

Rossby wave activity associated with Euro-Atlantic weather regimes in high-resolution climate simulations

A diagnostic for Rossby wave activity based on Local Finite Amplitude Wave Activity (LWA) in isentropic coordinates:

$$LWA(\lambda, \phi, \theta, t) = \frac{-1}{\cos \phi} \int_{\phi}^{\phi + \Delta \phi} [(PV - Q)\sigma] a \cos \phi' d\phi'$$

$$PV = \frac{f + \zeta}{\sigma}$$

$$\sigma = -g^{-1} \frac{\partial p}{\partial \theta}$$

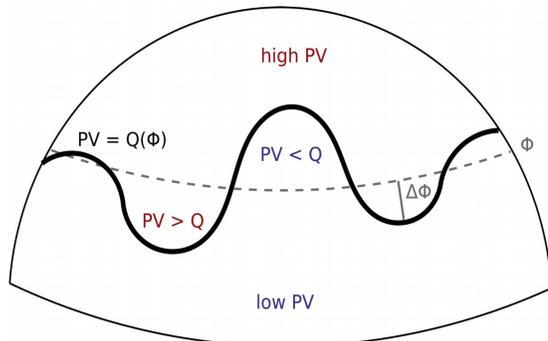


Figure 1: schematic of LWA in isentropic coordinates. Q represents a particular PV contour associated with a given latitude circle Φ such that they enclose the same isentropic layer mass.

LWA is a positive definite quantity proportional to the meridional displacement of Potential Vorticity (PV) with respect to zonal symmetry (see Figure 1). LWA can be used to quantify the local (in longitude) waviness of a given PV field. Figure 2 shows how the LWA climatology clearly identifies the North Atlantic and Pacific storm tracks in the Northern Hemisphere.

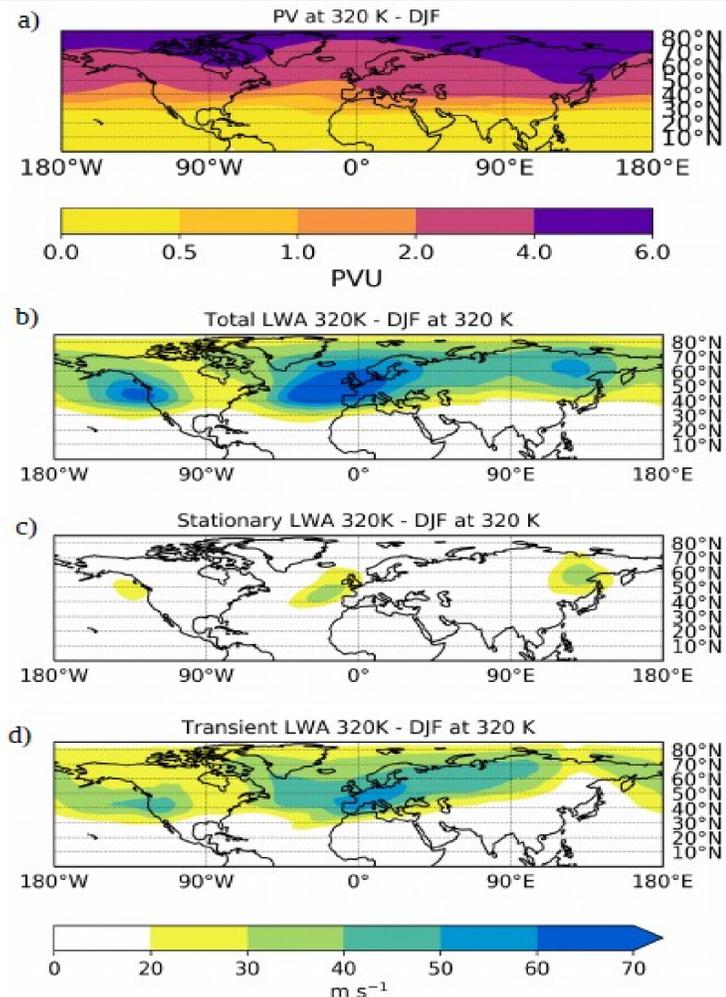


Figure 2: a) Ertel PV (in Potential Vorticity Units) on the 320K isentropic for DJF; b) LWA on the 320K isentropic for DJF; c) Stationary LWA component; d) Transient LWA component

Goals:

- Apply the LWA based diagnostic at first to reanalysis, then to coupled high-resolution climate simulations to identify and quantify Rossby wave activity
- Combine the LWA diagnostic with Euro-Atlantic Weather Regimes to analyse the large scale circulation associated with each regime in terms of Rossby wave activity
- Assess the performance of climate models (PRIMAVERA) in representing Rossby wave activity over the whole Northern Hemisphere and the Euro-Atlantic sector
- Quantify the impact of the horizontal resolution on the spatio-temporal behaviour of Rossby waves in climate models

Dataset:

- PRIMAVERA historical coupled simulations at standard and higher resolutions. Period considered is 1979-2015. Daily data of horizontal wind, temperature and geopotential are retrieved on 5 pressure levels between 850 and 100 hPa on a $2 \times 2^\circ$ regular grid for DJF.
- Standard res (LR) vs high-res (HR) in the atmosphere and in the majority of models also in the ocean.
- ERA 5 reanalysis covering the same period used as reference for comparison

Results:

- LWA diagnostic can be used as a metric to assess the performance of climate models in representing Rossby wave activity in the upper troposphere
- An increased horizontal resolution generally improves model performance (see Figure 4)
- No improvement in those models in which the horizontal resolution is increased only in the atmosphere but not in the ocean (CMCC and MPI). For these models the HR simulation is even worse than the LR one.

Reference:

- Ghinassi P., Fabiano F. and Corti, S., 2022: "How well is Rossby wave activity represented in the PRIMAVERA simulations?", Weather and Climate Dynamics

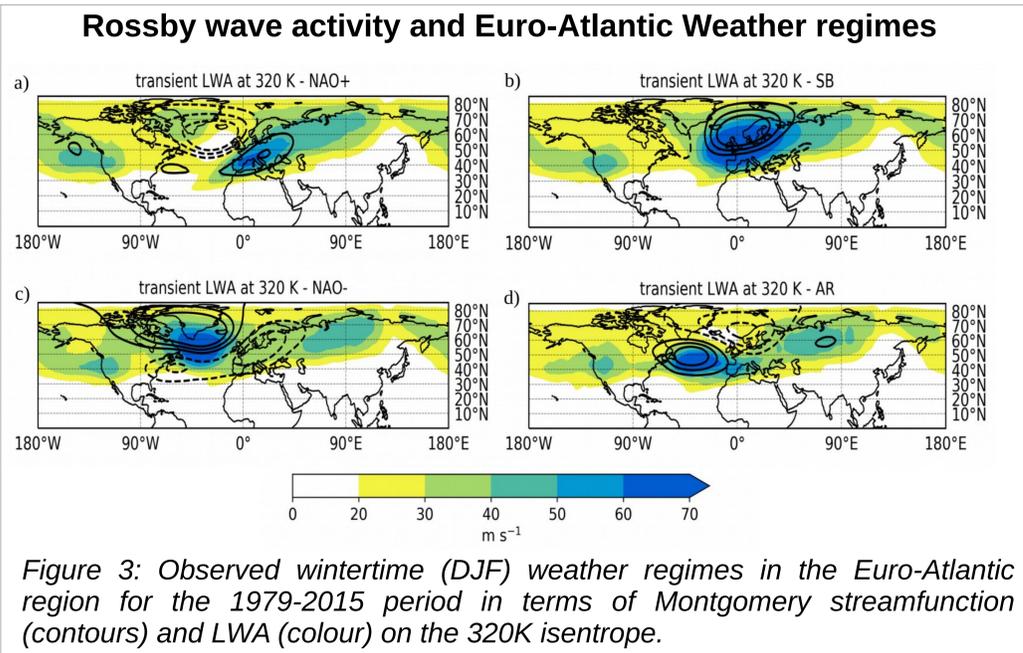


Figure 3: Observed wintertime (DJF) weather regimes in the Euro-Atlantic region for the 1979-2015 period in terms of Montgomery streamfunction (contours) and LWA (colour) on the 320K isentropic.

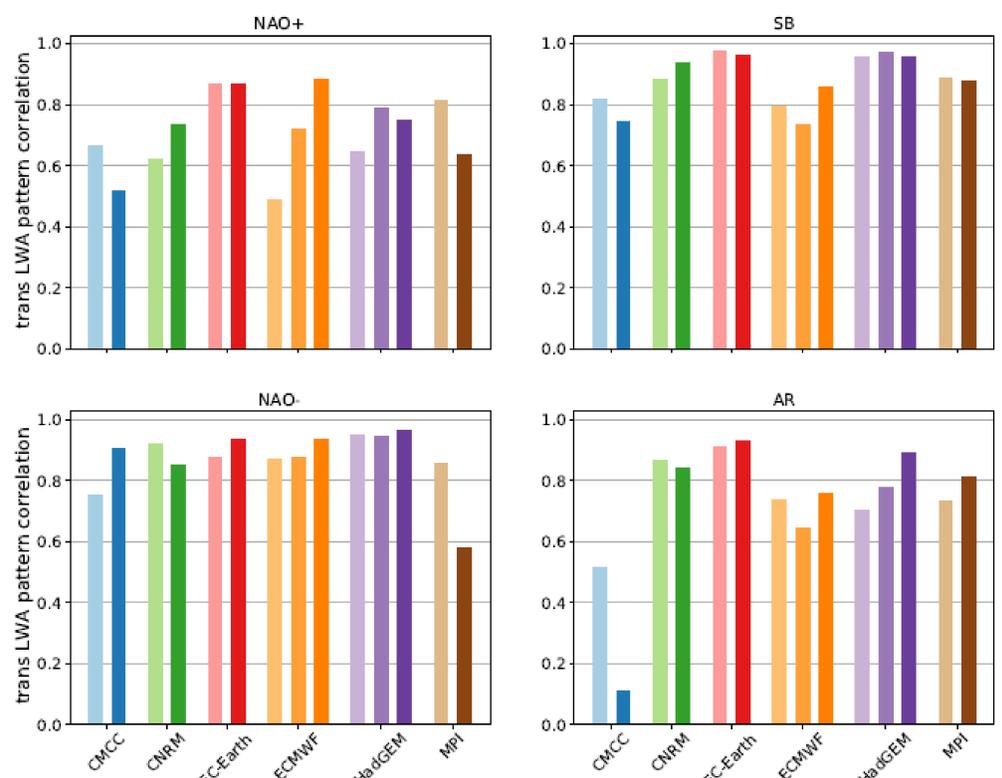


Figure 4: Pattern correlation in terms of transient LWA for the four Euro-Atlantic weather regimes.