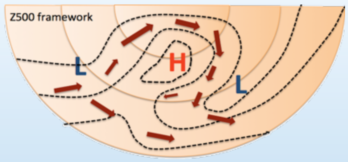
Atmospheric Blocking in the CMCC CMIP5 simulations

Paolo Davini[1,4] Chiara Cagnazzo[1], Pier Giuseppe Fogli[1],
Elisa Manzini[2], Silvio Gualdi[1,3], Enrico Scoccimarro[3], Antonio Navarra[1,3]

1 Centro Euro-Mediterraneo per i Cambiamenti Climatici, Bologna, Italy, (paolo.davini@cmcc.it)
2 MPI for Meteorology Hamburg, Germany
3 Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy
4 Università Ca' Foscari, Venezia, Italy

1. Introduction

Atmospheric blocking describes a mid-latitude weather pattern where a **quasi-stationary high-pressure system** modifies the westerly flow, "blocking" (or at least diverting) the eastward movement of the migratory cyclones (Rex, 1950a).

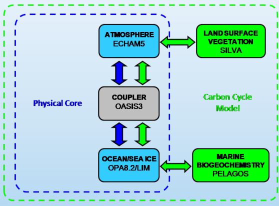


Blocking occurs throughout the year, even if it is more frequent during winter and spring, and **it typically develops at the end of the Pacific and Atlantic eddy jet streams**, and it affects significantly the weather of the underlying regions, sometimes **leading to cold spells in winter** and heat waves in summer (Trigo et al. 2004, Buehler et al., 2010).

Correct detection and forecast of blocking is still an open issue for both climate and NWP models: the **underestimation of the blocking frequency**, especially the one occurring **over the Euro-Atlantic sector**, is generally accepted as a common: these biases usually lead to significant errors in the representation and prediction of temperature and precipitation patterns over Europe. Moreover, **blocking appears to be connected to the many different components of the climate system**, as **Sudden Stratospheric Warmings** (Martius et al. 2009) and the **North Atlantic Oscillation** (Woollings et al, 2008).

This work goes in the direction of exploiting the CMCC model simulations in order to **get insight of the interconnection between blocking and other components of the climate system**, and, in the same time**, trying to establish what is the cause behind the biases in blocking representation**.

2. Data and Model simulations



Name	CMCC-CM	CMCC-CMS	CMCC-CESM
Oceanic component	OPA 8.2/LIM	OPA 8.2/LIM	OPA 8.2/LIM
Oc. Resolution	2°x2° - 31 levels	2°x2° - 31 levels	2°x2° - 31 levels
Atmospheric component	ECHAM5	ECHAM5	ECHAM5
Atm. Hor. Resolution	T159 (0.8 deg)	T63 (1.8 deg)	T31 (3.75 deg)
Atm. Ver. Resolution	31 levels	95 levels	39 levels
Model Top	10 hPa	0.01 hPa	0.01 hPa
100-1 hPa	5 levels	44 levels	17 levels
Oceanic Biogeochemistry	NO	NO	YES
Terrestrial Carbon Cycle	NO	NO	YES

Historical simulation of **three different coupled versions of the CMCC model** has been evaluated in order to compare the results with **NCEP / NCAR reanalysis.** **Two of them have a full resolved stratosphere.**

3. Blocking Detection

For the blocking detection is adopted the **bidimensional** extension of the **Tibaldi and Molteni (1990) index.**

Blocking events are recognized when the **inversion of the meridional gradient of geopotential height at 500 hPa occurs.** An additional constrain is applied northward to exclude fake blocking events.

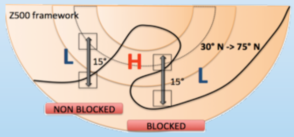
Blocking index is calculated from **35° N to 75° N: minimum spatial dimension (15° lon), quasi-stationarity and temporal persistence (5 days) are applied.**

$$GHGS = \left[\frac{Z(\phi_o) - Z(\phi_s)}{\phi_o - \phi_s}\right]$$

$$GHGN = \left[\frac{Z(\phi_n) - Z(\phi_o)}{\phi_n - \phi_s}\right]$$

(1) $GHGS > 0$

(2) $GHGN <$ -10 m/deg latitude.



4. NCEP/NCAR Reanalysis Blocking Climatology

Blocking frequency was calculated for the **winter season** (DJF) from 1951 to 2005.

The two classical area of blocking over **Pacific** and **Atlantic** basin emerges as totally different.

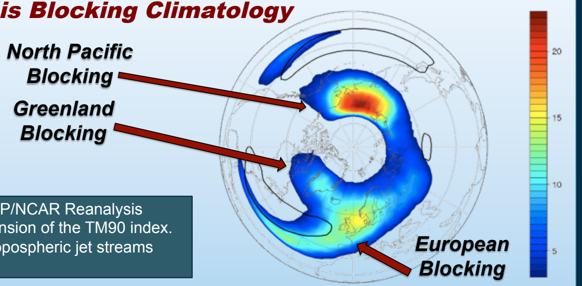


Figure 1: Blocking frequencies in DJF NCEP/NCAR Reanalysis 1950-2005 as shown by bidimensional extension of the TM90 index. Black contours shows the position of low tropospheric jet streams (U850 more than 8 m/s).

5. CMCC Models Blocking Climatology

CMCC-CEMS T31L39 ***CMCC-CMS T63L95*** ***CMCC-CM T159L31***

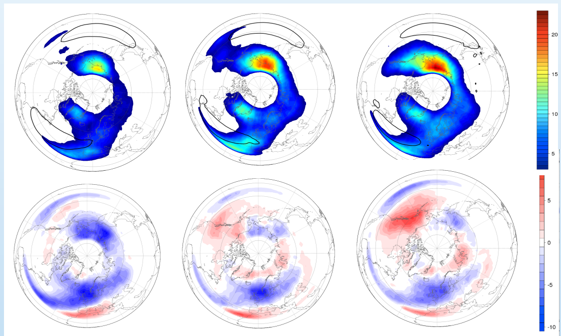


Figure 2: As Figure 1 (upper panels) and their anomalies with respect to NCEP/NCAR Reanalysis (lower panels) in the 3 CMCC simulations.

CMCC models underestimate the bulk of events on Europe (Figure 2), while there is agreement in representation of the Greenland blocking. **Biases** in the **climatological jet streams are tightly linked to the frequency of mid-latitude blocking** detected.

6. New Blocking Diagnostics

- **Blocking Intensity Index:** a measure of how the meridional circulation is perturbed, a 2D extension of the index developed by Wiedenmann et al. (2002).
- **Meridional Gradient Index:** a measure of the intensity of the easterlies associated with the blocking.
- **Average duration** of the blocking events.
- **Wave Breaking Index**: provide information of whether the blocking is associated to cyclonic or anticyclonic Rossby Wave Breaking.

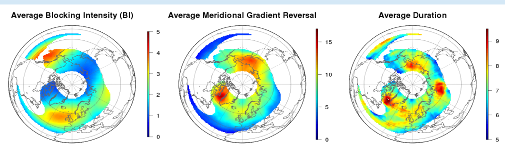
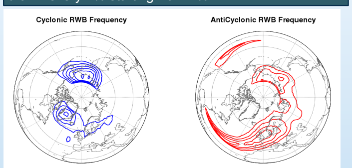


Figure 3: From left to right, Blocking Instensity index, Meridional Gradient Reversal and Duration as computed for the DJF 1951-2005 of NCEP/NCAR Reanalysis .

Figure 4: Frequency for cyclonic (left) and anticyclonic wave breaking (right) associated to blocking for DJF 1951-2005 of NCEP/NCAR Reanalysis. Contours are drawn every 2% starting from 4%.



The **diagnostics suggest dynamical differences** (in terms of duration, wave breaking, intensity and more) between **High Latitude Blocking and Mid-Latitude Blocking.**

Models replicate the main properties of the blocking events but duration, suggesting that the bias is related mainly to persistence and frequency.

7. Blocking and Atlantic Jet Displacements

Azores	Europe	Greenland	Iberian Wave Breaking (IWB)
50W-20W 30N-40N	15W-20E 47.5N-62.5N	70W-20W 62.5N-72.5N	30W-10W 37.5N-47.5N

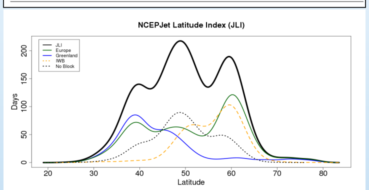


Figure 5: PDF for Jet Latitude Index (JLI, black line) as introduced by Woollings et al. (2010) for NCEP/NCAR Reanalysis in DJF 1951-2005. Blue, green and yellow line represent JLI when blocking is occurring over Greenland, Europe and IWB sector respectively. Dotted line represents JLI distribution when no blocking is occurring in the 3 sectors.

Euro-Atlantic Blocking appears to be strictly linked to the Atlantic jet displacements, studied via the **Jet Latitude Index (JLI)** introduced by Woollings et al. (2010).

Southern jet displacements are linked with Greenland blocking, confirming the NAO/Blocking hypothesis of Woollings et al. (2008).

Northward jet displacements are linked with blocking occurring over the **southern side of the jet**.

Models bias strengthen this idea, **suggesting that blocking acts perturbing jet from the its average "non perturbed" state.**

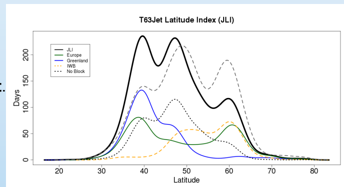


Figure 6: As Figure 5, but for CMCC-CMS simulation. Dashed line is the JLI for NCEP/NCAR Reanalysis

Conclusions

The adoption of **new bidimensional index** allows a more detailed study of different physical feature of blocking events:

• **Pacific and Greenland blocking shows similar diagnostics (Fig. 3 and 4)** and can be considered as **high-latitude blocking (HLB)** in agreement to the definition by Berrisford et al. (2007)**.** On the other side**, European Blocking behaves differently than HLB**, showing that **just the European one can be considered as a "real" blocking events** and suggesting the possibility that they are governed by different dynamics.

• **The Euro-Atlantic winter variability,** expressed via the **JLI** (Fig. 5 and 6), **can be associated with the occurrence/absence of blocking:** this is confirmed by CMCC model bias, even if the impact on the jet is more clear for Greenland blocking than for European blocking.

• **CMCC models (Fig. 2) show general underestimation of European blocking**, even if they possess **good representation of the North Atlantic Oscillation**.

• As **European Blocking appears to be not correlated to the phase of the NAO**, studying blocking events is a key element to capture the variability over the Euro-Atlantic region in climate simulations.

Main References

- Berrisford, P., B. Hoskins, and E. Tyrilis, 2007: Blocking and Rossby Wave Breaking on the Dynamical Tropopause in the Southern Hemisphere. Journal of the Atmospheric Science, 64, 2881–2898.
- Scherrer et al. Two-dimensional indices of atmospheric blocking and their statistical relationship with winter climate patterns in the Euro-Atlantic region. Int. J. Climatol. (2006) vol. 26 (2) pp. 233-249
- Tibaldi S. and F. Molteni. On the operational predictability of blocking. Tellus A (1990) vol. 42 (3) pp. 343-365
- Woollings et al. A New Rossby Wave–Breaking Interpretation of the North Atlantic Oscillation. Journal of the Atmospheric Sciences (2008) vol. 65 (2) pp. 609-626
- Woollings, T., A. Hannachi, and B. Hoskins, 2010b: Variability of the North Atlantic eddy- driven jet stream. Quarterly Journal of the Royal Meteorological Society, 136, 856–868.