spring climate
Herceg Bulić and Kucharski (J Clim 2014)

NAO signature in SPEEDY

Seasonal persistence

DJF

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

**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 members (35)
ENSO signal and noise in SPEEDY
ENSO signal and noise in SPEEDY
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 \textit{WINTER} \rightarrow \textit{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